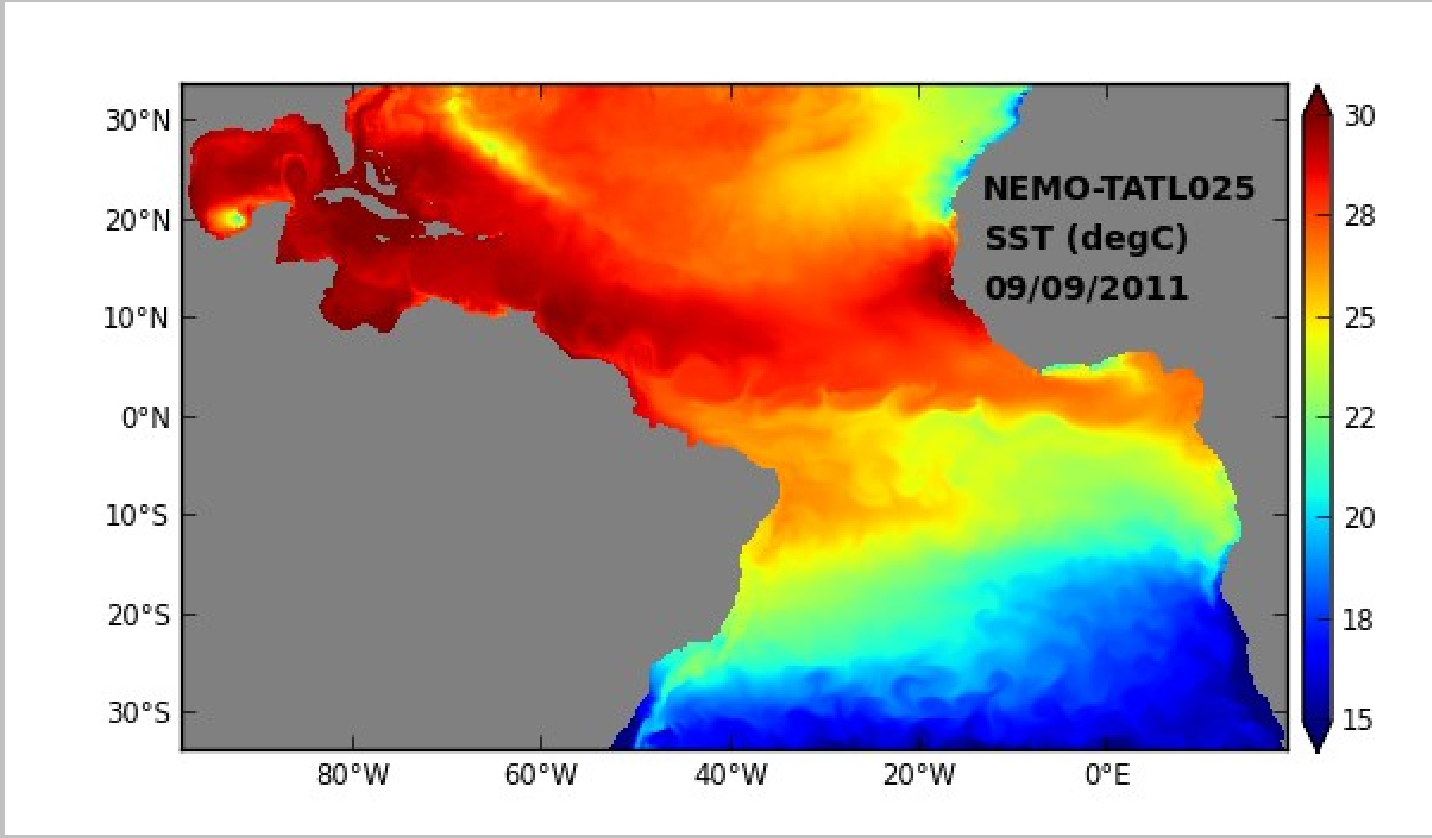
Do the Amazon and Orinoco freshwater plumes really matter for hurricane-induced ocean surface cooling ?



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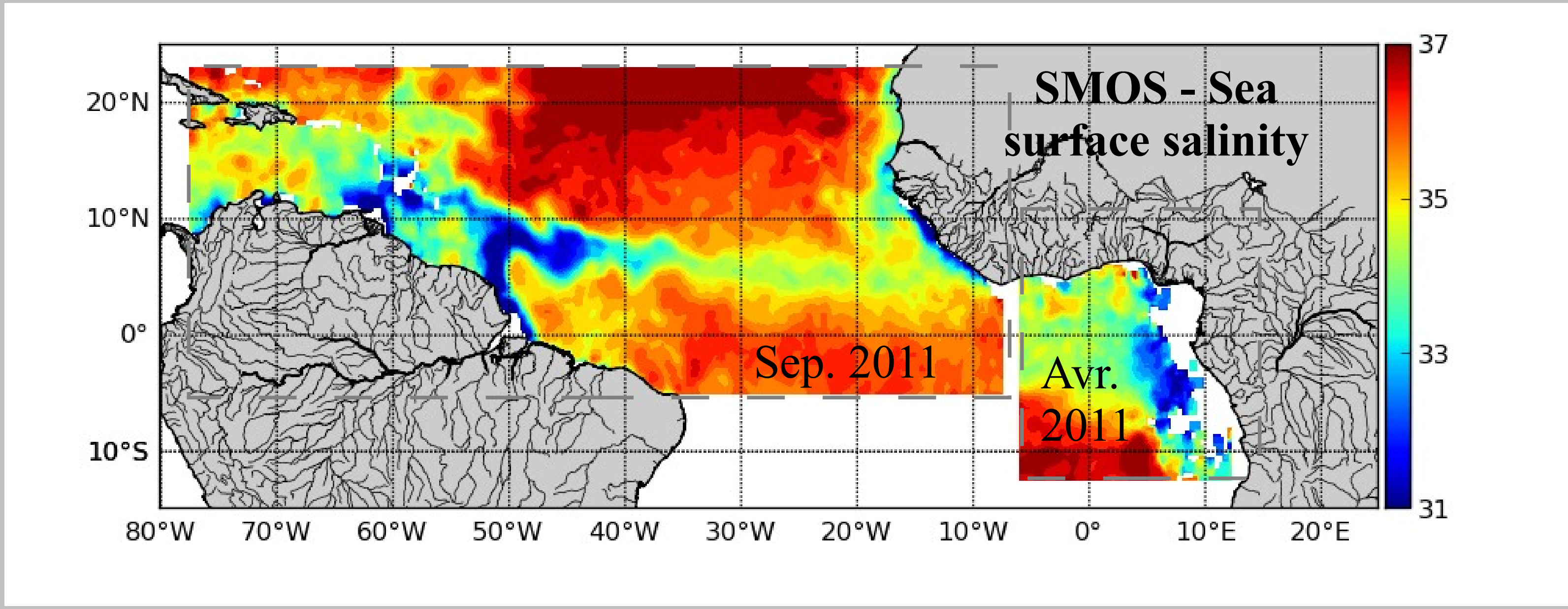
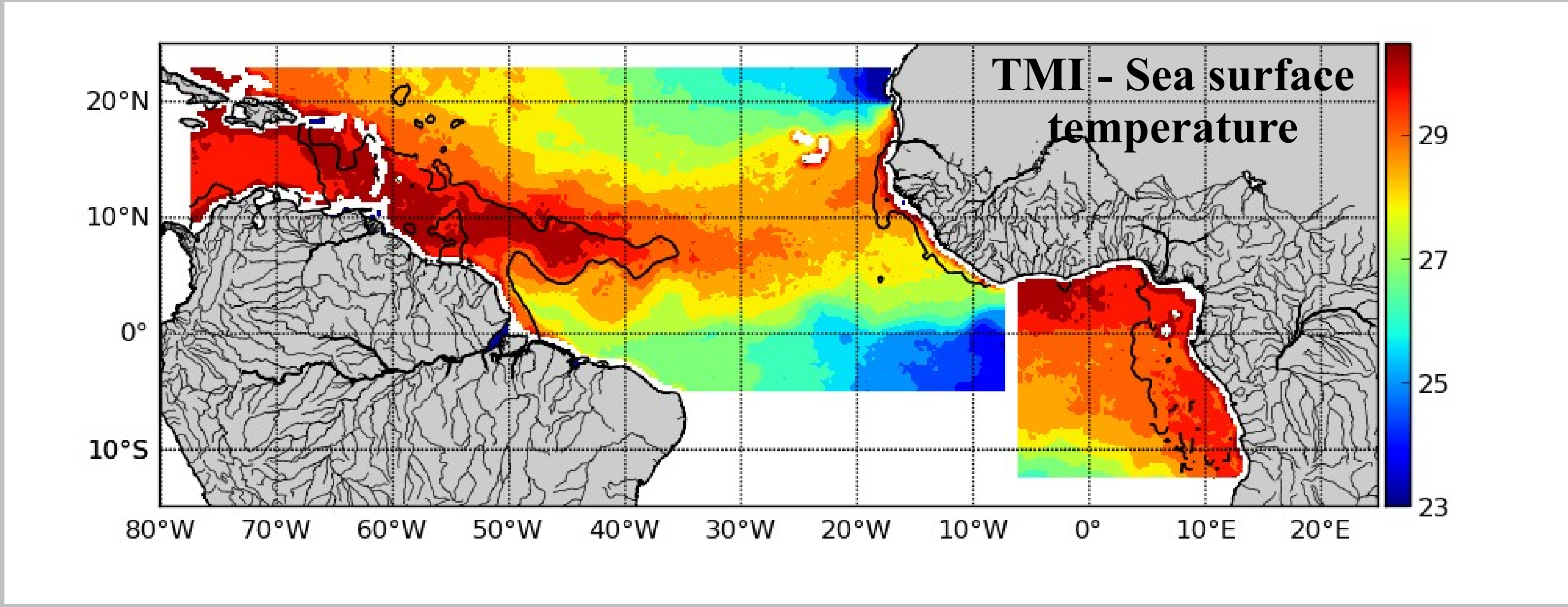
LEGOS, Toulouse, France

IASCLiP Virtual Workshop – September 2015

Amazon and Orinoco runoffs influence the large scale salinity and temperature distribution





Mechanisms

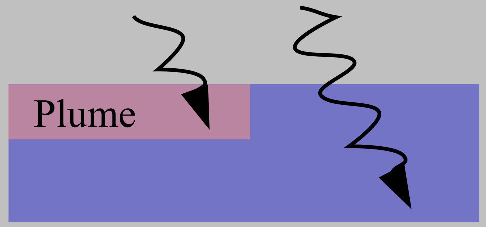
1. Density difference between the plume and the subsurface waters.

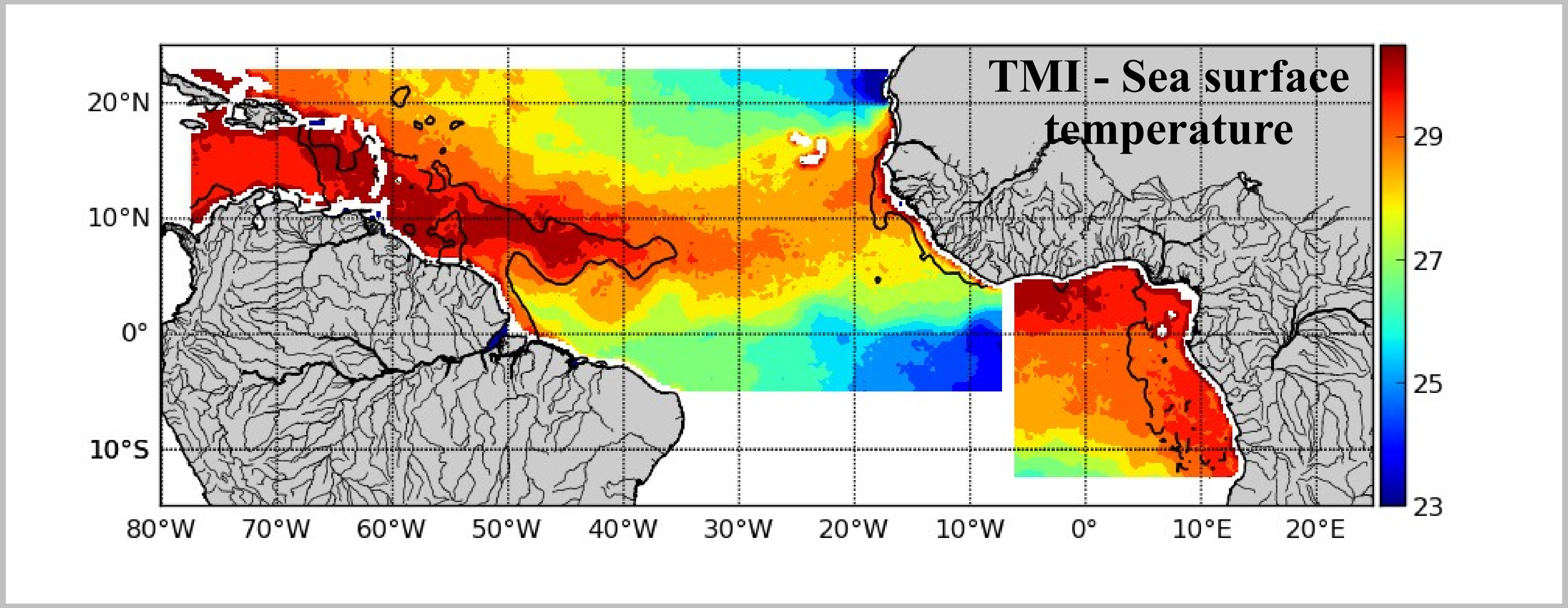
→ Limits the vertical mixing and maintains the warm waters at the surface

[e.g., Pailler et al. ,1999, Foltz et al. 2009, Balagaru et al. 2012]

2. Phytoplankton, dissolved organic matters, sediments

→ Capture the incoming solar radiation in the first meters *[Murtugudde et al, 2002, Newinger and Toumi 2015]*

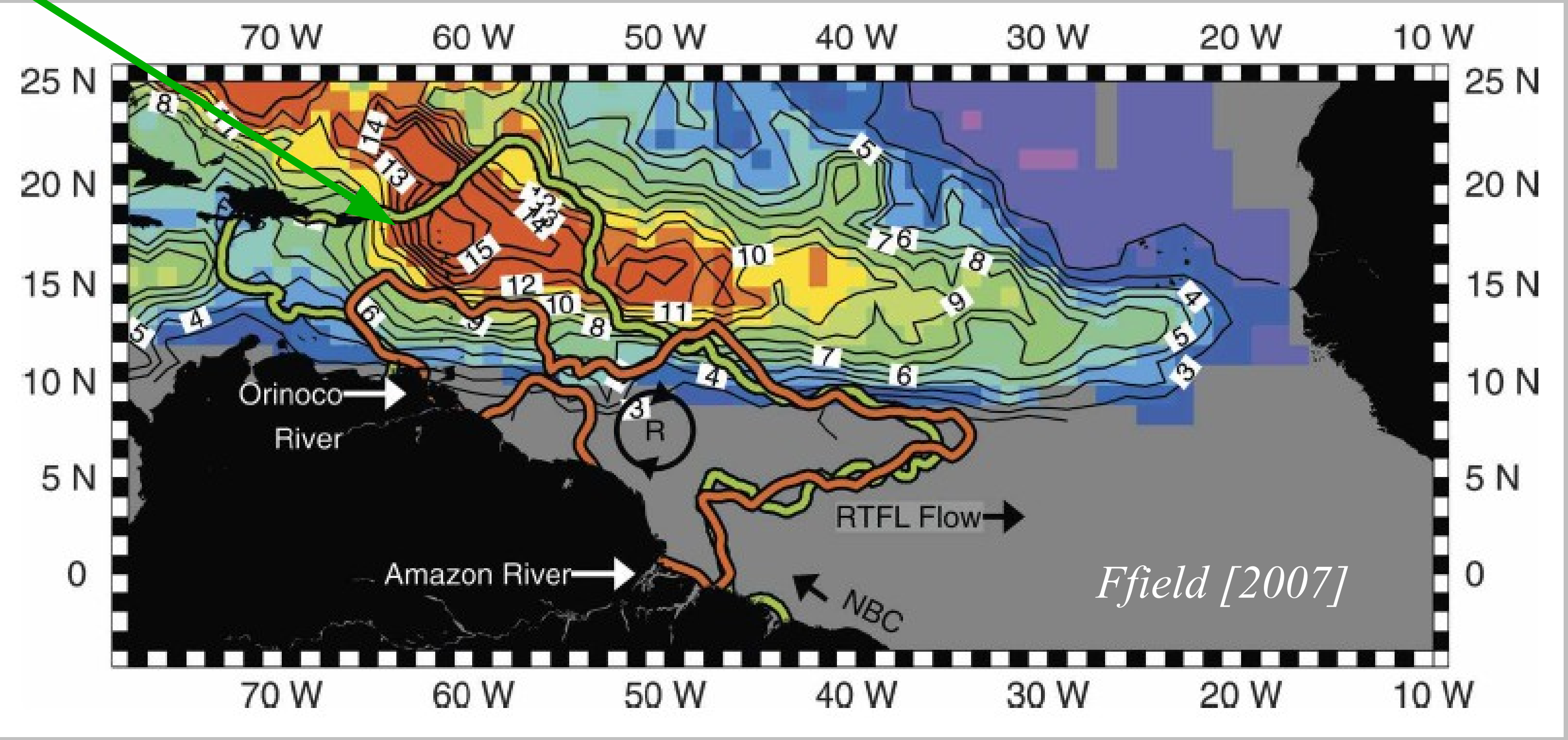




Tropical cyclones (TC) often pass directly over the plume

Historical region of the plume

1960-2000 tropical storms and hurricanes paths



Ffield [2007] observed that 68% of all category 5 Atlantic hurricanes during the 1960-2000 time period passed directly over the historical region of the plume

→ Amazon and Orinoco : active players of TC intensification in the region ?

River plumes = active players of TC intensification ?

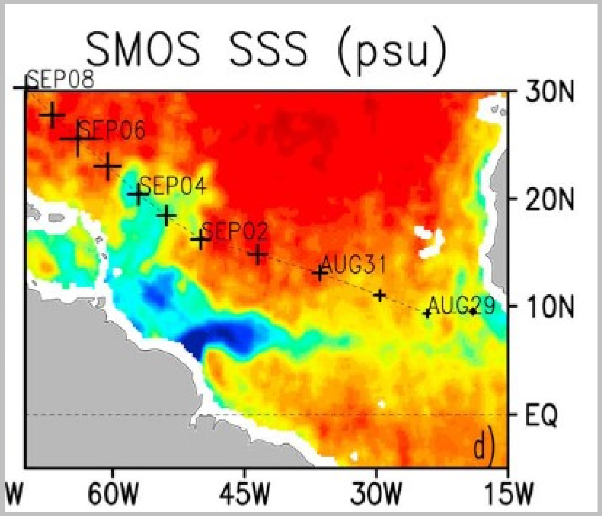
Two causal relationships between the river plumes and tropical cyclogenesis are generally proposed :

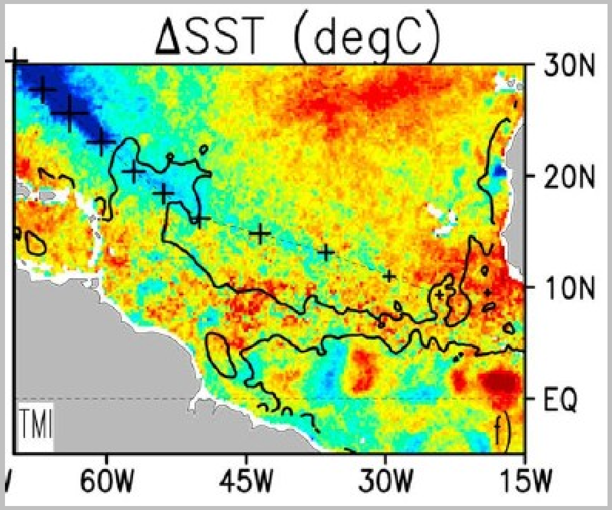
1) The presence of particularly warm SSTs over river plumes could favor their development (e.g. Vizy and Cook [2010] show a great sensitivity of summertime climate and hurricane intensity and frequency to temperature anomalies over the Amazon-Orinoco plume region)

2) Inhibition of TC-induced surface cooling by the presence of strong haline stratification and barrier layers could favor TC intensification by weakening the cool wake and its impact on the hurricane growth potential [Schade and Emanuel 1999, Balaguru 2012a, Newinger and Toumi 2015].

Observations of surface cooling inhibition

a) Hurricane Katia [*Grodsky et al. 2012*]

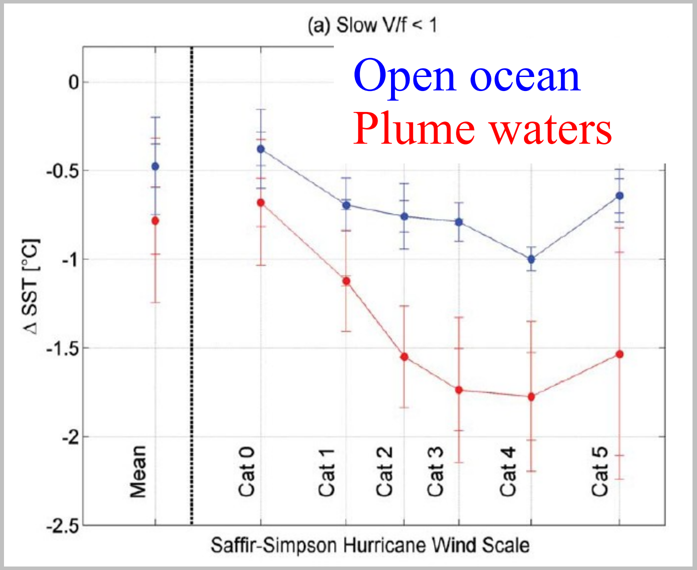




→ surface cooling is weaker within the plume

b) Ensemble of storms tracks *[Reul et al. 2014]*

→ cooling systematically reduced by ~50% in plume waters compared to surrounding waters



Are these differences due to barrier-layer effects ?

Objectives of this study :

1) clarify and quantify the impact of the Amazon and Orinoco freshwater flux on the TC response.

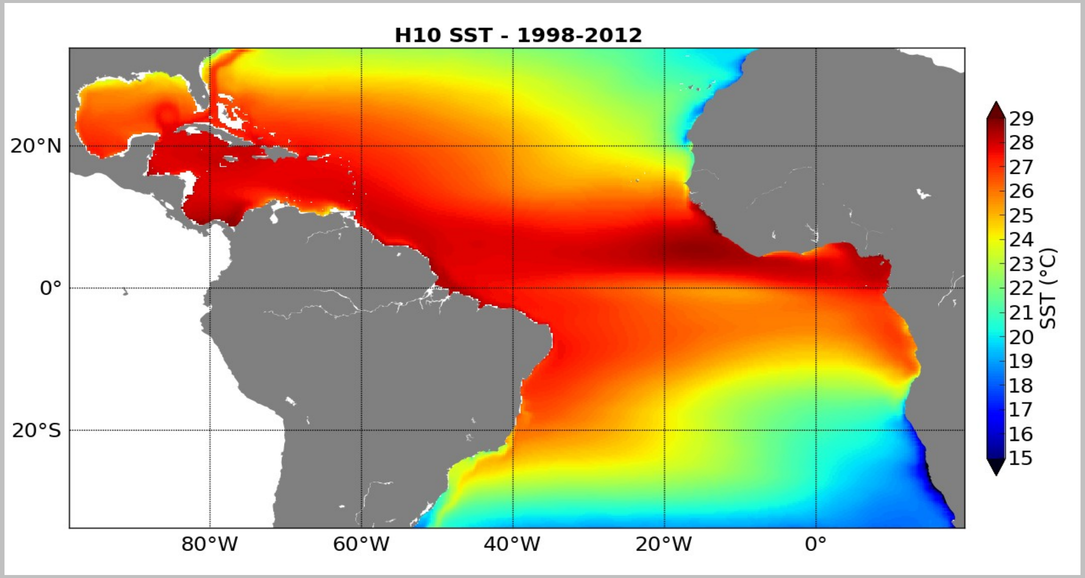
2) detail the processes setting the characteristics of the sea surface cooling induced by tropical cyclones specifically in the region of the Amazon-Orinoco plume.

3) explain the difference of cooling between the plume region and the open ocean region.

Regional ocean model and observations

→ **REGIONAL OCEAN MODEL**

Code : NEMO 3.6
Grid : ORCA025 (1/4°)
Vertical levels : 75 (~1m near the surface)
Boundaries: Daily /Global reanalysis GLORYS2V3
Atm. forcing: ERA Interim + SW LW and P corrections + Large and Yeager [2009] bulk formula
Period analyzed: 1998 – 2012
Outputs: 1 day average



Two experiments : - REF (with Dai and Trenberth 2002 runoff forcing)
- NO-RUNOFF

→ **OBSERVATIONS**

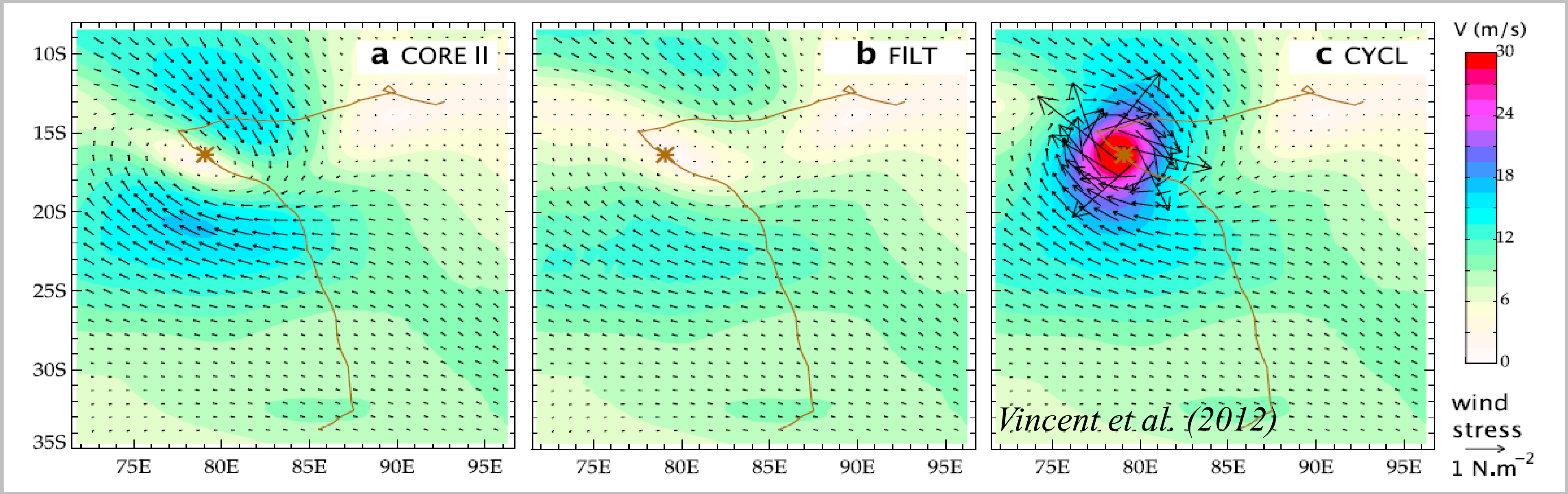
IBTRaCS storm tracks and intensity
Microwave OI SST (TMI+AMSR-E) : ¼ deg
ISAS (Argo based climatology of T and S; Gaillard et al. 2012)
MLD and BLT climatology by de Boyer Montégut et al.

Hurricane forcing strategy (1/2)

Hurricane winds poorly represented in reanalysis products (COREII, ERA-I) + linear interpolation of the forcing at each model time step erodes fast moving wind patterns

Our hurricane forcing strategy follows the method described in Vincent et al. (2012) :

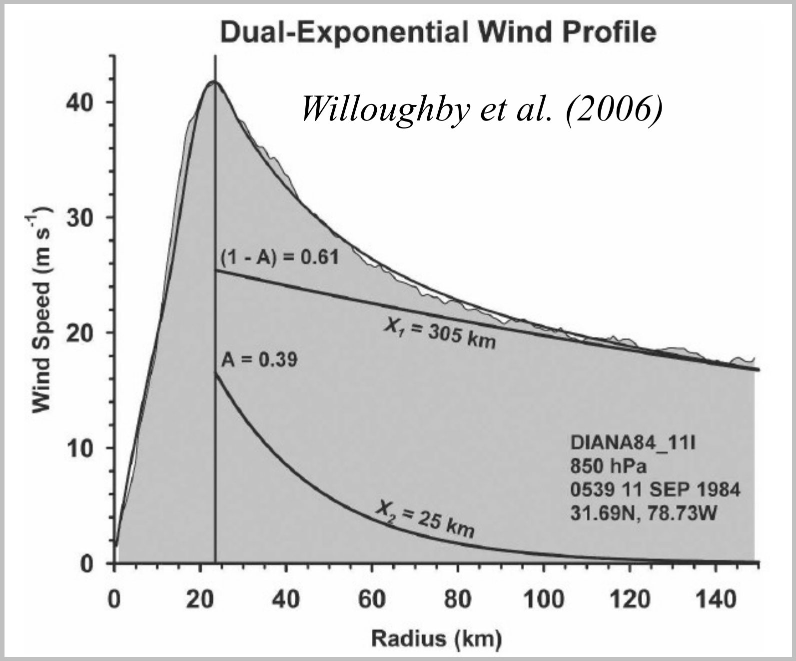
→ Hurricanes position and intensity are from IBTRaCS (6h and 10mn-sustained wind product)
→ Filter out the residual TC signature (11-day running mean within 600km around each vortex)
→ At <u>each time model time step</u> (300 seconds) a TC wind pattern is superimposed



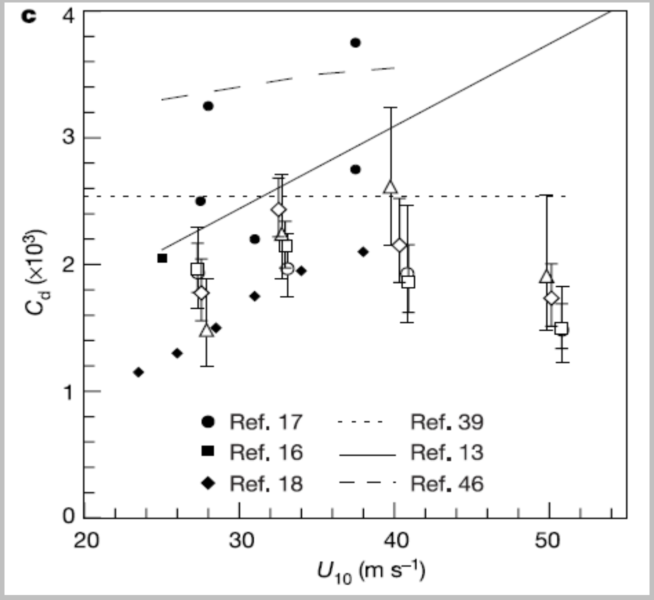
Ensure that both temporal and spatial evolution of the TC are captured in the model !

Hurricane forcing strategy (2/2)

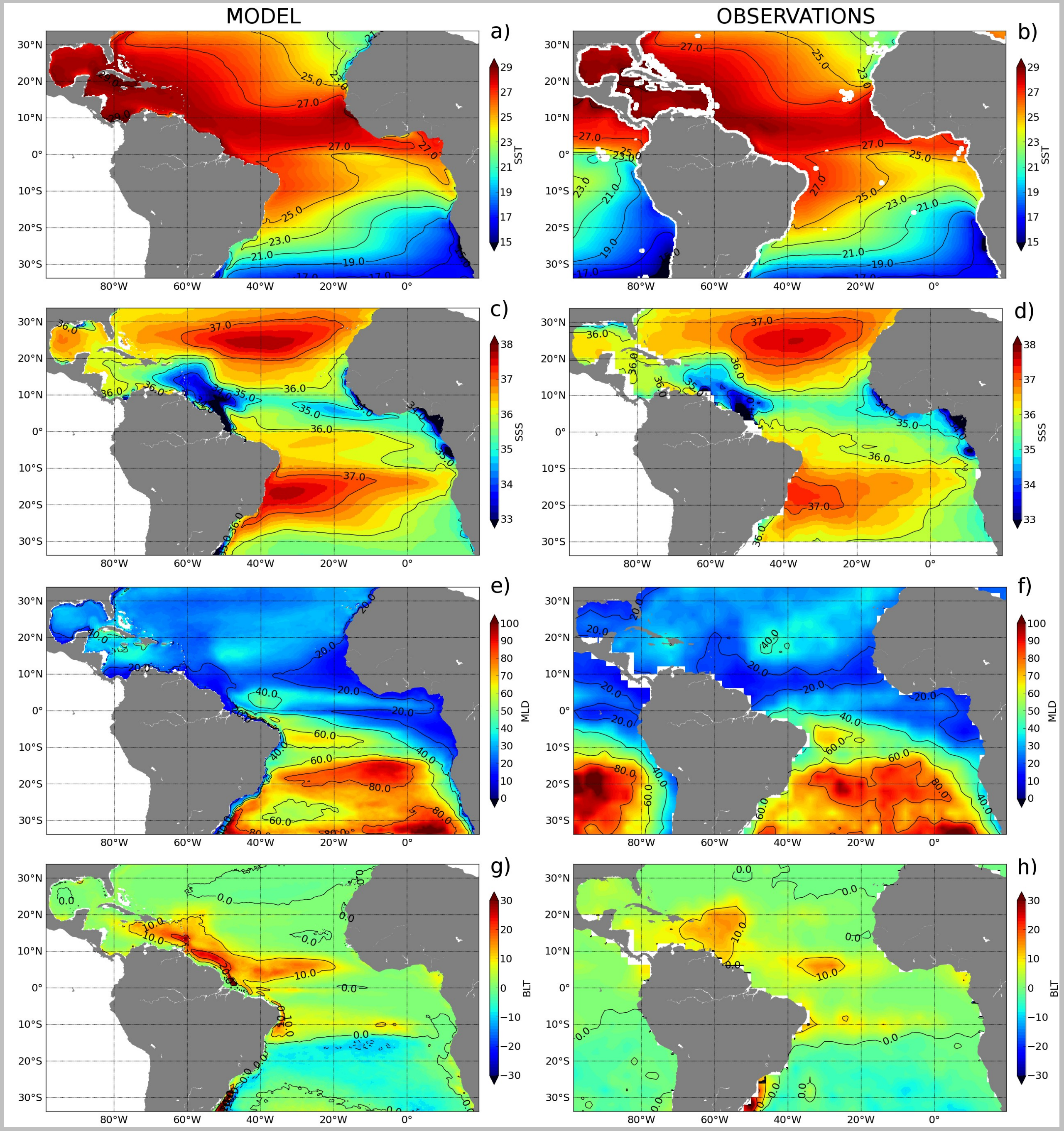
→ **TC wind pattern computed using Willoughby et al. [2006] idealized vortex** (based on a statistical fit to observed TC winds)



→ **Modified drag coefficient for u10 > 33m/s** in order to mimic the observations by Powel et al. [2003] which show a reduction of the drag coefficient at very high wind speed.



Background oceanic conditions in June-November



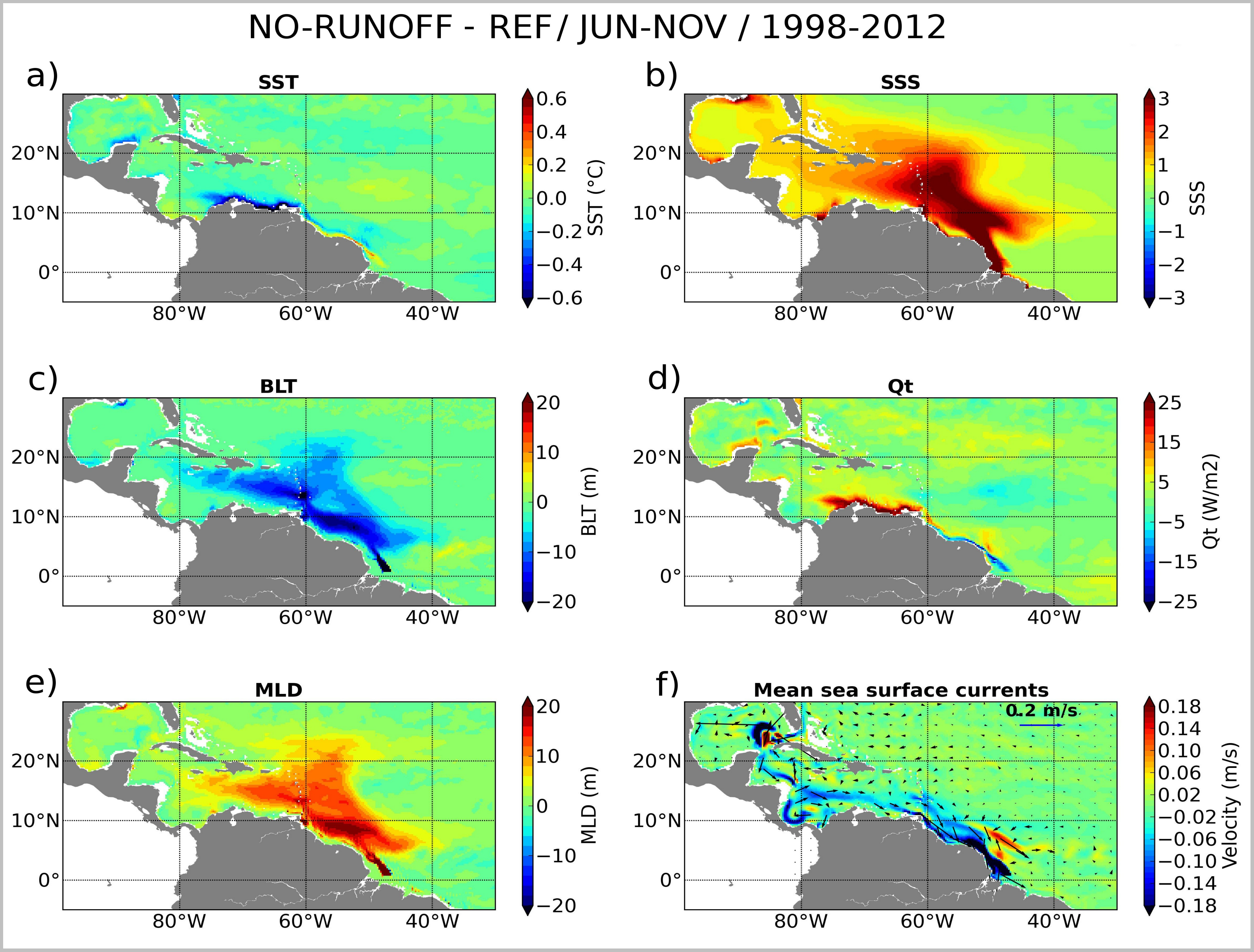
SST

SSS

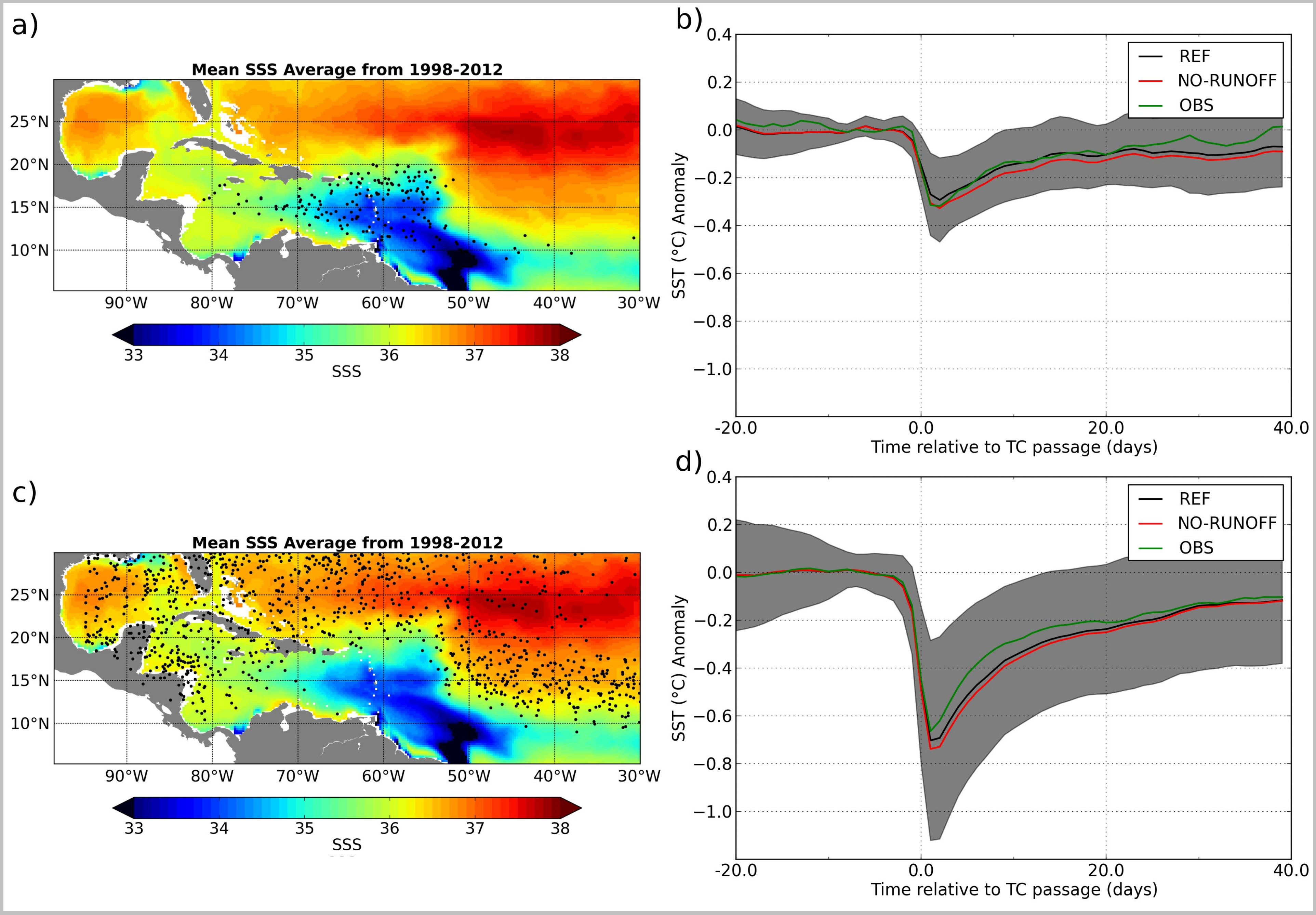
MLD

BLT

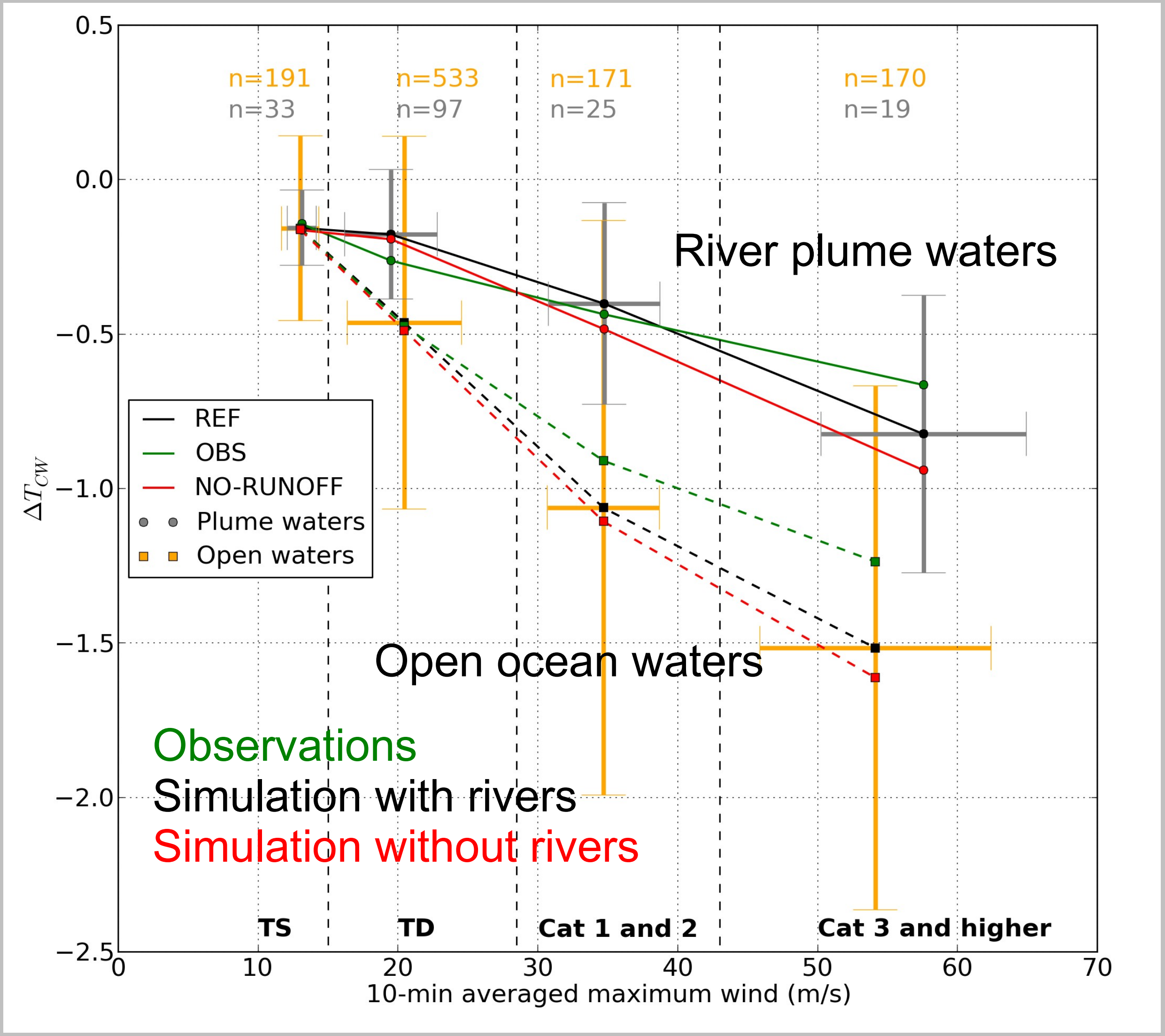
Sensitivity of the background conditions to the presence of runoff



Composite SST wake



Distribution of mean SST maximum cooling (in °C)



No significant difference between REF and NORUNOFF (only +10% cooling without runoff)

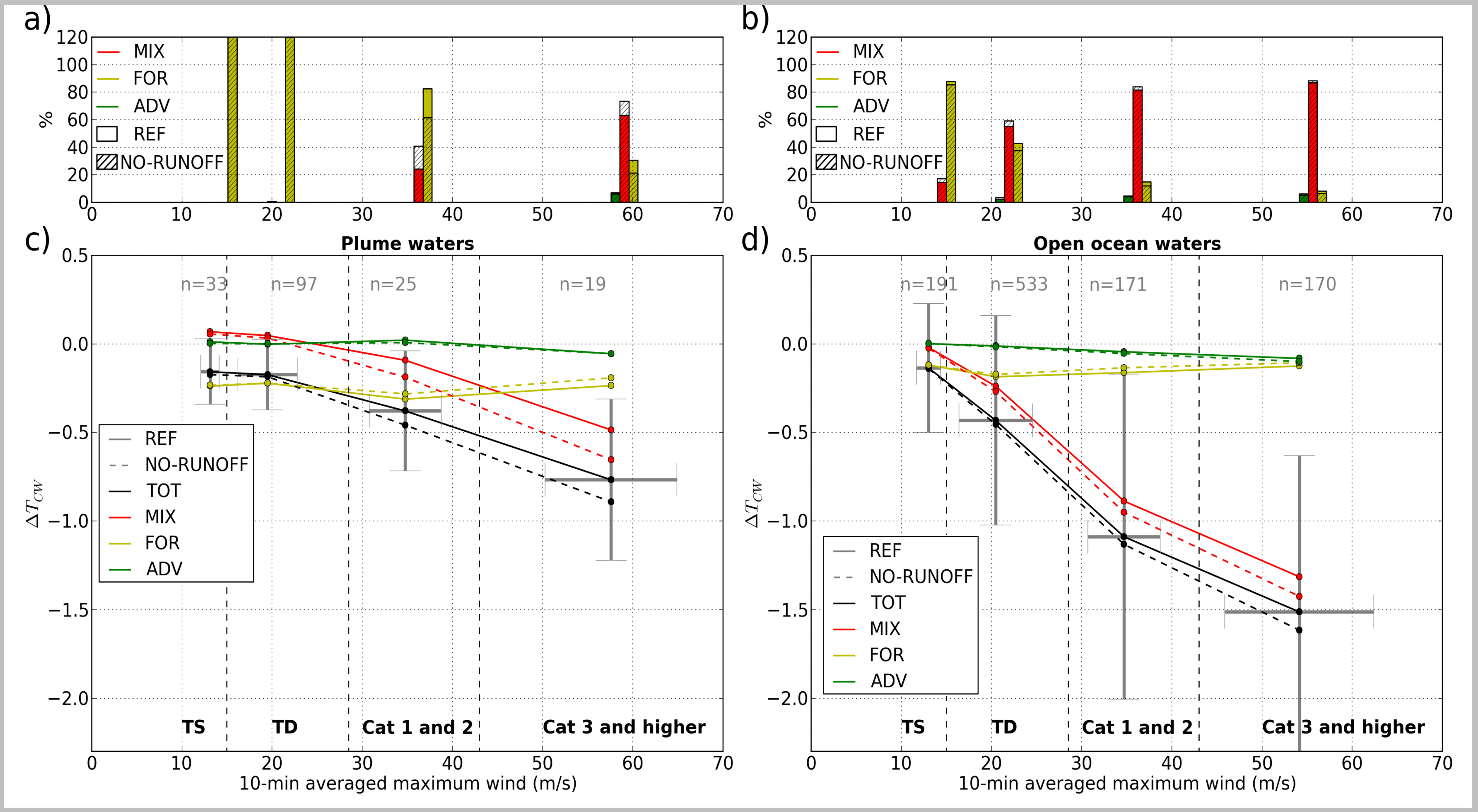
→ Salt stratification cannot explain the 50% cooling difference between the plume and surrounding waters.

Processes at play in the ML cooling

Online computation of daily mixed layer heat balance [Menkes et al., 2006] :

$$\partial_t <T> = \underbrace{- <u.\partial_x T - v.\partial_y T - w.\partial_z T>}_{A} + \underbrace{<D_l T>}_{B} \underbrace{- \frac{1}{h}\frac{\partial h}{\partial t}(<T> - T_{z=-h})}_{C} + \underbrace{\frac{Q^* + Q_s(1 - f_{z=-h})}{\rho_0 C_p h}}_{D} \underbrace{- \frac{1}{h}(K_z \partial_z T)_{z=-h}}_{E}$$

Total | Advection | Air-sea fluxes | Vert. mixing



Plume waters | Open ocean

Why the surface cooling contribution of vertical mixing is weaker in the plume region (in both experiments) ?

Two metrics were found to be useful :

1) Cooling Inhibition index (CI; Vincent et al. 2012)

$$CI = \left[\Delta E_p \left(-1^{o} C \right) \right]^{1/3} \quad \Delta E_p \left(\Delta T \right) = \int_0^{h_m} \left(\rho_f - \rho_i \left(z \right) \right) gz dz$$

This index is a proxy for the amount of energy required to cool the ocean surface by one degree by vertical mixing only.

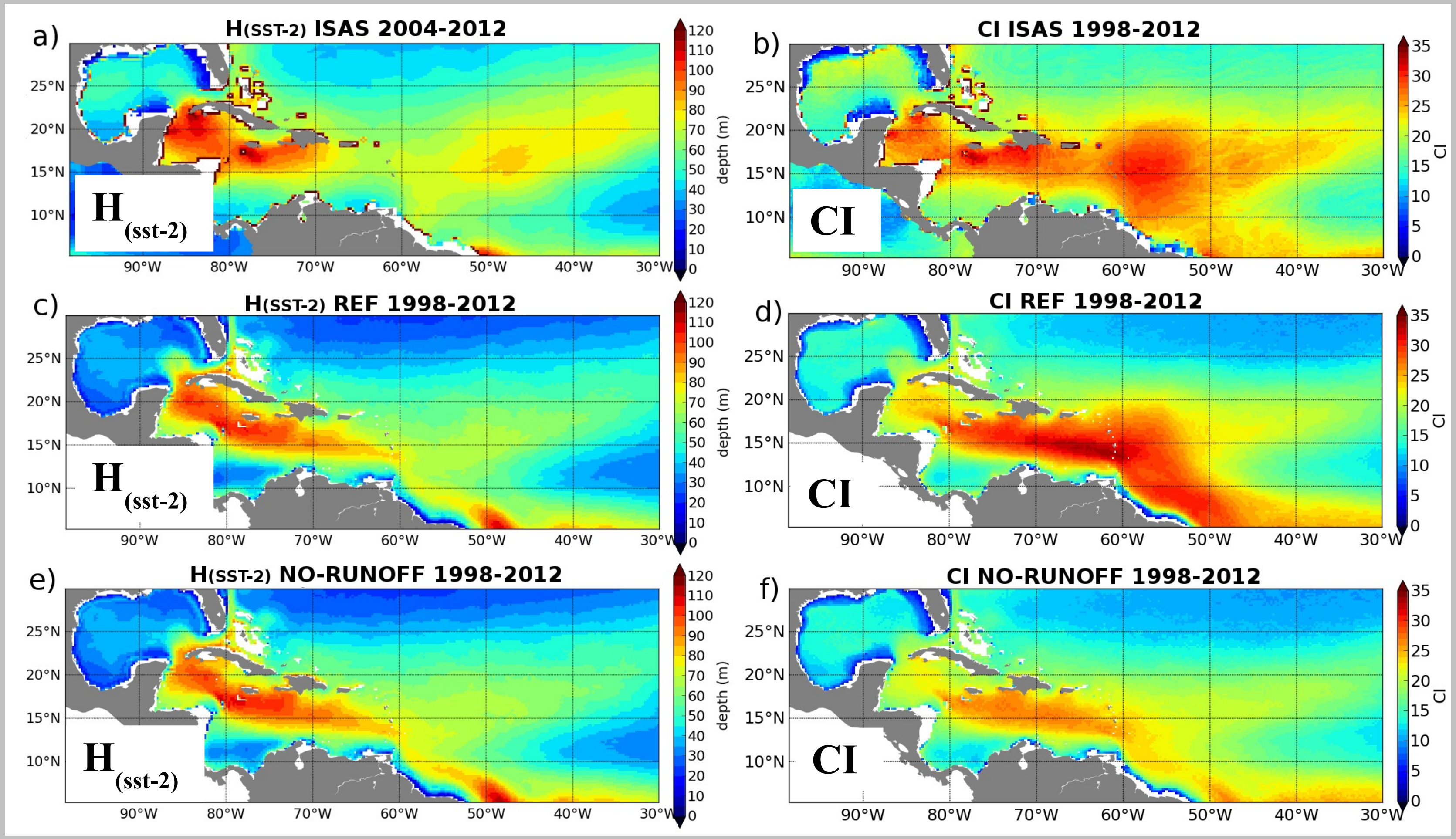
2) Depth at which ocean temperature is 2°C below the SST : $\mathbf{H_{(SST-2)}}$

Why the surface cooling contribution of vertical mixing is weaker in the plume region (in both experiments) ?

OBS

REF

NO RUNOFF

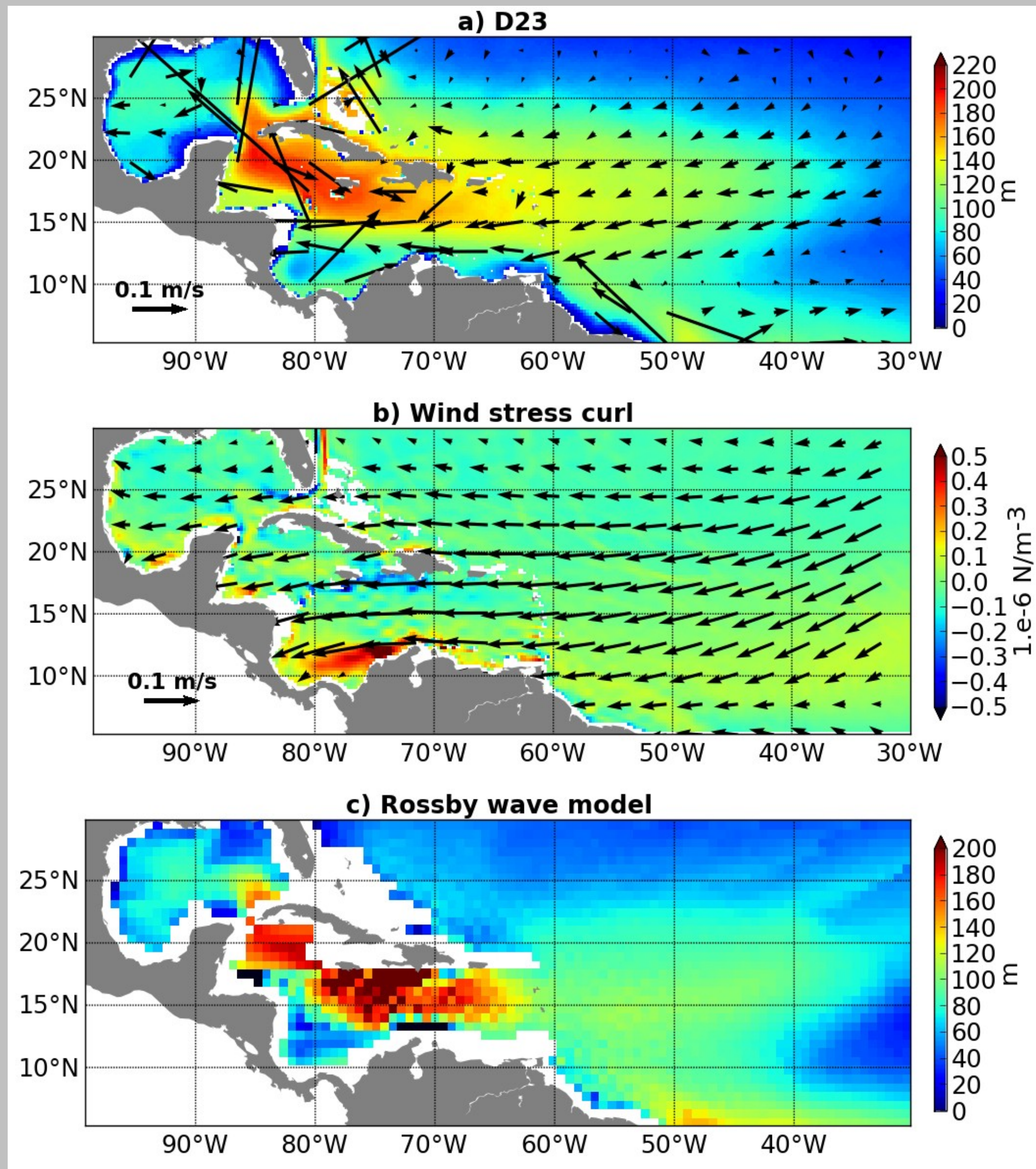


→ Weak sensitivity of H(sst-2) to river runoff !

→ 20% decrease of CI without runoff

Larger thermal content in the plume area than north of 20°N.

Wind driven large heat content coincident with the river plume area



Depth of the isotherm 23°C

Wind stress curl

Thermocline depth inferred from a long Rossby wave linear model [Kessler 2006]

Conclusions

→ Model results suggest that the effect of runoff and barrier layers on the tropical cyclones induced SST cooling only lead to a 10% weakening of the cooling.

→ Instead, we found that temperature stratification plays the main role in explaining the 50% observed differences in cooling between the plume and open ocean waters.

Hernandez et al., Do the Amazon and Orinoco freshwater plumes really matter for hurricane-induced ocean surface cooling ? In review for JGR ocean.

On going work

→ Development of a fully coupled regional model (NEMO-WRF) to test the sensitivity of cyclogenesis to river runoffs and ocean color.