(1)

Summary

- The Autumn season of 2000 saw record rainfall and flooding in western Europe. It was the wettest Autumn in England and Wales since records began in 1766, several regions from France to Norway received double their average rainfall and there were severe floods and mud-slides in the southern Alps (2).
- The extreme weather was linked to changes in the Atlantic jet-stream (3), which were part of an extensive pattern of anomalies stretching from mid-Atlantic across Eurasia (centre: left-panel).
- Wet UK Autumns in the preceding 42 years were associated with a remarkably similar pattern, closely resembling the Scandinavia pattern, which has previously been identified as a preferred pattern of northern hemisphere variability (4; centre: middle-panel).
- There was evidence in Autumn 2000 of anomalous descent and dryness in the tropics, over the Atlantic and South America. Precipitation variability there shows a weak (negative) correlation with the index of the Scandinavia pattern (5). Could anomalies in this region trigger the pattern?
- Numerical experiments with a barotropic model confirm this hypothesis, with anomalous tropical vorticity forcing generating a wavetrain extending over Europe (6; centre: right-panel).

The UK Record-Breaking Wet Autumn of 2000:

Patterns of variability associated with Autumn precipitation in the UK

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(7)

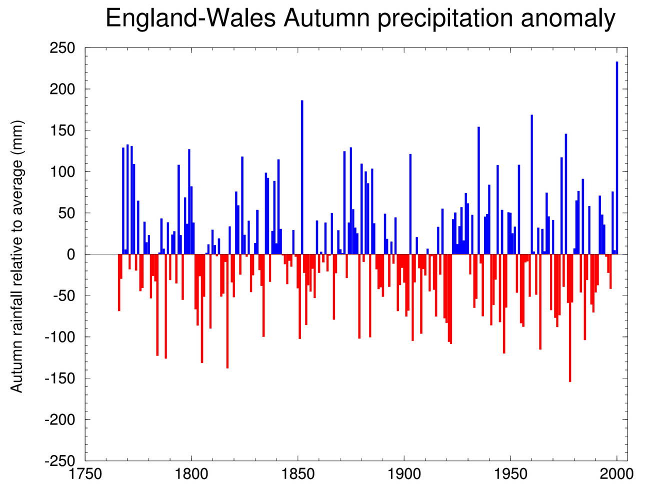
Discussion

- ***Seasonal forecasts*** have shown skill in predicting the large-scale climate anomalies associated with the last El Niño in 1997, but they were less successful in predicting the extreme Autumn 2000 European weather. The results here may provide a basis for understanding the current lack of predictability and improving forecast skill.
- Previous studies have shown the potential for ***Amazonian deforestation*** (either due to direct land-use changes or induced by climate change) to influence Atlantic and European climate in winter. Our results suggest that changes in Amazonian precipitation, associated with natural variability or deforestation, could influence European climate in Autumn.
- Further numerical experimentation is planned using a baroclinic global model, to investigate the wavelength of the response generated by the barotropic model, and the possible influence on the South American region of the anomalous Indonesian precipitation observed in Autumn 2000.
- The England-Wales precipitation time-series contains no significant trend in total Autumn precipitation, but there is the suggestion of increasing interannual variability, which warrants further investigation. Any such trend would increase the risk of future extreme events.

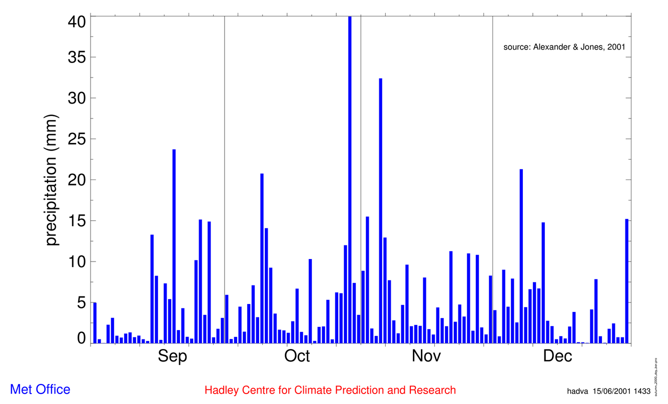
(2)

European Precipitation in Autumn 2000

England-Wales Autumn precipitation anomaly

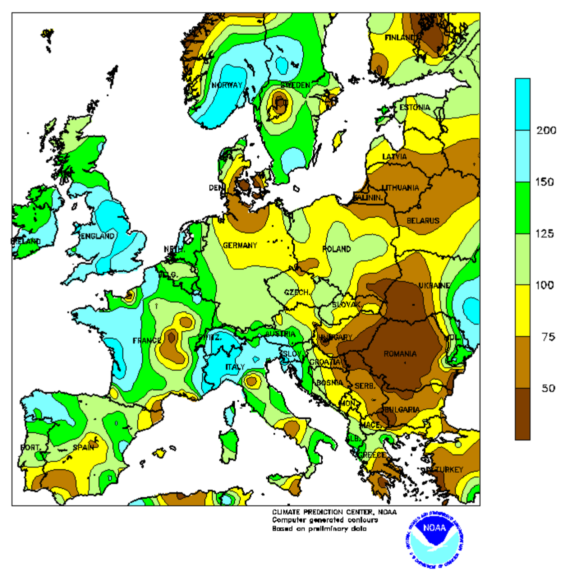


Daily precipitation for England and Wales (Sep – Dec, 2000)



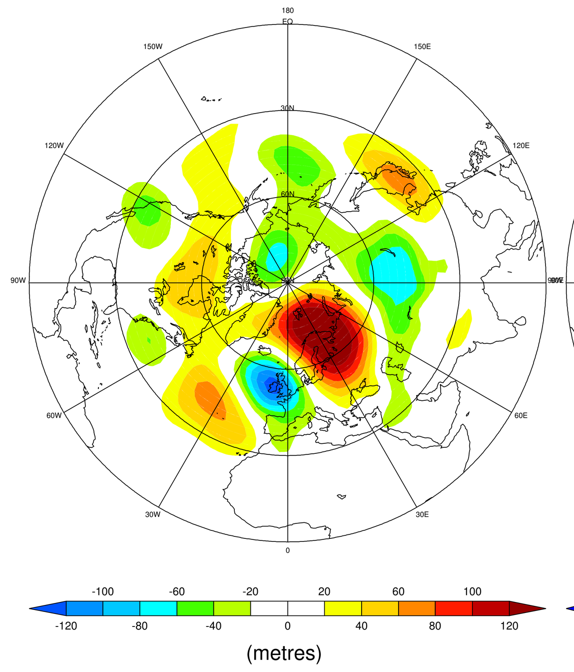
(courtesy of L. V. Alexander)

European Precipitation (percentage of normal)
Sep - Nov 2000

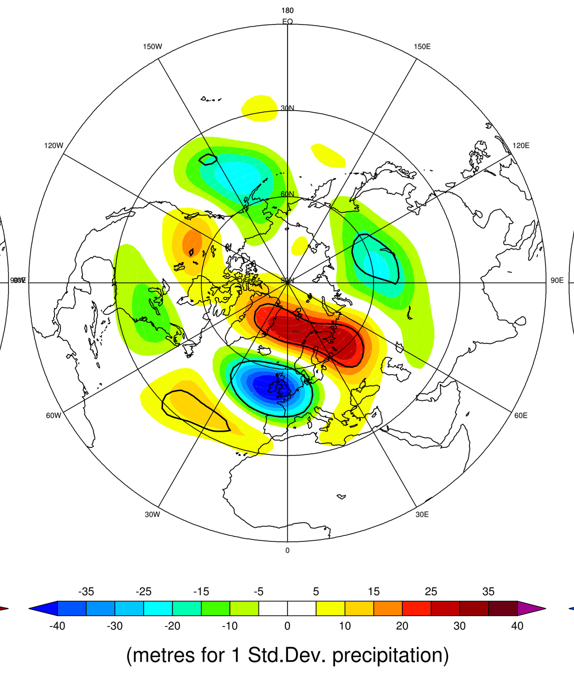


- The record England-Wales precipitation in Autumn 2000 amounted to 503mm, or 186% of the long-term average of 270mm.
- The persistent wet weather in the UK began in mid-September and lasted until mid-December.
- Most of western Europe was wet, with double the average in several regions. In contrast, large parts of central and eastern Europe were exceptionally dry (and warm).

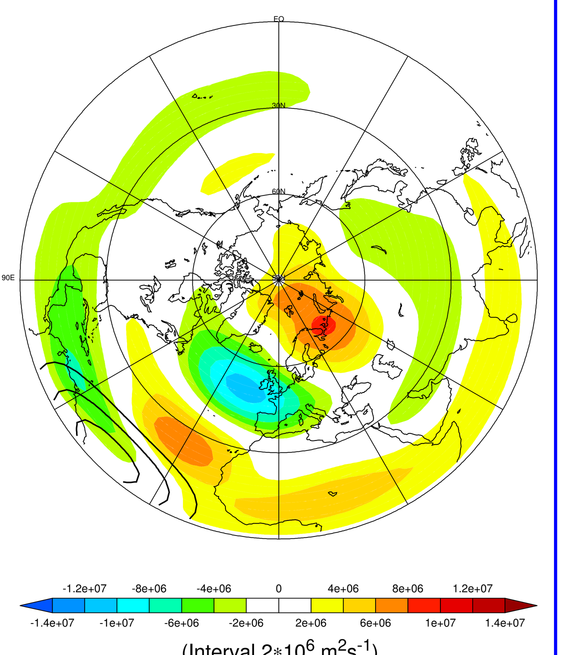
Observations - SON 2000	Regression on England-Wales precip	Barotropic model response
300hPa Geopotential Height	300hPa Geopotential Height	Streamfunction anomaly
ECMWF analyses	SON 1958-1999	Convergence forcing (45W,5N), (-*fD*)
Anomaly from ERA-15	(bold: 99% confidence level)	SON climate 300hPa basic state



(metres)



(metres for 1 Std.Dev. precipitation)



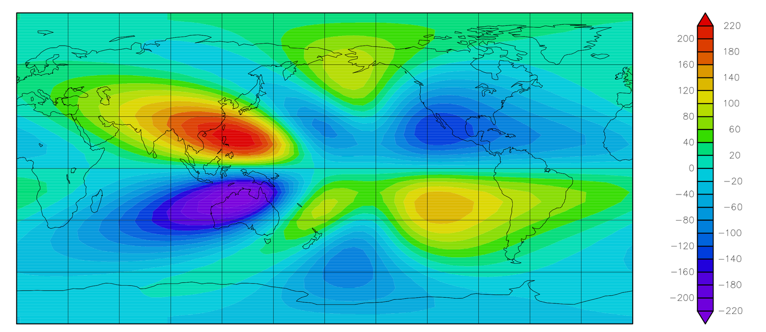
(Interval $2{\times}10^6$ m^2s^{-1})

(6)

Barotropic Model Experiments

- A global barotropic model has been used to investigate possible triggering of the Scandinavia pattern by anomalous tropical convergence over the Atlantic and South America.
- Idealised convergence centred on (45°W, 5°N) leads to a wavetrain propagating north-east over the Atlantic and Eurasia (centre-panel: right), similar to the Autumn 2000 anomalies and to the regressed field associated with wet UK Autumns.
- The response is robust to modest displacement of the forcing region and other modelling choices.
- The wavelength of the response is longer than observed, possibly due to omission of vertical structure in the barotropic model.

Example of the barotropic model's streamfunction response to equatorial divergence forcing over Indonesia, using a super-rotation basic-state.

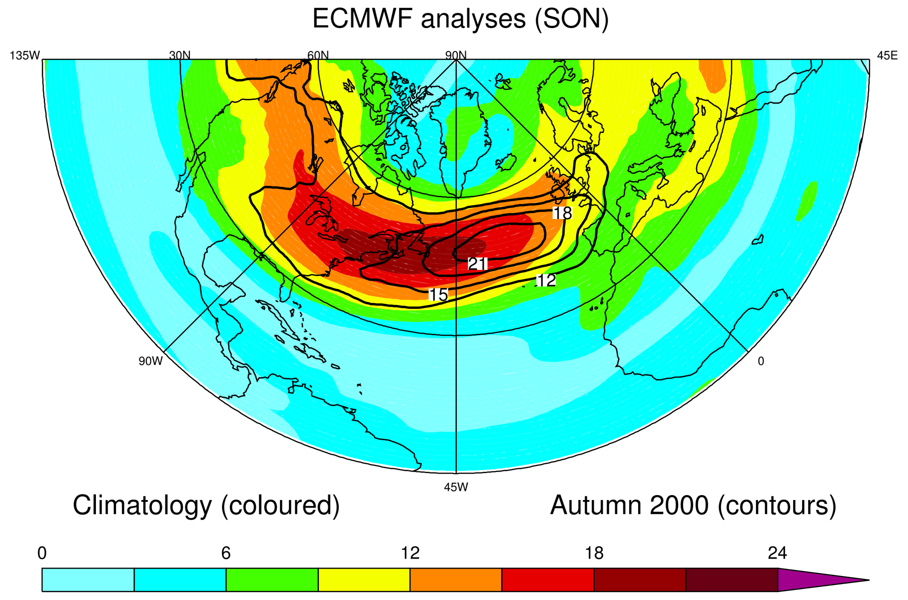


- The barotropic model simulates the global response of the vorticity field to specified vorticity forcing, associated with either divergence, orography or transient weather systems (Sardeshmukh and Hoskins, 1988, *J. Atmos. Sci.*, **45**, 1228-1251).
- In the tropics the model represents the upper tropospheric flow in the layer of divergent convective outflow. In the extra-tropics it represents the deep equivalent-barotropic atmospheric structure.
- The Autumn climatological flow at 300hPa has been held fixed in the model (by computing the climatological vorticity forcing necessary to maintain it against self-advection) and a specified convergence anomaly has been added. The model is integrated forward in time to obtain a steady state response. Linear damping is included to crudely represent non-adiabatic processes.

(3)

The Atlantic Jet-stream in Autumn 2000

Isotachs of the Autumn mean 500hPa wind
ECMWF analyses (SON)



- In Autumn 2000 the Atlantic jet-stream was displaced east, with an accentuated jet-exit region south of the UK.
- The displaced jet acted to "steer" intense weather systems repeatedly into western Europe.
- The weather systems tended to slow in the jet-exit, leading to prolonged precipitation events.
- There is dynamical forcing of a thermally indirect vertical circulation in a jet-exit, with ascent on the poleward side and descent on the equatorward side. In Autumn 2000 the ascent region was accentuated and displaced close to the UK.
- The displaced Atlantic jet-stream was part of an extensive pattern of large-scale anomalies, stretching from the mid-Atlantic across Eurasia. The pattern was dominated by low pressure over the UK and a strong ridge downstream, over Scandinavia (centre-panel: left).

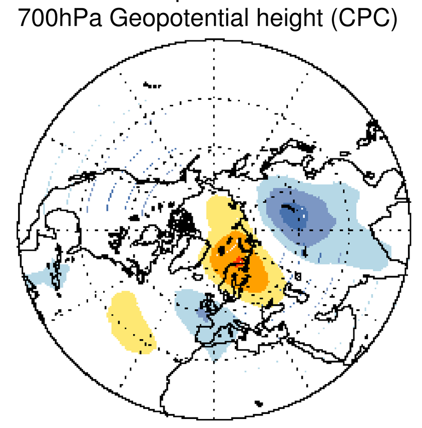
(4)

Previous wet Autumns: the Scandinavia Pattern

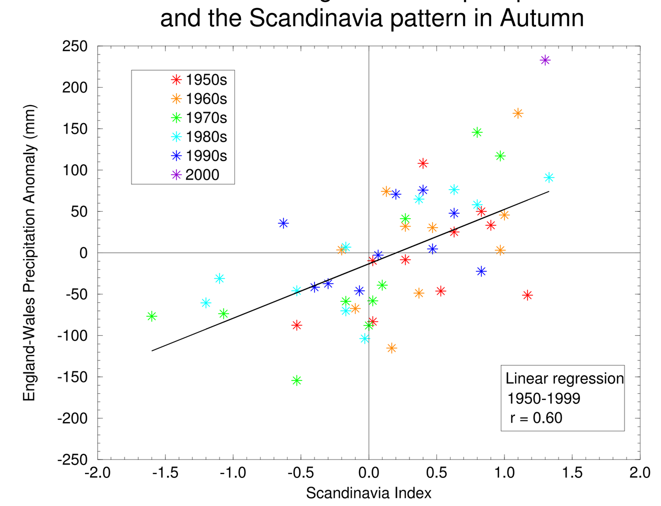
- A regression of geopotential height with England-Wales precipitation, for Autumns 1958-1999, results in a pattern of statistically significant anomalies remarkably similar to that in Autumn 2000 (centre-panel: middle). The regression pattern appears in other fields, such as sea level pressure.
- The seasonal England-Wales precipitation data are slightly skewed relative to a Gaussian distribution but a square root transform, which minimises skewness, and detrending make no discernable difference to the regressions.
- A composite of wet UK Autumns (>50mm anomaly) for 1958-1999 reveals a very similar pattern.
- The regression pattern closely resembles the ***Scandinavia pattern***, originally identified as a preferred pattern of northern hemisphere variability in a rotated principal component analysis by Barnston and Livezey (1987, *Mon. Wea. Rev.*, **115**, 1083-1126).
- A monthly index of the Scandinavia pattern, computed by NOAA's Climate Prediction Center (CPC), correlates with England-Wales precipitation for Autumn, with a correlation coefficient of 0.60.

Regressions using NCEP-NCAR reanalysis data were performed at the NOAA-CIRES Climate Diagnostics Centre, Boulder, Colorado, using their Web site at *http://www.cdc.noaa.gov/*.

Scandinavia pattern for October
700hPa Geopotential height (CPC)



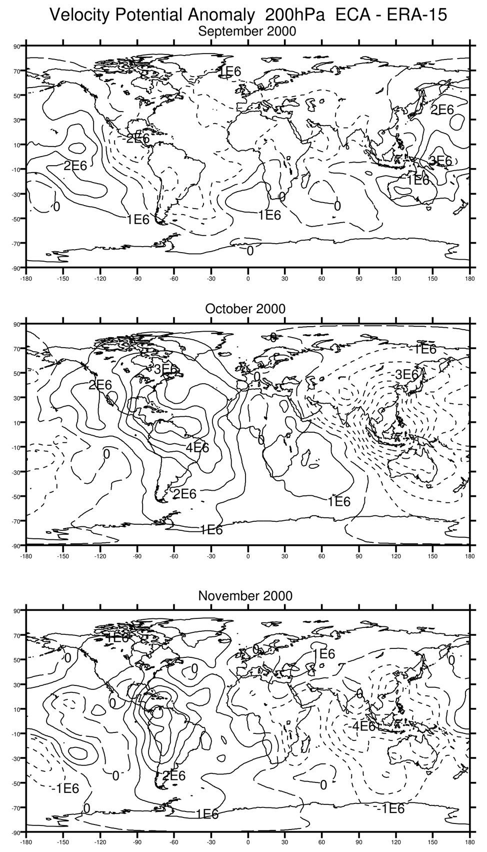
Incidence of England-Wales precipitation
and the Scandinavia pattern in Autumn



(5)

Links with Tropical South America

Velocity Potential Anomaly 200hPa ECA - ERA-15



- Two pieces of data suggest that the Scandinavia pattern in Autumn 2000, and possibly other years, may have been triggered by anomalous weather in the tropics, over the Atlantic and South America.
- First, both ECMWF and NCEP analyses showed a region of anomalous upper level convergence over this region in Autumn 2000 (left). Satellite derived monthly OLR anomalies were broadly consistent with the divergence anomalies.
- Second, there is a weak historical (negative) correlation between tropical South American precipitation and the Scandinavia pattern in Autumn, using a new precipitation dataset from 1960-1990 compiled by Webber and Willmott. The correlations are only marginally significant at the 95% level (right).
- There are stronger (positive) correlations of South American precipitation over Amazonia with the Southern Oscillation Index, so it may not be possible using observational data to separate the impact of South American and Pacific anomalies on the Scandinavia pattern and European weather.

Correlation between
South American Precipitation
and the Scandinavia Index
in Autumn (SON, 1960-90)