University: University of Utah

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Partners or Cooperative Project: Cooperative

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1. Summary of project objectives

The primary goal of this collaboration is to improve the gridded forecast process and the accuracy of graphical and digital forecasts produced by the National Weather Service over the Western United States. Specific objectives were:

1. to evaluate and advance the skill and utility of methods to post-process NWP model output over regions of complex terrain using high-density, multi-elevation observations provided by the MesoWest cooperative networks,

2. to develop and implement a post-processing system that provides the best possible gridded first-guess fields to forecasters and improves NWS graphical and gridded forecast products produced with the IFPS for public, aviation, and fire-weather applications,

3. to educate researchers about the gridded forecast process and operational forecasters about the strengths and weaknesses of surface sensible weather forecasts produced by NWP models and statistical techniques.

2. Project accomplishments and findings

The primary project accomplishments are:

1. development of a Kalman-filter (KF) based downscaling system for the NCEP/Eta model that produces hourly temperature, wind, and dewpoint forecasts and max/min temperature forecasts for 2300 MesoWest stations in the western States (WA, OR, CA, NV, AZ, MT, ID, WY, UT, CO, NM),

2. dissemination of the KF forecasts to the 5 partner forecast offices for use in operations,

3. evaluation of the skill and utility of the KF forecasts compared to direct model output and 7-day running-mean bias correction,

4. preparation and submission of a *Weather and Forecasting* paper that communicates project findings to the broad meteorological community (Cheng and Steenburgh 2007),

5. implementation of the KF forecast technique at the Boise FO with intent to distribute more broadly across the partner offices and other FOs.

Major findings are summarized by Cheng and Steenburgh (2007), which is presently under review and included with this project report. We evaluated three techniques for improving the accuracy of 2-m temperature, 2-m dewpoint, and 10-m wind forecasts produced by the Eta model (i) traditional Model Output Statistics (ETAMOS), requiring a relatively long training period, (ii) the Kalman filter (ETAKF), requiring relatively short initial training period (~4-5 days), and (iii) seven-day running mean bias removal (ETA7DBR), requiring a 7 day training period. Forecasts based on the ETAKF and ETA7DBR methods were produced for more than 2000 MesoWest observing sites in the western U.S. and disseminated to forecasters. However, our evaluation was based on subjective forecaster assessments and objective verification at 145 ETAMOS stations during summer 2004 and winter 2004-2005.

For the 145 site sample, ETAMOS produces the most accurate cumulative temperature, dewpoint, and wind speed and direction forecasts, followed by ETAKF and ETA7DBR, which have similar accuracy. Selected case studies illustrated that ETAMOS produces superior forecasts when model biases change dramatically, such as during large-scale pattern changes, but that ETAKF and ETA7DBR produce superior forecasts during quiescent cool-season patterns when persistent valley and basin cold-pools exist. During quiescent warm-season patterns, the accuracy of all three methods is similar. Although the improved ETAKF cold-pool forecasts are noteworthy, particularly since the Kalman Filter can help better define cold-pool structure by producing forecasts for locations without long-term records, alternative approaches are needed to improve forecasts during periods when model biases change dramatically. Nevertheless, ETAKF can very quickly be applied to nonconventional mesonet observations and to new numerical models and therefore can be an effective forecast tool in many situations.

3. Benefits and lessons learned: Operational Partner Perspective

The primary benefit for the operational partners is the development of a promising forecast technique for mesonet locations not addressed with nationally supported guidance. Recent changes to a gridded forecast system make it highly desirable for the operational partners to obtain reasonable forecast guidance for nonconventional mesonet locations. This technique provides reasonable guidance with a very short “training period”, so it is quickly able to give guidance for new mesonet sites, or for new or modified forecast models. The technique is already providing guidance for times and locations that are unavailable elsewhere.

Not only the development of the technique was beneficial, but the in-depth examination of the technique by the university provided other insights. The interaction with the university has been valuable in identifying the strengths and weaknesses of the forecast technique, including where and when it tends to be most accurate and when it has difficulties. This gives the operational forecasters much more understanding in using the technique, and confidence to use it in the right situations.

The computing environment at the University differs significantly from that available at the local NWS office, and this proved difficult to overcome. However, we were eventually able to overcome the differences and come up with software that works at the local NWS office. Further interaction to understand the different computing environments would probably help speed the transition of techniques between the University and the NWS.

4. Benefits and lessons learned: University Partner Perspective

The primary benefits of this project include the training of a post-doctoral research associate, increased knowledge concerning the strengths and weaknesses of KF techniques for operational forecasting, and improved interactions with several forecast offices. We have also learned that transferring code from a University to the NWS remains challenging, in part because of our extensive use of graphics, mathematical, and statistical libraries that may not be available on NWS hardware. These challenges should be taken into consideration earlier in the project.

5. Publications and presentations

- Cheng, W. Y. Y., and W. J. Steenburgh, 2007: Strengths and weaknesses of MOS, running-mean bias removal, and kalman filter techniques for improving model forecasts over the western U. S. *Wea. Forecasting,* in review.

- Cheng, W. Y. Y., and W. J. Steenburgh, 2006: An evaluation of post-processing methods to correct surface forecast biases in the Eta/NAM model over the western United States. 12th Conference on Mountain Meteorology, American Meteorological Society, Santa Fe, NM.

- Cheng, W. Y. Y., and W. J. Steenburgh 2005: A Kalman filter approach to correct surface forecast bias. Tenth Annual Workshop on Weather Prediction in the Intermountain West, Desert Research Institute, Reno, NV.

- Cheng, W.Y.Y. and W.J. Steenburgh, 2005: A Kalman filter approach to correct surface forecast bias. 21st Conference on Weather Analysis and Forecasting/17th Conference on Numerical Weather Prediction, American Meteorological Society, Washington, DC.

- Cheng, W.Y.Y. and W.J. Steenburgh, 2004: A Kalman filter approach to correcting surface forecast bias. Ninth Annual Workshop on Weather Prediction in the Intermountain West, University of Utah, Salt Lake City, UT.

- Informal visits and presentations at all five partner offices.

6. Summary of University/Operational partner interactions and roles

The University partners were responsible for the initial development of the KF forecast system, regular production of the forecasts at the University of Utah, and dissemination to the forecast offices. Evaluation of the forecasts was done subjectively by forecasters at the 5 NWS partner offices and objectively by scientists at the University of Utah. Subjective evaluations by forecasters were particularly useful for identifying situations where the KF performed well or poorly and stimulated the production and dissemination of maximum and minimum temparture forecasts, which were more useful on the GFE. University partners prepared a paper (Cheng and Steenburgh 2007) for *Weather and Forecasting* that described results of the objective verification and presented case studies suggested by the operational forecasters.

University and operational partners continue to collaborate on the transfer of the KF forecast system to the NWS GFE. Will Cheng and Tim Barker (NWSFO Boise) are spearheading this effort.

Given the geographic isolation of the various partners, project interactions primarily consisted of conference calls, e-mail correspondence, site visits by University scientists to the FOs, and group meetings at the Intermountain Weather Workshop or AMS conferences. Forecasts were disseminated from the University to the NWS offices via Internet.