European Flooding during Summer 2002

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Summer 2002 has seen the coincidence of several major climate anomalies: severe fluvial flooding across Europe, the worst monsoon failure in India for three decades and a developing El Niño. But was this mere coincidence, or could these separate events be connected?

Idealised modelling work by Rodwell and Hoskins (1996) found that the settled climate of the Mediterranean during summer is partly a result of the Asian summer monsoon. They found that the large upper-tropospheric anticyclone generated by off-equatorial monsoon heating interacts with the westerly flow over the Mediterranean to produce descent. This descent is localised by orography and strengthened by a feedback with local diabatic forcing dominated by radiative cooling. The well known northerly summer winds over the eastern Mediterranean are a manifestation of the air descending quasi-adiabatically along the sloping isentropes.

Climatologically, there is a temporal correlation between the Asian monsoon onset and the start of summer conditions in the Mediterranean, but is there a link between the interannual variability of the two regions? Could a weak Indian monsoon lead to weaker descent over the Mediterranean and southern Europe, setting an environment which allows more disturbed European summer weather? A simple correlation between 500hPa vertical motion from the NCEP reanalysis, averaged over the region 0:30E 35:45N, and All-India rainfall (AIR) for 1958-2000 gives a statistically significant correlation coefficient of 0.39, both for July (Fig.1) and JJA data. The correlation is larger outside the period 1976-1985, but is in fact negative within this 10-year period. The years of weakest European descent (1972, 1987) do coincide with monsoon drought periods. We conclude that there is a connection, but that other processes also exert an influence over southern European descent.

The two extreme years 1972 and 1987 were also years of El Niño onset, and Indian monsoon variability has been linked to ENSO (Parthasarathy et al 1991). By crudely including an index of equatorial Pacific SST, the correlation coefficient of Fig.1 is increased to 0.49 for JJA (not shown). It is possible that a combined AIR-ENSO index is identifying large-scale atmospheric patterns associated with monsoon variability and is removing some of the chaotic variability in AIR.

These results suggest a connection, albeit quite weak, between the Indian monsoon and large scale vertical motion over southern Europe. What about European rainfall? There is a negative in situ correlation between NCEP mid-level descent and rainfall (using the dataset of Hulme 1992) for the region 0:30E 35:45N (not shown), but correlating rainfall for this area directly with AIR produces no significant result. This perhaps points to a large stochastic element in the two rainfall timeseries.

Given the weakness of any possible link between summer weather in southern Europe and the Indian monsoon, what is the main influence on European summer rainfall? Fig.2 shows the correlation between the JJA rainfall averaged over the region 35:45N 0:30E and 200hPa geopotential height at each point on the globe, for the period 1958-2000. There is a clear signal of European blocking, with high(low) pressure over northern(southern) Europe. The blocking signal is quite robust for variations in the chosen rainfall region, such that the region of this summer's anomalous rainfall, roughly 40-50N 10:30E yields a very similar result.

There has been persistent European blocking during summer 2002, from July through to early autumn.

This height correlation pattern contrasts with those obtained for the negative-AIR and Niño 3.4 SST timeseries during northern summer (Figs.3,4). The similarity of these two latter patterns indicates the inverse relationship between Indian monsoon rainfall and El Niño. There is only a (non-significant) hint of high pressure over northern Europe or low pressure over southern Europe in these correlation maps.

During summer 2002 there was a gap between the timing of the worst part of the Indian drought (July) and the particular weather system which brought the crucial heavy rainfall to central Europe during early August. However, first, the modelling work of Rodwell and Hoskins does indicate a delay of around one week between changes in monsoon heating and Mediterranean descent and, second, large European rainfall earlier in the summer meant that the effect of the event in August was more devastating.

We intend to pursue this work using a combination of idealised modelling and further analysis of observational data.

Acknowledgements

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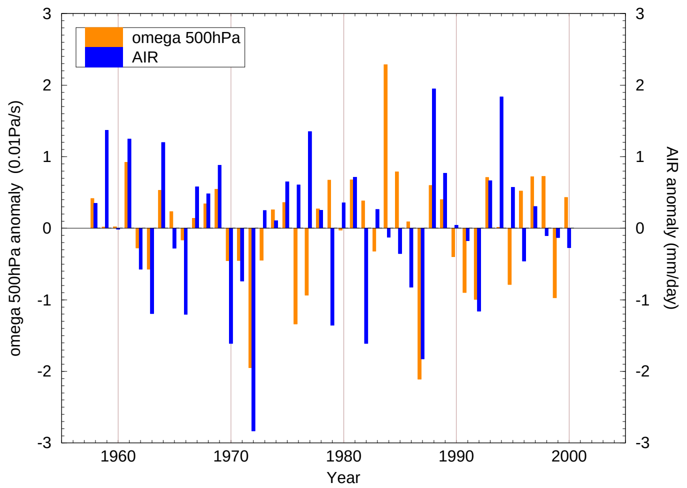
Figure Captions

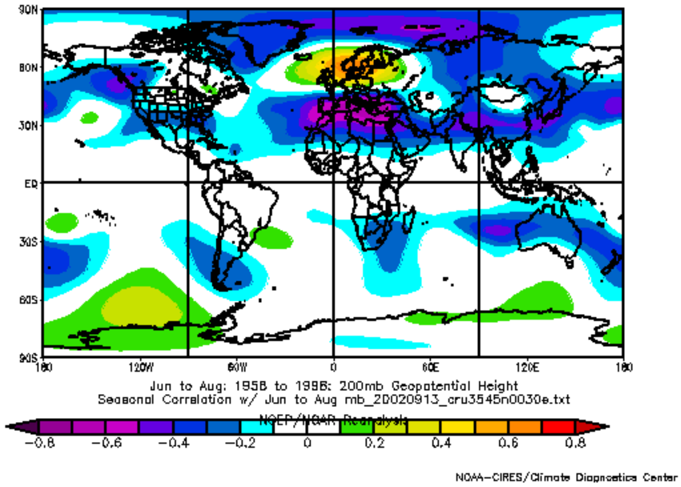
Fig.1 Detrended anomalies of All India rainfall (AIR: blue) and 500hPa descent for the region 0:30E 35:45N (omega from NCEP reanalysis data: orange) for July from 1958 to 2000.

Fig.2 Correlation map between precipitation over southern Europe (35:45N, 0:30E) and 200hPa geopotential height at each point on the globe, for JJA from 1958 to 2000. Correlations in excess of 0.31 are significant at the 95% level.

Fig.3 Correlation map between (the negative of) All India rainfall (AIR) and 200hPa geopotential height for JJA from 1958 to 2000. Correlations in excess of 0.31 are significant at the 95% level.

Fig.4 Correlation map between Niño 3.4 sea surface temperature and 200hPa geopotential height for JJA from 1958 to 2000. Correlations in excess of 0.31 are significant at the 95% level.





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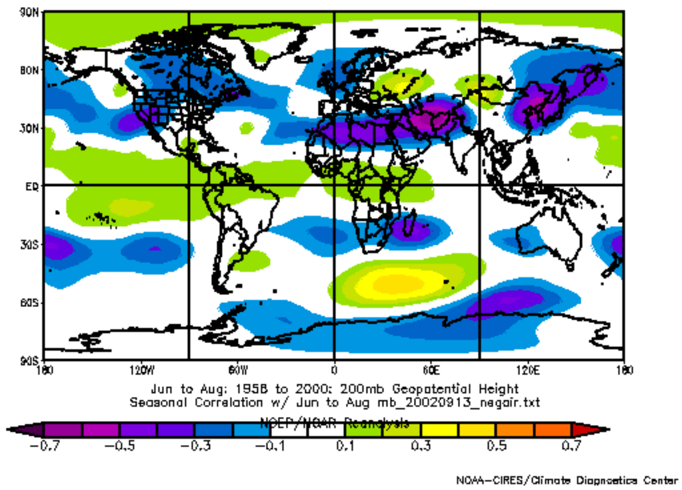

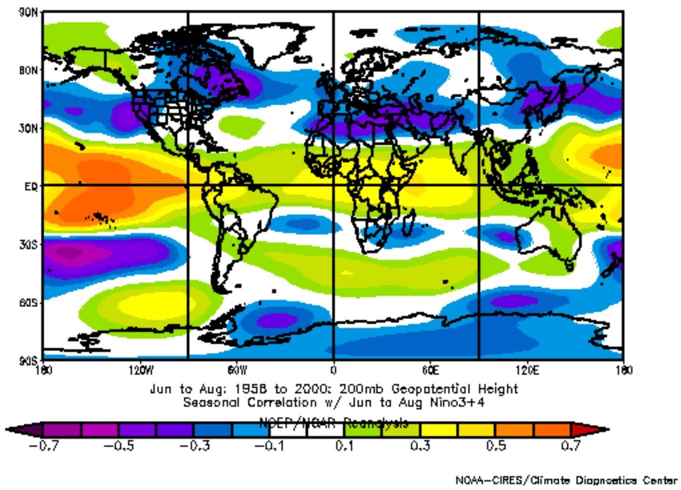

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