15.7a INTERANNUAL VARIABILITY OF TROPICAL DIURNAL SST VARIABILITY

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1. INTRODUCTION

Variability in sea surface temperatures (SSTs) in the tropical oceans is fundamentally coupled to variations in convection and cloud-radiation feedbacks. Numerous studies have documented the importance of several modes of SST variability in the Pacific, such as the ENSO cycle and its relationship to convection both locally and extratropically (e.g. Webster and Lukas, 1992; McPhaden et al., 1998). Interannual SST variability in the Atlantic, associated with ENSO (e.g. Chang et al. 1997), the so-called Atlantic dipole (e.g. Huang and Shukla, 1997), and equatorial warm events (Chang et all. 1997) are coupled with changes in the location of the ITCZ, which in turn affects rainfall over Africa (Wagner and da Silva, 1994). Tropical Indian Ocean SST variability, while varying with ENSO patterns, also exhibits a dipole behavior (e.g. Feng and Meyers, 2003) and has a strong seasonal behavior associated with the monsoons. For all of these time scales, SST can affect rainfall and convection in the Indian Ocean region (Perigaud et al., 2002).

Satellite skin SSTs provide useful spatial and temporal coverage when it comes to these studies. However, SST data sets obtained from satellite radiances are typically averaged to daily or weekly composite maps. This averaging removes the variability of the diurnal SST, or, if a preponderance of data is used from a particular time of day, biases the mean SST by not including the diurnal variability. In the tropics, the diurnal range in SSTs can have a significant magnitude of up to 3 °C or more (Fairall et al., 1996). To put this value in context, it should be noted that variations in the tropical western Pacific between El Niño and La Niña are on the order of 1 ^{o}C, It has also been shown that a 1°C error in the measurement of skin SSTs can lead to a 27 W m^{-2} error in the net surface heat flux in the tropical western Pacific (Webster et al., 1996).

One particular problem in developing a SST dataset that resolves diurnal change is how to obtain the amplitude of the diurnal cycle. An equation was developed to compute the amplitude of the diurnal change in skin SST, referred to here as dSST (Webster et al., 1996). This equation uses values of the magnitude of the peak solar insolation, the cumulative amount of daily precipitation, and average daily wind speed to compute the dSST.

Clayson and Curry (1996) have used this equation to develop a method for determining the diurnal SST cycle and this method has been applied to data obtained by the International Satellite Cloud Climatology Project (ISCCP) and Special Sensor Microwave/Imager (SSM/I) data to produce a daily diurnal variation in SST database for the global tropics during the years 1996-2000. This database represents a new way of studying variability of the upper ocean over many spatial and temporal scales.

This study will explore the variation of the dSST through empirical orthogonal function (EOF) analysis in the tropical ocean basins for the years mentioned. The dSST values examined will only take into account solar insolation and wind speed, since precipitation data is not yet available. Comparisons between the years will be shown to see how this variability changes climatologically. Certain regions will be focused upon such as the tropical Pacific to examine ENSO effects and the Indian Ocean for monsoon variability.

2. DATA AND METHODS

2.1 Data

Solar insolation data was obtained from ISCCP at 3 hour intervals and was at a 0.5 x 0.5 degree resolution. Winds were obtained from the Wentz SSM/I wind speed data set and also had a spatial resolution od 0.5^{o} x 0.5^{o}. Missing values were spatially interpolated and the wind speed was averaged for the day. Both the wind and solar insolation data was obtained for the period starting at 01 January 1996 and ending on 31 December 2000. Pre-dawn values of SST were retrieved from the ISCCP SST dataset (Rossow and Zhang, 1995). Comparisons of the dSST dataset with in situ measurements during the TOGA COARE period showed an average bias of 0.13 ^{o}C, a standard deviation of 0.31 ^{o}C, and a correlation of 0.85. Data were obtained from the Nauru '99 field study for comparisons. The data for the Nauru '99 cruise was collected from 15 June 1999 to 18 July 1999. dSST values from our current data set were compared to the ship values, and biases of under 0.1 ^{o}C, with standard deviations of 0.2^{o}C, were observed.

2.2 Method

Once the daily dSST files were created for the entire 1996 – 2000 period, a subset of the files were made for the Indian, Atlantic, and Pacific Ocean. An EOF analysis was run on the dSST data to determine its

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temporal and spatial variability. This produces an orthogonal spatial pattern called an eigenvector and a principal component time series for each mode. The modes are placed in order of the variance they explain. So, for example the first mode explains the greatest amount of variance in the data, the second mode describes the second greatest amount of variance in the data, and so on. Physical explanations for each mode had to be determined through visual analysis of the spatial patterns associated with their principal component time series.

3. ANALYSIS

3.1 Tropical Pacific

After performing an EOF analysis on the tropical Pacific region (120E-80W) it was found that the first mode could only explain 9% of the total variance in the diurnal amplitude of SSTs. Also, the first three modes combined could only explain about 18% the total variance. The reason for these small values is due to the large area examined and the many geophysical processes that are occurring at such high resolution.

Regardless of these numbers, there were interesting patterns that came out of the first modes. The first spatial eigenvector relating to the first mode is shown in Fig. 1. Here it is noticeable that negative weights dominate the Southern Hemisphere (SH) and positive weights dominate the Northern Hemisphere (NH). When the first spatial eigenvector is compared to its corresponding principal component time series (Fig. 2) it is apparent that this mode is related to the annual cycle of solar radiation. (All other images for the following modes discussed will be included in the poster but not this manuscript.) In the NH winter solar radiation is more direct in the SH and therefore leads to a greater increase in daily SSTs then in the NH. In the NH summer this pattern is reversed.

The second mode, which accounts for 5% of the variance, has an eigenvector spatial pattern showing positive weights in the central west pacific warm pool region and negative weights in the central east pacific cold tongue. The corresponding principal component time series also shows an annual cycle in this spatial pattern with mostly negative time coefficients in the first 6 months of the year and positive time coefficients in the last 6 months of the year.

3.2 Tropical Atlantic

Percentage of variance explained improved slightly in the Atlantic (80W-20E) with the first mode explaining 13% of the variance and a cumulative value of 23% in the first three modes. Obviously, there are still many processes in this large area that are influencing variability in dSST.

The first mode in the Atlantic is similar to the first mode in the Pacific in that it shows an annual cycle in dSST variability due to the solar insolation cycle. The second and third modes (6 and 4 percent of the variance respectively) are slightly more complex in their spatial eigenvectors and principal component time series. Throughout the first three modes it is apparent in the eigenvector spatial patterns that there is much variability in dSST off the African coast of Guinea, Sierra Leone, and Liberia.

3.3 Indian Ocean

The first EOF mode in the Indian Ocean (30E-120E) explained 17% of the variance, which was the best out of all three basins for the first mode. However, the first EOF eigenvector spatial pattern did not resemble that of the previous first mode patterns displayed in the Pacific and Atlantic. In those oceans negative weights dominated north of the equator and positive weights dominated the south showing the annual cycle of solar insolation. In the Indian Ocean almost the entire basin is dominated with positive weights in both NH and SH, with high variability in the Arabian Sea and Bay of Bengal. The first mode's associated principal component time series shows an annual cycle with mainly positive time coefficients in the NH winter and spring months and negative time coefficients in the summer months. This mode is most likely showing the variability due to the Indian monsoon.

The second mode (7% of the variance) shows the annual cycle of solar insolation with a spatial pattern and time series similar to the first mode of the other ocean basins. The third mode has a noisy principal component time series, but the eigenvector spatial map has a well defined pattern of strong negative weights directly east of the Somalian coastline and strong positive weights west of Sumatra. This mode explains only 4 percent of the variance, giving a cumulative total of 29 percent of the variance being explained by the first three modes.

4. SUMMARY

Using a new equation, formulated by Webster et al. (1996), to determine the amplitude of the diurnal change in SSTs a new dataset with these dSST values covering the tropical oceans from 1996-2000 was created. To examine the variability of the dSST for these years an EOF analysis was performed for the tropical Pacific, tropical Atlantic, and Indian Ocean basins. It was found that when looking at these large regions and with high resolution data of 0.25 x 0.25 degrees the first three modes could not explain a large amount of the variance.

The physical processes affecting the first few modes in each basin varied. The first mode in the Pacific and the Atlantic was due to the annual cycle of solar insolation, while the first mode in the Indian Ocean was due to the monsoon in this region. The second mode in the Indian Ocean matched more closely to the annual cycle in the first mode for the Pacific and Atlantic. The second mode in the Pacific showed a pattern of high variability in the warm west Pacific warm pool and cold tongue of the eastern Pacific. In the Atlantic the second mode was more difficult to explain from its spatial pattern and noisy time series. Mode 3 in all oceans became increasingly difficult to explain due to their noisy time coefficients and complex eigenvector spatial patterns.

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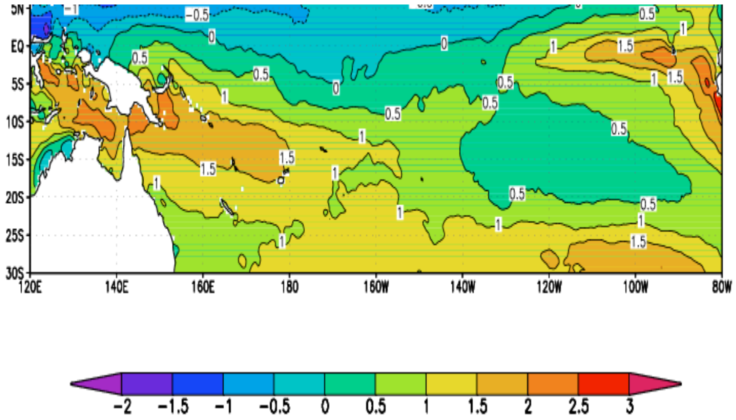

Figure 1. Spatial Eigenvector for Mode 1 of the Tropical Pacific

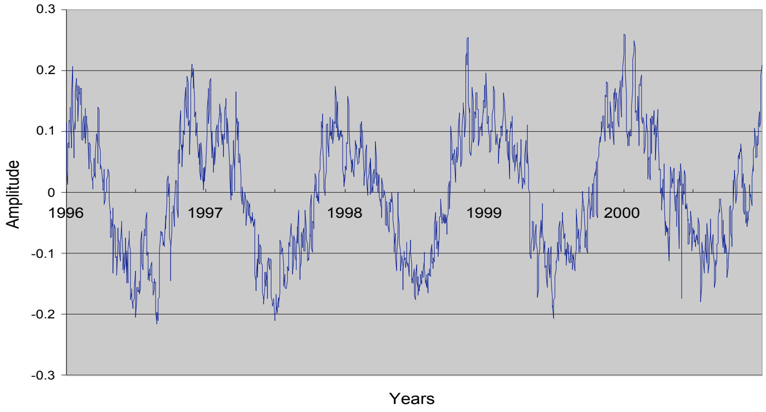

Figure 2. Principal Component Time Series for Mode 1 of the Tropical Pacific.