GLOBAL CHARACTERIZATION OF ROSSBY WAVES AT SEVERAL SPECTRAL BANDS

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INTRODUCTION

Rossby waves are the ocean's response to large scale perturbations, based on conservation of potential vorticity. Typically these waves are ~1,000–10,000 km long, have a period of months to years and cause a surface displacement of ~1–10 cm.

As a first approximation the ocean behaves as a two–layer system with the vertical displacement of the interface induced by Rossby waves. These vertical displacements are ~10–100 m.

These long, baroclinic waves are non–dispersive and transport energy westward to help maintain the mid–latitude gyres and to intensify the western boundary currents. The energy and the phase propagate westward at the same speed with a typical magnitude of 1–100 km/day.

The TOPEX/Poseidon altimeter (T/P) provided for the first time a long global time series of the sea surface height anomaly (η). Recent results based on T/P from [*Chelton and Schlax*(1996)] (CS) and [*Zang and Wunch*(1999)] (ZW) raised an interesting debate over the validity of the standard linear theory to estimate the Rossby wave phase speed.

In this study a series of finite impulse response (FIR) filters are used to separate the T/P η into several dynamical components. The phase speed c_p, period T, wavelength L, fractional variance V, amplitude A, and signal–to–noise ratio S/N are estimated.

The same technique has been successfully applied to compare heat storage from T/P and in situ data in [*Polito et al.*(2000)] since the effect of salinity on η is small [*Sato et al.*(1999)]. A modified Radon transform technique [*Polito and Cornillon*(1997)] was used to estimate c_p.

METHODS

The bin–averaged η data from the WOCE dataset (JPL/PODAAC) has the 8–year mean (93–00) removed and are bicubically interpolated in space to a $1^\circ \times 1^\circ$ grid. Maps of $\eta_o(x,y)$ for the Pacific, Atlantic, and Indian basins are converted to zonal–temporal diagrams of $\eta_o(x,t)$, one per latitude.

The η_o is decomposed through FIR filters into:

$$\eta_o = \eta_t + \eta_{24} + \eta_{12} + \eta_6 + \eta_3 + \eta_1 + \eta_K + \eta_E + \eta_r. \qquad (1)$$

- η_t is the non–propagating, **basin–scale** signal dominated by seasonality and ENSO.
- η_{24} to η_3 are long first–mode **Rossby waves** with approximate periods of **24, 12, 6, and 3 months.**
- η_1 has a period of **1.5** months and is dominated by **tropical instability waves** (TIWs).
- η_K is present only in the equatorial region as a fast eastward propagating semiannual signal identified as **Kelvin waves** .
- η_E includes **meso–scale eddies** and other features that cannot be identified as any of the above.
- η_r is dominated by small scale, high frequency residual.

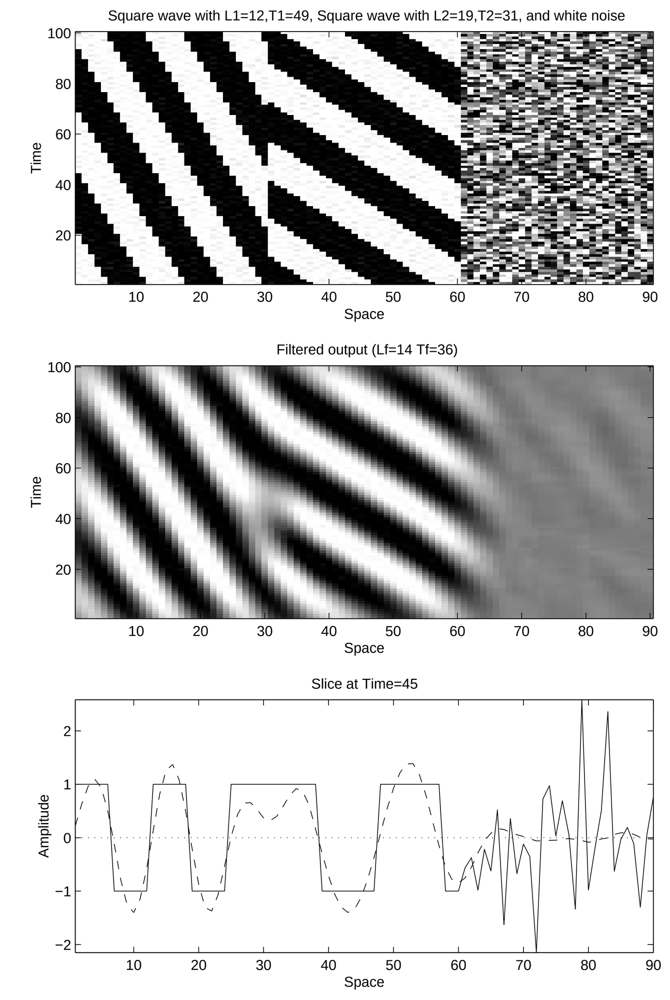

Figure 1: (Top) Input data with two square waves characterized by $L1$, $T1$, $L2$ and $T2$, and white noise. (Middle) Application of the filter characterized by L_f and T_f preserves the original phase, period, wavelength, and phase speed. (Bottom) Results for Time=45 with the original data (-) and the filtered data (--).

Figure 1 shows an example of the filter performance. Two square–waves and a random noise field form a single matrix. This matrix is filtered with one single FIR filter similar to the one used for the T/P data. The filter period, wavelength, and phase speed are slightly different from those used to build the input data. This test demonstrates that:

- filtering **does not change** the c_p, T, L, or A of the original signal.
- even when the filter does **not exactly** match the wave characteristics, its performance is **acceptable** (i.e. it has a finite bandwidth).
- the filter **does not create signals** from noise,
- **no particular wave form** is assumed or enforced.

RESULTS

A series of **FIR filters** is applied to η_o to obtain the components indicated in Equation 1 for all basins and latitudes.

Figure 2 shows the filtered fields and the average c_p at 28.5°N in the Pacific. The dash–dotted lines represent the mean phase speed as are **aligned, in average, with the propagation patterns.**

In Figure 3 the wave regimes that characterize the equatorial Pacific are shown. The basin–scale component η_t is dominated by ENSO which also modulates the η_1 signal, associated with tropical instability waves.

From the filtered components shown in Figures 2 and 3 the wave parameters for each **data block** measuring approximately T by L are estimated.

Figure 4 shows the rms amplitude of the filtered η components. The color codes are different and can be used to quantify the relative intensity of these fields.

The wave parameters are shown as a function of latitude in Figures 5, 6, and 7.

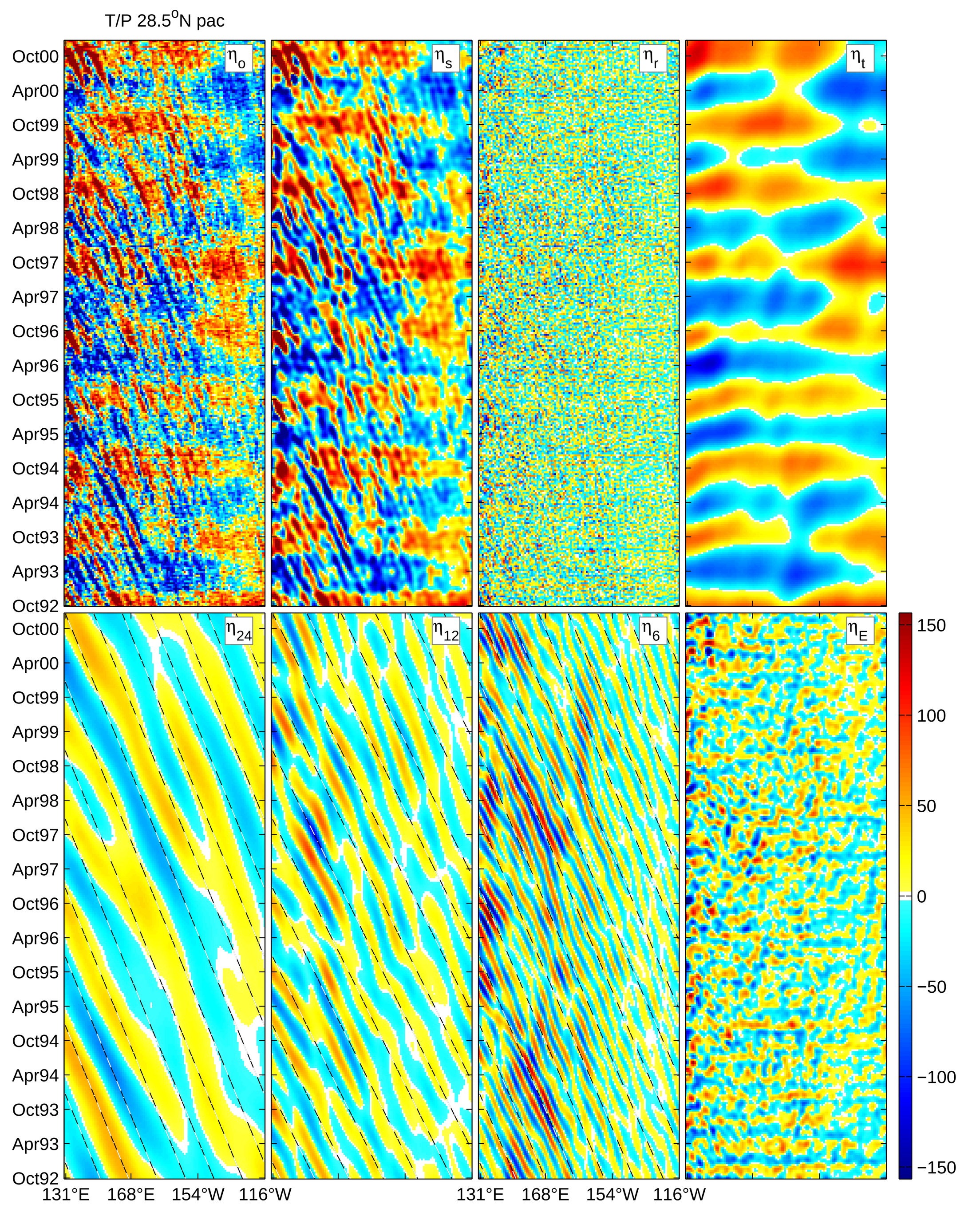

Figure 2: Original (η_o), sum of filtered (η_s), residual (η_r), and filtered sea surface height anomaly fields (η_t, η_{24}, η_{12}, η_6, and η_E), at 28.5°N in the Pacific, in mm. Dash–dotted lines are estimates for mean zonal phase speed.

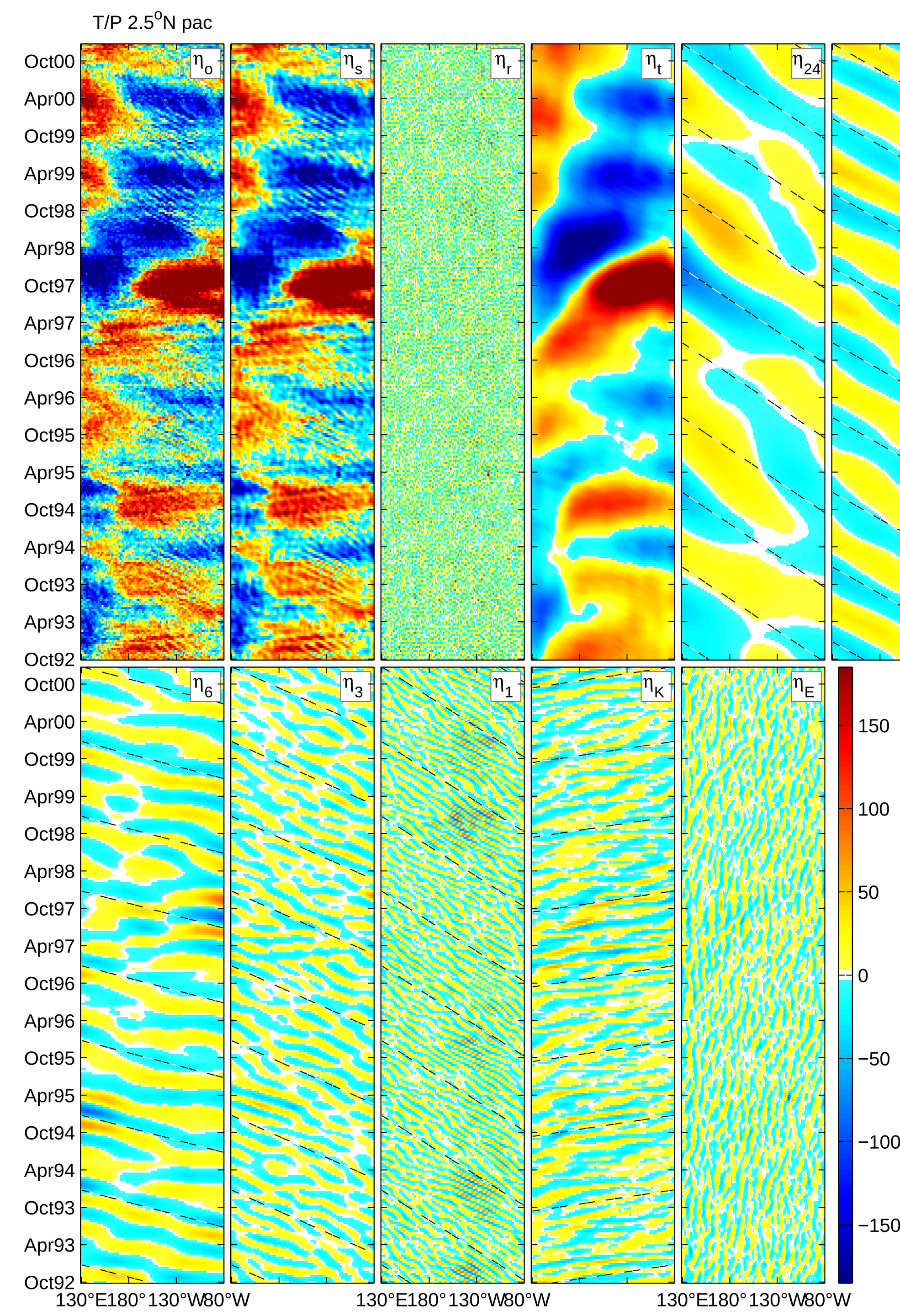

Figure 3: Similar to Figure 2 at 2.5°N in the Pacific showing the equatorial components.

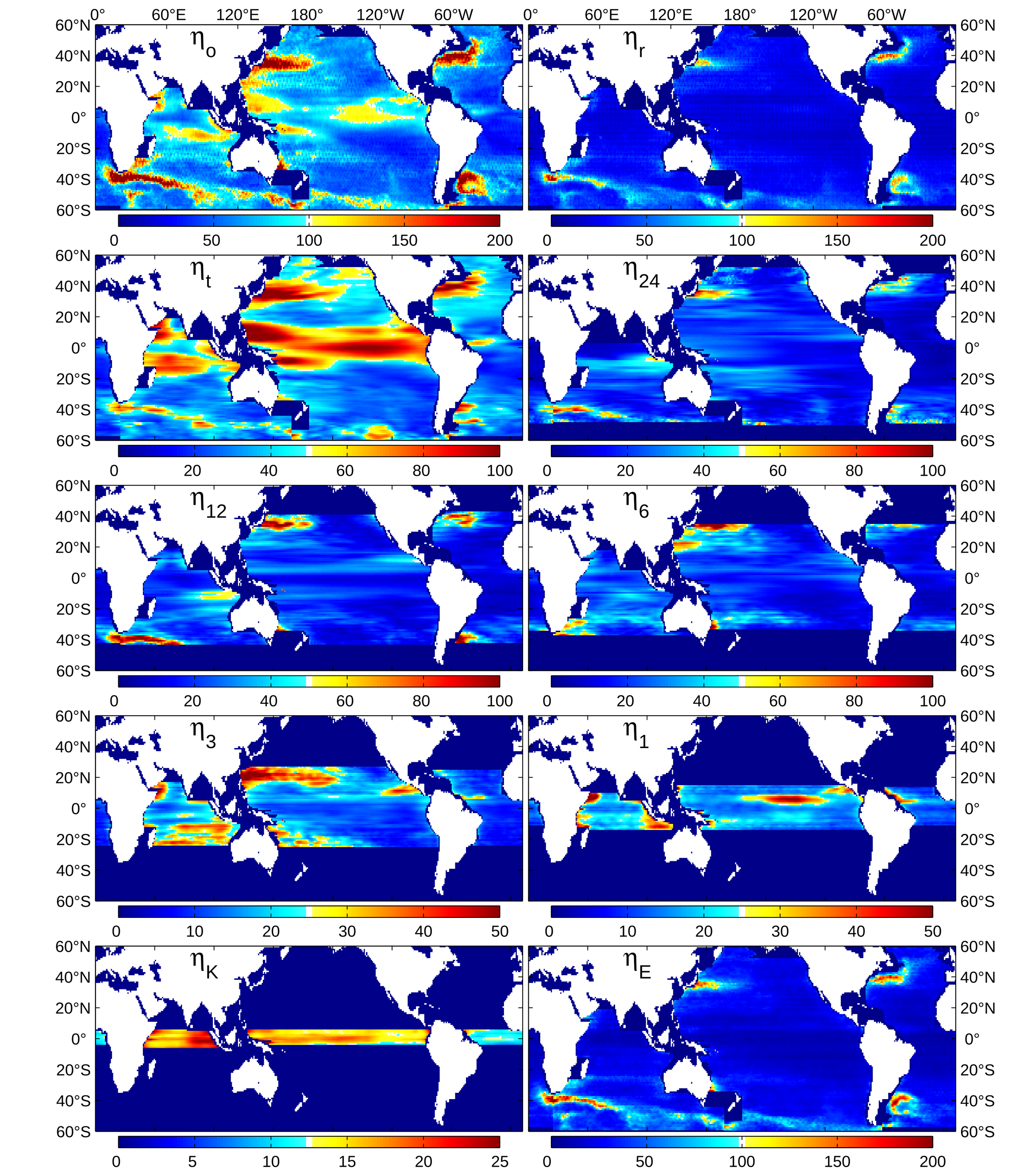

Figure 4: Rms amplitude (mm) of the filtered sea surface height components in mm, as in Equation 1. The latitudinal cut–off marks where the spatial resolution of T/P is no longer sufficient to sample the waves.

CONCLUSIONS

- Globally, the oceanic **Rossby waves behave approximately like free waves.** Our estimates of the average c_p are closer to the standard theory compared to those in CS, particularly at mid to high latitudes.
- In most cases our c_p estimates are **within the error bars of those in ZW,** including a few of their high–frequency cases that depart from the linear dispersion curve.

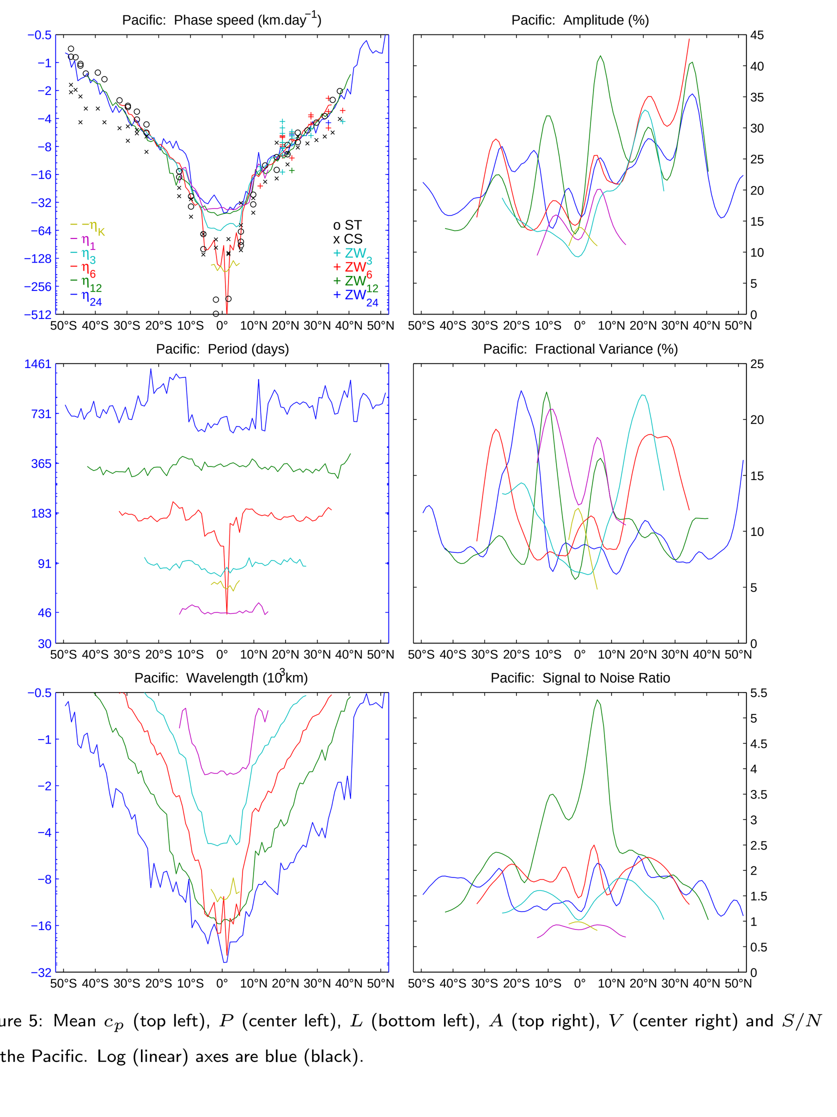

Figure 5: Mean c_p (top left), P (center left), L (bottom left), A (top right), V (center right) and S/N for the Pacific. Log (linear) axes are blue (black).

- There is a bias towards high values poleward of ~ 30° noticeable in Figures 5, 6 and 7 of ~ **25%,** much less than the factor of 2 from CS and less than the 50% from [*Killworth et al.*(1997)].
- The most important difference with respect to CS is that here the **spectral bands are treated separately.** It is possible that the remainder of the seasonal signal has biased the CS c_p estimates, which were based on the Radon transform, towards high values.

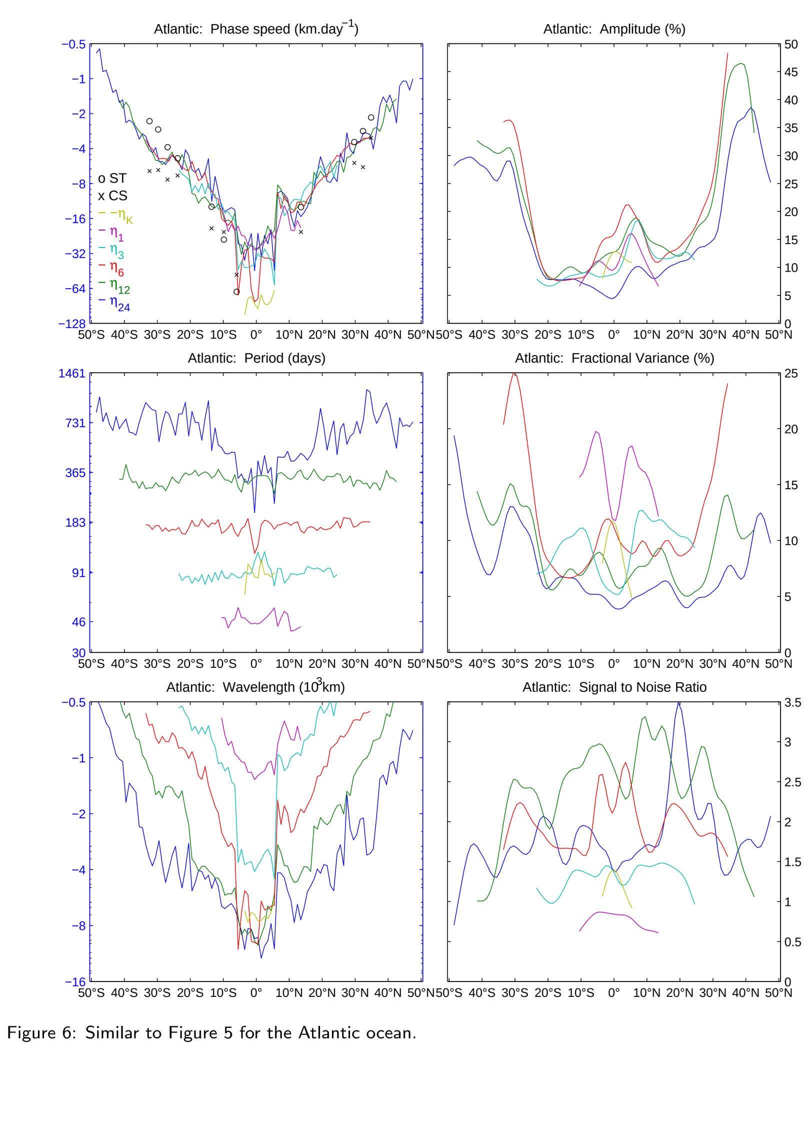

Figure 6: Similar to Figure 5 for the Atlantic ocean.

- Outside the equatorial region the c_p of the Rossby waves is indicative of the first baroclinic mode. An implication of this result is that the waves observed by the altimeter are a surface manifestation of the **vertical displacement of the main thermocline.**
- These waves change the local amount of heat stored in the water column, which surpasses that of the atmosphere by orders of magnitude. Therefore, Rossby waves have a potentially important influence on the **local climate variability** .

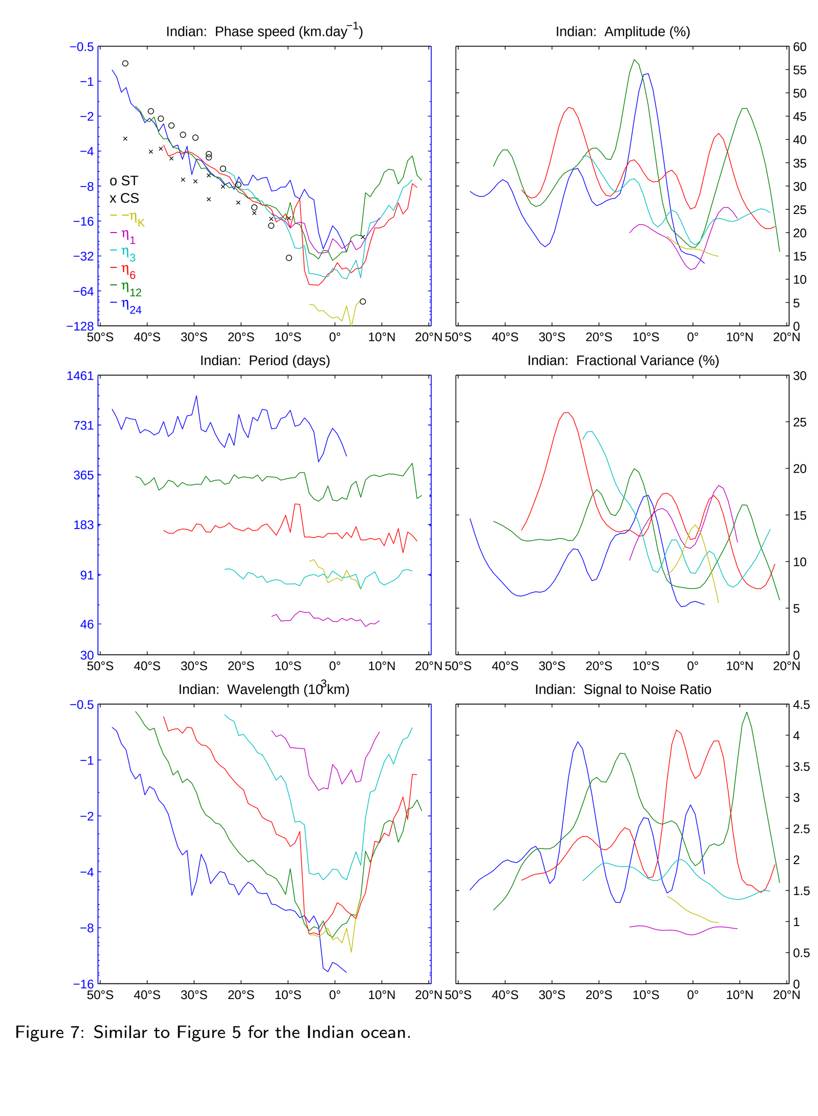

Figure 7: Similar to Figure 5 for the Indian ocean.

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