An investigation of the ocean’s role in Atlantic Multidecadal Variability

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2018 International AMOC Science Meeting
July 24, 2018 | Coconut Grove, FL
Motivations: AMV forcing mechanism

AMOC $\rightarrow$ AMV

AMOC drives AMV SSTA $\rightarrow$ ocean dynamics is a necessity

Atmospheric heating $\rightarrow$ AMV

Observations

Slab ocean models reproduce the observed AMV SSTA $\rightarrow$ ocean dynamics is **NOT** a necessity

Fig. 1 of Clement et al. (2015)

Models “disagree” on what drives AMV
Study Goal: Evaluate the role of ocean in AMV based on available observational records.

**EA** contributes to low frequency variability of AMV.
Approach: Mixed layer heat balance

\[ \frac{\partial T'_s}{\partial t} = -\tau^{-1} T'_s + N(0, \sigma^2) - \frac{Q_{\text{net}} h_m}{\rho_o C_p h_m^2} + Q'_{\text{ocean}} \]

Assumptions:
1) Atmospheric forcing is a normally distributed white noise.
2) MLD variability and ocean dynamics are neglected to isolate the contribution of atmospheric noise to AMV.

Define e-folding time: \[ \tau^{-1} = \frac{\alpha}{\rho_o C_p h_m} \]
Results from idealized red-noise model

\[ \frac{\partial T'_s}{\partial t} = -\tau^{-1} T'_s + N(0, \sigma^2) \]

\( \tau \): e-folding time (derived from ICOADS) \( \tau^{-1} = \frac{\alpha}{\rho_o C'_p h_m} \)

\( \sigma \): standard deviation of atmospheric heating (derived from 20CR and NCEP/NCAR dataset)

\( R^2 = 0.34 \) for \( \tau \), \( R^2 = 0.59 \) for \( \tau_{\alpha} \)
Observed vs. Modeled SSTA variability

Observed SSTA variability in the EA cannot be fully explained by the white noise of atmospheric forcing.
SSTA STD as a function of e-folding time & atmospheric forcing

![Graph showing SSTA STD as a function of e-folding time and atmospheric forcing. The graph includes contour lines and color gradients representing different values of TA and Obs. EASSTA STD parameters.](image-url)
Observed relationship b/w e-folding time & atmospheric forcing

\[ \tau = \frac{\rho_0 C_p h_m}{\alpha} \]

\[ \sigma = STD\left(\frac{Q'_{atmo}}{\rho_0 C_p h_m}\right) \]
Trade-off b/w e-folding time and atmospheric forcing and its implication for AMV SSTA

95% CI of observed parameters

TA parameter

EA parameter

Obs. EASSTA STD

Obs. TASSTA STD

K

0.2

0.3

0.30

0.25

0.20

0.15

0.10

0.05

Atmospheric forcing (σ, K/month)

e-folding time (DJF τ, months)
Ocean dynamics is needed for SSTA variability in the extratropical North Atlantic.
Conclusions

- The long persistence of AMV SSTA stems from the extratropics and is attributable to the deep MLD and weak damping.
- Atmospheric forcing can explain the SSTA variability in the tropical North Atlantic, but underestimates SSTA STD in the extratropics:
  - Red-noise model forced with observed atmospheric noise substantially explains 48% the SSTA STD in the extratropical North Atlantic.
  - the observed SSTA STD cannot be achieved with this model due to the trade-off between e-folding time and atmospheric heating rate.
  - Even with the inclusion of aerosol forcing and MLD variability, this 1-D model underestimates the SSTA variability in the extratropical North Atlantic.

Therefore, it appears that ocean dynamics is a necessity for AMV SSTA
THANK YOU!