Ocean Forecast Systems at NCEP: toward the Earth Model System

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Abstract

As prediction systems for the Earth are integrated in multi-model ensemble systems, it is of interest to examine the goals and the methodologies presently used for ocean forecast systems; and examine potential integration strategies for these systems within the Earth model system.

The current configuration of operational ocean forecast systems at the National Centers for Environmental Prediction (NCEP) in the United States of America includes an event driven coupled atmosphere-ocean for hurricane prediction; a real-time ocean forecast system for the Atlantic Sector, a global-regional nested grids wave forecast system for a short term prediction; and a climatology forecast system (CFS) with atmosphere, ocean and ice coupled models for a seasonal-to-interannual prediction.

A specific description of each system component including data, model and assimilation, will be presented. Plans for future developments in NCEP include two different resolution global ocean models 2/25-degree (current NRL global model) and a 1/7-degree; and a CFSRR (Climate Forecast System global Reanalysis and seasonal Reforecast). The latter is an integrated earth system with three core components: 1) analysis system, 2) atmospheric model, and 3) ocean model. The presentation will particularly focus on this Integrated Earth System.

Introduction

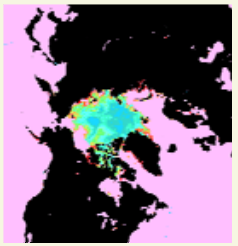
The overall goal is the accurate and concerted estimation of the states of the Earth system at different time and spatial scales. Over the past decades National Weather Prediction Centers have increase predictive skill at higher spatial resolution and time coverage of the atmosphere state for the short and seasonal range forecast problem. These results have been achieved, for the most part, with a minimal representation of other Earth system components: land, ocean and ice.

For the atmosphere short term (O1wk) forecast problem the sea surface state is assumed to respond slowly and its changes do not influence significantly the atmosphere state: an accurate sea surface temperature analyses suffices and an implicit bulk parameterization of the surface wave state suffice. For the ocean short term forecast problem the atmosphere state is assumed to be modified. In practice corrections of atmosphere-to-ocean fluxes based upon the evolving sea surface temperature and wave state are found to be fruitful.

For the atmosphere and ocean short term forecast problems eddy resolving spatial resolution and adequate representation of non explicitly resolved important processes (physics) is required.

At NCEP the eddy resolving Global Ocean model coupled to Global wave model and Ice model is necessary to support initial/boundary conditions of basin/regional models -RTOFS-Atlantic, NOS, IOOS, etc. regional and coastal modeling (National Backbone).

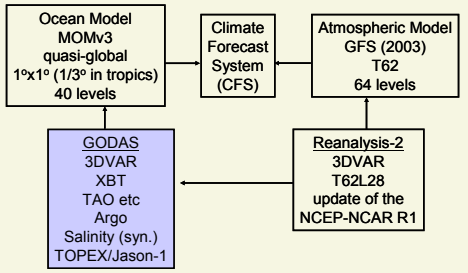
The natural setup for the short-term atmosphere and ocean forecasts is a fully coupled mode. Presently it is not computational feasible; thus useful and efficient model configurations, coupled data assimilation schemes and probabilistic representations need to be devised/understood. In particular, an approach followed for the Hurricane Forecast System is. illustrated bellow



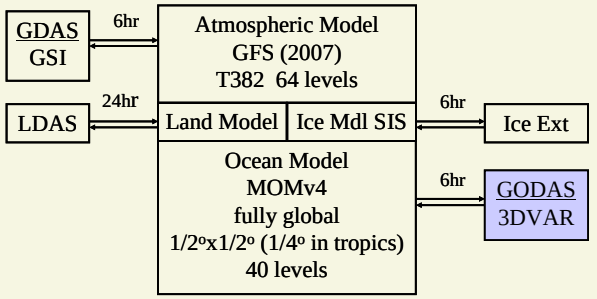
NCEP sea ice analyses

Seasonal to Interannual prediction

Climate Forecast System



Re-analyses Configuration



Active development efforts for coupled ocean models

Active coupling to ice, atmosphere and waves, with focuses on:

Ice and ice thermodynamics.

Waves: forcing and mixing.

Improved fluxes: air and water (waves as interface).

Assimilation / initialization focuses:

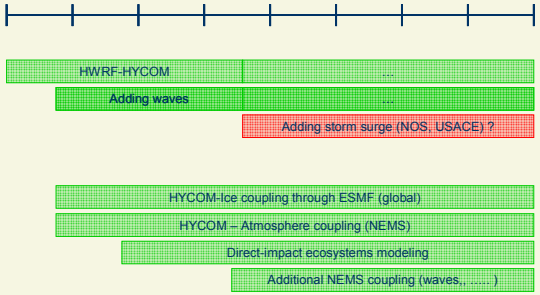
Acquire and use all available data.

Go towards a "framework" that is shared with the Navy, JCSDA, Academia (NOPP).

Define a standard ESMF interface for assimilation modules.

Algorithm improvements in:

- SSH signal and assimilation.
- Vertical distribution of data impact.
- Profile use and 3-D (4-D) assimilation.



A regional atmosphere-ocean coupled model

The NCEP hurricane-ocean modeling system is the HYCOM ocean model either forced by GFS, or coupled with HWRF – ***"HWRF-HYCOM"*** (Figure 1). The former composed of two systems: one for a basin-scale, fine domain ("**GFS-RTOFS**"); the other for a hurricane-regional scale, coarse domain ("**stand-alone**"), being nested in one-way from the basin-scale domain. The latter is designed for two-way coupling: atmospheric fluxes and SST are exchanged every 6 minutes.

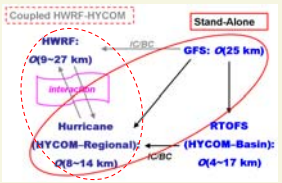


Figure 1. Ocean and atmospheric model components for "**stand-alone**" (red solid contour), "**HWRF-HYCOM**" coupled systems (red dashed contour), and "**GFS-RTOFS**".

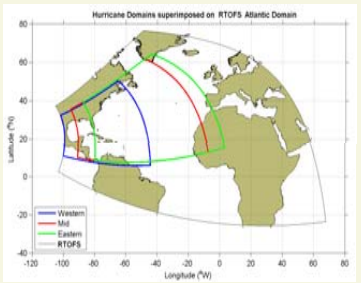


Figure 2. Three hurricane domains and RTOFS Atlantic basin nesting domain: The primary reason to have 3 nested domains is the computation efficient as it is placed to NCEP (National Center for Environmental Prediction) central operation..

Ensemble Coupled Forecast Systems

- To design a system that optimally captures initial and forecast states of both fast and slow sub-components
  - Follows from recommendations from a recent workshop on bridging the gap between weather and climate numerical predictions (Toth et al 2007)
- Initial ensemble perturbations for coupled systems
  - Research results available with the breeding technique (Cai et al 2003, Yang et al 2006)
- Ensemble Transform method
  - Tested for the atmosphere (Mozheng et al 2006)

Ensemble sub-seasonal forecasting

- Fully coupled OLA model
  - Captures variability and uncertainty of coupled system
  - out to 30 days
- Large hindcast dataset
  - Real-time
  - Upgrades frequently
- ET coupled
  - Represents analysis uncertainty of the coupled ocean-atmosphere system

Other Earth System Components: Biota

Ecosystems modeling:

Downstream applications (NOS, NMFS).

Including ecosystems impact where there is a direct feedback to the physical ocean prediction.

Chlorophyll → SST.

Also anorganic matter

Partnerships

Community models/modeling to leverage scarce resources.

CONOPS with clear roles for NCEP (Navy), NOS, IOOS, ….

Close collaboration with US Navy:

Accelerate NCEP global HYCOM capabilities.

NOAA as Navy data portal (outside Navy mission).

Close collaboration with JCSDA .

Data access (IOOS/DIF) / QC, assimilation methods.

Close collaboration with OAR:

Interaction and collaboration with sub-seasonal and seasonal forecasting groups

Global distributed high-resolution multi-model ocean ensemble.