EGU General Assembly 2018

Differing drivers of Atlantic variability on quasi- and multi-decadal timescales

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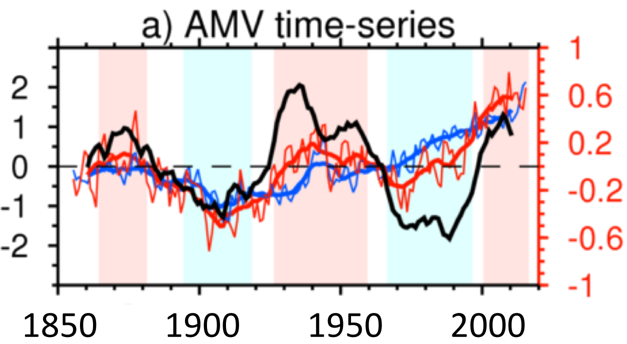
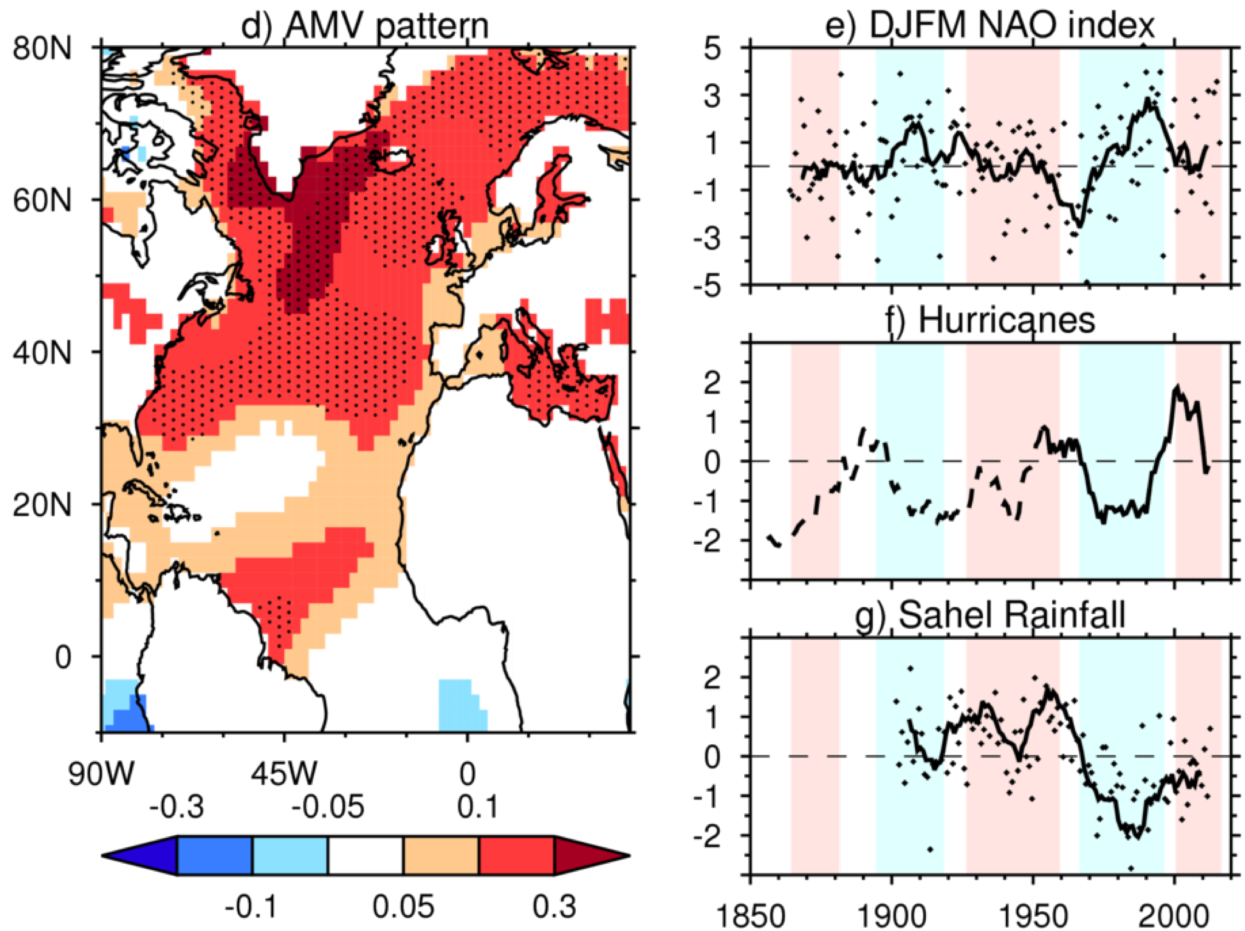
Atlantic Multidecadal Variability (AMV)



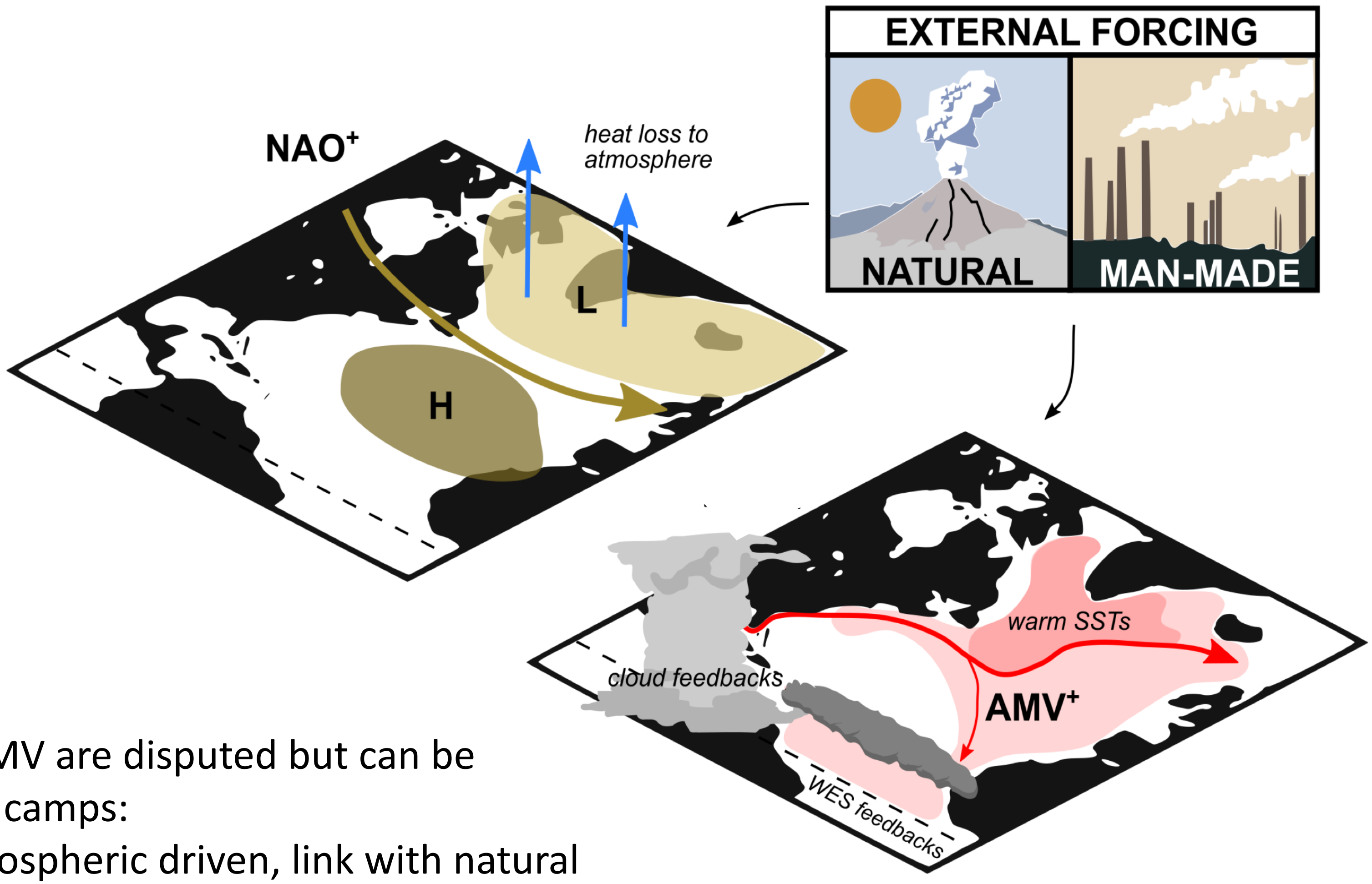
- The Atlantic is characterized by multiple decades of anomalously warm or cool SSTs known as AMV

- AMV is linked with a wide range of climate phenomena including Atlantic hurricanes and rainfall in the Sahel region of Africa



Sutton, R. T, McCarthy, G. D., Robson, J., Sinha, B., Archibald, A., and Gray, L. J. (2018) Atlantic Multi-decadal Variability and the UK ACSIS Programme *BAMS*

Drivers of AMV



The drivers of AMV are disputed but can be divided into two camps:

- External: atmospheric driven, link with natural and man-made aerosols, cloud feedbacks
- Internal: ocean circulation, Atlantic Meridional Overturning Circulation (AMOC) driven

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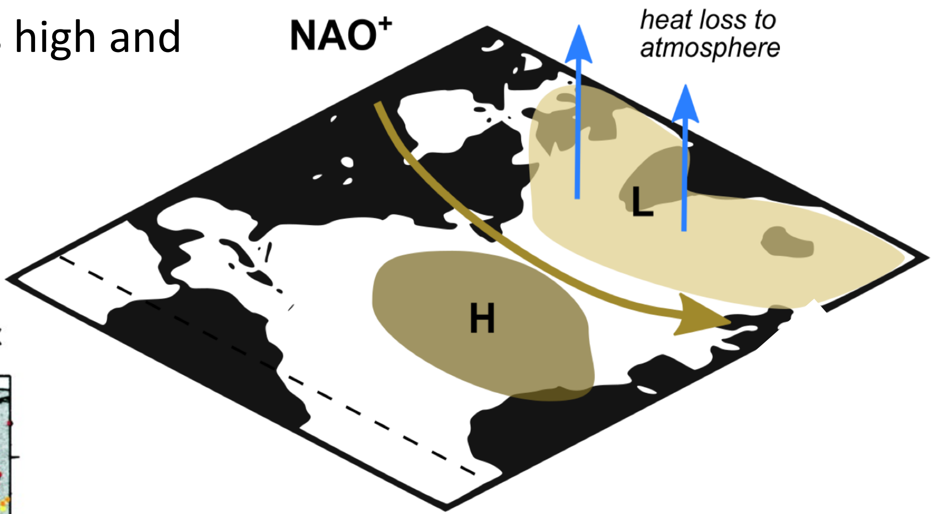
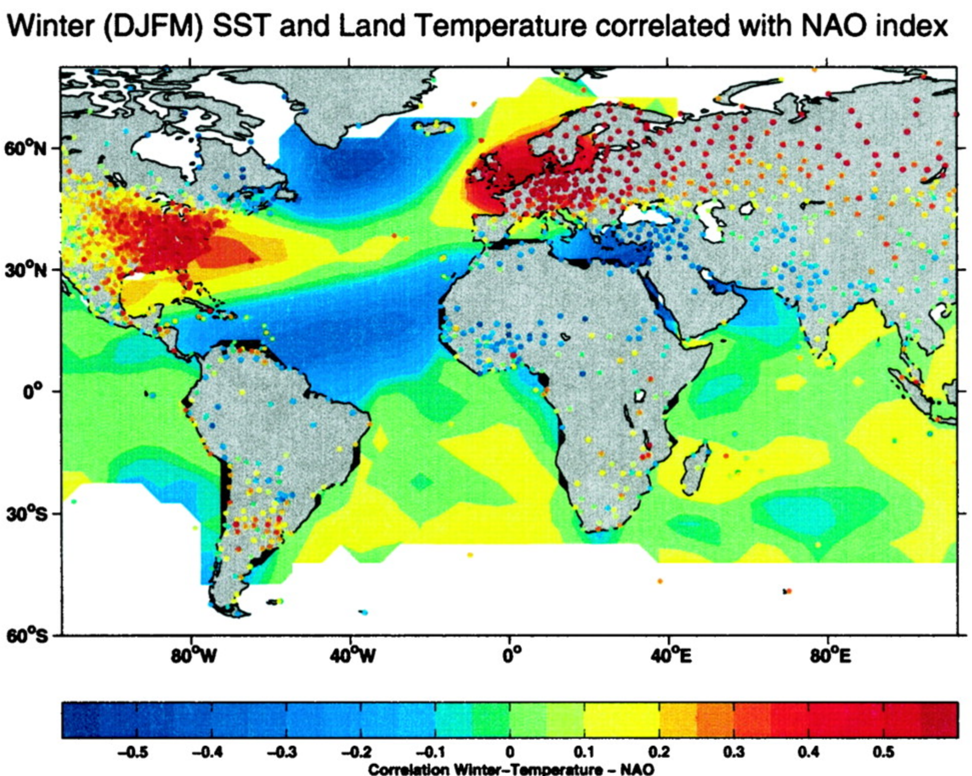
NAO heat-flux SST patterns

We will view the external forcing through the prism of the North Atlantic Oscillation (NAO):

- The leading mode of atmospheric variability in the North Atlantic
- Defined by relative intensities of the Azores high and Greenland low



Martin H. Visbeck et al. PNAS 2001;98:12876-12877



- Associated with a tripole pattern of SSTs

Sutton, R. T, McCarthy, G. D., Robson, J., Sinha, B., Archibald, A., and Gray, L. J. (2017) Atlantic Multi-decadal Variability and the UK ACSIS Programme *BAMS*

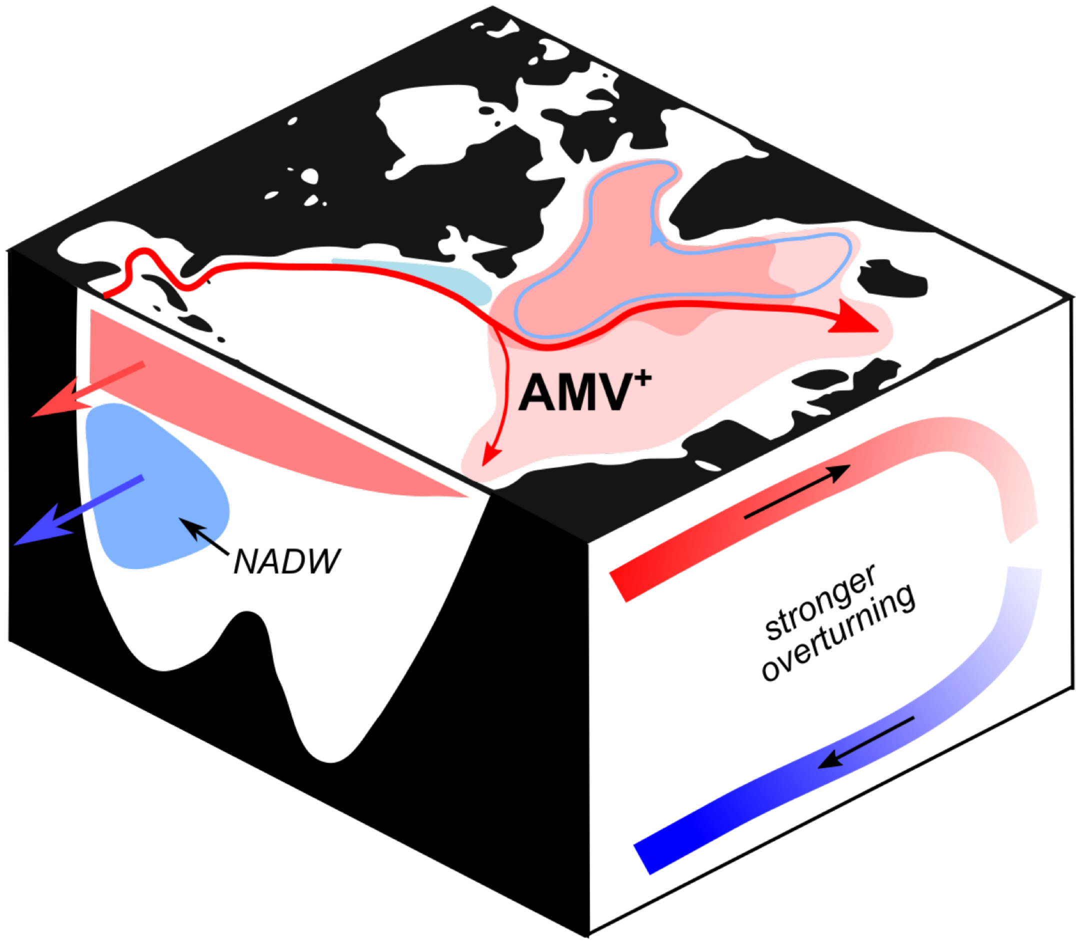
Ocean circulation SST patterns

The leading hypothesis for AMV is that it is controlled by variability in the Atlantic ocean circulation

A stronger AMOC transports more heat towards the subpolar gyre, raising heat content there and, eventually, raising SSTs

A stronger AMOC is associated with:

- More North Atlantic Deep Water
- A contracted subpolar gyre
- A fingerprint of cooling north of the Gulf Stream and warming in the subpolar North Atlantic



Sufficiently long timeseries of AMOC do not exist to prove this hypothesis

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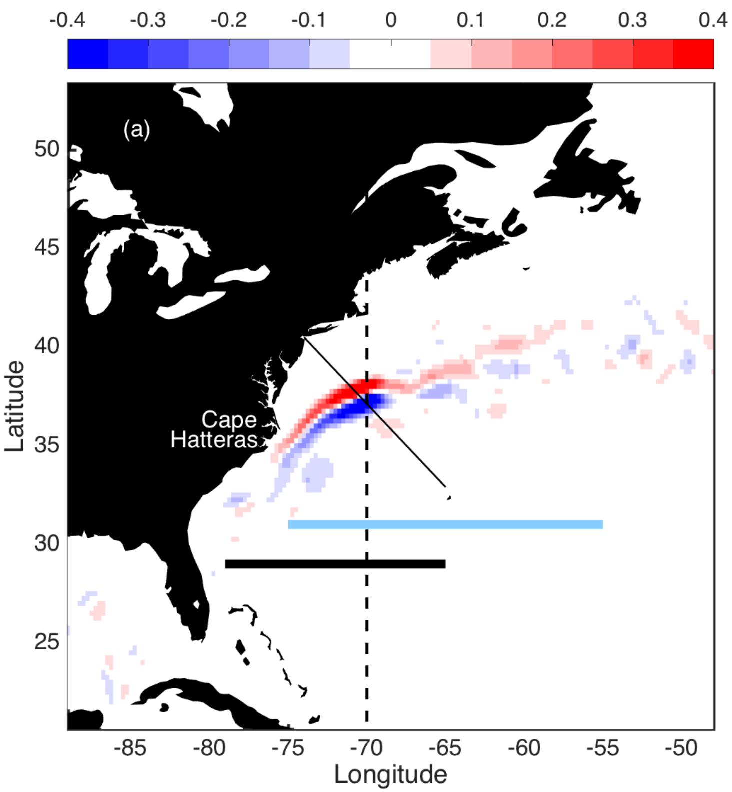
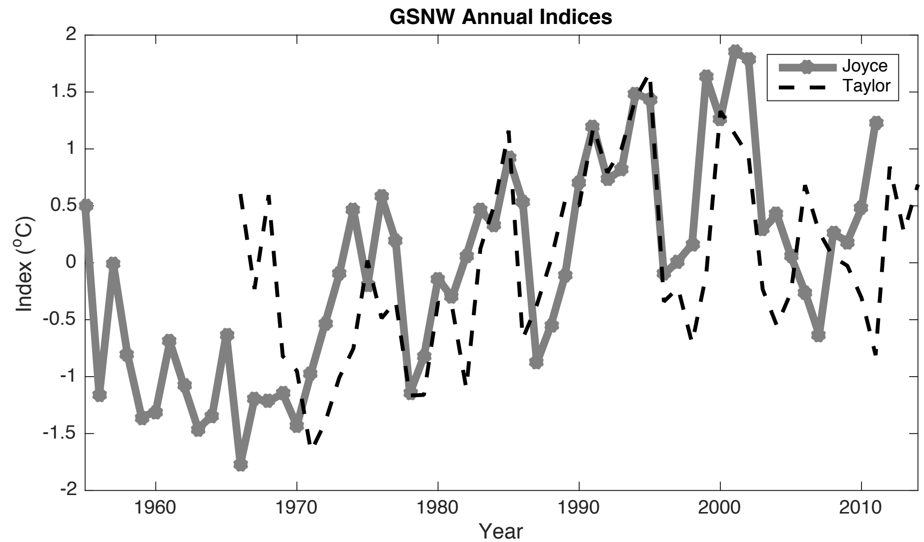
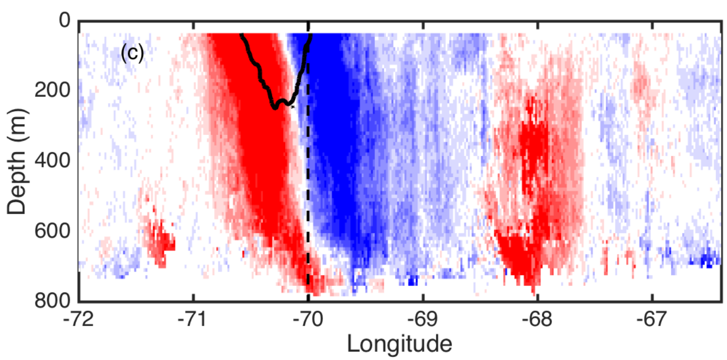
The Gulf Stream North Wall (GSNW)







GSNW variations are clearly visible in (a) surface and (c) subsurface velocity

Two timeseries of GSNW are available back to the 1960s and 1950s

Joyce index based on location of 15C isotherm at 200 m over longitude range of 55º to 75º W

Taylor index based on leading SST mode from 65º to 78ºW

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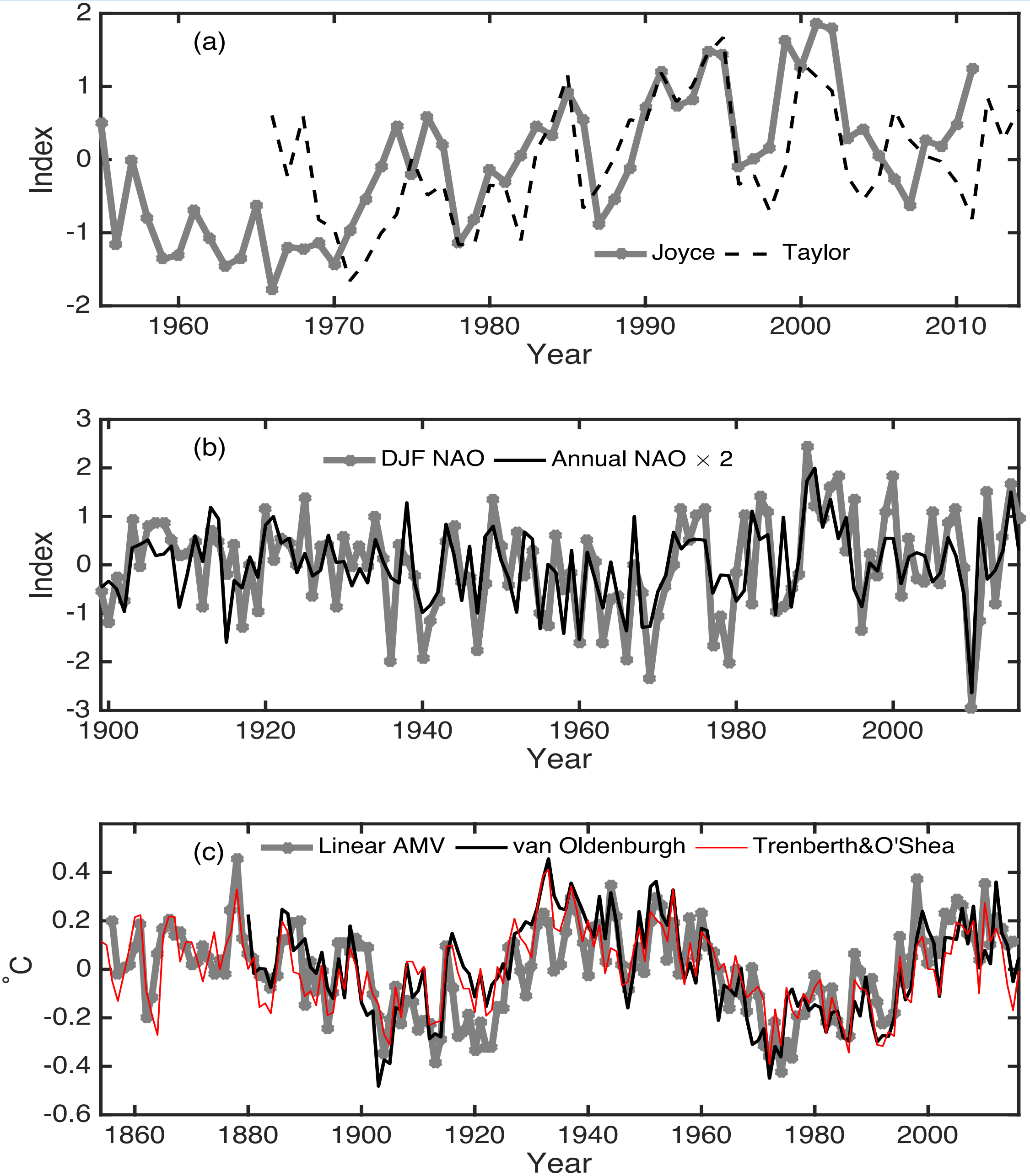
NAO, AMV, GSNW



We use these long timeseries of ocean circulation to address the question of whether AMV is externally or internally forced

The timeseries display variability and co-variability on multiple timescales

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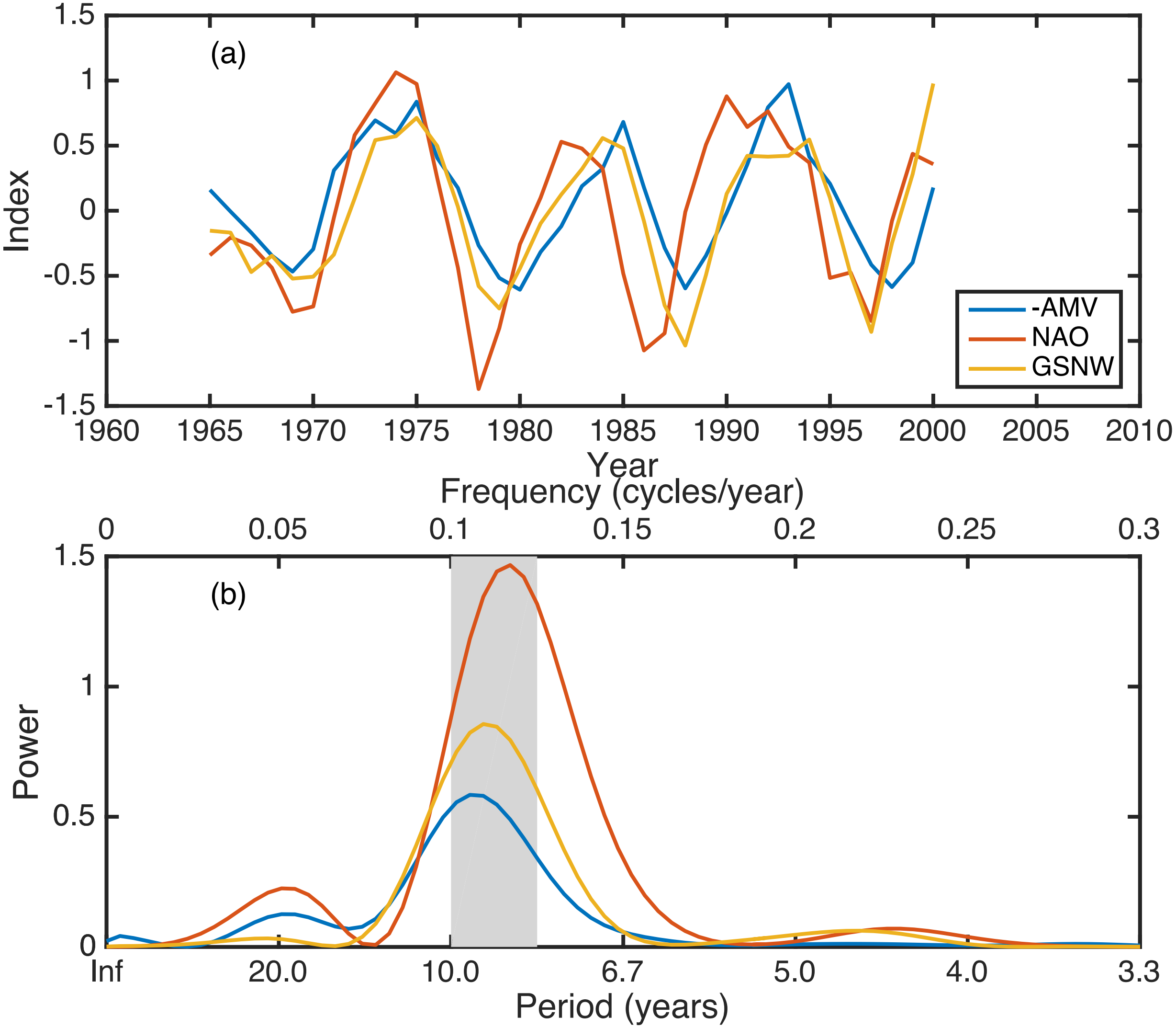
Quasi-decadal Variability



A 9-year mode is common to all and revealed by a 5-20 year band pass filter

NAO-GSNW positively related

Both are inversely related to the AMV

We refer to this as *quasi-decadal* variability as different modes emerge in NAO, AMV when longer timeseries are analysed

Relationship also discussed by Nigam et al., 2018, *GRL*

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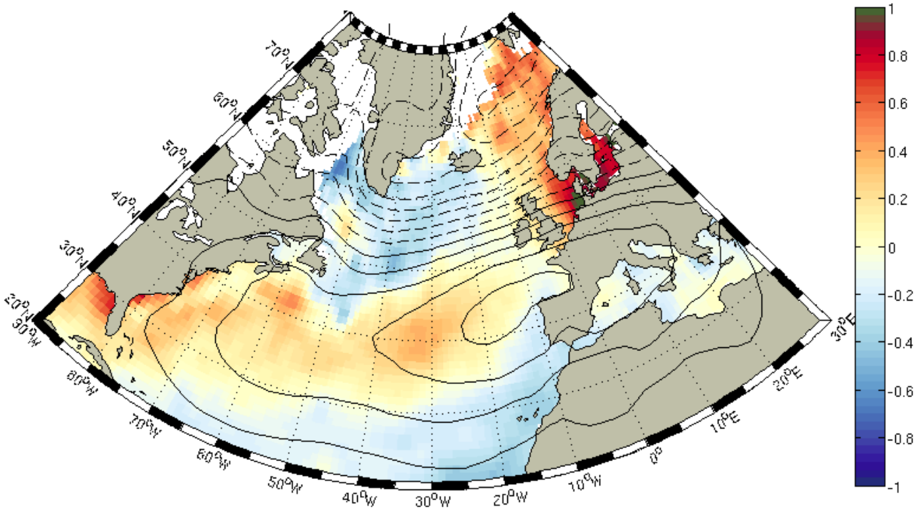
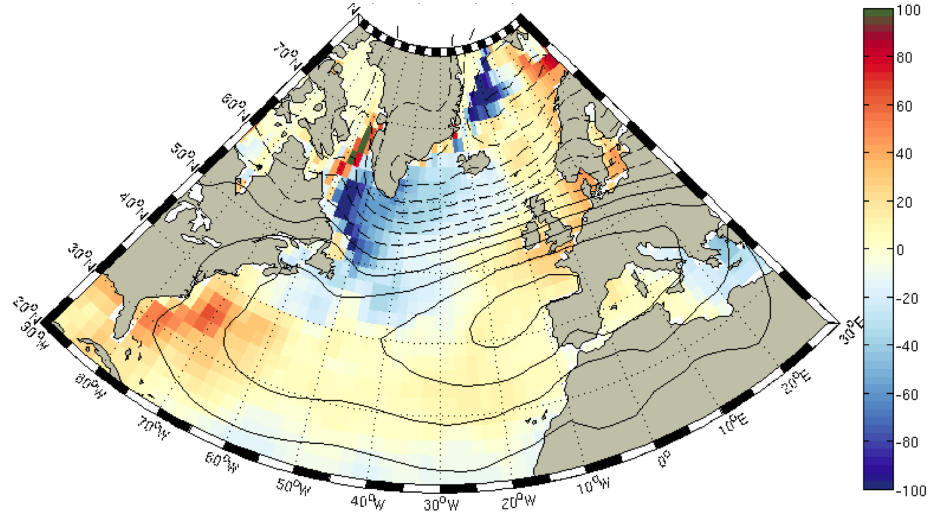
Quasi-decadal Variability

5-20 Year SST



5-20 Qnet



Air-sea heat fluxes associated with the NAO explain this mode of variability

We conclude that a distinct, oscillatory quasi-decadal variations exist in Atlantic SSTs and that this is externally driven

Similar to what was noted in Gulev et al., 2013, *Nature* but with explicit reference to the quasi-decadal mode

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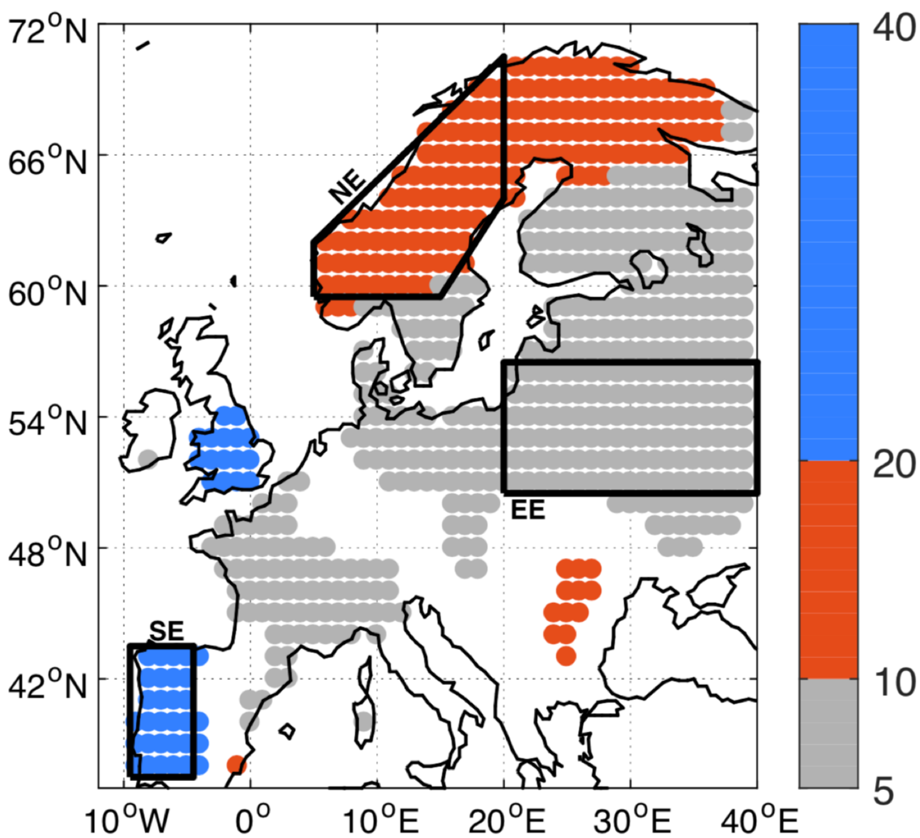
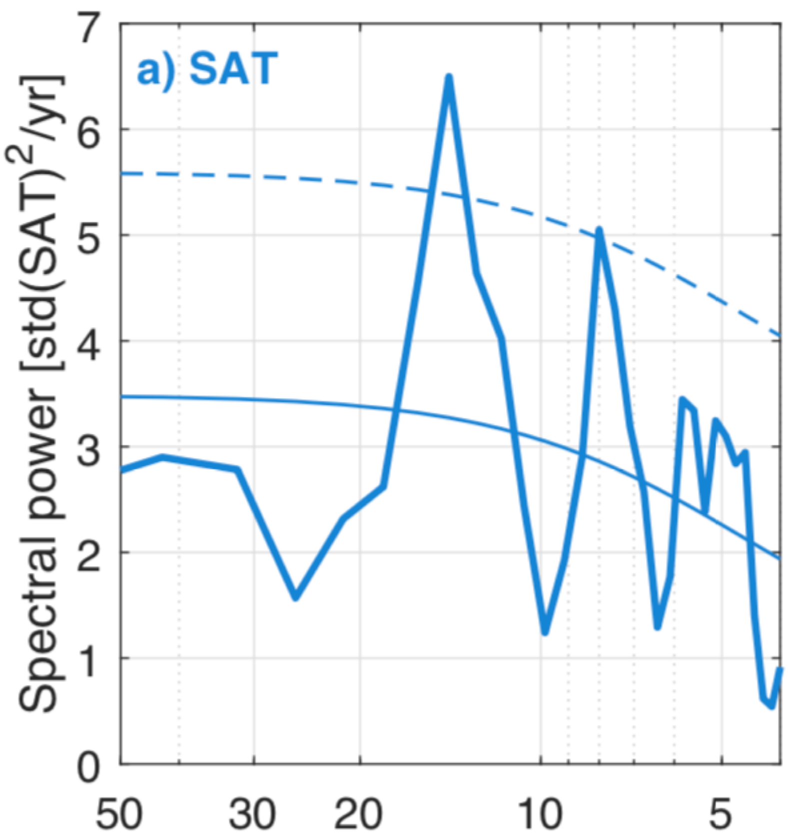
Quasi-decadal Variability

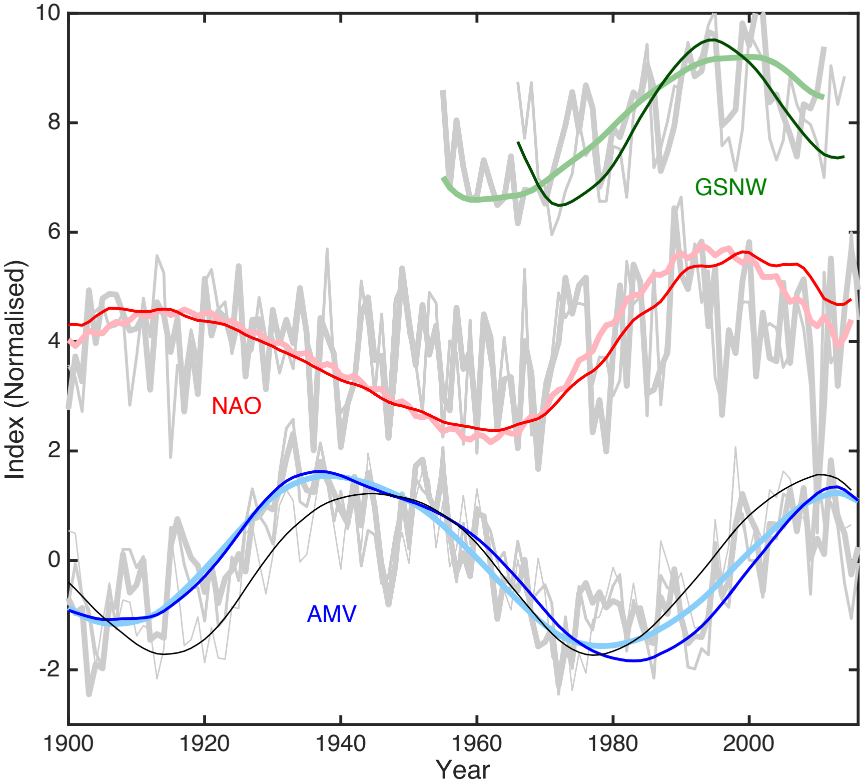
Quasi-decadal mode dominates winter temperatures in Scandinavia





Arthun et al., (2018) Timee scales and sources of European temperature variability

Multi-decadal Variability



Looking at longer timescales, the NAO and GSNW remain positively related

But the relationship with the AMV has changed markedly

The influence of the AMOC and ocean heat transport can mechanistically explain this relationship

This would suggest a **positive** AMOC-GSNW relationship. Note that the opposite sense is frequently stated i.e. a weakened AMOC, northward shift of GS

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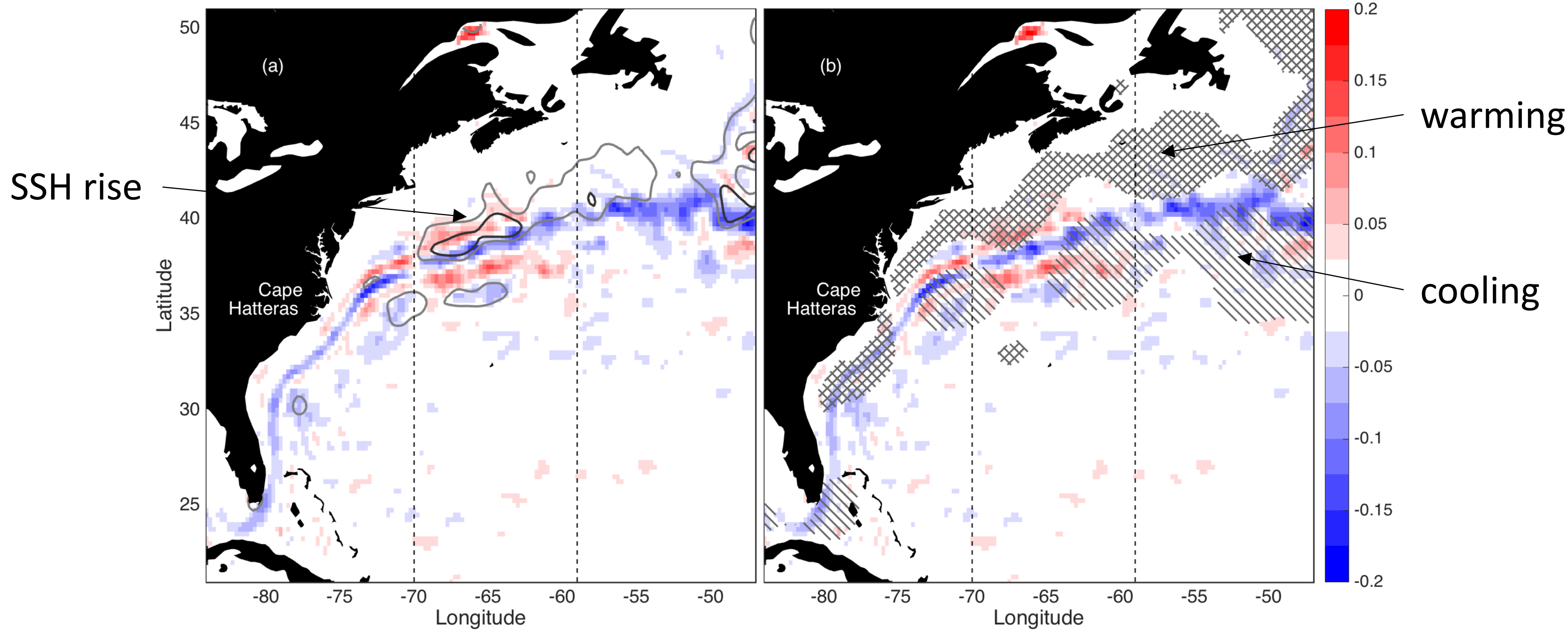
Ongoing Changes in the Gulf Stream



Velocity change between the periods 1995-2005 and 2005-2015
A weakening GS is visible west of 70W and east of 60W
In between, the pattern is a broadening
There has been warming north and cooling south of the GS
SSH has risen north of the GS
The patterns are better described as a weakening and broadening rather than a shift in positions

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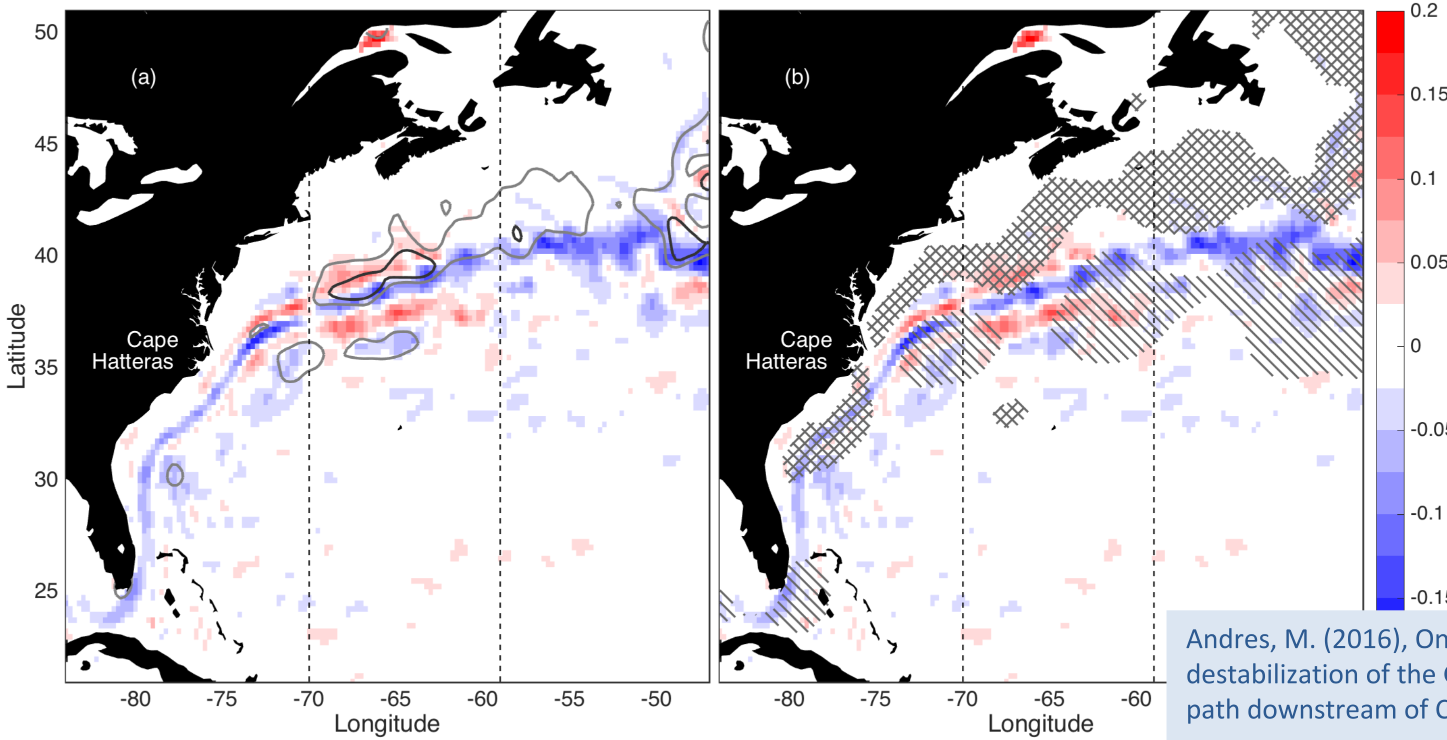
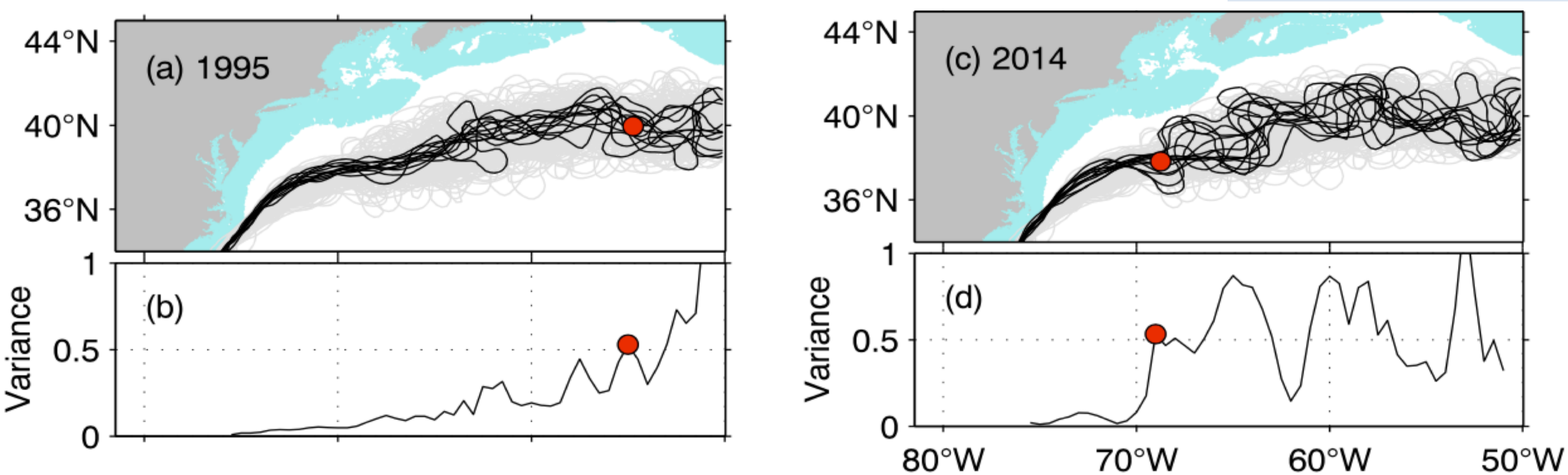


Andres, M. (2016), On the recent destabilization of the Gulf Stream path downstream of Cape Hatteras, *GRL*



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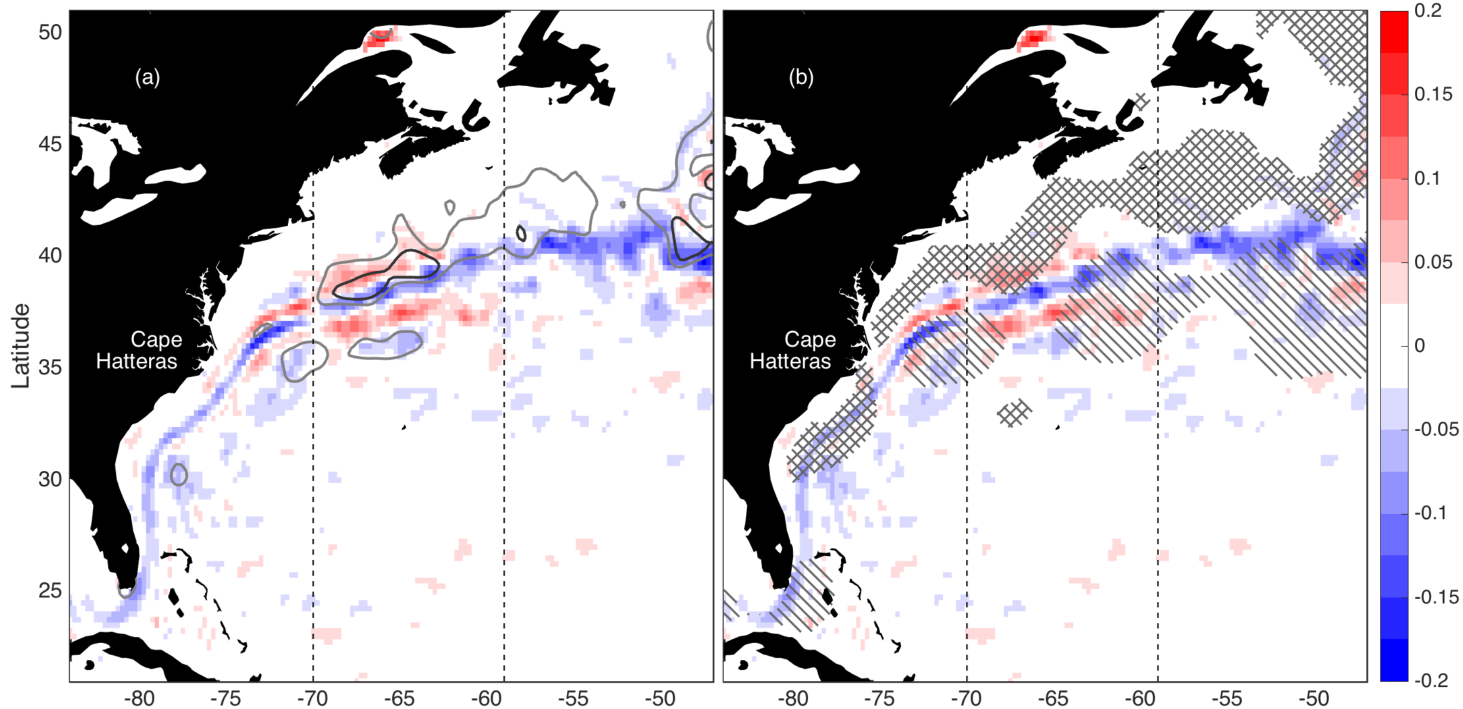
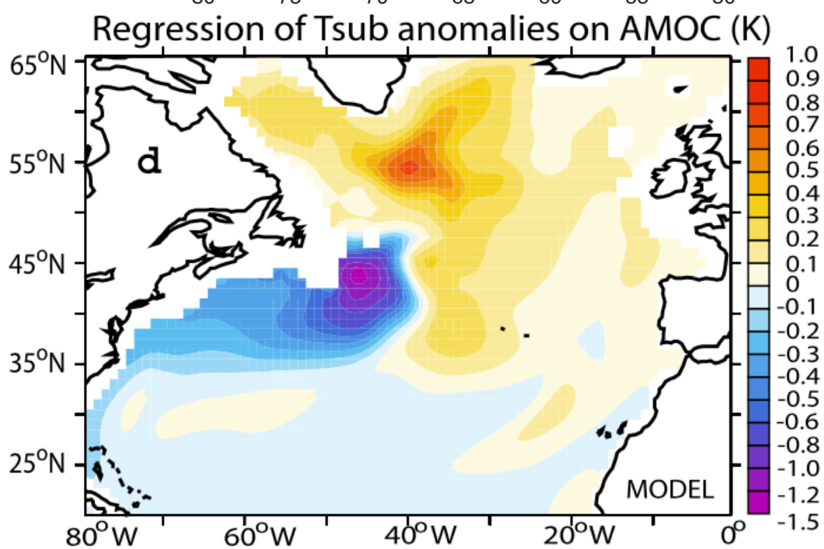
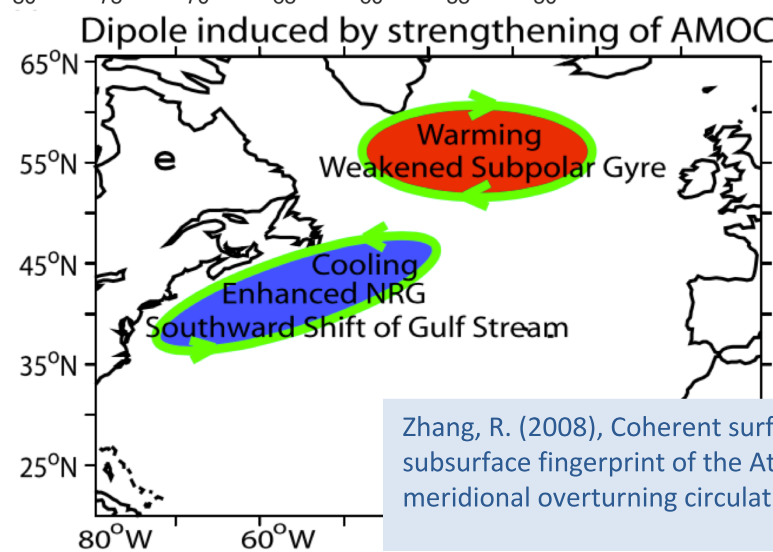
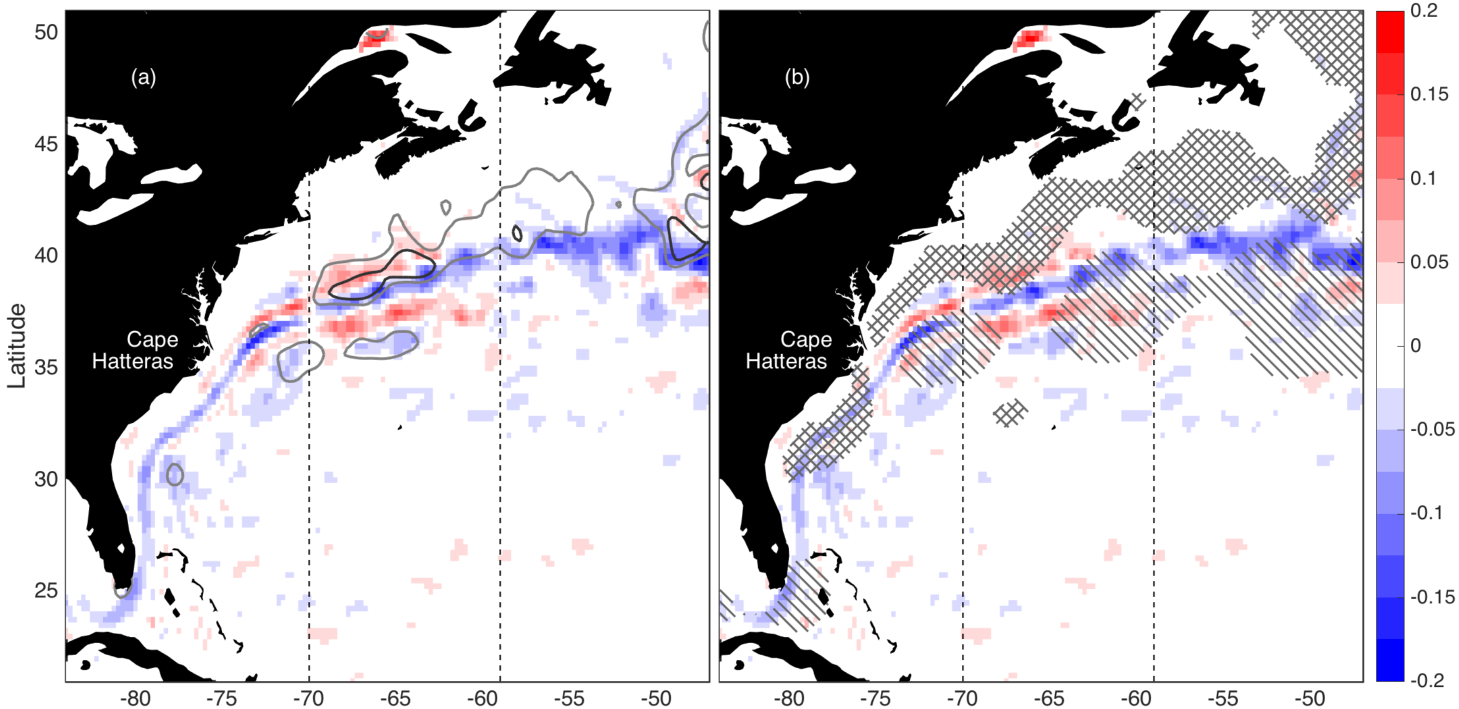


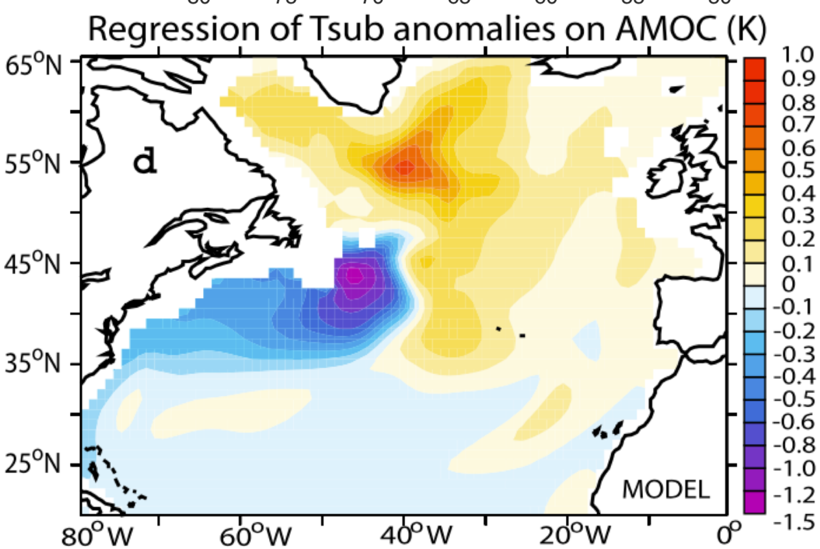


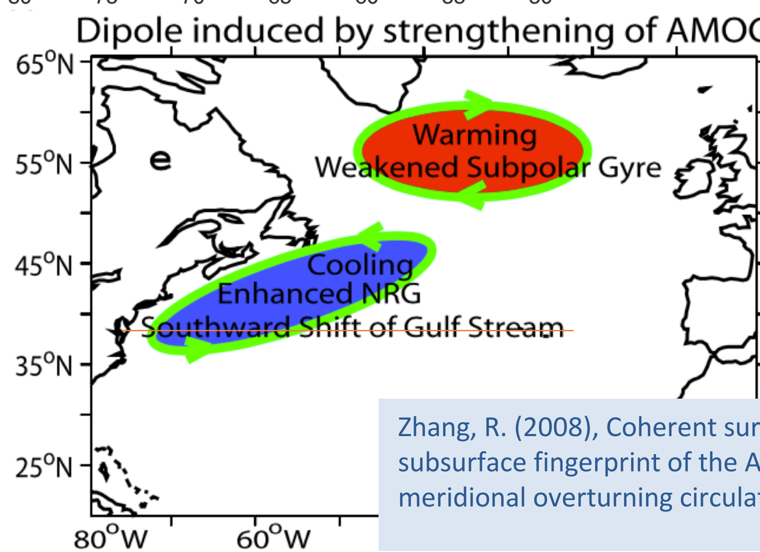


Zhang, R. (2008), Coherent surface-subsurface fingerprint of the Atlantic meridional overturning circulation, *GRL*

Ongoing Changes in the Gulf Stream

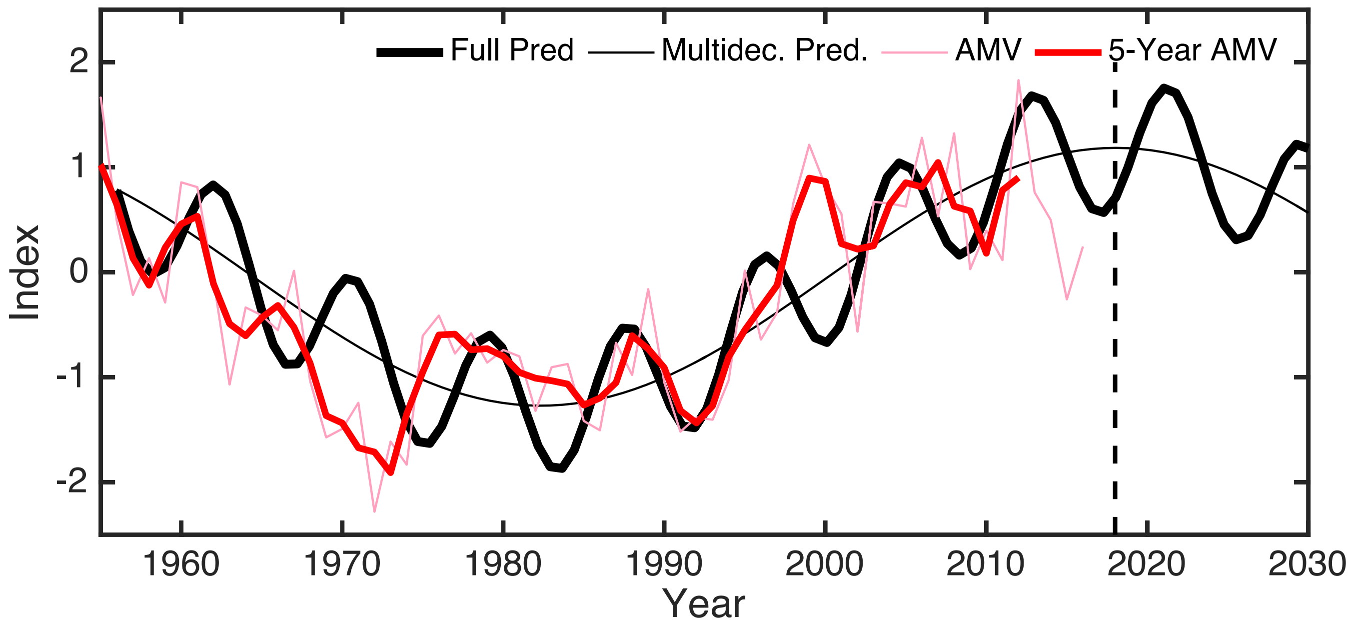






Zhang, R. (2008), Coherent surface-subsurface fingerprint of the Atlantic meridional overturning circulation, *GRL*

A prediction of AMV decline



$$\mathbf{AMV}(t) \approx -\alpha\, NAO_{QD}(t-\tau_1) + \beta\, NAO_{MD}(t-\tau_2),$$

Identification of a quasi-decadal oscillatory relationship between NAO and AMV and a long-lead relationship on multi-decadal timescales allows statistical prediction of the AMV allow for prediction of near-future AMV

We note that the quasi-decadal variability has an amplitude of half the multi-decadal variability

The AMV will begin its decline in 2018

Conclusions

- We identify quasi-decadal oscillatory variations in Atlantic SST associated with NAO air-sea heat flux forcing
- This relationship breaks down on multi-decadal timescales but the relationship between the NAO and GSNW remains
- Changes are ongoing in the Gulf Stream that are indicative of a shift towards a weakening AMOC
- Together, this allows us to predict an impending negative AMV, with large quasi-decadal variations superimposed

The Blue-Action project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727852