1. Introduction

1.1 Background and Charge

This report contains the annual evaluation of the National Centers for Environmental Prediction (NCEP) by the UCAR (University Corporation for Atmospheric Research) Community Advisory Committee for NCEP (UCACN, pronounced, "you-can").

The context for this report was created in November 2008 when UCAR was requested by NCEP to conduct a thorough and thoughtful review of the nine Centers that comprise NCEP, as well as the NCEP Office of the Director (OD). An Executive Committee plus five panels conducted the reviews, which are collectively referred to as the 2009 Review. The reports were completed in early 2010 and are available at http://www.vsp.ucar.edu/UCACN/index.html. One of the major recommendations of the 2009 Review was that NCEP should establish a permanent external advisory committee to provide guidance on improvement of products and services based on the latest advances in science and technology. As a result, UCACN was established by UCAR in March 2011; its primary responsibilities are:

1. To conduct a comprehensive review of NCEP (the nine Centers and the Office of the Director) every five years, starting in the year 2015.

2. In the years between the comprehensive reviews, to:
   a. Monitor progress of the Centers in the context of the NCEP strategic plan and previous UCACN recommendations, and provide informal updates and advice to NCEP leadership through the UCAR President (or designate).
   b. Provide input to the strategic planning and long-range goals of the Centers and NCEP as a whole.

In preparation for its annual meeting, originally scheduled for October 2013 but postponed to January 2014 due to personnel changes at the National Weather Service (NWS) and NCEP (primarily the appointment of the new NCEP Director, Bill Lapenta, on Jan. 6), the UCACN was provided with updated reports on activities and plans from each of the nine NCEP centers, including summaries of each center’s Annual Operating Plan for FY2014.

1.2. Procedure

The UCACN met with the NCEP Directors and other leaders of the 9 centers and the Office of the Director (OD) January 21-22, 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters in Riverdale Park, MD. Members in attendance included Fred Carr and Jim Kinter, co-chairs, Alan Blumberg, Lance Bosart, Gilbert Brunet, John Dutton, Bill Kuo, Gary Lackmann, Tsengdar Lee, Warren Qualley and Karen Shelton-Mur. The first day of the meeting was disrupted by a snow event that closed the Federal government. The portion of the UCACN meeting on that day took place remotely by teleconference and convened in situ on the second day. One UCACN member was designated as the “lead” for each center and was responsible for writing the individual reports. During the first day, the UCACN heard introductory remarks by newly appointed NCEP Director Bill Lapenta, who welcomed the committee and turned the program over to Dennis Staley. Staley provided an update on NCEP; a briefing on the recent NAS/NAPA...
report; a briefing on the Disaster Recovery Act (also called the Sandy Supplemental in light of the fact that the funds were provided as a means of enhancing preparedness for events like Hurricane Sandy); a summary of accomplishments in the past year and a look ahead at plans for FY14.

There were also presentations by Geoff DiMego on Integrated Regional Modeling, Dave Novak and Jon Gottschalck on the Weather-Climate Linkage, and Rick Knabb on Storm Surge and Inundation. All these briefings included contributions from several others at NCEP. The newly-appointed NWS Director, Louis Uccellini, also gave a briefing on the current status of budget and planning at NWS.

The UCACN meeting included separate breakout sessions on the three themes mentioned above as well as breakout sessions for all of the NCEP centers, followed by an executive discussion and a preliminary report back to NCEP on the Committee’s findings. The reports on the Office of the Director (OD) and nine NCEP Centers that follow are based on these discussions as well as material sent to UCACN in advance, the 2014 Annual Operating Plan (AOP), and, in several cases, site visits over the previous year.

Because the 2013 UCACN annual meeting was delayed until January 2014, a follow-up meeting of just the UCACN members was held on 4 February 2014 in Atlanta, GA (coincident with the American Meteorological Society Annual Meeting) at which this report was discussed and organized, and plans for changes in UCACN membership, site visits, and the 2015 Review of NCEP were discussed.

A complete list of acronym definitions appears at the end of this report as an Appendix.

Acknowledgment: The UCACN was once again provided with a wealth of information and complete cooperation by all members of the NCEP management and staff with whom it interacted, for which the UCACN expresses its satisfaction and gratitude. The UCACN also wishes to thank the UCAR Visiting Scientist Programs office, especially Ms. Susan Baltuch, who provided excellent logistical support, especially under the unusual circumstances due to the inclement weather and government closure on January 21.
2. Office of the Director

2.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP). NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD. Material for this Office of the Director (OD) report comes from the pre-meeting materials provided by NCEP, from discussions with the NCEP Director, and from the set of overarching issues and recommendations from the nine Center reports. The reader should also note that while most of the recommendations are directed to NCEP leadership, many are also intended for NCEP’s parent organizations, the National Weather Service and NOAA, since many issues can only be addressed at higher administrative levels.

2.2 NCEP Issues

On Wednesday, 22 January, G. Brunet, F. Carr and J. Kinter met with Bill Lapenta to discuss the Office of the Director activities and concerns. There was general agreement on the following issues:

- The Office of the Director (OD), together with NCEP Center Directors, needs to be more proactive and strategic in its planning. This planning must include a prioritization process.
- The OD is under-staffed to achieve effective decision-making and requires the creation of two important new positions: a Deputy Director and a Chief Scientist. This is necessary to enable the NCEP Director:
  - To have time for strategic planning, working on high-level issues, and maintaining a community and international presence
  - To enhance productive liaisons with OAR and NESDIS within NOAA, and other Federal agencies that have weather and climate interests
  - To identify and hire an outstanding scientific leader who can be the focal point for R&D progress at NCEP
- NCEP would gain more scientific stature in the community if its short- and long-term R&D strategy in weather and environmental prediction were led by a Chief Scientist. The Chief Scientist would need to be responsible for the full chain of innovation from research to operational implementation. To achieve this, he or she would need to be accountable to both NWS and OAR leadership. The Chief Scientist would need to establish the long-term NCEP science strategy and its implementation. He or she will need to fully control the financial resources from NWS, in coordination with the NCEP Director and OAR leadership, needed to achieve NCEP R&D portfolio goals (e.g. the R&D component of the Sandy Supplemental and other targeted funds for weather and environmental forecasting). He or she should be a civil servant but might possibly be an IPA. The Chief Scientist
should lead the implementation of academic and governmental R&D partnerships (e.g., the new NCEP-NSF visiting scientist program). As an example, this could include a joint Weather-Climate research program in which universities can compete for funding to help NCEP achieve its long-term goals (e.g. unified modeling).

- The planned NWS HQ reorganization, initiated to increase NWS efficiency and clarity, may introduce more complexity (e.g., NCEP being funded under multiple budget categories). This issue also justifies the addition of a Deputy Director.
- The Deputy Director should be someone from within the NCEP organization, and would deal more with day-to-day operational issues. This approach has been implemented at the British Met Office and Environment Canada. This also could be an approach for career development and leadership succession at NCEP.

2.3 Findings and Recommendations – Report-out Discussion

At the end of the site visit, UCACN members met with NCEP Directors and other NWS and OAR leaders. There were five overall themes that UCACN thought were key to the ability for NCEP to make significant progress:

1. **Workforce management**: This includes more timely filling of vacancies, especially in leadership positions, creation of new positions, and hiring/retaining top young scientists.

2. **Science-based computer “trade-space” decision-making**: A process is needed to determine the relative use of computer resources for increased model resolution and ensemble size, more complex data assimilation, more sophisticated physics, new re-forecast strategy, etc. External partners (e.g., OAR, universities) will be needed to help do the necessary research for science-based decisions.

3. **Unified modeling framework**: This should be a long-term goal, and it is recognized that an interim goal should be the reduction of the number of modeling systems to only two, a GFS/CFS system and a very-high resolution convection-resolving system.

4. **“Second to None” charge**: NCEP should commit to the charge of the NRC report with this title to produce the world’s best numerical guidance.

5. **Interface with research community**: Partnerships are necessary since NCEP can’t do it all. NCEP needs internal infrastructure to serve visitors well, but needs resources to do this. For example, NCEP needs to set up a system such that outsiders, not just visitors, can use and test NCEP models. (This is already partially done at the DTC, but not for all NCEP models).

Additional comments and suggestions from the report-out discussion included:

- There is excitement about additional HPC resources coming from the Sandy Supplemental, but this comes with a concomitant need to make science-based decisions about how best to use them. (Note: this excitement has been tempered with the delay caused by the sale of IBM’s HPC business to Lenovo, a Chinese company - see the NCO report.)

- The NCEP strategic plan was last written in 2008 - thus it needs to be re-done. Preparation of a strategic plan should be largely completed before the next major review of NCEP.
Findings and Recommendations for NCEP that Need the Assistance of NWS and NOAA

A. Over-Arching Issues

- There is a need to study ways that numerical guidance could be made more useful, e.g., inclusion of uncertainty estimates, re-forecasts available for calibration, improvement of MOS, etc., For example, need to decide whether forecast ensemble members are more valuable than re-forecast ensemble members.
- It was suggested that UCACN should state priorities – since if NCEP is being asked to do more with less, what is absolutely imperative to do first? One response is that NCEP workforce issues should be addressed first, since so many staff and leadership positions are unfilled - plus the aforementioned need for a Chief Scientist and Deputy Director.
- NCEP can also do less with less by jettisoning low-priority products - but NCEP leadership needs to back up Center decisions on product termination.
- It is imperative that NCEP leadership focus strongly on the future - it needs a modeling strategy that is bold, aggressive, and realistic, all at the same time. [For example, NCEP should consider a “skunk works” model, in which 2-3 top people from NCEP, OAR, NCAR, and other institutions be relieved of current duties to come up with a plan for the next-generation, unified model.]
- NCEP shouldn't try to do it all but should foster relationships with other entities, agencies, etc. For example, SWPC relies on DOD, NASA and FAA to fulfill its mission on a daily basis.
- NCEP should consider using a portion of $14.8M funding increase for Research-to-Operations (R2O) to support the NCEP visiting scientist program and encourage other parts of NOAA to do the same.
- Most of milestones in the 2009 Review have been addressed, are obsolete, overtaken-by-events or not-resourced. UCACN can now concentrate more on assisting with strategic planning and conducting the 2015 review.

Findings and Recommendations for NCEP that Need the Assistance of NWS and NOAA

A. Over-Arching Issues

- Continue to ensure that NCEP has world-leading computational and IT resources (e.g., storage and bandwidth) for both operations and R&D. Special attention is needed in light of international developments in the HPC vendor community.
- Create an external grants program for weather and NWP in OAR (consistent with recent SAB report on NOAA R&D portfolio).
- Recognize that the increasing importance of ensembles and probabilistic forecasting requires that the NWS and NCEP have a world-class Statistical Forecasting Group. We recommend that the MOS part of MDL be relocated to NCEP, along with the addition of top statisticians. Among other benefits, this would greatly improve the effectiveness of the current “blender” project to improve statistical guidance.
- Solve the personnel office problems that make it difficult to fill vacancies, and cause leadership gaps; create a strategy to hire and retain best people.
- Develop a strategic plan for unified atmospheric, oceanic and coupled modeling system in concert with other parts of NOAA and the weather & climate enterprise (see skunk works suggestion above).
• Work with NOAA/NWS to reduce its reliance on extramural funding and avoid mission creep.
• Develop a strategic multi-agency plan for sustaining the North American Multi-Model Ensemble (NMME).
• Use the OFCM initiative to unify space weather capability across the space weather community as a guide to manage space weather issues among NWS, NESDIS, NASA and Air Force.

B. Important but More Specific Issues

• Strengthen partnerships to develop next data assimilation and ensemble systems, e.g., a hybrid EnKF-4DVar system
• Develop strategic plans (with partners) for (a) Global weather and climate model; (b) Regional and storm-scale modeling; (c) Ocean, coastal and storm-surge & inundation modeling; (d) Ecological forecasting capabilities
• Hire outstanding Directors of CPC, EMC, SWPC and WPC
• Hire a Deputy Director to oversee daily operations (position needs to be created)
• Strengthen test beds to accelerate R20 and O2R; create IT testbed in NCO
• Work to implement Impact-based Decision-support Services (IDSS)
• Stay involved with Open Environmental Information Services activities
• Support Visiting Scientist Programs with Universities and NOAA labs
• Think more globally about the role of NCEP (and NWS) w.r.t. the private sector development of regional and global modeling capabilities and collaboration with the private sector to improve, add value to, and deliver its products.
• Work with UCACN to form high-quality technical committees (linked to UCACN) to deal with specific modeling issues
3. Theme Discussion Summaries

3.1. Storm Surge and Inundation (SS&I)

3.1.1. Preface/Introduction

There were considerable discussions held among UCACN, NHC and OPC during the UCACN meeting of January 21-22, 2014 on the topic of storm surge and inundation (SS&I) forecasting. The goal was to learn and discuss the developments in the use of storm surge and inundation data and models so that we are better prepared for the next coastal storm. NHC took the lead in the discussions with OPC playing a supporting role.

Specifically the focus was to learn about plans for:

- Improving the design of storm surge research, surge monitoring networks, and coastal elevation mapping programs
- Sharing information on the state of knowledge on storm surge and wave modeling; topo/bathymetric elevation modeling; the collection of flood, tide, and storm surge monitoring data;

3.1.2. Overarching issues/recommendations

1. It is not clear who has made the road map for SS&I. The road map plans laid out by NHC/OPC are detailed but only to the extent of what they are going to do, not why they are doing them and certainly not the science bases for doing them.

2. Necessary ocean science leadership is missing within NCEP and NHC/OPC. A Science Operations Officer (SOO) on staff at OPC would greatly enhance progress on all levels. The SOO should be a scientist with skill sets with SS&I.

3. Oceanographic modeling at NCEP needs a home where adequate resources to support science and operations can be marshaled in support of NHC operations. Currently, NOAA/NCEP has operational oceanographic-related resources spread across too many groups and subgroups. Perhaps the surge modeling groups in MDL and NOS could be combined with NCEP’s Marine Modeling Branch.

4. The NHC is in critical need of access to additional IT support to facilitate the transfer of forecaster-generated in-house products to operations.

5. The role of SLOSH is clearly problematic. NHC/OPC views it as the primary forecast tool. Running thousands of cases to create an ensemble with a flawed model system doesn’t make for a viable product. Ways to verify the SLOSH modeling must be conducted and reported to the science community. Now upgrades are being put in place to SLOSH that have limited science behind them. The NOS is providing a gridded tide data for use with SLOSH. It would be important to understand how that tidal information was computed, the nature of the gridding and how that
information is used with SLOSH. Going away from parametric wind fields would be a big step forward too, but seems far off in the distance.

6. The approach to ensembles with SLOSH is simply to add all the ensemble members together and then divide by the number of members. Weighing the members by a metric having to do with likelihood or accuracy based on past experience could significantly strengthen their use.

7. The experimental inundation graphic is an excellent innovation. The exact use of this version questionable. The Tampa Bay example is quite coarse resolution. Flooding is a local to regional issue and making large scale FEMA type maps doesn’t help the public. The lower bound on the graphic's scale (0 to 3ft) is a big problem. Children and old people can drown in 3 ft of water, and labelling that as “Low Hazard” is wrong. The scale should be parsed into 0 to 1, then 2 to 3ft. That will alert the graphic’s user to know that some flooding will occur.

8. The role of the research community has not been a focus within NCI/OPC SS&I planning. That community is the best connector from national to local issues. They have also had considerable funding via Sandy appropriated funding and have considering moved the state of SS&I modeling forward. Expertise should be sought from external researchers and visiting scientists, and create a culture of collaboration. There are many scientific, technical, and resource trade-offs associated with SS&I work. One can imagine issues of model physics, spatial resolution, ensemble size, and even model diversity. NCEP cannot possibly do all that alone. They need to partner with the research community to fully explore solutions. Perhaps a committee of advisors could be formed.

9. It would be a great advantage if NCEP could make available to the public all the extreme wind event forecast track data. It would be important too to include forecasts from the European center too.

10. The Nearshore Wave Prediction System will be very useful if it matures in a science-based fashion. Rip current forecasts should be considered too.

3.1.3. Comments on recent progress with SS&I

The progress that has been achieved in the past year despite severe resource limitations, leadership changes and travel restrictions is encouraging. But in general I am struck by the poor use of “modern” storm surge models and ensemble techniques. Much of what I see going on was envisioned at least 5 years ago.

3.1.4. Comments on NCEP Production Suite

The point made several times was that sufficient computational resources did not exist at NCEP for running storm surge and inundation models. A scientifically weak plan was advanced as being the best that could be done with the resources available. Several research centers are running comprehensive storm surge forecast systems on $50K workstations. Clearly better computer resources could be found.
3.1.5. **Comments on Strategic Planning**

The plan for SS&I is not adequate to meet the needs of the coastal portion of the US. It is quite clear that the trajectory for progress for storm surge modeling at NCEP is on an upward path although not with a very large slope. The storm surge and inundation work has a good management team in place but they need science leadership and more computational resources.

The geographic focus of NHC/OPC’s storm surge and inundation work is not limited to any particular region. The Sandy Supplemental has provided a boost to NCEP’s SS&I technology. It is not clear though how much of the supplemental went to new SS&I work vs. getting old projects completed. Sandy affected regions should be a priority.

The use of SLOSH is not scientifically justified and NCEP and NWS leadership should insist upon a move to more physics-based modeling like ADCIRC. The SLOSH modeling team members are dedicated and energetic, however misguided.

Accurate storm surge modeling needs to be a priority within NWS and NCEP. The enterprise “Weather and Climate” should be changed to include storm surge and other water issues as “Weather, Climate and Water”.
3.2. Integrated Regional Modeling

3.2.1 Preface/Introduction

The second thematic discussion held at the Jan. 21-22 meeting was on Integrated Regional Modeling. Geoff DiMego, Branch Chief of the Mesoscale Modeling Branch in EMC, led the discussion. As has been mentioned, the discussions during the first day were over the phone, and the topic was revisited for a short time on the second day. Also, one of the UCACN Co-Chairs (FC) engaged NSSL and ESRL NOAA lab personnel on this issue subsequent to the UCACN meeting, and this summary is also informed by those discussions.

One of the major issues in regional modeling is how it should evolve given that the GFS resolution will soon become 13 km in Fall 2014. This is very close to the current 12-km NAM system, and, based on current verification scores (in which the 26-km GFS often verifies better than the NAM), the GFS should become superior to the NAM in most aspects. Given that there is still a need for an hourly updated analysis/forecast system, which the Rapid Refresh (RAP) provides, it would appear that RAP could satisfy very short-range forecast requirements and the GFS could satisfy current NAM requirements. If forecast timeliness is an issue, one could do a quick 84-hr run of the GFS at the 1-hr data-dump time of the NAM.

Many NCEP Centers (e.g., SPC, AWC, WPC, NHC) have expressed a need for forecasts from convection-resolving models. Thus it should be a goal of NCEP to have a very-high-resolution (3 km or less) forecast system in the near future, without stepping through, e.g., 10, 8, 5 km resolution progressions. If the area of the 3-km domain is large enough, NCEP could cease production of the many nested runs now made with the NAM.

Since it is doubtful that physics originally developed for models at 26, 40, 80 km or even coarser resolutions is still valid at 3 km, serious consideration should be given to revising (or obtaining new) physical process codes appropriate for these high-resolution models.

The short predictability period for convection requires an ensemble approach to enable probabilistic forecasts of high-impact weather. Thus an additional goal should be to move toward a high-resolution ensemble as soon as computational resources permit. There is a wealth of experience in this area resulting from the Spring Experiments at the Hazardous Weather Testbed (HWT) at NSSL/SPC/OU where 3- and 4-km ensemble systems have been run for the past 10 years. The current SREF system will no longer be needed once the new GEFS system comes on board in late 2014, since the GEFS should have superior skill.

Much of the above implies that “trade space” decisions on the new HPC system purchased with Sandy Supplemental funds will be crucial. A serious look should be taken at the current HPC usage diagram to see where resources could be obtained for the high-resolution deterministic and ensemble runs of the convection-permitting models. Removing the NAM and current high-resolution nests or windows will help, along with, e.g., moving climate runs to another system. Since trade-space decisions should be science-based, and that there are too many possibilities for NCEP alone to examine, community assistance, especially from OAR labs and the DTC, will be needed to explore the options.
3.2.2 Overarching issues/recommendations

The introduction above motivates the following recommendations:

- A major effort should be made to develop and implement a convection-resolving model (grid spacing ≤ 3 km) to provide high-impact weather guidance to the NCEP Centers and NWS Forecast Offices in support of NWS “Weather-Ready Nation” and “Warn on Forecast” goals.

- A similar effort should be made to create high-resolution regional ensemble guidance to enable reliable probabilistic forecasts. Multiple models could be considered for this ensemble but care should be taken that all model members can develop realistic convective structure and evolution. Other methods of creating ensemble members (e.g., stochastic physics) should be investigated.

- The 13-km GFS system (and corresponding GEFS) should make the NAM and current SREF systems no longer necessary. The GFS should be able to provide background fields for the regional systems.

- Consideration should also be given to the possibility that the aforementioned convection-resolving model could also be used for the hourly-updated RAP system. A reasonable goal is that if a truly unified modeling system at NCEP is at least a decade away, a strong effort should be made to reduce the number of systems to two, and make both of those systems very good.

- Community efforts should be engaged to assist NCEP in improving model physics appropriate for 1-3 km resolutions, assessing the value of improving vertical resolution, developing advanced data assimilation systems for convective weather, and examining “trade space” options that would permit more timely implementation of the high-resolution systems.

3.2.3 Comments on Strategic Planning

The UCACN received information on the OAR High Impact Weather Prediction Project (HIWPP) funded by the Sandy Supplemental. The goals of HIWPP are admirable, but it has the appearance of funding too many current efforts in OAR. It would be preferable if a strategic plan developed by OAR and NCEP together occurred ab initio, so that model and data assimilation development would be a truly collaborative effort. Instead, it still appears as if the two organizations are somewhat competitive, with, e.g., large NIM and FIM development efforts occurring without a clear pathway to operations.
In general, UCACN would like all modeling groups within OAR to convene with NCEP to create more effective and efficient partnerships for model and DA development, creating a vision, mission and set of goals that take into account external needs.
3.3. Weather – Climate Linkage

3.3.1 Preface/Introduction

The linkage between weather and climate was the third thematic discussions at the UCACN meeting on 21-22 January 2014. Although weather and climate modeling have common roots in the numerical solution of the governing geophysical fluid dynamics equations of the global atmospheric (initially) and (later) oceanic circulation, the numerical weather prediction (NWP) and climate simulation enterprises have become separate entities with different constituencies, distinct detailed technologies, and even different specific jargon. Nevertheless, the common origin of these two sub-disciplines has been recognized in recent years as fundamental to them both and efforts to bring them together to address the problem of prediction are now underway (Palmer et al. 2008; Hurrell et al. 2009; Shapiro et al. 2010; Shukla et al. 2010). The essence of this “seamless” approach to weather and climate prediction is that they both, regardless of time scale, share common processes and mechanisms and are designed to work across a broad range of time scales and spatial resolutions, from initialized predictions to long-term projections. Furthermore, interactions across time and space scales are fundamental to the climate system itself – there are no obvious “spectral gaps” in Nature that distinguish “weather processes” from “climate processes”.

There are several requirements that weather and climate prediction have in common:

• Data assimilation capability, to make best use of available observations to generate initial conditions, to facilitate analysis of model parameter sensitivity and uncertainty quantification, and to assess the incremental benefit of new observations.
• Unified physical parameterizations and numerical algorithms that can be applied across all scales at which they are needed.
• Simulation skill evaluated on both weather and climate timescales.
• Collaboration among experts in weather prediction, including mesoscale extratropical and tropical systems, and climate modeling, particularly the representation of interactions between the atmosphere and ocean and the atmosphere and land surface.
• Solving forward problems in numerical fluid dynamics, which requires substantial, dedicated supercomputing and data analysis and management infrastructure.

While it can be argued that some of the processes that are important on decadal and longer time scales are unimportant for weather prediction, and similarly argued that issues of importance for short-term weather prediction, such as tropical cyclone trajectories, have little bearing on climate prediction, there is a growing recognition that many of the processes included in weather and climate models are in truth relevant for both. To give a simple example, within the past decade, it has become common practice in NWP, especially for tropical cyclones, to employ a model that includes a representation of the upper ocean, either with a mixed-layer model or a dynamical ocean model. This tendency to view the weather and climate models as commonly formulated is even more apparent in the development of subgrid-scale parameterizations.

Verification and validation of weather and climate models is likewise becoming seamless. It is recognized that using climate models in a forecast mode with an initialized atmosphere and ocean state that are derived from an external source provides a rigorous check on the performance of climate models. Even simpler, NWP models can be tested and evaluated on climate time scales (up to a season) and climate models can be tested and
evaluated in NWP mode with short-range forecasts initialized from and verified against appropriate reanalyses. As described in Palmer et al. (2009), this allows fast model physics to be evaluated and tuned using forecasts rather than just climatology. This method has its limitations – it can be compromised by initialization transients and does not employ a sophisticated data assimilation capability – but it represents a relatively easy intermediate step toward full seamless weather and climate prediction.

From a more practical point of view, the generation of operational weather and climate forecasts is already viewed as a “seamless suite” of products by the U.S. National Weather Service. There is a continuum in time scale from the shortest lead-time at which warnings and alerts must be issued, to intermediate lead-times when watches and forecasts are issued. Beyond that, threat assessments, guidance and outlooks are typically generated at increasingly long lead-times. This continuum reflects both the nature of requirements for information about the future weather and climate as well as the increase of uncertainty associated with increasing lead-time. Nevertheless, in practice, NCEP and NWS view this continuum as divided into several discrete lead-time bins for which different models are used.

It is this question about whether the seamless nature of weather and climate and the NWS product suite should be reflected in the modeling strategy that was discussed at the weather-climate linkage session. Dave Novak, Mike Halpert and Arun Kumar participated with several members of UCACN in a lively conversation about the real-world requirements to generate week 2-4 forecast products, which are currently under-represented in the seamless suite of NCEP products. Several examples where weather and climate issues were recently in the news were described:

- When will the next “atmospheric river” event occur to relieve the California drought?
- Can we provide better anticipatory information about extreme events such as were associated with the “polar vortex” excursion in winter 2014?

In the discussions, it became clear that there are near-term issues (extending the official weather forecast to 10 days, week-2 forecast guidance etc.) that require attention, as well as longer-term issues associated with exploring the “trade-space” in computing resources that must be addressed more strategically.

### 3.3.2 Overarching issues/recommendations

The result of the discussion was primarily a better understanding of the nature of the weather-climate linkage, both in scientific terms and operational imperatives. A number of recommendations emerged from the discussion. NCEP should

- Determine how best to use NMME forecasts at shorter leads, e.g., for 1-10 days (enhanced ensemble) and 2-4 weeks (probabilistic) forecasts
- Evaluate methods of creating ensembles for long-lead weather and short-term climate prediction
- Consider reforecasts for validation and calibration of weather and climate forecast ensembles
- Evaluate, in collaboration with strategic partners, the role that NCEP should play in the Earth System Prediction Capability, being led by the U.S. Navy
- Investigate, in collaboration with strategic partners, high-performance the computing and data resources trade space for model spatial resolution, ensembles (size and method of generation), improving sub-grid scale physical parameterizations, data assimilation, reanalysis and reforecasts.
• Consider creating an Extreme Forecast Index, similar to that produced by ECMWF, among other weather-climate products.

3.3.3 Comments on Strategic Planning

The issues raised about the weather-climate linkage naturally led to discussion of more long-term strategic issues. As was recommended by UCACN in 2012 and as mentioned elsewhere in this report, NCEP should develop a strategic plan for a unified atmospheric, oceanic and coupled modeling system in concert with other parts of NOAA and the broader weather and climate enterprise, which can address some of these issues. A natural component of this strategic planning exercise is a rationalization of the process for developing the next generation Climate Forecast System, which now seems to be behind the original planned schedule for implementation in 2018.
4. Aviation Weather Center

4.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

4.2 Overarching issues/recommendations

The AWC management’s attitude and enthusiasm is on a truly positive trajectory in spite of past and some current challenges. They and their staff have made some great strides serving their many customers, and they have opportunities to re-shape the way that they do business that will strengthen their relationship with those customers.

- The National Aviation Meteorologist (NAM) program, begun in summer 2012, has been a resounding success.
  - The two National Aviation Meteorologists (NAMs), Michael Eckert and Brandon Smith, were recipients of the NOAA Administrator’s Award, which is NOAA’s premier award.
  - Two additional FTEs will be added to the staff in the near future, an MIC and a third NAM.
- The Aviation Weather Testbed (AWT) was successfully established in 2010 and has hosted forecasters and users for a number of experiments during its short life.
- Many milestones achieved by the AWC were on the list of Recommendations from the 2009 NCEP Review Team report and the 2011 UCACN report.
- The AWC will experience a huge loss in personnel due to retirement in the next several months.
- FAA/NTSB and other stakeholders are leveraging requirements which are outdated, time consuming, or getting out of control.
- Three new recommendations are made, two of which have to do with the establishment of points of contact for aviation weather requirements within 1) the FAA, and 2) the NWS, and the third having to do with the AWT.

4.3 Comments on Center's recent progress

The AWC completed all ten of their externally-tracked milestones for FY13, with many of them directly related to recommendations in previous NCEP Review and UCACN reports. Further, they are in line with the AWC’s strategic plan. Any outstanding issues have either been overcome by events or are described below.

Details

NAMs:
This service has equaled and possibly surpassed its goals, one of the reasons for the NOAA Administrator’s Award being given to the NAMs. Many positive comments have been made
by FAA customers about the service provided by the NWS. There have been some questions raised by some CWSU personnel about the role of the NAMs, and this is an area which should be addressed by NWS HQ and AWC management.

The NWS and FAA are in the process of adding an additional NAM and an MIC, making a total of four FTEs working at the ATCSCC. As was the case when hiring the first two NAMs, it is critical that the two people hired possess exceptional communication skills (e.g. be able to quickly learn Air Traffic Management-speak (ATM-speak)) and be knowledgeable in aviation meteorology. To maintain this positive momentum, it’s incumbent upon the management team of the AWC to have a regular dialog with the management team at the ATCSCC.

AWT:
Since the test bed isn’t funded, the work is largely out of hide, which has both an upside - they aren’t constrained by tasks assigned by the funding organization - and a downside - the experiments aren’t as robust as they could be without a funding stream. David Bright mentioned that he is thinking about establishing an executive oversight committee as an unbiased small group from the academic, public and private sectors.

Personnel:
By mid-2014, eight forecasters, including four lead forecasters, will have retired and the position announcements for the new hires will need to be adjusted because the roles/responsibilities are changing. The Collaborative Convective Forecast Product (CCFP) starts on March 1, and due to the decrease in number of personnel, management will have to cover many shifts.

The AWC has an opportunity with the upcoming turnover to adjust the culture of their organization and the way that they do business. Customer requirements that are sometimes at odds with each other (more below), product/service consistency and resource challenges will force the AWC to decide on new approaches to their work. The most obvious route is to maximize their use of automation in areas that don’t require the full involvement of the staff meteorologists. As an example, the AWC is considering dismantling the CCFP desk and automating it. The resources could be spent on developing/producing the Aviation Weather Statement (AWS), a product/service driven by the CDM. AWC management is working with the bargaining unit leadership to discuss mutually agreeable and optimum ways forward.

Customer requirements:
AWC is at a crossroads. The NTSB has just added GA weather hazards to the “most wanted list”. This means that it will need to identify and communicate hazardous weather to the GA community – yet another new requirement. It seems logical to drop some of the products and services provided by the AWC, for example text area forecasts. Of course, this needs to be done in concert with their customers. They plan to begin talks with AOPA, FAA and others. This can be challenging because 1) different customers have different product/service priorities, and 2) it has been difficult to get a single voice of the customer at the FAA.

One of the continuing challenges that the AWC and the NAMs face is ensuring the consistency of their aviation weather products. There are four different groups of NWS forecasters (WFO, CWSU, AWC, NAM) who produce various aviation products (e.g. Terminal
Aerodrome Forecasts (TAFs), Center Weather Advisories (CWAs), AIRMETs and SIGMETs, Aviation Weather Statements (AWSs)); when one of them is issued or changed, the others need to be amended as appropriate. But there's no solid mechanism to do that at this point. Yet, to the user the inconsistencies can be quite noticeable.

**Recommendation:** Secure agreement with the FAA about who/which group will be their point of contact regarding requirements for NWS aviation weather products and services.

**Recommendation:** Secure agreement within the NWS about which office is the point of contact for the FAA, AOPA, and other aviation weather customers.

### 4.4 Comments on NCEP Production Suite

The AWC continues to pursue clouds, ceilings and visibility as a high priority and in the process has increased collaborations with EMC and the AAWU. EMC has been very cooperative in investigating improvements to C&V post-processing algorithms and has collaborated closely with AWC. EMC produced two substantial improvements to their ceiling and visibility calculations in the SREF (the second is ongoing and currently in the parallel SREF evaluation before transitioning to operations). David Bright and two members of the AWC’s Support Branch plan to visit the AAWU early this spring as part of this modeling ceiling and visibility improvement effort. The operational transition of the HRRR is appropriate and timely, and AWC fully supports the transition plans presented in Geoff DiMego’s presentation. EMC and AWC have both increased NWS/ensemble prediction emphasis on aviation variables and emphasis seems appropriate.

**Recommendation:** With significantly improved NWS modeling guidance (due to SANDY supplemental) leading to enhanced anticipated Meteorologist-Over-The-Loop (MOTL) aviation weather predictive capabilities, the Aviation Weather Testbed should assume a significant leadership role in the creation, design, and operational implementation of shorter-term NextGen decision support service (DSS) improvements positively affecting the NAS. These model upgrades and resulting DSS are fully complementary to the expanding NWS presence in the FAA National Command Center. Moreover, the AWT is already hosting GOES-R pseudo-data testing which has already achieved very positive operational attention at the ATCSCC.

### 4.5 Comments on Strategic Planning

**Regional Modeling Suite:**
The AWC fully supports the ensemble framework proposed by EMC, i.e. every deterministic model has an accompanying ensemble system for confidence, probabilistic forecasting, and decision support. The possible addition of every ensemble also including a reforecast, if resources permit, is also endorsed. Additional research is required to address the “trade space” of the ensemble system, that is optimal configuration of membership size, horizontal and vertical resolution, physics, etc. Vertical resolution may be particularly important for improved cloud, ceiling, and visibility prediction which appears to be an emerging concern of the NTSB. A recent topic brought to the attention of the AWC from the ATCSCC is upper tropospheric ozone, which is predicted by the GFS/GEFS; although the AWC has not yet made use of these forecasts, they may be of growing importance particularly for polar routes. The AWC is pleased with the support provided by EMC to accomplish the AWC
mission, and will defer the discussion concerning a unified modeling system to the experts in modeling and those responsible for producing the NWP guidance for the broad NWS mission.

Weather-Climate Linkage:
There is limited direct impact to the AWC. Projects like the NWS “Blender Project” designed to produce a consistent and scientifically based model consensus in days 3 to 10 would affect strategic planning guidance provide by the AWC, particularly during peak flying periods such as holidays and national events.

Storm Surge and Inundation
This really isn’t applicable to the AWC, except possibly that they might provide decision support for airport planning in coastal areas.

The AWC’s FY14 milestones are reasonable, achievable and logical. They are as follow:

- Operational implementation of a real-time production dashboard for situational awareness ensuring timely delivery of products (ongoing goal, see next milestone);
- Operational implementation of the Aviation Winter Weather Dashboard (generated by the CDM Weather Evaluation Team) (completed);
- Implementation of a modernized www.AviationWeather.gov utilizing an Open Geospatial Consortium (OGC) Web Mapping Service (WMS) (completed, new web page to be rolled out by Q3);
- Ensemble Processor availability within the AWT for real-time diagnostics and the research of ensembles for advanced probabilistic forecasting (to be completed by Q4);
- AWC Low-level Significant Weather Chart availability through Common Support Services- Weather (CSS-Wx, a NextGen initiative) (to be completed by Q4);
- Completion of one interactive experiment in the AWT (scheduled for Aug 11, 2014 - to be completed in Q4);
- Increased services in the NAM program (ongoing, to be completed by Q3 with new hires);
- Establishment of an agreement with DHS Customs and Border Patrol to provide impact decision support services for the Tethered Aerostat Radar System program (cancelled due to costs to DHS);
- Acquisition and replacement of AWC’s end-of-life Wide Area Network (WAN) router, Local Area Network (LAN) switches and firewalls (ongoing: facility recabled, new switches on order, firewalls being replaced, to be completed by Q4).
5. Climate Prediction Center (CPC)

5.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP). NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Climate Prediction Center. A summary of the discussion, findings and recommendations from that session is given below.

5.2 Summary

CPC developed a new strategic plan and then lost its leader to a promotion. It is stalled to a considerable extent by vacancies in key positions, including a permanent director, by the apparent lack of a collaborative NCEP modeling strategy, and by the de facto delay of the development of a next-generation Climate Forecast System (CFS). NOAA and NCEP should commit to development of a new climate prediction model with a bold and aggressive plan, perhaps using the skunk works concept of an empowered, effective, and administratively isolated group highly focused on a significant and critical objective with the capability to entrain external expertise.

5.3 Recent Accomplishments

CPC reports a number of recent accomplishments, including

- A new strategic plan was developed with a formal process that involved separate all-day meetings of employees and stakeholders followed by a two-day decision and writing session. The UCACN members assigned to CPC participated in these meetings and applaud the new CPC strategic plan. Unfortunately, approval for the plan at NWS headquarters has stalled after the first set of recommended revisions was completed and the plan resubmitted during September, 2013.

- The external contract for the 30 contractor employees at CPC was successfully transferred to a new firm, Innovim. All contract employees, including the on-site supervisor, are now associated with Innovim.

- The CPC website was redesigned and implemented to make the main products more available, take advantage of GIS data bases, and provide more educational materials including video segments. UCACN regrets that it did not hear more about this redesign and wonders whether CPC will attempt to measure the efficacy of the new format, perhaps by contacting users.

- Funding was secured from the Climate Program Office Modeling, Analysis, Predictions and Projections (CPO MAPP) program to support the first steps toward a comprehensive 70-year re-analysis starting in approximately 1948 and extending to the present. UCACN hopes that community input will be sought to ensure that this
reanalysis meets wide objectives and that metrics with which to judge success are established in advance and can illuminate the planning and computational strategy.

- The CPC branch names were modified to better represent responsibilities, but these new names do not seem to be reflected on the website page describing branch functions because it was last updated in 2004.

### 5.4 Challenges and Opportunities

The enthusiasm in CPC generated by the strategic planning process seems to have been dissipated by an evident lack of NCEP focus and commitment to improvement of the climate prediction computer models and by uncertainty and stress generated by the apparent NOAA inability to respond to serious personnel challenges.

**Numerical Climate Prediction Models**

The NOAA and NCEP excitement about the new capabilities being created by the Sandy supplemental appropriation and additions to the NCEP base funding do not seem to be reflected yet in tangible plans for major improvements in the numerical climate models on which CPC and a wide range of users and providers depend. The responsibility for the development, implementation and maintenance of the present Climate Forecast System Version 2 (CFSv2) resides in the Environmental Modeling Center (EMC). Despite some flaws in the accompanying reanalysis, the CFSv2 was deployed successfully and has been operational since 2011. CPC led an effort to create a vision for development of CFSv3 with community involvement, but all work on that project seems to have stopped and the internal NCEP team disbanded. No formal explanation for abandoning the effort has been given to UCACN.

CPC, EMC, and CPO all have interests and responsibilities relative to the numerical climate prediction models and all three should be committed to cooperating to create the best possible model. Both CPC and CPO have stated intents to lead such an effort. The CFS or its successor represents a significant national commitment and capability and should be promoted more aggressively and managed more effectively by NCEP and NOAA than it is now.

Development of a new CFS will face the model specification trade-space challenge now evident in many NCEP modeling activities: **Determine the optimum combination of model 3D spatial and temporal resolution, number of ensemble members, frequency and length of model runs, and reforecast strategy (including integration with reanalysis) and implementation.** Comprehensive climate system re-analysis may also be a part of this trade space. To UCACN’s knowledge, there has been no formal effort to explore the trade space in search of choices that will provide optimum climate forecast performance. The problem is perhaps more complicated now than previously because of the recognition that static forecast histories may no longer be adequate for the model calibration process that is essential for subseasonal and seasonal numerical forecasts. Moreover, computing the forecast history along with the operational forecasts permits the models to be improved and modified as they are used rather than being held frozen throughout their period of active use. The trade space exploration could require considerably more computer capability than possessed by NOAA and the possibilities of using computers of agencies such as DOE, NASA, and NSF should be considered.
An NCEP commitment to a unified modeling effort might be advantageous to the climate prediction models. Present evidence cited by CPC is that the Global Forecast System (GFS) used for the daily forecasts is superior to the CFS in week two, presumably owing to its higher resolution and more recent vintage of the physical parameterizations.

A number of alternatives should be thoroughly explored in the search for a foundation and framework for a new NCEP model and a new climate model. The new Model for Prediction Across Scales (MPAS) being developed by the National Center for Atmospheric Research (NCAR) and the Los Alamos National Laboratory (LANL) features some new approaches to spatial grids and internal nesting. The models being developed by the NOAA Earth System Laboratory (FIM and NIM) have attractive features, including the possibility of using isentropic vertical coordinates that provide a more realistic portrayal of thermodynamic structure than do quasi-horizontal coordinates. There also are a number of other promising developments in the academic community.

The most rapid progress might be made by creating a model development team composed of a limited number of both NOAA and community scientists, giving it an empowering charter and plentiful human and computer resources to explore, innovate, and experiment. Such a team should be shielded from other responsibilities and should operate with some degree of isolation. The Lockheed Skunk Works that flourished during and since World War II might provide a model.\(^1\) If designed carefully, given an imaginative charter and an effective leader, and managed skillfully (from afar), then such a skunk works modeling project could be a major success and a triumph for CPC, EMC, CPO, and indeed, NOAA itself.

The main lessons that might be inferred from successful skunk-work efforts are that the team must be highly focused, be given adequate resources, be governed by dictates or MOUs that ensure independence, and be assured that a route to operations for its products will established at the time the work begins.

Accelerating and advancing the national numerical climate prediction capability could be a significant collaborative initiative for the new directors of the National Weather Service, NCEP, the CPO, and eventually, a new director of CPC. It is time to create a bold, innovative, and aggressive plan for a new Climate Forecast System, to engage the community to contribute to its development and success, and thereby provide Americans affected by climate variability with the best climate forecasts in the world.

**Demands from Afar**
The NWS and NCEP (including EMC, CPC, and NCO) have a direct and heavy responsibility for providing computer-based weather and climate prediction for all American civilian activities. In recent years there have been initiatives to merge some of those NWS activities with numerical forecast or research efforts of other civilian and military agencies. While

\(^1\) A skunk works can be described as "... an especially enriched environment that is intended to help a small group of individuals design a new idea by escaping routine organizational procedures. The research and development ... workers in a skunkworks are usually specially selected, given special resources, and work on a crash basis to create an innovation.", according to Everett Rogers, *Diffusion of Innovation*, Free Press, 5\(^{th}\) edition, 2003, cited on the Wikipedia page for skunkworks. A detailed history of the Lockheed skunk works and its remarkable accomplishments including the recent Stealth fighter airplane can be found in Ben Rich and Leo Janos, *Skunk Works*, Little Brown and Company, 1994.
such a concept might sound advantageous in the abstract, it might also impose unfunded and onerous burdens on NCEP that would degrade rather than improve its products. Thus UCACN, accepting some responsibility (however minor) for guarding the scientific and financial integrity of the civilian forecast system, must examine these ideas carefully and explore their implications with NWS and NCEP executives. The topic should be high on both the UCACN and NCEP agenda for future work. Demands from afar could be most unfortunate and costly.

**Work Force Issues**

CPC shares the frustration of NCEP and the NWS with NOAA personnel policies and work force management that seem incapable of filling critical vacancies in a timely manner. CPC has some six unfilled vacancies out of 49 staff members (greater than 12 per cent!) and has a vacant branch chief position that is being rotated among staff members, each of whom can only serve for a limited period according to NOAA policy. Currently, there is no eligible candidate.

But most significantly, the position of permanent CPC director has been effectively vacant for a year now and apparently there has been no approval for starting a search. Although the acting director is performing competently, the CPC needs a permanent director to set priorities, envision new and exciting directions, and represent CPC to NCEP, NWS, NOAA, and the community of users and interested climate scientists and modelers.

**Climate Test Bed**

The mission of the Climate Test Bed (CTB) is “to accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services”.

The CTB is managed in CPC, but the resources are provided by CPO, essentially by funding proposals made to it for studies to be performed in the CTB. Thus CPC has little control over the direction or foci of the CTB efforts, a situation that has been noted by the CTB Scientific Advisory Board. The challenging project to find the optimum point or region in the model trade space could be a joint CPC-community effort that would be ideal for a CTB, but would require substantial funding and perhaps daunting computer resources. But unless the optimum combination is found, the operational models will likely be less than optimum and perhaps thus consume unnecessary resources throughout their operational history.

**NMME**

The National Multi-Model Ensemble (NMME)\(^2\) is an ambitious and laudable attempt by NOAA and a number of other agencies to bring the results from a variety of climate prediction models together to form a multi-model ensemble that will presumably be more skillful than the individual models’ forecasts. The NMME website asserts that the project “is currently delivering real-time seasonal-to-interannual predictions”.

However, there is some confusion about whether NMME is in a research or quasi-operational mode. A CPC scientist reported that the model data and reforecasts are readily and regularly used in the preparation of forecasts; indeed, such forecasts are available in

\(^2\)Increasingly known as the North American Multi-Model Ensemble because of the contribution of Canadian compute climate forecasts, even though the acronym will remain NMME.
graphical form on the NMME website but with very little explanation \(^3\). In contrast, a UCACN member reports that his company has not been able to access the digital version of forecasts on an operationally useful schedule. The model information at the International Research Institute for Climate and Society (IRI) updates only quarterly and not all models have history data; the CPC site (ftp://ftp.cpc.ncep.noaa.gov/NMME/realtime/) recommended to the company by CPC as a site for the digital data has not been updated since July, 2013.

CPC reported during the review that the model data and the retrospective forecasts needed for calibration would soon be hosted by NCAR, as part of the more generously funded Phase II that will enjoy stronger commitments from the participating organizations.

To date, then, the NMME project has demonstrated considerable progress. But while the NMME is a powerful idea, it is not yet an idea whose potential has been realized.

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\(^3\) Have they been calibrated to remove bias and adjust the variance? If so, how? Are all models given equal weight or are the more skillful models given greater emphasis? A set of forecasts is presented with a "skill mask" that is not defined but that turns a very large fraction of the globe grey with no forecast.
6. Environmental Modeling Center

6.1 Preface/Introduction

The UCACN held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP). The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Environmental Modeling Center. In addition, Gilbert Brunet visited EMC on 23 January, and had discussions with Derber and Kleist (Global forecast system and DA); Zhu (GEFS and NAEFS); Saha, Ek, Moorthi, Behringer, Huang and Kumar (CFS, NMME and NOAA reanalysis); Ek (Land Surface Systems); and Tolman and Chawla (Ocean and Wave Modeling). A summary of the discussion, findings and recommendations from that session is given below.

6.2 Overarching issues/recommendations

6.2.1 Unified modeling framework

The name of the game for a given computer capability and capacity is to strike a fine balance between different approximations in numerical algorithms, advanced physics, 4D data assimilation techniques, and utilization of new observational systems. This is a tremendous challenge that requires a tightly coordinated critical mass of scientific and technical personnel. This challenge is getting more and more difficult because of the increasing complexity, space-time resolution, quality, and accuracy requirements of these Numerical Environmental and Weather Prediction (NEWP) systems. This increasingly jeopardizes the efficiency of carrying out technological transfer activities in a timely manner and affordably in a multi-model and multi-disciplinary environment. Hence more and more it is recognized worldwide (e.g. United Kingdom Met Office, Chinese Meteorological Agency, Environment Canada, Australian Bureau of Meteorology, Meteo-France) that this scientific and technical bottleneck can be surmounted resourcefully by a teamwork approach based on a unified modeling (UM) system. UM systems are also considered by many NWP centers as the low-cost and shortest pathway to develop seamless numerical weather, climate and environmental prediction systems at all space and time scales.

The UM discussion needs to be increasingly nurtured inside NCEP. In general EMC staff doesn’t seem to be against the UM approach and agree there are benefits to such approach. As an example there have been discussions of the success of the Hurricane-WRF (HWRF): there would have been a better return on investment for other forecast applications had this been done inside a UM framework. EMC is understaffed and mostly constrained by day-to-day obligations (e.g. Sandy Supplemental deliverables), so they have no time for long-term strategic investments like a UM framework. Hence the UM needs to be supported in a non-disruptive manner as: a collective and long term NOAA (and partners) strategic R&D project in close collaboration with EMC. It was noted also that a UM is not synonymous with a community model. A UM needs to be flexible enough to facilitate collaboration with expert communities and the main NCEP collaborators (e.g. modular code, documentation and user friendly coupling tools), but at the same time it must have state-of-the-art operational performance (e.g. highly scalable on HPC).
Along these lines two important new elements seem to be relevant:

1) NCEP should have a designated Chief Scientist in control of all the resources for Earth System Prediction R&D. This seems the only way to bring unity and a common scientific vision within NCEP for Earth System Prediction at all space and time scales.

2) MOA ESPC Charter: This is a great opportunity for the U.S. government. This top-down approach combined with an effort to develop Earth System Prediction tools (e.g. ESMF) could be what is missing to promote at least in one of the partner agencies the establishment of a UM framework.

**Recommendation:** A unified modeling framework is an important long-term goal for NCEP. An interim goal should be the reduction of the number of modeling systems to only two, a global weather and climate system (GFS/CFS) and a very-high resolution convection-resolving system. Given the fact that EMC staff is constrained by day-by-day obligations, NCEP should consider a ‘skunk works’ approach, in which 2-3 top people from NCEP, OAR, NCAR, and other institutions be relieved of current duties to develop a plan for the next-generation, unified model. It would be appropriate for the NCEP Chief Scientist to lead this ‘skunk works’ team.

### 6.2.2. Aligning budget to function and linking to performance

More independent model verification activities are needed. A modern NEWP system needs to attain a certain level of quality and accuracy for a multitude of geophysical variables and products: this can only be achieved with the help of numerous and complex R&D numerical experiments. We recommend that NCEP should have business performance measures that are linked to global and regional NEWP systems that are shared and monitored by OAR and NCEP. As an example OAR needs to set realistic expectations and understand the operational constraints of an operational NEWP system, including computer efficiency of models, hence the importance to have shared metrics between NCEP and OAR. This is a good way to bring corporate focus on common goals and to help management in their decision-making.

A proper verification framework can help to establish decision-making tools to guide future R&D investments (e.g. global vs. regional). As an example: The Met Office UKV regional deterministic Numerical Weather Prediction (NWP) system outperforms significantly over the UK territory the global NWP system that provides its boundary conditions. The added value of UK NWP relative to the global NWP system in the last five years is shown in Fig. 1. The comparison is based on the Met Office UK Index that focuses on the predictive skill for surface weather (temperature, wind, visibility, total cloud, cloud base height and precipitation).

The UKV has been more skillful than the Global deterministic system by at least 8% in the last year. The Global NWP system improvements included in the baseline above is approximately 1-2% each year. An added value of 8% for UKV represents 4-8 yrs lead over the global NWP system, hence justifying greatly the continued Met Office investment in convective scale NWP, or even accelerating it. This unprecedented added value in predictive
skill is believed to be due in great part to UKV significant higher space-time resolution, improved physics and data assimilation advances.

![Relative Index](image)

Figure 1: Relative benefit (%) of UK NWP compared with the Global NWP system at the Met Office.

**Recommendation:** NCEP should establish business performance measures that are linked to global and regional NWP systems, as well as a verification framework that can be used as decision-making tools to guide future R&D investments (e.g. global vs. regional). For example, one can ask what is the value added by HWRF over GFS in terms of hurricane track and intensity forecast? What is the value added by NAM over GFS (particularly, the 13-km GFS) in terms of precipitation forecast? Such decision-making support tools would help guide the foci of different regional systems and assist in decision-making concerning the allocation of human and computing resources.

### 6.2.3. Convection resolving ensemble forecast system

As discussed in section 3.2 Integrated Regional Model, many NCEP Centers (e.g., SPC, AWC, WPC, and NHC) have expressed a need for forecasts from convection-resolving models. Moreover, the need to provide probabilistic forecasts of high-impact weather requires an ensemble approach. NCEP should establish a goal to operate a nationwide very-high resolution (3-km or less) ensemble forecast system in support of NCEP forecast centers within five years. Such a goal is very ambitious and extremely challenging. In addition to the demand of huge computing resources, there are many scientific and technical challenges facing the development of various aspects of a convection-resolving ensemble forecast system, including (i) initial condition perturbation, (ii) model perturbation, (iii) post-
processing, (iv) ensemble calibration, and (v) ensemble verification. Development of advanced data assimilation systems and robust approaches to handle model physics uncertainties (stochastic physics) suitable for a convection-resolving model are also required. NCEP should solicit the participation of and contributions from the broad research community on these development efforts, as well as examining the ‘trade space’ options that would permit a timely implementation of the high-resolution ensemble forecast system. The High-Resolution Rapid Refresh Ensemble (HRRRE) that is already in planning will be a good starting point for such a system.

**Recommendation:** NCEP should set a goal to operate a convection-resolving ensemble forecast system within five years. NCEP should seek the participation and contributions from the broad scientific community to develop such a system. Collaboration with ESRL and DTC on this effort should be seriously considered.

### 6.2.4. Next-Generation Global Prediction System

Subsequent to the UCACN meeting in January, UCACN learned about the NWS Research to Operations (R2O) Initiative, which is a NOAA program to expand and accelerate critical weather forecasting research to operations to address growing service demands and increase the accuracy of weather forecasts. An important project supported by the NWS R2O initiative is the development of a Next-Generation Global Prediction System (NGGPS). It is anticipated that the NGGPS will be a non-hydrostatic, very-high resolution (capable of resolving convection) global model, equipped with advanced data assimilation system and advanced physical parameterization, that is capable of providing effective forecasts of hurricane and other high-impact weather systems. The NGGPS project is on a fast track. NWS hopes to select a dynamic core for the model within two years, and have a full model developed in five years. This is a very exciting new development. The decision on NGGPS is very critical, as it will have far reaching impact on the entire U.S. meteorological community for many years to come, for the following reasons: (i) it is an opportunity to make a NCEP operational global model truly a US ‘national’ model, which is jointly developed and supported by the US research and operational communities; (ii) the NGGPS will serve as a solid foundation for the ‘unified modeling’ framework for NCEP operation; and (iii) the NGGPS offers an opportunity for the US to regain its leadership in operational global NWP. One of the goals of HIWPP (High-Impact Weather Prediction Project), a Sandy Supplemental project residing at OAR, is to test next-generation weather prediction models in real-time running mode. The HIWPP and NGGPS are obviously related and could complement each other. Close coordination between NGGPS and HIWPP is needed.

**Recommendation:** We recommend establishing a UCACN sub-committee to provide scientific and technical advices to support the development and execution of the NGGPS project.

### 6.2.5 Community interaction

**(1) Increased interaction with international community**

We have seen good progress (e.g. engagement in the Working Group on Numerical Experimentation, or WGNE, and international meetings organized at NCEP), but EMC needs to continue sustaining this effort:
- Support and participate in the WWRP HIWeather, Polar Prediction Project (PPP), and Subseasonal to Seasonal (S2S) projects, which are the new “THORPEX legacy projects” that will be the focus of WWRP over the next decade or so;
- Participation in international conferences aligned with NCEP goals (e.g. World Weather Open Science Conference, Montreal, 2014)

The new NCEP building (NCWCP) has state-of-the-art meeting and conference rooms. This building could become a world focal point for workshops on weather and climate prediction issues. This would permit NCEP (like ECMWF has been doing for decades) to tap world expertise to help advance its own goals. This should leverage the NCEP Visiting Scientist Program.

(2) **Develop IT infrastructure to support collaboration with research community**

To encourage the transition from research to operations (R2O) in numerical weather prediction, it is important to make NCEP modeling systems and data sets easily accessible to the research community. EMC should develop an IT infrastructure that can support a research modeler (or a visiting scientist) to conduct model experiments, with alternative physics or modeling components, using the operational systems. Such an NWP IT environment would foster close collaboration between research modelers and EMC staff, leading to accelerated model improvement.

(3) **Engage research community in performing tests/studies of modeling trade space.**

EMC emphasized that they need help with the ‘trade space” in testing different modeling systems. To make this a reality, funds need to be made available to support the engagement of the research community. One possible avenue is funding from a revamped (but relabeled) USWRP. Another possibility is to get NSF interested in supporting modeling research, as a partnership with NOAA. NCEP should actively pursue these (and other) possible funding mechanisms to engage the research community.

### 6.3 Comments on Strategic Planning

The EMC staff is understaffed and mostly constrained by day-to-day obligations, and have little time to invest in strategic planning. The limited strategic planning is mostly focused on the immediate next operational implementation, within a one-year time frame. While we have seen roadmaps from various modeling teams based on the production suite review, we have not seen a coordinated and comprehensive strategic plan for the entire EMC modeling suite. Also, these roadmaps appear to be developed independently by different modeling teams, with little coordination or communications among the teams. For example, we would expect significant sharing of modeling resources and expertise between mesoscale modeling and hurricane modeling, and therefore, the strategic plans from both teams should be coordinated to ensure optimal use of resources. Also, as pointed out in section 3.2 of the report, the operation of a 13-km GFS forecast system and the corresponding GEFS should make the NAM and SREF systems no longer necessary. The 13-km GFS is expected to provide improved background and lateral boundary conditions for all regional systems, including the HWRF. This will require careful examination of the purposes of these regional
systems. For example, if the hurricane track and intensity forecast are well taken care of by the 13-km GFS, track and intensity forecast should not be the main purpose of HWRF. Rather, HWRF should be directed to provide high-resolution guidance on precipitation, winds, and inundation forecasts, within two days. It is anticipate that an operational 3-km global forecast system will be developed in 5-10 years, as the outcome of the Next-Generation Global Prediction System (NGGSP). A convection-resolving global forecast would require review and modification of the entire NCEP operational modeling suite. Developing a well-coordinated strategic plan for the entire EMC modeling suite is extremely important to guide the overall modeling system development.
7. National Hurricane Center

7.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP's headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the National Hurricane Center. A summary of the discussion, findings and recommendations from that session is given below.

7.2. Overarching issues/recommendations

1) NOAA/NHC is to be commended for developing an innovative new and effective SS&I visualization product that should be an effective warning tool for serving the information needs of those people at risk during SS&I events. However, UCACN is concerned that the numerical driver for the SS&I visualization product is obsolete. It is absolutely critical that NOAA/NCEP devote sufficient resources to the development of state-of-the-art oceanographic models that can be used operationally in support of SS&I events. Oceanographic modeling at NCEP needs a home where adequate resources to support science and operations can be marshaled in support of NHC operations. Currently, NOAA/NCEP has operational oceanographic-related resources spread across too many groups and subgroups.

2) The operational applicability of the well-known SLOSH model can be questioned in today's world. The SLOSH model has the great advantage that thousands of cases can be run cheaply and quickly to produce a statistically robust ensemble solution. At issue from a science perspective is the operational value and utility of the SLOSH ensemble, given that the underlying barotropic SLOSH model system is flawed. Also at issue is whether the SLOSH ensemble model system can be updated sufficiently to be state-of-the-art scientifically or whether it would be better to invest the necessary time, effort and treasure in generating a new oceanographic model. At the very least, research should be directed at ways to “handicap” the SLOSH ensemble members by a metric that represents the likelihood of individual member verification and accuracy.

3) The issue of oceanographic model improvement needs to be thoroughly discussed in the larger science and operational communities. Also, NHC and OPC should work together to ensure that the necessary ocean science leadership is in place to facilitate progress in producing a new oceanographic model. Adding a SOO position
to the OPC who can work with the NHC would be a productive step, especially if the SOO would have a good science background in physical oceanography in general and SS&I in particular. The Nearshore Wave Prediction System will be very useful if it matures in a science-based fashion. The larger scientific community needs to be involved in decision-making for new state-of-the-art oceanographic prediction systems.

4) The NHC is in critical need of access to additional IT support to facilitate the transfer of forecaster-generated in-house products to operations. This is a general problem across NCEP but is especially important at NHC, given the need to generate the next-generation oceanographic model to drive the SS&I operational products.

5) UCACN applauds the continuing improvements in hurricane track forecasting and the very recent improvements in hurricane intensity forecasting. These improvements are a tribute to the collaborative efforts of the scientific and operational communities despite the large budgetary constraints on computational and staff resources.

7.3 Comments on recent progress with SS&I

The NHC is to be commended for making progress in SS&I modeling over the last year despite severe resource constraints, leadership changes, the sequestration, and travel restrictions. That said, progress relative to the increasing scientific state-of-the-art has been more limited. It is critical that the scientific basis for operational SS&I models and the construction of ensemble forecasts from these models be upgraded.

7.4 Comments on the NCEP Production Suite

The point was made numerous times in committee discussions and in discussions with members of the scientific community that sufficient resources do not exist at NCEP for running state-of-the-art SS&I models.

7.5 Comments on strategic planning

A more focused and visionary science plan is needed to secure improvements to SS&I models. Although progress is being made in this area at NCEP, greater and more rapid progress would be likely with additional scientific leadership and more computational resources. Moving beyond the SLOSH SS&I model should be a scientific priority within NCEP and the NWS.
8. NCEP Central Operations

8.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including NCEP Central Operations (NCO). Unfortunately, the meeting on January 21, 2014 was canceled due to the Federal Government close down during a snowstorm. The entire meeting was shortened and NCO was not on the agenda. A summary of the discussion, findings and recommendations associated with NCO from the overall meeting is given below.

8.2. Overarching issues/recommendations

Although NCO was not called out for special attention on the UCACN meeting agenda, a couple of challenges and overarching issues surfaced during the meeting. Overall, NCO continues to make excellent progress working with EMC and continues to streamline the integration and testing of NCEP model production suites. This has resulted in a shortened transition from research codes to operation. NCO also has been involved significantly in the Sandy relief bill and was able to secure additional funding to enhance the research and operational high-performance computing (HPC) at NCEP. The upgrade is projected to be near 2 Pflops.

The HPC acquisition follows the existing strategy, endorsed by the UCACN, to acquire an x86 commodity processor-based computer from IBM. However, this strategy has become a major risk, which is discussed below. An additional issue surfaced when the new NCEP Director William Lapenta raised concerns about a proposal to incorporate an NWS Telecommunications Operations Center networking group of roughly 100 people into NCO.

There are three key themes on which NCO should focus as an organization over the next 12 months.

(1) Finding: NCEP has the budget, through the Sandy Supplemental, for a major upgrade to its HPC systems. Although moving to the IBM iDataPlex based supercomputer represented a good strategy a year ago, with the result that all major weather research HPC centers are using the same system architecture, it has become a major risk this year due to the announced selling of the IBM X-system business unit in January 2014 to Lenovo, a Chinese company. The Commerce, Justice, and Science Appropriations Bills in 2013 and 2014 have specifically prohibited federal agencies from buying Chinese-made information technology products without the FBI's approval. This has a major impact on the proposed acquisition schedule of the new supercomputer.
Because of the above reasons, the NOAA HPC program has restarted the HPC procurement in August 2014. This restarted procurement might take another year and is thus significantly behind the original planned schedule.

The UCACN members do not anticipate new market disruptions experienced this year will reoccur any time soon. However, in a highly volatile period of time in HPC, we have the following recommendation:

**Recommendation:** NCO should continue to reach out to and collaborate with other weather research organizations such as NCAR, NASA Goddard and universities to mitigate the risk in computing. Many other organizations have quasi-operational weather and climate prediction activities, and, because of the research nature of the activities, there is a less stringent operational computing requirement and thus the facilities can be more adaptive to the rapidly changing computing environment. For example, in addition to the IBM cluster, NASA Goddard is running weather research codes on clusters made by Dell and SGI that have a similar architecture to the IBM cluster. The NASA-NOAA-DOD Joint Center for Satellite Data Assimilation maintains two similar Linux-based clusters at the University of Wisconsin. By keeping the NWS code current on other organizations’ clusters. NCEP not only will reduce the risk in changing computing platform but also can enhance the collaboration between NCO and other research organizations and create a pipeline of knowledge transfer.

Some of the research organizations are joining forces to explore future computing architectures such as NVIDIA GPUs and Intel Phi. For example, NASA Goddard, NOAA GFDL, and NCAR are working together to explore how to use multi-core heterogeneous HPC. UCACN strongly encourages NCO to reach out to these research organizations and keep up to date about the latest developments. This is the overhead an operational organization must pay to stay current. By collaboratively working with other organizations on selected research and development efforts, NCO will significantly reduce future risk in the operational computing environment.

Finally, NCO should proactively lead EMC and all other major users to carefully plan for the model upgrade schedule and manage the computing resource and the associated expectation. The overall HPC technology is constantly changing, so NCO should maintain the expertise in porting the existing model codes to the new HPC architectures.

**(2) Finding:** NWS management has proposed to merge a NWS Telecommunications Operations Center (TOC) networking group of roughly 100 people into NCO.

**Recommendation:** The incorporation of a large operational organization into NCO may be daunting. The concern from the new NCEP Director is legitimate, and UCACN members have similar concerns. Nevertheless, there is a true strategic advantage for NCO to absorb this networking operational center. By managing and controlling a fundamental shared resource among NWS organizations, NCO will gain control over the architecture and procurement schedule that will greatly enhance the dissemination of
modeling and gridded analysis products. This will enable much more sophisticated 4-D data visualization and center-based local modeling efforts.

The UCACN members recognize the significant risk accompanying the incorporation of the NWS TOC into NCO. We urge NWS to properly fund the combined organization, and, very importantly, fully fill every management position of this new organization.

(3) Finding: There has been no visible activity/action for the software engineering testbed recommended in the last UCACN report. NCO has made limited progress building toward a model development and testing environment, which enables the incorporation of both internal and external new research results. This environment should minimally include tools for sound software engineering practice, automatic unit and regression testing, advanced modular verification and validation (V&V), a visual workflow engine, and an advanced data management system. Software engineering practice has improved significantly but is not ubiquitous yet. The relationship between NCO and EMC continues to improve. However, it is not evident that both organizations continue to commit to continuous improvement.

**Recommendation:** A successful weather forecast operation should include a strong logistical operational support including software engineering, automatic testing and integration and documentation. We view the current software engineering support at NCEP continues to be suboptimal. The developers at EMC and other centers need training and support in software engineering and modular design and testing principles. NCO should focus on the automation of the entire design, development, testing, and deployment process. While considering budget initiatives, NCEP should consider putting a lot more emphasis on logistics. The weather forecast enterprise needs automation to move to a more advanced and more efficient state.

NCO and EMC need to work together to continue to streamline the regression and integration testing and cut down transition time. This can be achieved by creating a joint task force composed of both EMC and NCO personnel to define the testing and acceptance processes to plan for model improvements and put them into packages or suites.

In addition, NCO and EMC should take concrete steps toward building external user interfaces. This is especially important for the NCEP Visiting Scholar Program. A good metric is the time taken by the on-boarding process, with a target of one day.

Finally, all the above may look very daunting. The UCACN committee recommends that NCO may want to start with a small task force to plot a roadmap forward. The composition of the task force may comprise of technology-savvy scientists and engineers from internal and external partner organizations.
9. **Ocean Prediction Center**

9.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Ocean Prediction Center.

9.2 Findings and Recommendations

Due to the weather-impacted nature of the meeting, the discussion of OPC-specific issues was abbreviated and largely handled during the major thematic discussion on Storm Surge and Inundation issues (see Section 3.1 above). Some issues raised in the 2012 UCACN report on OPC are listed below as reminders that these issues are ongoing:

- There is a need for a more strongly coordinated NOAA-wide ocean modeling strategy. Specifically, a stronger connection with the Coastal Survey Development Lab (CSDL) in NOS is needed, given that EMC lacks the requisite expertise for ocean model development. The UCACN recommends stronger and more direct collaboration between CSDL, EMC, and OPC in hydrodynamic model development. External to NOAA, these efforts would benefit greatly from leverage with ongoing work by the U.S. Navy and several universities.

- The expansion of OPC into ecological prediction is a strategic goal of the center, but it is not clear that OPC has the expertise in house to sustain this effort. The University of Maryland Eastern Shore and Virginia Institute of Marine Sciences are nearby universities that have in-house expertise that could be engaged to get the ecological forecasting initiative up and running.
10. Storm Prediction Center

10.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Storm Prediction Center. A summary of the discussion, findings and recommendations from that session is given below.

10.2. Overarching issues/recommendations

- The SPC is in critical need of a dedicated mesoscale and storm-scale model that can be used for operations and for operations-related research purposes. The most attractive pathway for moving forward with this operational need is to work with the HRRR through the Assimilation and Modeling Branch people in the GSD part of ESRL group in Boulder.

- The SPC is state-of-the-art when it comes to applying ensemble forecasting techniques to operations. They need additional resources to: 1) enable forecasters to develop new operational ensemble forecasting techniques applicable to mesoscale and storm-scale severe weather phenomena, and 2) continue and expand their highly successful and pioneering annual spring experiment that has proven to be very effective in the transfer of research knowledge to operations.

- The SPC has a continuing and critical need to increase the number of operational forecasters to hasten the development of new forecaster-driven operational products and their subsequent from research to operations.

- The SPC has a continuing and critical need to procure additional research to operations support to help ensure that a wealth of potential new operational forecast products can achieve this needed transition more quickly and more efficiently.

- There was a strong consensus expressed by SPC leaders and forecasters that NCEP should move to a high-resolution, convection-allowing ensemble forecast system as soon as possible. UCACN strongly endorses this perspective by the SPC leaders and forecasters. Given that the operational NCEP GFS model will be run on a 13 km grid soon, it makes less and less sense from a science or operational perspective to continue running the 13 km SREF. Severe weather guidance needed by SPC forecasters needs to be generated from 3- or 4-km gridded forecasts as soon as
possible. The scientific basis for this recommendation follows from the results of SPC's outstanding annual Spring Forecast Experiment (SFE) where the operational utility of high-resolution, convection-allowing ensemble model forecasts has been demonstrated to the participants.

10.3 Comments on the Hazardous Weather Testbed and the Annual Spring Forecasting Experiment

The SPC has conducted a very successful annual SFE for ~10 years. The SFE is noteworthy for the regular participation of scientists and forecasters in the national and international community. In recent years, the SFE has focused on how to use ensemble forecast products derived from high-resolution, convection-allowing models to make real-time probabilistic forecasts of convective initiation, mode, and distribution. These forecasts have enabled SFE participants to better assess the state-of-the-art of convective storm forecasting and to identify significant problems with these models (e.g., the ensemble forecasts are too underdispersive). The SFE makes it abundantly clear that the SPC is state-of-the-art when it comes to ensemble forecasting of convective storms and the preparation of operational products based on the ensemble forecasts. This success is a great credit to SPC leadership, the quality, expertise, and dedication of SPC forecasters, and the outstanding contributions of the SPC technical staff in developing new operational products.

10.4. Comments on strategic planning

The leadership of the SPC has discussed a comprehensive and visionary plan to improve the state-of-art of convective storm forecasting. The success of this plan rests on (1) transferring knowledge gained by SPC forecasters and NSSL scientists that relate to the fundamental scientific understanding of the structure and evolution of severe convective storms to the creation of new operational forecast products, and (2) enabling the SPC to gain access to a dedicated high-resolution, convection-allowing ensemble forecast model. The SPC operational forecasters are state-of-the-art in their knowledge of the dynamical and thermodynamical processes that govern the occurrence of severe convective storms. They are publishing new knowledge on severe convective storms regularly in *Weather and Forecasting* and the *Monthly Weather Review*. In order to ensure that the SPC remains state-of-the-art in the area of severe convective storm forecasting it is urgent that NCEP create a dedicated high-resolution, convection-allowing, storm-scale ensemble forecast model. Success in this endeavor may require that EMC/NCO rethink their CPU allocation diagram to allow the SPC to achieve this goal.
11. Space Weather Prediction Center

11.1. Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Space Weather Prediction Center. A summary of the discussion, findings and recommendations from that session is given below.

11.2. Overarching issues/recommendations

Even though 2013 saw precedent-setting events such as continued budget cuts due to sequestration, a government shut-down and no SWPC director for over two years, SWPC’s attitude and enthusiasm shows that they are ready to tackle adversity and initiate change. The following are areas that continue to have the most impact to SWPC’s operations.

1. NESDIS still has not fully embraced SWX data processing for upcoming missions (GOES-R & DSCOVR). UCACN recommends that SWPC continue to work with NWS, NCEP and NESDIS leadership to find a way to fund and integrate level 2 products for 2015 and beyond.

2. SWPC is dependent on aging research spacecraft to support its operational mission. The operational coronograph, the LASCO instrument on SOHO, is currently 17 years past its mission design. UCACN recommends that SWPC work within NOAA to fund an operational coronograph replacement and ensure that NESDIS add a satellite/coronagraph to its near term budget (2017-2018). The UCACN also recommends that SWPC identify a contingency plan for space weather forecasting in the event that the SOHO spacecraft were to fail before a replacement is in place.

3. Below par NOAA HR process and hiring freeze has reached a critical mass within SWPC. The UCACN recommends that NCEP continue to work with NWS and NOAA leadership on process improvement for the hiring of all center personnel.

4. NOAA-NASA mission creep still occurring. The UCACN recommends that information sharing and collaboration between both agencies remain transparent and leadership from NOAA and NASA continue to work to prevent inadvertent information dissemination that could damage their public image. In addition to continuing the ongoing meetings between both management and working teams, plans for personnel exchange between NASA/CCMC and NOAA/SWPC should be acted upon in FY2014.

5. NOAA Applied Space Weather Research - UCACN understands that major expenditures by either NWS or NOAA in the area of space weather research will not
be coming and that the original idea of establishing a space weather research component within NOAA is not attainable in the foreseeable future. The UCACN recommends that SWPC continue its efforts to enhance relationships with funding agencies (NSF and NOAA) to steer basic space weather research towards operational gaps. In addition, an external steering committee (with membership from NASA, NSF, and DOD at a minimum) should be established to help SWPC communicate its needs to these funding organizations.

11.3. Comments on Center’s recent progress

SWPC’s 2013 accomplishments are in line with their strategic plans and most of the recommended actions from 2009 and 2011 have been closed out or revised to fit with changing needs. The major highlights for FY13 are as follows:

- Whole Atmosphere Model (WAM) is being integrated into NCEP Environmental Modeling System.
- Ovation Auroral & SEAESRT Space Craft Charging models implemented into Operations
- New plain language text forecast and scientific discussion products operational
- Prototype regional geomagnetic/E-field product developed in collaboration with USGS
- Updated Government Performance and Results Act (GPRA) for Geomagnetic forecast
- NOAA/NASA Governance document established
- Back up COOP site established in NWS Cheyenne - SWPC has been working to make its APS in College Park fully operational. SWPC has also established COOP alternatives for its forecast office in North Boulder at a UCAR facility, and the WFO in Cheyenne, and are currently working to update their MOU with AFWA which provides them with forecast office backup capabilities while they are relocating to one of these locations
- The COSMIC-2 mission has been turned into an official NOAA program and the funding is more secure. Therefore, the previous recommendation that SWPC continue to work with NWS, NESDIS, and UCAR to ensure that the COSMIC-2 mission is adequately funded is no longer relevant.
- While not in FY13, selection of a Geospace model was finalized in Dec 2013. This effort involved collaboration between NASA GSFC’s CCMC to conduct model runs on five Magnetohydrodynamic (MHD) models and two empirical models. Two model performance reports were evaluated by SWPC and the Space Weather Modeling Framework was selected for transition to operations. The Weimer model was also selected for transition if time and resources allow

Other lingering issues continue with respect to:
- NESDIS is still not fully embracing SWX data processing for upcoming missions (GOES-R & DSCOVR) and the continued challenges with NESDIS to provide GOES-NOP data to the SWPC backup processors in College Park. NESDIS hopes to have data flowing to its Alternate Processing Site (APS) in College Park by early 2014. While discussions are ongoing between all levels of NWS and NESDIS (up to the AA
level), there is still no resolution for these issues and some are out of SWPC’s control.

- Mission Creep into SWPC service mission by elements of the space weather enterprise beyond SWPC
- NOAA HR process below par: There are now 10 total Fed vacancies at SWPC, this is 20% of SWPC’s federal staff. The lengthy hiring process within NOAA is a recurring theme that impacts all centers. They are now down to 3 of their 12 forecast staff and have just recently lost another back-up forecaster to retirement. In addition, two IT positions have remained vacant for 2.5 years now. Overtime and staff morale are serious concerns of SWPC management as this situation lingers. There is one bright spot to acknowledge however, after being vacant for two years the position announcement for the SWPC director was posted on January 16, 2014, and, subsequent to the UCACN meeting, has been filled by Thomas Berger.

11.4. **Comments on NCEP Production Suite**

- SWPC continues its march into the modeling era.
- The selection of a Geospace model to transition into full operations by FY2015, their work with EMC on the WAM model, and collaboration with the USGS on an E-field model for the North American power grid are all excellent examples of positioning themselves for the future. Through coordination efforts with NCEP, SWPC has ensured that it will have adequate super computing resources to support the R2O and full operational runs of all of these new model systems.
- The mission of the Space Weather Prediction Testbed (SWPT) has been actively engaged in several activities such as: pushing for advances in the WSA-Enlil model; coordinating with NASA on a Geospace model selection; and evaluation of possible aviation radiation models for use in SWPC forecast operations. The SWPT is working to establish a Steering Committee and held a preliminary meeting with potential board members of the steering committee during the Dec 2013 AGU meeting.

11.5. **Comments on Strategic Planning**

SWPC’s FY14 milestones include:

- Continued development of the Whole Atmosphere Model (WAM)
  - Couple to SWPC ionosphere model
  - FY17 Planned WCOSS Implementation
- Geospace Model
  - Running in Development to end of FY14
  - Implementation on WCOSS end of FY15
  - Highly dependent on Budget
- AWIPS-2
  - Forecaster training/familiarization – Prep for OTE
- DSCOVR – Ground system deployed at SWPC
- Close all POA&Ms from Feb 2013 A&A
  - SWPC College Park backup – NESDIS Data feed
- Website – Work with NOAA WOC to implement FY13 work
  E-field Product – Finish work started with USGS in FY13

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12. **Weather Prediction Center**

12.1. Preface/Introduction

The University Corporation for Atmospheric Research (UCAR) Community Advisory Committee for the National Centers for Environmental Prediction (NCEP), which is abbreviated UCACN, held its annual meeting on 21-22 January 2014 at the National Center for Weather and Climate Prediction (NCWCP), NCEP’s headquarters facility operated by the National Oceanic and Atmospheric Administration (NOAA) in Riverdale Park, MD.

Due to wintry weather, the first day of the meeting was held via teleconference, and for WPC lead Gary Lackmann, the second day was as well. A trip to the WPC during the Winter Weather Experiment was conducted by Lackmann in February 2013 and he participated in (and helped to coordinate) an ensemble-prediction demonstration on 11 March 2014.

The UCACN meeting included separate breakout sessions for subsets of the NCEP centers, including the Weather Prediction Center. A summary of the discussion, findings and recommendations from that session is given below.

12.2. Overarching issues/recommendations

Overarching issues include:

a.) Staffing issues. As for many NCEP centers, staffing shortfalls at WPC are creating a major obstacle to progress, and limit development activities, in particular. The WPC leadership has taken a creative approach, carving out time for forecasters who are interested in development work to undertake such work, and utilizing the NOAA rotational assignment program, for example. The transition to AWIPS-2 has exacerbated the staffing issues. Until staffing issues are resolved, WPC will be constrained in what development activities it can undertake.

b.) The “blender” ensemble technique, SREF clustering, and other probabilistic forecast techniques have demonstrated considerable advantage. Evidently, the in-house WPC bias-corrected blender product outperformed MOS by a considerable margin during the recent “polar vortex” arctic outbreak (Dave Novak, personal communication). However, this broaches the topic of MOS. NOAA’s MDL is involved in the national blender effort, and the UCACN acknowledges this effort, but it seems that MDL could partner more strongly with WPC (and NCO) to assist in ensemble analysis, display, and forecasting techniques. Also, additional access to ECMWF ensemble and extended range data would be beneficial, as would a clearer agreement to use ECMWF products in the blender.

c.) There was considerable discussion of the “weather-climate linkage”, and the need to develop additional forecast products that bridge the gap between WPC and CPC products. It is evident that the numerical guidance available to support this endeavor is less than optimal. But more importantly, development effort is required here. At what lead time does skill vanish? A complete set of reforecasts needs to be analyzed to determine what skill is available. Additionally, how are forecasts with 1-2 week lead time best communicated? Probabilistic product formats are needed,
and discussions with end-users are needed to inform product type and format. While interactions with CPC on this issue seem healthy, more resources are needed, especially in development of an extended-range reforecast dataset to aid the development of week 1-2 forecast products. Again, continuing to build a stronger partnership with MDL may facilitate this effort, and help alleviate the shortage of development personnel at WPC. A significant overarching issue that came to light during the winter 2014 meeting was the issue of NWP ensemble post-processing and visualization. It is unclear which entity within NCEP is responsible for development related to these areas. Some of this activity takes place at EMC, some at NCO, some at MDL, and some individual centers also perform their own post-processing and visualization. Part of the problem is the transition to AWIPS-2, which features limited ensemble capabilities, and which has consumed considerable resource. At present, there may be duplication of effort, and there is clearly a lack of synergy and limited development activity for ensemble post-processing, analysis and visualization. At the ECMWF, powerful interactive visualization techniques have recently been developed that enable forecasters to interrogate ensemble output in unique ways. While higher resolution and larger ensembles are needed, the path towards improved weather forecasting is not simply a matter of model resolution. An organized approach to ensemble post-processing, analysis, and visualization is a critical requirement that cannot be neglected if NCEP hopes to assume a position of worldwide forecasting leadership. As a start, a centralized approach to ensemble post-processing is needed, along with a strategy to develop tools that will allow forecasters to analyze and visualize ensemble output in an advanced fashion.

12.3. Comments on Center’s recent progress

A notable advance at WPC has been the advent of the Winter Weather Experiment and the Flash Flood Experiment, which are loosely modeled after the SPC/NSSL Spring Experiment. These programs allow forecasters and visitors to interact while applying and exploring cutting-edge techniques and products. Utilization of ensemble information and high-resolution NWP output are at the forefront in these efforts, and this aligns strongly with strategic plans and recommendations from the 2009 review. The WPC leadership is to be commended for expending the resources needed to undertake these activities, particularly in light of current staffing shortages.

The UCACN also applauds the establishment of the Met Watch Desk, again in a resource-limited environment. This was a bold move, in that no additional resources were provided for this activity. Efforts to streamline the previous produce suite were required in order to allow this activity to move ahead.

12.4. Comments on NCEP Production Suite

WPC has made excellent progress, especially given resource limitations. It is evident that they are engaging the broader community in a meaningful way, and their goals are scientifically credible and worthwhile. Whether they are attainable or not depends on staffing, and the ability to modify their product suite.

A challenge facing the WPC is balancing short-range product development and issuance with new week 1-2 products (in collaboration with CPC). The need for additional...
streamlining of the WPC product suite remains strong. Several examples were given of hurdles relating to product retirement. For instance, there are currently two versions of the short-range aviation forecast, one that is nearly automated (utilizing the NDFD), and another that requires considerable manual analysis effort. There is evidently an international requirement for the labor-intensive version of the product, and the FAA is also involved in this discussion. If WPC were allowed to switch entirely to the newer (automated) version of this product, it would free resources for other areas, including extended-range forecasting and further automation and ensemble product development efforts.

Given limited development staffing, stronger partnership with MDL and NCO would be highly beneficial, especially in the probabilistic product arena.

12.5. Comments on Strategic Planning

(a) Regional Modeling Suite: The WPC could utilize high-resolution (convection allowing) ensemble information in their forecasting. Significant utilization of ECMWF NWP output indicates that there is room for improvement in the NCEP modeling suite. There is also an issue related to QPF in landfalling tropical cyclones, because the HWRF QPF skill is not an improvement focus.

(b) Weather-Climate Linkage: Before product generation can proceed, additional research into available skill is needed, perhaps utilizing reforecast datasets. Also required is a survey of the user community, to see what products and product formats are useful. These prerequisite efforts require development staffing, which is in short supply at WPC. Partnering with CPC will help, but leveraging MDL, NCO, or other entities would also help. Finally, numerical guidance for the week 1-2 lead time is currently of questionable utility.
**Appendix: Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAWU</td>
<td>Alaska Aviation Weather Unit</td>
</tr>
<tr>
<td>ACE</td>
<td>Advanced Composition Explorer</td>
</tr>
<tr>
<td>ACSWA</td>
<td>American Commercial Space Weather Association</td>
</tr>
<tr>
<td>ADCIRC</td>
<td>ADvanced CIRCulation model</td>
</tr>
<tr>
<td>AFB</td>
<td>Air Force Base</td>
</tr>
<tr>
<td>AFWA</td>
<td>Air Force Weather Agency</td>
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<tr>
<td>AIRMET</td>
<td>Airmen’s Meteorological Information</td>
</tr>
<tr>
<td>AMB</td>
<td>Assimilation and Modeling Branch (GSD/ESRL)</td>
</tr>
<tr>
<td>AMS</td>
<td>American Meteorological Society</td>
</tr>
<tr>
<td>AOC</td>
<td>Airline Operations Center (NOAA)</td>
</tr>
<tr>
<td>AOML</td>
<td>Atlantic Oceanographic and Meteorological Laboratory</td>
</tr>
<tr>
<td>AOP</td>
<td>Annual Operating Plan</td>
</tr>
<tr>
<td>AOPA</td>
<td>Aircraft Owners and Pilots Association</td>
</tr>
<tr>
<td>AR</td>
<td>Alaska Region</td>
</tr>
<tr>
<td>ARWG</td>
<td>Aviation Requirements Working Group</td>
</tr>
<tr>
<td>ASDI</td>
<td>Aircraft Situation Display for Industry</td>
</tr>
<tr>
<td>ATCSCC</td>
<td>Air Traffic Control System Command Center</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>AWC</td>
<td>Aviation Weather Center</td>
</tr>
<tr>
<td>AWIPS</td>
<td>Advanced Weather Information Processing System</td>
</tr>
<tr>
<td>AWIPS-2 (or II)</td>
<td>Advanced Weather Information Processing System (generation 2)</td>
</tr>
<tr>
<td>AWRP</td>
<td>Aviation Weather Research Program</td>
</tr>
<tr>
<td>AWS</td>
<td>Aviation Weather Statement</td>
</tr>
<tr>
<td>AWT</td>
<td>Aviation Weather Testbed</td>
</tr>
<tr>
<td>AWWD</td>
<td>Aviation Winter Weather Dashboard</td>
</tr>
<tr>
<td>BoM</td>
<td>Bureau of Meteorology (Australia)</td>
</tr>
<tr>
<td>BP</td>
<td>Business Processes</td>
</tr>
<tr>
<td>CAAC</td>
<td>Civil Aviation Authority of China</td>
</tr>
<tr>
<td>CAPS</td>
<td>Center for Analysis and Prediction of Storms (OU)</td>
</tr>
<tr>
<td>C&amp;V</td>
<td>Ceiling and Visibility</td>
</tr>
<tr>
<td>CCFP</td>
<td>Collaborative Convective Forecast Product</td>
</tr>
<tr>
<td>CCMC</td>
<td>Community Coordinated Modeling Center (NASA)</td>
</tr>
<tr>
<td>CDM</td>
<td>Collaborative Decision Making (FAA)</td>
</tr>
<tr>
<td>CFS</td>
<td>Climate Forecast System</td>
</tr>
<tr>
<td>CIMMMS</td>
<td>Cooperative Institute for Mesoscale Meteorological Studies (OU)</td>
</tr>
<tr>
<td>CIO</td>
<td>Chief Information Officer</td>
</tr>
<tr>
<td>CIRA</td>
<td>Cooperative Institute for Research in the Atmosphere</td>
</tr>
<tr>
<td>CIRES</td>
<td>Cooperative Institute for Research on Environmental Systems</td>
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<tr>
<td>CMA</td>
<td>China Meteorological Administration</td>
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<tr>
<td>COLA</td>
<td>Center for Ocean-Land-Atmosphere Studies</td>
</tr>
<tr>
<td>CONUS</td>
<td>Continental United States</td>
</tr>
<tr>
<td>COOP</td>
<td>Continuity Of Operations Plan</td>
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<tr>
<td>COSMIC-2</td>
<td>Constellation Observing System for Meteorology Ionosphere and Climate</td>
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<tr>
<td>CP</td>
<td>Customers and Partners</td>
</tr>
<tr>
<td>CPC</td>
<td>Climate Prediction Center</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Name</td>
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<td>--------------</td>
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<tr>
<td>CPHC</td>
<td>Central Pacific Hurricane Center</td>
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<tr>
<td>CPO</td>
<td>Climate Program Office</td>
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<tr>
<td>CSDL</td>
<td>Coastal Survey Development Lab</td>
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<tr>
<td>CSS-Wx</td>
<td>Common Support Services- Weather (NextGen)</td>
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<td>CTB</td>
<td>Climate Test Bed</td>
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<tr>
<td>CWA</td>
<td>Center Weather Advisory</td>
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<tr>
<td>CWSU</td>
<td>Center Weather Service Unit</td>
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<tr>
<td>DA</td>
<td>Data Assimilation</td>
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<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
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<tr>
<td>DMSP</td>
<td>Defense Meteorological Satellite Program</td>
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<tr>
<td>DoC</td>
<td>Department of Commerce</td>
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<tr>
<td>DoD</td>
<td>Department of Defense</td>
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<tr>
<td>DoE</td>
<td>Department of Energy</td>
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<tr>
<td>DoI</td>
<td>Department of the Interior</td>
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<tr>
<td>DSCOVR</td>
<td>Deep Space Climate Observatory</td>
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<tr>
<td>DSS</td>
<td>Defense Security Service (also, Decision Support Service)</td>
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<tr>
<td>DTC</td>
<td>Developmental Testbed Center</td>
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<tr>
<td>ECFP</td>
<td>Extended Convective Forecast Product</td>
</tr>
<tr>
<td>ECWMF</td>
<td>European Center for Medium-range Weather Forecasting</td>
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<tr>
<td>EF</td>
<td>Ecological Forecasting</td>
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<tr>
<td>EFDC</td>
<td>Environmental Fluid Dynamics Code</td>
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<tr>
<td>EIS</td>
<td>Environmental Information Services (as in “Open EIS”)</td>
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<tr>
<td>EMC</td>
<td>Environmental Modeling Center</td>
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<tr>
<td>EnKF</td>
<td>Ensemble Kalman Filter</td>
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<tr>
<td>ENSO</td>
<td>El Niño and the Southern Oscillation</td>
</tr>
<tr>
<td>ESMF</td>
<td>Earth System Modeling Framework</td>
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<tr>
<td>ESPC</td>
<td>Earth System Prediction Capability</td>
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<tr>
<td>ESRL</td>
<td>Earth System Research Laboratory</td>
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<tr>
<td>EuroSIP</td>
<td>European Seasonal to Interannual Prediction system</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<tr>
<td>FBI</td>
<td>Federal Bureau of Investigation</td>
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<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<tr>
<td>FIM</td>
<td>Flow-following (Finite-volume) Icosahedral-grid Model</td>
</tr>
<tr>
<td>FOC</td>
<td>Full Operational Capability</td>
</tr>
<tr>
<td>4DVar</td>
<td>Four-Dimensional Variational (Data Assimilation)</td>
</tr>
<tr>
<td>FSSE</td>
<td>Florida State Superensemble</td>
</tr>
<tr>
<td>FTE</td>
<td>Full-Time Equivalent</td>
</tr>
<tr>
<td>FVCOM</td>
<td>(Unstructured Grid) Finite Volume Coastal Ocean Model</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
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<tr>
<td>GA</td>
<td>General Aviation</td>
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<tr>
<td>GEFS</td>
<td>Global Ensemble Forecast System</td>
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<tr>
<td>GFDL</td>
<td>Geophysical Fluid Dynamics Laboratory</td>
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<tr>
<td>GFE</td>
<td>Graphical Forecast Editor</td>
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<tr>
<td>GPS</td>
<td>Global Forecast System</td>
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<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
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<tr>
<td>GOES</td>
<td>Geostationary Operational Environmental Satellites</td>
</tr>
<tr>
<td>GPRA</td>
<td>Government Performance and Results Act</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GPU</td>
<td>Graphical Processing Unit</td>
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<tr>
<td>GSD</td>
<td>Global Systems Division</td>
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</table>
HAO  High Altitude Observatory
HDQ (or HQ)  Headquarters
HEC  High-End Computing
HF  High-Frequency
HFIP  Hurricane Forecast Improvement Project
HFO  Honolulu Forecast Office
HIWeather  High Impact Weather Project (in WWRP)
HIWPP  High Impact Weather Prediction Project (in OAR)
HMT  Hydrometeorological Testbed
HPC  High Performance Computing (or, formerly, Hydrometeorological Prediction Center, now called Weather Prediction Center)
HRD  Hurricane Research Division
HRRR  High-Resolution Rapid Refresh
HRRRE  High-Resolution Rapid Refresh Ensemble
HSU  Hurricane Specialist Unit
HWRF  Hurricane Weather Research and Forecasting (model)
HWT  Hazardous Weather Testbed
HYCOM  Hybrid Coordinate Ocean Model
IAP  Integrated Action Plan
IATA  International Air Transport Association
ICAO  International Civil Aviation Organization
IDSS  Impact-based Decision Support Services (or System)
IOOS  International Ocean Observing System
IRI  International Research Institute for Climate and Society
IS  Information Systems
ISI  Intraseasonal, Seasonal and Interannual
ISO9001  International Organization for Standardization (quality management standards)
IT  Information Technology
IWT  Integrated Warning Team
JHT  Joint Hurricane Testbed
KMA  Korea Meteorological Administration
LANL  Los Alamos National Laboratory
LASP  Laboratory for Atmospheric and Space Physics
LTSSA  Long-Term Sustainability of Space Activities
MADIS  Meteorological Assimilation Data Ingest System
MAPP  Modeling, Analysis, Predictions and Projections (in CPO)
MCS  Mesoscale Convective System
MHD  Magnetohydrodynamic
MIC  Meteorologist in Charge
MISST-2  Multi-Instrument Sea-Surface Temperature (2nd field program)
MJO  Madden-Julian Oscillation
MME  Multi-Model Ensemble
MOA  Memorandum of Agreement
MOS  Model Output Statistics
MOTL  Meteorologist-Over-The-Loop
MOU  Memorandum of Understanding
MPAS  Model for Prediction Across Scales
MS  Master of Science
MV  Mission and Vision
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>OS-21</td>
<td>Marine Branch (OCWWS)</td>
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<tr>
<td>OST</td>
<td>Office of Science and Technology</td>
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<tr>
<td>OSTP</td>
<td>Office of Science and Technology Policy</td>
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<tr>
<td>OU</td>
<td>University of Oklahoma</td>
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<tr>
<td>Open EIS</td>
<td>Open Environmental Information Services</td>
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<tr>
<td>PBL</td>
<td>Planetary Boundary Layer</td>
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<tr>
<td>Pflops</td>
<td>Peta (one quadrillion) floating point operations per second</td>
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<tr>
<td>POA&amp;M</td>
<td>Plan of Action and Milestones</td>
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<tr>
<td>POC</td>
<td>People and Organizational Culture</td>
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<tr>
<td>POM</td>
<td>Pacific Ocean Model</td>
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<tr>
<td>PPP</td>
<td>Polar Prediction Project (in WWRP)</td>
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<tr>
<td>PR</td>
<td>Pacific Region</td>
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<tr>
<td>PS</td>
<td>Products and Services</td>
</tr>
<tr>
<td>Q1(2,3,4)</td>
<td>First (Second, Third, Fourth) Quarter (of fiscal year)</td>
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<tr>
<td>QMS</td>
<td>Quality Management System</td>
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<td>QPE</td>
<td>Quantitative Precipitation Estimates</td>
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<tr>
<td>QPF</td>
<td>Quantitative Precipitation Forecasts</td>
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<tr>
<td>R2O</td>
<td>Research to Operations</td>
</tr>
<tr>
<td>RA4 (or RA-IV)</td>
<td>Regional Association IV (Caribbean)</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>RAL</td>
<td>Research Applications Laboratory</td>
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<td>RAP</td>
<td>Regional Area Prediction</td>
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<td>RCC</td>
<td>Regional Climate Center</td>
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<td>RFC</td>
<td>River Forecast Center</td>
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<td>RISA</td>
<td>Regional Integrated Sciences and Assessments</td>
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<td>ROC</td>
<td>Regional Operations Centers</td>
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<tr>
<td>(or Radar Operations Center)</td>
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<tr>
<td>(or Relative Operating Characteristic)</td>
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<td>ROMS</td>
<td>Regional Ocean Modeling System</td>
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<td>RUC</td>
<td>Rapid Update Cycle (model)</td>
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<td>S2S</td>
<td>Subseasonal to Seasonal (project) (in WWRP)</td>
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<td>SAB</td>
<td>Science Advisory Board (NOAA)</td>
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<td>SDR</td>
<td>Subcommittee for Disaster Reduction</td>
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<td>SEAESRT</td>
<td>Space Environmental Anomalies Expert System Real Time</td>
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<td>Space Environmental Gap Analysis</td>
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<td>SFE</td>
<td>Spring Forecast Experiment (SPC)</td>
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<td>SIGMET</td>
<td>Significant Meteorological Advisory</td>
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<td>SLOSH</td>
<td>Sea, Lake and Overland Surges from Hurricanes</td>
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<td>SOHO</td>
<td>SOlar &amp; Heliospheric Observatory</td>
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<td>SOO</td>
<td>Science and Operations Officer</td>
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<td>SPC</td>
<td>Storm Prediction Center</td>
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<td>SREF</td>
<td>Short-Range Ensemble Forecasts</td>
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<tr>
<td>SS&amp;I</td>
<td>Storm Surge and Inundation</td>
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<tr>
<td>SSUSI</td>
<td>Special Sensor Ultraviolet Spectrographic Imager</td>
</tr>
<tr>
<td>SSWIM</td>
<td>Social Science Woven into Meteorology</td>
</tr>
<tr>
<td>ST (also S&amp;T)</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>SWH</td>
<td>Significant Wave Height</td>
</tr>
<tr>
<td>SWOT/C</td>
<td>Strengths, Weaknesses, Opportunities and Threats/Challenges</td>
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<td>SWPC</td>
<td>Space Weather Prediction Center</td>
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<tr>
<td>SWPT</td>
<td>Space Weather Prediction Testbed</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>SWX</td>
<td>Space Weather</td>
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<td>TAF</td>
<td>Terminal Aerodrome Forecast</td>
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<tr>
<td>TAFB</td>
<td>Tropical Analysis and Forecast Branch</td>
</tr>
<tr>
<td>TC</td>
<td>Tropical Cyclone</td>
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<tr>
<td>TFM</td>
<td>Traffic Flow Management</td>
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<tr>
<td>THORPEX</td>
<td>The Observing System Research and Predictability Experiment</td>
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<td>TOC</td>
<td>Telecommunications Operations Center</td>
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<tr>
<td>TSB</td>
<td>Technical Services Branch (NHC)</td>
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<td>UCACN</td>
<td>UCAR Community Advisory Committee for NCEP</td>
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<td>UCAR</td>
<td>University Corporation for Atmospheric Research</td>
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<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UKMO</td>
<td>United Kingdom Meteorological Office</td>
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<tr>
<td>UKV</td>
<td>Variable-resolution UK Model</td>
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<tr>
<td>UMES</td>
<td>University of Maryland Eastern Shore</td>
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<tr>
<td>UM(S)</td>
<td>Unified Modeling (System)</td>
</tr>
<tr>
<td>UNCPUOS</td>
<td>United Nations Committee on the Peaceful Uses of Outer Space</td>
</tr>
<tr>
<td>UNSWOC</td>
<td>Unified National Space Weather Operational Capability</td>
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<tr>
<td>USAF</td>
<td>United States Air Force</td>
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<td>USGS</td>
<td>United States Geological Survey</td>
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<tr>
<td>USWRP</td>
<td>United States Weather Research Program</td>
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<tr>
<td>V&amp;V</td>
<td>Verification and Validation</td>
</tr>
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<td>VIMS</td>
<td>Virginia Institute of Marine Science</td>
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<tr>
<td>VSP</td>
<td>Visiting Scientist Program</td>
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<tr>
<td>WAFC</td>
<td>World Area Forecast Center</td>
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<tr>
<td>WAM</td>
<td>Whole Atmospheric Model</td>
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<tr>
<td>WAN</td>
<td>Wide Area Network</td>
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<tr>
<td>WCM</td>
<td>Warning Coordination Meteorologist</td>
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<tr>
<td>WCROSS</td>
<td>Weather and Climate Operational Supercomputing System</td>
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<td>WCRP</td>
<td>World Climate Research Program</td>
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<tr>
<td>WET</td>
<td>Weather Evaluation Team</td>
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<td>WFO</td>
<td>Weather Forecast Office</td>
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<tr>
<td>WGNE</td>
<td>Working Group on Numerical Experimentation</td>
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<td>WMO</td>
<td>World Meteorological Organization</td>
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<td>Web Mapping Service</td>
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<td>WOF</td>
<td>Warn on Forecast</td>
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<td>WRF</td>
<td>Weather Research and Forecasting (model)</td>
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<tr>
<td>WWB</td>
<td>World Weather Building</td>
</tr>
<tr>
<td>WWRP</td>
<td>World Weather Research Program</td>
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