OBSERVING OCEANIC PLANETARY WAVES FROM SPACE: TWO DECADES OF PROGRESS

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1. INTRODUCTION

The good quality of altimetric measurements of sea surface height (SSH) from the various missions launched since the early 1990s has made possible accurate, sustained observations of meso- and large-scale westward propagating features in the global ocean. These features are the surface manifestation of planetary waves (also known as Rossby waves) and eddies. As a result, our knowledge on the characteristics of ocean dynamics at these scales has dramatically improved. Here we review some of the results of two decades of observations and highlight the importance of multi-parameter (height, temperature and chlorophyll) observations, including those from the various instruments on Envisat, in the study of these features.

With the advent of satellite altimetry in the early 1990s, it was quickly realized that westward propagating features, originally interpreted as planetary waves, are nearly ubiquitous in the world's oceans [1]. Such features appear clearly in longitude/time sections of SSH anomaly (SSHA) data, and at mid-latitudes travel up to 2–3 times faster than the classic theory for planetary waves predicted. This finding stimulated a thorough revision of the theoretical framework that has greatly reduced the discrepancy between predicted and observed speeds [2][3][4][5]. The subsequent improvement in the space/time resolution from the merging of TOPEX/Poseidon (then Jason-1, and now Jason-2) data with ERS-1 (then ERS-2, and now Envisat) data has allowed a sizeable leap forward in knowledge, clearly demonstrating that mesoscale eddies account for a large percentage of the ocean surface variance [6][7] that was previously interpreted as waves.

Other intriguing questions opened by the altimetric observations still remain partially unsolved. Some of those questions are strictly confined to the realm of ocean dynamics, like the existence of waveguides for energy propagation in the oceans or the decomposition of the propagating features into normal vertical modes [8]; but others, stemming from the concurrent observation of propagating signals in complementary data sets, like Sea Surface Temperature (SST) from infrared radiometers [9][10] and chlorophyll from ocean colour sensors [11][12], could imply a role of the features in ocean-atmosphere interactions and in the oceanic carbon cycle. We discuss these multiparametric observations in section 3. First we deal with the issue of separating planetary waves from eddies, in order to assess where the contribution of planetary waves remains significant.

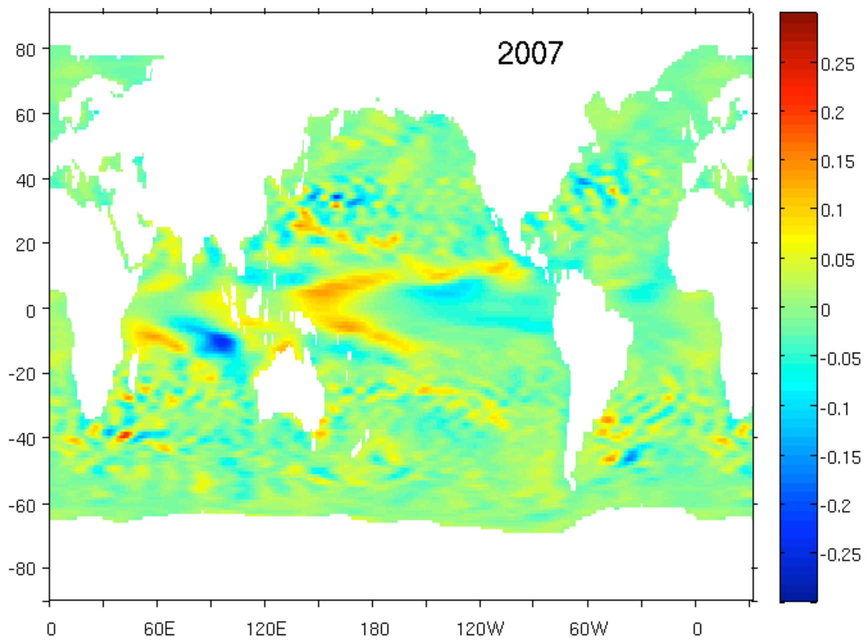

Fig. 1: Sea Surface Height anomaly (m) from multimission satellite altimetry data in April 2007. For this figure the original data from AVISO have been low-pass filtered with a cut off of 20 times the Rossby radius of deformation or 1000 km, whichever the higher, and then westward-only filtered.

2. ISOLATING THE PLANETARY WAVE SIGNALS

While [7] has unambiguously demonstrated that eddies dominate the ocean variability at mid latitudes and at scales of O(100–300km), a simple low-pass filtering of SSH anomalies (SSHA) like the one shown in fig.1 shows that superimposed to the eddies there feature whose shape and scale correspond to those expected for long planetary waves – such are for instance the very large-scale features seen in fig. 1 in the tropical Pacific and Indian Ocean, as well as the large-scale undulations seen at mid-latitude.

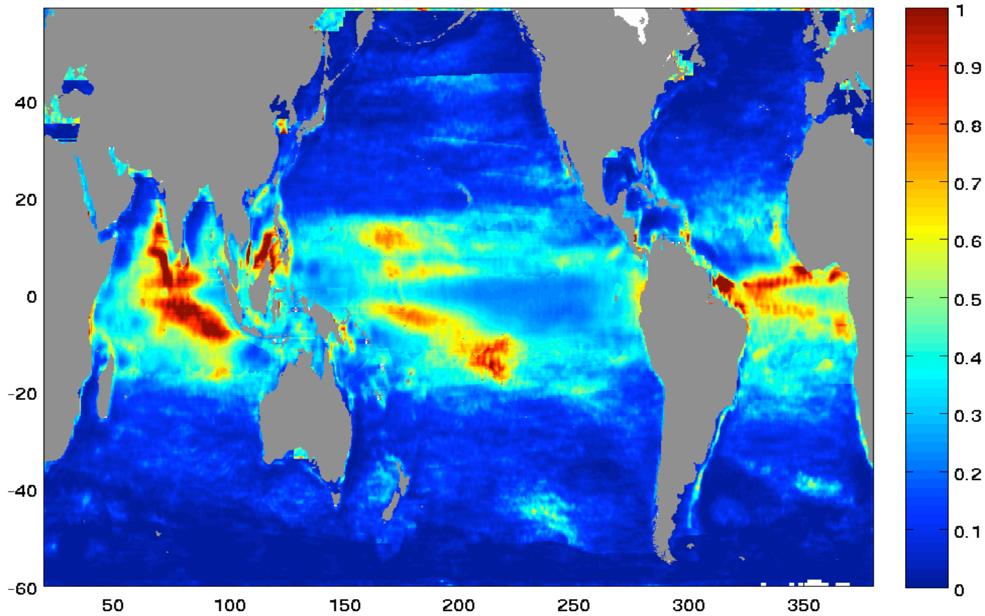

Fig. 2: Fraction of overall SSHA variance left after the filtering described in the text and therefore interpreted as due to planetary waves.

To estimate the fraction of SSH variability due to the waves, we started from the overall SSHA record and removed a synthetic eddy field reconstructed on the basis of the global catalogue of eddies in [7]. Then we computed, in each location of the world's ocean, the wavenumber/frequency spectra of this residual field and filtered it to pass only that region of the spectrum bounded by the wavenumber axis (ω = 0) and by the $\omega = f(k)$ dispersion curve for the first-mode baroclinic planetary wave, computed according to one of the extended theories [3]. The ratio of the variance of this filtered residual field to the variance of the overall SSH field is shown in figure 2. It shows that in the tropics there are regions where the signal due to planetary waves is predominant. The relative importance of the waves decreases at mid-latitudes, in accordance with [7].

3. MULTIPARAMETRIC OBSERVATIONS AND THE CONTRIBUTION BY ENVISAT

Concurrent observations of westward propagating features in SST and ocean colour have started a lively field of investigation on what could be the mechanisms responsible for the observed signals, some of which were first modelled in [13]. Envisat, in virtue of its payload including an altimeter (RA-2), an infrared sensor (AATSR) and an ocean colour sensor (MERIS), is particularly suited for this kind of multiparametric observations. A good example of the features as seen by the suite of instruments on Envisat is shown in figure 3 for a longitude/time section at 32°N in the North Atlantic (in the left panel in fig. 3, RA-2 altimetry has been merged with other available altimeters).

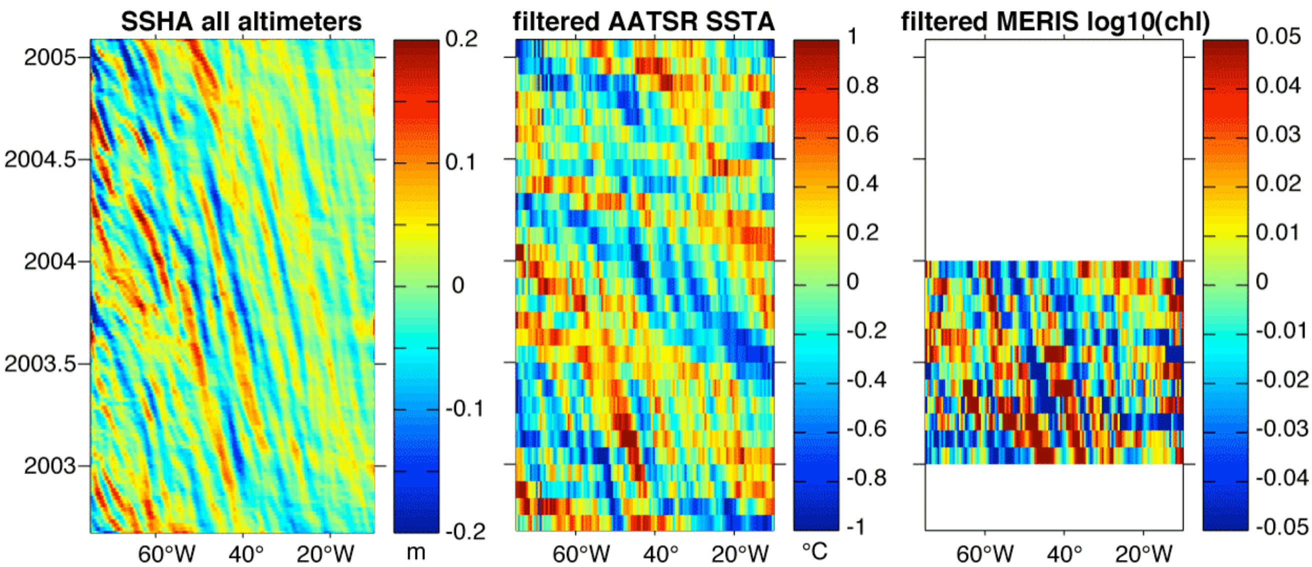

Fig. 3: The signature of westward-propagating features at 32°N, 70°–10°W in the North Atlantic as seen by the suite of instruments on EnviSat.

Combined modelling and observational studies in the North Atlantic have found that vertical mechanism like upwelling of nutrients due to the passage of waves are at best of regional relevance [14][15]; conversely, horizontal advection seems to be the main mechanism responsible for the observed signal over large part of the globe, as recently confirmed also for eddies [16]. This is seen, for instance, by looking at the phase of the peak in cross-spectra of SSH and chlorophyll (fig. 4), which shows abrupt 180° shifts; on closer inspection and comparison with the North-South gradient of surface chlorophyll (not shown here), the location of the phase shifts appear to coincide with the regions where the gradient changes sign, which is exactly what would be expected if horizontal advection were the dominant mechanism [13].

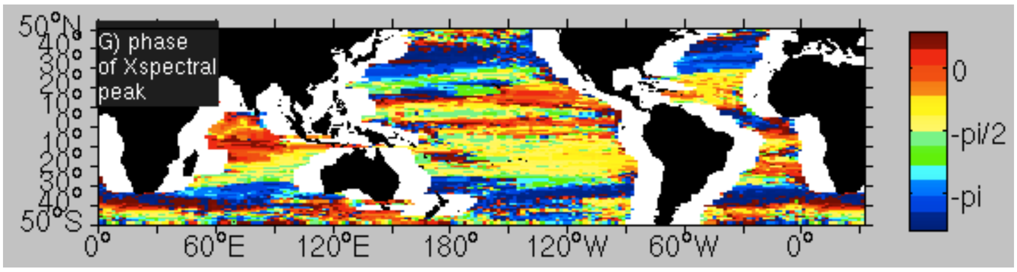

Fig. 4: Phase of the peak in the cross-spectra of surface-derived Chlorophyll and SSHA, computed with the technique described in [13], with updated data records.

4. REFERENCES

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