# Surface Heat Balance Estimates for the Tropical Atlantic Using PIRATA Data

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## 1. Introduction

Rainfall variability in the northeast South America and in Africa's Sahel region is profoundly influenced by sea surface temperature (SST) anomalies. Ping Chang and Li (1997) proposed that decadal variations in the tropical SST dipole may be attributed to a thermodynamically unstable ocean–atmosphere interaction between wind–induced heat fluxes and SST anomalies. Within this framework the importance of the heat flux estimation through the tropical ocean surface becomes evident. The main objective of this study is to estimate each component of the heat budget equation (Equation 2) in the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) region. In addition, the contribution of each heat component to the temperature tendency of the mixed layer is estimated.

## 2. Methodology

The PIRATA project maintains a set of twelve ATLAS moorings in the tropical Atlantic since 1998 (Figure 1). Vertical profiles of water temperature and salinity, air temperature, wind speed and direction, relative humidity, rain and short wave radiation are made in 10–minute intervals. Daily means are estimated on-board from the high frequency measurements and transmitted by a satellite link. Near real–time quality controlled data are made available *via* internet.

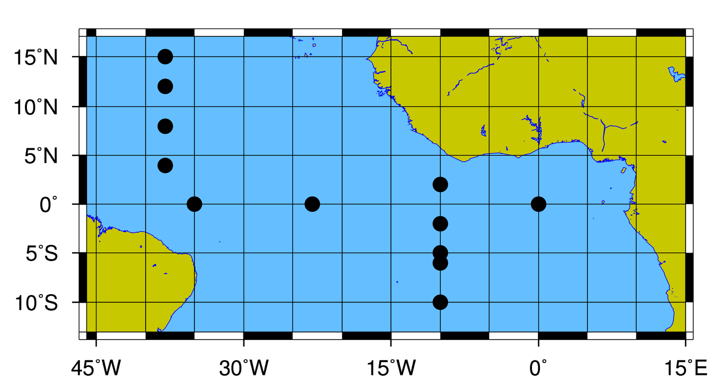


Figure 1: *Study area with the PIRATA buoy positions.*

The heat flux balance in the mixed layer is illustrated in Figure 2 and described by Equations 1 and 2.

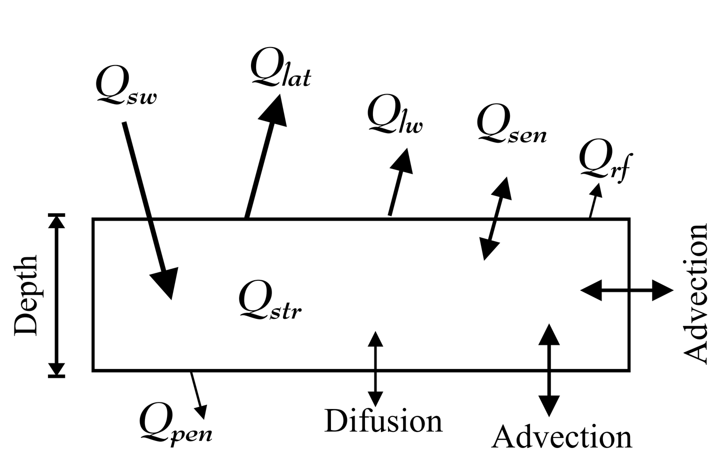


Figure 2: *Heat fluxes components of mixed layer.*

$$Q_0 = Q_{sw} + Q_{lw} + Q_{lat} + Q_{sen} + Q_r \quad (1)$$

$$Q_{tot} = Q_0 + Q_{pen} + Q_{adv} + Q_{str} \quad (2)$$

$Q_0$ → Total Surface Heat Flux
$Q_{sw}$ → Short Wave
$Q_{lw}$ → Long Wave
$Q_{lat}$ → Latent
$Q_{sen}$ → Sensible
$Q_{rf}$ → Precipitation
$Q_{tot}$ → Effective Mixed Layer Total
$Q_{pen}$ → Flux Through Mixed Layer Base
$Q_{adv}$ → Horizontal Advection
$Q_{str}$ → Storage

The collected time series has gaps due to sensor failures, vandalism, and maintenance schedule constraints. The lack of wind data is particularly problematic because it is necessary in the estimation of several components in Equation 1. The resulting fragmented time series would make the spectral estimation difficult to impossible. Therefore, gaps in the wind time series were filled with QuikScat scatterometer data Castelão (2002).

The daily mean PIRATA data are used to estimate the surface heat fluxes using a bulk formulation (Fairall et al., 1996; Pawlowicz et al., 2001). Subsurface temperature profiles were used to estimate the mixed layer depth, the short wave heat loss at the base of the layer, and its heat storage. The contribution of each heat component to the temperature tendency of the mixed layer is estimated.

## 3. Results

Our results (Figures 3 and 4) indicate that the major balance is between the incoming short wave radiation and the energy loss as latent heat, both in the order of 100 $Wm^{-2}$. The loss accounted by the sensible and long wave heat fluxes are much smaller, on the order of 10 $Wm^{-2}$. The heat flux due to rain is negligible when integrated over a long period. However, in extreme events it can become comparable to the total net flux. The influence of atmospheric systems in the heat budget is generally indirect as the cloud coverage reduces the incidence of short wave radiation.

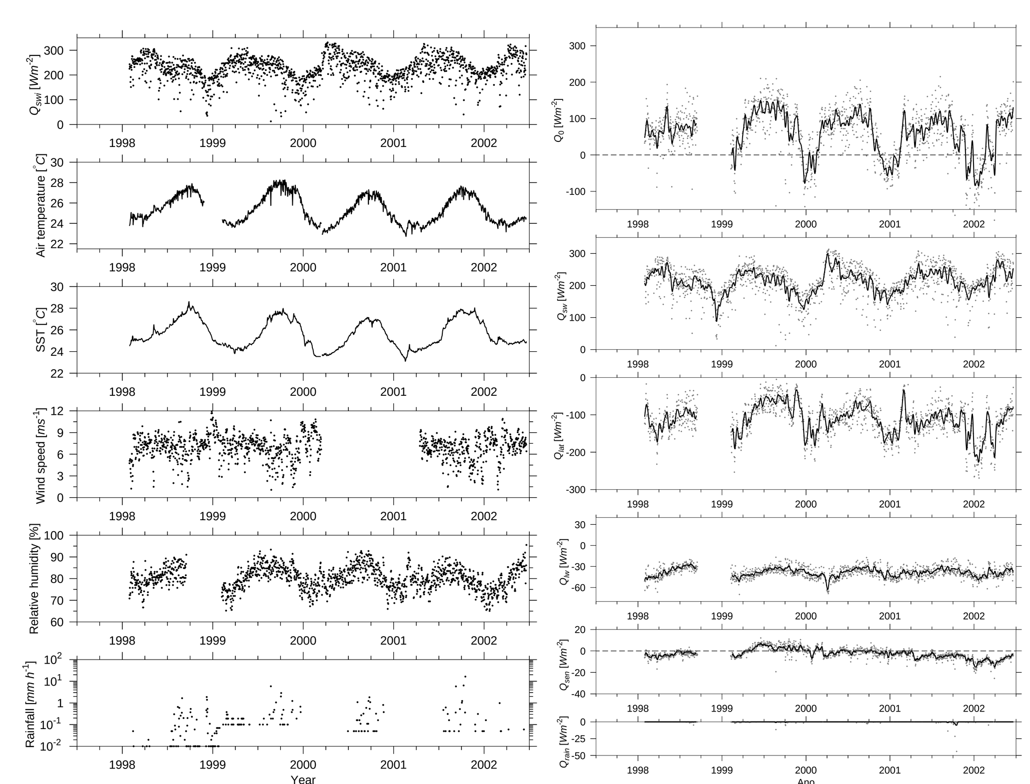

Figure 3: *Variables measured from buoy 15°N 38°W (left) and surface heat flux components.*

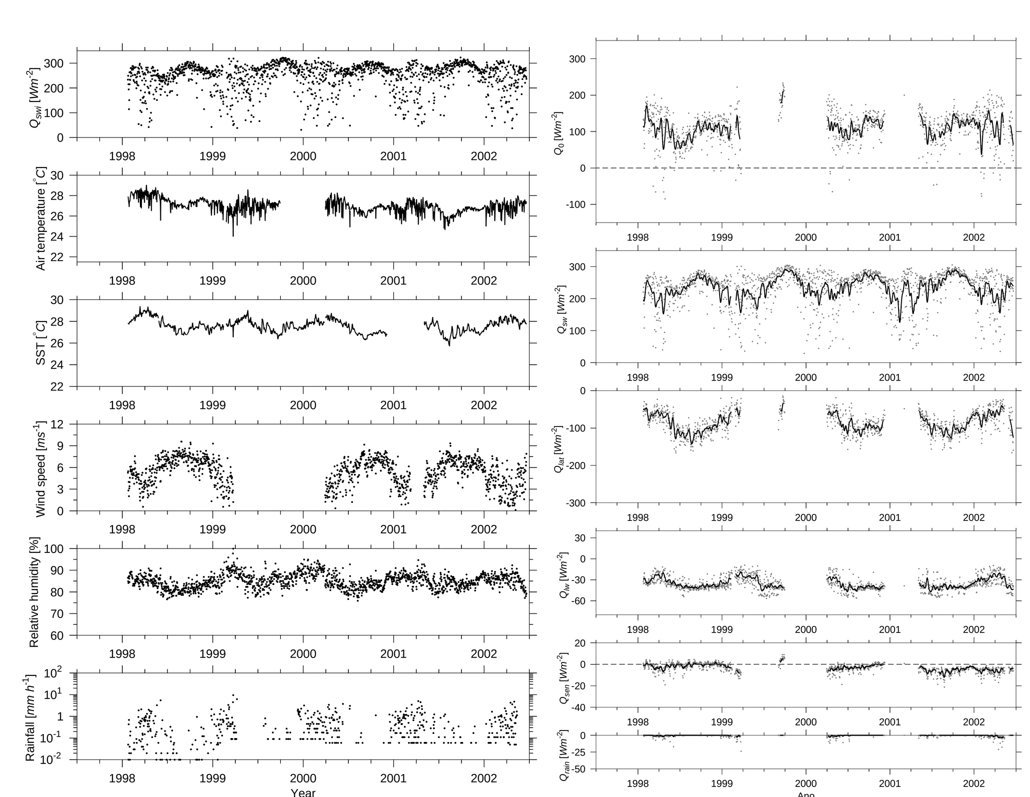

Figure 4: *Variables measured from buoy 00° 35°W (left) and surface heat flux components.*

The heat flux time series were analyzed using the Lomb-Scargle periodogram. Unlike traditional spectral estimation techniques this method allows for discontinuities in the input data. Most terms of Equation 1 are dominated by an annual cycle.

The largest amplitude of the annual signal of the total surface heat flux of approximately 50 $Wm^{-2}$ is observed at the highest latitudes of the domain (15°). The seasonal amplitude decreases near the equator.

Near equator the components are out of phase, thus (Figure 3) the amplitude of the seasonal cycle decreases and (Figure 4) a semi–annual signal becomes more prominent.

Reliable spectral estimation results are limited to a single peak because of the frequency and size of the data gaps and the relatively short time series. This problem will be minimized as the time series grows.

A high correlation (greater than 90%) is observed between the total surface balance ($Q_{tot}$) and the mixed layer heat storage ($Q_{str}$). This suggests that surface fluxes are more important than advective and diffusive processes in determining the mixed–layer temperature.

However, there periods of low correlation when changes in the mixed layer temperature are likely to be dominated by advective and diffusive processes (Figure 5).

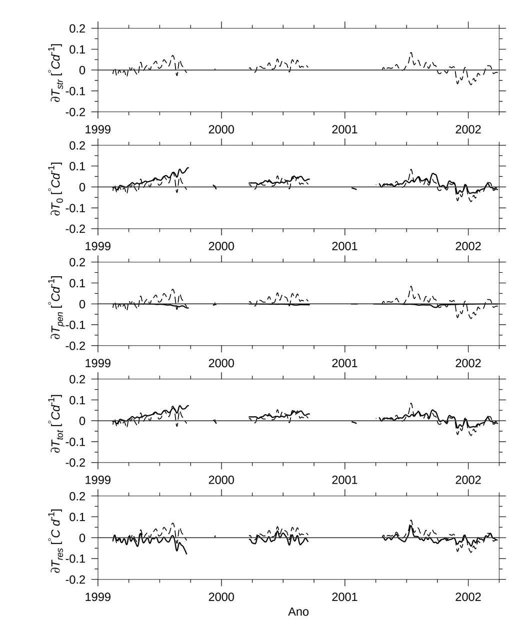

Figure 5: *Temperature variation tendency by the different heat fluxes*

## 4. Conclusions

The amplitude of the seasonal heat flux signal is a function of latitude that decreases near the equator. The largest amplitudes of approximately 50$Wm^{-2}$ were observed at 15°N.

Near the equator the change of phase between the seasons in the hemispheres induces a significant semi–annual signal in the heat flux. The amplitude of this signal surpasses that of the annual cycle.

Due to the time series length and intermittence, only the annual peak is statistically robust for most buoys. The Lomb–Scargle method for spectral estimation proved adequate in face of a fragmented time series.

The surface processes determine most of the variability in the mixed layer temperature. Advective and diffusive processes play a secondary role most of the time.

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