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Moving Freshwater to the Ocean: Hydrology-Ocean Model Coupling

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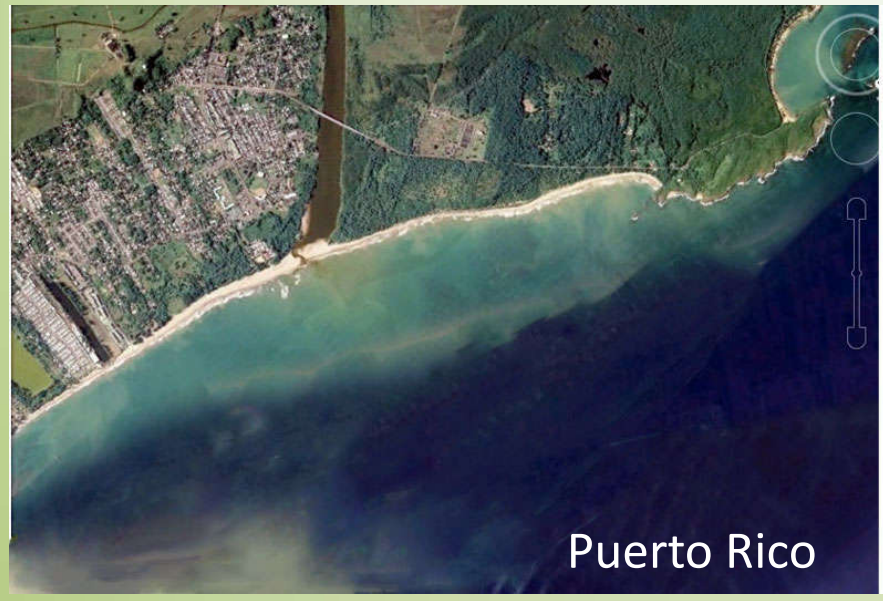
Freshwater Runoff in the Ocean



Ocean dynamics *near the coast and offshore* are altered by incoming freshwater

Multi-scale processes

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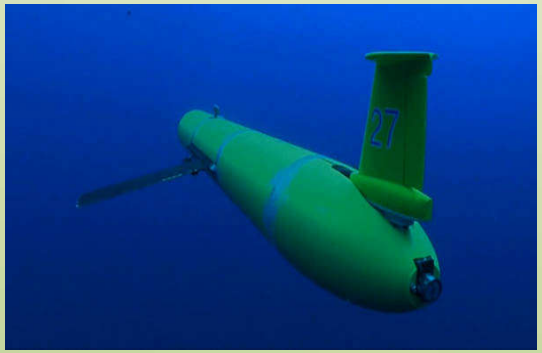
The Problem

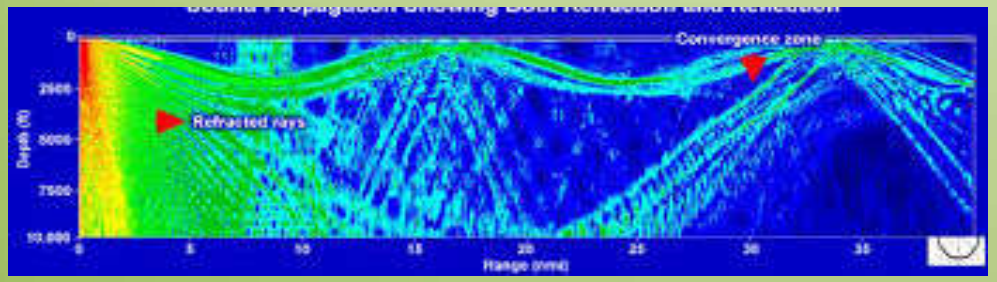
Global, Relocatable coastal ocean prediction capability uses a **Global River Database**

Propulsion Systems

Glider Deployments



Acoustic Propagation



- Monthly mean discharges
- Fixed, coarse, resolution
- **No rainfall-runoff events**

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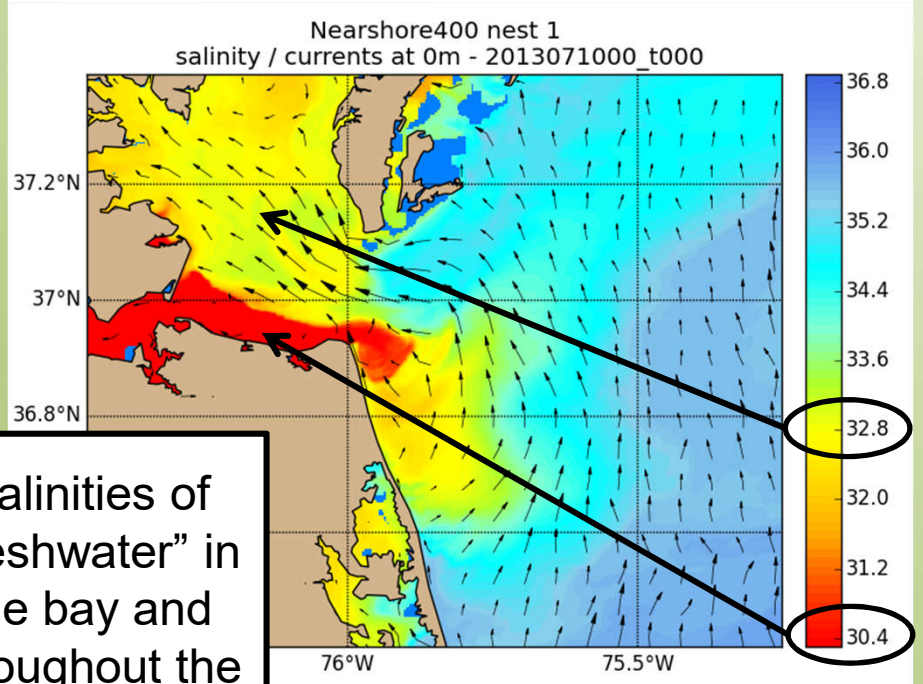
The Problem

Freshwater is not adequately accounted for in regional or coastal operational Navy ocean models

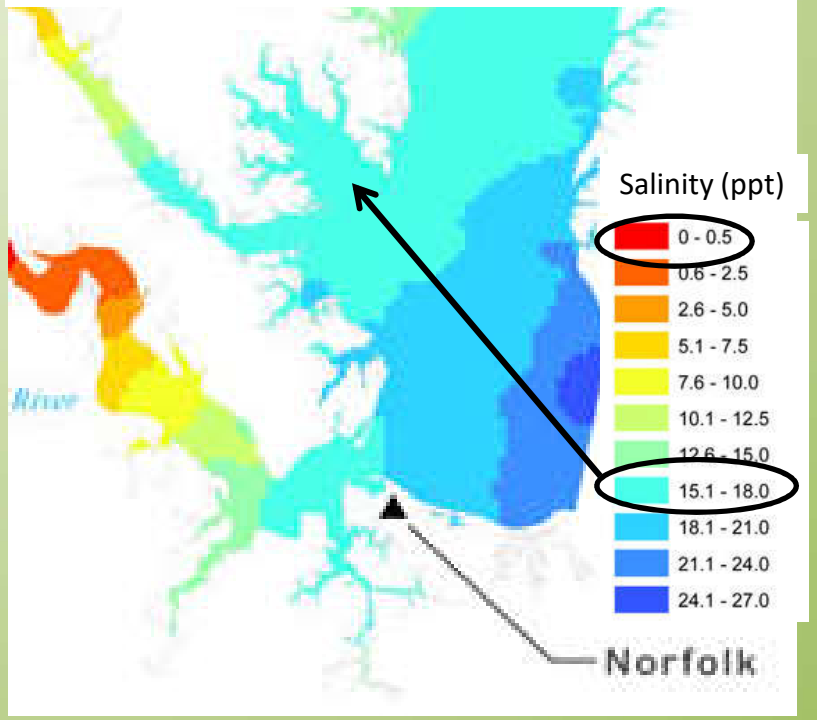
Coupled NCOM-SWAN Surface Salinity



Salinities of "freshwater" in the bay and throughout the coastal zone are too high!!

Trident Warrior, Jul. 2013, Chesapeake Bay

Mean Surface Salinity (1985-2006)



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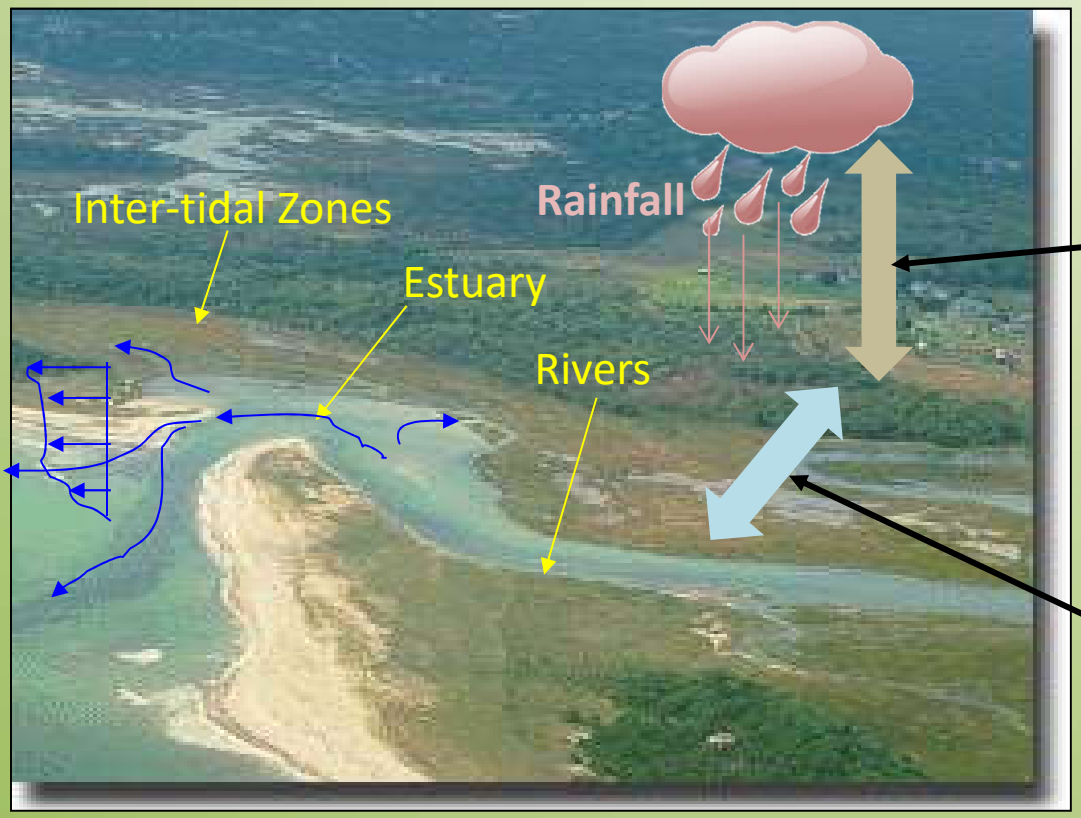
Approach

How do we get more accurate quantities of freshwater to the ocean?

Hydrology-Ocean Model Coupling

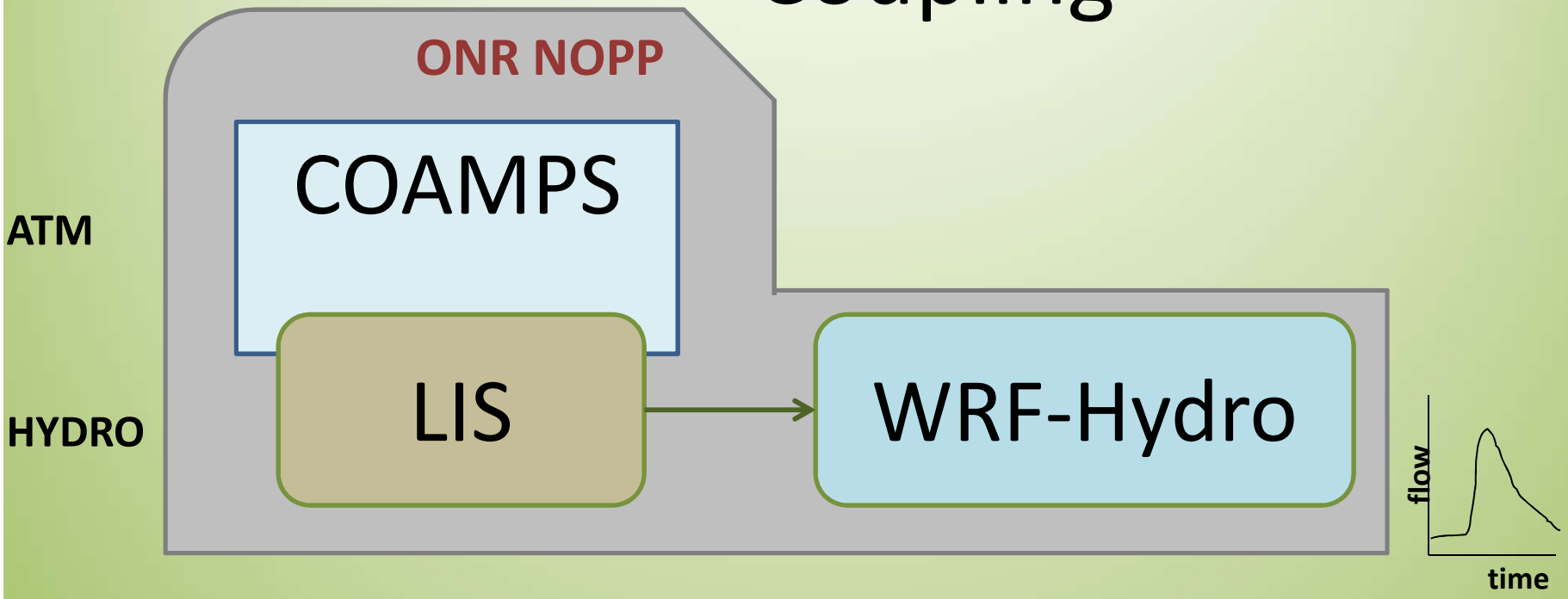


Hydrology Model Components

Land Surface Model

Overland Flow/River Routing

Atmosphere-Hydrology Model Coupling



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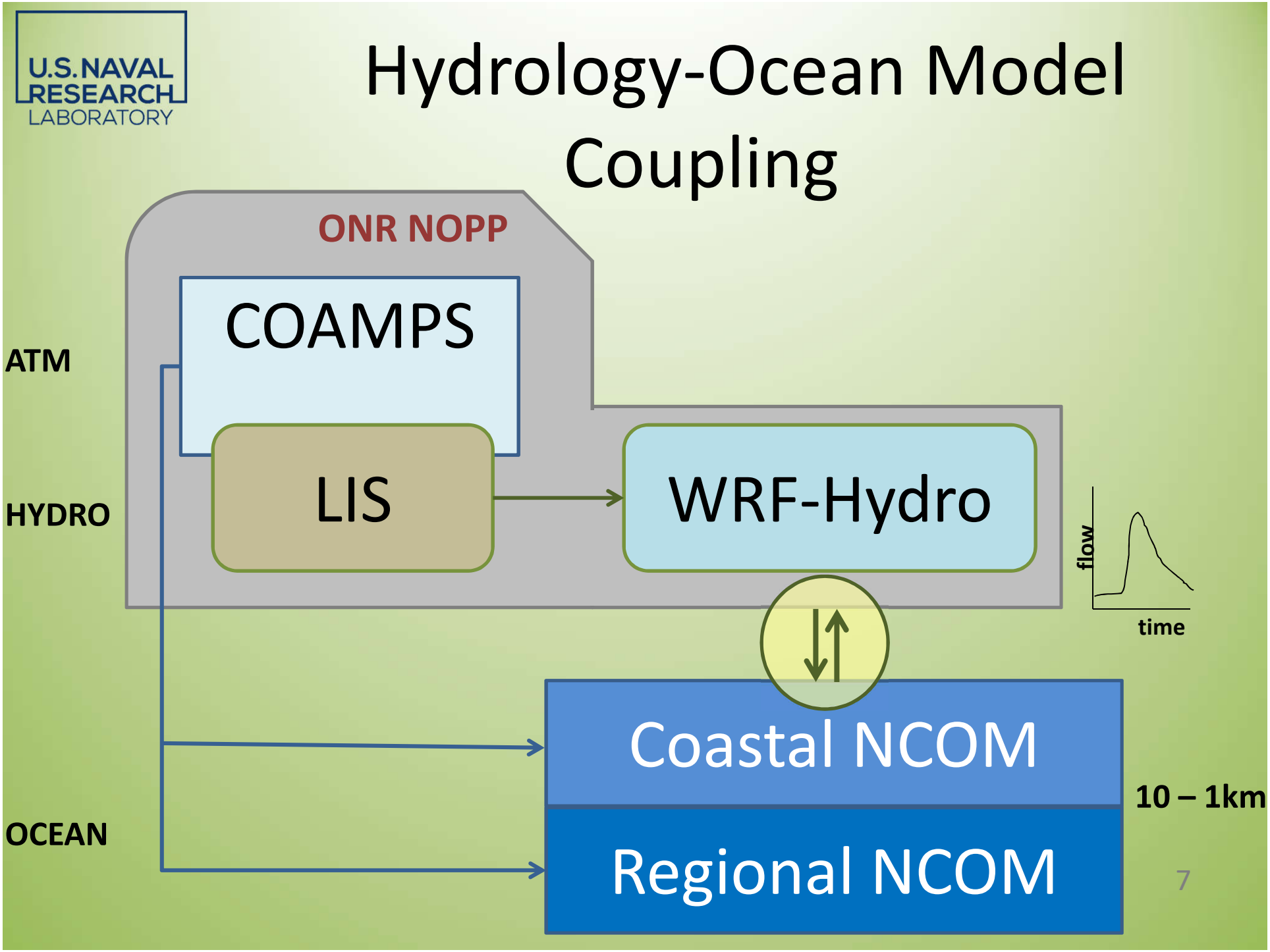
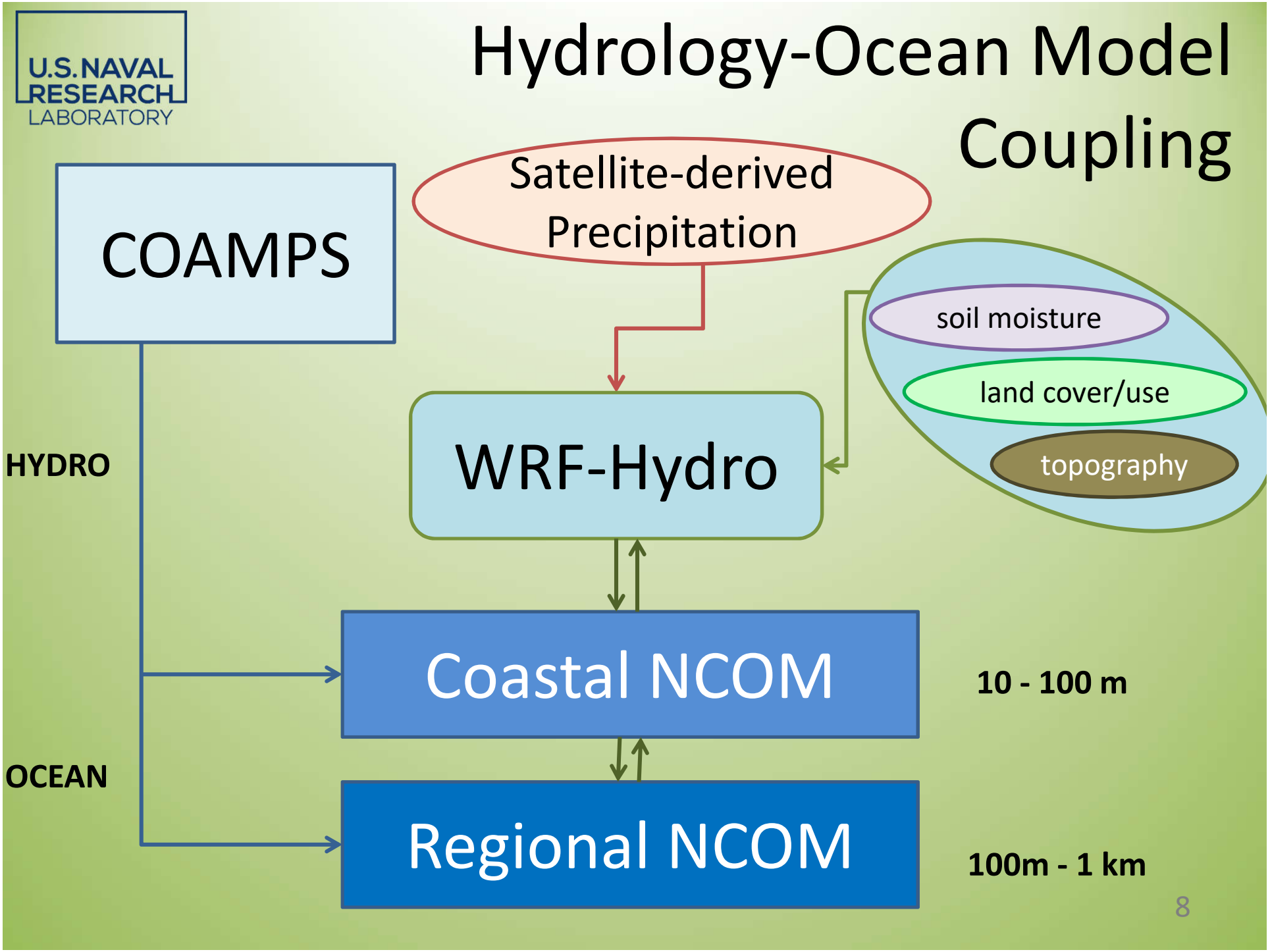
Hydrology-Ocean Model Coupling



Hydrology-Ocean Model Coupling



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Satellite-Based Precipitation

- Accurate precipitation estimates
- Efficiency gains in using an external source of rainfall
- Flexibility to evaluate the effects of latency and resolution on freshwater reaching the coastal ocean

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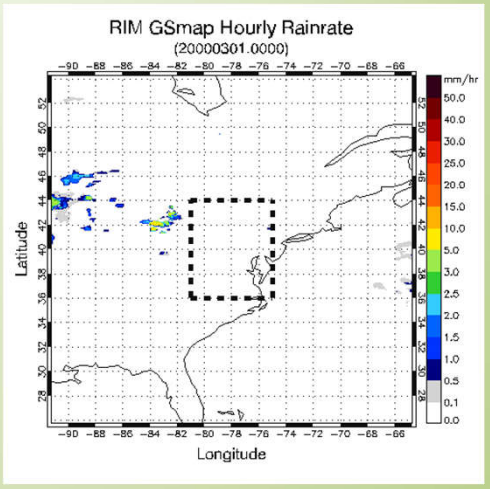
Satellite-Based Precipitation

JAXA GSmap Precipitation

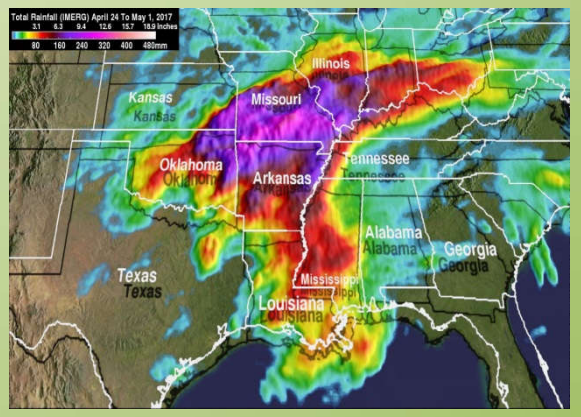
- hourly rainfall, 0.1 deg. res.
- a blended PMW+radar and IR sensors + surface rain gauge measurements



Hourly Gsmap rainfall
Mar-Dec 2000

NASA GPM Precipitation

- Global, 30 min. rainfall, 0.1 deg. res.
- Integrated, multi-satellite retrievals for GPM data (IMERG)
  - PMW or radar rain retrievals used as calibrator for IR rain retrievals



Example of IMERG 7-day rainfall accumulation
April 24-May 1, 2017

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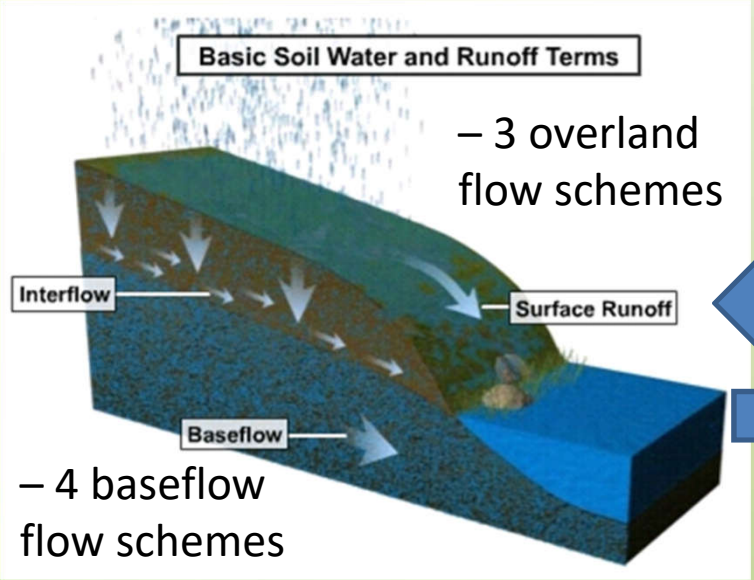
Surface Hydrology

WRF-Hydro

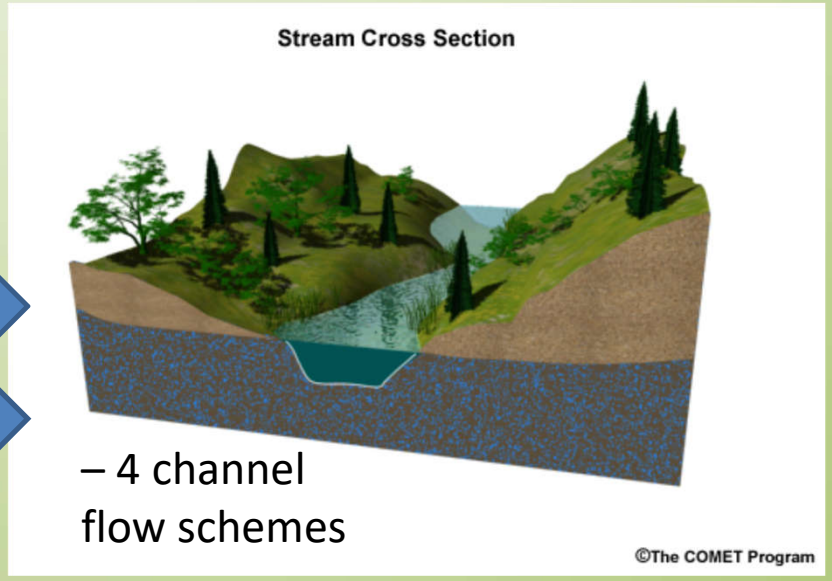
Terrain Routing Models:
Overland, subsurface flow



– 3 overland flow schemes

– 4 baseflow flow schemes

Channel & Reservoir Routing Models:
Hydrologic and Hydraulic



– 4 channel flow schemes

Output Variables:
Stream Inflow, Surface Water Depth, Groundwater Depth, Soil Moisture

Output Variables:
Streamflow, River Stage, Flow Velocity, Reservoir Storage & Discharge

– multi-scale, multi-resolution, portable/scalable across computing platforms

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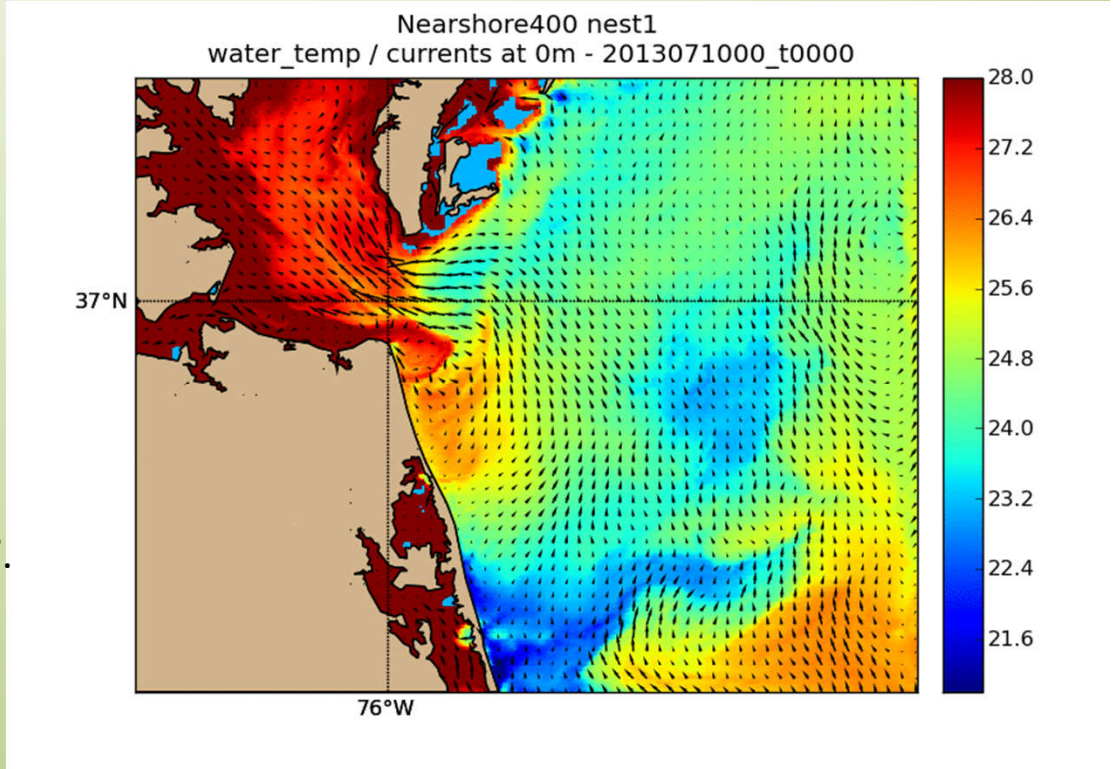
Navy Coastal Ocean Model

- Flexible variant of the Princeton Ocean Model (POM).
- Options for vertical coordinate:
  - all sigma, all z-level, or a mixture of the two (hybrid).
  - sigma generalized, z-levels allow partial cells.
- Choices of mixing formulations.
- Choices of boundary conditions (Flather, Orlanski, etc.)
- Tide, river, and wind forcing.
- Code structure consistent with COAMPS®.
- Scaleable and efficient on a variety of computers.
- ESMF extensions added for coupling efforts.
- Wetting/drying implemented based on Oey (2005, 2006)



Allard et al. 2014.
The US Navy coupled ocean-wave prediction system.
Oceanography 27(3):92–103,

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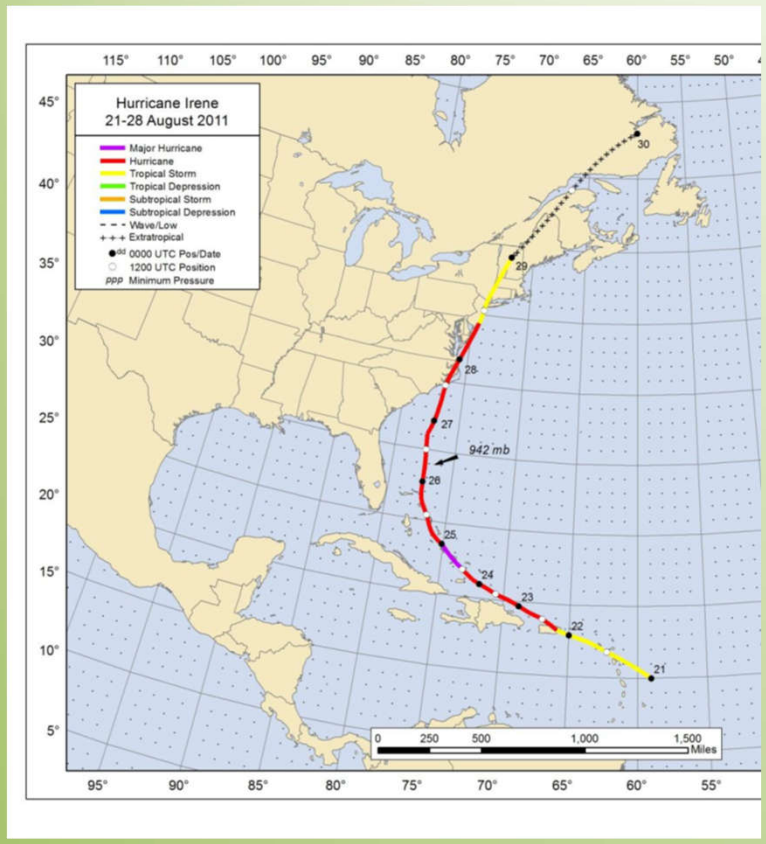
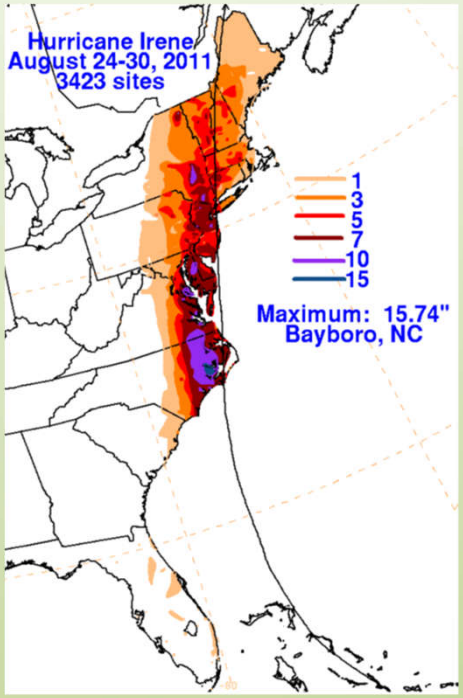
Application: Hurricane Irene

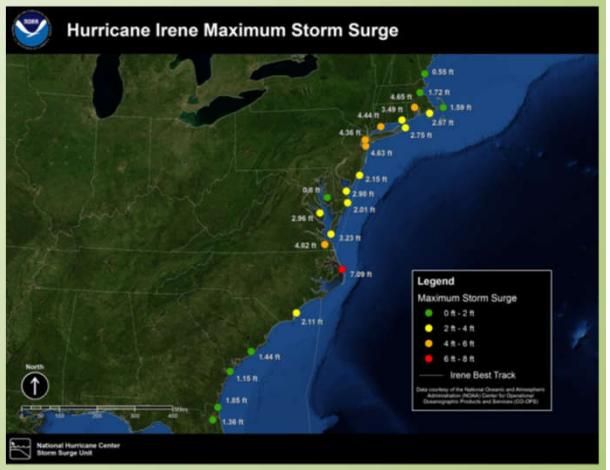
Maximum Rainfall and Storm Surge



Best track positions for Hurricane Irene, 21 -28 August 2011.



Rainfall totals associated with Hurricane Irene.



Selected storm surge values in feet associated with Hurricane Irene

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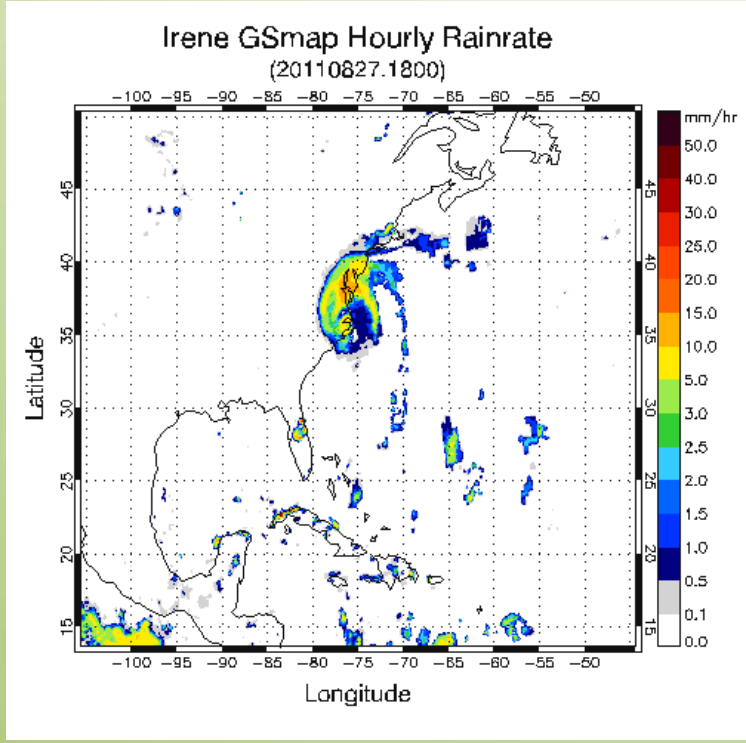
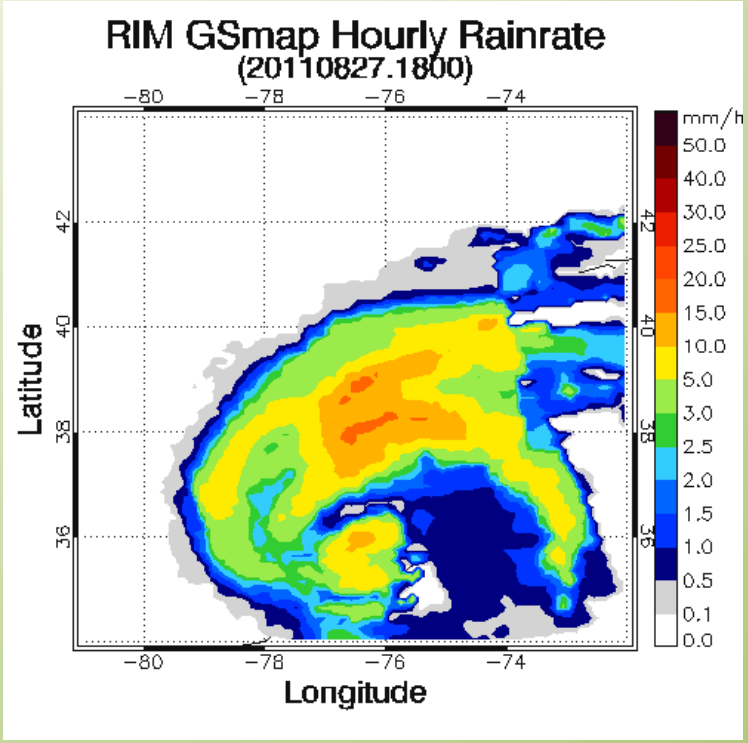
Application: Hurricane Irene

Satellite Precipitation (GSMap)





H. Irene Rainfall Rate 28 Aug. 2011

Japanese GSMaP Satellite, ~ 10km resolution, hourly

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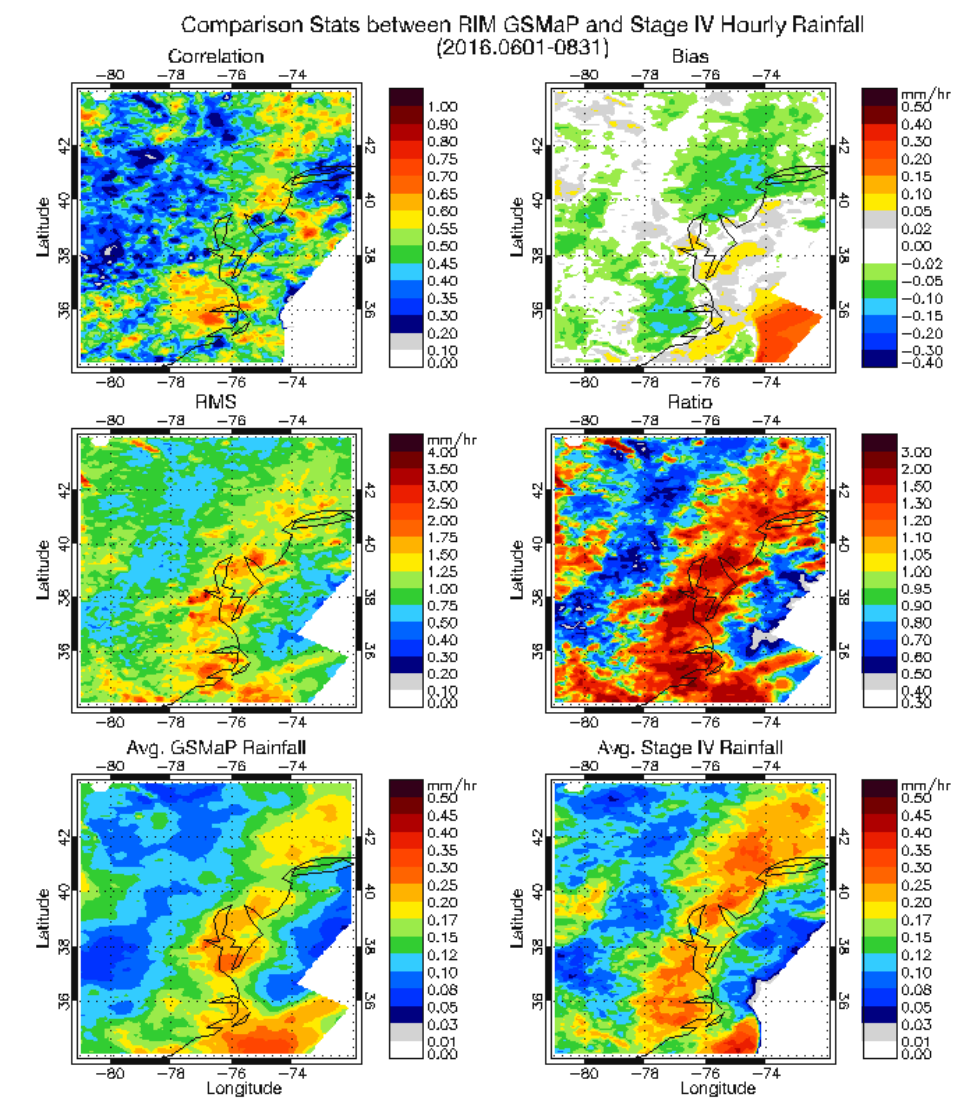
Application: Hurricane Irene

GSMap Spatial Error Distribution



Comparisons to NOAA Stage IV Hourly Rainfall

Downscaled:
4 km to ~ 10 km

Period:
1 Jun – 31 Aug 2011

Mean error < 5%

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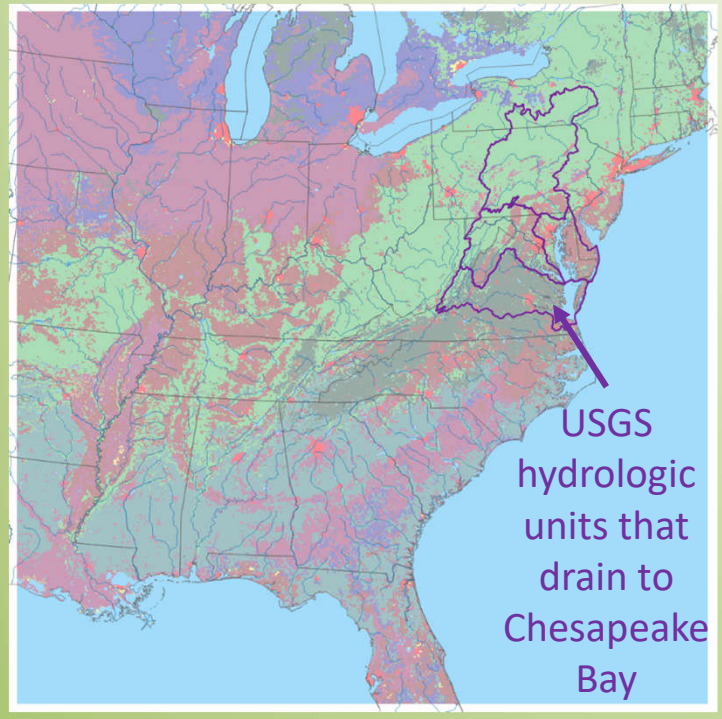
Application: Hurricane Irene

WRF-Hydro



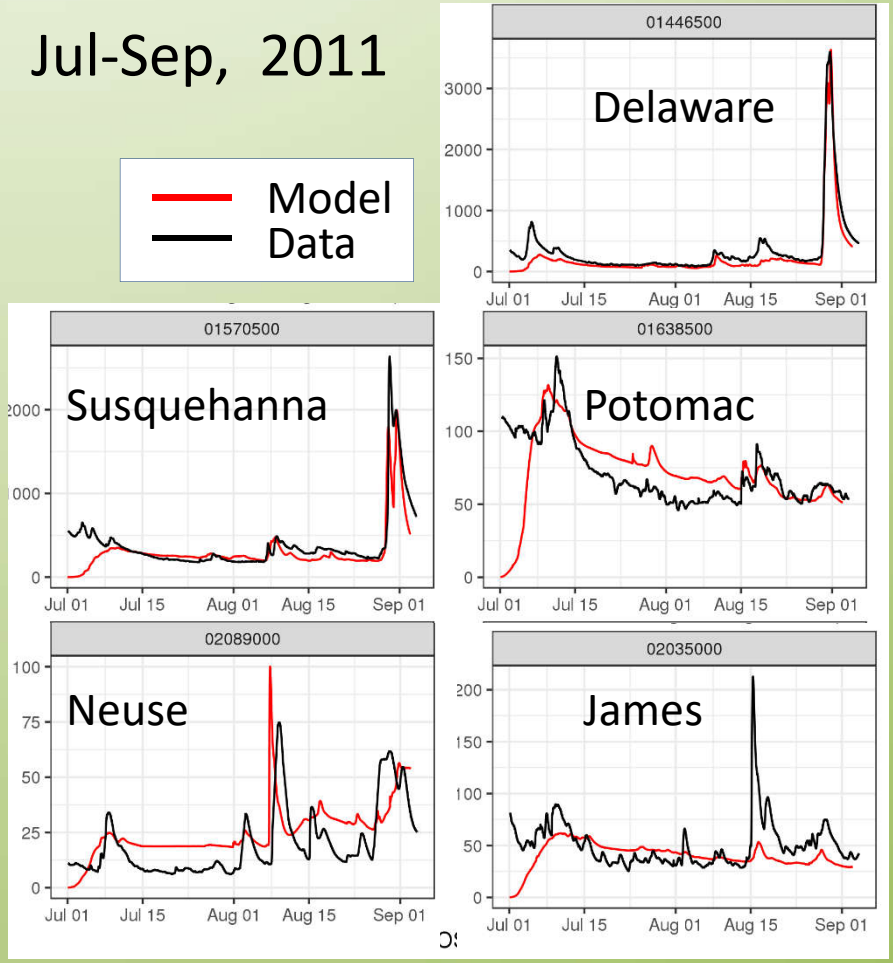
Domain, 2011

Gridded channel routing being used

Courtesy of Aubrey Dugger (NCAR)

Uncalibrated Streamflow Comparisons

Jul-Sep, 2011



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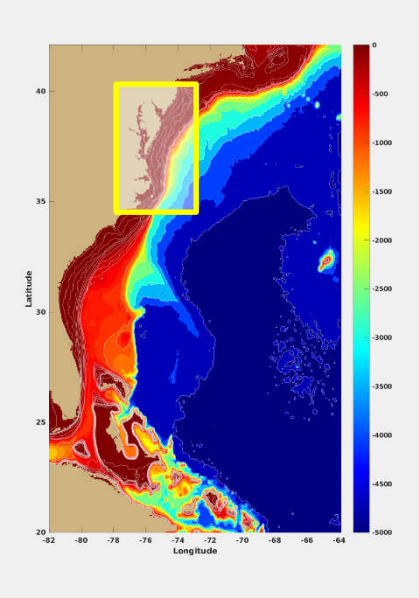
Application: Hurricane Irene

Navy Coastal Ocean Model (NCOM)

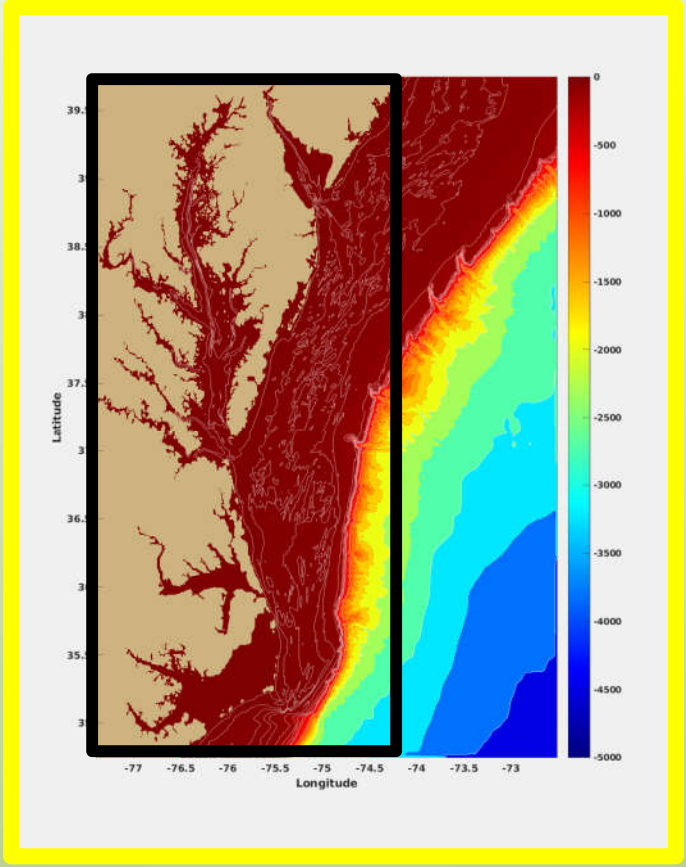


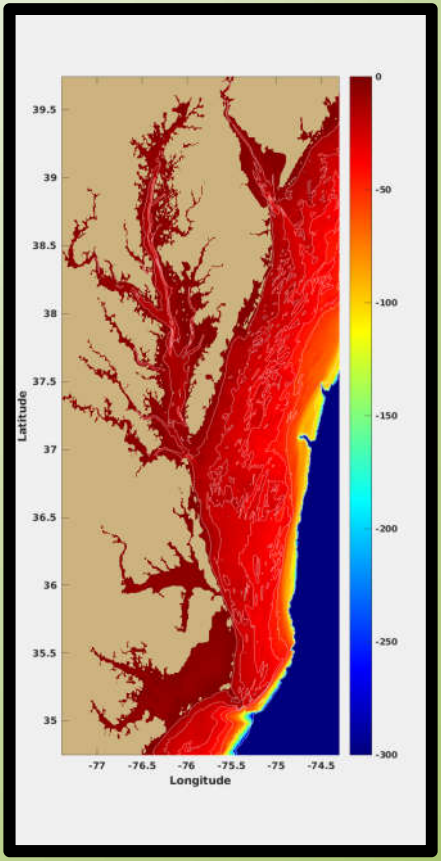
Operational US East Domain for IC/BC

~ 3.8km resolution

49 layers

climatological rivers





- NOAA Coastal Relief Map (3 arc sec ~ 90m)
- 500 m resolution
- 50 vertical levels (30 sigma, 20 z)

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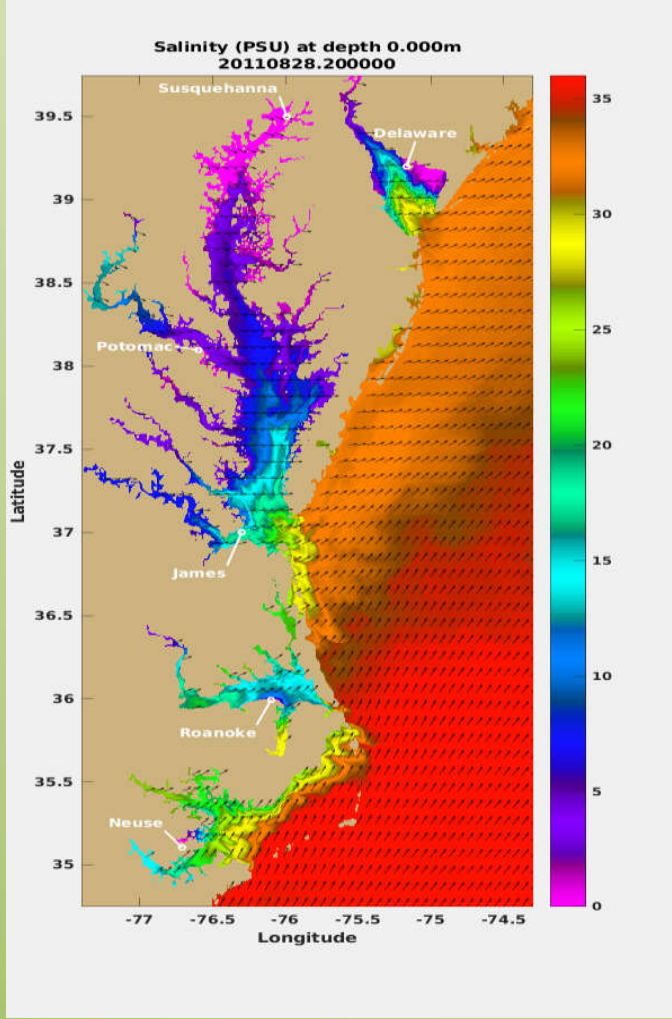
Application: Hurricane Irene

Navy Coastal Ocean Model (NCOM)



- April – September 2011
- 6 rivers, monthly mean data
- COAMPS West Atlantic 0.2 deg
  - turned off moisture flux
- Wetting/drying
- 0.2 m upper layer depth
- 2.0 m min. depth

Surface Salinity 28 Aug 2011 20:00

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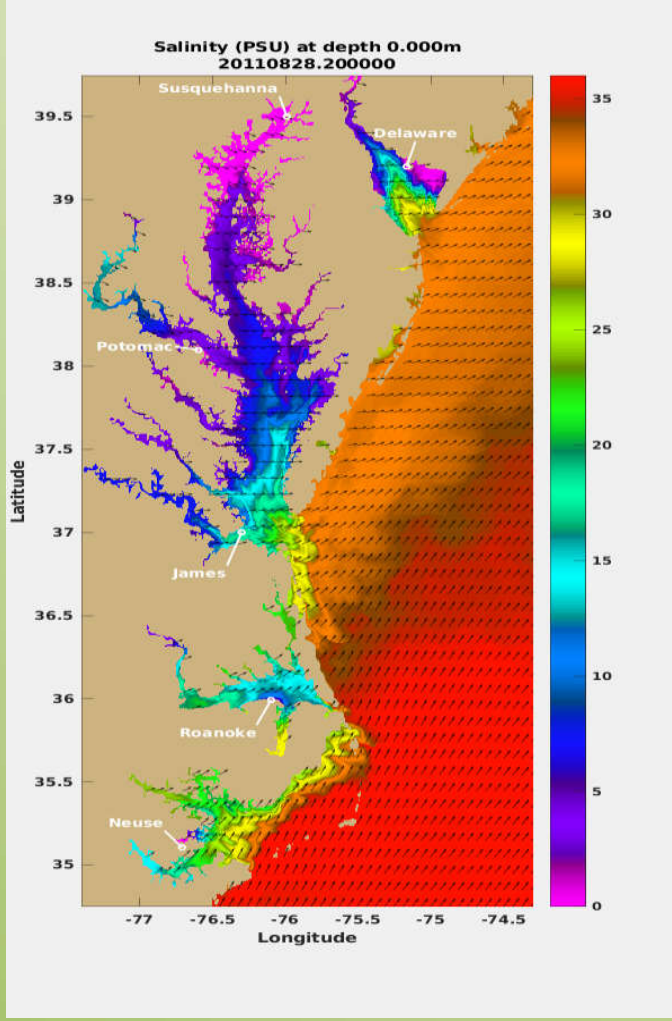
Application: Hurricane Irene

Navy Coastal Ocean Model (NCOM)



Preliminary Experiments

- Offline one-way coupling
- Exchange streamflux only
- Compare simulations using:
  - monthly mean discharges
  - USGS hourly discharges
  - WRF-Hydro streamflow

Surface Salinity 28 Aug 2011 20:00

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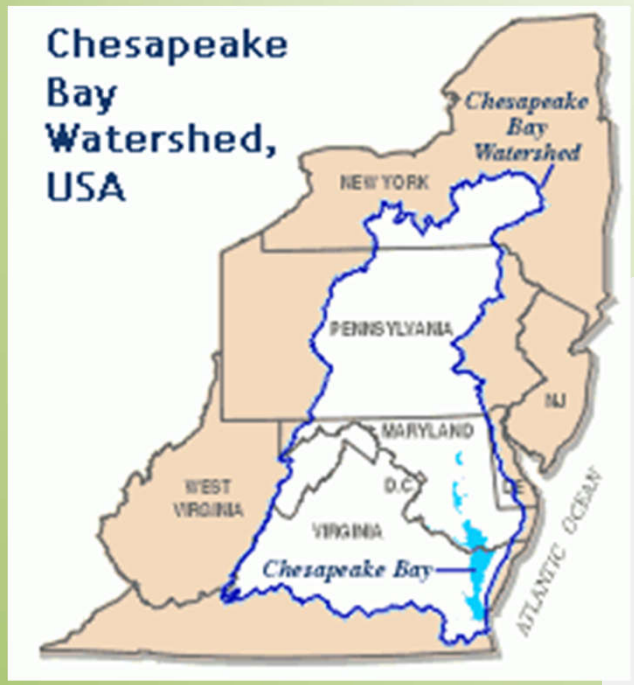
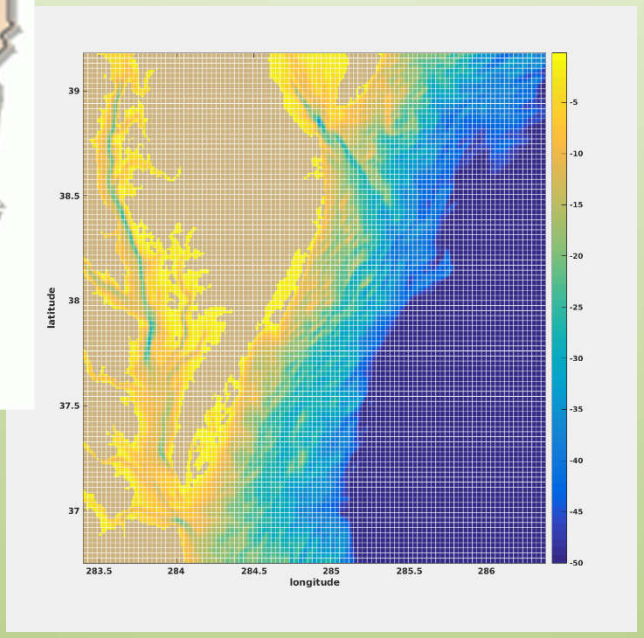
Hydrology-Ocean Model Coupling



WRF-Hydro Hydrology Model



NCOM Coastal Ocean Model

Technical Challenges

- Placement and resolution of the land-margin interface
- Dynamically consistent spatial exchange of information
- Temporally-integrated coupling for efficiency

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Hydrology-Ocean Model Coupling

What is optimal placement and resolution of hydrology-ocean coupling interface?

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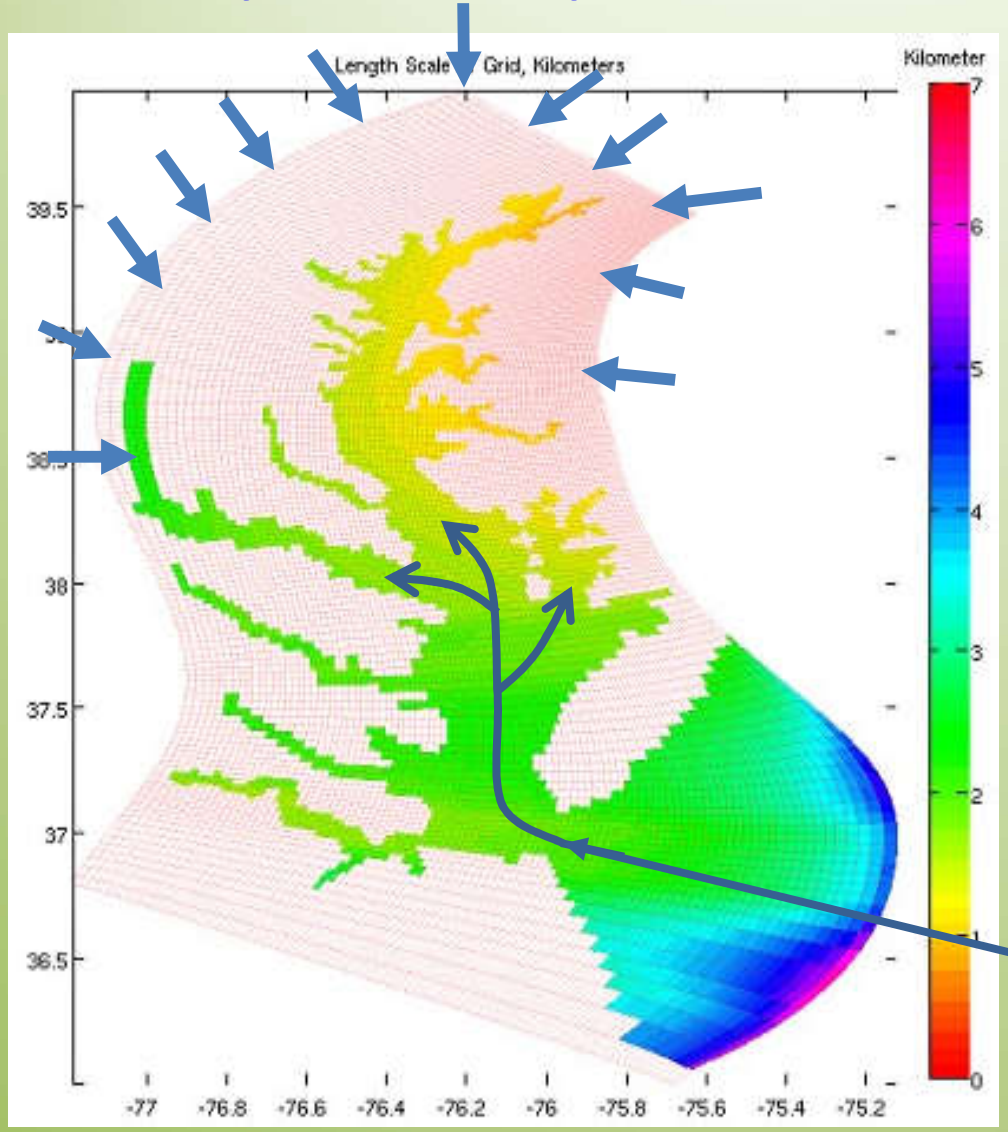
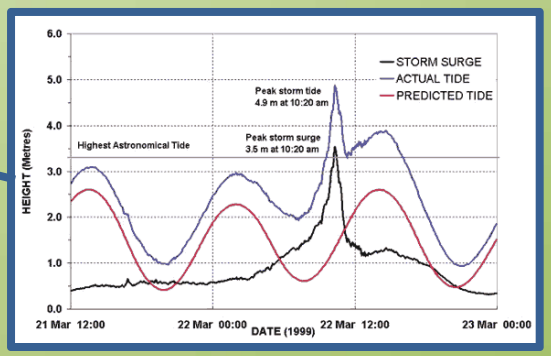
Hydrology-Ocean Model Coupling

Dynamically Consistent Spatial Coupling



- Apply hydrology model fluxes via a distributed flux boundary condition within the coastal model
- Accommodate inland propagating tides and surge within the coupler



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Hydrology-Ocean Model Coupling

Develop Efficiency in the Coupler

WRF-Hydro
Hydrology Model

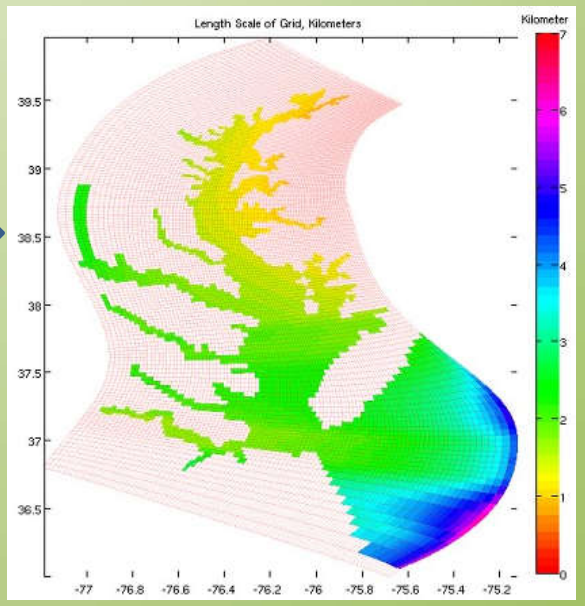
Δt = sec

Exchange water levels, water flux, temperature

Coupler

Δt = hours

NCOM Coastal
Ocean Model



Δt = sec

Accumulate freshwater from rainfall-runoff over event time scales?

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Summary

Issues for Hydrology-Ocean Model Coupling

- Location of the hydrology-ocean model exchange interface
- Temporal frequency of the exchange
- Consistency in the topography/bathymetry information across the two models
- What about wind over the land?
- Availability of global, high resolution databases to initialize the hydrology model