Impact of atmospheric coastal jet off central Chile on sea surface temperature:
A numerical study of the case of October 2000

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Introduction

The cool waters off central Chile [36°S-26°S] are principally maintained by coastal upwelling, which is driven by persistent low-level along-shore southerly winds (the Coastal Jet, CJ). The southerly jet events off central Chile occur year round but are more frequent during the upwelling season in summer. The jet is characterized by an elongated maximum of surface wind speed ($10 m.s^{-1}$) with its axis at about 150 *km* off the coast and a cross-shore scale of about 500 *km*. The available observations (essentially remote sensing) show the CJ activity is seasonally phase locked with SST, with a peak season in August-October. They also suggest that the statistically dominant forcing mechanisms of the SST cooling during CJ event is a combination of seaward advection of temperature resulting from Ekman transport, air-sea heat exchange, and Ekman-driven coastal divergence (Renault et al., 2009).

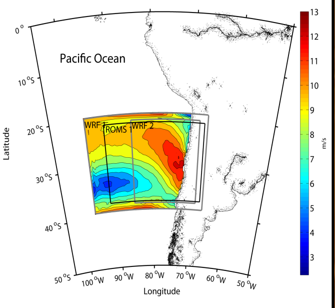

Fig 1: Model configurations.

In this work - using high-resolution model, focus is given on the October 2000 Coastal Jet event (Garreaud et al., 2005, Renault et al., 2009). After validating the model, the main statistical 3D characteristics of the oceanic response to a CJ event are analyzed. In particular, taking advantage of the model resolution, a complete heat budget within the mixed layer during this CJ event is estimated, both in the coastal area and in the vicinity of the CJ core. The results show that coastal upwelling and vertical mixing are the main contributors of the observed cooling in the coastal area, whereas, in the neighborhood CJ core, the ocean temperature cooling is a combination of advection, heat fluxes, vertical mixing and mixing layer entrainment.

Models and methodology:

Atmospheric model: WRF → Forcing → **Oceanic model: ROMS**

Atmospheric model: WRF

- two nested grids : ***30km. and 10km***,
- 47 vertical sigma levels.
- Boundary conditions: NCEP
- SST forcing: TMI
- Period: 1998-2000 (6 months high res.)

Oceanic model: ROMS

-32 sigma levels, spatial resolution : 10*km*.
-Boundaries conditions : SODA.1.4.2 (Carton and Giese, 2008).
-Blend WRF 30km and WRF 10km.
-bulk formulation.

The October 2000 Costal Jet

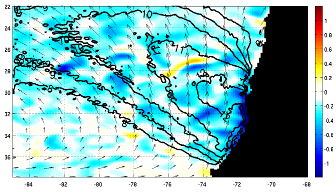

Fig. 6: Mean wind speed and direction and mean SST (degrees) anomaly during the CJ peak.

3th October -> 15th October :

- CJ characteristic close to Renault et al., 2009; Garreaud and Muñoz, 2005.

Atmospheric CJ , wind peaking to $12 m.s^{-1}$

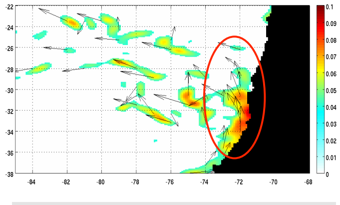

Fig. 8: Mean currents anomaly related to the CJ (m/s)

→ Alongshore geostrophic current jet and a westward Ekman transport.

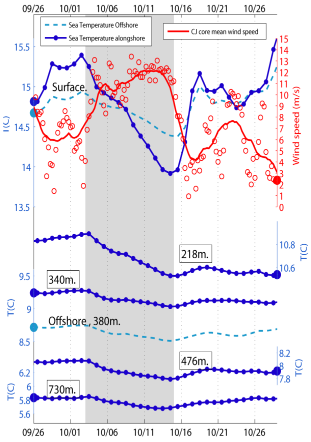

Fig. 7: Temporal evolution of ocean temperature and surface wind speed , October 2000.

→The oceanic response : a cooling

- Close to the coast : -1.4°C
- Vicinity of the jet :-0.6°C

→Temperature vertical structure has a similar response than the one described in Renault et al. (2009) .

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WRF validation

Surface wind speed and direction compare very well with QuikSCAT : correlation >0.8

The first three dominant bivariate EOF modes of QuikSCAT wind components are reproduced by WRF : see figure 2

The atmospheric fields used to force the oceanic simulation are in good agreement with the climatologic ones.

Vertical structure of the Coastal Jet off Central Chile is well simulated (not shown)

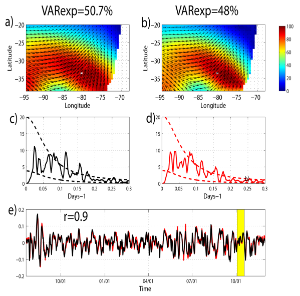

Fig. 2:First EOF mode of the wind components.

ROMS Validation.

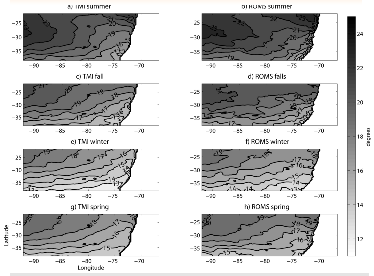

Fig. 3: SST Seasonal cycle, estimated over the 1999-2000 period : on the left TMI and on the right ROMS.

→Good agreements with the TMI measured SST.

Seasonal cycle is well reproduced (figure 3) and presents weak bias.

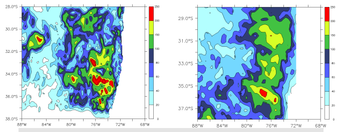

Fig. 5: Mean EKE (cm/s)2) : a) AVISO, b) ROMS

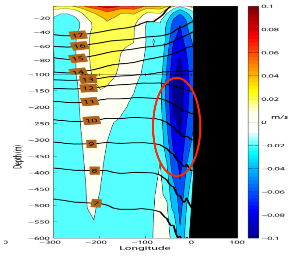

Fig. 4: Mean current (color) and temperature (contour) section around 30°S.

→Vertical structure :

- Core position and intensity of the undercurrent comparable to the one estimated in some studies (Pizarro et al., 2002; Dewitte et al., 2008).
- Temperature is realistic with the isotherms sloping upward close the coast in the first 80 m.

→Mean ROMS EKE is in good agreement with AVISO both in terms of intensity and spatial distribution

Heat Budget

$$\partial_t T = - < U\partial_x T + V\partial_y T + W\partial_z T > - \frac{1}{h}\frac{\partial h}{\partial t}\left(SST - T_{z=h}\right) + \frac{Q}{\rho_0 C_p h} + k_v \frac{\partial_t{}^2 T}{\partial z^2}$$

Model allows us to refine and close the heat budget of Renault et al., 2009 :

Vertical mixing and the mixed layer entertainment term play an important role !

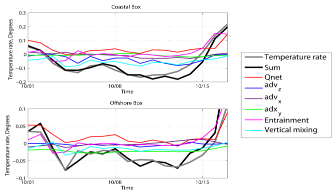

Fig. 10: Temperature tendency term

CJ→ clear sky→ shortwave heat flux increase but heat loss by latent and longwave is also large during the CJ.

→The mixed layer entertainment term: temperature variation at the beginning (deepening) and at the end of CJ (swallowing).

presence of mesoscale activity → horizontal advection plays a weaker role than the observed..

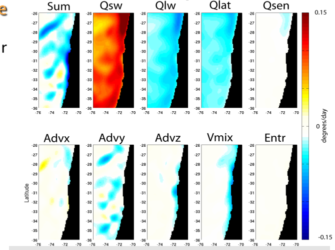

Fig. 9: Heat budget: patterns for the different SST tendency terms

→ Coastal area (satellite blind zone) :

Oceanic response essentially driven by the vertical advection (upwelling) and by the vertical mixing and the heat fluxes

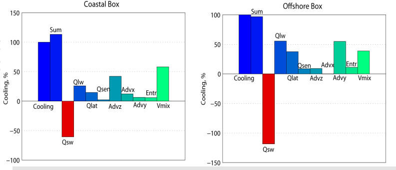

Fig. 11: SST Tendency terms at the peak phase of the event for the coastal box (left) and the offshore box (right).

Conclusion:

- Both atmospheric features of the CJ and the associated oceanic response are **realistically simulated.**
- **Ocean temperature drops** in the vicinity of the Jet and in the coastal area
- Simulations allow for **carrying a comprehensive heat budget** during the different phase of the CJ at both sites (off and at the coast).
- **Vicinity of the CJ** : horizontal advection and the heat fluxes, also by the vertical mixing.
- **Close to the coast** : vertical advection and vertical mixing.
- In both of case, **the mixed layer entertainment term** explains the temperature variation at the beginning and at the end of the CJ.
- We confirm the **existence of a geostrophic alongshore oceanic current** associated to the CJ that was detected from altimetry in Renault et al. (2009).