A new record of Atlantic sea surface salinity from 1896–2013 reveals the signatures of climate variability and long-term trends (and possibly the AMOC)

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Outline

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2. **Dataset construction**
3. **Leading regional variability**
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   - Climate variability: AMO and NAO
4. **Long-term trends**
5. **Discussion: Potential AMOC signatures**

Motivation

Sea surface salinity (SSS) integrates evaporation, precipitation, and runoff: the “ocean rain gauge”

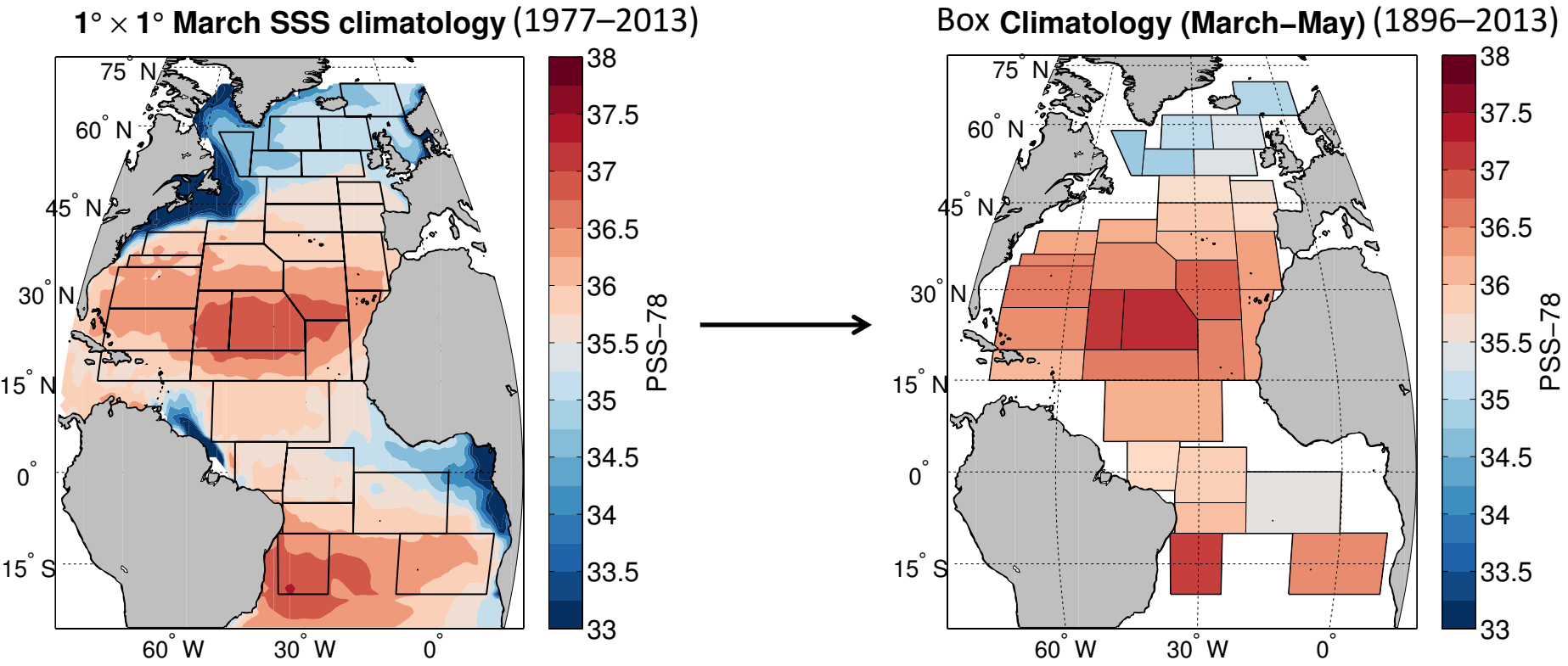
Atlantic surface salinity may influence the strength of deep convection & the meridional overturning circulation (AMOC)

Long time series beginning before the 1950s are rare, limiting our ability to resolve modes of variability and separate the forced signals

Dataset construction

Sources: oceanographic sections, weather ships, ships-of-opportunity transects, Nansen bottles, CTD casts, PIRATA moorings, and Argo floats

Data binned into 32 boxes from 20°S–70°N



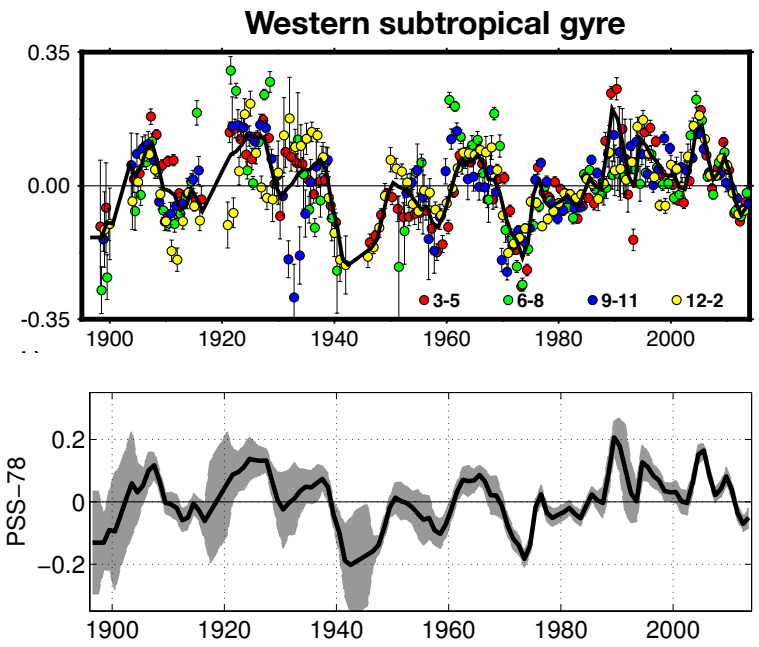
Updated & extended from *Reverdin et al. (2007)*

Dataset construction

Measurements are median-averaged into 3-month seasons; seasonal error term is calculated based on deviations from medians

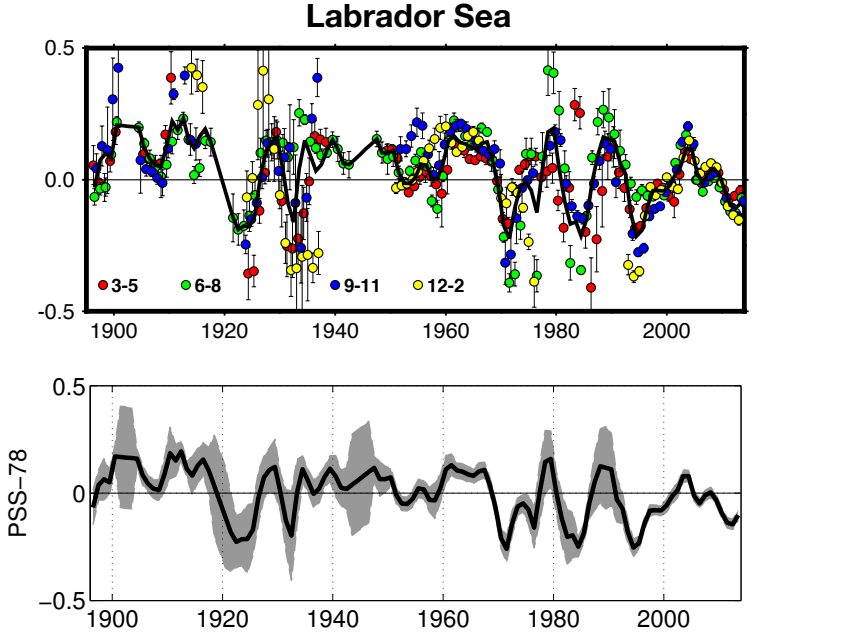
Seasons are 1-2-1 smoothed, and averaged inversely weighted by error

Some seasons with high error and/or low coverage are excluded (e.g. rainy season under the ITCZ, winter in the western SPG)



colored dots: seasonal medians

annual (1-2-1 filtered) time series ± 2 error terms



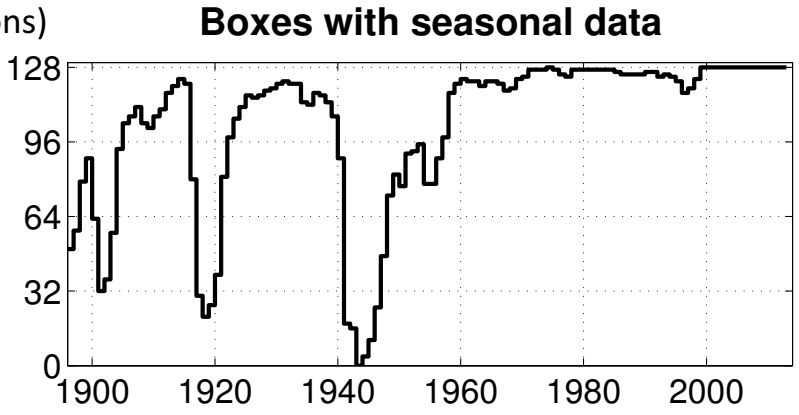
Dec–Feb not included in annual timeseries

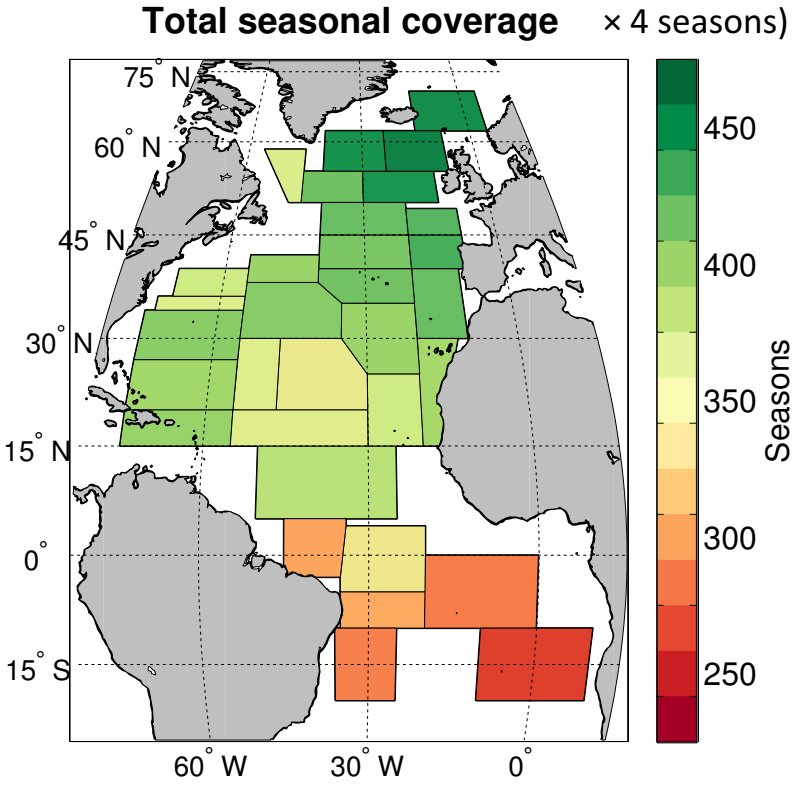
Dataset construction

Data from 1896–2013, minimal coverage during WWI and WWII

Short gaps (<5 yrs.) are interpolated linearly, larger gaps filled by regressing neighboring boxes

max. 128 (32 boxes × 4 seasons)





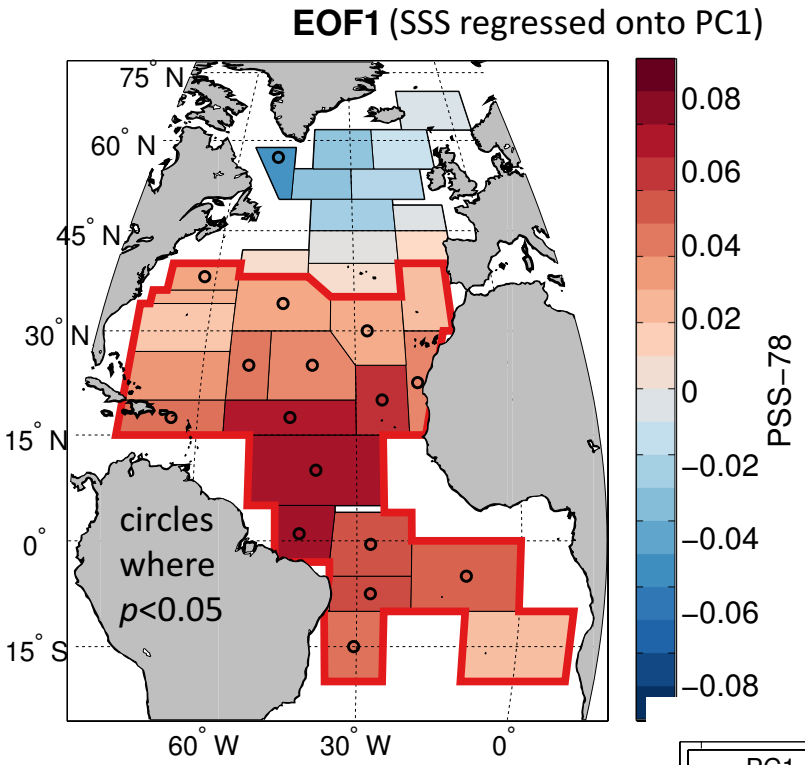
max. 472 (118 years × 4 seasons)

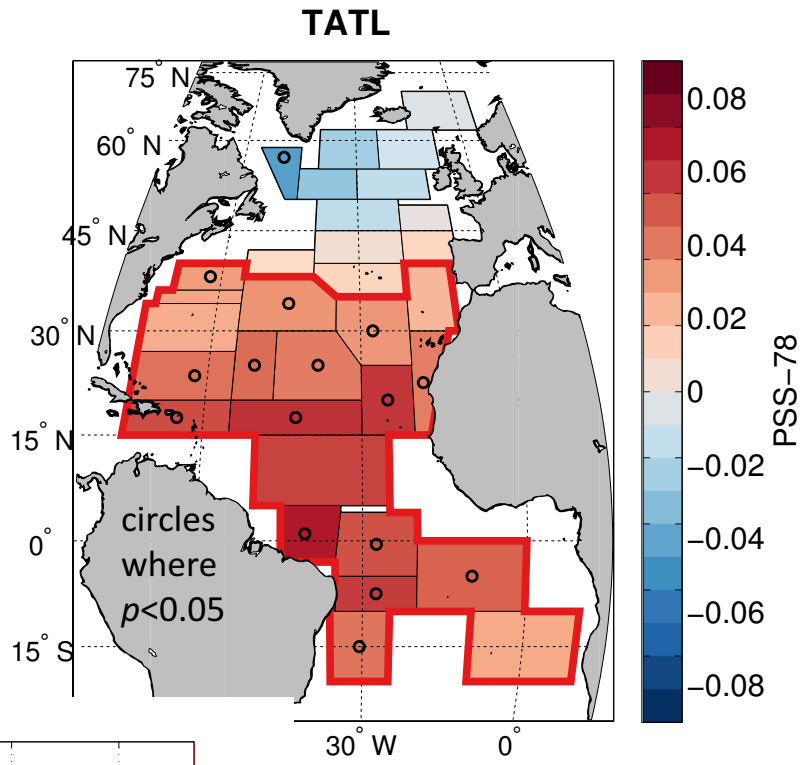
Leading regional variability

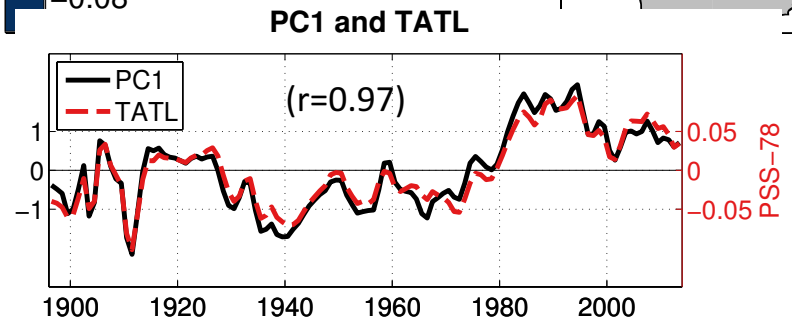
EOF1 (29% variance explained) features a north–south dipole

PC1 is strongly correlated with area-averaged SSS from 20°S–40°N

-> referred to as TATL





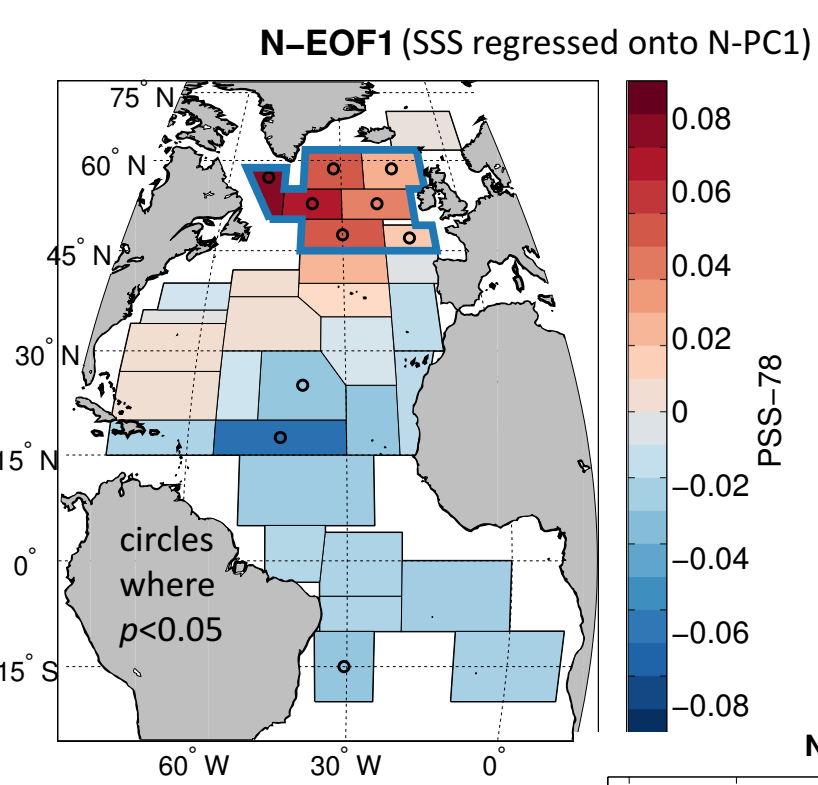


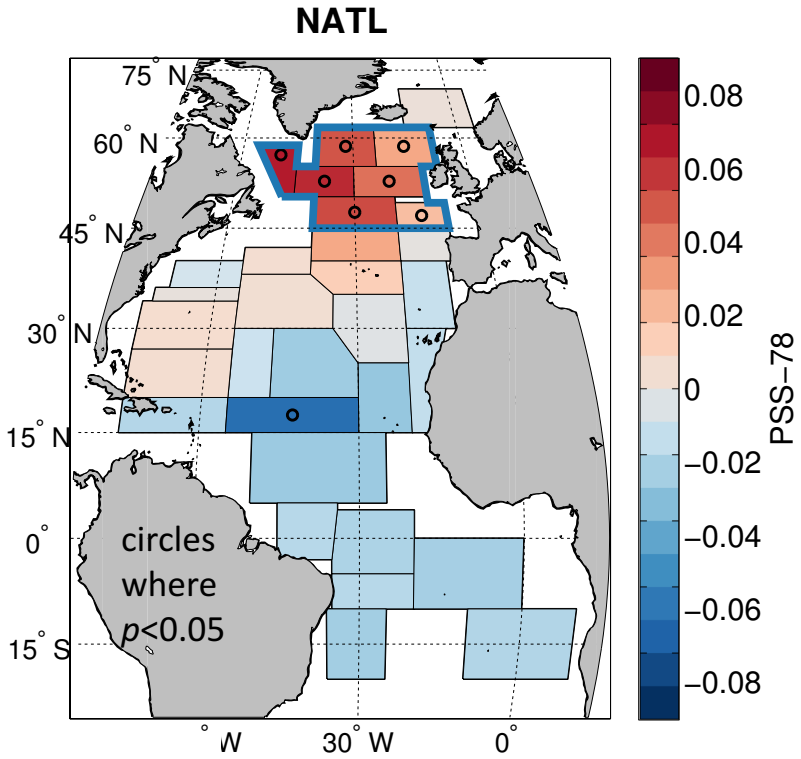
Leading regional variability

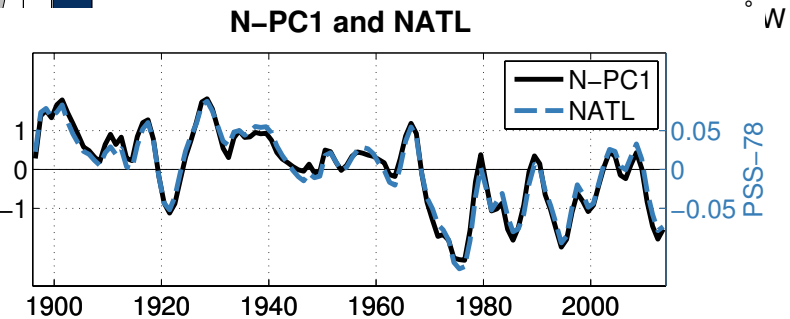
EOF1 north of 45°N (N-EOF1; 51% northern variance explained)

N-PC1 is strongly correlated with area-averaged SSS from 45°–62°N

->referred to as NATL





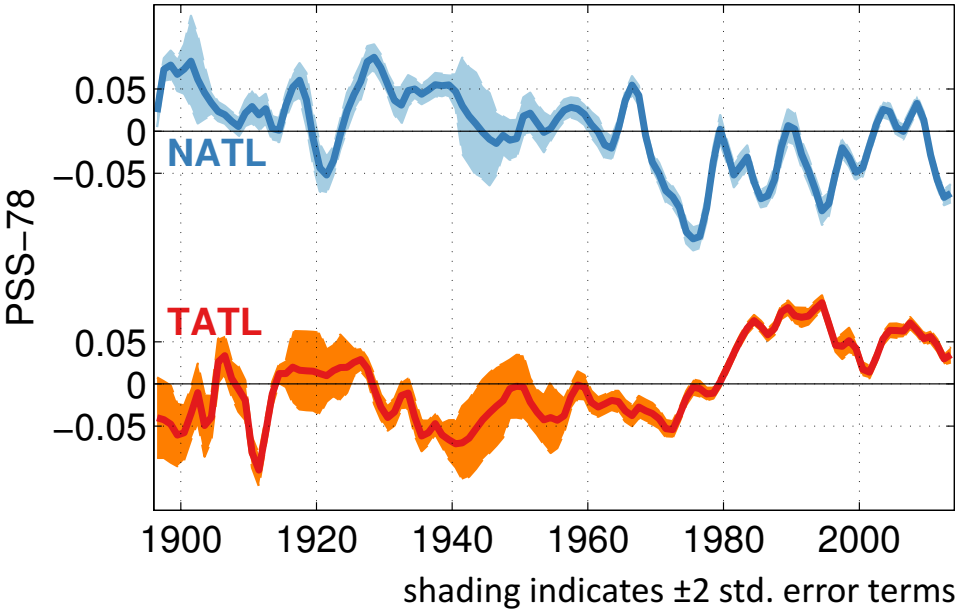


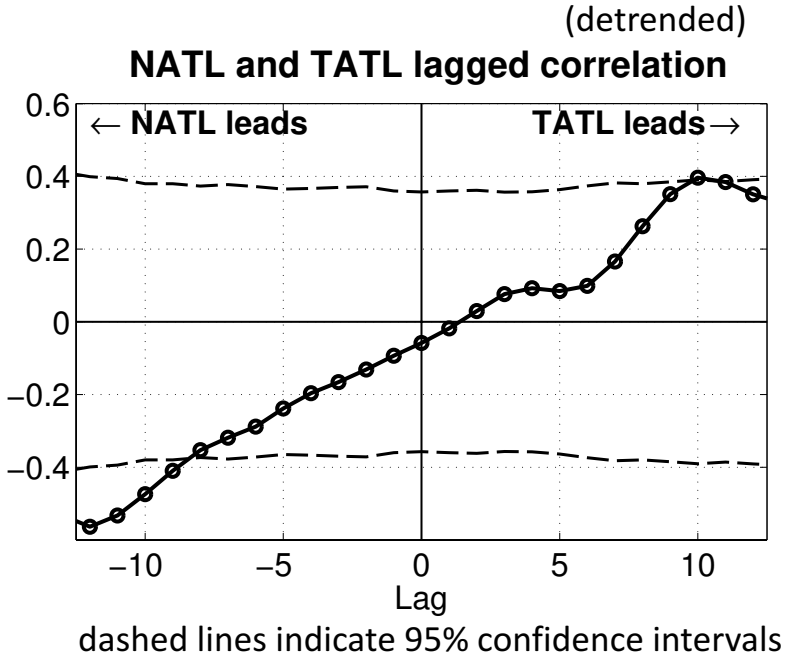
Leading regional variability

TATL strongly increased from 1975–1990, with an overall positive trend

NATL has a long-term freshening trend, with notable freshening around 1970 (Great Salinity Anomaly)

NATL and TATL are significantly correlated when NATL leads by about a decade

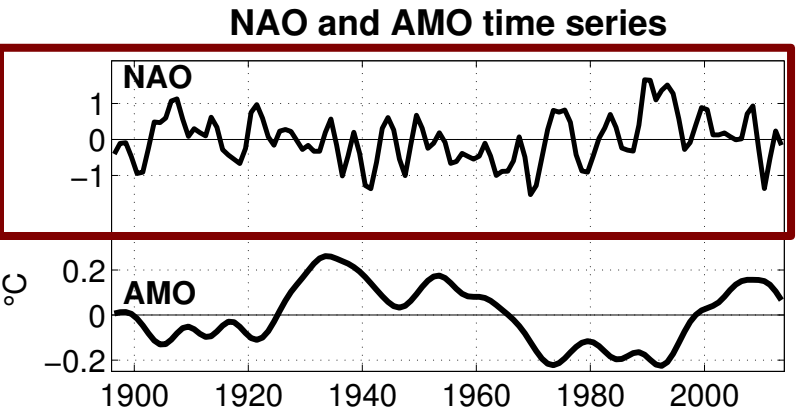


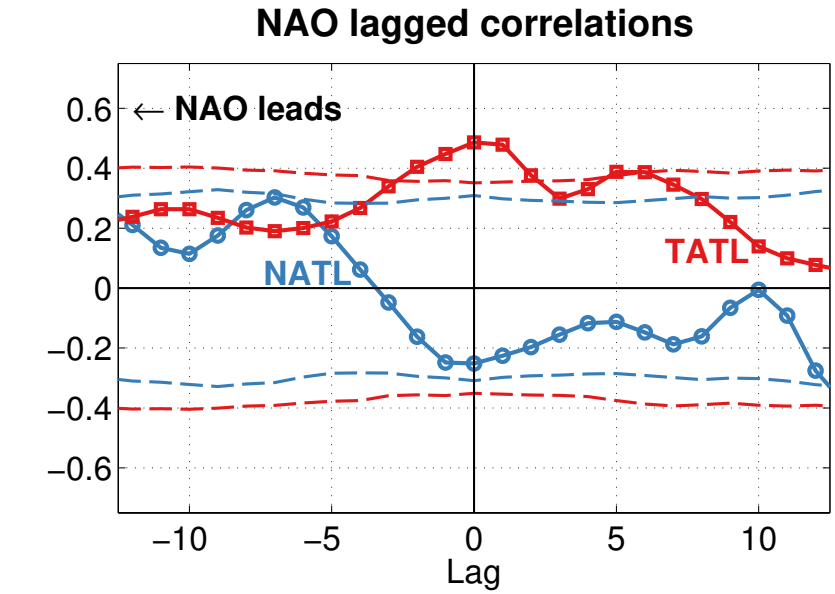


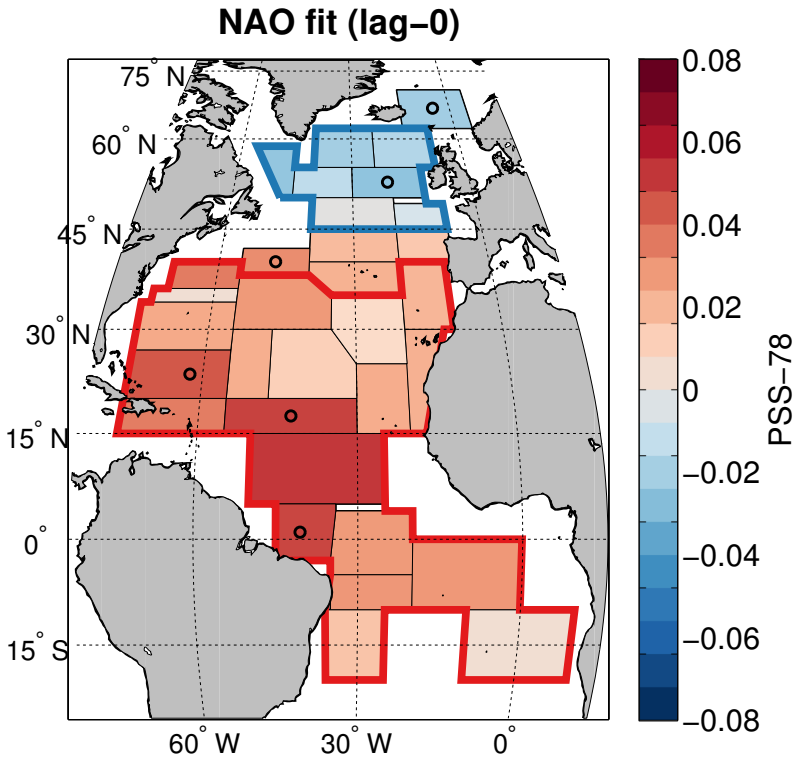
Leading regional variability: NAO

The NAO projection is a north–south dipole

TATL is strongly correlated with the NAO at lag-0



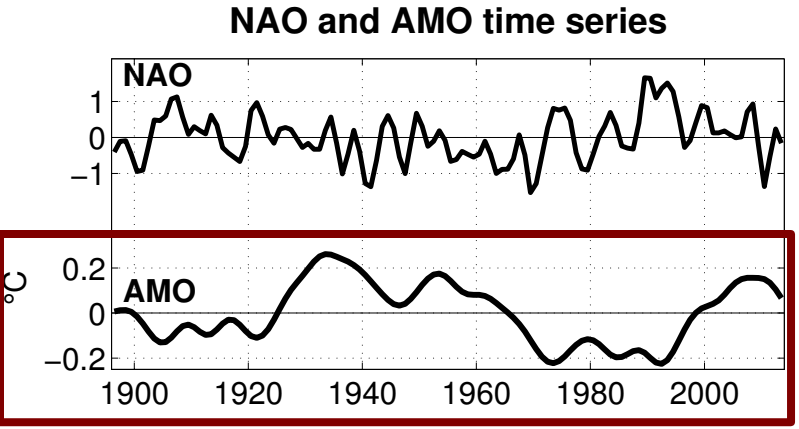


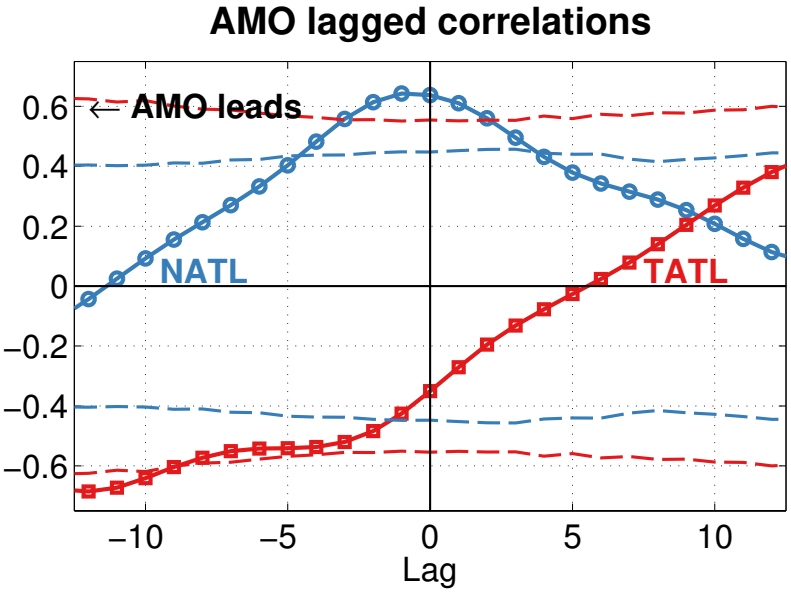


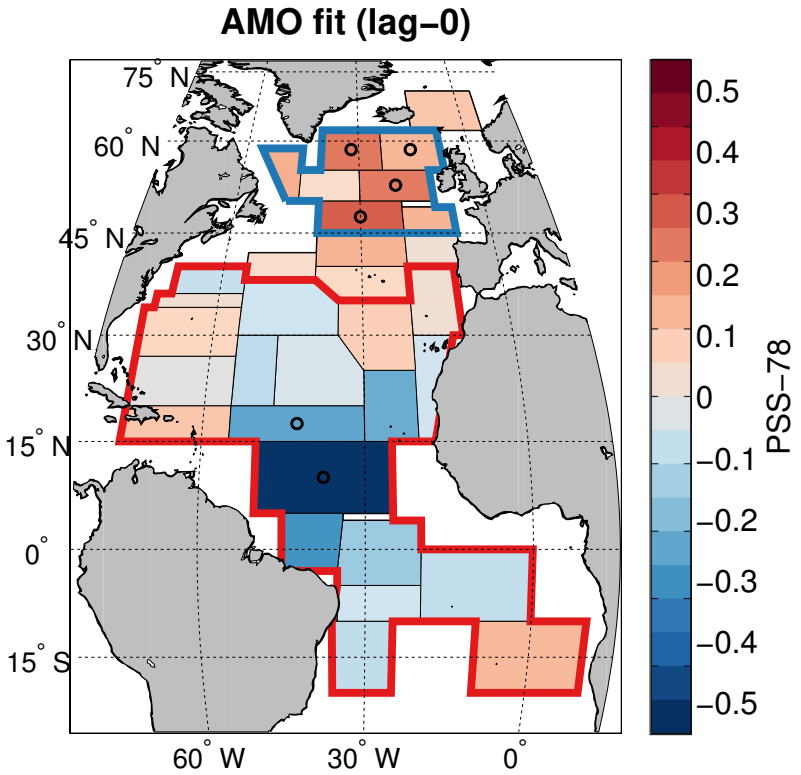
Leading regional variability: AMO

The AMO projection is positive in the subpolar Atlantic and negative in the northern tropical Atlantic

NATL is strongly correlated with the AMO at lag-0

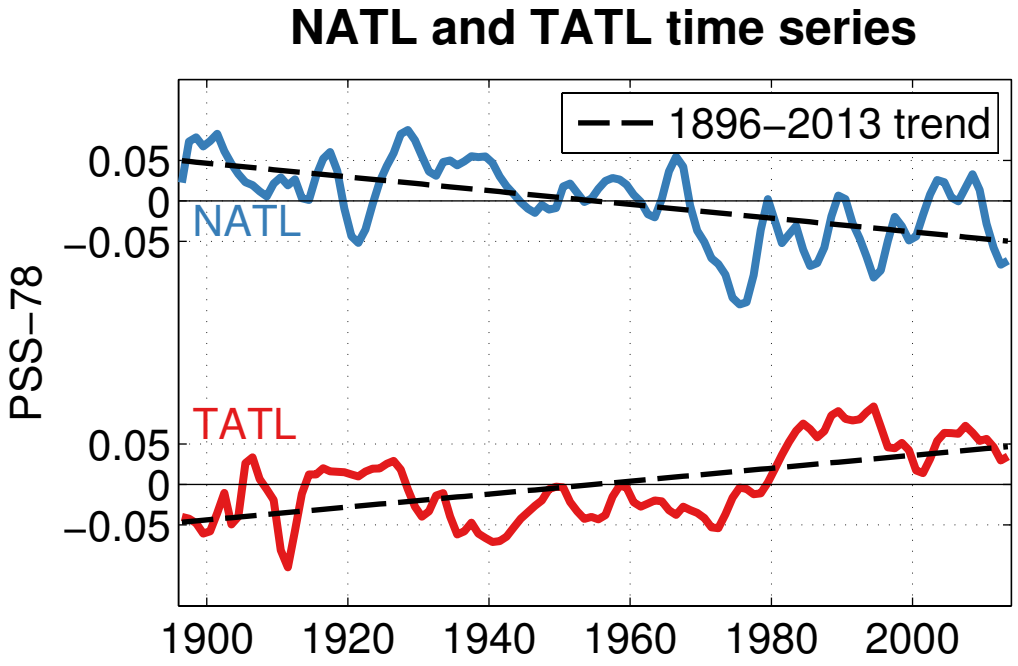


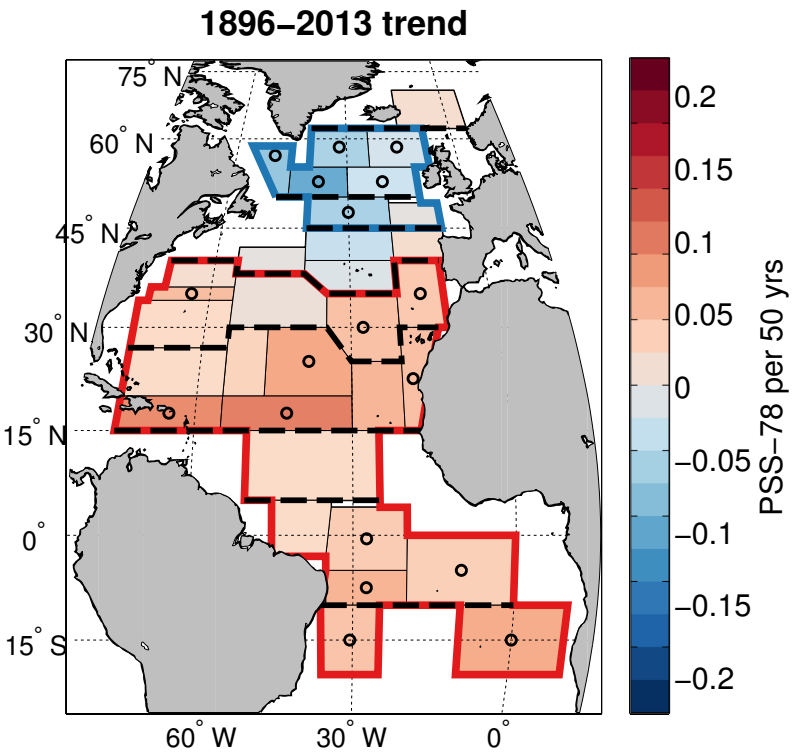




Long-term trends

The 1896–2013 trend shows salinification in low latitudes and freshening at high latitudes

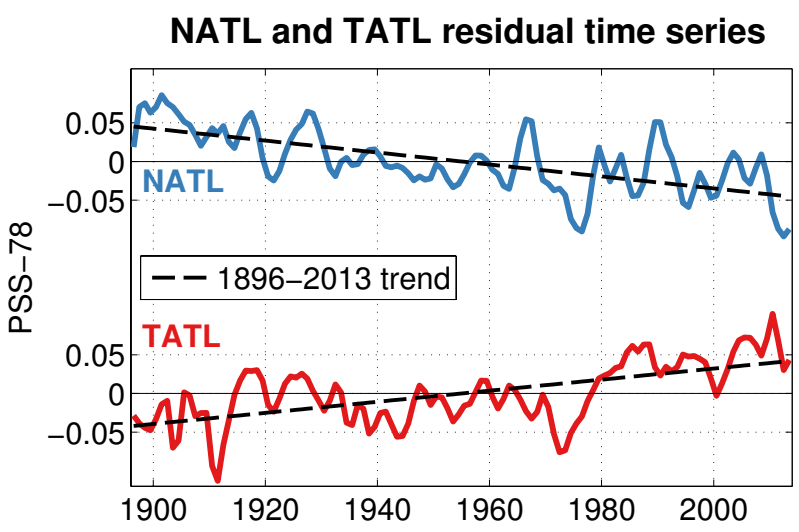


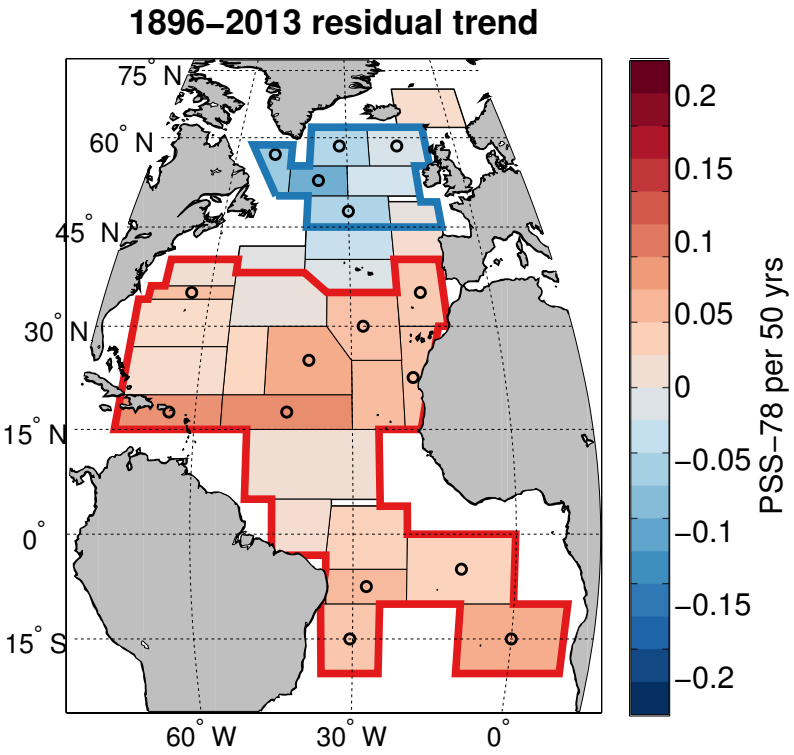


Long-term trends

Regressing out the (lag-0) AMO & NAO has little effect on the long-term trend magnitude

SSS = B_1NAO + B_2AMO + ε (ε = residual SSS)





Summary

The leading SSS variability, area-averaged SSS south of 40°N (TATL), projects onto the NAO & lags the AMO by a decade

Subpolar SSS (NATL) varies in phase with the AMO

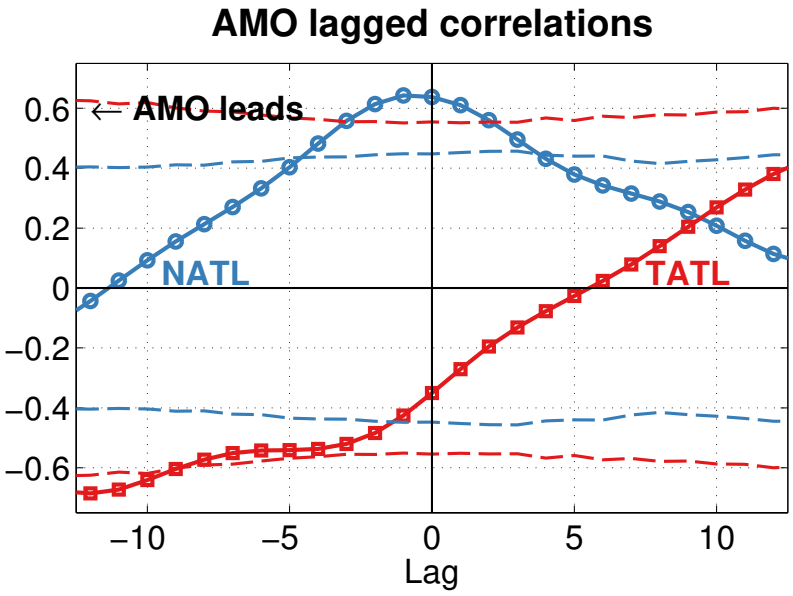
Long-term SSS trends show freshening in the subpolar Atlantic and salinification in the low latitudes

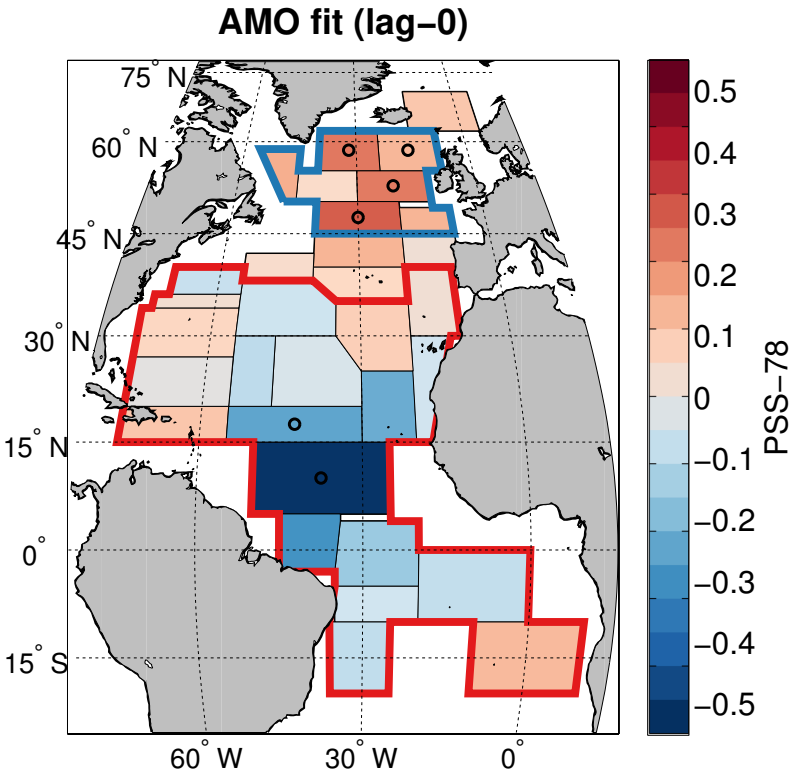
Discussion: Potential AMOC signatures

(1) The strong lag-0 NATL/ AMO correlation supports an increase of northward saline waters with positive AMO

Consistent with a role of the AMOC in the AMO

[e.g. *Delworth et al. 1993; Vellinga and Wu, 2004; Latif et al. 2004; Knight et al. 2005*]





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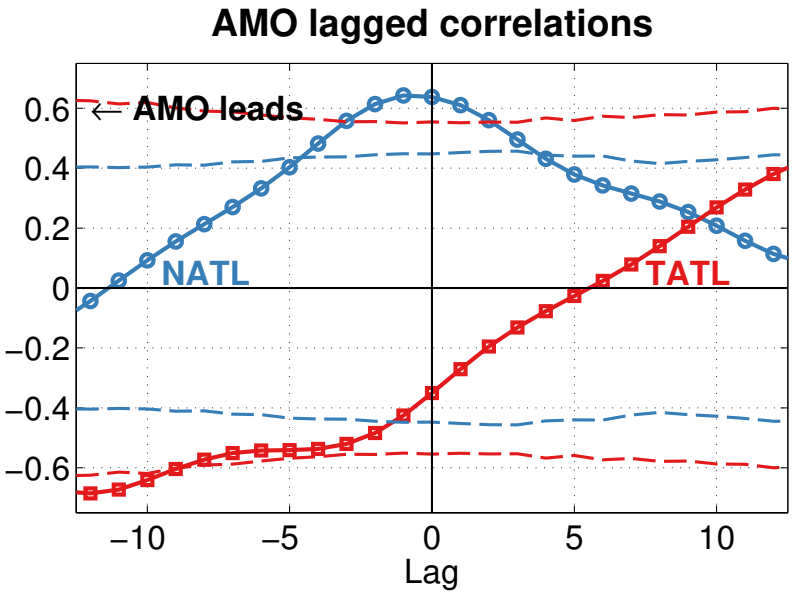
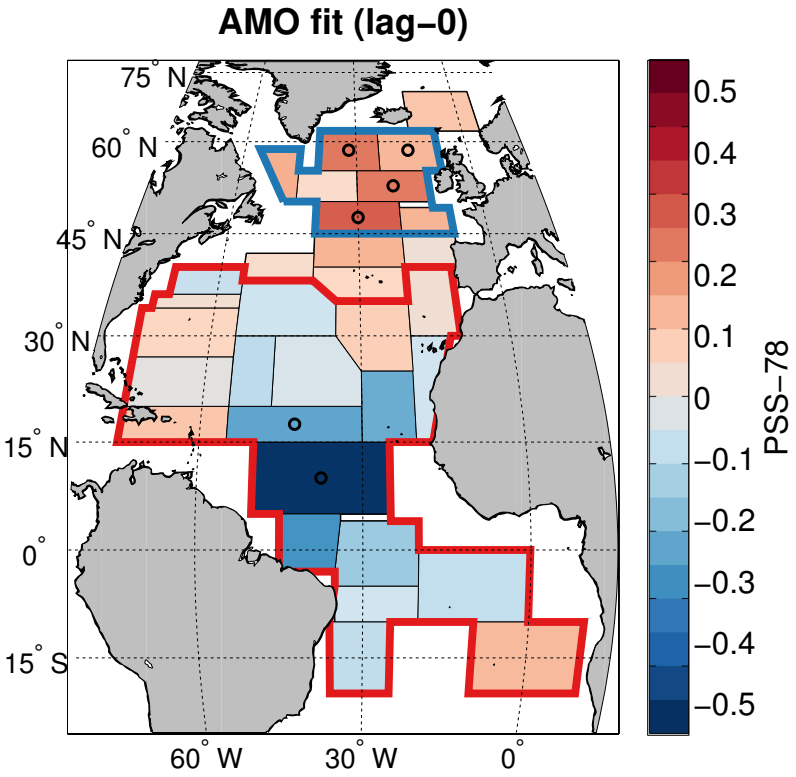




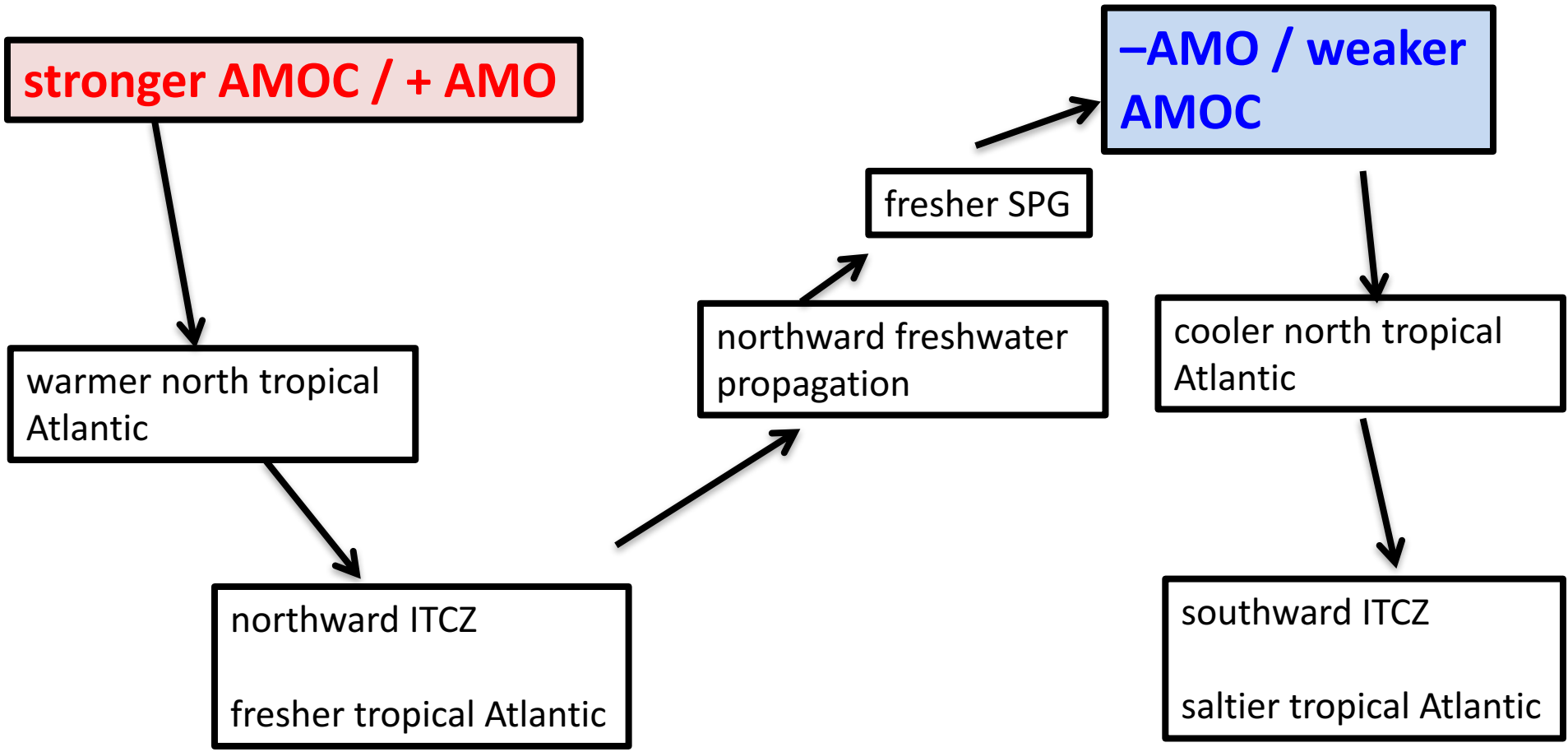
Is the NATL SSS /AMO correlation consistent with AMO found in slab ocean models?

[*Clement et al. 2015*]

Discussion: Potential AMOC signatures

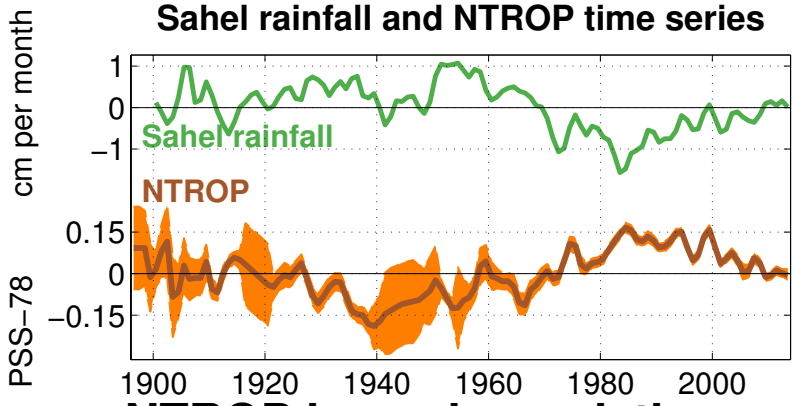
(2) AMO and tropical Atlantic SSS relationship consistent with a negative multidecadal/centennial AMOC feedback from models

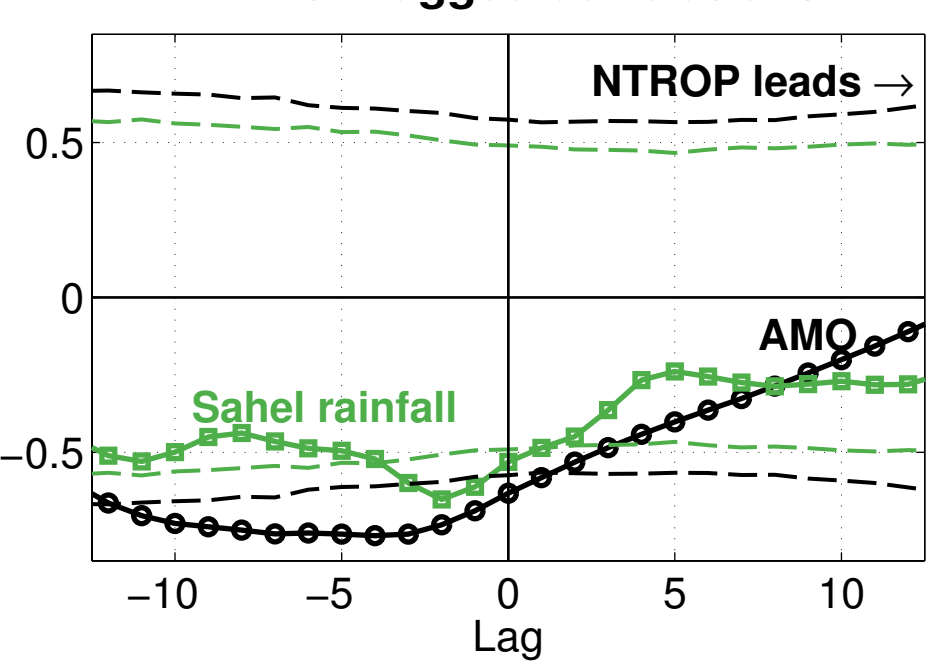
[*Vellinga & Wu, 2004; Mignot & Frankignoul 2010*]

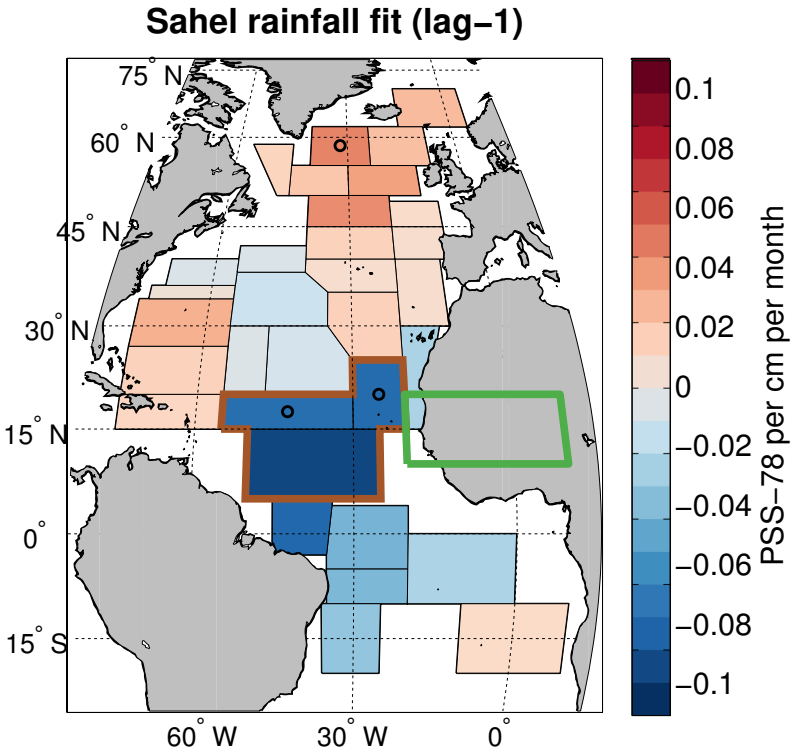


Discussion: Potential AMOC signatures

Northern tropical Atlantic SSS (referred to as NTROP) is negatively correlated with Sahel rainfall and the AMO with a short lag







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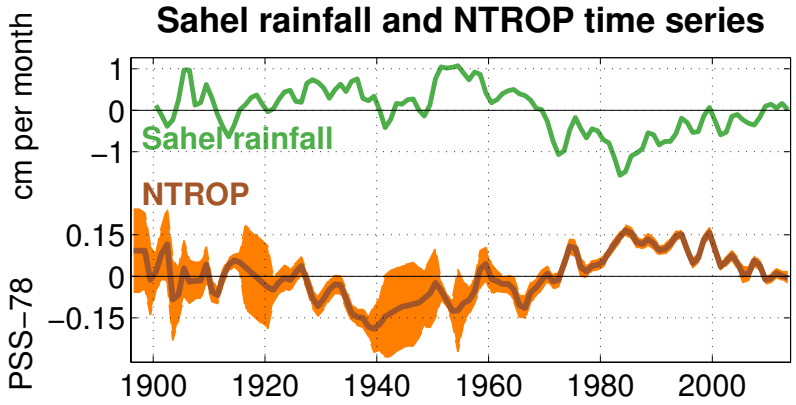
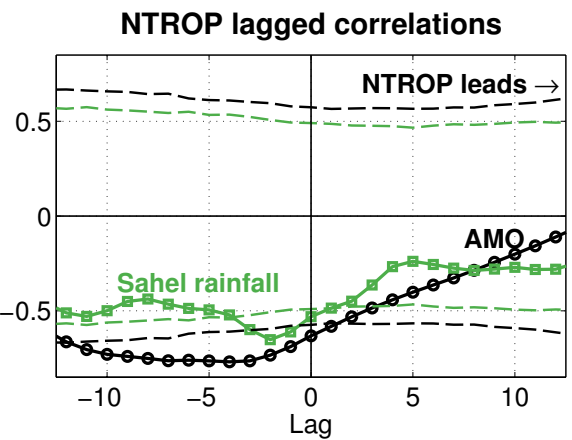
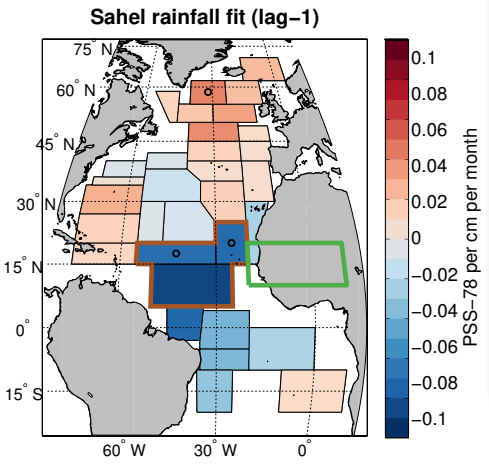
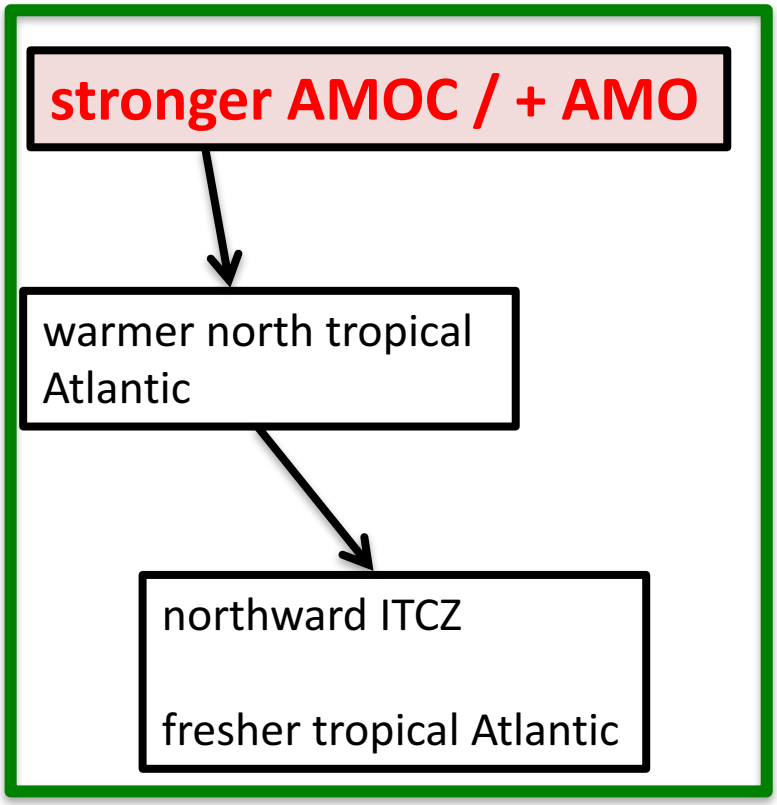


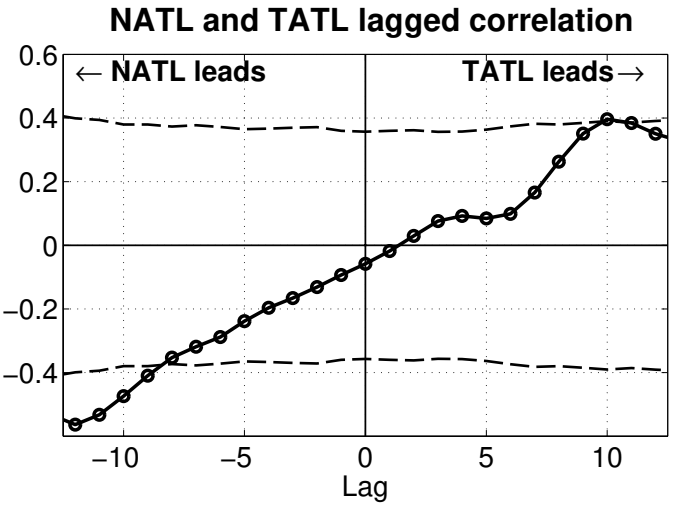


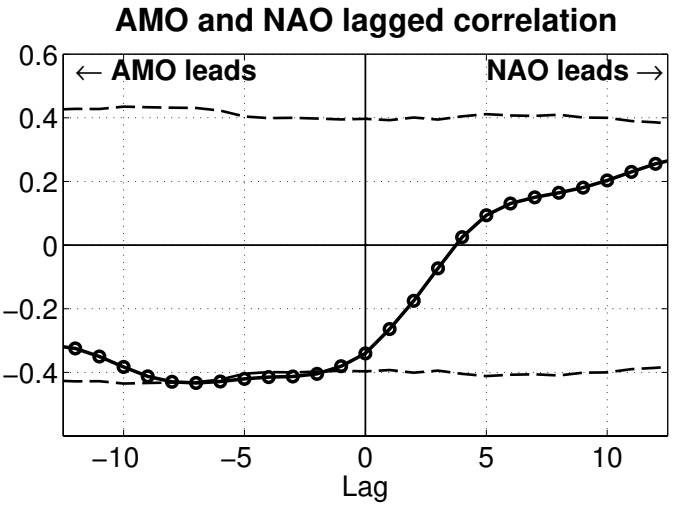


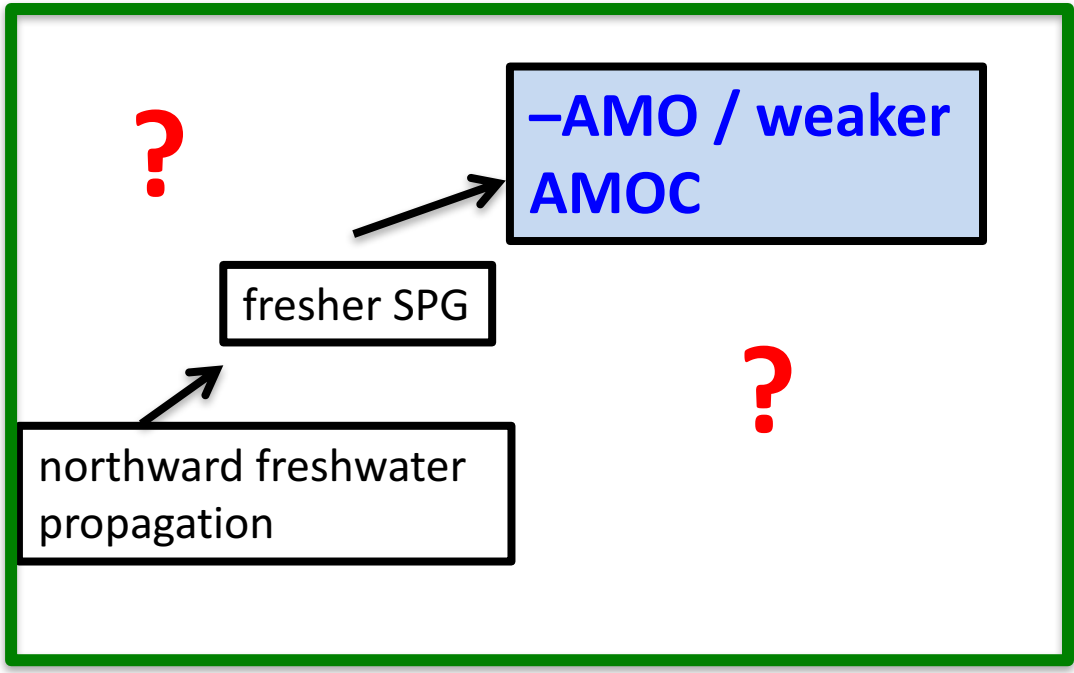


Discussion: Potential AMOC signatures

Does the decade lag of the NATL and AMO reflect a propagation of the AMO signal through the ocean, or direct NAO effects?



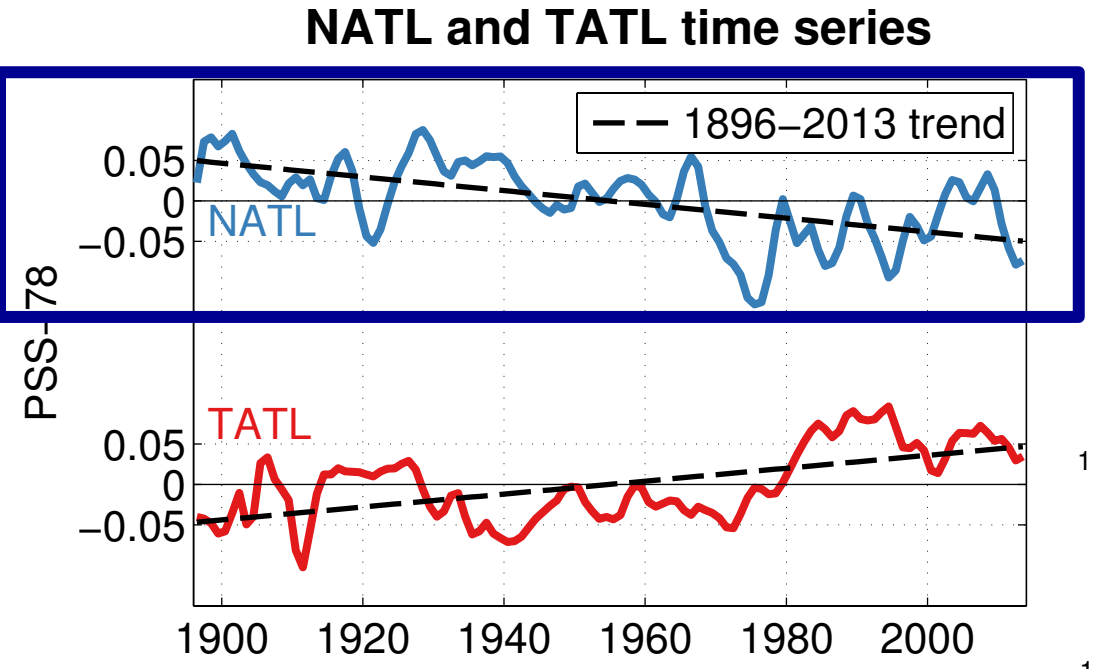


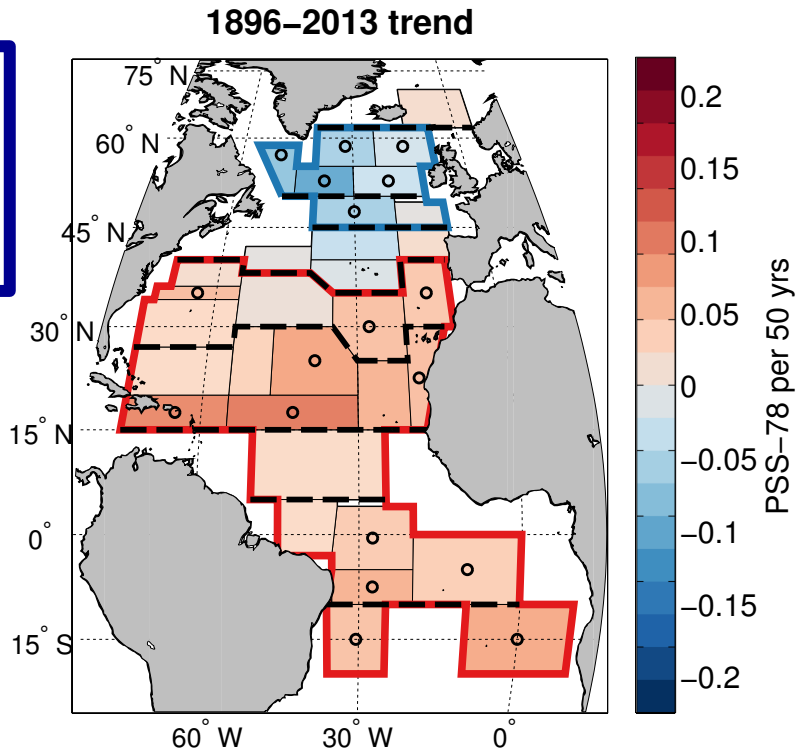


Discussion: Potential AMOC signatures

(3) Does the long-term subpolar freshening imply reduced convection and a slowdown of the AMOC?

[*Rahmstorf et al. 2015; Liu et al. 2017*]





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