SPATIAL DECOMPOSITION OF SST-SSH RELATIONSHIPS IN RELATION TO THE IDENTIFICATION OF SQG-LIKE UPPER OCEAN DYNAMICS FROM SPACE

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1. INTRODUCTION

Theoretical and observation-driven results, as for example the Surface Quasi Geostrophic theory (SQG) [1], [2], demonstrate that the upper ocean dynamics involve specific dynamical mode characterized by relationships between SST (Sea Surface Temperature) and SSH (Sea Surface Heights) fields. From the observations of microwave Sea Surface Temperature Fontanet et al [3] conclude that SST could be used to complement altimeter data (SSH) to derive sea surface current. Nevertheless this SQG-based method only applies when SST is a good proxy of the density. Such situation arises when environmental conditions favors the homogeneization of the mixed-layer. In this study, we further address the joint analysis of SST-SSH fields and propose a novel approach to spatially decompose their relationships. We focus on an SSH-SST observation datasets obtained during the year 2004, corresponding to a particularly well-sampled period for altimetry to explain where and when a theory such as SQG could be applied.

2. REMOTE SENSING DATA

In this work, we address a mutual analysis of microwave SST and altimetry. As altimetric data, we use the daily time Maps of Absolute Dynamic Topography (MADT) produced by Collecte Localisation Satellites (CLS) available online at http://www.aviso.oceanobs.com/. The considered SST data is the daily optimally interpolated microwave SSTs provided by Remote Sensing System (RSS) available online at http://www.ssmi.com/. The two data sources are interpolated at the same spatial resolution, i.e. $1/4^\circ$. Whereas the daily SST series actually involve daily satellite measurements, the daily MADT maps roughly refer to a weekly temporal resolution, as narrow-swath altimetry sensors involve a weekly revisit time. The SST and SSH anomalies are then obtained as high-pass filtered fields, to analyze scales smaller than approximately 300km. The considered study area is the Agulhas return current for the year 2004.

3. METHOD

The overall linear correlation between anomaly of SSH and SST during the year 2004 in the region of the Aghulas return current presented in fig 1 clearly exhibit a seasonal cycle, which stress that the SQG theory may not hold everywhere and everyday. We clearly distinguish seasonal regimes. During the winter months, a marked strong correlation between fields of SSH and SST anomalies is clearly observed. During the summer months, a much lower correlation is found. To illustrate this seasonal phenomenon we show on the fig 2 (a) and (b) the map of SSH anomaly for the days characterised by the minimum and maximum of correlation respectively. We depict the contours of the SST anomaly. We can observe that areas of negative SSH anomaly always match negative SST anomaly in the both cases. It is not the case for the areas of positive anomaly. They may be covered by positive SST anomaly for high global correlation values but not for low correlation values. To further investigate the space-time variabilities of these SST-SSH relationships, we develop a novel methodology to spatially decompose these relat and spatially distinguish correlated vs. non-correlated patterns. We proceed as follows to define a local correlation measure applied to the level-sets of the SSH anomaly. Let us denote by $\{\alpha_i\}$ a set of SSH anomaly levels regularly sampled between the observed minimum and maximum values. Let us consider an index $i$ such that $\alpha_i < 0$. We aim at computing a correlation

*Thanks to AVISO and RSS projects for providing data.
measure to evaluate to extent to which the SSH anomaly level-set, defined by $SSH_a < \alpha_i$, truly match negative SST anomalies. To this end, we construct an array $SSH_{\alpha_i}$ corresponding to $SSH_a < \alpha_i$ and set his values to -1. A second array is constructed $SST_{\alpha_i}$ corresponding to the same point but set to -1 when the corresponding $SST_a$ is negative and set to 1 when $SST_a$ is positive. Formally, it resorts to:

$$SSH_{\alpha_i} = \begin{cases} \text{SSH}_a(SSH_a < \alpha_i) = -1 \\ \text{SSH}_a(SSH_a > \alpha_i) = 1 \end{cases}$$

$$SST_{\alpha_i} = \begin{cases} \text{SST}_a(SSH_a < \alpha_i) = \{ -1 \text{ if } SST_a < 0 \\ 1 \text{ if } SST_a > 0 \} \\ \text{SST}_a(SSH_a > \alpha_i) = \{ 1 \text{ if } SST_a > 0 \\ -1 \text{ if } SST_a < 0 \} \end{cases}$$

Conversely, for $\alpha_i > 0$, we resort to:

$$SSH_{\alpha_i} = \begin{cases} \text{SSH}_a(SSH_a > \alpha_i) = -1 \end{cases}$$

$$SST_{\alpha_i} = \begin{cases} \text{SST}_a(SSH_a > \alpha_i) = \{ 1 \text{ if } SST_a > 0 \\ -1 \text{ if } SST_a < 0 \} \end{cases}$$

Overall, for level $\alpha_i$, the proposed correlation measure amounts to compute the sum of the product of the two arrays $SSH_{\alpha_i}$ and $SST_{\alpha_i}$, divided by their length.

$$R(\alpha_i) = \frac{1}{N(\alpha_i)} \sum_i (SSH_{\alpha_i}SST_{\alpha_i})$$

where $N(\alpha_i)$ is the total number of point respecting $SSH_a(SSH_a > |\alpha_i|)$. When $R(\alpha_i) = 1$ means that the whole SST anomaly have exactly the same sign than SSH anomaly above the threshold $\alpha_i$. In a opposite way, when $R(\alpha_i) = 0$, indicates that half of the area of SST anomaly have the opposite sign of the SSH anomaly above the threshold $\alpha_i$. For any pair of SST and SSH anomaly fields, this methodology provides us an evaluation of the SST-SSH relationship decomposed according to the level-sets of the SSH anomaly. A global correlation measure can be derived as mean over all the level-sets. Similarly, we can identify the level-sets associated with large (resp. low) correlation values to spatially decompose the SST-SSH relationship.

4. RESULTS

We apply the propose methodology to the considered SST-SSH dataset. To better illustrate our results, we distinguish summer and winter periods, according to the periods below and above the median global SST-SSH correlation (fig 1). For each period, we calculate a mean value of the mutual correlation coefficient $R(\alpha_i)$ for each anomaly level $\alpha_i$. Results are presented on fig 3. We observe high correlation when reaching the extremum of SSH anomaly in the both case winter and summer. Weaker correlation values are found when SSH anomalies approach zero. The mutual correlation corresponding to negative SSH anomaly is quite similar in winter and summer but differs significantly for positive SSH anomaly values. We can see weaker correlation regarding the positive SSH anomaly in summer than in winter. This assymetry confirms the observations already made on the fig 2. Accordingly, such an effect affects and weakens the overall SST/SSH correlation during the summer months. We can also remark on fig 2 (a) that the areas of positive SSH anomalies are not fully disconnected from the areas of positive SST anomalies. For these cases, observations demonstrate a systematic spatial shift between them. This suggests the influence of the mixed layer depth and wind speed to control the spatial correspondence between SST and SSH anomalies, especially below regions of positive SSH anomalies. Our results suggest that reconstruction of low resolution altimeter fields from high resolution SST fields is only possible in areas correspondings to high SST/SSH correlation values. Nevertheless some future works could be done in order to take into account the spatial shift between high SSH and SST anomalies especially in summer.

5. REFERENCES


Fig. 1. Overall correlation between SSH and SST anomaly during the year 2004 in the region of Agulhas return current

Fig. 2. (a) Map of the SSH anomaly for the day 32 characterised by the minimum of the correlation $SST_a/SSH_a$. (b) Map of the SSH anomaly for the day 257 characterised by the maximum of the correlation $SST_a/SSH_a$. SST anomaly is represented in contour.
Fig. 3. Mean temporal mutual correlation during winter and summer.