Reduced-dimension methodology to reconstruct spatial fields of mean state Atlantic Ocean SST anomalies over the past 8 ka

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ABSTRACT

This study presents a methodology to reconstruct the spatial evolution of Atlantic Ocean sea surface temperatures (SSTs) using reduced-dimension methods with alkenone proxy records scattered throughout the domain. In the reduced-dimension methodology, present day spatial patterns of the full gridded SST field are linearly related to the present day SST patterns of the limited field - a field comprised of present day SSTs at 17 core locations. This relationship is used in conjunction with a Holocene limited SST field to project Holocene full field SSTs. The spatial reconstructions suggest an enhanced dipole pattern during early Holocene (12 ka BP) that weakens to present day with gradual warming of the tropics and cooling in the subtropics.

DATA

Contemporary Data:

- NOAA NCEI Extended Reconstruction
    - Gridded 2° x 2°
    - Annual averages (April to following May)
    - [*Smith et al.* 2008]

Holocene Data:

- 17 Alkenone SST records
    - See Figs. 1 and 2.
    - Original calibrated SSTs used
    - [*various refs*]

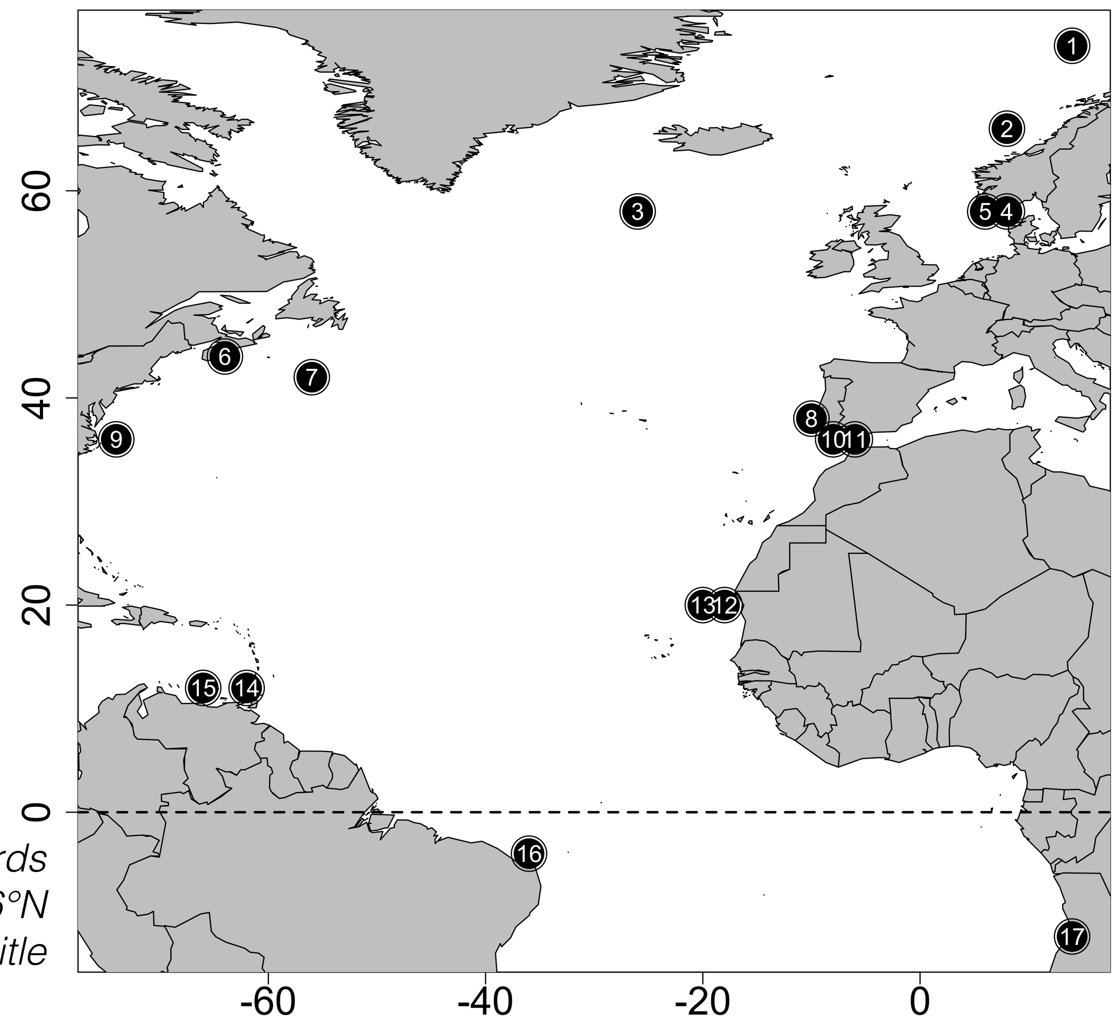


Figure 1. Map of seventeen alkenone SST proxy records collected for the Atlantic Ocean domain of 20°S to 76°N and 76°W to 20°E. Numbers correspond to sub-plot title numbers in Fig. 2.

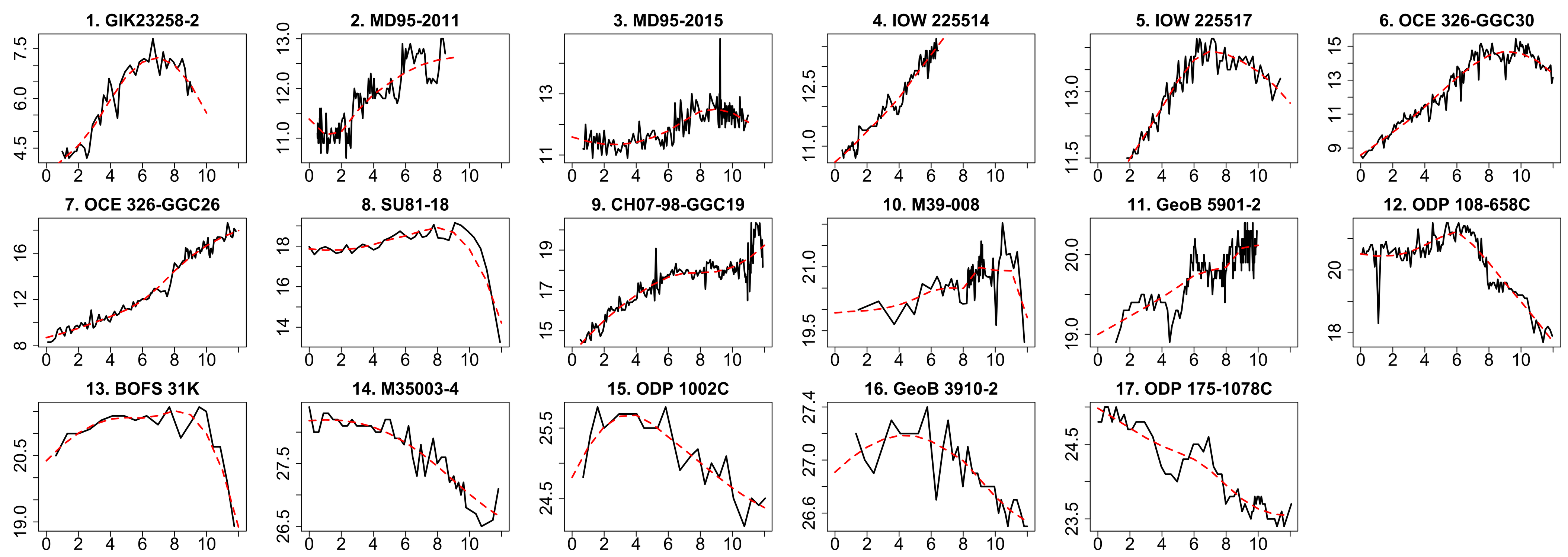


Figure 2. Reconstructed sea surface temperatures (SSTs) for the seventeen alkenone cores depicted in Fig. 1. Black lines show the SST trend over the past 12 ka BP as determined by alkenone paleo-thermometry and various calibration equations. Dotted lines show smoothed records as determined by a local polynomial fit using a 70% neighborhood.

MODEL

(i) Perform a Principal Component Analysis (PCA) on 1854-2015 avgerage annual SSTs gridded over Atlantic Ocean Domain. $[T]$ = full field SSTs, $[Y]$ = full field PCs, $[U]$ = full field eigenvector matrix.

$$[T]_{161\times1604} = [Y]_{161\times1604}\,[U]_{1604\times1604}$$

(ii) Perform a PCA on 1854-2015 average annual SSTs on the "limited field" (17 locations where we have Holocene proxy data). $[T']$, $[Y']$, and $[U']$ = same as in (i) but for the limited field.

$$[T']_{161\times17} = [Y']_{161\times17}\,[U']_{17\times17}$$

(iii) For 12 ka BP, model the leading 3 PCs of (i) (53% of variance) each as functions of the leading 2 limited field PCs from (ii) (65% of variance).

$$y_1 = f(y'_1, y'_2)$$
$$y_2 = f(y'_1, y'_2)$$
$$y_3 = f(y'_1, y'_2)$$

(iv) Arrange proxy data in 1 x 17 matrix and transform the proxy SSTs for 12 ka BP to PC-space by multiplying by the limited field eigenvector matrix. $[P]$ = 12 ka BP SSTs, $[Y^P]$ = 12 ka BP PCs.

$$[Y^P]_{1\times17} = [P]_{1\times17}\,[U']_{17\times17}$$

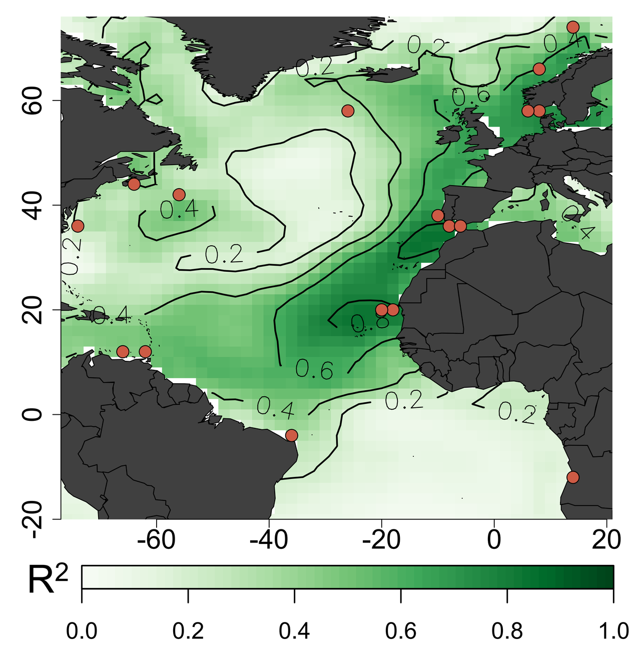
(v) Using the regressions formed in step (iii), along with the 12 ka BP PCs from (iv), we reconstruct the full field PCs at 12 ka. $[Y^R]$ = reconstructed PCs for full field 12 ka BP.

$$[Y^R]_{1\times1604}$$

(vi) Full field PCs are back-transformed to data-space by multiplying by the transpose of the full field eigenvector matrix. $[T^R]$ = reconstructed SSTs for full field 12 ka BP. Repeat steps (i-iv) for 10, 8, 6, 4 and 2 ka BP.

$$[T^R]_{1\times1604} = [Y^R]_{1\times1604}\,[U]^T_{1604\times1604}$$

CALIBRATION



Using the reduced-dimension model, which relates the full-field spatial patterns of SSTs to SSTs at each of seventeen core locations, we can reconstruct the contemporary 1854-2015 period. To determine skill, we correlate these reconstructed SSTs and actual SSTs at each grid point and plot the squared correlation coefficient. The best skill is seen in a band that extends from the northeastern coast of South America to the NW coast of Africa and up into the northeastern Atlantic. The worst skill is located in the southern sub-tropics and the central part of the Atlantic, where few SST records exist.

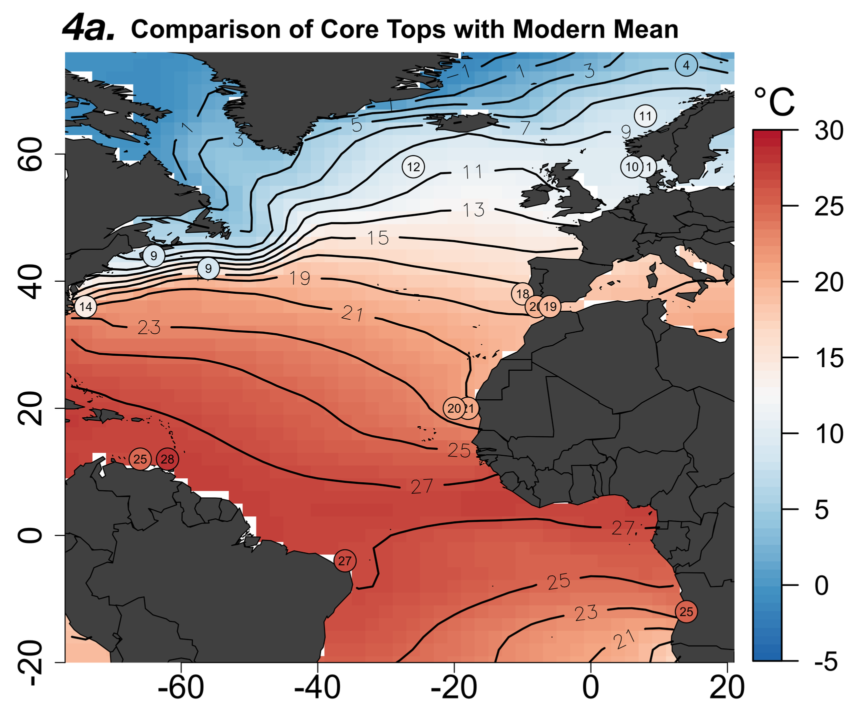
Figure 3. Squared correlation coefficient between 1854-2015 actual annual average SSTs and 1854-2015 reconstructed SSTs using the reduced-dimension model of 17 locations

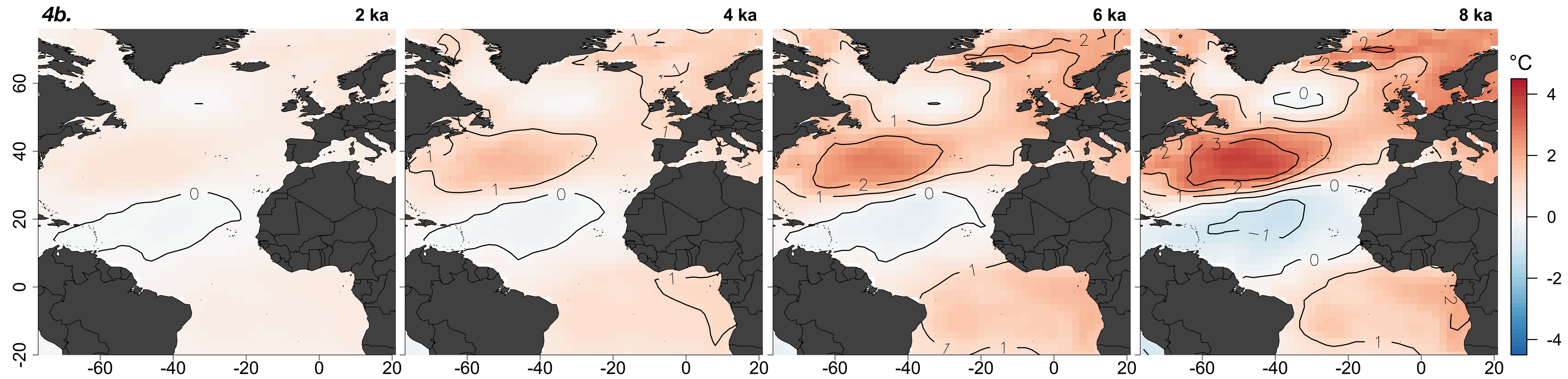
RESULTS

The resulting spatial temperature evolution shows cooling in the sub-tropics and warming in the tropics, which is consistent with other studies [*Kim et al.* 2004; *Lohmann et al.* 2013]. These results agree with those of *Lohmann et al.* [2013] who noted that simulated Holocene SST patterns underestimate alkenone-based SST trends. Future work involves including more records to make this an expansive multi-proxy study and to develop a way to differentiate between long term trends and AMOC variability.

Figure 4a. *The first panel compares core top values of reconstructed SSTs with the average annual SSTs from modern data. SSTs are contoured in 2°C intervals.*

Figure 4b. *The four panels to the right show the reconstructed fields of Atlantic Ocean annual SST anomalies for 2, 4, 6, and 8 ka BP, from left to right. SSTs are contoured in 1°C intervals.*





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