The NOAA Environmental Modeling System (NEMS)

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NOAA/NWS/NCEP
The EMC Mission.....

In response to operational requirements:

- **Develop and Enhance** numerical guidance
  - Improve NCEP’s numerical forecast model systems via:
    - Scientific upgrades
    - Optimization
    - Additional observations

- **Transition** operational numerical forecast models from research to operations
  - Transform & integrate
    - Code
    - Algorithms
    - Techniques
  - Manages and executes transition process including technical and system performance review before implementation

- **Maintain** operational model suite
  - The scientific correctness and integrity of operational forecast modeling systems
  - Modify current operational system to adapt to ever-present external changes
NWS Seamless Suite of Forecast Products Spanning Weather and Climate

NCEP Model Perspective

Outlook
Guidance
Threats
Assessments
Forecasts
Watches
Warnings & Alert Coordination

Forecast Lead Time

Minutes
Hours
Days
1 Week
2 Week
Months
Seasons
Years

Forecast Uncertainty

Benefits

Life & Property
Aviation
Maritime
Space Operations
Fire Weather
Emergency Management
Commerce
Energy Planning
Hydropower
Reservoir Control
Agriculture
Recreation
Ecosystem
Health
Environment

- Climate Forecast System
- North American Ensemble Forecast System
- Global Ensemble Forecast System
- Global Forecast System
- Short-Range Ensemble Forecast
- North American Mesoscale
- Rapid Update Cycle for Aviation
- Dispersion Models for DHS
- Real Time Ocean Forecast System
- Waves
- Hurricane WRF & GFDL
- Space Weather
- Tsunami
Linkage of Model Systems Within Production Suite

Global Data Assimilation

CLIMATE
CFS
GFS + MOM3/4

Global Forecast System

North American Mesoscale
NMM

Hurricane
GFDL
HWRF (NMM)

Coupled

Oceans
HYCOM
WaveWatch III

Dispersion, Ash, Smoke & Dust
ARL’s HYSPLIT

Severe Weather
NMM + ARW

Air Quality
NAM + EPA/ARL’s CMAQ

North American Ensemble Forecast System
GFS + Canadian Global +…

Regional Data Assimilation

Short-Range Ensemble Forecast
NMM + ARW + ETA + RSM

Very Short Range Ensemble Forecasts
Time-Lagged RUC+NAM

Rapid Update for Aviation
GSD’s RUC

~3.5B Obs / Day
'Mostly' Satellite + Radar

GFS + Canadian Global +…
NOAA Environmental Modeling System

- A shared, portable, high performance software superstructure and infrastructure

- For use in operational prediction models at National Centers for Environmental Prediction (NCEP)

- National Unified Operational Prediction Capability (NUOPC) with Navy and Air Force

- Eventual support to community through Developmental Test Center (DTC)

- [http://www.emc.ncep.noaa.gov/NEMS/](http://www.emc.ncep.noaa.gov/NEMS/)
Motivation for NEMS

- Develop a common superstructure for all NCEP models
- Modularize large pieces of the models with ESMF components and interfaces
- Divide atmospheric models down into Dynamics and Physics components but no further
- Take history file I/O outside the science parts and into a common Write component
- Keep science code and parallelization code in the respective models the same as before
<table>
<thead>
<tr>
<th>Name</th>
<th>Project</th>
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<tbody>
<tr>
<td>Tom Black</td>
<td>NAM</td>
</tr>
<tr>
<td>Dusan Jovic</td>
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<tr>
<td>Jim Abeles</td>
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<td>S Moorthi</td>
<td>GFS</td>
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<tr>
<td>Henry Juang</td>
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<td>Jesse Meng</td>
<td>Land</td>
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<td>Jim Geiger</td>
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<tr>
<td>Sarah Lu</td>
<td>GOCART</td>
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<tr>
<td>Arlindo da Silva</td>
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<tr>
<td>Tom Henderson</td>
<td>FIM</td>
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<td>Jim Rosinski</td>
<td></td>
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<tr>
<td>Eugene Mirvis</td>
<td>DTC</td>
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</tbody>
</table>
Below the dashed line the source codes are organized by the model developers.
Operational Implementation Q3FY11

- 12 km NAM will still run to 84 hr
- Fixed domain nests run to 60 hr
  - 4 km CONUS
  - 6 km Alaska
  - 3 km HI & PR
- Single locatable 1.33 km (CONUS) or 1.5 km (Alaska) nest to 36 hr
- Nests
  - Static, 1-way
  - Boundaries from parent every timestep
  - Nest is “grid-associated” with parent (same orientation w.r.t. earth)
  - Moving nests and 2-way interaction under development
- Dynamics, physics and chemistry run on the same grid in the same decomposition
- GOCART does not own aerosol tracers (i.e., do not allocate aerosol tracer fields)
- **PHY2CHEM coupler component** transfers/converts data from physics export state to GOCART import state
  - Convert units (e.g., precip rate, surface roughness)
  - Calculations (e.g., soil wetness, tropopause pressure, relative humidity, air density, geopotential height)
  - Flip the vertical index for 3D fields from bottom-up to top-down
- **CHEM2PHY coupler component** transfers data from GOCART export state to physics export state
  - Flip vertical index back to bottom-up
  - Update 2d aerosol diagnostic fields
NEMS Delivery Plans

• 2011
  – GFS
  – GEFS
  – Postprocessor
  – FIM
  – Multimodel ensemble
  – GRIB2 output

• 2012+
  – NMM nested in GFS
  – Moving nests
  – Coupled ocean atmosphere
  – Tiled land model
  – netCDF output
  – ARW
Questions Welcome

For the past several years, a common modeling framework called the NOAA Environmental Modeling System (NEMS) has been in development to...
NWS Seamless Suite of Forecast Products Spanning Weather and Climate

**NCEP Model Perspective**

- Forecast Lead Time
  - Outlook
  - Guidance
  - Threats
  - Assessments
  - Forecasts
  - Watches
  - Warnings & Alert Coordination

- Forecast Uncertainty
  - Years
  - Seasons
  - Months
  - 2 Week
  - 1 Week
  - Days
  - Hours
  - Minutes

**Benefits**

- **Climate Forecast System**
  - North American Ensemble Forecast System
    - North American Mesoscale
    - Rapid Update Cycle for Aviation
    - Dispersion Models for DHS
  - Global Ensemble Forecast System
  - Global Forecast System
  - Short-Range Ensemble Forecast
  - North American Mesoscale

- **Real Time Ocean Forecast System**
  - Waves
  - Hurricane WRF & GFDL

- **Space Weather**
  - Tsunami
Production Suite on Supercomputer

January 2010

Development Work

Fence

High Water Mark

Time of the day (utc)

Number of Nodes
Production Suite on Supercomputer

December 2010

Capacity Change:
50% increase in production
80% decrease in development
Mid Q3 FY11
Includes: GEFS Prod & Para, SREF Prod & Para, 37 nodes for HRW/Hurricanes
Comparison of the NCEP and ECMWF Production Suites from a Computational Perspective

CPU Utilization for 24 Hour Cycle of Production Suite on IBM P6

ECMWF: 2 cycles/day; NCEP 4 cycles/day
NCEP: note complexity of production suite (many colors)
ECMWF: fills the “valleys” in production; NCEP developing capability
Comparison of the NCEP and ECMWF Production Suites from a Computational Perspective

CPU Utilization for 24 Hour Cycle of Production Suite on IBM P6

With compute capacity scaled......

ECMWF: High water mark is ~210 nodes (EPS)
NCEP: maximum available for production ~132 nodes
NCEP: High water mark is ~ 110 nodes
Comparison of the NCEP and ECMWF Production Suites from a Computational Perspective

CPU Utilization for 24 Hour Cycle of Production Suite on IBM P6

ECMWF to a IBM P7 in late FY11

ECMWF: High water mark is ~210 nodes (EPS)
NCEP: maximum available for production ~132 nodes
NCEP: High water mark is ~110 nodes
NCEP Aggressively Porting Codes to Other Compute Centers

• Current Porting Activities:
  - HEVDAS development in Boulder
  - NASA—ARC, GSFC (JCSDA), projects
  - Benchmarks for computer acquisition
  - In discussion with NSF

• Coming Attractions:
  - NOAA Climate Computing at ORNL (GAEA)
  - NOAA R&D at Fairmont WV—First drop early FY12
  - Upgrade of Operational Compute in FY14

Schedule for NOAA Computing at ORNL CRAY XT6 (GAEA)

<table>
<thead>
<tr>
<th>Milestone Date</th>
<th>System Configuration/Milestone</th>
<th>CPU Cores</th>
<th>Tflops</th>
<th>Memory Per Core (GB)</th>
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</thead>
<tbody>
<tr>
<td>October ’10</td>
<td>CMRS.1 Available to Users</td>
<td>~31,000</td>
<td>260</td>
<td>~2.67</td>
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<tr>
<td>October ’11</td>
<td>CMRS.2 Available to Users</td>
<td>~78,000</td>
<td>720</td>
<td>2.0</td>
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<td><strong>Oct ’11 – Feb ’12</strong></td>
<td><strong>CMRS.1 + CMRS.2</strong></td>
<td><strong>~109,000</strong></td>
<td><strong>980</strong></td>
<td><strong>2.0</strong></td>
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<tr>
<td>February ’12</td>
<td>CMRS.1 Upgrade</td>
<td>~41,000</td>
<td>386</td>
<td>2.0</td>
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<tr>
<td><strong>Feb’12 – Sep’14</strong></td>
<td><strong>Final CMRS Configuration</strong></td>
<td><strong>119,000</strong></td>
<td><strong>1,106</strong></td>
<td><strong>2.0</strong></td>
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