What Can COADS Tell Us? Potential and Limitations

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Abstract

Some of the potentials and limitations in the COADS sea surface temperature (SST) are examined. In particular, we address uncertainties due to a) secular changes in the sampling array and those due to b) consistent under-sampling of some areas for the entire record. The first set of questions relate the use of COADS to the examination of long time series for global change studies, the second to systematic uncertainties in the analysis of contemporary spatial analysis.

Introduction

Historical analyses of SST fields depend on the data coverage provided by ships and, to a lesser extent, buoys. This data coverage has not been constant over time. In the past hundred years there have been dramatic and potentially very significant shifts in the data distribution over the oceans due to changes in commercial shipping lanes, conversion from wind powered to steam driven ships, and the opening of major canals. In the first part of this study we provide preliminary estimates of the uncertainty in analyses of SST fields and in basin scale area averages over the past 110 years that can be ascribed to changes in the sampling array.

In the second part of the study rotated principal component analyses (RPCA) based on NMC blended in-situ and satellite SST data (Reynolds, 1988) are compared to a COADS-based analyses for the six-year period 1982 to 1987. This comparison provides some measure of limitations in the definition of SST patterns associated with a less-than-full data field.

Analysis

Uncertainties due to temporal changes in the array

In this initial analysis SST for three decades representing epochs with different ship track patterns (the 1880's, 1920's and 1970's) are examined for a winter and summer month (February and August). Only the August analysis is presented here. The data are extracted from the COADS Monthly Summary Trimmed Groups.

The data distributions in each decade (for Augusts) are illustrated in Fig. 1. During the 1880's the most heavily sampled regions were in the North Atlantic and, in the South Atlantic, along the ship tracks rounding Cape Horn and Cape of Good Hope. The Pacific was much less well sampled particularly in the north central and western regions. During the 1920's there was an important increase in the number of ship observations in the North Atlantic and dramatic shift in the sampling patterns. In particular the opening of the Panama Canal is reflected in the significant changes in ships tracks in the Pacific east of the dateline. By the 1970’s most of the oceans are relatively well sampled with the exceptions of areas south of 40°S, the eastern Pacific, parts of the central Pacific, and the western South Atlantic.

To effectively convert these data distributions into a SST field, or normalized SST field, we specify a 1°C SST anomaly for all observations. We then analyze the resulting fields using an optimum interpolation (OI) with a first guess of 0°C. This technique separates the effect of natural spatial variations in SST from those differences due solely to changes the sampling array. The resulting analyzed fields e.g., Fig. 2, closely reflect patterns represented by the respective sampling arrays but also provide a means to quantify the effects of sampling.

The effects of sampling on basin-scale SST averages for 5 ocean basins, as well as a global mean, are summarized in Fig. 3. Thus the analysis for 1970’s in the North Pacific is close to “perfect” with a mean anomaly of 0.93°C versus an anomaly of only 0.21°C if the North Pacific is sampled with the array available in the 1880’s. The difference between these two estimates (0.72°C) is an estimate of sampling uncertainty due to the changes in ship tracks. We see similar sampling differences for the other ocean basins. Although the estimates generally improve with time it’s interesting to note, Fig. 3, that the South Atlantic was actually better sampled in the 1880’s compared to the 19201s.

The differences between the 1970’s value in each basin and a full field analysis value of 1.0°C can also be thought of as the sampling differences between in-situ only and blended in situ/satellite analyses.

While these results are preliminary they suggest that sampling uncertainties are non-negligible and need to be quantified in any analysis of long SST time series.

Contemporary Spatial Analyses

COADS is based on in-situ data only. While contemporary in-situ data coverage is generally quite good, e.g., 1970’s Fig. 1, areas of the central and eastern equatorial Pacific and of the southern oceans, in general, are not as well sampled as the rest of the globe. Virtually complete spatial coverage is currently possible through the use of satellite data, either on its own, or through the use of satellite data in conjunction with in-situ observations.

We compare rotated principal component analyses (RPCA) of SST anomalies based solely on in-situ COADS, Fig. 4, to analyses of SST anomalies based on satellite blended (Reynolds, 1988) fields, Fig. 5, for the six-year period 1982 to 1987. The analyses are restricted to the tropical Pacific (20°N to 20°S, 120°E to 80°W) where we are certain to identify interannual climate variations associated with the El Niño/Southern Oscillation (ENSO).

Comparison of Figs. 4 and 5 illustrates significant differences even though both analyses show patterns associated with the 1982/83 and 1986/87 ENSO episodes. Thus, while the leading two modes in both sets of RPCAs explain comparable percent of the variance (30% and 10% in the COADS RPCA, 29% and 15% in the blend) there are considerable differences in the character of these patterns. In particular, in both leading modes the COADS- based RPCA analysis is unable to resolve the eastern Pacific SST patterns. In addition, the orientation and magnitude of eigenmode 2 are significantly different for the blended RPCA analysis compared to the RPCA mode 2 based on the COADS, Fig. 4 and 5, even though the time series for each of these modes indicate that both analyses are attempting to capture the same phenomenon.

The analysis of higher order modes (not shown) shows virtually no correspondence between the analyses based on COADS and those based on the in-situ and satellite blend. This suggests limitations on the use of COADS SST for detailed studies of interannual variability even in the contemporary epoch.

Summary

The COADS data provide a means for assessing the magnitude of sampling uncertainties in long time series used in climate change research. The full potential of COADS for climate change research may be realized by exploiting this almost unique capability to quantify the magnitude of uncertainty.

The contemporary COADS data, from the 1960's on forward, have the spatial and temporal coverage required to identify and examine several aspects of interannual climate variability. Nonetheless, certain areas of the global oceans continue to be poorly sampled by ships of opportunity. The limitations of COADS for these areas should be acknowledged both in the data set documentation and in analyses based on COADS.

Reference

Reynolds, R.W.,1988: A real-time global sea surface temperature analysis. *Journal of Climate*, 75-86.

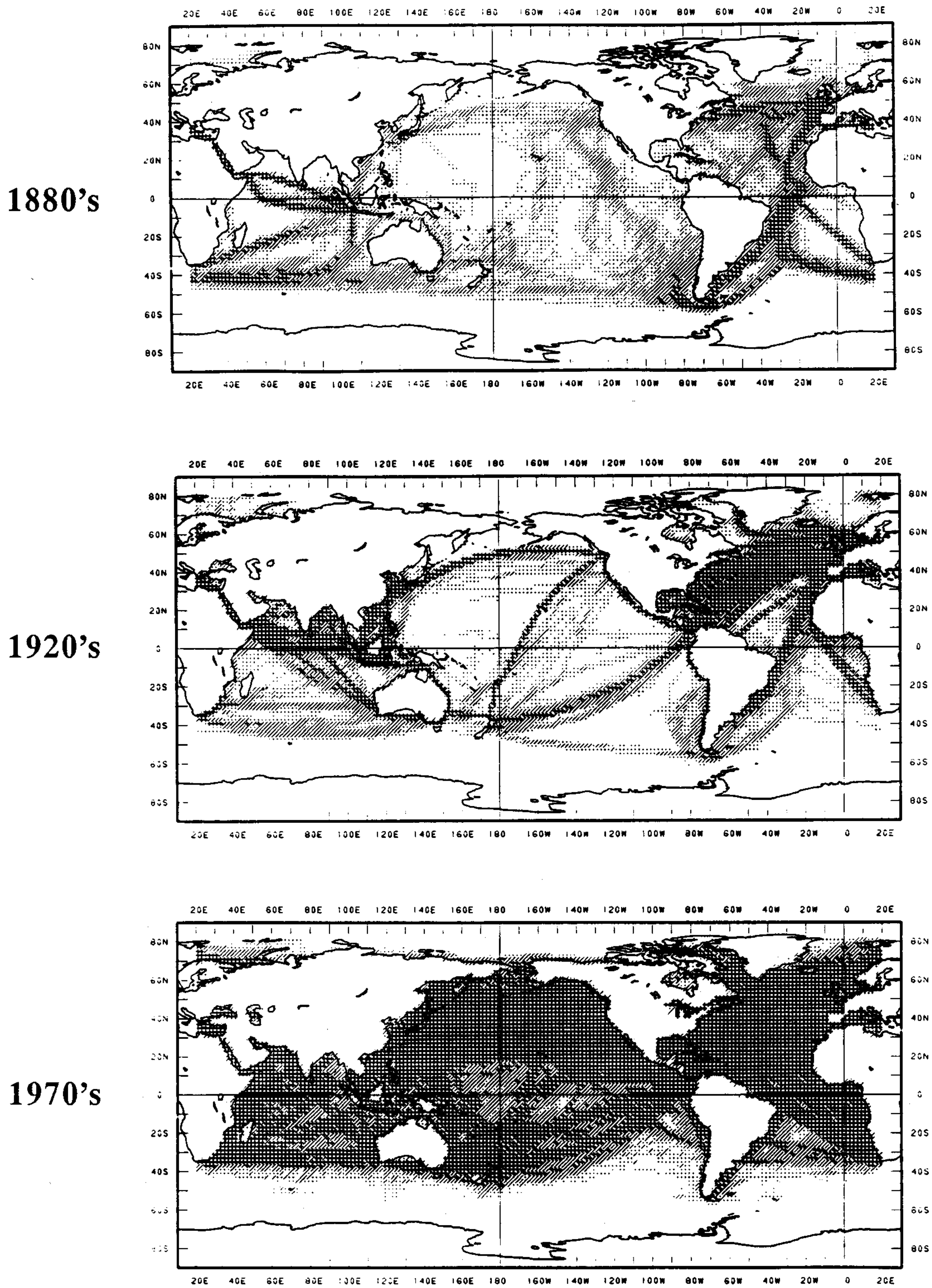

Figure 1. The number of years in the decade with observations in August. Dots represent 2° boxes with obs in 1 to 3 years. Slashes represent 4 to 7 years. Plus signs represent 8 to 10 years.

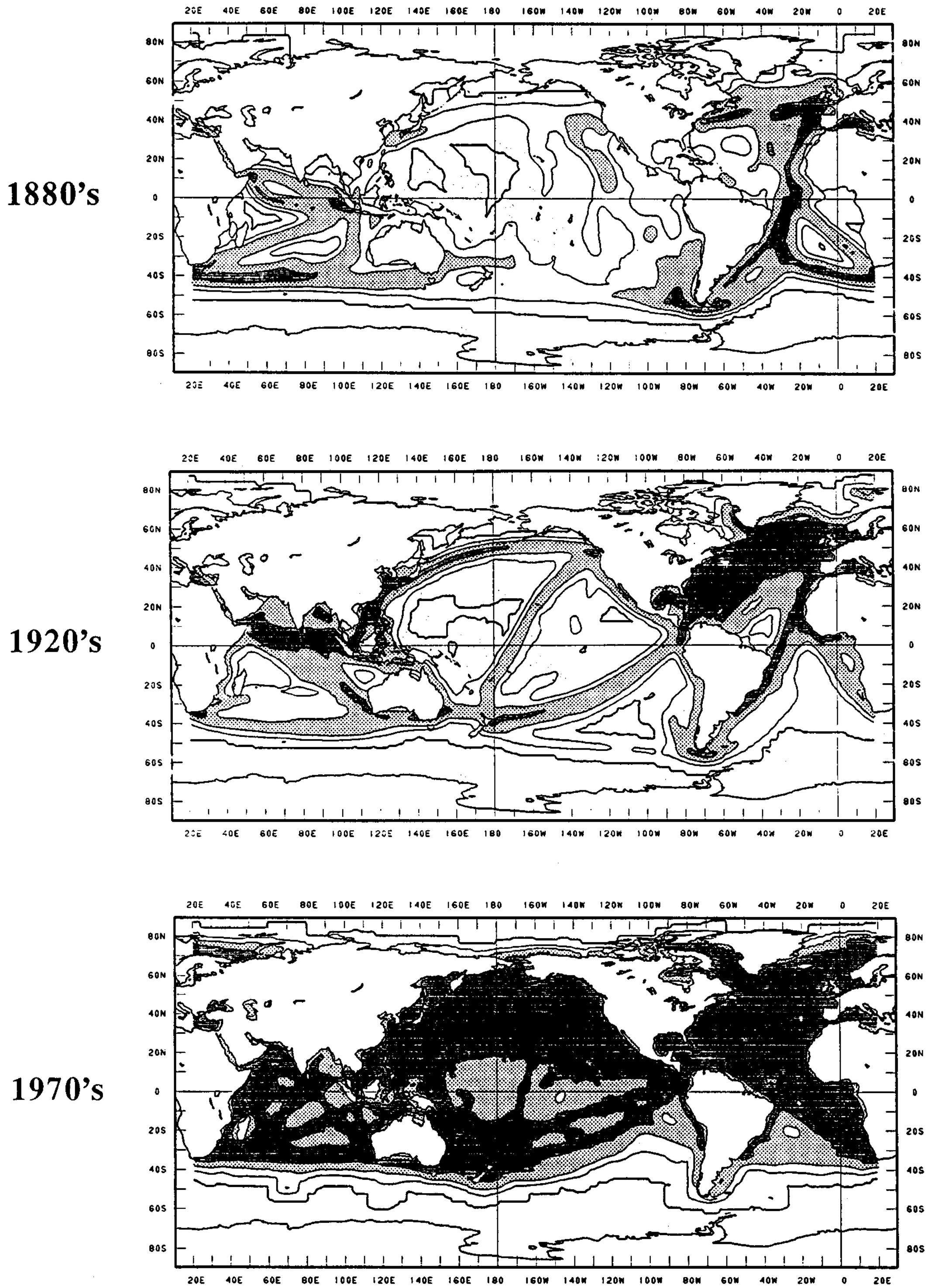

Figure 2. Decadal means of normalized SST for August. Heavy contours are at 0°C. Light contours are at 0.3°C, 0.6°C, and 0.9°C. Regions between 0.6°C and 0.9°C are lightly shaded. Regions greater than 0.9°C are heavily shaded.

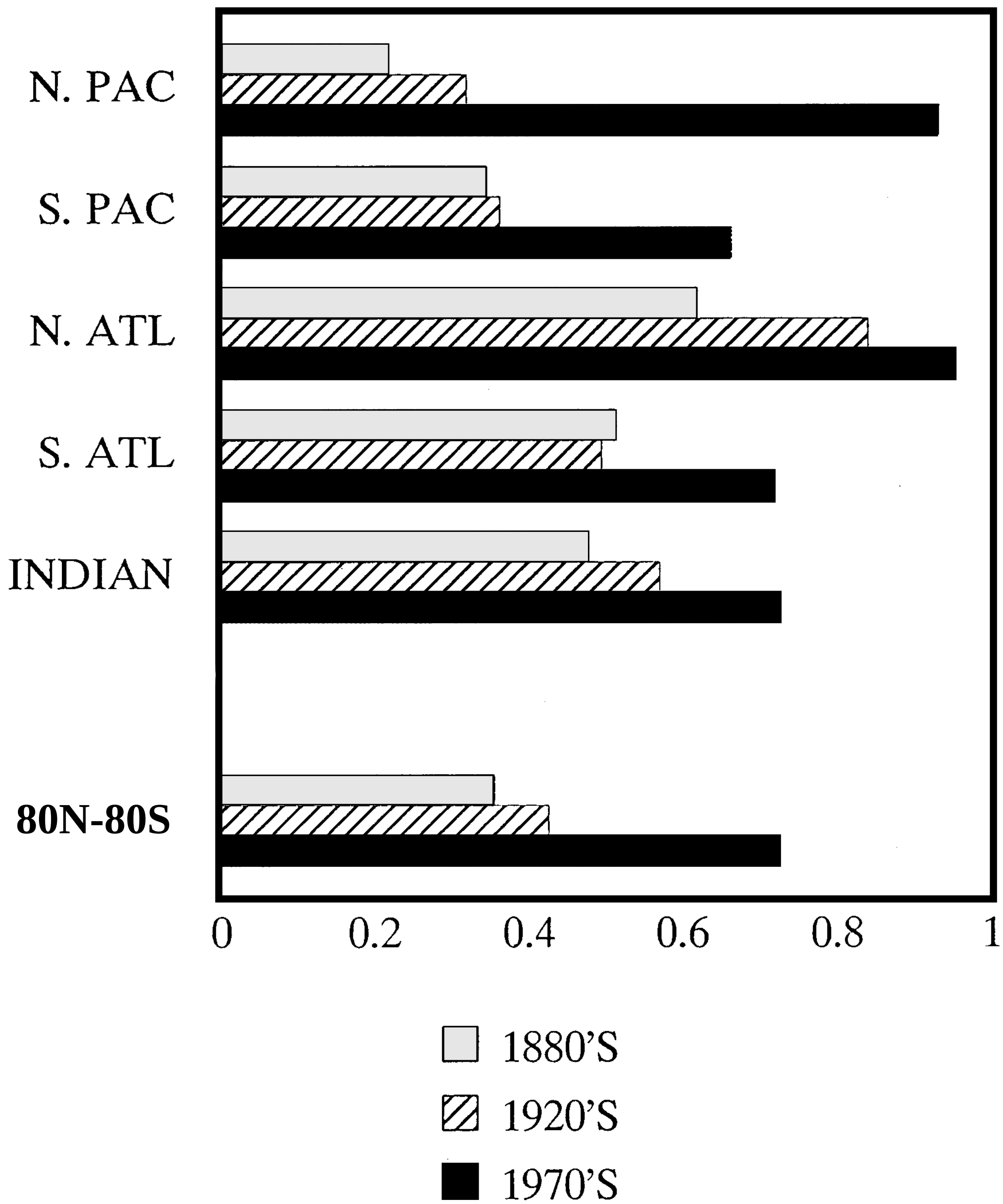

Figure 3. Decadal means of normalized SST (°C) for August averaged over each ocean basin. Ocean areas only. Each box is area-weighted.

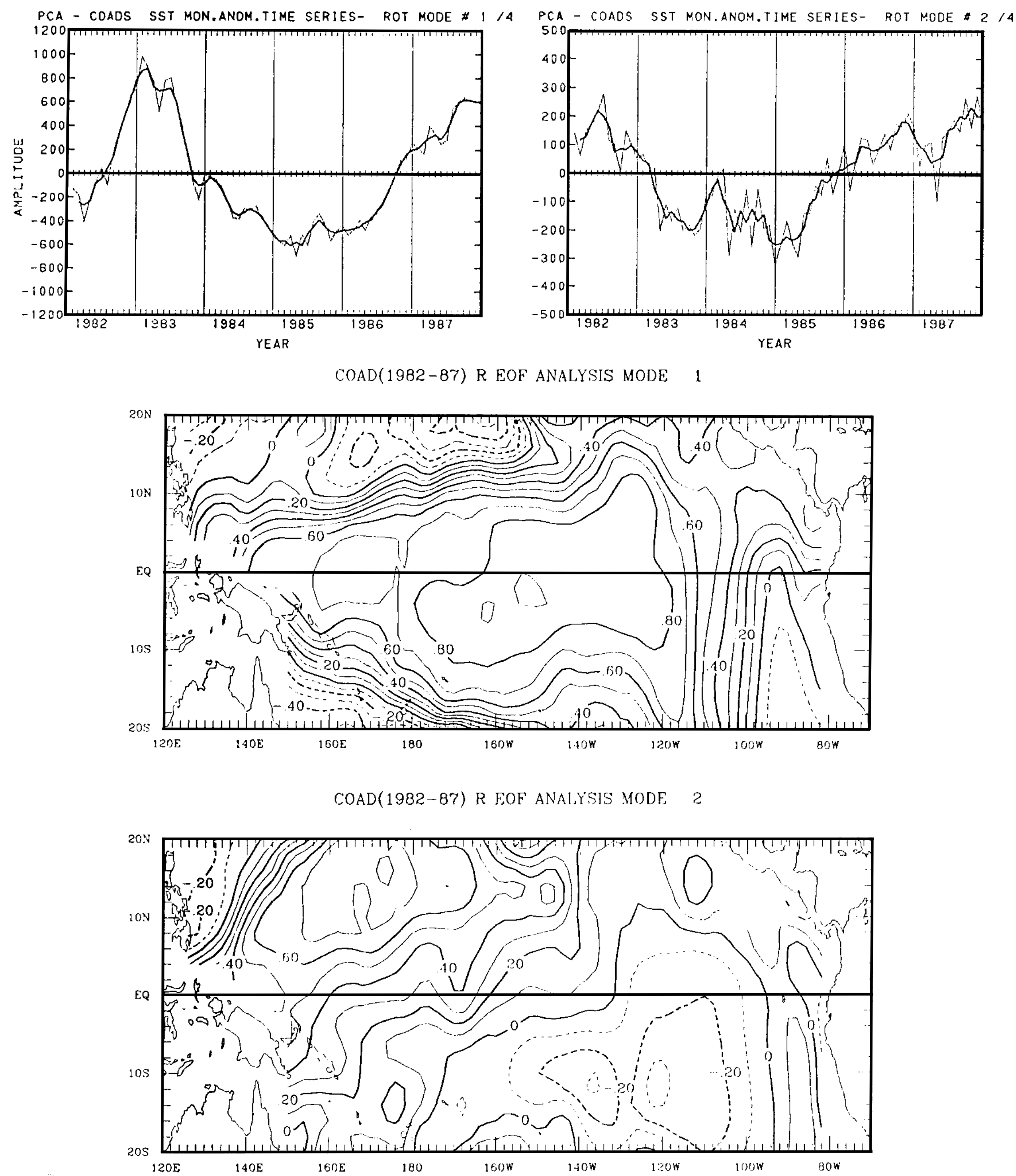

Figure 4. The time series and the spatial loading patterns for the two leading principal components of the COADS based monthly SST anomalies from 1982 to 1987.

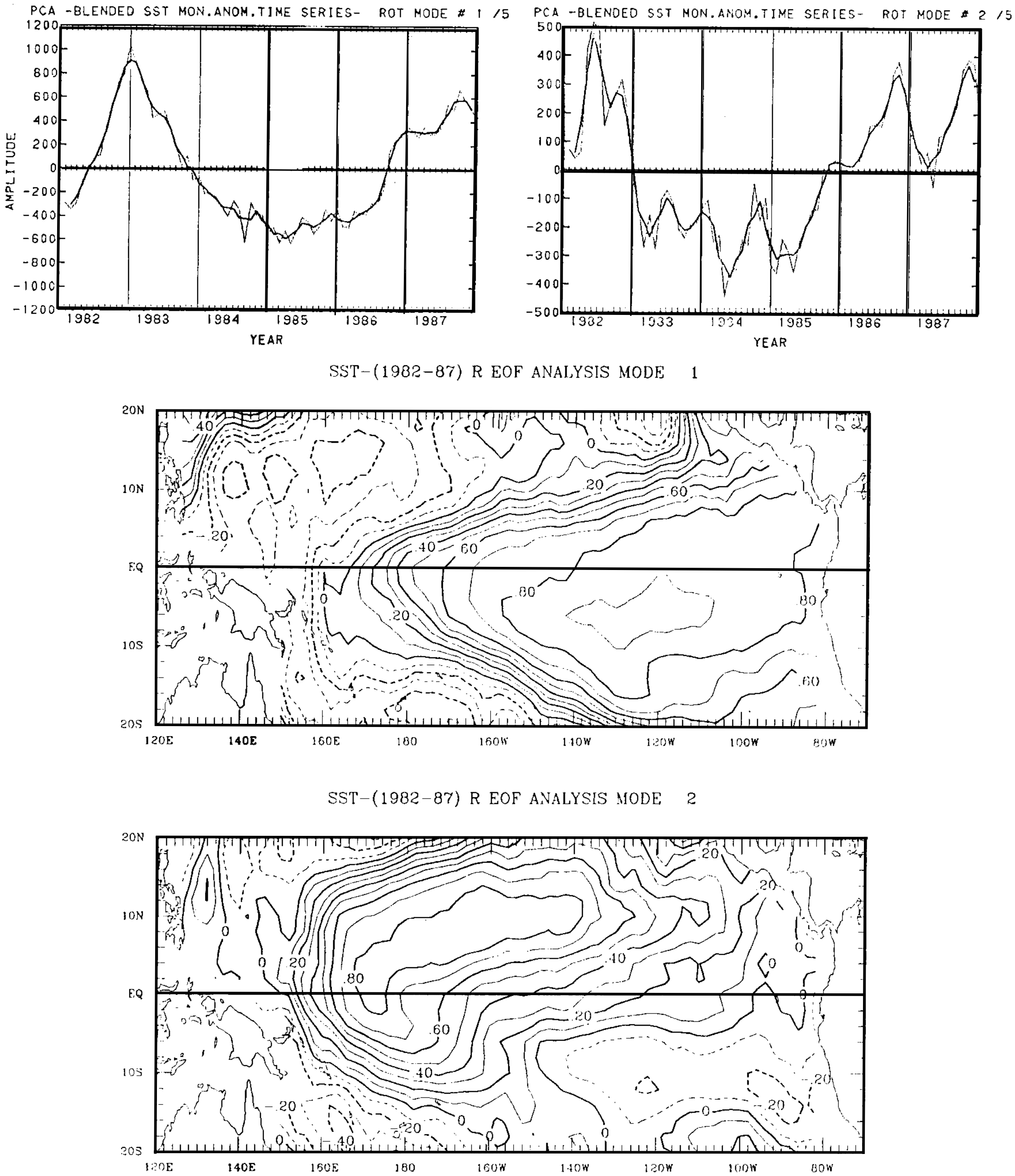

Figure 5. The time series and the spatial loading patterns for the two leading principal components of the CAC based monthly SST anomalies from 1982 to 1987.