The time-evolution of climatically significant salinity trends in the World Ocean

James Reagan[1,2], Dan Seidov[2], Tim Boyer[2], Melissa Zweng[2]

[1]UMD/ESSIC/CICS-MD
[2]NOAA/NESDIS/NCEI-MD

Contact E-mail: james.reagan@noaa.gov

Outline

- Background
  - Discuss Salinity and Evaporation/Precipitation over the Global Ocean
- Address two unanswered questions
  1. Are long-term trends in NSS persistent at shorter time scales?
  2. Can changes in NSS over time periods ranging from 20-50 years reveal climatic changes in the global hydrological cycle?
- Conclusions
- Current/Future Work

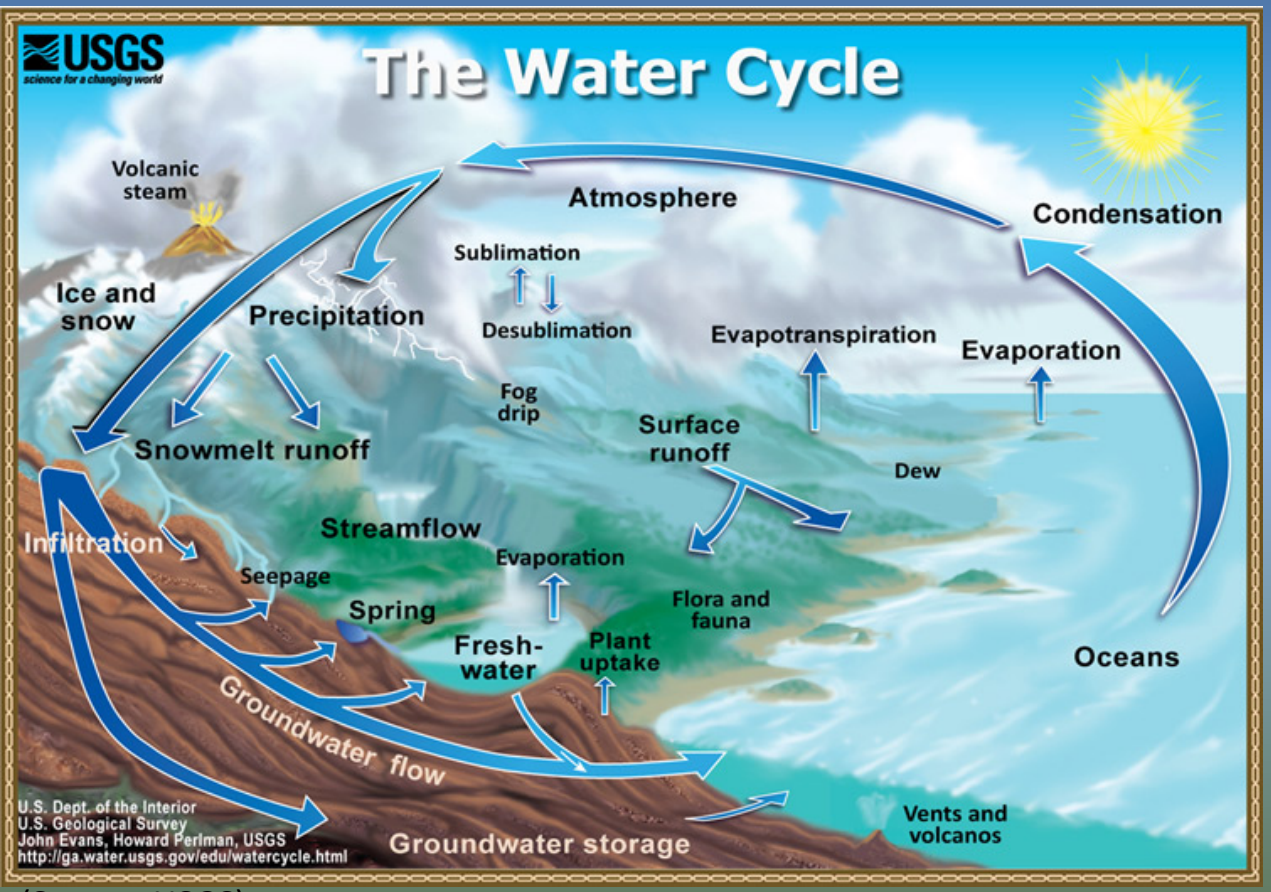
Salinity and Evaporation/Precipitation: What is their relationship?

$$\frac{dS_m}{dt} = \frac{(E-P)S_m}{h_m} - \mathbf{u}_e \cdot \nabla S_m - \mathbf{u} \cdot \nabla S_m + \kappa \nabla^2 S_m - w_e \frac{\Delta S_m}{h_m} - \mathbf{u} \cdot \nabla h_m \frac{\Delta S_m}{h_m} - F_i \frac{(\rho_i S_i - \rho_0 S_m)}{\rho_0 h_m}$$

(from Close and Goosse, 2013)

E > P = Salinity Increases
P > E = Salinity Decreases

The Water Cycle



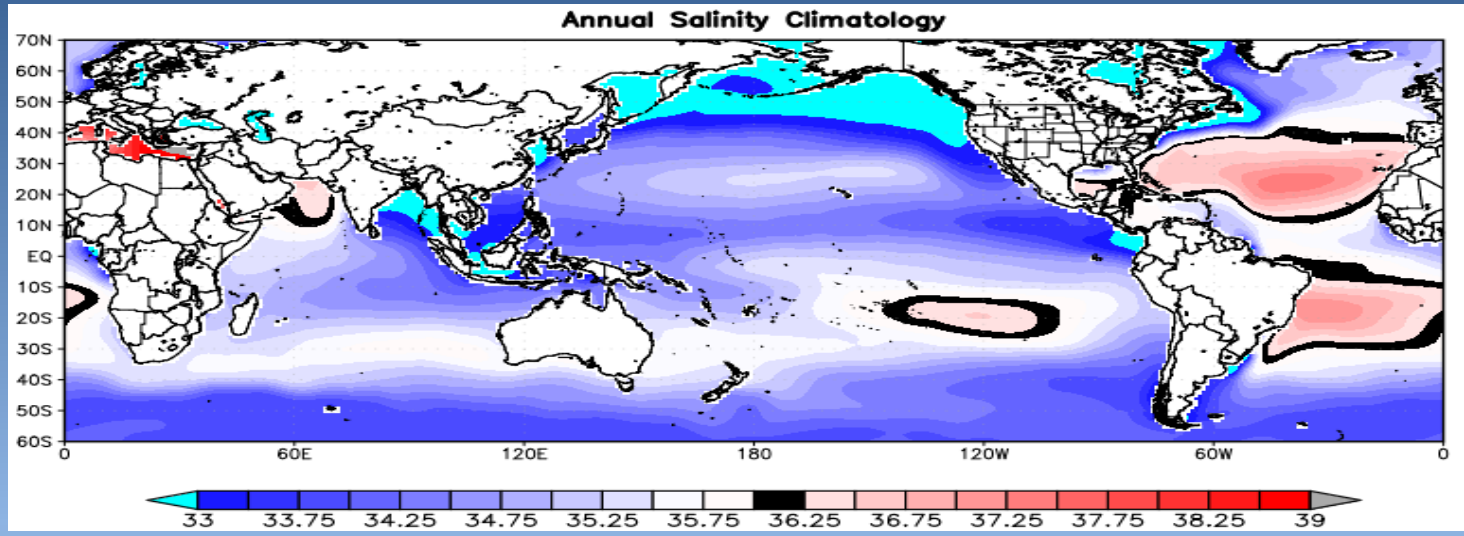
(Source: USGS)

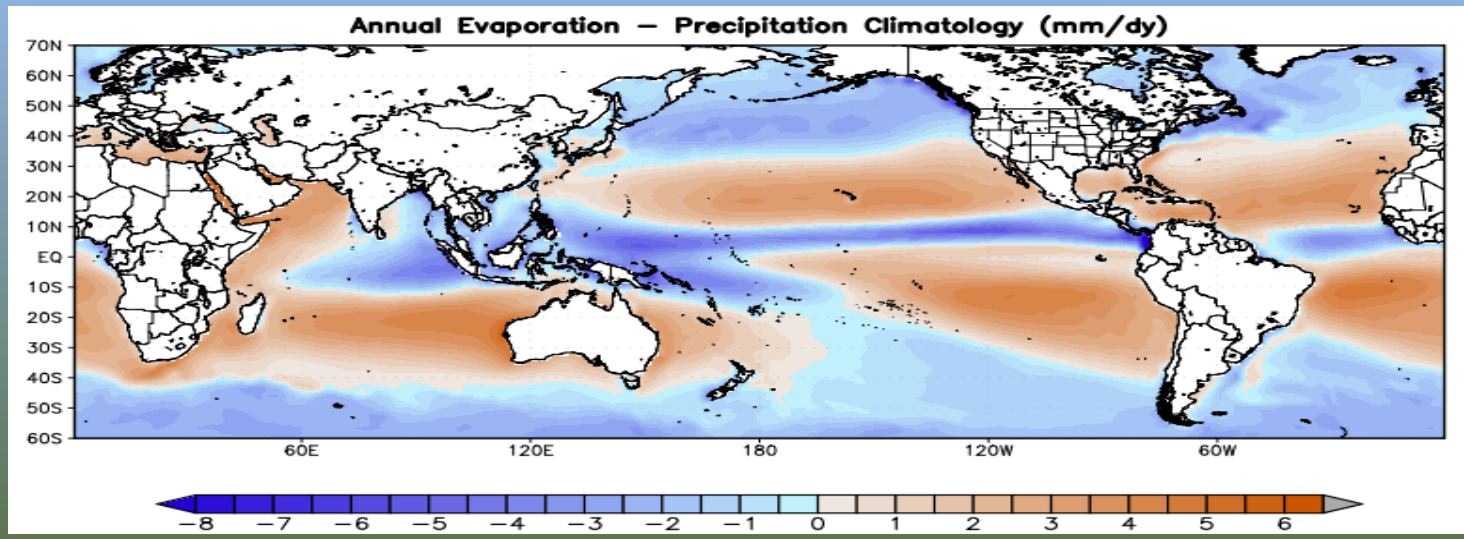
Quick Facts

- Ocean covers over 70% of the globe
- Ocean experiences ~86% of global evaporation and ~78% of global precipitation (Schmitt, 1995)
- Expected to amplify in a warming world (Held and Soden 2006) which could lead to an increase in floods and droughts (Trenberth, 2011).

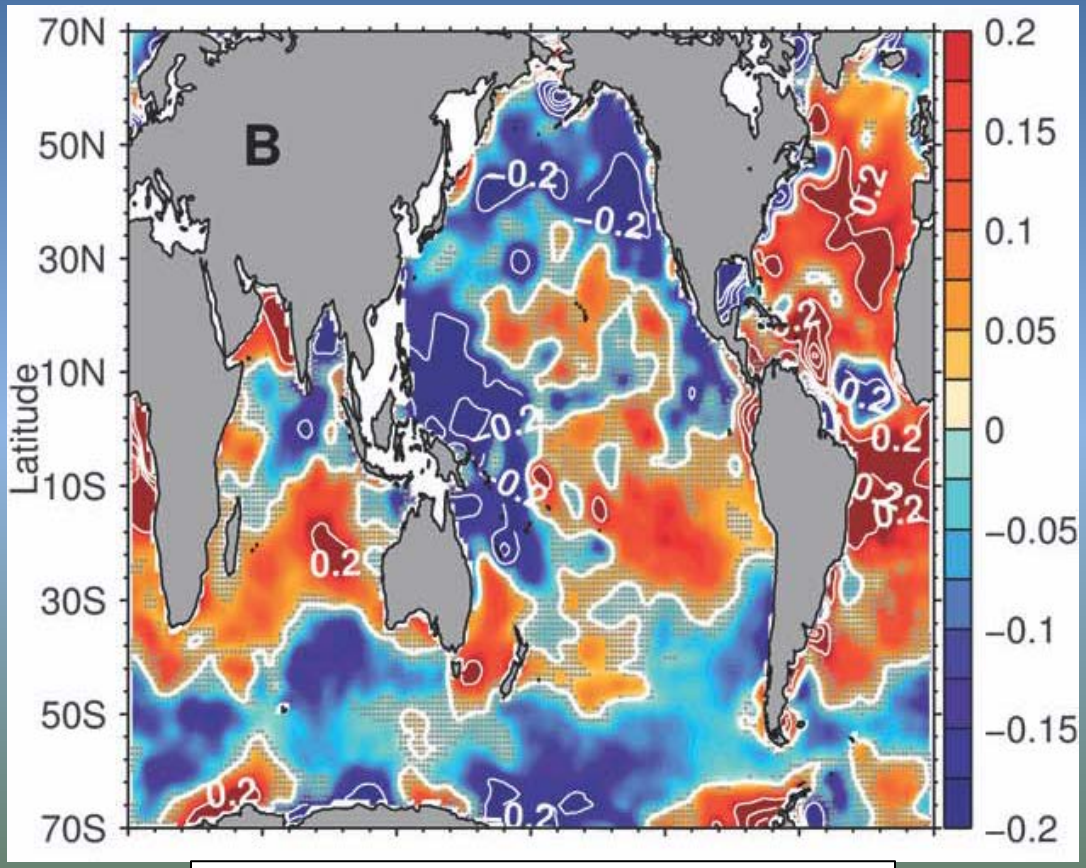
Near-surface Salinity (NSS) vs E-P

- Long-term means of NSS are highly correlated to the long-term means of E-P.





NSS: A proxy for estimating changes in the global hydrological cycle



1950-2008 NSS Trend (pss/50yr)
(from Durack and Wijffels 2010)

- It is well documented that salty regions are becoming saltier and fresh regions fresher (e.g., Boyer et al., 2005; Hosoda et al., 2009; Durack and Wijffels, 2010, etc.).
  - This implies that the mean salinity pattern is strengthening.
- E-P fluxes over the ocean have been difficult to use due to the uncertainty of the data (Lagerloef et al., 2010).
  - NSS can be used as a "natural rain gauge" to study freshwater fluxes in the ocean.
- Durack et al. (2012) estimated, through observed changes in salinity coupled with output from global climate models, that the mean NSS pattern amplified by 8% and the global hydrological cycle amplified by 4% from 1950-2000. The Earth's surface warmed by 0.5°C during this time (Trenberth et al. 2007).

Questions to Address

1. Are long-term trends in NSS persistent at shorter time scales?
2. Can changes in NSS over time periods ranging from 20-50 years reveal climatic changes in the global hydrological cycle?

Data

- Objectively Analyzed Pentadal (5-year) Salinity Anor
  - Der[illegible] from the World Ocean Database (Boyer et al.,
  - Da[illegible]
  - Ave[illegible] of 0-10m layer
- Worl[illegible] 2009)

6 National Services and International Leadership

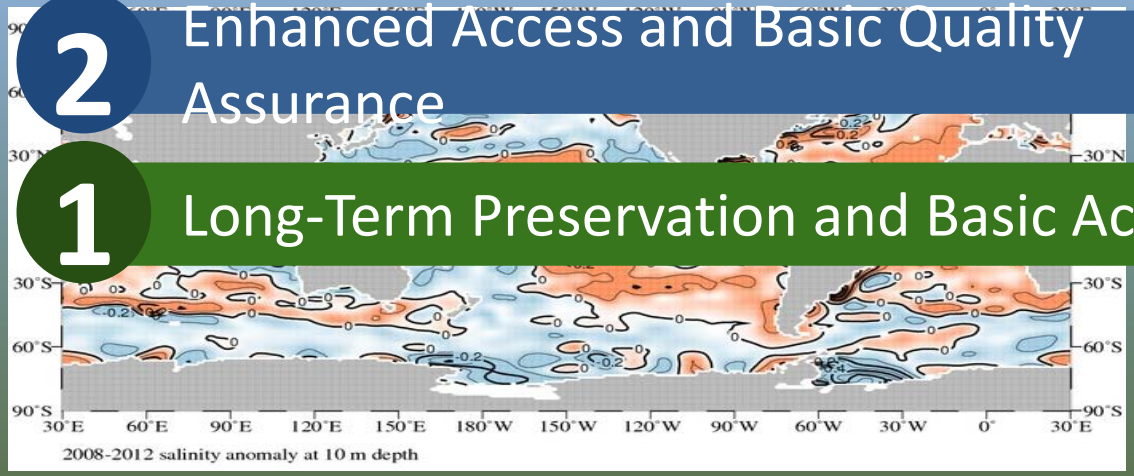
5 Authoritative Records

4 Derived Products

3 Scientific Improvements

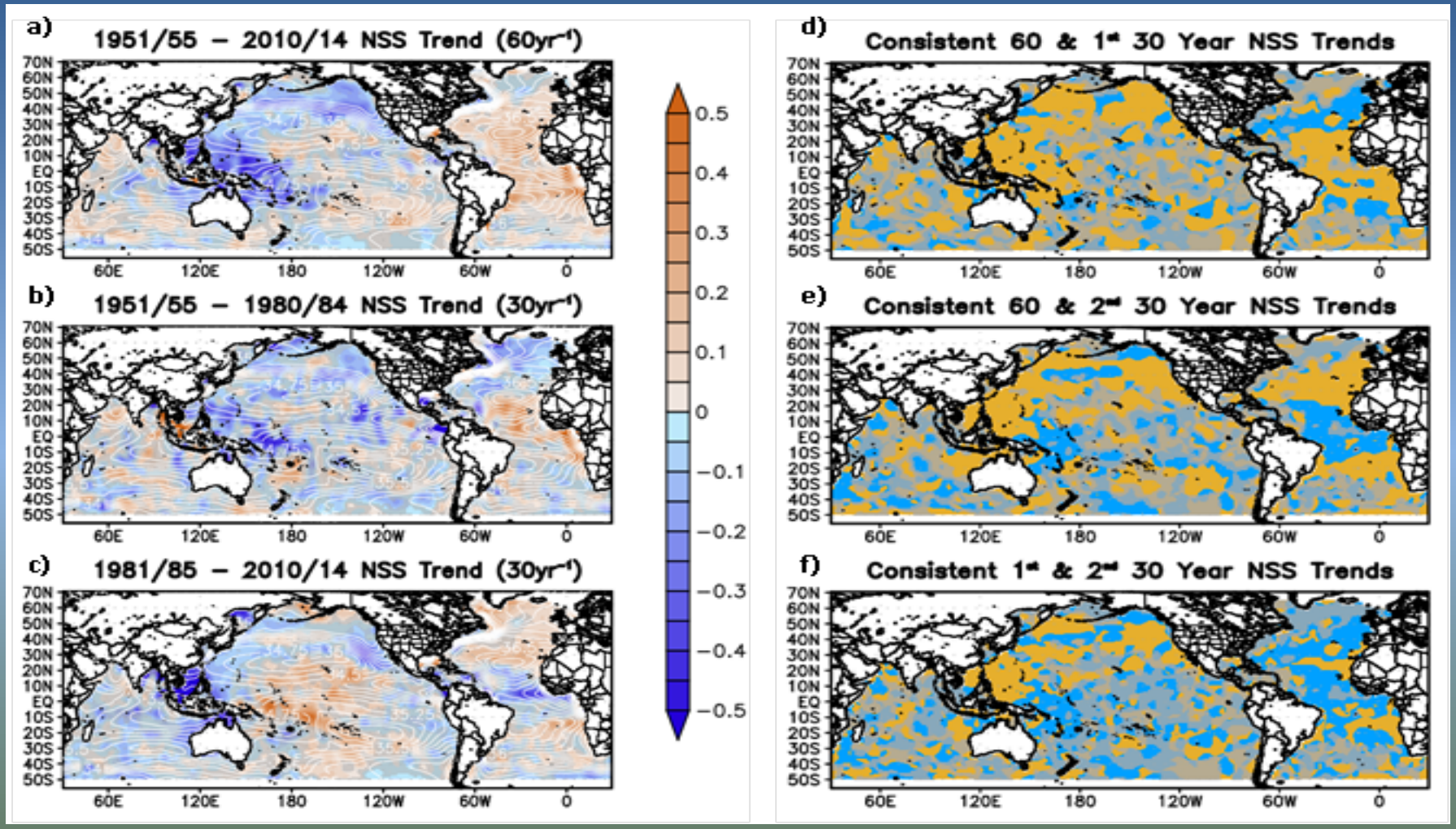
2 Enhanced Access and Basic Quality Assurance

1 Long-Term Preservation and Basic Access



2008-2012 salinity anomaly at 10 m depth

Decomposing 60-year NSS trends



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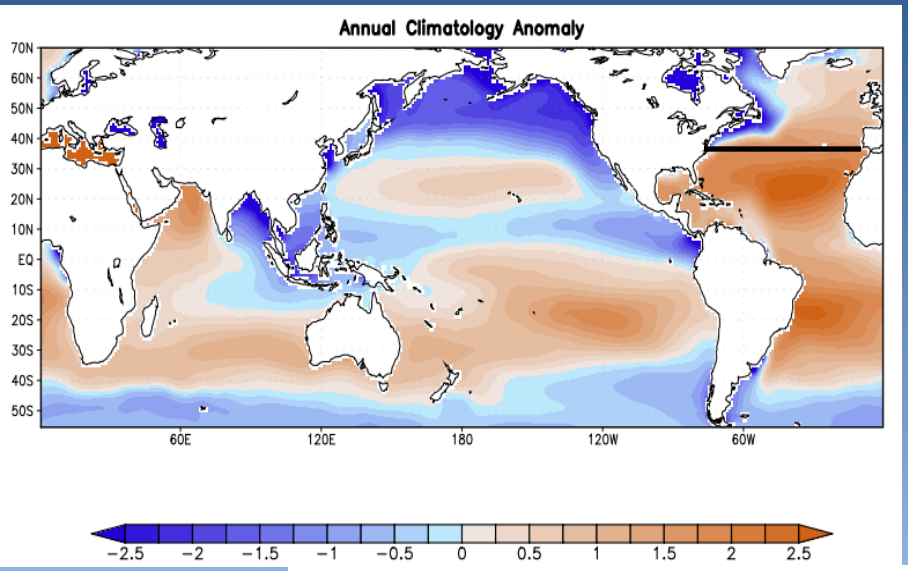
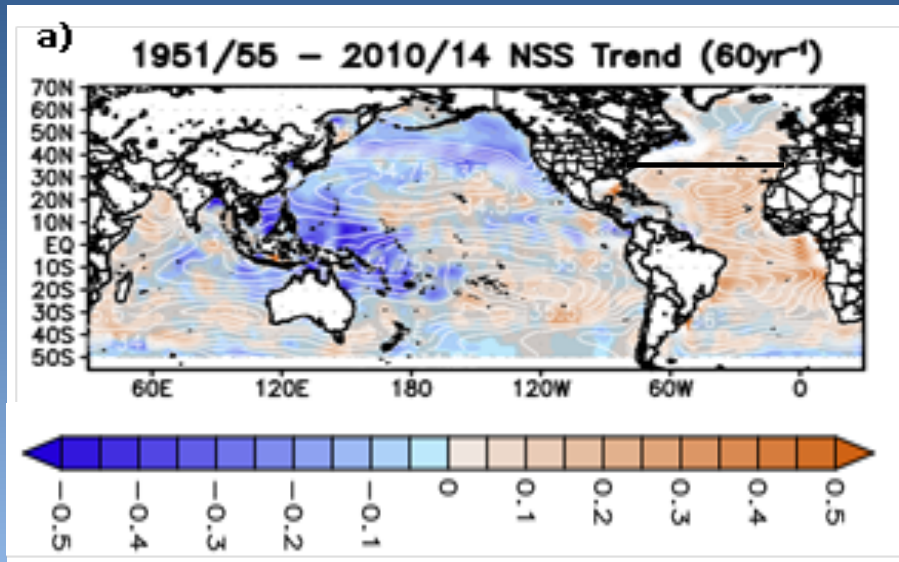
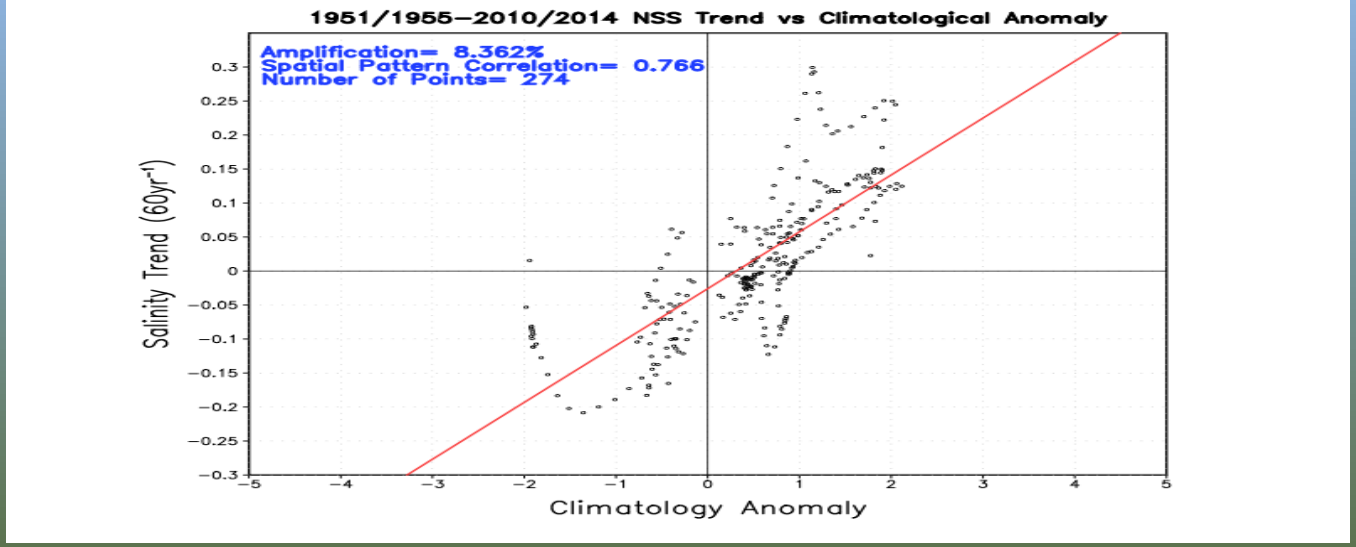
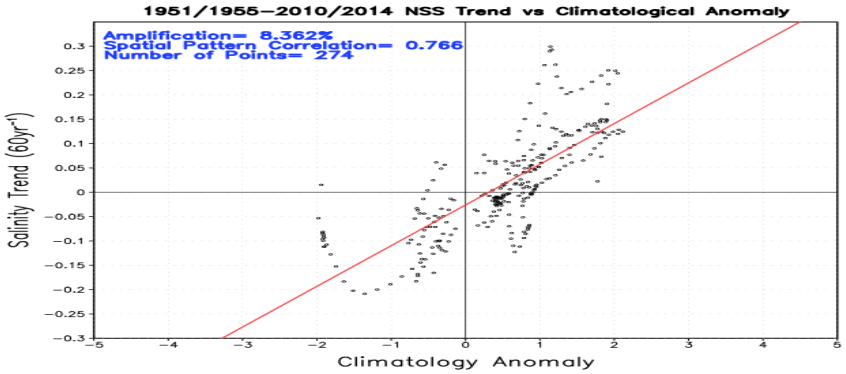
NSS Pattern Amplification Concept

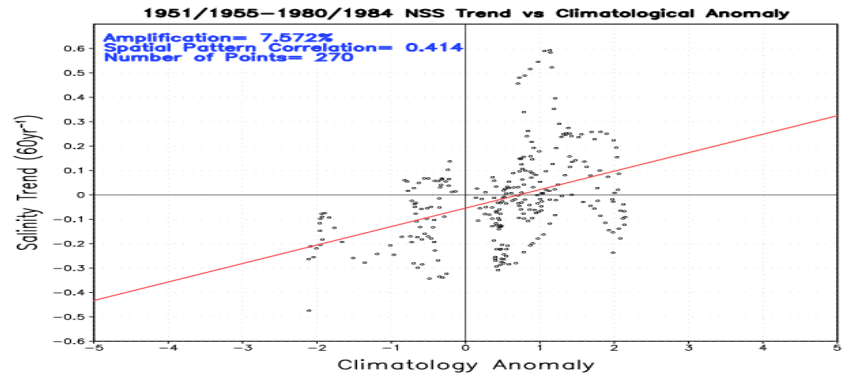


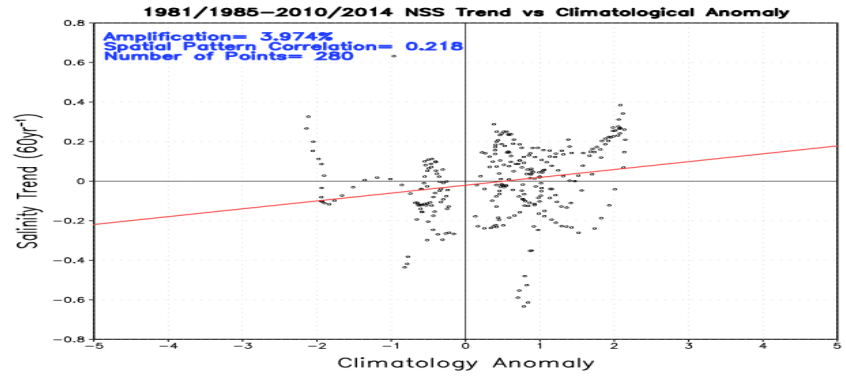




NSS Pattern Amplifications for 60 and 30 Year Periods

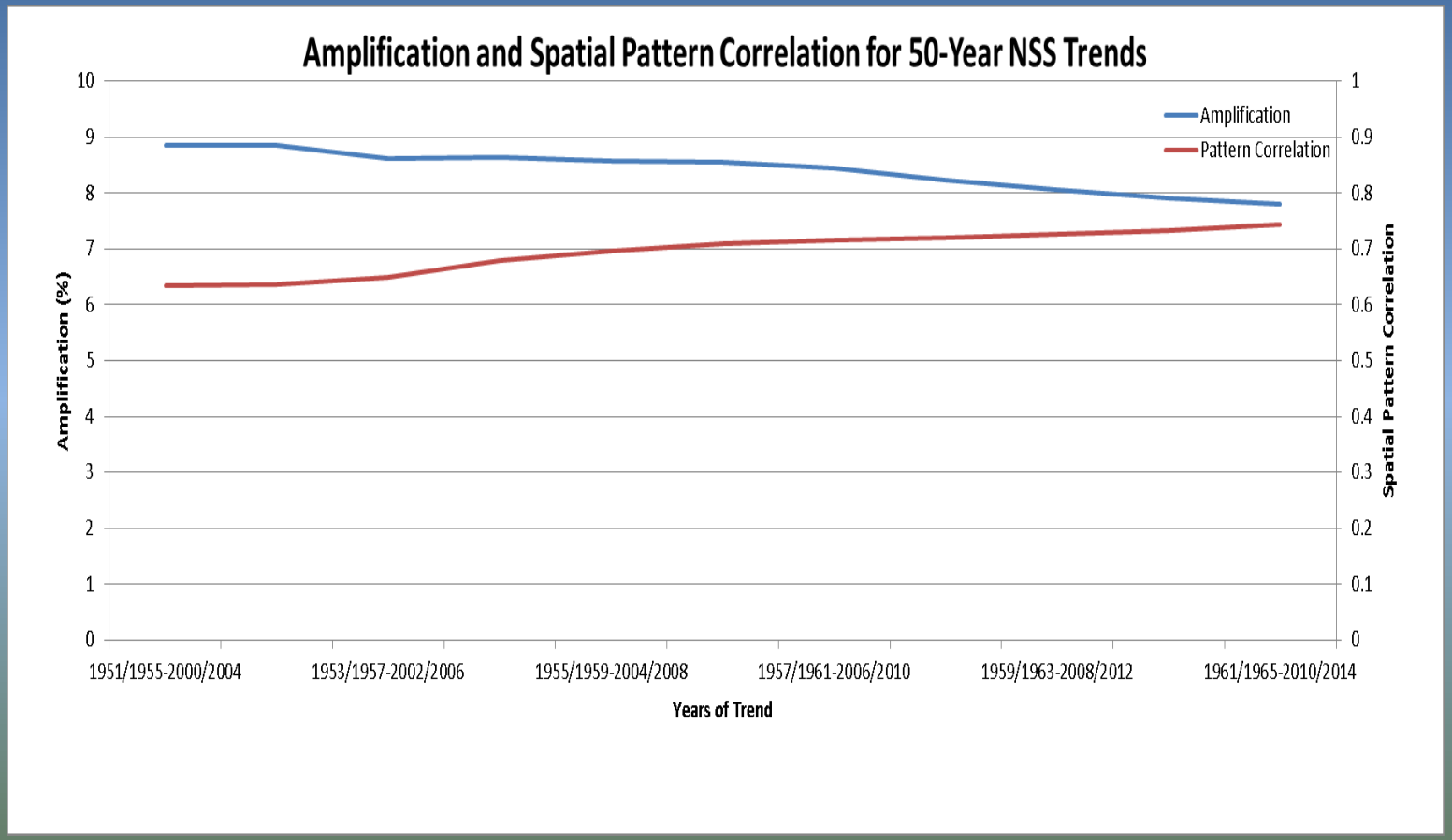




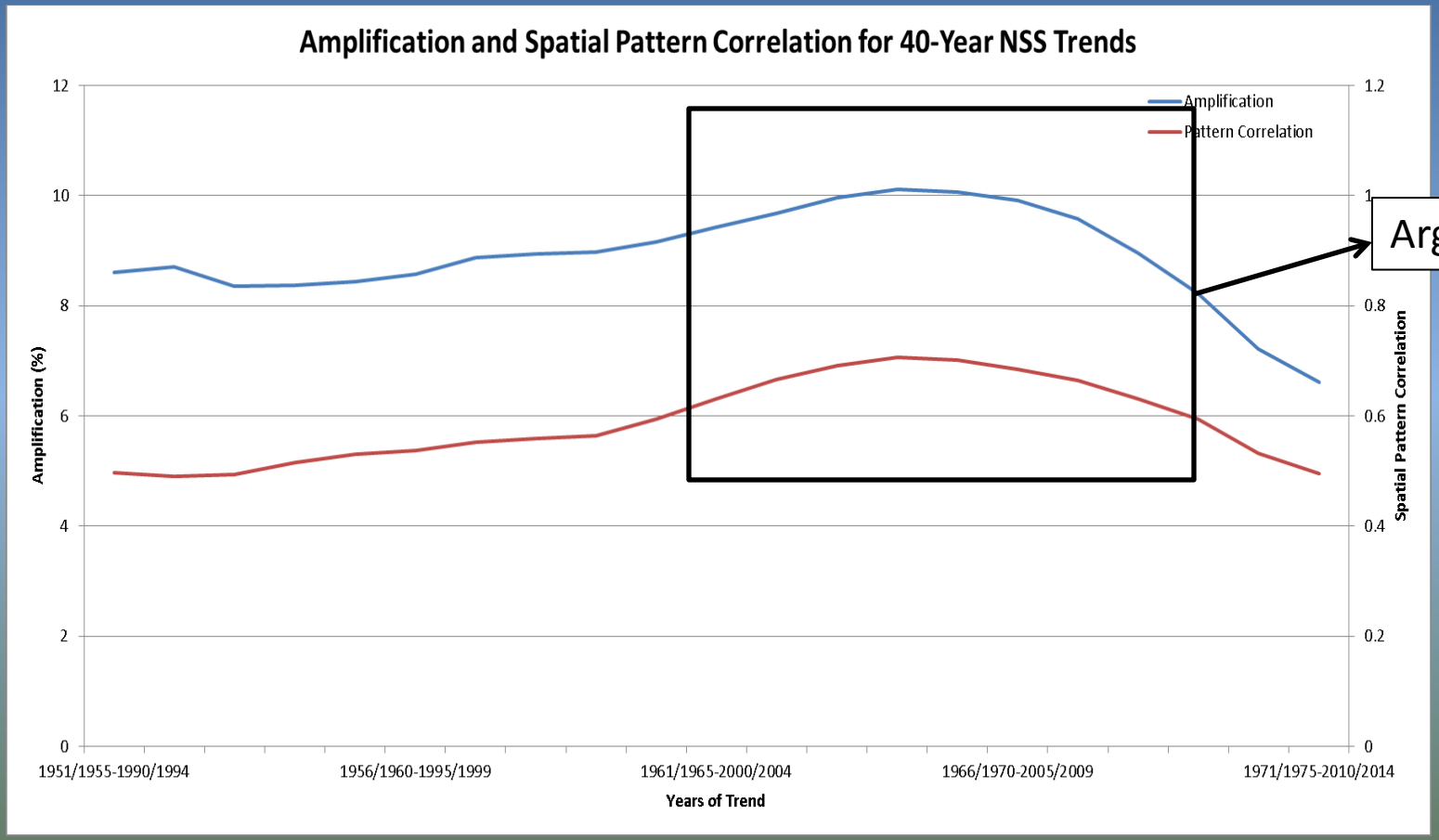


Trend Years	Pattern Amplification (%)	Spatial Pattern Correlation
1951/55-2010/14	8.362	0.766
1951/55-1980/84	7.572	0.414
1981/85-2010/14	3.974	0.216

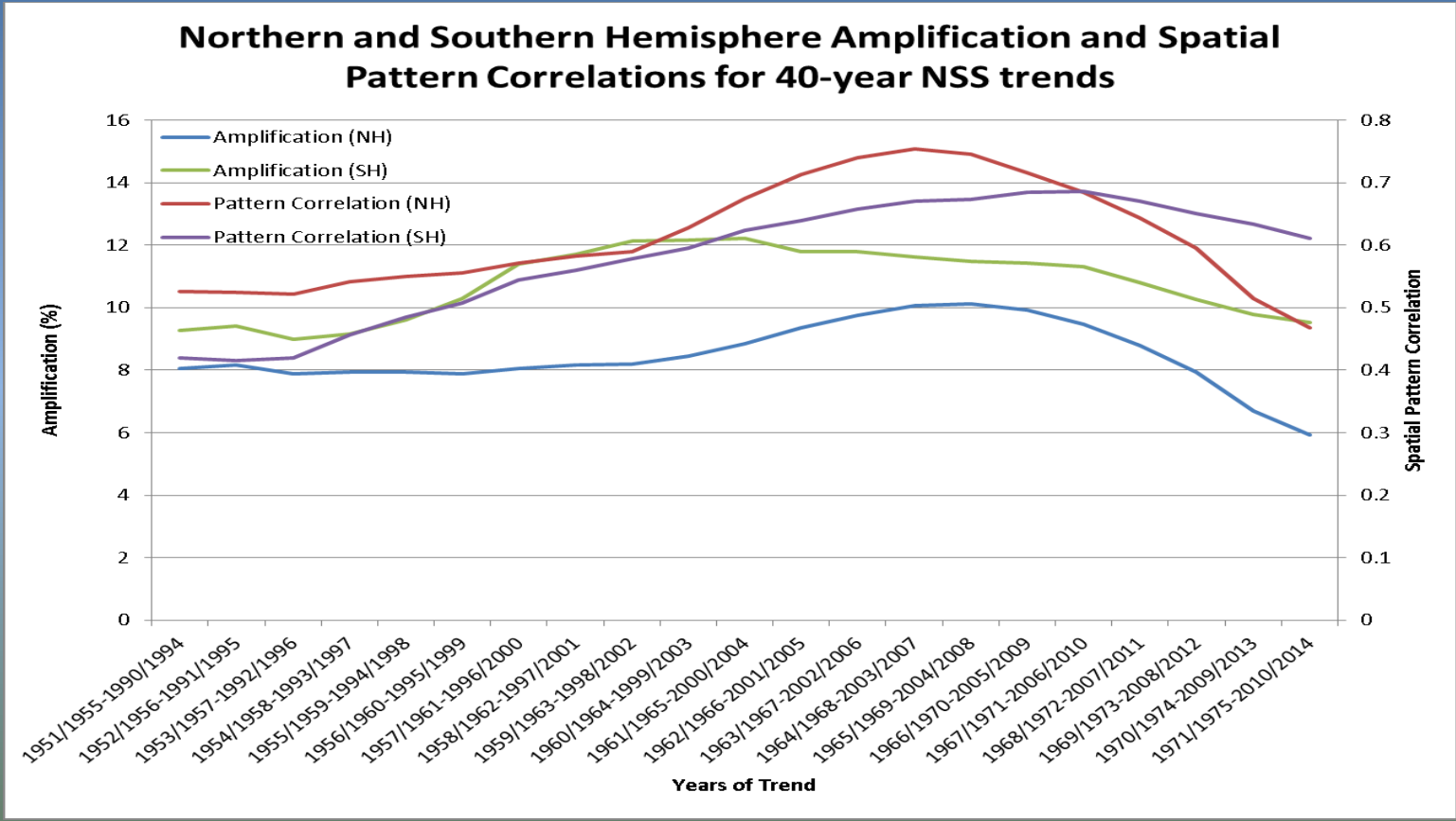
NSS Pattern Amplification for 50-year Time Periods



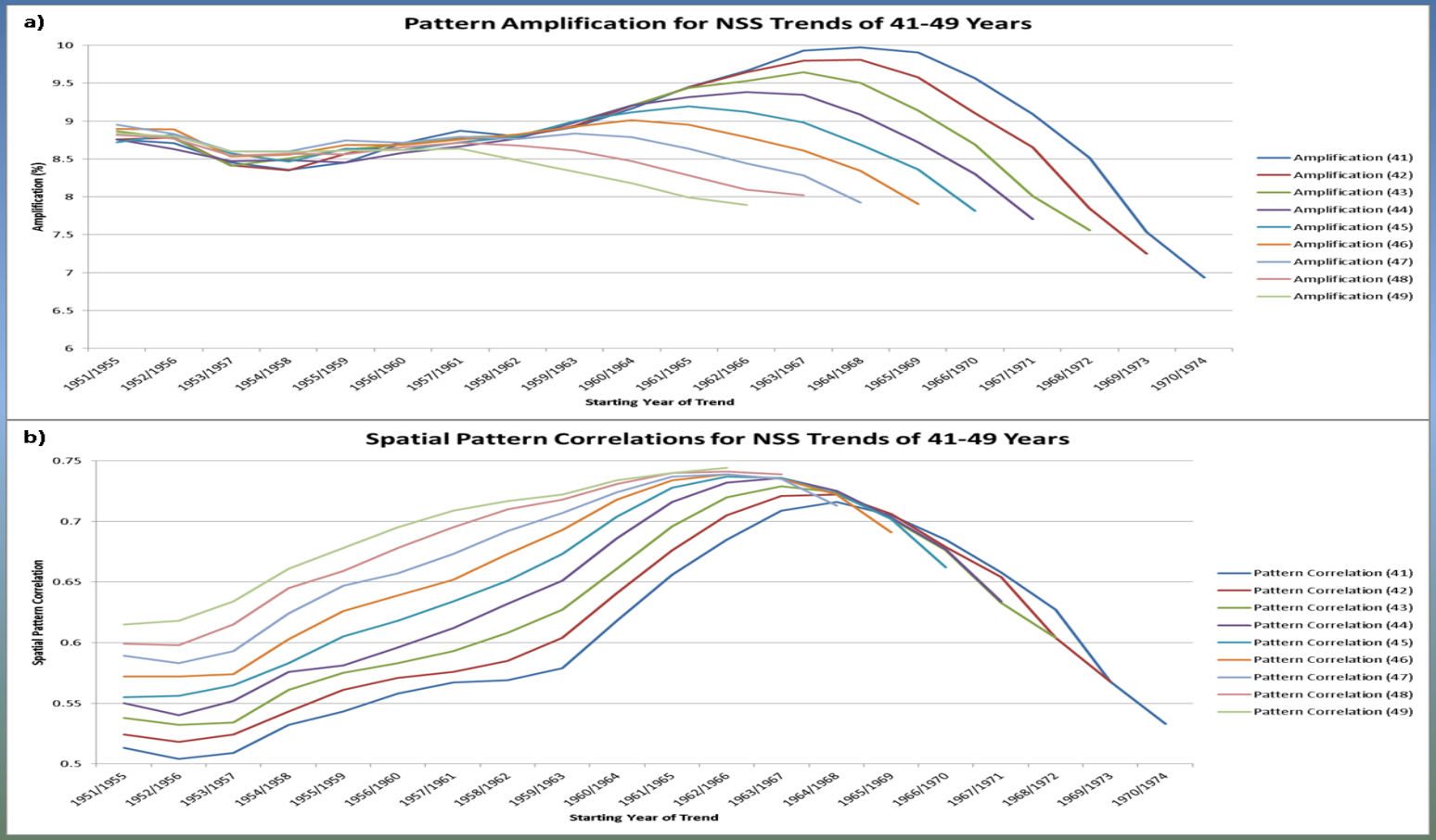
NSS Pattern Amplification for 40-year Time Periods



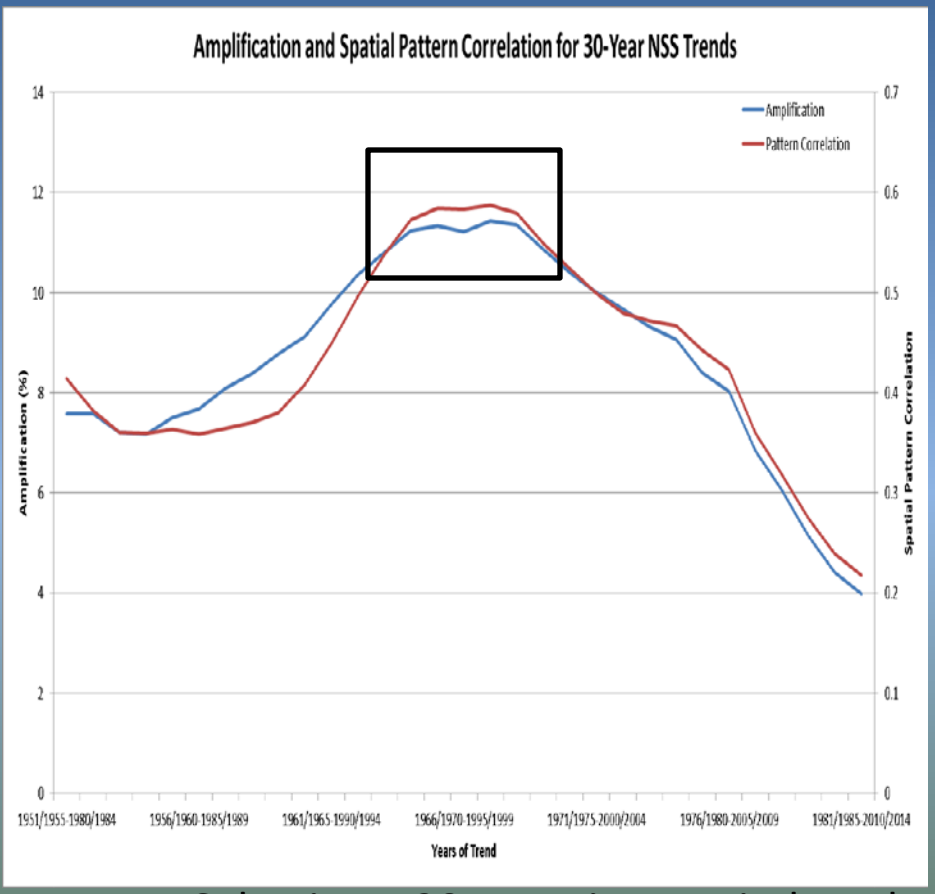
NSS Pattern Amplification for 40-year Time Periods for Northern and Southern Hemispheres

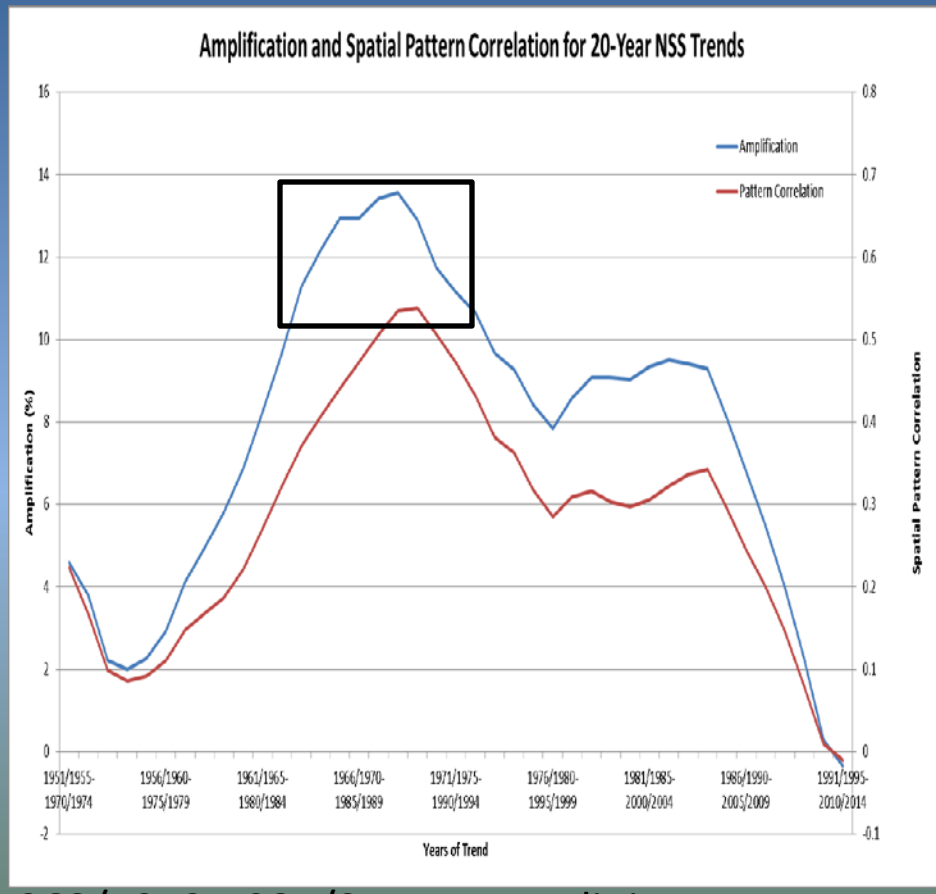


NSS Pattern Amplification for 41-49 Year Time Periods



NSS Pattern Amplification for 30 and 20-Year Time Periods





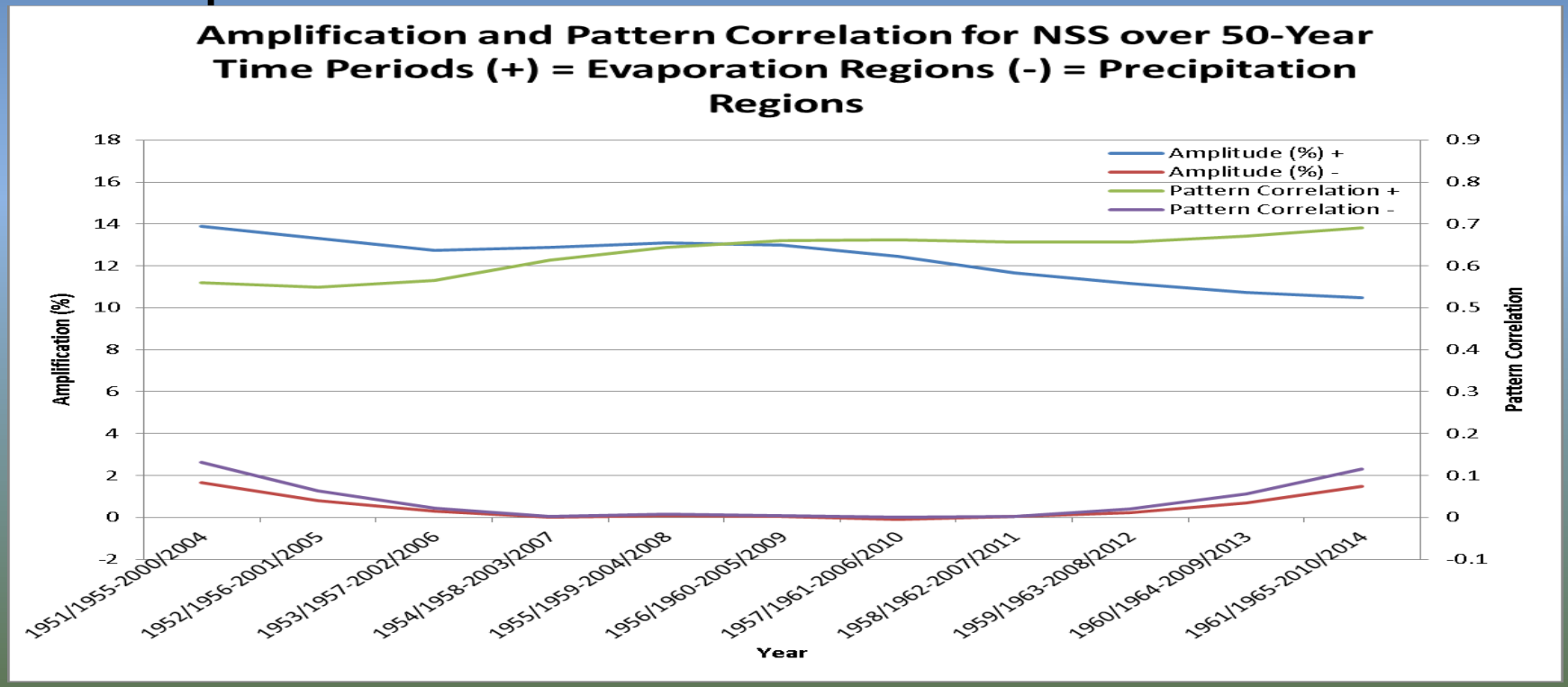
- Selecting a 20-year time period, such as 1968/1972-1987/91, to use salinity as a proxy to estimate secular changes in the global hydrological cycle would yield misleading results.

Conclusions

- Most of the ocean has not experienced monotonic linear trends in NSS over the past 60-years.
- If NSS changes are to be used as a proxy to confidently estimate secular changes in the global hydrological cycle, then a minimum period spanning ~48 years should be used.
  - NSS changes on shorter (<48) time periods may be influenced by decadal and shorter-term variability which can obscure the estimated secular changes of the global hydrological cycle.
- Long-term monitoring of global salinity is important.

Current/Future Work

- Separate high (evaporation dominated) and low (precipitation dominated) regions in NSS amplification calculations



Data Sets

- World Ocean Database: https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html
- World Ocean Atlas: https://www.nodc.noaa.gov/OC5/woa13/
- Pentadal Salinity Anomalies: https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/
- OAFlux Evaporation: http://oaflux.whoi.edu/evap.html
- GPCP Precipitation: http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html

Thank you

Questions?