The Morphology of Northern Hemisphere Blocking

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ABSTRACT

The morphology of regional blocking in the Northern Hemisphere is discussed using the 40-yr ECMWF Re-Analysis (ERA-40) dataset and a measure of blocking based on the reversal at storm-track latitudes of meridional $\theta$ contrasts on a potential vorticity (PV) surface representative of the tropopause. The focus is on cyclonic and anticyclonic Rossby wave breaking that is inherent to the blocking development, and the extent to which this is determined by the climatological jet position and the ambient shears. More generally, the importance of the climatological planetary scale is discussed. The approach is mainly through composite behavior, but informed by consideration of many individual events. A diversity of behavior is found with longitude in both winter and summer, and there is a striking reversal of the sense of the wave breaking between the two seasons that is generally consistent with the difference in the jet locations. Preferred behaviors are found in various regions and seasons, and retrogression of blocking is discussed.

1. Introduction

A comprehensive climatology of Northern Hemisphere (NH) blocking according to the 40-yr European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-40) data has been presented in Tyrlis and Hoskins (2008, hereafter TH). This study was based on the use of an index, $B$, of the meridional contrast about a central blocking latitude (CBL) of the potential temperature ($\theta$) on a potential vorticity (PV) surface considered to be the dynamical tropopause, the 2-PVU surface [where 1 PV unit (PVU) = $10^{-6}$ m$^2$ s$^{-1}$ K ks$^{-1}$]. The basic characteristic of blocking is considered to be a reversal of the usual situation, with (potentially) warmer air being found at higher latitudes. Additional characteristics required for real blocking are larger than synoptic longitudinal extent and duration. An interpretation of the basic blocking requirement is that large-scale wave breaking at the tropopause level is occurring. In this paper the diversity with longitude and time of year of the morphology and evolution of blocking will be studied, with a particular focus on the nature of the wave breaking that occurs.

The discussion will be mostly given in terms of the behavior of composites of blocking events. However, a large number of individual events have been looked at and experience from these will be used, where appropriate, to aid the interpretation of the composite results.

Areas of strong baroclinicity act as waveguides along which Rossby waves can propagate, amplify, and eventually break (e.g., McIntyre and Palmer 1983; Nakamura and Plumb 1994) leading to an overturning of the meridional $\theta$ gradient on the 2-PVU surface. In the framework of “PV thinking” (Hoskins et al. 1985), wave breaking consists of the cyclonic or anticyclonic rotation around one another of a poleward extrusion of high-$\theta$ air and an equatorward extrusion of low-$\theta$ air. Four characteristic types of wave breaking are shown in Fig. 1. The two equatorward breaking cases, LC1 and LC2, were introduced by Thornicroft et al. (1993) based on two contrasting baroclinic wave life cycles. LC2 (Fig. 1c) is dominated by the extrusion of a trough and its cyclonic breaking. In LC1 (Fig. 1a) this behavior was evident at early stages, but the later, large-amplitude behavior was dominated by an anticyclonic breaking behavior. Peters and Waugh (1996) noted the importance of poleward breaking and introduced the two characteristic types P1 and P2 (Figs. 1d,b) that are mirror images of the LC1 and LC2 types, respectively. P2, like LC1, is dominated by anticyclonic breaking, and P1, like LC2, is dominated by cyclonic breaking.

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The importance of the location of the synoptic development with respect to the midlatitude jet in determining the nature of the breaking was discussed by Thorncroft et al. (1993) and stressed by Peters and Waugh (1996). Further emphasis of this has been given in a Southern Hemisphere context by Hartmann and Lo (1998), Hartmann and Zuercher (1998), and Peters and Waugh (2003). The jet locations are indicated in each panel of Fig. 1. When the breaking occurs equatorward of the jet, as in LC1 and P2 (top row of Fig. 1), background anticyclonic wind shear dominates and anticyclonic wave breaking occurs. In LC1, the cyclonic circulation associated with any equatorward extrusion of low-θ air is suppressed, leading to thinning troughs and possibly to the development of a cutoff low (Thorncroft et al. 1993). In P2 the anticyclonic circulation associated with any poleward intrusion of high-θ air is enhanced, and following the evolution pattern P2 (Fig. 1b) a strong blocking-like ridge tends to develop (Peters and Waugh 1996). When the wave breaking occurs poleward of the jet (bottom row of Fig. 1) the ambient cyclonic shear favors the development of wide and strong troughs, as in LC2, and prevents the building of strong ridges, as in P1.

In all the cases described above, a reversal in the meridional θ gradient on the 2-PVU surface is observed and the possibility of blocking is recognized by the index β being positive. However, the overturning is weaker in cases P1 and especially in case LC1, and the development may decay on synoptic time scales. Larger cyclonic or anticyclonic cutoffs and stronger blocking events may be expected to be associated with the evolution patterns LC2 or P2, respectively. Note that blocking here is defined in terms of the tendency (through inversion) for easterlies and that in LC2 it is the cyclone on the equatorial side and in P2 the poleward anticyclone that tends to dominate.

In a real situation it is always arguable how to separate the wave from the ambient flow whose cyclonic or anticyclonic shear theory suggests it plays a vital role in determining the sense of the breaking of the wave. As background information, relevant for the discussion of blocking composites, the climatological average θ and zonal wind on 2 PVU are given in Fig. 2. Also included in each panel is the CBL, which, consistent with the notion of blocking the storm track, is specified as the smoothed latitude of maximum synoptic time-scale upper-tropospheric transient eddy kinetic energy. As discussed in detail in TH, it is taken to be independent of time of year, but a reversal of the θ contrast is looked for at this latitude and also 4° to the north and south. In the winter the jet is equatorward of the CBL everywhere except near the west coast of Europe and to a lesser extent North America. These are also regions of
major climatological ridges and significant blocking. The Atlantic jet tilts from southwest to northeast and the subtropical jet picks up over Africa. Related to these features, the mean ridge near 0° has a slight anticyclonic P2 character. In the summer the jets move poleward at most longitudes, with the exception being the eastern Atlantic.

In this paper, after a description of the methodology in section 2, section 3 discusses the morphology and evolution of winter blocking composites for a representative set of sectors. The consistency between the differences in wave breaking and the ambient shear is considered. Summer blocking morphology is analyzed in section 4, and some concluding remarks are given in section 5.

2. Methodology

Throughout this study the ERA-40 dataset was used. This is described in detail by Uppala et al. (2005) and covers the period September 1957 until December 2001. The PV–θ index $\theta$ was used for the identification of blocking. As discussed above, it is a macroscale measure of the reversal of the usual θ gradient on the 2-PVU surface at latitudes close to the location of the maximum in climatological transient eddy activity (see TH for more details). As in TH, the term local and instantaneous blocking (LIB) refers to the occurrence of positive $\theta$. Sector blocking (SB) is said to occur when in a 45° sector LIB occurs in a continuous region of at least 15° of longitude. The term sector blocking episode (SBE) describes the SB events that persist for at least 5 days. It is these SBEs, with their duration and size criteria, that are taken to be blocks in this paper. The SBE onset day is taken to be the first day of each SBE event. Composite fields of $\theta$ on the 2-PVU surface and some other variables have been produced for all SBE days, including the onset day. To show the evolution, composites have also been produced for onset days alone and for specific times lagged with respect to onset days. Winter is taken to be the period December–February (DJF) and summer the period June–August (JAS). The anomalous fields of $\theta$ on the dynamical tropopause have been produced with respect to a climatological mean for the satellite part of the ERA-40 period.

3. Winter blocking

The morphology of winter blocking around the Northern Hemisphere is illustrated in Fig. 3, which shows the fields of $\theta$ on the 2-PVU surface correspond-
ing to the composites of winter days characterized by the occurrence of SBE in the sectors centered at the longitude indicated on the top of each panel. (Each panel is centered at the central longitude of the sector featured.) For sectors other than the ones illustrated here there is a smooth transition between these distinctive patterns. It is clear that in the winter, when blocking is the most frequent around the Northern Hemisphere (TH), there are significant differences in its signature in different regions.

**Fig. 3.** Composites of winter SBE days in representative sectors around the NH. The field shown is $\theta$ on the 2-PVU surface. The central longitude of each sector and the membership of each composite (in parentheses) are indicated at the top of each panel. Each panel is centered at the central longitude of the sector featured.
a. Europe/eastern Atlantic

Blocking in Europe/eastern Atlantic is represented by the composite behavior at 20°E shown in Fig. 3a. The signature clearly resembles the final stages of anticyclonic wave-breaking P2. The time development with respect to the onset day is indicated by the composites in Fig. 4. The trough over the east coast of North America progresses, and ahead of it high-θ air of subtropical origin is advected poleward, with a hint of cyclonic wave breaking in the western Atlantic (Fig. 4b). However as this poleward extrusion of subtropical air progresses into the eastern Atlantic and Europe, anticyclonic wave breaking occurs (Figs. 4c,d) resulting in a blocking anticyclone through amplification of the ambient planetary ridge (Fig. 2a). The polar air advected equatorward and westward in the wave breaking can lead to a cutoff low to the south.

Another picture of this evolution is given by Fig. 5, which presents the evolution in terms of the anomalies in θ on the 2-PVU surface for the same set of days. Four days before onset (Fig. 5a) it is seen that the trough structure over eastern North America was associated with cold and warm anomalies that can themselves be viewed as part of a wave train curving from 45°N, 70°E down into the subtropical Atlantic. Two days before onset (Fig. 5b) there is now also a wave train, with a synoptic wavelength along the storm track from the east coast of North America to eastern Europe. This is suggestive of weather systems being present in the storm track and having a particular phase before onset. Further diagnostics in Tyrlis (2005) are in accord with the importance for the onset of European blocking of preceding upstream storm-track enhancement and mid-ocean poleward displacement proposed by Nakamura and Wallace (1990) and other authors. By the onset day (Fig. 5c) the eastern portion of the wave train has progressed whereas the western portion has moved little, so that the warm anticyclonic blocking high anomaly near 0° can be viewed as part of a longer-wavelength wave train from the west coast of North America to Europe. Three days after onset (Fig. 5d) it is apparent that this wave train has been quasi-stationary since onset apart from in its eastern portion. This is in agreement with the stationary wave preceding onset result of Nakamura and Wallace (1990) as their definition of onset would correspond to about 3 days after onset here.

b. Asia

Blocking in Asia is represented by the composite picture at 80°E shown in Fig. 3b. An evolution pattern similar to that in Europe (not shown) characterizes the
building of blocking in western and central Asia, although the reversal of the meridional $\theta$ gradient is weaker here. (It is seen in the 302–306-K contours near 80°E and 60°N.) The amplified ridge near 0°E in the composite reflects the fact that winter blocking in Asia is frequently preceded by blocking over Europe. The composite evolution (not shown) exhibits an amplified warm European ridge 2 days before onset. The poleward part of this ridge extends eastward and leads to wave breaking near 80°E. A prerequisite for the eastward expansion of the European blocking ridge appears to be the existence of an unusually active storm track and a poleward displaced jet in the Arctic Sea. This implies that anticyclonic wind shear prevails at midlatitudes over central Asia (Tyrlis 2005). As disturbances propagate along the Arctic coast of Asia, poleward extrusions of high-$\theta$ air break anticyclonically and cut off to the north of the pool of very cold air residing over Siberia.

c. Western and central Pacific

Blocking for these regions is represented by the composites for 140°E and 180° given in Figs. 3c,d. In both regions cyclonic wave breaking is evident, consistent with the equatorward location of the jet here. The composite evolution for 140°E shown in Fig. 6 indicates a

![Fig. 5](image1.png)

**Fig. 5.** Evolution of winter SBE in the sector centered at 20°E as shown by composites of anomalies of $\theta$ on the 2-PVU surface.

![Fig. 6](image2.png)

**Fig. 6.** Evolution of winter SBE in the sector centered at 140°E as shown by composites of anomalies of $\theta$ on the 2-PVU surface.
behavior that is frequently seen in individual cases. Winter blocking in the west Pacific is produced by rapid retrogression of blocking in the central Pacific, with cyclonic wave breaking then occurring related to the amplified planetary trough over the east coast of Asia (Fig. 2a). This evolution pattern is consistent with that discussed in detail in Woollings et al. (2008), who utilized the methodology of Berrisford et al. (2007) to consider wave breaking at all latitudes, and not only along the CBL at which it may block the eastward progression of middle-latitude weather systems.

Composites from 6 to 2 days before onset in the central Pacific (e.g., Fig. 7a) show a slowly amplifying northeast–southwest-oriented dipole anomaly in \( \theta \) near 220\(^\circ\)E with the high region to the north forming the upstream portion of a synoptic-scale wave train from there to the Atlantic. In the final two days to onset the dipole intensifies and expands to the west. At the same time the wavelength in the wave train over North America increases (Fig. 7b). There is no indication here or in further diagnostics (Tyrlis 2005) of enhanced upstream storm-track activity, but, consistent with the \( \theta \) dipole, this activity is shifted both north and south during the whole period.

d. Eastern Pacific–western North America

The composite \( \theta \) on 2 PVU for blocking at the representative longitude 230\(^\circ\)E is shown in Fig. 3e. The trough–ridge–trough structure here is an amplification of the climatological structure (Fig. 2a). The symmetry of the meridionally aligned ridge is in contrast to the regions farther west in the Pacific. The lack of tilt is consistent with the smaller ambient shear in this region (Fig. 2c), and both P2 and LC2 evolution patterns are found to occur here during the winter. The P2-type pattern is always realized through an anticyclonic wave breaking over the eastern Pacific resembling the winter European blocking described above. The LC2-type evolution pattern is realized through a cyclonic wave breaking in the central Pacific or sometimes over western North America. In the second case it leads to the retrogression of a cutoff low in the vicinity of the Rockies (Tyrlis 2005). The result of these two asymmetric types of development as well as some more symmetric events is the \( \Omega \) composite blocking signature, which has been discussed by Robertson and Ghil (1999) and Pelly and Hoskins (2003).

Three days prior to onset, consistent with the occurrence of the upstream LC2 events, the composite given in Fig. 8a shows an intense zonally oriented Pacific baroclinic region (and implied jet) almost up to the date line, at which there is a strong diffuence with the \( \theta \) contours to the north almost meridional and the high-\( \theta \) region to the north linking with the ambient ridge over the east coast of North America. In the subsequent days leading to onset, the region of high-\( \theta \) air appears to move eastward, leading to an amplification of the ridge (Fig. 8b). Downstream of this, low-\( \theta \) air is advected equatorward in the lee of the Rockies (Fig. 8c). Five days after onset the composite indicates a tendency for cyclonic wave breaking involving the amplified ridge and the upstream trough (Fig. 8d).

Statistical analysis given in Tyrlis (2005) also suggests another interesting connection. The occurrence of simultaneous blocking in the Atlantic and Pacific regions is consistent with random behavior. However, there appears to be an increased probability of eastern Pacific blocking from some 7 to 16 days after Atlantic blocking. Further evidence for this is provided by the 250-hPa streamfunction composite for 15 days before SBE onset at 230\(^\circ\)E in Fig. 9a, which shows a strong anticyclonic anomaly in the Atlantic. For smaller lags, in the next 10 days, the anticyclone moves eastward and then westward, maintaining its amplitude. By 3 days before onset (Fig. 9b) it has moved over North America and weakened somewhat. This composite is for the same

![Fig. 7. Evolution of winter SBE in the sector centered at 180° as shown by composites of anomalies of \( \theta \) on the 2-PVU surface.](image-url)
day as in Fig. 8a and the anticyclone over North America corresponds to the weakness of the trough there. The subsequent new ridge development over the Gulf of Alaska must be an upstream adjustment, perhaps through the LC2-type developments seen over western North America.

e. Central and eastern North America

The blocking composite \( \theta \) on 2 PVU for 270°E, representative of this sector, is given in Fig. 3f. The cyclonic LC2 flavor here is apparent and is consistent with the strong background cyclonic wind shear with the jet some distance to the south (Fig. 2c). An indication of the composite evolution is given in Fig. 10. The composite one day before onset (Fig. 10a) reflects the fact that blocking in this sector is very frequently preceded by an enhanced ridge and perhaps blocking on the west coast of North America. As mentioned above, the latter tends to be followed by a plunge of low-\( \theta \) air east of the Rockies. Related to this is an increase in baroclinicity over the southeast United States and often intense LC2-type cyclogenesis. Two days after onset (Fig. 10b), the trough has cut off with a broad anticyclone on its poleward side.

f. Western and central Atlantic

The winter blocking composite signature at 330°E (Fig. 3g) again shows a more symmetrical signature somewhat like that in the eastern Pacific. As in that region, both cyclonic and anticyclonic developments

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**Fig. 8.** Evolution of winter blocking (SBEs) in the eastern Pacific sector centered at 230°E as shown by composites of \( \theta \) on the 2-PVU surface for times lagged with respect to SBE onset days there.

**Fig. 9.** Evolution of winter blocking (SBEs) in the eastern Pacific sector centered at 230°E as shown by composites of 250-hPa streamfunction anomalies for (a) 15 days and (b) 3 days prior to SBE onset days in this sector.
are found but the former dominates, as suggested by the slightly upstream tilt of the blocking ridge axis. The evolution of the composite shown in Fig. 11 reflects the dominance of “hybrid” events in which a transition between the two patterns is observed. An anticyclonic wave breaking leads to an enhanced ridge or blocking over the eastern Atlantic–western Europe (Fig. 11a). Then cyclonic wave breaking occurs on its upstream side with retrogression of the ridge, the onset and day 3 composites (Fig. 11b) being quite similar to the composite of all the days in Fig. 3g. The presence of both anticyclonic P2 and cyclonic LC2 patterns in the area, as well as the transition between them, is consistent with the ambient zones of cyclonic and anticyclonic wind shear that exist in the western and eastern Atlantic, respectively, associated with the tilt of the Atlantic jet. Much more discussion of wave breaking in this region is given in Woollings et al. (2008).

4. Summer blocking

In Fig. 12 a summary of blocking in summer is provided by the composites for SBE days of $\theta$ on the 2-PVU surface for the same set of representative longitudes as was shown for the winter in Fig. 3. (The summer climatological average for this field is given in Fig. 2b.) The overall aspects that are apparent are that the numbers of events are generally smaller and, like the climatological average, the amplitudes of the meridional displacements are considerably reduced. These aspects are consistent with TH.

Looking in more detail it is striking that the sense of the wave breaking in the different sectors tends to reverse from winter to summer. In Europe and Asia, winter blocking had an anticyclonic signature and in summer it is more symmetric but has a slight cyclonic flavor. In the Pacific and Atlantic (see particularly Figs. 12e,g), the cyclonic signature of winter blocking is replaced by anticyclonic in summer. Summer blocking over North America will not be discussed as it is even less frequent than winter blocking in this region. Considering the 2-PVU climatological winds for summer shown above in Fig. 2d, in the Atlantic and Pacific the jet has moved poleward to the latitude of the CBL so that the strong ambient cyclonic shear of the winter is no longer present. In contrast, in the European region, the jet latitude is similar to that in winter and there is now no tilt. Over Asia there is now a significant cyclonic shear.
poleward of the westerly jet that is now present north of the Tibetan Plateau. The summer blocking signatures and their changes from winter are therefore generally consistent with their wave-breaking development being influenced by the ambient shears.

Fig. 12. Composites of summer SBE days in representative sectors around the NH. The field shown is $\theta$ on the 2-PVU surface. The central longitude of each sector and the membership of each composite (in parentheses) are indicated at the top of each panel.

The development of blocking around the hemisphere will not be discussed in such detail as for winter, but some aspects that are special to summer will be highlighted. The composite signature in Europe is the result of a
number of events with either a cyclonic LC2 signature or an anticyclonic P2 signature. In Asia there is a particular kind of development. The summer monsoon anticyclone tends to split with centers over northwest India and southeast China (e.g., Dunkerton 1995; Dethof 1999) and a small-scale, upper-level trough resides between them at around 80°E. This is particularly marked in July but there are indications of it in the climatological seasonal mean in Fig. 2b. The development of the July blocking composite is illustrated in Fig. 13. As suggested by this, often in this region streamers of low-θ (high PV) air move equatorward in the wake of transient activity at higher latitudes (Fig. 13a). At onset day (Fig. 13b), the tip of the trough has cut off, with signs of LC2 behavior. The cutoff cyclonic vortex moves south (Fig. 13c) and on the cyclonic side of the jet engages the warm air to produce a poleward extrusion of that in a further cyclonic wave-breaking event (Fig. 13d). Dethof (1999) discussed these synoptic developments and stressed their importance for moistening the summer stratosphere through the poleward extrusion of moist air from the troposphere in the monsoon region. The frequent summer blocking in this region is predominantly weak and transient (TH).

The summer mean composite signature of blocking at 140°E (Fig. 12c) shows a broad ridge over the region rather than a coherent blocking signature. Such a signature is more evident when composites for individual months are considered, especially August. The poleward extrusion of high-θ subtropical air over eastern China and the start of an anticyclonic P2-type wave breaking are clear in the August composite for the day prior to onset shown in Fig. 14a.

The anticyclonic wave breaking in the summer in the central and eastern Pacific is associated with the climatological mid-Pacific trough (Lu and Dong 2001), which is clear in the August climatology given in Fig. 14b. Its existence is dynamically linked with the deep convection observed in the Asian monsoon anticyclone area (Hoskins and Rodwell 1995). In the latter part of the summer the North Pacific subtropical high extends toward the northwestern Pacific (e.g., Lu and Dong 2001) and the baiu rainy season in China and Japan ends (e.g., Krishman and Sugi 2001). At the same time the region of transient activity moves to the Okhotsk Sea. As synoptic disturbances originating from this area reach the vicinity of the ambient mid-Pacific trough, they amplify and break anticyclonically, enhancing the weak climatological reversal of the meridional θ gradient to produce frequent blocking (Fig. 12d).

As suggested by the composite (Fig. 12e), summer blocking over the eastern Pacific–western North
America region consists mainly of weak anticyclonic wave breaking as extrusions of high-θ air move north-eastward.

As in the central Pacific an upper-level trough characterizes the upper-level summer climatology over the eastern Atlantic, though it is weaker here (Figs. 2b and 14b). Again the synoptic systems moving in to the trough region lead to anticyclonic breaking and the amplification of the trough ridge structure seen in the composite (Fig. 12g).

5. Concluding comments

Following TH, the definition of blocking used in this paper may be summarized as a reversal of the usual meridional θ contrast on horizontal scales of 1500 km or larger, and lasting at least 5 days, occurring on the dynamical tropopause in the neighborhood of the latitude of the climatological storm track (the CBL). From invertibility it implies a disruption of the westerly flow in that neighborhood. A cyclone on the equatorial side is considered to be a possible feature of blocking just as much as an anticyclone on the poleward side, though the duration of the former is likely to be shorter because of the latent heating it tends to encourage (Hoskins et al. 1985). With this definition, Rossby wave breaking is integral to blocking, particularly its onset phase. This is confirmed by the various composites shown here.

The change in blocking characteristics with longitude and from winter to summer is striking. One particular aspect of interest has been the cyclonic (LC2 or P1 or both) or anticyclonic (LC1 or P2 or both) nature of the wave breaking and its possible determination by the climatologically ambient jet shear in the region. More generally there is interest in the extent to which the planetary-scale flow determines blocking locations and the diversity of characteristics of the blocking that occurs.

In the oceanic regions and North America, the cyclonic (LC2) wave-breaking signature in winter is consistent with the equatorward location of the jet. In the summer the jet is close to the CBL over the oceans and, over the western oceans an anticyclonic (warm extrusion P2) development occurs on average. The eastern oceans–western continents are the regions of strong climatological winter ridges. The Atlantic jet is close to the CBL in the eastern Atlantic–west European region. The anticyclonic (P1) signature appears to be an amplification of the tilted mean planetary wave structure, including the SW–NE tilt of the jet. In the Pacific the jet is less tilted, and in the eastern Pacific–western North America region it remains generally equatorward of the CBL and there is a more mixed signature of the wave breaking. Asian winter blocking occurs equatorward of an Arctic jet and its anticyclonic nature appears to reflect this as well as the European blocking that extends into the region. Summer blocking (as defined here) in the central and eastern ocean basins is dominated by the mean planetary wave troughs with their anticyclonic wave-breaking signature. Eastward-moving synoptic systems move into phase with them and reinforce the wave breaking. The frequent summer blocking over Asia occurs near a mean trough in the northern flank of the monsoon anticyclone and is again associated with eastward-moving synoptic systems. Cyclonic wave breaking occurs on the poleward side of the strong jet north of the Tibetan Plateau, and warm moist air from the monsoon anticyclone is entrained into the higher-latitude stratosphere.

In the transition seasons, which have not been discussed above [but for which some details are given in Tyrlis (2005)], it is found that in general the blocking behavior is similar to that in winter, but with reduced meridional displacement amplitude.

The retrogression of blocking both in the Atlantic and the Pacific found here has often been commented...
upon. In addition, it has been found here that European blocking tends to progress into Asia. More interestingly, there is evidence of Atlantic–European blocking preferentially occurring about 1–2 weeks before eastern Pacific blocking. This appears to be through westward movement of European–Atlantic blocking anticyclones to North America followed by planetary wave adjustment and the onset of blocking in the eastern Pacific.

Considering the total picture of blocking behavior summarized above, the importance for regional blocking of the mean planetary scale flow including its jet shears is clear and generally consistent with theoretical expectation. It could be questioned whether the results are biased by the use of the same CBL throughout the year. However, the jet movement in latitude is generally greater than that of the storm track, and as discussed in more detail in TH the latter is partially allowed for by seeking reversals in a latitudinal band around the CBL. Following the development and use in Berrisford et al. (2007) and Woollings et al. (2008) of a measure of Rossby wave breaking at all latitudes, it will be of interest to also consider the cyclonic and anticyclonic nature of this wave breaking and its consistency with the climatological ambient shears.

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