J7.4 NORTHERN HEMISPHERIC FLOOD FINGERPRINTS

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1. INTRODUCTION

Flooding causes billions of dollars in damage every year across the Northern Hemisphere. The synoptic patterns creating these catastrophic flooding events share common patterns, or fingerprints. Root et al. (2007) demonstrates that there are repeatable atmospheric fingerprints for mid-Atlantic U.S. flooding events. From this basis we hypothesize that there are common fingerprints not only for mid-Atlantic floods, but also for floods across the mid-latitudes of the Northern Hemisphere. Multiple cases from the mid-latitudes of the Northern Hemisphere for which over 2 inches (~50 millimeters) of rain fell in an 18-hour period are evaluated by obliquely rotated Empirical Orthogonal Functions, based on the spatial correlations of the standard anomalies of four atmospheric fields: 850 hPa zonal wind component U, 700 hPa meridional wind component V, precipitable water PWAT, and mean sea level pressure SLP. The maps of the first six EOFs are fingerprints and may be interpreted as different synoptic patterns driving Northern Hemispheric flooding events. Ultimately, identifying the primary synoptic patterns that cause significant flooding events may lead to better flood forecasts and to prevention of life and property loss.

2. DATA AND METHODOLOGY

2.1 Case Selection

The flooding events come from three sources: The National Climate Data Center event database, the CPC MORPHing technique CMORPH, and the *Encyclopedia Britannica* disaster articles from 1979 to 1999. Over 300 events from North America, Europe, and Asia are assessed using Japanese 25-year Reanalysis (JRA25) data.

Because surface rainfall totals are not available for flood cases outside of North America, an objective method for assessing the likely rainfall amount is needed. This assessment compares JRA25 data with North American cooperative observing network (COOP) reports. Because the JRA25 data performs within 10% in estimating rainfall amounts in North American flood cases, JRA25 rainfall estimates are used for all cases across the Northern Hemisphere.

Two hundred events from North America, Europe, and Asia in which approximately 2 or more inches of rain fell in an 18-hour period, including the 6-hour time period of the flood and the 6-hour periods before and after the event, are selected for the analysis (Fig.1).

2.2 Extraction of Four Atmospheric Variables

For each case 850 hPa U-wind, 700 hPa V-wind, precipitable water, and mean sea level pressure values are retrieved from the NCEP-NCAR Global Reanalysis dataset comprising of 17 pressure levels on 2.5º by 2.5º grids. To mitigate the effects of seasonal variation in the values, standard anomalies SA are calculated at each grid point via:

$$SA = \frac{(A - \mu)}{\sigma} \quad (1)$$

where A is the atmospheric variable value, μ is the mean of the 17-day average centered on a given date, and σ is the value of one standard deviation given a 30-year climatology.

Values are excerpted for a 9 X 9 array of grid point values surrounding the flood event. A grid spanning 22.5º by 22.5º mitigates the influence that a microscale or mesoscale event may have on a given location and displays only the primary synoptic pattern.

2.3 Rotated Empirical Orthogonal Functions

Empirical Orthogonal Functions (EOFs) basically reduce a dataset to a smaller one that contains linear combinations of the original data, capturing the maximum possible variance in the original dataset. A small set of uncorrelated variables is much easier to understand and to use

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in further analyses than is a larger set of correlated variables (Dunteman, 1989). Maps displaying these rotated EOFs reveal the synoptic patterns, or fingerprints, in the underlying dataset by displaying the most variation amongst all cases.

Richman (1986) explains in great detail why rotating EOFs allows for a better analysis of meteorological data. Rotation minimizes the effect of domain shape dependence, as well as subdomain instability. Unrotated EOFs depend heavily on the domain shape, or the geography of the domain, as opposed to the underlying variance. A similar issue exists when subdividing the domain. Basically, EOFs obtained for a large domain become compressed to fit a specific subdomain region and do not explicitly explain the pattern within that subdomain. Rotated solutions, however, are less influenced by domain and subdomain restrictions. Richman (1986) continues that unrotated solutions suffer from large sampling errors when the eigenvalues of a data set are close numerically. He concludes his argument by stating that underlying correlation fields are depicted properly by rotated EOFs, and meteorological patterns become clearer using rotation.

3. RESULTS OF ROTATION

Both orthogonal and oblique rotations are performed on the standardized anomaly dataset. Although simple structure is desired, it is not practical using actual data. Ideally, simple structure assigns one EOF, or storm type, to each case; in reality, however, most cases are described by a combination of several rotated EOFs. The EOF rotation simple structure reveals that an oblique rotation of six factors results in the most meaningful meteorological synoptic patterns. The meteorological patterns represented by the resulting six EOFs account for 61% of the variance in the 200 cases.

Figure 2 represents the obliquely rotated third component that can be interpreted as a classic Nor'easter. A strong low in the southeastern quadrant of the domain in blue color (Fig. 2b) creates significant low-level positive vorticity, which can be seen by the distinct counter-clockwise circulation of the winds aloft. The 700 hPa V-wind (Fig. 2d) shows southerly flow in red color in the southeast portion of the domain with strong northerly flow in blue color across the central and southwestern parts of the domain. The 850 hPa U-wind (Fig. 2c) indicates an easterly flow in blue color in the north central portion of the map and a strong westerly flow in red in the southern part of the domain. Finally, precipitable water (Fig. 2a) is greatest on the eastern side of the low in red color, where the moisture from the south is the largest and overrunning dominates. On the schematic, this moisture infused area is indicated by an "M". Precipitable water is the least in the central and western portions of the domain in blue color and is indicated by a "D", representing dry air, on the schematic.

4. CONCLUSIONS

Oblique, six-factor rotation of the EOFs is performed on the standardized anomalies of four atmospheric fields for 200 mid-latitude Northern Hemispheric flooding events. Six distinct fingerprints may be discerned to represent 61% of the variance of floods across the Northern Hemisphere. These fingerprints represent a large percentage of the synoptic patterns that drive significant flooding across the mid-latitudes. What can be objectively identified can in time be predicted more accurately based on operational, numerical modeling guidance.

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FIGURES

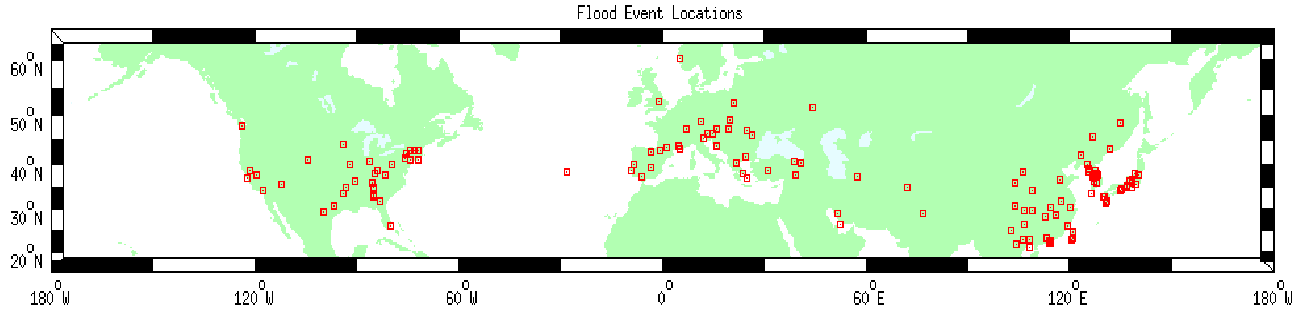

Fig. 1. Location of 200 cases selected across the mid-latitudes of the Northern Hemisphere in which 2 or more inches of rain fell in an 18-hour period.

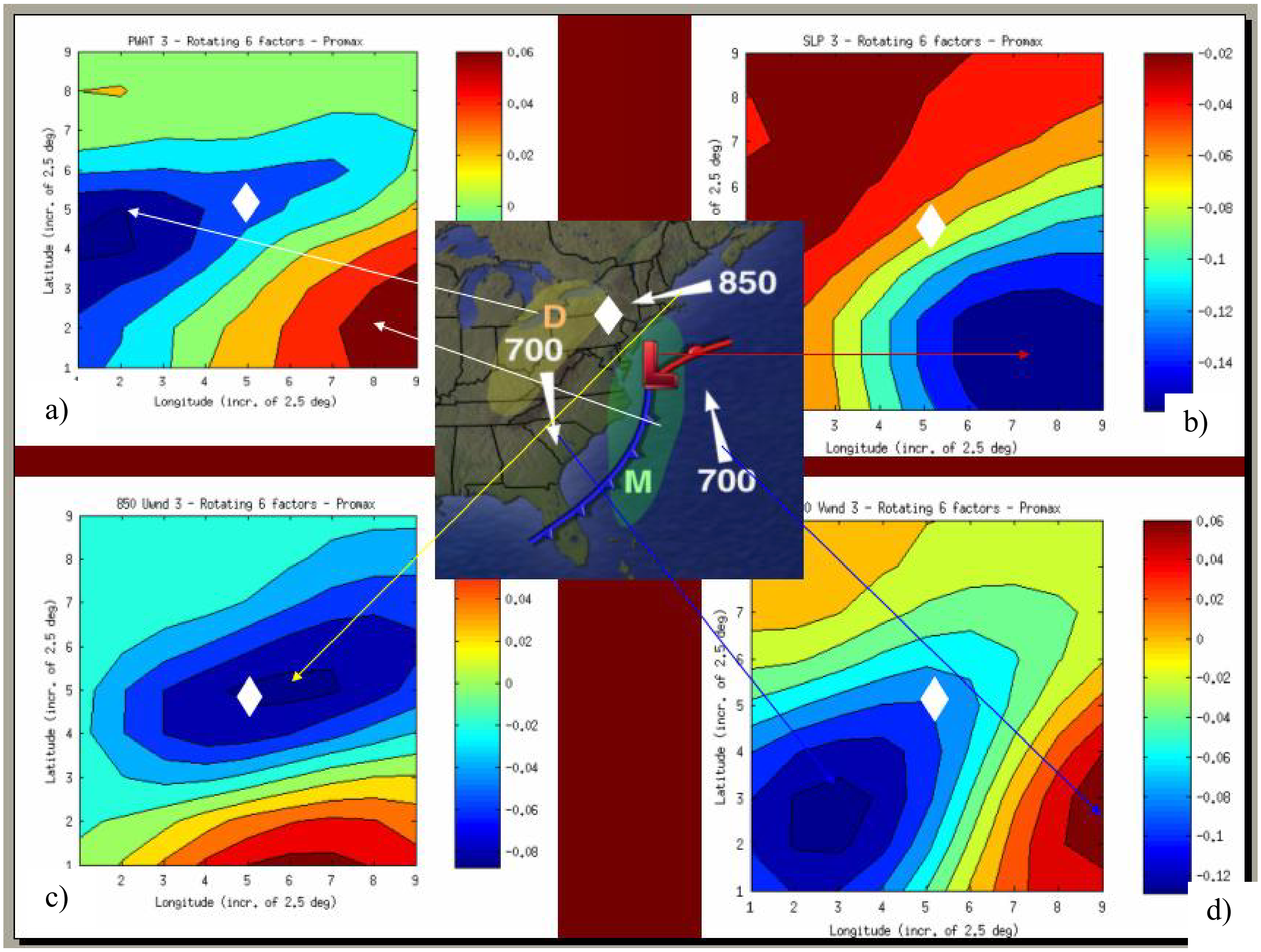

Figure 2. The third obliquely rotated component that represents a classic Nor'easter fingerprint. The upper left panel (a) shows precipitable water; the upper right (b) shows sea level pressure; the lower left (c) shows 850 hPa U-wind; the lower left (d) shows 700 hPa V-wind. Note that the flood occurs in the center of each grid at point (5,5).