The Next Generation Global Prediction System and the NCEP Production Suite

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Presentation Outline

- NWS and the Weather Ready Nation
- Current state of NOAA operational modeling
- The UMAC—external advise on the modeling suite
- Next Generation Global Prediction System
- Is a unified weather to climate guidance suite possible at NOAA/NCEP?
- If YES, how do we get there…
NWS Strategic Outcome: A Weather- and Water-Ready Nation

“Ready, Responsive, Resilient”

Becoming a Weather-Ready Nation is about building community resiliency in the face of increasing vulnerability to extreme weather, water and climate events.

Better forecasts and warnings  Actionable environmental intelligence
Consistent products and services  Connecting forecasts to decisions

Involves the entire US Weather, Water and Climate Enterprise WORKING TOGETHER

We have 3460 WRN Ambassadors
January 2016 Blizzard & Costal Storm: Connecting All of the Pieces

<table>
<thead>
<tr>
<th>Jan 15 - 18</th>
<th>Jan 19</th>
<th>Jan 20</th>
<th>Jan 21</th>
<th>Jan 22</th>
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<tbody>
<tr>
<td>Medium range products begin identifying heavy snow threat for the end of next week</td>
<td>Confidence increasing</td>
<td>Partner Coordination/ Briefings</td>
<td>Fed./state/local govts make critical decisions before the snow begins</td>
<td>Snow begins in the Mid-Atlantic</td>
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<td>NWS offices begin briefing partners on potential storm</td>
<td>Partner Coordination/ Briefings</td>
<td>Blizzard Watches Issued</td>
<td>Snow forecast adjusted to include NYC in Blizzard Warning</td>
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<td></td>
<td>Media interviews</td>
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<td>Blizzard Warnings Issued</td>
<td>Schools/Govt Close Flights Canceled Roads Closed</td>
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**Map**

- Winter storm could impact 75 million people
- Residents in at least 12 states are being asked to prepare for potentially damaging winter weather

**Images**

- Image of winter storm
- Image of traffic control

**Additional Information**

- State of Emergency Declared:
  - North Carolina
  - Virginia
  - West Virginia
  - District of Columbia
  - Maryland
  - Pennsylvania
  - New Jersey
  - New York

- 1 pm: Press Briefing
January 2016 IDSS Example: Long Island Expressway comparison to 2013

2013 Snowstorm

2016 Snowstorm

The Past

With NWS Impact-Based Decision Support Services (IDSS)
NWS Strategic Outcome: Weather-Ready Nation

NWS Strategic Goals

• Improve **Weather** Impact-Based Decision Support Services
• Improve **Water** Forecasting Services
• Enhance **Climate** Services and adapt to climate-related risks
• Improve sector-relevant information in support of **economic productivity**
• Enable environmental forecast services supporting **healthy communities and ecosystems**
• Sustain a highly skilled, professional **workforce** equipped with training, tools, and infrastructure to meet mission

Operational numerical guidance:

**Foundational tools to used to improve public safety, quality of life and make business decisions that drive U.S. economic growth**

**Prediction is what makes NOAA/NWS unique and indispensable!**
1955 - US Weather Bureau First Operational Production Suite

Baroclinic:
- 300 km / 3-layer CONUS to 36 hr
- 1500z run
- Started 2100z
- Finished 2230z

Thermotropic:
- 375 km / 2 layer No. Am to 36 hr
- 0300z run
- Started 1000z
- Finished 1230z

Barotropic:
- 600 km / 1 layer ~NHemis to 72 hr
- 0300z run
- Started 1230z
- Finished 1300z

500mb Height
72h Forecast Valid 03Z 11 March 1956
Seamless Suite of Operational Numerical Guidance Systems

Spanning Weather and Climate

Forecast Lead Time

Outlook
Guidance
Threats Assessments
Forecasts
Watches
Warnings & Alert Coordination

Forecast Uncertainty

Forecast Lead Time

Forecast Uncertainty

Minutes
Hours
Days
1 Week
2 Week
Months
Seasons
Years

Benefits

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

- Coupled Space Weather
- National Water Model

Benefits

• Climate Forecast System
  • North American Multi-Model Ensemble System
  • North American Ensemble Forecast System
  • Global Ensemble Forecast System
  • Global Forecast System
  • Global Dust
  • Short-Range Ensemble
  • Land DA
  • Wave Ensemble
  • North American Mesoscale
  • Waves
  • Global Ocean
  • Bays
  • Fire Wx
  • Regional Hurricane
  • Space Weather
  • Storm Surge
  • Rapid Refresh
  • HRRR
  • Ozone
  • Tsunami
  • Nearshore Wave

• Dispersion (smoke)
Hurricane Sandy (2012) Raises Public Awareness of Modeling...

European weather forecasts superior to US models

The predictions from European computer models, which have 10 times the computing ability of the National Weather Service, have increasingly become more accurate than our models with the starkest example being Hurricane Sandy. NBC’s Al Roker reports.

Why America Has Fallen Behind the World in Storm Forecasting

By Richard B. Rood

The superior performance of the European GFS model, in high impact storms after Snowsquall - has raised the question: good? Guest contributor Richard Rood*

As early as 1995, the weather...

Operational Computer Upgrade

Increased HPC capacity to 2.8 petaFLOPs
(for primary and backup, respectively—for a total of 5.6 PF)
Accepted for Operations: November 30th, 2015
### An Example of Complexity

- **Regional Hurricane**
  - GFDL
  - WRF-NMM

- **Regional NAM**
  - NMMB
  - NOAH

- **Short-Range Ensemble Forecast**
  - WRF(ARW, NMMB, NMM)

- **High Res Windows**
  - WRF(ARW, NMMB)

- **Rapid Refresh**
  - WRF ARW

- **Ecosystem**
  - EwE

- **Waves**
  - WaveWatch III
  - NWPS

- **Surge**
  - SLOSH

- **Dispersion**
  - HYSPLIT

- **Air Quality**
  - CMAQ

- **Wind Waves**
  - WaveWatch III
  - NWPS

- **Ocean**
  - HYCOM

- **Regional Bays**
  - Great Lakes (POM)
  - N Gulf of Mexico (FVCOM)
  - Columbia R. (SELFIE)
  - Chesapeake (ROMS)
  - Tampa (ROMS)
  - Delaware (ROMS)
  - San Francisco (FVCOM)

- **North American Bays**
  - Great Lakes (POM)
  - N Gulf of Mexico (FVCOM)

- **North American Land**
  - Sea Ice

- **North American Ensemble Forecast System**
  - GFS, MOM4, NOAH, Sea Ice

- **Global Forecast System**
  - GFS, MOM4, NOAH, Sea Ice

- **Global Ensemble Forecast System**
  - 21 GFS Members

- **North American Ensemble Forecast System**
  - GEFS, Canadian Global Model

- **North American Land Surface Data Assimilation System**
  - NOAH Land Surface Model

- **NEMS Aerosol Global Component (NGAC)**
  - GFS & GOCART

- **Space Weather**
  - ENLIL GeoSpace

- **High Resolution**
  - WRF ARW
Modeling CONUS & O-CONUS: Expensive and Requires Nesting...

North American Model (NAM)
- Runs 4x/day
- Outer grid at 12 km to 84hr
- Multiple Nests Run to ~48hr
  - 4 km CONUS nest
  - 6 km Alaska nest
  - 3 km HI & PR nests
  - 1.3km DHS/FireWeather/IMET

Rapid Refresh (RAP)
- Runs 24x/day to 18h
- 13 km Domain includes Alaska
- 3 km HRRR runs 24x/day out to 15h

High Res Windows (HiRESW)
- Typically run 2x/day
- 4 km WRF-NMM
- 5.15 km WRF-ARW
- 48 hr fcsts from both

Short Range Ensemble Forecast System
- Runs 4x/day
- 21 members out to 72h
- 16km CONUS grids
RECOMMENDATIONS

- **Reduce complexity** of the NCEP Production Suite
- Create a **unified collaborative strategy** for model development across NOAA
- Leverage the **capabilities of the external community**
- Continue to **enhance High Performance Computing capabilities**
- Execute strategic and implementation plans based on stakeholder **requirements**

UMAC Key Finding

U.S. Environmental Prediction now has the potential to rapidly progress to world leadership. This requires a new level of organization and the use of evidence-driven decision making.
Next Generation
Global Prediction System (NGGPS)

- Identify and adopt an advanced non-hydrostatic dynamic core and evolve it to meet operational needs for the foreseeable future

- Evidence based decision making process to ensure scientific integrity and excellence

- Enhanced O2R2O process and a unified and efficient infrastructure for community engagement and rapid transition of advanced research into operations

- Seamless solutions for tropical weather and climate in a unified global-to-local-scale modeling framework

High-resolution nested grid simulations using HiRAM and Finite Volume 3 (FV3)
Immediate Priorities for NGGPS and the FV3 Dynamic Core

1. Implement the FV3 within the GDAS/GFS application
   - Test plan developed
   - Replaces the spectral core
   - GFDL, EMC and PSD working together
   - Implementation date in FY19

2. Make FV3 available to “superusers”
   - Inside NOAA to start (GSD, AOML, NSSL)
   - Must consider code management governance and process
   - Can not distract developers working GFS implementation

3. Assess best approach to making system “community” based
   - Review proven approaches (i.e., WRF, CESM, etc.)
   - Required to leverage expertise outside NOAA
   - High priority for NOAA to facilitate R2O and O2R

4. Systematically test FV3 at convective permitting scales-- UNIFIED System Possible
   - Similar to global dynamic core testing
   - NSSL, GSD, EMC, GFDL, NCAR, academia
Coordination of Unified Modeling activities over near term (~0-3 yrs)

- NCEP/EMC Director is now leading collaborative initiative to build near-term Strategic Implementation Plan (SIP) to synchronize community activities under single plan

- Collaborative approach starts with core partners and then build out to larger community. Initial core partners include:
  - NOAA (NWS, OAR, NOS, NESDIS), NCAR (MMM, CGD, RAL/DTC), NASA/GMAO, Navy/NRL, JCSDA

- Initial SIP meeting scheduled for Nov 16-17 in Boulder
  - Identify roles/responsibilities for each partner org
  - Assemble working groups to build out functional areas of SIP

- Next SIP meeting (~mid-2017 in DC) to incorporate WG output into comprehensive SIP >> executable plan for all to work from!
Factors Influencing Evolution of the Production Suite

- Global systems increase horizontal & vertical resolution
  - GFS satisfies NAM requirements to day 3
  - GEFS satisfies SREF requirements to day 3
  - GEFS reforecasts are a new requirement
  - Couple space weather with terrestrial on global scale

- Regional systems (NAM, RAP and HRRR) shift to convection permitting ensembles
  - HRRRE to satisfy WOF requirements
  - Regional hurricane applications must be considered

- Emerging requirements at weeks 3 & 4 and sub-seasonal to seasonal (S2S)
  - Coupled GEFS extended to 30-days
  - CFS and NMME for seasonal
  - Coupled ice, ocean, land, atmosphere, areosols

- Plans for WATER must be coordinated with forcing systems
  - NWM connection to atmospheric systems
  - Tropical and Extratropical Surge—strategic plan needed
  - Coastal bay models for ports
The NOAA Operational Modeling Strategy...High Level Perspective

Need to emphasize ensembles
- Ensembles for convective allowing, medium and seasonal
- Challenge to demphasize deterministic solutions
- New metrics for high impact weather and associated ensembles

Priorities for end-to-end model development:
1. Data assimilation (methodology and observations)
2. Resolution—horizontal and vertical
3. Physics & coupling earth system components
   - Clouds, microphysics, radiation, land, ocean, ice, aerosols
   - Knowing how and when to couple components
4. Post processing techniques
5. Dynamic core

Must consider advanced HPC technologies
- Massively parallel codes and systems
- Power becomes the limiting factor
- Prepare for exascale systems
Engaging the External Community Through NOAA Testbeds

Service – Science Linkage with the Outside Community: Accelerating the R2O Transition Process

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<thead>
<tr>
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<th>Testbed</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>EMC</td>
<td>Developmental Test Center</td>
<td>DTC</td>
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<tr>
<td></td>
<td>Joint Center for Satellite Data Assimilation</td>
<td>JCSDA</td>
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<tr>
<td>CPC</td>
<td>Climate Testbed</td>
<td>CTB</td>
</tr>
<tr>
<td>NHC</td>
<td>Joint Hurricane Testbed</td>
<td>JHT</td>
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<td>HPC</td>
<td>Hydrometeorological Testbed</td>
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<td>SPC</td>
<td>Hazardous Weather Testbed with NSSL</td>
<td>HWT</td>
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<tr>
<td>SWPC</td>
<td>Space Weather Prediction Testbed</td>
<td>SWT</td>
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<tr>
<td>AWC</td>
<td>Aviation Weather Testbed</td>
<td>AWT</td>
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Final Thoughts….

- Unprecedented opportunity and political support for operational modeling
  - Hurricane Sandy was 4 years ago and the clock is ticking LOUDLY to deliver results
  - Modeling a foundational component of the weather, water and climate enterprise
  - Members of community passionate and opinionated

- External reviews have forced the issue of a “unified” approach to modeling within NOAA
  - Simplify and unify production suite
  - Maximizes utilization of resources (personnel and HPC)
  - Must optimize interaction with community for O2R2O

- NOAA must leverage expertise across the community
  - We can’t do this alone—NGGPS provides opportunity for NWS and NOAA
  - NOAA centers and labs must collaborate rather than compete
  - Must optimize interaction with community for O2R2O
  - Plenty of science and work required----Data assimilation, physics, convective allowing ensembles, coupled earth system approach, etc.
  - Working with NAVY, NCAR, NASA effectively but need more engagement with NSF Programs and DOE
THE STRENGTH OF A COMMON GOAL

- Attractive working terms and environment to attract and retain the required talent
- ECMWF inspiring and attracting international scientific and computing collaboration across the Member States and beyond
- A powerful, energy-efficient and resilient infrastructure, including a high-performance computing facility, systematically seeking to minimise its environmental impact
- Scalable and efficient modelling and processing codes that encompass a comprehensive Earth system approach

Can the U.S. identify and achieve a common goal?
Can the U.S. identify and achieve a common goal?

THE UNCOORDINATED GIANT

Why U.S. Weather Research and Prediction Are Not Achieving Their Potential

BY CLIFFORD MASS

Although the U.S. meteorological community has made significant strides in weather prediction, more closely coordinated research and operations would accelerate progress.

There can be little doubt that weather prediction in the United States has improved considerably over the past several decades. Synoptic-scale numerical prediction models, such as the National Centers for Environmental Prediction’s (NCEP’s) Global Forecast System (GFS), are producing far more...