2.7 USING SHORT RANGE ENSEMBLE MODEL DATA IN NATIONAL FIRE WEATHER OUTLOOKS

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1. INTRODUCTION

The Storm Prediction Center (SPC) in Norman, OK prepares national Fire Weather Outlooks valid for 24 hour periods covering the current day and the next day. The purpose of the fire weather program is to provide national fire weather guidance for use by the National Weather Service, as well as other federal, state, and local government agencies. The product is intended to delineate areas of the contiguous U.S. where the pre-existing fuel conditions combined with predicted weather conditions, including dry thunderstorms, result in a significant threat of wildfires.

The SPC Fire Weather Outlook contains both a text discussion and corresponding graphic for each of the two forecast periods. An example of a fire weather graphic is given in Figure 1, with a critical area over Idaho, Montana, Wyoming, Utah and Colorado. Real-time fire weather forecasts and discussions are available at http://www.spc.noaa.gov/products/fire_wx/.

Figure 1. *Day 1 SPC Fire Weather Outlook graphic showing a critical area over parts of the western U.S., valid 12 UTC 8 July 2003 to 12 UTC 9 July 2003.*

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Recently, SPC forecasters have begun using output from the National Centers for Environmental Prediction (NCEP) Short-Range Ensemble Forecast (SREF) system as guidance for the national Fire Weather Outlooks. The use of the SREF enhances the forecast process by quantifying the likelihood that key fire weather parameters will reach or exceed critical thresholds.

The 15 member SREF is run twice daily at 09 UTC and 21 UTC and produces forecasts out to 63 hours. In an effort to account for model/physics uncertainty, the SREF system includes five members of the Eta model employing the Betts-Miller-Janjic convective parameterization, the Eta model employing the Kain-Fritsch (KF) convective parameterization, and the regional spectral model (RSM). Each five member group consists of a control member (i.e., no initial perturbation) plus four members with perturbed initial conditions. The current grid spacing is 48 km, and NCEP is currently testing an upgrade to 32 km (J. Du, 2003, personal communication). Additional post-processing of the NCEP SREF output is done at the SPC to produce meteorological diagnostics and ensemble statistics relevant to the SPC mission. See Du and Tracton (2001) for more information concerning the NCEP SREF.

The SPC issues forecasts for three types of Fire Weather Outlook areas: a Critical Fire Weather Area, an Extremely Critical Fire Weather Area, and a Critical Fire Weather Area for Dry Thunderstorms. The forecast of critical areas depends on both anticipated weather and antecedent conditions over the given geographic region.

The majority of SPC outlooks are issued for *critical* fire weather conditions, while *extremely critical* outlooks are reserved for times when weather conditions are expected to deviate significantly from climatological normals and/or fuels are extremely dry. Finally, *critical areas for dry lightning* are issued when an outbreak of dry thunderstorms is expected to occur. (For the purposes of the SPC Fire Weather Outlook, a dry thunderstorm is defined as one producing less than one-tenth of an inch of rain.)

This paper will briefly describe how SREF output is utilized at the SPC as one ingredient to prepare fire weather forecasts. In addition, verification techniques of the SPC fire weather forecast are presented.

2. USE OF SREF OUTPUT

The operational application of SREF guidance was formally proposed by the research community in the 1990s (e.g., Brooks et al. 1995; Fritsch et al. 1998), with operational pilot programs occurring only recently (e.g., Stensrud et al. 1999). Studies have shown that root-mean-square forecast error is reduced by using the ensemble mean rather than an individual model (Leith 1974; Du et al. 1997). Unfortunately, the relationship between SREF ensemble member spread and the accuracy of the ensemble mean has been found to be low (Stensrud et al. 1999). This means the ensemble itself may not be very useful for predicting the skill of its mean. Despite this shortcoming, which is probably due to the under-dispersive nature of most ensemble systems (Hamill and Colucci 1998; Stensrud et al. 1999), previous studies have found uncalibrated probability forecasts from short-range ensembles contain sufficient resolution to be more skillful than the binary forecast provided by a single, higher-resolution deterministic model (Wandishin et al. 2001; Bright and Mullen 2002).

In 2002, the SPC began an intensive period to customize SREF guidance and explore its usefulness toward SPC operations (Bright et al. 2003). Nearly 300 SREF fields are routinely available to SPC forecasters. Among these are basic variables such as wind, temperature, and relative humidity at various levels (2 or 10 meter AGL and several isobaric levels), and many derived diagnostics (e.g., Haines Index; Fosberg Fire Weather Index). Forecasters can interrogate a wide variety of ensemble statistics (e.g., mean, median, standard deviation), probabilities, combined probabilities, or individual member output. The most commonly used ensemble products are summarized below.

Mean and Spread:

The ensemble arithmetic average and the ensemble standard deviation are displayed together. Averaging tends to smooth small scale features, which over time normally results in a better overall forecast. But, this averaging will also smooth gradients and/or small scale features, which may or may not be beneficial depending upon the predictability of the feature. An example of a mean/spread chart is shown in Fig. 2.

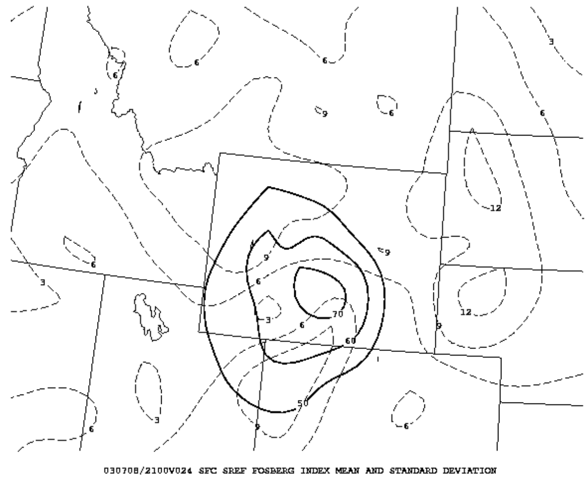

Figure 2. *Mean Fosberg Fire Weather Index (FWI) (solid) and its standard deviation (dashed) from the 24-hr SREF valid 2100 UTC 8 July 2003. (See section 3 for a discussion of the Fosberg FWI.)*

Probability:

At the SPC, the probability charts are generally considered the most useful product derived from the SREF. Currently, only uncalibrated (or raw) probabilities are used. In other words, these probabilities may not necessarily represent the true expected frequency of occurrence of the event, but simply indicate the percentage of ensemble members meeting some defined condition. Examples are shown in Figs. 3 and 4.

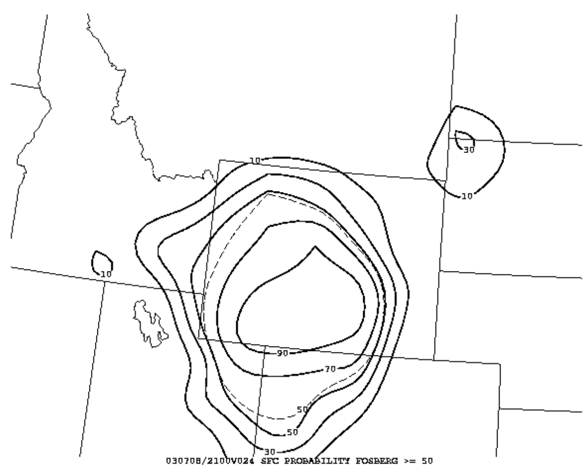

Figure 3. *As in Fig. 2, except probability of Fosberg FWI $\geq$ 50 (solid; percent) and the mean Fosberg FWI value of 50 (single dashed contour).*

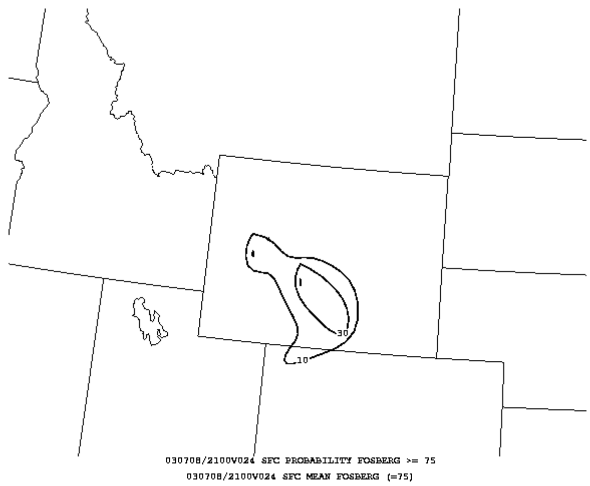

Figure 4. *As in Fig. 2, except probability of Fosberg FWI ≥ 75 (solid; percent).*

Median/Max/Min:

This type of display can highlight the spatial variability of the SREF. The median value is plotted, along with a contour of the SREF "maximum" (or union) and "minimum" (or intersection). The maximum contour reflects the location where all members meet or exceed the lowest median contoured value, and the minimum line shows where at least one member equals or exceeds that threshold (Fig. 5). This provides a quick way to see the central tendency predicted by the SREF and get an indication of its spatial variability.

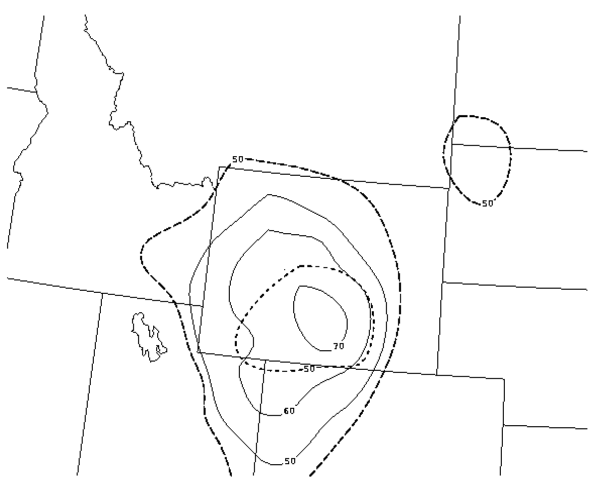

Figure 5. *As in Fig. 2, except the median Fosberg FWI (solid, contouring starts at 50) with the maximum (or union) of all SREF members (long dashed; single contour value of 50) and the minimum (or intersection) of all SREF members (short dashed, single contour value of 50).*

Extreme Value:

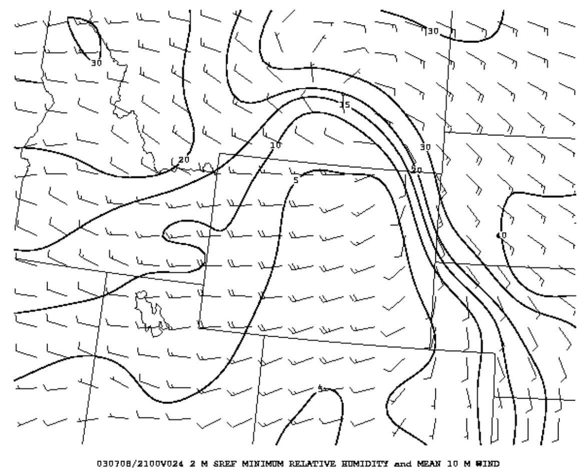

Figure 6. *As in Fig. 2, except the minimum 2-meter RH (solid, percent) predicted by the SREF with mean 10-meter wind (kts) overlaid.*

The ability to plot the extreme value (maximum or minimum) at every grid point is also useful for exploring "worst case" scenarios.. An example showing the minimum RH is provided in Fig. 6.

Spaghetti:

Ensemble spaghetti (or single value contour plots from all members) are available for most fields. SPC experience indicates that the usefulness of spaghetti charts is situation dependent. They provide a convenient way to spot outliers, any clustering by SREF model, the location of higher-resolution models relative to the SREF, and/or to quickly visualize SREF spread. But, spaghetti charts can also be "messy" and difficult to interpret. When attempting to assess the likelihood of a particular solution, SPC forecasters generally prefer to view the probability charts.

3. Case Study: 8 July 2003 Forecast and Verification

One very useful derived diagnostic the SPC produces from the SREF is the Fosberg Fire Weather Index (FWI) (Fosberg 1978). The FWI is an objective index that relates wind, temperature and relative humidity to fire weather conditions and the behavior of wildfires. The index incorporates only the weather conditions, not the fuels. Several sets of conditions were defined by Fosberg to apply this to fire weather management. The upper limits have been set to give an index value of 100 if the moisture content is zero and the wind is 30 mph. Thus, the index numbers range from 0 to 100, and if any number is larger than 100, it is set to 100.

Specific criteria which modulate the FWI include surface relative humidity, surface temperature, and surface wind. Generally, for national guidance purposes, temperatures above 60 F, RH values less than 20%, and sustained surface winds above 20 mph will result in Fosberg values above 50, which is a minimum threshold for critical fire weather conditions. As a general rule, SPC forecasters tend to pay special attention to areas expected to have 3 or more hours of a FWI above 50.

Forecasts of the FWI are available from the SREF (examples of some of these SREF products were presented in Figs. 2-6).

Verification of a critical event where the SREF accurately predicted FWI is shown in Figs. 7-8. The observed fire danger rating values from the National Fire Danger Rating System (NFDRS) prior to the event were all in the High to Extreme range, suggesting that the combination of weather and fuels was supportive of problem fire activity. In addition, minimum RH values were forecast to be less than 10 percent with sustained surface winds at or above 20 mph (Fig. 6). In this case, the SREF maximum FWI exceeded 80 for a number of hours during the afternoon of 8 July 2003. Based in part on this guidance, a critical fire weather outlook was issued for portions of Wyoming, Utah, Colorado, Montana and Idaho.

SPC Fire Weather Outlooks are verified by using the SPC Fosberg Fire Weather Index (SFWI). The SFWI is simply the FWI calculated using the SPC surface objective analysis (Bothwell et al. 2002). For this approach to be valid the temperature must exceed 60F and the NFDRS fire danger rating must be at or above High.

An example of a specific case is given in Figure 8. This chart shows the critical fire weather outlook issued on 8 July 2003 (also shown in Figure 1), with *observed* maximum Fosberg values at 2100 UTC 8 July. Maximum Fosberg values were above 50 across much of Wyoming, and exceeded 90 in central Wyoming.

Figures 3 and 4 illustrate forecast Fosberg values valid for the same period, showing the SREF output accurately delineated the area of high Fosberg FWI potential. Of course, construction of the fire weather forecast is considerably more complex than simply applying the few charts presented here. Additional SREF fields, higher-resolution numerical models, forecast soundings (or vertical profiles of temperature, moisture, and wind), and detailed analysis of observed surface and free-air data are incorporated into the SPC forecast process. Nevertheless, this brief case study serves to illustrate that the addition of NCEP SREF has proved useful to SPC fire weather forecasters.

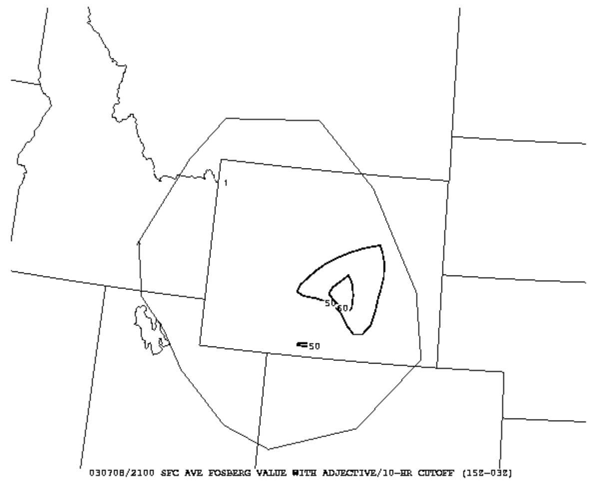

Figure 7. *SPC Average Adjective Fire Weather Index valid 2100 UTC on 8 July 2003.*

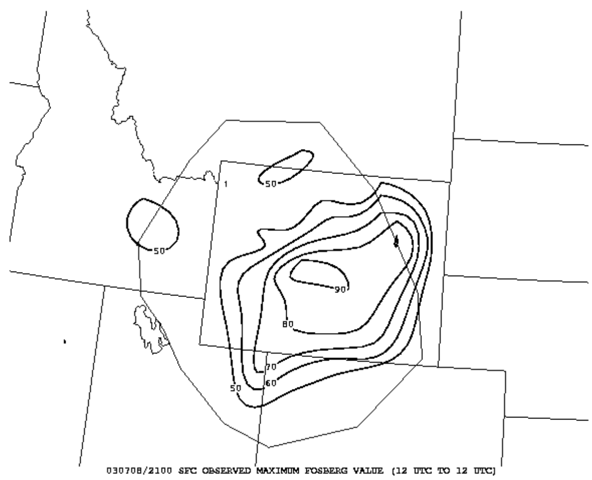

Figure 8. *SPC Observed Maximum Fosberg FWI (12 UTC to 12 UTC).*

4. CONCLUSIONS

The use of SREF guidance is becoming more common in operational forecasting, and the SPC is now using it routinely for fire weather forecasting. The SREF has been found useful for assessing the likelihood that key fire weather parameters may meet or exceed critical values, while the mean fields are often viewed to see the most likely outcome (in a smoothed, statistical sense).

The statistical fields displayed from the SREF data allow forecasters to quickly and easily assess areas where temperature, relative humidity and winds may reach critical threshold values.

Short term ensembles will become a standard tool in operational forecasts in the future. The SPC is already implementing this latest technology. It is hoped that by incorporating SREF output, improved forecast products will result.

5. ACKNOWLEDGMENTS

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6. REFERENCES

SPC Fire Weather Web Page:
http://spc.noaa.gov/products/fire_wx/

Bothwell, P.D., J.A. Hart and R.L. Thompson, 2002: An integrated three-dimensional objective analysis scheme in use at the Storm Prediction Center. Preprints, *21st Conf. Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., J117-J120.

Bright, D.R., S.J. Weiss, J.J Levit, and D. J. Stensrud, 2003: The Utility of Short-Range Ensemble Forecasts in the Real Time Prediction of Severe Convective Weather at the Storm Prediction Center. Preprints, *Tenth Conference on Mesoscale Processes*, Portland, OR, Amer. Meteor. Soc., CD-ROM, 2.8.

Bright, D.R., and S. L. Mullen, 2002: Short-Range Ensemble Forecasts of Precipitation during the Southwest Monsoon. *Wea. Forecasting*, **17**, 1080-1100.

Brooks, H. E., M. S. Tracton, D. J. Stensrud, G. DiMego, and Z. Toth, 1995: Short-range ensemble forecasting: Report from a workshop, 25-27 July 1994. *Bull. Amer. Meteor. Soc.*, **76**, 1617-1624.

Du, J., and M. S. Tracton, 2001: Implementation of a real-time short range ensemble forecasting system at NCEP: An update. Preprints, *9th Conf. On Mesoscale Processes*, Ft. Lauderdale, FL, Amer. Meteor. Soc., 355-356.

Du, J., S. L. Mullen, and F. Sanders, 1997: Short range ensemble forecasting of quantitative precipitation. *Mon. Wea. Rev.*, **125**, 2427-2459.

Fosberg, M.A., 1978: Weather in Wildland Fire Management: The Fire Weather Index. *Proc. Conference on Sierra Nevada Meteorology,* Amer. Meteor. Soc., 1-4.

Fritsch, J. M., R. A. Houze Jr., R. Adler, H. Bluestein, L. Bosart, J. Brown, F. Carr, C. Davis, R. H. Johnson, N. Junker, Y. H. Kuo, S. Rutledge, J. Smith, Z. Toth, J.W. Wilson, E. Zipser, and D. Zrnic, 1998: Quantitative precipitation forecasting: Report of the eighth prospectus development team, U.S. Weather Research Program. *Bull. Amer. Meteor. Soc.*, **79**, 285-299.

Hamill, T.M., and S. J. Colucci, 1998a: Evaluation of the Eta-RSM ensemble probabilistic precipitation forecasts. *Mon Wea Rev.*, **126**, 711-724.

Leith, C.E., 1974: Theoretical Skill of Monte Carlo Forecasts. *Mon. Wea. Rev.*, **102**, 409-418.

Stensrud, D.J., H. E. Brooks, J. Du, M. S. Tracton, and E. Rogers, 1999: Using ensembles for short-range forecasting. *Mon. Wea. Rev.*, **127**, 433-446.

Wandishin, M. S., S. L. Mullen, D. J. Stensrud, and H. E. Brooks, 2001: Evaluation of a short-range multimodel ensemble system. *Mon. Wea. Rev.*, **129**, 729-747.