Trends in SST submesoscale gradients in the South Atlantic Ocean using Terra and Aqua MODIS data

Marouan Bouali, Olga Sato and Paulo Polito

Instituto Oceanografico da Universidade de Sao Paulo;

marouan.bouali@usp.br, marouanbouali@gmail.com

Laboratório de Oceanografia por Satélites

Instituto Oceanográfico

FAPESP

1. INTRODUCTION

High resolution satellite imagery of Sea Surface Temperature (SST) usually displays a variety of geometrical structures such as filaments, meanders, eddies and vortices. These discontinuities are associated to elevated thermal gradients and in the submesoscale domain have spatial and temporal scales of the order of 1 km and 1 day respectively.

Increasing evidence from modelling and observational efforts show that these patterns are part of an intermediate class of ocean processes that lay between mesoscale flows and microscale turbulence and can also influence climate and weather patterns due to the exchange of energy along the ocean-atmosphere interface.

This is a major motivation to analyze the spatial and temporal characteristics of ocean submesoscale dynamics from satellite data and derive statistical inferences of long term changes.

2. OBJECTIVES

In this work we used 12 years (2003-2014) of nighttime 4 µm level 2 SST derived from both Terra and Aqua MODIS data. Specific goals of this study aim to :

1) Determine the location of intense submesoscale frontal activity in the South Atlantic Ocean (SAO) from decadal maps of thermal gradients magnitudes

2) Characterize the seasonal and interannual variability of thermal fronts

3) Analyze long term changes in the magnitudes of SST gradients to determine whether a significant trend, possibly connected to climate variables, can be identified.

3. METHODOLOGY

We specifically used the 4 µm level 2 MODIS SST product (http://oceancolor.gsfc.nasa.gov) because it is generated with the MCSST formulation which does not include a first guess SST field. In fact, the level 4 reference SST field commonly used in the NLSST algorithm may «artificially» transfer SST trends into those of SST gradients and mislead the interpretation of thermal fronts temporal evolution.

We used data from both Terra and Aqua for consistency check. Given our focus on spatial variations of SST instead of SST values, we developed a specific processing chain to mitigate major issues in the quality of the original product that includes stripe noise correction and improved cloud masking.

Our processing chain is illustrated in figure 1 and its impact on monthly and annual maps of SST gradients magnitude is shown in figure 2.

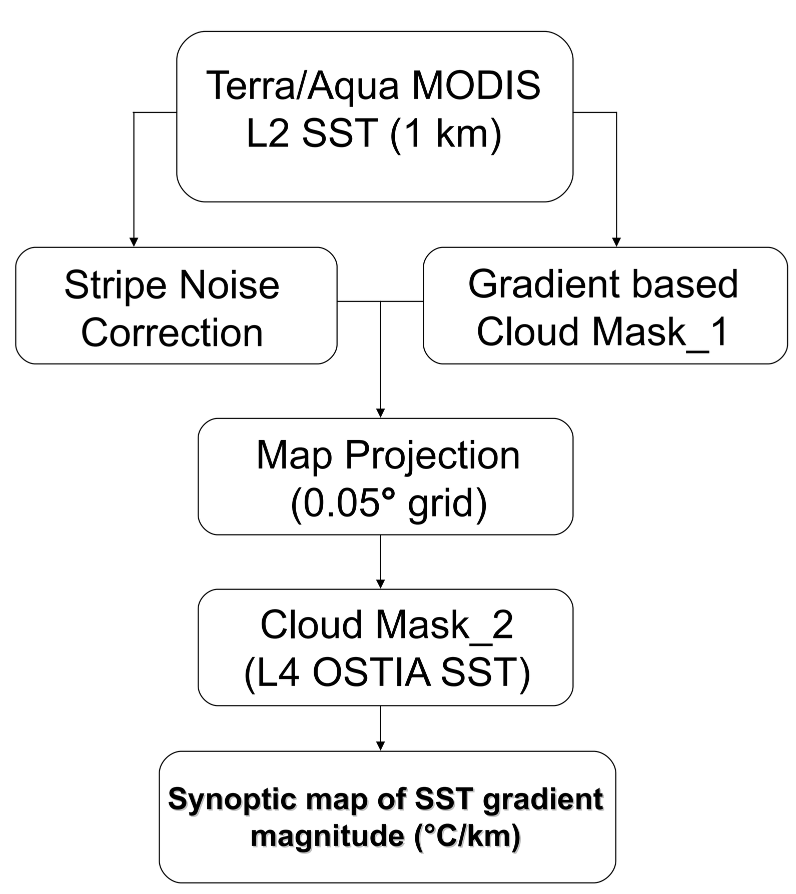

Fig. 1. Processing chain from level 2 SST to level 3 maps of SST gradient magnitudes.

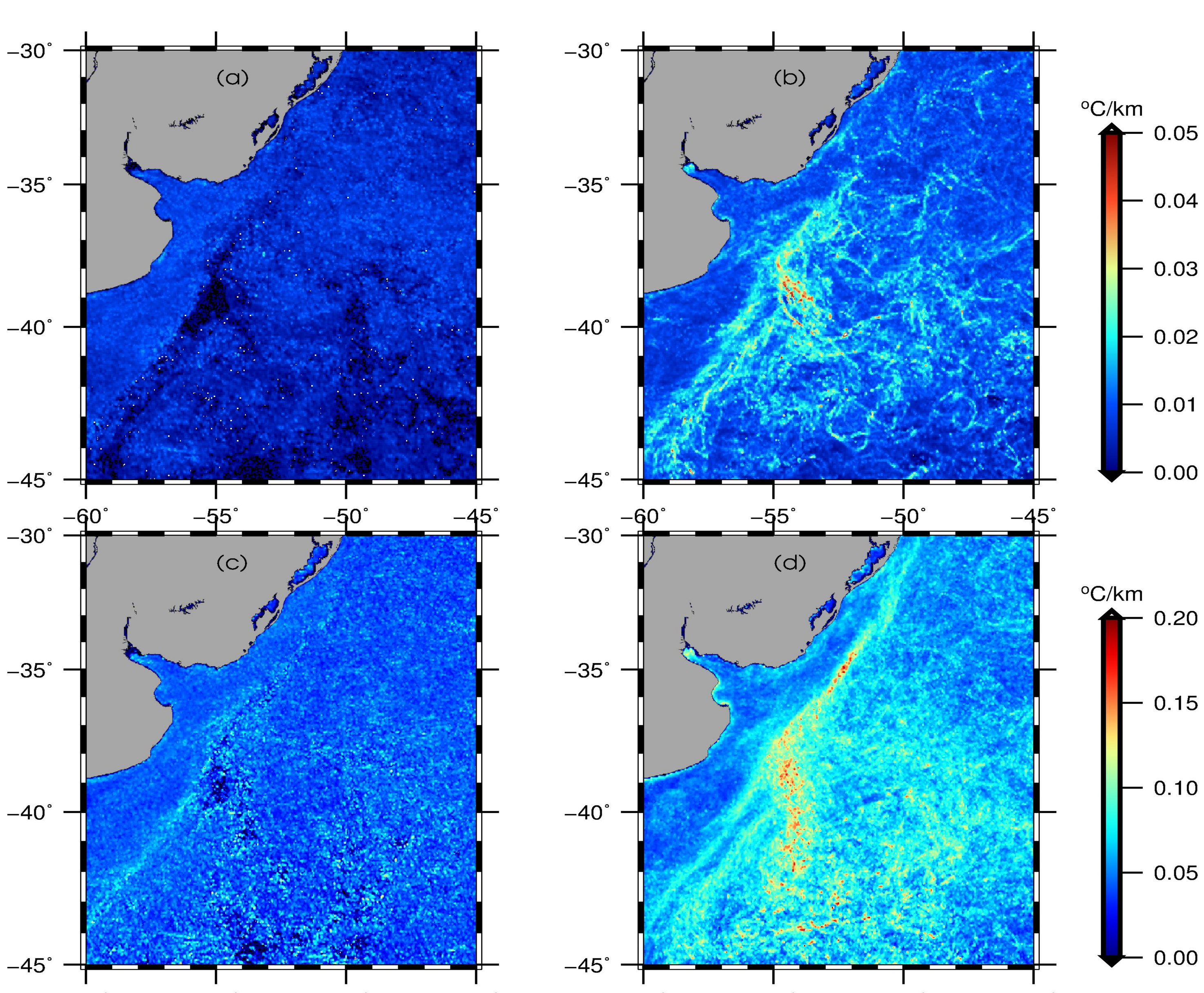

Fig. 2. Seasonal map of summer 2007 (top) and annual map of 2007 (bottom) of SST gradient magnitude in the Brazil-Malvinas confluence region obtained from MODIS level 2 original product (left) and post-processed product for stripe noise correction and improved cloud masking (right)

4. RESULTS

Seasonal cycle of SST gradients

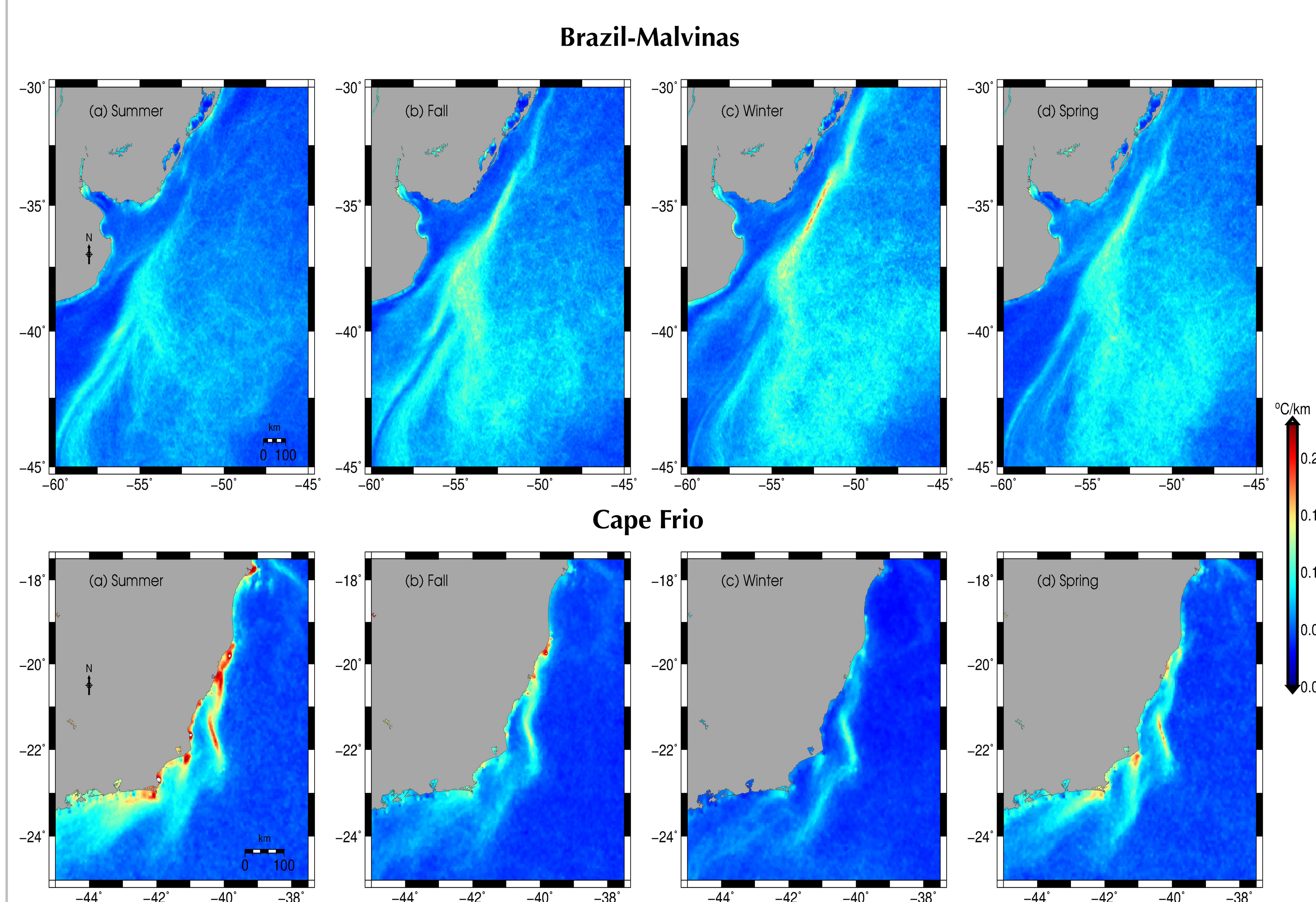

Fig. 3. Seasonal maps (0.05°) of SST gradient magnitude in the Brazil-Malvinas confluence region and Cape Frio

Interannual variability and long term trends

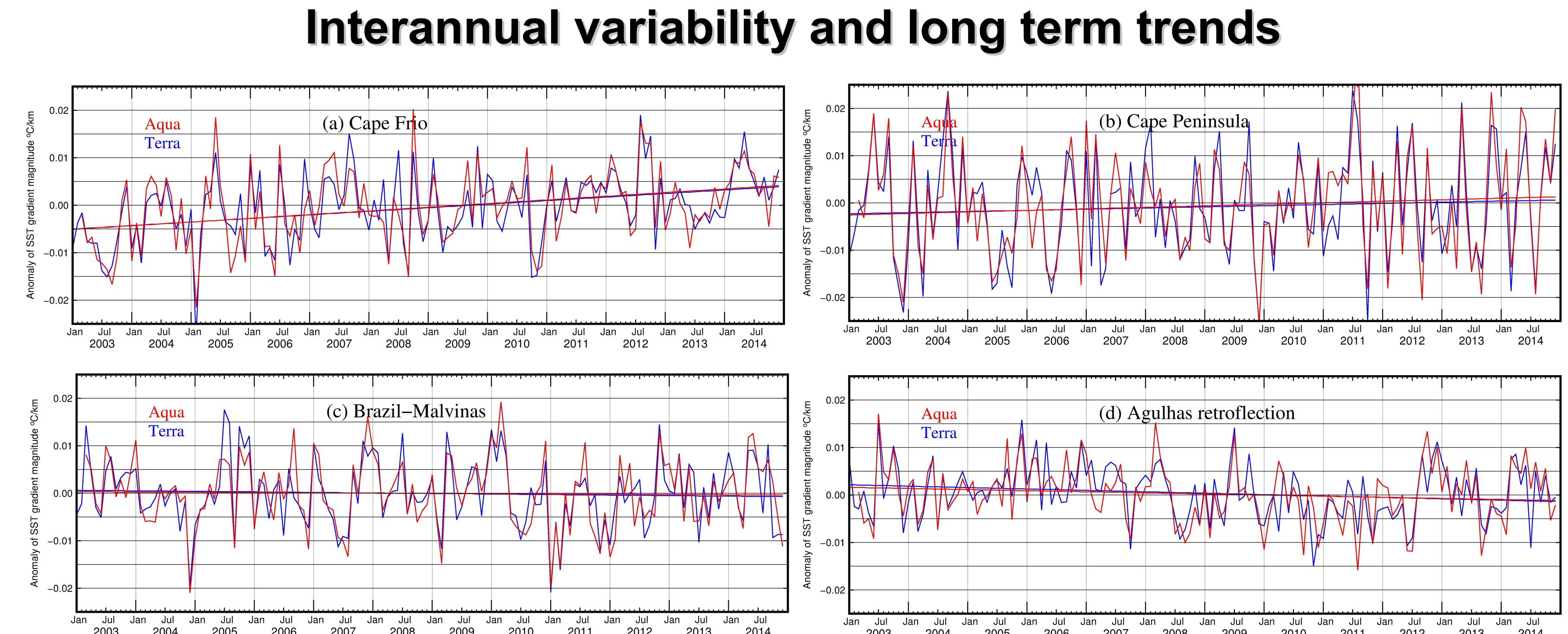

Fig. 4. 12 years time series of SST gradient magnitude in (a) Cape Frio (b) Cape Peninsula (c) Brazil-Malvinas (d) Agulhas retroflection zone

We used a 12 years composite map of SST gradients magnitude to identify regions of the South Atlantic Ocean with intense frontal activity. We noted a clear seasonal cycle in the magnitude of SST gradients that differs depending on the processes involved in the formation of submesoscale fronts. In upwelling coastal regions (Cape Frio, Cape Peninsula, coasts of Namibia and Angola) maximum and minimal frontal activity occur during summer and winter respectively. An almost opposite cycle is observed in confluence regions (Brazil-Malvinas, Agulhas retroflection), with minimum frontal activity occuring in summer.

The 12 years time series of SST gradients derived from Terra and Aqua are consistently correlated and show relatively weak interannual variability in most dynamic regions of the SAO with coefficient of variations below 5 %.

Except for the Cape Frio upwelling region where SST gradient magnitudes appear to have increased by ~14 % from 2003 to 2014, we did not detect any significant trend in the SAO.

5. CONCLUSION

- We used more than 350,000 high resolution synoptic images to investigate trends in the magnitude of SST gradients in the South Atlantic Ocean.
- Major post-pocessing was needed to mitigate data quality issues related to noise and cloud detection
- Despite the sensivity of gradients to the spatial consistency of satellite imagery, the strong correlation between Terra and Aqua MODIS observations suggests a reliable representation of the spatial and temporal characteristic of ocean thermal dynamics in the SAO
- The growing importance of thermal fronts in physical oceanography is an incentive to :
  - Also quantify the «geometrical» accuracy of operational SST products
  - Distribute SST frontal products (synoptic, monthly and seasonal composites) for direct use

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