Impact of climate change on wind driven upwelling season off the coast Peru-Chile

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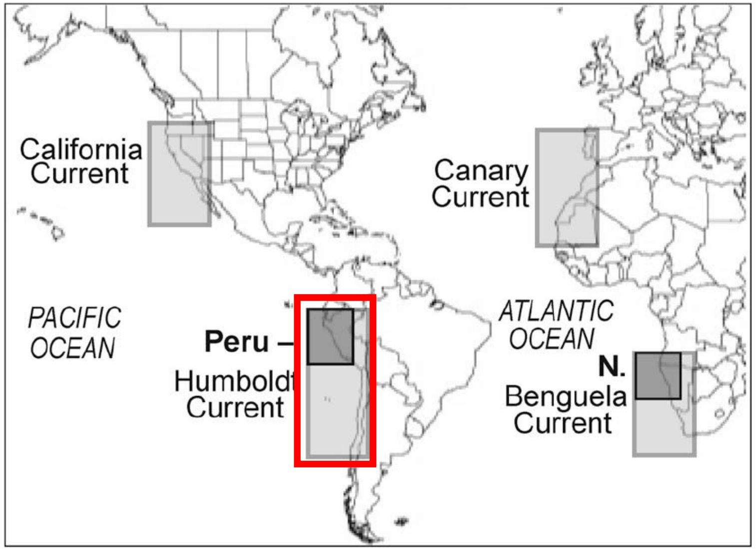
Climate and regional change, 16-19 November 2010

Surface wind is a key aspect of the regional environment

Exceptionally high biological productivity of the coastal ocean off Chile and Peru is due to the upwelling of cold, nutrient-rich waters.

Eastern Boundary Upwelling Systems



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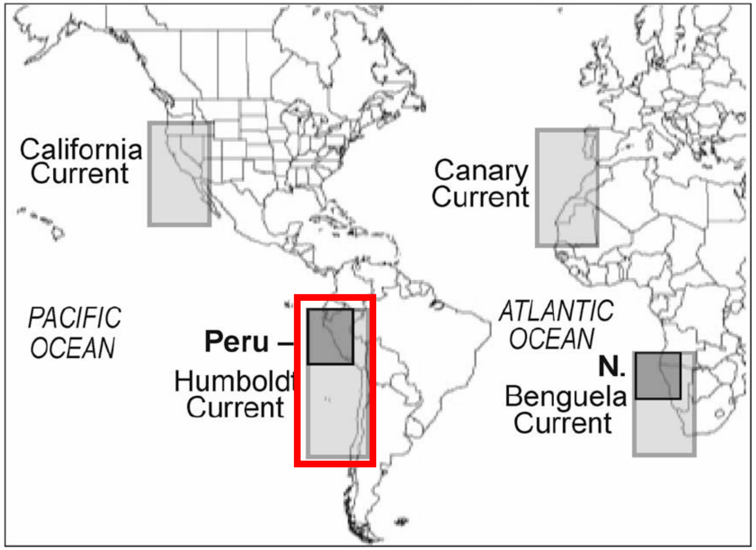

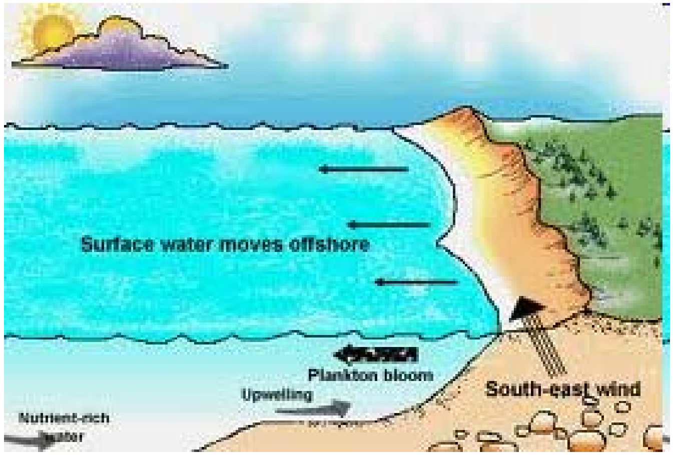

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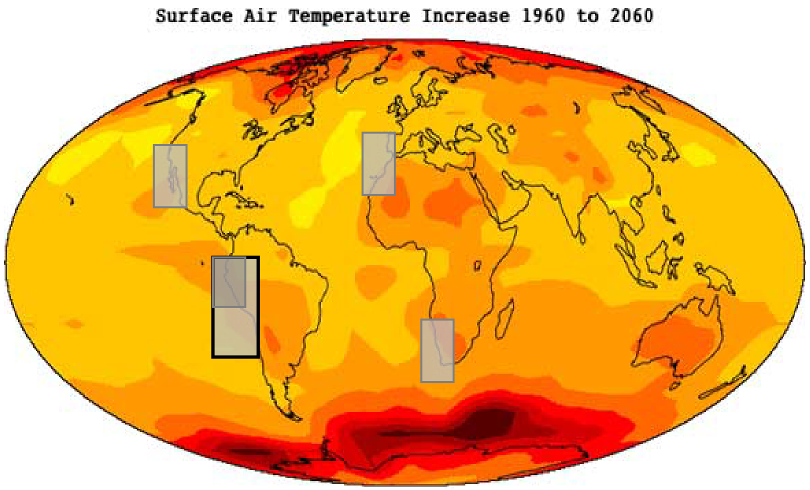


Objective: Assess the impact of climate change associated to increasing green house gases on regional low-level wind.

Outline

1. Introduction

2. Present climate wind regime

3. Large–scale CGCMs projections

4. Downscaling
   a) General idea + Method used
   c) Validation

5. Regional wind change

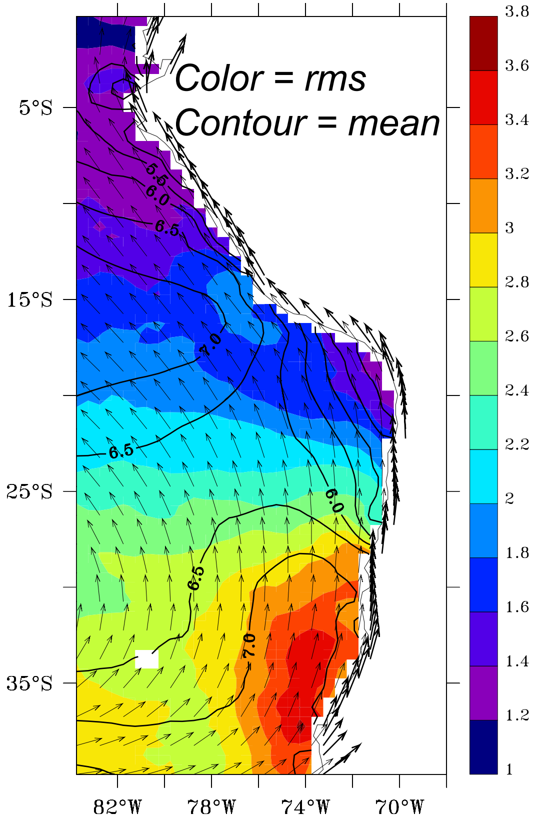
6. Summary

7. Out-going work & Perspectives

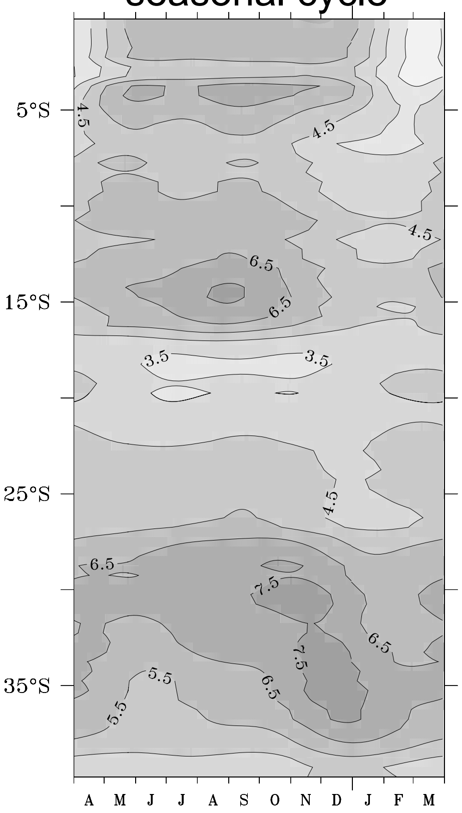
Alongshore wind regime

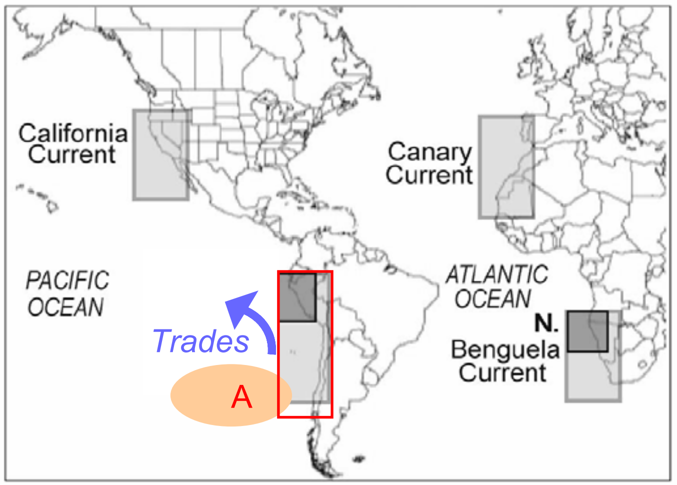
QuikSCAT 2000-2009

10m-wind



Alongshore wind seasonal cycle

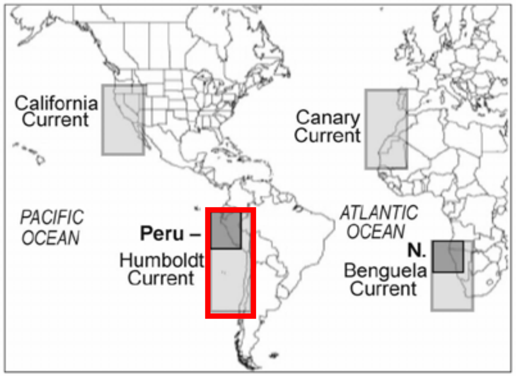


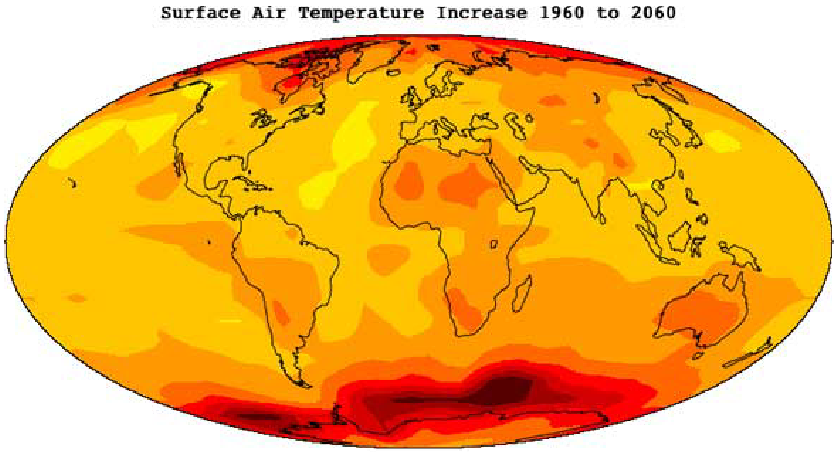


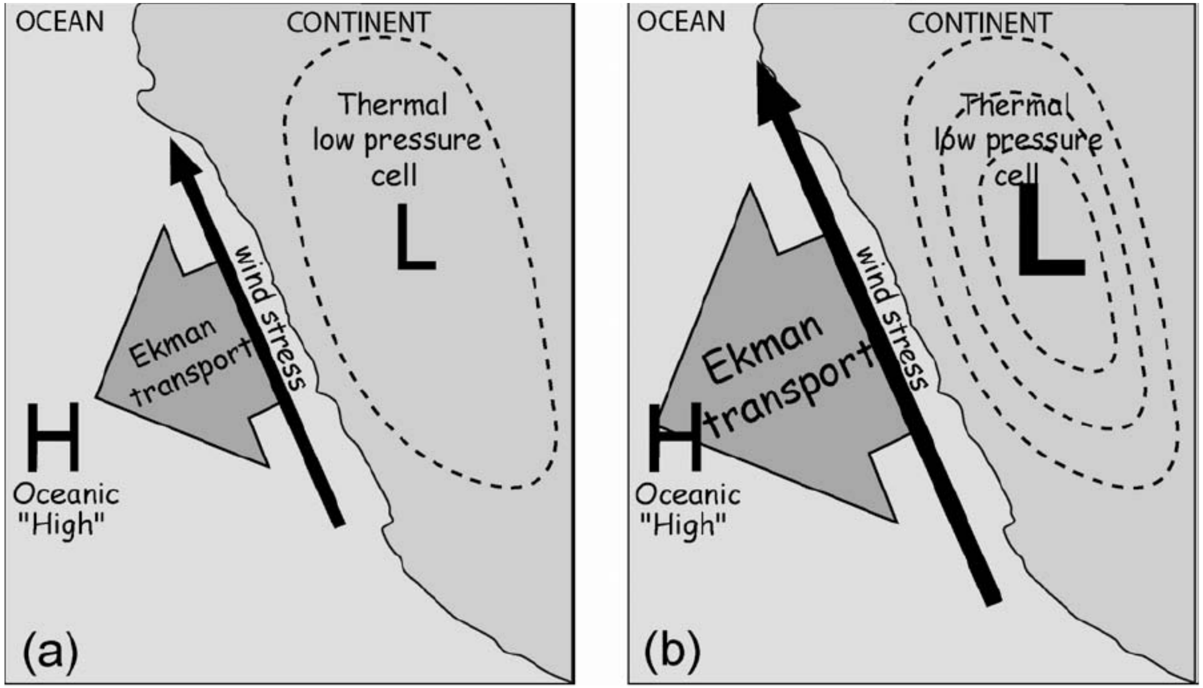
Two regions of Coastal Jet events with local maxima in mean wind and variance near the coast

- off Central Peru (~15°S)
- off Central Chile (~30°S)

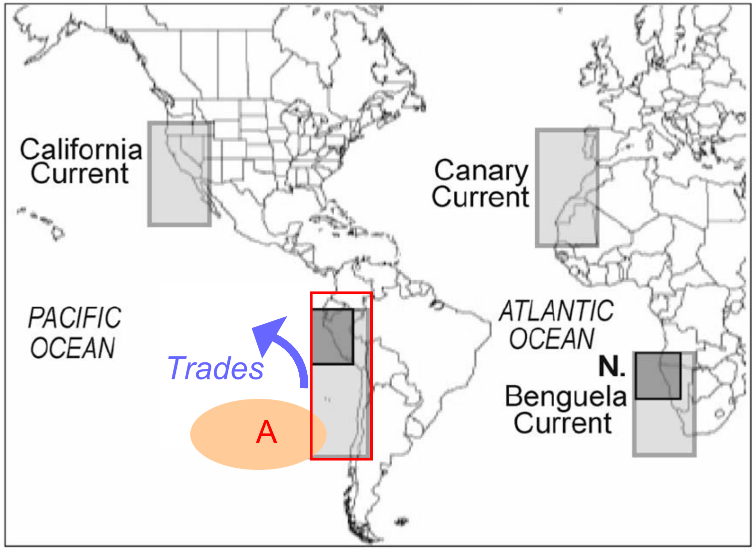
Bakun's hypothesis(1990)







Future change in large-scale conditions



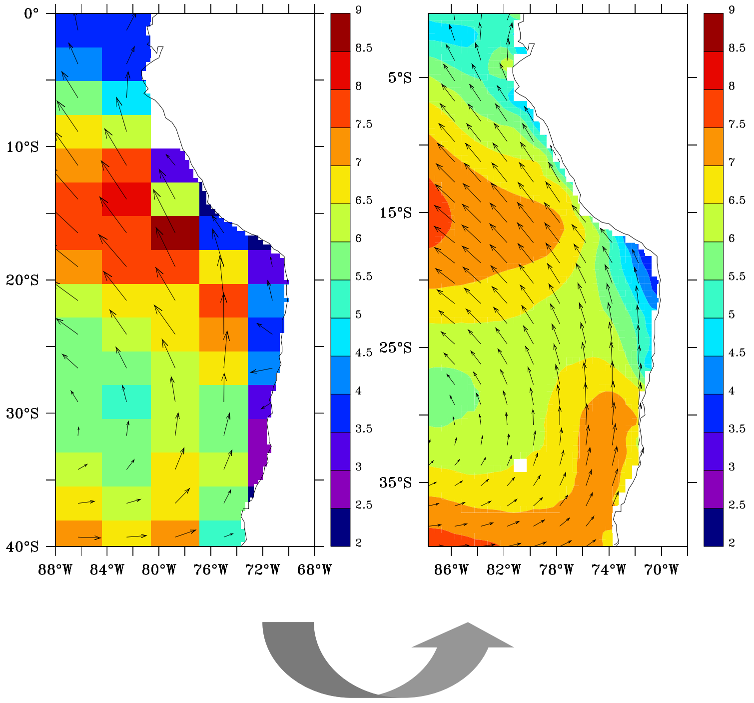
- The climate projections of the IPCC GCMs show an increase in surface pressure just to the south of the SEP anticyclone (Garreaud and Falvey, 2009). The resulting increase in meridional pressure gradient drives an intensification of the southerly alongshore flow between about 25°S and 40°S.

- In the tropics, the IPCC models predict a reduction of the mean Walker (Vecchi and Soden, 2007) and Hadley circulations (Zhang and Song, 2006; Held and Soden, 2006; Gastineau et al., 2008)

Downscaling of the CGCM output. Method

10m wind speed simulated by a CGCM

10m wind speed from QuikSCAT



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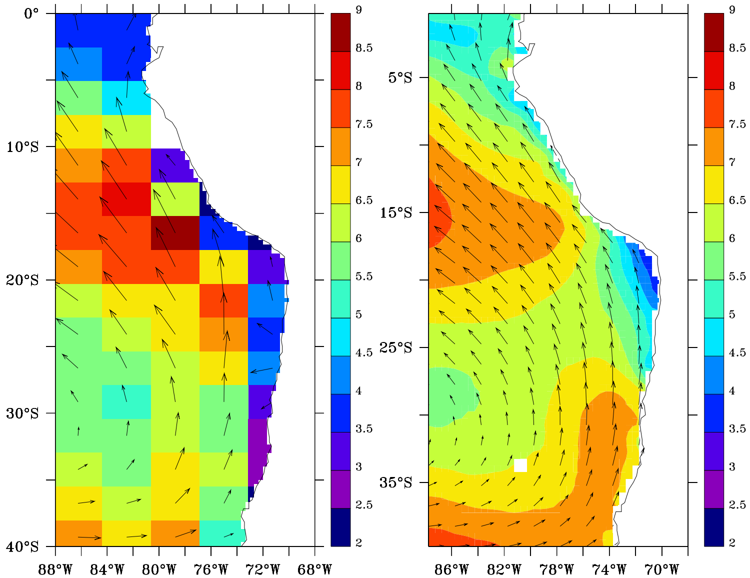


Statistical downscaling

Relationship between the large-scale predictors and region variables of interest

$$Y_{obs} = F(X_{obs}) + \varepsilon \quad \longrightarrow \quad F(X_{CGCM}^{Future}) \approx Y^{Future}$$

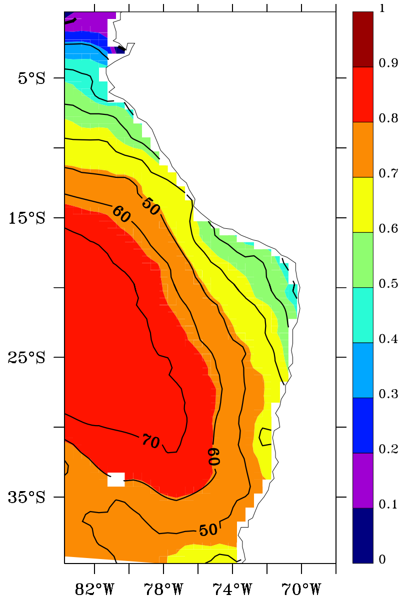
Y – regional variables (predictands)
X – large-scale variables (predictors)
ε – error

F – Multiple linear regression
Y – 10 m wind from QuikSCAT 2000-2008, 0.5x0.5°
X – 10 m wind + SLP from NCEP, 2.5°x2.5°

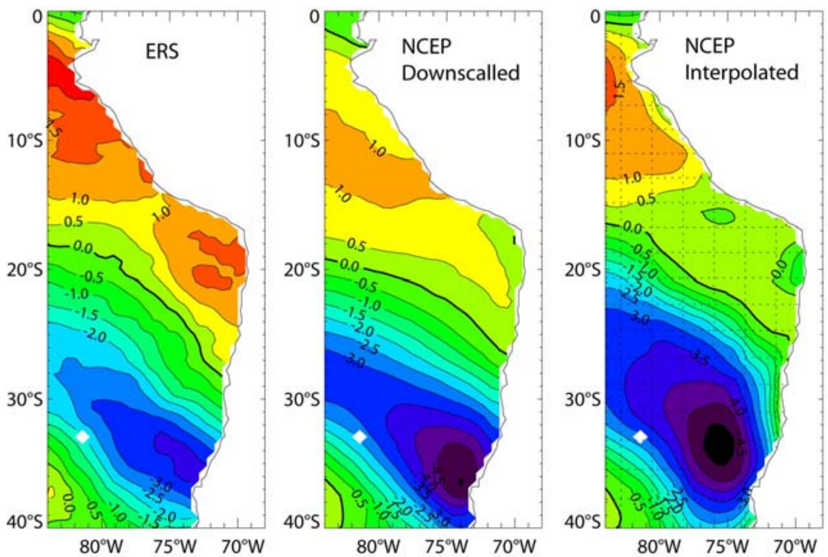
Validation of the downcaling method

- The skill of the downscaling method is assessed by comparing with the surface wind derived from the ERS satellite measurements, with in-situ wind observations collected by ICOADS and through cross-validation

Correlation between downscaled products over 1992-1999 and ERS wind (contour – explained variance in %)



El-Nino (Sep 1997) – La-Nina (Dec 1998)



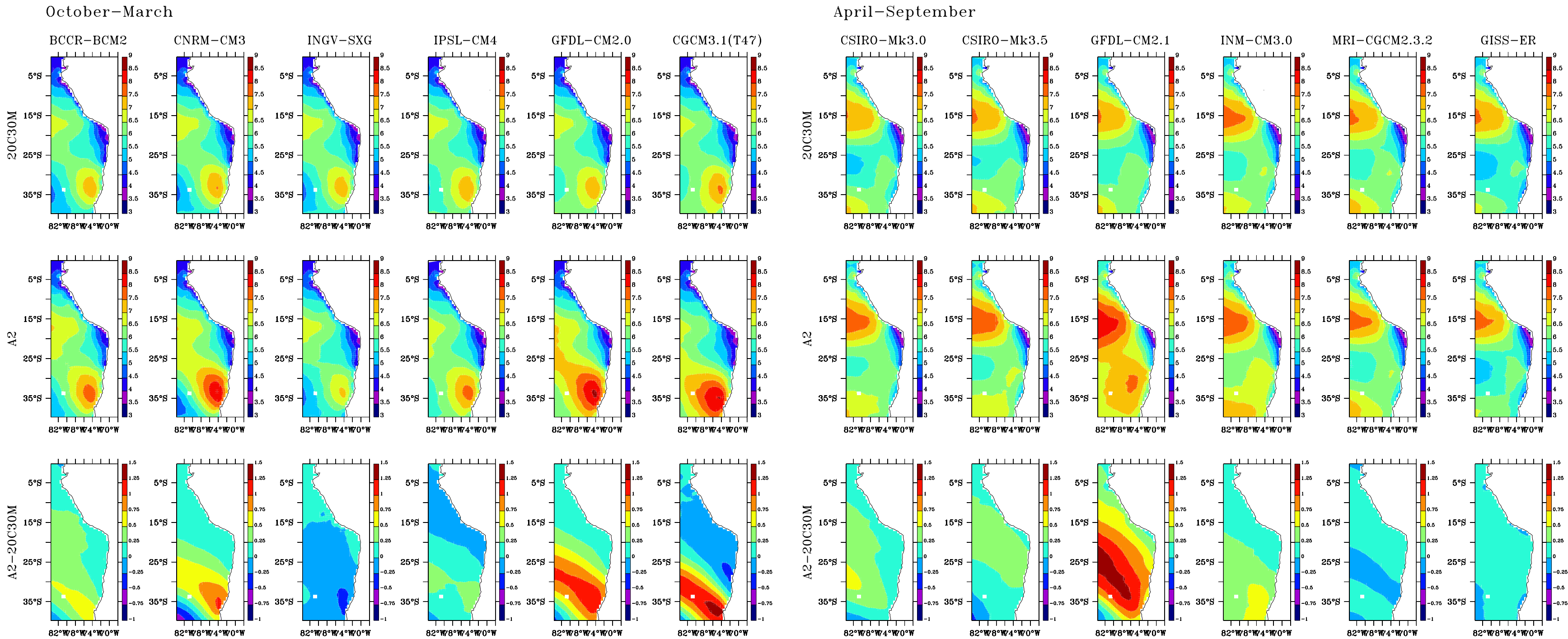
(*Goubanova et al., Climate Dynamics 2010*)

CGCMs and scenarios

Present climate scenario – **20C3M** 1981-2000
Future climate scenario - **A2 SRES** 2081-2100

BCCR - BCM2.0	*Bjerknes Centre for Climate Research*	**Norway**
CGCM3.1(T47)	*Canadian Centre for Climate Modelling & Analysis*	**Canada**
CNRM - CM3	*Météo-France / Centre National de Recherches Météorologiques*	**France**
CSIRO - MK30	*CSIRO Atmospheric Research*	**Australia**
CSIRO - MK35	*CSIRO Atmospheric Research*	**Australia**
GFDL - CM2.0	*US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory*	**USA**
GFDL - CM2.1	*US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory*	**USA**
INGV – SXG	*Instituto Nazionale di Geofisica e Vulcanologia*	**Italy**
IPSL - CM4	*Institut Pierre Simon Laplace*	**France**
INM-CM3.0	*Institute for Numerical Mathematics*	**Russia**
MRI - CGCM2_3_2	*Meteorological Research Institute*	**Japan**
GISS-ER	*NASA / Goddard Institute for Space Studies*	**USA**

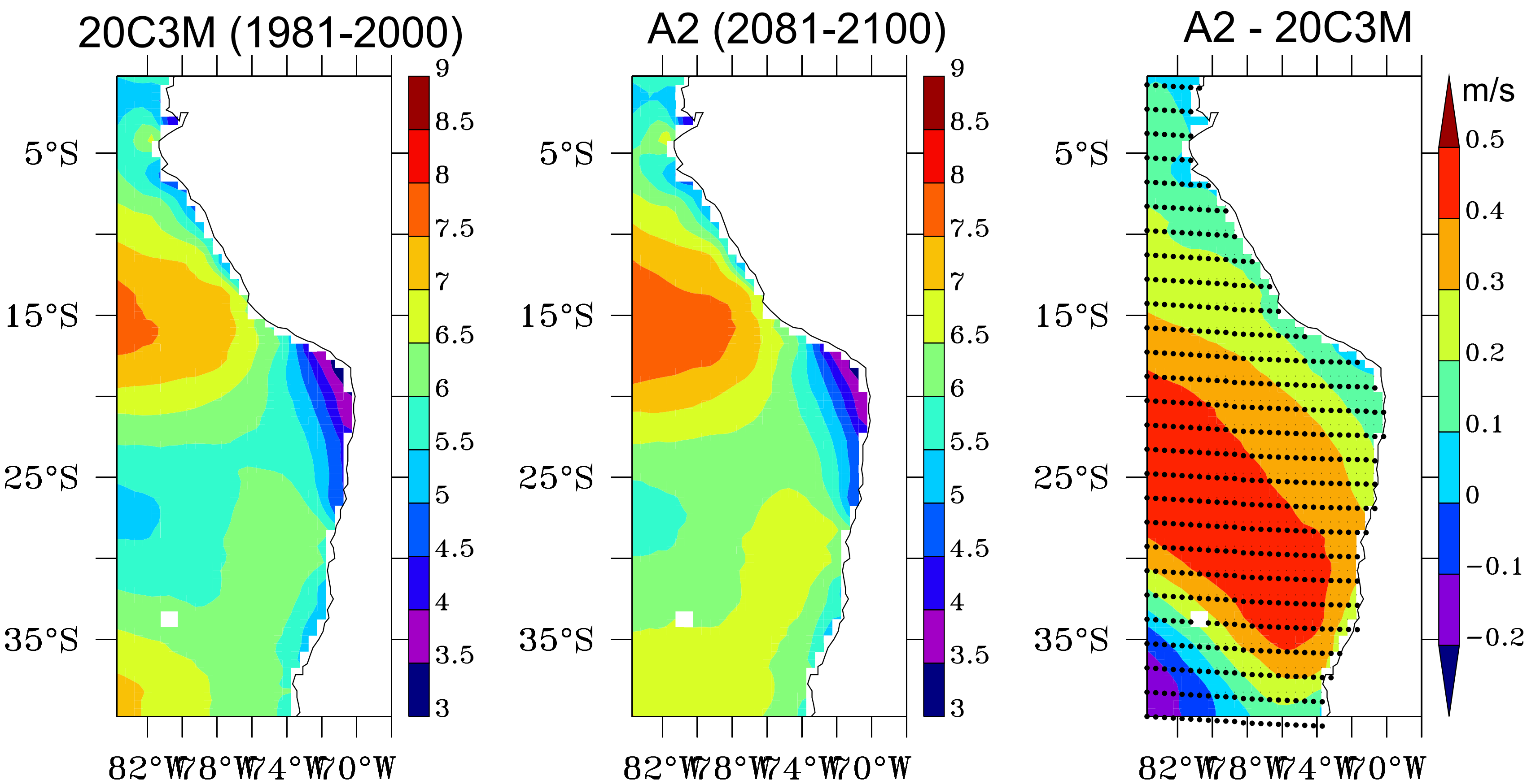
Results



October−March
April−September
BCCR−BCM2
CNRM−CM3
INGV−SXG
IPSL−CM4
GFDL−CM2.0
CGCM3.1(T47)
CSIRO−Mk3.0
CSIRO−Mk3.5
GFDL−CM2.1
INM−CM3.0
MRI−CGCM2.3.2
GISS−ER
20C30M
A2
A2−20C30M

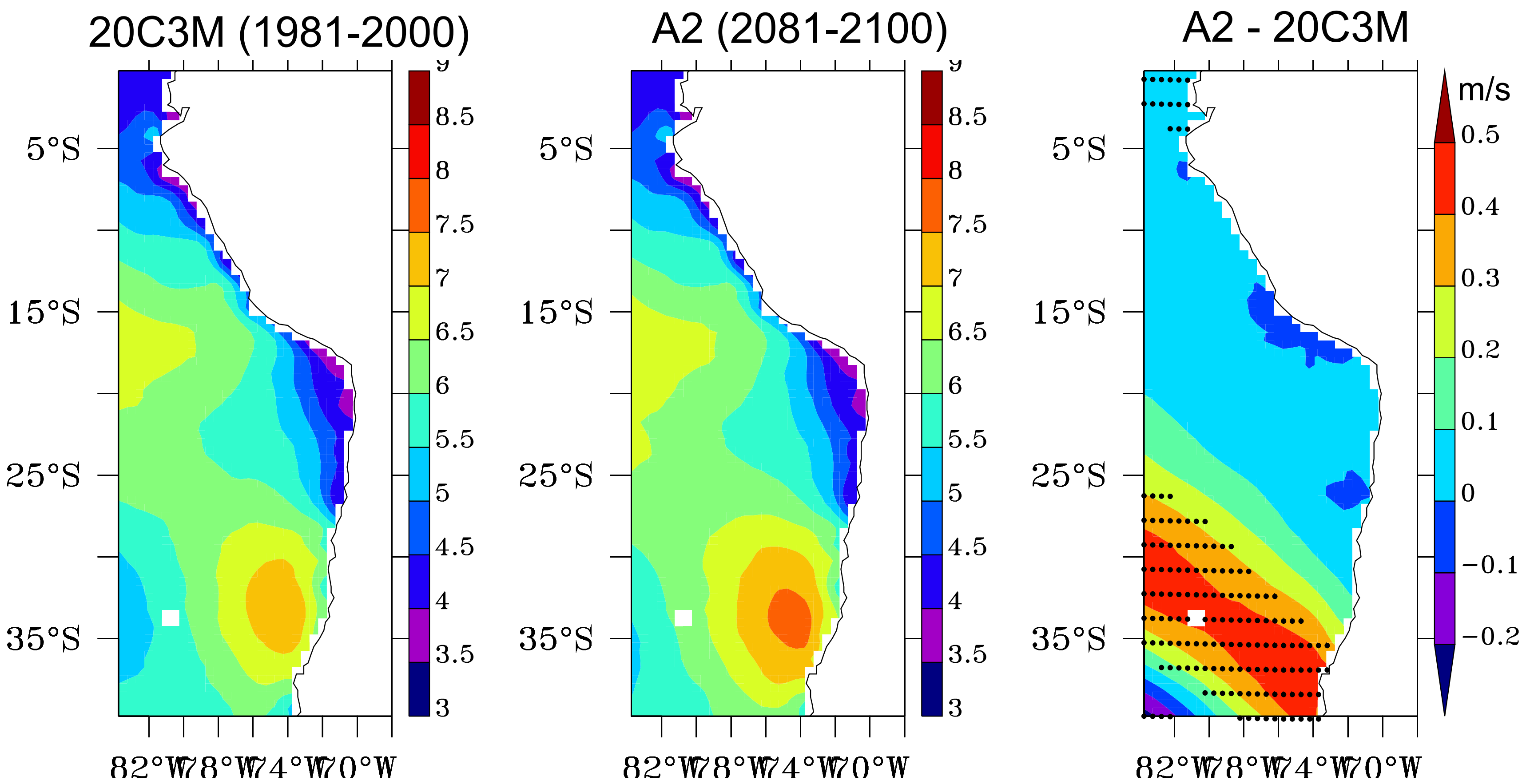
Winter change

April – September
Multimodel ensemble mean



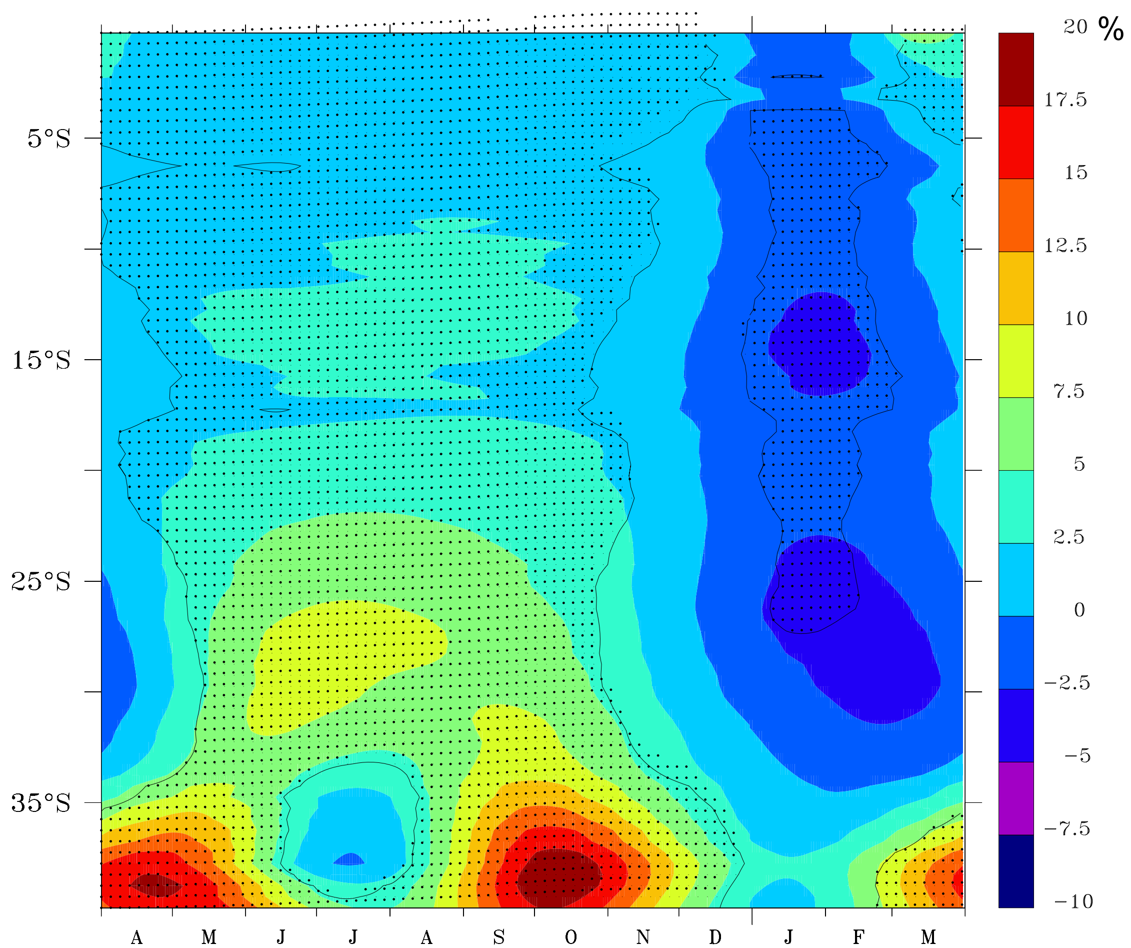
Summer change

October – March
Multimodel ensemble mean



Seasonal cycle change

Change in alongshore wind seasonal cycle: A2 – 20C3M



Seasonal cycle change

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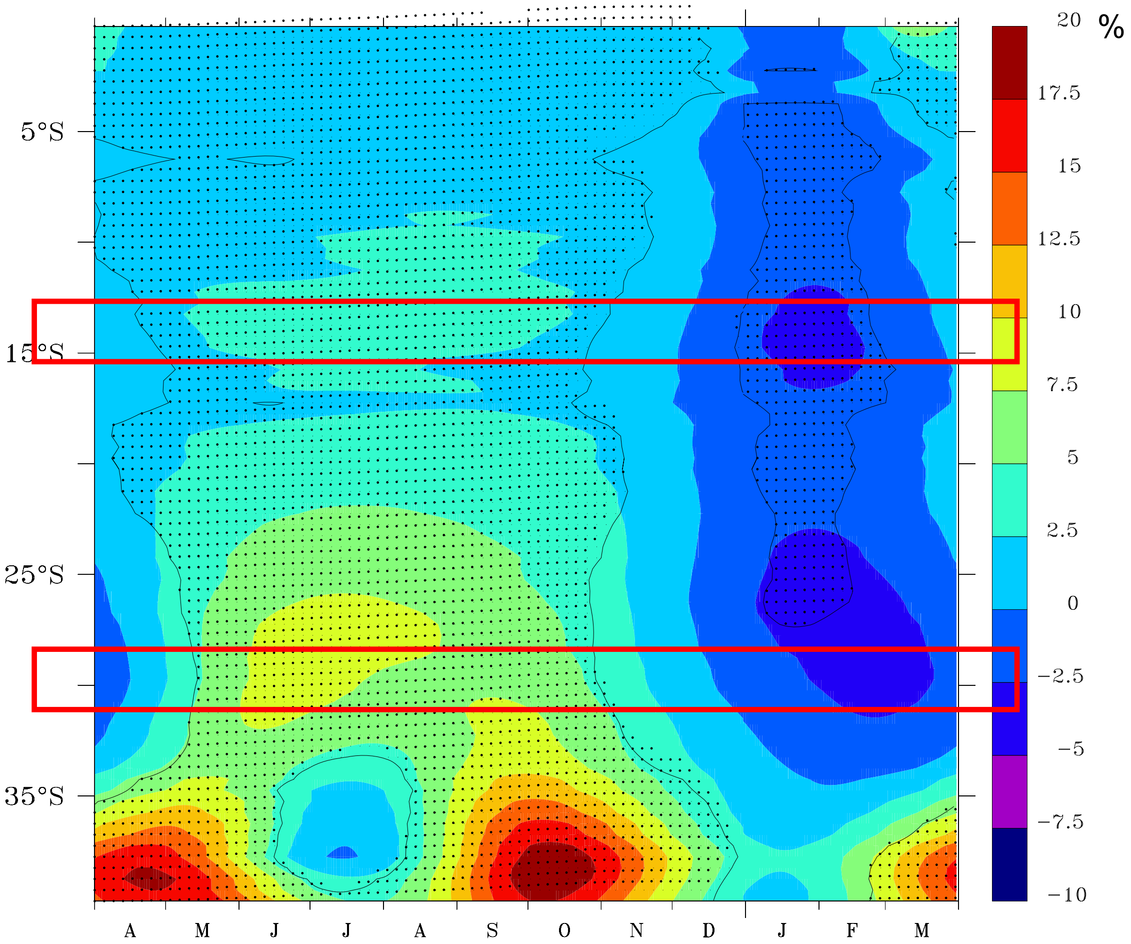
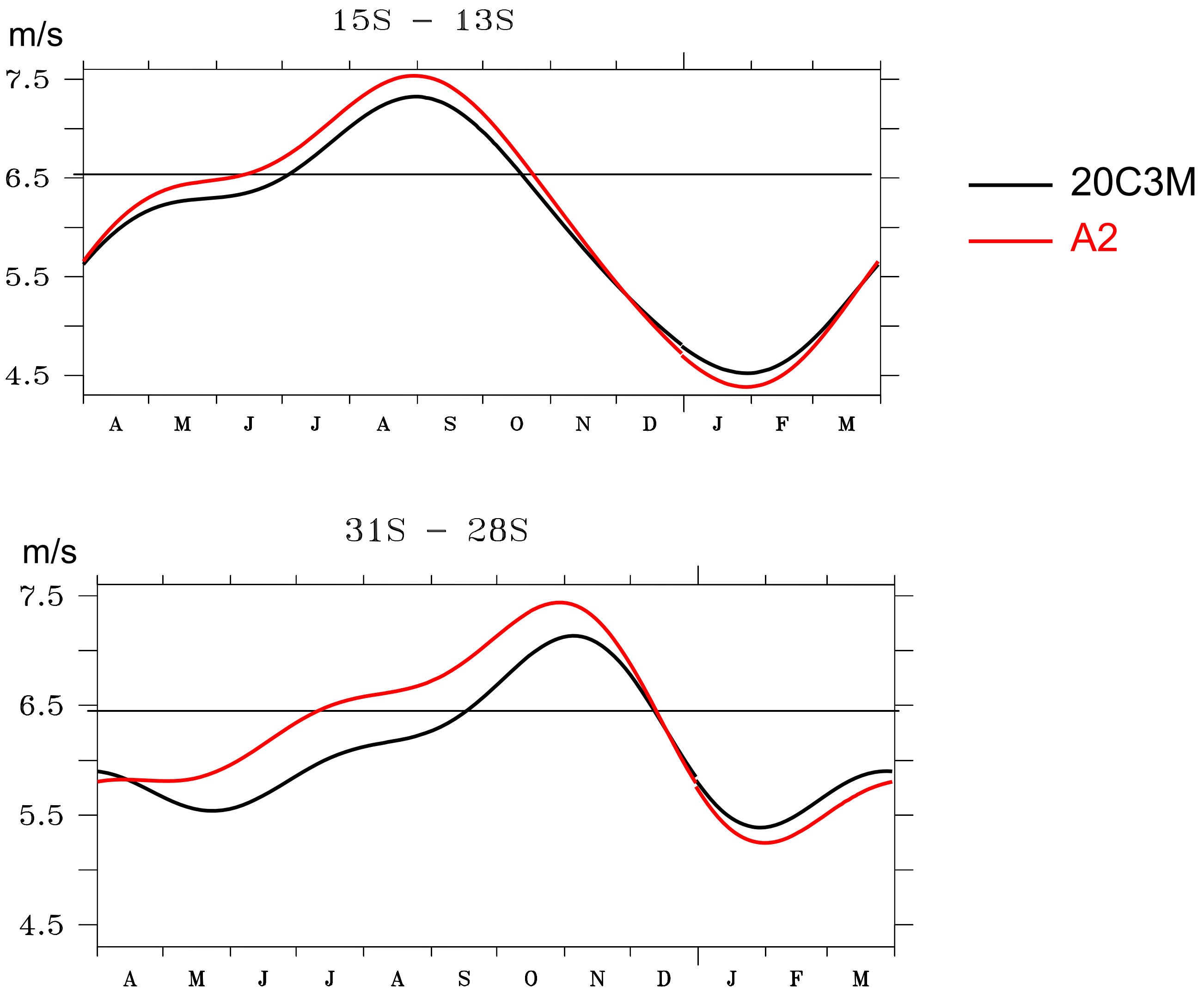


Seasonal cycle change



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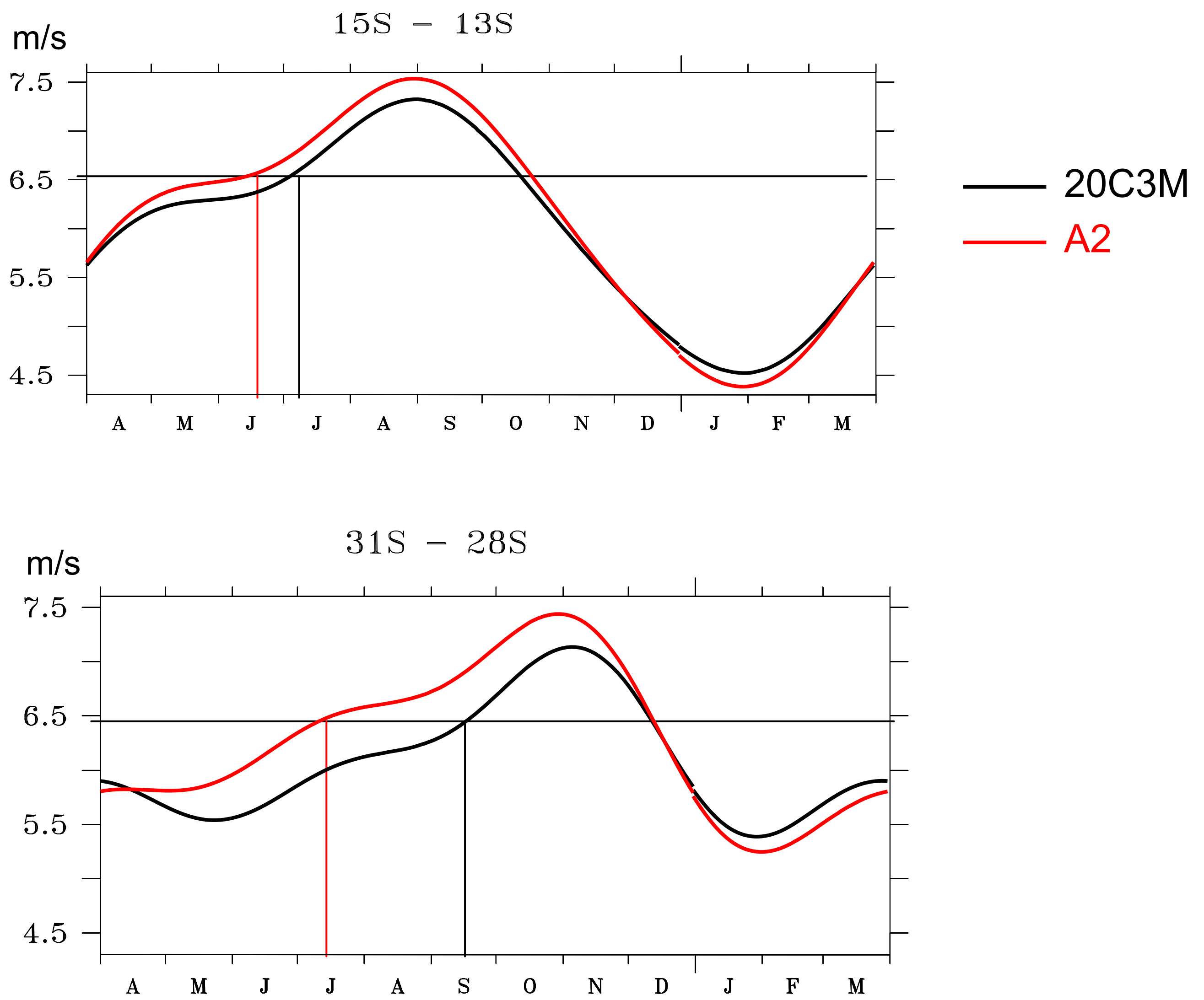


Regional change in wind regime. Summary

1. Significant increase in upwelling favorable wind for the winter season: it reaches 7.5% off Central Peru and 20% off Central Chile

2. Intensification of the coastal jet core off Chile in summer

3. A significant decrease (~5%) of along-shore wind off Peru during DJF

4. Increase of seasonal cycle in both zones of the coastal jet

5. Longer duration of the upwelling favorable season by ~3 weeks (2 months) off Central Peru (Chile).

- Off Chile the change is consistent with increasing surface pressure south of the SEP anticyclone and with a dynamical downscaling experiment using PRECIS regional model (Garreaud and Falvey, 2009).
- Off Peru the change is weak; apparently inconsistent with some observational record ..

On-going work & Perspectives

1. Using of statistically downscaled wind in order to force regional oceanic model (ROMS) under climate scenarios (*Echevin et al 2010, submitted*)

2. Dynamical downscaling of wind using WRF model (CORDEX project):

   - Wind + <u>Heat flux</u> for ROMS

   - Study relative role of large- and small scale processes associated with change in wind

Thank you!

Wind off Central Peru: Variability at ENSO scale

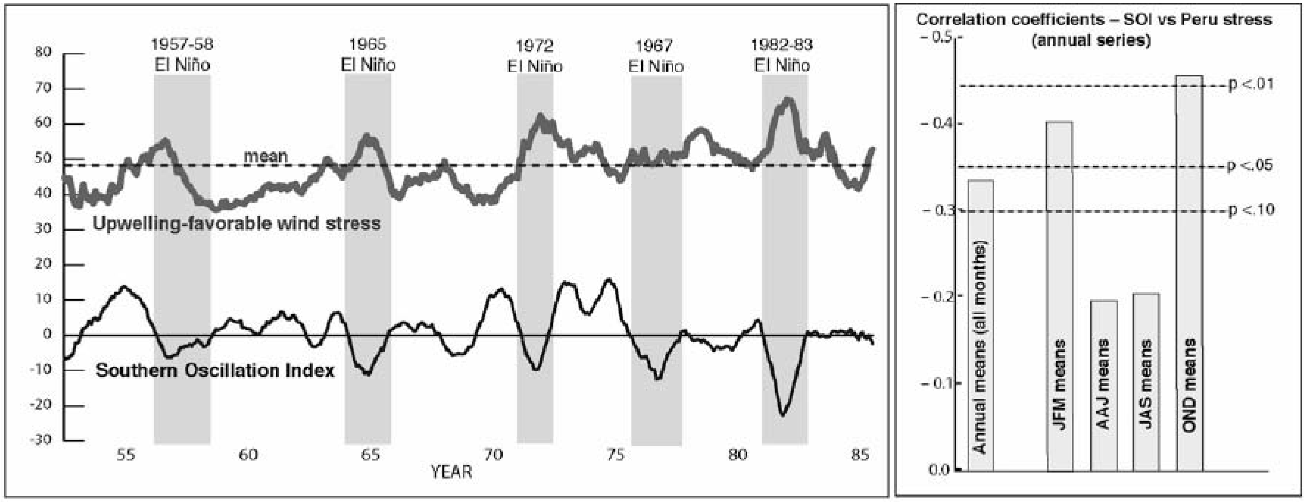
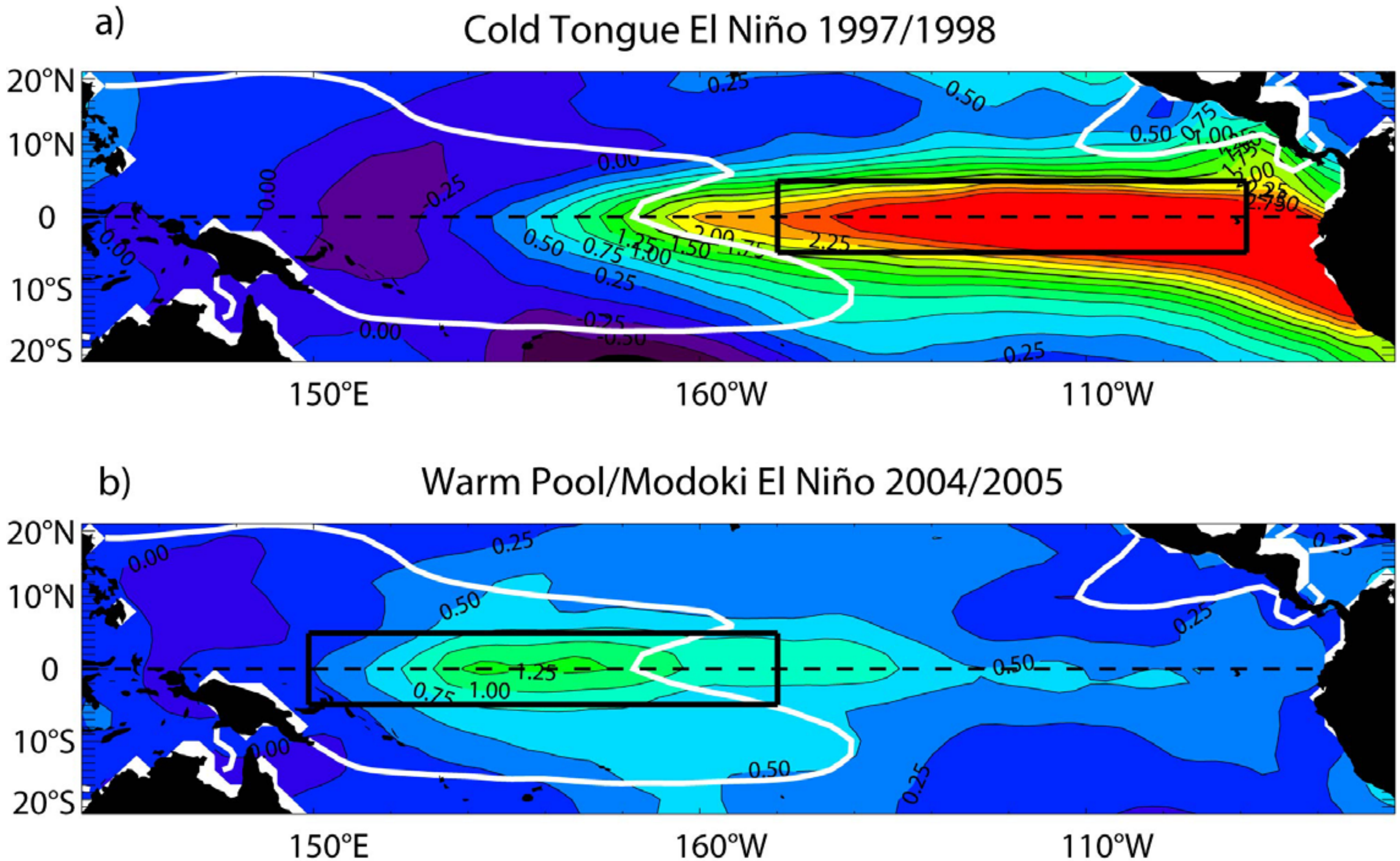


Fig. 6. Left panel: Anti-correlation, on the ENSO time scale, of low-pass-filtered (12-month running means of monthly values) Pacific trade wind strength (Southern Oscillation Index) and intensity of upwelling-favorable wind stress off Peru (as reported by Bakun and Mendelssohn (1989)). Right panel: Correlation coefficients between series of annual and quarterly means of unfiltered monthly values of the two time series. Significance levels (two-tailed tests) are indicated.

Tongue El Niño versus Warm Pool (Modoki) El Niño

DJF



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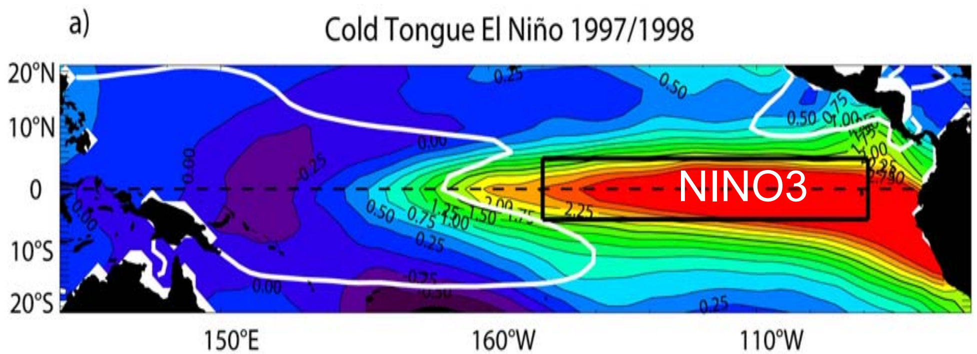
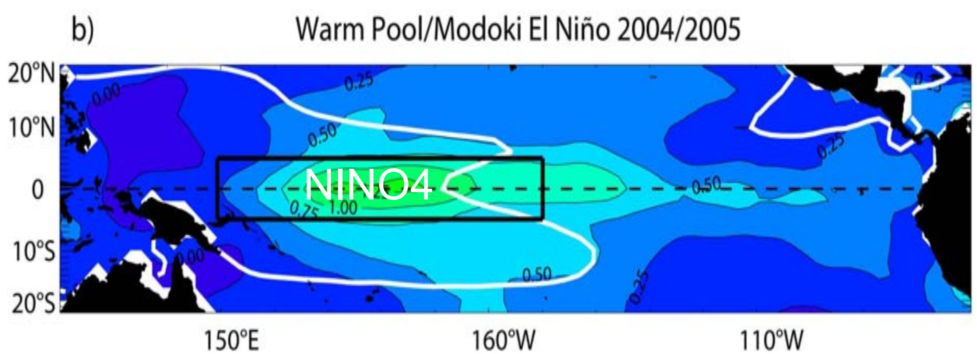
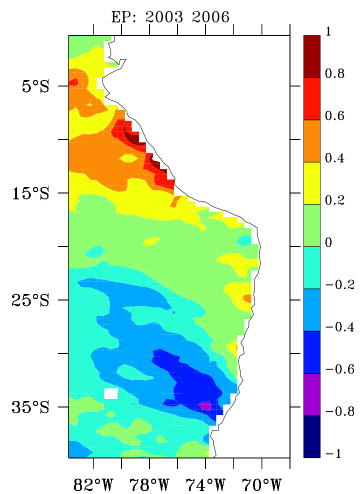
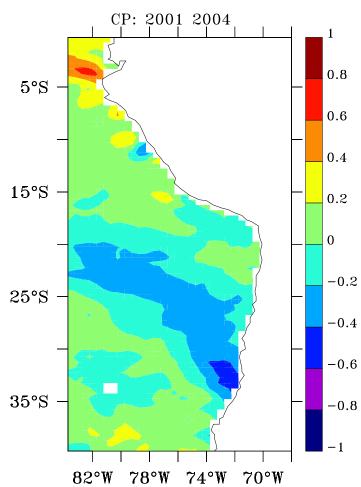




2000-2009





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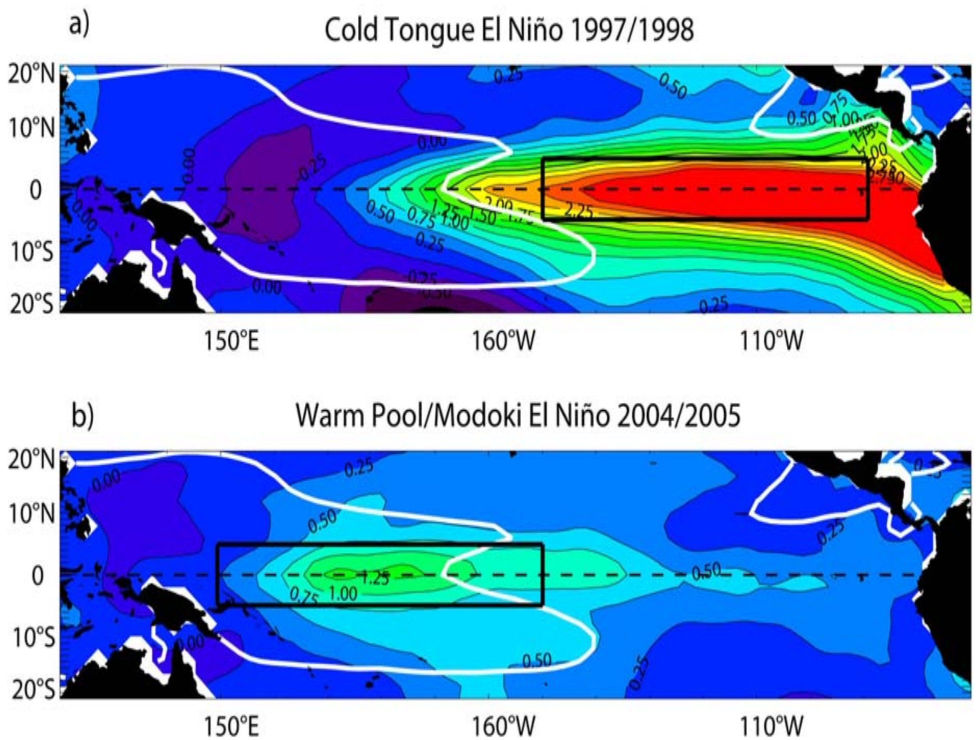
DJF



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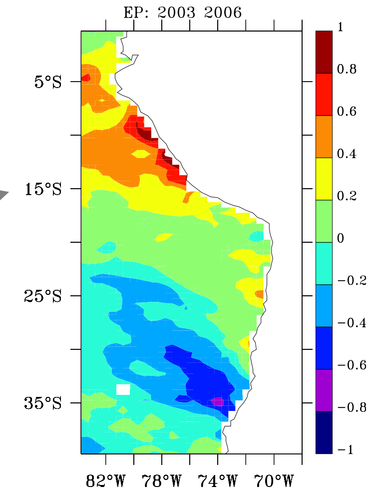

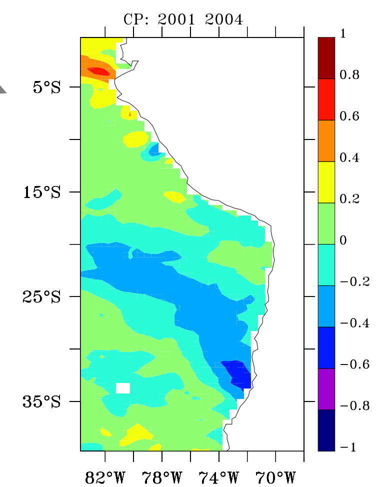

Projections of anthropogenic climate change are associated with an increased frequency of the Warm Pool El Niňo compared to the Cold Tongue El Niňo (*Yeh et al., 2009*).