JP2.17

ATMOSPHERIC BLOCKING AND PATTERNS OF LOW-FREQUENCY VARIABILITY ARISING FROM THE BREAKING OF UPPER LEVEL ROSSBY WAVES

T. J. Woollings[1], **B. J. Hoskins and M. Blackburn**

Department of Meteorology, University of Reading,
Reading, RG6 6BB, UK

Several studies have shown a clear link between weather and climate in the more frequent occurrence of blocking weather regimes in the North Atlantic during negative periods of the North Atlantic Oscillation (NAO). The key question is whether negative NAO conditions cause increased blocking occurrence, or whether the negative NAO signal is simply a reflection of a more frequent occurrence of blocking.

Blocking is known to arise from the breaking of upper level Rossby waves, so here, and in Woollings et al. (2006), we investigate this question by applying a wave-breaking index to the ERA-40 reanalysis data. This index is a two-dimensional extension of the blocking index of Pelly and Hoskins (2003), which uses the reversal of the potential temperature gradient on the dynamical tropopause to characterise wave-breaking. This reveals two key areas of wave-breaking in the Northern Hemisphere, where cyclonic wave-breaking acts to deform the climatological troughs lying to the north-west of the Atlantic and Pacific basins. In general, the events identified here do not exhibit the characteristic dipole structure in absolute geopotential height which is associated with blocking, so we refer to these simply as wave-breaking events.

In the Atlantic, these wave-breaking events are shown to give rise to anomaly patterns which are normally associated with the negative phase of the NAO (Figure 1). Similar events occur in the Pacific, and these, in turn, generate anomalies associated with a pattern of variability known as the Western Pacific Pattern (WPP). However, here we show that it is not the NAO or WPP that is affecting the occurrence of wave-breaking, but that the influence is the other way around. The NAO and WPP are essentially measures of the average strength of the zonal flow, and this is affected by variations in the frequency of wave-breaking occurrence.

Figure 2 shows that much of the interannual NAO variability, and almost all of the decadal variability, is associated with variations in wave-breaking occurrence. In contrast, while wave-breaking in the Pacific does affect the WPP from year to year, it is not associated with WPP variability on the decadal timescale. This suggests that on these timescales the WPP is controlled by other processes, most likely the Pacific North America pattern, or PNA.

In both sectors, storm track variations and downstream blocking act as precursors to wave-breaking events. Additionally, in the Atlantic a quasi-stationary Rossby wave-train is often seen just before wave-breaking, stretching across North America from the Pacific (Figure 3). This opens up a mechanism by which variability or change in the Tropical Pacific could affect Atlantic wave-breaking, and hence the NAO.

Variability in the stratosphere may also exert some control over the occurrence of wave-breaking in both sectors. In the period before wave-breaking, an equatorward shift in the stratospheric jet is followed some days later by a similar shift in the tropospheric jet, as shown for the Atlantic in Figure 3.

To conclude, Rossby wave-breaking emerges as a key mechanism responsible for mid-latitude atmospheric variability. It is largely responsible for the anomalies associated with patterns of low-frequency variability, especially the NAO. Wave-breaking provides an attractively simple conceptual model with which to view the NAO. External forcings can be viewed as having a direct effect which adjusts the basic state in some way, and an indirect NAO response if this new state is more, or less, conducive to the occurrence of wave-breaking, or if the

*t.j.woollings@rdg.ac.uk

preferred location of wave-breaking is altered.

References

Pelly, J. L. and B. J. Hoskins, 2003: A new perspective on blocking. *Journal of the Atmospheric Sciences*, **60**, 743–755.

Woollings, T. J., B. J. Hoskins, and M. Blackburn, 2006: The North Atlantic Oscillation and West Pacific Pattern: Low frequency variability arising from the breaking of upper level Rossby waves. *Journal of the Atmospheric Sciences*, submitted.

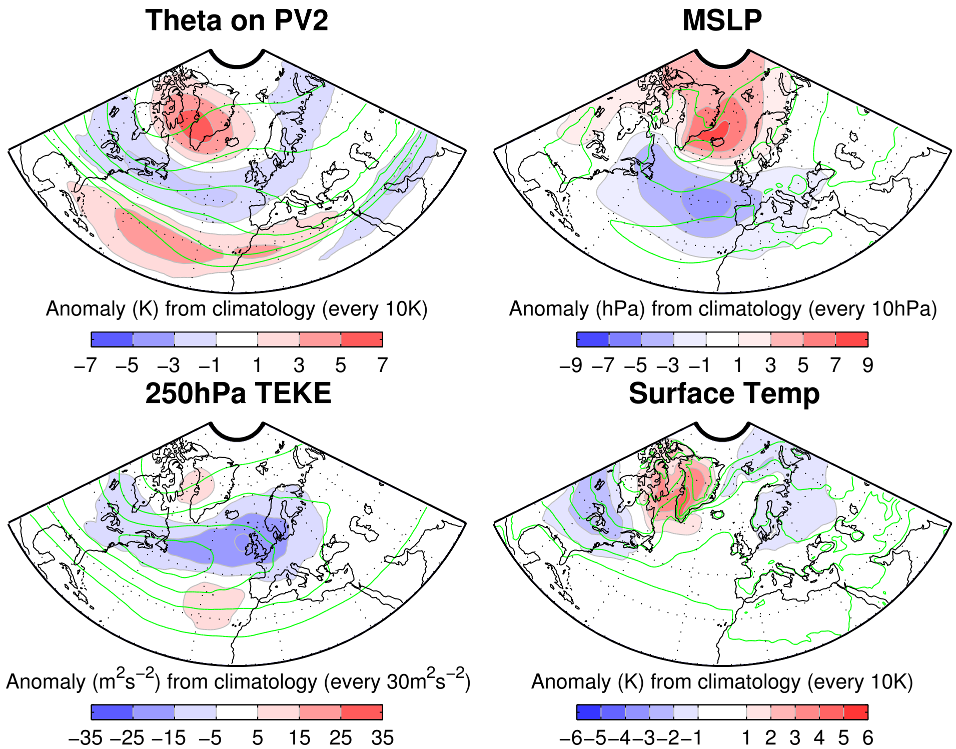

Figure 1: Composite anomaly maps of all winter days in ERA-40 during which an upper level Rossby wave-breaking event was identified over the Atlantic. This shows the signature of wave-breaking in potential temperature θ on the tropopause (the PV2 surface), Mean Sea Level Pressure, 250hPa Transient Eddy Kinetic Energy and surface temperature. In each case the winter climatology is contoured in green. During a wave-breaking there is a large anticyclonic anomaly at upper levels in the vicinity of Southern Greenland, with a strong jet lying to the south of this. The storm track is weakened, particularly on its poleward side, and the surface anomalies are very reminiscent of the negative phase of the NAO.

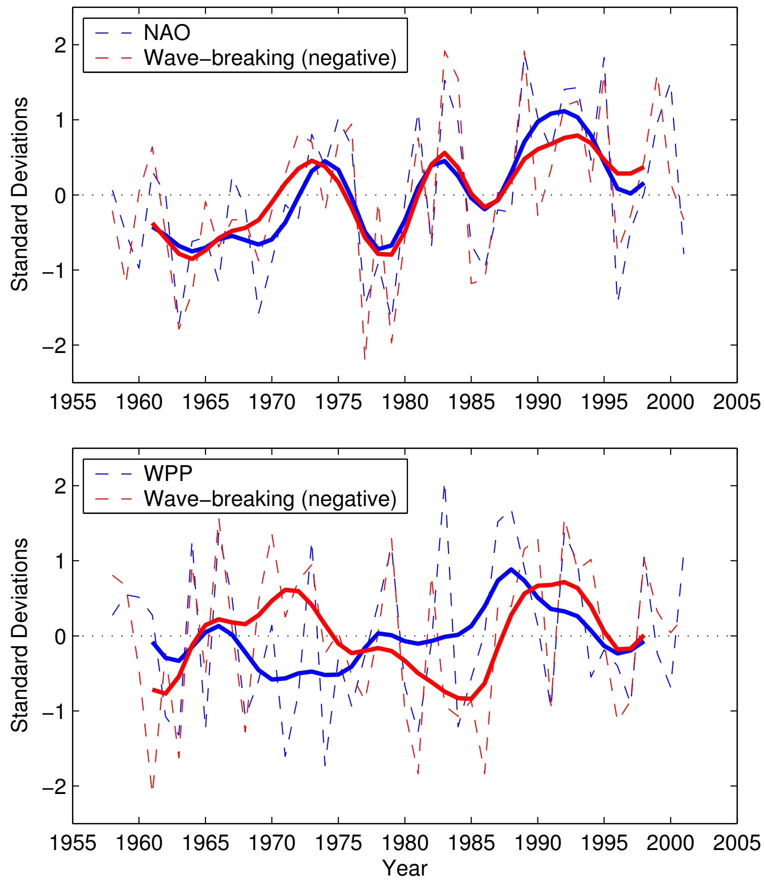

Figure 2: The North Atlantic Oscillation (NAO; top panel) and Western Pacific Pattern (WPP; bottom panel) indices are compared to an index of the occurrence of wave-breaking in each sector. This latter index is simply the negative of the number of wave-breaking days per season, which has been normalised. The solid lines show versions which have been smoothed using a low-pass filter with weights 1, 3, 5, 6, 5, 3, 1.

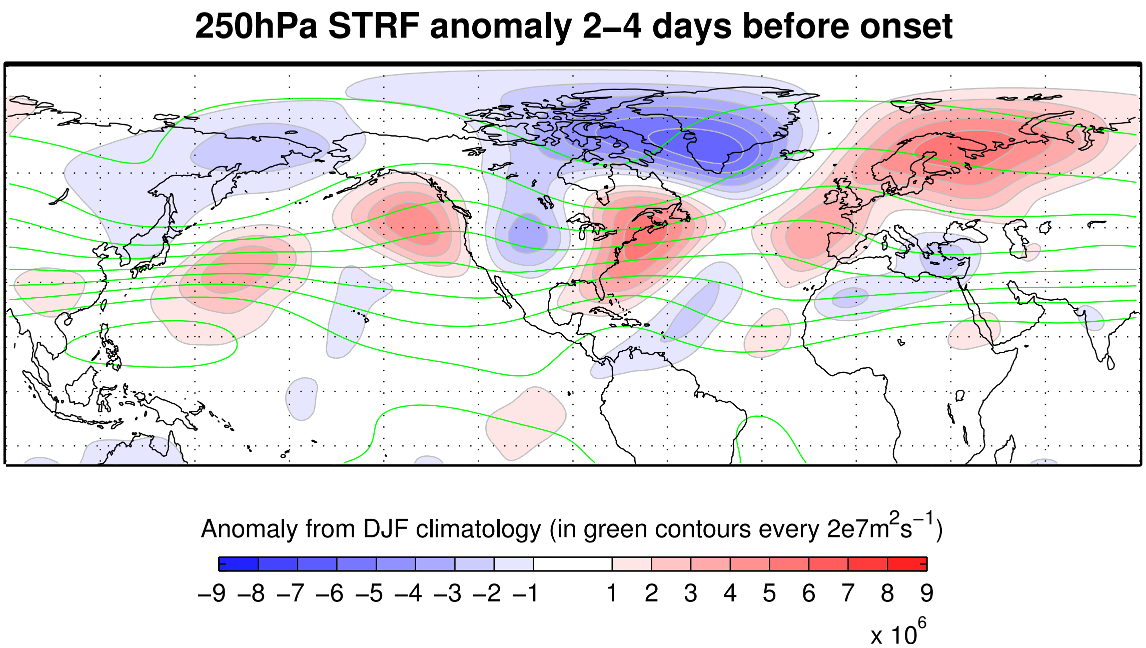

Figure 3: A composite of the 250hPa streamfunction anomaly over two to four days before the onset of wave-breaking in the Atlantic. The large positive anomaly over Northern Europe indicates that these events are often preceded by European blocking, and there is also evidence of a Rossby wave-train of anomalies stretching across North America from the Pacific.

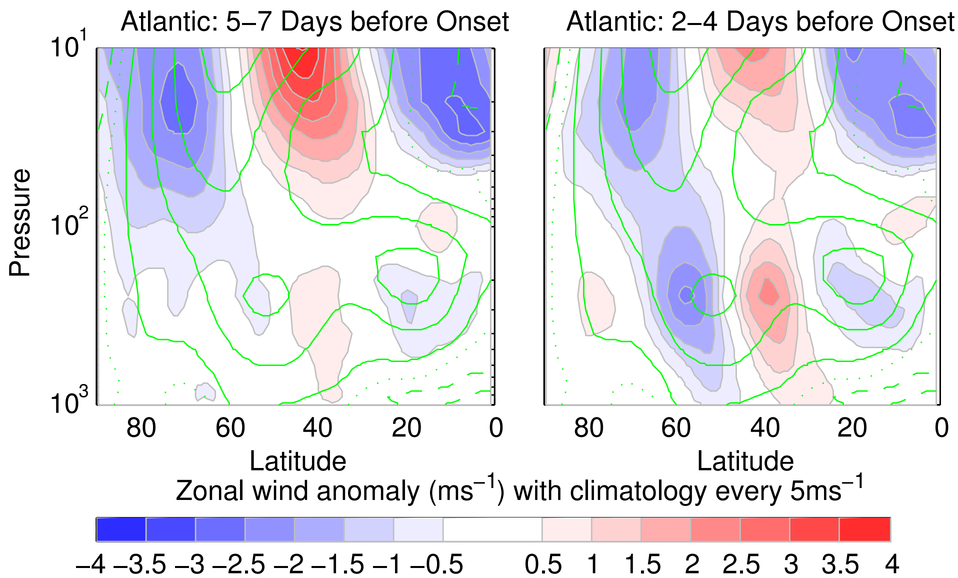

Figure 4: Composite anomalies of the zonal wind averaged over 0-60 $^\circ W$ in the period leading up to wave-breaking in the Atlantic. Almost a week before onset the stratospheric jet is shifted south of its climatological position, and a few days after this the tropospheric jet exhibits a similar shift.