An event-based approach to understanding decadal AMOC fluctuations and their impacts

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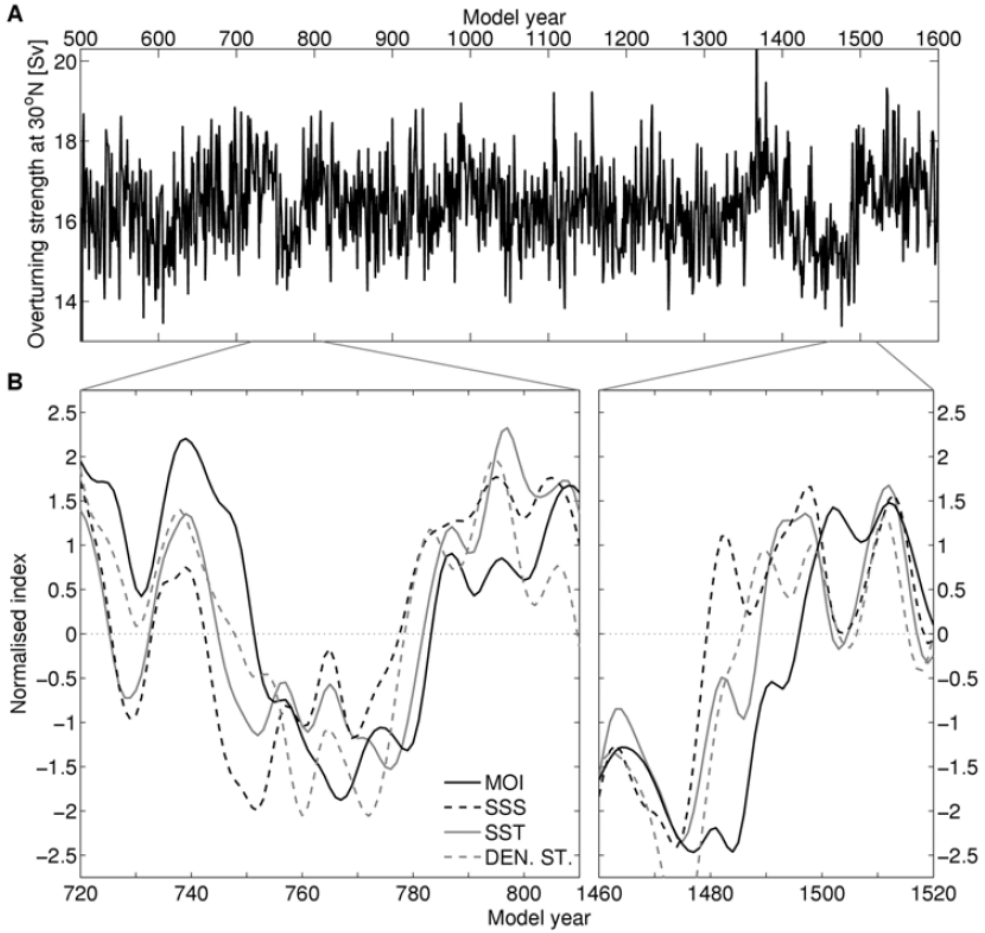
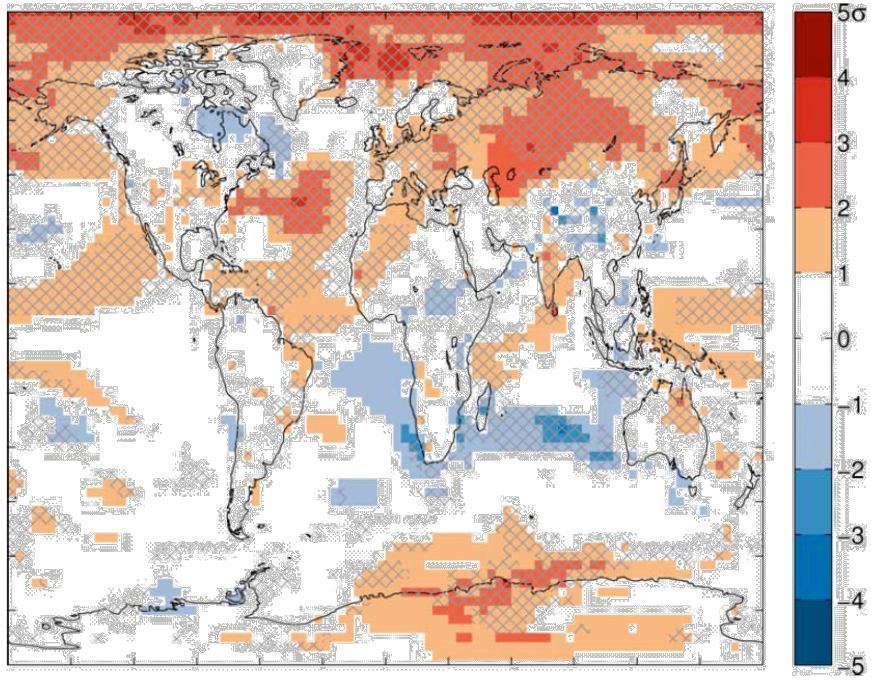
Unforced decadal changes in AMOC strength



Composite of decadal surface air temperature change



Hawkins & Sutton (2008)

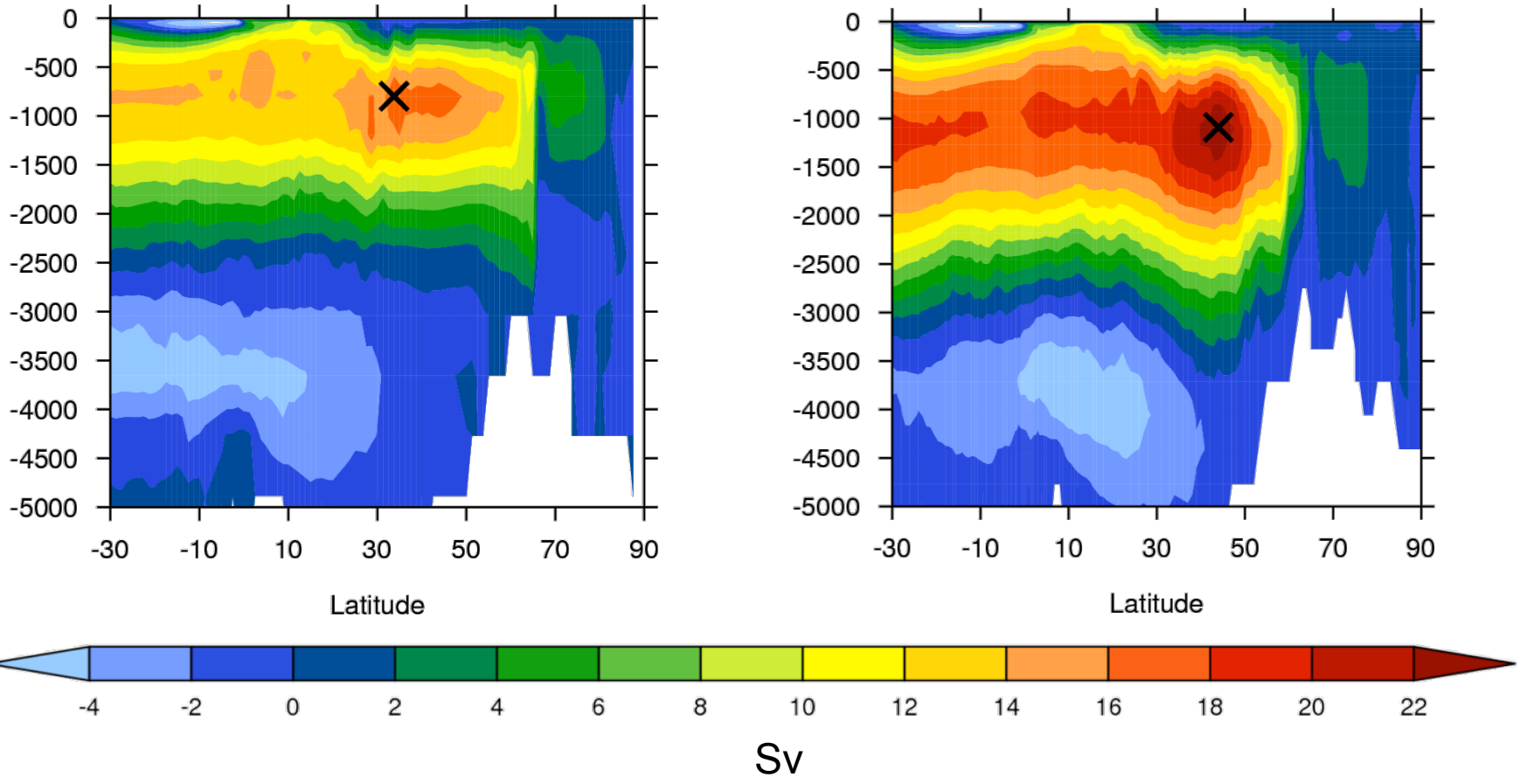
Questions

1. Do models exhibit common signatures of decadal AMOC events?
2. How important is the latitude at which AMOC events are detected?
3. Are the impacts of positive events equal and opposite to the impacts of negative events?
4. What controls the European temperature response?
5. Are the models' AMOC events similar to observed decadal changes in the North Atlantic?

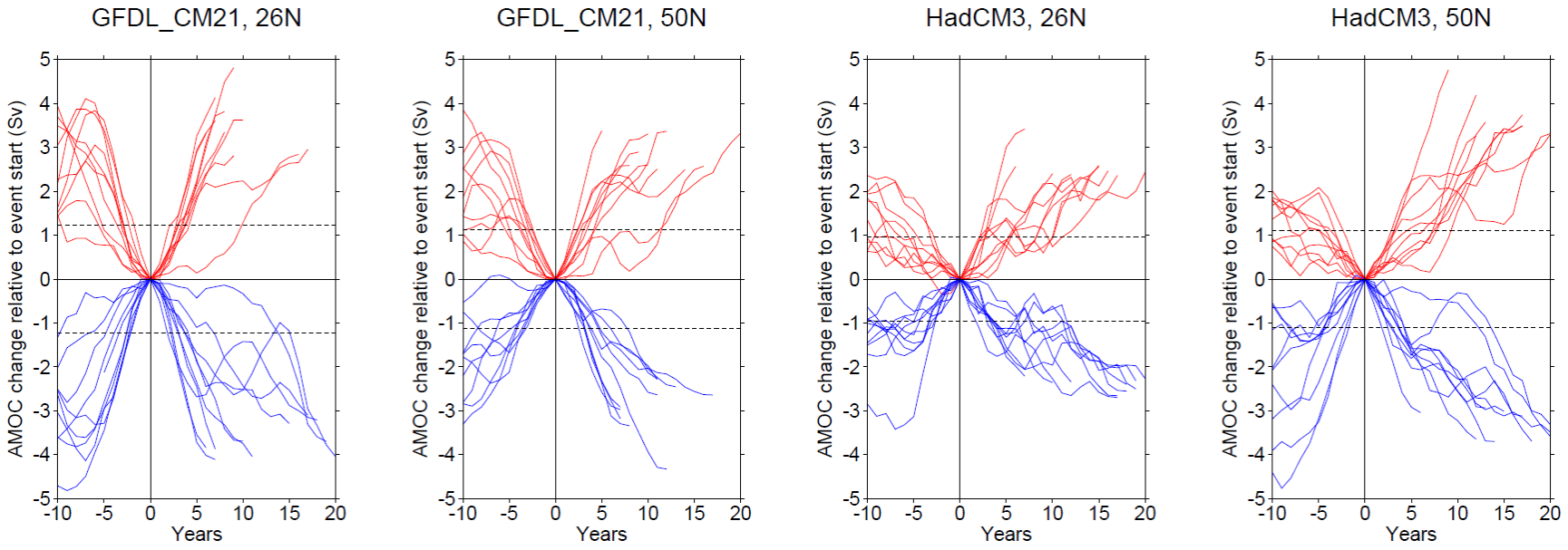
Models

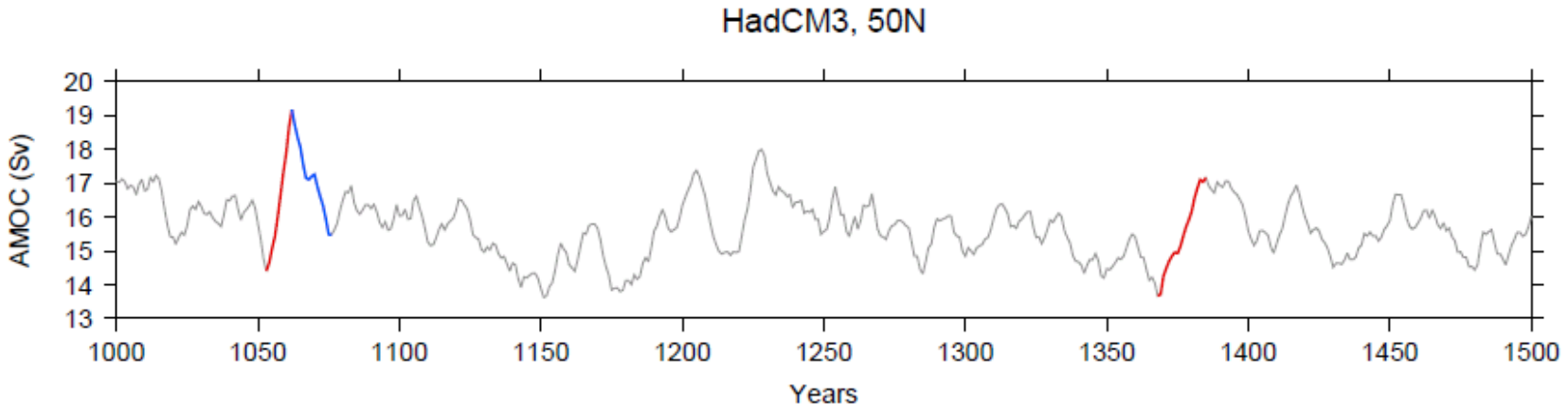
HadCM3
5000-year control simulation

GFDL CM2.1
500-year control simulation

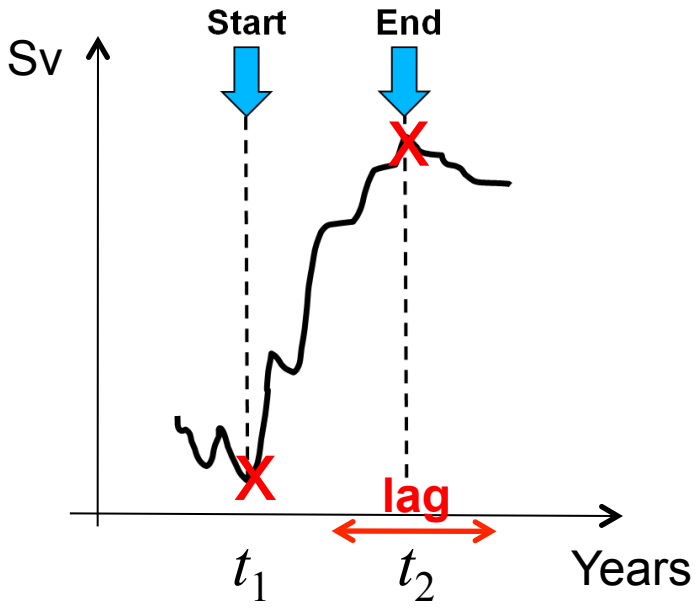


The 10 largest AMOC events of each sign





Defining climate field anomalies



$$x = \frac{1}{N} \sum_{N} \frac{\Delta \text{field(lag)}}{\Delta \text{AMOC}}$$

- Standardise by AMOC change
- Averaged over 10 events (N=10)
- Lags (of both sign) relative to event end
- Annual mean data

Meridional coherence of events: GFDL CM2.1

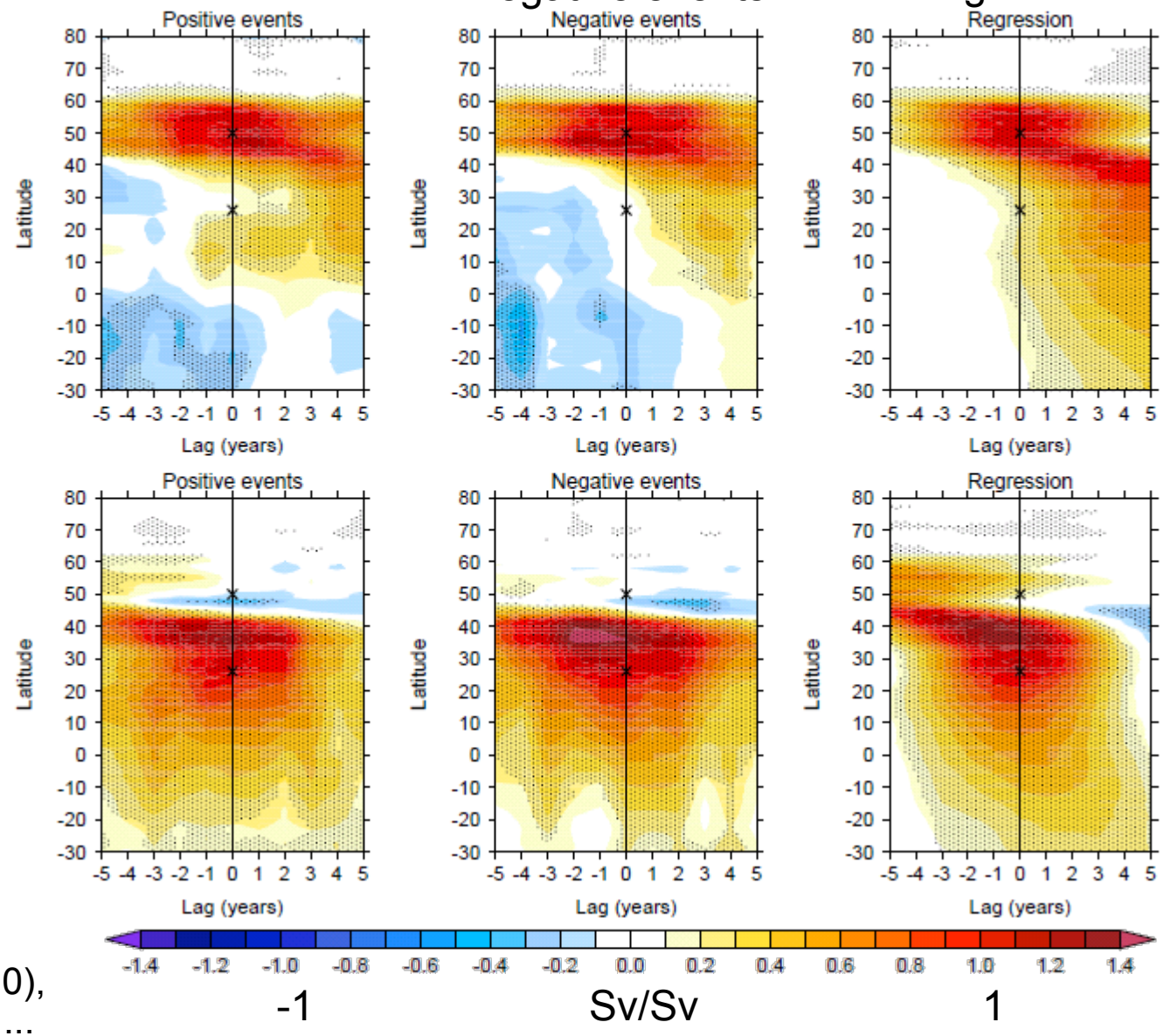
Positive events | Negative events | Regression

Events detected at 50°N

$$\frac{\Delta AMOC(\phi)}{\Delta AMOC(50°N)}$$

Events detected at 26°N

$$\frac{\Delta AMOC(\phi)}{\Delta AMOC(26°N)}$$



See also Zhang (2010), Getzlaff et al (2005), ...

Meridional coherence of events: HadCM3

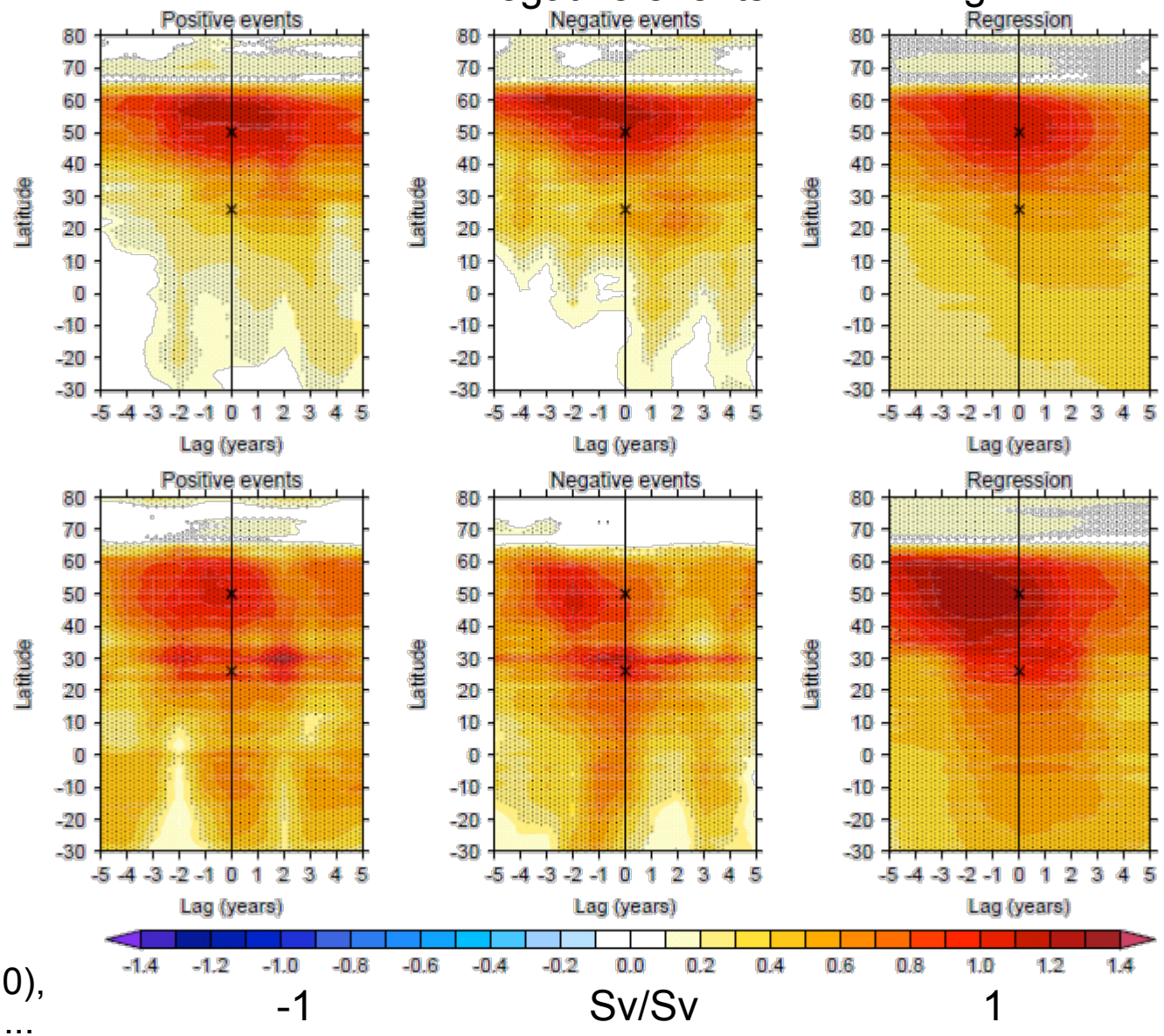
Positive events | Negative events | Regression

Events detected at 50°N

$$\frac{\Delta AMOC(\phi)}{\Delta AMOC(50°N)}$$

Events detected at 26°N

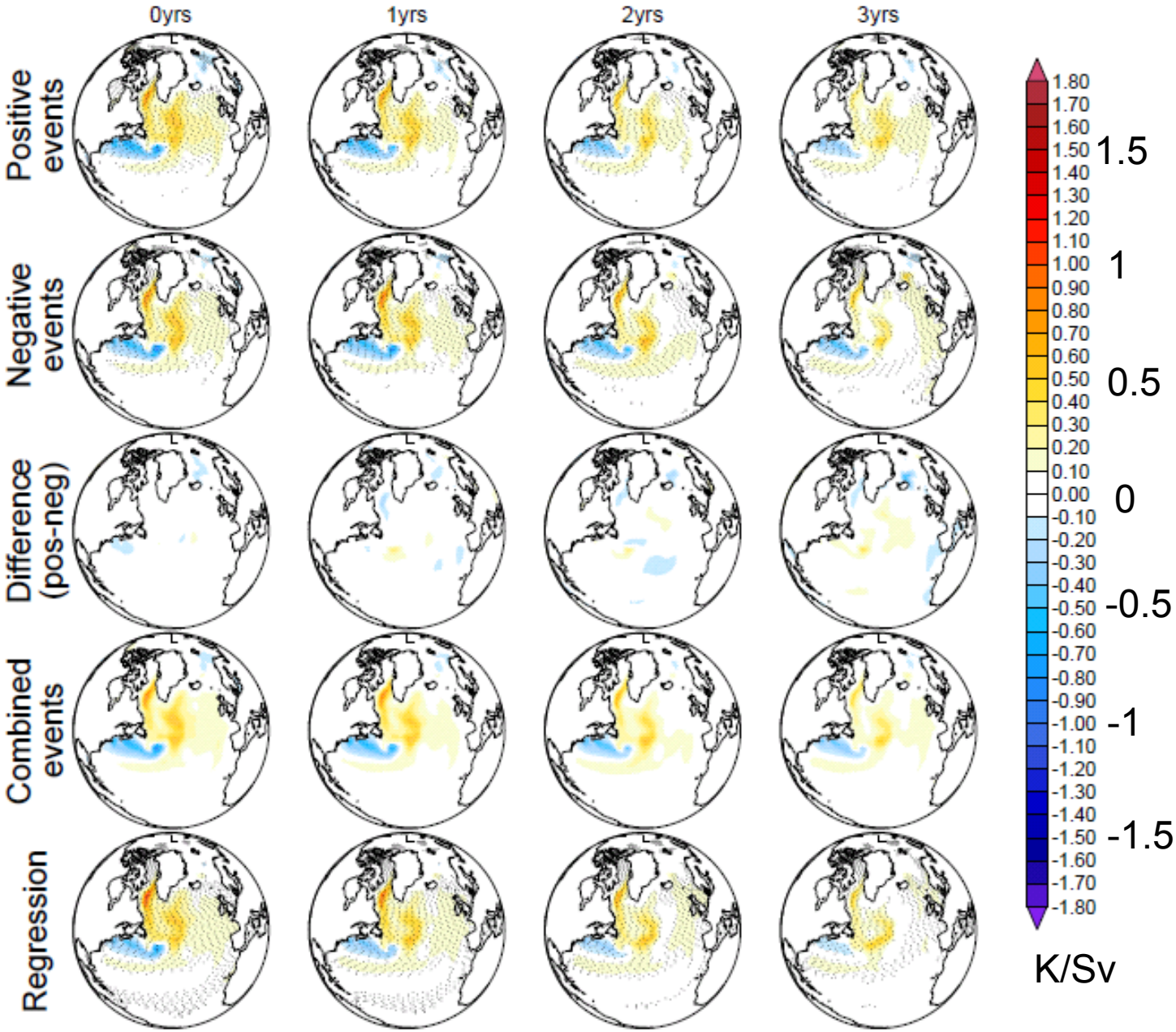
$$\frac{\Delta AMOC(\phi)}{\Delta AMOC(26°N)}$$



See also Zhang (2010), Getzlaff et al (2005), ...

SST changes: GFDL CM2.1

26°N events



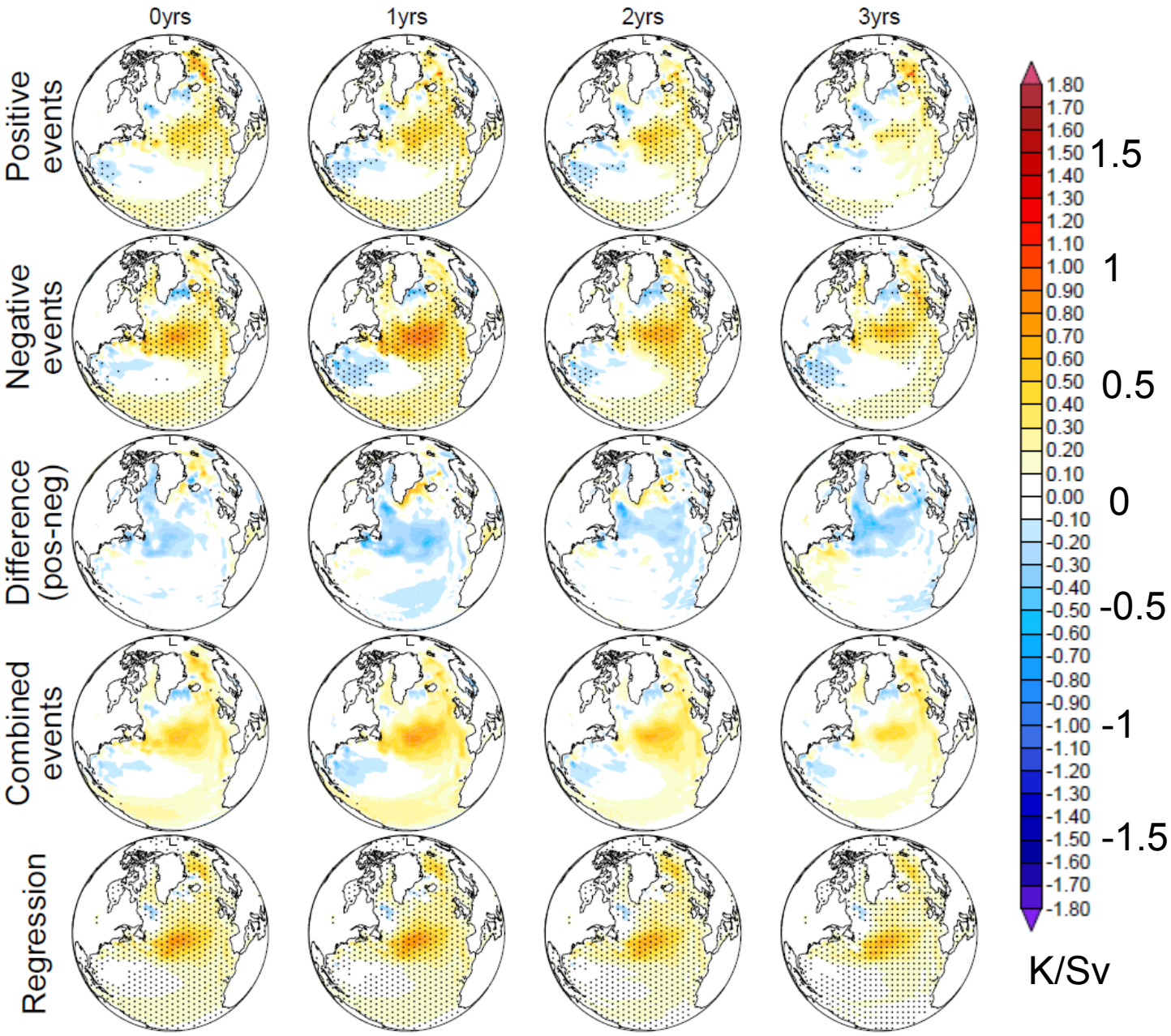
$$\frac{\Delta SST}{\Delta AMOC(26°N)}$$

SST response to events of each sign in GFDL CM2.1 approximately equal and opposite.

c.f. Zhang (2008)

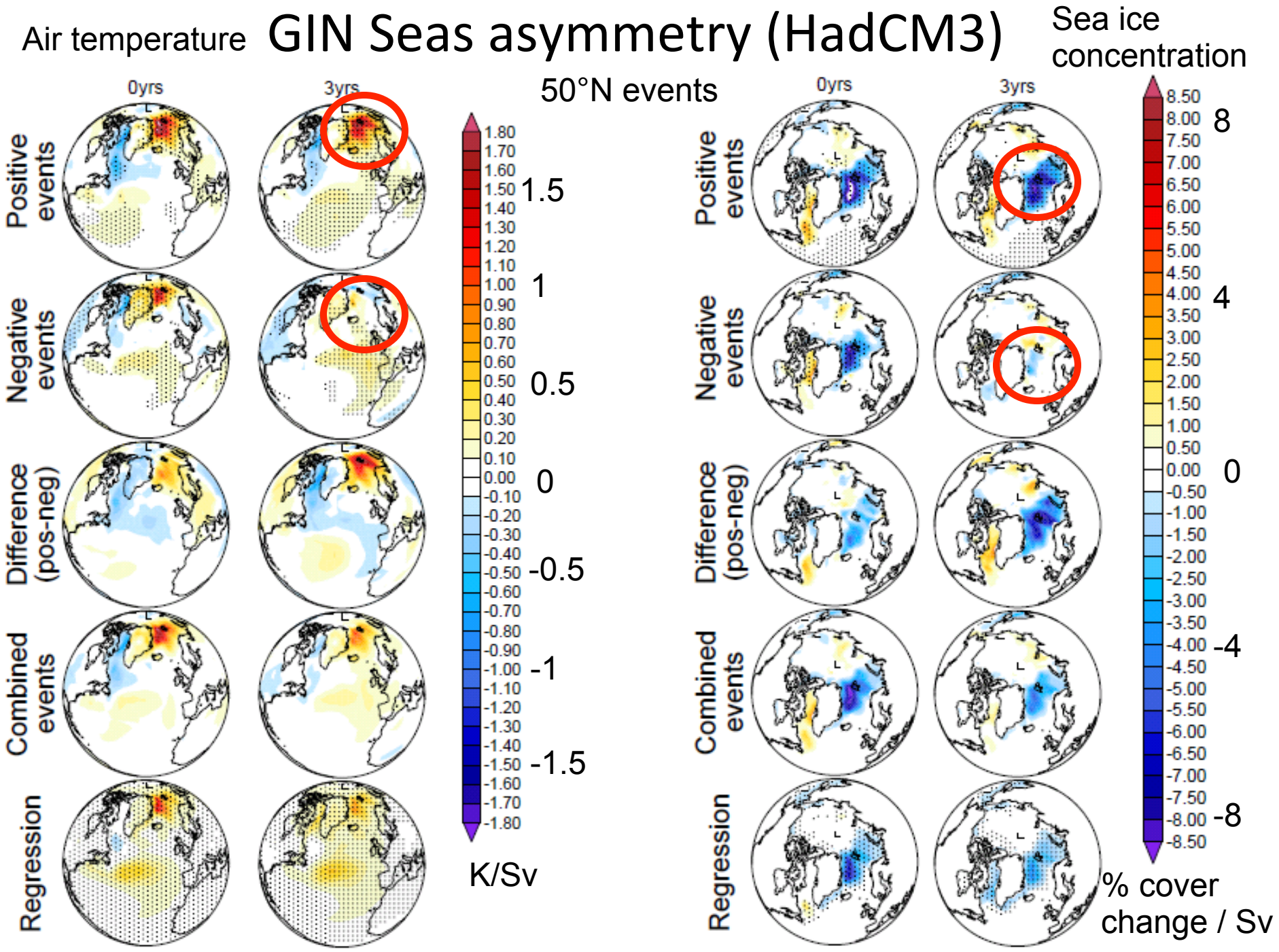
SST changes: HadCM3

26°N events



$$\frac{\Delta SST}{\Delta AMOC(26°N)}$$

In HadCM3 the SST response to negative events is stronger than the response to positive events.

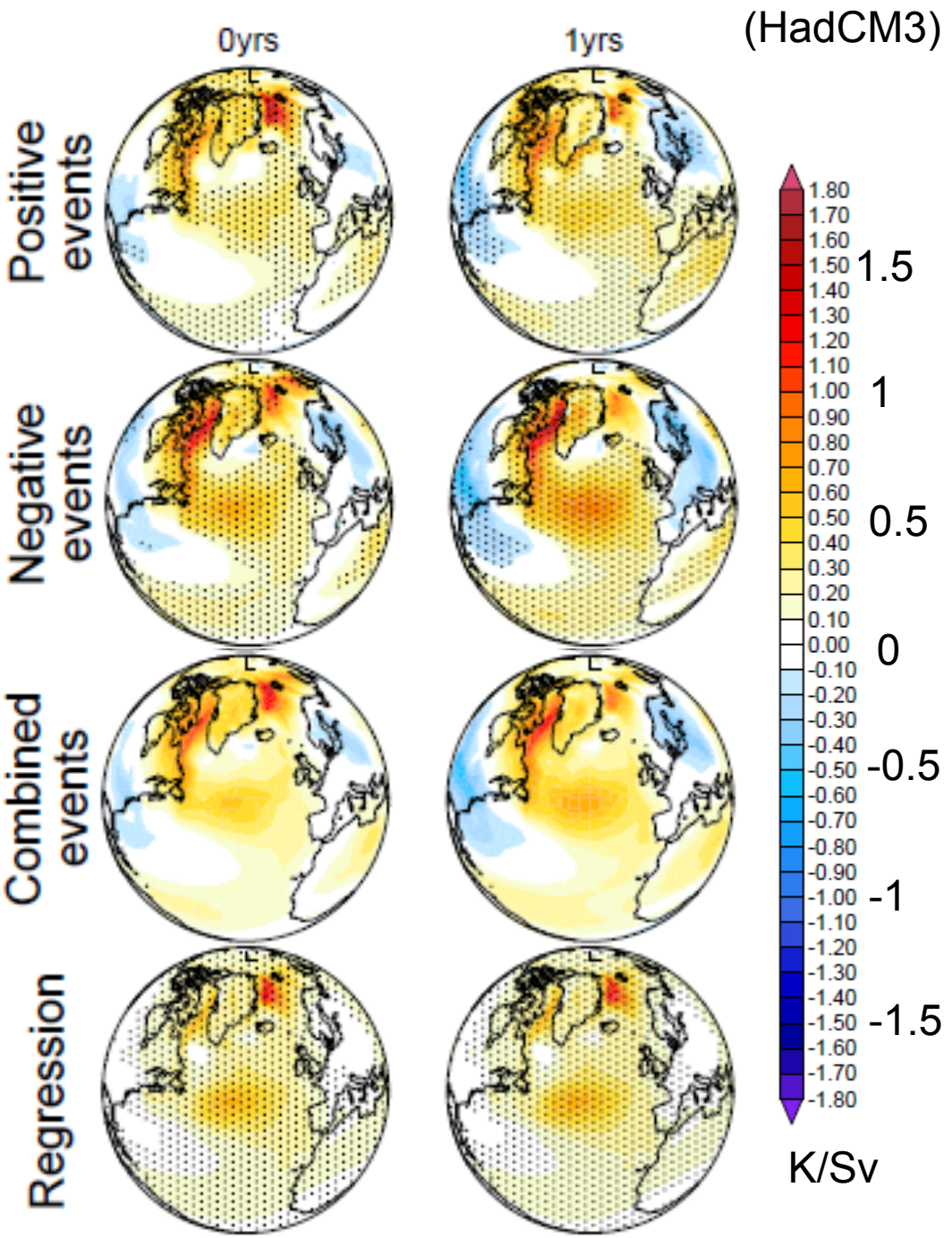

Air temperature
GIN Seas asymmetry (HadCM3)
Sea ice concentration
50°N events
0yrs
3yrs
Positive events
Negative events
Difference (pos-neg)
Combined events
Regression
1.80 1.70 1.60 1.50 1.40 1.30 1.20 1.10 1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00 -0.10 -0.20 -0.30 -0.40 -0.50 -0.60 -0.70 -0.80 -0.90 -1.00 -1.10 -1.20 -1.30 -1.40 -1.50 -1.60 -1.70 -1.80
1.5
1
0.5
0
-0.5
-1
-1.5
K/Sv
8.50 8.00 7.50 7.00 6.50 6.00 5.50 5.00 4.50 4.00 3.50 3.00 2.50 2.00 1.50 1.00 0.50 0.00 -0.50 -1.00 -1.50 -2.00 -2.50 -3.00 -3.50 -4.00 -4.50 -5.00 -5.50 -6.00 -6.50 -7.00 -7.50 -8.00 -8.50
8
4
0
-4
-8
% cover change / Sv

Subdued response in European air temperature

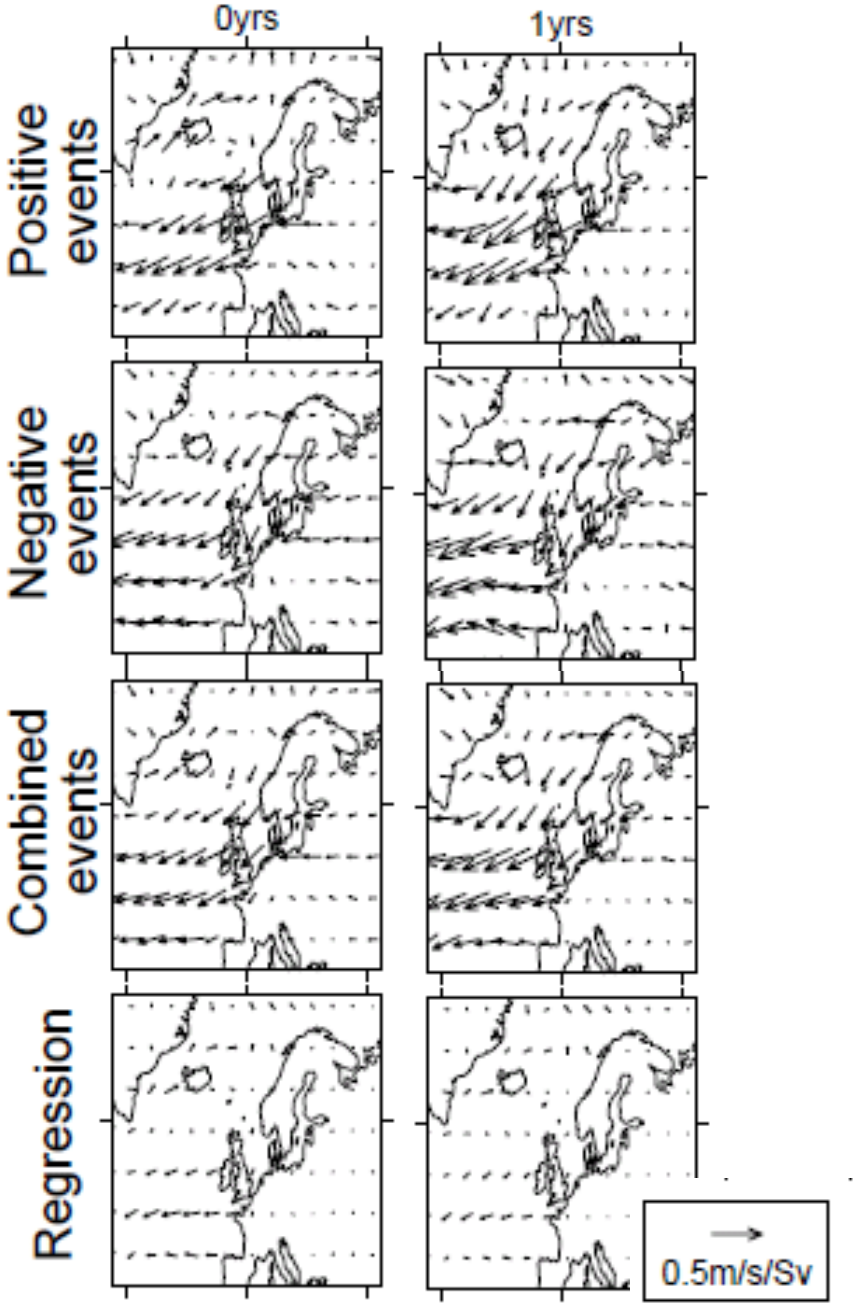
Despite a positive ΔSAT/ Δ AMOC signal over the ocean, there is no such response over Europe.

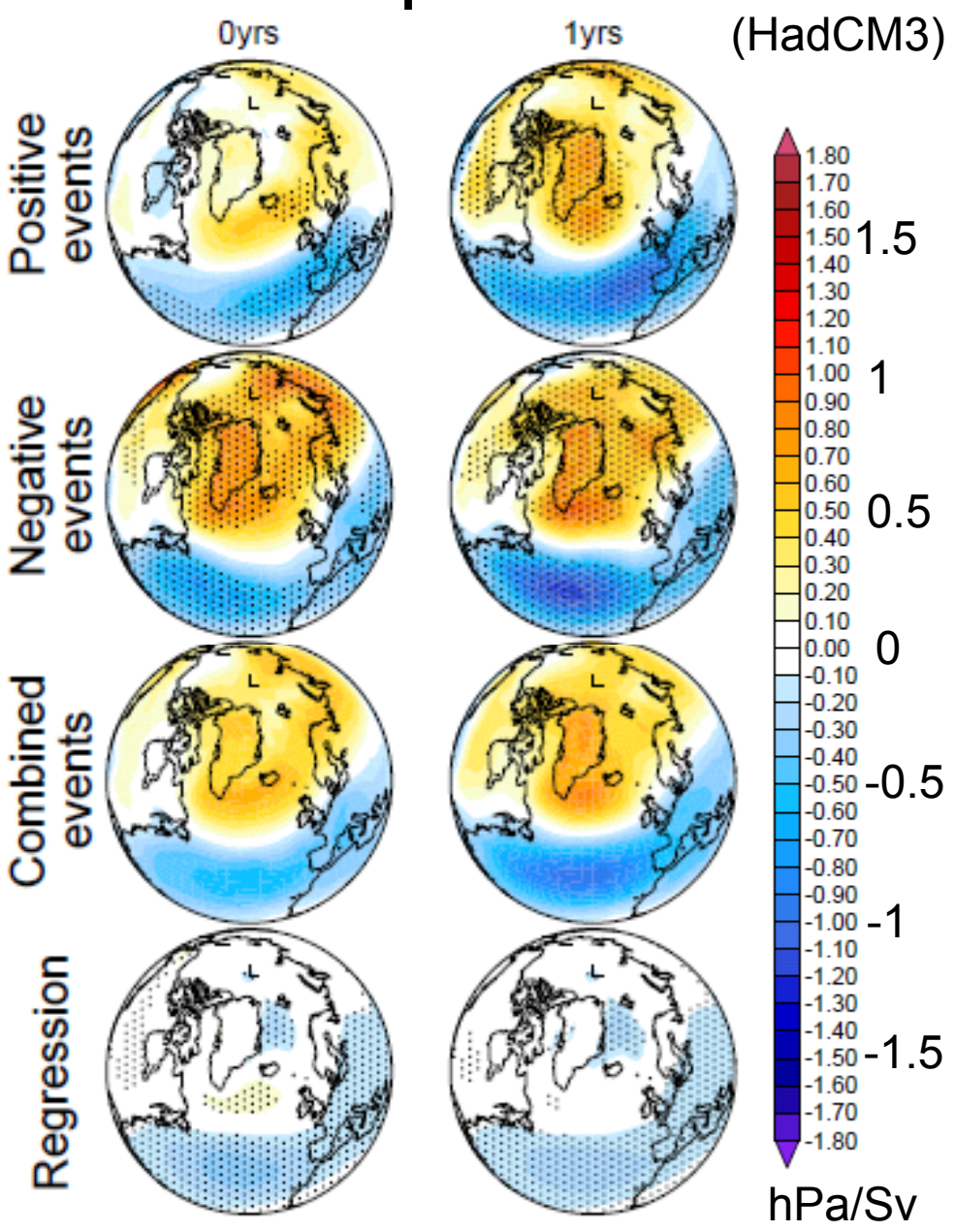
Since Western Europe usually has a strong maritime influence, why is the land response so weak?

The land-sea difference is most pronounced for negative events.



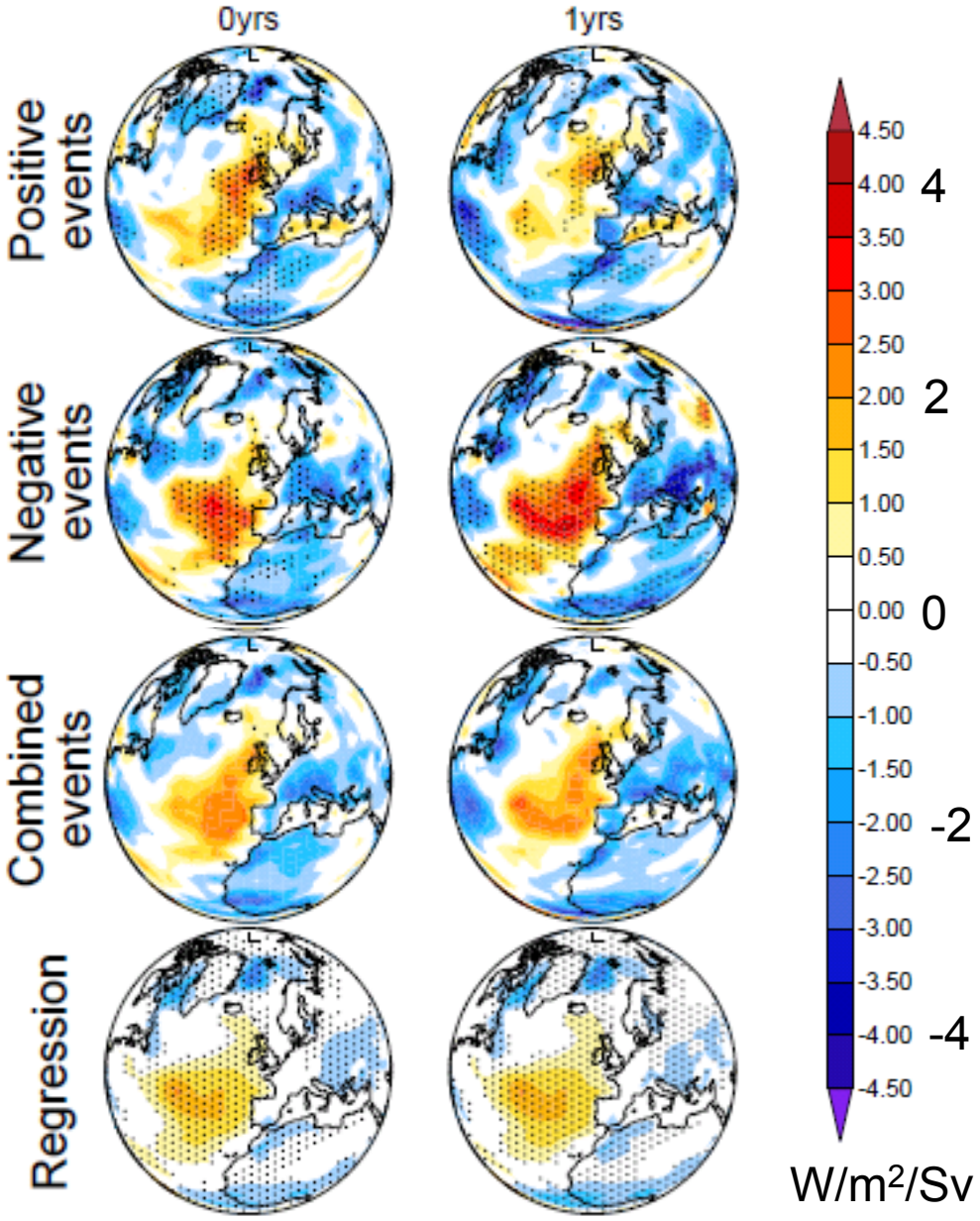
Near-surface winds & sea level pressure





Land-sea contrast in cloudiness?

(HadCM3)



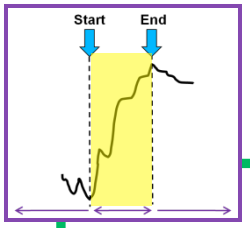
Increase in surface downward shortwave radiation over ocean, decrease over land for positive AMOC events. Opposite (and stronger) for negative events.

May suggest (for positive events) a reduction in oceanic cloud cover (warming) and increased clouds over land (cooling).

Appears consistent with AMOC collapse experiment of Laurian et al (2010).

Comparison with mid-90s North Atlantic warming event: SST

e.g., Robson et al (2012)



Start → Stages during AMOC increase [Normalised event length] → End

GFDL CM2.1

start 0.25 0.5 0.75 end

HadCM3

start 0.25 0.5 0.75 end

HadISST

1986 1997

-1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

-1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5

Anomaly from time mean (deg C)

Summary

Examining decadal-scale AMOC fluctuation events in control simulations of AOGCMs (HadCM3 and GFDL CM2.1)

Events detected separately at 26°N and 50°N show meridional coherence over a range of latitudes; events in HadCM3 show greater coherence.

The two models show some similar characteristics of AMOC events, but spatial patterns differ somewhat (e.g., SST changes).

SST changes associated with positive and negative events in GFDL CM2.1 are approximately equal and opposite. In HadCM3, the SST changes associated with negative events are stronger than for positive events, and there are local asymmetries that may be linked to sea ice changes.

HadCM3 shows a subdued temperature response in Europe. This may be linked to changes in winds and/or differences in cloud cover changes over land and ocean.

Preliminary work suggests there might be some similarity between the fingerprints of the model events and the observed North Atlantic warming event in the mid 1990s.

Thank you
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