Internal Variability of the Atlantic and Pacific Oceans

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1 Abstract

A 40 year integration of an eddy resolving numerical model of the tropical Atlantic and Pacific is analyzed to quantify the interannual variability that is caused by internal variability of ocean dynamics. For the Atlantic, it is found that, except for the spring position of the SST maximum, the strength of internal variability in the tropical Atlantic is comparable to published mid-latitude values but is dwarfed by the strength of the seasonal cycle. During spring however, the equatorial meridional SST gradient is very weak, and internal oceanic variability causes a variability in the position of the SST maximum that is comparable to its observed variability. It is shown that these variations in the SST are due to Tropical Instability Waves (TIWs) whose strength varies from year to year, even under climatological forcing. The results suggests that in winter, the predictability of the location of the tropical SST maximum is limited to the persistence time of SST anomalies which is approximately 100 days.
The results are similar for the Pacific, where the TIWs are even stronger and the SST anomalies project directly on the zonal SST gradient. This suggests that interannual SST anomalies that are caused by aperiodic TIWs can influence or precondition an El Niño event and limit its predictability to the persistence time of SST anomalies which is approximately 100 days.

2 The Mechanism

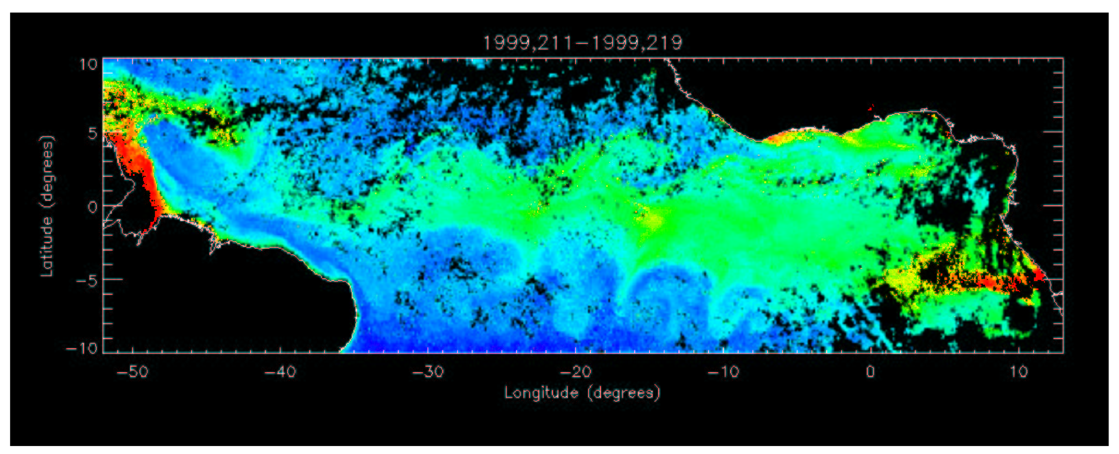

Figure 1: TIWs as seen in the Atlantic by SeaWiFS (courtesy of M. Uz). Note the cusps in ocean color along 4^oS and 4^oN.

A review of the observations shows that in both oceans the TIW energy is centered around the equator and is largely confined to the upper thermocline in the eastern part of the tropics (Weisberg and Weingartner (1988); Chelton et al. (2000)). Their periods are approximately one month, their wavelength between 600km and 1200km. Due to their nonlinear generation mechanism (instabilities of the zonal currents), their strength can vary from year to year even under constant forcing (Jochum et al. (2004)). This means that, because they are a major contributor to the equatorial mixed layer heat budget (Hansen and Paul (1984)), the annual mean SST also differs from year to year. Here this effect is quantified and put in relation to the observed interannual variability.

3 The Equatorial Atlantic

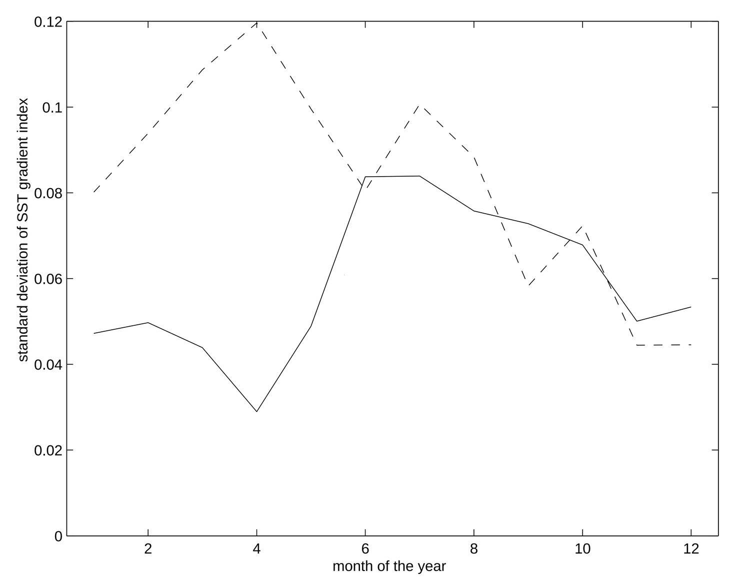

Figure 2: The seasonal cycle of the standard deviation of the SST gradient index in the Atlantic for the observations (dashed line) and the internal variability from the model (solid line). The index is here computed as the difference between the zonally averaged (35^oW to 15^oW) SST between the equator and 1^oN and the equator and 1^oS.

Interannual variability in the tropical Atlantic is usually captured by two different indices: the Atlantic Niño and the Gradient Index. While internal variability explains not more than 10% of the observed variability of the Atlantic Niño, the figure demonstrates that it explains a substantial part of the variablity in the Gradient Index: for the narrow strip between 1^oN and 1^oS it accounts for all the observed interannual variability from summer to winter and about half of it during spring (see Figure 2). The respective values for the domain between 5^oN and 5^oS are 50% and 15%.

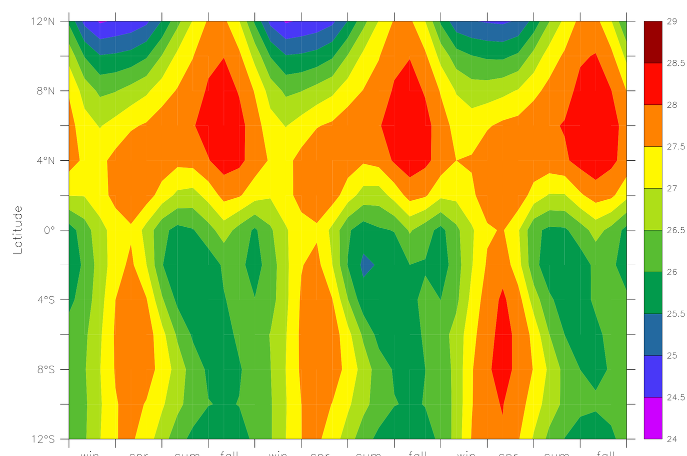

Figure 3: 3 years of SST averaged from 35^oW to 15^oW. Note the strong SST gradient around the SST maximum at 6^oN during summer and the weak gradient during spring, especially the reversal of the SST gradient in the third spring.

Although the relative importance of the internal variability seems to be smaller in spring because of the weaker TIWs, it is most important then because of the weak SST gradients in spring. Small changes can lead the cross equatorial SST gradient to reverse during spring with potentially dramatic impacts on the ITCZ position.

4 The Equatorial Pacific

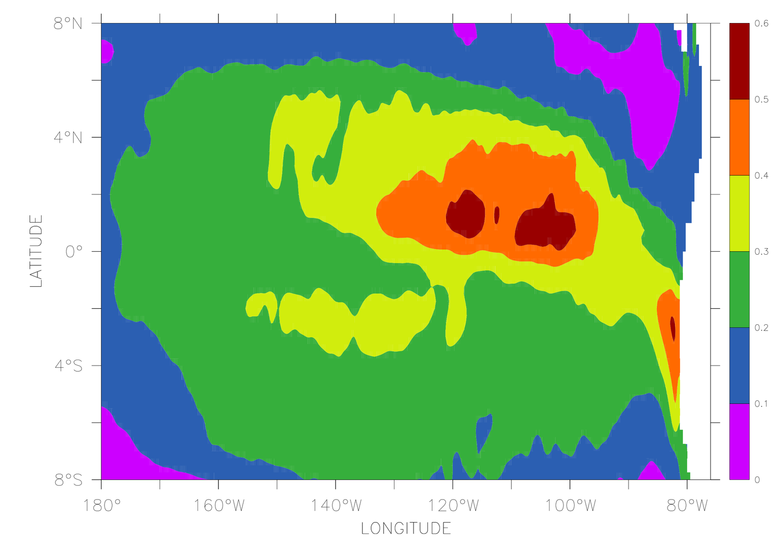

Figure 4: Standard deviation of interannual SST in the Pacific ocean.

The effect of the TIWs on the interannual SST variability is even larger in the Pacific. This is because the TIWs are stronger than in the Atlantic and they are operating on a twice as large meridional SST gradient. Near and in the equatorial cold tongue the interannual variability due to TIWs accounts for 40% of the observed variability, a large number given that the observed signal is dominated by positive ocean-atmosphere feedbacks (ENSO). The internal oceanic variability is a source of stochastic noise which as large as the one of westerly wind bursts.

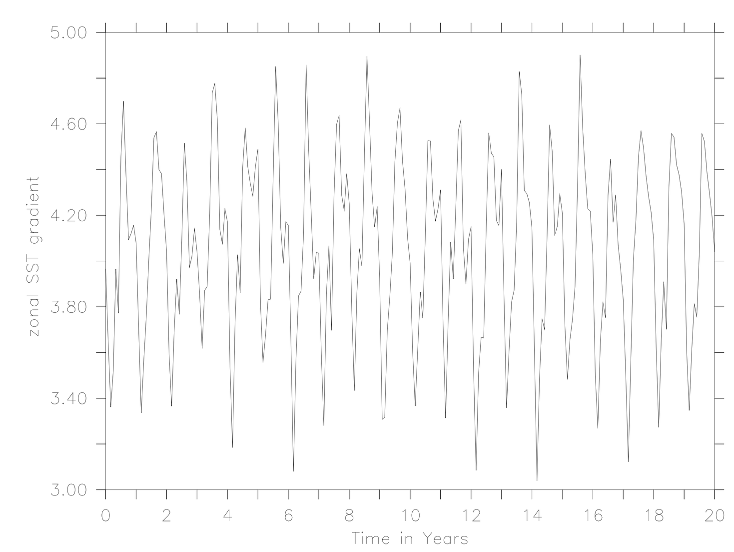

Figure 5: Difference between the western basin SST (averaged from 3^oS - 3^oN and from 160^oE - 160^oW) and the eastern basin SST (averaged from 3^oS - 3^oN and from 160^oW - 90^oW).

The effect of this internal variability on the zonal SST gradient looks rather small compared to the mean, but it should be noted that the internal variability can substantially affect the seasonal cycle of the gradient (Figure 5). During spring the SST gradient is weakest and favors the development of El Niño (Zebiak and Cane (1987)). At this time, the east-west SST difference can be anywhere between 3 K and 3.6 K, simply because of internal variability.

5 Summary

Due to their nonlinear generation mechanism and their large contribution to the equatorial mixed layer heat budget, TIWs in the Atlantic and Pacific cause significant *interannual* SST variability. Thus, TIWs have to be considered as a major source of stochastic noise that projects on the meridional mode in the Atlantic and the zonal mode (El Niño) in the Pacific. This could limit the predictability for tropical climate to the persistence time of equatorial SST anomalies which is approximately 100 days.

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