Assessing the Long-Term SST Response of the Red Sea to Natural Climate Variability

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Abstract

Recent observations of warming trends in the Red Sea raise more attention to the response of the basin under a warming climate. Using two remotely sensed datasets, the Hadley Centre Sea Ice and Sea Surface Temperature [HadISST] and Extended Reconstructed Sea Surface Temperature [ERSST.v3], we investigate the reported sudden increase in the Red Sea sea surface temperatures (SST) in terms of average and maximum and assess their relation to multi-decadal climate variability. Prior to the analysis, the two datasets are successfully validated with respect to their ability to reproduce the recent observed and reported trends and their spatial features. Analysis of long-term SST variability revealed a sequence of alternating and similar in amplitude positive and negative trends, characterized by a period of nearly 70 years. Similar oscillations have been reported in other basins and have been related to atmospheric disturbances associated with the Atlantic Multidecadal Oscillation (AMO). A point-by-point spectral analysis of SST evolution shows a significant correlation with the basic modes of the AMO that explains a large fraction of its temporal and spatial variability. Projections on the major modes of the spectral analysis suggest a possible decreasing effect on local SST in the near future. Under this assumption, recent projected trends in the Red Sea may be exaggerated, whilst trends that may be related to anthropogenic influence could be masked by the projected negative influence of the AMO in the near future.

ASSESING THE SST RESPONSE OF THE RED SEA TO NATURAL CLIMATE VARIABILITY

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Introduction

Recent observations of warming trends in the Red Sea raise more attention to the response of the basin under a warming climate. We investigate the reported increase in the Red Sea sea surface temperature (SST) in the last decades using datasets with different temporal coverage and assess their relation to multi-decadal climate variability. The examination of long term datasets reveals substantial variability in various time scales. Analysis shows that recent trends are strongly influenced by a low frequency signal related to the Atlantic Multidecadal Oscillation (AMO). When these modes are included in future projections of SST, long term trends could be masked by the negative influence of the AMO in the near future.

Datasets

Four publically available SST datasets were examined and compared to investigate on the evolution of SST in the Red Sea.

For the assessment of recent trends, we examine two very high resolution, remotely sensed SST reconstructions:

- **NCDC-L4, blended, global OI analysis (AVHRR)**
- **METOFFiCE Operational SST and Sea ice analysis (OSTIA)**

For the long term trend analysis two historical SST reconstructions were utilized:

- **Hadley Centre Sea Ice and Sea Surface Temperature [HadISST]**
- **NOAA's extended Reconstructed SST [ERSST.v3]**

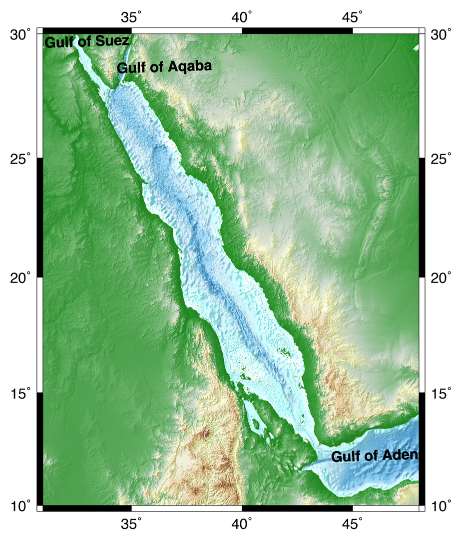
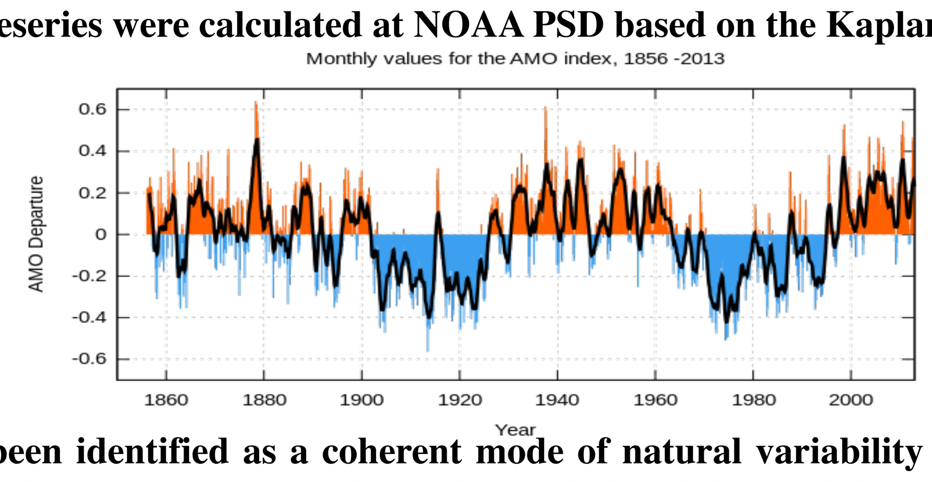


Fig 1. Map of the Red sea region

Natural Climate Modes - AMO

The Atlantic Multidecadal Oscillation (AMO) is a climate cycle defined by the patterns of Sea Surface temperature (SST) in the North Atlantic Ocean with an estimated period of 60-80 years. The specific timeseries were calculated at NOAA PSD based on the Kaplan SST dataset [4].



The AMO has been identified as a coherent mode of natural variability and has been associated with important climate impacts, such as the multidecadal variability of North American and European summer climate and the northern hemispheric mean surface temperature [4, 5].

Assessing Trends

During the recent period (1985-2015) all datasets agree on the recent observed and reported [1,2] trends and their spatial features (not shown). Trends based on longer time series are significantly lower.

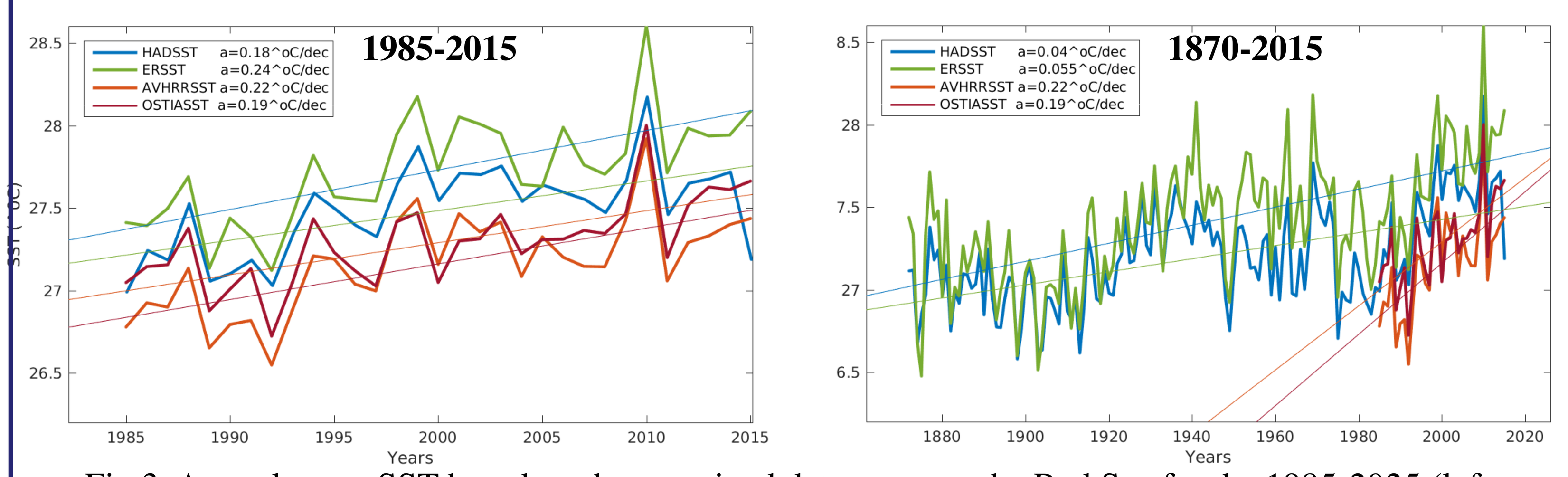


Fig 3. Annual mean SST based on the examined datasets over the Red Sea for the 1985-2025 (left panel) and 1870-2015 (right panel) periods with their respective linear trends

Analysis of long-term SST variability revealed a sequence of alternating and similar in amplitude positive and negative trends, characterized by a period of nearly 70 years.

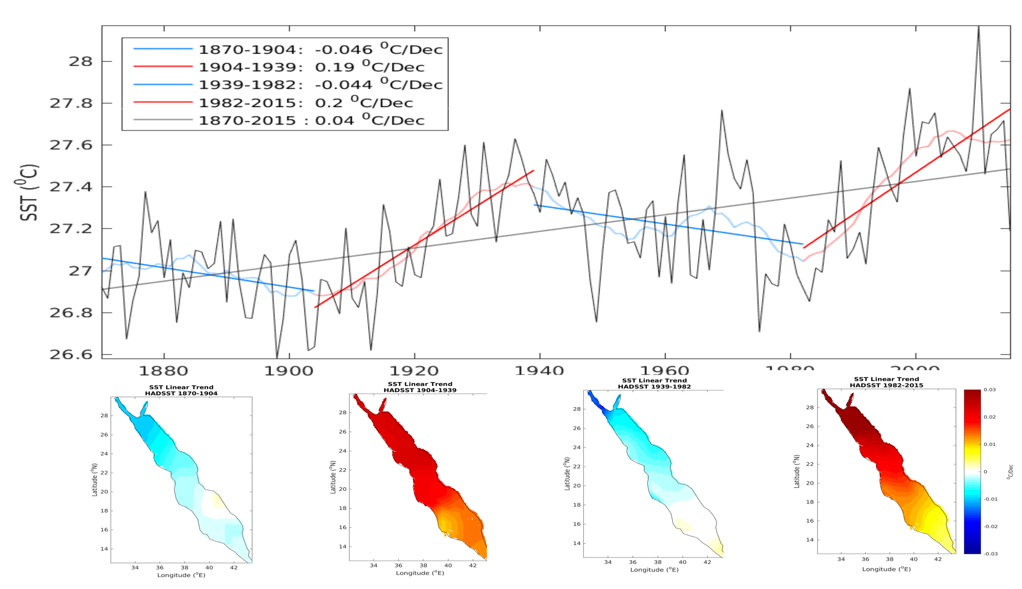


Fig 4. Annual mean SST based on HADISST dataset over the Red Sea for the 1870-2015 period with the identified positive and negative trends (upper panel) and their respective spatial patterns (lower panels)

Low Frequency Signals

Relative Similar oscillations have been reported in other basins and have been related to atmospheric disturbances associated with the AMO [2].

A point-by-point singular spectral analysis (SSA) of annual mean SST and AMO was applied in order to identify their dominant modes of variability. The first modes (most dominant) were used for the reconstruction of the time series (Fig. 5).

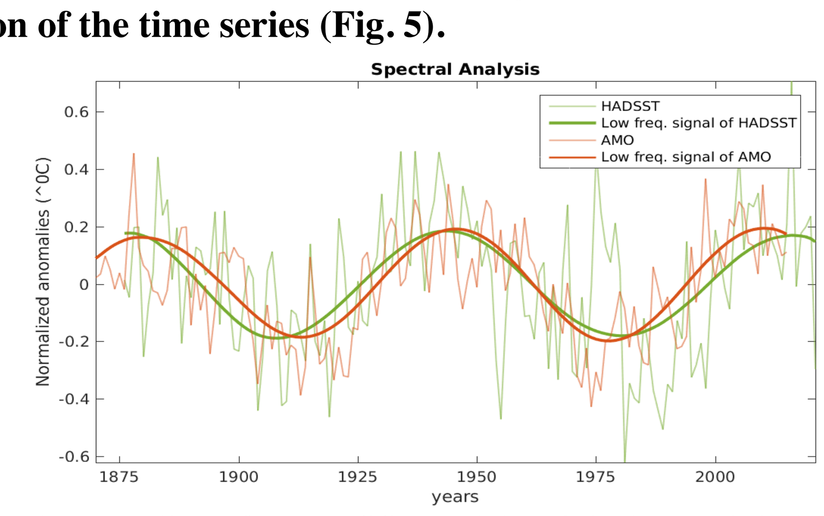


Fig 5. Normalized anomalies of HADISST and AMO index and their low frequency signals obtained by SSA analysis.

Analysis shows a significant correlation with the basic modes of the AMO (Fig 6b) and explains a large fraction of its spatial and temporal (Fig 6a) variability (20-55% for annual means).

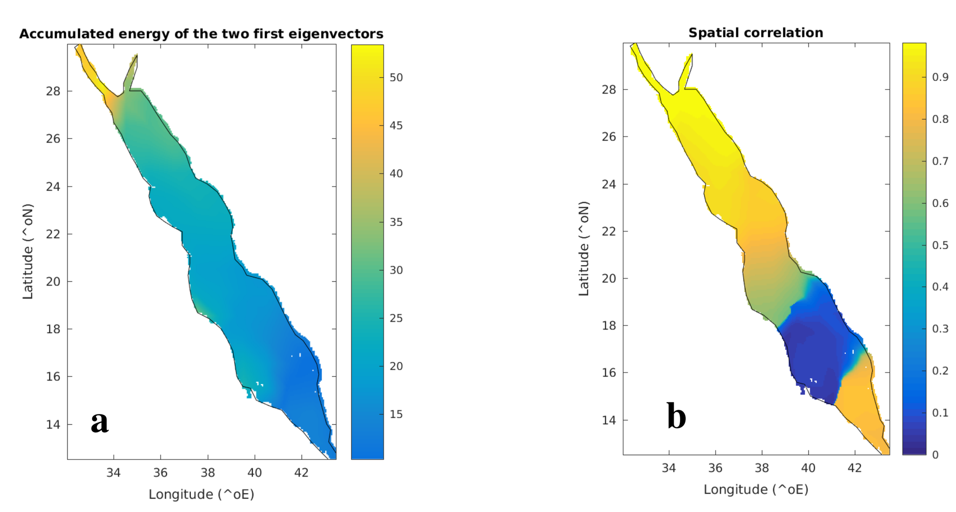


Fig 6. Maps of accumulated energy in the first two modes of SSA for HADISST (a) and correlation with the respective modes of AMO (b).

Future Projections

The low frequency signal obtained based on the major modes of the spectral analysis presents a periodicity of about 70 years. The signal is fitted using a sinusoidal function and projected in the future.

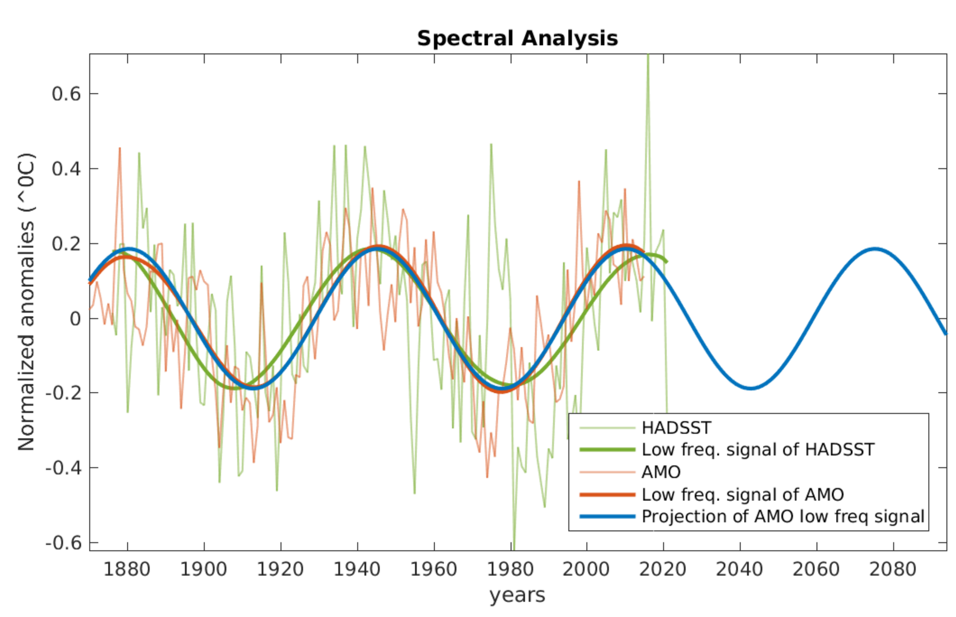


Fig 7. Sinusoidal projection of AMO low frequency signal.

Projections of the major modes of the spectral analysis suggest a possible decreasing effect on local SST in the near future. Under this assumption, recent trends related to anthropogenic influence may have been exaggerated, whilst projected trends in the Red Sea could be masked by the negative influence of the AMO in the near future.

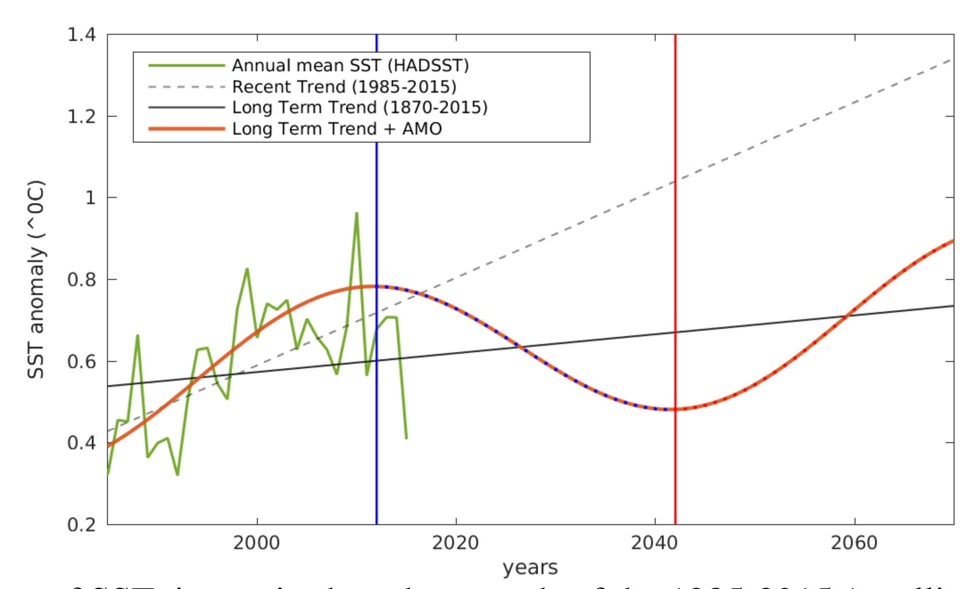


Fig 8. Projection of SST timeseries based on trends of the 1985-2015 (satellite era), 1870-2015 periods and AMO low frequency signal.

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