Use of Hurst Analysis and Renyi Entropy to Detect and Characterize PDO Impacts on Climate Variability in Alaska #T105B

[1]J. Talbot, [1]U.S. Bhatt, [2]D. E. Newman, [2]R. Wackerbauer, [3]R. Sanchez and [4]I.V. Polyakov, [1]H. Angeloff, [5]R. Thoman, [1]P. Bieniek

[1] Geophysical Institute & Dept. Atmospheric Sciences at U. Alaska Fairbanks (UAF), [2] Dept. of Physics UAF, [3]Carlos III, Dept. of Physics, [4]International Arctic Research Center, UAF [5]NOAA/NWS, Fairbanks

World Climate Research Program, Open Science Conference, Denver CO, October 25, 2011

Main Results

- Hurst analysis indicates SAT becomes less random at 5-15 year timescale at various Alaska stations after 1976.
- Renyi analysis displays a tendency towards more order after 1976. (Potential usefulness for seasonal predictability)
- NCEP/NCAR Reanalysis SAT also displays shift towards more persistence/order after 1976.
- Stations with enhanced persistence have increased oceanic influence (more maritime) after 1976.

Goal and Method

Goal: **Apply methods from nonlinear dynamics community to characterize observations and climate models. These methods provide additional tools with which we can better validate GCMs.**

2 Nonlinear Methods:

a) Hurst Exponent (Long time scales 5-15 yrs)

- **Rescaled Range Method**
- **H = 0.5 random, H < 0.5 antipersistent, H > 0.5 persistent (predictable)**

b) Renyi Entropy (Short time scales ~10 days)

- **take the anomaly data set, and transform to 0's & 1's**

  e.g. {0.12, -0.02, 0.73, 1.23, 0.67, -0.09, -0.24 ...}

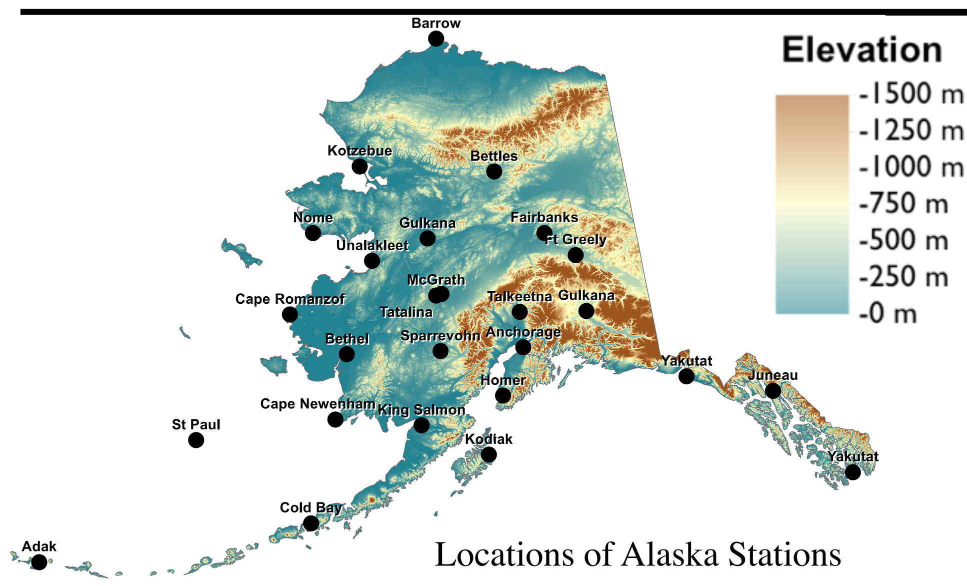
  becomes { 1, 0, 1, 1, 1, 0, 0 ...}
- **Count clusters of numbers called 'words', e.g. 000,001,010 etc**
- **Bigger (smaller) q weights the entropy with more (less) probable words**

Data: a) Daily Alaska station T and SLP are from NCDC Global Summary of the Day data set. (1946-2007).

b) NCEP/NCAR reanalysis, 20th Century Reanalysis, CCSM4

c) Zhang et al. (2004) SLP based storm track data

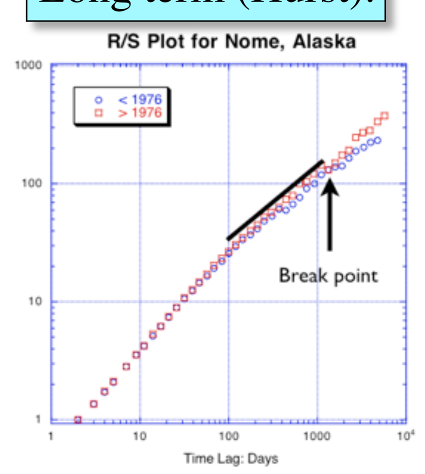
Hurst and Renyi Change after 1976 Shift

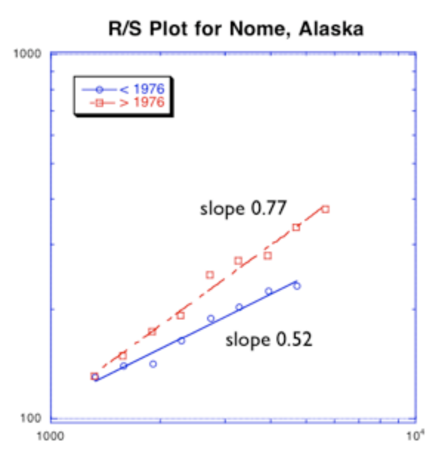


Locations of Alaska Stations

- **R/S analysis for full period displayed signs of nonstationarity.**
- **1948-75 & 1976-2007 analyzed separately.**
- **Numerous Alaska stations display more persistence after 1976.**

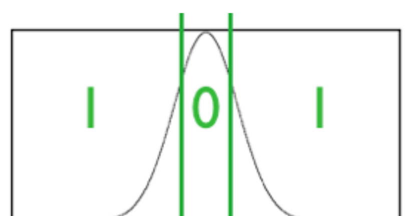
Long term (Hurst):

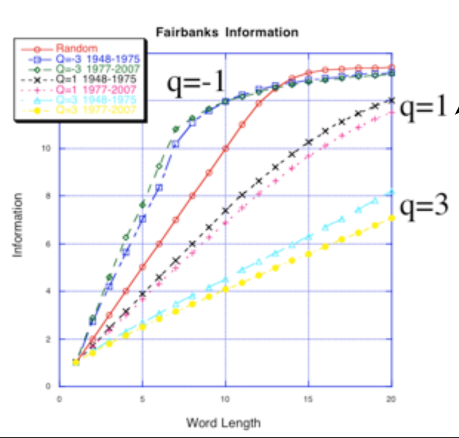




More random

Short term (Renyi):





More random

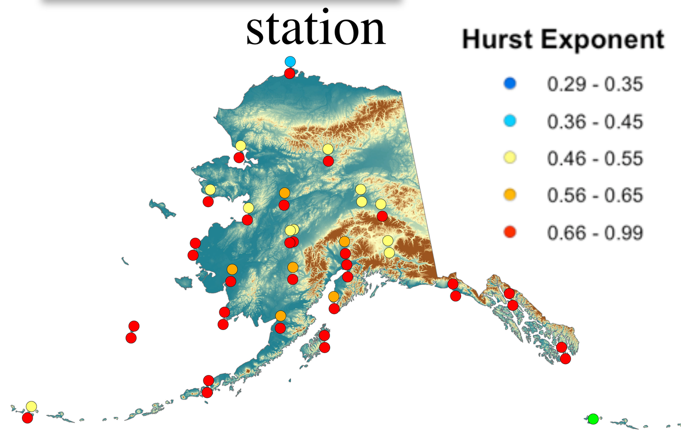
- **Quartile partition used to avoid describing autocorrelation.**
- **There is increased order for common and rare events.**
- **NCEP/NCAR Reanalysis SAT also display a shift towards more order after 1976.**

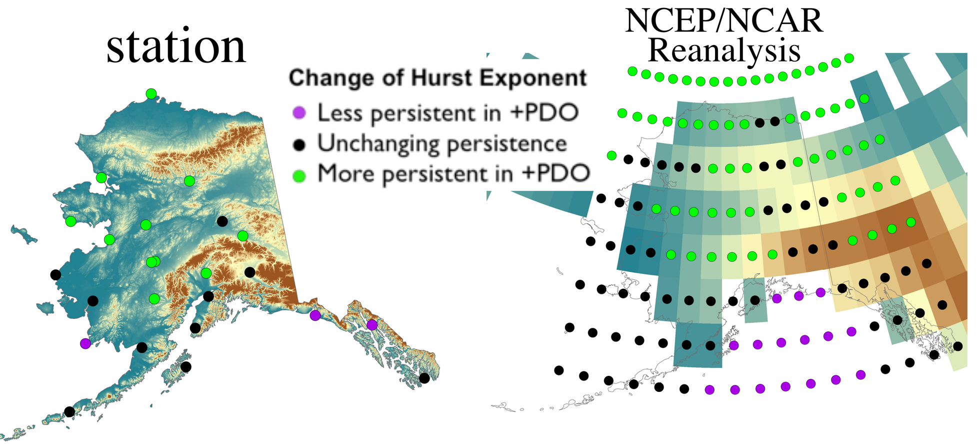
Station & NCEP Results Compare Favorably (SAT & SLP)

- **SAT is less random on long term & short term during +PDO**

Long term (Hurst):

SAT

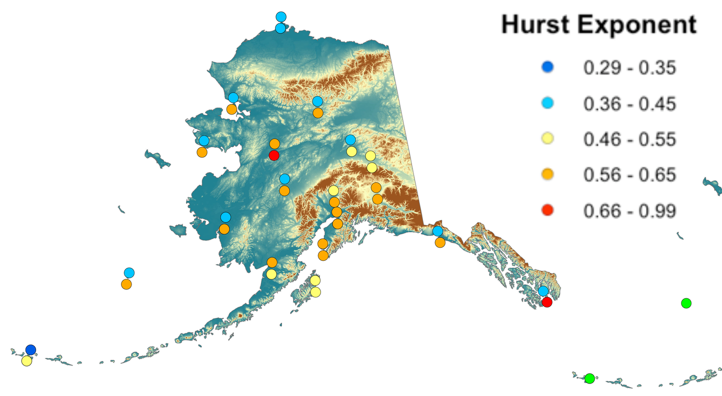


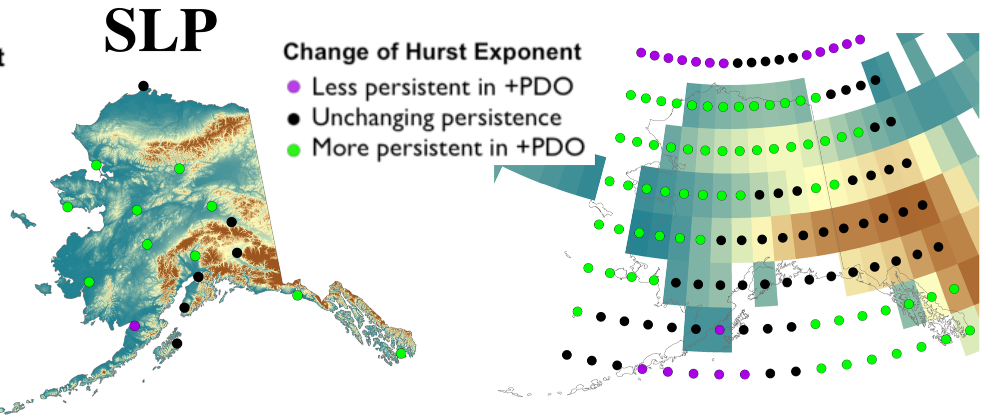


Top dot: H for 1948-1975
Bottom dot: H for 1977-2007

Change of H in +PDO compared to -PDO

SLP

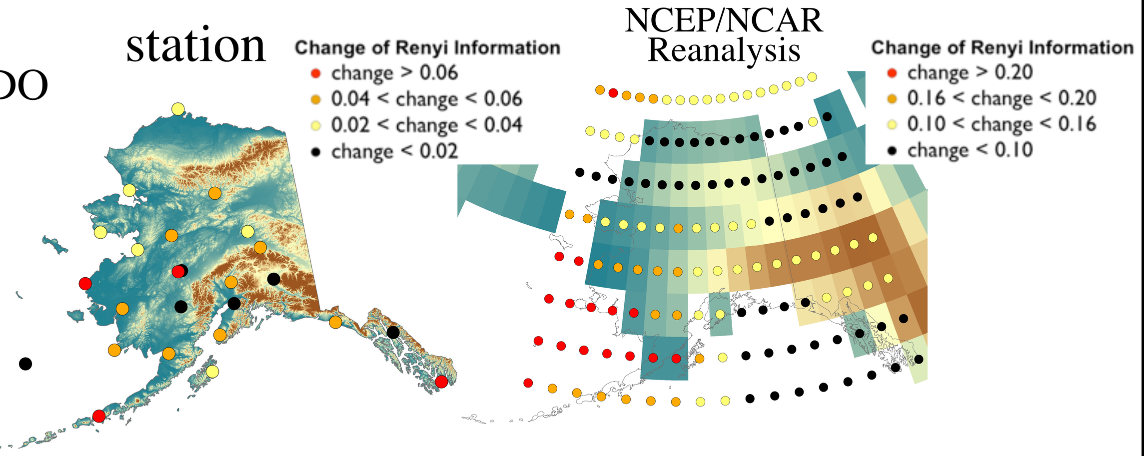




Short term (Renyi):

- SLP shows no change with PDO
- SAT less random with +PDO
- SAT change exaggerated in NCEP/NCAR Reanalysis

SAT



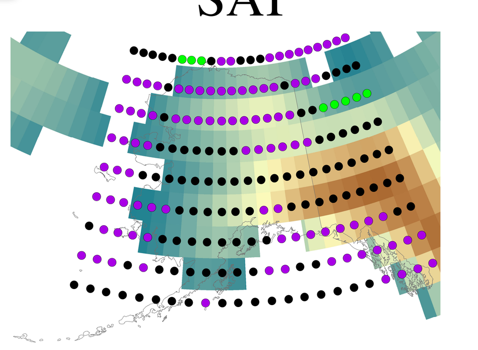
Do all +PDO phases display less randomness?

20th Century Reanalysis: 1925-1945 (+PDO) compared to 1948-1975 (-PDO)

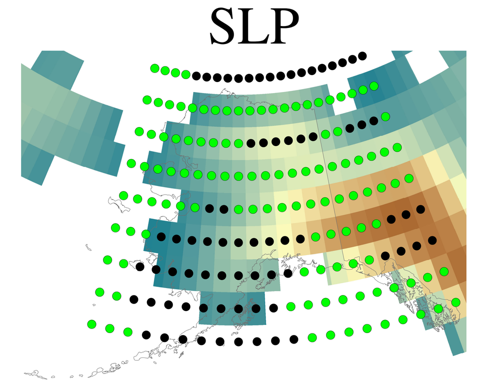
Long term (Hurst):

No: 20th Century SAT very inaccurate compared to NCEP/NCAR SAT

SAT



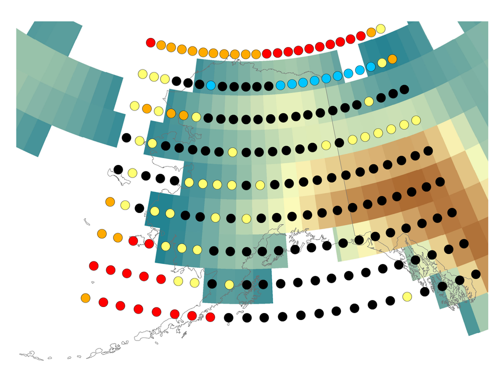
SLP



Yes: 20th Century assimilated SLP accurate compared to NCEP/NCAR SAT

Short term (Renyi):

SAT

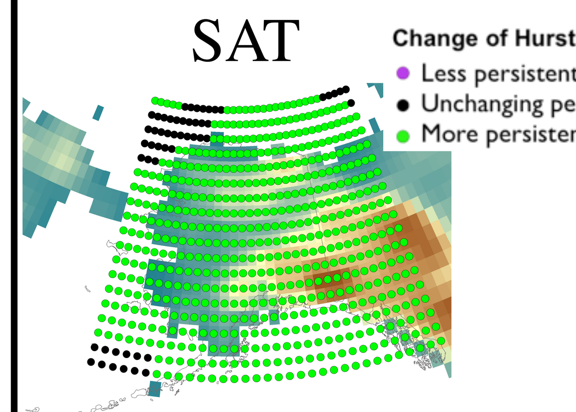


Maybe: Different than station data: there is a difference, but 20th Century Reannalysis emphasizes the difference over the South Bering Sea

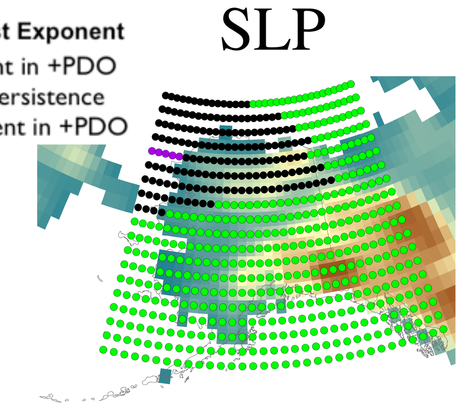
Does CCSM4 Change With Pacific Decadal Variability?

Long term (Hurst): CCSM4 20th Century Run Short term (Renyi):

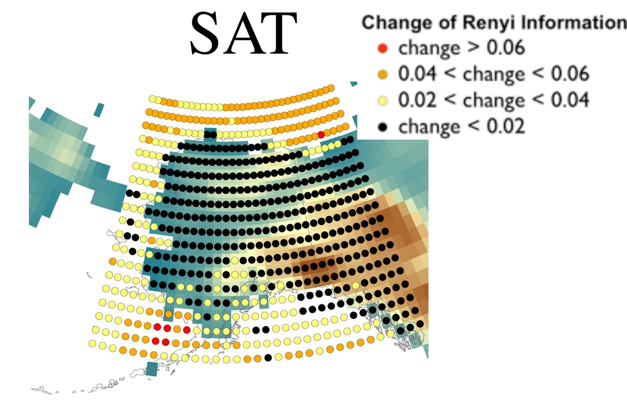
SAT



SLP



SAT

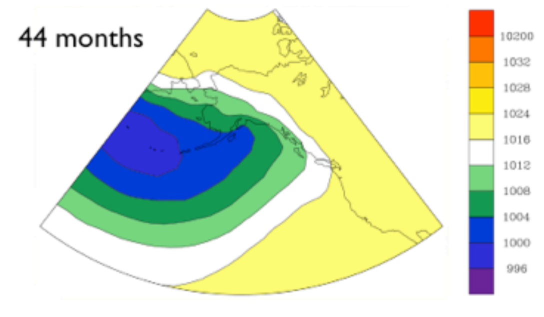


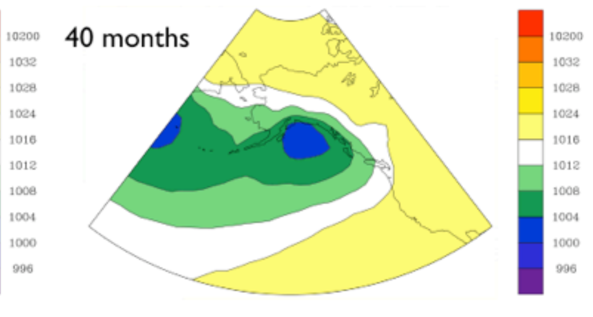
SAT most accurate compared to NCEP for long term; SLP overestimates persistence during both phases of the PDO, and is inaccurate in Northwest Alaska. Both SAT and SLP have overestimated persistence during +PDO.

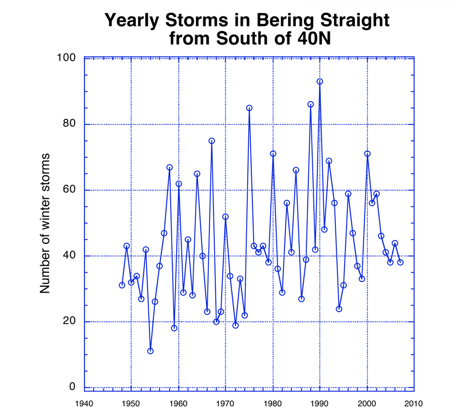
Short term increase of order during +PDO seen mostly over water. The short term effect seen in observations is not well propagated over land in the model.

Synoptic and Climate Explanation of Less Randomness

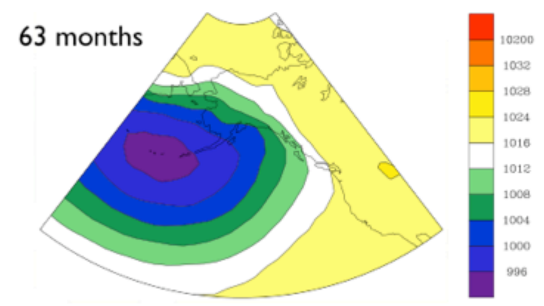
Winter 1948-1975

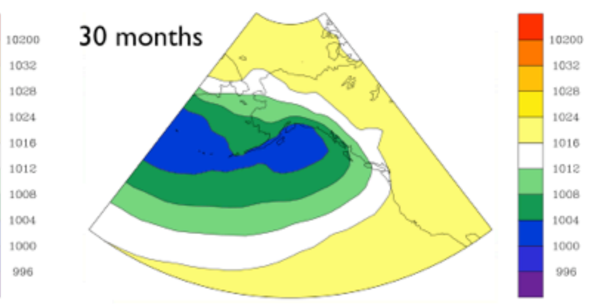


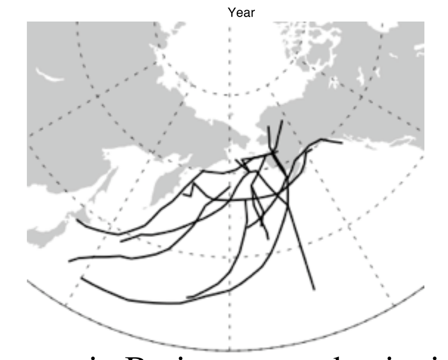




Winter 1977-2007







- This SLP pattern more common during +PDO. Equal frequency during -PDO
- This SLP pattern less common during +PDO. Equal frequency during -PDO
- Increase in Bering storms beginning below 40°N.
- No increase seen in total number of Bering storms.

1. During +PDO, station temperatures became more correlated (particularly those that become more persistent) with the Aleutian Low.

2. During +PDO, Aleutian Low becames stronger and more consolidated.

3. The strong low brings more warmer 'southern' storms into the Bering.

4. The storms increase 'maritime' influence consistent with larger persistence near coasts (Friedrich and Blender, 2003).

Applications of Methods:

★These methods have a useful place as *part* of your toolbox.

★ If climate models don't show the same 'dynamics' as observations then approach long-term studies cautiously.

★ These methods help point towards (*not determine*) where models need to be improved.

★ These methods provides hints as to what type of physics you need.

Acknowledgements

This work is supported by funding from the Department of Energy through grant number DE-SC0001898 .