Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE

Rising Tides and Changing Waters

Understanding and Updating the National Tidal Datum Epoch

Center for Operational Oceanographic Products and Services

Datum Updates

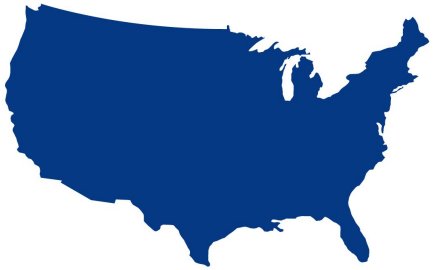
National Tidal Datum Epoch

International Great Lakes Datum

*Binational effort with Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

National Tidal Datum Epoch

What Does it Mean?



National

United States and its territories

Tidal Datum

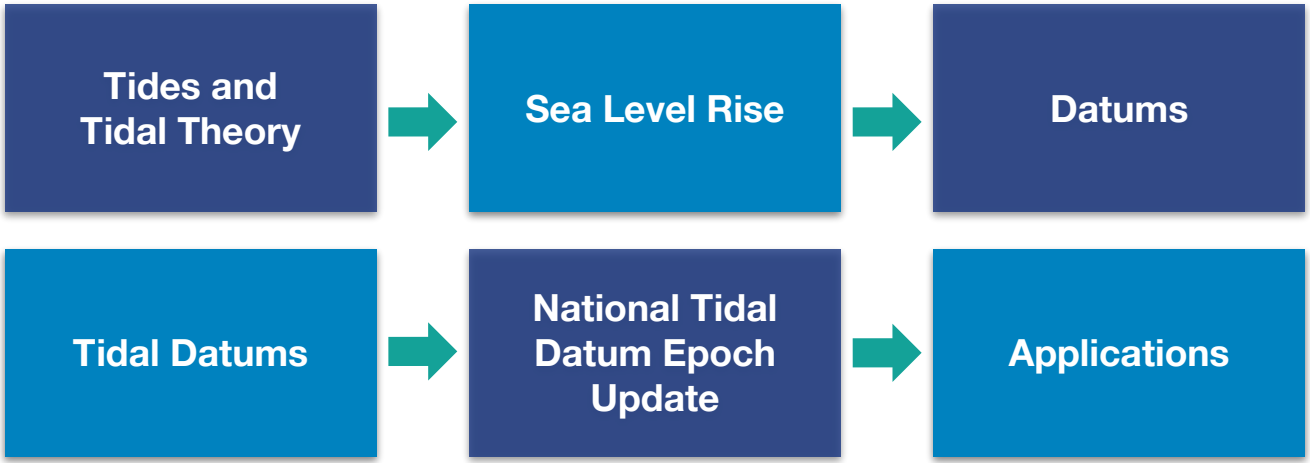
Average tide level over an epoch

Epoch

A period of time (19 years)

Understanding and Updating the National Tidal Datum Epoch

Topics Covered



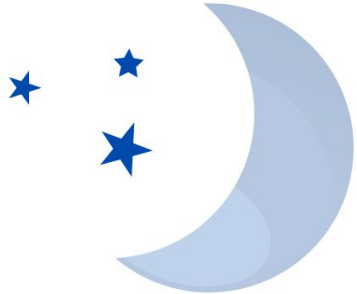
Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE

Tides and Tidal Theory

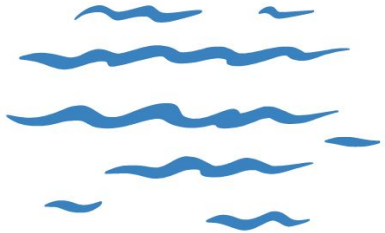
Source: NOAA Images

Tides and Tidal Theory

Forces that Generate Tides



Astronomical Effects



Hydrodynamics

Meteorological Effects

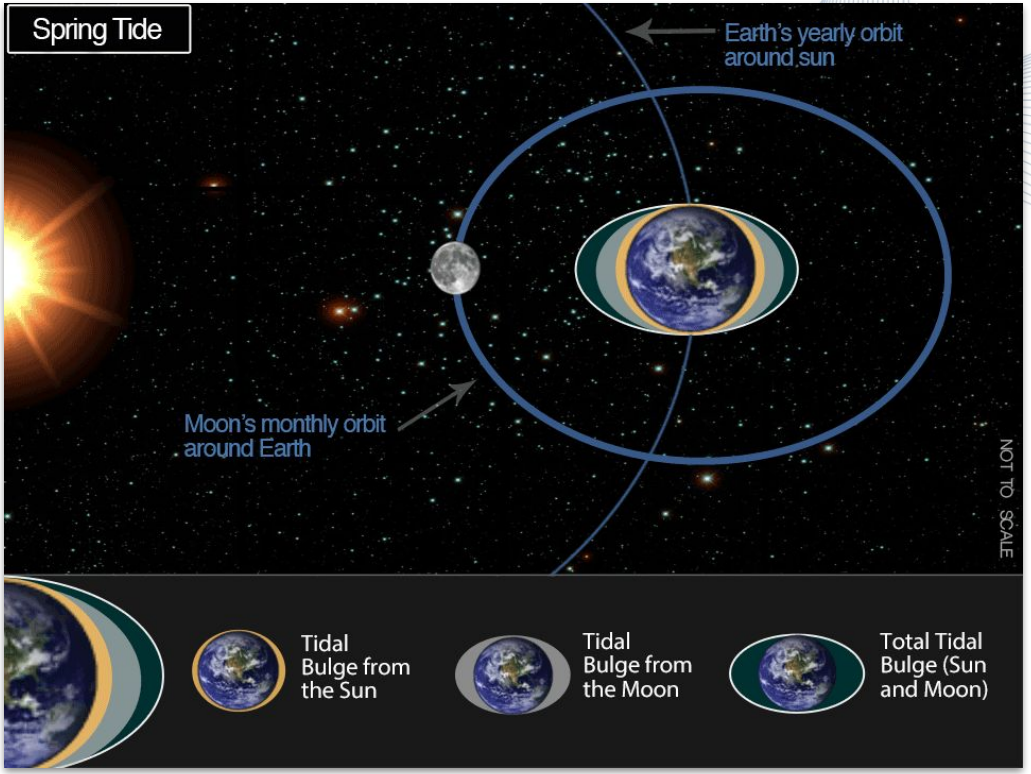
Tides and Tidal Theory

Astronomical Effects

The alignment of earth, moon, and sun causes tides

Changing alignment causes change in gravitational pull

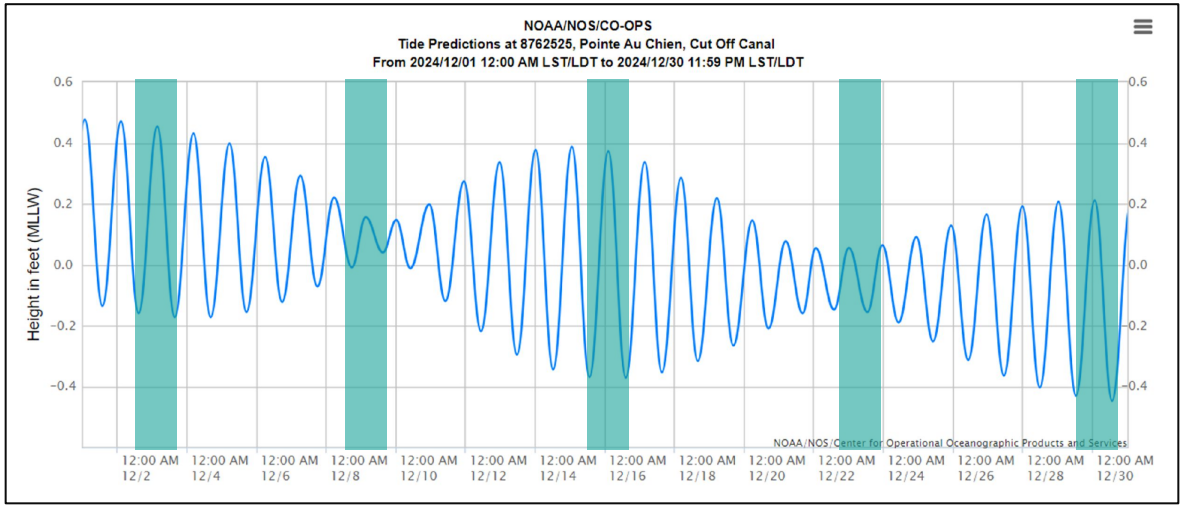
These movements are regular and predictable



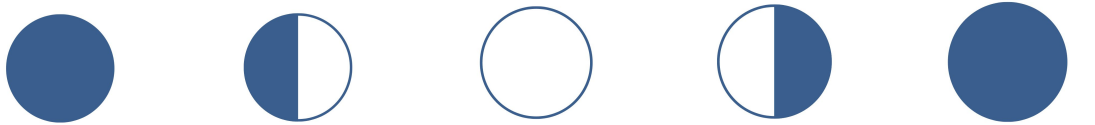
Source: NOS Ocean Facts

Tides and Tidal Theory

Astronomical Effects



Moon Phases



Spring Tide | **Neap Tide** | **Spring Tide** | **Neap Tide** | **Spring Tide**

Tides and Tidal Theory

Hydrodynamics

Physics of water movement

How water interacts with coastlines and the seafloor

Other factors include: water depth and coastline configuration

Source: NOAA Images

Tides and Tidal Theory

Meteorological Effects

Weather patterns impact tides

Some places are more affected by weather than others

Any weather can impact tides, not just storms

Source: NOAA Images

Tides and Tidal Theory

Meteorological Effects

STATION	TIDAL	NON-TIDAL
Boston, MA	98.2%	1.8%
Baltimore, MD	44.8%	55.2%
Charleston, SC	91.2%	8.8%
Galveston, TX	39.5%	60.5%
San Francisco, CA	98.6%	1.4%
Seattle, WA	98.8%	1.2%

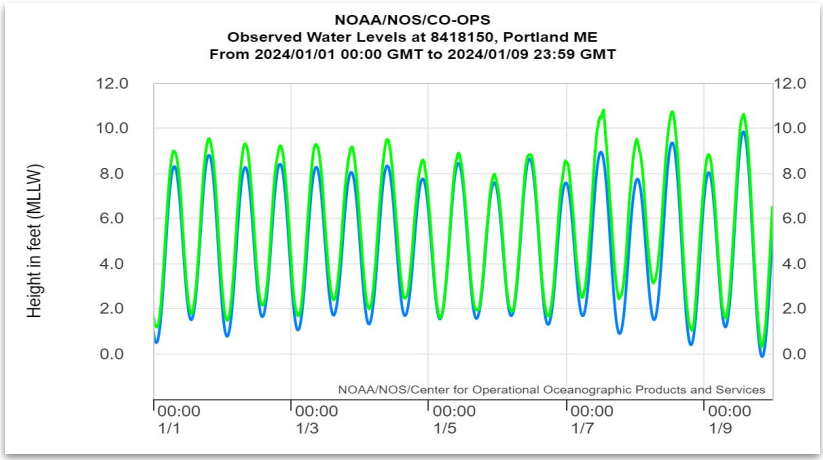
Easy to predict

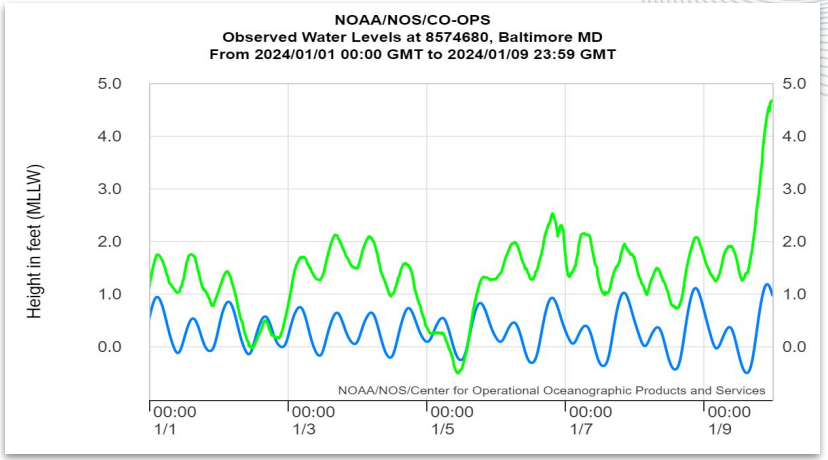
Difficult to predict

Comparison of tidal vs. non-tidal effects, reduction of variance statistics from one-year harmonic analysis.

Tides and Tidal Theory

Meteorological Effects





Portland, Maine

Heavily influenced by astronomical forces

Tides are easy to predict

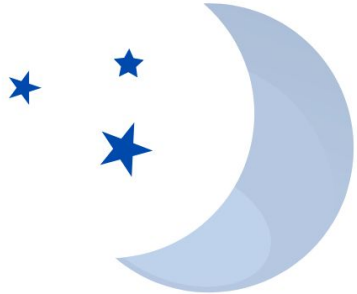
Baltimore, Maryland

Heavily influenced by meteorological forces

Tides are hard to predict

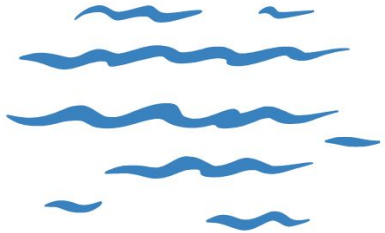
Tides and Tidal Theory

Forces that Generate Tides



Astronomical Effects

Alignment of Earth, Moon, and Sun



Hydrodynamics

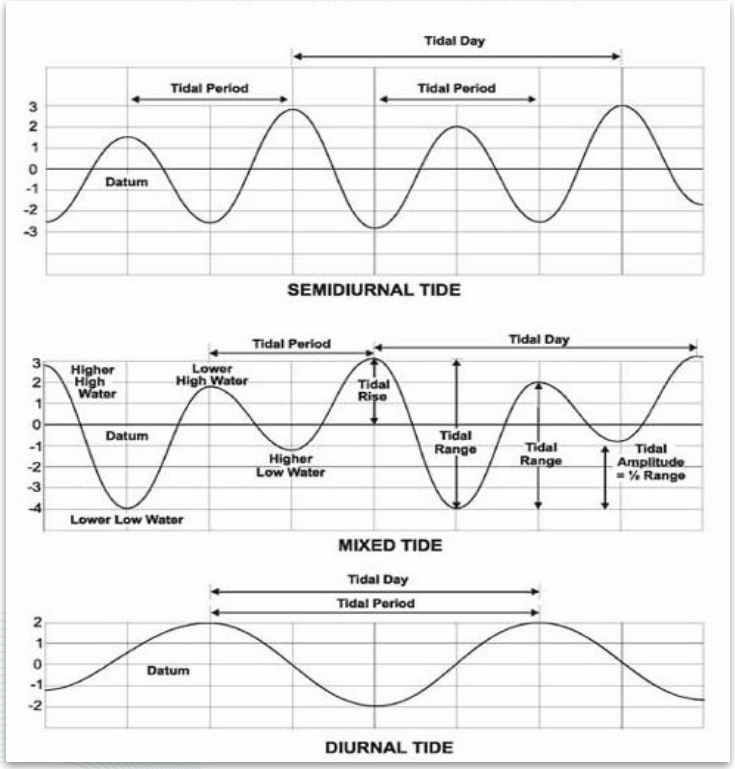
Bathymetry, water depth, coastline configuration

Meteorological Effects

Weather patterns, not just storms

Tides and Tidal Theory

Types of Tides



Semidiurnal

- Two high tides and two low tides per day
- Heights of tides are about the same
- East Coast

Mixed

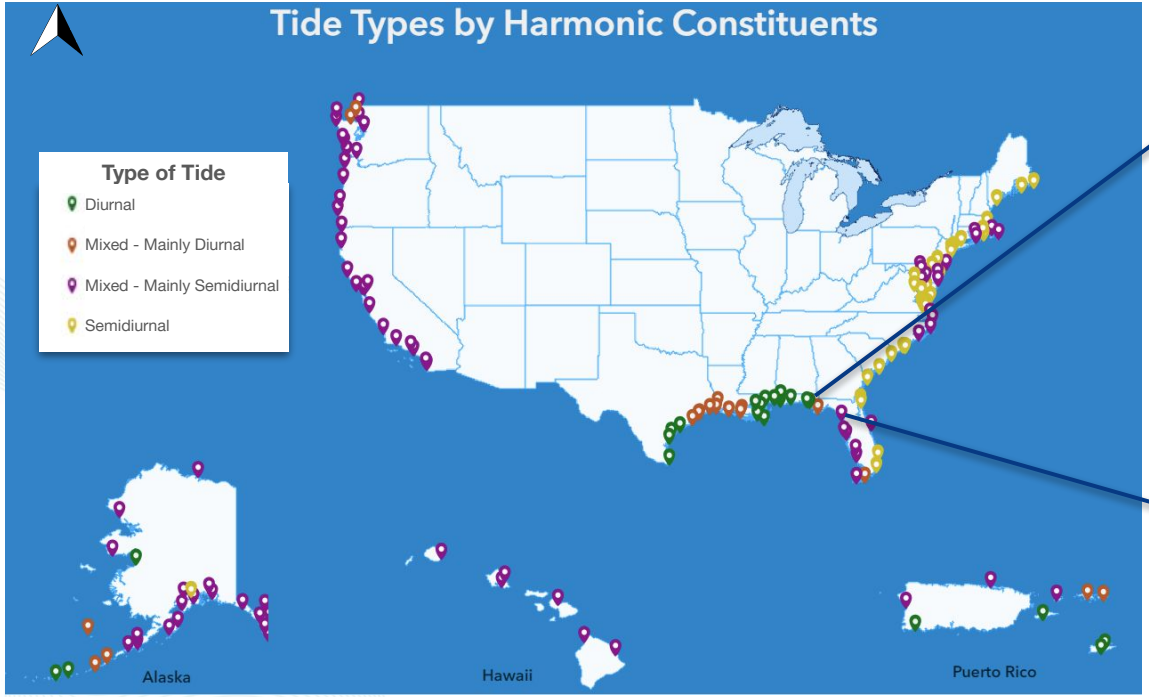
- Two high tides and two low tides per day
- Height of high and low tides varies significantly
- West Coast

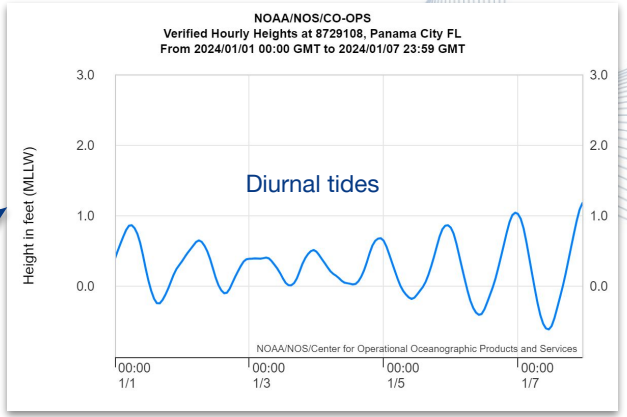
Diurnal

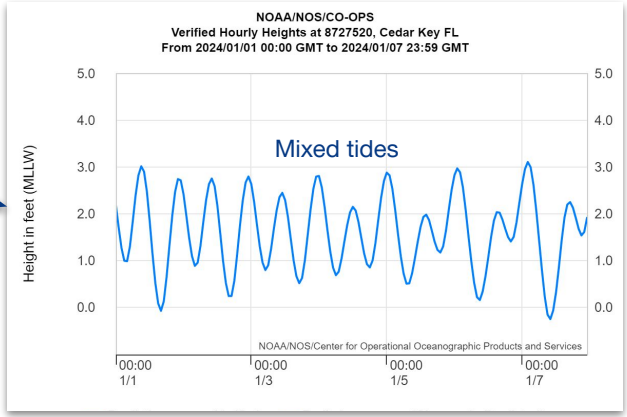
- One high tide and one low tide per day
- Gulf Coast

Tides and Tidal Theory

Types of Tides - Florida

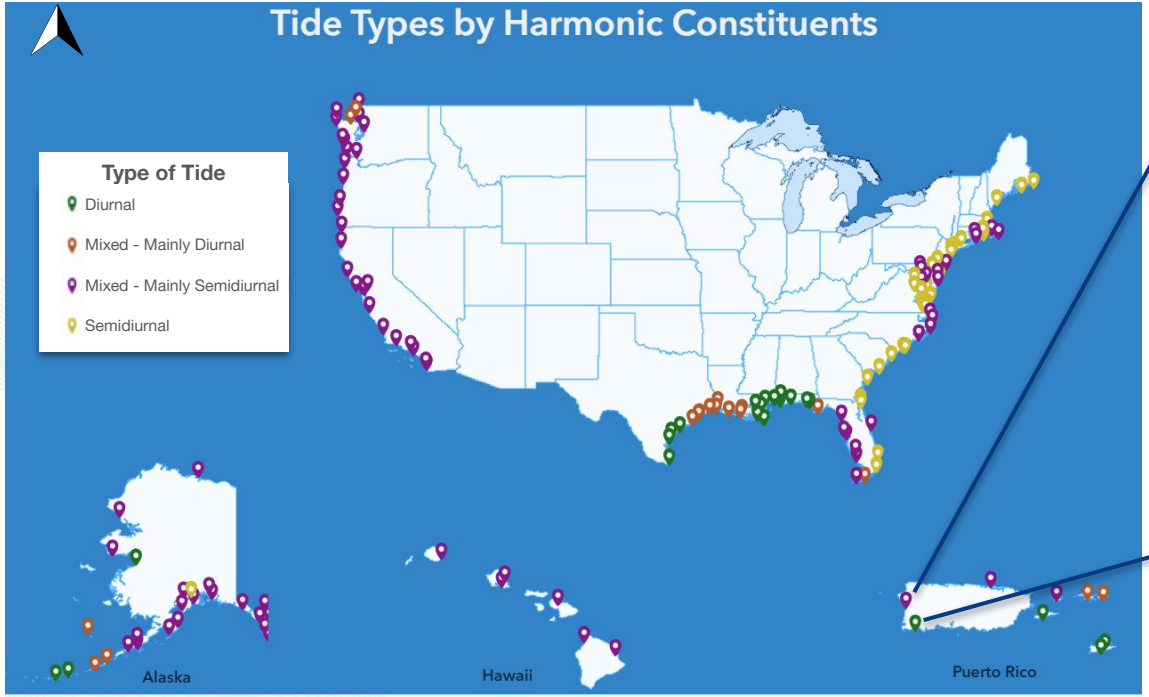


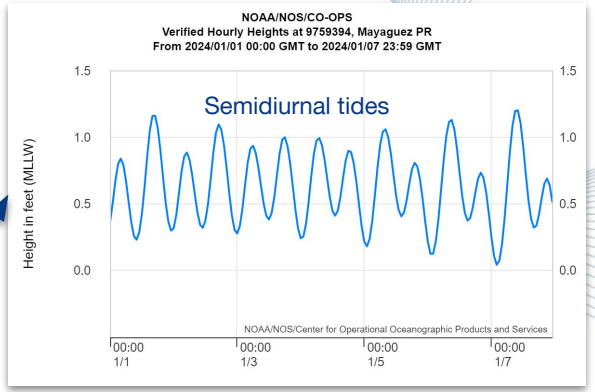




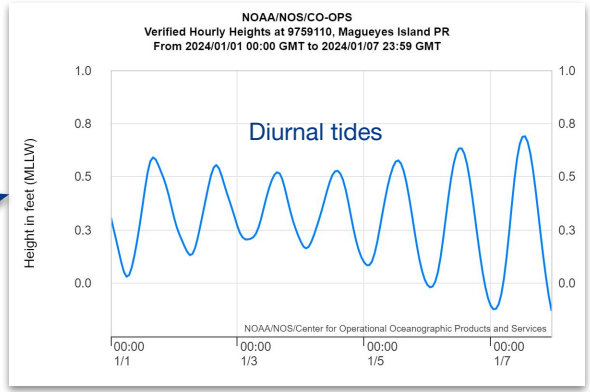
Tides and Tidal Theory

Types of Tides - Puerto Rico





Distance between these stations:
16.5 miles



Tides and Tidal Theory

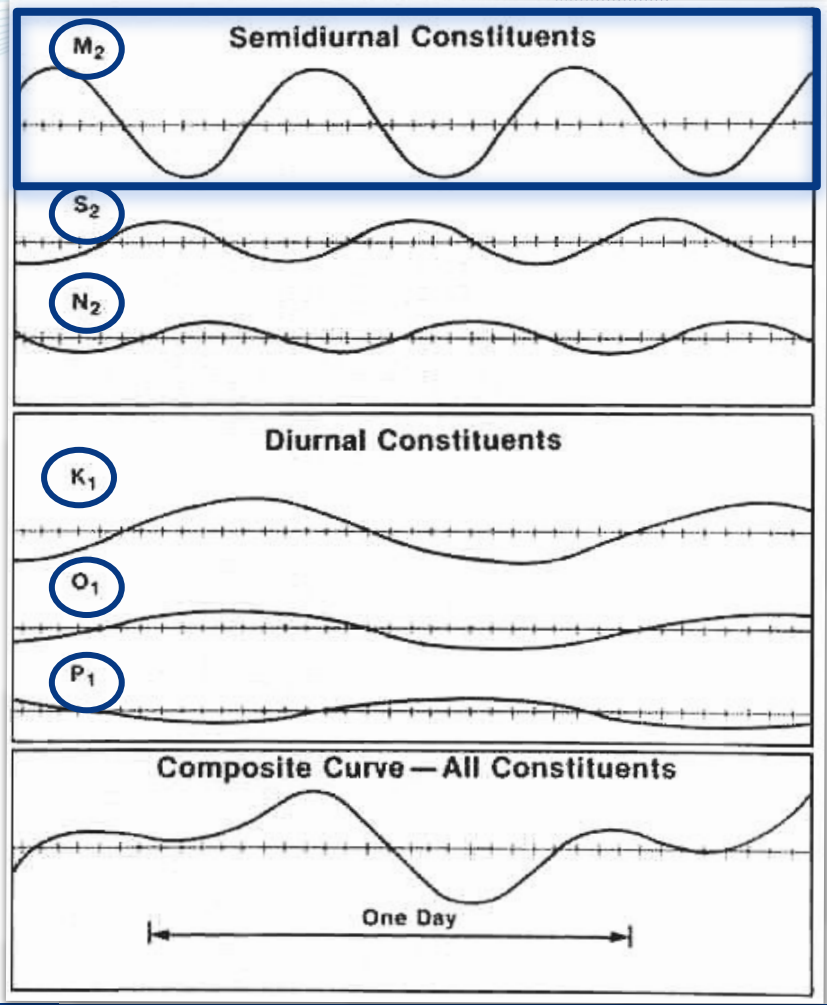
Harmonic Constituents

Each motion of the earth, sun, and moon has an impact on tides.

Each motion is known as a harmonic constituent.

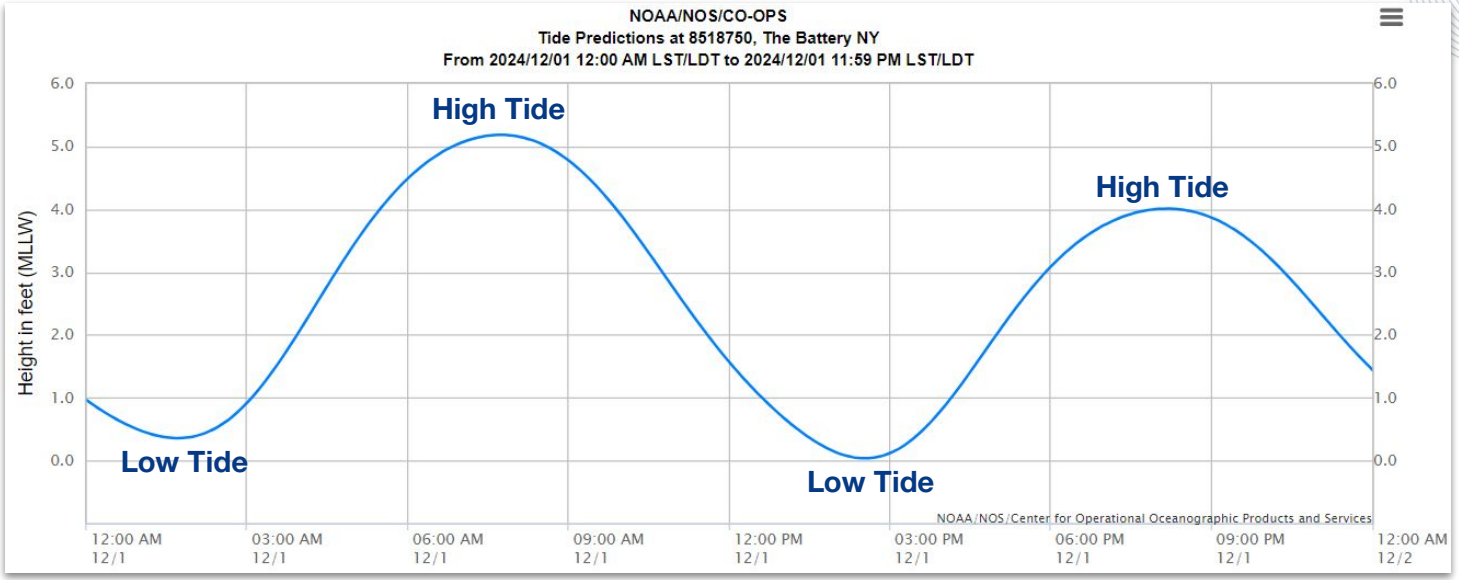
There are hundreds of harmonic constituents, 37 are used to make predictions.

The moon has the strongest impact.



Tides and Tidal Theory

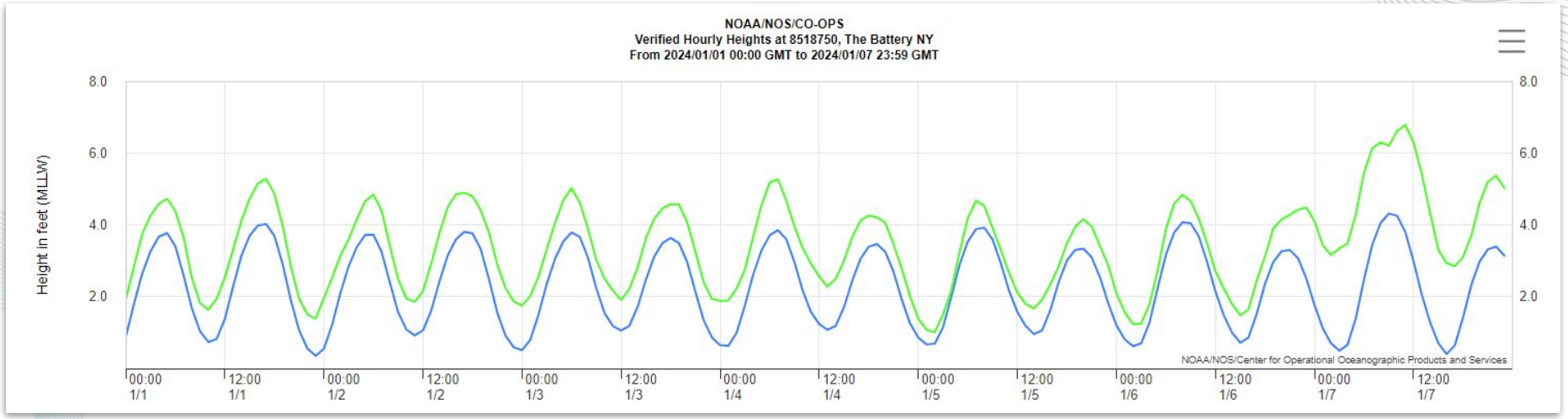
Tide Predictions and Observations



Hydrograph representing one day of tides at The Battery, NY.

Tides and Tidal Theory

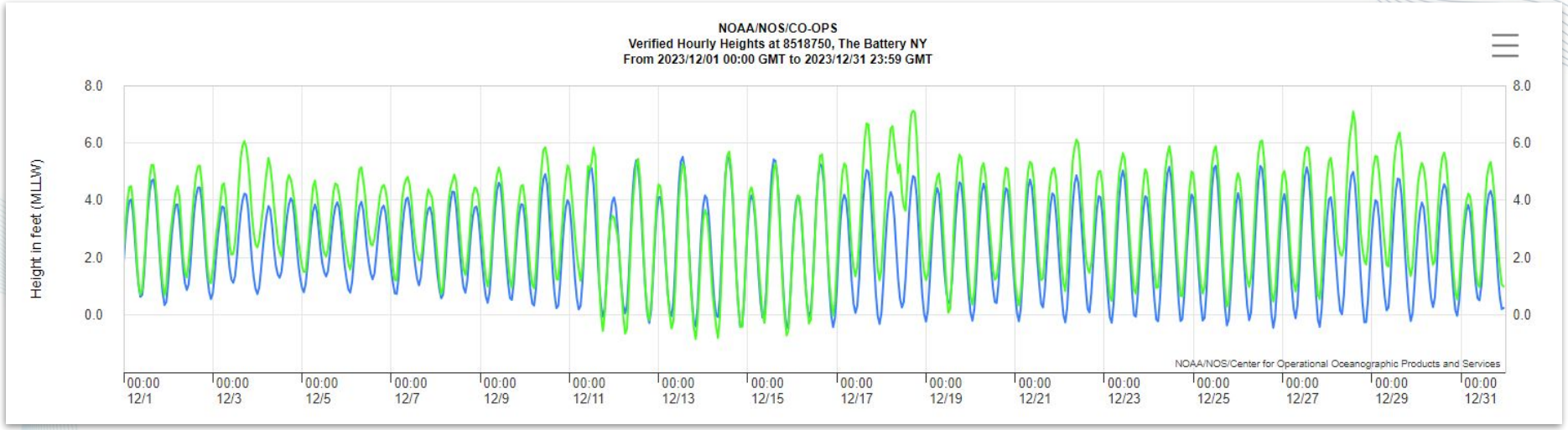
Tide Predictions and Observations



Hydrograph representing one week of tides at The Battery, NY.

Tides and Tidal Theory

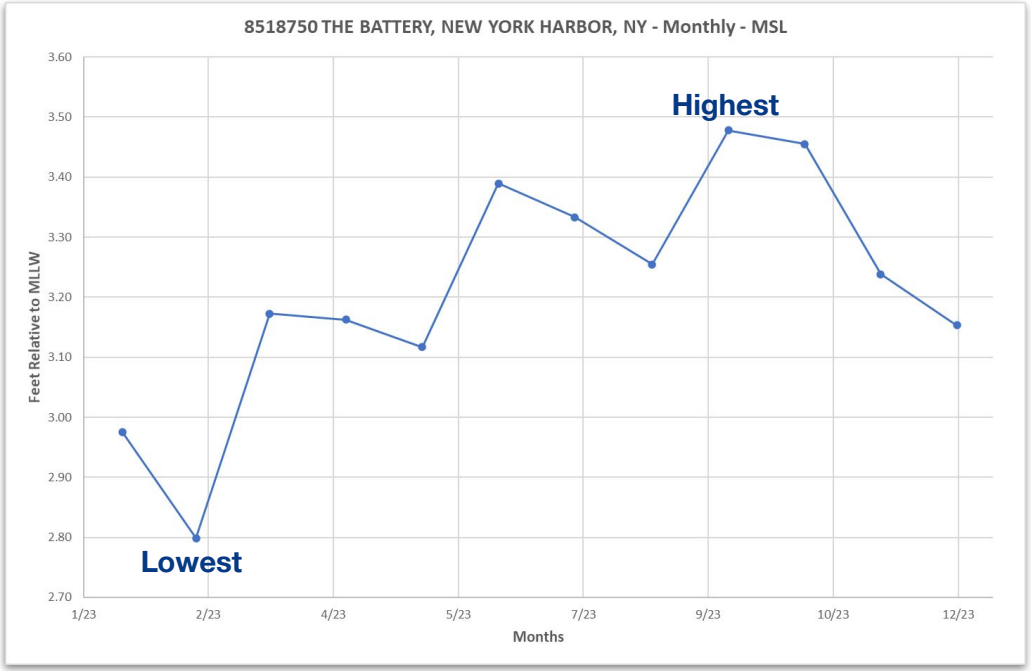
Tide Predictions and Observations



Hydrograph representing one month of tides at The Battery, NY.

Tides and Tidal Theory

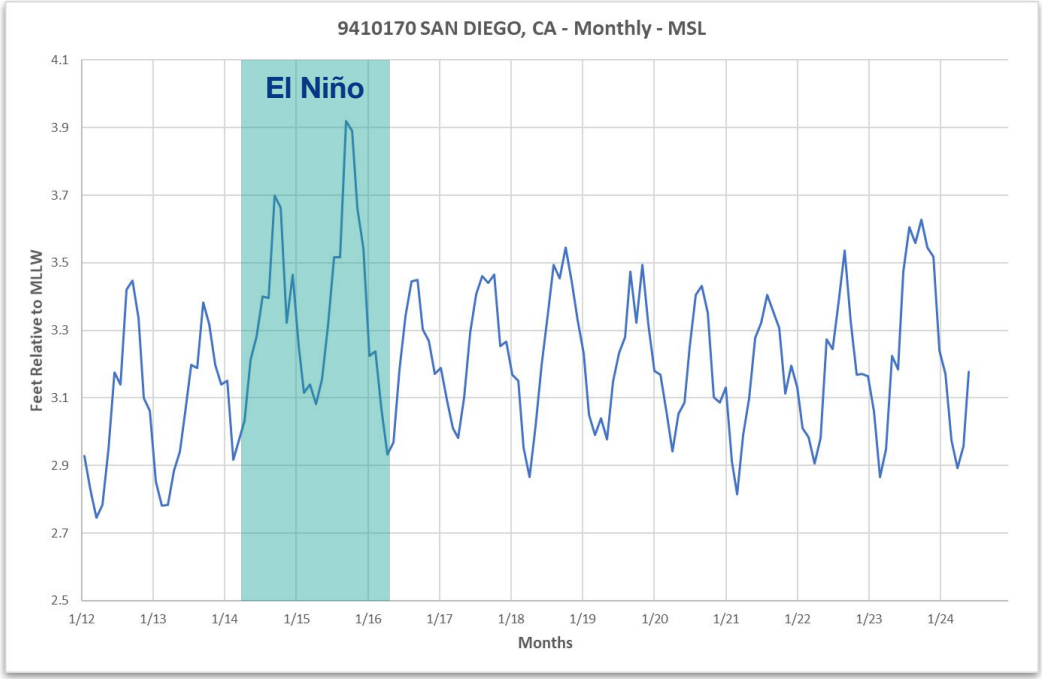
Tide Predictions and Observations



Monthly mean sea level at The Battery, NY over a one year period.

Tides and Tidal Theory

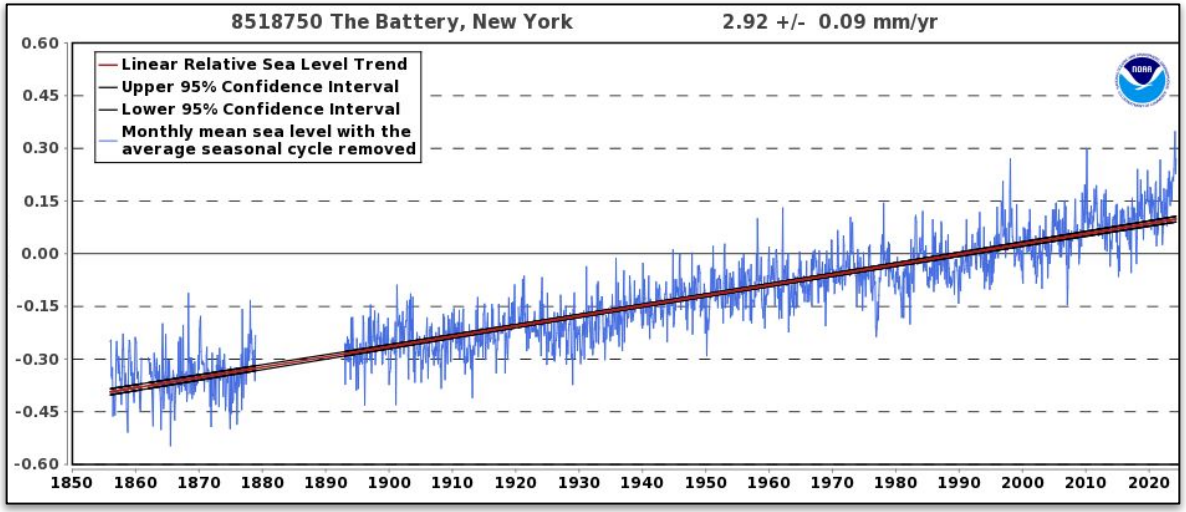
Tide Predictions and Observations



Monthly mean sea level in San Diego, CA over multiple years of observation.

Tides and Tidal Theory

Tide Predictions and Observations



The relative sea level trend is 2.92 millimeters/year with a 95% confidence interval of +/- 0.09 mm/yr based on monthly mean sea level data from 1856 to 2023 which is equivalent to a change of 0.96 feet in 100 years.

Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE

Sea Level Rise

Sea Level Rise

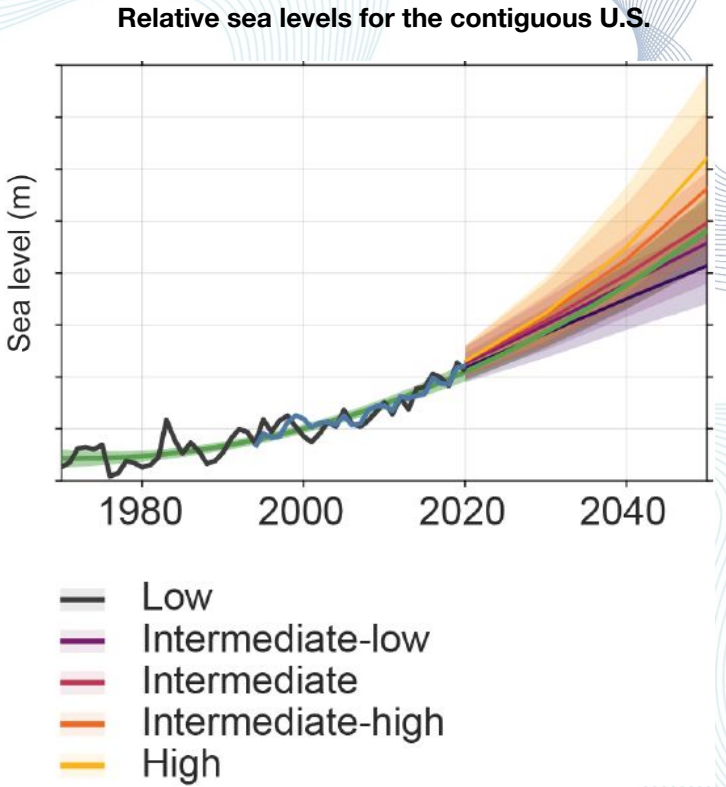
Observed and Future Trends

Sea levels have risen in the past 50 years

Sea levels will continue to rise due to thermal expansion, melting ice, and ice disintegration

There are uncertainties about *how much* and *how fast* sea levels will rise

The rate and amount of sea level rise depends on future carbon emissions



Relative sea levels for the contiguous United States from 2020 to 2050 relative to a baseline of 2000. Source: 2022 multi-agency Sea Level Rise Technical Report

Sea Level Rise

Relative Sea Level

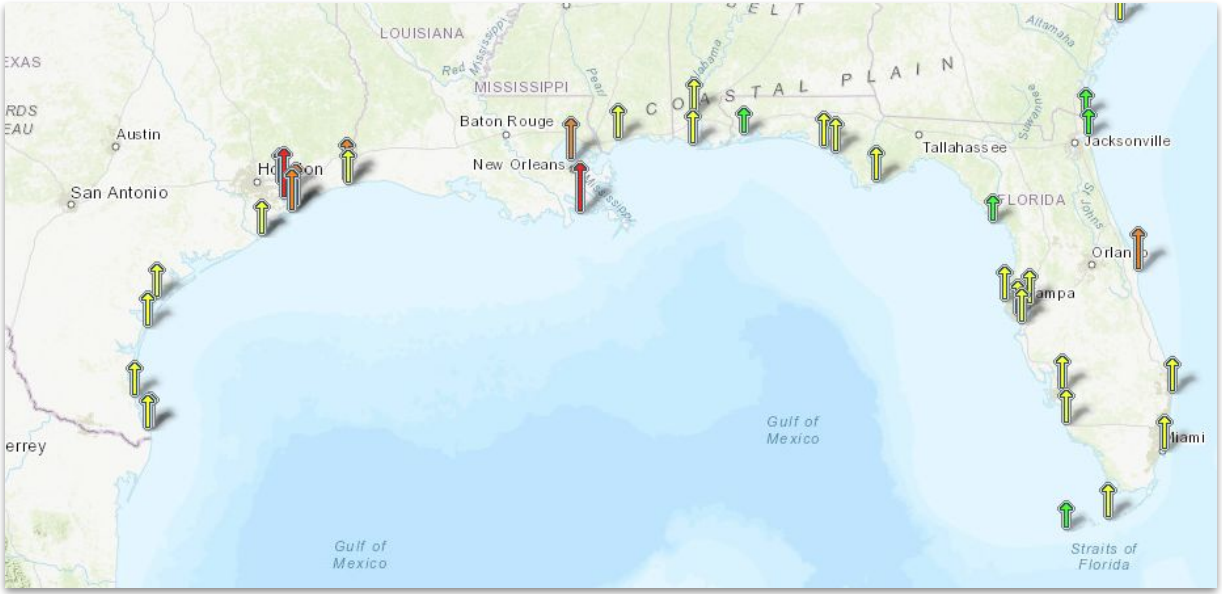
Relative Sea Level Trends

mm/yr (feet/century)

Above 9 (Above 3)	6 to 9 (2 to 3)	3 to 6 (1 to 2)	>0 to 3 (0 to 1)	-3 to 0 (-1 to 0)	-6 to -3 (-2 to -1)	-9 to -6 (-3 to -2)	Below -9 (Below -3)

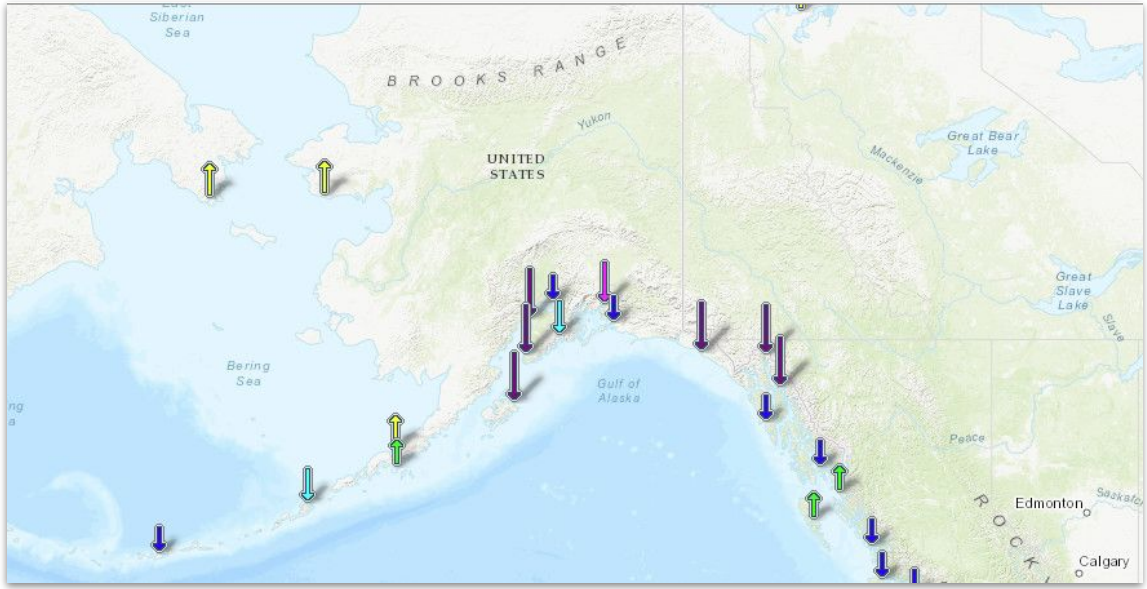
Sea Level Rise

Relative Sea Level in the Gulf of Mexico



Sea Level Rise

Relative Sea Level in Alaska



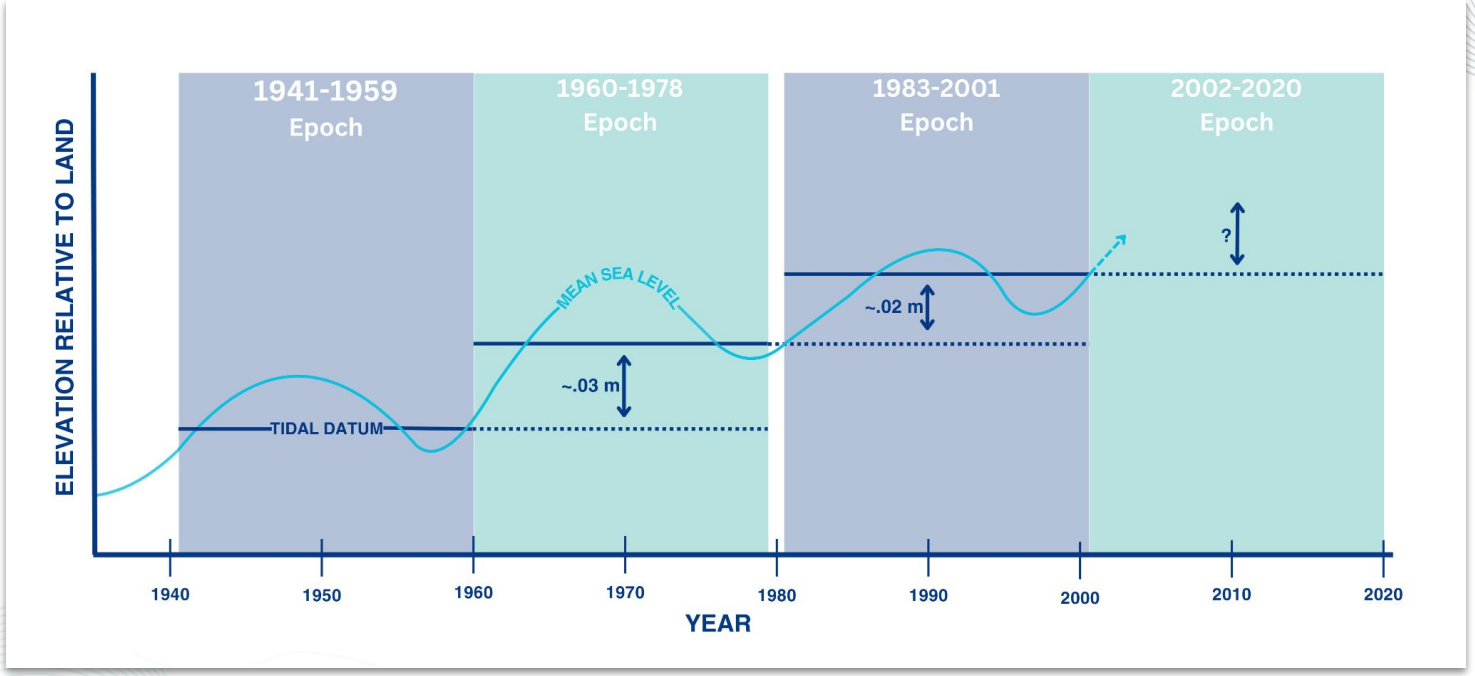
Relative Sea Level Trends

mm/yr (feet/century)

Above 9 (Above 3)	6 to 9 (2 to 3)	3 to 6 (1 to 2)	>0 to 3 (0 to 1)	-3 to 0 (-1 to 0)	-6 to -3 (-2 to -1)	-9 to -6 (-3 to -2)	Below -9 (Below -3)

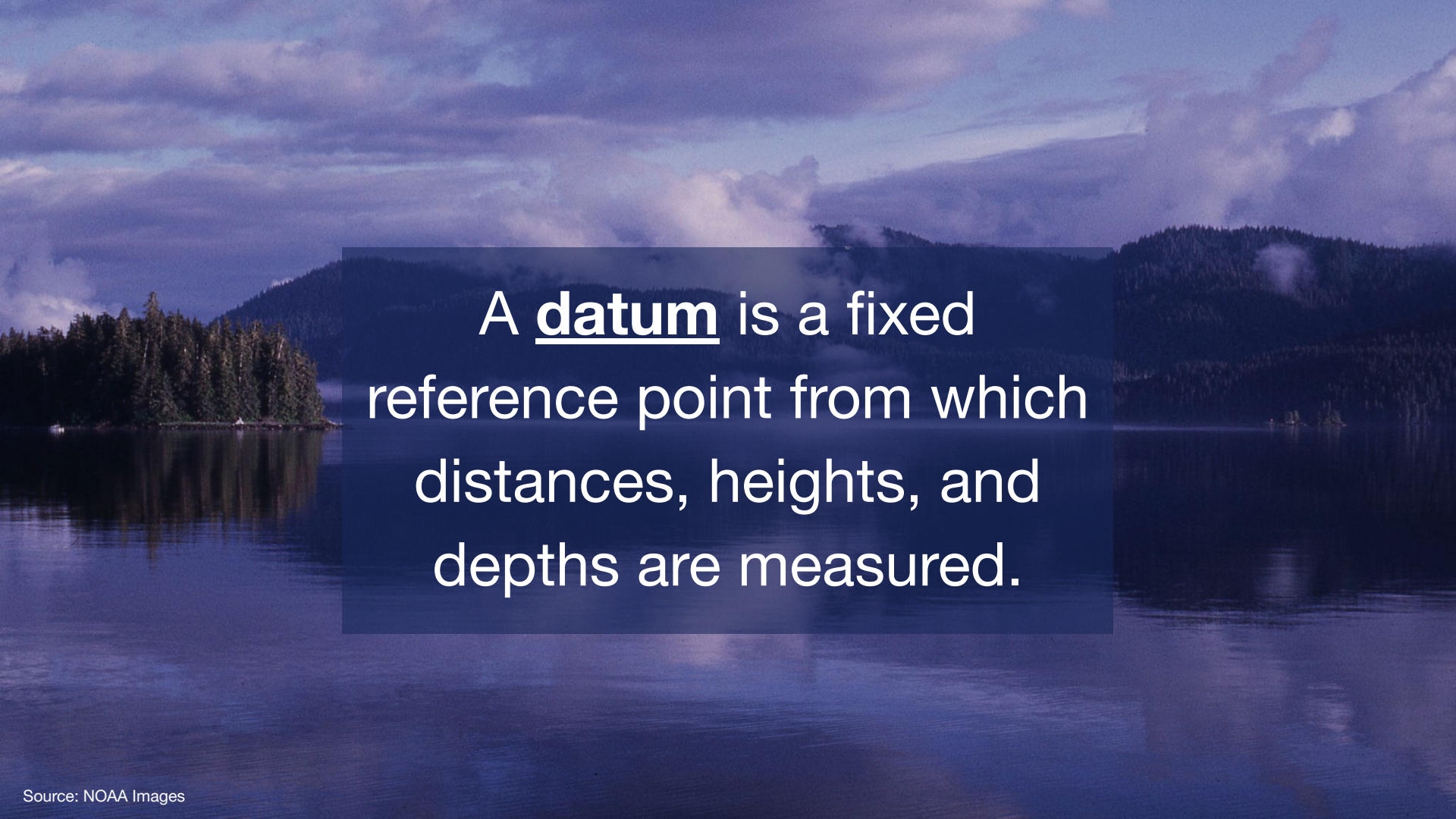
Sea Level Rise

Future Epochs



Graphic depicting National Tidal Datum Epochs since 1940 and Mean Sea Level increase between epochs.


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE
Datums



A **datum** is a fixed reference point from which distances, heights, and depths are measured.

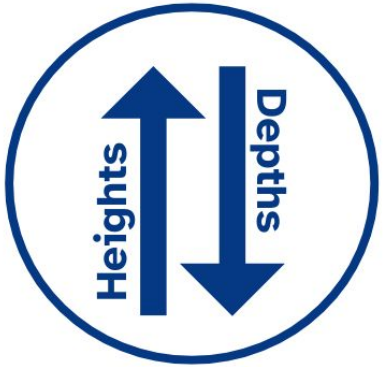
Source: NOAA Images

Datums

Horizontal vs Vertical

Horizontal Datum

Reference point from which distances are measured



Vertical Datum

Reference point from which heights and depths are measured

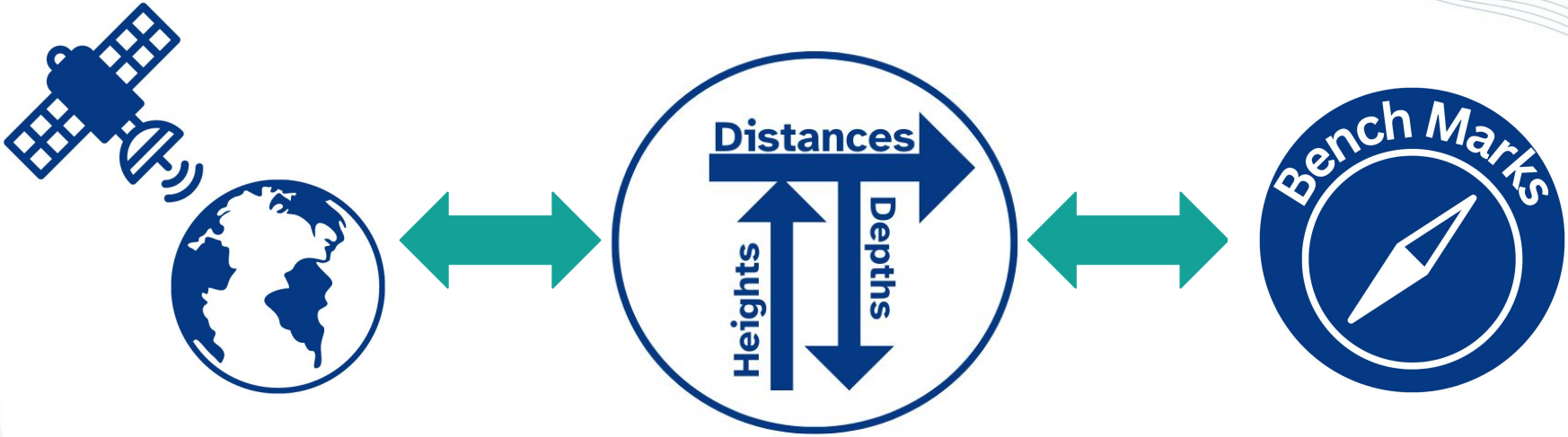
Datums
Bench Marks

- Physical markers used as reference points
- North American Vertical Datum (NAVD 88)
  - Official vertical datum of US
  - Uses network of bench marks

Source: NOAA Images

Datums

Technological Advancements

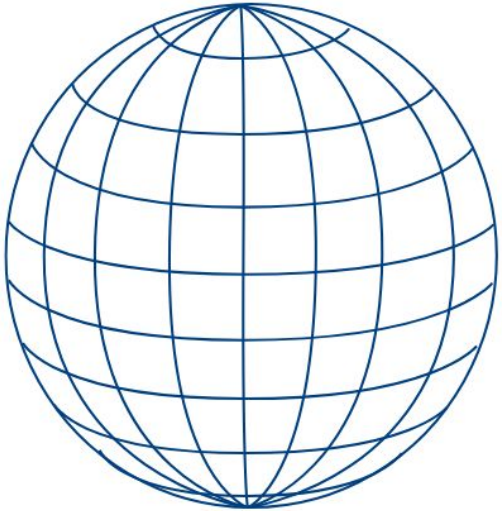


Datums

Ellipsoids and Geoids

Datums

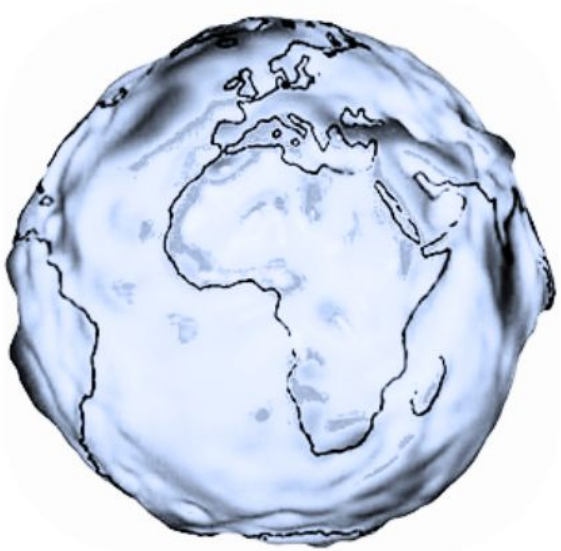
Ellipsoid



- Perfect mathematical model of earth
- NAVD83 based on ellipsoid
- Used for GPS, latitude and longitude, movement of tectonic plates
- Does not account for gravitational forces

Datums

Geoid



- Represents earth's global sea level
- Accounts for gravitational differences across the planet
- Best to model water flow

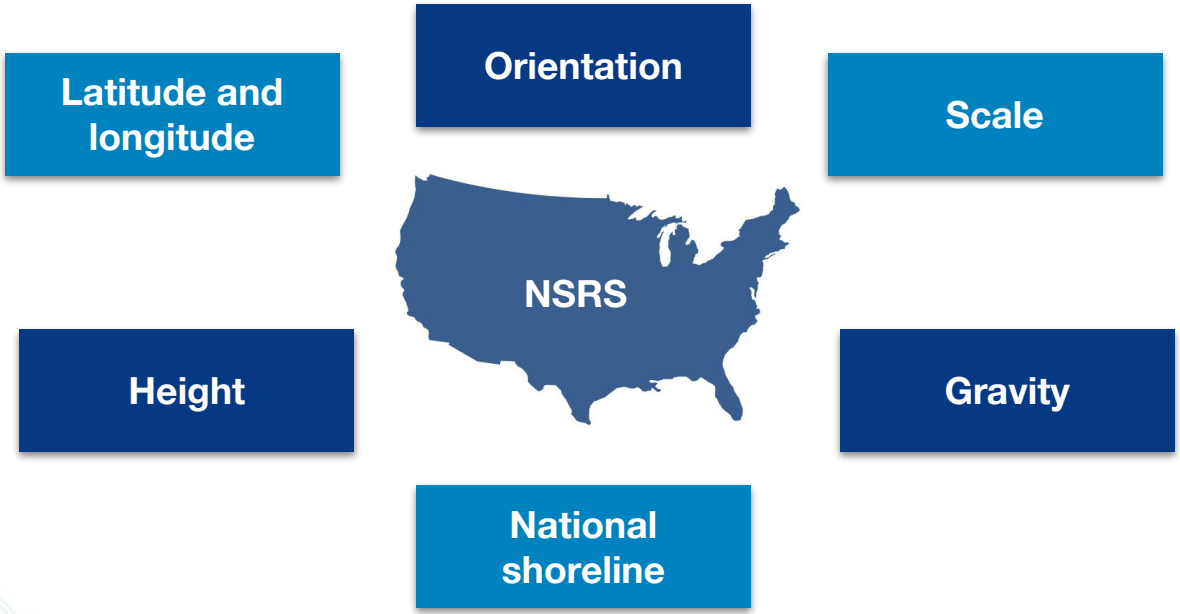
Datums

Geopotential Datums

Ellipsoid + **Geoid** → **Geopotential**

Datums

National Spatial Reference System (NSRS)



Datums

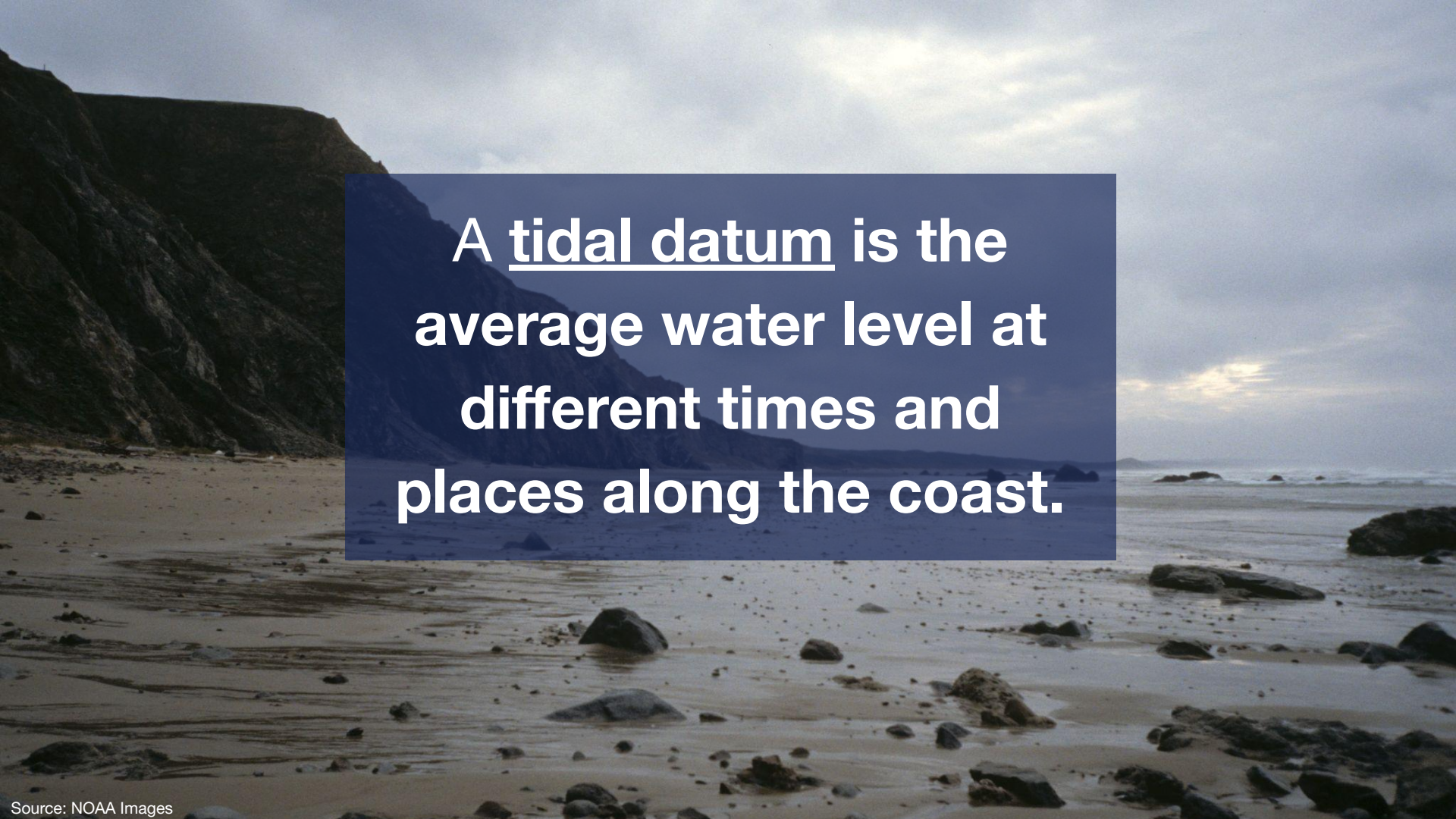
National Spatial Reference System (NSRS)

North American Vertical Datum of 1988

Relies on bench marks
Outdated
Only one of many reference frames being replaced

North American-Pacific Geopotential Datum of 2022

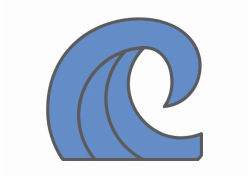
Will rely on satellite and global positioning data



Source: NOAA Images

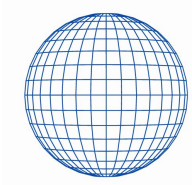
Datums

Uses



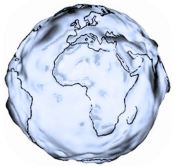
Tidal

Coastal engineering
Marine navigation
Flood risk management
Surveying and mapping



Ellipsoid

Coordinate systems
Latitude/longitude
Movement of tectonic plates



Geoid

Gravitational field monitoring
Vertical datum for mapping
Oceanography

Geopotential

Gravitational field monitoring
Satellite orbit monitoring
Navigation

Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE

Tidal Datums

Source: National Ocean Service

Tidal Datums

Commonly Used in the United States

Mean Lower Low Water

Mean High Water

Mean Higher High Water

Tidal Datums

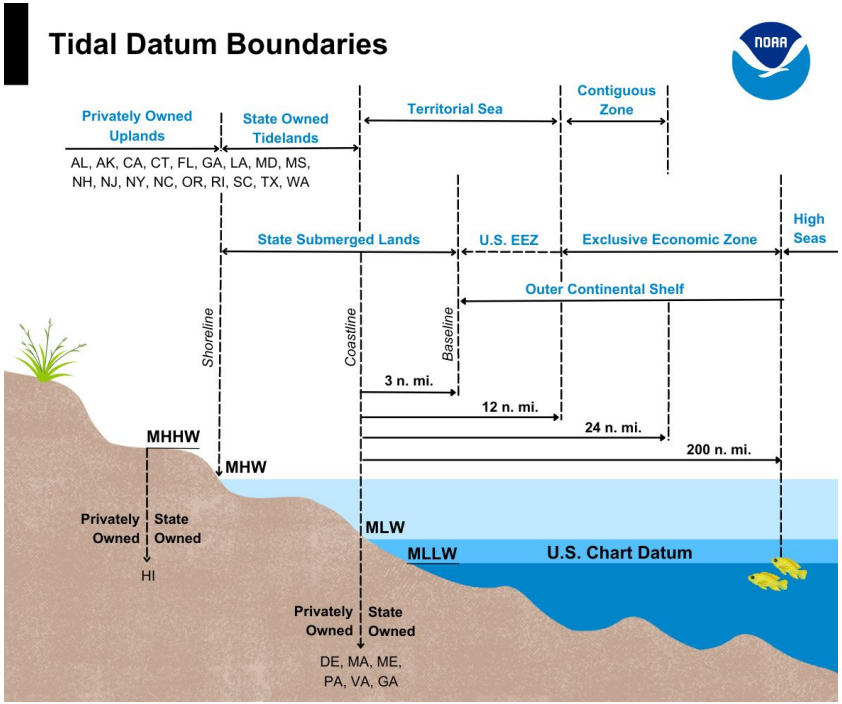
Mean Lower Low Water (MLLW)

- Average of the lowest low tides over 19 years
- Good reference for shallow water
- Used for navigational charts

Source: NOAA Images

Tidal Datums

Mean Lower Low Water (MLLW)

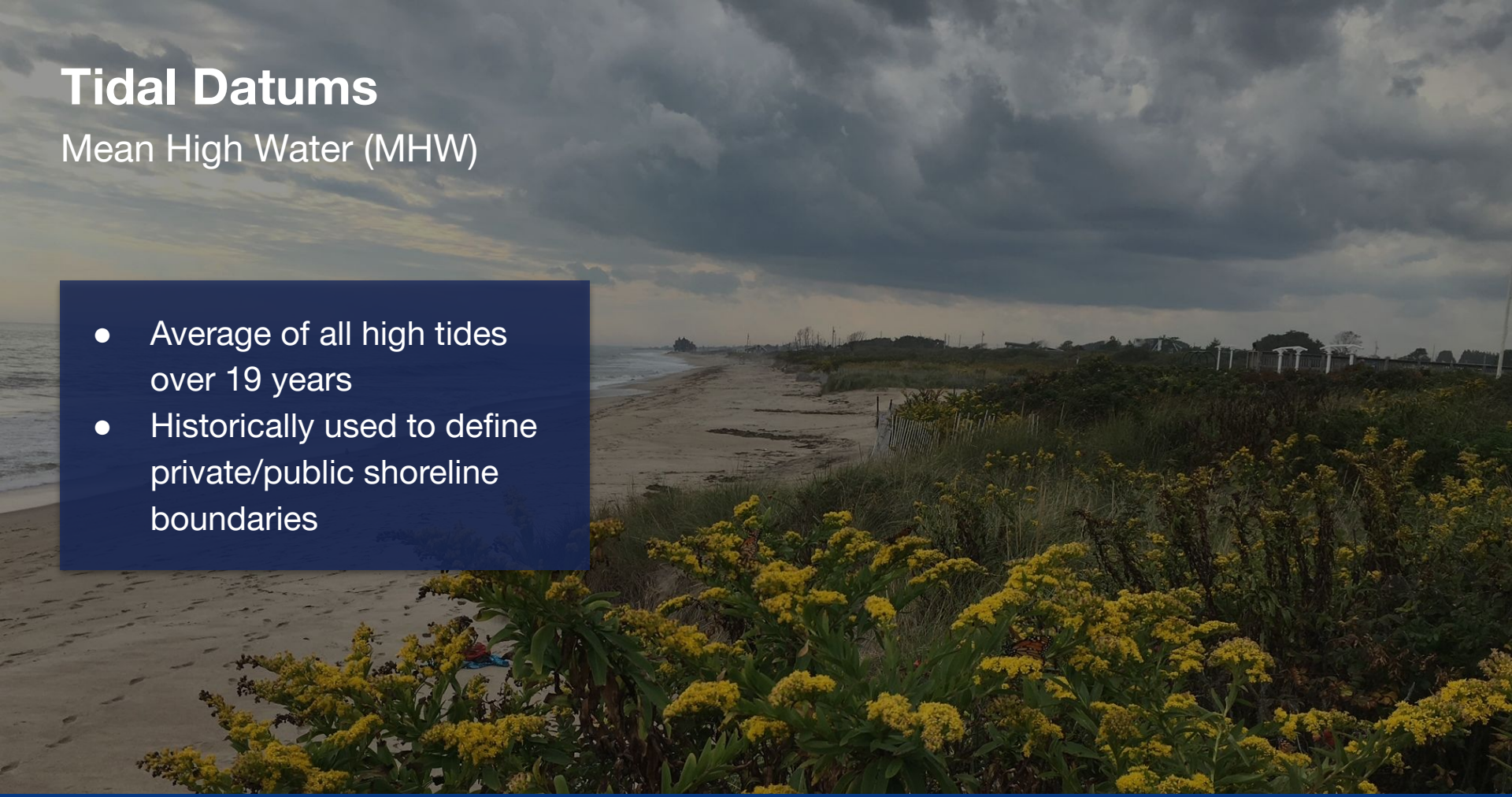


Graphic depicting how tidal datums are used to define legal marine boundaries.

Tidal Datums

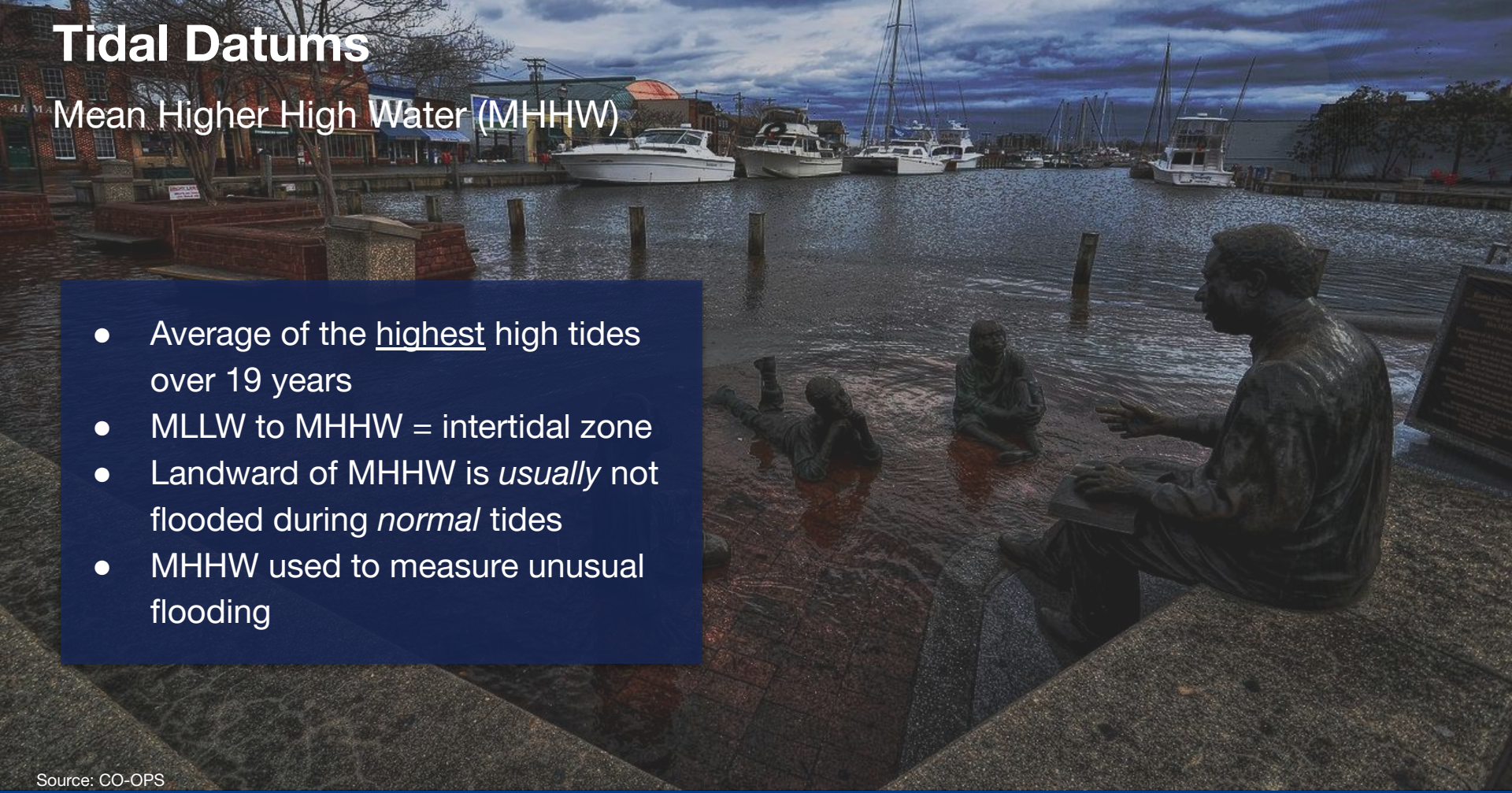
Mean High Water (MHW)

- Average of all high tides over 19 years
- Historically used to define private/public shoreline boundaries



Tidal Datums

Mean Higher High Water (MHHW)

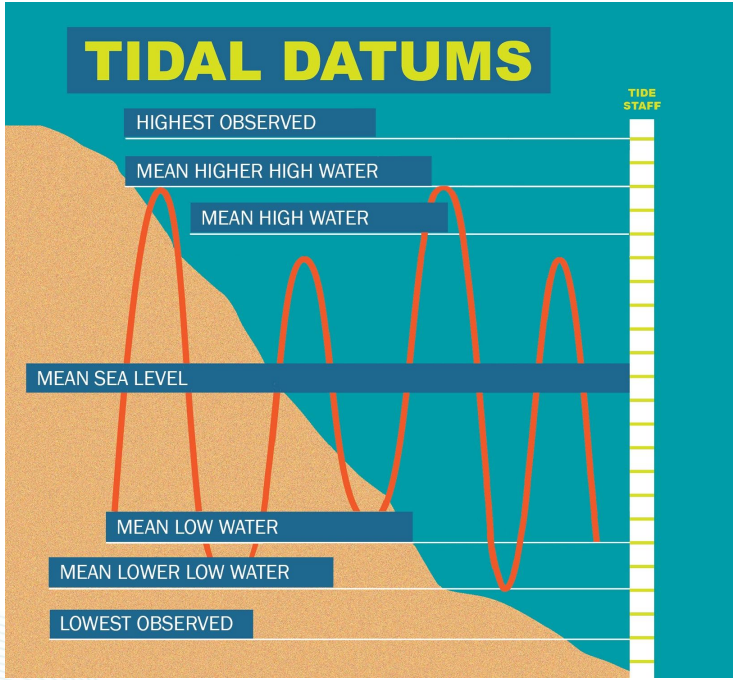


- Average of the highest high tides over 19 years
- MLLW to MHHW = intertidal zone
- Landward of MHHW is *usually* not flooded during *normal* tides
- MHHW used to measure unusual flooding

Source: CO-OPS

Tidal Datums

Other Tidal Datums

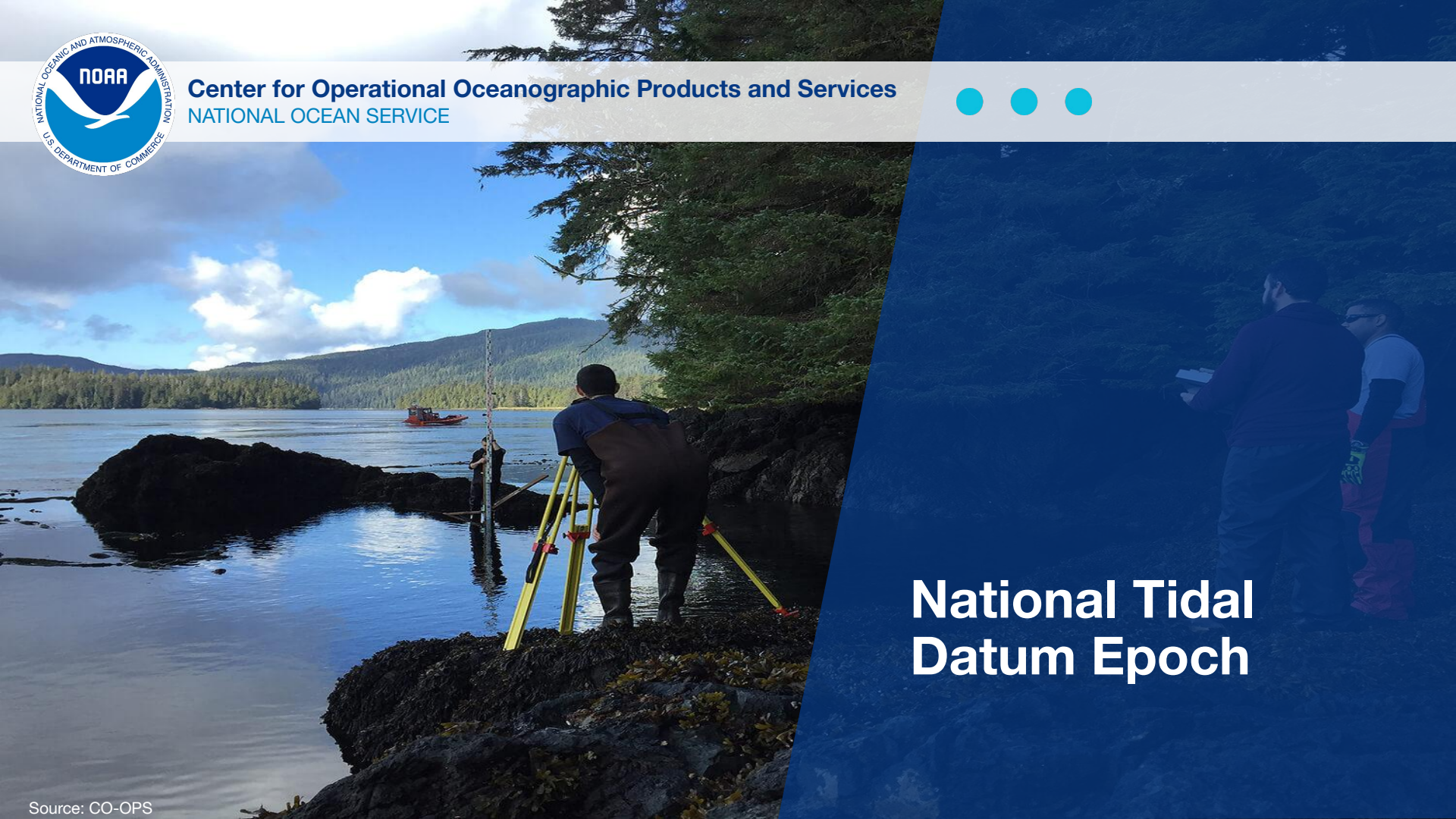


Highest Observed Tide

Mean Sea Level

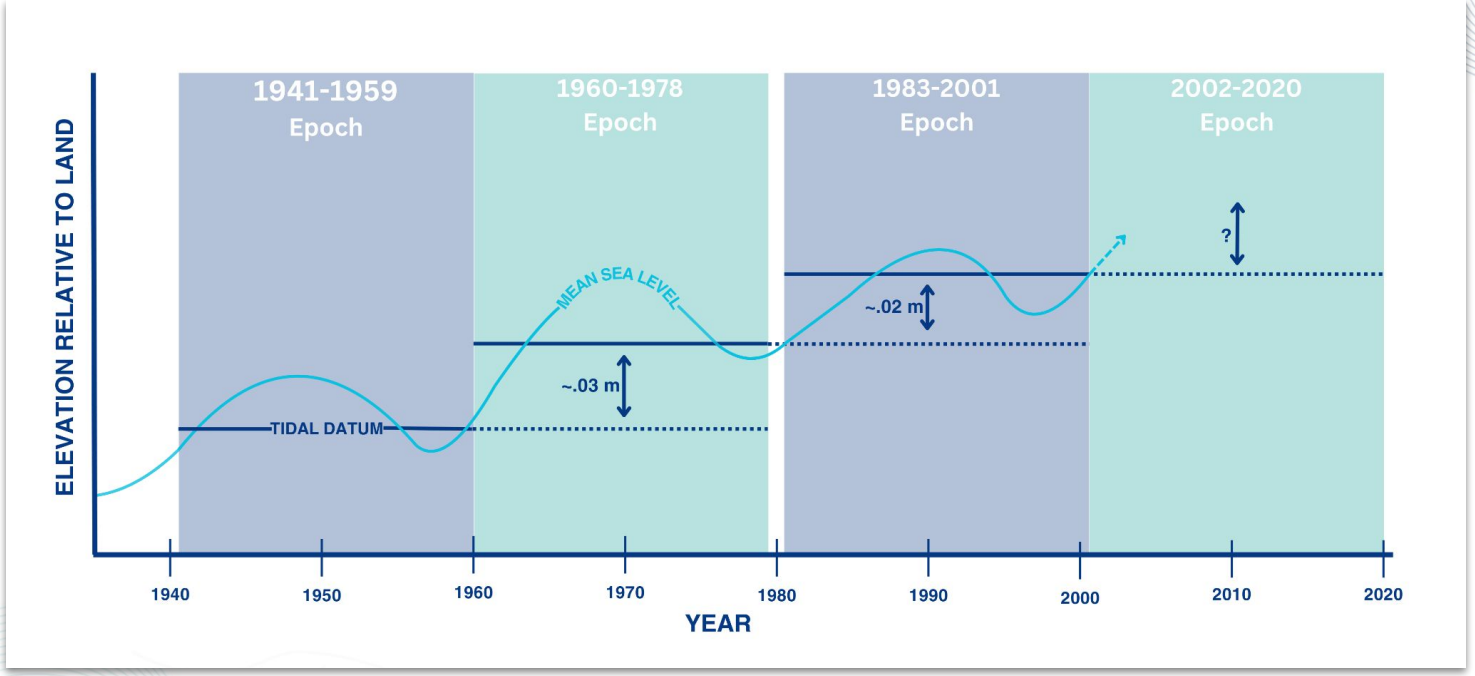
Mean Low Water

Lowest Observed Tide


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE
National Tidal Datum Epoch
Source: CO-OPS

National Tidal Datum Epoch

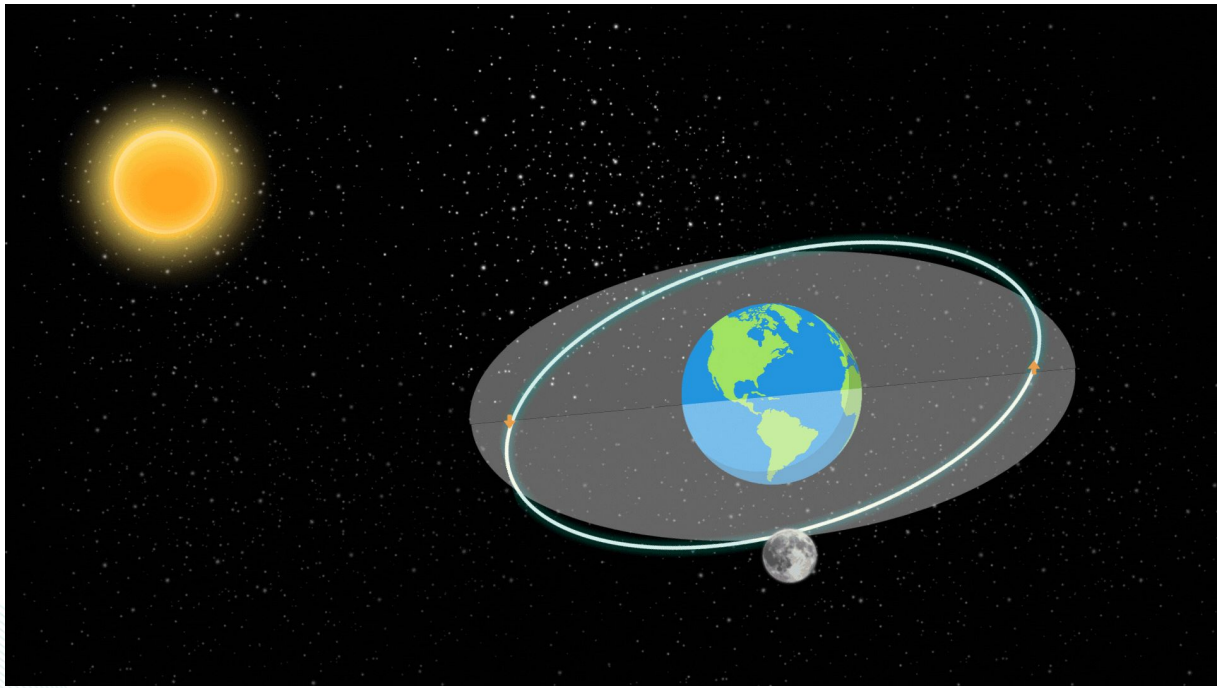
Updates



Graphic depicting National Tidal Datum Epochs since 1940 and Mean Sea Level increase between epochs.

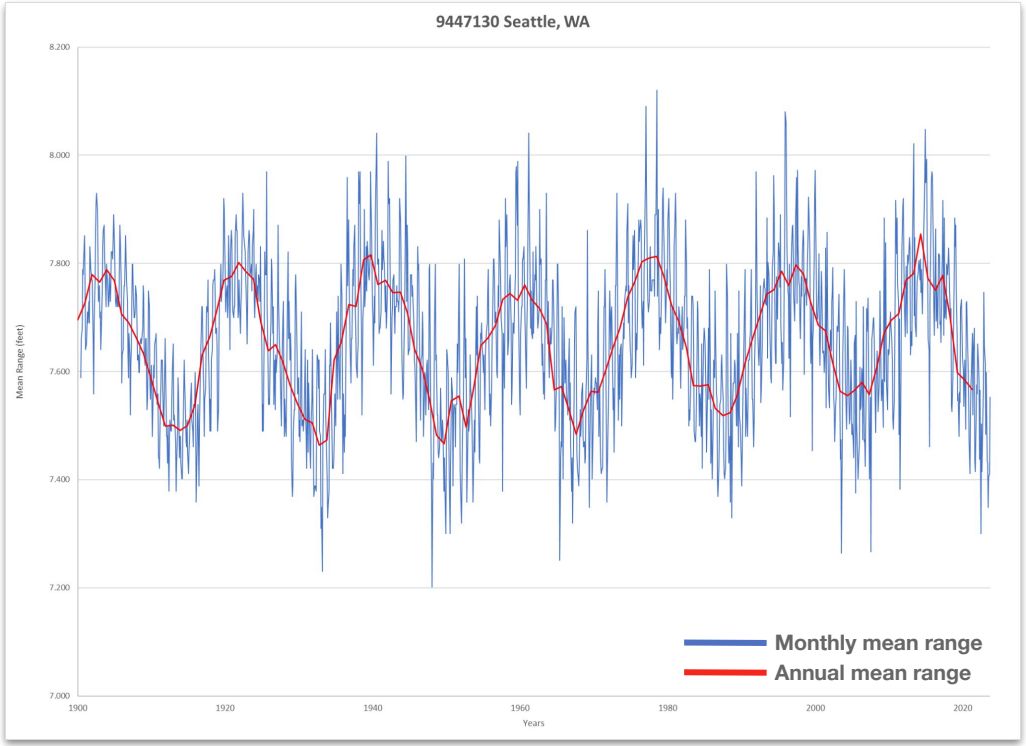
National Tidal Datum Epoch

Metonic Cycle



National Tidal Datum Epoch

Metonic Cycle



This graph depicts multiple Metonic Cycles in Seattle, WA. Here, the blue line represents the monthly mean range of tides and the red line represents the annual mean range of tides. From peak to peak, or trough to trough, is the 18.6 year period.

National Tidal Datum Epoch

Tide Stations

Primary Stations

>19 years worth of data

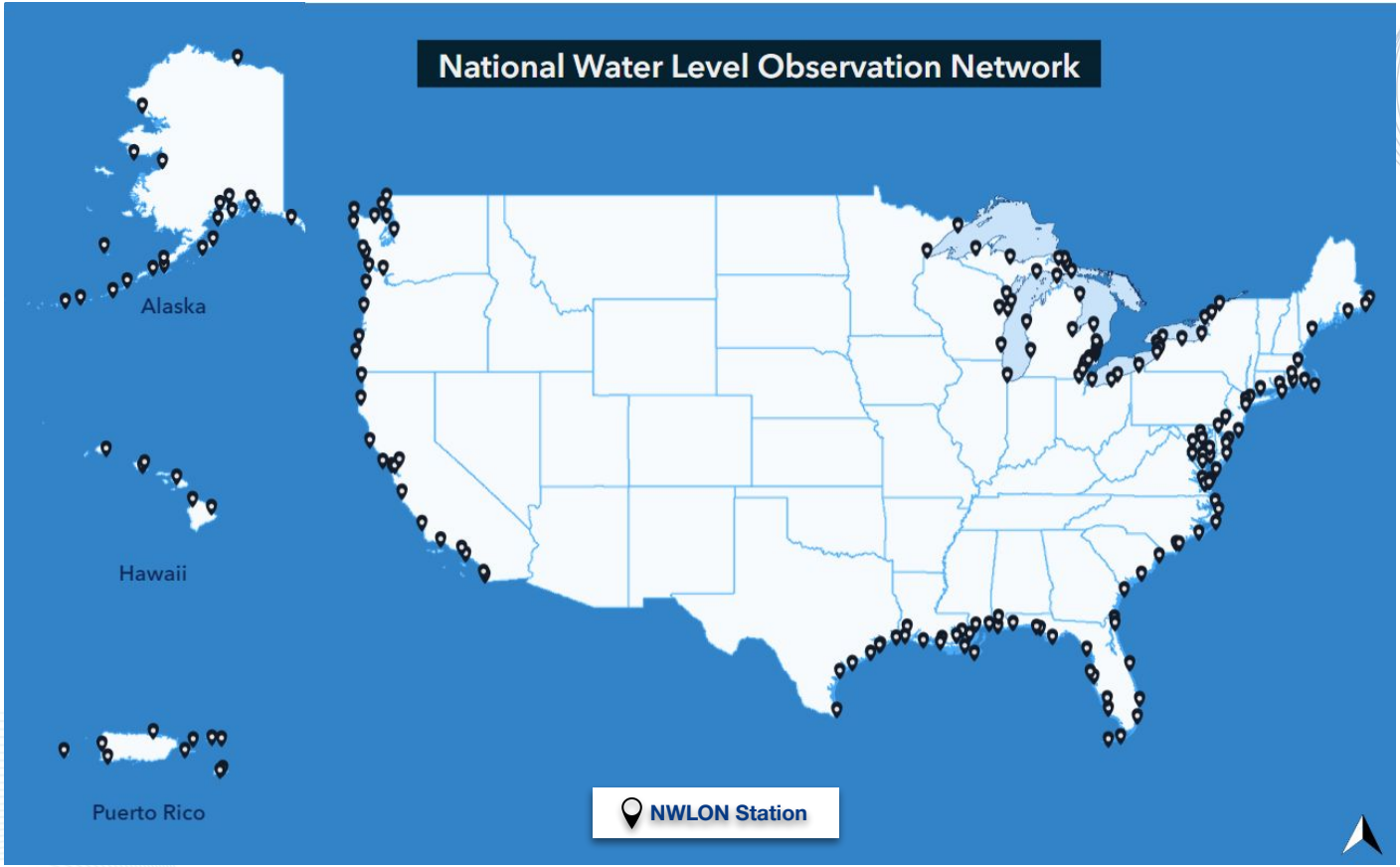
Secondary Stations

≥1 year of data
<19 years

Tertiary Stations

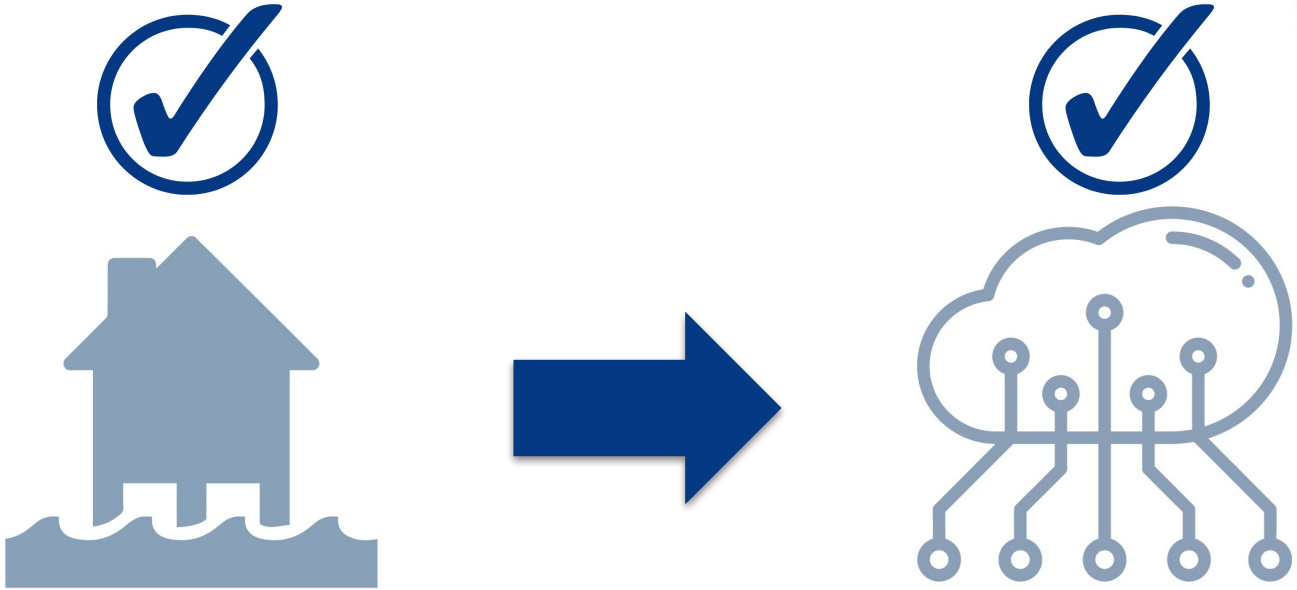
≥30 days of continuous data <1 year

National Tidal Datum Epoch



National Tidal Datum Epoch

Quality Assurance and Quality Control



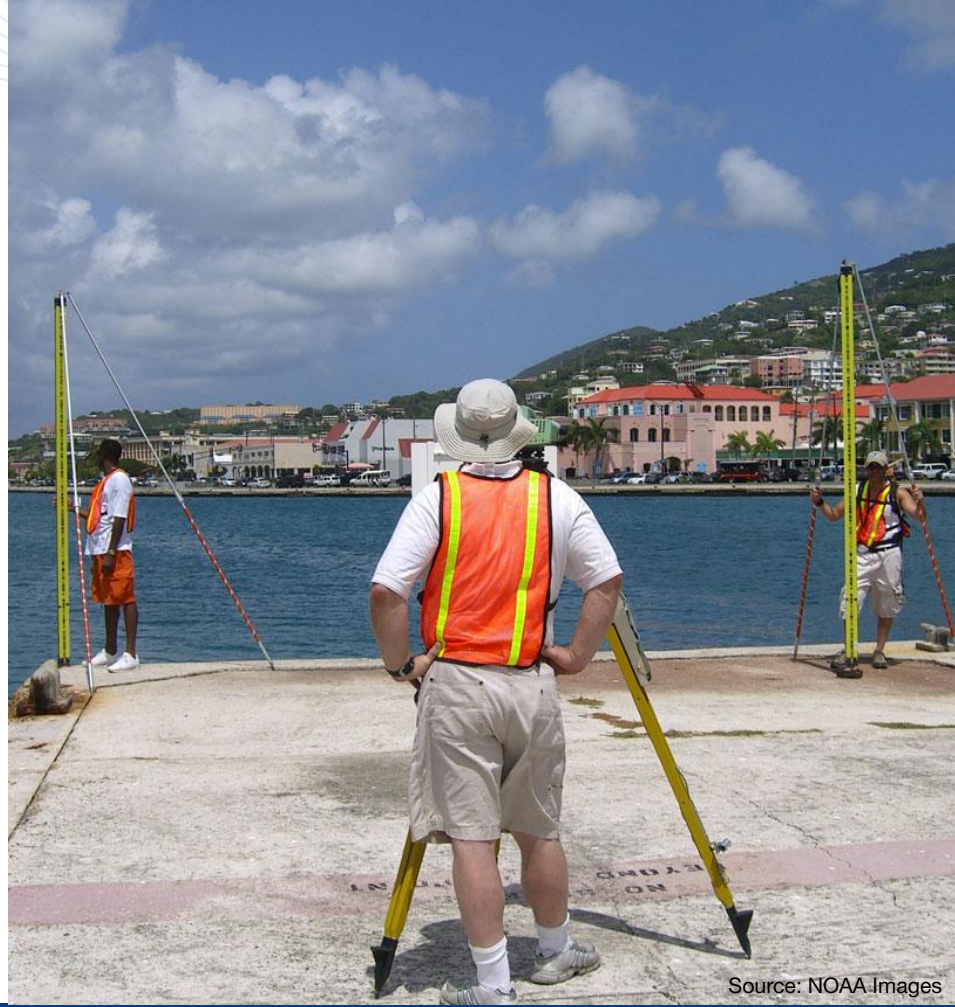
National Tidal Datum Epoch

Bench Marks

National Tidal Datum Epoch

Leveling

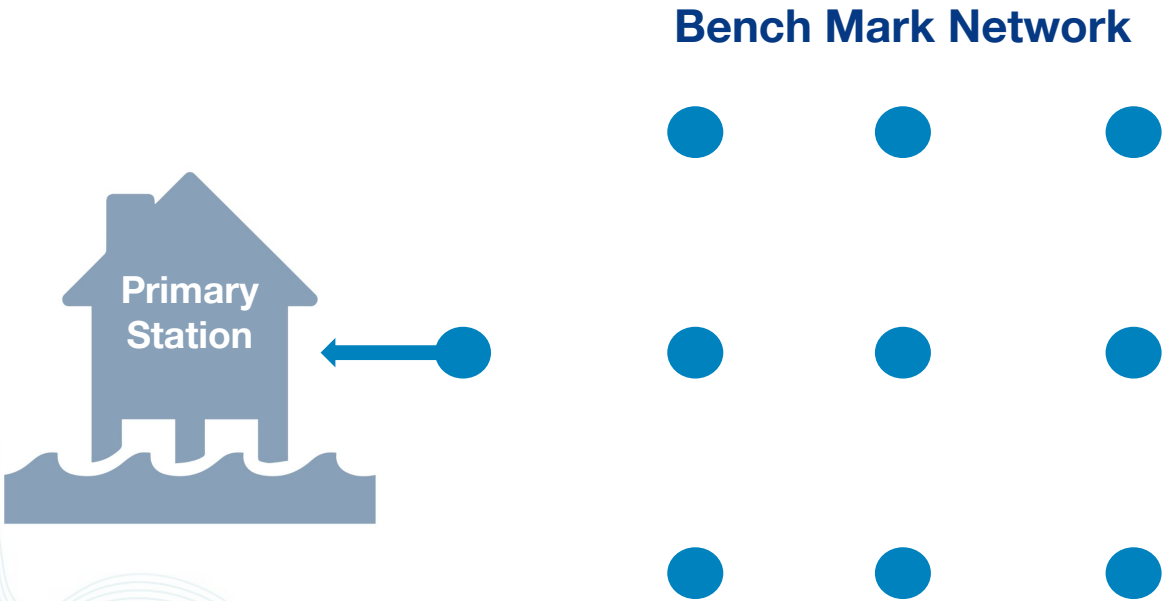
- **Determines heights of points on earth's surface**
- **Way to understand the ups and downs of terrain**
- **Helps create elevation maps**
- **Determines water level changes over time**



Source: NOAA Images

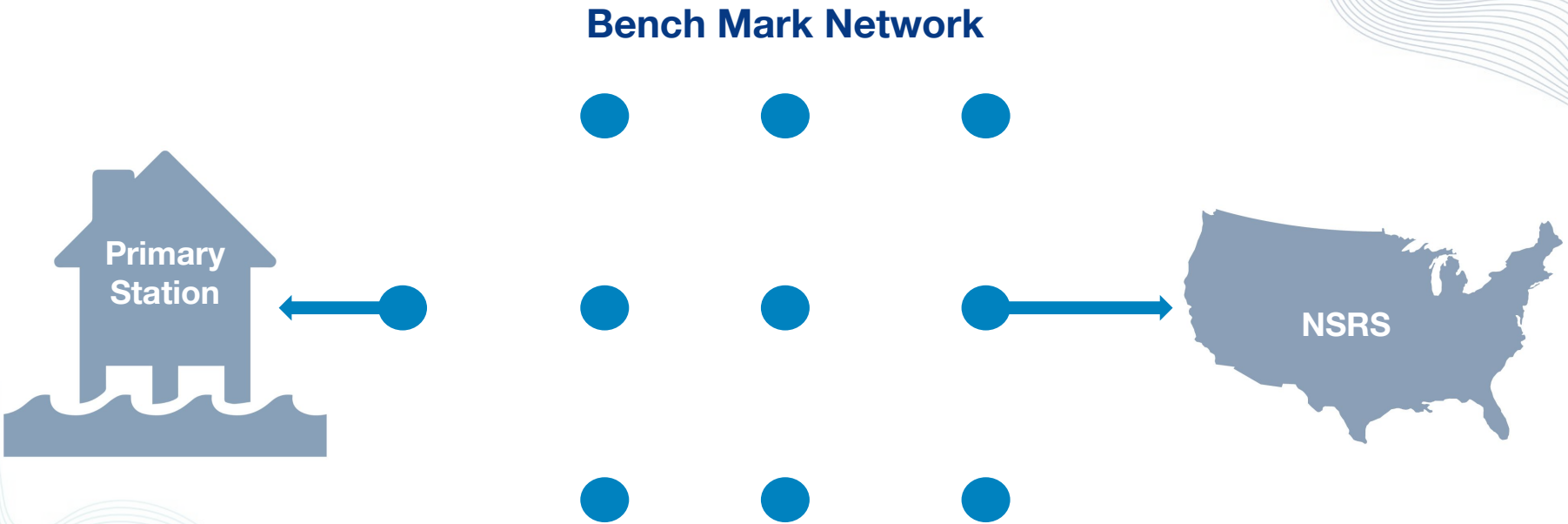
National Tidal Datum Epoch

Bench Mark Networks



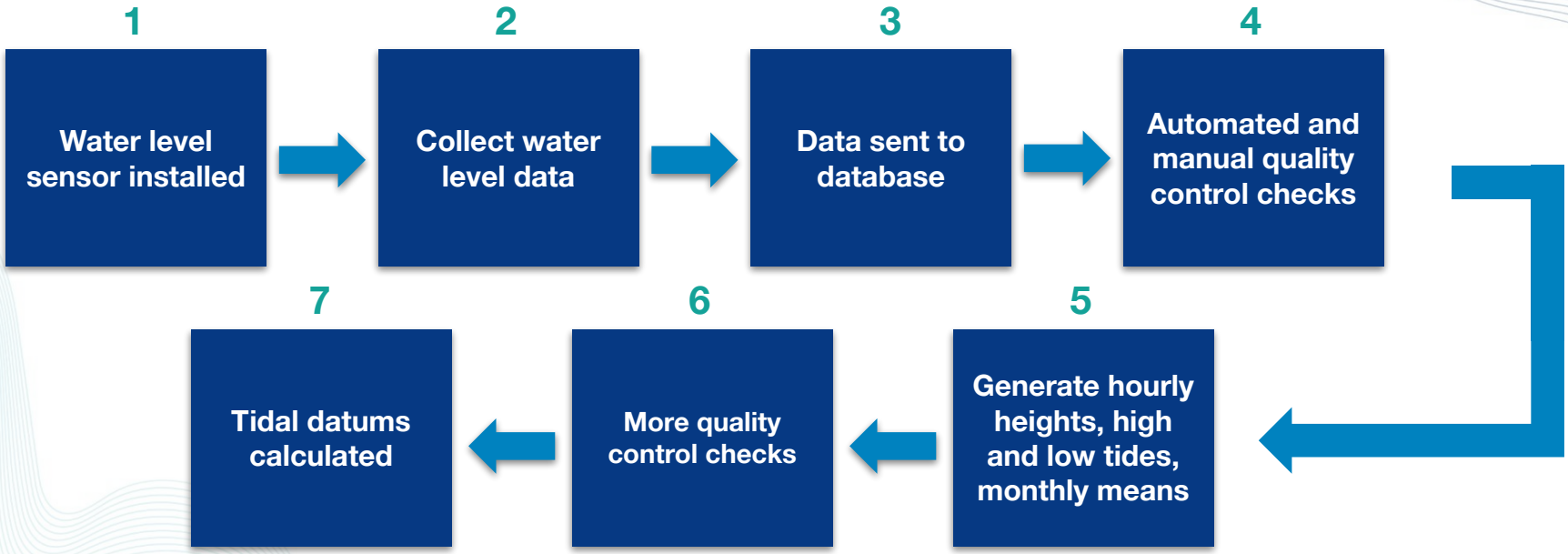
National Tidal Datum Epoch

Bench Mark Networks



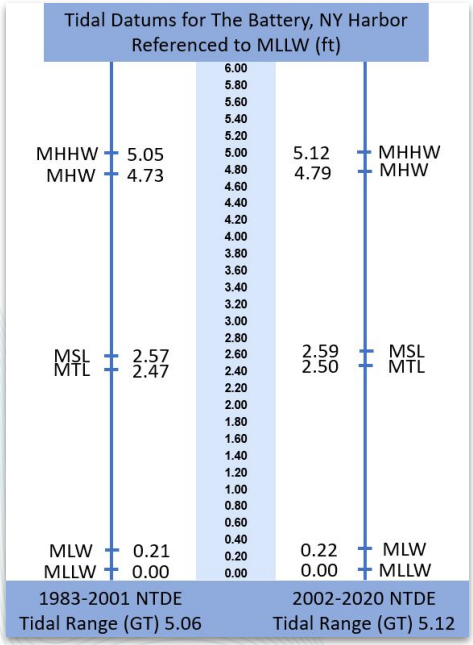
National Tidal Datum Epoch

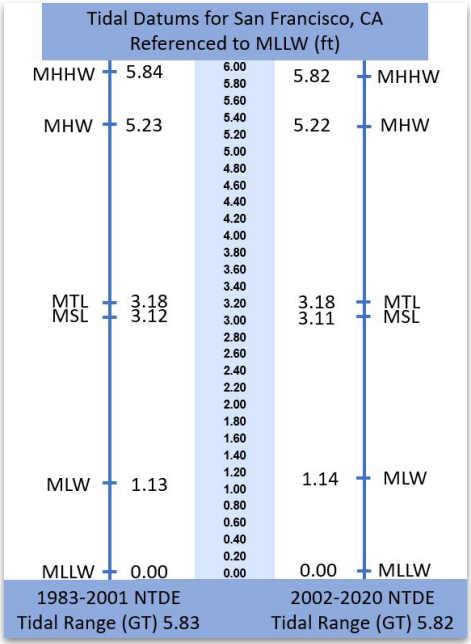
Data Flow

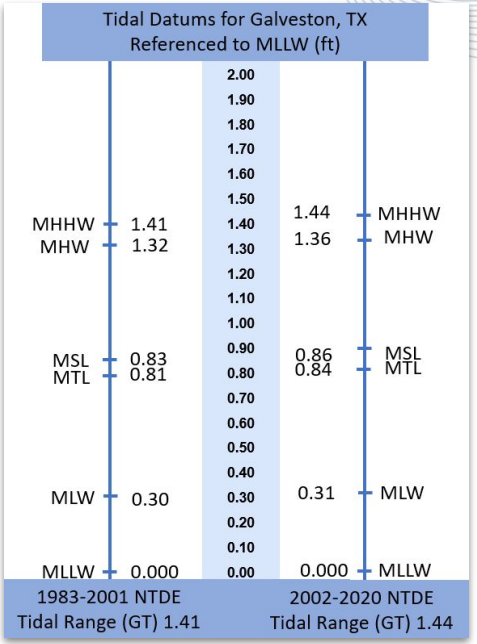


National Tidal Datum Epoch

Datum Changes







National Tidal Datum Epoch

Metadata

Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE

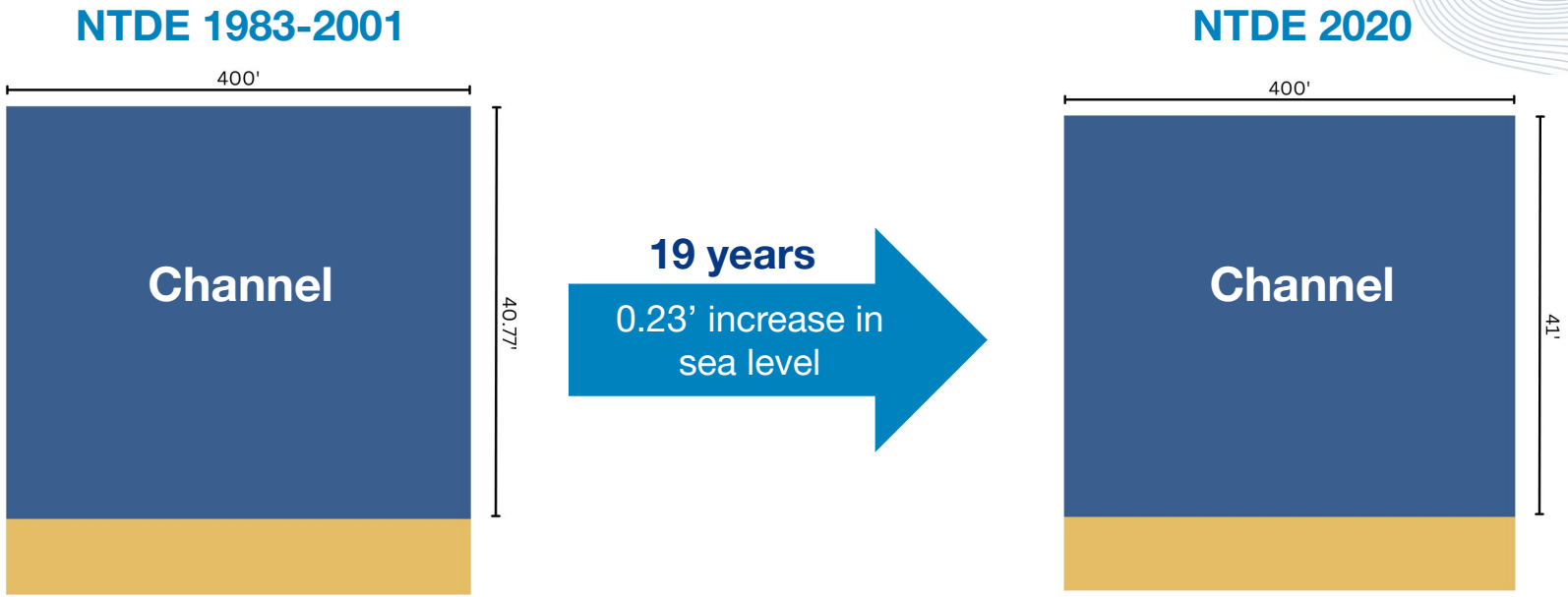
Applications

Using Datums

Source: NOAA Images

Applications

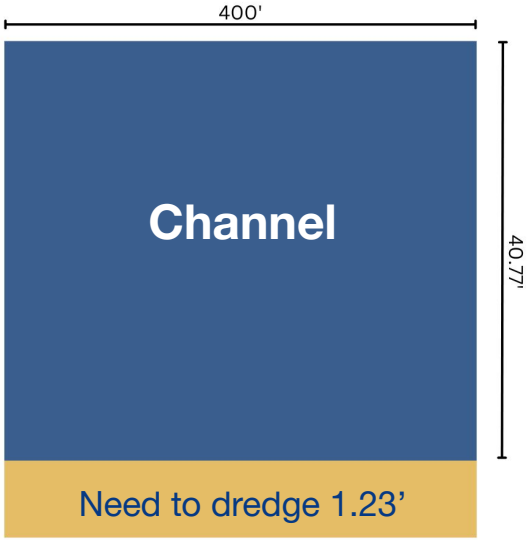
Channel Dredging



Applications

Channel Dredging

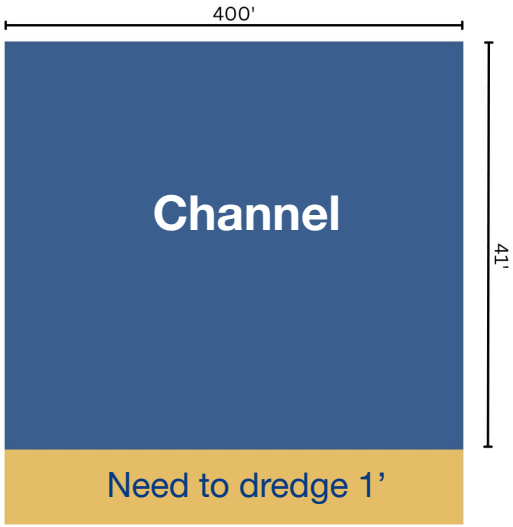
NTDE 1983-2001



$340,740

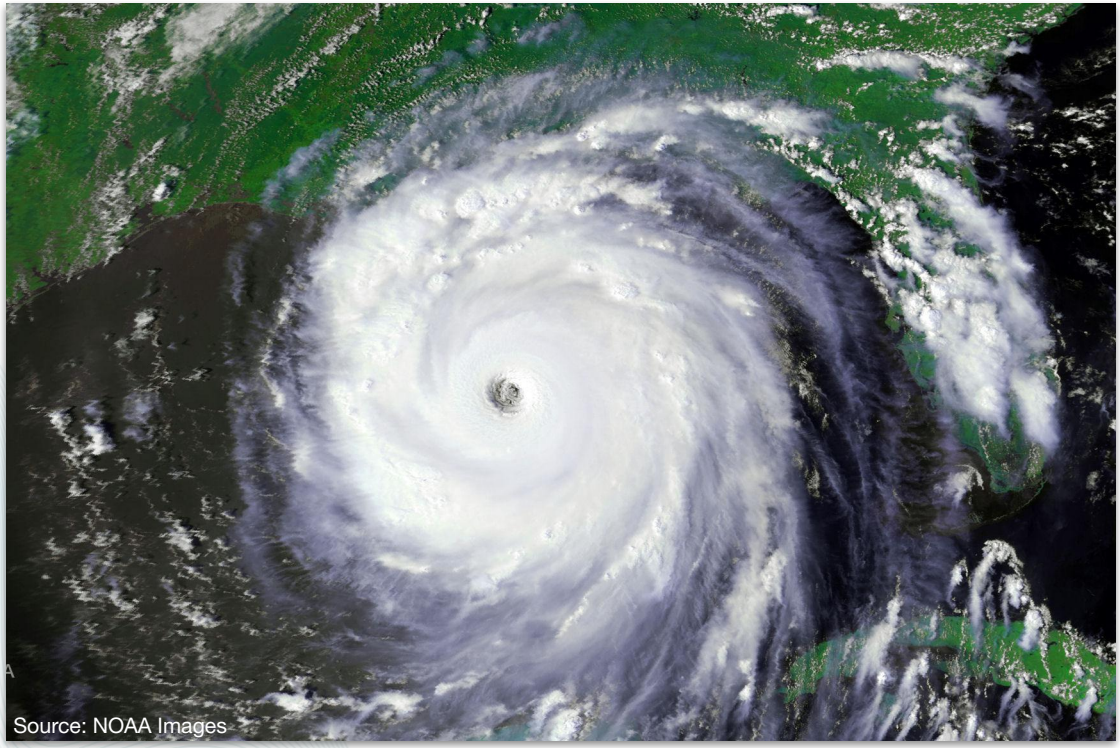
Desired Depth: 42’

NTDE 2020



Applications

Hurricane Katrina



Source: NOAA Images

Applications

Hurricane Katrina

- **Inconsistent use of datums**
- **Mean Low Gulf Datum ≠ Local Mean Sea Level**
- **Epochs were not referenced**
- **Lead to disjointed system of levees**
- **USACE are updating guidance and re-evaluating projects**

Source: NOAA Images

Applications

Preparing for an Update

Document

Save all metadata, including data sources, publication dates, epochs, and reference datums.

Plan

Ensure projects are ready for this change.

Stay Informed

Follow National Ocean Service on social media and email tide.predictions@noaa.gov.


Center for Operational Oceanographic Products and Services
NATIONAL OCEAN SERVICE
Review
Source: NOAA Images

Review

- Explain factors that influence tides and their predictions
- Identify common tidal datums used in the United States
- Emphasize the importance of checking datum metadata
- Explain the significance and usage of different datums
- Understand the process for and importance of updating the NTDE
- Recognize the impacts of the new NTDE

Questions?

tide.predictions@noaa.gov