Is the Atlantic Multidecadal Variability forced by weather noise or ocean dynamics?

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1. Background and Problem of Study

Changes in North Atlantic sea surface temperatures (SSTs) on decadal time scales (Atlantic Multidecadal Variability, AMV) are associated with marked climate anomalies worldwide. Numerous studies have investigated the role of ocean circulation and of coupled ocean-atmosphere interactions in driving the AMV. *Yet, there is no consensus as to whether the AMV is primarily modulated by oceanic or atmospheric processes.*

Using a model-based approach, the AMV is decomposed into the contributions of global and regional weather noise and of ocean dynamics

2. Methodology

Experimental Design

A 5-member ensemble of coupled historical (1870-1998) CCSM3 simulations, one of which, denoted as Historical1, is taken as the analog of a single realization of the observed climate system.

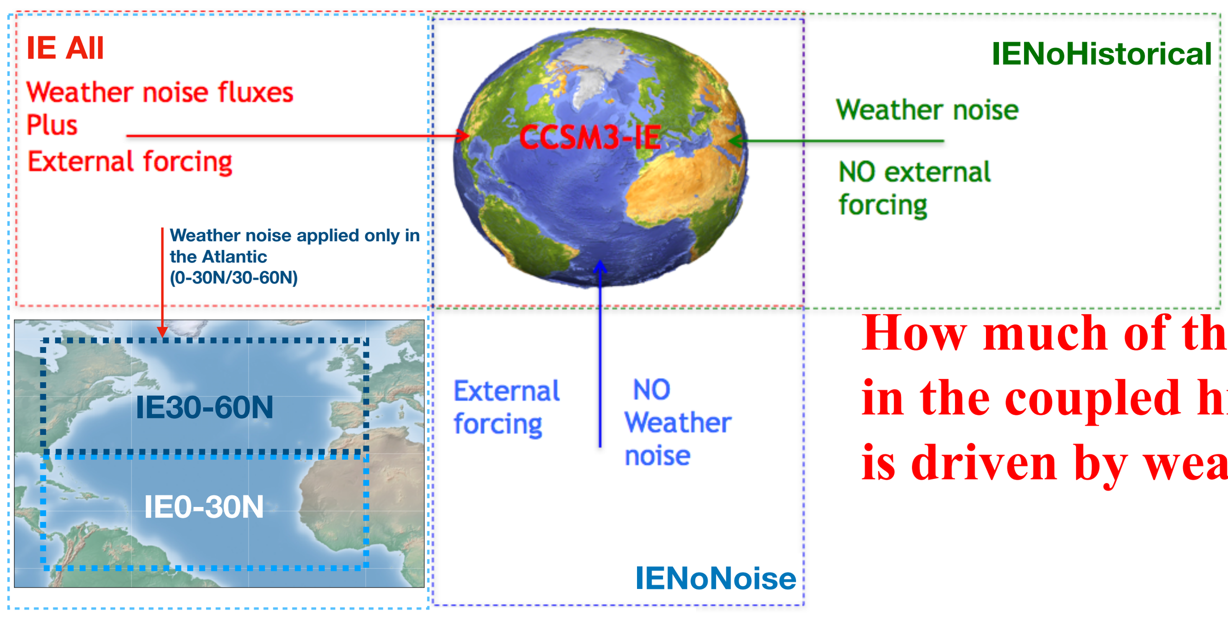
Any variable in Historical1, $T_{Historical1}$, can be decomposed as $T_{Historical1} = T^{Ext} + T^{Int}_{Historical1}$. The externally-forced component is taken as the ensemble mean of the simulations; the internally-generated component is the residual.

An atmospheric variable, $T^{Int}_{Historical1}$, is separated into the weather noise component, $T^{Int\ WeaNoise}_{Historical1}$ and that due to other sources of internal variability $T^{Int\ Other}_{Historical1}$.

$T^{Int\ WeaNoise}_{Historical1}$ is estimated as the difference between $T_{Historical1}$ and the mean of a 6-member ensemble of CAM3 atmospheric-only historical simulations forced by the Historical1 SST.

Historical1 weather noise surfaces fluxes (heat, wind stress, fresh water) are used to force the Interactive Ensemble (IE).

Interactive Ensemble Experiments



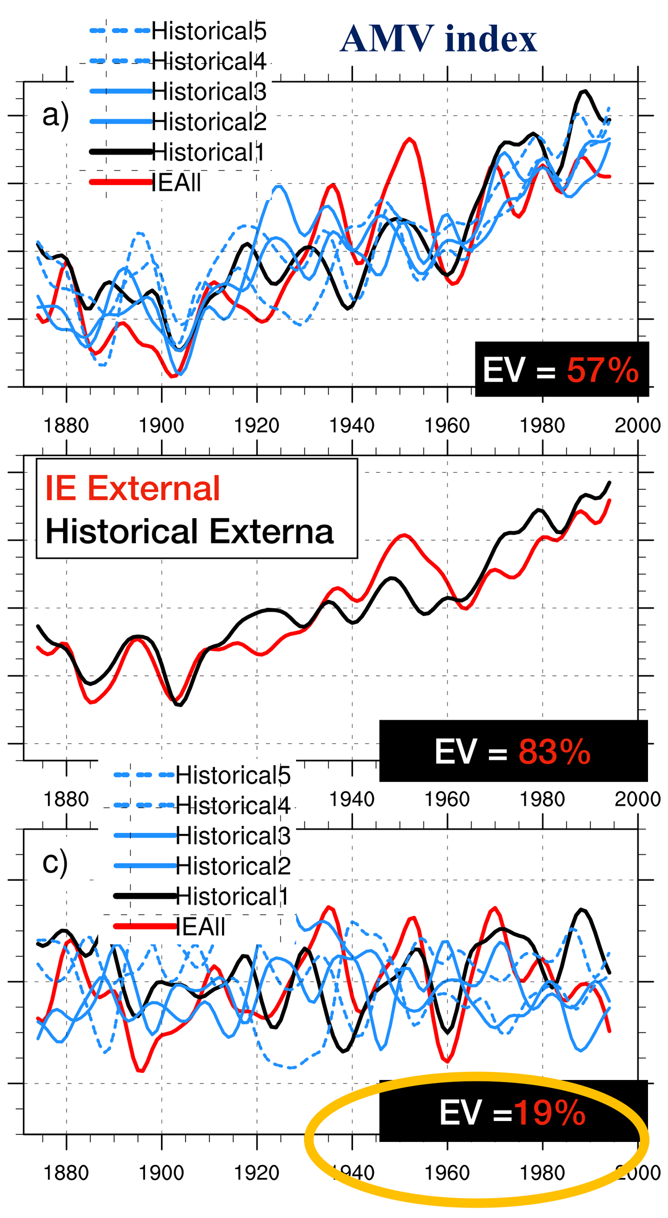
How much of the AMV variability in the coupled historical simulation is driven by weather noise?

AMV Definition

- The AMV is defined as the annual mean SST averaged over North Atlantic between 0º - 60ºN and low-pass filtered at decadal scale Lanczos smoothing.
- The IE results are bias corrected. Reductions of the explained variance due to unphysical noise in the results due to the small sizes of the CGCM ensemble, SST forced AGCM ensemble, and IE AGCM ensemble are estimated and removed.

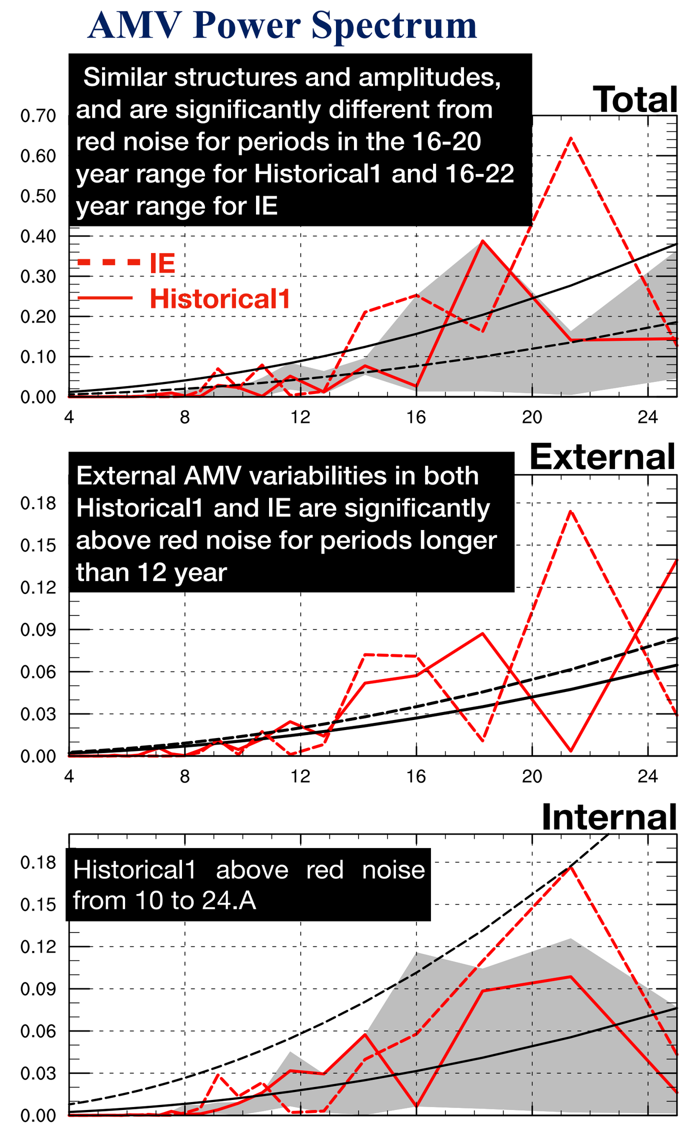
3. Results: AMV index and Pattern Decomposition

AMV index

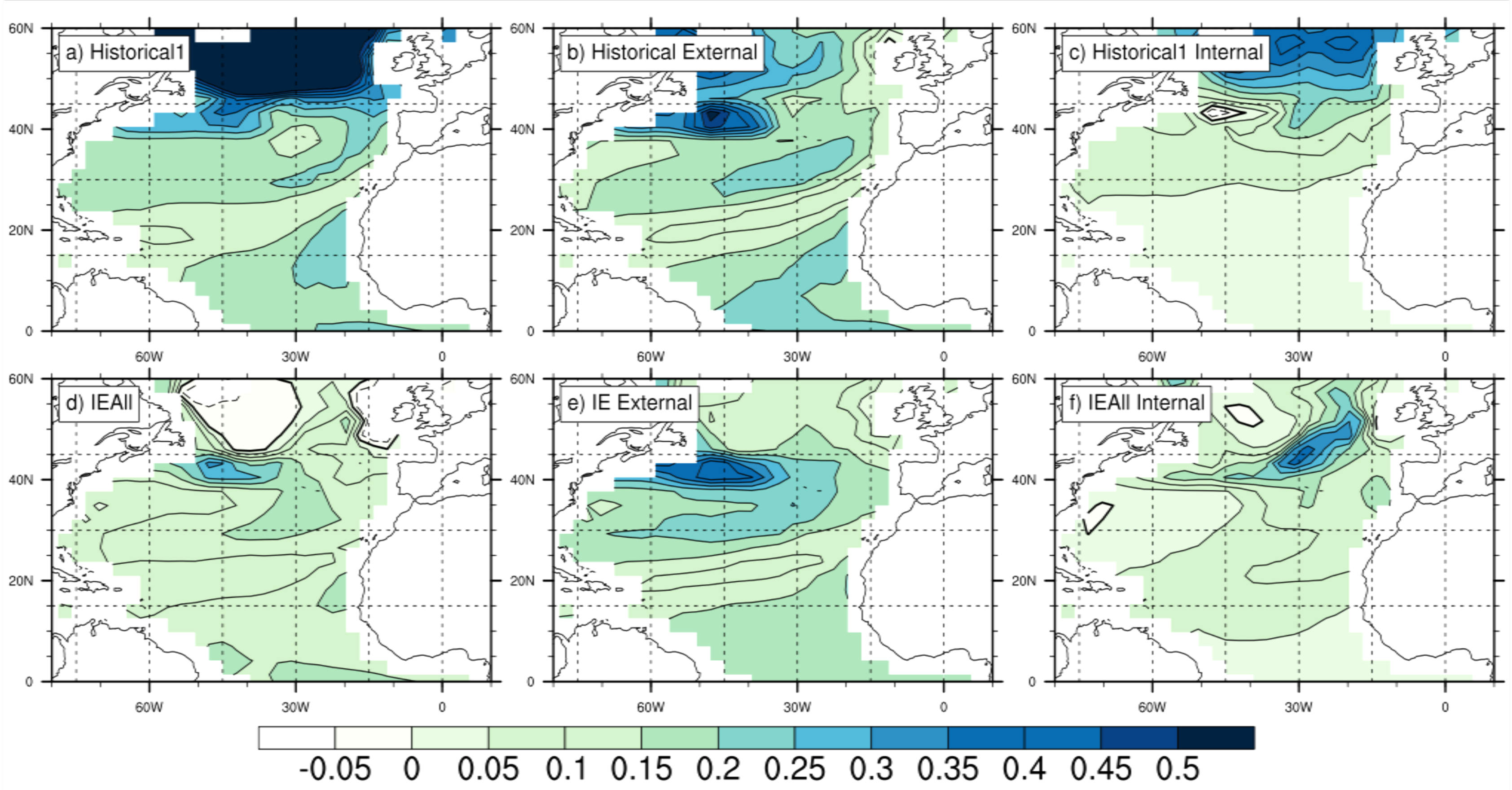


- The Explained variance(EV) is used as the main metric for comparison of Historical1 with IE simulations and IE simulations with each other.

AMV Power Spectrum



AMV Pattern (SST regressions on the AMV index)



- Similar patterns between the IE and Historical with single signed positive anomalies throughout the North Atlantic associated with a positive AMV index
- Differences between Historical1 and IEAll AMV structures in the north hint to the importance of ocean dynamical processes not involving weather noise forcing

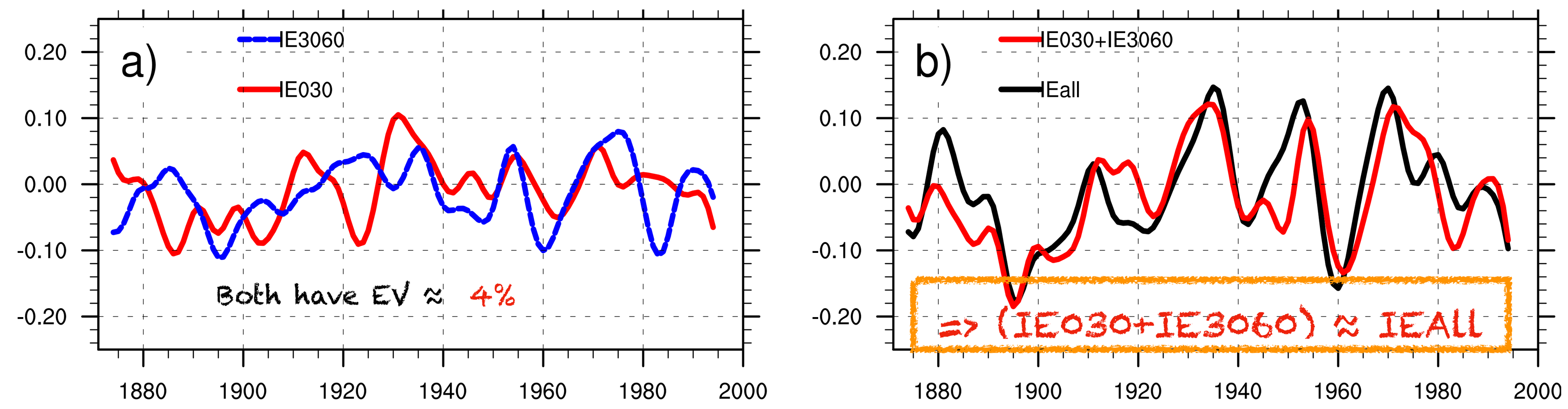
4. Results: Regional weather noise forcing

- Historical1 related mostly (highest correlations) to regional simulations (0-30N and 30-60N) followed by correlations to Historical1 total and IE.
- Internal AMV in IEAll can be explained by the combined responses to independent weather noise forcing in the southern and northern parts of the North Atlantic. Their mutual explained variance is 4%.
- Although weather noise structures can physically connect the weather noise of the two regions (Colfescu and Schneider 2017), the small explained variance indicates this does not seem to be important as far as the internal AMV.

AMV Indices Correlations

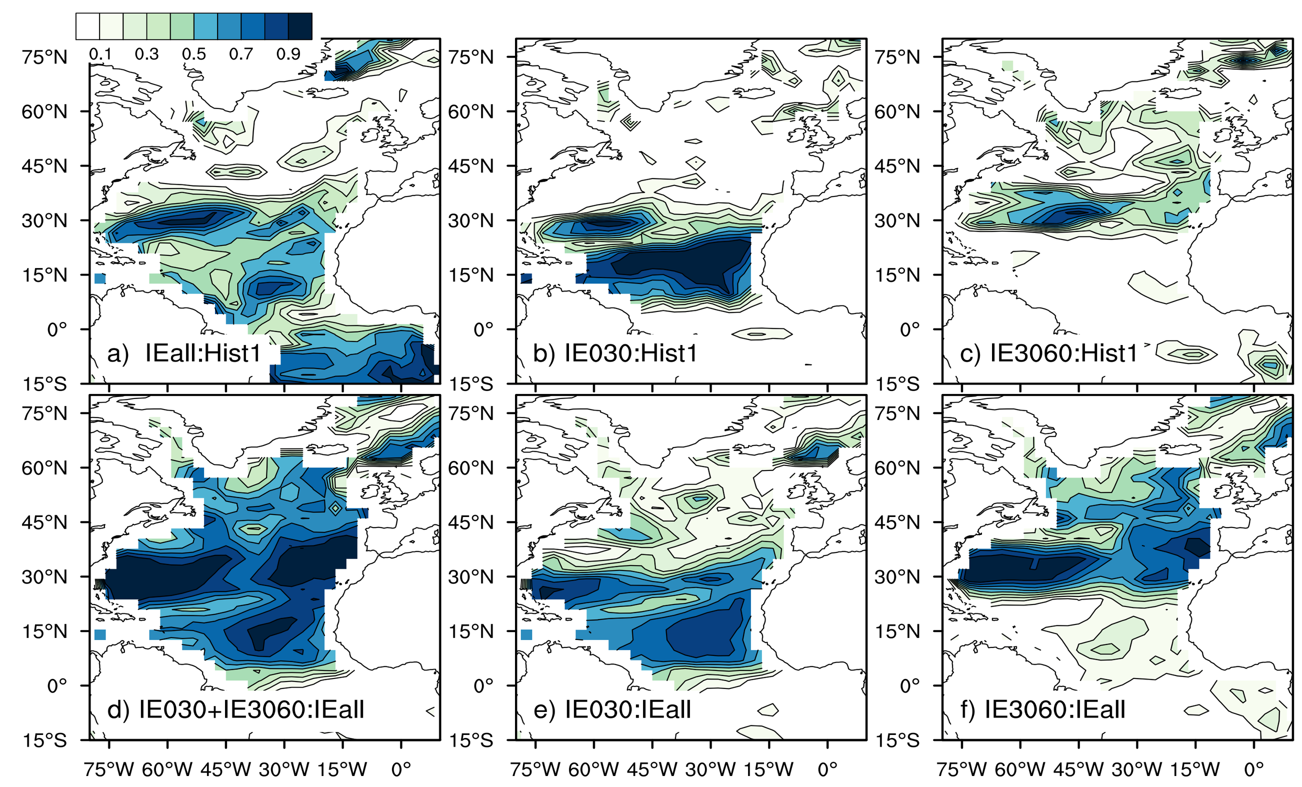
	Historical1	Historical1 Internal	IEAll	IE External	IEAll Internal	IE 0-30N	IE 30-60N	IE 30-60N Internal	IE 0-30N Internal
Historical1	1	0.3	0.73	0.66	0.04	0.67	0.76	0.04	0.04
Historical1 Internal	0.3	1	0.22	0.09	0.1	0.14	0.17	0.08	0.05
IEAll	0.73	0.22	1	0.63	0.22	0.77	0.76	0.06	0.14
IE External	0.66	0.09	0.63	1	0.03	0.83	0.83	0.02	0
IEAll Internal	0.04	0.1	0.22	0.03	1	0.01	0.01	0.38	0.38
IE 0-30N	0.67	0.14	0.77	0.83	0.01	1	0.75	0	0.17
IE 30-60N	0.76	0.17	0.76	0.83	0.01	0.75	1	0.07	0.01
IE 30-60N Internal	0.04	0.08	0.06	0.02	0.38	0	0.07	1	0.05
IE 0-30N Internal	0.04	0.05	0.14	0	0.38	0.17	0.01	0.05	1

Internal AMV in regional simulations

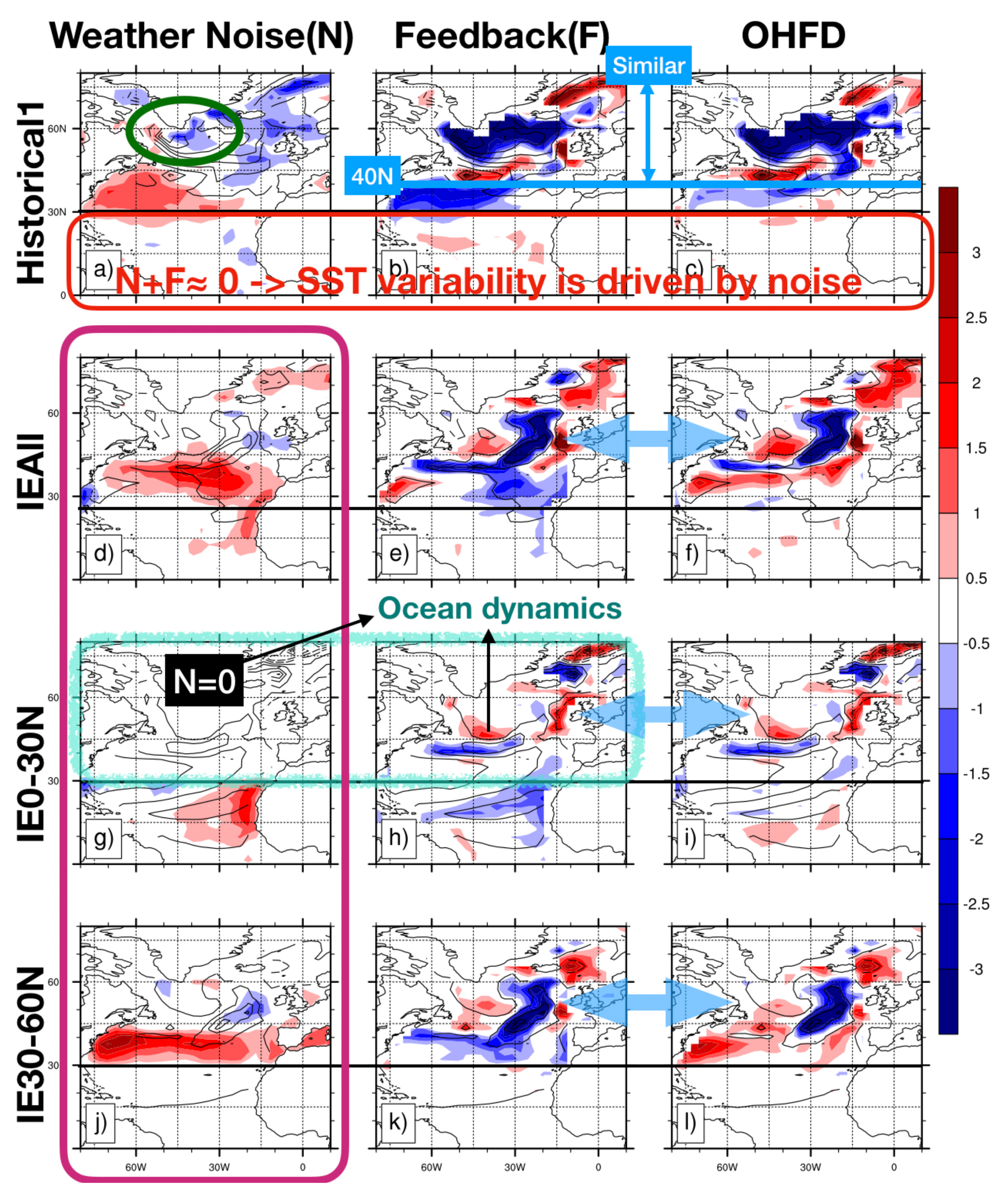


Ratio of explained variances of multidecadal and longer time scale internal variability

- Together, the two regional simulations account for the EV between IEAll and Historical1;the SST variability in the SPG is due to other processes than weather noise.
- In IEAll the weather noise forces more than 60% of the internal SST in the AMV region, including the SPG



5. Results: Regional Noise Ocean Dynamics in Simulated AMV



- F is locally strongly negatively correlated with SST anomalies
- South of about 30°N the SST variability is driven by N
- OHFD becomes the dominant forcing north of about 40°N, as F is similar to A
- N in Historical1 cools and opposes warming from the ocean circulation OHFD in the region of strong positive SST anomalies surrounding the southern tip of Greenland. SST is strongly forced by OHFD here.
- The results for the global and regional noise forcing IE simulations are consistent with a linear response to the regional noise forcing. Then OHFD is forced by the atmospheric noise with little contribution from other sources in those runs.

6. Conclusion

- **Weather noise forcing can explain about 19% of the variance of the internal AMV**
- **The weather noise heat flux provides the main forcing in the 0-30N region**
- **Between 30-50N, ocean dynamics is more important, but the ocean dynamics contribution is primarily weather noise forced**
- **Northern part variability of the AMV can be attributed mostly to ocean dynamics**

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