Preliminary Comparison of North Atlantic SST Anomalies Between COADS and AVHRR-Derived Fields

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The balances of heat and salt (hence buoyancy) within the surface layer of the ocean significantly influence the Earth's climate system because they affect the exchanges of heat, mass, and dissolved constituents such as $C0_2$ between the atmosphere and deeper ocean waters. An understanding of the dynamical processes controlling the balances of heat and salt in the ocean surface layer, in particular the dynamical processes controlling anomalous variability in heat and salt, is necessary to understand the ocean's role in climate. The creation of the COADS dataset has made it possible to generate monthly global maps of SST and SST anomaly (SSTA). COADS SST maps (the trimmed monthly summaries at 2° latitude-longitude resolution) of reasonable quality have been available continuously from shortly after World War II to the present. Since late 1981, a global SST dataset of reasonable quality (the Multi-Channel SST, or MCSST, product) has been generated from satellite AVHRR infrared images (McClain et al., 1985). Errors present in both of these products limit their usefulness for studies of climate in general, and for studies of the dynamical processes that force SSTA variability in particular. Significant improvements in the quality of these SST datasets axe anticipated over the next few years. It therefore seems reasonable to determine the quality of the currently- available products to assess their present strengths and limitations and to provide a benchmark against which the future improvements in quality can be assessed. Such a comparison has recently been performed by Bates and Diaz (1991) regarding the quality of these products for basin- to global-scale climate studies. The present study focuses on the impact that errors present in these SST products will have on studies designed to quantify the influence of different dynamical processes on SSTA variability.

The relative importance of different dynamical processes in forcing SSTA variability depends on factors such as location, season, and the, space-time scales of the variability. For example, the open-ocean eddy field can drive SSTA variability through horizontal heat advection and by modifying the vertical heat flux at the mixed-layer base. The resulting eddy-driven SSTA variability is expected to be dominated by space scales of O(100) to O(1000) km and time scales of tens to hundreds of days. The influence of horizontal eddy heat advection is relatively weak in summer when strong solar heating weakens surface horizontal temperature gradients in the mixed layer. At larger space and longer time scales, SST anomalies arise due to processes such as surface heat flux variability and horizontal heat advection by the gyre-scale currents. To determine the usefulness of the COADS and MCSST products for studying the SSTA response to these and other dynamical processes, it is necessary to quantify the accuracy with which these products represent variability at different space and time scales and at different locations in the ocean. A preliminary study designed to address this question was conducted by statistically comparing MCSST and COADS SST maps for the time interval 1984-89. Analyses were performed using SST maps on the 2° COADS grid, which required all available daily MCSST retrievals for a given month to be averaged within 2° boxes to generate the MCSST maps. For both COADS and MCSST, SSTA maps were calculated by removing the 1960-89 mean annual cycle calculated from COADS SST maps.

We first consider the largest (basin-wide) scales. Biases between the two datasets, defined here as COADS minus MCSST SST, axe likely to be a significant problem at these large scales. The mean bias over the 1984-89 time interval has a predominantly zonal banded structure away from boundary current regions (Fig. 1). COADS is warmer than MCSST within the North Atlantic subpolar gyre, is colder than MCSST within the northern and central part the North Atlantic subtropical gyre, is warmer than MCSST throughout the entire tropical Atlantic, is colder than MCSST throughout the central latitudes of the South Atlantic subtropical gyre, and is warmer than MCSST at the southern edge of the analysis domain. Further insight into the nature of these basin-scale biases is gained by contouring the zonally-averaged bias (excluding boundary current regions) as a function of time and latitude (Fig. 1). First, the positive COADS bias in the tropical Atlantic probably results in part from the lingering effects of El Chichón volcanic aerosols during 1984 and most of 1985. Second, a strong annual cycle in zonally-averaged bias exists at some latitudes. North of 40°N, COADS tends to be warmer (colder) than MCSST during boreal winter (summer). Between about 10 and 25°N, COADS tends to be warmer (colder) than MCSST during boreal summer (winter). Between about 20 and 30°S, COADS tends to be colder than MCSST during austral summer, although this is the weakest of the three visually-evident annual cycles. Inspection of 1984-89 mean SSTA maps (not shown) for both the COADS and MCSST datasets reveals that the mean zonal banded structure dominating the COADS minus MCSST bias map in Fig. 1 is present only in the MCSST map. Further, inspection of COADS and MCSST zonally-averaged SSTA contoured as a function of time and latitude over the 1984-89 interval (not shown) reveal that the MCSST maps alone contribute to the annual cycles observed in the bias (Fig. 1). These large temporal changes in SST bias, which will adversely impact studies of SSTA dynamics, are primarily a satellite problem. The annual cycles observed at some latitudes could be due in part to annual cycles in moisture, aerosols, etc., that are not properly accounted for in generating the MCSST product.

Zonal-time spectral analysis is used to assess the accuracy with which both datasets represent SSTA variability as a function of space and time scales. The zonal-time autospectra of COADS and MCSST SSTA at 29°N (Fig. 2, left), a latitude where the MCSST bias annual cycle was small, reveal the dominance of wavelengths exceeding 2000 km, or more than 1/3 of the basin width, in both COADS and MCSST fields. Significant coherence is observed between the two fields at these large wavelengths, especially at periods equal to and exceeding 1 year where the squared coherence is between 0.6 and 0.8. Also evident is the tendency for large energy density to follow the first-mode baroclinic Rossby wave dispersion curve in the MCSST spectrum. This tendency is only slightly evident in the COADS spectrum, but both fields are significantly coherent at wave-numbers and frequencies near the dispersion curve for wavelengths exceeding about 700 km. This signal represents the westward-propagating SSTA variability forced by horizontal heat advection due to baroclinic eddy currents that was documented by Halliwell et al. (1991). The spectra at 29°N were also calculated after removing zonally averaged SSTA at each time (which removes the zero-wavenumber variability) to reduce leakage from these energetic fluctuations (Fig. 2, right). Large-scale variability still dominates, but now this dominance is confined primarily to periods exceeding a few months. The SSTA response to baroclinic eddies is more clearly resolved.

Zonal-time spectra of SSTA (calculated after removing zonally- averaged SSTA at each time) at four other latitudes (Figs. 3 and 4) reveal large changes as a function of latitude, both in the spectral shapes and in the capability of the COADS and MCSST products to resolve SSTA variability. The tropical Atlantic is considered first (Fig. 3). At 15°N (Fig. 3, left), both the COADS and MCSST autospectra are approximately white at large scales and low frequencies in contrast to the corresponding autospectra at 29°N (Fig. 2, right). Also, little coherence is observed between the two fields at 15°N. These observations suggest that the signal-to-noise ratio is poor for both datasets. The noise level at 15°N is about equal to the noise level present in the 29°N spectra (estimated as the relatively flat energy levels present at large frequency and wave-number). The difficulty in detecting large-scale SSTA variability at 15°N is thus due primarily to the relatively weak anomaly signal present at this latitude. At 1°S (Fig. 3, right), large-scale, low-frequency SSTA variability is detected in the MCSST field, but not in the COADS field. The noise level in the COADS spectrum is one order of magnitude larger than the noise level in the MCSST spectrum, and it is one order of magnitude larger than the noise levels present in all spectra at 15°N and 29°N. The significant coherence that exists for large-scale, low-frequency anomaly variability at 1°S indicates that this signal is present in the COADS field. However, the high noise level prevents the large-scale, low-frequency peak from being detected in the COADS spectrum.

Considering the subtropical South Atlantic, noise in the COADS spectrum is as large at 23°S (Fig. 4, left) as it is at 1°S. However, since large scale SSTA variability at interannual periods is an order of magnitude more energetic at 23°S, the spectral peak is detectable in the COADS spectrum. The MCSST spectrum is substantially more red than the COADS spectrum over most of wave-number-frequency space due to the lower noise levels present in this dataset at this latitude. Some significant coherence between COADS and MCSST anomalies is present at long wavelengths, both at interannual periods and at periods between 4 and 6 months. At 35°S (Fig. 4, right), the magnitude of SSTA variability is much larger, exceeding the magnitudes observed at 29°N. This leads to an improved signal-to-noise ratio in both datasets as revealed by the greater similarity in spectral shapes and the relatively high coherence at large wavelengths.

The present analysis has succeeded in highlighting some of the problems present in COADS and MCSST SST fields that will impact studies of the dynamics of SSTA variability in the Atlantic Ocean. At basin-wide scales, large time-dependent biases present in the MCSST product are a very significant problem. One source of this problem is volcanic aerosols that can persist for at least 2-3 years. Also, a large annual cycle in the MCSST bias is present in some latitude bands. At space scales smaller than basin-wide, the primary problem is the high noise levels present in the COADS dataset at some latitudes, presumably arising from poor sampling in some regions of the ocean. This is a particularly bad problem in the tropical Atlantic where SSTA variability is not as energetic as in other regions. In the subtropical Atlantic, an eddy-forced SSTA response was detected. by both datasets, although marginally by the COADS dataset. Substantially improved COADS and MCSST datasets will become available in the near future; repeating the tests described here will quantify the degree of improvement and identify the limitations of both datasets for planned studies of SSTA variability in the Atlantic.

References

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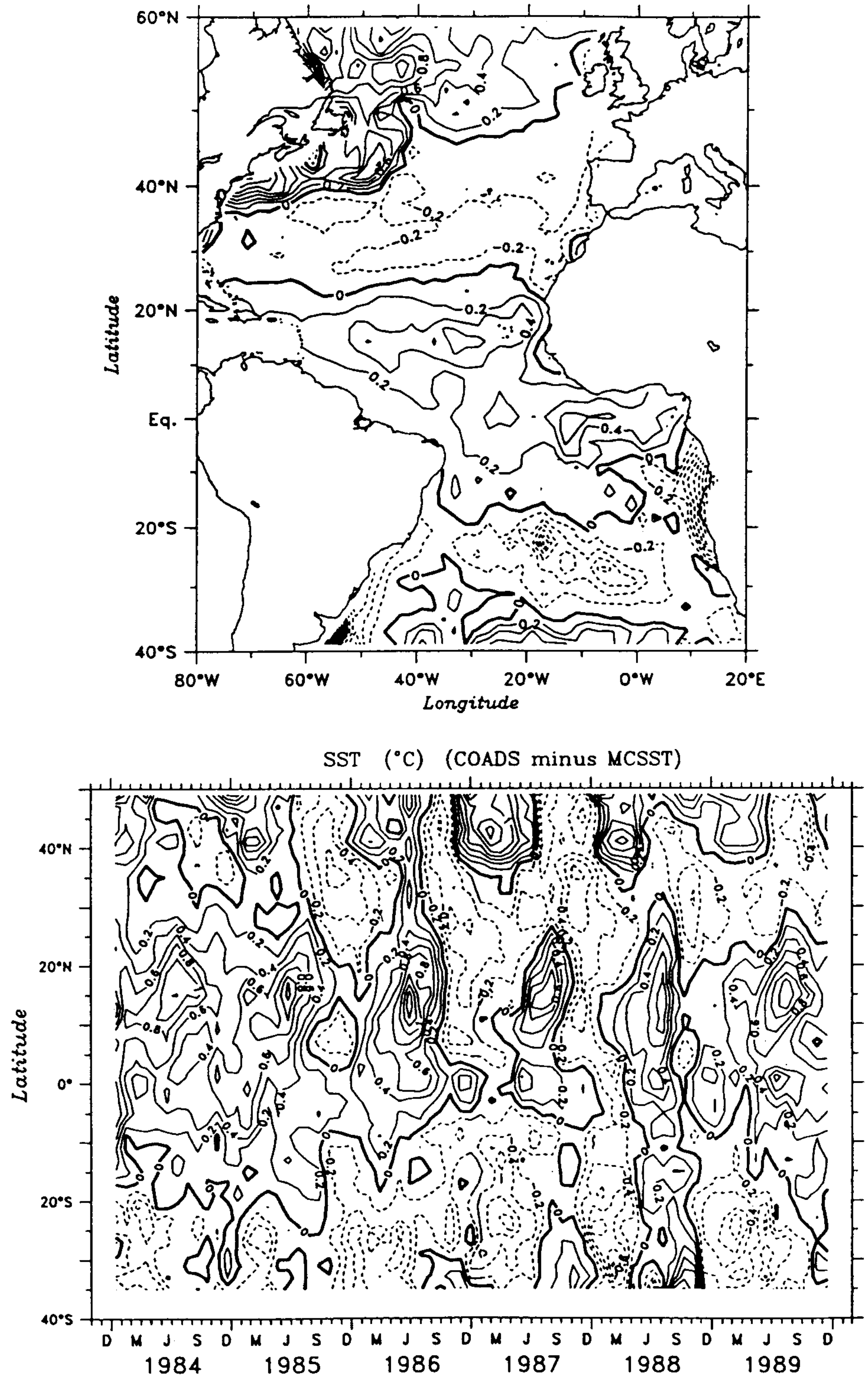

Figure 1. Mean SST bias (COADS minus MCSST) over the 1984-89 time interval (top). The temporal variability in the zonally-averaged SST bias over the same time interval (bottom).

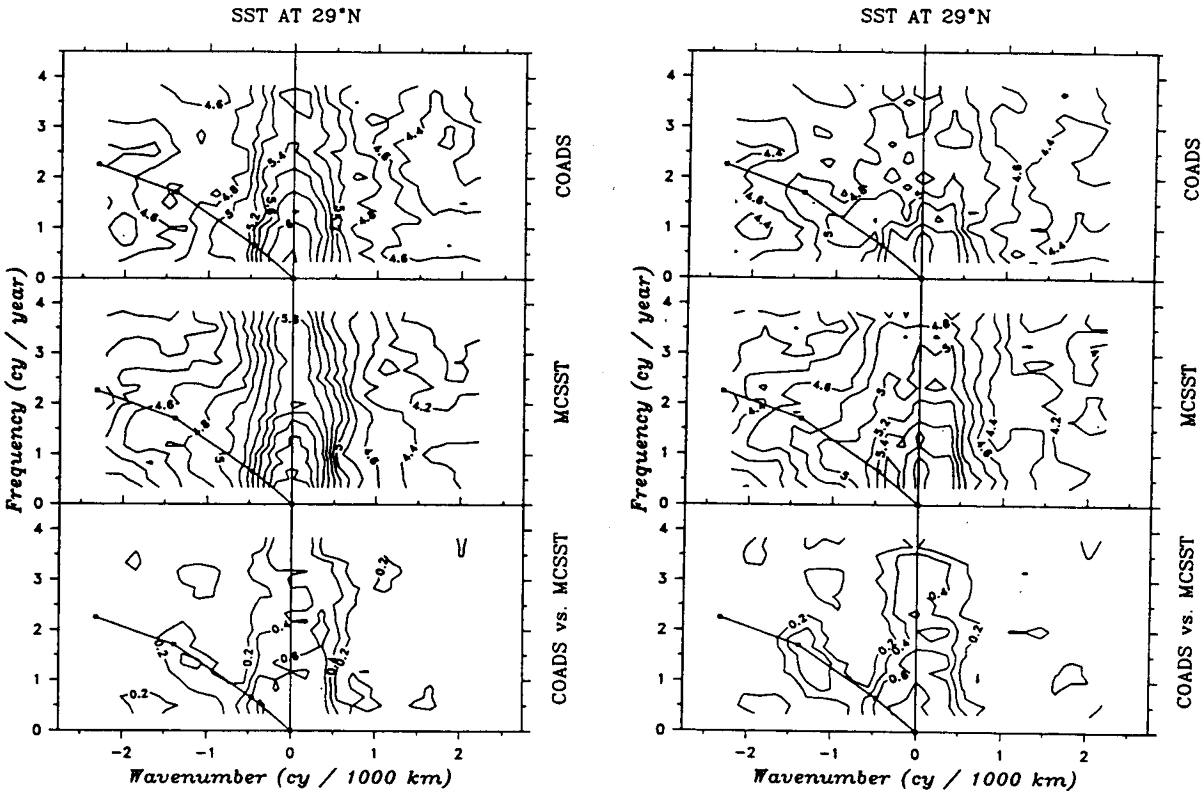

Figure 2. Zonal time autospectra of COADS and MCSST SSTA variability (top and middle) and the squared coherence between them (bottom) at 29°N. The base-10 logarithm of energy density is graphed for these and subsequent autospectra. The autospectra and squared coherence graphed on the left (right) side were calculated without (with) zonally-averaged SSTA at each time removed.

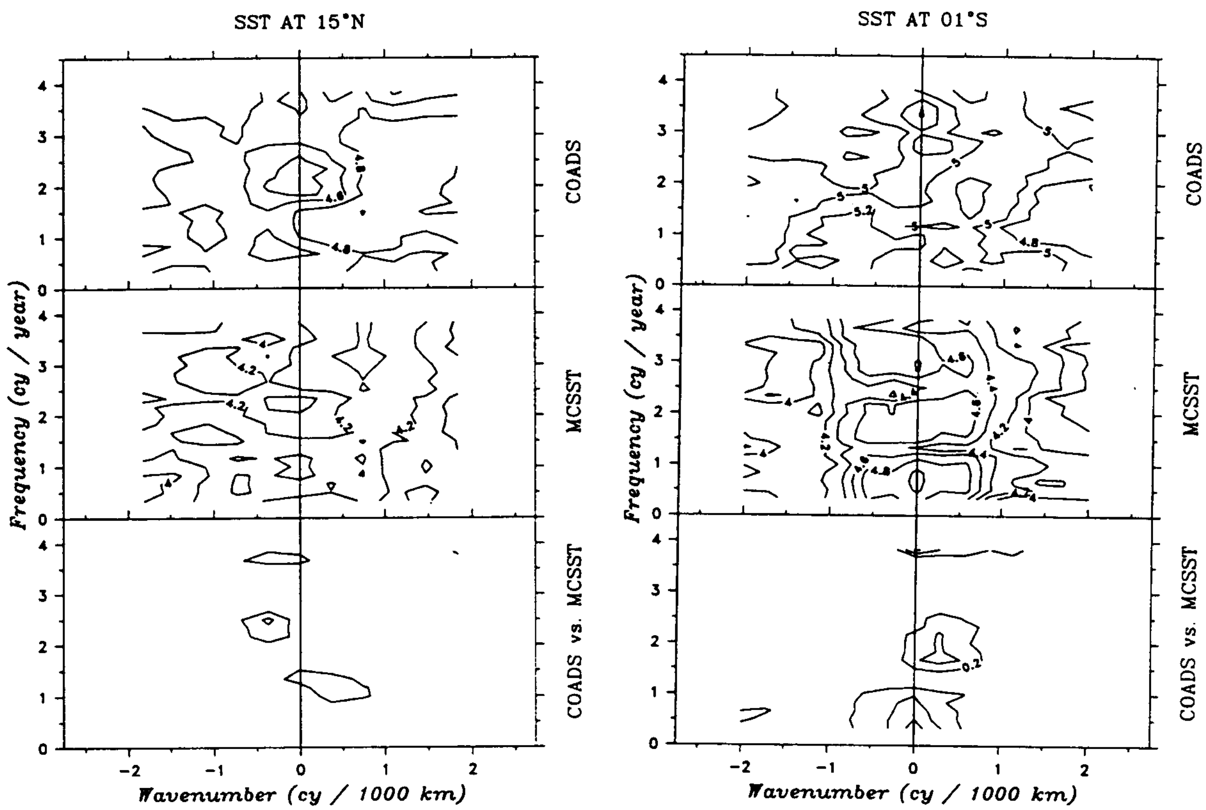

Figure 3. Zonal time autospectra of COADS and MCSST SSTA variability (top and middle) and the squared coherence between them (bottom) at 15°N (left) and 1°S (right). These functions were calculated with zonally-averaged SSTA at each time removed.

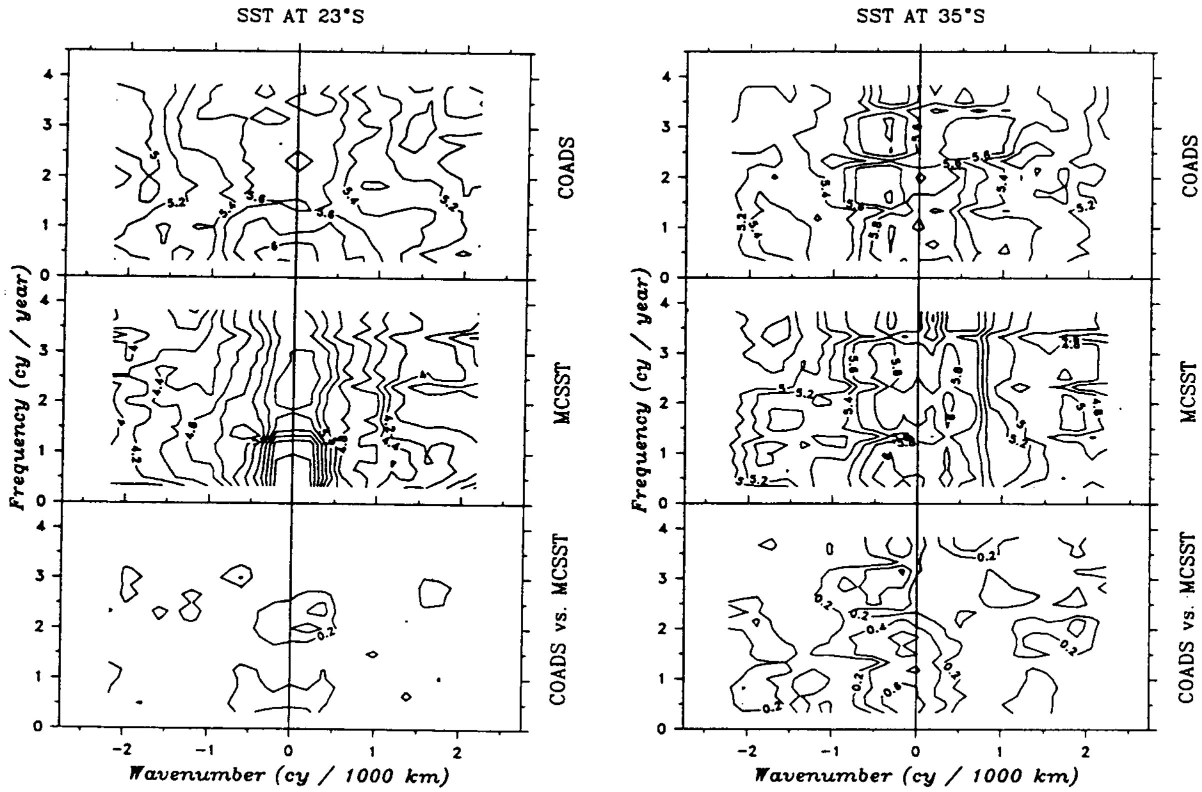

Figure 4. Same as Fig. 2, for 23°S and 35°S.