



Tide stuff...

US Harbors

11/17/2021

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*“Today’s Flood is
Tomorrow’s High Tide” -
Margaret Davidson*



- Terminology related to products
 - Sea Level Trends
 - Model Forecasts
 - Tide Predictions
 - High Tide Flooding Outlooks
- Who we are and what we do
 - History, approaches, locations, why
- Products for coastal management decision makers
 - What's available now, what's coming in the future



Terminology - Relative Sea Level Trends

The sea level trends measured by tide gauges that are presented here are local relative sea level (RSL) trends as opposed to the global sea level trend. Tide gauge measurements are made with respect to a local fixed reference on land. RSL is a combination of the sea level rise and the local vertical land motion. The global sea level trend has been recorded by satellite altimeters since 1992 and the latest global trend can be obtained from [NOAA's Laboratory for Satellite Altimetry](#), with maps of the regional variation in the trend. The [University of Colorado's Sea Level Research Group](#) compares global sea level rates calculated by different research

East Coast West Coast Gulf Coast Alaska Hawaii Global

View in Google Earth



The map above illustrates relative sea level trends, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

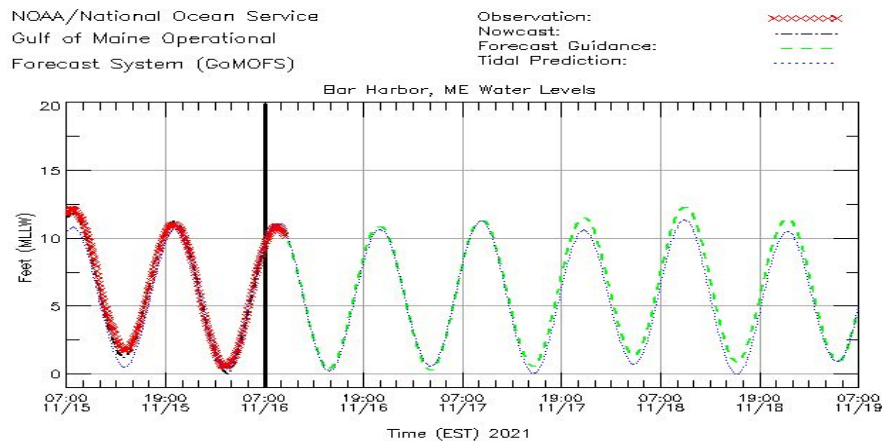




● Terminology

- **Operational Forecast Systems** - An operational, computer-generated product based on a hydrodynamic model that puts out water level forecasts for up to 5 days in advance. Typically they incorporate multiple types of data from water levels (both NOAA and other agencies), winds, salinity, temperature, among others.

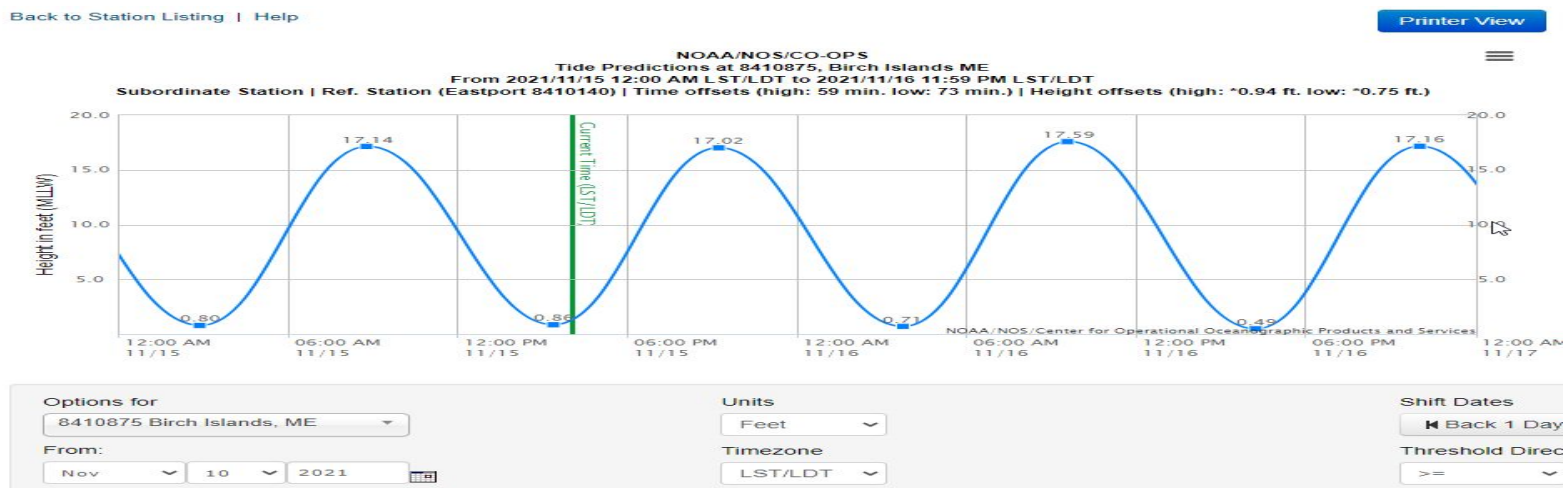
Gulf of Maine
Operational
Forecast System





● Terminology

- **Tide Prediction** - Modern predictions are a summation of the astronomical influences of the relative positions of the Sun, Moon, and the Earth. No climatologies involved. The high and low tide predictions are referenced to MSL and therefore can't reflect any changes in relative sea level. Predictions don't change that much and when they do it's most frequently attributed to a large dredging project that changes the hydrodynamics.

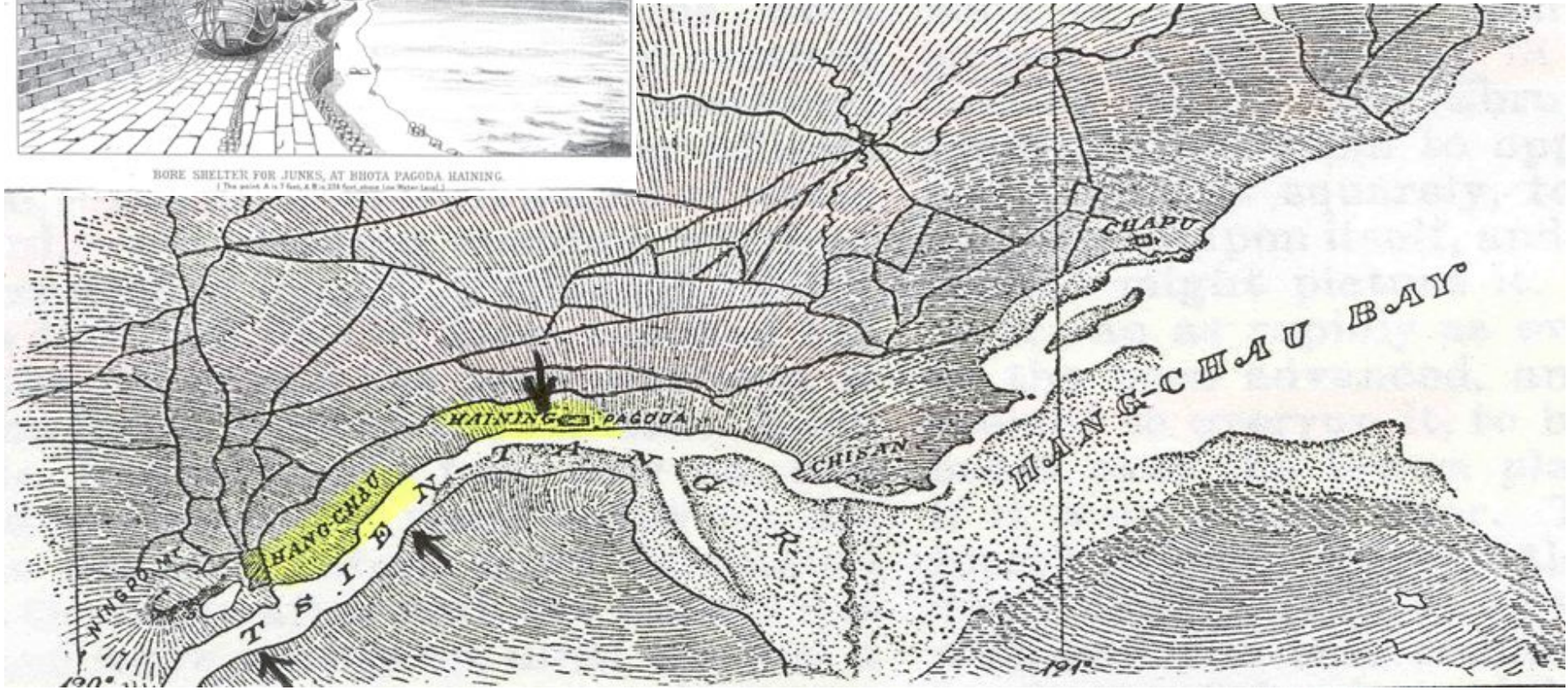


Terminology - Tide Predictions/ History



BORE SHELTER FOR JUNKS, AT BHOTA PAGODA HAINING.
The point A is 7 feet, & B is 218 feet, above low Water Level.

Qiantang River Tidal Bore - 1056





● Tide Predictions

- NOAA has roughly 3500 tide prediction locations. About 1200 are derived from modern methods, the rest are what we call “subordinate” and utilize simple range/phase adjustments to an operating station’s data
- For what it’s worth, we also have roughly 2500 tidal current predictions and about 900 of those are derived from the more modern harmonic analysis method



WAIT! It's flooding... What's in a name

King Tide

- The highest tide of the year
- The highest few tides of the year
- Higher than normal high tides
- Etc, etc.....

Perigean Spring Tide



But “tidal” flooding also means....

it’s predictable!



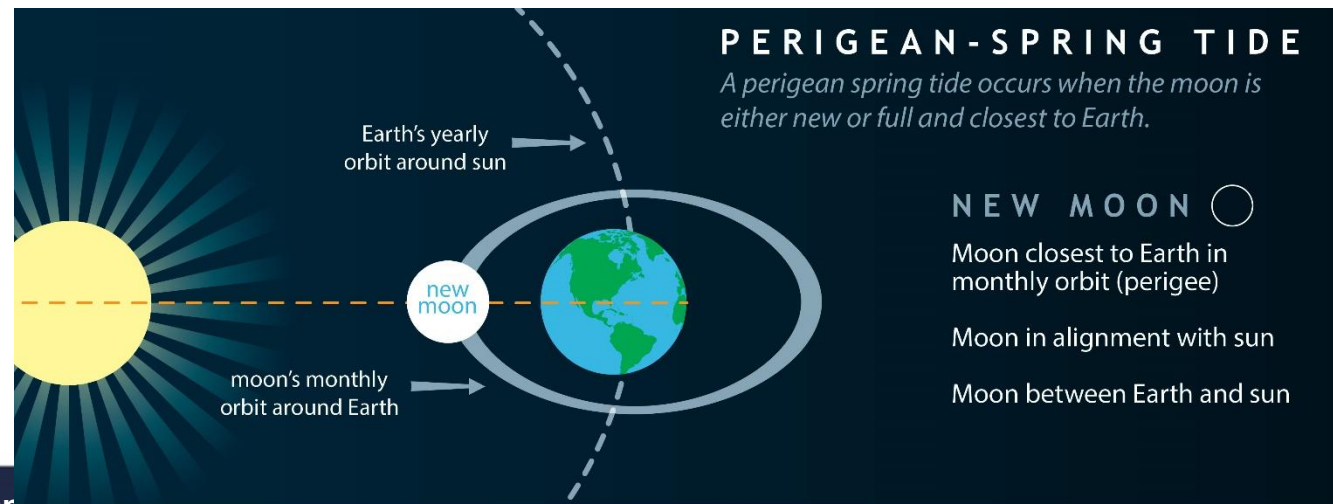
What is a perigean spring tide?

Perigee

- Moon is at its closest point to earth in its elliptical orbit
- Happens once a lunar-month!

Spring tide

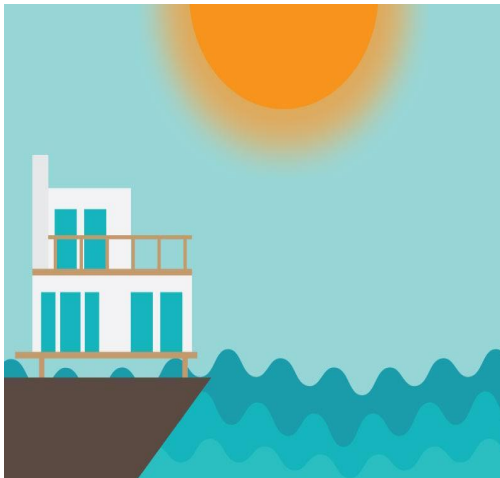
- The earth, moon and sun align to maximize tidal force
- Every ~14 days during a new or full moon



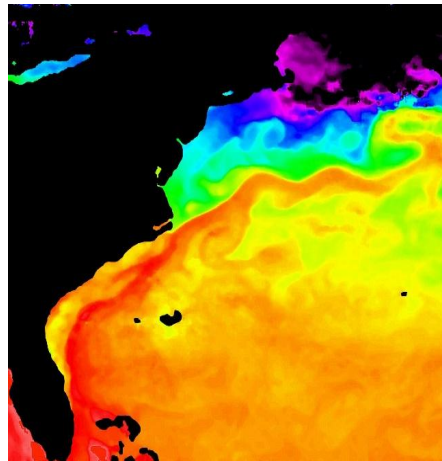


The sun, the moon and... the seasons?

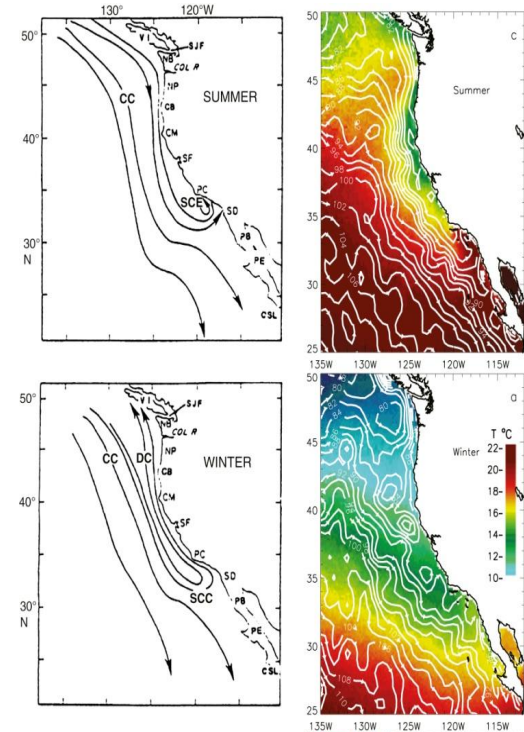
Thermal
contribution



Gulf Stream
Transport



Seasonal mean
winds





The NWLON Network

- 210 locations in tidal coastal areas and the nontidal Great Lakes

<https://tidesandcurrents.noaa.gov>

NOAA TIDES & CURRENTS

Home About What We Do News Education Search

High and Low Water Conditions.

Choose a state on the map to access your local water levels, tide and current predictions, and other oceanographic and meteorological conditions, or search below.

Search:



NWLON History

- In 1807 Thomas Jefferson signed "An Act to provide for surveying the coasts of the United States" and the appreciation for coastal observations grew from there. The National Water Level Observation Network (NWLON) has been operating continuously in some locations since the 1850s, San Francisco being our longest continuously operating station.
- Surveying coastal waters, using geodetic leveling to connect points on land, and making tide observations have all been in concert for about as long as we have been a country BUT our approaches are vastly different now, in all three aspects.
- Now the Office of Coast Survey (OCS), the National Geodetic Survey (NGS), and the Center for Operational Oceanographic Products and Services (CO-OPS) are sister offices within NOAA's National Ocean Service.



- “Tide” stations measure sea level relative to the elevation of the local land
 - ✓ Sea level trends determined from tide station records
 - ✓ Defined as “Relative Mean Sea Level Trends”



1806-1854	Manual readings on tide staffs
1854-1970	Float/wire sensor and analog strip chart recorders
1970-1993	Float/wire sensor and digital punch paper tape
1993-2014	Acoustic sensors and data transmission via satellite; additional environmental sensors added
2014-Present	Transition to microwave water level sensor technology



Old vs New Observations

Distant Past	Present
Simple technologies	Multiple advanced technologies
Some guy named Joe out on a pier reading a tide staff once an hour and writing it down	<ul style="list-style-type: none">● Microwave radar WL sensors● Acoustic WL sensors● Density-compensating dual pressure WL sensors● Acoustic Doppler Current Profilers (ADCP)● Meteorological sensors● GNSS sensors for geodetics● Satellite-based data telemetry



Old vs New Network

Distant Past	Present
Single purpose network	Multi-purpose network
Navigation & nautical charts	Tide data Current data Hydrographic data Historical data Sea level trends Coastal meteorological data Operational Forecasting



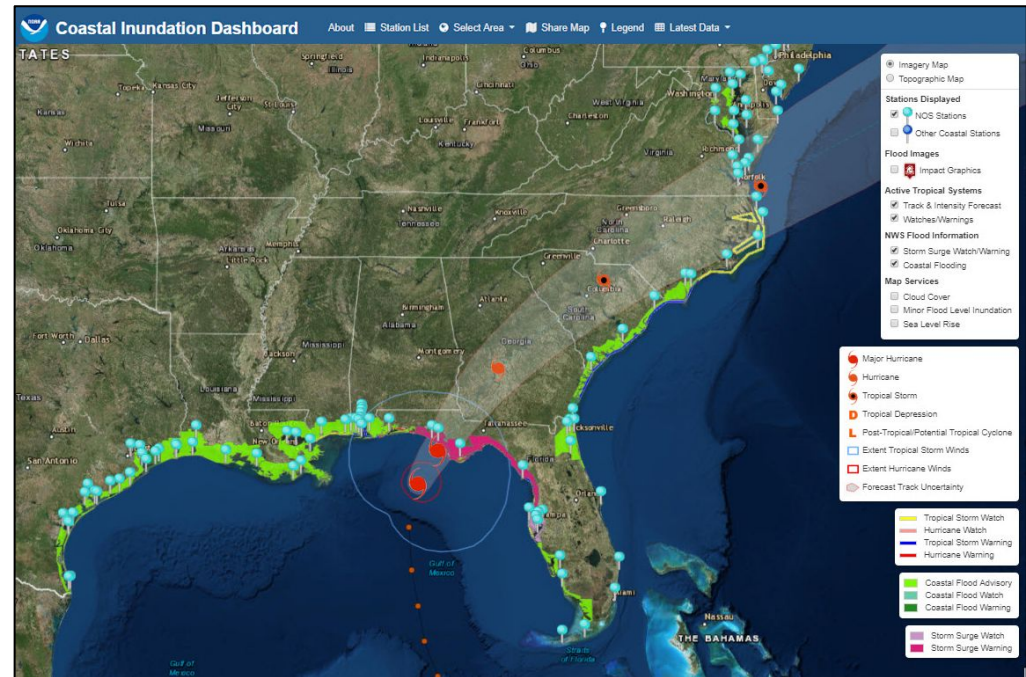
Products for coastal management

- Coastal Inundation Dashboard
- High Tide Flooding Bulletin
- Global and Regional Sea Level Rise Scenarios



Coastal Inundation Dashboard

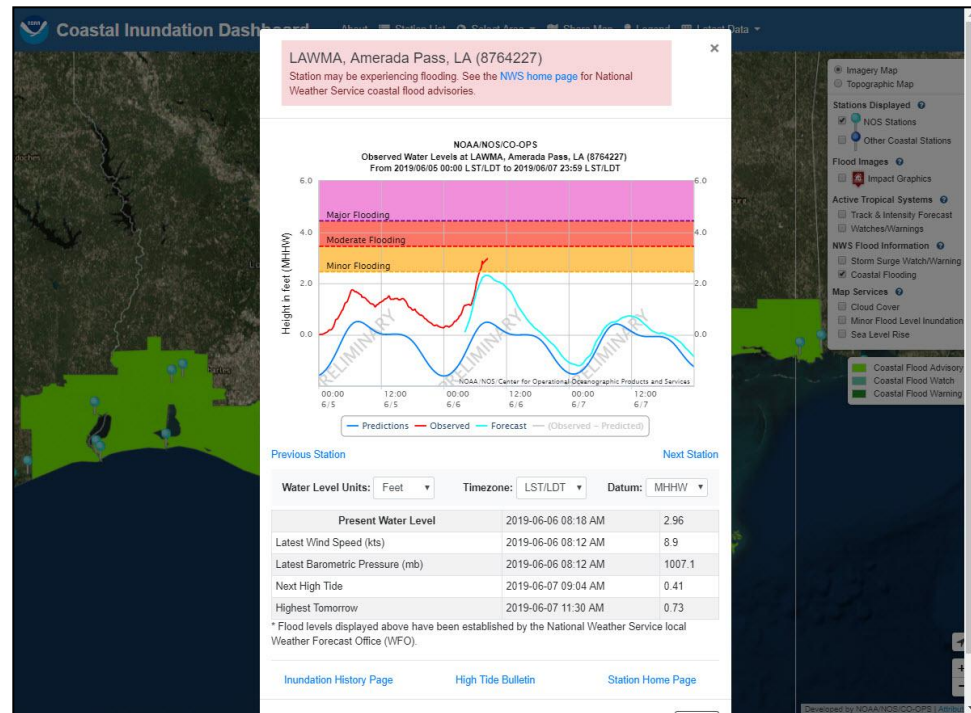
- Interactive map-based web application targeted towards coastal decision makers and planning community
- Real-time & historic flood information at NOS water level stations
- Customizable - create your own custom map URL!
- Water levels relative to MHHW (average daily highest tide)





Coastal Inundation Dashboard



- Integrates NOS and other relevant NOAA flood information
 - Local NWS weather forecast office (WFO) flood thresholds
 - Tropical cyclone forecast information from National Hurricane Center (NHC)
 - Coastal flood advisory & storm surge watch/warning
 - OCM Sea Level Rise Viewer
- Compares observed water levels with known flood impact thresholds automatically!





Flood Impact Thresholds

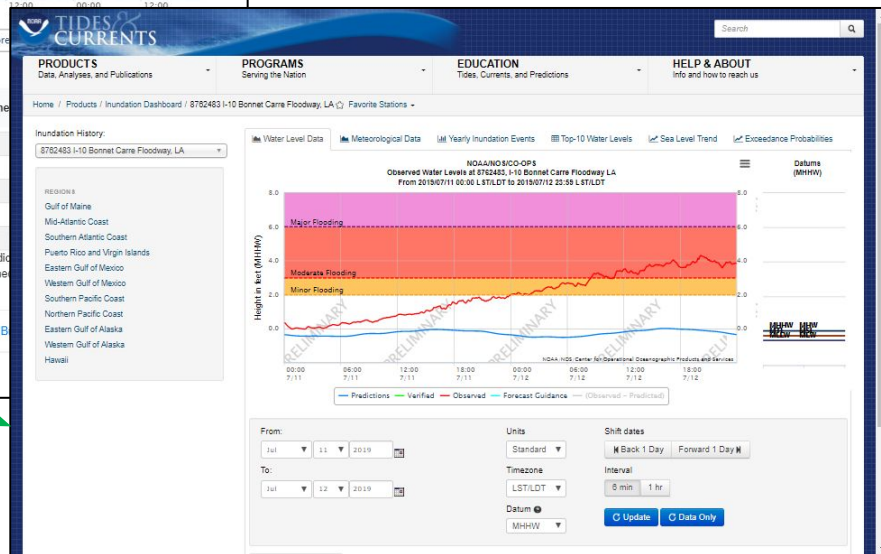
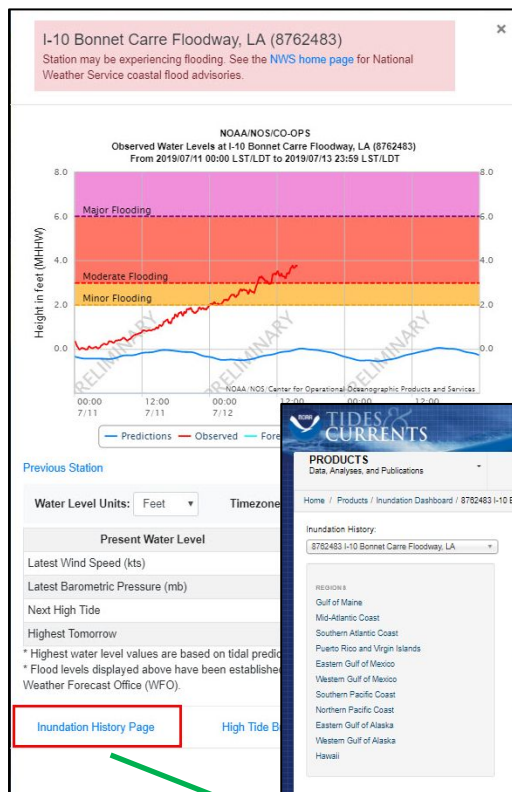
- Takes into account local geography and infrastructure (WFO specific)
- Provides a trigger point for issuing NWS coastal flood advisory products
- CO-OPS has analyzed available NWS minor flood levels nationwide to derive a consistent impact level relationship that can be applied at most coastal regions

 <h2 style="text-align: center;">Coastal Flooding Thresholds</h2> 			
	Minor (CF Advisory)	Moderate (CF Warning)	Major (Warning)
Picture	 <p style="text-align: center;">Westport</p>	 <p style="text-align: center;">Lindenhurst</p>	 <p style="text-align: center;">New Haven</p>
Hazard	<ul style="list-style-type: none"> • Low threat of property damage...and no direct threat to life. • 1 to 2 ft of inundation in shoreline and vulnerable areas. 	<ul style="list-style-type: none"> • Elevated threat of property damage...with a risk to life if one places themselves in unnecessary danger. • 2 to 3 ft of inundation in shoreline and vulnerable areas. • Minor to no inundation of surrounding coastal communities. 	<ul style="list-style-type: none"> • Significant threat to life and property. • 3-5+ ft of inundation in shoreline and other vulnerable areas. • Minor to moderate inundation (1 to 3 ft) of surrounding coastal communities that rarely experience coastal flooding.
Impact	<ul style="list-style-type: none"> • A few shoreline and vulnerable area roadways and adjacent properties will experience shallow flooding. 	<ul style="list-style-type: none"> • Several shoreline and vulnerable area home and businesses will experience water inside. • Several low-lying coastal and shoreline roads will be closed. • A few cars may take on water or even be destroyed. 	<ul style="list-style-type: none"> • Evacuations will be necessary for the most vulnerable shoreline and coastal areas. • Many coastal communities will experience damage...with some shoreline and flood prone homes and businesses being destroyed. • Many cars will likely be submerged or washed away. • Several sections of nearshore roads and escape routes will be impassable and a few could be washed out. • Flood waters may extend well inland in low lying areas.



Coastal Inundation Dashboard: Inundation History

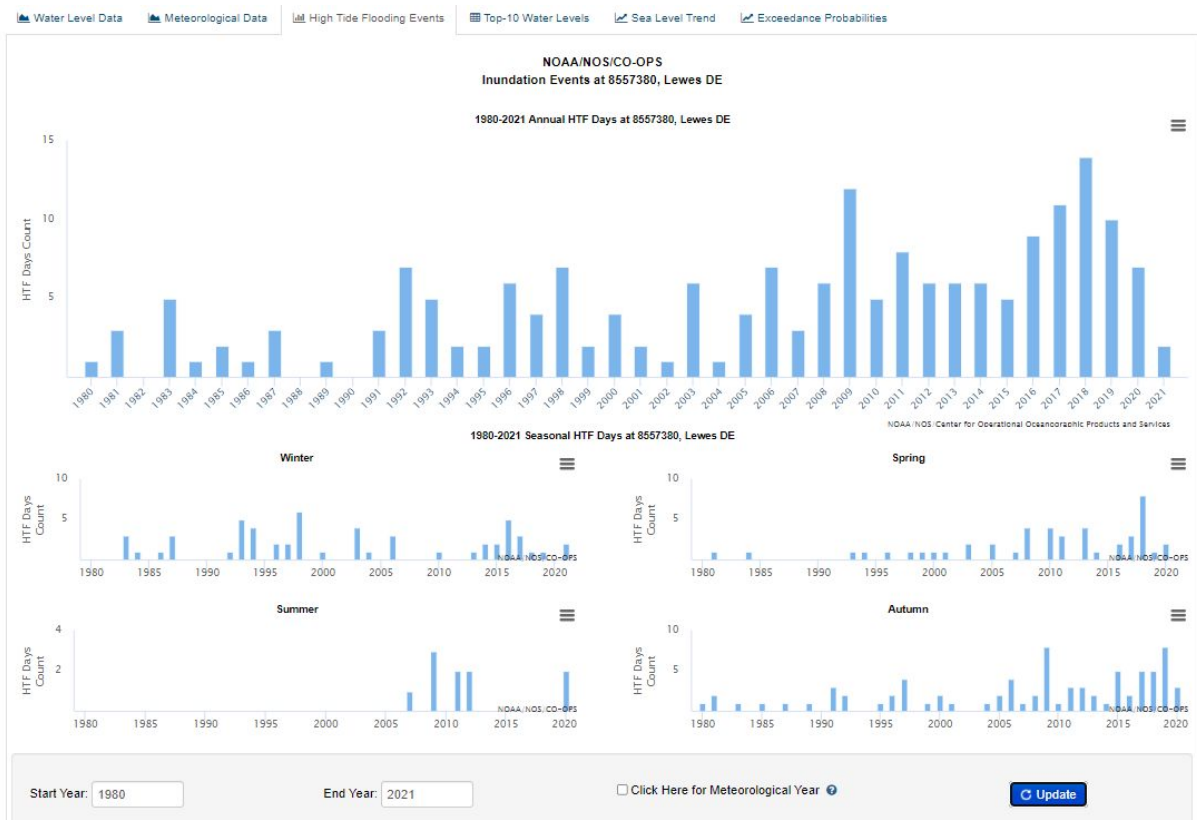
- Available by clicking *Inundation History Page* on any station pop-up
- Access real-time and historical water level & meteorological data
- Yearly Inundation Events
- Top-Ten Water Levels
- Sea Level Trend
- Exceedance Probabilities





Coastal Inundation Dashboard: Yearly Inundation Events

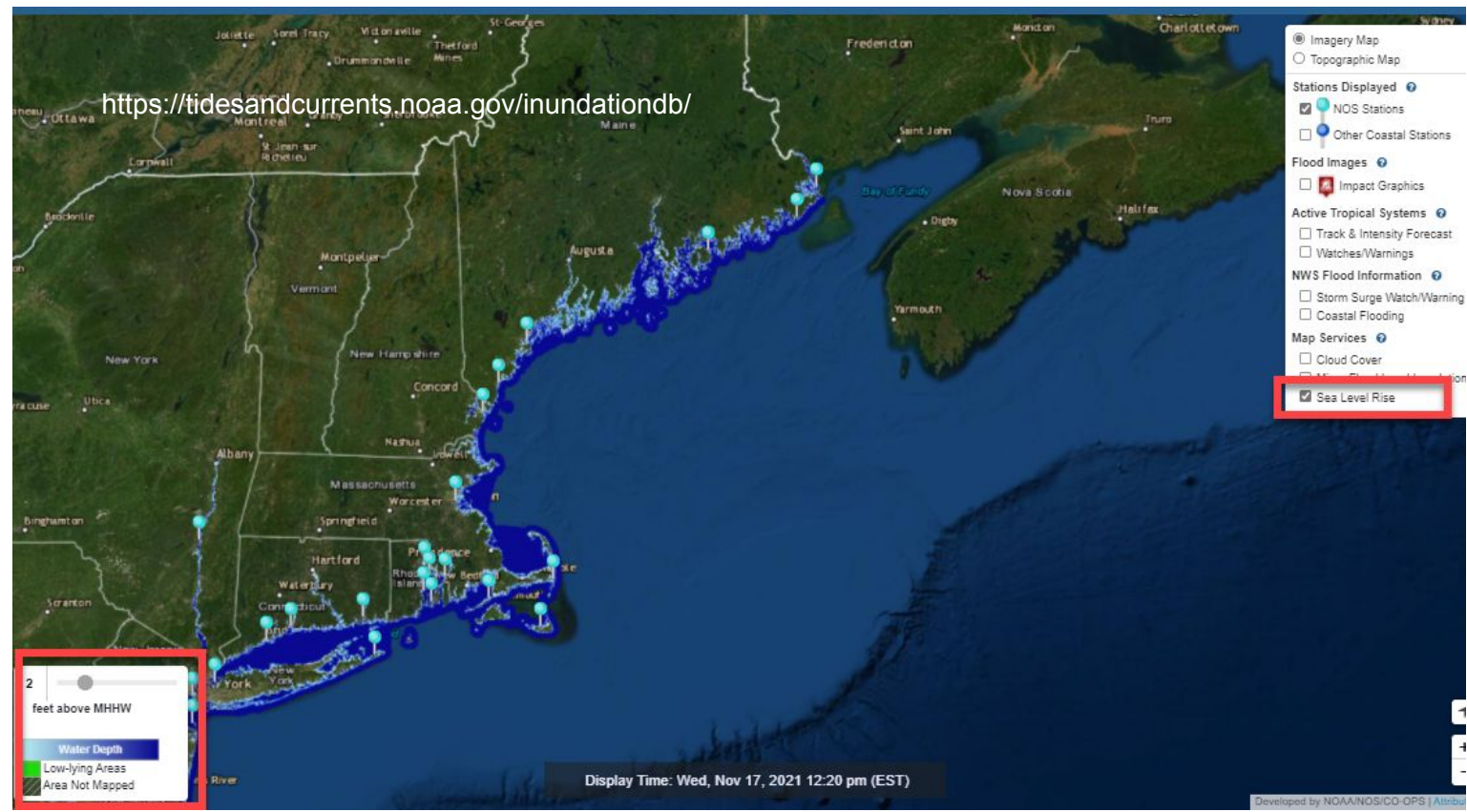
- Annual number of days where water levels have exceeded minor flooding threshold





Coastal Inundation Dashboard - Sea Level Rise Viewer

Courtesy of the Office of Coastal Management - Sea Level Rise viewer embedded in the Dashboard





High Tide Bulletin

High Tide Flooding

NOAA Seasonal Bulletins and Annual Reports

NOAA seasonal high tide flooding bulletins show when regions around the nation may experience higher than normal high tides. Bulletins are updated quarterly.

NOAA annual high tide flooding reports present a summary of events for the previous calendar year and expected events for the current year.

2021

[Fall 2021 Bulletin: September - November](#)

[Summer 2021 Bulletin: June - August](#)

[Spring 2021 Bulletin: March - May](#)

More Information

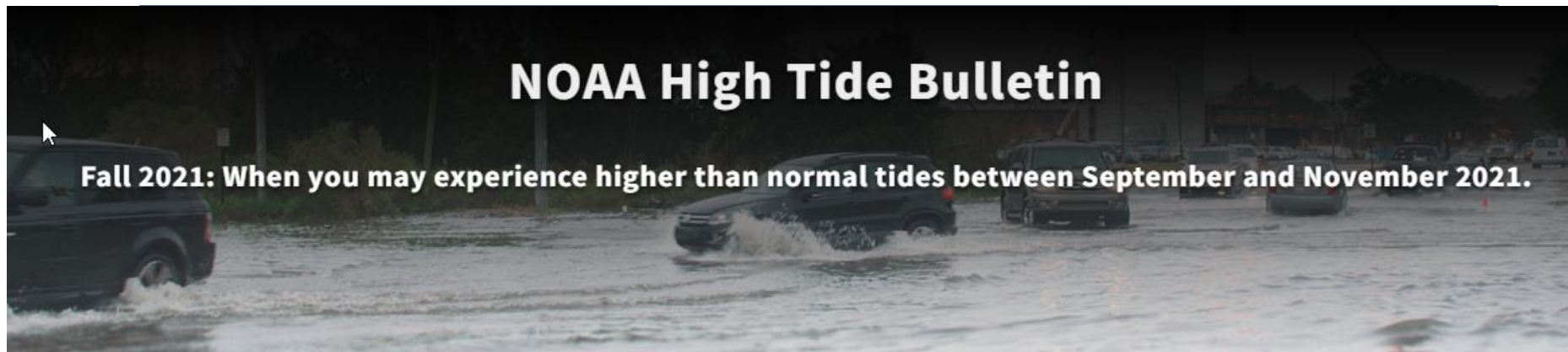
[Center for Operational Oceanographic Products and Services](#)

Did you know?

The Center for Operational Oceanographic Products and Services (CO-OPS) and its predecessors have gathered oceanographic data along our nation's coasts for over 200 years to protect life, property, and the



High Tide Bulletin



The rising and falling of the sea is a phenomenon upon which we can always depend. [Tides](#) are the regular rise and fall of the sea surface caused by the gravitational pull of the moon and sun and their position relative to the earth. There are some factors that cause the tides to be higher than what is "normally" seen from day to day. This bulletin tells you when you may experience higher than normal high tides for the period of time between September and November 2021.

We also publish [annual high tide flooding reports](#) that present a broad outlook of

[Select Your Region](#)

Select your region to see when you may experience higher than normal tides that may cause flooding.

[NOAA Coastal Inundation Dashboard](#)

The NOAA Coastal Inundation Dashboard provides real-time water



High Tide Bulletin

NORTHEAST OUTLOOK

Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and New York

Dates:

- No dates in September
- October 6-11
- November 4-9

Locations:

Tide stations at the following locations have the greatest chance of seeing high tide flooding:

- Bar Harbor, Maine; Portland, Maine; Boston, Massachusetts; Providence, Rhode Island; Kings Point, New York
- [Visit the NOAA Coastal Inundation Dashboard for this region to view real-time water levels with forecasts out to 48 hours.](#)

Why will they be higher than normal?

- A perigean spring tide will be occurring. This is when the moon is either new or full and closest to earth. Higher than normal high tides and lower than normal low tides will occur.
- Mean sea level is generally higher in the early fall months due to warmer, expanding ocean water and changes in weather patterns.

What kind of impact might I expect along the coast?

- Low lying areas may flood, however high tides alone will likely not cause a significant impact on the coast in most areas unless accompanied by a storm or strong winds.
- Lower than normal low tides will also occur.



High Tide Flooding - Looking forward

NOAA Technical Report NOS CO-OPS 086

PATTERNS AND PROJECTIONS OF HIGH TIDE FLOODING ALONG THE U.S. COASTLINE USING A COMMON IMPACT THRESHOLD



Photo: New York City Harbor

**Silver Spring, Maryland
February 2018**

- Identify the importance of thresholds at the local scale
- Work by William Sweet, et. al, to establish National Ocean Service (NOS) thresholds against which data can be referenced. *Not supplanting local thresholds set by local weather forecast offices (WFOs), but establishing an approach to regionalizing impact potential.



Patterns and Projections... High Tide Flooding Using a Common Impact Threshold



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Patterns and Projections cont.

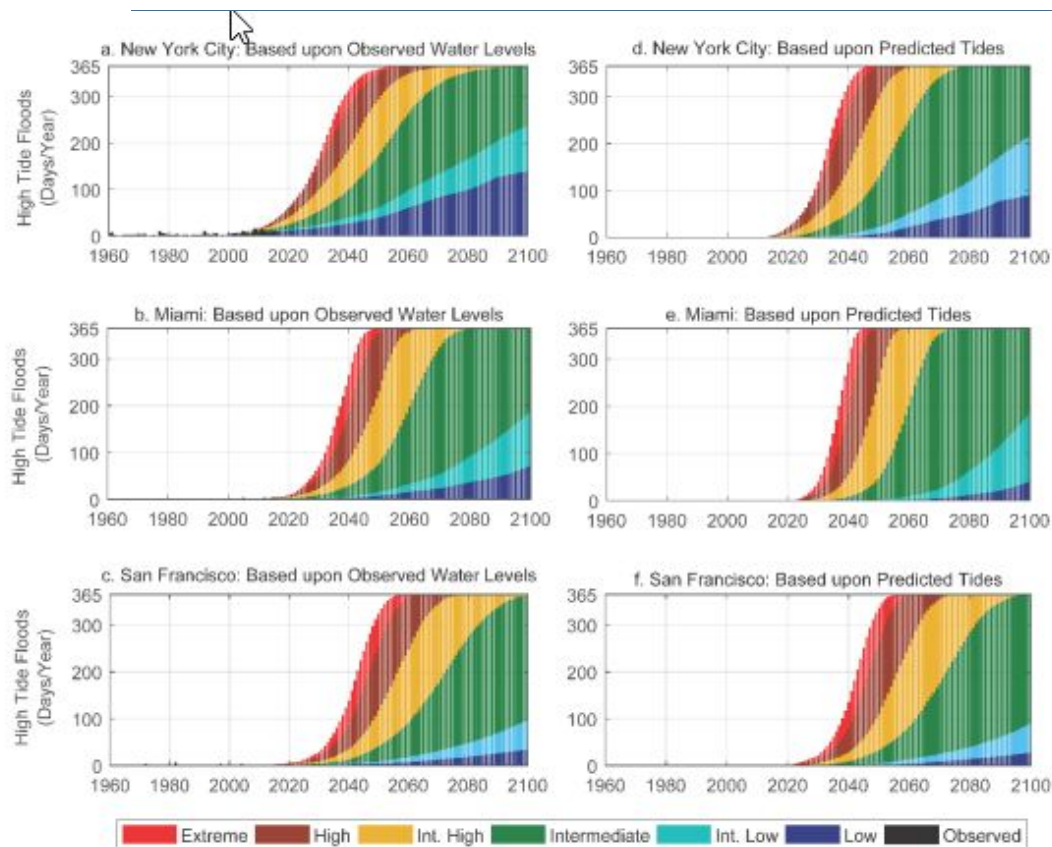


Figure 14. Projected annual frequencies of high tide flooding in response to scenarios of global sea level rise (Sweet et al., 2017) estimated at NOAA tide gauges in a) New York City (The Battery), b) Miami (Virginia Key), Florida and c) San Francisco, California considering observed patterns (combined tidal and nontidal water level components) and d), e) and f) at the same locations but assuming predicted tide forcing only. Derived high tide flood levels are 0.56 m, 0.53 m and 0.57 m, respectively.

Figure 14. Projected annual frequencies of high tide flooding in response to scenarios of global sea level rise (Sweet et al., 2017) estimated at NOAA tide gauges in a) New York City (The Battery), b) Miami (Virginia Key), Florida and c) San Francisco, California considering observed patterns (combined tidal and nontidal water level components) and d), e) and f) at the same locations but assuming predicted tide forcing only. Derived high tide flood levels are 0.56 m, 0.53 m and 0.57 m, respectively



Patterns and Projections cont.

- An Interagency approach
 - NOAA, NASA, Academia, Other Fed/State Agencies, etc.
- Improved gridded products
 - Higher resolution (out years)
 - More outreach related to these products



Where are we going - Sea Level Scenarios

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

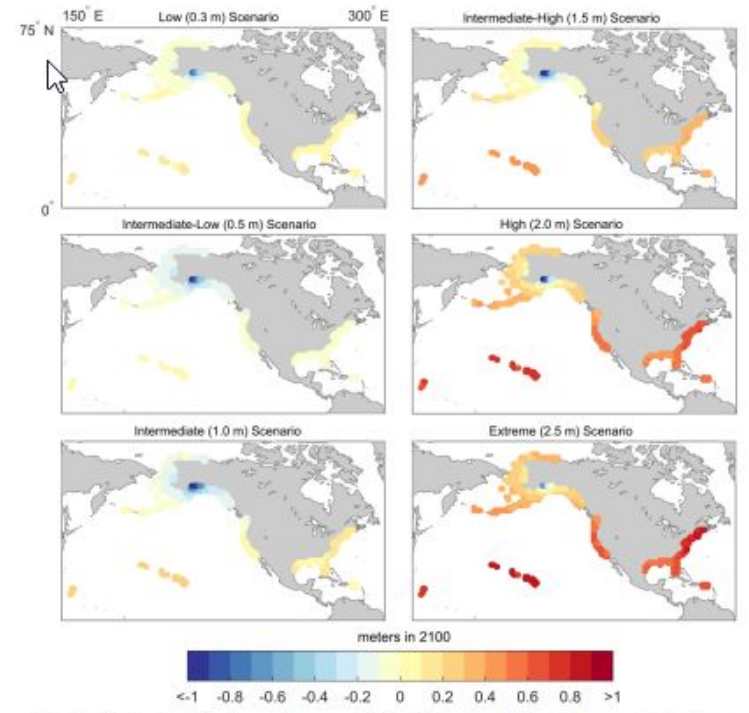


Figure 9. Climate-related RSL change at 1-degree resolution for 2100 (in meters) relative to the corresponding (median-value) GMSL rise amount for that scenario. To determine the total climate-related RSL change, add the GMSL scenario amount to the value shown.





So what can you do in your local community?

-
- The future of sea level rise “observations” is a combination of models and satellite altimetry. Thirty years of robust observation just doesn’t make sense for most locations. A couple of years could provide localized parameters that compare with the gridded scenarios.
 - In situ observations in local communities can certainly provide important information around coastal hazards, like tsunamis, extreme water levels, and can be used to generate tidal datums. Those datums can be integrated into models.
 - Similarly, one of the most impactful types of observation is GNSS near the coast. Vertical land motion is a dynamic that could very much use some additional observation.



Questions?