

Latest Developments to Improve Operational Storm Surge & Tide Forecasting Systems at the US National Ocean Service



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Summary

- NOAA / Ocean Service Storm Surge Products
- Extratropical Forecast
 - ESTOFS-Atlantic
 - ESTOFS-Pacific
 - ESTOFS-Micronesia
 - Dissemination
 - Global ESTOFS
- Alaska Coastal Ocean Forecast System (ALCOFS)
- On-Demand Forecast (HSOFS)
- Hindcast / Reanalysis (Named Storm Event Model)
- Modeling Frameworks & Infrastructure
- Precision Navigation



NOAA / Ocean Service Storm Surge Products

- Extratropical Storm & Tide Operational Forecast System (ESTOFS)
- Hurricane Surge On-Demand Forecast System (HSOFS)
 - Short-Term Ensemble Forecast
 - Post-Landfall Ensemble Hindcast
- COASTAL Act Named Storm Event Model (NSEM)

- ran by NCEP/NCO continuously - ran by NHC pre- / post-landfall
- post-event coupled reanalysis



Component	ESTOFS-ATL	ESTOFS-PAC	ESTOFS-MIC	HSOFS-ATL (forecast)	HSOFS-ATL (hindcast)	NSEM (COASTAL Act)
Grid resolution	160+ m	2+ km	200+ m	160+ m	160+ m	160+ m
Forcing	GFS 13km	GFS 55km	GFS 13km	NHC Advisory	NHC Track	HWRF/URMA/ RTMA
Ensembles	1	1	1	7+	6-9	1
Forecast frequency/ lead time	4/day up to 7 days	4/day up to 7 days	4/day up to 7 days	Every near- landfall advisory	Post-landfall hindcast	Post-landfall hindcast/reanalysis
Inland flooding	Yes	No	Yes	Yes	Yes	Yes
Coupling	No	No	No	No	No	WW3 via NUOPC
Data assimilation	No	No	No	Yes	Yes	Yes

ESTOFS – Atlantic

In operation since 2012

Major Upgrade (April 24 2017)

- Covers US East and Gulf Coast + Caribbean
- HSOFS grid + inland flooding
- 200 m coastal resolution
- 1.8M nodes
- GFS 13-km forcing

Cycles 00z, 06z, 12z and 18z 6-hr nowcast + 180-hr forecast

- Provides live boundary conditions for
 Nearshore Wave Prediction System (NWPS)
- 6-min water levels at 128 coastal tide gauges
- Hourly water levels for the whole domain





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

ESTOFS – Pacific

In operation since 2014

- Covers US West Coast + Hawaii
- 1-3 km coastal resolution
- 132K nodes
- No inland flooding
- GFS 55-km forcing

Cycles 00z, 06z, 12z and 18z 6-hr nowcast + 180-hr forecast

- Provides live boundary conditions for Nearshore Wave
 Prediction System (NWPS)
- 6-min water levels at 71 coastal tide gauges
- Hourly water levels for the whole domain

Future upgrades will include

- Increase forcing resolution to 13km
- Update model grid







ESTOFS – Micronesia

In operation since Feb 2018

- Covers Palau, Mariana Islands, Fed State of Micronesia, Marshall Islands, Wake Island
- Up to 200 m coastal resolution
- Overland up to 10m elevation



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



- GFS 13-km forcing
- 24-hr nowcast + 180-hr forecast
- Will provide live boundary conditions for regional wave models
- Water levels at 4 CO-OPS tide gauges and 40+ populated islands and warning points

Digital: NOAA NOMADS server

Basic Graphics: Ocean Prediction Center (OPC)



https://ocean.weather.gov/

NORA

Dissemination



NowCOAST (NOS)

https://nowcoast.noaa.gov

ПОАА

Dissemination

ПОАА

Experimental Dissemination on Polar



Storm Surge & Tide Operational Forecast

National Ocean Service • Coast Survey Development Laboratory

EXPERIMENTAL

is is an experimental web portal for graphic visualization of the operational and experimental results from the storm surg I tide forecast systems being developed and tested by the National Ocean Service.

STOPS model output is NOT a total water level guidance. Actual water levels can be significantly higher than forecast due aves, steric effect and other components not presently included in the ESTOPS.

ase check with your regional National Weather Service forecast service for the official water level

ESTOFS-Global (Experimental) Latest Forecast Cycle:





ESTOFS-Atlantic Latest Forecast Cycle:

National Hurricane Center's Five-Day Graphical Tropical Weather Outlook in the Atlantic



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

Dissemination

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Domain Reports:

- Max Forecasted Elevations
- Time Series + Observations

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

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NOAA / NATIONAL OCEAN SERVICE ACTIVE STATIONS

Observed Coastal Water Level Anomalies

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

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DD4: Pringle



Amplitudes and phases for M2 tidal harmonic derived from 90-days preliminary test run with 4-20 km spatial resolution (global ADCIRC setup and mesh provided by Johannes Westerink, University of Notre Dame)

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

Global ESTOFS

Tentatively scheduled Q4FY20



Maximal 7-days CWL forecast, issued 20191003.t00z

Maximal 7-days GFS winds, issued 20191003.t00z

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



estofs.glo.2019103100.htp



Global ESTOFS

estofs.glo.2019103100.cwl





estofs.glo.2019103100.swl



Global ESTOFS

Proposed features:

- Driven by GFS (FV3)
- Includes ice drag in high latitudes (ice cover input)
- WL correction from RTOFS baroclinic component
- Possible combination with WL Data Assimilation
- Refined coastal & upland res at the US lands
- Provides Boundary Conditions to NWPS anywhere in the world
- Provides Initial Conditions for relocatable HSOFS anywhere in the world
- Provides coastal anomaly estimates along the US coasts



Future upgrades

- Further refinement of the mesh resolution in the US
- GFS Precipitation
- NWM River Coupling
- Sea Ice Model Coupling
- Waves?

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Global ESTOFS

NOAA



Alaska Coastal Ocean Forecast System (ALCOFS)

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E1: Westerink



NOAA

Custom Ensemble Perturbations Track Shift + Any other parameter perturbation



HSOFS: Hurricane Storm Surge On-Demand Forecast System

HSOFS v1: June 2016 HSOFS v2: June 2019

- Provides 6 member ensemble guidance for tide and surge from tropical cyclones impacting US East, Gulf coasts and the Caribbean:
 - NHC Official advisory
 - Custom combinatory perturbations
- Assimilates the observed WL anomalies
- Uses ADCIRC to provide a large scale domain with local resolution down to 200 m and employs advanced physics
 - HSOFS grid is 1.8M nodes
 - Covers entire US East/Gulf/Caribbean up to 10m elevation
- Shares the grid with Extratropical Storm and Tide Operational System (ESTOFS)



HSOFS Ensemble Tracks and Ensemble Peak Flood. 2016 Hermine



HSOFS Coverage/Bathymetry

- 2016 Season:
 - Hermine
 - Matthew
 - Nicole
- 2017 Season:
 - Harvey
 - Irma
 - Nate
- 2018 Season:
 - Florence
 - Michael
- 2019 Season:
 Barry



Florence 2018





Florence 2018





Relocatable worldwide











Hindcast / Reanalysis

The Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act

- NOAA develops multi-component Named Storm Event Model (NSEM) to lower costs to FEMA's National Flood Insurance Program (NFIP) by better discerning wind vs water damage in "indeterminate losses"
- Detailed post-storm assessment in the aftermath of a damaging tropical cyclone that strikes the U.S. or its territories, 90% accuracy required

Wind, Precip Reanalysis Surge Model Wave Model

Hydrology



- The skill analysis is confined to a duration of an event, e.g.:
 - High-water mark (HWM) data validation
 - Skill against coastal tide gauges during the storm
- Last issued inundation *forecast* to guide placement of HWM data
- Coastal anomalies to reduce *hindcast* bias
- Fully coupled ADCIRC/WaveWatch III to *hindcast* the best estimate of inundation



BB3: Abdolali

JJ1: Flowers

https://www.weather.gov/sti/coastalact

Modeling Frameworks & Infrastructure

Optimal Mesh Generation

- OceanMesh2D
 - Developed by UND (William Pringle and Keith Roberts)
 - Coastline-driven
 - MATLAB-based
- Geomesh
 - Developed by CSDL (Jaime Calzada)
 - DEM-driven
 - Python-based
 - Using Jigsaw core triangulation

Model Automation

- ADCIRCPy
 - Developed by CSDL (Jaime Calzada)
 - End-to-end preprocessing

Operational Support

• CSDLPy2

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- Developed by CSDL (Sergey Vinogradov)
- ESTOFS, ETSS, SFAS parsers
- Validation tools -- PARA, PROD, HINDCAST
- Graphics





Office of Coast Survey

NOAA

Beyond paper charts: Electronic Display Systems





Office of Coast Survey

Vector database of chart featuresBuilt to IHO's S-57 standard

- Displays ENC's and integrates a variety of real-time information
- Meets IHO regulations and is an alternative to paper charts



(ECDIS - Electronic Chart Display and Information System)



Precision Navigation



- S-100
- Water Levels and Surface Currents





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