Problem Set 3

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The El Niño–Southern Oscillation (ENSO) has signals and impacts throughout the atmosphere–ocean system. A large number of climate indices are used to describe these phenomena. The traditional indices of ENSO variability are based on sea surface temperature (SST). The current standard for determining the ENSO state is the Oceanic Niño Index (ONI), which is defined as the three-month running mean SST anomaly in the east–central tropical Pacific (120–170°W) between 5°S and 5°N (this domain is also called the Nino3.4 region, as we will see later).

3.1 Start by reading in the four SST-based indices from enso_indices_sst.csv and putting them in a pandas `DataFrame`. It may be useful to know that you can use the first column of a csv file to define the index of your `DataFrame` by setting the keyword `index_col` equal to `0`.

   (a) The data are provided once per month between January 1950 and December 2016. Convert the index of your `DataFrame` to a `PeriodIndex`. Make sure you read the documentation carefully — there may be more than one step involved.

   (b) Using the ONI, how strong was the strongest El Niño during 1950–2016? In which month and year did this El Niño occur? How strong was the strongest La Niña during the 1980s? Does the 75th percentile of ONI qualify as an El Niño? Use tools from pandas to answer these questions. Make sure you include the approaches you use in your python script.

   (c) Some ENSO indices also include information about atmospheric variability. Add columns to your `DataFrame` that represent sea level pressure variations (the Southern Oscillation Index or SOI; enso_indices_soi.csv), the upper tropospheric branch of the tropical Pacific Walker circulation (enso_indices_u200.csv), the zonal precipitation gradient along the tropical Pacific (EPSI; enso_indices_epsi.csv), and the Multivariate ENSO Index or MEI (enso_indices_mei.csv). The last of these aims to capture the joint variability of several aspects of the atmospheric and oceanic circulations. Calculate and print the cross-correlation matrix for these and the SST-based indices. Use seaborn to plot this cross-correlation matrix. Which of these indices do you think is most 'general' and why? Try to base your reasoning on data analysis. Does it match your expectation based on what you know about the indices and how they are calculated? Do you think this 'most general' index is also the most useful? Why or why not?

   (d) Add a categorical variable to your `DataFrame` that takes the value 'El Nino' when ONI > 0.5, 'La Nina' when ONI < -0.5, and 'Neutral' when $-0.5 \leq$ ONI ≤ 0.5. Calculate the mean of every column for the 'El Nino' category.

(e) Among ENSO's effects, perhaps the most far-reaching is its redistribution of tropical convection. As we will see later in the semester, the atmospheric heating associated with tropical convection drives many aspects of the global atmospheric circulation. The redistribution of tropical convection between the western tropical Pacific and the central tropical Pacific by ENSO variability thus modifies the global atmospheric circulation in a number of ways. Add a column to your `DataFrame` that represents the mean anomaly in outgoing longwave radiation along the equator between 160°E and 160°W (enso_indices_olr.csv). Note that the second file includes some missing data points that are indicated by the value '–99.9'. When you read in the file, make sure that these data are treated as missing. Check the documentation, remembering that pandas treats missing data as `NaN`. What is the correlation between ONI and the OLR anomaly? What are the average OLR anomalies for the 'El Nino' and 'La Nina' classes you created in part (d)? What do these results indicate about how convection changes in this part of the tropical Pacific under El Niño and La Niña?