Predictability of North Atlantic SST and Ocean Heat Content from Observations

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Motivation

- North Atlantic sea surface temperature (SST) has impacts on climate.
- North Atlantic is a region of high initial value predictability for SST and upper ocean heat content.
- Models differ substantially on degree of predictability in North Atlantic.

Objective

Estimate predictability of North Atlantic SST and upper ocean heat content purely from observations.

Diagnostics for SST and upper ocean heat content

- SST: wintertime SST best reflects ocean memory
- Ocean heat content: heat contained in the layer between surface and maximum climatological mixed layer depth (D):

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

- Gridded datasets: restrict all analyses 1945—present

Wintertime SST: $\overline{SST}_w$	H (yearly and winter) : $\overline{H}$, $\overline{H}_w$
ERSST v5 (Smith et al., 2008)	Ishii (Ishii et al., 2006)
HadI SST (Rayner et al., 2003)	EN4.2.1 (Good et al., 2013)
COBE SST2 (Hirahara et al., 2014)	Cheng OHC (Cheng et al., 2017)

Maximum climatological mixed layer depth (D)

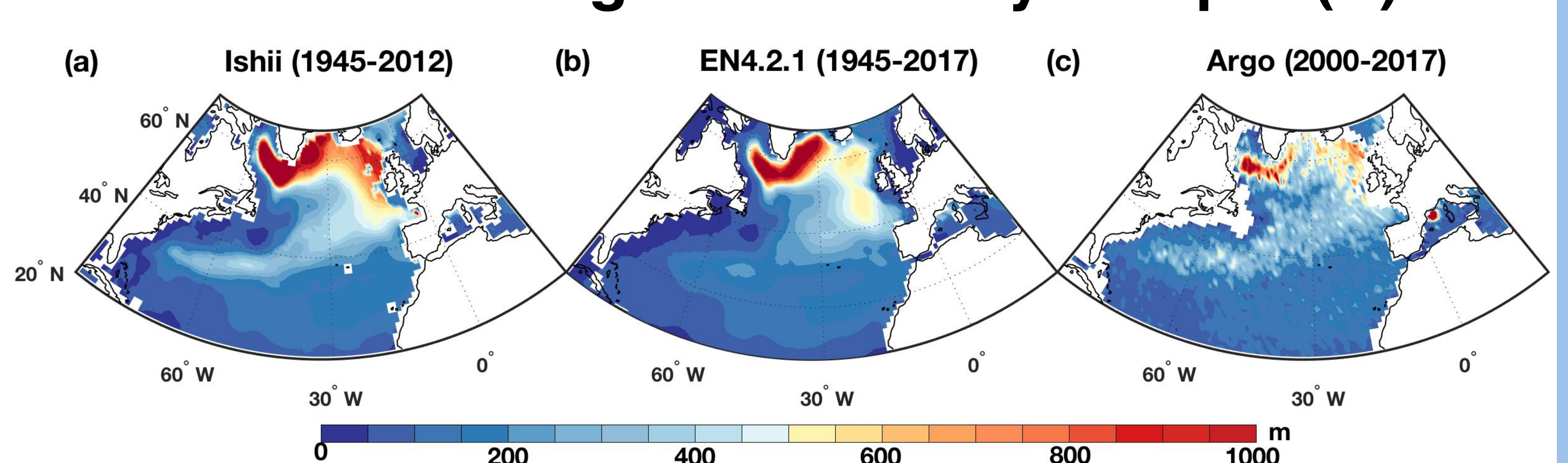

Figure 1: The maximum climatological mixed layer depth (D) from (a) Ishii, (b) EN4.2.1, and (c) the Argo mixed layer depth product (Holte et al., 2017).

Predictability timescale

Measure of the decorrelation timescale following DelSole (2001):

$$T_2 = \int_{-\infty}^{+\infty} \rho_\tau^2\, d\tau = 1 + 2\sum_{k=1}^{\infty} \rho_k^2,$$

- ρ_τ is the autocorrelation function at lag τ.
- ρ_k is the discrete autocorrelation.

- Fit an autoregressive (AR) model to the time series
- Use the AR parameters to derive the theoretical autocorrelation function, ρ_k^*.
- Integrate ρ_k^* to calculate T_2.
- Tried AR orders 1—3 and found little sensitivity to AR order, use AR2.

Decorrelation timescales for H and SST

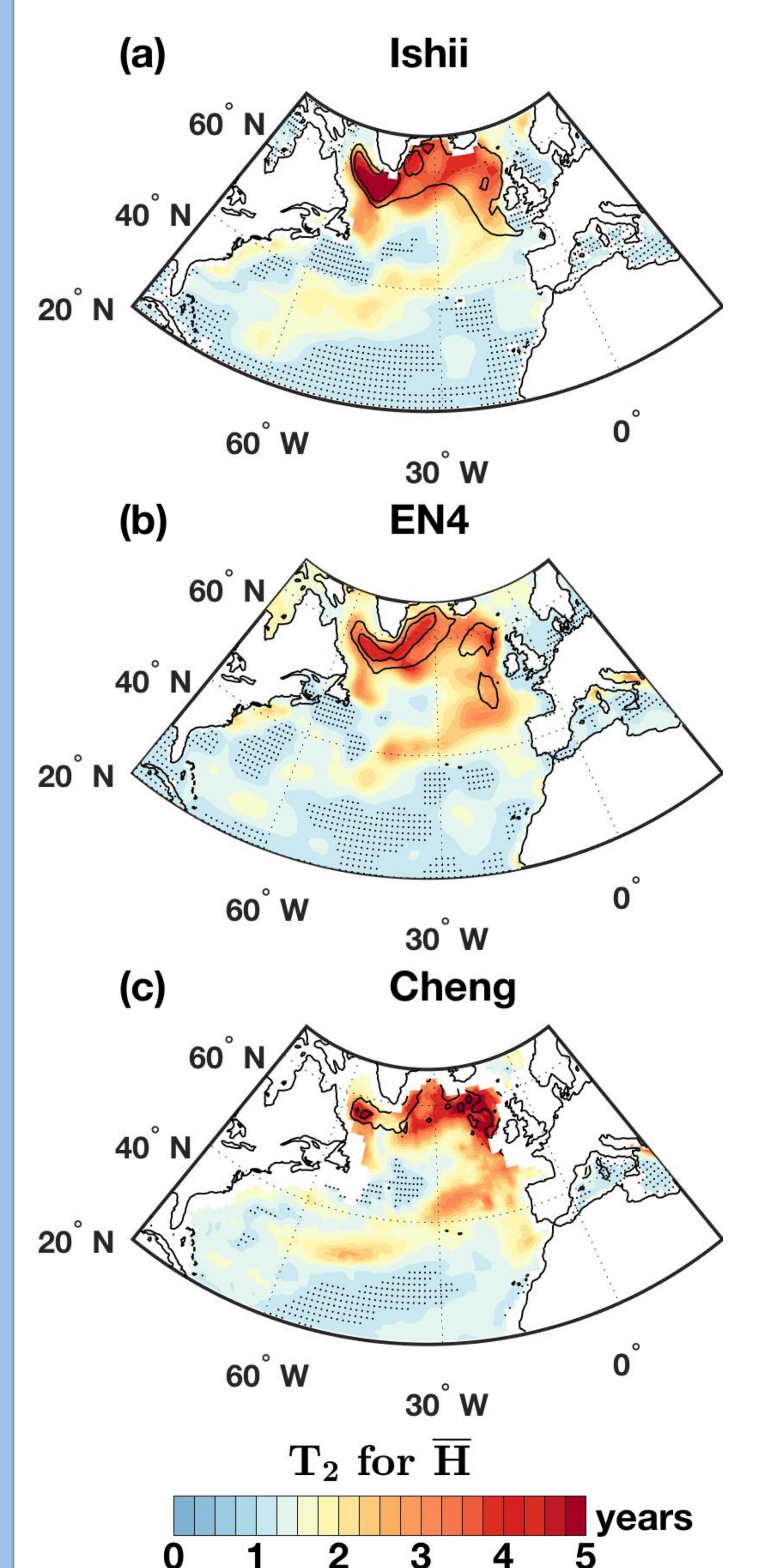

Figure 2: T_2 for H from (a) Ishii, (b) EN4, and (c) Cheng. Black dots are points where T_2 is not significant at the 90% confidence level. Black contours show D at levels 500, 1000, and 1500 m.

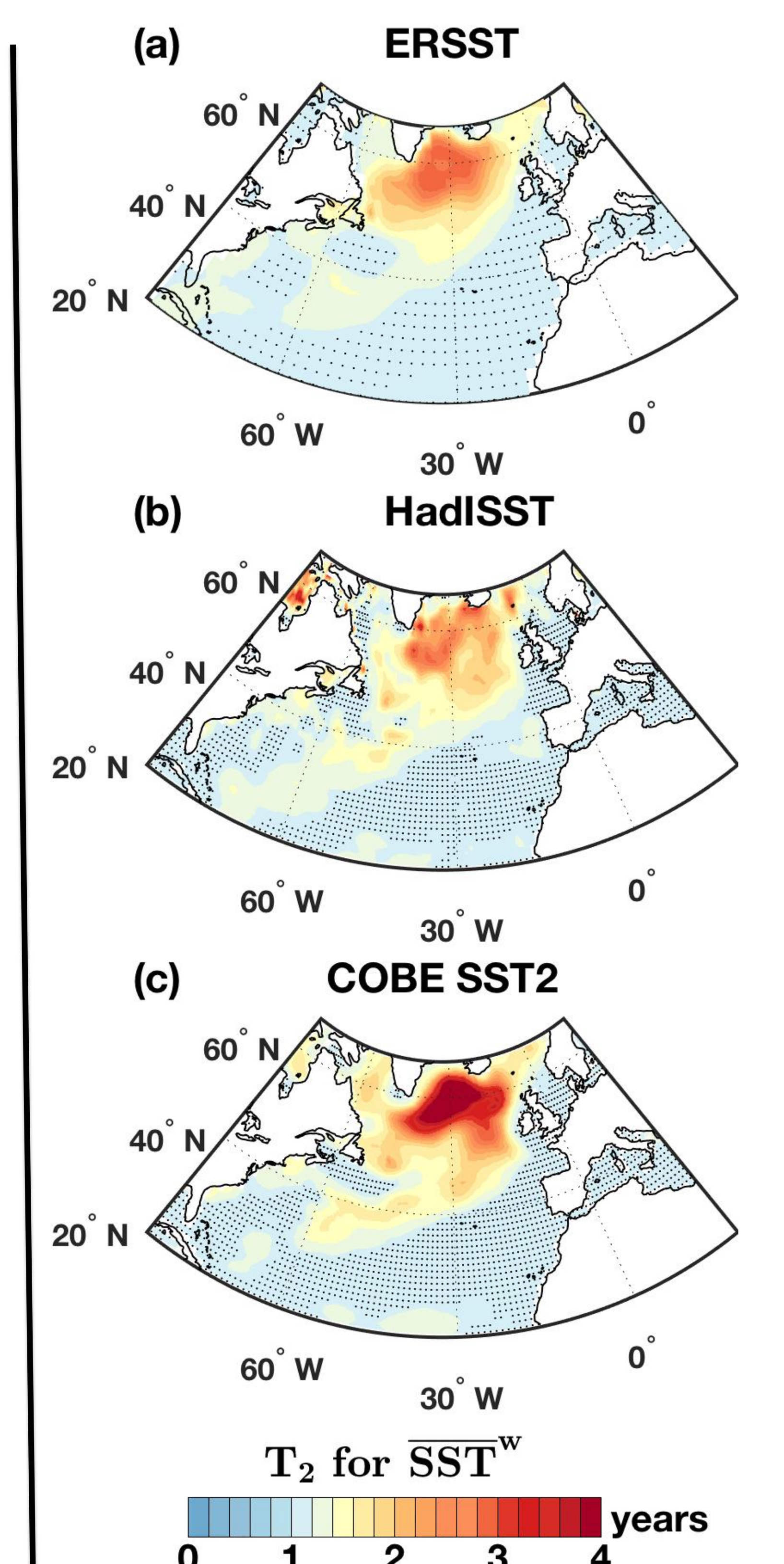

Figure 3: T_2 for wintertime SST from (a) ERSST, (b)HadISST, and (c) COBE SST2. Black dots are points where T_2 is not significant at the 90% confidence level.

Comparison: H vs. SST timescales

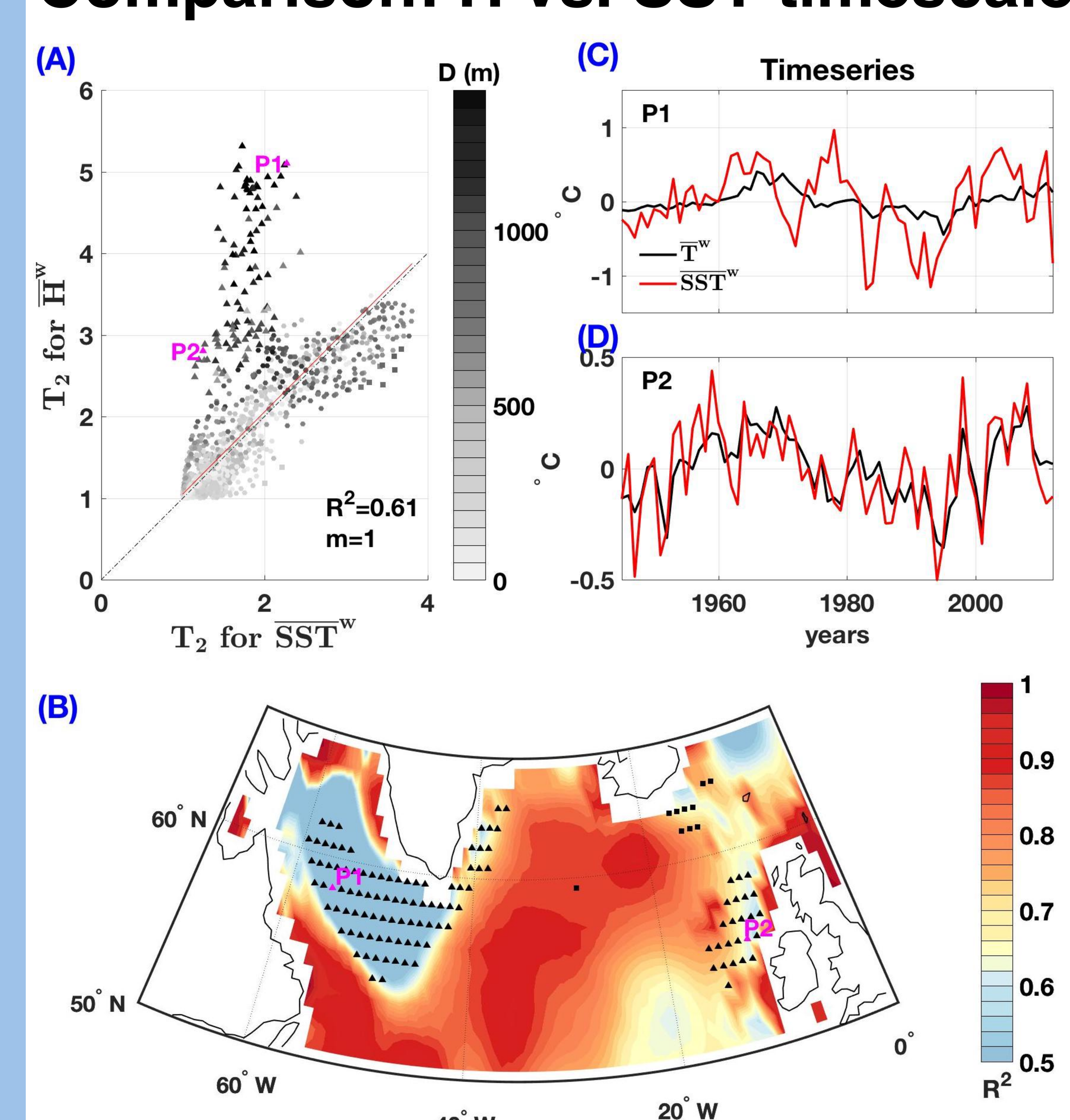

Figure 4: Comparison of T_2 for SST and H using Ishii :

(A) Scatter plot showing T_2 for SST & H for points in the extra-tropical North Atlantic (ETNA). The points are shaded (grey-scale) to reflect their value of D. The red line shows the linear fit.

(B) Map of the spatial distribution of the outliers based on the linear fit. Colors show squared correlation between wintertime H & SST.

(A-B) Triangles (squares) are points that are two standard deviations above (below) the best fit line.

(C-D) Time series of (red) SST & (black) temperature averaged over layer from the surface to –D.

Relationship: decorrelation timescales and D

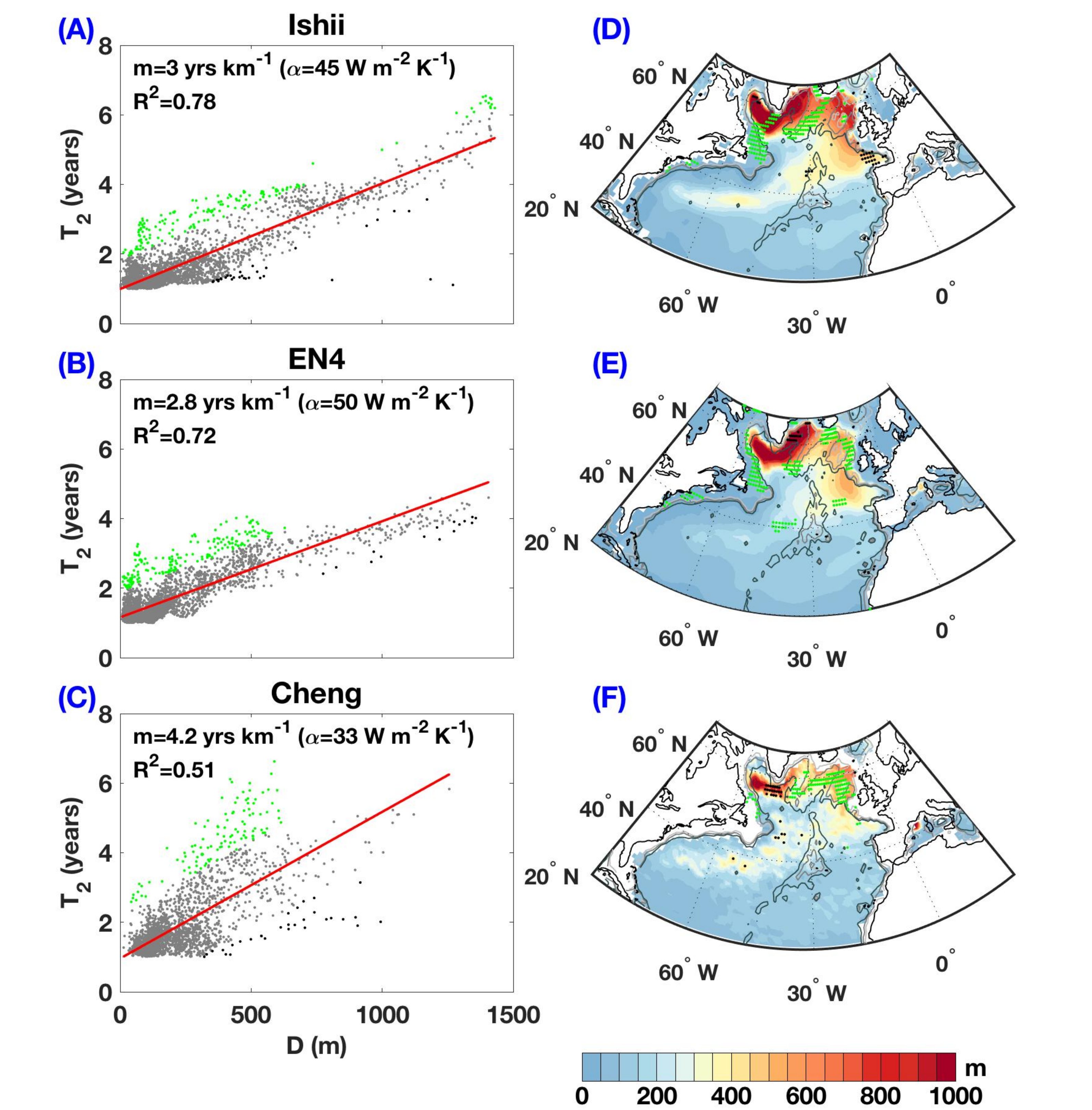

Figure 5: Relationship between decorrelation timescale and D:

(A-C) Scatterplots of T_2 for H for all points in the ETNA for (A) Ishii, (B) EN4, and (C) Cheng. The red line is a linear fit between T_2 and D. The values of R^2 and the slope, m, and the corresponding value in the units of α are given in the top left corner of each plot.

(D—F) Spatial distribution of the outliers based on the linear fit. The underlying colors are D and the contours show bathymetry at depths of 1, 2, and 3 km, respectively.

**In all panels, green (black) points are more than 2 standard deviations above (below) the best fit line.

Conclusions

1. Ocean predictability measures: wintertime SST & H, heat contained between surface and the maximum climatological mixed layer depth.
2. Decorrelation timescales for SST and H are longest in the subpolar gyre.
3. Decorrelation timescales for SST and H are similar except in regions with very deep mixed layers, where timescales for H are much larger.
4. Decorrelation timescales are related to the maximum climatological mixed layer depth (D). Spatial variations in D explain:
   - 51-78% of decorrelation timescales for H.
   - 26-40% of decorrelation timescales for wintertime SST.

References:

M.W. Buckley, T. DelSole, M.S. Lozier and L. Li, Predictability of North Atlantic SST and Ocean Heat Content from Observations, submitted to *J. Climate*.