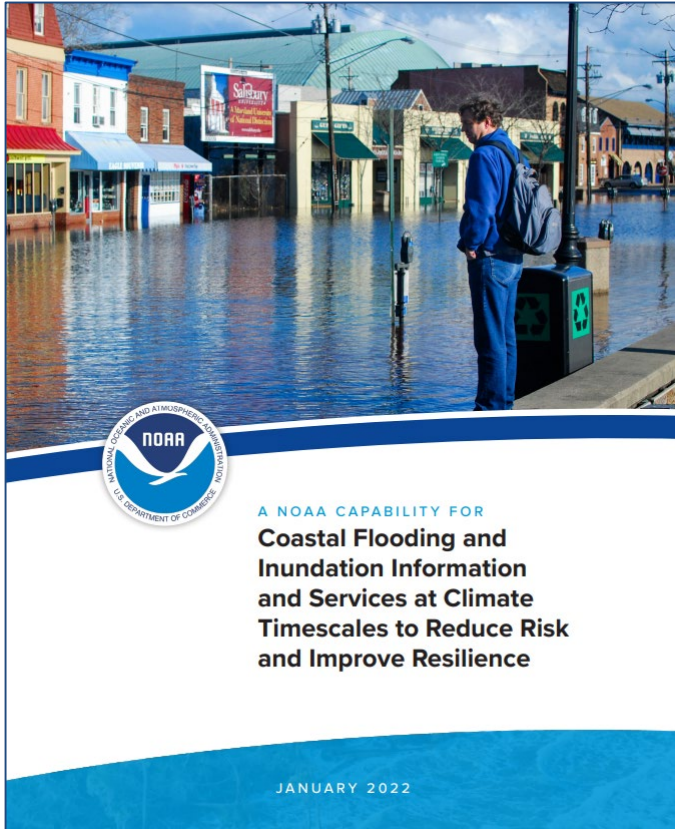# Coastal Inundation at Climate Timescale:
A 5-year Plan for Improving Science, Products & Services

2022 Hydrographic Services Review Panel

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September 22, 2022

The Center for Operational Oceanographic Products & Services

Building a Coastal Inundation Capability Framework

A NOAA CAPABILITY FOR
Coastal Flooding and Inundation Information and Services at Climate Timescales to Reduce Risk and Improve Resilience

JANUARY 2022

Challenges:

- Our coast are increasingly at risk of coastal inundation from rising seas and more frequent and intense storms owing to our changing climate.

- No extant capability that provides comprehensive, reliable, authoritative data, information regarding future coastal inundation risk while incorporating all causative components across multiple time horizons and spatial scales.

- No comprehensive point of access to this information, or decision-support services that adequately translate science into decision making on the status, rates, patterns, predictions, and projections of coastal flooding and related physical and socio-economic risks.

Inundation Services on the Weather-Climate Continuum

Geographic Scale:
Regional to Global with **Timescales**

Water Level Monitoring (Quicklook)	**High Tide Flooding Bulletin**	**The State of High Tide Flooding Outlook**	**National Climate Assessments (NCA5) SLR Projections**
Weekly	*Seasonal*	*Annual*	*Decadal to Centennial*

- The **current suite** of NOS **High Tide Flooding & water level prediction products** on the weather to climate continuum are disconnected.
- Products are **limited to NOAA tide gauges.**

Coastal Inundation & Climate Timescales

- NOAA envisions a **centralized, integrated, operational framework of coastal inundation** information and service delivery.

- This capability will produce and deliver **authoritative, easily accessible data** and **products complemented by tools**, applications, and nationally consistent **decision-support services** that enable **all communities to advance the resilience** of the Nation to coastal inundation now and in the future.

- [White Paper](#) used to guide the work to be completed on BIL Provision 3 Seasonal to Annual Outlook

BIL Provision 3: Seasonal to Annual Outlooks

- Making **infrastructure resilient against the impacts of climate change** and extreme weather.

- Enabling the **prediction of sea level anomalies** between tide station observations.
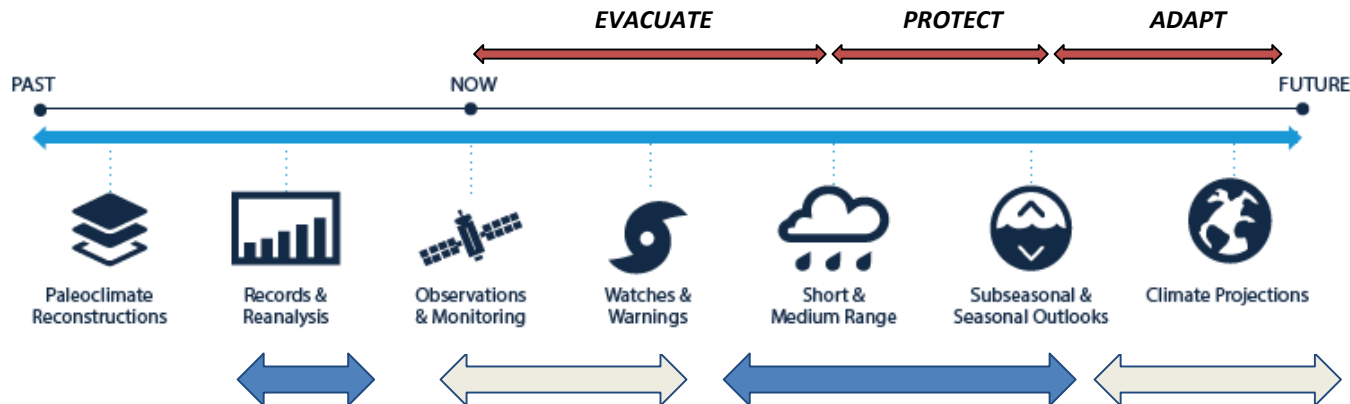
- Seasonal to **sub-seasonal projections**.

Resilient Infrastructure

Investment in Environmental Remediation

NOAA Inundation Services Anticipated with BIL Funding

What NOAA currently provides:

- Real-time inundation info (observations and monitoring), and predictions out to one week
- Prediction of sea level rise decades out, up to the next century at tide gauges

NOAA Services to improve with BIL funding:

- Baseline climatology and monitoring
- Subseasonal to annual outlooks

Anticipated White Paper Inundation Products from BIL Funding

Data Product Line	Description
Baseline Climatologies	Mean and extreme still water and freshwater (waves and rainfall) through National 2-D gridded 40 year climatology and associated probabilities ever 500m.
Trends and Monitoring	Historical up to real time coastal flood monitoring and reporting of magnitude and frequency of mean and extreme water level (Integrate/total water not capable under IIJA).
Attribution of Patterns & Processes	Detection/Attribution of primary modes of variability by starting at tide gauges with the potential to move towards gridded model output/altimeter every 500m. Focus on the attribution of the causes leading to coastal flooding.
Sub-Seasonal to Annual Outlooks	Integrated Monthly-to-annual outlook of the probabilities of coastal inundation through likelihood of day and frequency of still water at tide gauges and gridded ~every 500m.

Current HTF & Coastal Inundation Service Gaps By Timescale

	Past Baseline Conditions/ Climatologies	Trends, Monitoring, and Attribution	Real-time/ Nowcast	Subseasonal	Seasonal to Annual	Decadal to Century
Spatially Resolved High Tide Flood Info (500m)	Service Available	Service Available	Service Available	Service Available	Service Available	Service Available
Spatially Resolved High Tide Flood Info (500m)	Service Gap	Service Gap	Service Gap	Service Gap	Service Limited	Service Limited
Obs-based Forecasts/ Outlooks/Projections	N/A	N/A	Service Available	Service Limited	Service Available	Service Available
Spatially Resolved Forecasts/ Outlooks/ Projections	N/A	N/A	Service Available	Service Gap	Service Gap	Service Limited
Decision Support Framework (i.e. Dashboard)	Service Limited	Service Available	Service Available	Service Gap	Service Gap	Service Gap
Maps and Visualizations (i.e. SLR Viewer)	Service Gap	Service Limited	Service Available	Service Gap	Service Gap	Service Limited

Legend: Service Available | Service Limited | Service Gap

5 Year Plan: HTF & Coastal Inundation Services with BIL

	Past Baseline Conditions/ Climatologies	Trends, Monitoring, and Attribution	Real-time/ Nowcast	Subseasonal	Seasonal to Annual	Decadal to Century
Spatially Resolved High Tide Flood Info (500m)						
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Obs-based Forecasts/ Outlooks/Projections	N/A	N/A				
Spatially Resolved Forecasts/ Outlooks/ Projections	N/A	N/A				
Decision Support Framework (i.e. Dashboard)						
Maps and Visualizations (i.e. SLR Viewer)						

**Service Available**   **Service Limited**   **Service Gap**

Current BIL Initiatives

- Filling gaps between observations

- Creating access to authoritative information across all U.S. States and Territories, regardless of location.

- Modeling water level observations every 500 meter along the coast - including bays, estuaries, and coastal river-mouth entrances.
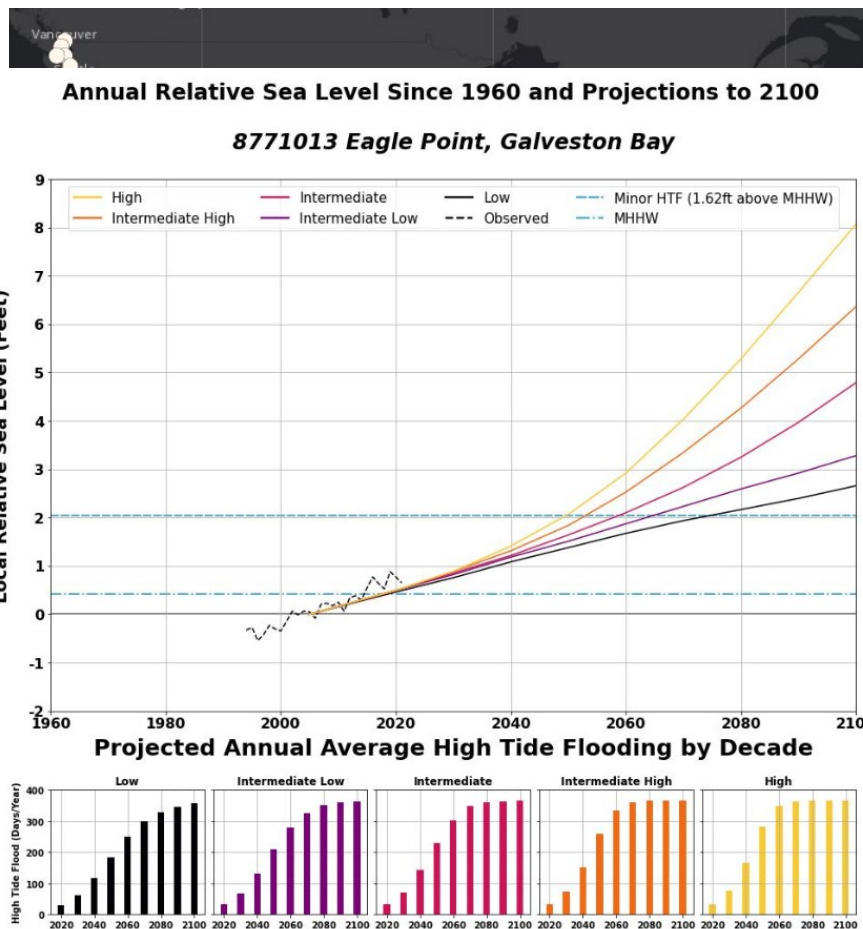
- Results contribute to 5th National Climate Assessment

Applying Enhancements

- **Increased accuracy** through a probabilistic method of predicting sea surface anomalies.
- Providing **data between the observations**: 500 meter resolution at the coast, and 2500m resolution further offshore - in line with model output resolution.
- Creating a mesh of **historical data and climatologies** builds the **framework for future projections** between NWLON stations
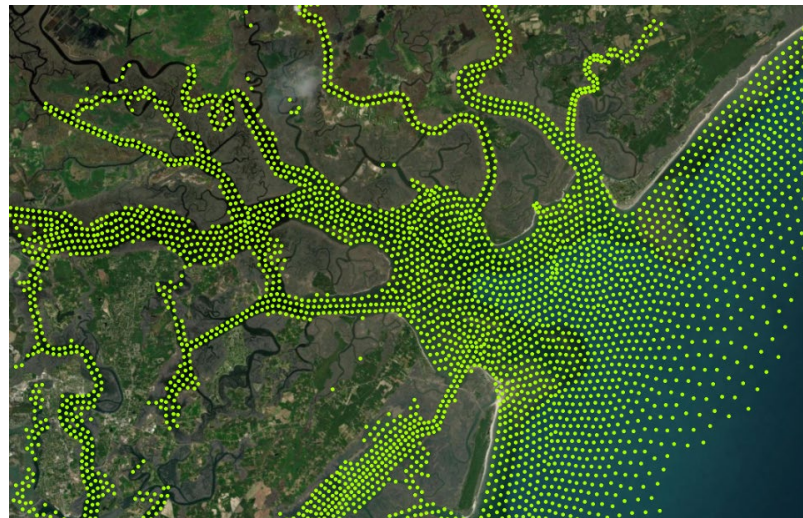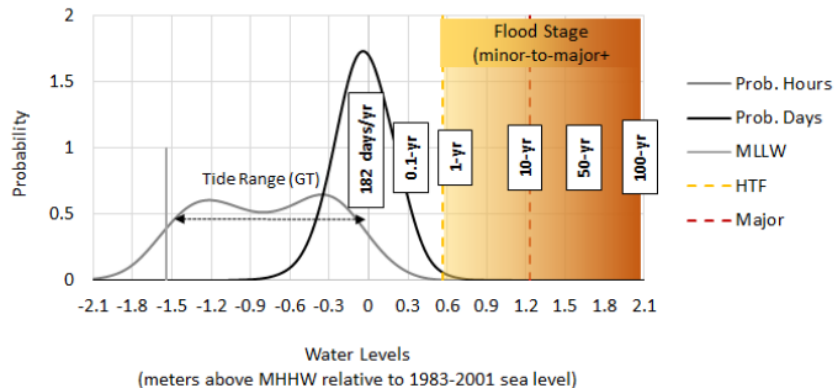
The Power of Observation

- Data is gathered from **97 stations** within the **National Water Level Observation Network**.

- **Decadal projections** used to calculate annual High Tide Flooding (HTF) events are enhanced by integrating updated Sea Level Rise (SLR) Scenarios outlined in the **2022 U.S. Interagency Sea Level Rise Technical Report**.

- **Updated methodology** enhances the way **sea level rise scenarios** can be visualized alongside high water marks, **observed water levels** and **minor high tide flooding** thresholds.

Annual Relative Sea Level Since 1960 and Projections to 2100

8771013 Eagle Point, Galveston Bay

Projected Annual Average High Tide Flooding by Decade

The Geospatial Advantage

- Moving away from a static PDF report…

- And stepping into the world of **interactive GIS**-based visualizations!

- National Outlook, **regional summaries, decadal projections**, and **inundation thresholds** in one place!
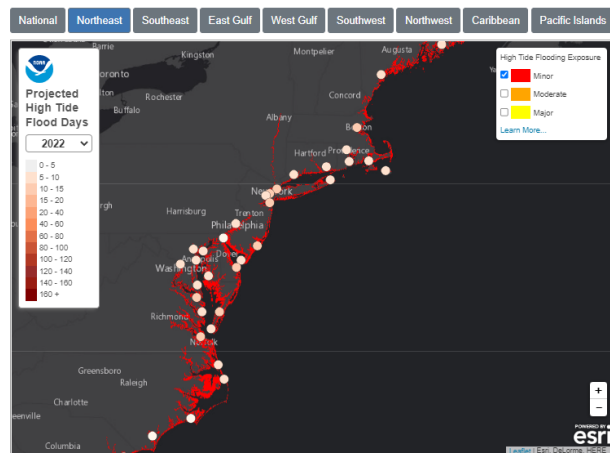
A map showing the projected number of high tide flooding days at National Water Level Observation Network stations at yearly intervals out to 2050. Flooding thresholds supplied by NOAA's Office for Coastal Management.

Northeast State of High Tide Flooding & 2022 Outlook

The northeast is one of the areas most impacted by high tide flooding in the U.S. This year's outlook predicts a fewer number of high tide flooding days due to Earth's place at the furthest proximity from the moon in a Perigean cycle. However, when comparing this year's projections to the average number of high tide flooding days in the year 2000, the northeast has seen a nearly 200% increase in high tide flooding days. 6 to 11 high tide flood events are predicted.

Flooded Battery Park Tunnel after Hurricane Sandy.
Photo Credit: Timothy Krause, October 31, 2012.
Location: The Battery, Manhattan, New York

The State of High Tide Flooding and 2022 Outlook

High-tide flooding, often referred to as "king tides," "nuisance," or "sunny day" flooding, is becoming increasingly common due to years of sea level rise. High Tide Flooding (HTF) is defined as the overflow or excess accumulation of ocean water at high tide that covers low-lying areas, and typically occurs when tides reach anywhere from 1.75 to 2 feet above the daily average high tide and start spilling onto streets or bubbling up from storm drains. As sea level rise continues, damaging floods that happened decades ago only during a storm now happen more regularly, like during a full-moon or with a change in prevailing winds or currents.

Coastal communities across the U.S. continue to experience more frequent high-tide flooding, forcing residents and visitors to deal with flooded shorelines, streets and basements. Similar to 2022 meteorological conditions, many regional HTF frequencies were lower, likely related to continued effects of La Niña; a periodic meteorological event affecting coastal storm tracks and bringing cooler than normal ocean surface temperature and lower than normal sea surface heights along parts of the Pacific Ocean, including the western U.S.

As science advances, so does our ability to predict high tide flooding. This year's Outlook is enhanced by methods outlined in the U.S. Federal Sea Level Rise and Coastal Flood Hazard Task Force's 2022 Sea Level Rise Technical Report; an inter-agency effort to update sea level rise scenarios to emphasize the amount of expected rise by 2050 to inform community planning initiatives.

National Outlook:

- The frequency of high tide flooding across the country continues to increase. This year, due to lingering climatological effects from La Niña and Earth's location in the perigean cycle, coastal areas aren't predicted to experience a record number of flood events compared to last year.

- This year, eastern U.S. and Gulf state communities will continue to experience an over 150% increase in HTF compared to the year 2000, limited only by periodic weather and climate events.

- High tide flooding is anticipated to continue with frequency over the next meteorological year with a **National outlook of 3 to 7 days likely**.

- From May 2021 to April 2022, 3 locations monitored by NOAA tied or broke their records for the number of HTF days along the U.S. Southeast Atlantic and Gulf coastlines. On the Atlantic coast, Reedy Point, DE broke its previous record with 6 events, and Springmaid Pier, SC, near Myrtle Beach, tied its 2021 record with 11 high tide flooding events. In the Pacific, Kwajalein Island observed 4 high tide flooding days, also one more event than in 2021.

- Regional locations like the Northeast Atlantic, Western Gulf, Southeast Atlantic and Eastern Gulf coasts may see some of the highest levels. Lingering effects of La Nina will minimize the amount of HTF expected along Pacific and U.S. Island coastlines. These stats do not include the potential for flooding due to wave action and/or weather-related events.

- By 2050, high tide flooding on a national scale is expected to be between about 45 - 70 days/year on average. These long term projections are based on the range of expected relative sea level rise by 2050 using information from the 2022 Sea Level Rise Technical Report.

- Coastal flood warnings for significant risks to life and property, will become much more commonplace as we approach mid-century.

Increasing   Accelerating

Bringing Data to Life
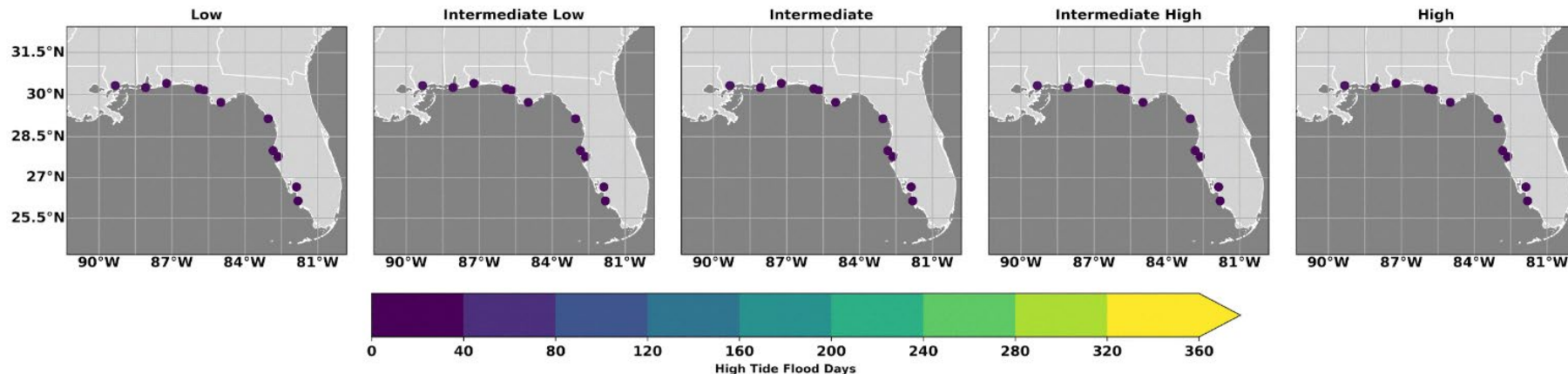
- Dense text become **organized attribute tables.**

- **Impact graphics** show the ways high tide flooding can impact regional landmarks.

- **Dynamic visualizations** show **decadal projections** for regional high tide flooding based on **updated sea level rise scenarios.**

**East Gulf State of High Tide Flooding & 2022 Outlook**

This region of coastline is routinely impacted by severe weather that often contributes to flood events. Coupled with land subsidence and sea level rise, high tide flooding events are more frequent. This year's outlook predicts fewer flood events due to Earth's place at the furthest proximity from the moon in the Perigean cycle. Though this year's outlook is moderate, the eastern Gulf region has seen an almost 200% increase in high tide flooding events since

| National | Northeast | Southeast | East Gulf | West Gulf | Southwest | Northwest | Caribbean | Pacific Islands |

Eastern Gulf
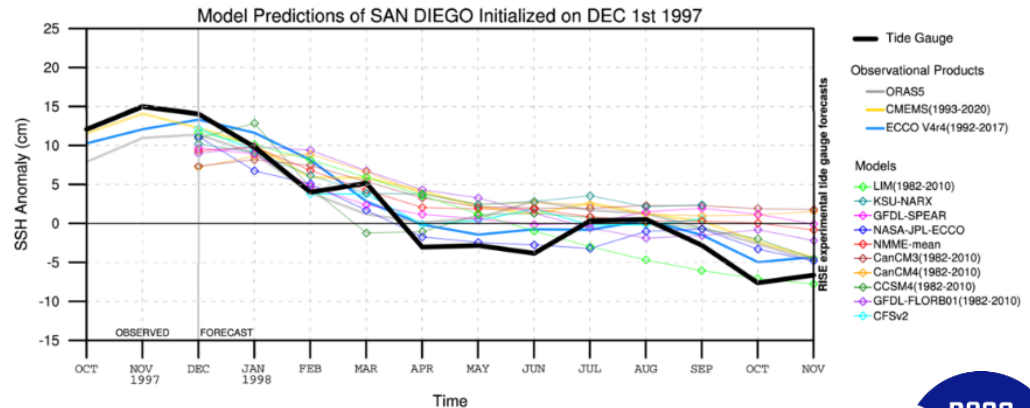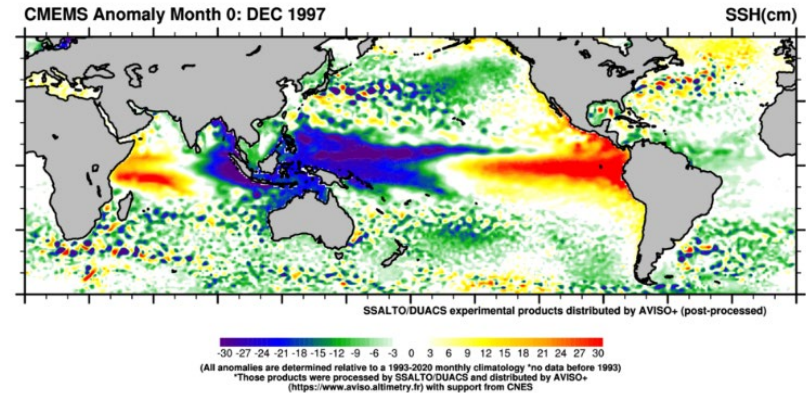**Projected Decadal High Tide Flooding: 2020**

FY23-24 Development

- **Integrating high tide flooding statistics** in the Coastal Inundation Dashboard.
- **Combining** annual outlooks with **seasonal High Tide Flooding Bulletin forecasts.**
- **Integrated models & observations** to predict future conditions.
- Develop a **500m resolution** coastal grid to **predict** potential **high tide flooding** between tide stations.

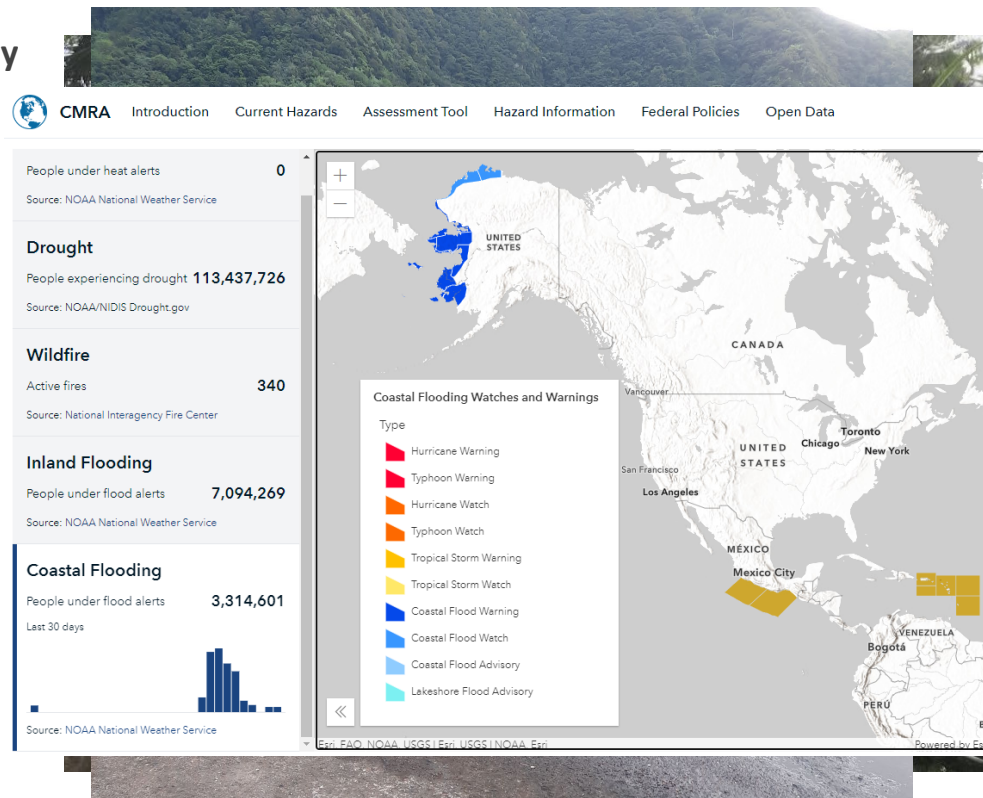Difference fields (colors in meters) on Oct. 5, 2016 00:00 UTC
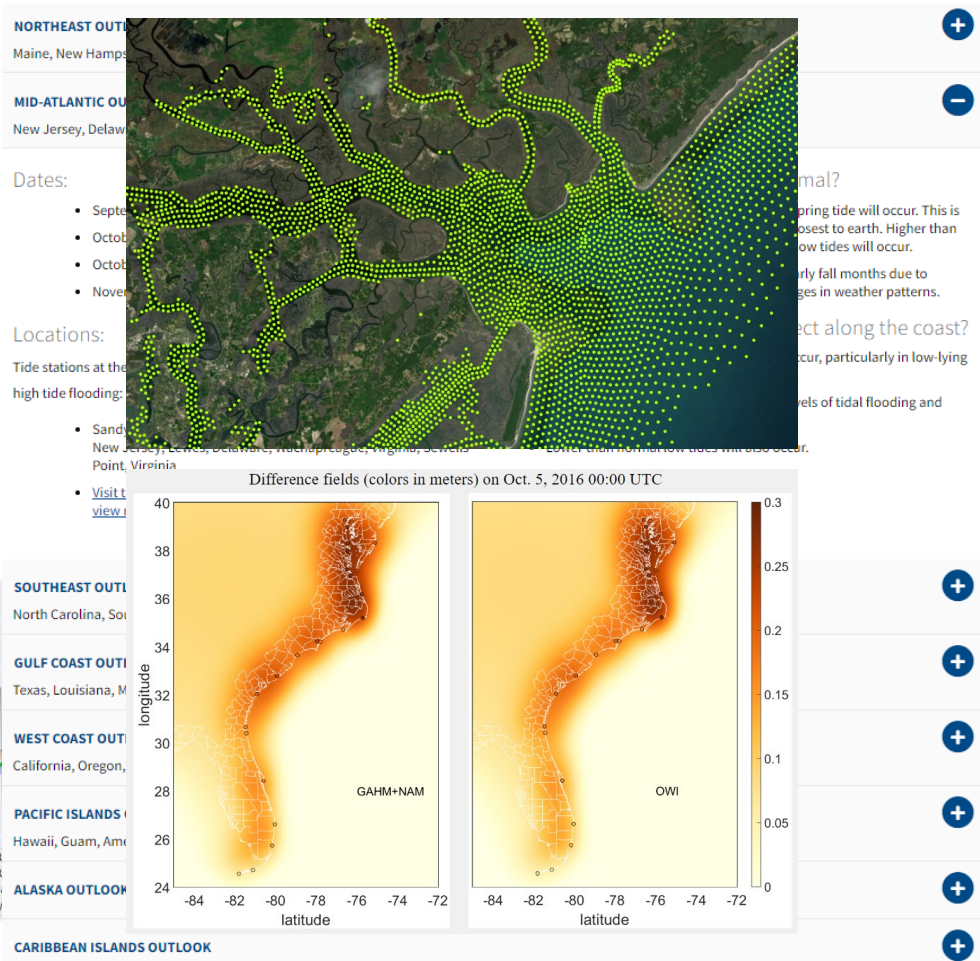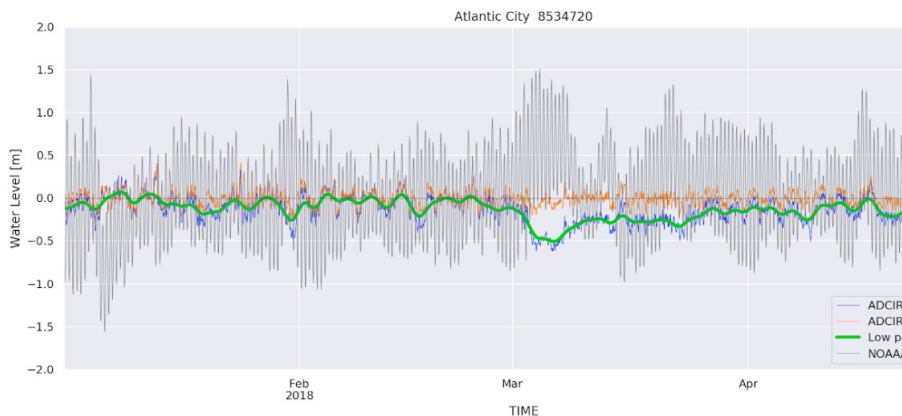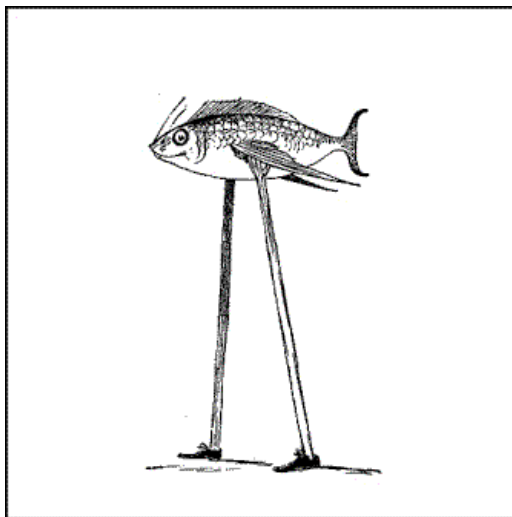
Planning a 5 year Strategy

- Working with NASA and NOAA OAR PSL, GFDL, and GLERL to **expand global experimental sea level anomaly forecasts** to tide stations, and eventually to a grid system to predict flooding and extremes between tide stations.

- Localized sea levels vary due to changes in the land along the coast. The Global Navigation Satellite Systems (GNSS) and synthetic aperture radar (SAR) are two **satellite-based observing techniques** that will play an important role in monitoring **vertical land motion (VLM)** through BIL. 50-60 CORS will be co-located near NWLON stations to improve VLM monitoring throughout our Nation.

CMEMS Anomaly Month 0: DEC 1997   SSH(cm)

SSALTO/DUACS experimental products distributed by AVISO+ (post-processed)

-30 -27 -24 -21 -18 -15 -12 -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30

(All anomalies are determined relative to a 1993-2020 monthly climatology *no data before 1993)
*Those products were processed by SSALTO/DUACS and distributed by AVISO+
(https://www.aviso.altimetry.fr) with support from CNES

Model Predictions of SAN DIEGO Initialized on DEC 1st 1997

Summary of Expected Improvements in 5 Years

- Establishment of an authoritative and **nationally consistent suite of inundation data** for hazard planning & mitigation.

- Model & observation integration to **understand present and future coastal inundation risk**.

- Providing **data between tide stations** with 500m geospatial grids.

- **Continuous user & stakeholder engagement** for better product development.

- Universal accessibility of data to **better serve underrepresented communities**.

Questions?