Decadal Variability in the South Atlantic Ocean

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1 Introduction

The South Atlantic Ocean plays a crucial role in the global Thermohaline Circulation as it transports large amounts of heat and salt towards and across the equator. Changes in the composition and thus the buoyancy of South Atlantic waters can affect the Atlantic Thermohaline Circulation (Weijer et al. 2001). It is therefore interesting to search for the origin of anomalies in South Atlantic water mass characteristics.

The South Atlantic Ocean receives large amounts of warm and salty water from the Indian Ocean via the so-called Agulhãs leakage, the *warm water path* of Gordon's (1986) Global Conveyor Belt. This water than flows northward along the coast of Africa as the Benguela Current, crosses the Atlantic south of the equator and enters the Northern Hemisphere along the coast of Brazil. Cold water enters through Drake Passage (*cold water path*) and flows northward along the coast of South America as the Falkland or Malvinas Current. At about 45°S, the Confluence region, it encounters the southward flowing Brazil Current and is deflected eastward. It finally reaches the area near the southern tip of Africa, where part of it branches directly into the Benguela Current (de Ruijter et al. 1999).

2 Method and Results

Both the warm and the cold water path thus come together near Cape Town. This is the key region to investigate origin and destination of water mass anomalies. To do so I define an index time series from the SST anomaly in this region (average over 10-18°E and 26-34°S) and correlate it backward and forward in time (i.e., at respectively negative and positive lags) with SST anomalies. This approach follows the one used by Sutton and Allen (1997) to track North Atlantic SST anomalies.

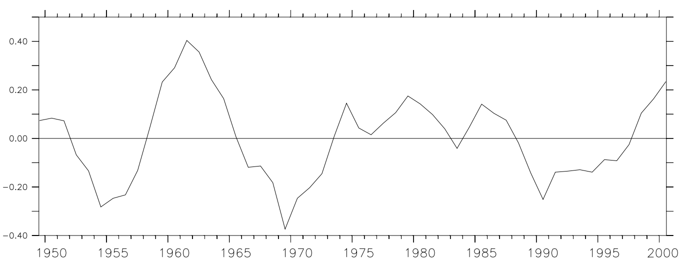

Figure 1: NCEP/NCAR SST anomalies averaged over 10-18°E and 26-34°S (1949-2000).

The SST product used is the one that entered the NCEP/NCAR reanalysis (Kalnay et al. 1996) as the lower boundary condition. It is available for the period 1949-2000. After removing the annual cycle and a linear trend, (austral) winter means (May-September) were calculated and smoothed by a five year running mean. This heavy filtering ensures that only decadal scale fluctuations remain. The resulting index time series is shown in Figure 1. It is characterized by large anomalies before approximately 1970, followed by a nearly constant period until about 1990, after which anomalies get larger again. This time series is significantly correlated with the time series of the third EOF of SST anomalies over the South Atlantic (50-0°S, 70°W-20°E). The EOF pattern resembles that of the correlation pattern at zero lag (see below). The third EOF explains nearly 16% of the variance.

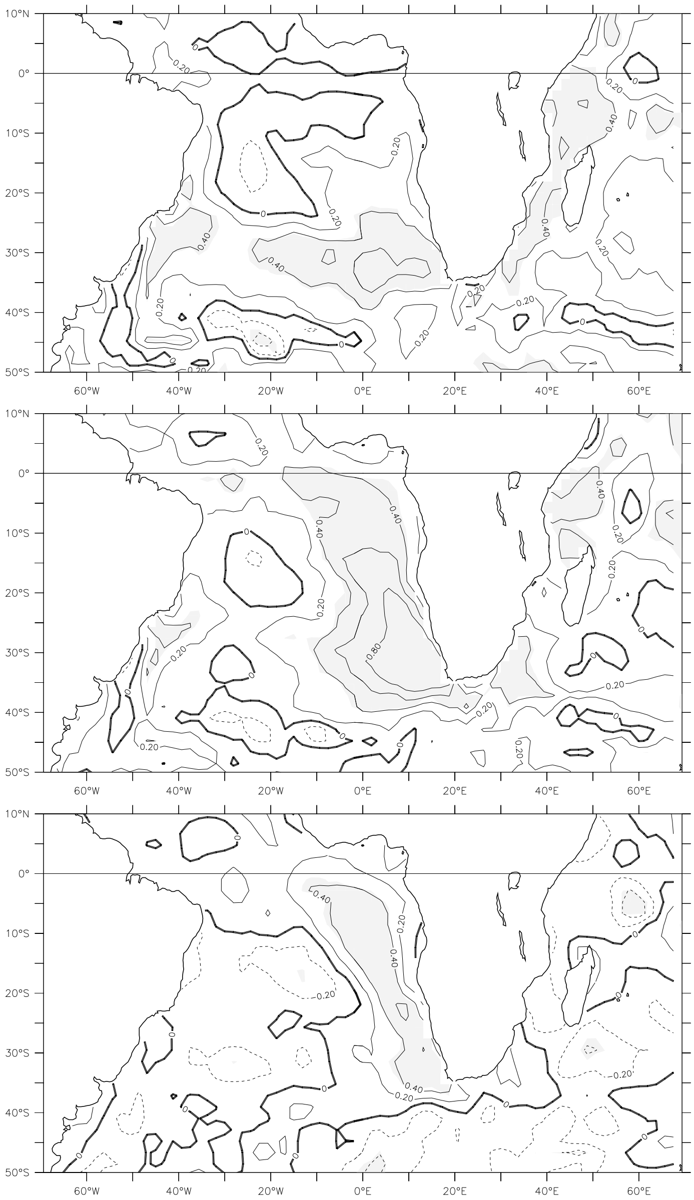

Figure 2: Correlation between index time series (Figure 1) and SST anomalies at lag -2 (upper panel), 0 (middle), and +2 (lower). Lag is positive when index time series leads. Shaded areas indicate significance exceeding 99%.

The correlation of the index time series with SST for three different lags is shown in Figure 2 (lag positive if index time series leads). At lag 0 (middle panel) a large area of positive correlation following the path of the Benguela Current can be seen. At negative lags (upper panel) high correlations are found to the west of the index region and along the coast of East Africa. Inspecting a range of negative lags (not shown) reveals that the area of positive correlation in the South Atlantic starts to appear at approximately lag -5 (i.e., about five years before it peaks in the index region) in the Confluence region. Subsequently, it travels eastward and develops into the large area of positive correlation shown in the middle panel. At the same time the area of positive correlation in the Indian Ocean moves towards the tip of South Africa. It is, however, difficult to decide whether it really enters the South Atlantic or whether it is reflected into the Indian Ocean in the Agulhãs Retroflection Zone, as the regions of positive correlation in both ocean basins are always separated by a small area of near zero correlation. At positive lags (lower panel), i.e., after the peak in the index region, the area of positive correlation fades away in the Benguela Current.

3 Discussion and Conclusions

From this analysis the following picture emerges. SST anomalies originate in the Confluence region from where they spread eastward until they span the whole basin. In the region near South Africa (our index region) they may or may not be amplified by anomalies entering the South Atlantic from the Indian Ocean. The Benguela Current subsequently transports the anomalies northwestward into the tropical Atlantic. In this picture the cold water path plays an important role, at least for the spreading of SST anomalies.

The index time series (Figure 1) displays some oscillatory behavior, at least during its first half. It is therefore not surprising that the positive correlations discussed above are preceded and followed by negative correlations at lags around ±10. However, the length of the time series (52 years) is too short to confidentially identify oscillations with such a long period.

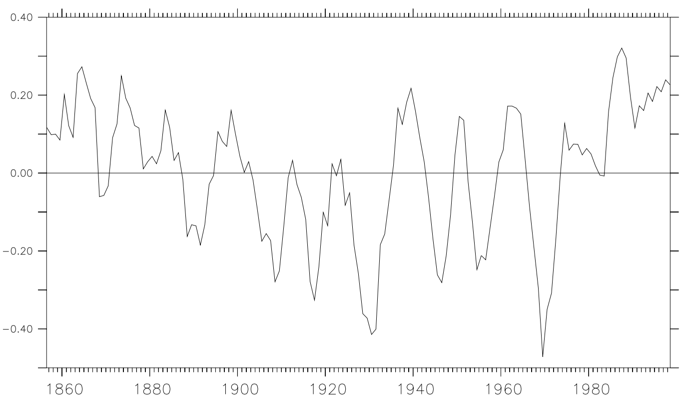

Figure 3: Kaplan SST anomalies averaged over 10-18°E and 26-34°S (1856-1998).

To overcome this problem I tried to reproduce the results using the Kaplan (1998) reconstruction, which covers a much longer period. Although the corresponding index time series (Figure 3) clearly oscillates with a period of approximately 12 years, the correlation plots (not shown) do not display any significant negative correlations. Furthermore, the spreading path identified above from the NCEP/NCAR data is not reproduced. Instead, a clear connection with the Indian Ocean is found. However, the Kaplan dataset has a resolution of only 5°lat/lon, compared to 1.875°for the NCEP/NCAR data set, so that the narrow currents around South Africa are not adequately resolved. This resolution problem may also cause the spreading path across the South Atlantic not to show up.

It may be clear from the foregoing discussion that the robustness of the results presented needs further investigation. Investigations should also address the subsurface ocean where large amounts of anomalous waters may be transported while being masked by SSTs that have locally been generated by air-sea exchange.

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