HIGH RESOLUTION 3D VELOCITY FIELD RECONSTRUCTION FROM SATELLITE SEA SURFACE TEMPERATURE OBSERVATIONS IN THE MEDITERRANEAN SEA

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Abstract

Recent studies suggest that the dynamics in the upper layers of the ocean can be modeled with an effective version of the Surface Quasi-Geostrophic (eSQG) equations. The validity of this approach implies that the 3D velocity field can be reconstructed for the firsts 300-500 m from a Sea Surface Temperature (SST) snapshot. Then, the main objectives of this study are to investigate the applicability of the eSQG approach in the Mediterranean sea and to determine if the eSQG approach can be used to reconstruct vertical velocities from real infrared satellite data. To this end we will focus on the comparison of satellite derived fields with in situ measurements.

Keywords: Western Mediterranean, Remote Sensing, Mesoscale Phenomena, Instruments And Techniques, Currents

An important problem in oceanography is the estimation of the synoptic 3D velocity field, which is currently available only from expensive and labour-intensive in situ measurements. Altimeters measurements allow us to reconstruct the 2D velocity field of the ocean's surface with resolutions of the order of 100-150 km. However, high resolution satellite observations in the visible and infrared parts of the spectrum have shown an ocean very active at scales between 10 and 100 km. Although Sea Surface Temperature (SST) observations in the infrared spectrum provide a qualitative picture of the ocean dynamics at these scales, it is very diffiult to extract surface velocities from them and it is impossible to access vertical velocities.

Recent advances in our understanding of the dynamics of the upper layers of the ocean suggest that these can be modeled with an effective version of the Surface Quasi-Geostrophic (eSQG) equations [1]. The validity of this approach implies that, in situations for which the SST anomaly is representative of the density anomaly below the mixed layer, the stream function and density anomaly can be reconstructed for the firsts 300-500 m with resolutions of 10 km from a single SST image as

$$\hat{\psi}(\vec{k},z) = \frac{g\alpha}{\rho_0 f_0 n_T}\frac{\hat{T}_s(\vec{k})}{k}\exp(n_0 k z)$$

and

$$\hat{b}(\vec{k},z) = -\frac{g\alpha}{\rho_0}\hat{T}_s(\vec{k})\exp(n_0 k z).$$

Here ˆ stands for the horizontal Fourier, k is the wave-vector modulus, f_0 is the Coriolis frequency, g the gravity constant, α the thermal expansion coefficient, n_0 is a "mean" Brunt-Väissälä and n_T an "effective" Brunt-Väissälä frequency that takes into account the contribution of the interior PV and the partial compensation of thermal fronts by salinity [1,2]. n_0 is usually derived from existing observations of the large-scale density field while n_T is usually estimated comparing surface fields with independent observations [2,3]. Furthermore, as it has been shown by [1, 4], vertical velocities can be diagnosed as

$$\hat{w}(\vec{k},z) = -\frac{1}{n_T^2}\left[\widehat{J(\psi_s,b_s)}\exp(n_0 k z) + \widehat{J(\psi,b)}\right],$$

which is an alternative to the classical Omega equation.

The Mediterranean is an area that could benefit significantly from the use of infrared SST imagery to study the surface circulation at scales below 100 km. On one side, the percentage of pixels without clouds is quite high. On the other side, an important part of the mesoscale dynamics is not readily observable with existing altimeters since the Rossby radius of deformation is of 10-15 km.

As in [5], we have started our study analyzing in situ and satellite data from the Omega campaign. The data analyzed corresponds to the three consecutive samplings of the northern part of the Western Alboran Gyre carried on between October 1 - October 11, 1996 (see the figure). They consisted on temperature and salinity measurements obtained from an undulating CTD and velocities from a ship mounted ADCP . On the other side, satellite data consisted on nighttime infrared measurements from the AVHRR sensor on the NOAA-14 satellite provided by MeteoFrance.

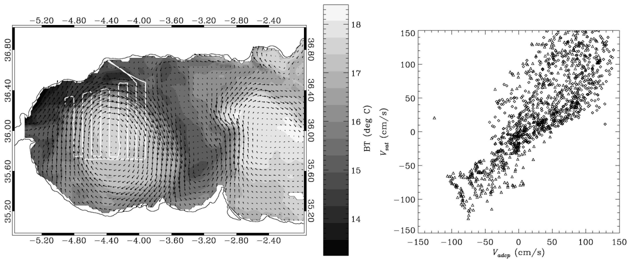

Fig. 1. Left: Brightness Temperature corresponding to October 8, 1996 with the derived surface velocities and the ship track between October 6 and October 9 superimposed. Right: scatter plot between surface velocities measured by the ADCP instrument and geostrophic velocities estimated from satellite data.

To estimate the velocity field using the above equations we need to reduce the noise level of satellite images. Therefore, we used Brightness Temperatures (BT) from channel 4 of the AVHRR instrument instead of SST and we further reduced the noise level using a wavelet-based denoising method. Then, the resulting geostrophic surface velocities (see the example in the figure) were linearly interpolated in time and space to the positions of real velocities observed by the ADCP. Preliminary results (see the figure) revealed a relatively good coincidence between both fields with a linear correlation of 0.8. In this case the "effective" Brunt-Väisälä frequency, n_T, was set to match the kinetic energy of ADCP velocities. The ability to reconstruct vertical velocities is under study.

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