¿Qué dinámica controla los escenarios futuros del viento favorable a la surgencia frente a Perú y a Chile?

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Simposio: Un Océano Cambiante. Perspectivas, Oportunidades y Desafíos para la Oceanografía Chilena
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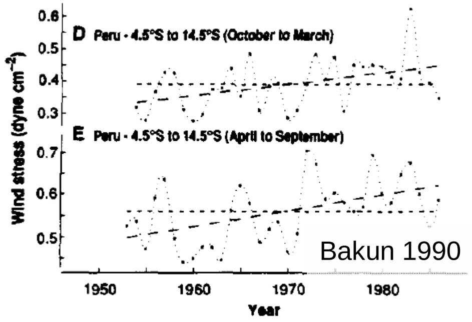
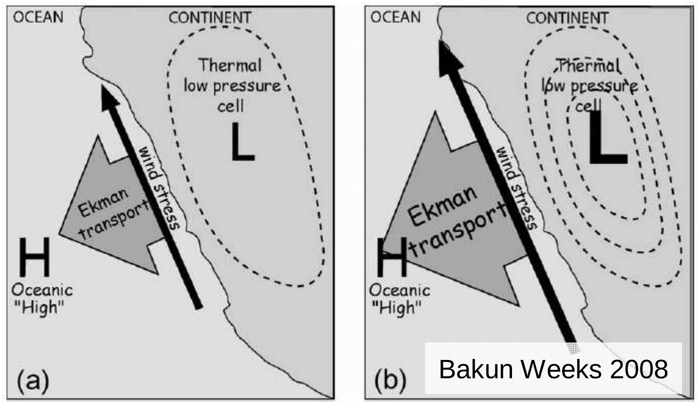
Introduction

Coastal Wind Change Theories off Peru-Chile



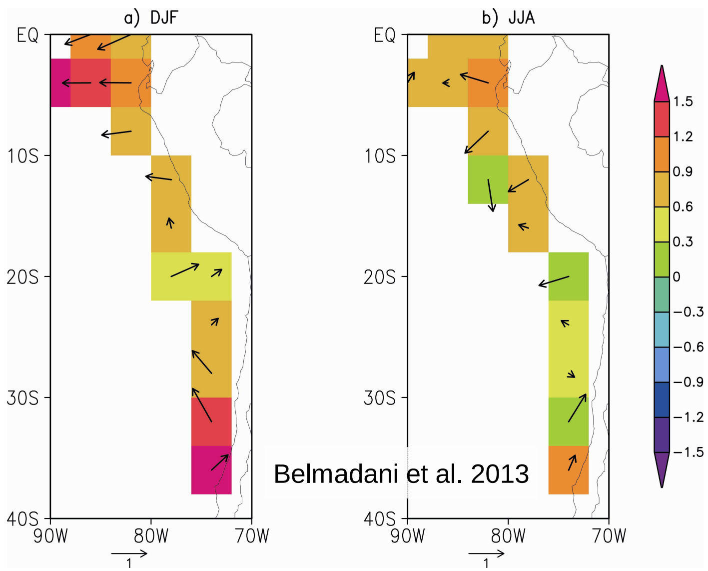
Increased upwelling-favorable winds off Peru in ICOADS ship observations



Bakun's Hypothesis: increased land/sea temperature gradient intensifies low pressure cell over land & geostrophic wind

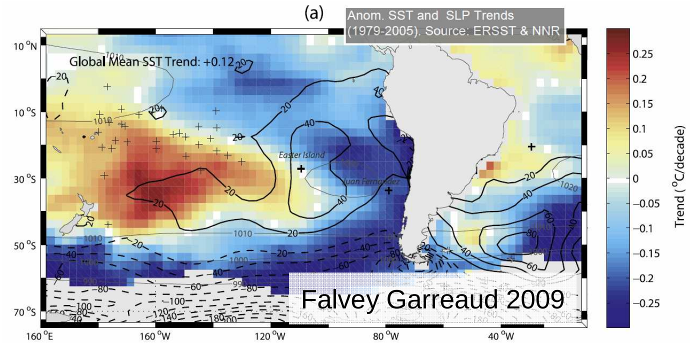
But ship wind data have spurious trends due to increased anemometer height (Cardone et al. 1990)

No clear trend off Peru & strengthening off central Chile (30-35°S) in WASWind corrected winds (Tokinaga Xie 2011)

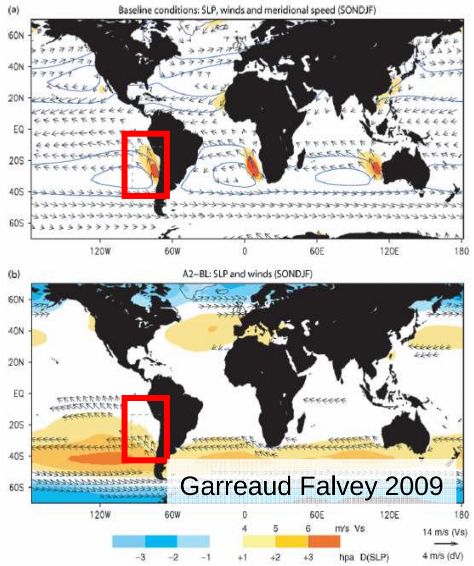


Introduction

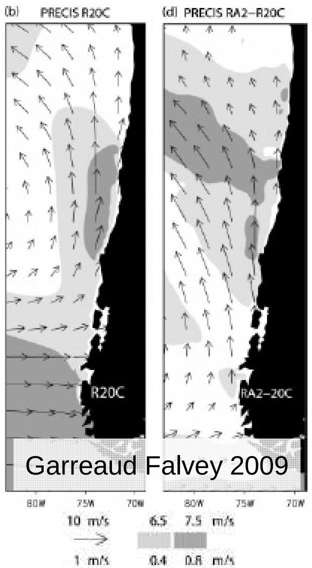
Coastal Wind Change Theories off Peru-Chile (2)



Surface cooling in eastern South Pacific in ERSST and HadISST analyses



Strengthening & poleward expansion of South Pacific anticyclone in CMIP3 GCM projections for 21st century



Increased winds off Chile in PRECIS-UKMO-HadCM3 RAM projections

Frictional balance near the Andes (Muñoz Garreaud 2005)

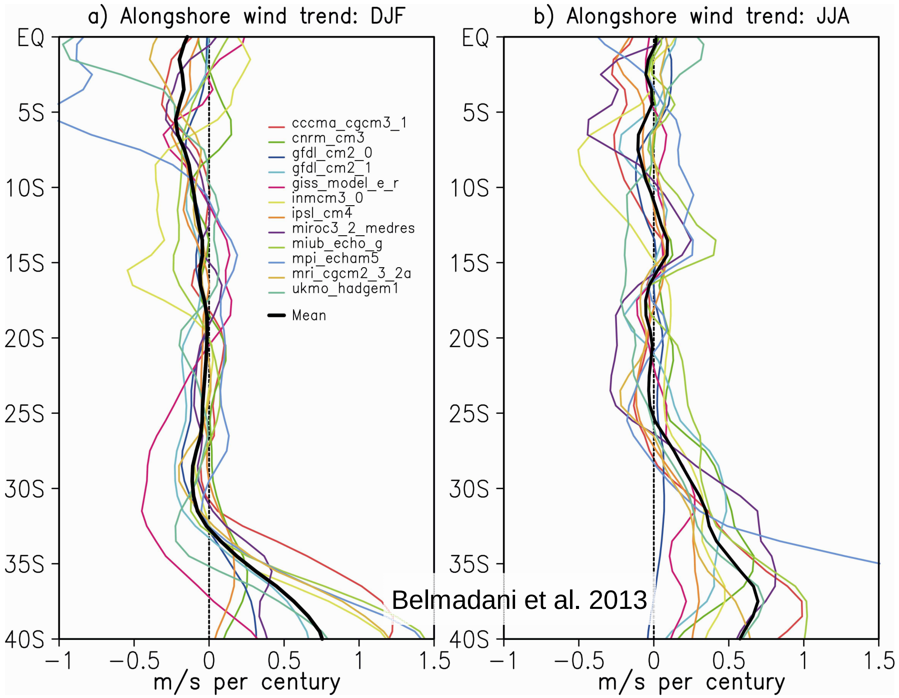
$$\frac{\partial V}{\partial t} = -\frac{1}{\rho}\frac{\partial P}{\partial y} + V_m$$

Alongshore wind driven by alongshore pressure gradient

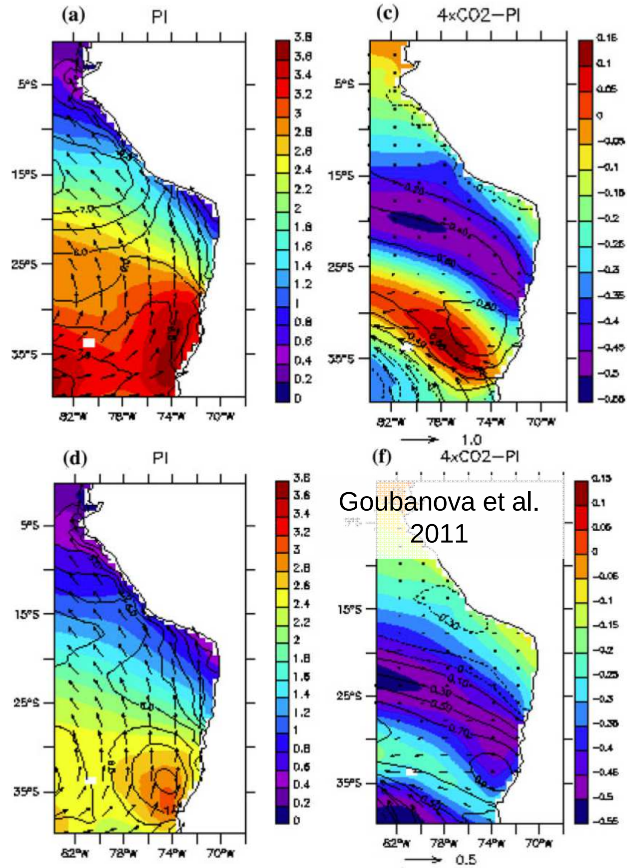
$$V \approx \frac{-1}{c\rho}\frac{\partial P}{\partial y}$$

Introduction

Contrasted Projections for Peru and Chile



Increased winds off central Chile but no clear agreement off Peru in GCM response



Increased winds off Chile / Reduced winds off Peru in statistically downscaled IPSL-CM4 GCM projections

=> What drives future wind scenarios off the coast of Peru and Chile?

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Dynamical Downscaling

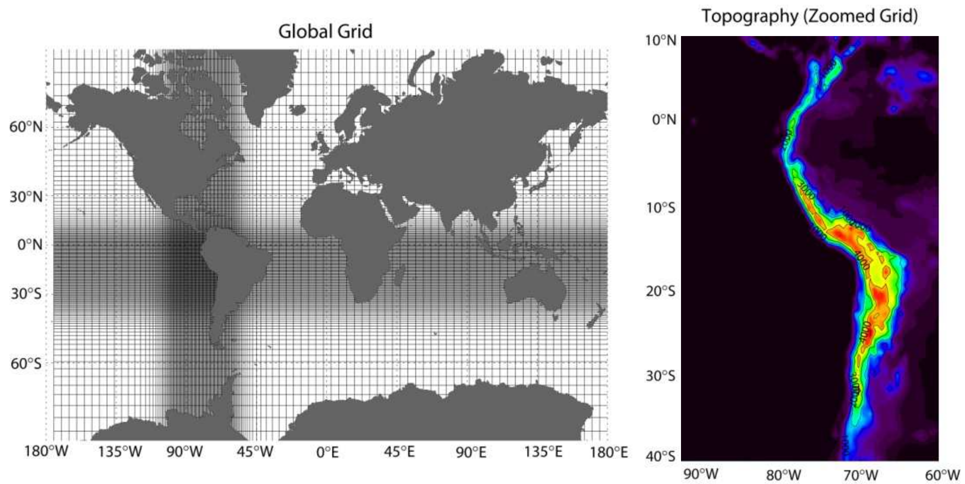
LMDz05

Atmospheric GCM 4.9°x2.4°, **0.5° zoom over Peru-Chile**, 19 vertical levels (Hourdin et al. 2006)

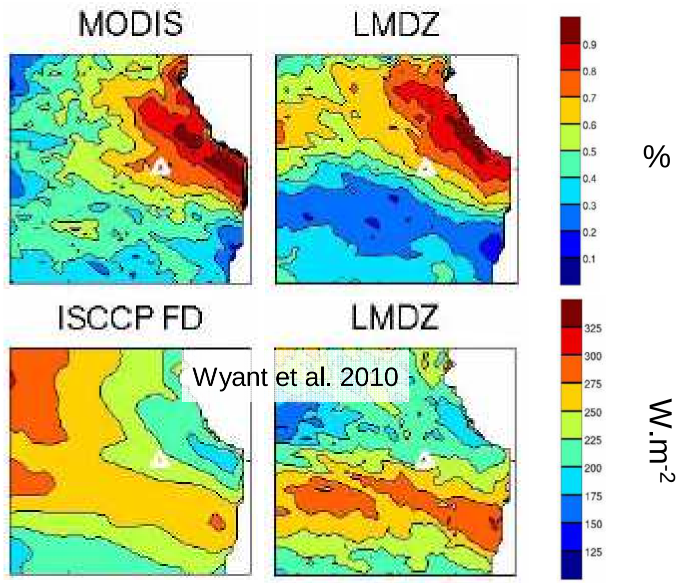
Forcing: * SST Climatology (AMIP, Hurrell et al. 2008) **+ GCM increment** (IPSL-CM4)

*** CO_2** from **20C3M**, **PIcntrl**, stabilized **1pctto2x** and **1pctto4x** scenarios

10-yr runs **CR** (validation), **PI** (reference), **2CO2**, **4CO2** (global warming)



LMDz05 global and zoomed grids



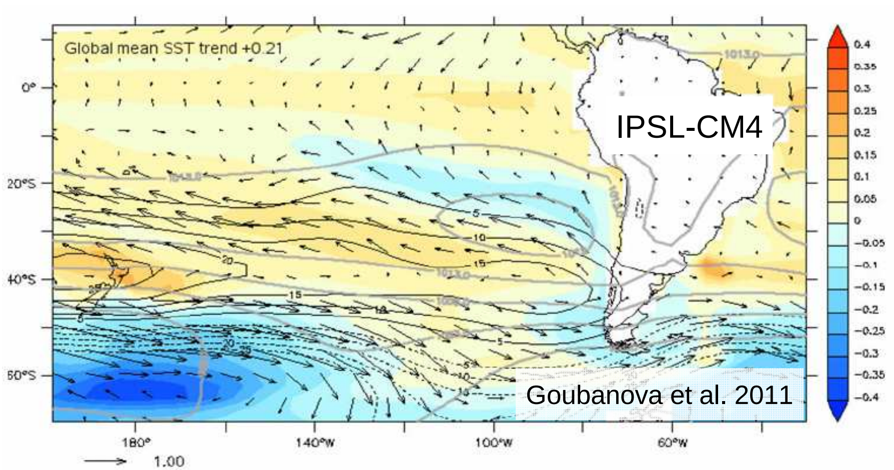
Low clouds and ↓SW radiation in LMDz and observations (Oct 2006)

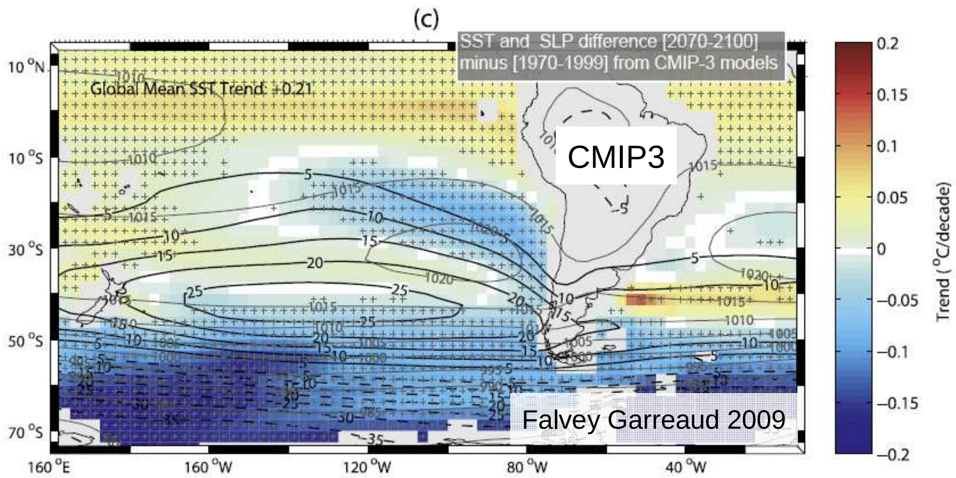
Dynamical Downscaling

IPSL-CM4

CMIP3 GCM 3.75°x2.54°L19 (atmosphere), 2°x1°L31 (ocean) (Marti et al. 2010)

- **Response to global warming similar to CMIP3 ensemble mean**
- **Reproduces observed South Pacific anticyclone** (Garreaud Falvey 2009)
- **Comparison dynamical / statistical downscalings** (Goubanova et al. 2011)





Similar SST/SLP responses to global warming

Dynamical Downscaling (2)

LMDz1

8°x2.6° global, **1° zoom over South America,** 2-way nesting with global 3.75°x2.5° (Junquas et al. 2013)

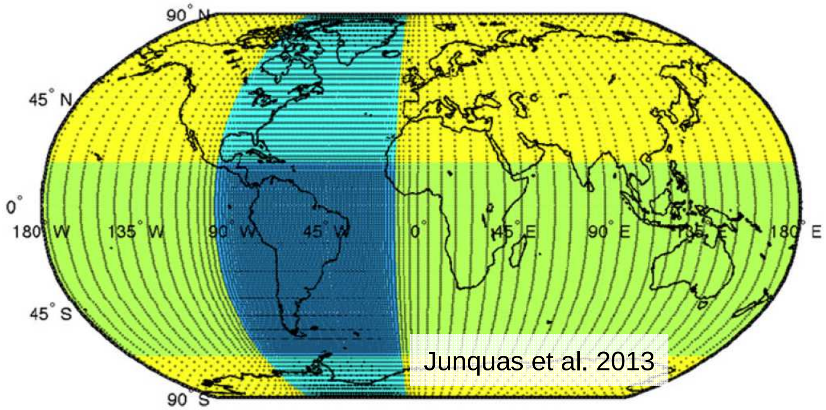
Forcing: * **SST Clim.** (AMIP) **+ GCM increment** (**A1B** multimodel mean)

* **CO_2** from **20C3M**, and **doubled**

DJF runs CR (validation/reference), **FSSTG** (global warming)

• **Sensitivity to the chosen models and climate scenarios**

• Reproduces well the observed rainfall (Junquas et al. 2013).



LMDz1 global and zoomed grids

Multimodel mean (9)

CCCma CGCM3.1-T47, CCCma CGCM3.1-T63, CSIRO-MK3.0, GFDL CM2.0, GFDL CM2.1, MIROC3.2(hires), MIROC3.2(medres), MIUB-ECHO-G, UKMO-HadCM3

The “best” for Southeastern South America precipitation (Junquas et al. 2012)

GCMs and Observations

CMIP3 GCMs (12)

CCCma CGCM3.1-T47, CNRM-CM3, GFDL CM2.0, GFDL CM2.1, GISS-ER, INM-CM3.0, IPSL-CM4, MIROC3.2(medres), MIUB-ECHO-G, MPI-ECHAM5, MRI CGCM2.3.2A, UKMO-HadGEM1

- To discuss regional trends in the context of large-scale changes
- GCMs chosen for data availability

SCOW and **ERA-Interim**

Scatterometer Climatology of Ocean Winds (Risien and Chelton 2008) **surface winds 0.25°**.

ECMWF ERA-Interim reanalysis (Dee et al. 2011): **wind/temperature vertical profiles 1.5°**, 37 p-levels

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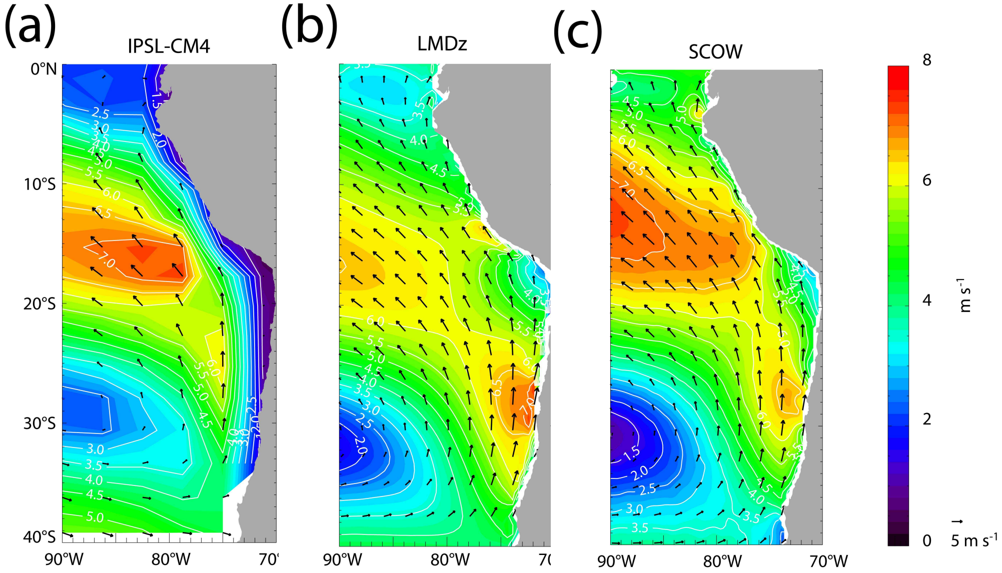
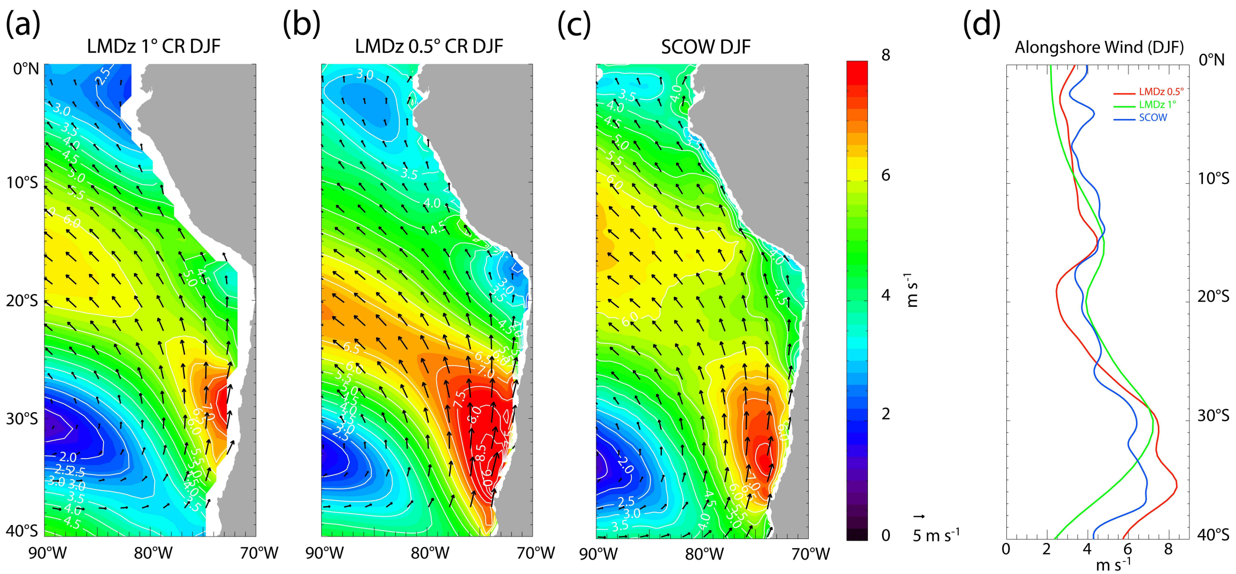
Surface Winds



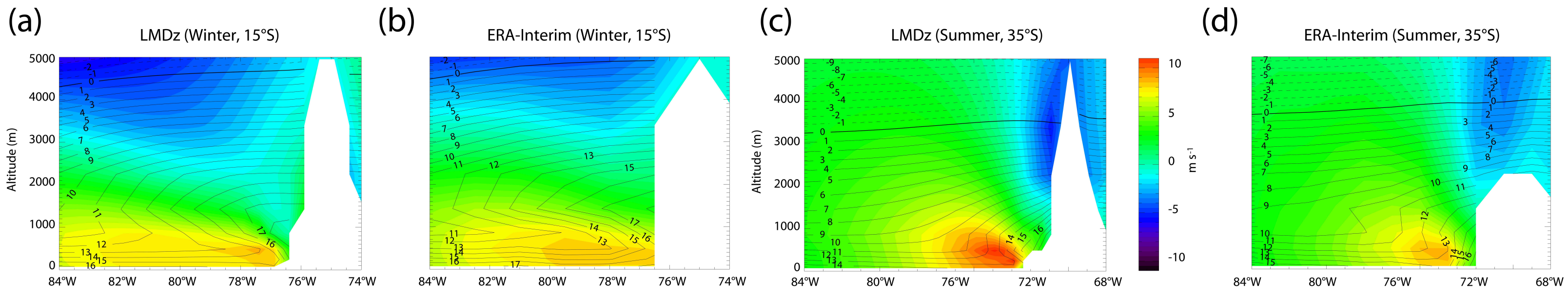
Downscaling: clear improvement in LMDz05 compared to IPSL-CM4 despite strong coastal jet

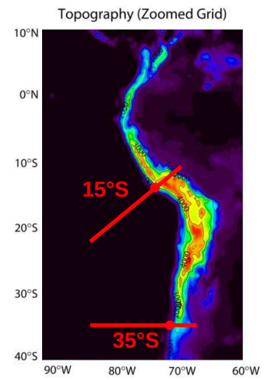


LMDz1 equally skilled in reproducing SCOW e.g. displaced coastal jet but right amplitude

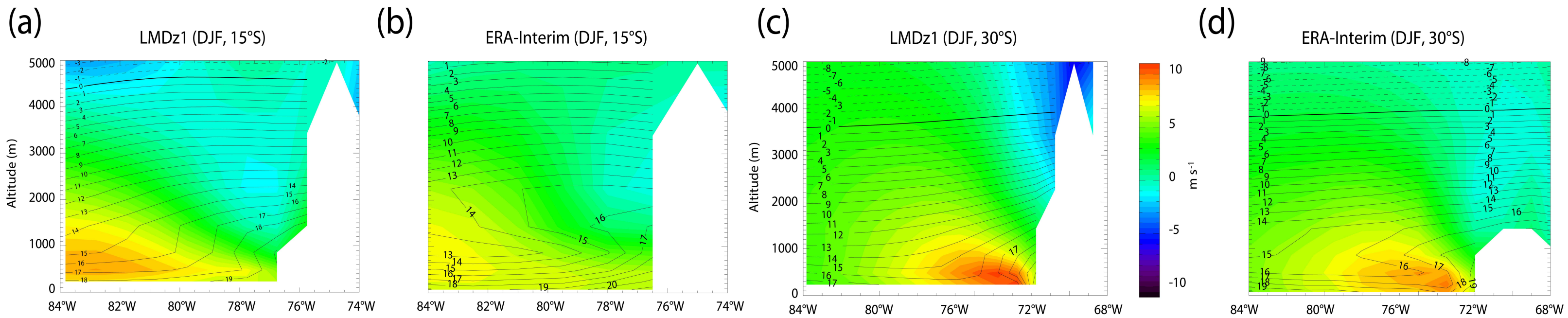
Validation

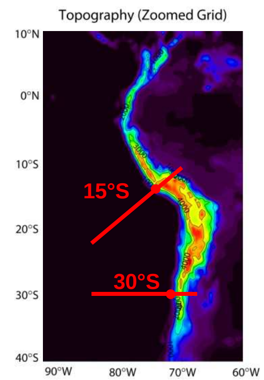
Seasonal Coastal Jets: Vertical Structure





LMDz05 vertical structure agree with ERA-Interim (e.g. boundary layer, coastal jets, temperature inversion) despite overestimated jet @35°S





LMDz1 wind vertical structure agree with ERA-Interim despite displaced jet @30°S

But weak inversions with cold bias = common problem in models (Garreaud et al. 2001)

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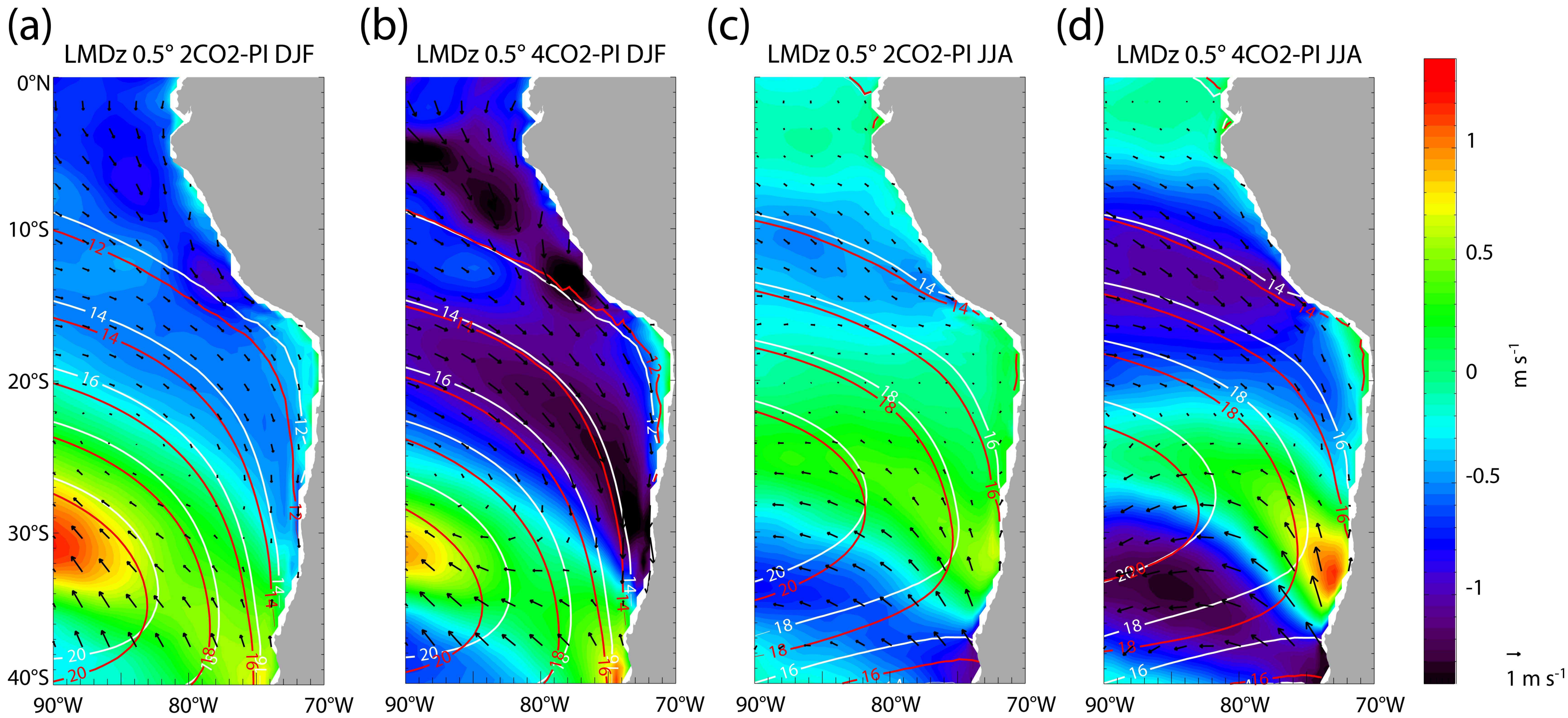
Changes in Winds and Anticyclone



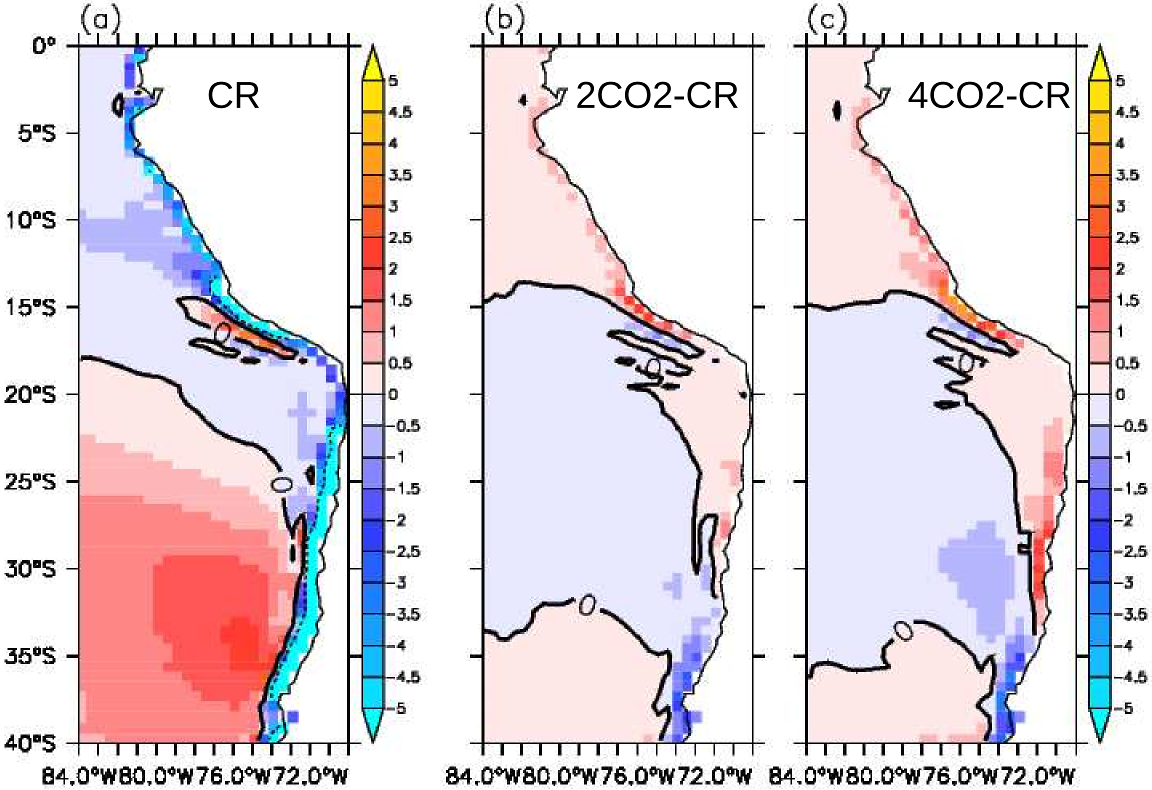
Increased winds off central Chile, reduced winds off Peru

Anticyclone southward shift consistent with IPSL-CM4

Largest changes in summer. Quasi-linear response to CO_2 increase

Similar to Goubanova et al. 2011 with stronger summer wind decrease off Peru

Changes in Wind Stress Curl



Cyclonic nearshore WSC associated with wind drop-off contributes to coastal upwelling

Small-scale noise near 15°S (bias)

Response similar to alongshore wind: increase off central Chile, reduction to the north

Quasi-linear response to CO_2 increase

Role of the Alongshore Pressure Gradient

Alongshore momentum budget

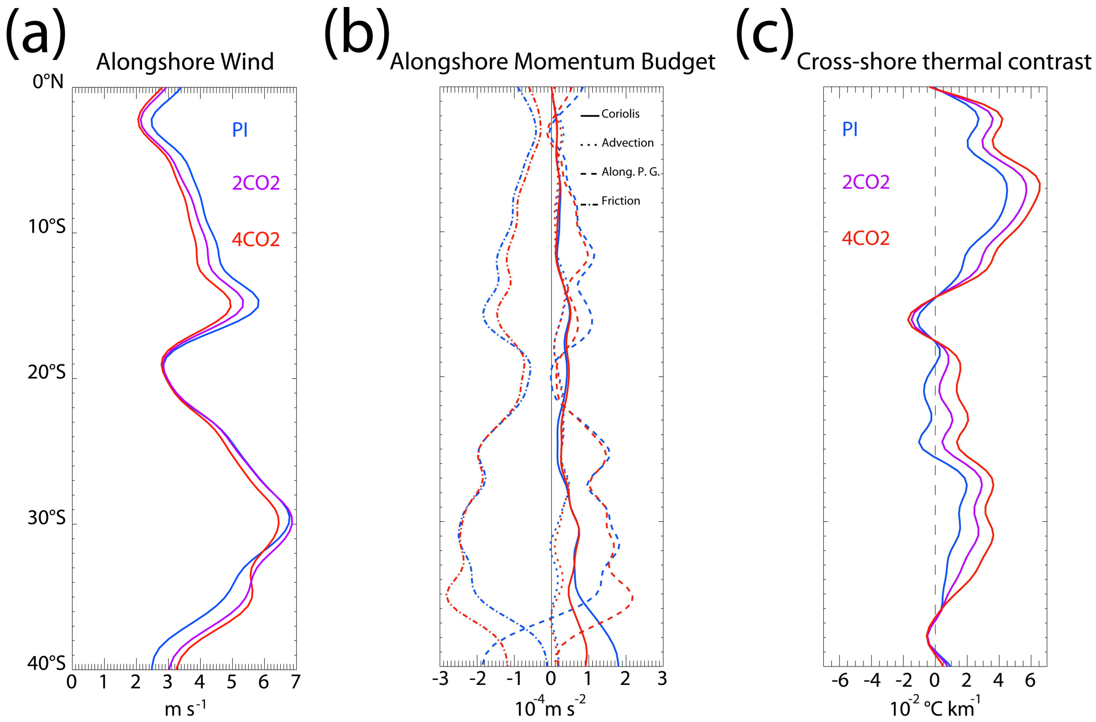
$$\underbrace{-U\frac{\partial V}{\partial x}-V\frac{\partial V}{\partial y}-W\frac{\partial V}{\partial z}}_{\text{Advection}}\underbrace{-\frac{1}{\rho}\frac{\partial P}{\partial y}}_{\text{Along. P. G.}}\underbrace{-fU}_{\text{Coriolis}}\underbrace{+V_m}_{\text{Friction}}=0$$

Similar to Muñoz Garreaud 2005

$$-\frac{1}{\rho}\frac{\partial P}{\partial y} \qquad +V_m \approx 0$$

Reduced Peru winds associated with **reduced along. P. G.**

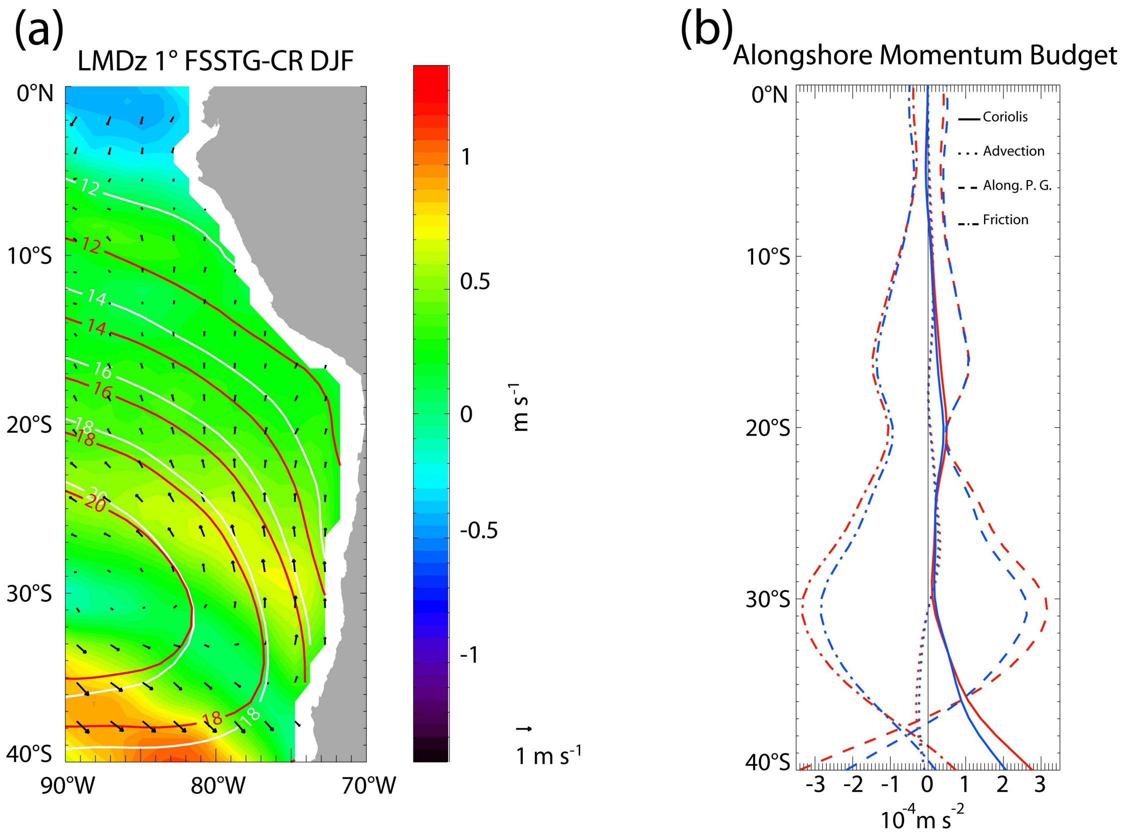
Increased Chile winds associated with **poleward shift / increase of max. along. P. G.**



Alongshore and cross-shore P. G. are in phase as in Muñoz Garreaud 2005 (not shown)

But land/sea thermal contrast increases everywhere => Bakun's hypothesis not confirmed off Peru

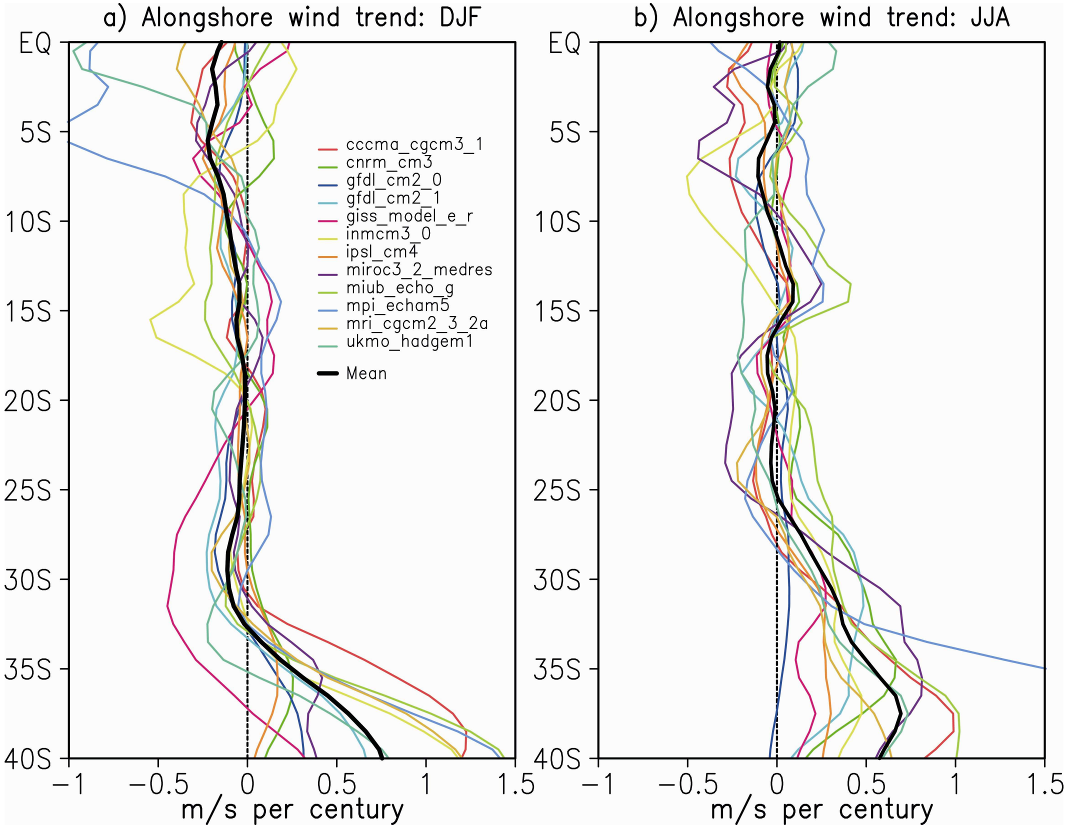
Sensitivity to Model and Scenario: LMDz1



Moderate wind and along. P. G. increase except near the equator

Anticyclone intensification, no shift: overestimated in IPSL-CM4?

Origin of Alongshore Pressure Gradient Changes



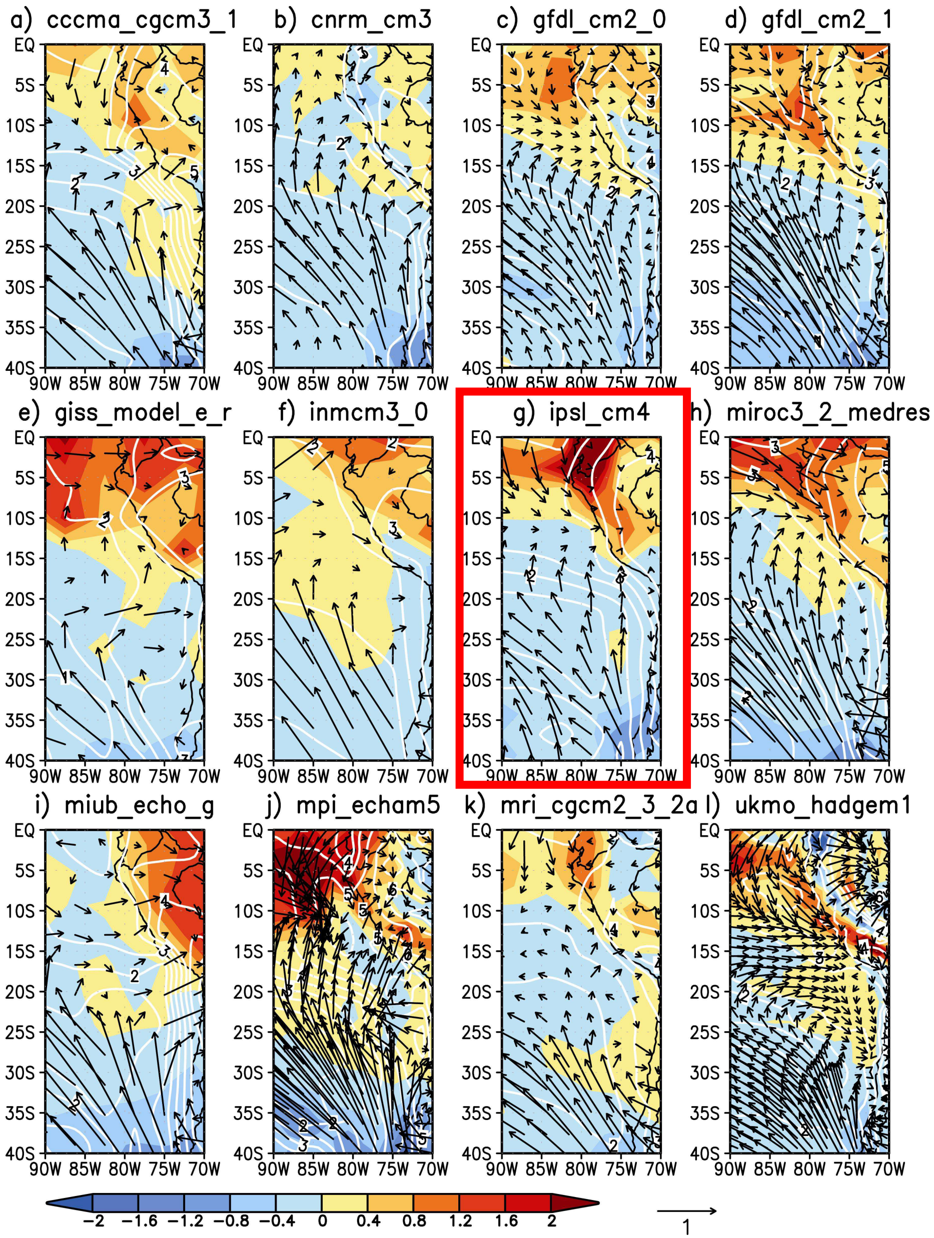
Off Chile: along. P. G. changes driven by **South Pacific anticyclone** (strength, position)

Off Peru: *** the anticyclone may be too far away** for its intensification to have an influence (LMDz1), but its poleward shift may play a role (LMDz05).

* large dispersion in GCM response off Peru suggests **other mechanisms may be at play**.

⇒ Precipitation/Wind/SST feedbacks in the tropics?

Precipitation/Wind/SST in GCMs

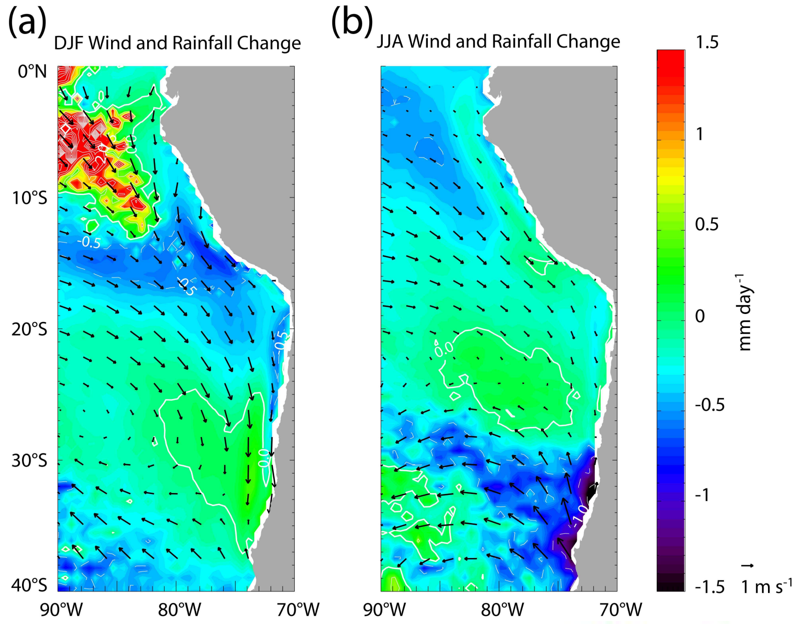


Warm and moist biases off Peru in CMIP3 GCMs (Christensen et al. 2007)

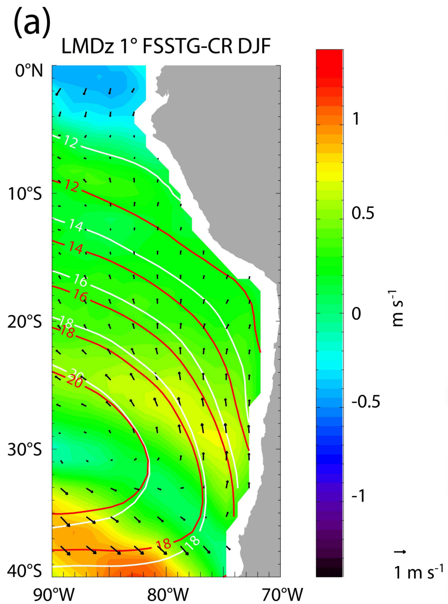
Strong warming off northern Peru with **increased rainfall** and **northwesterly anomalies** in many GCMs including IPSL-CM4

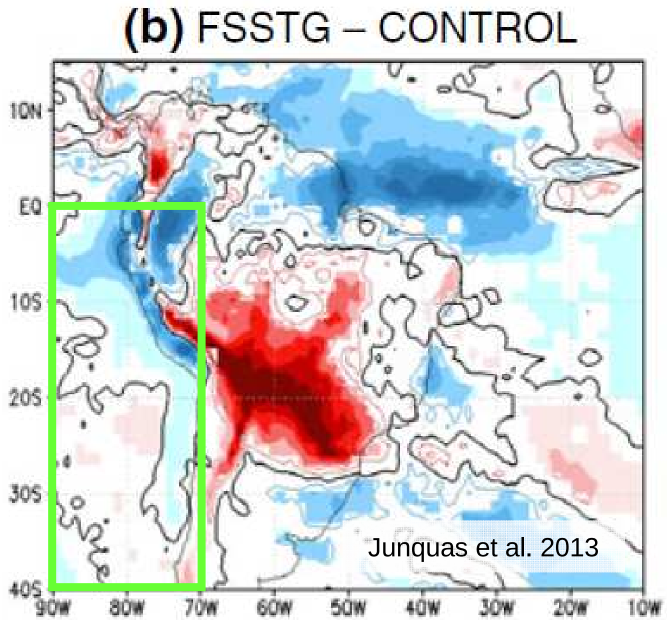
Likely associated with **increased convection**

Precipitation/Wind in LMDz



LMDz05 reproduces the **increased rainfall and reduced winds off northern Peru** in summer





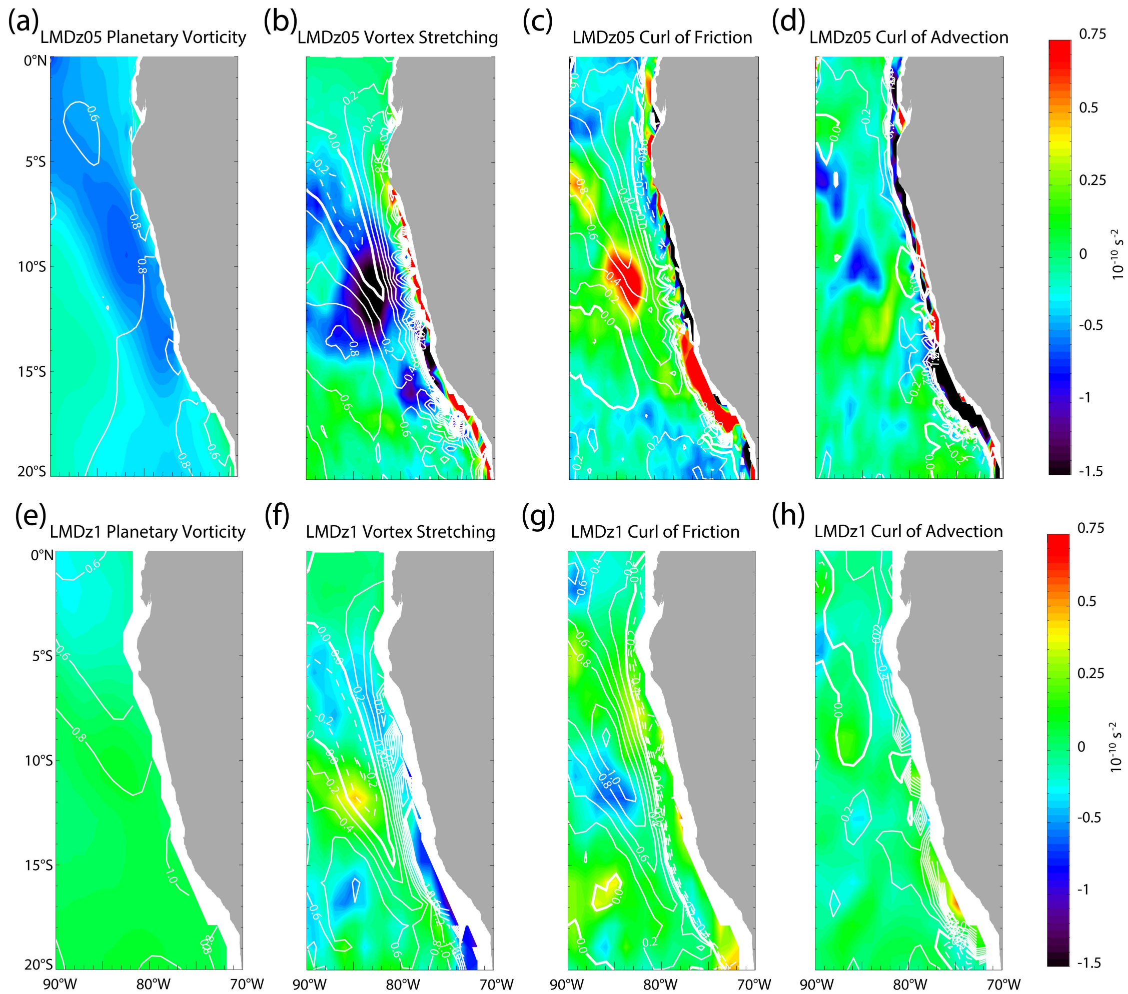
LMDz1 has **increased rainfall south of northerly anomalies**

Changes

Meridional Wind and Convection

Vorticity budget

$$\underbrace{\beta V}_{\text{Planetary Vorticity}} \approx \underbrace{f\frac{\partial W}{\partial z}}_{\text{Vortex Stretching}} + \underbrace{\left(\frac{\partial V_m}{\partial x} - \frac{\partial U_m}{\partial y}\right)}_{\text{Curl of Friction}} - \underbrace{\left(\xi\frac{\partial U}{\partial x} + U\frac{\partial \xi}{\partial x} + \xi\frac{\partial V}{\partial y} + V\frac{\partial \xi}{\partial y} - \frac{\partial W}{\partial y}\frac{\partial U}{\partial z} + \frac{\partial W}{\partial x}\frac{\partial V}{\partial z} + W\frac{\partial \xi}{\partial z}\right)}_{\text{Curl of Advection}}$$



Similar balance in both RAMs

- βV balanced by $\partial V_m/\partial x - \partial U_m/\partial y$ in regions of convection ($f\,\partial W/\partial z < 0$)
- βV balanced by $f\,\partial W/\partial z$ further south
- Advection is generally weak

@5-15°S in LMDz05, balanced βV and $f\,\partial W/\partial z$ **negative anomalies** explain wind anomaly collocated with rainfall increase.

@5-10°S in LMDz1, weak $f\,\partial W/\partial z$ **anomalies** cause no wind change despite the rainfall increase

@0-5°S in both RAMs, balanced βV **and** $\partial V_m/\partial x - \partial U_m/\partial y$ **negative anomalies** suggest equatorial wind changes are driven by different processes.

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Conclusion

• **Dynamical downscaling** off **Peru-Chile** to study the response of **alongshore wind** and wind stress curl to idealized **climate scenarios**.

• **LMDz05** forced by IPSL-CM4: **weakening of upwelling-favorable winds and Ekman pumping off Peru and northern Chile**, **intensification off central Chile** with a quasi-linear response to CO_2 increase.

• **LMDz1** forced by multimodel mean: **moderate weakening off northern Peru and intensification elsewhere**.

• **Opposed wind projections for Peru and Chile may be robust** features in the CMIP3 climate scenarios.

Conclusion

- Consistently with previous studies, **the alongshore wind is driven by the alongshore pressure gradient** (frictional balance resulting from the Andes). Thus **the increased Chile winds are likely due to poleward shift and/or an intensification of the South Pacific anticyclone**.
- **The reduced Peru winds in summer may be related to anomalous upward motion and increased rainfall associated with enhanced warming in the tropics** in GCMs and LMDz05.
- The strong biases off Peru in GCMs **do not allow assessing the relevance of the precipitation/SST/wind changes to the real climate**.

Gracias por su atención !