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12-Hour Thunderstorm Probability Forecasts for Alaska

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FIRST BULLETIN ON THIS SUBJECT

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This bulletin, which was prepared by Mr. Ronald M. Reap of the Techniques Development Laboratory, describes the new Model Output Statstics (MOS) 12-hour thunderstorm probability forecasts for Alaska that are transmitted via high speed line from the National Meteorological Center (NMC). The forecast equations were derived from a developmental sample containing lightning predictand data and predictors from NMC's operational Nested Grid Model (NGM). Lightning location data for Alaska were obtained from the Bureau of Land Management's (BLM's) automated network of direction finding stations.

Implementation of thunderstorm probability forecasts from the new equations took place in the NMC job stream on May 16, 1990. The forecasts for the May 15 to September 15 warm season will be available twice daily to Alaska, starting in May 1991.

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THUNDERSTORM PROBABILITY FORECASTS FOR ALASKA

by Ronald M. Reap

1. INTRODUCTION

This bulletin describes the 12-hour (hr) thunderstorm probability forecasts for Alaska. The probability equations were developed from NGM forecast fields and lightning location data from the BLM automated network. The forecasts are valid for the 6-18 hr and 30-42 hr intervals following 1200 UTC and the 18-30 hr interval following 0000 UTC. The forecast equations give the probability of two or more cloud-to-ground lightning strikes per 47 kilometer (km) grid block during the 12-hr valid periods. All forecast intervals are centered on 0000 UTC (1500 Local Standard Time), the time of maximum thunderstorm activity in Alaska (Reap, 1990). Starting in May 1991, probability forecasts for the May 15 to September 15 warm season period will be transmitted twice daily, at approximately 0400 and 1600 UTC, to Alaska via high-speed digital line from NMC. The WMO header for this bulletin is YDTA98 KWBC.

The approximate geographical area for which the forecasts are generated is shown in Figure 1. The new forecasts are similar in form to the thunderstorm probability forecasts based on lightning location data that were implemented in 1986 for the western United States (National Weather Service (NWS), 1986; NWS, 1987). The development of thunderstorm probability forecast equations for Alaska was initiated in September 1989 in response to a request from the Alaska Region Headquaters' Scientific Services Division. Objective thunderstorm guidance was not available to forecasters at that time. The primary use of the guidance is to identify in advance regions of potential wildfire activity caused by lightning.

2. DEVELOPMENT

2a. Method

Previous evaluations of lightning location data from automated networks across the United States have clearly revealed the ability of lightning data to accurately delineate convective activity (Reap, 1986; Reap and MacGorman, 1989). As a result, thunderstorm forecast equations for Alaska were derived by applying screening regression techniques and the MOS approach (Glahn and Lowry, 1972) to relate the lightning predictand data to large-scale meteorological predictors obtained from NMC's NGM.

2b. Predictand/Predictor Sample

Lightning location data from the BLM network were obtained for the warm season period from May 1st through September 30th for the years 1987-1989. The 3-year sample contained a total of 82,279 flashes for the 284 days with recorded data during the period of our analysis. Following initial processing, the lightning data were referenced to a grid covering Alaska. The grid mesh length is nominally 47 km. Thunderstorm frequency, or the fraction of 47 km grid blocks with two or more flashes to ground, was 3.3% for the 12-hr forecast intervals in the three warm seasons used in the developmental sample. Frequencies for the three 12-hr forecast intervals are identical since all intervals cover the same period of the day.

The predictor sample included a standard set of over 100 basic and derived predictors from the NGM. The predictors were offered to the screening regression procedure as possible indicators of cloud-to-ground lightning over Alaska. The analysis of lightning data and forecast model fields was limited to grid blocks within the state landmass (Fig. 1); no blocks over water were used in the regression procedure.

2c. Forecast Equations

Forecast equations were developed by use of linear screening regression analysis on the developmental sample of archived NGM forecasts and lightning location data. Table 1 shows the 12 predictors in the forecast equations for the 6-18 hr and 30-42 hr projections following 1200 UTC. The most significant difference in the selection of NGM predictors, compared to thunderstorm equations developed for similar mountainous regions in the western United States (NWS, 1986), is the marked emphasis on the static stability over the Alaskan interior. In most previous developments, the K stability index (George, 1960) was usually the leading term for predicting general thunderstorm activity. Table 1, however, shows that thunderstorms over Alaska are most highly correlated to the 850-500 mb temperature lapse rate, the thermal term in the K index. The importance of the vertical temperature profile is clearly shown in Table 1 by the selection of temperature variables at several levels. The emphasis on the static stability reflects the fact that adequate moisture is almost always available for convective activity over Alaska. Air-mass thunderstorms associated with intense solar heating and little vertical wind shear are the norm during the abbreviated Alaskan summer (Grice and Comisky, 1976). Thunderstorms occur almost every day during the June to July period, when about 90% of the lightning strikes also occur (Reap, 1990). Moisture terms appear in Table 1, but are generally somewhat down the list in terms of importance. On any given day, however, local moisture convergence could be very important to the production of high flash accumulations (Reap, 1990).

The sine and cosine of the day of the year in Table 1 represent climatic contributions that tend to maximize the thunderstorm probabilities in mid-summer. Freezing level height is a measure of the proximity of cloud electrical charge to ground and, hence, a measure of the likelihood of lightning discharges to ground. Interpreting the predictors shown in Table 1 in a general physical sense, we see that maximum thunderstorm probabilities exist at climatically favorable times of the year where: 1) the atmosphere is statically unstable; 2) local maxima of wind or moisture convergence occur; 3) southerly winds are found between 850 and 500 mb in association with an upper trough; and 4) sufficiently deep moisture exists for significant convection to occur.

2d. Verification

Typical examples of the accuracy and reliability (bias) of the 12-hr operational probability forecasts for Alaska are shown in Figure 2. The verification statistics were computed for the 6-18 hr projection following 1200 UTC from the dependent data samples for 1987 and 1988. Past experience in verifying thunderstorm probability forecasts has shown no significant degradation in performance on independent data. As usual, the solid, bold diagonal line in Figure 2a represents perfect forecast reliability or zero bias. As shown in Figure 2a, the

6-18 HR	30-42 HR
500-850 mb Temperaure Lapse Rate	500-850 mb Temperature Lapse Rate
700 mb Potential Temperaure	700 mb Potential Temperature
Height of Freezing Level	Height of Freezing Level
950 mb Wind Convergence	700 mb Relative Humidity
K Stability Index	500 mb Temperature
Cosine Day-of-Year	Sine Day-of-Year
500 mb Height	950 mb Wind Convergence
500 mb v-Wind Component	1000 mb Temperature
850 mb Moisture Convergence	500 mb v-Wind Component
950 mb Moisture Convergence	850 mb v-Wind Component
1000 mb Temperature	950 mb Moisture Convergence
300 mb Potential Temperature	850 mb Moisture Convergence

Table 1. NGM predictors in probability equations for 6-18 hour and 30-42 hour projections following 1200 UTC.

forecasts for the 6-18 hr projection were highly reliable for the dependent data. The expected accuracy of categorical forecasts for the 6-18 hr projection is shown in Figure 2b. These statistics compare favorably to those obtained for the western United States (NWS, 1987) in a successful development effort for a mountainous region similar to Alaska.

The range of forecast probabilities in Figure 2b is somewhat low, 0-22%, reflecting the relatively low frequency of thunderstorm occurrence in Alaska compared to that found in the contiguous United States. The magnitude of the probability forecast is not, however, nearly as important as its ability to accurately delineate the potential areas of thunderstorm activity. The sample forecast in Figure 1 can be used to illustrate the effect of selecting one of the various threshold values shown in Figure 2b. The threshold values are, in effect, probability values that could be selected by the forecaster to prepare categorical (yes/no) forecasts of thunderstorm activity. If, for example, a threshold value of 0.11 (11%) is selected, we find that the area defined by this probability isoline would, on average, contain about three-fourths of the recorded lightning strikes to ground, as shown by the probability of detection (POD) of 0.75 in Figure 2b. Referring to Figure 1, we find that the 11% probability isoline does in fact contain most of the lightning flashes recorded that day. Selection of an appropriate threshold value by the local forecaster is ultimately based on experience gained by using the probability guidance over an extended period of time.

3. PRODUCT CONSIDERATIONS

Although the sample forecast in Figure 1 is shown in graphical form, the 12-hr probabilities are actually transmitted as non-displayable gridded data, i.e., grid point values in the GRIdded Binary (GRIB) format (Stackpole, 1991). The gridded forecasts are transmitted from NMC via high-speed digital line to the PRIME computer located at the Weather Service Forecast Office in Anchorage where initial processing occurs. The data are subsequently transmitted to the 25 workstations in the Anchorage, Fairbanks, and Juneau forecast offices with personal computer workstations. The gridded data are then decoded, contoured, and displayed for immediate use by local forecasters.

4. FORECAST IMPLICATIONS

As is the case with all MOS forecasts, the probability forecasts for Alaska are dependent on the accuracy of the NGM forecasts used as input. Despite the high resolution of the lightning predictand data, which can provide climatic insights on the mesoscale with respect to thunderstorm activity over Alaska (Reap 1990), the ultimate resolution of the probability forecasts is determined by the relatively smooth large-scale forecast fields from the NGM. Therefore, the probability guidance may, on occasion, have to be used with caution if the forecaster detects possible errors in the model predictions. In general, the guidance should be used to identify large-scale regions of expected thunderstorm activity (or the lack of activity) one to two days in advance.

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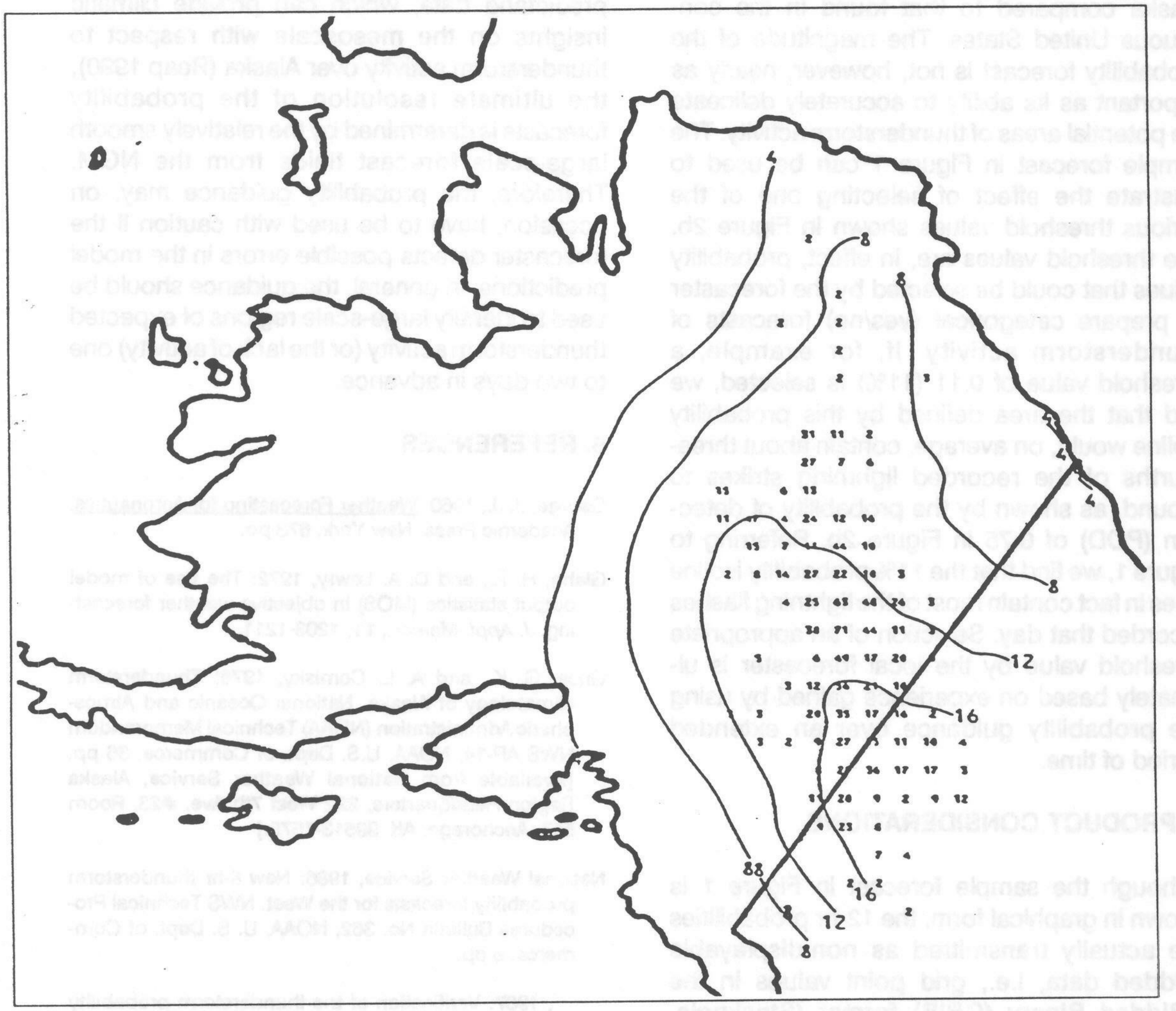

Figure 1. Probabiltiy of two or more lightning strikes during the 6-18 hour interval following 1200 UTC on June 11, 1988. Number of observed ground strikes is plotted for each grid block reporting two or more strikes.

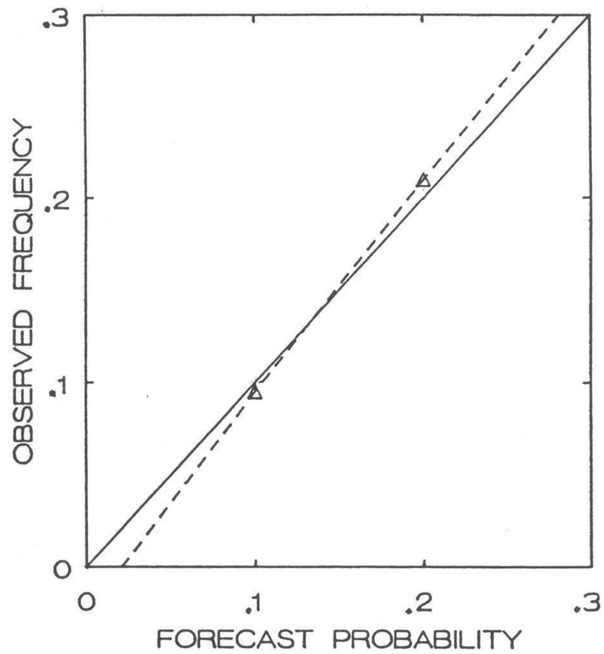

Figure 2a. Observed frequency of two or more lightning strikes per 47 kilometer grid block as a function of forecast probability.

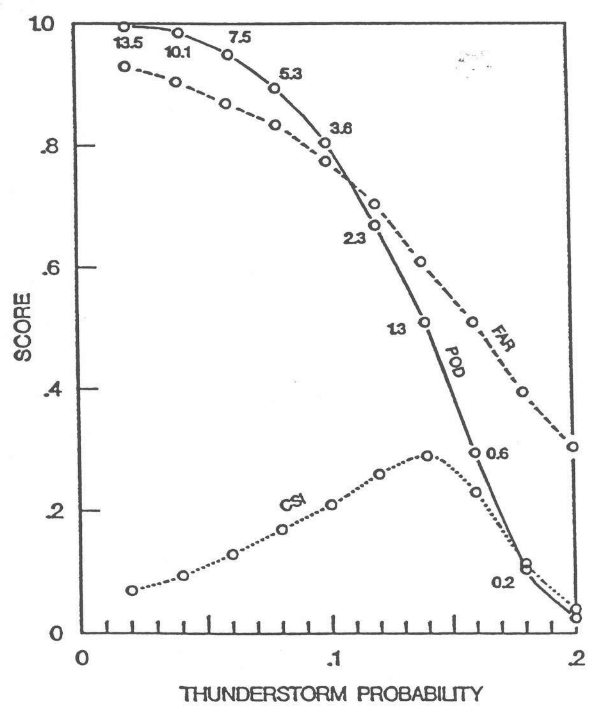

Figure 2b. Critical success index (CSI), false alarm ratio (FAR), and probability of detection (POD) for categorical thunderstorm occurrence based on various probability thresholds. Bias is shown by numbers plotted along POD curve.