Relationship of the Arctic and Antarctic Oscillation to the Outgoing Longwave Radiation

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1. Introduction

The Arctic Oscillation (AO) in conjunction with the North Atlantic Oscillation (NAO) is a leading mode of climate variability in the Northern Hemisphere extratropical circulation (e.g. Thompson and Wallace, 1999). The phase of this phenomenon at upper levels is strongly related to the strength and location of the polar jet stream. Specifically it has been shown that this leading pattern of intraseasonal climate variability is related to day-to-day weather, particularly the extreme events.

One suggestion is that AO/AAO variations are related to the dynamics of the stratosphere and to troposphere-stratosphere interaction (Baldwin and Dunkerton, 2001; Zhou et al., 2001;2002; Wallace and Thompson, 2002). On a time scale of several weeks this appears to happen through the interaction of the mean flow and upward propagating energy fluxes (Charney and Drazin, 1961). On longer time-scales this may be influenced by the changes in ozone and/or carbon dioxide. Another suggestion is that the AO/AAO variations at the surface are related to the atmospheric radiation budget and internal dynamics of the troposphere (Yang et al., 1999; Limpasuvan and Hartmann, 2000).

In particular, Limpasuvan and Hartmann(2000) (hereafter referred to as L&H) have examined the NCEP/NCAR reanalyses and within their Figure 4 they depict the zonal mean zonal wind composites for the AO/AAO high phase, low phase and their difference. Also depicted are the mean meridional winds along with the associated vertical motions. For the High minus Low phase (hereafter referred to as H-L), the analyses depict downward motion in the mid-latitudes of each hemisphere. This, in turn, suggests a decrease of clouds associated with an increase in the outgoing longwave radiation (OLR). Thus, independent OLR data can provide a test of the reanalysis results.

The objective of this paper, then, is two-fold. Within the first part we will demonstrate through AO/AAO composite analysis that the NCEP/NCAR reanalysis OLR agree with the independent observations of the broadband satellite instruments from ERBE between 50N and 50S, both in zonal averages and in geographically mapped space. We then utilize the reanalysis data to extend the AO/AAO composite information to the regions poleward of 50N and 50S.

2. Data

For this study we focused on two data sets. The first is the OLR calculations determined from the NCEP/NCAR reanalyses (e.g. Yang et al., 1999). The second is from the non-scanner broadband radiation data from the Earth Radiation Budget instruments (ERBS) from Wielicki et al. (2002).

The monthly AO index is constructed by projecting the montyly (00Z) 1000mb height anomalies poleward of 20°N onto the loading pattern of the AO which is defined as the leading mode of Empirical Orthogonal Function (EOF) analysis of monthly mean 1000 hPa height during 1979-2000 period . The AAO is computed in a similar manner, but at 700 hPa. The data have been treated the same as the OLR.

3. Results

To help delineate the signal from the noise, we have focused on all months that exceed the 1 standard deviation as being high/low index. The majority of the cases occur in the winter months and in the following analysis we focus on two basic periods; all months and the months January-March and May-July for the northern and southern hemisphere, respectively.

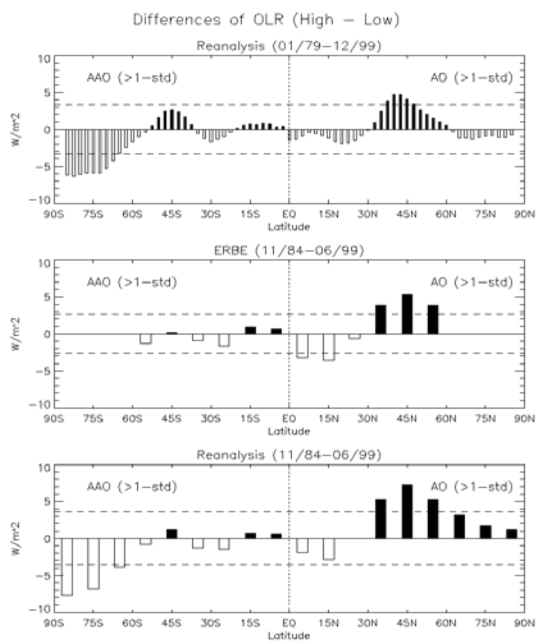

Fig. 1

Figure 1 depicts the OLR differences for the High Index minus the Low Index cases as a function of latitude for the three all-month data sets. Note that for the AO we have restricted the analysis to the northern hemisphere and the AAO to the southern hemisphere. This aspect will be re-examined below in the discussion of mapped features. The top diagram is for the reanalysis period 1979-1999 with a latitudinal resolution of 2.5 degrees. We see that the mid-latitudes for both hemispheres show a positive effect of 2-4 W/M^2 with the impact greater in the northern hemisphere. In addition there is an approximate 1 W/M^2 positive impact in the tropical southern

hemisphere. Elsewhere, the impacts are negative with the largest in the polar southern hemisphere of about -6 W/M^2. The middle panel is for the ERBS data and we see that there is considerable agreement in the general pattern. To aid the comparison of the two data sets we present in the bottom panel the results for the reanalysis restricted to the more limited time period 1984-1999 and averaged over the 10 degree ERBS latitude bands. Overall we see substantial consistency between the latitudinal patterns of the ERBS and reanalysis results though there are some small differences in the amplitude.

One peculiar element is the difference in the pattern between the reanalysis in the polar northern hemisphere. For the longer period the AO impact is slightly negative whereas for the shorter period it is slightly positive.

The above information is all based on the zonal average data without consideration of the spatial distribution.

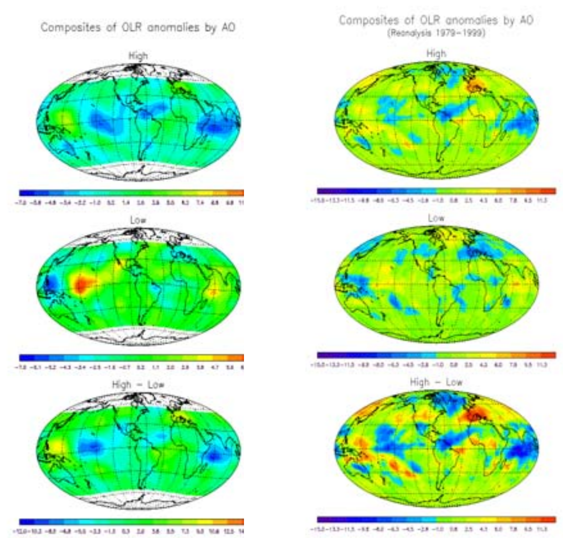

Fig.2

Within Figure 2 we have utilized the OLR data from the reanalyses (2.5x2.5 degree lat/lon resolution) for the period 1979-1999 to develop composite maps of the OLR anomalies by AO for all months that exceeded the 1 standard deviation value of the AO . That is, we have first compiled each month climatology based on the entire record and then developed a composite of the anomalies based on the AO record. Note that in contrast to the zonal average results which were restricted to the northern hemisphere for the AO, we now present the AO results over the globe so that there is no artificial boundary at the equator. The top panel is the high index case, the middle panel the low index and the bottom panel the high-minus-low. For this diagram the blue values represent low OLR and cloudy areas, the yellow areas the opposite. Thus, in the top panel we see the relatively clear area over Europe as the storm track and cloudy area is toward the North Atlantic. This is just opposite of the low index and the bottom panel shows this feature to be one of the most substantive impacts of the AO. The composites do not clearly depict the Pacific storm track, partly because the Pacific storm track is weaker and partly because the Pacific storm track and jet stream are more closely related to the PNA pattern (the second EOF mode) than the AO In addition to the North Atlantic/Europe effect, we see that there are several other centers of impact within the tropics and even into the southern hemisphere and the question is how much significance to ascribe to these results.

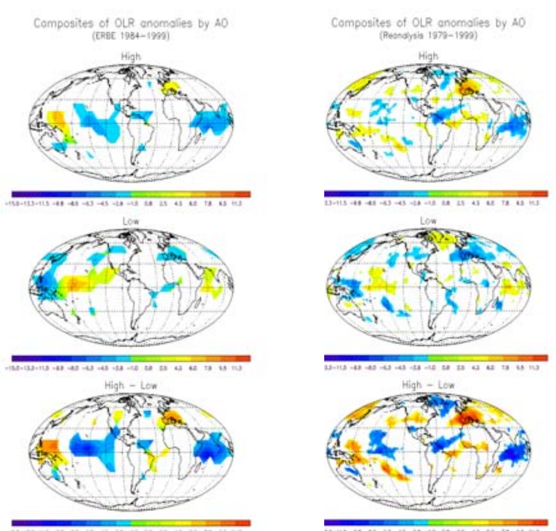

Fig.3

In order to answer this question we have examined the composite statistics using a random time series as a surrogate for the AO. For each grid point the monthly value is composited from the random time-series utilizing the same criteria as above. This is done 100 times. For each case a mean and standard deviation is calculated. The grand-average of the mean and standard deviation is then computed.

Using the above values of standard deviation, we have plotted within Figure 3, the composite values that exceed the two-standard deviation value for the AO-reanalysis and the AO-ERBS. In each diagram we present the results for the high AO, low AO and high minus low AO cases, but for the sake of brevity we will concentrate our discussion on the latter diagrams. Figure 3 shows that for the high-low case a major impact is over the north-Atlantic/Europe area which is related to the well known relationship of the AO to the storm tracks in this area. In addition, though, we see a major influence on the radiation properties over the Asian continent as well as significant influence in the tropical regime. It is interesting to note that in the northern hemisphere the impact in the mid-latitudes is basically positive whereas for the tropics it varies in sign. Hence, the zonal average results depicted earlier indicated a relatively lower overall impact in the tropical bands. We are not aware of any previous associations of the AO with cloud and radiative effects in the tropics. One point, in particular, we will have to investigate is possible cross- association of tropical phenomena (e.g. sea surface temperature with AO variability). We see that a very similar pattern exists though the ERBS amplitude and patterns are somewhat lower and smoother due to the inherent smoothing of the non-scanner data.

Not shown, but for the AAO, we see relatively little strong association with the major impacts in the polar southern hemisphere, the Indonesian and equatorial Pacific areas and some small areas in South America. There is very little extension of the AAO signal into the northern hemisphere.

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