Perspectives on U.S. NWP and EPIC
from
NCEP/NWS/NOAA NWP Review Committees

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History of NCEP/NWS/NOAA NWP Review Activities

- **November 2008**: NCEP Director (Louis Uccellini) asked UCAR to host a "Deep Dive" review of NCEP, which was led by Fred Carr and Jim Kinter (5 teams of 7 each plus Exec. Comm.)
- **2009**: Review team wrote 10 reports (9 NCEP Centers plus Office of Director), with 263 Recommendations
- **2011-2015**: UCACN (UCAR Community Advisory Committee for NCEP) - Led by Carr and Kinter, then by Gary Lackmann and Peter Neilley; wrote 5 annual reports
- **2015**: NCEP Director (Bill Lapenta) created UCACN Modeling Advisory Committee (UMAC) to provide "comprehensive technical review of NCEP Production Suite"; led by Carr and Ricky Rood; wrote 3 reports
- **2018**: UMAC and UCACN sunsetted; Community Modeling review Committee (CMrC) created by OSTI and OAR-OWAQ; led by Carr and Kinter; first report Dec. 2018

UMAC Overarching Finding

NOAA's organization of Numerical Weather Prediction (NWP) is unusual in many respects.

No other peer environmental prediction service:

- **separates its basic research and development from its applied, operational model implementation**
- **produces such a diversity of prediction systems, most without the critical mass of resources to make them world-best**
- **lacks top-level oversight spanning the research to applied development to operations**

This situation makes it extremely challenging for the U.S. to have world-best NWP.

The U.S. needs seamless and effective collaboration among NOAA units coupled with strong leadership.

Primary UMAC Recommendations for NCEP Modeling Suite - 2015

- Reduce complexity of the NCEP Production (Unified Forecast System - UFS)
- Create a unified collaborative strategy for development across NOAA
- Leverage capabilities of external community
- Continue to enhance High Performance Computing capabilities
- Execute strategic and implementation plans based on stakeholder requirements

UMAC Statement on Community

- **Though a significant community has been engaged in the NGGPS and SIP processes, continued engagement and future success is not assured. Resources are now needed to support community participation in model development and evaluation. A governance structure that incorporates community involvement in an effective manner needs to be stood up.**

- **UMAC offered the following definition of a successful community:**

  "A vibrant, active and very large set of users of the model who have downloaded, installed and frequently run the model, and are willing to share their technical experiences and scientific knowledge of the model with others."

Other Important UMAC and CMrC Recommendations

- NCEP/NWS/NOAA should produce a visionary, readable and highly visible strategic plan for U.S. NWP to share community-wide, coupled with a public announcement.
- The UFS should be well-documented, with a well-resourced support system (tutorials, workshops, help desk, computing resources, user-friendly workflow and software environment, etc.) and a mechanism for feedback from model stakeholders.
- NOAA should incentivize stakeholders to collaborate with NOAA on NWP R&D.
- HPC: Need stable, ambitious multi-year plan; research HPC needs to be >> operational capacity; must have "HPC investment balancing", in which disk storage, archival storage, memory, interconnect bandwidth and distribution capabilities, as well as software to support data management and workflow are provided to optimize both operational and R&D effectiveness; explore use of cloud computing
- Need coherent and collaborative effort linking all aspects of water-related products

Other Important UMAC & CMrC Recommendations (2)

- NOAA needs a coordinated strategy across line offices on how to invest in and collaborate on a UFS that integrates NOAA labs, CIs and centers as well as the non-NOAA community
- Strong ties between NOAA and UCAR/NCAR/UCP are essential
- There needs to be a better balance in UFS funding, both internally and externally, between short-term, implementation-related projects (RL 6-7-8) and projects that will lead to UFS improvements in the 4-10 year time frame (RL 3-4-5)
- There needs to be a process, based on coordination among SIP WGs, EMC, OAR, etc., for articulating the most crucial UFS science needs to the OAR and external communities
- Who's in charge? Better clarity is needed on the relative roles and responsibilities of leaders in EMC, NCEP, OAR, UFS SC, NWS HQ, NCAR/UCAR and now EPIC

UMAC and CMrC appreciate the substantial commitment by NWS and OAR to a unified modeling approach, the engagement and involvement of the external community and the shared goal of making the U.S. world-best in NWP

Actions taken by NOAA/NWS/NCEP in Response

- Develop strategic plan for unified atmospheric, oceanic and coupled modeling system in concert with other parts of NOAA and the weather & climate enterprise (NGGPS; UFS)
  - Strategic Plan and Roadmap conceived
  - NCEP has partnered with other parts of NOAA and the outside community to develop a unified modeling Strategic Implementation Plan (initiated by Mike Farrar) and selected a new atmospheric dynamical core (FV3)
    - Initiated by Louis Uccellini; led by Ming Ji, Fred Toepfer, Tim Schneider & others in OSTI
    - Evidence-based, open and objective selection process undertaken by Dynamic Test Group (DTG)
    - Major NOAA-wide effort to implement FV3GFS (in operations in May 2019)
    - Steering Committee led by Ricky Rood and Hendrik Tolman
- Strengthen partnerships to develop next data assimilation & ensemble systems - e.g., hybrid EnKF-4DVar; NMME
  - Development of JEDI data assimilation infrastructure
- Accelerate R20 and O2R
  - Developed SIP WG process; additional funding for external investigators
- Work with its Centers on Impact-based Decision-support Services (IDSS)
  - IDSS fully ingrained into NCEP Service Centers
- Support Visiting Scientist Programs - Universities; NOAA labs
  - A few people have visited, but the program is sub-critical

What hasn't NOAA done yet?

- Support a community of users - still no documentation, tutorials/workshops, easy-to-use workflow, access to HPC, shared tools for prep and post, etc.
- Implement an accelerated and transparent R2O process - still operating as before
- Articulate the set of research priorities for each forecast application (air quality, short-range weather, hurricane, medium-range weather, sub-seasonal to seasonal, coastal, marine and cryosphere, space weather)
- Implement an advanced data assimilation system competitive with ECMWF (including improved use of available data sources and better QC)
- Reduce the number of regional models and clarify the path to one regional model and one hi-res ensemble - still have NAM, NAM-nests, RAP, HRRR, HWRF, HMON, SREF, HREF2, with new ones (SAR, HAFS) in pipeline
- Engage community in planning for coupled / Earth system modeling - e.g., which forecast applications? Reanalysis and reforecast requirements?

Our View of Vital Next Steps
(i.e. - new actions that need to be taken)

- See slides 4-7, 9!
- NOAA must be "all-in" in developing and deploying UFS
  - Accelerate innovation into NOAA operations - a cultural as well as programmatic challenge
  - Provide scientific community with credible scientific tools for research to benefit NOAA
- Those parts of NOAA labs involved with NWP should integrate and closely coordinate UFS activities - there should be no independent model development
- NOAA leadership should set goals for & demand accountability in achieving world-best NWP
  - Consider appointing a "NWP Czar", with budget and decision authority across line offices
- Need a clear, broad & stakeholder-vetted set of metrics for model verification
  - New reanalyses/reforecasts for effective post-processing
- Need a broader "Water Initiative"
  - Water-related NWP is not well-coordinated across NOAA and not state-of-the-art

Our View of Vital Next Steps (2)

- **EPIC should be established outside NOAA**
- **EPIC should have a physical hub as a focal point for UFS expertise & community support**
  - "Sub-hubs", located elsewhere but with highly-desired expertise, could be created
  - Funding needs to go to groups most capable of doing work, not spread too thinly
- **Once highest priority UFS needs are articulated (via coordination among SIP WGs, EMC, OAR, etc.), NOAA should bring together teams of experts from all sectors to address problems ("tiger teams" if short-term; "skunk-works" if long-term)**
- **Work with stakeholders for assistance acquiring HPC - both "big iron" and in the cloud**
- **Rethink structure/purpose of external grants programs; need strong Visiting Scientist program**
- **Need 5-10 year vision for S2S, including institutional structure for coupled model evaluation and clear/transparent definitions of process, metrics, goals and resp.**

1. Given your experience with the R2O process, what are the most important <u>risks</u> EPIC must address in order to be successful?

- Engaging the external community ineffectively - need to coordinate model-improvement research and testing among EMC, NOAA labs, universities and private sector. If use SIP WGs, a decision-making process needs to be established
- Alienating the external community - need a decision-making process that values input from outside EMC, e.g., by using the SIP WGs
- Insufficient funding to external community for accelerated R2O - need to determine, augment and coordinate available funding sources
- Insufficient HPC - need to provide critical mass of research computing capacity, i.e., 5X operational capacity
- Impedance mismatch between conservative implementation schedule and potential future rate of code changes - need to include NCO in discussions and decisions
- Ineffective user support - need to set up and manage user support system that enhances productivity of external community

2. How do we incentivize participation in EPIC?

- Ensure sufficient funding for the external community
- Increase funding for projects that are “higher in the funnel” (RL 4-5-6 levels)
- Ensure sufficient research HPC for entire community (NOAA and non-NOAA)
- Create attractive Visiting Scientist Program in NOAA labs & centers
- Provide effective user support system and workflow environment
- Show interest in external research activities and consider innovative ideas for transition to operations
- Reach out to PIs to motivate them to contribute to the UFS - people will participate if they think that their work has the potential to have an impact

3. What are the most important NWP problems to address immediately after EPIC is instantiated?

- More advanced QC and DA algorithms
- Holistic approach to improvement of physics
- Creation of one regional model to replace NAM, RAP, HRRR, etc.
- Techniques to create single-model ensembles with spread and reliability as good as from multi-model ensembles
- On S2S time scales, beating down systematic errors (cold tropical SST, diminishing variability, weak coupling of land surface and atmosphere, etc.)

4. UMAC and CMrC has been instrumental in evolving NOAA's NWP strategy. How do these groups now catalyze tactical involvement of the community in executing those strategies, in part through EPIC?

- CMrC should be given the appropriate charge to review EPIC and UFS activities (FACA issue needs to be addressed)
- To review certain specialty areas (ocean, hydrology, air quality, etc.), sub-groups under the purview of CMrC could be created to provide the required guidance
- CMrC could occasionally poll community to seek input on role of EPIC
- CMrC could help reach out to external PIs to encourage them to contribute to research benefitting UFS

5. How do you see U.S. NWP becoming part of a larger "community-based Earth System Modeling"?

- Via a successful instantiation of EPIC, which would engage the external community, develop inter-agency collaborations, provide strong user support, provide adequate HPC, etc.

6. What new technologies do you see enhancing full Earth system modeling?

- Advanced HPC; being part of exascale project
- Cloud computing
- Deep learning (AI) methods to better represent processes and uncertainty
- Enhanced observations - new satellites/channels, lower-tropospheric profiling networks, more ocean and ice data, etc.
- Holistic view of QC, DA and model integration to enable optimal use of new and available observations, and more efficient model improvement (better model → better first guess → smaller increments → better use of obs)

7. How do you envision EPIC providing greater ease for the academic communities to participate in the development and improvement of NOAA model and data techniques?

- Need a strong and effective user support system; elements include:
  - Accurate, thorough and understandable documentation of all UFS components
  - Easy-to-use workflow environment with sample workflows for all forecast applications
  - HPC access with minimal approval wait time
  - Tutorials, workshops and online courses (that could be prepared by academic partners)
  - Help desk - single point of contact for external community
  - Graphics/validation/verification tools
  - A physical hub that is a focal point for UFS expertise, community involvement and user support

8. How might EPIC change the paradigm in which you structure your programs and research opportunities with respect to partnering with NOAA?

- Vision: UFS is the model system of choice for all weather and climate prediction research activities (e.g. - graduate students and post-docs would use UFS for their research problems)
- EPIC participants could identify the most important research needs of the UFS, which could motivate the research problems that people work on
- Research programs based on partnering with NOAA would require EPIC to be suitably resourced and stable - i.e. - a long-term, reliable partner

9. What funding opportunities are you hoping will result from standing up EPIC?

- Increased research funding for external community (but need NOAA/OAR/NCEP collaborators for effective coordination)
- Increase funding for projects that are "higher in the funnel" (RL 4-5-6 levels) for research that benefits UFS 4-10 years from now
- In addition to needed research on DA, physics, coupled models, etc., EPIC could perhaps connect with relevant parts of NOAA and other agencies to support research in related areas; e.g., to:
  - Space weather, hydrology, oceans, cryosphere, air chemistry, etc
  - Assess greatest observational needs via OSSEs, OSE, FSO
  - Improve HPC efficiency (going from 4% to 8% of peak capacity is a new supercomputer) (UMAC recommended a HPC Testbed)

Questions?

CMrC Charter

- The CMrC was chartered by the NWS Office of Science and Technology Integration (OSTI) and the OAR Office of Weather and Air Quality (OWAQ) to:
  - Operate as an independent, ad hoc review committee aligned with the Modeling Programs in the NWS and OAR, including weather across time and space scales, including S2S, as well as space weather, air quality, water and surge modeling.
  - Represent NOAA research community and gain a comprehensive understanding of NOAA's operational weather and climate modeling strategy, priorities, resource requirements, developmental approaches, investment strategies, and scientific and technical challenges.
  - Meet annually and provide to NOAA a written summary of findings and recommendations by individual members of the CMrC.
- CMrC membership includes 12-14 subject matter experts in Earth system numerical modeling, including atmosphere, water/ocean, space weather and air quality, selected by the Directors of OSTI and OWAQ from academia, NGOs, private sector and Federal and state agencies

CMrC Members

• **Cecilia Bitz**	Univ. Washington	**Ricky Rood** (ex-officio)	Univ. Michigan
• **Fred Carr** (Co-Chair)	Univ. Oklahoma	**Elena Shevliakova**	OAR/GFDL
• **Alicia Karspeck**	Jupiter Intel	**Hendrik Tolman** (ex-officio)	NOAA NWS
• **Jim Kinter** (Co-Chair)	George Mason U.	**Ryan Torn**	Univ. Albany
• **Cliff Mass**	Univ. Washington	**John Wilkin**	Rutgers Univ.
• **Rohit Mathur**	EPA	**Eric Wood**	Princeton Univ.
• **Lorenzo Polvani**	Columbia Univ.	**Fuqing Zhang**	Penn. State Univ.

(*) Lisa Goddard, Columbia Univ.

UMAC Members

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