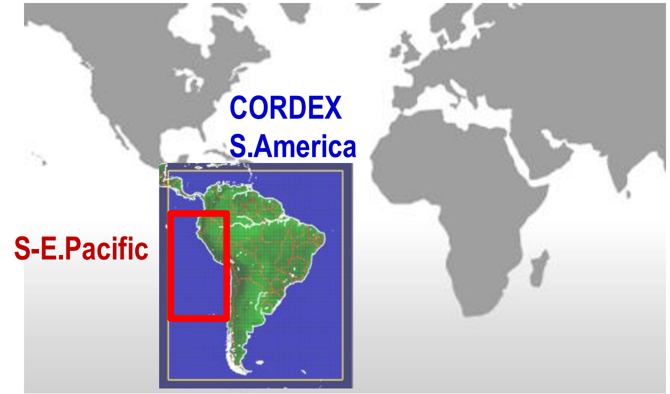
CORDEX LAC workshop, 11-13 September 2013



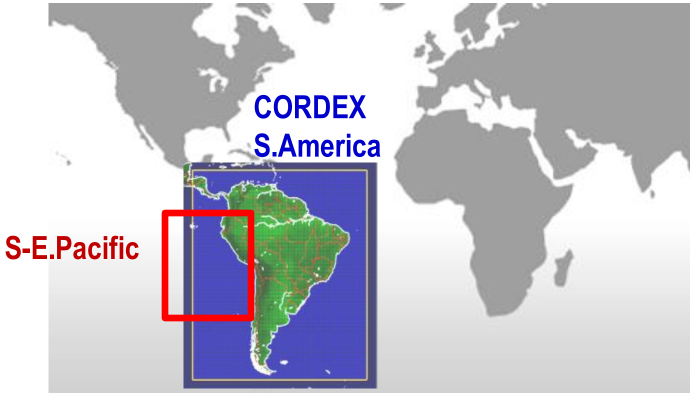
Challenges in downscaling air-sea interactions along the West coast of South America

Katerina Goubanova (IRD)

LEGOS (Toulouse, France): Boris Dewitte, Séréna Illig, Gildas Cambon

IGP (Lima, Peru): Ken Takahashi

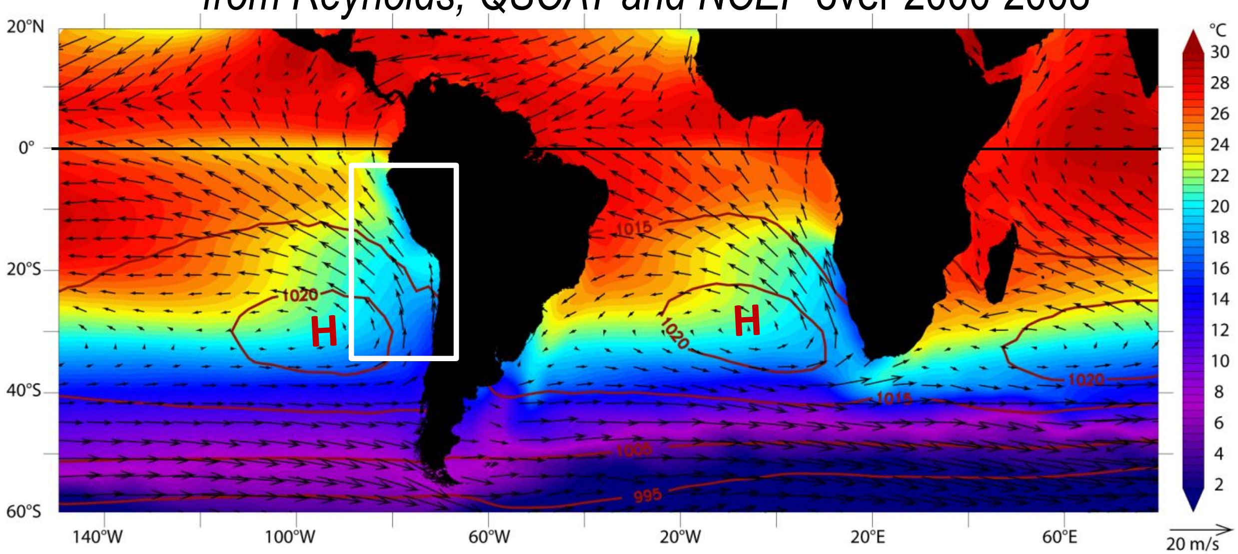
Outline



I. Motivations: main climate features and challenges for studying
II. Actual strategies for downscaling experiments
III. Role of air-sea interactions
IV. Conclusions (recommendations, perspective)

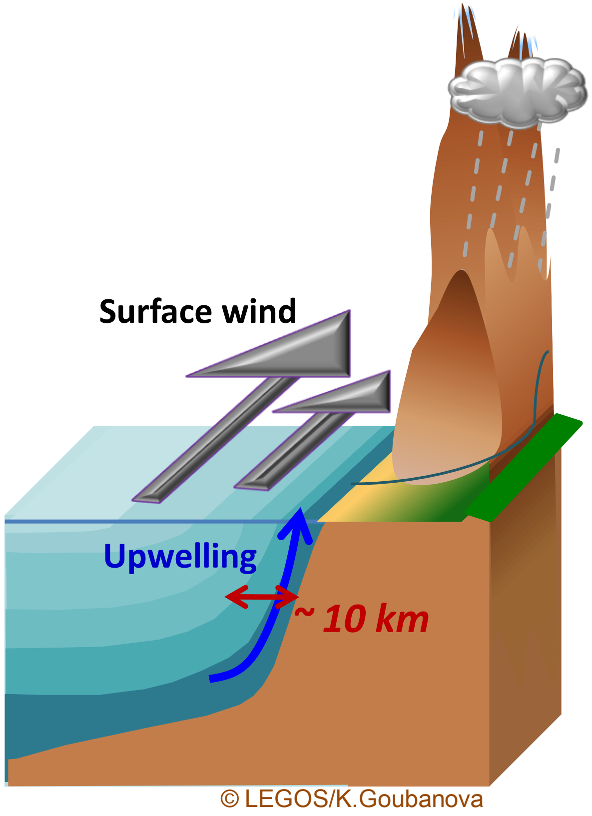
Southeastern Pacific climate

Mean SST (colour,°C), wind (arrows, m/s) and SLP (contour,hPa)
from Reynolds, QSCAT and NCEP over 2000-2008



<u>Wind-driven coastal upwelling:</u>

- **Ekman transport**
  along-shore wind intensity
- **Ekman pumping**
  wind spatial pattern (curl)



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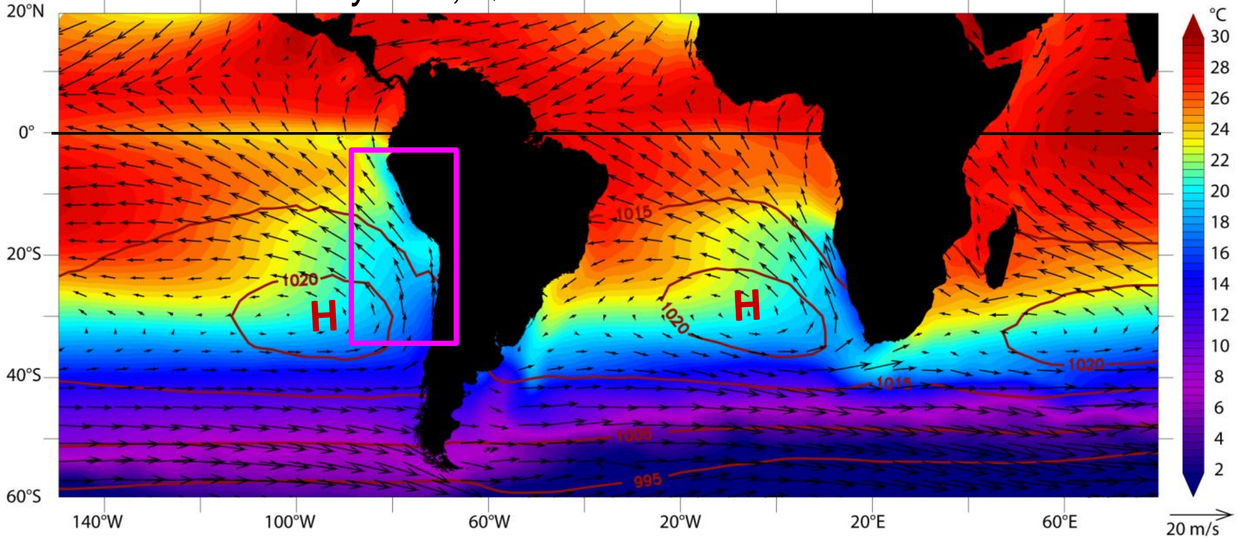

Wind-driven coastal upwelling:

- **Ekman transport**
  along-shore wind intensity
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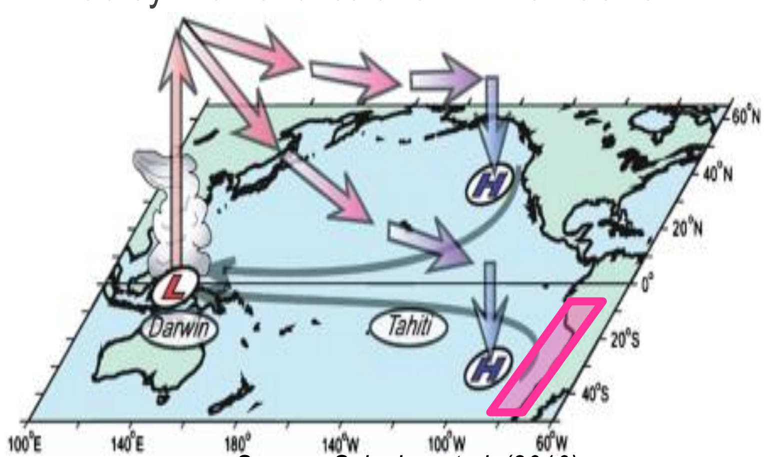
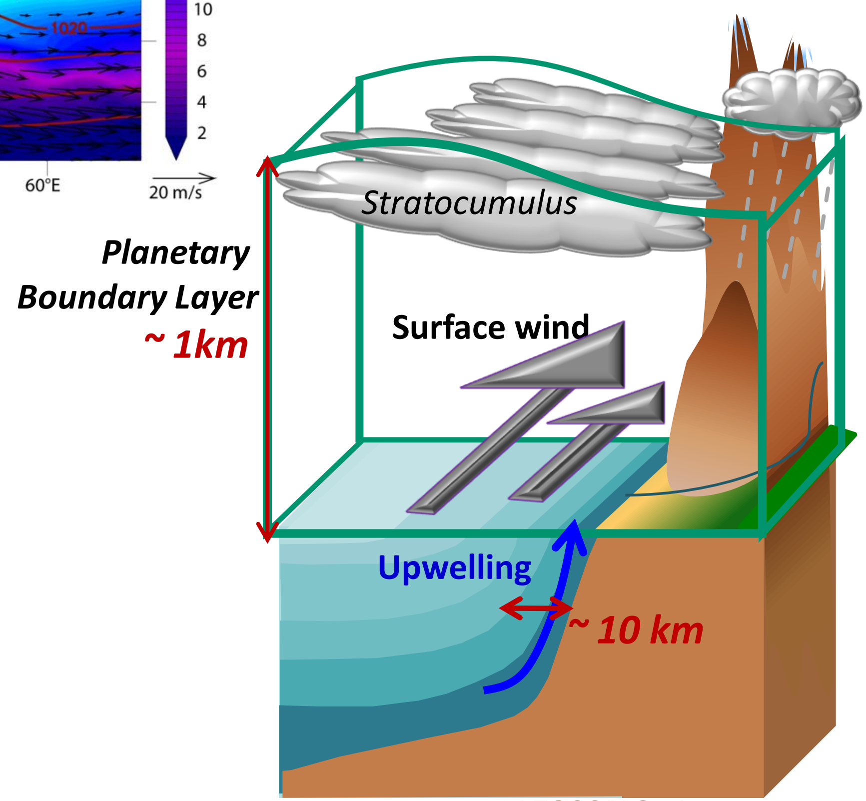
  wind spatial pattern (curl)

Hadley-Walker circulation in the Pacific

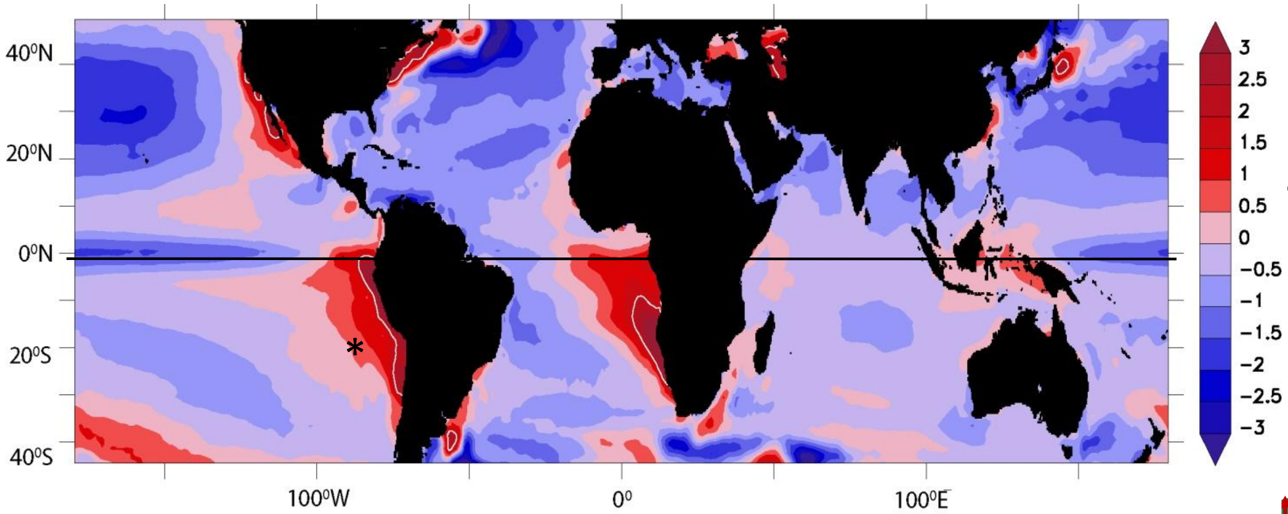


Source: Schwing et al. (2010)



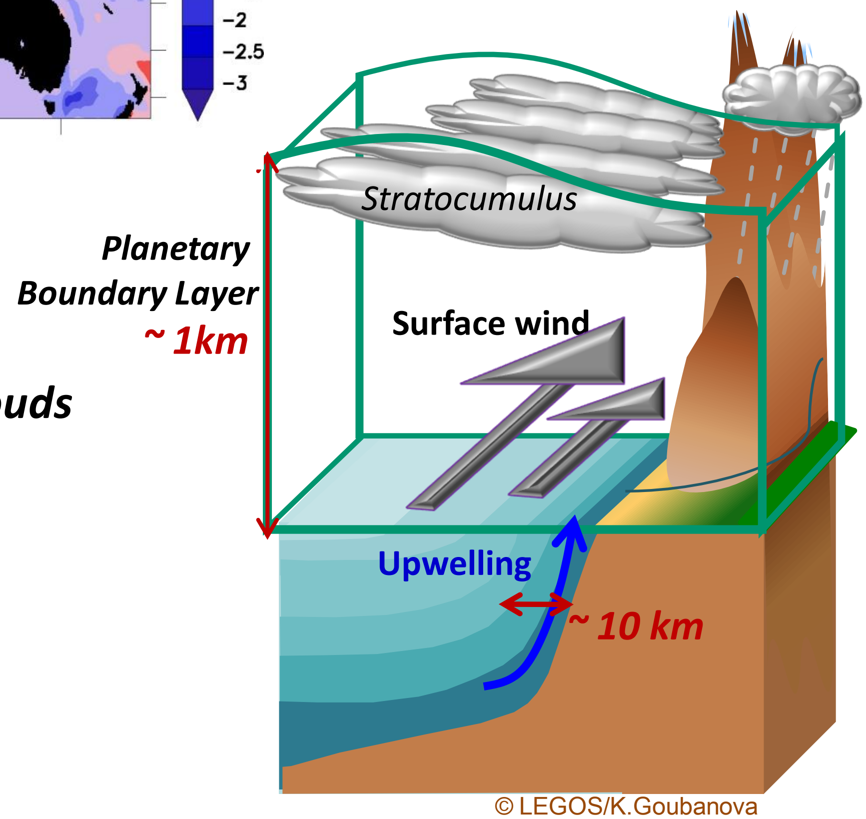
Challenges for climate modeling

Difference between observed mean SST and simulated by a 12 CGCMs ensemble (20C3M) (°C)



Strongest warm CGCMs biais in Humboldt and Benguela!

- ***Resolution (ocean & atmosphere)***
- ***Atmospheric model : underestimation of low clouds***
- ***Strong air-sea interaction -> bias amplification***



Towards better understanding air-sea interaction

VAMOS Ocean-Cloud-Atmosphere-Land interactions Study in the Southeastern Pacific

Progress in understanding:

-coastal circulation and upper-ocean heat budget
- vertical structure of PBL and diurnal cycle
- factors controlling precipitation and formation of pockets of open cells in the Sc decks
- aerosol impacts on cloud

cf. Mechoso et al., BAMS-2013 for the overview of main findings

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cf. Mechoso et al., BAMS-2013 for the overview of main findings

An exemple of current unsolved issues:

Ocean surface heat budget in southeastern Pacific

Colbo and Weller (2007):

Net heat flux at surface = **44W/m²**

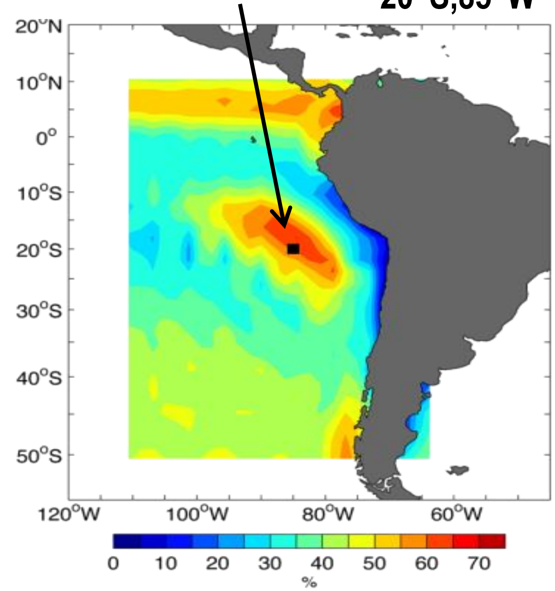
Mean gyre circulation ≈ **50%**

50% ???? **Role of horizontal eddy heat flux?**

→ **Debate in the community:**

Zheng et al. (2010), Toniazzo et al. (2010), Colas et al. (2010), Holte et al.(2013)

Location of the «Stratus» moorning (WHOI) 20°S,85°W

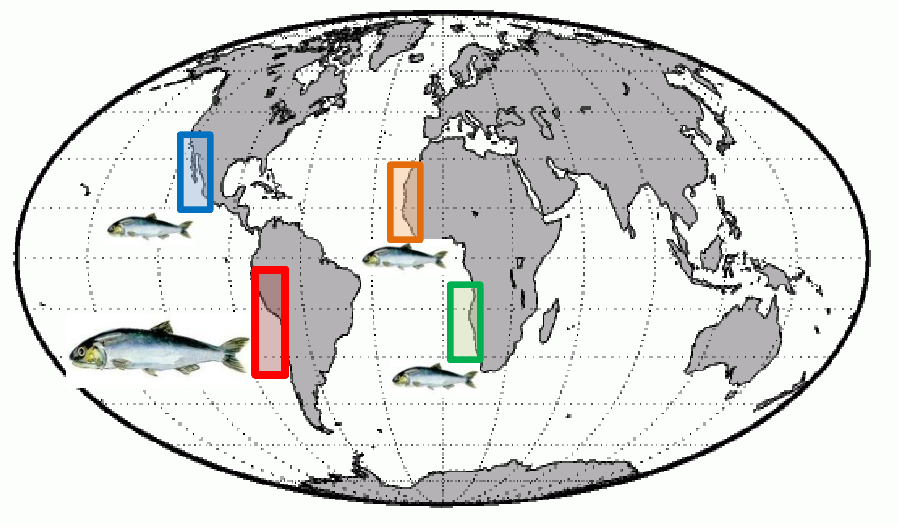


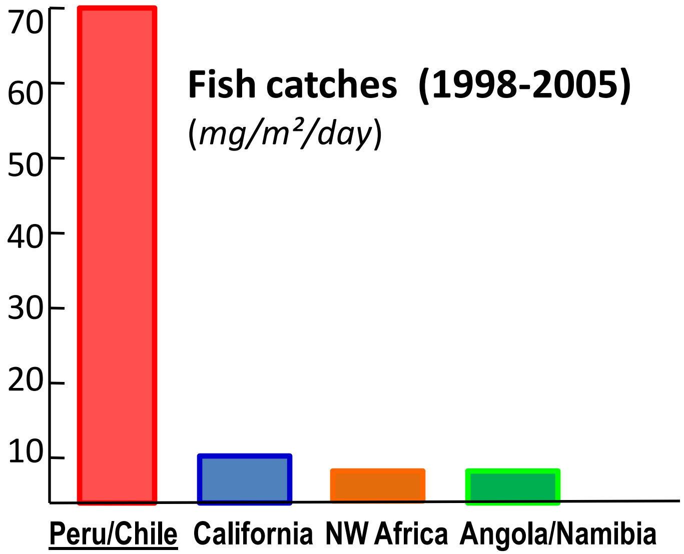
Source: Colbo and Weller (2007)

Socio-economic challenge: marine resources

Four major Eastern Boundary Upwelling Systems:

30% of world's fish catches over less than 1% of world's ocean





(adapted from Chavez&Méssie,2009)

Need for realible forecasts and **projections at regional scale** !

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Climate change downscaling experiments

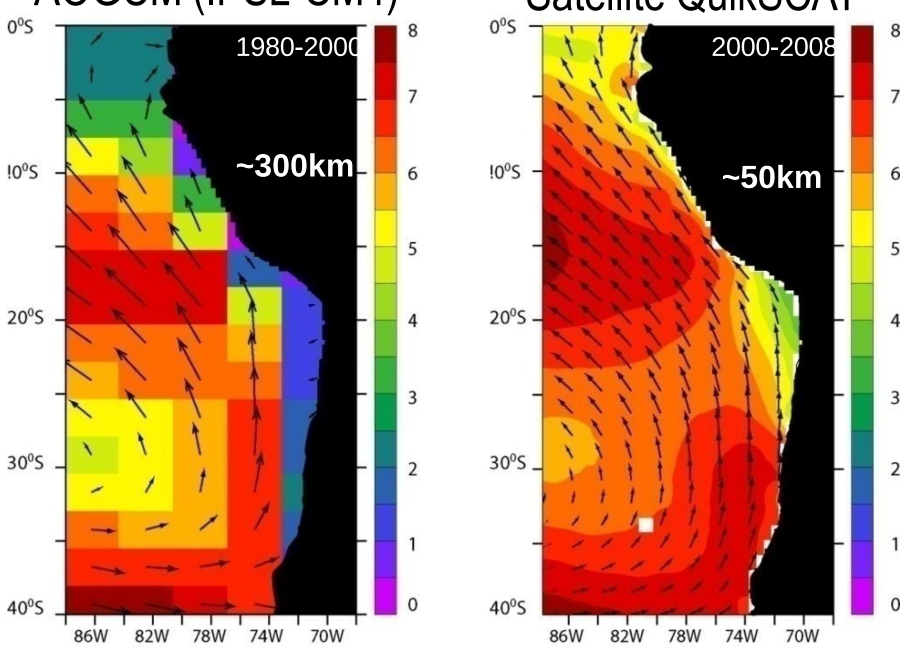
French ANR PCCC (Peru-Chile Climate Change) and **PEPS** (Peru Ecosystem Projection Scenarios)
FP7 MEECE (Marine Ecosystem Evolution in a Changing Environnement)

General objective:
- Evaluating regional impact of the climate change on near-coastal oceanic circulation and marine ecosystem

Actual approach: Regional oceanic models (ROMS) in « forced » mode

Crucial issue:
<u>Atmospheric forcing (wind)</u>
(a) Relatively high resolution
(b) Realistic spatial patterns (curl)

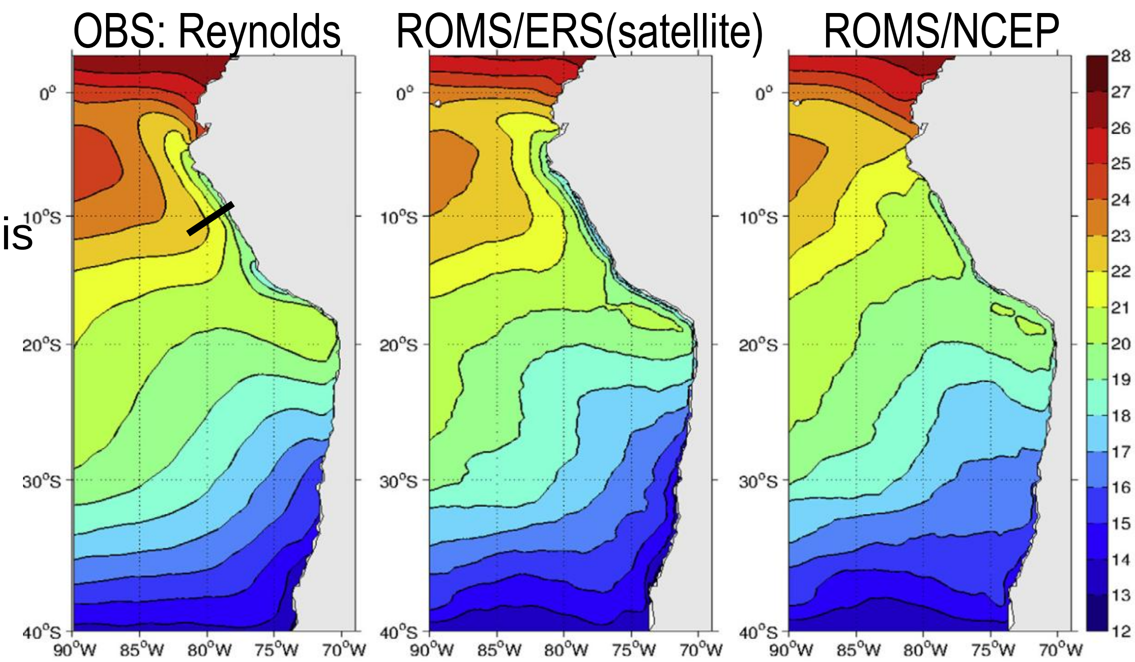
Sea surface wind at 10m off Peru/Chile



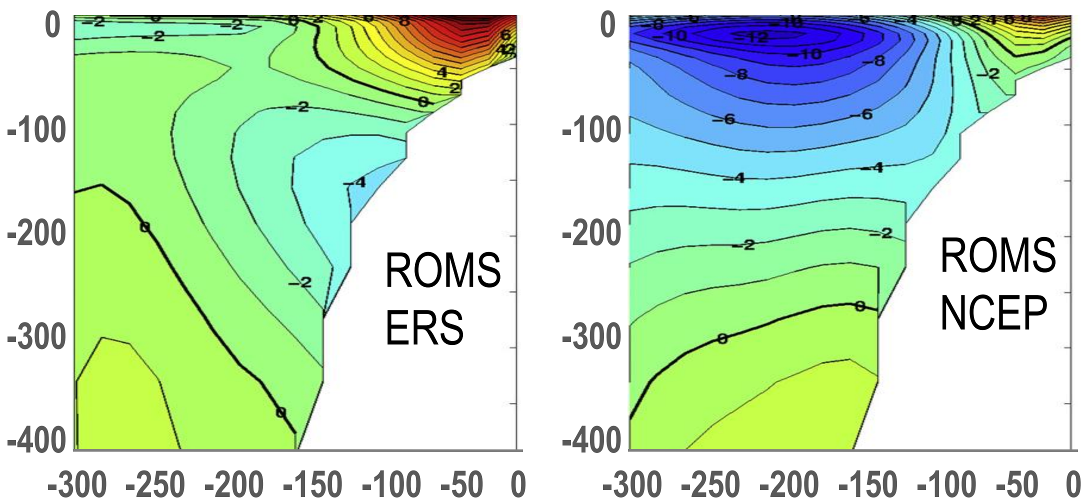
Atmospheric forcing: importance of resolution

- Ocean model : **ROMS**
- Resolution : 1/6°
- 1992 – 2000 (3yr spin-up)
- OBC:5days SODA ocean reanalysis
- Atmospheric forcing:
  Water & heat fluxes from COADS
  Wind stress: cf. caption

Sea Surface Temerature



Vertical section of meridional current average between 7°-13°S



→ Need for wind downscaling

Cambon et al. (2013)

Atmospheric forcing: importance of resolution

Exemple from sensitivity tests of a regional oceanic model to wind forcing from different datasets (NCEP_DS)

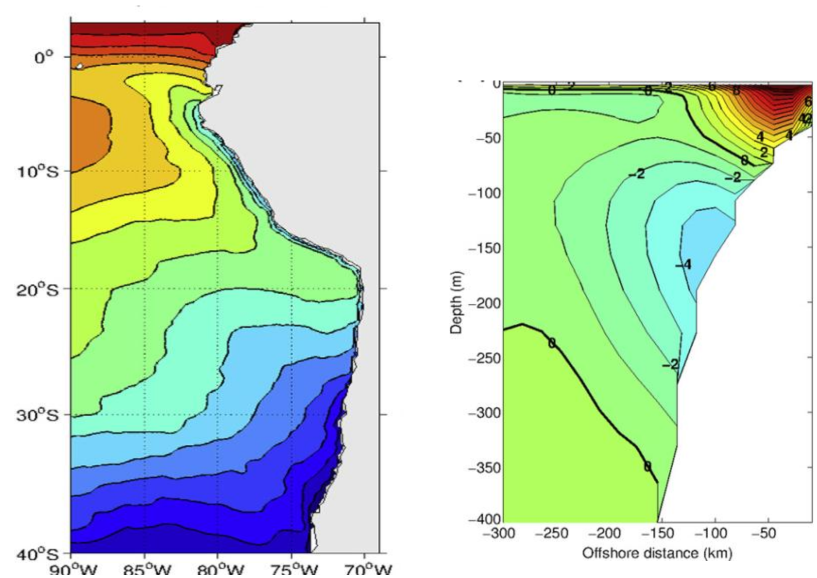
- Ocean model : **ROMS** at 1/6° resolution
- 1992 – 2000 (3yr spin-up)
- OBC: 5days SODA oceanic reanalysis
- Water & heat fluxes forcing : from COADS clim

***Statistical downscaling of wind*:**

$$Y^{QSCAT}_{2000-2008} = F(X^{NCEP}_{2000-2008}) + \varepsilon$$

$$F(X^{AOGCM}_{period}) -> Y_{period}$$

ROMS/NCEP_DS 0.5°x0.5°

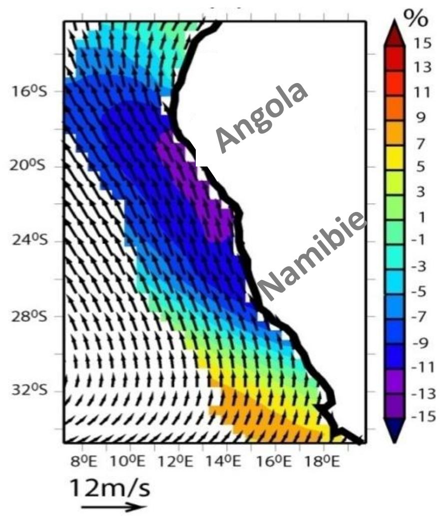


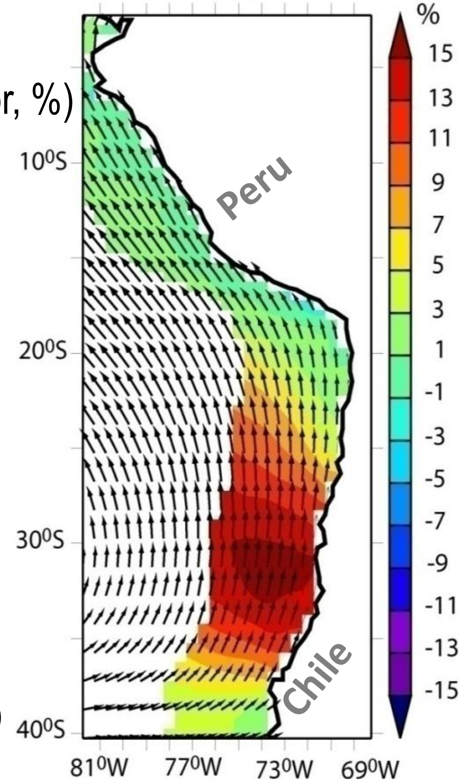
Cambon et al. (2013)

Wind response to global warming

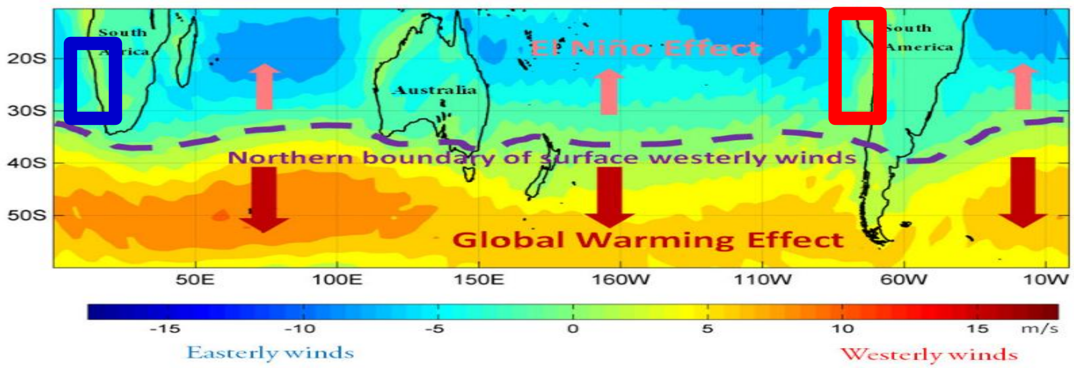
Statistical downscaling experiments for a CGCMs (IPSL-CM4): 4xCO2 – PI (Jul-Dec)

Relatif change of upwelling favorable wind (color, %)





Goubanova et al., ClimDyn (2011)
Goubanova, SOLAS NL (2011)



Peru/Chili:
In agreement with modeling studies
Garreaud and Falvey (2009)
Belmadani et al. (2013) submitted

Image: CSIRO

First regional downscaling experiments: conclusions

Statistical downscaling of the wind allowed estimating in a first approximation sensitivity of the regional ocean circulation to warmer climate, 2xCO2 and 4xCO2, (Wind vs Stratification) and evaluating potential impact on ecosystem (Stratification, Eddy activity vs O_2).

Limitations of the approach used:

1) Heat flux to force the ocean
2) « Forced » mode for coupled system:
   Impact of SST anomalies or mesoscale structures of SST on wind (and PBL?)
1) Other potentially important processus
   - sea-land contrast (*coastal cloud: Enfield, 1981; Vargas et al. 2007;*
     enhaced land heating relative to ocean: Bakun, 1990)
   - precipitation/wind/SST (*relationship between alongshore wind and vertical motion*
     increased precipitation over the Tropics :
     Belmadani et al., 2013 submitted) → air-sea coupling

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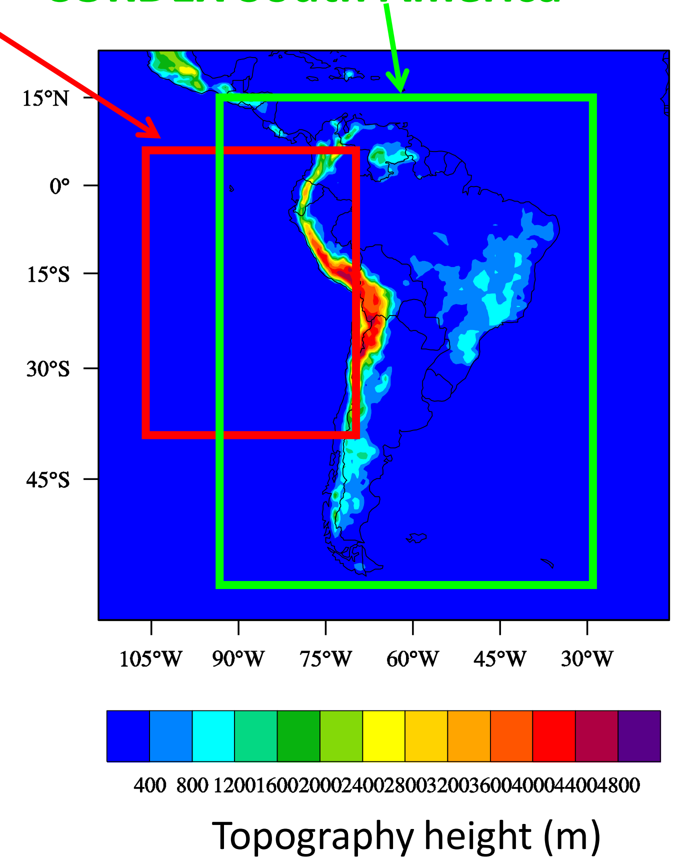
CORDEX-WRF team at the IPSL (Paris, France) coordinated by P.Drobinski (LMD) & S.Bastin (LATMOS)

- **WRF-ARW 3.1.1**
- Domain **110W°-35°W, 20°N-60°S:** Region PCCC + CORDEX South America
- Resolution **50km** (196x210x**35lev.**)
- *Physical options:*
  Microphysic : WSM 5-class
  LW&SW radiations : RRTMG
  Land surface/surface layer: Pleim-Xiu
  PBL : ACM2 (Pleim)Cu: Grell-Devenyi

WRF/ERAI, 1989-2009 done
WRF/IPSL-CM5, RCP8.5, 1980-2050 is running

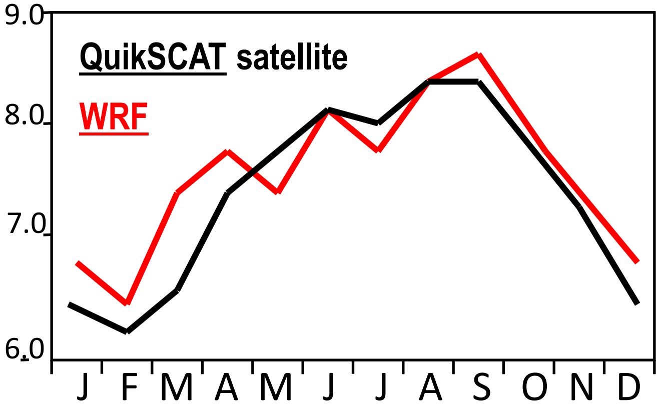


→Focus on **surface wind (and heat flux)** over the PCCC oceanic region

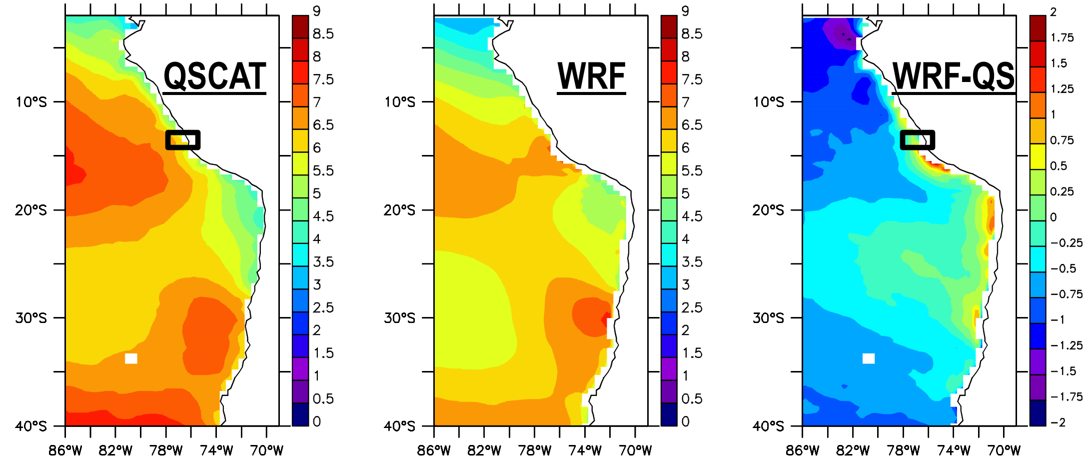
Surface wind validation

Validation of wind at 10m from control run : ERA-Interim forcing, 1989-2008 (m/s)

Seasonal cycle over 200km coastal band off Central Peru (14-15°S)



Winter mean:Spatial patterns and amplitude



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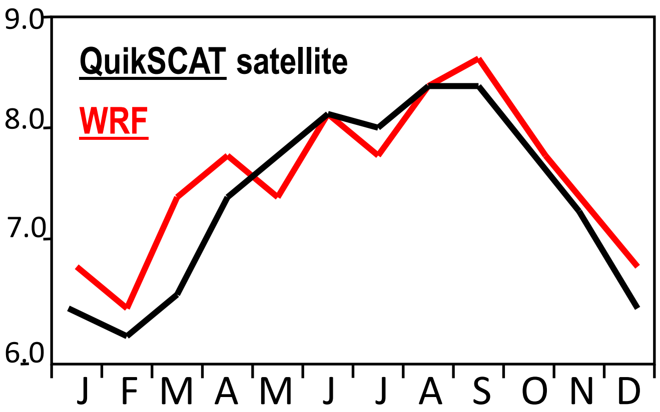

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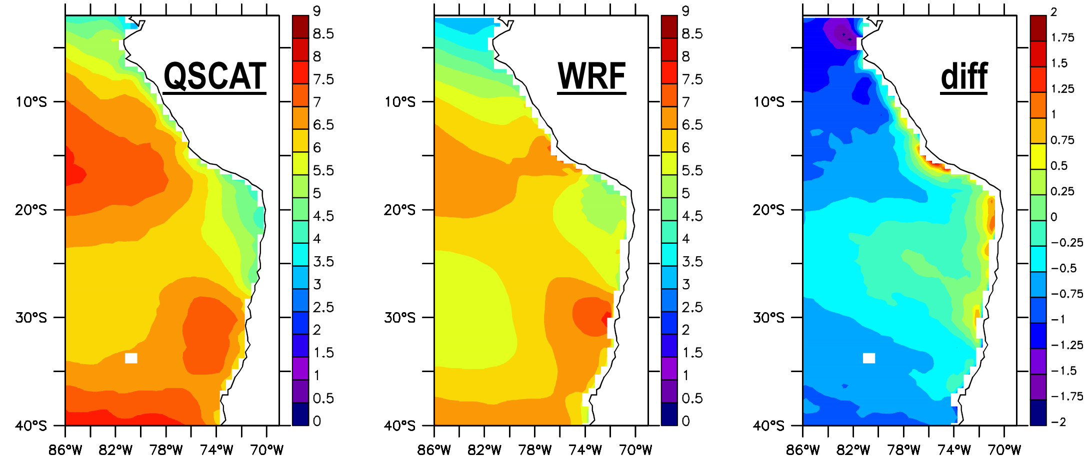
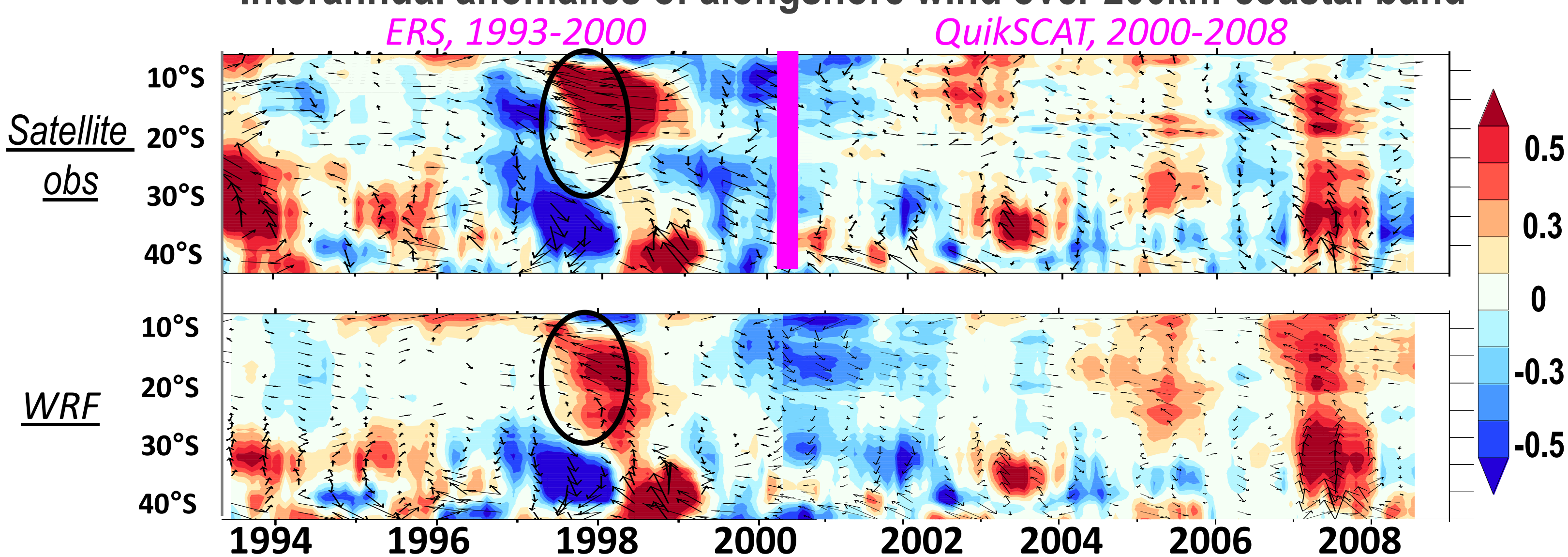
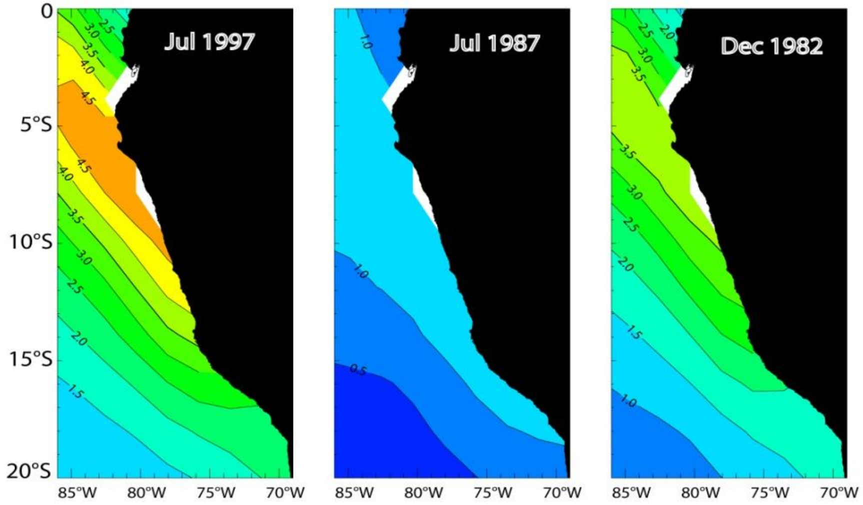


Interannual anomalies of alongshore wind over 200km coastal band

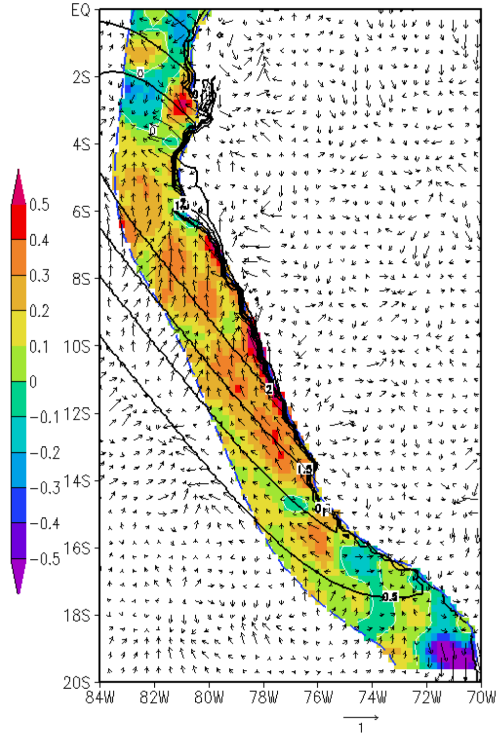


Wind response to SST anomaly: East-Pacific El Niño

SST anomalies during El Niño along the coast off Peru



Idealised SST anomalies (°C,contour) and Wind 10m (arrows/color, m/s)



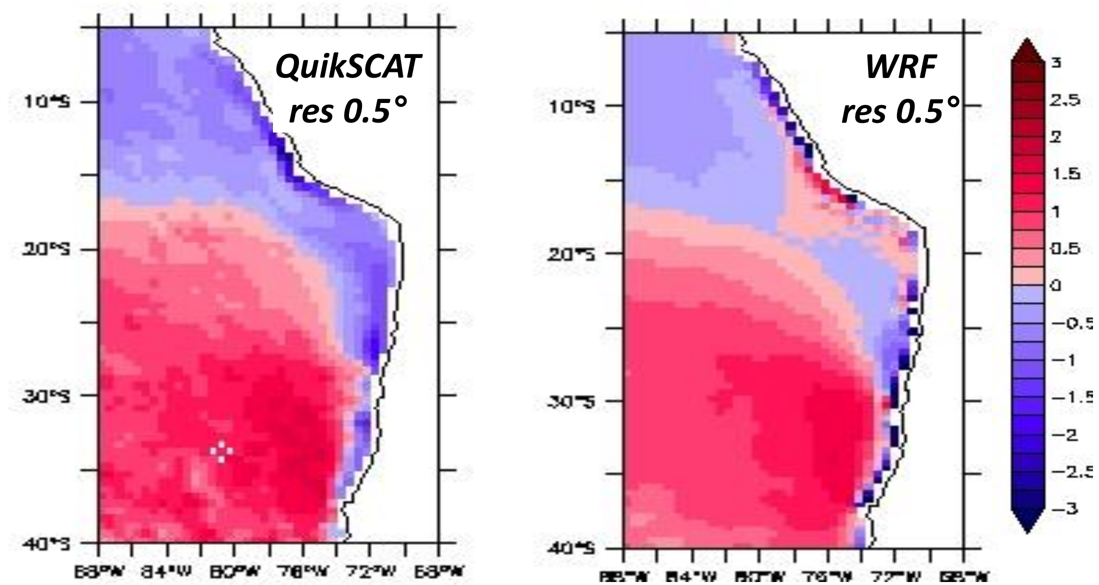
Courtesy: K. Takahashi

→ **Adjustment of pressure gradient to meridional SST gradient**

Lindzen and Nigam (1987)

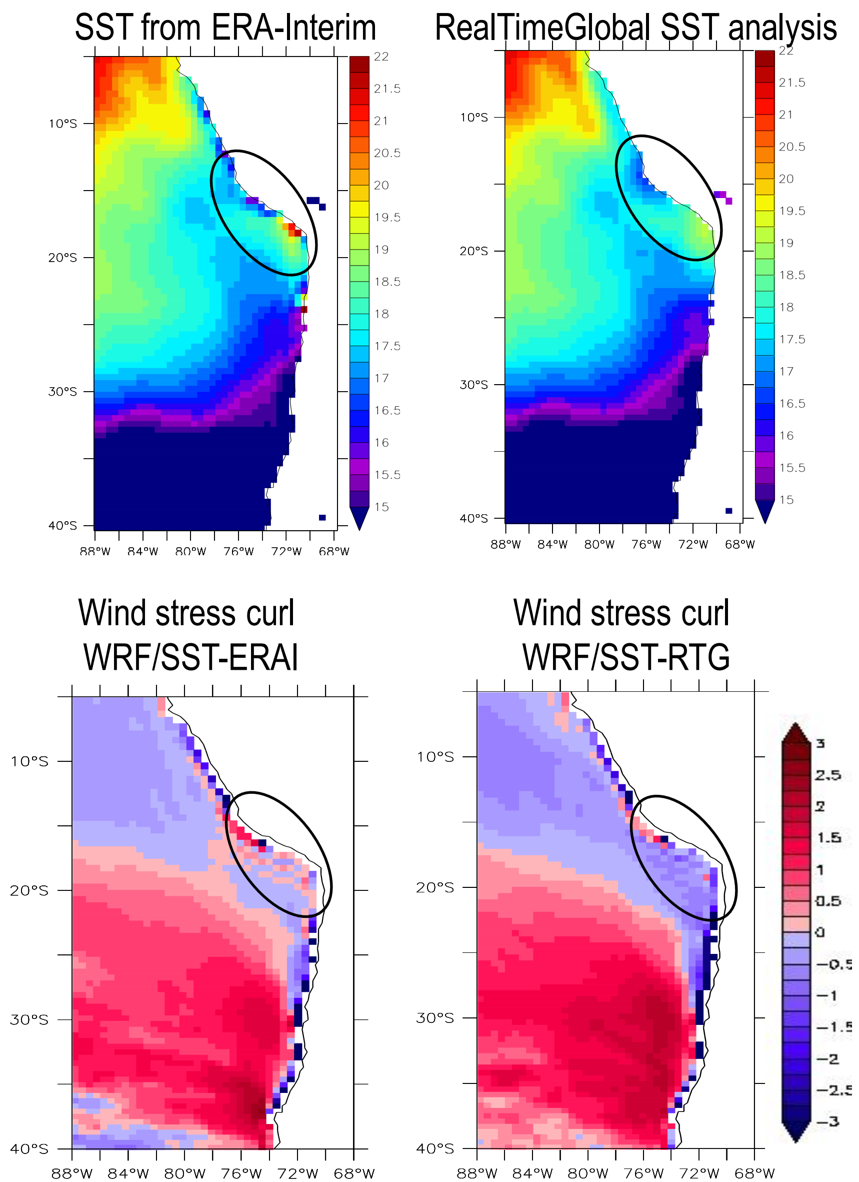
Surface wind validation from WRF/ERAI

Wind stress curl, October mean 2000-2008 (10^7 Pa/m)

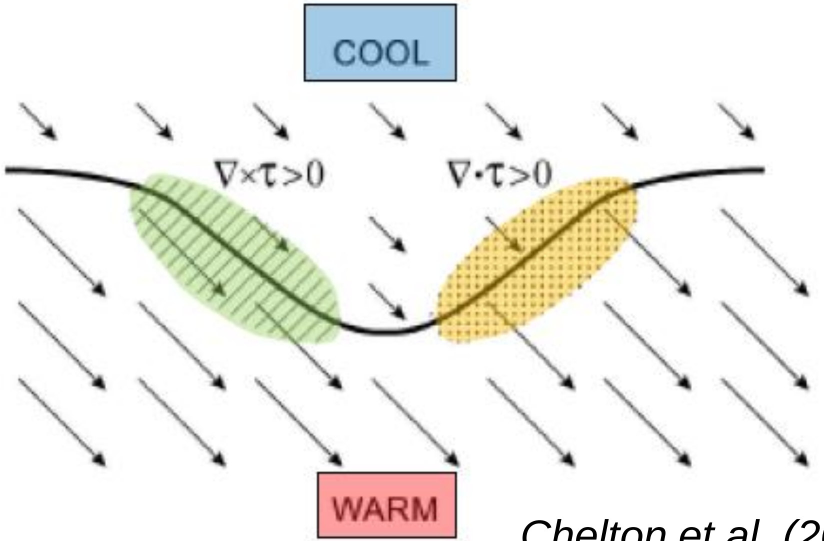


Response of wind to SST

Oct2002,WRF/CORDEX configuration



Possible explanation

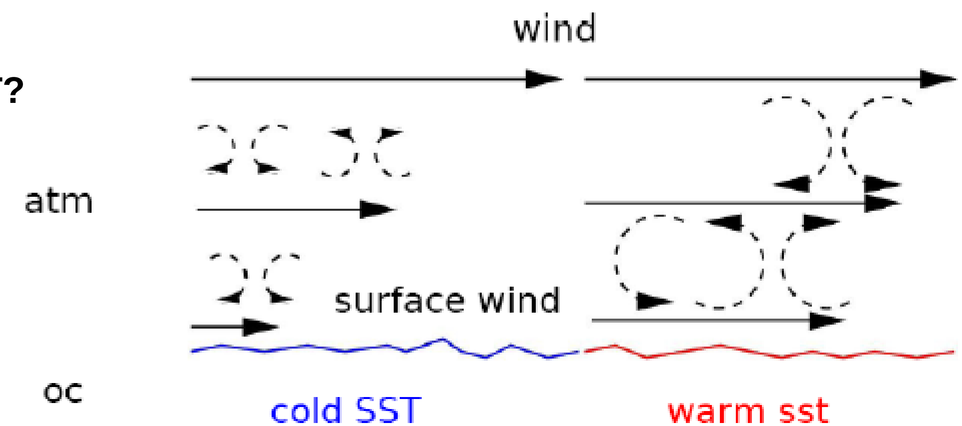


Chelton et al. (2007)

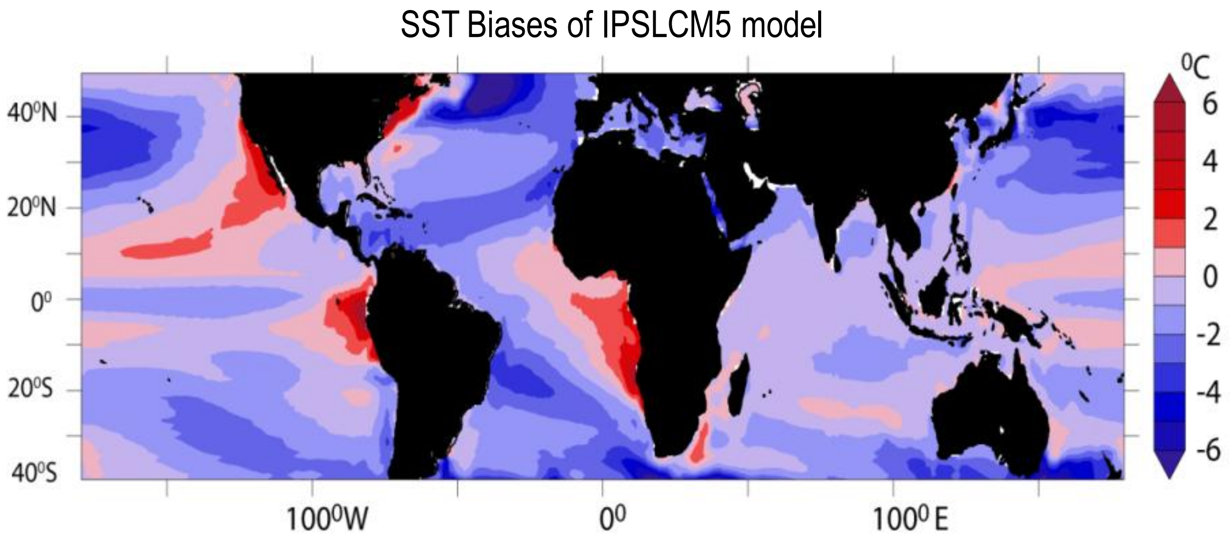
Wind curl: $\nabla \times \boldsymbol{\tau} \sim \underbrace{\nabla T \times \hat{\boldsymbol{\tau}} = |\nabla T| \sin\theta}_{\text{Crosswind SST Gradient}}$

Wind divergence: $\nabla \cdot \boldsymbol{\tau} \sim \underbrace{\nabla T \cdot \hat{\boldsymbol{\tau}} = |\nabla T| \cos\theta}_{\text{Downwind SST Gradient}}$

Modulation of PBL stability by SST?



SST forcing from AOGCMs for regional projections



→ Need for SST « correction » to perform CORDEX future projections?

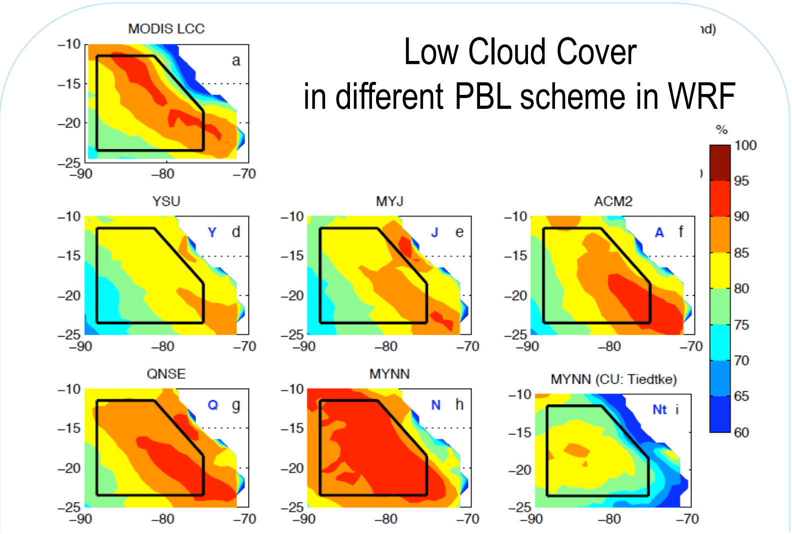
Also important for African monsoons (*S.Bastin, pers.comm*)

Conclusion-Perspective

Regional climate change in the South Eastern Pacific is an air-sea coupled problem and should be adressed in a coupled framework !

<u>On-going work</u>: developpement of regional air-sea coupled model (WRF/ROMS) configuration for South Eastern Pacific

Caution: biases in atmospheric model (low clouds, ITCZ) -> potential amplification



Courtesy: A. Jousse

Thank you for your attention !