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A climatological study of the Mechanisms Controlling the Seasonal Meridional Migration of the Atlantic Warm Pool in an OGCM

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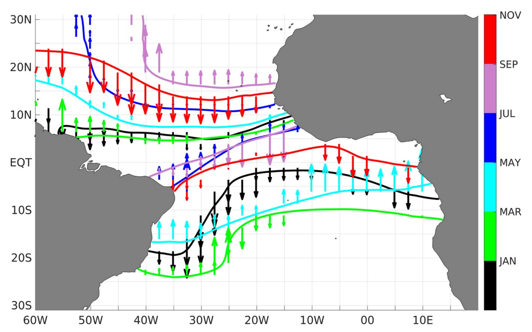
CONTEXT AND OBJECTIVES

The tropical Atlantic Warm Pool is one of the main drivers of the marine intertropical convergence zone and the associated coastal North-east Brazilian and West-African monsoons. Its meridional displacement is driven by the solar cycle, modulated by the atmosphere and ocean interactions, which nature and respective proportions are still poorly understood.

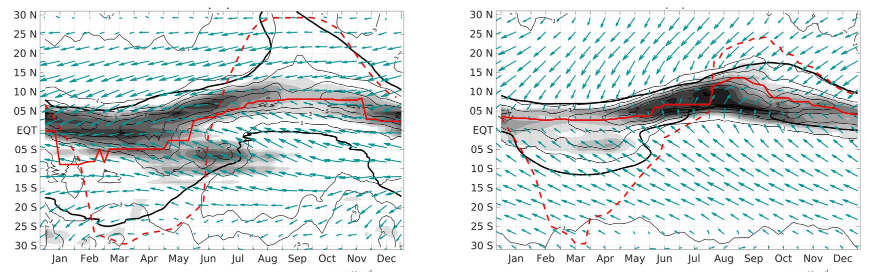
The aim of this study is to quantify the contribution of each oceanic process and air-sea fluxes on the AWP meridional migration with a Ocean General Circulation Model (NEMO-ATLTROP025), by constructing a diagnostic equation of AWP boundaries velocities.

AWP definition : choice of the meridional AWP boundaries

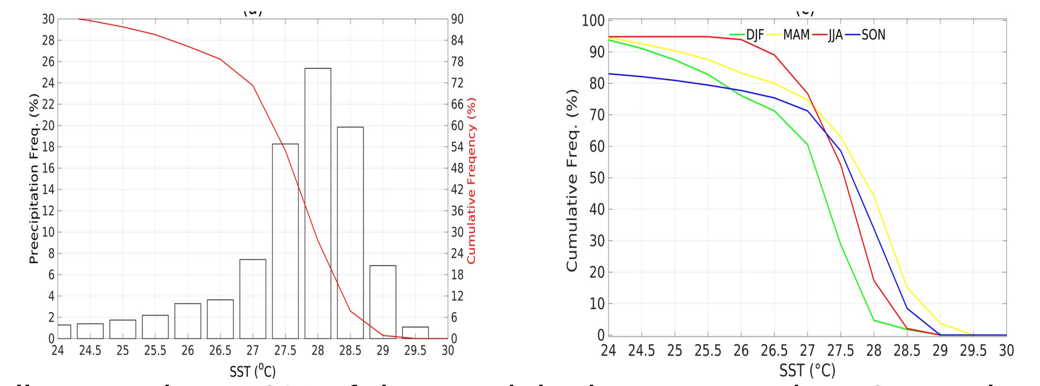


Strong seasonal variation of the AWP extension and migration.

The AWP migration velocity depends of the longitude.



Intense rain and surface wind convergence colocalized with the AWP. Strong zonal assymetry of the AWP extension and displacement.



Overall, more than 72% of the precipitation greater than 3 mm.day-1 is noted above the 27°C isotherm.

In boreal winter, ~60% of the precipitation is observed above 27°C isotherm while for the other seasons, more than 70% of the precipitation is located above the AWP.

Overall, in the tropical Atlantic, ~70% of precipitation is observed above the 27°C isotherm.

AWP migration velocity equation

Exact meridional AWP velocity : $V=\frac{\Delta y}{\Delta t}$

The linearized meridional velocity

Lagrangian variation of the SST meridional evolution:

$$dT(y,t)=\frac{\partial T}{\partial t}.dt+\frac{\partial T}{\partial y}.dy$$

For a given isotherm : $\frac{\partial T}{\partial t}.dt=-\frac{\partial T}{\partial y}.dy$; $V=\frac{dy}{dt}=-\frac{\partial_t T}{\partial_y T}$

$$V^* = -\frac{\partial_t T}{\partial_y T}$$ Linearized equation

With

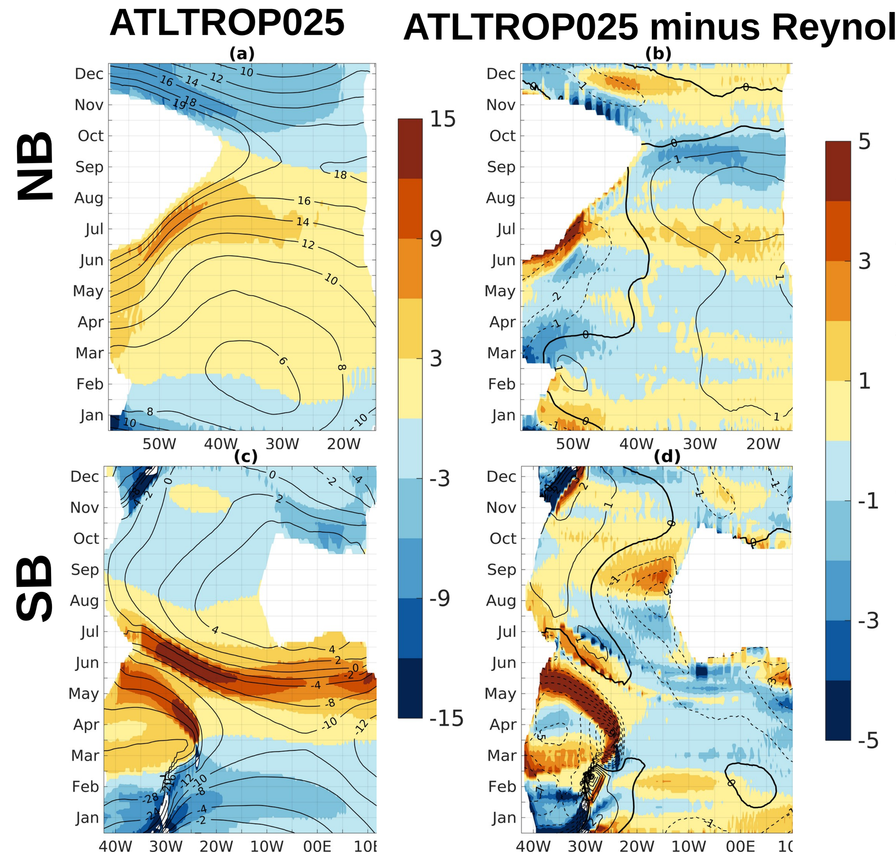
$$\partial_t\langle T\rangle = -\underbrace{\langle u.\partial_x T\rangle-\langle v.\partial_y T\rangle+\langle D_l(T)\rangle}_{Contrib(1)} - \underbrace{\frac{1}{h}\frac{\partial h}{\partial t}(\langle T\rangle-T_{z=-h})-\langle w.\partial_z T\rangle-\frac{1}{h}(K_z\partial_z T)_{z=-h}}_{Contrib(2)} + \underbrace{\frac{Q_{ns}+Q_s(1-f_{z=-h})}{\rho_0 C_p h}}_{Contrib(3)}$$

$$V_{ocean}=-\frac{Contrib(1)+Contrib(2)}{\partial_y SST}\ ,\quad V_{air-sea}=-\frac{Contrib(3)}{\partial_y SST}$$

$$V^* = V_{ocean}+V_{air-sea}$$

RESULTS

Validation of the AWP migration simulated by OGCM

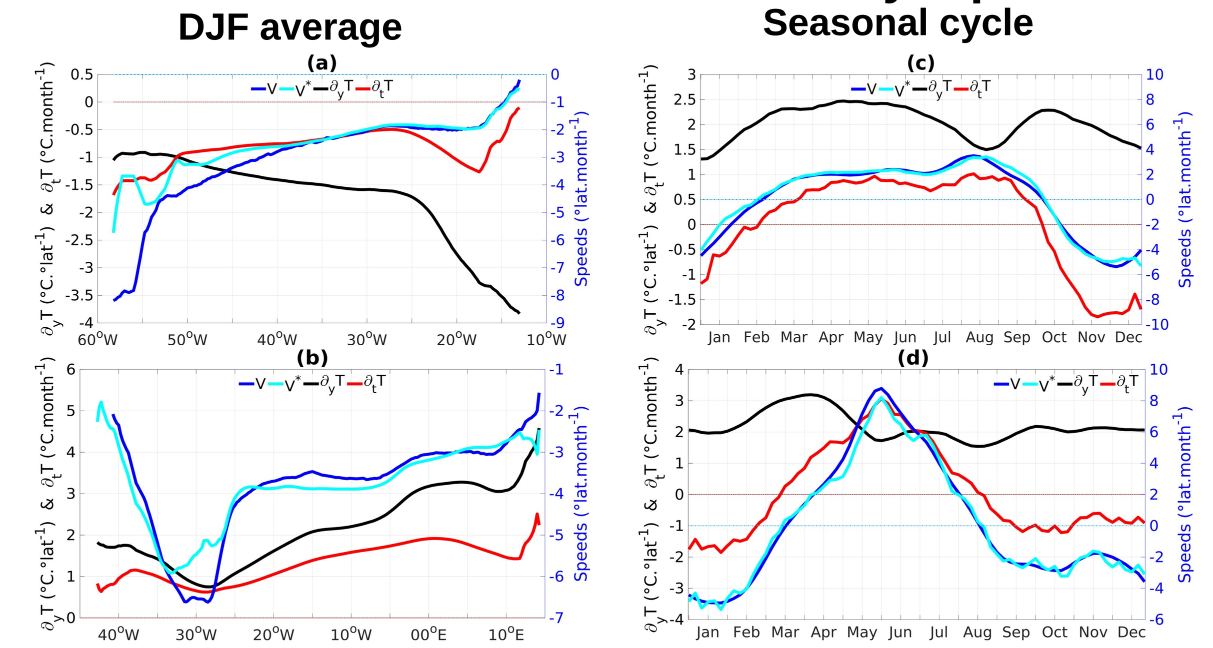


Overall, the spatiotemporal variability of the AWP velocity simulated by ATLTROP025 is comparable to observation.

We note small differences in the simulated and observed meridional position of the AWP boundaries.

Velocity (shading) and latitude (contour) of the AWP boundaries

Validation of the linearized velocity equation

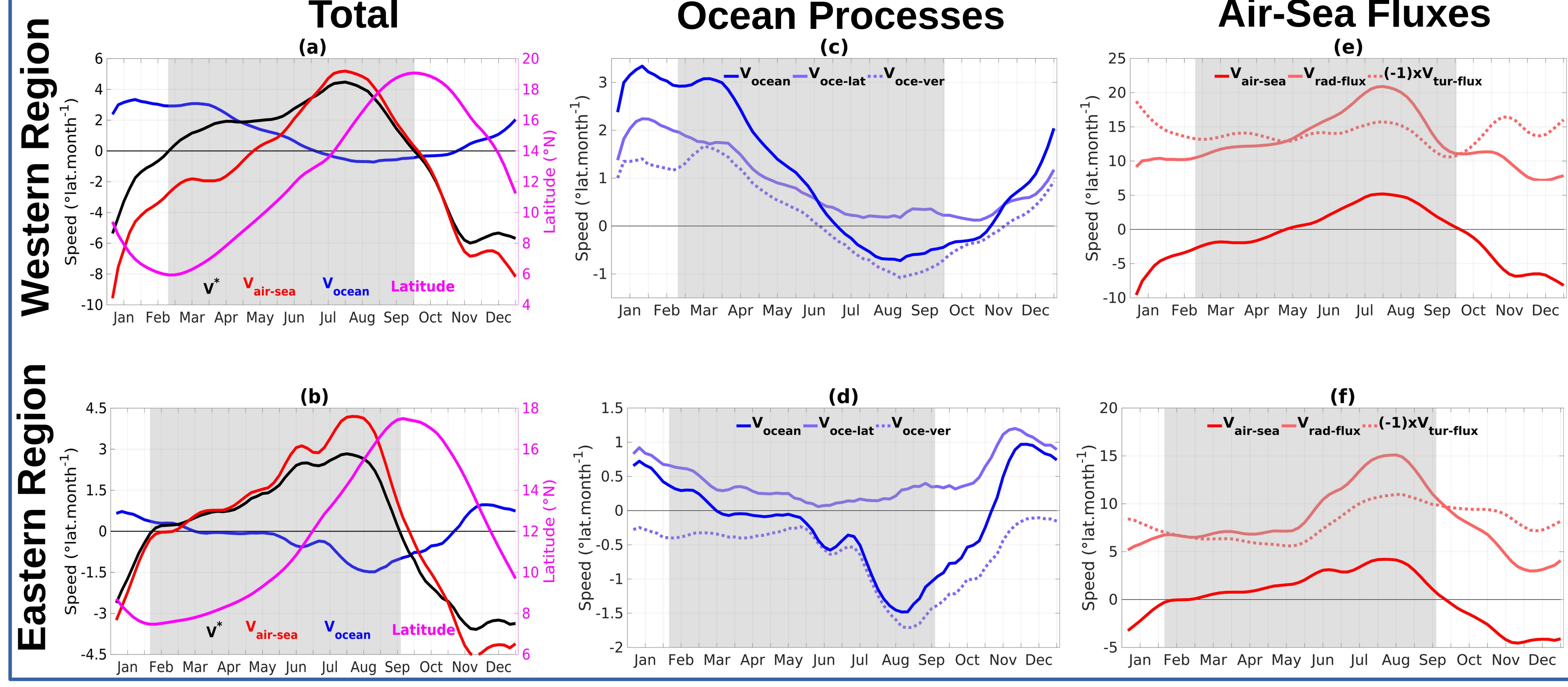


Overall, a good saptiotemporal representation of V by V* in terms of phasing and amplitude.

The strong zonal velocity contrast most associated to the meridonal SST gradient.

The zonal structure is controlled by the mean meridional SST gradients, while their temporal variations are forced by the SST time-derivative.

Seasonal migration of the northern boundary (NB)



Similar mechanisms of the migration are noted in E30 and W30 sectors (a,b) but with significantly different amplitudes and phases.

Northward migration phase : MJJAS

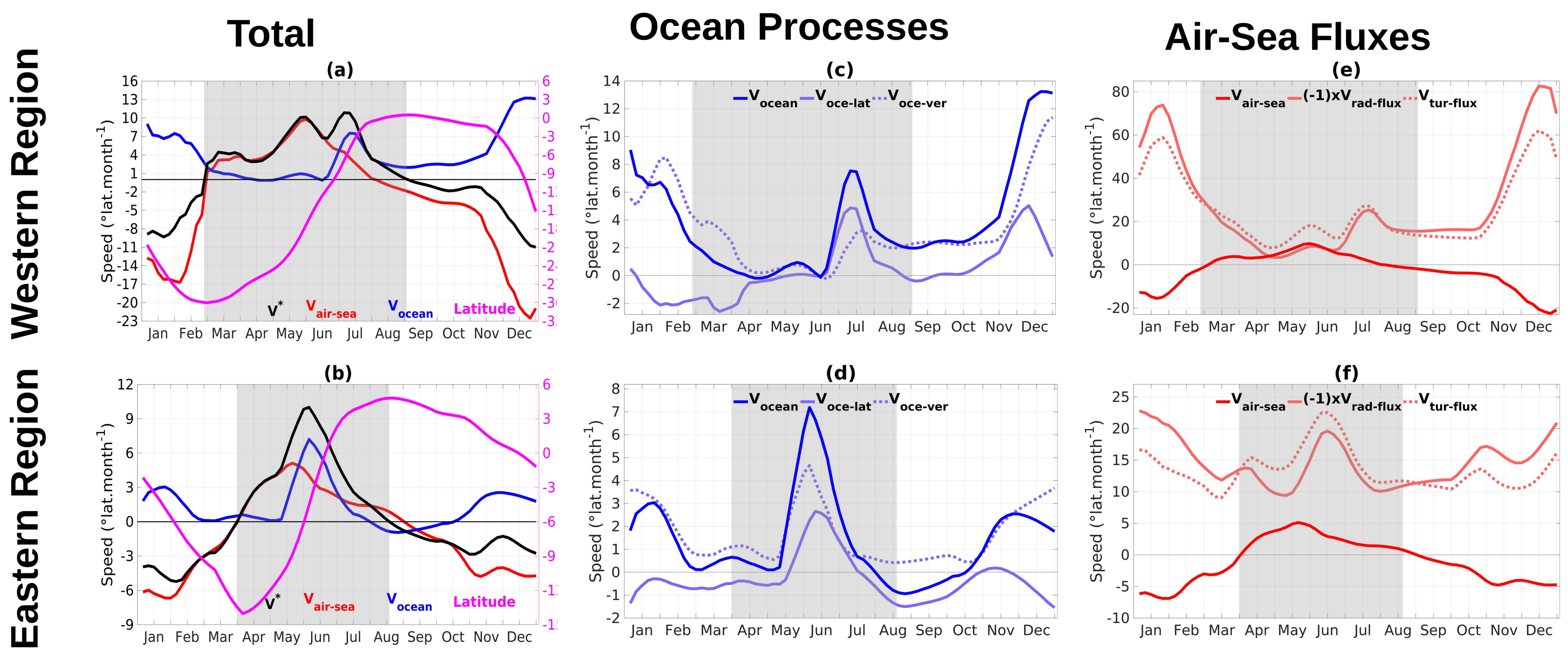
Overall, migration dominate by air-sea fluxes thorgthout the solar heating.

Ocean processes dampt the NB migration

Northward NB migration initiate by ocean processes in the northwestern tropical Atlantic.

Strong ocean opposition to the migration via a strong cooling by mixing

Seasonal migration of the southern boundary (SB)



Significant contribution of both air-sea fluxes and ocean processes on the SB migration.

First the northward migration is essentialy due to the air-sea fluxes effect from March (April) to Jun (July) via the heat latent loss.

From June (july) the ocean processes effect becomes intense and dominate the migration by inducing cooling via horizontal advection and vertical mixing.

CONCLUSIONS

AWP associated to the ITCZ define as a region surronded by 27°C isotherm

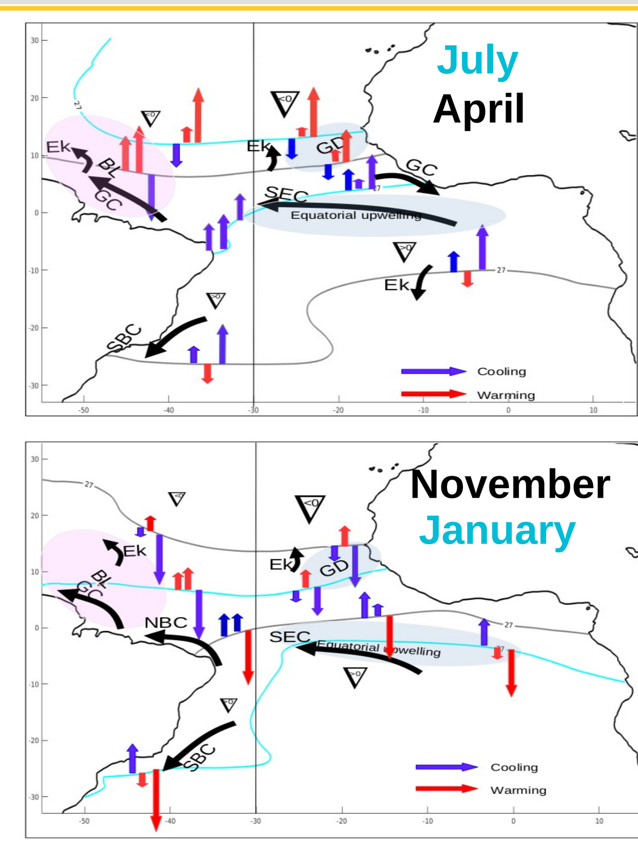
Zonal averages on each side of 30°W, defined as the E30 and W30 sectors, show a good co-localization of the AWP and the ITCZ.

Depending on the considered areas and seasons, 60% to 80% of the rainfall greater than 3 mm.day-1 is shown in the region where the temperature exceeds 27°C.

We demonstrates that the important zonal variations of velocity are mainly explained by the strong meridional SST gradients to the east which weakens the migration in the east, compared to the west

.

Overall, our results indicate that the ocean is often a brake on the migration imposed by the net air-sea flux. However, it is a driving force in the boreal spring in the northwest, where it removes the heat accumulated under the barrier layers zone, and in the boreal spring and summer near the equator where the equatorial upwelling drives the AWP northward. The use of the diagnostic equation for migration velocities can be generalized to the quantification of the causes of anomalies in the positioning of the AWP and ITCZ relative to the seasonal cycle, in the intra-seasonal or low-frequency ranges.



Northward migration

Southward Migration

REFERENCES

– **Cintra**, M.M.; Lentini, C.A.D.; Servain, J.; Araujo, M. and Marone, E. Physical processes that drive the seasonal evolution of the Southwestern Tropical Atlantic Warm Pool. Dyn. Atmos. **2015**, 72 (2015) 1-11.
– **Clement**, A.C.; Seager, R. and Murtugudde, R. Why Are There Tropical Warm Pools? J. Clim. **2005**, 18, 5294-5311.
– **Graham**, N.E. and Barnett, T.P. Sea surface Temperature, Surface Wind Divergence, and Convection over Tropical Oceans. Report 30 October **1987**. http://www.sciencemag.org/ on November 28, 2014.
– **Peter**, A.C.; Le Hénaff, M.; du Penhoat, Y.; Menkes, C.E.; Marin, F.; Vialard, J.; Caniaux, G. and Lazar, A. A model study of the seasonal mixed layer heat budget in the equatorial Atlantic. J. Geophys. Res. **2006**, 111, C0014. DOI : 10.1029/2005JC003157, 2006.
– **Wang**, C. and Enfield, D.B. The tropical Western Hemisphere warm pool. Geophys. Res. Lett., **2001**, 28 N° 8. pp. 1635-1638, 2001.

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