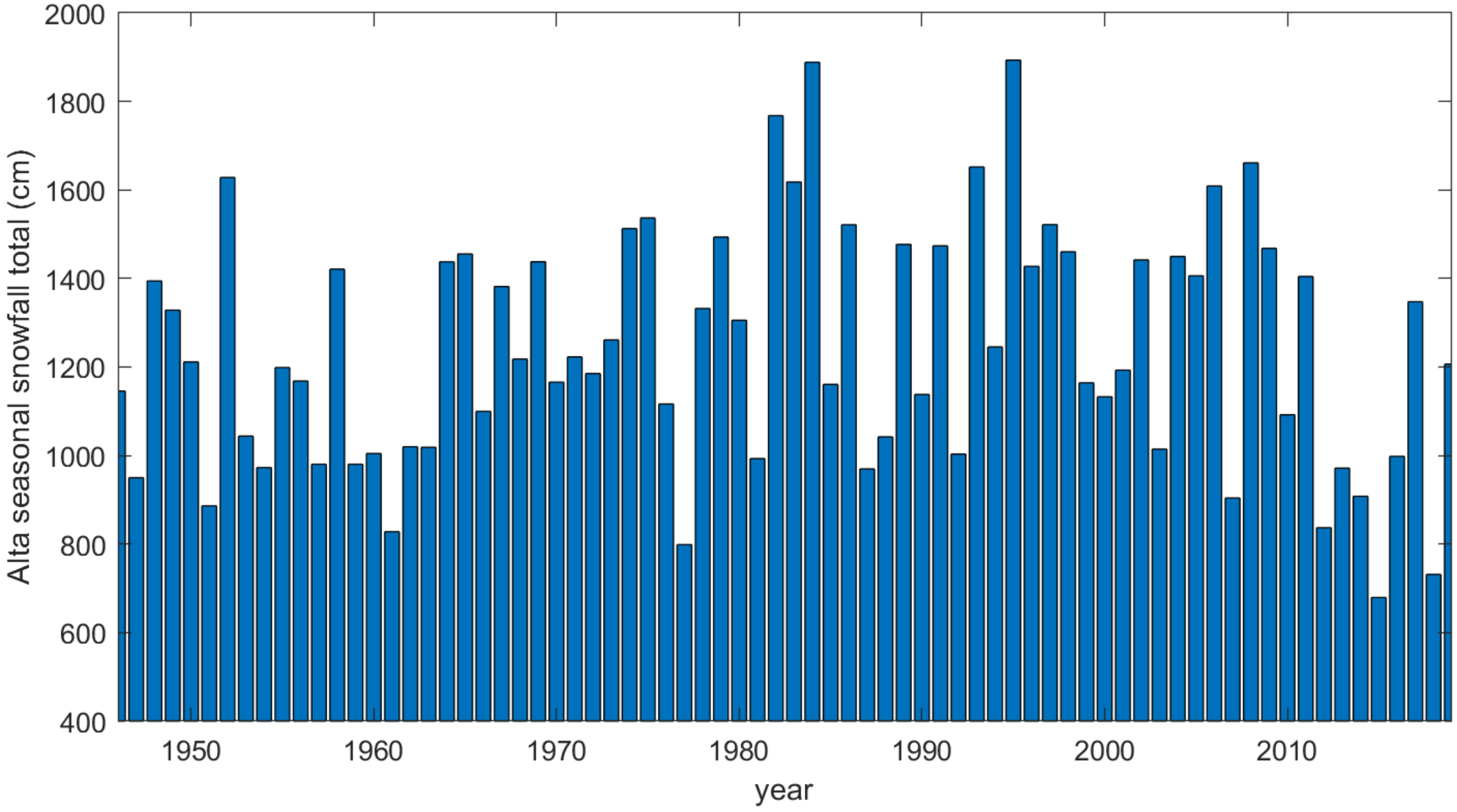
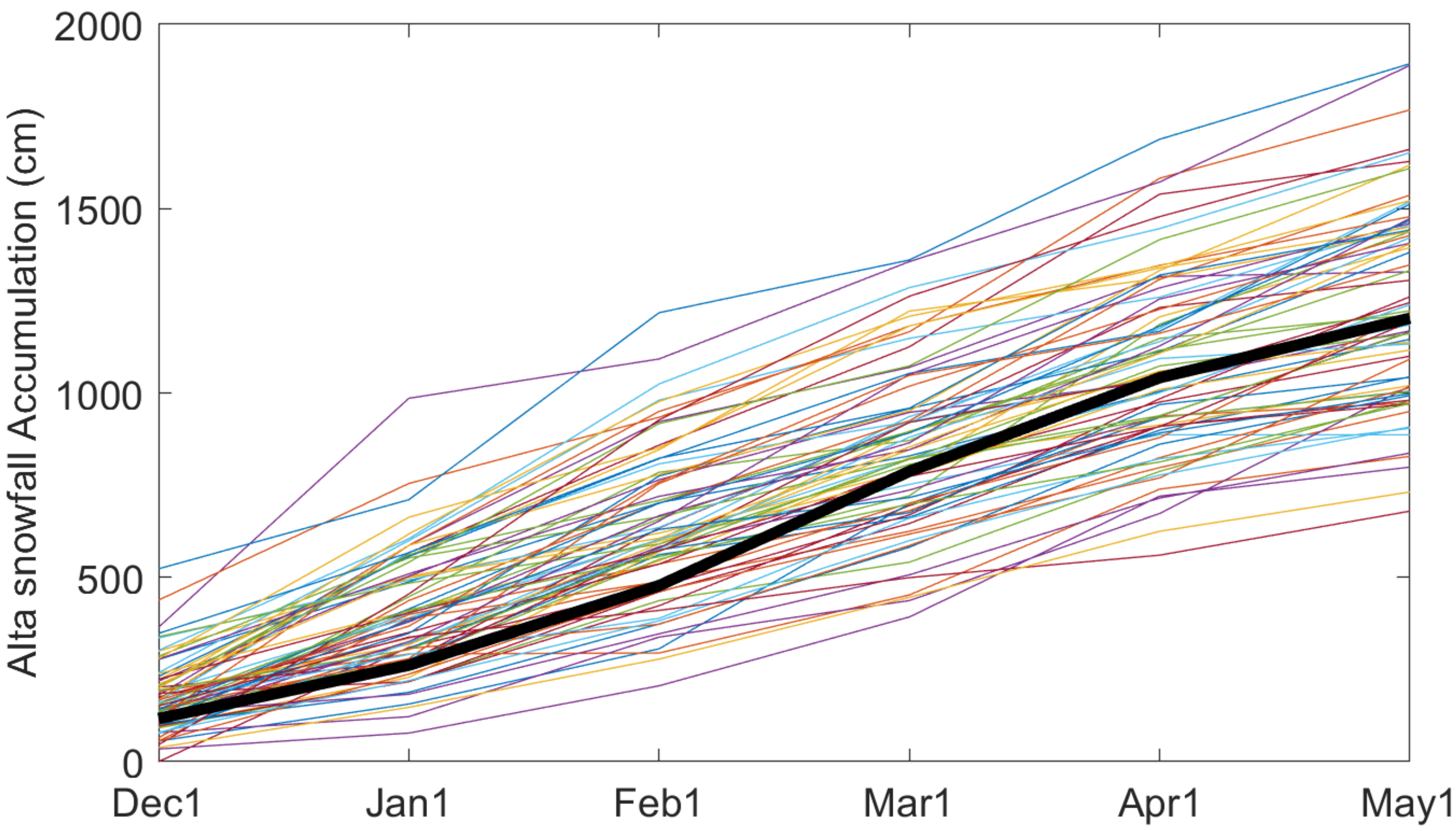
Alta Snowfall Seasonal Totals



https://utahavalanchecenter.org/alta-monthly-snowfall

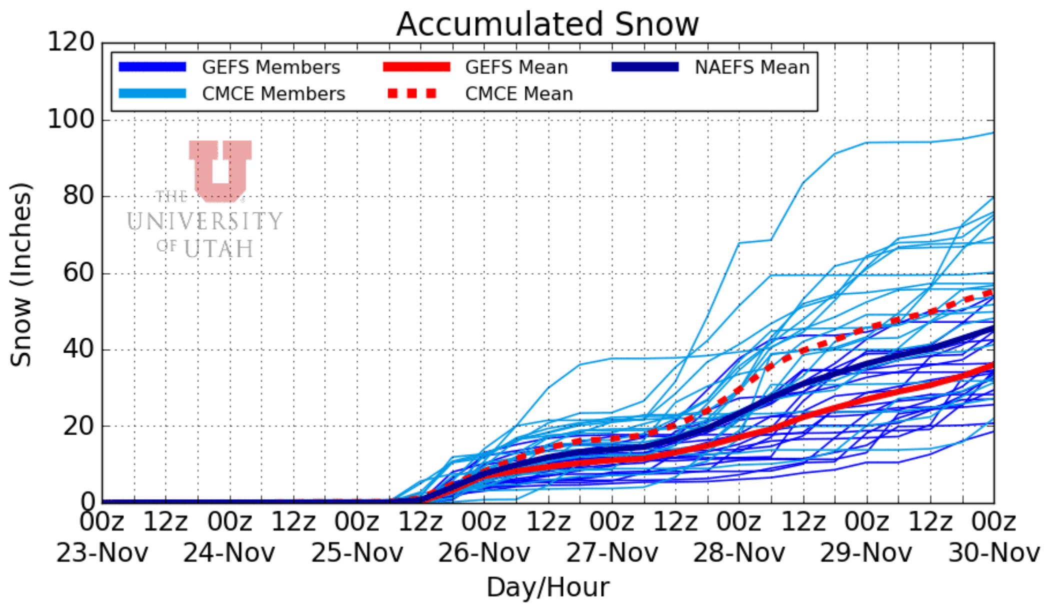
Atla Snowfall Accumulation Each Winter



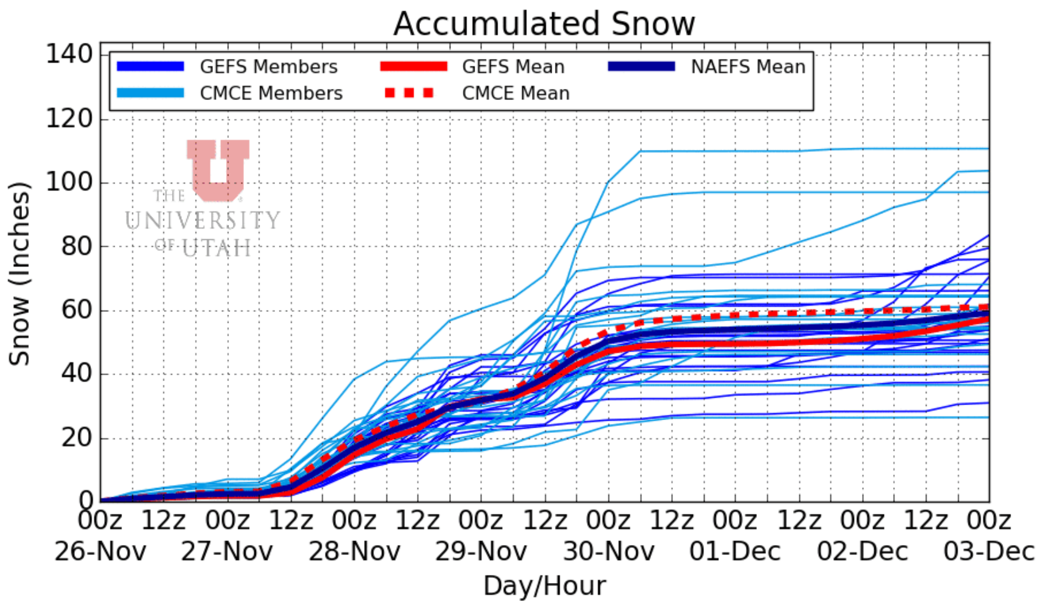
Predict May 1 Snowfall from Dec 1 Snowfall
Below< 121 cm; Above> 193 cm
So far: ~40 cm at Alta Guard

Case 1. Predictor: Dec1 total snowfall (cm)					
Predictand: May 1 Total snowfall at Alta (cm)		Below (E_1)	Near (E_2)	Above (E_3)	M Marginal Totals
	Below (M_1)	14	10	1	25
	Near (M_2)	7	7	10	24
	Above (M_3)	4	7	14	25
	E Marginal Totals	25	24	25	74

Ensemble Forecasts of Snow at Alta-Collins



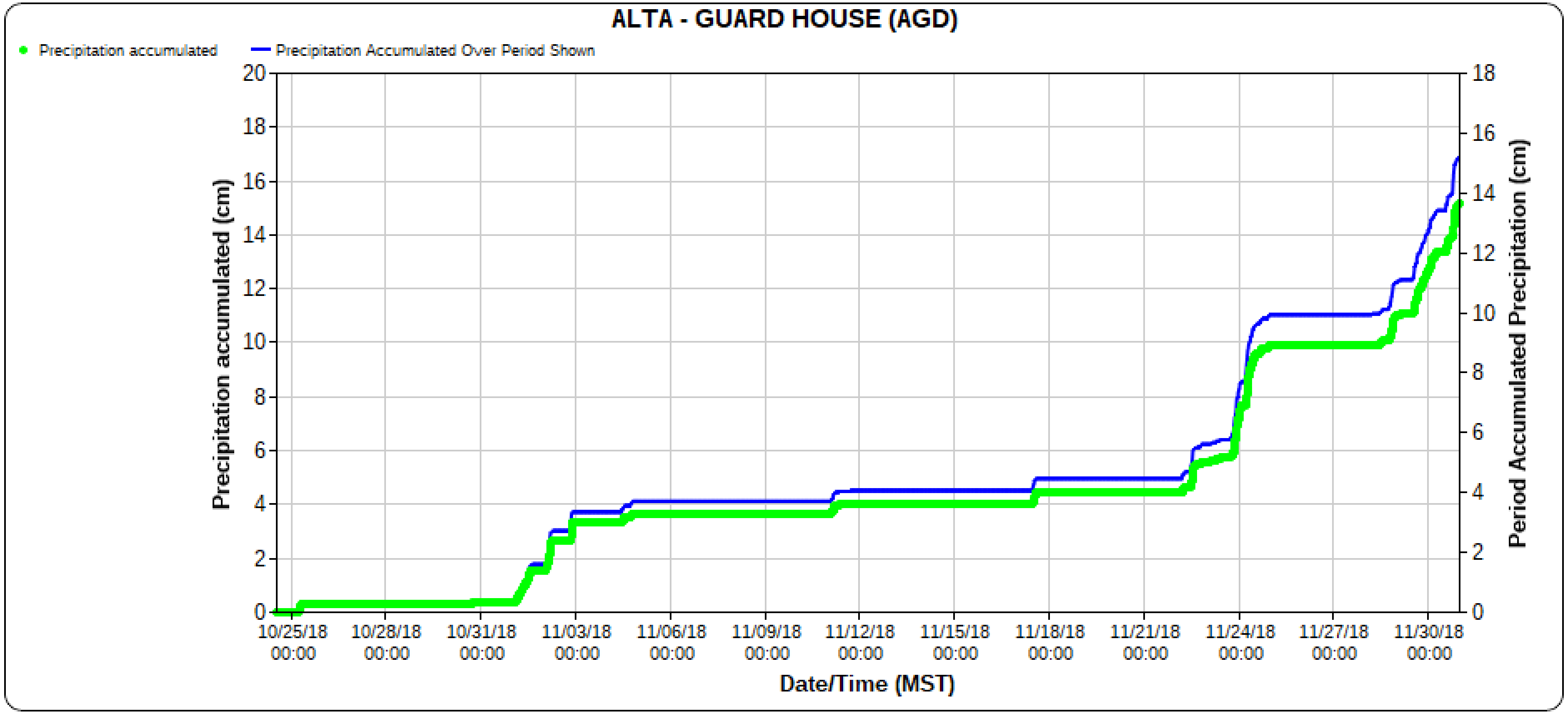
Saturday forecast
Ensemble Forecasts of Snow (10-100inch)
Canadian mean: 55 inch (~135 cm)
GFS mean: 40 inch (~90 cm)



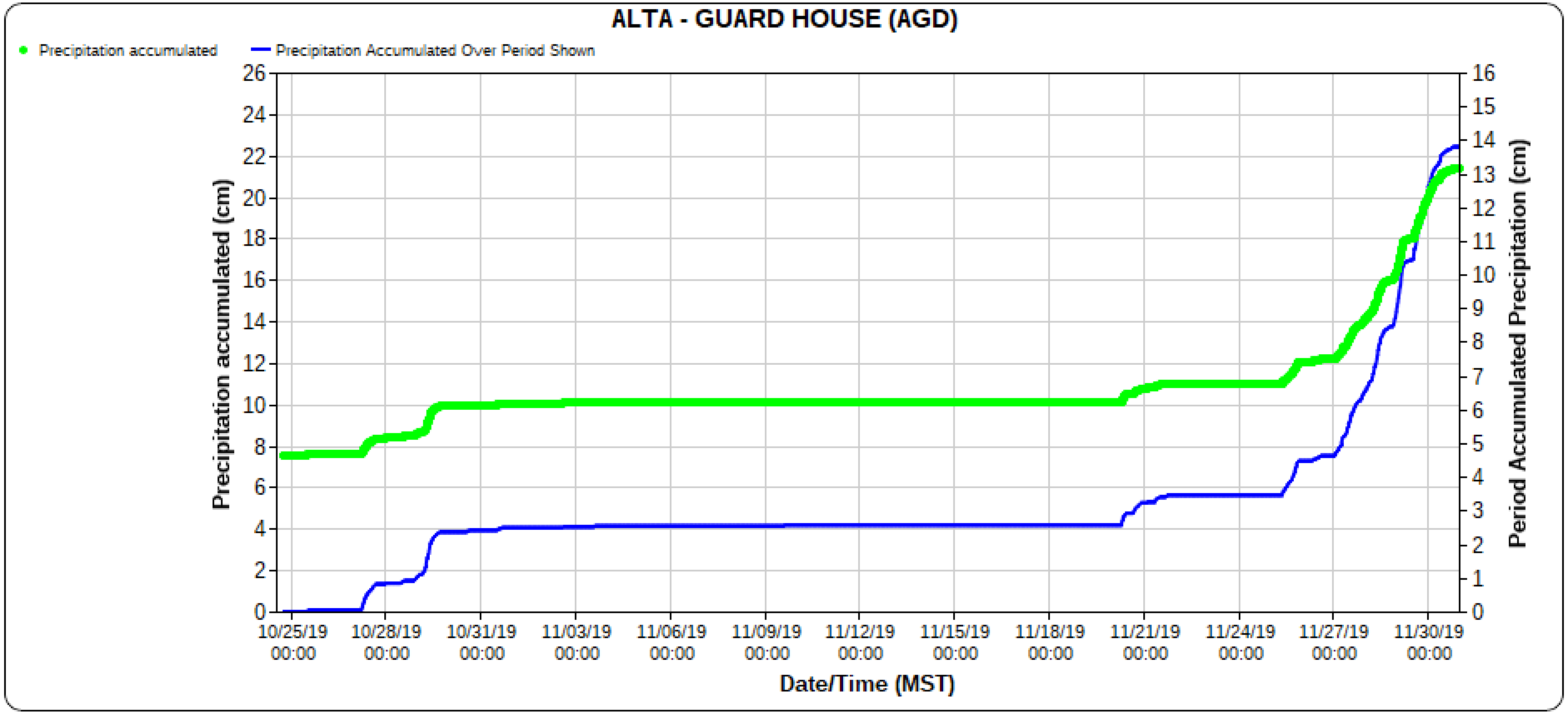
Tuesday forecast ending Dec 1
Ensemble Forecasts of Snow (20-110inch)
Canadian mean: 60 inch (~150 cm)
GFS mean: 50 inch (~125 cm)

http://weather.utah.edu/index.php?runcode=2019112600&t=naefs&d=PL&r=CLN

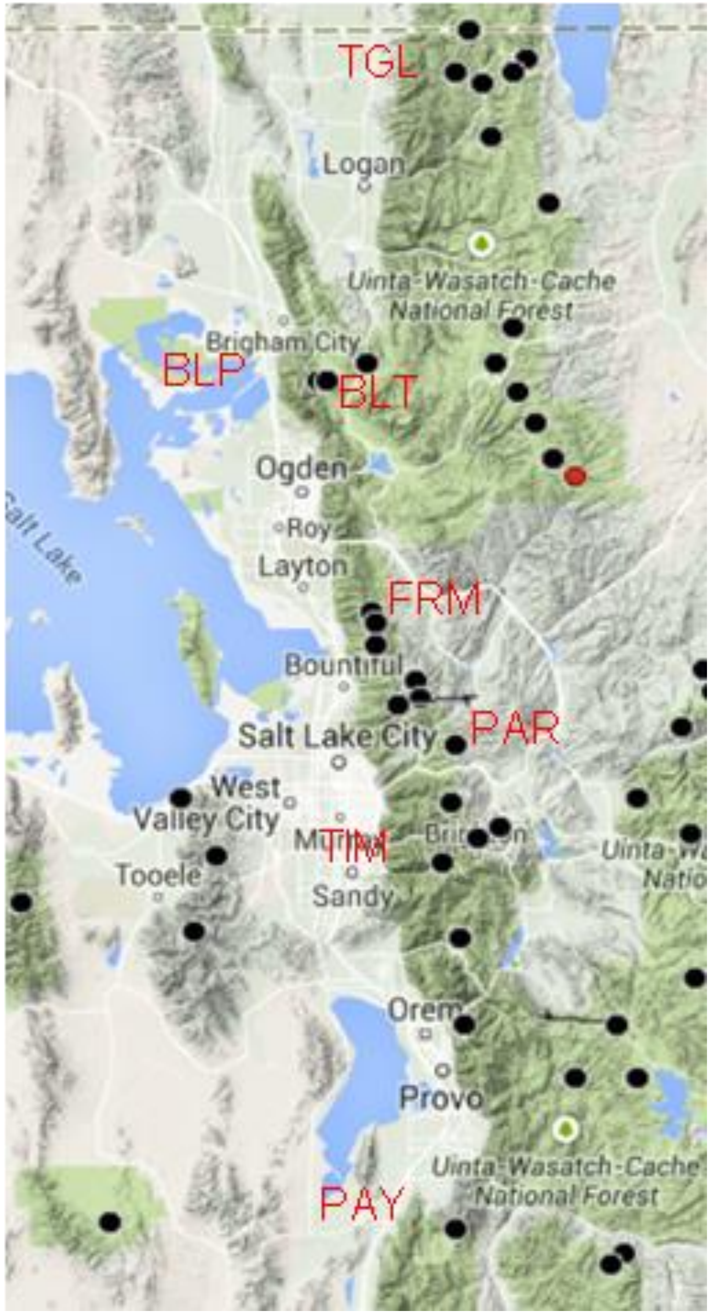
Last year: 117 cm snowfall, 15 cm SWE
SW/LW = ~8% density



So how much fell? 67 inches (170 cm)?
Or ~14 cm of SWE w 8% density, then 112 cm?



SNOTEL Sites



Accumulated Annual Precipitation

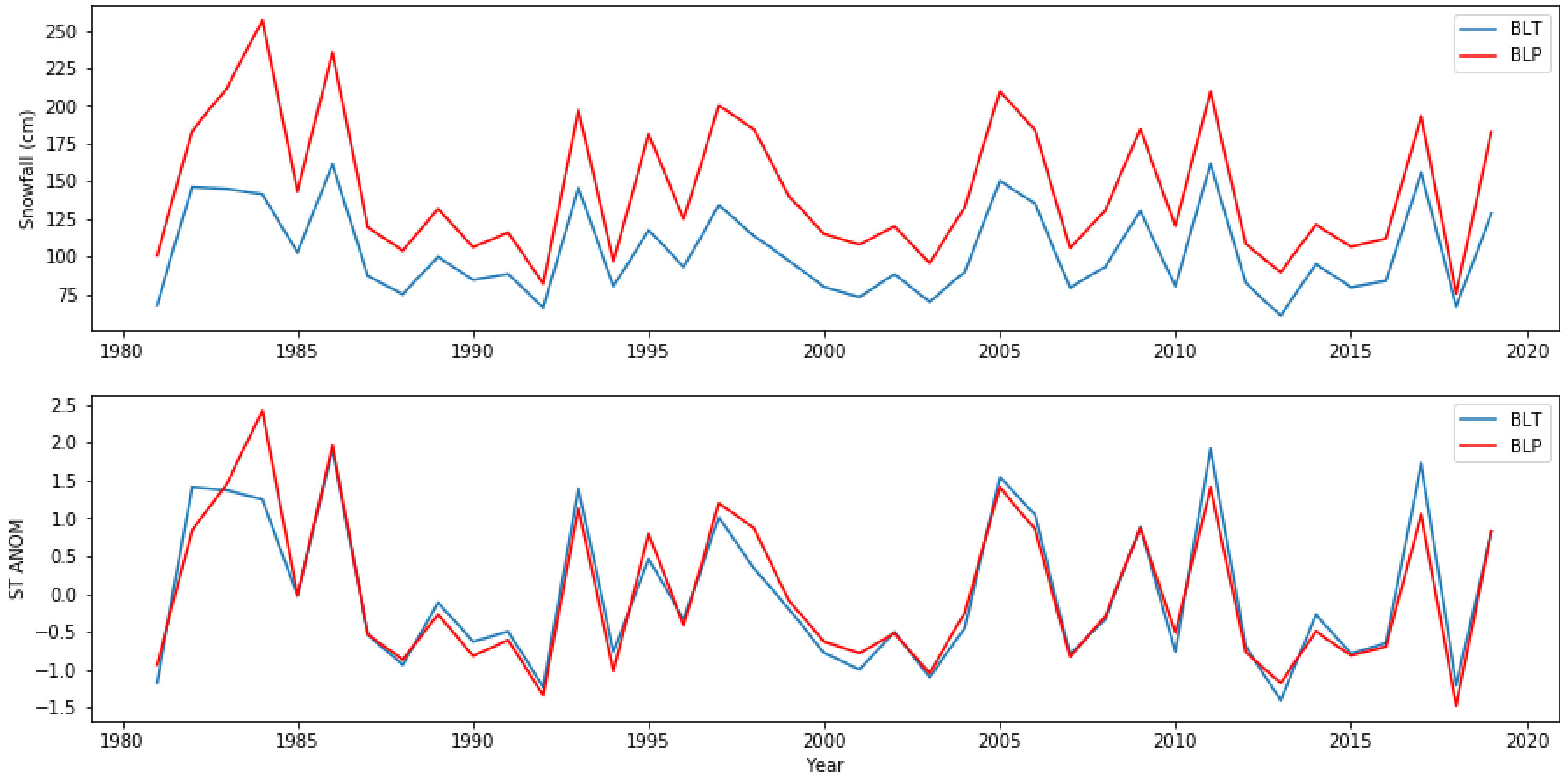


Figure 4.2. Time series (cm) of seasonal total precipitation at Ben Lomond Peak and Trail (top panel) and standardized anomalies (nondimensional) of the time series in the lower panel.

Scatter plots

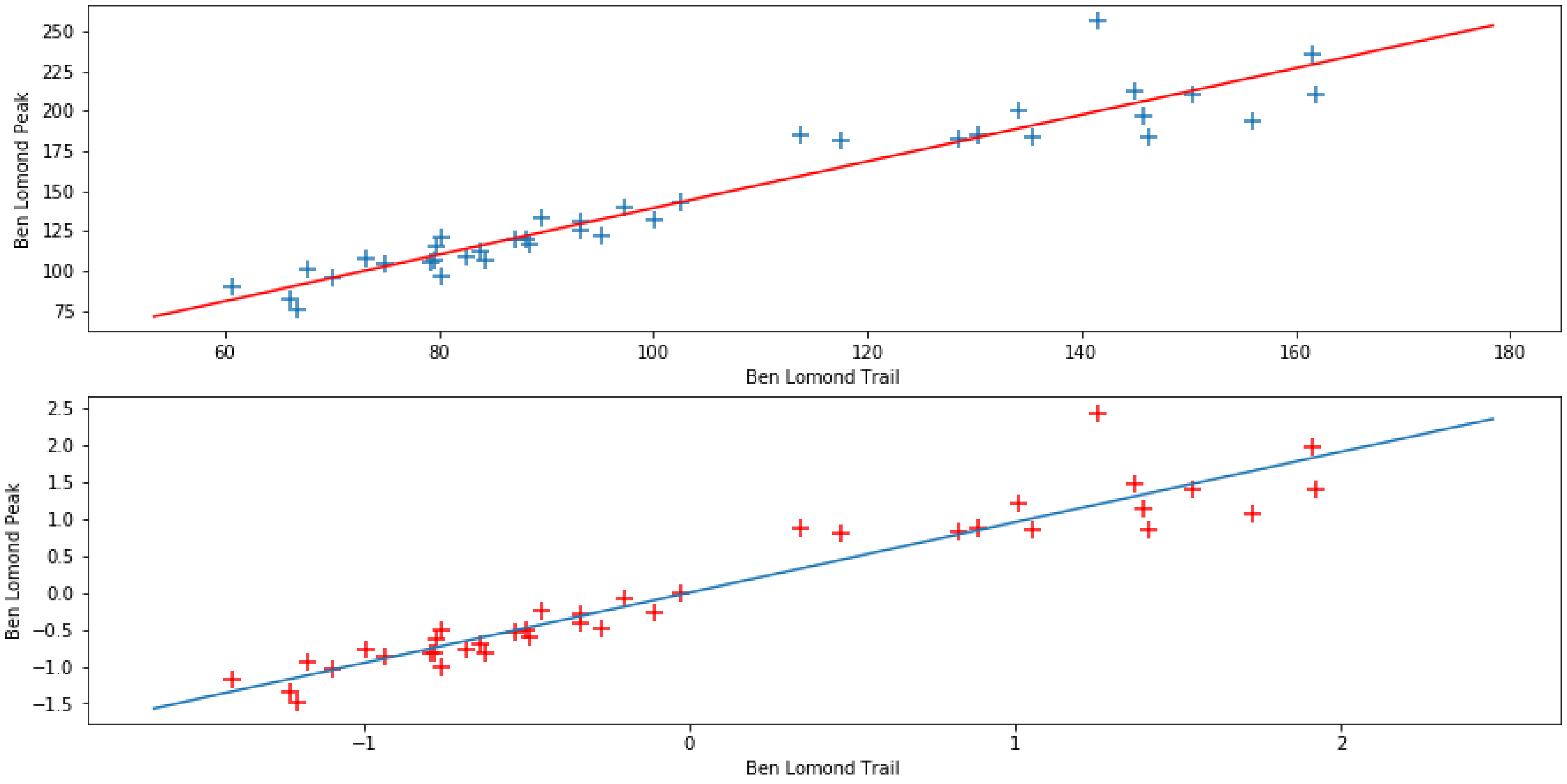


Figure 4.3. Scatter plot of total precipitation (cm) at Ben Lomond Peak vs. Trail (top panel) and of their standardized anomalies (bottom panel).

Estimating Values of One Variable From Another

- X- Ben Lomond Trail
- Y- Ben Lomond Peak
- Want to estimate Peak from Trail
- Use pairs of observations from sample
- Need to determine coefficient b or r
- b- slope of linear estimate
- r- linear correlation

$$\hat{y}_i = \bar{y} + b(\hat{x}_i - \bar{x})$$

$$\hat{y}^*{}_i = r\hat{x}^*{}_i$$

Definitions

- Estimate $\hat{y}_i = \bar{y} + b(\hat{x}_i - \bar{x})$
- Error of estimate $e_i = y_i' - \hat{y}_i'$
- Want $\sum_{i=1}^{n} e_i^2$ to be a minimum
- Need to find the value of b that minimizes that sum

$$\frac{\partial}{\partial b} \sum_{i=1}^{n} e_i^2 = 0$$

$$b = \overline{x_i' y_i'} / \overline{(x_i')^2} = \overline{x_i' y_i'} / s_x^2$$

- The value of b that minimizes the total error in the sample

Linear Correlation

$$r^2 = b^2 s_x^{\ 2} / s_y^{\ 2} = (\overline{x_i' y_i'})^2 / (s_x^{\ 2} s_y^{\ 2}) \qquad r = (\overline{x_i' y_i'}) / \sqrt{\overline{x_i'^2}\ \overline{y_i'^2}}$$

$$x_i^{\ *} = x_i' / s_x, y_i^{\ *} = y_i' / s_y, r = (\overline{x_i^* y_i^*})$$

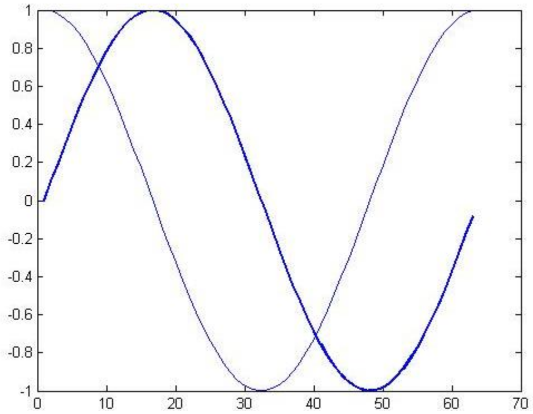
$$1 = r^2 + \frac{\overline{e_i^2}}{s_y^{\ 2}}$$

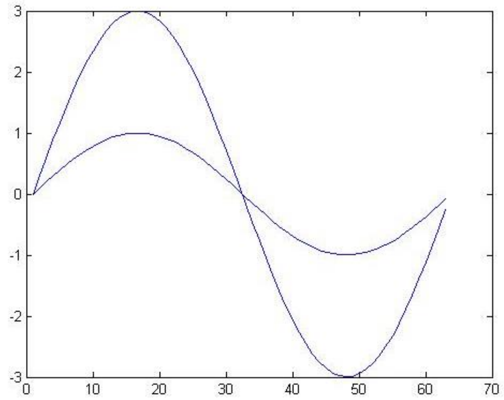
y’s total sample variance = fraction of variance estimated by x + fraction of variance NOT explained by x

- Dimensionless number relates how departures of x and y from respective means are related taking into account variance of x and y
- r = 1. Linear fits estimates ALL of the variability of the y anomalies and x and y vary identically
- r = -1 perfect linear estimation but when x is positive, y is negative and vice versa
- r = 0. linear fit explains none of the variability of the y anomalies in the sample. Best estimate of y is the mean value

Stop and think before blindly computing correlations

- tendency to use correlation coefficients of 0.5 - 0.6 to indicate “useful” association.
  - 75%-64% of the total variance is NOT explained by a linear relationship if the correlation is in that range
- linear correlations can be made large by leaving in signals that may be irrelevant to the analysis. Annual and diurnal cyles may need to be removed
- large linear correlations may occur simply at random, especially if we try to correlate one variate with many, many others
- relationships in the data that are inherently nonlinear will not be handled well
- when two time series are in quadrature with one another then the linear correlation is 0
- Linear correlation provides no information on the relative amplitudes of two time series



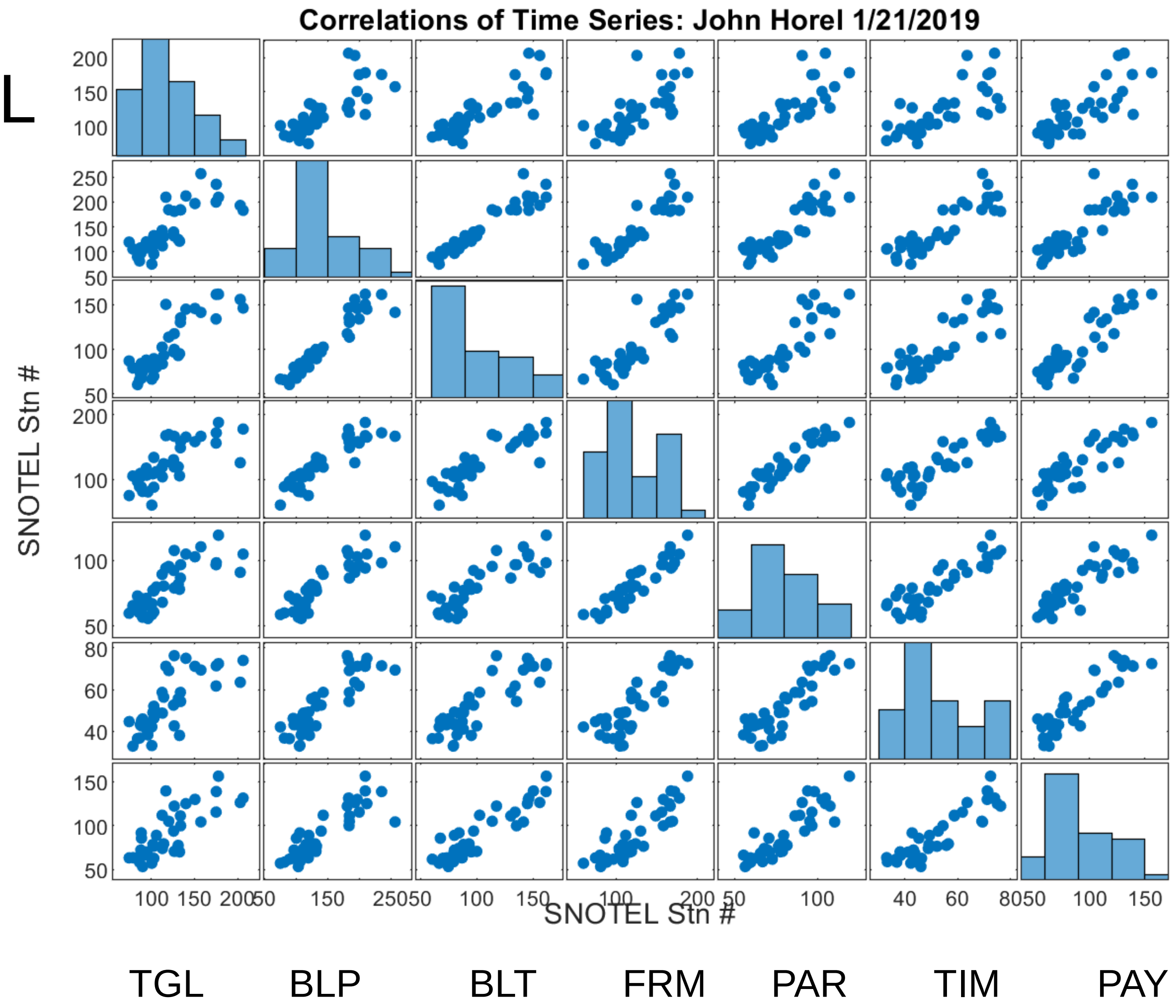


Multivariate Linear Correlations

$$\vec{X}* = \begin{bmatrix} x*_{11} & x*_{12} & \dots & x*_{17} \\ x*_{21} & x*_{22} & \dots & x*_{27} \\ \dots & \dots & \dots & \dots \\ x*_{n1} & x*_{n2} & \dots & x*_{n7} \end{bmatrix}$$

- 7 stations and n=39 years
- Standardized anomalies

- TGL


Correlations of Time Series: John Horel 1/21/2019
SNOTEL Stn #
SNOTEL Stn #
TGL
BLP
BLT
FRM
PAR
TIM
PAY

Hovmuller Diagram

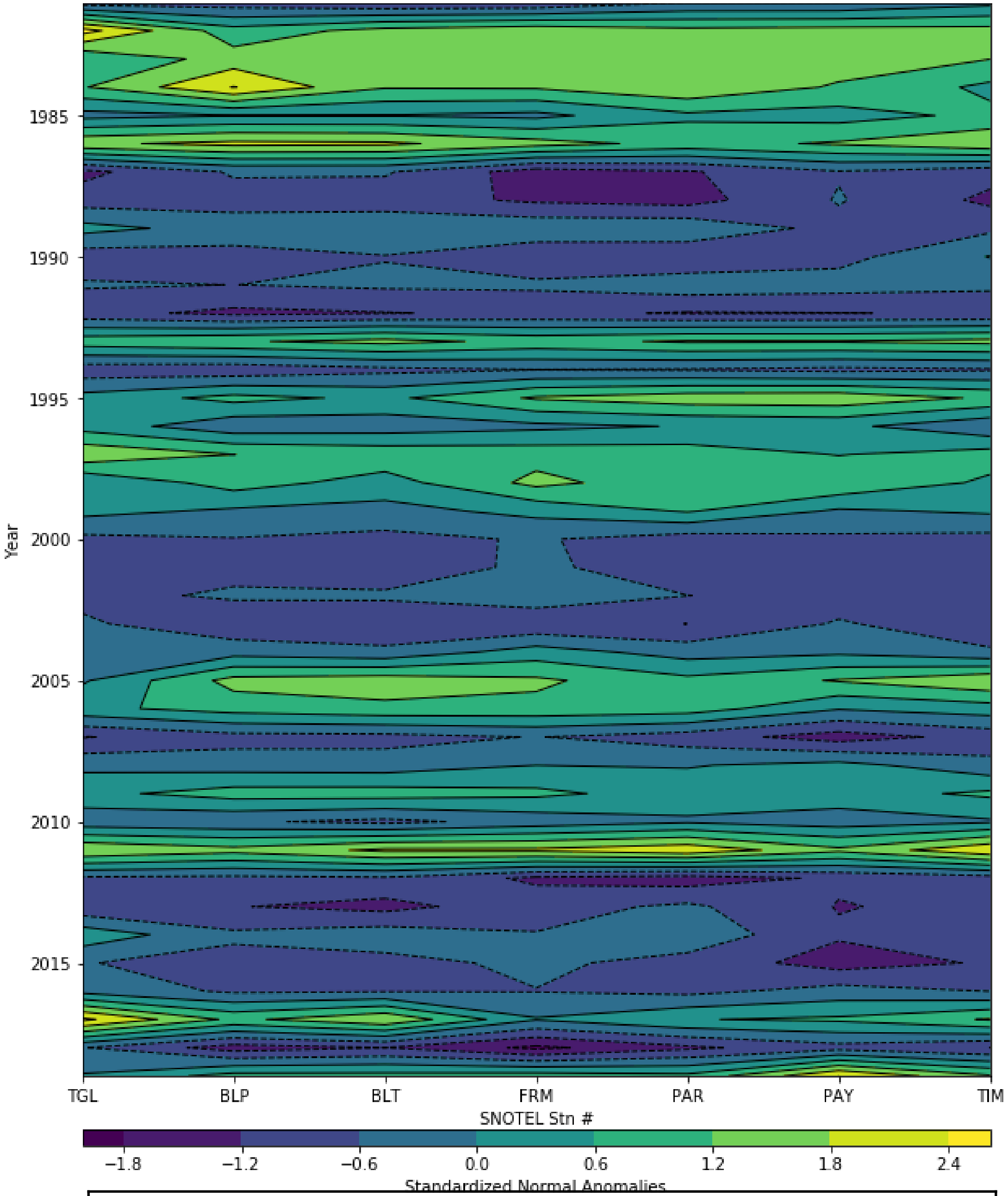
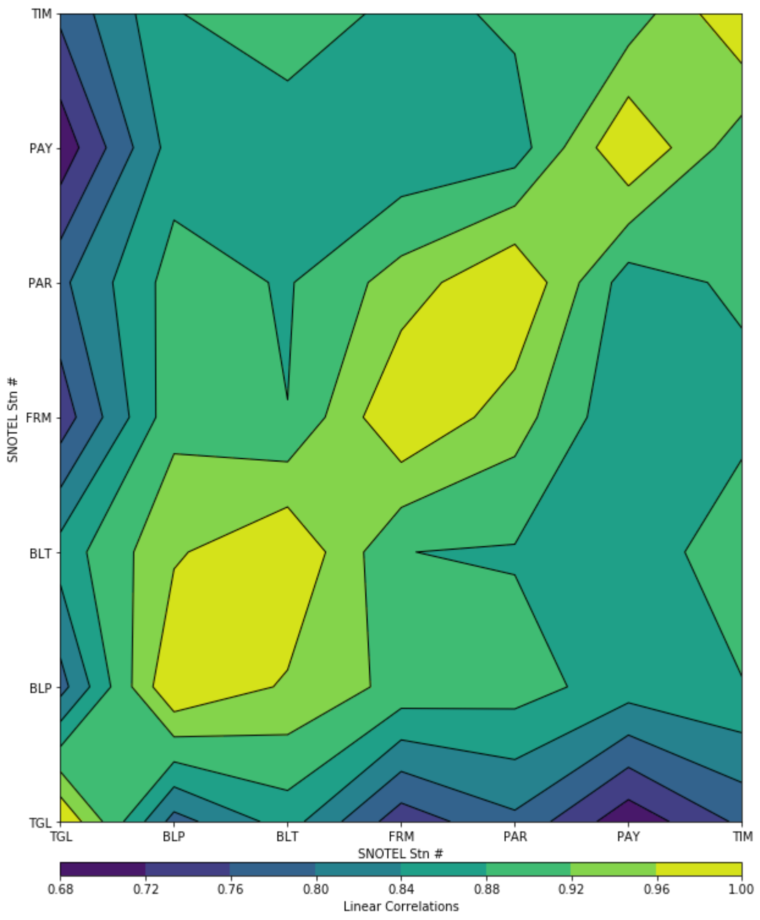


Figure 4.6. Hovmuller diagram (time increasing down the page and location advancing across the page) of standardized precipitation anomalies.

Multivariate Linear Correlations



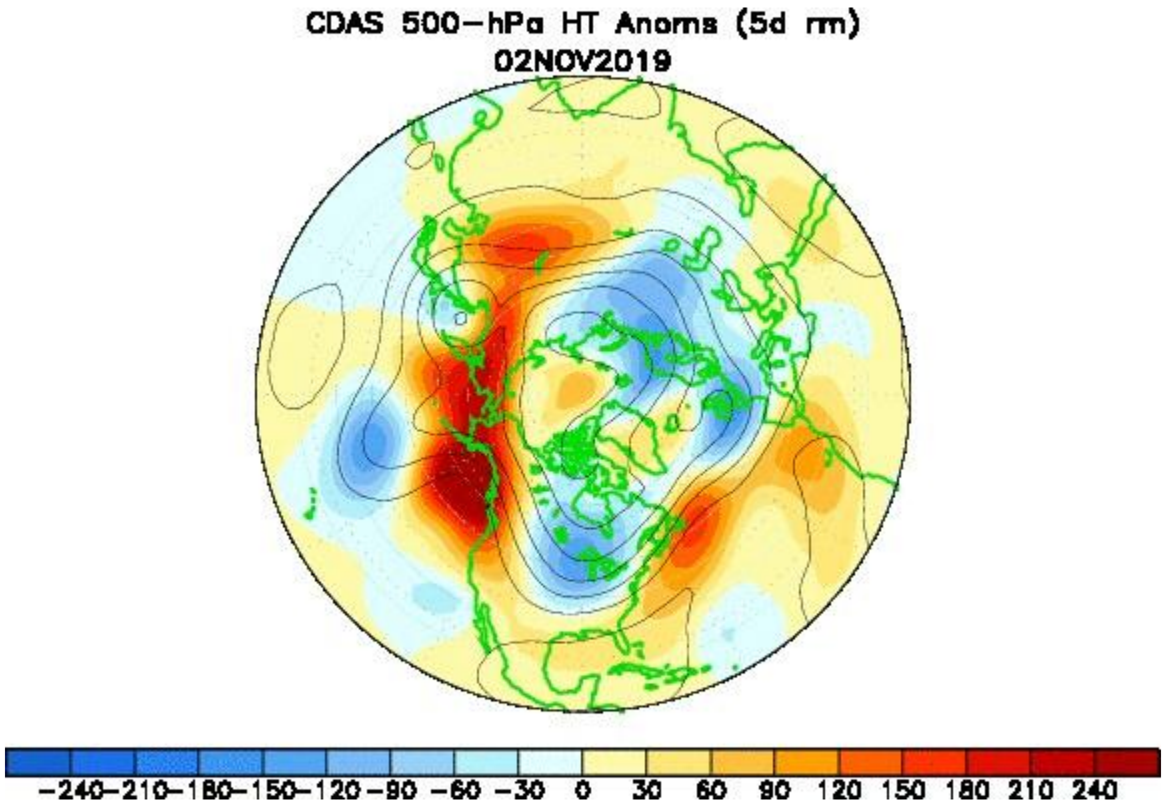
$$\vec{X}* = \begin{bmatrix} x*_{11} & x*_{12} & \cdots & x*_{17} \\ x*_{21} & x*_{22} & \cdots & x*_{27} \\ \cdots & \cdots & \cdots & \cdots \\ x*_{n1} & x*_{n2} & \cdots & x*_{n7} \end{bmatrix}$$

$$\vec{R} = \vec{X}*^{T} \ \vec{X}*/n$$

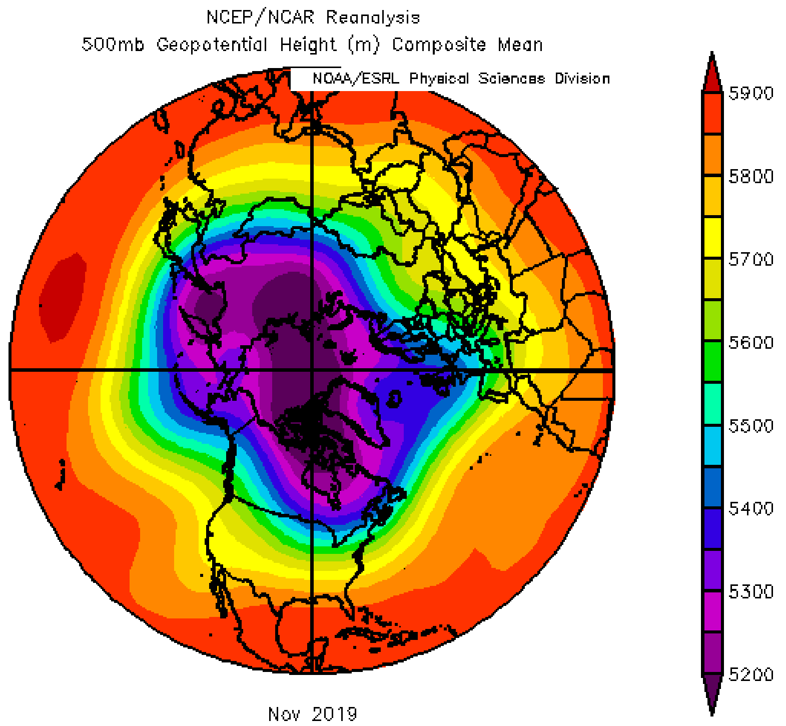
Figure 4.7. Correlation between all pairs of precipitation time series computed over the 39 year sample.

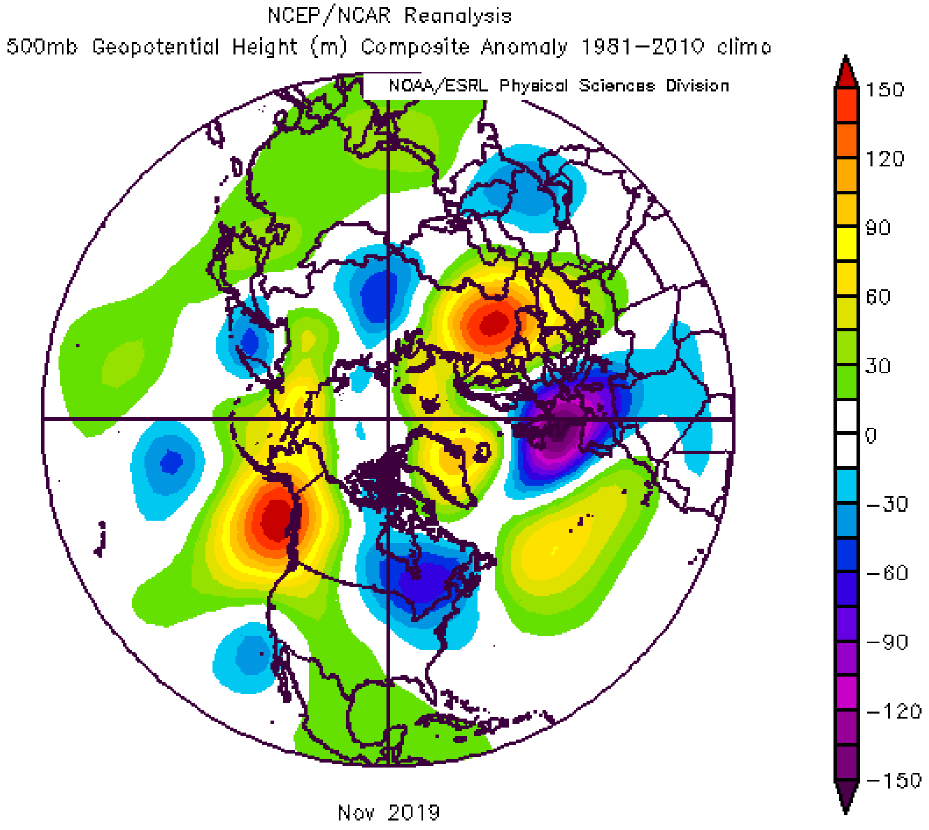
Daily Anomaly Maps

http://www.cpc.ncep.noaa.gov/products/intraseasonal/z500_nh_anim.shtml



November 2019 500 hPa mean height and departures from long term mean





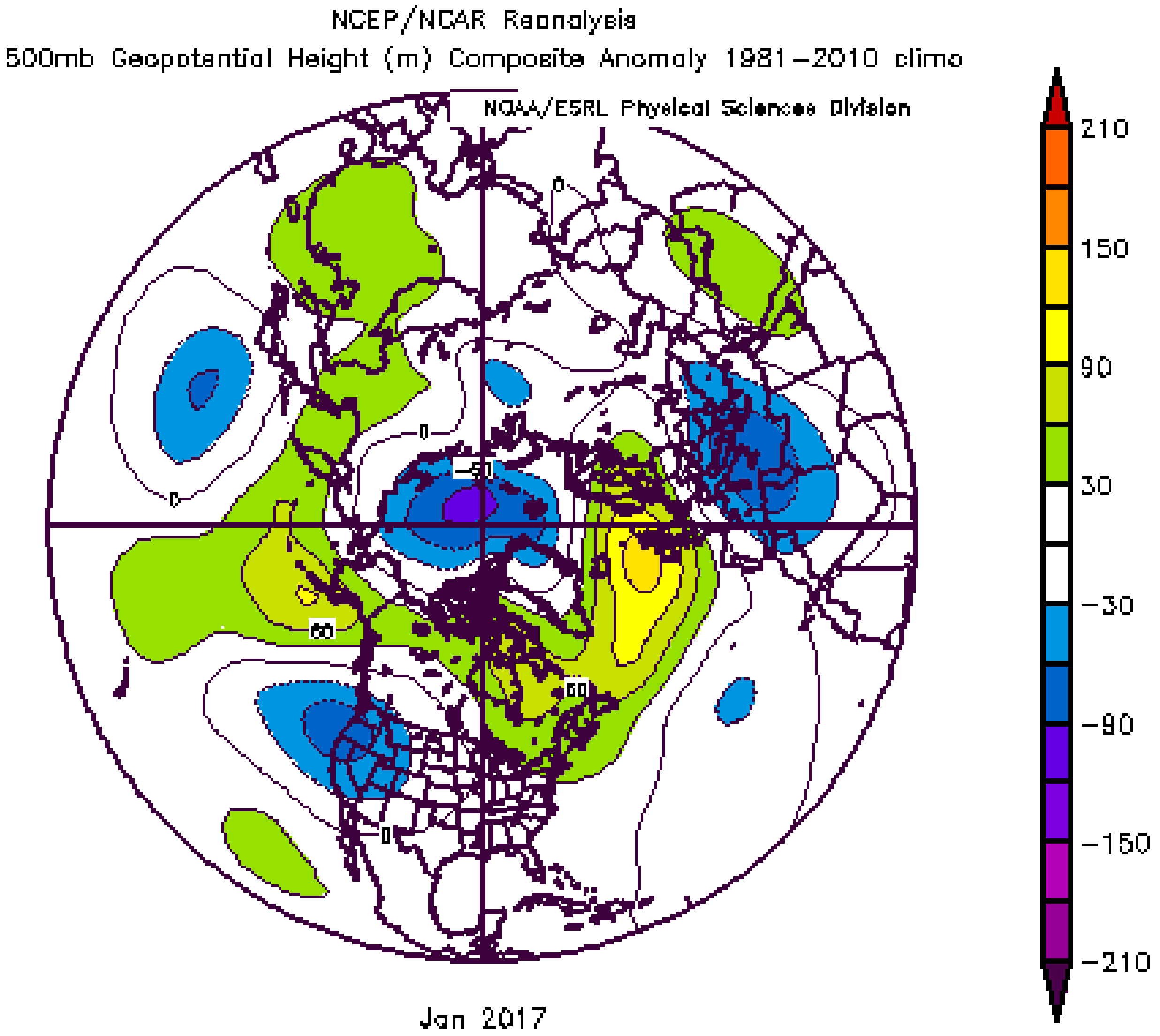
Teleconnection

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

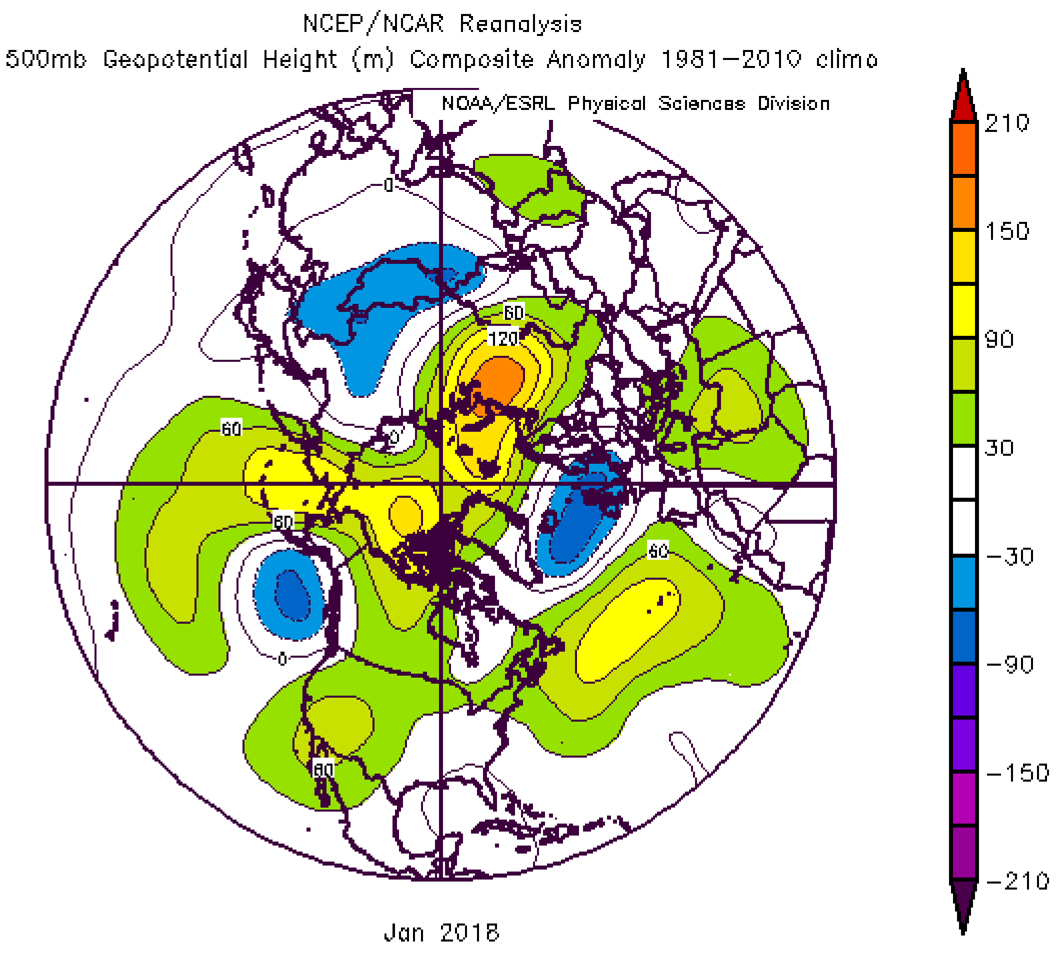
http://www.cpc.ncep.noaa.gov/data/teledoc/teleintro.shtml

Teleconnections: "the study of blobs"

500 hPa Height Anomalies
Jan 2017

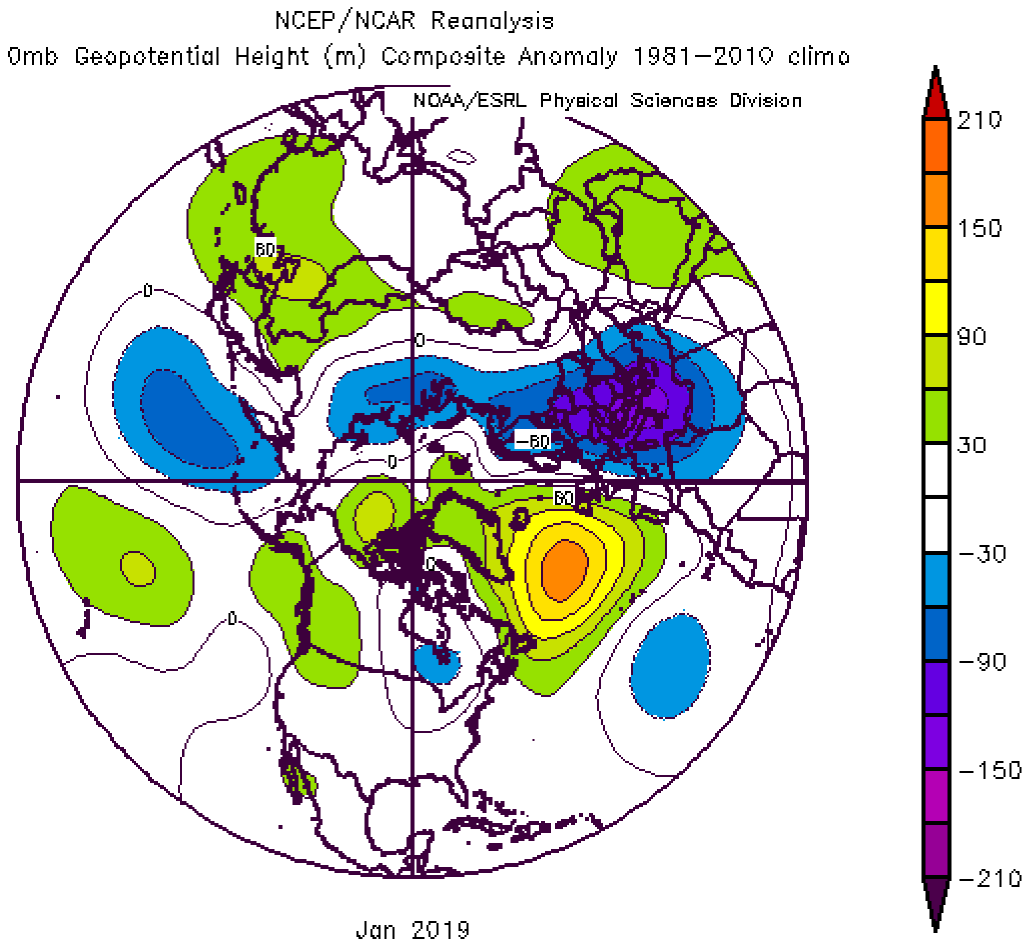


500 hPa Height Anomalies
Jan 2018



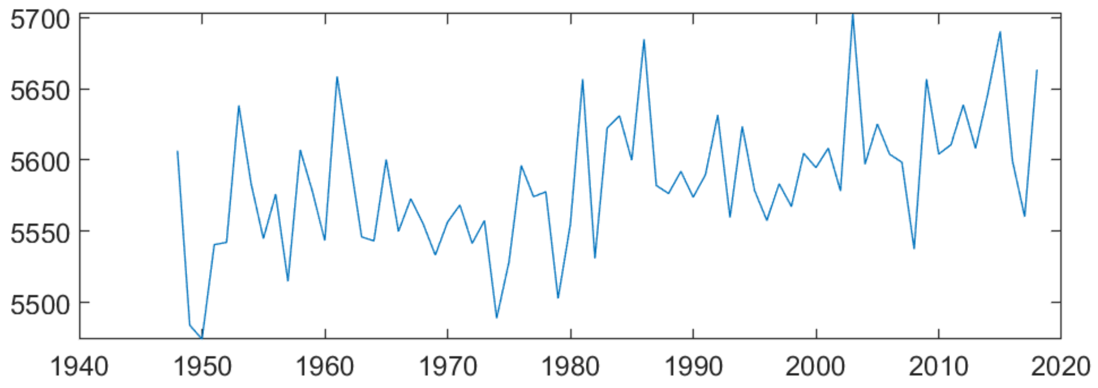
500 hPa Height Anomalies
Jan 2019

https://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl

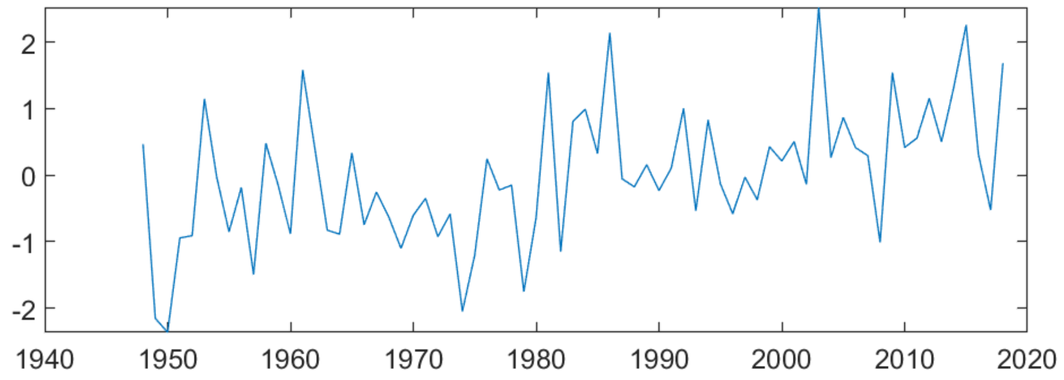


January SLC 500 hPa time series

hPa



Std
anom

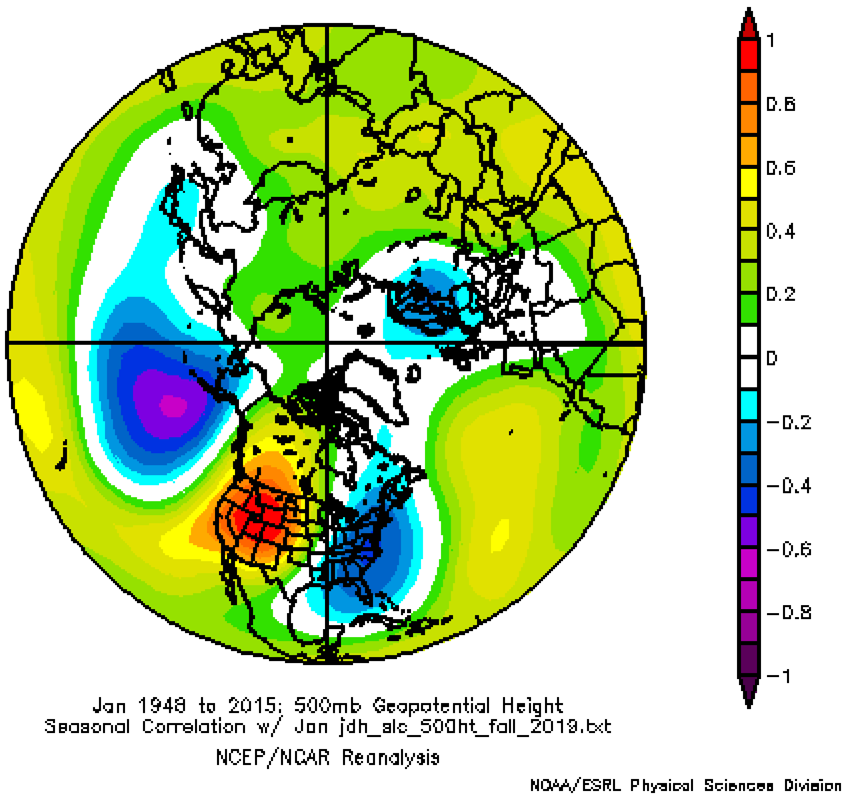


Correlate 500 hPa heights over SLC with every other point in NH: a teleconnection map

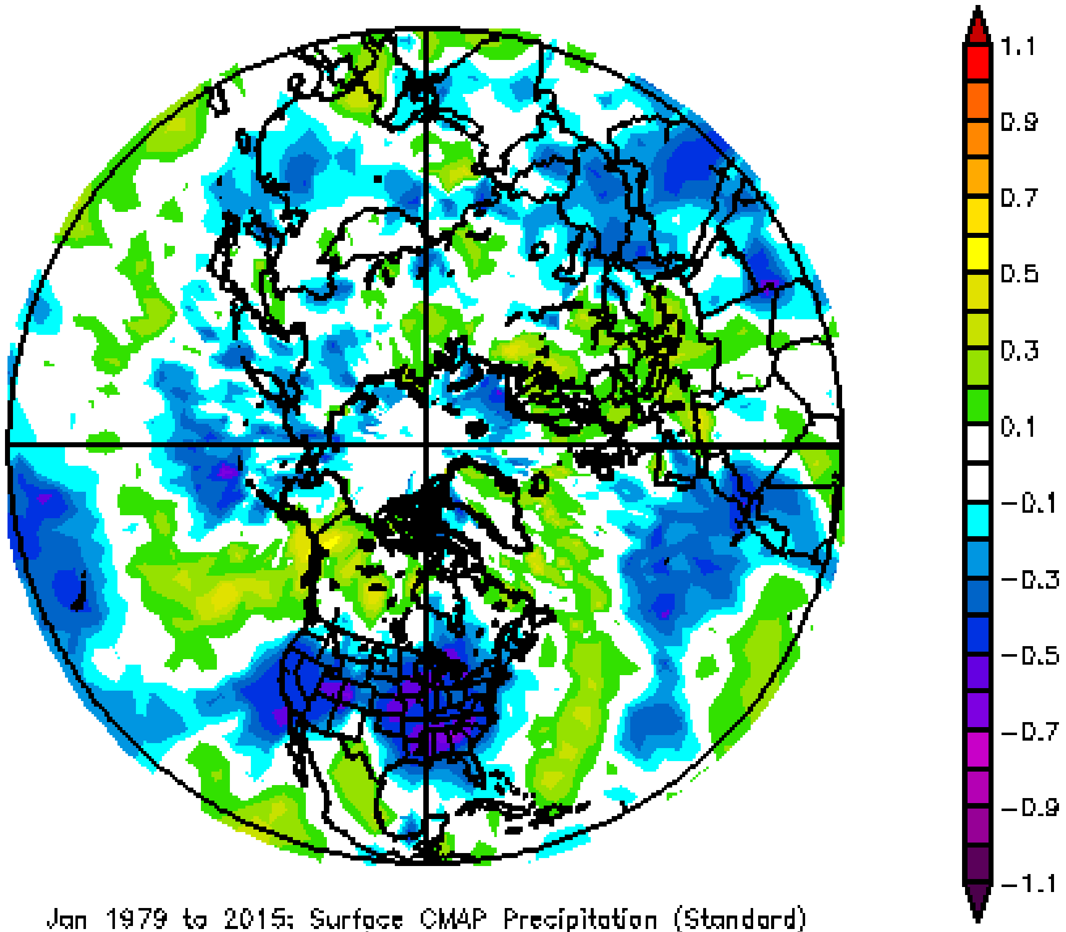
- Create a time series for SLC: location 42.5 40.0 247.5 250. 500 mb

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



Jan 1979 to 2015: Surface CMAP Precipitation (Standard)
Seasonal Correlation w/ Jan jdh_slc_500ht_fall_2019.txt

CMAP Standard Precipitation

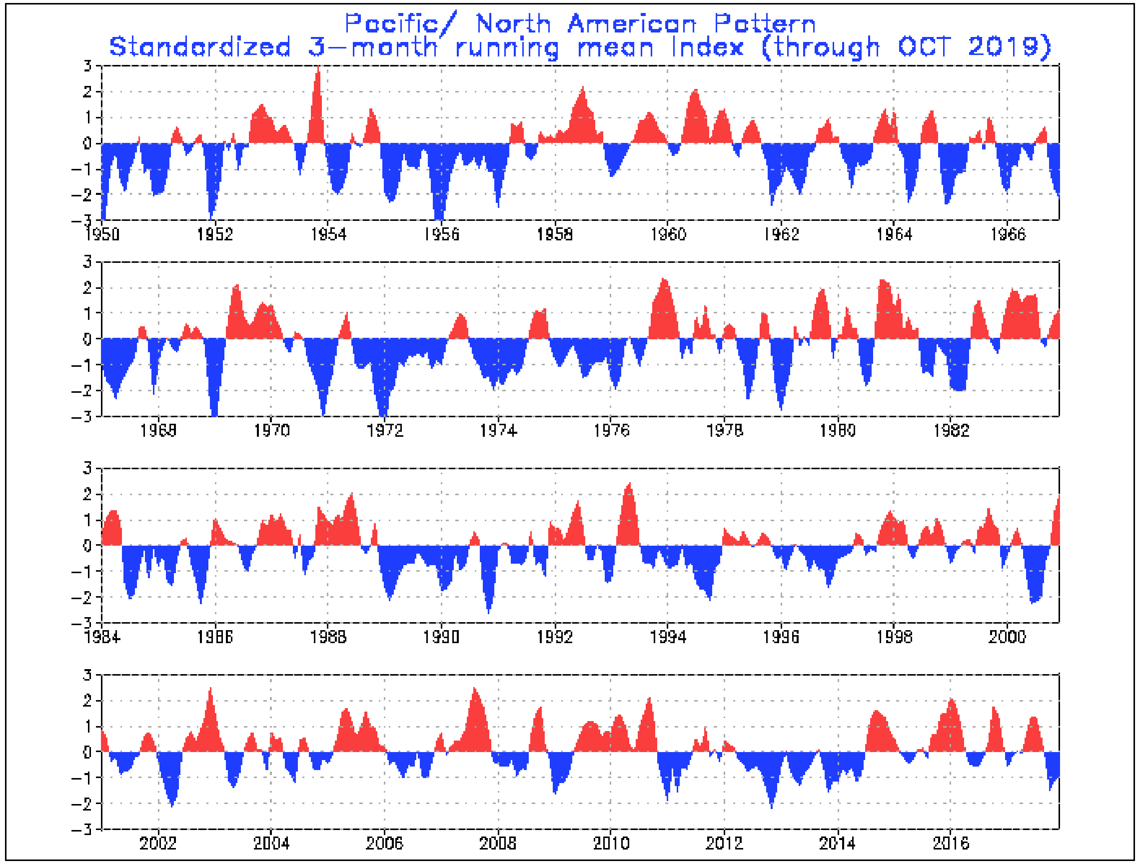
NOAA/ESRL Physical Sciences Division

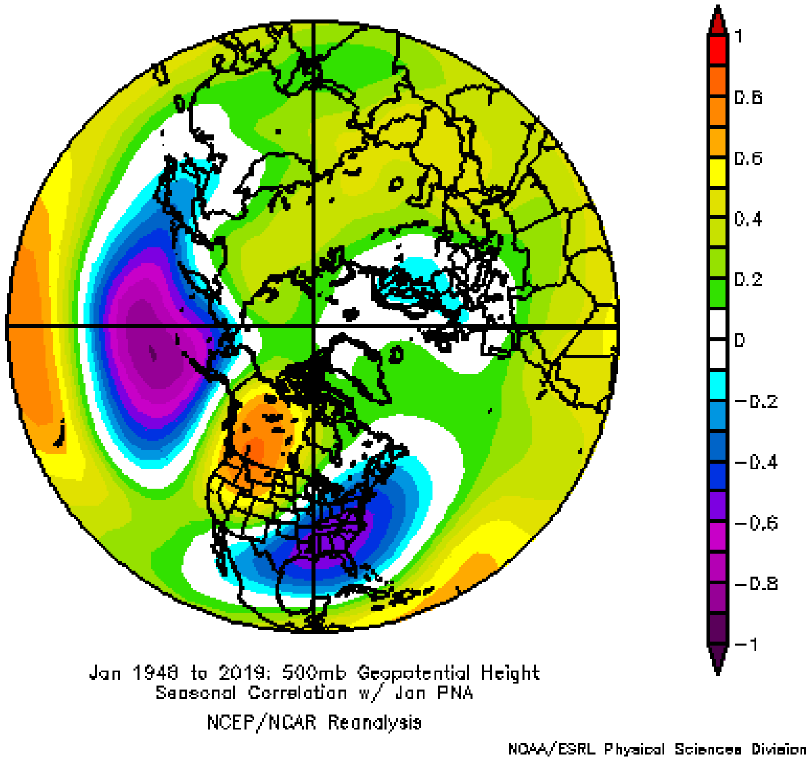
Near SLC
When 500 hPa heights above normal, then precipitation below normal
When 500 hPa height below normal, then precipitiation above normal

What about elsewhere?

PNA Teleconnection Pattern

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

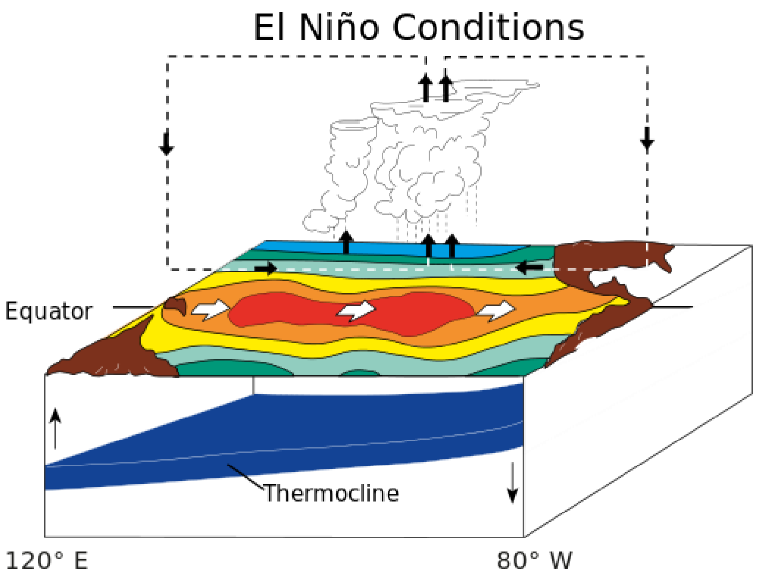


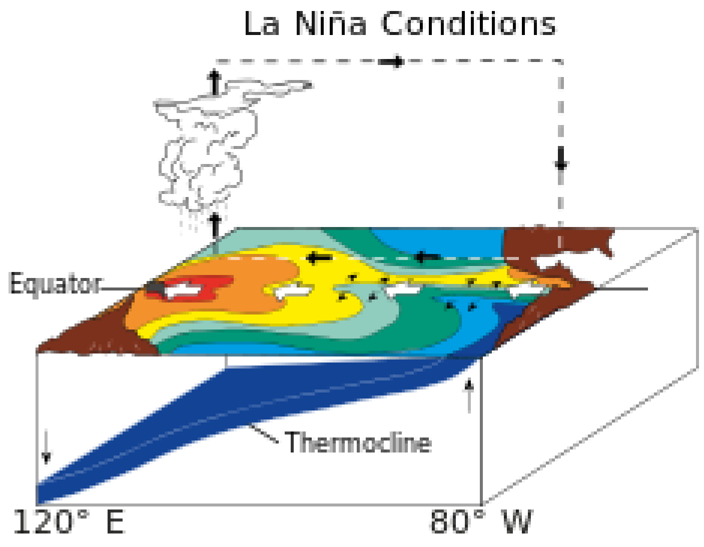


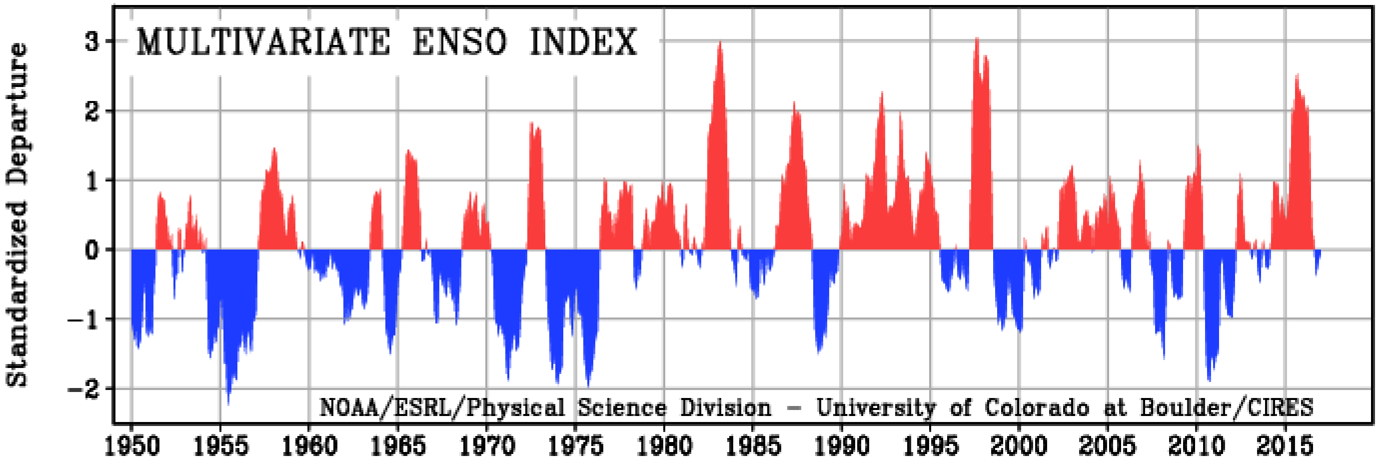
Pacific North American teleconnection

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

ENSO Teleconnections







ENSO Related Linear Correlation Coefficients

TABLE 1. Matrix of contemporaneous correlation coefficients (×100) between the time series shown in Figs. 2, 3, 4, 7 and 10. The number of winter seasons used in each correlation, if less than the complete 28 seasons (1951–78), is indicated in parentheses.

	SST Index	SLP Index	200 mb Index	PNA Index	WP Index	Tarawa rainfall	Canton rainfall	Christmas rainfall	Fanning rainfall
SST Index									
SLP Index	−83								
200 mb Index	80	−68							
PNA Index	46	−31	57						
WP Index	67	−57	44	−00					
Tarawa rainfall	78	−71	63	32	65				
Canton rainfall	82 (23)	−65 (23)	61 (23)	40 (23)	65 (23)	60 (23)	(23)		
Christmas rainfall	64 (24)	−49 (24)	57 (24)	40 (24)	48 (24)	55 (24)	82 (19)	(24)	
Fanning rainfall	79 (23)	−60 (23)	69 (23)	38 (23)	70 (23)	72 (23)	85 (18)	84 (23)	(23)

Horel and Wallace (1981)

ENSO Teleconnections

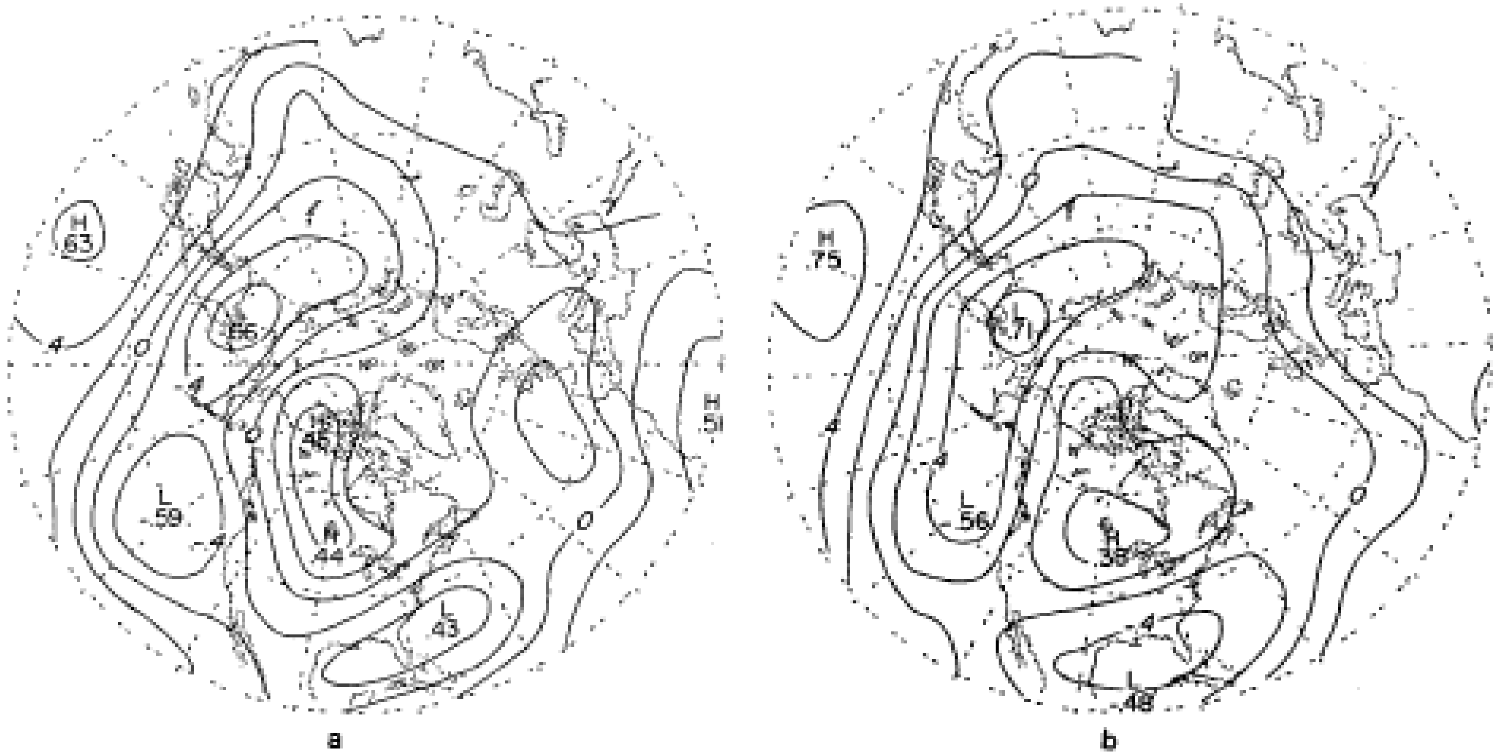


FIG. 9. Correlation coefficients between 700 mb geopotential height at gridpoints poleward of 20°N and (a) the Sea Surface Temperature Index, (b) December–February rainfall at Fanning, (c) our Southern Oscillation Index, and (d) the tropical 200 mb Index. Contour interval 0.2. The locations of the centers of action of the Pacific/North American and West Pacific patterns are denoted, respectively, by dots and open circles in Fig. 9d.

Teleconnections

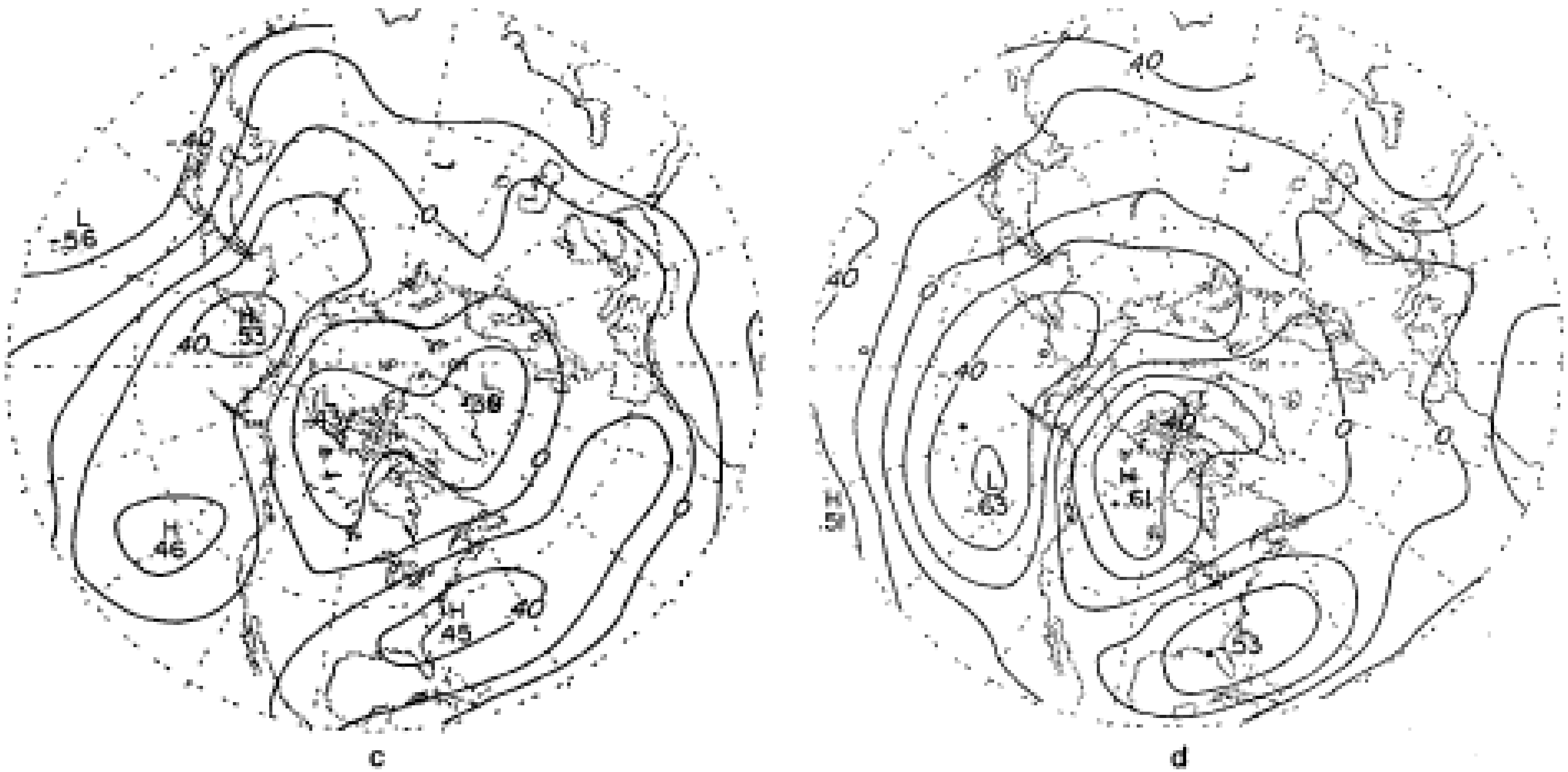


FIG. 9. Correlation coefficients between 700 mb geopotential height at gridpoints poleward of 20°N and (a) the Sea Surface Temperature Index, (b) December–February rainfall at Fanning, (c) our Southern Oscillation Index, and (d) the tropical 200 mb Index. Contour interval 0.2. The locations of the centers of action of the Pacific/North American and West Pacific patterns are denoted, respectively, by dots and open circles in Fig. 9d.

Correlation

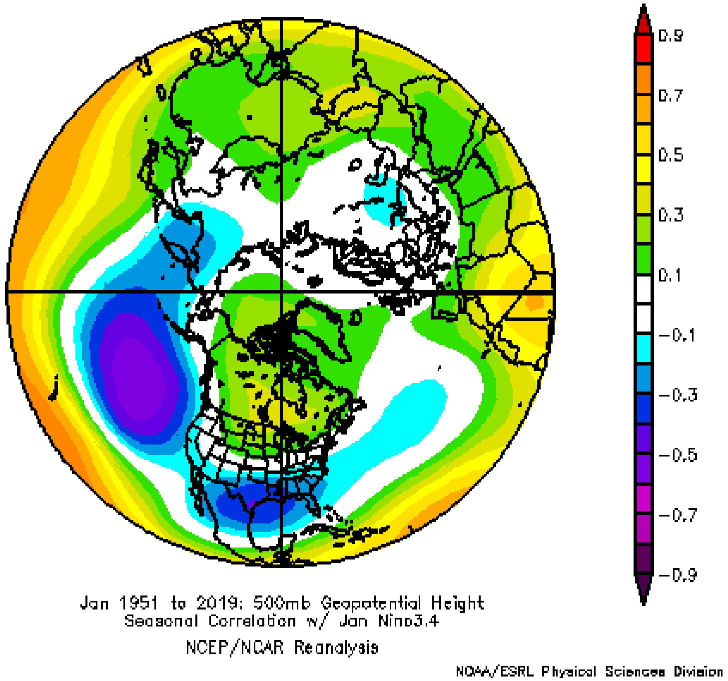


Figure 4.9a. Correlation between the equatorial Pacific SST index during January from 1951-2019 with 500 mb height anomalies in the Northern Hemisphere.

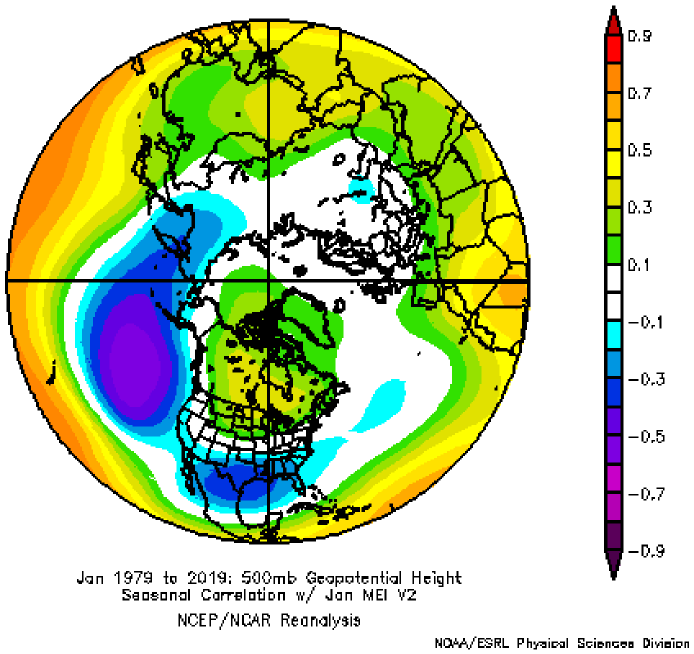


Figure 4.9b. Correlation between the equatorial Pacific SST MEI index during January from 1979-2019 with 500 mb height anomalies in the Northern Hemisphere.

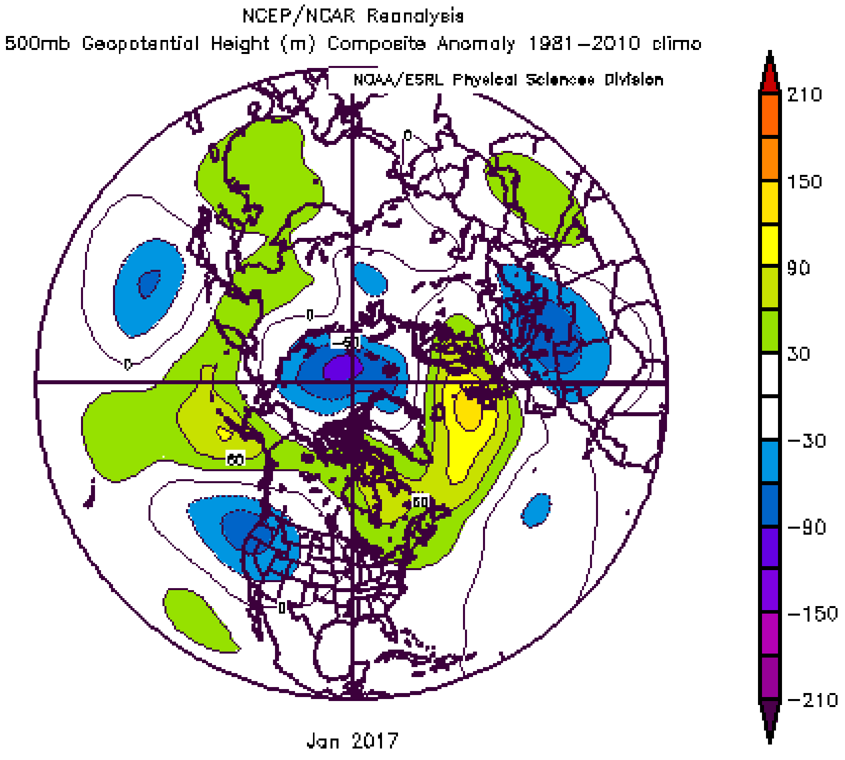
Correlating Maps Rather Than Time Series

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

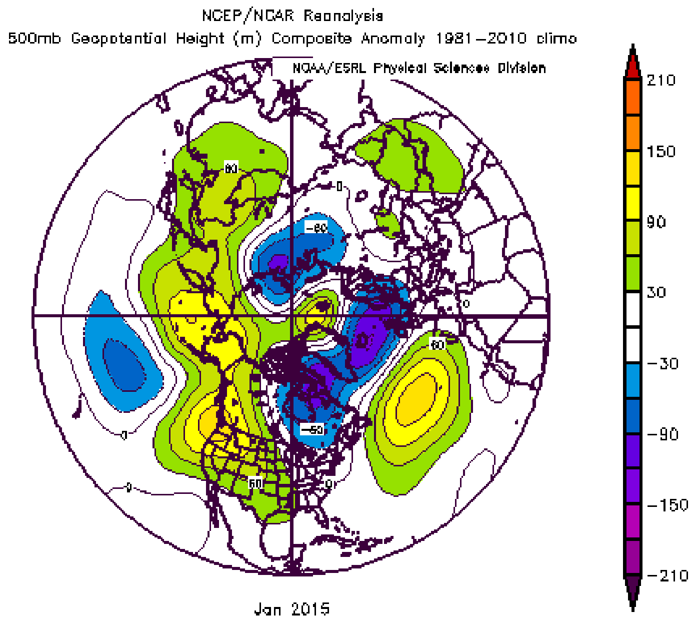
$$\vec{S} = \hat{\vec{X}} *^{T} \hat{\vec{X}} * \;/\, m$$

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

How similar are these two anomaly maps?



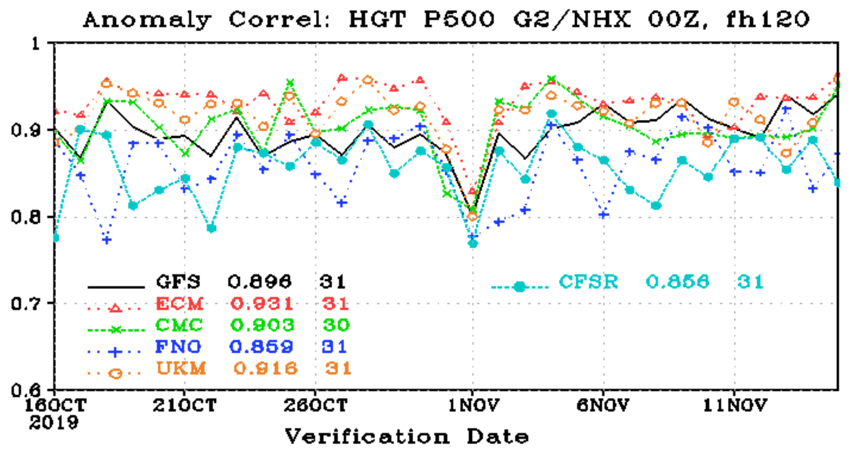
JAN 2017

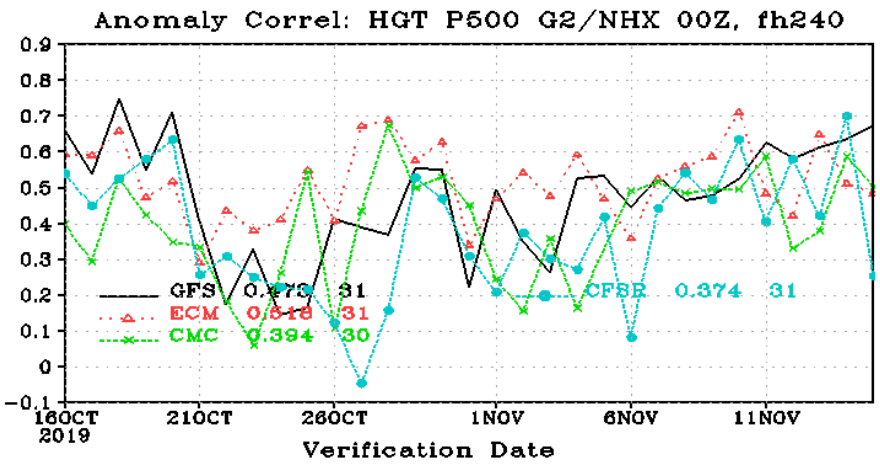


Jan 2015

Computing similarity between maps

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





Assignments: wrapping things up

- Read Chapter 4 notes
- Complete linear correlation assignment in class today
- Online final posted