Flow Regimes:

Evaluations of targeting field experiments include the characterization of the predominant flow regime typically as either zonal or non-zonal. Various means of classifying the flow include zonal and blocking indices, teleconnection patterns and predominant wave amplitude. On a hemispheric scale the flow regime during the Northern Hemisphere winter might be classified according to the 'wave amplitude regime' (Hansen et al., 1993). This method described in Hansen el al (1993) is based on their finding that the amplitude of planetary scale waves in the 500mb flow has a bimodal probability density distribution with mode-2 corresponding to the high amplitude (non-zonal) wave regime and mode-1 with more zonal flow. This method is sufficient for determining the general nature of the flow regime however it does not provide a means of quantifying precisely how zonal or non-zonal the flow may be.

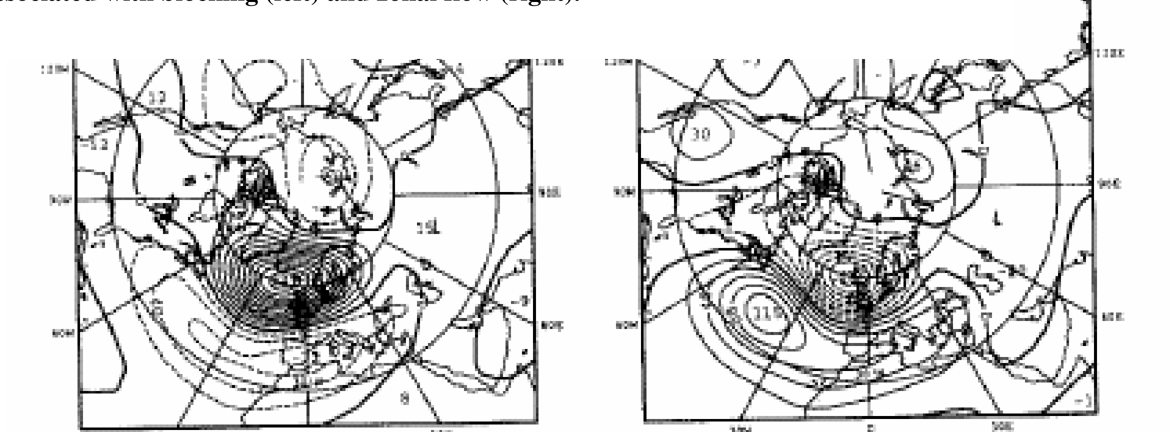
A more quantitative method that has been used since the 1930's is the "zonal index" (Namias, 1947). This index is based on the strength of the westerly component of the geostrophic wind between 35°N and 55°N and is customarily computed at the 700mb level or at sea level. Strong geostrophic westerly flow would imply a zonal regime while weak westerlies or easterly flow would indicate a non-zonal regime. This method can be applied either regionally or over the entire hemisphere.

Another closely related index is the "blocking index" (Tibaldi and Molteni, 1990) which classifies the flow as either zonal or blocked depending on the value of the 500mb geopotential height gradient from 60°N to 80°N (GHGN) and 60°N to 40°N (GHGS), plus or minus 5 degrees. Flow is considered blocked if the northern index (GHGN) is less than -10 m/deg latitude and the southern index is greater than 0. The southern index would be expected to have the most relevance for our purposes since the forecast verification regions for WSR are situated in the mid-latitudes. The blocking index can be converted to a zonal index by assuming an f-plane and using the height gradient to compute the geostrophic wind from the zonal equation $U_g = -1/f\ \delta\phi/\delta y$. At a central latitude of 50°N the zonal index is equal to GHGS multiplied by -.03845. John D. Horel (1985) used this index in the region of maximum blocking at 55°N, 165°W in the Pacific to quantify the flow regime based on a comparison with climatology. Strongly zonal flow is characterized by large positive geostrophic wind anomalies while non-zonal or blocked flow would be associated with negative anomalies.

Blocked regimes the Atlantic are most frequently associated with large positive geopotential anomalies centered at 60°N with negative anomalies to the south (Liu, 1993). Strong zonal flow was found to have the same anomaly pattern but with the opposite sign (Liu et al 1995). The spatial pattern of the geopotential height anomalies from Liu et al (1995) are shown in figure 1. The anomaly pattern of zonal (blocked) flow in the Atlantic closely corresponds with the positive (negative) phase of the winter NAO teleconnection pattern as identified in the analysis of Barnston and Livezey (1986) and illustrated in figure 2. The correspondence of the negative phase of the NAO and blocking in the Atlantic is confirmed by Benedict et al (2003).

An important teleconnection pattern in the Pacific, the PNA, was found to be inconsistent or out of phase with the blocking pattern (Hanson et al 1993) and therefore probably would not be a good indicator of flow regime. However the anomaly pattern over the continental U.S., shown in figure 3, suggests that the positive phase of the PNA would be associated with more non-zonal flow over the continent and therefore might be relevant to describing the flow for that region. Hanson et al (1993) found the Pacific blocking pattern corresponded to the non-zonal mode-2 of the "wave amplitude regime" and concluded that the two quantities represent the same phenomenon. This result would suggest that either the blocking or zonal indices would be a better measure of flow regime in the Pacific region.

Figure 1(from Liu et al, 1995): the spatial pattern of the geopotential height anomalies associated with blocking (left) and zonal flow (right).



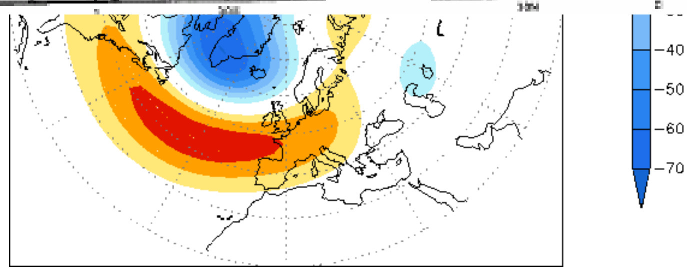


Figure 2: The geopotential height anomalies associated with the positive phase of the NAO

The southern blocking index (GHGS), NAO index and zonal index at 500mb should give a good quantitative measure of the Atlantic flow regime while the blocking index and zonal index and anomaly would be the best measures of flow regime in the Pacific region. The PNA is not expected to be associated with the zonality of the flow regime in the Pacific but may be useful, along with the zonal and blocking indices, for quantifying the flow over the continental United States. The three regions, Atlantic, Continental and Pacific may have different characteristic flow patterns at any given time and therefore must be considered separately. The region where the flow regime might influence the predicted and actual signal associated with the targeted observation would be expected to vary in time as the signal progresses eastward. Assuming that the signal due to observations over the Pacific propagates at a speed of approximately 30 degrees per day, the flow regime in the Pacific would have the greatest influence for the first 24 to 48 hours after the observation time, the Continental U.S. flow regime would be more important for the next 24 to 48 hours. After approximately 72 hours the flow over the Atlantic would be expected to have the greatest significance.

Data and Methods:

The mean and wind and geopotential height values used to calculate the blocking and zonal indices were obtained from the NCEP/NCAR reanalysis that is available on the NOAA, Climate Diagnostics Center, Daily Climate Composites website. The climatology values used to calculate the geopotential wind anomalies are from the same source and include the time period from 1968 to 1996. The 24 hour mean value for each of the WSR observation days was used in the calculations of the zonal and blocking indices. The blocking indices were computed according to equation (1) in the appendix and averaged over the three values of δ at each gridpoint from 180°W to 20°E at 2.5 degree resolution. Then a single value was obtained for each of three regions by taking the maximum value of GHGS across each region. The maximum value defines the upper limit of the degree of blocking so that a given region is considered blocked if any gridpoint in that region is blocked. The Pacific region includes the longitudes from 180°W to 122.5, the Continental region extends from 120°W to 82.5°W and the Atlantic region includes the longitudes from 80°W to 0°. The zonal indices were then computed for each region using this maximum geopotential height gradient and the value of f at 50°N. The geostrophic wind anomaly for the Pacific blocking region was obtained in a similar manner using the daily and climatological geopotential height gradient caluculated using the average of 9 points centered on 50°N, 165°W and 9 points centered at 30°N, 165°W using the same methodology as in John D. Horel (1985).

The North Atlantic Oscillation (NAO) index and Pacific, Northwest Pattern (PNA) values for each WSR observation day were obtained from the NOAA, National Weather Service, Climate Prediction Center's "Teleconnections" website. These values have been normalized by the standard deviation of the climatological value interpolated to each specific day.