

On the Connection Between Low-frequency Modulation of Large-scale Weather Regimes and Springtime Extreme Flooding over the Midwest of the United States

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1. Introduction

The April 2011 flood event in Ohio River Basin and related lower Mississippi River floods was the latest of a set of major such flooding events recorded over the twentieth century (defined in terms of a 10-year return maximum in streamflow). Composite analysis of these events reveals an anomalous northward moisture transport in a “moist conveyor belt” from the Gulf of Mexico and the tropical Atlantic, focused by convergence associated with the “Bermuda High” and the synoptic events impinging on it (Nakamura *et al.* 2011). The questions of whether the recent 2011 event heralds a return of more frequent flooding, and the degree of potential climate predictability of such events both require a better understanding of how the frequency and intensity of the synoptic events responsible for the floods vary on interannual to interdecadal timescales, and are thus potentially influenced by large-scale modes of low frequency climate variability.

2. Data and methodology

We employ an analysis of daily weather regimes over North America [30°N–50°N, 105°W–75°W] derived from NCEP-NCAR reanalysis 700hPa geopotential height data using a K-means cluster analysis (*e.g.* Robertson and Ghil 1999) for the March–May (MAM) season, 1961–2011

(<http://iridl.ldeo.columbia.edu/SOURCES/NOAA/NCEP-NCAR/CDAS-1/DAILY/>),

together with a complementary analysis of daily rainfall gridded gauge-based data over the Ohio River Basin, [88°W–84°W, 36–40°N] for the same period using a hidden Markov model (HMM; *e.g.* Greene *et al.* 2008), based on the CPC Unified Precipitation dataset 1979–2011

(http://iridl.ldeo.columbia.edu/SOURCES/NOAA/NCEP/CPC/UNIFIED_PRCP/). Ten-year flood events were estimated from daily

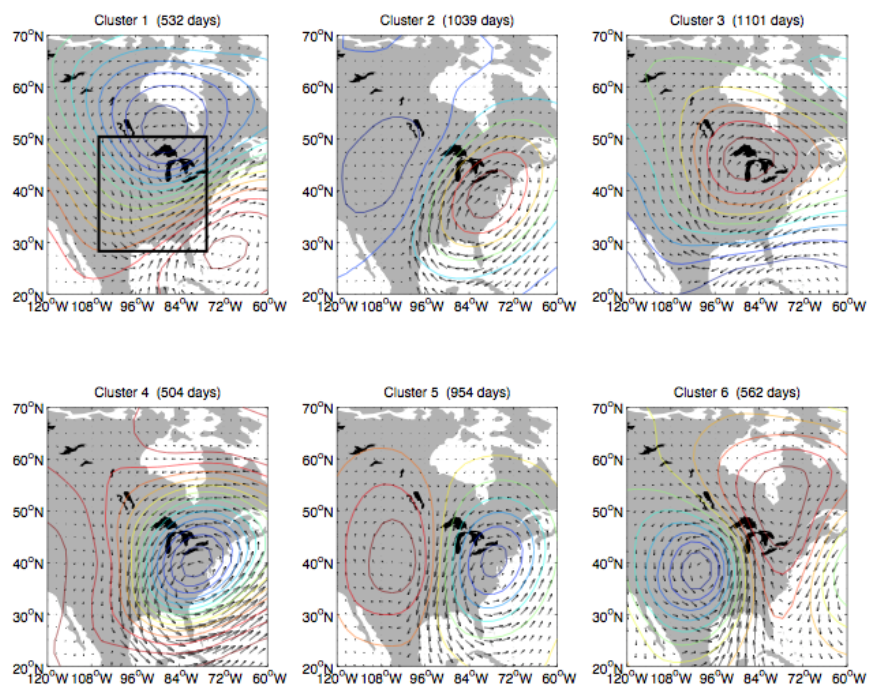


Fig. 1 Six-cluster K-means solution, showing 700hPa geopotential height anomalies (CI 20 gpm), together with anomaly composites of vertically integrated moisture fluxes. Panel titles give the number of MAM days assigned to each cluster. Box in first panel indicates the region used in the K-means analysis.

river discharge data at 7 gauging stations in sub-basins of the Ohio River based on the Hydro-Climatic Data Network (HCDN) of the U.S. Geological Survey (Nakamura *et al.* 2011).

3. Results

The K-means six-cluster solution was found to yield a near-maximum classifiability index (Michelangeli *et al.* 1995), within the range of $K = 5 - 10$, and was selected for further analysis; it is depicted in Fig. 1 in terms of geopotential height anomalies from the long-term MAM average, with vertically-integrated moisture flux anomaly composites superimposed. Clusters 1, 2 and 6 are each associated with southerly moisture advection over the eastern U.S.

To determine whether these flow regimes were active during past extreme flooding events in the Ohio River basin, the frequency of occurrence of each regime (*i.e.* cluster) during the 10-day period preceding five 10-year MAM flood events during the 1961–1996 period (Nakamura *et al.* 2011) is plotted in Fig. 2a; there is a clear preference for clusters 1 and 2 during the lead up to these five events.

The association between cluster frequency and the El Niño-Southern Oscillation is plotted in Fig. 2b, in terms of the anomaly correlation between the Nino34 index, averaged over each MAM season, 1961–2011. There is a tendency for clusters 1 and 2 to be preferentially associated with La Niña events, statistically significant at the 99% confidence level.

Figure 3 shows the daily evolution of rainfall and cluster membership during April 2011, when extreme floods were recorded on the Ohio River, peaking on 27 April. Much of the month was characterized by cluster 2, with clusters 1 and 6 also playing role. All three of these circulation types are characterized by strong northward moisture fluxes from the Gulf of Mexico.

4. Discussion and concluding remarks

The work reported here demonstrates clear associations between synoptic circulation types and historical flood events on the Ohio River. Anomalous southerly fluxes of moisture from the Gulf of Mexico are pronounced in weather types that occurred in connection with these floods. Two of these circulation types are preferentially associated with La Niña, providing one causal mechanism for the recent flooding during April of 2011. Daily rainfall states identified using a rainfall-based Hidden Markov Model indicate a clear eastward propagating synoptic scale wave (not shown). Further work is underway to isolate in more detail the pathways between climate anomalies and extreme flood events through the intermediaries of large-scale atmospheric circulation patterns and synoptic-scale waves.

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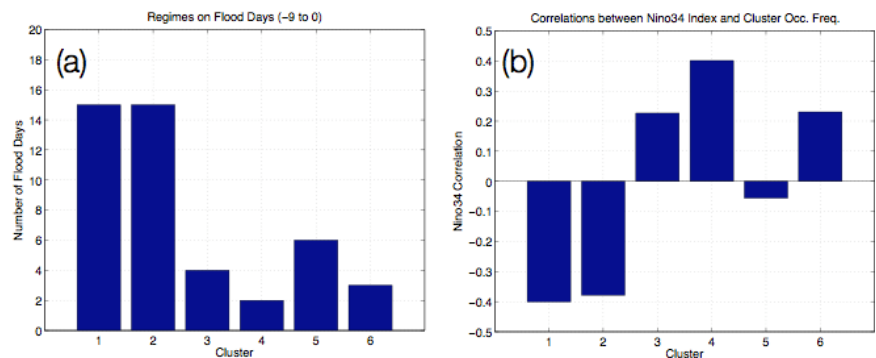


Fig. 2 (a) Frequency of occurrence of each cluster during the 10-day period preceding five 10-year MAM flood events: 13 May 1961, 5 March 1963, 10 March 1964, 25 May 1968, and 4 May 1996. (b) Anomaly correlation between the number of days in each cluster in each MAM season, and the value of the Nino34 index.

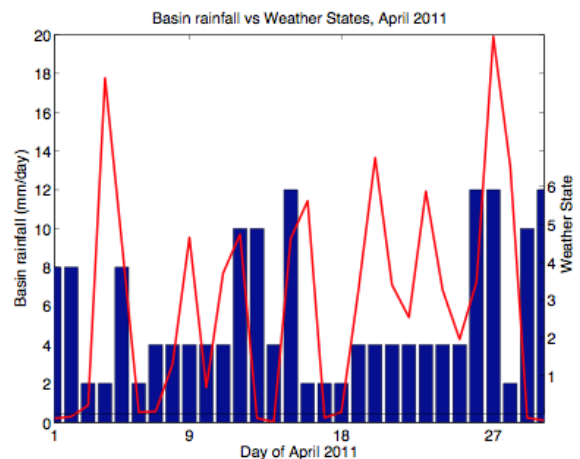


Fig. 3 Daily rainfall averaged over the Ohio Basin (red curve), together with cluster membership (bars), during April 2011.

5. References

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