ATSR SST Observations of the Tropical Pacific Compared with TOPEX/Poseidon Sea Level Anomaly

J.P.Angell and S.P.Lawrence
Earth Observation Science Group, Dept. Physics and Astronomy, Space Research Centre, University of Leicester, Leicester, LE1 7RH, UK
e-mail: jpa2@le.ac.uk**,** spl5@le.ac.uk

Abstract

Spatially-averaged sea surface temperature data from the Along Track Scanning Radiometer instrument onboard the ERS-1 mission are analysed for evidence of ocean long wave activity in the tropical Pacific Ocean (within 5° latitude of the equator). Specifically the data are investigated for the signatures of Kelvin, Rossby and tropical instability waves. These waves are readily identifiable in sea level anomaly data from the TOPEX/Poseidon altimeter mission, and these data are used to gauge the effectiveness of the ATSR-1 instrument for such observations. Tropical instability waves are observed by ATSR-1 in the northern hemisphere. Kelvin waves are observed in the sea surface temperature data, although not every Kelvin wave in the TOPEX/Poseidon data is captured by the ATSR-1. It is suggested that sub-surface dynamics, especially the depth of the thermocline, are important factors in the appearance of the sea surface temperature signal of the Kelvin waves. In contrast there is no evidence of first mode Rossby wave activity in the ATSR-1 data at these latitudes.

Introduction

A phenomenon of major importance is the El Niño event (Philander, 1990), which has a huge impact on the Earth's ocean-atmosphere and climate system. Large-scale waves, known as Kelvin waves, are acknowledged as an integral part of the El Niño-Southern Oscillation (ENSO) system (McCreary, 1976, Kessler *et al*, 1995). The role of tropical instability waves and Rossby waves, especially in relation to the reflection of Kelvin waves from the Eastern boundary, is also an important factor in the ENSO system (Angell and Lawrence, 1999).

Rossby and Kelvin waves affect the thermocline depth, and hence the ocean's temperature profile, as well as the sea surface height. The waves can either raise or lower the thermocline, leading to a decrease or increase, respectively, in the sea surface height. A lowering of the thermocline (downwelling) leads to a warming effect in the region of the disturbance, since the cooler water under the thermocline is forced down and replaced by warmer water. The opposite is true for a raising of the thermocline i.e.there is a cooling associated with an upwelling event. For the first-baroclinic mode, variations in the sea surface height are inversely mirrored in the thermocline depth, with approximately three orders of magnitude greater amplitude (Gill, 1983). Hence a one centimetre sea level rise will correspond to a ten metre thermocline depression, and a significant variation in the upper-ocean thermal structure. These waves can be identified in data from the TOPEX/Poseidon (T/P) mission, which provides an unprecedented accuracy for a space-borne altimeter mission. The impact of these changes on the ocean-atmosphere system, however, will depend on the boundary between the ocean and atmosphere – specifically the sea surface temperature. Data from the Along Track Scanning Radiometer (ATSR) are analysed to see if the waves are observable with the instrument, and also to provide a measure of the impact of these waves on the sea surface temperature (SST).

Data
The five-day ASST products provided by the Rutherford Appleton Laboratories were used in this analysis. The data have a one degree spatial resolution, and cover the time period August 1991 to July 1995. A crude 4 –year climatology was produced from the data in order to produce ASST 'anomalies'. This is necessary for the identification of the waves. The T/P Sea Level Anomaly (SLA) data used in this study were pre-processed by the Collecte Localisation Satellites (CLS) Space Oceanography group using conventional repeat-track analysis (Le Traon *et al*, 1994), relative to a 3 year mean of T/P sea level data. The data have been processed here into 2.8° longitude by 1° latitude bins. The data covers a period from October 1992 to July 1997. Due to the nature of this study, only data from each instrument laying in the 'overlap' period (that is October 1992 to July 1995) is analysed.

Results
The results are presented in the form of time-longitude plots, in which zonally moving waves, such as Rossby, Kelvin and tropical instability waves, will be represented by lines of varying slope. The data from the two instruments have been plotted for the same time and longitude scales, to allow comparison.

Kelvin Waves
Kelvin waves have been detected in the ASST data set in time-longitude plots from 0-1°N (Figure 1). On comparison with the equivalent T/P data (Figure 2) it is clear that ATSR does not detect all the Kelvin waves present. The waves that have been identified were determined by eye to have speeds of approximately 2.5 ± 0.5 m/s, which appear slightly slower than the speed of 3 ± 0.5 m/s from T/P data. It is suggested that sub-surface dynamics, and especially the depth of the thermocline, are vital for the appearance of the SST signature of the Kelvin waves.

Rossby waves
Figure 3 depicts SLA data from 4-5°N which has been projected onto theoretical meridional modes by a decomposition method developed by Boulanger and Menkes (1995). The data has been filtered to remove the annual signal, as we are interested in the intraseasonal not annual waves. Rossby waves are apparent in the SLA data of Figure 3 with a phase speed of 1 ± 0.2 m/s. Figure 4 depicts the equivalent time-longitude plot for the ASST data. There is no evidence of the Rossby waves observed in the T/P data appearing here. There does appear to be a faint signal of an westerly propagating wave, but this has a speed of approximately 0.5m/s and is likely to be an artifact of some annual signal.

Tropical Instability Waves
Tropical instability waves are apparent in both Figures 3 and 4. They are higher frequency waves, with a period around thirty days and a wavelength of 1500km. One of the TIW wave fields is magnified for ATSR and T/P in Figures 5 and 6 respectively. A 2-d Fourier transform is performed on the data to ascertain the wavelength and period. The ATSR records a period of 33 days and a wavelength of 1550 km, whilst T/P records a period of 31 days and a wavelength of 1400 km. There appears to be a phase lag between the data sets, where the SLA precedes the SST by approximately 10 days. This may be a consequence of the different sampling characteristics of the instruments, although it is unclear at present.

Conclusions/Future Work
ATSR, whilst not improving the detection of the waves under study, provides valuable data on the effect of the Kelvin and tropical instability waves on surface temperatures, and hence the atmosphere. We are currently investigating this atmospheric effect, with an aim to establishing

the importance of the waves to the ocean-atmosphere system. The instrument also helps to provide additional insight into the underlying dynamics and profile of the ocean by the appearance (or not) of the SST signature of the Kelvin waves, and this is also under investigation.

References

Angell, J.P. and S.P.Lawrence, Evidence for Rossby Wave Control of Tropical Instability Waves in the Pacific Ocean, submitted May, 1999

Boulanger, J. and C.Menkes, Propagation and Reflection of Long Equatorial Waves in the Pacific Ocean during the 1992-1993 El Niño, J.Geophys.Res., 100, C12, 25041-25059

Gill, A.E., An Estimation of Sea-Level and Surface-Current Anomalies During the 1972 El Niño and Subsequent Thermal Effects, J.Phys.Oceanogr., 13, 586-606, 1983

Kessler, W.S., M.J.McPhaden and K.Weickmann, Forcing of Intraseasonal Kelvin Waves in the Equatorial Pacific, J.Geophys.Res., 100, C6, 10613-10631, 1995

Le Traon, P.Y., J.Stum, J.Dorandeu, P.Gaspar and P.Vincent, Global Statistical Analysis of TOPEX/Poseidon data, J.Geophys.Res, 99, 24619-24631, 1994

McCreary, J.P., Eastern Tropical Ocean Response to Changing Wind Systems: With application to El Niño, J.Phys.Ocean., 6, 632-645, 1976

Philander, S.G.H., El Niño, La Niña and the Southern Oscillation, Academic Press, San Diego, CA, 1990

Figure Captions

Figure 1 ASST time-longitude plot 0-1°N depicting Kelvin waves

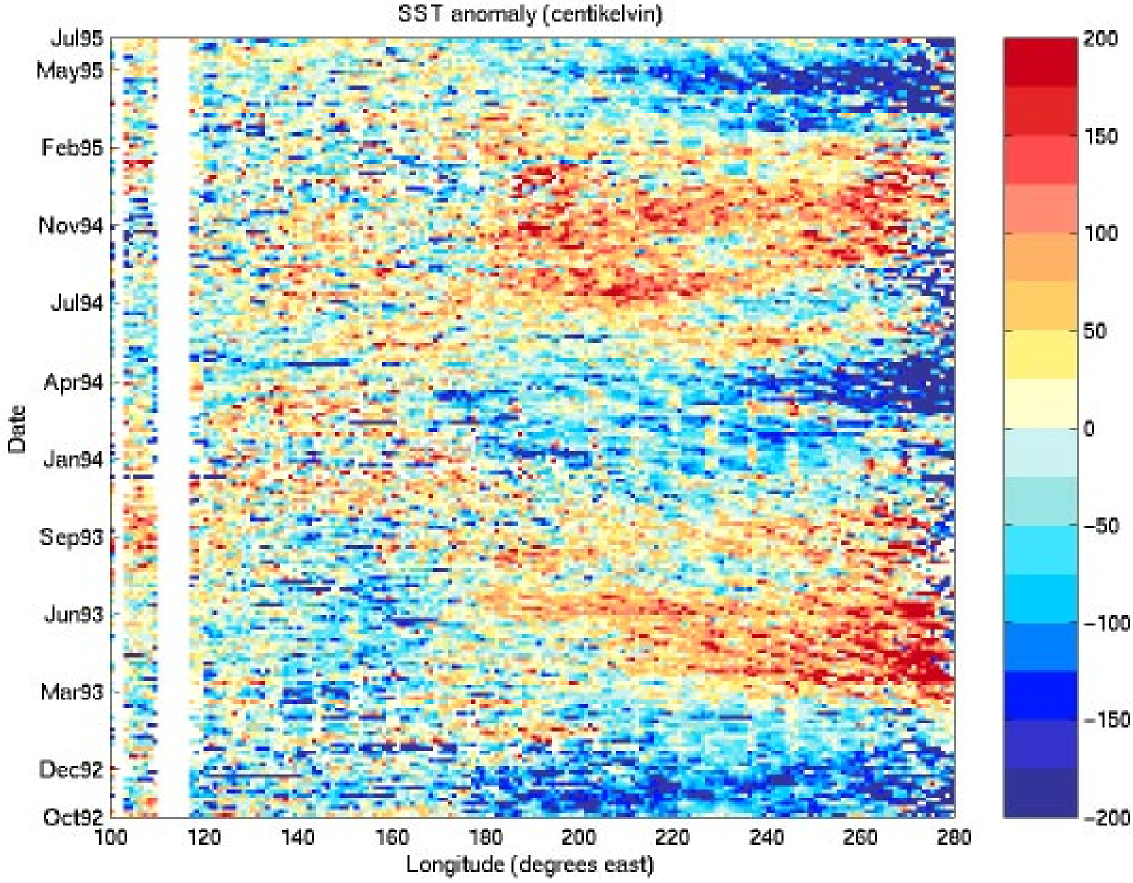
Figure 2 SLA time-longitude plot 0-1°N depicting Kelvin waves

Figure 3 1st Rossby coefficients (decomposed SLA) time-longitude plot 4-5°N, annual signal removed

Figure 4 ASST time-longitude plot 4-5°N, annual signal removed

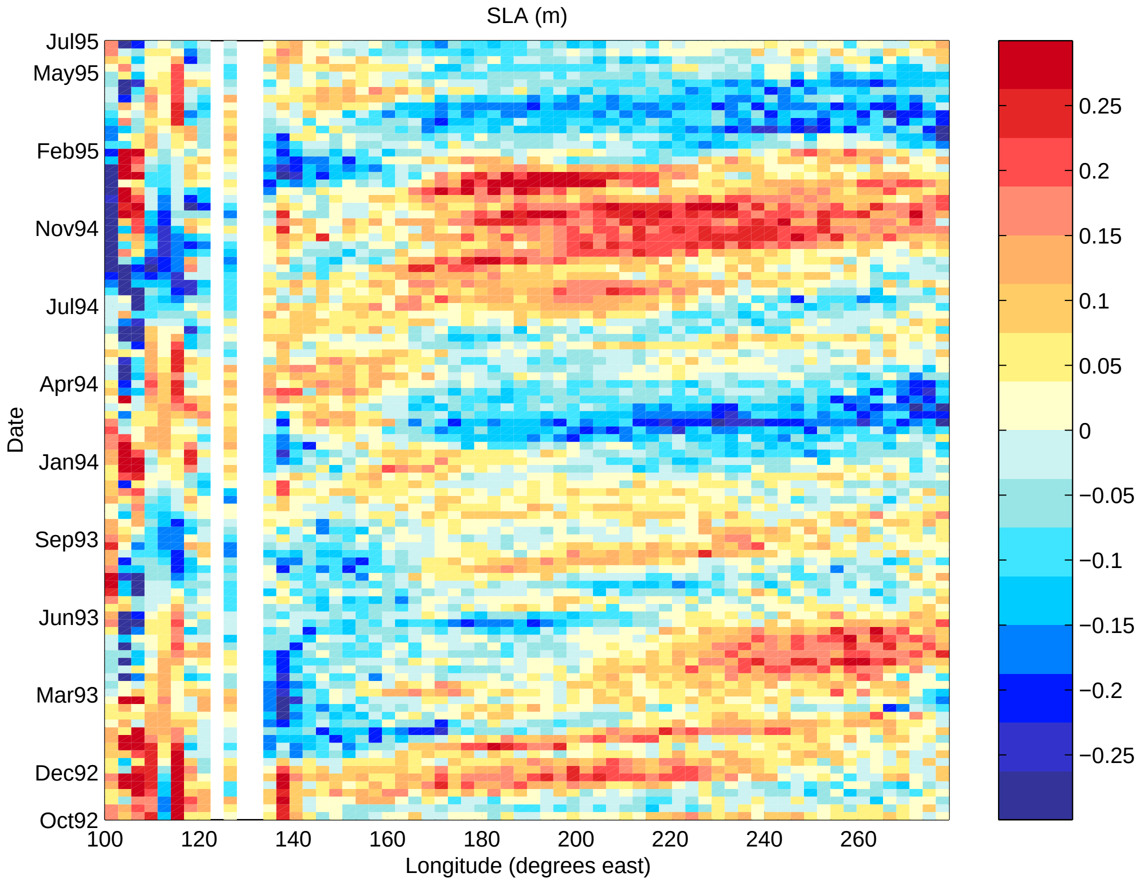
Figure 5 ASST TIW field (4-5°N)

Figure 6 SLA TIW field (4-5°N)



SST anomaly (centikelvin)
Date
Jul95
May95
Feb95
Nov94
Jul94
Apr94
Jan94
Sep93
Jun93
Mar93
Dec92
Oct92
100
120
140
160
180
200
220
240
260
280
Longitude (degrees east)
200
150
100
50
0
−50
−100
−150
−200

Figure 1



SLA (m)
Jul95
May95
Feb95
Nov94
Jul94
Apr94
Jan94
Sep93
Jun93
Mar93
Dec92
Oct92
Date
100
120
140
160
180
200
220
240
260
Longitude (degrees east)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25

Figure 2

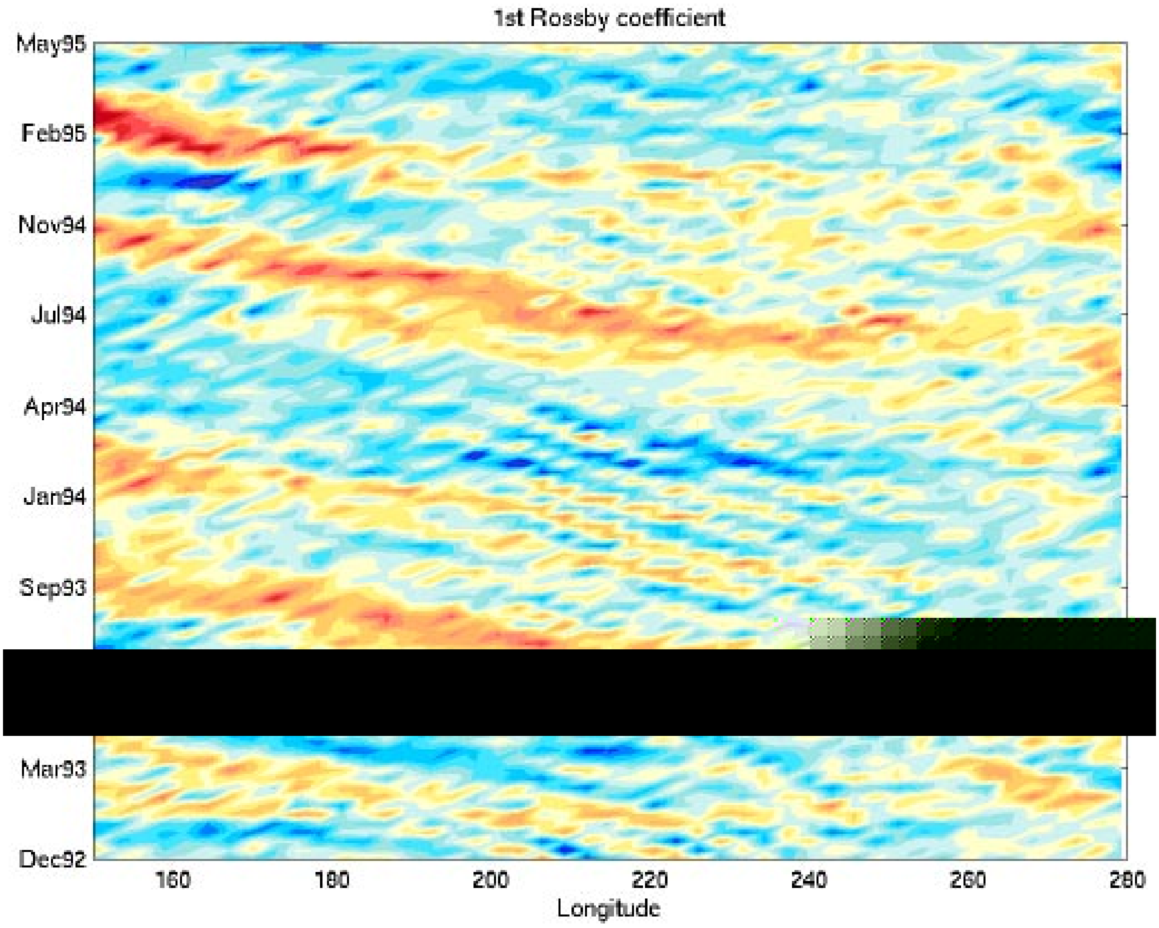

1st Rossby coefficient
May95
Feb95
Nov94
Jul94
Apr94
Jan94
Sep93
[redacted]
Mar93
Dec92
160
180
200
220
240
260
280
Longitude

Figure 3

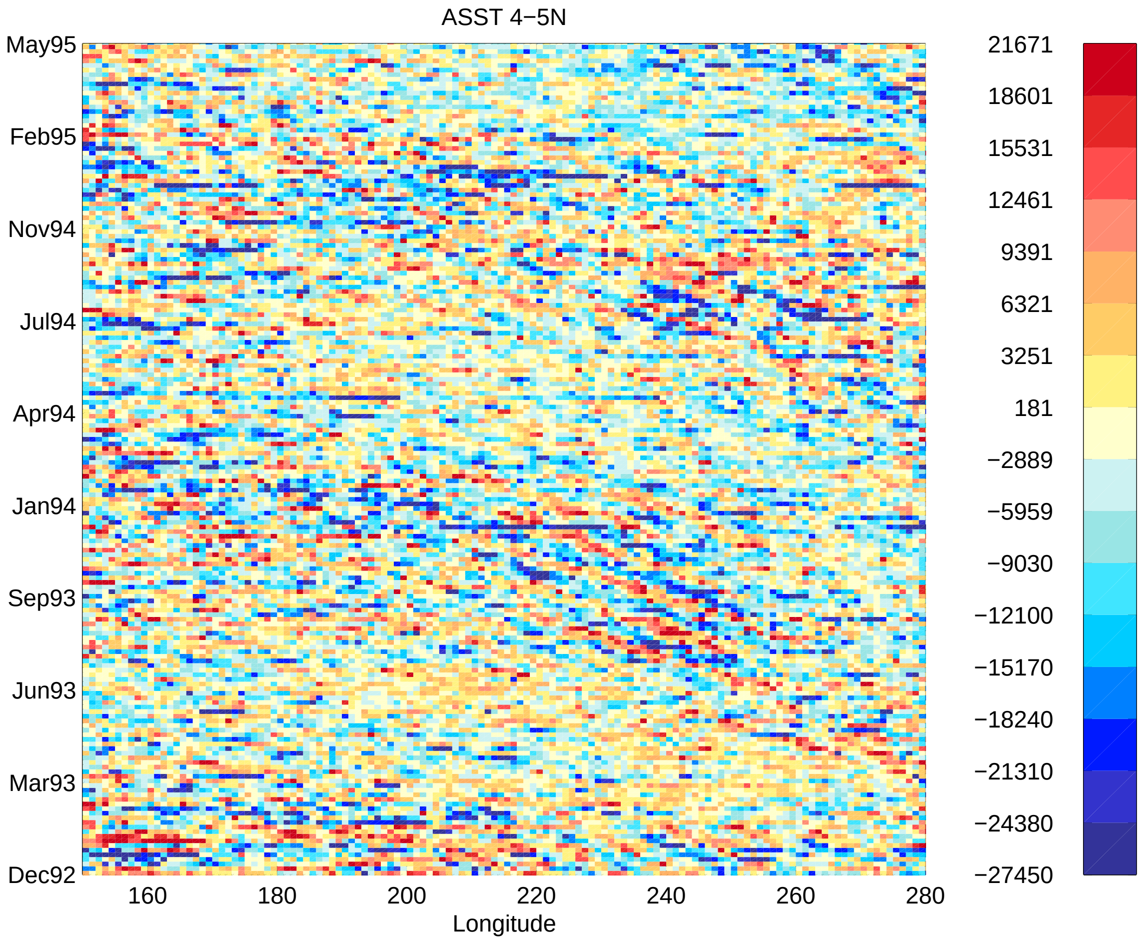
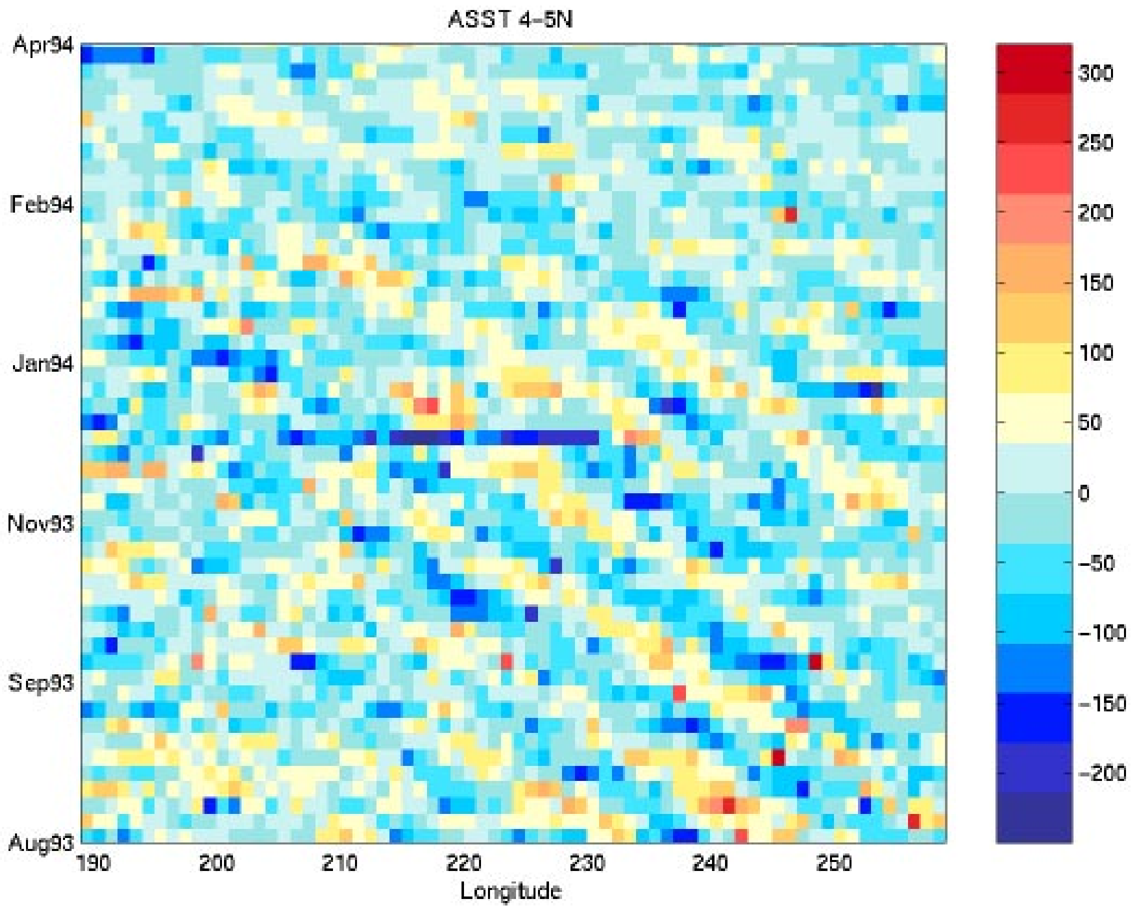

ASST 4−5N
May95
Feb95
Nov94
Jul94
Apr94
Jan94
Sep93
Jun93
Mar93
Dec92
160
180
200
220
240
260
280
Longitude
21671
18601
15531
12461
9391
6321
3251
181
−2889
−5959
−9030
−12100
−15170
−18240
−21310
−24380
−27450

Figure 4



ASST 4-5N
Apr94
Feb94
Jan94
Nov93
Sep93
Aug93
190
200
210
220
230
240
250
Longitude
300
250
200
150
100
50
0
−50
−100
−150
−200

Figure 5

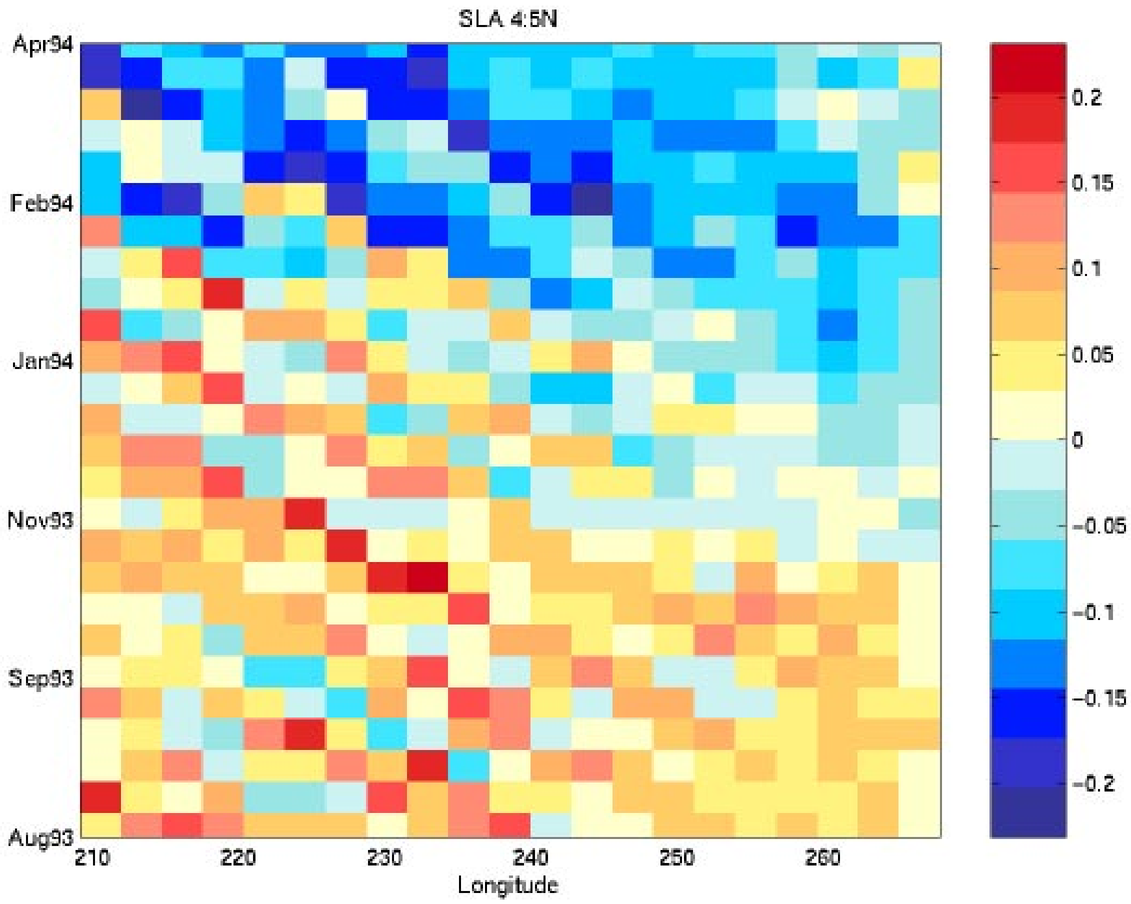

SLA 4.5N
Apr94
Feb94
Jan94
Nov93
Sep93
Aug93
210
220
230
240
250
260
Longitude
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2

Figure 6