The Significance of Persistence Timescales of the Northern Annular Mode

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1 Abstract

An analysis is made examining persistence timescales of the Northern Annular Mode (NAM) within the ECMWF ERA40 dataset. Features in these are found to be not dissimilar to features found in previous analyses using NCEP data. A critical assessment of the wintertime tropospheric maximum in persistence timescales has found a link with low frequency variability. We conclude these timescales are less likely to be associated with particular meteorological events, than to the integrated effect of a number of events throughout winter. This work has further established the use of Empirical Mode Decomposition in diagnosing non-stationary modes in environmental data and in particular, those associated with the the timeseries of the NAM.

2 Theory & Methodology

The horizon of predictability for weather forecasting is generally acknowledged to be less than 10 days. Beyond these times, the chaotic nature of weather reduces forecast skill considerably. However, other aspects of climate variability are more predictable: summers are generally warm and settled, winters cold and inclement. Seasonal predictions of ENSO are made which impact beyond the tropical Pacific and the North Atlantic Oscillation is known to be associated with patterns of wintertime behaviour in Northern Europe. The latter is also associated with similar patterns in the stratosphere, the Annular Modes. The predictability timescales for these modes are thought to be long, opening the prospect of improved tropospheric forecasting. We are interested in better establishing the nature of these modes of variability.

The NAM index was diagnosed using daily height data from the ECMWF ERA40 dataset (Uppala *et al.*, 2005) and persistence times calculated. The NAM was identified as the leading empirical orthogonal functions (EOF) of daily zonal mean wintertime geopotential height on individual pressure surfaces. The EOF patterns were constructed from height anomalies poleward of 20° N. These were constructed from deseasonalised data which were then smoothed using a 90–day filter. The full timeseries of the original model height anomalies were then projected onto the leading EOF pattern, retrieving a principal component timeseries. Lagged autocorrelations were then calculated employing a Gaussian smoother to recover decorrelation time scales as a function of time of year. These were taken to be the first instance by which the lagged decorrelation times reduced by a factor 2.71. The NAM persistence timescales for 1980–1999 are shown in figure 1. This procedure closely follow those employed by Baldwin *et al.* 2003. One difference being that the EOFs are based on zonally averaged height data, as opposed to full field data (M. Baldwin, *pers. com.*).

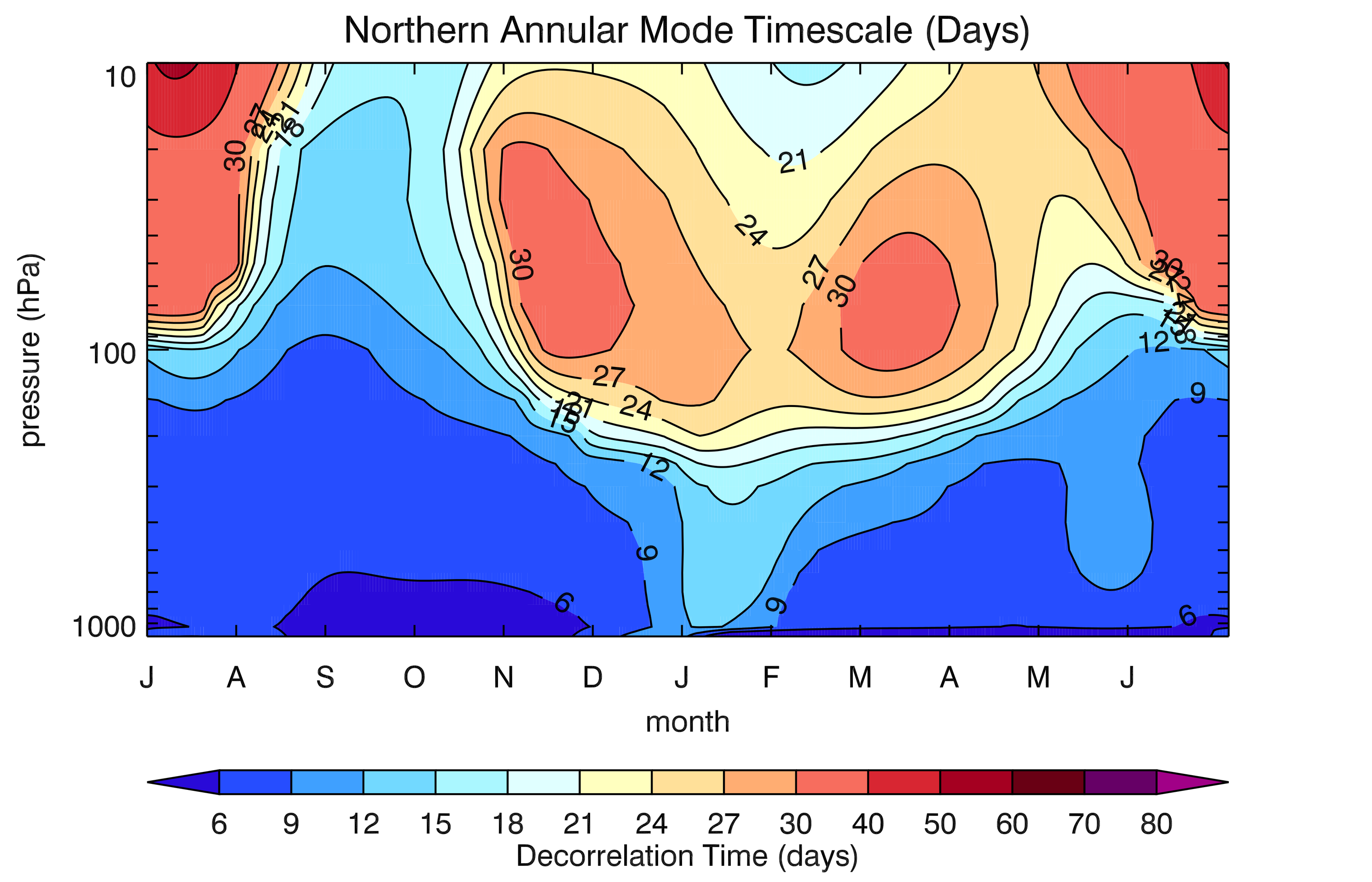

Figure 1 Height-time plots showing e-folding times of the NAM, defined as the first EOF of NH height anomalies from ERA40. The data are calculated using a Gaussian weighted filter for the period 1980-1999.

To better interpret the origin of these persistence timescales, one must establish whether they arise from particular meteorological events or are artefacts from our analysis. Our approach is to use Empirical Mode Decomposition (Huang *et al.* 1998). This technique reduces a given timeseries of data into a finite set of Intrinsic Mode Functions (IMF). Conceptually similar to Fourier components, these modes differ by having time-dependent frequencies. As such, they lend themselves to describing processes/variability which are aperiodic in time. In this respect, EMD is similar to wavelet transforms. Huang *et al.* 1998 state that an intrinsic mode function should satisfy two conditions: (1) in the whole data set, the number of extrema and the number of zero crossings must either equal or differ at most by one; and (2) at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero.

3 Results

Figure 2 shows the persistence timescales for the NAM defined at 500 hPa, as a function of time of year. Unlike the data in figure 1, these are defined for the period 1990–1999. Similarly to figure 1, a maximum is seen in the unfiltered data around January and peaks around 20 days. The NAM anomaly timeseries for this period reduces to ten distinct IMFs. We arbitrarily define a 'high-frequency' set to comprise the first 5 IMFs. The persistence times for these data do not show the same peak in January.

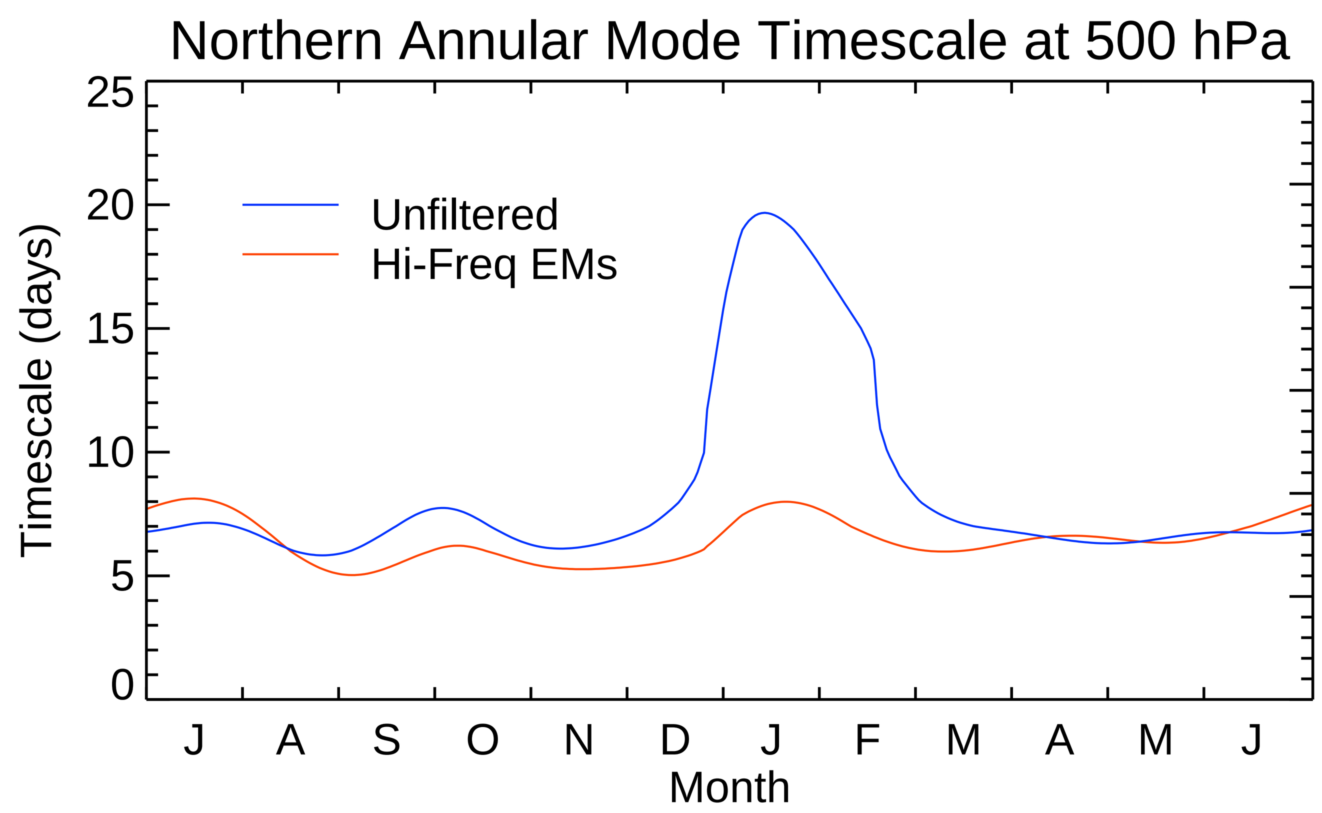

Figure 2 Timeseries of e-folding times for the NAM, defined as the first EOF of NH height anomalies at 500 hPa from ERA40. Shown is the sum of the first 5 IMFs (red) and the unfiltered data (blue). The data are calculated using a Gaussian weighted filter for the period 1990-1999.

Figure 3 shows height-time plots for various combinations of the IMFs. The top-left panel shows the original unfiltered data for the winter 1998–1999. This particular year was noted for having two Sudden Stratospheric Warmings (SSW) events. The top-right panel shows the "high-frequency" IMFs. Like the unfiltered data, they show both warming events clearly. The bottom-right panel shows the remaining 5 low-frequency IMFs. It is noted that throughout the winter and between 1000–10 hPa, the NAM index is positive everywhere. The bottom-left panel shows the first IMF. Coincident with the warming events are wave-like structures, which are coherent in height. Both the EOF and EMD analyses are performed independently on individual pressure surfaces. This and the location of these structures, suggest these likely to be real, rather than artefacts of the analysis.

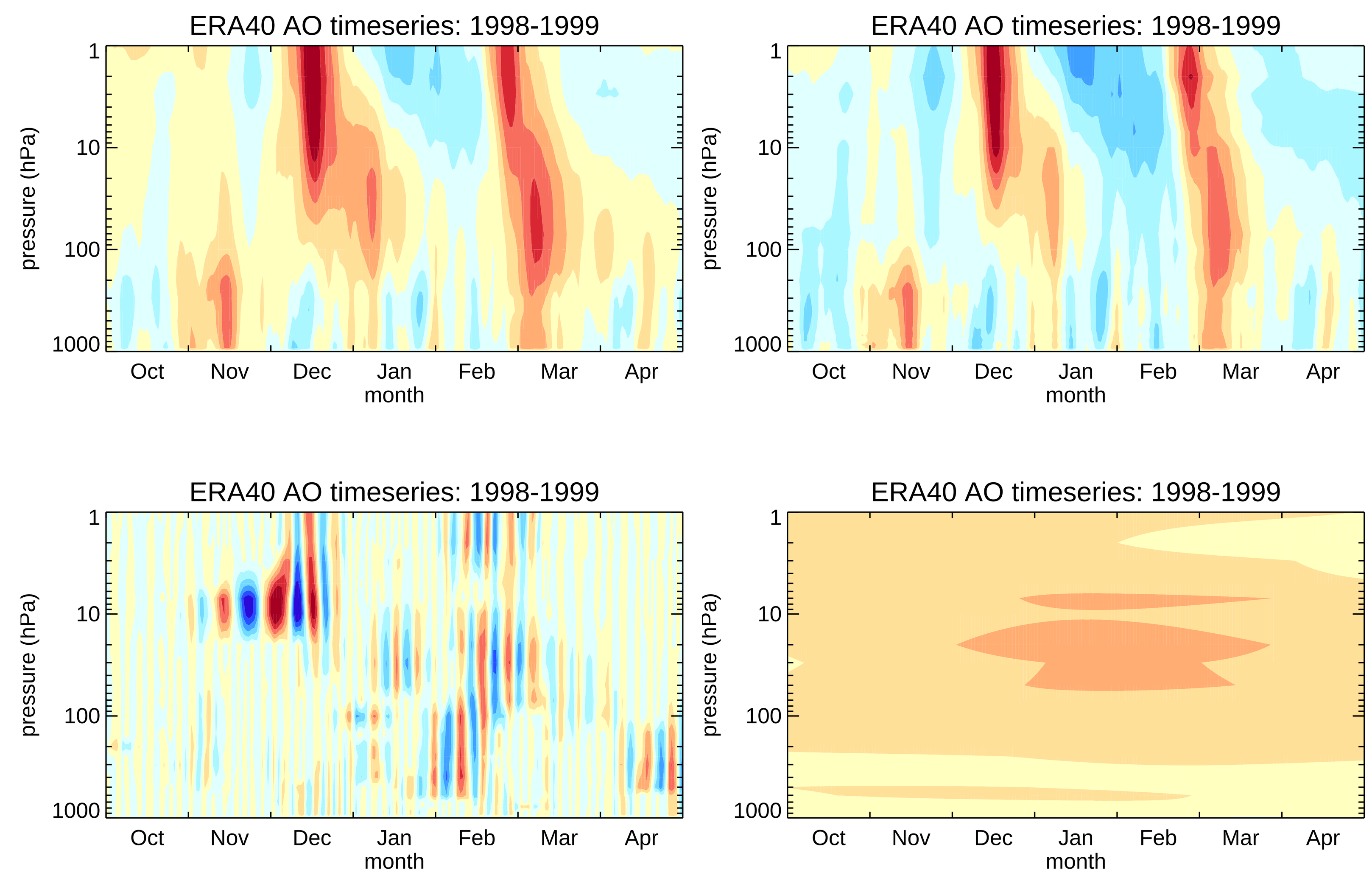

Figure 3 Height-time plots of the NAM for the boreal winter 1998–1999. Shown here are: the first 5 (top–right) and last 5 IMFs (bottom–right), the first IMF (bottom–left) and the unfiltered data (top–left). Timeseries are normalised by their standard deviation at each pressure surface. The contour interval is 1, with blue–hues denoting negative anomalies and red–hues positive anomalies.

4 Discussion

An investigation into the origin of tropospheric Annular Mode persistence timescales has been made using the ECMWF ERA40 dataset. Empirical Mode Decomposition analysis has been used to separate high and low variability. It is found that low frequency tropospheric variability inflates NAM timescales during winter. It is hypothesized that although individual (stratospheric) events do not seem appear to be associated with these elevated timescales, we do not discount low frequency variability arising from an accumulation of such events. We also highlight coherent high-frequency structures in the low-order IMFs. These appear to be linked with SSW events and are seen to precede these. Further work is required to establish their significance.

5 References

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