Real-Time and Retrospective Mesoscale Objective Analyses

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Meeting Summary

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Abstract

Over seventy individuals representing government agencies, research institutions, and commercial firms participated in a two-day workshop during June 2004 on mesoscale objective analysis and its potential value for a variety of environmental applications. This meeting, sponsored by the National Weather Service (NWS) Office of Science and Technology and the United States Weather Research Program (USWRP), was motivated by the ongoing effort of the NWS to provide forecasts out to seven days on a fine-resolution grid. In addition, demands for high-resolution objective analyses are growing rapidly across the environmental community to support a variety of needs. Meeting participants recommended that every effort should be made to proceed rapidly to foster an Analysis of Record (AOR) program. Recognizing this need to proceed quickly, the Director of the NWS Office of Science Technology has appointed a Mesoscale Analysis Committee, and that Committee has already begun to recommend short-term and long-term goals for the AOR effort.

Capsule: Fine-scale analyses are in high demand to help create and verify gridded forecasts issued by the National Weather Service, as well as for many other environmental applications.

A comprehensive weather and climate observing system requires the integration and synthesis of observations into coherent gridded analyses of the past and current states of the atmosphere. As discussed by Trenberth et al. (2002) and Dabberdt et al. (2004b), major research challenges remain to fully exploit all of the existing and future observational resources and progress beyond the pioneering reanalysis efforts on the global (Kalnay et al. 1996) and regional (Mesinger et al. 2004) scales. Many weather and climate applications require gridded analyses at fine scale (1-5km), for which global (~200 km) and regional (~30 km) analyses are much too coarse. Although statistical and dynamical procedures to downscale coarse analyses to higher resolution are being evaluated by many researchers (e.g., Murphy 1999), those procedures are likely to incompletely capture local microclimates and the timing and intensity of localized severe weather.

High resolution analyses are especially needed now to help create and verify experimental gridded forecasts issued by the National Weather Service (NWS) out to seven days. As described by Glahn and Ruth (2003), the National Digital Forecast Database (NDFD) has a nominal grid spacing of 5 km across the United States and represents a blend of objective forecast guidance and forecaster edits. Early evaluation efforts of the new gridded forecasts have been hampered by the lack of gridded analyses of the forecast parameters, which include, among others, temperature, dew-point temperature, wind, precipitation, clouds, and weather. In addition, analyses play an important role in the forecast process and in generating forecast guidance through model post processing and statistical applications. Thus, the NWS has an immediate and critical need to produce real-time and retrospective analyses at high spatial and temporal resolution in order to facilitate the creation of the NDFD forecasts as well as verify their accuracy. The term "Analysis of Record (AOR)" has been coined previously to describe such analyses and implies that they should be of the highest quality possible subject to the limitations of the available observational resources and technologies, current scientific understanding, and the uncertainty implicit in any gridded analysis.

An AOR is, however, not a need of the NWS alone. Demands for high-resolution objective analyses are growing rapidly across the environmental community to support such activities as: mesoscale modeling for both operational weather forecasting and fundamental scientific investigation; dispersion modeling for real-time prediction of the transport of hazardous materials and air pollutants; homeland defense; aviation and surface transportation; and environmental issues from the coastal zone to national forests, including fire management (Dabberdt et al. 2004a, Fritsch and Carbone 2004). Additionally, accurate high-resolution analyses would help to form the basic building blocks of a climate database to assess the impacts of climate change on a regional scale.

The NWS Office of Science and Technology provided funding for a community meeting to discuss real-time and retrospective mesoscale analyses. Over seventy individuals representing government agencies, research institutions, and commercial firms participated in the two-day workshop held on 29-30 June 2004 in Boulder, Colorado, that was facilitated by staff of the United States Weather Research Program (USWRP). Meeting information, including presentations and preliminary recommendations, may be found on line at http://www.met.utah.edu/jhorel/homepages/jhorel/aofrs.htm. Invited presentations summarized the needs for fine-scale mesoscale analyses, linkages to other USWRP programs, current and future methodologies, and possible operational strategies. Breakout sessions emphasized translating the variety of needs for an AOR into specific requirements, identifying the observational resources required to develop reliable AORs and verify their accuracy, and evaluating the current capabilities to develop AORs and recommend ways that current deficiencies may be overcome. As summarized in the accompanying sidebar, a number of constructively competing pressures for

AORs emerged from the discussions during the meeting that will require additional research and discussion.

Sidebar: Analysis of Record Issues

- How can the needs for real-time analyses (with as little temporal latency as 30 minutes), with required stringent data cutoffs, be balanced against the need to provide retrospective analyses of the highest quality possible?
- Given the existing observational limitations, how can the AOR resolve both detailed microclimates as well as define synoptic and mesoscale weather features and localized severe weather?
- What elements and quality are required to verify NDFD forecasts compared to other needs for AORs?
- What role is appropriate for 2-dimensional surface analysis approaches and statistical and dynamical downscaling techniques?
- What are the computational and technological limitations for 3-dimensional data assimilation strategies?
- How can analysis errors due to the biases of the underlying modeling system be minimized?
- How can the uncertainty implicit in any analysis approach be quantified and expressed to the end user?
- What is possible now using existing resources and technologies, compared to what might be possible in a few years?

Recommendations

Workshop participants reached consensus on a number of recommendations regarding AORs. Clearly, no single solution is apparent at the present time. Recommendations included:

1. **Every effort should be made to proceed rapidly to foster an AOR program that will meet the diverse needs of the environmental community for high spatial and temporal resolution mesoscale analyses.** The AOR program is expected to require basic and applied research, transfer of resulting technologies to operations, and ongoing operational implementation. One of the reasons for moving quickly is that the NDFD forecasts of selected variables have just become operational.
2. **The AOR program should be viewed as leading to a suite of consistent products that meet the ongoing needs of the community.** For example, provisional mesoscale analyses available within roughly 30 minutes of the valid time are required by NWS forecasters to monitor current conditions and to initialize NDFD forecasts. Mesoscale analyses completed a day or so after the valid time would take advantage of more complete and diverse observational assets than would be available for the provisional analyses in near real time and would be of great value to many applications, including the verification of NDFD forecasts. The "gold standard" AOR would be an archive-quality analysis of base-state and sensible weather elements at mesoscale resolution, similar to previous global and regional reanalysis efforts.
3. **Community support for an AOR project must be broadened.** The need to provide input to, and verify, NDFD forecasts is a catalyst for mesoscale analyses, but is not an end in itself. A compelling business case must be developed for the AOR program that both broadens the awareness of the potential applications for AORs as well as broadens the funding base. Outreach to the regional and global climate change impact communities is a priority as well as to agencies that depend upon accurate environmental information (e.g., air and surface transportation, fire, air quality, homeland defense).
4. **Ongoing research and development efforts supported by other programs are critical to the future success of the AOR program.** For example, continued support is critical for

research and development of variational and ensemble filter techniques for the Weather Research and Forecasting (WRF) model. Further, the COOP modernization program will greatly enhance the observational resources required for the AOR (NWS 2004). Current plans envision stations to be equipped with temperature and precipitation sensors only. However, the baseline infrastructure will allow for additional sensors such as pressure, wind, and relative humidity sensors. Installation of these additional sensors is recommended at the time of initial installation at as many locations as possible.

5. **A Mesoscale Analysis Committee (MAC) should be formed that reports to the Director of the NOAA/NWS Office of Science and Technology in order to meet the immediate needs of the NWS for an AOR, as well as expand community support for an AOR project**. Lead sponsorship by the NWS for an AOR effort will help to maintain focus on the core goals required to foster the AOR program.

Workshop Outcomes

Based upon the recommendations of the Workshop participants, the MAC, under the auspices of the NWS Office of Science and Technology, was established during August 2004 to address critical science and technology needs for high-resolution objective analyses of the atmosphere. The current activities of the MAC and list of committee members are available on line at http://www.met.utah.edu/jhorel/homepages/jhorel/mac.htm. During the first meeting of the MAC in October 2004, the Committee recommended that initial efforts should focus upon making rapid progress (~6 months) to provide prototype real-time mesoscale analyses (RTMAs) and establish a framework for developing an AOR program. The prototype RTMAs will be developed through collaboration between staff of the Environmental Modeling Center of the National Centers for Environmental Prediction, NOAA Forecast Systems Laboratory, Office of Hydrological

Development, and National Environmental Satellite and Data Information Service.

Linkages to the Ongoing Analysis of the Climate System

As part of the effort of the MAC to broaden community support for an AOR program, it became apparent that the goal to develop fine-scale retrospective analyses is closely related to a proposed national program for the Ongoing Analysis of the Climate System (OACS). The concept of the global OACS was developed initially in a Workshop in August 2003 during which the participants concluded that the United States should establish a national program to provide a retrospective and ongoing physically consistent synthesis of earth observations in order to achieve its climate monitoring, assessment, and prediction goals. (Further information on the OACS is available at http://www.joss.ucar.edu/joss_psg/meetings/climatesystem.) The proposed program would comprise a substantial data development activity, a research element to improve methods and products, and an on-going operational production component with periodic reanalyses.

The proposed development strategy for the OACS breaks the task primarily into global analyses during three periods: the satellite era (post 1979), the upper-air observations era (post 1950), and the historical era (post 1850). In addition, a fourth regional analysis component at much finer spatial resolution was recommended to be explored as well. It was recognized that many climate applications to hydrology, agriculture, and health require analyses at resolutions as fine as 1 km. Hence, the MAC will consider developing an implementation plan that capitalizes upon linkages with the OACS.

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