6.2 Can Possible Heavy Rainfall Events Be Identified By Comparing Various Parameters To The Climatological Norms?

Richard H. Grumm
National Weather Service
227 West Beaver Ave.
State College, PA 16803
Email: richard.grumm@noaa.gov

Norman W. Junker
National Weather Service
Hydrometeorological Prediction Center-NCEP
Room 410, NOAA Science Center
Camp Springs, MD 20746
Email: norman.junker@noaa.gov

Robert Hart
The Pennsylvania State University
University Park, PA 16801
Email: hart@ems.psu.edu

Lance F. Bosart
University at Albany/SUNYA
Albany, New York 12222
Email: bosart@atmos.albany.edu

1. INTRODUCTION

The synoptic and mesoscale patterns associated with heavy rainfall have long been established as critical knowledge for meteorologists attempting to forecast heavy rain. Junker et al. (1999), studying heavy rainfall events associated with the Midwest floods of 1993, categorized heavy rainfall events based on the areal extent of the 75 mm (3") or greater isohyet. They found only subtle differences existed in the synoptic and mesoscale patterns between the larger, more widespread (category 4; 3" area greater than 7416 km^2) heavy rainfall events and the smaller, less widespread (category 0; 3" area less than 74 km^2) rainfall events. Unfortunately, they were unable to find an easy method to distinguish between a category four and category one event.

Grumm and Hart (2000) and Hart and Grumm (2000) examined both the climatological and forecast aspects of heavy rainfall events in the eastern United States. They found several clear signatures associated with many of the larger heavy rainfall events. In general, the 850 hPa specific humidity (q), u- and v-wind components appeared to be good predictors of heavy rainfall events. These fields tended to deviate by more than two standard deviations (SDs) from normal during heavy rainfall events. This varied by event type. For example with cold fronts, the heavy rain was often associated with three to four SDs above normal 850 hPa v-wind components and q anomalies. However, with cut-off lows, the q anomalies were small but there were large 500 hPa height anomalies and 850 hPa u-wind anomalies. Applying the climatological data to model forecast fields revealed that in two record warm season rainfall events during the summer of 2000, the Eta 850 hPa u-wind and 500 hPa height anomalies were over three SDs below normal. Due to the proximity of the Atlantic Ocean to the east, the moisture anomalies were not particularly strong. During this study, there was no available precipitable water (PW) climatology.

Following the ingredients-based forecast methodology of Doswell et al. (1996), Junker and Schneider (1997) determined several useful heavy rainfall forecast tools including high PW values, high relative humidity values, and warm mid-tropospheric temperatures. It appeared that the their category three (3" contour 3709 to 7416 km^2) and four events were often associated with higher PW and relative humidity values then lower category events. Junker and Schneider (1997), examining cases associated with the historic Midwest floods of 1993, emphasized the need for forecasters to be able identify conditions conducive for heavy rainfall. Critical thickness and PW values, along with areas of strong low-level inflow were deemed important considerations when forecasting heavy rain. One goal of this study was to build a PW climatology and assess its utility as a predictor of heavy rainfall events similar to the method shown by Grumm and Hart (2000b) and proposed by Junker and Schneider (1997).

In this paper, an examination is made of heavy rainfall events across the United States. An examination of parameters believed to be critical

* *Corresponding author address*: Richard H. Grumm, 227 West Beaver Ave, State College, PA 16803; email: richard.grumm@noaa.gov

in forecasting heavy rainfall events is presented. Key fields, such as PW anomalies relative to climatology, moisture flux, and wind anomalies are examined to determine their utility in developing a method to forecast these events.

2. METHOD

The heavy rainfall cases used in this study were extracted from the Hydrometeorological Prediction Center (HPC), a center within the National Centers for Environmental Prediction (NCEP), reanalysis rainfall data archive. Ten years of rainfall events in which 15-cm (6") or greater rainfall were observed were used in the study. From these data, climatology was established showing the seasonal and geographic locations of these large rainfall events. Individual cases were than used to see what parameters from each event and region might provide clues as the potential for heavy rainfall. The United States was divided into seven general regions including the Northeast, East, Southeast, South, Plains, Northwest and West. The regional breakdown was to examine the parameters associated with heavy rainfall in each region.

The gridded climatological data were retrieved from the NCEP reanalysis project (Kalnay et al. 1996). The 30-day running means and standard deviations were obtained using the 30-year period from 1961-1990. Additional reanalyzed climatological fields provided a complete reanalysis data set from 1 January 1948 through 31 August 2000 for use in diagnosing historic weather events as described by Hart and Grumm (2001). In addition to the traditional fields, such as heights, temperatures, winds, and mean-sea level pressure, a climatology of PW was developed for this study. All equivalent potential temperature (θ_e) data were derived from the other fields and no θ_e mean or standard deviation is available or shown.

All data were displayed using GRADS. (http://grads.iges.org/grads/) GRADS was used to compute theta-e, divergence and other derived parameters from the NCEP reanalysis data at each grid point. Traditional fields (heights, u- and v-wind components, temperatures, and specific humidities) were available at all mandatory pressure levels (i.e.: 1000, 850, 700, 500, 300 and 250 hPa). These fields were plotted using GRADS and often shown in conjunction with how this field departed from normal by the deviation in standard deviations from normal, called *standardized anomalies*. These standardized anomalies were derived by subtracting the 30-day centered mean climatological value from the model forecast divided by the 30-day standard deviation. Departures of +1 to -1 standard deviations from normal at are not shown since they are considered normal. Additional fields, including mean sea-level pressure and thickness climatologies were also available.

The maximum and minimum anomalies for each parameter were loaded into SQL for quick examination and computation of relevant statistics. The data in the tables in the following section were retrieved from this database.

3. RESULTS

i. Overall Statistics

Table 1 shows the PW anomaly by region. The data include the mean, maximum, and lowest value of the maximum for each geographic domain. During the heavy rain events used in this study, the most anomalous PW values were in the eastern US and along the West Coast. The largest PW anomaly was observed in the southeast. However, in the East and Northwest, the lowest observed maximum was over two SDs above normal during large heavy rain events.

PW Anomalies			
Region	**Mean**	**MAX**	**MIN**
Northeast	2.85	3.31	1.81
East	3.16	5.37	2.36
Southeast	3.13	**6.56**	1.30
South	2.64	4.18	**0.00**
Plains	2.48	3.91	1.30
Northwest	3.22	4.34	2.33
West	3.33	5.37	1.81
TOTAL	2.84	6.56	0.00

Table 1. Precipitable water standardized anomalies by region. Data include the mean anomaly for all events, the maximum, and the minimum value of the positive anomaly

The 850-hPa u-wind component anomaly is shown in Table 2. These data show that with the exception of the East Coast, westerly wind anomalies dominate the heavy rainfall events. The third column, the minimum, shows the lowest value of the u-wind component, or the strongest easterly wind anomaly. The strongest easterly wind anomalies with heavy rainfall events appear to be confined to the eastern United States. The mean of the u-wind anomalies is highest in the

East and Southeast. Strong easterly flow is common to flood and heavy rainfall events in the eastern United States.

850 hPa u-wind component Anomalies			
Region	**Mean**	**MAX**	**MIN**
Northeast	2.29	2.67	-4.60
East	2.68	3.79	-4.20
Southeast	2.62	5.30	-4.60
South	2.33	4.86	-3.85
Plains	2.50	4.73	-3.94
Northwest	2.56	3.80	-2.86
West	3.27	5.44	-3.69
TOTAL	2.58	5.44	-4.60

Table 2. 850 hPa u-wind standardized anomalies by region. Data include the mean of the positive (westerly) winds, maximum (westerly), and minimum (easterly) wind values.

Mean sea-level pressure anomalies (not shown) indicated that heavy rain events along the coasts were more often associated with a deep cyclone, relative to inland events. The mean MSLP anomalies were –3.32 and –2.74 along the West and East Coasts, respectively. The largest single anomaly was –7.10 along the southeastern United States, associated with a tropical storm.

ii. Western United States

Heavy rainfall events in the western United States have a distinct orographic component. Therefore, strong westerly winds over the Pacific Ocean impinging upon the mountains directly impact the heavy rainfall in the western States. The case from 5 January 1995 is an excellent example of strong westerly 850 hPa winds, with a westerly wind component in excess of 5 SDs above normal, into the terrain. The more southwesterly oriented jet events bring in some of the highest PW values. During several of these southwesterly flow events, the PW anomalies were in excess of +3 SDs above normal (9 Mar 1995; 12 Nov 1994; 14 Feb 1995).

A representative southwesterly flow case occurred on 28 February 1991 (Fig. 1) when the PW anomalies exceed 5 SDs above normal. In addition to the high PW anomalies, there was a surge of high θ_e air into the region along with low-level moisture convergence. The 850-hPa westerly winds were also anomalously strong in southern California near the region of heaviest rainfall.

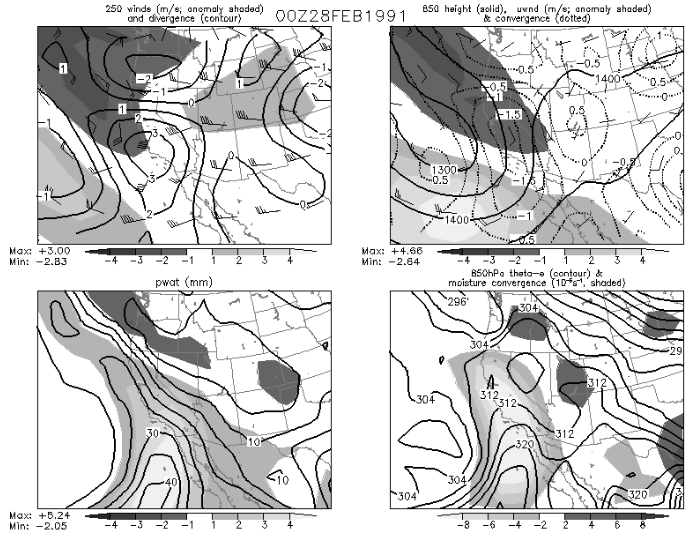

Figure 1. Analysis of the heavy rainfall event of 28 February 1991. Data include a) 250 hPa winds and u-anomaly with divergence, b) 850 hPa u-winds, u-wind anomalies, and divergence, c) Precipitible water (cm) and anomalies, and d) 850 hPa equivalent potential temperature (K) and moisture convergence. All anomalies are standardized anomalies.

The more westerly flow cases are typically associated with lower PW anomalies. In these cases, such as the event of October 1992 (not shown), the strong westerly winds oriented orthogonal to the terrain play a critical role in the heavy rainfall for these types of events. The mean 250 hPa u-wind anomaly during West Coast rain events is the highest of any region averaging around +2.79 SDs above normal. During the warm season, when the westerlies weaken, heavy rainfall events along the West Coast are not very common.

iii. Southern United States

Southern US heavy rainfall events dominated the data set. This region was clearly an area susceptible to frequent heavy rainfall events. This area has a large summer-autumn tropical influence and has many distinct Maddox event types. A classic example of an overrunning return flow event is shown in Figure 2. This event was characterized by heavy rains, with a large area of over 12.5 cm of rain, in eastern Texas and Louisiana. The 250 hPa wind anomalies show the jet entrance region over the low-level baroclinic zone, depicted by the θ_e gradient in the lower right panel. The PW anomaly clearly shows the return flow of warm moist air over the frontal zone over eastern Texas and Louisiana.

Several of the late-summer and autumn heavy rainfall events had a clear tropical connection. Many of the higher PW anomalies and low-pressure anomalies, including a -7.14 event, were associated with these types of events.

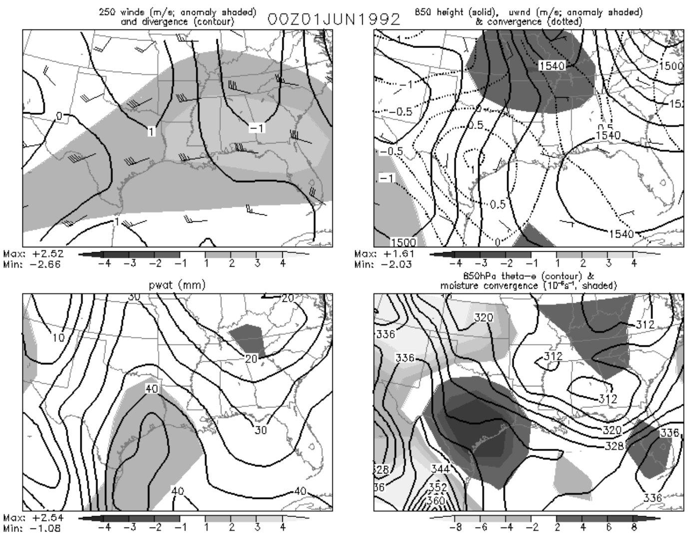

Figure 2. As in Figure 1, except valid at 0000 UTC 01 June 1992 and centered over the southern United States.

4. CONCLUSIONS

An examination of heavy rainfall events across the United States appears to show some regional character to the large-scale conditions associated with these events. In most cases, relatively high PW anomalies and moisture convergence appeared to play a significant role in the heavy rainfall.

The winds appeared to have a regional character. Strong westerly winds dominated along the West Coast and the highest positive 250 hPa u-wind anomaly was observed with a West Coast event. The highest PW anomalies in the western United States required a stronger southwesterly flow.

In the eastern United States, strong low-level southwesterly winds and high PW anomalies played a key role in several events. However, strong u-wind anomalies and relatively lower PW anomalies were associated with other heavy rainfall event types.

The majority of anomalous cases were observed over the southern United States. The largest mean-sea level pressure anomaly (-7.14) was observed in the southeastern United States. On average, deep low pressure appeared to be quite common with heavy rainfall events along both coasts.

Although all the events shown appear to have been related to relatively anomalous conditions, the largest anomalies appeared to occur in regions with the greatest impact of oceanic effects. Further research will be conducted to determine critical forecast parameters of these and other heavy rainfall events.

5. ACKNOWLEDGEMENTS

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