J6.5 IMPACTS OF RESOLUTION ON GRIDDED PROBABILITY THUNDERSTORM FORECAST GUIDANCE

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1. INTRODUCTION

The Meteorological Development Laboratory (MDL) is responsible for producing the Model Output Statistics (MOS) guidance (Glahn and Lowry 1972). As part of this guidance, equations to predict the probability of thunderstorms were derived for the contiguous U.S. (CONUS) by using cloud-to-ground lightning data and output from numerical weather prediction models. Output from both the Global Forecast System (GFS; Iredell and Caplan 1997) and the Eta model (Black 1994) was used to generate forecast equations.

As the horizontal resolution of the numerical models is increasing, we are updating our thunderstorm equations to reflect the increase in resolution in both time and space. Our latest research concentrates on issues related to shorter temporal and smaller spatial resolutions. We are developing a set of Eta-based probability forecast equations for both a 40-km grid spacing and, possibly, a 20-km grid spacing over the CONUS. In addition, we are increasing the temporal resolution of both the GFS and Eta guidance by generating forecast equations for 3-h forecast periods.

Many interesting issues have arisen from the increase in the temporal and spatial resolution. Different user communities have different guidance needs. Guidance developed to support the Storm Prediction Center's (SPC) convective outlook product may not require the same resolution as guidance intended for the aviation community. Should we try to meet the needs of all users with one complete system, or is it more practical to develop packages with different resolutions customized for different user communities? In previous work, we have seen that as the resolution of the guidance increases in time or space, the range of the probability values becomes smaller. In general, as the grid box and time period become smaller, the probability of the event occurring in the grid box during the time period is also smaller. At what point is the probability value too small to be useful? Another issue is the areal coverage of the forecasts. Will the forecast patterns for a 40- and 20-km product look similar, even if the actual values of the probabilities are different? Are seasonal and diurnal variations in lightning climatology important in determining increases in both the temporal and horizontal resolution? Finally, comparing the skill of the guidance at different resolutions is difficult. Can a meaningful objective measure be employed when the guidance is on different grids? As we increase the resolution of the guidance, we may produce more detail in the forecasts, but the verification scores may not reflect an increase in skill if the higher resolution forecasts have position or timing errors. Some of these questions are examined in this paper, and examples of the guidance at different resolutions valid during a thunderstorm outbreak are shown.

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2. OBSERVED LIGHTNING RELATIVE FREQUENCIES

In the current MOS system, the thunderstorm predictand is defined as the occurrence of one or more cloud-to-ground lightning strikes in a grid box during the forecast period. Observations of cloud-to-ground lightning data from the National Lightning Detection Network (NLDN) are used to define the events, and to derive lightning relative frequencies for use as potential predictors in the MOS thunderstorm development. Although the lightning data are random in space and time, each strike report contains information including the latitude, longitude, and time of the strike. In earlier Eta- and GFS-based MOS thunderstorm developments (Hughes 2001, 2002), a grid of 113x89 blocks, each approximately 48 km on a side covering the CONUS, was used to locate the observed lightning data.

The NLDN data set is a continuous record from January 1, 1988, through the present. The network was upgraded in 1994 (Cummins et al. 1998), so data before 1994 are not included in the development of the observed relative frequencies. Observed monthly relative frequencies are generated for the same space and time resolutions as the desired thunderstorm guidance. In previous developments, 5 years of lightning data were placed on the 48-km grid to develop monthly lightning relative frequencies. Millions of lightning reports were processed, and it was assumed there were no missing reports. These observed lightning reports were summed for 6-, 12-, or 24-h periods for each month. With the collection of more observed lightning data, and the requirement of the guidance at a higher resolution, the relative frequencies have been updated to reflect these changes. The most recent cloud-to-ground lightning relative frequencies processed cover 3- and 6-h time periods on a 20-km grid, and include 8 years of observations. The characteristics of the observed relative frequencies over differing time periods and different times of the year may give the first indications of the predictability of the event.

Figures 1 and 2 show two extreme examples of the distribution of thunderstorm events. Figure 1 represents the lightning climatology on a 40-km grid for a 24-h period during July. Figure 2 is a map of lightning relative frequencies on a 20-km grid covering the 6-h time period from 1800-0000 UTC during January. On the 40-km grid, lightning is expected more than 80% of the time during a 24-h period in July over parts of Florida and New Mexico. Lightning is a much rarer event, however, when seen on a 20-km grid during a 6-h period in January. Only in a few grid boxes do the relative frequencies exceed 5%.

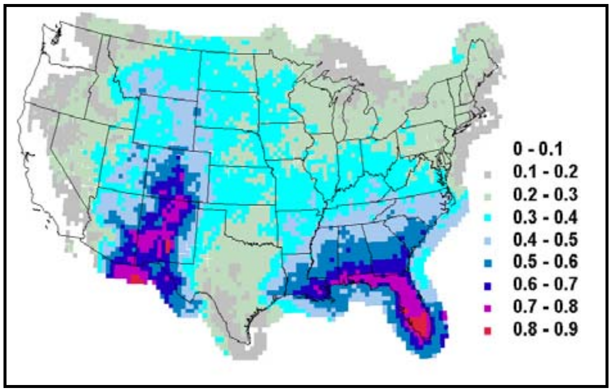

Figure 1. Monthly 24-h (ending at 0000 UTC) cloud-to-ground lightning relative frequency for July on a grid at 40 km resolution.

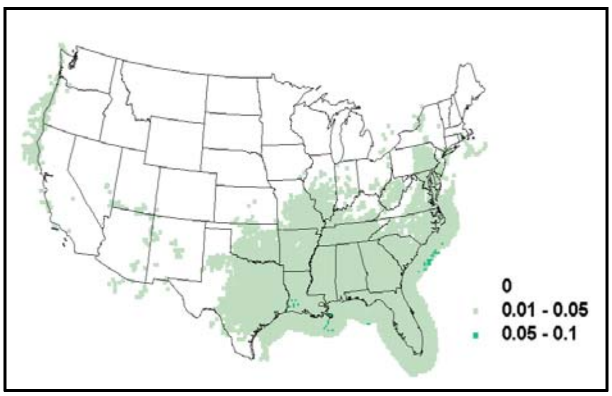

Figure 2. Monthly 6-h (ending at 0000 UTC) cloud-to-ground lightning relative frequency for January on a grid at 20 km resolution.

3. GFS AND ETA-BASED MOS THUNDERSTORM GUIDANCE

MOS forecast equations were developed by applying linear multiple regression techniques to relate the occurrence of thunderstorms to forecast variables from the numerical model. A regionalized approach was used for the equation development, meaning data for all grid boxes were combined into a single region. Thunderstorm probability forecasts are currently produced from these equations for 6-, 12-, and 24-h periods from all four cycles of the GFS, out to 84 hours in advance. Thunderstorm guidance is also available from our extended range system based on 0000 UTC GFS model output for 12- and 24-h periods out 192 hours in advance. In addition to the GFS systems, thunderstorm probability forecasts are generated from the 0000 and 1200 UTC cycles of the Eta model for 6-, 12-, and 24-h periods out to 60 hours in advance.

For the past year, development has been underway to update the current set of Eta- and GFS-based gridded thunderstorm guidance with additional model data, and increased time and space resolution. Some of the upcoming changes include using a 40-km grid, more commonly in use at NWS Weather Forecast Offices (WFOs), and the addition of 3-h time periods. Testing is also underway to assess the feasibility of developing 3- and 6-h forecast equations on a 20-km grid. A comparison of forecasts at these differing resolutions is provided later in this paper.

4. USER REQUIREMENTS

Our goal in developing any of the MOS guidance products is, of course, to meet the needs of the forecasters. For the past several years, SPC has been particularly helpful by providing feedback and requirements for thunderstorm guidance. SPC is clear in its definition of a thunderstorm or severe weather event. SPC's probabilistic convective outlook products represent the probability of one or more events occurring within 25 miles of any point, for one, two, or three days in advance. Our current suite of thunderstorm products, developed on a 48-km grid, and covering forecast periods of 6-, 12-, and 24-h periods out to 84 hours in advance, was developed with those needs in mind.

The needs of the aviation community are somewhat different. Aviation forecasters require guidance valid for smaller forecast periods, for example, 1-, 2-, 3- or 6-h time periods, usually valid out to no more than 24 hours in advance. MDL currently produces a 0-3 h probability of lightning forecast product (Kitzmiller 2002), but there is still a need for additional guidance products. Plans are underway to update the Local AWIPS MOS Program (LAMP) which will provide more detailed short-range guidance for the aviation community (Glahn and Ghiradelli 2004). Requirements passed along to us from the Aviation Weather Center (AWC) include guidance on grids with 20-km, or even 10-km resolution, and forecast projections covering 6 hours or less. As mentioned earlier, we are testing MOS thunderstorm guidance developed on a 20-km grid and valid for 3- and 6-h time periods out to 36 hours in advance.

Finally, in the National Digital Forecast Database (NDFD), the NWS is providing forecasts at time scales as small as hourly and space scales of a few kilometers (Glahn and Ruth 2003). Less emphasis will be placed on our traditional MOS text messages at WFOs, as we provide gridded, or digital, forecasts on matching scales.

How do we generate and disseminate probabilities of thunderstorms in an intelligent way, so the values of the probabilities have enough magnitude to be useful, and indicate some level of confidence? Should we expect the probabilities valid for a 5-km grid box to behave in the same manner as probabilities valid for a 40-km grid box?

As previously mentioned, the definition of a thunderstorm event is the probability of one or more cloud-to-ground lightning strikes in a grid box, over the desired time period, whether 1 hour or 24 hours. As we increase the resolution of the guidance, both in time and space, the magnitude of the probabilities will decrease, as the likelihood of an event at an exact time and point in space approaches zero. The next section of this paper illustrates some differences in the forecast characteristics of probability guidance developed on different grids.

5. AUGUST 26, 2002 CASE STUDY

Strong daytime heating led to widespread convective activity on August 26, 2002, late in the afternoon through early evening. Strong instability resulted in 11 tornadoes and 300 reports of damaging wind or hail during the outbreak. During a single 24-h period from 0000 UTC on August 26 through 0000 UTC on August 27, 2002, more than 246,000 cloud-to-ground lightning strikes were recorded by the NLDN. More than 60,000 strikes occurred in just the 3-h period ending at 0000 UTC on August 27.

Two years of Eta model output, from July 2000 - October 2001, were used to develop MOS thunderstorm equations for the summer season (July 1 - October 15). Equations were developed for 3-h periods on both a 40- and 20-km grid. Although the Eta model output fields and lightning observations were interpolated to different grids, the regression program selected similar predictors for the two systems, which included the vertical velocity, the lifted index from 950 hPa, the equivalent potential temperature, and the product of the K-index and observed relative frequency of lightning. Forecasts were generated on independent data from each set of equations for the summer of 2002.

MOS thunderstorm probability forecasts and observations of lightning valid for the 3-h period ending at 0000 UTC on August 27, 2002, are shown in Fig. 3. The map in the top left portion of the figure shows the forecasts on a 40-km grid, contoured every 10%, with maximum values exceeding 70%. The map in the top right portion of the figure shows the forecasts on the 20-km grid, also contoured every 10%. Notice the difference in coverage and magnitude, as the forecasts on the 20-km grid barely reach 40%. The diagram in the lower-left portion of the box contains the observed lightning strikes, located on a 20-km grid, during the forecast period. Finally, the lower right map of Fig. 3 shows the same forecasts generated on the 20-km grid, with the contouring interval changed from every 10% to every 5%. The coverage and patterns are almost identical to the forecasts generated on the 40-km grid. No changes were made to the 20-km forecasts, only the contour intervals used for the display were changed.

It would not be wise to derive too many generalities from one case study, but it is interesting to see how

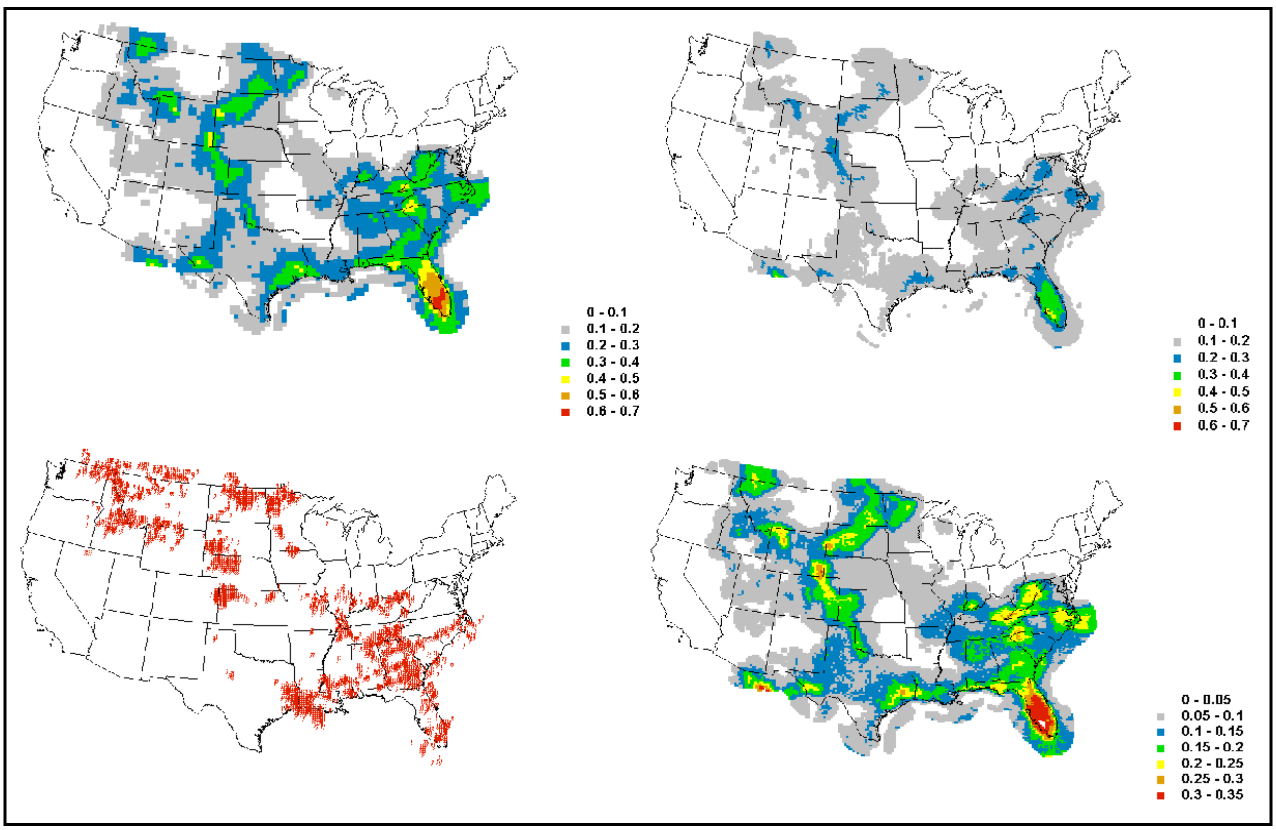

Figure 3. Comparisons of Eta MOS 21-24h probability of thunderstorm forecasts and cloud-to-ground lightning observations for the period ending at 0000 UTC on August 27, 2002.

remarkably similar the forecasts are to one another, except for their difference in magnitude. If a user simply looks at a text message containing thunderstorm probability values valid for a specific location, he or she may be inclined to regard the guidance on the finer grid as being less skillful, simply because the probability values are smaller. It will be a challenge for us to find a way to convey the usefulness of the probabilities on smaller grids. This could involve scaling the probability values, educating the users about the significance of the probability values as the resolution increases, and increasing and improving our dissemination of graphical products.

5. EVALUATION OF PROBABILITY FORECASTS

Work is still ongoing to determine the best way to compare the skill of guidance developed on different grids. One approach taken thus far has been to look at the percentage of improvement over climate in the Brier score. This is done by matching the observations and climatic relative frequencies to the same grid as the forecasts, thereby normalizing the scores before comparing the skill of different forecast systems. Verification results from this study will be presented at the conference.

6. FUTURE WORK

In 2004, the current set of Eta MOS thunderstorm guidance will be upgraded for the 0000 and 1200 UTC cycles, by using Eta model output archived at a higher resolution to generate forecasts valid on a 40-km grid. Additional projections out to 84 hours in advance, for 6-, 12- and 24-h periods will be added to the system . Plans are also underway to develop a limited set of Eta-based thunderstorm guidance for Alaska. Equations will also be developed from Eta model output to generate guidance for 3-h time periods, beginning with the 3-6 h forecast projection and ending with the 33-36 h projection. This work is in support of aviation needs, and as possible input to the LAMP system. These equations may be developed on a 40- or 20-km grid, or both, in accordance with available resources and user requirements. Plans are also underway to develop a limited set of Eta-based thunderstorm guidance for Alaska.

To accommodate the need for high-resolution digital guidance, a project is underway to develop a MOS system on a grid with 2.5- to 5-km horizontal resolution (Dallavalle et al. 2004). This MOS system is intended to support WFO forecasters as they prepare products for NDFD. This project will include the development of thunderstorm probability guidance on the high-resolution grid. For additional information on the progress of this work, as well as additional presentations and verification results when they are completed, please visit:
http://www.nws.noaa.gov/mdl/synop/topics/tsvr .

Acknowledgments

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