Predictability of North Atlantic Ocean Heat Content

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Predictability of North Atlantic SST and ocean heat content

- North Atlantic is a region of high predictability of sea surface temperatures and ocean heat content, as seen by:
 - initialized predictions (e.g., Smith et al., 2007; Keenlyside et al. 2008; Yeager et al., 2012)
 - statistical estimates of predictability (e.g., Branstator et al., 2012; Branstator and Teng, 2012; DelSole et al., 2013)
- Degree of predictability varies substantially between models.
 - Branstator et al., 2012 find that predictability of upper ocean heat content varies widely amongst CMIP5 models, particularly in the North Atlantic.
 - DelSole et al., 2013 identify common predictable components in CMIP5 models.

This work: calculate statistical measures of predictability timescales from ocean data products and CMIP5 models.

- 1. What portion of geographic variations in predictability timescales can be explained by variations in climatological wintertime mixed layer depths?
- 2. How realistic are predictability timescales in CMIP5 models?

FOCUS OF THIS TALK: predictability timescales in gridded observational products and ocean reanalysis

(talk to me or see Fall 2016 NOAA webinar for discussion of CMIP5 models).

Predictability of ocean heat content

Measure of ocean heat content: heat contained in the layer between the surface and the maximum climatological (i.e., wintertime) mixed layer depth (D).

$$H = \rho_o C_p \int_{-D}^{\eta} T \, dz$$

- Layer of the ocean that interacts with the atmosphere seasonally.
- H covaries with SST on interannual timescales (Buckley et al., 2014).
- Meaningful heat budgets can be computed for this layer (Buckley et al., 2014, 2015).

Can geographic variations of predictability of H be related to variations in D, i.e., higher predictability where wintertime mixed layers are deeper?

Simple statistical measures of predictability

1) e-folding timescale: $ho_{ au}=e^{-| au|/ au_d}.$

 ρ_{τ} is the autocorrelation function (ACF)

2) Decorrelation time: $T_1 = \frac{1}{2} \int_{-\infty}^{\infty} \rho_{\tau} d\tau.$ (DelSole, 2001)

3)

Decorrelation time:
$$T_2 =$$
 (DelSole, 2001)

$$T_2 = \int_{-\infty}^{\infty} \rho_{\tau}^2 d\tau.$$

- $T_1 = T_2 = \tau_d$ for exponential decay.
- In other cases, the three measures may differ.



Estimating T_1 and T_2

Integrate temperature over D \rightarrow heat content (H)

IF HAVE LONG TIMESERIES (e.g., CMIP5 models)

- Calculate sample autocorrelation function (ρ_{τ}) at each gridpoint.
- Sum ρ_{τ} and ρ_{τ}^2 from lag 0 to lag τ_* to get T_1 and T_2 , respectively. $\tau_d <<\tau_* << t_1$ (t_1 is length of time series)

IF HAVE SHORT TIMESERIES (e.g., observationally-based products)

- The sample autocorrelation function will be noisy.
- Instead fit an autoregressive (AR) model at each gridpoint and use AR parameters to calculate theoretical autocorrelation function (ρ_{τ}^{*})
- Integrate ρ_{τ}^{*} and $(\rho_{\tau}^{*})^{2}$ to find T₁ and T₂, respectively.

Estimating T_1 and T_2

TODAY: Focus is on estimating T₁ and T₂ in two data-based products

- Ishii, gridded observational product (1945—2012)
- GFDL Ensemble Coupled Data Assimilation (ECDA v3.1, 1961-2012)

DETAILS:

- Restrict both to common period, 1961—2012.
- Use yearly averages of H

(results are similar for wintertime averages).

- Detrend prior to computing AR fits.
- Tried AR order 1—3 and found little sensitivity to AR order particularly for AR order greater than 2.
- Present results for AR2.

Maximum Climatological Mixed Layer Depth (D)



Predictability of H in Ishii



- Longest predictability timescales are in the subpolar gyre.
- T_1 and T_2 are very similar (periodic variability not playing a role).
- For all points in North Atlantic correlation between T_1 , T_2 is 0.98.

Ishii: Predictability of H in the North Atlantic



- ~60% of spatial variance of predictability timescales explained by variations in D.
- Slope of fit suggests a damping parameter ~30 W m⁻² K⁻¹ in accord with estimates in literature (e.g., Frankignoul, 1981).
- More outliers with higherthan-expected predictability (black points) than lowerthan-expected predictability (green points).

Outliers: predictability timescale not explained by D



- Most outliers are in the subpolar gyre.
- Most outliers have higher-than-expected predictability.
- Large region higher-than-expected predictability just south of very deep D.

Predictability of H in ECDA v3.1



- Longest predictability timescales are in the subpolar gyre.
- T_1 and T_2 are very similar (periodic variability not playing a role).
- For all points in North Atlantic correlation between T_1 and T_2 is 0.98.

ECDA: Predictability of H in North Atlantic



- ~70% of spatial variance of predictability timescales explained by variations in D.
- Slope of fit suggests a damping parameter ~20 W m⁻² K⁻¹ in accord with estimates in literature (e.g., Frankignoul, 1981).
- More outliers with higherthan-expected predictability (black points) than lowerthan-expected. predictability (green points).

Outliers: predictability timescale not explained by D



- Most outliers are in the subpolar gyre.
- Most outliers have higher-than-expected predictability.
- In regions with large gradients in D, predictability doesn't follow local D.

Conclusions & Future Work

- Introduced diagnostic H: heat content in the layer between the surface and the climatological wintertime mixed layer depth.
- H is a useful diagnostic to estimate ocean predictability.
- Used gridded observational products (e.g. Ishii) and ocean reanalyses (e.g. ECDA) to estimate 2 statistical measures of predictability of H: T₁ and T₂.
- Predictability timescales are longest in the subpolar gyre.
- T₁≈ T₂, suggesting periodic variability does not play a role, at least on the timescales that can be resolved by our data-products (1961-2012).
- Predictability timescales are related to the wintertime mixed layer depth, D.
- ~60-70% of spatial variations in T₁, T₂ can be explained by variations in D.
 FUTURE WORK
- Apply to other gridded observational products and ocean reanalysis.
- Work to better understand regions of high predictability, where H does not follow D.
- Compare to CMIP5 models to access their realism.