Deep jets in the deep equatorial Atlantic cause climate variability

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Climate variability in the tropical Atlantic is affected by the ocean in many ways. Besides large-scale ocean-atmosphere interactions, it was found that the deep equatorial Atlantic also plays an important role in tropical climate. Equatorial deep jets that are generated in the deep ocean (perhaps as deep as several thousand meters) and propagate their energy toward the sea surface are found to affect sea surface temperature, wind, and rainfall in the tropical Atlantic region and constitute a 4 ½ -year climate cycle.

The dominant climate phenomenon in the tropical Atlantic is a north/south movement of the tropical rain belt, which on average extends from equatorial South America across the Atlantic to the southern part of West Africa. This rain band is caused by the convergence of the northeast and southeast trades and is commonly referred to as the Inter Tropical Convergence Zone. It moves with the sun to the north in early boreal summer and reaches its northernmost position in August. Then it moves back south as the season progresses. The associated rain areas are displaced not only over the ocean but also over continental Africa where they are referred to as the African monsoon. It is characterized by a two-time reversal of winds during the course of a year, leading to the formation of rainy and dry seasons. Despite the dominant annual cycle in the Atlantic, sub-Saharan Africa experiences strong multi-year to multi-decadal climate variability with great impact on water supply, agriculture, tropical diseases, and infrastructure of the respective countries.

While long-term, decadal and multi-decadal fluctuations may be associated with the general temperature gradient between the North and South Atlantic, for example due to changes in the meridional overturning circulation, year-to-year fluctuations may depend more on the surface temperature of the adjacent seas particularly the central and eastern equatorial Atlantic. With the appropriate prediction of sea surface temperatures, it would thus be possible, in principle, to forecast the rainfall, its starting date and strength, not only for the next rainy season but for the next few years as well – a tremendous benefit for the people living in these regions. The atmospheric and oceanic processes responsible for the change in sea surface temperature, however, are still not understood well enough to be implemented correctly in models to allow an accurate prediction of the African monsoon.

Oceanographers from IFM-GEOMAR, in collaboration with their colleagues from the Woods Hole Oceanographic Institution (WHOI, USA), are now able to demonstrate the existence

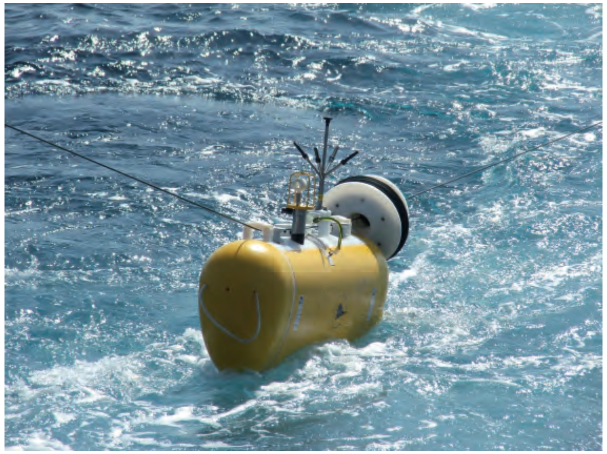

Figure 1: A "Profiler" is an instrument moored to the ocean floor by steel wire several km in length. The Profiler autonomously moves up and down the mooring wire between 1000 and 3500m depth, measuring currents, temperature, salinity and pressure along the way. Higher up on the mooring wire are additional instruments, such as acoustic current meters, temperature and salinity recorders. This entire platform allows us to continuously monitor the Atlantic at depth.

of regular interannual temperature fluctuations which have an effect on the rainfall of the region but cannot be traced back to previously known sources related to the large-scale ocean-atmosphere interactions.

As part of a multi-year international research programme, scientists involved in the Tropical Atlantic Climate Experiment (TACE) have attempted for many years to track the causes, effects and potential periodicities of

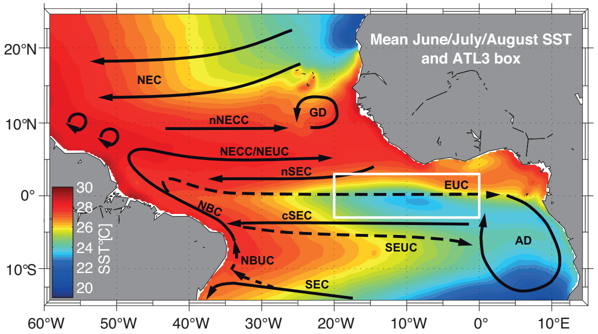

Figure 2: Sea surface temperature is one of the determining factors for rainfall fluctuations over West Africa. For example, if the equatorial cold water tongue in the Gulf of Guinea forms particularly early during the boreal summer months, the likelihood of early rainfall over West Africa is high. If the cold water tongue remains relatively warm, the onset of rainfall over land is delayed, but the rainfall itself will be heavier. After Brandt et al., 2011.

climate fluctuations in the tropical Atlantic. The German contribution to this programme, supported by the Federal Ministry of Education and Research ("Nordatlantik" project) and the German Science Foundation (as part of the Kiel Special Research Project SFB754 "Climate - Biogeochemical Interactions of the Tropical Oceans") includes deep-sea moorings along the equator. These moorings consist of several km of mooring wire held upright in the water column by flotation and buoys. Instruments are mounted along the wire to continuously record current speed and direction, salinity and temperature, thereby allowing the observation of long-term changes in the deep ocean. Furthermore, data on ocean currents is also available from freely drifting deep-sea buoys (the so-called Argo floats) and on the sea surface and the atmosphere from various satellite-based sensors. The time series obtained over the past ten to twenty years have revealed previously unknown fluctuations of currents and temperatures at the surface of the tropical Atlantic which have a regular cycle of 54 months, or 4 ½ years. The 4½ cycle at the surface is connected to fluctuations in ocean currents that are observed throughout the water column down to 3000 m depth with speeds of 10-20 cm/sec known as the "Equatorial Deep Jets". These jets flow along the equator, crossing the entire Atlantic, with flow reversals every few hundred meters in depth. The jets are generated in the deep ocean, and their energy apparently propagates upwards through the water column. Once near the surface, their energy affects currents and temperatures leading to the 4 ½ year cycle that influences the atmosphere.

Up to now, state-of-the-art high-resolution ocean models are not able to simulate the generation and propagation of equatorial deep jets in a realistic way. Ongoing research at GEOMAR includes continuing the measurements in the equatorial Atlantic that are required to describe the long time scales involved, as well as process modelling designed to develop understanding of the dynamical nature of these peculiar features of the equatorial ocean. The goal of this research is to include the effect of equatorial deep jets in climate models, either by parameterizing or direct simulation, in order to facilitate more reliable predictions of tropical climate variability in the future.

References

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