Intercomparison of the Characteristics of 6-year SMMR-SST and SHIP-SST Variations as Identified by Cross-Spectrum Analysis

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Abstract

The 6 years (1/79 to 12/84) SMMR (Scanning Multichannel Microwave Radiometer) and ship observed zonal monthly SST (Sea Surface Temperature) time series of 60 S to 60 N are used in the cross-spectrum studies. The parameters, which have been computed, are power spectral density (PSD) of time series, Coherence Square, admittance, amplitude, and phase relationship between two time series. The Fast Fouries Transform (FFT) is used to obtain the PSD as a function of the selected frequency interval.

The Coherence Square was tested for the statistical significance. The results illustrate that the variations of annual cycle and semi-annual cycle are above 95% significant level. The amplitude and phase relationships of these seasonal variations are discussed. Other amplitude variations of long period (or linear trend) are also given.

The latitudinal variations of both data are analyzed in this report. It also presents the variation results of SMMR-SST in comparison to the results of SHIP-SST.

It is well known that SST is one of the key parameters to be produced in EOS (Earth Observation System) and NPOESS (National Polar-orbit Operational Environmental Satellite System). The In-Situ data set of ATLAS8 (a set of SST data in monthly 1 degree and 5 degree area grids – 1856 to 1995) is also available in the JPL/NASA Physical Oceanography DAAC. In the future, a detail spectrum analysis of this 20th century SST or other geophysical data set, with FFT in comparison to Wavelet Transfer, will be very useful and significant contributions to the global change studies.

I. Data and Procedures

The six years monthly time series (January 79 to December 84) of derived SMMR and observed by ship data was obtained from SMMR SST processing group. The reason for selecting this time period is to maintain the same regression retrieval from SST of SMMR. A slight modification was used in the derived SST of SMMR after January 85 retrieval data.

The size of ship's data sample of every 10 degrees latitude is reasonably good except at 60 S and 60 N. At these highest latitude ship-data, the sample sizes were too small for some months and also for some months were missing (January, February, March and April, 1983 at 60 N).

Our objective of this study is to examine the relationship between the variations of equatorial SST and other latitudes (latitudial variation of SMMR SST and SHIP SST). It also is used to check the differences between SMMR and SHIP time series data. A cross-spectral technique is used to determine where these variations are related or to explain the cause of these variations. The relationship can be tested by an evaluation of the coherence square as a function of frequency band between two spectra of the time series. The statistical significance of the coherence square was tested by a method given in Panofsky and Brier (1958) and clarified by Julian (1975) and used by Oltmans and London (1981) and others.

The procedures of the cross-spectral method are same for given two time series, therefore, these steps are summarized below for SST time series :

1. Compute cospectrum and quadrature spectrum from two time series, The unit DB-Log10 (power) is used.
2. Use fast Fourier transform (FFT) to obtain the power spectral density (PSD) as a function of the frequency band from method of Welch (1967), Jenkins and Watts (1968), and Agnew (1979). The PSD is obtained for time series 1 and 2. It should be noted that because of restrictions in FFT used, the length of time series must be a highly composite number.
3. The power spectral density can be expressed as _ A**2 T, where A is amplitude and T is the record length of time series (e.g., Panofsky and Brier, 1958; Agnew, 1979). Hence, from known power spectral density and record length of time series, one should be able to calculate the amplitude "A" for each desired frequency.
4. In this paper, the PSD of time series one, the PSD of time series two, coherence square, admittance (square root of ratio of two time series PSD), phase relationship, and the amplitude of time series 1 and 2 are calculated for each frequency band.

5. The width of frequency band (dF) depends on the section length of time series. To maximize the use of the available data (1/79 to 12/84; six year total length), 60 months of section length is selected. This selection frees the restrictions in the FFT used and obtains the desire frequency cycle (i.e., annual cycle, 1 cycle/year; semi-annual cycle, 2 cycle/year; etc.).
6. From 60 months section length of time series, the Nyquist frequency or last frequency, FN can be calculated as _ dt = 6 cycle/year. Where data time interval (dt) equals to one month in this study. The width of frequency band dF = 0.2 cycle/year (i.e., 0.2, 0.4, 0.6, ..., 5.6, 5.8, 6.0 cycle/year).
7. The amplitude of annual oscillation can be represented by the amplitude of 1 cycle/year. The amplitude of semi-annual oscillation is the amplitude of 2 cycle/year. The quasi-biennial-oscillation (QBO) can be obtain from amplitude of 0.4 and 0.6 cycle/year (30 months and 22 months period). The linear trend of the time series may be approached from longest period of the section length frequency (0.2 cycle/year).

II. Sample Results

The detail results or conclusions will be discussed in the COAA 2000 Second Conference. Here just shows the annual oscillation amplitude and phase relationship for SMMR and SHIP results from 60 S to 60 N. (See Figures 1 and 2). A complete report of this study is also available given in Cheng (2000).

III. Future Studies

From above studies and in addition with available 100 years of Global SST data through JPL Physical Oceanography DAAC, many characteristics of the spectral results can be analyzed in the future. A few examples are listed below.

1. The SMMR (or other sensors) SST stepwise regression retrieval will be improved if it separates to obtain the regression coefficients for low-latitudes (< 45 degree) and high-latitudes (> 45 degree).

2. Detect bias from various period of data archived by different observing systems / instruments (sensors) / algorithms.

3. Derive the yearly annual amplitude and in comparison with long-term changes (e.g. each decade to century) – One should be able to answer such that the temperature (SST) is warming and also extreme temperature (summer is hotter and winter is colder) is happening etc.

4. Study the relationship / connection between SST and other geophysical parameters (e.g. rainfall) or atmospheric & oceanic events (e.g. hurricanes, El Nino, La Nina etc).

5. Aside from seasonal (mainly semi-annual and annual) variations, quasi-biennial oscillations (QBO, 20 to 28 months), southern oscillations (3 to 5 years period) – Any effects by sun spot activities (11 years period), ocean tide epoch (19 years period) or others.

6. Intercomparison the spectral characteristics difference between FFT – linear frequency and Wavelet Transfer – non-linear frequency.

IV. References

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Figure 1. The SMMR and SHIP Equator annual phase lag from other latitudes

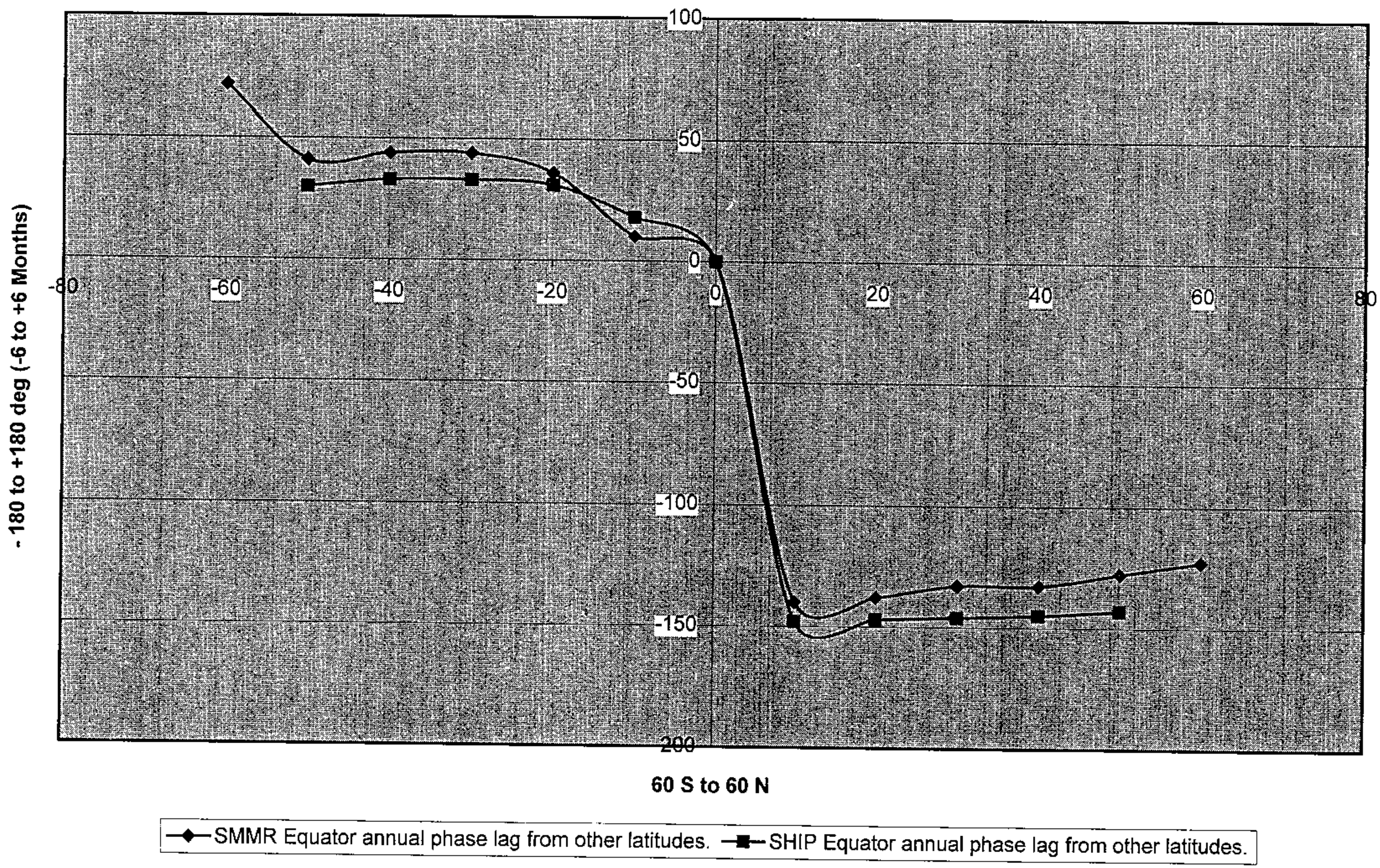

Figure 2. The latitudinal annual amplitude distribution for SMMR and SHIP