P5.1 ALTERNATIVE APPROACHES TO CURRENT NOWCASTING SCHEMES

Steven A. Lack
George L. Limpert
Neil I. Fox
University of Missouri-Columbia, Columbia, Missouri

## 1. INTRODUCTION

Over the last few years the development and implementation of various nowcasting schemes has accelerated throughout the international community. These schemes have advanced from simple linear extrapolation to those systems which extrapolate radar echoes by incorporation techniques such as: spatial cascades, hierarchical clusters, fuzzy logic, neural networks, or Bayesian statistics. In more recent developments these nowcast schemes have been blended with high resolution numerical weather prediction (NWP) models and are run in an ensemble framework to optimize performance over the 0-6 hour forecast period (Fox and Wilson, 2005). Although nowcasting schemes have become more and more complex requiring greater computational power, there are few novel approaches that can be applied to basic schemes to provide alternative nowcasts that may be useful to a variety of end users, including hydrometeorologists. The approaches that will be discussed herein include both running the Warning Decision Support System – Integrated Information (WDSS-II) K-means nowcasting tool (Lakshmanan *et al.*, 2003) in an ensemble framework and adjusting the Spectral Prognosis nowcaster (S-PROG) (Seed, 2003) to run without the reduction of reflectivity over time to yield a worse case scenario product.

## 2. WDSS-II

WDSS-II is a platform primarily used for diagnosing and disseminating severe weather information. Included in the package are products that include hail, mesocyclone, and tornado detection algorithms along with rainfall estimation and other products useful for operational forecasting. A nowcasting tool (K-means) is also available in the package which gives the forecaster a pseudo-radar reflectivity image at user-specified lead times.

The K-means product uses a hierarchical clustering technique to find storms at different spatial scales and estimate the motion at these various scales to provide a useful nowcast. The tracking approach uses a combination of motion estimates for groups of storms rather than individual storms while estimating the motion of these groups of storms at various scales. The forecast images are calculated by a matrix of a smoothed mean absolute error and adjusted according to data based on the centroid (Lakshmanan *et al.* 2003).

* *Corresponding author address:* Steven A. Lack, 302 ABNR Building, Univ. of Missouri-Columbia, Dept of Soil, Environmental, and Atmos. Science, Columbia, MO, 65211; email: SALack@mizzou.edu

The nowcast scheme also handles growth and decay by keeping information on the mean values of reflectivity of the cluster. Within the WDSS-II software package (Hondl, 2002) the threshold of reflectivity used to identify clusters can be selected by the user.

### 2.1 *WDSS-II Ensemble Methodology*

The methodology for an alternate application for the WDSS-II nowcasts is quite simple. The user can select different ranges of reflectivity on which to calculate the storm motion to generate the nowcast. The default storm motion calculation within the segmotion algorithm utilizes a range from 20-60 dBZ, which then gets divided into bins for storm motion calculation. By simply changing the lower and upper end of the range, the user can alter the bins thus changing how the storm motion is calculated at the different scales. Systematically altering the range of reflectivity and running the nowcaster multiple times can be used to generate an ensemble product by taking the mean of the solutions. Although the ensemble image generated may not give the best skill scores, it can be used to determine the value of the individual members that make up the ensemble.

### 2.2 *WDSS-II Results*

The example of the ensemble product from the K-means nowcaster presented here comes from 30 December, 2005 in the American River basin in the Sacramento area. The case involves a long duration stratiform event with some periodic embedded convection (Fig. 1).

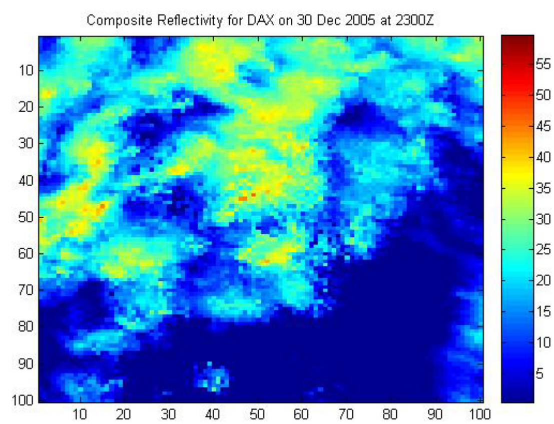


**Fig. 1: Composite reflectivity (1-km resolution) centered over DAX at 2300Z on 30 Dec 2005, color scale is dBZ.**

There were multiple thresholds selected for the ensemble experiment; however, only a few of the selected thresholds will appear for comparison. The ensemble member using the motion estimate from the 15-50 dBZ threshold is shown in Fig. 2. The mean product and the other members are slightly different especially in terms of the heavier cells; however the 15-50 dBZ yields the best skill scores.

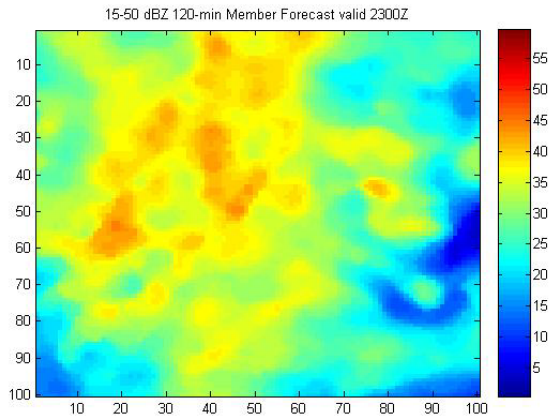


**Fig. 2: WDSS-II 120-min reflectivity forecast using a 15-50 dBZ threshold, valid at 2300Z (1-km resolution) centered over DAX on 30 Dec 2005, color scale is dBZ.**

Some basic skill scores including probability of detection (POD), false alarm rate (FAR), and critical success index (CSI) will be shown comparing the individual members of the ensemble with the mean solution. In this example, the mean of the ensemble members does not yield the best skill scores. However, one can do a quick view of skill scores on the individual members to give some insight as to which threshold works the best for this long duration stratiform event

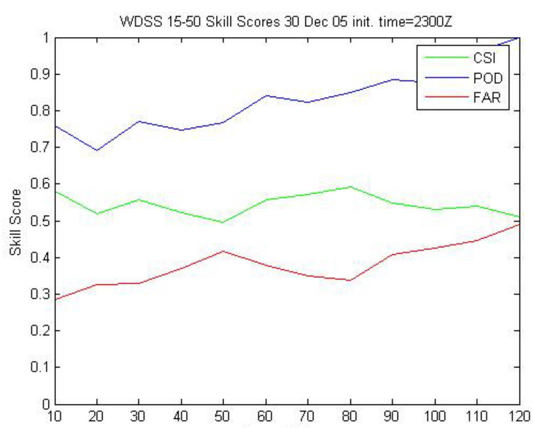


**Fig. 3: The skill scores for 10-min increments out to 2 hours lead time, valid 30 Dec 2005 at 2300Z for the 15-50 dBZ threshold member. CSI values remain relatively constant around 0.5 for the 2-h period.**

with embedded convection. The best member was found with a 15-50 dBZ range which would allow for the motion of the majority of the lower reflectivity clusters around 15-30 dBZ while still incorporating clusters of embedded convection over 40 dBZ (Fig. 3). The mean solution did not perform as well over the time period because some of the higher end thresholds (30-60 dBZ for example) miss the larger scale clusters dominant in the image (Fig. 4). However, the mean does outperform the default threshold of 20-60 dBZ within the WDSS-II segmotion algorithm as well as the best overall threshold (15-50 dBZ) for the first hour.

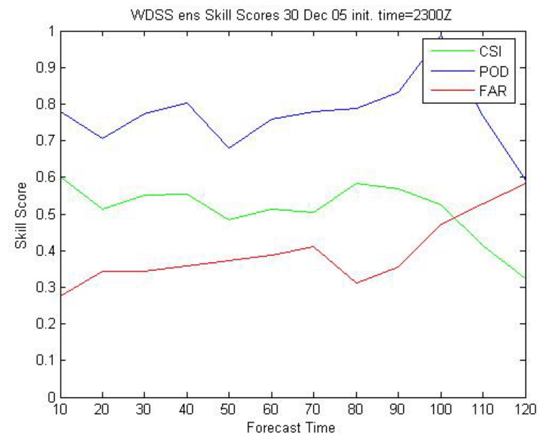


**Fig. 4: The skill scores for 10-min increments out to 2 hours lead time, valid 30 Dec 2005 at 2300Z for the mean forecast, note the drop-off in skill after 90 min.**

## 3. S-PROG

The original S-PROG routine was developed by the Bureau of Meteorology Research Centre and has since been modified for use in the Short Term Ensemble Prediction System (STEPS: Seed *et al.* 2005) developed for use by the UK Met Office, which allows for the blending of nowcast products with numerical weather prediction (NWP models). The original framework of the S-PROG scheme will be examined and modified for the work herein. S-PROG is a nowcasting system which works on advection, but uses the fact that uncertainty exists at the smaller short-lived scales in convective environments. This leads to a systematic reduction in the reflectivity of smaller-scale convective features over time. It also leads to a slight dispersion of weaker larger-scale reflectivity to give some kind of implicit measure of uncertainty.

### 3.1 *S-PROG Adjustment Methodology*

S-PROG's main strength is that it displays implicit uncertainty by using physical characteristics of storms observed in nature. However, its shortcomings include using only one advection for the entire domain and the fact that it may smooth out important convective elements over time. This can lead to an underestimation of forecast rainfall for a given basin.

This appears to happen most in events that are stratiform in nature but contain smaller convective elements. The convective elements embedded in stratiform precipitation appear more spatially random throughout the duration of the event than the parent low reflectivity area of precipitation. However, losing the possibility of these convective elements existing in the future gives a misleading quantitative precipitation forecast (QPF) to hydrologists. It is therefore necessary to somehow retain these smaller more variable areas of embedded convection.

The idea is to give the forecaster a worse-case scenario based on the advection vector calculated from the spatial decomposition model. This is simply accomplished by finding the maximum reflectivity contained in the original radar data and the maximum reflectivity in the S-PROG forecasting solution. Dividing the original maximum reflectivity by the forecast maximum reflectivity yields an intensity adjustment factor which is always greater than one. In the examples given, 90% of this intensity factor is used to ensure the solutions do not blow up to entirely unrealistic solutions. This can be adjusted in future runs and be based on storm type.

### 3.2 *S-PROG Results*

The results shown are from the aforementioned flooding event focusing on the Sacramento area including the American River basin. As the lead time is increased in the original version of S-PROG, the reflectivity both disperses and weakens to illustrate the uncertainty in extrapolation as widespread weaker stratiform areas tend to persist longer than embedded convective elements. Although embedded convection is less predictable due to its random nature, weakening the entire reflectivity in the domain can lead to an underestimation in QPF over longer lead times. Fig. 4 shows S-PROG at a 60-min lead time with no enhancement of reflectivity, while Fig. 5 shows the same time period with the adjustment to enhance reflectivity. Comparisons can be made with Fig. 1 as the valid time is 2300Z.

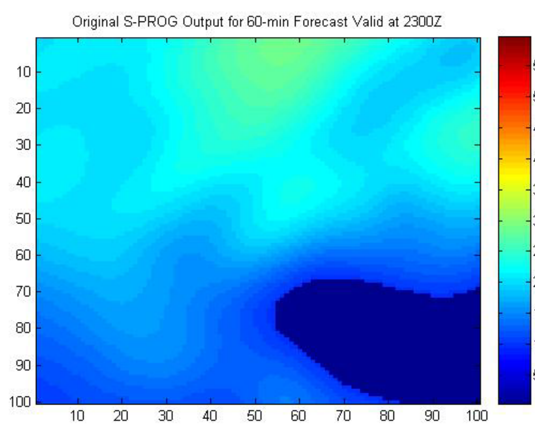


**Fig. 4: The original S-PROG 60-min nowcast of reflectivity valid at 2300Z, scale is dBZ.**

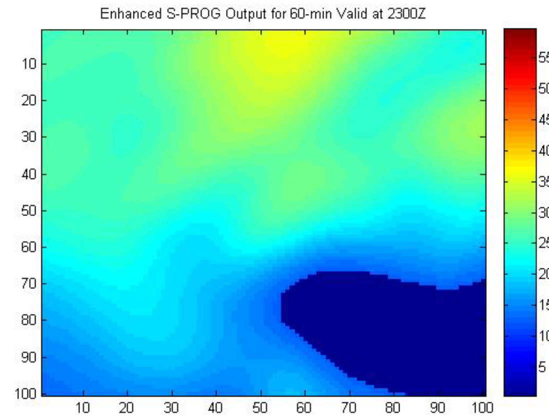


**Fig. 5: The enhanced S-PROG 60-min nowcast of reflectivity valid at 2300Z, scale is dBZ.**

The following images illustrate the effectiveness of using an enhanced reflectivity product based on the original S-PROG algorithm by showing resulting rainfall accumulation forecasts after 60 minutes. The original rainfall accumulation highlights totals of around 2 mm for most of the northwest portion of the domain with values approaching 4 mm for some of the isolated heavier precipitation (Fig. 6). The Z-R relationship used is the standard stratiform $Z=200R^{1.6}$. Although these rainfall totals seem low for an hour, the total precipitation for the basin over a 3 day period ranging from 30 Dec 2005 to 1 Jan 2006 was well over 100 mm on already saturated ground. The original S-PROG accumulations only yield a QPF for the northwest portion of the domain after 60 minutes near 1.5 mm with a lack of higher embedded totals as would be expected due to the dispersive nature of the scheme (Fig. 7). In the case of the adjusted S-PROG, the rainfall total over 60 minutes shows a slight overestimation in reflectivity over the northwest portion of the domain with values approaching 3.5 mm in a more widespread pattern than the actual radar derived accumulation (Fig. 8). The enhancement of reflectivity in the domain is coupled with some dispersion for uncertainty in areal coverage as in the original S-PROG routine. This product potentially could be useful in a worse-case scenario for hydrometeorologists in charge of predicting river flood stages and corresponding warnings.

## 4. CONCLUSION

The descriptions of the alternative approaches to both the K-Means nowcaster contained in WDSS-II and the enhancement to S-Prog show easy approaches to improve operational quantitative precipitation forecasts. Ensemble methodologies in synoptic and mesoscale models have shown promise in giving implicit uncertainty that give forecasters extra confidence in forecasting atmospheric conditions. Utilizing ensembles in nowcasting applications has produced similar successes, and although the WDSS-II nowcast ensemble mean discussed here did not produce the best results it can yield important insights on what reflectivity thresholds

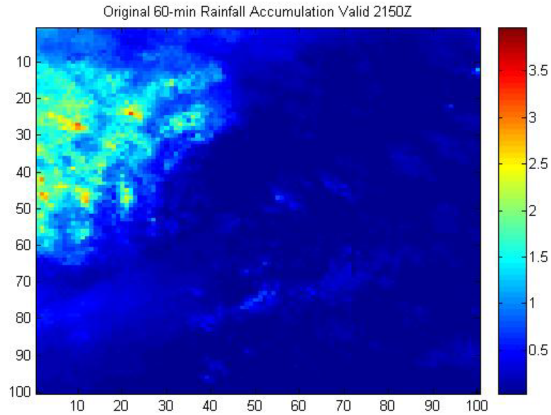


**Fig. 6: The actual radar 60-min rainfall accumulation valid at 2150Z, scale is mm.**

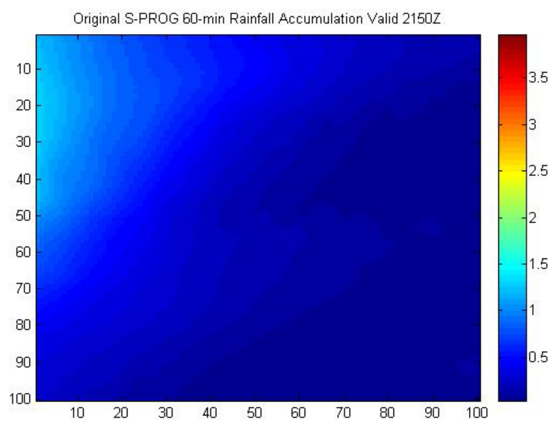


**Fig. 7: The original S-PROG 60-min rainfall accumulation valid at 2150Z, scale is mm.**

to use in particular meteorological situations. Finally, utilizing an enhancement of S-PROG reflectivity output, while keeping the spatial decomposition methodologies inherent to the original scheme, has shown effectiveness in indicating a widespread worse-case scenario.

## 5. FUTURE WORK

Future work in the area of altering these current nowcasting schemes will be ongoing as part of research to incorporate high resolution models (RUC and WRF) with current nowcasting schemes. For example, combinations of meteorological variables derived from these high resolution NWP models will be used to grow or decay storm cells where necessary with in a domain rather than having a generic growth/decay mechanism which may be too simplistic to yield useful nowcasts. Information such as horizontal velocity vectors with components perpendicular to the topography of the American River basin for orographic enhancement may be of interest to hydrometeorologists in the Sacramento area. Incorporating physics to enhance or decay precipitation values over time in different nowcasting schemes may vary with geography and season.

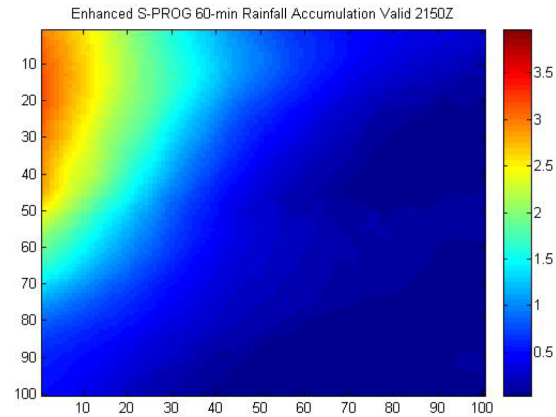


**Fig. 8: The enhanced S-PROG 60-min rainfall accumulation valid at 2150Z, scale is mm.**

## 6. REFERENCES


Fox, N.I. and J.W. Wilson, 2005: Very short period quantitative precipitation forecasting. *Atmos. Sci. Letters*, **6**, 7-11.

Hondl, K. 2002: Current and planned activities for the warning decision support system-integrated information (WDSS-II). *21st Conference on Severe Local Storms*, Amer. Meteorol. Soc., San Antonio, TX.

Lackshmanan, V., R. Rabin, and V. DeBrunner, 2003: Multiscale storm identification and forecast. *Atmos.. Res.*, **67-68**, 367-380.

Seed, A., 2003: A dynamic and spatial scaling approach to advection forecasting. *J. Appl. Meteorol.*, **42**, 381-388.

Seed, A., N. Bowler, and C. Pierce, 2005: Short term ensemble prediction system (STEPS): an empirical treatment of forecast uncertainty. WWRP: Symposium on Nowcasting and Very Short Range Forecasting, Toulouse, France, CD-ROM.