A Vision of the Future USWRP
A White Paper
5/04/03

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Introduction

The United States Weather Research Program (USWRP) is now approximately 10 years old and it is time to evaluate both its effectiveness and the effectiveness of weather prediction in the U.S. in general. This document considers such issues and suggests that weather prediction in the U.S. suffers from significant deficiencies and that the USWRP should be reconstructed to better address these problems. A more holistic and engaged approach to the USWRP is suggested, and a general USWRP workshop for considering major issues is recommended as a first step. The focus of this report will be short-term weather prediction from 0 through 72 h.

Weather Prediction in the U.S.: Not Living Up to its Potential

There can be little doubt that major progress has been made in the weather prediction enterprise in the U.S. Synoptic-scale numerical prediction models (e.g., NCEP GFS) are producing far more accurate forecasts of major cyclonic systems and other large-scale features than 10 years ago. Higher resolution mesoscale models often produce realistic mesoscale structures, a situation unheard of a decade past. A new national Doppler radar system (WSR-88D), even with substantial gaps, has afforded improved prediction of severe convective storms and better short-term forecasts of precipitation over the entire nation. Ensemble prediction techniques have proven their value for synoptic scale forecasts, and hurricane track forecasts has evinced steady improvement. Improved data assimilation and the use of new observing platforms have made possible better initializations and subsequent forecasts. The community has moved quickly to take advantage of the Internet as a means for distribution of forecasts and weather information. But these successes, as important as they are, must be contrasted with significant problems that currently plague the weather forecasting community and promise to continue to diminish its potential.

1. Mesoscale Model Development: Too Many Models and Too Little Cooperation and Focus

The history of mesoscale model development and application for operational short-term forecasting in the U.S. is one of too many models, too little national cooperation, and the lack of critical mass. Today there are at least ten mesoscale modeling systems (Eta, MM5, RAMS, ARPS, COAMPS, WRF, RSM—to name only some major ones) being developed or maintained at disparate centers. Although the U.S. is endowed with substantial depth in its weather modeling community, the result of so many platforms is that for any one platform insufficient resources have been available for the necessary, but time consuming, efforts to evaluate and improve model physics, numerics and data assimilation. An argument can, of course, be made that diversity and competition promotes creativity and spurs development. But such arguments can be taken so far, particularly when the number of experts in specific areas of model development and physics in the U.S. is relatively small. The European Center for Medium Range Weather Forecasting (ECMWF) has shown the value of focused cooperative effort by building one medium range forecasting model system by combining experts and resources. The fact the ECMWF global model is the world's best speaks eloquently for such concentrated effort.

The history of operational mesoscale model development in the U.S. provides many cases of inexplicable decisions, often with unfavorable outcomes. For example, when NCEP decided to begin mesoscale forecasting they did not carefully evaluate mesoscale models already developed in the U.S. (e.g., MM4, RAMS) but rather took on an untested model with an unevaluated vertical coordinate system (Eta) because of its supposed superiority in terrain. Ironically, it turned out that the Eta vertical coordinate has substantial problems and performs particularly poorly in terrain when applied at high resolution, having little ability to simulate mountain waves and downslope windstorms. In addition, problems with excessive blocking and poorly simulated precipitation near terrain (and elsewhere) have made this model a candidate for replacement. The Eta has been driven by a data assimilation system that consistently produces inferior initializations to those provided by the AVN/GFS forecasting system. As a result, the AVN/GFS synoptic evolutions are consistently superior to those of the Eta and the higher resolution of the Eta often goes to waste. Because of the Eta model deficiencies and the lack of community support services, the university community has never put much effort into improving the Eta model. This schism between operational and research communities has had very negative implications for advancement in mesoscale prediction.

Past development of the nominal community research mesoscale model (the Penn. State/NCAR model. MM4/5) has been characterized by substantial progress in the face of inadequate resources. Development of the MM5 at NCAR has been grossly underfunded, typically at the level of around ONE full time equivalent (FTE), with the remainder coming from segregating funds from applied projects such as the Hong Kong airport prediction system. The result of these side projects is a substantial drain on the creative talents at NCAR. In contrast, the NCAR global circulation model group enjoys 5-10 FTEs. Why is so much support available for prediction of global warming, whose impact is unsure at best, while weather prediction, of great value to protecting life and property, is a poor stepchild?

One of the more encouraging developments in the modeling arena has been the nascent WRF model, an attempt to create a state-of-the-art mesoscale model that would serve both the operational and research communities. The idea of a community model has attracted wide-ranging support and a start has been made, mainly by staff at NCAR. Unfortunately, WRF has not received sufficient financial backing to be developed in an expeditious manner. Development is now at least a year behind schedule, with crucial capabilities such as nesting and nudging not yet available. Both the front end (data acquisition and assimilation) and back end (display and manipulation packages) are lacking. Another source of concern is that the definition of WRF has been fluid with various centers seeing the system as more of a wrapper in which they can maintain their own "dynamical core." Although varying dynamical cores can provide a useful test bed for various dynamical configurations and facilitate ensembles, it can also serve as a sophisticated approach to maintain less capable old models.

A particular area of concern is the manifest deficiencies in the physical parameterizations of numerical models, with particular problems being evident in microphysics, boundary layer, and radiation physics. The need for work in this area has become particularly acute as models move to higher resolutions, often requiring different parameterization approaches. With the national effort being dissipated over a large number of modeling systems, there has been a lack of critical mass (both of people and resources) for attacking parameterization problems.

Another problem deals with operational regional analysis. Currently, the main operational regional analysis and short-term prediction system is the Rapid Update Cycle (RUC), which uses a different (hybrid) model than NCEP's own mesoscale model (Eta). Of course, this prevents joint improvements or consistency between nation's two main operational mesoscale systems, and insures inefficient and wasteful development. National weather service forecasters are faced with the perplexing (and frequent) dilemma of differences in the initializations and short-term forecasts of the RUC and Eta. And of course, there are other competing regional analysis systems (such as LAPS and ADAS). Again, the U.S. development effort is too unfocused, with each project lacking the resources to produce the level of products required by the operational community.

2. The Human Role in Forecasting: Lack of Coherent Approach

A great deal of attention needs to be addressed to the role of the human in the forecasting process, since the effective generation and optimal application of forecasts depends on the effective use of human personnel. Unfortunately, the ineffective use of human forecasters is now a major stumbling block for nearly all operational entities. Military forecasting is currently undermined by insufficiently trained forecasters attempting to provide critical products in regions in which they have little familiarity. For example, in the U.S. Navy the bulk of the forecasting is done by individuals with only a few months of meteorological training and little background in math and science. Their commanding officers, often possessing M.S. degrees in meteorology from the Navy Postgraduate School, are rarely involved in the forecasting process and are burdened with administrative and other duties. The constant rotation in duty station hampers Navy meteorologists from developing competency in forecasting for the locale in which they are stationed. As a result, there is a heavy dependence on model output and too little critical analysis. In addition, the interactive systems used by Navy personnel for viewing and evaluating weather information are generally inferior, both to the state-of-the-art and that available to civilian forecasters. To put great resources into numerical weather prediction while underinvesting in human resources insures that U.S. military personnel do not enjoy the weather support they deserve.

National Weather Service forecasters, although enjoying far greater educational background and the luxury of permanence in their forecasting stations, also face uncertainty and difficulties. For example, the new IFPS system for forecast preparation and dissemination has substantial flaws that force forecasters to spend large amount of time on unproductive grid editing. Forecaster reaction has been negative and the system threatens to decrease NWS forecast skill (see Mass 2003 for an analysis of IFPS issues). The scoring system used by the NWS (comparison to MOS) often produces timid forecasters that shrink form deviating too greatly from objective, statistical guidance, even when they believe it is in error. NWS forecasters spend too little time on where they could be highly productive—the production and dissemination of short-term nowcasts and forecasts. They have few tools for communicating forecast uncertainty and confidence, a critical aspect of the forecast process.

Considering the critical nature of the human impact on the development, dissemination and application of forecast guidance, all U.S. forecasting entities need to carefully evaluate the role of human forecasters and how they can be better trained, equipped, and supported. Clearly, this is a major issue that can no longer be ignored by the USWRP.

3. Probabilistic Short-Range Forecasting and Prediction of Forecast Skill

As computer power has increased over the past several decades, the short-term prediction community has put the overwhelming majority of its computational and development resources into increasing resolution and improving model physics. In contrast, for medium range forecasting an increasing proportion of computer resources has gone into ensemble prediction, which accepts the essentially probabilistic nature of weather forecasting. Uncertainties in initial state and model physics occur and couple with the chaotic nature of the atmosphere; thus, the mesoscale community is fooling itself and its users by concentrating on deterministic high resolution forecasting, at the expense of probabilistic prediction based on ensembles and other means.

NCEP, FNMOC, AFWA have short-changed investment in short range ensemble forecasting (SREF). FNMOC and AFWA have basically avoided the whole issue and do not have any active program in SREF (although some encouraging conversations with FNMOC leadership suggests this may soon change). NCEP has continued a very limited SREF effort over the past few years that has suffered from little investment in either manpower or resources. Without much computer resources availability, the current NCEP ensemble system is very coarse (48-km grid spacing) and thus of marginal value for many mesoscale applications. Furthermore, the breeding method is used in several of the NCEP SREF members even though it is probably inappropriate for SREF use.

One of the greatest deficiencies of current forecasting practices is the lack of information provided on the expected forecast skill of predictions. Little investment has gone into development of new objective forecast skill prediction tools (such as those based on ensemble forecast spread), and little thought has been given to products that could communicate the subjective evaluation of forecast skill by human forecasters. Perhaps the only such product is the NWS forecast discussion, whose value is still clouded by the use of arcane contractions and abbreviations left over from teletype days. Both creating the technology to predict forecast skill and new approaches to communicating forecast reliability and expected skill should be priorities of the USWRP.

4. Testing and Verification

Most measures of mesoscale forecast skill used by operational forecast entities are inadequate. In reality, the atmospheric sciences community does not really know how to do mesoscale verification of even deterministic forecasts. How does one handle accurate structures that are delayed or misplaced? Does one verify on model grids or at observation locations? These and many other basic questions are extant, and the community is just beginning to think about it (as shown by the 2002 verification workshop in Boulder). There is even less experience with probabilistic forecast verification tools. Besides better measures and understanding of verification (and how verification needs vary by user type), there is an acute need to develop an infrastructure for testing and evaluating mesoscale models, so hard numbers, not opinion or turf battles, help make the key decisions on where resources are placed. The National Model Development Testbed Center (DTC) idea discussed in recent USWRP meetings is a good one, assuming it is independent and not on such a grand scale that funding becomes prohibitive or the time horizon gets too delayed. As noted below, smaller testbeds at regional prediction centers could also be useful.

5. The Need for Better Support for Applied Research and Increased Cooperation Between the Research and Operational Communities.

With the availability of far more observational and model data, the potential for coupling the resulting data streams with a wide range of applications (e.g., air quality, transportation weather) has never been greater. Unfortunately, much of the potential is not being realized because U.S. applied meteorological research has been inadequately funded. NSF has discouraged applied research proposals, the USWRP has had only very limited funds for applied research, and Federal agencies such as NOAA have kept most research support in-house. It is time to deal with this issue. Joint projects in areas such as roadway weather, air quality modeling, aviation weather, weather and energy, and a number of others should take place on both the national and regional efforts. Entraining the user community into joint, cooperative ventures will provide needed energy and impetus to the USWRP, as well as garnering additional support.

6. The Need to Provide Better Diagnostic and Short-term Forecast Information to Users

Perhaps the greatest failure of the weather prediction community is its inability to provide accurate and timely information on what is happening now and will happen during the next few hours. After a huge investment in weather radars and weather satellites, rapidly increasing numbers of aircraft observations, and access to increasing volume of surface reports, we often have a very good idea of what is happening now and how the weather will involve in the short run. Unfortunately, this information rarely gets communicated to the public and other users because of lack of resources and tools to do so. When NWS forecasts go awry there is often no correction until the next regular forecast release. This deficiency becomes more acute as capability for rapid distribution of weather information is becoming available (Internet, graphics-capable cell phones, etc).

USWRP: Unfocused, Underfunded, and Disconnected from the User Community

The USWRP has the clear goal of improving weather forecasting and the application of weather information in the United States ("to weatherproof the nation"). To do this, it promised to harness and join the efforts of the research and operational communities. An early direction of the effort was to gather groups of scientists into Prospectus Development Teams (PDTs) to study specific issues. Over 8 years there have been ten PDTs, dealing with a wide range of topics including heavy precipitation, hurricane forecasting, hydrometeorology, and societal impacts. Producing interesting summaries of specific topics, these gatherings and their associated reports have had only a small impact on either the science or operational aspects of the field. Their reports also become increasingly out of date as the field rapidly changes and evolves. Another major USWRP activity has been scientific symposia dealing with warm and cool season precipitation as well as hurricane prediction. Such meetings have generally consisted of several days of short scientific presentations with little discussion, creative or otherwise; like the PDT's such symposia have had little lasting impact. The USWRP has been associated with or has had a role in organizing several field programs, such as THORPEX, IMPROVE, and IHOP. Although some of the experiments have produced significant data sets of value to the forecasting enterprise, others have been of questionable value. The lack of community discussion, evaluation, and prioritization of proposed field programs has been a major weakness of the USWRP in specific and the U.S. meteorological community in general. A lack of focus has resulted in there being too much money spent on too many field programs.

In an attempt to bring some focus to the USWRP and to appeal to funding agencies, three main areas thought to be of considerable interest and impact were identified: hurricane landfall, precipitation, and observations/data assimilation. The hope that these important topics would resonate with funding agencies and users groups, and thus bring substantial additional resources into the USWRP, has failed to be realized. In fact, these topics appear to be too diffuse and research oriented to appeal to the weather user community (from Federal agencies to the private sector). Furthermore, the identification of three foci discourages other interests from joining the USWRP. There should be only one focus of the USWRP: improvement of the value of weather forecasts to the public and other users. With meager funding and too little focus to the USWRP research efforts, the university and operational communities have increasingly become cynical about the value of USWRP either as an engine of research or of operational application.

The USWRP has evolved into a diffuse collection of initiatives and field programs without a central vision and without clear priorities. There is little sense of a community working together towards specific and important goals, other than "weatherproofing the nation." A profound deficiency has been the lack of an USWRP oversight group representing the meteorological and user communities as a whole. Rather, a narrow collection of government agencies (the IWG) has guided the direction of the USWRP. Clearly, the USWRP has suffered from a beltway/Boulder myopia with far too much stress on Federal agencies as both benefactors and beneficiaries. NOAA-centricity has been particularly noteworthy. Although NOAA is clearly important to the national weather enterprise (and is the lead federal agency in such matters), it only represents a portion (and a rapidly declining one at that) of the weather forecasting community, as state, local agencies, and businesses increasingly participate in both the prediction and use of weather information[1]. Air quality prediction, private sector forecasting, transportation weather interests, and innumerable others are growing in size and importance.

Another major problem is the USWRP's lack of a holistic approach to weather prediction and information application. Observation quality/quantity, data assimilation, numerical models, post-processing of model output, the role of human forecasters, forecast distribution and communication, and forecast verification are some of the issues that must be considered simultaneously. Failure dealing with one can greatly lessen the value of the others. For example, the NWS's failure to properly plan its new weather forecast distribution system (IFPS) greatly threatens the integrity and skill of its products, even though the forecasting models have become more skillful. The relatively poor training of military forecasters and their frequent movement has hurt military weather prediction skill, even though the numerical guidance and worldwide communication are improving. The holistic approach needs to extend to securing an overall view of the entire U.S. forecast enterprise to minimize duplication of effort, to maximize the use of limited

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[1] Consider that in 1980 virtually all of the U.S. NWP efforts were concentrated at NMC and FNMOC. Today NWP has spread to the Air Force (AFWA), dozens of universities, dozens of State and regional agencies, and a number of private enterprises. Clearly, there are far more player in the weather prediction business and the USWRP must reflect this change to remain relevant.

resources, and to encourage competition when useful. No Federal agency or collection of Federal agencies can take on this role, due to self-interest, competition for funds, or a limited viewpoint. Only a collection of U.S. weather interests, resident in some national entity can take on this role. The cost of the USWRP's ineffectiveness in providing such national scientific oversight has substantially hurt U.S. weather prediction and diagnosis capabilities.

There have been a few encouraging developments with the USWRP of late, none being as important as the WRF model development effort it has fostered. But as noted above, WRF is underfunded and underorganized, with several agencies looking at it as more as a "framework" that a cooperative communal development platform. Particularly, important is the lack of an organized effort or funding for the improvement of WRF physics parameterizations. The proposed National Model Testbed is also a promising idea, but there are concerns regarding the grand plans (and even grander budgets) and the long time lines for its development.

A New Vision for the USWRP

American weather forecasting is not living up to its potential. To effectively utilize the nation's enormous scientific and operational resources requires a radical change in the organization of its research and operational assets. The USWRP could provide some of the required leadership, but to do so would require a very different vision and approach. As outlined below there are five major elements to the proposed USWRP:

1. Viewing the forecast process more holistically.
2. Changing the management structure, partially by being more inclusive.
3. Making regional prediction and research an important component of the USWRP
4. Working more closely with the user communities and setting up national and regional application testbeds.
5. Making applied research an important component.

This section will outline specific steps that need to be taken.

1. The USWRP must consider the whole forecast process, including how the end products are used.

The approach taken by the USWRP has been highly academic and narrow, with little appreciation of the entire end-to-end forecast problem. The essential goal of the USWRP must be the improvement in the quality and value of weather information provided to the user community. But it cannot stop there. The USWRP must not only improve forecasts and observational data but assist users and potential users understand the value of accurate weather information for their needs.

To provide users with improved weather information requires a holistic view of the whole forecast process from data collection and modeling through its use by the user community. To take on such a full-ranged view, the USWRP should begin by dropping the current narrow triad of foci (precipitation, hurricane track forecasts, data acquisition/assimilation) and reorganize into a process and application oriented form. The goal of the USWRP should be to facilitate improved weather forecasts and their useful application. Only research that directly leads to improved forecasts within 5-10 years should be supported.

2. *A new management structure will be needed to do this effectively.*

The USWRP should establish an oversight committee of 10-15 members with wide-ranging (and rotating) membership from the research, operational, and user communities (civilian—including private sector-- and military). There should also be representation of the regional consortia, which will become an important component of the USWRP. This committee should represent all U.S. weather interests and not be dominated by one or few agencies. A possible distribution of membership is shown in Table 1. The IWG would be discontinued. The USWRP oversight group would be responsible for setting the agenda for the

USWRP, determining priorities, managing the USWRP, and deciding on the use of funds. This group will also evaluate potential USWRP field program participation. It would meet regularly, with physical meetings at least twice a year and monthly conference calls. An important component of each meeting will be to review concrete measures of progress towards improving weather prediction in the U.S., such as verification scores for model and human forecasters.

A collection of standing working groups dealing with the following topics should be established.

1. Data Availability and Assimilation
2. WRF Model Development
3. The Role of Human Forecasters
4. Ensembles, statistical postprocessing, and probabilistic prediction
5. Forecast and Model Verification
6. Human Impacts and Weather Applications

The working groups would provide advice and information to the oversight committee, and would manage the various subareas under the policy guidance of the oversight committee. The Scientific Steering Committee would be disbanded, since its functions would be replaced by the above working groups and the new oversight committee. The working groups will be made up of experts and users in the various topic areas, providing fresh guidance, in contrast to the static PDT approach used previously. At oversight committee meetings, the chair of each of these working groups would report on progress (or lack of progress) towards USWRP goals, the most important being the improvement of objective forecast skill and the creation of beneficial weather applications.

The areas of responsibility of the six working groups will be as follows:

<u>Data Availability and Assimilation</u>: Examine and make recommendations regarding observational data availability over North America and around the world. This group would be responsible for evaluating the current observational network and making recommendation regarding specific new observing systems, targeted observation programs, and relevant programs such as THORPEX. This group would advise USWRP and the other WRF committees on recommended approaches for mesoscale and synoptic scale data assimilation, and will make recommendations regarding the collection of heterogeneous mesoscale networks.

<u>WRF Model Development:</u> The most important specific goal of the USWRP will undoubtedly be the development and evaluation of the WRF model, including its dynamical core, physical parameterizations, and data assimilation routines. This working group has the critical responsibility for actively managing the WRF model development, including the numeric core, physical parameterizations, and WRF data assimilation approaches (the latter in concert with the data availability and assimilation committee with whom at least one member will be shared). An important task of this group will be to review the adequacy of WRF physical parameterizations and to recommend active research/development/field experiments for physics in need of improvement

<u>The Role of Human Forecasters:</u> This group will examine the current approaches used by civilian, military, and private forecasters in the forecasting process and will recommend ways in which human contributions can be enhanced. Among the areas within the charge of this group is the adequacy of current forecasting tools (such as IFPS), forecast automation, and forecaster training.

<u>Ensembles, statistical postprocessing, and probabilistic prediction</u>: This working group will examine the potential of ensemble systems for producing calibrated statistical forecasts both on the synoptic and mesoscale and will appraise the adequacy of current efforts in the operational and research communities. The charge of this committee will extend to statistical processing, including MOS, neural nets, and model

bias removal, and the communication of probabilistic information (including prediction of forecast skill) to users.

Forecast and Model Verification: This working group will take on the critical (and underdeveloped) area of model and forecast verification, with particular emphasis on mesoscale verification. This group will supervise the USWRP participation in the National Model Testbed, develop standard verification approaches for use in national and regional forecasting efforts, and be responsible for the production of real-time verification statistics for major U.S. modeling systems that will be used for guidance in USWRP development efforts.

Human Impacts and Weather Applications: This working group will supervise the USWRP's weather application activities, including the national applications testbeds and other USWRP application products (including air quality modeling and transportation weather). It will also provide advice on the relationship of the weather prediction community and users, including products and capabilities that require active community development. The communication and distribution of weather information will also be under this committee's purview.

In addition to oversight and working group committee meetings, there would be topic workshops that would include one or several of the above committees, and annual or biennial plenary meetings that would be wide ranging. The latter meeting would be expected to include several hundred participants and would provide an excellent forum for determining the priorities and expectations of the large community. Meetings would provide equal time to presentations and discussion.

Day by day management of the USWRP will fall to the chief officer, who would need to be an individual of substantial scientific credibility (like the current science officer), and USWRP administrative staff.

3. Regional Prediction Should Become an Integral Part of USWRP

Weather varies across the nation. Not only do weather phenomena vary geographically, but the data collection, data assimilation, or modeling approaches ideal for one section of the country is often not appropriate in another. Just as important, the needs and expectations of the user communities vary as well. Regional numerical weather prediction and data gathering efforts have begun to spring up across the U.S., and these efforts should become an integral part of the USWRP. Specifically, the USWRP should foster the development of 6-10 regional environmental prediction and research centers, each dealing with a (relatively) meteorologically uniform section of the nation (e.g., Northwest, Alaska, SW US, Intermountain U.S, SE U.S, and N.E. US. Northern Plains, Southern and Central Plains, Great Plains, Hawaii and Pacific). Each center would run a mesoscale model (hopefully WRF) in real-time and would help gather local data assets for its own use and for distribution to national centers. These centers would evaluate model performance over their regions as well as work on model improvements and regional enhancement that could be shared with others. Such regional model evaluation will effectively reveal deficiencies in the WRF and help address them.

Regional meteorological research would be another function of these groups, examining regional mesoscale and synoptic circulations in a comprehensive way. Regional centers would develop close ties with the local user communities, working to develop new data feeds and applications. Regional prediction centers would not be limited to meteorological prediction, but would be encouraged to extend their activities into air quality, hydrological, and road weather prediction as well. Each would have a close relationship with local National Weather Service and military weather prediction offices, as well as NCEP, FNMOC, and AFWA--with a two-way transfer of data and forecasts.

Core funding for such regional efforts would come through USWRP, but it would be expected that as the regional centers mature a considerable portion of their support would come from regional agencies and users. The experience of the Northwest, Utah, and Oklahoma regional prediction efforts is that additional sources of support can be acquired when a relationship with local user communities is established.

In summary, regional centers will greatly extend the reach of the USWRP by facilitating regional NWP and research, help integrate the USWRP with user communities, and provide a potent source of additional funding. They will provide a complementary and synergistic approach to the efforts of national centers.

3. *National Application Initiatives and Testbeds Should Be Established*

One of the most serious deficiencies of the USWRP has been a lack of integration with user communities. This situation both isolates researchers from the consumers of meteorological information and denies the USWRP a potential source of funding. One way of addressing this issue, as noted above, is the establishment and fostering of regional environmental prediction and research centers. But there is another complementary approach that should also be considered: the establishment of national application testbeds in important areas such as air quality modeling, hydrological modeling, road/weather information systems, and hurricane landfall. The basic idea of these testbeds is that research and real-time operations are inseparable: one must build operational testbeds for key applications and verify their products operationally to inform the research efforts. Users get a taste of the potential of new technologies, while researchers get immediate feedback on their work. Users feel like they are a part of the research effort and getting advantage from it, encouraging financial or other support. User interest provides meaning and encouragement to researchers.

One example is air quality prediction. Recently, there has been substantial USWRP interest in this area and a meeting is planned later this spring. Some regional groups are already experimenting with the coupling of air quality and mesoscale models. Others are using mesoscale models to produce new products for predicting smoke dispersion, wildfire management, and ventilation. Considering both the importance and interest in this issue, the USWRP should foster an effort to couple air quality models and WRF. Potentially cosponsored by EPA, U.S. Forest Service and regional air quality agencies, regional and national real-time air quality prediction testbeds should be created and carefully evaluated. The regional efforts would probably be done in concert with the regional centers, while national testbeds could be done jointly with NCEP, NCAR, FSL or a consortium of other groups. Another issue is road/weather information systems that couple mesoscale models, meso-networks, and road condition prediction systems and other transportation-related applications. A few test projects are in place today (Foretell in Iowa, Washington State DOT), but the evaluation of weather/transportation information systems need to take place on a national scale.

4. A Strong Applied Research Effort Should Be Established

The U.S. meteorological research effort, though formidable, has suffered from a lack of funding for applied weather prediction research, particularly at universities and the private sector. USWRP funding for forecasting-related research has been sorely lacking, with only a small fraction of proposals being funded. Equally as serious, the priorities for funding have been limited to the narrow USWRP foci, denying funding to areas critical for the future of U.S. weather prediction. Furthermore, some of the funded proposals have not produced work that will clearly contribute to increased forecasting skill or better meteorological applications during the next few years.

To address these problems two actions must be taken. First, only projects that will have a significant and demonstrable contribution to weather forecasting and weather application skill during the next five years should be funded. Basic research with a long timeline to application should be funded by NSF or other agencies through existing grant programs. Second, additional funding needs to be secured from current and new sources. Although this is more easily said then done, it is hoped that the clear priorities of the new USWRP, the clear route of the research to valued applications and forecast skill, and the closer relationship to the user community should facilitate additional funding.

A Basic Principle: Weather Research and Operations are Inseparable

A central idea of this note is that weather research and operational forecasting are inherently intertwined. To improve weather forecasting requires a holistic view of the whole process. Creating and evaluating improvements can only be made under the guidance of operational application. That is why the USWRP must integrate research and operational testing at a number of levels from national to local. A successful forecast is much more than NWP, but includes human interaction and evaluation at a number of levels. An analogy might be the improvement of the quality of music produced by a symphony orchestra. Consider a US Music Research Program directed towards improvement of the total listener experience. If it were like the current USWRP it would be trying to perfect the design of particular instruments, hoping the end effect would be good and that people would be willing to pay to hear the resulting concert. Some instruments produced by such an effort might end up unplayable or unpleasant, and there would be little guarantee that the orchestra first full concert would be a success (or would have any paying concertgoers). A far better approach would be to get small groups of musicians, instruments designers, and potential listeners together in small groups to comprehensively test musical ideas and new instruments on wide variety of pieces, with successful ideas being passed onto the larger orchestra for further testing (again with a wide range of compositions and a variety of members of the community present). Concert goers would get the product they want and might even offer funds to support the effort.

As part of this principle, the USWRP must include the whole weather community, including the private sector and other user groups.

A Summary Schematic

The new USWRP structure is illustrated in Figure 1.

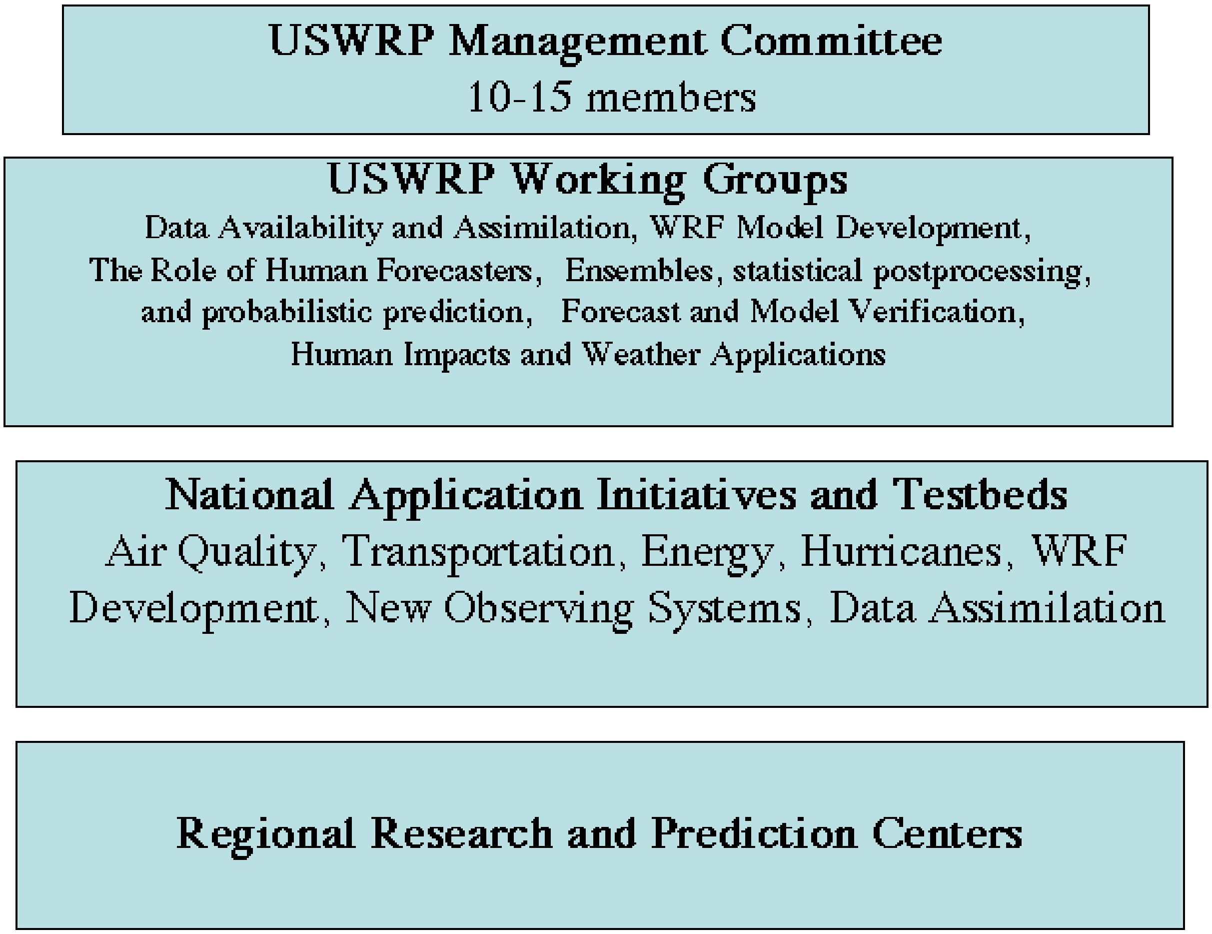

Figure 1: Schematic of the proposed new USWRP structure.

A First Step

Although the above discussion examines several problems with the USWRP and the US forecasting enterprise, it is motivated by an optimism that great strides can be made quickly if the U.S. weather prediction community can better focus and organize its efforts. The potential improvements in the value of weather information to the user community during the next 5-10 years could be extraordinary, changing the lives of all Americans in a very positive way. The USWRP can play a major role in this evolution. As a first step towards building a new USWRP, the cold season and other workshops should be cancelled, and a plenary meeting of the U.S. forecasting and application community should be called. This meeting, perhaps coincident with the AMS annual meeting in Seattle, would provide large blocks of organized discussion time to review the U.S. forecasting enterprise and the USWRP in specific, and would break into working groups to create the blueprint of the future USWRP effort..

Table 1: Possible Membership of the USWRP Management Committee (UMC)

NSF
Two University representatives
NOAA
Navy
Air Force

Two Regional consortium representatives
ONR
Private Sector member
Two members from user community (e.g., U.S. DOT, EPA, Forest Service, State and local agencies)