HALMOS COLLEGE OF NATURAL SCIENCES AND OCEANOGRAPHY

ARCTIC THAW: Environmental Exploitation for Economic Profit

By

Stephen F. Moulton

Submitted to the Faculty of
Halmos College of Natural Sciences and Oceanography
In partial fulfillment of the requirements for
The degree of Master of Science with a specialty in:

Coastal Zone Management

Nova Southeastern University

December 18, 2019

A Capstone Paper

Submitted in Partial Fulfillment of the Requirements for the Degree of

Masters of Science:

Coastal Zone Management

Stephen F. Moulton
Nova Southeastern University
Halmos College of Natural Sciences and Oceanography

December 2019

Approved:

Capstone Committee Approval

Major Professor :_______________________________
David Kerstetter, Ph.D.

Committee Member :____________________________
Bernard Riegl, Ph.D.

Table of Contents

List of Figures:

List of Tables:

Abstract:

"Arctic Thaw: Environmental Exploitation for Economic Profit," is a comprehensive, interdisciplinary assessment of Arctic climate change (CC) impacts. Arctic CC alters the regions' temperature, annual ice cover, and sea levels. This alteration influences the global economy through enriched international trade and fossil hydrocarbon extraction developments. This capstone examines the Arctic's response to CC through economic statistical analysis, tracking relative sea-level (RSL) trends, as well as performing hydrographic and modeling reviews. The Northern Rim Countries (NRCs) economic analysis assesses potential CC and GSLR impacts by applying statistical techniques to calculate its effect on each country's gross domestic product (GDP). The tidal data analysis includes both Arctic and Pacific NW tidal stations mean sea level trends, which projects GSLR for each station. Arctic sea ice melt also increases shipping opportunities, which consequently amplifies marine casualty statistics. Maritime casualties raise pollution threats to the Arctic's indigenous communities and its endangered species. The United States Coast Guard (USCG) conducted the Port Access Route Study (PARS) to mitigate casualty risk by identifying vessel traffic routes. This study examines the PARS hydrographic data, as well as the courses implemented to safeguard the environment. This review also interprets model analysis and biota case studies in forecasting the adverse GSLR social and economic impacts (Douglas, 2010). Lastly, this capstone explores existing mitigation strategies and policies in determining its adequacy in addressing the Arctic's vulnerabilities. The policy review includes NRCs mitigation efforts, the Polar Code, and other Arctic ecosystem legislation implemented to counterbalance the developing economic exploits.

Key Words:

Hydrography, AIS, NWLON, NOAA, USCG, regression, VDatum, Glacial Isostatic Rebound (GIR), Polar Code, IMO

Introduction:

Climate Change (CC) affects the Arctic's integrated environmental ecosystem on many fronts, including economy, infrastructure, biota, and cultural identity. The resultant cryospheric variations of CC alter temperature, annual ice cover, and sea level (SL) (Serreze and Barry, 2005). In turn, these alterations influence the global economy, through enhanced international trade and fossil hydrocarbon exploitation. Currently, the USGS estimates that the Arctic could contain 13% of the world's oil and 30% of its natural gas. The ensuing interest in these resources helps to generate funding for continued research and development of the Arctic (Anderson, 2009). Sea ice reduction, climate variability, and global sea level rise (GSLR) associated with warming all contribute to Arctic resource development. The resulting regional impact of CC, therefore, warrants a comprehensive, interdisciplinary assessment.

This study analyzed the eight northern rim countries (NRCs) economics to interpret potential CC and GSLR's impact. The NRCs include: Canada, Denmark, Finland, Sweden, Iceland, Norway, Russia, and the United States. The economic data compiled for analysis was sourced from the Central Intelligence Agency's (C.I.A.'s) World Factbook. CIA's data provided the economic categories of each NRC impacted by GSLR for statistical analysis. To perform the investigation, "R" software calculated the GSLR impact through individual NRC datasets. The dataset analysis generated scatterplots and boxplots to demonstrate the GSLR and GDP relationship.

Each county's data fit best with "Multiple Linear Regression (MLR)" analysis. Multiple linear regression integrated the GSLR-susceptible economic parameters as measurement variables for correlation with the GDP. This fundamental analysis first established hypotheses and tests that the data meets the parametric assumptions of normal distribution and being homogeneous. Data analysis involves the "stepwise-forward" method for MLR findings.

In some instances, the dataset did not fit into a linear equation. In these circumstances, "Curvilinear Regression (CR)" analysis was performed to determine which equation to fit the data curve. Through establishing the fit, the investigation determined which economic impact variables affected the NRC's GDP.

Greenland's ice sheet extent, south of the Arctic Circle, was also monitored as a case study by University of California, Berkeley. Its calculated melt rate can have economic consequences for both policy development and land use regulations. Despite GSLR consequences, some view its tracking through melt rate calculations skeptically. This skepticism is due to conflicting estimates between tide gauge predictions and physical process comparisons (Schlegel, 2011).

Further GSLR impact analysis includes Arctic tidal data. Various Arctic and Pacific NW tidal stations were selected to demonstrate GSLR. The station selection criteria required adequate time in service, as well as being able to provide SL trends. The selected stations provided tides in 30-day increments, for 2007 and 2017 autumn periods. The station downloads served as inputs to calculate the tidal datum and overall SL trends. Additionally, SL data were used to plot yearly MSL trends against time and to project SL change rates for the selected tide station.

Overall, Arctic hydrocarbon development is a complex process. While the Arctic's oil reserve extension into the deep sea is unknown, oil companies also experience extraction complications in a remote, unforgiving environment, compounded further with logistic and shore transport difficulties. As Arctic development creates a rise in shipping rates, it also amplifies marine casualty statistics in the region. As such, this increase in Arctic shipping necessitates additional navigation safety measures. Currently, the Arctic lacks aids to navigation (ATONS). Additionally, charts are inadequate due to depth sounding discrepancies, while navigation publications are also often limited in scope, including Coast Pilots, Light Lists, Sailing Instructions, and Chart 1.

In efforts to correct this growing issue, the United States Coast Guard (USCG) responded with the "Port Access Route Study (PARS)." Initially, USCG proposed seven routing options within US jurisdiction for the area north of 50° latitude, west of 155° longitude. Upon further review, PARS was adjusted to follow Arctic traffic patterns, minimize course alterations, and maintain maximum distance from shore. Upon ratification by the International Maritime Organization (IMO), USCG next sought out updating the applicable PARS charts with accurate hydrographic data. Most existing Arctic charts are unreliable with sparse soundings and prevalent hydrographic decay (Gonsalves, 2016). Ultimately, the PARS corridor mission is to safeguard the environment from increased vessel traffic hazards. To resolve the charting issue, NOAA received orders to survey various critical segments within the PARS corridor (Coast, 2016).

Currently, numerical models best represent Arctic climate change. Initially, models predicted a gradual sea ice reduction. However, improved projections now yield higher loss rate estimates, due to factoring in sea-ice albedo impact. Model analyses also forecast the adverse social and economic effects associated with GSLR (Douglas, 2010). Generally, accelerating ice melt leads to predictions for increased resource extraction, regional development, and territorial conflicts.

Ultimately, climate change (CC) impacts dictate the need for complex Arctic management. As Arctic trade expands, a flexible offshore resource framework becomes necessary, with decision-making occurring in both the commercial and government sectors. Also, the region typically has unstable sovereignty, in which aboriginals are often the dominant settlement, further compounding decision-making intricacy. In terms of Arctic navigation, there is limited seabed knowledge of the new shipping lanes provided by ice reduction. Obtaining this knowledge will require the integration of advanced technology on the part of multiple users. Lastly, the Arctic requires research councils for oil spill response due to the likely increase in maritime incidents. Arctic management must incorporate a strategic approach while also establishing a new institutional network. Doing so could provide improved resource management through international and domestic laws and policies. (Abate, 2015).

Significance for Review:

This study is a comprehensive review of CC impact on the Arctic, including effects of ice melt, GSLR, and regional economics. The study examines economic statistics, RSL trends, hydrography, modeling, and discusses mitigation strategies. Arctic sea ice melt has an indisputable global, economic, and environmental impact. Resource extraction, GSLR, and CC all contribute to the region's vulnerability. This vulnerability is evident with increased human activity directly corresponding to marine casualty frequency. New shipping routes and territories for resource extraction due to sea ice cover reduction could provide regional economic opportunities. However, mitigating the developmental impacts on the Arctic ecosystem requires new legislation and protective infrastructure to counterbalance these economic exploits. Arctic development would likely include oil and gas extraction, tourism growth, and additional shipping ports. Failure to adequately prepare for the Arctic's economic development, in conjunction with CC impact, could result with catastrophic consequences for the region's future. This capstone explores ongoing and potential resultant Arctic development in response to CC impacts, current mitigation strategies, as well as determining if preparations adequately address unique Arctic vulnerabilities.

Towards this end, this review interprets Arctic CC impacted economics data through standard statistical analysis. This analysis compares the NRC's gross domestic product (GDP) against the GLSR economic affected variables over ten years (2008 – 2018). The GSLR impacted parameters include the NRC's annual oil production, exports, and reserves; natural gas production, exports and reserves; and merchant marine shipping. The capstone's economic analysis aims to determine the developmental impact on the Arctic. The statistical analysis attempts to discern the NRC's affected GDP relative to CC and commercial impact predictor variables.

Next, this review explores the scale of Arctic ice melt impact through tides analysis. Alaska tides data verifies a contrast with GSLR through indicating Glacial Isostatic Rebound (GIR) effect. SE AK station datum calculations substantiate GIR's occurrence, as its data displays dropping relative sea levels (RSLs) (Louis, 2017). Overall, GSLR causes harm worldwide, as further exacerbated with prevalent resource extraction subsidence. However, the Arctic seemingly gains economic advantages through new real estate acquired.

The Arctic region must adequately prepare for marine vessel traffic increase in direct correlation with enhanced ice melt. As the increased vessel traffic raises maritime casualty events, it also garners pollution threats to AK's endangered species, remote native communities, and means for subsistence. In efforts to mitigate this threat, the USCG conducted the Port Access Route Study (PARS) to identify traffic routes through analyzing Automated Identification System (AIS) tracking data. The PARS findings concluded that most Arctic groundings were preventable through enacting a route which avoids weak survey areas. This review evaluates the corridor's development while also performing hydrographic analysis relative to GSLR.

Additionally, this review discusses the Arctic ice melt mitigation efforts in response to continued and future industrial development. Arctic policies for environmental stewardship must be comprehensive through addressing CC impacts. This study explores economic incentives for Arctic natives, through NRC legislature compensation, while granting companies hydrocarbon access and development. However, the potential environmental impact also warrants NRC's policy adjustments to manage this risk. The Arctic's industrialization impact requires improved scientific and international institution cooperation of relevant marine activities, including shipping, fishing, resource extraction, and scientific research. Once established, a joint global network could better regulate these marine activities.

1. **Economic Impacts**

A. World Economy

The world's economic trade patterns could be heavily impacted through Arctic development, in which its sea ice melt results with world trade systems shifting through the newly generated shipping routes. These shorter Arctic routes provide strategic advantages for trade-dependent nations. Evidence in this Arctic shipping alteration is evident with Automatic Identification System (AIS) vessel tracking, as well as through individual Arctic country reporting. USCG verifies this rising Arctic shipping trend through its reported AIS statistics, which compile the vessels tracked north of the Bering Strait. In the last ten years alone, the number of vessels operating in the Arctic has grown by 128% (Committee, 2019). Other Arctic countries have similar projections. Russia's state-run nuclear energy company, "Rosatom" projects an annual freight traffic increase to 72.5 million tonnes (80 million tons) to ship through the Northern Sea Route (NSR) by 2024. This freight traffic increase contrasts from 17.9 tonnes (19.7 million tons) shipped in 2018 (Schuler, 2019). See Figures 1 - 4 graphs below to see the growing trend in vessel traffic and Arctic shipping route activity over the past several years.

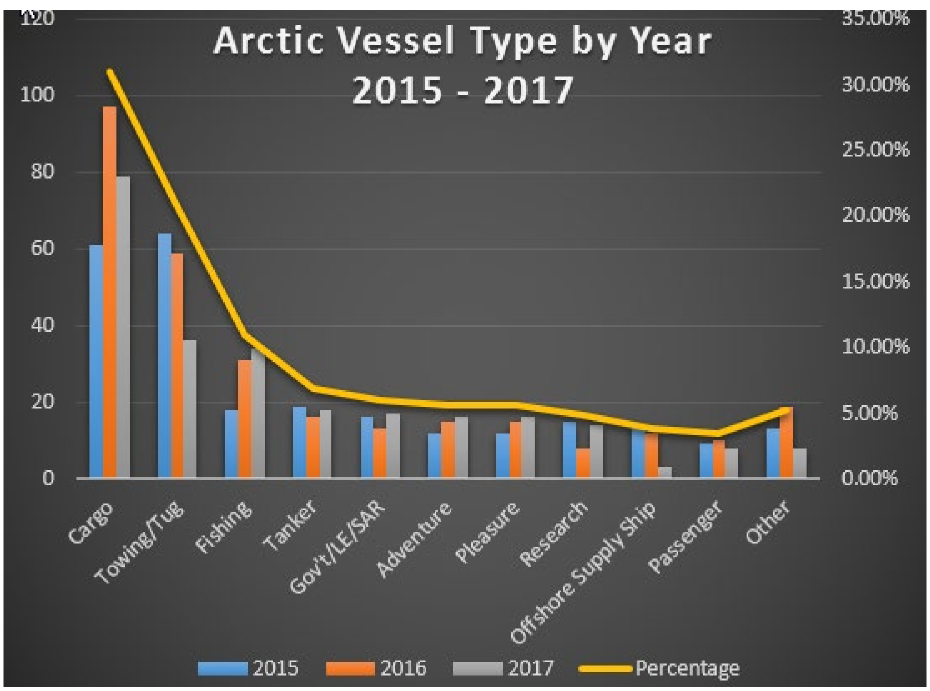


Figure 1: Arctic vessel type 2015-17, Automated Identification System (AIS) data (Committee, 2019).

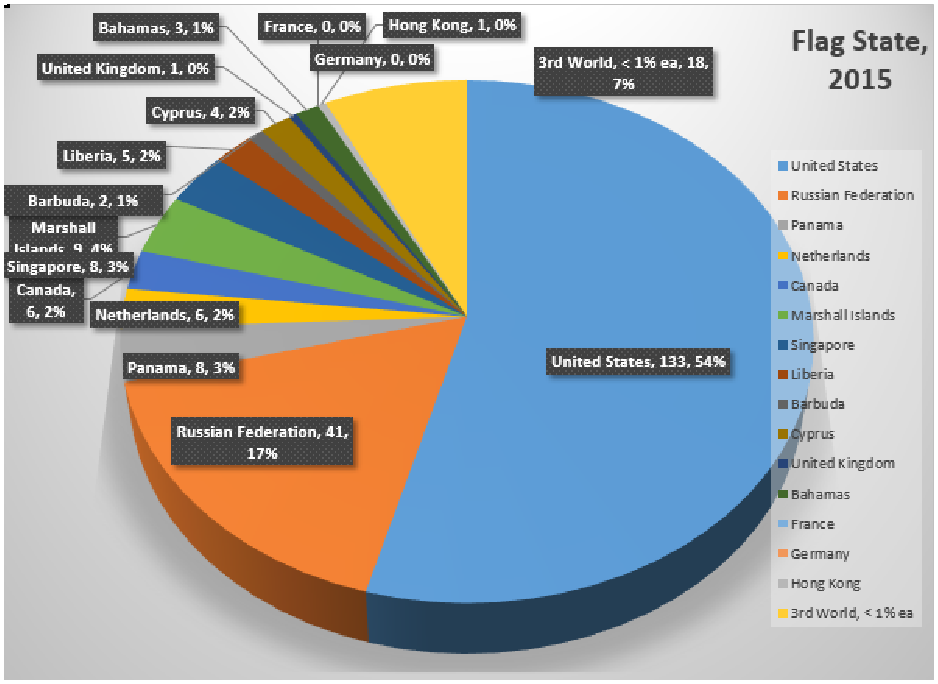


Figure 2: 2015 Arctic vessels by flag state, Automated Identification System (AIS) data (Committee, 2019).

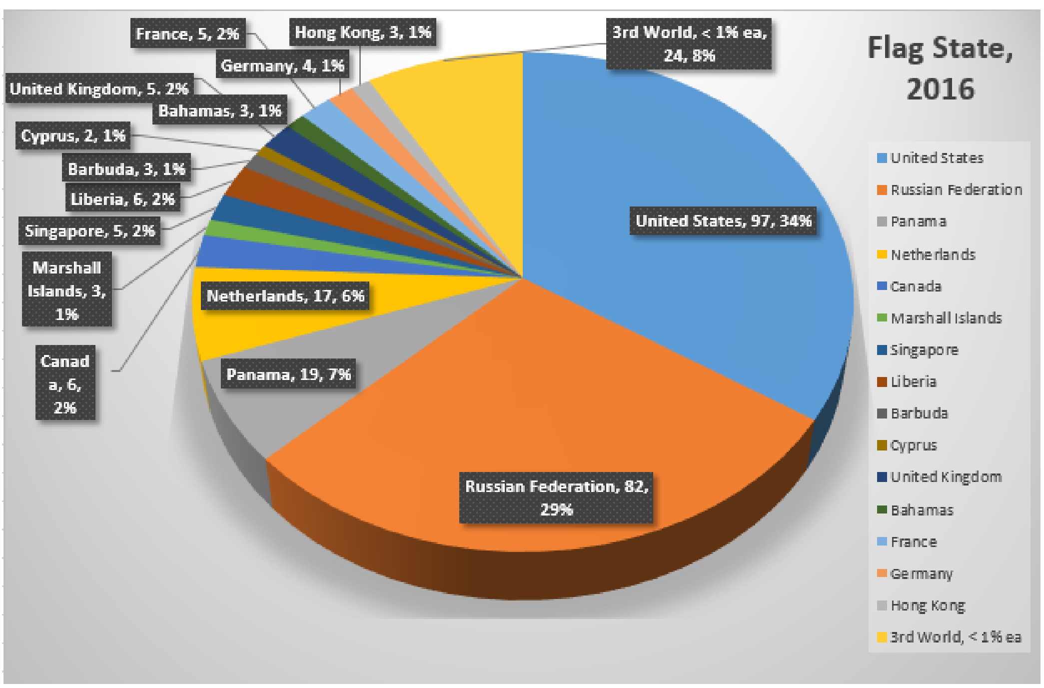


Figure 3: 2016 Arctic vessels by flag state, Automated Identification System (AIS) data (Committee, 2019).

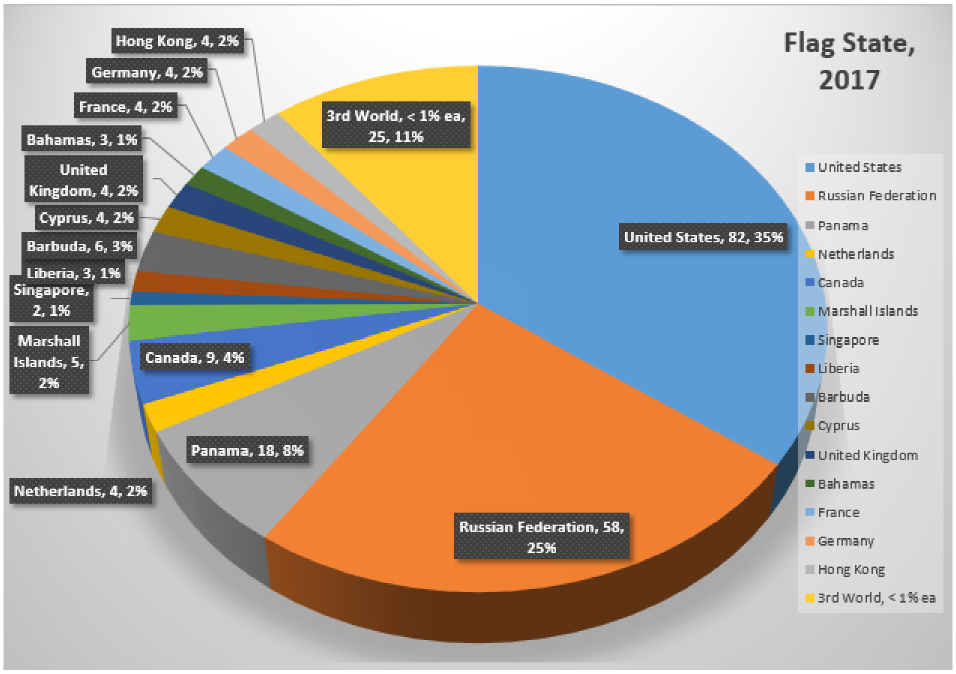


Figure 4: 2017 Arctic vessels by flag state, Automated Identification System (AIS) data (Committee, 2019).

Although this trade shift through the Arctic does provide economic incentives, the route alterations also raise regional competition and disputes. This economic shift therefore requires political, legal, economic, environmental analysis, and interdisciplinary governance (Hong, 2012). The Arctic trade route is a shorter transit, from NW Europe to the Far East, which increases trade volume overall. Although the Arctic route creates new jobs and prosperity, conversely the Middle East trade diminishes, which results with economic pressure and Suez Canal revenue losses (Brown, 2015). See figure one for the defined Arctic boundary.

2013).

Figure 5: Arctic Monitoring and Assessment Program (AMAP), Arctic boundary (from Smits, 2014).

Arctic CC overall affects the global economy in several sectors. Warming temperatures, rising populations, and industry expansion all indirectly intensify ongoing sea ice reduction (Haglund, 1983). The reduced sea ice creates resource development opportunities through oil and gas reserve exploration, mining, hydroelectricity, infrastructure, production technology, and transportation. Negative CC impacts include a reduced ice cover, which provides less meltwater for hydroelectricity. Climate change is also detrimental to infrastructure, in which linear construction suffers from permafrost melt, as the soil's spatial variations with ice content result with a differential settlement. This settlement creates slope instability in both new and existing construction (Prowse, 2009).

In contrast, economic benefits from Arctic CC exists with yielding more exploratory and extraction opportunities for oil and gas development. Increased offshore exploration, drilling, and commercialization through CC, are evident with improved shipping routes, new fishery grounds, as well as energy and mineral production opportunities. However, Arctic commercialization must also address the environmental concerns of increasing anthropogenic activity. Northern rim countries (NRCs) must, therefore, identify adaptive strategies to oppose negative CC impacts through supporting energy-related investments in improving research and technology. (Masters, 2013).

Infrastructure development is increasing in the following measures. As the navigation season extends from CC, the marine transportation must match this growth through expanding its supporting components, including search and rescue (SAR), weather forecasting, port facilities, and vessel operational support. Specifically for the US, its lacking Arctic infrastructure requires overall development, as well as repairs to its existing structures. As CC threatens to warm the ~70% pan-Arctic permafrost domain, these impacts include the Dalton highway, Trans-Alaska pipeline, and "distance early warning line" sites. To mitigate and expand the US infrastructure, see the approved projects and proposals below in figures 5 and Table 1 (Projection, 2019; Prioritization, 2016).

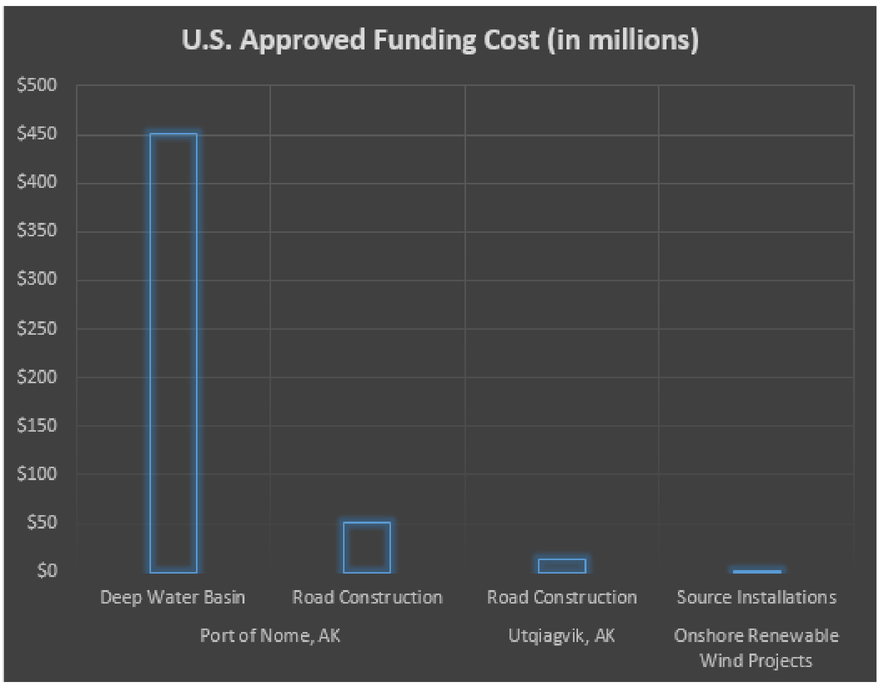


Figure 6: US development graph, derived from approved US projects (Projection, 2019).

Table 1: US infrastructure proposal table, derived from proposed US Arctic projects (Prioritization, 2016).

Proposal	Project
Navigable Waterways	Designate: Port Clarence - Arctic maritime place of refuge Review: Port Clarence facilities - assess adequacy as support facilities for ships in need of assistance Support: Arctic Waterways Safety Committee - bring stakeholders together Leverage existing data-sharing frameworks: (Data.gov/AK Regional Response Team/AK Ocean Observing System) facilitate waterways planning / response to environmental emergencies Leverage international partnerships: support waterways coordination Coordinate stakeholder research efforts: de-conflict research within commercial and subsistence use areas Designate M-5 AK Marine Highway Connector: connect the Arctic Ocean and the Northwest Passage
Physical Infrastructure	Prioritize: Arctic port reception facilities-support international regulatory needs and future growth Expand: Arctic coastal and river water-level observations-support flood and storm- surge warnings Review: US Arctic maritime commercial activities -identify major infrastructure gaps to promote safe and sustainable Arctic communities Co-locate: Continuously Operating Reference Stations (CORS) and National Water Level Observation Network (NWLON) stations-improve Arctic geospatial framework with positioning and water levels.
Information Infrastructure	Improve: weather/water/climate predictions-equivalent level of service as is provided to the rest of US Implement: short-range, sea-ice forecasting capability Prioritize: hydrography/charting-US maritime Arctic Advance Arctic communication networks-ensure vessel safety Port Access Route Study (PARS): provide routes for vessel traffic in the US Arctic Expand satellite Automatic Identification System (AIS) capabilities for offshore activity information
Marine Transportation System Response Services	Collaboration: State/local authorities-ensure Arctic maritime and aviation infrastructure readiness for emergency response / SARs Coordination: international-provide engagement opportunities across Federal and international Arctic response community Support: Pan-Arctic response equipment database development, best practices, and information sharing for Arctic oil spill response guideline development

Outside of US considerations, the next flag state with the highest level of infrastructure development is Russia. Russia's Arctic infrastructure development is evident with two current projects, the Kamchatka Peninsula LNG terminal, and the Trefoil military base. The proposed

LNG terminal would yield a 20 million ton capacity to support eastbound LNG shipments from the Yamal and Arctic LNG 2 Russian projects. Additionally, the Trefoil military base, located on the Franz Josef Land, is a 14,000 square mile air defense base. Its construction is the first of four additional newly proposed bases in the Russian Arctic as part of an overall strategy for resource extraction (Projection, 201p).

Overall, Arctic regional development correlates with maritime transport service demands. As Arctic ice melts, it alters global energy dynamics and economics through the resulting new shipping lanes. These lanes include the Northwest Passage, the Northeast Passages, and the Northern Sea Route. See Figure 2 for reference.

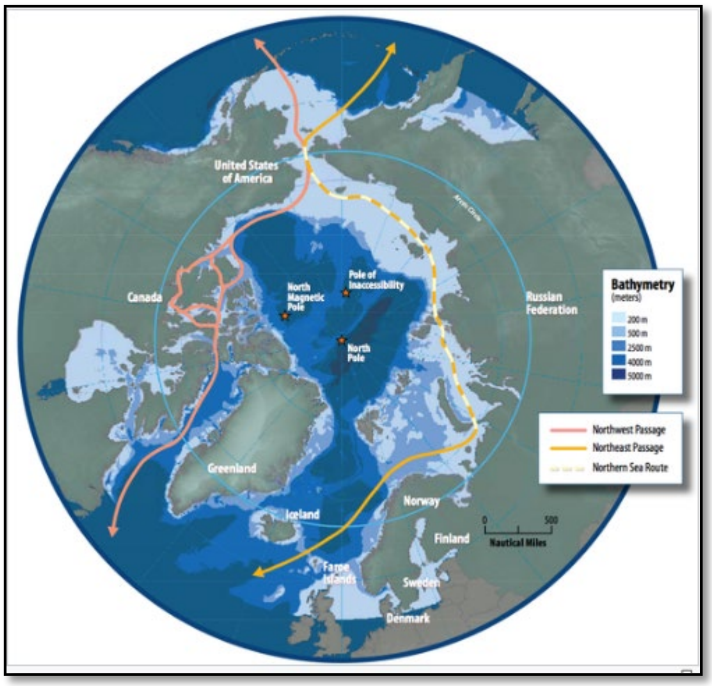


Figure 7: Arctic Northeast, Northwest Passages and the Northern Sea Route (from Wikipedia, 2019)

The Arctic sea lanes increase access for resource extraction, thereby requiring additional marine transport networks (Masters, 2013). Subsequently, this increased marine traffic raises environmental risks, including oil spills and wildlife disturbance. Global warming also induces permafrost thaw, which leads to regional infrastructure impacts to structures built on permafrost. As a result, new design and construction must factor for differential settlement, soil spatial variations, and ice content (Prowse, 2009).

USGS Arctic oil and gas assessments have resulted in universal development interests. The vast oil and gas resource estimates have resulted in the NRC's offshore development. Arctic development creates jobs and revenue, while also fulfills energy needs (Anderson, 2009). Northern rim countries are also experiencing a rise in research and development, military exercises, and UNCLOS (United Nations Convention on the Law of the Sea) seafloor claims. Additionally, private capital investments have grown exponentially in NRC ports, railroads, and LNG development. Arctic interest also cultivated tourism with enhanced media publicity (Smith, 2011). This Arctic economic development is especially evident in Russia, which has produced an offshore oil volume equivalent to Saudi Arabia's (Smith, 2011).

B. Global Sea Level Rise Economic Impact on Northern Rim Countries

i. Economic Analysis:

This study examined eight northern rim countries (NRC) for interpreting GSLR's economic impact through statistical analysis. The NRCs include: Canada, Denmark, Finland, Sweden, Iceland, Norway, Russia, and the United States. While this study does not provide a full economic Arctic analysis, it does examine the essential Arctic resources which have increased accessibility due to CC. These resources are hydrocarbon-based products, including oil and natural gas production, exports, and proven reserves. A warmer climate with less ice coverage expands the region's capacity for hydrocarbon exploration and drilling. The NRC economic analysis, therefore, interprets petroleum production, as well as commercial shipping, as by-products of the Arctic's CC impact.

For analysis, each NRC's economic factors, as impacted by GSLR, were compiled into datasets. These economic parameters include: oil production, exports, and proven reserves; natural gas production, exports, and proven reserves; and merchant marine shipping. The data provided, in a specific format, then allowed for statistical analysis measures with "R" software. The GSLR projected impact on the economic parameters is then tracked over a ten year period (2008 – 2018). The NRC's gross domestic product (GDP) comparison against these variables provided the GLSR economic impact. The Central Intelligence Agency's (C.I.A.'s) World Factbook source data provided the NRC's statistics for this analysis. The C.I.A. acquires this data for processing and conversion into intelligence briefings for US policymakers. As such, this data provides fundamental NRC economics. The raw data collection is integrated, evaluated, and then declassified for public availability (Central, 2018). In the instance of NRC GSLR impacted economics, these specific data downloads provide the opportunity for further analysis and interpretation. Additionally, each GDP measurement is on a purchasing power parity (PPP) basis (Central, 2018). See all NRC Economy datasets in Appendix A.

To perform the analysis, "R" software served as the primary means for the data's statistical calculations. This integrated suite provides data controls, management, and diagram outputs. R's economic analysis bases its findings on its arrays and matrices design. This analytical software allows the user to interpret data and graph the results through its programming language "S." Through these measures, the collective datasets were processed to generate results in determining the GSLR impact on each NRC's GDP (Venables, 2018).

This study tailored individual datasets for each NRC for import into R. R analysis next generates scatterplots and boxplots to visualize the relationship between GSLR and GDP. Each GDP measurement is on a purchasing power parity (PPP) basis. The PPP calculation interprets the GDP into the cost of the US dollar value. The total of all those goods and services equals the country's economic output, which is the country's gross domestic product as measured by PPP. Additionally, all economic parameters are numeric, which allowed plotting results to visually indicate GSLR impact. The response GDP plots on the Y-axis, while the explanatory predictor variables plot on the x-axis. Often, these datasets require log or square root transformations to fit the data linearly. Additionally, some NRC's warranted alternative analysis due to the curving data points. Each NRC analysis includes initial scatterplots, which are Cartesian coordinate diagrams displaying the NRC's predictor variables relative to the GDP (McDonald, 2014). See "R" transcripts in Appendix B.

ii. Multiple Linear Regression (MLR):

Each NRC's initial analysis was first fit with the Multiple Linear Regression (MLR) approach. The independent economic parameters served as measurement variables susceptible to GSLR impact and provided a means to determine their individual effect on each country's GDP. This analysis scripts in the R program, which presents findings as record keeping transcripts (Appendix B). All NRC economic variables serve as predictors, or independent variables (IVs). These variables include petroleum entries, oil production, proven reserves and exports; natural gas exports, production, and proven reserves; and overall merchant marine shipping transportation. The IVs variations on the NRC's GDP, being the dependent variable (DV), ultimately determines the GSLR overall impact. Multiple linear regression analysis allows the user to select an equation which best predicts the GDP as a linear function of GSLR's impact (Figueiredo, 2017). Multiple linear regression essentially determines the functional relationship between the NRC's GDP and the GSLR economic impact. The resultant GDP variation determines GSLR's correlation and significance to each country. This method additionally determines which measured variable holds the most impact on the GDP (Venables, 2018).

The MLR analytical approach determines the cause and effect relationship with each NRC's GDP, as each selected economic variable correlates with GSLR. To begin, each NRC analysis, the null hypothesis first establishes that there is no measurable relationship between GSLR's impacted economic parameters and its GDP. A supported null hypothesis, therefore, leads to the conclusion concludes that the MLR's predicted GDP values are no closer to the actual indiscriminate GDP values (McDonald, 2014). For each NRC, MLR was used to test the null against the GSLR impact hypothesis. The determined probability value (PV) guided the MLR equation selection. In this occasion, the probability that if the null hypothesis is correct, the statistical summary would be greater than or equal to the actual observed results (Figueiredo, 2017).

After establishing the hypotheses, the data's parametric assumptions were confirmed by testing for both normal distribution and homogeneity. Normal data has an even distribution, evident in the boxplots, and does not demonstrate skewness. The homogeneity of variance further tests that the data's distribution around the mean are considered equal among compared variables. Essentially, the data spread around scatterplot trend lines on the plots should not expand or decrease with increasing values of the predictor variable (Figueiredo, 2017).

Upon clearing these data checks, the data must also demonstrate no multicollinearity. Multicollinearity is when one predictor variable in a multiple regression model highly correlates with another predictor variable. With the predictor variables correlating, each can be used to predict the other. In essence, this is a problem for regression estimates, as multicollinearity creates unreliable regression estimates. Although collinear predictor regression models can determine relationships with the outcome variable, it will not give valid results about the individual predictors. With multicollinearity models, the predictors are redundant concerning the other correlated predictors. As such, analysis requires selecting only one of the two highly correlated economic variables for the MLR analysis. Removing variables, one by one, continues until meeting the multicollinearity assumption (Figueiredo, 2017).

Upon meeting all necessary parametric assumptions, the datasets are now ready for MLR through the stepwise forward method. The simplest model (with the most significant predictor) has individual GSLR economic variables added to it to determine which impacts the GDP. The derived R^2 is the multiple determinations coefficient, which concludes how well the MLR equation fits the data. R^2ranges from 0, with no relationship, to 1, which demonstrates no difference between the observed and predicted GDPs. Ultimately, the derived MLR equation selection best fits the linear relationship between GDP and the predictor variables (McDonald, 2014).

iii. Curvilinear Regression (CR):

Despite MLR being the primary analytical approach, there were several instances where the data spread did not fit a linear equation. With these datasets, the parametric assumptions were not met, even after transformations were applied. Instead, a graphed curved line required curvilinear regression (CR) analysis. This method selection best determines the GLSR's economic variables related to each NRC's GDP (McDonald, 2014).

Curvilinear regression begins through determining the data relationship and which analytical approach to take. Scatterplot analysis identifies this data relationship for each predictor against the GDP. The curved line first fits the graph's data points. The non-linear regression method implements if the relationship reaches a plateau. However, if the non-linear regression does not necessarily plateau, the polynomial regression or GAM approach was selected. The chosen equation best fits the plot. In most circumstances, these equations are exponential, power, logarithmic, or trigonometric (Figueiredo, 2017).

Ultimately, the CR's equation fits the curve, whereby defining the GSLR economic impact variables relative to the NRC's GDP. These results also undergo quality assurance (QA) tests through the Spearman Rank correlation. This non-parametric test determines the association between the economic GSLR impacts and the GDP and ensures that all data points are independent of each other.

iv. Results:

1. Canada:

Overall, Canada's access to Arctic resources has increased due to the CC sea ice melt. Oil and natural gas production, exports, and proven reserves are now more accessible with the Arctic's shrinking ice coverage along Canada's shelf, as well as due to extended navigation seasons. As such, Canada's capacity for hydrocarbon exploration and drilling, as well as commercial shipping, has risen in recent years. The following economic analysis cannot conclusively determine CC impact on Canada's GDP, but it can serve as a correlation with Arctic development.

For Canada's economic analysis, performing a linear regression with a CC economic variable, a scatter plot of the GDP against the independent economic parameter provides a good indication of the nature of the relationship. However, as there are multiple CC parameters potentially affecting Canada's GDP when generating scatter plots of the GDP against each of the economic variables, the linear regression does not take into account the effect of the other economic parameters in the model. As such, MLR models were applied to determine the economic variable with the most significant impact on Canada's GDP.

First, Canada's data was accepted as normal, as its PV = 0.6085, > 0.05. Canada's data has a normal distribution, as evident in the boxplots, and does not demonstrate skewness. Additionally, its homogeneity of variance did not show evidence in a spread of data around scatterplot trend lines on the plots of the first column, as the plots generally did not expand or decrease with increasing values of the predictor variables. On verifying the lack of multicollinearity assumption, some predictor variables proved highly correlated (> 0.5) and required removal, including oil reserves, natural gas exports, and production. Upon meeting the multicollinearity assumption, the summary models generated the R^2 coefficient of determination.

R^2 percent is a measure of the regression relationship between Canada's natural gas reserve variation in explaining its GDP variation. Canada's R^2 is 88.9%. This high R^2 percentage demonstrates high confidence in Canada's functional relationship between its natural gas reserves and its GDP. As such, Canada's natural gas reserves significantly explain Canada's GDP, precisely 88.9% of the variation in GDP.

To illustrate Canada's natural gas reserve functional relationship with its GDP, an added variable (AV) plot controls the presence of the other predictors. The AV line slope is the coefficient of Canada's natural gas reserve in the full regression. Each data point equates to an annual reporting statistic for Canada's GDP relative to its natural gas reserve. This partial regression plots the residuals from the fitted line in the AV plot and are the same as the residuals from the complete regression. The AV plot below in figure 8 demonstrates a functional relationship between Canada's GDP and its natural gas reserves.

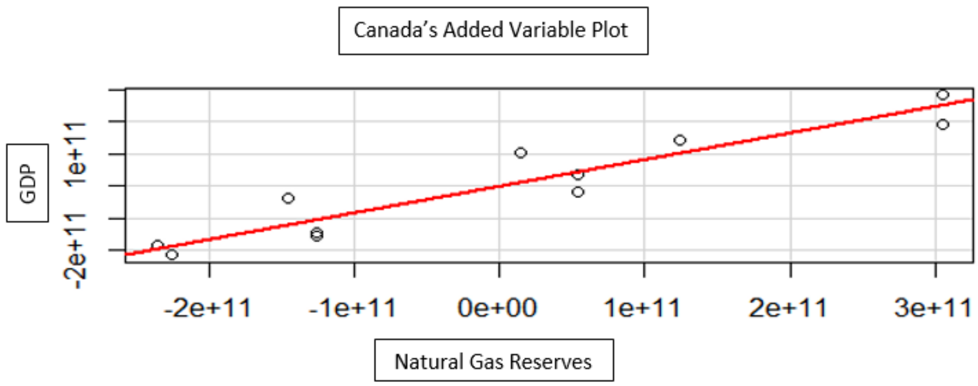


Figure 8: Canada's added variable (AV) plot demonstrates a high functional relationship between its gross domestic product (GDP) and its climate change impacted natural gas reserves.

2. Denmark:

Denmark is also experiencing increased access to the Arctic's hydrocarbon-based resources, as well as expanding shipping lanes due to the sea ice melt. However, despite this regional accessibility, the hydrocarbon-based production numbers have conversely fallen off in recent years. The global market's falling oil prices, diminishing mineral prices, and an overall depletion of existing North Sea oil reserves have ultimately postponed its extraction efforts. However, Denmark's future projects do indicate that its economy is headed for recovery while being further supplemented with increased Arctic shipping opportunities. While the hydrocarbon analysis did not establish a positive correlation with Denmark's GDP, its rising shipping vessel traffic did have a significant economic impact. Again, the following economic analysis cannot conclusively determine CC impact on Denmark's GDP, but it does serve as a correlation with Arctic development.

As with Canada, Denmark's variables were all quantifiable, as all data points were discrete counts of its annual GDP (response variable) and its CC economic impacted parameters (independent variables). As all variables are quantifiable, with implied causality, and multiple predictors, multiple linear regression was again the chosen analytical method. Through performing a MLR with the CC economic variables, this analysis seeks to define the functional relationship between the variables and Denmark's GDP. The resultant best-fit equation, which fits the data linearly, is then modeled with a resultant R^2 percent. This R^2 percentage, on the 0-1 scale, can, therefore, be interpreted for its functional relationship.

However, Denmark's data were not normal, as its determined probability value (PV) = 0.00469, <0.05, as calculated with the Shapiro normality test. With Denmark's PV at < 0.05, it failed the assumption that the data has a normal distribution. This non-normal data was also evident in that it did not have a normal distribution in the boxplots, and it demonstrated skewness overall. Square root transformations applied to the data also failed to meet the required parametric assumptions for MLR. As a result, each of Denmark's CC economic parameters was tested individually against its GDP through curvilinear regression (CR) analysis.

Curvilinear regression permits the user to fit an equation with a curved data line. The selected equation produces a curved line which fits with the data points. The equation fit is next compared to more complicated equations to further define the functional relationship between the variables. Ultimately, CR determines the independent predictor variable's relationship with the dependent variable. For Denmark, predictor's natural gas and oil production, exports, and proven reserve individual scatterplots all reached plateaus with Denmark's GDP. Therefore, the hydrocarbon-based parameters were fit with logarithmic equations, and the model summaries yielded new PV's for each parameter. Upon performing the parameter model summaries, all PV's were < 0.05, which indicates that each hydrocarbon parameter holds a significant impact on Denmark's GDP. See appendix B for Denmark's transcript for detailed results.

While the hydrocarbon-based parameter scatterplots plateaued, Denmark's merchant marine shipping data did not, which therefore warranted polynomial regression. The vessel data was fit to a polynomial model of a higher order and then compared to the fit of models of a lower order polynomial. Upon establishing a PV at > 0.05, the null hypothesis proved acceptable, and the lower order model summaries yielded a PV at < 0.05. This new PV, therefore, also determined that merchant marine shipping numbers also holds a significant impact on Denmark's GDP. This is likely due to the impact from Maersk Group, in which ~50% of its fleet is under the Danish flag. In 2012, the Maersk Group contributed 2.5% of the country's total gross domestic product (Infographic, 2015). See the figure below, which plots the shipping vessel functional relationship with Denmark's GDP.

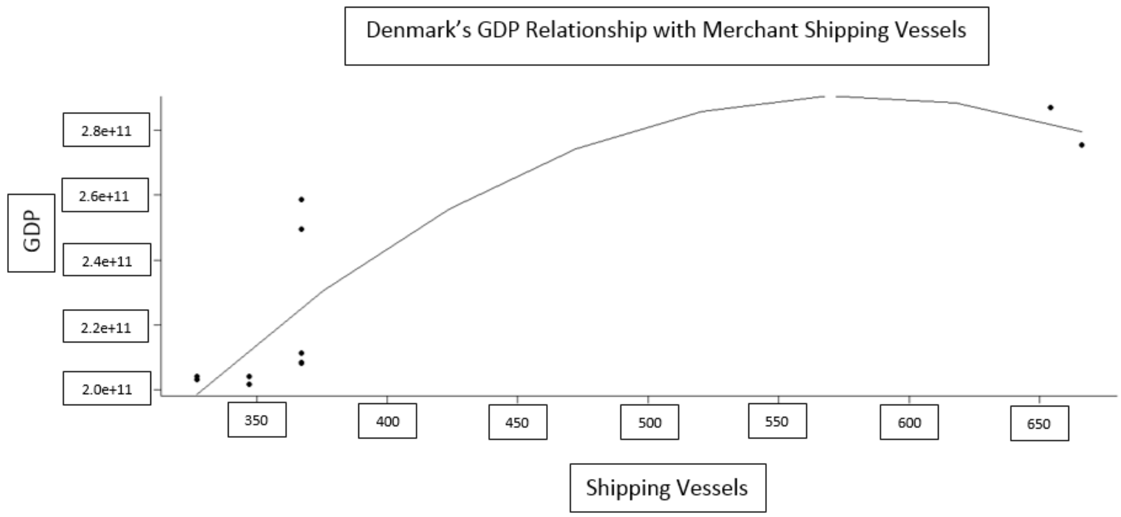


Figure 9: Denmark's curvilinear regression results: gross domestic product (GDP) relationship with merchant mariner numbers.

3. Finland:

Finland's dataset (see appendix A) excluded oil reserves and natural gas exports and proven reserves, as there was no production in these fields. It also ceased producing oil exports after 2011, and oil production overall in 2014. Primarily, the remaining GDP functional relationships were consequently limited to its natural gas production and merchant marine shipping vessels. Overall, Finland is also experiencing increased access to the Arctic's hydrocarbon-based resources and expanding shipping lanes due to the sea ice melt. However, although the ice melt improved Finland's accessibility, the global economy shifted due to US shale hydraulic fracturing, and high Persian Gulf production, which inundated the oil market. The lower overall crude oil prices, being $60.07 per barrel (Macrotrends, 2019), has limited Finland's Arctic extraction viability. Finland's Arctic production efforts were further dampened by environmental opposition, harsh Arctic weather, and uncharted waters. To date, most oil exploratory attempt have yielded disappointing results. See the world-historic oil price trend graph below.

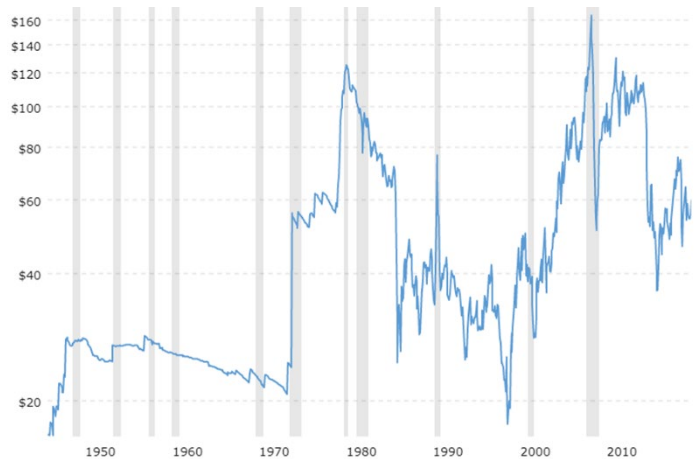


Figure 10: West Texas Intermediate (WTI or NYMEX) crude oil prices per barrel (1946-present) (Macrotrends, 2019).

For statistical analysis, Finland's quantifiable variables had implied causality and warranted the MLR approach in determining its GDP relationship with the CC economic variables. Finland's data were not normal, as its initial was PV = 0.04447, < 0.05, it did not have a normal boxplot distribution, and it also demonstrated skewness. However, after performing square root scale transformations, the scatterplot data point corrected the linearity, and its homogeneity of variance did not expand or decrease with increasing predictor values.

Next, although some economic predictor variables were highly correlated (>0.5), its variance inflation was < 5; and its tolerance was > 0.2. As such, there was no multicollinearity, and the analysis met all assumptions. Summary models generated the R2 coefficient of multiple determinations, in which its percent's were interpreted for the economic parameters functional relationship with Finland's GDP. Specifically, natural gas production significantly explains Finland's GDP, at 94.6% of the variation in GDP. Again, the following economic analysis cannot conclusively determine CC impact on Denmark's GDP, but it does serve as a correlation with Arctic development. See the figure below, which plots Finland's natural gas production and its functional relationship with its GDP.

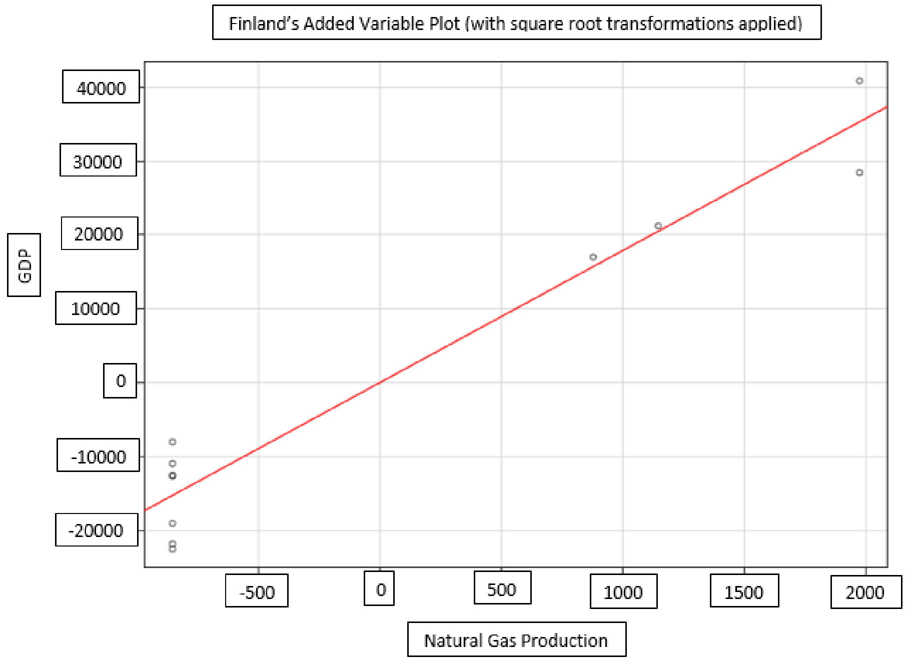


Figure 11: Finland's added variable (AV) plot, or partial regression plot, between its gross domestic product (GDP) and its natural gas production.

4. Iceland:

Initial dataset import excluded: oil products, reserves, natural gas products, exports, reserves, as Iceland does not have any generated for the years in this study. Due to the limitation in data present, only two data points were available, being oil exports and merchant marine shipping vessels. Further, Iceland ceased oil exports in 2011. Although it's shipping vessels increased by 31 vessels from 2017-2018, overall the data limitations did not permit adequate analysis. The data limitations did not allow establishing a statistical relationship, and therefore could not be performed. Appendix A and B include the Iceland dataset and R script attempt.

5. Norway:

Overall, Norway is gaining Arctic access through sea ice melt, including continental shelf hydrocarbon exposure and expanding shipping lanes. However, Norway has also failed to improve its GDP through this access, as the extraction logistical difficulties are prevalent with its Arctic expeditions. Despite CC improving Norway's access through ice pack reduction, oil and gas extraction proves problematic when factoring the Arctic's icebergs and floes. Additionally, CC intensifies Arctic weather and storms, while onshore permafrost thaw complicates pipeline and support facility construction. Additionally, the Arctic has limited airports and roads, as well as insufficient search and rescue resources. Oil companies report that current Arctic hydrocarbon extraction costs 3-5 times more expensive than onshore (Myers, 2015).

For statistical analysis, Norway's data were not normal in distribution, as its initial was PV = 0.03764, <0.05. Its non-normal data was evident in that it did not have a normal distribution in the boxplots, while also demonstrating skewness. However, after performing a square root scale transformations, the Shapiro-Wilk normality test calculated a PV = 0.04616, = 0.05, while also improving the scatterplot data linearity. The data homogeneity of variance also did not expand or decrease with increasing values of its predictors. Next, the Norway data met the lack of a multicollinearity assumption with the highly correlated (> 0.5) variable removal. Oil reserves, natural gas exports, and production held the highest correlations. Upon removal, the multicollinearity test confirmed the data variance inflation was at < 5, and its tolerance was > 0.2. As a result, Norway's analysis met the parametric assumptions. The summary model resulted in oil exports significantly explaining Norway's GDP, precisely 69.3% of the GDP variation. See the added variable (AV) plot below, which illustrates Norway's GDP relationship with oil exports. This plot highlights the marked drop-off in oil exports over the past ten years, despite CC and Arctic warming. See Appendix A and B for the Norway dataset and R script.

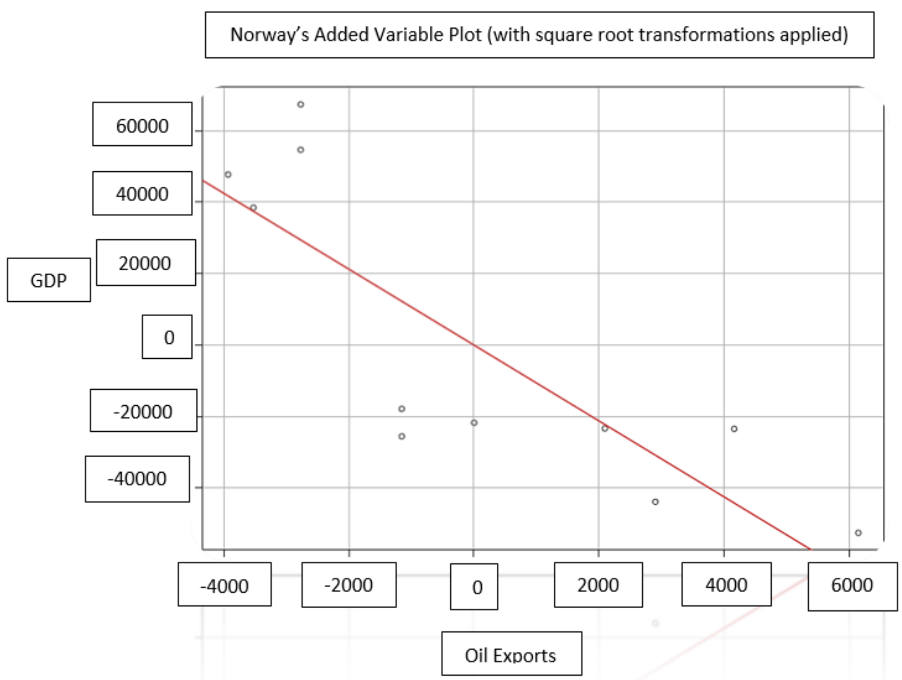


Figure 12: Norway's added variable (AV) plot between its gross domestic product (GDP) and its oil exports. Norway's export production dropped significantly in recent years, despite improved accessibility to new proven reserves.

6. Russia:

The multiple linear regression (MLR) analytical approach again sought to establish Russia's CC economic parameter relationship with its GDP. However, Russia's data were not normal, with the Shapiro-Wilks resultant PV = 0.01328, < 0.05. This non-normal data was evident in that it did not have a normal distribution in the generated boxplots, and also demonstrated skewness. Even after performing both square root and log10 scale transformations, the PV remained < 0.05. As the data did not meet the parametric assumptions, even after transformations, curvilinear regression (CR) analysis tested each independent variable against Russia's GDP.

Curvilinear regression permits statistical analysis with non-parametric data through fitting an equation on Russia's curved data line. Each CC predictor variable with non-linear data was fit with logarithmic equations to match the data's curve. For relationships that reached a plateau, the logarithmic summary models established new PVs. Oil production, exports, and reserves; natural gas exports and reserves; and merchant shipping models yielded PVs < 0.05, which indicates that they hold a significant impact on Russia's GDP.

However, upon processing natural gas production, its scatterplot data did not reach a plateau and therefore required polynomial regression. Russian gas production data was first fit to a polynomial model of a higher order and then compared to the fit of models of a lower order polynomial. Upon establishing that the models were equal, the null hypothesis proved acceptable, and the lower order model summary yielded a PV = 0.5049. Ultimately, this >0.05 PV indicates that Russia's natural gas production does not have a significant impact on Russia's GDP. See the figure below for Russia's relationship with its oil production, and see the appendix B, Russian R script, for the detailed analysis.

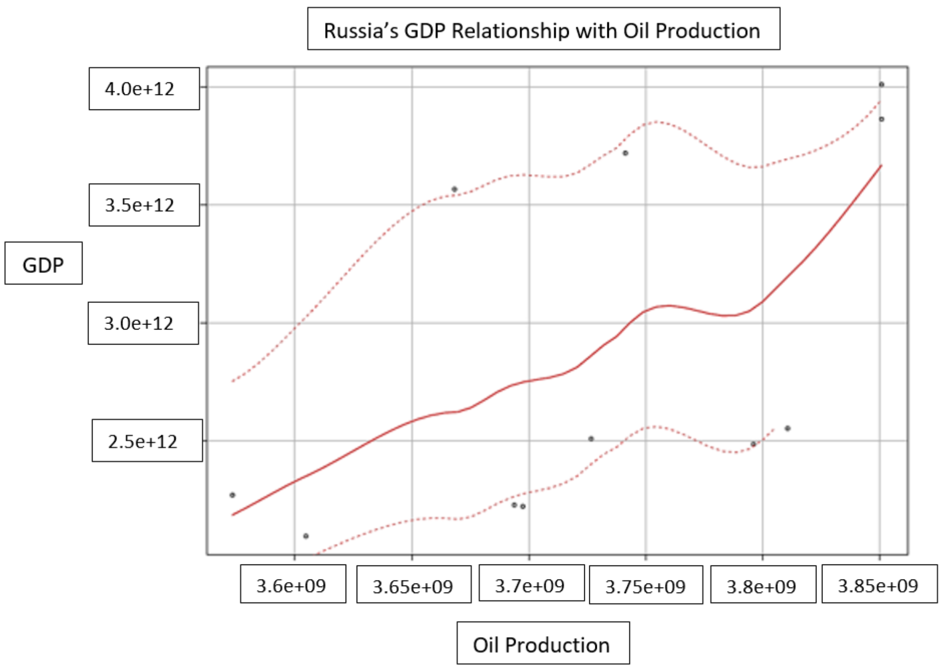
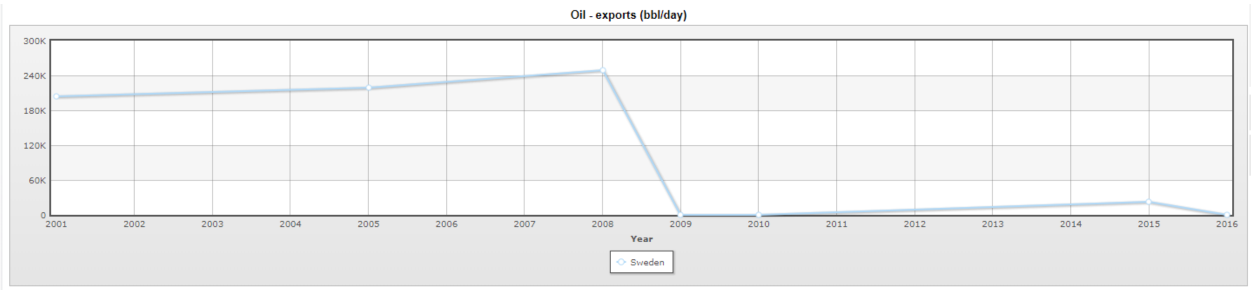


Figure 13: Russia's curvilinear regression plot: establishing the functional relationship between its gross domestic product (GDP) and oil production.

7. Sweden:

Sweden's statistical analysis included datasets with reported oil exports during the study's timeframe (2008-2018). However, Sweden does not have oil reserves, as its geology is metamorphic crystalline basement rock. Although this geology contains appreciable metal deposits, it is not a source of crude oil. Therefore, Sweden is heavily dependent on oil imports from Norway, Denmark, and Russia. These NRC's extract crude oil from the North Sea for export. Sweden's own reported oil export statistics result from its refinery capacity. During the time of this study, Sweden imported more oil than it consumed, in which its efficient refineries turned the excess oil into exports towards its GDP. However, in 2007, Sweden's benefit from this oil refinery decreased drastically due to the North Sea oil reserve depletion. As a result, oil exporters dropped distribution shares to Sweden (EIA, 2012). Moreover, Sweden's statistical complications resulted from the 2009 recession. Sweden's overall GDP fell by 6.5% due to a negative economic trend, while its industrial production dropped by 9.0%. Sweden's economic stagnation, industrial production decline, and the North Sea oil reserve depletion all contributed to the end of Sweden's oil exports (theglobaleconomy.com, 2019). Although Sweden's GDP is not a result of the CC parameters, its oil export statistics do translate into potential economic ramifications with an overreliance on fossil fuels. Sweden's oil export decline in 2008 is evident in the figure below. (CIA World Factbook, 2019).



Country	2001	2005	2008	2009	2010	2015	2016
Sweden	203,700	219,200	248,500	0	0	23,210	0

Figure 14: Sweden's oil refinery and export decline in 2008 from the depleted North Sea oil reserves (retrieved from indexmundi.com, compiled with CIA World Factbook Data, 2019).

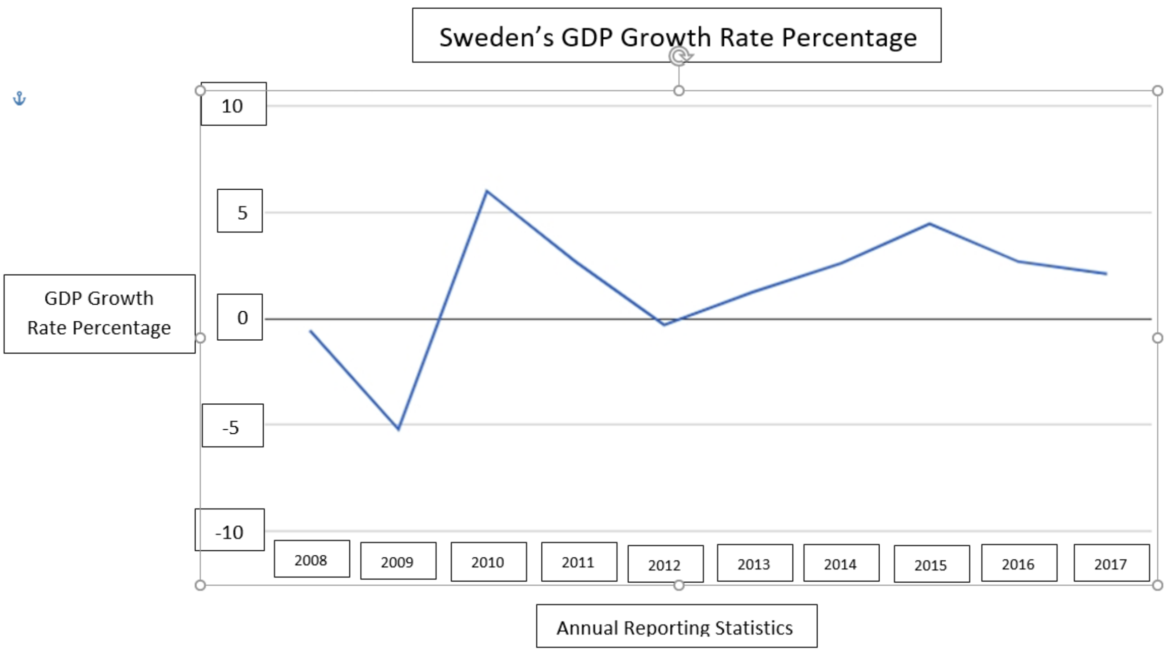


Figure 15: Sweden's GDP growth rate percentage, indicates the evident 2009 recession, as impacted by depletion of the North Sea oil reserves (retrieved from: TheGlobalEconomy.com, World Bank, 2019).

For Sweden's statistical analysis, its data were normal, and its scatterplot held linear trend lines. The Shapiro-Wilk test (H0: data is normal) PV = 0.154, >0.05, while the data's homogeneity of variance did not expand or decrease with increasing values of its predictors (was not funnel-shaped data). As such, Sweden's analysis met all parametric assumptions.

Next, Sweden's lack of multicollinearity assumption verified its variance inflation at < 5, and its tolerance was > 0.2. As there was no multicollinearity, the data were then fit into a multiplicative model. Through using the stepwise forward method, Sweden analysis began with the simplest model and then added variables to it to determine which parameters held a significant effect on its GDP. Each predictor was tested separately to determine which had the most significant impact. In the end, the GDP and oil exports model held the highest significance, with the summary model concluding that oil exports significantly explain Sweden's GDP, precisely 54.3% of the GDP variation. An AV Plot illustrates Sweden's GDP relationship with oil exports, and highlights the marked drop-off in oil exports over the past ten years, despite CC and Arctic warming. See Appendix A and B for the Sweden dataset and R script.

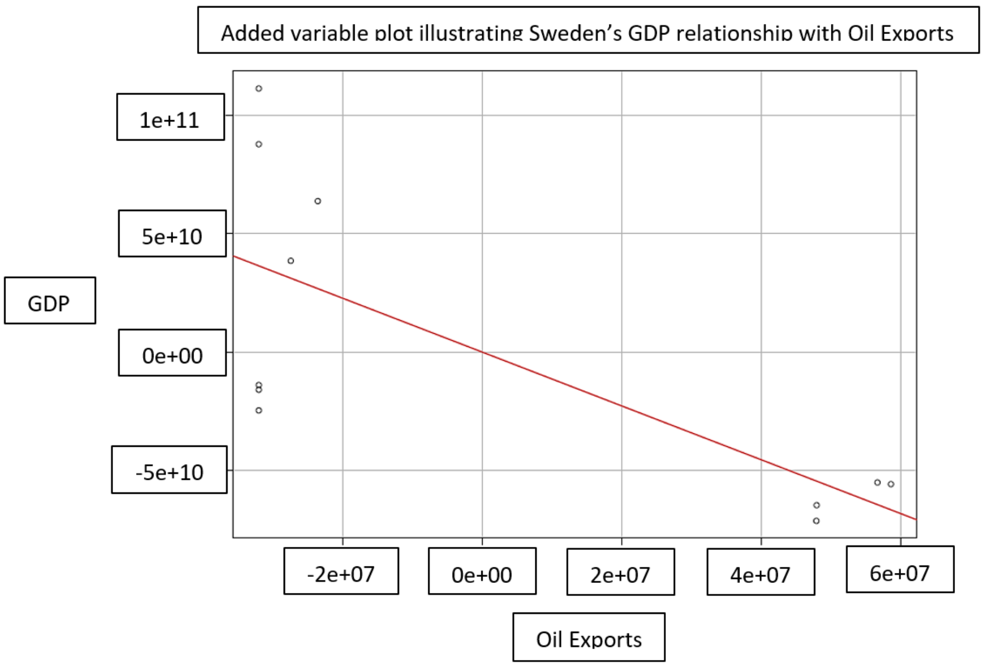


Figure 16: Sweden's added variable (AV) plot between its gross domestic product (GDP) and its oil exports, which experienced a drastic reduction following 2008.

8. United States:

For the United States (US), this capstone's statistical analysis approach is limited, as the US has the world's largest economy. As such, many factors contribute to the GDP, in which the resultant GDP variation derived from this analysis cannot designate its oil reserves as the primary contributor. Rather, this analysis must instead hold interpretation in establishing the functional relationship between US oil reserves and its GDP. However, the study is restricted from putting stock in the numeric determinations from the analysis. Despite these limitations, the analysis does establish a functional relationship with the US GDP and its CC economic parameters.

This analysis first confirmed the data were continuous and held implied causality between the variables. As such, MLR was again established as the analytical approach in determining the

US GDP relationship with CC. The US data proved normal, with a linear scatterplot and a Shapiro-Wilk test result with a PV = 0.6803, >0.05. Additionally, the data homogeneity of variance did not expand or decrease with increasing values of the predictors, and it did not resemble a funnel shape.

Next, the lack of multicollinearity test established a high correlation between natural gas production, export, and reserve (> 0.5 variance inflation (VIF) and tolerance at < 0.2). This high correlation required parameter removal from the model until meeting the multicollinearity assumption with a VIF < 5 and tolerance > 0.2. Upon meeting all parametric assumptions, a multiplicative model was fit for MLR analysis. To process, the stepwise forward method began with the simplest model and then added variables in determining which variable led to a significant effect. The US summary model concludes that oil reserves significantly explains the US GDP, precisely 76.9% of its variation. See the added variable (AV) plot below, which illustrates the US's GDP relationship with its oil reserves. See Appendix A and B for the US dataset and R script.

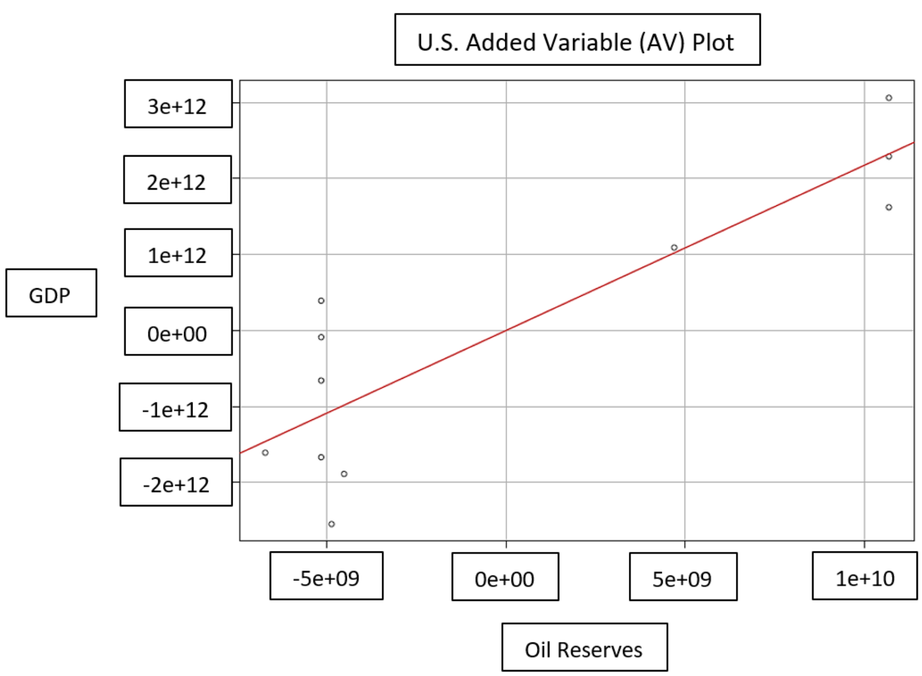


Figure 17: US Added Variable (AV) Plot between its Gross Domestic Product (GDP) and its Oil Reserves.

The graph below portrays the R^2 findings, which is the percentage calculation of the primary predictor accounting for each countries variation in GDP. The R^2 percentage is the end determination as to how well the regression equation fits the data. The $R^2$is the coefficient of multiple determination, in which 0% = no relationship between the country's GDP and the climate change economic parameters. However, 100% = a perfect equation fit, in which there is no difference between the observed and expected values. Through using this statistical analysis, this capstone ultimately aimed to understand the functional relationship between each northern rim countries GDP and the CC economic impact of. See the GDP variation figure below, in which the R^2values indicate the level to which the statistical analysis established a functional relationship between each country's GDP with the economic CC parameters.

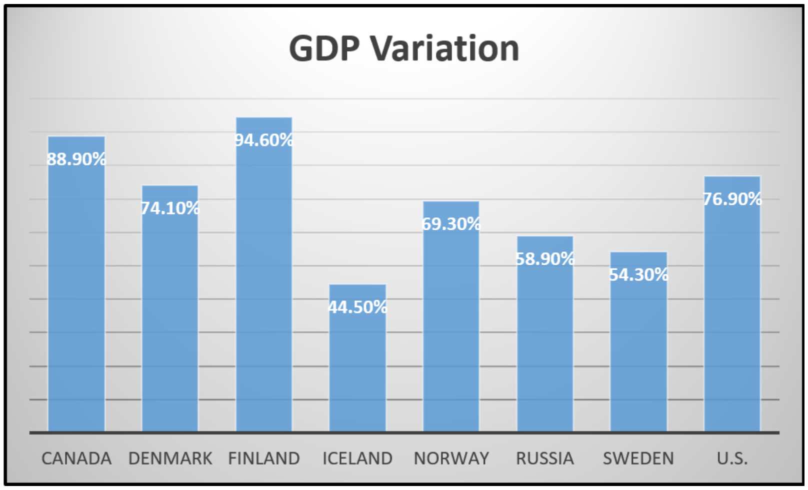


Figure 18: Bar graph displaying each NRC's variation in GDP, based on the R^2percentage calculated in the statistical analysis. Each percentage represents the GDPs functional relationship with the climate change predictor variables.

While this statistical analysis is not conclusive, it does give insight into each country's GDP relationship with the CC impacted economic parameters.

2. Sea Level Rise: Ice Decline, Tidal Analysis, and Sea Level Trends

A. Ice Decline

Current ice decline projections estimate that GSLR will continue as it has over the past 30 years. GSL rates increased by ~2mm (0.078") /year during the 20th century (Willis, 2010). Global sea level rise impact assessments integrate climatology model predictions, geological record comparisons, and supportive case studies. Scientists first generate accurate GSLR estimates through factoring ocean, land, ice, and atmospheric inputs. Specifically, GSLR models include rising ambient temperatures, ocean water thermal expansion, coastal land subsidence, and increased land ice melt. Additionally, observations, satellite-based altimetry records, and ocean-ice interaction data are used to reinforce the model estimates (Roemmich et al., 2006). Scientists are also able to ascertain accelerated ice melt with time-lapse cameras and submerged electronic sensors (Smith, 2011). Policy planning must next integrate GSLR impact assessments with Arctic coastline, communication, and infrastructure vulnerabilities and damage probabilities. Global sea level rise impacts require additional considerations through social, economic, cultural, and ecological perspectives. Arctic coastal zone management must, therefore, develop effective mitigation and adaptation strategies (Kumar, 2006).

Since 1978, satellite observations have been tracking monthly ice deterioration, while also highlighting notable events. For example, in 2002, extreme conditions developed, in which an earlier springtime melt combined with the ice failing to return to the post summertime melt. Arctic scientists observe these monthly ice average patterns to determine the Arctic's natural variability. Ice pattern analysis can then predict significant atmospheric circulation oscillations and warming temperatures (NASA, 2005). The Arctic's decreasing ice range is evident with satellite imagery tracking its recession over the past few decades. As climate change and global warming intensify, the ice extents recede further with each summer, and fails to recover during the winters. The image below captures this trending ice recession.

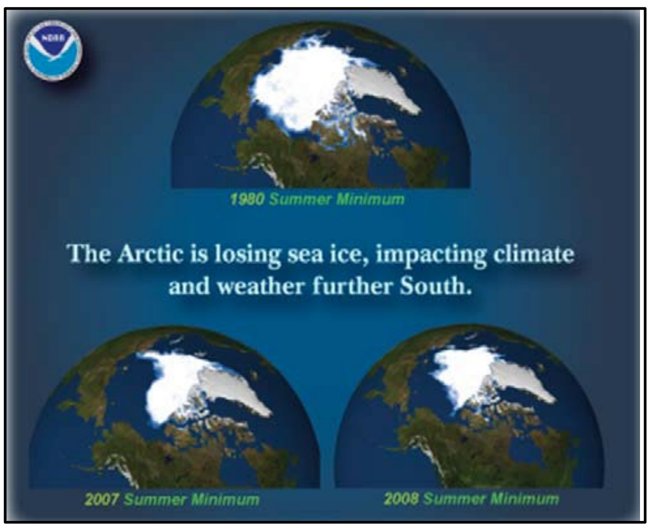


Figure 19: Sea Ice Decline. NOAA's Arctic Vision & Strategy (from NOAA, 2011).

The graph below further depicts the falling area coverage of the Arctic's sea ice. As the decades track the coverage in square kilometers, a noticeable decline is evident beginning in the early 2000s. Whereas in the late 1990s, the Arctic covered > 6 million km^2, it currently ranges to < 4 million km^2. Unfortunately, this sea ice declining trend presently continues unabated.

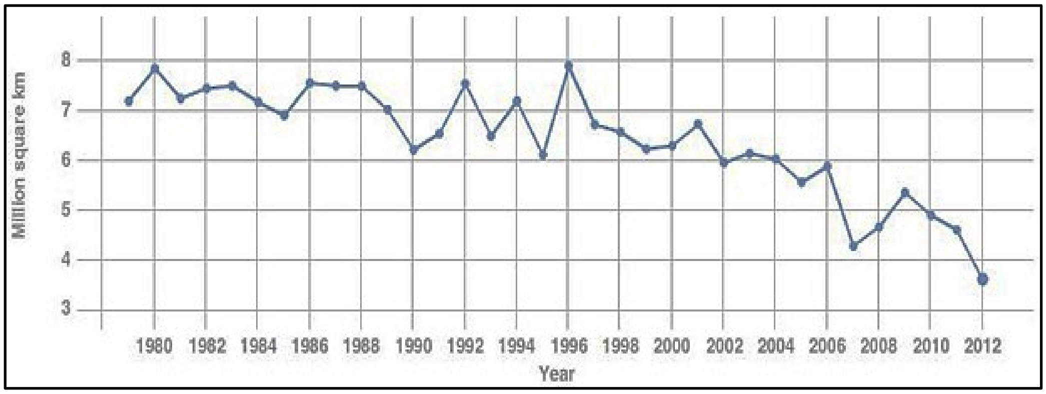


Figure 20: Annual Summer Sea Ice Decline (Masters, 2013).

The total GSLR impact depends on climate change, sea level, and management strategies. Presently, integrated model outputs predict a higher inundation flooding frequency throughout low-level coastal areas, resulting in periodic and permanent effects. Mitigation requires identifying vulnerable areas through coastal planning and research. Arctic assessments must also include the integration of top impact events (i.e., ice-sheet collapse) to form coastal climate policies (Nicholls, 2003). Global sea level rise planning must establish impact guidelines, adaptation processes, and support policy response. Impact assessments should also provide flood plain mapping and hazard boundaries (Capital Regional District, 2015). Additionally, GLSR economic impacts require effective policy and land use regulations. These impacts include transportation, communication, and business disruptions, as well as shoreline erosion and infrastructure storm damage (Showstack, 2000).

Despite the advancement in climatology, the science community does maintain a level of skepticism towards GSLR's tracking reliability. Climatologists are in consensus that CC is occurring, due to anthropogenic impacts from CO2 emissions, deforestation, and methane production. However, the climate change estimated impact overall remains uncertain, due to the required assumptions and simplifications in modeling outcomes. Additionally, models often generate conflicting impact estimates with different measurement and mechanism methods (Nicholls, 2003).

Satellite-radar altimeter observations and tide gauge records provide direct GSLR measurements. NOAA generates tide gauge predictions through data trends, hydrographic observation, temperature, and salinity inputs. This output ultimately results with a GSLR at ~1.5 - 2 mm (0.059 - 0.078") per year (Louis, 2017). In contrast, scientists also gauge ocean volume and mass variability by measuring ice melt and thermal expansion (Showstack, 2000). This

Indirect approach derives GSLR through tracking the ocean's mass and volume change from temperature and salinity data. These indirect calculations contrast with gauge measurements with a lower GSLR, being ~0.5 mm (0.019") per year (Miller & Douglas, 2004). This prediction discrepancy between methods could be due to tide gauge amplification. Gauge amplification can result from localized warming, glacial isostatic adjustments, or coastal epeirogeny. As such, some tide stations may require an additional correction (Miller& Douglas, 2006).

B. Tides Analysis:

The tidal data source of this study is from the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service (NOS) Center for Operational and Oceanic Products and Services (CO-OPS). CO-OPS collects and distributes observed and predicted water levels (WL) and currents data. This data ultimately supports safe maritime commerce shipping. The National Water Level Observation Network (NWLON) and Physical Oceans Real-Time Systems (PORTS) programs manage tidal and current information. These networks collect WL and currents data for branch processing, QC, and dissemination to the US public (Louis, 2017). This study utilizes the Alaskan (AK), Washington (WA), and Oregon (OR) tidal stations and sea level (SL) trends to determine the GSLR impact in the Arctic region.

The Earth's tidal phases stem from the sun and moon's gravitational forces. Additionally, the oceanic tidal rise and lowering WLs experience localized impacts due to coastal and seafloor geography. CO-OPS records this tide ranges through its NWLON of approximately 250 WL stations. CO-OPS has stations throughout the US east, west, and Gulf coasts, as well as the Great Lakes region. Ultimately, the collected data provides a vertical tidal datum control for the US (Louis, 2017).

Within this network, CO-OPS designates long-term stations as primary controls for computing the National Datum Tidal Epoch (NDTE). Mainly, datum control stations obtain continuous coastal WLs for > 19 years, with planned future operations. Control stations provide the continuous WL record for its given locality and serve as a datum control for its national application. Control station installation and maintenance, therefore, requires high precision to maintain accuracy. The station components consist of a microwave water level (WL) sensor, a shelter for electronic component housing, solar panels, backup batteries, a backup WL sensor (air pressure system), and ancillary geophysical instruments. The collected data is transmitted via a GOES antennae every six minutes for near-real-time data records. The station transmits the tides elevation data for compilation and reporting through NOAA's CORMS (Continuous Operations Real-Time Monitoring System) (Louis, 2017).

Secondary stations are short-term systems, which are installed to supplement larger and more complex geographical areas, which are usually bays, estuaries. They are used to reduce hydrographic survey soundings to MLLW. Secondary stations typically operate > 1 year and < the 19 years required for a control designation. Although secondary stations do not meet the control station standards, NOAA verifies its data with simultaneous comparisons with a nearby control station. Last, tertiary WL stations operate at > 1 month, but < 1 year. These short-term WL stations also have their data reduced to an equivalent 19-year tidal datum with simultaneous comparisons to a nearby control station. This data is also collected primarily for hydrographic survey support (Louis, 2017).All tidal stations require annual calibration to existing land benchmarks with known elevations. This leveling exercise monitors the networks vertical stability (National, 2018). However, the Arctic is a complex and dynamic environment for WL measurements, in which its remote access limits the support required for annual station maintenance. Additionally, the Arctic further experiences severe weather conditions and extreme tidal ranges due to the river and glacial runoffs (Louis, 2017). See images below for the various datum measurements provided by tide gauge stations.

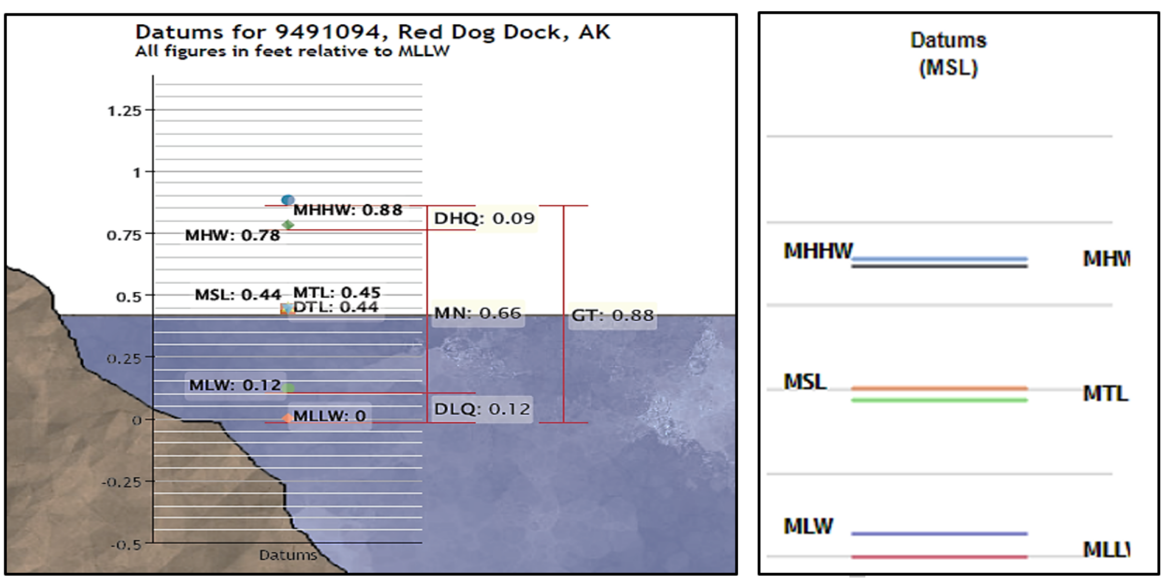


Figure 21: Various datum measurements for a given tidal station (after Louis, 2017).

This study incorporates 16 Arctic and Pacific NW tidal stations, consisting of both control and secondary stations. All chosen tidal data is from the autumn months of 2007 and 2017. August/September best represents SL trends, over the ten years, as global warming annually induces peak ice-melt during this season. Autumn, therefore, corresponds with the highest GSLR potential. This study includes the Pacific NW stations to contrast with the Arctic datums. However, as NOAA's NWLON is US based, the study excludes foreign country tidal data.

This study's selected stations all have adequate time in service to provide SL trends. Additionally, NOAA verifies all tidal data accuracy with annual differential leveling surveys, which confirms the gauges' vertical stability. NOAA surveyors measure the gauge elevation for comparison with an established benchmark network of known elevations. Principally, this benchmark network serves as the gauge's vertical datum reference point. The surveyors verify elevations with an electronic leveling instrument, which measures and records the mark elevations by placing a digital barcode rod on each disk. The network elevations are then compared with the WL gauge to ensure vertical stability. While control stations require a 10+ benchmark network, secondary and tertiary only require five marks. Often, a station loses vertical stability from Earth's crustal movements or changes in local tide characteristics (Louis, 2017).Each station's datum analysis encompasses 30 days from 2007 and 2017 autumn periods. This data was uploaded into the NOS "Tidal Analysis Datum" calculator, which then computes the tidal information for WL analysis. The calculator utilizes algorithms, defined time zones, designated control stations, and quality control (QC) checks to calculate the preliminary datums. The resultant spreadsheet provides station highs, lows, monthly means, and a "least square polynomial curve (LSPC)." The calculator derived elevations for the selected tidal phase, as well as its MWL (Louis, 2017). Ultimately, these datums served as a local WL measurement reference. Elevation accuracy overall depends upon the input data's quality. (National, 2019).

This study generated tidal datums for each selected station during both 2007 and 2017 autumn months (National, 2018). See images below for each stations WL analysis. See Appendix C for each tide datasheets.

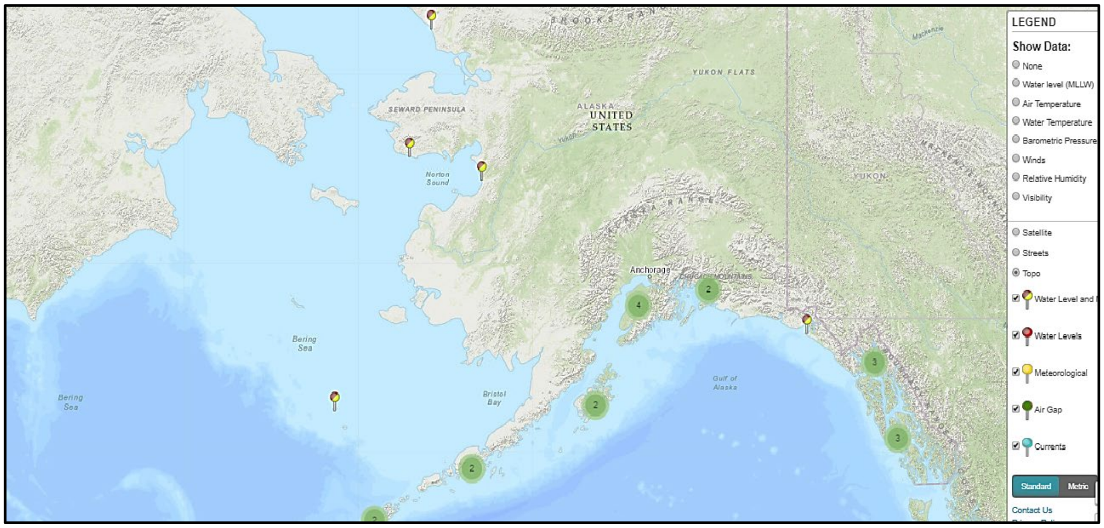


Figure 22: Arctic region for tide stations selected (after National, 2018).

C. Tidal Station Results:

The Arctic tides data analysis itself does not support evidence of GSLR. From the stations analyzed, 9 of the 16 tide stations showed only a slight increase in MSL in the Alaska region over these ten years. However, this unexpected finding is interpreted as the effect of glacial isostatic adjustment, or rebound effect (GIA/GIR). Although this analysis was a simple spot check report, and not sufficiently comprehensive, these results ultimately supports Glacial Isostatic Rebound (GIR) evidence (NOS, 2018). In the graph below, the yearly MSL was plotted against time, while projecting the SL change rates relative to the selected Arctic area. This SL change contrasts with the Arctic's vertical land movement (Figure 24).

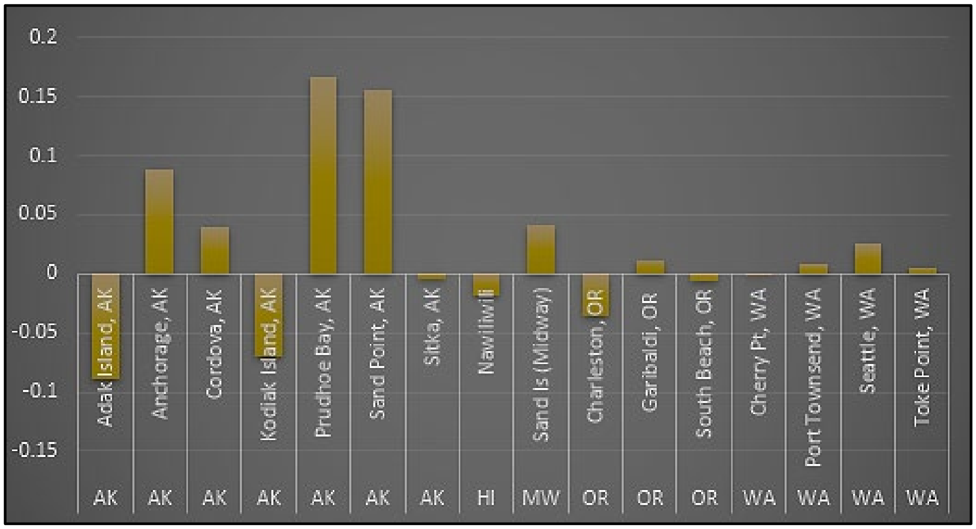


Figure 23: Tidal stations differenced between 2007 and 2017. Note Southeast Alaska stations indicating Glacial Isostatic Rebound (GIR) with falling Sea Level trends, despite Global Sea Level Rise.

In the Arctic, vertical and land movement results from numerous geological processes. These processes include subsidence due to oil and water removal; earthquakes; and glacial isostatic rebound (GIR), due to melting glaciers and plate tectonics. This Arctic vertical land movement factors with its overall water balance (WB), in which the Arctic's WB coincides its polar ice cap and glacier melt with its vertical land mass rise. To accurately represent the WB in the Arctic, the analysis must, therefore, isolate and remove the vertical land movement factors. Upon factoring for vertical land movement, the Arctic's WB remains at ~10-20 cm (3.94-7.87") /century, despite the findings from individual stations (Chen, 2016).

D. United States Sea Level (SL) Trend Results:

This study interpolated the Alaska SL trends through the vertical land motion differences, as evident with the 20th-century Global Sea Level Rise (GSLR), at 1.7 +/- 0.3 mm (0.07 +/- 0.01") /year (NOS, 2018). The graphs below demonstrate the contrast between the Arctic and North Pacific's trending GSLR rates. For the North Pacific, most stations indicate a steady SLR, with positive millimeters measured for the given time recorded. However, in contrast, the Alaskan stations mostly record negative numbers, with the sea level lowering in most recorded places.

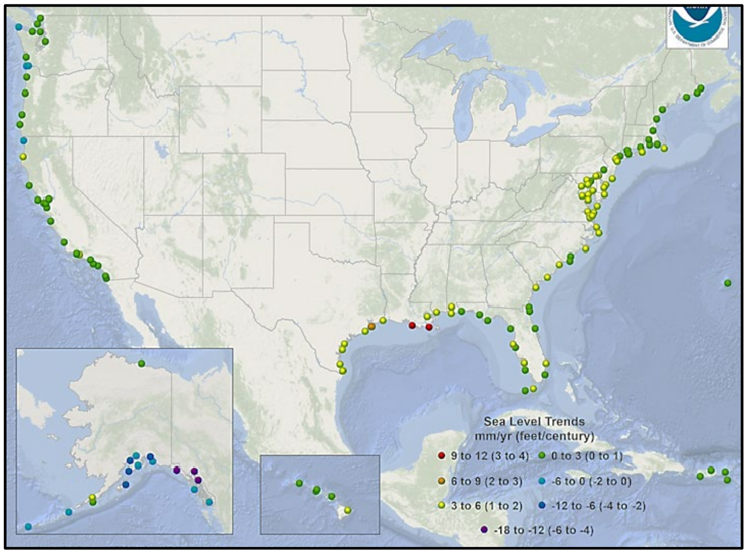


Figure 24: Tidal stations in AK were demonstrating GIR, in stark contrast with the SL trends in all other coastlines over the past century. The Global and US SLR datasets are included in Appendix C (from National, 2018).

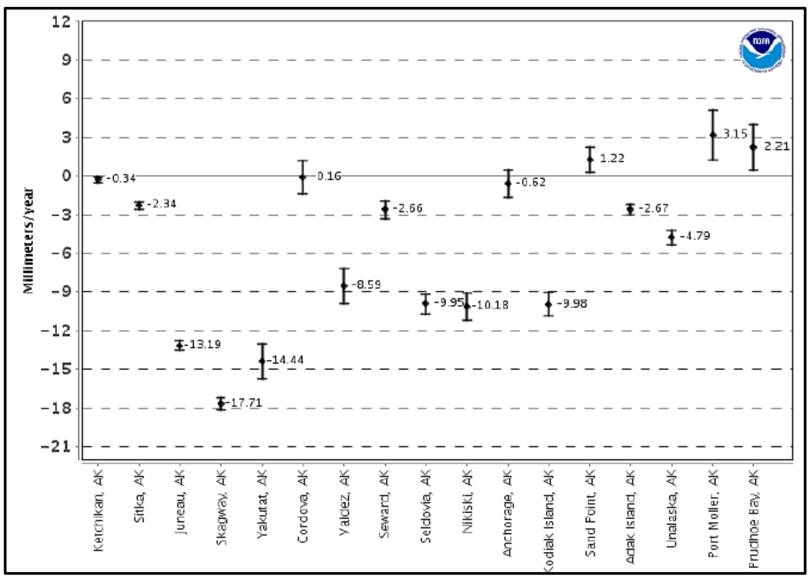


Figure 25: The Sea Level (SL) trend comparison graph for Alaska plots the millimeters/year on the Y-axis and the station's location on the X-axis (95% confidence intervals). Small intervals inversely reflect the more extended datasets, while the larger intervals reflect only ~30-40 years. Datasets extend back to the station's installation date, with the longer intervals indicating a 1940's installation.

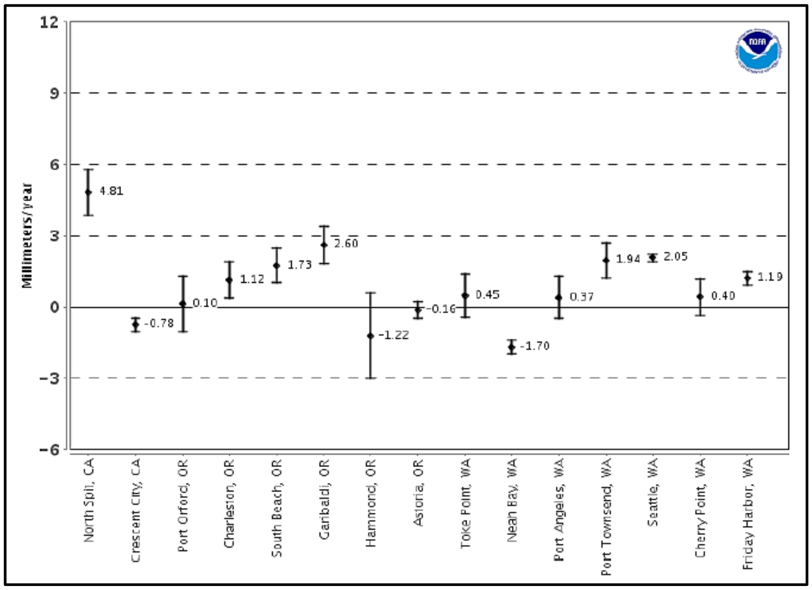


Figure 26: The Sea Level (SL) trend comparison graph for the Pacific Northwest plots the millimeters/year on the Y-axis and the station's location on the X-axis (95% confidence intervals). Small intervals inversely reflect the more extended datasets, while the larger intervals reflect only ~30-40 years. Datasets extend back to the station's installation date, with the longer intervals indicating a 1940's installation.

Global sea level rise model estimations are accurate only through the inclusion of all climate change parameters. Climate change is interdisciplinary, in which models must factor for rising global ambient temperatures, ocean water's thermal expansion, coastal zone subsidence, as well as increased sea ice melt. Additionally, sea-level measurements must reflect an adjustment for coastal epeirogeny. SLR models must, therefore, account for Earth's crustal response to glacial isostatic rebound (GIR) (Schlegel, 2011). As a result, geophysical model accuracy remains heavily dependent upon the proper interpretation of GIR. Recent projections rate the GSLR at ~1-2 mm/year (Miller, 2006).

Accurate GSLR predictions are only possible through an interconnected and interdisciplinary approach. As such, SL trend analysis must include the ocean's mass increase due to glacial ice melt and volume change from global warming's thermal expansion (Miller, 2006). Models also apply subtle gravity field fluctuations, which estimates ice sheet mass loss. Although this study's limitations are through focusing on tides data alone, the provided analysis does indicate that GIR is evident in the region. For further analysis, scientists can combine tides records with ocean models and satellite observations. Through this approach, researchers can ground-truth altimetry data with verified tides, which serves as a calibration technique for modeling projections (Willis, 2010). However, only further calibration, subsequent studies, and extended data periods can

GSLR projections gain accuracy. Scientists must also eliminate data biases by incorporating independent observation systems (Willis, 2010).

E. Tidal Station Sea Level Trend Data:

See the individual station results below, which reports sea levels for the selected period for each station. This study's limitations in the analysis are through available means of data collection. While NOAA established a comprehensive tides network, the US overall does not support a worldwide network. However, the available stations did prove an adequate recorded history in water levels to derive sea level trends. Further analysis gave insights towards the trajectory of each station's SL trends. In this approach, each station's "apparent secular trend" is essentially the slope of a least-squares line of regression throughout recorded mean sea-level values.

i. Adak Island, AK (9461380):

The Adak Island RSL trend derives from the station's 1957-2017 monthly Mean Sea Level (MSL) data, which equates to -0.27m (-0.88') every 100 years. Adak's RSL trend is -2.67mm (-0.11")/yr. with +/-0.41 mm (0.02")/yr. (95% confidence interval). See graph below.

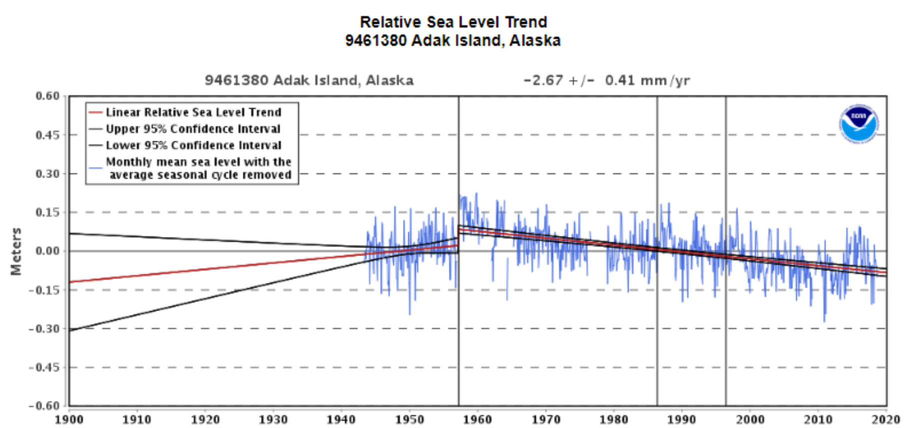


Figure 27: The Adak Island Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

ii. Anchorage, AK (9455920):

Anchorage's RSL trend is -0.67mm (-0.03")/yr. with +/-1.03 mm (0.04")/yr. (95% confidence interval). The RSL derives from the station's 1972-2017 monthly MSL data, which equates to –0.06 m (0.20') every 100 years. See graph below.

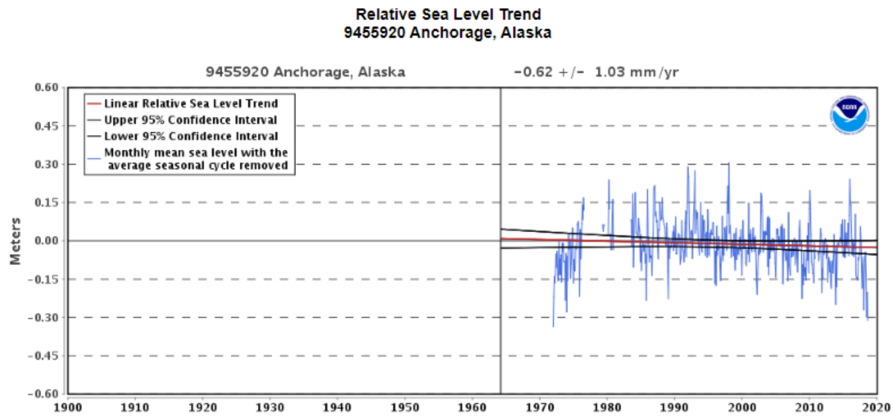


Figure 28: Anchorage Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

iii. Cordova, AK (9454050):

Cordova's RSL trend is -0.16 mm (-0.01")/yr. with +/-1.25 mm (0.05")/yr. (95% confidence interval). The RSL derives from the station's 1988-2017 monthly MSL data, which equates to -0.02 m (0.05') every 100 years. See graph below.

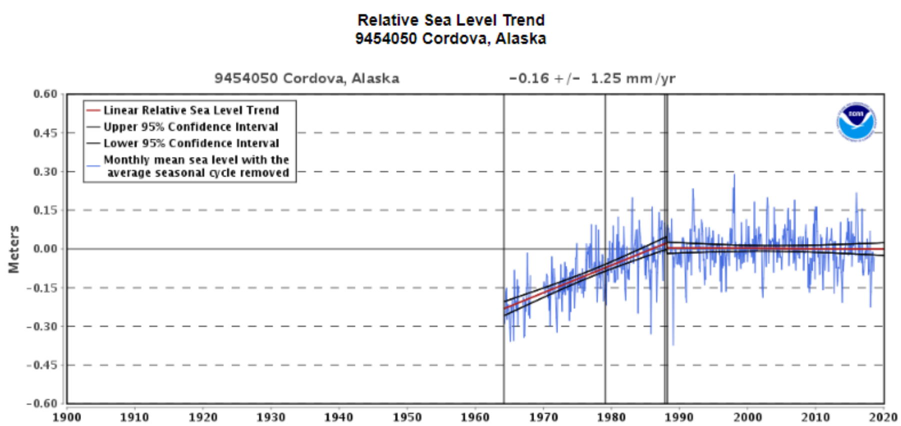


Figure 29: Cordova Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

iv. Kodiak, AK (9457292):

Kodiak's RSL trend is -9.98 mm (-0.39")/yr. with +/-0.91 mm (0.04")/yr. (95% confidence interval). The RSL derives from the station's 1975-2017 monthly MSL data, which equates to -1 m (-3.27') every 100 years. See graph below.

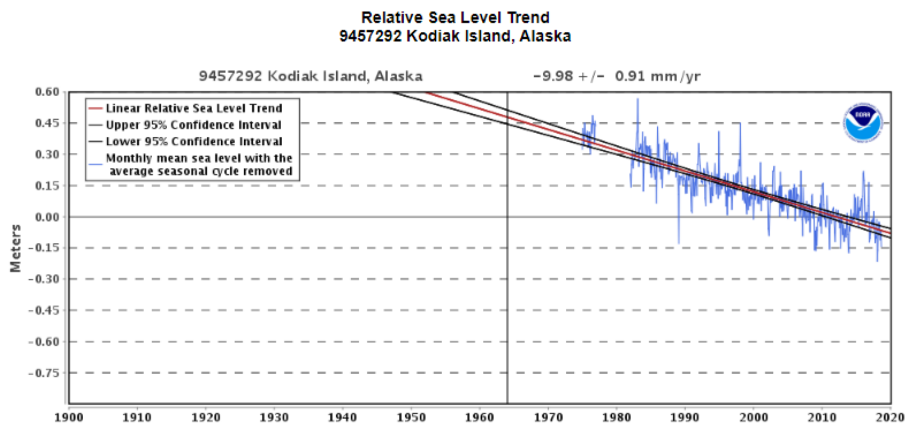


Figure 30: Kodiak Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

v. Prudhoe Bay, AK (9497645):

Prudhoe Bay is the furthest north of all stations in this study. Prudhoe's RSL trend is + 2.21 mm (0.09")/yr. with +/-1.76 mm (0.07")/yr. (95% confidence interval). The RSL derives from the station's 1988-2017 monthly MSL data, which equates to + 0.22 m (0.73') every 100 years. See graph below.

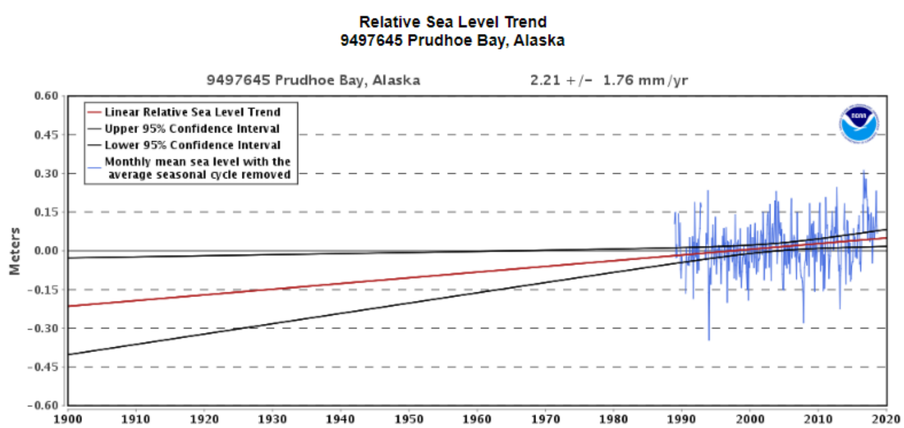


Figure 31: Prudhoe Bay Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

vi. Sand Point, AK (9459450):

Sand Point's RSL trend is + 1.22 mm (0.05")/yr. with +/-0.93 mm (0.04")/yr. (95% confidence interval). The RSL derives from the station's 1972-2017 monthly MSL data, which equates to + 0.12 m (0.40') every 100 years. See graph below.

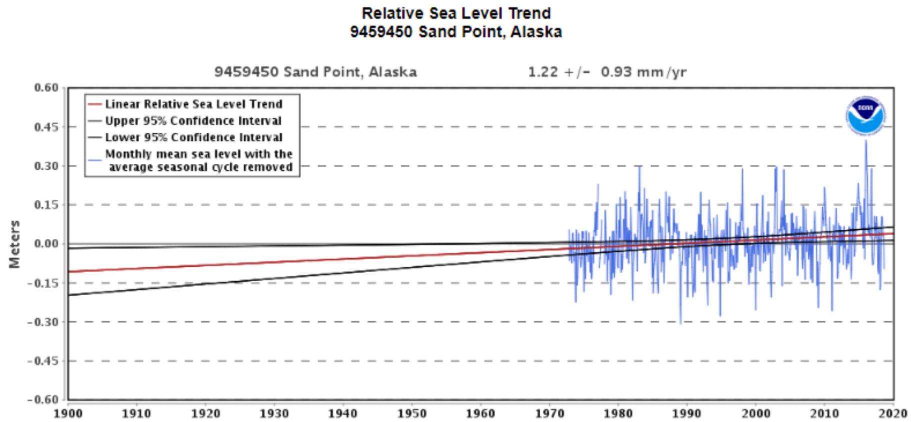


Figure 32: Sand Point Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

vii. Sitka, AK (9451600):

Sitka's RSL trend is -2.34 mm (-0.09")/yr. with +/-0.27 mm (0.01")/yr. (95% confidence interval). Sitka's RSL derives from the station's 1924-2017 monthly Mean Sea Level (MSL) data, which equates to -0.23m (-0.77') every 100 years. See graph below.

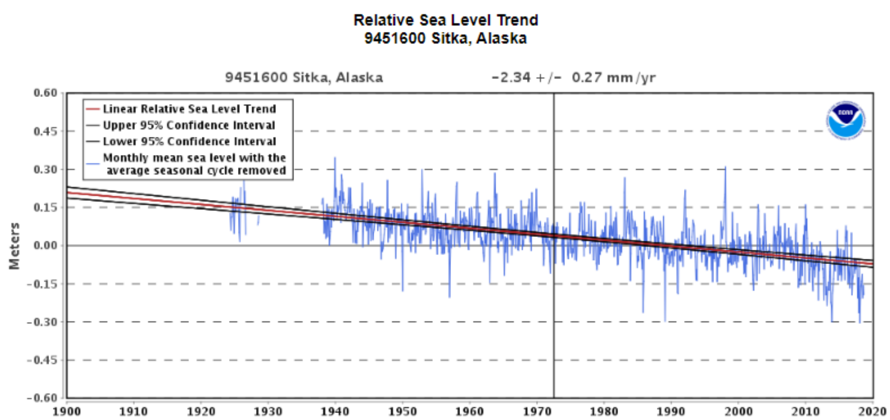


Figure 33: Sitka Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

viii. Nawiliwili, HI (1611400):

Nawiliwili's RSL trend is + 1.65 mm (0.06")/yr. with +/-0.45 mm (0.02")/yr. (95% confidence interval). The Relative Sea Level (RSL) derives from Nawiliwili's 1955-2017 monthly Mean Sea Level (MSL) data, which equates to +0.16m (0.54') every 100 years. See graph below.

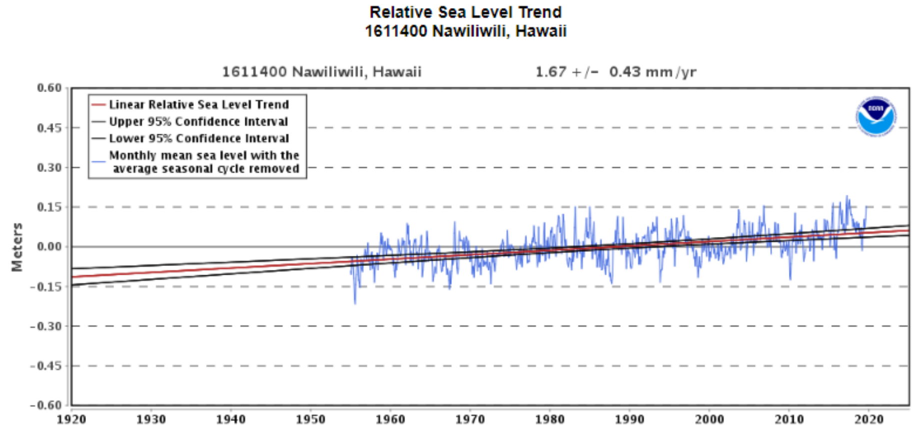


Figure 34: Nawiliwili Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

ix. Sand Island (Midway) Atoll, MW (1619910):

The Sand Island (Midway) Atoll's relative SL (RSL) trend is +1.34 mm (0.05")/yr. with +/-0.43 mm (0.02")/yr. (95% confidence interval). The RSL derives from the station's 1947-2017 monthly MSL data, which equates to +0.13m (0.44') every 100 years. See graph below.

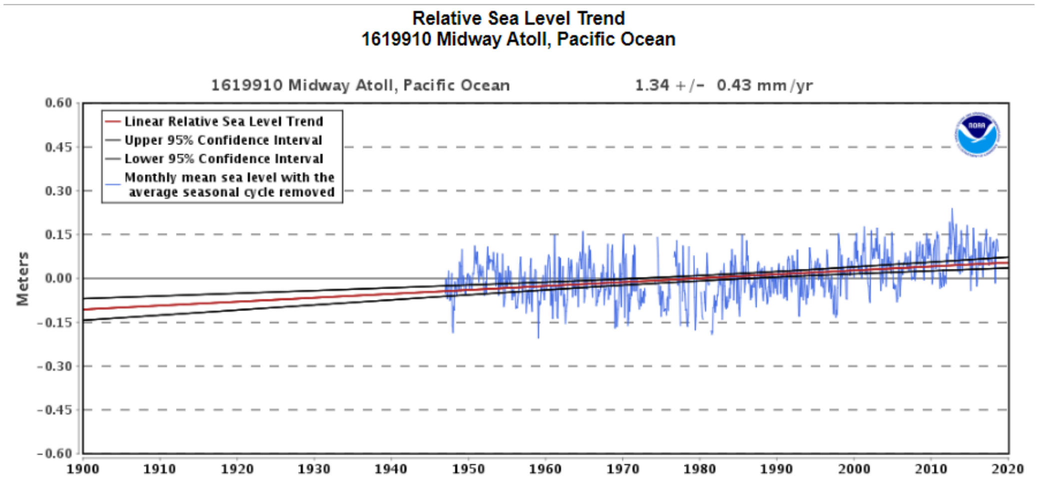


Figure 35: Sand Island (Midway) Atoll Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

x. Charleston, OR (9432780):

Charleston's relative SL (RSL) trend is +1.12 mm (0.04")/yr. with +/-0.77 mm (0.03")/yr. (95% confidence interval). The RSL derives from the station's 1970-2017 monthly MSL data, which equates to +0.11m (0.37') every 100 years. See graph below.

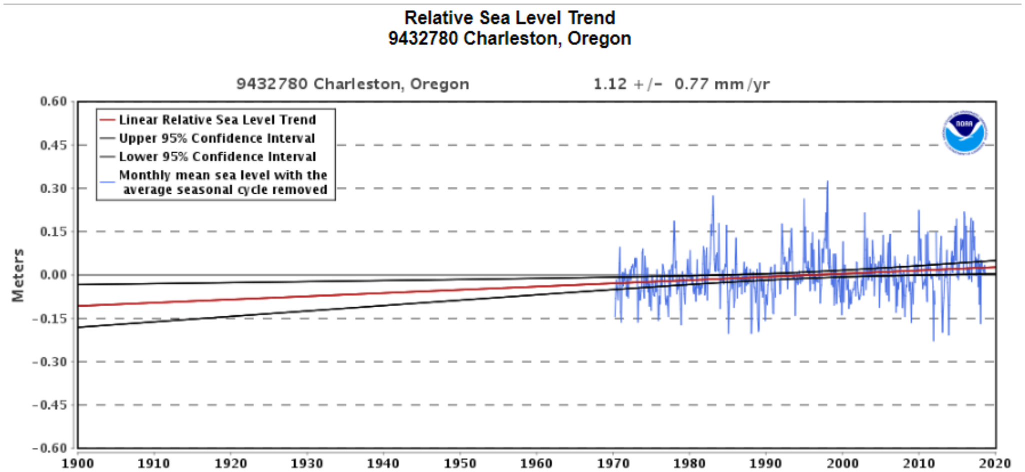


Figure 36: Charleston Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xi. Garibaldi, OR (9437540):

Garibaldi's relative SL (RSL) trend is +2.6 mm (0.10")/yr. with +/-0.79 mm (0.03")/yr. (95% confidence interval). The RSL derives from the station's 1970-2017 monthly MSL data, which equates to +0.26m (0.85') every 100 years. See graph below.

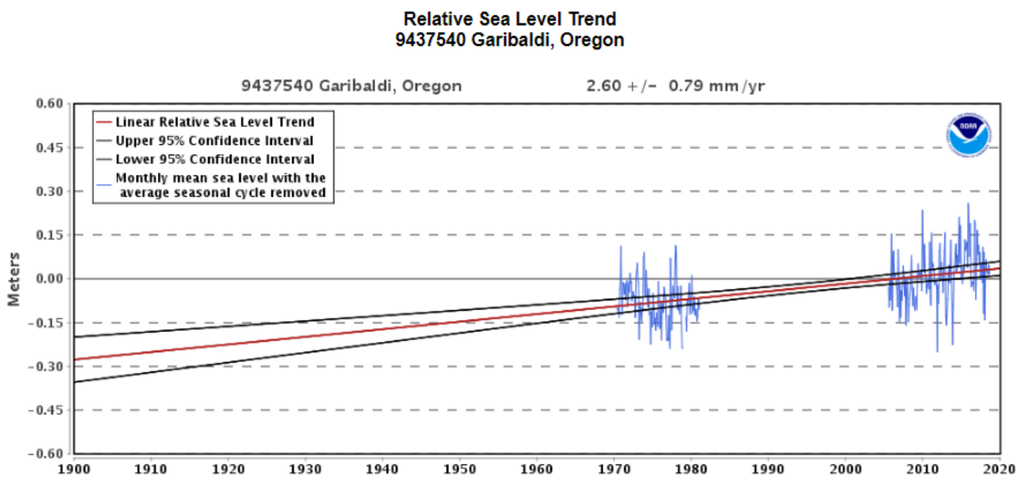


Figure 37: Garibaldi Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xii. South Beach, OR (9435380):

South Beach's relative SL (RSL) trend is +1.73 mm (0.07")/yr. with +/-0.72 mm (0.03")/yr. (95% confidence interval). The RSL derives from the station's 1967-2017 monthly MSL data, which equates to +0.17m (0.57') every 100 years. See graph below.

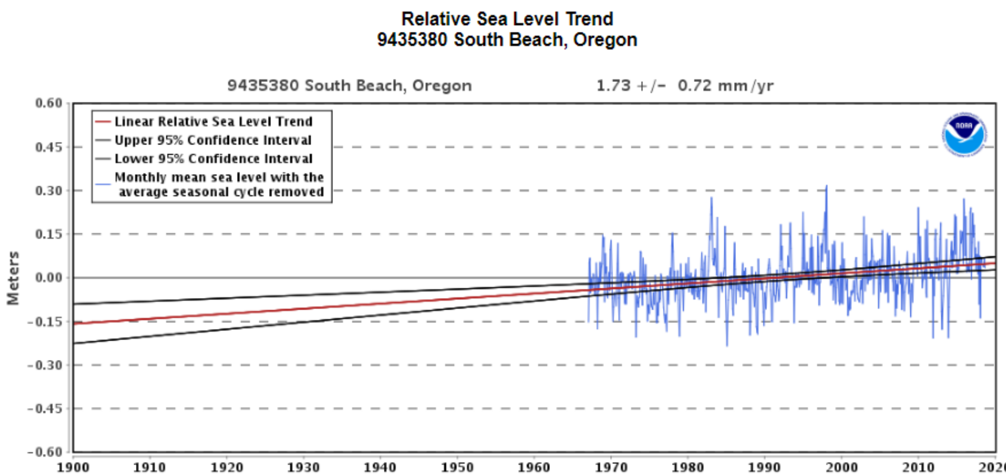


Figure 38: South Beach Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xiii. Cherry Point, WA (9449424):

Cherry Point's relative SL (RSL) trend is +0.4 mm (0.02")/yr. with +/-0.76 mm (0.03")/yr. (95% confidence interval). The RSL derives from the station's 1973-2017 monthly MSL data, which equates to +0.04m (0.13') every 100 years. See graph below.

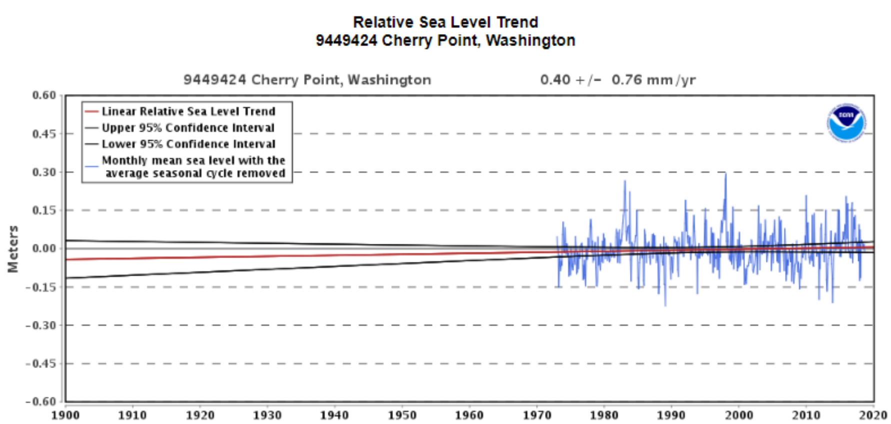


Figure 39: Cherry Point Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xiv. Port Townsend, WA (9444900):

Port Townsend's relative SL (RSL) trend is +1.94 mm (0.08")/yr. with +/-0.75 mm (0.03")/yr. (95% confidence interval). The RSL derives from the station's 1972-2017 monthly MSL data, which equates to +0.19m (0.64') every 100 years. See graph below.

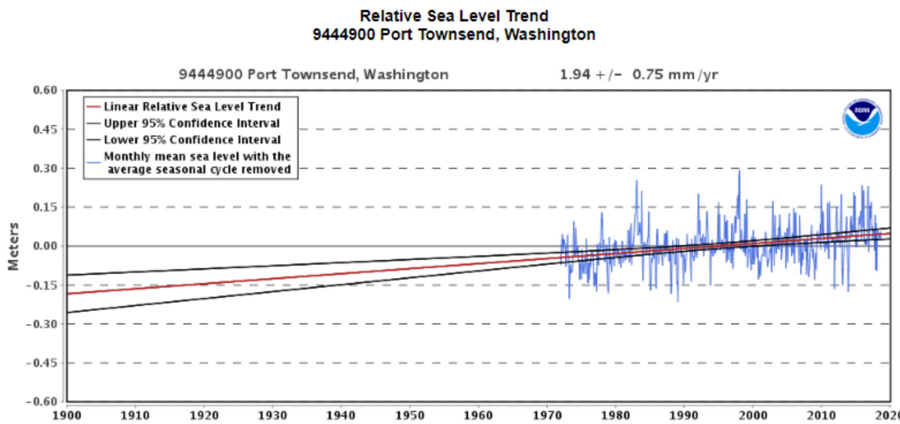


Figure 40: Port Townsend Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xv. Seattle, WA (9447130):

Seattle's relative SL (RSL) trend is +2.05 mm (0.08")/yr. with +/-0.15 mm (0.01")/yr. (95% confidence interval). The RSL derives from the station's 1899-2017 monthly MSL data, which equates to +0.20m (0.67') every 100 years. See graph below.

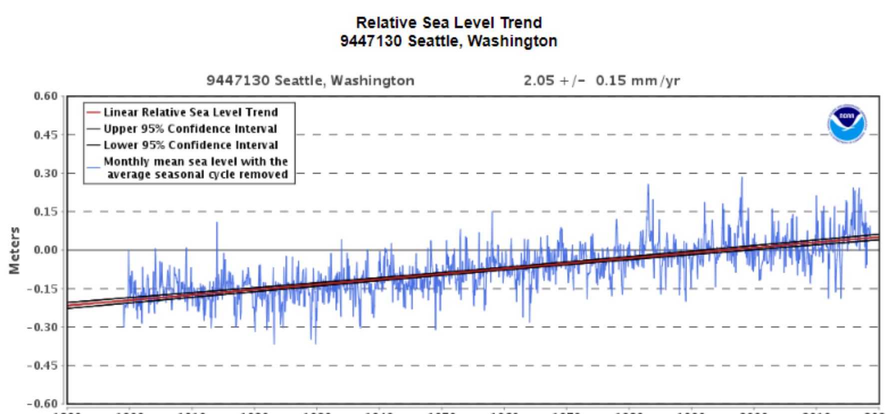


Figure 41: Seattle Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

xvi. Toke Point, WA (9440910):

Toke Point's relative sea level (RSL) trend is +0.45 mm (0.02")/yr. with +/-0.9 mm (0.04")/yr. (95% confidence interval). The RSL derives from the stations 1973-2017 monthly mean sea level (MSL) data, which equates to +0.05m (0.15') every 100 years. See graph below.

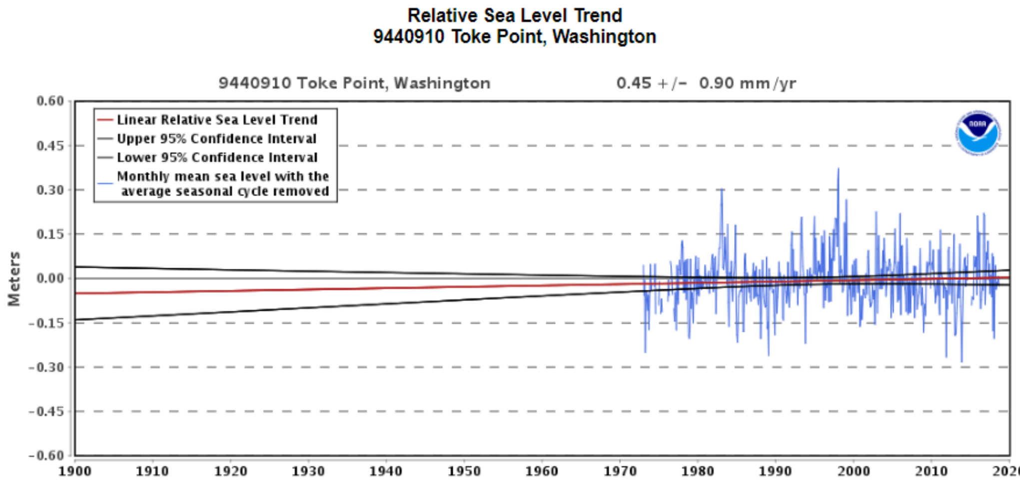


Figure 42: Toke Point Relative Sea Level (RSL) graph plots the RSL height in meters on the Y-axis and the station's data period on the X-axis.

F. Tides Analysis Conclusions:

Alaska's falling MSLs contrasts with GSLR, yet AK does draw a parallel with "glacial isostatic rebound" (GIR). Currently, Earth's surface dynamics include fluctuating temperatures, plate tectonics, as well as ongoing ice-age ramifications, despite the ice age's occurrence 16,000 years ago. During the ice age, the Northern Hemisphere's glaciers created land depressions beneath the miles-thick ice weight. Additionally, the glacier weight also raised the land on the ice's perimeter. This "fore bulge" is evident on the US east coast and the Great Lakes region. As the glacier recession collapsed the fore bulge, these perimeter masses began to descend. Ongoing fore bulge subsidence, or GIR, is further compounded with oil, gas, and water resource extraction, as well as GSLR (National, 2019).

In contrast, AK's regional experience with GIR results in land mass rising. Current glacial recession, being exacerbated with global warming, creates a GIR projected rise rate at 30.0mm (1.18")/yr. (Snay, JGR). This rise is evident with the tidal analysis provided. Despite GSLR occurring in the majority of the world, GIR is offering real estate gains for AK residents. However, GIR also creates detrimental ecosystem impacts in AK, including estuary evaporation, red algae blooms, and salmon recolonization. Currently, scientists are continually modifying GIR models for increased accuracy. Glacial isostatic rebound vertical measurement uncertainty values require further calibration (Chen, 2016).

This study's tides analysis verifies both the ongoing GIR in SE AK, as well as the contrasting GSLR, as indicated by the Pacific NW station datum calculations. Global sea level rise causes economic hardships worldwide, with further exacerbation from subsidence with resource extraction. However, the Arctic experiences financial gains through the coastal real estate acquired with lowering RSL trends. Although scientists GIR models require improved vertical measurements, the tidal data does verify that Arctic ice melt proves to be an economic advantage for NRCs (Chen, 2016).

Lastly, stations with a rising RSL trend contribute to the overall GSLR balance. It is also indicative of the ongoing SE AK's GIR impact, which contrasts with the Pacific Ocean's SLR. In this study, each station with a positive RSL trend was plotted on an annual and by century basis. See below for final SLR summary trend tables on first an annual SLR in millimeters per year, and then the next century projection in feet. All Northern Pacific station trends graphed below held positive SLR trends, while Alaska stations had a negative SL balance as a potential consequence of GIR.

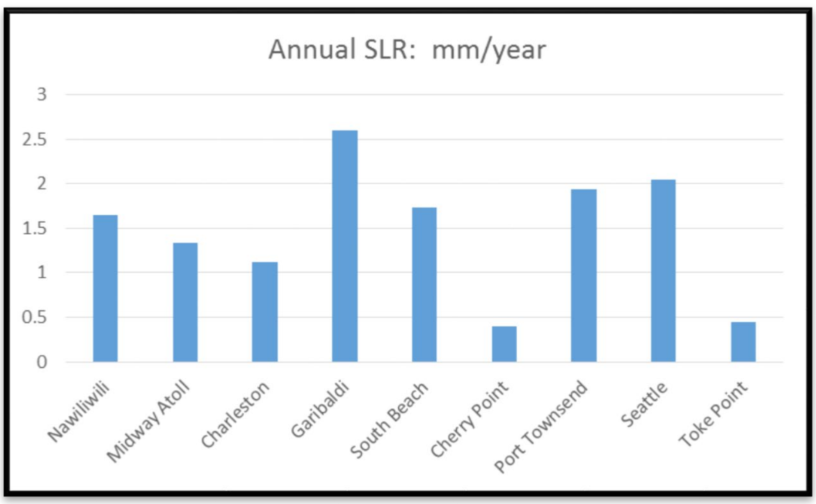


Figure 43: Sea level rise trends for the Northern Pacific tide stations with positive RSL trends, as plotted on an annual basis in mm/year.

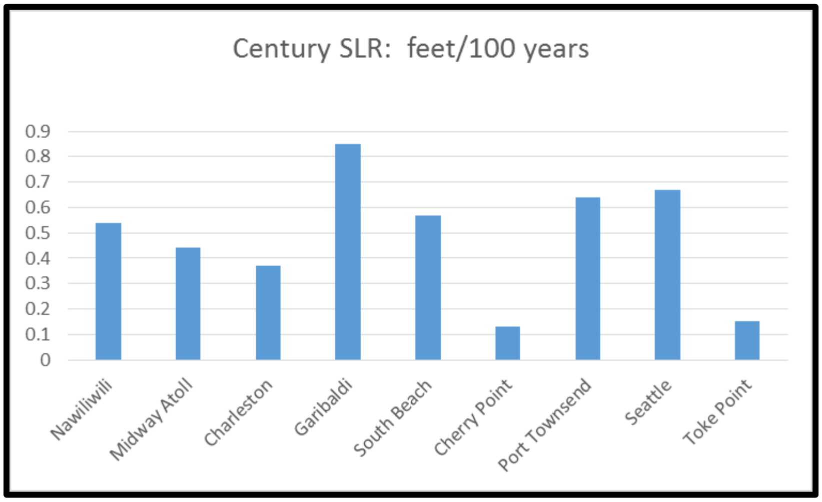


Figure 44: : Sea level rise trends for the Northern Pacific tide stations with positive RSL trends, as projected for the next 100 years in feet.

3. Unintended Consequences: Climate Change (CC), Cultural, and Biota Impacts

A. Climate Change (CC) and its Cultural Impacts:

Climatology investigates the Arctic's integrated environmental system through sea ice reduction, permafrost thaw, and biological reactions ("Impacts of Global Climate Change," 1997). Arctic research documents climate-induced variations fundamentally shifting the ecosystem (Serreze & Barry, 2005). Climate change analysis includes monitoring CO_2 emissions, which exceeds Earth's natural rate due to increased molecule dwell time. Additionally, the greenhouse gas effect (GHG) creates high CO2 concentrations, resulting in a thermal impulse and warming trends (Steinbruner, 2013). Rising temperatures then, in turn, produce intense water cycles, GSLR, and alters climate feedback. Climate change includes permafrost carbon feedback, atmospheric circulation, and GHG emission rates. In the end, this Arctic evolution creates an adaptation burden for society and requires global mitigation (Serreze & Barry, 2005).

Climate change can affect the Arctic's water supply, food production, human health, and the environment. The Arctic ecosystem also becomes more susceptible to extreme weather events, including flooding and high winds. This intensified weather in turn damages transportation, infrastructure, and creates port vulnerability and closing costs (Pappis, 2011). Concurrently, glacial retreats can create water supply issues. As seasonal snow-packs melt with warmer temperatures, the glacier reduces their water storage capacity required for sustaining agriculture. As a result, CC may involve engineering storage solutions (i.e., building reservoirs) and other technological adaptations (Smith, 2011).

The uncertainties associated with Arctic CC warrants continuous monitoring and risk prevention analysis (Serreze & Barry, 2005). For instance, hydrological cycle data processing can generate climate variability trajectories as well as provide time series data, water temperature, and salinity vertical distribution tables to identify anomalies. Long-term data trends can also validate ice condition variability and fishery dynamics (Matishov et al., 2014).

Arctic ice cover variation, between extent and retreat, alters the regional ecosystem's chemical and biological components. Therefore, the global ocean thermohaline circulation transforms with the increased freshwater input from ice melt. Sea ice melt also increases the ocean surface and varies the air-sea interface ratio. As a result, higher atmospheric natural gas diffusion will enhance cloud condensation. This enhanced condensation shifts the Earth's radiation balance, thereby influencing regional temperature and climate (Qu, 2015). Also, the predicted freshwater source and storage fluctuations have an unknown impact on the Arctic ecosystem, including ice cover variation impacts to the marine food web. Abundance surveys assess ground fish, and crab distribution, and determines current responses to CC. Arctic climatology must include further considerations of new abiotic conditions and organism responses (Arico, 2015).

The Arctic's cryospheric fluctuations also affect the region's cultural identity. The increased activity from marine resource accessibility creates societal impacts in shipping, tourism, and industrial development (Hovelsrud, 2011). Furthermore, regional expansion and globalization leave an unstable Arctic sovereignty, as aboriginal settlements are often the dominant human presence. These settlements can experience rapid population growth which must adapt to ice loss. Industrial development also conflicts with the native community's traditional subsistence methods. Consequently, native settlements routinely oppose state legislation for oil company proposals (Abate, 2015).

Thus Arctic development must engage natives for policy input and decision-making. Offshore resource management should also be flexible concerning the native communities. Towards this end, the 1971 "Alaska Native Claims Settlement Act" (ANCSA) was an aboriginal Alaskan initiative. ANCSA served as a US property rights settlement, whereby recognizing aboriginals as Alaska's largest private landowners. Due to this initiative, natives now receive economic gains from Alaska's hydrocarbon development (Smith, 2011).

B. Biota Impact:

NOAA's Aerial Surveys of Arctic Marine Mammals (ASAMM) project provides mammal sighting counts for ecosystem abundance and distribution mapping. ASAMM tracks all marine mammals above 140°169'W, 68°72'N, and its surveys date back to 1979. ASAMM incorporates reliable data collection procedures to develop population estimates, from the mammal's abundance, as well as in determining the mammal's role in the Arctic ecosystem. These survey aircraft provide real-time mammal location and numbers to tracking research vessels, as well as for mitigation with offshore oil exploration and oil spill response purposes. The survey crews communicate with shore parties via satellite phone.

Marine mammal assessments are crucial for updating Arctic ecosystem dynamics due to ongoing CC impacts. The Arctic marine ecosystem is experiencing earlier sea ice melt, followed by its delayed refreeze in the fall. This lengthened navigation season (~JUL-OCT) permits increased anthropogenic activities, vessel traffic, and oil and natural gas exploration, development, and production (Ferguson, 2019). Through further incorporating these current and projected anthropogenic activities, policymakers can interpret survey data to implement protective protocols. These protocols include the Endangered Species Act, US National Environmental Policy Act, and the Marine Mammal Protection Act (Ferguson, 2019).

The bowhead whale population is growing, in large part due to CC and Arctic sea ice melt. Bowhead birth rates rose ~12%, which resulted with a 3.7% population growth overall (DeMarban, 2018). This population growth contrasts with the assumption that CC negatively impacts all Arctic marine mammals. Prolonged open sea water, with the average sea ice decline at 10% per decade, improves living conditions for the bowhead food source of krill and other crustaceans. The decreased coverage enhances ocean exposure to sunlight, wind, and storm surge. This exposure facilitates water column mixing and nutrient upwelling. In turn, the bowhead's enhanced sustenance improves its health, resistance to disease, and results with the higher birth rates (DeMarban, 2018).

Sub-Arctic whale populations are also growing in response to CC's sea ice melt. In addition to ASAMM surveys, NOAA also tracks marine mammal abundance through hydrophone acoustic buoys, which tracks mammal calling activity. Researchers deployed hydrophone acoustic mooring buoys to record the whale calls. NOAA next verified that the calling activity was in agreement with prior aerial and acoustic surveys. As such, the data confirmed that the whale calling rates were adequate for use in representing the species presence (Berchok, 2015). These Bering Strait acoustic studies cited an increase in Arctic whale's southern migration, including beluga and bowheads, as well as increased sub-Arctic whales migrating north, with humpback, fin, and orcas. Overall, the Arctic's ice melt expands marine mammal habitat ranges, in which sub-Arctic whales increasingly transit north to the nutrient-rich Chukchi Sea (Hickey, 2014).

Scientists can further verify the distribution and abundance reports, from aerial surveys and research vessel reporting, with the marine mammal acoustics. Researchers can evaluate acoustic studies with anthropogenic impacts, including offshore drilling, seismic surveys, and construction. As such, scientists can infer mammal abundance and distribution change based on existing environmental conditions or from anthropogenic activities. Environmental conditions range from sea ice, water temperature, currents, salinity, or prey abundance.

Researchers can also apply future environmental conditions to the ASAMM and acoustic survey marine mammal abundance and distribution data. Climate model predictions incorporate projected sea ice coverage, environmental conditions, and periods of ice-free water with marine mammal data. As the sea ice retreats with enhanced melting from advection, solar heating further warms the Arctic's sea surface temperature. This warming deteriorates the Arctic's salinity gradient and water column stratification. As a result, the Arctic experiences enhanced nutrient mixing. This mixing increases benthic biomass production rates, which accelerates primary and secondary productivity. The resultant surge in pelagic food supplies, therefore, restructures the Arctic ecosystem. This restructure is evident with the bowhead population growth rate, which are generalist feeders (Berchok, 2015).

Overall, new Arctic marine mammal migration patterns do create an unknown impact, despite an overall improved range. Potential adverse side effects from new migrations include introducing new competition for food, habitat, and even communications with acoustic space (Hickey, 2014). Additionally, sea ice melt also increases ship traffic, as evident with USCG tracking vessel movements through the two international shipping lanes. Increased marine traffic escalates vessel strike potential for migrating marine mammals. Vessels can also introduce new diseases and invasive species to the Arctic ecosystem (DeMarban, 2018). Arctic conservation groups made efforts to mitigate this by advocating for ship speed limits through the Arctic Council. Slower vessel speeds will improve the odds for marine mammal collision avoidance, as well as decrease vessel noise pollution. A ship's propeller and motor noise raise ambient noise levels, thereby inhibiting marine mammal communications. Anthropogenic noise is especially concerning for whales, which use sound to navigate for both food and mating purposes (Hickey, 2014).

4. Northern Rim Country Development: Background, Vessel Traffic Projections, Port Access Route Study, and Chart Comparisons

A. Background:

In efforts to define the Arctic's hydrocarbon development potential, the petroleum industry uses published oil seeps, deposits, and shale extraction records and prospecting permits. Logistically, offshore production requires support structures and shoreline pipelines for processing. Structures can be located on existing ice, as well as placed on artificial gravel, steel, or concrete islands. However, offshore production structures become uneconomical at > 25-30 meter (82.02-98.43') water depths (Anderson, 2009).

Arctic development raises both the vessel traffic, as well as the corresponding potential surge in marine casualties. Marine casualties are events or a sequence of events that results in a person's death or severe injury. Marine casualties also include a ship's damage through groundings or collisions, or in equipment failure, including ship navigation. Last, casualties include engineering failures with the loss of propulsion, power, steering, or navigation equipment. Arctic marine casualties, however, are complicated through first responder delays. These delays are due to a lack of a support infrastructure, which includes refuge ports, search and rescue operations, nautical charts, and weather/ice forecasting. As a result, Arctic shipping considerations necessitate infrastructure investments, updated rules, and regulations, a vessel traffic service, as well as improved spill response. Requisite technological advancements also include implementing double-acting hull technology for ice-breaking cargo shipping (Anderson, 2009). Towards this end, the National Research Council completed a spill evaluation to determine the Arctic's response capacity. This assessment derived from workshops, conventions, regulations, historical petroleum development, and case studies, as well as engineering, technology, policies, procedures, and available equipment (National Research Council, 2014). Altogether, these components factor and define the Arctic's response aptitude (Gryc, 1991).

Arctic shipping growth also necessitates additional measures for ensuring navigation safety. The new northern routes require safety assessments to determine shipping feasibility due to the ongoing ice reduction. Climate change complicates ship navigation, as wind and hydrologic regime shifts and intensifies vessel icing. Vessel icing is especially dangerous in the Arctic for marine operations. As ice accrues on vessels, it raises the ship's center of mass. In doing so, this offsetting mass results with a loss in vessel stability, which can create hazardous rolling, pitching, capsizing, and topside flooding. In addition to instability, a ship's communications, navigation, weapons, and deck equipment can become inoperable due to vessel icing. Safety concerns also develop as shipping lanes expand, which yields deficient seabed knowledge, regarding narrow passages and minimum "under keel" clearances. Arctic shipping must also factor in navigation season extensions by incorporating linear time schedules with predictive year-round ice conditions (Pastusiak, 2016). This forecasting is possible through IPCC models, which improves navigation safety by calculating the ice cover variation. Ice cover calculations allow companies to project potential profits by using vessel speed and voyage time. Shipping companies can also predict losses accrued due to limited refueling and repair ports (Pastusiak, 2016). Vessel ice classifications and propulsion system type (i.e., nuclear power) are also a safety consideration. Additional reinforcement and other measures define a vessel's ice class for ship navigation through sea ice. The specific classifications also have performance requirements. Although a ship lacking an ice classification saves on fuel consumption and weight, lower classed vessels also generate higher repair costs through hull, propulsion, and steering damage (IACS, 2011).

Lastly, the Arctic has severe limitations with aids to navigation. Current charts lack reliability due to numerous sounding discrepancies, while Arctic publications overall are insufficient, including Coast Pilots, Light Lists, Sailing Instructions, and Chart 1. Items included in these publications are information about harbors or anchorages, descriptions of towns and what services might be available, descriptions of shoreline features, descriptions of current weather or sea conditions, and local knowledge that may help a mariner navigate more safely. The Light List is a detailed list of navigation aids published by most maritime nations. In the US, the USCG and NGA publish this list to provide mariners comprehensive information on ATONs (Aids to Navigation), including lighthouses, buoys, radio, and day beacons, and RACONs. RACONs are radar beacons, which are identifiable with its specific radar signal. The US DOC/NOAA/DoD/and NGA all contribute to the US Chart No. 1 production. Chart 1 defines the symbols, abbreviations, and terms used for both paper and electronic navigational charts. Coast Pilots provide supplementary nautical information, which cannot fit on the charts, and serve as guides for coastal and intra-coastal waters. OCS of NOAA authors nine Coast Pilot volumes annually. However, despite the production of these mariner resources, the Arctic suffers from limited vessel accessibility. As such, its publications lack the frequent updates that are evident in more populated regions, as local mariner knowledge and reporting provide much of this navigation information. Although the Arctic's current inaccessibility limits nautical reporting, this information will increase as the vessel traffic continues to grow (Department, 2019). See the image below for Arctic shipping routes through US waters, as well as the feasibility of an oil spill response.

Figure 45: Arctic shipping routes and oil spill response (National Research Council, 2014)

B. Vessel Traffic Projections:

The Arctic's maritime traffic has increased by 128% over the past decade. This vessel increase is 2-3 times the number transiting in 2008. Arctic vessel activities include natural resource extraction and exploration, commercial shipping, oceanographic research, and tourism. This vessel traffic is also projected to grow as sea ice continues to decline. Overall, Arctic governments continue to invest in shipping opportunities through exploiting shorter trade routes. Researchers and tourists are also attracted to the sea ice declines accessibility, which creates longer navigation seasons overall. However, such marine vessel growth in these extreme environments can only maintain safe operations by establishing foreseeable environmental conditions (Committee, 2019).

USCG and vessel traffic services (VTS) monitor ship transits through AIS (Automatic Identification System) data. AIS is a network of vessel transponders, consisting of a GPS receiver and electronic navigation sensors. AIS transmits the vessel's data to satellites via a VHF transmitter to provide the vessel's information, including identification, destination, position, speed, and course. The IMO's SOLAS requires AIS aboard foreign vessels with > 300 gross tonnages (GT), as well as for all passenger ships. Through 2015-2017, 281 vessels transited the US Arctic, in which most were US-flagged vessels, with 50% being tug and cargo, 10% fishing, and 7% tankers. These statistics indicate that the commercial sector will continue to drive Arctic infrastructure development in support of its growing shipping activities. Toward this end, the US maritime community is developing new ice-class vessels for safer Arctic transits and further define shipping routes as natural resource activities continue to increase. Overall, this Arctic vessel activity is projected to increase 3-4 times its current number, with estimates at > 500 vessels transiting by 2030 (Committee, 2019). As a result, the changing Arctic marine environment warrants additional infrastructure planning and development with CC considerations. While the US continues to develop ice-strengthened ships, it must also account for infrastructure modifications through CC's uncertainties with the infrastructure's sustainability (Committee, 2019).

C. Port Access Route Study (PARS) Corridor:

The increased vessel traffic resulting from glacial and polar ice cap recession created the need for the USCG's Port Access Route Study (PARS). The increased marine casualties in vessel groundings, propulsion loss, and collisions prompted the USCG to adopt routing measures to mitigate against such incidents. The USCG's MISLE (Maritime Information Systems and Law Enforcement) database served as the incident source. The MISLE database tracks vessel and port marine pollution and shipping incidents, which can be either accidental or deliberate. MISLE is accessible to the public through the Port State Information Exchange (PSIX), which contains over 650,000 US and foreign-flagged vessel information. Portions of both MISLE and PSIX are accessible to the public to facilitate the Freedom of Information Act (FOIA). The data provides information on both US flag and foreign vessels, as well as its history with USCG contacts. (Coast, 2016).

Initially, USCG proposed seven routing options within US jurisdiction for the area north of 50° latitude, west of 155° longitude. The primary areas of avoidance included: Big and Little Diomede, St Lawrence, King, and Nunivak Islands. These proposed options were four nautical miles (NMs) in length as a 2-way route. USCG forwarded all seven recommendations to the International Maritime Organization (IMO) for review. The vessel routing system was an effort to safeguard the Arctic's marine environment from the increased traffic from > 362.87 tonne (400 gross tons) vessels. This increase in activities correlates inversely with the decreased ice in the Arctic and the Chukchi Sea. As the ice recedes, cargo, passenger, adventure tourism, oil and gas exploration, and research activities increase. (Coast, 2016). See images below for AIS traffic data.

Figure 46: Automatic Identification System (AIS) Vessel traffic at > 400 Gross Tons (GT)

Upon further review, USCG's PARS proposal fit into existing ship routing criteria for following vessel traffic patterns, minimizing course alterations, and maintaining the maximum distance from shore. Other considerations were avoiding environmentally sensitive areas, route length, and accuracy of existing nautical charts. Upon refinement, IMO approved a two-way route as opposed to implementing a Traffic Separation Scheme (TSS). This decision allows more space for vessel navigation, while also upholding collision avoidance regulations under COLREG rule 10. Rule 10 mandates that the IMO's two-way route does not relieve vessels of their obligation to obey all other navigation rules of the road. The PARs route is applicable for all vessels > 362.87t (400 GT). Automated Identification System (AIS) AIS tracking data was critical in plotting the PARS corridor to correspond with existing traffic patterns and enhance the likelihood that vessels will follow the route. See images below for both the PARS route and the existing AIS vessel traffic (IMO, 2017).

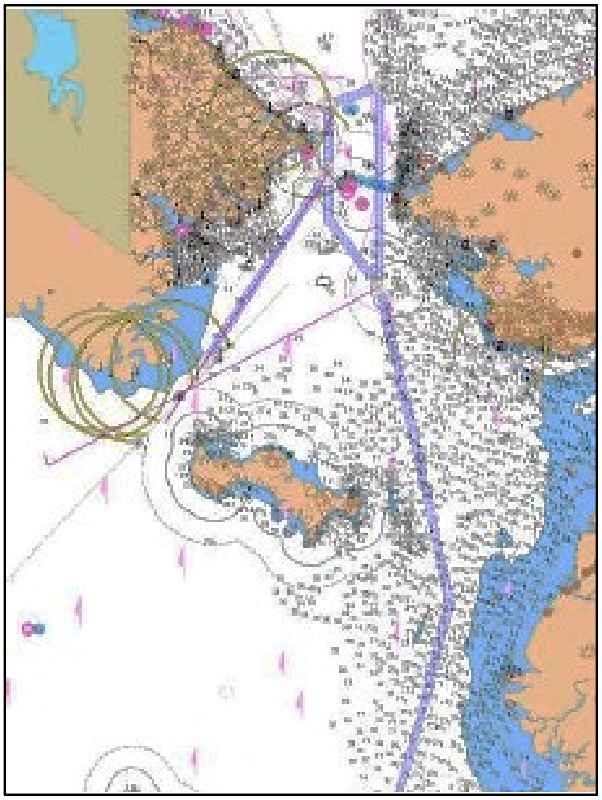


Figure 47: Port Access Route Study (PARS) corridor (IMO, 2017).

With the PARs corridor given final IMO approval, the next issue remained the existing hydrographic data, most of which proved inadequate for USCG recommendations. As a result, NOAA's Office of Coast Survey (OCS) and Office of Marine and Aviation Operations (OMAO) received orders to update the PARs corridor to modern survey standards. However, as the entire passage was > 1 296.4 SKMs (square kilometers, or 700,000 SNMs (square nautical miles), NOAA first prioritized areas in search of hazards at < 18.28m (60') at regions with the highest concentrations of vessel traffic. Upon verifying no such risks existed with this criterion in the finalized corridor, the PARs corridor received the final USCG designation as a "viable, continuous navigation corridor" (Coast, 2016).

The primary consideration in the PARs Corridor design was to safeguard the environment from the hazards of increased vessel traffic and enhanced risk of marine casualties. The route essentially condenses the vessels into a narrow corridor to decrease marine traffic's footprint, while also improving environmental sustainability. The PARs, therefore, directs the traffic between the Unimak Pass and the Bering Strait, while maintaining the maximum distance from shore. This system ultimately clears the environmentally sensitive areas while also safeguarding the vessels from shoals and affording the maximum amount of sea room for steering and propulsion casualties. The increased distance from shore provides more time for the ships to respond appropriately as well as enhancing the chance of rendering assistance in case of emergency. Lastly, the route also accounts for the ice migrant pattern changes as the Arctic melt exacerbates (IMO, 2017). USCG compiled marine casualty statistics from the commercial sector during 2005-16. Most vessel groundings were attributed to existing discrepancies in the chart soundings. These hydrographic surveys date back to the original lead line surveys performed by Russia in the 1800s. As a result, the PARS investigations concluded that such groundings were preventable by designing the PARs route to avoid these weak survey areas (Coast, 2016). Due to the USCG's PARS investigation results, NOAA received orders to survey various critical segments within the PARS corridor (Fairweather, 2018).

After NOAAS Fairweather (FA) surveyed the designated PARS survey area with its Multibeam EchoSounder (MBES) sonars, FA reduced the recorded ship soundings to MLLW for charting purposes. Tide reduction is a correction applied to the ship's survey data to account for the rising and falling tides. All nautical chart soundings are corrected to MLLW, as this is the lowest elevation point and is the most critical for a ship's draft considerations. The nearest tide station's data is applied to the ship's sounding data to reduce it to the MLLW. This correction technique referred to as tidal zoning. The survey echo-soundings initially convert to MLLW through using the observed tide data from the CO-OPS NWLON network, primarily from the Nome tide station. However, for finalizing the data at MLLW, an Ellipsoidally Referenced Zone Tide (ERZT) separation model was computed to best accurately represent the actual sounding's reductions (Commerce, 2019).

i. Port Access Route Study Survey Results:

This PARS survey demonstrates the GSLR impact with the contrasting survey soundings from previously recorded charted soundings. The chart discrepancies with the new survey soundings are reportable as either inaccuracy with the original hydrographic survey, or provide evidence of GSLR changing the water levels, resulting in a difference in sounding depths. To perform the chart comparison, the largest scaled Electronic Nautical Chart (ENC US3AK89A, 8th ed., scale 1:315, 350) and Raster Nautical Chart (RNC 16220, 6th ed., 5/1, by scale 1:315, 350).

Through using specialized software, the collected soundings and contour layers were then overlaid on the chart to assess existing discrepancies between the charted and newly surveyed soundings. Overall, the survey soundings and contours were mostly in agreement with the sparse existing charted soundings. However, there were also numerous areas found with deeper existing soundings from those previously mapped (NOAAS, 2018). Although it is unclear if these discrepancies are a direct result from GSLR definitively, these findings do support such a hypothesis. NOAA conducted the first official PARS survey in June of 2018. The enclosed survey findings exhibit the PARS hydrographic results. See the images and data collected below.

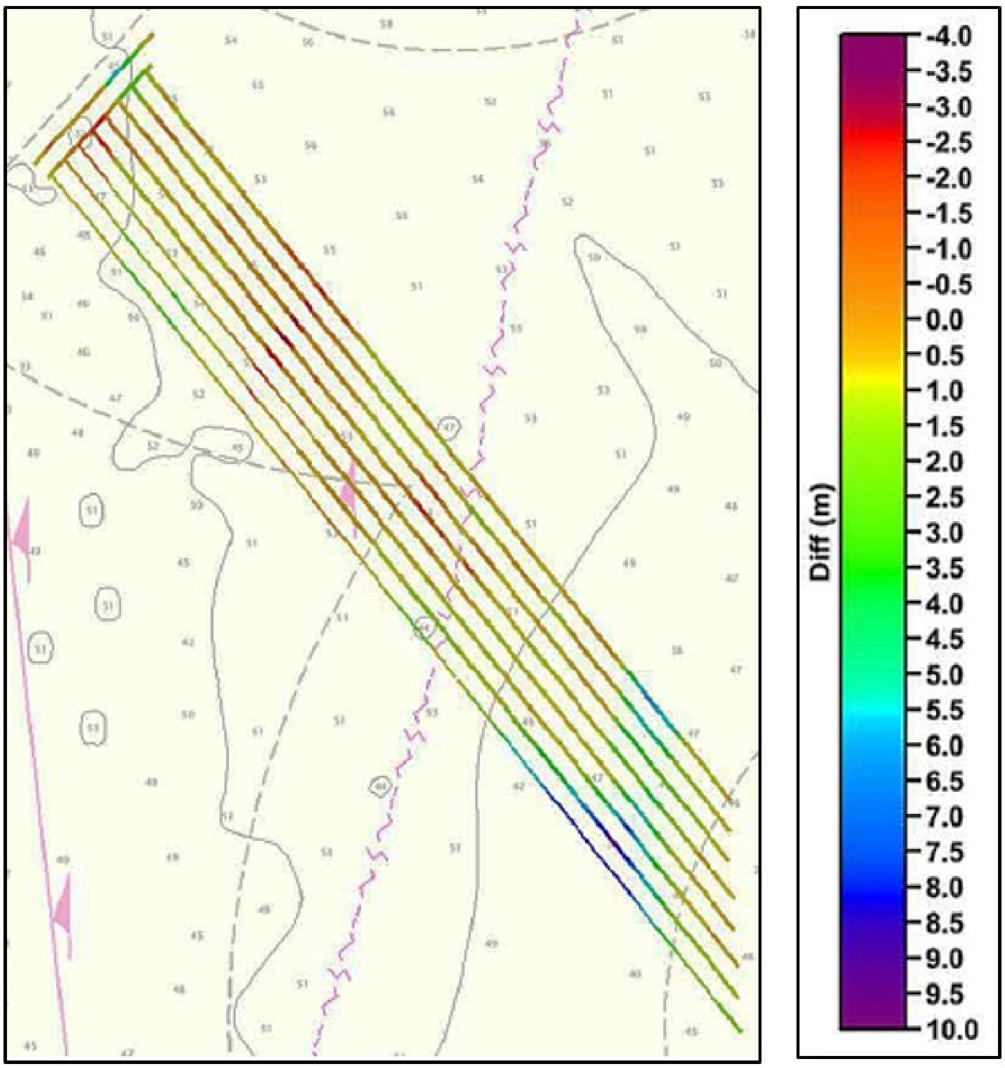


Figure 48: Port Access Route Study (PARS) survey comparison with Electronic Navigational Charts (ENC) US3AK89M and Raster Navigational Charts (RNC) 16220 (CARIS, 2019).

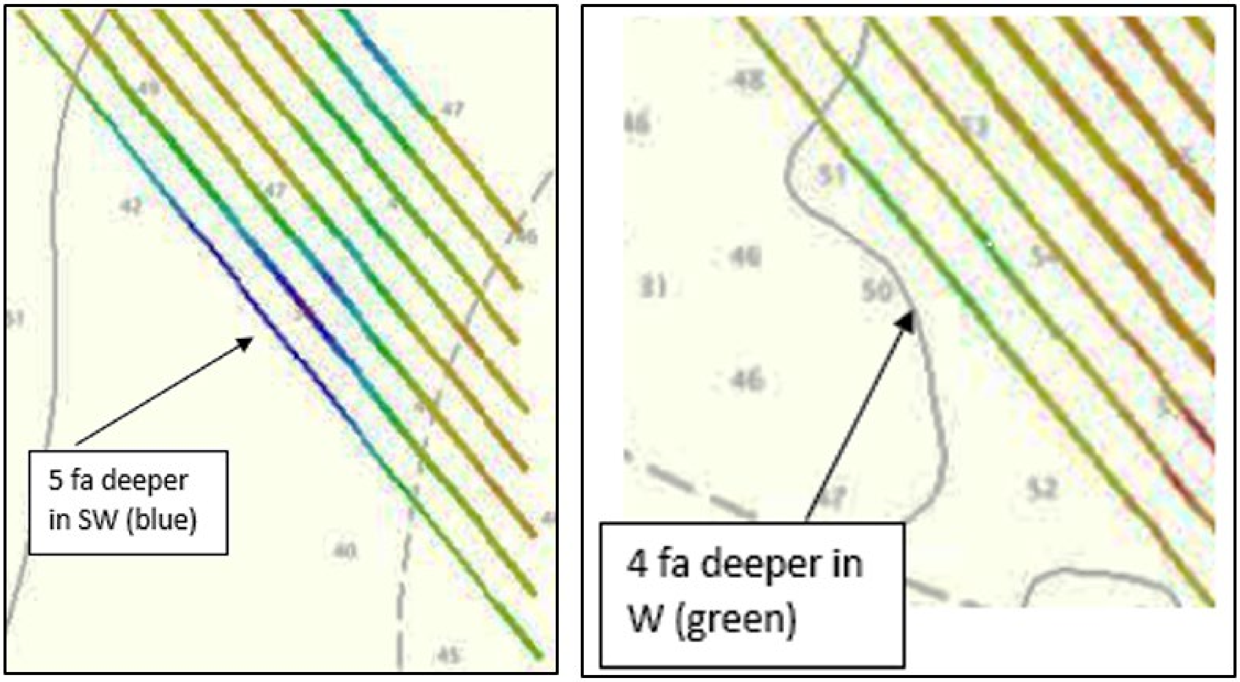


Figure 49: South West (SW) survey: 5 fathoms (fa) deeper soundings vs. charted depths (blue shades) and 4 fa deeper in the W (green shades) (CARIS, 2019).

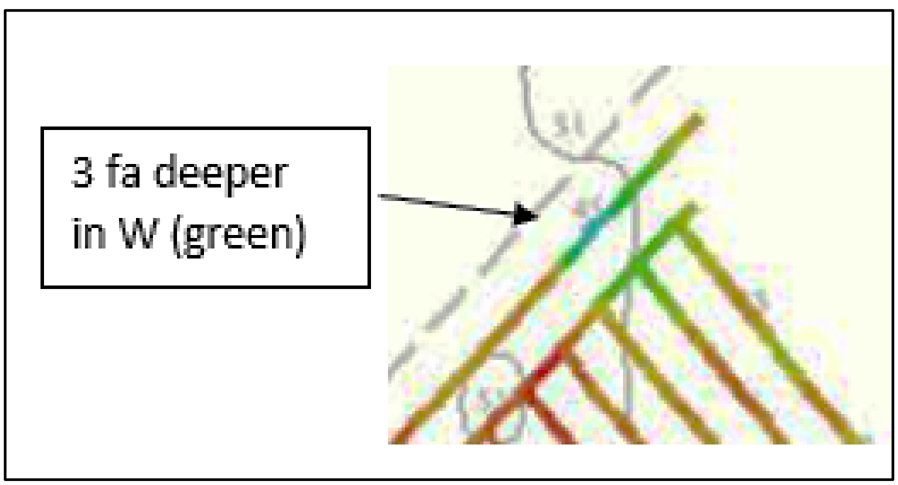


Figure 50: North survey: 3 fathoms (fa) deeper soundings vs. charted depths (green shades).

Although the PARS soundings were mostly in agreement with the previously charted values, this study theorized that GSLR impacts would be more prevalent in nearshore glacier environments. Arctic glaciers, overall, are the most susceptible to CC's global warming impact. This study recorded various chart comparisons near tidewater glaciers in search of GSLRs. The glacier chart comparisons used existing charts in contrast with newly collected soundings. This chart contrast ultimately demonstrates either shoaling or deepening soundings, which portrays GSLR trends through any discrepancies discovered. In this study, the chart comparison results display shoaler areas with red soundings, agreement areas in green, and deeper soundings in blue. The chart comparisons ultimately support evidence of GSLR in the Arctic, as evident with the data and images below (CARIS, 2019).

D. Chart Comparisons

Although the PARS soundings were mostly in agreement with the previously charted values, this study theorized that GSLR impacts would be more prevalent in nearshore glacier environments. Arctic glaciers, overall, are the most susceptible to CC's global warming impact. This study recorded various chart comparisons near tidewater glaciers in search of GSLRs. The glacier chart comparisons used existing charts in contrast with newly collected soundings. This chart contrast ultimately demonstrates either shoaling or deepening soundings, which portrays GSLR trends through any discrepancies discovered (CARIS, 2019).

A caveat to the projected chart comparisons exists in that hydrographic charted data relies on the source data, as well as the chart compilation's accuracy. NOAA compiles nautical charts with survey data from numerous sources, over generations of collection efforts. Survey pioneers utilized lead lines and sextants for hydrographic measurements, and frequently Arctic charts are outdated to the 19th century or earlier if charted at all. As such, source data often contrasts with today's highly accurate multi-beam echo sounders (Hydrographic, 2019).

Although NOAA's charting upholds the strictest hydrographic standards with sounding accuracy, this does little to correct the errors in the past collection efforts. Russian surveyors primarily charted Arctic shorelines with lead line, before the US Alaskan purchase in 1867 for $7.2 million. Often, Alaska's coastlines are so remote and difficult to access; many were charted based on photogrammetric or plane table surveys, and typically average over 30 years old.

Additionally, all chart compilations before today's modern computer era required manual compilation by hand. Although these high-detail survey drawings are to chart scale, the data necessary state or local coordinate system reference, as well as further conversion to the chart's horizontal datum (e.g., the North American 1927 (NAD27). With this upgrade to digital, these scanned charts often created biased variations and positional discrepancies. Overall, most nautical chart soundings sourced from surveys earlier than 1940. To date, only ~10 of the global ocean has been charted. The ocean floor is also a dynamic environment, with regular depth change from hurricane disturbance or coastal disaster debris, which creates vessel navigational hazards. See the diagram below, which calculates a chart's current "hydrographic health" when factoring for survey data accuracy depreciation over time. Due to these limitations, chart comparisons warrant hydrographic liabilities with charting accuracy in the remote Arctic region. (Hydrographic, 2016).

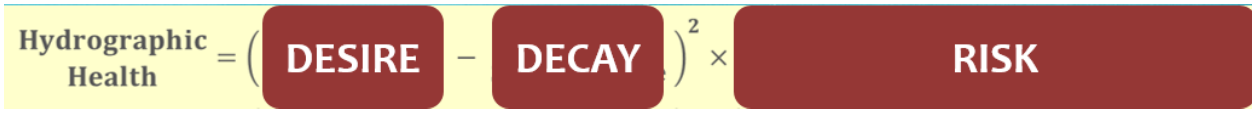


Figure 51: Hydrographic health model used to determine surveying needs by stakeholders (Hydrographic, 2019).

The following chart comparison for Hubbard, Sawyer, and Taku glaciers display shoaler areas with red soundings, agreement areas in green, and deeper soundings in blue. See figures below.

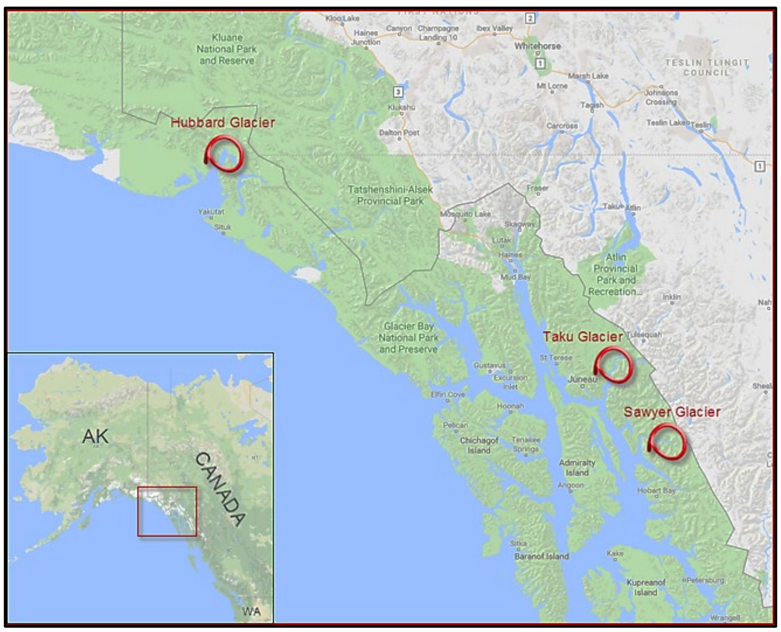


Figure 52: Hubbard, Sawyer, and Taku glacier soundings for chart comparisons.

i. Hubbard Glacier Comparison

The Hubbard glacier is subject to drastic ice loss, as evident with the contrasting images below. The ice loss may result with Glacial Isostatic Rebound (GIR) effect, in which the Earth's crust experiences large ground movement, post Arctic ice melt.

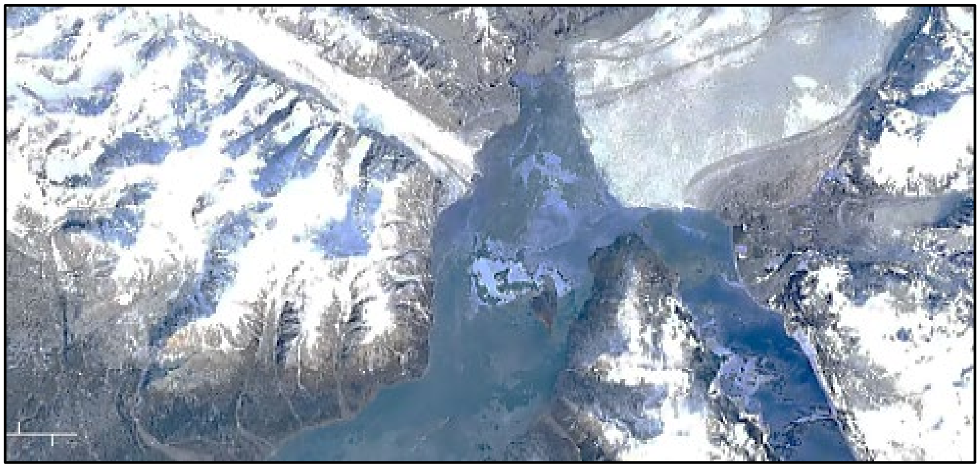


Figure 53: Hubbard Glacier 1984 (Google, 2019).

Figure 54: Hubbard Glacier 2016 (Google, 2019).

In the following Hubbard glacier chart comparisons, most soundings indicate shoaler depths. These shallower depths contrast with GSLR overall, as well as the belief that global warming's ice melt would yield deeper depth soundings. However, the shallower depths could be an indication of GIR.

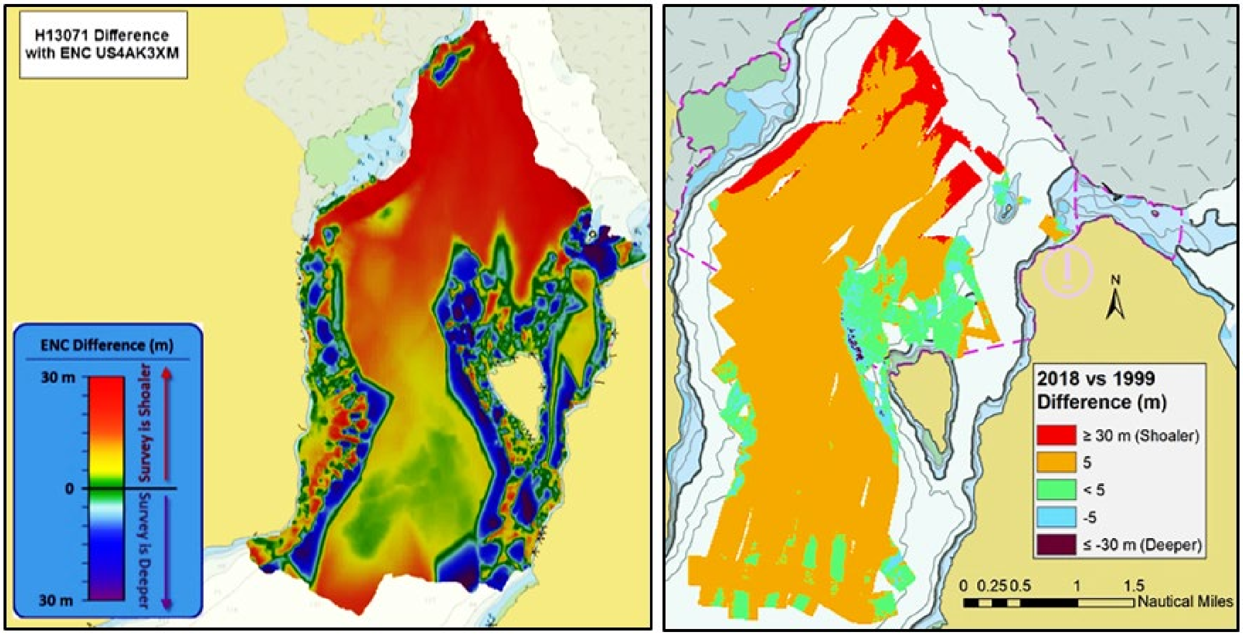


Figure 55: Hubbard Glacier Chart Comparison (ArcGIS, 2019).

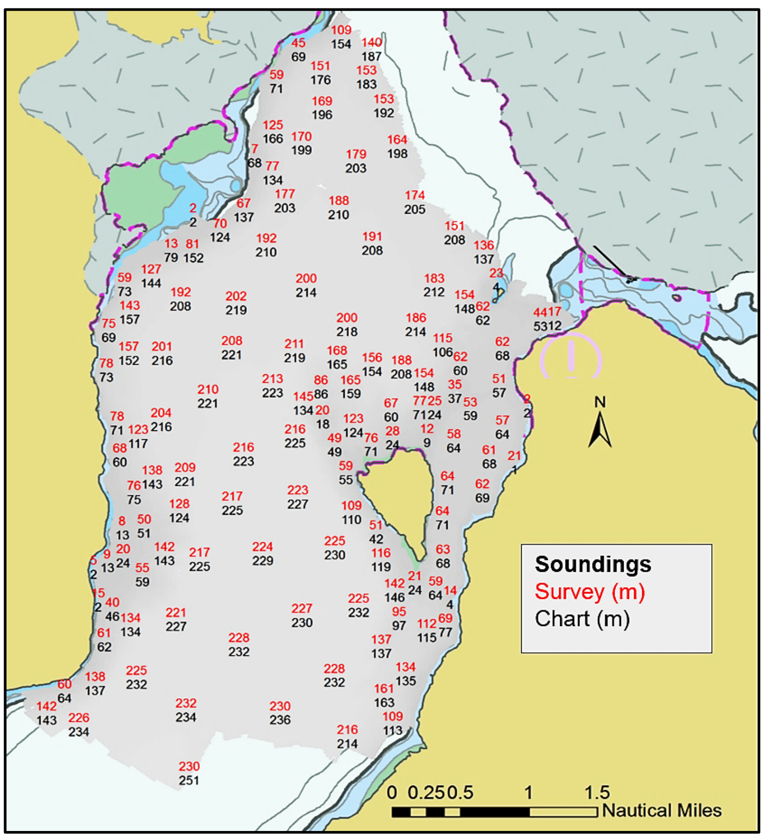


Figure 56: Hubbard Glacier Chart Comparison (ArcGIS, 2019).

ii. Sawyer Glacier Comparison

The Sawyer glacier also demonstrates a stark contrast in ice coverage loss over the past 35 years of global warming.

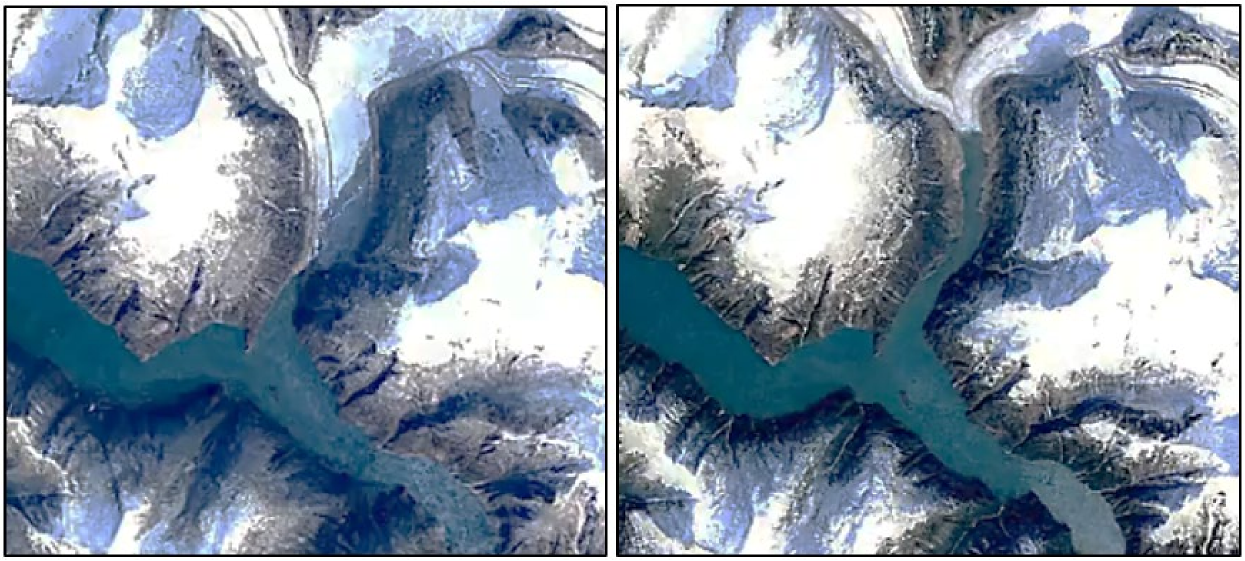


Figure 57: Sawyer Glacier 1984, 2016 (Google, 2019).

Similar GIR evidence exists in Sawyer, as its soundings are also shoaler further inland. However, there also exist some deeper soundings towards the sea. Given that Sawyer remains in a dynamic fjord region, GIR proves to be more challenging to establish.

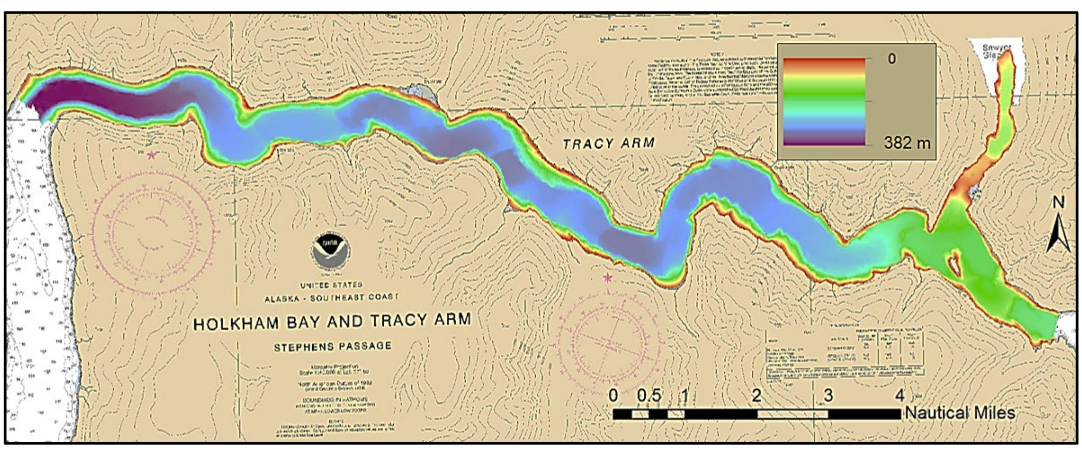


Figure 58: Sawyer Glacier Chart Comparison (ArcGIS, 2019).

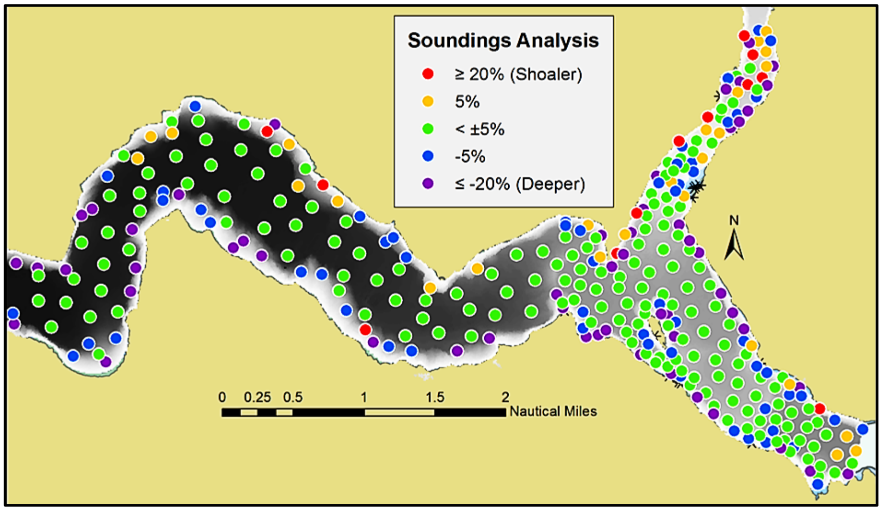


Figure 59: Sawyer Glacier Chart Comparison (ArcGIS, 2019).

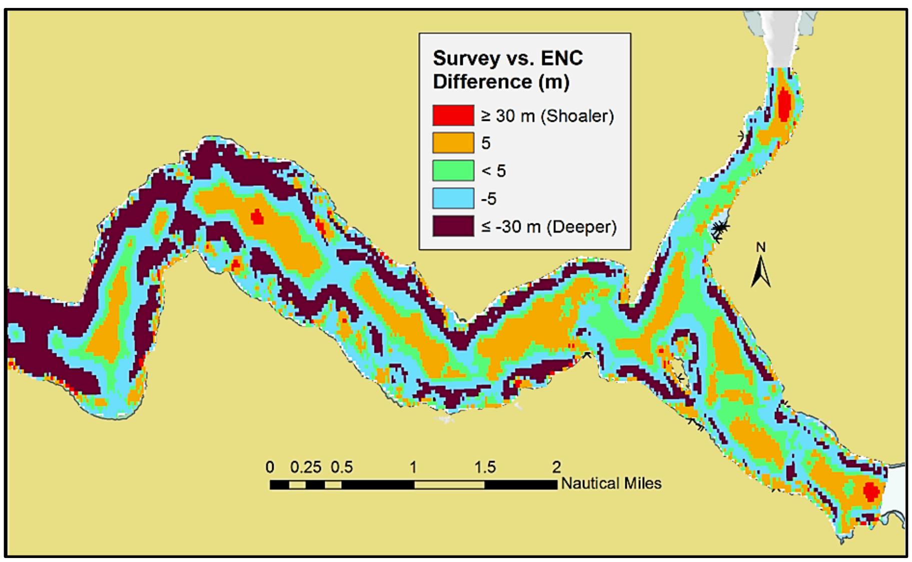


Figure 60: Sawyer Glacier Chart Comparison (ArcGIS, 2019).

iii. Taku Glacier Comparison

Last, Taku Glacier ice melt, in which its lowland areas may be rising along the coast with the glacial retreat. See Figure 61 for a depiction of this ice loss.

Figure 61: Taku Glacier 1984, 2016 (Google, 2019).

Most soundings close to the Taku glacier ascertain shoaler depths. These shoal depths may indicate GIR, despite intensified ice melt with global warming, as well as GSLR (ArcGIS, 2019). Overall, these glacial chart comparisons may support evidence of GSLR in the Arctic, as evident with the provided data and images. However, this GIR potential must also be factored with the existing nautical chart inaccuracies. See images below for this chart comparison analysis.

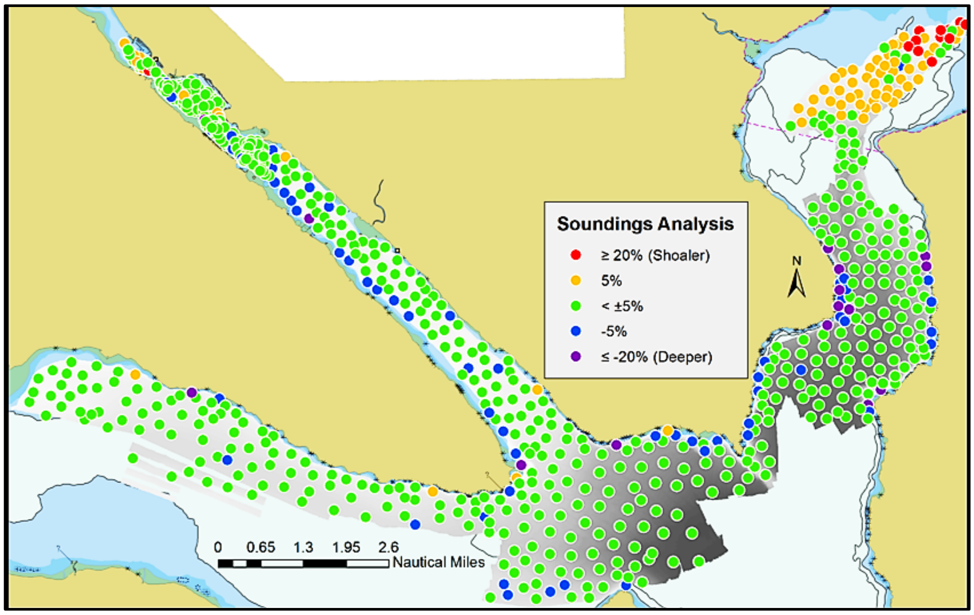


Figure 62: Taku Glacier Chart Comparison (ArcGIS, 2019).

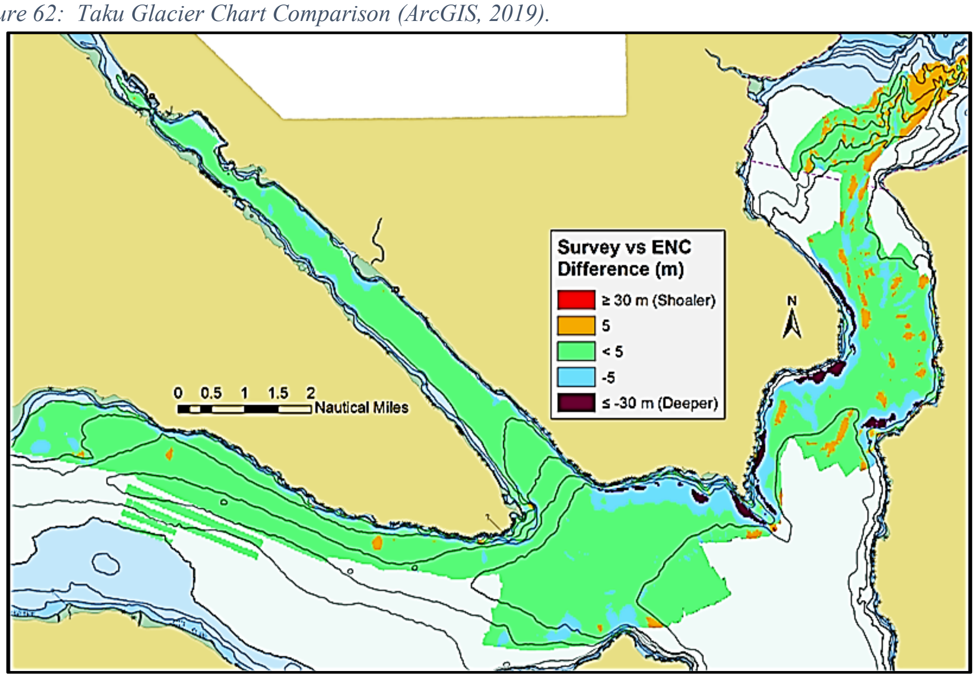


Figure 63: Taku Glacier Chart Comparison (ArcGIS, 2019).

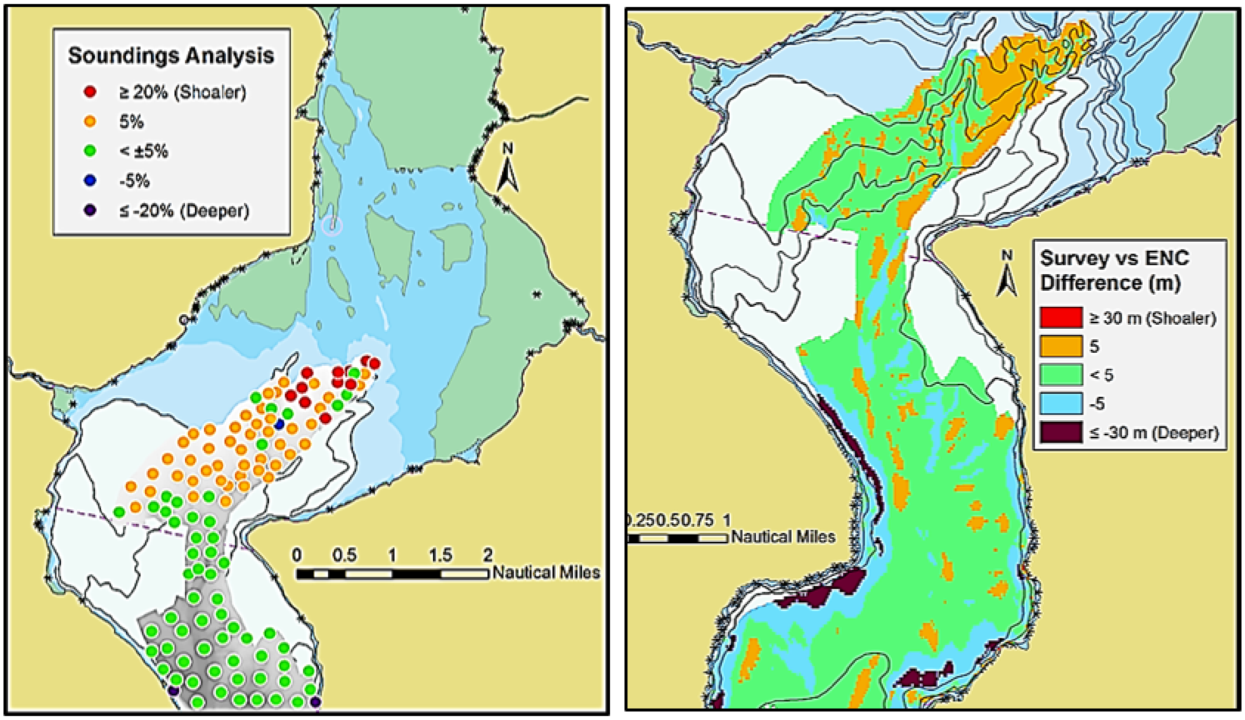


Figure 64: Taku Glacier Chart Comparison (ArcGIS, 2019).

5. Modeling

Overall, numerical models best represent Arctic climate status. These models provide ecosystem alterations and feedback analysis through inputting variable components. Scientists can also use models to delineate differences by comparing and contrasting observations. Models use observation variability to predict future marine sea-ice outputs. Controlled simulations designate model boundaries through varying atmospheric conditions and sea-ice extents (Douglas, 2010). The model outputs can also generate shipping estimates for the NSR and NW/NE Passages. Model derived outputs are applied in strategic planning for governments, environmental agencies, and the global maritime industry (Stephenson & Smith, 2015). Scientists use general circulation models (GCMs) to predict the overall GSLR impact, while model subsets address prevalent uncertainties (Douglas, 2010).

Model predictions contrast with the Arctic's historical trends and climatology. Initially, Arctic climate models predicted a gradual sea ice reduction. However, regional warming accelerated with the GHG effect. This warming created an ice-albedo impact, in which as the climate warms, the rising temperatures decreases snow and ice cover (Douglas, 2010). The reduced sea ice reduces the surface's light reflectivity, and the exposed ocean then absorbs extra energy and releases heat, which intensifies global warming. Decreased reflectivity, therefore, serves as a reinforcing climate feedback loop through magnifying this positive feedback system (Smith, 2011). Ice-albedo creates milder winter temperatures and further alters atmospheric circulation, precipitation, and jet stream patterns. Understanding this feedback system is critical for accurately modeling Arctic ice decline (Hohenegger, et al., 2012). The analysis must also identify and track the ice retreat's critical threshold, which can generate irreversible ice cover melt (Eisenman & Wettlaufer, 2008). See the model image below with near ice free summers predicted by 2035.

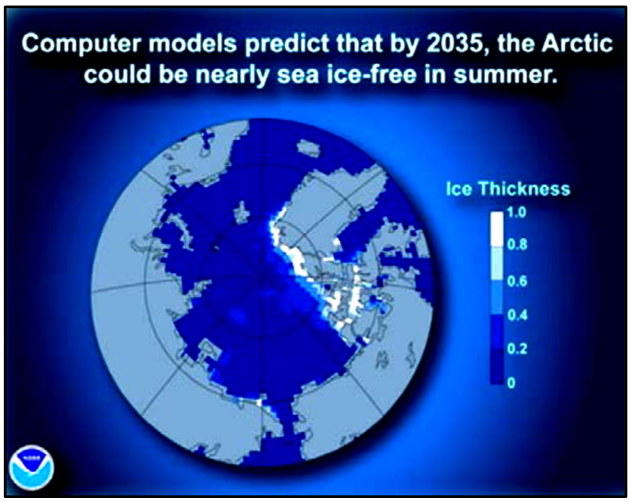


Figure 65: Computer Model Predictions (NOAA, 2011)

Interdisciplinary spatial modeling evaluates CC's negative social and economic impacts. These spatial models use hydrographic and topographic survey data to generate risk assessments to identify liabilities. Model input includes GSLR, storm surge, and extreme weather events. Lastly, inter-ecosystem interaction models can gain a processed-based understanding through monitoring Arctic change (Wrona et al., 2016). Coastal community decision-makers can then apply predictions derived from these models for mitigation efforts (Douglas, 2010).

Climate change modeling experiences the highest uncertainty with accurate coastline elevation predictions. As such, a correct vertical datum reference is critical for predicting GSLR impacts. However, as GSLR progresses inland, the tidal datums require transformation between datums for mapping, charting, and geospatial applications. This required transformation often creates errors and uncertainty in the model calculations. To negate this uncertainty, NOAA created the VDATUM (vertical datum) software program, which converts elevation datasets through processing the data ellipsoidally.

VDATUM first references bathymetric and topographic data to the digitized ellipsoid GEOID. The ellipsoid is a digital elevation model that serves as Earth's reference surface. The ellipsoid accounts for Earth's naturally uneven shape for digitization into a smooth reference surface. VDATUM next transfers the measured elevation data to the ellipsoid and then converts it to the tidal datum, or MLLW. VDATUM accurately translates elevation data between the different vertical datums, including MLLW, MHHW, MHW, and MSL. Fundamentally, the reprocessed data transforms the model's vertical uncertainties into extended coverage of data.

Ultimately, elevation data transfers to the ellipsoid for generating accurate WL inundation models, which is critical for predicting GSLR impact. Climate change models further incorporate topographic LIDAR (light detection and ranging) data, which surveys collected from aircraft, to create digital coastline, elevation models. Models also input traditional topography and gravity fields, which determines floodwater direction and height. Additionally, climatologists can use storm surge forecasts with translating projections into MHHW elevations over the NTDE (National Tidal Datum Epoch). Climate change model outputs wave propagation, coastal flooding, and erosion rate predictions. Global sea level rise model accuracy is essential for critical and strategic decision making and emergency response (White, 2019).

6. Policy: Issues and Legislation

The Arctic ice reduction results in human expansion to once inaccessible areas. This development includes varying activities, such as shipping, tourism, commercial fisheries, and hydrocarbon exploration. (Jacobs, 2013). However, the impacts of these activates are inherently complex due to varying environmental sensitivities (Smith, 2011). Developmental concerns exist with navigation rights, fisheries management, resource prospects, and shorter shipping routes. Arctic offshore oil expansion stands juxtaposed to environmental preservation and policy development must consider all of these complexities (Abate, 2015).

The Arctic's continental shelf development can become geopolitically significant, through resultant competition, failed diplomacy, and international territorial conflicts (Bruun & Medby, 2014). Currently, regional militarization and boundary issues are arising in efforts to control the new shipping routes. This militarization leads to concerns that ice reduction trajectories could ultimately result in an arms race between the United States and Russia (Holt & McFadden, 2015).

Fundamentally, Arctic shipping regulations are essential in integrating the United Nations Convention on the Law of the Sea (UNCLOS), regional and sub-regional agreements, national, and subject laws (Weidemann, 2014). As such, the UNCLOS "Arctic Waters Pollution Prevention Act" (AWPP) defines offshore water jurisdictions while also enhancing coastal state powers. AWPP's Article 234 outlines the Northern Sea Route's "Rules and Navigation on Seaways." Additionally, the "Arctic Environmental Protection Strategy" (AEPS) serves as a joint action plan, which shares scientific data and research. AEPS defines environmental and development activity concerns, as well as tracks pollution sources, sinks, and effects (Ringbom, 2015). Despite this progression, the Arctic still lacks a unified legislative strategy for addressing ice melt implications. This lacking strategy is particularly concerning due to expanding naval and maritime operations.

In terms of marine environmental protection, Arctic pollution control measures must use collaborative research (Weidemann, 2014). This research requires cooperation between all Arctic rim countries and partnership agencies, including NGOs, academia, and stakeholders. Arctic research should cover physical and biological processes, economic issues, and social impacts. Arctic management should also enact international and domestic laws and policies to establish coastal jurisdictions and maritime zones (NIC & USARC, 2007). Lastly, the UNCLOS application can balance Arctic rights and interests with regard to navigation, research, and exploration (Campbell, 2008).

World leaders established the Arctic Council (AC) to address existing Arctic policy deficiencies. This intergovernmental forum fosters coordination and cooperation between Arctic states while centrally focusing on its environmental protection and sustainable development issues. Current AC countries include the US, Canada, Denmark, Finland, Iceland, Norway, Russia, and Sweden. AC also represents the indigenous communities, including the Aleut, Arctic Athabaskan, Saami, Gwich'in, Inuit, and the Russian Association of Indigenous People of the North (Arctic, 2015).

Overall, the AC produces comprehensive environmental, economic, and social impact assessments through its working groups. Since its enactment in ~1995, AC passed three legally binding agreements between Arctic states. These agreements exist for Aeronautical and Maritime Search and Rescue, Marine Oil Pollution Preparedness and Response, and Enhancing International Arctic Scientific Cooperation. AC expects all Arctic states to implement the agreed standards and guidelines, as the AC itself holds no enforcement authority (Arctic, 2015).

Additionally, the International Maritime Organization (IMO) enacted the Polar Code (PC) protective policy for all ships operating in polar waters (both Arctic and Antarctic). PC became an IMO enforceable act on January 1, 2017, which covers both safety and pollution prevention regulations. PC regulations are listed in both SOLAS and MARPOL and cover ship requirements, including design, construction, equipment, search and rescue, environmental protection, and training as relevant to ship operations in polar waters. Its regulations cover ship structure, stability, watertight integrity, machinery, operational safety, fire and lifesaving equipment, communications, and navigation planning. PC also mandates training and manning requirements in compliance with current STCW standards

Through this act, the IMO also designates ship classifications as "A" (operating in medium first-year ice), "B" (operating in thin first-year ice), and "C" (operating in open water or ice conditions less than both A and B). This required PC classification certifies vessel requirements through assessing the proposed operational range, conditions, and hazards. The PC certification also assesses the vessel's limitations, plans, procedures, and safety equipment (International, 2019).

For the Arctic specifically, the PC has a mandatory Vessel Traffic Service (VTS) reporting area in the Barents region. IMO requires all vessels > 5,000 gross tons, tankers, HAZMAT cargo, tows > 200m, or are in "Not Under Command (NUC)" or "Restricted in Ability to Maneuver (RAM)" navigation status must comply with a VTS check-in. The Arctic PC also established ship routing measures to decrease the risk of incident and marine casualties. These voluntary measures include six two-way routes, six precautionary areas, and three areas to be avoided for all vessels > 400 GT (International, 2019).

7. Conclusion

Overall, while the melting ice does make some economic opportunities viable, these opportunities do come at a cost from a global perspective. While a shorter trade route through the Arctic will increase trade volume and decrease shipping times, this trade route shift also creates economic pressure and revenue losses in the traditional courses (e.g., Suez Canal). Additionally, the Arctic requires new infrastructure to support these economic opportunities, i.e. oil and gas extraction, tourism growth, as well as the necessary supportive shipping ports. The new infrastructure also necessitates design and construction considerations for building in the Arctic, including differential settlement, soil spatial variations, and ice content. While resource development opportunities exist with ongoing ice melt, all Arctic activities must also contend with opposition and resistance from environmental stewards.

This study analyzed a ten year period (2008 – 2018) to assess the Arctic ice melt's economic impact. My approach compared the NRC's gross domestic product (GDP) against the GLSR economic impacted variables. This analysis generated scatterplots displaying predictor variables relative to the GDP, being based on purchasing power parity (PPP). The study also derived the quantifiable impacts and overall significance of the economic variables. First, MLR analysis determined which impacted economic variables held the most impact on the GDP. The initial review sought to prove the null hypothesis correct, in which the statistical summary is greater than the actual observed results. By removing the individual variables, one at a time, the analysis continued until meeting the multicollinearity assumption. This derived MLR equation selection "best fit" the linear relationship between GDP and the predictor variables. However, in some situations, the datasets required non-parametric tests, in which the data did not fit in a linear relationship. These NRC's warranted CR analysis to ensure that all data points were independent of each other and to best determine the GLSR economic variables related to the GDP.

The NRC GSLR economic analysis results begin with Canada. Summary model generation first meets the multicollinearity assumption. End findings were that natural gas reserves significantly explains 88.9% of the variation in Canada's GDP. For Denmark, although most CR analyses indicated an inverse relationship, due to Denmark's falling GDP, the CR did correlate well with the increased merchant shipping. Finland's results were that natural gas production significantly explained 94.6% of the variation in GDP. Iceland's merchant shipping held 44.5% of the difference in Iceland's GDP. Norway's oil exports substantially explain 69.3% of the change in GDP. For Russia's oil production and natural gas reserves proved to have a significant effect on Russia's GDP. Sweden summary models conclude that oil exports significantly explain 54.3% of Sweden's GDP variation. Lastly, the US multiplicative model was fit, in which the summary model found that oil reserves significantly explains 76.9% of GDP variation. These numbers are indicative of GDP variations, resulting from the economic variables impacted with SLR and Arctic ice melt. However, this economic analysis approach should not be viewed as conclusive, yet this inquiry does indicate that GSLR is shaping the globe's economics and is useful for providing awareness and correlation to the potential impact as a whole.

In terms of GSLR itself, scientists use general circulation models (GCMs) to predict the overall impact. Through these models, Arctic coastal zone management (CZMT) can develop and implement mitigation and adaptation strategies. Arctic scientists observe monthly ice average patterns to monitor the ice's natural variability. This data's interpretations can then predict atmospheric circulation oscillations and warming temperatures. Ultimately, these models predict a complete sheet-melt would raise the GWB by < 7 meters.

Global sea level rise remains projected to ~1.5 - 2 mm (0.06- 0.08") per year and is predicted to disrupt transportation, communication, and business with exacerbating shoreline erosion. For this study, NOAA tide gauge data projected WL trends through hydrographic observations, temperature, and salinity inputs. Alaska (AK) tide station data and sea level (SL) trends next factored into the Arctic region's GSLR. The study results compared with the Pacific NW stations, including Washington (WA), Oregon (OR), and Pacific Islands, for contrast with the Arctic datums generated. Notable differences include the Arctic's severe weather conditions, extreme tidal ranges from the river and glacial runoff, and GIR. Overall, this study was limited to NOAA's US based NWLON, which excluded foreign country tidal data. The tidal datums generated for each selected station consisted of 2007 and 2017 autumn months. The study's suggested revisions include additional Q.C. measures. These measures could address localized ocean warming, glacial isostatic adjustments, and coastal epeirogeny issues. This Q.C. may be possible through improved modeling efforts with VDATUM application.

As it stands, the tide station data QC exists with the annual leveling surveys performed by CO-OPS during annual station maintenance. This geodetic leveling verifies the station's vertical stability by measuring to established benchmark (BM) elevations. Currently, the GWB remains at ~10-20 cm (3.94-7.87")/century, (1.5-2.0 mm (0.06- 0.08")/yr.), despite conflicting SL data from individual AK stations. The AK tidal stations validated GIR, which contrasted with the GSLR trends and the GWB overall. For most AK station's calculated data, a lowering RSL trend verifies the GIR impact. Some AK stations did have a rising RSL trend. However, these station's locations were not in SE AK. Thus, these AK stations did not experience GIR impacts. As such, these station's data further support the ongoing GSLR. The Prudhoe Bay station, being the furthest north of all stations in this study, had a RSL trend at + 2.21 mm/yr., + 0.73'/100 yrs. Sand Point is further in the Aleutian's Peninsula, with a RSL trend at + 1.22 mm/yr., or + 0.40'/100 yrs. Lastly, Arctic stations with a rising RSL trend contributes to the overall GSLR balance. The ongoing SE AK's GIR impact, however, contrasts with the Arctic and Pacific Ocean's rising SLR.

Conclusions derived from this tides analysis verifies both the ongoing GIR in SE AK, as well as the contrasting GSLR, as indicated by all stations datum calculations. The tides analysis results in the contrast for GSLR impacts. While GSLR is causing harm worldwide, as exacerbated with compounding subsidence from resource extraction, the Arctic again seems to gain economic advantages through real estate acquired with the lowering RSL trends. While scientists continue to modify GIR models with improved vertical measurements, tidal data overall does verify that Arctic ice melt is turning into an economic advantage for NRCs.

Overall, Arctic regional ice melt creates adaptation burdens for Arctic indigenous populations. Climatology impacts include new abiotic conditions and organism response considerations. Due to CC impact, AK natives routinely oppose oil company proposals. This opposition, in turn, often results in economic gains for the local population through the compensation state legislature from companies granted hydrocarbon access and development. Again, Arctic ice melt seemingly turns a profit for those most impacted by CC.

Further adjustments to developing the Arctic warrants shipping industry technological advancements. Shipping companies are now implementing double-acting hulls for ice-breaking capabilities. Currently, most ships lack ice classification, which saves fuel consumption and weight. However, this savings also results in higher repair costs through the hull, propulsion, and steering damage from the ice.

The USCG first attempted to address these Arctic shipping industry issues, in both the government and commercial sectors, through MISLE data compilations, in which the marine casualty increase corresponded with the vessel traffic increase. Increasing Arctic traffic exacerbates the threat to endangered species and remote communities. Through AIS tracking, USCG first plotted a PARS corridor to correlate with existing traffic patterns. This plotting approach enhanced the likelihood that vessels would follow the proposed route. USCG area investigations verified that the PARS was a "viable, continuous navigation corridor," and concluded that most Arctic groundings were preventable through enacting the route and avoid weak survey areas. This study also provides the PARS hydrographic survey results, which indicate the safety and security that the corridor provides.

However, in analyzing individual glaciers, including Hubbard, Sawyer, and Taku, most hydrographic survey soundings indicated shoaler depths when located closer to glaciers. These shoaler depths contrast from both the charted depths and the GSLR, GWB as a whole. Although these shallower depths differ the theory that increased ice melt would yield deeper soundings, this shoaling does indicate the occurrence of GIR.

To improve governmental response to Arctic Ice melt, NRC can also implement modeling through VDatum SLR computation applications. Arctic governments, environmental agencies, and the global maritime industry can interpret these model outputs for strategic planning. Coastal community decision-makers can then apply predictions derived from these models for mitigation efforts.

Arctic development also results in issues of navigation rights, fishery management, resource prospects, and shorter shipping route. As Arctic offshore oil expansion conflicts with environmental preservation, Arctic policy development must be comprehensive in planning for CC. Northern rim countries must adjust their policies to manage ice melt impacts through improved scientific and international institution cooperation. Once established, a joint global network could better regulate marine activities. This regulation includes shipping, fishing, resource extraction, and scientific research. As naval and maritime operations expand, so too must its UNCLOS application in balancing Arctic rights with vessel navigation, research, and exploration.

In conclusion, this capstone builds a comprehensive investigation demonstrating evidence of Arctic ice melt, GSLR, and data trending towards regional development. The Arctic's new accessibility for resource extraction ensures the Arctic's inevitable evolution. As such, NRCs must safeguard the Arctic from the resultant economic development. The world's technological advancements, coinciding with global warming's ice deterioration, warrant practical protective measures. The PARS corridor, among other IMO, Arctic Council regulations, are the first steps towards safeguarding the Arctic. As Arctic glaciers continue to recede; proactive, meaningful legislation enforcement must occur through enacted policies. Northern rim countries must, therefore, authorize law enforcement agencies the power to uphold this new legislation. Additionally, the costs and consequences for each Arctic development project must be evaluated with the highest standards to protect the environment's exposure. Although economic profits are strong motivators, only practical safeguarding measures can ensure that the Arctic's development will be far advanced from past unregulated global events.

Literature Cited

2015 Annual Report: Advancing Knowledge of Earth's Frozen Regions. (2015). *National Snow and Ice Data Center, University of Colorado Boulder.* Retrieved from nsidc@nsidc.org.http://nsidc.org/sites/nsidc.org/files/files/NSIDC_Annual_Report_2015_web.pdf

Abate, R. (2015). *Climate Change Impacts on Ocean and Coastal Law: U.S. and International Perspectives.* New York, NY: Oxford University Press.

Anderson, A.M. (2009). *After the Ice: Life, Death, and Geopolitics in the New Arctic.* New York, NY: HarperCollins Publishers.

Arico, S. (2015). *Ocean Sustainability in the 21st Century.* Cambridge, UK: Cambridge University Press.

Berchok, C.L., J.L. Crance, E.C. Garland, J.A. Mocklin, P.J. Stabeno, J.M. Napp, B.K. Rone, A.H. Spear, M. Wang, and C.W. Clark. (2015). Chukchi Offshore Monitoring In Drilling Area (COMIDA): Factors Affecting the Distribution and Relative Abundance of Endangered Whales and Other Marine Mammals in the Chukchi Sea. Final Report of the Chukchi Sea Acoustics, Oceanography, and Zooplankton Study, OCS Study BOEM 2015-034. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115-6349.

Bjola, C. (2013). Keeping the Arctic 'cold': The Rise of Plurilateral Diplomacy? *Global Policy, 4(4),* 347-358.

Brown, P. (2015). Arctic Ice Melt to Redraw Global Shipping Routes. Responding to Climate Change. *The Climate News Network.* Retrieved from: https://climatenewsnetwork.net/

Bruun, J.M., & Medby, I.A. (2014). Theorizing the Thaw: Geopolitics in a Changing Arctic. *Geography Compass, 8(12),* 915-929.

Campbell, M.L. (2008). *United States Arctic Ocean Management & the Law of the Sea Convention.* U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, General Counsel for International Law, Washington, DC.

Capital Regional District: Coastal Sea Level Rise Risk Assessment. (2015). AECOM, Victoria, BC, Canada.

Chapin, F.S., Hoel, M., Carpenter, S.R., Lubchenco, J., Walker, B., Callaghan, T.V., Folke, C., Levin, S.A., Maumller, K.G., Nilsson, C., Barrett, S., Berkes, F., Creacutepin, A., Danell, K., Rosswall, T., Starrett, D., Xepapadeas, A., & Zimov, S.A. (2006). Building Resilience and Adaptation to Manage Arctic Change. *Ambio: a Journal of the Human Environment, 35(4),* 198-202.

Chen, J. (2016). *Melting Glaciers Are Wreaking Havoc on Earth's Crust.* Retrieved from https://www.smithsonianmag.com/science-nature/melting-glaciers-are-wreaking-havoc-earths-crust-180960226/

Central Intelligence Agency [US]. (2018). *The World Factbook.* Retrieved from https://www.cia.gov/library/publications/resources/the-world-factbook/

DeMarban, A. (2018, May 13). Bowhead whales, dwellers of icy seas, enjoy steady growth off Alaska in the age of climate change. Anchorage Daily News. Retrieved from: https://www.adn.com/alaska-news/2018/05/13/bowhead-whales-dwellers-of-icy-seas-enjoy-steady-growth-off-alaska-in-the-age-of-climate-change/.

Douglas, D C. (2010). *Arctic Sea Ice Decline: Projected Changes in Timing and Extent of Sea Ice in the Bering and Chukchi Seas.* U.S. Dept. of the Interior, U.S. Geological Survey, Reston, VA.

EIA. (2012). *Petroleum products import and export statistics.* Retrieved from: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=65&aid=3&cid=DA,&syid=1984&eyid=2009&unit=TBPD Accessed 2012-09-20

Eisenman, I. & Wettlaufer, J.S. (2008). Nonlinear Threshold Behavior During the Loss of Arctic Sea Ice. *National Academy of Sciences of the United States of America*. Retrieved from: www.pnas.org/cgi/doi/10.1073/pnas.0806887106

Ferguson, M. (2019). The Aerial Surveys of Arctic Marine Mammals (ASAMM) Project: Critical to understanding the arctic ecosystem and managing arctic natural resources in the present and future. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115-6349.

Figueiredo, J. (2017). *Biostatistics – Week 4 Multiple Linear and Curvilinear Regression Lecture.* Biostatistics OCOR 5603. [Online Lecture]. Nova Southeastern University (NSU). Fort Lauderdale, FL.

Google Earth Engine. (2019). *Google Earth Timelapse.* Retrieved from https://earthengine.google.com/timelapse

Gonsalves, M., Allen, C., Fandel, C., Gallagher, B., Hick, L., Keown, P. (2016). Risk, Desire and Decay: Establishing Survey Priorities through the Assessment of Hydrographic Health. *Canadian Hydrographic Conference.*

Gryc, G. (1991). History of Petroleum Development in Arctic Alaska. *AAPG Bulletin (American Association of Petroleum Geologists), 75(3),* 587.

Haglund, D.K. (1983). Maritime Transport in Support of Arctic Resource Development. *Cold Regions Science and Technology, 7,* 231-249.

Hickey, H. (2014, February 26). Whales, ships more common through Bering Strait. UW News. Retrieved from https://www.washington.edu/news/2014/02/26/whales-ships-more-common-through-bering-strait/.

Hohenegger C., Alali B., Steffen K.R., Perovich D.K., & Golden K.M. (2012). Transition in the Fractal Geometry of Arctic Melt Ponds. *The Cryosphere, 6,* 1157–1162.

Holt, L. & McFadden, C. (2015). *Arctic Meltdown: How Rising Temperatures Are Triggering a New Cold War.* New York, NY: NBC Universal Media, LLC.

Hong, N. (2012). The Melting Arctic and Its Impact on China's Maritime Transport. *Research in Transportation Economics, 35,* 50-57.

Hovelsrud, G.K, Poppel, B., van Oort, B., & Reist, J.D. (2011). Arctic Societies, Cultures, and Peoples in a Changing Cryosphere. *Ambio, a Journal of the Human Environment, 40(1),* 100-110.

Indexmundi. (2019). *Historical Data Graphs by Year.* Retrieved from: https://www.indexmundi.com/g/g.aspx?c=sw&v=95.

Infographic: Maersk's Contribution to Denmark. (2015). Retrieved from: https://worldmaritimenews.com/archives/155150/infographic-maersks-contribution-to-denmark/

International Association of Classification Societies. (2011). *Requirements Concerning Polar Class.* IACS Requirements.

International Code for Ships Operating in Polar Waters (Polar Code): Shipping in Polar Waters. (2019). Retrieved from http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx.

International Maritime Organization Sub-Committee on Navigation, Communications, and Search and Rescue. (2017). *Routing Measures and Mandatory Ship Reporting Systems: Establishment of two-way routes and precautionary areas in the Bering Sea and Bering Strait*. (5th session). Author.

Jacobs, J.D. (2013). The Fast-Changing Arctic: Rethinking Arctic Security for a Warmer World. *Arctic, Antarctic, and Alpine Research, 46(2),* 527-528. DOI: http://dx.doi.org/10.1657/1938-4246-46.2.527

Kumar, P.K.D. (2006). Potential Vulnerability Implications of Sea Level Rise for the Coastal Zones of Cochin, Southwest Coast of India. *Environmental Monitoring and Assessment, 123,* 333–344. DOI: 10.1007/s10661-006-9200-2

Louis A. Licate, L.A., Huang, L., & Dusek, G. (2017). *NOAA Technical Report NOS CO-OPS 085: A Comparison of Datums Derived from CO-OPS Verified Data Products and Tidal Analysis Datum Calculator.* National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (DOC), National Ocean Service (NOS), Center for Operational Oceanographic Products and Services (CO-OPS). Silver Spring, MD.

Masters, Jonathan. (2013). The Thawing Arctic: Risks and Opportunities. *Council on Foreign Relations (CFR).* Retrieved from: http://www.cfr.org/arctic/thawing-arctic-risks-opportunities/p32082

Matishov, G.G, Berdnikov, S V., Zhichkin, A P., Dzhenyuk, S L., Smolyar, I., Kulygin, V.V., … Levitus, S. (2014). NOAA Atlas NEDIS, 78: Atlas of Climatic Changes in Nine Large Marine Ecosystems of the Northern Hemisphere. *International Ocean Atlas and Information Series, 14,* 1-131. doi.org/10.7289/V5Q52MK5

McDonald, J.H. (2014). *Handbook of Biological Statistics*. 3rd edition. Sparky House Publishing. Baltimore, MD.

Miller, L, & Douglas, B.C. (2004). Mass and Volume Contributions to Twentieth-Century Global Sea Level Rise. *Nature, 428,* 406-409.

Miller, L., & Douglas, B.C. (2006). On the Rate and Causes of Twentieth Century Sea-Level Rise. *Philosophical Transactions of Royal Society A, 364,* 805-820. DOI:10.1098/rsta.2006.1738

Myers, S.L., & Krauss, C. (2015). *Melting Ice Isn't Opening Arctic to Oil Bonanza*. Retrieved from: https://www.nytimes.com/2015/09/08/world/europe/melting-ice-isnt-opening-arctic-to-oil-bonanza.html

NASA. (2005). *Continued Sea Ice Decline in 2005: Image of the Day.* Retrieved from: https://earthobservatory.nasa.gov/IOTD/view.php?id=5887

National Ice Center (NIC) & U.S. Arctic Research Commission (USARC). (2007). *Impact of an Ice-Diminishing Arctic on Naval and Maritime Operations (Summary Report).* Washington, D.C: U.S. Government Printing Office.

National Oceanic and Atmospheric Administration (NOAA). (2011). *NOAA's Arctic Vision & Strategy.* Washington, DC: U.S. Government Printing Office.

National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS). (2019). *What is glacial isostatic adjustment?* Retrieved from https://oceanservice.noaa.gov/facts/glacial-adjustment.html

National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Center for Operational Oceanographic Products and Services (CO-OPS). (2018). *Water Levels - Station Selection.* Retrieved from https://tidesandcurrents.noaa.gov/

National Oceanic and Atmospheric Administration (NOAA), Office of Coast Survey (OCS). *Field Procedures Manual*. (2019). Silver Spring, MD. Author.

National Oceanic and Atmospheric Administration (NOAA), Office of Coast Survey (OCS). (2019). *Hydrographic Surveying*. Retrieved from: https://oceanservice.noaa.gov/navigation/hydro/.

National Research Council. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment.* Washington, DC: The National Academies Press.

Nicholls, Robert J. (2003). *OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers: Case study on sea-level rise impacts.* Organization for Economic Cooperation and Development (OECD), Paris, France.

NOAAS Fairweather. (2018). *Descriptive Report Memo: Submission of Survey D00247*. National
Oceanic and Atmospheric Administration Office of Coast Survey. Seattle, WA.

Pappis, C.P. (2011). Chapter 4: Climate Change and Supply Chain Operations. *Climate Change, Supply Chain Management, and Enterprise Adaptation: Implications of Global Warming on the Economy,* 93-126. DOI: 10.4018/978-1-616.

Pastusiak, T. (2016). *The Northern Sea Route As a Shipping Lane: Expectations and Reality.* Switzerland: Springer International Publishing.

Prowse, T.D., Furgal, C., Chouinard, R., Melling, H., Milburn, D., & Smith, S.L. (2009). Implications of Climate Change for Economic Development in Northern Canada: Energy, Resource, and Transportation Sectors. *Ambio, a Journal of the Human Environment, 38(5),* 272-281. DOI.org/10.1579/0044-7447-38.5.272

Qu, Bo. (2015). The Impact of Melting Ice on the Ecosystems in Greenland Sea Correlations on Ice Cover, Phytoplankton Biomass, AOD and PAR. *Springer Briefs in Environmental Science.* DOI 10.1007/978-3-642-54498-9

Ringbom, H. (2015). *Jurisdiction over Ships: Post-UNCLOS Developments in the Law of the Sea.* Leiden, the Netherlands: Koninklijke Brill NV.

Roemmich, D., Willis, J., & Gilson, J. (2006). *Ocean warming and sea level rise: Understanding Sea-level Rise and Variability.* [PowerPoint slides]. WCRP/COPES Workshop, UNESCO, Paris, France.

Schlegel, N.J. (2011). *Determining Greenland Ice Sheet Sensitivity to Regional Climate Change: One-Way Coupling of a 3-D Thermo-Mechanical Ice Sheet Model with a Mesoscale Climate Model.* Retrieved from http://escholarship.org/uc/item/5648g9d2

Serreze, M.C., & Barry, R.G. (2005). *The Arctic Climate System*. New York, NY: Cambridge University Press.

Showstack, R. (2000). Recommendations Provide Direction for Sea-Level Rise Research. *Eos, Transactions American Geophysical Union, 81(32),* 364.

Schuler, M. (2019). Northern Sea Route Shipping Expected to Quadruple by 2024. Retrieved from http://gcaptain.com/northern-sea-route-shipping-expected-to-quadruple-by-2024/.

Sigler, M.F., Aydin, K.Y., Boveng, P.L., Farley, E.V., Heintz, R.A., & Lauth, R.R. (2015). *AFSC Processed Report: Alaska Fisheries Science Center Loss of Sea Ice (LOSI) Plan for Fy15 - Fy19.* NOAA, National Marine Fisheries Service, Seattle WA.

Smith, L.C. (2011). *The World in 2050: Four Forces Shaping Civilization's Northern Future.* New York, NY: Penguin Group.

Smits, C., van Tatenhove, J., & van Leeuwen, J. (2014). Authority in Arctic governance: changing spheres of authority in Greenlandic offshore oil and gas developments. *Int Environ Agreements, 14,* 329–348. DOI 10.1007/s10784-014-9247-4.

Steinbruner, J.D., Stern, P.C., & Husbands, J.L. (2013). Climate and Social Stress: Implications for Security Analysis. *The National Academies Press.* Retrieved from: http://nap.edu/14682. DOI 10.17226/14682

Stephenson, S. R., & Smith, L.C. (2015). Influence of climate model variability on projected Arctic shipping futures. *Earth's Future, 3,* 331–343. DOI:10.1002/2015EF000317.

Sutherland, M. (2004). *Sea-Level Rise and Coastal Zone Management.* Athens, Greece: Workshop – Hydro, WHS2.1 Sea Level Rise and Coastal Zone Management.

Sutherland, M. (2011). *Sea Level Rise Modelling In a Caribbean Small Island Developing State. Hydro International.* Netherlands: Geomares Publishing. Retrieved from: http://www.hydro-international.com/content/article/sea-level-rise-modelling

The Arctic Council: A backgrounder. (2015). Retrieved from https://arctic-council.org/index.php/en/about-us.

The Global Economy. (2019). *Sweden: Economic growth, Quarterly*. Retrieved from: https://www.theglobaleconomy.com/Sweden/GDP_per_capita_PPP/

The Impacts of Global Climate Change in the Bering Sea Region: An Assessment Conducted by the International Arctic Science Committee Under Its Bering Sea Impacts Study (BESIS). (1997). Fairbanks, Alaska: Workshop, BESIS Project Office.

United States Coast Guard: Seventeenth Coast Guard District. (2016). *Preliminary Findings: Port Access Route Study: In the Chukchi Sea, Bering Strait, and Bering Sea.* [Docket Number USCG-2014-0941 and USCG-2010-0833]. Author.

United States Committee on the Marine Transportation System (2019). *A Ten Year Projection of Maritime Activity in the U.S. Arctic Region, 2020-2030.* Washington, D.C., 118 p.

United States Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. (2019). Hydrographic Surveys Specifications and Deliverables. Silver Spring, MD. Author.

Varis, O. (2006). Backyard of the Rich North: the Climate Change; related Vicious Circle of the Arctic Zone. *Ambio: a Journal of the Human Environment, 35(4),* 176-181.

Venables, W.N., & Smith, D.N. (2018). *An Introduction to R: Notes on R: A Programming Environment for Data Analysis and Graphics.* Version 3.5.1. R Core Team.

Weidemann, L. (2014). *International Governance of the Arctic Marine Environment: With Particular Emphasis on High Seas Fisheries.* Switzerland: Springer International Publishing.

Macrotrends. (2019). *Crude Oil Prices - 70 Year Historical Chart.* Retrieved from: https://www.macrotrends.net/1369/crude-oil-price-history-chart

White, S. (2019). Vertical Datum Transformation: Integrating America's Elevation Data. Retrieved from vdatum.noaa.gov

Wikipedia contributors. (2019, February 10). Arctic shipping routes. In Wikipedia, The Free Encyclopedia. Retrieved 12:58, September 5, 2019, from https://en.wikipedia.org/w/index.php?title=Arctic_shipping_routes&oldid=882603040

Willis, J.K, Chambers, D.P., Kuo, C.Y., & Shum, C.K. (2010). Global Sea Level Rise: Recent Progress and Challenges for the Decade to Come. *Oceanography. 23(4),* 26-35.

Wrona, F.J., Johansson, M., Culp, J.M., Jenkins, A., Mård, J., Myers-Smith, I.H., Prowse, T.D., Vincent, W.F., & Wookey, P.A. (2016). Transitions in Arctic Ecosystems: Ecological Implications of a Changing Hydrological Regime. *Journal of Geophysical Research: Biogeosciences, 121(3),* 650-674. DOI:10.1002/2015JG003133.

Appendix A:

Northern Rim Country Economy Datasets

Canada Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	1.25E+09	3.09E+09	1.79E+11	1.87E+11	1.07E+11	1.65E+12	175	1.27E+12
2009	1.22E+09	8.84E+08	1.78E+11	1.71E+11	1.03E+11	1.64E+12	175	1.30E+12
2010	1.2E+09	7.3E+08	1.75E+11	1.61E+11	9.47E+10	1.75E+12	184	1.34E+12
2011	1.27E+09	7.04E+08	1.75E+11	1.52E+11	9.24E+10	1.75E+12	184	1.33E+12
2012	1.31E+09	4.95E+08	1.74E+11	1.60E+11	9.27E+10	1.73E+12	181	1.45E+12
2013	1.41E+09	5.26E+08	1.73E+11	1.43E+11	8.83E+10	1.93E+12	181	1.47E+12
2014	1.41E+09	5.75E+08	1.73E+11	1.43E+11	8.83E+10	1.93E+12	181	1.52E+12
2015	1.46E+09	6.41E+08	1.73E+11	1.45E+11	8.25E+10	1.89E+12	181	1.59E+12
2016	1.34E+09	1.17E+09	1.71E+11	1.52E+11	7.8E+10	2.00E+12	181	1.63E+12
2017	1.34E+09	9.75E+08	1.70E+11	1.50E+11	7.83E+10	2.18E+12	181	1.68E+12
2018	1.34E+09	9.75E+08	1.70E+11	1.50E+11	7.83E+10	2.18E+12	639	1.77E+12

Denmark Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	1.15E+08	1.17E+08	1.19E+09	9.22E+09	4.52E+09	7.05E+10	327	2.03E+11
2009	1.05E+08	1.05E+08	1.06E+09	1.01E+10	5.52E+09	6.13E+10	327	2.04E+11
2010	95666500	98002500	1.06E+09	8.4E+09	3.98E+09	6.13E+10	347	2.04E+11
2011	90337500	97345500	8.12E+08	8.17E+09	3.52E+09	5.81E+10	347	2.02E+11
2012	80701500	62451500	9E+08	7.07E+09	3.13E+09	5.2E+10	367	2.09E+11
2013	75701000	56648000	8.05E+08	6.41E+09	2.98E+09	4.3E+10	367	2.08E+11
2014	75701000	56648000	8.05E+08	6.41E+09	2.98E+09	4.3E+10	367	2.11E+11
2015	65043000	46866000	8.05E+08	4.85E+09	2.24E+09	4.3E+10	367	2.5E+11
2016	57049500	35926950	6.11E+08	4.63E+09	2.09E+09	2.99E+10	367	2.59E+11
2017	51319000	28605050	4.91E+08	4.62E+09	2.19E+09	1.69E+10	666	2.75E+11
2018	51319000	28605050	4.91E+08	4.62E+09	2.19E+09	1.69E+10	654	2.87E+11

Finland Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	3267115	46099500	0	0	0	0	98	1.88E+11
2009	3572985	48545000	0	0	0	0	98	1.94E+11
2010	3182070	47632500	0	0	0	0	93	1.85E+11
2011	3182070	48764000	0	0	0	0	93	1.86E+11
2012	0	0	0	0	0	0	97	1.98E+11
2013	4938450	0	0	0	0	0	97	1.94E+11
2014	4938450	0	0	0	0	0	97	1.96E+11
2015	0	0	0	3000000	0	0	97	2.21E+11
2016	0	0	0	4000000	0	0	97	2.25E+11
2017	0	0	0	8000000	0	0	105	2.32E+11
2018	0	0	0	8000000	0	0	267	2.44E+11

Iceland Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	0	314192	0	0	0	0	2	1.22E+10
2009	0	1085875	0	0	0	0	2	1.29E+10
2010	0	698975	0	0	0	0	2	1.19E+10
2011	0	441285	0	0	0	0	2	1.18E+10
2012	0	0	0	0	0	0	2	1.3E+10
2013	0	0	0	0	0	0	2	1.27E+10
2014	0	0	0	0	0	0	2	1.31E+10
2015	0	0	0	0	0	0	2	1.42E+10
2016	0	0	0	0	0	0	2	1.52E+10
2017	0	0	0	0	0	0	2	1.65E+10
2018	0	0	0	0	0	0	33	1.76E+10

Norway Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	9.36E+08	9.91E+08	6.87E+09	9.26E+10	8.61E+10	2.24E+12	688	2.47E+11
2009	9E+08	8.7E+08	6.68E+09	9.92E+10	9.52E+10	2.31E+12	688	2.76E+11
2010	8.58E+08	7.52E+08	6.68E+09	1.04E+11	9.89E+10	2.31E+12	632	2.76E+11
2011	7.79E+08	7.97E+08	5.67E+09	1.06E+11	9.98E+10	2.04E+12	632	2.55E+11
2012	7.29E+08	6.42E+08	5.32E+09	1.03E+11	9.83E+10	2.01E+12	585	2.78E+11
2013	6.94E+08	5.85E+08	5.37E+09	1.15E+11	1.07E+11	2.07E+12	585	2.74E+11
2014	6.94E+08	5.85E+08	5.37E+09	1.15E+11	1.07E+11	2.07E+12	585	2.82E+11
2015	6.63E+08	4.76E+08	5.83E+09	1.09E+11	1.03E+11	2.09E+12	585	3.45E+11
2016	5.88E+08	4.58E+08	5.1E+09	1.09E+11	1.14E+11	1.92E+12	585	3.56E+11
2017	6.02E+08	5.09E+08	6.61E+09	1.17E+11	1.12E+11	1.86E+12	1585	3.65E+11
2018	6.02E+08	5.09E+08	6.61E+09	1.17E+11	1.12E+11	1.86E+12	1585	3.8E+11

Russia Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	3.6E+09	1.85E+09	6E+10	6.56E+11	2.37E+11	4.76E+13	1074	2.1E+12
2009	3.57E+09	2.5E+09	6E+10	6.62E+11	2.43E+11	4.76E+13	1074	2.27E+12
2010	3.69E+09	1.98E+09	7.42E+10	5.84E+11	1.79E+11	4.76E+13	1097	2.23E+12
2011	3.7E+09	2.66E+09	6E+10	6.1E+11	2.23E+11	4.76E+13	1097	2.22E+12
2012	3.73E+09	1.98E+09	6E+10	6.7E+11	2.04E+11	4.76E+13	1143	2.51E+12
2013	3.8E+09	1.71E+09	8E+10	6.73E+11	2E+11	4.78E+13	1143	2.49E+12
2014	3.81E+09	1.72E+09	8E+10	6.7E+11	1.96E+11	4.78E+13	1143	2.55E+12
2015	3.67E+09	1.69E+09	8E+10	6.68E+11	1.96E+11	4.78E+13	1143	3.57E+12
2016	3.74E+09	1.78E+09	8E+10	6.04E+11	1.85E+11	4.78E+13	1143	3.72E+12
2017	3.85E+09	1.87E+09	8E+10	5.99E+11	1.98E+11	4.78E+13	1143	3.86E+12
2018	3.85E+09	1.87E+09	8E+10	5.99E+11	1.98E+11	4.78E+13	2572	4.01E+12

Sweden Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	857750	80008000	0	0	0	0	195	3.39E+11
2009	1303780	80044500	0	0	0	0	195	3.45E+11
2010	1764045	90702500	0	0	0	0	163	3.54E+11
2011	1764045	88768000	0	0	0	0	163	3.55E+11
2012	0	0	0	0	0	0	135	3.96E+11
2013	4113550	0	0	0	0	0	135	3.85E+11
2014	4113550	0	0	0	0	0	135	3.94E+11
2015	3066000	4595350	0	0	0	0	135	4.48E+11
2016	0	8471650	0	0	0	0	135	4.73E+11
2017	0	0	0	0	0	0	190	4.97E+11
2018	0	0	0	0	0	0	368	5.21E+11

United States Dataset

Year	oil_prod	oil_exports	oil_reserve	nat_gas_pr	nat_gas_ex	nat_gas_re	merch_ma	GDP
2008	3.09E+09	4.25E+08	2.1E+10	5.46E+11	2.33E+10	5.98E+12	422	1.38E+13
2009	3.11E+09	5.23E+08	2.13E+10	5.82E+11	2.85E+10	6.73E+12	422	1.44E+13
2010	3.31E+09	6.22E+08	1.91E+10	5.93E+11	3.04E+10	6.93E+12	418	1.47E+13
2011	3.54E+09	7.01E+08	2.07E+10	6.11E+11	3.22E+10	7.72E+12	418	1.47E+13
2012	3.29E+09	15987000	2.07E+10	6.51E+11	4.27E+10	7.72E+12	393	1.57E+13
2013	4.06E+09	15198600	2.07E+10	6.81E+11	4.58E+10	9.46E+12	393	1.62E+13
2014	4.06E+09	15198600	2.07E+10	6.81E+11	4.58E+10	9.46E+12	393	1.67E+13
2015	4.11E+09	24626550	3.05E+10	6.88E+11	4.45E+10	8.73E+12	393	1.74E+13
2016	3.44E+09	4.24E+08	3.65E+10	7.66E+11	4.29E+10	1.04E+13	393	1.8E+13
2017	3.23E+09	2.16E+08	3.65E+10	7.66E+11	5.05E+10	8.71E+12	393	1.86E+13
2018	3.23E+09	2.16E+08	3.65E+10	7.66E+11	5.05E+10	8.71E+12	3611	1.94E+13

Appendix B:

Northern Rim Country “R” Data Transcripts

```
#Moulton: Canada Dataset (2008-2018)

#RQ: How does Canada's proven oil and natural gas production, exports, and reserves, and merchant shipping
relate with its GDP?
#Objective: Test a specific null hyp or effects

#H0: Canada's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Canada's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.
#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping
numbers
#All variables are continuous (investigating relationships)
#Implied causality between the variables

#Multiple continous predictors: multiple linear regression View()
library(lme4)
library(car)

attach(Canada_corrected_dataset)

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_re
serves+merch_marine)

shapiro.test(GDP)
#p-value = 0.6085, >0.05, do not reject null hypothesis, accept data as normal

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column
#do not expand or decrease with increasing values of IV's (do not resemble a funnel)
#Parametric Assumptions are met

#Checking the Lack of Multicollinearity assumption:
cols<-c(2,3,4,5,6,7,8)
cor(Canada_corrected_dataset[,cols])

#                    oil_prod oil_exports oil_reserves nat_gas_prod nat_gas_exports
    #oil_prod         1.00000000 -0.34789841 -0.5899201 -0.7515934     -0.6513788
    #oil_exports      -0.34789841 1.00000000 0.4316363 0.7731814       0.4688639
    #oil_reserves     -0.58992014 0.43163634 1.0000000 0.7594029       0.9660634
    #nat_gas_prod     -0.75159336 0.77318141 0.7594029 1.0000000       0.8144034
    #nat_gas_exports -0.65137876 0.46886390 0.9660634 0.8144034        1.0000000
    #nat_gas_reserves 0.56310729 -0.25130537 -0.9402850 -0.6715484     -0.9050313
    #merch_marine      0.08243089 -0.01509311 -0.4555786 -0.1620388     -0.3852129
    #              nat_gas_reserves merch_marine
```

```
#oil_prod              0.5631073 0.08243089
#oil_exports           -0.2513054 -0.01509311
#oil_reserves          -0.9402850 -0.45557862
#nat_gas_prod          -0.6715484 -0.16203885
#nat_gas_exports       -0.9050313 -0.38521294
#nat_gas_reserves       1.0000000 0.53708481
#merch_marine           0.5370848 1.00000000
```

#some predictor variables are highly correlated (more than 0.5)
#determining the variance inflation and their inverses (tolerances) of the variable:

#First run: all predictor variables
#Variance inflation
vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_prod + nat_gas_exports + nat_gas_reserves + merch_marine))

```
#            oil_prod    oil_exports    oil_reserves    nat_gas_prod nat_gas_exports
#            3.681637    7.086726       28.760825       17.426094    21.065751
#nat_gas_reserves        merch_marine
#           16.279521    1.684241
```

#Tolerances
1/vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_prod + nat_gas_exports + nat_gas_reserves + merch_marine))

```
#            oil_prod    oil_exports    oil_reserves    nat_gas_prod  nat_gas_exports
#          0.27161831    0.14110888     0.03476952      0.05738521    0.04747042
#nat_gas_reserves        merch_marine
#          0.06142687    0.59373942
```

#The Variance inflation is > 5
#tolerance is < 0.2
#there is multicollinearity
#assumption is not met

remove the ONE variable which is most highly correlated to the other variables: oil-reserves vif (lm (GDP ~ oil_prod + oil_exports + nat_gas_prod + nat_gas_exports + nat_gas_reserves + merch_marine))

```
#      oil_prod     oil_exports   nat_gas_prod  nat_gas_exports nat_gas_reserves    merch_marine
#      3.592822     5.926617      15.074816     10.070146       9.855129            1.666915
```

still not good
remove another variable which is most highly correlated to the other vars. # to do that redo correlation

cols<-c(2,3,5,6,7,8)
cor(Canada_corrected_dataset[,cols])
# var that should be removed is natural gas exports (highly correlated with nat-gas-reserves and nat-gas_prod)

vif (lm (GDP ~ oil_prod + oil_exports + nat_gas_prod + nat_gas_reserves + merch_marine))

#oil_prod oil_exports nat_gas_prod nat_gas_reserves merch_marine
#3.577352 5.827305 14.631983 4.184810 1.638227

still not good
remove another variable which is most highly correlated to the other vars. # to do that redo correlation

cols<-c(2,3,5,7,8)
cor(Canada_corrected_dataset[,cols]) #
remove nat. gas production

vif (lm (GDP ~ oil_prod + oil_exports + nat_gas_reserves +merch_marine))
#oil_prod oil_exports nat_gas_reserves merch_marine
#1.733590 1.147616 2.305203 1.565284

1/vif (lm (GDP ~ oil_prod + oil_exports + nat_gas_reserves +merch_marine))
#oil_prod oil_exports nat_gas_reserves merch_marine
#0.5768376 0.8713713 0.4338013 0.6388617
assumption met: no multicollinearity

# do multiple linear regression, start with the multiplicative model:
model1<-lm (GDP ~ oil_prod + oil_exports + nat_gas_reserves + merch_marine+
oil_prod:oil_exports+oil_prod:nat_gas_reserves+oil_prod:merch_marine+
oil_exports:nat_gas_reserves+oil_exports:merch_marine+
nat_gas_reserves:merch_marine)

summary(model1)
# you only have 11 observations (years), thus cannot test the effect of 10 effects (4 main effects 6 interactions) because there is not enough degrees of freedom to do that
# thus instead of using the backward stepwise method (start with most complex model and remove insignificant variables to simplify it),
#use forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).
to determine which should be the variable to start with, first test each predictor separately # and see which has the most signicant effect

model2<-lm(GDP~oil_prod)
summary(model2)#p=0.0315

model3<-lm(GDP~oil_exports)
summary(model3)#p=0.3837

model4<-lm(GDP~nat_gas_reserves) summary(model4)
#p=1.36e-05 --> most significant

model5<-lm(GDP~merch_marine)
summary(model5)#p=0.0681

start with model 4

model4<-lm(GDP~nat_gas_reserves)
summary(model4) #1.36e-05

add second most significant predictor to model

model6<-lm(GDP~nat_gas_reserves+oil_prod) summary(model6)

oil prod not significant. # stop,

keep model4

summary(model4) #1.36e-05

#Estimate Std. Error t value Pr(>|t|) #(Intercept) -
5.888e+10 1.826e+11 -0.322 0.754
#nat_gas_reserves 8.239e-01 9.691e-02 8.502 1.36e-05 *** #Residual
standard error: 5.863e+10 on 9 degrees of freedom #Multiple R-
squared: 0.8893, Adjusted R-squared: 0.877
#F-statistic: 72.28 on 1 and 9 DF, p-value: 1.357e-05
Natural gas reserves significantly explain canada GDP , specifically explain 88.9% of the variation in GDP.

#illustrating the relationships between the GDP and each of the GSLR economic predictors: avPlots

(model4, ask = F)

detach(Canada_corrected_dataset)

#Moulton: Denmark Dataset (2008-2018)

#RQ: How does Denmark's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Denmark's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Denmark's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression View()

```
library(lme4)
library(car)

attach(denmark_dataset)

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_reserves+merch_marine)
```

#Linearity of data points on a scatter plot: trendlines and lowess smoother on plots of the first column are fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

```
shapiro.test(GDP)
#p-value = 0.004388, <0.05, data is not normal
```

#Checking Homogeneity of variance:
Data spread around scatterplot trend line on the first column plots
does not expand / decrease with increasing values of predictors
does not resemble a funnel)

#All variables do not meet the parametric Assumptions: #
shapiro: data not normal
#Trying sqrt transformations on asymetric boxplot variables:

GDP and merchant marines

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_reserves+sqrt(merch_marine))

shapiro.test(sqrt(GDP)) #data:
sqrt(GDP)
#W = 0.77701, p-value = 0.00469

#p-value = 0.00469, <0.05, reject null hyp, data is not normal #Parametric

assumptions are not met (even after transformations) #Curvilinear

Regression

#Curvilinear Regression: Performing for each independent variable against GDP #GDP

and oil production (1 of 7)

scatterplot (GDP ~ oil_prod, reg.line = F)
#Relationship reaches a plateau (Non-linear Regression)
#Analysis: Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_prod), start=list(a=1))
summary(model)

#Formula: GDP ~ a * log(oil_prod)

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 1.256e+10 5.944e+08 21.13 1.25e-09 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 3.577e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 2.925e-09

#p-value = <0.05 (1.25e-09), reject null hypothesis, Oil production is a significant impact on GDP. #GDP

and oil exports (2 of 7)

scatterplot (GDP ~ oil_exports, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_exports), start=list(a=1))

```
summary(model)
#Formula: GDP ~ a * log(oil_exports)

#Parameters:
# Estimate Std. Error t value Pr(>|t|)
#a 1.270e+10 6.501e+08 19.54 2.69e-09 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 #Residual

standard error: 3.861e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1 #Achieved
convergence tolerance: 5.294e-09

#p-value = <0.05 (2.69e-09), reject null hypothesis, Oil exports are a significant impact on GDP. #GDP

and oil reserves (3 of 7)

scatterplot (GDP ~ oil_reserves, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_reserves), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(oil_reserves)

#Parameters:
# Estimate Std. Error t value Pr(>|t|)
#a 1.112e+10 5.227e+08 21.28 1.17e-09 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 3.552e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 1.523e-09
#p-value = <0.05 (1.17e-09), reject null hypothesis, Oil reserves are a significant impact on GDP. #GDP

and Natural Gas Production (4 of 7)

scatterplot (GDP ~ nat_gas_prod, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(nat_gas_prod), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(nat_gas_prod)
```

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 1.009e+10 4.699e+08 21.47 1.07e-09 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 3.522e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 7.371e-09
#p-value = <0.05 (1.07e-09), reject null hypothesis, natural gas production is a significant impact on GDP. #GDP

and natural gas exports (5 of 7)

scatterplot (GDP ~ nat_gas_exports, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(nat_gas_exports), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(nat_gas_exports)

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 1.044e+10 4.884e+08 21.36 1.12e-09 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 3.539e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 6.398e-10
#p-value = <0.05 (1.12e-09), reject null hypothesis, natural gas exports are a significant impact on GDP. #GDP

and natural gas reserves (6 of 7)

scatterplot (GDP ~ nat_gas_reserves, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(nat_gas_reserves), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(nat_gas_reserves)

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 9.318e+09 4.553e+08 20.46 1.72e-09 *** #---

```
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 3.691e+10 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 1.963e-09
#p-value = <0.05 (1.72e-09), reject null hypothesis, natural gas reserves have a significant impact on GDP.

#GDP and merchant marines (7 of 7) scatterplot (GDP ~

merch_marine, reg.line = F)
#Relationship does not necessarily plateau (Polynomial Regression)

mod.lm3 <- lm (GDP ~ poly (merch_marine, 3, raw=T)) mod.lm2
<- lm (GDP ~ poly (merch_marine, 2, raw=T)) anova(mod.lm3,
mod.lm2)
#Analysis of Variance Table

#Model 1: GDP ~ poly(merch_marine, 3, raw = T) #Model
2: GDP ~ poly(merch_marine, 2, raw = T) # Res.Df RSS Df
Sum of Sq F Pr(>F)
#1 7 2.6644e+21
#2 8 2.7469e+21 -1 -8.2483e+19 0.2167 0.6557

#p-value: 0.6557, >0.05, accept null hyp; models are equal, keeping the lower order model (2)
summary(mod.lm2)
#Call:
# lm(formula = GDP ~ poly(merch_marine, 2, raw = T))

#Residuals:
#                Min        1Q     Median        3Q       Max
#-1.718e+10 -1.254e+10 -4.207e+09 5.133e+09 3.322e+10

#Coefficients:
#                                  Estimate Std. Error t value Pr(>|t|)
#(Intercept)                          -1.957e+11 2.746e+11 -0.713 0.496
#poly(merch_marine, 2, raw = T)1  1.680e+09  1.196e+09   1.405   0.198
#poly(merch_marine, 2, raw = T)2 -1.452e+06  1.186e+06  -1.224   0.256

#Residual standard error: 1.853e+10 on 8 degrees of freedom
#Multiple R-squared:  0.7406,                 Adjusted R-squared:  0.6758
#F-statistic: 11.42 on 2 and 8 DF, p-value: 0.004527

#p-value: 0.004527, <0.05, reject null hyp, merchant marines numbers have a significant impact on GDP.

#Summary plot:
plot(GDP~merch_marine,pch=16,axes=F,xlab='',ylab='')
```

```
axis(1,cex.axis=0.8)
mtext(text='Merchant Marine', side=1,line=3)
axis(2,las=1)
mtext(text='GDP',side=2,line=3)
box(bty='l')
IVpred<-seq(min(merch_marine),max(merch_marine),l=8)
points(IVpred,predict(mod.lm2,data.frame(merch_marine=IVpred)),type='l')

#all anlaysis indicates each variable has sig impact on GDP

detach(denmark_dataset)
```

#Moulton: Finland Dataset (2008-2018)

#RQ: How does Finland's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Finland's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Finland's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression View()

```
library(lme4)
library(car)

attach(Finland)
```

#Skipped 0 columns (non factors) on dataset import:
#oil reserves, nat gas exports and reserves = 0/non factors

```
scatterplotMatrix(~GDP+oil_prod+oil_exports+nat_gas_prod+merch_marine)
```

#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

```
shapiro.test(GDP)
```

#Shapiro-Wilk normality test #data:
GDP
#W = 0.85137, p-value = 0.04447
#p-value = 0.04447, <0.05, reject null hyp: data is not normal
#All variables do not meet the parametric assumptions, asymetrical boxplots

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs

#does not resemble a funnel

#variables do not meet the parametric Assumptions
#Attempting scale transformations and then checking parametric assumptions #of transformed data

scatterplotMatrix(~sqrt(GDP)+sqrt(oil_prod)+sqrt(oil_exports)+sqrt(nat_gas_prod)+sqrt(merch_marine) #scatter plot

data point linearity: first column trendlines and lowess smoother plots:
#fairly linear

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel

#Parametric assumptions are met after transformation

#Checking the Lack of Multicollinearity assumption:
cols<-c(2,3,4,5)
cor(Finland[,cols])

```
#              oil_prod oil_exports nat_gas_prod merch_marine
#oil_prod      1.0000000 0.4545695 -0.7100292 -0.3525968
#oil_exports 0.4545695 1.0000000 -0.5116129 -0.2651330
#nat_gas_prod -0.7100292 -0.5116129 1.0000000 0.6406710
#merch_marine -0.3525968 -0.2651330 0.6406710 1.0000000
```

#Nat gas prod and merch marine variables are highly correlated (more than 0.5)
#determining the variance inflation and their inverses (tolerances) of the variable:
#includes transformations

#First run: all predictor variables

#Variance inflation

```
vif (lm (sqrt(GDP) ~ sqrt(oil_prod) + sqrt(oil_exports) + sqrt(nat_gas_prod) + sqrt(merch_marine)))
#sqrt(oil_prod) sqrt(oil_exports) sqrt(nat_gas_prod) sqrt(merch_marine)
#         2.983692        1.559872        3.687259        1.546105
```

#Tolerences:

```
1/vif (lm (sqrt(GDP) ~ sqrt(oil_prod) + sqrt(oil_exports) + sqrt(nat_gas_prod) + sqrt(merch_marine)))
#sqrt(oil_prod) sqrt(oil_exports) sqrt(nat_gas_prod) sqrt(merch_marine)
#        0.3351552        0.6410781        0.2712042        0.6467867
```

#VIF is < 5; tolerance is > 0.2 #There is no multicollinearity

#Assumption is met

#Fitting a multiplicative model with the data transformed

mod1.lm <-lm(sqrt(GDP) ~ sqrt(oil_prod) + sqrt(oil_exports) + sqrt(nat_gas_prod) + sqrt(merch_marine) + sqrt(oil_prod):sqrt(oil_exports) + sqrt(oil_prod):sqrt(nat_gas_prod) + sqrt(oil_prod):sqrt(merch_marine) + sqrt(oil_exports):sqrt(nat_gas_prod) + sqrt(oil_exports):sqrt(merch_marine) + sqrt(nat_gas_prod):sqrt(merch_marine))
summary (mod1.lm)

#use forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).
#determine which should be the variable to start with: test each predictor separately #and see which has the most signicant effect

model2<-lm(sqrt(GDP)~sqrt(oil_prod))
summary(model2) #p= 0.002107 model3<-
lm(sqrt(GDP)~sqrt(oil_exports))
summary(model3) #p= 0.02429
model4<-lm(sqrt(GDP)~sqrt(nat_gas_prod))
summary(model4) #p=5.39e-07--> most significant
model5<-lm(sqrt(GDP)~sqrt(merch_marine))
summary(model5) #p=0.03265

# start with model 4
model4<-lm(sqrt(GDP)~sqrt(nat_gas_prod))
summary(model4)#p-value: 5.39e-07

# add second most significant predictor to model model6<-
lm(sqrt(GDP)~sqrt(nat_gas_prod)+sqrt(oil_prod))
summary(model6)#p-value: 5.488e-06

oil prod not significant. # stop,
keep model4
summary(model4)#p-value: 5.39e-07

#Estimate Std. Error t value Pr(>|t|)
#(Intercept) 4.378e+05 2.067e+03 211.87 < 2e-16 ***
#sqrt(nat_gas_prod) 1.788e+01 1.429e+00 12.51 5.39e-07 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 5533 on 9 degrees of freedom #Multiple R-squared: 0.9456, Adjusted R-squared: 0.9396
#F-statistic: 156.5 on 1 and 9 DF, p-value: 5.39e-07

#Natural gas production significantly explains Finlands GDP,
#specifically explains 94.6% of the variation in GDP.

#Illustrating relationship: between GDP and Natural Gas Production: avPlots

(model4, ask = F)

detach(Finland)

#Moulton: Iceland Dataset Analysis (2008-2018)

#RQ: How does Iceland's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Iceland's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Iceland's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression

View() library(lme4)
library(car)

attach(Iceland_corrected)

#Skipped 0 columns (non factors) on dataset import:
#oil products/reserves, nat gas products/exports/reserves = 0/nonfactors

scatterplotMatrix(~GDP+oil_exports+merch_marine)

#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear #Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

shapiro.test(GDP)
#Shapiro-Wilk normality test #data:
GDP
#W = 0.86548, p-value = 0.06779
#p-value = 0.06779, >0.05, accept data as normal

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel

```
#Parametric assumptions are met

#Checking the Lack of Multicollinearity assumption:
cols<-c(2,3)
cor(Iceland[,cols])

#                    oil_exports merch_marine
#oil_exports 1.0000000  -0.2065971
#merch_marine -0.2065971 1.0000000

#determining the variance inflation and their inverses (tolerances) of the variable:

#Variance inflation:

vif (lm(GDP ~ oil_exports + merch_marine))
#oil_exports merch_marine
#   1.044585            1.044585

#Tolerences:

1/vif(lm(GDP ~ oil_exports + merch_marine))
#oil_exports merch_marine
# 0.9573177 0.9573177

#VIF is < 5; tolerance is > 0.2 #There is
no multicollinearity #Assumption is
met

#Fitting a multiplicative model

mod1.lm <-lm(GDP ~ oil_exports +merch_marine +oil_exports:merch_marine)
summary (mod1.lm)

#use forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).
#determine which should be the variable to start with: test each predictor separately #and see
which has the most signicant effect

model2<-lm(GDP~oil_exports)
summary(model2)#p= 0.121 model3<-
lm(GDP~merch_marine)
summary(model3)#p=0.025 --> most significant

#start with model 3
model3<-lm(GDP~merch_marine)
summary(model3) #p=0.025
# add second most significant predictor to model
model4<-lm(GDP~merch_marine+oil_exports)
```

summary(model4)#p-value: 0.03154 # oil
exports not significant.
# stop, keep model3
summary(model3)
#Estimate Std. Error t value Pr(>|t|)
#(Intercept) 1.306e+10 5.213e+08 25.055 1.23e-09 ***
#merch_marine 1.382e+08 5.145e+07 2.685 0.025 * #--
-
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 1.521e+09 on 9 degrees of freedom
#Multiple R-squared: 0.4448, Adjusted R-squared: 0.3831
#F-statistic: 7.21 on 1 and 9 DF, p-value: 0.025

#Merchant marine significantly explains Iceland's GDP, specifically explain44.5% #of the variation in GDP.

#Illustrating relationship: between GDP and each of the predictors: avPlots

(model3, ask = F)

detach(Iceland)

#Moulton: Norway Dataset Analysis (2008-2018)

#RQ: How does Norway's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Norway's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Norway's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression

View() library(lme4)
library(car)

attach(Norway)

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_reserves+merch_marine)

#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

shapiro.test(GDP)
#Shapiro-Wilk normality test

#data: GDP
#W = 0.84583, p-value = 0.03764

#p-value = 0.03764, <0.05, data is not normal

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel

#Some variables do not meet the parametric Assumptions #Trying
transformations

```
scatterplotMatrix(~sqrt(GDP)+sqrt(oil_prod)+sqrt(oil_exports)+sqrt(oil_reserves)+sqrt(nat_gas_prod)+s
qrt(nat_gas_exports)+sqrt(nat_gas_reserves)+sqrt(merch_marine))
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

shapiro.test(sqrt(GDP)) #Shapiro-
Wilk normality test

#data: sqrt(GDP)
#W = 0.85261, p-value = 0.04616
#0.05, data is normal, parametric assumptions are met

#Checking the Lack of Multicollinearity assumption:
cols<-c(2,3,4,5,6,7,8)
cor(Norway[,cols])

#                   oil_prod oil_exports oil_reserves nat_gas_prod nat_gas_exports
    #oil_prod          1.0000000 0.9587762 0.4710002 -0.8612286      -0.9311844
    #oil_exports       0.9587762 1.0000000 0.4859124 -0.8322714      -0.9033016
    #oil_reserves      0.4710002 0.4859124 1.0000000 -0.3083585      -0.3993303
    #nat_gas_prod     -0.8612286 -0.8322714 -0.3083585 1.0000000      0.9062451
    #nat_gas_exports -0.9311844 -0.9033016     -0.3993303  0.9062451   1.0000000
    #nat_gas_reserves 0.9039086 0.7553120      0.3597822  -0.7420615  -0.7872170
    #merch_marine      -0.4417257  -0.3127569   0.5149803  0.5174563   0.4451918
#                  nat_gas_reserves merch_marine
#oil_prod                0.9039086  -0.4417257
    #oil_exports         0.7553120 -0.3127569
    #oil_reserves        0.3597822 0.5149803
    #nat_gas_prod       -0.7420615 0.5174563
    #nat_gas_exports     -0.7872170  0.4451918
    #nat_gas_reserves      1.0000000  -0.5877324
    #merch_marine        -0.5877324  1.0000000

#some predictor variables are highly correlated (more than 0.5)
#determining the variance inflation and their inverses (tolerances) of the variable:

#First run: all predictor variables #Variance
inflation (with transformations)
vif (lm (sqrt(GDP) ~ sqrt(oil_prod) + sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) +
sqrt(nat_gas_exports) + sqrt(nat_gas_reserves) + sqrt(merch_marine)))
#   sqrt(oil_prod)          sqrt(oil_exports)    sqrt(oil_reserves)
#              704.03737         181.52505        62.48200
```

```
#sqrt(nat_gas_prod) sqrt(nat_gas_exports) sqrt(nat_gas_reserves) #
                11.32768            33.59669           230.91081
#sqrt(merch_marine) #
                91.25795

#Tolerances
1/vif (lm (sqrt(GDP) ~ sqrt(oil_prod) + sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) +
sqrt(nat_gas_exports) + sqrt(nat_gas_reserves) + sqrt(merch_marine)))
#   sqrt(oil_prod)                 sqrt(oil_exports)     sqrt(oil_reserves)
#               0.001420379          0.005508882          0.016004610
#sqrt(nat_gas_prod) sqrt(nat_gas_exports) sqrt(nat_gas_reserves) #
                0.088279330          0.029764841          0.004330676
#sqrt(merch_marine) #
                0.010957950

#The Variance inflation is greater than 5 and/or tolerance is smaller than 0.2, #thus
there is multicollinearity (assumption is not met)

#2nd run:
#Removing highest correlated predictor variable: oil_prod #testing
variance inflation and tolerances to the new model:

vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(nat_gas_exports) +
sqrt(nat_gas_reserves) + sqrt(merch_marine)))
#   sqrt(oil_exports)                sqrt(oil_reserves)     sqrt(nat_gas_prod)
#                    7.557735           46.937175           10.391873
#sqrt(nat_gas_exports) sqrt(nat_gas_reserves)                  sqrt(merch_marine)
#                   11.360845           37.480169                  65.926150

#Tolerances
1/vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(nat_gas_exports)
+ sqrt(nat_gas_reserves) + sqrt(merch_marine)))
#   sqrt(oil_exports)                sqrt(oil_reserves)     sqrt(nat_gas_prod)
#                  0.13231478           0.02130507       0.09622904
#sqrt(nat_gas_exports) sqrt(nat_gas_reserves)                  sqrt(merch_marine)
#                  0.08802162           0.02668078                  0.01516849

#Variance inflation > 5
#Tolerance < 0.2
#There is multicollinearity (assumption is not met)

#2nd run:
#redo correlation; removing oil_prod from col:
cols<-c(3,5,6,7,8)
cor(Norway[,cols])
#                       oil_exports nat_gas_prod nat_gas_exports nat_gas_reserves
#oil_exports           1.0000000   -0.8322714              -0.9033016       0.7553120
#nat_gas_prod                  -0.8322714    1.0000000       0.9062451       -0.7420615
```

```
#nat_gas_exports -0.9033016      0.9062451     1.0000000      -0.7872170
#nat_gas_reserves 0.7553120     -0.7420615    -0.7872170       1.0000000
#merch_marine       -0.3127569   0.5174563     0.4451918      -0.5877324
#              merch_marine
#oil_exports              -0.3127569
#nat_gas_prod              0.5174563
#nat_gas_exports     0.4451918
#nat_gas_reserves   -0.5877324
#merch_marine        1.0000000
```

#var that should be removed is natural gas exports (highly correlated with nat_gas_prod)

```
vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(nat_gas_reserves)
+ sqrt(merch_marine)))
#   sqrt(oil_exports)    sqrt(oil_reserves)    sqrt(nat_gas_prod)
#   5.071766             44.207735             9.144693
#sqrt(nat_gas_reserves)          sqrt(merch_marine)
#                   36.381558    62.349664

1/vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) +
sqrt(nat_gas_reserves) + sqrt(merch_marine)))
#   sqrt(oil_exports)    sqrt(oil_reserves)    sqrt(nat_gas_prod)
#   0.19716999           0.02262048            0.10935304
#sqrt(nat_gas_reserves)          sqrt(merch_marine)
#                  0.02748645    0.01603858
```

#Variance inflation > 5
#Tolerance < 0.2
#There is multicollinearity (assumption is not met)

#3rd run:
#redo correlation; removing nat_gas_exports from col:

```
cols<-c(3,5,7,8)
cor(Norway[,cols])
#                     oil_exports nat_gas_prod nat_gas_reserves merch_marine
#oil_exports          1.0000000  -0.8322714            0.7553120  -0.3127569
#nat_gas_prod               -0.8322714   1.0000000      -0.7420615   0.5174563
#nat_gas_reserves   0.7553120  -0.7420615                1.0000000  -0.5877324
#merch_marine               -0.3127569   0.5174563      -0.5877324   1.0000000
```

#var that should be removed is nat_gas_reserves (highly correlated with oil_exports)

```
vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(merch_marine)))
#sqrt(oil_exports) sqrt(oil_reserves) sqrt(nat_gas_prod) sqrt(merch_marine)
#3.845168                 4.279598       4.608345       4.475230

1/vif (lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(merch_marine)))
#sqrt(oil_exports) sqrt(oil_reserves) sqrt(nat_gas_prod) sqrt(merch_marine)
```

```
#0.2600666                    0.2336668        0.2169976        0.2234522

#Variance inflation < 5
#Tolerance > 0.2
#assumption met: no multicollinearity

model1<-lm (sqrt(GDP) ~ sqrt(oil_exports) + sqrt(oil_reserves) + sqrt(nat_gas_prod) + sqrt(merch_marine) +
sqrt(oil_exports): sqrt(oil_reserves)+ sqrt(oil_exports): sqrt(nat_gas_prod) + sqrt(oil_exports):
sqrt(merch_marine) + sqrt(oil_reserves): sqrt(nat_gas_prod) + sqrt(oil_reserves): sqrt(merch_marine) +
sqrt(nat_gas_prod): sqrt(merch_marine))
summary(model1)

#use forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).


# to determine which should be the variable to start with, first test each predictor separately # and
see which has the most signicant effect

model2<-lm(sqrt(GDP)~sqrt(oil_exports)) summary(model2)
#p= 0.001475--> most significant model3<-
lm(sqrt(GDP)~sqrt(oil_reserves)) summary(model3) #p=
0.9637
model4<-lm(sqrt(GDP)~sqrt(nat_gas_prod)) summary(model4) #p=
0.03131
model5<-lm(sqrt(GDP)~sqrt(merch_marine)) summary(model5) #p=
0.03284

# start with model 2
model2<-lm(sqrt(GDP)~sqrt(oil_exports))
summary(model2) #p-value: 0.001475

# add second most significant predictor to model
model6<-lm(sqrt(GDP)~sqrt(oil_exports)+sqrt(nat_gas_prod))
summary(model6)#p-value: 0.008409

#nat_gas_prod not significant. # stop,
keep model2

summary(model2)

#                              Estimate Std. Error t value Pr(>|t|)
#(Intercept)                  818082.971 60172.141 13.596 2.64e-07 ***
#sqrt(oil_exports)    -10.618                  2.356 -4.506 0.00148 **
#---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 #Residual

standard error: 25120 on 9 degrees of freedom
```

#Multiple R-squared: 0.6929,	Adjusted R-squared: 0.6588
#F-statistic: 20.31 on 1 and 9 DF, p-value: 0.00147

#oil_exports significantly explain canada GDP, specifically explain 69.3% of the variation in GDP.

#illustrating the relationships between the GDP and oil_exports:

avPlots (model2, ask = F)

detach(Norway)

#Moulton: Russia Dataset Analysis (2008-2018)

#RQ: How does Russia's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Russia's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Russia's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression

View() library(lme4)
library(car)

attach(Russia)

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_reserves+merch_marine)
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

#Shapiro-Wilk normality test
shapiro.test(GDP)
#data: GDP
#W = 0.81137, p-value = 0.01328
#p-value = 0.01328, <0.05, data is not normal, reject null hyp

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel

#Some variables do not meet the parametric Assumptions #Trying transformations

```
scatterplotMatrix(~sqrt(GDP)+oil_prod+oil_exports+sqrt(oil_reserves)+sqrt(nat_gas_prod)+sqrt(nat_gas
_exports)+sqrt(nat_gas_reserves)+sqrt(merch_marine))
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear

#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

#Shapiro-Wilk normality test
shapiro.test(sqrt(GDP)) #data:
sqrt(GDP)
#W = 0.82101, p-value = 0.01778

scatterplotMatrix(~log10(GDP)+oil_prod+oil_exports+log10(oil_reserves)+log10(nat_gas_prod)+log10(n
at_gas_exports)+log10(nat_gas_reserves)+log10(merch_marine))
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear

#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is asymmetric/not normal).
#Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

#Shapiro-Wilk normality test
shapiro.test(log10(GDP))
#p-value = 0.02405, <0.05, data not normal, reject null hyp #Parametric

assumptions are not met (even after transformations) #Curvilinear

Regression

#Curvilinear Regression: Performing for each independent variable against GDP #GDP

and oil production (1 of 7)

scatterplot (GDP ~ oil_prod, reg.line = F)
#Relationship reaches a plateau (Non-linear Regression)
#Analysis: Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_prod), start=list(a=1))
summary(model)

#Formula: GDP ~ a * log(oil_prod)

#Parameters:
# Estimate Std. Error t value Pr(>|t|)
#a 1.300e+11 1.025e+10 12.68 1.73e-07 *** #---
```

#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 7.494e+11 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 2.314e-09

#p-value = <0.05 (1.73e-07), reject null hypothesis, Oil production has a significant impact on GDP. #GDP

and oil exports (2 of 7)

scatterplot (GDP ~ oil_exports, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_exports), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(oil_exports)

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 1.339e+11 1.072e+10 12.49 2.01e-07 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 7.606e+11 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 7.05e-09

#p-value = <0.05 (2.01e-07), reject null hypothesis, Oil exports have a significant impact on GDP. #GDP

and oil Reserves (3 of 7)

scatterplot (GDP ~ oil_reserves, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(oil_reserves), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(oil_reserves)

#Parameters:
Estimate Std. Error t value Pr(>|t|)
#a 1.148e+11 8.931e+09 12.85 1.53e-07 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 7.403e+11 on 10 degrees of freedom

#Number of iterations to convergence: 1 #Achieved
convergence tolerance: 1.189e-08

#p-value = <0.05 (1.53e-07), reject null hypothesis, Oil reserves have a significant impact on GDP. #GDP

and Natural Gas Production (4 of 7)

scatterplot (GDP ~ nat_gas_prod, reg.line = F)
#Relationship does not necessarily plateau
#Polynomial Regression

mod.lm3 <- lm (GDP ~ poly (nat_gas_prod, 3, raw=T)) mod.lm2
<- lm (GDP ~ poly (nat_gas_prod, 2, raw=T)) anova(mod.lm3,
mod.lm2)
#Analysis of Variance Table

#Model 1: GDP ~ poly(nat_gas_prod, 3, raw = T) #Model
2: GDP ~ poly(nat_gas_prod, 2, raw = T) # Res.Df RSS Df
Sum of Sq F Pr(>F)
#1 7 3.4283e+24
#2 8 4.7586e+24 -1 -1.3302e+24 2.7161 0.1433

#p-value: 0.1433, >0.05, accept null hyp; models are equal, keeping the lower order model (2)
summary(mod.lm2)
#Call:
#lm(formula = GDP ~ poly(nat_gas_prod, 2, raw = T))

#Residuals:
Min 1Q Median 3Q Max
#-9.648e+11 -5.686e+11 -5.784e+09 6.093e+11 9.721e+11

#Coefficients:
Estimate Std. Error t value Pr(>|t|)
#(Intercept) -5.735e+13 1.829e+14 -0.313 0.762
#poly(nat_gas_prod, 2, raw = T)1 1.992e+02 5.807e+02 0.343 0.740
#poly(nat_gas_prod, 2, raw = T)2 -1.639e-10 4.596e-10 -0.357 0.731

#Residual standard error: 7.712e+11 on 8 degrees of freedom
#Multiple R-squared: 0.157, Adjusted R-squared: -0.05369
#F-statistic: 0.7452 on 2 and 8 DF, p-value: 0.5049

#p-value: 0.5049, >0.05, accept null hyp, natural gas production does not have a significant impact on GDP.

#Summary plot:
plot(GDP~nat_gas_prod,pch=16,axes=F,xlab='',ylab='')

```
axis(1,cex.axis=0.8)
mtext(text='Natural Gas Production', side=1,line=3)
axis(2,las=1)
mtext(text='GDP',side=2,line=3)
box(bty='l')
IVpred<-seq(min(nat_gas_prod),max(nat_gas_prod),l=8)
points(IVpred,predict(mod.lm2,data.frame(nat_gas_prod=IVpred)),type='l')

#GDP and natural gas exports (5 of 7) scatterplot (GDP ~

nat_gas_exports, reg.line = F)
#Relationship reaches a plateau (Non-linear Regression)
#Analysis: Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(nat_gas_exports), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(nat_gas_exports)

#Parameters:
# Estimate Std. Error t value Pr(>|t|)
#a 1.10e+11 8.76e+09 12.55 1.91e-07 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 7.566e+11 on 10 degrees of freedom

#Number of iterations to convergence: 1
#Achieved convergence tolerance: 1.633e-09

#p-value = <0.05 (1.91e-07), reject null hypothesis, natural gas exports have a significant impact on GDP. #GDP

and natural gas reserves (6 of 7)

scatterplot (GDP ~ nat_gas_reserves, reg.line = F) #Relationship
reaches a plateau (Non-linear Regression) #Analysis:
Logarithmic: DV~a*log(IV)

model <- nls(GDP~a*log(nat_gas_reserves), start=list(a=1))
summary(model)
#Formula: GDP ~ a * log(nat_gas_reserves)

#Parameters:
# Estimate Std. Error t value Pr(>|t|)
#a 9.098e+10 7.191e+09 12.65 1.77e-07 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 #Residual

standard error: 7.512e+11 on 10 degrees of freedom
```

#Number of iterations to convergence: 1 #Achieved
convergence tolerance: 3.861e-09

#p-value = <0.05 (1.77e-07), reject null hypothesis, natural gas reserves has a significant impact on GDP. #GDP

and merchant marines (7 of 7)

scatterplot (GDP ~ merch_marine, reg.line = F)
#Relationship does not necessarily plateau (Polynomial Regression)

mod.lm3 <- lm (GDP ~ poly (merch_marine, 3, raw=T)) mod.lm2
<- lm (GDP ~ poly (merch_marine, 2, raw=T)) anova(mod.lm3,
mod.lm2)

#Analysis of Variance Table

#Model 1: GDP ~ poly(merch_marine, 3, raw = T) #Model
2: GDP ~ poly(merch_marine, 2, raw = T) # Res.Df RSS Df
Sum of Sq F Pr(>F)
#1 7 2.2180e+24
#2 8 2.3228e+24 -1 -1.0482e+23 0.3308 0.5832

#p-value: 0.5832, >0.05, accept null hyp; models are equal, keeping the lower order model (2)

summary(mod.lm2)
#Call:
lm(formula = GDP ~ poly(merch_marine, 2, raw = T))

#Residuals:
Min 1Q Median 3Q Max
#-6.078e+11 -3.663e+11 -1.866e+08 3.410e+11 7.682e+11

#Coefficients:
Estimate Std. Error t value Pr(>|t|)
#(Intercept) -2.578e+13 1.149e+13 -2.245 0.0550 .
#poly(merch_marine, 2, raw = T)1 3.621e+10 1.473e+10 2.458 0.0395 *
#poly(merch_marine, 2, raw = T)2 -9.574e+06 3.997e+06 -2.396 0.0435 * #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 5.388e+11 on 8 degrees of freedom
#Multiple R-squared: 0.5885, Adjusted R-squared: 0.4857
#F-statistic: 5.721 on 2 and 8 DF, p-value: 0.02867

#p-value: 0.02867, <0.05, reject null hyp, merchant marines numbers have a significant impact on GDP.

#Summary plot:

```
plot(GDP~merch_marine,pch=16,axes=F,xlab='',ylab='')
axis(1,cex.axis=0.8)
mtext(text='Merchant Marine', side=1,line=3)
axis(2,las=1)
mtext(text='GDP',side=2,line=3)
box(bty='l')
IVpred<-seq(min(merch_marine),max(merch_marine),l=8)
points(IVpred,predict(mod.lm2,data.frame(merch_marine=IVpred)),type='l')

#all anlaysis indicates each variable has sig impact on GDP except nat gas prod

detach(Russia)
```

#Moulton: Sweden Dataset Analysis (2008-2018)

#RQ: How does Sweden's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: Sweden's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: Sweden's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression

View() library(lme4)
library(car)

#Oil Reserves and Natural Gas predictors were excluded from dataset as nonfactors.
attach(Sweden)

scatterplotMatrix(~GDP+oil_prod+oil_exports+merch_marine)
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is symmetric/normal). #Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

#Shapiro-Wilk normality test
shapiro.test(GDP)
#p-value = 0.154, >0.05, data is normal

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel #Parametric

assumptions are met

#Checking the Lack of Multicollinearity assumption: cols<-
c(2,3,4,5)
cor(Sweden[,cols])
# oil_prod oil_exports merch_marine GDP

#oil_prod 1.00000000 -0.060335647 -0.446398687 -0.3748900
#oil_exports -0.06033565 1.000000000 -0.008522306 -0.7366069
#merch_marine -0.44639869 -0.008522306 1.000000000 0.4405900
#GDP -0.37489001 -0.736606908 0.440590016 1.0000000

#No predictor variables are highly correlated (>0.5)
#determining the variance inflation and their inverses (tolerances) of the variable:

#First run: all predictor variables
#Variance inflation
vif (lm (GDP ~ oil_prod + oil_exports + merch_marine))
#oil_prod oil_exports merch_marine
#1.255313 1.005238 1.250834

1/vif (lm (GDP ~ oil_prod + oil_exports + merch_marine)) #
oil_prod oil_exports merch_marine
#0.7966140 0.9947896 0.7994665

#Variance inflation is < 5
#Tolerance is > 0.2
#There is no multicollinearity (assumption is met) #Fitting

a multiplicative model with the data

mod1.lm <-lm(GDP ~ oil_prod +oil_exports + merch_marine
+oil_prod:oil_exports+oil_prod:merch_marine +oil_exports:merch_marine)
summary (mod1.lm)

H0: GDP is not affected by the IV's #use

forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).

to determine which should be the variable to start with, first test each predictor separately # and
see which has the most signicant effect

model2<-lm(GDP~oil_prod)
summary(model2)#p=0.256 model3<-
lm(GDP~oil_exports)
summary(model3) #p=0.009723 --> most significant
model4<-lm(GDP~merch_marine) summary(model4)
#p=0.175

# start with model 3 model3<-
lm(GDP~oil_exports)
summary(model3) #0.009723

```
# add second most significant predictor to model
model6<-lm(GDP~oil_exports+merch_marine)
summary(model6)#p-value: 0.005218 #merch_marine:
not significant (>model 3). #stop, keep model3
summary(model3) #1.36e-05

#                          Estimate Std. Error t value Pr(>|t|)
#(Intercept) 4.461e+11 1.783e+10 25.013 1.25e-09 ***
#oil_exports -1.135e+03 3.473e+02 -3.267 0.00972 ** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 4.621e+10 on 9 degrees of freedom
#Multiple R-squared:  0.5426,                 Adjusted R-squared:  0.4918
#F-statistic: 10.68 on 1 and 9 DF, p-value: 0.009723

#Oil Exports significantly explains Sweden's GDP, specifically 54.3% of the variation in GDP. #Illustrating

relationship: between GDP and each of the predictors:

avPlots (model3, ask = F)

detach(Sweden)
```

#Moulton: United States Dataset Analysis (2008-2018)

#RQ: How does United State's proven oil and natural gas production, exports, and reserves, and merchant shipping relate with its GDP?

#Objective: Test a specific null hyp or effects

#H0: United State's oil/gas reserves, production, exports, and merchant shipping are not related to its overall GDP.
#H1: United State's oil/gas reserves, production, exports, and merchant shipping are related to its overall GDP.

#DV - response variables (continuous): GDP
#IV - predictor variables (continuous): oil/gas exports/production/proven reserves; marine shipping numbers

#All variables are continuous (investigating relationships)
#Implied causality between the variables
#Multiple continous predictors: multiple linear regression

View() library(lme4)
library(car)

attach(United_States)

scatterplotMatrix(~GDP+oil_prod+oil_exports+oil_reserves+nat_gas_prod+nat_gas_exports+nat_gas_reserves+merch_marine)
#scatter plot data point Linearity: first column trendlines and lowess smoother plots: fairly linear
#Checking the normality of the response variable:
#Boxplot of GDP response variable (top left in the diagonal of the figure panel is symmetric/normal). #Confirming GDP normality with the Shapiro-Wilk test (H0: data is normal):

Shapiro-Wilk normality test
shapiro.test(GDP)
#p-value = 0.6803, >0.05, data is normal

#Checking Homogeneity of variance:
#Spread of data around scatterplot trend line on the plots of the first column: #Do not expand or decrease with increasing values of IVs
#does not resemble a funnel #Parametric

assumptions are met

#Checking the Lack of Multicollinearity assumption: cols<-
c(2,3,4,5,6,7,8)
cor(United_States[,cols])

```
#                    oil_prod oil_exports oil_reserves nat_gas_prod nat_gas_exports
    #oil_prod          1.0000000 -0.56360598 -0.1119491 0.2208362     0.4275851
    #oil_exports       -0.5636060 1.00000000 -0.1649569 -0.4629088    -0.7194287
    #oil_reserves      -0.1119491 -0.16495687 1.0000000 0.8492215     0.6245116
    #nat_gas_prod      0.2208362 -0.46290884 0.8492215 1.0000000      0.9140847
    #nat_gas_exports 0.4275851 -0.71942869    0.6245116   0.9140847    1.0000000
    #nat_gas_reserves 0.5908893 -0.49637875   0.5493858   0.8486843    0.8119654
    #merch_marine      -0.2306392 -0.08431971  0.4671101  0.4120672    0.3668417
#                 nat_gas_reserves merch_marine
#oil_prod                0.5908893  -0.23063915
    #oil_exports         -0.4963787 -0.08431971
    #oil_reserves        0.5493858 0.46711013
    #nat_gas_prod        0.8486843 0.41206720
    #nat_gas_exports        0.8119654 0.36684165
    #nat_gas_reserves       1.0000000 0.10629100
    #merch_marine          0.1062910 1.00000000

#some predictor variables are highly correlated (more than 0.5)
#determining the variance inflation and their inverses (tolerances) of the variable:

#First run: all predictor variables
#Variance inflation:

vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_prod + nat_gas_exports + nat_gas_reserves +
merch_marine))
#             oil_prod    oil_exports    oil_reserves    nat_gas_prod nat_gas_exports
#             29.19686      10.59610      101.82271     1111.75717     347.98625
#nat_gas_reserves             merch_marine
#            155.15783        1.66148

#Tolerances:

1/vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_prod + nat_gas_exports +
nat_gas_reserves + merch_marine))
#             oil_prod    oil_exports    oil_reserves    nat_gas_prod  nat_gas_exports
#          0.034250262    0.094374375    0.009820992    0.000899477    0.002873677
#nat_gas_reserves             merch_marine
#          0.006445050    0.601873138

#VIF > 5 and tolerance < 0.2
#There is multicollinearity (assumption is not met)

#2nd run:
#removing the ONE variable highly correlated to the other variables: nat_gas_prod (correlates with Nat_gas
exports/reserves)

vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_exports + nat_gas_reserves + merch_marine))
```

```
#    oil_prod                   oil_exports     oil_reserves nat_gas_exports nat_gas_reserves
#    3.212351                       3.621196        3.144528        9.156804        6.149063
#merch_marine #
                 1.652189

#doesn't pass #3rd

run:
#rerunning correlation cols<-
c(2,3,6,7,8)
cor(United_States[,cols])
#                              oil_prod oil_exports nat_gas_exports nat_gas_reserves merch_marine
          #oil_prod            1.0000000 -0. 56360598       0.4275851        0.5908893 -0.23063915
          #oil_exports          -0.5636060 1.00000000        -0.7194287        -0.4963787 -0.08431971
          #nat_gas_exports 0.4275851      -0.71942869          1.0  00000        0.8    19654 0.36684165
          #nat_gas_reserves 0.5908893      -0.49637875         0.8   19654        1.0    00000 0.10629100
          #merch_marine        -0.230639  -0.08431971        0.3  68417        0.1    62910 1.00000000

# var that should be removed is nat_gas_reserves (highly corr. w/nat_gas_export and Oil_prod)

vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + nat_gas_exports + merch_marine))
#oil_prod                  oil_exports oil_reserves nat_gas_exports  merch_marine
#2.009678                      2.966085       2.745116       5.627053       1.492458

#doesn't pass #4th

run:
#rerunning correlation cols<-
c(2,3,6,8)
cor(United_States[,cols])
#                             oil_prod oil_exports nat_gas_exports merch_marine
#oil_prod                     1.0000000 -0.56360598       0.4275851  -0.23063915
#oil_exports                  -0.5636060  1.00000000      -0.7194287  -0.08431971
#nat_gas_exports  0.4275851 -0.71942869                     1.0000000   0.36684165
#merch_marine    -0.2306392 -0.08431971                     0.3668417   1.00000000

# var that should be removed is nat_gas_exports (highly corr. w/oil_prod and merch_marine ) vif (lm

(GDP ~ oil_prod + oil_exports + oil_reserves + merch_marine))
#oil_prod oil_exports oil_reserves merch_marine
#1.676485                  1.631779     1.322973     1.370736

1/vif (lm (GDP ~ oil_prod + oil_exports + oil_reserves + merch_marine)) #
oil_prod oil_exports oil_reserves merch_marine
#0.5964861 0.6128280 0.7558734 0.7295350

# assumption met: no multicollinearity
```

#doing multiple linear regression, start with the multiplicative model:

model1<-lm (GDP ~ oil_prod + oil_exports + oil_reserves + merch_marine+
oil_prod:oil_exports+oil_prod:oil_reserves+oil_prod:merch_marine+
oil_exports:oil_reserves+oil_exports:merch_marine+ oil_reserves:merch_marine)

summary(model1) #p-value: 0.1341 #use
forward stepwise method
#(start with the simplest model, and add variables to it if those lead to a significant effect).

to determine which should be the variable to start with, first test each predictor separately # and
see which has the most signicant effect

model2<-lm(GDP~oil_prod)
summary(model2)#p=0.5503 model3<-
lm(GDP~oil_exports)
summary(model3)#p=0.1243 model4<-
lm(GDP~oil_reserves)
summary(model4) #p=0.0003965--> most significant
model5<-lm(GDP~merch_marine)
summary(model5)#p=0.0885

#start with model4
model4<-lm(GDP~oil_reserves)
summary(model4) #0.0003965

# add second most significant predictor to model
model6<-lm(GDP~oil_reserves+merch_marine)
summary(model6) # 0.001967 #merchant_marines: not
significant.
#stop, keep model4

summary(model4)
# Estimate Std. Error t value Pr(>|t|)
#(Intercept) 1.071e+13 1.066e+12 10.041 3.46e-06 ***
#oil_reserves 2.175e+02 3.978e+01 5.468 0.000397 *** #---
#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#Residual standard error: 9.414e+11 on 9 degrees of freedom
#Multiple R-squared: 0.7686, Adjusted R-squared: 0.7429
#F-statistic: 29.89 on 1 and 9 DF, p-value: 0.0003965

#oil_reserves significantly explains US GDP , specifically explain 76.9% of the variation in GDP.

#Illustrating relationship: between GDP and each of the predictors:

```
avPlots (model4, ask = F)

detach(United_States)
```

Appendix C:

Tidal Datasheets

Appendix C:

Tidal Datasheets

State	Station	Station ID	Lat	Long	2007 (m)	2017 (m)	Tidal Datum Analysis Period	Control Station	↑ / ↓	diff: 2007 to 2017 (+/-)
AK	Adak Island	9461380	51° 51.8' N	176° 37.9' W	0.714	0.625	2007 & 2017: 09/01-30	9450460 Ketchikan	↓	-0.089
AK	Anchorage	9455920	61° 14.2' N	149° 53.4' W	4.906	4.995	2007 & 2017: 09/01-30	9455760 Nikiski	↑	0.089
AK	Cordova	9454050	60° 33.5' N	145° 45.3' W	2.127	2.166	2007 & 2017: 09/01-30	9450460 Ketchikan	↑	0.039
AK	Kodiak Island	9457292	57° 43.8' N	152° 30.8' W	1.445	1.375	2007 & 2017: 09/01-30	9457804 Alitak	↓	-0.07
AK	Prudhoe Bay	9497645	70° 24.7' N	148° 31.9' W	0.152	0.319	2007 & 2017: 09/01-30	9450460 Ketchikan	↑	0.167
AK	Sand Point	9459450	55° 19.9' N	160° 30.2' W	1.152	1.308	2007-08/01-31; 2017 - 09/01-30	9450460 Ketchikan	↑	0.156
AK	Sitka	9451600	57° 3.1' N	135° 20.5' W	1.666	1.661	2007 & 2017: 09/01-30	9451054 Port Alexander	↓	-0.005
HI	Nawiliwili	1611400	21° 57.2' N	159° 21.3' W	0.306	0.287	2007 & 2017: 09/01–30	1615680 Kahului, Kahului Harbor	↓	-0.019
MW	Sand Is (Midway)	1619910	28° 12.7' N	177° 21.6' W	0.137	0.179	2007 & 2017: 09/01-30	1611400 Nawiliwili	↑	0.042
OR	Charleston	9432780	43° 20.7' N	124° 19.3' W	1.309	1.273	2007 & 2017: 09/01-30	9437540 Garibaldi	↓	-0.036
OR	Garibaldi	9437540	45° 33.3' N	123° 55.1' W	1.426	1.438	2007 & 2017: 09/01-30	9439040 Astoria	↑	0.012
OR	South Beach	9435380	44° 37.5' N	124° 2.7' W	1.41	1.404	2007 & 2017: 09/01–30	9437540 Garibaldi	↓	-0.006
WA	Cherry Pt	9449424	48° 51.8' N	122° 45.5' W	1.618	1.617	2007 & 2017: 09/01-30	9449880 Friday Harbor	↓	-0.001
WA	Port Townsend	9444900	48° 6.8' N	122° 45.6' W	1.543	1.551	2007 & 2017: 09/01-30	9449880 Friday Harbor	↑	0.008
WA	Seattle	9447130	47° 36.1' N	122° 20.3' W	2.062	2.088	2007 & 2017: 09/01-30	9449880 Friday Harbor	↑	0.026
WA	Toke Point	9440910	46° 42.5' N	123° 58' W	2.123	2.128	2007 & 2017: 09/01-30	9441102 Westport	↑	0.005

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/23 22:40:15

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.155
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.062
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.652
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.655
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.714
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.243
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.204

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.094
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.038
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.819
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.957

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.495	Date	=	2007/09/07 09:12
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.363	Date	=	2007/09/05 16:12

Detailed Output

Run Time: 2018-11-23 22:40:16
Using CO-OPS_9461380_wlSEP07.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2007-09-02 21:54:00 for min time/range.
Deleting 2 tides at 2007-09-03 23:42:00 for min time/range.
Deleting 2 tides at 2007-09-25 02:06:00 for min time/range.
39 highs 39 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 0.645
Highest Water Level: 1.511
Lowest Water Level: -0.381
Duration: 29 days, 23:54:00
High Tides Found: 39
Low Tides Found : 39
Tides per day: 2.6
Diurnal Using DIUR
12 Highs
27 Higher Highs
10 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 1.495
MHHW = 1.083
MHW = 0.991
MSL = 0.645
MLW = 0.164
MLLW = 0.130
LWL = -0.363

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -3.629
Mean Diff MTL = -3.691

Mean_Diff_DTL = -3.586
Mean_Ratio_MN = 0.207
Mean Ratio GT = 0.203
Mean_Diff_MHHW = -5.453
Mean_Diff_MHW = -5.273
Mean_Diff_MLW = -2.109
Mean_Diff_MLLW = -1.719
Mean Ratio DHQ = 0.339
Mean Ratio DLQ = 0.080

Corrected values for MN, GT, MTL, DTL
0.819 0.957 0.652 0.655
Corrected values for DHQ, DLQ
0.094 0.038
Corrected values for MHHW, MHW, MLW, MLLW
1.142 1.047 0.257 0.168

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 1.495 (2007/09/07 09:12)
MHHW = 1.155
MHW = 1.062
DTL = 0.655
MTL = 0.652
MSL = 0.714
MLW = 0.243
MLLW = 0.204
DHQ = 0.094
DLQ = 0.038
GT = 0.957
MN = 0.819
LWL = -0.363 (2007/09/05 16:12)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

(http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/23 22:42:18

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.992
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.920
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.619
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.503
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.625
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.318
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.010

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.072
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.308
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.602
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.907

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.296	Date	=	2017/09/15 08:18
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.316	Date	=	2017/09/16 17:30

Detailed Output

Run Time: 2018-11-23 22:42:19
Using CO-OPS_9461380_wl_SEP17.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2017-09-12 22:30:00 for min time/range.
Deleting 2 tides at 2017-09-15 01:12:00 for min time/range.
Deleting 2 tides at 2017-09-17 02:12:00 for min time/range.
Deleting 2 tides at 2017-09-30 00:48:00 for min time/range.
48 highs 48 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 0.560
Highest Water Level: 1.313
Lowest Water Level: -0.325
Duration: 29 days, 23:54:00
High Tides Found: 48
Low Tides Found : 48
Tides per day: 3.2
Semi-Diurnal - Using EXHL
24 Highs
24 Higher Highs
24 Lows
24 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 1.296
MHHW = 0.906
MHW = 0.855
MSL = 0.560
MLW = 0.245
MLLW = 0.033
LWL = -0.316

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -3.718

Mean Diff MTL = -3.724
Mean_Diff_DTL = -3.738
Mean_Ratio_MN = 0.152
Mean Ratio GT = 0.193
Mean_Diff_MHHW = -5.570
Mean_Diff_MHW = -5.423
Mean_Diff_MLW = -2.025
Mean_Diff_MLLW = -1.907
Mean Ratio DHQ = 0.261
Mean Ratio DLQ = 0.642

Corrected values for MN, GT, MTL, DTL
0.602 0.907 0.619 0.503
Corrected values for DHQ, DLQ
0.072 0.308
Corrected values for MHHW, MHW, MLW, MLLW
1.025 0.897 0.341 -0.020

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 1.296 (2017/09/15 08:18)
MHHW = 0.992
MHW = 0.920
DTL = 0.503
MTL = 0.619
MSL = 0.625
MLW = 0.318
MLLW = 0.010
DHQ = 0.072
DLQ = 0.308
GT = 0.907
MN = 0.602
LWL = -0.316 (2017/09/16 17:30)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

(http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9455760 Nikiski

Date of Analysis: 2018/11/23 23:12:24

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	8.845
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	8.617
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.666
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.453
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.906
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.715
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.063

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.228
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.652
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	7.902
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	8.810

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	10.302	Date	=	2007/09/30 05:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.727	Date	=	2007/09/29 12:12

Detailed Output

Run Time: 2018-11-23 23:12:24
Using CO-OPS_9455920_wlSEP07.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 5.051
Highest Water Level: 10.313
Lowest Water Level: -0.815
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9455760

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
8.273 8.050 5.142 5.356 5.453 2.661 2.011
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
6.262 5.390 0.223 0.650 4.216 7.567 1.189

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 10.302
MHHW = 8.890
MHW = 8.706
MSL = 5.051
MLW = 0.736
MLLW = 0.104
LWL = -0.727

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.450
Mean Diff MTL = -0.690
Mean_Diff_DTL = -0.689
Mean_Ratio_MN = 1.466
Mean Ratio GT = 1.407

Mean_Diff_MHHW = 0.581
Mean_Diff_MHW = 0.577
Mean_Diff_MLW = -1.957
Mean_Diff_MLLW = -1.960
Mean Ratio DHQ = 1.020
Mean Ratio DLQ = 1.004

Corrected values for MN, GT, MTL, DTL
7.902 8.810 4.666 4.453
Corrected values for DHQ, DLQ
0.228 0.652
Corrected values for MHHW, MHW, MLW, MLLW
8.854 8.627 0.704 0.051

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 10.302 (2007/09/30 05:36)
MHHW = 8.845
MHW = 8.617
DTL = 4.453
MTL = 4.666
MSL = 4.906
MLW = 0.715
MLLW = 0.063
DHQ = 0.228
DLQ = 0.652
GT = 8.810
MN = 7.902
LWL = -0.727 (2007/09/29 12:12)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9455760 Nikiski

Date of Analysis: 2018/11/23 23:15:19

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	9.080
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	8.796
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.761
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.551
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.995
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.726
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.037

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.284
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.689
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	8.071
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	9.128

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	9.859	Date	=	2017/09/09 05:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.456	Date	=	2017/09/19 22:24

Detailed Output

Run Time: 2018-11-23 23:15:19
Using CO-OPS_9455920_wl_SEP17.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 5.102
Highest Water Level: 9.875
Lowest Water Level: -0.523
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9455760

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
8.273 8.050 5.142 5.356 5.453 2.661 2.011
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
6.262 5.390 0.223 0.650 4.216 7.567 1.189

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 9.859
MHHW = 8.990
MHW = 8.818
MSL = 5.102
MLW = 0.735
MLLW = 0.229
LWL = -0.456

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.361
Mean Diff MTL = -0.595
Mean_Diff_DTL = -0.591
Mean_Ratio_MN = 1.498
Mean Ratio GT = 1.458

Mean_Diff_MHHW = 0.785
Mean_Diff_MHW = 0.748
Mean_Diff_MLW = -1.938
Mean_Diff_MLLW = -1.966
Mean Ratio DHQ = 1.274
Mean Ratio DLQ = 1.059

Corrected values for MN, GT, MTL, DTL
8.071 9.128 4.761 4.551
Corrected values for DHQ, DLQ
0.284 0.689
Corrected values for MHHW, MHW, MLW, MLLW
9.058 8.798 0.723 0.045

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 9.859 (2017/09/09 05:36)
MHHW = 9.080
MHW = 8.796
DTL = 4.551
MTL = 4.761
MSL = 4.995
MLW = 0.726
MLLW = 0.037
DHQ = 0.284
DLQ = 0.689
GT = 9.128
MN = 8.071
LWL = -0.456 (2017/09/19 22:24)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/18 22:51:17

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.882
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.616
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.077
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.982
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.127
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.539
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.085

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.266
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.453
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.078
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.787

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.830	Date	=	2007/09/28 22:54
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.748	Date	=	2007/09/28 04:30

Detailed Output

Run Time: 2018-11-18 22:51:17
Using CO-OPS_9454050_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 2.058
Highest Water Level: 4.838
Lowest Water Level: -0.751
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 4.830
MHHW = 3.818
MHW = 3.556
MSL = 2.058
MLW = 0.450
MLLW = 0.049
LWL = -0.748

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -2.216
Mean Diff MTL = -2.266
Mean_Diff_DTL = -2.259
Mean_Ratio_MN = 0.778
Mean Ratio GT = 0.804

Mean_Diff_MHHW = -2.718
Mean_Diff_MHW = -2.708
Mean_Diff_MLW = -1.823
Mean_Diff_MLLW = -1.800
Mean Ratio DHQ = 0.964
Mean Ratio DLQ = 0.946

Corrected values for MN, GT, MTL, DTL
3.078 3.787 2.077 1.982
Corrected values for DHQ, DLQ
0.266 0.453
Corrected values for MHHW, MHW, MLW, MLLW
3.877 3.612 0.543 0.087

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 4.830 (2007/09/28 22:54)
MHHW = 3.882
MHW = 3.616
DTL = 1.982
MTL = 2.077
MSL = 2.127
MLW = 0.539
MLLW = 0.085
DHQ = 0.266
DLQ = 0.453
GT = 3.787
MN = 3.078
LWL = -0.748 (2007/09/28 04:30)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/18 22:53:38

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.923
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.655
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.104
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.997
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.166
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.552
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.068

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.268
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.484
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.102
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.810

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	4.238	Date	=	2017/09/08 23:30
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.441	Date	=	2017/09/20 16:00

Detailed Output

Run Time: 2018-11-18 22:53:38
Using CO-OPS_9454050_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 2.101
Highest Water Level: 4.238
Lowest Water Level: -0.457
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 4.238
MHHW = 3.799
MHW = 3.607
MSL = 2.101
MLW = 0.462
MLLW = 0.129
LWL = -0.441

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -2.177
Mean Diff MTL = -2.239
Mean_Diff_DTL = -2.244
Mean_Ratio_MN = 0.785
Mean Ratio GT = 0.809

Mean_Diff_MHHW = -2.677
Mean_Diff_MHW = -2.671
Mean_Diff_MLW = -1.808
Mean_Diff_MLLW = -1.811
Mean Ratio DHQ = 0.970
Mean Ratio DLQ = 1.011

Corrected values for MN, GT, MTL, DTL
3.102 3.810 2.104 1.997
Corrected values for DHQ, DLQ
0.268 0.484
Corrected values for MHHW, MHW, MLW, MLLW
3.918 3.649 0.558 0.076

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 4.238 (2017/09/08 23:30)
MHHW = 3.923
MHW = 3.655
DTL = 1.997
MTL = 2.104
MSL = 2.166
MLW = 0.552
MLLW = 0.068
DHQ = 0.268
DLQ = 0.484
GT = 3.810
MN = 3.102
LWL = -0.441 (2017/09/20 16:00)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9457804 Alitak

Date of Analysis: 2018/11/23 23:30:08

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.713
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.435
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.414
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.382
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.445
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.393
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.066

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.277
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.327
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.042
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.648

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.455	Date	=	2007/09/28 23:30
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.417	Date	=	2007/09/28 05:00

Detailed Output

Run Time: 2018-11-23 23:30:08
Using CO-OPS_9457292_wl_SEP07.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.371
Highest Water Level: 3.463
Lowest Water Level: -0.466
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9457804

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
5.286 5.041 3.497 3.614 3.592 2.188 1.708
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
3.578 2.854 0.245 0.479 Null 4.576 10.625

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 3.455
MHHW = 2.659
MHW = 2.385
MSL = 1.371
MLW = 0.338
MLLW = 0.044
LWL = -0.417

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -2.169
Mean Diff MTL = -2.200
Mean_Diff_DTL = -2.115
Mean_Ratio_MN = 0.716
Mean Ratio GT = 0.740

Mean_Diff_MHHW = -2.574
Mean_Diff_MHW = -2.606
Mean_Diff_MLW = -1.794
Mean_Diff_MLLW = -1.656
Mean Ratio DHQ = 1.131
Mean Ratio DLQ = 0.682

Corrected values for MN, GT, MTL, DTL
2.042 2.648 1.414 1.382
Corrected values for DHQ, DLQ
0.277 0.327
Corrected values for MHHW, MHW, MLW, MLLW
2.712 2.435 0.394 0.052

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.455 (2007/09/28 23:30)
MHHW = 2.713
MHW = 2.435
DTL = 1.382
MTL = 1.414
MSL = 1.445
MLW = 0.393
MLLW = 0.066
DHQ = 0.277
DLQ = 0.327
GT = 2.648
MN = 2.042
LWL = -0.417 (2007/09/28 05:00)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9457804 Alitak

Date of Analysis: 2018/11/23 23:32:56

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.676
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.369
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.338
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.291
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.375
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.307
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.027

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.306
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.334
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.062
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.667

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.858	Date	=	2017/09/06 10:12
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.342	Date	=	2017/09/20 16:42

Detailed Output

Run Time: 2018-11-23 23:32:57
Using CO-OPS_9457292_wl_SEP17.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.346
Highest Water Level: 2.862
Lowest Water Level: -0.351
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9457804

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
5.286 5.041 3.497 3.614 3.592 2.188 1.708
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
3.578 2.854 0.245 0.479 Null 4.576 10.625

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.858
MHHW = 2.565
MHW = 2.366
MSL = 1.346
MLW = 0.303
MLLW = 0.070
LWL = -0.342

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -2.239
Mean Diff MTL = -2.276
Mean_Diff_DTL = -2.206
Mean_Ratio_MN = 0.723
Mean Ratio GT = 0.745

Mean_Diff_MHHW = -2.631
Mean_Diff_MHW = -2.671
Mean_Diff_MLW = -1.881
Mean_Diff_MLLW = -1.780
Mean Ratio DHQ = 1.251
Mean Ratio DLQ = 0.698

Corrected values for MN, GT, MTL, DTL
2.062 2.667 1.338 1.291
Corrected values for DHQ, DLQ
0.306 0.334
Corrected values for MHHW, MHW, MLW, MLLW
2.655 2.370 0.307 -0.072

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.858 (2017/09/06 10:12)
MHHW = 2.676
MHW = 2.369
DTL = 1.291
MTL = 1.338
MSL = 1.375
MLW = 0.307
MLLW = -0.027
DHQ = 0.306
DLQ = 0.334
GT = 2.667
MN = 2.062
LWL = -0.342 (2017/09/20 16:42)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/16 13:36:14

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.321
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.254
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.157
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.134
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.152
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.059
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.008

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.067
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.067
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.195
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.323

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.591	Date	=	2007/09/11 08:54
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.437	Date	=	2007/09/25 14:48

Detailed Output

Run Time: 2018-11-16 13:36:15
Using CO-OPS_9497645_wl_2007.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2007-09-04 20:48:00 for min time/range.
Deleting 2 tides at 2007-09-06 18:24:00 for min time/range.
Deleting 2 tides at 2007-09-07 06:48:00 for min time/range.
Deleting 2 tides at 2007-09-08 02:42:00 for min time/range.
Deleting 2 tides at 2007-09-09 04:30:00 for min time/range.
Deleting 2 tides at 2007-09-21 02:24:00 for min time/range.
Deleting 2 tides at 2007-09-21 19:24:00 for min time/range.
Deleting 2 tides at 2007-09-22 12:36:00 for min time/range.
Deleting 2 tides at 2007-09-23 21:00:00 for min time/range.
45 highs 46 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 0.083
Highest Water Level: 0.598
Lowest Water Level: -0.446
Duration: 29 days, 23:54:00
High Tides Found: 45
Low Tides Found : 46
Tides per day: 3.0
Semi-Diurnal - Using EXHL
23 Highs
22 Higher Highs
23 Lows
23 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 0.591
MHHW = 0.246
MHW = 0.180
MSL = 0.083
MLW = -0.016
MLLW = -0.076
LWL = -0.437

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007

From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -4.191
Mean Diff MTL = -4.186
Mean_Diff_DTL = -4.107
Mean_Ratio_MN = 0.049
Mean Ratio GT = 0.069
Mean_Diff_MHHW = -6.290
Mean_Diff_MHW = -6.084
Mean_Diff_MLW = -2.289
Mean_Diff_MLLW = -1.925
Mean Ratio DHQ = 0.242
Mean Ratio DLQ = 0.140

Corrected values for MN, GT, MTL, DTL
0.195 0.323 0.157 0.134
Corrected values for DHQ, DLQ
0.067 0.067
Corrected values for MHHW, MHW, MLW, MLLW
0.305 0.236 0.077 -0.038

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.591 (2007/09/11 08:54)
MHHW = 0.321
MHW = 0.254
DTL = 0.134
MTL = 0.157
MSL = 0.152
MLW = 0.059
MLLW = -0.008
DHQ = 0.067
DLQ = 0.067
GT = 0.323
MN = 0.195
LWL = -0.437 (2007/09/25 14:48)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/16 13:41:09

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.438
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.386
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.301
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.253
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.319
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.215
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.129

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.052
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.086
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.171
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.280

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.925	Date	=	2017/09/30 03:06
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.118	Date	=	2017/09/08 16:48

Detailed Output

Run Time: 2018-11-16 13:41:10
Using CO-OPS_9497645_wl_2017.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2017-09-28 16:06:00 for min time/range.
Deleting 2 tides at 2017-09-30 07:48:00 for min time/range.
54 highs 53 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 0.254
Highest Water Level: 0.959
Lowest Water Level: -0.125
Duration: 29 days, 23:54:00
High Tides Found: 54
Low Tides Found : 53
Tides per day: 3.6
Semi-Diurnal - Using EXHL
27 Highs
27 Higher Highs
27 Lows
26 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 0.925
MHHW = 0.355
MHW = 0.318
MSL = 0.254
MLW = 0.145
MLLW = 0.085
LWL = -0.118

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -4.024
Mean Diff MTL = -4.042
Mean_Diff_DTL = -3.988

Mean_Ratio_MN = 0.043
Mean Ratio GT = 0.059
Mean_Diff_MHHW = -6.121
Mean_Diff_MHW = -5.960
Mean_Diff_MLW = -2.125
Mean_Diff_MLLW = -1.855
Mean Ratio DHQ = 0.188
Mean Ratio DLQ = 0.181

Corrected values for MN, GT, MTL, DTL
0.171 0.280 0.301 0.253
Corrected values for DHQ, DLQ
0.052 0.086
Corrected values for MHHW, MHW, MLW, MLLW
0.474 0.360 0.241 0.032

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.925 (2017/09/30 03:06)
MHHW = 0.438
MHW = 0.386
DTL = 0.253
MTL = 0.301
MSL = 0.319
MLW = 0.215
MLLW = 0.129
DHQ = 0.052
DLQ = 0.086
GT = 0.280
MN = 0.171
LWL = -0.118 (2017/09/08 16:48)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/16 14:12:50

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-08-01 - 2007-08-31

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.155
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.950
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.162
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.061
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.152
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.375
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.021

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.204
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.396
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.576
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.168

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.416	Date	=	2007/08/27 09:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.573	Date	=	2007/08/12 17:06

Detailed Output

Run Time: 2018-11-16 14:12:51
Using CO-OPS_9459450_wl_AUG07.csv
7440 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2007-08-22 20:36:00 for min time/range.
59 highs 59 lows
Data Start: 2007-08-01 00:00:00
Data End : 2007-08-31 23:54:00
Mean Water Level: 1.111
Highest Water Level: 2.420
Lowest Water Level: -0.576
Duration: 30 days, 23:54:00
High Tides Found: 59
Low Tides Found : 59
Tides per day: 3.8
Semi-Diurnal - Using EXHL
30 Highs
29 Higher Highs
30 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
8 / 2007 :
HWL = 2.416
MHHW = 2.142
MHW = 1.921
MSL = 1.111
MLW = 0.323
MLLW = -0.050
LWL = -0.573

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

8 2007 8 2007
From 8 / 2007 to 8 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -3.191
Mean Diff MTL = -3.181
Mean_Diff_DTL = -3.180
Mean_Ratio_MN = 0.398

Mean Ratio GT = 0.460
Mean_Diff_MHHW = -4.465
Mean_Diff_MHW = -4.387
Mean_Diff_MLW = -1.974
Mean_Diff_MLLW = -1.896
Mean Ratio DHQ = 0.740
Mean Ratio DLQ = 0.826

Corrected values for MN, GT, MTL, DTL
1.576 2.168 1.162 1.061
Corrected values for DHQ, DLQ
0.204 0.396
Corrected values for MHHW, MHW, MLW, MLLW
2.130 1.933 0.392 -0.009

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.416 (2007/08/27 09:36)
MHHW = 2.155
MHW = 1.950
DTL = 1.061
MTL = 1.162
MSL = 1.152
MLW = 0.375
MLLW = -0.021
DHQ = 0.204
DLQ = 0.396
GT = 2.168
MN = 1.576
LWL = -0.573 (2007/08/12 17:06)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9450460 Ketchikan

Date of Analysis: 2018/11/16 14:07:15

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.299
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.098
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.327
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.217
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.308
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.556
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.131

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.201
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.425
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.542
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.075

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.556	Date	=	2017/09/04 09:24
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.222	Date	=	2017/09/17 15:18

Detailed Output

Run Time: 2018-11-16 14:07:16
Using CO-OPS_9459450_wl_2017.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.243
Highest Water Level: 2.566
Lowest Water Level: -0.245
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 58
Tides per day: 3.9
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9450460

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
6.595 6.320 4.241 4.343 4.345 2.366 1.887
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
4.708 3.953 0.276 0.479 Null 3.105 9.409

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.556
MHHW = 2.184
MHW = 2.039
MSL = 1.243
MLW = 0.477
MLLW = 0.184
LWL = -0.222

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -3.035
Mean_Diff_MTL = -3.016
Mean_Diff_DTL = -3.024
Mean_Ratio_MN = 0.390
Mean_Ratio_GT = 0.441

Mean_Diff_MHHW = -4.292
Mean_Diff_MHW = -4.239
Mean_Diff_MLW = -1.793
Mean_Diff_MLLW = -1.756
Mean Ratio DHQ = 0.728
Mean Ratio DLQ = 0.887

Corrected values for MN, GT, MTL, DTL
1.542 2.075 1.327 1.217
Corrected values for DHQ, DLQ
0.201 0.425
Corrected values for MHHW, MHW, MLW, MLLW
2.303 2.081 0.573 0.131

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.556 (2017/09/04 09:24)
MHHW = 2.299
MHW = 2.098
DTL = 1.217
MTL = 1.327
MSL = 1.308
MLW = 0.556
MLLW = 0.131
DHQ = 0.201
DLQ = 0.425
GT = 2.075
MN = 1.542
LWL = -0.222 (2017/09/17 15:18)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9451054 Port Alexander

Date of Analysis: 2018/11/25 00:05:36

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.038
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.812
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.652
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.547
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.666
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.493
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.055

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.227
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.439
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.318
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.980

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.817	Date	=	2007/09/29 22:54
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.499	Date	=	2007/09/29 04:48

Detailed Output

Run Time: 2018-11-25 00:05:37
Using CO-OPS_9451600_wl_SEP07.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.539
Highest Water Level: 3.814
Lowest Water Level: -0.506
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9451054

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
4.476 4.217 2.812 2.902 2.894 1.587 1.147
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
3.329 2.630 0.259 0.440 1.505 3.336 9.601

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 3.817
MHHW = 2.922
MHW = 2.698
MSL = 1.539
MLW = 0.378
MLLW = -0.019
LWL = -0.499

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.236
Mean Diff MTL = -1.250
Mean_Diff_DTL = -1.265
Mean_Ratio_MN = 0.882
Mean Ratio GT = 0.895

Mean_Diff_MHHW = -1.437
Mean_Diff_MHW = -1.406
Mean_Diff_MLW = -1.094
Mean_Diff_MLLW = -1.092
Mean Ratio DHQ = 0.875
Mean Ratio DLQ = 0.997

Corrected values for MN, GT, MTL, DTL
2.318 2.980 1.652 1.547
Corrected values for DHQ, DLQ
0.227 0.439
Corrected values for MHHW, MHW, MLW, MLLW
3.039 2.811 0.493 0.055

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.817 (2007/09/29 22:54)
MHHW = 3.038
MHW = 2.812
DTL = 1.547
MTL = 1.652
MSL = 1.666
MLW = 0.493
MLLW = 0.055
DHQ = 0.227
DLQ = 0.439
GT = 2.980
MN = 2.318
LWL = -0.499 (2007/09/29 04:48)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9451054 Port Alexander

Date of Analysis: 2018/11/25 00:08:25

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.065
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.831
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.655
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.546
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.661
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.479
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.009

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.234
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.470
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.352
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.034

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.226	Date	=	2017/09/08 23:06
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.336	Date	=	2017/09/20 15:36

Detailed Output

Run Time: 2018-11-25 00:08:26
Using CO-OPS_9451600_wl_SEP17.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.497
Highest Water Level: 3.229
Lowest Water Level: -0.340
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9451054

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
4.476 4.217 2.812 2.902 2.894 1.587 1.147
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
3.329 2.630 0.259 0.440 1.505 3.336 9.601

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 3.226
MHHW = 2.843
MHW = 2.681
MSL = 1.497
MLW = 0.306
MLLW = -0.015
LWL = -0.336

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.241
Mean Diff MTL = -1.247
Mean_Diff_DTL = -1.266
Mean_Ratio_MN = 0.894
Mean Ratio GT = 0.911

Mean_Diff_MHHW = -1.405
Mean_Diff_MHW = -1.388
Mean_Diff_MLW = -1.107
Mean_Diff_MLLW = -1.127
Mean Ratio DHQ = 0.905
Mean Ratio DLQ = 1.068

Corrected values for MN, GT, MTL, DTL
2.352 3.034 1.655 1.546
Corrected values for DHQ, DLQ
0.234 0.470
Corrected values for MHHW, MHW, MLW, MLLW
3.071 2.829 0.480 0.020

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.226 (2017/09/08 23:06)
MHHW = 3.065
MHW = 2.831
DTL = 1.546
MTL = 1.655
MSL = 1.661
MLW = 0.479
MLLW = 0.009
DHQ = 0.234
DLQ = 0.470
GT = 3.034
MN = 2.352
LWL = -0.336 (2017/09/20 15:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details   Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 1615680 Kahului, Kahului Harbor

Date of Analysis: 2018/11/24 23:30:30

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.646
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.490
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.301
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.342
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.306
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.112
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.058

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.155
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.055
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.378
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.569

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.737	Date	=	2007/09/07 23:54
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.033	Date	=	2007/09/29 08:30

Detailed Output

Run Time: 2018-11-24 23:30:31
Using CO-OPS_1611400_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2007-09-06 06:06:00 for min time/range.
Deleting 2 tides at 2007-09-20 05:54:00 for min time/range.
52 highs 51 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 0.356
Highest Water Level: 0.741
Lowest Water Level: -0.041
Duration: 29 days, 23:54:00
High Tides Found: 52
Low Tides Found : 51
Tides per day: 3.4
Semi-Diurnal - Using EXHL
26 Highs
26 Higher Highs
26 Lows
25 Lower Lows

1 Monthly plots generated

Control Datums for: 1615680

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
1.422 1.313 1.079 1.074 1.075 0.835 0.736
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
0.686 0.478 0.109 0.099 Null 6.640 0.240

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 0.737
MHHW = 0.659
MHW = 0.553
MSL = 0.356
MLW = 0.153
MLLW = 0.104
LWL = -0.033

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.768
Mean Diff MTL = -0.773
Mean_Diff_DTL = -0.737

Mean_Ratio_MN = 0.791
Mean Ratio GT = 0.830
Mean_Diff_MHHW = -0.794
Mean_Diff_MHW = -0.826
Mean_Diff_MLW = -0.719
Mean_Diff_MLLW = -0.681
Mean Ratio DHQ = 1.427
Mean Ratio DLQ = 0.553

Corrected values for MN, GT, MTL, DTL
0.378 0.569 0.301 0.342
Corrected values for DHQ, DLQ
0.155 0.055
Corrected values for MHHW, MHW, MLW, MLLW
0.628 0.487 0.116 0.055

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.737 (2007/09/07 23:54)
MHHW = 0.646
MHW = 0.490
DTL = 0.342
MTL = 0.301
MSL = 0.306
MLW = 0.112
MLLW = 0.058
DHQ = 0.155
DLQ = 0.055
GT = 0.569
MN = 0.378
LWL = -0.033 (2007/09/29 08:30)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 1615680 Kahului, Kahului Harbor

Date of Analysis: 2018/11/24 23:33:31

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.611
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.484
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.286
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.311
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.287
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.089
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.033

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.127
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.056
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.395
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.577

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.826	Date	=	2017/09/05 01:24
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.179	Date	=	2017/09/17 17:18

Detailed Output

Run Time: 2018-11-24 23:33:31
Using CO-OPS_1611400_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2017-09-13 02:36:00 for min time/range.
Deleting 2 tides at 2017-09-14 04:42:00 for min time/range.
Deleting 2 tides at 2017-09-26 00:06:00 for min time/range.
52 highs 53 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 0.453
Highest Water Level: 0.834
Lowest Water Level: 0.168
Duration: 29 days, 23:54:00
High Tides Found: 52
Low Tides Found : 53
Tides per day: 3.5
Semi-Diurnal - Using EXHL
26 Highs
26 Higher Highs
27 Lows
26 Lower Lows

1 Monthly plots generated

Control Datums for: 1615680

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
1.422 1.313 1.079 1.074 1.075 0.835 0.736
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
0.686 0.478 0.109 0.099 Null 6.640 0.240

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 0.826
MHHW = 0.733
MHW = 0.646
MSL = 0.453
MLW = 0.259
MLLW = 0.224
LWL = 0.179

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.787
Mean Diff MTL = -0.788

Mean_Diff_DTL = -0.768
Mean_Ratio_MN = 0.827
Mean Ratio GT = 0.841
Mean_Diff_MHHW = -0.816
Mean_Diff_MHW = -0.828
Mean_Diff_MLW = -0.747
Mean_Diff_MLLW = -0.719
Mean Ratio DHQ = 1.163
Mean Ratio DLQ = 0.562

Corrected values for MN, GT, MTL, DTL
0.395 0.577 0.286 0.311
Corrected values for DHQ, DLQ
0.127 0.056
Corrected values for MHHW, MHW, MLW, MLLW
0.606 0.485 0.088 0.017

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.826 (2017/09/05 01:24)
MHHW = 0.611
MHW = 0.484
DTL = 0.311
MTL = 0.286
MSL = 0.287
MLW = 0.089
MLLW = 0.033
DHQ = 0.127
DLQ = 0.056
GT = 0.577
MN = 0.395
LWL = 0.179 (2017/09/17 17:18)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 1611400 Nawiliwili

Date of Analysis: 2018/11/24 23:15:15

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.319
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.268
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.142
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.130
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.137
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.015
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.073

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.050
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.088
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.253
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.389

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.543	Date	=	2007/09/30 18:18
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.064	Date	=	2007/09/02 12:36

Detailed Output

Run Time: 2018-11-24 23:15:16
Using CO-OPS_1619910_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 0.246
Highest Water Level: 0.564
Lowest Water Level: -0.071
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 1611400

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
1.255 1.131 0.976 0.944 0.949 0.758 0.697
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
0.558 0.373 0.124 0.060 Null 7.970 1.740

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 0.543
MHHW = 0.423
MHW = 0.380
MSL = 0.246
MLW = 0.113
MLLW = 0.041
LWL = -0.064

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.807
Mean Diff MTL = -0.802
Mean_Diff_DTL = -0.846
Mean_Ratio_MN = 0.679
Mean Ratio GT = 0.696

Mean_Diff_MHHW = -0.929
Mean_Diff_MHW = -0.865
Mean_Diff_MLW = -0.739
Mean_Diff_MLLW = -0.762
Mean Ratio DHQ = 0.406
Mean Ratio DLQ = 1.471

Corrected values for MN, GT, MTL, DTL
0.253 0.389 0.142 0.130
Corrected values for DHQ, DLQ
0.050 0.088
Corrected values for MHHW, MHW, MLW, MLLW
0.326 0.266 0.019 -0.065

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.543 (2007/09/30 18:18)
MHHW = 0.319
MHW = 0.268
DTL = 0.130
MTL = 0.142
MSL = 0.137
MLW = 0.015
MLLW = -0.073
DHQ = 0.050
DLQ = 0.088
GT = 0.389
MN = 0.253
LWL = -0.064 (2007/09/02 12:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 1611400 Nawiliwili

Date of Analysis: 2018/11/24 23:18:07

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.362
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.310
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.183
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.180
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.179
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.056
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.031

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.052
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.086
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.255
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.385

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.621	Date	=	2017/09/12 20:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.145	Date	=	2017/09/13 14:36

Detailed Output

Run Time: 2018-11-24 23:18:08
Using CO-OPS_1619910_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 0.385
Highest Water Level: 0.636
Lowest Water Level: 0.141
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 1611400

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
1.255 1.131 0.976 0.944 0.949 0.758 0.697
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
0.558 0.373 0.124 0.060 Null 7.970 1.740

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 0.621
MHHW = 0.552
MHW = 0.514
MSL = 0.385
MLW = 0.262
MLLW = 0.209
LWL = 0.145

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.765
Mean Diff MTL = -0.761
Mean_Diff_DTL = -0.796
Mean_Ratio_MN = 0.683
Mean Ratio GT = 0.690

Mean_Diff_MHHW = -0.873
Mean_Diff_MHW = -0.819
Mean_Diff_MLW = -0.703
Mean_Diff_MLLW = -0.719
Mean Ratio DHQ = 0.418
Mean Ratio DLQ = 1.436

Corrected values for MN, GT, MTL, DTL
0.255 0.385 0.183 0.180
Corrected values for DHQ, DLQ
0.052 0.086
Corrected values for MHHW, MHW, MLW, MLLW
0.382 0.312 0.055 -0.022

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 0.621 (2017/09/12 20:36)
MHHW = 0.362
MHW = 0.310
DTL = 0.180
MTL = 0.183
MSL = 0.179
MLW = 0.056
MLLW = -0.031
DHQ = 0.052
DLQ = 0.086
GT = 0.385
MN = 0.255
LWL = 0.145 (2017/09/13 14:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9437540 Garibaldi

Date of Analysis: 2018/11/20 14:29:01

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.359
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.165
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.315
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.217
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.309
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.466
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.077

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.194
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.389
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.699
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.281

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.738	Date	=	2007/09/28 20:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.383	Date	=	2007/09/30 04:00

Detailed Output

Run Time: 2018-11-20 14:29:01
Using CO-OPS_9432780_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.197
Highest Water Level: 2.790
Lowest Water Level: -0.405
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9437540

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.750 3.534 2.482 2.582 2.586 1.631 1.214
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.536 1.903 0.216 0.417 Null 2.087 8.585

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 2.738
MHHW = 2.248
MHW = 2.056
MSL = 1.197
MLW = 0.341
MLLW = -0.017
LWL = -0.383

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.273
Mean Diff MTL = -1.267
Mean_Diff_DTL = -1.265
Mean_Ratio_MN = 0.893
Mean Ratio GT = 0.900

Mean_Diff_MHHW = -1.391
Mean_Diff_MHW = -1.370
Mean_Diff_MLW = -1.164
Mean_Diff_MLLW = -1.138
Mean Ratio DHQ = 0.900
Mean Ratio DLQ = 0.933

Corrected values for MN, GT, MTL, DTL
1.699 2.281 1.315 1.217
Corrected values for DHQ, DLQ
0.194 0.389
Corrected values for MHHW, MHW, MLW, MLLW
2.359 2.164 0.467 0.076

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.738 (2007/09/28 20:36)
MHHW = 2.359
MHW = 2.165
DTL = 1.217
MTL = 1.315
MSL = 1.309
MLW = 0.466
MLLW = 0.077
DHQ = 0.194
DLQ = 0.389
GT = 2.281
MN = 1.699
LWL = -0.383 (2007/09/30 04:00)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9437540 Garibaldi

Date of Analysis: 2018/11/20 14:26:36

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.353
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.147
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.279
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.185
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.273
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.411
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.022

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.206
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.388
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.737
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.326

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.600	Date	=	2017/09/20 07:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.107	Date	=	2017/09/17 11:36

Detailed Output

Run Time: 2018-11-20 14:26:36
Using CO-OPS_9432780_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.265
Highest Water Level: 2.615
Lowest Water Level: -0.123
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9437540

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.750 3.534 2.482 2.582 2.586 1.631 1.214
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.536 1.903 0.216 0.417 Null 2.087 8.585

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.600
MHHW = 2.280
MHW = 2.136
MSL = 1.265
MLW = 0.392
MLLW = 0.118
LWL = -0.107

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.309
Mean Diff MTL = -1.303
Mean_Diff_DTL = -1.297
Mean_Ratio_MN = 0.913
Mean Ratio GT = 0.917

Mean_Diff_MHHW = -1.394
Mean_Diff_MHW = -1.387
Mean_Diff_MLW = -1.219
Mean_Diff_MLLW = -1.199
Mean Ratio DHQ = 0.951
Mean Ratio DLQ = 0.931

Corrected values for MN, GT, MTL, DTL
1.737 2.326 1.279 1.185
Corrected values for DHQ, DLQ
0.206 0.388
Corrected values for MHHW, MHW, MLW, MLLW
2.356 2.147 0.412 0.015

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.600 (2017/09/20 07:36)
MHHW = 2.353
MHW = 2.147
DTL = 1.185
MTL = 1.279
MSL = 1.273
MLW = 0.411
MLLW = 0.022
DHQ = 0.206
DLQ = 0.388
GT = 2.326
MN = 1.737
LWL = -0.107 (2017/09/17 11:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9439040 Astoria

Date of Analysis: 2018/11/20 13:48:44

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.539
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.337
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.420
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.328
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.426
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.504
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.118

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.203
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.386
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.833
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.418

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.920	Date	=	2007/09/29 22:00
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.455	Date	=	2007/09/29 03:42

Detailed Output

Run Time: 2018-11-20 13:48:45
Using CO-OPS_9437540_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.256
Highest Water Level: 3.024
Lowest Water Level: -0.464
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9439040

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.305 3.099 1.993 2.068 2.054 1.036 0.681
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.624 2.062 0.207 0.355 0.615 2.966 9.156

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 2.920
MHHW = 2.400
MHW = 2.193
MSL = 1.256
MLW = 0.294
MLLW = -0.090
LWL = -0.455

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.642
Mean Diff MTL = -0.648
Mean_Diff_DTL = -0.665
Mean_Ratio_MN = 0.889
Mean Ratio GT = 0.922

Mean_Diff_MHHW = -0.771
Mean_Diff_MHW = -0.767
Mean_Diff_MLW = -0.529
Mean_Diff_MLLW = -0.560
Mean Ratio DHQ = 0.978
Mean Ratio DLQ = 1.088

Corrected values for MN, GT, MTL, DTL
1.833 2.418 1.420 1.328
Corrected values for DHQ, DLQ
0.203 0.386
Corrected values for MHHW, MHW, MLW, MLLW
2.534 2.332 0.507 0.121

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.920 (2007/09/29 22:00)
MHHW = 2.539
MHW = 2.337
DTL = 1.328
MTL = 1.420
MSL = 1.426
MLW = 0.504
MLLW = 0.118
DHQ = 0.203
DLQ = 0.386
GT = 2.418
MN = 1.833
LWL = -0.455 (2007/09/29 03:42)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9439040 Astoria

Date of Analysis: 2018/11/20 13:51:50

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.559
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.345
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.430
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.348
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.438
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.516
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.135

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.214
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.381
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.829
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.400

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.794	Date	=	2017/09/19 07:42
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.133	Date	=	2017/09/17 12:12

Detailed Output

Run Time: 2018-11-20 13:51:50
Using CO-OPS_9437540_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.360
Highest Water Level: 2.804
Lowest Water Level: -0.128
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9439040

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.305 3.099 1.993 2.068 2.054 1.036 0.681
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.624 2.062 0.207 0.355 0.615 2.966 9.156

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.794
MHHW = 2.456
MHW = 2.304
MSL = 1.360
MLW = 0.389
MLLW = 0.096
LWL = -0.133

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.630
Mean Diff MTL = -0.638
Mean_Diff_DTL = -0.645
Mean_Ratio_MN = 0.887
Mean Ratio GT = 0.915

Mean_Diff_MHHW = -0.755
Mean_Diff_MHW = -0.760
Mean_Diff_MLW = -0.515
Mean_Diff_MLLW = -0.535
Mean Ratio DHQ = 1.036
Mean Ratio DLQ = 1.073

Corrected values for MN, GT, MTL, DTL
1.829 2.400 1.430 1.348
Corrected values for DHQ, DLQ
0.214 0.381
Corrected values for MHHW, MHW, MLW, MLLW
2.550 2.339 0.521 0.146

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.794 (2017/09/19 07:42)
MHHW = 2.559
MHW = 2.345
DTL = 1.348
MTL = 1.430
MSL = 1.438
MLW = 0.516
MLLW = 0.135
DHQ = 0.214
DLQ = 0.381
GT = 2.400
MN = 1.829
LWL = -0.133 (2017/09/17 12:12)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9437540 Garibaldi

Date of Analysis: 2018/11/20 14:07:05

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.558
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.357
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.424
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.315
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.410
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.490
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.070

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.201
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.420
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.866
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.487

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.004	Date	=	2007/09/28 20:48
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.396	Date	=	2007/09/30 04:00

Detailed Output

Run Time: 2018-11-20 14:07:06
Using CO-OPS_9435380_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.298
Highest Water Level: 3.063
Lowest Water Level: -0.402
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9437540

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.750 3.534 2.482 2.582 2.586 1.631 1.214
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.536 1.903 0.216 0.417 Null 2.087 8.585

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 3.004
MHHW = 2.448
MHW = 2.249
MSL = 1.298
MLW = 0.365
MLLW = -0.022
LWL = -0.396

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.172
Mean Diff MTL = -1.158
Mean_Diff_DTL = -1.167
Mean_Ratio_MN = 0.981
Mean Ratio GT = 0.981

Mean_Diff_MHHW = -1.191
Mean_Diff_MHW = -1.177
Mean_Diff_MLW = -1.140
Mean_Diff_MLLW = -1.143
Mean Ratio DHQ = 0.932
Mean Ratio DLQ = 1.008

Corrected values for MN, GT, MTL, DTL
1.866 2.487 1.424 1.315
Corrected values for DHQ, DLQ
0.201 0.420
Corrected values for MHHW, MHW, MLW, MLLW
2.559 2.357 0.491 0.071

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.004 (2007/09/28 20:48)
MHHW = 2.558
MHW = 2.357
DTL = 1.315
MTL = 1.424
MSL = 1.410
MLW = 0.490
MLLW = 0.070
DHQ = 0.201
DLQ = 0.420
GT = 2.487
MN = 1.866
LWL = -0.396 (2007/09/30 04:00)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9437540 Garibaldi

Date of Analysis: 2018/11/20 14:11:30

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.580
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.372
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.414
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.311
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.404
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.457
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.038

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.208
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.419
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.915
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.544

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.875	Date	=	2017/09/20 07:42
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.083	Date	=	2017/09/17 11:36

Detailed Output

Run Time: 2018-11-20 14:11:31
Using CO-OPS_9435380_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.396
Highest Water Level: 2.898
Lowest Water Level: -0.091
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9437540

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.750 3.534 2.482 2.582 2.586 1.631 1.214
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.536 1.903 0.216 0.417 Null 2.087 8.585

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.875
MHHW = 2.507
MHW = 2.361
MSL = 1.396
MLW = 0.438
MLLW = 0.142
LWL = -0.083

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.178
Mean_Diff_MTL = -1.168
Mean_Diff_DTL = -1.171
Mean_Ratio_MN = 1.006
Mean_Ratio_GT = 1.003

Mean_Diff_MHHW = -1.167
Mean_Diff_MHW = -1.162
Mean_Diff_MLW = -1.173
Mean_Diff_MLLW = -1.175
Mean Ratio DHQ = 0.964
Mean Ratio DLQ = 1.004

Corrected values for MN, GT, MTL, DTL
1.915 2.544 1.414 1.311
Corrected values for DHQ, DLQ
0.208 0.419
Corrected values for MHHW, MHW, MLW, MLLW
2.583 2.372 0.458 0.039

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.875 (2017/09/20 07:42)
MHHW = 2.580
MHW = 2.372
DTL = 1.311
MTL = 1.414
MSL = 1.404
MLW = 0.457
MLLW = 0.038
DHQ = 0.208
DLQ = 0.419
GT = 2.544
MN = 1.915
LWL = -0.083 (2017/09/17 11:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/18 22:40:10

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.785
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.520
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.633
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.352
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.618
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.746
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.055

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.265
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.801
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.774
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.827

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.921	Date	=	2007/09/30 02:00
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.398	Date	=	2007/09/08 16:48

Detailed Output

Run Time: 2018-11-18 22:40:11
Using CO-OPS_9449424_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 57 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.531
Highest Water Level: 2.933
Lowest Water Level: -0.401
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 2.921
MHHW = 2.571
MHW = 2.427
MSL = 1.531
MLW = 0.755
MLLW = -0.004
LWL = -0.398

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.989
Mean Diff MTL = -0.974
Mean_Diff_DTL = -1.004
Mean_Ratio_MN = 1.208
Mean Ratio GT = 1.196

Mean_Diff_MHHW = -0.793
Mean_Diff_MHW = -0.830
Mean_Diff_MLW = -1.118
Mean_Diff_MLLW = -1.215
Mean Ratio DHQ = 1.347
Mean Ratio DLQ = 1.147

Corrected values for MN, GT, MTL, DTL
1.774 2.827 1.633 1.352
Corrected values for DHQ, DLQ
0.265 0.801
Corrected values for MHHW, MHW, MLW, MLLW
2.745 2.511 0.754 -0.041

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.921 (2007/09/30 02:00)
MHHW = 2.785
MHW = 2.520
DTL = 1.352
MTL = 1.633
MSL = 1.618
MLW = 0.746
MLLW = -0.055
DHQ = 0.265
DLQ = 0.801
GT = 2.827
MN = 1.774
LWL = -0.398 (2007/09/08 16:48)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/18 22:42:59

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.812
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.523
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.624
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.366
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.617
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.725
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.051

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.289
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.776
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.798
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.848

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.873	Date	=	2017/09/19 00:36
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.123	Date	=	2017/09/15 14:48

Detailed Output

Run Time: 2018-11-18 22:42:59
Using CO-OPS_9449424_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.600
Highest Water Level: 2.877
Lowest Water Level: -0.119
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.873
MHHW = 2.588
MHW = 2.444
MSL = 1.600
MLW = 0.836
MLLW = 0.235
LWL = -0.123

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.990
Mean Diff MTL = -0.983
Mean_Diff_DTL = -0.990
Mean_Ratio_MN = 1.224
Mean Ratio GT = 1.205

Mean_Diff_MHHW = -0.790
Mean_Diff_MHW = -0.836
Mean_Diff_MLW = -1.130
Mean_Diff_MLLW = -1.190
Mean Ratio DHQ = 1.467
Mean Ratio DLQ = 1.111

Corrected values for MN, GT, MTL, DTL
1.798 2.848 1.624 1.366
Corrected values for DHQ, DLQ
0.289 0.776
Corrected values for MHHW, MHW, MLW, MLLW
2.748 2.505 0.742 -0.016

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.873 (2017/09/19 00:36)
MHHW = 2.812
MHW = 2.523
DTL = 1.366
MTL = 1.624
MSL = 1.617
MLW = 0.725
MLLW = -0.051
DHQ = 0.289
DLQ = 0.776
GT = 2.848
MN = 1.798
LWL = -0.123 (2017/09/15 14:48)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/19 13:32:47

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.656
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.414
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.543
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.284
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.543
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.672
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.068

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.242
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.740
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.742
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.717

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.801	Date	=	2007/09/30 01:06
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.461	Date	=	2007/09/08 15:30

Detailed Output

Run Time: 2018-11-19 13:32:48
Using CO-OPS_9444900_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
Deleting 2 tides at 2007-09-22 03:18:00 for min time/range.
56 highs 56 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.456
Highest Water Level: 2.796
Lowest Water Level: -0.465
Duration: 29 days, 23:54:00
High Tides Found: 56
Low Tides Found : 56
Tides per day: 3.7
Semi-Diurnal - Using EXHL
28 Highs
28 Higher Highs
28 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 2.801
MHHW = 2.453
MHW = 2.322
MSL = 1.456
MLW = 0.680
MLLW = -0.021
LWL = -0.461

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.064
Mean Diff MTL = -1.064
Mean_Diff_DTL = -1.072
Mean_Ratio_MN = 1.186

Mean Ratio GT = 1.149
Mean_Diff_MHHW = -0.911
Mean_Diff_MHW = -0.935
Mean_Diff_MLW = -1.193
Mean_Diff_MLLW = -1.232
Mean Ratio DHQ = 1.229
Mean Ratio DLQ = 1.060

Corrected values for MN, GT, MTL, DTL
1.742 2.717 1.543 1.284
Corrected values for DHQ, DLQ
0.242 0.740
Corrected values for MHHW, MHW, MLW, MLLW
2.627 2.406 0.679 -0.058

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.801 (2007/09/30 01:06)
MHHW = 2.656
MHW = 2.414
DTL = 1.284
MTL = 1.543
MSL = 1.543
MLW = 0.672
MLLW = -0.068
DHQ = 0.242
DLQ = 0.740
GT = 2.717
MN = 1.742
LWL = -0.461 (2007/09/08 15:30)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/19 13:36:20

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.647
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.414
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.554
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.293
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.551
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.693
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.052

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.233
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.745
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.720
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.702

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.681	Date	=	2017/09/18 23:30
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.129	Date	=	2017/09/15 13:24

Detailed Output

Run Time: 2018-11-19 13:36:21
Using CO-OPS_9444900_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.534
Highest Water Level: 2.686
Lowest Water Level: -0.130
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 2.681
MHHW = 2.455
MHW = 2.339
MSL = 1.534
MLW = 0.800
MLLW = 0.222
LWL = -0.129

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -1.056
Mean Diff MTL = -1.053
Mean_Diff_DTL = -1.063
Mean_Ratio_MN = 1.171
Mean Ratio GT = 1.143

Mean_Diff_MHHW = -0.923
Mean_Diff_MHW = -0.941
Mean_Diff_MLW = -1.166
Mean_Diff_MLLW = -1.203
Mean Ratio DHQ = 1.184
Mean Ratio DLQ = 1.068

Corrected values for MN, GT, MTL, DTL
1.720 2.702 1.554 1.293
Corrected values for DHQ, DLQ
0.233 0.745
Corrected values for MHHW, MHW, MLW, MLLW
2.615 2.400 0.706 -0.029

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 2.681 (2017/09/18 23:30)
MHHW = 2.647
MHW = 2.414
DTL = 1.293
MTL = 1.554
MSL = 1.551
MLW = 0.693
MLLW = -0.052
DHQ = 0.233
DLQ = 0.745
GT = 2.702
MN = 1.720
LWL = -0.129 (2017/09/15 13:24)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/19 14:02:46

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.576
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.268
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.028
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.730
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.062
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.788
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.073

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.308
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.861
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.479
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.646

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.834	Date	=	2007/09/29 01:06
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.452	Date	=	2007/09/30 08:36

Detailed Output

Run Time: 2018-11-19 14:02:47
Using CO-OPS_9447130_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.975
Highest Water Level: 3.839
Lowest Water Level: -0.463
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 58
Tides per day: 3.9
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 3.834
MHHW = 3.322
MHW = 3.154
MSL = 1.975
MLW = 0.818
MLLW = 0.001
LWL = -0.452

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.545
Mean Diff MTL = -0.579
Mean_Diff_DTL = -0.626
Mean_Ratio_MN = 1.688
Mean Ratio GT = 1.542

Mean_Diff_MHHW = -0.042
Mean_Diff_MHW = -0.103
Mean_Diff_MLW = -1.055
Mean_Diff_MLLW = -1.210
Mean Ratio DHQ = 1.566
Mean Ratio DLQ = 1.234

Corrected values for MN, GT, MTL, DTL
2.479 3.646 2.028 1.730
Corrected values for DHQ, DLQ
0.308 0.861
Corrected values for MHHW, MHW, MLW, MLLW
3.496 3.238 0.817 -0.036

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.834 (2007/09/29 01:06)
MHHW = 3.576
MHW = 3.268
DTL = 1.730
MTL = 2.028
MSL = 2.062
MLW = 0.788
MLLW = -0.073
DHQ = 0.308
DLQ = 0.861
GT = 3.646
MN = 2.479
LWL = -0.452 (2007/09/30 08:36)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9449880 Friday Harbor

Date of Analysis: 2018/11/19 14:05:55

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.659
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.357
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.049
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.775
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.088
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.740
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.085

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.302
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.825
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.617
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.790

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.704	Date	=	2017/09/21 00:54
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.120	Date	=	2017/09/16 15:18

Detailed Output

Run Time: 2018-11-19 14:05:56
Using CO-OPS_9447130_wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 2.071
Highest Water Level: 3.703
Lowest Water Level: -0.119
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9449880

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.538 3.341 2.356 2.607 2.561 1.872 1.174
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.364 1.469 0.197 0.698 Null 6.505 0.460

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 3.704
MHHW = 3.386
MHW = 3.235
MSL = 2.071
MLW = 0.894
MLLW = 0.255
LWL = -0.120

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.519
Mean Diff MTL = -0.558
Mean_Diff_DTL = -0.581
Mean_Ratio_MN = 1.781
Mean Ratio GT = 1.603

Mean_Diff_MHHW = 0.008
Mean_Diff_MHW = -0.045
Mean_Diff_MLW = -1.072
Mean_Diff_MLLW = -1.170
Mean Ratio DHQ = 1.534
Mean Ratio DLQ = 1.182

Corrected values for MN, GT, MTL, DTL
2.617 3.790 2.049 1.775
Corrected values for DHQ, DLQ
0.302 0.825
Corrected values for MHHW, MHW, MLW, MLLW
3.546 3.296 0.800 0.004

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.704 (2017/09/21 00:54)
MHHW = 3.659
MHW = 3.357
DTL = 1.775
MTL = 2.049
MSL = 2.088
MLW = 0.740
MLLW = -0.085
DHQ = 0.302
DLQ = 0.825
GT = 3.790
MN = 2.617
LWL = -0.120 (2017/09/16 15:18)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Get Adobe Reader (http://www.adobe.com/products/acrobat/readstep2.html)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9441102 Westport

Date of Analysis: 2020/01/02 19:06:35

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2007-09-01 - 2007-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.702
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.478
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.454
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.354
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.471
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.431
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.007

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.224
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.424
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.047
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.694

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.242	Date	=	2007/09/29 22:06
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.434	Date	=	2007/09/29 04:06

Detailed Output ✖

Run Time: 2020-01-02 19:06:36
Using CO-OPS__9440910__wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
57 highs 58 lows
Data Start: 2007-09-01 00:00:00
Data End : 2007-09-30 23:54:00
Mean Water Level: 1.323
Highest Water Level: 3.378
Lowest Water Level: -0.437
Duration: 29 days, 23:54:00
High Tides Found: 57
Low Tides Found : 58
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
28 Higher Highs
29 Lows
29 Lower Lows

1 Monthly plots generated

Control Datums for: 9441102

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.700 3.475 2.307 2.407 2.398 1.339 0.914
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.786 2.137 0.225 0.425 Null 2.061 8.551

SUBORDINATE MONTHLY MEANS:
9 / 2007 :
HWL = 3.242
MHHW = 2.562
MHW = 2.341
MSL = 1.323
MLW = 0.291
MLLW = -0.089
LWL = -0.434

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2007 9 2007
From 9 / 2007 to 9 / 2007
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.936
Mean Diff MTL = -0.953
Mean_Diff_DTL = -0.953
Mean_Ratio_MN = 0.958
Mean Ratio GT = 0.967

Mean_Diff_MHHW = -0.998
Mean_Diff_MHW = -0.997
Mean_Diff_MLW = -0.908
Mean_Diff_MLLW = -0.907
Mean Ratio DHQ = 0.996
Mean Ratio DLQ = 0.998

Corrected values for MN, GT, MTL, DTL
2.047 2.694 1.454 1.354
Corrected values for DHQ, DLQ
0.224 0.424
Corrected values for MHHW, MHW, MLW, MLLW
2.702 2.478 0.431 0.007

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.242 (2007/09/29 22:06)
MHHW = 2.702
MHW = 2.478
DTL = 1.354
MTL = 1.454
MSL = 1.471
MLW = 0.431
MLLW = 0.007
DHQ = 0.224
DLQ = 0.424
GT = 2.694
MN = 2.047
LWL = -0.434 (2007/09/29 04:06)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details | Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.

CO-OPS Tidal Analysis Datum Calculator (index.jsp)

Data and Resources

- User Guide (docs/UserGuide.pdf)
- Technical Report (docs/TechnicalReport.pdf)
- CO-OPS Special Publication 1 - Tidal Datums and Their Applications (https://www.tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf)
- CO-OPS Special Publication 2 - Tidal Datum Computation Handbook (https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf)
- CO-OPS Special Publication 3 - Tidal Analysis and Predictions (https://www.tidesandcurrents.noaa.gov/publications/Tidal_Analysis_and_Predictions.pdf)
- FAQs (docs/FAQs.pdf)
- Datums Page and Associated Information (https://tidesandcurrents.noaa.gov/stations.html?type=Datums)

Back to Datum Calculator Homepage (index.jsp)

Tidal Datums

Control Station: 9441102 Westport

Date of Analysis: 2020/01/02 19:08:13

Datums by Monthly Means Simultaneous Comparison (MMSC):

Tidal Datum Analysis Period: 2017-09-01 - 2017-09-30

Data Unit: Meters

MHHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.705
MHW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.471
MTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.427
DTL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.333
MSL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	1.447
MLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.383
MLLW (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.033

DHQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.234
DLQ (https://tidesandcurrents.noaa.gov/datum_options.html)	=	0.415
MN (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.089
GT (https://tidesandcurrents.noaa.gov/datum_options.html)	=	2.734

HWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	3.126	Date	=	2017/09/19 07:42
LWL (https://tidesandcurrents.noaa.gov/datum_options.html)	=	-0.202	Date	=	2017/09/17 12:30

Detailed Output ✖

Run Time: 2020-01-02 19:08:13
Using CO-OPS__9440910__wl.csv
7200 data points loaded.
Interval: 0:06:00

All calculations and results are in Meters

West coast/Pacific station:
Using Standard Range Ratio Method

Sampling Rate: 240 per day. Using cutoff frequency of 4.0 per day
58 highs 57 lows
Data Start: 2017-09-01 00:00:00
Data End : 2017-09-30 23:54:00
Mean Water Level: 1.390
Highest Water Level: 3.126
Lowest Water Level: -0.205
Duration: 29 days, 23:54:00
High Tides Found: 58
Low Tides Found : 57
Tides per day: 3.8
Semi-Diurnal - Using EXHL
29 Highs
29 Higher Highs
29 Lows
28 Lower Lows

1 Monthly plots generated

Control Datums for: 9441102

MHHW, MHW, DTL, MTL, MSL, MLW, MLLW
3.700 3.475 2.307 2.407 2.398 1.339 0.914
GT, MN, DHQ, DLQ, NAVD, LWI, HWI
2.786 2.137 0.225 0.425 Null 2.061 8.551

SUBORDINATE MONTHLY MEANS:
9 / 2017 :
HWL = 3.126
MHHW = 2.593
MHW = 2.434
MSL = 1.390
MLW = 0.334
MLLW = 0.044
LWL = -0.202

TIDAL DATUMS BY Monthly Means Simultaneous Comparison:

9 2017 9 2017
From 9 / 2017 to 9 / 2017
1 Months of control station means retrieved.
1 months in the analysis

Mean_Diff_MSL = -0.960
Mean Diff MTL = -0.980
Mean_Diff_DTL = -0.974
Mean_Ratio_MN = 0.978
Mean Ratio GT = 0.981

Mean_Diff_MHHW = -0.998
Mean_Diff_MHW = -1.004
Mean_Diff_MLW = -0.956
Mean_Diff_MLLW = -0.950
Mean Ratio DHQ = 1.039
Mean Ratio DLQ = 0.978

Corrected values for MN, GT, MTL, DTL
2.089 2.734 1.427 1.333
Corrected values for DHQ, DLQ
0.234 0.415
Corrected values for MHHW, MHW, MLW, MLLW
2.702 2.471 0.383 -0.036

Datums by Monthly Means Simultaneous Comparison (MMSC):
HWL = 3.126 (2017/09/19 07:42)
MHHW = 2.705
MHW = 2.471
DTL = 1.333
MTL = 1.427
MSL = 1.447
MLW = 0.383
MLLW = -0.033
DHQ = 0.234
DLQ = 0.415
GT = 2.734
MN = 2.089
LWL = -0.202 (2017/09/17 12:30)

Meters

That is all.

The datums calculated here are for planning purposes only and should not be used for safe navigation or coastal construction.

Show Details Download Result

Process another file (index.jsp)

Tidal Datum Calculator Product Disclaimer

The tool provides water level analysis support with computing tidal datums. A tidal datum is a standard elevation defined by a certain phase of the tide and can be used as references to measure local water levels. The accuracy of tidal datum elevations is dependent on the quality of the data input into the tool. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference and is not appropriate for navigation, establishing land boundaries, permitting or other regulatory purposes.