Stratospheric Involvement in Blocking

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Summary

The links between stratospheric variability and tropospheric blocking are investigated in the ERA-40 reanalysis and in a 40 year simulation of a stratosphere resolving version of the Hadley Centre model HadGAM1*.

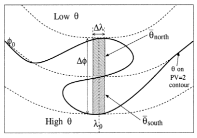
The general approach is to use daily EOFs of 10hpa geopotential height (Z10) to characterise stratospheric variability and to correlate the principal component (PC) timeseries with a blocking index. This identifies blocking regions which are related to stratospheric variability, and then composites of the tropospheric and stratospheric flow show the evolution of these events.

There are significant correlations between the stratosphere and blocking at several locations in both hemispheres. The nature of the connection is very different for different blocking locations. It is possible that in several cases the blocking and the stratospheric variations are both consequences of wave activity in the troposphere.

* Thanks to Sarah Ineson for the HadGAM1 data.

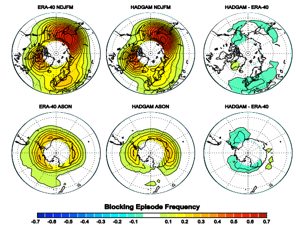
Blocking Index

The blocking index is an extension of that used by Pelly and Hoskins (JAS 2003). It identifies blocking as a reversal of the usual meridional gradient of potential temperature on the dynamical tropopause (PV2 surface). This is designed to find the Rossby wave-breaking signature characteristic of blocking. An instantaneous blocking is defined at each point on a grid if the difference θ_{north}-θ_{south} is positive, and then time and space scales are imposed to ensure the events are large-scale, long-lasting and quasi-stationary. This identifies traditional mid-latitude blocking, as seen over Europe, and also so-called high-latitude blocking.

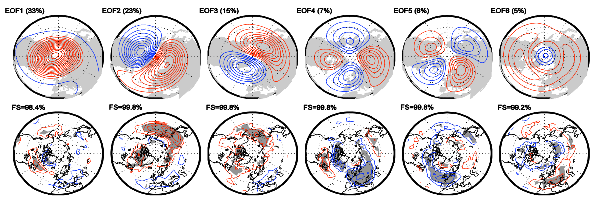


Blocking Climatology

The blocking episode frequency (fraction of days for which a blocking episode is seen) is shown below. The stratospheric active seasons (NDJFM and ASON) are used. In general, HadGAM1 represents blocking occurrence very well compared to ERA-40, but it does underestimate European Blocking by about a third.

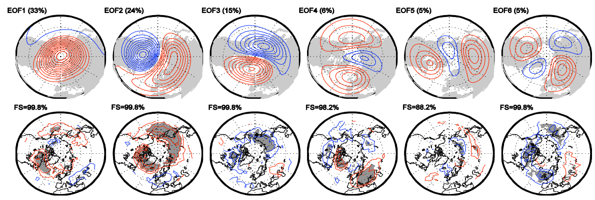


Correlation maps: ERA-40



Top row: the daily Z10 EOFs from ERA-40 for the northern hemisphere NDJFM.
Bottom row: simultaneous correlation maps of the blocking episode index at each point with the principal component timeseries. The contour interval is 0.05, with positive correlations in red. Shading indicates 95% significance using a T-test with an estimated independent sample size. Field significance (FS) is estimated by a Monte Carlo permutation method.

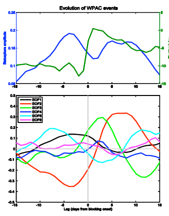
Correlation maps: HadGAM1



As left but for HadGAM1. The model underestimates the occurrence of wavenumber 2 disturbances in the stratosphere. This may be related to the underestimate of European blocking, as there is a link between the two.

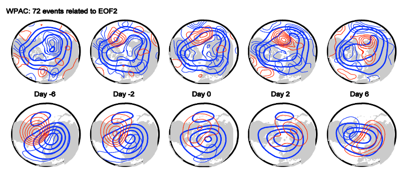
Composite evolution

Composite of the instantaneous blocking index and stratospheric disturbance (the root sum square of the PCs, weighted by their eigenvalues) for all West Pacific events.

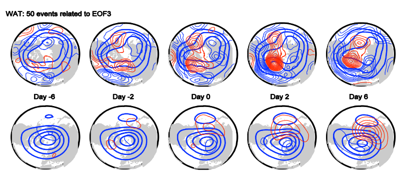


Composite evolution of the individual PCs (in standard deviations). Day 0 is the blocking onset day.

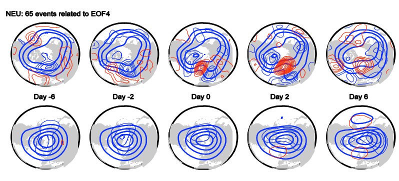
We now show composites of the tropospheric and stratospheric evolution of blocking at various locations in the ERA-40 data. These composites are centred on the blocking onset day (day 0) at locations identified as having high correlations.
In some cases not all events are shown, only those for which the evolution of a particular PC matches the mean evolution (in order to give clearer composites). For example over the West Pacific there is a clear link to EOF2 (see left), so only events matching this evolution are composited (as right). In this region, blocking is associated with the transition from a disturbed polar vortex (displaced over Eurasia) to a more zonal vortex.



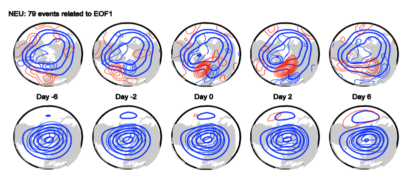
Composites of 250 hpa streamfunction (top) and 10 hpa Geopotential height (bottom). Thick contours show the full fields and thin contours the anomalies. Cyclonic fields are in blue and anticyclonic fields are in red. The contour intervals are 2×10^{-7} and 2×10^{-6} s^{-1} for streamfunction and 500 and 100m for geopotential height, with zero contours omitted. Day 0 is the blocking onset day.



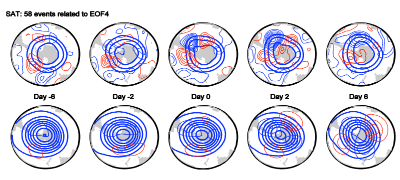
High-latitude blocking over the western North Atlantic tends to lead to a displacement of the polar vortex towards the Atlantic.



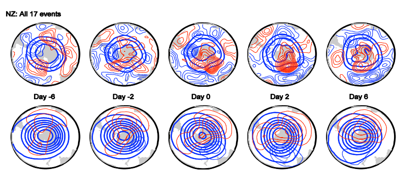
Blocking over Northern Europe can lead to a wavenumber two disturbance to the polar vortex...



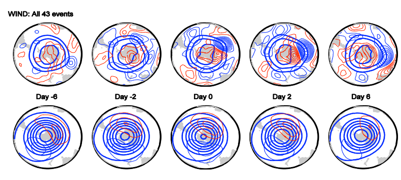
... however if the polar vortex is too strong beforehand there is a wavenumber one disturbance instead.



In the South Atlantic blocking accompanies an amplification of a wavenumber two disturbance in the stratosphere.



Over New Zealand blocking is very rare, but seems to be linked with a disturbance in the stratosphere.



Blocking in the West Indian Ocean tends to occur during a stratospheric wavenumber one disturbance.