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On the relationship between surface winds convergence and SST over the tropical Atlantic: Case of July

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Abstract

Using a mixed layer model (MLM), satellites and reanalyses datasets over the 2000-2009 decade, we provide a comprehensive explanation of monthly-mean climatology as well as month-to-month change of surface wind convergence budget over the tropical Atlantic. Relative influence of the SST (Sea Surface Temperature) forcing is also examined. MLM assumes a subcloud layer momentum force balance between pressure gradients, Coriolis acceleration, linearized friction and downward momentum mixing, and utilizes boundaries conditions from reanalyses. Diagnostics with this model are also extended by the approach of Takatama et al. (2012), which express the near-surface convergence as a sum of terms relating to pressure adjustment, downward momentum mixing, and horizontal advection. Pressure contribution is linearly decomposed into boundary layer (defined as the region below 850 hPa) and free tropospheric components. While month-to-month change is highly controlled by the geostrophy within pressure contribution dominated up to 60% (50%) by the tropospheric component in ERA-I (CFSR), for monthly-mean state budget, results subdivide the marine Inter-Tropical Zone (ITCZ) into two parts. An "oceanic ITCZ" (defined as region between 10-50°W and 5-12°N in July), where pressure contribution appears northward shifted compared to observations and reanalyses; and an "coastal one" (Guinea Gulf and Northeastern Brazilian coasts), where horizontal advection and pressure contributions control the surface wind convergence, with the pressure as the first order driver. This pressure contribution has been shown largely dominated by its component below the boundary layer closely related to SST.

Introduction

❑ Surface wind interaction with the Sea Surface Temperature (SST) and convection in the intertropical convergence zone (ITCZ) are pivotal to climate variability in the region on several range of time scales (Mitchell and Wallace 1992, Li and Philander 1997, Gu and Adler 2004, Back and Bretherton 2009a, de Coëtlogon at al. 2010).

❑ Understanding the dynamics of surface winds has been a challenging research topic

❑ McGauley et al. (2004) and Back and Bretherton 2009a : Central to the problem of surface winds are two issues:
➢ the mechanism(s) determining the surface pressure gradient
➢ the mechanism(s) determining surface winds in a given pressure field.

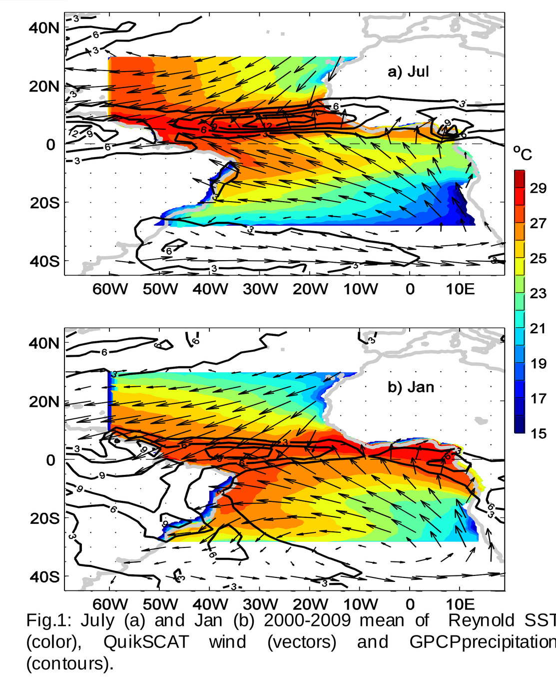
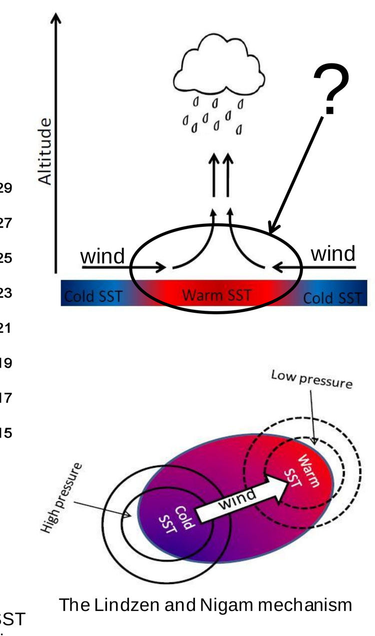


Fig.1: July (a) and Jan (b) 2000-2009 mean of Reynold SST (color), QuikSCAT wind (vectors) and GPCPprecipitation (contours).



The Lindzen and Nigam mechanism

1) *What are the dominant processes of the momentum balance in the Atmospheric Boundary Layer (ABL) under tropical Atlantic ITCZ?*
2) *What are the fractional contributions to the surface pressure gradient of the horizontal mass distribution in the ABL (i.e., the effect of the SST) and of the overlying free troposphere (the effect of elevated diabatic heating and waves)?*
3) *Are SST gradient and surface wind correlated and it is possible to identify Lindzen and Nigam's mechanism in the tropical Atlantic?*

Data & Methodology

- ERA-interim (0.75x0.75) and CFSR (0.5x0.5) reanalyses
- QuikSCAT wind (0.25x0.25)
- Reynolds SST (0.25x0.25)
- Period times of study 2000-2009;

1) Surface winds convergence budget using the Stevens et al. (2002) and Mixed Layer Model (MLM) and the Takatama et al. (2012) approach.
2) Decomposition of the pressure contribution onto ABL and free tropospheric components.
3) Relation between the horizontal mass distribution and SSTs

Results

July-mean (2000-2009) convergence budget

❑ **Approach of Back and Bretherton (2009a)**

$$f\mathbf{k}\times\mathbf{U} + \rho_0^{-1}\nabla P_s = \frac{w_e(\mathbf{U}_T - \mathbf{U})}{h} - \frac{w_d(\mathbf{U})}{h},$$

$$U = \frac{U_T\epsilon_e\epsilon_c + V_T f\epsilon_e - \rho_0^{-1}(f\partial P_s/\partial y + \epsilon_c \partial P_s/\partial x)}{\epsilon_c^2+f^2},$$

$$V = \frac{V_T\epsilon_e\epsilon_c - U_T f\epsilon_e + \rho_0^{-1}(f\partial P_s/\partial x - \epsilon_c \partial P_s/\partial y)}{\epsilon_c^2+f^2},$$

where $\epsilon_e = w_e/h$ and $\epsilon_c = (w_e + w_d)/h$

$\vec{U}(P_s, \vec{U}_T)$

$$div(\vec{U}(P_s,\vec{U}_T)) = div(\vec{U}(P_s,0)) + div(\vec{U}(0,\vec{U}_T))$$

Convergence = - divergence

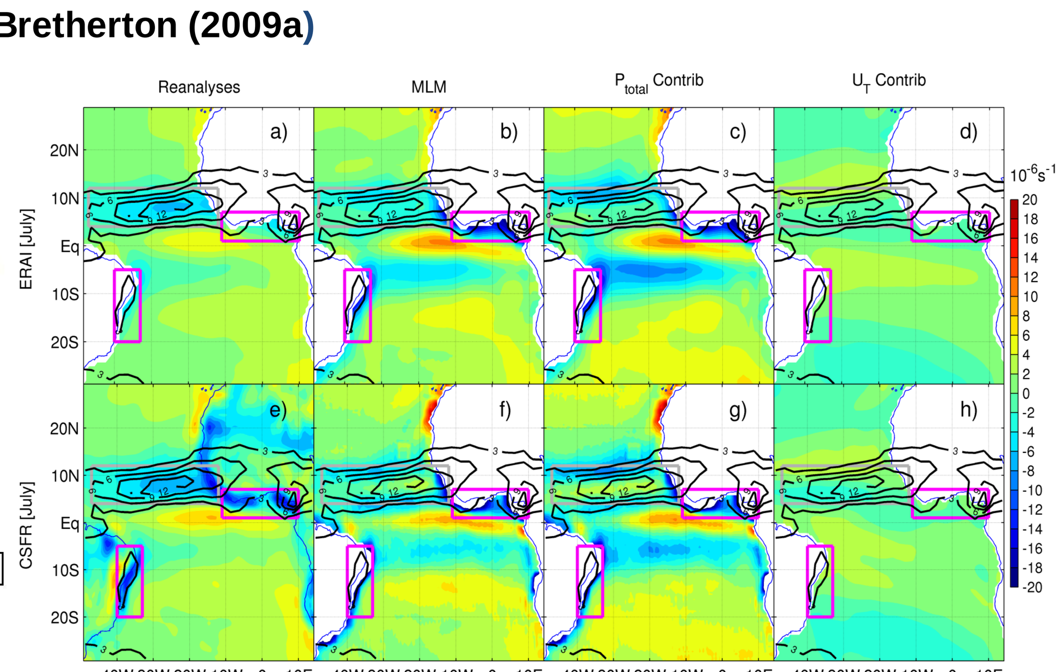
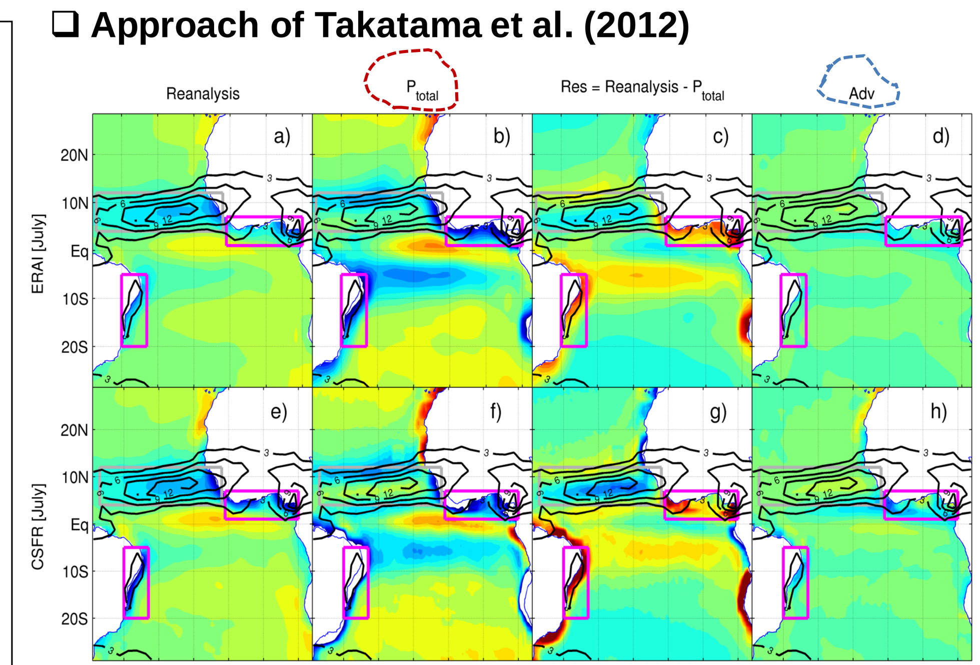


Fig.2 : Convergence budget using the approach of Back anfd Bretherton (2009a). Couleur: Wind divergence, Contours: GPCP Precipitation

❖ Pressure contributions (from the 2 approaches) are similar.
❖ Results subdivides the ITCZ onto 2 zones:
➢ An "oceanic ITCZ" (grey box): where surface convergence is explain by the pressure and advection.
➢ A "coastal ITCZ" (magenta boxes) , where the pressure and the horizontal advection represent the main forces drivers.

❑ **Approach of Takatama et al. (2012)**



$$-U_x - V_y = \left[+\frac{\varepsilon}{\varepsilon^2+f^2}\nabla^2 P + M_1P_x + M_2P_y\right] + \left[-\frac{\varepsilon}{\varepsilon^2+f^2}\frac{\nabla\cdot\tau(Z)}{Z} - \frac{f}{\varepsilon^2+f^2}\frac{\nabla\times\tau(Z)}{Z} - M_1\frac{\tau^x(Z)}{Z} - M_2\frac{\tau^y(Z)}{Z}\right] + \left[-\frac{\varepsilon}{\varepsilon^2+f^2}\nabla\cdot A - \frac{f}{\varepsilon^2+f^2}\nabla\times A - M_1A^x - M_2A^y\right],$$

$$M_1 = [\varepsilon/(\varepsilon^2+f^2)]_x + [-f/(\varepsilon^2+f^2)]_y$$

$$M_2 = [f/(\varepsilon^2+f^2)]_x + [\varepsilon/(\varepsilon^2+f^2)]_y$$

Fig.3: Convergence budget using the approach of Takatama et al. (2012). Couleur: Wind divergence, Contours: GPCP Precipitation

Pressure contribution decomposition

$P_{Total} = P_S$ = ABL contrib (P_{BL})+ Free tropospheric contrib (P_T)

$$P_T = 850hPa + \rho_{850hPa}(Geop_{850hPa} + \overline{Geop}_{850hPa})$$

← Geopotential mean over 30°S-30°N

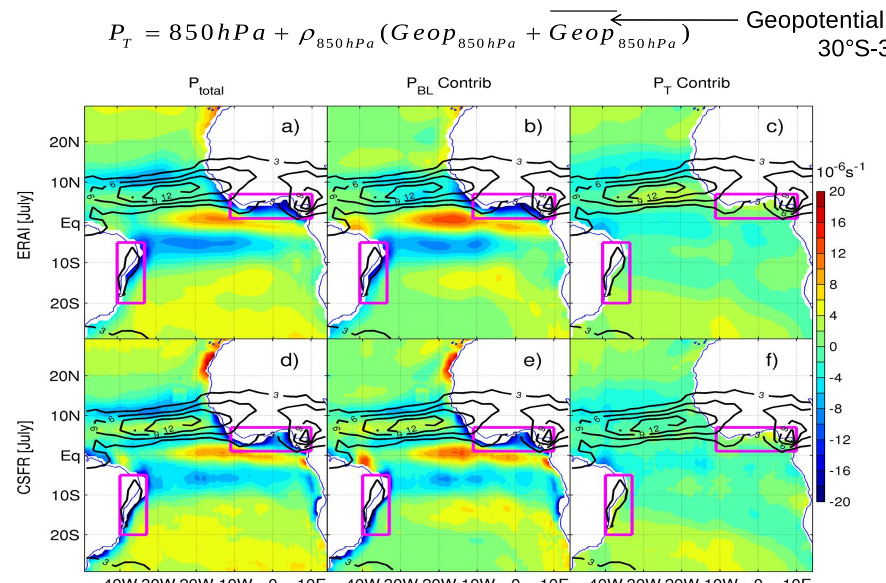


Fig.4 : Total pressure contrib. decomposition onto boundary and free troposphere components. Couleur: Wind divergence, Contours: GPCP Precipitation

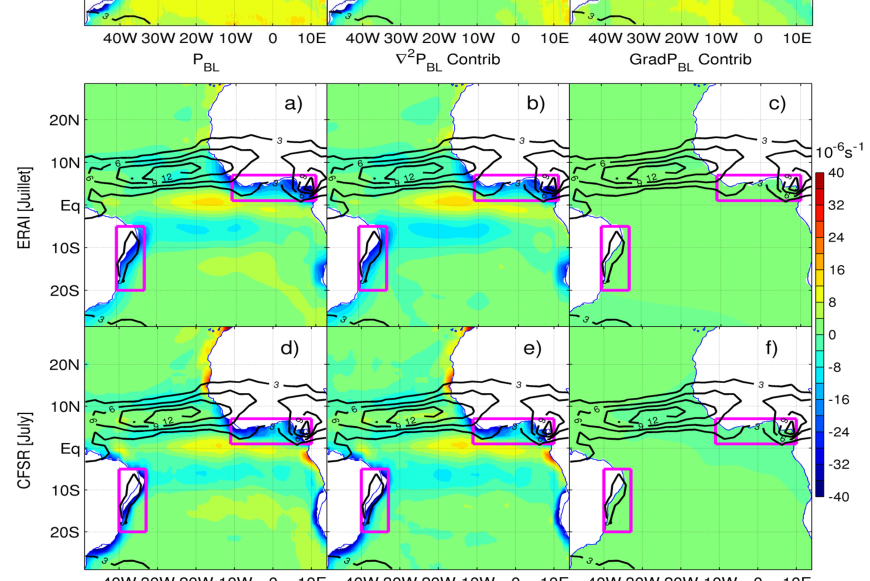


Fig.5 : Boundary contrib. decomposition onto the Laplacian and the simple gradients components. Couleur: Wind divergence, Contours: GPCP Precipitation

The total pressure contribution under the "coastal ITCZs" is mainly dominated by its boundary contribution, which is in turn controlled by the component due to its Laplacian.

Connexion to SST

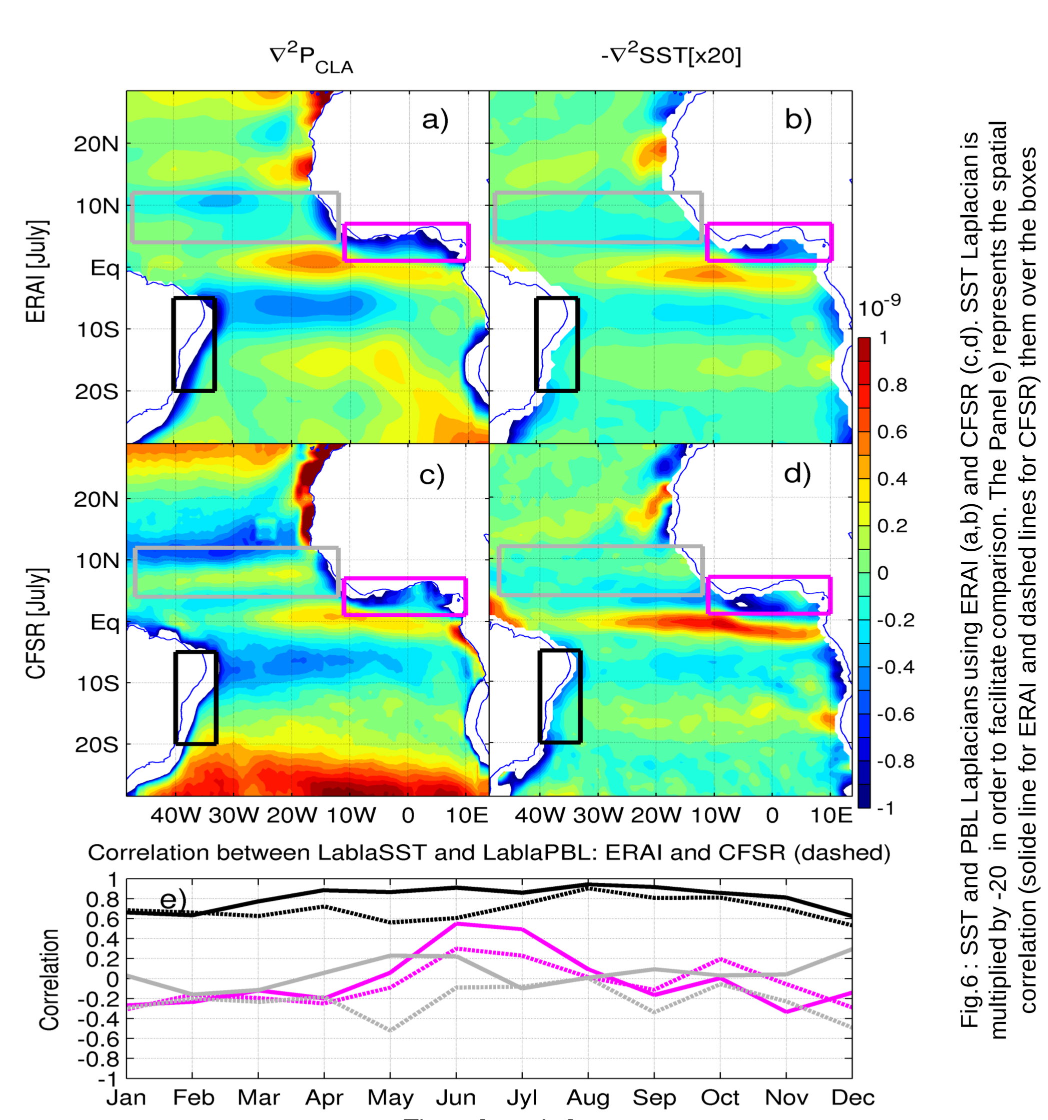


Fig.6 : SST and PBL Laplacians using ERAI (a,b) and CFSR (c,d). SST Laplacian is multiplied by -20 in order to facilitate comparison. The Panel e) represents the spatial correlation (solide line for ERAI and dashed lines for CFSR) them over the boxes

❖ The Laplacian of PBL is highly correlated to that of the SST in both ERAI and CFSR reanalyses, within those in CSFR always lower than those in ERAI over all boxes?
❖These correlations are more important over the Brazilian Northeastern coast.

Month-to-month surface winds convergence change

$$\frac{\partial\vec{U}}{\partial t} = \underbrace{-\frac{1}{\rho_o}\vec{\nabla}P}_{a} + \underbrace{f\vec{k}\wedge\vec{U}}_{b} + \underbrace{\vec{A}}_{c} + \underbrace{\vec{E}}_{d} + \underbrace{\vec{F}}_{e}$$

a) Pressure
b) Coriolis
c) Horizontal Advection
d) Entrainment
e) Friction

$$\frac{\partial(div\vec{U})}{\partial t} = div\left(-\frac{1}{\rho_o}\vec{\nabla}P + f\vec{k}\wedge\vec{U} + \vec{A} + \vec{E} + \vec{F}\right)$$

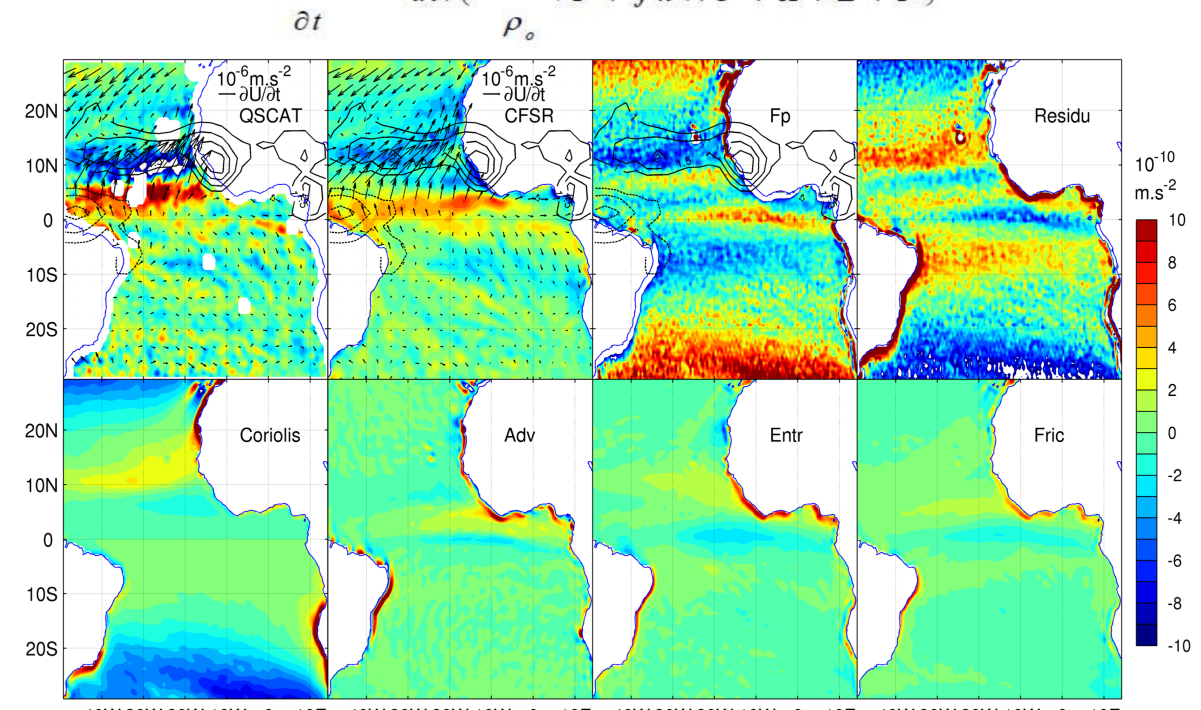


Fig.7: July-to-August convergence budget in CFSR. Divergence change (colors), wind change (arrows) and precipitation change (contours).

July-to-August surface wind convergence is controlled by the pressure and the Coriolis forces, i.e. by the geostrophy.

Conclusion

❑ Using ERAI and CFSR reanalyses, our results seem to confirm those of Back and Bretherton (2009a, affirming that surface wind convergence is mainly dominated by the pressure contribution closely related to SST drribution) only over the coastal area such as Guinea Gulf and the Brazialian Northeastern coast.
❑ We also note that over these coastal regions horizontal advection contribution is too important.
❑ Over the open ocean surface pressure and horizontal advection contributions do not represent the dominants terms on the convergence budget. Effect of elevated diabatic heating and waves could then be the main surface wind convergence driver there.

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Acknowledgements

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