Methods used to Verify the 2000 CCFP Forecasts

Statistical results are computed by the Real-Time Verification System (RTVS; Mahoney et al. 1997), developed by the Forecast Systems Laboratory with funds provided by the Federal Aviation Administration Aviation Weather Research Program (Sankey et al. 1997). Statistical results for the 1999 CCFP is described in Mahoney et al. 2000a and Mahoney et al. 2000b.

1. Description of the Forecast Products

Collaborative Convective Forecast Product (CCFP) - This experimental forecast was generated from input provided by participating airline, Center Weather Service Units (CWSU) and Aviation Weather Center (AWC) meteorologists, and staff at the FAA Air Traffic Control System Command Center. The CCFP product was generated as a graphic depicting forecasts of convective activity valid at specific times. Forecasts were issued at 0300, 1500, 1900, and 2300 UTC with 2-, 4-, and 6-h lead times.. The forecast product was ultimately used by decision-makers for routing traffic around convective areas (Phaneuf and Nestoros 1999).

Preliminary Forecast - The Preliminary forecast (Phaneuf and Nestoros 1999) was generated by AWC meteorologists as a precursor to the CCFP. The forecast was made available to the CCFP participants, who evaluated the forecast and provided feedback that was ultimately incorporated into the CCFP. Forecasts were issued at 0200, 1400, 1800, and 2200 UTC with 3-, 5-, and 7-h lead times.

2. Verifying Observations

The National Convective Weather Detection Product (NCWD) and the Convective SIGMETs (C-SIGMETs), used to verify the CCFP and Preliminary forecasts are described here. In the 2000 evaluation, the C-SIGMETs were added as verifying observations, while radar and lighting data used independently were discontinued (Mahoney et al. 1999).

The NCWD (Mueller et al. 1999) combines a 2-dimensional mosaic of radar VIL data (a change from using radar reflectivity in 1999) with radar-derived cloud top data and a grid of lightning detections from the NLDN. The cloud top data primarily are used to remove anomalous propagation and ground clutter, and the lightning data help to keep the NCWDP current, since lightning data have a lower latency than radar data. The NCWDP fields were available on a 4-km grid, with convective storms delineated by a threshold of 40 dBZ, or more than 3 lightning strikes in 10 minutes.

The C-SIGMETs, generated by AWC forecasters, is an operational text forecast of convective activity. The forecast is issued hourly and is valid for up to 2 h (NWS 1991). However, in the evaluation of the CCFP and the Preliminary forecasts, the C-SIGMET is treated as a detection forecast, valid only at the issuance time. These forecasts are issued to capture severe or embedded thunderstorms that are either occurring or forecasted to occur for more than 30 minutes of the valid period. C-SIGMETs are also issued for thunderstorm lines and areas of active thunderstorms affecting at least 3,000 square miles.

3. Mechanics

Before forecasts were matched to observations, a 20-km grid was laid over the observation field. Each box on the overlay grid was assigned a *Yes* or *No* value depending on whether a positive observation fell within the 20-km box. For each 20-km box, the criteria used in this study to define a positive observation for each type of verification observation included: 1) one 4-km box of NCWDP with a dBZ greater than 40 that fell in the 20-km box and 2) a portion of a C-SIGMET interesting a 20-km box. The same procedures were performed for the forecasts, with a 20-km box labeled with a *Yes* forecast when any part of the forecast polygon intersected that box. If a forecast polygon did not intersect the 20-km box, then a *No* forecast was assigned to that box. Other grid sizes have been tested. Results are presented in Mahoney et al. 2000b.

A filter was applied to the NCWDP observations in an attempt to screen out isolated short-lived convection. In this case, a 20-km box was assigned a *Yes* observation only when 12 or more 4-km NCWDP boxes meeting the 40 dBZ and greater criteria were activated. Otherwise, a *No* observation was assigned to the 20-km box.

Once this process was complete, each box on the 20-km observation grid was matched to each 20-km box on the forecast grid. This technique produced the forecast/observation pairs used to generate the verification statistics. For example, a *Yes* forecast box and a *Yes* observation box would produce a *Yes-Yes* pair. Similarly, a *Yes* forecast and *No* observation would produce a *Yes-No* pair, and so on, filling in the four cells of the statistical contingency table (described further in Section 4).

Observations that fell within a 10-minute time window prior to the forecast valid time were mapped to the 20-km grid and used for verification. A second time window, $\pm$ 10 minute window was added to the 2000 evaluation where observations that feel within this 20 minute window were mapped to the 20-km grid used for verification.

Two forecasting domains were applied to the CCFP and Preliminary forecasts. First was the *national* domain where the area covered extended from the Atlantic Ocean on the east to the Pacific Ocean on the west, and from the U.S.-Canadian border on the north to the U.S.- Mexican border on the south. The second domain included the *CCFP* domain used in the 1999 evaluation where the boundaries extended west from the Atlantic Ocean to a north-south line east of Denver, Colorado as shown in Fig. 1.

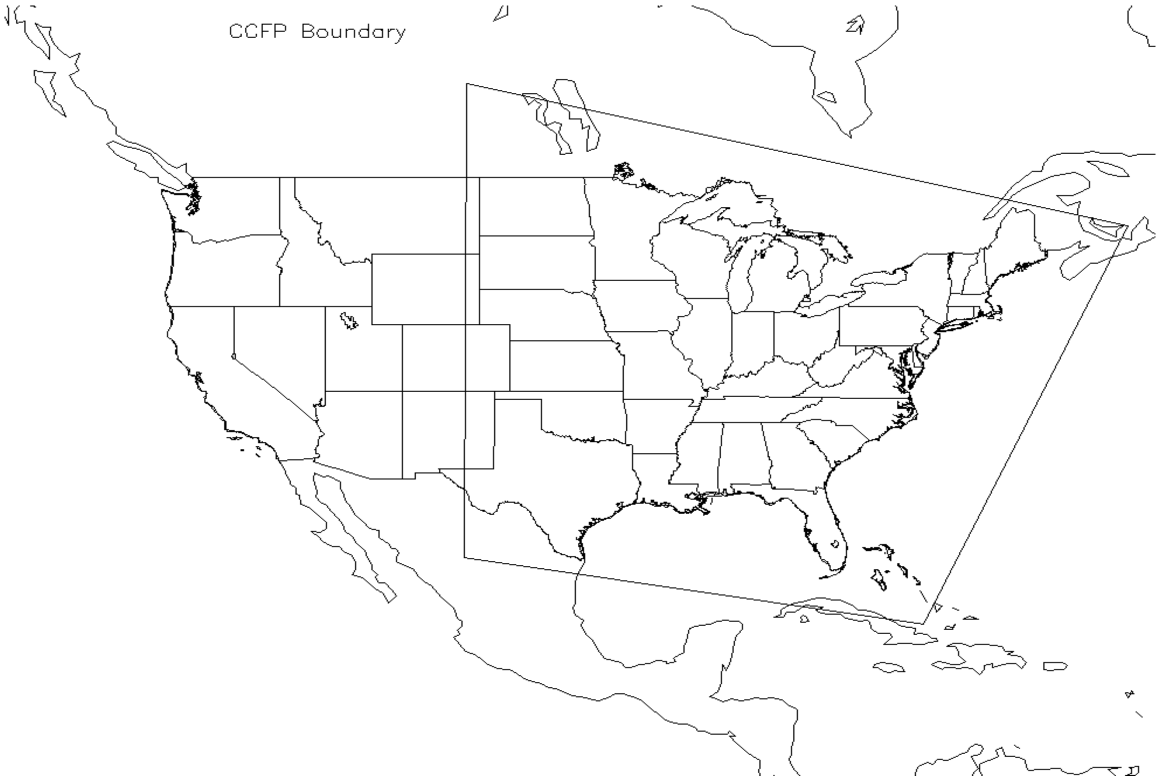

Figure 2. Solid line represents geographic boundary defined for the CCFP domain used in this exercise.

4. Verification Methods and Stratifications

Verification methods are based on standard verification concept (Murphy and Winkler 1987 and Brown et al. 1997). The *Yes/No* forecast/observation pairs were used to create counts, to fill in a 2x2 contingency table like the one shown in Table 1 (Brown et al. 1997). That is, for a given forecast, all of the 20-km boxes with a *Yes* forecast and a *Yes* observation were counted to obtain YY; all of the 20-km boxes with a *Yes* forecast and a *No* observation were counted to obtain YN; and so on. Individual forecast contingency tables were accumulated to obtain tables representing particular days, months, or other periods (including the entire forecast period).

Table 1. Basic contingency table for evaluation of dichotomous (e.g., Yes/No) forecasts. Elements in the cells are the counts of forecast-observation pairs.

Forecast	*Observation*		*Total*
	Yes	***No***	
Yes	YY	YN	YY+YN
No	NY	NN	NY+NN
Total	YY+NY	YN+NN	YY+YN+NY+NN

Table 2 lists the verification statistics that were included in the evaluation, with PODy, PODn, and FAR representing the basic verification statistics. General descriptions of these statistics include the following:

- PODy and PODn are estimates of the proportions of *Yes* and *No* observations, respectively, that were correctly forecast (e.g., Brown et al. 1997).
- FAR is the proportion of *Yes* forecasts that were incorrect.
- Bias is the ratio of the number of *Yes* forecasts to the number of *Yes* observations, and is a measure of over- or under-forecasting.
- The Critical Success Index (CSI), also known as the Threat Score, is the proportion of hits that were either forecast or observed.
- The True Skill Statistic (TSS) (e.g., Doswell et al. 1990) is a measure of the ability of the forecast to discriminate between *Yes* and *No* observations; TSS also is known as the Hanssen-Kuipers discrimination statistic (Wilks 1995).
- The Heidke Skill Score (HSS) is the percent correct, corrected for the number expected to be correct by chance.
- The Gilbert Skill Score (GSS) (Schaefer 1990), also known as the Equitable Threat Score, is the CSI corrected for the number of hits expected by chance.
- The % Area is the percent of the total possible area that had a *Yes* forecast (Brown et al. 1997).

Table 2. Verification statistics used in this study.

Statistic	***Definition***	***Description***
PODy	YY/(YY+NY)	Probability of Detection of “Yes” observations
PODn	NN/(YN+NN)	Probability of Detection of “No” observations
FAR	YN/(YY+YN)	False Alarm Ratio
CSI	YY/(YY+NY+YN)	Critical Success Index
Bias	(YY+YN)/(YY+NY)	Forecast Bias
TSS	PODy + PODn – 1	True Skill Statistic
HSS	[(YY+NN)-C1]/(N-C1), where N=YY+YN+NY+NN C1=[(YY+YN)(YY+NY) + (NY+NN)(YN+NN)] / N	Heidke Skill Score
GSS	(YY-C2)/[(YY-C2)+YN+NY], where C2=(YY+YN)(YY+NY)/N	Gilbert Skill Score
% Area	(Forecast Area) / (Total Area) x 100	% of the area of the continental U.S. where convection is forecast to occur

The convective areas defined by the CCFP were stratified using 4 types of criteria: maximum tops (e.g. height), areal coverage, probability of occurrence, and growth rate. No attempt was made to verify the growth rate. The statistical results were also stratified using these categories. The stratification criteria and their categories are:

1) Maximum Tops (Height). Statistics were stratified by max tops.

- At or above 25,000 ft;
- 25 - 31,000 ft;
- 31 - 37,000 ft; and
- Above 37,000 ft.

2) Areal Coverage. Statistics were generated for each of the coverage categories, however, no attempt was made to vary the observation criteria within a specific coverage category. The actual coverage was computed by summing the 20-km boxes for the observations and is available on the daily displays.

- 25% and above;
- 25 - 49%;
- 50 - 74%; and
- 75% and above.

3) Probability of Occurrence. Statistics were stratified by probability of occurrence.

- High (70 - 100%);
- Medium (40 - 69%); and
- Low (1 - 39%).

5. References

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