THE IMPACT OF LARGE-SCALE CIRCULATION REGIMES ON EXTREME WEATHER OVER PACIFIC AND NORTH AMERICA

Sara Amini

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Outline

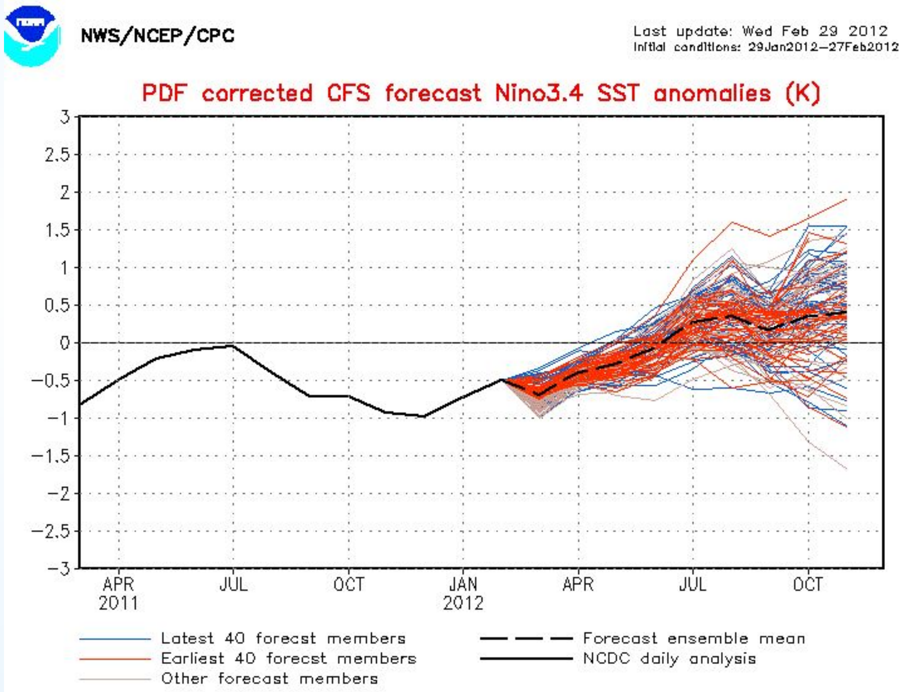
- Introduction
- Hypotheses
- Data sets
- Methodology
- Regime-dependent shifts in storminess
- Summary and Conclusions

Introduction

- Much attention has been paid to the simulation of precipitation (in particular) from various weather and climate models, although precipitation is one of the most poorly simulated and predicted quantities (5-7 days in advance).
- On the contrary, the current generation of forecast have shown generally good skill in simulating the large-scale fields of geopotential height and winds (a couple of months in advance).
- Since the frequency of occurrence of individual types of weather is modulated by changes in the planetary scale patterns, one may expect that patterns of storminess and extreme weather may be directly linked to the circulation regimes.

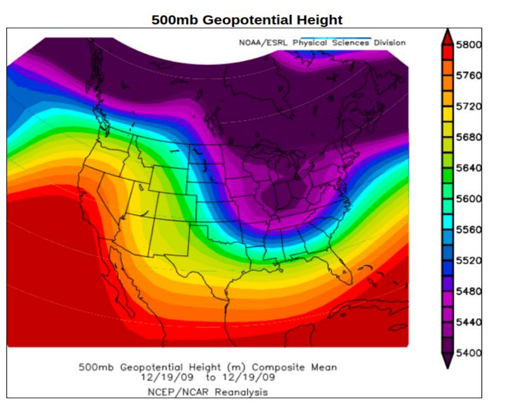
Ensemble Members

If ensembles are close to each other, we can say the variable is predictable in the region, but as the ensembles spread, which happens as time passes, the variable becomes less predictable.

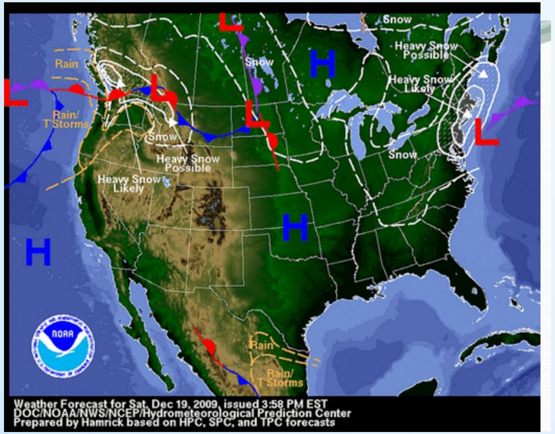


Geopotential Height (Z)

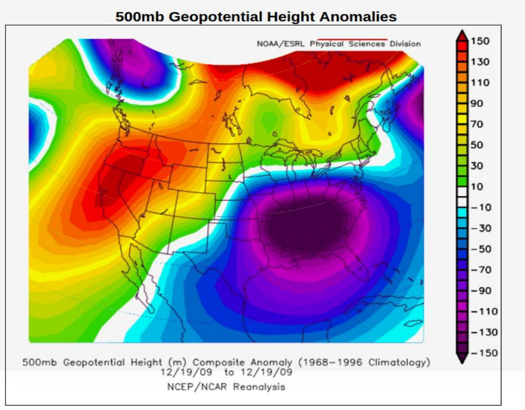
Geopotential height approximates the actual height of a pressure surface above mean sea-level. Therefore, a geopotential height observation represents the height of the pressure surface on which the observation was taken.



Since cold air is more dense than warm air, it causes pressure surfaces to be lower in colder air masses, while less dense, warmer air allows the pressure surfaces to be higher. Thus, heights are ***lower*** in **cold** air masses, and ***higher*** in **warm** air masses.



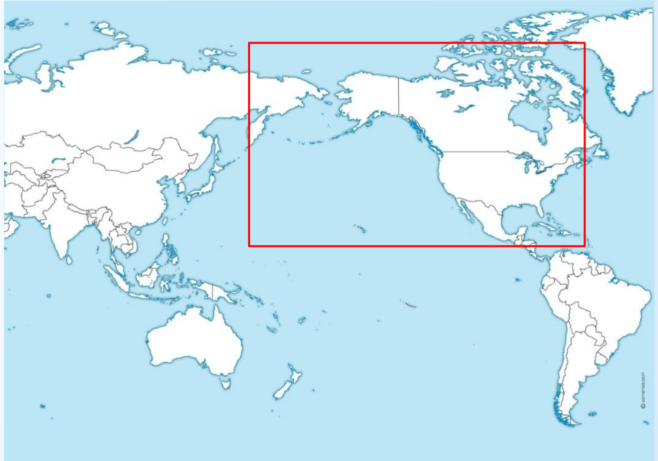
Geopotential height anomalies consist of deviations in the geopotential height field from average values.



What is our approach?

“Circulation Regimes”

Circulation regimes are preferred states of the large-scale circulation. These regimes are normally identified and studied over a region with a horizontal length scale of the order of tens of thousands of kilometers (planetary scale). In this study, the Pacific-North America domain has been chosen and the connection between circulation regimes and the associated pattern of storm related quantities (e.g. extreme precipitation) will be investigated over this domain.



Hypotheses

- The circulation regimes that are preferred large-scale states, strongly influence the weather (storm-related) quantities, including precipitation extremes over Conterminous United States.

- This influence is robust enough and reproducible enough in forecast models, to provide the scientific basis for possible future forecasts of extreme weather using circulation regimes.

Data sets

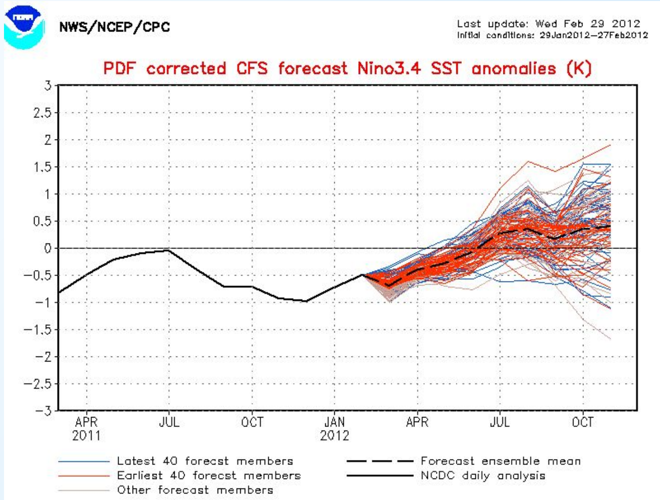
Period of December-February for the 35 winters: 1980/1981-2014/2015.

- **ERA-Interim reanalysis**
- **Reforecast data set:**

METIS reforecasts have been produced by a COLA/ECMWF project (PI Ben Cash).

ECMWF coupled model, consisting of Integrated Forecast System (IFS) atmospheric model (at resolution TC 199) coupled to the 1.0^{o} ocean model (IFS 60 km horizontal resolution, 91 levels).

Ensembles of 25 six-month reforecasts from start date of November 1st

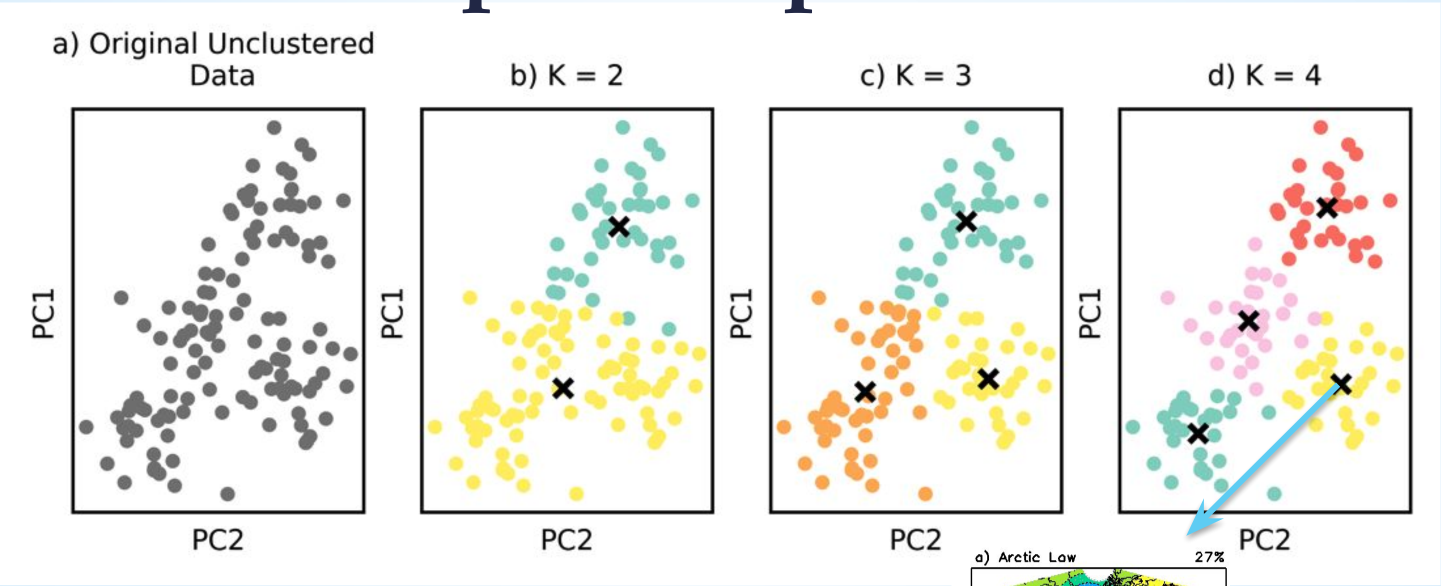


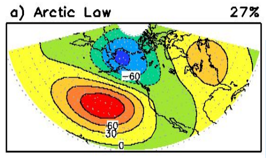
Methodology

Circulation Regimes

- We worked with data vectors of Z500 over the Pacific-North America region.
- The field was first filtered in time (to remove rapid synoptic scale transients) by forming running five-day means and had the climatological seasonal cycle removed.
- A principal component analysis was applied to the vector, with the leading 12 modes explaining approximately 80% of the total (normalized) variance. The principal component (PC) time series constitute the coordinates of the system in a 12-dimensional phase space.

Applying k-means algorithm in a 2D phase space

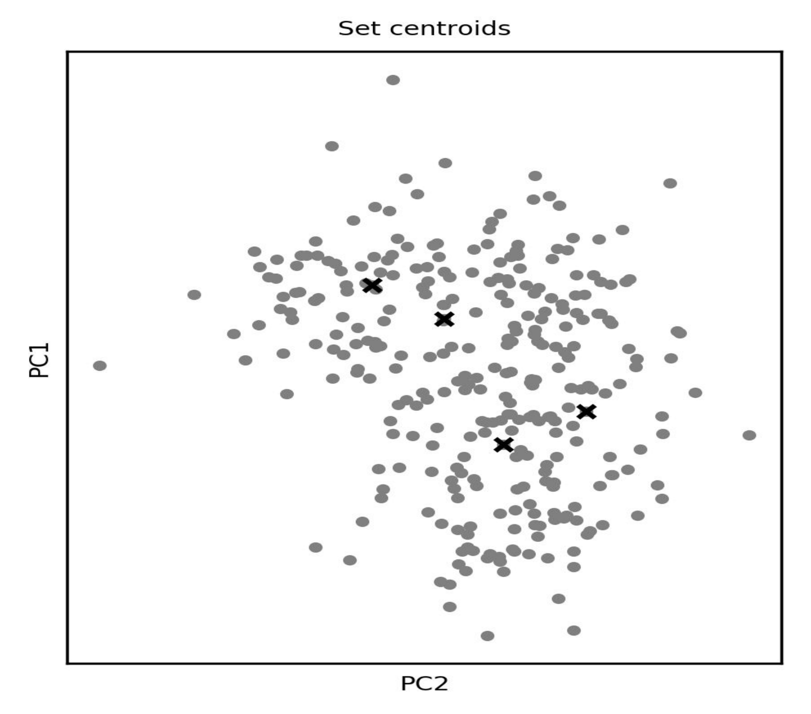




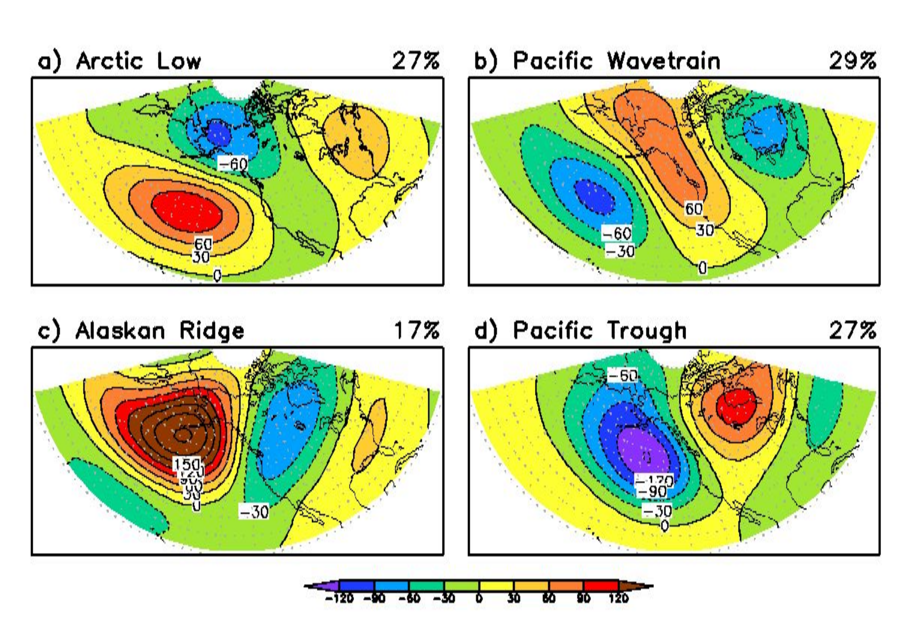
Each point is one state

Cluster analysis finds groups of states that are clumped together.

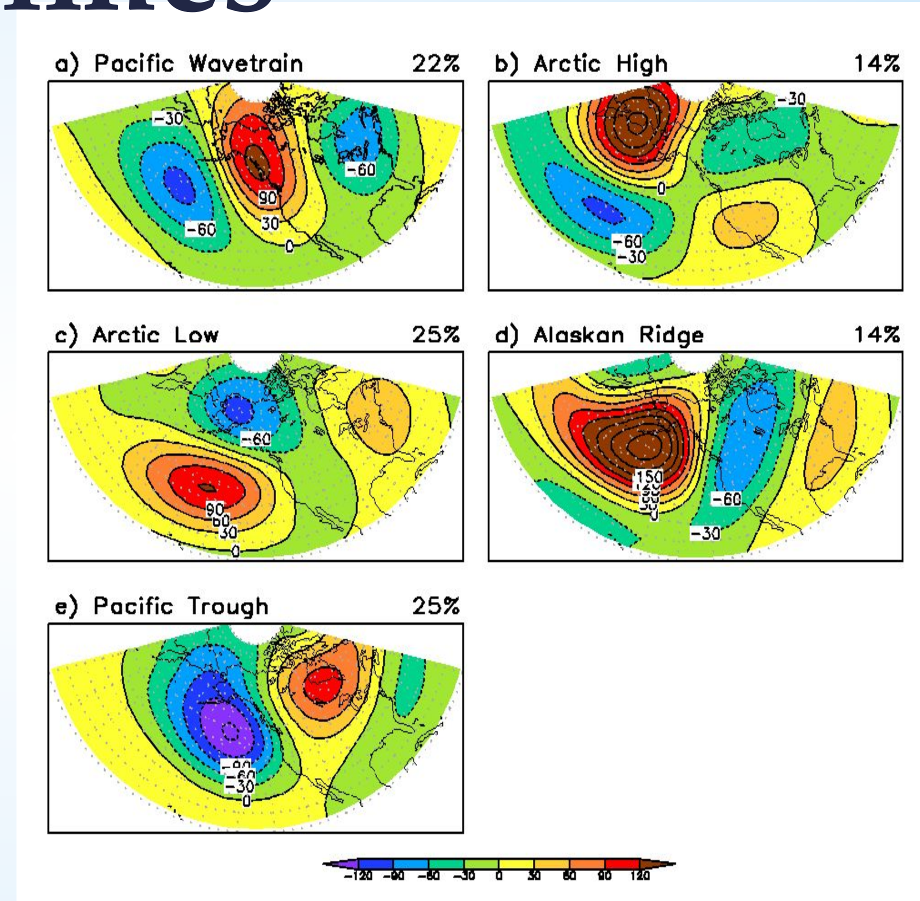
How K-means algorithm works?



Circulation Regimes



The maps of Z500 for k = 4



Amini and Straus (2018)

The maps of Z500 for k = 5

Methodology

- For each regime we present:

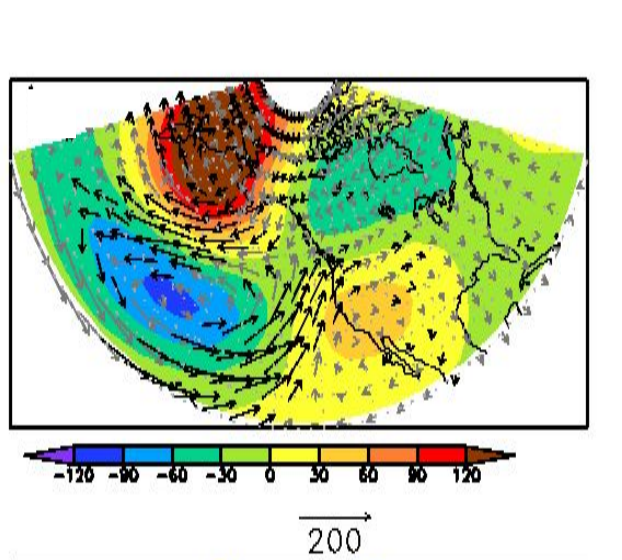
the ratio (r) of the frequency of occurrence of extreme precipitation (5^{th} and 95^{th} percentile) in each regime to that expected based on the climatology of the extremes and the number of states in any particular regime.

$$r = \frac{\text{number of states (days) in cluster A with precipitation value greater than } 95^{th} \text{ (or } 5^{th}\text{) percentile}}{\text{number of states (days) that are assigned to cluster A } \times \text{ 0.05 (or 0.95)}}$$

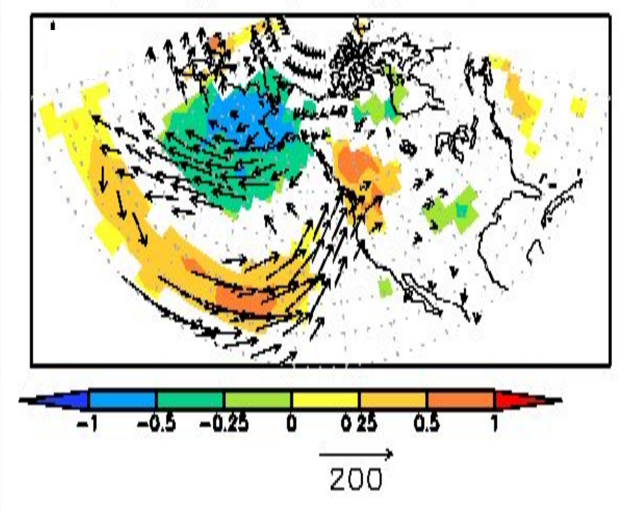
Statistical significance of each cluster-related map is assessed by using bootstrap resampling (with replacement).

Regime-Dependent Shifts in Storminess

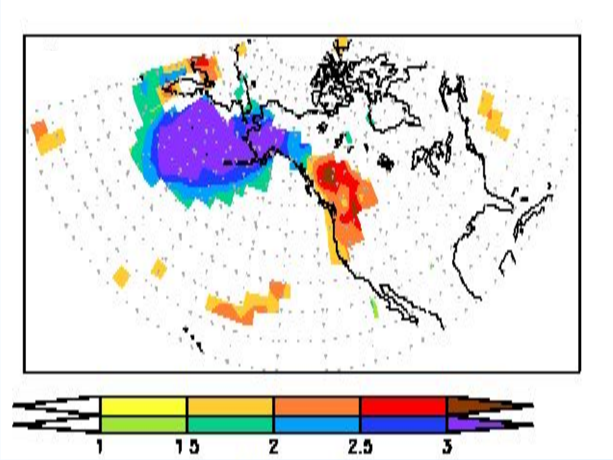
Arctic High



Z500 composite anomalies (shading; units of m), Significant anomalous vertically integrated moisture flux (arrows, units of $kgm^{-1}s^{-1}$).



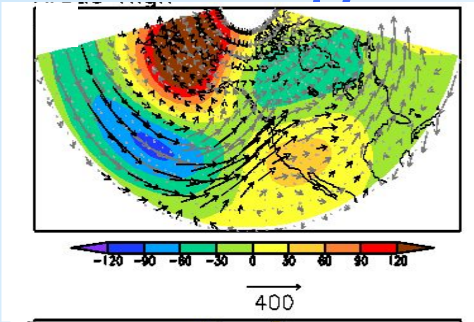
Normalized shift in precipitation mean (units of standard deviation)

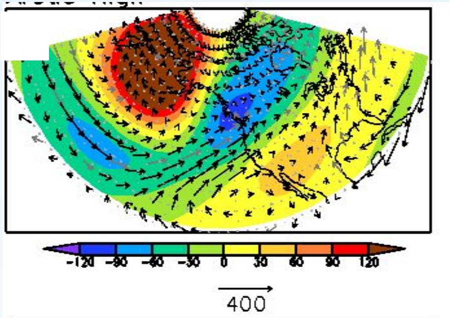


Ratio of extreme precipitation (95^{th} percentile) and intra-seasonal drought (5^{th} percentile) in upper and lower color bar, respectively.

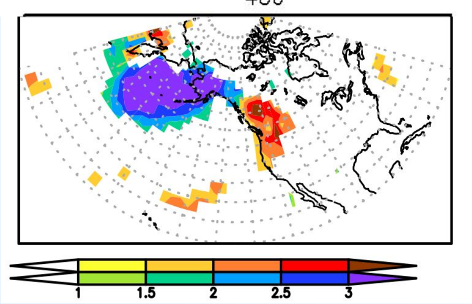
Amini and Straus (2018)

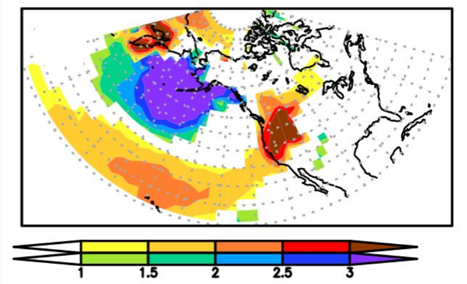
Arctic High





Z500 composite anomalies (shading; units of m), Total vertically integrated moisture flux (arrows, units of $kgm^{-1}s^{-1}$).





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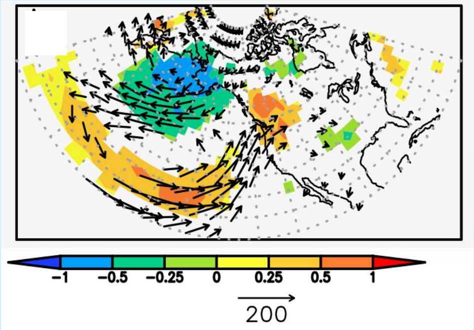
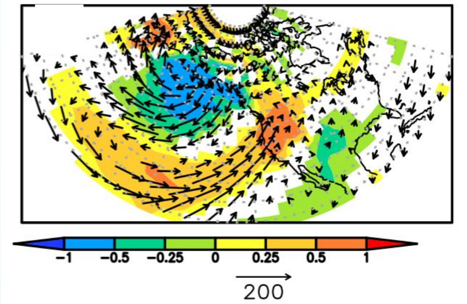




Normalized shift in precipitation mean (units of standard deviation)

ERA-Interim (OBS)

METIS (MODEL)

Amini and Straus (2018)

Summary and Conclusion

1. Climate Models have high skill in predicting large-scale circulations (e.g. Geopotential Height)

2. Climate Models have low skill in predicting storm related quantities (e.g. extreme precipitation)

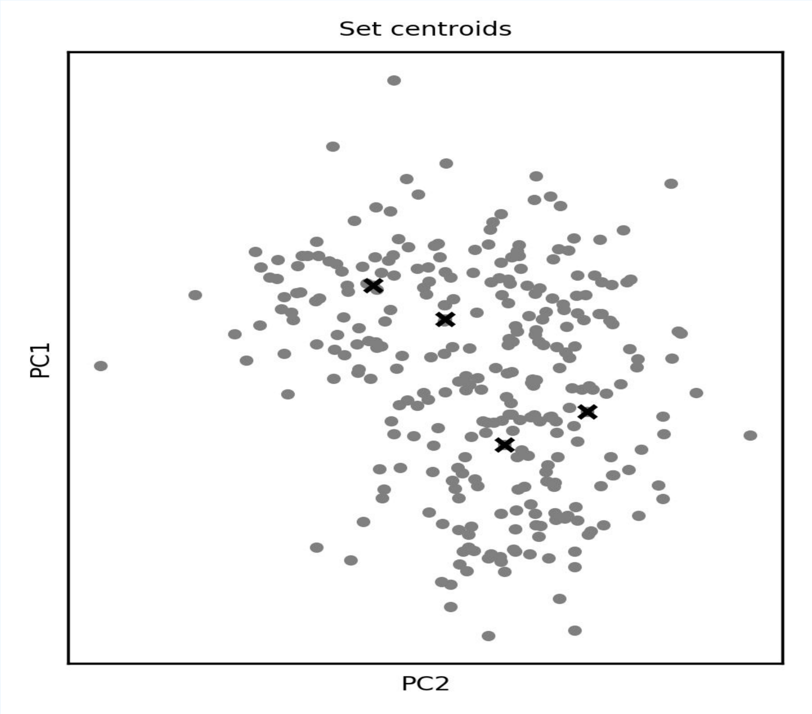
3. The circulation regimes strongly influence the weather (storm-related) quantities.

4. This influence is robust and reproducible in forecast models.

5. As the patterns of circulation regimes are predictable, the connection between large-scale circulation regimes and storm related quantities has real implications for predictability in mid-latitudes. This link can be expanded upon for further climate studies and used as a basis for predicting the extreme events.

Thank You

How K-means algorithm works?



Spatial Correlation

1. calculates the area average aa1 and aa2 for the two input grids, g1 and g2
2. subtracts the area average from each grid: g1=g1-aa1 and g2=g2-aa2
3. calculates g1*g2, as well as the squares of each grid, g1*g1 and g2*g2.
4. calculates the area average of the squares of each grid (s1 and s2) and the area average of the product of the two grids (c)
5. result is c/sqrt(s1*s2)

Statistical Significance Test

Bootstrap resampling method:

Repeat 1000 time:{

For each day_i from $year_y$:{

synthetic.day[day_i,$year_y$] = pick a random day from 35 DJF (sampling *with replacement)*

if (cluster.index[day_i,$year_y$]==cluster.index[(day_{i-1},$year_y$]){

synthetic.day[day_i,$year_y$] = (synthetic.day[(day_{i-1}+1),$year_y$])

}

}