Problem Set 7

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7.1 Here we will calculate the Arctic Oscillation (AO) index and evaluate the relationship between the AO and the EAWM. The AO index is calculated by projecting 1000 hPa geopotential height anomalies onto the loading pattern of the AO. This loading pattern is defined as the leading empirical orthogonal function (EOF1) of monthly mean 1000 hPa geopotential height anomalies poleward of 20°N during 1979–2000.

(a) Using the provided data file, select the spatial domain 20°N to 90°N and the time period 1979–2000. Calculate the mean annual cycle and the geopotential height anomalies relative to this mean annual cycle (specifically, we want to calculate the January anomalies relative to the 1979–2000 January mean, February anomalies relative to the 1979–2000 February mean, etc., rather than calculating anomalies relative to the 1979–2000 annual mean).

(b) Use the eofs module to calculate the first EOF of the monthly mean 1000 hPa geopotential height anomalies during 1979–2000. Plot the spatial pattern of the leading EOF and the time series of its principal component (PC). Calculate the standard deviation of the first principal component over 1979–2000 (Do not scale the PCs before doing this calculation!) — we will use this in part (c). The example provided during class uses the eofs.iris submodule, which is based on the iris framework, but you can use one of the other submodules if you prefer.

(c) Calculate monthly mean anomalies of 1000 hPa geopotential height over/ the entire 1958–2015 time period. Project these anomalies onto the leading EOF pattern you calculated in part (b) to generate a time series of the pseudo-PC1 (see the documentation for Eof.projectField()). Normalize this pseudo-PC1 time series by the 1979–2000 standard deviation of the actual PC1 to get the AO index. Note that EOFs have no intrinsic sign, so you may also need to multiple your time series by -1 to get the AO index. Check your EOF against the standard loading pattern provided by NOAA CPC to see whether this is necessary in your case. Save the AO index to a file.

(d) Use the results of part (c) to calculate the DJF-mean AO index for the winters of 1958–2014, and plot it together with the standardized DJF-mean EAWM index you constructed in problem set 5. Calculate the correlation between these two indices and evaluate its statistical significance. Include this correlation coefficient (R) on your time series plot. Remove the linear trends from both indices and re-calculate the correlation.

(e) **Extra credit:** Calculate the 5-year rolling mean of the DJF AO index and plot it together with the standardized DJF EAWM index.

(f) **Extra credit:** Under Student's t test, the critical correlation coefficient for statistical significance at a given confidence level is

$$R_c = \frac{t_c}{\sqrt{n - 2 + t_c^2}},$$

where n is the number of paired samples and t_c is a critical t value that depends on the number of degrees of freedom ($n - 2$) and the desired confidence level. For example, if t_c corresponds to the 95% confidence level with $n - 2$ degrees of freedom, this means that the integral of the t distribution with $n - 2$ degrees of freedom between $-t_c$ and t_c equals 0.95 (i.e., that 95% of the distribution lies between $-t_c$ and t_c). Calculate the effective sample size for the correlation between the AO and EAWM indices (problem set 7), and use this to re-evaluate the statistical significance of the correlations you calculated in part (d). You may wish to consult the solutions for problem sets 6 and 7, and/or the documentation for scipy.stats.t.