Real-time Ocean Forecasting Needs at NCEP

National Weather Service

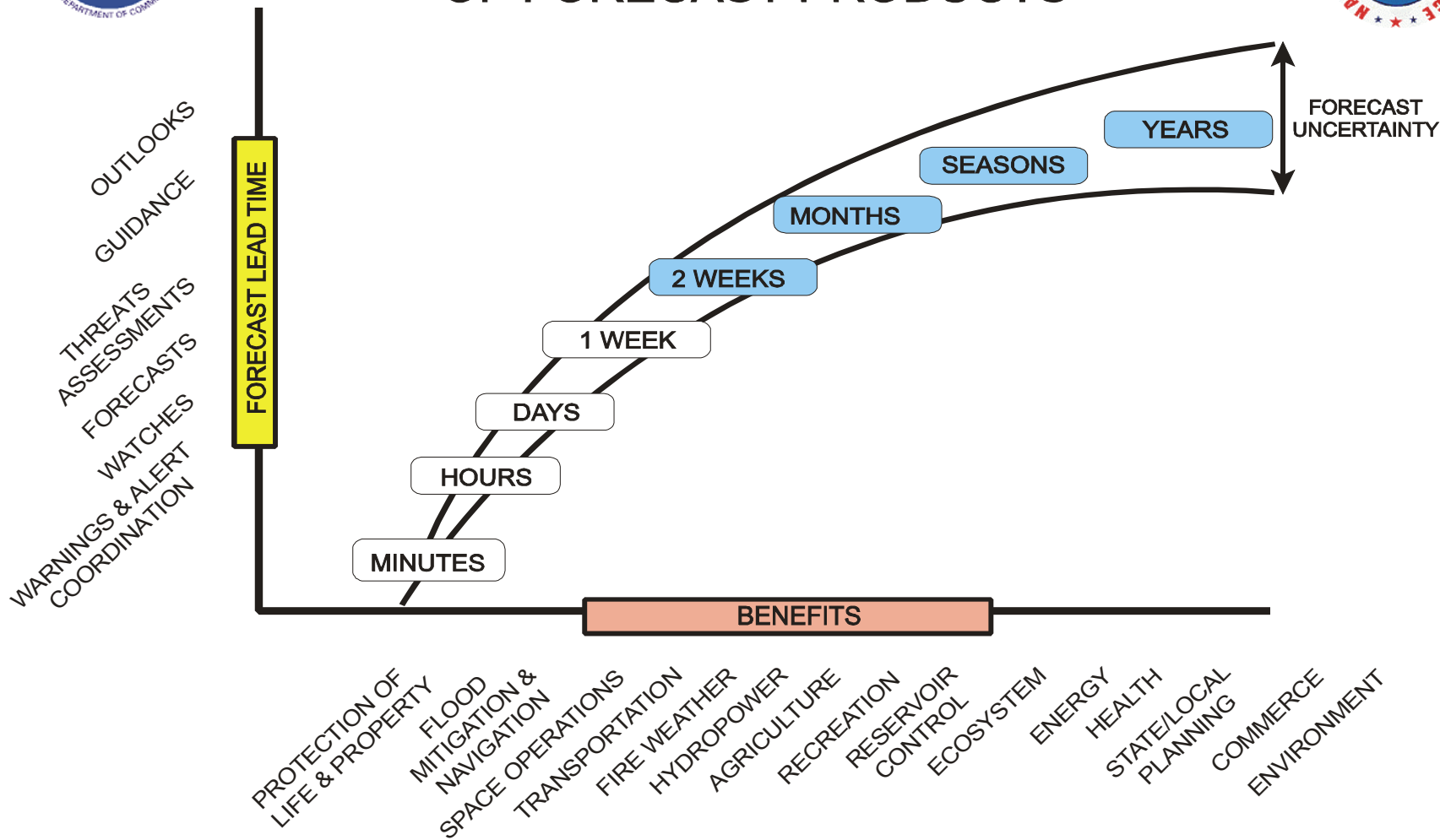D.B. Rao

NCEP Environmental Modeling Center

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NWS SEAMLESS SUITE OF FORECAST PRODUCTS

FORECAST LEAD TIME

OUTLOOKS
GUIDANCE
THREATS ASSESSMENTS
FORECASTS
WATCHES
WARNINGS & ALERT COORDINATION

YEARS
SEASONS
MONTHS
2 WEEKS
1 WEEK
DAYS
HOURS
MINUTES

FORECAST UNCERTAINTY

BENEFITS

PROTECTION OF LIFE & PROPERTY
FLOOD MITIGATION & NAVIGATION
SPACE OPERATIONS
TRANSPORTATION
FIRE WEATHER
HYDROPOWER
AGRICULTURE
RECREATION
RESERVOIR CONTROL
ECOSYSTEM
ENERGY
HEALTH
STATE/LOCAL PLANNING
COMMERCE
ENVIRONMENT

Criteria for implementation of analysis or forecast models

- Forecast performance (meets defined metrics if new or is as good as or better than an existing model if one already exists)
- Technical maturity
- Computational performance
- Maintenance &sustainability

2. Operational Real-Time Daily Ocean State Products

- Wave Modeling
  - Global and Regional
  - Unified model approach
  - NOAA Wavewatch III

- Regional Ocean forecast System
  - Gulfstream analysis & forecast support

-Global Sea Surface Temperature (Blended analysis)

-Global and Regional Sea Ice products (Analysis and ice drift forecast models)

(Last 2 items are not covered in this presentation. Go to

http://polar.ncep.noaa.gov for examples)
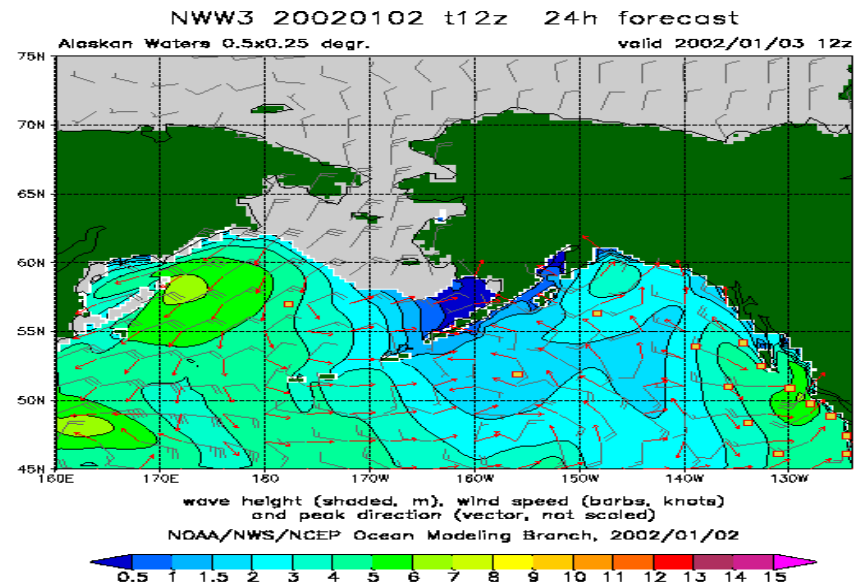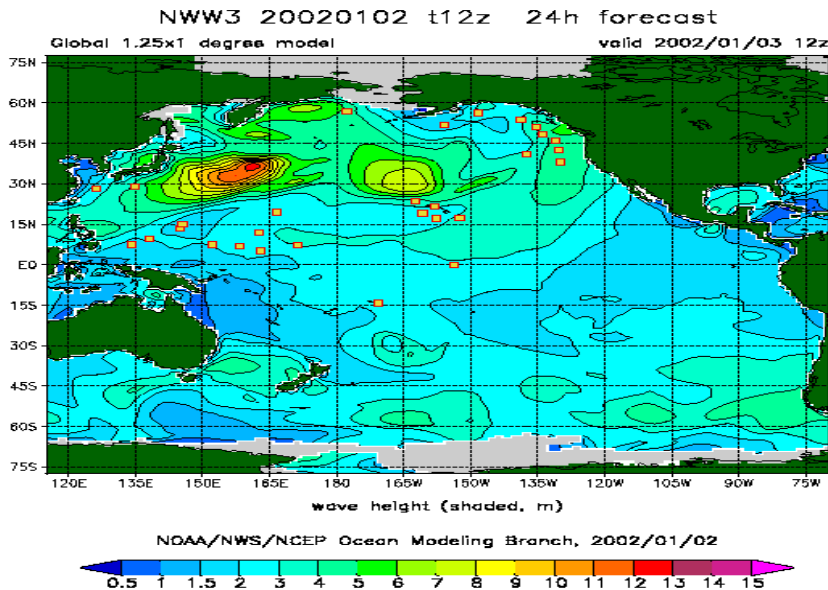
Users of Real-Time Ocean Forecasts

- Tropical Prediction Center.
- Ocean Prediction Center
- Marine Focal Points at NWS Field Forecast Offices.
- National Ocean Service (NOS).
- National Marine Fisheries Service (NMFS).
- Research Community.
- Coast Guard (toxic spills, search & rescue).
- Shipping and boating.
- Recreational Community
- Geophysical Exploration

Operational Wave Models

- The operational wave model at NCEP is NOAA WAVEWATCH III, that is, the generic WAVEWATCH III model with GFS forcing (+ GFDL forcing for hurricanes).
  - Global 1.25°x1° model, and regional 0.25° models.
  - Intermediate water depth physics (i.e., outside surf zone).
    - Adding new surf zone physics relatively simple.
    - Not yet implemented based on spatial resolution.
  - Fixed water level, no currents.
    - Wave model ready for unsteady water levels and currents.
    - Waiting for reliable operational model input.

NCEP/MMAB Wave Products

NWW3 20020102 t12z 24h forecast
Global 1.25x1 degree model   valid 2002/01/03 12z
wave height (shaded, m)
NOAA/NWS/NCEP Ocean Modeling Branch, 2002/01/02

NWW3 20020102 t12z 24h forecast
Alaskan Waters 0.5x0.25 degr.   valid 2002/01/03 12z
wave height (shaded, m), wind speed (barbs, knots)
and peak direction (vector, not scaled)
NOAA/NWS/NCEP Ocean Modeling Branch, 2002/01/02

- Global and regional models for Alaskan Waters and Western North Atlantic and Eastern Pacific with up to 168 h forecasts, 4 times daily
  - Hurricane wave model combining global and GFDL model winds (Atlantic & East Pacific)

- NOAA Wavewatch III operational at FNMOC
- Recent NWW3 upgrades
    Propagation
    Sub-grid islands
- Next NWW3 upgrade
    Data assimilation (improves 0-12 h forecasts)

Future Wave Modeling Plans
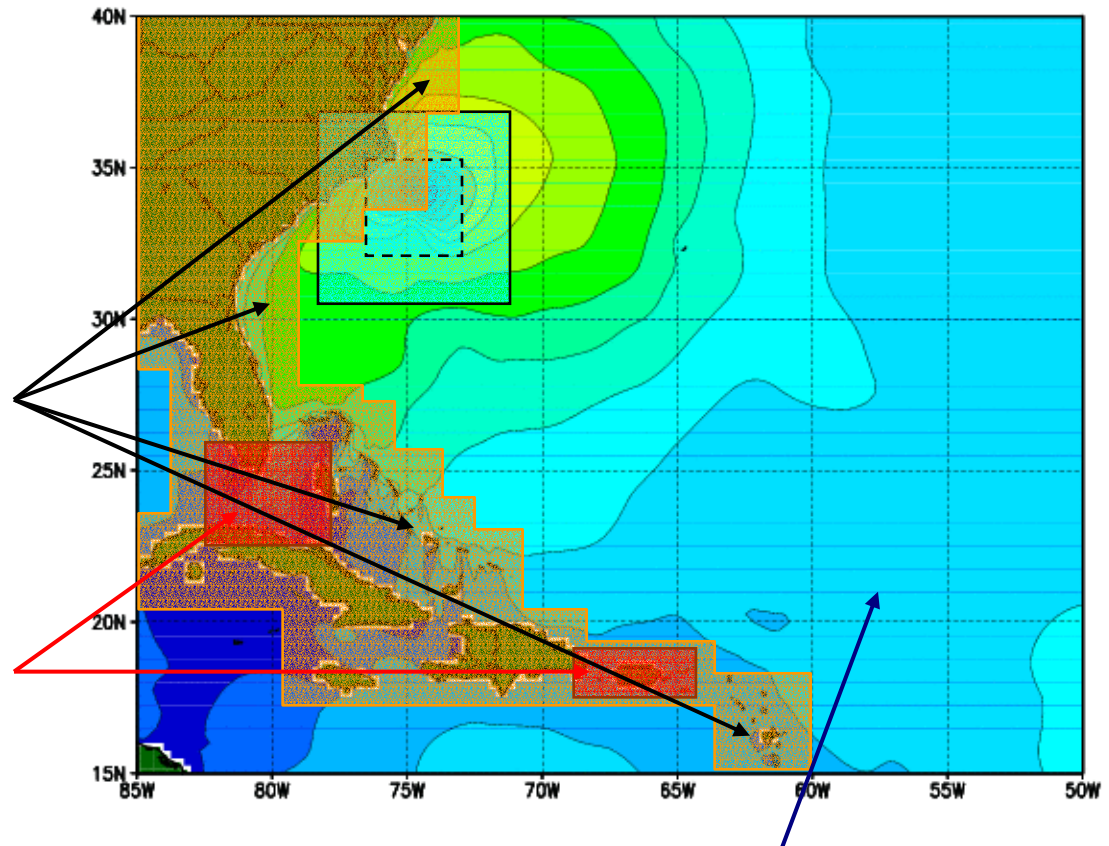
-Development of Multi-scale Wave Model

- Coupling to real-time ocean and hurruicane forecast models

Multi-scale wave model

Deep ocean model resolution dictated by GFS model

Higher coastal model resolution dictated by model economy

Highest model resolution in areas of special interest

Hurricane nests moving with storm(s) like GFDL and WRF

Required Operational Ocean Circulation Forecast Models for NCEP

1. Real-Time Basin Scale Ocean Models-Support for coastal and regional ocean modeling (shelf, bays, estuaries, Hurricane & Storm Surge prediction)

2. Real-Time Daily Global Ocean State (NWP applications and Basin scale ocean models)

3. Global ocean on seasonal time scale

4. Global ocean for climate change time scale

Present Capability in Real-Time Ocean Forecasting

- A Regional Ocean Forecast System (ROFS) for the East Coast of U.S. using the POM

- Became operational in March 2002 (Received Excellence in Partnering Award in the Coastal Marine Demonstration Project by NOPP)

Prediction of SST, Gulfstream, Tides and Water Levels,   Boundary Conditions for Bays and Estuaries, Search & Rescue Operations, Toxic Spill Containment, Ecosystem Management,..

Features: Primitive Equations, Forced by ETA Model Fluxes; Assimilation of SST, XBT, altimetry.

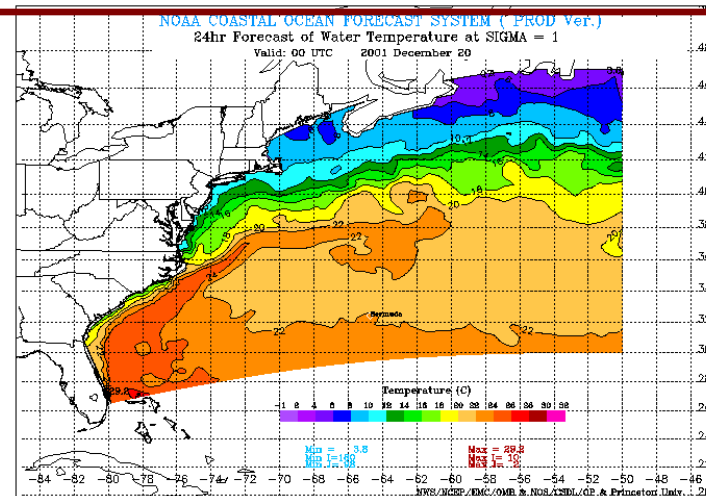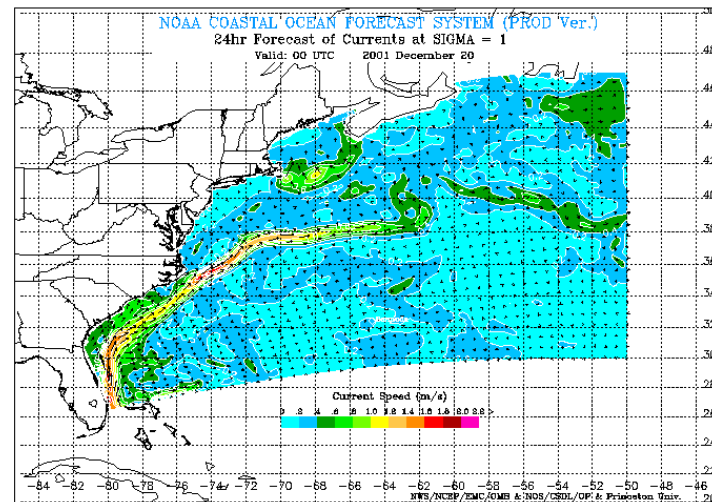## Regional Ocean Forecast System (ROFS)

Princeton Ocean Model

Domain: East Coast

Vertical Coordinate: Sigma (19 levels)

Horizontal Resolution: 10 km near coast to 20 km in deep ocean

Lateral Boundary Condition: Monthly mean values for temperatures, salinity, and transport at the open ocean boundaries and monthly mean values for river run-off at the coastal boundaries

SST

Surface Currents

Development Plans
Basin & Regional Scale Ocean Models

- Establish operational high resolution (*eddy resolving*) real-time ocean forecast systems (*~1 week*) in the Atlantic and Pacific oceans Basins with US deep and coastal waters well resolved.

  -*Nowcast and forecast of sea levels, current temperature, salinity. Emphasis on US coastal ocean, Loop current, Gulf Stream, etc.*

  -*Provide seamless boundary and initial conditions to regional ocean physical and bio-geo-chemical models.*

  -*Coupled atmosphere-ocean Hurricane/Typhoon & Ocean-Wave forecasts.*

  -*Coupled ocean-storm surge/inundation models.*

Development Plans
Global scale Ocean Model

- Establish a real-time operational medium resolution (*1/4 deg or matching scale*) World oceans forecast system for medium range (up to 6 weeks)

  - *Boundary conditions for basin scale ocean models*
  - *SST estimate to support NWP (regional and global)*
  - *Coupled global atmosphere-ocean forecast system.*

Real-Time Ocean State Forecasting

- Approach
  - Consistent and unified modeling approach is preferable to address forecast needs on global scale, basin scale, and coastal scale domains
  - Deep open ocean processes, shallow coastal ocean processes, and the transition from one regime to the other need to be accurately resolved
  - A generalized vertical coordinate approach is being tested and evaluated for accurate depiction of the ocean conditions in all the relevant domains of an ocean basin
  - Model structure will be compliant with ESMF and the future Hybrid Ocean Modeling Environment (HOME)
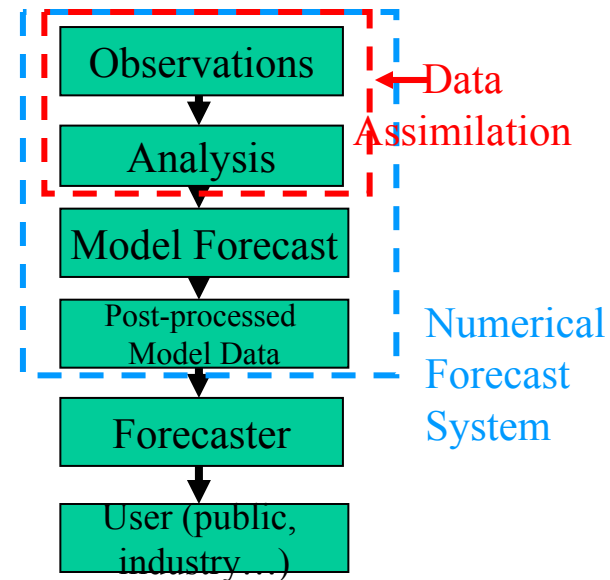
Strategy

- **Collaborate with partners for technology infusion into NWS operational modeling environment**
  - E.g. Work with HYCOM community in implementing a real-time ocean forecast capability at NCEP
  - Provide feedback on new model development, observations to scientific community
- **Provide operational forecasts, analyses and observations to users**
  - Provide routine ocean state products on relevant time and space scales
  - Quality controlled, uniformly formatted ocean observations
- **Use ocean models coupled to atmosphere to improve environmental forecast systems**
- **Participate in community efforts to demonstrate capabilities**
  - International experiments
    - E. g., Contribution to real-time Global Ocean Data Assimilation Experiment (GODAE) products
  - Collaborative efforts
    - E.g. With NOS on storm surge, with WRF on hurricane coupling
  - Software engineering, system compatibility
    - E.g., Earth System Modeling Framework (ESMF)

Ocean Forecast System Elements

– Data retrieval and Quality Control
– Data archive (MODS-BUFR)
– **Dynamical Model (HYCOM) (NOPP support)**
– Data Assimilation (NOPP Support)
– Nowcast/Forecast
– Ocean Analyses and Diagnostics
– Data and Model Visualization
– **Coupling with downscaled systems**
  • Local (Bay & Estuary) models (NOS)
  • Ecosystem models (TBD)
  • Storm surge models (EMC & NOS)
  • Earth System Modeling Framework compatibility (NOAA)

Observations

← Data Assimilation

Analysis

Model Forecast

Post-processed Model Data

Numerical Forecast System

Forecaster

User (public, industry…)

HYCOM RelatedCollaborations

- **NRL**
  - **HYCOM model algorithms:**
    - **Advection schemes RSMAS**
    - **HYBGEN GISS**
    - **Vertical mixing and diffusivity GISS**
    - **One way nesting NRL**
  - **Overall software support.**
- **RSMAS**
  - **Modeling consultations**
  - **Hurricane research**
- **AOML**
  - **Salting algorithms**
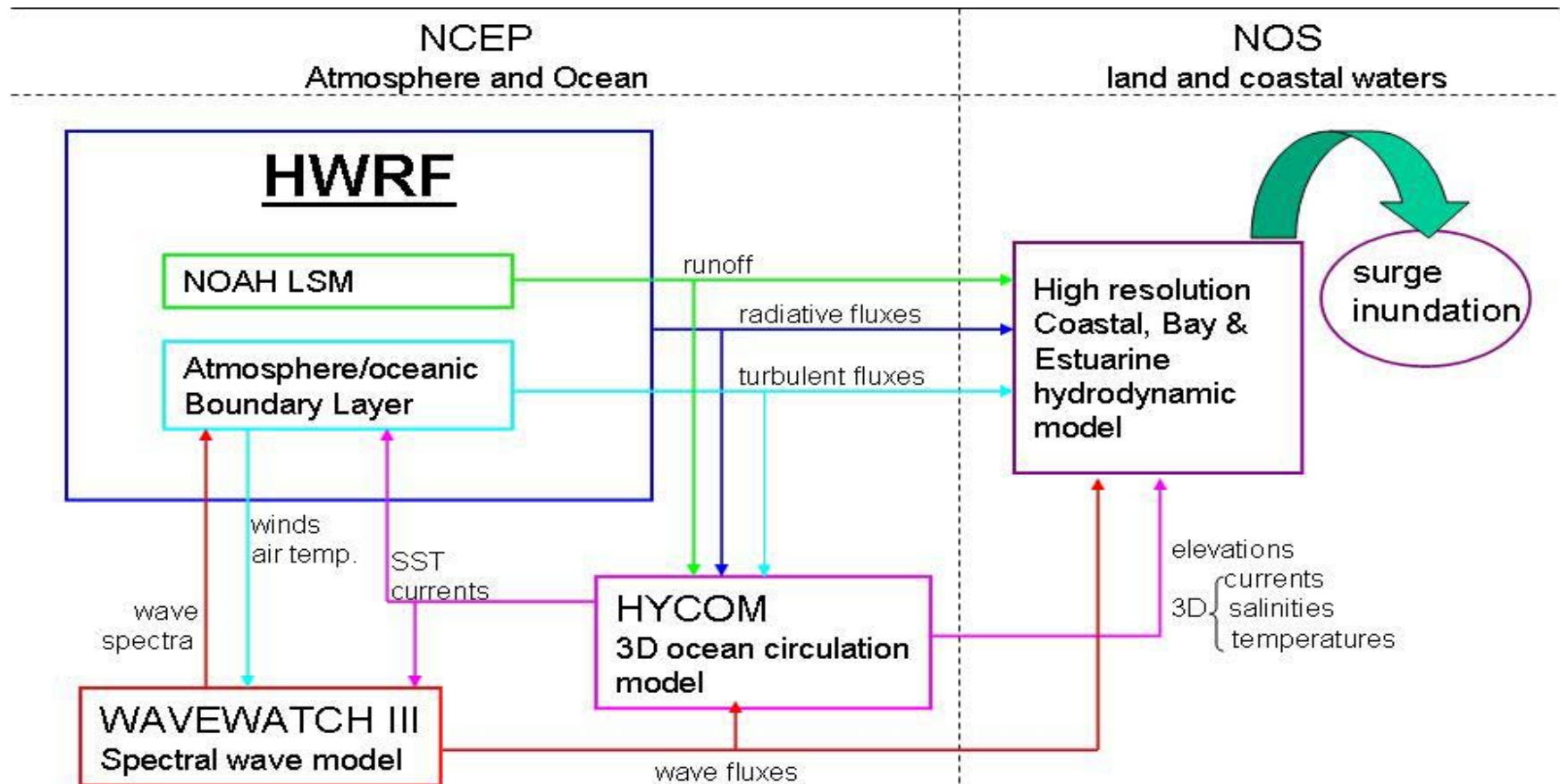
2. Daily Basin Scale Ocean State

- Progress (NOPP funding)
  - HYCOM installed and running in Atlantic domains.
  - Atmospheric forcing: GFS.
  - Daily pre-operational model implementation runs (with SST data assimilation, river discharges, & boundary tidal forcing)
  - Setup of data streams for model validation and assimilation.

Hurricane Impacts Modeling

- Coupled hurricane ocean model to improve storm intensity when ocean interaction is strong
    - Slow moving storms
    - Motion over shallow mixed layers
    - Motion across strong SST gradients
    - Gulf Stream & Loop Current
  - Currently GFDL hurricane-POM coupled model used (operational in 2001)
  - Improved flexibility for system relocation
    - Cover the full variety of hurricane genesis locations hurricane genesis locations
    - Basin scale real-time ocean system described above
  - Future development includes
    - Coupled wave forecast upgrade
    - Coupled Hurricane Weather Research and Forecast (WRF) model

Hurricane-Wave-Ocean-Surge-Inundation Coupled Models

NCEP
Atmosphere and Ocean

NOS
land and coastal waters

HWRF

NOAH LSM

Atmosphere/oceanic Boundary Layer

runoff

radiative fluxes

turbulent fluxes

High resolution Coastal, Bay & Estuarine hydrodynamic model

surge inundation

winds
air temp.

SST
currents

wave spectra

elevations

3D { currents
salinities
temperatures

HYCOM
3D ocean circulation model

WAVEWATCH III
Spectral wave model

wave fluxes

Ongoing projects

- Real-Time Ocean Forecast System (Atlantic). Preparations underway for operational implementation in FY2006 (NOPP).

- Coupled ocean/storm-surge & inundation. Collaboration with NOS.

- Hurricane atmosphere-ocean coupled model. Collaboration with URI.

- Sea surface skin temperature prediction.

NCEP plans for 2006-2008 (NOPP)

- **Improvement of the Real-Time Ocean Forecast System for the Atlantic Basin .**
  - Model and data assimilation improvements
    - Ice model
    - Runoff, NOAH inputs.
    - NN based data operator for altimeter for data assimilation.
    - Assimilation of other data sets (XBT's, profilers, etc)
  - Interaction with users
    - Improvement of model and data products.

NCEP plans for 2006-2008

- **Improvement of Real-Time Ocean Forecast Systems**
  - **Coupled model applications**
    - **Hurricane**
    - **Surge and inundation**
    - **NOPP funded RT-OFS (Atlantic) plays a key role in these activities**

- **Implementation of basin scale Real-Time Ocean Forecast System for the Pacific**
  - **US continental coast and Hawaii.**