Assignment: Module 3

Learning Goals

Subject knowledge:

- Weather regimes
- Link of weather regimes to surface weather conditions
- Circulation and soil moisture anomalies associated with droughts

Analysis skills:

- apply a simple running mean low-pass filter
- remove the seasonal cycle
- detrend data
- apply the K-mean cluster analysis to extract weather regimes
- construct composite means using multi-year daily data
- test the significance of the composite anomalies
- Understand how the sample size affects the composite analysis

Problems 1

We will identify weather regimes over North American in boreal winter using 500-hPa daily mean geopotential height (H500) data from the NCEP/NCAR reanalysis-II. Please take the following steps to extract weather regimes:

1) Read the daily data from Dec 1 to Feb 28 for each winter from 1979 Dec to 2021 Feb over the domain of (10–70N, 150–40W). Here the winter season is defined as Dec 1-Feb 28, and Feb 29 is neglected for a leap year.
2) Calculate the 5-day running means from Dec 3-Feb 26 for each winter. Note that no average is taken for the first two days and the last two days of each winter.
3) Remove the seasonal cycle by subtracting the long-term mean during 1979-2020 on a daily basis (i.e., for each calendar day from Dec 1 to Feb 28) and at each grid point.
4) Detrend the data on a daily basis (i.e., for each calendar day from Dec 1 to Feb 28) and at each grid point.
5) Set k=4 and apply the K-mean cluster analysis to H500
6) Construct and plot the composite mean H500 for each regime
7) Calculate the frequency of occurrence of each weather regime
8) Sort the weather regimes in the order of decreasing frequency of occurrence, and relabel the weather regimes
9) Save the weather regime label for each day in an output file

Input data (H500 from NNR2): /data/zhuowang/b/shared/NNR2/daily/hgt.YYYY.nc

Time period of analysis: Dec 1979-Feb 2021

Sample Script:
/data/zhuowang/a/zhuowang/ATMS521/Sample_Scripts/weather_regime_DJF_incomplete.py

Output: the daily weather regime labels; a figure showing the mean H500 for each weather regime; weather regime frequency

Hints: You can use the “KMeans” function:

https://scikit-learn.org/stable/modules/generated/sklearn.cluster.KMeans.html

Problems 2

In this problem we will examine the link of weather regimes to surface weather conditions by construct the composite anomalies of daily mean precipitation for each weather regime.

1) Read the daily data from Dec 1 to Feb 28 for each winter from 1979 Dec to 2021 Feb over the domain of (10–70N, 150–40W).
2) Calculate the daily anomalies by removing the seasonal cycle, which is defined as the long-term mean during 1979-2020 for each calendar day and at each grid point.
3) Read the daily weather regime label that you have saved from Problem #1
4) Construct the composite mean anomalies for each weather regime and perform a one-sample, two-sided t-test for the significance of the anomalies
5) Plot the composite mean anomalies for each regime and highlight the anomalies with the p-value no larger than 0.01.

Input data: Daily mean CPC precipitation

/data/zhuowang/b/zhuowang/Data/CPC_Global/precip.YYYY.nc, where YYYY the four-digit year. More information about the data source can be found at https://psl.noaa.gov/data/gridded/data.cpc.globalprecip.html

Time period of analysis: Dec 1979-Feb 2021

Output: plots of precipitation composite anomalies

(Hints: 1) Please note that the CPC precipitation data are undefined over ocean. In some python functions you need to pay attention to how missing data should be handled; 2) see t-test at https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.ttest_1samp.html)

Problems 3

Repeat the calculations in Problem #2 for the daily minimum temperature (Tmin)

Input data: Daily mean CPC minimum temperature

/data/zhuowang/b/zhuowang/Data/CPC_Global/tmin.YYYY.nc, where YYYY the four-digit year.

Time period of analysis: Dec 1979-Feb 2021

Output: plots of Tmin composite anomalies

Problems 4

SPI is a commonly used index for meteorological droughts. In this problem we will examine the atmospheric circulation and soil moisture anomalies associated with the droughts over the US Great Plains. Please do the following:

1) read the monthly mean SPI data at the three-month scale ("spi3" in the file) during June-August (JJA) 1979-2012, and create a time series of the SPI index by averaging the SPI over (32-45°N, 105-85°W). Your monthly mean time series should have the length of 102 (=34 years *3 months).

2) Calculate the monthly mean anomalies of 500-hPa geopotential height (H500) with respect to the long-term mean over 1979-2012 for each calendar month (i.e., June, July and Aug).

3) Construct the composite anomalies of H500 for the months when SPI<=-0.75, and test the significance of the anomalies using one-sample, two-sided t-test. Plot the composite anomalies of H500 with the significant anomalies outlined.

4) Repeat the calculations in 4.2) for 0-10 cm soil moisture.

5) Briefly discuss how the atmospheric circulation anomalies and soil moisture anomalies are connected to the drought conditions over the Great Plains.

6) Please repeat the calculations in 4.2 with a different threshold SPI<=-1.0. How do you results here differ from those in 4.2)? How do you explain the differences?

[When the threshold SPI<=-1.0 is used, the sample size is reduced from 10 to 4. The signals are stronger but less areas exceed the significance level]

Input data:

/data/zhuowang/b/zhuowang/Data/SPI/spi3_6_12_1deg_cru_ts_3_21_1949_2012.nc

/data/zhuowang/b/shared/NNR2/monthly/hgt.mon.mean.nc

/data/zhuowang/b/shared/NNR2/monthly/soilw.0-10cm.mon.mean.nc

More information about the SPI data can be found at https://rda.ucar.edu/datasets/ds298.0/

Time period of analysis: 1979-2012

Output: plot of H500 composite anomalies; plot of soil moisture composite anomalies