Detection of Rossby Waves in Ocean Colour Data

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ABSTRACT

This paper deals with some observations of the signature of mid-latitude planetary waves (Rossby waves) in global chlorophyll-a data from the Ocean Colour and Temperature Scanner (OCTS) and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). By producing longitude-time plots of the merged OCTS and SeaWiFS monthly composites we detect, at some latitudes, westward propagating signals whose characteristics are consistent with those expected for long-wavelength baroclinic Rossby waves. The propagating signals are superimposed on the much stronger annual phytoplankton cycle, however their detection may be enhanced by band-pass filtering the longitude-time plots. The propagation speed depends on latitude, with speed increasing equatorward, as expected for Rossby waves. We show an initial comparison of the results with those obtained from sea surface height data. Finally, we discuss possible explanations for the phenomenon

INTRODUCTION

Oceanic planetary waves or Rossby waves are of great importance for ocean circulation and climate. They transport momentum and information across the main oceanic basins, affect currents and delay the effects of climatic anomalies such as El Niño. Owing to their dimensions, and in particular their surface amplitude of just a few centimeters coupled with a wavelength of some hundreds of kilometers, they cannot be directly observed from ships. Recent advances in satellite oceanography, and in particular the accuracy of the retrieval of Sea Surface Height (SSH) by satellite-borne radar altimeters such as the TOPEX/POSEIDON and those on board ERS-1 and ERS-2, have allowed a detailed study of these waves and proven them to be almost ubiquitous and to travel faster than previously expected [1]. The signature of Rossby waves has also been observed in the global Sea Surface Temperature (SST) dataset. A comprehensive review of the techniques used to extract the information about Rossby waves from satellite data, as well as of the main results, is in [2].

Having observed Rossby wave propagation in global satellite datasets of SSH and SST, it is a natural step to examine global datasets of ocean colour (chlorophyll-a contained in phytoplankton) which are becoming increasingly available. This paper presents some results of observations of Rossby waves in the global ocean colour record built from NASDA's Ocean Colour and Temperature Scanner (OCTS) and NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) datasets.

DATA AND METHODS

In virtue of the early launch (August 1996) of OCTS on board the Japanese satellite ADEOS (whose operation was unfortunately terminated on 30 June 1997 because of a major failure of the solar array) and the subsequent (August 1997) launch of SeaWiFS, the scientific community has access to an almost 4-year long time series of ocean colour data. This is now being extended by SeaWiFS itself and the recently launched Moderate resolution Imaging Spectrometer (MODIS)

For the purposes of this study we used OCTS Global Area Coverage (GAC) level 3 Binned Map data (monthly chlorophyll-a composites) which are currently available from NASDA-EORC. The data have been processed with version 4 chlorophyll algorithm and cover the period November 1996 to June 1997 (8 months in total). For SeaWiFS we used GAC level 3 data from NASA-GSFC DAAC. The data have been reprocessed by GSFC with version 2 chlorophyll algorithm. The present study includes 20 months of SeaWiFS data, from October 1997 to May 1999.

The original OCTS and SeaWiFS data are on a 0.0879° x 0.0879° grid, which is far too detailed for observing large-scale features like Rossby waves. So the data have been rebinned onto a 0.5° x 0.5° grid, still more than enough to detect large-scale propagating signals. This additional binning reduces the noise and the effect of potential remnant cloud contamination on the data. Finally OCTS and SeaWiFS datasets have been merged into a single dataset covering 31 months from November 1996 to May 1999, with a three-month gap in summer 1997.

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Since Rossby waves propagate mainly zonally, they can be observed in longitude-time plots of satellite data. Propagating waves appear as diagonal features in the plots, and their speed can be estimated with various techniques as summarized in [3]. These techniques have been developed on SSH and SST data but their application can be extended to Ocean Colour data. However, in some cases it has been necessary to filter the data taking the zonal gradient and applying a bandpass filter in order to highlight the weak propagating signals, which are otherwise hidden by the much stronger annual phytoplankton cycle.

RESULTS AND DISCUSSION

The results presented in this paper are extracted from a set of longitude-time plots for every 0.5° step in latitude from 42°S to 42°N. These plots show, at a significant number of latitudes in different oceanic basins, propagating signals whose signature is consistent (in terms of speed, westward direction and wavelength) with that expected for Rossby waves.

The Indian Ocean at 34.25°S is one location where the propagating signals in the longitude-time plots are visible. Fig. 1 a) shows the longitude/time plot of OCTS and SeaWiFS chlorophyll concentration. Some diagonal features propagating westward can already be detected in this plot, superimposed on the much stronger annual signal. However, to improve the visibility of the alignments of westward-propagating features, we have enhanced the plot by taking the zonal gradient and bandpass filtering (Fig. 1 b). The westward propagating signals are clearer in the SeaWiFS portion of the plot, mainly due to the shortness of the OCTS time series. However in some cases it can be observed that the alignments in the OCTS data and those in the SeaWiFS data have approximately the same slope and the latter lie on the continuation of the former. The speed of the propagating features can be measured directly on the plot in Fig. 1 b) and turns out to be about 3 cm/s, which is consistent with that expected for 1st mode baroclinic Rossby waves in this part of the ocean [4]. In the same ocean, at 14.75°S (Fig. 2), the propagating signals are still visible in the SeaWiFS data (there is only a hint of them in OCTS data) and travel significantly faster (about 6-8 cm/s), as demonstrated by their slope.

A global study of the occurrence and characteristics of Rossby waves in ocean colour data is currently underway. This includes a comparison of the results obtained from ocean colour with those obtained from altimetry. As an example of this comparison, Fig. 3 shows the longitude/time plots of the combined OCTS/SeaWiFS dataset versus the longitude/time plots of the TOPEX/POSEIDON SSH dataset, around 22°S in the Pacific. The propagating signals in ocean colour and T/P altimetry have similar slope (i.e., similar speed). More often, the speed of propagation observed in ocean colour differs from that observed in altimetry. As different baroclinic modes of propagation of Rossby waves travel at different speeds (the higher the mode number, the lower the speed), this fact could indicate that phytoplankton is more affected by different modes from those that affect the SSH field.

The detectability of Rossby waves in ocean colour data means that these waves have some effects on the phytoplankton cells. Without undertaking a detailed discussion of the possible mechanisms, which would be far

a) b)

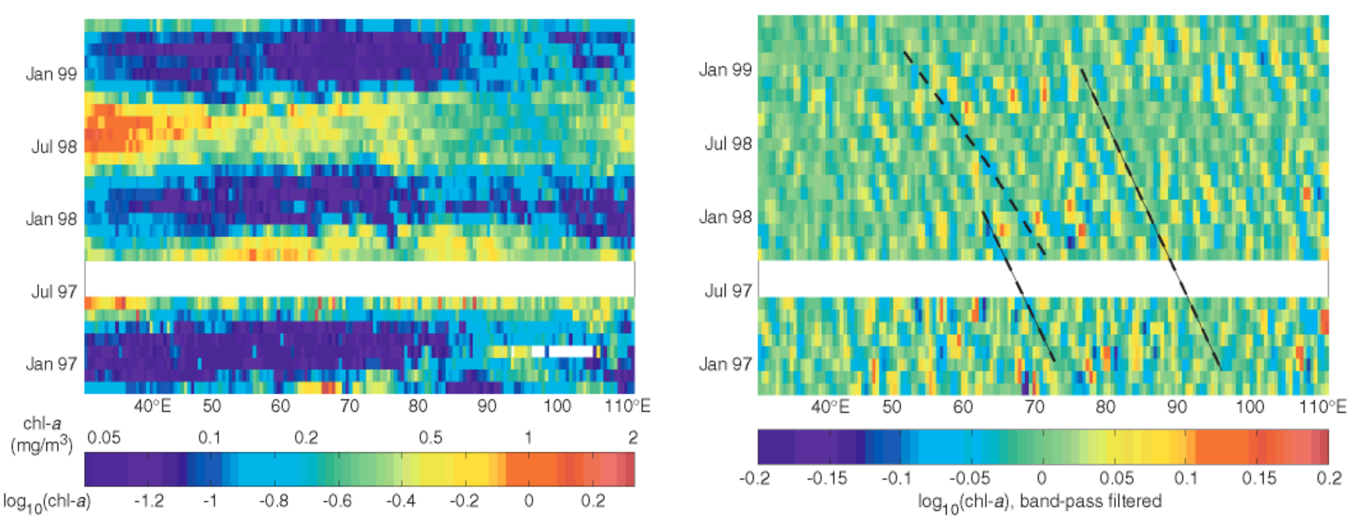

Fig. 1 a) Longitude /time plot of the OCTS/ SeaWiFS composites at 34.25°S in the Indian Ocean b) same as in a), after taking the zonal gradient and bandpass filtering. Three alignments of crests and troughs are highlighted by dashed lines.

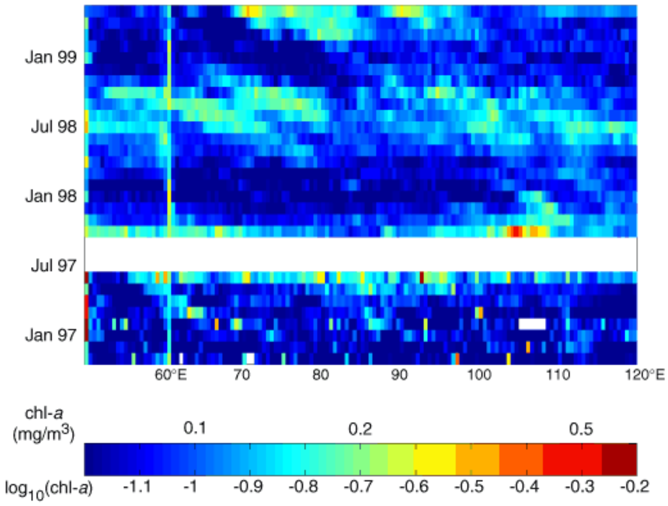

Fig. 2 – Longitude/time plot of the OCTS/ SeaWiFS composites at 14.75°S in the Indian Ocean.

beyond the scope of the present paper, we can at least indicate two ways in which the waves would have a visible effect on ocean colour. One would be a pure advection of the cells due to the modification of the thickness of the mixed layer by the passage of the wave, without any modification of the depth-integrated cell population or of the cell physiological state. In other words, if more or less cells are moved into the upper part of the mixed layer (the only part observable by an ocean colour sensor) this affects how much chlorophyll is detected. A more complex mechanism would bring into play the upwelling/downwelling of nutrients associated with the structure of Rossby waves at depth and thus would imply a direct effect of the waves on the growth and physiologic state of the cells. It is clear that a comprehensive study of the amplitude and phase relationship between the signatures of Rossby waves in the different datasets (SSH,SST,ocean colour) is needed to shed some light on the interaction between physics and biology and improve our knowledge of such a fascinating phenomenon.

ACKNOWLEDGMENTS

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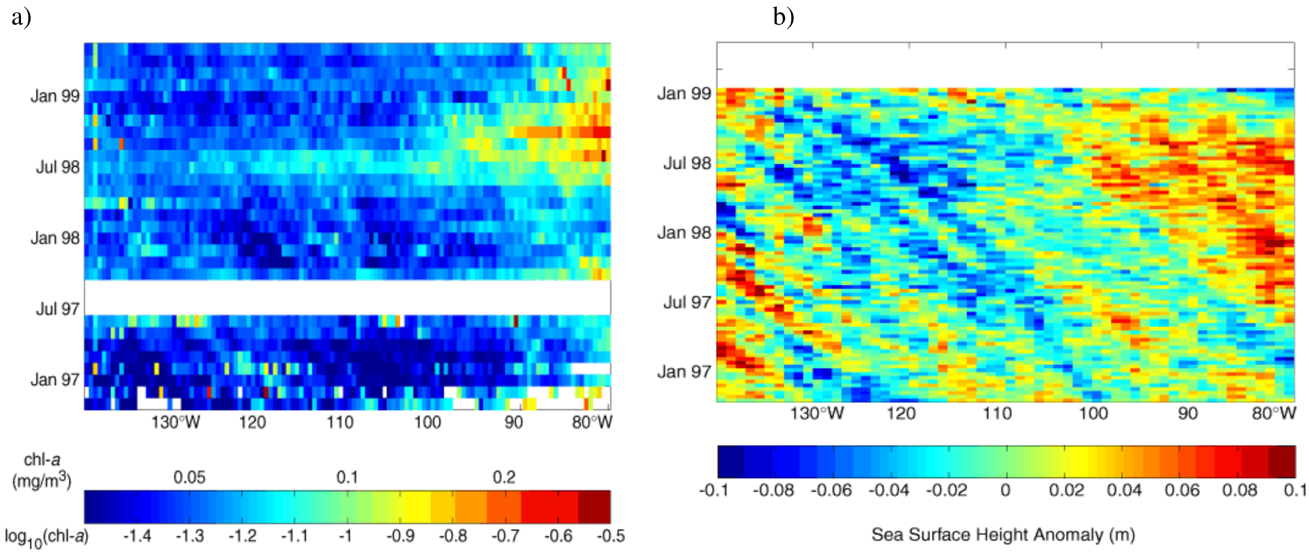

Fig. 3 a) Longitude /time plot of the OCTS/ SeaWiFS composites at at 21.75°S in the Pacific; b) Longitude /time plot of the TOPEX/POSEIDON SSH at 22°S in the Pacific.