The European flooding of Summer 2002 and its global connections

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Summary

- Summer 2002 was one of the wettest in decades for many European countries. During early August, weather systems brought widespread heavy rainfall to central Europe, causing severe flooding along all the major rivers.
- We have investigated the large scale atmospheric patterns and global connections associated with these events and with historical summer variability over Europe.
- Concurrently with events in Europe, India suffered its worst monsoon drought for three decades during July and early August 2002. We have confirmed that a theoretical connection between the monsoon and Mediterranean summer weather does link interannual variability in the two regions.
- A developing El Niño during 2002 may have influenced the Indian monsoon.
- Atmospheric blocking is the primary large scale pattern associated with wet summers over central and southern Europe.
- "Downstream development" in a wave packet from the north Pacific produced one of the two weather systems which brought the heavy rain to central Europe.

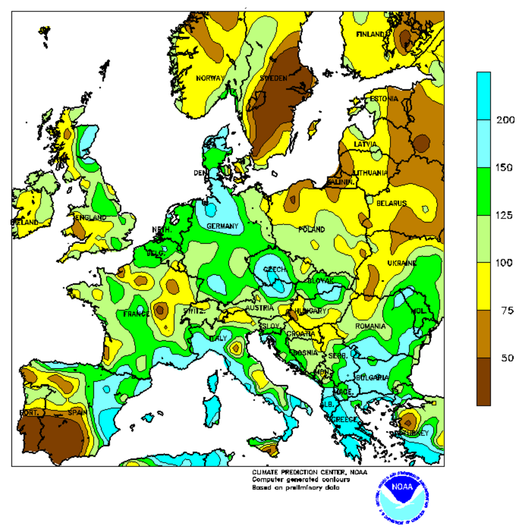
Conclusions

- Individual weather systems generate the precipitation that leads to flooding, but a variety of large scale atmospheric processes sets the regional environment within which these weather systems grow and propagate.
- Summer weather and precipitation over central and southern Europe are influenced by several regional and remote atmospheric teleconnections:
  - European blocking alters the path of Atlantic weather systems, allowing them to propagate into Europe on a more southerly track.
  - A weak Indian monsoon forces Mediterranean descent less strongly, allowing less settled weather to develop.
- Extreme events involve strong signals which help us to identify atmospheric teleconnections and patterns of variability.
- Climate and weather prediction models need to capture these processes if they are to successfully simulate regional climate variability.

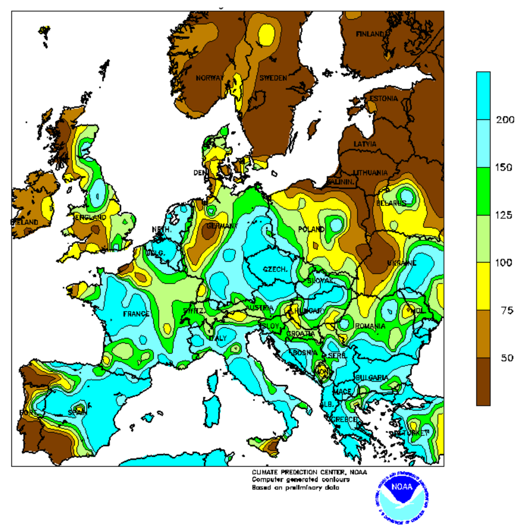
(1) European Precipitation Anomalies

(percentage of normal)

JJA 2002



August 2002

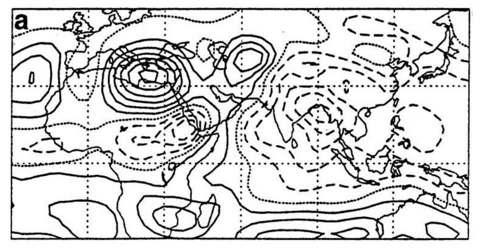


- Summer 2002 was extremely wet over central and southern Europe.
- Absolute anomalies were smaller over the Mediterranean, due to a drier climatology.
- Larger and more extensive wet anomalies occurred in August, with very dry conditions over northern Europe.
- Weather systems on 6-8th and 11-13th August each brought over 150mm rain to parts of central Europe.

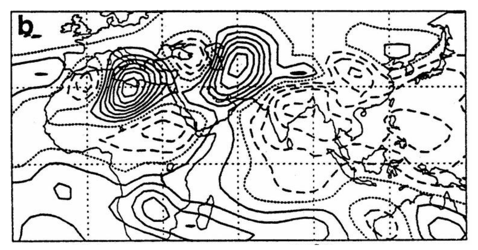
(3) The Monsoon and Mediterranean Descent

- Idealised modelling work by Rodwell & Hoskins (1996, *QJRMS*) linked the settled summer climate of the Mediterranean to the period of the Asian summer monsoon.
- Monsoon heating generates a large upper-level anti-cyclone which extends westwards.
- The anticyclone interacts with westerly winds over the Mediterranean to produce descent.
- This descent is localised by orography and strengthened by a feedback with local diabatic forcing.
- The northerly winds over the eastern Mediterranean in summer are a manifestation of air descending quasi-adiabatically down the sloping isentropes.
- Rodwell & Hoskins showed that mid-level descent over the Mediterranean coincides with the period of the Asian monsoon, from June to September.
- Could interannual variability in these two regions also be linked?

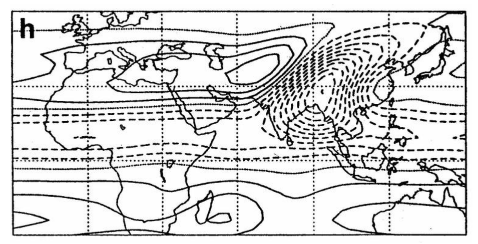
JJA mid-level descent: ω(477hPa)



ECMWF analyses 1983-1988



Full model: global heating and orography

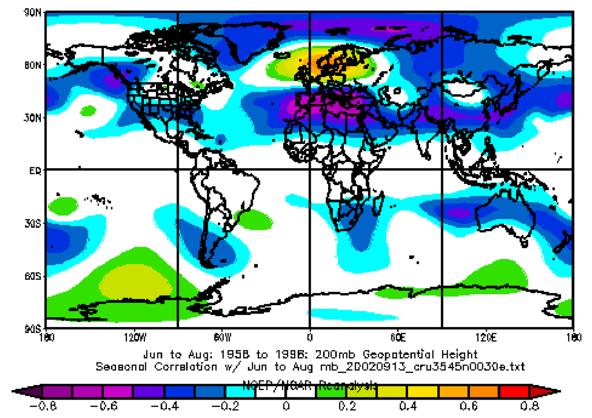


Idealised monsoon heating (25°N), no orography

(5) European Summer Precipitation and Blocking

Given the relatively weak relationship between southern European precipitation and the monsoon, what large scale pattern correlates with European summer precipitation?

Correlation map of 200hPa geopotential height with JJA precipitation [35-45N,0-30E]

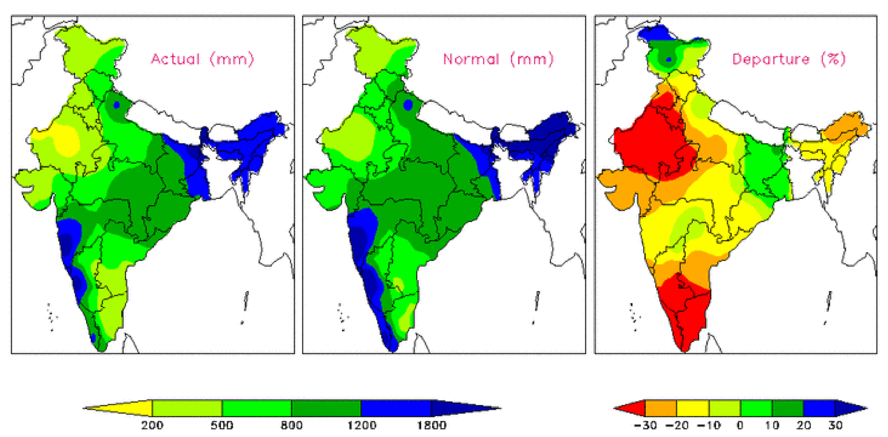


- Correlate precipitation over southern Europe [35-45N,0-30E] with atmospheric data at each point on the globe for summer, 1958-1998.
- European blocking emerges as the clear dominant influence, with high(low) pressure over northern(southern) Europe.
- The same signal emerges for summer precipitation over central Europe, [40-50N,10-30E].
- Blocking was a persistent feature of summer 2002, from July through to early autumn.
- A blocking anticyclone over Europe diverts the jetstream and storm-track to its north and south, with a tendency for Atlantic weather systems and cut-off lows to propagate into the Mediterranean.

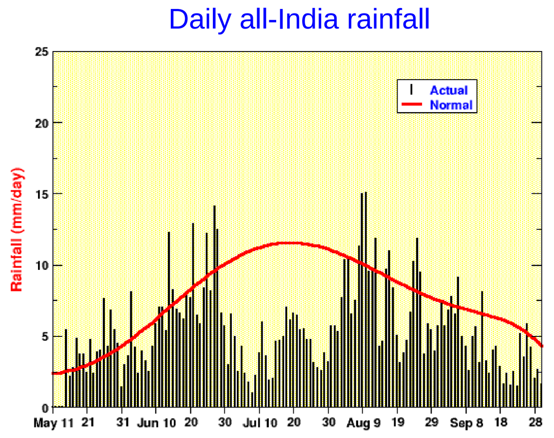
Precipitation data from the CRU global dataset over land: Hulme et al (1998).
Atmospheric data from the NCEP/NCAR Reanalysis.
Regressions performed at the NOAA Climate Diagnostics Centre website www.noaa.cdc.gov

(2) Indian Monsoon Drought

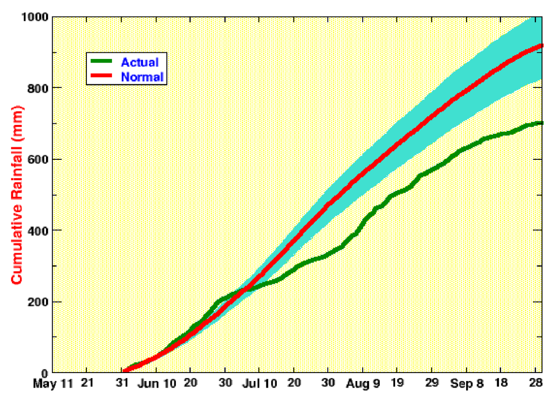
All-India Rainfall (AIR) - seasonal total June-Sept. 2002



Daily all-India rainfall



Accumulated rainfall

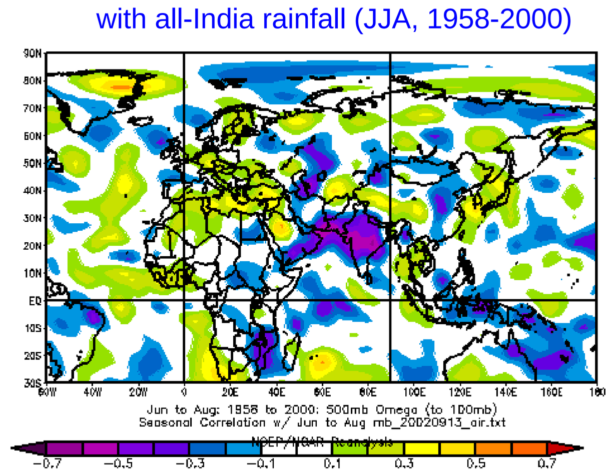


- There was a prolonged drought during July and early August 2002, with less than half the normal all-India rainfall.
- This was the worst monsoon drought for three decades (since 1972).
- Was the developing El Niño a factor in both these years? There is a known anticorrelation between El Niño and Indian monsoon rainfall (Parthasarathy et al, 1991, *J. Climate*).

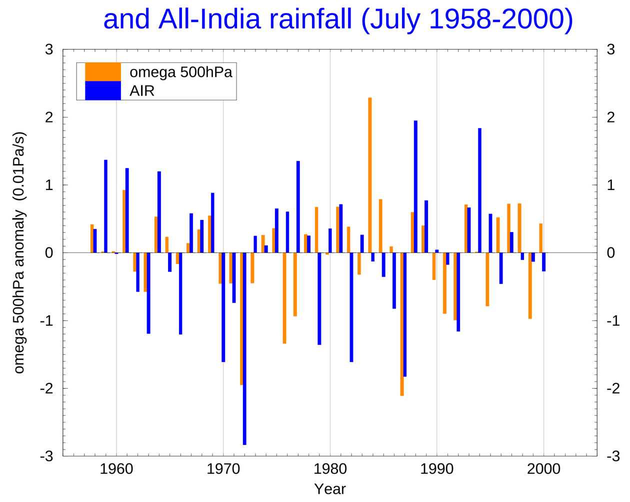
Data and images courtesy of K. Rupa Kumar & J.V. Revadekar

(4) Historical Correlations

Correlation map of 500hPa descent with all-India rainfall (JJA, 1958-2000)



Mediterranean descent [35-45N,0-30E] and All-India rainfall (July 1958-2000)



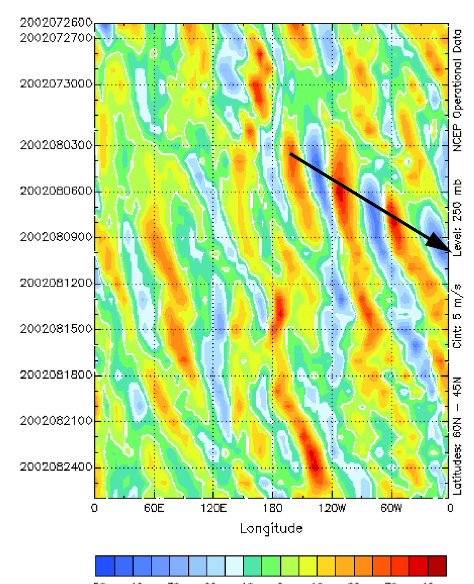
- Interannual variability of Mediterranean summer descent and Indian monsoon rainfall *is* correlated.
- Niño 3.4 sea surface temperature is correlated with both, suggestive of an El Niño impact on the monsoon.
- Mediterranean descent is well correlated with (lack of) in-situ rainfall.
- However Indian rainfall is not significantly correlated with Mediterranean (or central European) rainfall.

July 1958-1998 correlations:

	N34	AIR	Med_w	Med_p
N34		*-0.41*	*-0.38*	*0.31*
AIR	*-0.41*		*0.39*	*-0.18*
Med_w	*-0.38*	*0.39*		*-0.61*
Med_p	*0.31*	*-0.18*	*-0.61*	

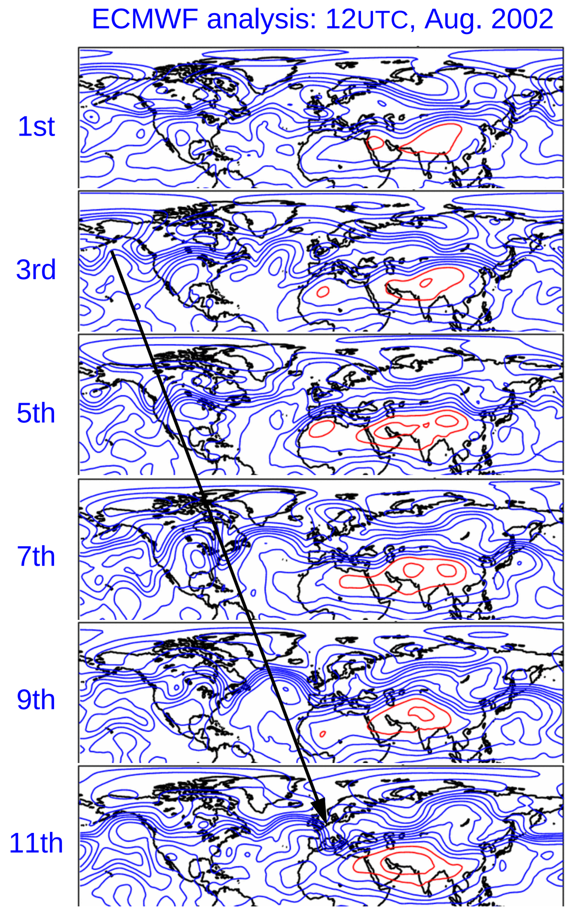
N34 : Niño 3.4 SST anomaly
AIR : All-India rainfall
Med_w : 500hPa descent, [35-45N,0-30E] : NCEP/NCAR Reanalysis
Med_p : Mediterranean precipitation, [35-45N,0-30E] : Hulme et al (1998)
A correlation of 0.31 is significant at the 95% level.

(6) Downstream Development



Meridional wind anomaly 250hPa, 45-60N 26 July - 26 Aug. 2002

Streamfunction at 250hPa ECMWF analysis: 12UTC, Aug. 2002



- During early August 2002, a Rossby wave packet propagated from the north Pacific across America and the Atlantic into Europe, where the jetstream was split by a blocking anticyclone.
- A strong Atlantic ridge and European trough within the wave packet steered a weather system from the UK into the Mediterranean, where it developed strongly and moved north-east over central Europe.
- This system was more characteristic of a winter storm. It brought over 150mm to large parts of central Europe on 11-13th August, only a week after a similar but more zonally propagating weather system.