The Role of Ocean Processes within Coupled Variability in the Tropical Atlantic

Natalie Burls, Chris Reason, Pierrick Penven and George Philander

Email: natalie.burls@ uct.ac.za
Department of Oceanography, University of Cape Town

Introduction

Comparing oceanic variability in the equatorial **Atlantic** with that of the equatorial **Pacific** it is apparent that while the inter-annual **El Niño Southern Oscillation signal dominates in the Pacific**, the **seasonal cycle dominates in the Atlantic**. This is best illustrated by **Figure 1**. The nature of SST variability in **the central-eastern equatorial Atlantic is strikingly different** from that of the Pacific.

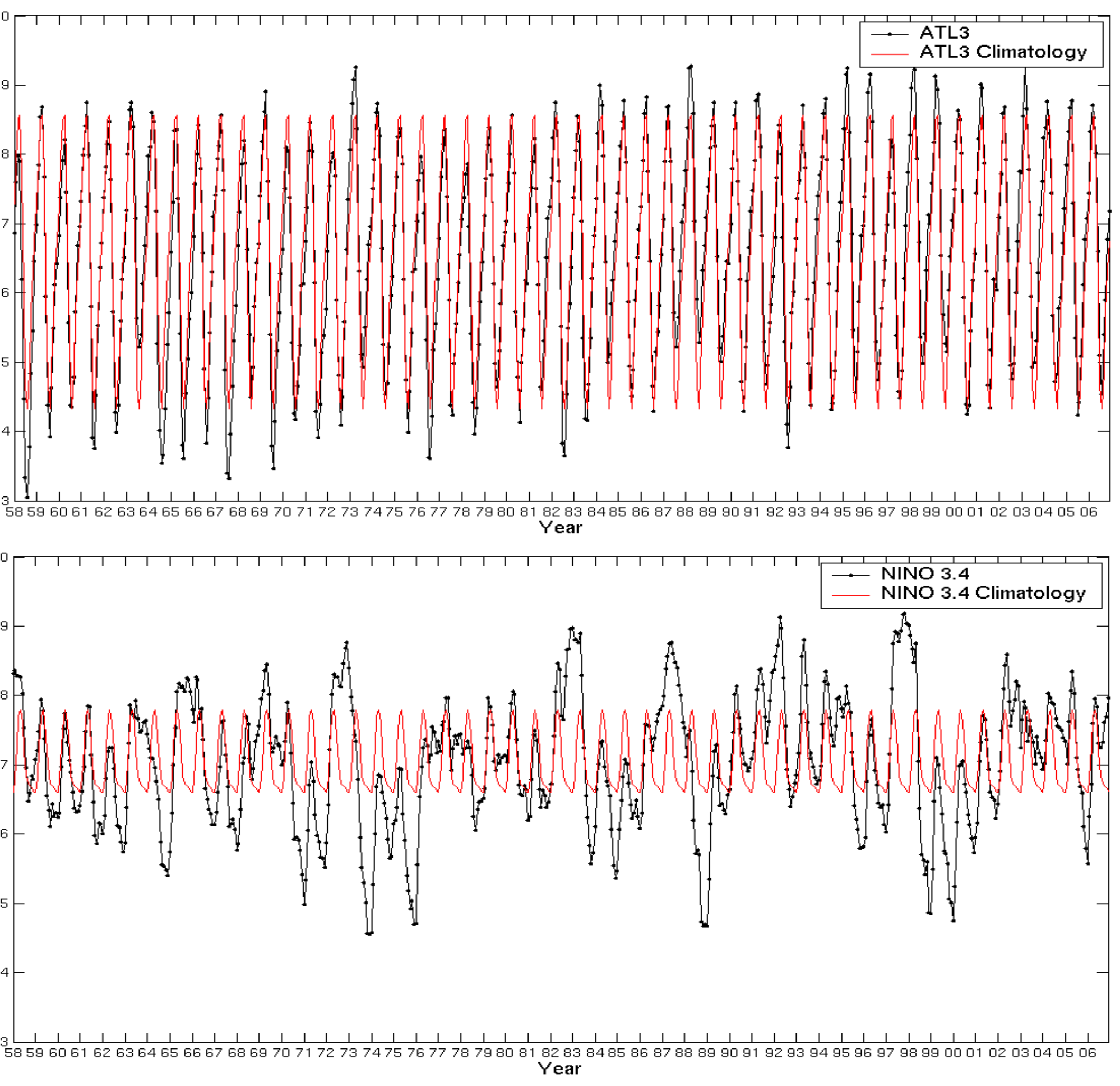

Figure 1: A comparison between Atl3 (5°N-5°S 120°W-170°W) SST and Niño 3.4 (3°N-3°S 20°W-0°E) SST created using NCDC SST data.

What is the implication of this dominant seasonal cycle on inter-annual variability in the tropical Atlantic? **Do the physical ocean processes involved in inter-annual SST variability differ from those of the seasonal cycle, or are the processes the same except for a modulation in either phase or amplitude?**

Energetics of variability in the equatorial Pacific vs the equatorial Atlantic

Pacific

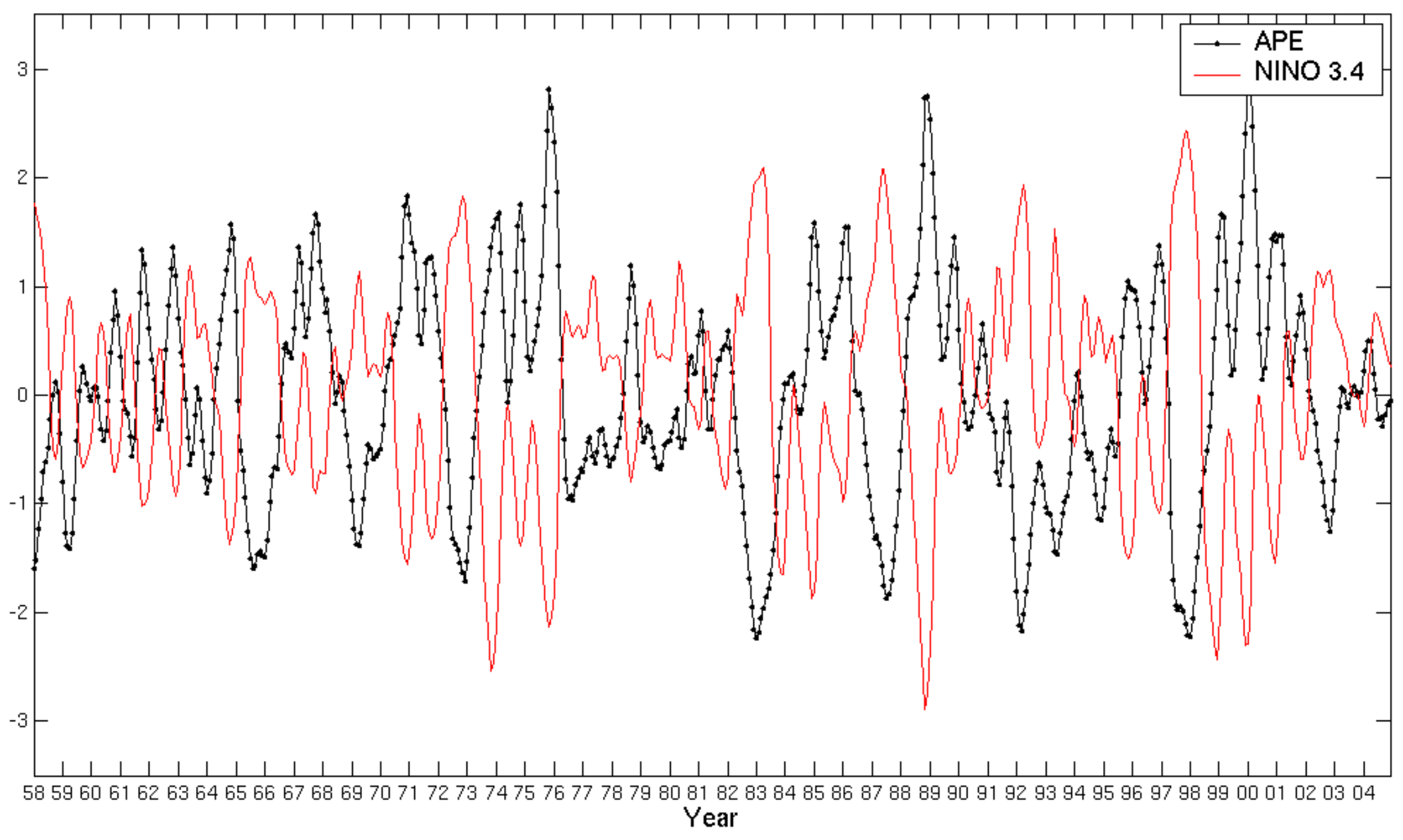

Figure 2: Niño 3.4 SST vs APE integrated over 5°N-5°S 150°E-100°W 30-300m . APE calculated using SODA salinity and temperature output.

Atlantic

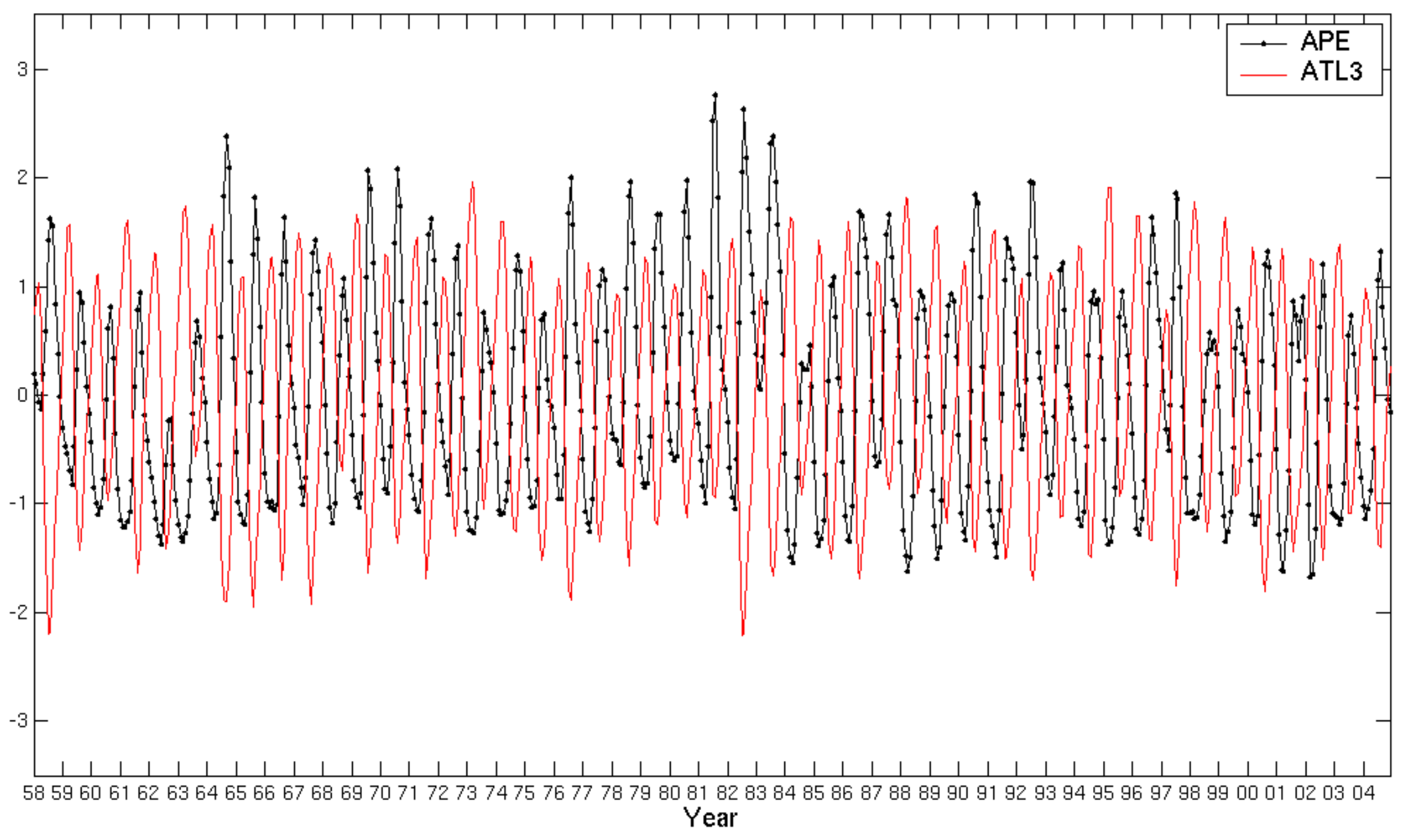

Figure 3: Atl3 SST vs APE integrated over 3°N-3°S 15°E-45°W 30m-300m. APE calculated using SODA salinity and temperature output.

Inter-annual SST fluctuations in the central-eastern equatorial Pacific are the result of equatorial upwelling acting on either an anomalously deep or shallow thermocline. These thermocline depth anomalies are due to changes in the east-west slope of the thermocline which can be evaluated in terms of gravitational Available Potential Energy (APE). **Inter-annual SST anomalies in the Niño 3.4 region are highly correlated with fluctuations in the amount of APE in the equatorial Pacific** (Figure 2).

APE is gained during the transition from El Niño to La Niño and **lost during the transition from La Niño to El Niño**. Inter-annual SST anomalies in the Pacific can therefore be regarded as surface expressions of upper ocean energy changes (Goddard and Philander, 2000).

APE changes in the Pacific are due to the redistribution of mass. The dominant term forcing these changes is the bouyancy power term - vertical motion of the mass feild. Work done by the wind goes toward driving changes in APE by doing work against pressure gradients and genertaing bouyancy power. The transition from La Nina to El Nino or visa versa starts when surface currents associated with the thermocline perturbations in the western equatorial Pacific affect the work done by the wind (Goddard and Philander, 2000).

In comparison, seasonal changes in SST and APE are small. Seasonal SST changes are forced by anomalous Ekman pumping acting on a seasonally invariant thermocline (McPhaden et al, 1998).

The large **seasonal fluctuations in Atl3 SSTs are highly correlated with changes in equatorial APE** (Figure 3).

Similarly, **Inter-annual APE anomalies and SST anomalies correlate well, particularly during boreal summer** (Figure 4).

Inter-annual variability in APE appears to be due to a **modification of the processes forcing seasonal APE fluctuations.** To test this hypothesis an investigation into the energetics of equatorial Atlantic oceanic variability will shed light on the mechanisms forcing both seasonal and inter-annual APE changes.

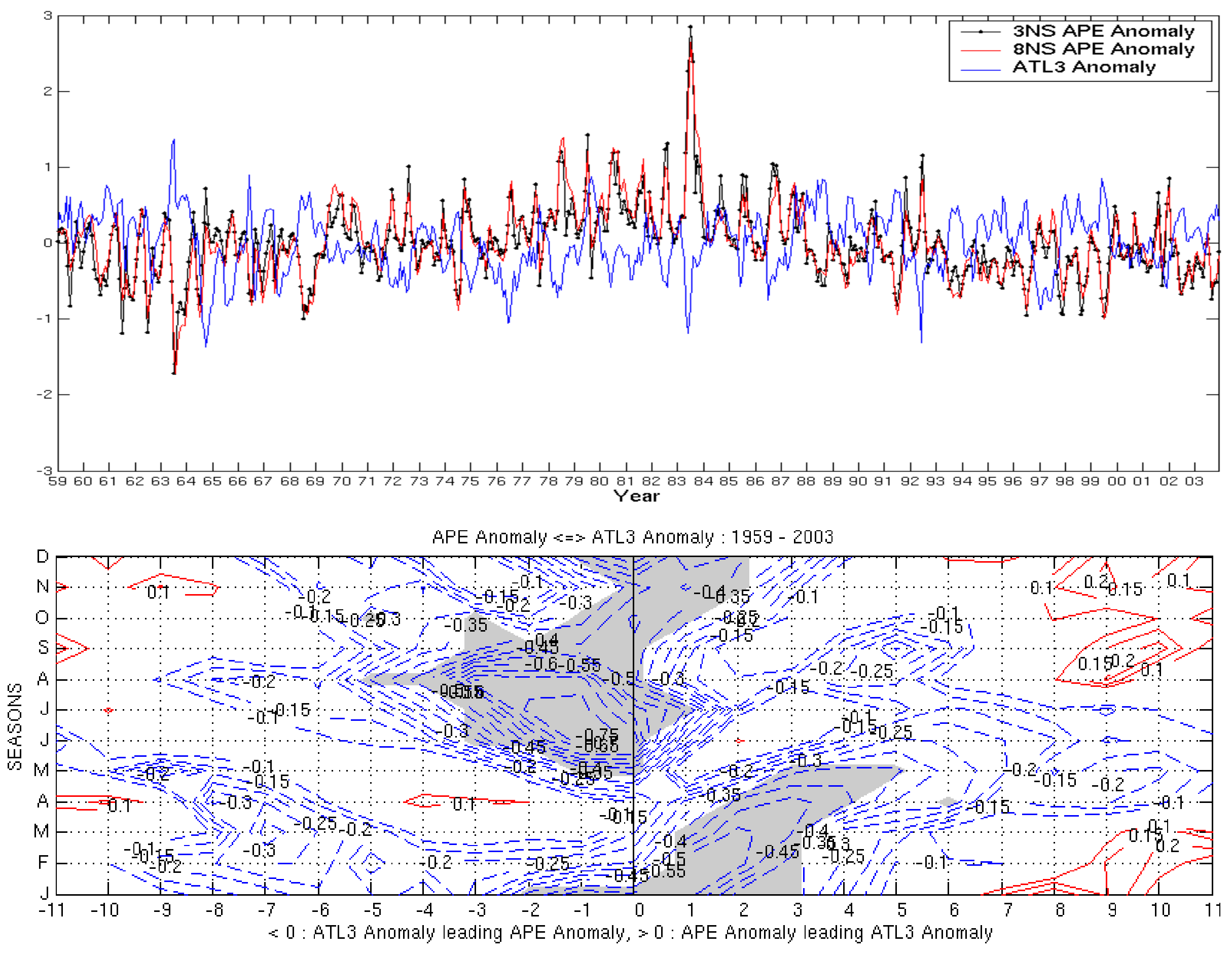

Figure 4: (Top) Inter-annual Atl3 SST anomalies vs anomalies in APE integrated over 3°N-3°S and 8°N-8°S 15°E-45°W 30m-300m. APE calculated using ROMS output. (Bottom) Seasonal dependence of correlation between Atl3 SST anomalies and 3°N-3°S APE anomalies.

Modeling Approach

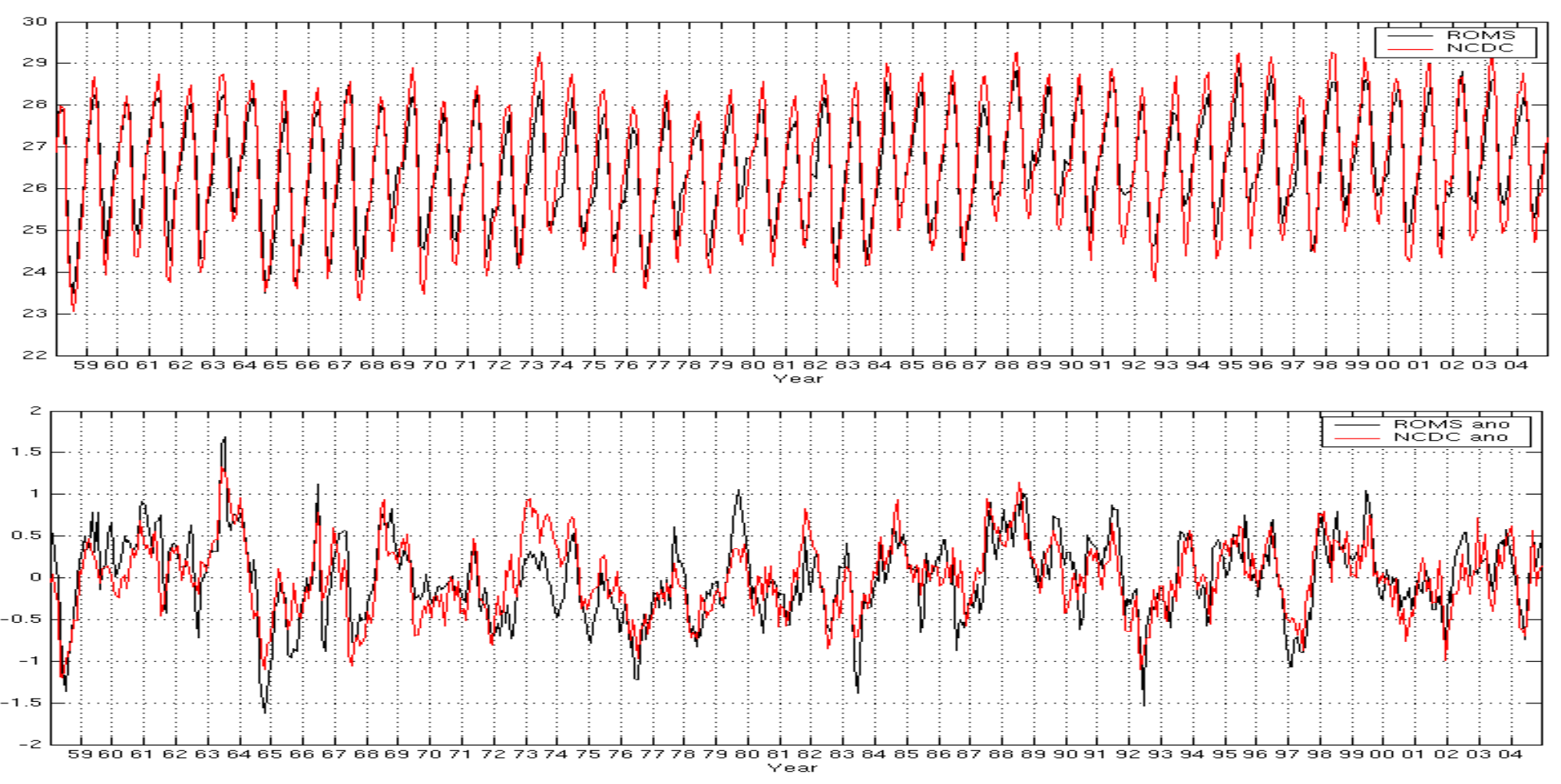

Figure 5: (Top) Absolube Atl3 SST ROMS vs NCDC SST. (Bottom) Inter-annual anomalies in Atl3 SST ROMS vs NCDC SST.

The Regional Ocean Modelling System (ROMS) is used to under take both **realistic and idealized simulations** of the tropcal Atlantic.

Realistic Simulation

ROMS is used to simulate conditions in the tropical Atlantic from 1958-2004 and the two day average output used to perform an energetics analysis. SODA re-analysis data provides the lateral boundary conditions and NCEP re-analysis data provides the bulk atmospheric forcing. This configuration, which is a work in progress, is currently run at 1/3 of a degree (Figure 6).

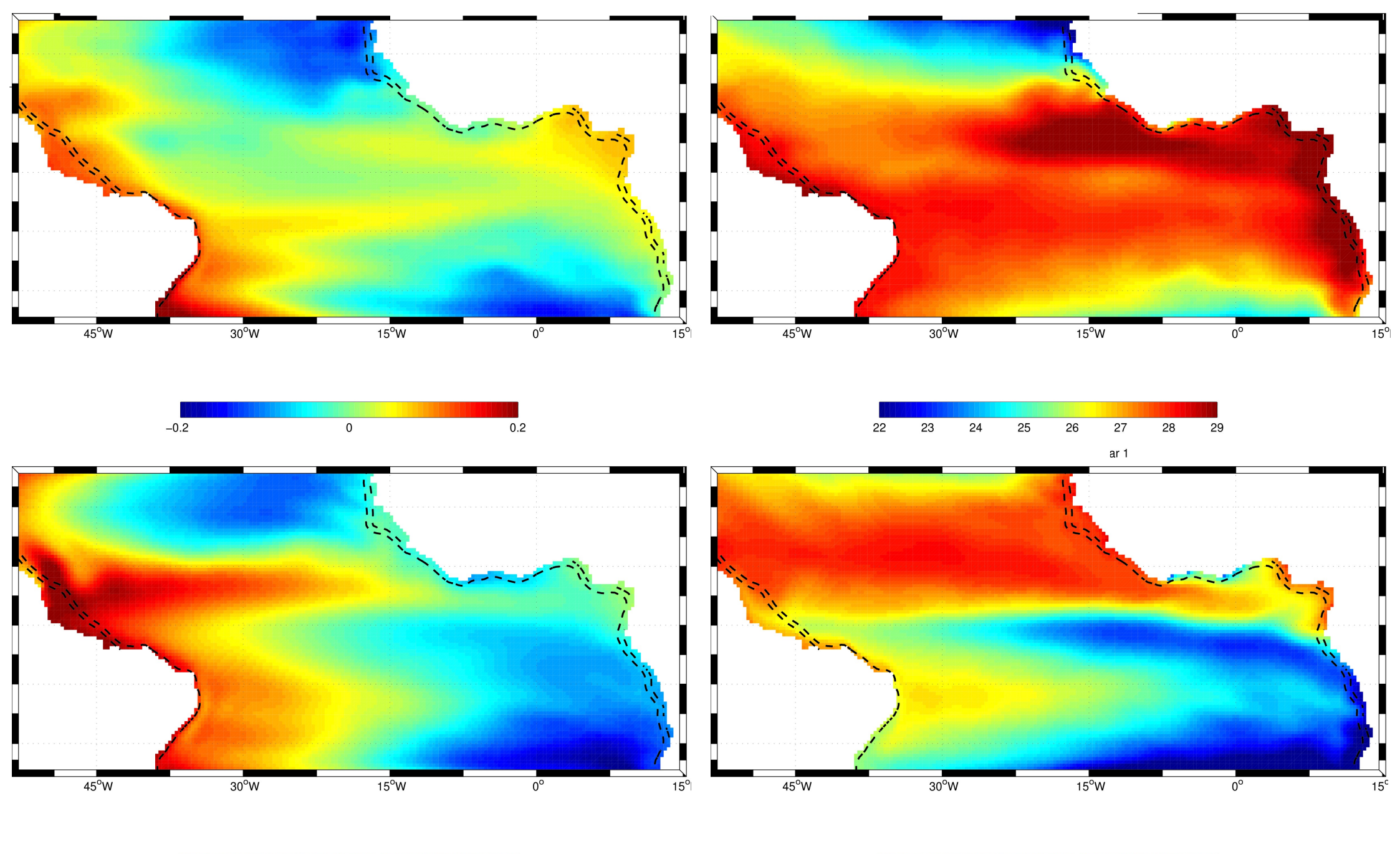

Figure 6: Simulated climatological SSH (Left) and SST (Right) for the month of **April (Top)** and the month of **August (Bottom)**.

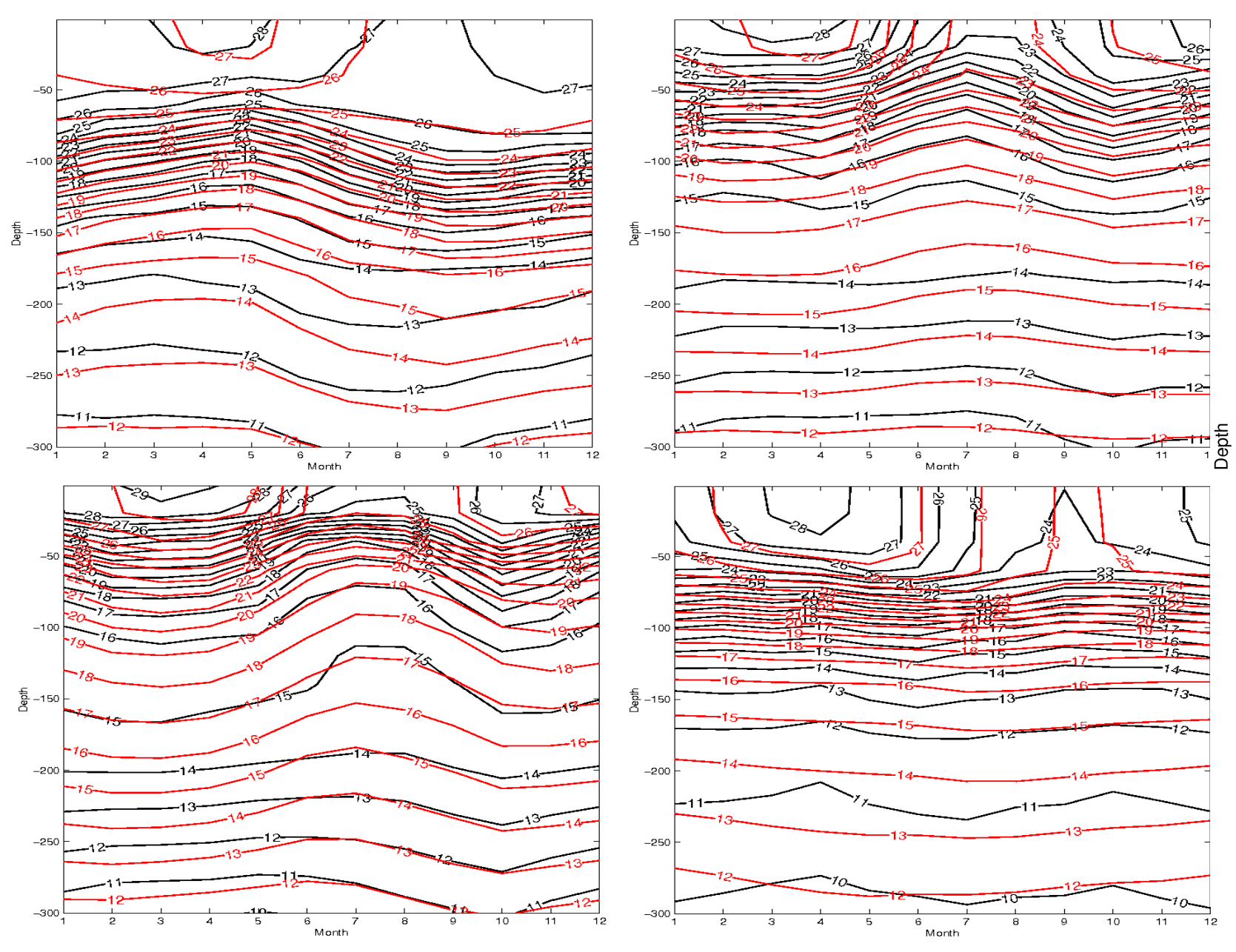

Figure 7: Climatological temperature profiles at (Top Left) 0°N 35°W (Top Right) 0°N 10°W (Bottom Right) 0°N 0°E (Bottom Left) 6°S 10°W, Pirata mooring data (black) vs Simulation (red).

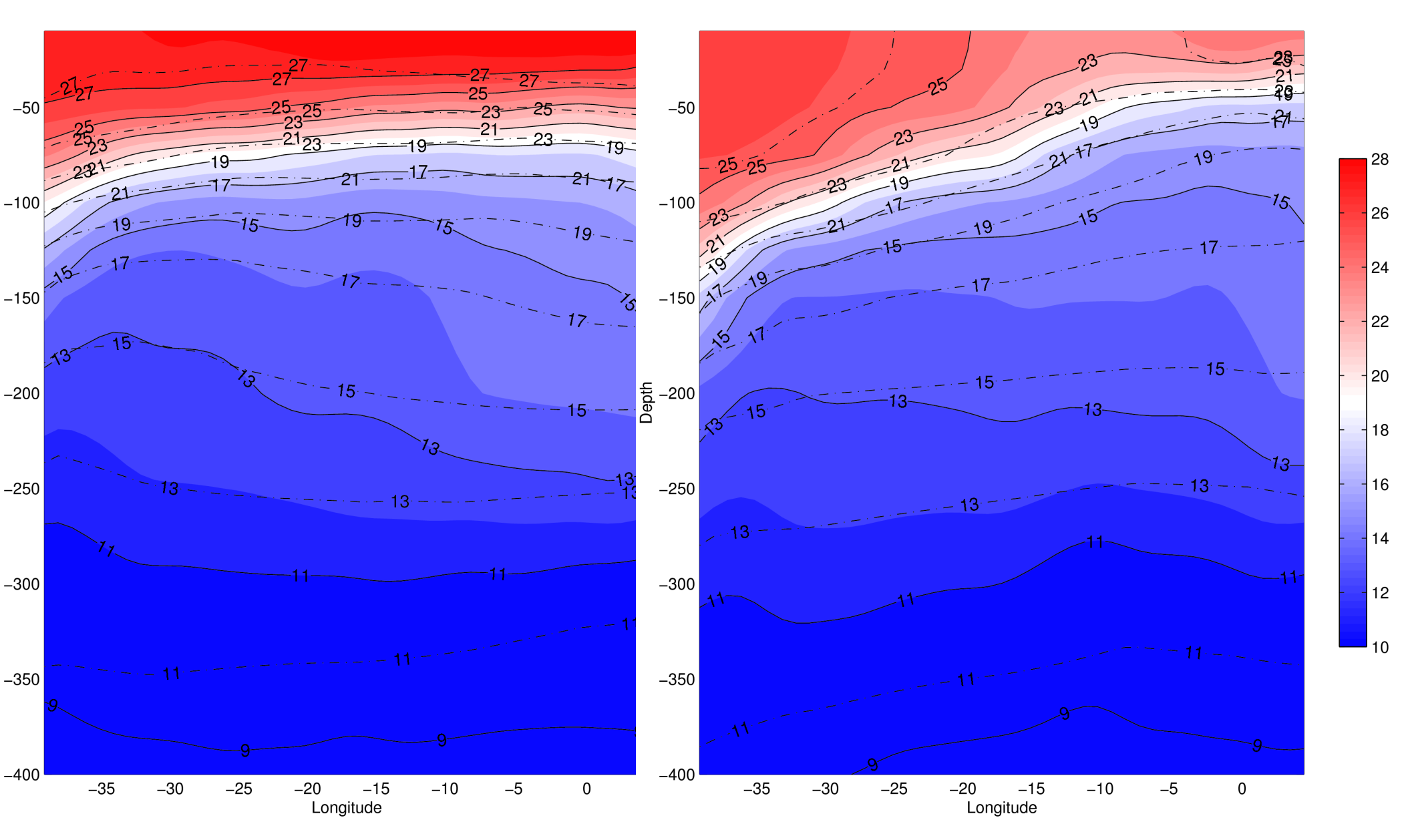

Figure 8: Cross-section of temperature along the equator (Left) **April** (Right) **August** climatology, World Ocean Atlas data (solid black and colour contours) over-layed with simulated data (dashed contours).

Energetics Analysis - Preliminary Results

The terms forcing APE changes have been calculated for the oceanic volume between 8°N-8°S, 45°W-15°E and 30m-300m as well as for the equatorial region between 3°N-3°S.

The dominant terms contributing to seasonal changes in APE between 8N-8S are - buoyancy power, the advection of APE through the walls of the volume and shear in the stability profile (Figure 9).

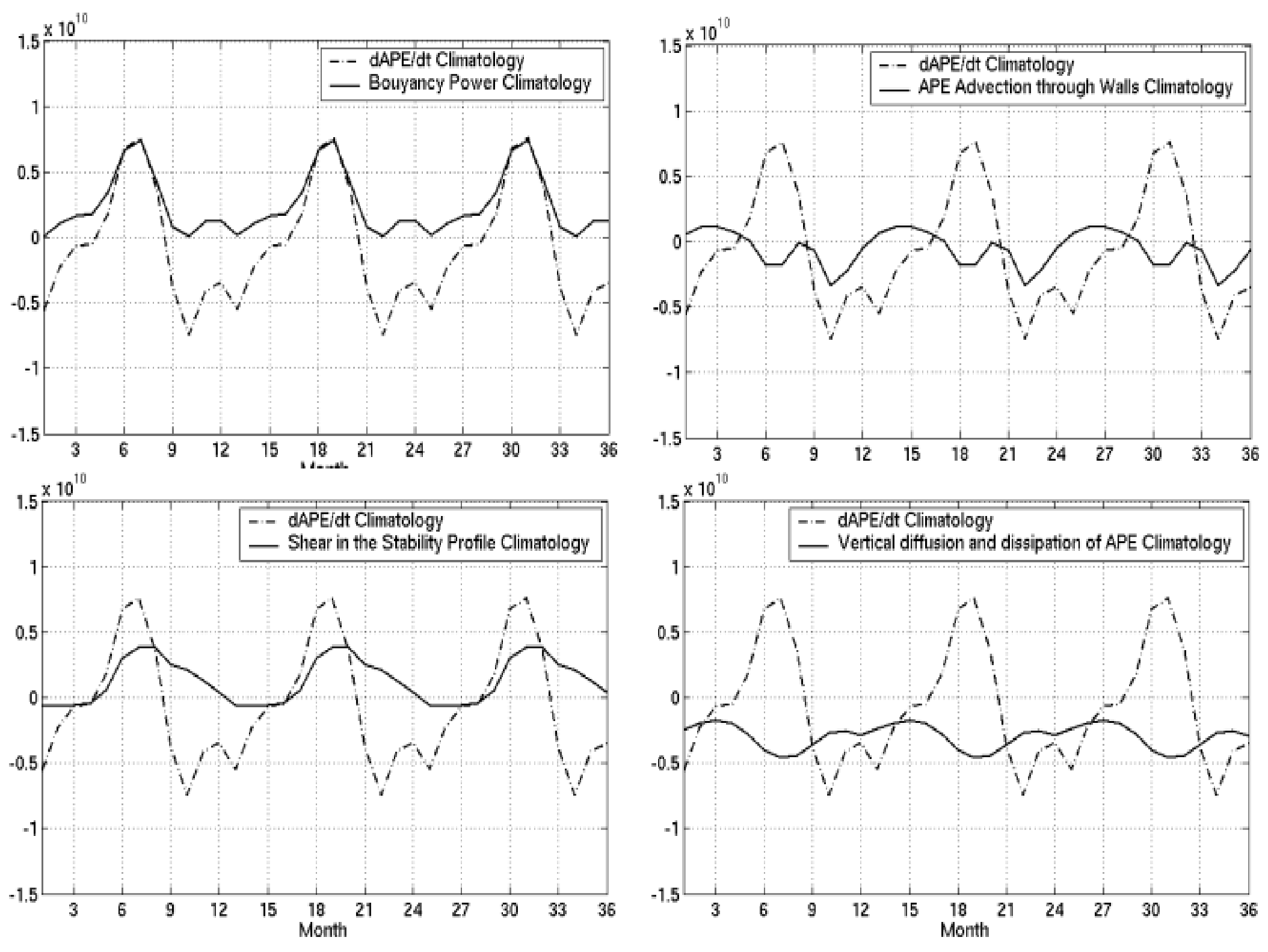

Figure 9: Terms from the APE equation forcing seasonal changes APE integrated over 8°N-8°S 15°E-45°W 30m-300m.

Inter-annual anomalies in seasonal APE changes correlate best with anomalous contributions from the Buoyancy Power term (Figure 10).

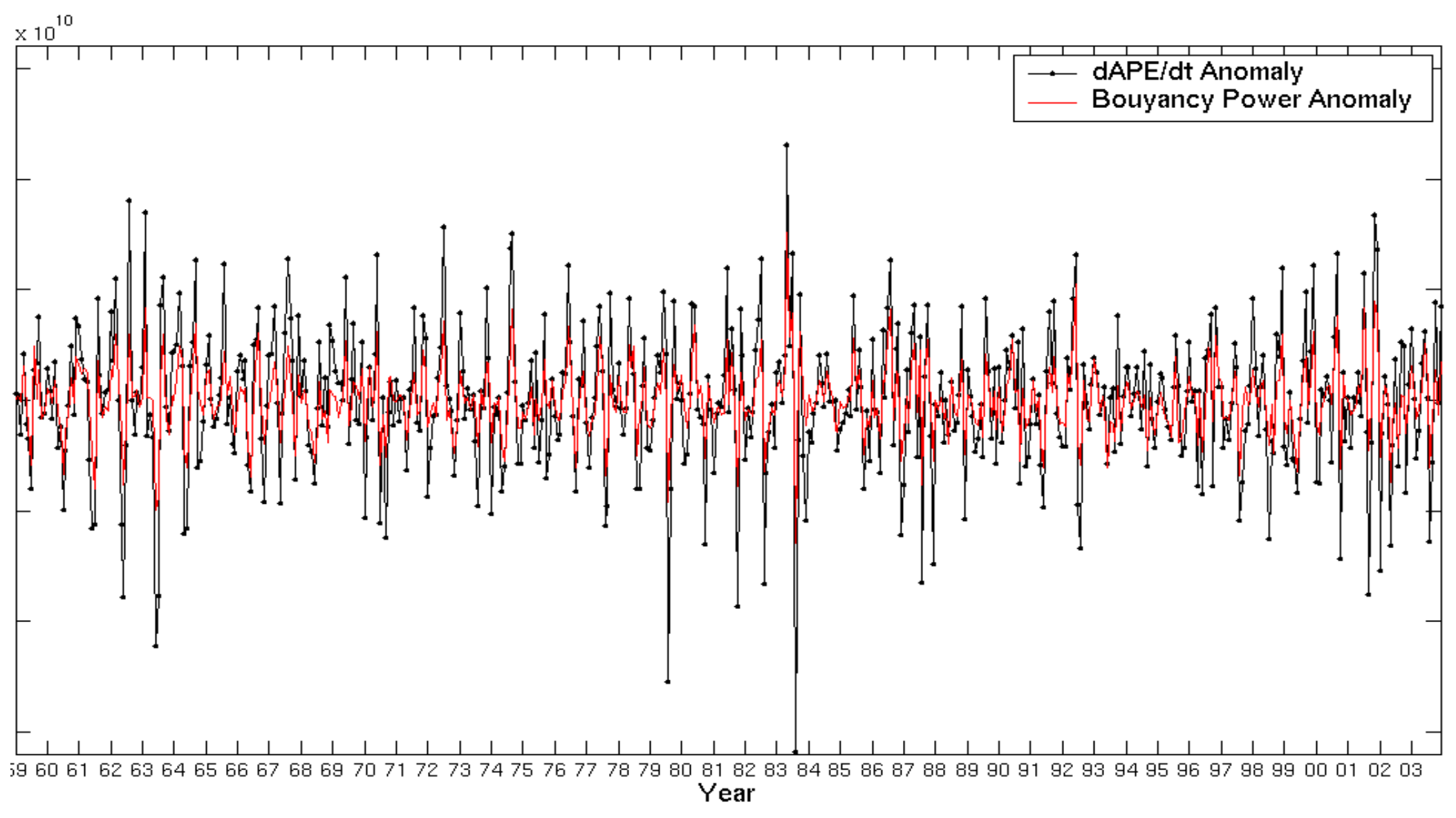

Figure 10: Inter-annual anomalies in the rate of change of APE and Bouyancy Power for the oceanic volume 8°N-8°S 45°W-15°E 30m-300m. Correlation Coefficient 0.9

Future Work

- Focusing in on the terms forcing APE changes associated with individual warm and cold events.

- Examining the evolution of bouyancy perturbations against the mean state.

- An evaluation of the Kinetic Energy equation to asses sources of bouyancy power.

- Idealized experiments.

Acknowledgments

The NRF/CNRS/French Embassy Doctoral Support Programme for making possible this research visit to France.
The Center for High Performance Computing for providing the modelling platform used.
The South African National Research Foundation (NRF) and the University of Cape Town postgraduate funding office.

References

Goddard, L. and S. G. H. Philander. 2000. " The energetics of El Nino and La Nina" JOC 13:1496-1516.
McPhaden et al. 1998. "The Tropical Ocean Global Atmosphere observing system: A decade of progress" JGR 103:14169-14240.