Subtropical North Atlantic preconditioning key to skillful subpolar gyre prediction

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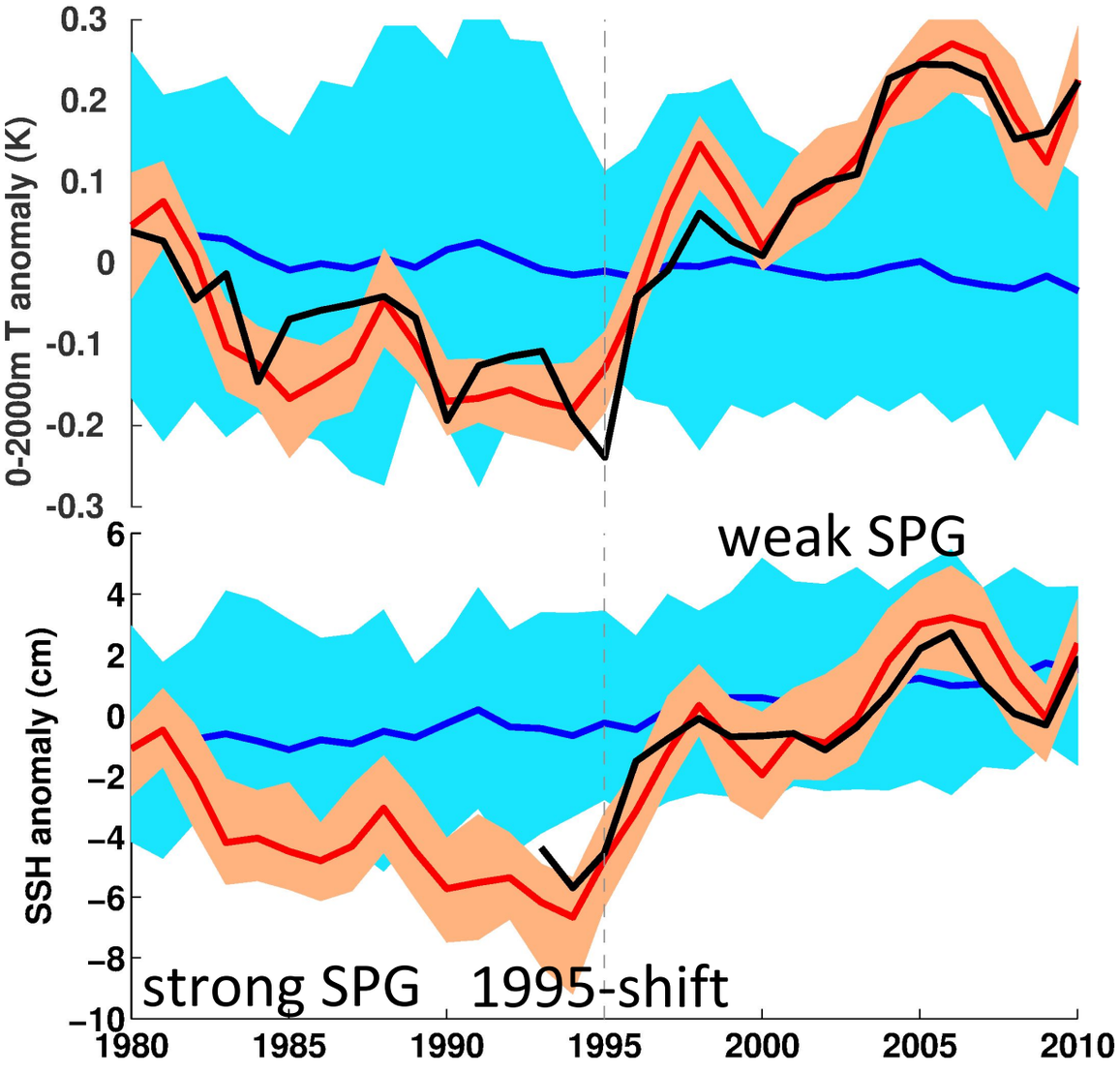
[4]Bjerknes Centre for Climate Research, Bergen, Norway

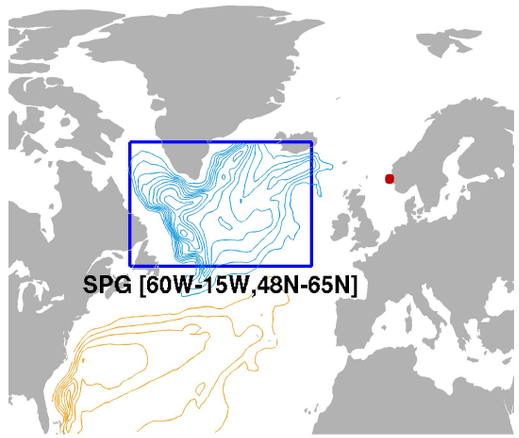
BFS BCPU INES

SPG prediction with NorCPM-SSTA



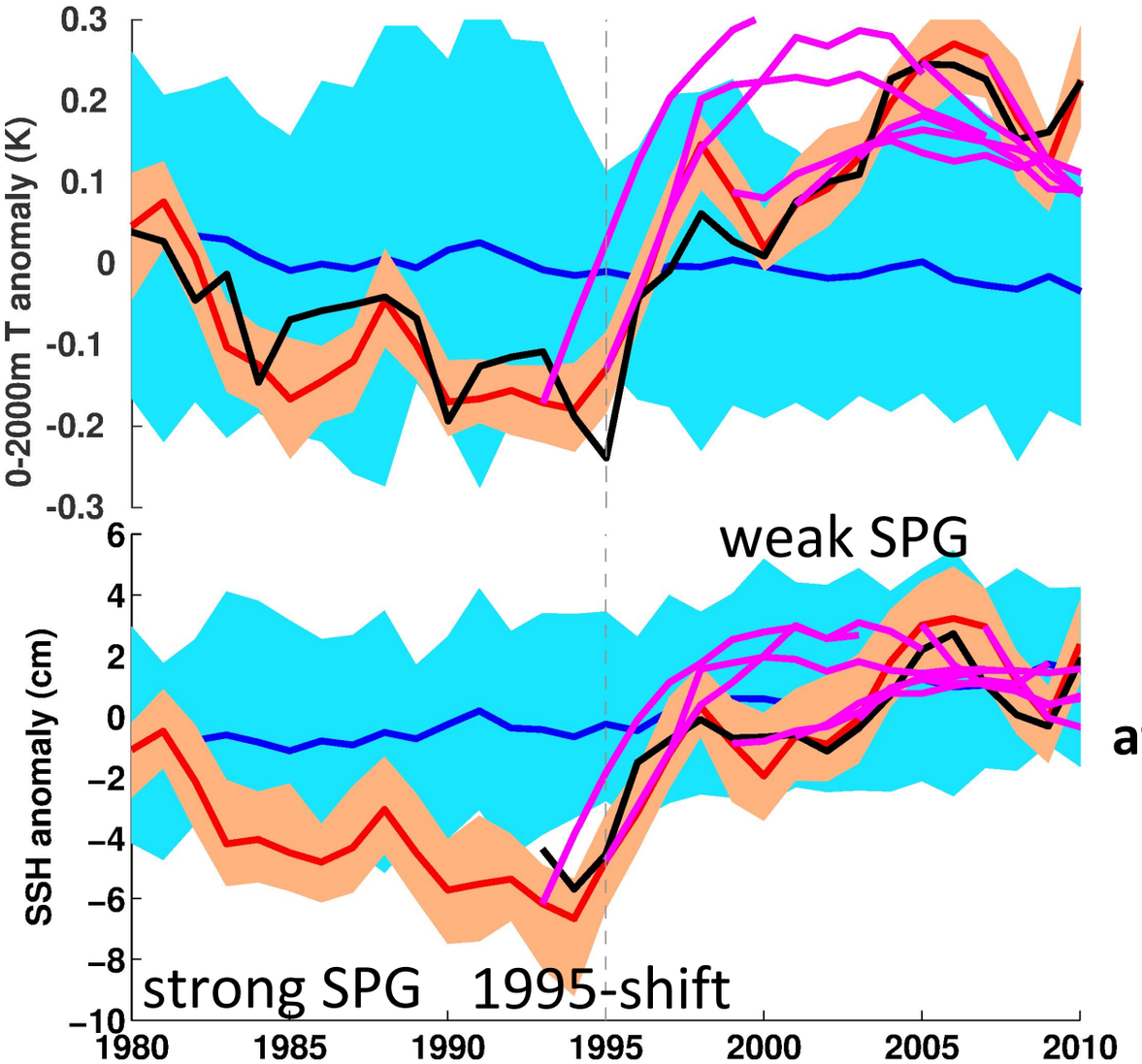
EN4 T/S analysis; altimetry observations

30-member NorESM hist. ensemble (solid=mean, shading=min/max)



30-member NorCPM-SSTA reanalysis using anomaly EnKF assimilation of SST obs.

SPG prediction with NorCPM-SSTA



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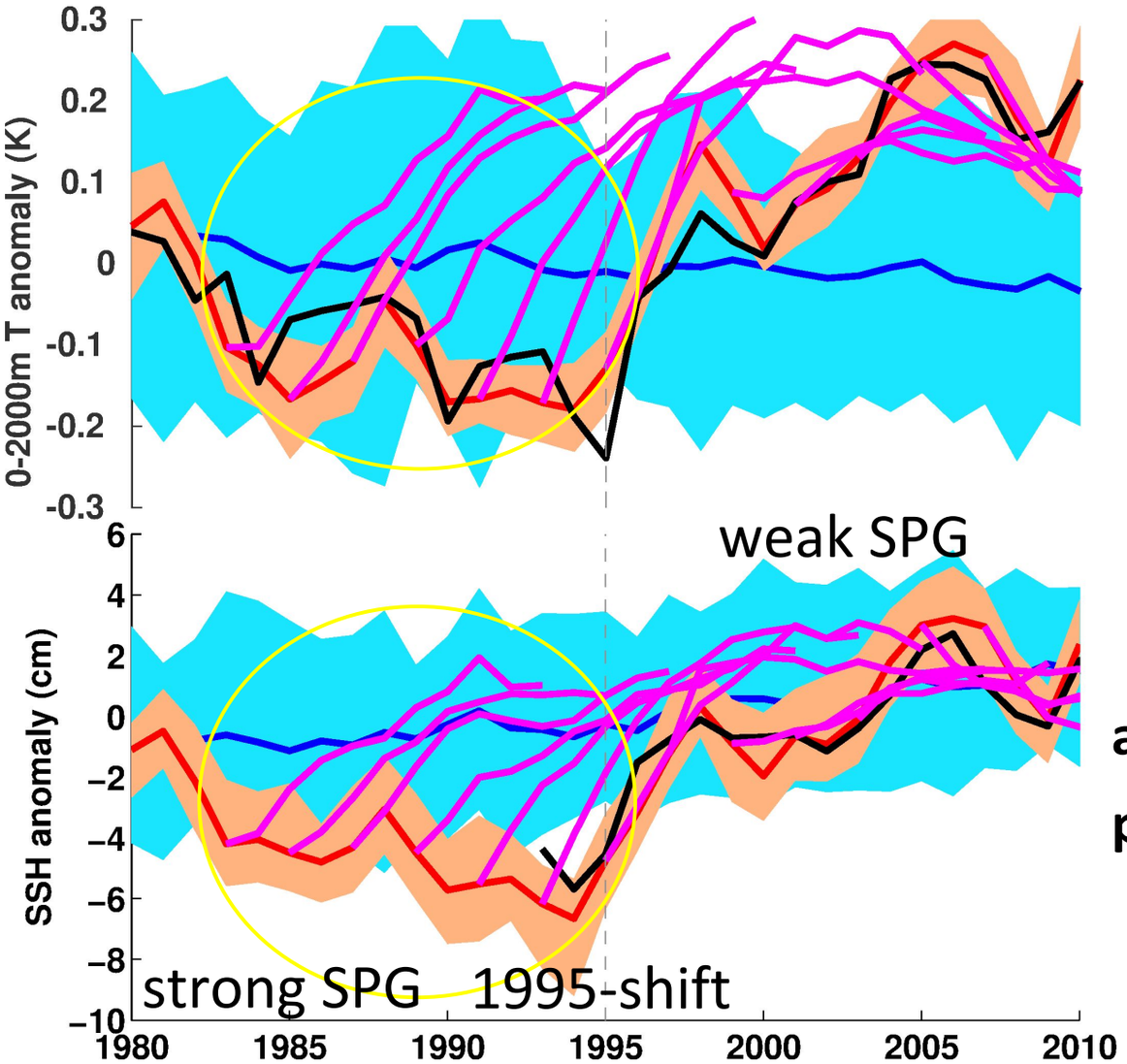
20-member hindcasts initialised from NorCPM-SSTA reanalysis

after 1994 – hindcast trends match observed trends ✓

SPG prediction with NorCPM-SSTA



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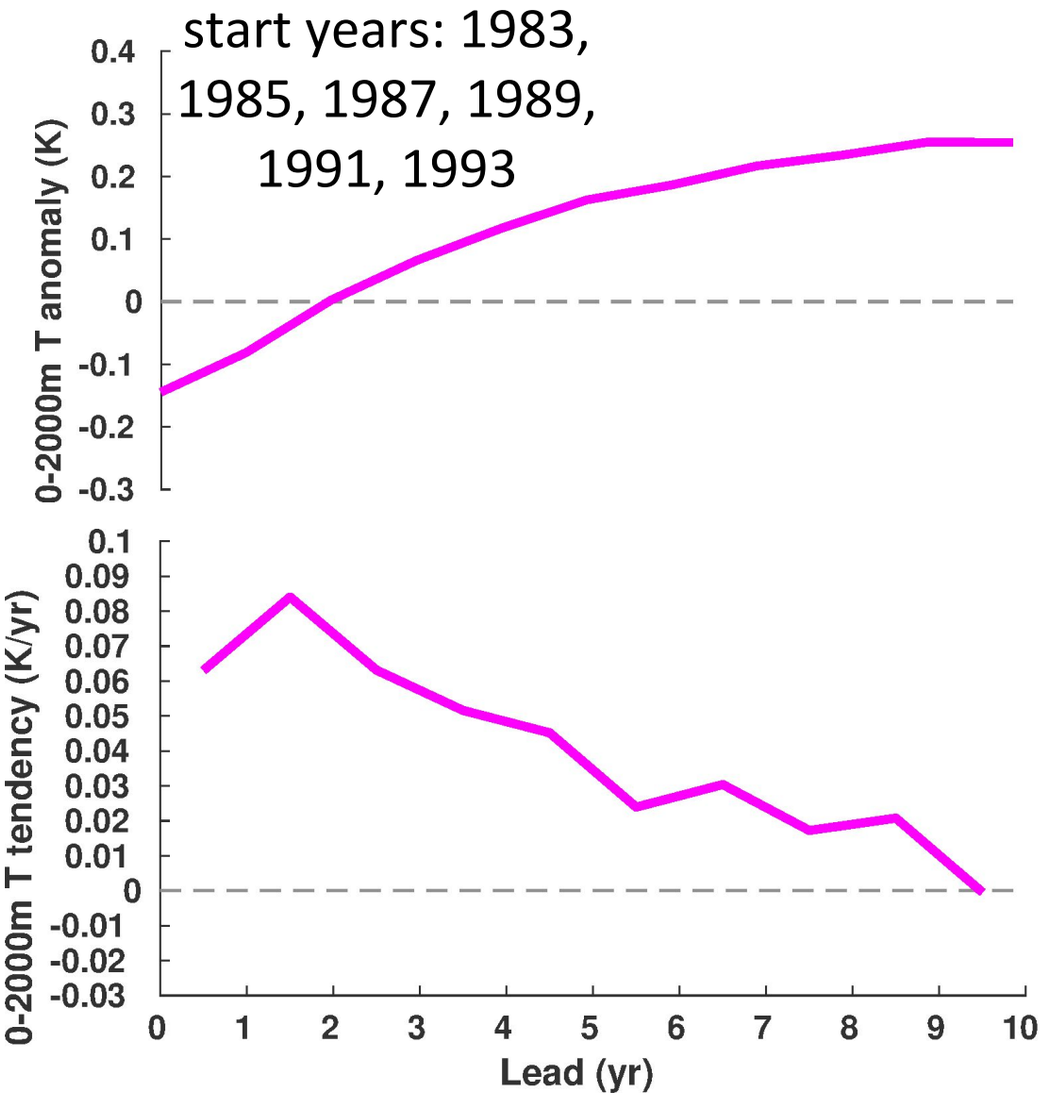
after 1994 – hindcast trends match observed trends ✓

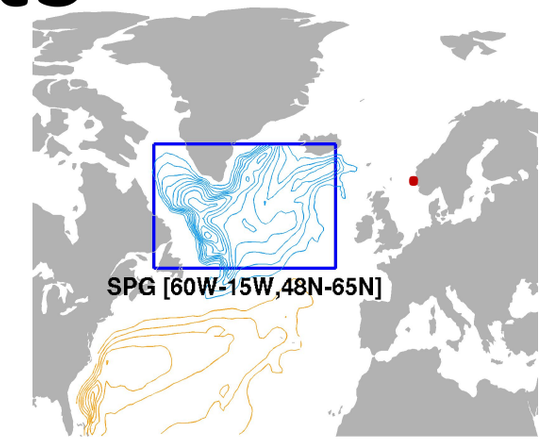
prior 1994 – hindcasts opposite to observed trends ✘

Causes for false SPG warmings?

Possible to rectify?

SPG heat budget analysis from composite of pre-1995 hindcasts





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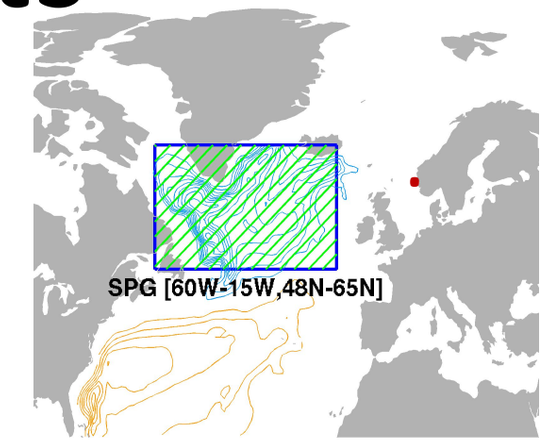

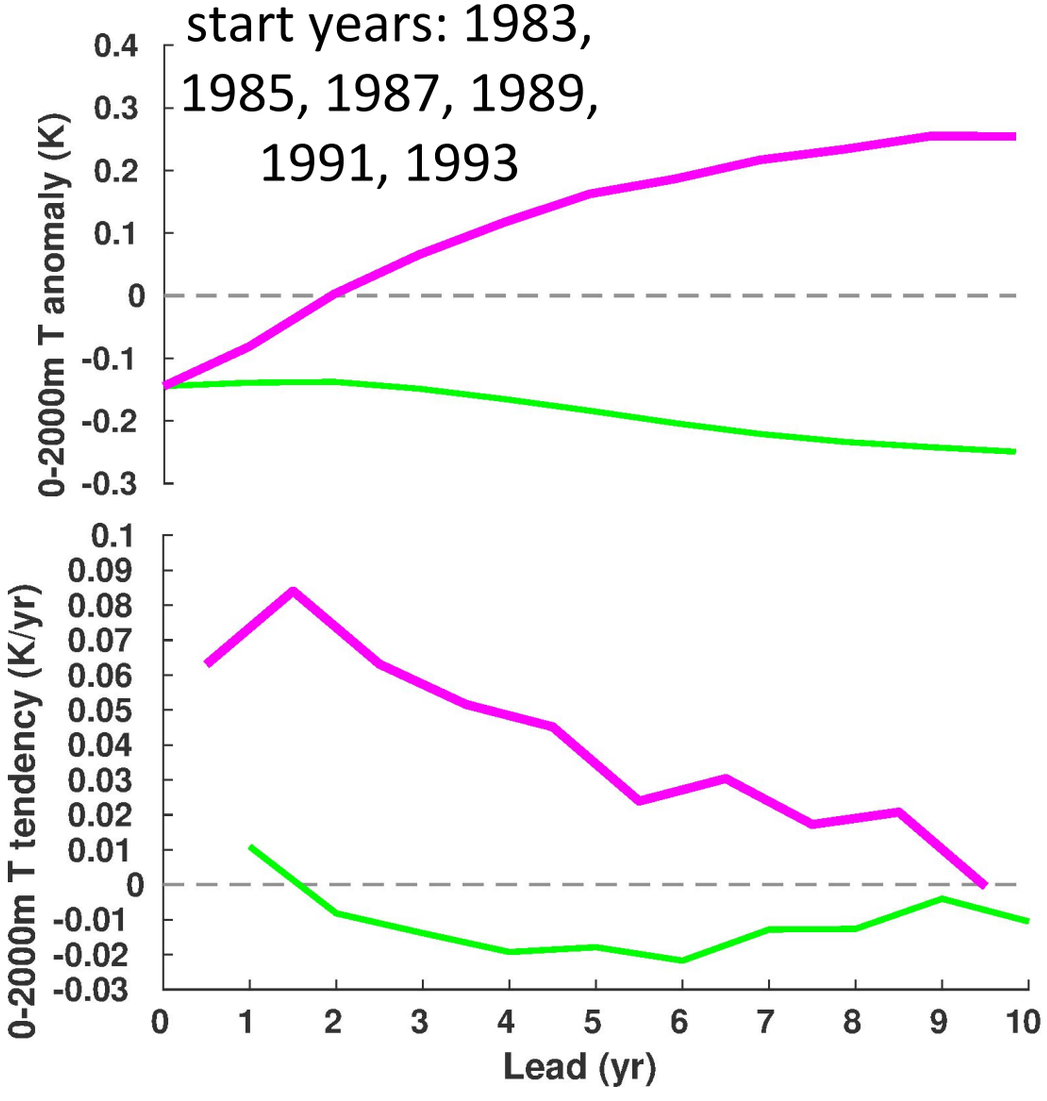

SPG surface flux: weak warming, moderate cooling

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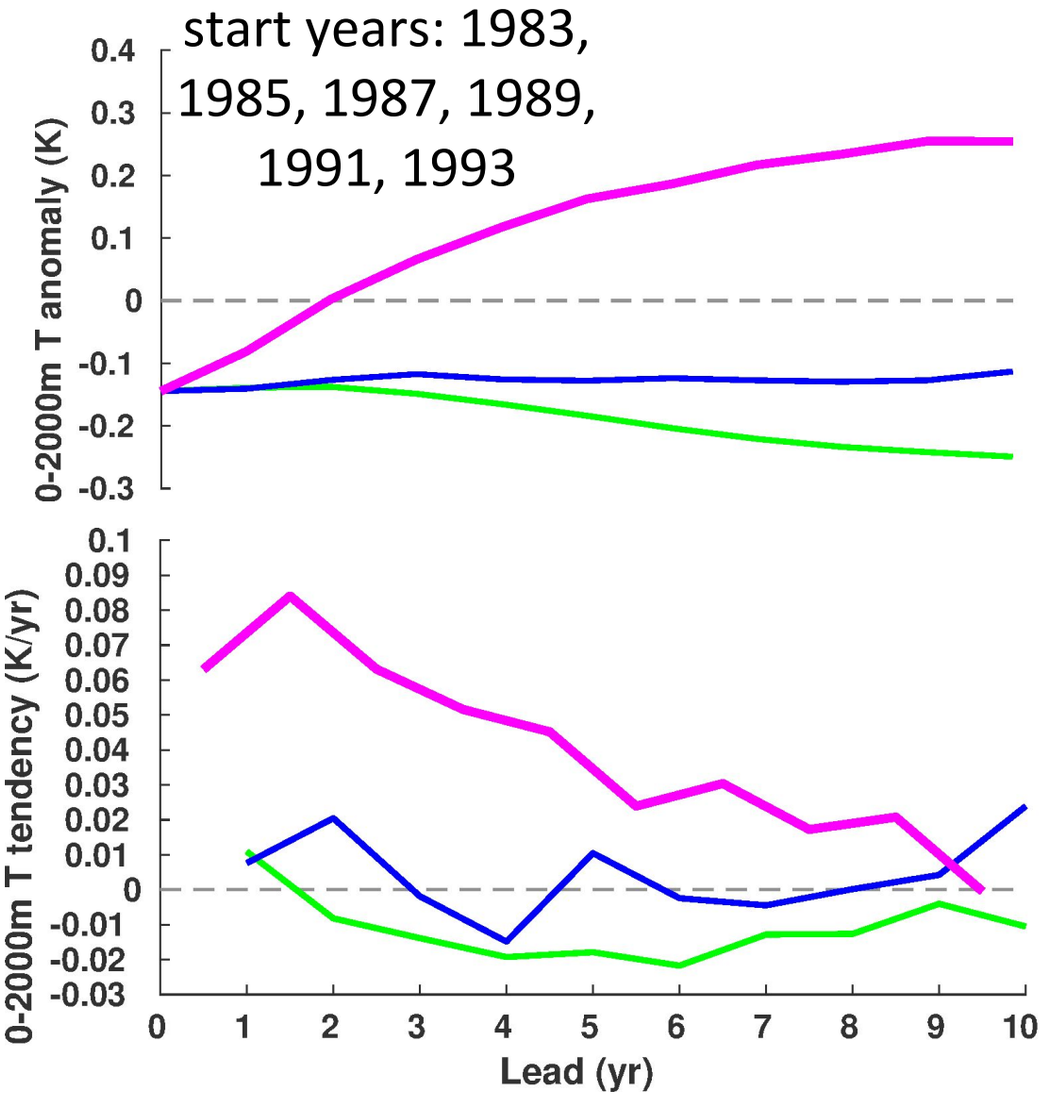
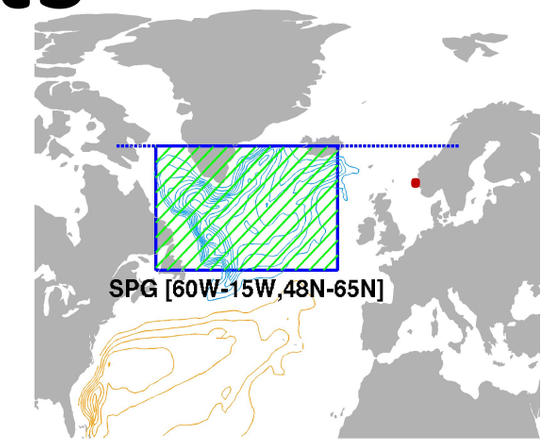


$T_{hind} - T_{free}$

surface flux

trans 65°N



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heat trans. at N. boundary: negligible effect

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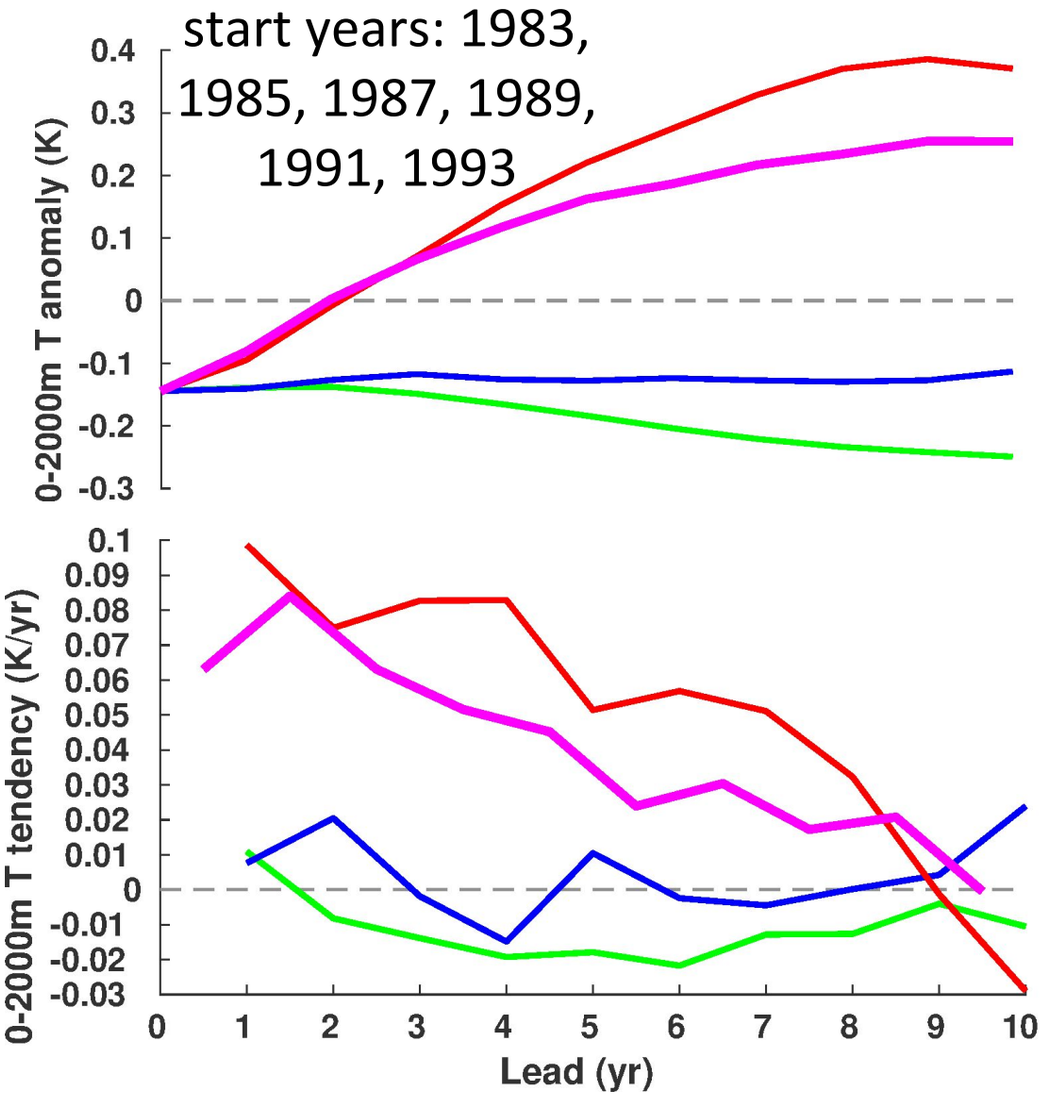
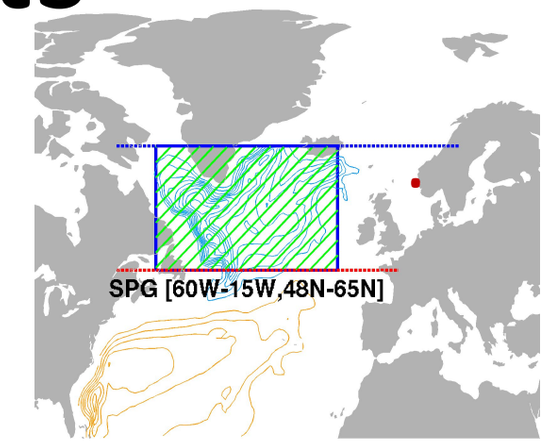


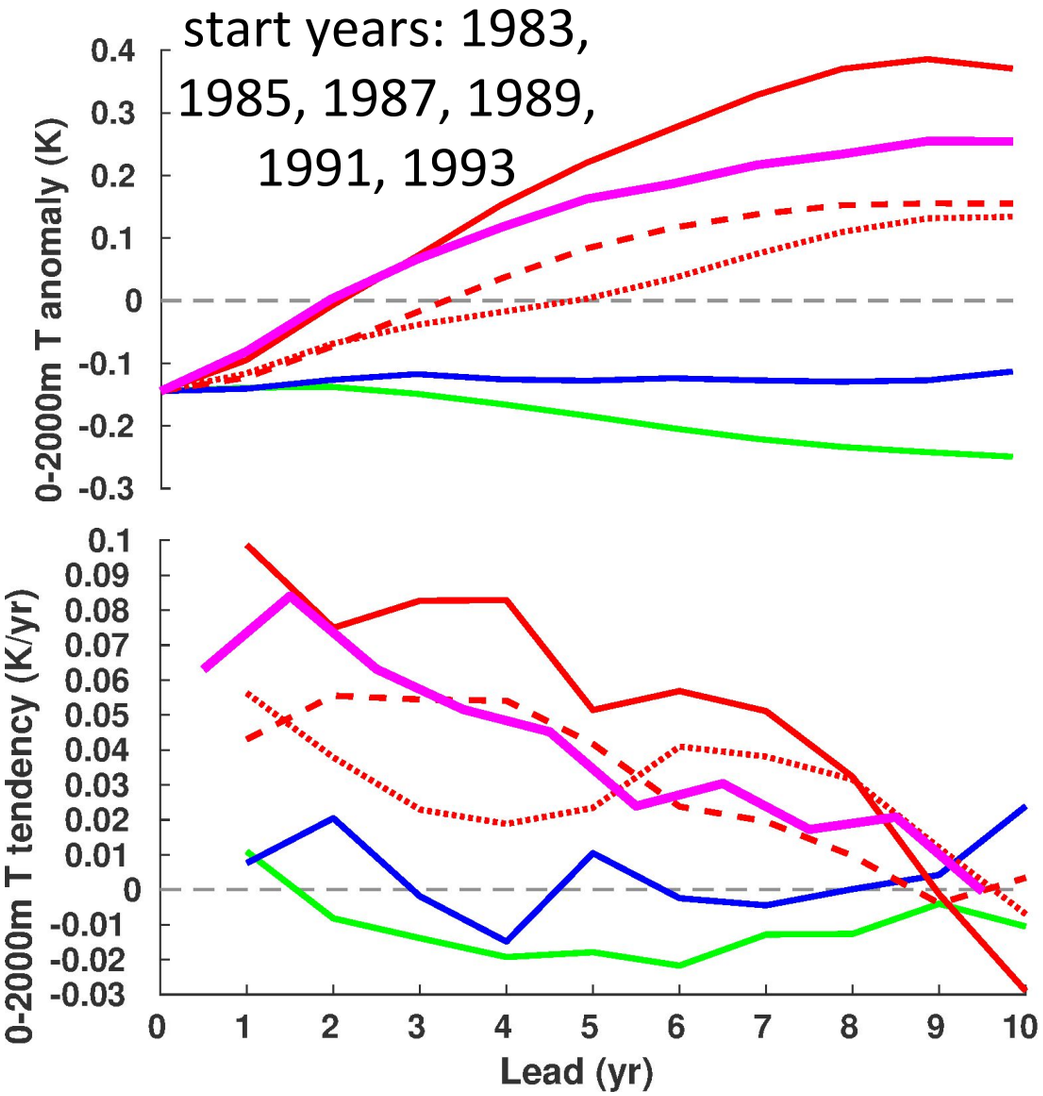


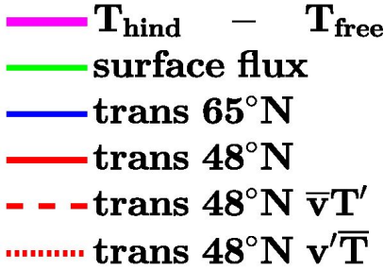
SPG surface flux: weak warming, moderate cooling

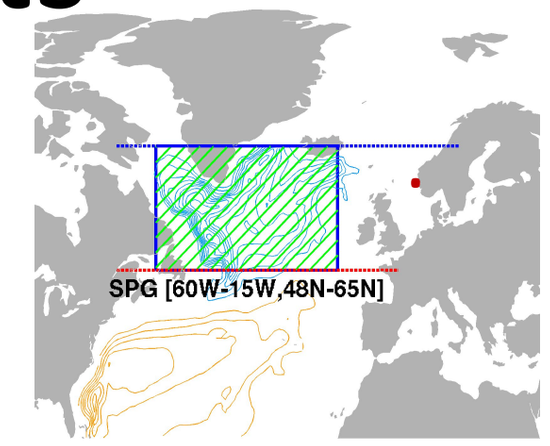
heat trans. at N. boundary: negligible effect

heat trans. at S. boundary: **fully explains SPG warmings**

SPG heat budget analysis from composite of pre-1995 hindcasts







SPG surface flux: weak warming, moderate cooling

heat trans. at N. boundary: negligible effect

heat trans. at S. boundary: **fully explains SPG warmings**

- **largest: mean advection of anomalous temperature**
- **second: anomalous advection of mean temperature**

$\bar{v}, \bar{T}$: free historical simulations
v', T' : hindcast minus free historical

Composite anomaly patterns of 0-2000m temperature and salinity

<u>Initialisation</u>

cold Subpolar North Atlantic

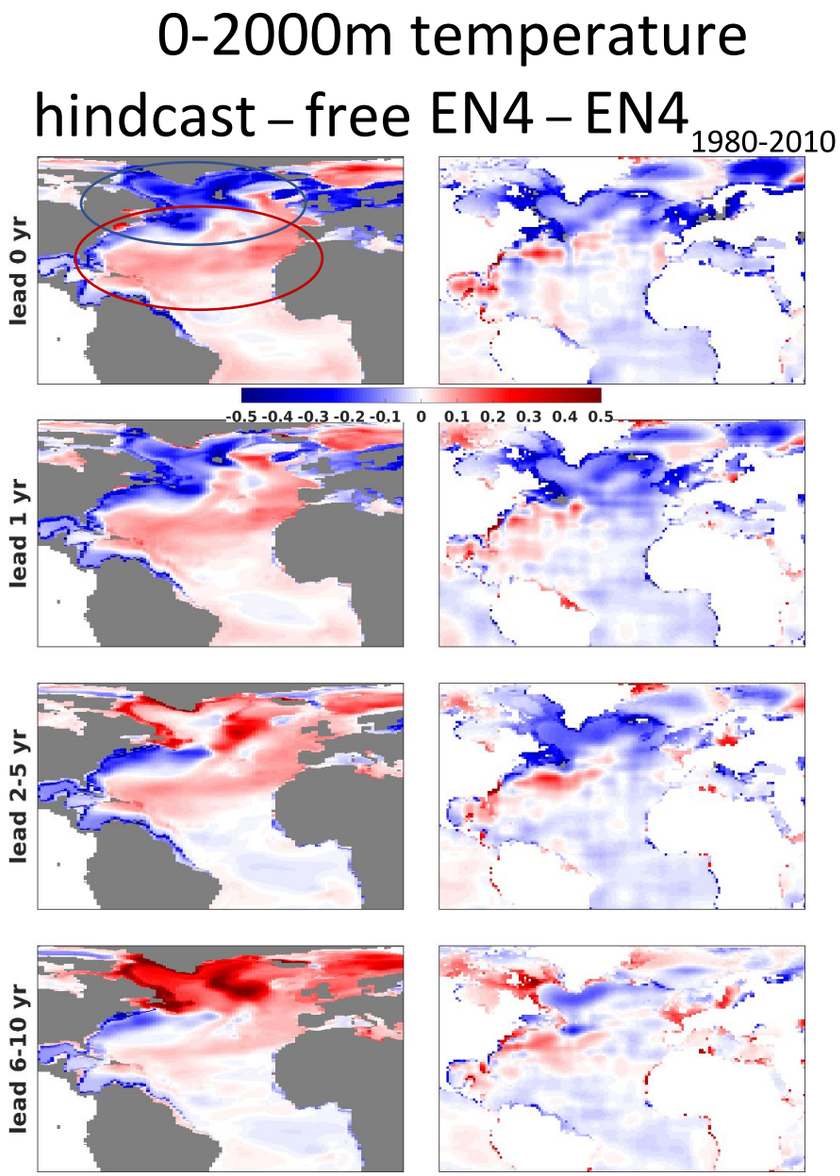
too warm sub-trop. North Atlantic

↓

excessive mer. temperature gradient

↓

SPG warming by mean adv. of anomalous temperature



start years: 1983, 1985, 1987, 1989, 1991, 1993

Composite anomaly patterns of 0-2000m temperature and salinity

<u>Initialisation</u>

cold Subpolar North Atlantic

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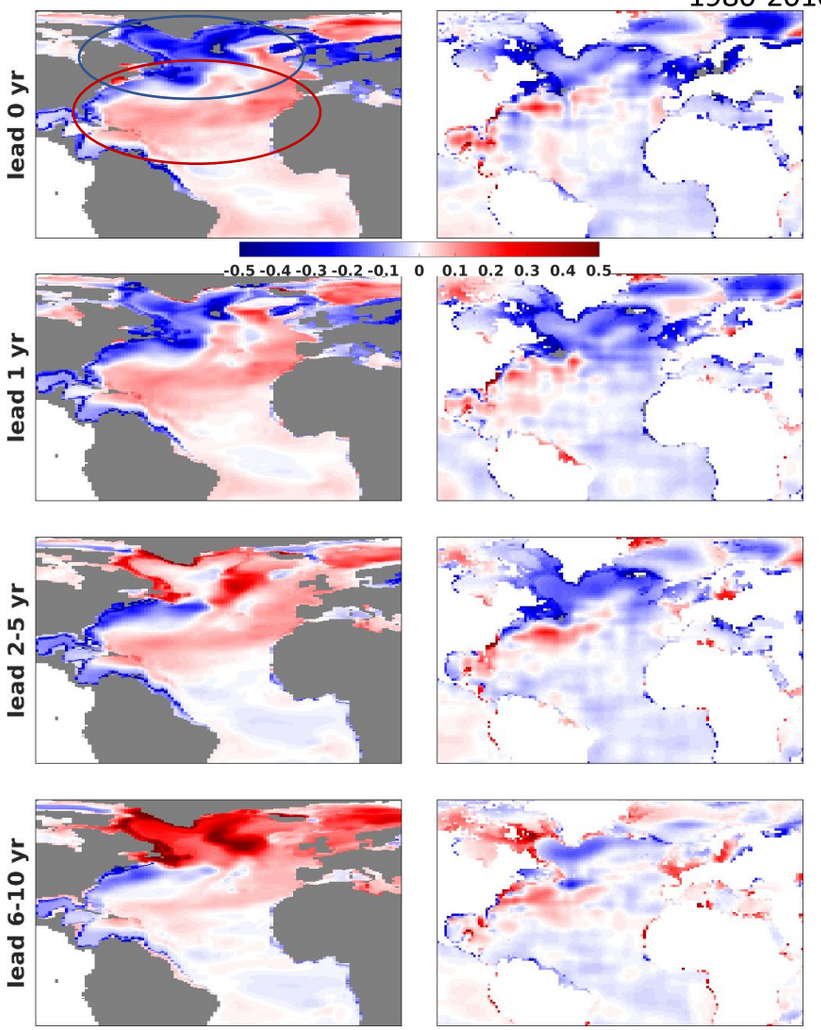
SPG warming by mean adv. of anomalous temperature

0-2000m temperature hindcast – free EN4 – EN4 1980-2010



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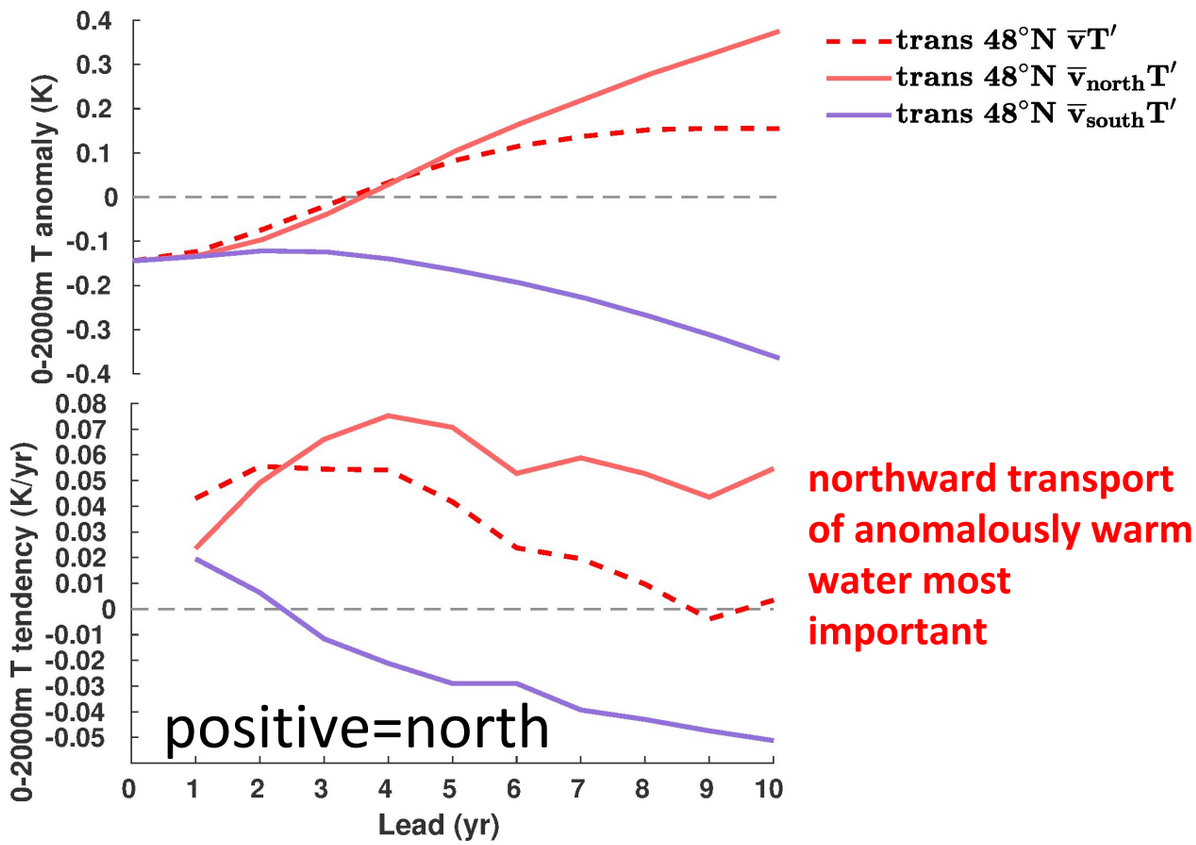
Relative importance of subpolar vs subtropical temperature anomalies



northward transport of anomalously warm water most important

$\bar{v}_{north}T'$: masked southward flow
$\bar{v}_{south}T'$: masked northward flow

Composite anomaly patterns of 0-2000m temperature and salinity

<u>Initialisation</u>
cold Subpolar North Atlantic

too warm sub-trop. North Atlantic

↓

excessive mer. temperature gradient

↓

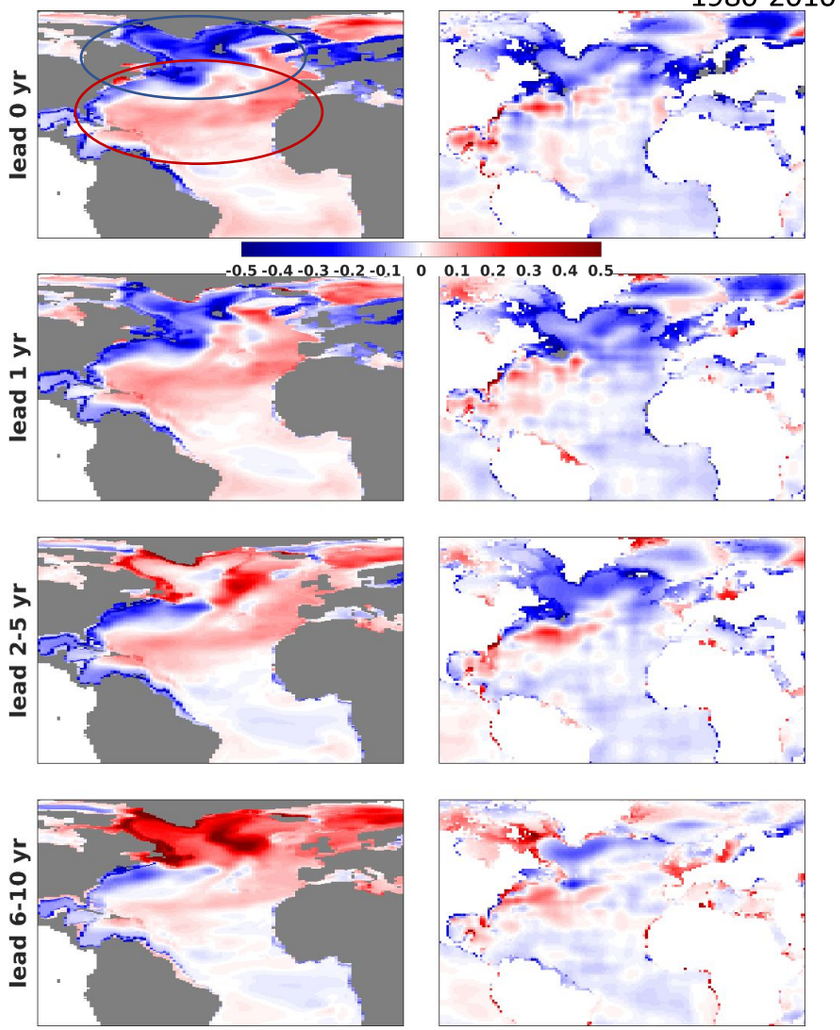
SPG warming by mean adv. of anomalous temperature

0-2000m temperature

hindcast – free EN4 – EN4$_{1980\text{-}2010}$

0-2000m salinity

hindcast – free EN4 – EN4$_{1980\text{-}2010}$



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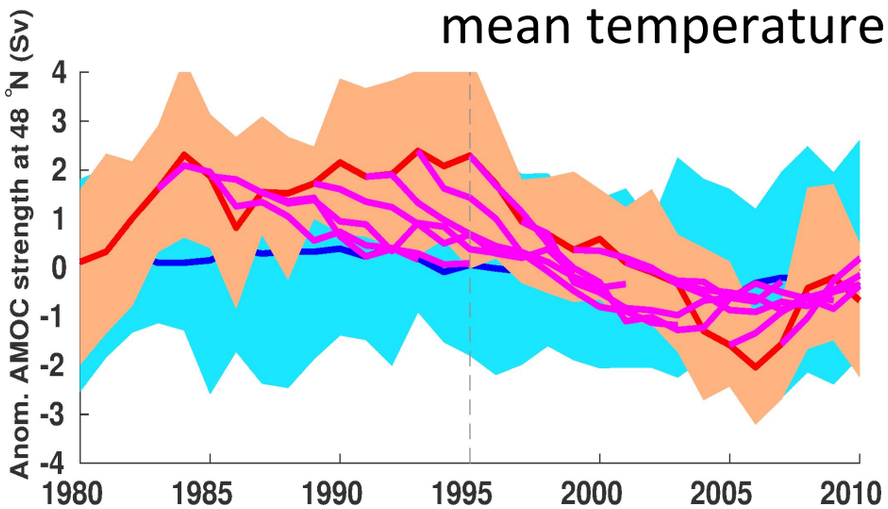
<u>Initialisation</u>
too saline North Atlantic

↓

too strong AMOC

↓

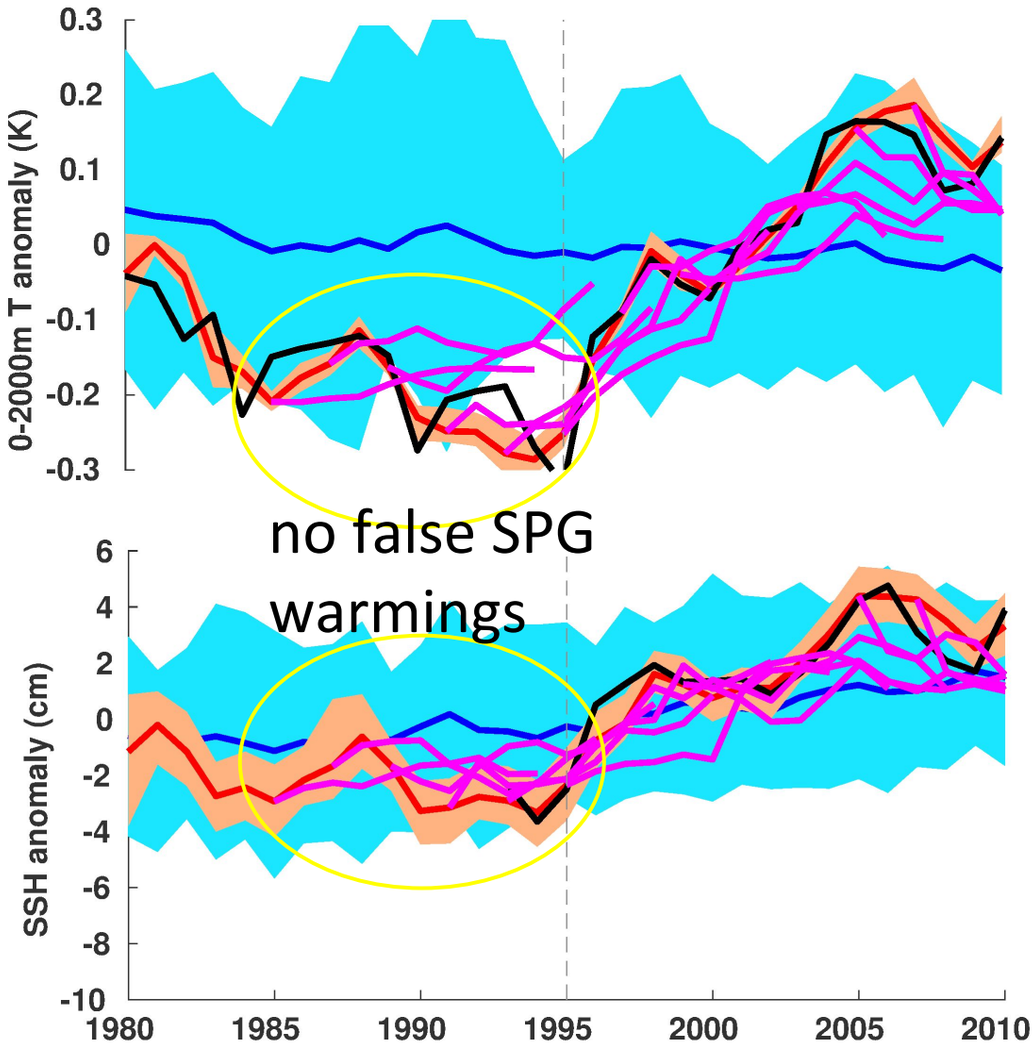
SPG warming by anom. advection of mean temperature

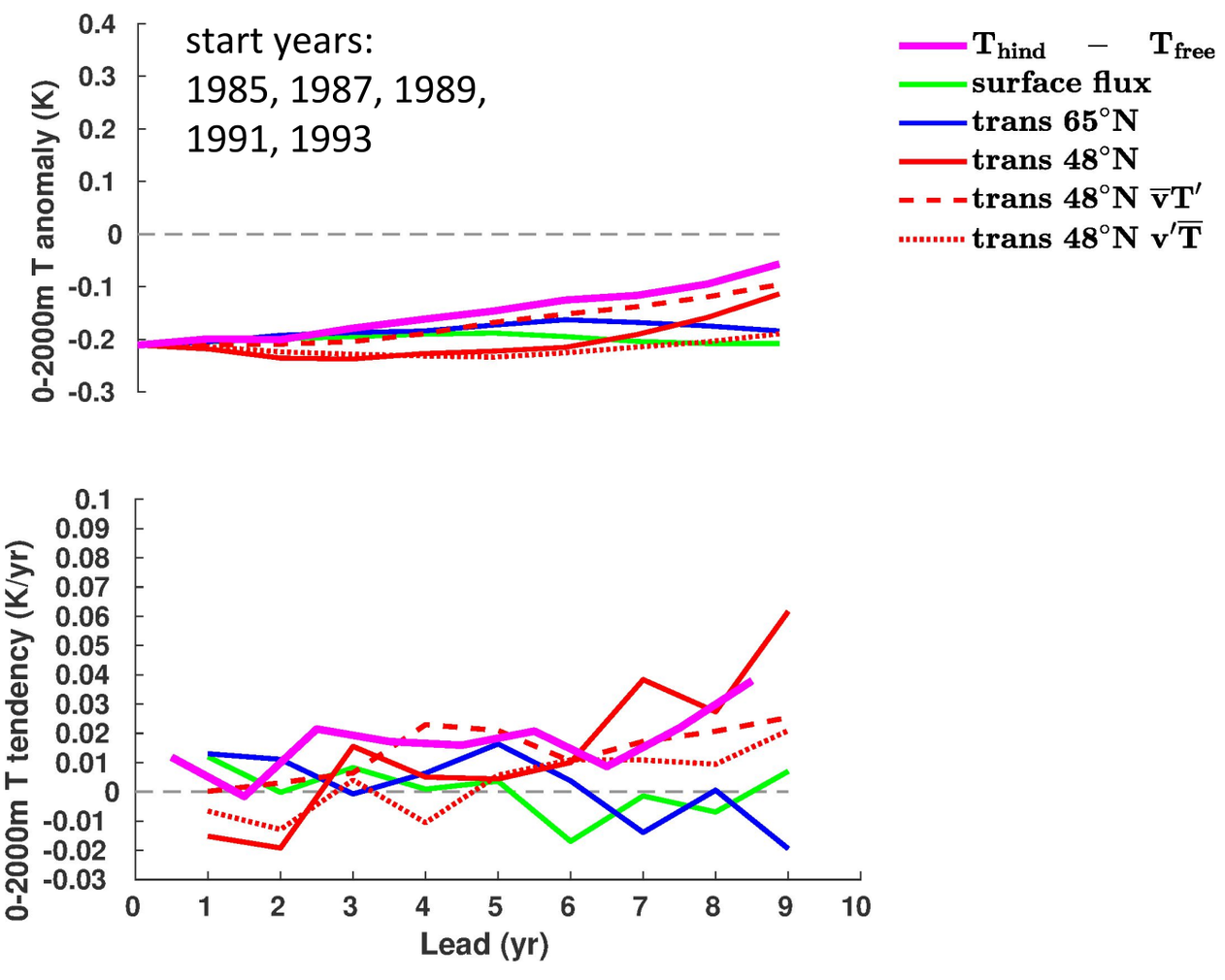


NorCPM-SSTA simulates false SPG warmings prior 1995 due to initialisation errors in the subtropical and subpolar NA

Can we fix it?

Anomaly assim. of SST & **T/S profiles**





Anomaly assim. of SST & **T/S profiles**

<u>Initialisation</u>
cold Subpolar North Atlantic

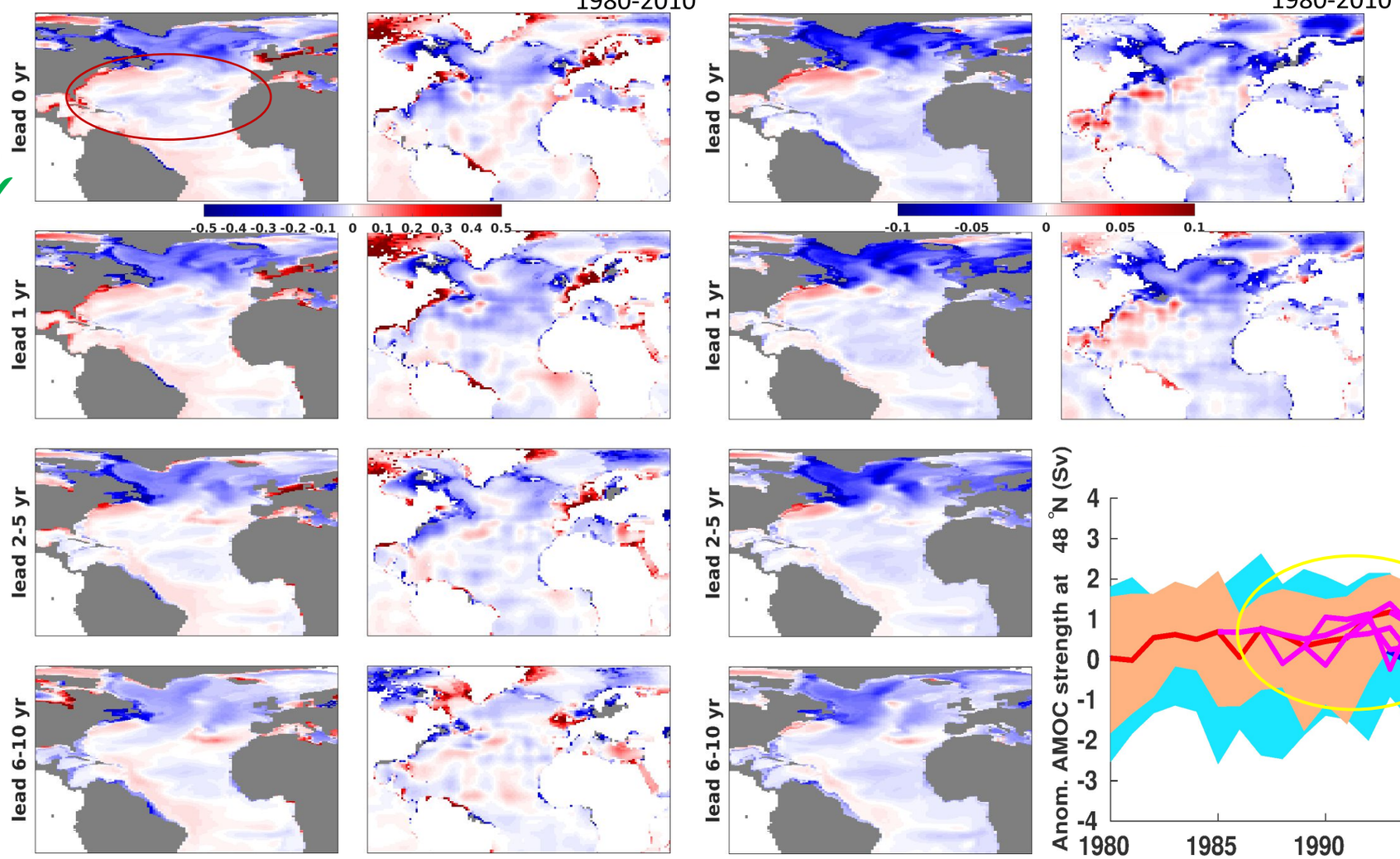
neutral subtrop. North Atlantic ✓

0-2000m temperature

hindcast – free EN4 – EN4 1980-2010

0-2000m salinity

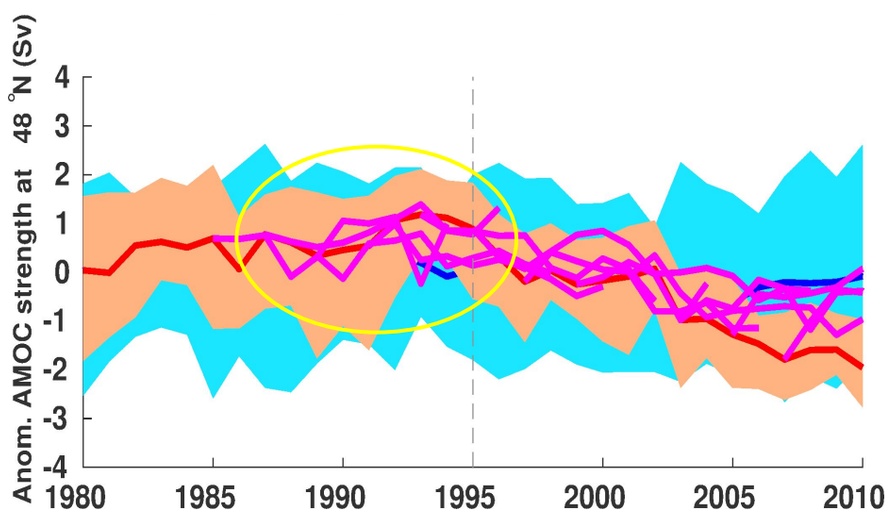
hindcast – free EN4 – EN4 1980-2010



<u>Initialisation</u>
fresh North Atlantic

↓

moderate AMOC strength ✓



start years: 1985, 1987, 1989, 1991, 1993

Summary

Initialisation errors in subtropical heat content contribute to false SPG warmings through mean advection of anomalous temperature.

Initialisation errors in N. Atlantic salt content contribute through anomalous advection of mean temperature by strengthening AMOC.

T/S profile assimilation (in addition to SST) into NorCPM reduces the initialisation errors and thus leads to better SPG predictions.