

# Exploring the Spatial Coherence of High and Low Latitude North Atlantic Sea Surface Temperature Anomalies from Paleoclimate Proxy Data



K. Halimeda Kilbourne, Drew Hobbs,  
Hunter Hughes, Agraj Khare, Zoraida  
Perez-Delgado

University of Maryland

CENTER FOR ENVIRONMENTAL SCIENCE

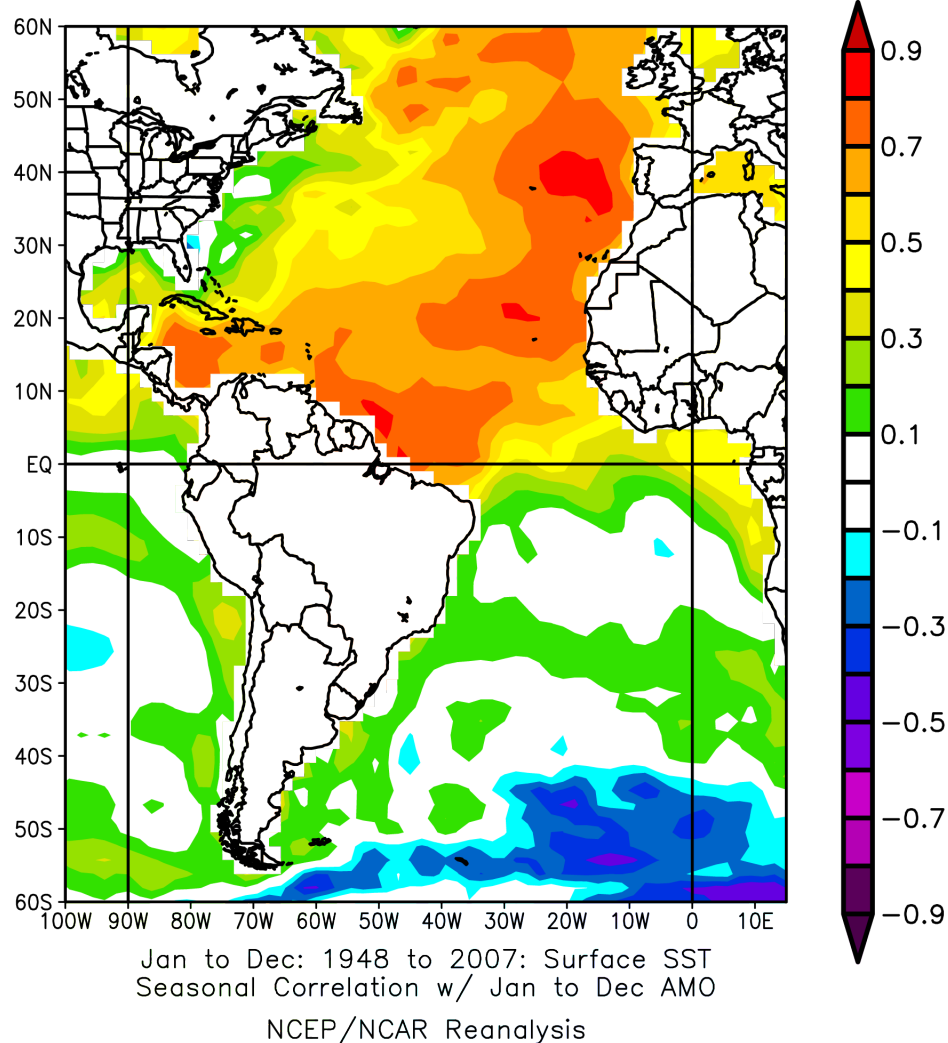
CHESAPEAKE BIOLOGICAL LABORATORY

# Atlantic Multidecadal Variability

Mechanistic focus on high  
latitudes

Are the tropics involved,  
either actively or passively?

Longer records of climate  
needed to understand this  
timescale – paleoclimate!



# THE DAY AFTER TOMORROW



Finding Truth in  
the Day After  
Tomorrow:  
AMOC in the past  
present and  
future

# Delworth et al. 2017

Observations of SST and NAO

SST at 60-30N lags DJFM NAO by ~20 years.

NAO is positive, SST 20 years later is positive.

Tropical signal is weak

Do we see a similar response in proxy datasets?

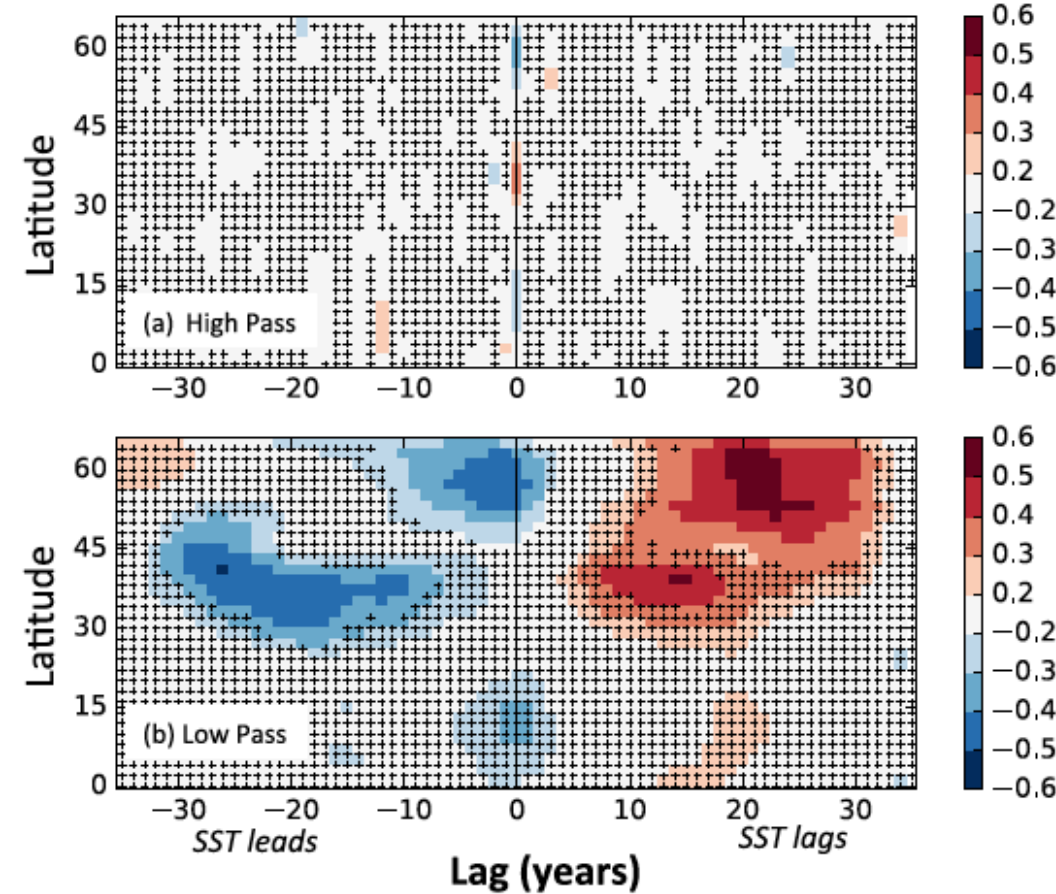


FIG. 1. Zonal averages of the lagged correlations between annual mean SST and the NAO (for DJFM) based on observations. Correlations were first computed at each grid point and then zonally averaged from 60° to 20°W. Negative (positive) lags denote



# Driving Questions

1. Can we see a similar relationship between NAO and high latitude SST in recent paleoclimate records
2. Was the relationship similar during the pre-industrial era
3. How do the tropical SST anomalies fit in?
  - a) Do the tropical compilations correlate to each other?
  - b) Do they correlate with high latitude SSTs during the pre-industrial and modern eras?
  - c) Do they correlate with NAO and with what lag relationships?

# Proxy Data Selection Criteria

- Regional compilations in high or low latitudes
- Temporal resolution < 30yrs/sample
- Includes substantial portion of 20<sup>th</sup> Century

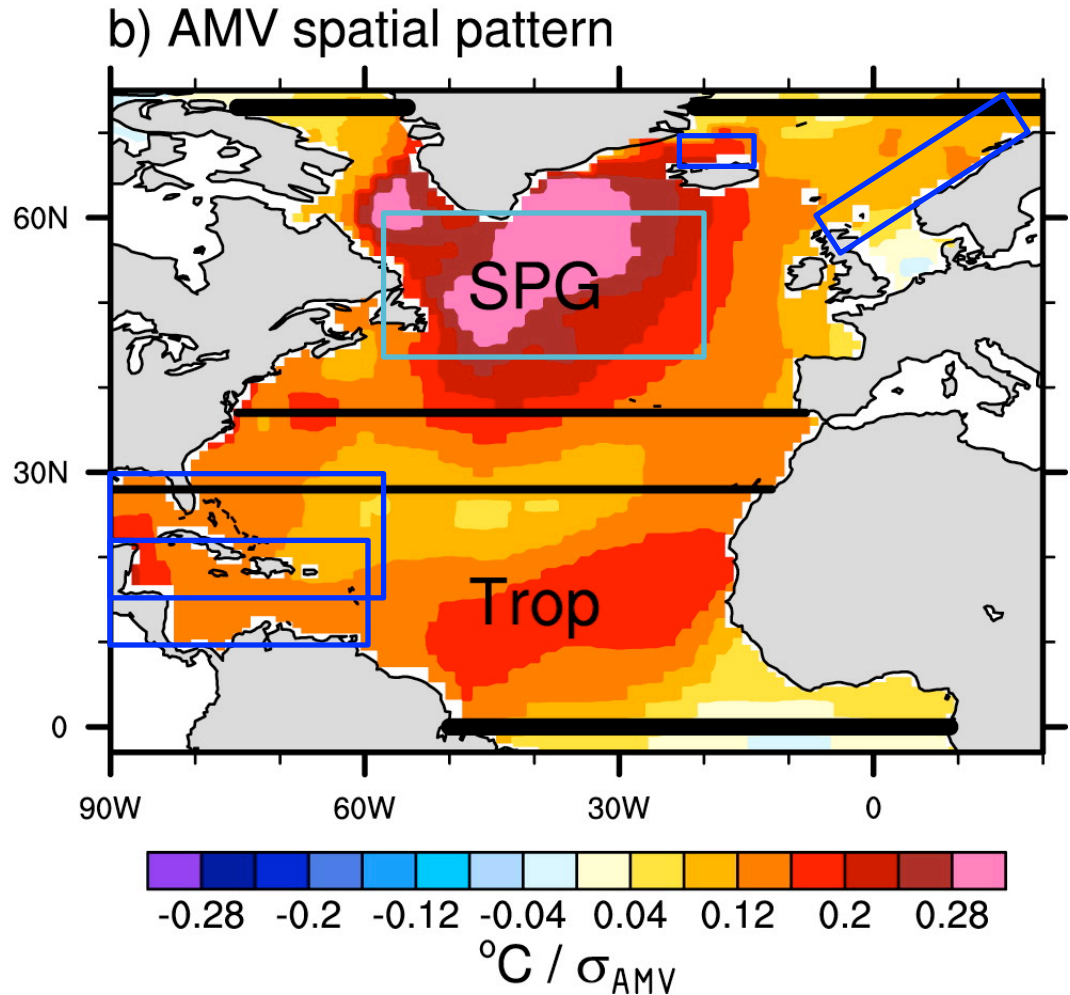
# The Data

Study Reference	Variable	Time Resolution	Temporal Range (C.E)
Kilbourne et al., 2014	Caribbean SST reconstruction	5 years/sample	1225-2000
Tierney et al., 2015	Tropical Atlantic SST reconstruction	annual	1552-2007
Cunningham et al., 2013	Iceland SST reconstruction	25yr low pass filtered	1000-1975
Cunningham et al., 2013	Norwegian Sea SST reconstruction	25yr low pass filtered	1000-1975
Ortega et al., 2015	NAO reconstruction	annual	1049-1969
Jones et al., 1997	NAO index (Iceland-Gibraltar)	monthly	1824-present

Internal component of  
North Atlantic SST index  
(*sensu* Ting 2009)  
regressed on ERSST v3b  
10-yr Low pass filtered.

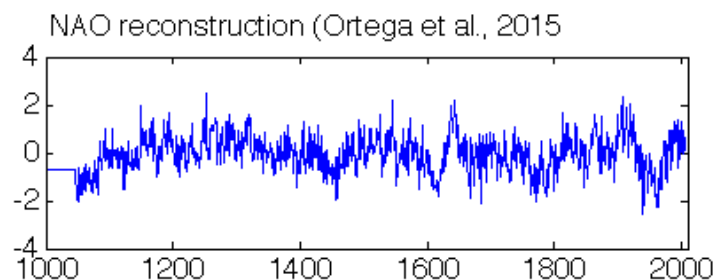
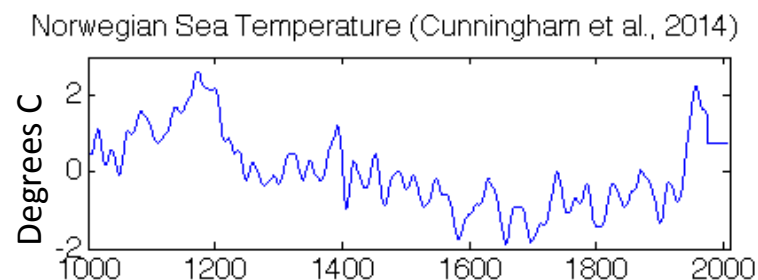
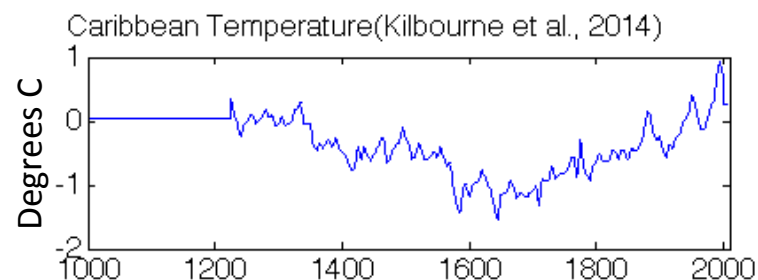
Blue boxes represent  
approximate areas  
represented by proxy  
data

From Ruprich-Robert et al., 2017

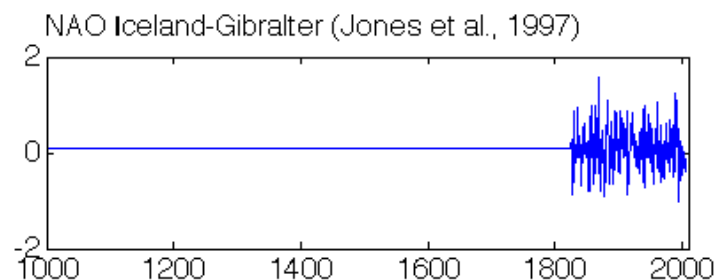
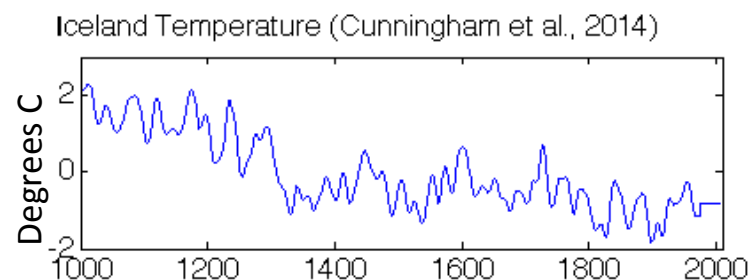
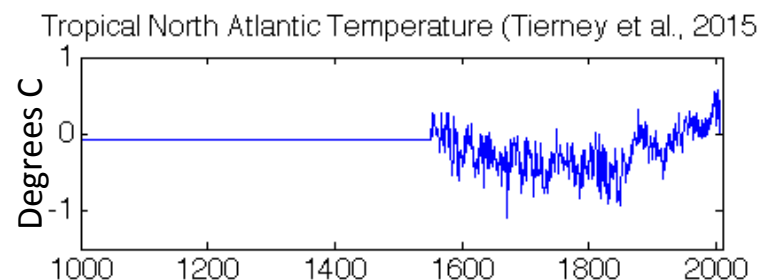




Resolution: Annual to 25yr-low Pass filtered



Overlapping Time Span of Proxies: 1969-1552



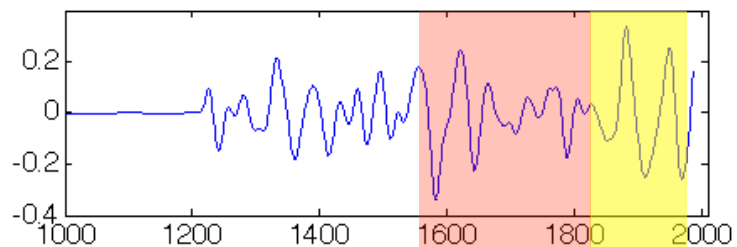
# Data Analysis

- Modern Era 1826-1969
- Pre 20<sup>th</sup> Century 1560-1826
- Lagged Correlation Analysis of common periods.
- Significance of correlations account for serial autocorrelation of the data, based on the monte-carlo approach of Ebisuzaki (1997).

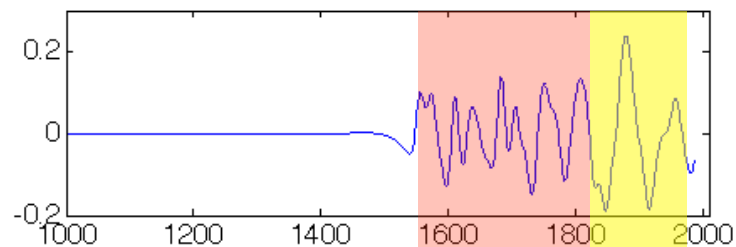
# Data Processing

- Interpolated to annual
- De-trended with 200yr Loess filter
- Low pass filtering:
  - 25yr half amplitude Gaussian convolution filter

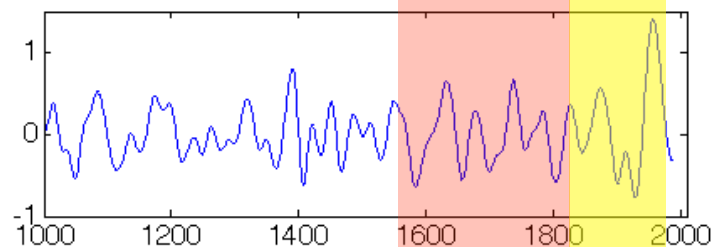
Caribbean Temperature(Kilbourne et al., 2014)



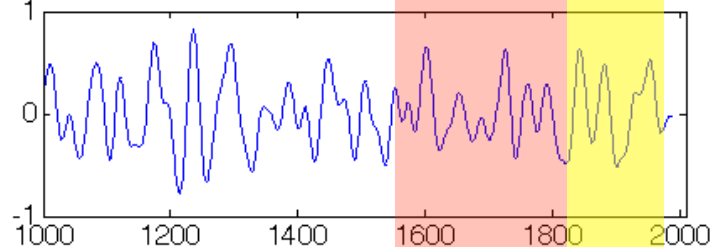
Tropical North Atlantic Temperature (Tierney et al., 2015)



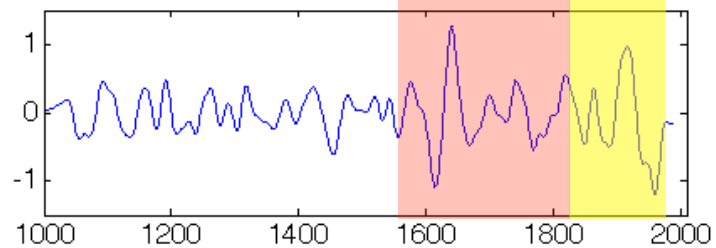
Norwegian Sea Temperature (Cunningham et al., 2014)



Iceland Temperature (Cunningham et al., 2014)



NAO reconstruction (Ortega et al., 2015)





# Lagged Correlation analysis of Proxy NAO against Proxy high latitude SST anomalies

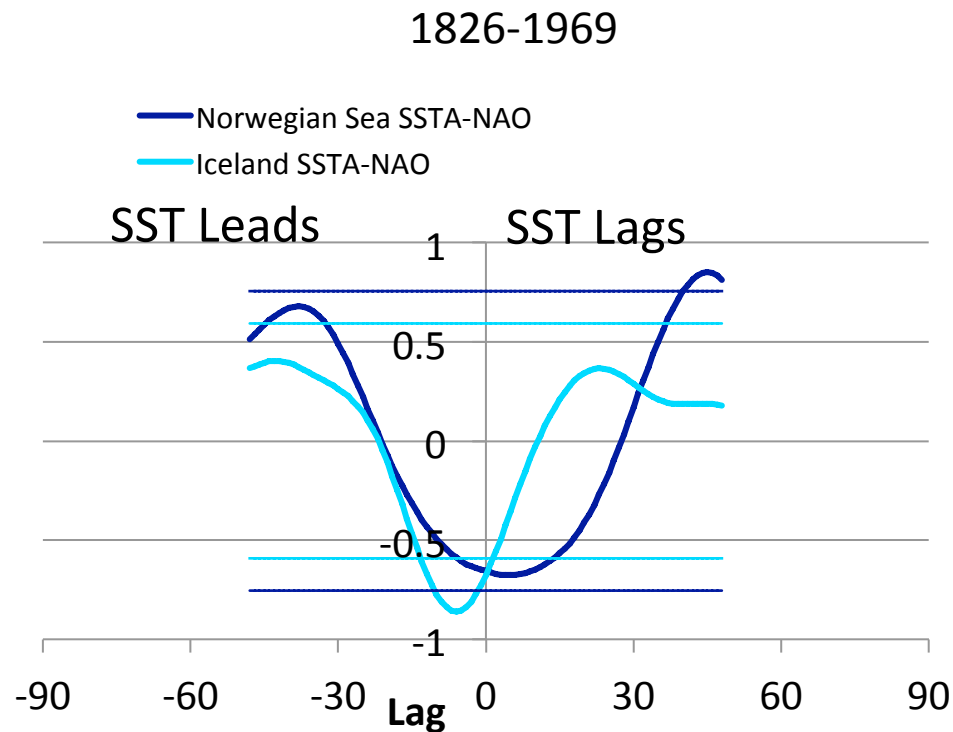
Similarly to Delworth et al., 2017

instrumental data analysis:

- Negative relationship between SST and NAO at zero and small lags
- Positive correlation with SST lagging NAO on decadal timescales

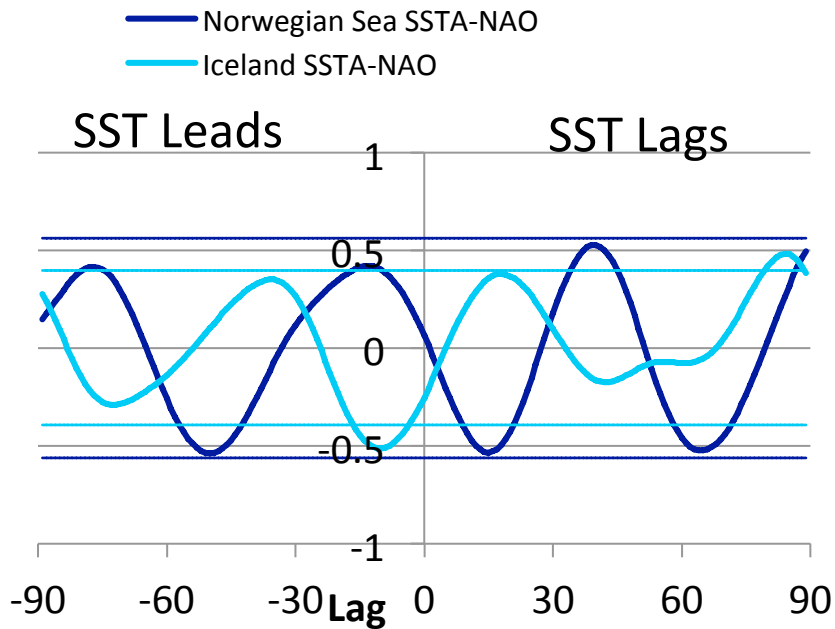
Different:

- Long lag relationship significant Norwegian Sea region, but not Iceland.
- Lag of maximum positive correlation occurs at ~40 years for Norwegian Sea instead of 20

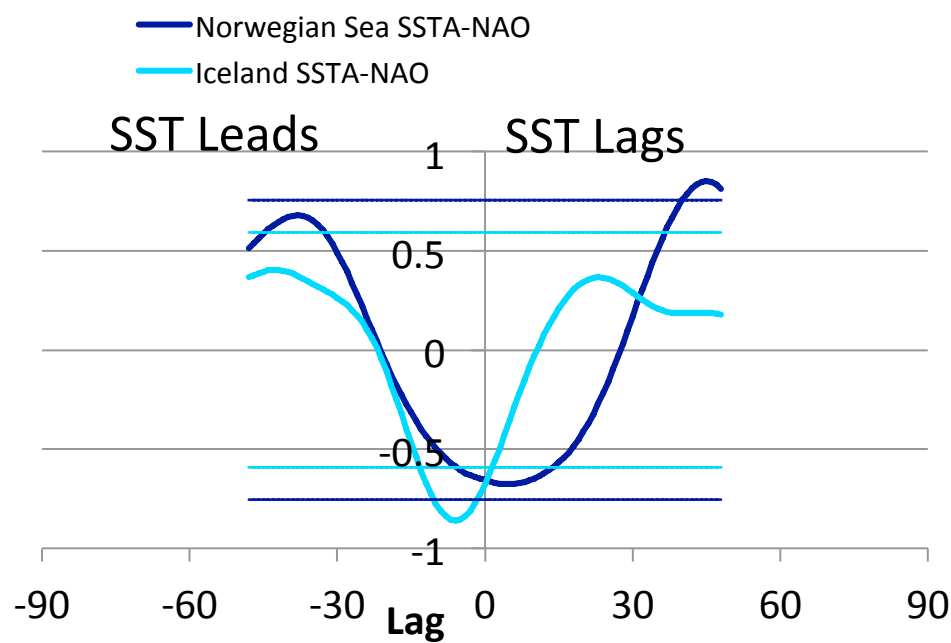


# Lagged Correlation analysis of Proxy NAO against Proxy high latitude SST anomalies

1560 - 1826

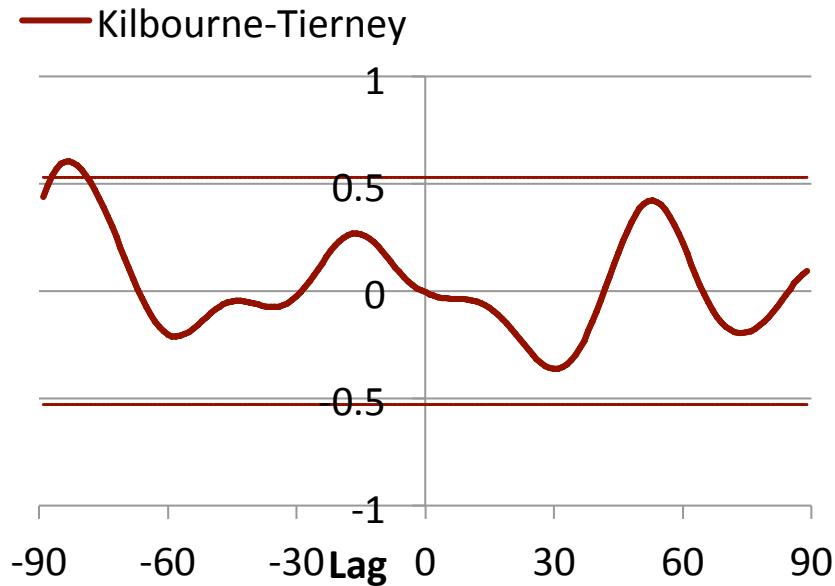


1826 - 1969

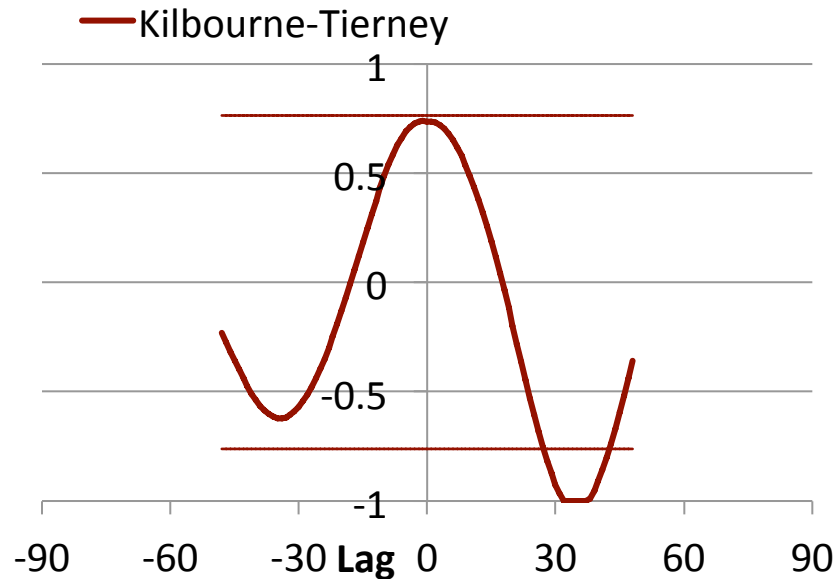


# 3a Tropical SST Proxy correlations

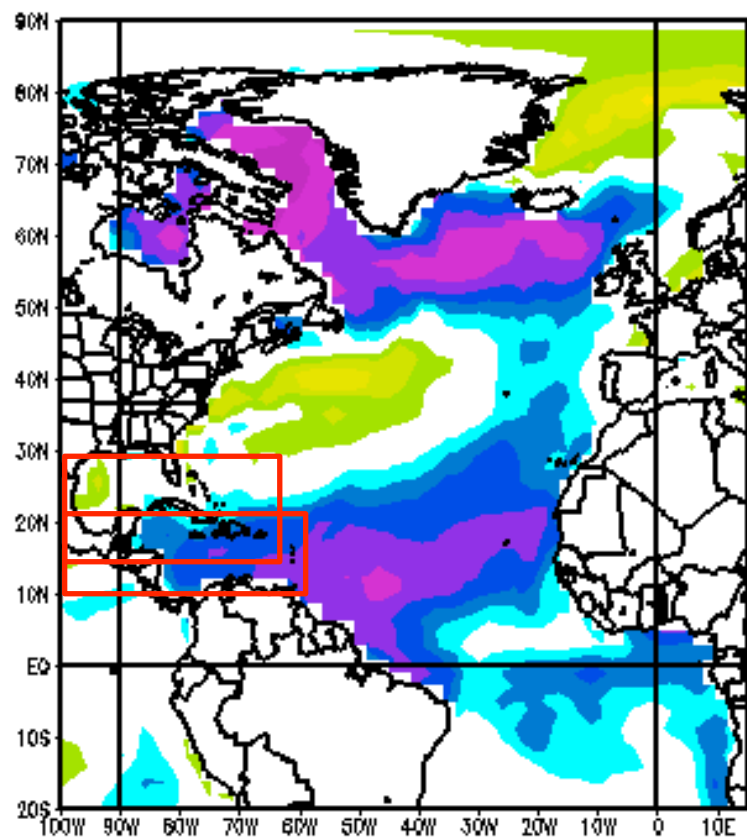
1560 - 1826



1826 - 1969



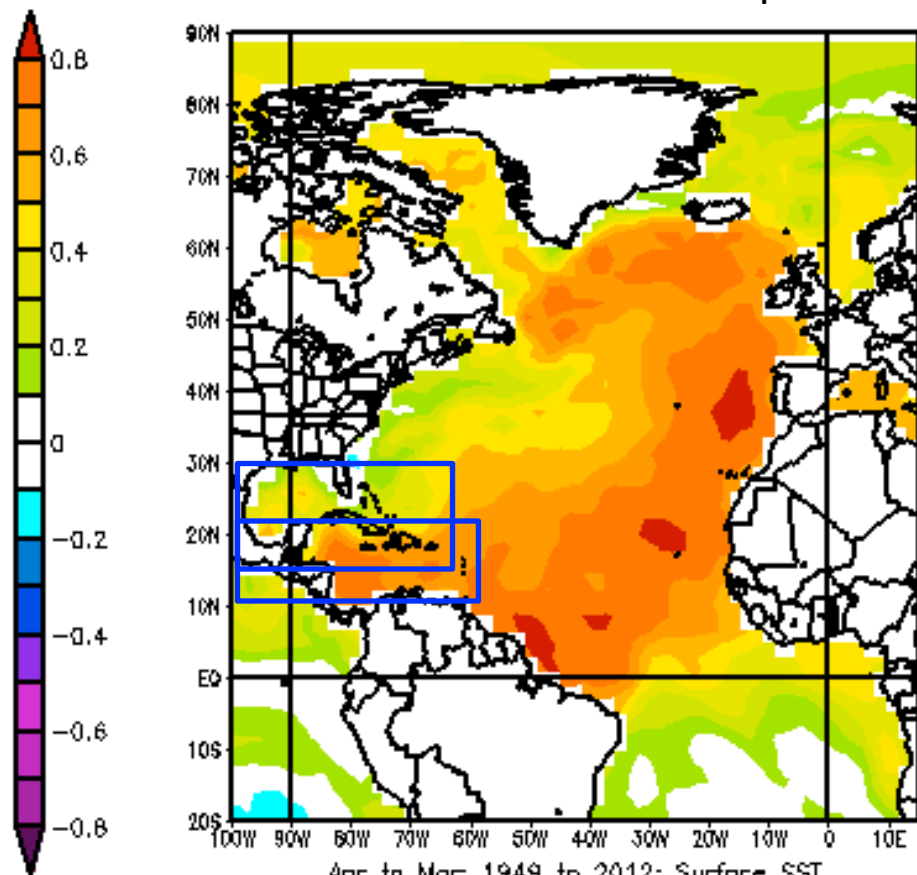
# NAO-SST correlation map



Apr to Mar: 1949 to 2012; Surface SST  
Seasonal Correlation w/ Apr to Mar NAO

NCEP/NCAR Reanalysis

# NASSTI-SST correlation map



Apr to Mar: 1949 to 2012; Surface SST  
Seasonal Correlation w/ Apr to Mar NASSTI

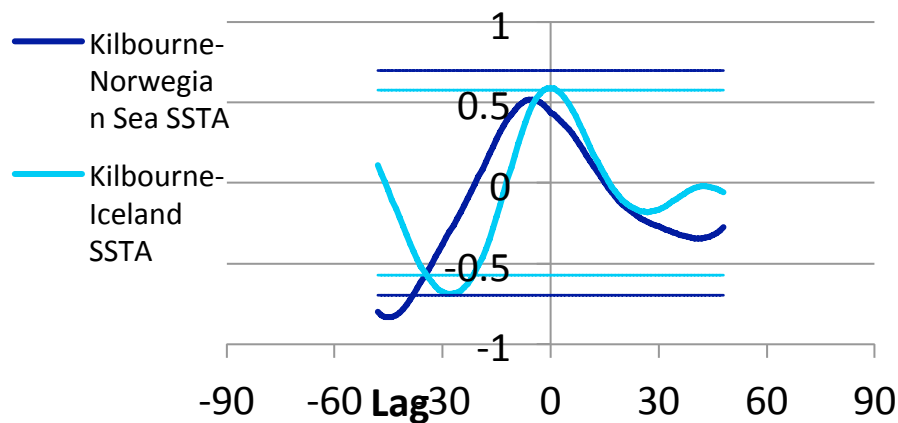
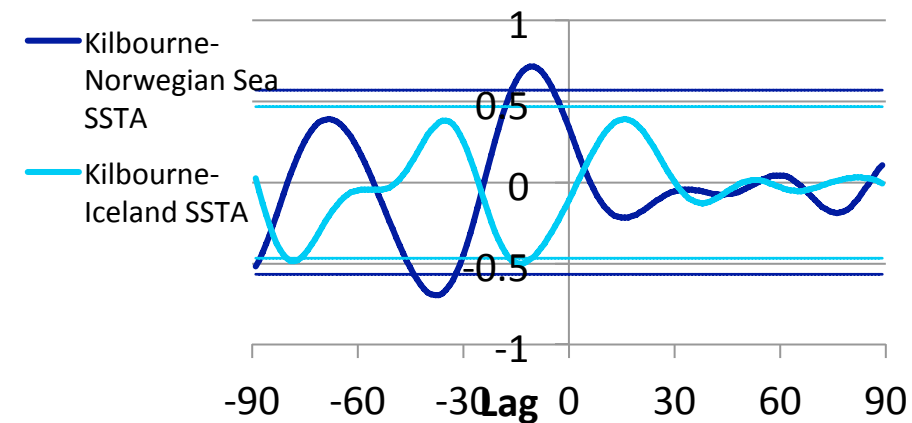
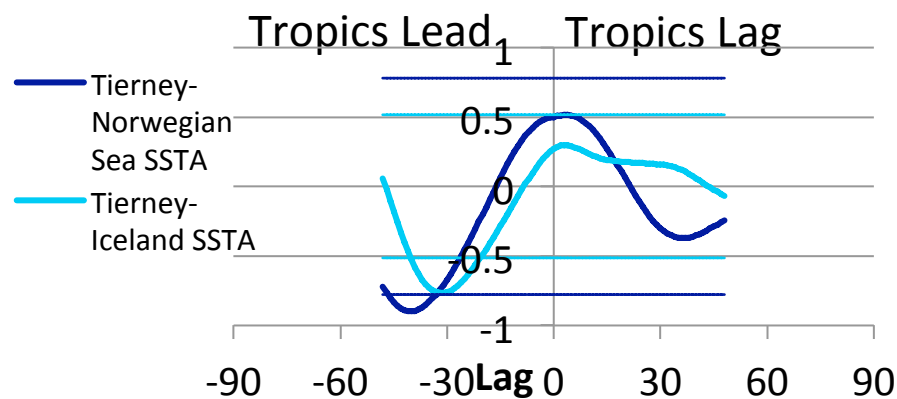
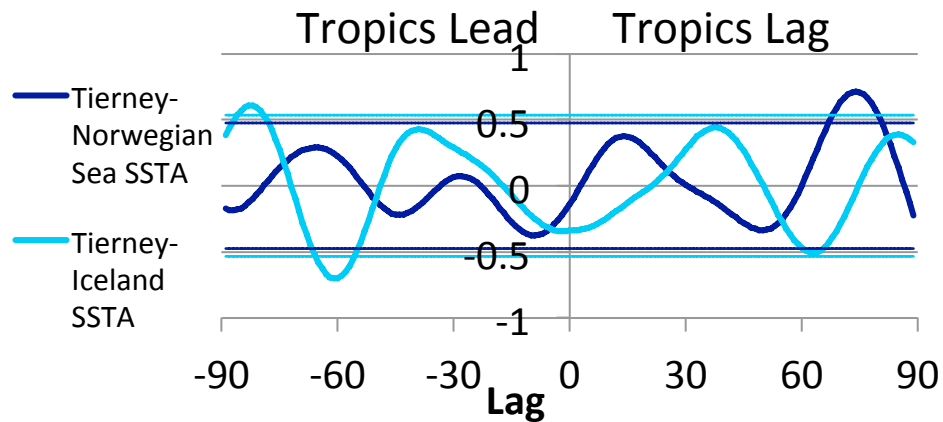
NCEP/NCAR Reanalysis



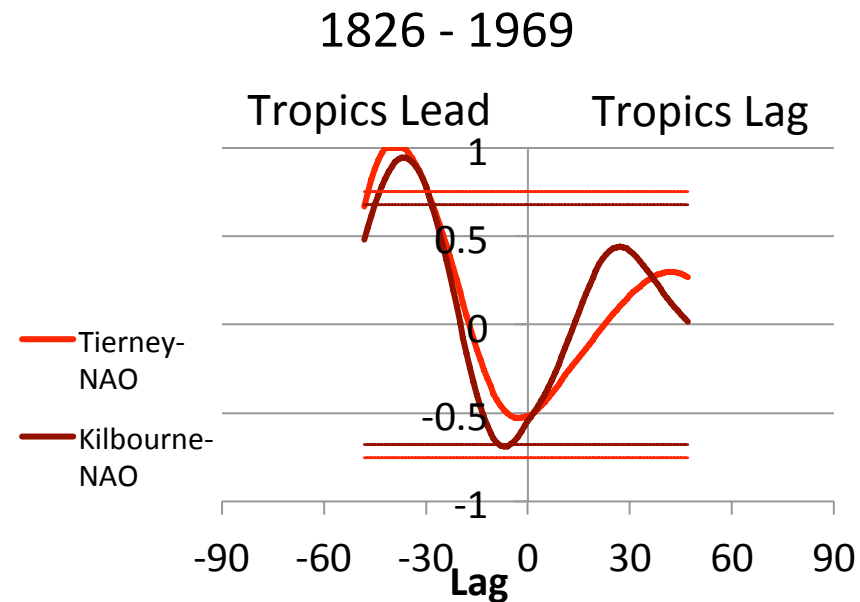
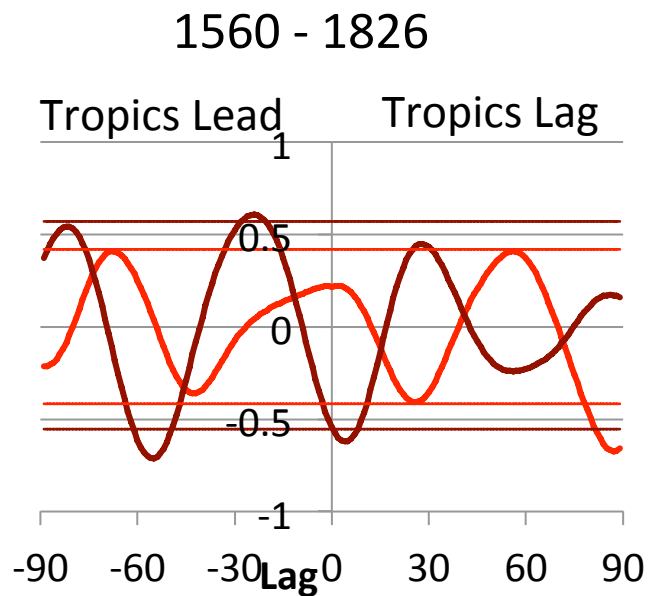
# 3b High vs Low Latitude Correlations

1560 - 1826

1826 - 1969

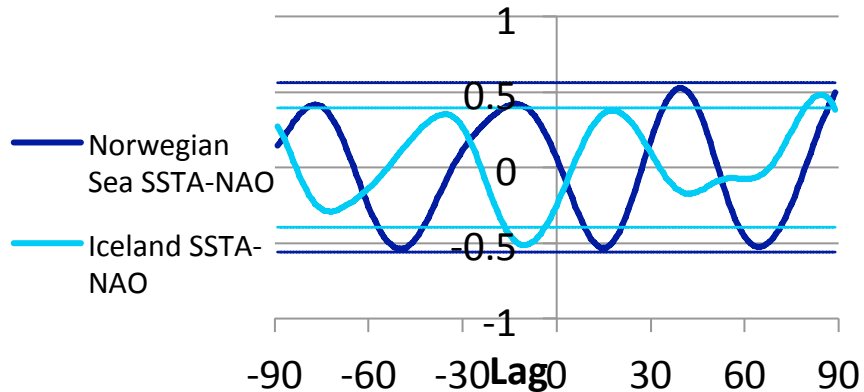


# 3c Tropics correlated to NAO

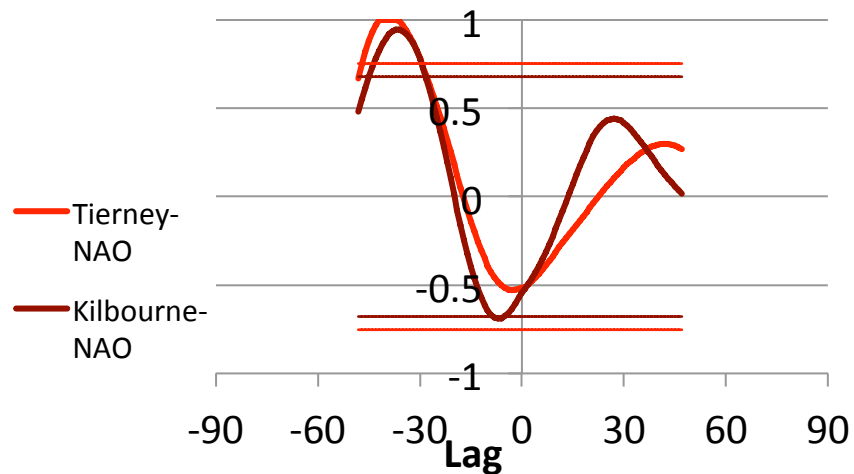
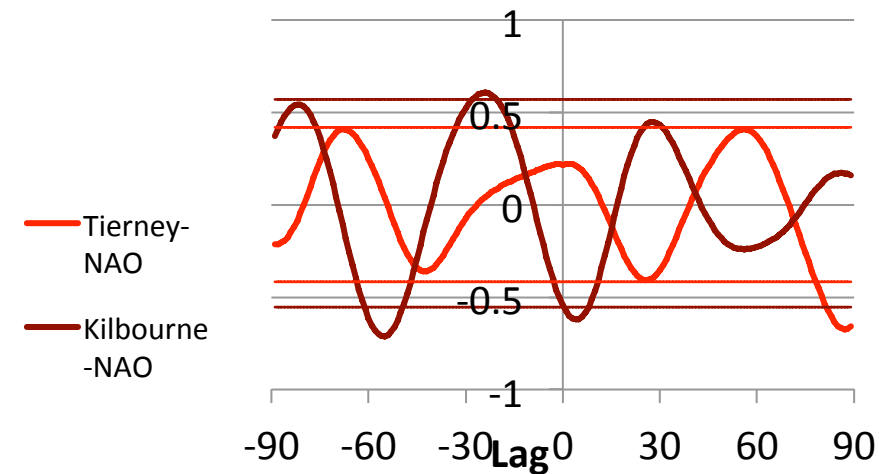
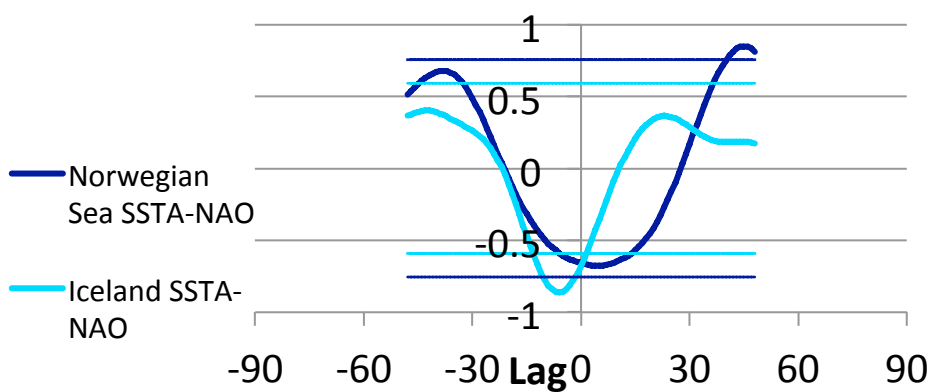


# 3c High and Low Lats vs NAO

1560 - 1826



1826 - 1969



# Conclusions

During the modern era, proxy records of SST and NAO have similar relationships as seen in modern observations.

The relationships are not stable with time

Tropical SST seems to lead NAO by ~30 years and lead high latitude SST by 11-14 yrs

## Where do we go from here?

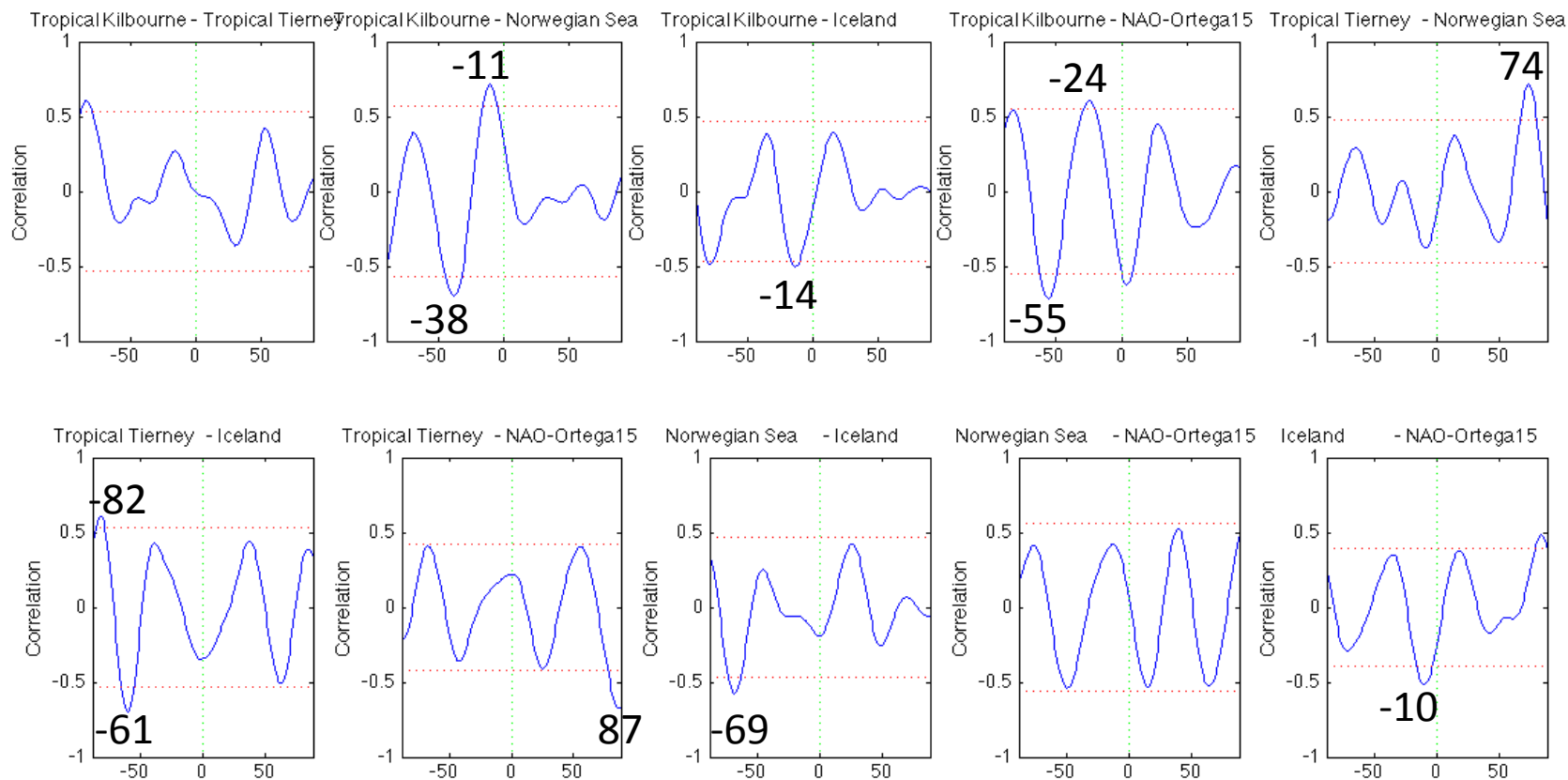
Do these relationships fit a dynamical model?

More work needed to better constrain regional SST history



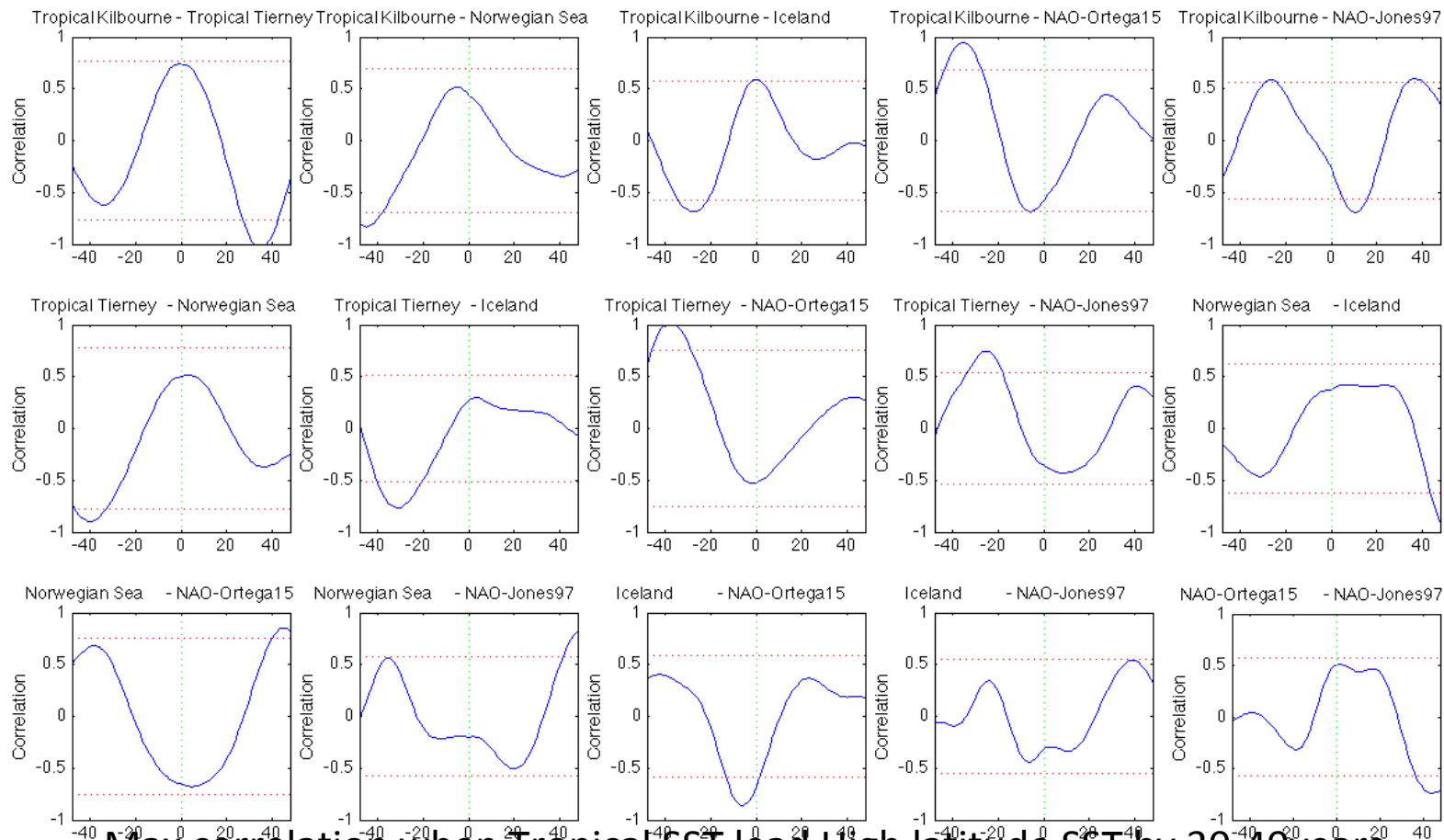


# Pre-Industrial 1560-1826



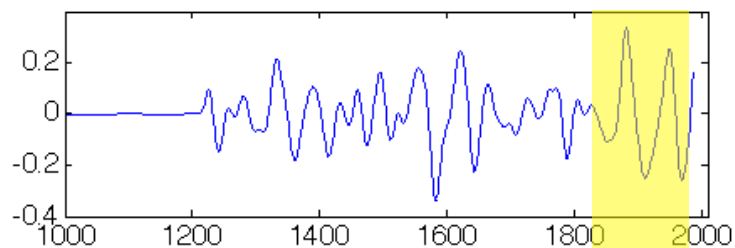
Tropical SST signals are not coherent – different choice of data inclusion and different processing

# Modern Era 1826-1969

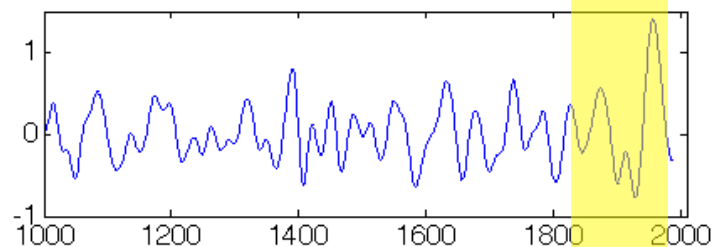


Max correlation when Tropical SST lead High latitude SST by 30-40years

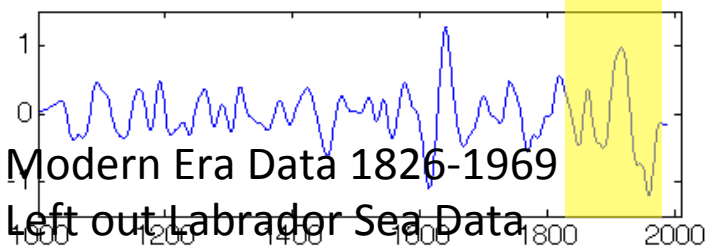
Caribbean Temperature (Kilbourne et al., 2014)



Norwegian Sea Temperature (Cunningham et al., 2014)



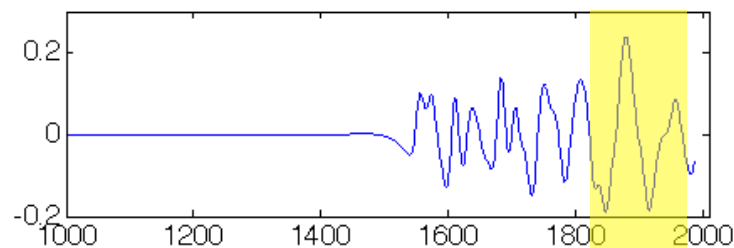
NAO reconstruction (Ortega et al., 2015)



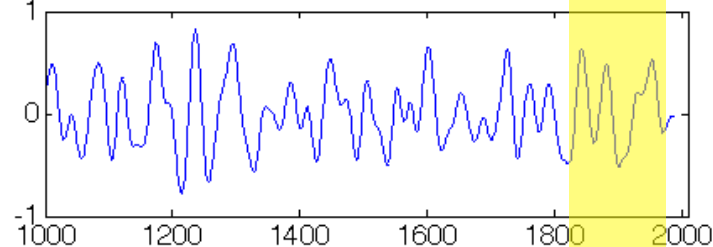
Modern Era Data 1826-1969

Left out Labrador Sea Data

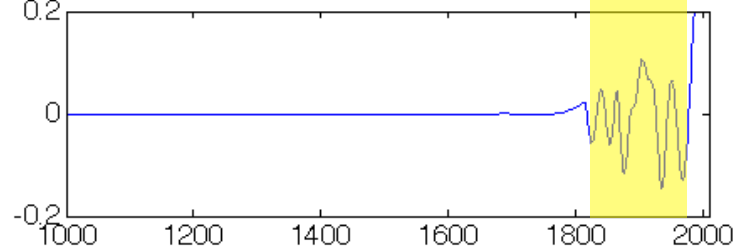
Tropical North Atlantic Temperature (Tierney et al., 2015)



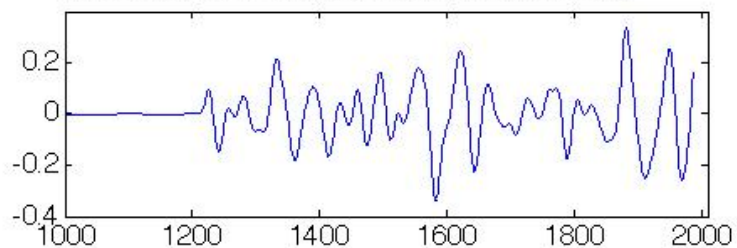
Iceland Temperature (Cunningham et al., 2014)



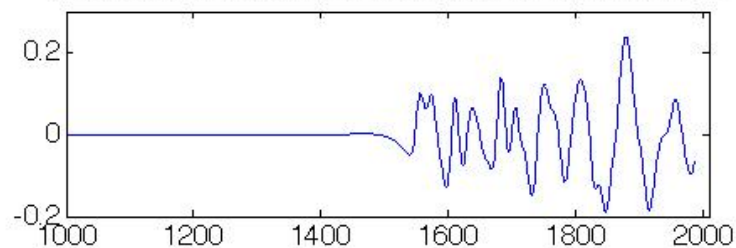
NAO Iceland-Gibraltar (Jones et al., 1997)



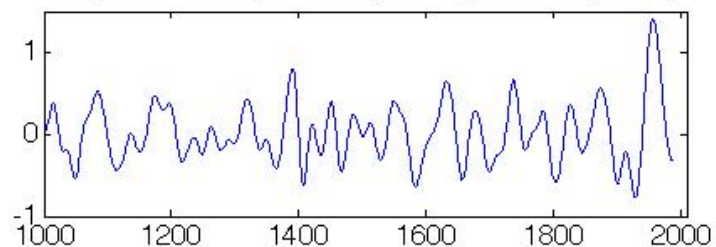
Caribbean Temperature(Kilbourne et al., 2014)



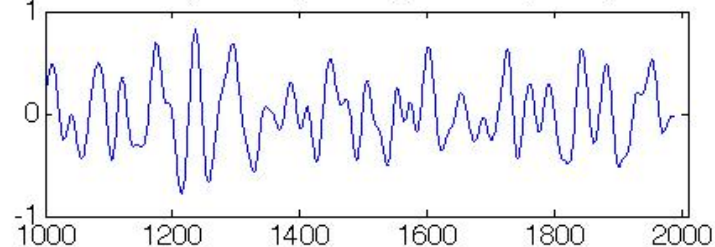
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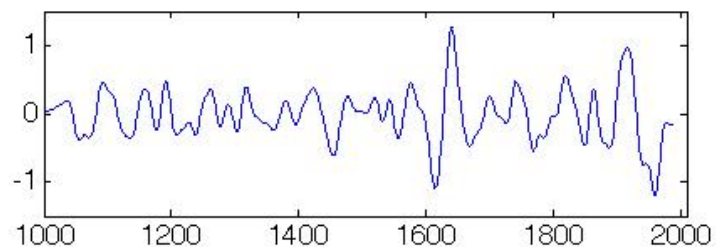
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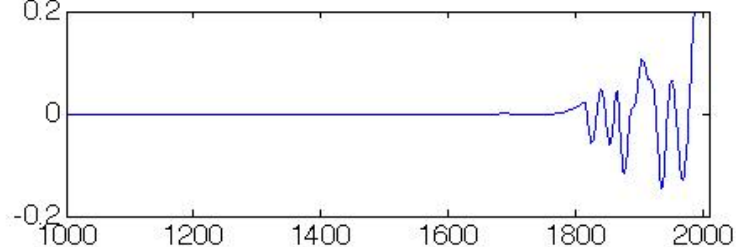
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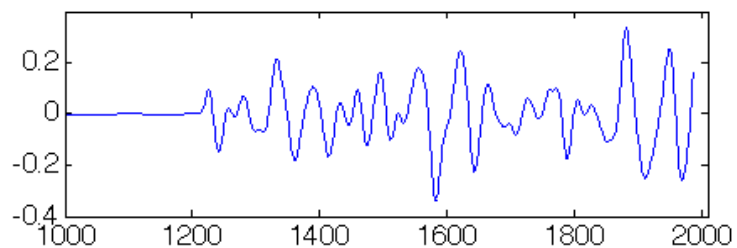
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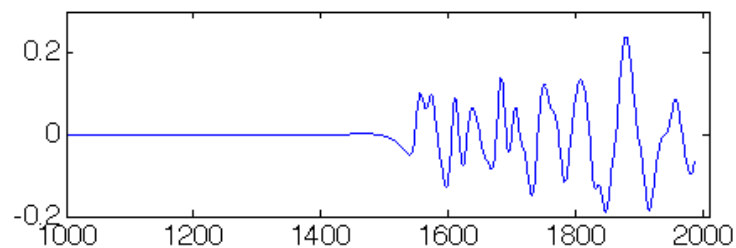
NAO Iceland-Gibraltar (Jones et al., 1997)



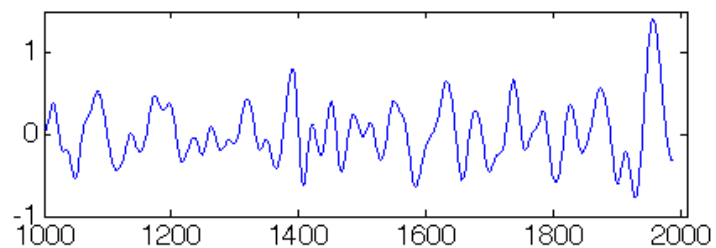
Caribbean Temperature(Kilbourne et al., 2014)



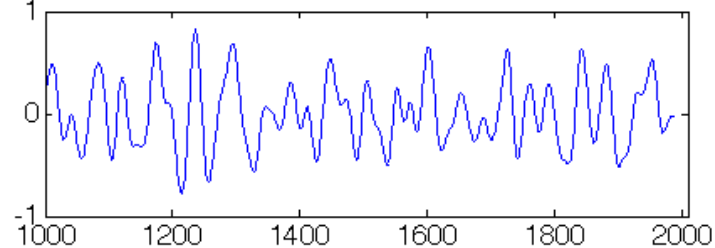
Tropical North Atlantic Temperature (Tierney et al., 2015)



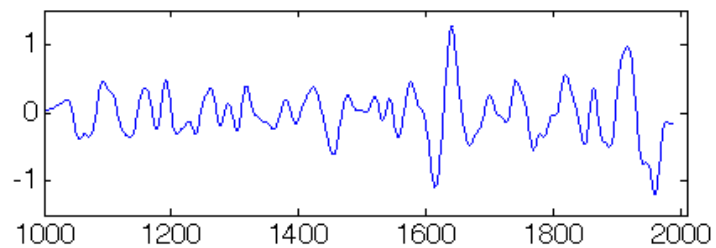
Norwegian Sea Temperature (Cunningham et al., 2014)



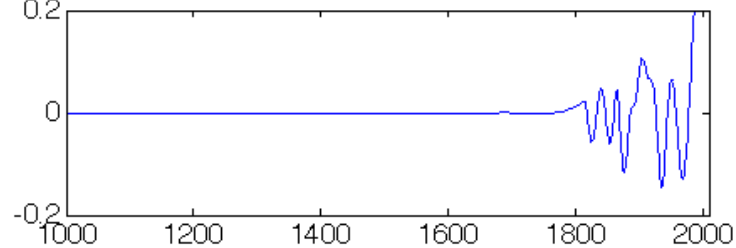
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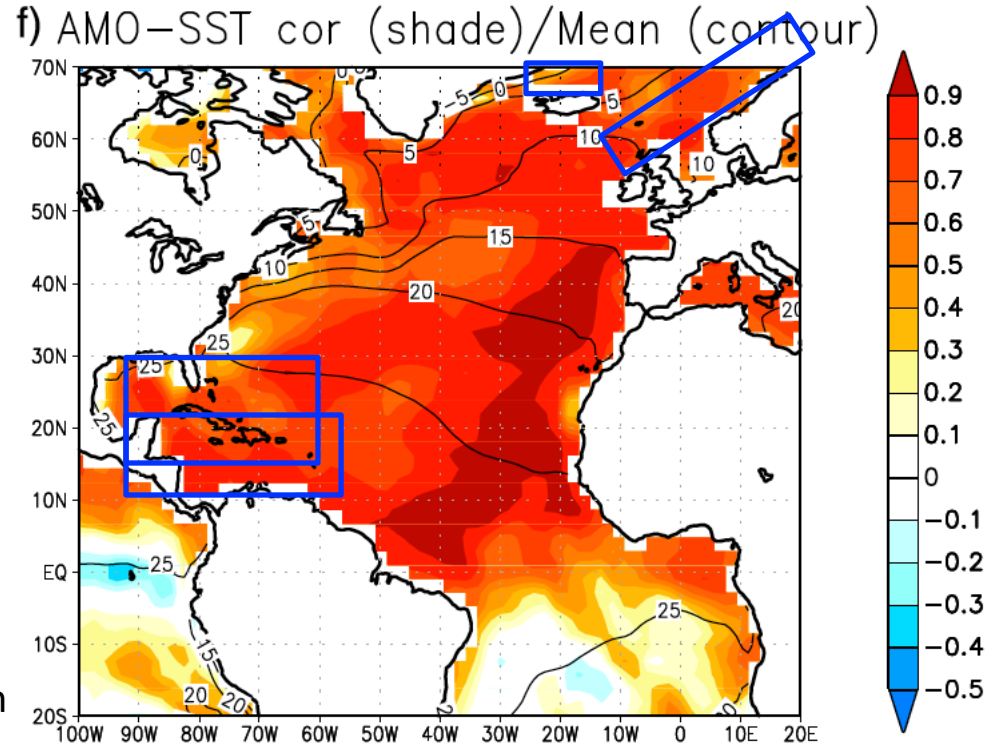
NAO reconstruction (Ortega et al., 2015)



NAO Iceland-Gibraltar (Jones et al., 1997)



Blue boxes represent approximate areas represented by proxy data



Alexander et al., 2014, Fig.2f: Long term mean SST (contoured) and the correlation between AMO index (c.f. Enfield 2001) and the 10-year running mean SST from HadISST