Institut de recherche pour le développement

SATELLITE OBSERVATIONS OF TROPICAL INSTABILITY WAVES IN THE EQUATORIAL ATLANTIC

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Abstract – Long timeseries of gridded sea surface temperature and sea level anomalies satellite data are used to document the spatial and temporal variability of the surface signature of Tropical Instability Waves (TIWs) in the Atlantic Ocean. These waves are observed to propagate westward on both sides of the equator, though of lesser amplitude in the southern hemisphere. It is shown that the TIWs north and south of the equator are significantly correlated, suggesting that they are dynamically linked. A method based on Radon transform and least-squares minimization problem, originally developped by Cipollini et al. (2006), is applied to study the evolution of TIWs properties during their westward propagation.

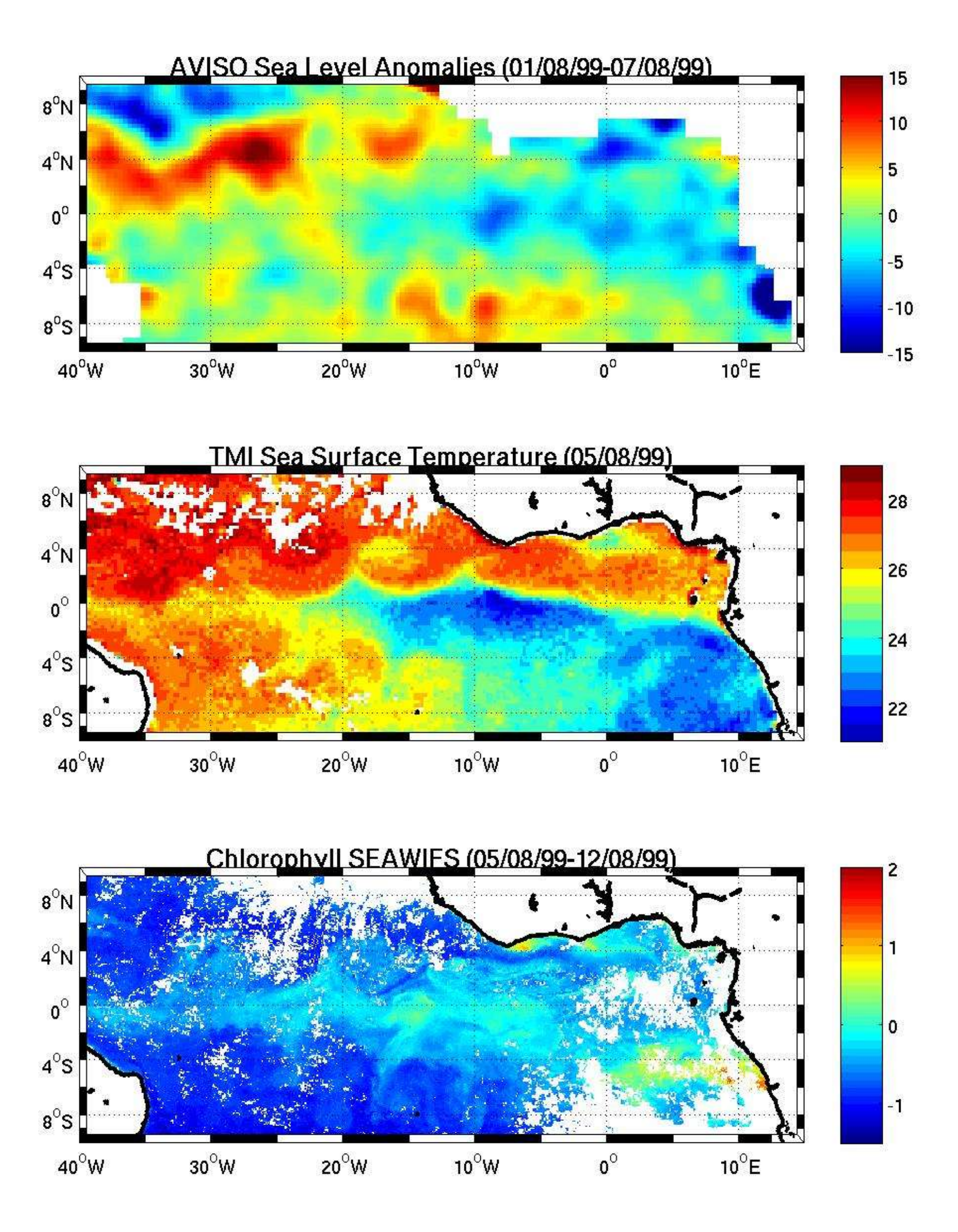

Fig.1 : Satellite observations of SLA (T/P-ERS), SST (TMI) and chlorophyll (SeaWifs) around August 5th, 1999.

Background – Satellite fields of sea level anomalies (SLA), sea surface temperature (SST) or surface cholorophyll (Fig. 1) reveal the existence, close to the equator, of large mesoscale undulations that propagate westward during the boreal summer and fall in the Atlantic and Pacific oceans. These so-called Tropical Instability Waves are generated by barotropic and/or baroclinic instabilities [Yu et al., 1996] and are observed to be a significant contributor for horizontal heat fluxes in the equatorial oceans [Jochum et al., 2004; Peter et al., 2006], to play an active role in the ecosystem of these regions [Menkès et al., 2002] and to generate strong local anomalies in the atmosphere just above [Caltabiano et al., 2006]. These features are well observed in the northern hemisphere, where they form as waves or vortices, but are poorly documented in the southern hemisphere.

This poster discusses the main characteristics, geographical distribution, interannual variability and westward evolution of properties of these waves in the Atlantic ocean from satellite observations of SST (TRMM-TMI) and SLA (2-satellite gridded product from AVISO) for the period 1998-2004.

Spectral analysis – The power spectral density of SLA and SST (Fig. 2) is computed for the midbasin to highlight the dominant periods and wavelengths of the TIWs: even though (sub)seasonal timescales dominate the tropical Atlantic variability, enhanced intraseasonal variability is found at 4°N-4°S in SLA and 2°N-2°S at periods between 20 and 40 days, and for wavelengths between 800 and 1200 km: this variability is larger in the northern hemisphere but still exists south of the equator, and corresponds to TIWs. Since the TIWs power spectral density is mostly isolated in time from lower frequency variability, we can filter the original satellite SST and SLA datasets with a 20-40 days passband Lanzcos filter to get the TIWs-filtered anomalies that are discussed hereafter.

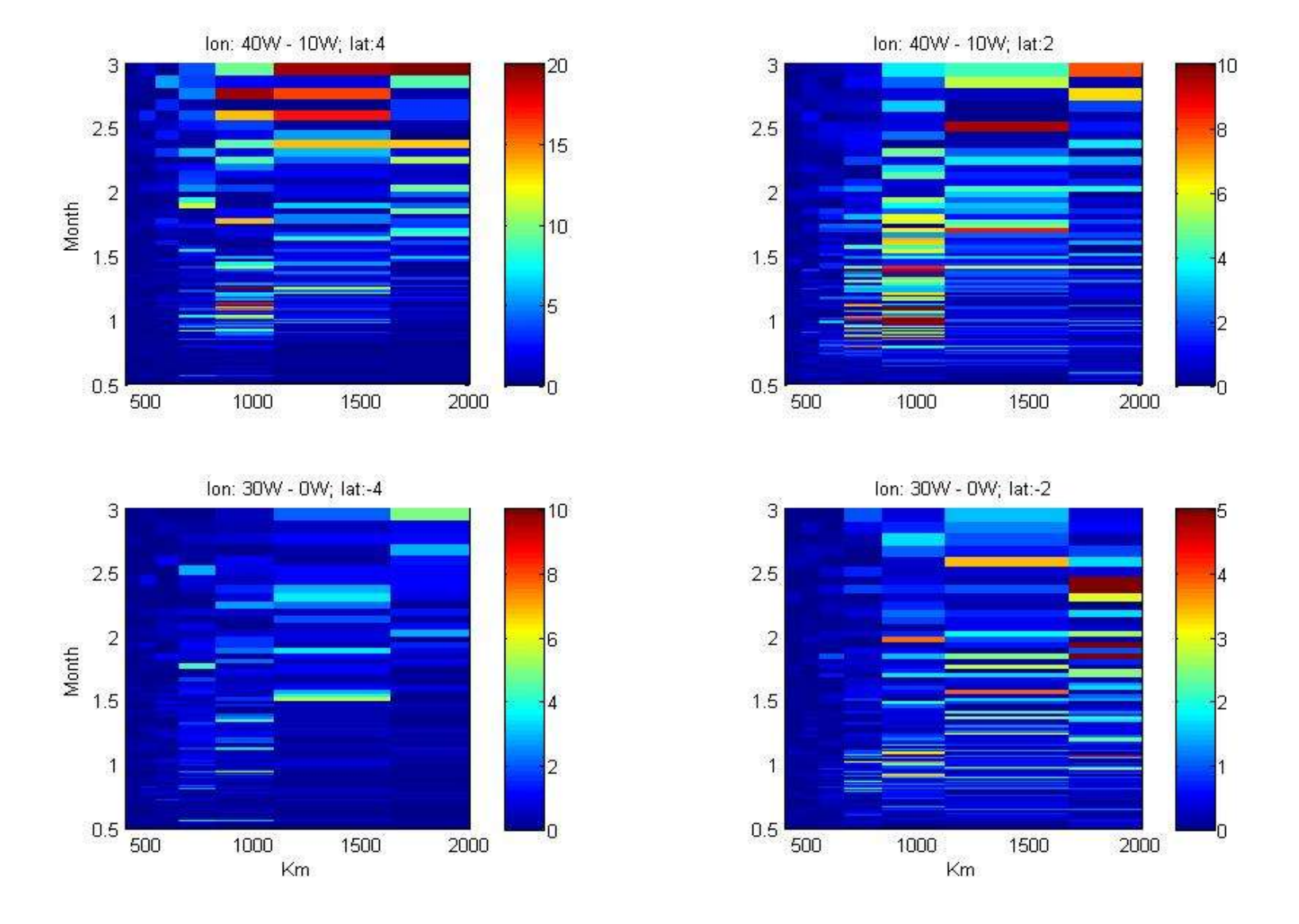

Fig. 2 : Power spectral density (squared modulus of the 2D Fourier transform) in the midbasin for 1998-2004 of SLA (left) at 4°N (upper) and 4°S (lower), and of SST (right) at 2°N (upper) and 2°S (lower).

Geographical distribution and interannual variability – The standard deviation of the TIWs-filtered SLA and SST anomalies (Fig.3) for the whole period 1998-2004 confirms that the maximal TIWs-filtered variability lies in the northern hemisphere (4-5°N for SLA and 0-2°N for SST) and that variability is also presenti, though about twice weaker, in the southern hemisphere. While the variability in SLA is mainly zonal (along 5°N, 2°S and 5°S), the variability in SST mostly follows the westward meridional excursion of the northern thermal front that separates the seasonal equatorial cold tongue from the northernmost warmer waters, with additional secondary regions of variability close to 4°N and 2°S in the midbasin and in the southern part of the Guinea Gulf. The latitudes where this intraseasonal variability is maximum remains nearly constant every year, but its intensity experiences a strong interannual variability: in particular, TIWs are respectively the most and less intense in both SST and SLA, both north and south of the equator, in 2002 and 2000.

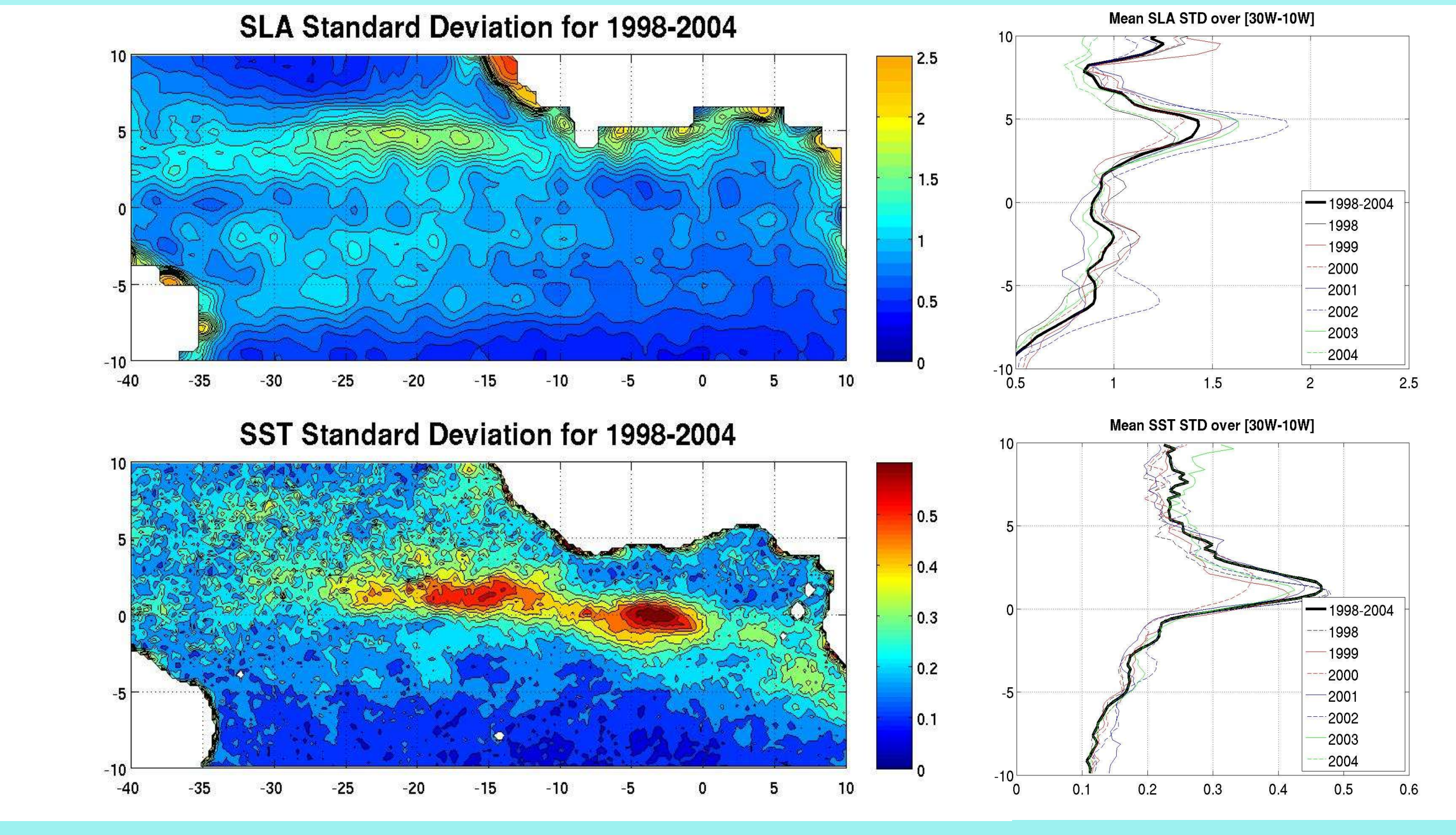

Fig.3 : Standard deviation of SLA (upper) and SST (lower) TIWs-filtered anomalies for the 1998-2004 period: geographical distribution (left) and 30W-10W average (right).

Spatial coherence – The maximum of intraseasonal variability associated with TIWs is observed at 22°W-5°N for SLA and 18°W-2°N for SST (Fig. 3). Time correlation maps of TIWs-filtered SLA and SST anomalies with respect to these points is computed to infer the spatial coherence of these waves (Fig. 4). A significant correlation is obtained for both SLA and SST timeseries north and south of the equator for the whole period 1998-2004, suggesting a dynamical link, in the mid-basin, between the TIWs SLA signatures at 5°N, 2°S and 5°S and the TIWs SST signatures at 2°N and 2°S. The lags between the points of maximum variability and their southern symmetric is 14 days for SLA and 8 days for SST. Note also the correlation between mid-basin TIWs and their counterparts in the south of Guinea Gulf.

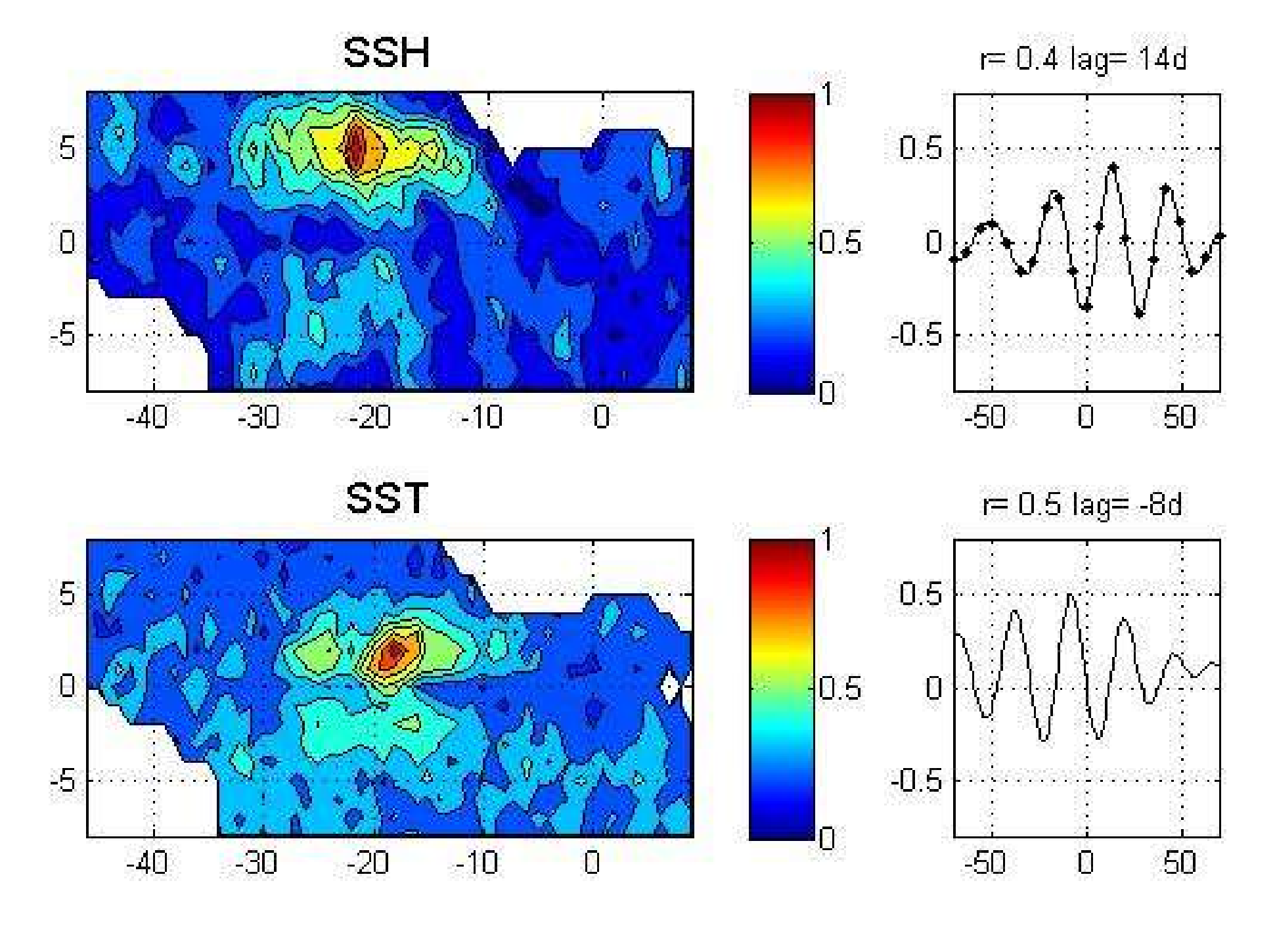

Fig. 4 : Left: Correlation maps for SLA (upper) and SST (lower) TIWs-filtered anomalies with the points of higher variability (respectively 22°W-5°N and 18°W-2°N). Right: phase lags between the same points and their symmetric in the southern hemisphere.

Lagrangian tracking – TIWs are observed in boreal summer to propagate westward in both hemispheres (Fig. 5a). In order to study the evolution of TIWs properties during their propagation, the Rossby waves tracking tool (SOFT: Satellite-based Ocean Forecasting Tool) originally developped by Cipollini et al. for midlatitudes has been adapted to the tropics where wave propagations are quicker. The method lies on the subdivision of a longitude-time plot at a given latitude in overlapping subwindows; in each subwindow, a number of elementary gaussian-shape waves are fitted by a least-square minimization of their parameters (amplitude, width, position, velocity); finally trajectories of each single wave is reconstructed by joining the elementary waves of subsequent subwindows. The method is capable to track TIWs of greatest amplitude both in the northern and the southern hemispheres, for example in 2002 (Fig 5a). The westward evolution of reconstructed TIWs amplitude and velocity for 2002 is presented in Fig. 5b: TIWs amplitudes are maximal between 20W and 30W at these latitudes and can reach respectively 8 and 4 cm north and south of the equator; velocities are westward and of order 40-50 cm/s for this year at these longitudes in each hemisphere, but are generally seen to decrease suddenly to about 20 cm/s west of this region. It is not clear for the moment if this decrease is a physical feature or a bias of gridded SLA product (Fig. 6) in which the longitudinal location of satellite data define artificial propagation tracks that are comparable to TIWs propagation lines.

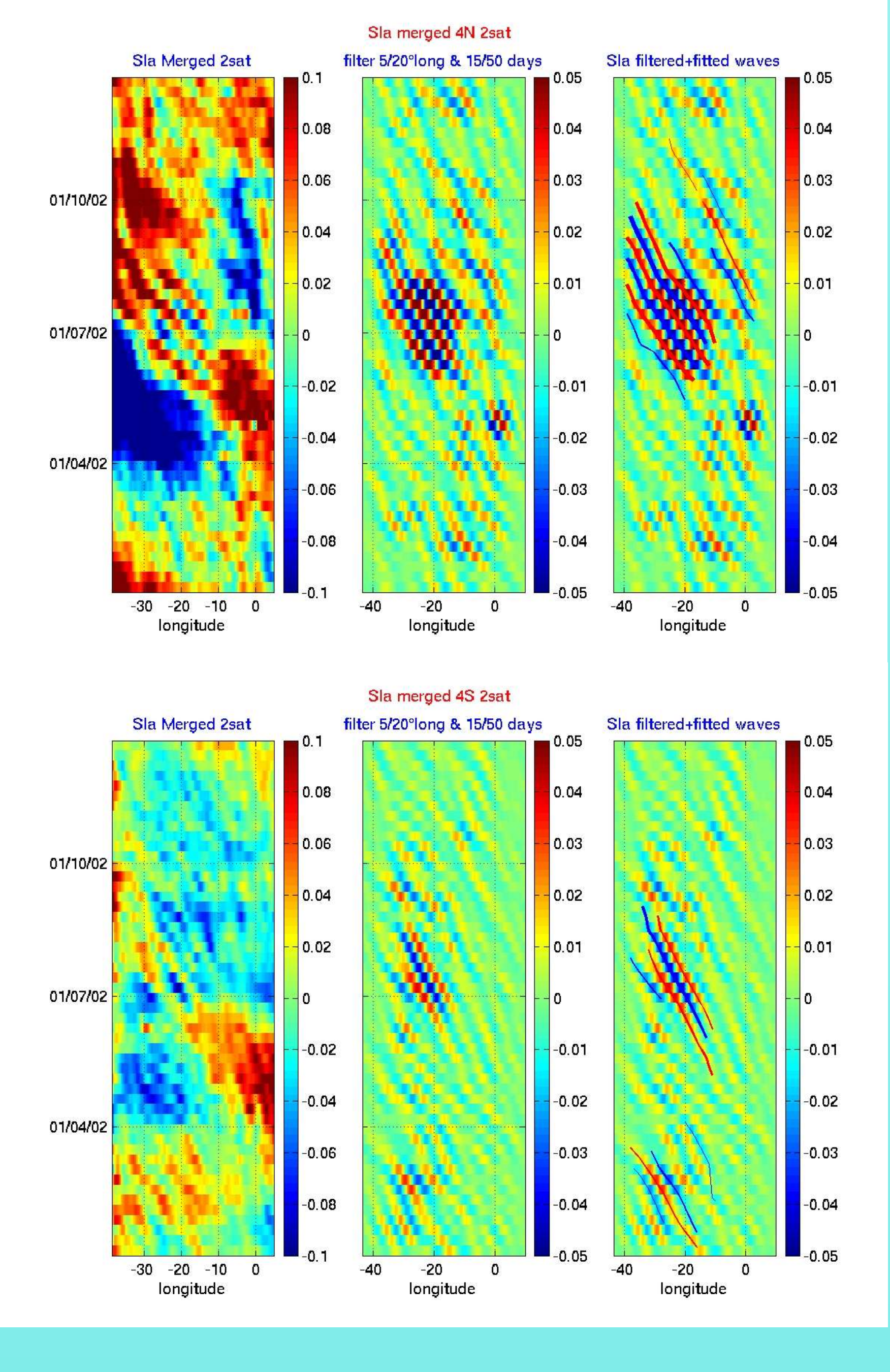

Fig. 5a : Total (left) and TIWs-filtered (middle) SLA in 2002 and reconstructed tracks (right) at 4°N (upper) and 4°S (lower). Waves tracks are recomputed following Cipollini et al. (2006).

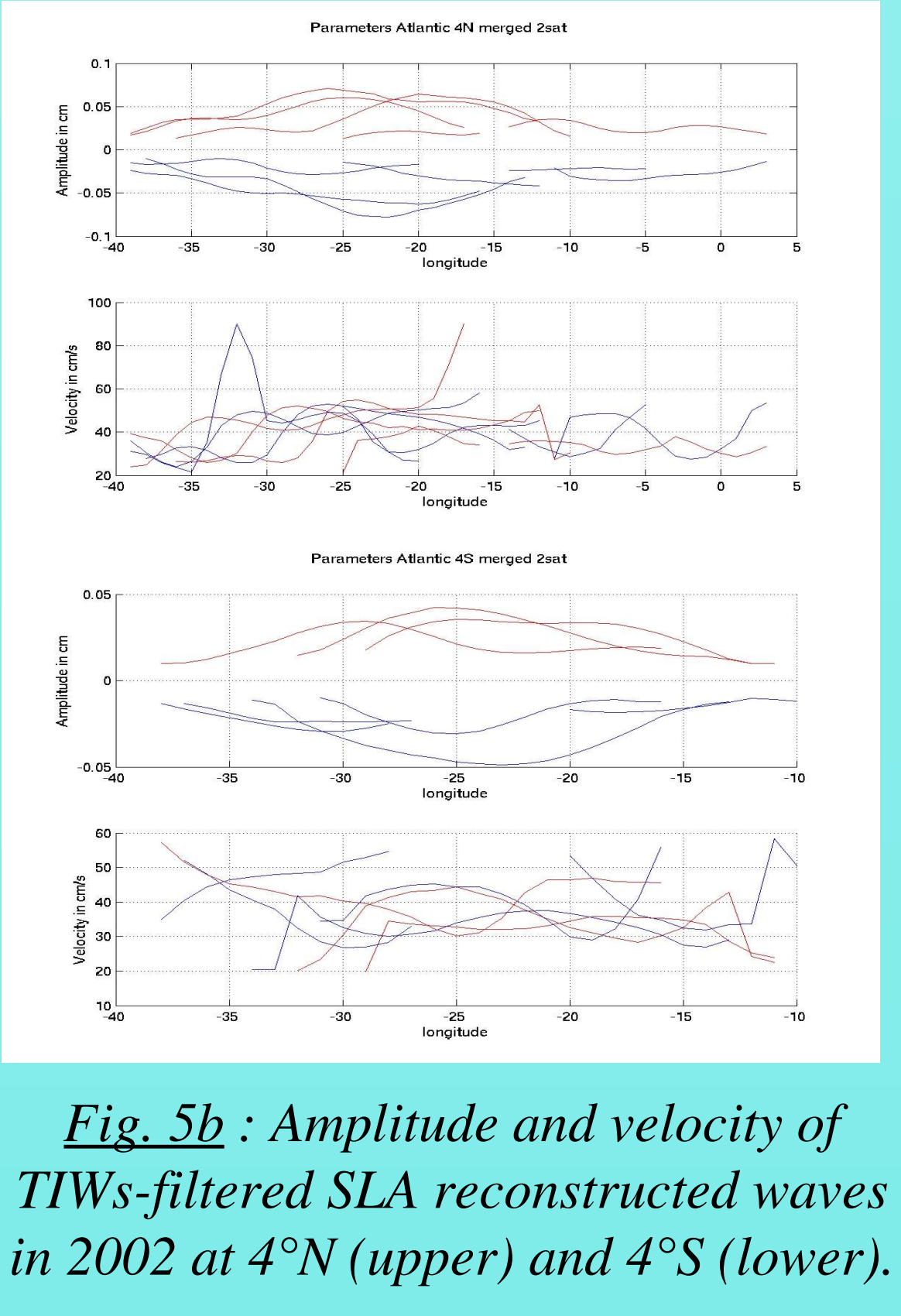

Fig. 5b : Amplitude and velocity of TIWs-filtered SLA reconstructed tracks in 2002 at 4°N (upper) and 4°S (lower).

Conclusion – The main properties of the oceanic surface signature of the TIWs in the Atlantic ocean have been discussed from timeseries of SLA and SST gridded satellite observations over the years 1998-2004. TIWs are observed north AND south of the equator, even though northern TIWs are larger, and their amplitude is subject to important interannual variability. It is demonstrated that TIWs of each hemisphere are significantly correlated in SST and in SLA, suggesting that they are dynamically linked. Finally a wave tracking tool has been used to describe the westward evolution of TIWs properties and reveal the possible bias due to artificial propagation lines in relation to the altimeter satellite tracks.

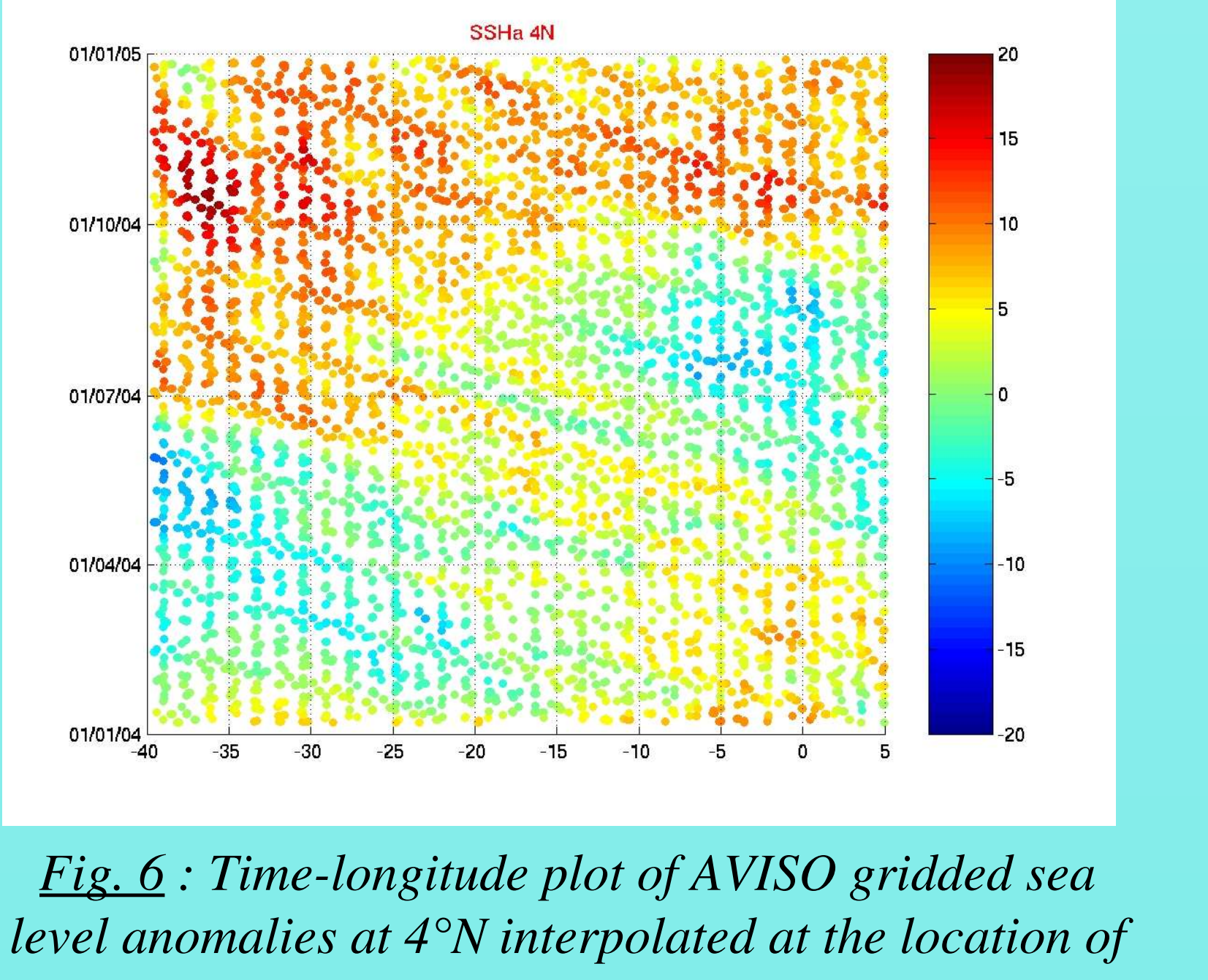

Fig. 6 : Time-longitude plot of AVISO gridded sea level anomalies at 4°N interpolated at the location of the 4 available altimeter satellite tracks in 2004.

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