

Climate Impact and GIS Education Using Realistic Applications of Data.gov Thematic Datasets in a Structured Lesson-Based Workbook

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ABSTRACT: This project created a workbook which teaches Earth Science to undergraduate and graduate students through guided in-class activities and take-home assignments organized around climate topics which use GIS to teach key geospatial analysis techniques and cartography skills. The workbook is structured to the White House's Data.gov climate change themes, which include Coastal Flooding, Ecosystem Vulnerability, Energy Infrastructure, Arctic, Food Resilience, Human Health, Transportation, Tribal Nations, and Water. Each theme provides access to framing questions, associated data, interactive tools, and further reading (e.g. The US Climate Resilience Toolkit and National Climate Assessment). Lessons make use of the respective theme's available resources. The structured thematic approach is designed to encourage independent exploration. The goal is to teach climate concepts and concerns, GIS techniques and approaches, and effective cartographic representation and communication results; and foster a greater awareness of publicly available resources and datasets. To reach more audiences more effectively, a two level approach was used. Level 1 serves as an introductory study and relies on only freely available interactive tools to reach audiences with fewer resources and less familiarity. Level 2 presents a more advanced case study, and focuses on supporting common commercially available tool use and real-world analysis techniques.

Goals and Objectives of this Study

- 1) Develop an Earth Science geospatial analysis **workbook** around climate resources and data provided through the Climate Data Initiative (CDI) website, and
- 2) Develop a **workbook** which can be used by other teachers and material developers and which highlights the utility of both CDI and CRT in such pedagogical applications
- 3) Report on progress from last year's presentation [Griffin et al., 2016]

Climate Data Initiative (CDI)

The focus of Climate.Data.gov is on providing data related to climate change that can help inform and prepare America's communities, businesses, and citizens.

CDI currently identifies **9 major topical areas** and organizes information about each based on (a) data and (b) resources available both of which are used here. (<http://www.climate.data.gov>)

The screenshot shows the Climate.Data.gov website interface. At the top, there is a navigation bar with the logo and links for DATA, TOPICS, IMPACT, APPLICATIONS, DEVELOPERS, and CONTACT. Below this is a blue header with the word 'CLIMATE' and a search bar. A main navigation bar lists 'Themes', 'Data', 'Resources', 'Challenges', 'FAQ', and 'Contact Climate'. A sidebar on the left lists various topics: Arctic, Coastal Flooding, Ecosystem Vulnerability, Energy Infrastructure, Food Resilience, Human Health, Transportation, Tribal Nations, and Water. The main content area shows a list of resources related to climate change, with a 'U.S. Climate Resilience Toolkit' logo and a link to visit the toolkit.

Resources (non-GIS*)

The screenshot shows a grid of map resources on the Climate.Data.gov website. The grid includes several map thumbnails with titles such as 'About U.S. Natural Gas Pipelines', 'Accelerating Offshore Wind Development', 'Concentrating Solar Power Facilities and Solar Potential', 'Energy Consumption per Person in United States', 'Energy Expenditure per Person per State', 'Existing Hydropower Assets', 'Natural Gas Exploration, Resources, Reserves and Production', 'Non-powered Dam Resource Assessment', and 'Nuclear Materials Facilities'. Each map thumbnail includes a small description and a 'View' button.

*not specifically GIS-related, many of these are however portals to access and download geospatially-referenced datasets

Data (GIS-specific)

The screenshot shows a search results page on the Climate.Data.gov website. The page displays '111 datasets found' and lists several datasets with their titles, descriptions, and 'View' buttons. The datasets include 'U.S. Hourly Precipitation Data', 'Military Installations, Ranges, and Training Areas', 'National Flood Hazard Layer (NFHL)', 'National Oceanic and Atmospheric Administration - The National Flood Hazard Layer (NFHL)', 'National Oceanic and Atmospheric Administration - Storm Data', 'Annual Distribution and Production of Oil and Gas Wells by State from 1919-Latest Year Available', and 'U.S. Monthly Climate Normals (1981-2010)'. The page also features a search bar, filters for location and topic, and a 'Sort by' dropdown menu.

Welcome to UAH ESS414 [Geospatial Applications]



Earth System Science (ESS) 414 was formerly based around the GEO Societal Benefit Area Themes *[more to come on this]*, but was reworked to focus on the **Climate Data Initiative (CDI)** and **Climate Resilience Toolkit (CRT/NOAA)**. The goal was to continue to communicate and teach key geospatial analysis and cartographic concepts but within a new framework focused on the use of open-access federal geospatial datasets and allowing students to identify and study climate-related issues. Another goal was to demonstrate the utility of the CDI/CRT framework as a teaching tool and to provide increased visibility.

- Fall 2016
- 16-week class
- 14 students
- Lecture + Labs
- Focus on Earth Sciences
- Real-world Applications
- 9 CDI Themes

Course Schedule:

Topic	Assignments	Readings
Week 1		
9/26	Introduction; Syllabus/Course Structure	CFR on Canvas 8/21
Week 2		
9/27	Cartography / CDI / Arc Intro / Web Map Slides	Example Map Due 3pm
9/27	Coastal Flood Risk(CFR) (CRT Identify Problems; NCA Readings)	CFR Slide Due 3pm
Week 3		
9/31	Coastal Flood Risk(CFR) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome
10/1	Coastal Flood Risk(CFR) (CRT Determine Vulnerabilities & GIS Lab)	FR on Canvas 9/4
Week 4		
10/8	Food Resilience(FR) (CRT Identify Problems; NCA Readings)	FR Slide Due 3pm
10/8	Food Resilience(FR) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (CFR) Due W on Canvas 9/21
Week 5		
10/15	Food Resilience(FR) (CRT Determine Vulnerabilities & GIS Lab)	
10/17	Water(W) (CRT Identify Problems; NCA Readings)	W Slide Due 3pm
Week 6		
10/22	Water(W) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (FR) Due 3pm
10/24	Water(W) (CRT Determine Vulnerabilities & GIS Lab)	EV on Canvas 9/25
Week 7		
10/29	Ecosystem Vulnerability(EV) (CRT Identify Problems; NCA Readings)	EV Slide Due 3pm
10/31	Ecosystem Vulnerability(EV) (CDI Data Resources Discussion & Web Lab; CDI Lab Takehome / GIS Lab (W) Due 3pm	
Week 8		
10/31	Ecosystem Vulnerability(EV) (CRT Determine Vulnerabilities & GIS Lab) Grade: Proposal Due 3pm	
10/31	NO CLASS (Fall Break)	HR on Canvas 10/9
Week 9		
10/31	Human Health(HH) (CRT Identify Problems; NCA Readings)	HH Slide Due 3pm
10/31	Human Health(HH) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (EV) Due EW on Canvas 10/26
Week 10		
10/30	Human Health(HH) (CRT Determine Vulnerabilities & GIS Lab)	All Drug/Website/Story Maps Due 3pm
10/30	Arctic(A) (CRT Identify Problems; NCA Readings)	EW Slide Due 3pm
Week 11		
10/30	Arctic(A) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (HH) Due 3pm
10/30	Arctic(A) (CRT Determine Vulnerabilities & GIS Lab)	EI on Canvas 10/30
Week 12		
11/2	Energy Infrastructure(EI) (CRT Identify Problems; NCA Readings)	EI Slide Due 3pm
11/2	Energy Infrastructure(EI) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (A) Due 3 T on Canvas 11/6
Week 13		
11/20	Energy Infrastructure(EI) (CRT Determine Vulnerabilities & GIS Lab)	
11/20	Transportation(T) (CRT Identify Problems; NCA Readings)	T Slide Due 3pm
Week 14		
11/17	Transportation(T) (CDI Data Resources Discussion & Web Lab)	CDI Lab Takehome / GIS Lab (EI) Due 3pm
11/20	Transportation(T) (CRT Determine Vulnerabilities & GIS Lab)	
Week 15		
11/24	Grad Student Presentations	CDI Lab Takehome / GIS Lab (T) Due 3pm
11/28	NO CLASS (Thanksgiving)	
Week 16		
12/1	Grad Student Presentations	All Final Website/Story Maps Due 3pm
Week 17		
12/8	FINAL EXAM	

Climate-Focused Model for Applications

DATA TOPICS IMPACT APPLICATIONS DEVELOPERS CONTACT

CLIMATE

Themes Data Resources Challenges FAQ Contact Climate

- Arctic
- Coastal Flooding
- Ecosystem Vulnerability
- Energy Infrastructure
- Food Resilience
- Human Health
- Transportation
- Tribal Nations
- Water

U.S. Climate Resilience Toolkit

Visit the [Climate Resilience Toolkit](#) to access resources and a framework for understanding and addressing

<http://www.climate.data.gov>

National Climate Assessment

HIGHLIGHTS REPORT

OUR CHANGING CLIMATE SECTORS REGIONS RESPONSE STRATEGIES

Northeast	Northwest
Southeast	Alaska
Midwest	Hawaii and Pacific Islands
Great Plains	Oceans
Southwest	Coasts
Climate Science Supplement	FAQs

Water Energy, Water, and Land
Urban
Transportation Indigenous Peoples
Agriculture Land Use and Land Cover Change
Forests Rural Communities
Ecosystems Biogeochemical Cycles
Human Health

<http://www.globalchange.gov>

Sector Themes: *Coastal Flooding; Ecosystem Vulnerability; Energy Infrastructure; Food Resilience; Human Health; Transportation; Tribal Nations; Water* | **Region Themes:** *Arctic*

Approach: Thematic Course Modules

Nine thematic areas were divided over the course of the semester, making approximately 1.5 weeks per theme. This time was divided between identifying and discussing climate change-related issues and addressing them using CDI-catalogued datasets and GIS techniques.

Each **theme thus formed a “module”** with each module broken up as follows:

- 1) **“Identifying the Problem”** (from CRT)
 - a) Reading and discussion of relevant *National Climate Assessment* chapters
 - b) Identifying and presenting a summary of a *recent peer-reviewed case study* which uses geospatial analysis to study an aspect of the module theme, usually using Google Scholar to locate the published case study

- 2) **“Determining Vulnerabilities”** (from CRT)
 - a) *Group discussion and presentation of resources* available through CDI’s theme
 - b) *Guided take-home activity* highlighting multiple resources and identifying key geographic concepts and data formats through CDI’s Resources pages.
 - c) *GIS-centered activity* focused on data access and download via CDI to address “problems” as identified in Step 1, requiring the use of GIS software and culminating in a map submitted.

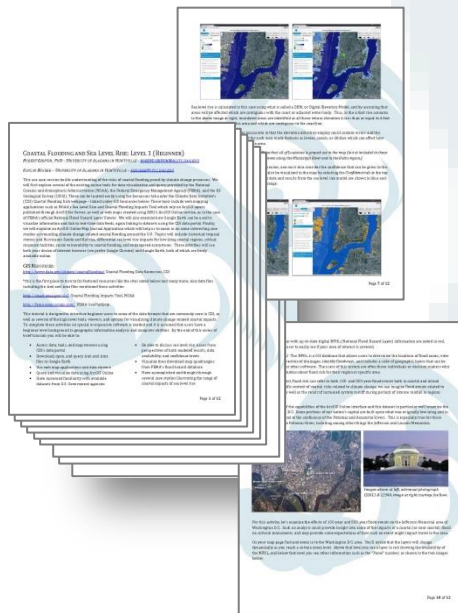
Workbook Guided Activities – CDI Resources

A guided series of step-by-step instructions and explanations of resources and file types, including case study locations are provided for students to review and explore data available. This is intended as a more structured version of their group activities, highlighting particular tools and data resources for them as a class.

Theme: *Coastal Flood Risk (CFR)*

- 1) *Review Data Formats – KML/KMZ*
- 2) *Differentiate between web map applications (eg ArcGIS Server or Arc Online) and downloadable data such as Google Earth files*
- 3) *Explore case studies using the Sea Level Rise and Coastal Flooding Impacts Viewer (NOAA)*
- 4) *Explore case studies using FEMA's National Flood Hazard Layer and download example pdf files showing flood zones*

**These activities do not rely on a commercial GIS software package like ESRI ArcGIS. Rather they use in-browser web GIS tools or free resources such as Google Earth or Adobe Acrobat to open and, in some cases, explore files.*



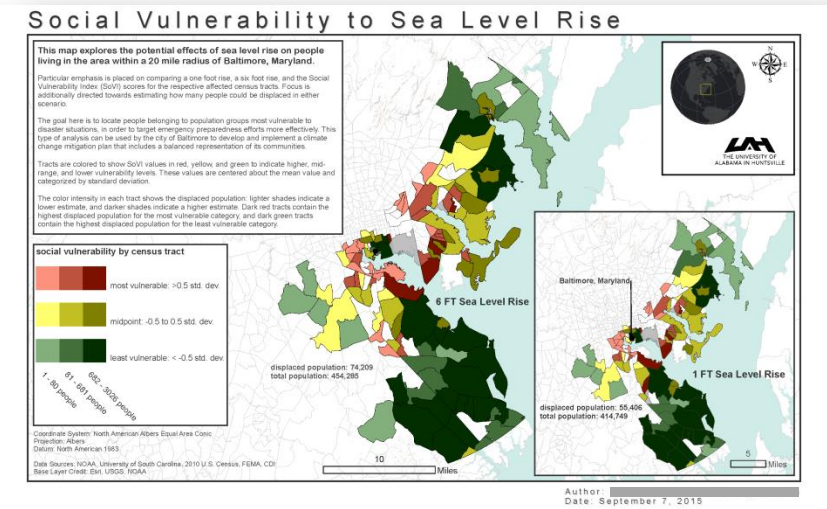
Workbook GIS Labs – CDI-catalogued Data



NCA Key Message #3: Socioeconomic disparities create uneven exposures and sensitivities to growing coastal risks and limit adaptation options for some coastal communities, resulting in the displacement of the most vulnerable people from coastal areas.

CDI Framing Question #4: Where are vulnerable populations, infrastructure, and sectors in relation to the flooding risk areas?

Concepts: Social Vulnerability Index; Sea Level Rise impacts
Data Access: SOVI, FEMA, NOAA SLR, US Census
GIS Analyses: raster-vector conversions, zonal statistics, symbology, cartography, projections

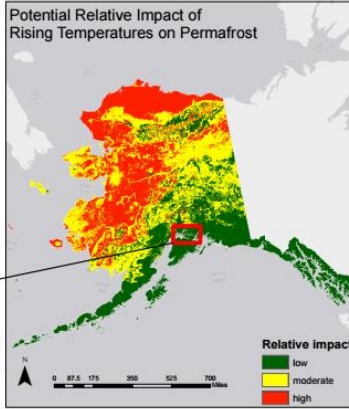


Arctic

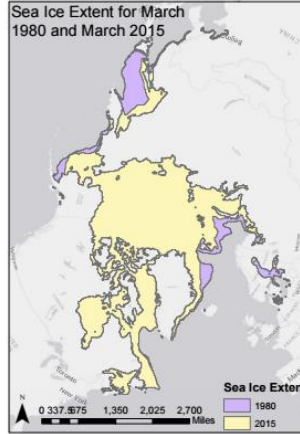


Impact of Climate Change on the Arctic

These maps illustrate the impact of climate change on the Arctic. The map on the left shows the potential impact of rising temperatures on permafrost and areas of high population density. The inset map shows that there will be a larger impact on Anchorage, Alaska as permafrost melts. The map on the right presents the changing extent of sea ice for the month of May. Since 1980, there has been a decrease in sea ice extent of 18, 569 km. Sea ice provides an important habitat for polar bears.



Map by [redacted] Right Projection: NAD 1983 Alaska Albers; Left Projection: Stereographic North Pole
Data credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community, CDC, US Census.



Framing questions from CDI theme

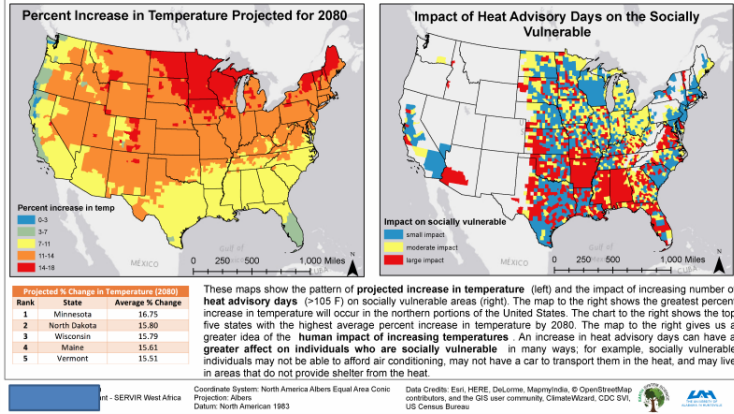
- To what extent are Alaska's people and infrastructure at risk from subsidence due to thawing permafrost, and how will changing climate patterns affect these potential hazards?
- How may the habitats of iconic Arctic species be affected by changes in sea ice extent over time?

Data resources accessed through CDI

- National Oceanic and Atmospheric Administration, (NOAA)
- National Snow Ice Data Center (NSIDC)
- AOS Arctic Data Integration Portal

Human Health

The Impact of Increasing Temperatures on Health in the United States



Framing questions from CDI theme

- What risk factors make individuals or communities more vulnerable to climate-related health effects?
- How will rising temperatures and greater heat advisory days in regions impact human health populations in those regions?

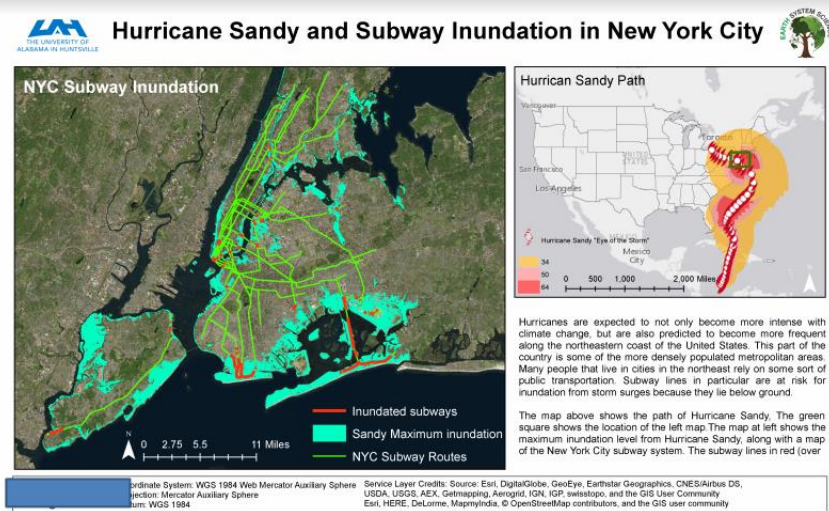
Data resources accessed through CDI

- The Nature Conservancy Climate Wizard
- CDC WONDER North America Land Data Assimilation System
- Social Vulnerability Index (SoVI)

Transportation

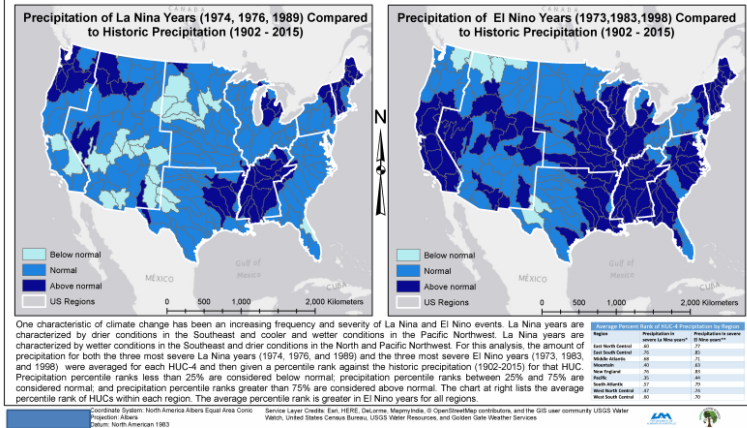
Framing questions from CDI theme

- How will climate trends affect transportation systems and their future design?
- What parts of the transportation system will be most vulnerable to climate change?
- How can climate information most effectively be translated for use by transportation practitioners?
- How will climate adaptation need to be integrated into existing transportation management systems?
- What tools and datasets apply broadly to different transportation users and sectors?



Water

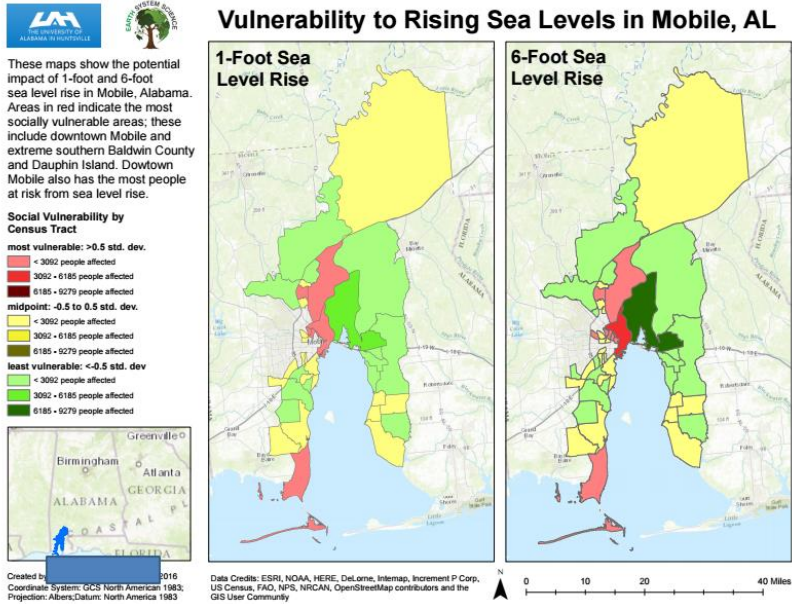
The Impact of La Nina and El Nino on Precipitation in the Continental US



Framing questions from CDI theme

- How could La Nina affect runoff levels in 2017?
- How can stream runoff data be used as a proxy for the impacts of El Nino and La Nina years on precipitation patterns in the United States?
- How can runoff percentiles be used to compare data for a particular year (or month) to historical averages?

Coastal Flooding



Framing questions from CDI theme

- What areas are currently at greatest risk of coastal flooding?
- What areas will be affected in the future as sea level rises?
- Where are vulnerable populations, infrastructure, and sectors in relation to the flooding risk areas?

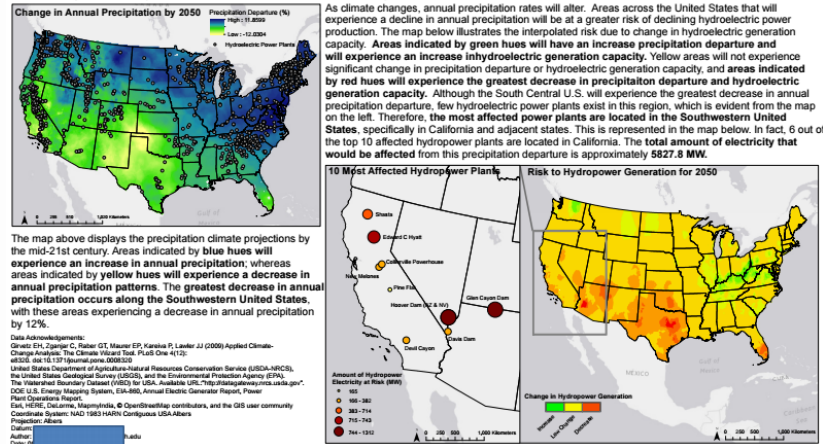
Data resources accessed through CDI

- Federal Emergency Management Agency (FEMA)
- USGS Coastal Vulnerability to Sea Level Rise
- USC Social Vulnerability Index (SoVI)

Energy Infrastructure

Hydroelectric Generation Risk due to Climate Change

Assessing Risk to Hydroelectric Power Plants from Changes in Precipitation



Framing questions from CDI theme

- How are fundamental energy resources impacted by climate?
- How might changes in climate and natural resource availability impact energy conversion infrastructure and processes?

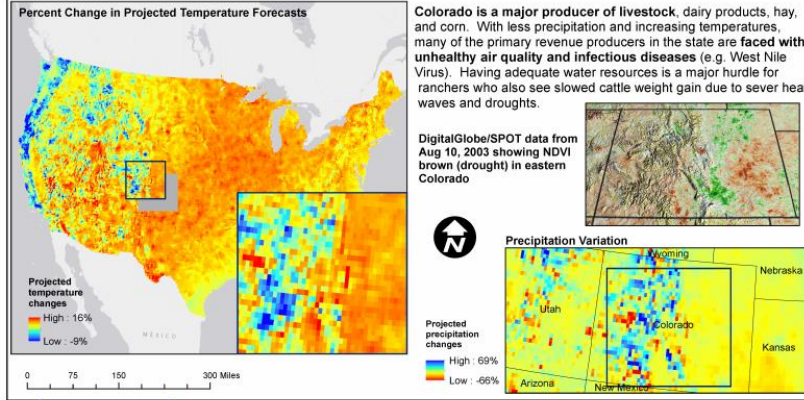
Data resources accessed through CDI

- The Nature Conservancy Climate Wizard
- USGS National Hydrography Dataset
- Department of Energy U.S. Energy Mapping System

Food Resilience

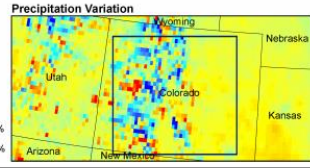
Vulnerability to Agriculture in the Midwest

A Look at Food Resilience with Past and Projected Climate Data to 2080



Colorado is a major producer of livestock, dairy products, hay, and corn. With less precipitation and increasing temperatures, many of the primary revenue producers in the state are faced with unhealthy air quality and infectious diseases (e.g. West Nile Virus). Having adequate water resources is a major hurdle for ranchers who also see slowed cattle weight gain due to severe heat waves and droughts.

DigitalGlobe/SPOT data from Aug 10, 2003 showing NDVI brown (drought) in eastern Colorado



Data Acknowledgments: The Nature Conservancy ClimateWizard past 50 years and end of century data for precipitation and average temperature; National Agricultural Statistical Service (NASS) cropland national dataset; NASA/Goddard Space Flight Center Scientific Visualization Studio.

Author: [redacted]@uah.edu, 10/27/2016
Coordinates: [redacted] [redacted]
Projection: Albers
Datum: North American 1983

Framing questions from CDI theme

- How will crop yield and production of other food products be affected by changes in climate?
- What types of food and locations will be most vulnerable to changes in climate?

Data resources accessed through CDI

- USDA National Agricultural Statistics Service
- CDI Food Resilience Resources

Geospatial Concepts Teaching Results:

Geoprocessing operations and workflows; Spatial and attribute query; Projections and coordinate systems; Raster operations, calculations, and zonal statistics (spatial analysis); Map layout and cartography; Data symbology and display

**focus for these activities and GIS analysis was on ESRI ArcGIS 10.3 with Spatial Analyst extension*

Climate Data Initiative Teaching Results:

Available data resources, tools, and featured content; Familiarity with website; Linking questions to data, analysis, then interpretation of results; Awareness of federal resources and climate change impacts; Ability to link concepts and problems identified using CRT's model with data and analysis using data query in CDI

Thank you, any questions?