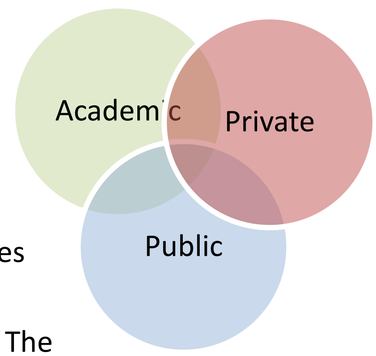
American Meteorological Society

Commission on Weather and Climate Enterprise

Board on Enterprise Communication

Forecast Improvement Group

Summary Recommendations



Over a one year period ending in June, 2013, over one hundred forty members of the public, private, and academic weather communities came together to discuss priorities for significantly improving forecasting capabilities. The community participated in a number of face-to-face meetings, telecoms and email exchanges focusing on issues at the core of improving weather forecasts: computing—including big data issues, modeling—including data assimilation, and observations. The overarching goal of all discussions was that the end users need to have better products that can support vital decisions. Specifically, this group focused on changes that would make significant improvements on zero to ten day forecasts, with the understanding that many of these changes would result in improvements in the ten to thirty day forecast as well. Recognizing that many end users receive their final products from private sector efforts, recognizing the critical role of research scientists to improving all aspects of forecasting and recognizing the critical role of NOAA in research and operation of forecasting, representatives of these communities gathered to critically examine options for significant improvements in forecasting. Given the complexity of weather forecasting, a variety of views were presented on how to proceed as a community. Consensus, rather than complete agreement was sought and obtained on a number of fundamental issues. The process resulted in a set of recommendations which can most easily be summarized by the need for modeling and observations that can produce forecasts of unprecedented accuracy, with the computing power to support these efforts. The community continued to reinforce that stronger collaborations and new business models, will be needed to both improve forecasting capabilities and assure that users will be able to make full use of the improved forecasts.

Key Recommendations:

1) Significantly improve the community's computing power for both development of new models and delivering accurate forecasts.
2) Increase and focus efforts to both develop and run global models.

3) Develop a coordinated national program to develop regional modeling techniques.
4) Support active collaboration between public, private, and academic sectors with models particularly in their final stages of development.
5) Embrace alternative data sets and alternative business models to acquire key measurements that can improve forecasting research and operations.
6) Prioritize observational data and act on these prioritization efforts.
7) Strengthen relationships within the public, private, academic, and user communities to assure economic and efficient development and use of forecasting capabilities.

Of these recommendations, the final recommendation, to improve relationships within the public, private and academic arenas, was considered by many to be the most important one. The strengths of these three communities offer complementary and mutually supportive sets of expertise, resulting in unprecedented delivery of useful weather forecasts. The relationships continue to improve over the years, as the weather enterprise addresses its expanding role in the nation.

Supporting information for the recommendations

The results of key discussions are summarized below, with each section number headed by the summary statement for that discussion.

1) Significantly improve the community's computing power for both development of new models and delivering accurate forecasts.

   The computing breakout group endorsed what has been stated many times by many groups: that both the research and operational communities need significantly more computing capabilities. In plenary, there was no dispute of this need and the increase in computing power was seen as a necessary step to allow for significant and sustained improvements in computing.

   Issues related to the expense of weather computing were discussed. One issue raising the cost of current operational computing is the high demand on reliability. High reliability levels significantly limit the computing architecture that can be used and raise the cost considerably. All agreed that the appropriate level of reliability needed to be addressed because higher reliability negatively impacts the accuracy of the current and future weather forecasts.

   The group stressed the need for the modeling community to be ready to use new computing capabilities, including the code adjustments which take time. New computing technologies will require foresight and active collaboration to assure that the best and most cost effective computing capabilities will be available to support weather forecasting.

The issue of the growth in volume, velocity, and variety of data is expanding rapidly and will continue, requiring new approaches to the community working with those data. The private sector is developing a number of approaches to the big data issue. It will likely be very appropriate for the weather community to focus on the principle of bringing the processing as close to the data to maximize the improvements in forecasting. This approach may require both academic and private sector researchers to work more closely with NOAA's computing centers because large amounts of data necessary to produce useful products cannot be easily transported. A variety of solutions were suggested including a virtual commercial data center and using pilot efforts to explore alternative business models.

2) Increase and focus efforts to both develop and run global models.

Global models are the foundation for almost all other forecasting, thus improving global models will improve forecasting for many public and private efforts. The group agreed that support for high-resolution global models should include both support for development of future global models and computational resources for running existing global models. This issue was brought up in many of the telecoms, as well as at the first two meetings of the AMS Forecast Improvement Group. The private sector members of the weather enterprise have expressed strong support of additional effort on global models because it allows them to provide better services to their customers.

Several specific issues were cited as key to improving global models and their usefulness to the broad weather community. The highest priority for improvement was development of significantly enhanced methods of initializing weather models with data (data assimilation techniques). This priority was strongly endorsed by public, private and academic sector participants. In addition, a renewed emphasis on parameterization schemes and evaluation of modeling structures (dynamic cores) was considered critical for long-term and continued improvement of global models. And finally, developing the science necessary to run the global models accurately at high resolution was viewed as a major goal of the individual efforts to improve modeling.

The current computing power allocated for running global models operationally was considered to be significantly lower than what is needed. Higher spatial resolution, more ensemble members, more frequent model runs, and a more advanced data assimilation system will be possible with increased computing power dedicated to global models. Running a more advanced data assimilation system was viewed as the highest priority, while more advanced physics and dynamic cores on higher resolutions were a close second priority. In all cases, more computational resources will be required, as is reflected in the recommendations in 1) above.

There was general agreement that a "community" version of the global model would facilitate more contributions to code development from industry and academia. Institutional support, guidance, and focus to coordinate all efforts would assure that efficiently improved forecasts. The community has had considerable success coordinating and improving regional weather forecast models, through the WRF effort; lessons learned from this effort can and should be applied to the development of a global community model. A facility similar to the Developmental Testbed Center would be required to manage the development, as well as studies to evaluate the impacts of existing and proposed observations on forecast accuracy. Community involvement, together with thoughtful, targeted activities will greatly enhance the forecasting capabilities of the country.

Some discussion focused on what could be removed from the current computational schedule. This led to some frustration in that, similar to observations, it was difficult to discontinue models, even if their value was considered limited. There was general agreement that a priority list of operational model runs should be formed with more community involvement, and some mentioned that some models like the climate models could be run on a more "relaxed" schedule or operational reliability.

3) <u>Develop a coordinated national program to develop regional modeling techniques.</u>

National-scale and regional (non-global) modeling offers high resolution forecasting which is critical for a variety of applications where high spatial and temporal resolution are needed including severe storm predictions, precipitation, renewable energy, turbulence forecasts and every day uses. While progress is being made toward high resolution, convection resolving (3km) global models, such models will likely not be fully developed for operational use within the next few years. Currently, NOAA, some academic institutions and a number of private companies are involved in running regional models. Several institutions—public, private and academic are involved in research and development of limited area models with a number of promising aspects which have not yet been fully developed including ensemble forecasting; high resolution rapid refresh; boundary layer dynamics and advanced data assimilation techniques. The development of these promising ideas are, to varying degrees, limited by the resources available to support their development and transfer their use into operations.

There are a number of strong research projects on regional modeling which are producing promising results. These efforts include improved assimilation programs, higher resolution physics parameterization, high resolution rapid refresh models, ensemble forecasting, verification mechanisms for high resolution ensemble forecasting and user interface testing and development. The current research ideas which show significant promise far exceed the current funding available to support their continued development. These activities need to be supported in order to assure current and future improvement in forecasting capabilities. Research on regional models should be funded to take place in government, academic and private institutions through a coordinated program to support and evaluate a variety of research ideas. This research will be necessary before strong recommendations can be made on specific details regarding operational regional modeling approaches—for instance how many ensemble models should be run at what resolution and with what post-processing are all outstanding research questions. The funds currently do not exist to support the research program needed to address these issues to the level which would allow significant and continued improvement in forecasting capabilities.

4) Support active collaboration between public, private, and academic sectors with models in their final stages of development.

There was continued strong support for more active collaboration with respect to forecast models in their final stages of development. This approach, previously referred to as "Research Regular," and more recently named "Real-Time Research" by Louis Uccellini, has a number of advantages. First, it allows academic and private sector users to give feedback, evaluation, and suggestions for development on a broad range of issues related to the model. Second, the approach allows private sector users immediate access to output from state-of-the-art models, instead years later once the model goes through the arduous process of becoming operational.

A key to Real-Time Research is that the models would be run at a high level of reliability (over 90%), but with changes and improvements made as needed, with appropriate communication to users. It was pointed out that this approach was not new, and had been used successfully in the past. This recommendation was for significantly increased use of Real-Time Research and for more active involvement of both academic and private sector colleagues in giving feedback. It was also noted that this would not and should not be a replacement for operational forecasts.

5) Embrace alternative data sources and alternative business models to acquire key measurements that can improve forecasting research and operations.

Observational systems continue to advance technologically. The weather forecast community needs to embrace existing, but underutilized data as well as new data sources; and support the efforts to make full use of these data. Examples of new observational capabilities include new scanning lidar capabilities, Global Positioning System analyses, and even social media reports. Research is needed to understand the optimal ways to use these additional observations to support weather forecasting capabilities.

Just as new observational systems need to be embraced, a large variety of alternative business models may be useful to assure that observations are obtained in a cost effective manner to support weather forecasting. These new models may include buying observational data and implementing long-term data purchasing contracts to allow data providers the financial assurance and confidence needed to justify investments in additional observing capabilities, and protecting the use of those observations so that the suppliers can have a robust business position. The group agreed that the final criteria of which observations and which business models was the extent to which these approaches positively impacted the quality, accuracy, and timeliness of the forecast to the end user.

6) Prioritize observational data and act on these prioritization efforts, including targeted measurements for severe storms or critical situations.

A number of important studies have already taken place evaluating the value of different observations to forecasting. These rather sophisticated efforts should be the guiding principle for investing in future observations. Furthermore, the existing efforts to evaluate the forecast benefit of observations should be expanded and coordinated. The multiplicity of applications of weather forecasts implies that a set of metrics, rather than just one, will be most useful for assuring an improved observational suite.

There was a significant endorsement for the value of observations to be evaluated relative to their costs. This new business approach, examining return on investment, was seen as an appropriate assurance that finite funds be spent appropriately in support of improved weather forecasting.

Deploying targeted measurements, under specific circumstances when additional observations could improve the weather forecast, were agreed to be an important move forward, allowing for improved return on investment. Such targeted observations could include unmanned aircraft when severe storm events are expected, ocean measurements when current observations are known to be lacking, or new types of measurements not yet identified. Deploying these observation systems only when required is a further return-on-investment approach being embraced for all observations.

7) <u>Strengthen relationships within the public, private, academic, and user communities to assure economic and efficient development and use of forecasting capabilities.</u>

While listed last in the list, this issue was considered by many to be one of the top priorities for moving forward. The theme came up when addressing modeling, computing and observational issues and was strongly endorsed when the group met as a whole. There was a call for stronger collaboration between the agencies involved in weather forecasting, within agencies, across the broad research communities, between operational and research communities, between public and private entities and, especially between the developers, producers, and users of forecasting information. The end users, whether sophisticated corporate consumers of information, government planners or individuals were considered so important, that their inclusion in the AMS Forecast Improvement Group was strongly endorsed.

Current efforts are underway to encourage and promote collaborations within the community, including the newly formed Earth System Prediction Capabilities, represented at this meeting by Jessie Carman. Significantly increased collaboration was called for in all areas. Discussions within the computing section, focused on the benefits of allowing researchers and private sector developers to work closely with the data, particularly when the efforts required access to large amounts of data. Discussions within the observation section focused on a variety of alternative business models which could supply critical observations without releasing the ownership of the observations to the full international community. Discussions within the modeling section focused on establishing arrangements to promote collaboration, development of new models, and access to advancement in model output earlier. Throughout these discussions, barriers were identified, but the strong intent to work collaboratively also offered a number of potential.

The focus of forecast improvement from zero to ten days was agreed to cover a broad range of disciplines, requiring a multiplicity of approaches. The variety of end users was similarly identified as requiring a multiplicity of approaches. The community discussions did not identify this as a formidable problem, with the general sentiment being that the weather enterprise was ready and perhaps even eager to work together towards addressing these issues.

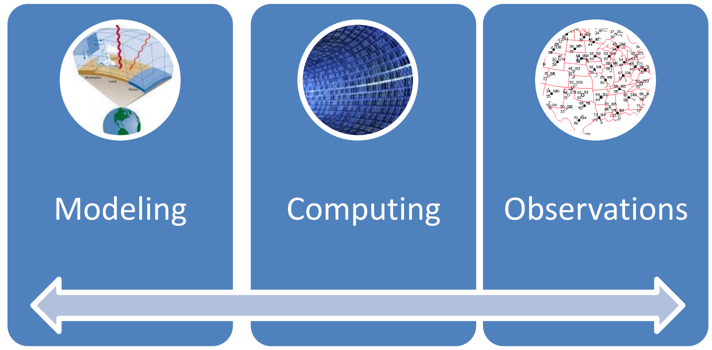
AMS Forecast Improvement Group

The American Meteorological Society's Board on Enterprise Communication is working with members of the public, private, and academic sectors to develop a path for achieving the best possible weather forecasts for the end user. The goal of this group is to develop consensus across their respective communities on the most fruitful direction to build weather forecasting capabilities of unprecedented accuracy and then working jointly to assure continued improvement. A number of significant discussions focused on three important issues for moving the community forward: modeling, computing, and observations. These discussions have resulted in a set of recommendations on productive paths forward.

The AMS Forecast Improvement Group's goals were to: 1) develop a common understanding and consensus on the path forward for improved forecasts; 2) identify priority recommendations on computing, modeling, and observations; and 3) discuss immediate next steps to start on the path toward improved forecasting capabilities. Discussions were based on, but not limited to, recommendations that were developed in previous Forecast Improvement Group discussions. Meeting and telecom summaries from these previous discussions are all available at:

http://cires.colorado.edu/science/groups/weatherhead/activities.html

Coordination



It should be noted that the recommendations presented by the AMS Forecast Improvement Group in this document are representative of the discussions of this group and do not represent a formal statement of the full membership of the American Meteorological Society. The recommendations are in general agreement with current spending plans from the Sandy Supplemental and base funding plans for NOAA and NSF but offer a more extensive vision for improved forecasting.. The plans offered here are considerably more ambitious and comprehensive than previously presented. This set of recommendations is unique in that it involves coordinated efforts of the public, private, and academic communities to define a path forward which would allow significant and sustained improvements in weather forecasting. The proposed efforts offer to make full use of the strengths of the public, private, and academic communities, while assuring a high return on investment from all public funding. These improvements in forecasting capabilities are critical for economic health, resilience, and sustained recovery of the country. Representatives from the entire weather forecasting community were involved in developing this plan. The community is ready, capable, and eager to provide significant improvements to strengthen this nation's critical infrastructure.

Appendices

Appendix: Summary of AMS Meeting on April 5, 2013 in College Park MD

April 5, 2013 Meeting Goals

The AMS Forecast Improvement Group's meeting goal was to: 1) develop a common understanding and consensus on the path forward for improved forecasts; 2) identify priority recommendations on computing, modeling, and observations; and 3) discuss immediate next steps to start on the path toward improved forecasting capabilities. Discussions were based on, but not limited to, recommendations that were developed in previous Forecast Improvement Group discussions. Meeting and telecom summaries from these previous discussions are all available at:

http://cires.colorado.edu/science/groups/weatherhead/activities.html

Agenda

8:30 Opening Remarks: Bill Gail, Betsy Weatherhead

9:00 Summary of basic statements from previous telecoms on modeling: Neil Jacobs, Airdat

9:30 Summary of basic statements from previous telecoms on computing: Mark Govett, NOAA

9:45 Summary of basic statements from previous telecoms on Observations: Bob Atlas, NOAA

10:00 Synthesis discussion: Frank Parker

10:30 Break

11:00 Breakout groups to identify key issues, priorities, and resources

12:15 Lunch

1:00 Breakout report: Modeling: Neil Jacobs, Airdat

1:30 Breakout report: Computing: Ben Kyger, NOAA

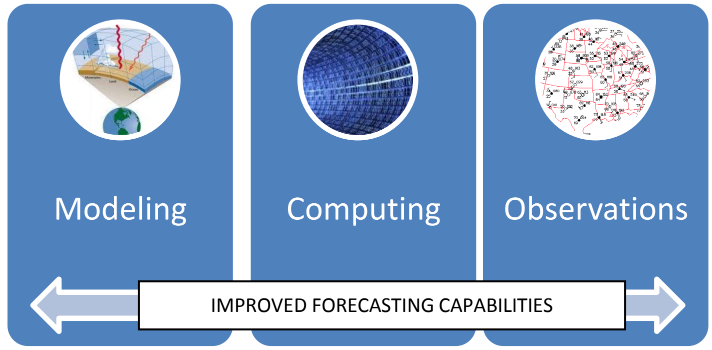
1:45 Breakout report: Observations: Tom Fahey, Delta Airlines

2:00 Feedback and convergence

2:30 Break

3:00 Priorities and next steps

4:00 Adjourn



Key Discussion Points

IMPROVED FORECASTING CAPABILITIES

Discussions focused on significantly improving current fore continued improvements in the future. There is a widespread recognition of the importance of the important and growing roles of the academic and private sectors in improving weather forecasting capabilities. The US Weather Enterprise is currently under-performing, but has the expertise and vision to make significant improvements in weather services to save lives and property as well as support a strong and expanding national economy. Experts in the weather enterprise—representatives from the public, private, and academic communities—are willing to identify and work together on a path toward significantly improved weather forecasting capabilities.

Summary

Discussions focused on significantly improving current forecasting capabilities and assuring continued improvements in the future. The discussions started with Bill Gail and Betsy Weatherhead summarizing the importance of planning for future success and the necessity for the experts in the weather enterprise—representatives from the public, private, and academic communities—to identify and work together on a path toward significantly improved weather forecasting capabilities. These introductory statements were followed by summaries of previous telecoms of the AMS Forecast Improvement Group that took place in the prior month. These telecoms focused on modeling, computing, and observational issues. The group agreed to work from recommendations presented in those telecoms as well as any significant and constructive ideas emerging from the meeting. Breakout sessions addressed these three key issues, identifying the top few priorities in each area, as well as addressing cross-disciplinary and overarching issues. The results of these breakout sessions are summarized below, with each section number headed by the summary statement for that discussion.

Attendees:

Sharon Abbas, CCS

Troy Anselmo, SAIC

Bob Atlas, NOAA

Randy Bass, FAA

Marty Bell, Weatherflow

Stan Benjamin, NOAA

Barb Brown, NCAR

Jim Brylawski, Geonor

Bill Callahan, Earth Networks

Fred Carr, U. Oklahoma

Jessie Carman, NOAA

Mike Charles, NOAA

Joel Cline, DOE

John Cortinas, NOAA

Jun Du, NOAA

Pam Emch, Northrup Gruman

Tom Fahey, Delta Airlines

Tom Fahy, Capitol Group

Bill Gail, Global Weather Corp.

Mark Govett, NOAA

David Green, NOAA

Sue Haupt, NCAR

Mike Henry, UCAR

Mark Hoekzema, Earth Networks

Ben Kyger, NOAA

John Lanicci, Embry Riddle University

Bill Lapenta, NOAA

Steve Lord, NOAA

Ron McHenry, SGT

Anne Miglarese, PlanetIQ

Peter Neilley, The Weather Companies

Melissa Ou, NOAA

Frank Parker, NOAA

Paul Pisano, DOT

Gary Rasmussen, AMS

Marc Schwartz, NREL (retired)

Bashwar Sen, Northrup Gruman

Leonard Smith, Oxford University

Fred Toepfer, NOAA

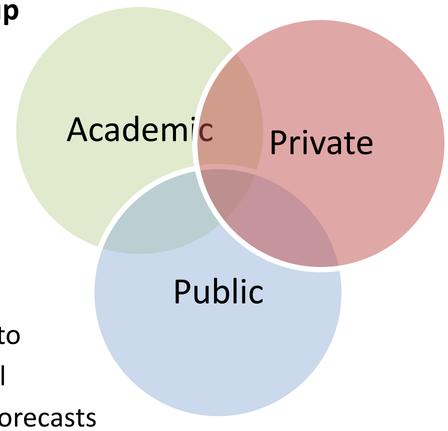
Zoltan Toth, NOAA

Steve Tracton

Betsy Weatherhead, U. Colorado

Steve Woll, Weatherflow
John Zack, Meso

Additional participants were allowed to join via GoToMeeting and via conference call-in capabilities, although these remote capabilities did not allow for easy participation from off-site parties.



Appendix: Summary of AMS telecom on Forecast Improvement Group for March 7, 2013

Lead: Mark Govett

Subject: Computing

Need for Computing Capabilities

There was fully agreed consensus that more computing resources are needed to advance weather prediction. The needs are strong within both the operational community and the research communities. It was noted that the accuracy of forecasts is strongly linked to horizontal resolution and that some of the difference in horizontal resolution between NWS operational models and ECMWF was explained by the resolution at which the models are run.

Operational Computing

Cost of operational computers is considerably higher than cost of research computers because of the need for running at 99.9% reliability. If this requirement were relaxed, computing resources could be put towards other efforts, including running models at higher horizontal resolution. Some on the call explained that as users of the model output, they felt the 99.9% reliability should not be relaxed. The strong demand on reliability makes computer acquisition both expensive and time consuming for operational use. Reliability over 98% can require a full redundancy of computing systems. The suggestion was made that a careful examination of the reliability versus improved accuracy would be a useful exercise.

Research Computing

Research computing often requires 3-5 times more resources to develop and test a model than it requires to run the model. Reliability of runs for research computing has not been a critical issue, with runs often successful at a 90% level on current systems. It was noted that ECMWF puts a higher ratio of their computing time toward research than NOAA does. It was also noted that increased research computing reduces the time for transitions of research to operations.

Increases in Computing Power

Computing power continues to increase within NOAA (NCEP's capacity has tripled in the last 2.5 years), but these increases do not keep pace with the modeling needs, nor do they match the rate at which ECMWF increases their computing capability. The increase in model resolution improves forecast accuracy but significantly increases computing needs. The running of ensemble forecasts can also improve forecast value and quantify the situational uncertainty, but this also significantly increases computing needs. Together the current needs demand an increase of at least a factor of ten to keep pace with both model resolution and ensemble needs, with more regular and larger performance boosts thereafter than has been common over the past decade.

Multiplicity of Models

The multiplicity of models and applications puts additional strain on the existing computing resources. Convergence of models can release some of the strain. The convergence of models has direct impact on computational needs.

Computational Improvements

Fine-grain computing and new types of computer processors are being explored within the research community in part because it can offer both speed and cost savings. These technological advancements are as important to the operational community because of the high reliability requirements.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 8, 2013

Lead: Bob Atlas

Subject: Observations

Need for Observations

A number of statements were agreed on during the telecom, the first being: Improved observations can improve forecasting in multiple ways including initializing models, validation, and improving models. This will become particularly important with the further development of global cloud resolving models. This discussion included comments about the multiple users of data, including fire fighters, disaster response and climate researchers. There was at least one comment that the costs should be born by the full community that will benefit from the observations.

There was clear support for ongoing and comprehensive metadata.

Some special cases were noted where the need for data was targeted, including the need for local data with short-term forecasting including nowcasting, observations in extreme events, and gathering observations in all weather conditions. For some special cases, UAS and conventional aircraft may be deployed to fill critical gaps. The planetary boundary layer was mentioned as an area where the data need may be growing and under-fulfilled.

Long-term measurements with known data quality with timely availability of data are important principles.

Evaluation of Data

There was also a broad consensus that we need to optimally design the global observing system to improve forecasting in a cost-effective manner. It was also felt that some level of built-in redundancy is needed so that the sudden or unexpected loss of one monitoring system would not hurt the forecasting capabilities. It was agreed that Observation System Simulation Experiments, Observation System Experiments (OSSEs) in combination with real data denial experiments, should be utilized for this purpose.

Observation costs
There was consensus that all designs include a cost analysis that includes the cost of maintenance and replacement, not just the purchase cost. Finite budgets, even increased from existing levels, require careful assessment of costs, cost over-runs and extraneous versus key measurements.

Non-traditional observations
Modern, social-media and webcasting approaches to some types of weather observations are becoming useful and more common, yet the forecasting community has not fully determined how to incorporate these types of observations to their most full advantage.

Incorporation of data
A strong plea was made for the appropriate inclusion of all available data. The use of all available data could be optimized, however some political and logistical constraints exist. We have a global observing system and we need to use all observations. Chinese satellites were mentioned as one source of data which were possibly under-utilized.

Space Weather
Space weather is a field which is specifically observation limited. The case was made that small collaboration could offer large payoff with sharing platforms including satellite, planes and ground based stations.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 8, 2013

Lead: Tom Hamill

Subject: Modeling

Data Assimilation

Of many ways to improve global NWP, there was strong agreement that data assimilation is particularly important. Current improvements in data assimilation have made strong positive impacts and further improvements would likely to continue to offer significant improvements in forecasting accuracy. It was noted that data assimilation implicitly wraps up other aspects like ensembles, model development, and parameterizations, for assimilations need good first guess forecast(s) to provide quality initial conditions. This holistic aspect requires a coordinated approach.

Dynamical cores

Currently there are a larger number of different modeling systems in use across the U.S., including many quasi-independent global prediction systems even within NOAA. Many dynamical cores may provide diversity of solutions for the forecaster but may be difficult to maintain, and with fewer people to upgrade each model, the pace of improvements of each may be slower. However, converging on a single dynamical core was considered a formidable challenge, in part because of organizational attachments. There was agreement that we needed more objective ways to compare dynamical cores, including DCMIP-type tests, but including additional criteria. It was generally agreed that there are other considerations such as computational efficiency, portability, and extensibility of code that should be evaluated in selecting a dynamical core. Having a way of evaluating possible future dynamical core in this manner may facilitate fewer of them being used more broadly, increasing the ability of the enterprise to collaborate.

There was some agreement that deciding on a particular high-resolution, global non-hydrostatic dynamical core may not be a critical issue in the coming few years but might well play a lead role in a ten-year time frame, when improvements in computing capacity make convection-permitting global models feasible. There was some discussion on what procedures might allow us to make decisions about developing current generation models; this discussion included how well such dynamical may perform on possible future as well as meteorological concerns. Standardized tests of such dynamical can and should expand upon DCMIP type tests to include the ability to simulate common high-impact weather phenomena, e.g., supercells. It was also noted that two different models may achieve the same level of detail at different grid spacings, one with reduced grid spacing but higher-order numerics, and issues such as these need to be considered.

Coordination of model development

Regarding the separate centers and organization of efforts engaged in improving weather forecast models, the idea of re-organization was discussed, with a variety of options expressed concerning whether tweaks or an overhaul are necessary. The diversity of interests that US NWP serves, such as the preservation of personal safety and property, maritime, economic and recreational interests, was cited as a significant distinction from ECMWF and a potential reason why there were a multiplicity of parallel approaches on numerical weather prediction within the US. It was offered that some aspects of the US model development community were under-resourced, such as the (directed) funding for collaborative projects between universities, labs, and EMC.

Evaluation of model improvements

The multiplicity of numerical weather prediction goals and funding sources were cited as a problem in evaluating progress in forecasting capabilities. There was a concern that for many of the agencies involved in weather prediction research and for program managers in those agencies, their metric for success is often not operational forecast improvements but rather publications. It was noted that progress most often occurs when individuals in operations facilities like EMC make strong partnerships with people at labs or universities to work collaboratively, through to completion. Facilitating the ability to have more of these types of small success stories will be very helpful. Evaluation of monitoring of success and improvements in forecasting was agreed to be useful, although problematic to implement.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 14, 2013

Lead: Justin Sharp

Subject: Computing

NOAA's Diverse Mission and Need for Focus

The diversity of applications running on NOAA's operational computers was discussed. A strong contrast was made between ECMWF's more narrow focus, along ECMWF's higher operational computing capabilities that make them able to run their model with higher accuracy. The diversity of NOAA's applications may not be able to be changed: "NOAA's mission is NOAA's mission." However, increased focus on a few specific issues would allow considerably more success on those core issues. There was considerable support for NOAA providing both global and regional models.

Regional models can be run remotely at regional forecast offices and by private companies. However, High Resolution Rapid Refresh (HRRR) models cannot easily be run anywhere but on centralized, government facilities. The regional model output is critical for the core mission to save lives and properties. Whether the regional modeling could be dispatched (run at regional offices), bought from private companies or alternatively prioritized was discussed with no real consensus on the best path forward. The strong demand from NOAA for its HRRR model output to be made available now was noted as a reason that perhaps NOAA needs to continue producing the best possible regional forecasts.

The lack of focus with computing capabilities results in many good products, but few great ones. The lack of a strong global model is resulting in US companies and agencies to reach out and buy ECMWF global model products. Increased computing capabilities put toward global products would result in significantly increased global model products which are currently used by many US companies for decision support. Bill mentioned that about 5% of the current NCEP computer power is used for global modeling .

Requirement of Reliability Needs Re-examination

The demand that NOAA create runs at a very high level of reliability dictates, to a large extent, the cost of the computing, and therefore the limitations of what can be run. The demand for 99+% reliability is very challenging computationally, requiring redundancy of computing capability and more expensive computer purchases. The source of the 99+% reliability was traced back to the 1990's, but with no specific document easily accessible on the issue, although it may have been linked to a Cray fire. A number of alternative solutions to this problem were suggested. As the community moves more and more towards ensemble models, the 99+% reliability may be achieved from some number of runs being carried out successfully, thus removing the need for full redundancy. The existence of other modeling centers (ECMWF, Canada, USNAVY) could supply a back-up for the small fraction of run failures, allowing again for 99+% reliability in terms of products delivered without excessive redundancy or computing costs. Reciprocal deals could be made with these various groups. The issue of re-examining the reliability issue was agreed on by the group as being highly important for computer allocation decisions and has a strong, direct effect on computing costs.

Complexity of Computing Capabilities

It was pointed out and agreed, at several different points, that the computing issue is far more than the cpu power. The reliability of product delivery is strongly affected by inflow and outflow of complex data structures. The cost of computing is far more than the cost of buying computers and extends to personnel and electricity bills, all issues that flow directly into costs.

Current and Future Computing Needs – Mission Driven Requirements

The correct way to determine what the computing needs are—both for the present and in the future—is to determine the requirements to run specific models at particular spatial and temporal resolution, with a specified level of reliability. Such exercises have been done and often result in computing needs a factor of 1000 or more beyond what exists today. High spatial resolution computing and ensemble forecasting are key drivers in the increased needs. Such numbers are not necessarily useful because the realization of funds to support these recommendations is unlikely. However, for operational needs, the factor of 100 times current capabilities was cited as a reasonable amount for operational needs. For research needs, a set amount of funding can result in much more computing power because of the relaxed reliability standards; a figure of 6 to 1 was cited as the approximate amount of computer power that can be purchased for the same price based on the lower reliability requirement of research simulations. Alternative technologies including gpu's may, in the near future, provide a cheaper alternative for computing, particularly for research computing because of untested reliability issues.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 15, 2013

Lead: Bill Callahan

Subject: Observations

Optimal observation system

The optimal forecasting system needs a carefully planned observation system that makes best use of available data, identifies objectively where and what type of new observations are needed and makes appropriate use of new business models to assure cost effective acquisition of new models.

New Business Models

The traditional business model for observations in support of weather forecasting has been that government has purchased, deployed and maintained observing systems. The observations have then been publicly available for all and in some cases served multiple purposes. New business models have exploited instruments that exist for other purposes, involve non-governmental entities deploying new instruments and selling the data to government and commercial entities to support weather forecasting and other specialized needs.

New business models have the potential to be highly cost effective for the weather forecasting community but offer new challenges. One challenge is that long-term observation systems require long-term, guaranteed funding. A second challenge is that business models often require that the data be sold to multiple recipients; this cost sharing approach can only work if the data used to support weather forecasting is obtained/procured with limited data redistribution rights and potentially other limitations. It was pointed out that this new business model is being increasingly embraced by different parts of the federal government (NASA for example) to considerable success. It was highlighted that recent efforts to leverage aviation data in this matter has been challenging. One issue was that airlines perceive that they were not appropriately reimbursed (valued) for their efforts to provide data. Any new business model must be developed in a matter that is sustainable for the data providers.

WMO Resolution 40 was also discussed relative to the current impact on the US modeling efforts and potential new business models. Questions were raised as to whether the US is going above and beyond the required level of data sharing relative to other countries and if so, perhaps the US federal government should reconsider its current position. By providing more data than is received, the US is positioning itself in a weaker position regarding NWP data assimilation and potentially putting domestic private sector organizations at a competitive disadvantage.

Carefully Planned Observing Systems

The need for a carefully planned observing system was reiterated by the group. The need for OSSE's and data denial experiments was supported. There was also a request for distribution of existing papers on the subject. Evaluation of the importance of data depends on forecast application and timescale. There needs to be consensus on defining timeframes; for example nowcasting (0-3 hours), short-term forecasting (6-24 hours) and medium range forecasting (24 hours to ten days) may be the highest priority time frames. Evaluation of ground-based, in situ and remote sensing, particularly satellite data needs to be carried out with a full understanding of the characteristics of each. The OSSE testbed has been developed to be able to look at orbital, ground based and in situ with equal skill. One approach offered was to not view the various sensors as competitors, but to recognize the important role of ground-based observations in validating and adding value to satellite measurements. It was pointed out that NASA always viewed the ground calibration as an integral part of any satellite operations…the ongoing requirement for this needs to be considered. This unified approach will be critical to assuring that the observation systems can support significantly improved forecasting capabilities.

Economic efficiencies

The government is currently able to buy observational data for a fraction of the cost to deploy and maintain instruments and networks themselves. This economic efficiency allows more data to be purchased and tested. However, the current system is somewhat complicated/disjointed because private networks are growing in a manner consistent with their respective business needs, and not being dictated, for instance, by OSSE experiments or in a centrally coordinated fashion. Private sector companies are proliferating and have increasingly large amounts of data ready to support improved weather forecasting. Data sharing rights, metadata and long-term contracts will play into the success of these private efforts. OSSE's and data denial experiments will be critical to determining which data are most critical to improved weather forecasting capabilities.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 15, 2013

Lead: Bill Lapenta

Subject: Modeling

Research to Operations

All concerned want the best models to transition from research to operations. Both general models and specific components of models require careful evaluation for selection of transition to operations because the transition process is time consuming and difficult. The Developmental Testbed Center was cited as an example for how models can be evaluated through a jointly funded entity. A number of organizations including ECMWF and UKMet Office offer examples of successful approaches to engaging researchers and transitioning recent research into operations. It was noted that the multiple models currently supported by NOAA required to meet a large operational scope offers more challenges for transitioning research to operations than, for instance, the ECMWF's unified model approach to forecasting. Nonetheless, ideas for developing a strong research community and efficient research to operations transitions were discussed and agreed on by researchers who had extensive background with other institutions.

Research to Operations – Time for transition

The timescales necessary for transitioning new scientific advances from research to operations is considered too slow by many. A number of issues were cited for why the transition takes so much time, including the need to mitigate risk in an operational environment, systematic and statistically significant pre-implementation testing, ability to engage with researchers who have new advances, fully tasked staff at EMC and the lack of infrastructure to properly support the collaboration necessary to support the transition of advances from research to operations. Some of the recommendations proposed here would significantly improve the time for transition to operations.

Targeted Investments

Several mechanisms are available for supporting targeted investments in collaboration between the research and operations community. NOAA needs to identify development priorities for the operational modeling suite components and hold workshops and invite members of the scientific community who are subject matter experts in the priority areas. Once priorities and potential solutions are identified, funding opportunities (i.e., post-doc's, new hires and visiting scientists) can be used to work on those targeted issues. Collaboration can be fostered and, most critically, forecasting capabilities can be strategically improved. This will require the community to work effectively with NOAA to be appropriately supported to establish priorities and advance solutions.

Computer allocation for research and research to operations efforts needs to remain strong for numerical forecasting capabilities to continue to advance. It was noted that ECMWF strives to keep their operational computing resources to between ten and twenty percent of their total computing allocation. Investment in both research and research to operations is vital to significantly improving and maintaining strong forecasting capabilities.

Research to Operations –Engaging Researchers

Many in the academic and research communities have external pressures (e.g. publication, teaching), that inhibit their ability to devote the time required to the process of working with NOAA scientists to get recent research into operations. A number of structural changes could promote significantly increased engagement in the future, including having targeted workshops to engage the research community on specific tasks, new funding sources and more robust visiting scientist programs. Improved funding for researchers to work with NOAA during the transition process would help, as would assuring that NOAA workers have enough time to properly work with researchers. This funding cannot come from NSF because the work to support improved forecasting capabilities with transition to operations is considered too applied for NSF support. Workshops could also be used to educate researchers on the process of transitioning advancements into operations, which would result in a more unified community that could more efficiently advance forecasting capabilities.

Visiting Scientist Programs

A robust visiting scientist program could target specific needs in operational models. Making the visiting scientist positions attractive (i.e., reward incentive), and allowing NOAA to solicit ideas and select appropriate participants would have strong benefit to operational model development and associated improvement of the numerical guidance. Current programs are small and should be increased by a factor of five or more from current funding. Additional support would be needed to assure that NOAA staff has enough time to work effectively with scientists during their visits. An ancillary benefit of the visiting scientist program is that it would allow research scientists to develop a better understanding of NOAA's priorities and become immersed in the research to operations process.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 20, 2013

Lead: Ben Kyger

Subject: Computing

Effect of Reliability on Computing Capacity

Reliability of forecast runs is a critical component for determining computing costs and therefore computing capacity. Current capabilities are to supply forecast runs with 99.8% reliability, which includes software reliability; by contrast, research computers often run at 90% reliability and therefore can afford to procure greater capacity. There are strong needs for this high level of reliability, particularly during periods of severe weather. Relaxing reliability—if appropriate—would allow the procurement of additional computing resources that could be used for improving new or existing models - including running existing models at higher resolution. Although current reliability levels were thought to be near where they should be, this was considered a serious issue and one that has not been considered by the entire weather enterprise.

Allocation of Computing Resources

Discussions and decisions on allocation of computing resources are now more open than they have been in the past. Bill Lapenta leads discussions on allocation of research computers for NOAA; NCEP facilitates discussions on operational computing allocation several times a year. It was agreed that the more transparent the process is, the better for the community.

Transition to operations challenges

Computing architecture directly affects speed, reliability and cost of forecasting runs. Transferring weather forecast models from one system to another is time consuming for both people and computing systems when the architectures are different (Linux versus AIX). Machine dependent changes for code must be appropriately identified to allow for continued collaboration in the current multiple-architecture environment of the weather enterprise. In addition to architecture, firewalls, computing access and changing or different configurations can slow the transitions to operations, although some of these issues are becoming easier to address now than they were in the past. Changes in architectures and computing technologies mean that reasonable plans with specific architectural recommendations can only safely be made for roughly five years into the future.

Computing Requirements for Advancing Forecasting Capabilities

The US forecasting capabilities could be significantly improved with greater operational computing capacity. Moving models from research to operations is sometimes constrained by the capacity available on computers, for instance the transfer of the High Resolution Rapid Refresh Model to operational mode has been significantly slowed by the lack of operational computing. Under the current operational computer contract, upgrades are automatic and therefore not easily affected by budget changes. There is full replacement every 2.5 years, which often involves a tripling of computational power. The current operational computer contract includes hardware, storage, floor space, electricity, maintenance and support. The budget for computing has not kept pace with the need, with the result being lower forecasting capabilities (accuracy and products) than would otherwise exist. Expected funds from the Sandy Supplemental budget may allow for a step-wise increase in computing capabilities that may allow the US to come close to parity with other forecasting centers around the world, but this parity will not last long if the US funding situation does not change. The roughly flat budget for computational funding has been a contributing factor to the US falling behind other countries in forecasting capabilities. While some have advocated for a large increase in computational resources, an increase by a factor of 10 to 100 would be very difficult to adjust to without an appropriate increase in support for modeling and other components of the forecasting system. The US will require a budget increase between 1.2 and 2.0 times the current budget to stay competitive with other forecasting organizations around the world after the stepwise increase has been completed.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 21, 2013

Lead: Scott Mackaro

Subject: Modeling

Emphasis on Global Models

There was consensus on the following statement: Any additional funding provided by the Congress to enable the US to lead the world in operational numerical weather prediction should be used to support research, development, and implementation of a state-of-the-art global modeling system including all aspects including appropriate observations, computing capabilities and data assimilation development. This was supported because it was recognized that improvements in global modeling would have positive impacts on many "down-stream" products and models, including regional, air quality and ocean modeling. The better the deterministic model, the better the entire production suite becomes.

The Global Model of the Future

There are strengths and some weaknesses in having the global model of the future be a community model. The GFS did not start as a community model, but significant steps have been taken, particularly in the last few years, to make it more of a community model with code sharing and careful documentation. However, the GFS remains difficult for users. There will be a workshop this summer, to help teach people how to work with the GFS. One reason for staying with the GFS is that there is a well-developed plan on how to continue to manage and develop the GFS for five or more years into the future. Any competing model would need to show a superior advantage and have a similarly well-developed plan for maintaining and continued improvements.

The structure surrounding the global model and all modeling of the future was considered to be very important. Improvements in any future global models need to be carried out strategically: specific issues will need to be identified and evaluated; then targeted investments will need to be made on the issues where improvement is likely to be strongest. This approach is agreed to be needed for all issues including model resolution, data assimilation and specific model physics. The structure further needs to consider the appropriate incorporation of feedback and analysis of model performance.

The appropriate structure for a global model, particularly if it is a true community model will be critical for continued advances in modeling. The appropriate structure includes, planning, documentation, sharing of information and continual testing. The development and maintenance of this structure requires significant commitment.

Modeling – Computing Interactions

The interaction between models and computing specifications was discussed in some detail. It was strongly agreed that improvements in modeling, computing and observations needed to be balanced, that improvements in one was not a strong path for improving weather forecasting capabilities. Improving computing capabilities alone, was also not considered a strong option for improving weather forecasting capabilities. The upgrade cycle for computer procurements is not as regular or as strong as it should be. New technologies may help considerably in running models, but these technologies will not be the solution to the forecasting challenge. NWS' current procurement system does not support strategic and targeted computing purchases as well as it should.

Modeling – Observations Interactions

There is a clear need for observations to not only support operational forecasting but also to support model development. It was pointed out that ECMWS modelers are heavily involved in campaigns to improve model physics. The US needs to adopt this approach to assure continued model and forecasting improvements. Some physics packages, particularly clear sky radiation, are considered well advanced. Other physics options, particularly those related to moist processes, continue to warrant improvements. Both coordinated efforts and increased funding will be needed to make significant progress on these issues. Computational access and intellectual collaboration are also key factors that will need to be in place to make progress. There was also strong support that modeling requirements should drive computing acquisition, not the reverse. Boundary Layer measurements were identified as an area where there is an increase in the demand for global observations.

Coordination Across Agencies

Currently, several different agencies are involved in funding modeling, and observations that support weather forecasting: NOAA, NASA, DOD and NSF. Each agency supports efforts that are relevant to that agency's mission. Nonetheless to improve weather forecasting capabilities, these agencies need to be significantly more communicative and, ideally, more coordinated in how they invest in both modeling and observations. This coordination requires commitment and must be maintained to support both efficient and successful improvements in forecasting capabilities.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 22, 2013

Lead: Leon Benjamin

Subject: Observations

Targeted Measurements

There was consensus on the following statement: A need exists for weather observations that can deployed rapidly to remote, inaccessible or critical locations. These types of weather observations would be useful for severe weather forecasting, including tropical cyclones, research campaigns, fire weather. Targeted measurement capabilities could have additional societal benefits including assessment of and weather support after major natural disasters, major manmade disasters such as large industrial accidents or terrorists attacks, and military operations. Possible targeted measurements could be obtained from both large and small unmanned aerial vehicles as well manned aircraft, deployed radar, targeted use of sondes, as well as other possible methods.

Measurements Attributes

Observations are one of the key components to improved forecasts. A number of attributes contribute directly to whether observations are useful to improving forecasts. These attributes include: accuracy, latency, model use availability, frequency, representativeness, location, model value, types of observations. These attributes contribute to whether forecasts are accurate as well as post-event analysis and research studies. Each type of observation will have different attributes. There was strong consensus that no one type of observation or set of attributes would be sufficient to support significantly improved forecasting capabilities.

Integration of Observations into Forecast Models

There is some concern that observational data contributed to NOAA in support of forecast models are not being used in the operational forecast. Several possible reasons were identified, including that the data were contributed too late, or did not have the correct qualifiers. An additional, related problem is that the contributed data were fully ingested but were not useful to the forecast. For significantly improved forecasts, all useful data need to be fully incorporated. Not all data that could be useful are being ingested for use, including some satellite data and many local networks. All contributed data should be evaluated both for whether the data were fully ingested and for the extent to which the data helped for the forecast. Data providers need feedback on the extent to which their data were used and assisted the current forecasts; ideally this feedback should be automated and delivered in near real time.

For determining how well data help a forecast, two avenues were proposed: OSSE/data-denial experiments and adjoint statistical studies. The latter approach is considerably less costly, but requires that the models be run in a mode that supports these statistical analyses. Observations that are not significantly useful to operational forecasts may be useful for research that support forecast model improvement or may be valuable as back-up measurements should other observation systems fail. However, observations that are not useful may be both hurting forecasts and wasting resources, underscoring the importance of continuous evaluation of observations.

Data Ingest and sharing

MADIS is a current interface for submitting and retrieving data from NOAA. MADIS supports nine levels of restricted data so that submitted data is not shared beyond the level that the contributor of the data has agreed to. The purpose of the restrictions is to respect the business model of those supplying data; this was considered to be a good attribute, to be carried forward. There was some concern about the ease of use of MADIS and whether MADIS contained all observations pertinent to forecasting. With respect to ease of use; both software changes and more avenues for educating users would be useful.

Summary of AMS telecom on Forecast Improvement Group for March 27, 2013

Lead: Barb Brown

Subject: Modeling

Evaluation of Models

There was strong consensus that increased evaluation efforts would be needed to help improve forecasting capabilities in the future. However, single metric evaluation was not appropriate given the large variation in applications of forecasting models, and new methods are required, particularly as models are run at higher resolution and user applications become more important. Model-based forecasts provided to the NWS by non-governmental organizations need to be evaluated in a consistent way with all publicly available forecast models. Efforts at model evaluation through the Developmental Testbed Center (DTC) are a good starting point but future efforts should be significantly expanded. There is a need for a stronger focus on global models and much more involvement of all potentially interested parties. Such an effort would require significantly increased resources to allow for computing, documentation, more advanced analyses and increased community involvement.

Improved Research To Operations

A number of formidable obstacles for research to operations efforts were cited and solutions were outlined. Notably, computational capabilities were cited as a significant hurdle for Research to Operations efforts, thus significantly improved computing capabilities are a necessary part of the solution. Incentives for researchers to work to transition their efforts into operations were discussed including dedicated journals to reward academic researchers, more collaboration opportunities at NCEP, and targeted funding opportunities. There was a stated desire for end users to be more involved in helping establish the priorities for Research and Research to Operations investments.

The system of running advanced models before those models were transitioned into operations was discussed, a system that has recently been coined “Research Regular.” It was pointed out that such a system was not new and had been both successful and useful for a number of years. There was general support for the system with a stated desire for more communication between the developers of the models and the users of the models, to allow clarification of potential risks and alerts when changes were made to the model, as well as appropriate feedback that could aid model development.

Global Community Model

Benefits and detriments to having a global community model were acknowledged, with some comments that ECMWF has an easier mission because of their single model focus. A community model (a critical aspect of O2R) is viewed as a requirement to make R2O successful. Comparisons were made with the development of the WRF model, which was generally considered to be a successful effort. There was considerable question of whether it would be possible or even advantageous to get all of the existing research groups to abandon their individual global models in support of a single global community model. One proposal was to have the identification of the next global model that will be run operationally by NOAA. Such a system would allow researchers to understand which model they may want to work on when they are developing modeling components. An expanded DTC facility to support R2O and O2R with global modeling systems could include support of community code for the modeling systems, extensive and expanded model testing and evaluation, and support of capabilities to allow researchers to work more closely with operational forecast model developers to help bring new capabilities into the operational modeling system.

Increased Collaboration

Throughout the discussions a common theme of increased collaboration was agreed as important for significantly improving forecasting systems. Addressing the many fragmented aspects of the weather forecasting community was viewed as critical to success. Fragmentation was identified as inter-agency, intra-agency, across sectors, and across research groups. There was a call for more collaboration on global modeling, model evaluation, establishment of priorities for research and establishment of priorities for computing. While not mentioned on the call, this increased collaboration is very much in line with the Open Weather and Climate Services fundamental approach proposed to and accepted by NOAA.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 29, 2013

Lead: Troy Anselmo

Subject: Computing

Big Data

In contrast to some of the previous computing discussions, this entire telecom focused on computing issues other than the amount of processing power needed to develop and run weather forecasting models. The issue of big data was described as covering a diverse set of issues including: computing, storage, analysis and transmission. Of these issues, it was acknowledged that analysis and transmission are currently barriers to the US having significantly improved forecasting capabilities, even given the current modeling capabilities. As the weather forecasting systems in this country advance, these problems of analysis and transmission are likely to increase, perhaps even at the rate of Moore's Law or Moore's Law squared. A number of tools to address big data are being developed and currently in use; developments in this area are proceeding rapidly but there are no simple solutions. The pressure to handle large amounts of data will grow significantly, and will require intelligent approaches, potentially new tools and possibly closer collaborations within the weather enterprise.

Increase Demand for More Data

Several factors all point to a significantly increased demand for more weather data: weather forecasts are being used for an increasingly diverse set of topics, each with their own requirements; society's reliance on accurate, tailored forecasts continues to increase; future forecast data will likely have higher spatial resolution; and ensemble forecasts will produce an increase in output. The current demands for data are not being met: as an example, there is increasing need for forecast data to be delivered at high spatial resolution (sub-hour frequency) which is not being met by NOAA's operational forecast system. The recent Open Weather and Climate Services report brought as an example the need for turbulence products which require large amounts of high spatial and high temporal resolution data; current and likely future transmission will not support the data needs for these products. Higher temporal resolution of model output is a current, unmet need within the weather enterprise; as model spatial resolution increases and ensemble forecasting increases; this increase in data will not likely be easily transmitted to all who need the data. Transmission of data is and will continue to be a critical limitation of the weather enterprise unless new solutions are developed.

Scalable Computing Resources

A problem for the entire weather enterprise computing effort is developing computational systems, including model runs, analysis and transmission, that can be scaled up for intensified work when the weather system demands it, such as during high convective situations or hurricane development. The sporadic nature of these intensive computation needs, means that effective planning of computation resources for challenging weather situations means that during normal weather situations, computational resources may be available for research or maintenance purposes. While no complete resolution to this issue was identified, a number of possible approaches were suggested, including using the cloud and using NOAA's back-up computational capabilities during intense weather events. These ideas have not yet been appropriately addressed, but could in the near future.

Closer Partnerships

A strong principle of big data is to bring the analysis to the data as opposed to taking the data to the analysis. This solution was agreed as a perhaps inevitable resolution of some high-data product needs, for instance turbulence estimates, as listed above. However, a number of issues were identified as hurdles to "bring the analysis to the data." Many separate analyses may be requested to fill the diverse needs of the final users of weather data, while limited resources may be available to support all of the post processing requests. The solution of a significantly stronger and more open relationship between modeling centers, including NCEP, and users—both private sector and academic researchers—would be possible, but significant issues would need to be addressed. Some identified issues were the process for identifying which group gets to have close access to the data, cost of implementing the close-proximity post-processing, and potential impacts to the limited computational resources. Closer partnerships between modeling centers and both private sector and academic partners will likely be the solution that will allow significantly improved forecasting capabilities; the enterprise will need to address significant issues to arrive at that solution.

Appendix: Summary of AMS telecom on Forecast Improvement Group for March 29, 2013

Lead: Kevin Petty

Subject: Observations

Evaluation of Observations

There has been a considerable amount of work on understanding the importance of observations and how they can facilitate forecast improvements. This includes recent reports from the National Academies. The group was reminded that these types of works should be leverage in the process of identifying and selecting the most important steps that will lead to improved forecasts in the US.

There was a re-emphasis on the need for an evaluation of observations. Observations were recognized as important for research as well as running operational forecasts. With the multiplicity of applications for weather forecasting, it would be inappropriate to identify a single metric for evaluating the usefulness of observations, even when focusing solely on how well observations improve operational forecasts. As an example, observations that support hour ahead forecasts may not support five day forecasts. The weather community needs to better define what is meant by improved forecasts (e.g., what timeframe are we targeting), and develop a process(es) to focus on those improvements. We need to test the value of specific observations as they relate to specific forecast improvements, not rely on intuition. The value of observations needs to be taken into account the economic value of the improvement of the forecast, not just the impact on the forecast.

Evaluation techniques (e.g., OSE) need to be developed further to look at a variety of metrics, including severe weather and the effects of removing one observing system at a time. It is vital to understand and quantify the interdependencies as they relate to the use of various observation types in numerical weather prediction.

While redundancy was viewed as important and a positive aspect of future observing system, identifying critical areas which were under-monitored was also viewed as an important next step for planning the observing system of the future.

There was strong support for the coordination of existing efforts that evaluate observations. It was noted that some efforts are underway to start this coordination. It was also strongly supported that current evaluations were actionable, and that they should be used now for guidance with respect to support for observations, and not delayed until further research improved evaluation efforts.

Boundary Layer Observations

New applications of forecasting, including wind and solar renewable energy, convective storms and nowcasts (less than three hours) benefit from more boundary observations. Key parameters that were noted during the discussion included humidity and temperature profiles, soil moisture, as well as atmospheric measurements over bodies of water (including inland water). New observing systems are valuable and warrant further investigation to assure continued development and to allow expanded capabilities that can meet the needs of the future.

Global Measurements and Global Models

There was some support for the idea that global measurements were needed to improve forecasts within North America. This was considered particularly true to support research with global models, and also to support operational forecasts. Observations across the oceans, as well as observations to the west of North American, including Asia, may prove to be particularly important. The value of specific observations will likely change as global models start to have spatial resolution of current regional models.

Targeted Observations, Testbeds and Emerging Technologies

Targeted observations in response to critical weather situations have already shown their value, including observations using unmanned aircraft both in and over convective storms. A more coordinated effort is needed to develop targeted responses to developing critical weather situations, using a variety of observational techniques. Similarly, testbeds have shown tremendous value in improving forecasting for severe weather situation and in developing important new observational approaches.

Emerging technologies will be a key part of improved weather forecasting. The Department of Transportation is currently working out details for collecting and sharing weather and road condition data from cars. The value of this approach to general weather forecast is currently unclear, but early evaluation could guide future collection of observations.

Appendix: Summary of AMS telecom on Forecast Improvement Group for June 4, 2013

Lead: Cliff Mass

Subject: National and Regional Modeling

Current Situation

National-scale and regional (non-global) modeling offers high resolution forecasting which is critical for a variety of applications where high spatial and temporal resolution are needed including severe storm predictions, precipitation, renewable energy, turbulence forecasts and every day uses. While progress is being made toward high resolution, convection resolving (3km) global models, such models will likely not be fully developed for operational use within the next few years. Currently, NOAA, some academic institutions and a number of private companies are involved in running regional models. Several institutions—public, private and academic are involved in research and development of limited area models with a number of promising aspects which have not yet been fully developed including ensemble forecasting; high resolution rapid refresh; boundary layer dynamics and advanced data assimilation techniques. The development of these promising ideas are, to varying degrees, limited by the resources available to support their development and transfer their use into operations.

NOAA's Role in Regional Modeling

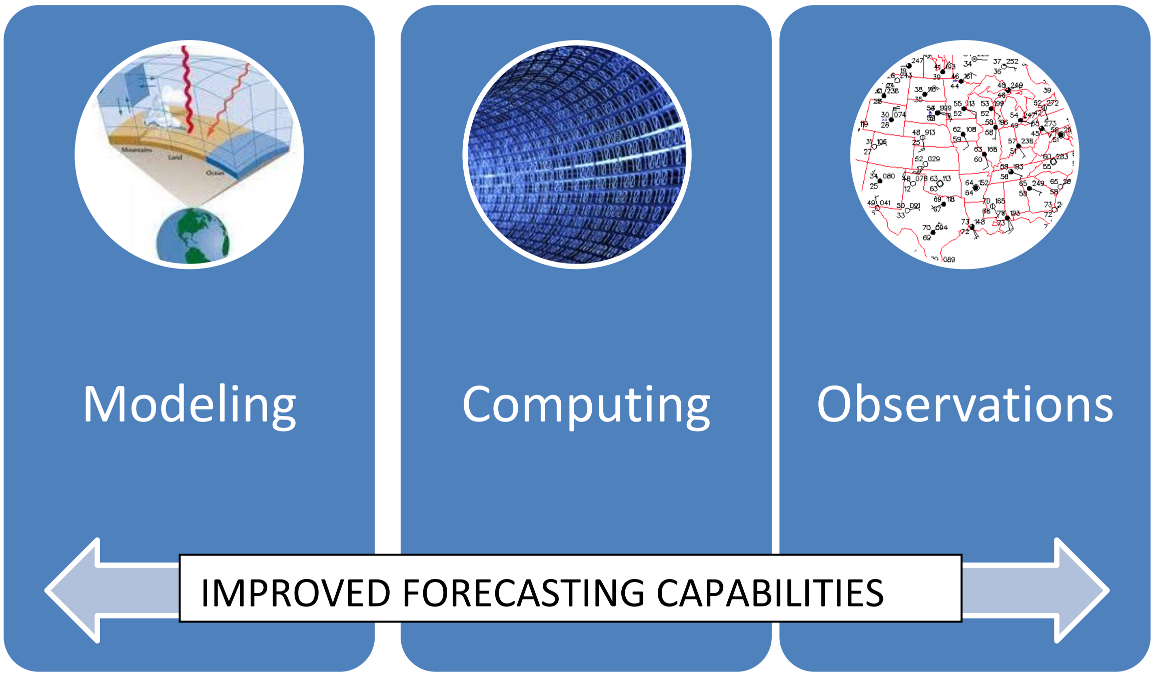
The possibility that NOAA should stop running regional (limited area or non-global) models was discussed at length, with a number of aspects of such a change discussed. This proposed change would likely involve NOAA purchasing output from regional models run by other entities, including academic and private institutions in order to fulfill its role to provide forecasts for the country. Possible benefits include: cost saving for NOAA, release of NOAA's computing resources for global models, ability for private sector to make profit, and competition may produce better products. The cost savings for NOAA, in particular, was questioned as private entities would not be able to sell their model output if NOAA will freely distribute it. Likely negatives include: limited regional model development; appropriate testing of new models (research to operations); and perhaps most importantly, uncertainty that NOAA would be able to fulfill all of its responsibilities, including agency to agency responsibilities. The idea was considered to have potential merit, and may be more appropriate at some point in the future. The consensus was that for now there is strong benefit to the country both to have NOAA active in developing and running regional models and to have a healthy, vibrant private sector involvement in value added and specialized regional forecasting. The precise dividing line for the role of NOAA and private sector in regional modeling was not easily identified in this discussion.

Continued Research in Regional Modeling

There are a number of strong research projects on regional modeling which are producing promising results. These efforts include improved assimilation programs, higher resolution physics parameterization, high resolution rapid refresh models, ensemble forecasting, verification mechanisms for high resolution ensemble forecasting and user interface testing and development. The current research ideas which show significant promise far exceed the current funding available to support their continued development. These activities need to be supported in order to assure current and future improvement in forecasting capabilities. Research on regional models should be funded to take place in government, academic and private institutions through a coordinated program to support and evaluate a variety of research ideas. This research will be necessary before strong recommendations can be made on specific details regarding operational regional modeling approaches—for instance how many ensemble models should be run at what resolution and with what post-processing are all outstanding research questions. The funds currently do not exist to support the research program needed to address these issues to the level which would allow significant and continued improvement in forecasting capabilities. US scientists are already coordinating existing activities on ensemble forecasting with a paper soon to come out in the Bulletin of the American Meteorological Society.

Computing for Regional Modeling

Computing resources will be needed to support both existing research and the coordinated research program proposed in the above paragraph. The computing resources from the Sandy Supplemental Funding, if allocated appropriately, should be sufficient for carrying out the near-term research into regional modeling. For long-term running of regional models by NOAA, along with the other weather model efforts, would likely take on the order of 10-15 Petaflops. This request for computing resources should not come at the expense of the effort to develop and run improved global models.



Appendix: Complementary Efforts to Examine Individual Components of the Weather Forecasting Enterprise:

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Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks, NAP, 2009.

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Towards Open Weather and Climate Services, NOAA SAB, 2011.