Recent European flooding events: atmospheric teleconnections and mechanisms

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NERC Centres for Atmospheric Science
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CGAM

NCAS Centre for Global Atmospheric Modelling

The University of Reading

- Outline -

Case Studies:

- Autumn 2000 – UK & western Europe
- Summer 2002 – central Europe

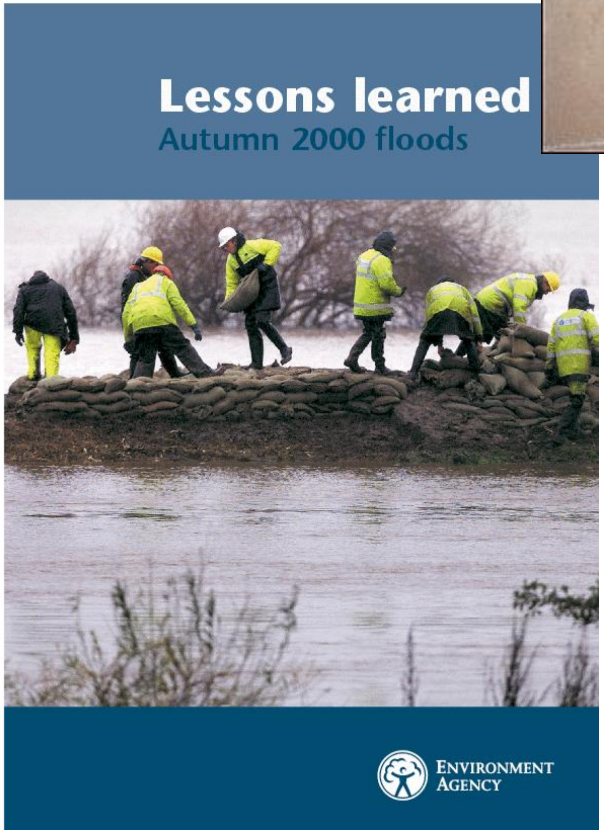
Methodology:

- Excess precipitation
- Weather systems
- Storm-track / jet organisation
- Larger scale connections – tropical & extratropical

Case 1: Autumn 2000

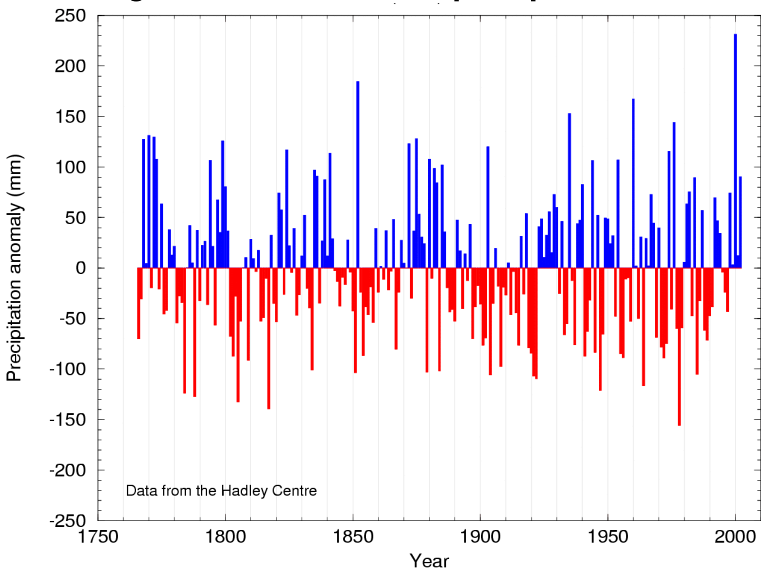
"A wake-up call for global warming"

John Prescott, UK Deputy Prime Minister

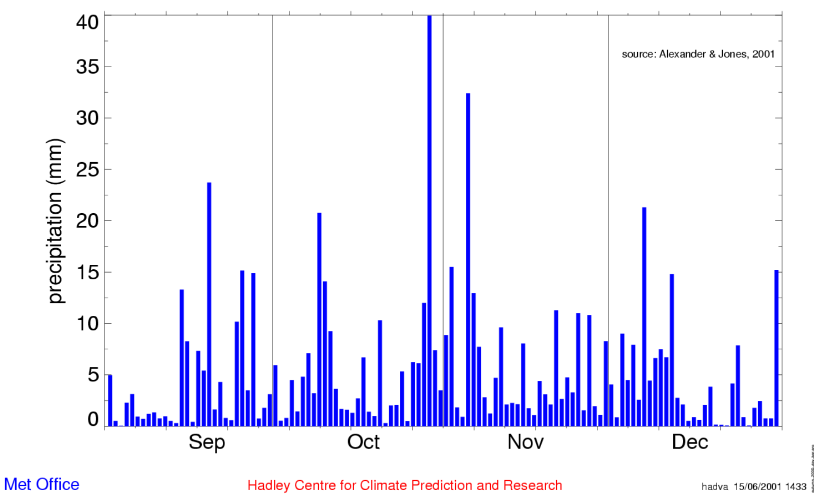


European precipitation in Autumn 2000

England-Wales Autumn precipitation anomaly

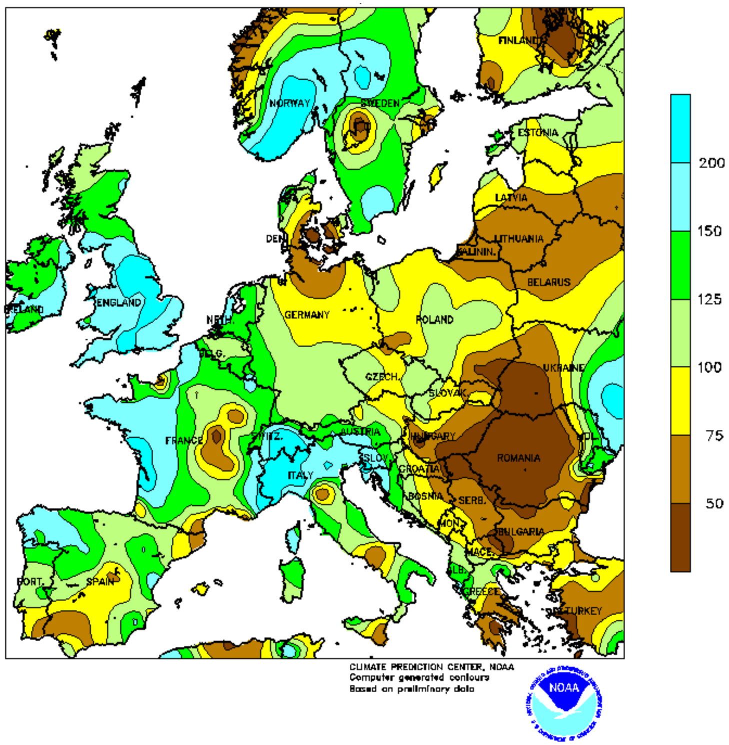


England-Wales daily precipitation (Sep-Dec 2000)



Courtesy of L.V. Alexander

European Precipitation (percentage of normal)
Sep - Nov 2000

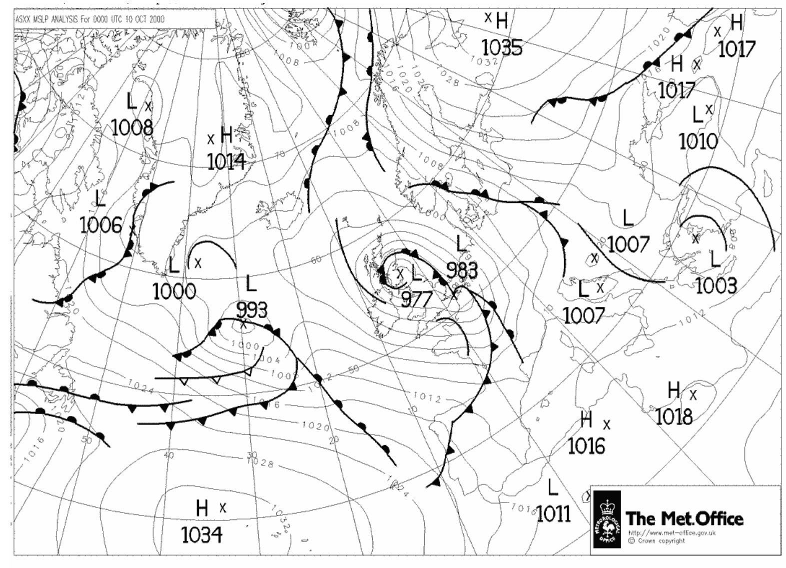


- Record England-Wales precipitation: 503mm, or 186% of long-term average.
- Persistent wet weather from mid-September to mid-December.
- Most of western Europe was exceptionally wet. Large parts of central and eastern Europe were exceptionally dry (and warm).

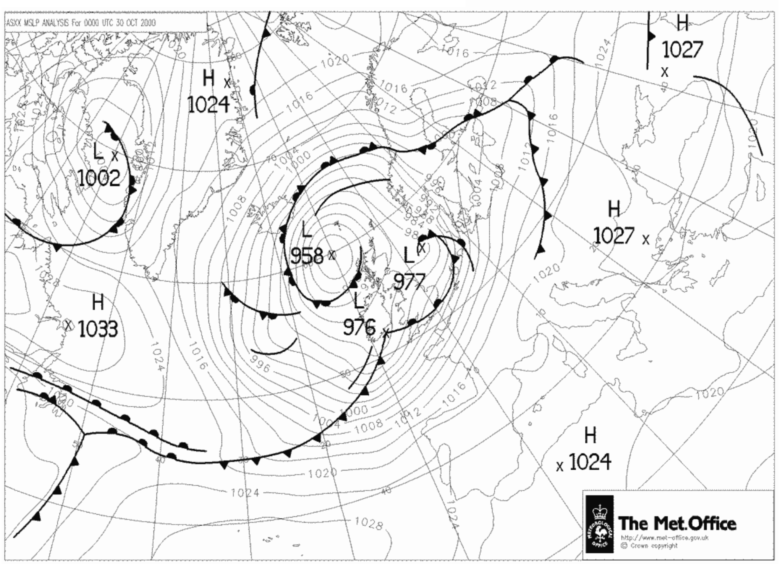
Synoptic Charts (UK Met Office)

- Multiple weather systems
- Several intense storms
- Stagnation over the UK

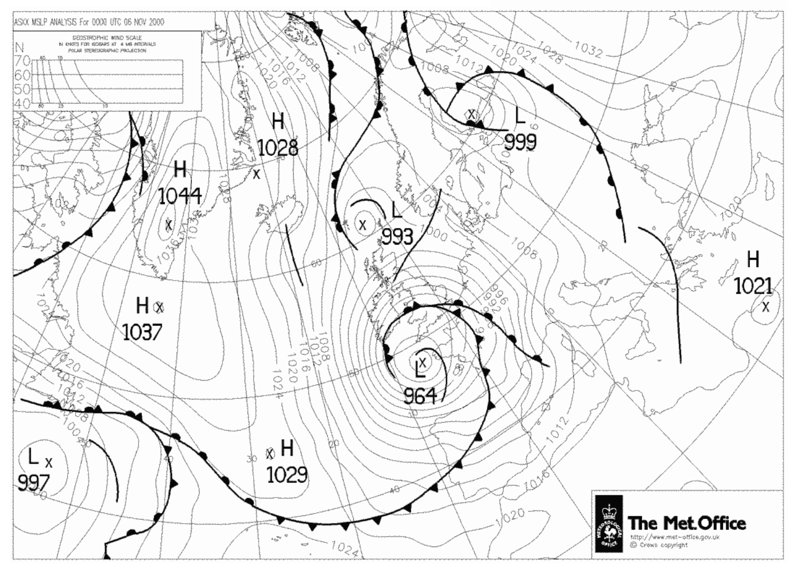
10 Oct. 2000 00Z



30 Oct. 2000 00Z



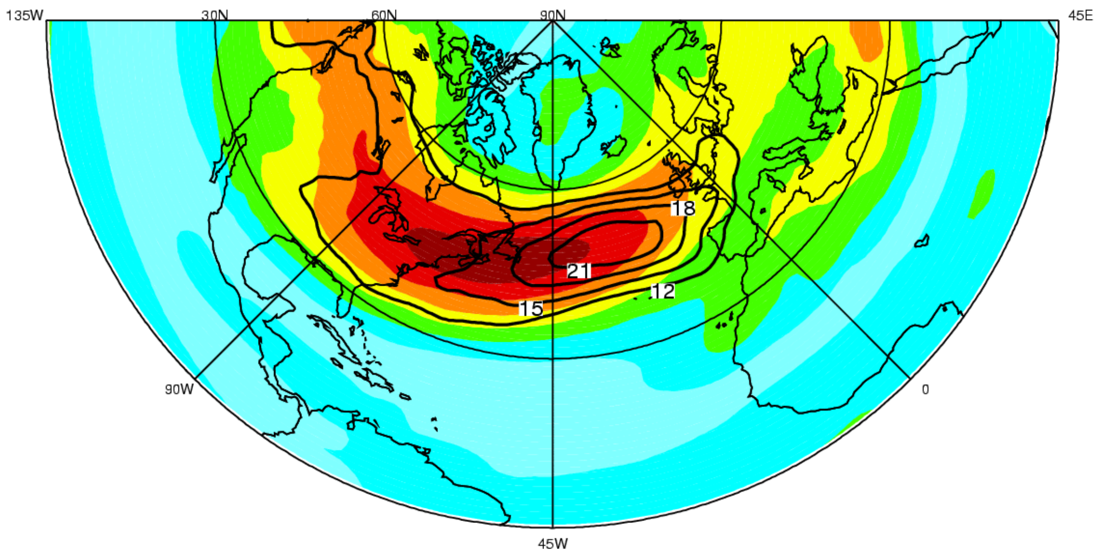
6 Nov. 2000 00Z



The Atlantic jet-stream in Autumn 2000

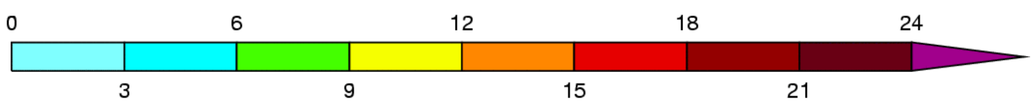
Isotachs of Autumn mean wind (500hPa)

ECMWF analyses (SON)



Climatology (coloured)

Autumn 2000 (contours)



(ms^{-1})

- Atlantic jet-stream displaced east
- Accentuated jet-exit region south of the UK
- Intense weather systems “streered” into western Europe
- Storms slowed in the jet-exit, leading to prolonged precipitation events
- Dynamically forced, thermally indirect vertical circulation in the jet-exit - accentuated and displaced close to the UK

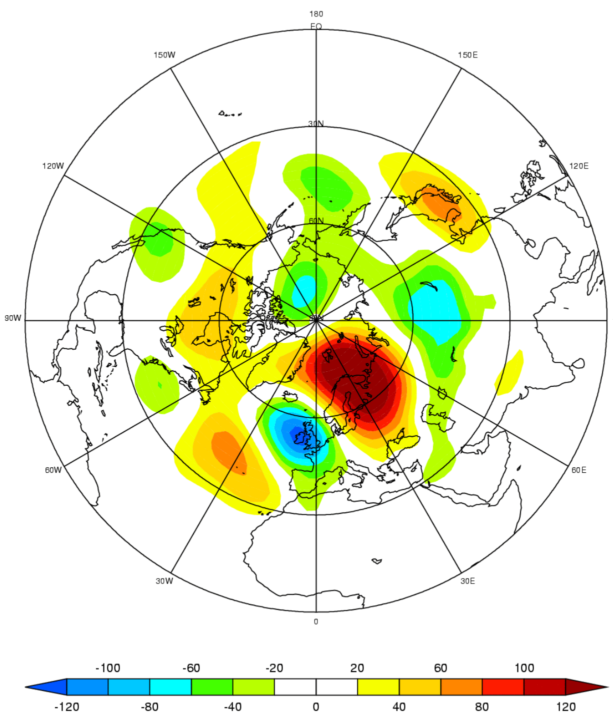
The wider (hemispheric) context

300hPa Geopotential height

SON 2000 Anomaly

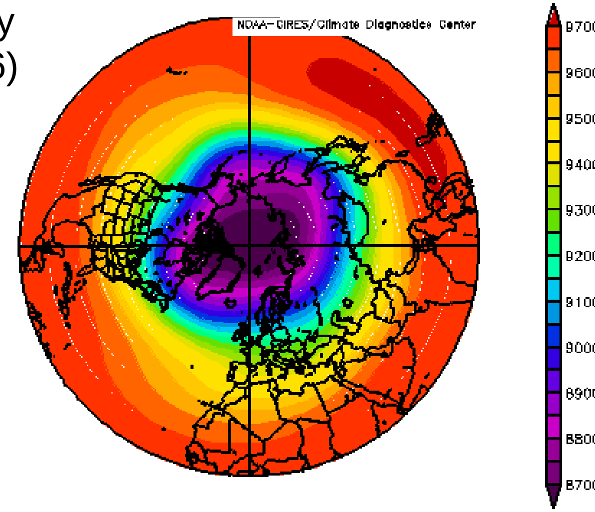
ECMWF analyses

Departure from ERA-15 climatology

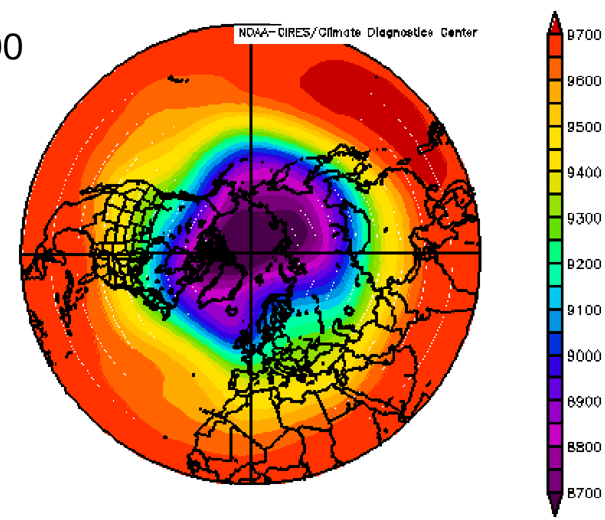


(metres)

Climatology
(1968-1996)



SON 2000



NCEP/NCAR Reanalysis data from www.noaa.cdc.gov

The historical context (1)

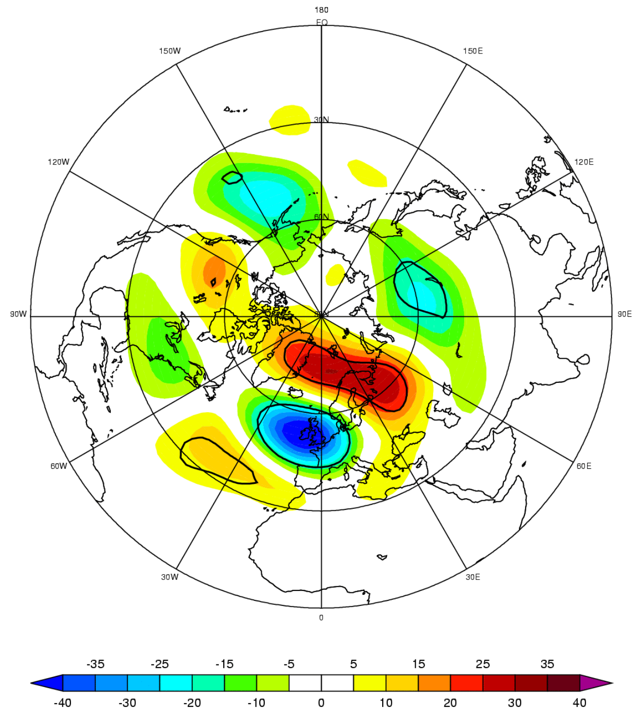
300hPa Geopotential height

Regression on England-Wales precipitation

SON 1958-1999

(bold: 99% confidence level)

- Geopotential height regressed against Autumn England-Wales precipitation (EWP) gives a pattern similar to SON 2000
- Regression of other fields gives consistent patterns (e.g. SLP, streamfunction)
- Composites for wet/ UK Autumns also gives similar patterns. Some differences for dry composites
- Hint of a signal from the north Pacific?



(metres for 1 Std Dvn precipitation)

Regressions performed at NOAA Climate Diagnostics Center: www.noaa.cdc.gov

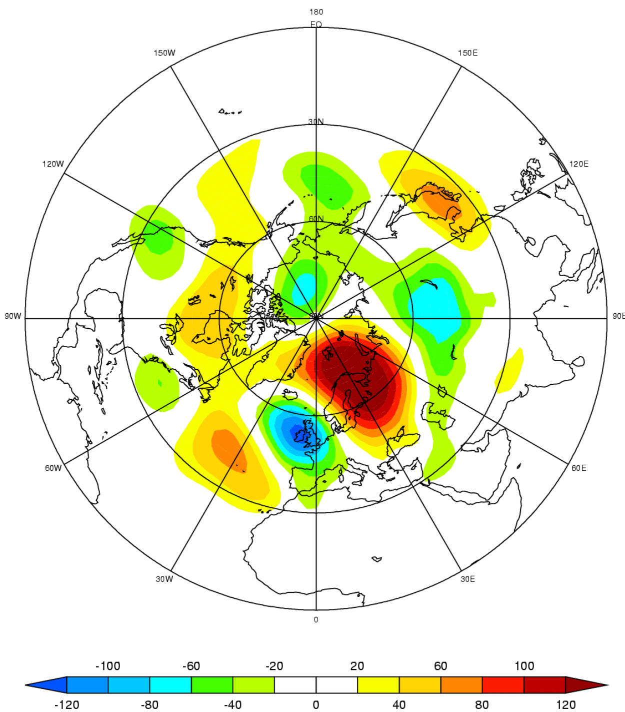
The historical context (1)

300hPa Geopotential height

SON 2000 Anomaly

ECMWF analyses

Departure from ERA-15 climatology

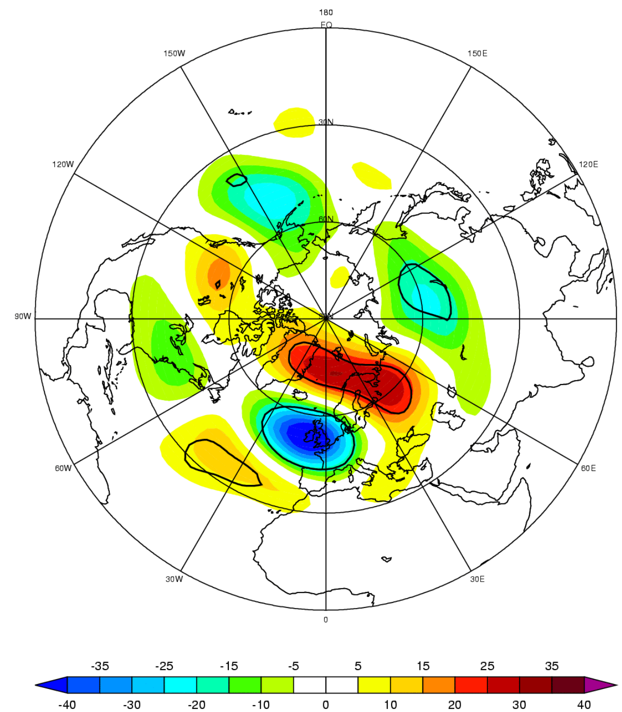


(metres)

Regression on England-Wales precipitation

SON 1958-1999

(bold: 99% confidence level)

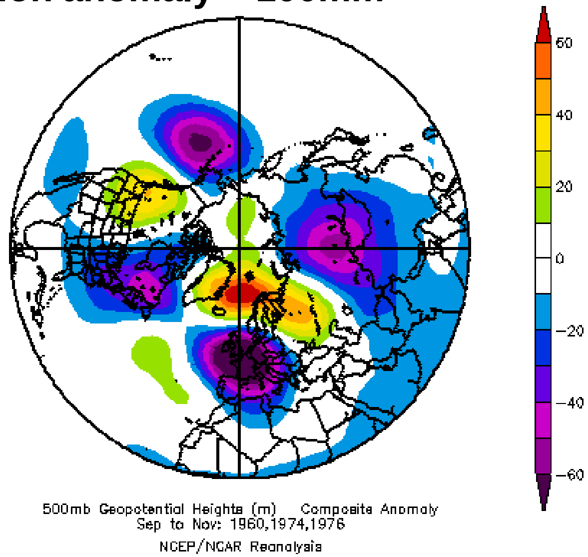


(metres for 1 Std Dvn precipitation)

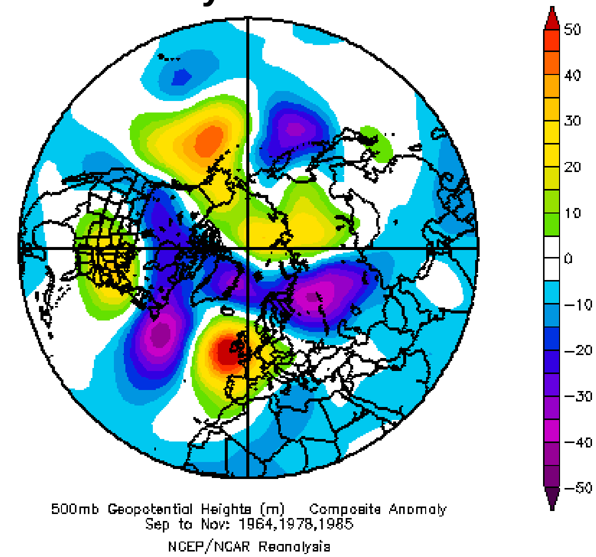
Regressions performed at NOAA Climate Diagnostics Center: www.noaa.cdc.gov

Autumn 500hPa height composites with EWP

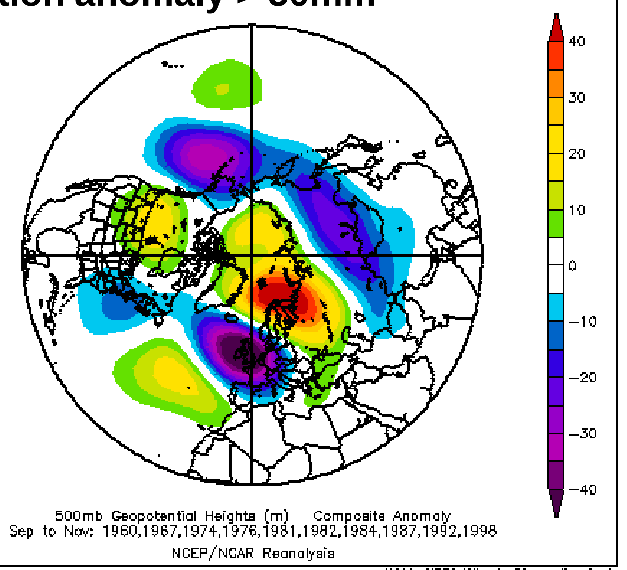
Precipitation anomaly > 100mm



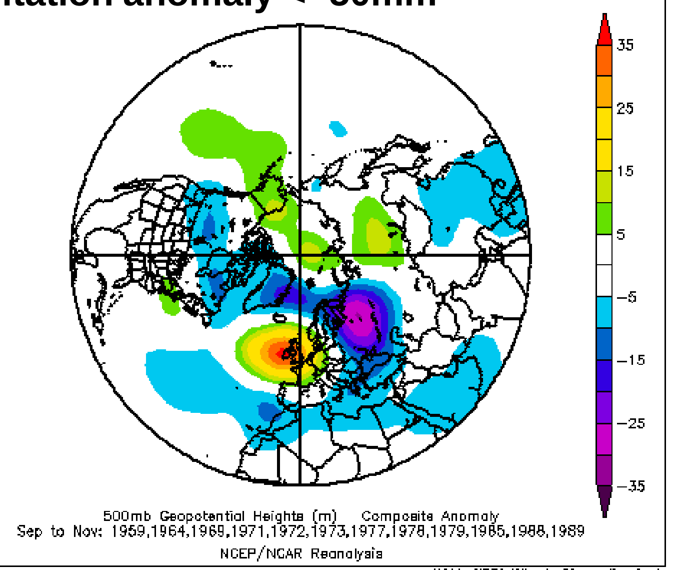
Precipitation anomaly < -100mm



Precipitation anomaly > 50mm



Precipitation anomaly < -50mm

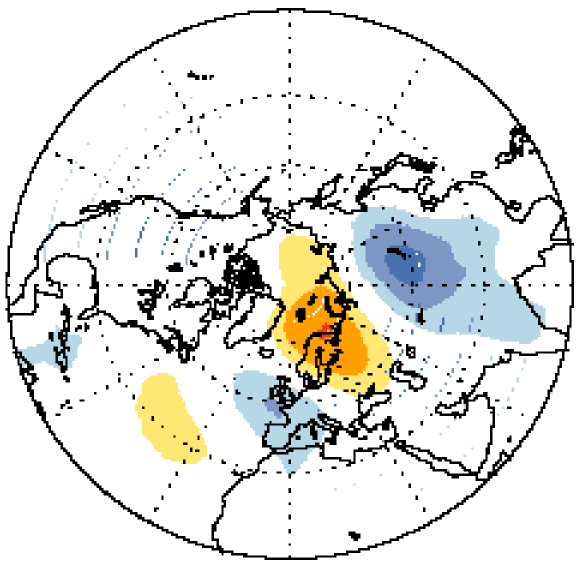


Data/plots at NOAA Climate Diagnostics Center: www.noaa.cdc.gov

The historical context (2)

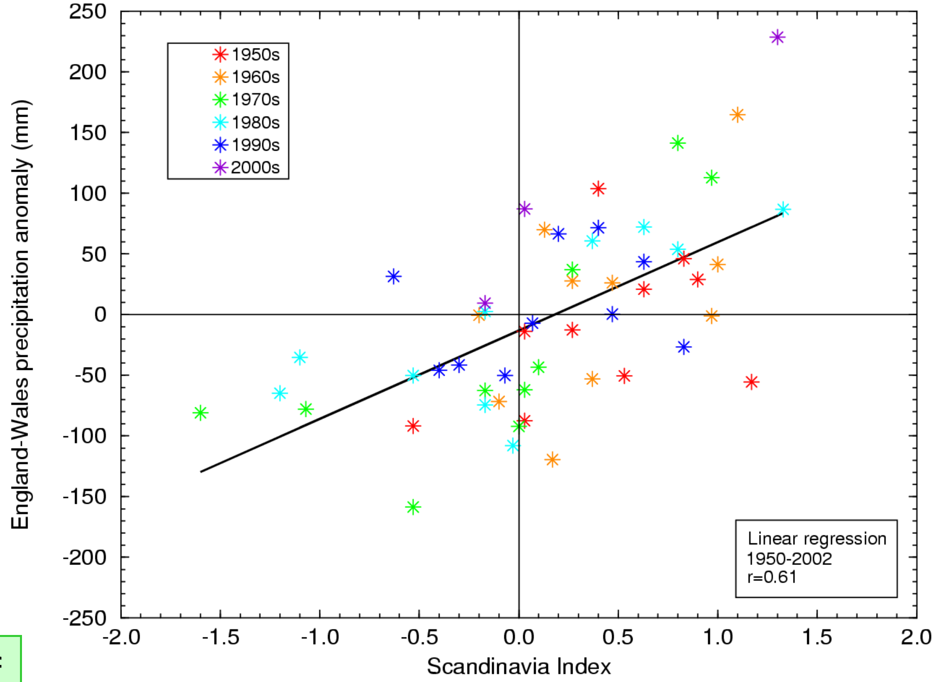
The Scandinavia pattern (Autumn)

NCEP/NCAR Reanalysis data



- Rotated Principal Component (EOF) of 700hPa height
- A leading mode of Autumn variability
- Sep-Nov data 1964-1994
- CPC reworking of Barnston & Livezey (1987)

Incidence of England-Wales precipitation and the Scandinavia pattern



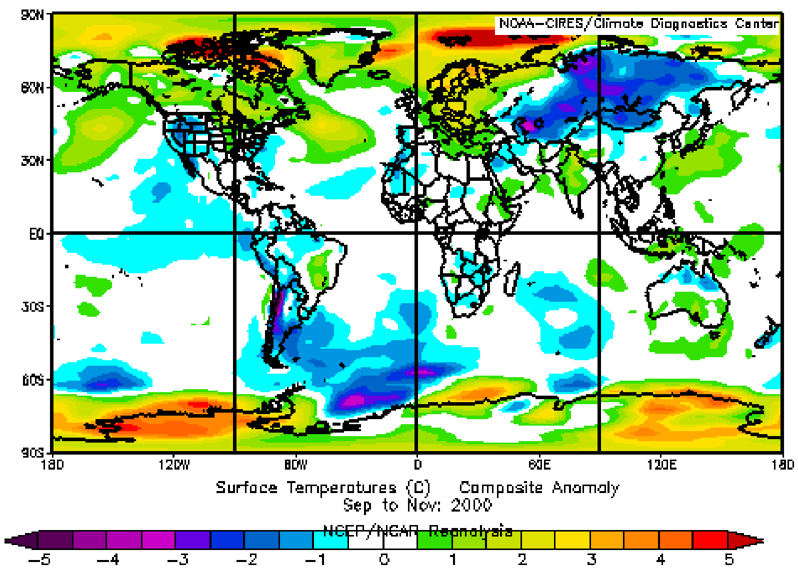
- Correlation 0.61 1958-2002
- Decadal timescale variability, but no trend

Climate Prediction Center: www.cpc.ncep.noaa.gov

Mid-latitude SST Forcing?

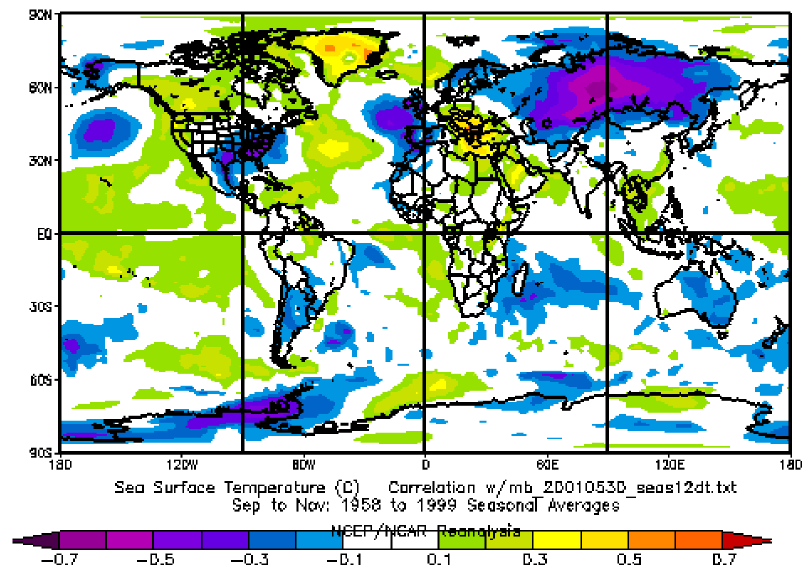
Surface Temperature Anomalies (SON 2000)

NCEP/NCAR Reanalysis



Surface Temperature regressed against England-Wales Precipitation

±0.3 correlation significant at 95% level



- Autumn 2000 anomalies similar to regressed pattern (Atlantic – Eurasia)
- Timing in 2000 suggests SST response to atmospheric anomalies (low-level meridional advection; enhanced ocean mixing)
- Obs. Atlantic anomaly equivalent-barotropic; theory suggests baroclinic local response to SST
- c.f. Ratcliffe & Murray (1970), Palmer & Sun (1985) ….

Tropical forcing from south America?

200hPa Velocity Potential

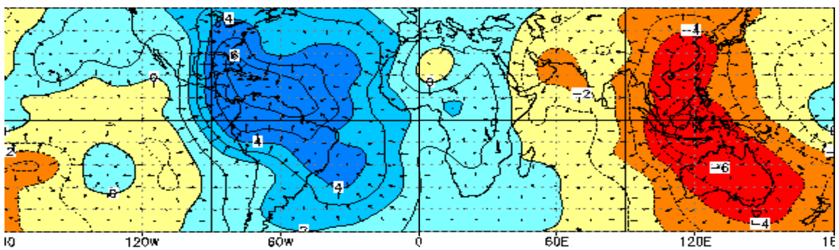
NCEP CDAS/Reanalysis

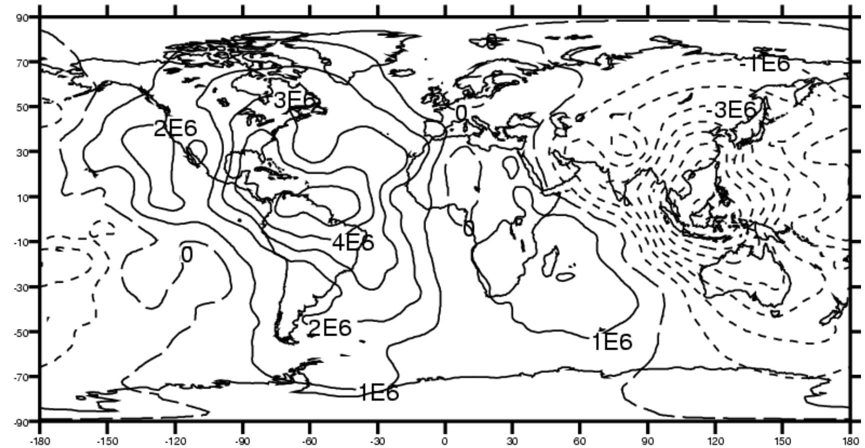
Anomalies from 1979-1995 average

ECWMF Operational Analyses

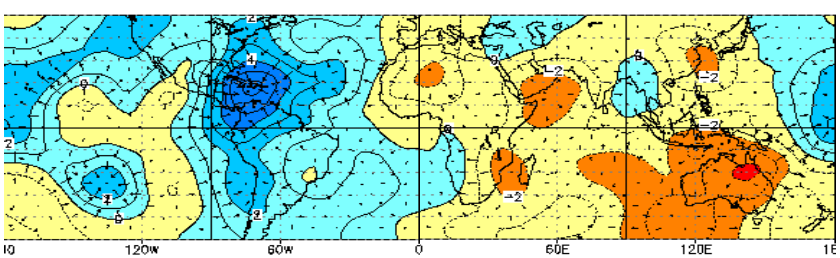
Anomalies from 1979-1993 ERA-15 average

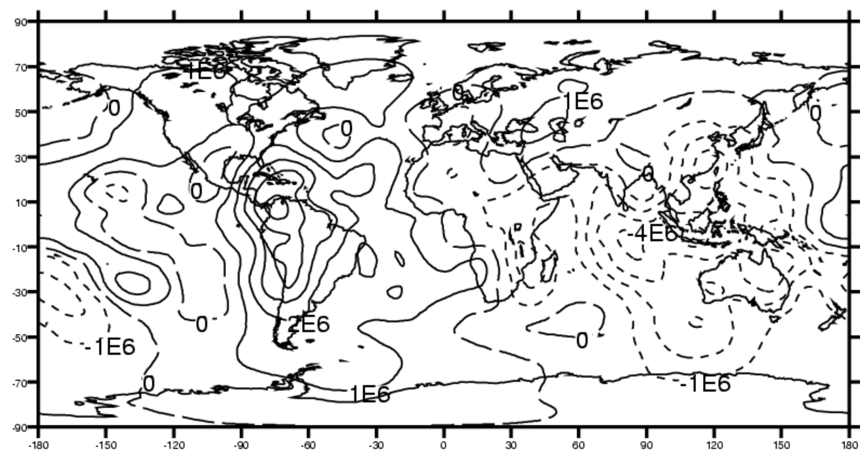
October 2000





November 2000





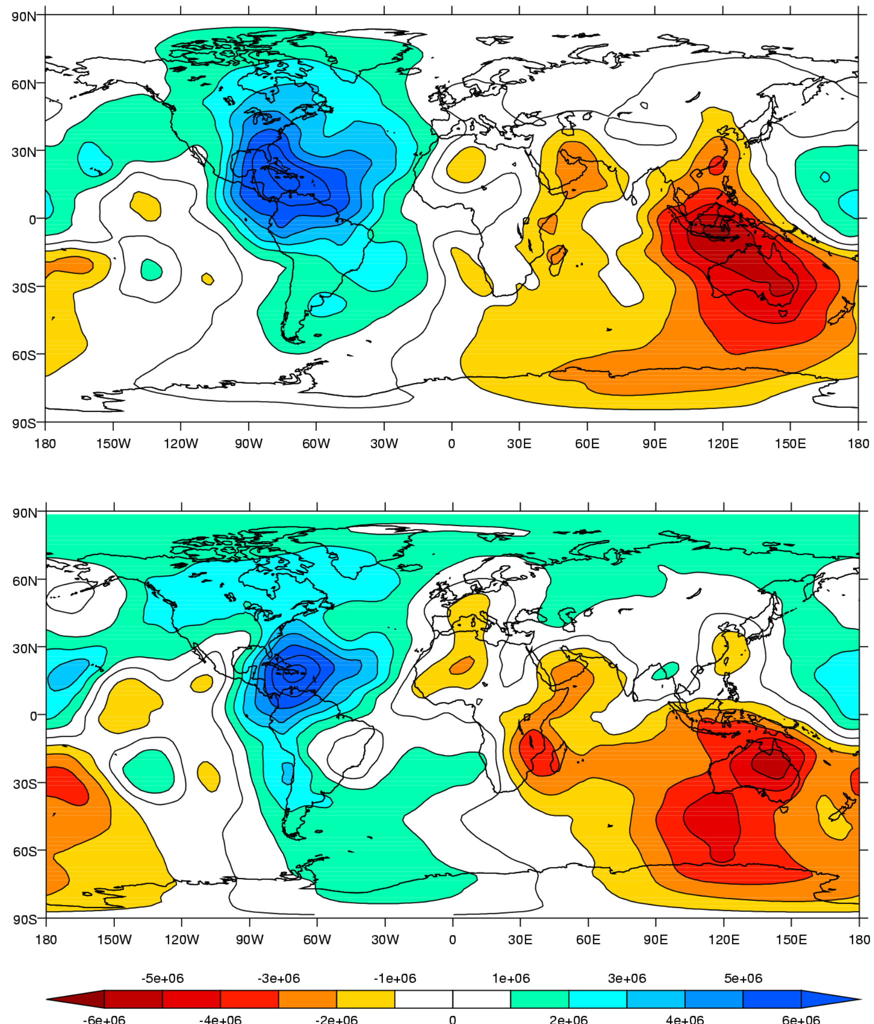
NCEP images from the Climate Diagnostics Bulletin

Tropical forcing from south America?

200hPa Velocity Potential

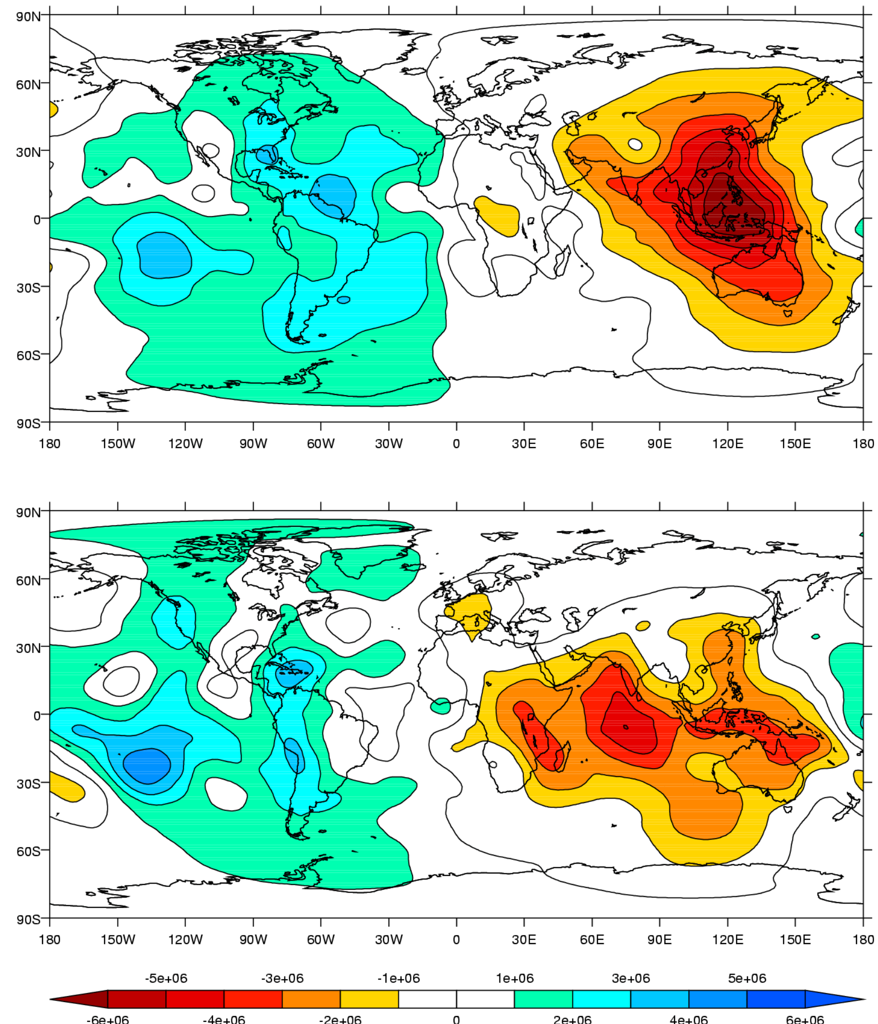
NCEP Reanalysis

Anomalies from 1968-1996 average



ECWMF ERA-40 Reanalysis

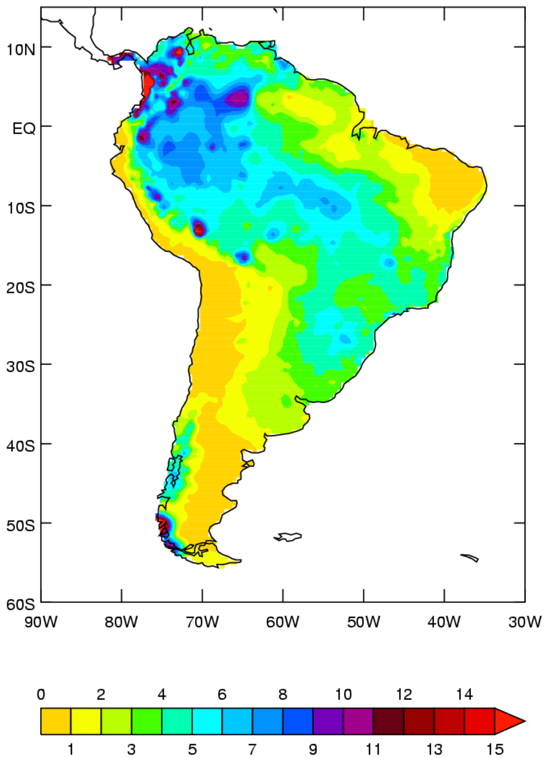
Anomalies from 1979-2001 average



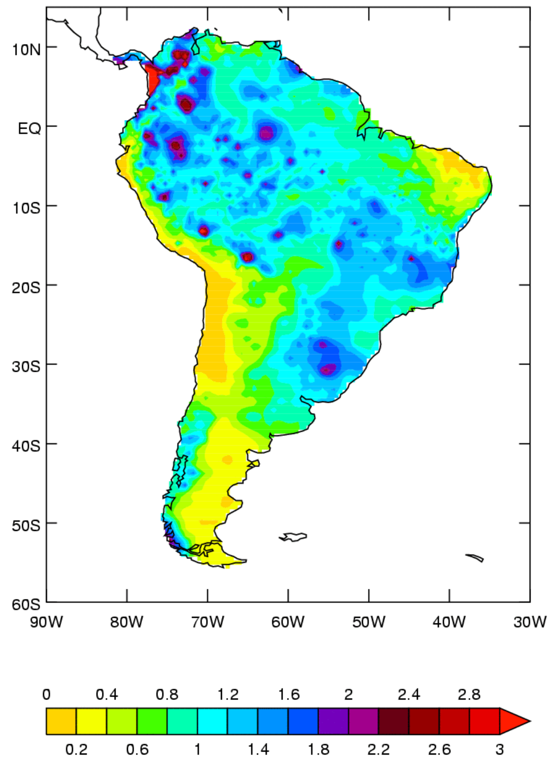
South American precipitation

Autumn (SON) 1960-1990

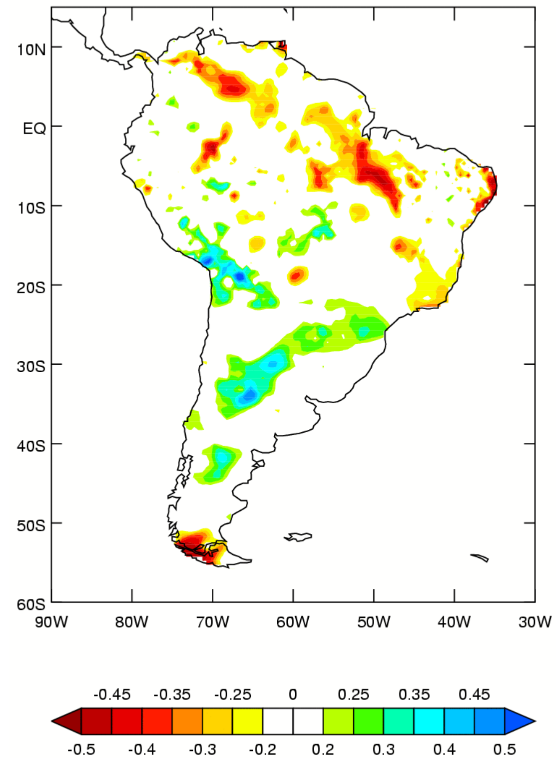
Climatological mean (mm)



Standard deviation (Interannual, mm)



Correlation with Scandianvia Index



- Region of marginally significant negative correlations north of 10°S
- Consistent with anomalous descent in Autumn 2000
- (Higher Amazonian correlations with Southern Oscillation Index)

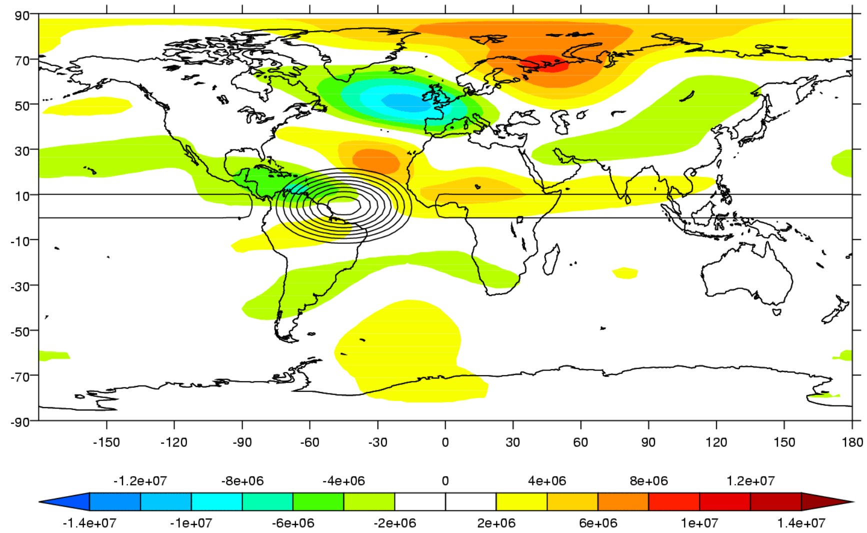
Data from Webber & Willmott, University of Delaware

Barotropic model: response to idealised forcing

Barotropic model

Streamfunction anomaly

Day 15 (~steady state)



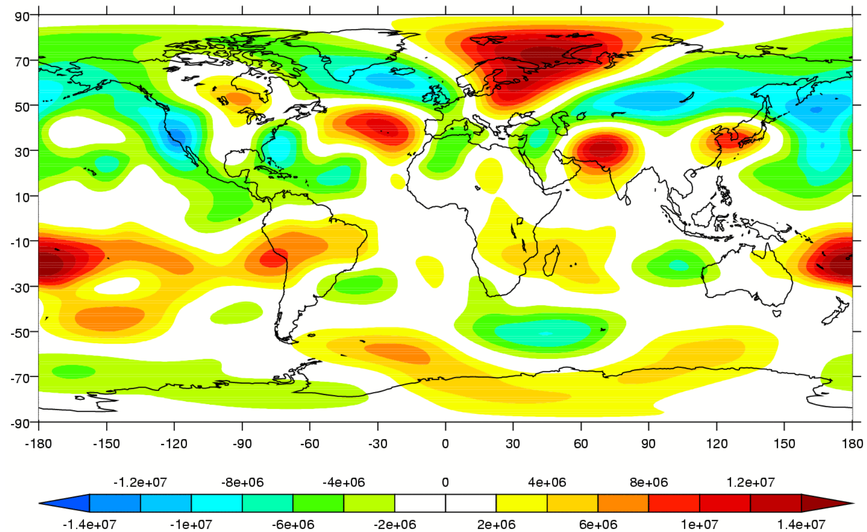
Model configuration:

- *SON climatology basic state*
- *Idealised convergence forcing*
- *Compare response (streamfunction) with analyses*

"Observations" / Analysis

Streamfunction anomaly 200hPa

October 2000 ERA40

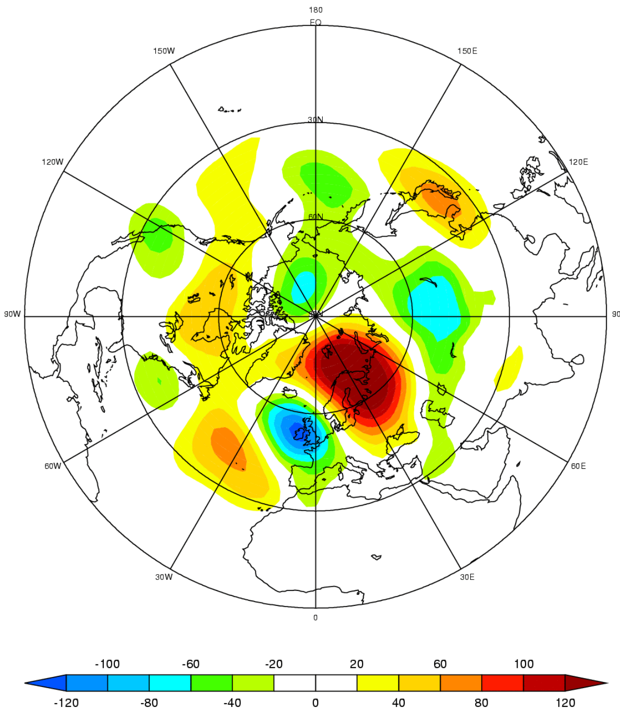


Analyses – SON 2000

300hPa Geopotential height

ECMWF analyses

Anomaly from ERA-15



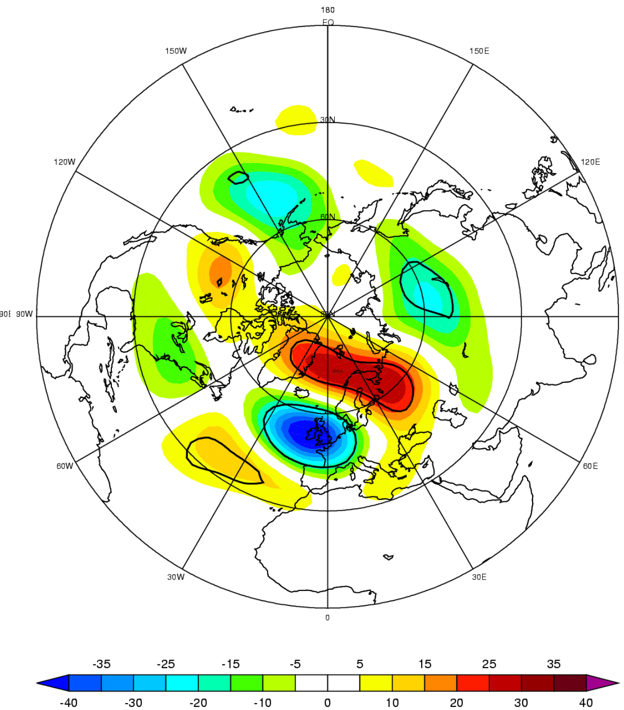
(metres)

Regression on England-Wales precipitation

300hPa Geopotential height

SON 1958-1999

(bold: 99% confidence level)



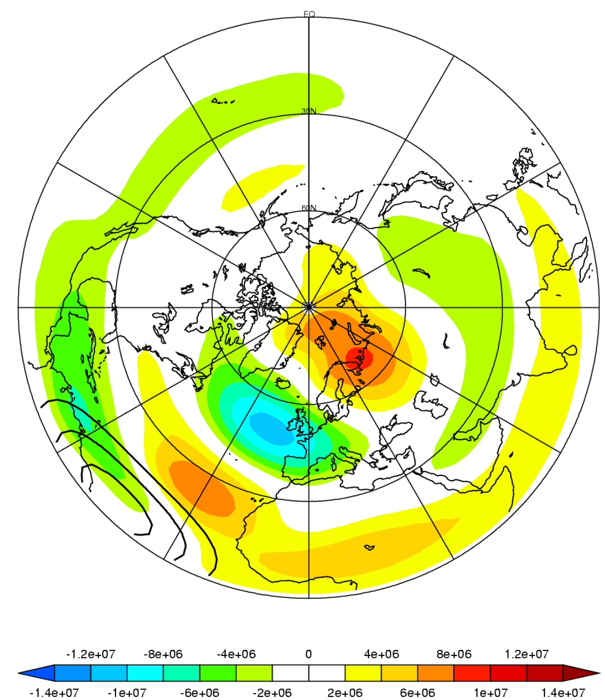
(metres for 1 Std Dvn precipitation)

Barotropic model response

Streamfunction anomaly

Convergence forcing (45W;5N), *-fD*

SON climate 300hPa basic state

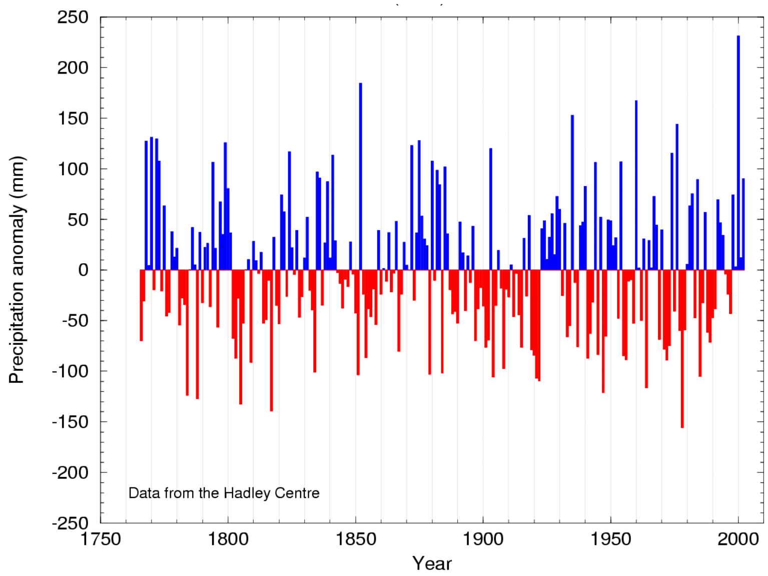


(Interval $2*10^6$ m^2s^{-1})

UK precipitation: evidence of climate change?

EWP Autumn (SON)

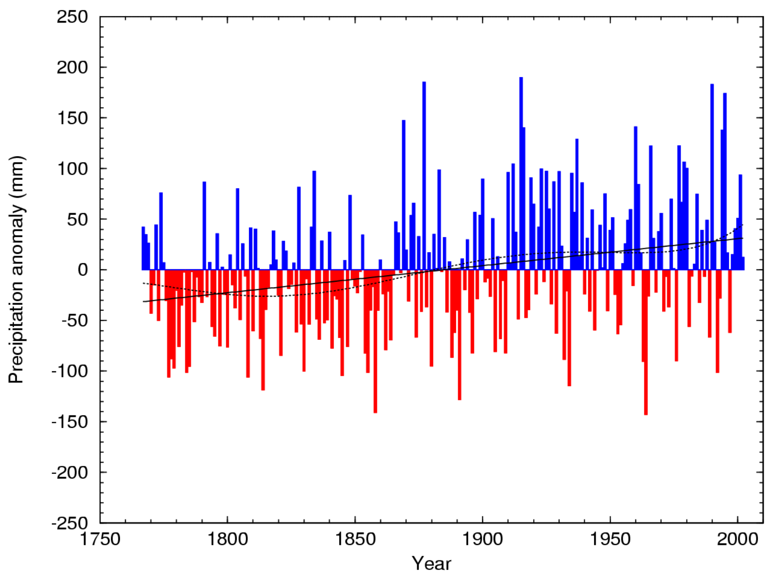
1766 – 2002



- No trend in mean
- Non-significant trend of increasing variability

EWP Winter (DJF)

1767 – 2002



- Increasing mean and variability
- c.f. CMIP GCM comparison – predict wetter winters for Europe due to climate change
- But no evidence that Autumn 2000 is part of such a trend from UK data

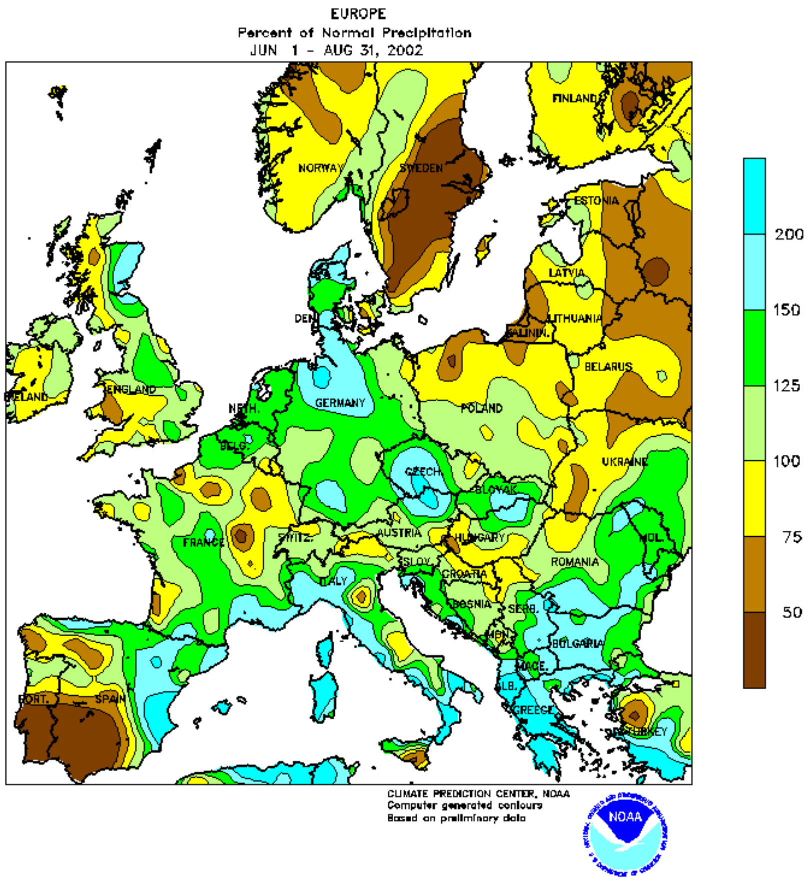
Conclusions (part 1)

- UK Autumn precipitation variability associated with the Scandinavia pattern
- Observational evidence of forcing from the tropical Atlantic / South America
- Confirmation by idealised modelling
- Amazonian deforestation and European climate?

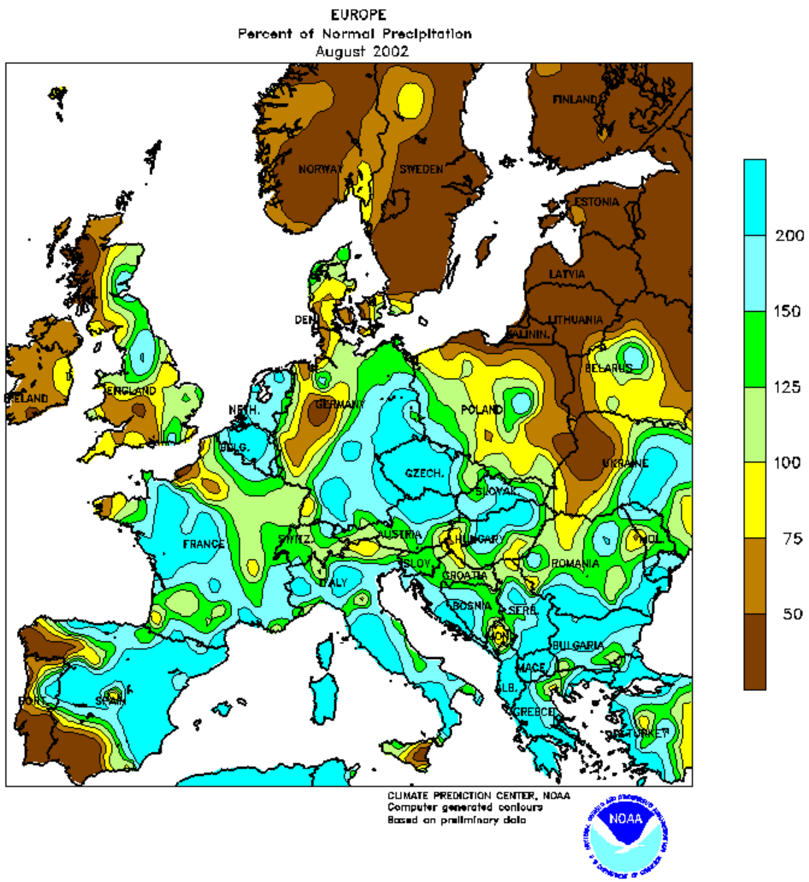
Case 2: Summer 2002: Central Europe

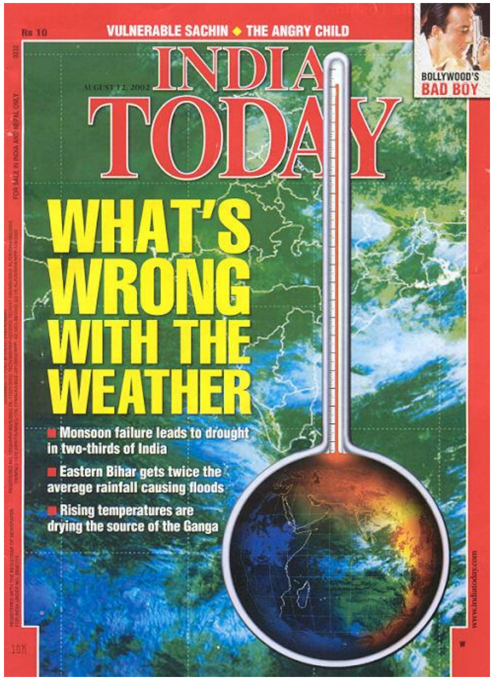
European Precipitation
(percent of normal)

JJA 2002



August 2002

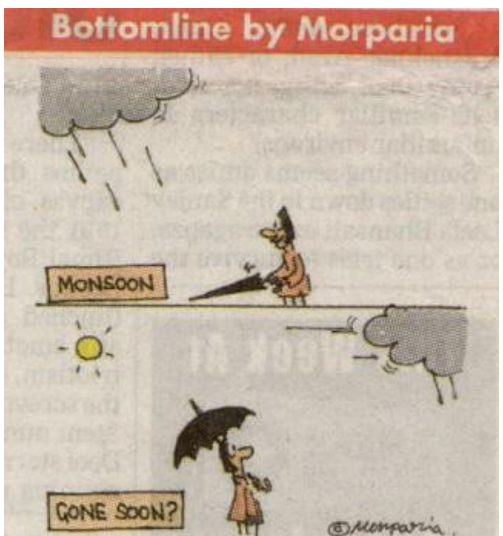




July Drought in India

Many states in state of worry over late rains

A farmer shows the state of his paddy that has dried up due to insufficient rain and water supply in Gidder village of Punjab.



Drought situation is serious, says Centre

New Delhi: Rejecting members' demand for full central control over calamity relief, the government on Friday announced in the Lok Sabha it would provide all possible assistance, including postponement of farm loan recovery in 12 drought-affected states, to mitigate the plight of people.

Replying to a two-day debate on drought and floods in various parts of the country, agriculture minister Ajit Singh said the onus of controlling, managing and executing such relief was on states as they alone were in a position to identify the areas worst affected by natural calamities.

Terming the drought situation as "very serious", he said among the badly hit were western Uttar Pradesh, Bundelkhand area, Rajasthan, Haryana and Delhi, as also Karnataka, Kerala, Nagaland and Orissa.

Asking the affected states to immediately start utilising the Calamity Relief Fund (CRF), Singh said the Centre had already taken steps to extend benefits under the fund to all farmers in affected areas.

The minister said the Centre was also ready to release the next instalment of CRF, which would be due only in October, if states utilised it properly. If CRF is inadequate, steps would be taken to provide help under the National Calamity Contingency Fund, he said.

Regarding the demand for waiving and writing off loans, he said he was in the process of discussing the matter with the finance minister as it involved much wider arena and different authorities.

Singh said the Centre had already held a stock-taking meeting with agriculture and relief ministers of 12 drought-affected states, at which it was decided to ask Nabard and co-operative agencies to postpone loan recovery from states and other borrowers.

As a measure to minimise the sufferings of farmers, sugar mill owners have been asked to immediately pay the outstanding Rs 1,000 crore to cane growers, he said. The Centre is also examining the possibility of bearing the cash component under the 'food for work' programme to states facing acute resource crunch.

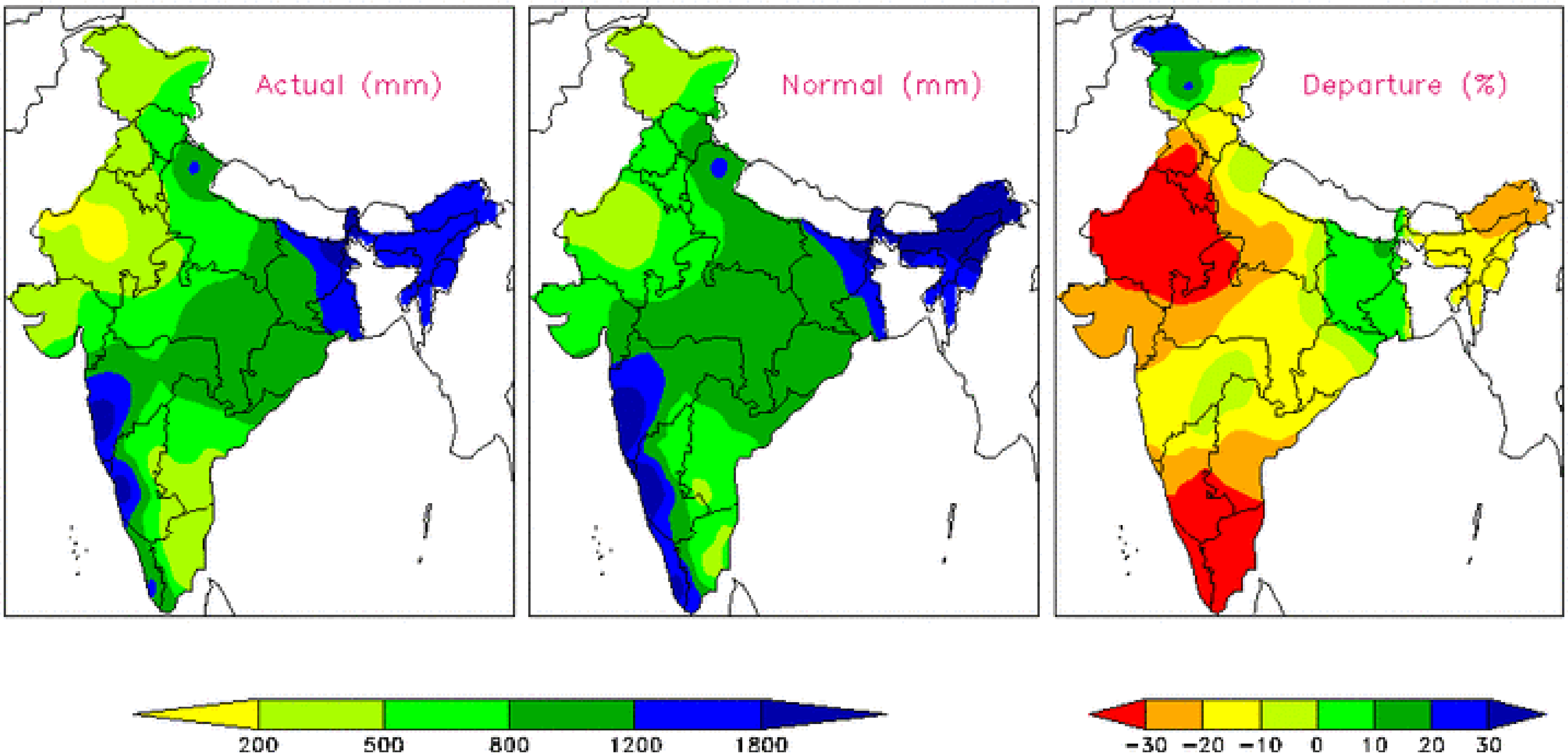
Stating that food output would be adversely affected due to drought conditions caused by poor monsoon, Singh said substantial damage had already been caused to coarse cereals like bajra, oilseeds and pulses. Paddy prospects would also be affected, though it may recover to some extent if rainfall takes place in the next 10 days, he said.

On the criticism that the meteorological department had failed in forecasting monsoons, he said there were so many variables in this science that it was not always possible to be accurate.

Singh expressed confidence that there would be no starvation anywhere due to drought and other calamities and said consumers would not be hit hard as the country had sufficient stocks of foodgrains and other commodities. An estimated 50 lakh tonnes of foodgrains would be needed for supply in affected states and the requirement would be met without much difficulty, he said. PTI

Indian Precipitation: summer totals

Rainfall for the period 1 June to 30 Sept., 2002

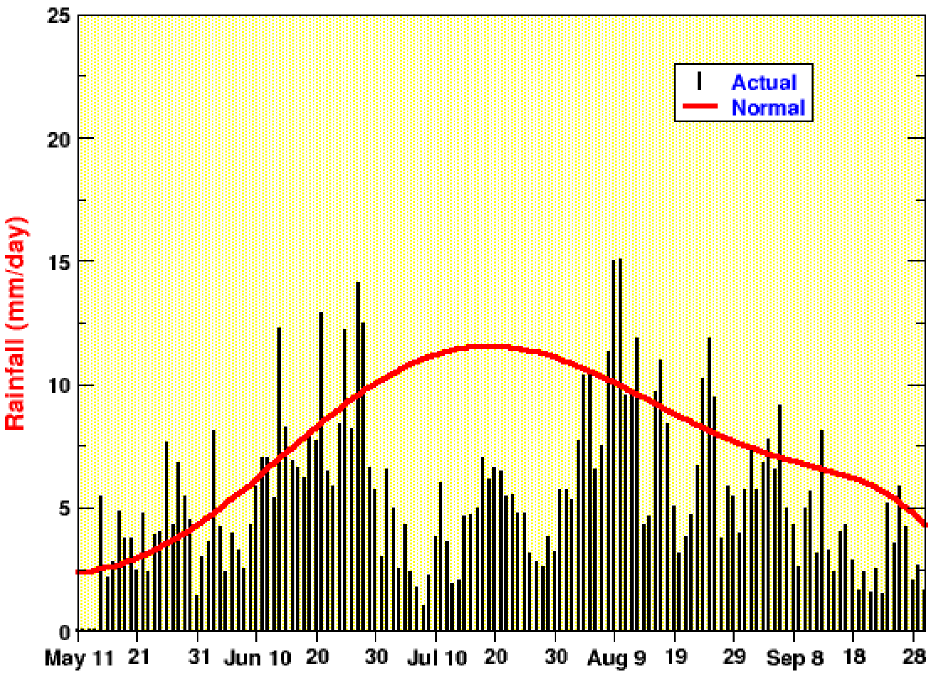


Monsoon Online: www.tropmet.res.in/~kolli/MOL

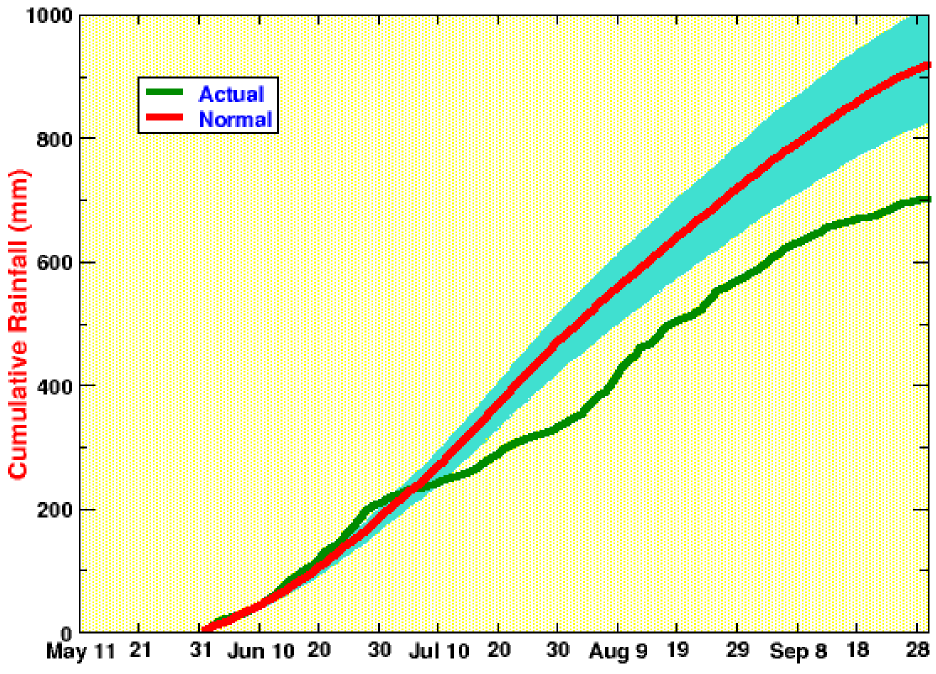
Source: K. Rupa Kumar & J.V. Revadekar

All-India Precipitation: seasonal evolution

Daily total (mm)



Daily accumulation



Source: K. Rupa Kumar & J.V. Revadekar

Could there be a link between these events?

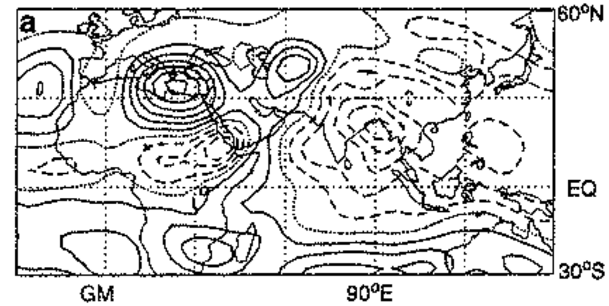
Theoretical?

Historical correlation of interannual variability?

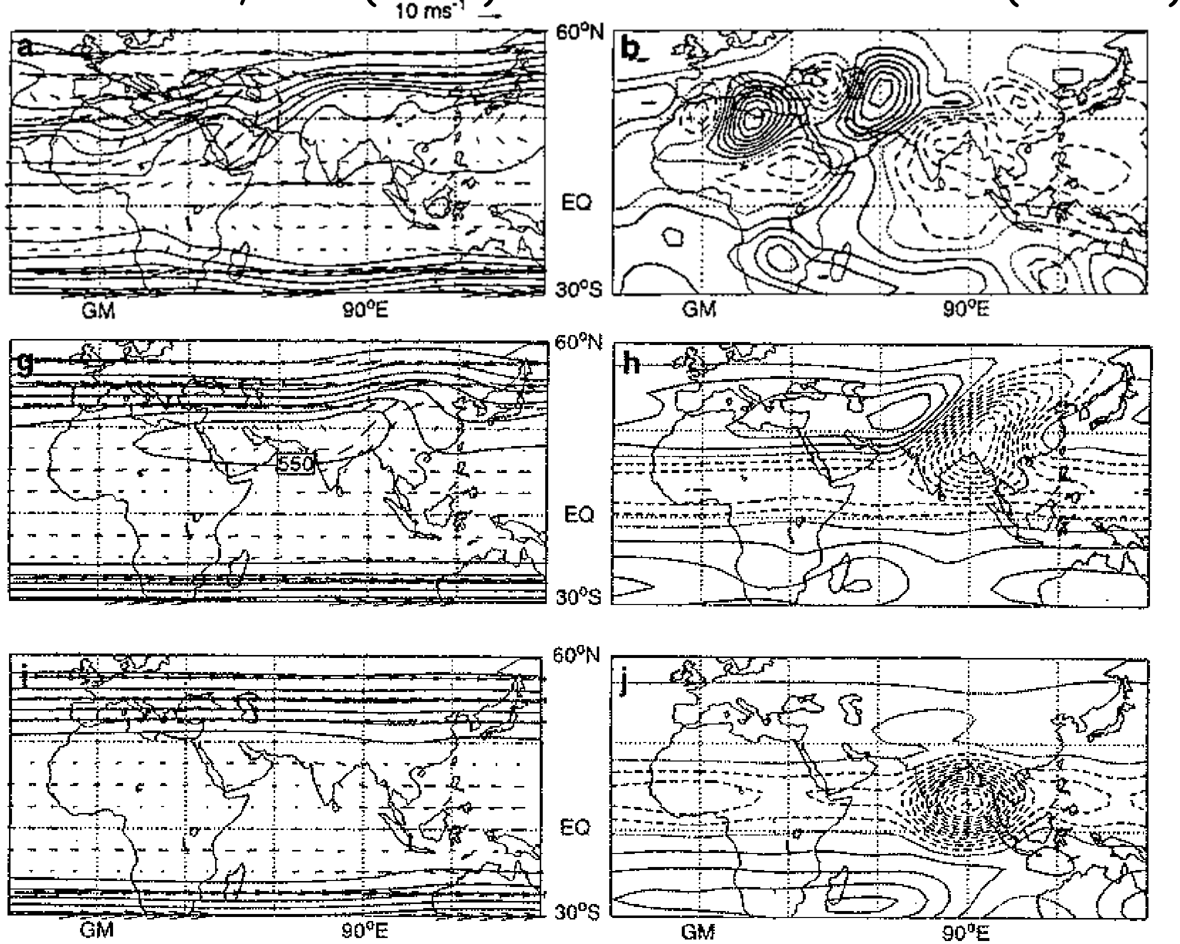
Monsoon / Mediterranean link

Idealised modelling:
Rodwell & Hoskins (1996)

Obs. JJA ω(477hPa)



Pressure, wind (325K) | Mid-level descent ω(477hPa)

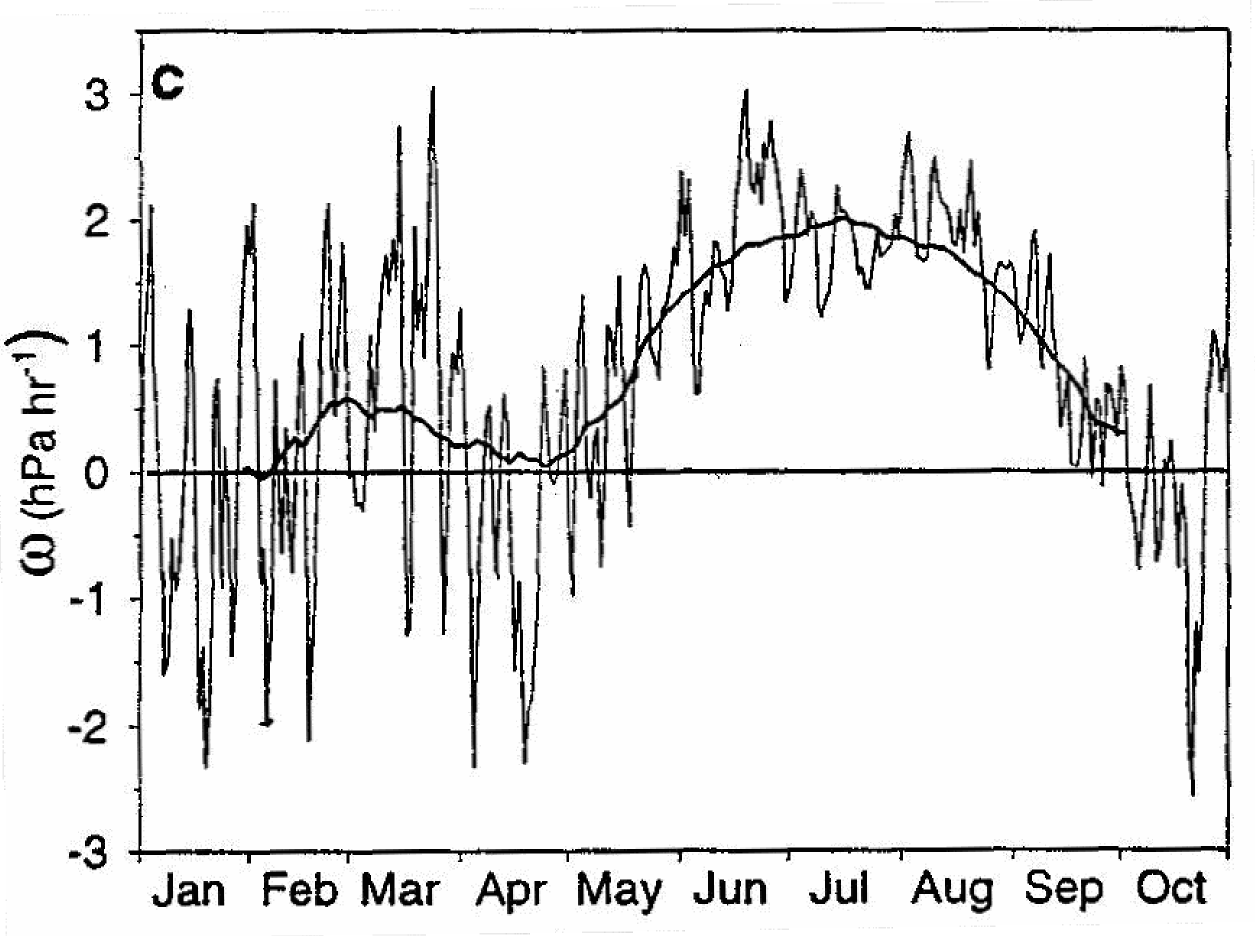


Full model: global heating and orography

Idealised monsoon heating (25°N), no orography

Idealised monsoon heating (10°N), no orography

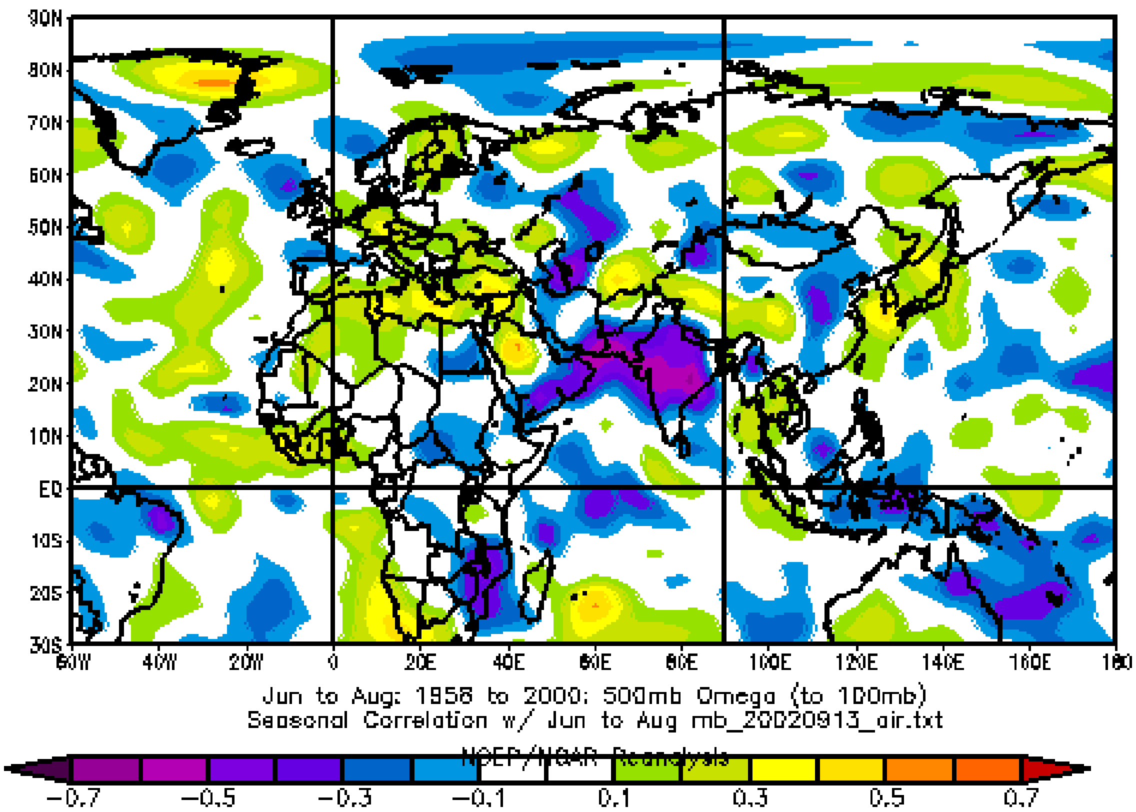
Rodwell & Hoskins (1996) continued…



Seasonal evolution of Mediterranean descent, 22:42°N, 8-37°E

477hPa ω from ECMWF analyses, 1994

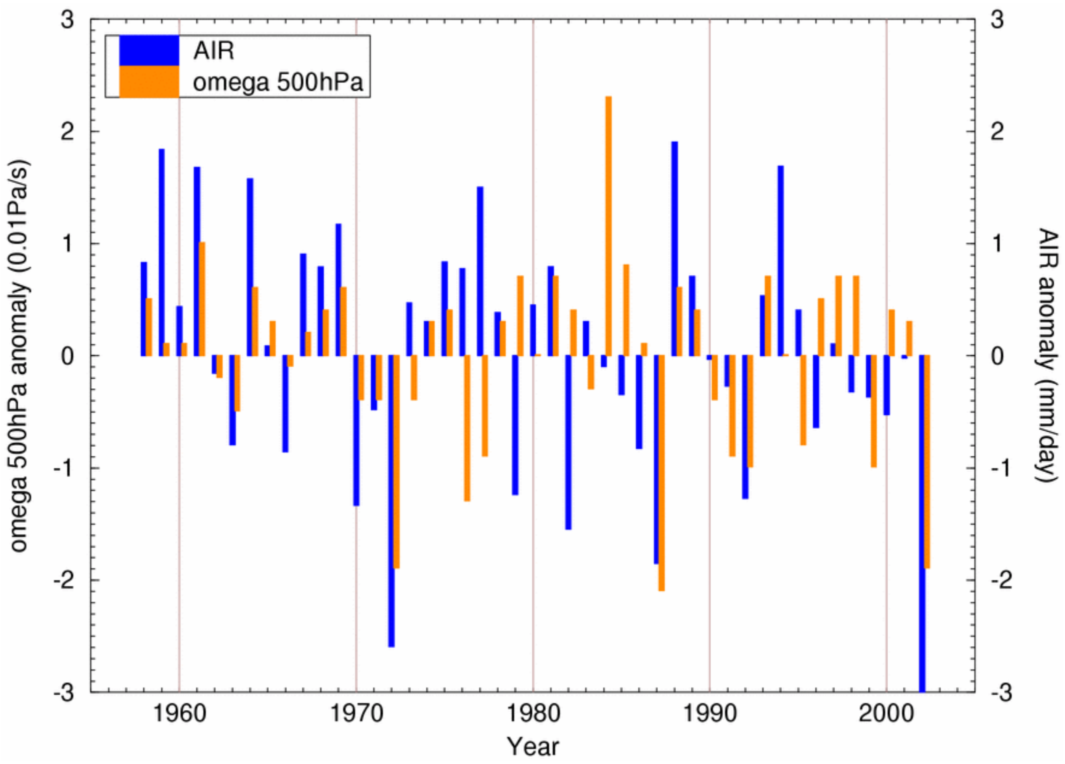
Indian monsoon rainfall and Southern European Descent (JJA)



NOAA–CIRES/Climate Diagnostics Center

- All-India rainfall index, 1958-2000
- NCEP/NCAR Reanalysis ω at 500hPa, global
- Interannual variability *is* correlated

Indian monsoon rainfall
and
Southern European Descent (July)

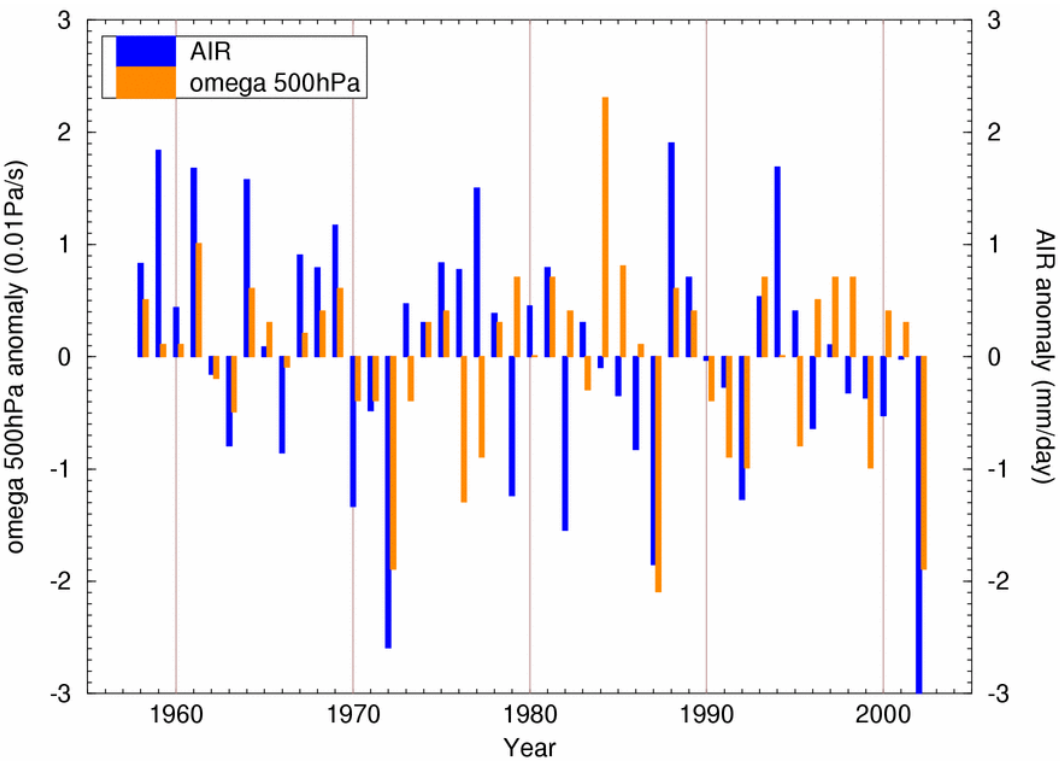


- NCEP/NCAR Reanalysis ω 35:45°N 0:30°E
- Correlation coefficient 0.39 (1958-2000)
- Higher correlation by crudely including a Pacific SST index
- But *no* correlation of AIR with European rainfall

Correlations between:

- Niño 3.4 SST
- All India rainfall
- w500 S. Europe [35-45N,0-30E]
- CRU Precipitation S.Europe

All-India rainfall and S. European descent
July 1958-2002 (not detrended)



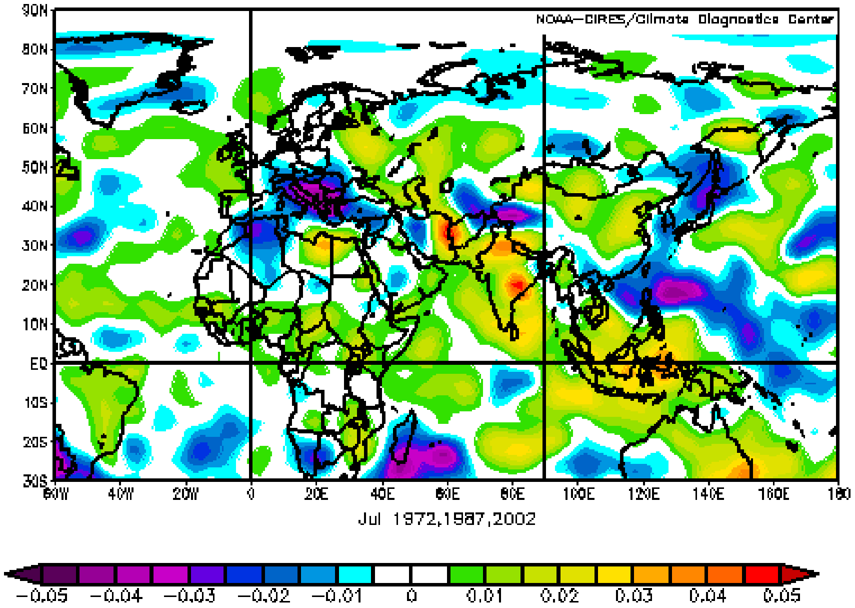
July 1958-1998

.	N34	AIR	w500	CRU
N34		-0.41	-0.38	0.31
AIR	-0.41		0.39	-0.18
w500	-0.38	0.39		-0.61
CRU	0.31	-0.18	-0.61	

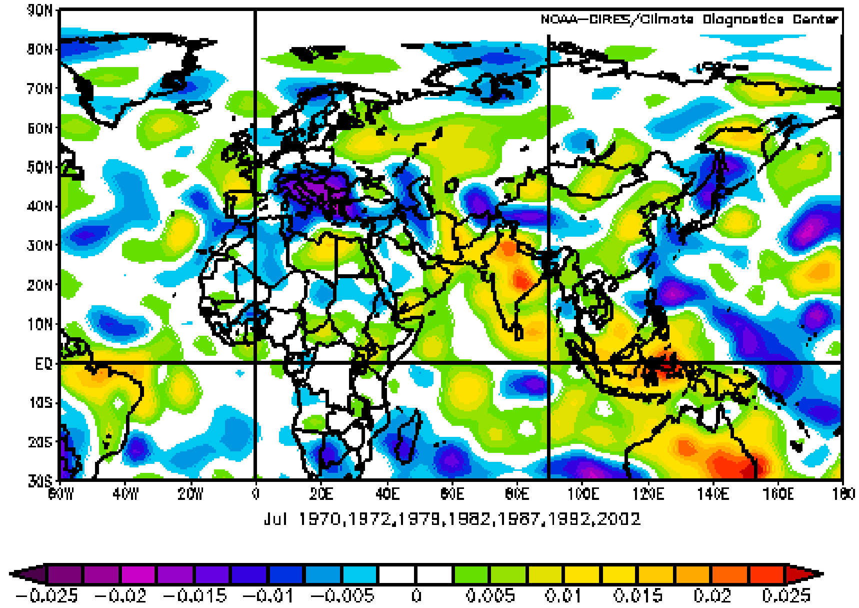
- All time-series detrended -

ω 500hPa : Dry monsoon composites for July

All-India rainfall : 3 driest months
July 1972, 1987, 2002



All-India rainfall : 7 driest months
(exceeding 1 std-devn)



- NCEP/NCAR reanalysis data captures the local Indian ω anomaly
- Ascent anomaly over southern Europe
- El Niño signal in Pacific (not shown)

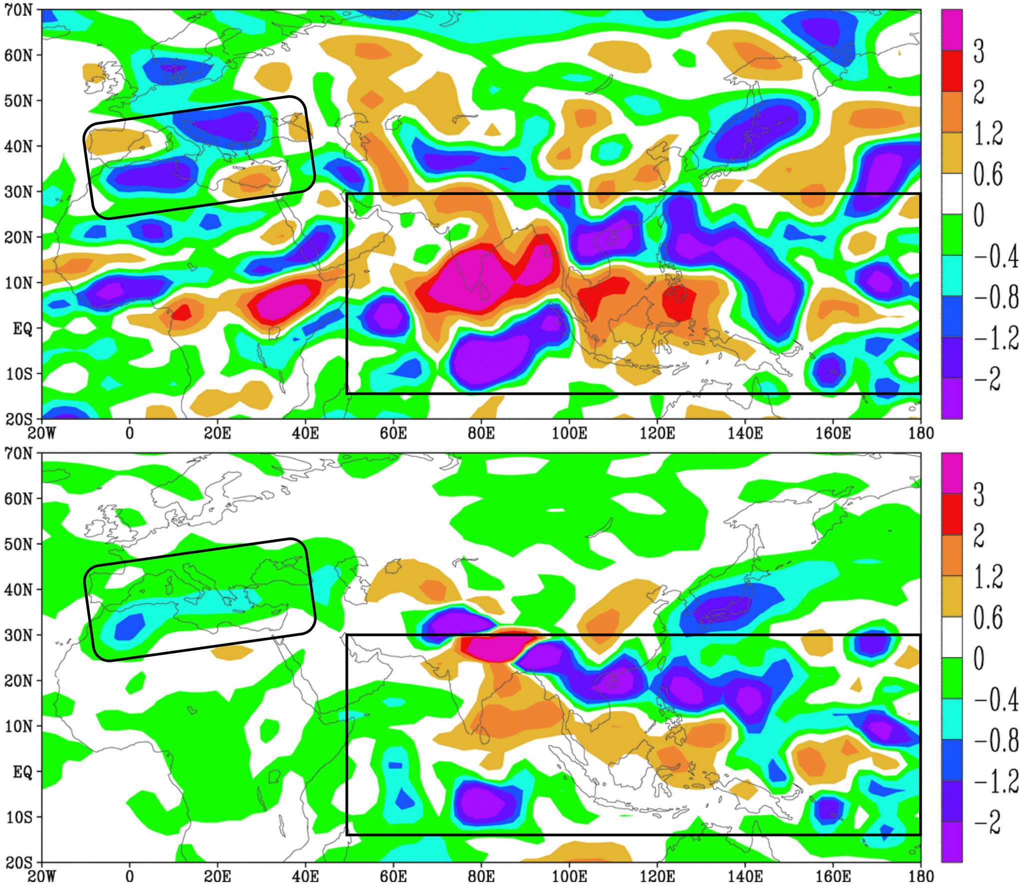
Baroclinic model response to July 2002 monsoon drought

- Model forced by monsoon heating anomaly [15S-30N; 50-180E]
- Heating from NCEP/NCAR reanalysis-2, 1958-2002
- Expected local (tropical) response: relative descent over monsoon region
- Also anomalous ascent over Mediterranean

Vertical motion anomalies at 500hPa

July 2002 analysis (top)

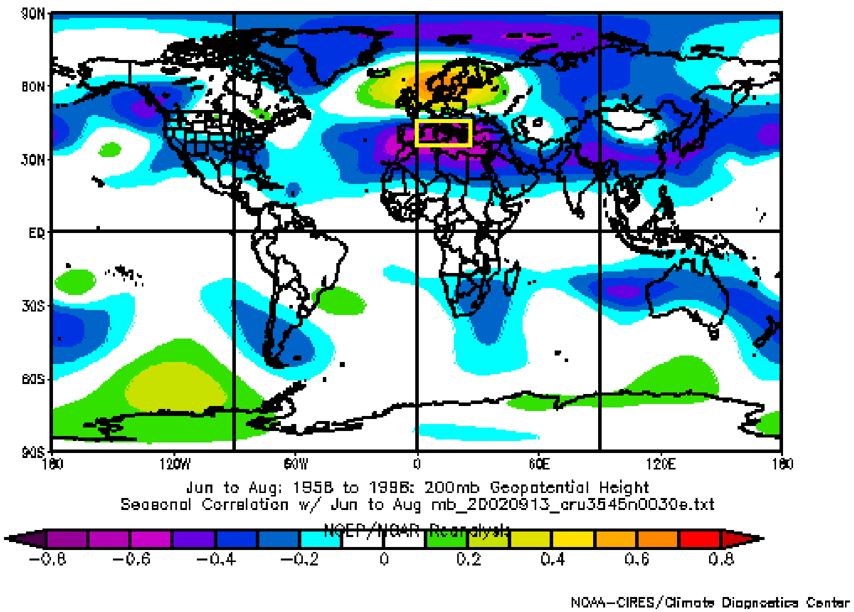
Model response to 2002 heating anomaly (bottom)



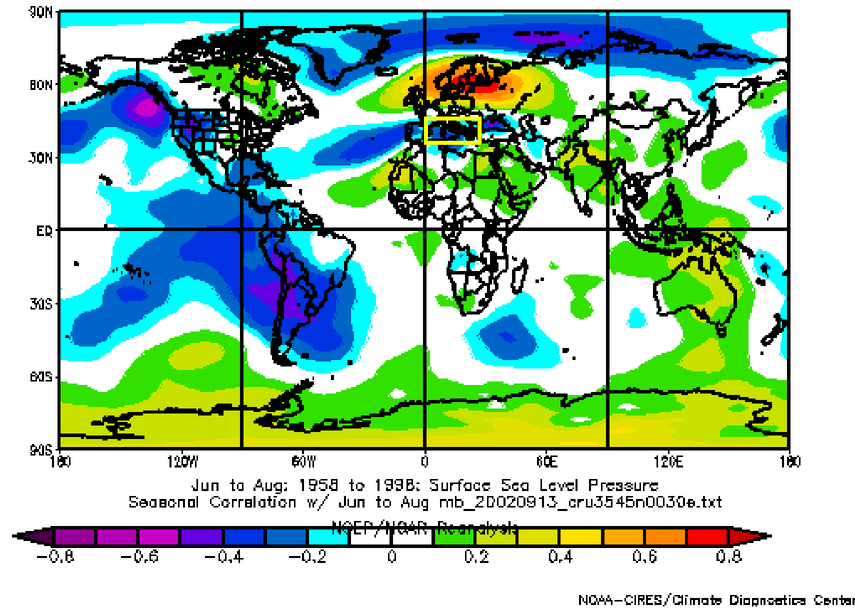
Ascent (blue); descent (red). ($hPa.hr^{-1}$)

Regressions with Southern European Rainfall (JJA)

200hPa Height



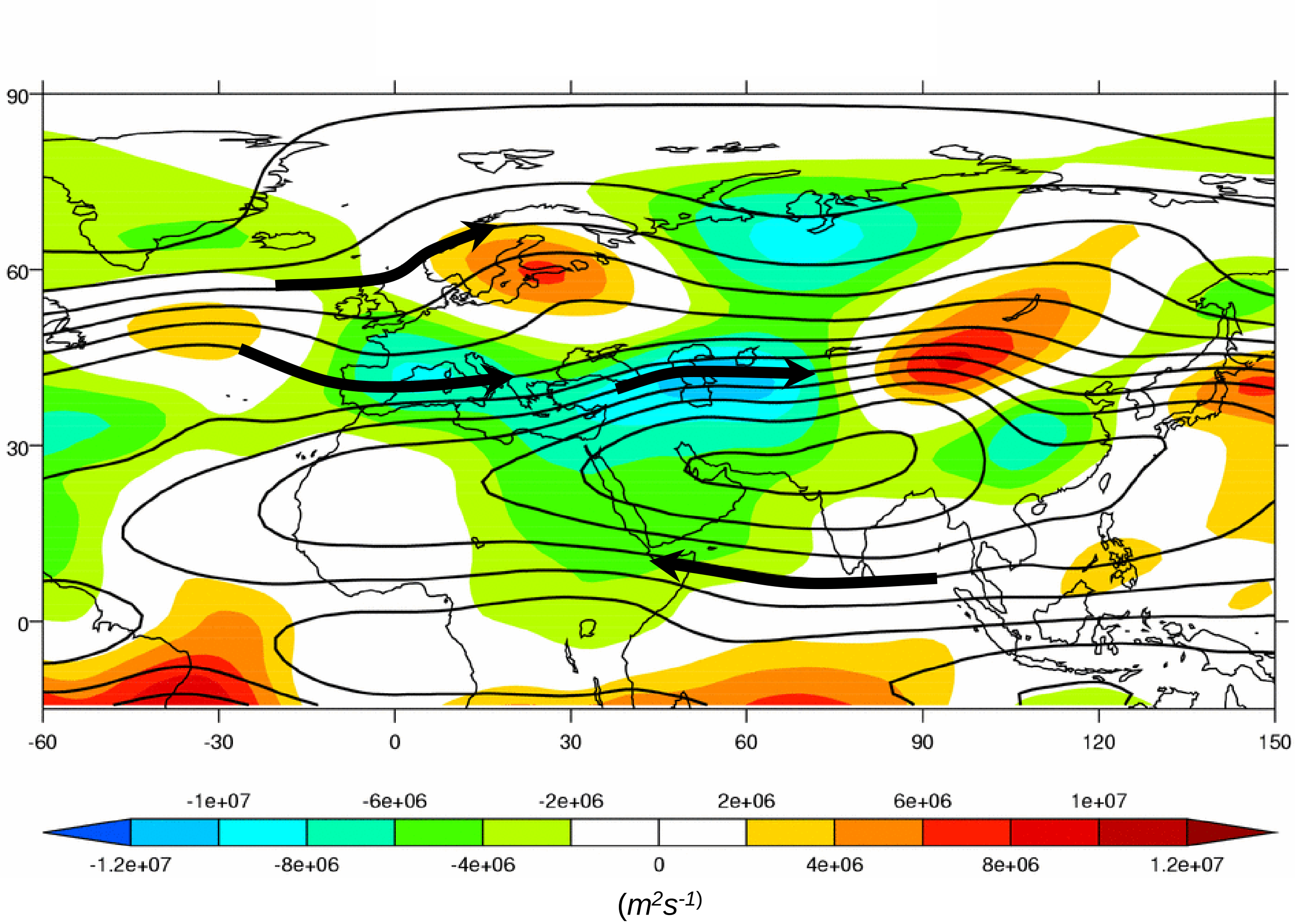
Sea level Pressure



- CRU land precipitation 35:45°N 0:30°E
- NCEP/NCAR Reanalysis height
- European Blocking pattern

What happened during Summer 2002?

Streamfunction anomaly at σ = 0.2101
July/August 2002

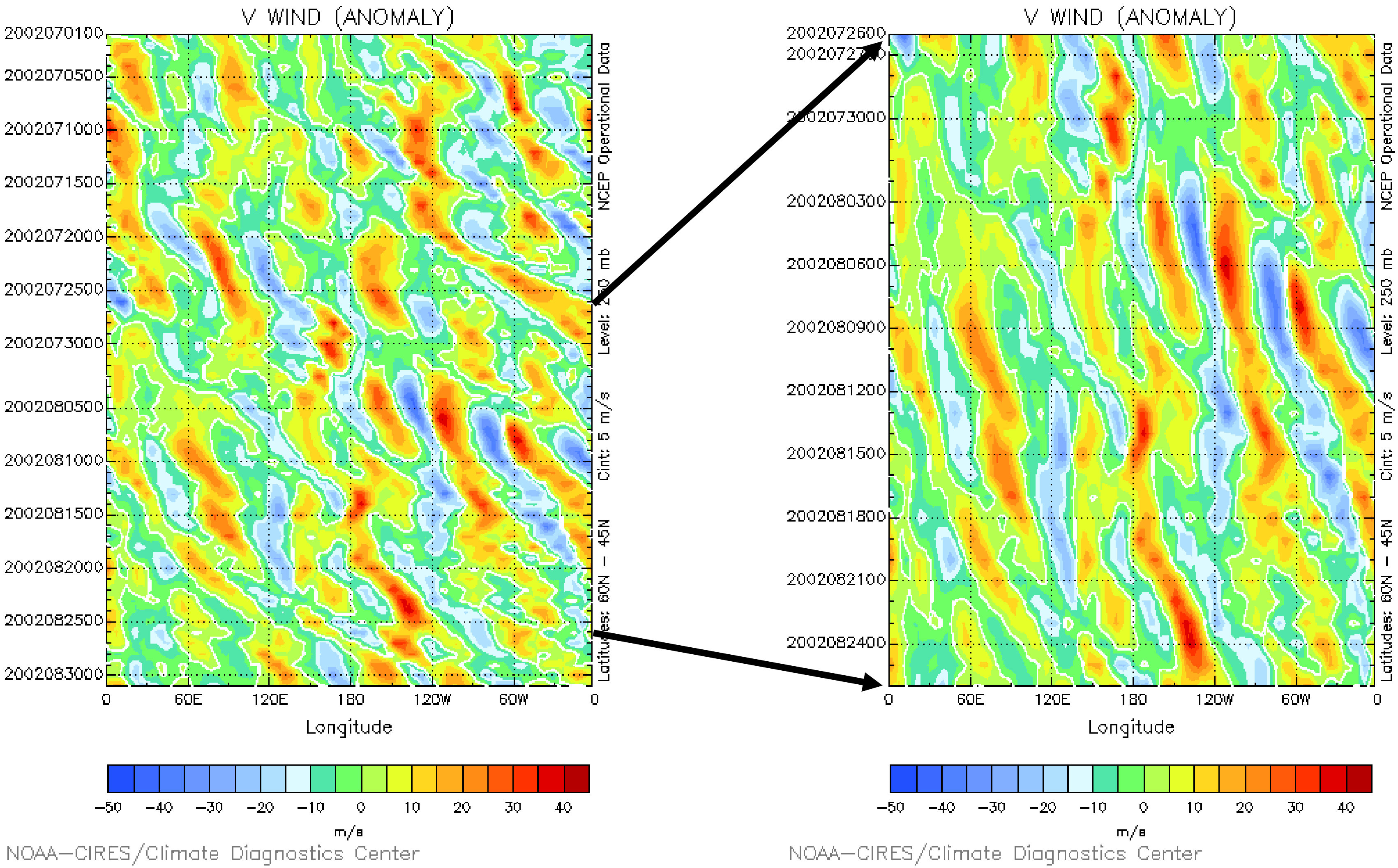


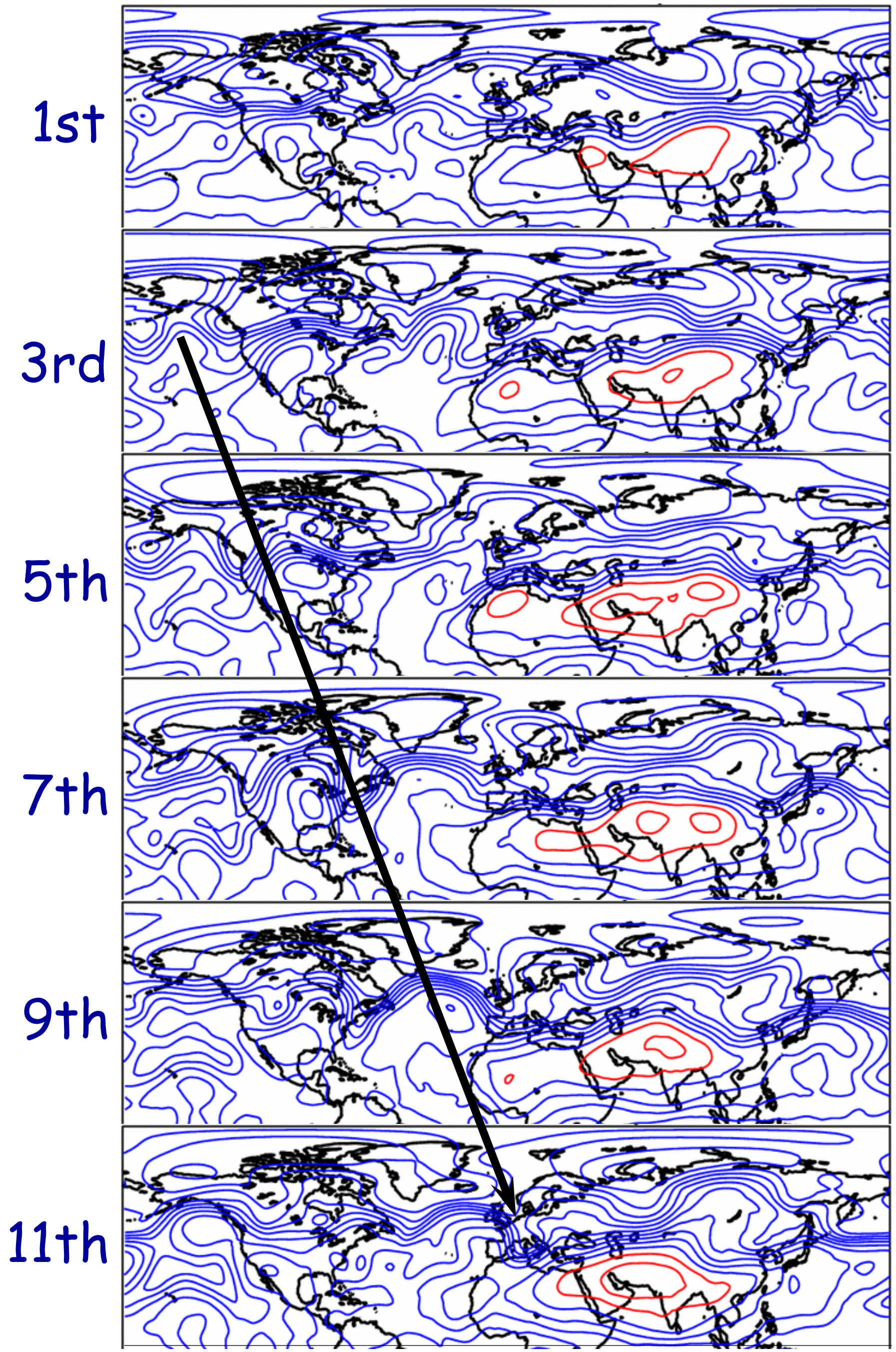
NCEP/NCAR Reanalysis data

Downstream Development

Meridional wind anomaly 250hPa, 45-60N

JA 2002 | 26 July – 26 Aug.





Downstream Development

250hPa Streamfunction

ECMWF analyses, 12UTC

1-11 August 2002

- NWesterly flow over UK into the Mediterranean, 9-11th Aug.
- A weather system followed this track and developed over Italy
- Then tracked NE bringing 150mm rain to much of central Europe

Conclusions (part 2)

- Multiple influences on southern European Summer variability
- Importance of European blocking
- Link to Asian summer monsoon: hypothesise that a strong monsoon break relaxes the usual dynamical constraint on Mediterranean descent, allowing disturbed weather to occur

- Implications for seasonal forecasting
- Will climate change alter these teleconnections?