On the stochastic null hypothesis for Atlantic multidecadal variability

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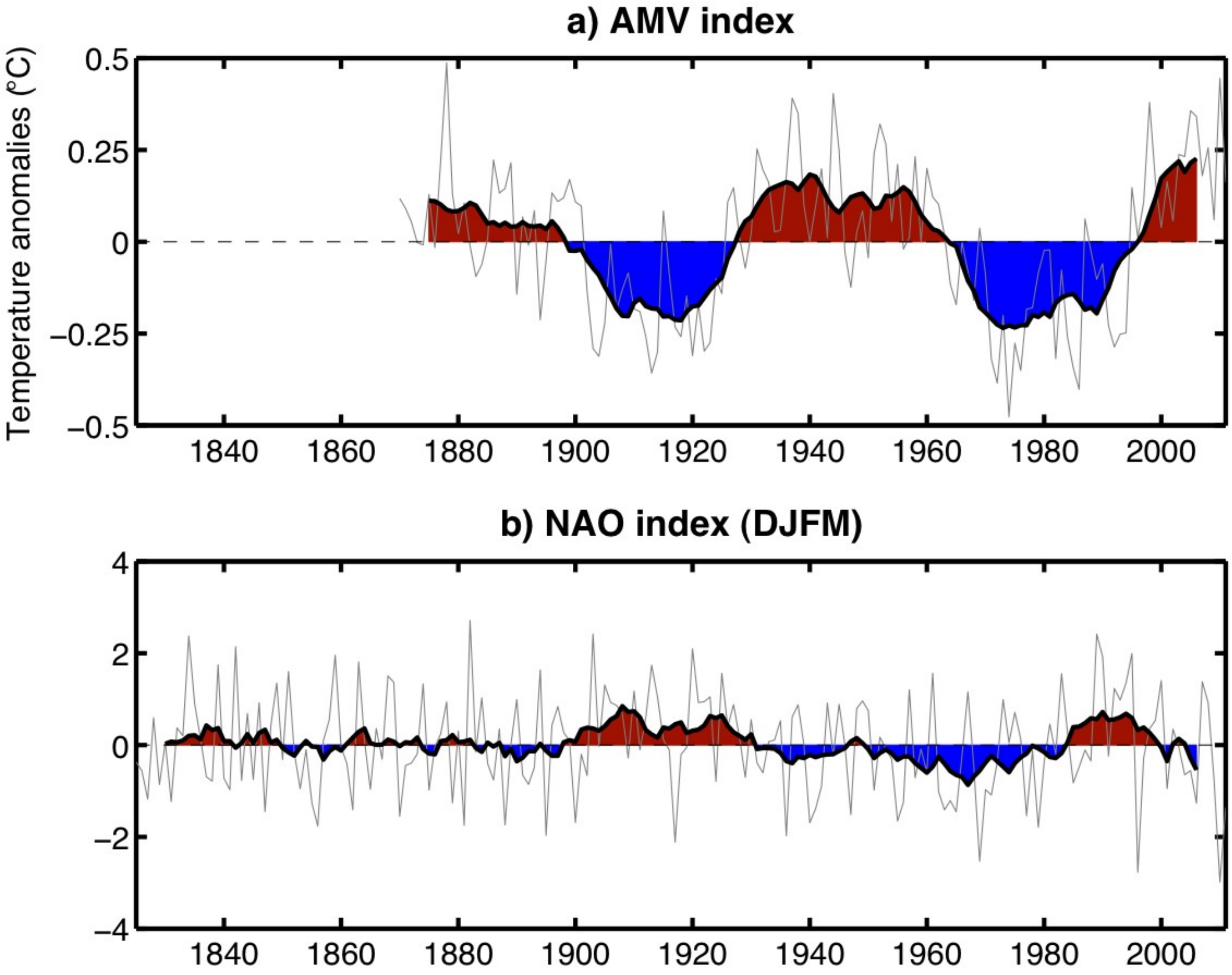
Motivation



Dynamical interest:

- Separate anthropogenic and natural variability
- Predictability

Questions?

- Can a stochastic, white noise NAO excite decadal to multidecadal ocean variability?
- How does North Atlantic ocean variability depend on the history of the NAO forcing?

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Strategy

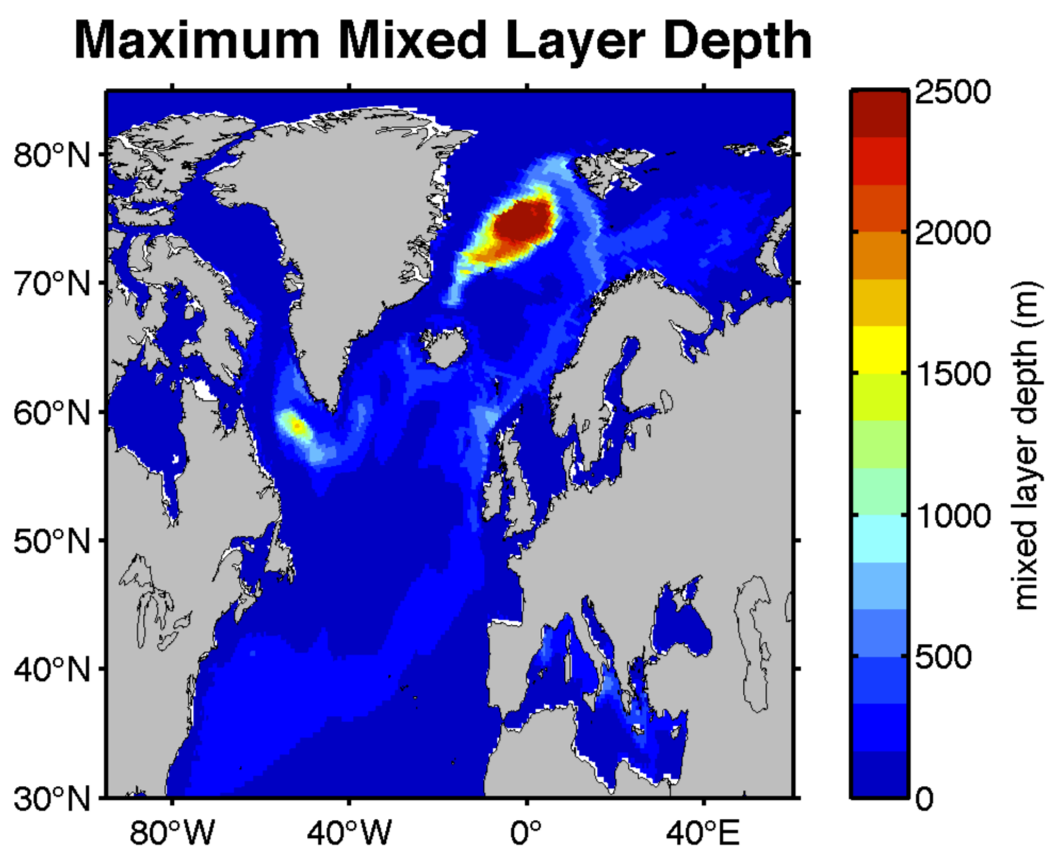
- ➔ Analyze ocean model integrations driven with the COREv2 forcing and forcing based on the NAO
- ➔ Analyze an ocean model integration forced with a white noise NAO – the stochastically-forced integration

Outline

- Model and experiments
- Stochastically-forced integration results
  - SPG Strength and AMOC
  - Reconstruction of AMOC index
    - ➔ Integrating the NAO
    - ➔ Auto-regressive processes
- Results

Ocean Model Description

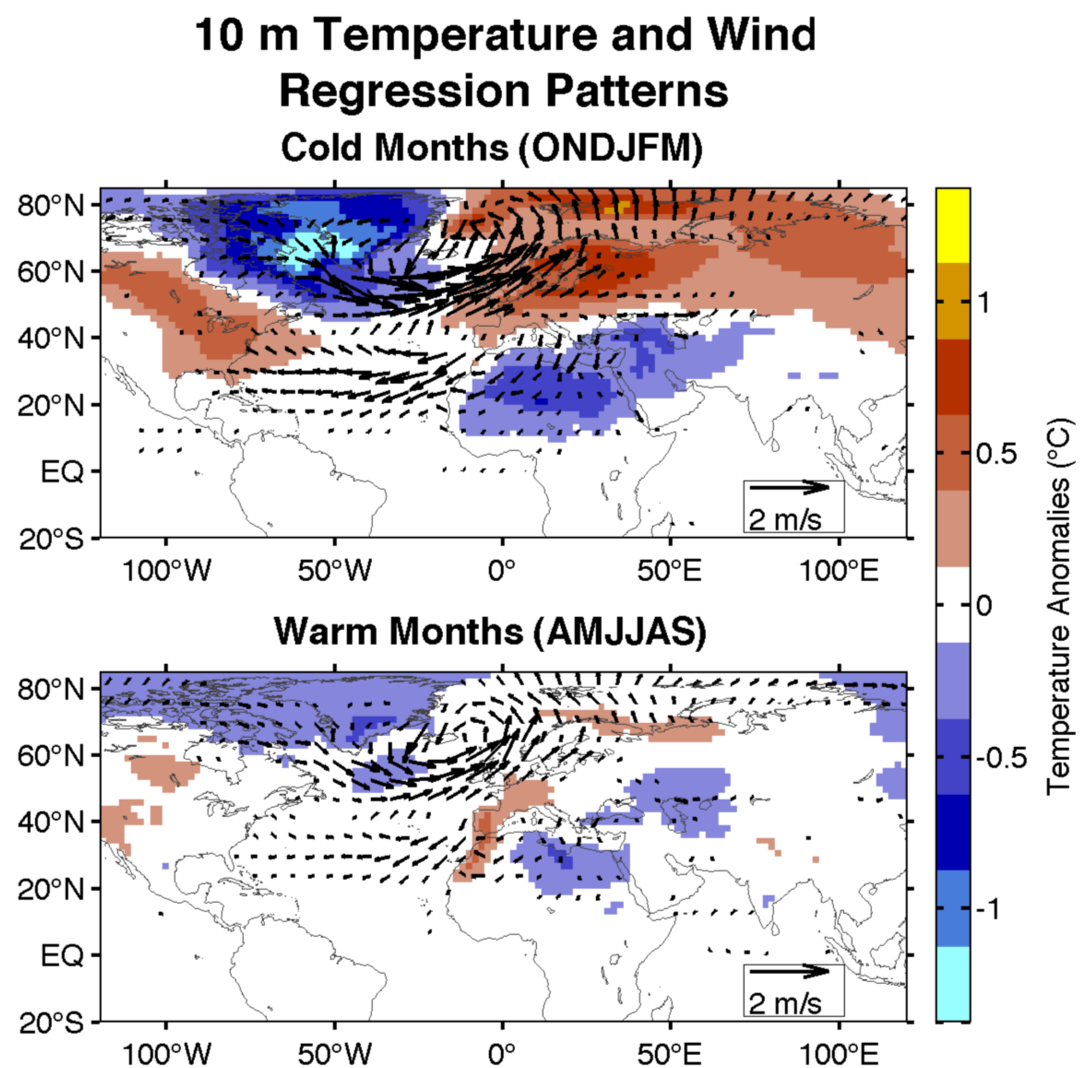
- NEMO 3.1, ORCA05, global domain with 0.5˚x0.5˚ horizontal resolution, 46 vertical levels, interactive sea-ice
- Atmospheric forcing: 10 m air temperature, 10 m winds, humidity, radiation and precipitation from COREv2,
  - fluxes computed by NEMO
- Salinity restored to Levitus with a time scale of 1/2 year



Experimental Setup

NAO forcing based Eden & Jung 2001:

- Regression of observed monthly NAO (Gibraltar – Iceland) onto COREv2 forcing data (1948-2006)
- NAO anomalies reconstructed for 1826-2010 then added to normal year forcing on a monthly basis
  - ➔ Strongest forcing during winter



Model Integrations

- Spin-up for 725 years using climatological forcing (normal year forcing) from COREv2

Model Integration	Short Name	Years	Description
Fully-Forced	FF	1948-2007	complete COREv2 forcing
NAO-Forced	NF	1826-2010	normal year forcing plus anomalies based on the observed NAO
Stochastically-Forced	SF	2000 years	normal year forcing plus anomalies from the stochastic NAO

- FF & NF: Integrated twice to avoid 'shocking' the system
- SF: first 150 years omitted from analysis

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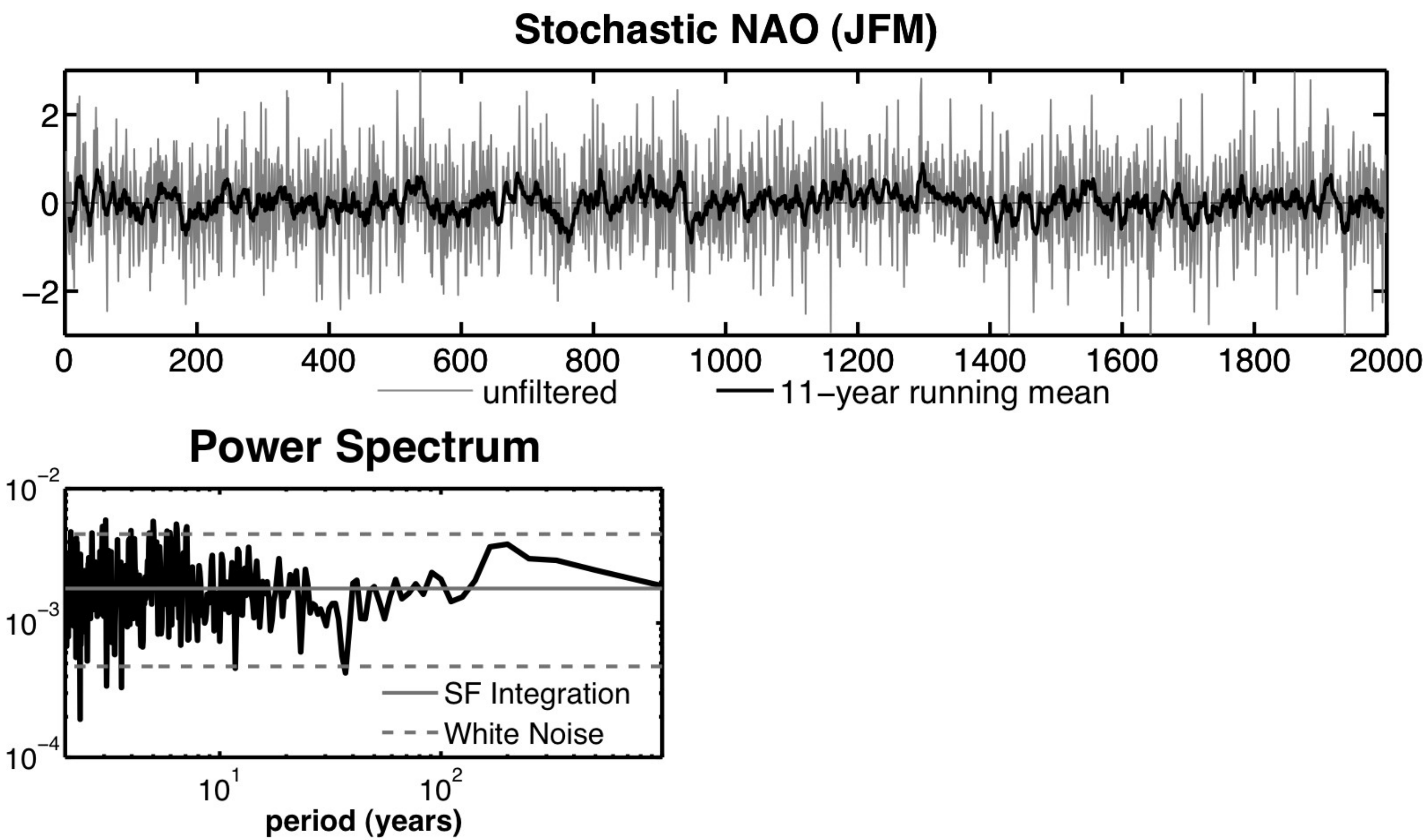
Stochastically-forced Integration



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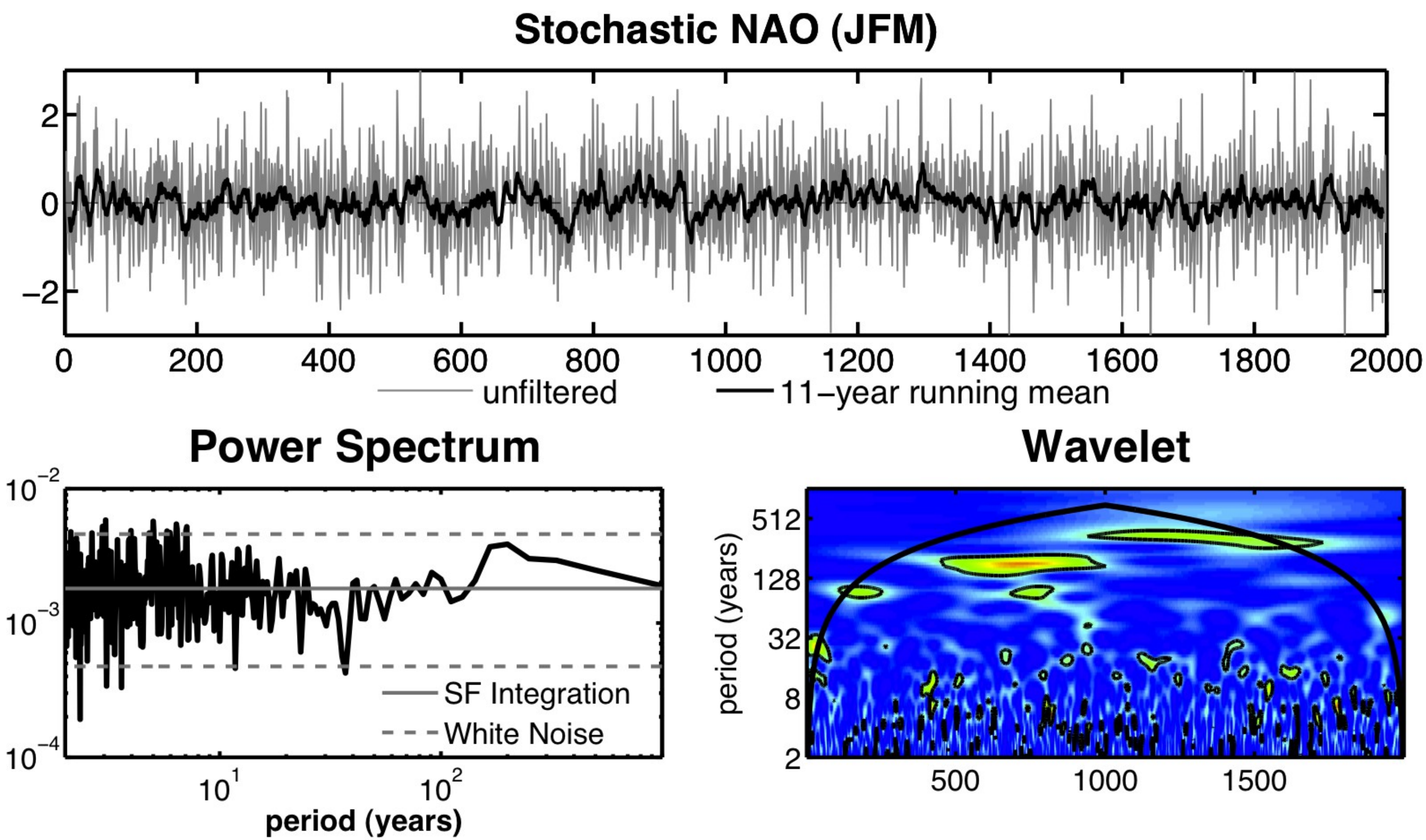
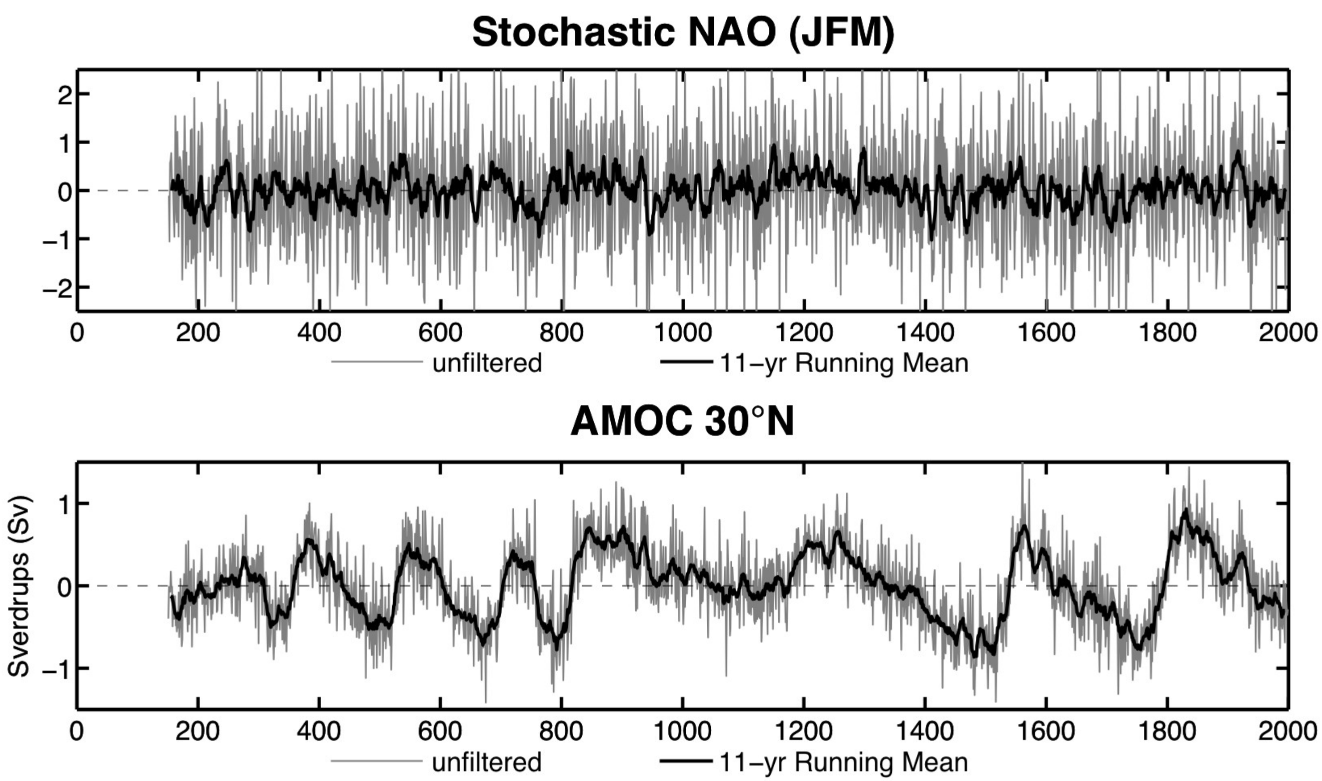
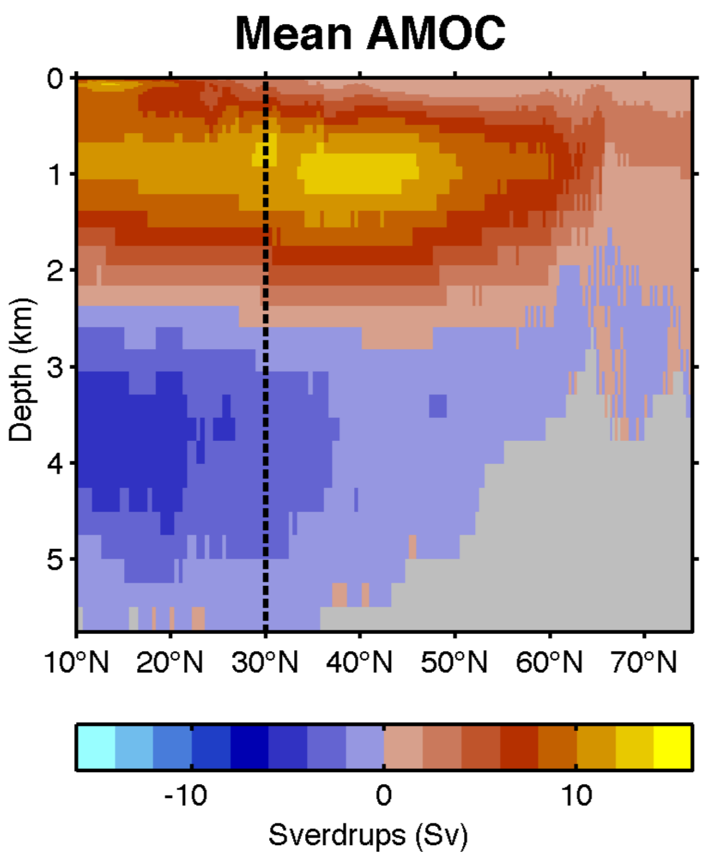
Stochastically-forced Integration



- Stochastic NAO is white-noise by construction
- The white-noise NAO index has some clear structure

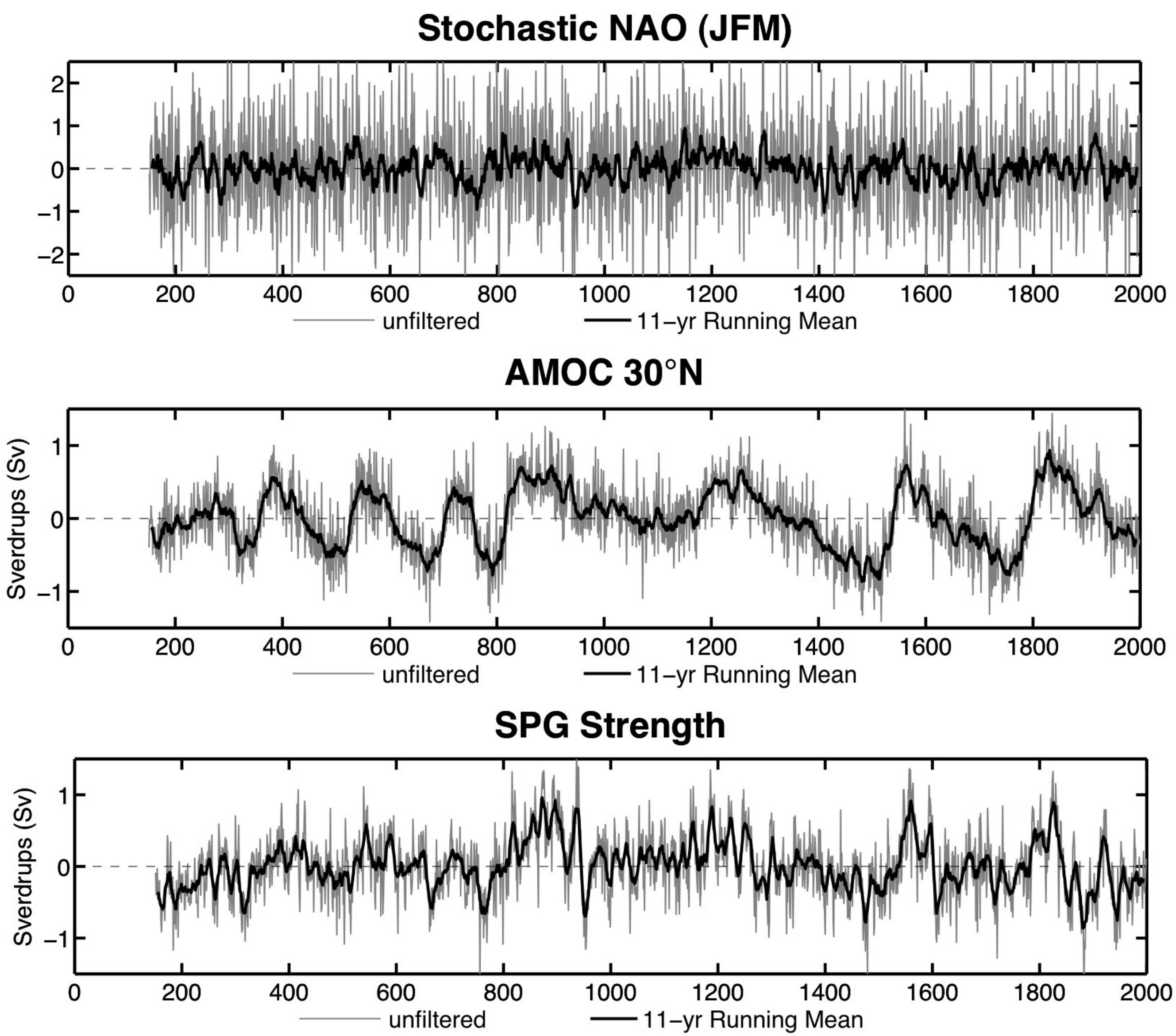
Stochastically-forced Results

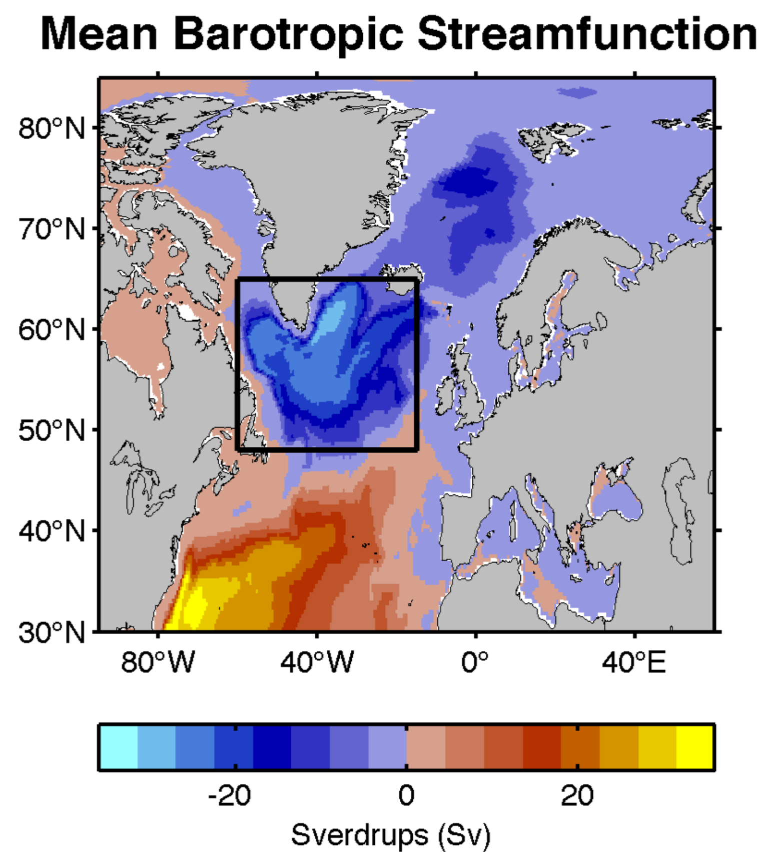




Atlantic Meridional Overturning Circulation (AMOC) 30°N: Maximum of annual mean Meridional Overturning Circulation at 30°N

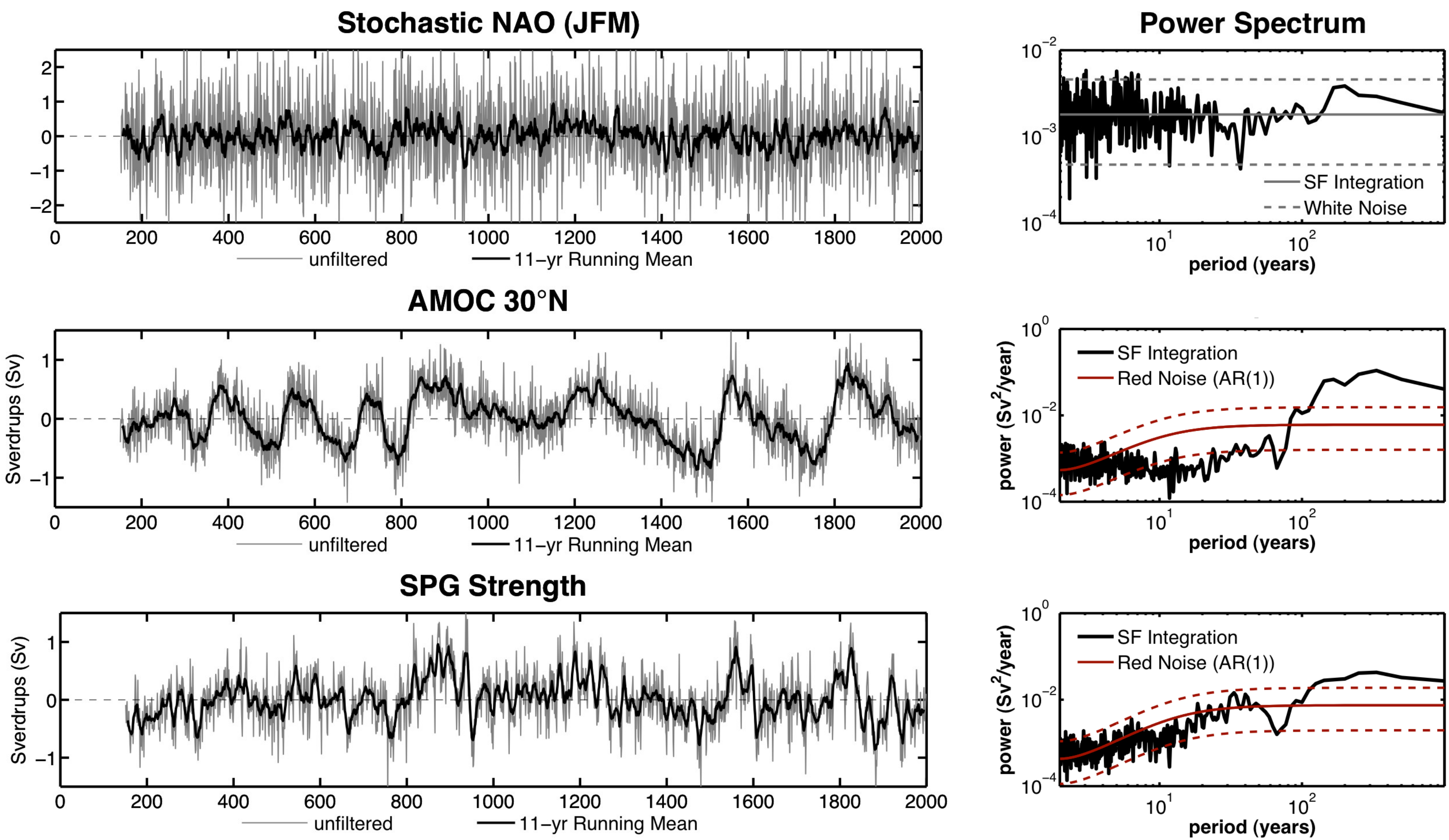
Stochastically-forced Results





Subpolar Gyre (SPG) Strength: Negative area average of annual mean barotropic streamfunction in the region 48° to 65°N, 60°W to 15°W

Stochastically-forced Results



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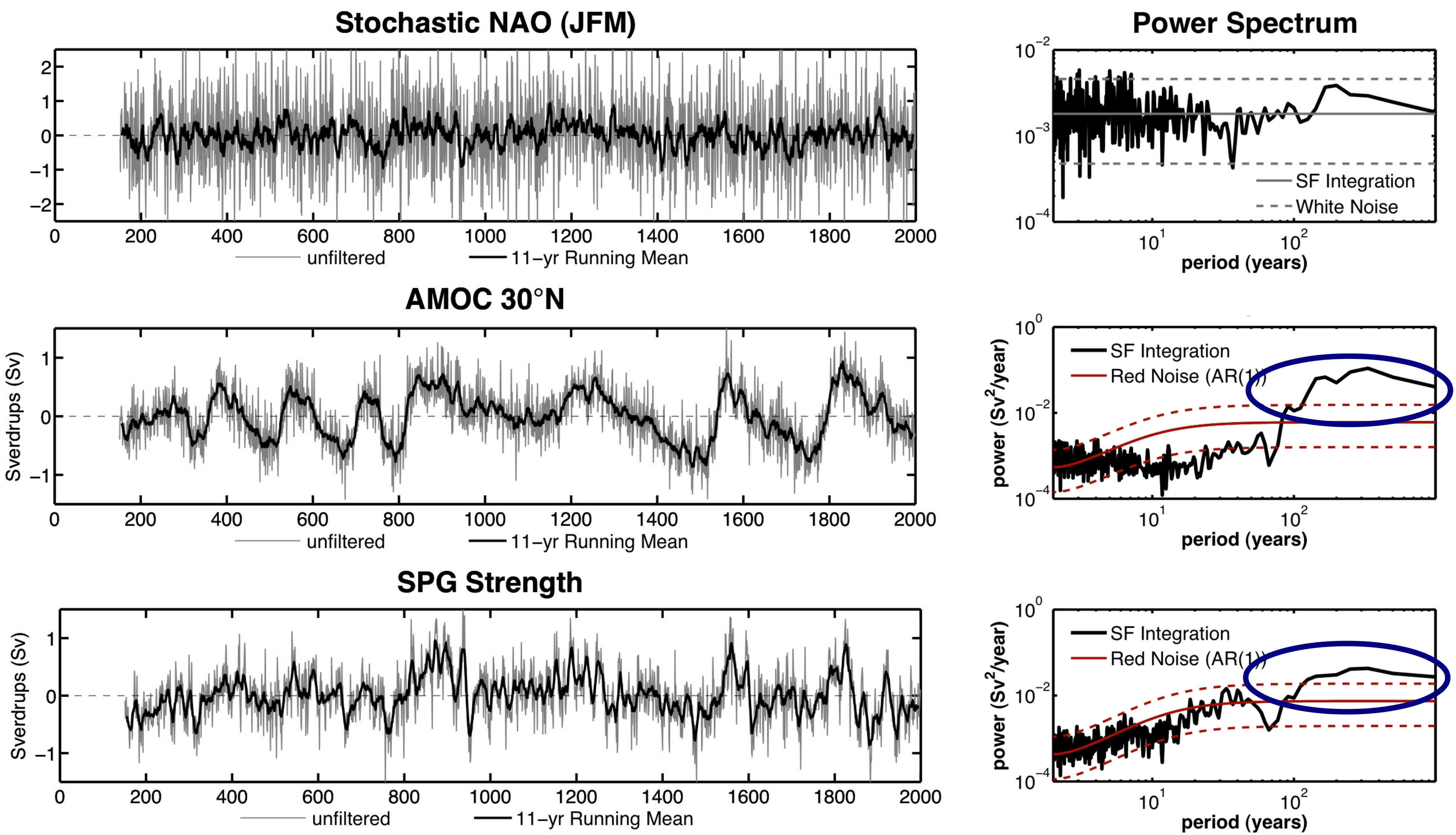

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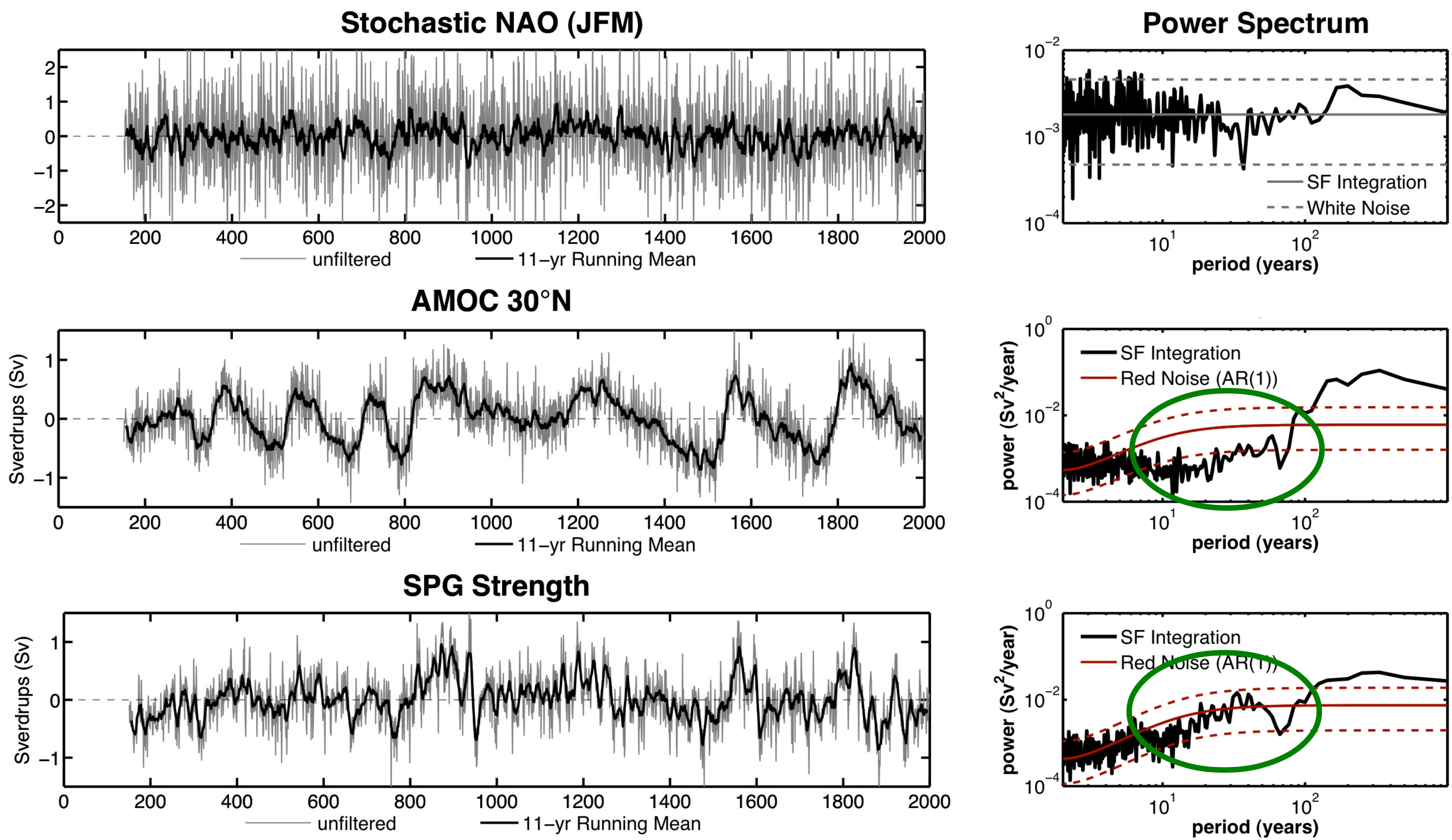

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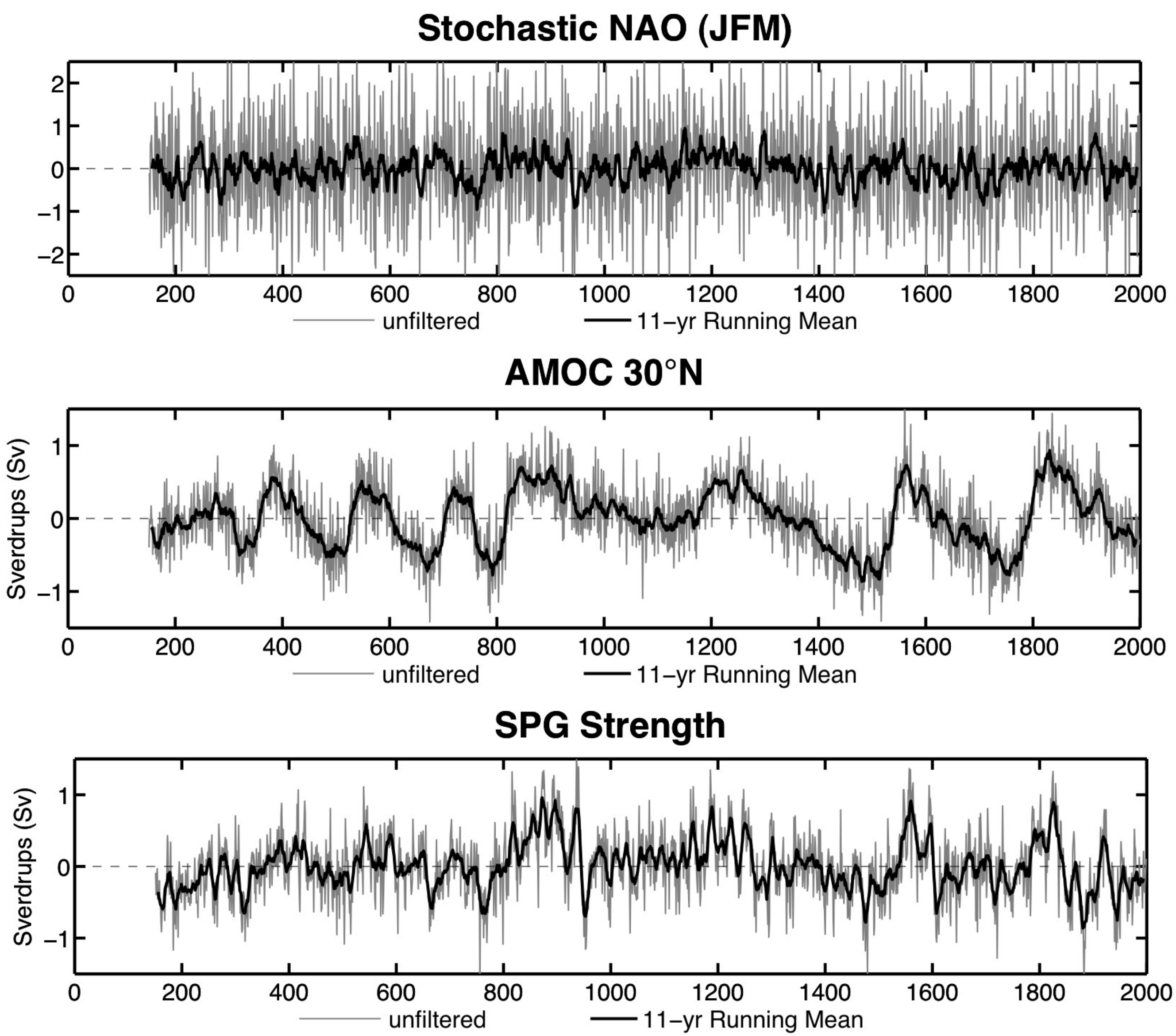

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- The AMOC at 30°N shows enhanced variability on timescales longer than approx. 86 years while the SPG strength has enhanced variability on timescales longer than approx. 15 years.

AMOC and the NAO

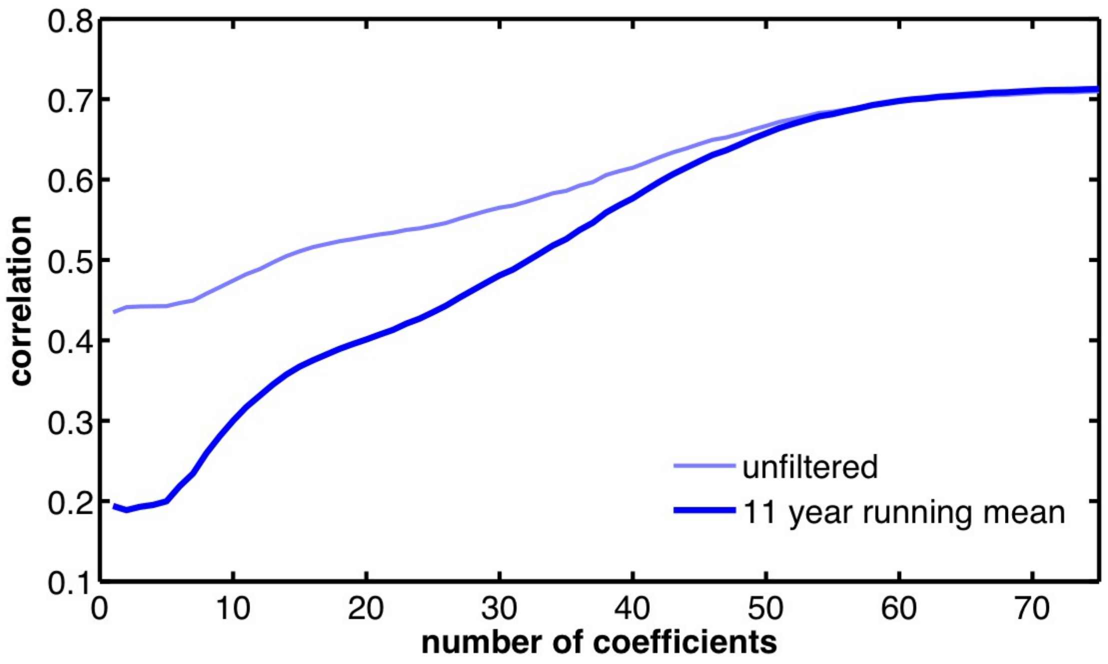
How does the AMOC at 30°N depend on the past history of the winter NAO?

Integrating the NAO

$$AMOC(t) = \alpha_0 + \sum_{k=1}^{q} \alpha_k NAO(t-k+1) + \xi(t)$$

- The α_k's are computed using linear regression

Correlation skill of integrated NAO with AMOC at 30°N



Integrating the NAO

$$AMOC(t) = \alpha_0 + \sum_{k=1}^{q} \alpha_k NAO(t-k+1) + \xi(t)$$

- The α_k's are computed using linear regression
- 53 coefficients required in our calculations
  - Implying an approx. 53 year adjustment time to the forcing

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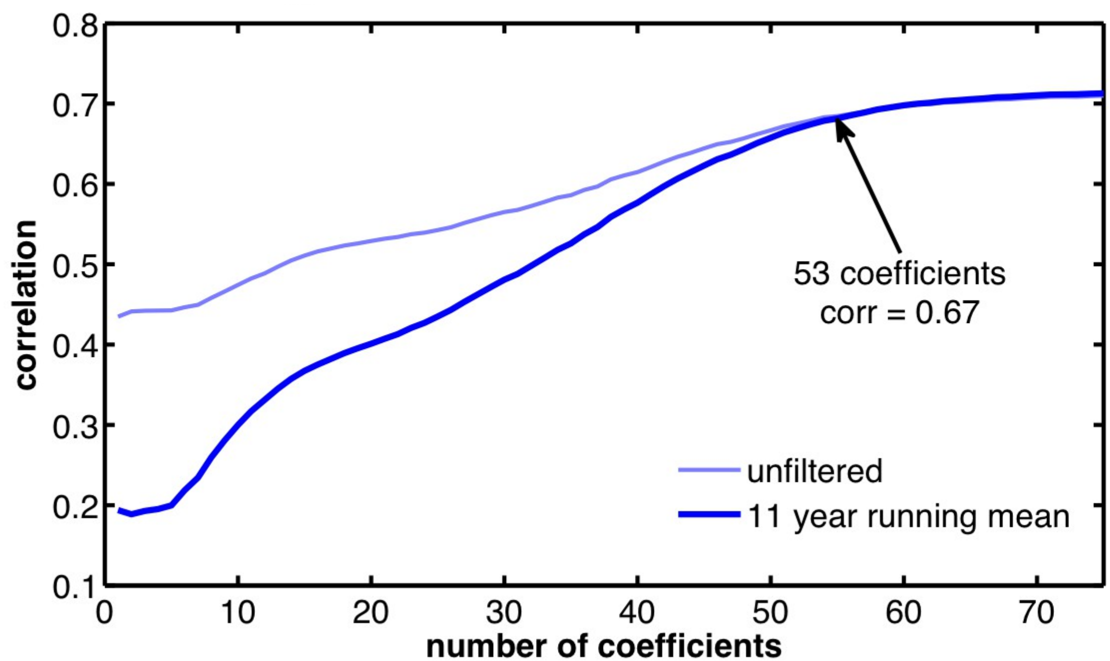

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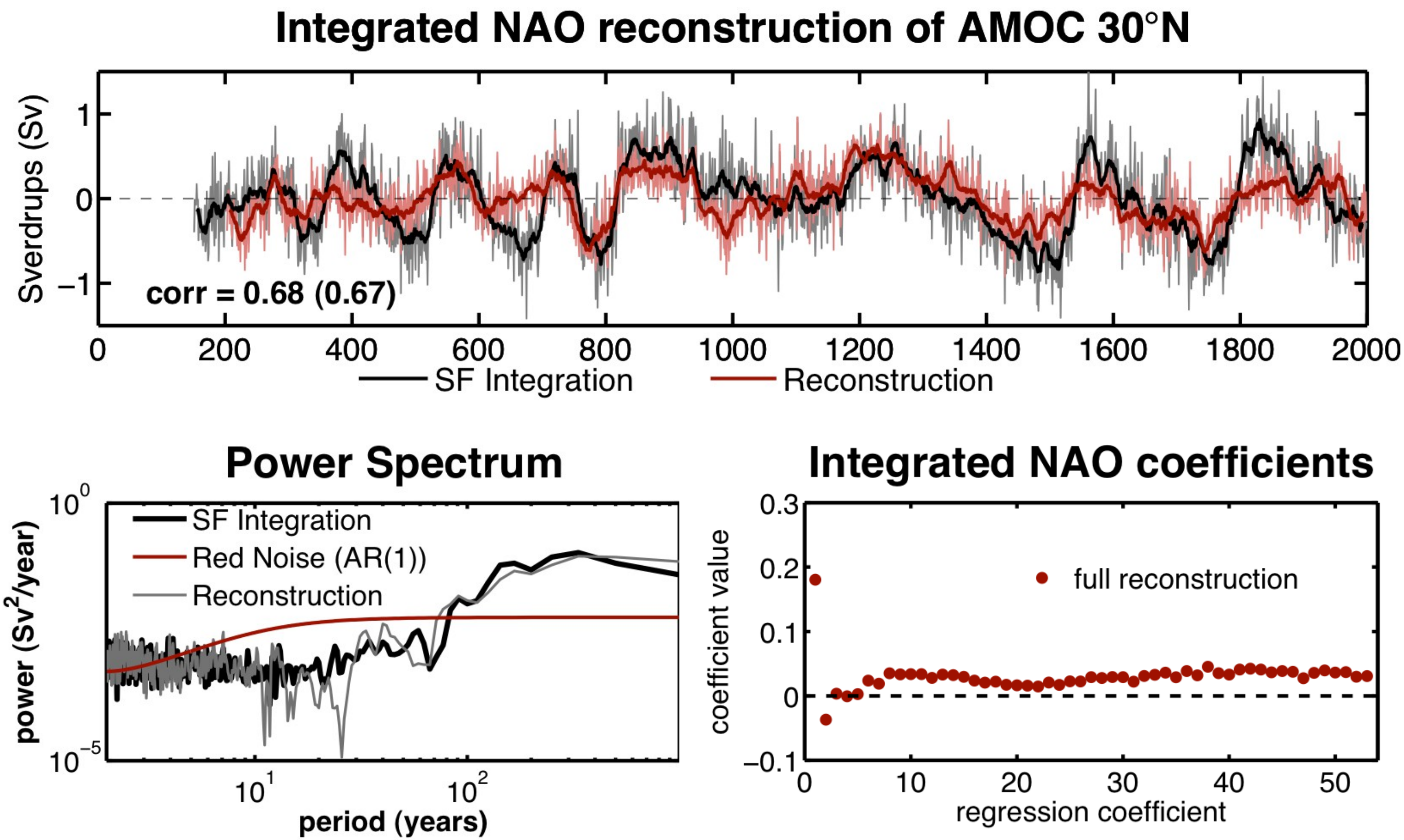
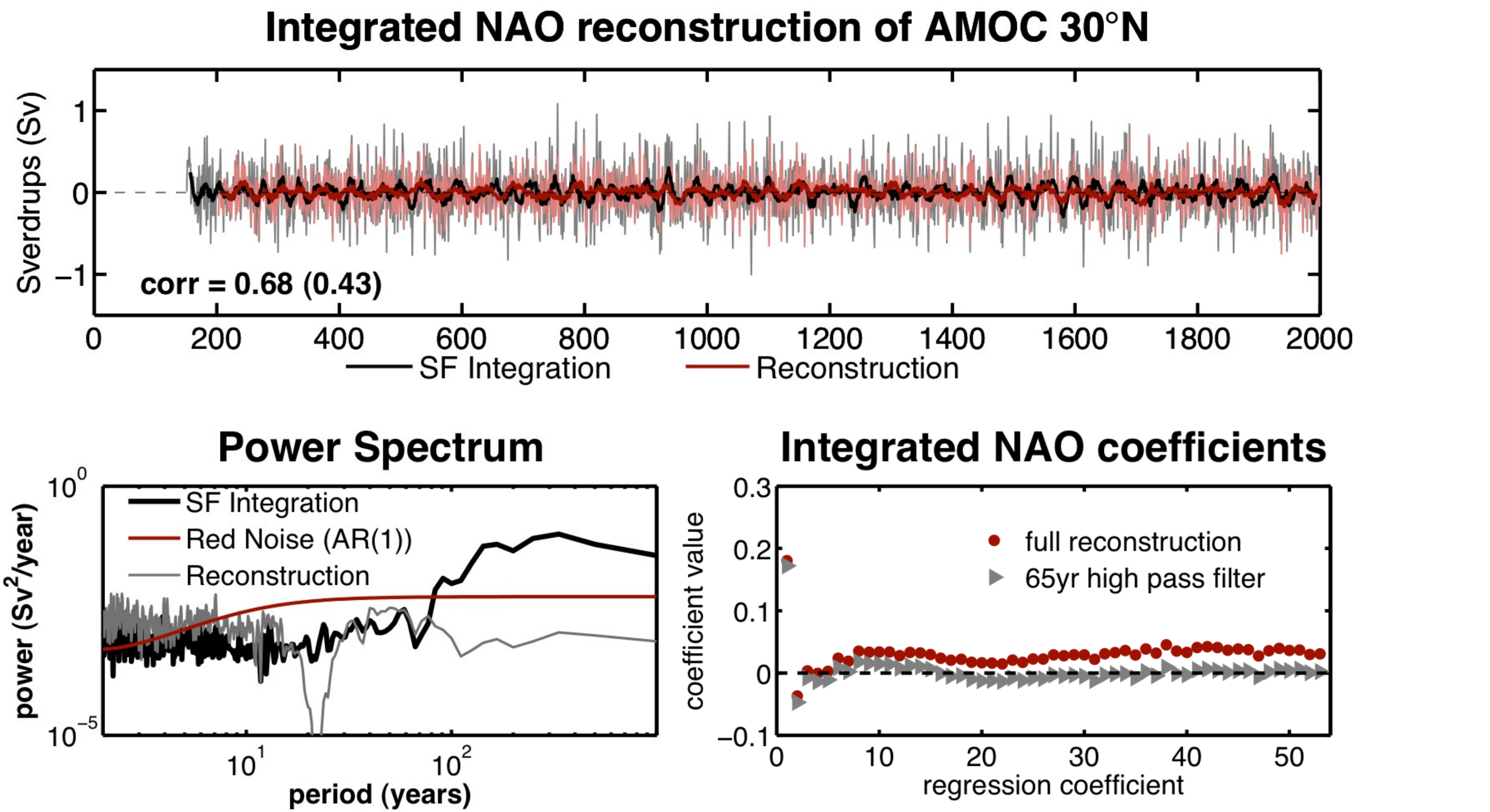


AMOC and Integrated NAO

15 year high-pass filtered



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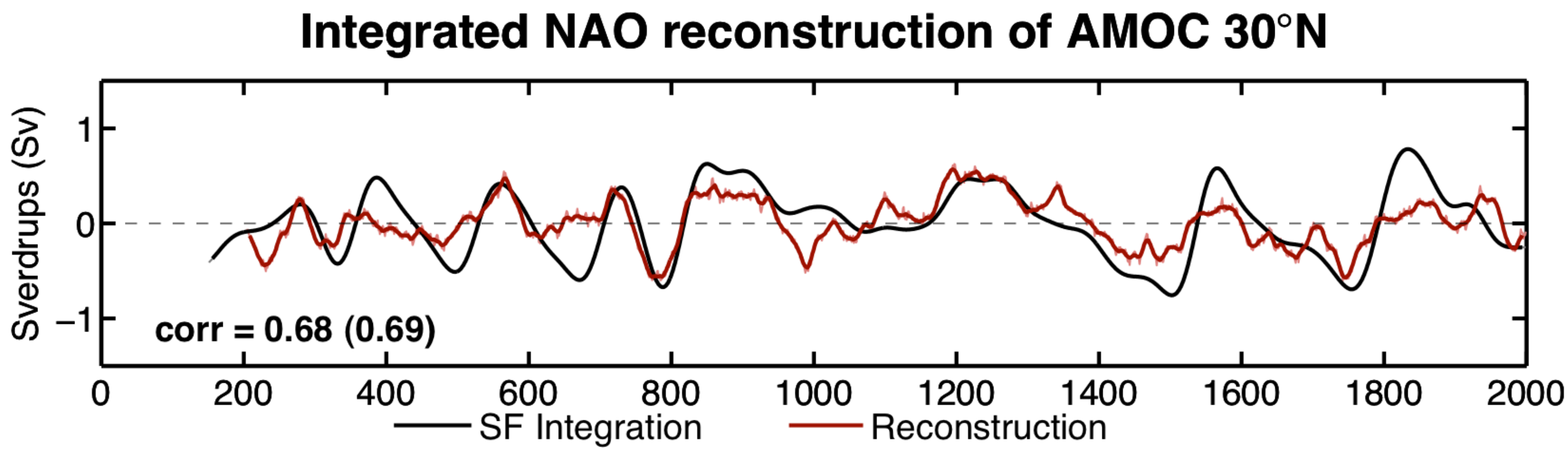
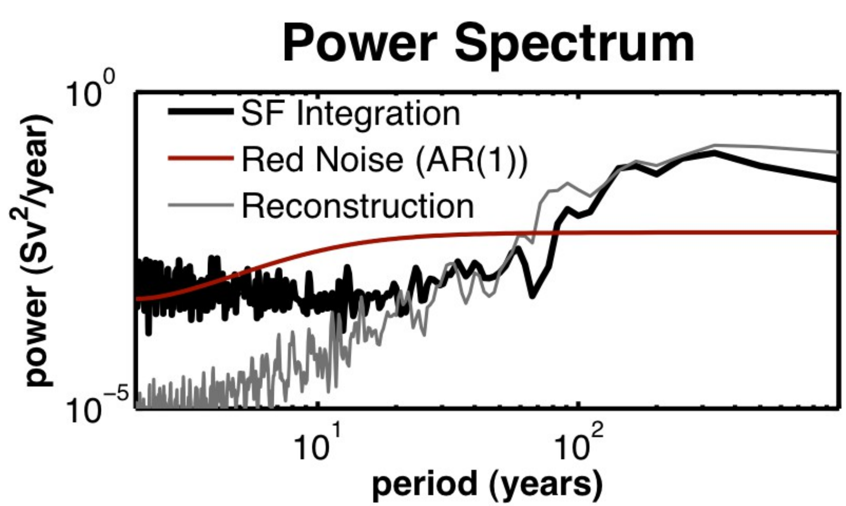
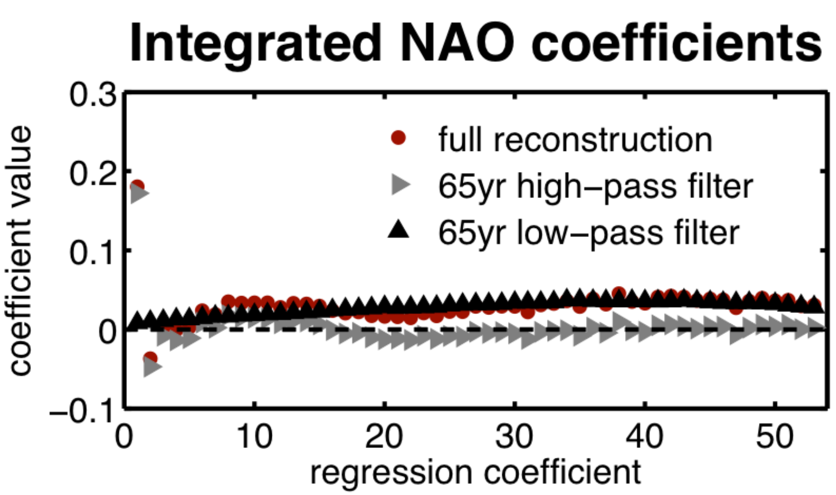






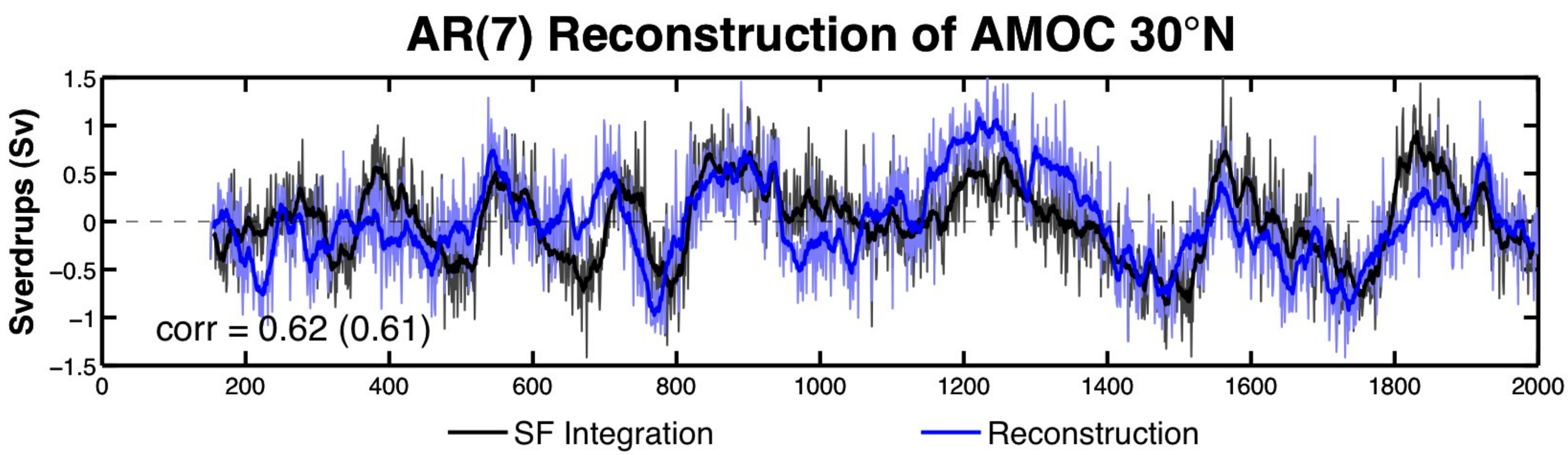
AR Representation of AMOC?

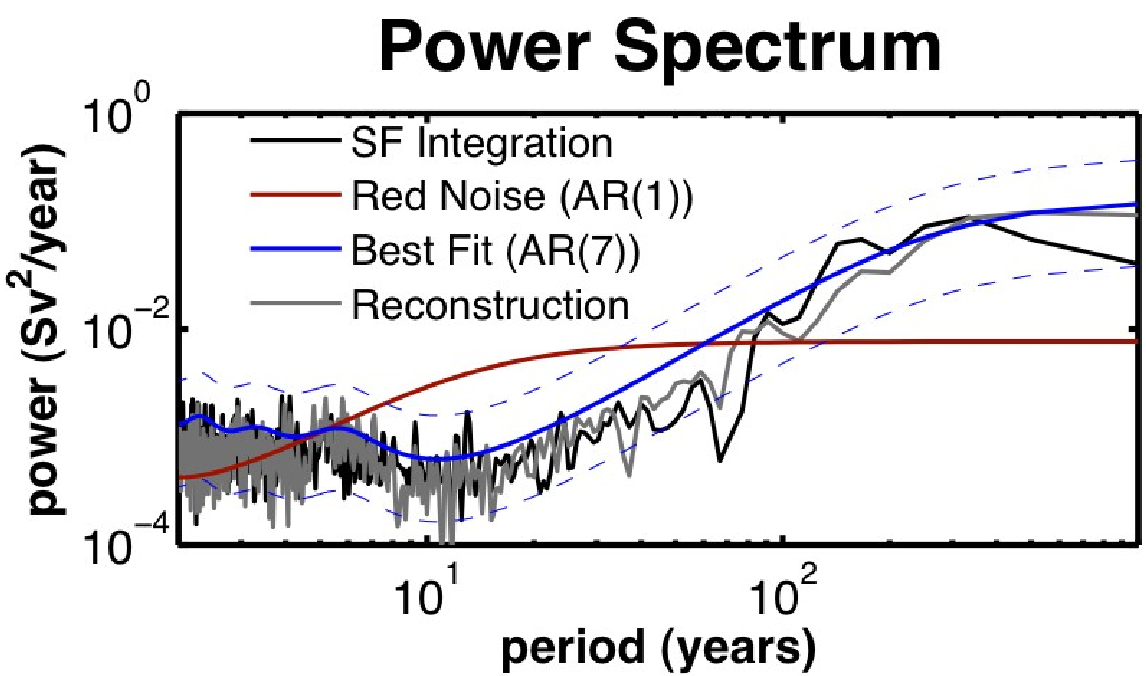
- Requiring 53 years of NAO data is not ideal for predictions!
- This suggests considering an AR process to reconstruct the AMOC

$$AMOC(t) = \sum_{h=1}^{p} \phi_h AMOC(t-h) + w(t)$$

- Coefficients, ϕ_h, are computed using the Yule-Walker equations

AR Representation of AMOC





- AR(7) reconstruction using winter NAO index is on par with the integrated NAO reconstruction

Results

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- The AMOC at 30°N (SPG Strength) does not satisfy an AR(1) process
  - ➔ Best fit for the AMOC at 30°N is an AR(7) process
  - ➔ Best fit for the SPG Strength is an AR(5) process