Spectral slopes and interannual-to-subannual variability ratios

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Introduction

Spectral slope is a statistic that describes the redness of a time series. It is computed by fitting a line to the plot of log frequency versus log spectral power density. Spectral slope is of particular use in climatology, as many geophysical time series can be described by power law processes [Wunsch 2003]. A number of publications have suggested broad implications of spectral slope for different time series [e.g., Blender and Fiedrich 2003, Hayers and Curry 2006, Koscielny-Bunde et al. 1998]. In this paper, we show first that the spectral slopes for surface air temperature, sea level pressure, and precipitation computed from months to decades correspond visually and mathematically to a straightforward climatological quantity, namely the log ratio of interannual to subannual variances. Second, we use the method of empirical orthogonal functions (EOFs) to identify the dominant modes responsible for spatial patterns of spectral slope. Notably, residual patterns after subtracting only a few leading EOFs appear to be dominated by latitudinal variability and land-sea contrast, particularly for precipitation. Finally, we interpret leading principal components as well-known modes of interannual variability.

Development

To investigate spectra for surface air temperature, sea level pressure, and precipitation computed from months to decades, we focus on the spectra of filtered datasets which are then weighted so that the squared spectral slope is maximized. This averaging procedure (discussed in the Development section) rather than the log of the average of the bin average values rather than the average of the log in order to retain a physically meaningful quantity. Interannual and subannual filtered datasets are computed using a symmetric four-pole low-pass Butterworth filter with half-power point at the annual cycle. Variances of interannual and subannual regimes are computed by finding the temporal variance at every point of the interannual and subannual datasets, respectively. EOFs and PCs are computed for the strictly interannual timeseries after inversely scaling the data at every geographical location by the corresponding standard deviation of subannual temperature. With this scaling, data variance at each location becomes precisely the local ratio of interannual to subannual variability (whose logarithm we have connected to the local spectral slope). Cross-correlations of principal components and climate indices are computed using their linearly detrended values.

Methods

Spectral slopes are computed by fitting a line via least-squares regression to the log power density spectrum of time series anomalies in log-frequency space. Power density spectra are estimated via the Thomson multi-taper method using 3 tapers. To avoid artifacts from the MTM procedure, the lowest three frequencies are discarded. So that the linear best-fit computation is not dominated by the greater density of high-frequency data points, spectra are binned and averaged in ten equally-spaced log-frequency bins. Intra-bin averages are computed over the log of the power-spectrum values. This averaging procedure (discussed in the Development section) rather than the log of the average of the bin average values rather than the average of the log in order to retain a physically meaningful quantity.

Conclusions

Quantitative connections have been shown between interannual phenomena and the leading principal components of a quantity that is directly related to spectral slope. We note in particular the importance of ENSO and Pacific Decadal Oscillation variability in determining these quantities. Spatial variability in spectral slope is drastically reduced by the subtraction of a small number of modes, suggesting that distinguishable dynamical processes and phenomena may be superimposed on a spectral profile which is constant over large regions. Future research will focus on the spectra of residual data after the removal of dominant modes and on developing statistics to characterize nonlinear spectra in a more nuanced way.

References


