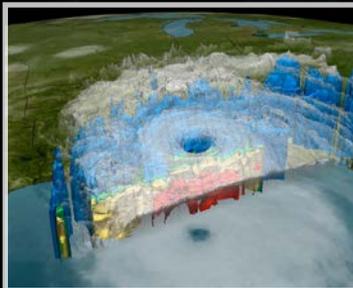
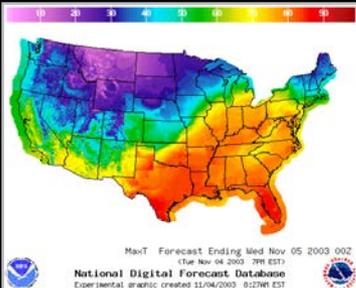
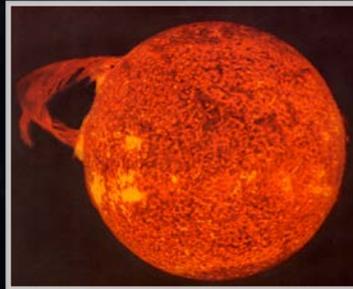
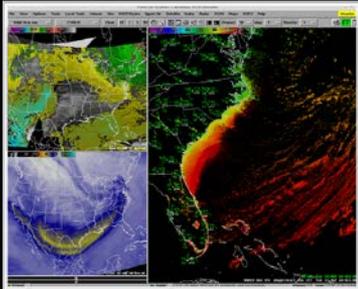


The National Centers for Environmental Prediction (NCEP): Thoughts On Operational Modeling.....



Dr. William M. Lapenta

Director, National Centers for Environmental Prediction

NOAA/National Weather Service

IQAGFR Meeting

1 September 2015



NWS Strategic Outcome: A Weather-Ready Nation

Becoming a Weather-Ready Nation is about building **community resiliency** in the face of increasing vulnerability to extreme weather

“Ready, Responsive, Resilient”

REQUIRES NWS TO:

- Fully Integrate our Field Structure:
 - Better Forecasts and Warnings
 - Ensure Consistent Products and Services
- Provide Impact-based Decision Support Services (IDSS)
- Deliver through Multiple and Reliable Dissemination Pathways
- Work with Partners to *gain needed response*; includes embedding NWS in Emergency Operations Centers

*We now have
Over 1200 WRN Ambassadors*

*Involves entire US Weather Enterprise WORKING TOGETHER
to achieve far-reaching national preparedness for weather events*



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:

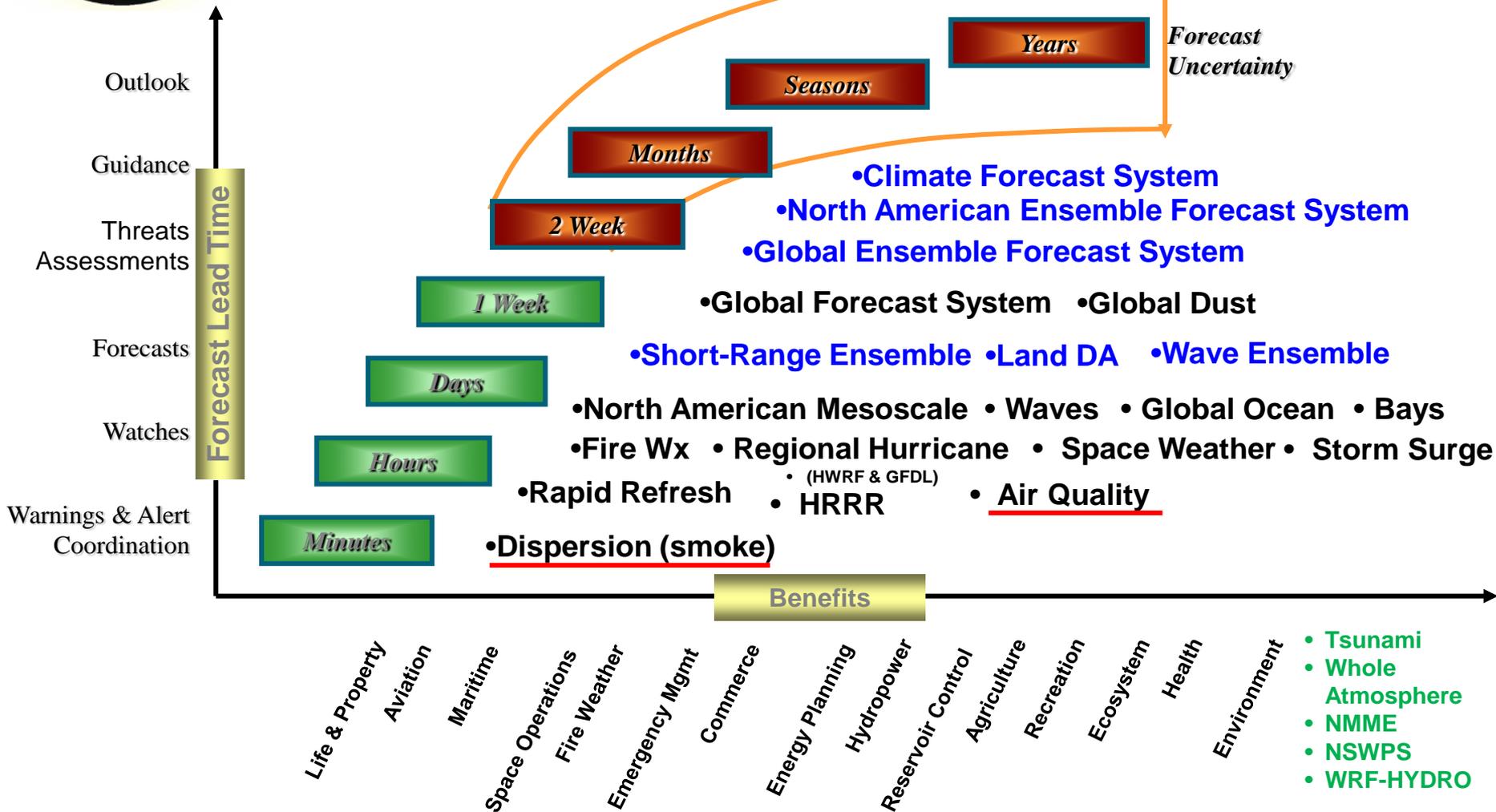
Foundational tools to used to improve public safety, quality of life and make business decisions that drive U.S. economic growth

Prediction is what makes NOAA/NWS unique and indispensable!



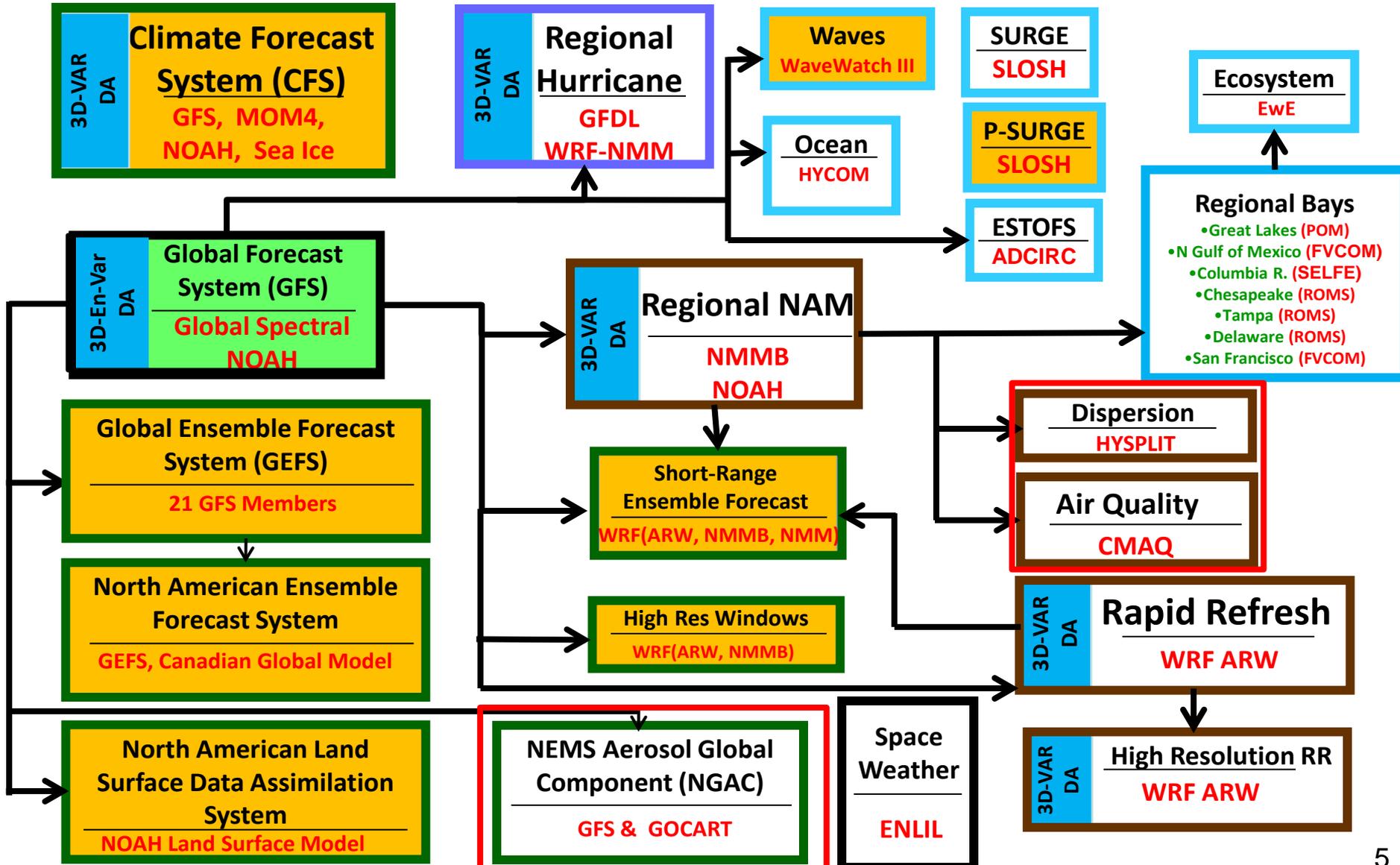
Seamless Suite of Operational Numerical Guidance Systems

Spanning Weather and Climate





NOAA's Operational Numerical Guidance Suite (June 2015)





Mapping NOAA Projects with Modeling into the Weather Ready Nation Goals



- Climate Modeling and Prediction
- National Earth System Prediction Capability
- North American Multi-Model Ensemble
- **Next Generation Global Prediction System**
- Hurricane Forecast Improvement Project
- Hi-Impact Weather Prediction Project
- Warn on Forecast
- Storm Surge Roadmap
- National Air Quality Forecast Capability
- Tsunami Modeling and Research
- Space Weather Modeling
- Ecological Forecasting
- Integrated Water Resources Science and Services

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



Sector-Relevant = Energy, Transportation, Agriculture, Coastal



University Center for Atmospheric Research Community Advisory Committee for NCEP (UCACN) Modeling Advisory Committee (UMAC)



- **First time with NOAA model developers, customers and external subject matter experts on modeling in the same room.**
- **Outcome: a set of recommendations that will be used to build a strategy to evolve the NPS over the next 5-10 years**
- **UMAC outcomes will inform:**
 - **The integrated NOAA modeling strategy**
 - **Priorities for NOAA funded research in modeling across line offices**
 - **AO's will allow external participation in research and development**
 - **Joint projects with NOAA scientists will be encouraged**
 - **External community becomes part of the development team**
 - **Involved in test plan development, execution and analysis (HWRP)**
 - **Enable NOAA to have a robust modeling program designed to meet agency mission**
- **Allows NOAA to step back and assess strategic evolution of the production suite**



UMAC Membership



First	Last	Affiliation
Christa	Peters-Lidard	NASA/GSFC
Alan	Blumberg	UCACN; Stevens Tech
Andy	Brown	Met Office
Cliff	Mass	U Washington
Ricky	Rood	U Michigan
Tom	Hamill	NOAA/ESRL
Chris	Bretherton	U Washington
Brian	Colle	Stony Brook
Jim	Doyle	NRL, Monterey
Ben	Kirtman	U Miami
Anke	Kamrath	NCAR
Eric	Chassignet	FSU, Director, COAPS
		UCACN; Weather Company
Peter	Neilley	
Fred	Carr	UCACN; U Oklahoma
Jim	Kinter	UCACN; COLA/GMU
Bill	Kuo	UCACN; DTC; NCAR
Gilbert	Brunet	UCACN; Met Office
Tsengdar	Lee	UCACN; NASA HQ

- Meeting 4-7 August 2015 in College Park
- 90 Participants across the community
- Preliminary findings and recommendations briefed to NOAA leadership
- Report to be published by the end of October 2015
- Materials available at:

https://www.earthsystemcog.org/projects/umac_model_advisory/



NOAA Operational System Attributes



Dispersion Modeling

System Name	Acronym	Areal Coverage	Horz Res	Cycle Freq	Fcst Length
Volcanic ash	HYSPLIT	Global	0.1 deg.	OD*	48 h
Regional Specialized Meteorological Center	RSMC	Global	0.3 deg.	OD	72 h
Dust	HYSPLIT	CONUS	0.1 deg.	6; 12z	48 h
Smoke	HYSPLIT	CONUS; HI; AK	0.15; 0.05; 0.10 deg.	24 h	48 h
WFO-HAZMAT /canned	HYSPLIT	CONUS	0.005 deg.	OD/ 6 h	16 h
Comprehensive Test Ban Treaty Organization	CTBTO	Global	1 deg.	OD	10-15 days

Air Quality : National AQ Forecasting Capability Surface O₃ and PM_{2.5}

System Name	Acronym	Areal Coverage	Horz Res	Cycle Freq	Fcst Length (hr)
North American Mesoscale (meteorology)	NAM	North America	12 km	6 hrly	84
NEMS GFS Aerosol Component (lateral boundary conditions)	NGAC	global	1°x1°	Daily	5 days
Community Multi-scale Air Quality Model (CMAQ)	AQM	CONUS; AK; HI	12 km	6 hrly	48 (6Z, 12Z)



Why Systems are Operational



Dispersion Systems:

- **Primary stakeholders and requirement drivers**
 - **WMO/International Atomic Energy Agency/NOAA RSMC/CTBTO MOA**
 - **Federal Aviation Agency (FAA)/ International Civil Aviation Organization (ICAO)/ Volcanic Ash Advisory Center (VAAC)**
 - **WFOs on demand dispersion of Hazardous Materials**
 - **State and local air quality forecasters and general public Air Quality Forecast System**

Air Quality : National AQ Forecasting Capability Surface O₃ and PM_{2.5}

- **Primary stakeholders and requirement drivers**
 - **State and local air quality forecasters, and the general public**



UMAC Preliminary Findings and Recommendations



UMACN Model Advisory Committee

Date: 20150807

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.



Difference Between Requests and Requirements



- **Everyone has requests**
 - from changing the size of a font
 - adjusting a formula in the database
 - the key is identifying which ones are requirements.

- **To request, means to ask for something**
 - It could be something you need, want, or just feel like asking for
 - I request help carrying my bags

- **To require, means you need something**
 - I require oxygen to live

- **functional requirements: What the system is supposed to do**

- **operational requirements: These are about how to run the system.**

- **technical requirements: These are about how the system is built.**



UMAC Preliminary Findings and Recommendations



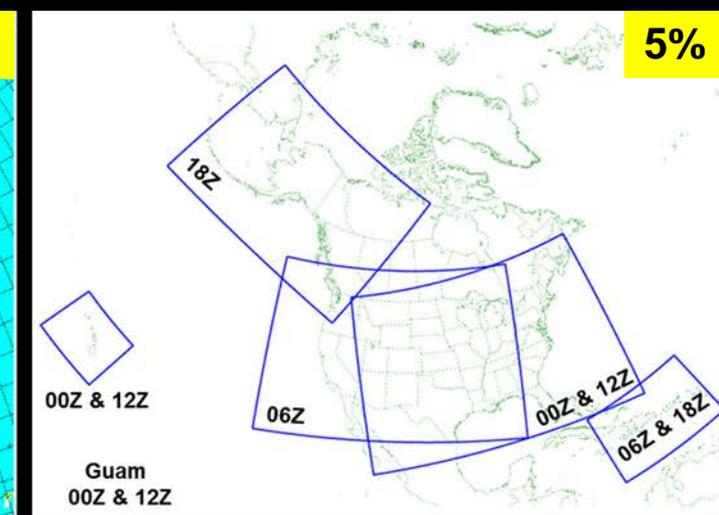
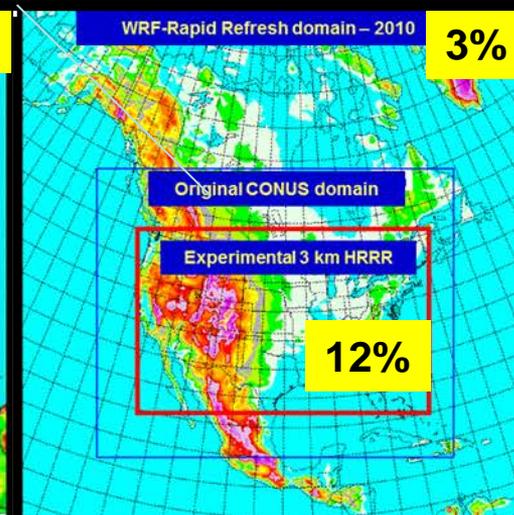
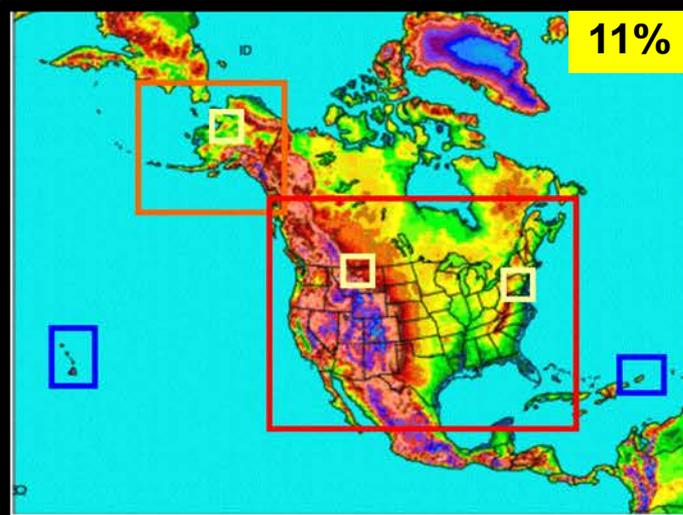
2. Transition to Evidence-Driven Decision Making.

One of the most striking observations of the committee is that the NOAA environmental modeling community lacks a rational, evidence-driven approach towards decision-making and modeling system development. The NGGPS effort is a good start in this direction.

Major new modeling initiatives (new distributed hydrological systems, additional rapid refresh implementations) must be evaluated for value to NOAA mission requirements before being made operational.



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

10%



UMAC Preliminary Findings and Recommendations



UCACN Model Advisory Committee

Date: 20150807

3. Reduce the Complexity of the NCEP Production Suite

The large number of modeling systems maintained by NCEP is overwhelming NCEP personnel, computer resources and stakeholders. It greatly reduces the ability of individual NCEP modeling systems to achieve excellence. A strategy for the phasing out of obsolescent models needs to be put in place.

NCEP has committed itself to one global atmospheric modeling system. It should make a similar commitment to only one regional atmospheric model. In the longer term, regional rapid refresh, hurricane, convection-allowing ensembles, and data assimilation should migrate towards one system.



BACKUP SLIDES



Air Quality : National AQ Forecasting Capability

surface O₃ and PM_{2.5}

Presented By: Pius Lee (OAR/ARL)

Contributors: Jeffery McQueen, Jianping Huang, Ho-Chun Huang

Perry Shafran (NCEP/EMC/MMB)

Jerry Gorline (NWS/MDL)

James Wilczak, David Alluded, Irina Djalalova (ESRL)

Ivanka Stajner, Sikchya Upadhaya (NWS/STI)

Jun Wang (NCEP/EMC/GMB)

Sarah Lu (NYU Albany)

Daniel Tong, Hyuncheol Kim, Li Pan (OAR/ARL & UMD)



Operational System Attribute(s)



System Name	Acronym	Areal Coverage	Horz Res	Cycle Freq	Fcst Length (hr)
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System Data Assimilation or Initialization Technique

System	Attributes
AQM	<p>Previous cycle model forecast provides the initial condition. Developmental predictions of particulate matter smaller than 2.5 μm in diameter ($\text{PM}_{2.5}$) are produced by this same operational system comprised of NAM and CMAQ model. Satellite observations constrain wildfire locations for smoke emissions. Bias correction of $\text{PM}_{2.5}$ predictions using surface AIRNow $\text{PM}_{2.5}$ observations is in testing.</p>



Why System(s) are Operational



- **Primary stakeholders and requirement drivers**
 - **State and local air quality forecasters, and the general public**
- **What products are the models contributing to?**
 - **AQ forecasts and alerts from local and state AQ forecasters**
- **What product aspects are you trying to improve with your development plans?**
 - **Up-to-date emissions (projections, smoke and dust)**
 - **Forecast initialization (data assimilation)**
 - **Refine resolution of predictions (horizontal for products, vertical to improve linkage with global models)**
- **Top 3 System Performance Strengths**
 - **Accuracy of surface O₃ forecast guidance**
 - **Timeliness and availability**
 - **Emerging developmental PM_{2.5} forecast capability**
- **Top 3 System Performance Challenges**
 - **Small-scale features (e.g., lake breezes) need finer resolution**
 - **Lag in emission inventory availability, need for up-to-date data**
 - **Quantitative prediction of PM_{2.5}**



System Evolution Over the Next 5 Years



- **Major forcing factors**
 - EPA National Ambient AQ Standards (NAAQS) are being tightened
 - Importance of characterizing global pollutant contributions to air quality as U.S. emissions decrease
- **Science and development priorities**
 - Improved PM_{2.5} emissions and modeling (e.g., Secondary Organic Aerosols (SOA))
 - Refine resolution (inline CMAQ with weather modeling in NEMS)
 - Data assimilation: initialization and emission constraints
- **What are your top challenges to evolving the system(s) to meet stakeholder requirements?**
 - Inline CMAQ for fine resolution forecast to capture large gradients
 - Reduce seasonal biases (e.g. SOA formation and loss mechanisms)
 - Dynamic boundary condition for gaseous and aerosol species
- **Potential opportunities for simplification going forward**
 - Unify smoke and dust emissions between HYSPLIT & CMAQ.
 - Coordination of composition modeling between the global model and CMAQ to improve their linkage through boundary conditions



Top 3 Things You Need From the UMAC



- #1 Recommend the complexity of aerosol and gaseous composition representation in the global model that is necessary to provide lateral boundary conditions for successful prediction of air quality for the U.S.**
- #2 Recommend the granularity of inlining for CMAQ to allow flexibility of its coupling to evolving earth modeling system capability and compatibility with the EPA-maintained CMAQ community code (e.g., Cloud processes and aqueous chemistry).**
- #3 Recommendation on chemical data assimilation priorities and ways of maintaining the impact from assimilation of observations into the following days' air quality predictions.**



Agenda Topic: Dispersion Modeling

Presented By: Barbara Stunder/Ariel Stein (OAR/ARL)
Contributors: Glenn Rolph, Tianfeng Chai (OAR/ARL),
Jeff McQueen, Ho-Chun Huang, Jianping Huang (NCEP/EMC)



Operational System Attribute(s)



System Name	Acronym	Areal Coverage	Horz Res	Cycle Freq	Fcst Length
Volcanic ash	HYSPLIT	Global	0.1 deg.	OD*	48 h
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Comprehensive Test Ban Treaty Organization	CTBTO	Global	1 deg.	OD	10-15 days

System Data Assimilation or Initialization Technique

System	Attributes
Smoke and Dust	Lagrangian particle attributes initialized from last forecast. Emission initialization from visible satellite (e.g. Hazardous Mapping System).
Volcanic Ash, RSMC, WFO-HAZMAT	Source location and strength (eruption height for volcano) provided by requester
CTBTO	Receptor location provided by requester

* OD: on demand/Emergency Response



Why System(s) are Operational



- **Primary stakeholders and requirement drivers**
 - WMO/International Atomic Energy Agency/NOAA RSMC/CTBTO MOA
 - Federal Aviation Agency (FAA)/ International Civil Aviation Organization (ICAO)/ Volcanic Ash Advisory Center (VAAC)
 - WFOs on demand dispersion of Hazardous Materials
 - State and local air quality forecasters and general public Air Quality Forecast System
- **What product aspects are you trying to improve with your development plans?**
 - **Provide uncertainty to modeled pollutant concentrations**
 - **Improve model accuracy**
- **Top 3 System Performance Strengths**
 - Only one HYSPLIT executable and library for all applications
 - Very low computational demand (2-7 min. for OD runs)
 - Lagrangian approach parallelized naturally. Can perform runs independently of each other and add the outputs.
- **Top 3 System Performance Challenges**
 - Need to continuously keep up with changes in operational meteorological datasets
 - Scarcity of verification data
 - Big uncertainty in real-time source terms



System Evolution Over the Next 5 Years



- **Major forcing factors**
 - Stake holders demand more accurate predictions with additional information about model uncertainty for dispersion applications
- **Science and development priorities**
 - Ensemble modeling (e.g. using SREF)
 - Increase resolution using the HRRR or NAM CONUS nest
 - In-lining with NWS meteorological models
 - Data assimilation of satellite and ground measurements
 - Implement Transfer Coefficients Matrix (TCM) method for varying initial source terms
- **What are your top challenges to evolving the system(s) to meet stakeholder requirements?**
 - Yearly frequency of implementations and the length of pre-operational testing delay implementation of model updates
 - Will require NWS technical and scientific support for transition to operations
- **Potential opportunities for simplification going forward**
 - Explore direct availability of meteorological variables relevant to dispersion
 - Consolidation into fewer meteorological models will help to simplify pre-processing and data flow.



Top 3 Things You Need From the UMAC



- 1. Facilitate flow of scientific ideas and information between dispersion and weather modelers (e.g. meteorological variables more relevant for dispersion applications; ensemble model design).**
- 2. Enable better integration of planning for dispersion services with the rest of weather service and modeling planning.**