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New Federal Sea Level Rise Scenarios for the U.S. Coastline

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New Federal Sea Level Rise Scenarios for the U.S. Coastline

Hampton Roads Sea Level Rise/Flooding Adaptation Forum
13 October 2017

Chris Weaver
National Center for Environmental Assessment
U.S. EPA Office of Research and Development

Outline

1. **SLR Task Force:** mandate, purpose, and history
2. **Progress to date:** global and U.S. regional SLR scenarios development, dissemination, and integration with coastal risk management tools
3. **Next steps:** development of new analyses and products
4. **SLR scenarios and risk:** key questions related to scientific assessment, risk management, and use of scenario information in planning

Federal SLR Task Force

Task Force Background

Strong demand for authoritative, consistent, accessible SLR and associated coastal flood hazard scenarios for the entire U.S. coastline, to support coastal preparedness planning and risk management

Much of the foundation already existing in individual agency efforts and capabilities, but with a lack of (1) synthesis and (2) nationwide coverage

In 2015, the WH Resilience Council directed the formation of the **Interagency Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Task Force**

Task Force Background

Co-chairs: John Haines (USGS), William Sweet (NOAA), Chris Weaver (EPA)
Participating agencies: DoD, EPA, FEMA, NASA, NOAA, USACE, USGS

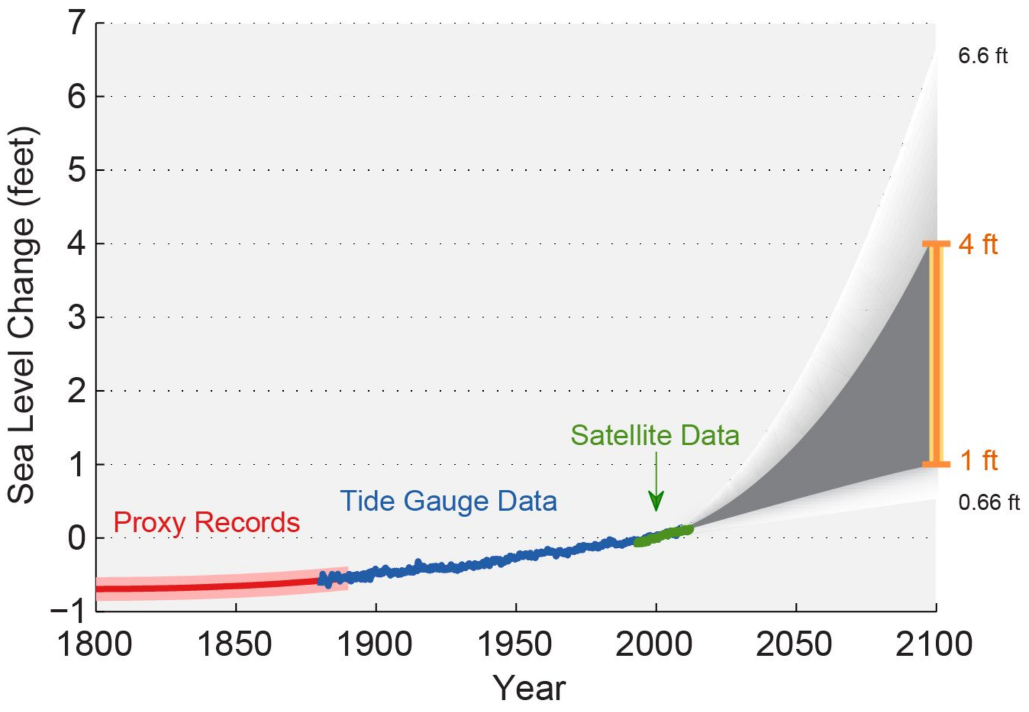
Initial set of key tasks for interagency coordination and development:

- Global SLR scenarios
- Regionalization of the global scenarios
- Integration with coastal risk management tools and processes

Also in direct support of the 4th National Climate Assessment (NCA4)

New Scenarios Development

Past and Projected Changes in Global Sea Level



National Climate Assessment (2014)

Scenarios from Parris et al. (2012), previous interagency effort

Before, we only had IPCC ...

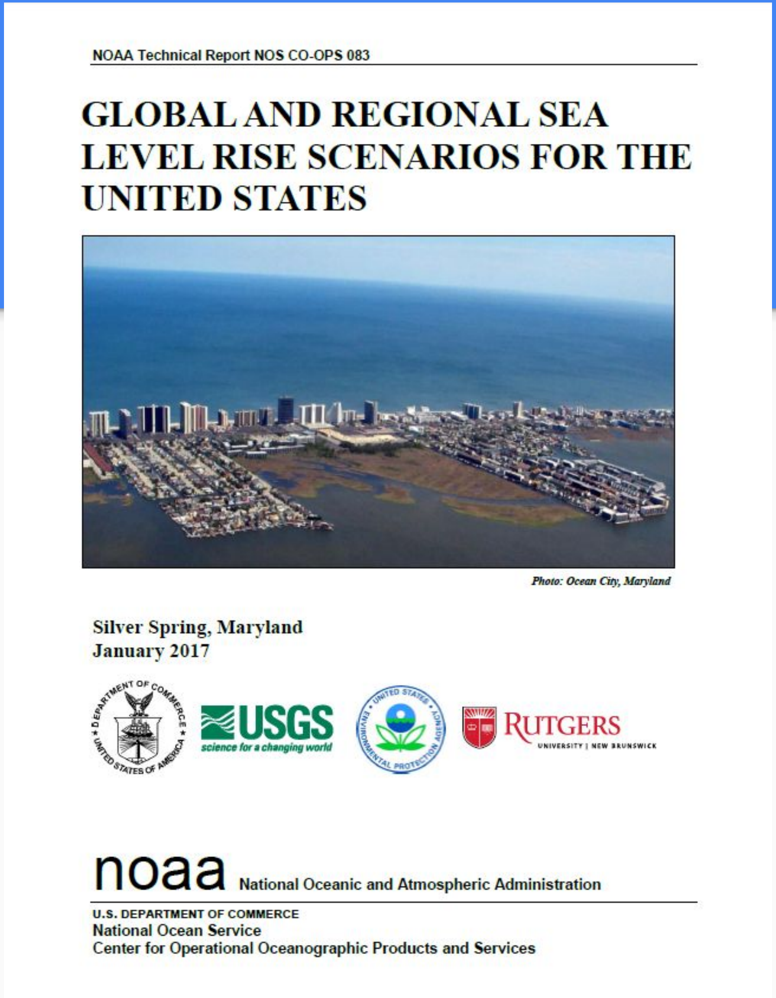
Scientific ‘best estimate’ based on numerous studies; represents range of scientifically plausible potential future SLR; meanwhile science evolves and the numbers shift …

Key Deliverable: Jan ‘17

1. Update Federal estimates of the range of future global SLR based on existing scientific evidence

   (0.3 - 2.5 m by 2100)

2. Develop scenarios of relative regional SLR across this range for the U.S. (incl. AK and HI), the Caribbean and the Pacific Island Territories



NOAA Technical Report NOS CO-OPS 083

GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

Photo: Ocean City, Maryland

Silver Spring, Maryland
January 2017

USGS science for a changing world
RUTGERS UNIVERSITY | NEW BRUNSWICK

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Summary of Report

Provides, for the first time, a set of regionally appropriate, gridded, relative SLR scenarios for the entire U.S. coastline, synthesizing the most up-to-date science

Fills a major gap in climate information needed to support a wide range of assessment, planning, and decision-making processes

Basis for future SLR estimates in the 4th National Climate Assessment (NCA4) cycle, including the Climate Science Special Report (CSSR; expected Nov 2017)

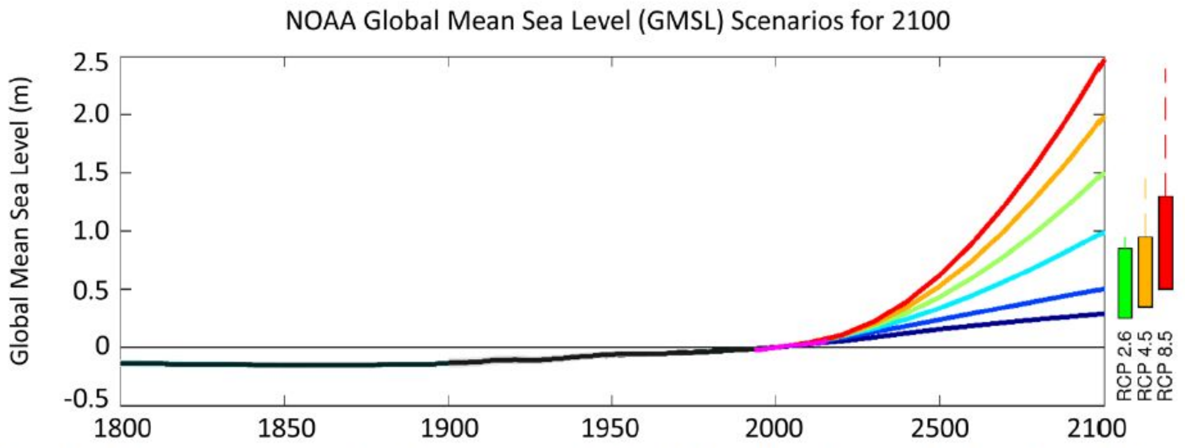


Figure 8. This study's six representative GMSL rise scenarios for 2100 (6 colored lines) relative to historical geological, tide gauge and satellite altimeter GMSL reconstructions from 1800–2015 (black and magenta lines; as in Figure 3a) and central 90% conditional probability ranges (colored boxes) of RCP-based GMSL projections of recent studies (Church et al., 2013a; Kopp et al., 2014; 2016a; Slangen et al., 2014; Grinsted et al., 2015; Mengel et al., 2016). These central 90% probability ranges are augmented (dashed lines) by the difference between the median Antarctic contribution of Kopp et al. (2014) probabilistic GMSL/RSL study and the median Antarctic projections of DeConto and Pollard (2016), which have not yet been incorporated into a probabilistic assessment of future GMSL.

Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

Global SLR Scenarios

- Divided the 0.3-2.5 m range into six discrete scenarios
- Each associated with a given probability of exceedance under different assumptions about GHG emissions
- Also looked out beyond 2100 to 2200

Regionalizing the Global Scenarios

Change in Relative Sea Level (RSL):

$$\Delta RSL = \Delta SL_{G} + \Delta SL_{RM} + \Delta SL_{RG} + \Delta SL_{VLM}$$

Global:
f(scenario, time epoch)

Regional:
f(oceanographic factors; dynamic SLR)

Regional:
f(changes in Earth's g-field due to ice melt redistribution)

Local:
f(uplift/ subsidence, GIA)

1-degree x 1-degree data product for the U.S. (incl. AK, HI, Caribbean, Islands)

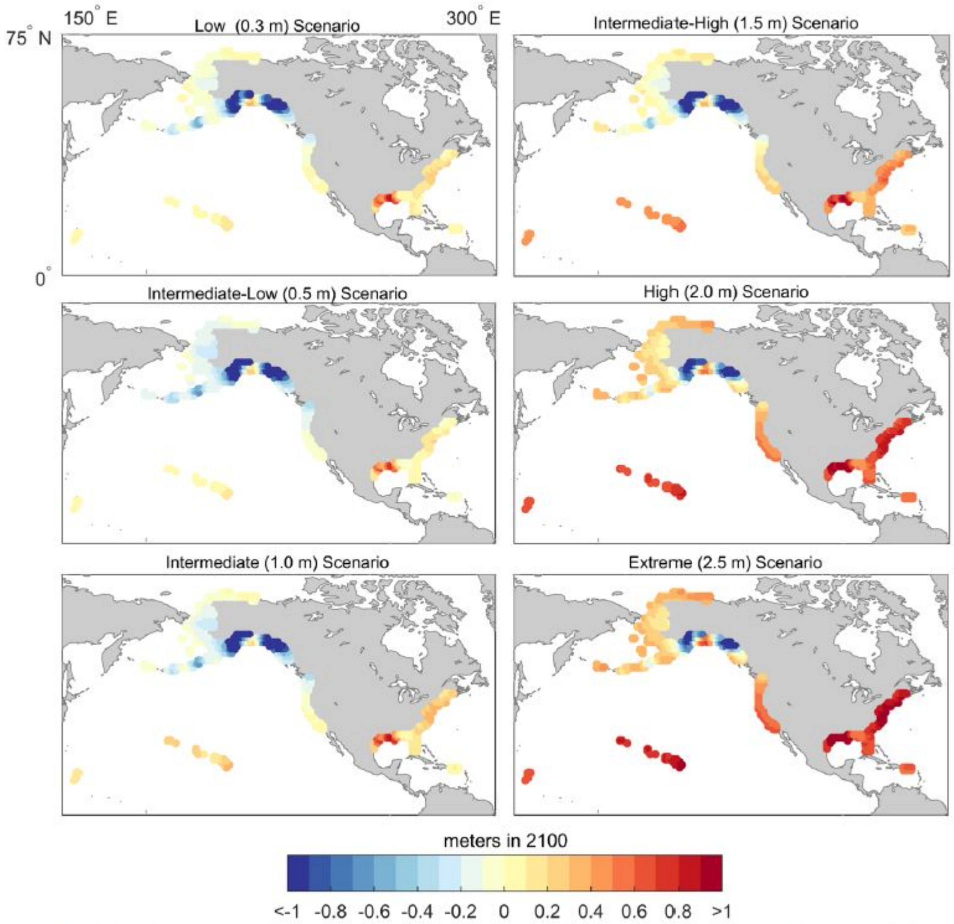
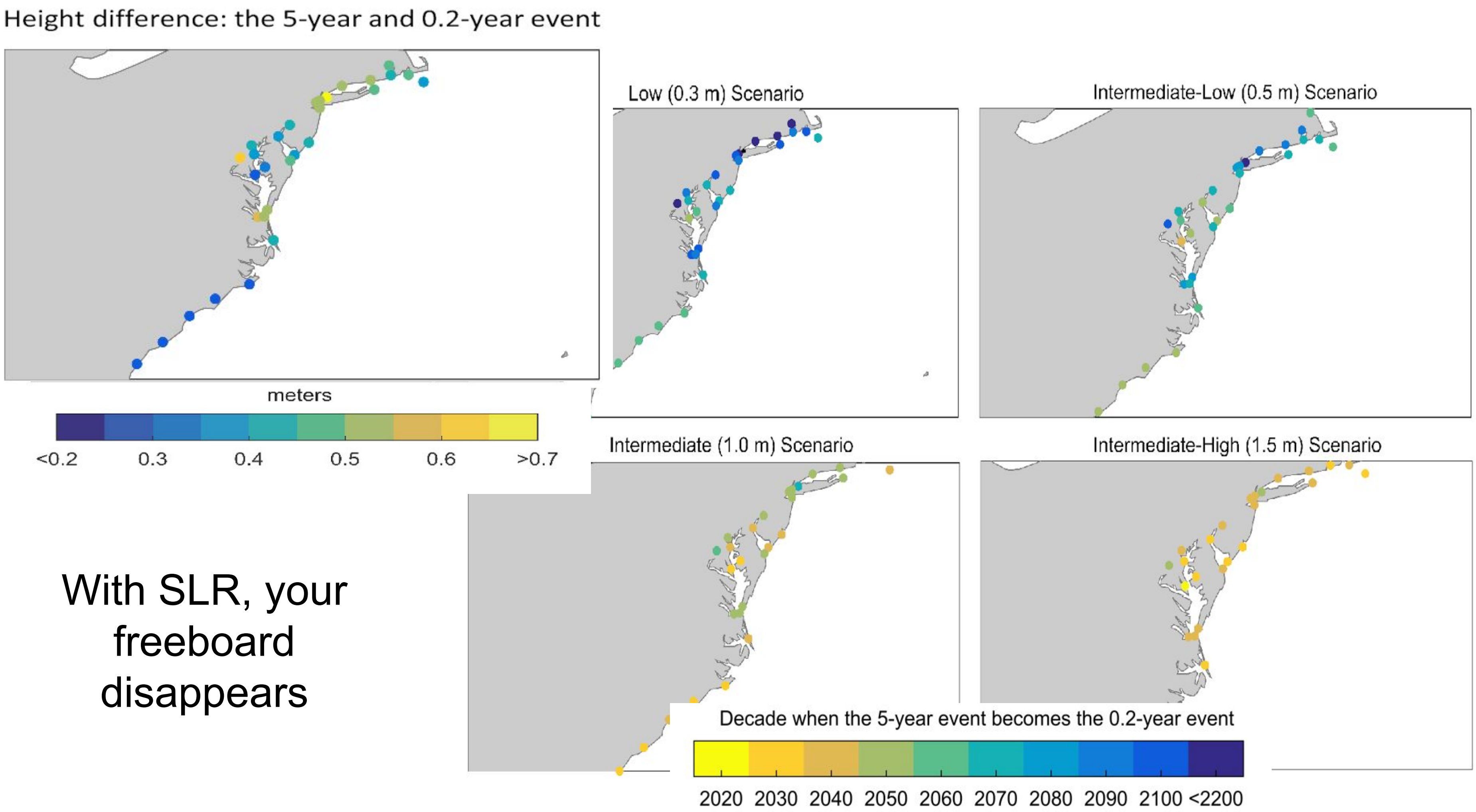


Figure 13. Total RSL change at 1-degree resolution for 2100 (in meters) relative to the corresponding (median-value) GMSL rise amount for that scenario. To determine the total RSL change, add the GMSL scenario amount to the value shown.

- Along essentially all U.S. coasts outside Alaska, RSL rise projected to be higher than the global average under the higher-end scenarios

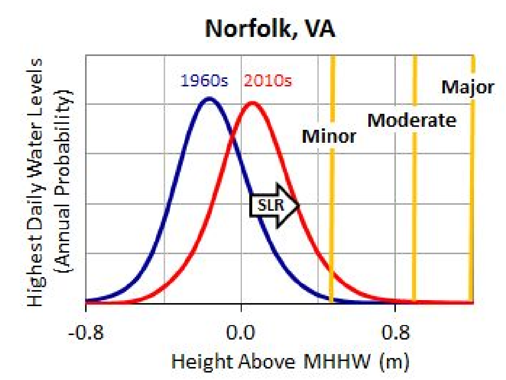
- Along much of the Pacific Northwest and Alaska coasts, RSL rise projected to be less than the global average

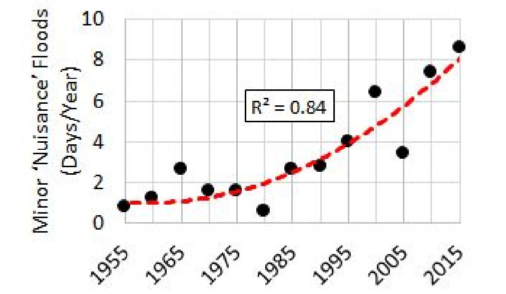
- RSL rise increases NOAA coastal flood ‘advisory’ and ‘warning’ conditions in coming decades within most U.S. coastal cities



With SLR, your freeboard disappears

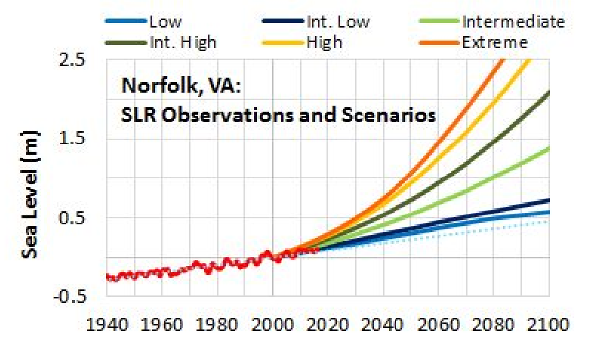
NOAA ‘Nuisance’ High Tide Monitoring and Future Scenarios

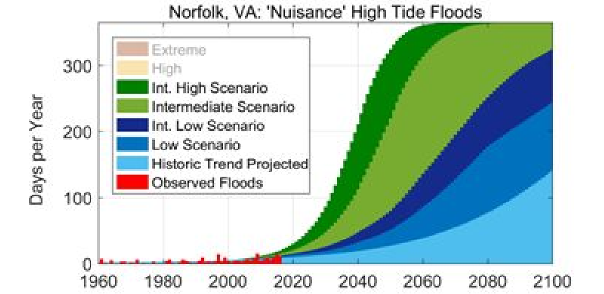


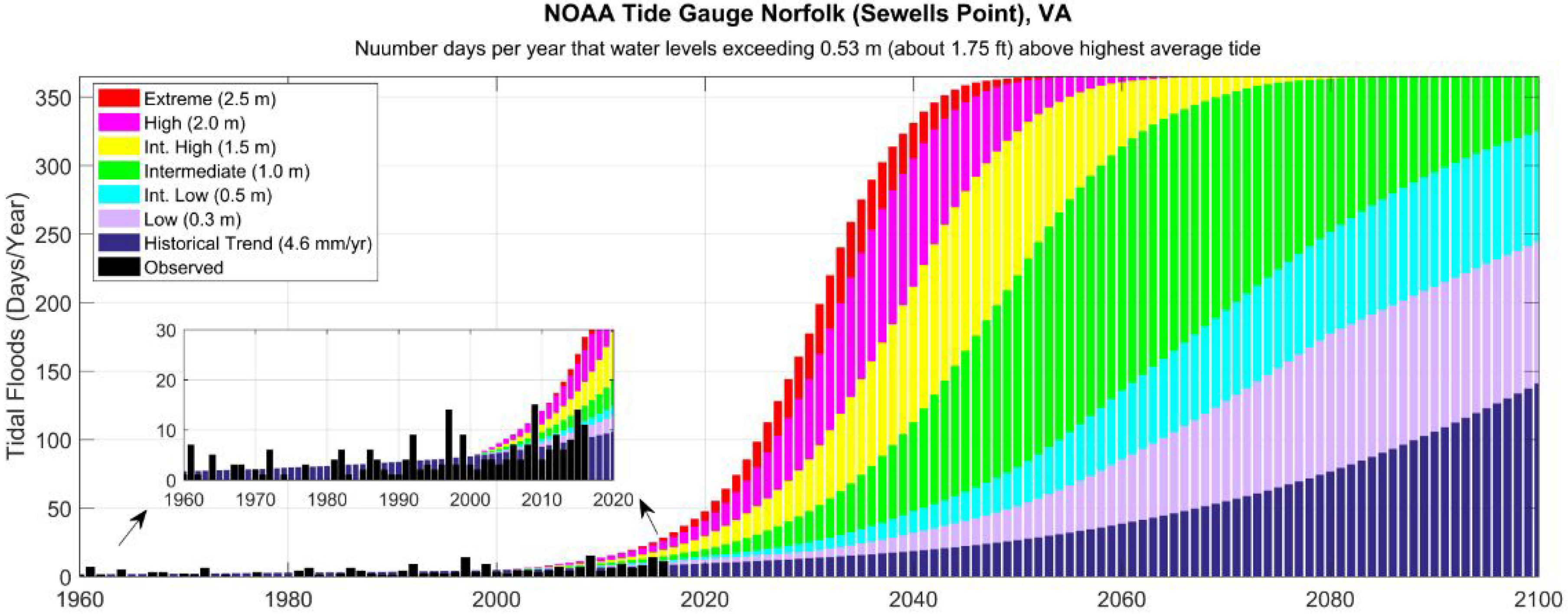


Due to SLR, flood risk is increasing; the annual frequency of minor flooding is accelerating in many U.S. cities (left).

Flood frequency monitoring relative to scenarios may assist in planning (right)






NOAA Tide Gauge Norfolk (Sewells Point), VA
Nuumber days per year that water levels exceeding 0.53 m (about 1.75 ft) above highest average tide
Extreme (2.5 m)
High (2.0 m)
Int. High (1.5 m)
Intermediate (1.0 m)
Int. Low (0.5 m)
Low (0.3 m)
Historical Trend (4.6 mm/yr)
Observed
Tidal Floods (Days/Year)
0
50
100
150
200
250
300
350
1960
1980
2000
2020
2040
2060
2080
2100
0
10
20
30
1960
1970
1980
1990
2000
2010
2020

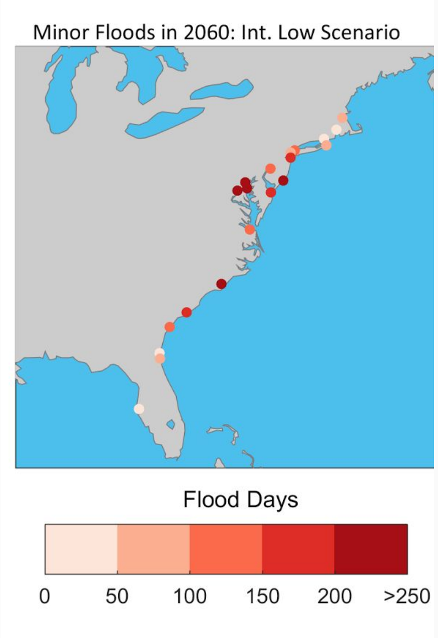
Current Status: Dissemination of Scenarios

- Report and raw data available now:
  - **https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf**
  - **https://tidesandcurrents.noaa.gov/publications/techrpt083.csv**
  - USGS ‘story map’ and geospatial viewer/access tool in development; coming soon
- In the process of integrating these updated scenarios into existing Federal tools and capabilities for coastal planning and decision support:
  - **NOAA SLR Viewer**
  - **USACE Sea Level Calculator**
  - **USGS Coastal Change Hazards Portal**
- In 4th NCA, CSSR (see also https://scenarios.globalchange.gov/sea-level-rise)

Next Steps: New Products

Next Steps: New Analyses and Products

(In process) Expanded spatial analysis of coastal flood frequency changes for most NOAA tide gauge locations implied by these new SLR numbers (e.g., subset shown right)



(Planned) Regional frequency analysis to produce a gridded set of extreme water level probabilities for U.S. coastline to assess future changes (away from tide gauges) using the SLR scenarios

Next Steps: New Analyses and Products

(Planned) Develop gridded set of extreme wave probabilities for U.S. to estimate scenarios of total water level (sea level, surge, waves) for U.S.

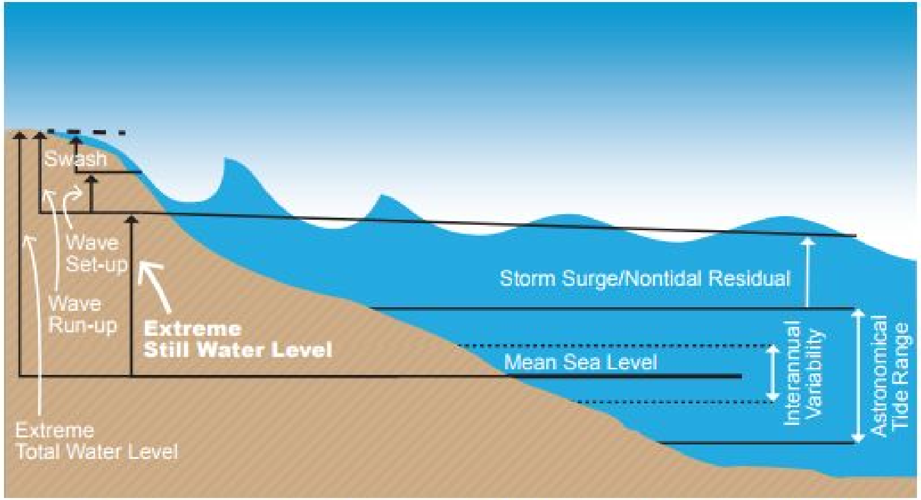
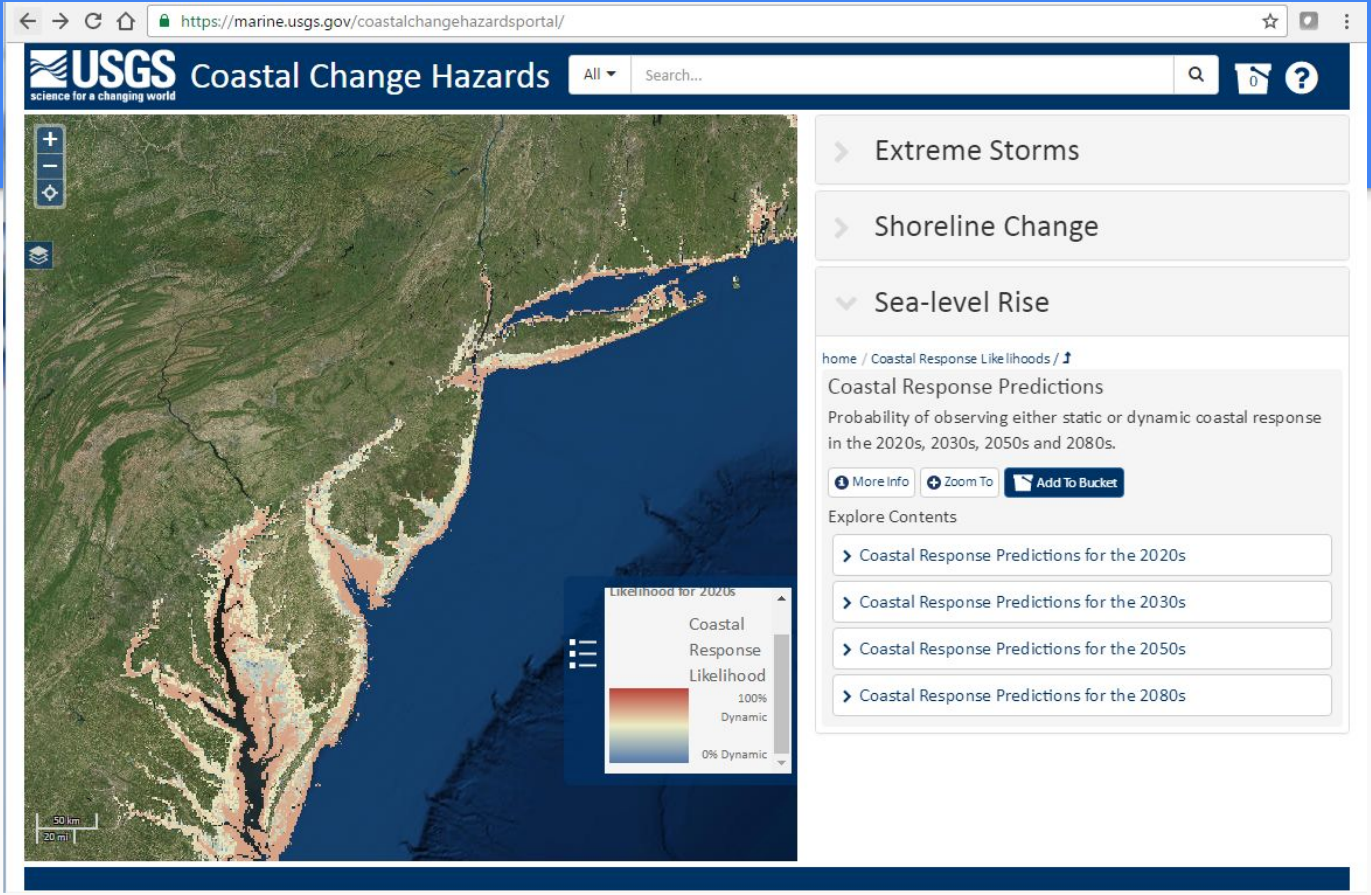


Figure 2.7 Components of Extreme Total Water and Extreme Still Water Level Measurements
This study focuses on Extreme Still Water Levels. (adapted from Moritz et al. 2015)

Next Steps: New Analyses and Products



(Planned) Integrate SLR and derivative scenarios into existing USGS landform change and coastal vulnerability tools

SLR Scenarios and Risk

Current Status: Translation & User Support

Task Force engaged in ongoing, but ad hoc, efforts to translate the technical information and provide guidelines on its use for a range of users

- Plan is to expand and systematize this part of the enterprise going forward

Task Force standing ready to provide support for resilient rebuilding in the Harvey-, Irma-, & Maria-affected areas, in collaboration with FEMA and others

- For example, see previous, USGCRP-coordinated post-Sandy efforts (http://www.globalchange.gov/browse/sea-level-rise-tool-sandy-recovery)

Risk Management in Coastal Environment

SLR presents major challenge for coastal communities:

- Direction is clear
- Impacts are manifesting now
- The pace of rise is likely to accelerate
- “When”, not “if”

Meanwhile, we have SLR science ...

Key Qs About Practical Applications

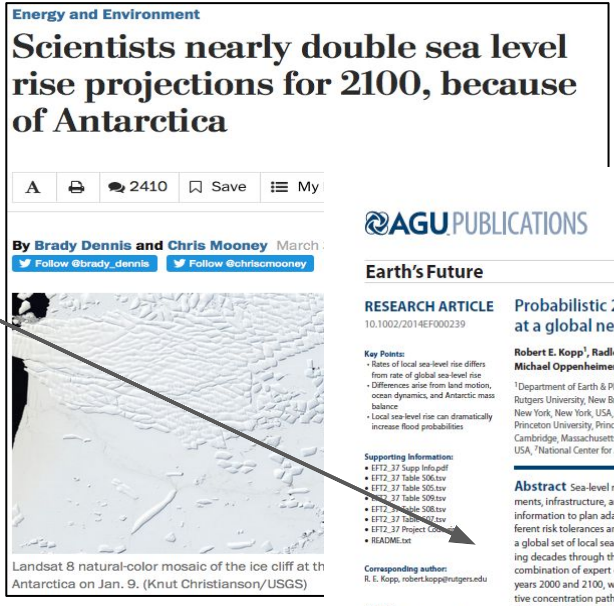
How to deal with multiple SLR assessments, scenarios, projections (& over such a wide range)?

What about the "worst case" scenarios (that keep getting worse)?

How about the new probabilistic projections?

What kinds of strategies are helpful for selecting relevant and useful scenarios for your needs?

There's so much SLR science! And it's changing so fast! What does it all mean for me??



Energy and Environment

Scientists nearly double sea level rise projections for 2100, because of Antarctica

A | 2410 | Save | My

By **Brady Dennis** and **Chris Mooney** March

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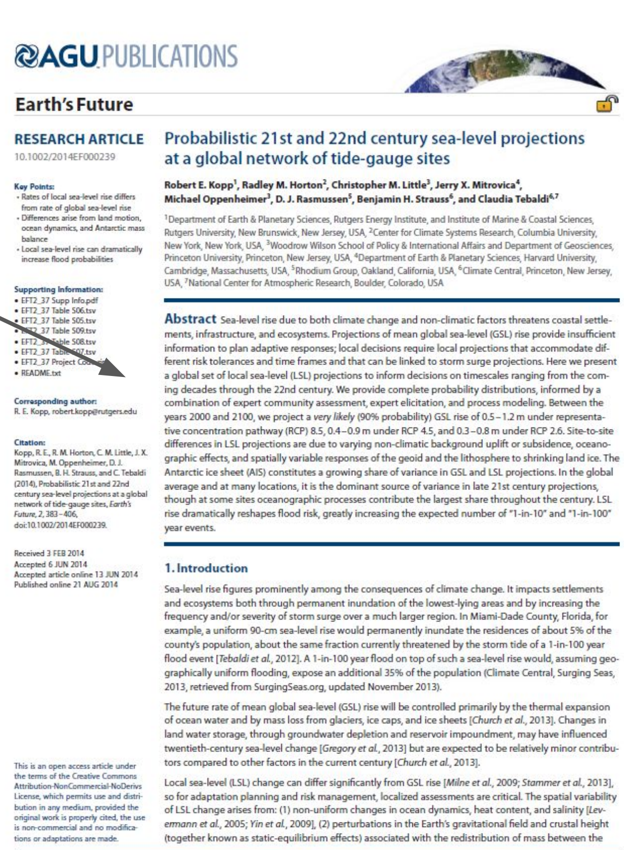
Landsat 8 natural-color mosaic of the ice cliff at th
Antarctica on Jan. 9. (Knut Christianson/USGS)



AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE

10.1002/2014EF000239

Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites

Robert E. Kopp[1], Radley M. Horton[2], Christopher M. Little[3], Jerry X. Mitrovica[4], Michael Oppenheimer[3], D. J. Rasmussen[5], Benjamin H. Strauss[6], and Claudia Tebaldi[6,7]

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Key Points:
- Rates of local sea-level rise differs from rate of global sea-level rise
- Differences arise from land motion, ocean dynamics, and Antarctic mass balance
- Local sea-level rise can dramatically increase flood probabilities

Supporting Information:
- EFT2_37 Supp Info.pdf
- EFT2_37 Table S06.tsv
- EFT2_37 Table S05.tsv
- EFT2_37 Table S09.tsv
- EFT2_37 Table S08.tsv
- EFT2_37 Table S07.tsv
- EFT2_37 Project Co
- README.txt

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Citation:
Kopp, R. E., R. M. Horton, C. M. Little, J. X. Mitrovica, M. Oppenheimer, D. J. Rasmussen, B. H. Strauss, and C. Tebaldi (2014), Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites, *Earth's Future*, 2, 383–406, doi:10.1002/2014EF000239.

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Abstract Sea-level rise due to both climate change and non-climatic factors threatens coastal settlements, infrastructure, and ecosystems. Projections of mean global sea-level (GSL) rise provide insufficient information to plan adaptive responses; local decisions require local projections that accommodate different risk tolerances and time frames and that can be linked to storm surge projections. Here we present a global set of local sea-level (LSL) projections to inform decisions on timescales ranging from the coming decades through the 22nd century. We provide complete probability distributions, informed by a combination of expert community assessment, expert elicitation, and process modeling. Between the years 2000 and 2100, we project a *very likely* (90% probability) GSL rise of 0.5–1.2 m under representative concentration pathway (RCP) 8.5, 0.4–0.9 m under RCP 4.5, and 0.3–0.8 m under RCP 2.6. Site-to-site differences in LSL projections are due to varying non-climatic background uplift or subsidence, oceanographic effects, and spatially variable responses of the geoid and the lithosphere to shrinking land ice. The Antarctic ice sheet (AIS) constitutes a growing share of variance in GSL and LSL projections. In the global average and at many locations, it is the dominant source of variance in late 21st century projections, though at some sites oceanographic processes contribute the largest share throughout the century. LSL rise dramatically reshapes flood risk, greatly increasing the expected number of "1-in-10" and "1-in-100" year events.

1. Introduction

Sea-level rise figures prominently among the consequences of climate change. It impacts settlements and ecosystems both through permanent inundation of the lowest-lying areas and by increasing the frequency and/or severity of storm surge over a much larger region. In Miami-Dade County, Florida, for example, a uniform 90-cm sea-level rise would permanently inundate the residences of about 5% of the county's population, about the same fraction currently threatened by the storm tide of a 1-in-100 year flood event [*Tebaldi et al.*, 2012]. A 1-in-100 year flood on top of such a sea-level rise would, assuming geographically uniform flooding, expose an additional 35% of the population (Climate Central, Surging Seas, 2013, retrieved from SurgingSeas.org, updated November 2013).

The future rate of mean global sea-level (GSL) rise will be controlled primarily by the thermal expansion of ocean water and by mass loss from glaciers, ice caps, and ice sheets [*Church et al.*, 2013]. Changes in land water storage, through groundwater depletion and reservoir impoundment, may have influenced twentieth-century sea-level change [*Gregory et al.*, 2013] but are expected to be relatively minor contributors compared to other factors in the current century [*Church et al.*, 2013].

Local sea-level (LSL) change can differ significantly from GSL rise [*Milne et al.*, 2009; *Stammer et al.*, 2013], so for adaptation planning and risk management, localized assessments are critical. The spatial variability of LSL change arises from: (1) non-uniform changes in ocean dynamics, heat content, and salinity [*Levermann et al.*, 2005; *Yin et al.*, 2009], (2) perturbations in the Earth's gravitational field and crustal height (together known as static-equilibrium effects) associated with the redistribution of mass between the

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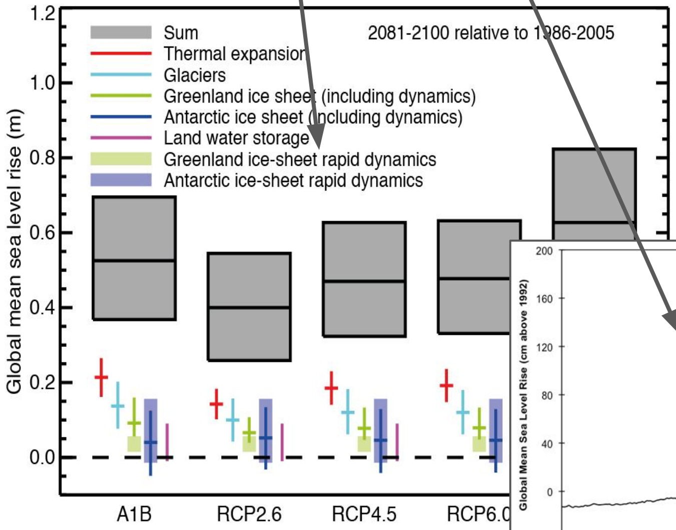
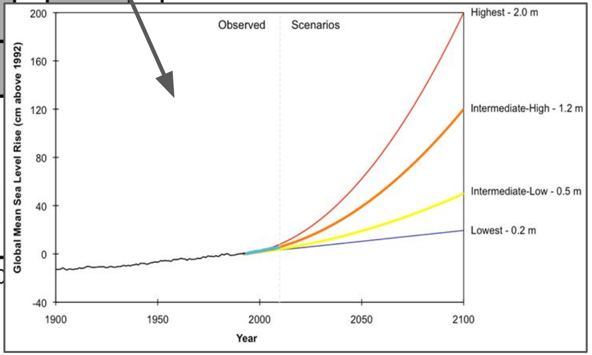




Scientific Synthesis and Integration

The new scenario products attempt to integrate scientific state-of-the-art:

- Increased upper bound to 2.5 m (by 2100) to acknowledge substantial new science since 2012
- Leveraged improved transparency and ‘scientific bookkeeping’ of Kopp et al. probabilistic approach to integrate multiple lines of scientific evidence and map discrete scenarios back to IPCC emissions pathways (RCPs)
- Comprehensively regionalized the global SLR scenarios for whole U.S. coastline

But … providing transparent guidance to make these science products more usable in practice remains an urgent work in progress

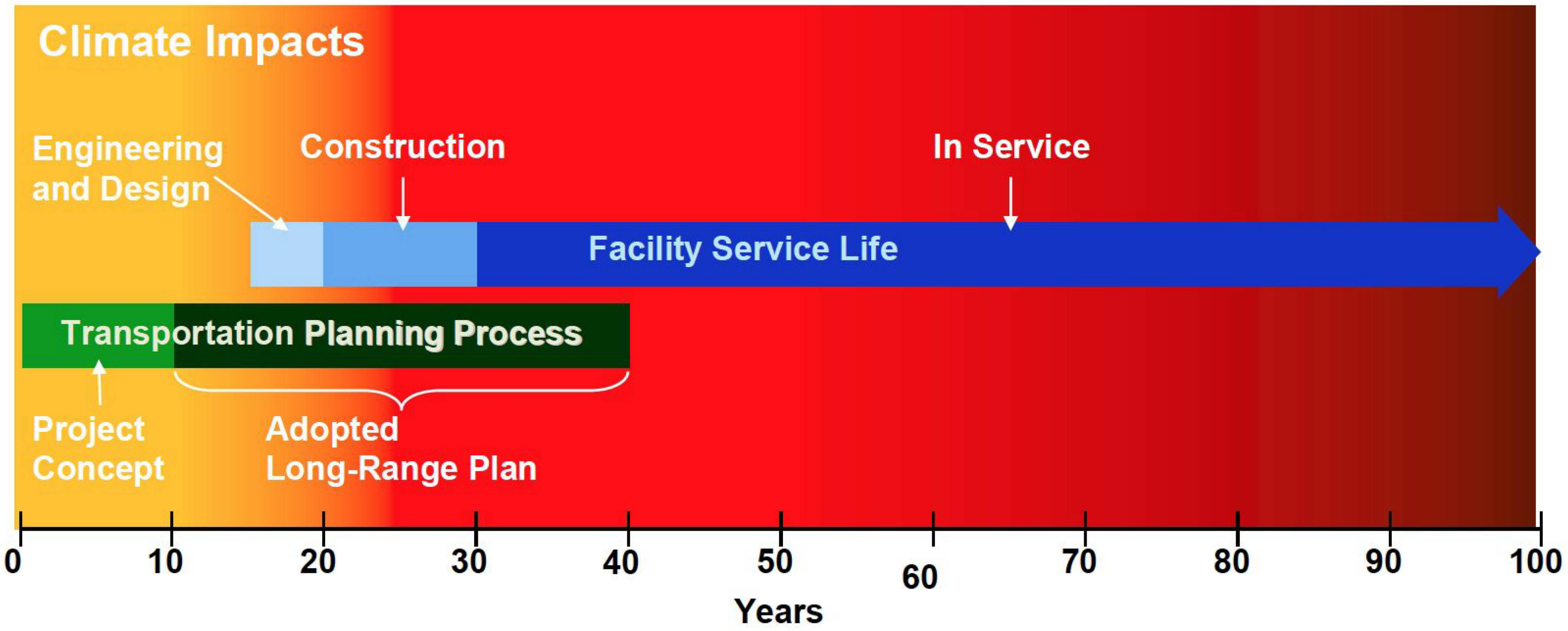
Key Qs About Practical Applications

How to deal with multiple SLR assessments, scenarios, projections (& over such a wide range)?

What about the "worst case" scenarios (that keep getting worse)?

How about the new probabilistic projections?

What kinds of strategies are helpful for selecting relevant and useful scenarios for your needs?



Many decisions are being made now
Not just short-term, but long-term too
For major infrastructure, 100 years from now is actually TODAY
Need to manage risk

Risk Framing: Core Principles

Define what we value (what is at risk); make this transparent, and put these things front and center in the assessment

Define what we wish to avoid (consequences) for these valued things

Carry out analyses to identify what risky outcomes can't be ruled out (prioritize according to which risks are greatest)

Don't just ask: "What's most likely to happen?" Also: "How bad could things get?"

Risk Framing: Notes on Use of Scenarios

What aspects of future change are most closely linked to climate-related risk and thus need to be assessed?

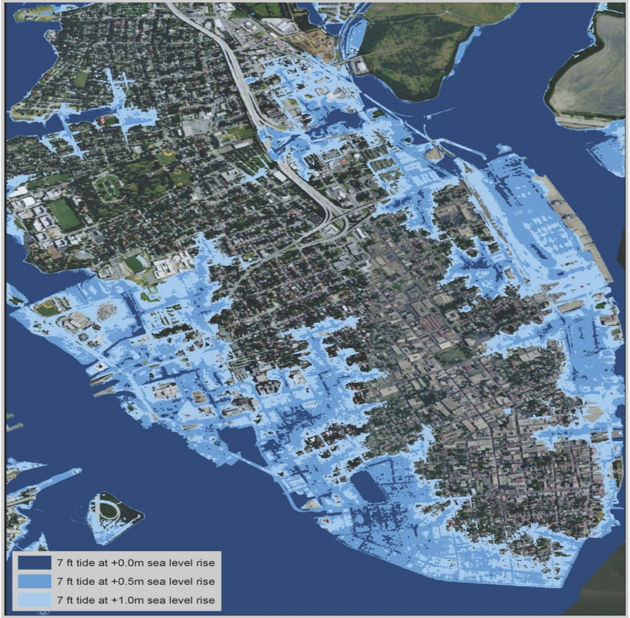
- Often extremes and threshold-crossing rather than simply the mean state
- Future changes that may be low-probability but have very large consequences
- Trends in other global change drivers that can increase exposure to climate-related risk (e.g., population growth), or interact with climate change to exacerbate risk

Scenarios play a key role in appropriately considering these in planning

Risk Framing: Notes on Use of Scenarios

Thinking and framing - cognitive benefits of scenarios:

- Can use multiple scenarios to bound risk and support near- and long-term planning
- Systematize consideration of key factors in climate hazard, vulnerability
- Force reorganization of mental models by challenging assumptions
- Help avoid ‘failures of imagination’



Risk Framing: Notes on Use of Scenarios

Disproportionate fraction of total risk may be associated with low-probability outcomes - plausible worst-case scenarios - we need to pay close attention to these when risk tolerance and flexibility are low

- High-value assets at risk (low tolerance for failure); long time horizons; limited ability to adapt, change, revisit the decision
- Need a plausible upper bound – used for guiding you as to your overall system risk, plus informing you what options need to remain open over the long term
- Can use scientific ‘best guess’ future as a lower bound in risk assessment, to be used as a benchmark for near-term planning; use monitoring to determine path

Questions & Discussion

Chris Weaver (weaver.chris@epa.gov)