SUMMER 1993 MEDIUM RANGE FORECASTS FOR THE UNITED STATES: A PERIOD OF FLOOD AND DROUGHT

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Summary: Following very wet antecedent autumn and spring seasons, the midwest section of the U.S. experienced unprecedented summer rainfall. The flooding of the Mississippi, Missouri and other drainages in the region led to the loss of dozens of lives and an estimated $10B (US) in damage. Official 6-10 day precipitation forecasts over the U.S. midwest were quite good during the catastrophic flooding which occured there during June through August. This paper discusses some relevant details of the observed conditions, the available guidance, including ensemble forecasts, and the preparation of official forecasts during this period.

1. INTRODUCTION

Official forecasts of Northern Hemisphere 500 hPa height and surface temperature and precipitation for the continental United States, averaged over days 6-10 in the future, are prepared and issued each Monday, Wednesday and Friday at the National Meteorological Center. As is illustrated in Figure 1, the operational forecast process begins with the formulation of a weighted average of 500 hPa height forecasts. Participants in the average include an optimally weighted average of the 13-members of the MRF ensemble forecast, as well as forecasts from ECMWF, UKMO, a barotropic model and a MRF forecast which has been corrected, via regression, for its biases during the recent past. Forecasts of temperature (T) and precipitation (R) are then formulated through the use of guidance consisting of specifications (a perfect prog technique) and accumulated model precipitation, respectively. Forecasters make use of the recent skill of the many forecast tools which are available in order to subjectively modify the guidance in order to produce the final forecast maps. Finally, these products are disseminated.

2. OBSERVED CONDITIONS

The Palmer Drought Severity Index (PDSI) provides a measure of long-term soil moisture conditions. Figure 2 shows that soil moisture as measured by the PDSI was high in both the Midwestern drought region and the drought region in the Southeast for the three seasons immediately prior to the summer. This widespread wetness was due, at least in part, to warm ENSO conditions at the time. Also clear from Figure 2 is the onset of drying (moistening) conditions over the Southeast (Midwest) starting in mid-April and continuing into the autumn. Figure 3 shows the spatial distribution of statewide average

PDSI as of early autumn, 1993. Excessively wet conditions are evident over the Midwest and the Southwest, while dry conditions prevail over the Southeast. Though not shown in Figure 2, surface temperatures were unusually cool over the wet region and extremely warm over the drough region. Figure 4 shows the average observed 500 hPa map for June-July, 1993. The height anomaly over the Northwest was more than four standard deviations larger than average.

The contrast between the cool-wet and hot-dry regions implied by Figure 3 effectively comprised a frontal boundary between the two regions. This strong surface temperature gradient contributed to an anomalous 200 hPa jet over the Southwest and the Central and Northern Great Plains during the summer. At lower levels, large amounts of moisture flowed from the Gulf of Mexico into the Midwest. Moisture from the saturated ground surface appears to have been a major source of moisture as well. The presence of the frontal surface, together with the strong jet and the vast supplies of moisture represented a most unfortunate and volatile combination which spawned frequent heavy precipation events. Many localities received an amount of precipitation equal to their annual average in a single week.

3. FORECASTS

While the precipitation guidance provided by the MRF over the Southeast was, by and large, within expecations, that over the Midwest was not. The primary tool for precipitation, designated "MR8" in this paper, is the accumulated precipitation for days 6-10. Figure 5 shows a time series of forecast and verifying observed precipitation categories averaged over 16 stations in the Midwest and subjected to a 7-day running mean. Note that days not explicitly covered by the official forecasts are assigned a forecast value persisted from the most recent prior day or two. Also, note that the three time series depicted on Figure 5 do not all begin at the same time. The curve for Official precipitation forecasts begins in early November, 1992. That for MR8 precipitation begins January 1, 1993, while that for the observed precipitation category begins April 1, 1993.

Precipitation categories are assigned values of 1 for below-median, 2 for near-median and 3 for above-median. The categories, or class limits, are determined separately for each station for each month of the year. The class limits for a humid station (e.g. one for which the occurences of no precipitation is less than 34 percent), such as those in the Midwest, are defined so that during one third of the 5-day periods during the climatological epoch the total precipitation at a station occurs in each of the three categories. Using only three categories throws away any information about the amplitude of the extremes but is useful in the current context to illustrate the biases in the forecast guidance.

During April the MR8, Official forecasts and the verifying observed conditions agreed fairly well.

However, a tendency for persistent wetness beginning in May was consistently forecast by the MR8 guidance to be dry. By mid-June forecasters were consistently, and appropriately, forecasting wet conditions while the guidance continued to be too dry by about 1 category. In fairness it should be noted that nearly all NWP models, within and outside of NMC had similar problems at this time. Subsequently, work carried out at ECMWF by Alan Betts has indicated that poor handling of soil moisture by the models was the culprit (Eugene Rasmussen, personal communication).

The reason for the success of the forecasters came not only from the observation that the model was too dry, but also from the consistently useful circulation pattern forecasts which the model made. MRF circulation forecasts allowed the forecasters to successfully anticipate, for example, the break during late July-early August (Fig. 5). The 13-case ensemble forecasts, which were routinely available, and which the forecasters had access to, allowed forecasters to assess the stability and reliability of the circulation patterns being forecast and contributed to their overall success. The ensemble forecasts are now assuming a major role in our 6-10 day forecast operation and this role will expand in the future.

4. CONCLUSIONS

An unusual set of surface and upper-air conditions conspired to produce catastrophic precipitation and flooding over the U.S. Midwest and drought over the Southeast. These conditions challenged both the NWP models, whose surface parameterizations had never been so sorely tested, and the forecasters who depend upon the models for guidance in preparing forecasts. Summer, 1993, MRF 6-10 day precipitation forecasts were too dry over wet regions by about one category. Forecasters successfully modified the precipitation guidance by using MRF circulation forecasts, indicating that the MRF forecasts were consistently useful, despite a clear problem with the influence of soil moisture upon precipitation. The MRF ensemble forecasts contributed to the success of forecasters in modifying MRF circulation forecasts to produce accurate precipitation forecasts.

models: ec, ensemble(mrf), obs, regression; m_i

v

model skill history

v

weights, w_i

v

official 500 hPa height forecast,

$$Z = [\sum_{i=1}^{N} w_i m_i] / N$$

v

T(regression(T),specified(Z)), R(MRF days 6-10)(MR8 "tool")

v

skill(station,time,tool)

* subjective interpretation of forecast flow patterns

v

official forecasts of T, R

v

dissemination Z, T, R forecasts via facsimile, AFOS

Figure 1. Schematic of 6-10 day forecast operation.

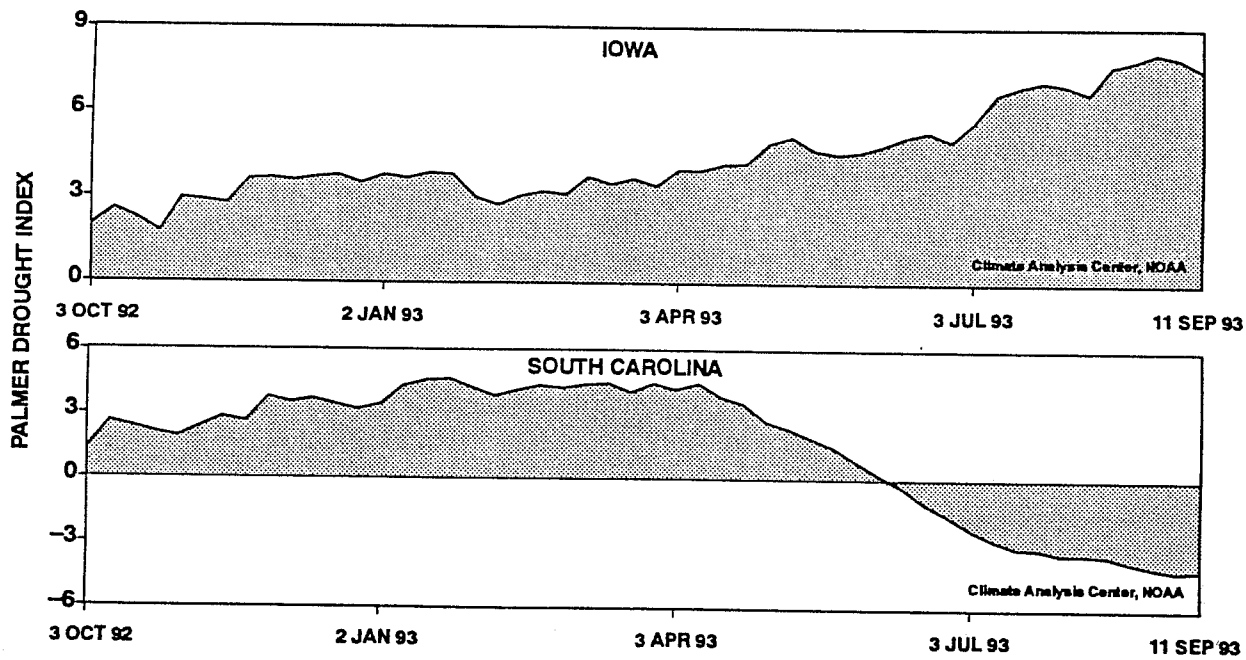
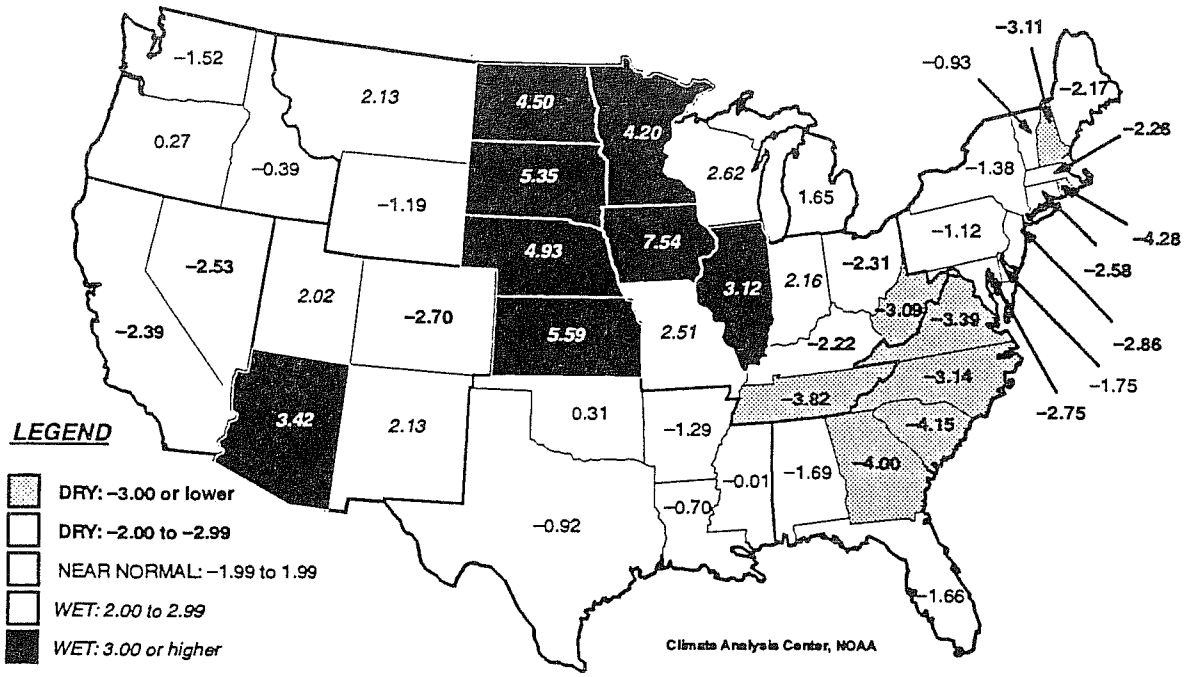


Figure 2. Area-weighted Palmer Drought Severity Index for Iowa and South Carolina.



AREA WEIGHTED PALMER DROUGHT INDEX BY STATES, as computed by the Climate Analysis Center. *The statewide index, based on the Palmer Drought Index from individual climate divisions, provides an estimate of long–term soil moisture. Unusually wet conditions prevailed across the north–central states while abnormal dryness is widespread across the Southeast. Iowa has been unusually wet for the entire hydrologic year (which began October 1) while South Carolina started wet, but an exceptional dry spell began in April and persisted throughout the summer.*

Figure 3. Area-weighted Palmer Drought Severity Index by states as of September 11, 1993..

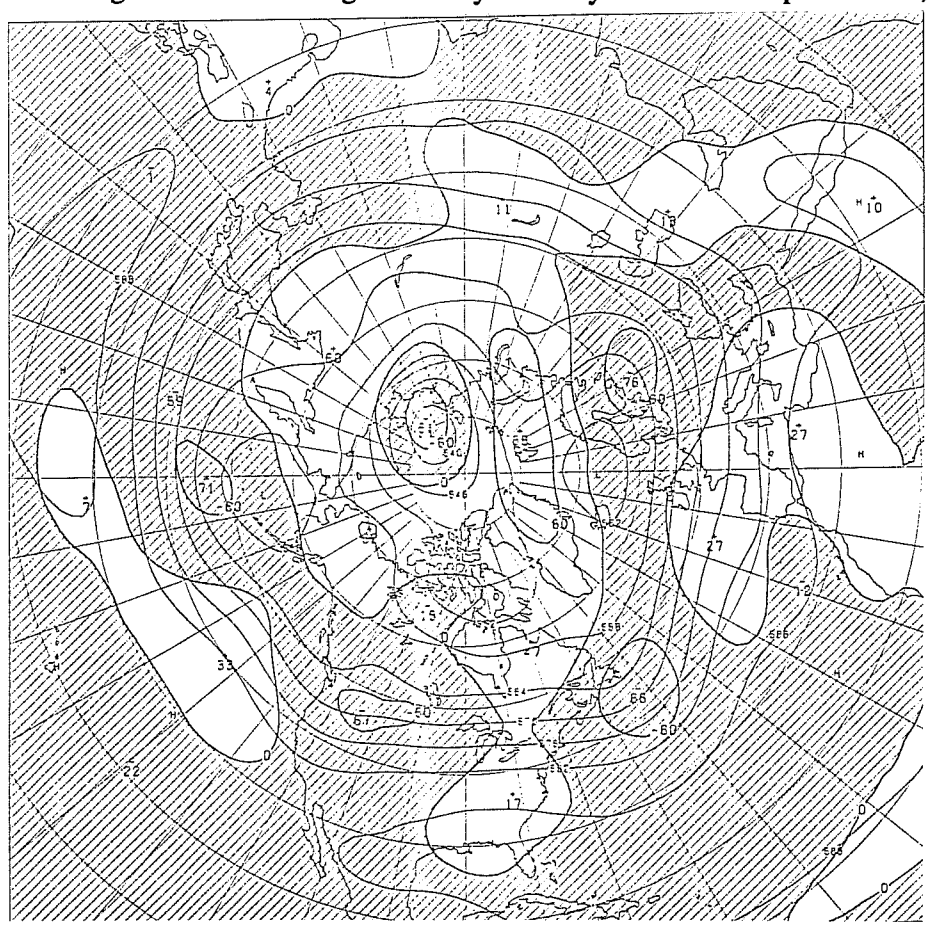


Figure 4. 61-day mean observed 500 hPa heights and anomalies, Junel-July 31, 1993. Negative anomalies are shaded.

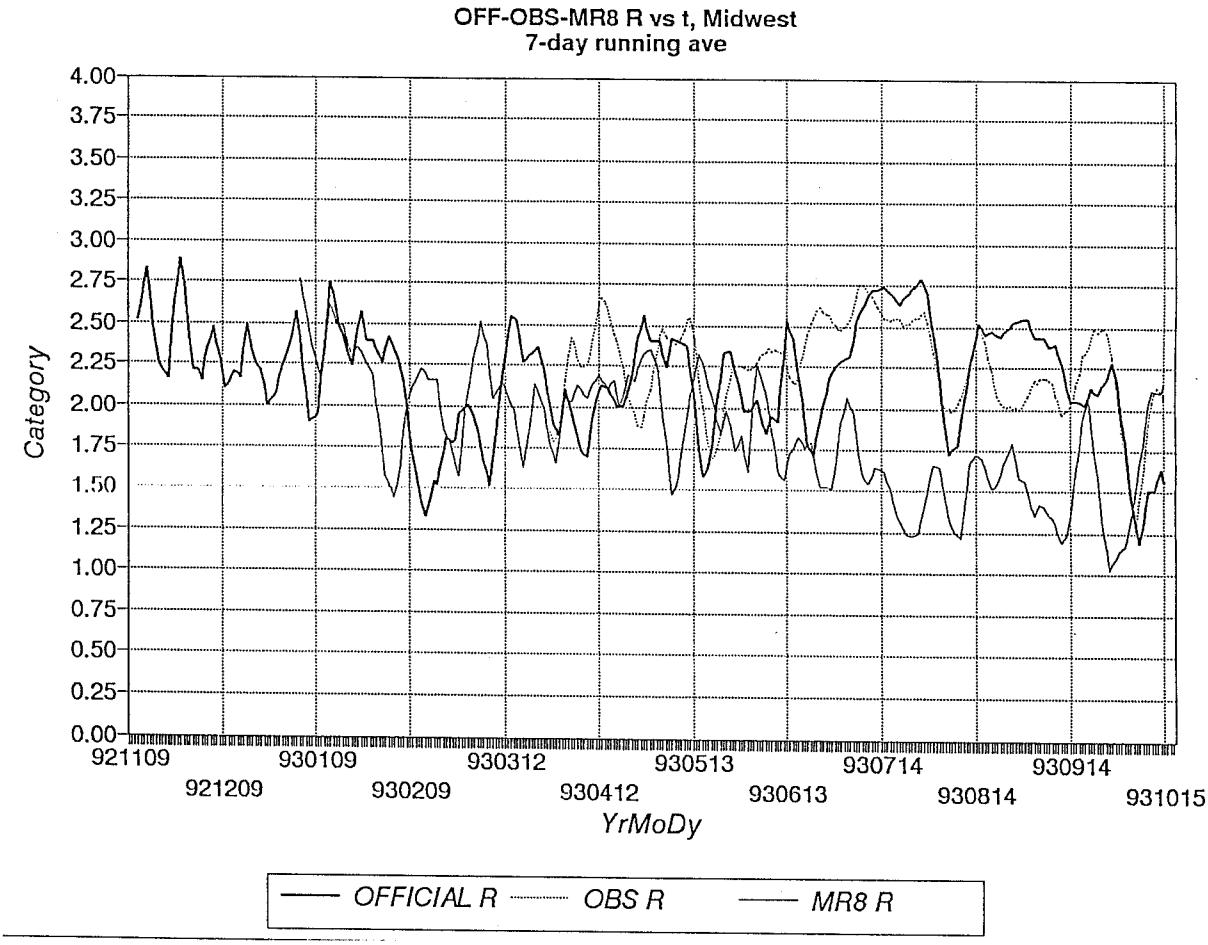


Figure 5. Time series of precipitation category for Official forecast (heavy solid), Verifying Observed (dotted), MR8 guidance (solid) for 16 Midwestern U.S. stations. A 7-day running mean has been applied to the daily values. Ordinate is precipitation category, abscissa is year-month-day, beginning November 9, 1992 and ending October 15, 1993.