Teleconnection

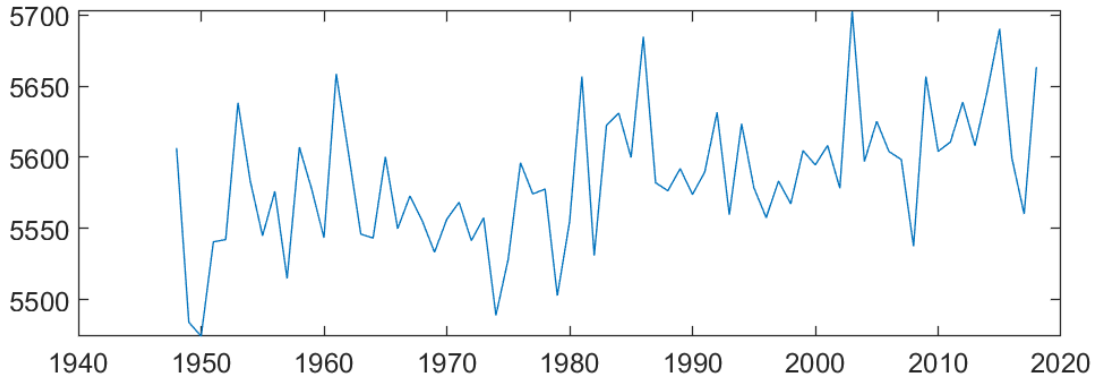
a causal connection or correlation between meteorological or other environmental phenomena that occur a long distance apart

http://www.cpc.ncep.noaa.gov/data/teledoc/teleintro.shtml

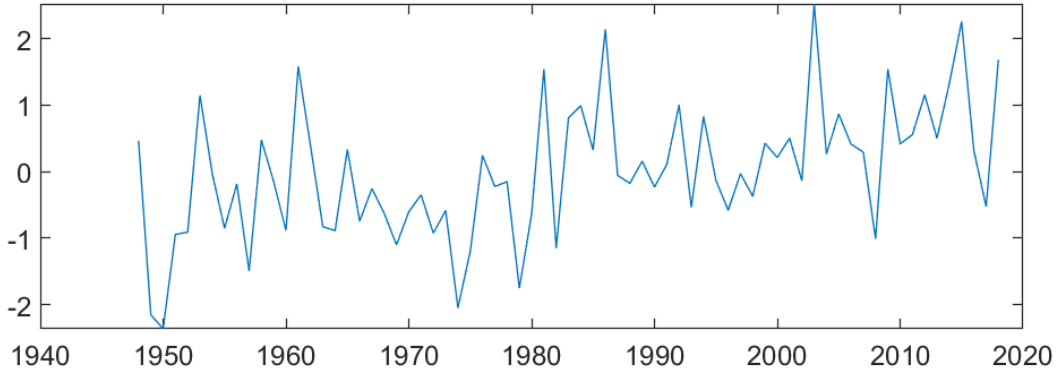
Teleconnections: “the study of blobs”

January SLC 500 hPa time series

hPa



Std anom



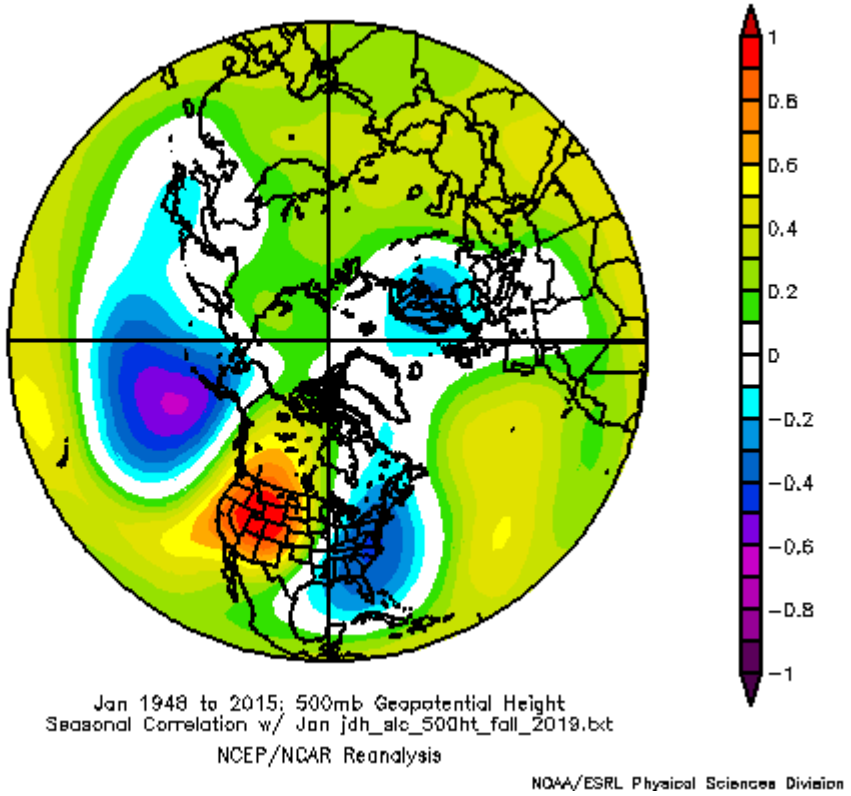
Correlate 500 hPa heights over SLC with every other point in NH: a teleconnection map

- Create a time series for SLC: location 42.5 40.0 247.5 250. 500 mb

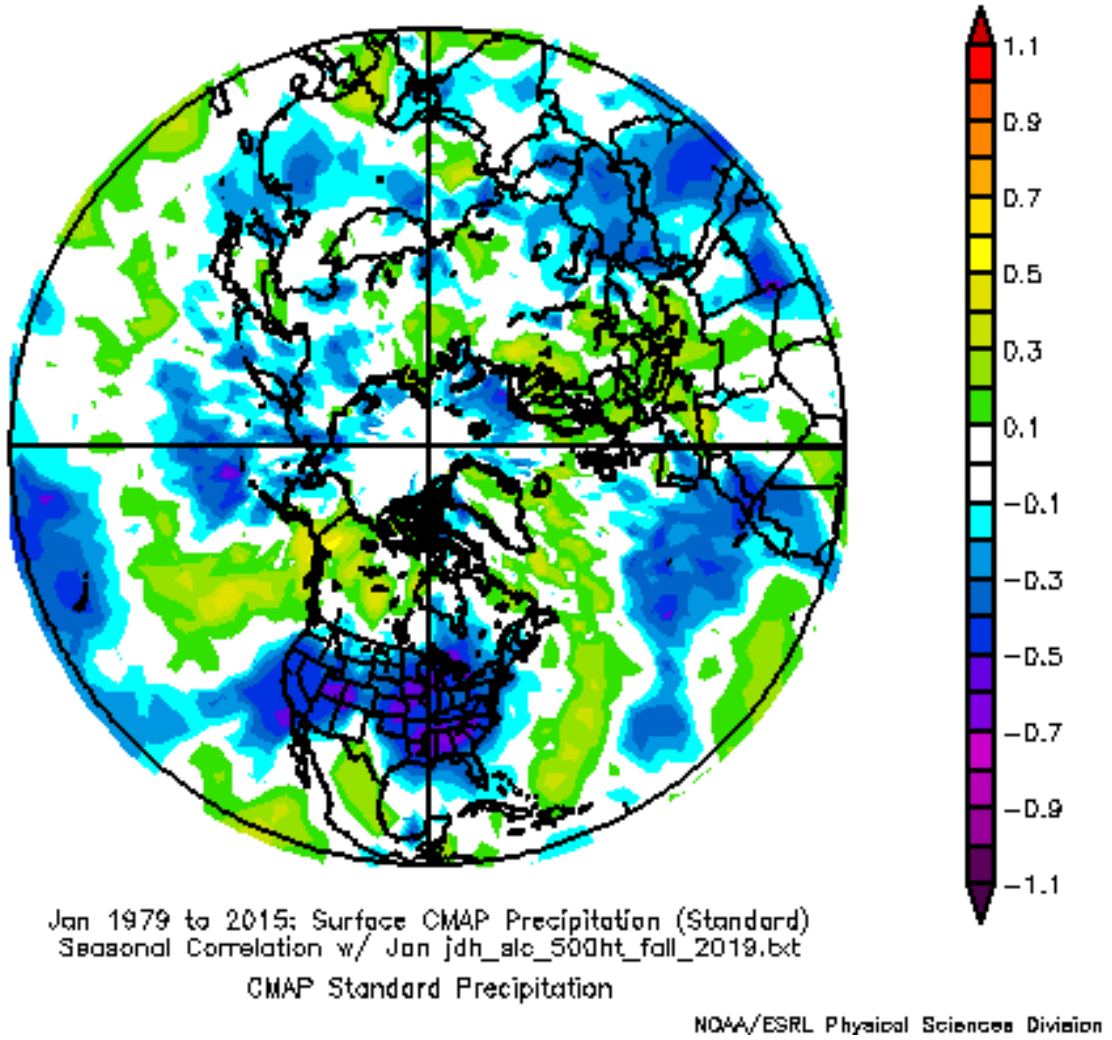
https://www.esrl.noaa.gov/psd/data/correlation/

/Public/incoming/timeseries/jdh_slc_500ht_fall2019.txt

- Create plot



Correlation between 500 hPa SLC time series and precipitation in the Northern Hemisphere

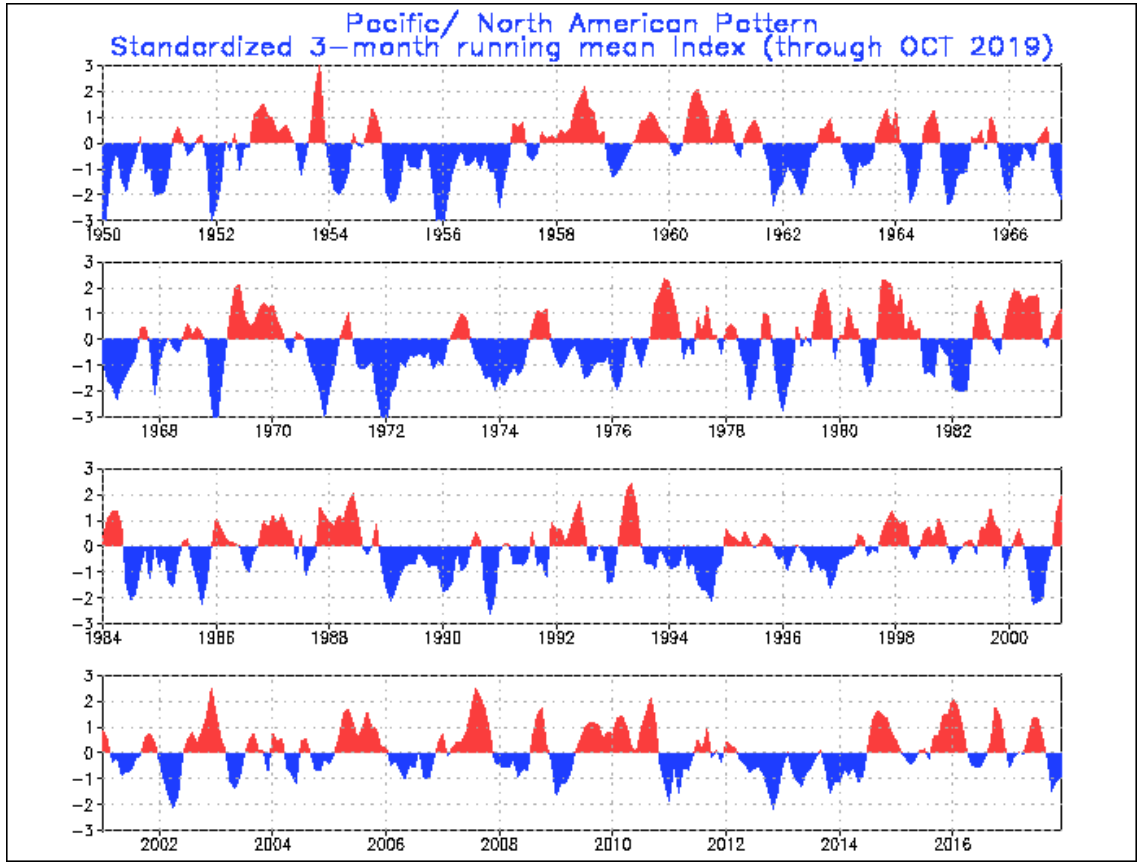


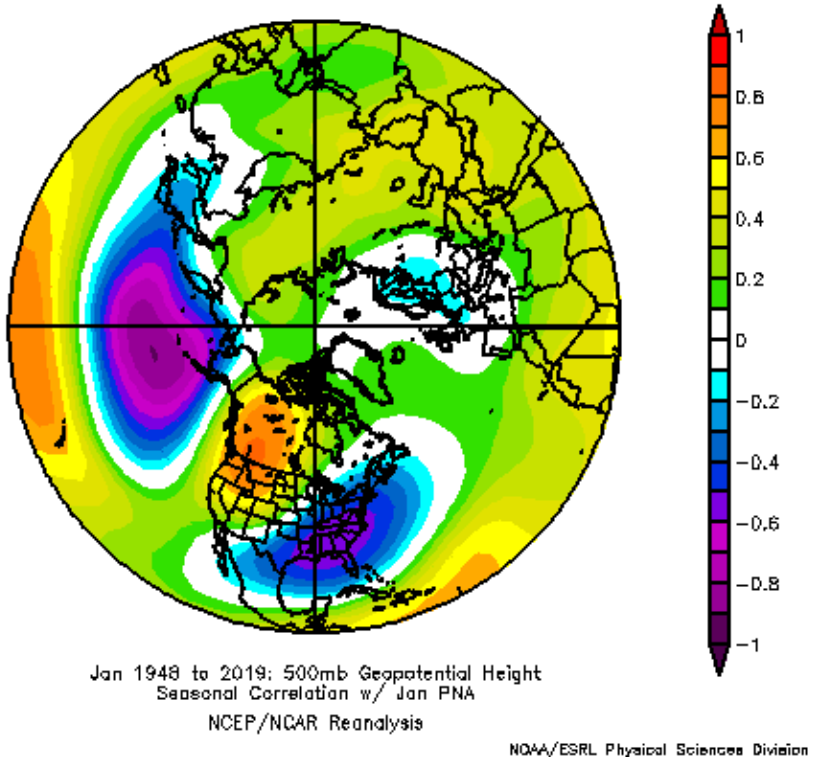
Near SLC
When 500 hPa heights above normal, then precipitation below normal
When 500 hPa height below normal, then precipitiation above normal

What about elsewhere?

PNA Teleconnection Pattern

PNA: https://www.esrl.noaa.gov/psd/data/correlation/

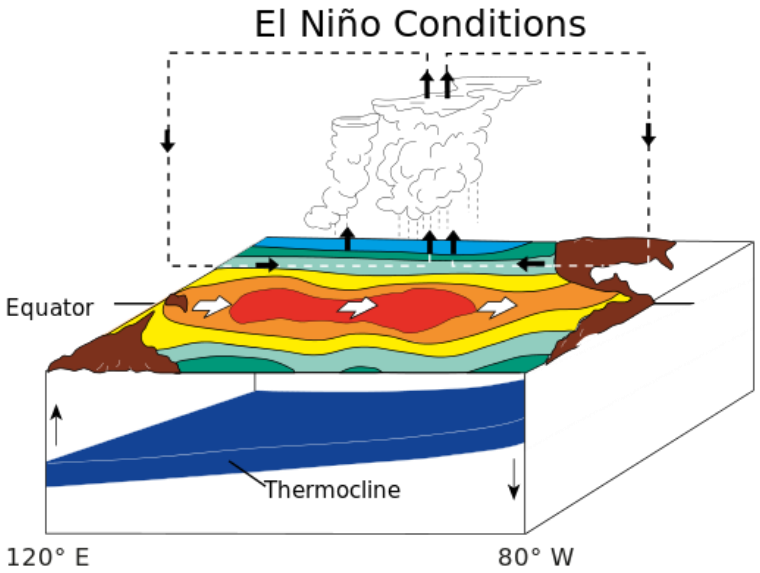


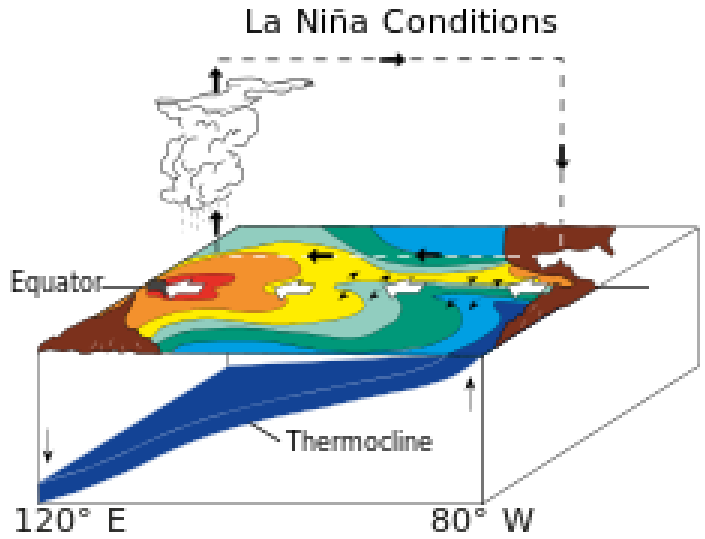


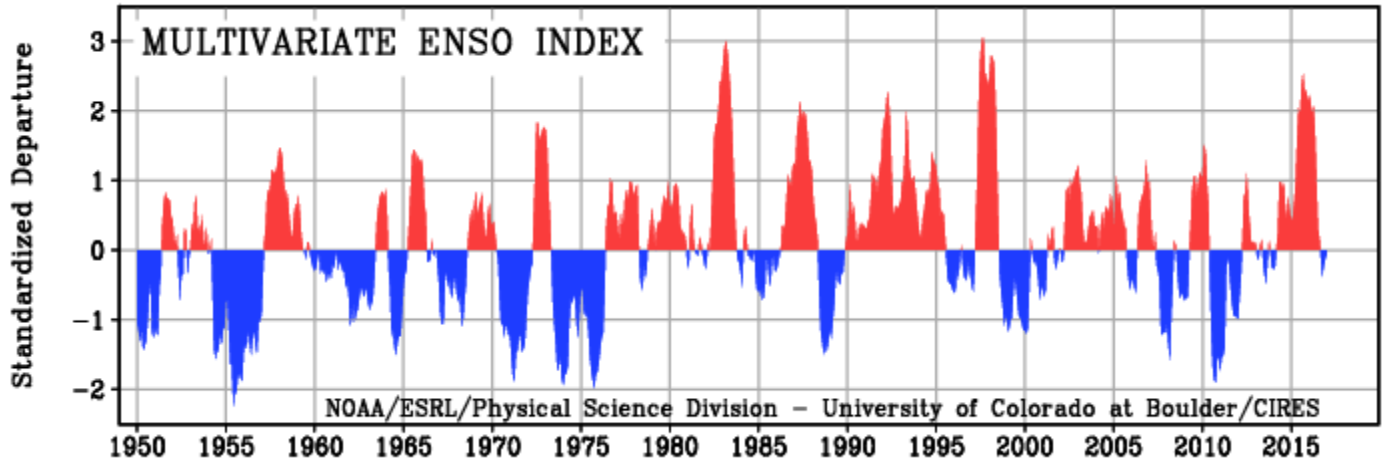
Pacific North American teleconnection

http://www.cpc.ncep.noaa.gov/data/teledoc/pna.shtml

ENSO Teleconnections







Correlation

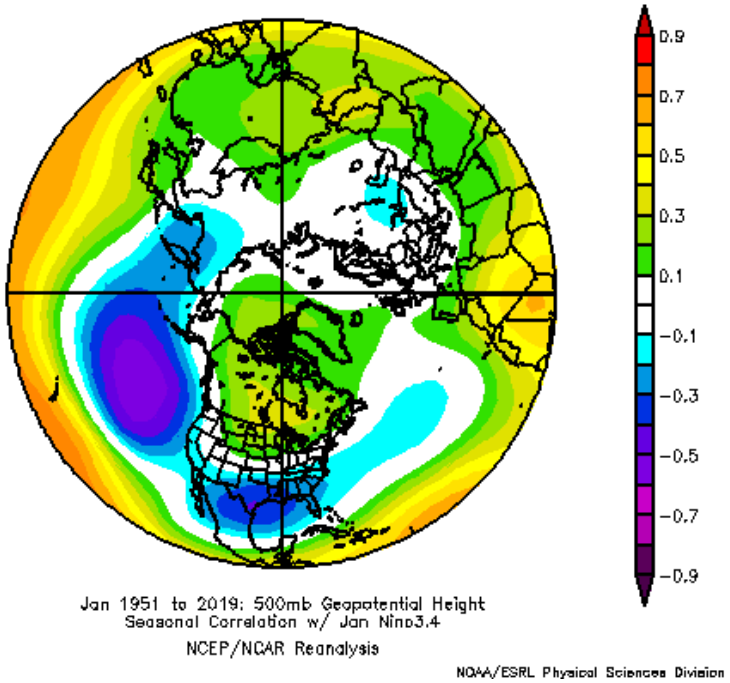


Figure 4.9a. Correlation between the equatorial Pacific SST index during January from 1951-2019 with 500 mb height anomalies in the Northern Hemisphere.

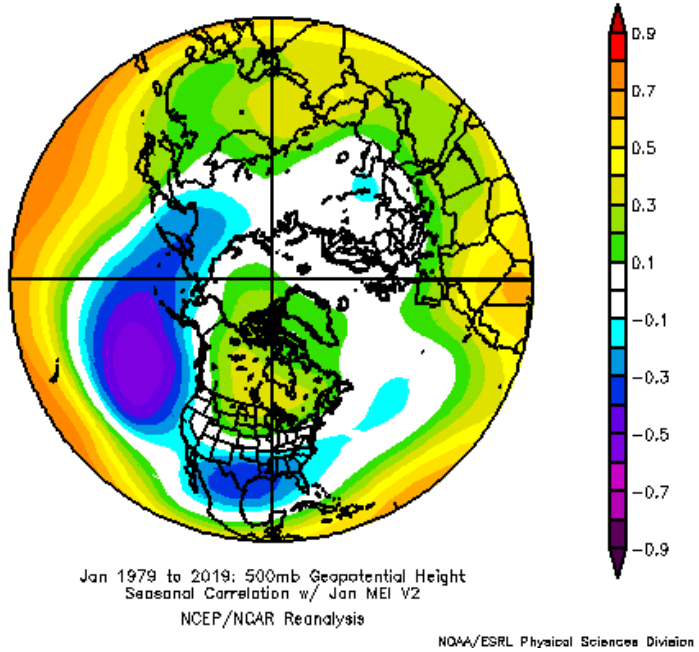


Figure 4.9b. Correlation between the equatorial Pacific SST MEI index during January from 1979-2019 with 500 mb height anomalies in the Northern Hemisphere.

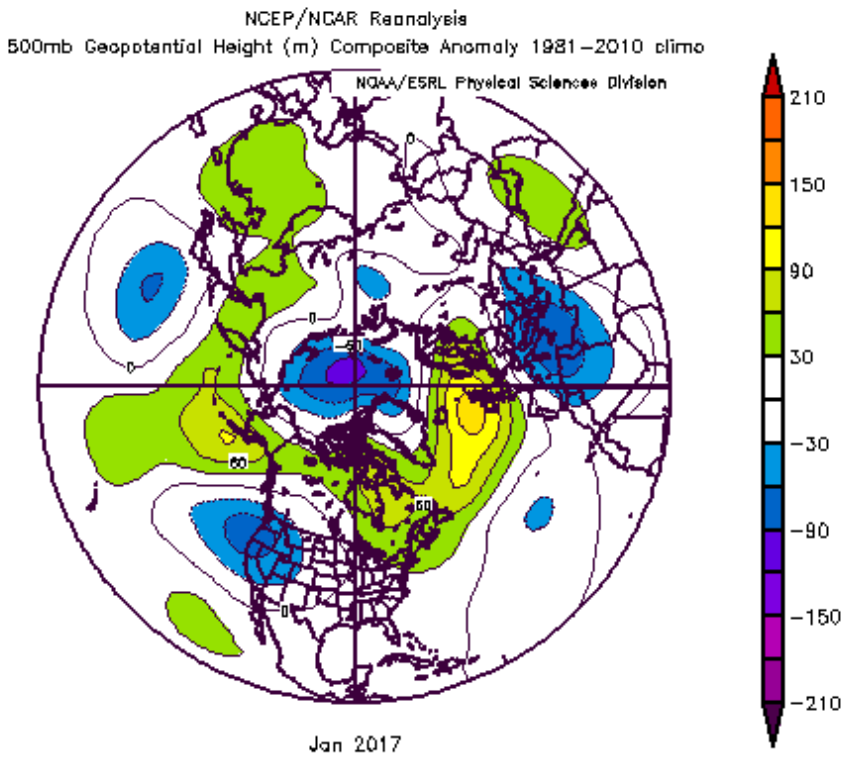
Correlating Maps Rather Than Time Series

$$\hat{\vec{X}} = \begin{bmatrix} \hat{x}_{1,1} & \hat{x}_{1,2} & \cdots & \hat{x}_{1,n} \\ \hat{x}_{2,1} & \hat{x}_{2,2} & \cdots & \hat{x}_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ \hat{x}_{m,1} & \hat{x}_{m,2} & \cdots & \hat{x}_{m,n} \end{bmatrix}$$

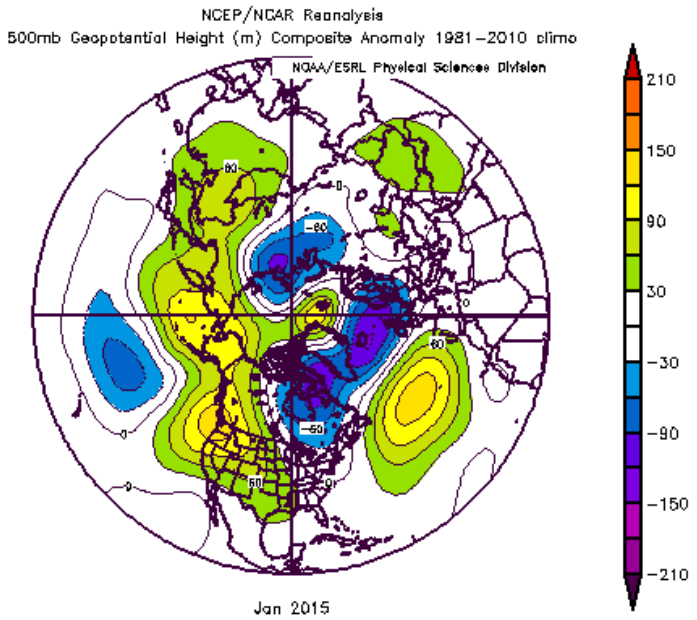
- Comparing variability over m locations at one time to the variability in all of the other n times

$$\vec{S} = \hat{\vec{X}} *^{T} \hat{\vec{X}} * \ / m$$

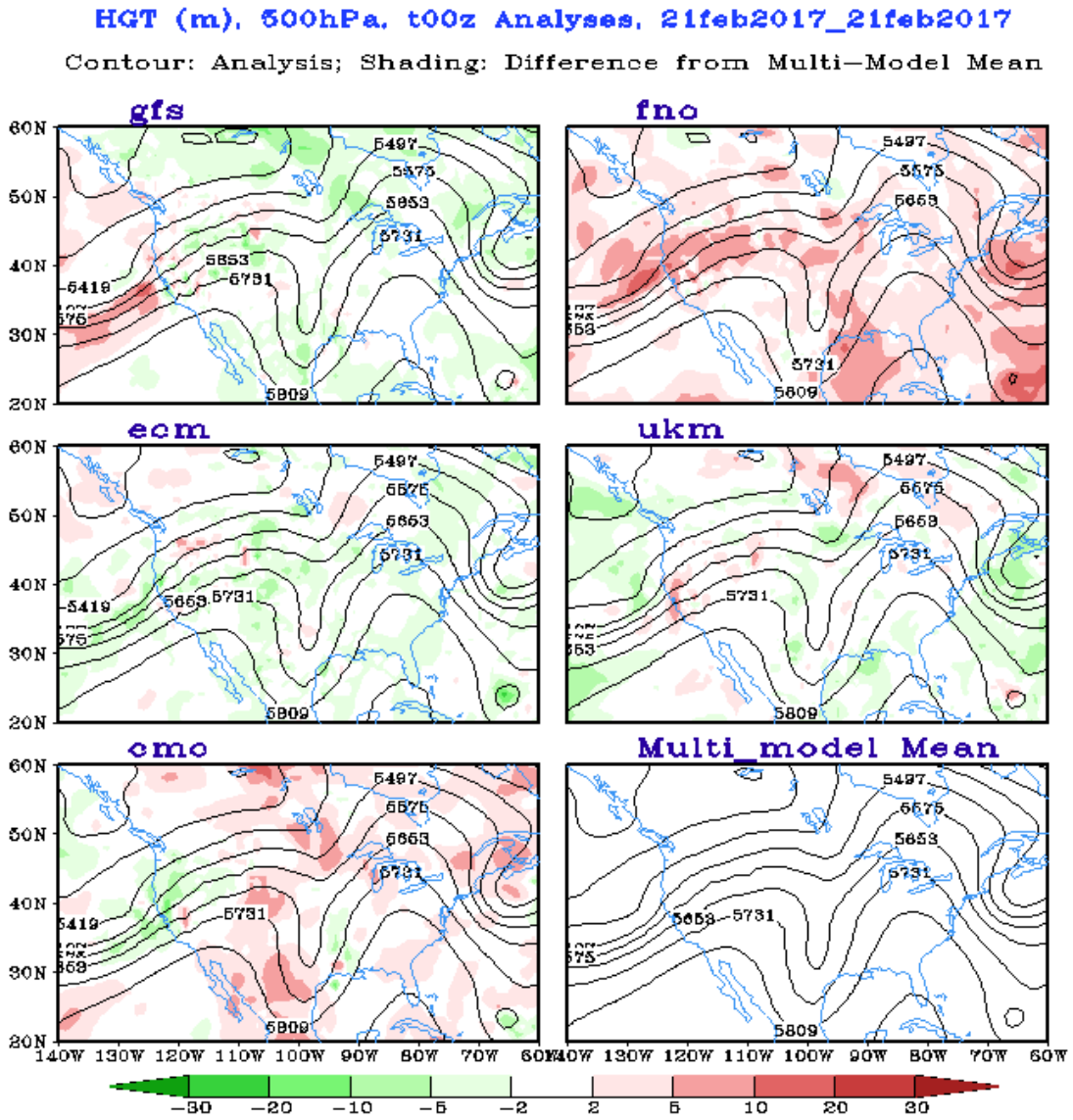
How similar are these two anomaly maps?



JAN 2017

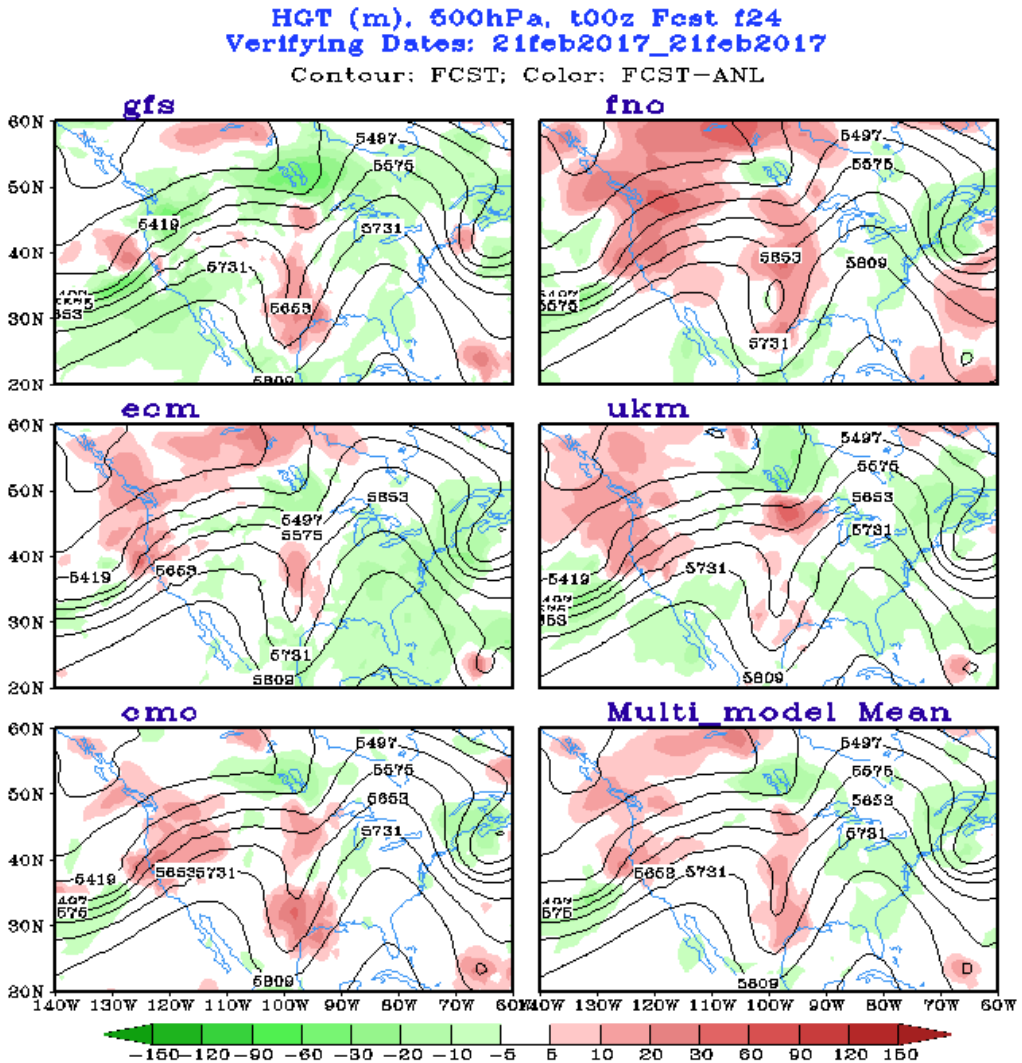


Jan 2015



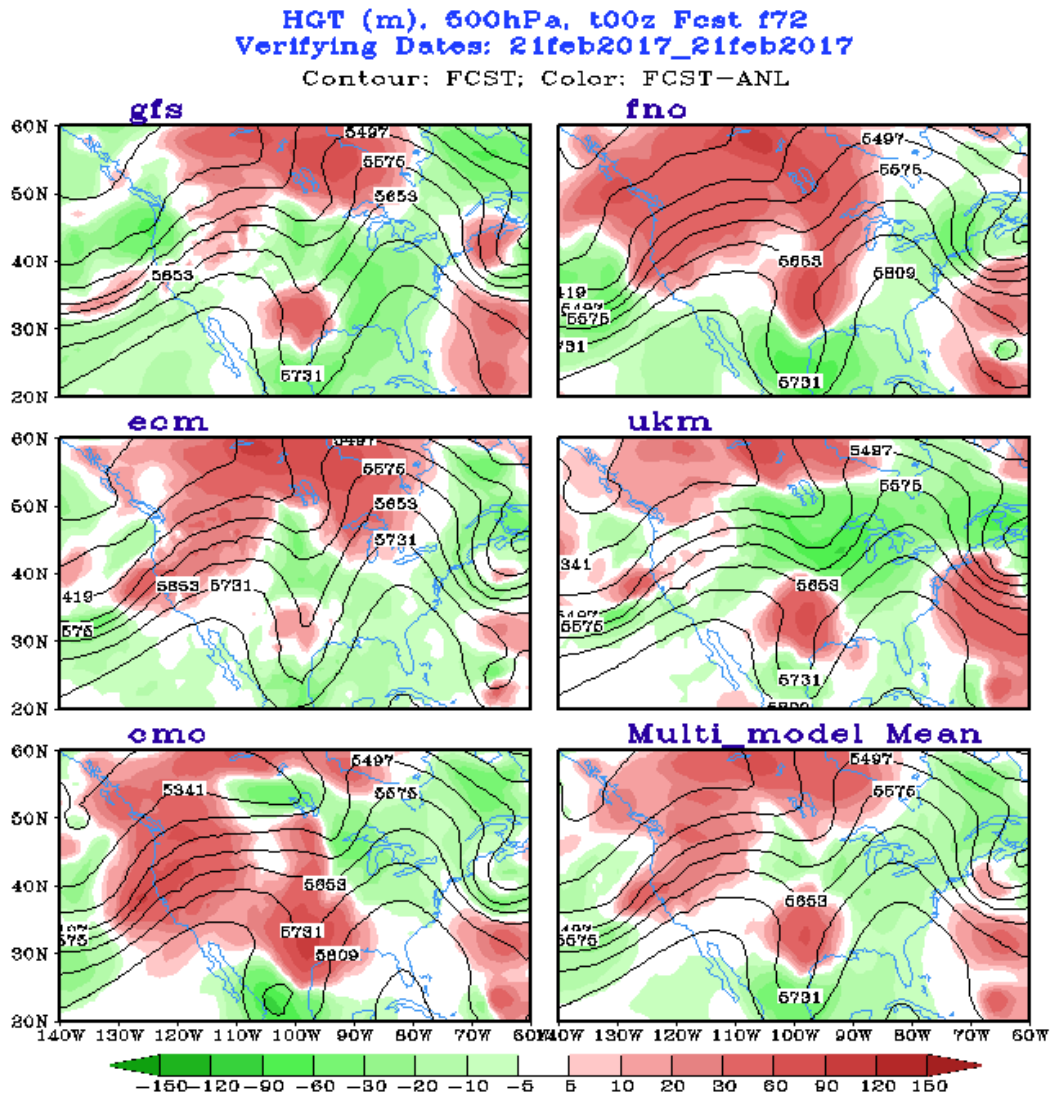
Compare analyses

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/



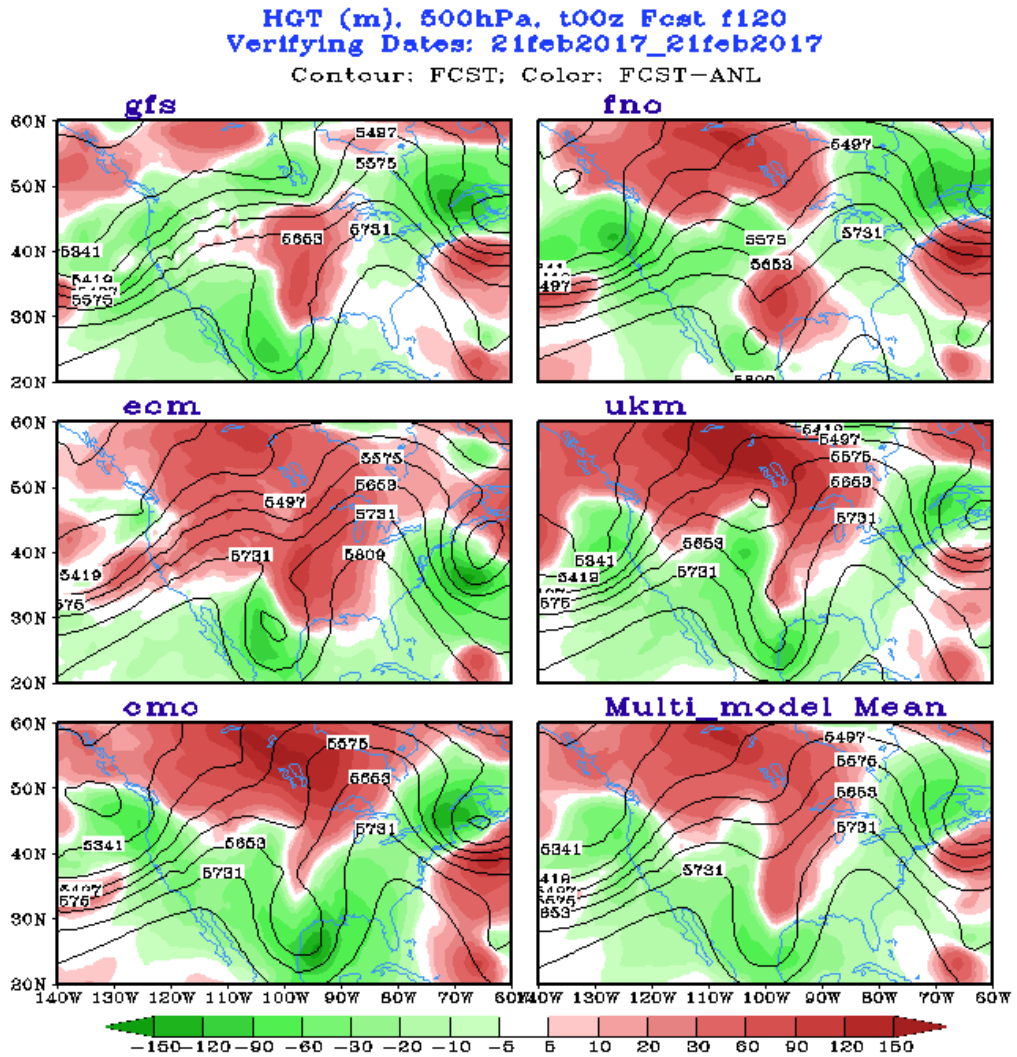
Verify 24 h Forecasts

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/



Verify 72 h Forecasts

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/

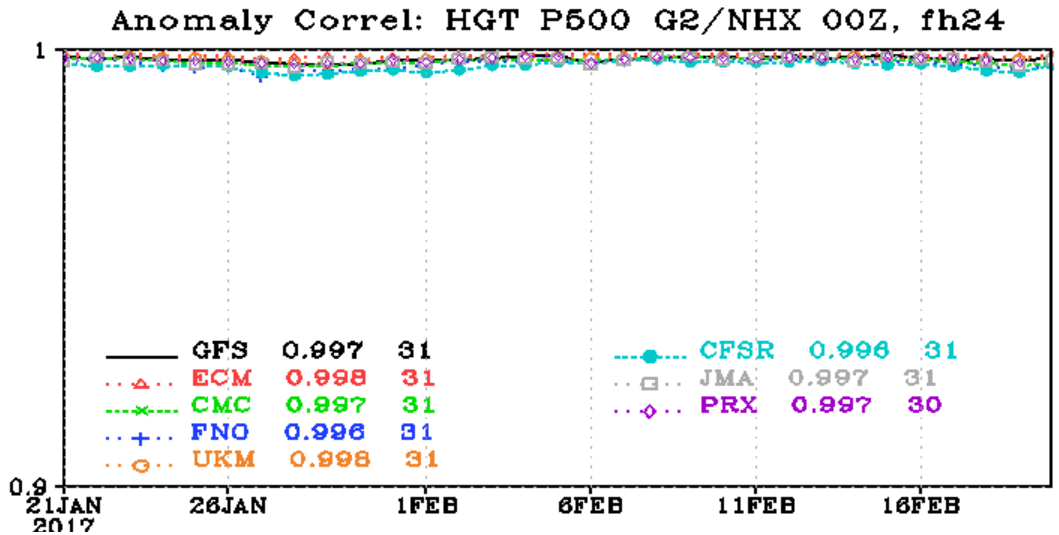


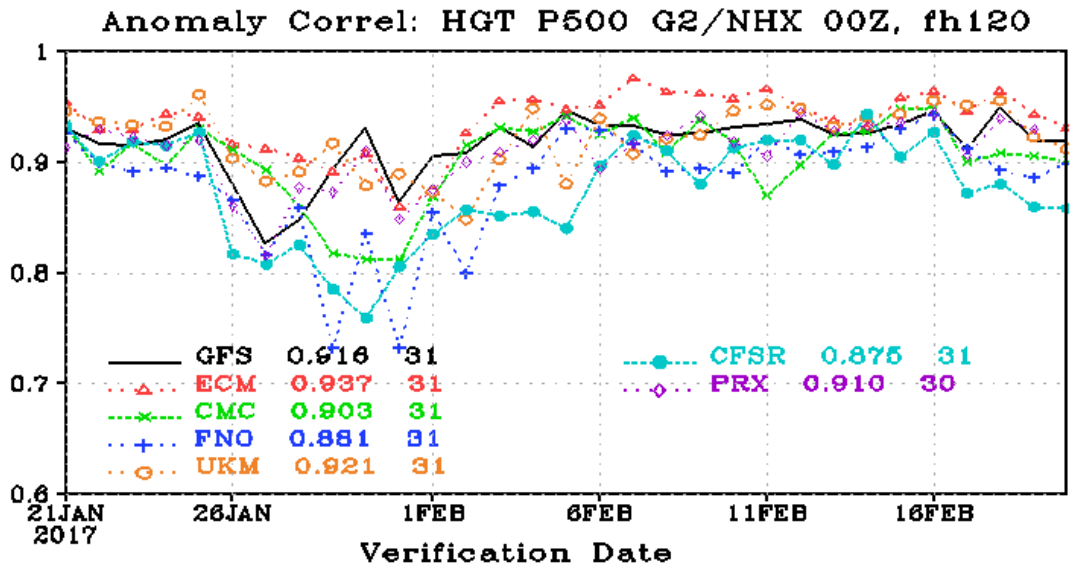
Verify 120 h Forecasts

http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/

Verifying Forecast Anomaly Maps

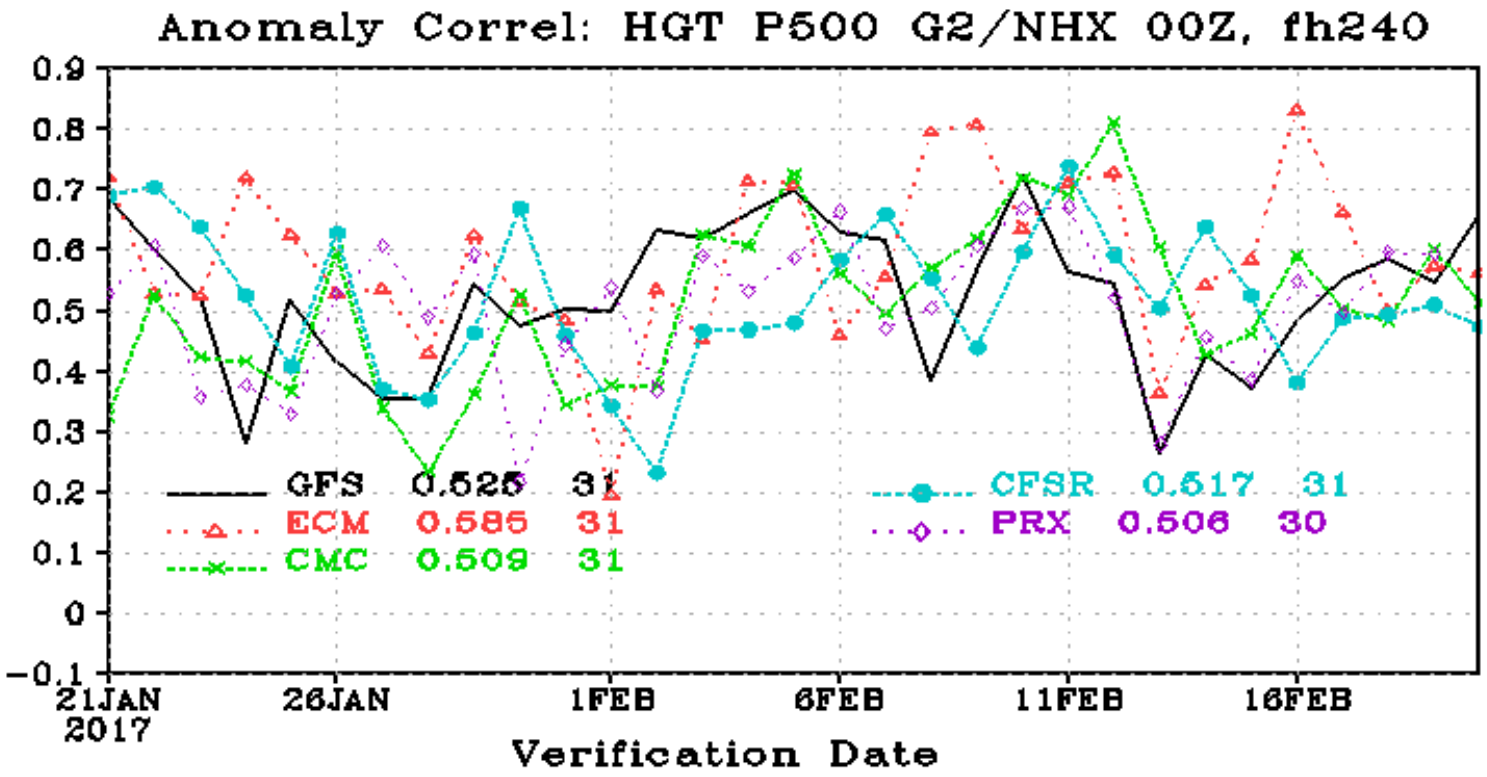
http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/



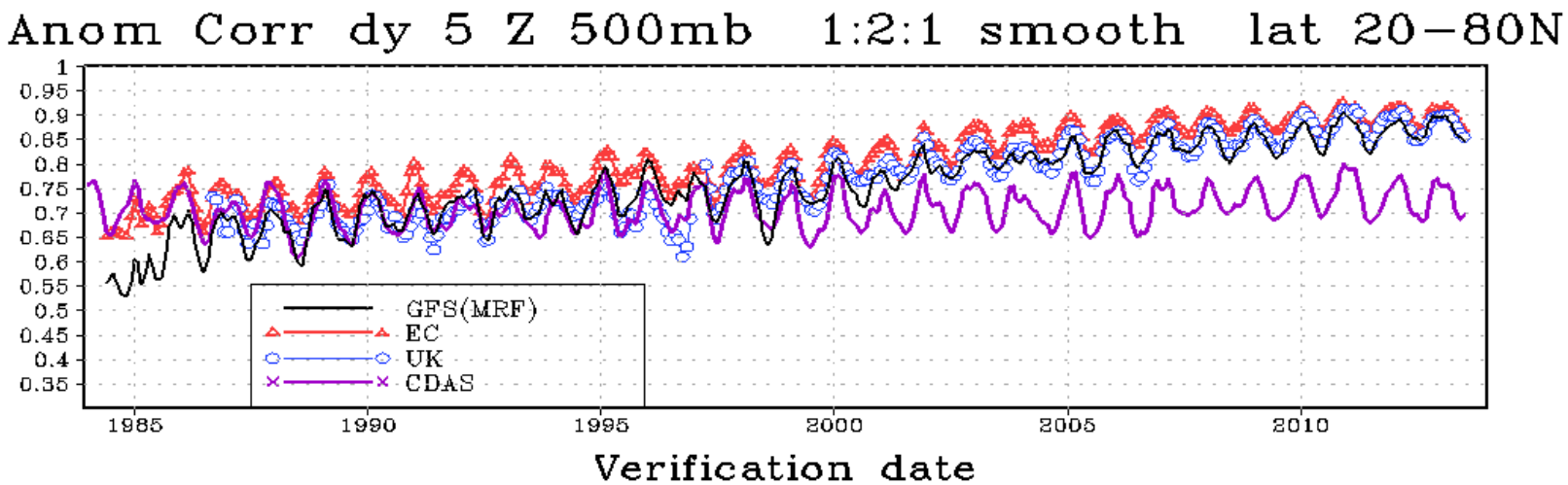


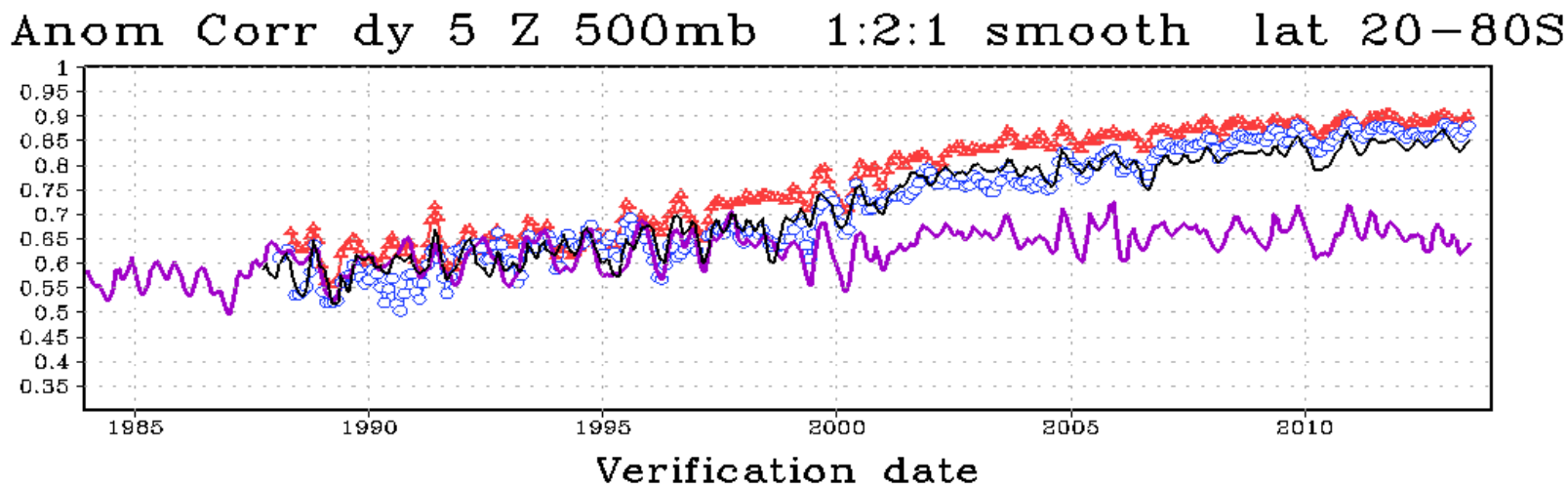
Verifying Forecast Anomaly Maps

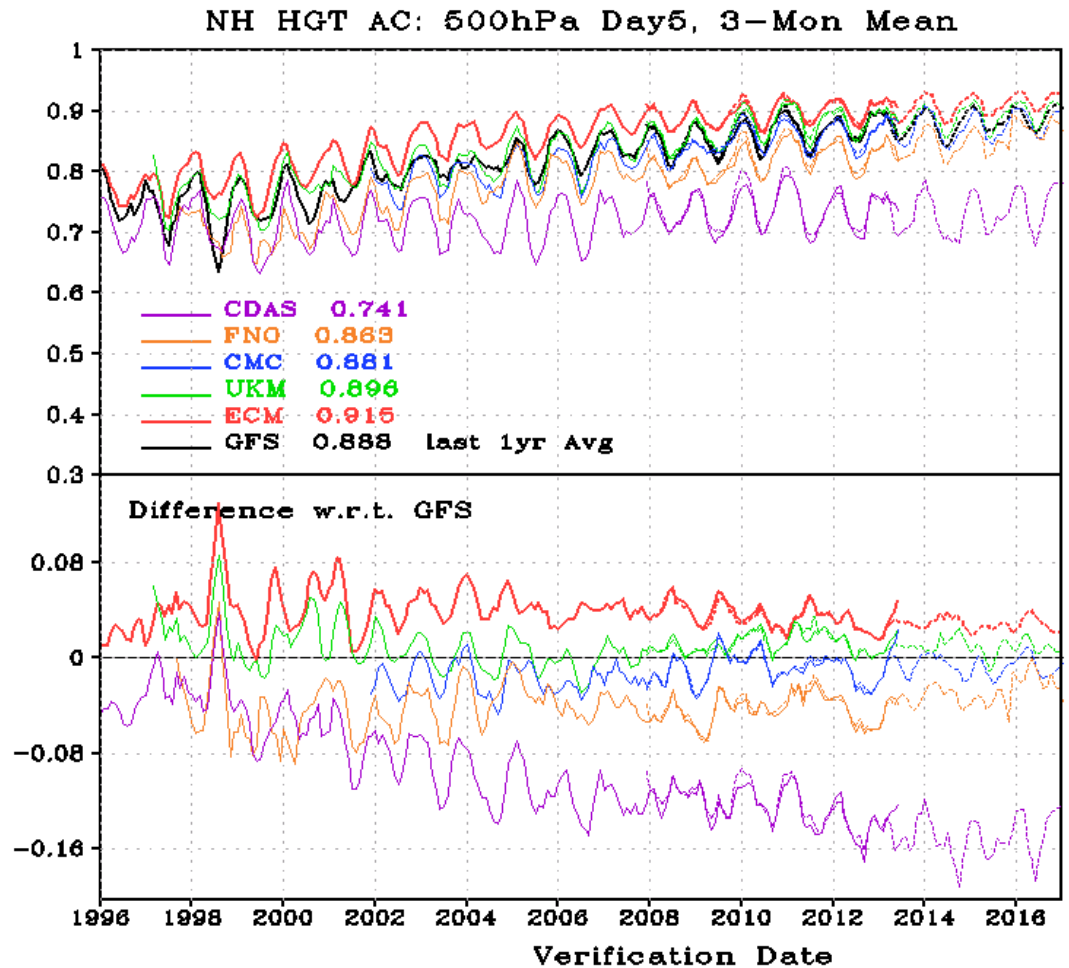
http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/



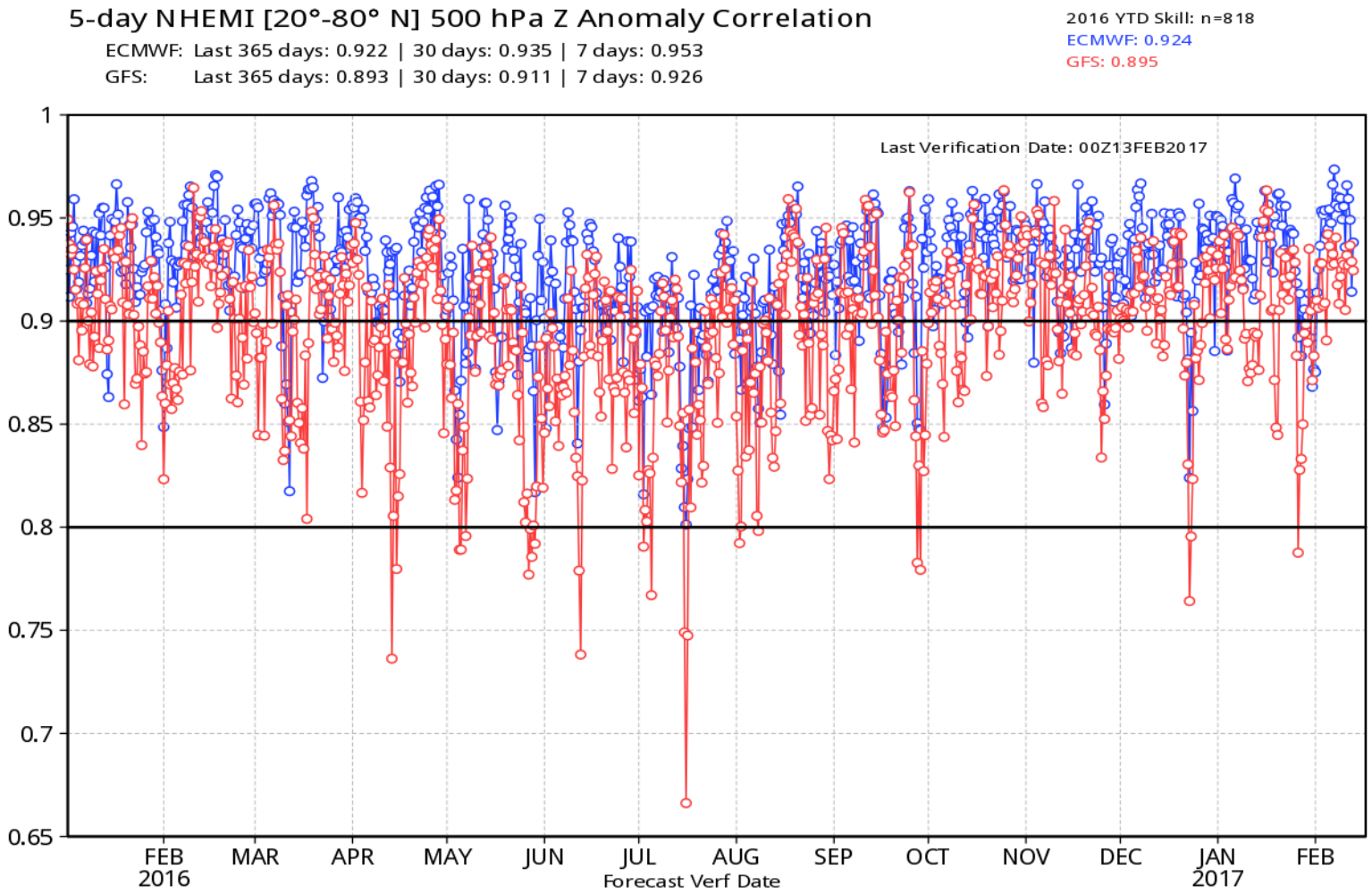
Comparing Forecast Anomaly Maps to Analyses






NH HGT AC: 500hPa Day5, 3-Mon Mean
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
CDAS 0.741
FNO 0.869
CMC 0.881
UKM 0.896
ECM 0.915
GFS 0.888 last 1yr Avg
Difference w.r.t. GFS
0.08
0
-0.08
-0.16
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Verification Date

Daily Showing Drop Offs

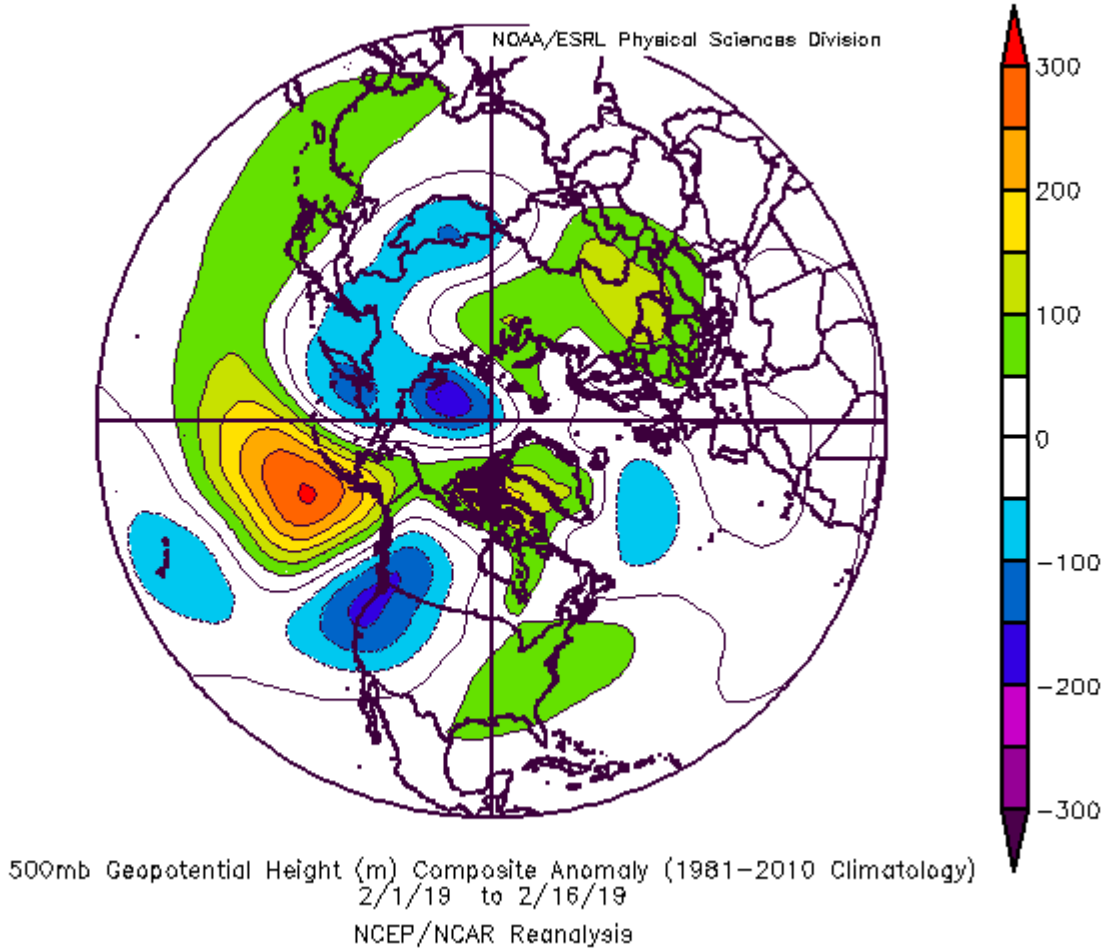


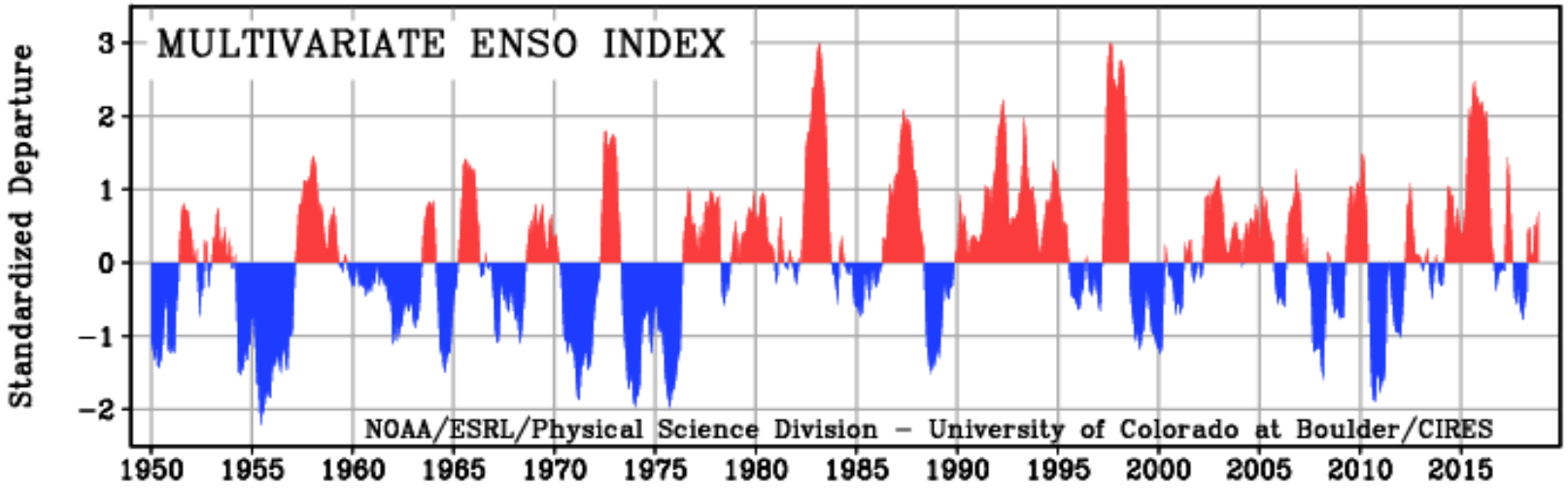
Compositing (Superposed Epoch)

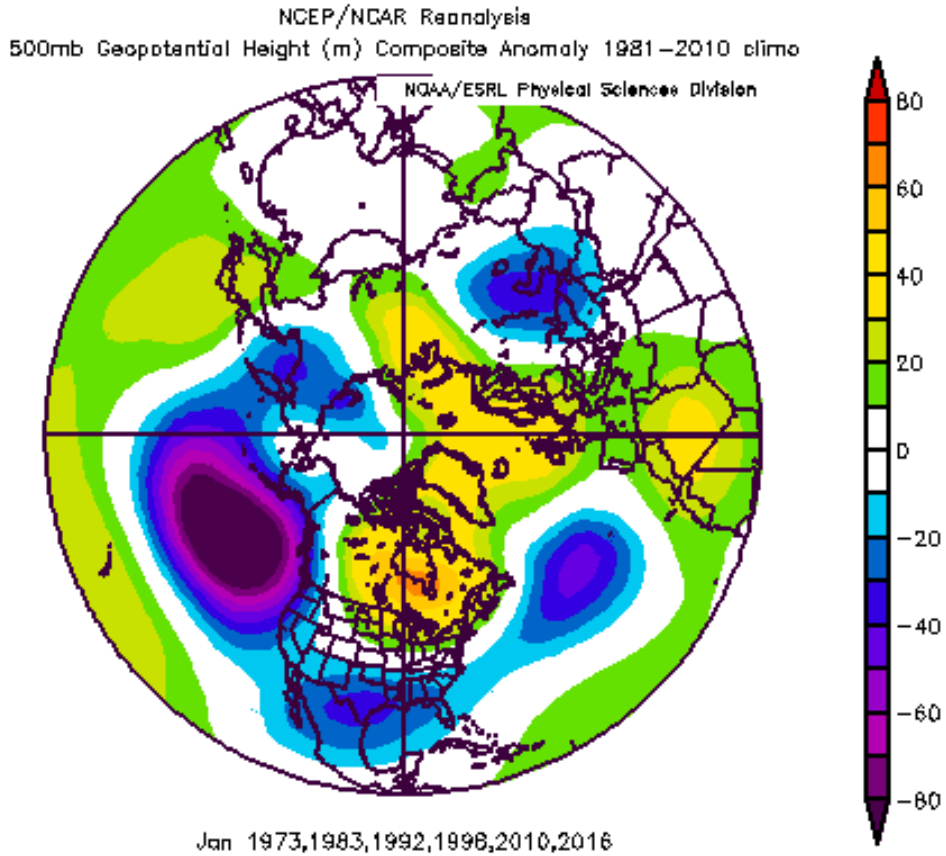
- Identify common characteristics of a sample of events
- Simplest- average conditions before, during, and after some “rare” event
- Has an advantage over linear correlation since no linear assumption necessary
- Limitation- to what extent does sample mean used in composite differ from population?
- Day composites: https://www.esrl.noaa.gov/psd/data/composites/day
- Monthly/seasonal composites:
- https://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl

Composite 500 hPa height anomaly over the first 16 days

Plot link




MULTIVARIATE ENSO INDEX
Standardized Departure
3
2
1
0
−1
−2
NOAA/ESRL/Physical Science Division – University of Colorado at Boulder/CIRES
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015

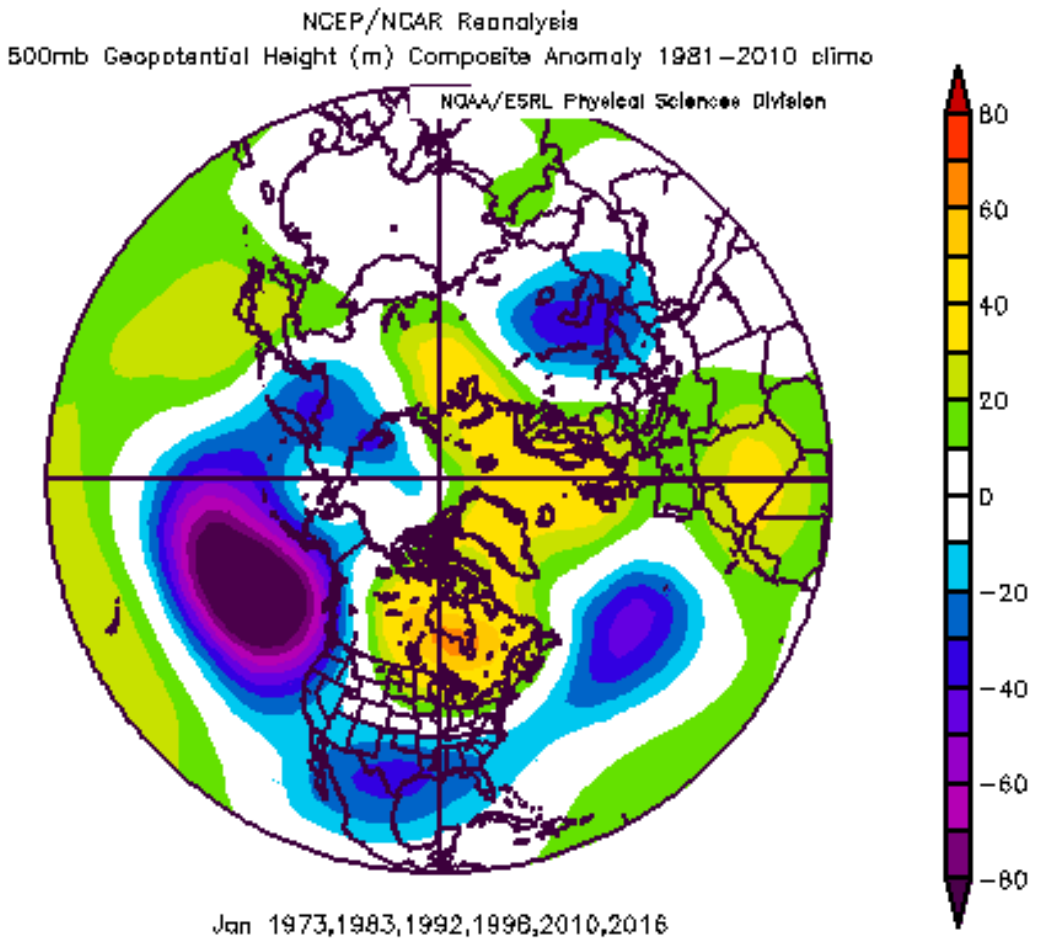

NCEP/NCAR Reanalysis
500mb Geopotential Height (m) Composite Anomaly 1981–2010 clima
NOAA/ESRL Physical Sciences Division
80
60
40
20
0
−20
−40
−60
−80
Jan 1973,1983,1992,1998,2010,2016

Compositing Steps

- Select the basis for compositing: why are you doing it? Physical reasoning hopefully?
- Define the categories on which you define the events: above, below normal? Or …?
- Compute the means and statistics for each category (minimum is standard deviation)
- Organize and display the results
- Validate the results:
  - Significance test? t test is the bare minimum to do
  - Reproduce in an independent sample?
  - Are the results sensible in space and time?
  - Is it consistent with theory?

How many spatial degrees of freedom?

- Count the anomaly blobs



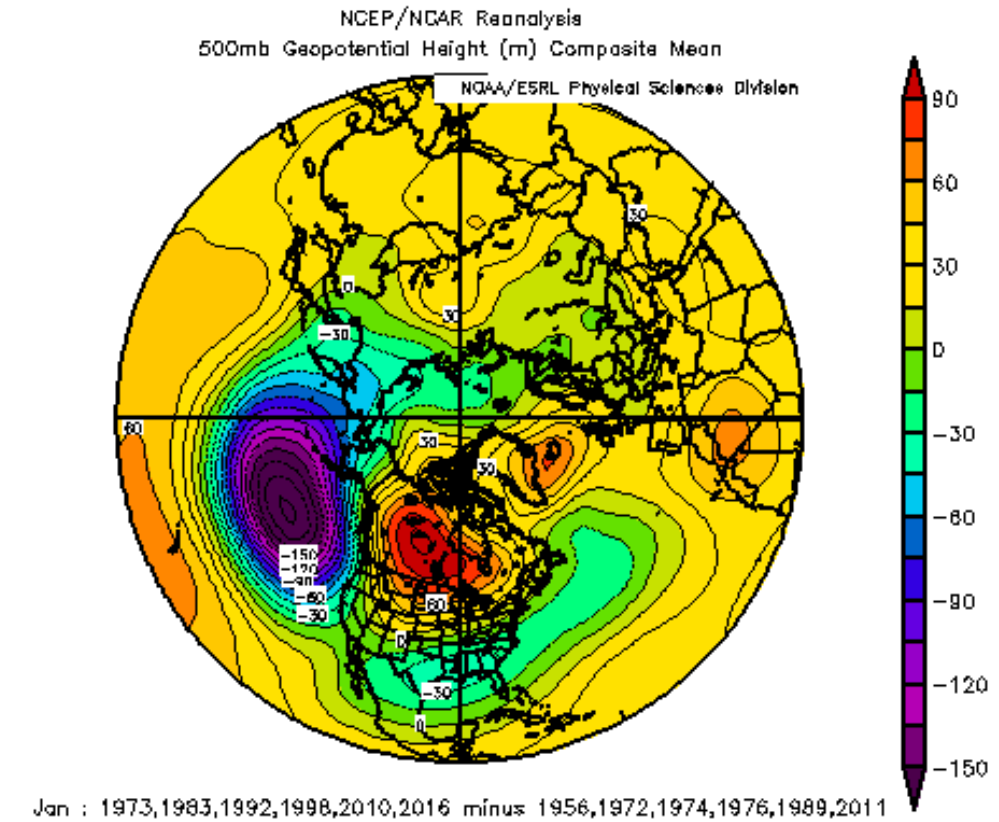
Don’t overdo it…

- Was there a reason a priori to expect the relationship?
- How arbitrary was the choice for defining the composites?
- How subjective and biased was your analysis? Did you tweak your approach to get better results?
- Do the results make sense?
- Are there simpler explanations possible?

Composite Difference Between Two Samples

- High MEI January's vs. Low MEI January's

Create plot



Significance test of difference between two sample means

- common compositing approach is to contrast circulation features associated with two extremes of an index: wet (dry) years in Utah precipitation or El Nino/La Nina seasons.
- Sample means can be computed from the same population or completely different batches of data
- An appropriate null hypothesis is that the population means are the same.
- 2-tailed test IF looking at both positive and negative differences.
- $t = (\bar{x}_1 - \bar{x}_2) / \sqrt{(n_1 s_1^{\ 2} + n_2 s_2^{\ 2})(1/n_1 + 1/n_2)/(n_1 + n_2 - 2)}$
- Signal is the difference between the two sample means with degrees of freedom n_1 and n_2,
- s_1 and s_2 are sample standard deviations.

Wilks (2016 BAMS)

- Computation of a single hypothesis test involves defining a null hypothesis H_0, which will be rejected in favor of an alternative hypothesis H_A if a sufficiently extreme value of the test statistic is observed
- Rejection of H_0 at a test level α occurs if the test statistic is sufficiently extreme that the probability- p value- of observing it or any other outcome even less favorable to H_0, if that null hypothesis is true, is no larger than α.
- If H_0 is rejected with α = 0.05 (the most common, although an arbitrary choice), the result is said to be significant at the 5% level

Wilks (2016 BAMS)

- Most people assume that if N hypothesis tests (for example, each point on a map) then will have on average, α N erroneous rejections of the null hypothesis
- Instead use False Discovery Rate (FDR)
  - Sort in ascending order p_i values from $i = 1, \ldots, N$ hypothesis tests such that $p_1 \leq p_2 \leq \ldots \leq p_N$.
  - Local null hypothesis is rejected if its p_i value is no larger than a threshold level p_{FDR} that depends on the distribution of the sorted p values:
  - $p_i \leq 2 \alpha i / N$
- Run fdr.m

Assignments: wrapping things up

- Read Chapter 4 notes
- Complete linear correlation assignment
- Complete composite assignment
- Online final posted

False Discovery Rate

Conservative way to estimate

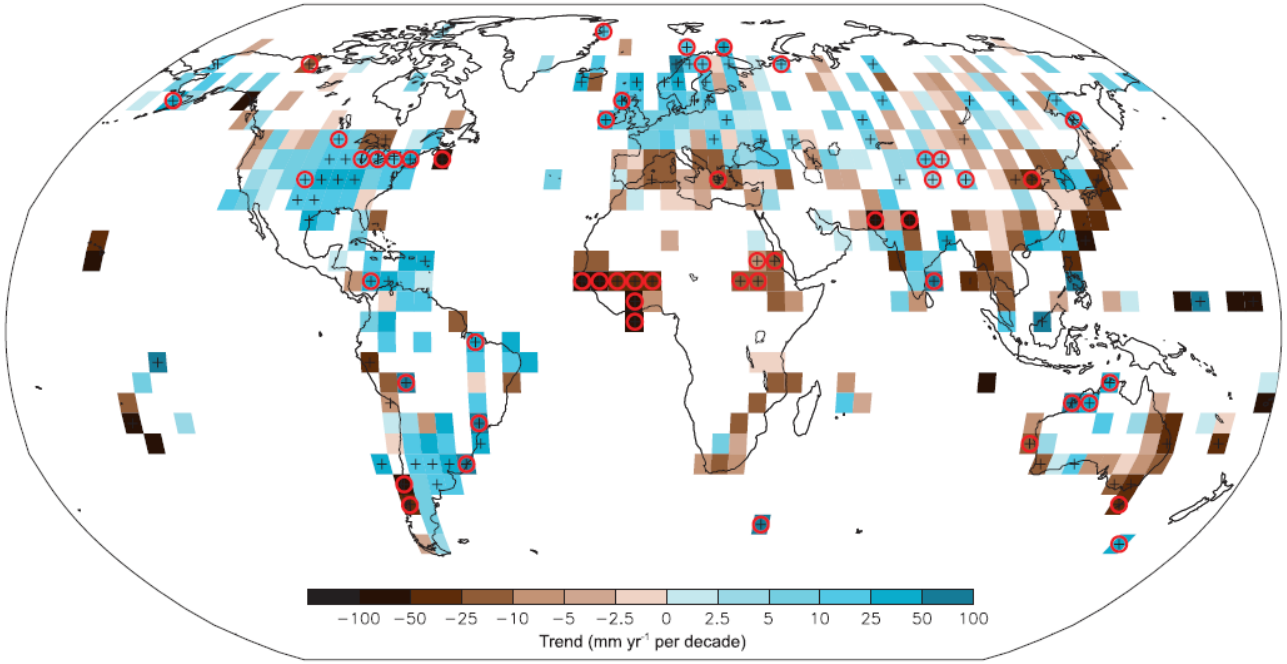


FIG. 7. Linear trends in annual precipitation during 1951–2010, based on data from the Global Historical Climatology Network (Vose et al. 1992). Grid elements with linear trends exhibiting local statistical significance at the $\alpha = 0.10$ level are been indicated by the plus signs, and those with p values small enough to satisfy the FDR criterion with $\alpha_{FDR} = 0.10$ [Eq. (3)] are indicated by the red circles. The figure has been modified from Hartmann et al. (2013, p. 203).

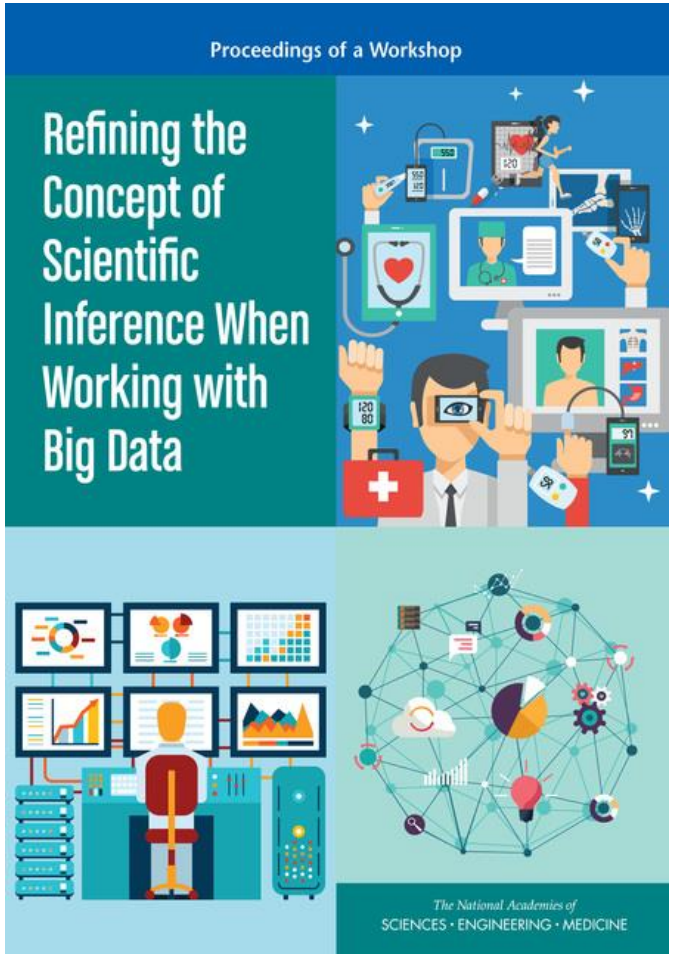
Course Learning Objectives

- State and use basic statistical metrics to analyze environmental information
- Develop proficiency to analyze environmental data sets
- State and demonstrate the characteristics of effective research; organize, quality control, and find relationship(s) among data

- **So…?**

You’ve been given weapons…

How are you going to use them?



June 2016

Scientific Inference

(1) big data holds both great promise and perils

(2) inference requires evaluating uncertainty

(3) statisticians must engage early in experimental design and data collection activities

(4) open research questions can propel both the domain sciences and the field of statistics forward

(5) Opportunities exist to strengthen statistics education at all levels

Tellus 1960

The Concentration and Isotopic Abundances of Carbon Dioxide in the Atmosphere

By CHARLES D. KEELING, Scripps Institution of Oceanography, University of California, La Jolla, California

(Manuscript received March 25, 1960)

Abstract

A systematic variation with season and latitude in the concentration and isotopic abundance of atmospheric carbon dioxide has been found in the northern hemisphere. In Antarctica, however, a small but persistent increase in concentration has been found. Possible causes for these variations are discussed.

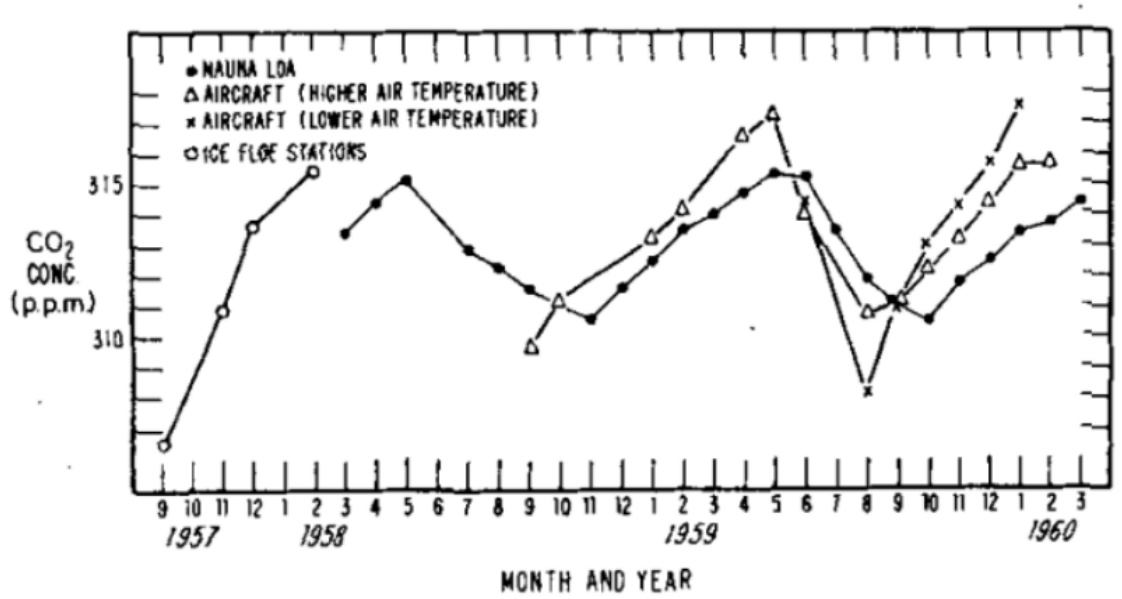
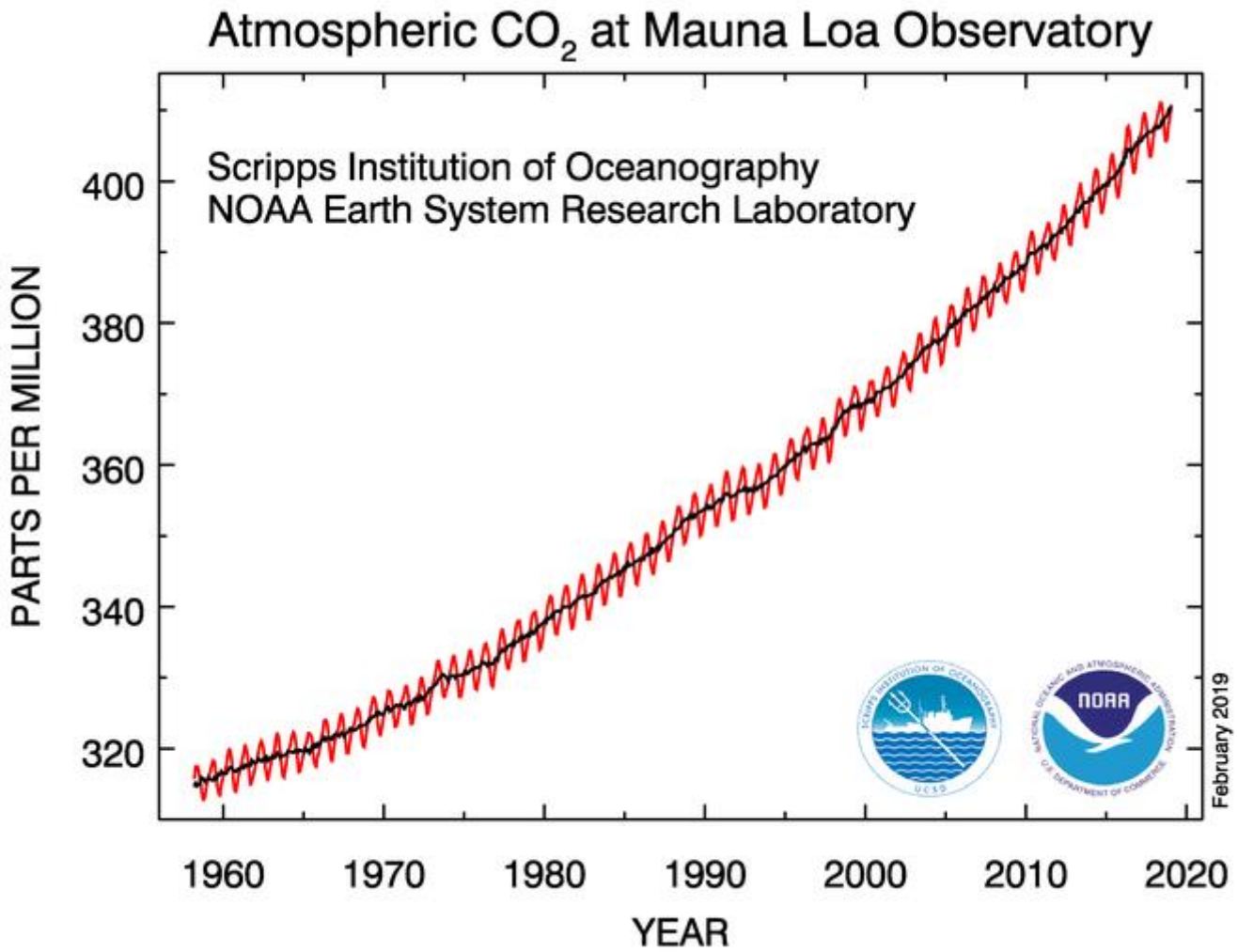
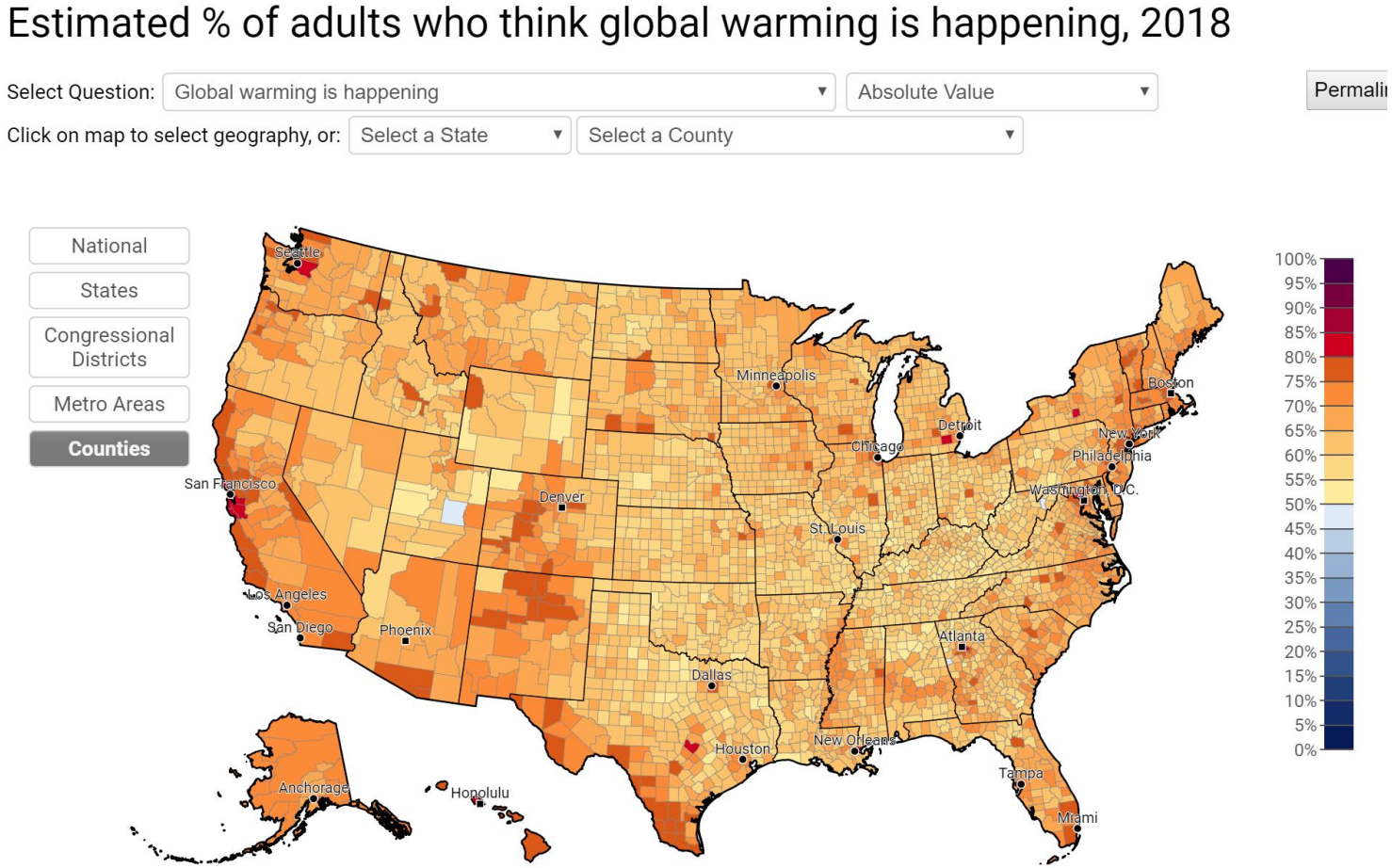


Fig. 1. Variation in concentration of atmospheric carbon dioxide in the Northern Hemisphere.

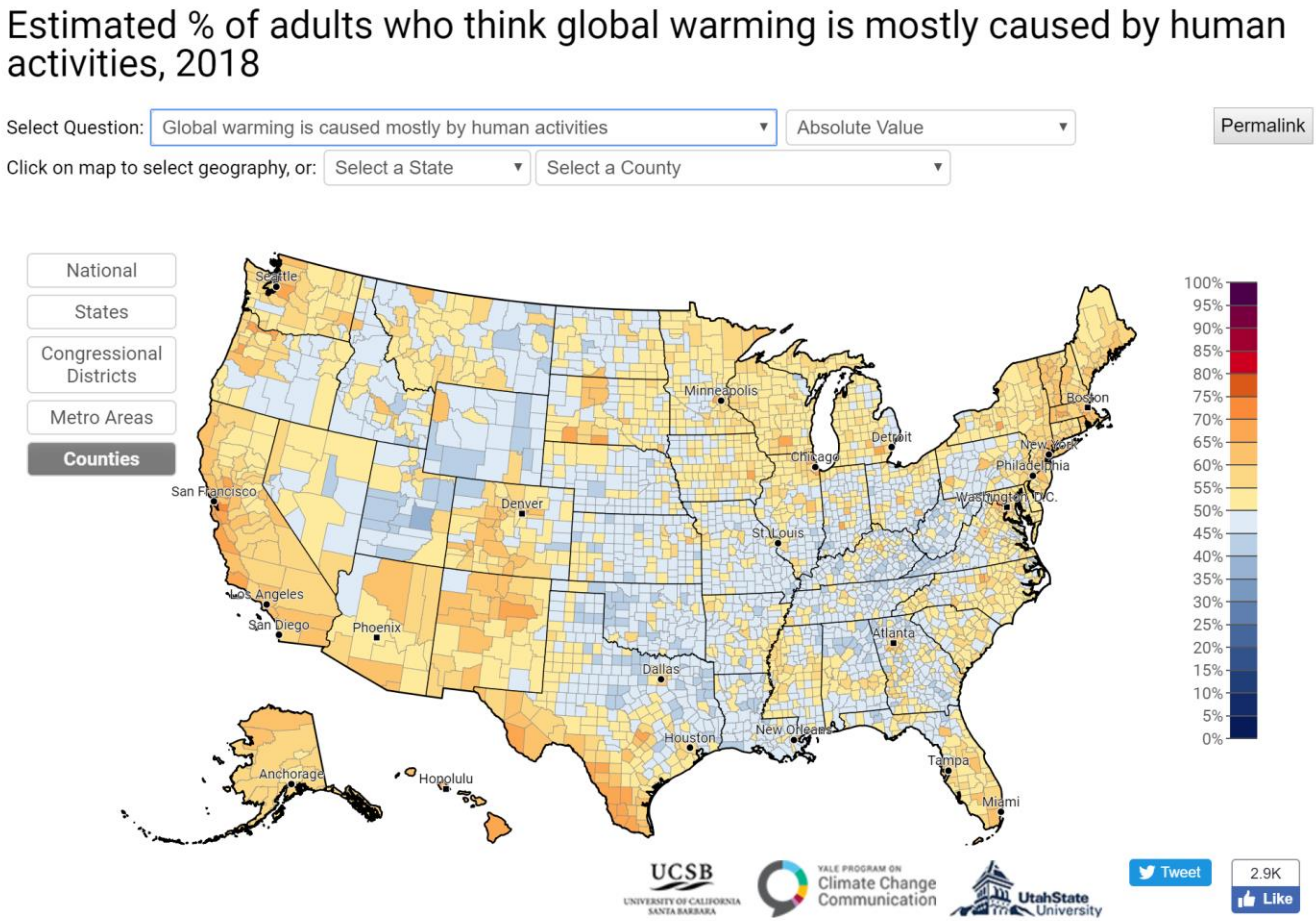

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
NOAA
February 2019

Yale



Most Americans -- in nearly every county across the United States-- understand the world is warming, according to Yale University research released

57 percent of Americans understand that humans are causing global warming

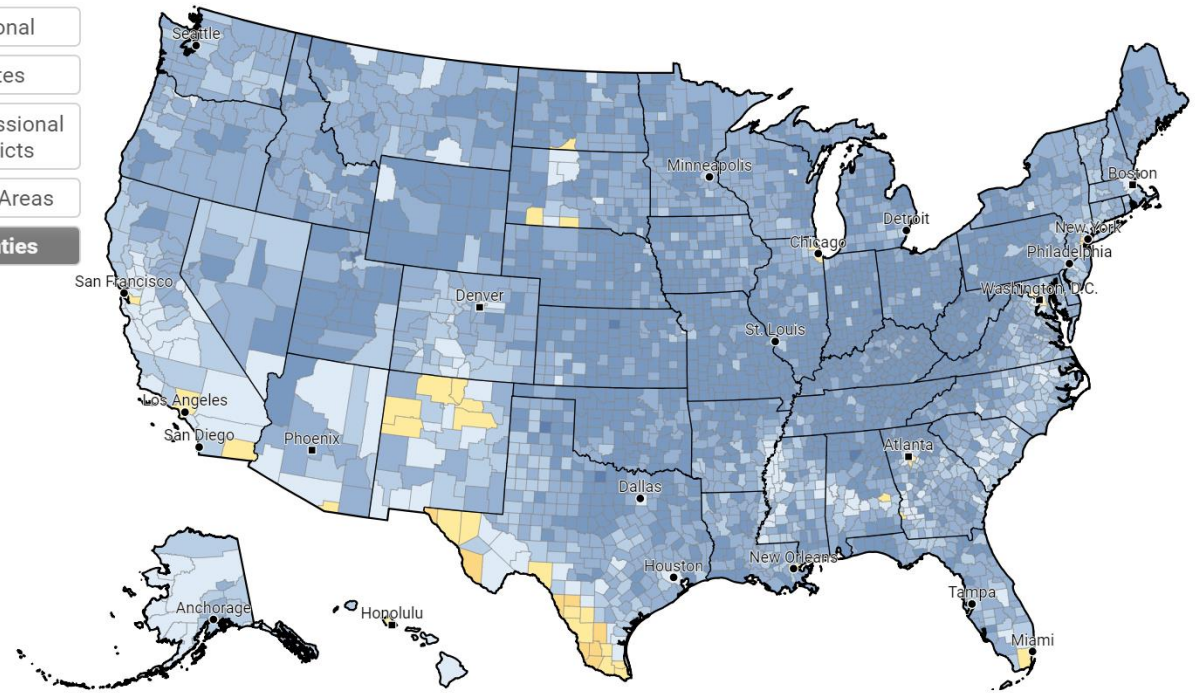


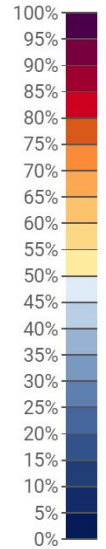
Estimated % of adults who think global warming will harm them personally, 2018

Select Question: Global warming will harm me personally ▼ | Absolute Value ▼ | Permalink

Click on map to select geography, or: Select a State ▼ | Select a County ▼

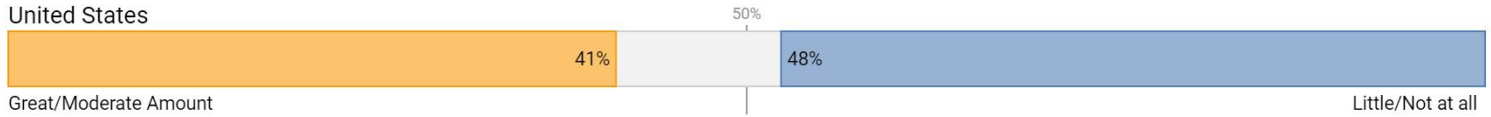
National
States
Congressional Districts
Metro Areas
Counties





UCSB University of California Santa Barbara | Yale Program on Climate Change Communication | UtahState University

Tweet | 2.9K Like

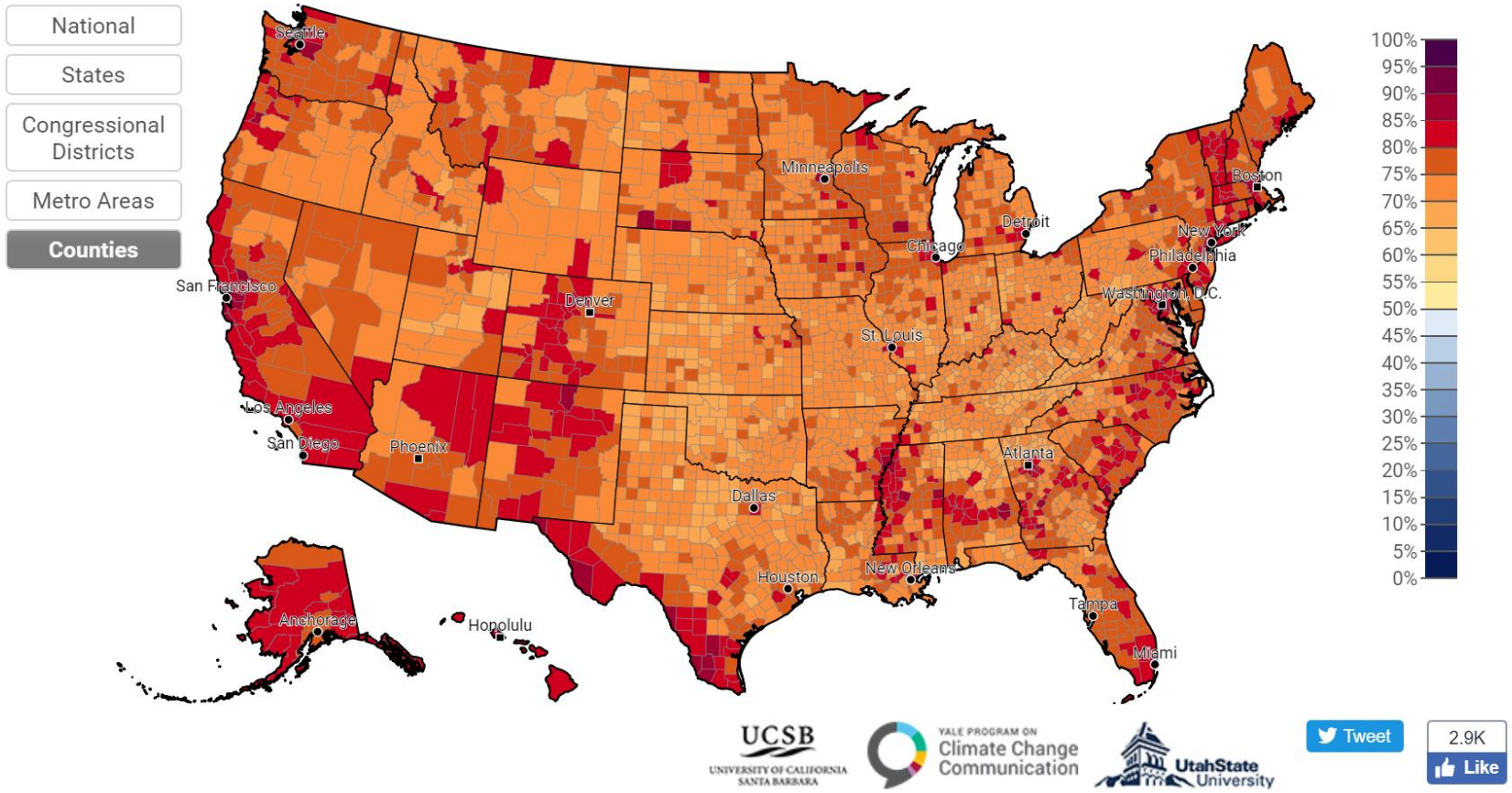


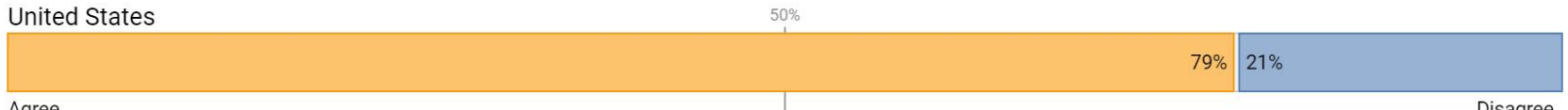
Ther ning

Estimated % of adults who believe schools should teach about the causes, consequences, and potential solutions to global warming, 2018

Select Question: Schools should teach about global warming | Absolute Value | Permalink

Click on map to select geography, or: Select a State | Select a County





What makes for meaningful environmental statistics?

Rank (1-high; 4 low) individually what you consider to be the most important and then discuss:

_____ records (high's/low's, extreme events)

_____ have high societal impact

_____ help to explain physical phenomena

_____ can be used to make empirical forecasts for commercial benefit (commodity or weather trading)

statistics can be used effectively to influence Utah public policy? And, if so, how?

- To prepare for rare events (mud slides, flash floods, high wind damage, earthquakes, etc.)

- To modify personal behavior that affects public resources (clear air, water, etc.)

- To plan for future water availability