Operational Ocean and Climate Modeling at NCEP

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Environmental Modeling Center
NCEP
Global Data Assimilation

Global Forecast System

Climate
CFS
MOM3

Hurricane
GFDL
HWRF

Regional
NAM
WRF NMM

North American Ensemble Forecast System
GFS, Canadian Global Model

Short-Range Ensemble Forecast
WRF: ARW, NMM, ETA, RSM

Oceans
HYCOM
Wavewatch III

Dispersion
ARL/HYSPLIT

Severe Weather
WRF NMM/ARW Workstation WRF

Air Quality
NAM/CMAQ

Rapid Update for Aviation

NOAH Land Surface Model
A. Operational forecasts
1. All forecasts are Atmosphere-Land-Ocean coupled
2. All systems are ensemble-based except daily, high-resolution run
3. All forecasts initialized with LDAS, GODAS, GSI from GFS initial conditions
4. Physics and dynamics packages may vary
   a. Anticipated that the weekly forecast will have most rapid implementations and code changes, seasonal configuration may be one (or at most two) versions behind weekly

<table>
<thead>
<tr>
<th>Forecast Product</th>
<th>Number of members per refresh period</th>
<th>Runs/day</th>
<th>Membership refresh period</th>
<th>Horizontal resolution (ratio, current value)</th>
<th>Forecast Length</th>
<th>Initialization technique</th>
<th>Computing resource ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily-hires</td>
<td>1</td>
<td>4</td>
<td>daily</td>
<td>1.0, T382</td>
<td>15 days</td>
<td>GSI</td>
<td>1.0</td>
</tr>
<tr>
<td>Weekly</td>
<td>80</td>
<td>80</td>
<td>daily</td>
<td>0.5, T170</td>
<td>15 days</td>
<td>ET breeding</td>
<td>2.5</td>
</tr>
<tr>
<td>Monthly</td>
<td>56</td>
<td>8</td>
<td>weekly (7 days)</td>
<td>0.5, T170</td>
<td>60 days</td>
<td>??</td>
<td>1</td>
</tr>
<tr>
<td>Seasonal</td>
<td>60</td>
<td>2</td>
<td>monthly</td>
<td>0.33, T126</td>
<td>1 year</td>
<td>Lagged analysis 2x daily</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Calculated from ratio of runs/day \* forecast length \* expense of each forecast#
# expense ratio is resolution**3
Satellite
(AVHRR, JASON, QuikSCAT)

In situ
(ARGO, Buoys, Ships)

Data Cutoff

OCEAN DATA ASSIMILATION

CFS-GODAS
NCO/ODA
EMC
NOPP-JPL (ECCO)

RT-OF-S-GODAE
NOPP
EMC

Shared history, coding, and data processing

MOM-3 ⇒ MOM-4 ⇒ HOME

OPNL OCEAN FORECASTS

Climate Forecast System

Real-Time Ocean Forecast System

http://cfs.ncep.noaa.gov/

http://polar.ncep.noaa.gov/of/s/

NASA-NOAA-DOD
JCSDA
AMSR, GOES,
AIRS, JASON, WindSat,
MODIS
Advanced ODA Techniques

CFS: 2 week data cutoff

RTOFS: 24 hour data cutoff

NASA-NOAA-DOD
JCSDA
AMSR, GOES,
AIRS, JASON, WindSat,
MODIS
Advanced ODA Techniques
CFS-next
For a new Climate Forecast System (CFS) implementation

Two essential components:

A new Reanalysis of the atmosphere, ocean, seaice and land over the 31-year period (1979-2009) is required to provide consistent initial conditions for:

A complete Reforecast of the new CFS over the 28-year period (1982-2009), in order to provide stable calibration and skill estimates of the new system, for operational seasonal prediction at NCEP.
1. Analysis Systems: Operational GDAS: Atmospheric (GADAS)-GSI Ocean-ice (GODAS) and Land (GLDAS)

2. Atmospheric Model: Operational GFS

3. Ocean Model: New MOM4 Ocean

4. Land Model: Operational Noah Land Model

5. Sea Ice Model: New Sea Ice Model
CFS-next: Jan 2010.

- improvements to the data assimilation of the atmosphere with the new NCEP Gridded Statistical Interpolation Scheme (GSI) and major improvements to the physics and dynamics of operational NCEP Global Forecast System (GFS)

- improvements to the data assimilation of the ocean and ice with the NCEP Global Ocean Data Assimilation System, (GODAS) and a new GFDL MOM4 Ocean Model

- improvements to the data assimilation of the land with the NCEP Global Land Data Assimilation System, (GLDAS) and a new NCEP Noah Land model
CFS-next (contd)

1. An atmosphere at high horizontal resolution (spectral T382, \(\sim 38\) km) and high vertical resolution (64 sigma-pressure hybrid levels)

2. An interactive ocean with 40 levels in the vertical, to a depth of 4737 m, and high horizontal resolution of 0.25 degree at the tropics, tapering to a global resolution of 0.5 degree northwards and southwards of 10N and 10S respectively

3. An interactive sea-ice model

4. An interactive land model with 4 soil levels
There are three main differences with the earlier two NCEP Global Reanalysis efforts:

• Much higher horizontal and vertical resolution (T382L64) of the atmosphere (earlier efforts were made with T62L28 resolution)

• The guess forecast will be generated from a coupled atmosphere – ocean – seaice - land system

• Radiance measurements from the historical satellites will be assimilated in this Reanalysis

To conduct a Reanalysis with the atmosphere, ocean, seaice and land coupled to each other will be a novelty, and will hopefully address important issues, such as the correlations between sea surface temperatures and precipitation in the global tropics, etc.
PROPOSED TIME LINE FOR COMPLETION OF CFSRR

• **January to December 2008**: Begin Production and Evaluation of the CFS Reanalysis for the full period from 1979 to 2008 (30 years)
• **January to December 2008**: Begin running CFS Retrospective Forecasts for 2 initial months: October and April, and evaluate the monthly forecasts as well as the seasonal winter (Lead-1 DJF) and summer (Lead-1 JJA) forecasts.
• **January to October 2009**: Continue running the CFS Reforecasts (for the rest of the 10 calendar months)
• **November 2009**: Begin computing calibration statistics for CFS daily, monthly and seasonal forecasts.

January 2010: Operational implementation of the next CFS monthly and seasonal forecast suite.
issues

• Integrated Earth System Analysis
  – Aerosol is in the plan for the operational data assimilation system and will be available at the next CFSRR
  – CO2 changes are already built in the current CFS Reanalysis
  – 20-century type of CMIP runs indicates that the CFS in the CFSRR system is capable of responding to the CO2 changes

• How can we accelerate the future CFSRR?
  – Data assimilation – combine satellite radiance usage with the earth system modeling to address atmosphere, ocean, land, ice, and biosphere
  – Improving both weather and climate signals in the fully coupled models
  – Resource needed to do both
Ocean and Wave Models
Satellite (AVHRR, JASON, QuikSCAT)
In situ (ARGO, Buoys, Ships)

Data Cutoff
CFS: 2 week data cutoff
RTOFS: 24 hour data cutoff

OCEAN DATA ASSIMILATION
CLIMATE FORECAST
OCEAN FORECAST

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NCO/ODA
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RT-OFS-GODAE
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Advanced ODA Techniques

Observations

MOM-3 → HOME

HYCOM → HOME

• Present capability:
  – Global multi-grid or mosaic approach with a global model consisting of many grids.
  – Hurricane wave models, to be transitioned to multi-grid global model approach.
  – Great Lakes wave models running off NAM and NDFD winds (FY08, new model).
  – Assimilation of altimeter and buoy data. To be transitioned to multi-grid approach.
  – Global wave ensemble, transitioning to new model (FY08), joint effort with FNMOC.
Example of consistency between grids. Consecutive plotting of all 8 grids as well as the Great Lakes Wave model.
Waves

Example of present operational resolution for Cook Inlet in Alaska
Hurricane modeling requires NCEP to include shallow water physics.

- Waves

- Hurricane modeling requires NCEP to include shallow water physics.
Waves

New concept of operations: NCEP model driven with either model (NAM) or forecaster (NDFD) winds.
Wave height increments from altimeter and buoy data. Moving toward assimilating all buoy and altimeter data in multi-grid model.
New ensemble with more realistic variability (shaded).

Old ensemble setup, ensemble with cycling of initial conditions and wind bias correction (BC).
Mean wave height (contours) and spread (shading)
2008/03/28 t06z 48h forecast
<table>
<thead>
<tr>
<th></th>
<th>RTG_SST</th>
<th>RTG_SST_HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Resolution</td>
<td>0.500 degree</td>
<td>0.083 degree</td>
</tr>
<tr>
<td>(Lon/Lat grid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-situ Data</td>
<td>Fixed buoys, drifting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>buoys, and ships</td>
<td></td>
</tr>
<tr>
<td>Satellite Data</td>
<td>NOAA 17 AVHRR</td>
<td>NOAA 17 and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOAA 18 AVHRR</td>
</tr>
<tr>
<td>Satellite Processing</td>
<td>NAVOCEANO</td>
<td>JCSDA Physical</td>
</tr>
<tr>
<td></td>
<td>Retrievals</td>
<td>Retrievals</td>
</tr>
<tr>
<td>Correlation length</td>
<td>450km – 100 km</td>
<td>450km – 50 km</td>
</tr>
<tr>
<td>scales for increments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(errors)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVHRR Limitation</td>
<td>Can not see through</td>
<td></td>
</tr>
<tr>
<td>(Serious)</td>
<td>clouds</td>
<td></td>
</tr>
<tr>
<td>Satellite data bias</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>correction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day to day change</td>
<td>(Large: 0.5 to 1.0)</td>
<td>Greatly reduced</td>
</tr>
</tbody>
</table>
Continuous need for including new and improved satellite data. Particular interest for AMSR data.

Used as a separate product, and for validating ocean modeling.
Northern and Southern Hemisphere daily ice concentration products based on SSMI data, including SSMI based weather filtering of data.
• Present capability at NCEP:
    • Deterministic 5-6 day forecast.
    • Assimilation of most available data with in-house assimilation schemes.
    • Run once per day.
  – MOM3-4 (GFDL) ocean model as part of the coupled Climate Forecast System (CFS).
    • Supporting MOM4 based Global Ocean Data Assimilation System (GODAS).
  – Test version of HYCOM-HWRF coupled hurricane model.
NCEP plans to adopt the Navy 1/12° global HYCOM model (common code)

2009: Run at NCEP with Navy initialization (NCEP winds)

2012: Full support at NCEP (DA & Winds)
Cold wake from Rita from NASA web site.

http://svs.gsfc.nasa.gov/vis/.../hurricanes2005_depc_tracksALL.0460.png
From coupled HYCOM-HWRF model at same valid time

And 36 hours earlier
Future Plans

• Implement global 1/12° HYCOM model at NCEP late 2009
  – Relies on close collaboration with Navy NRL (ESMF compliant)
  – Computing capacity for full operational support becoming available in 2011
  – NCEP will continue to provide a portal for dissemination of Navy and NOAA “products” from this global system

• High-resolution global model to support OPC services and coupled ocean-atmosphere modeling at NCEP
  – Initialization and boundary data for coupled hurricane models.
    • WRF-HYCOM coupled model in parallel testing in 2008.
  – Initialization for global coupled ocean-atmosphere models (near real time up to seasonal)
  – Work with GFDL on bridging the present modeling gap between near real time and climate ocean modeling.
  – Expand coastal forecast modeling capabilities (NOS, OAR and regional partners)
National Environmental Modeling System (NEMS) (uses standard ESMF compliant software)

- Analysis
- Ocean
- Wind Waves
- LSM
- AQ
- Ens. Gen.
- Ecosystem
- Etc.

- Application Driver

ESMF Superstructure (component definitions, "mpi" communications, etc)

- Atmospheric Model
  - Dynamics (1,2)
  - Physics (1,2,3)
  - Multi-component ensemble
  - Stochastic forcing

- ESMF Utilities (clock, error handling, etc)

- Bias Corrector
  - Post processor & Product Generator
  - Verification
  - Resolution change

Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISL, COAMPS...)/Physics (GFS, NRL, NCAR, GMAO, ESRL...)

* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC), NOAA/GFDL

2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments