IHO South-West Pacific HC ESTOFS workshop September 21/22, 2021

Opening remarks

Mr. Matthew Borbash
Capacity Building Coordinator
South-West Pacific Hydrographic Commission (SWPHC)
International Hydrographic Organization (IHO)

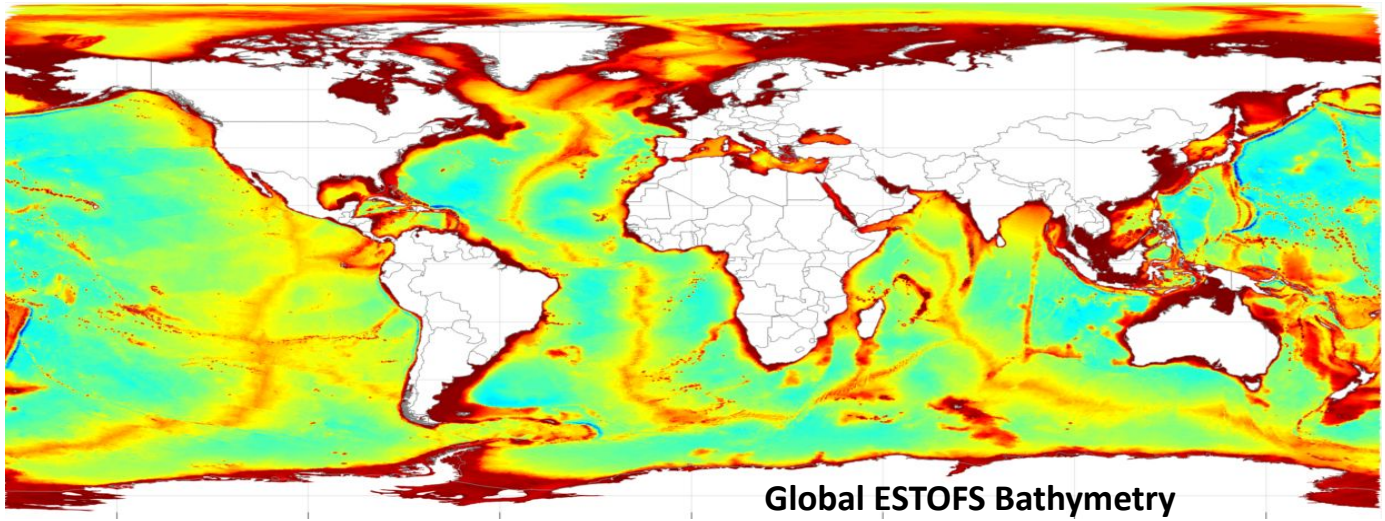
Mr. John Nyberg
Deputy Hydrographer
NOAA Office of Coast Survey

NOAA's Global Extratropical Surge and Tide Operational Forecast System (Global ESTOFS)

Supporting Coastal Resilience and Navigation Services

NOAA/National Ocean Service (NOS) Storm Surge Modeling Team

***Greg Seroka**, **Yuji Funakoshi**, **Michael Lalime**, Panagiotis Velissariou, Soroosh Mani, Zachary Burnett, Georgios Britzolakis, William Pringle, **Saeed Moghimi**, Edward Myers*



Global ESTOFS Bathymetry

IHO South-West Pacific HC ESTOFS workshop

September 21/22, 2021

Outline

- Overview of team
- Motivation and Introduction
- Overview of ESTOFS, products
- Future ESTOFS directions
- Cases using Coastal Emergency Risks Assessment (CERA) web portal
  - Hurricane Ida (2021)
  - Tides in Pacific
  - Typhoon in Pacific
- Stakeholder engagement and feedback tool demo
- CERA demo
- CERA workshop
- Q&A

It takes a village to raise a child…

NOAA/National Ocean Service (NOS) Storm Surge Modeling Team; Greg Seroka, Yuji Funakoshi, Michael Lalime, Zizang yang, Panagiotis Velissariou, Soroosh Mani, Zachary Burnett, Georgios Britzolakis, William Pringle, Saeed Moghimi, Edward Myers

Academic partners (>20 PIs, Scientists, Postdocs and PhD students)

- University of Notre Dame
- University of North Carolina at Chapel Hill
- Virginia Institute of Marine Science
- Argonne National Laboratory
- National Center for Atmospheric Research
- Texas Advanced Computing Center
- Columbia River Inter-Tribal Fish Commission
- Louisiana State University
- Sandia National Laboratories
- University of Massachusetts – Dartmouth
- Cooperative Institute for Great Lake Research
- Oregon State University

International partners

- Helmholtz-Zentrum Hereon, Germany
- Laboratório Nacional de Engenharia Civil, Portugal
- European Commission Joint Research Centre, Belgium
- International Hydrographic Organization
  - South-West Pacific Hydrographic Commission
- United Nations

NOAA and agency partners

- National Ocean Service
  - The U.S. Integrated Ocean Observing System
  - Center for Operational Oceanographic Products and Services
  - National Geodetic Survey
- National Weather Service
  - Office of Science and Technology Integration
  - Environment Modeling Center
  - Office of Water Prediction
- Oceanic and Atmospheric Research
  - Great Lakes Environmental Research Laboratory
- U.S. Geological Survey
- U.S. Environmental Protection Agency

Industrial and cooperative partners

- UCAR
- Spatial Front Inc
- Axiom

Products and Services of the NOS Surge Modeling Team

Operational

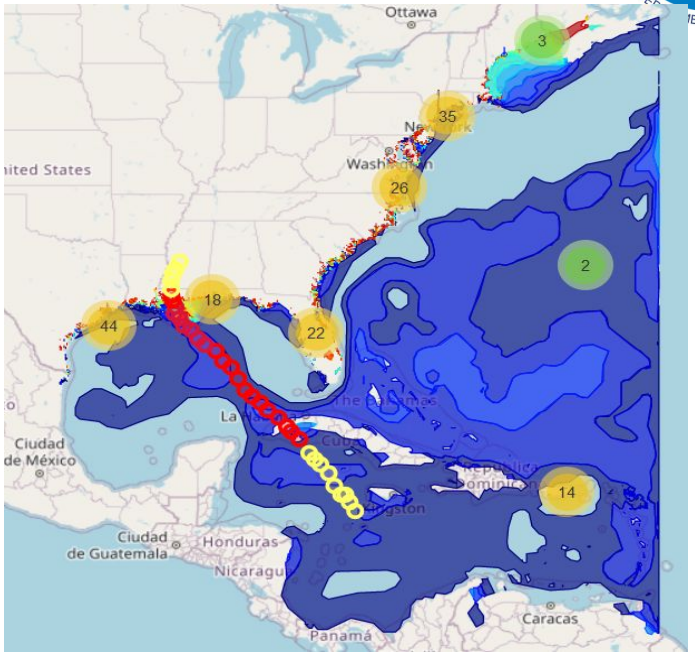
- Global Surge and Tide Operational Forecast System (ESTOFS-Global)

Pre-operational (R2O)

- Inland-Coastal Flooding Guidance System (ESTOFS-3D)

Research and development (R&D)

- COASTAL Act: Name Storm Event Model (NSEM)
- Hurricane Storm Surge On-Demand (HSOFS)
- Enhancing Northern Pacific Ocean Modeling
- Development of automated on-demand unstructured mesh generation

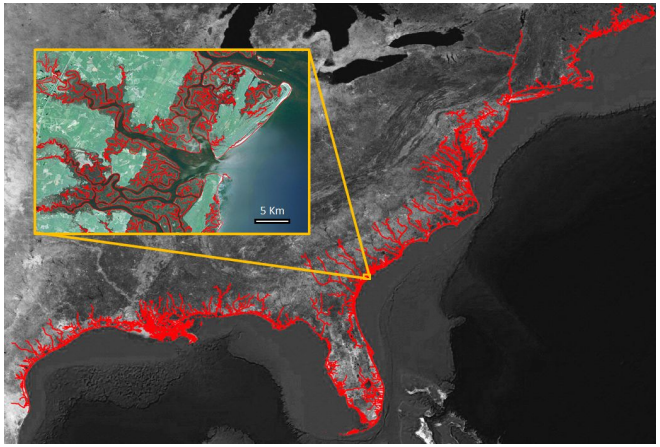


Pre-operational once-day STOFS-3D (SCHISM based)

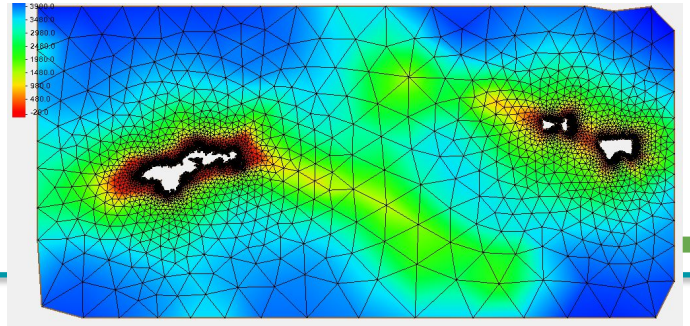
Hurricane Ida (Aug 2021)

Motivation

1. Flooding from storm surge is a significant risk to coastal cities globally
2. Globalization of maritime commerce drives a need for global navigation solutions
3. **A high resolution, operational, global storm surge and tide model** provides local, official water level forecast guidance across the world for:
   a) Extreme event mitigation, disaster reduction
   b) Marine navigation
4. Support Marine Spatial Data Infrastructure (MSDI)



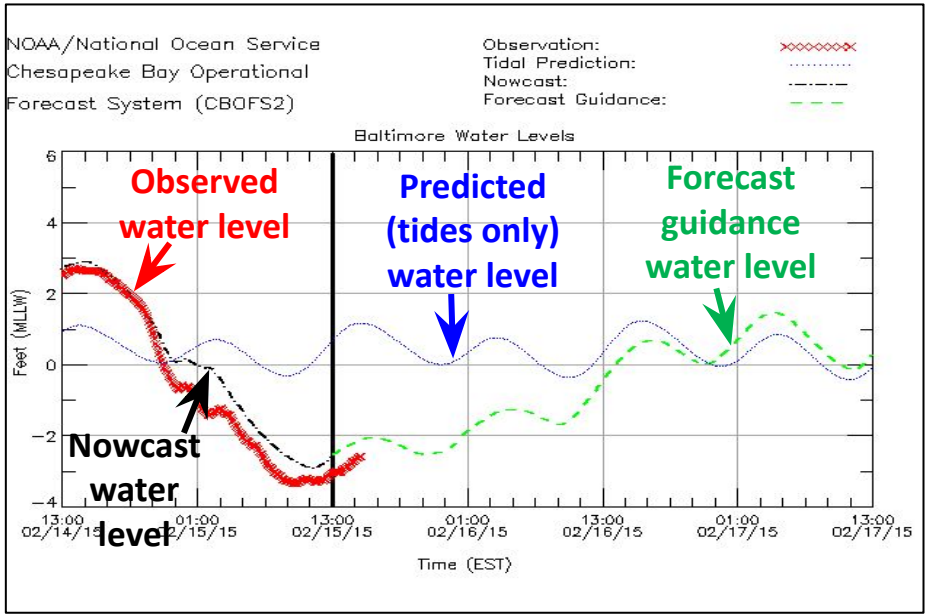
U.S. East Coast



Samoa

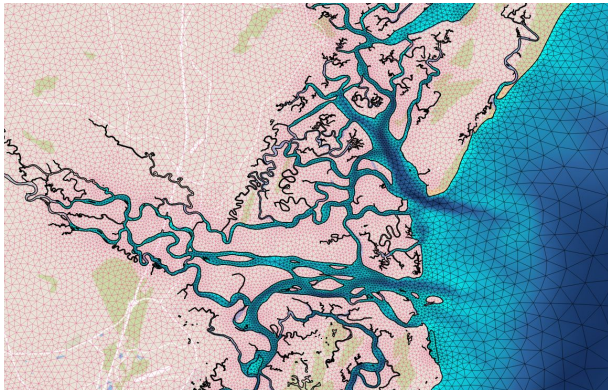
Why is coastal modeling important?

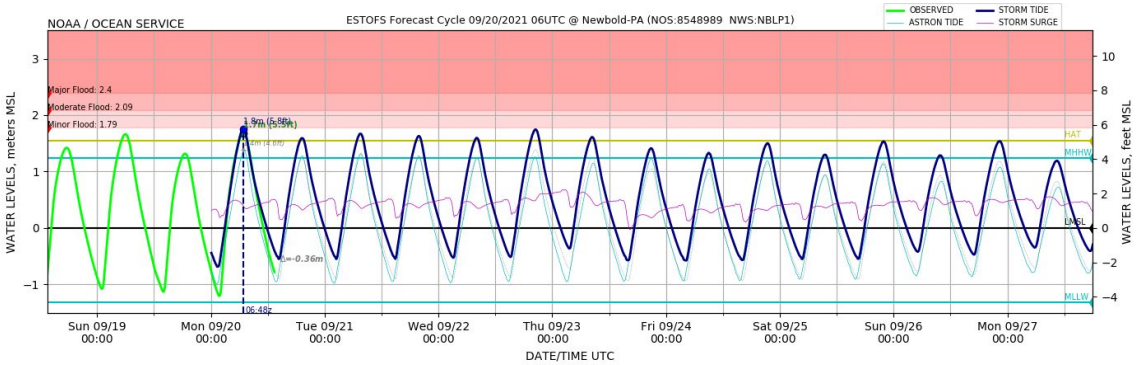
1. Models provide info. in between observations
2. Models provide info. about the future (**forecasts**)
3. Tide tables predict tides, but not changes in water levels & currents due to **wind**, **atmospheric pressure**, rivers, etc.
4. Operational coastal & ocean models provide local, official water level, water current, T/S forecast guidance for:
   a. **Marine navigation**
   b. **Coastal resilience**, disaster mitigation
   c. Ecology, fisheries science/management



What does Global ESTOFS incorporate in its forecasts?

- Global ESTOFS provides **water level** forecast guidance to end users
- **To do this, Global ESTOFS incorporates:**
  - **grid**: bathymetry, topography, shoreline, U.S. federal levees
  - **forcing**: tides, winds and atmospheric pressure (“storm surge”), sea ice
- **Global ESTOFS does NOT incorporate:**
  - river outflow, waves, seasonal variability, smaller-scale circulation, some poorly resolved weather

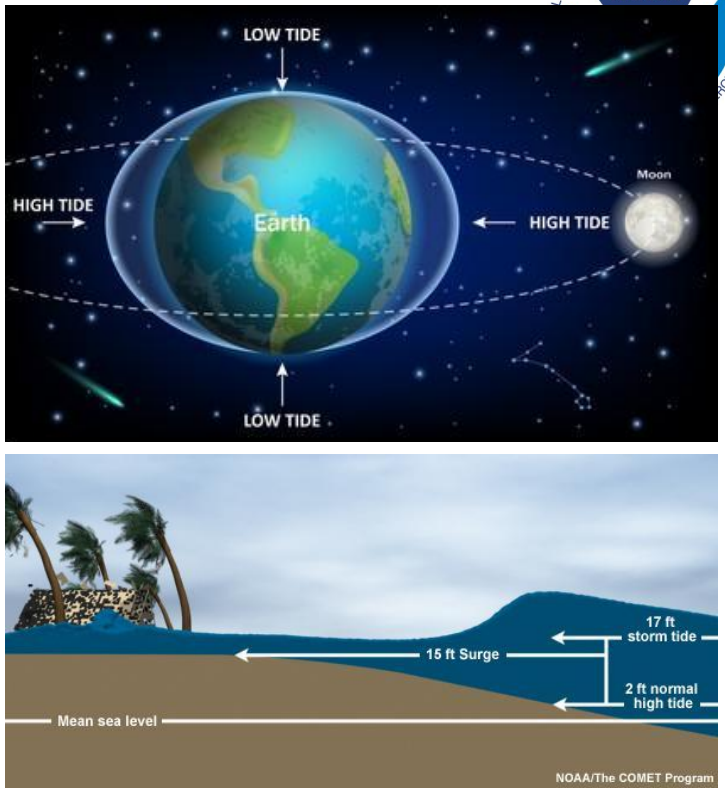




NOAA's Global ESTOFS:

Storm Surge, Tides

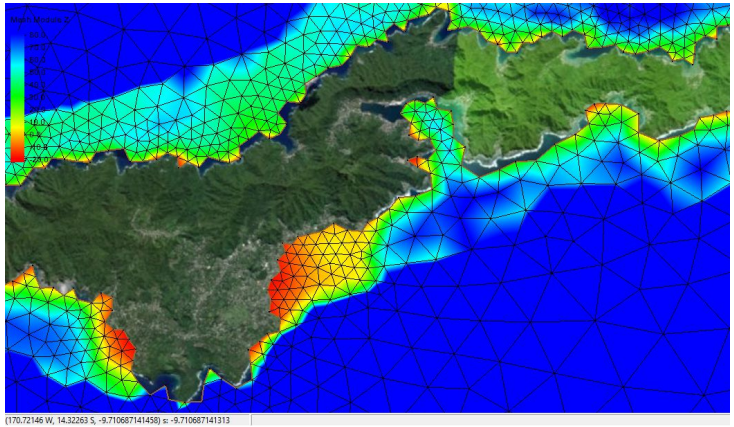
- ESTOFS is a global ocean model used to predict **tides** and **storm surge**:
  - **tides:** rise/fall of sea levels caused by astronomical (moon/sun) forces
  - **storm surge:** abnormal rise of water from storm, above tide
  - **storm tide:** combination of tides and storm surge
- ESTOFS outputs are an important source of information for **navigation safety (e.g. tides)** and **coastal resilience (e.g. storm surge)**.

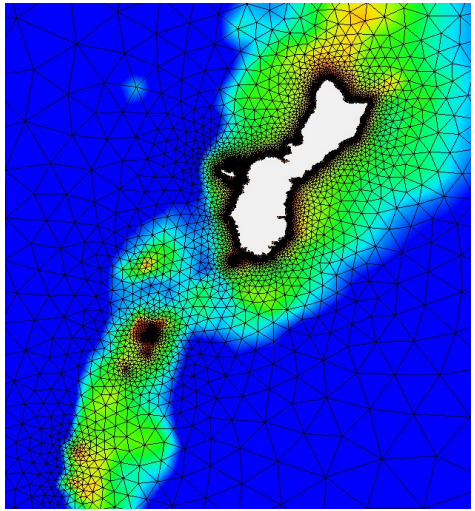


Diagrams showing components of storm tide: tides (top) and storm surge (bottom)

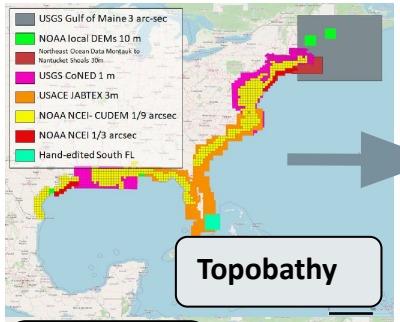
Importance of bathymetry

- **Bathymetry** is the most important control for model fidelity and accuracy
- **We are always looking for new bathymetry**
  - e.g. IHO Data Centre for Digital Bathymetry (DCDB)
  - We will describe later a bathymetry database we are building, and how you can provide us feedback and/or your data

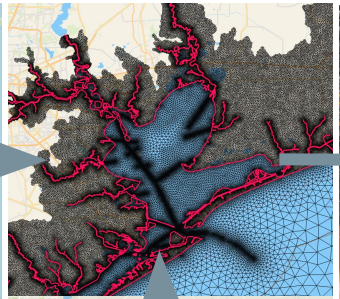


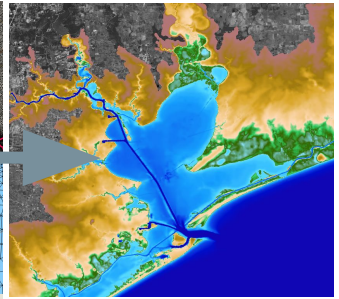


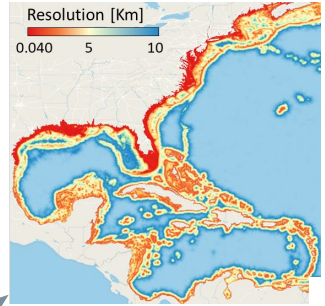
Data driven unstructured mesh generation



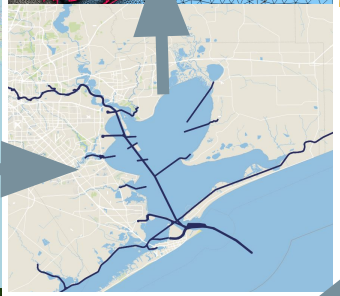
Topobathy

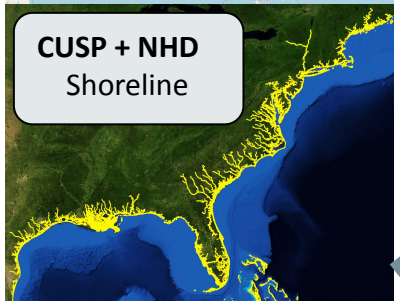






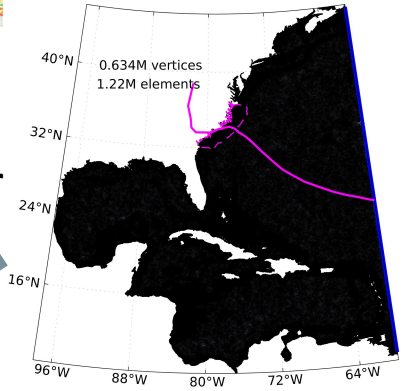
Levees and waterways databases

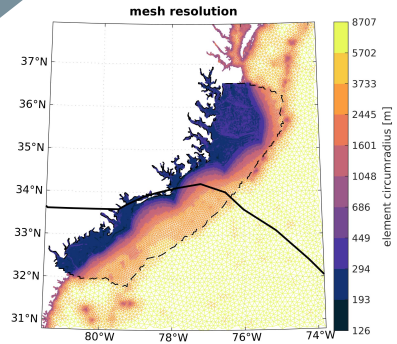




CUSP + NHD Shoreline

Mesh subsetting for Hurricane Florence for ADCIRC





Original HSOFS:
1.81M vertices
3.33M elements

→

Subset mesh
0.634M vertices
1.22M elements

On-demand unstructured mesh subsetting

ADCIRC as the Core Model

ADCIRC -- **AD**vanced **CIRC**ulation Model for Oceanic, Coastal and Estuarine Waters (Luettich and Westerink, 1991)

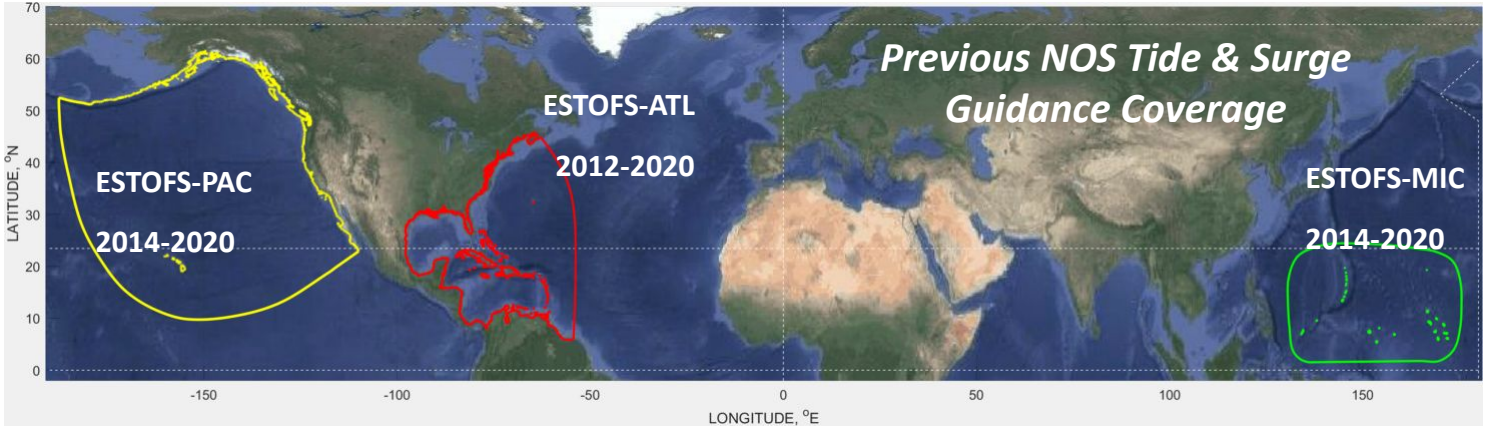
- Inland flooding and inundation
- High-resolution unstructured mesh
- Tides and storm surge non-linear interaction

ADCIRC v55 - latest stable release

- Internal tides dissipation (SAL)
- Gridded or parametric atmospheric forcing
- High-performance parallel computing environment
- Sea ice effect on wind drag
- Option for baroclinic pressure gradient
- Support for ESMF/NUOPC coupling

ADCIRC developers and users group meeting
NOAA - College Park, MD (2018)

Previous ESTOFS Coverage



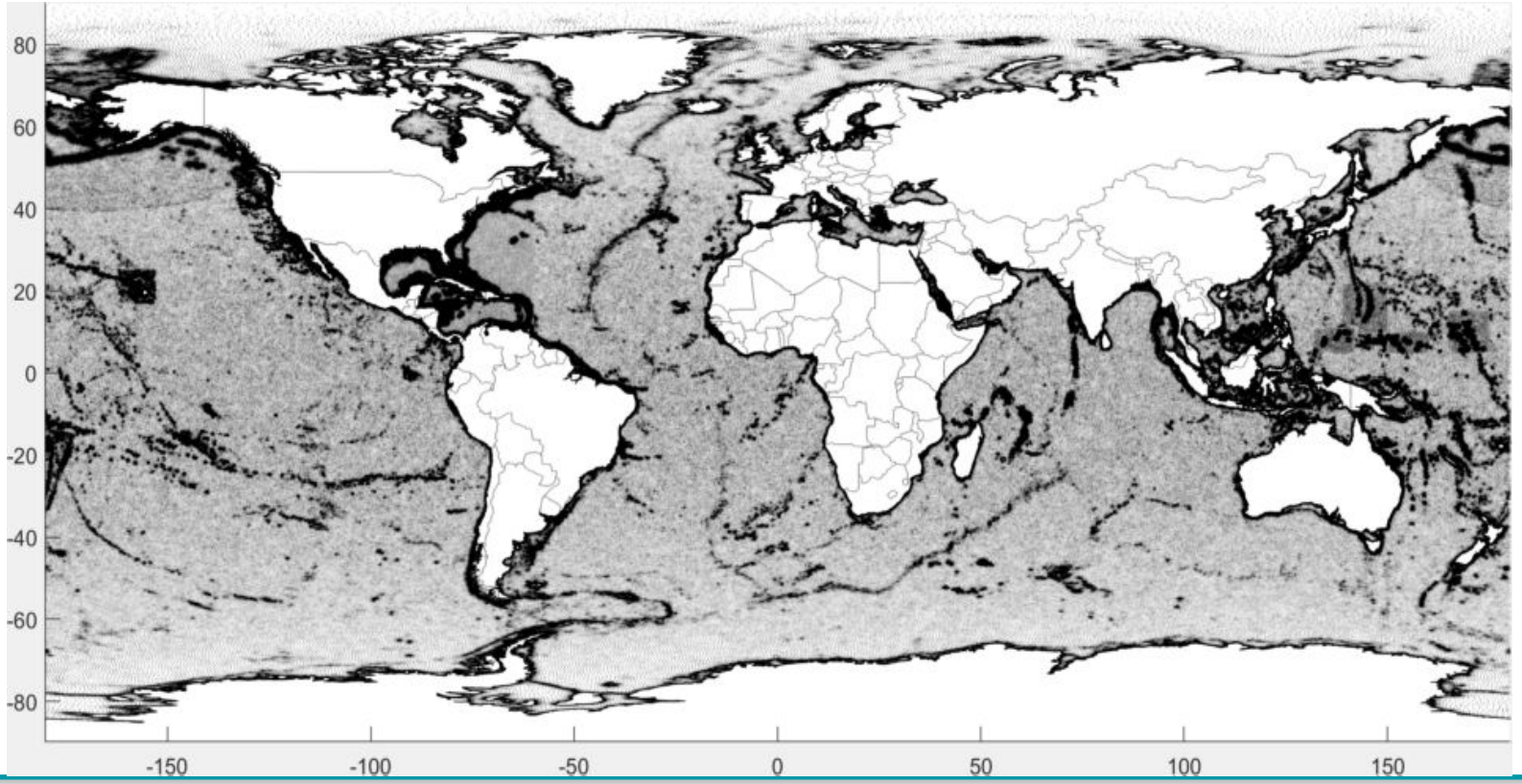
Gaps in Coverage:

- Western Alaska
- American Samoa
- Northwest Pacific
- Southwest Pacific
- Many others

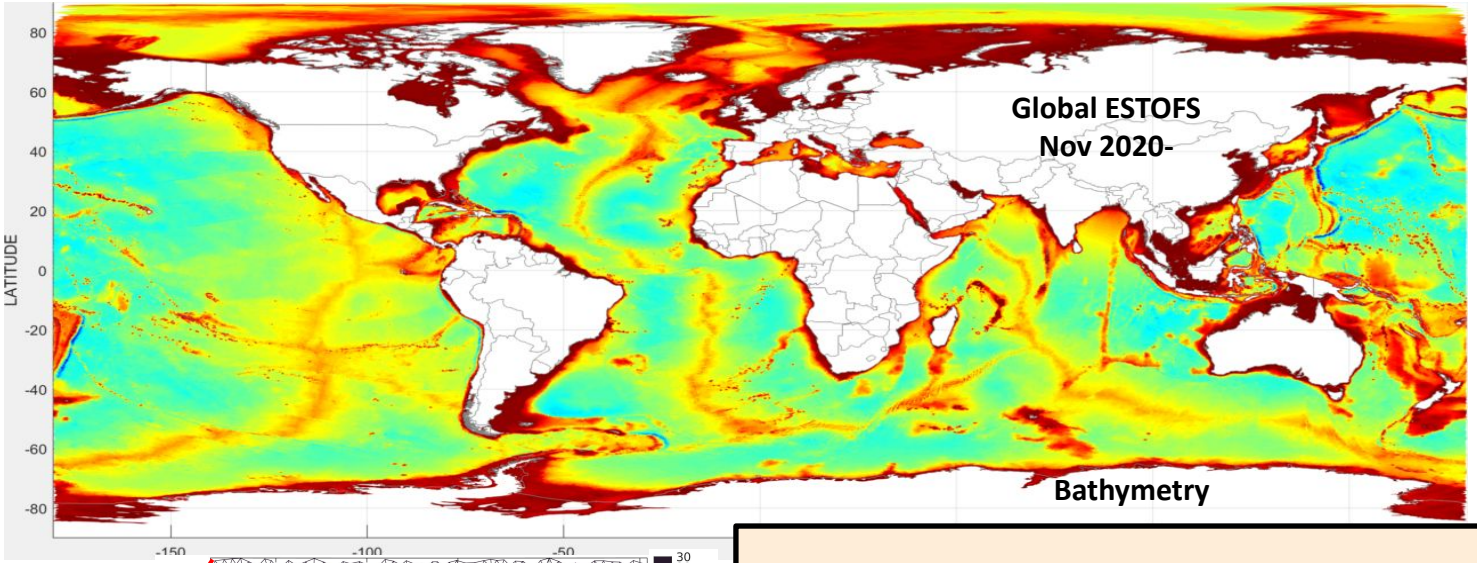
Operational Needs:

- Unification of ESTOFS modeling infrastructure
- Reduction of errors due to removal of the open ocean boundaries
- Inclusion of internal tide-induced dissipation in deep ocean
- Sea ice effect on wind drag
- Bias correction

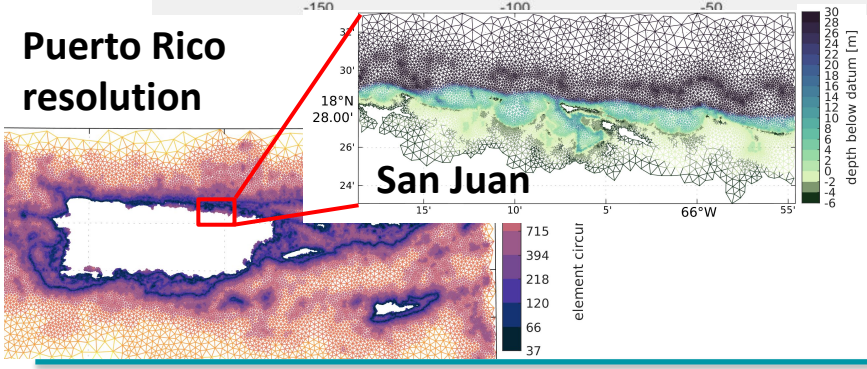
In 2020, we merged various local meshes with a base global mesh



Global ESTOFS Description



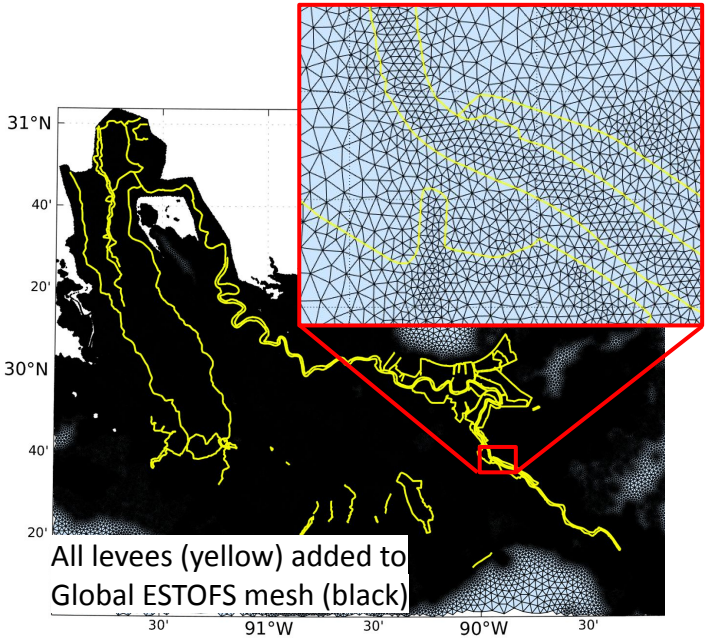
Puerto Rico resolution

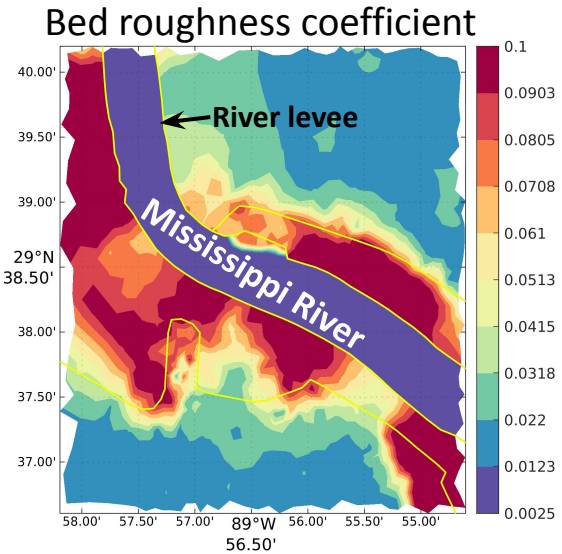


- **Model capabilities:** 7.5 day forecast water levels, every 6 hrs
- **Coastal resolution:** At least 1.5 km, up to 80 m globally
- **Highest resolution operational global surge model available today (to our knowledge)**
- **Next upgrade:**
  - Even higher resolution (25 m) in key ports
  - *Improving model bathymetry & shoreline

Global ESTOFS: Levees in Louisiana/Mississippi

- Levees, critical for flooding and navigation, included Global ESTOFS in July 2021





End users of Global ESTOFS

- **Storm surge forecasters**, e.g.
  - NWS Weather Forecast Offices (WFOs) to generate **flood** forecasts during winter storms
  - NOAA Ocean Prediction Center (OPC) for operational extratropical coastal storm surge forecasts

National Weather Service

Watches, Warnings & Advisories

weather.gov

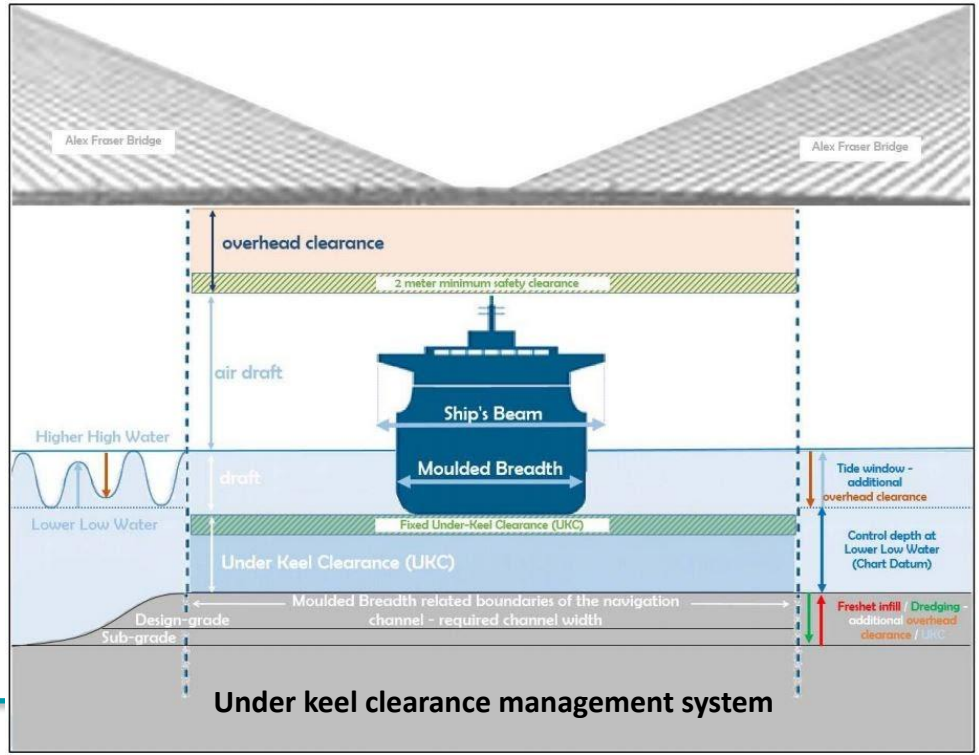
Local weather forecast by "City, St" or zip code City, St Go

Coastal Flood Statement

```
Coastal Hazard Message
National Weather Service Boston/Norton MA
1239 PM EST Fri Dec 18 2020

MAZ024-182200-
/O.NEW.KBOX.CF.S.0015.201218T1800Z-201218T2200Z/
Nantucket MA-
1239 PM EST Fri Dec 18 2020

* WHAT...1 foot or less of inundation above ground level expected
  in low-lying areas near shorelines and tidal waterways
  (4.6 to 5.1 feet Mean Lower Low Water).

* WHERE...Nantucket MA County.

* WHEN...Until 5 PM EST this afternoon.

* IMPACTS...Some water on low lying roads and property.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

Do not drive through flooded roadways.
```

NWS Coastal Flood Statement

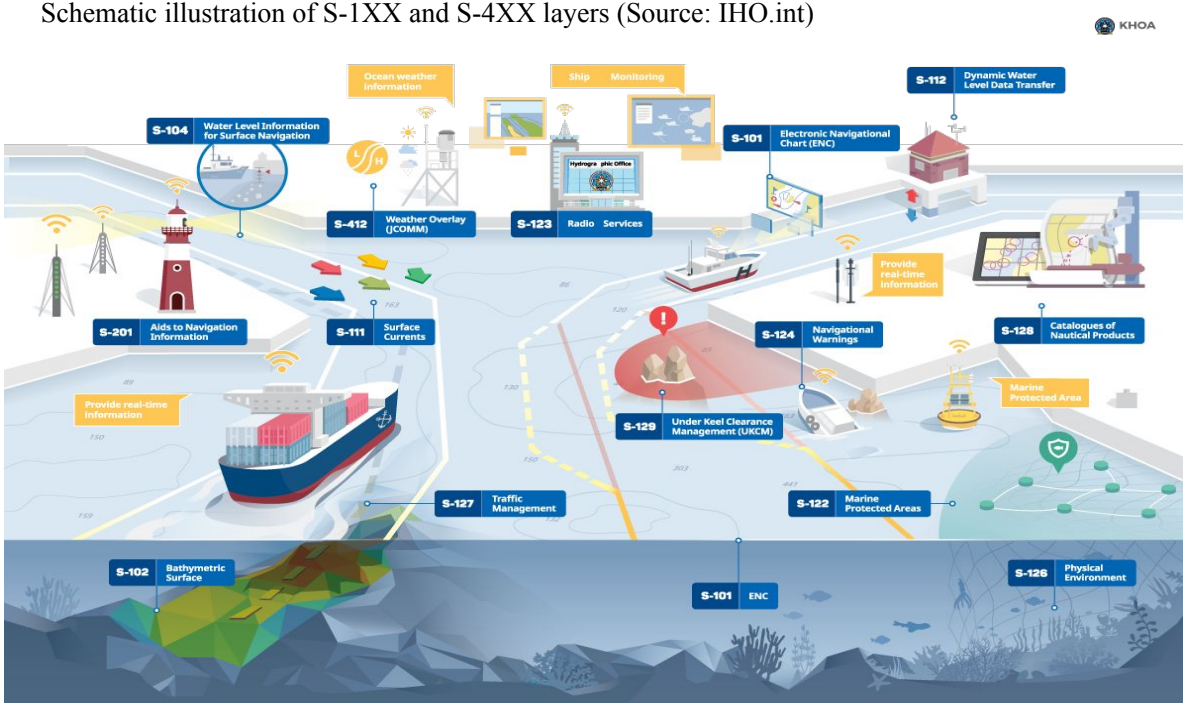
- **Mariners**, e.g.
  - Pilots of ships to **navigate** into ports safely and efficiently based on tide, current forecasts



Under keel clearance management system

Precision Marine Navigation

Schematic illustration of S-1XX and S-4XX layers (Source: IHO.int)



Electronic Chart Display and Information System (ECDIS) Layers

IHO: (S-101 to S-199)

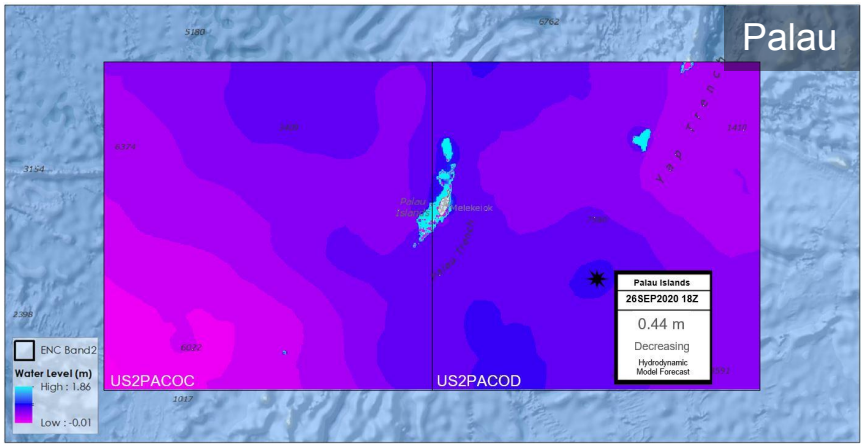
- S-101 Electronic Navigational Chart (ENC)
- S-102 Bathymetric Surface
- S-103 Sub-surface Navigation
- S-104 Water Level Information for Surface Navigation – in progress with NGS and CO-OPS
- S-111 Surface Currents

WMO/IOC: (S-411 to S-414)

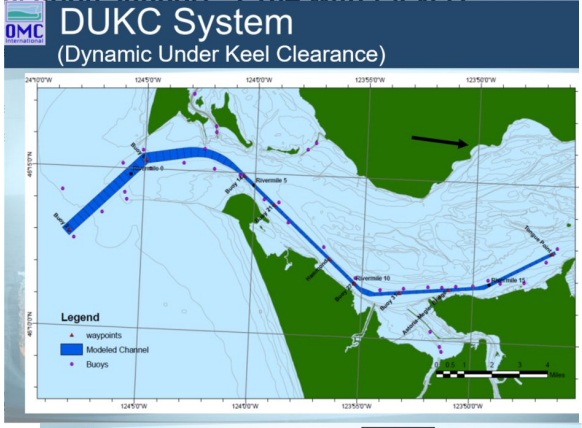
- S-411 JCOMM Ice Information
- S-412 JCOMM Weather Overlay
- S-413 Weather and Wave Conditions
- S-414 Weather and Wave Observations

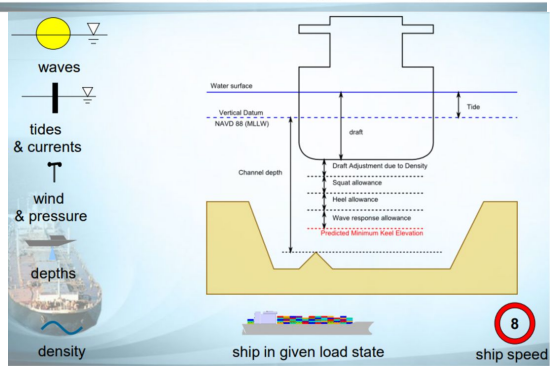
Navigation Support: S-104 water levels

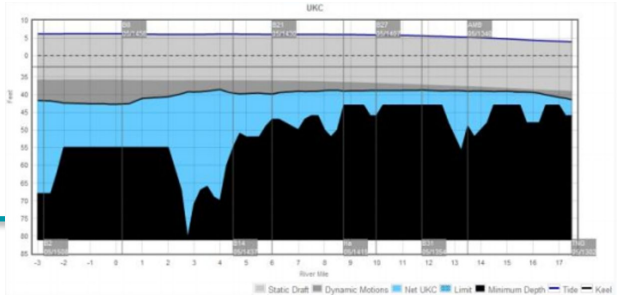
- One of our biggest challenges: our coastal ocean models are referenced to MSL. **For charting and navigation, we need to use chart datum, e.g. MLLW or LAT.**
- Global ESTOFS forecast guidance is being encoded in formats following IHO's S-100 Universal Hydrographic Data framework
- For example, **S-104 water levels relative to chart datum**
- Mariners can use water level forecasts for improved route monitoring



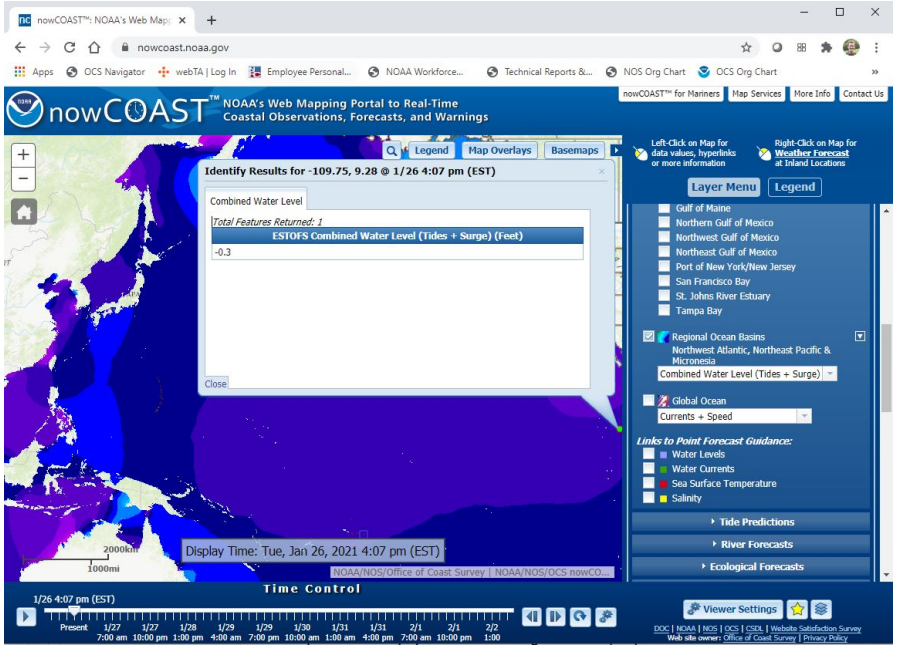
Prototype **S-104 water level forecast guidance from Global ESTOFS, produced and displayed on Electronic Navigational Chart (ENC) Band 2 tiles for Palau in the Pacific Ocean.**





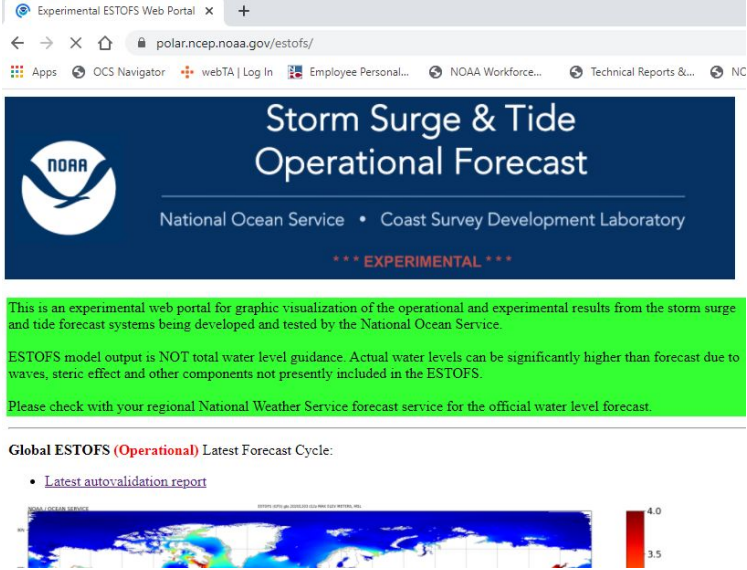


How to access Global ESTOFS results



nowcoast.noaa.gov

Screenshot of Global ESTOFS storm surge forecast guidance for Pacific region displaying nowCOAST's map viewer



polar.ncep.noaa.gov/estofs/

Screenshot of experimental ESTOFS landing page

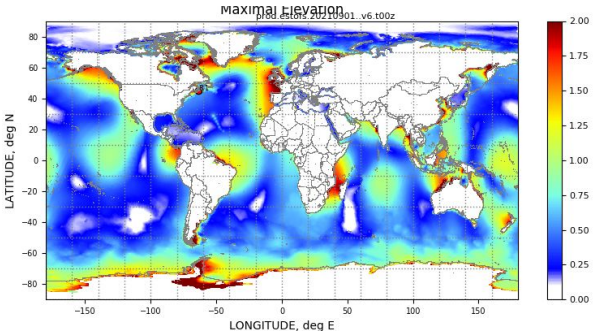
Other options:

National Weather Service (NWS) Ocean Prediction Center: https://ocean.weather.gov/estofs/estofs_surge_info.php

NWS NOMADS: https://nomads.ncep.noaa.gov/

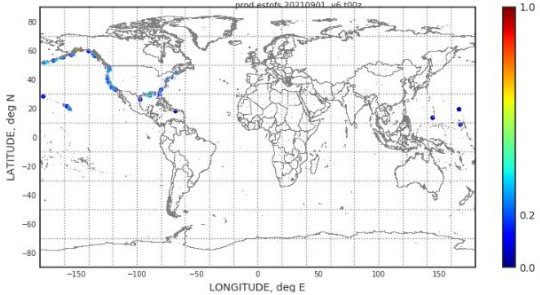
How to access Global ESTOFS results

ESTOFS Output Validation
Generated: 2021-09-01 11:07:50.425097 UTC

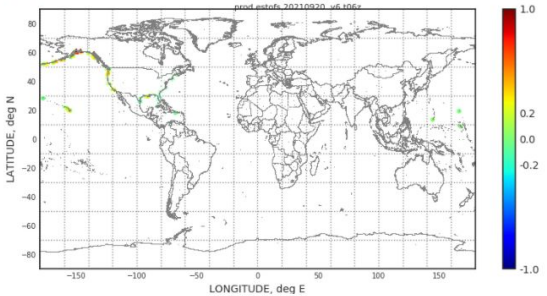


Average time-series statistics:

rmsd

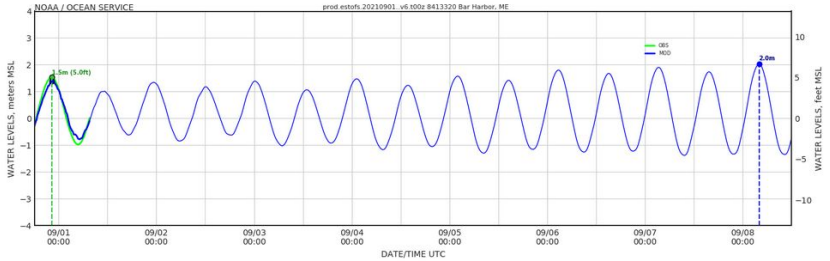


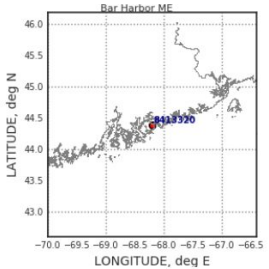
bias

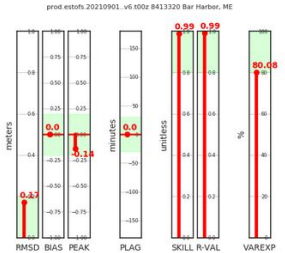


rmsd	peak	plag	bias	vexp	skil	rval	npts
0.17	0.11	-26.92	0.06	66.66	0.9	0.92	42.12

8413320: Bar Harbor ME





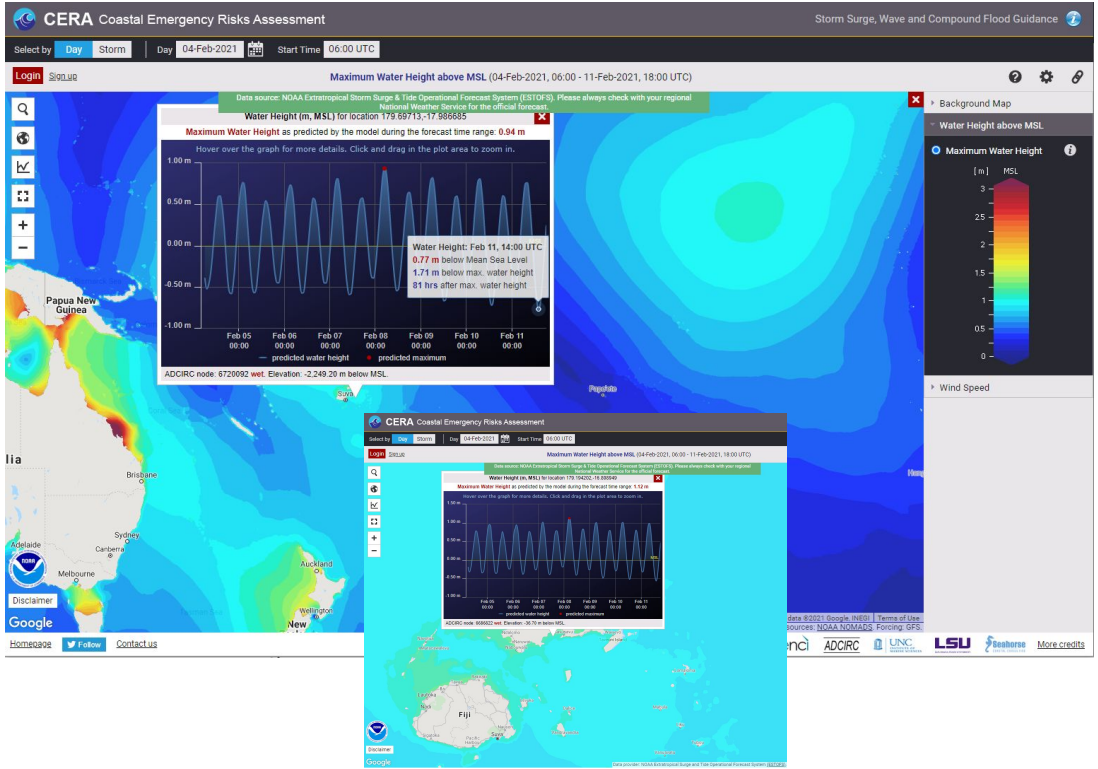


rmsd	peak	plag	bias	vexp	skil	rval	npts
0.17	-0.14	0.0	0.0	80.08	0.99	0.99	136

https://polar.ncep.noaa.gov/estofs/autoval/estofs.glo

Global ESTOFS storm surge latest **forecast guidance and statistics**

How to access Global ESTOFS results



https://cera.coastalrisk.live/

(Username: nos.surge@noaa.gov Password: nos.surge)

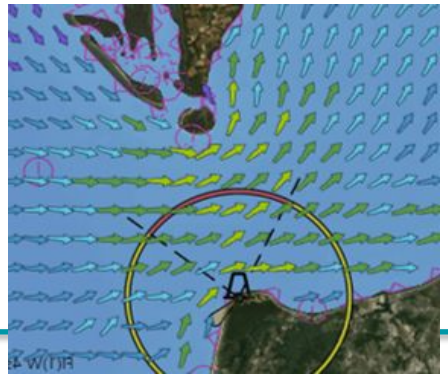
Screenshots of Global ESTOFS storm surge forecast guidance (zoomable)

registry.opendata.aws/noaa-gestofs

Screenshot of Global ESTOFS output on Amazon cloud (AWS) via NOAA Big Data

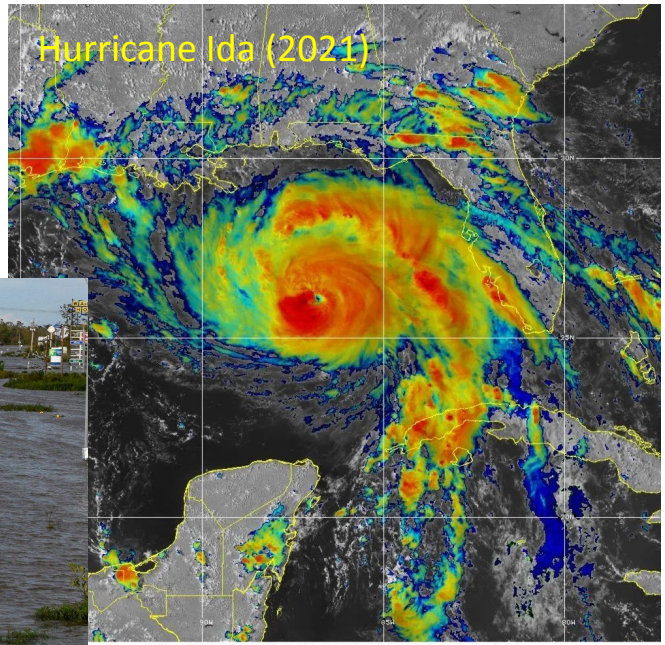
Future ESTOFS directions

- Upcoming upgrades include:
  - Remove “E” for Extratropical from name→ Global STOFS
  - Improve coastal inundation (flooding/drying) performance
  - Include new bathymetry (from you!)
  - Further improve coastal resolution, especially at Pacific ports
  - Include 3D component with inland flooding effect on coastal regions for Atlantic, and then Pacific
    - **S-111 high resolution surface currents**

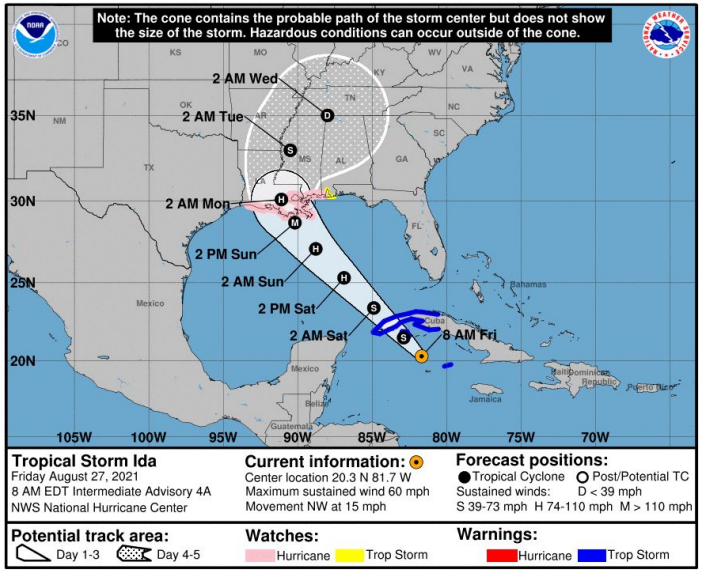


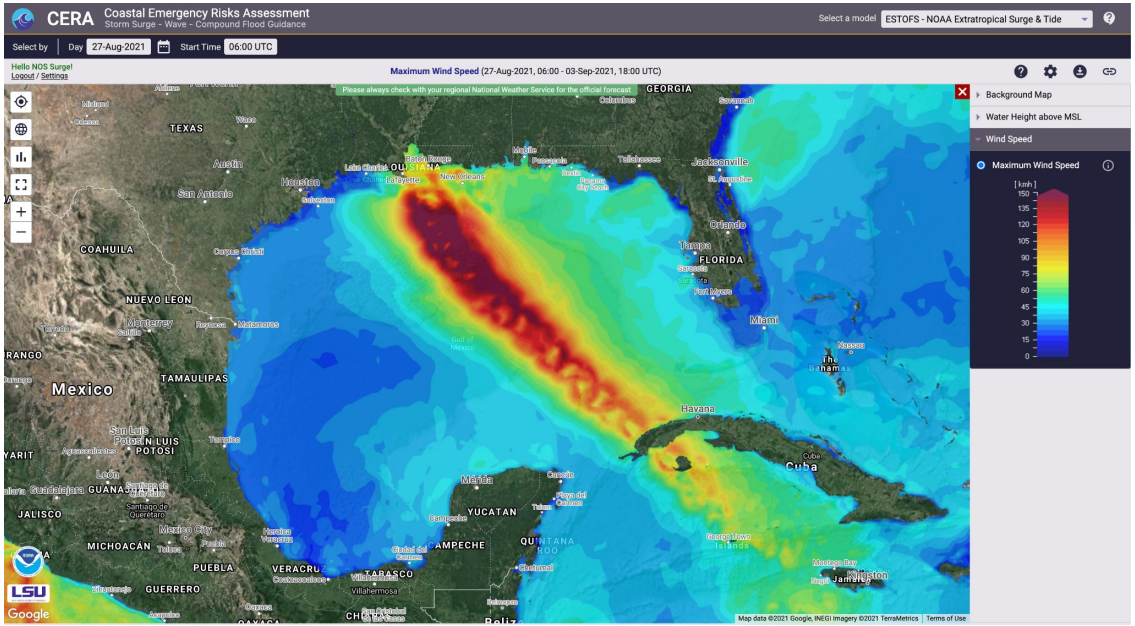
Cases using Coastal Emergency Risks Assessment (CERA) web portal

- Hurricane Ida (2021)
- Tides in Pacific
- Typhoon in Pacific



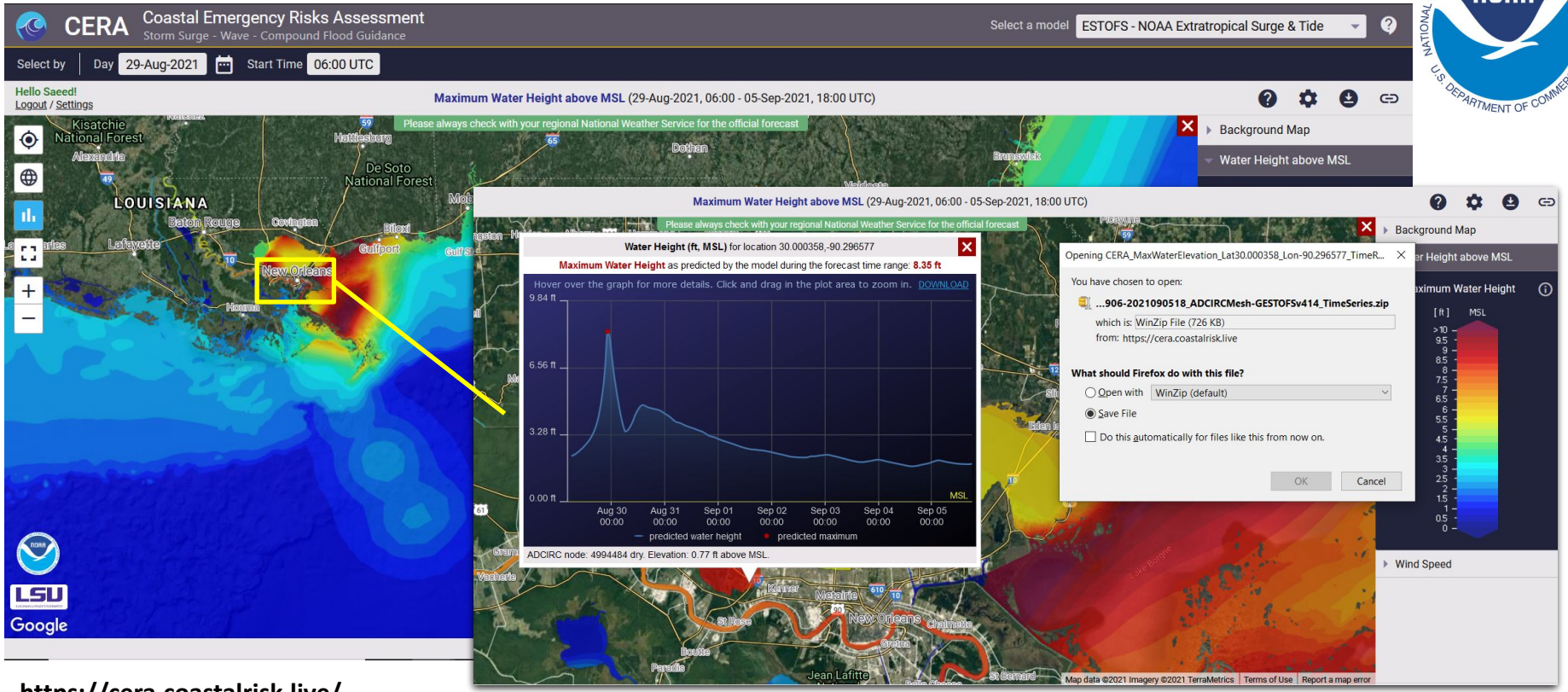
Hurricane Ida (August 2021)





CERA: Hurricane Ida (2021)

Storm surge (disaster mitigation use)

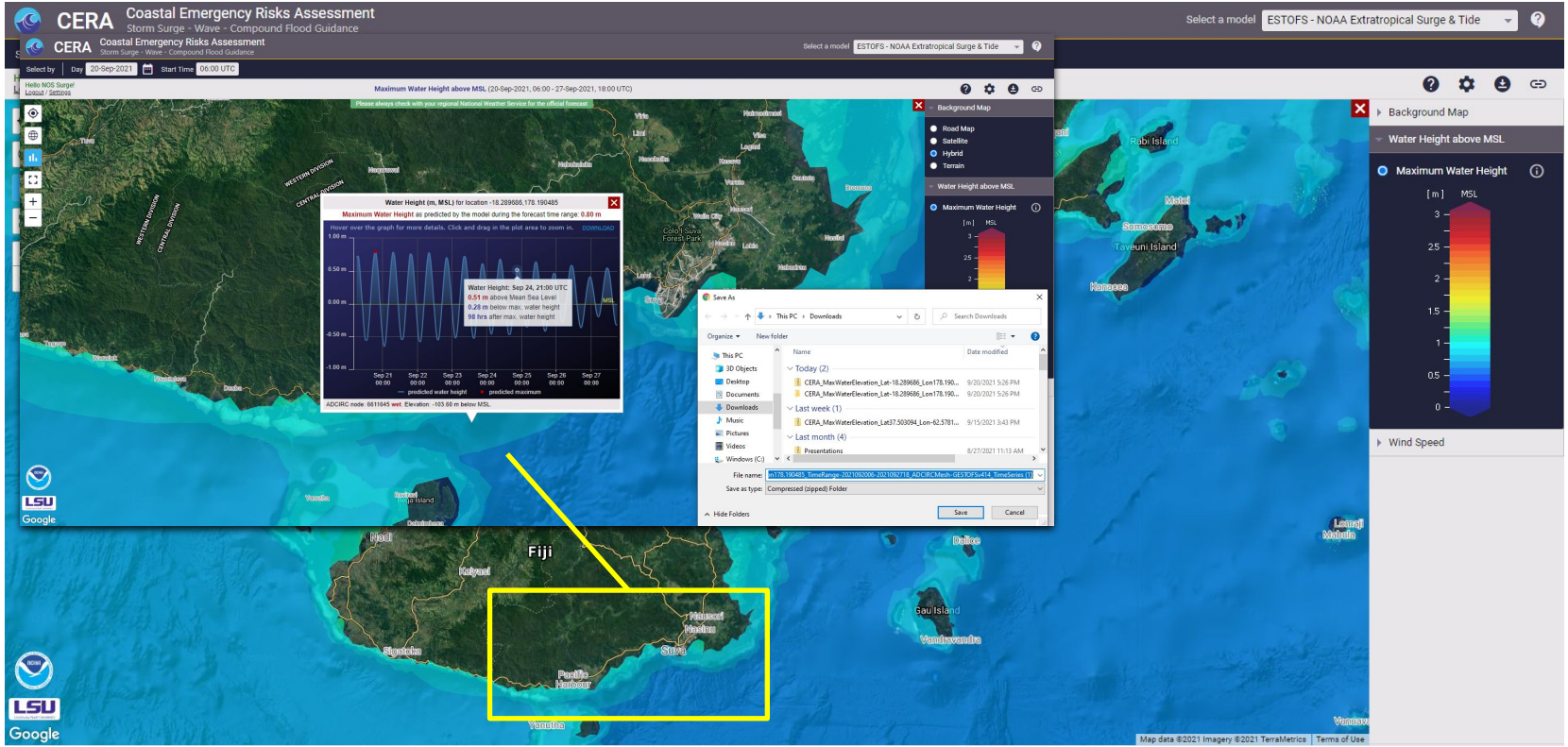


https://cera.coastalrisk.live/
(User: nos.surge@noaa.gov Password: nos.surge)

Screenshot of Global ESTOFS storm surge forecast guidance (zoomable)

CERA: Tides in Fiji

Tides (marine navigation use)

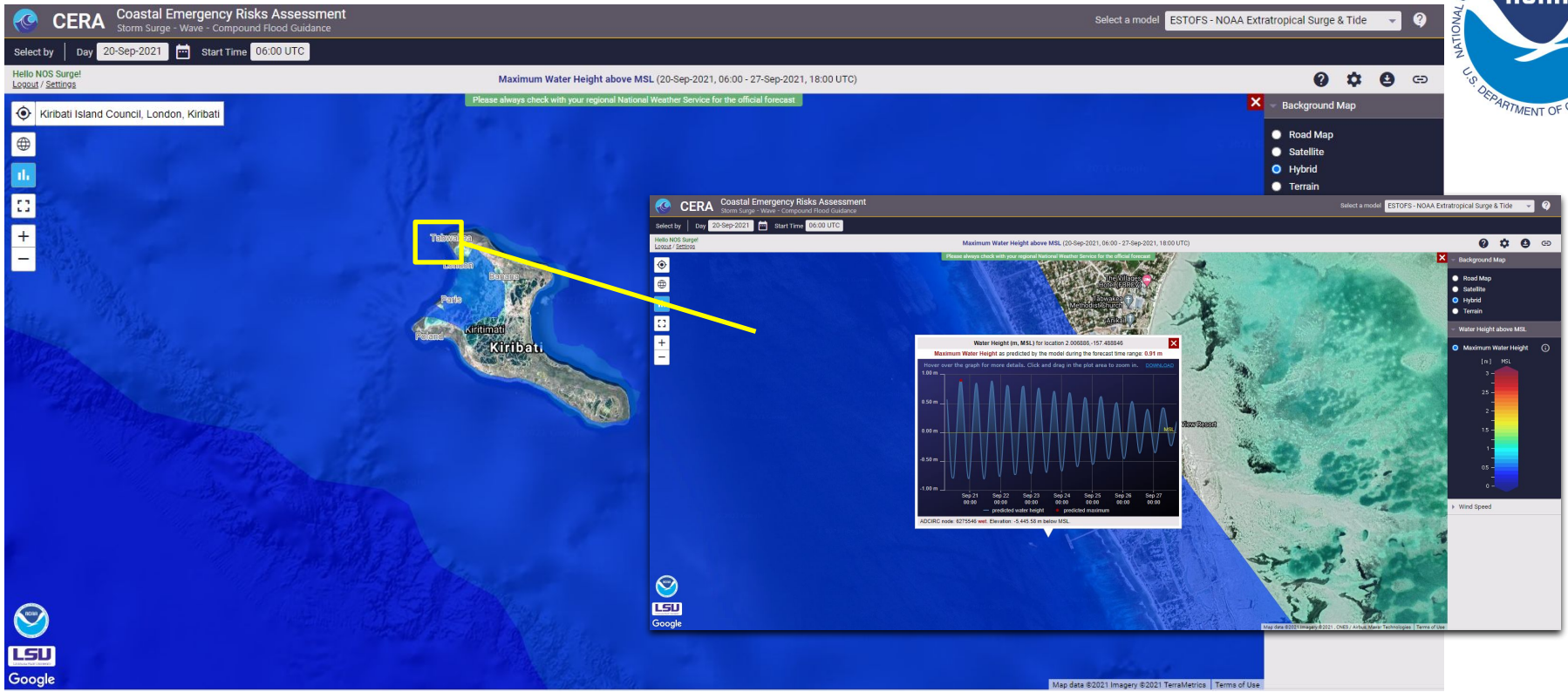


https://cera.coastalrisk.live/
(User: nos.surge@noaa.gov Password: nos.surge)

Screenshot of Global ESTOFS storm surge forecast guidance (zoomable)

CERA: Tides in Kiribati

Tides (marine navigation use)

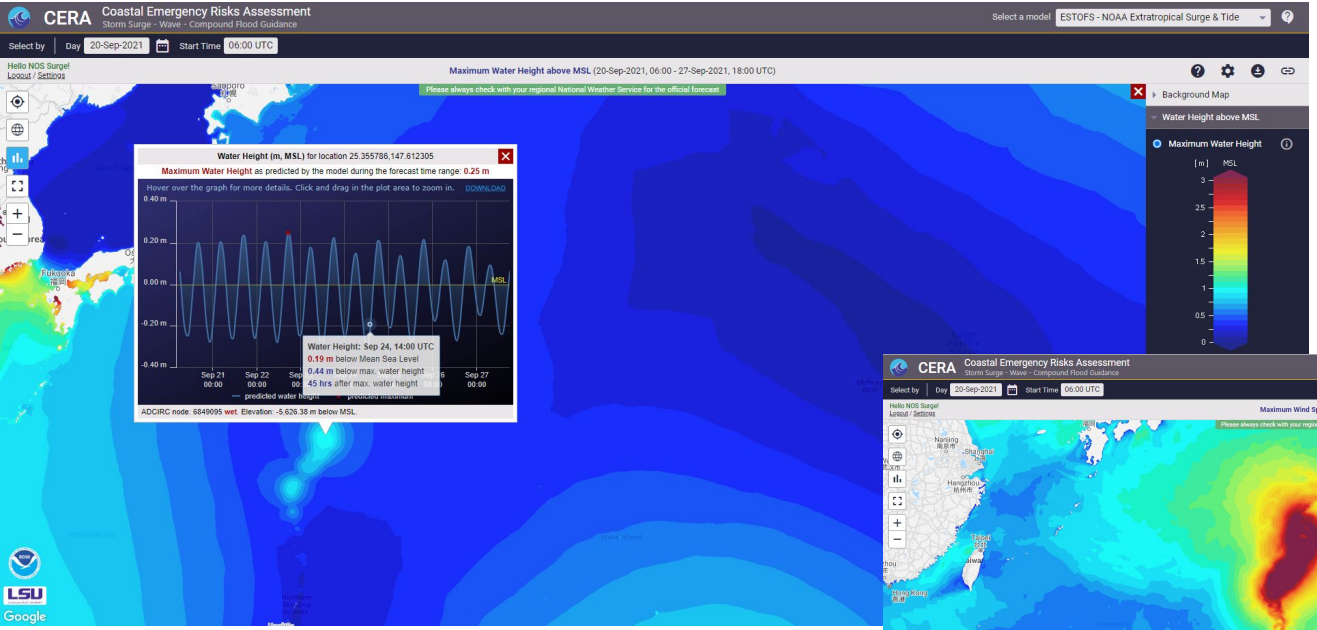


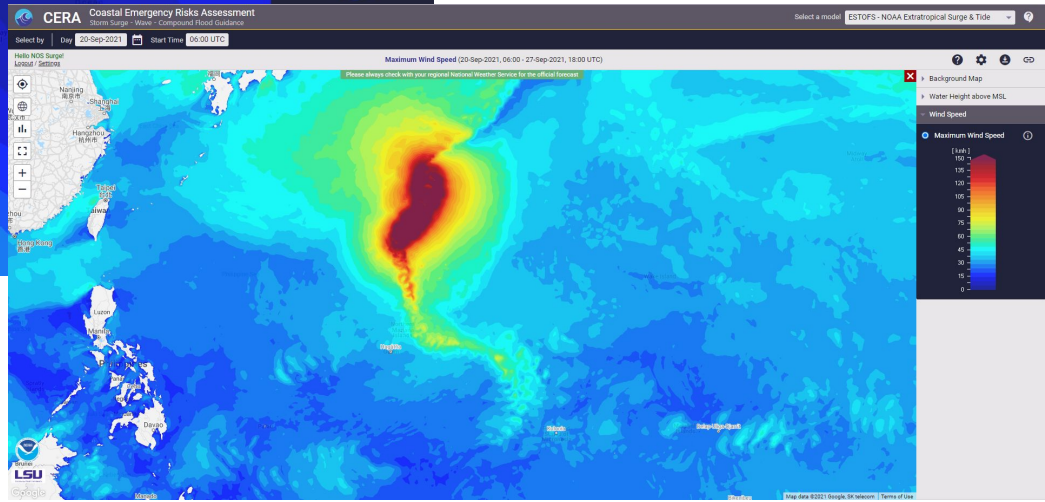
https://cera.coastalrisk.live/
(User: nos.surge@noaa.gov Password: nos.surge)

Screenshot of Global ESTOFS storm surge forecast guidance (zoomable)

CERA: Typhoon in Pacific

Storm surge (disaster mitigation use)





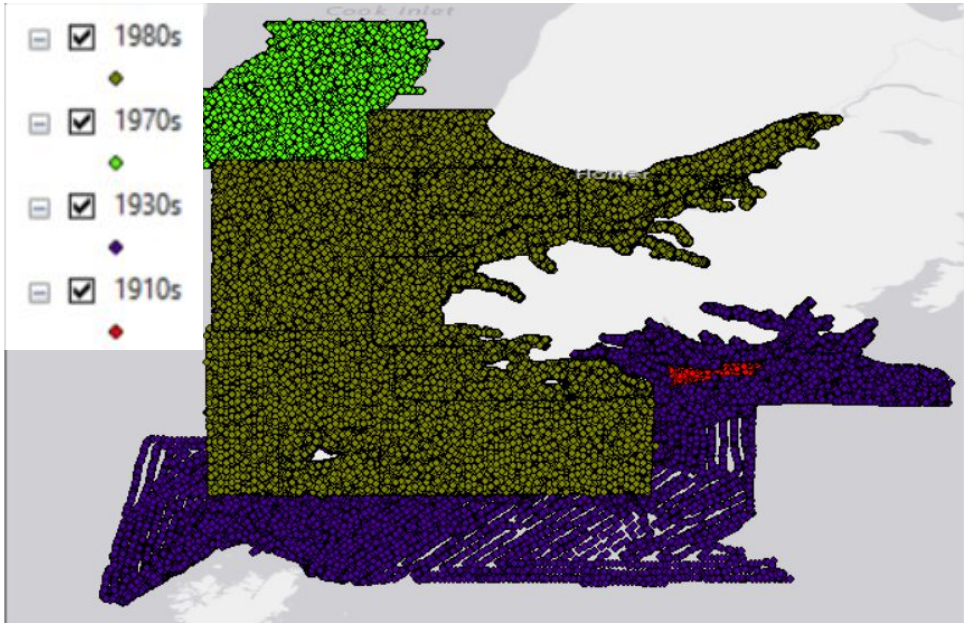
https://cera.coastalrisk.live/
(User: nos.surge@noaa.gov Password: nos.surge)

Screenshot of Global ESTOFS storm surge forecast guidance (zoomable)

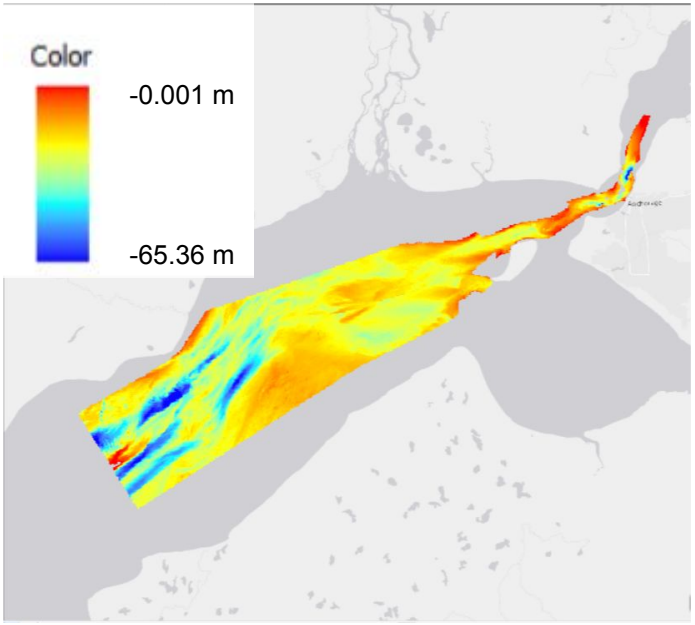
5 minute break

Improving Bathymetry to Improve Models

Point Soundings (Older Hydrographic Surveys)



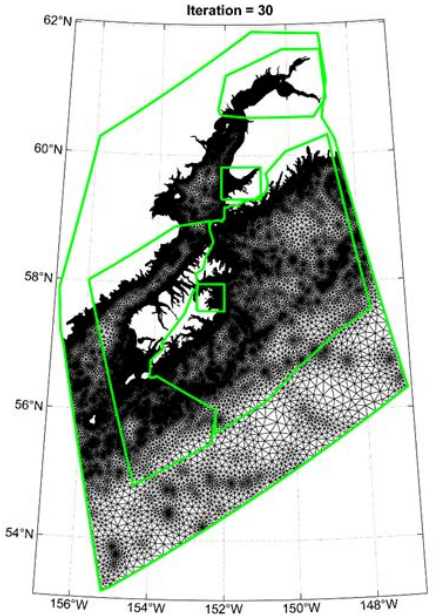
Bathymetric Attributed Grids (BAG) (Newer)



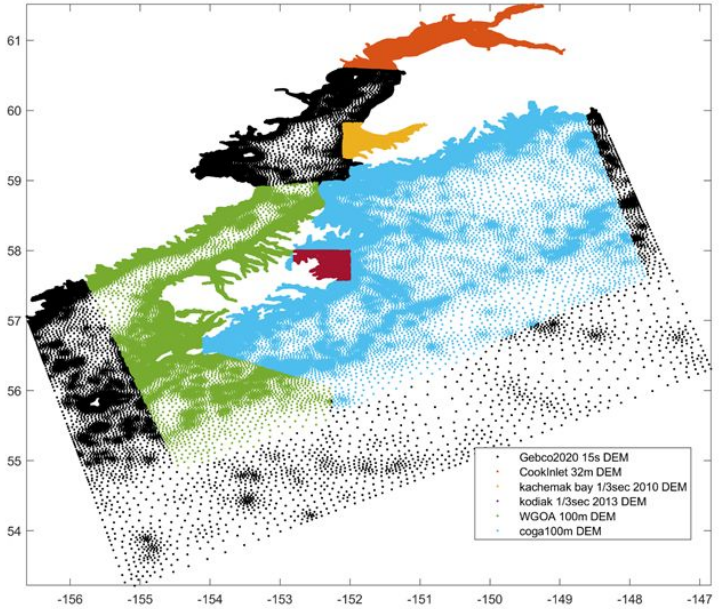
Upgrade Digital Elevation Models (DEMs) with newest bathymetry data to improve model fidelity/accuracy

Updated bathymetry data is incorporated into model

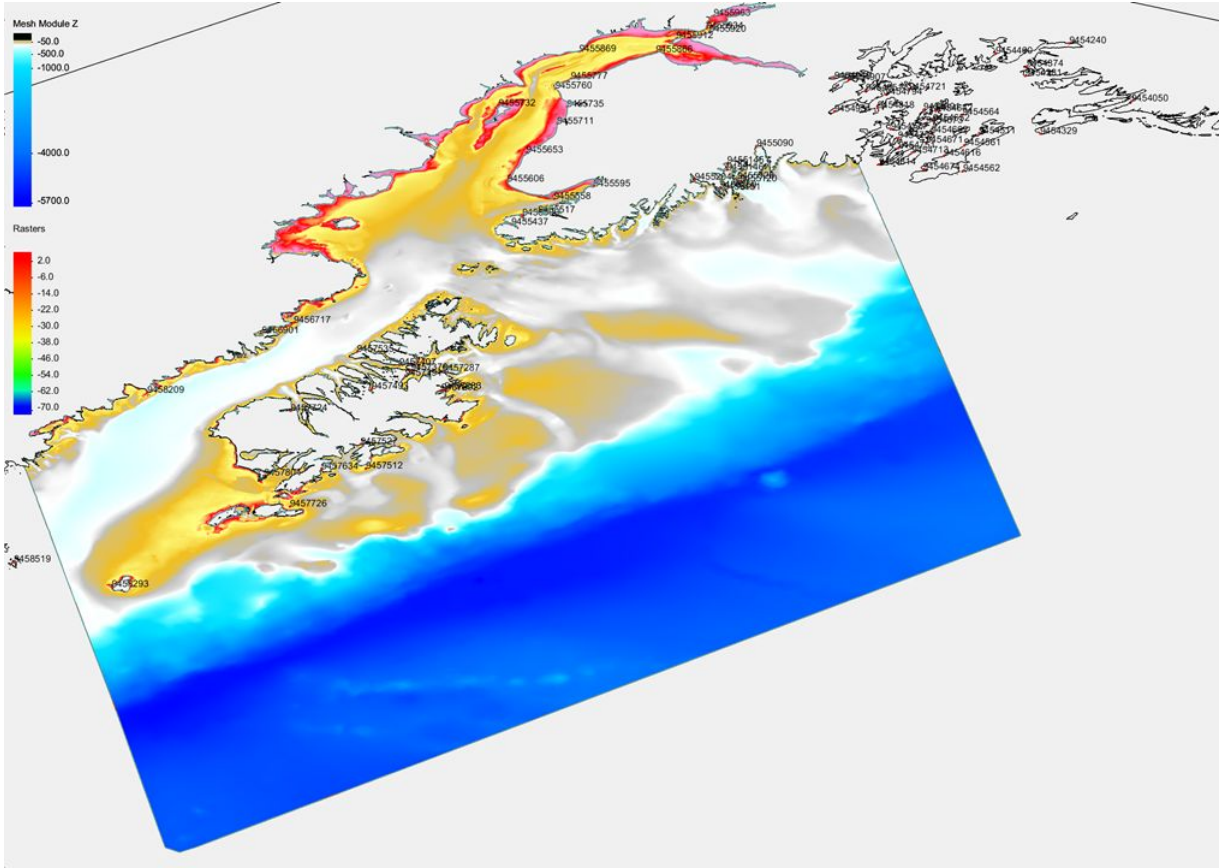
Setting up bathymetry sources in mesh



Various bathymetry sources used in mesh



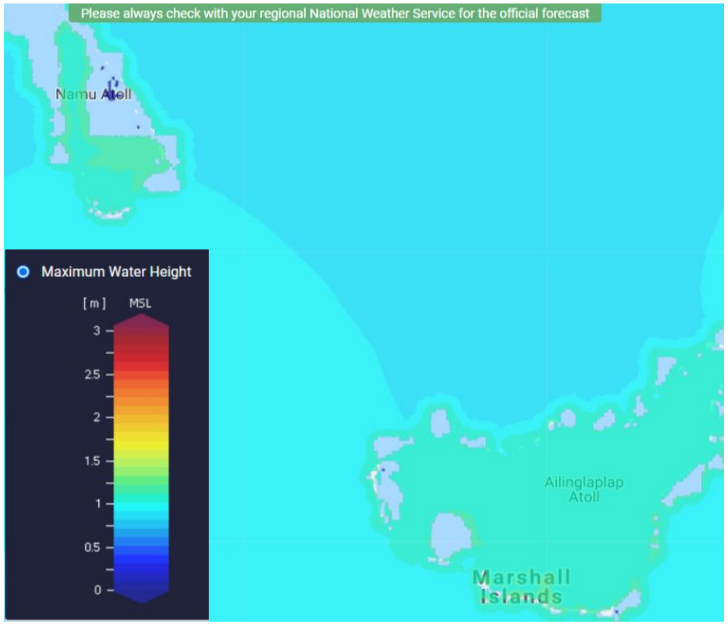
Bathymetry data in model ready for testing



Updated Bathymetry Improved Global ESTOFS

High (red) & low (blue) water spots before upgrade (Apr 2021)

Spots after upgrade (Sep 2021)

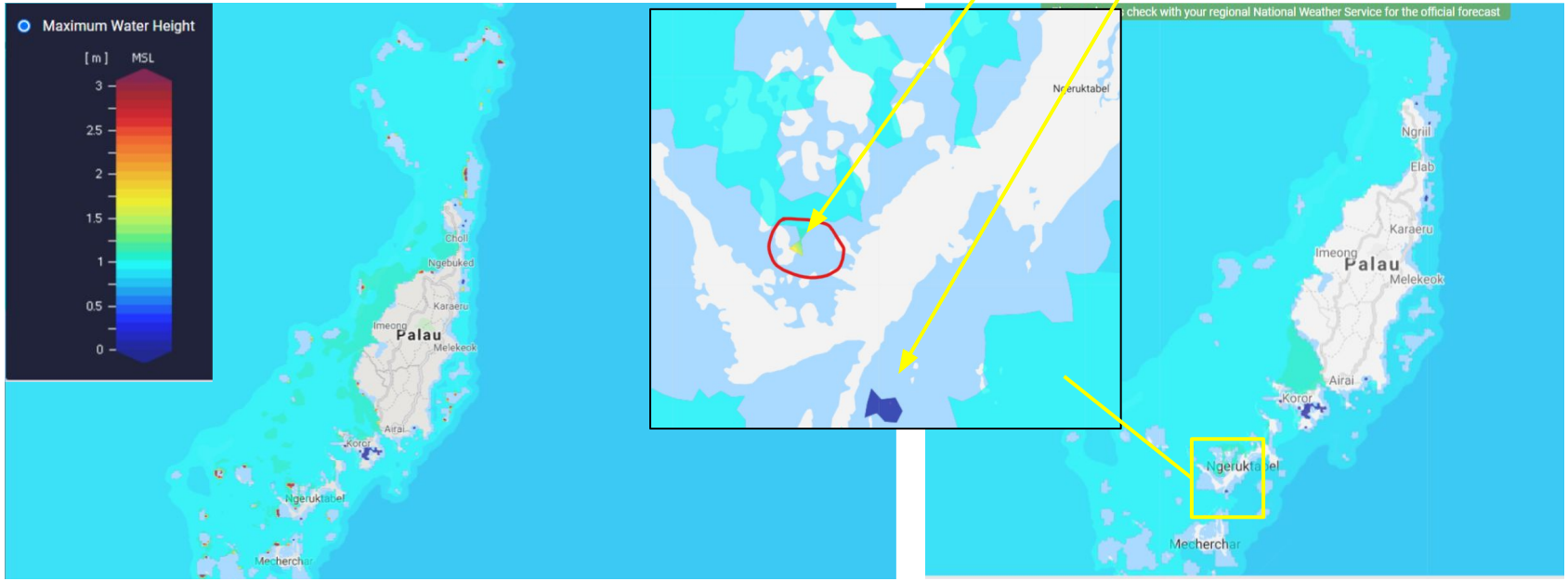


High water spots in the Marshall Islands greatly reduced, but improvements possible with new data

Updated Bathymetry Improved Global ESTOFS

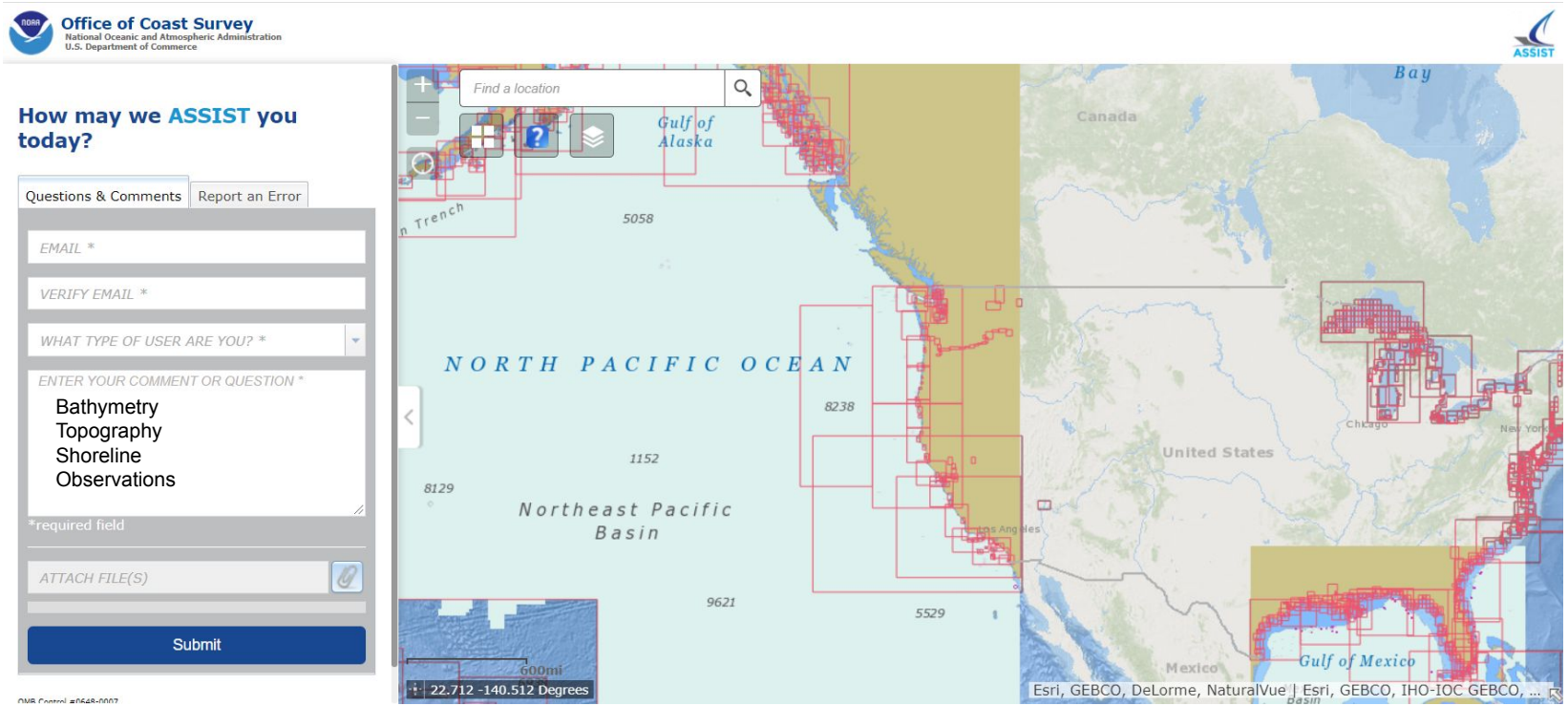
High (red) & low (blue) water spots before upgrade (Apr 2021)

Some transient spots still appear (Sep 2021)



Similarly around Palau, high water spots were greatly reduced, but we need your help and bathymetry data

ASSIST - Stakeholder Engagement and Feedback Tool

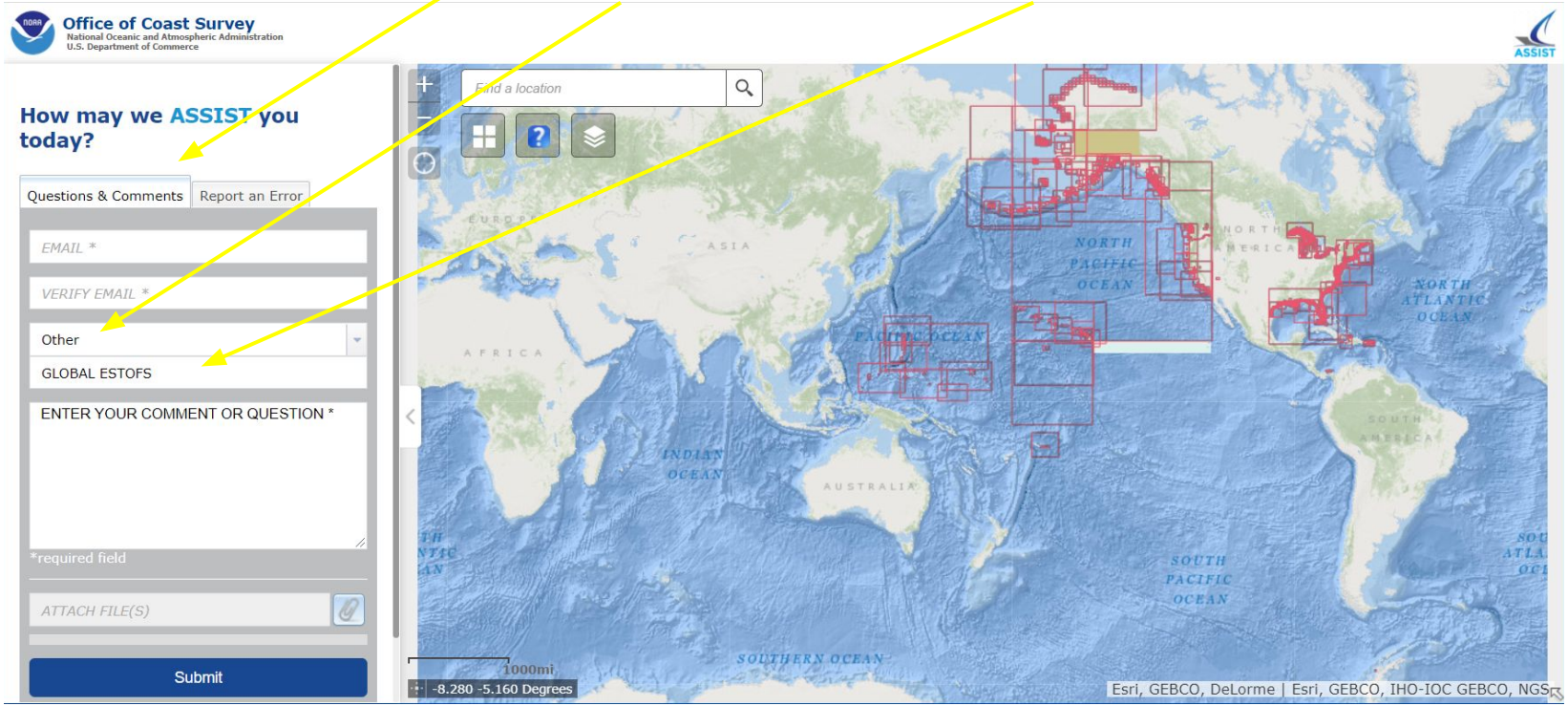


Homepage:

https://www.nauticalcharts.noaa.gov/customer-service/assist/

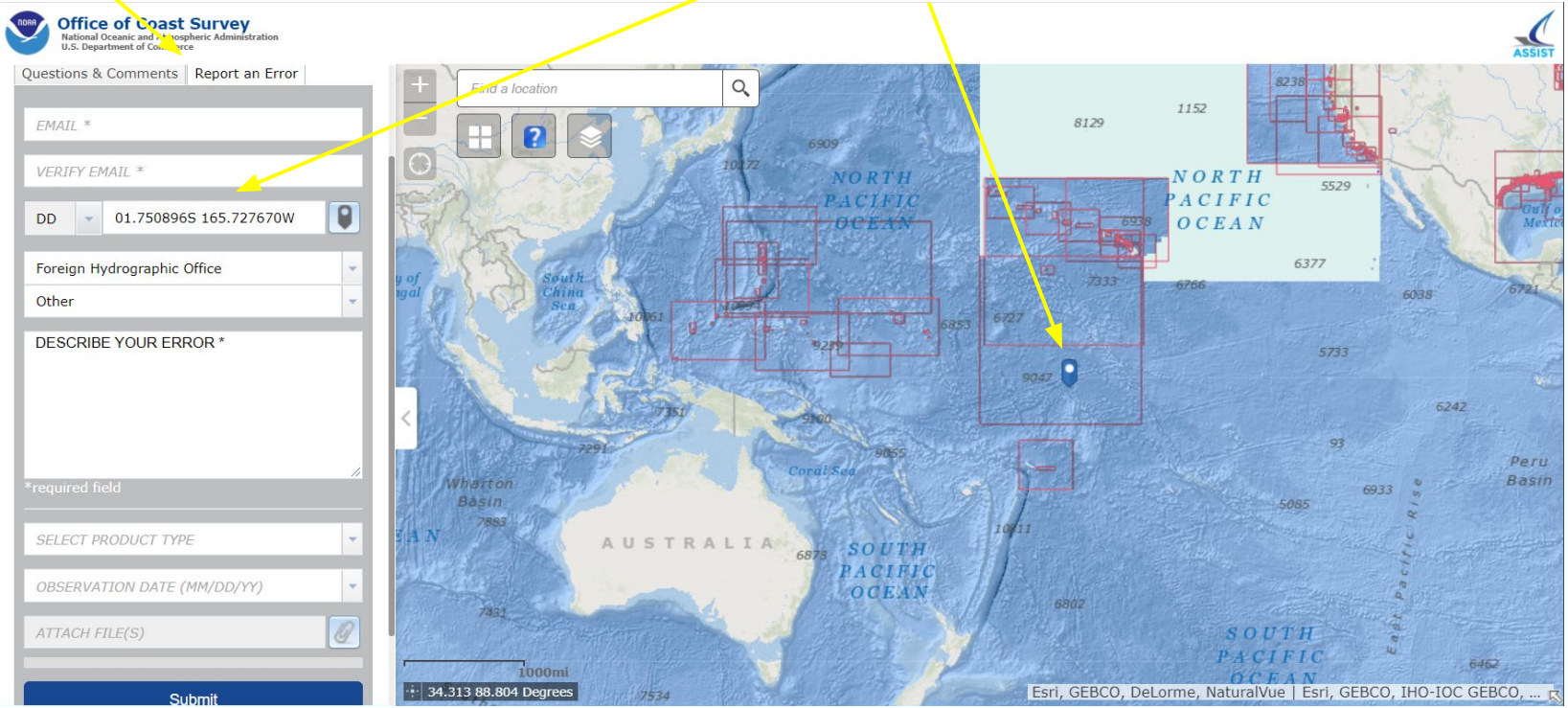
ASSIST - Stakeholder Engagement and Feedback Tool

Submit questions or comments as User ‘Other’ and specify ‘Global ESTOFS’



ASSIST - Stakeholder Engagement and Feedback Tool

Report errors - You can specify coordinates by typing or clicking on the map



Demo
cera.coastalrisk.live

(Username: nos.surge@noaa.gov Password: nos.surge)

1. Hurricane Ida

Demo

cera.coastalrisk.live

(Username: nos.surge@noaa.gov Password: nos.surge)

1. **Hurricane Ida**
2. **Tides (Fiji, Kiribati)**

Demo

cera.coastalrisk.live

(Username: nos.surge@noaa.gov Password: nos.surge)

1. **Hurricane Ida**
2. **Tides (Fiji, Kiribati)**
3. **Pacific typhoon**

CERA interactive workshop/discussion/Q&A

- Participants log in
  a. Go to the CERA web portal at https://cera.coastalrisk.live
  b. Click on the red "Login" button at the top left.
  c. Insert the username and password:
     Username: **nos.surge@noaa.gov**
     Password: **nos.surge**
  d. Once logged in, click on the "Select a model" dropdown menu at top right and click on "ESTOFS - NOAA Extratropical Surge & Tide"
  e. Explore the zoomable web interface!
- Go to area of interest
- Ask questions

CERA interactive workshop/discussion/Q&A (cont'd)

- 3 guiding questions:
  a. From the 26 August 2021 forecast for Ida, what is the maximum water height forecast by ESTOFS? (hint: near New Orleans, LA)
  b. From the 20 September 2021 forecast, about when does ESTOFS forecast the maximum water height to occur just offshore Suva, Fiji?
  c. From today's forecast, what is the minimum water height forecast by ESTOFS for your Pacific island/area of interest?
- Quirks we've encountered
- Q/A

CERA Tutorial:

a. https://cera.coastalrisk.live/cera_risk/_docs/CERA_tutorial.html

Thank you!

Contact: Michael.Lalime@noaa.gov

Reference links

CERA: https://cera.coastalrisk.live/

- User: nos.surge@noaa.gov, Password: nos.surge
- Tutorial: https://cera.coastalrisk.live/cera_risk/_docs/CERA_tutorial.html

ASSIST

- Homepage: https://www.nauticalcharts.noaa.gov/customer-service/assist/
- Help: https://www.nauticalcharts.noaa.gov/customer-service/assist.html

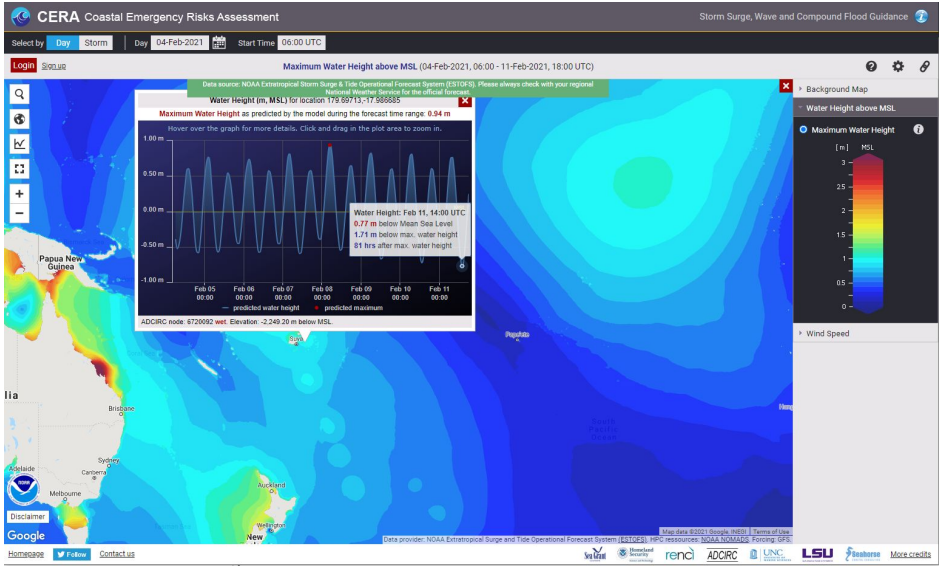
nowCOAST: https://nowcoast.noaa.gov/

Polar: https://polar.ncep.noaa.gov/estofs/

AWS: https://noaa-gestofs-pds.s3.amazonaws.com/index.html

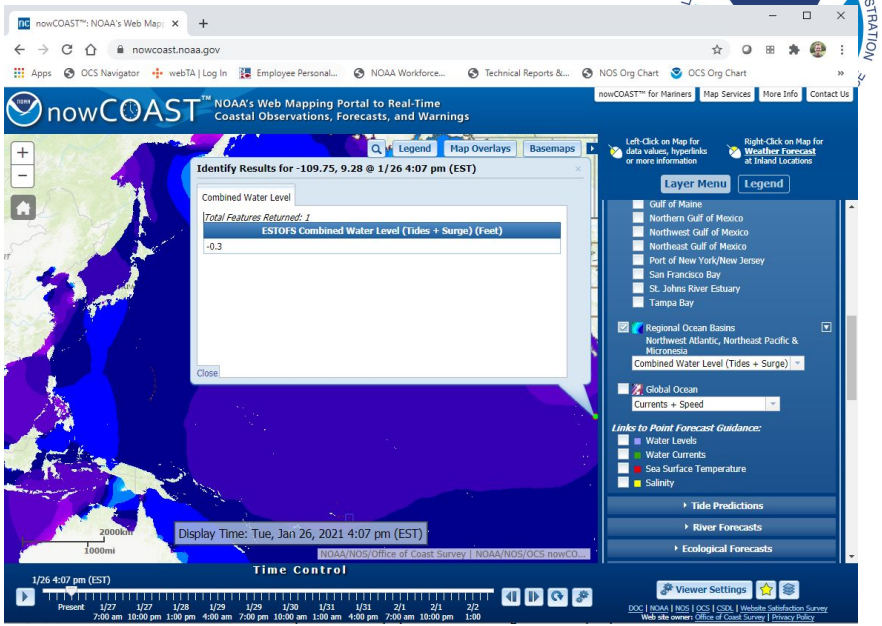
Supplementary slides

How to access Global ESTOFS results



cera.coastalrisk.live

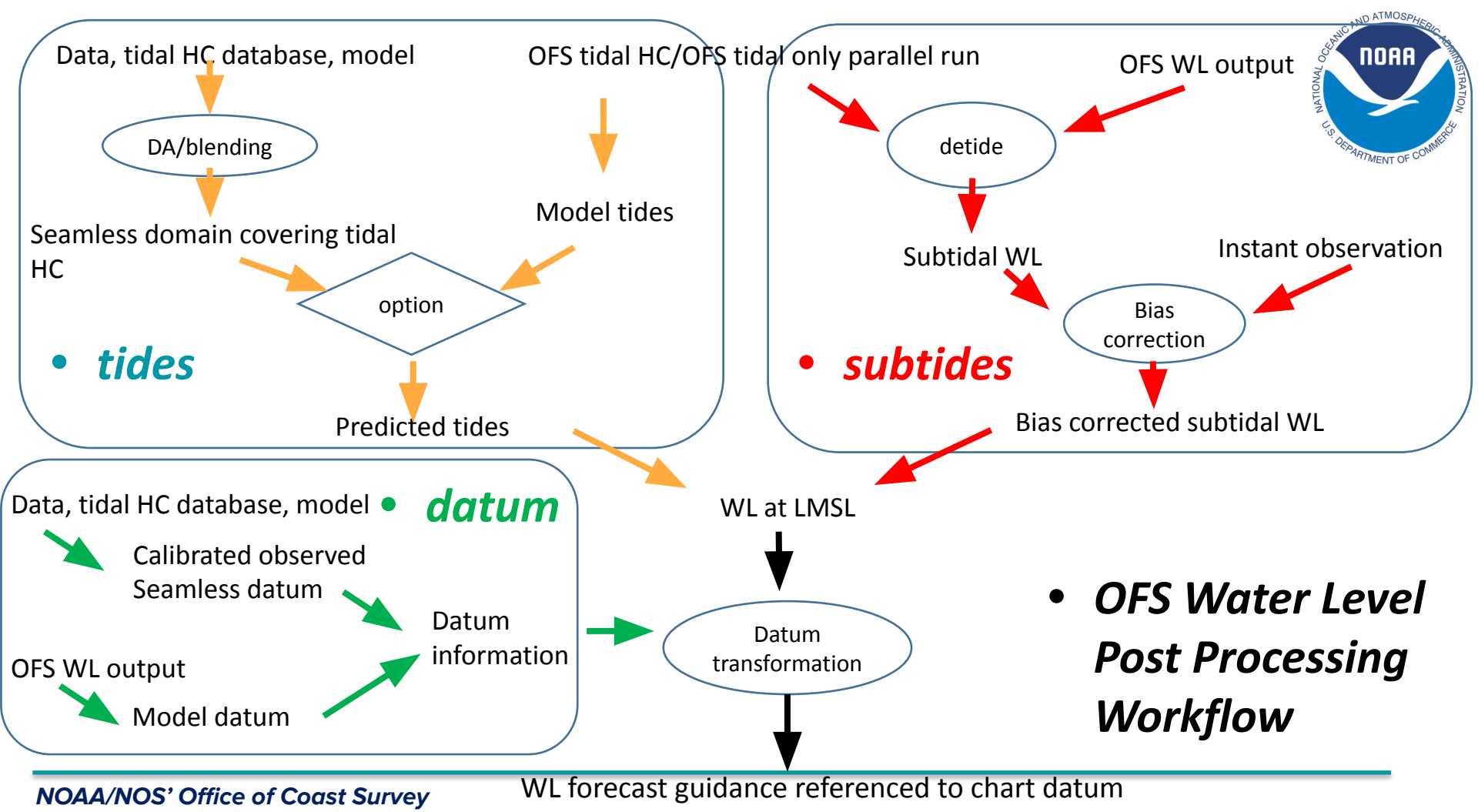
Screenshot of Global ESTOFS storm surge forecast guidance for SW Pacific displayed on CERA's map viewer (zoomable)



nowcoast.noaa.gov

Screenshot of Global ESTOFS storm surge forecast guidance for Pacific region displaying nowCOAST's map viewer (zoomable)

- **We are providing training workshops for the end user community to learn how to use the model forecast guidance**
- **Output available on Amazon cloud via NOAA Big Data (registry.opendata.aws/noaa-gestofs)**


Data, tidal HC database, model
DA/blending
Seamless domain covering tidal HC
OFS tidal HC/OFS tidal only parallel run
Model tides
option
• tides
Predicted tides
OFS WL output
detide
Subtidal WL
Instant observation
Bias correction
• subtides
Bias corrected subtidal WL
Data, tidal HC database, model
• datum
Calibrated observed Seamless datum
OFS WL output
Model datum
Datum information
WL at LMSL
Datum transformation
• OFS Water Level Post Processing Workflow
WL forecast guidance referenced to chart datum