**Report on the 7th Ensemble Users Workshop**

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**Introduction**

The 7th Ensemble Users Workshop took place at the NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, MD, on 13-15 June 2016. This workshop attracted over 150 participants representing a broad cross-section of expertise ranging from ensemble developers to end users of ensemble products. Starting in 2011, the Developmental Testbed Center (DTC) and the National Centers for Environmental Prediction (NCEP) have co-sponsored semi-annual ensemble user’s workshops. The 7th edition of the workshop focused on how to support the National Weather Service (NWS) as it moves toward a seamless operational ensemble forecast system at storm-to global spatial scales, from short-term to seasonal time scales, and from atmosphere-only to ocean-wave coupled ensemble prediction systems. One of the main goals was to bring together experts involved in the generation and use of NCEP ensembles. Another goal was to review progress on the generation and use of operational products since the last meeting in March 2014, and discuss plans for future efforts and collaboration. The ultimate motivation was to discuss how to convey forecast uncertainty in a user-relevant form. Workshops like these serve as an excellent mechanism for bringing together a broad range of people working on a similar problem to share information and ideas.

**Logistics and Organization**

In total, over 150 participants attended, with 18 people from NWS Headquarters/National Weather Center/ Meteorological Development Laboratory, 45 from NCEP, four from different NWS regions, 18 from Oceanic and Atmospheric Research, five from the Department of Defense, 14 from academia, 12 from private companies, and 33 from international organizations. A total of 59 oral presentations were given, with six poster presentations. Five speakers were also invited to present: Dave Novak (Weather Prediction Center), Dave DeWitt (Climate Prediction Center), Roberto Buizza (European Centre for Medium-Range Weather Forecasts), Nigel Roberts (UK Met Office) and Glen Romine (National Center for Atmospheric Research). A total of nine main sessions with three joint sessions were needed to cover all topics and all time scales, with reports from NCEP service centers, WFOs, and private users. An update and review of all ensemble forecast systems was as included, in addition to research community studies, and current exchange between national and international centers. Open discussions were also held, related to user requirements with regard to NCEP's operational plan, international collaboration, and research-to-operations/operations-to-research.

For further information regarding workshop organization, please see: http://www.dtcenter.org/events/workshops16/ensembles/

**Outcome**

A major recommendation is that ensemble development must be done in concert with the unification of the NCEP production suite. Currently, NCEP employs a range of deterministic and ensemble mesoscale and global models, but will be reducing that number in the future following recommendations from the UCACN Model Advisory Committee (UMAC). One step toward this unification involves the selection of the Geophysical Fluid Dynamics Laboratory (GFDL) FV3 dynamic core to replace the current Global Spectral Model (GSM) for both deterministic and ensemble global modeling. In addition, the last upgrade to the North American Model will be implemented operationally shortly, followed by potential future replacement by the FV3 for regional modeling. Therefore, close collaboration with NCEP and a concerted effort to work on ensemble development in the context of this model unification is extremely important.

Another key recommendation was to improve coordination and collaboration between research, development, and operational centers. Presentations from a number of different groups were made representing work being conducted at all resolutions and time scales, which illustrates potential pathways for future collaboration. For example, Glen Romine of NCAR presented work on the NCAR ensemble, Isidora Jankov presented NOAA Global Systems Division efforts to introduce stochastic physic perturbations into a High-Resolution Rapid Refresh (HRRR)-based ensemble, and Phil Pegion of the Physical Sciences Division of NOAA spoke about stochastic parameterization within the GFS ensemble. On longer time scales, Shan Sun presented work on sub-seasonal forecasting within a combined CFS/FIM-HYCOM ensemble. Projects from these four different groups provide ample opportunity for collaboration, and work has already begun to facilitate this interaction.

A current example of this kind of collaboration exists at the Hazardous Weather Testbed, which takes place every spring at NSSL. The Community Leveraged Unified Ensemble (CLUE) represents an effort to combine multiple deterministic and ensemble members using the same model specifications to create a “super”-ensemble that can be analyzed for effective convective-allowing ensemble design. Adam Clark of the National Severe Storms Laboratory presented work on the CLUE, showcasing how it provides an opportunity for collaboration between academic, government, and research-based organizations.

The need for enhanced international coordination and collaboration was also an important conclusion from the workshop. One presenter, Roberto Buizza, provided an overview of ECMWF ensemble status and future plans, illustrating the use of ensembles at multiple scales for both data assimilation and forecasts. Many of these techniques and findings are relevant for future operational ensembles at NCEP, and domestic model developers would benefit from international collaboration, particularly from centers overseas that have already implemented operational high-resolution ensembles.

Other findings include the need for improved data sharing, enhanced post processing and reforecasts, and the unification of verification metrics. An effort is also needed to focus on evidence-based decision making for model upgrades based on UMAC recommendations. Finally, consensus was that the World Meteorological Organization may be the best venue for advancing international collaboration through RDP/FDP projects.