Disentangling North Atlantic ocean-atmosphere coupling with circulation analogues

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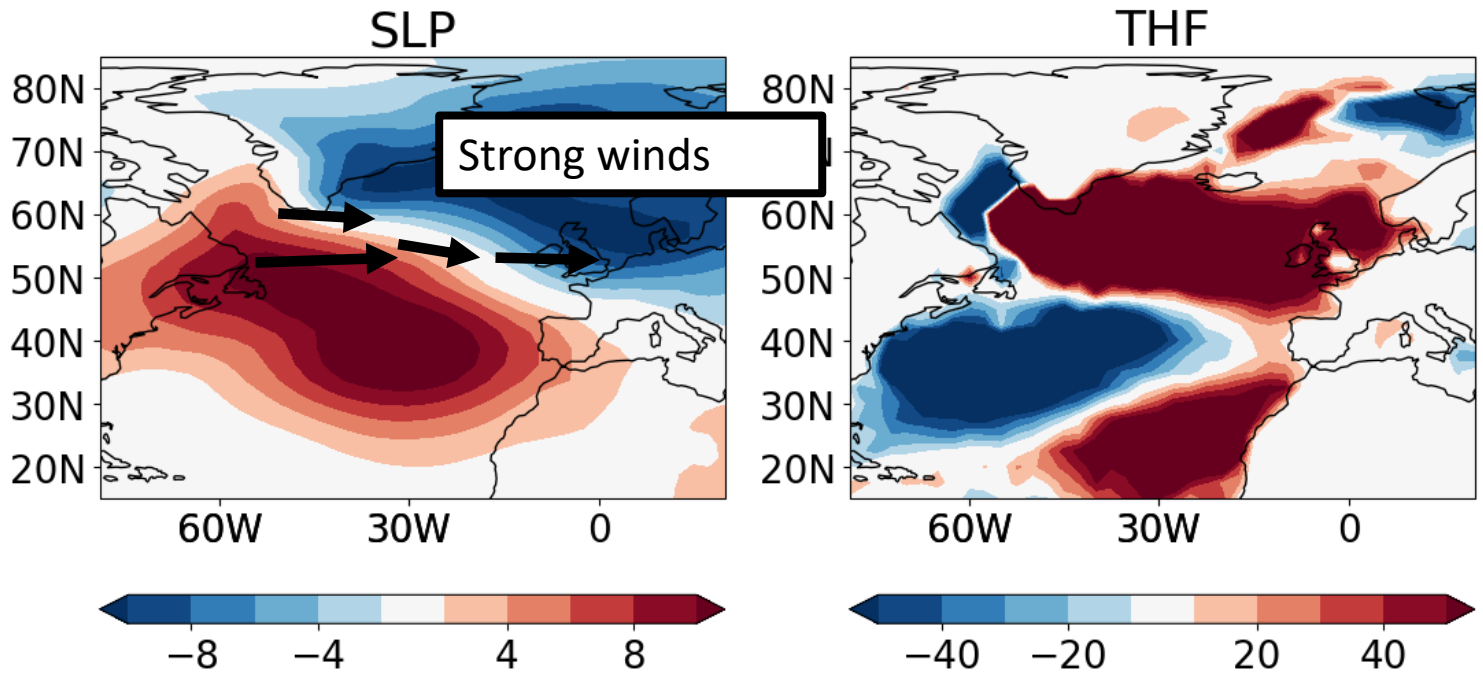
3. National Centre for atmospheric science, University of Reading

Ocean forcing of the atmosphere vs atmosphere forcing of the ocean

Positive NAO (January 1984)



Positive = heat flux out of the ocean

Ocean forcing of the atmosphere vs atmosphere forcing of the ocean

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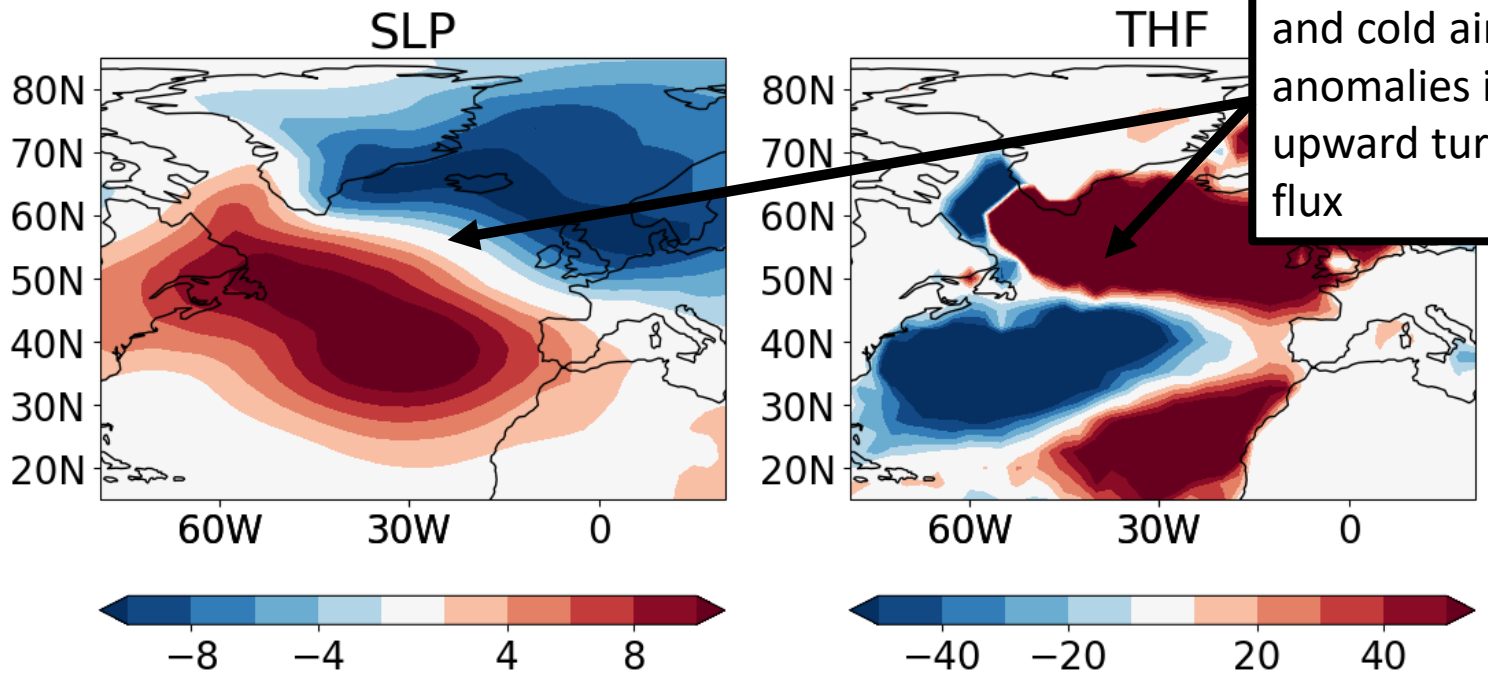

Stronger surface winds and cold air temperature anomalies increase upward turbulent heat flux

The dominance of atmospheric forcing on timescales < season, makes it difficult to disentangle the ocean impact on the atmosphere

Ocean forcing of the atmosphere vs atmosphere forcing of the ocean

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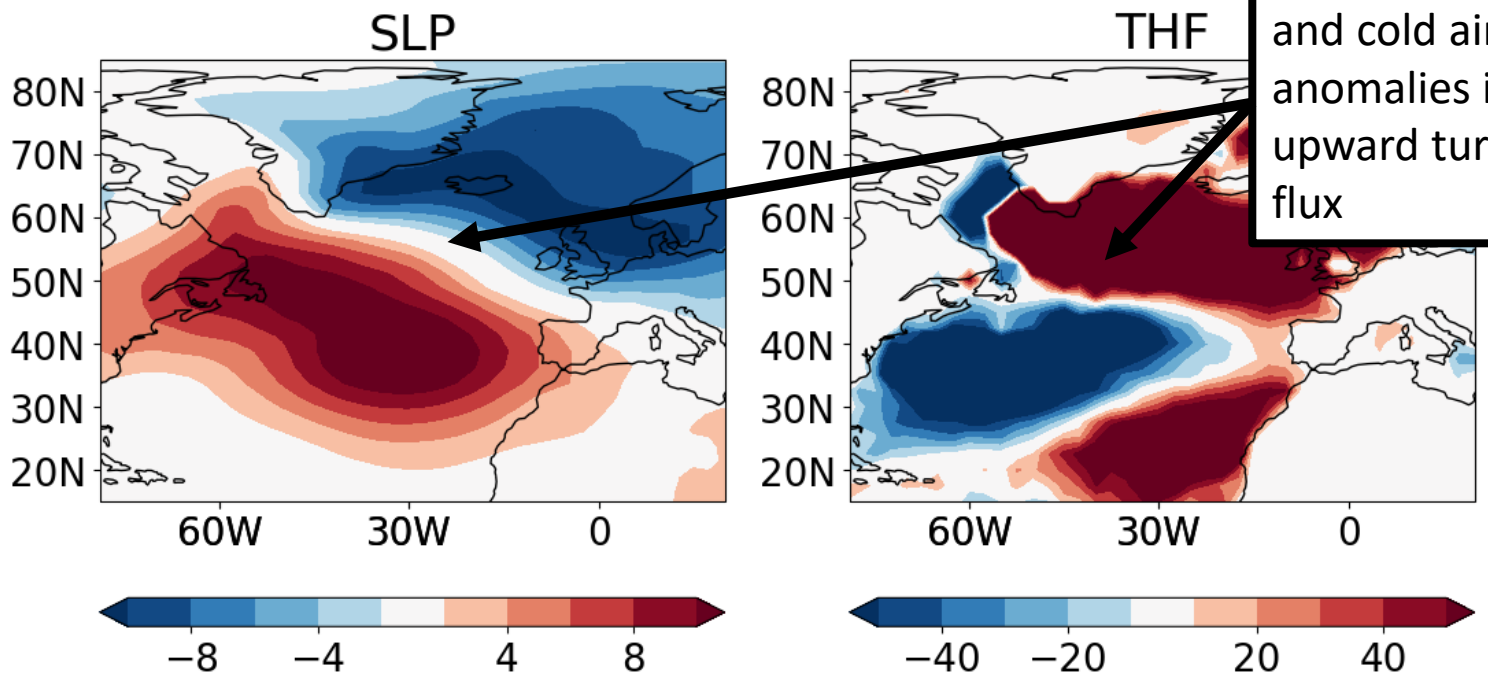

Stronger surface winds and cold air temperature anomalies increase upward turbulent heat flux

Aim: Find a method which can isolate the effect of the ocean on the atmosphere from the direct effect of atmospheric circulation on the ocean.

Circulation analogues algorithm

$$THF_{TOTAL} = THF_{CIRC} + THF_{RESIDUAL}$$

Circulation analogues algorithm

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Ocean influence on the atmosphere

Circulation analogues algorithm

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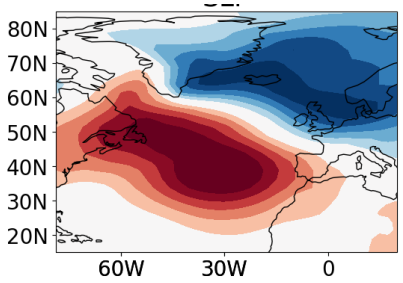

January 1984

Circulation analogues algorithm

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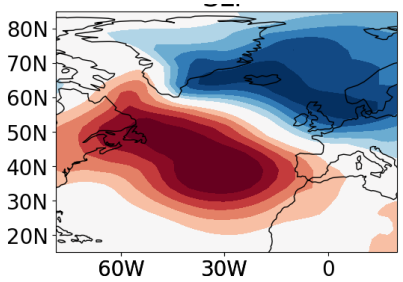
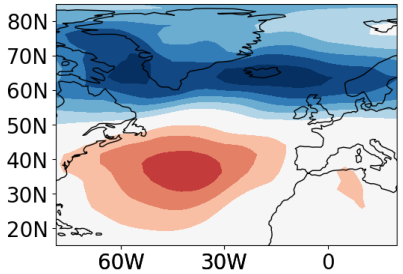
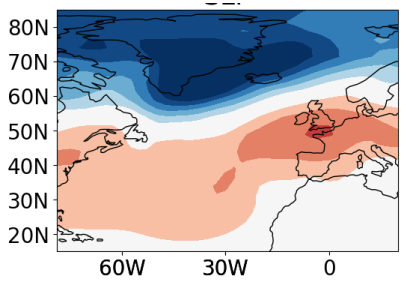


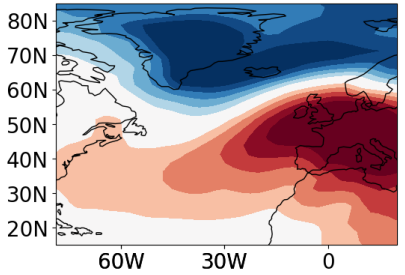
January 1984



January 1962



January 1957



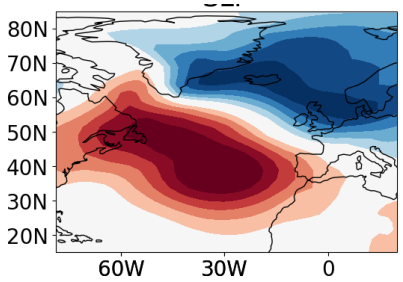
January 1989

Random sample of 50 other years

Circulation analogues algorithm

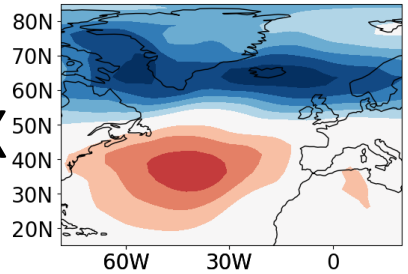
$$THF_{TOTAL} = THF_{CIRC} + THF_{RESIDUAL}$$

Multiple regression model



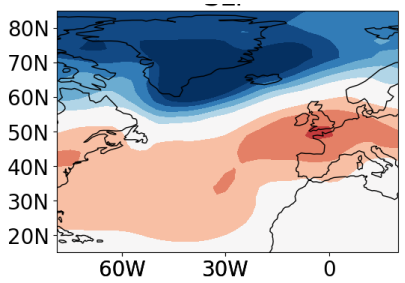
January 1984

$\approx 0.2X$



January 1962

$+ 0.1X$



January 1957

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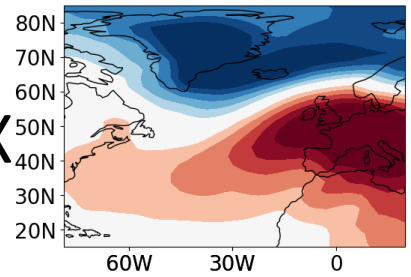

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Random sample of 50 other years

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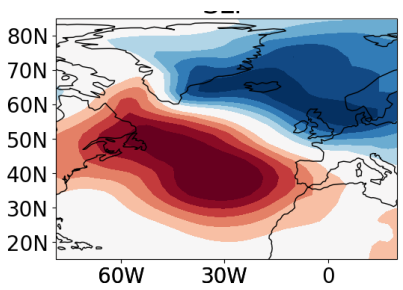

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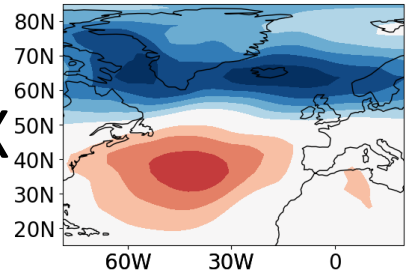

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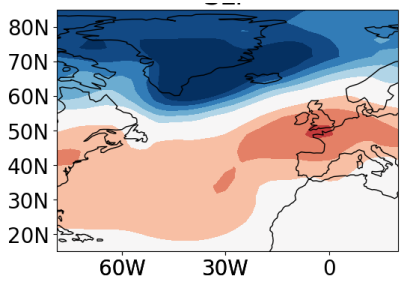

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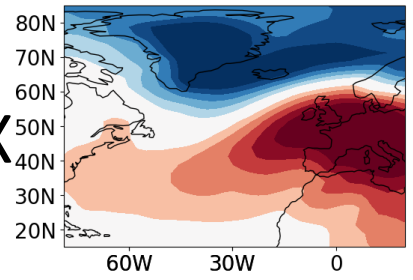
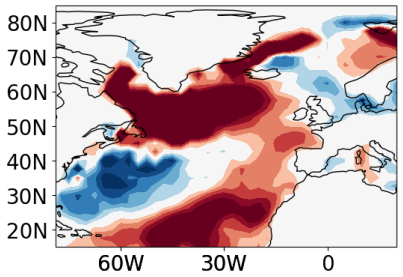


January 1989

$+ \ldots$

$THF_{CIRC} = 0.2X$



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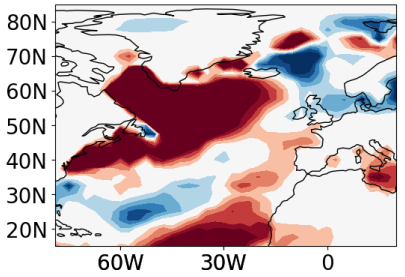

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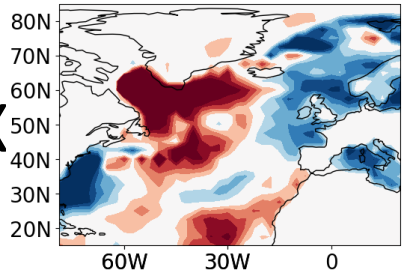


$+ \ldots$

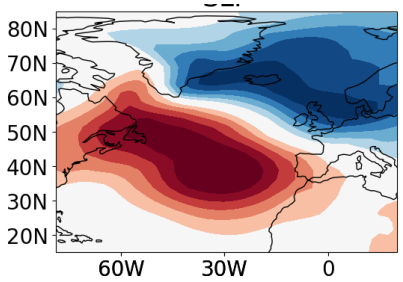
Use same weights to reconstruct ‘circulation-related’ heat flux

Circulation analogues algorithm

Do this 100 times and average for best estimate

$$THF_{TOTAL} = THF_{CIRC} + THF_{RESIDUAL}$$

Multiple regression model



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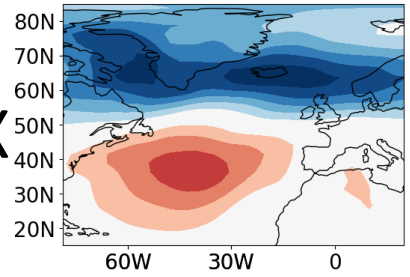

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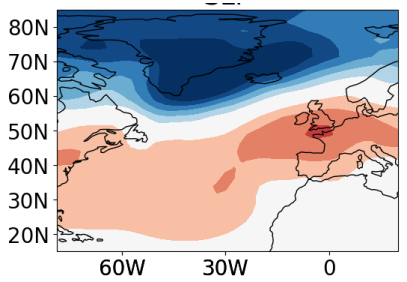

January 1957

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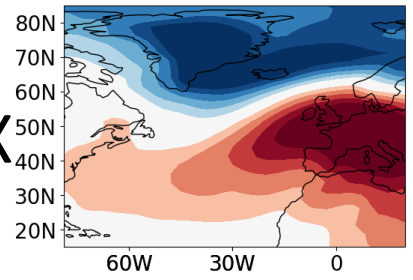
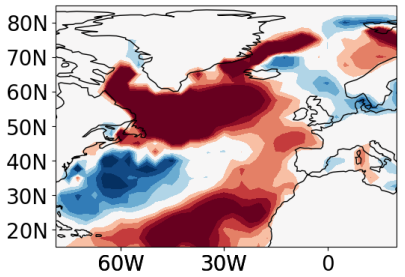


January 1989

$+ \ldots$

$THF_{CIRC} = 0.2X$



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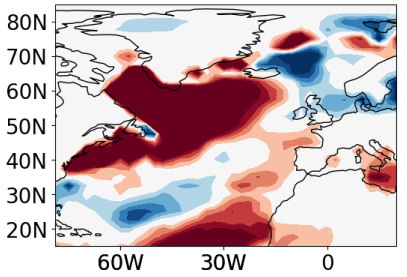

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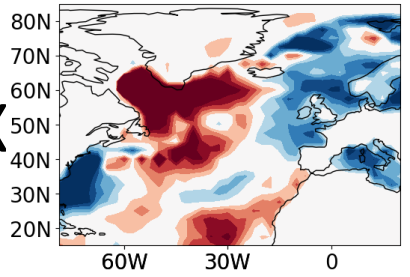


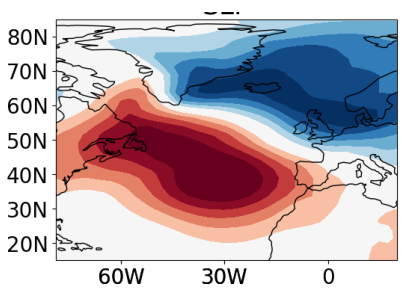
$+ \ldots$

Use same weights to reconstruct ‘circulation-related’ heat flux

Circulation analogues algorithm **… AND do it separately for Dec, Jan, etc then avg over DJFM**

$$THF_{TOTAL} = THF_{CIRC} + THF_{RESIDUAL}$$

Multiple regression model



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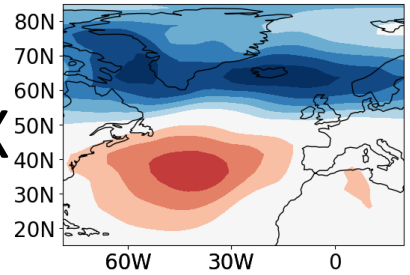

January 1962

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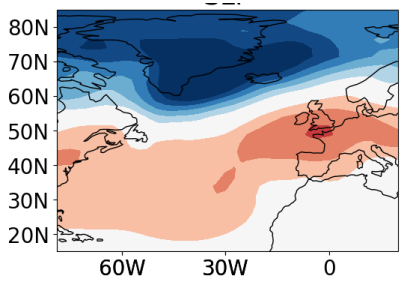

January 1957

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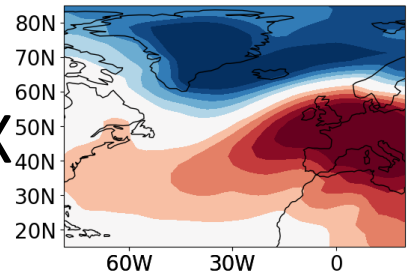

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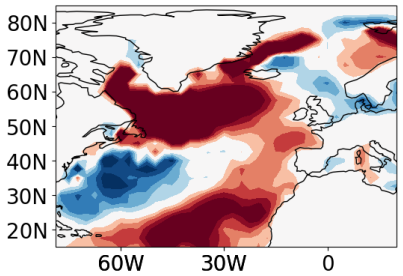

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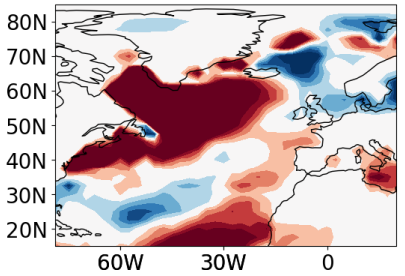

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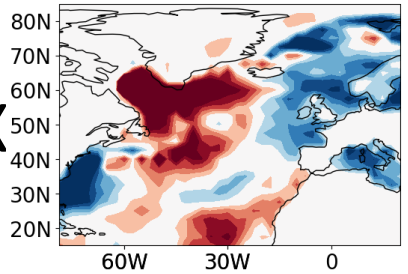
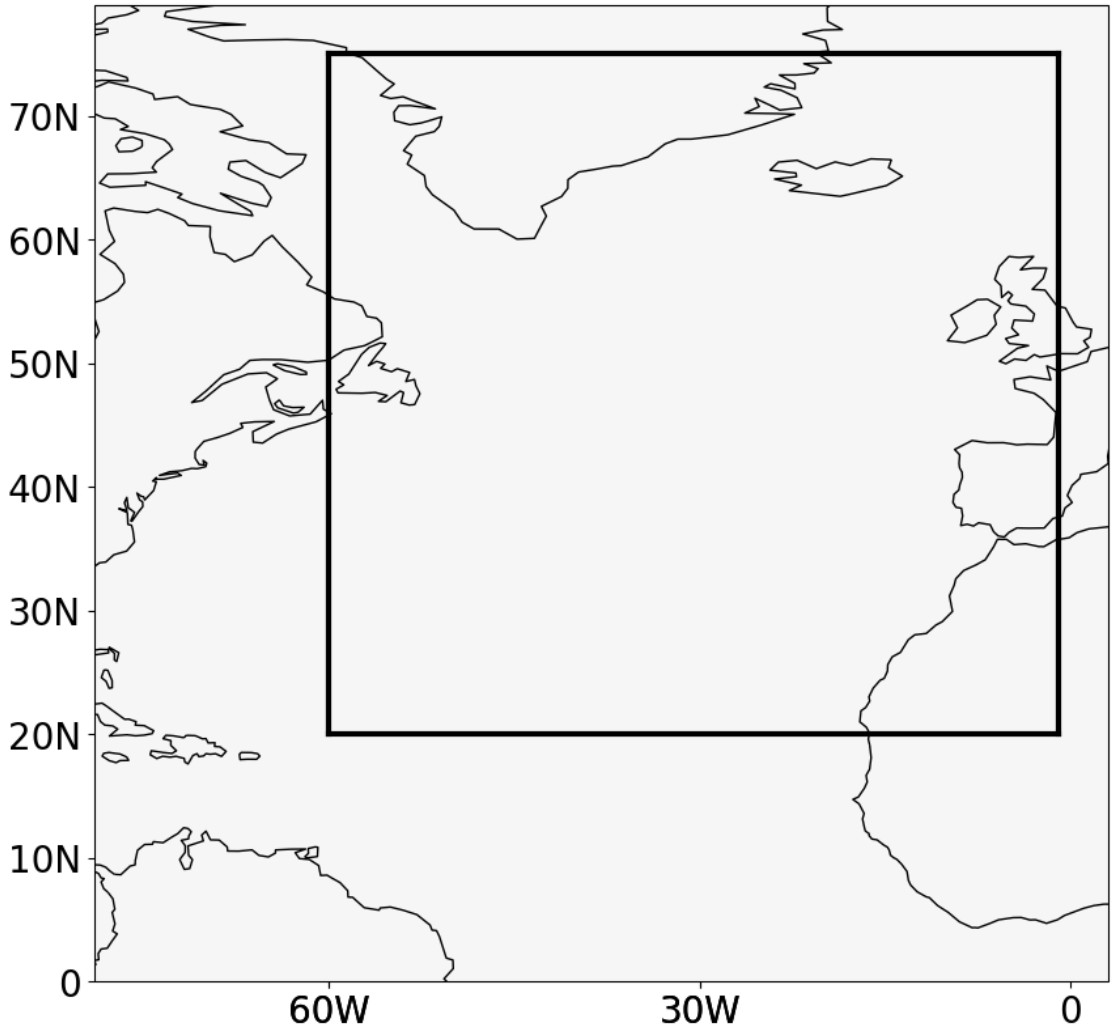


$+ \ldots$

Use same weights to reconstruct ‘circulation-related’ heat flux

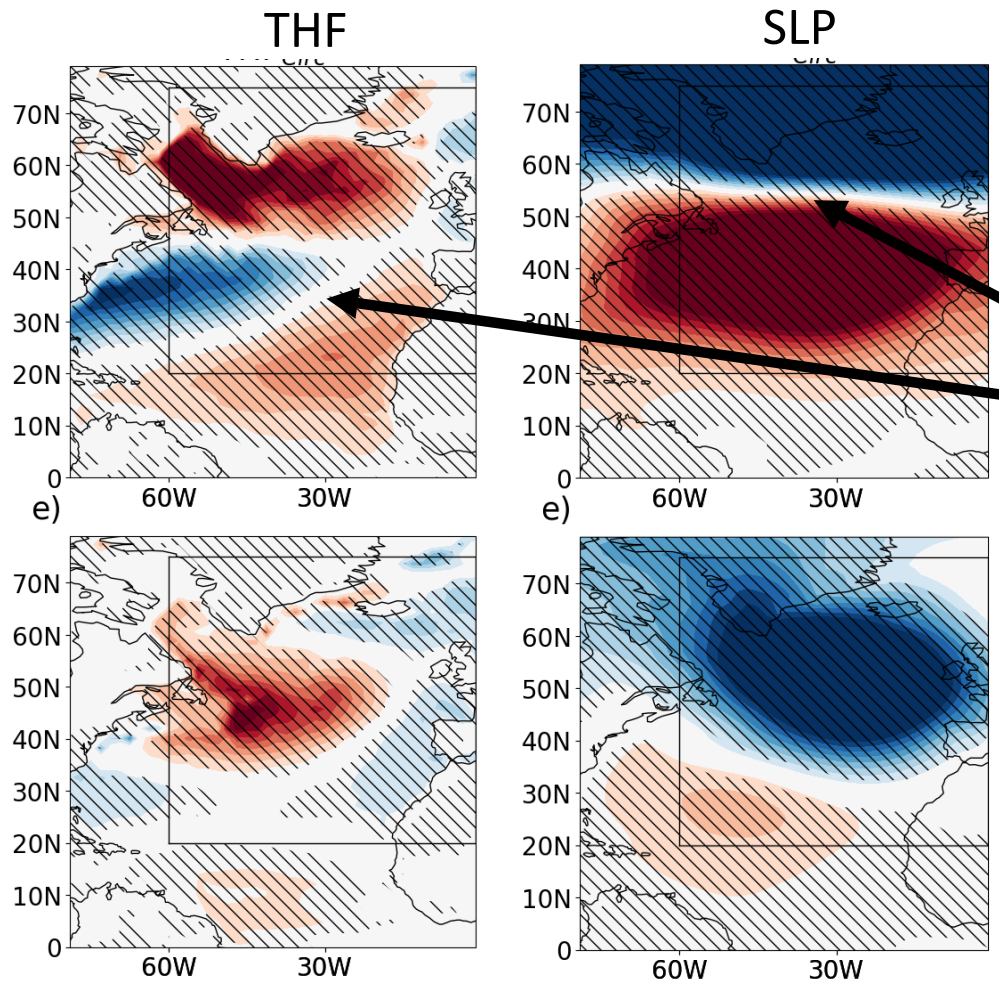
Applying to a piControl simulation

- UK Met Office's **HadGEM3-GC31-MM** model.
- **500 year** pre-industrial control run (no external forcing).
- Atmosphere: Approx 60km (N216) resolution, 85 levels
- Ocean: ORCA025 0.25°, 75 levels.
- Apply to the boxed region for **winter (DJFM)** season



Leading modes of heat flux decomposition

Circulation-related



First mode of circulation-related THF is NAO-like with tripole THF pattern

Leading modes of heat flux decomposition

Circulation-related

Residual

THF

SLP

THF

SLP

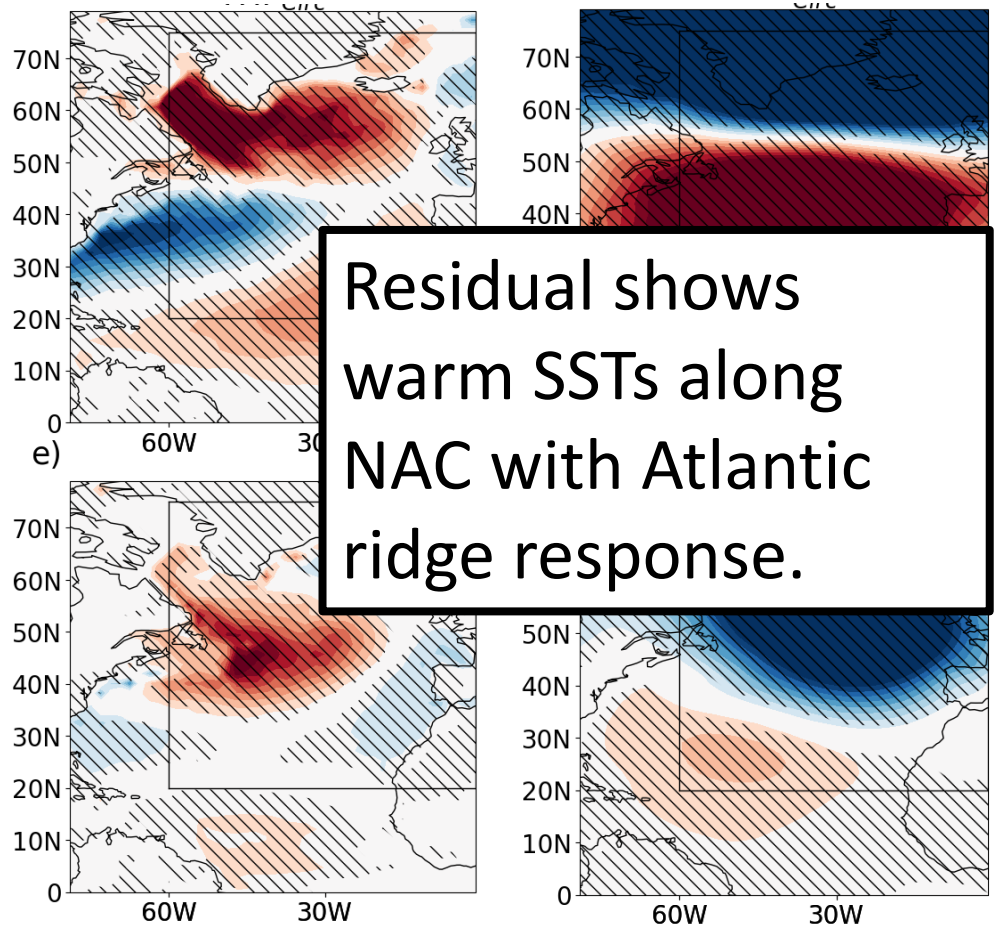
EOF 1

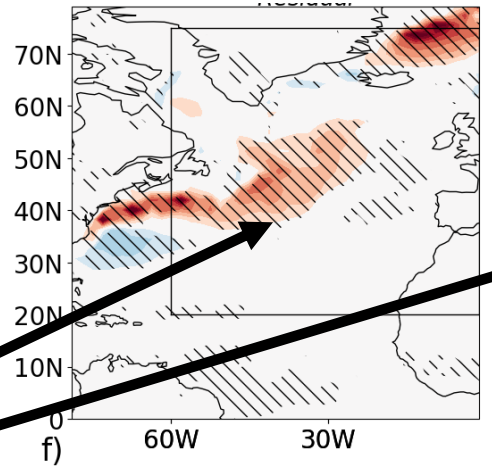
EOF 2

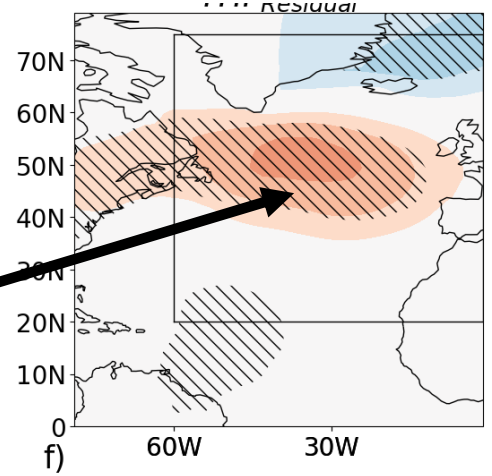
EOF 1

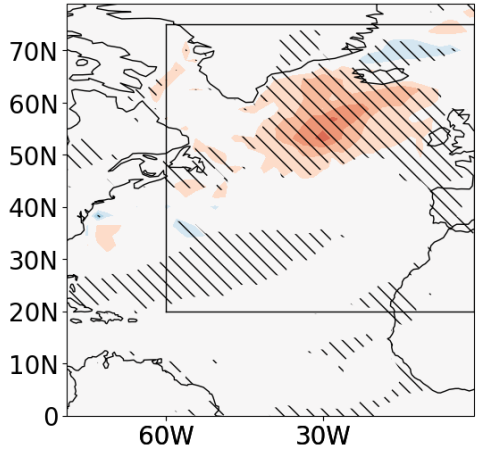
EOF 2

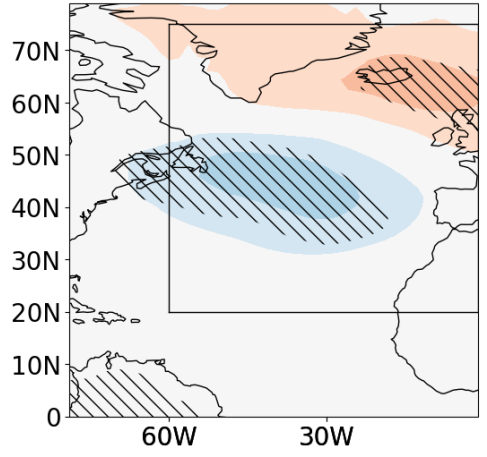
Residual shows warm SSTs along NAC with Atlantic ridge response.



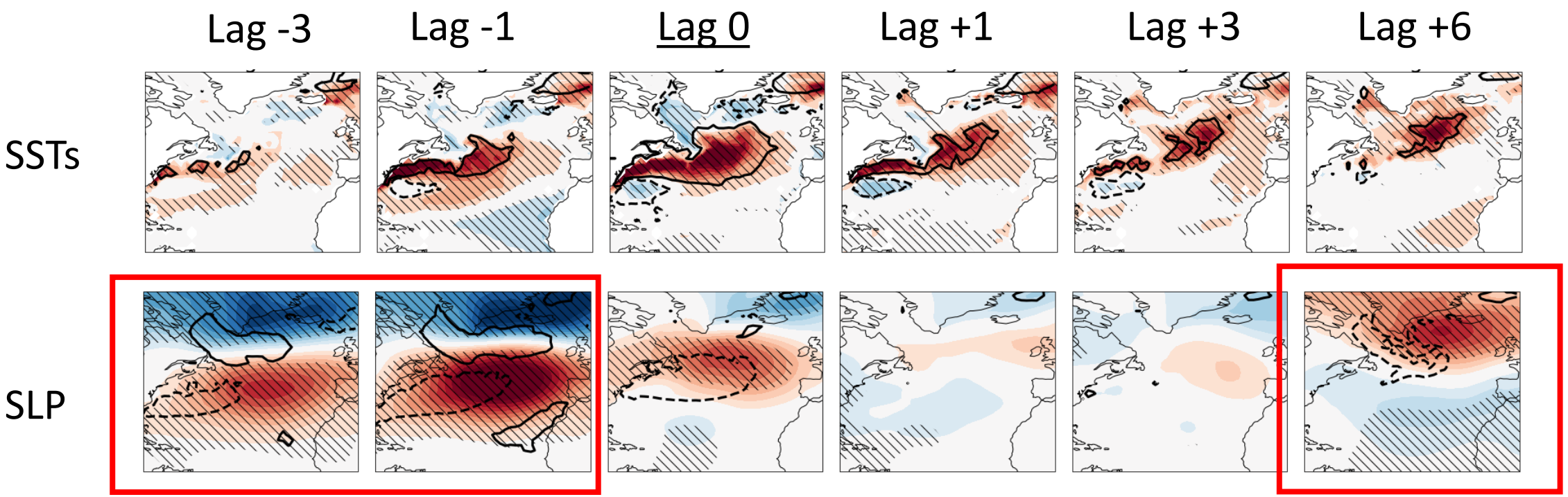




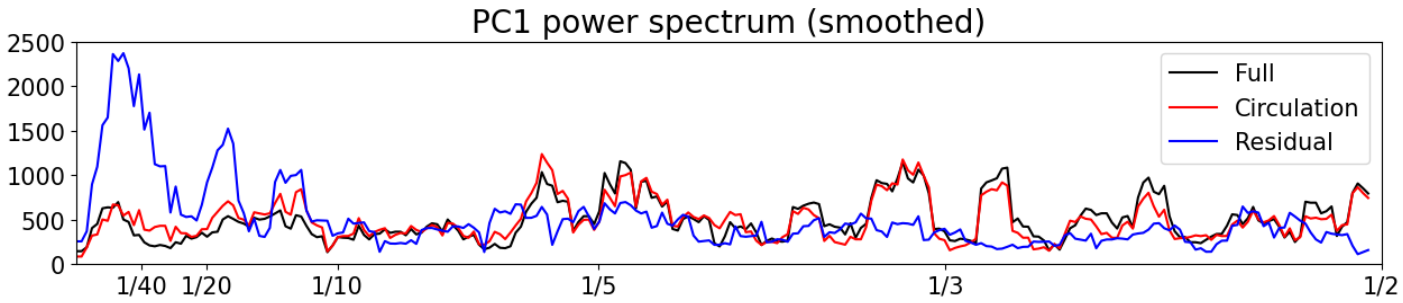




Evolution of ocean-forced THF EOF 1



Preceded by positive NAO



Negative NAO forced by SSTs

Summary

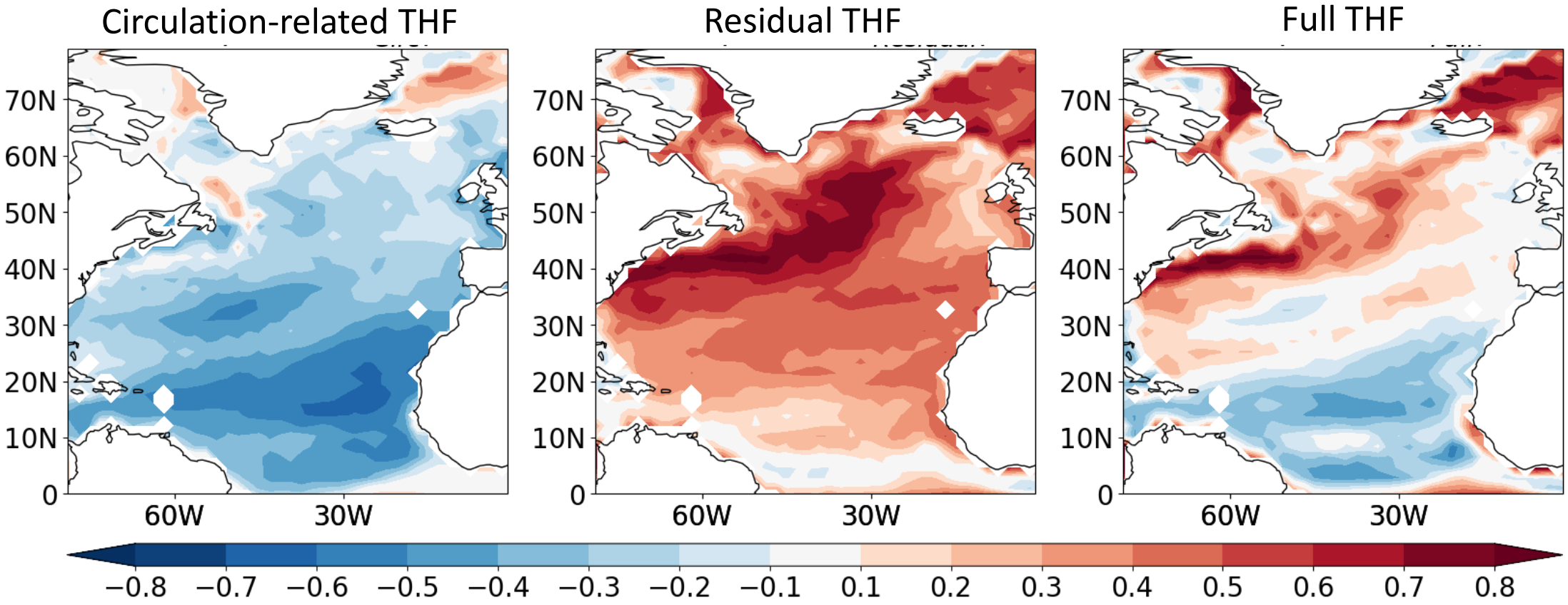
- Method to disentangle ocean forcing of atmospheric circulation from circulation effects on the ocean.
- piControl run shows ocean-THF variability linked to warm SST anomalies along North Atlantic Current (following positive NAO). Warm SSTs force an Atlantic ridge response.
- Second mode forces negative NAO.
- Next steps: apply this to reanalysis data, decadal hindcasts …
- Could be applied to other regions too!

Paper in preparation: “Disentangling North Atlantic ocean-atmosphere coupling with circulation analogues”

Additional slides

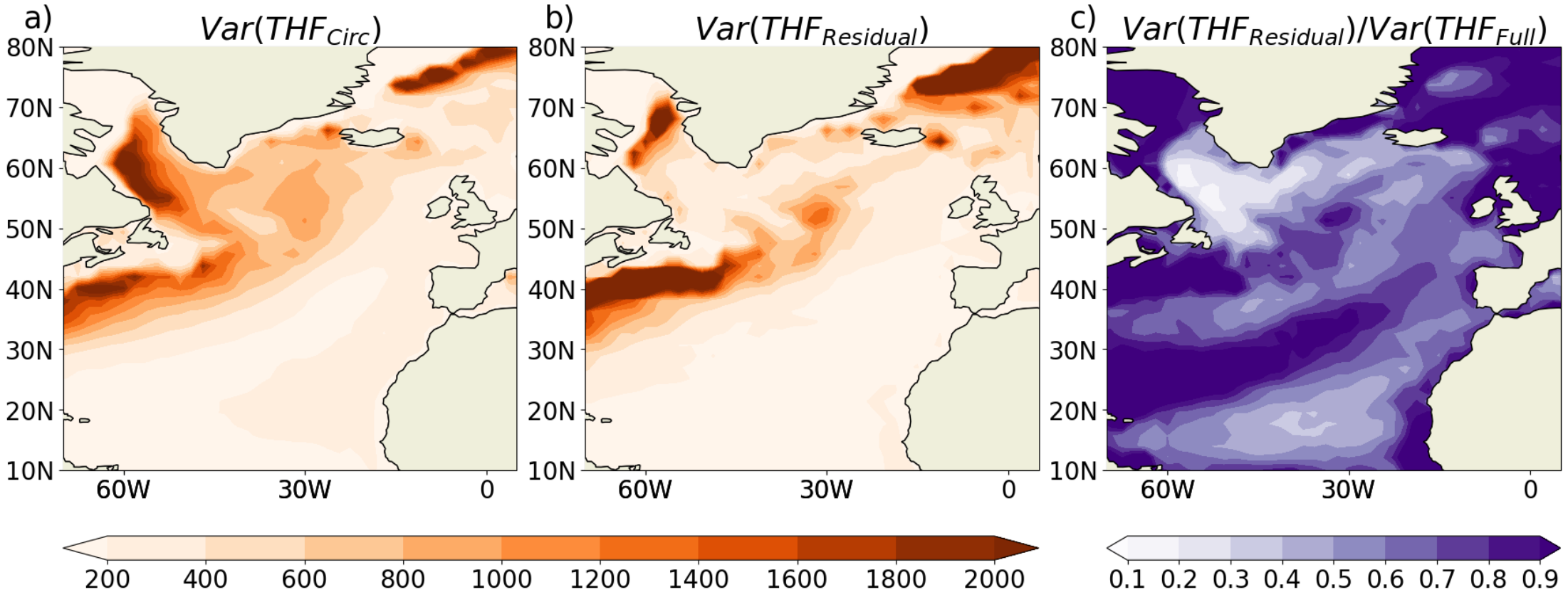
Showing the decomposition works

Blue = atmosphere forcing SST anomalies **Red = SSTs warming the atmosphere**



Grid-point correlations between SSTs and heat flux.

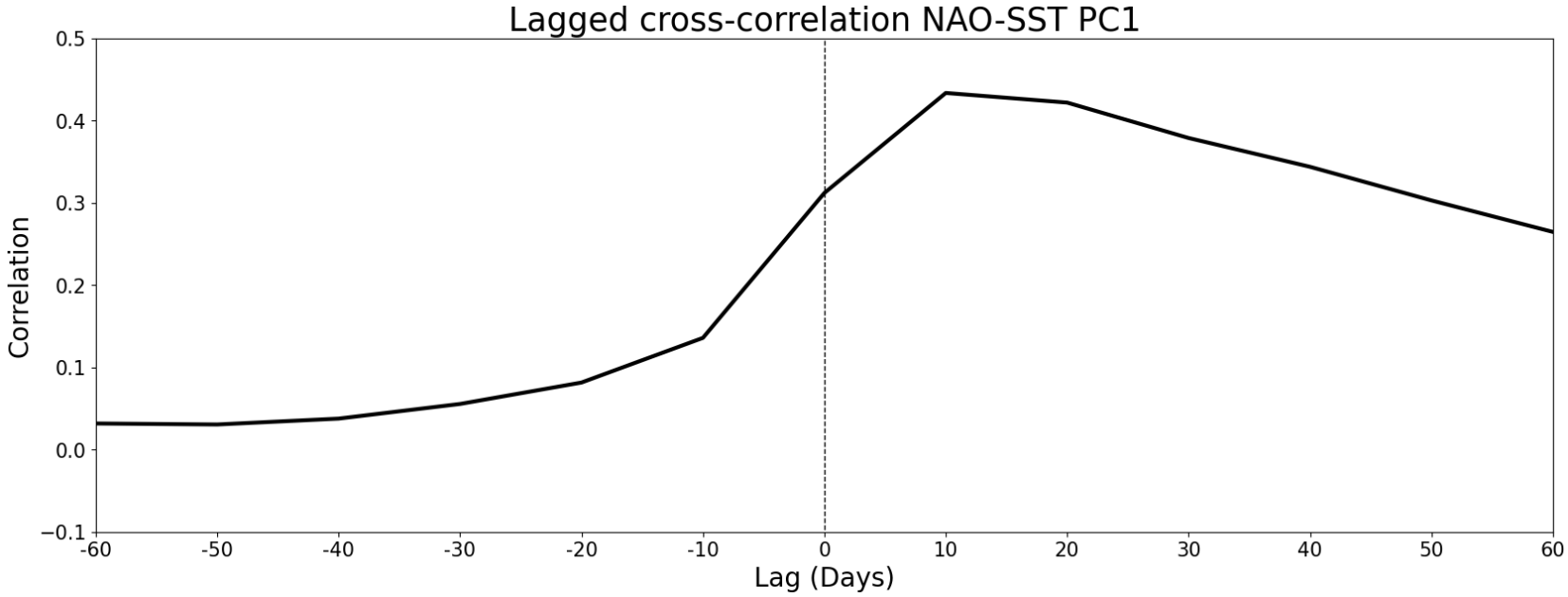
Variance explained by THF decomposition



Doesn’t this method remove SLP by construction?

The key is that we apply the reconstruction to each month (December, January…) separately and then average over DJFM.

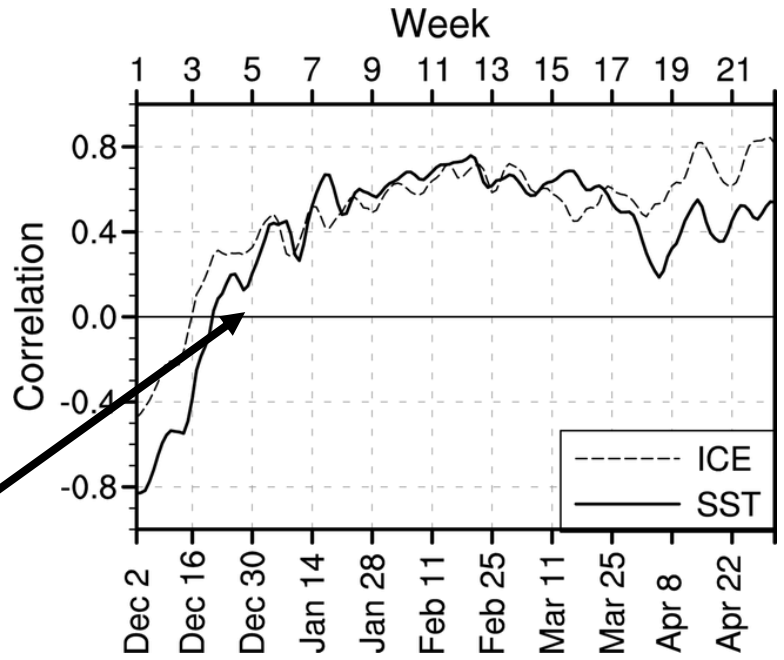
1) The atmosphere takes only about 2-3 weeks to have its maximum effect on SSTs



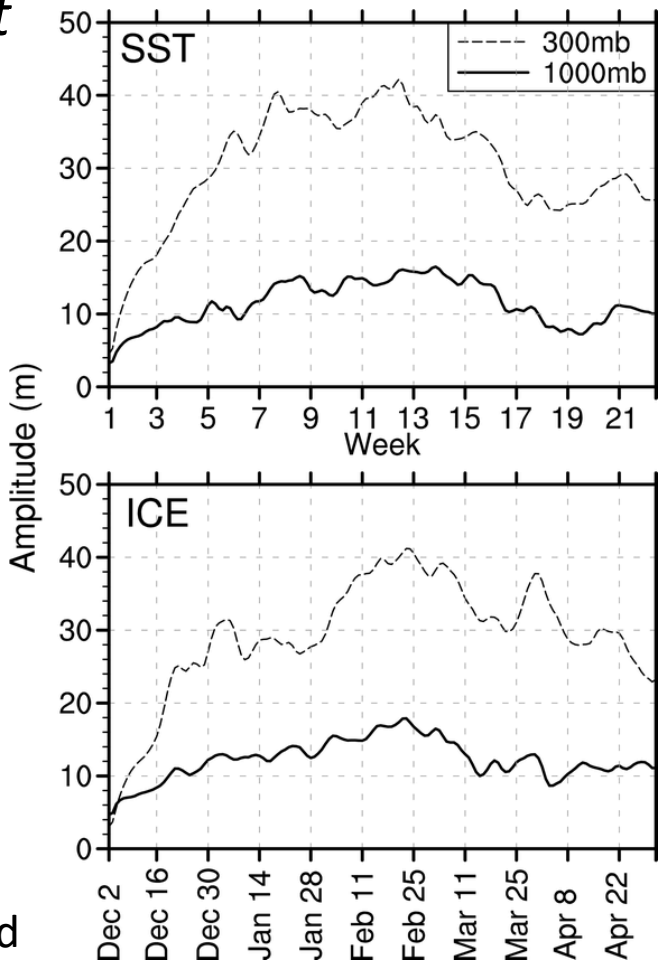
Doesn’t this method remove SLP by construction?

2) The circulation response takes 2 months or more to reach its maximum amplitude

Figures from Deser et al 2007



Initial baroclinic response followed by barotropic response

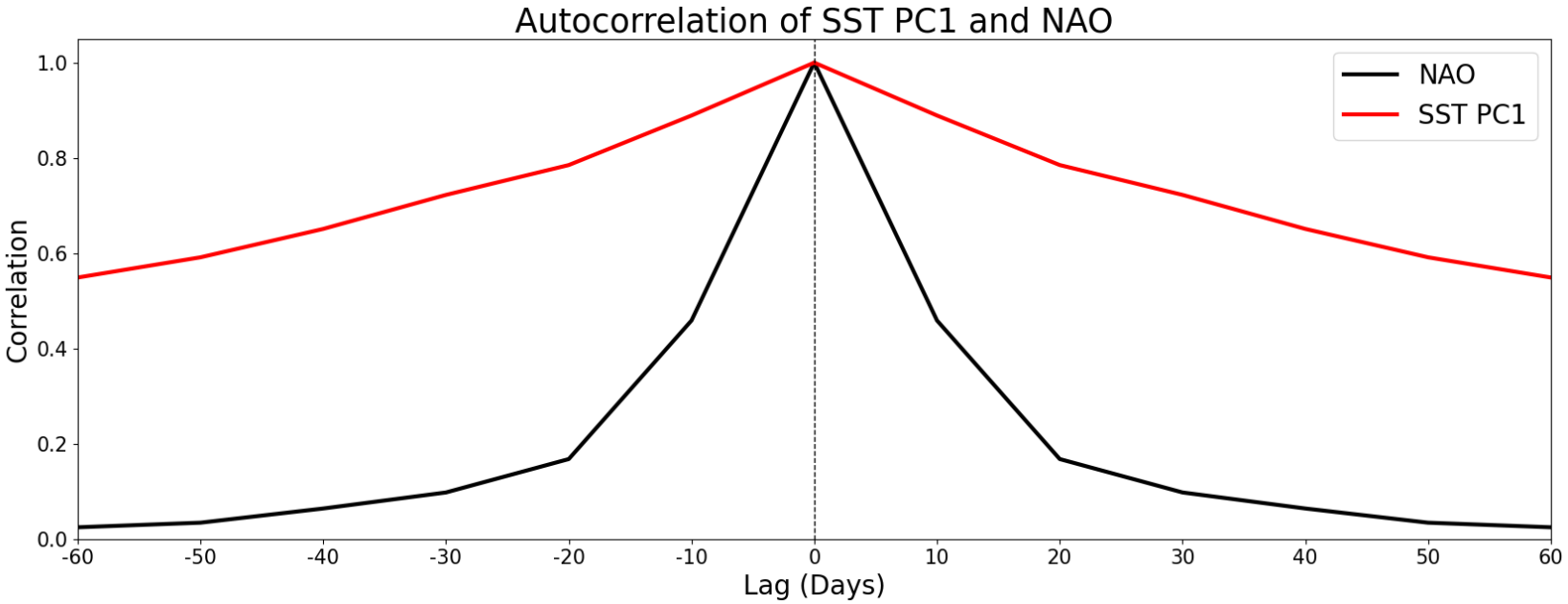


Correlation between 300hPa and 1000hPa response

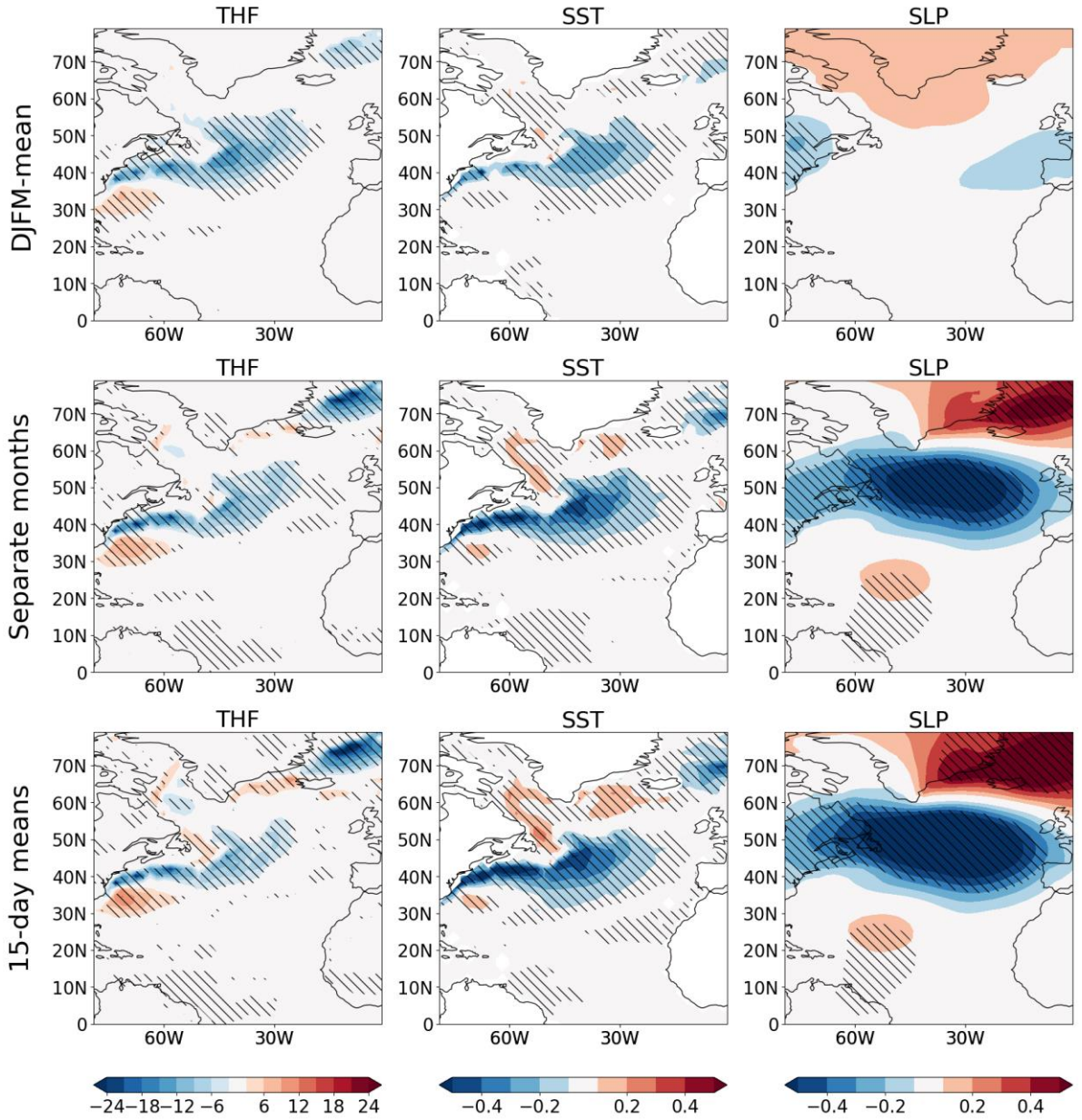
Doesn’t this method remove SLP by construction?

3) The circulation is uncorrelated after a month, but the SSTs persist

Hence, the circulation can affect SSTs in early winter, which persist to late winter and can then affect the circulation (which by this point has changed from its early winter state)

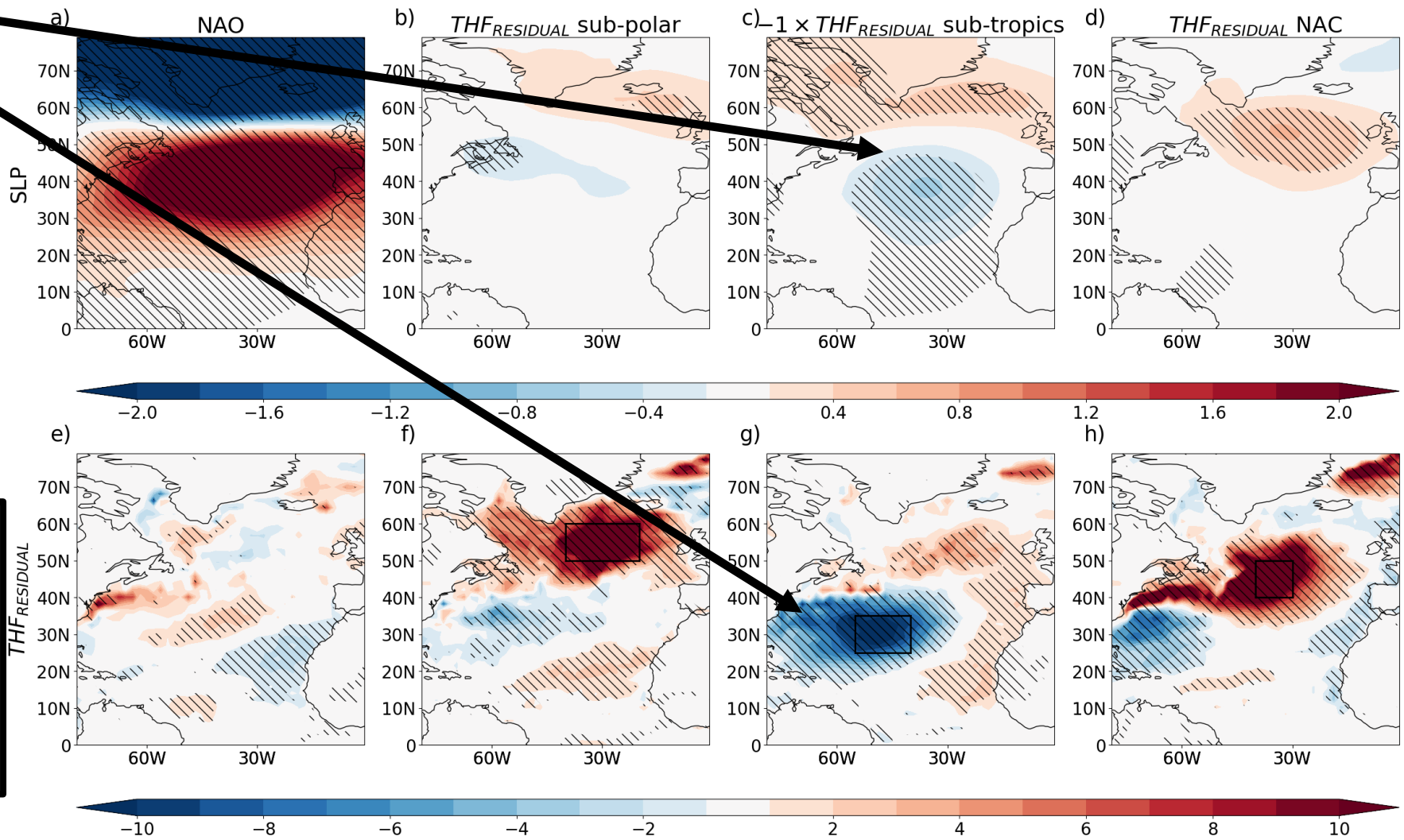


Performing decomposition on sub-seasonal timescales allows for SSTs affecting circulation



Residual EOF 1 calculated for the decomposition applied to (top) seasonal mean, (middle) individual months and then averaged over DJFM, (bottom) 15-day periods and then averaged over DJFM.

Western subtropical NAtl. has strongest influence on NAO



Regression of $THF_{RESIDUAL}$ and SLP on a,e) NAO index, b,f) sub-polar $THF_{RESIDUAL}$, c,g) subtropical $THF_{RESIDUAL}$ and d,h) North Atlantic Current $THF_{RESIDUAL}$