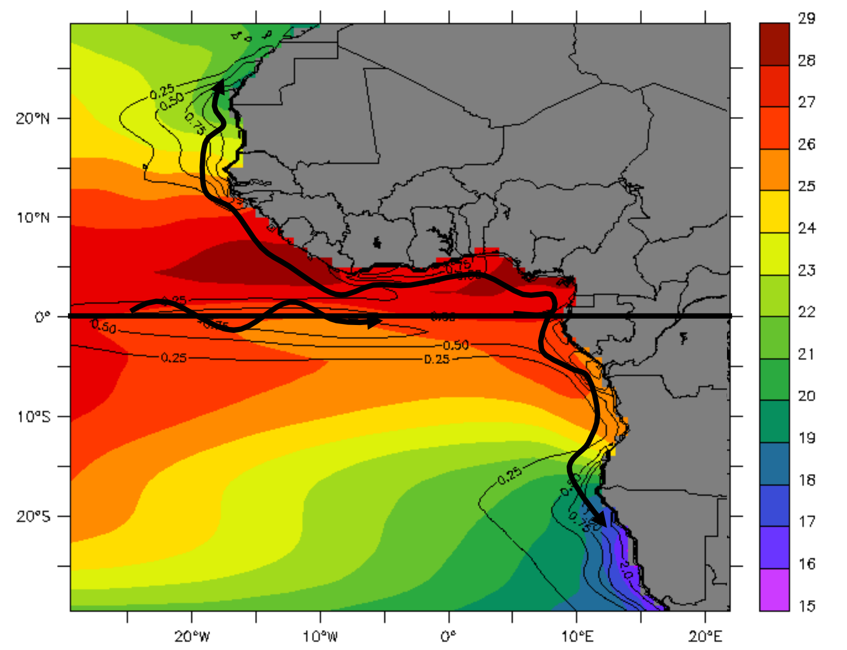
Teleconnections in EBUS:

a focus on oceanic coastally trapped waves

A. Lazar,
A.C. Peter, M. Wade, L. Poli, B. Sané

LOCEAN, Sorbonne University, Paris, France
LPAO, Dakar University, Senegal



Mean Reynolds SST (°C), ORCA05-PISCES Chl contours (mg/m³)

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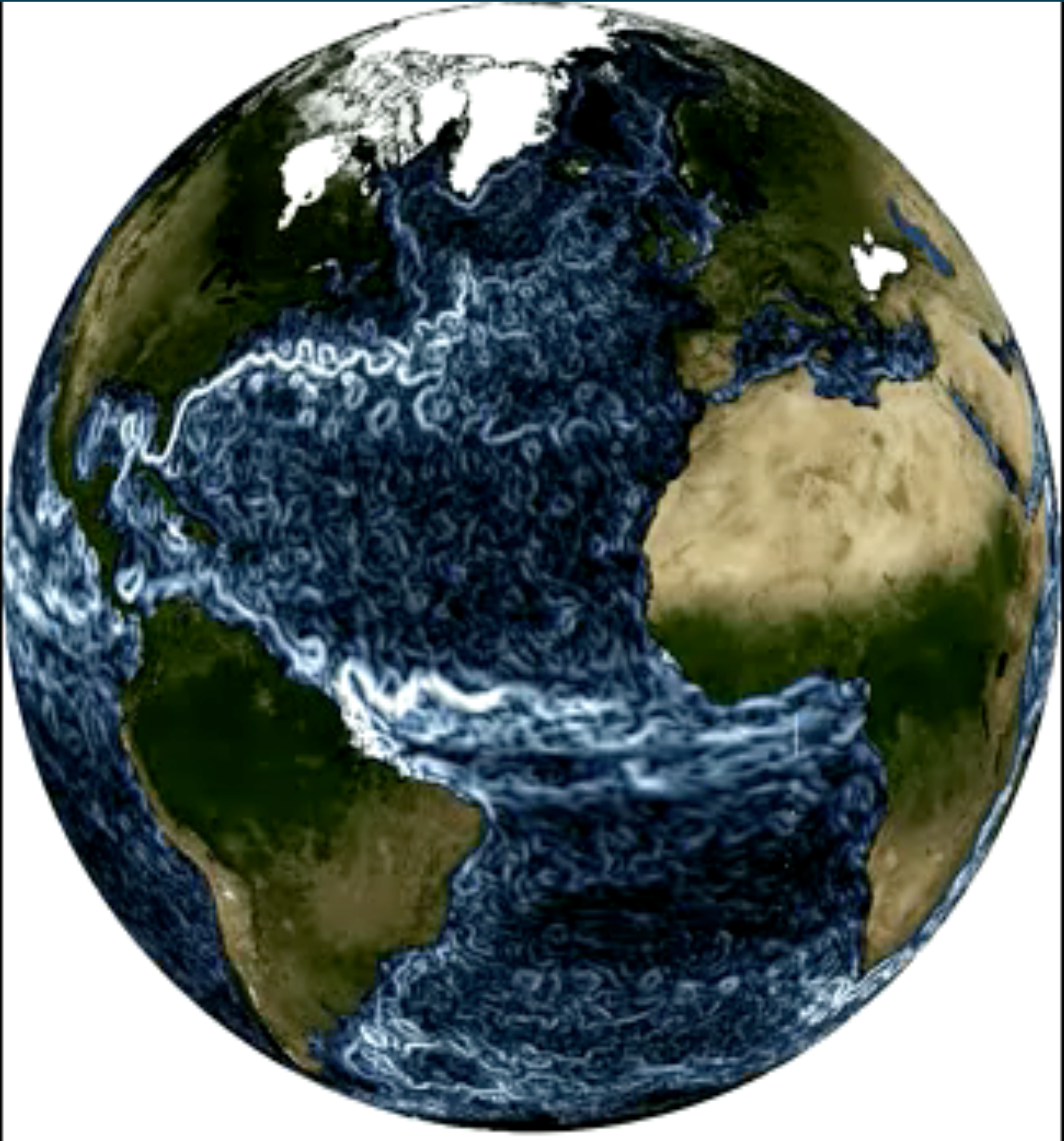

Teleconnections in EBUS:

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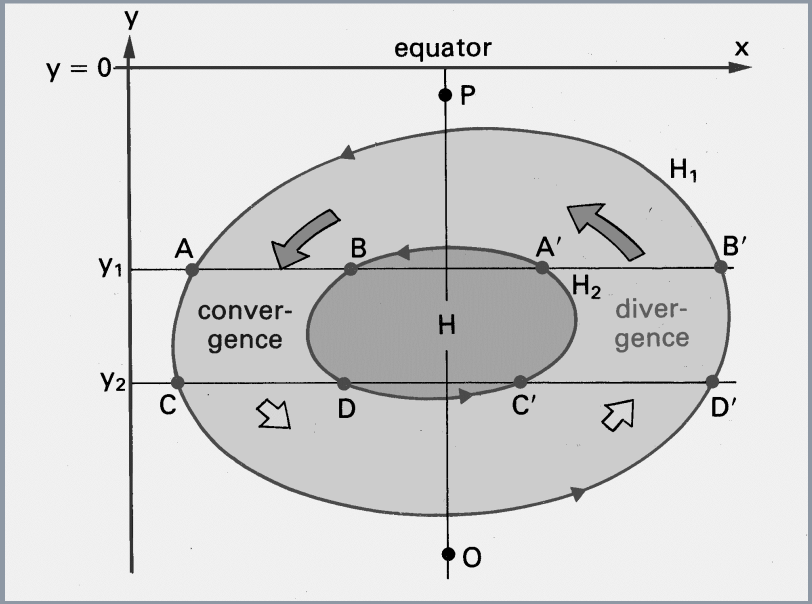


$$M_{tot} = \frac{gH\ \Delta\rho\ \Delta H}{f(y_1)} = \frac{\rho_o\, gH\ \Delta h}{f(y_1)}$$

$$M_{tot} = \frac{gH\ \Delta\rho\ \Delta H}{f(y_2)} = \frac{\rho_o\, gH\ \Delta h}{f(y_2)} .$$

$$g\ H\ \Delta\rho\ \Delta H \left(\frac{1}{f(y_1)} - \frac{1}{f(y_2)}\right) = g\ H\ \Delta\rho\ \Delta H\ \frac{\beta\ \Delta y}{f^2(y_1)}$$

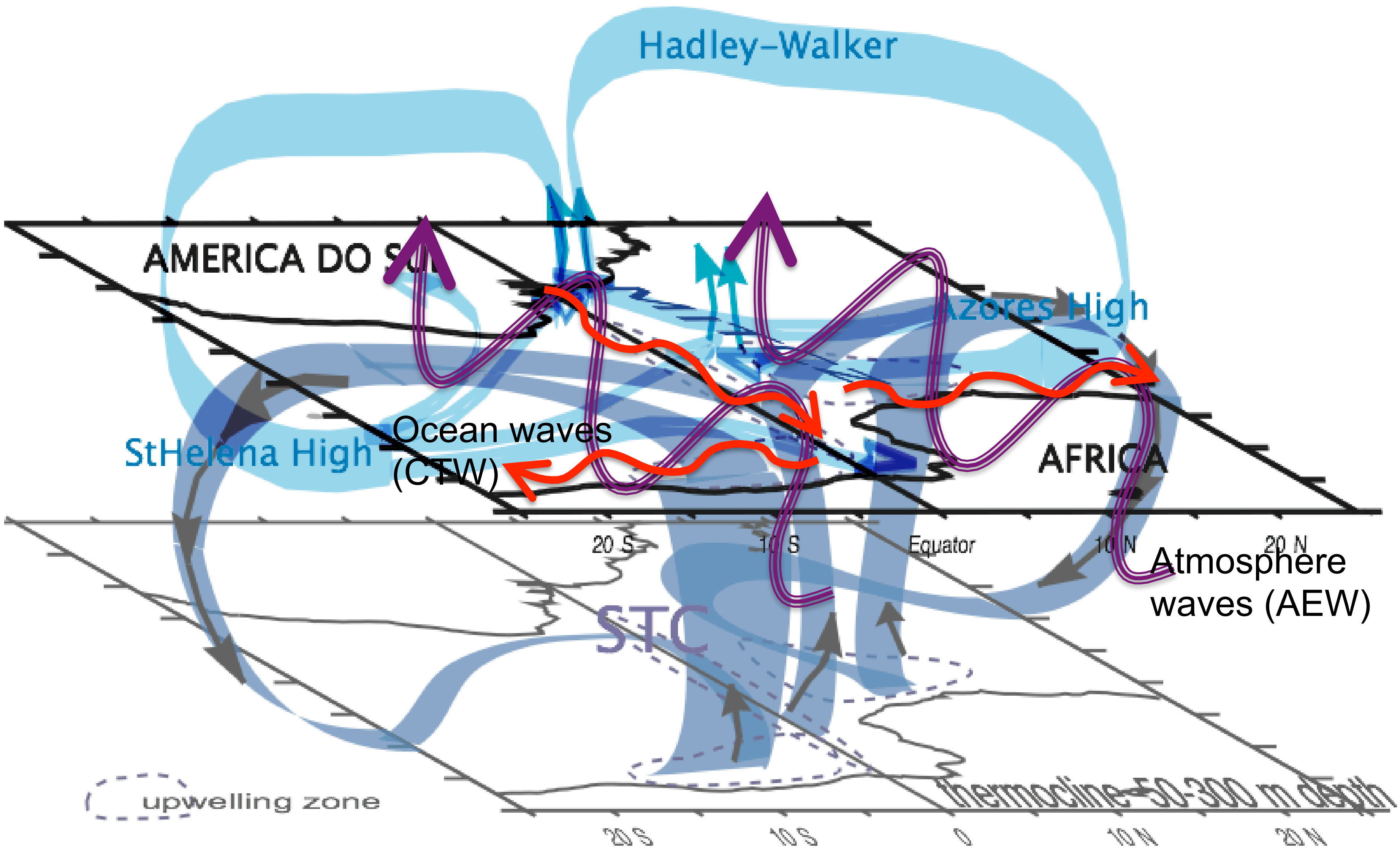
$$\rho_o \frac{\partial H}{\partial t} = \frac{gH\ \Delta\rho\ \Delta H\ \beta\ \Delta y}{f^2(y)\ \Delta x\ \Delta y} ,$$

$$\frac{\partial H}{\partial t} = \frac{\beta\ g\ H}{f^2(y)} \frac{\Delta\rho}{\rho_0} \frac{\partial H}{\partial x} .$$

$$c_R(y) = \frac{\beta\ gH\ (\Delta\rho/\rho_o)}{f^2(y)}$$

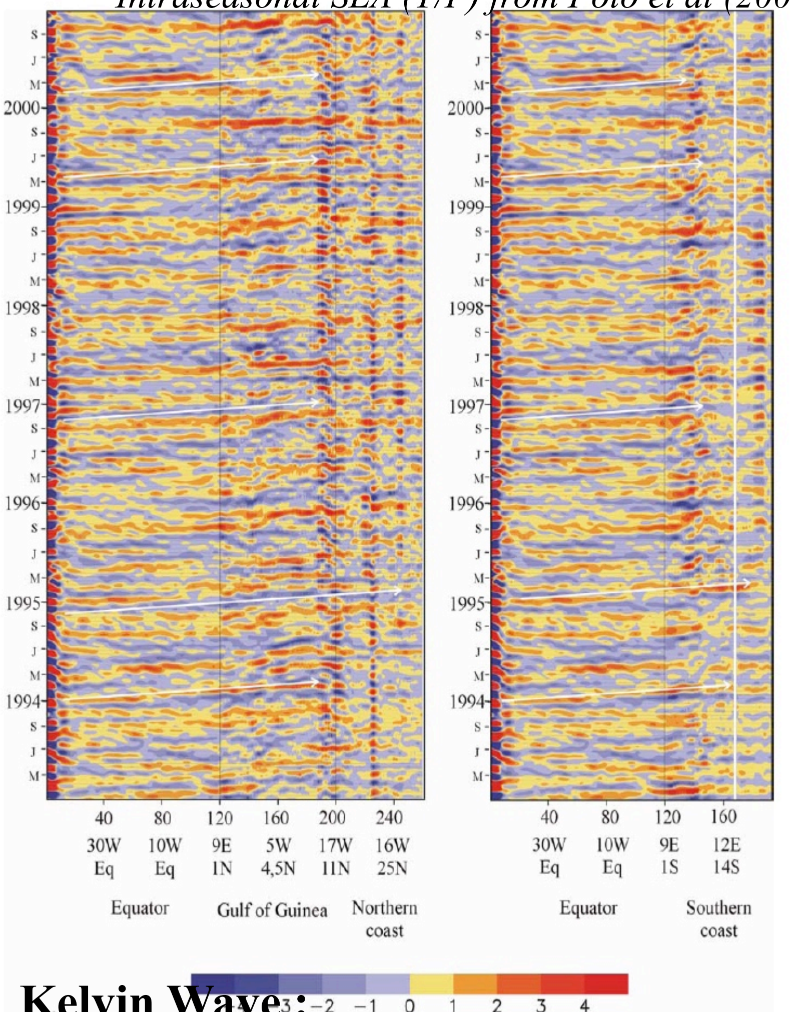
Thank you Mrs Tomczak & Godfrey

Atlantic tele-connections : a tri-dimensional schematic

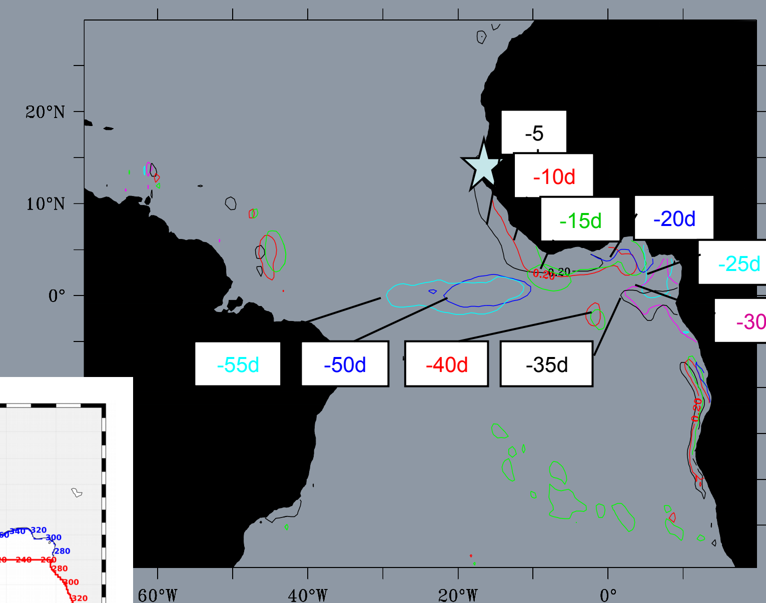


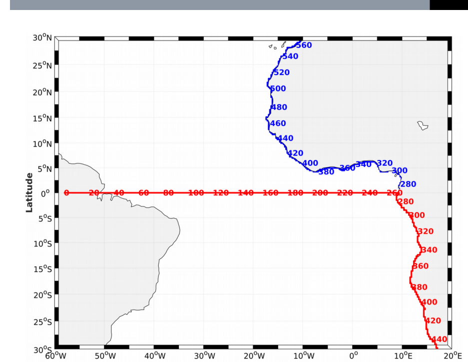
Equatorial and coastal waves in satellite SSH
A focus on intra-seasonal waves (1-3 months)

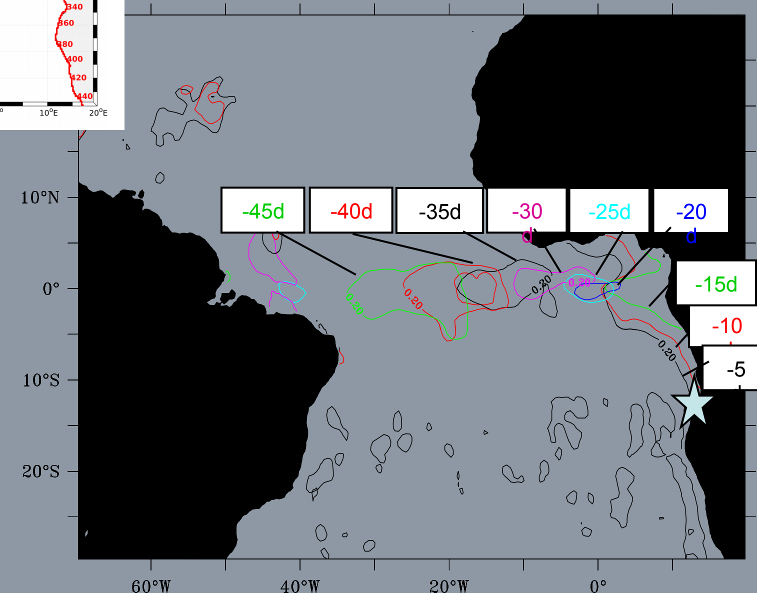
Intraseasonal SLA (T/P) from Polo et al (2008)



Lag correlations (0.2 contours) between T/P SLA (*) and SLA in the whole basin





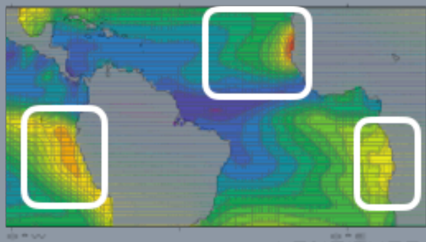


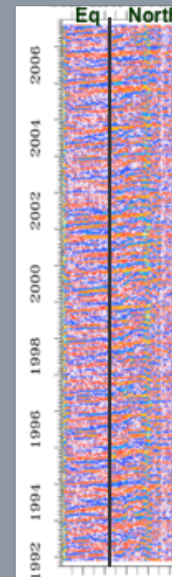
Kelvin Wave :

- propagate from western equator to 12°N and S at the african coasts
- ~2 months period, v Є [1.5, 2.1] m/s
- remote forcing in the coastal upwelling areas

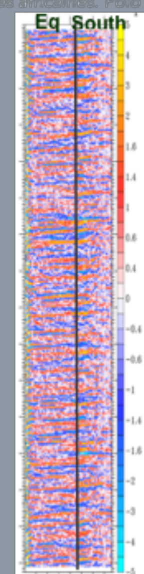
Equatorial and coastal waves impacts on SST

a significative fraction of the SST variability is forced by CTW





SSH Intrasaisonnière (cm) satellite :équateur et côtes africaines. Polo et al. 2008



1. Peru-Chili

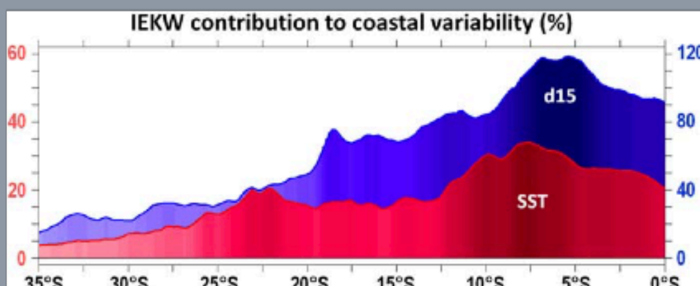
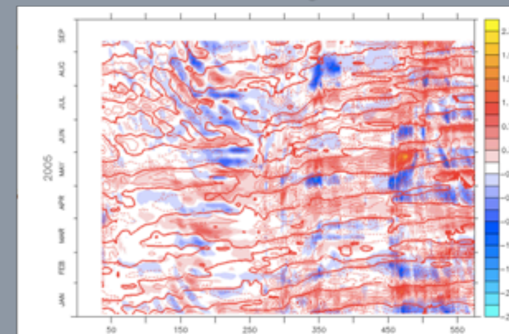


Figure 9. Intraseasonal variability (40-90 days) ratio (%) of variance between $ROMS^E$ simulation and $ROMS^{CR}$ as a function of latitude for the SST (red, left scale) and the depth of the 15°C isotherm (d15, blue, right scale) averaged in a 0.5° coastal band.

Illig et al. 2014

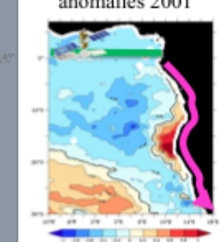
10-30% of intra-seasonnal variability (model)

2. Canary



ondes (rouge) et anomalies de SST intrasaisonnières (satellite)

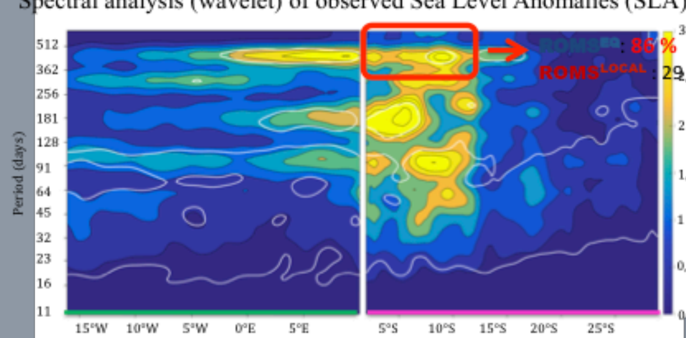
Satellite (TMI) SST anomalies 2001



3. Benguela

80% interannual variability (model)

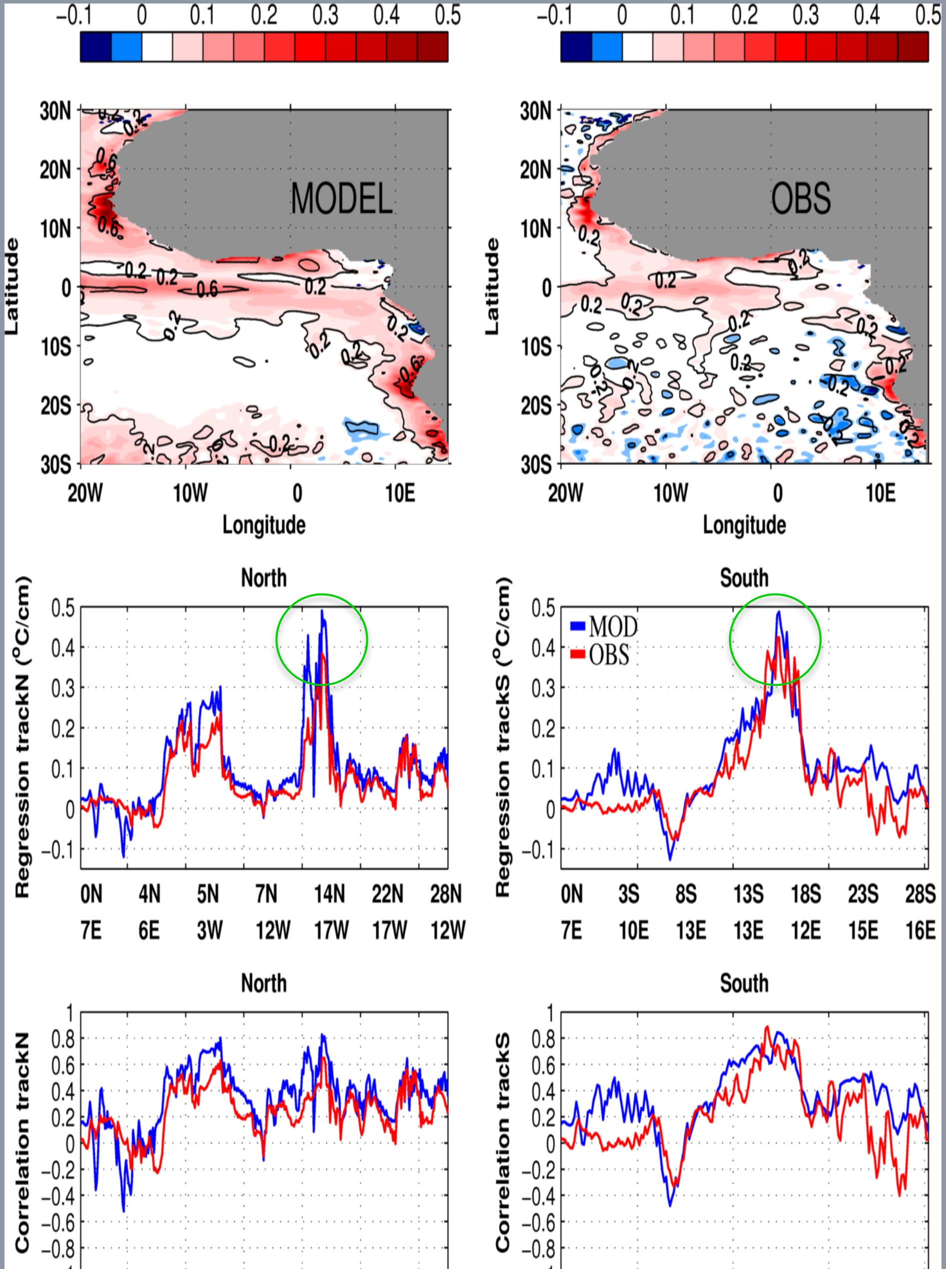
Spectral analysis (wavelet) of observed Sea Level Anomalies (SLA)



Bachèlery et al. 2015

Equatorial and coastal waves impact on SST: Atlantic

How much SST is impacted by SSH anomalies ?
(waves + local wind forcing)



0.4-0.5°C / cm in EBUS fronts

Upper boxes: Regressions maps in January-February-March of SSH onto SST for the period 2000-2007 for the Model: a) and Observation: b). Middle boxes: Regression along the Northern and Southern wave tracks respectively c) and d) for the Model (blue curve) and Observation (red curve). Lower boxes: Correlations along the wave tracks. Note that the seasonal cycle is removed before computing the regression and correlation.

=> model experiment

Methodology : Model used and experiments

- **Model :**

  - DRAKKAR ¼°, Tropical Atlantic configuration (30°N-30°S, 60°W-20°E), 46 vertical levels (6m resolution in surface) : ATLTROP025, coll. Charles Deltel (LOCEAN)

  - atmospheric forcing : DFS4 (Brodeau et al, 2007) from ERS wind stress and CORE data

- **Goal :**

  Discrimination of remote and local effect of wind stress on temperature evolution

- **Methodology** and **Experiments :**

  - climatological simulation (1988-2000)

  - « wind burst simulation » : climatological forcing + westerly wind burst : WWB

  - difference between both runs

-Diagnostic tool : mixed layer heat budget :

$$\partial_t T - Q \approx -u.\partial_x T - v.\partial_y T + \partial_z (K_z.\partial_z T) \approx \partial_t T_{ocean}$$

Methodology : Model used and experiments

westerly wind burst : WWB

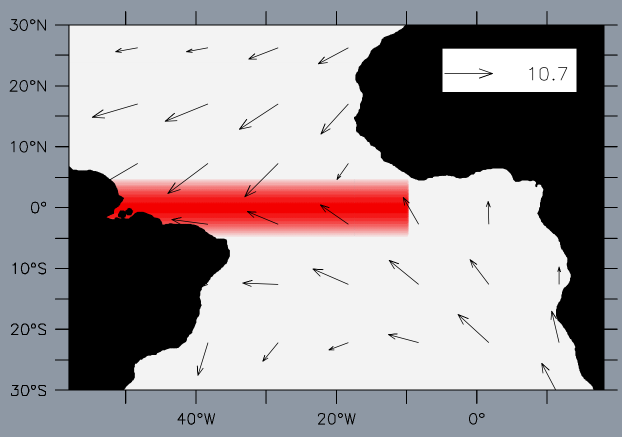
-from 5°N to 5°S , bresilian coast to 10°W

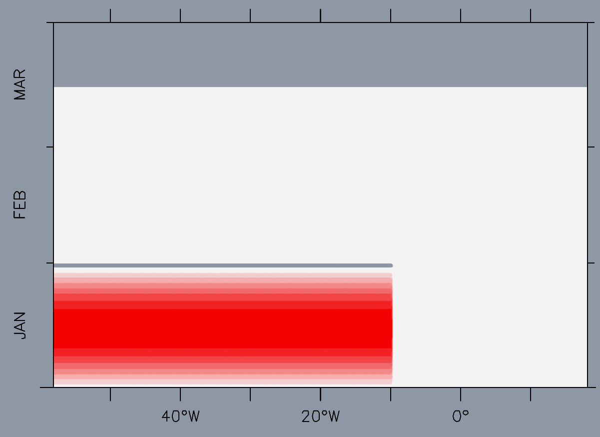
-2 months period, only positive phase

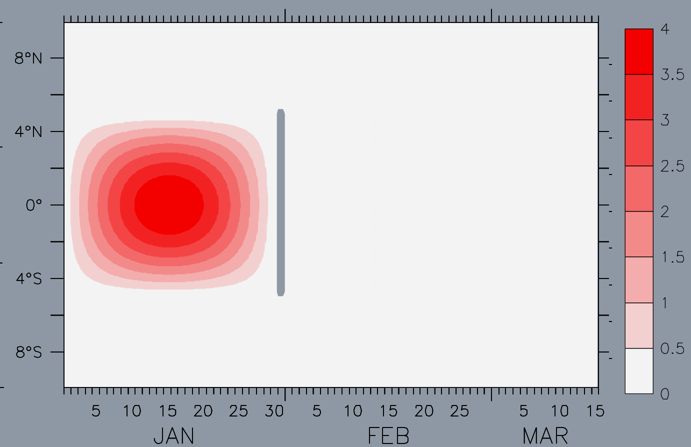
- phase speed of the first and second baroclinic mode in tropical Atlantic = 2.5 and 1.4 m/s (Illig et al, 2003)

- λ = 40° of longitude (deduced from observed wind stress variance); T= 2 months -> c = λ / T ≈ 1.6 m/s : combination of first and second modes at minimum

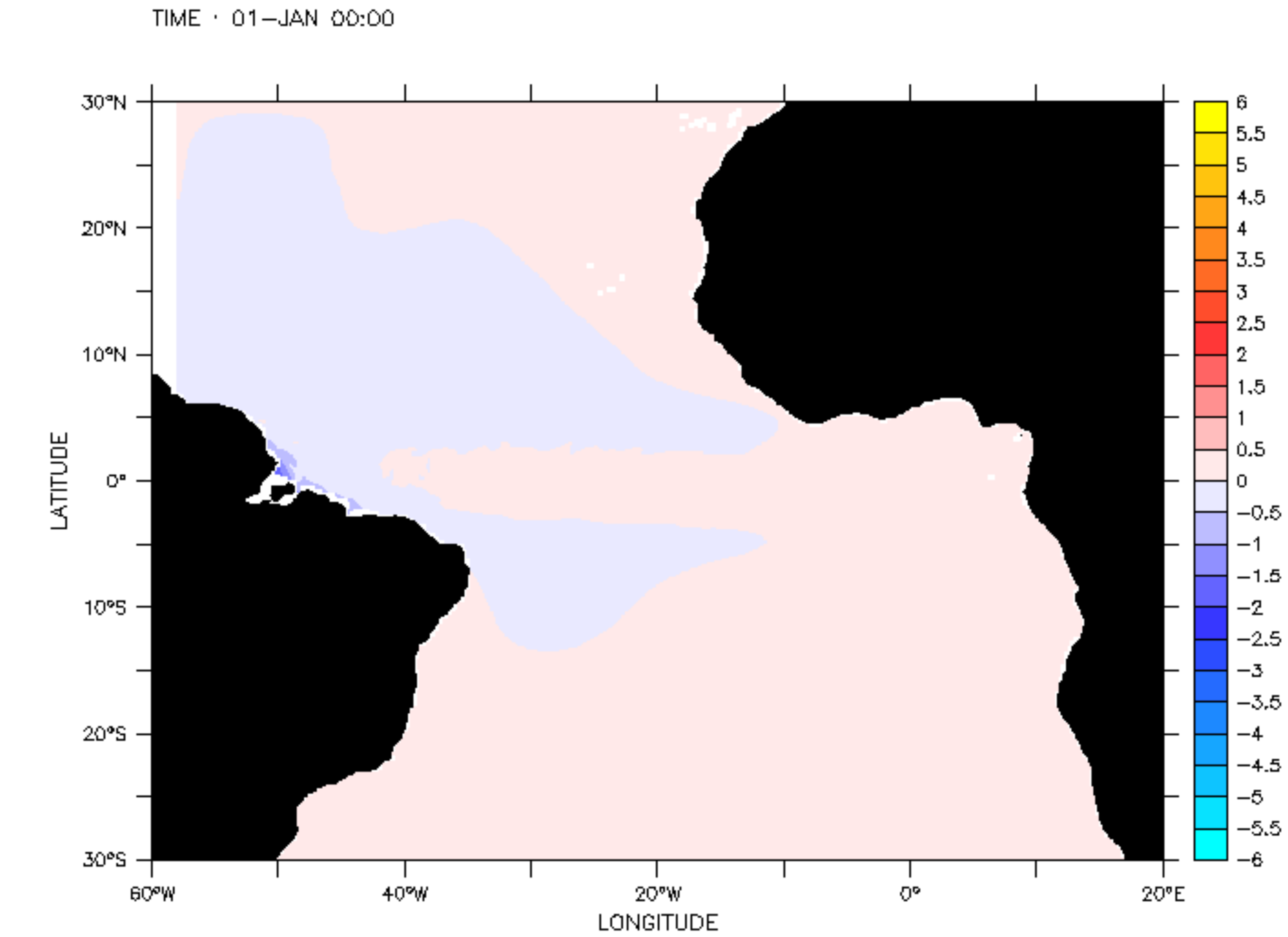
- wind burst imposed in January (to avoid TIWs)





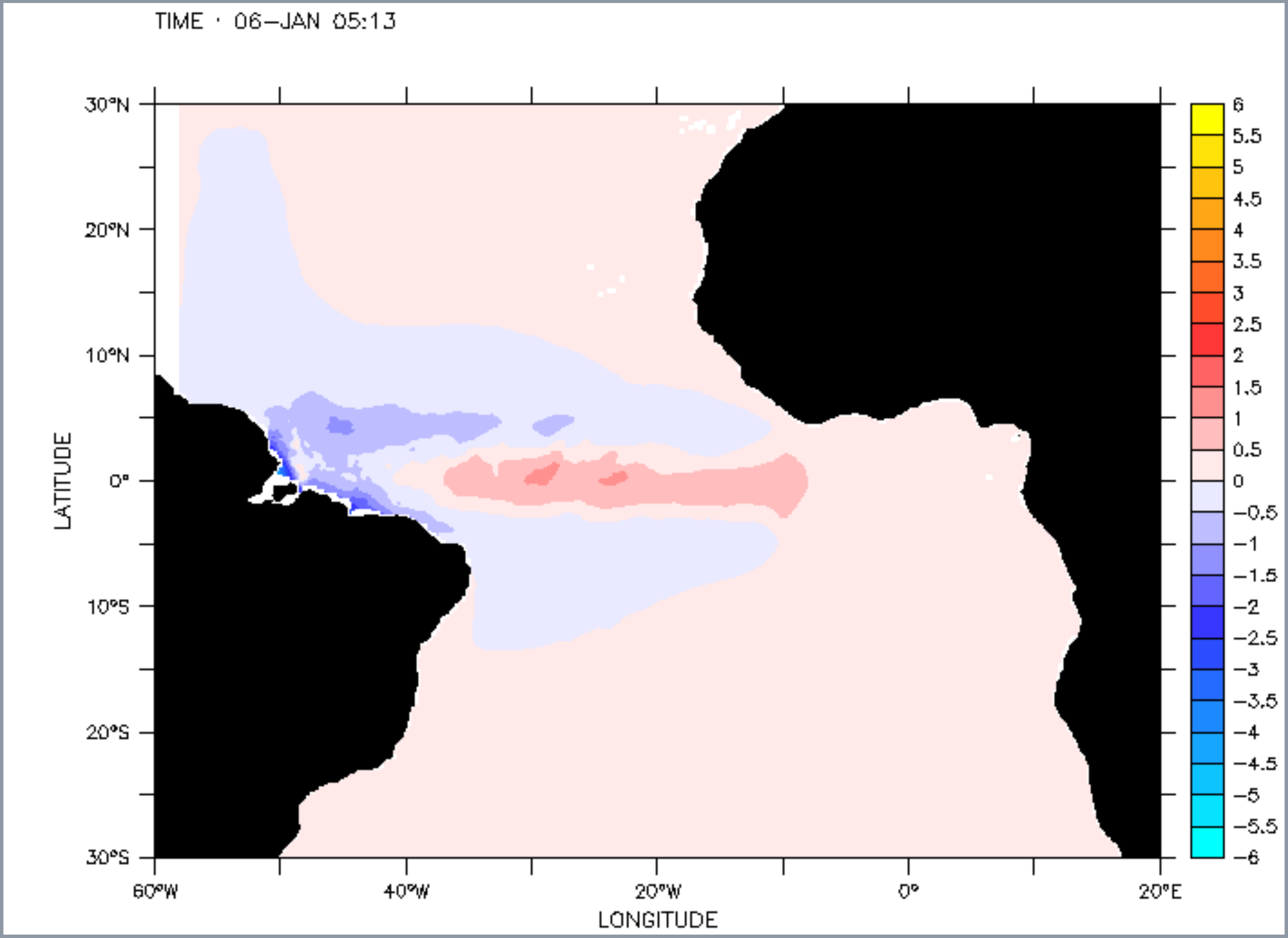


Results : Simulated coastal waves



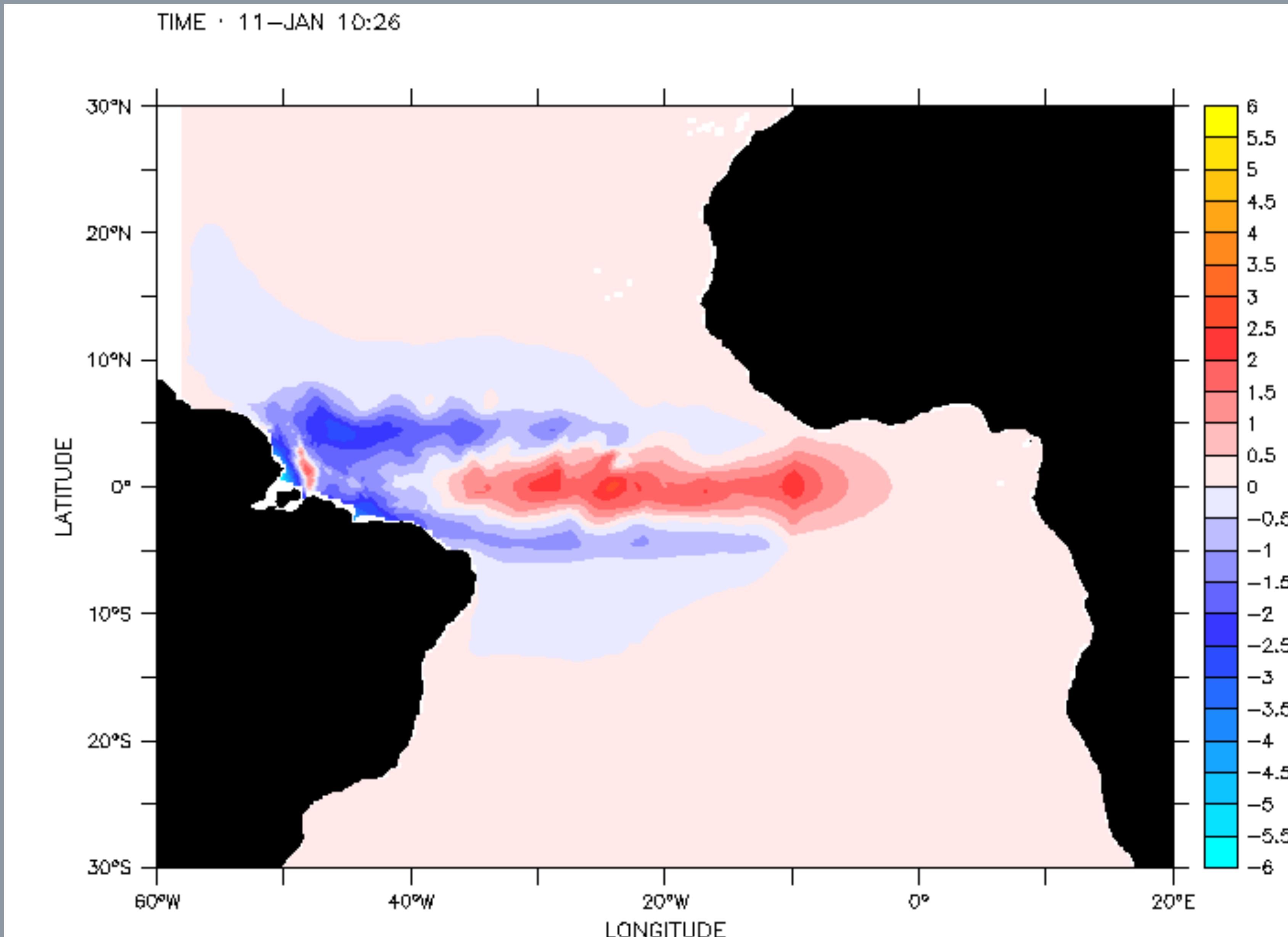
SSH anomaly (cm) : wbst - clim

Results : Simulated coastal waves



SSH anomaly (cm) : wbst - clim

<u>Results</u> : Simulated coastal waves



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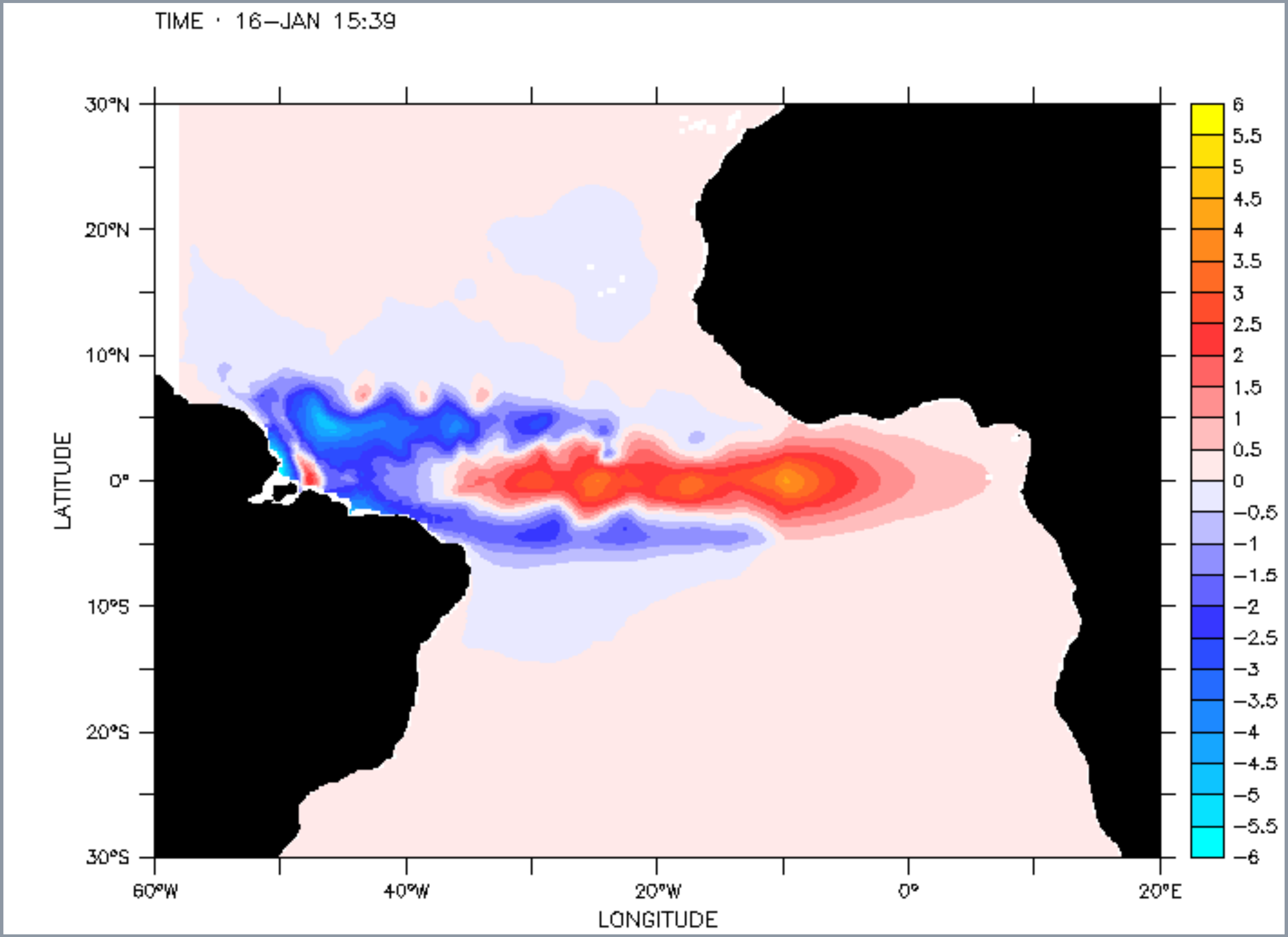

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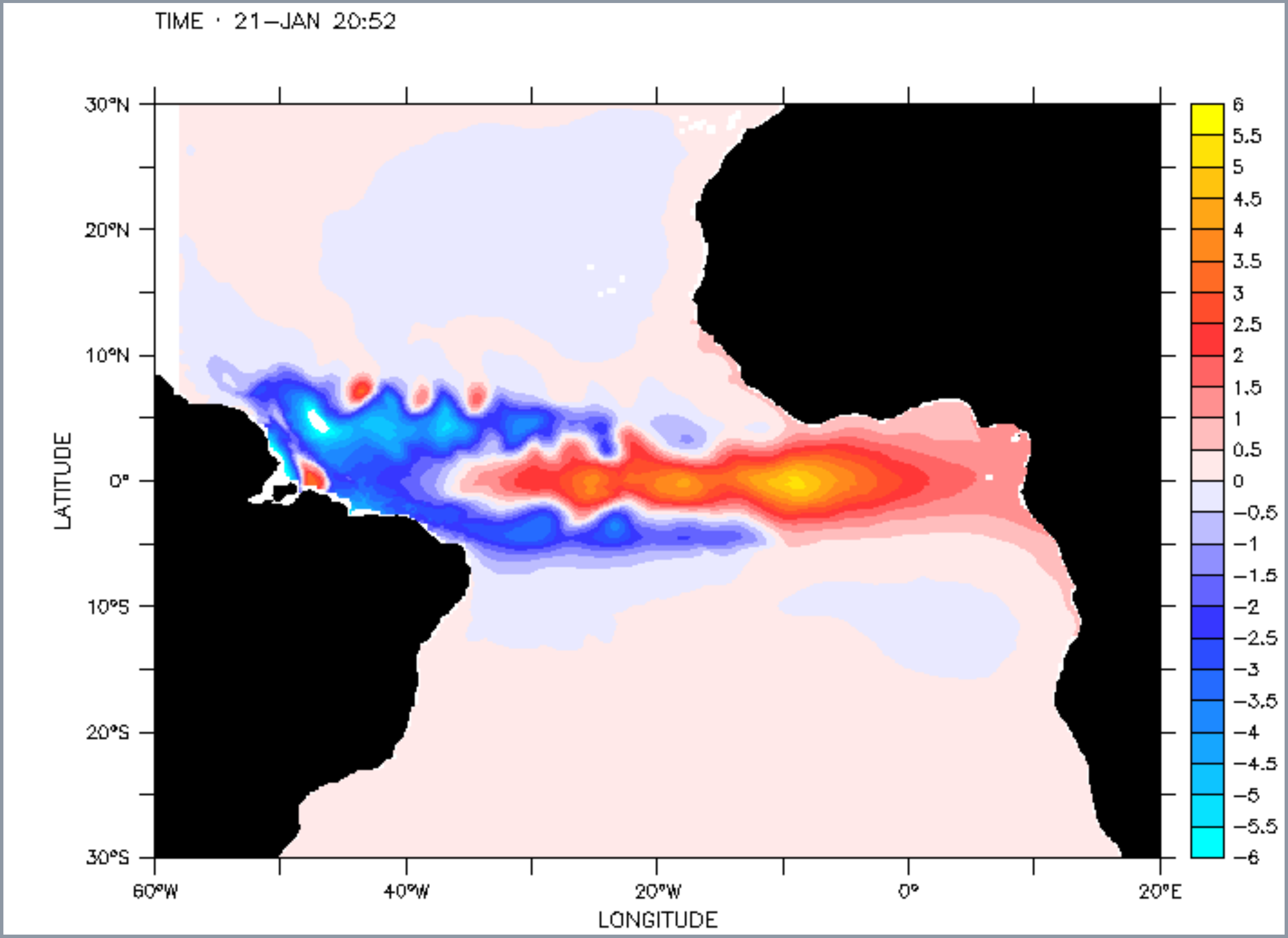
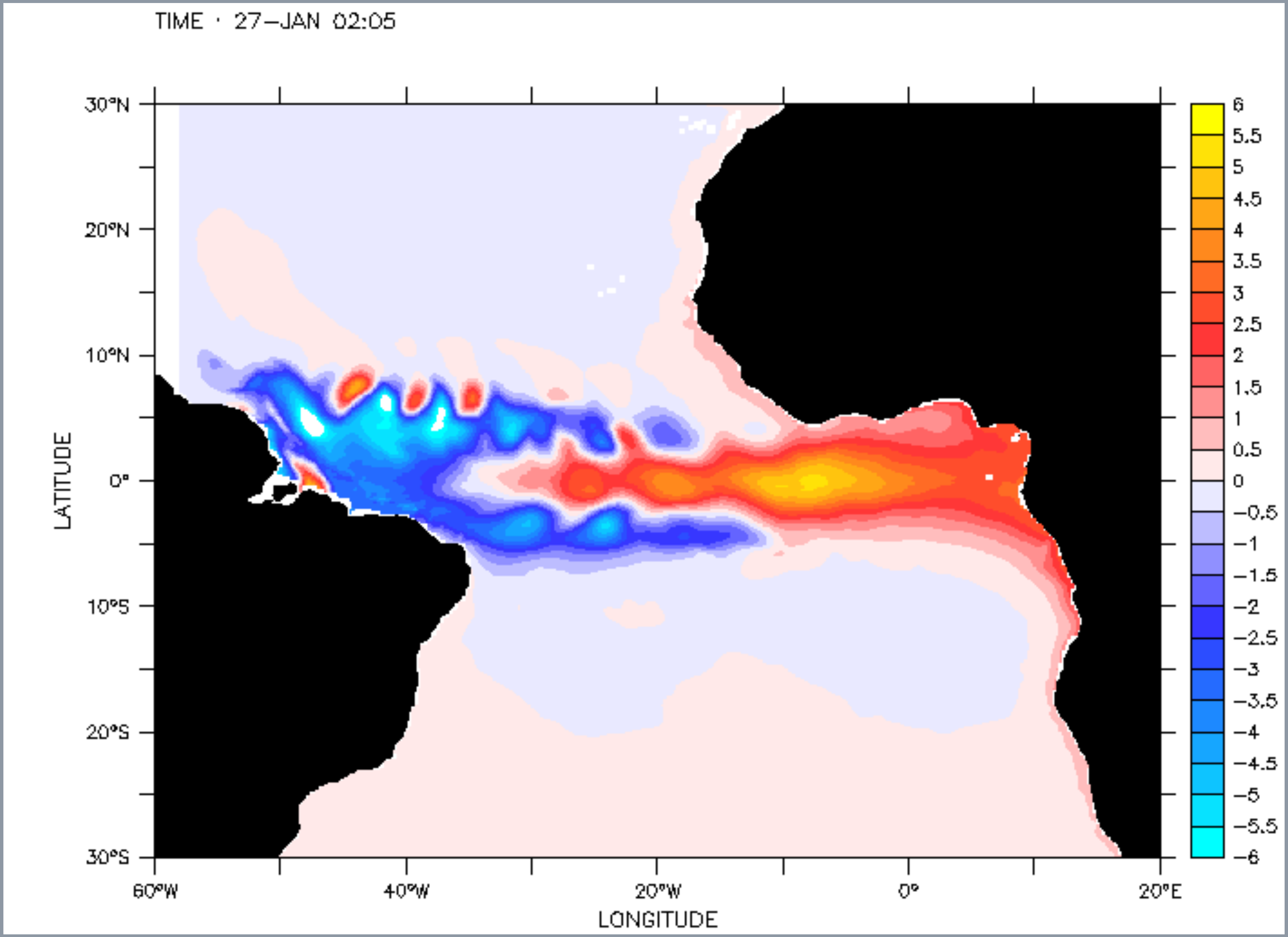


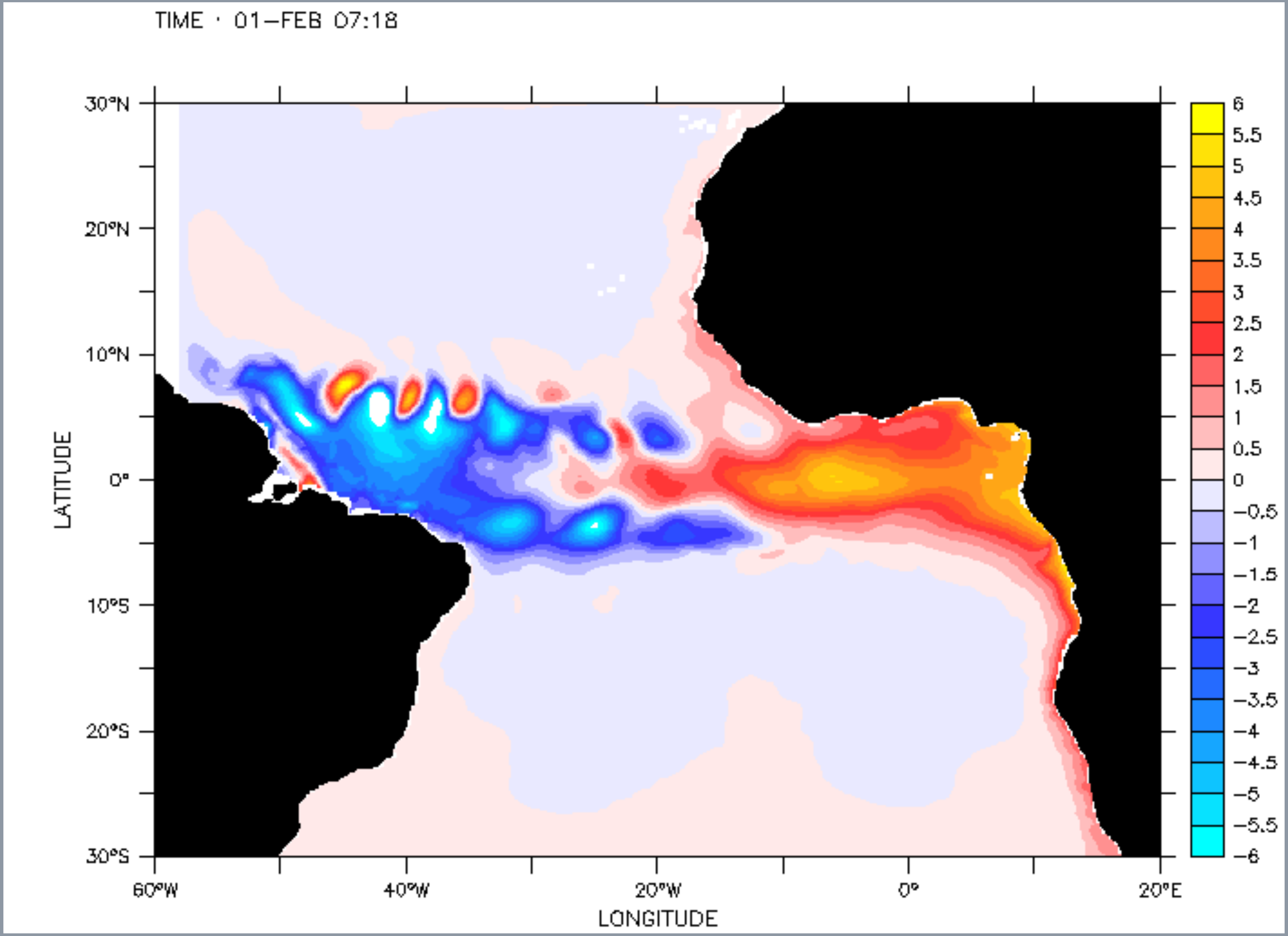
SSH anomaly (cm) : wbst - clim

<u>Results</u> : Simulated coastal waves



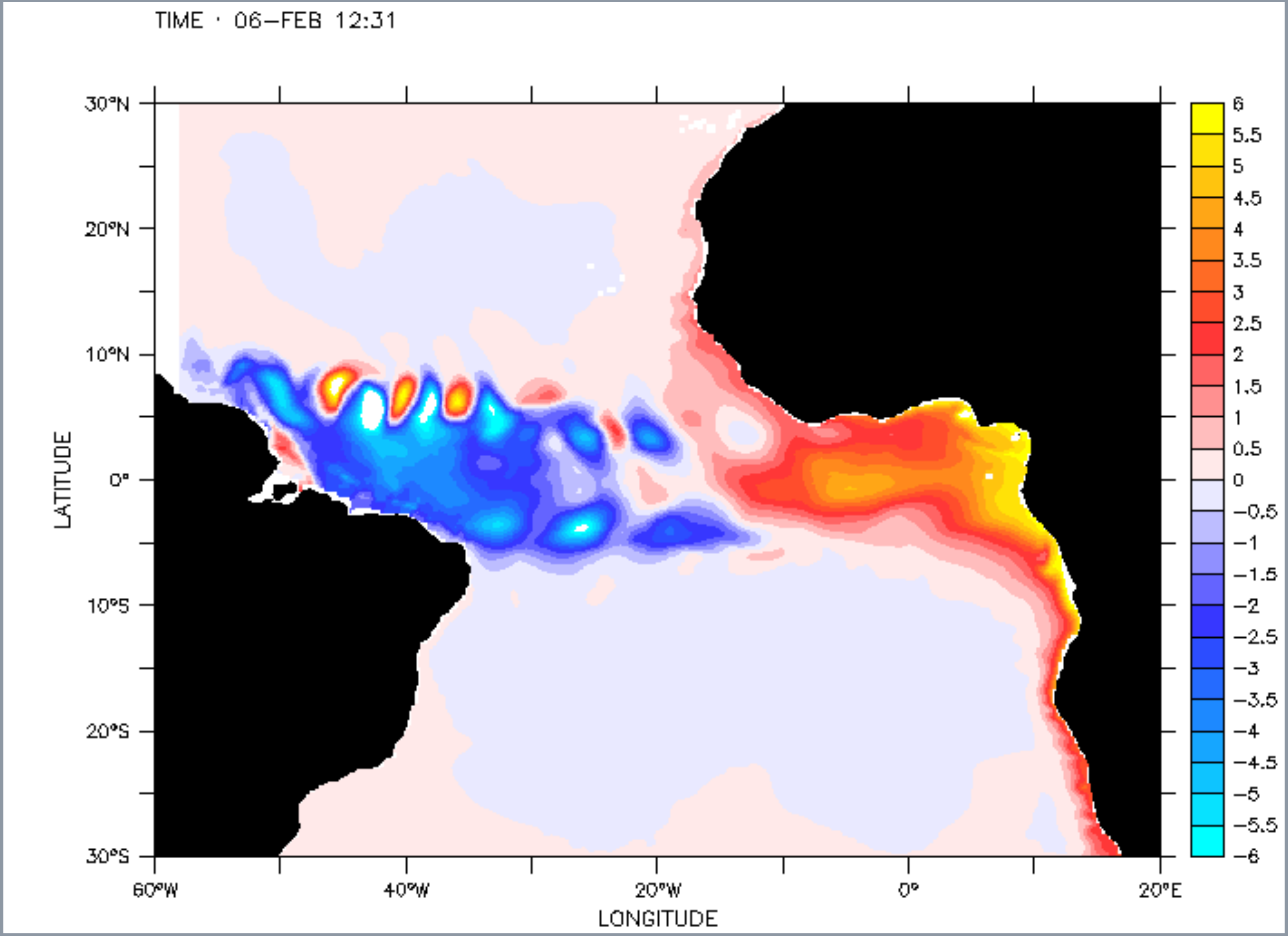
SSH anomaly (cm) : wbst - clim

<u>Results</u> : Simulated coastal waves



SSH anomaly (cm) : wbst - clim

Results : Simulated coastal waves



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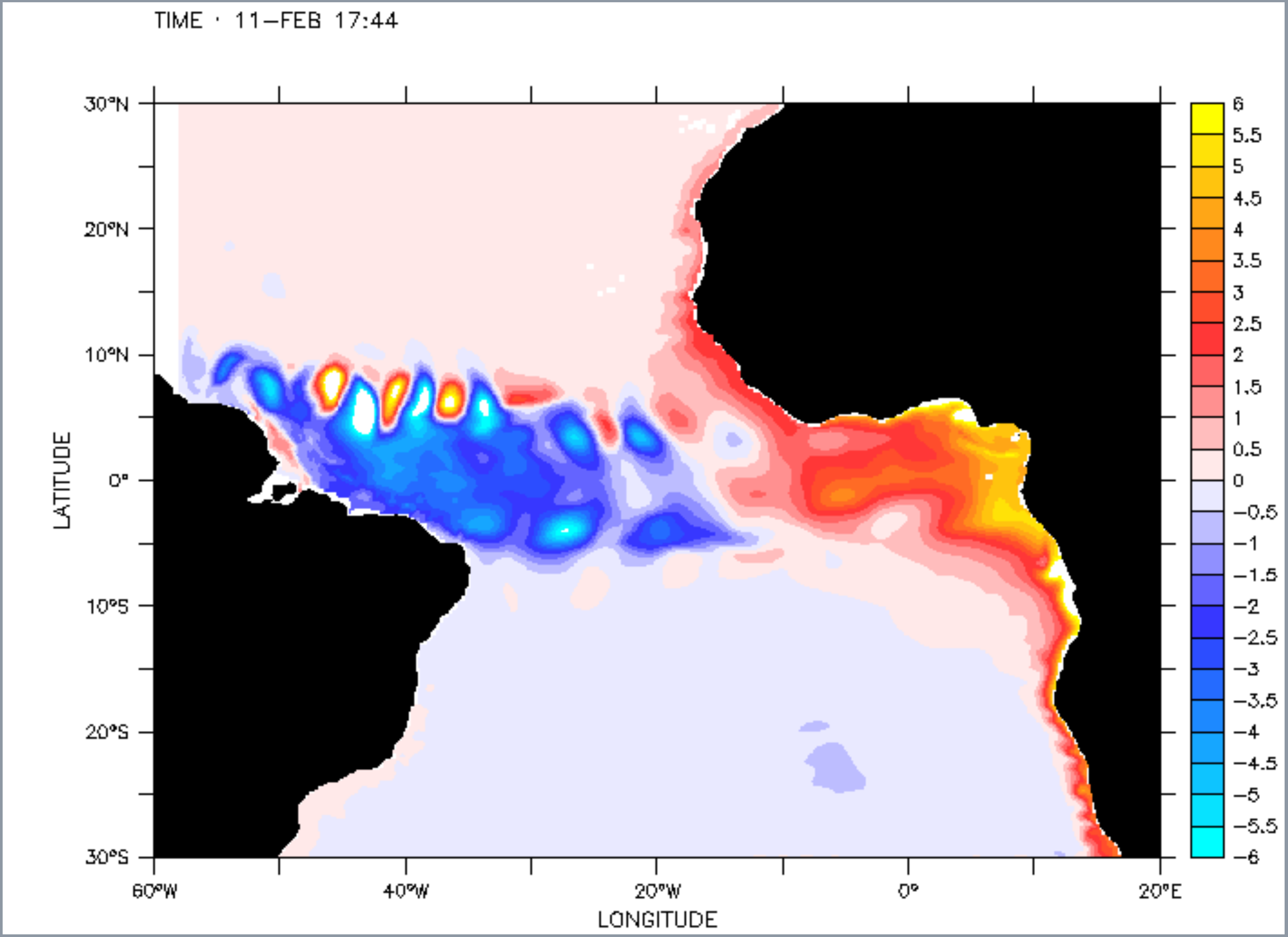

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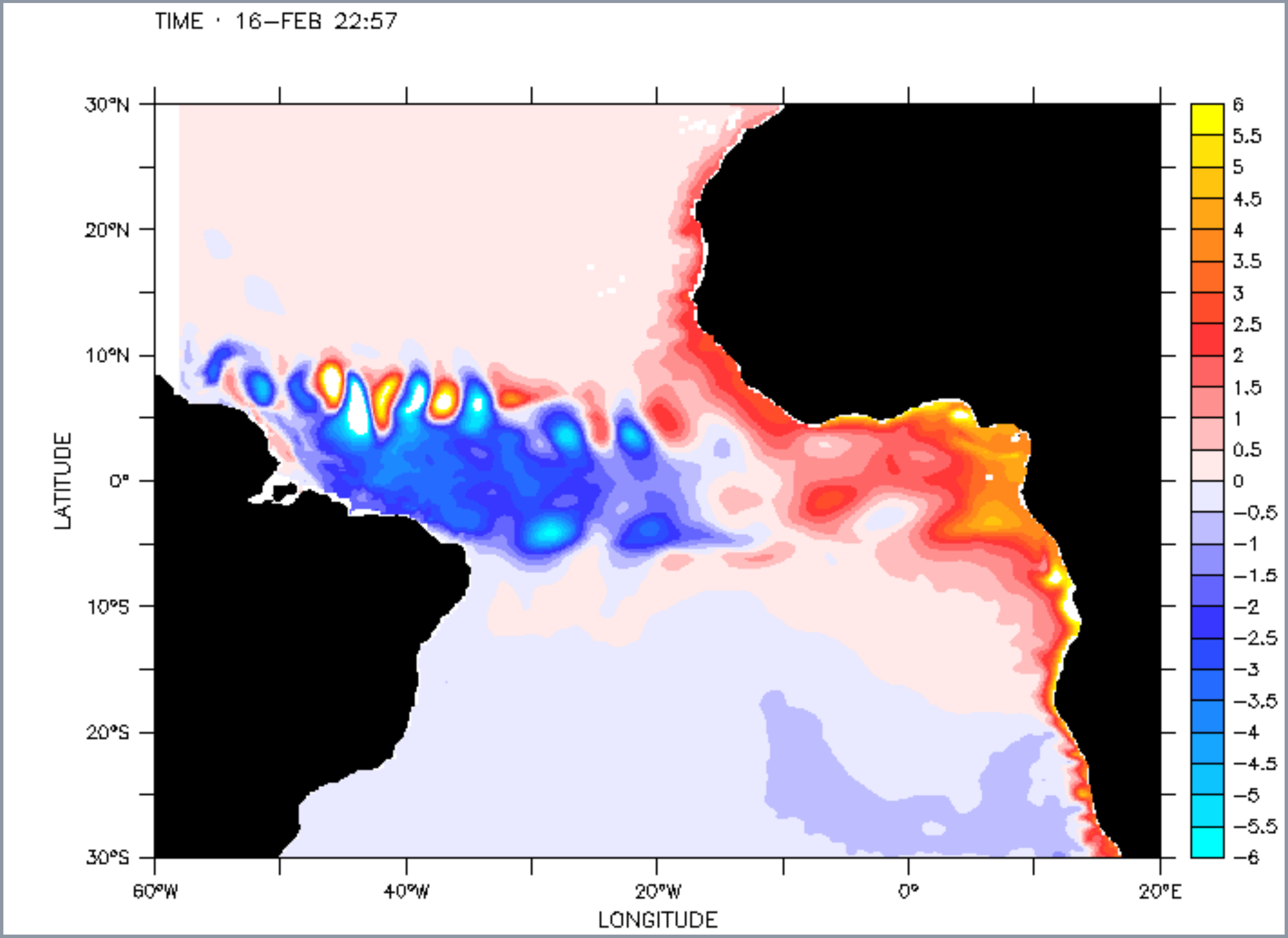

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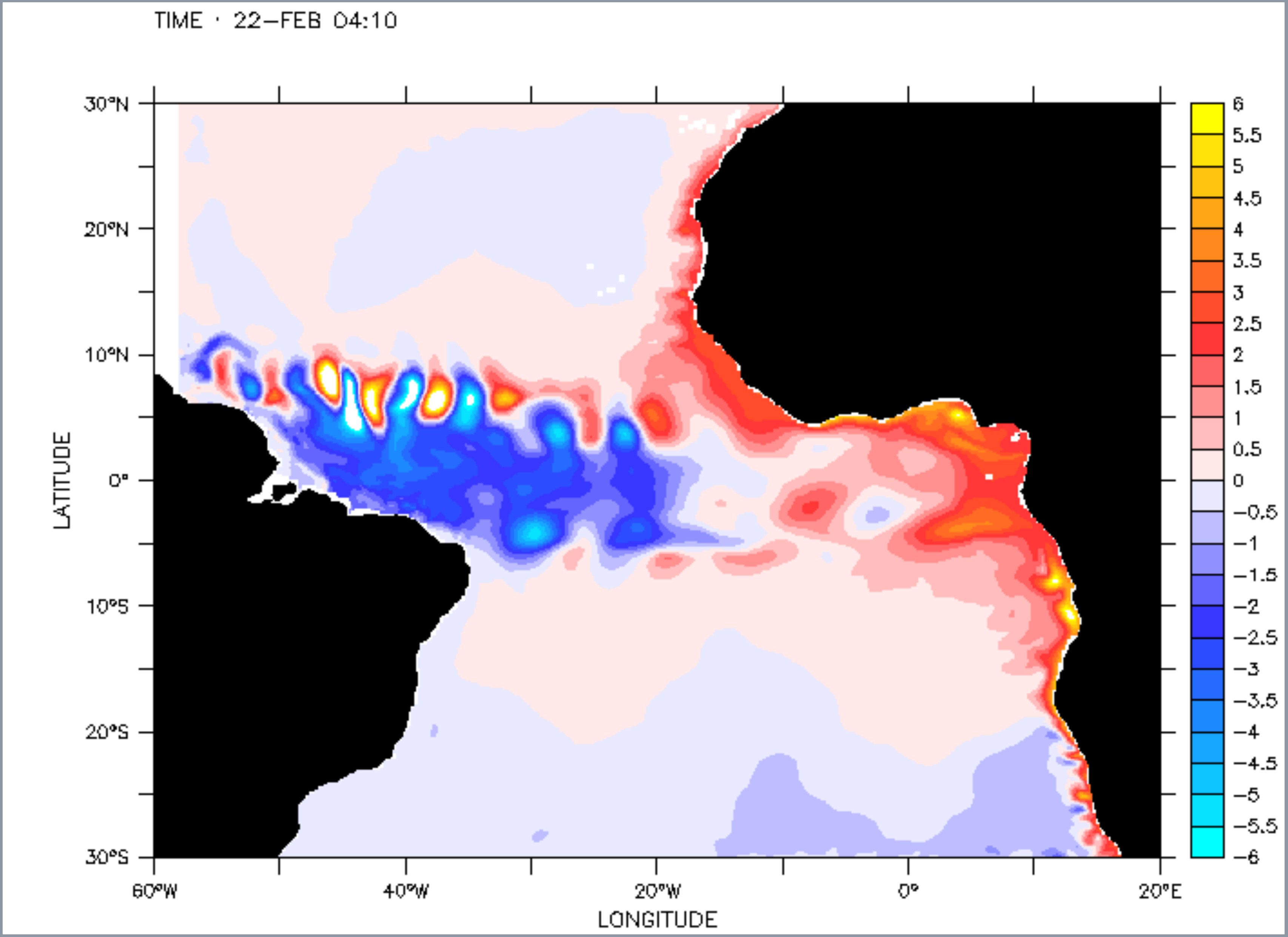

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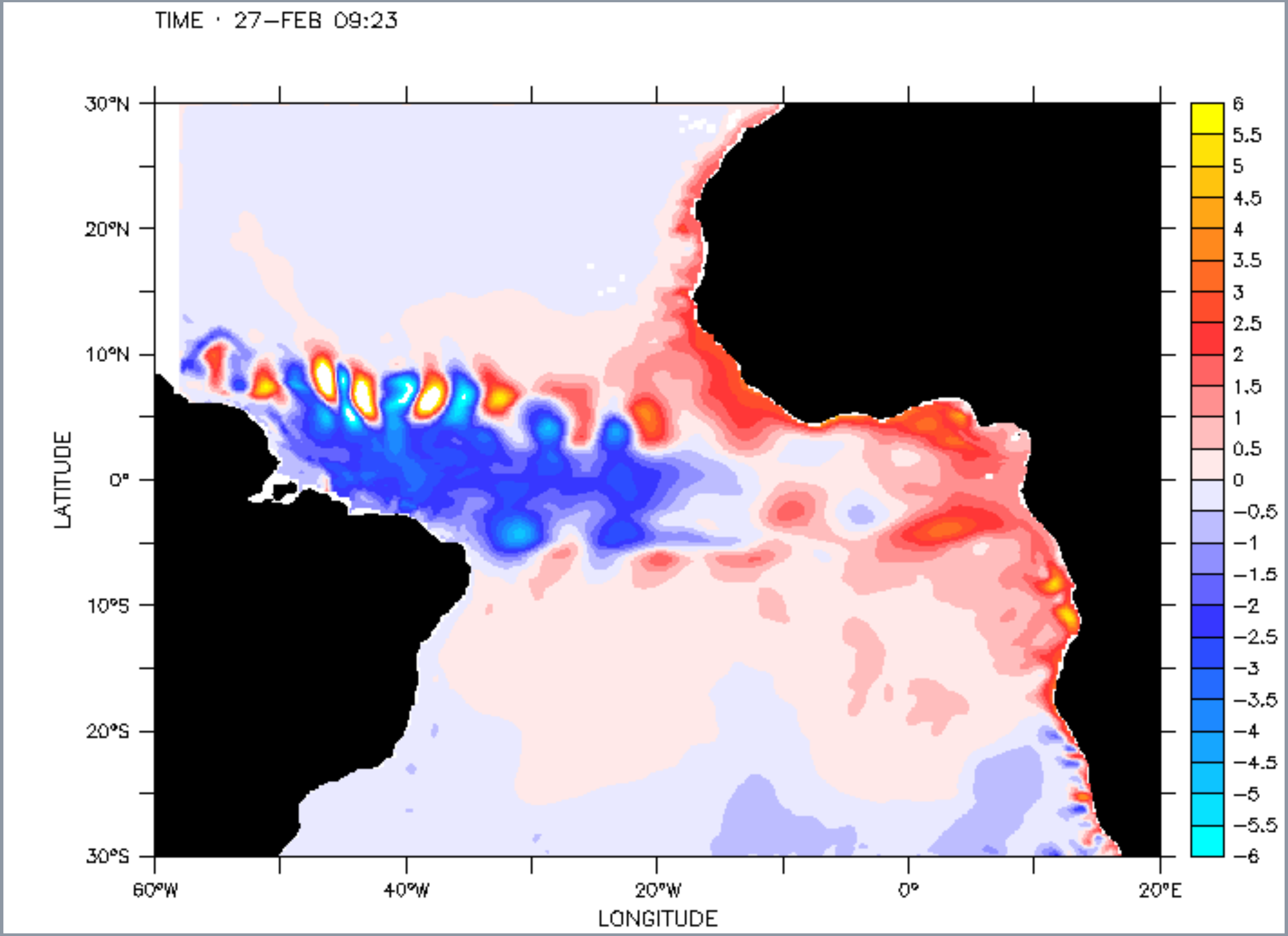

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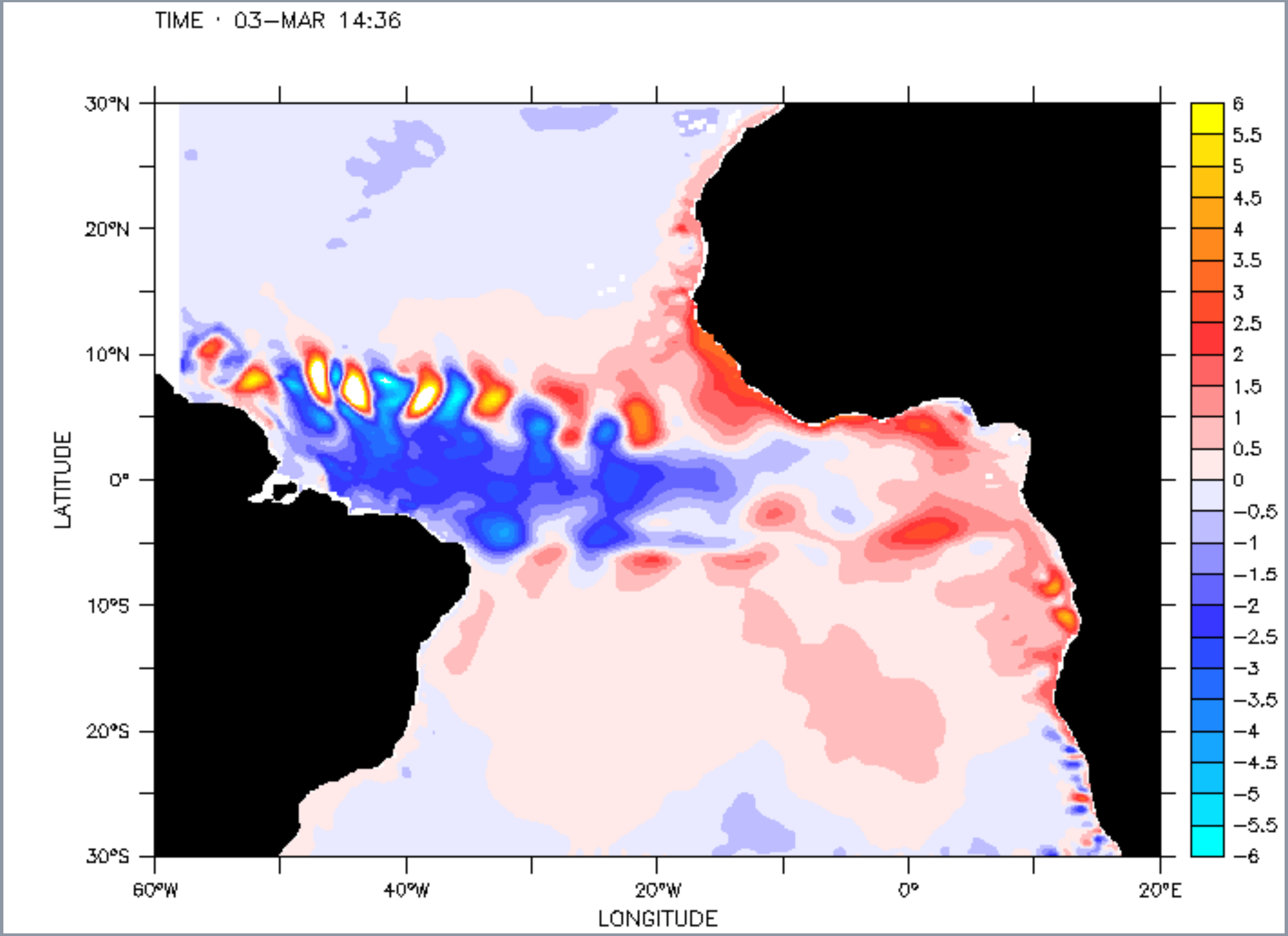

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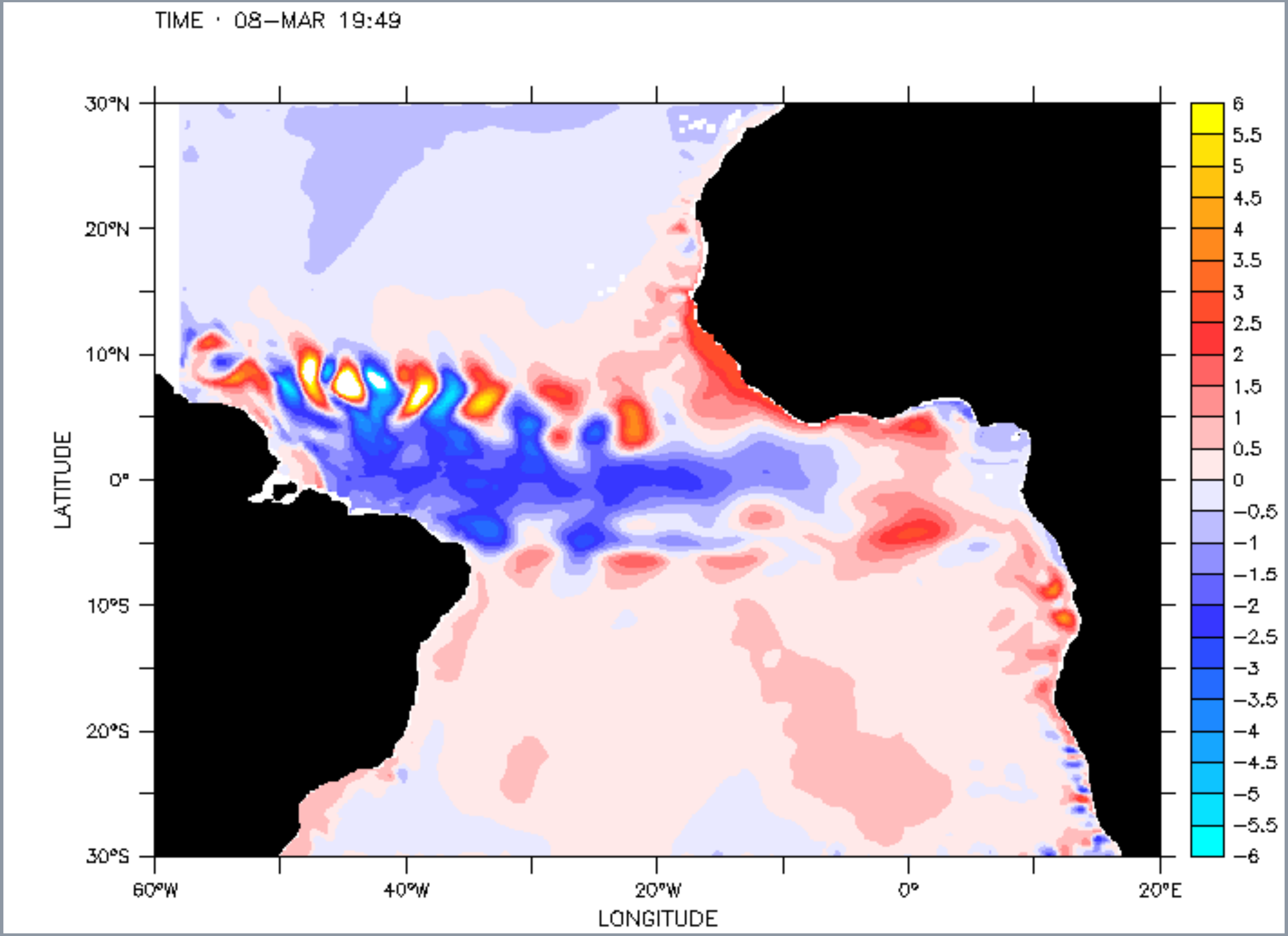

SSH anomaly (cm) : wbst - clim

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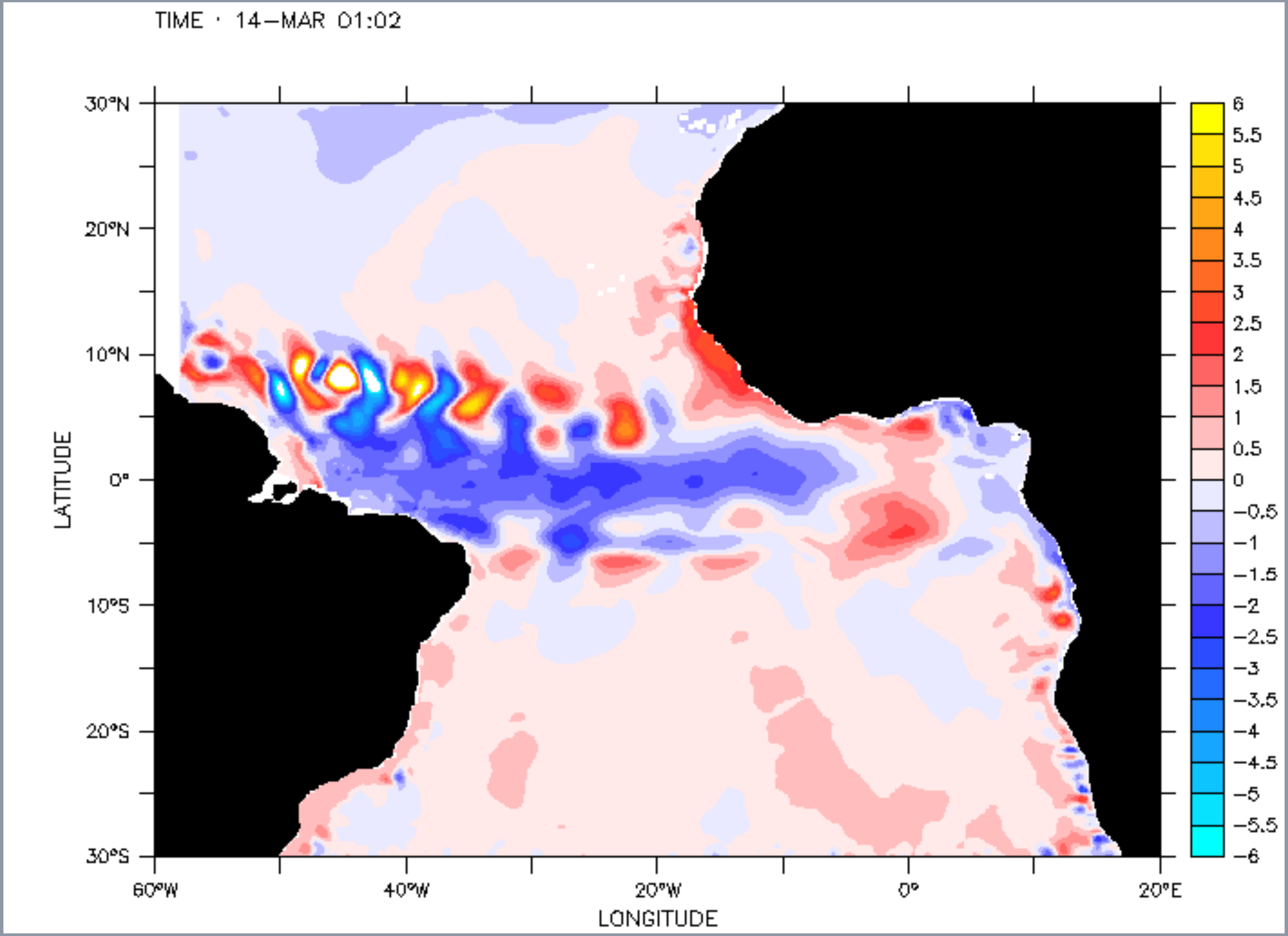

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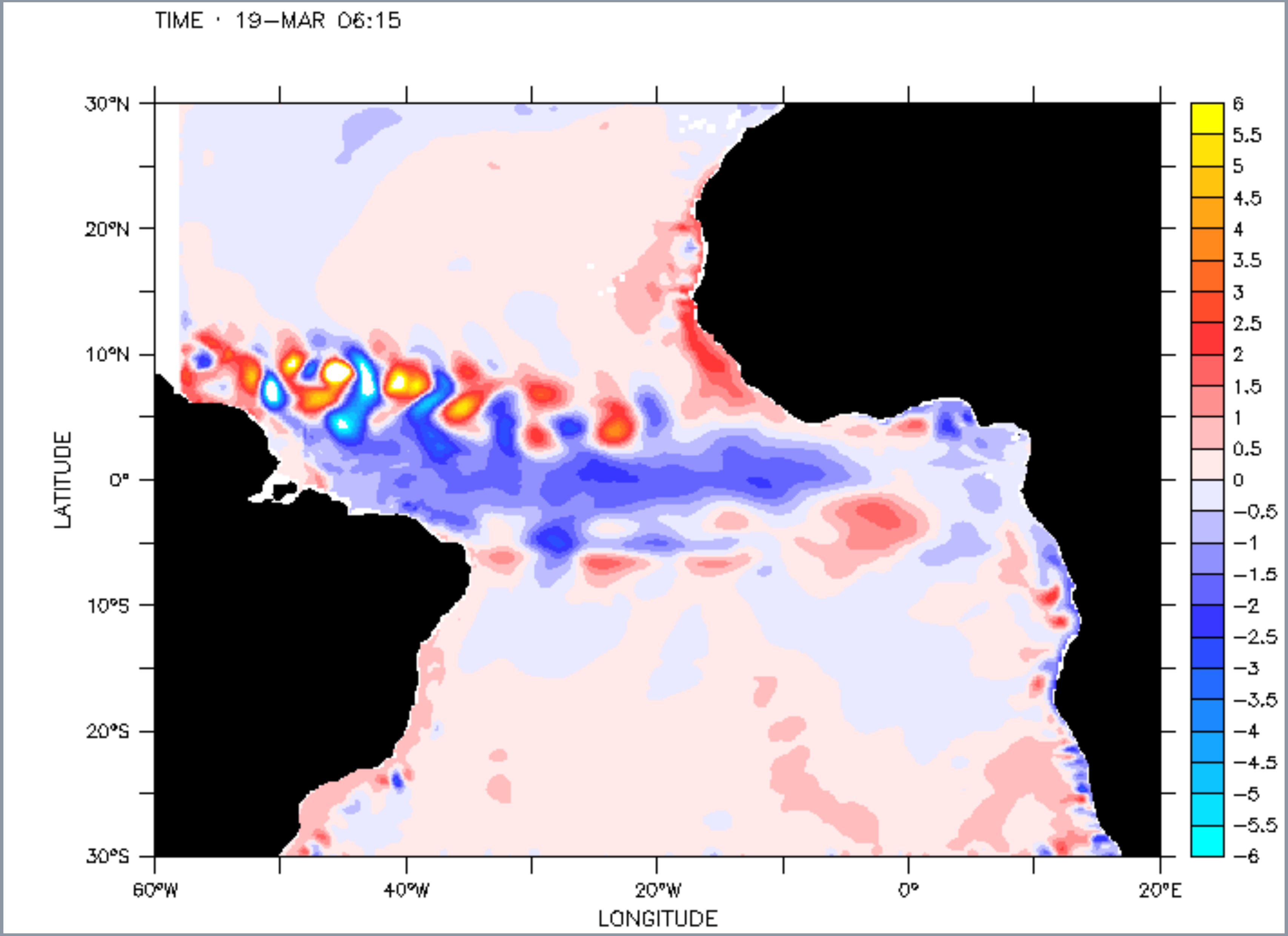

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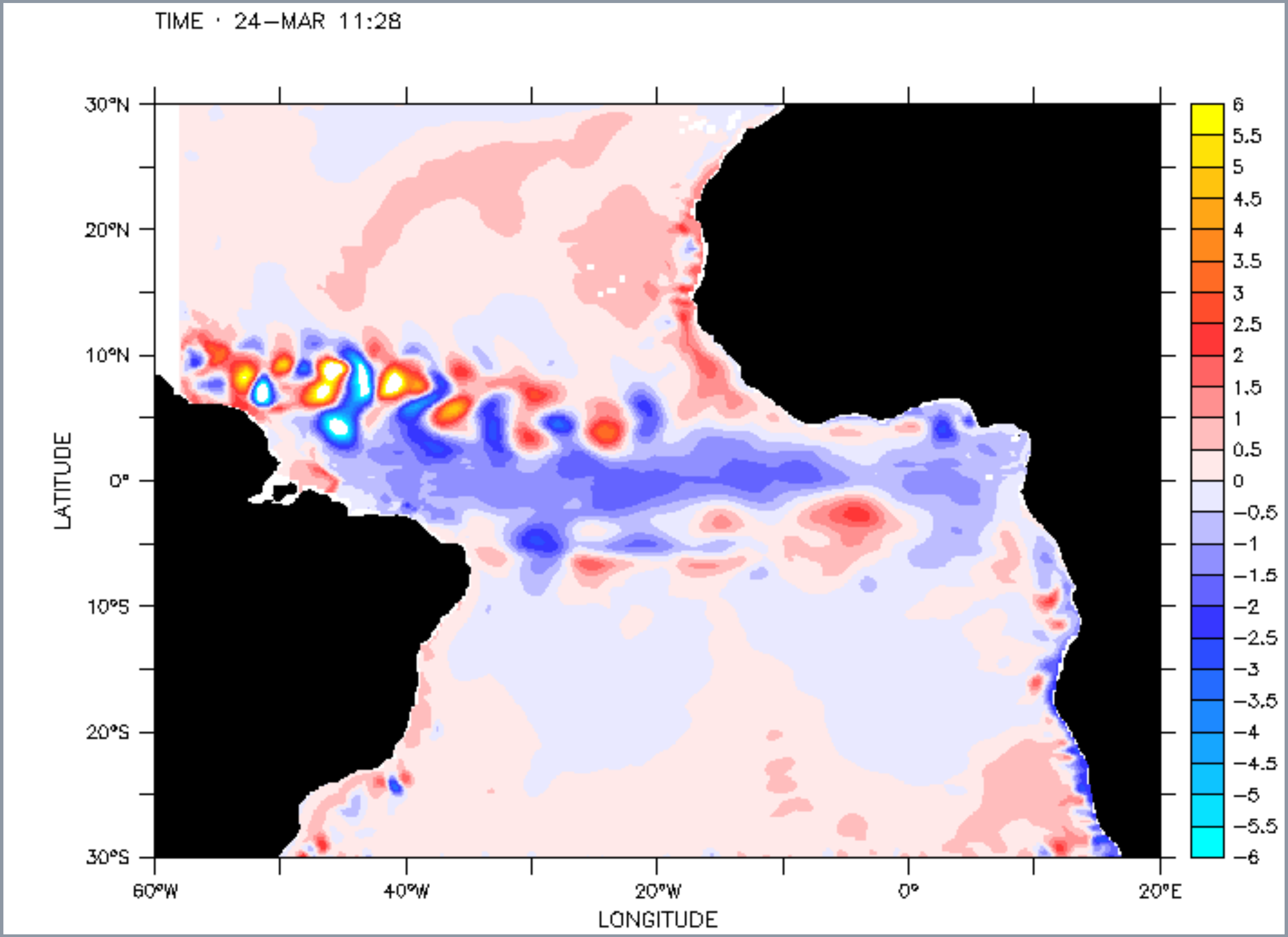

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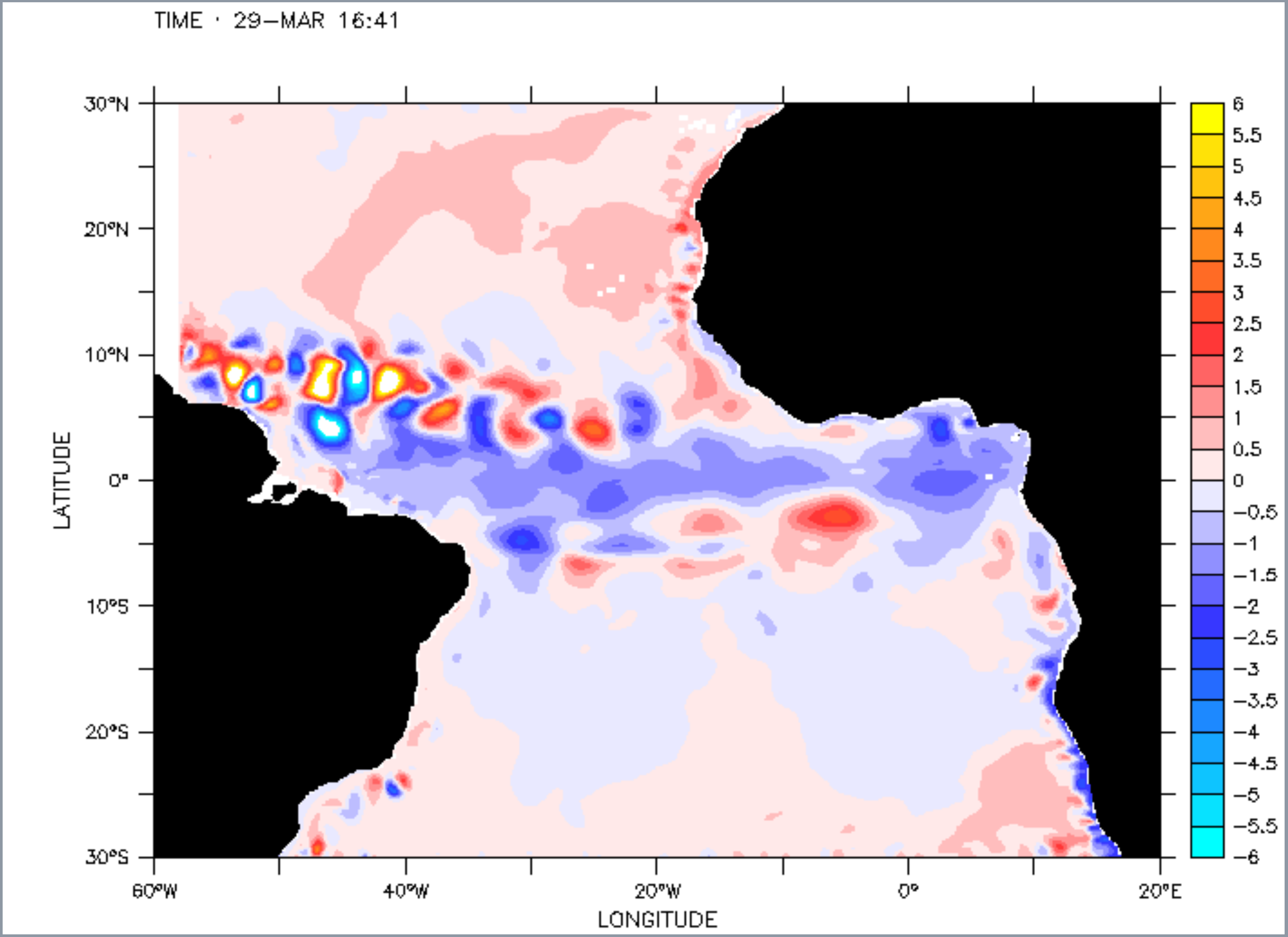

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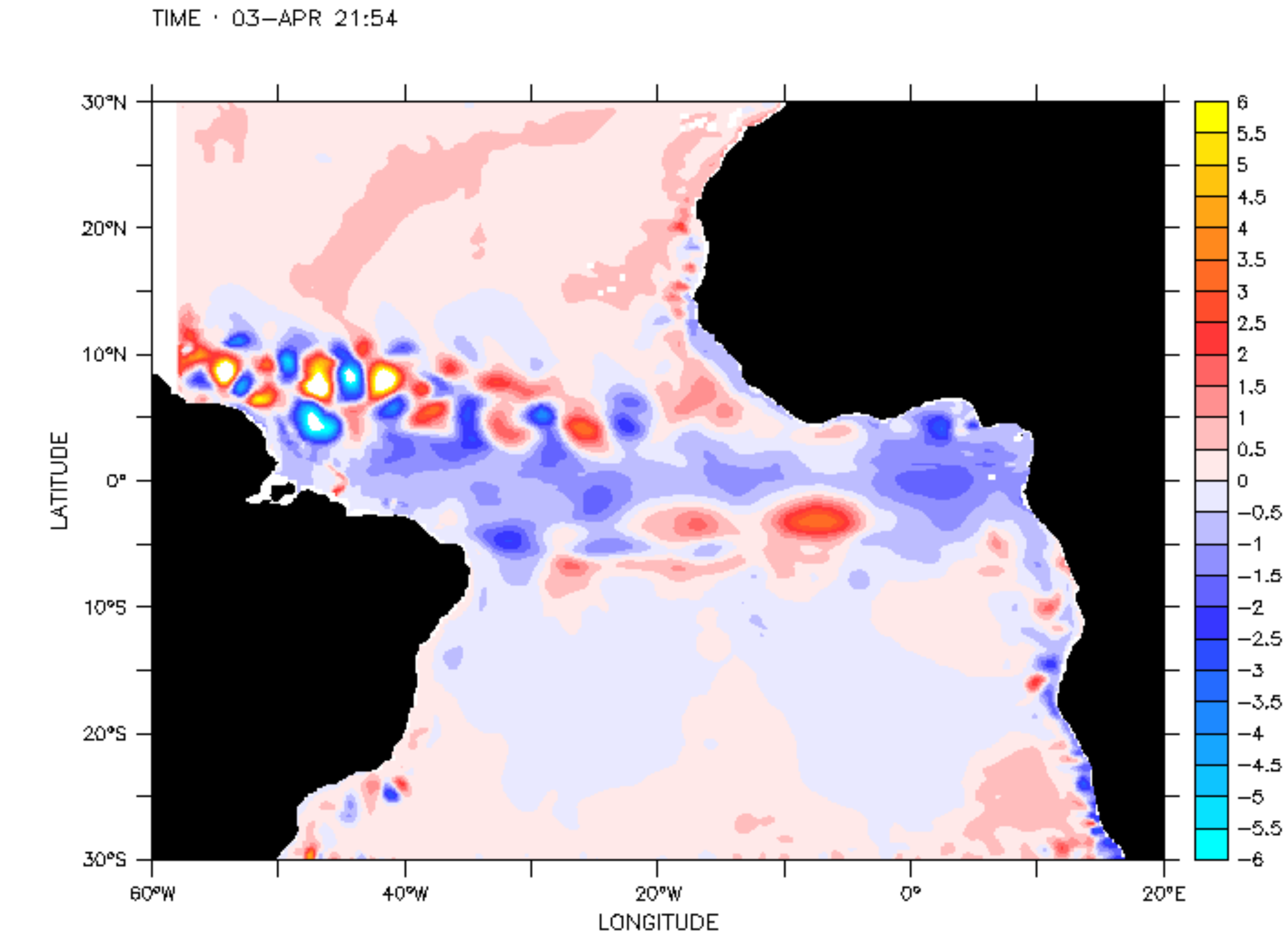

SSH anomaly (cm) : wbst - clim

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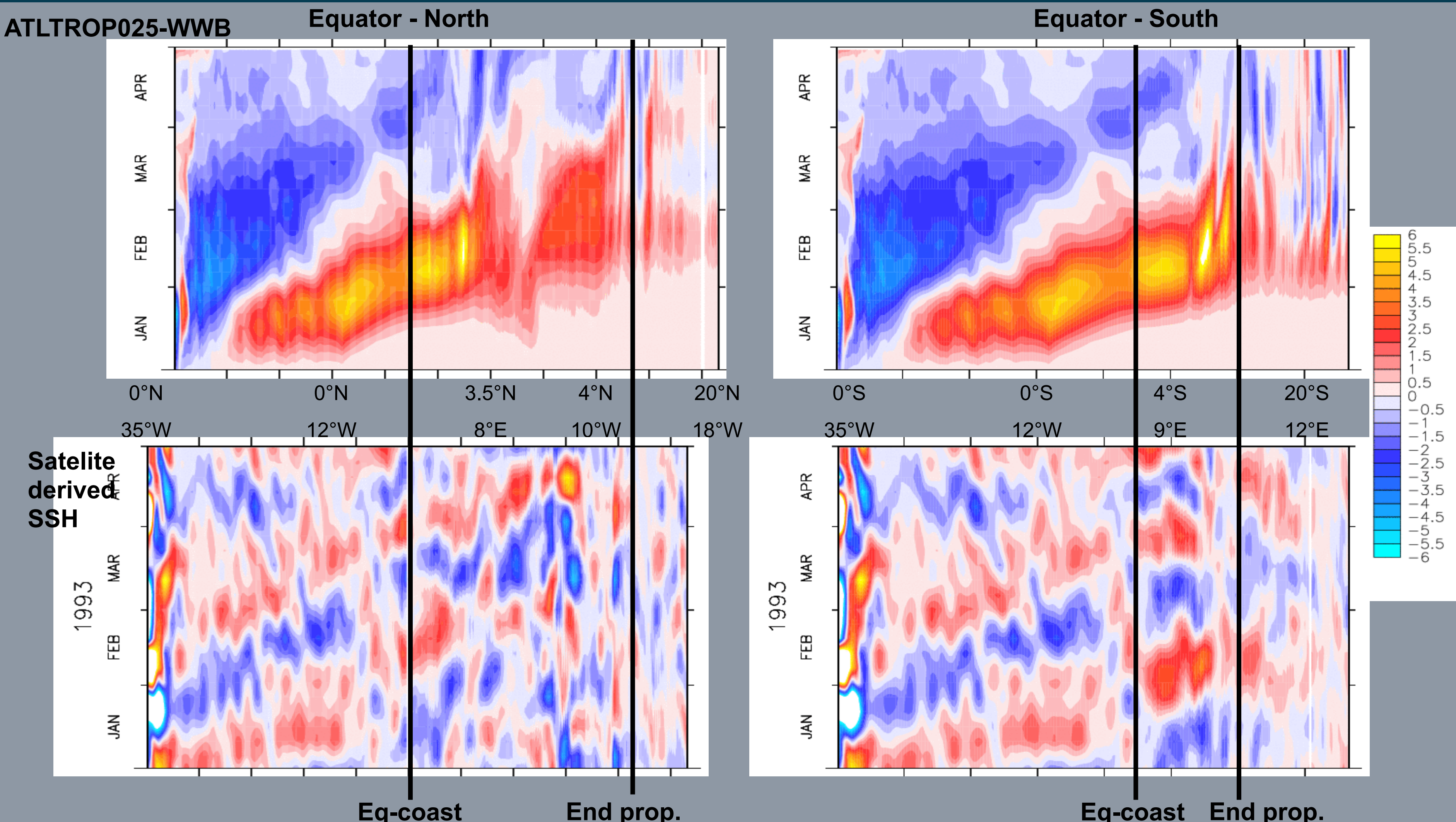
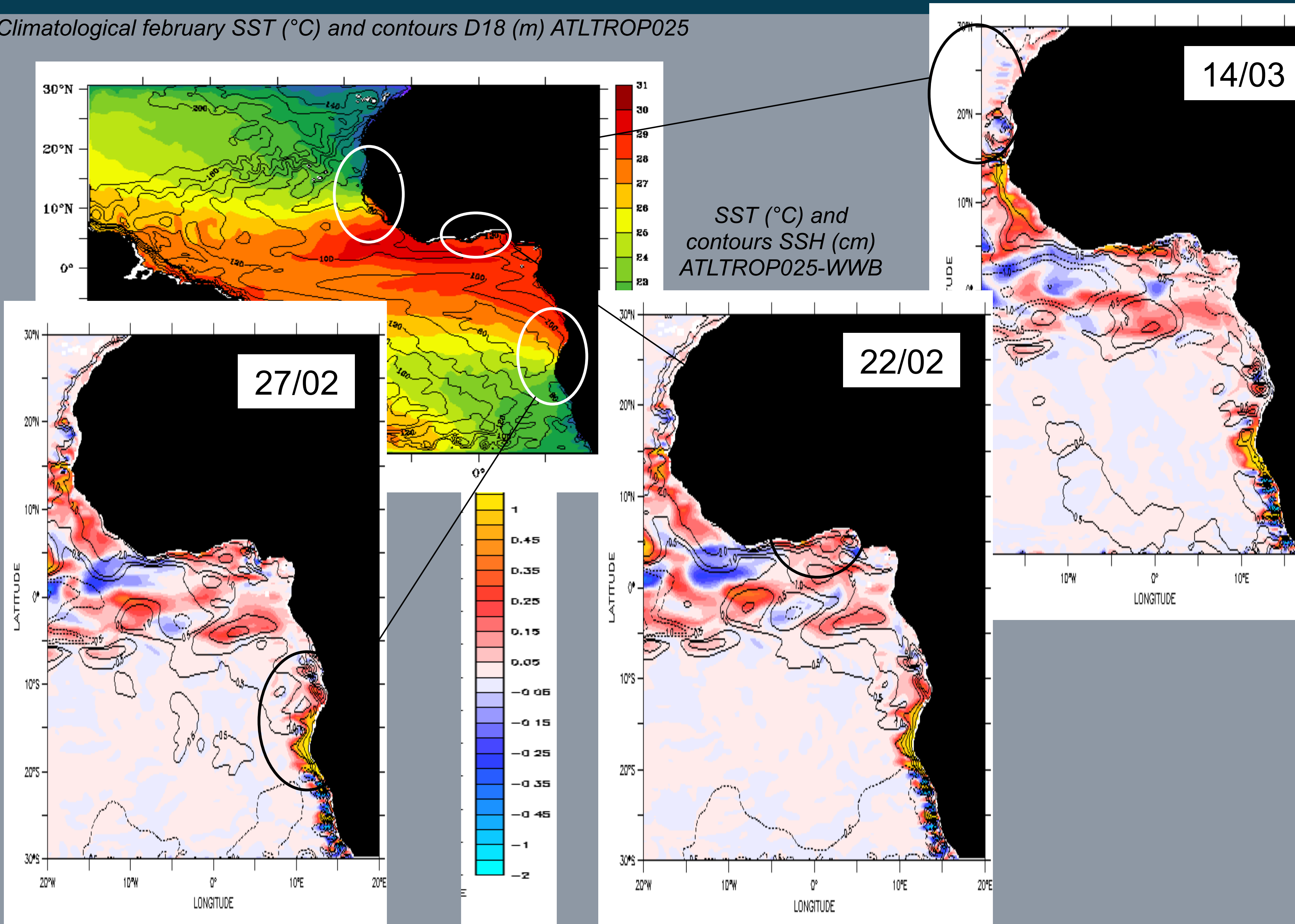


ATLTROP025-WWB and T/P SSH (m) along equator and coastal trajectories

➡ **Wave** : propagation from 30°W-eq to 12° N and S; v ≈ 1.9 m/s :
Very similar to observed Kelvin wave

Thermal impact of a january equatorial wave (model)

Climatological february SST (°C) and contours D18 (m) ATLTROP025

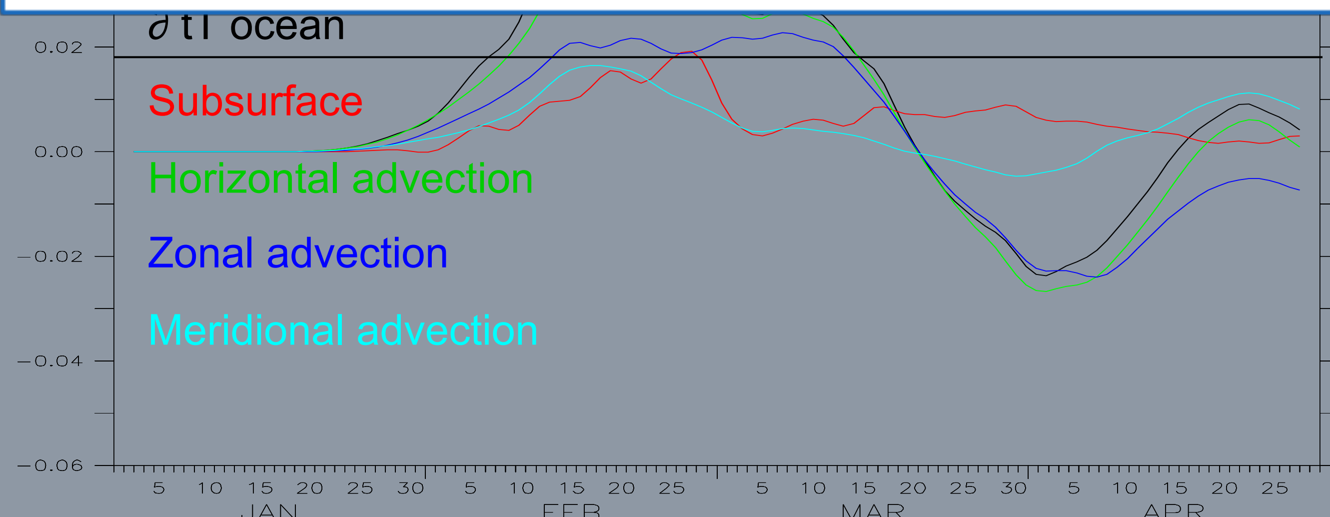


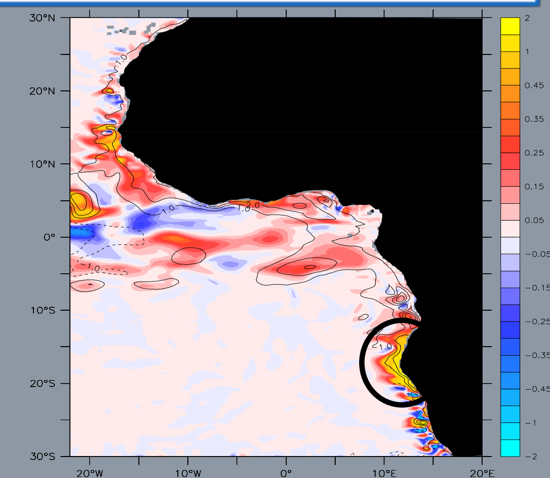
Results : Thermal impact of coastal waves : Angola upwelling

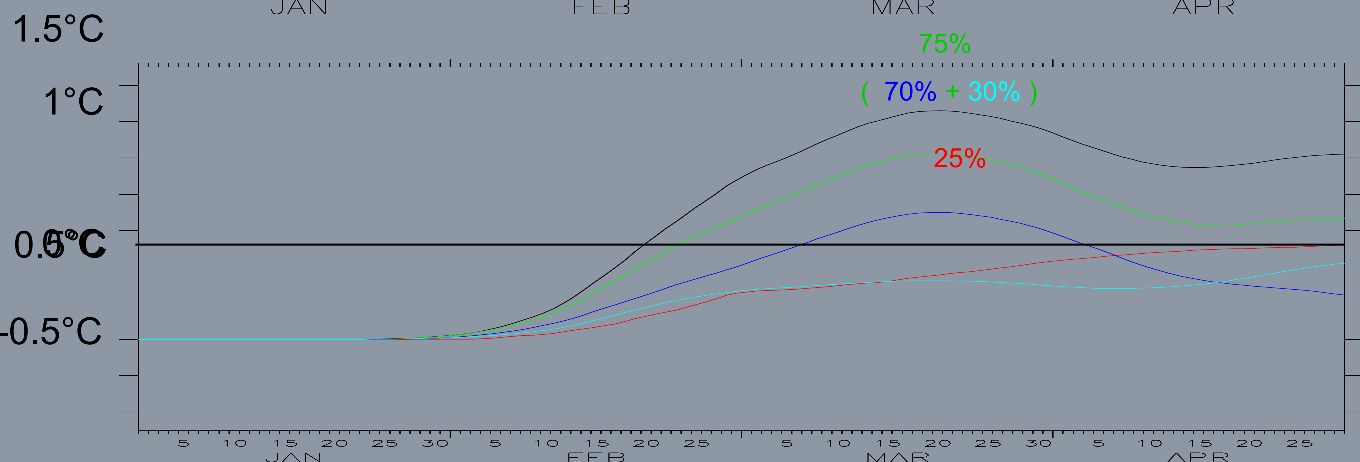
dSST/dt = ocean effect + atmosphere effect

horizontal dynamics — subsurface fluxes

$$\partial_t\langle T\rangle = -\langle u.\partial_x T\rangle - \langle v.\partial_y T\rangle + \langle D_l(T)\rangle - \frac{1}{h}\frac{\partial h}{\partial t}(\langle T\rangle - T_{z=h}) - \langle w.\partial_z T\rangle - \frac{1}{h}(K_z\partial_z T)_{z=h} + \frac{Q^* + Q_s(1-f_{z=h})}{\sigma_0 C_p h}$$

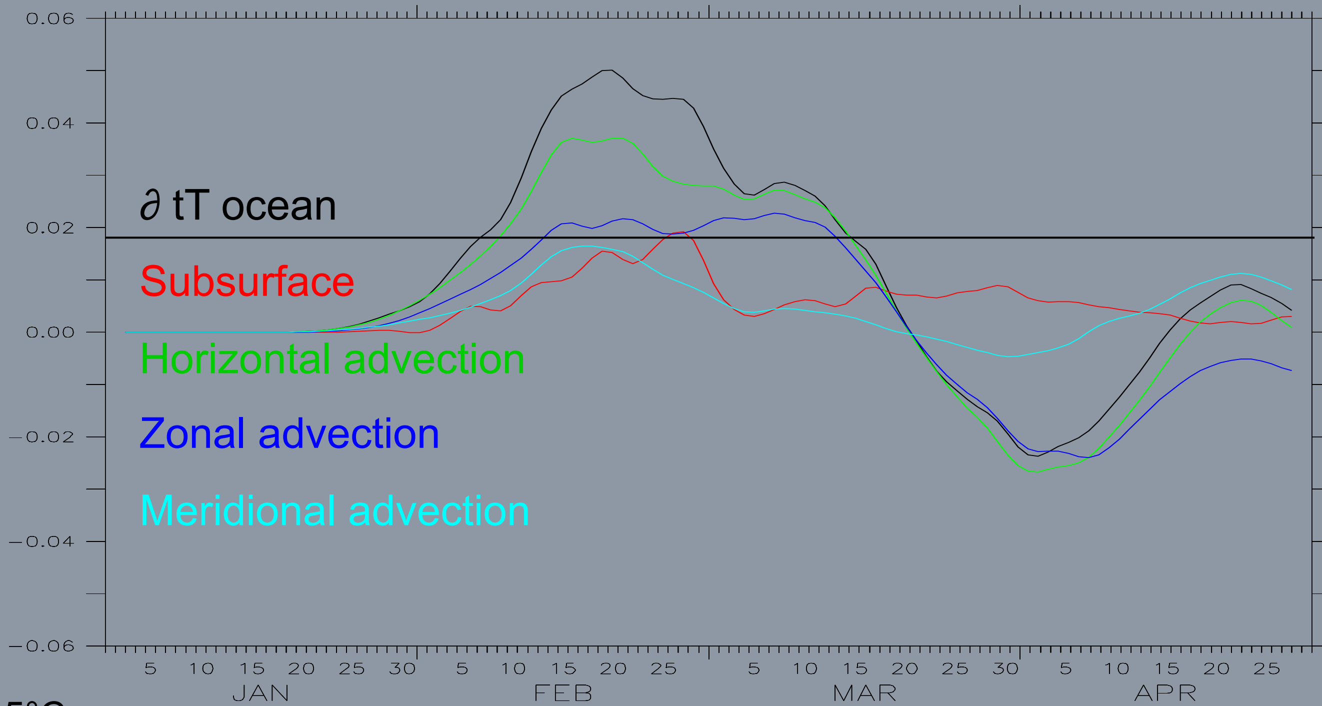


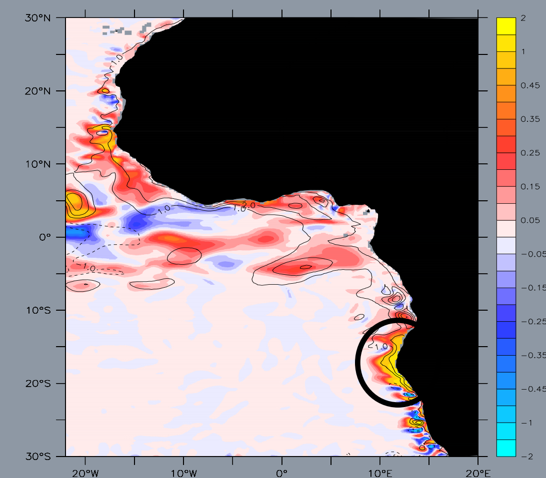


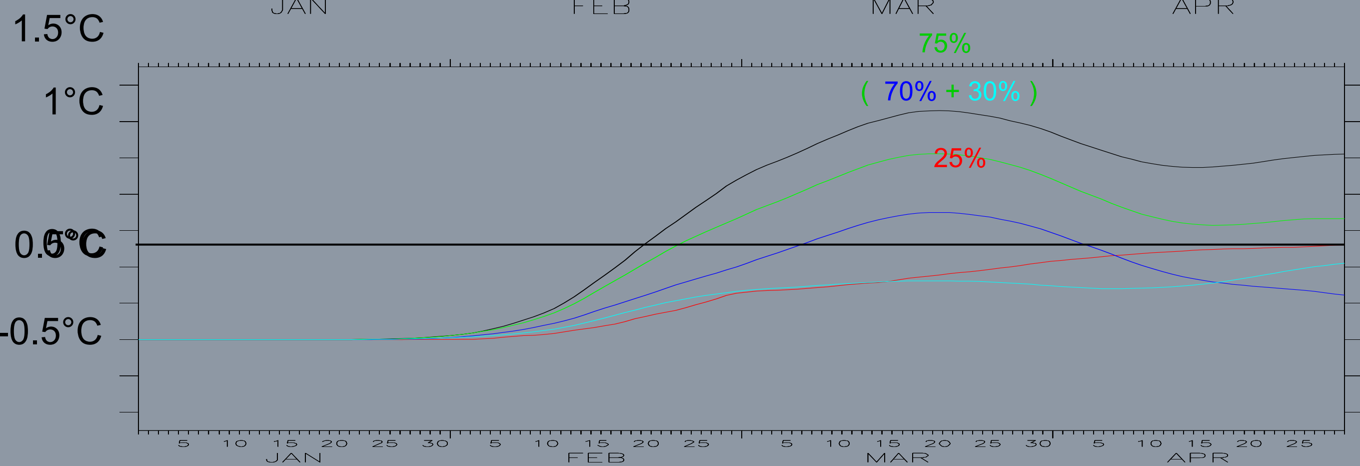


Mixed layer heat budget trends trends (°C/day), and integrated terms (°C)

Thermal impact of coastal waves : Angola upwelling

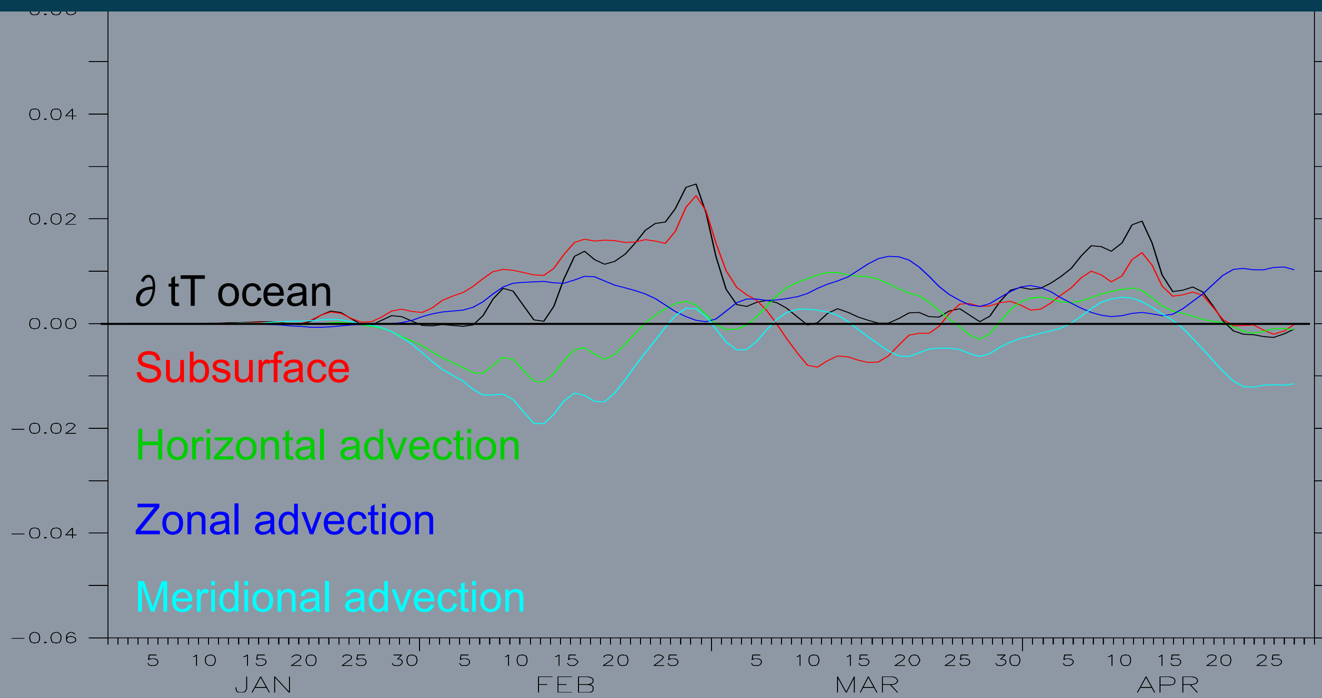


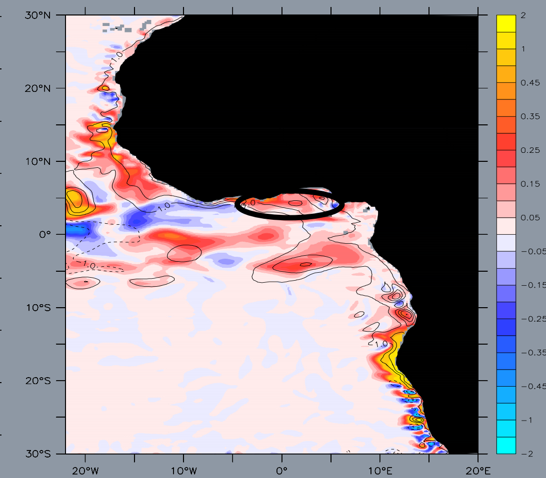


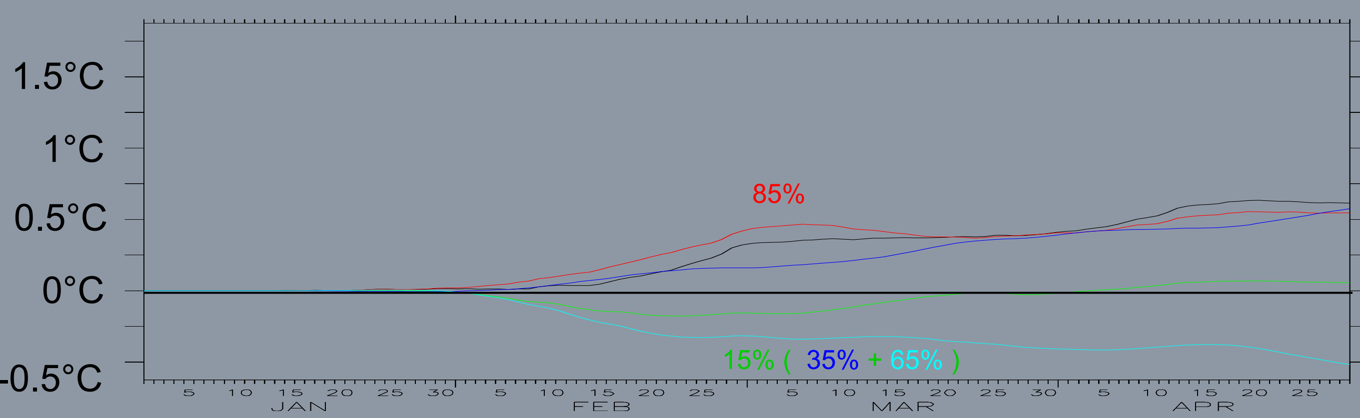


Mixed layer heat budget trends trends (°C/day), and integrated terms (°C)

Thermal impact of coastal waves : Guinea Gulf upwelling



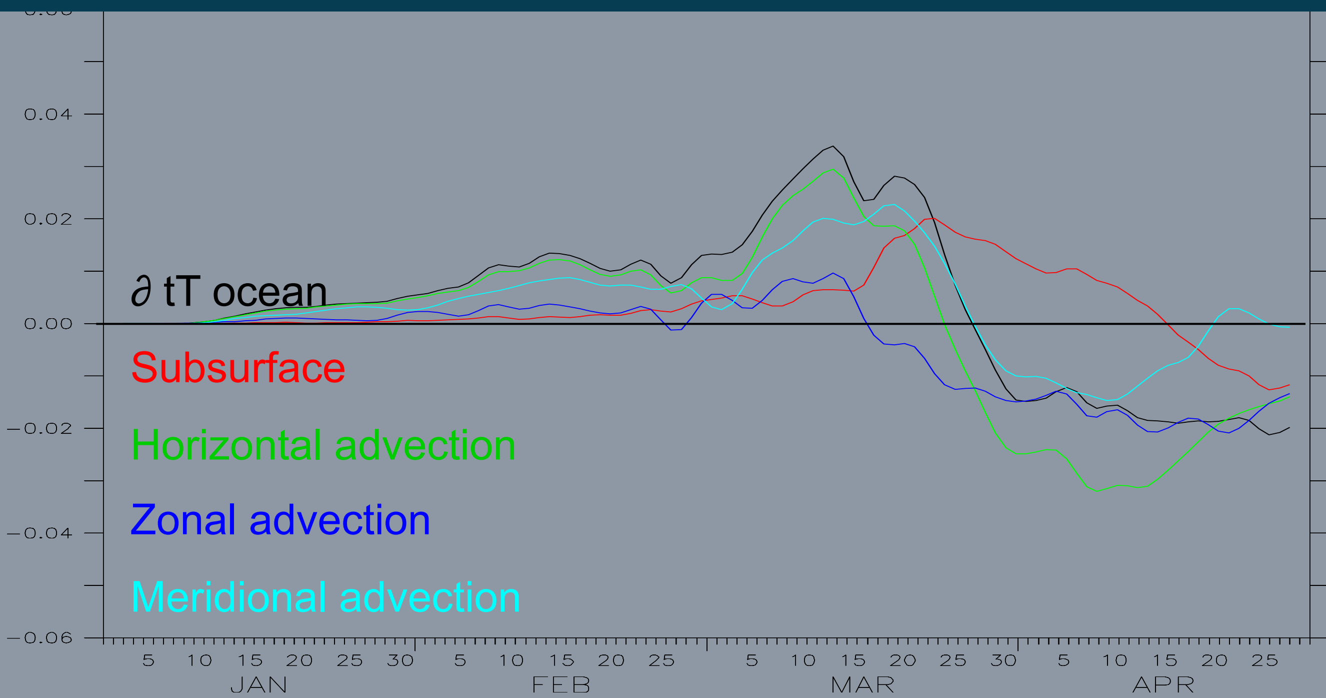


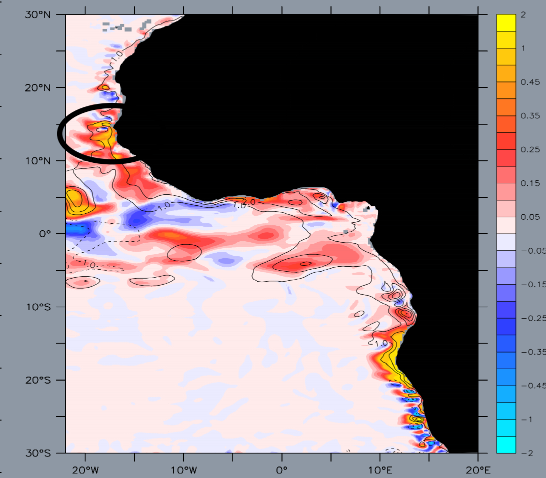


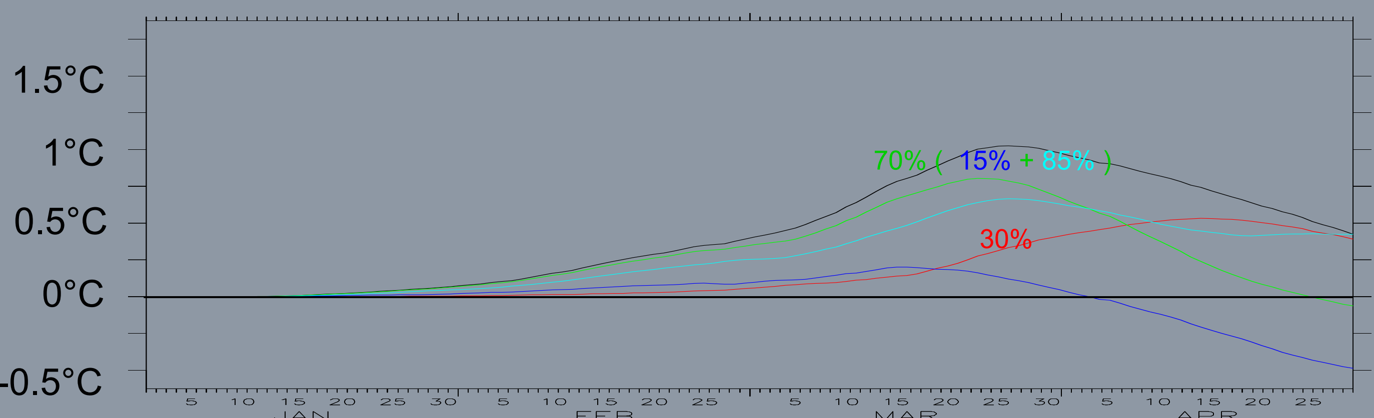
Total (upper) and integrated (lower) mixed layer heat budget trends (°C/day),

3.5°N, 6°E - 1°W@ave

Results : Thermal impact of coastal waves : Senegal upwelling



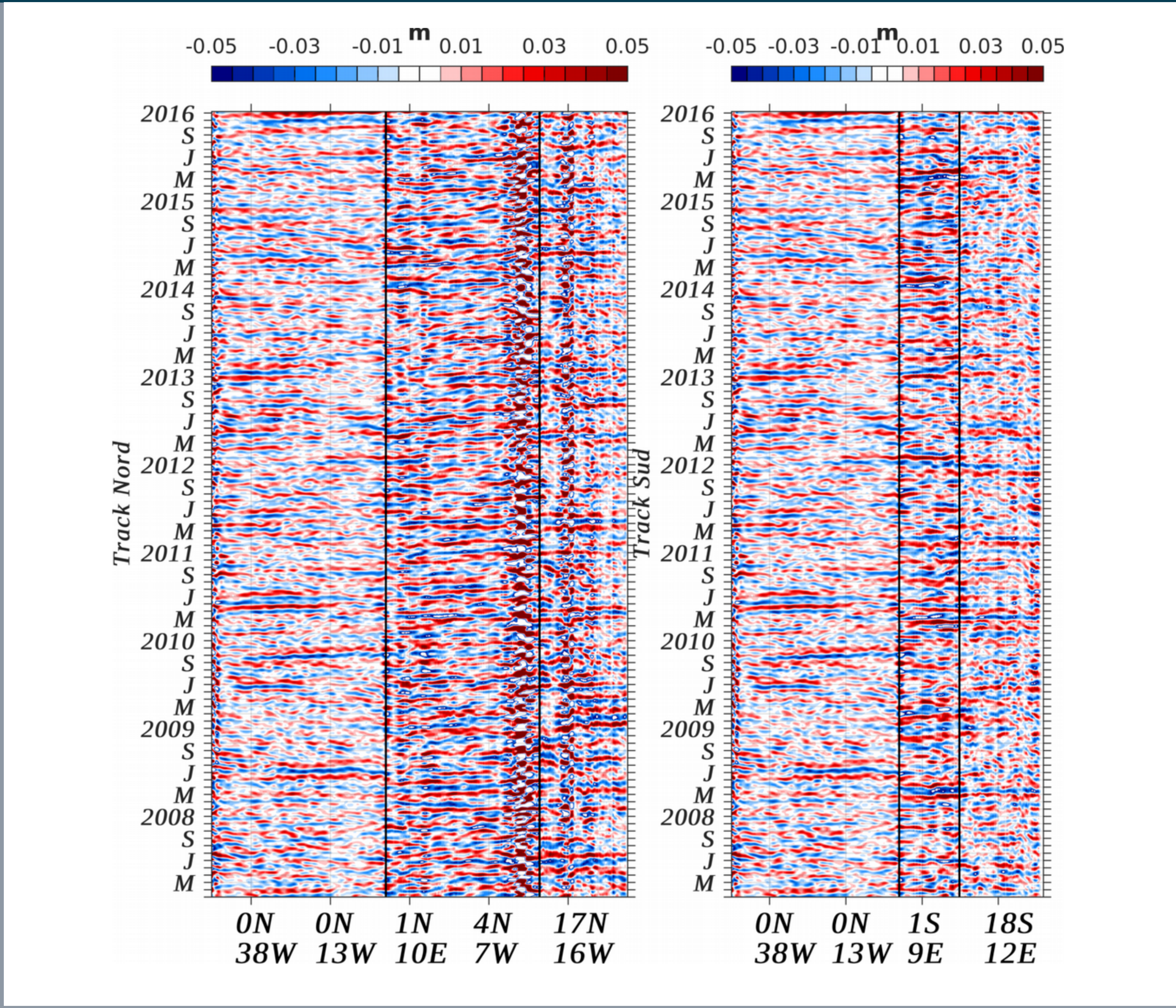




Total (upper) and integrated (lower) mixed layer heat budget trends (°C/day),

11°N - 18°N@ave

Equatorial and coastal intra-seasonal waves in satellite SSH: Need to extract a typical wave…

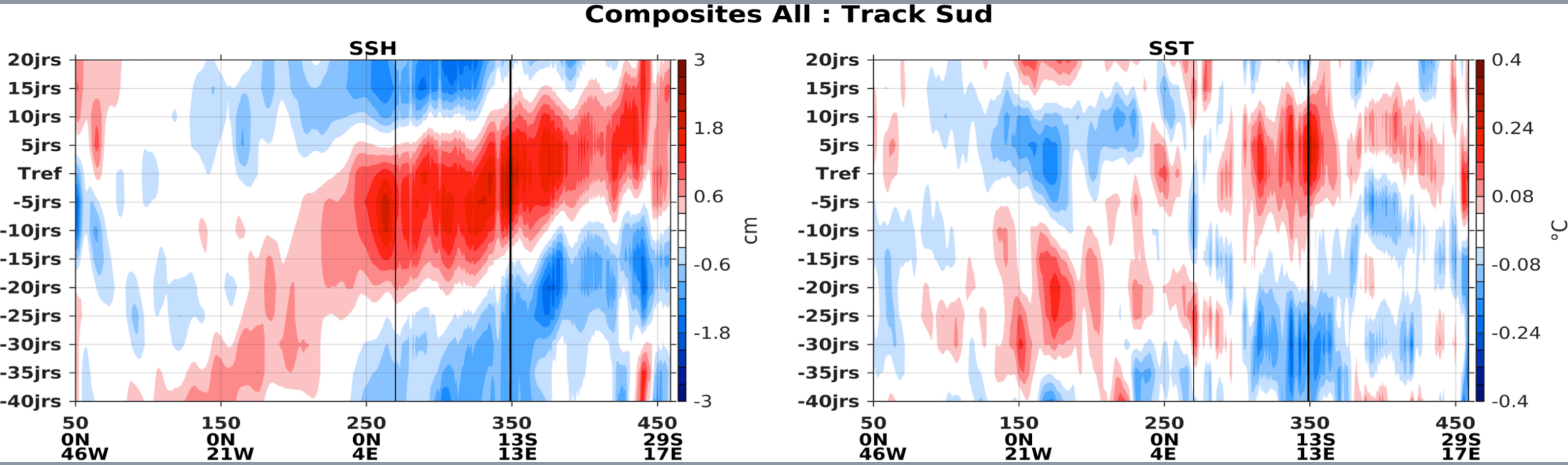


=> Composite wave reaching the north or south EBUS fronts

Composite intra-seasonal downwelling CTWs reaching the EBUS fronts

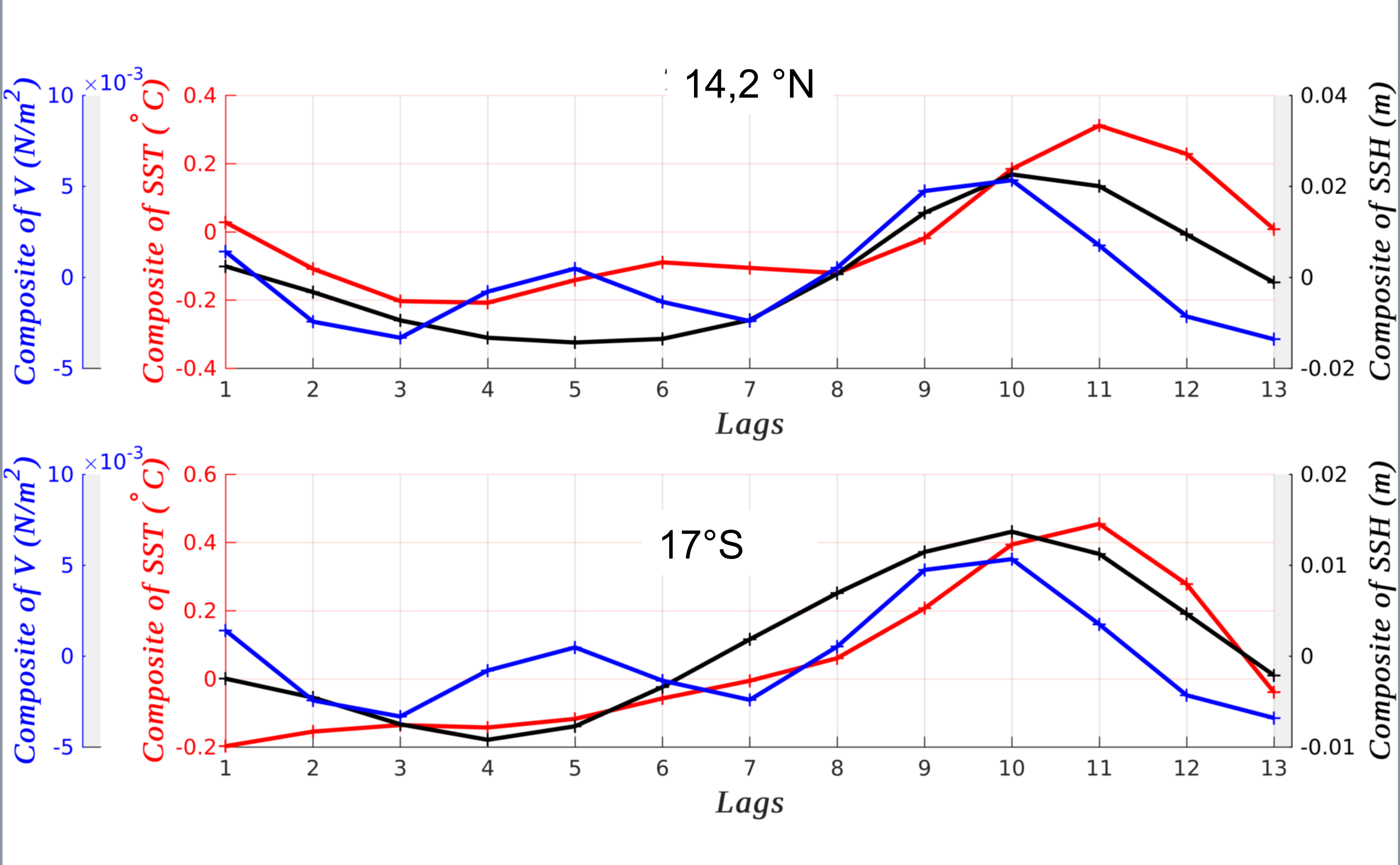
SSH, SST

Impossible d'afficher l'image. Votre ordinateur manque peut-être de mémoire pour ouvrir l'image ou l'image est endommagée. Redémarrez l'ordinateur, puis ouvrez à nouveau le fichier. Si le x rouge est toujours affiché, vous devrez peut-être supprimer l'image avant de la réinsérer.



Composite intra-seasonal downwelling CTWs reaching the EBUS fronts

SSH, SST, meridional Wind at the EBUS fronts



WIND IN PHASE with the WAVES!

Composite intra-seasonal downwelling CTWs reaching the EBUS fronts

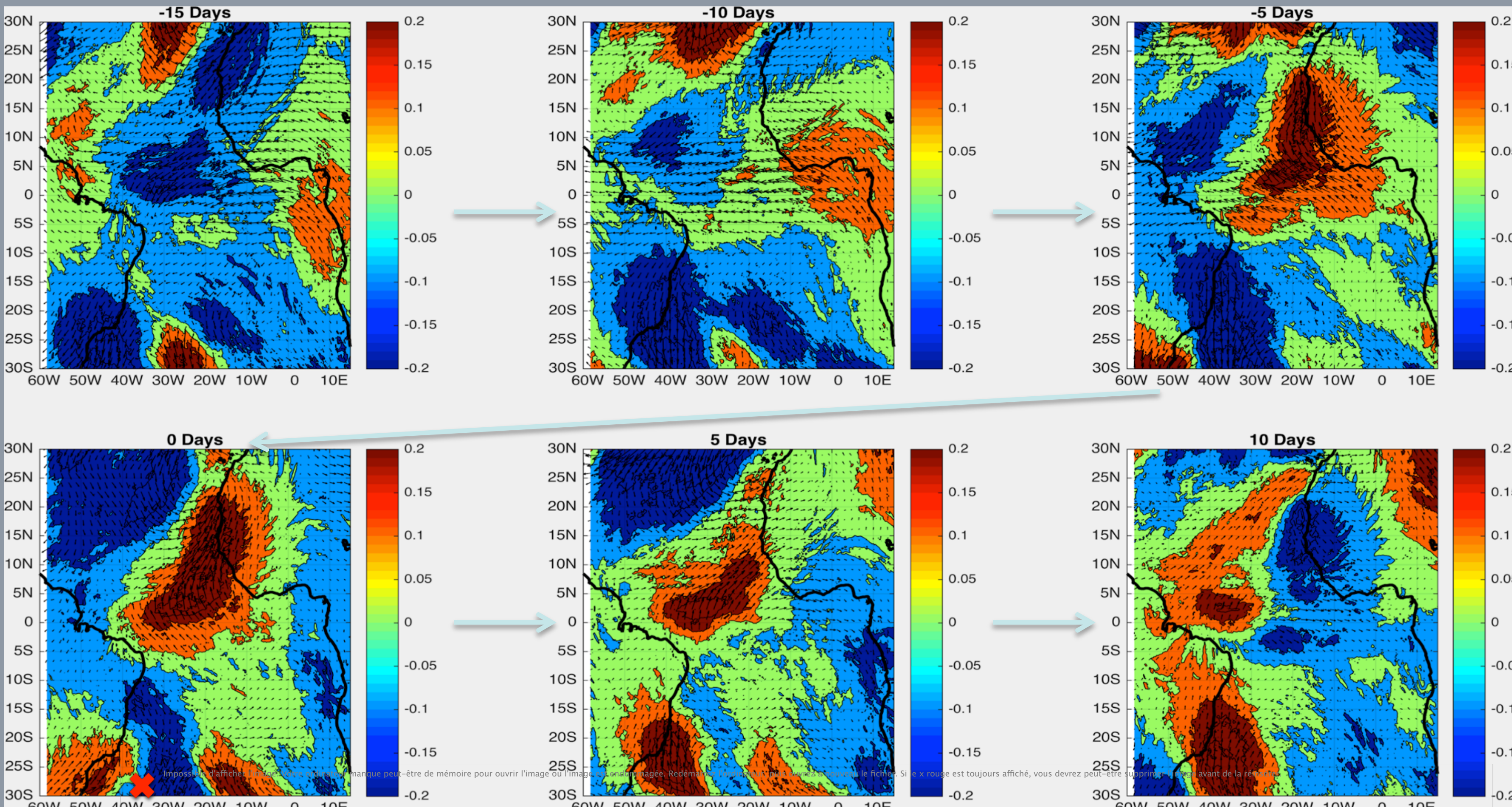
SSH, SST, Wind at the EBUS fronts

SSTA

Propagation of the wind ! Particularly the meridional component

Composite intra-seasonal downwelling CTWs reaching the EBUS fronts

Wind field anomaly ressembling an African Easterly Wave



Conclusion on the effect of an intraseasonal wave

-idealized winter downwelling intraseasonal wave similar to observed ones (amplitude, phase speed, pathways, etc)

-coastal downwelling Kelvin waves (~3cm) in January responsible of ~+ 1.5°C SST variation in coastal upwellings areas on 10° extension , comparable to observations

- similar thermal impact of the wave over the Beng uelaand Senegal upwelling fronts:

2/3 horizontal advection + 1/3 vertical diffusion

-opposite effects in the Gulf of Guinea upwelling

3/4 vertical diffusion - 1/4 horizontal advection

No universal effect, since it depends on the background state

Then…

Local wind forcing intra-seasonal fluctuations constructively or destructively interact…

…along Africa, the mean (composite) wave events appear to have constructive wind events associated to african easterly waves coming from the continent