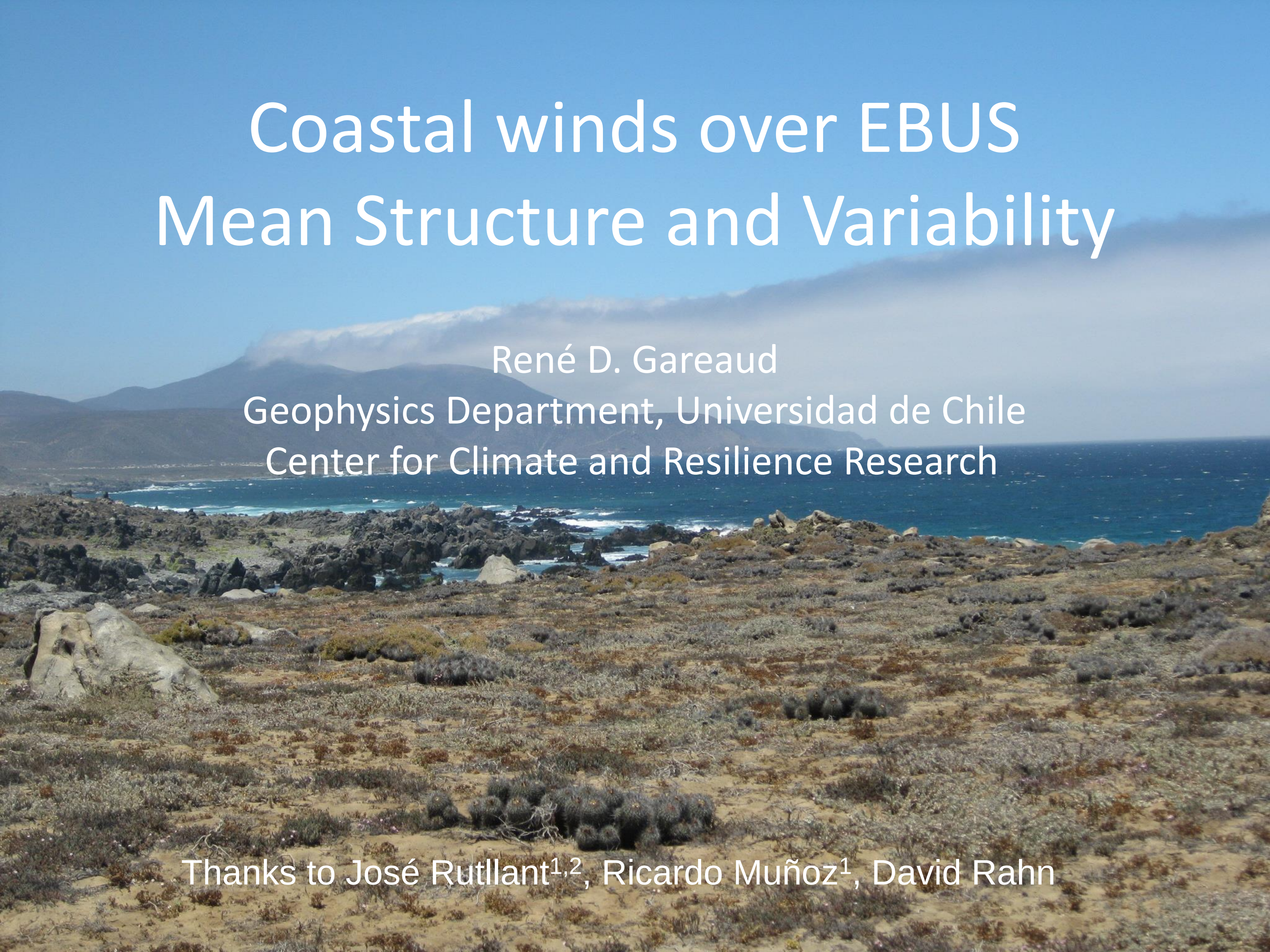


Coastal winds over EBUS Mean Structure and Variability

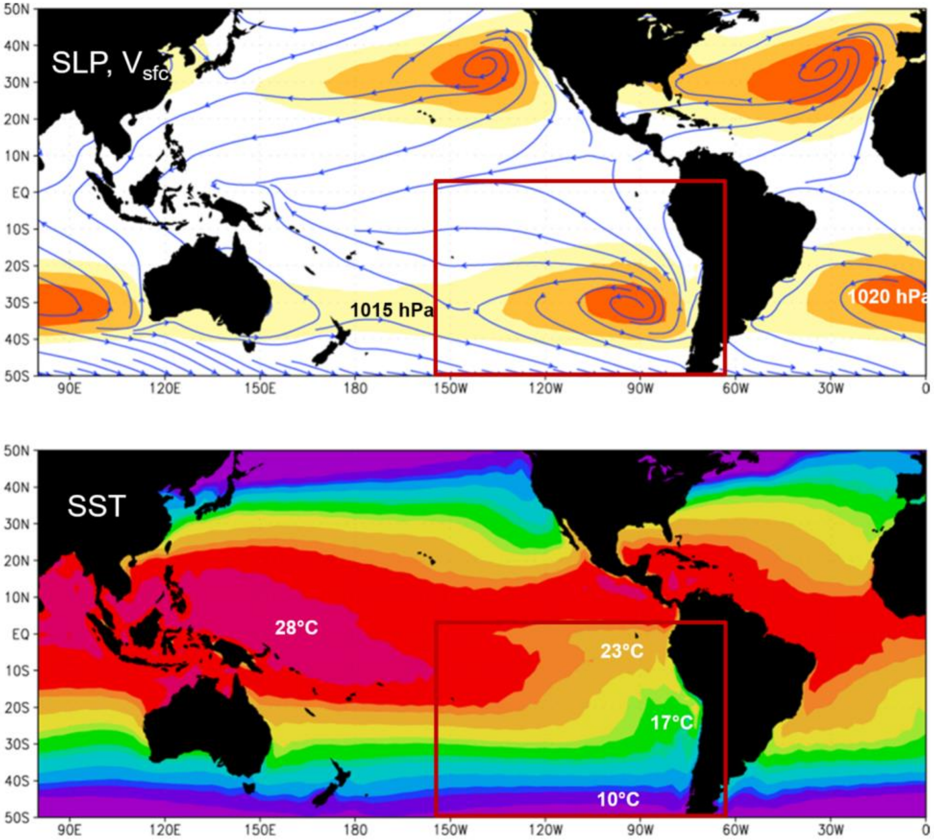
René D. Gareaud
Geophysics Department, Universidad de Chile
Center for Climate and Resilience Research

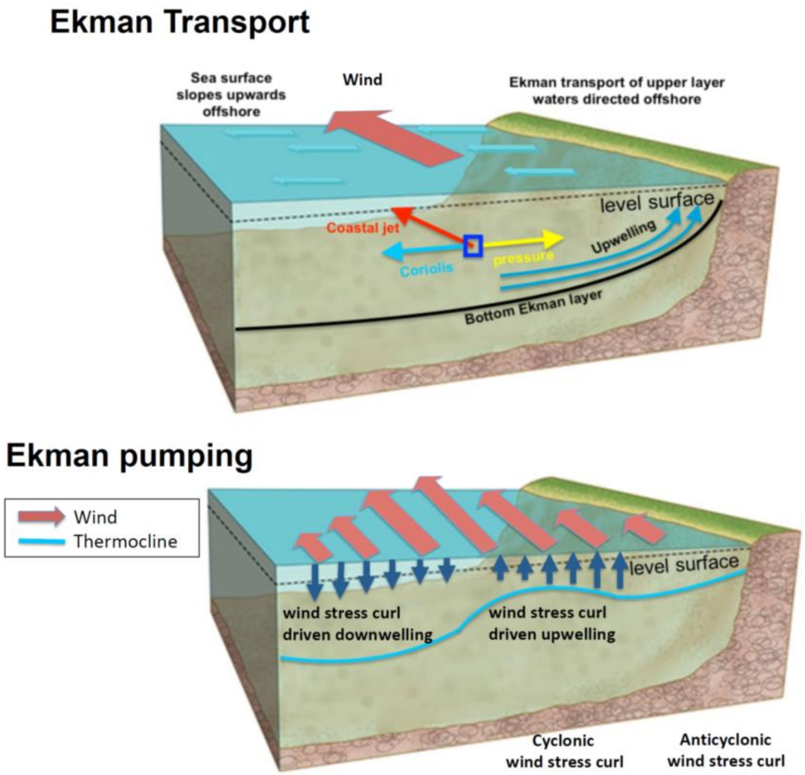
Thanks to José Rutllant[1,2], Ricardo Muñoz[1], David Rahn

Outline

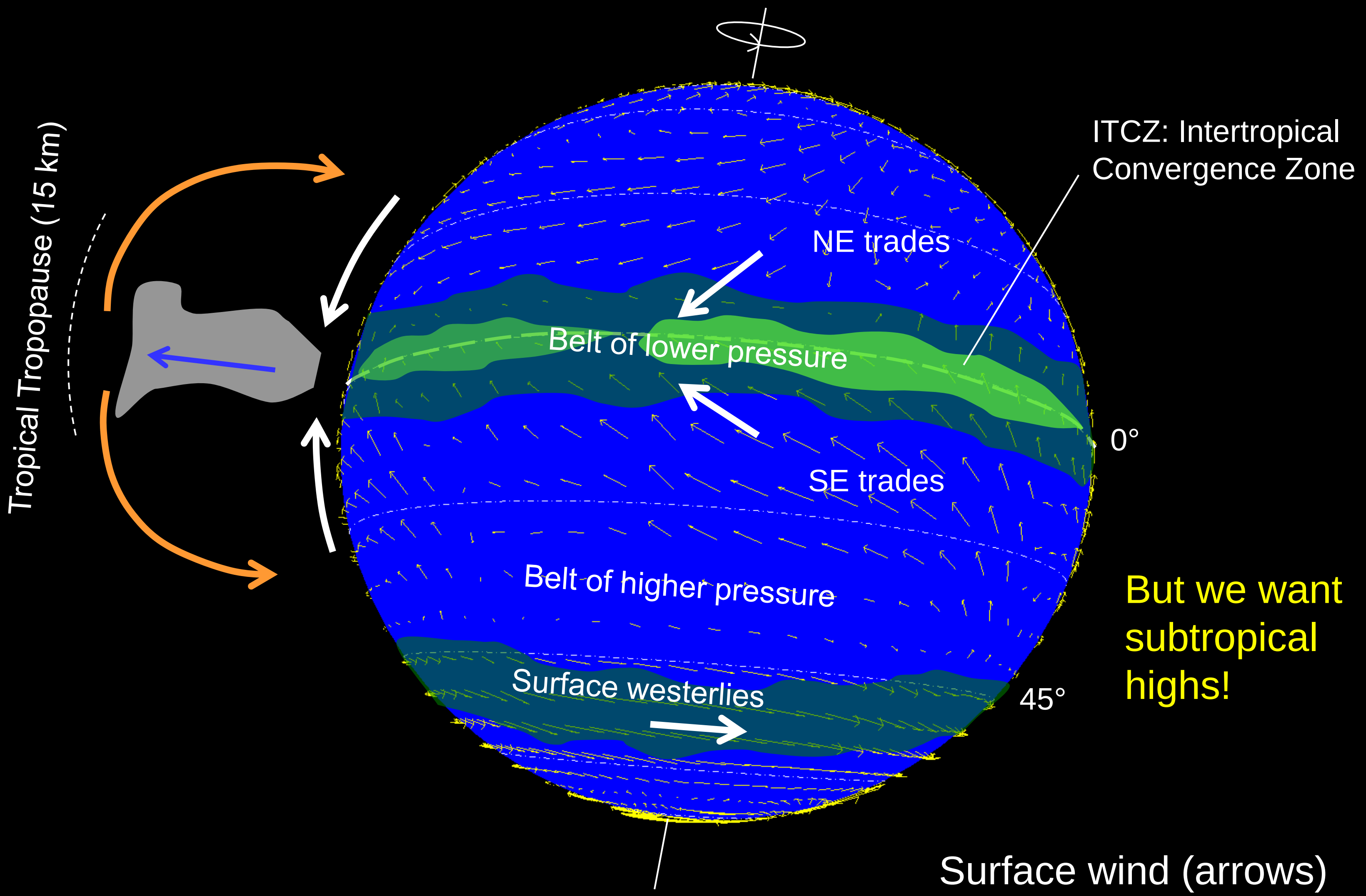
- Subtropical anticyclones: Hadley + Mnts + Monsoons
- Coastal jets (large-scale and local-scale mean structure)
- Coastal winds variability
- Extra bonus….when upwelling is gone….

EBUS: Subtropical anticyclones, equatorward flow and cold SST





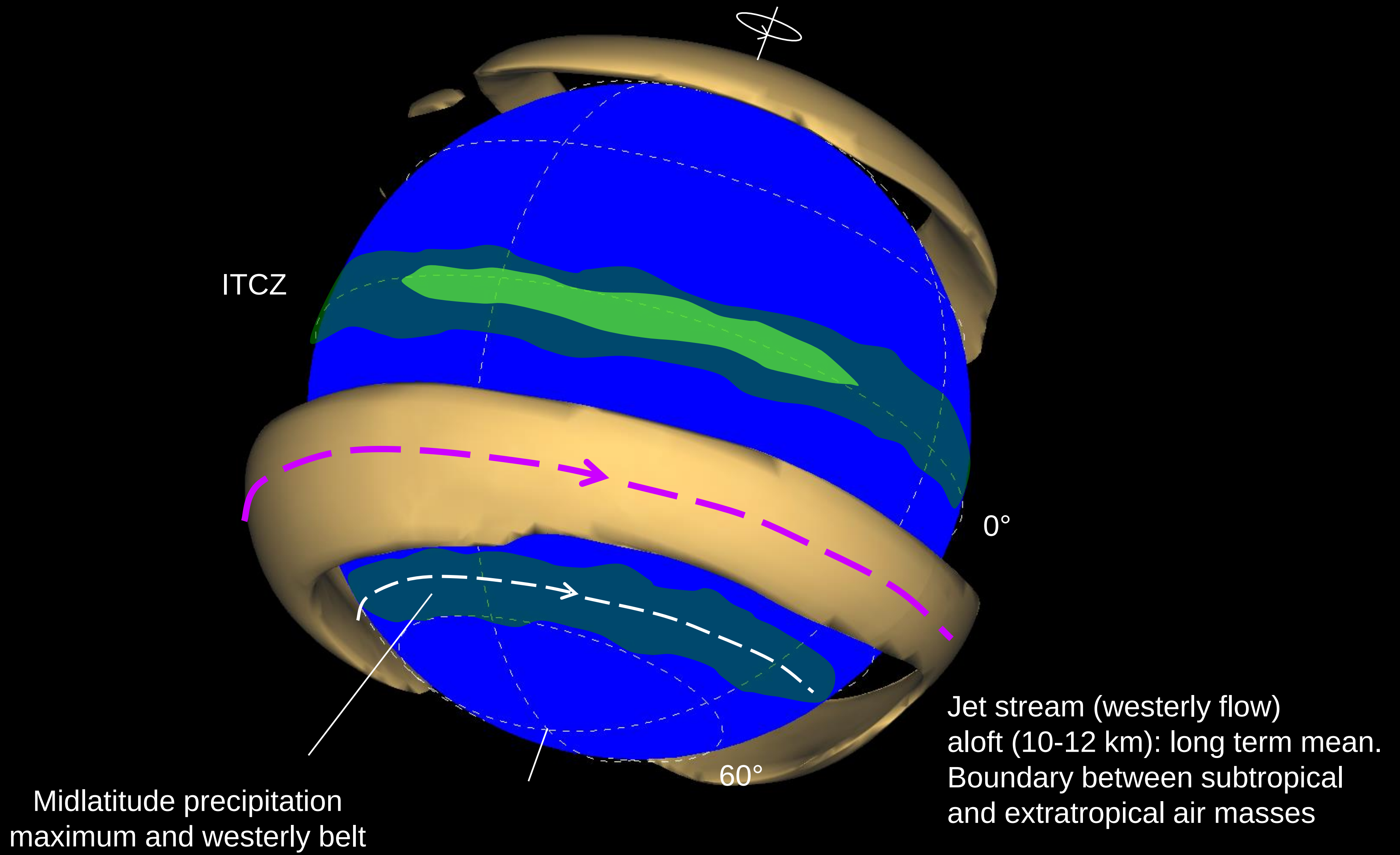
General circulation in an aqua-planet
Perpetual Equinox



But we want subtropical highs!

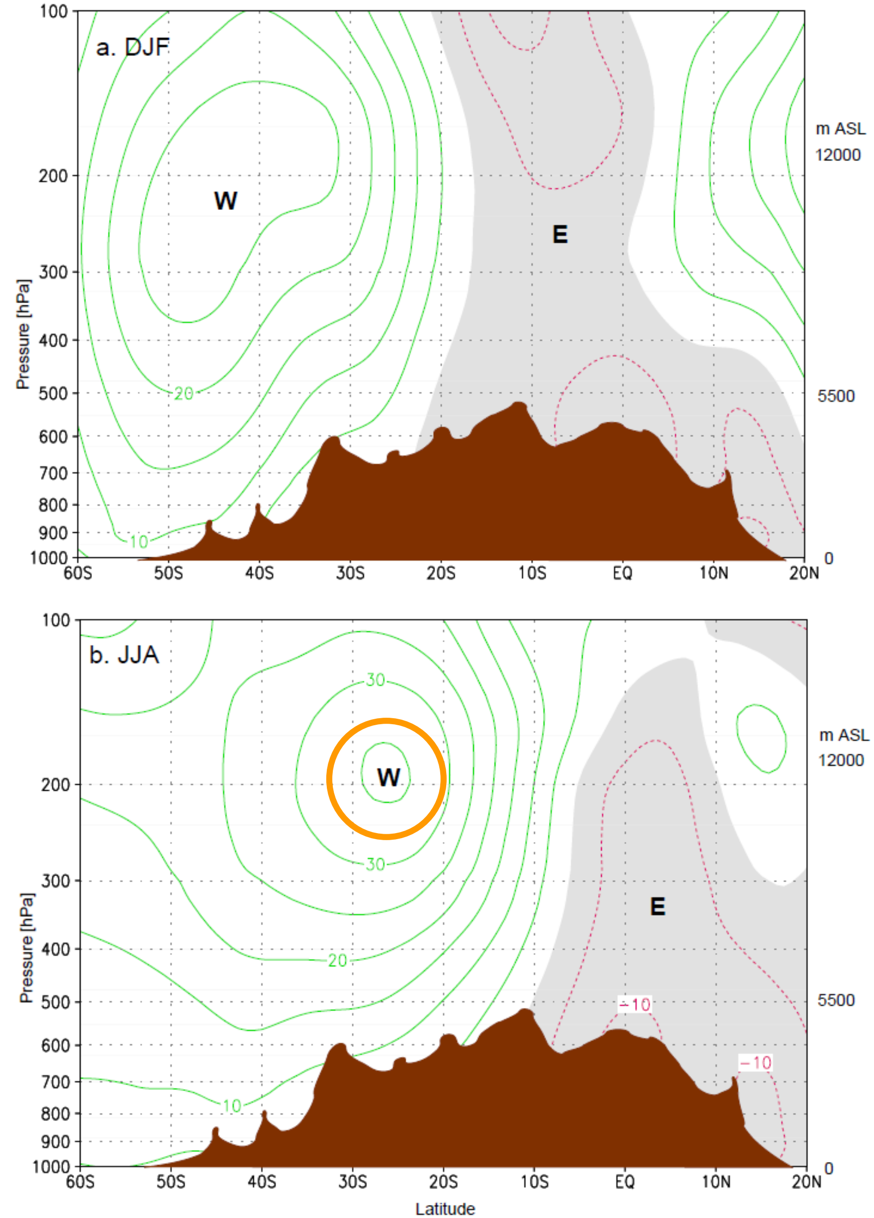
Surface wind (arrows)
Precipitation (green shadow)

General circulation in an aqua-planet
Perpetual Equinox



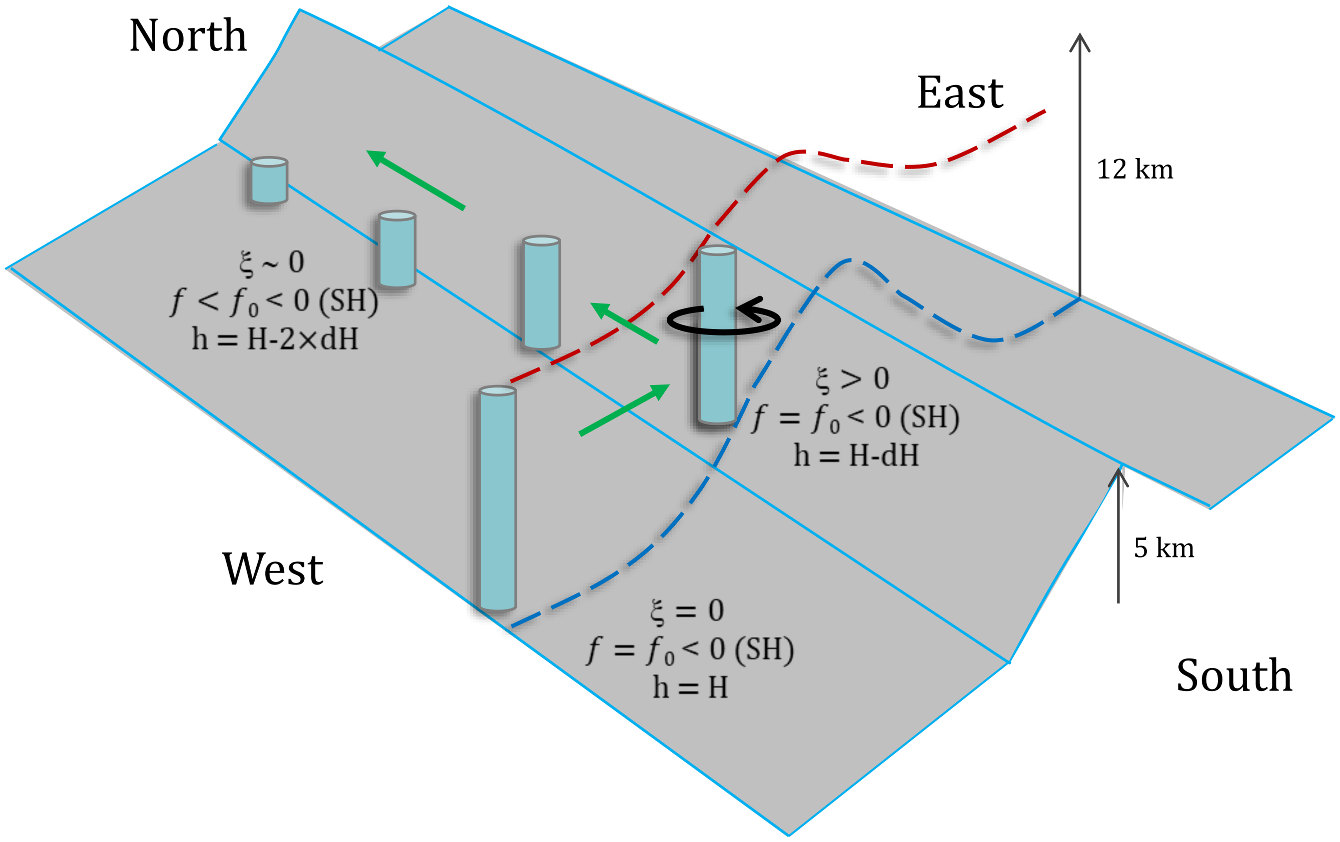
Atmospheric flow – mountain interaction

Zonal wind just upstream of the Andes (over the SE Pacific). Note that in winter the subtropical Jet (30ºS) impinges against the high Andes (not so much in summer).



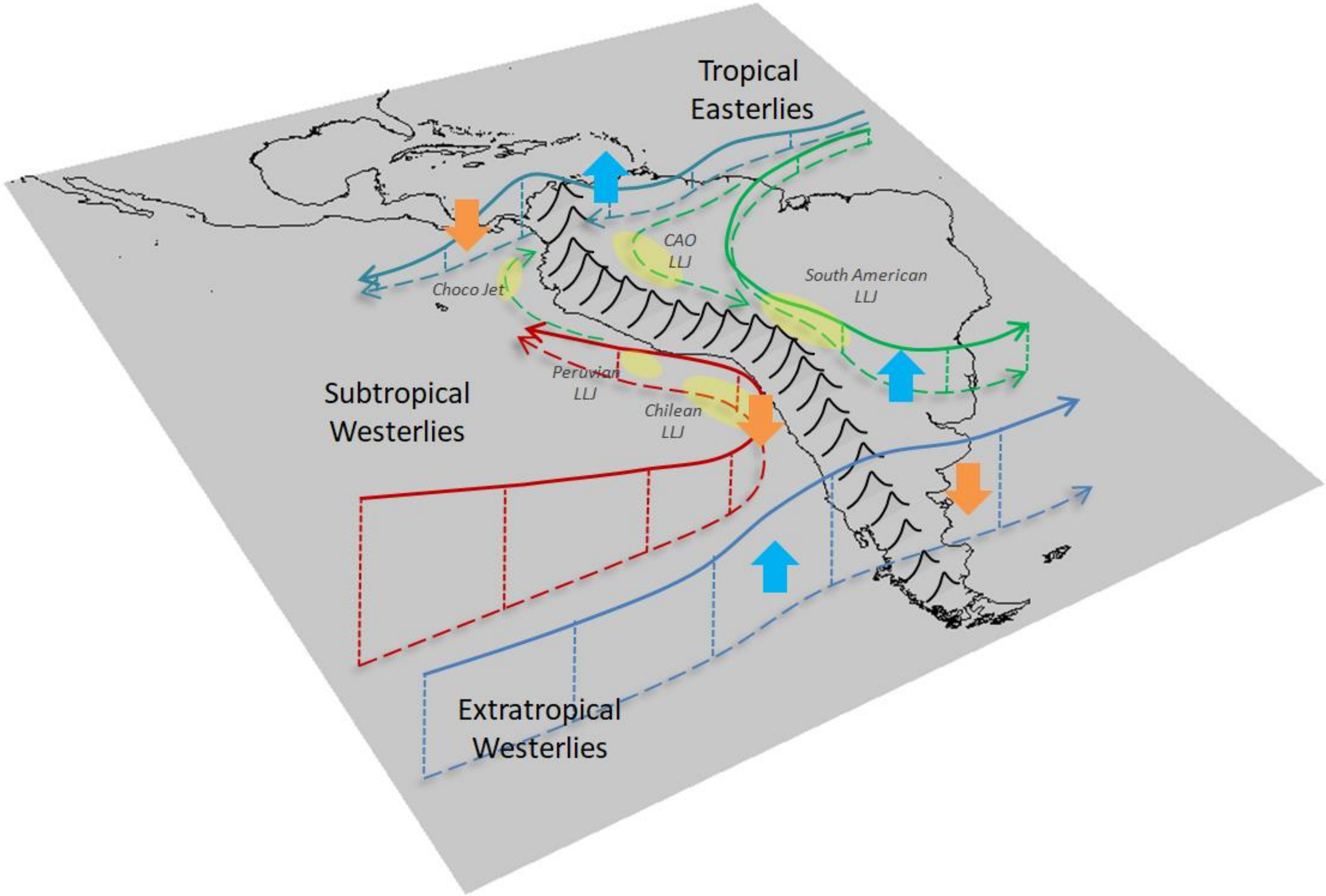
Atmospheric flow – mountain interaction

$$\frac{\xi + f}{H} = \text{constant}$$



Atmospheric flow – mountain interaction

$$\frac{\xi + f}{H} = \text{constant}$$



Austral winter: Mountain only run (no latent heating) is quite good in simulating the SEP anticyclone

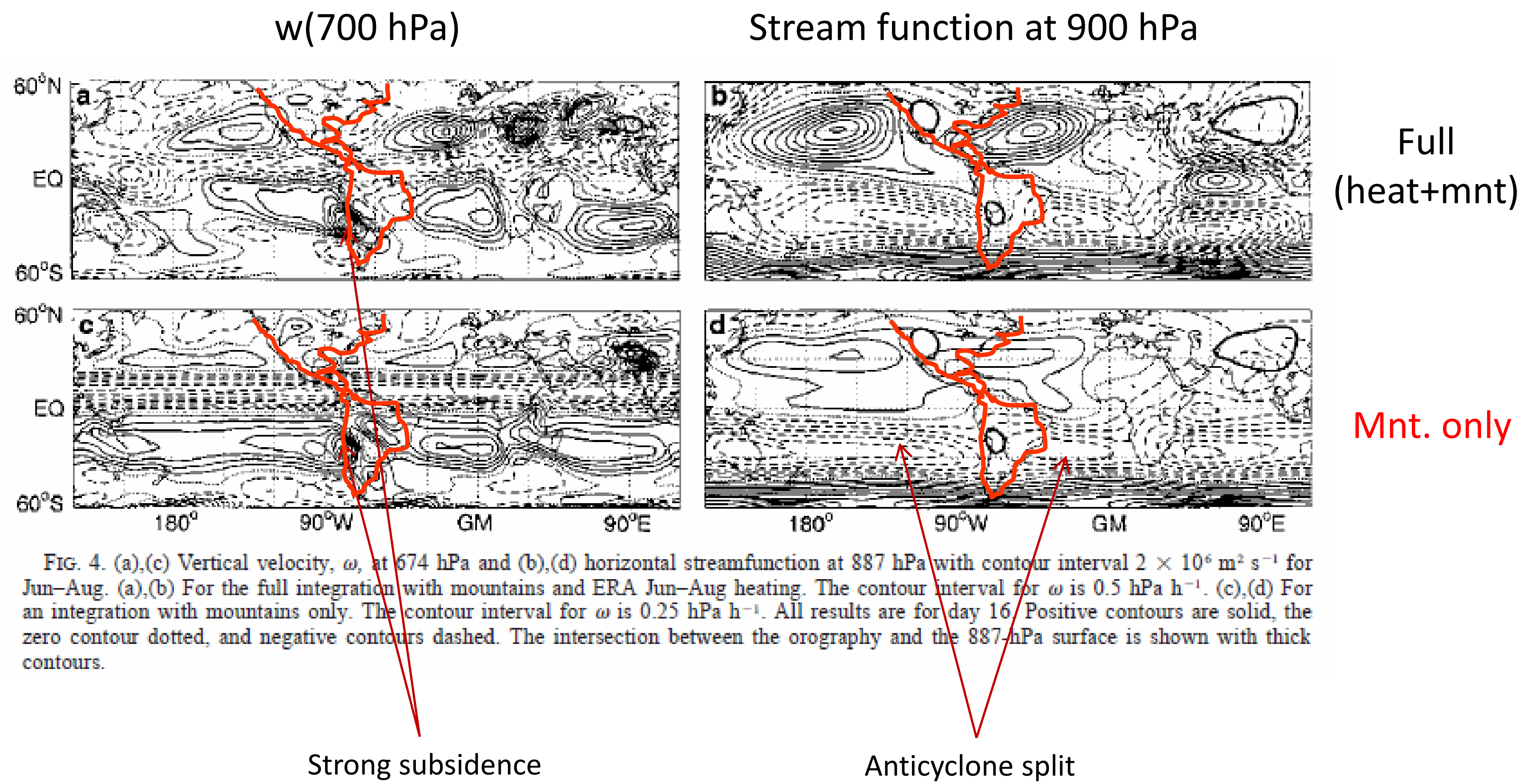
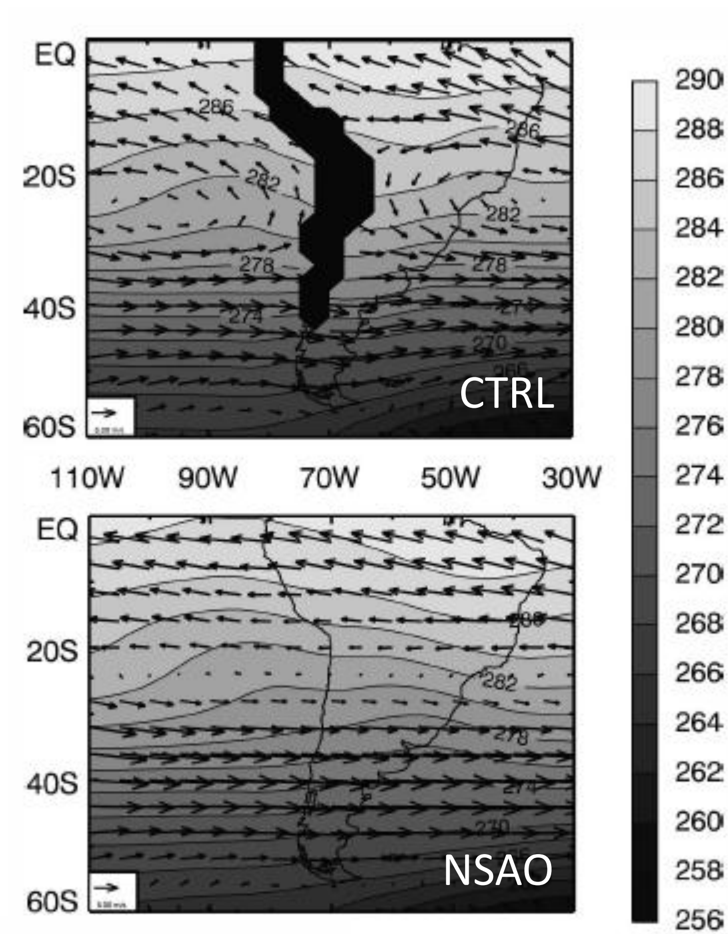


FIG. 4. (a),(c) Vertical velocity, ω, at 674 hPa and (b),(d) horizontal streamfunction at 887 hPa with contour interval $2 \times 10^6\ m^2\ s^{-1}$ for Jun–Aug. (a),(b) For the full integration with mountains and ERA Jun–Aug heating. The contour interval for ω is 0.5 hPa h^{-1}. (c),(d) For an integration with mountains only. The contour interval for ω is 0.25 hPa h^{-1}. All results are for day 16. Positive contours are solid, the zero contour dotted, and negative contours dashed. The intersection between the orography and the 887-hPa surface is shown with thick contours.

Rodwell and Hoskins 2001

Atmospheric flow – mountain interaction

July 850 hPa winds



Orographic Influences on Subtropical Stratocumulus

I. Richter and C. R. Mechoso

Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, Los Angeles, California

(Manuscript received 15 June 2005, in final form 6 January 2006)

Atmospheric flow – mountain interaction

Processes Controlling the Mean Tropical Pacific Precipitation Pattern. Part I: The Andes and the Eastern Pacific ITCZ

KEN TAKAHASHI AND DAVID S. BATTISTI

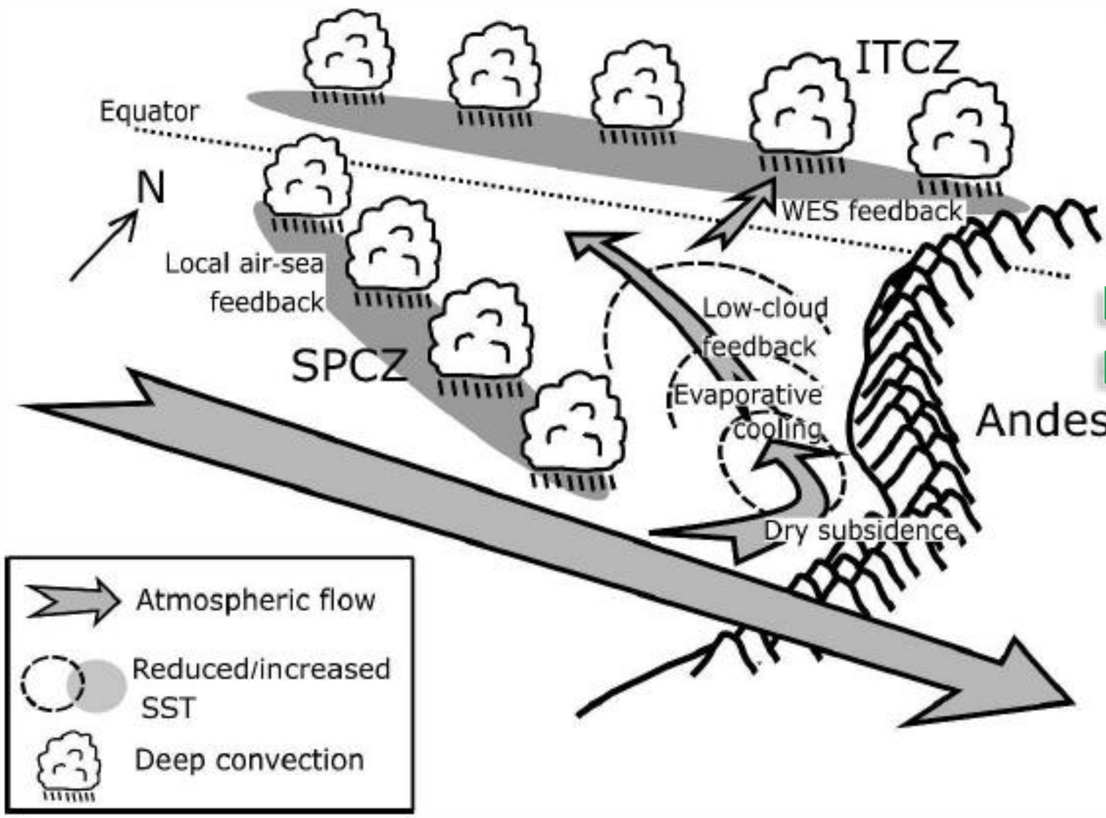


FIG. 13. Sketch summarizing some of the main processes discussed in the two parts of this study.

Low cloud feedback

Evaporative cooling

Atmospheric flow – mountain interaction

900 hPa wind & Temp

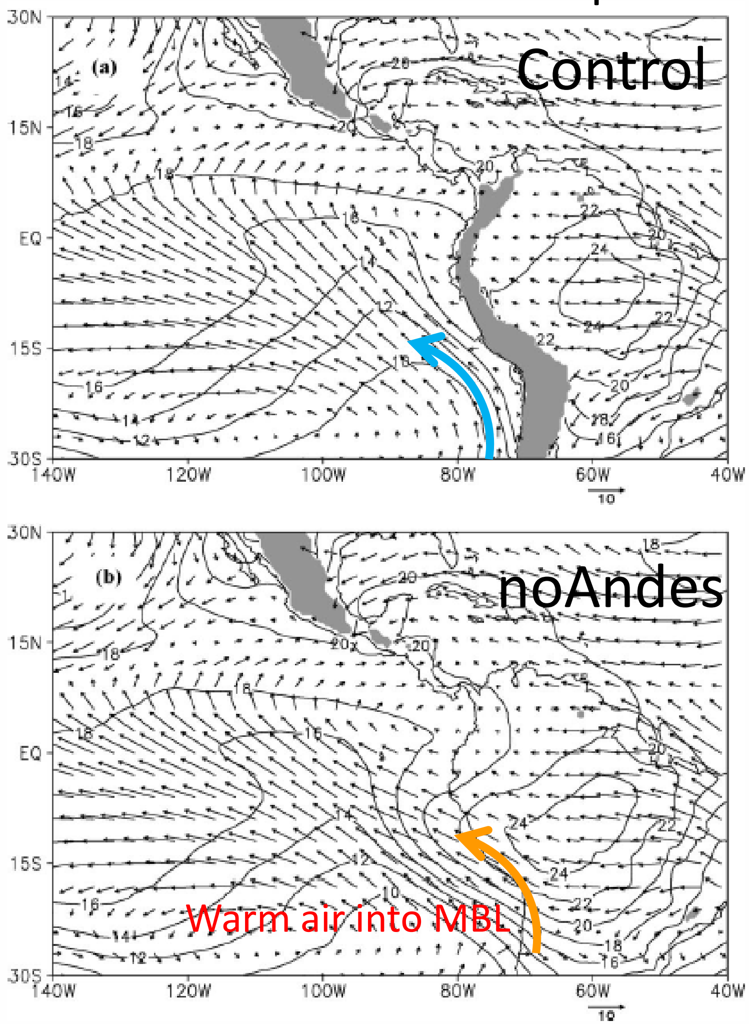


FIG. 6. Wind vectors (m s^{-1}) and temperature patterns at 900 mb for the (a) control and (b) no-Andes runs, averaged for Aug–Sep 1999. Contour interval is 2°C. Shaded portion indicates the topography higher than 1 km.

Clouds: Control - noAndes

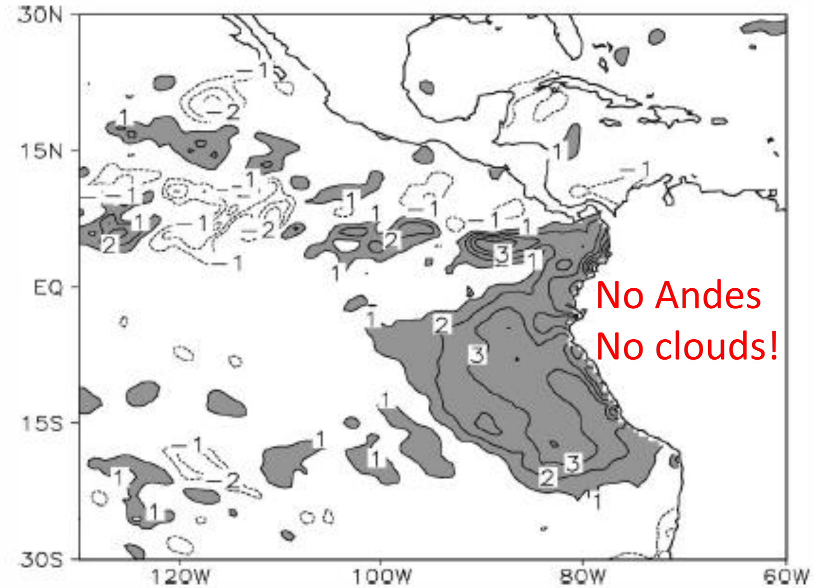


FIG. 8. Difference of vertically integrated liquid water content between the control and no-Andes runs, averaged for Aug–Oct 1999. Contour interval is 10^{-2} mm. Values greater than 10^{-2} mm are shaded.

Effects of the Andes on Eastern Pacific Climate: A Regional Atmospheric Model Study*

HAIMING XU AND YUQING WANG

International Pacific Research Center, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, Hawaii

SHANG-PING XIE

International Pacific Research Center and Department of Meteorology, University of Hawaii at Manoa, Honolulu, Hawaii

(Manuscript received 13 January 2003, in final form 4 August 2003)

Atmospheric flow – mountain interaction

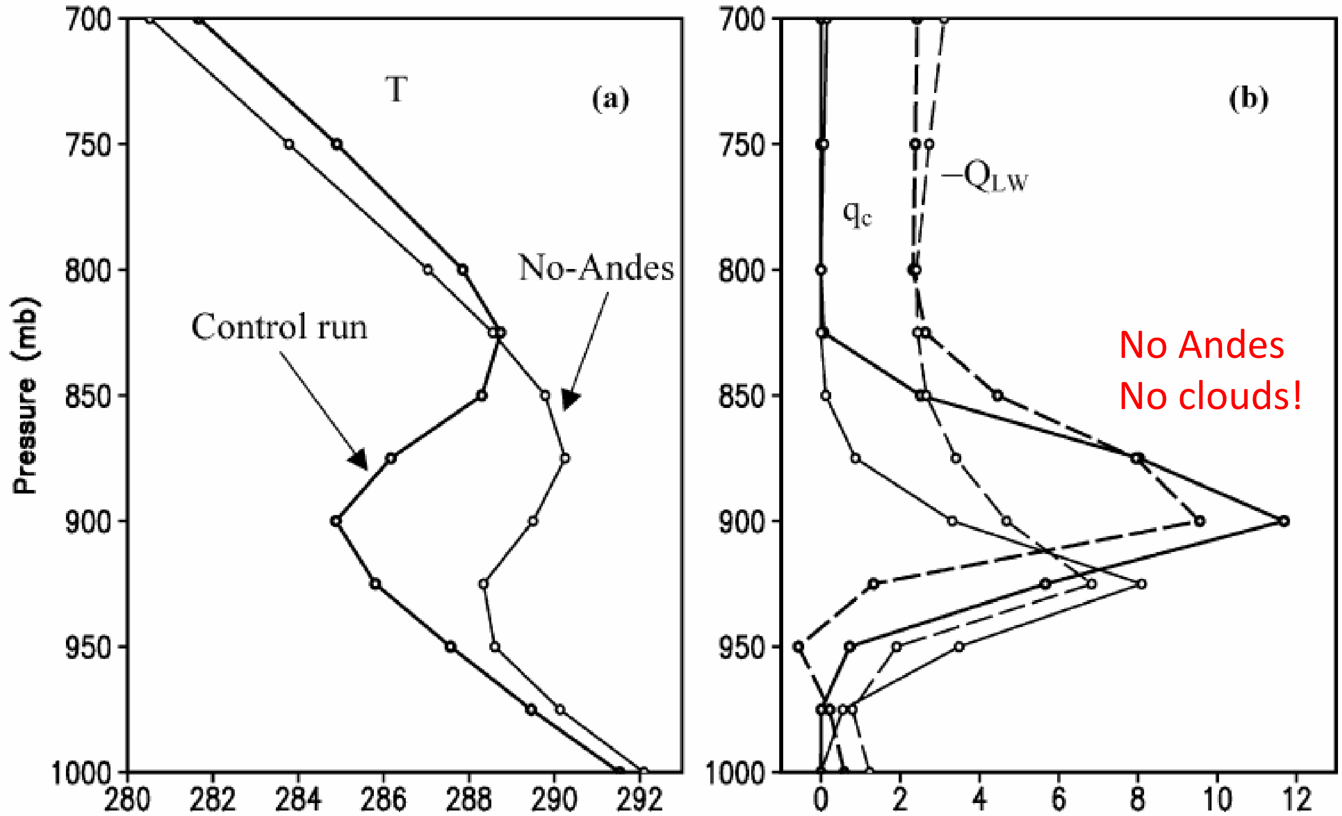


FIG. 5. Vertical profiles of (a) temperature (K), and (b) cloud liquid water mixing ratio (solid lines, 10^{-2} g kg^{-1}) and longwave radiation cooling rate (dashed lines, K day^{-1}) at 10°S, 90°W for control (heavy lines) and no-Andes (light lines) runs, averaged for Aug–Oct 1999. Note that the sign for the cooling rate is reversed.

Effects of the Andes on Eastern Pacific Climate: A Regional Atmospheric Model Study*

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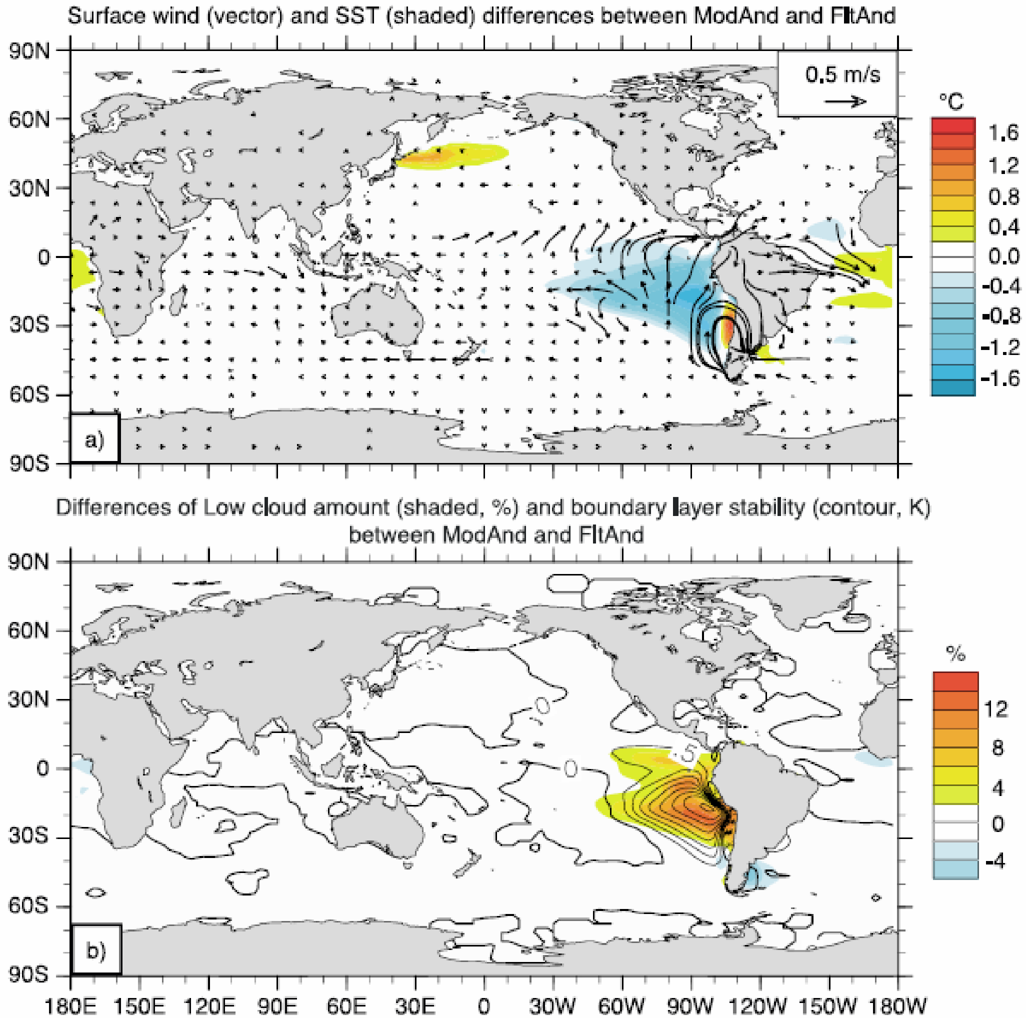
(Manuscript received 13 January 2003, in final form 4 August 2003)

Andean elevation control on tropical Pacific climate and ENSO

Ran Feng[1] and Christopher J. Poulsen[1]

SST and Sfc Wind: Control - No Andes

Clouds & LTS Control - No Andes

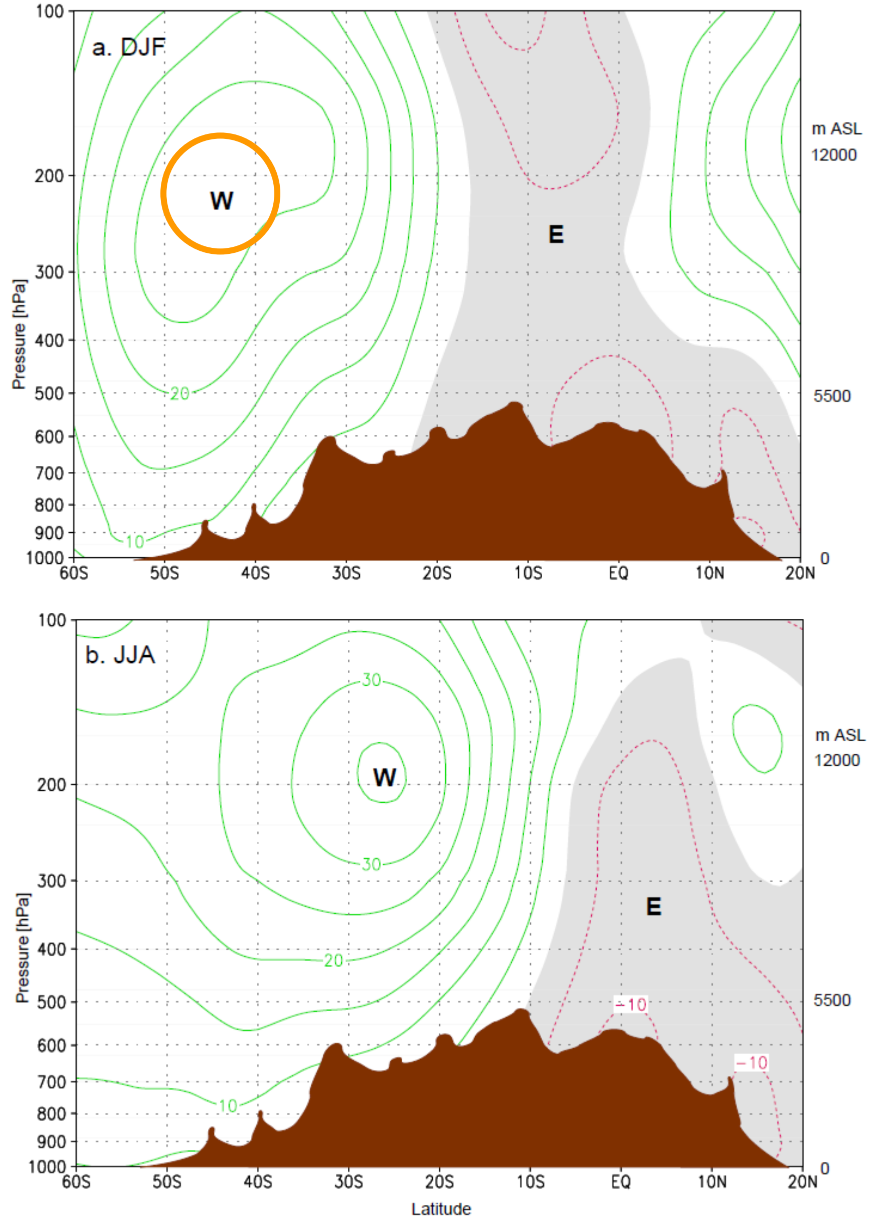


No Andes
No clouds!
Warm ocean…

Figure 2. Global responses of SST and low-level atmosphere to the Andean uplift from FltAnd to ModAnd. (a) Mean SST (°C, shaded) and surface wind (m/s, vectors) differences. (b) Differences of low-cloud fraction (%, shaded) and marine boundary layer stability (*K*, contour). The marine boundary layer stability is measured by taking the difference of equivalent potential temperature between 700 hPa and 1000 hPa. Only responses that have passed consistency tests are shown.

Monsoonal (continental heating) influence

Zonal wind just upstream of the Andes (over the SE Pacific). Note that in winter the subtropical Jet (30ºS) impinges against the high Andes (not so much in summer).



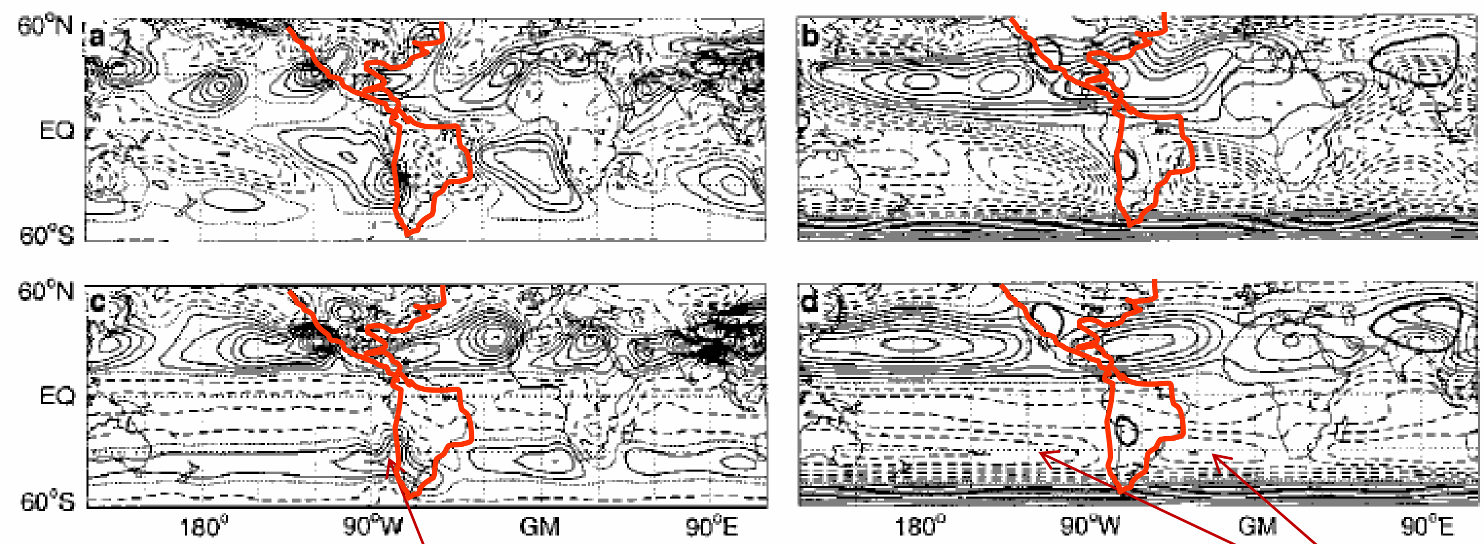
Austral summer: Mountain only run not good in simulating the SEP anticyclone. Continental heating is essential.

w(700 hPa)

Stream function at 900 hPa

Full (heat+mnt)

Mnt. only

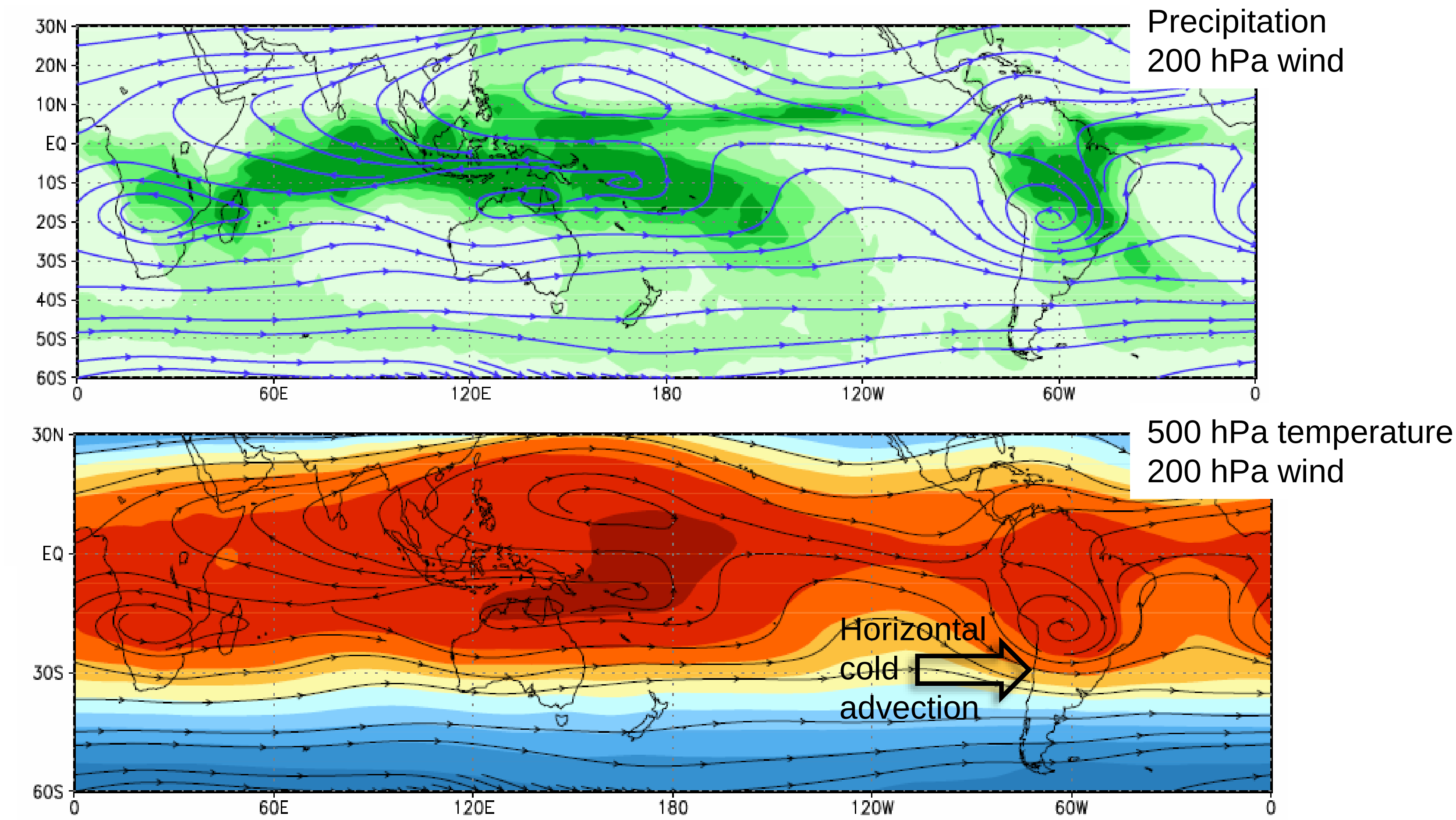


Subsidence in right place but only ¼ of the full value

Anticyclone split much weaker

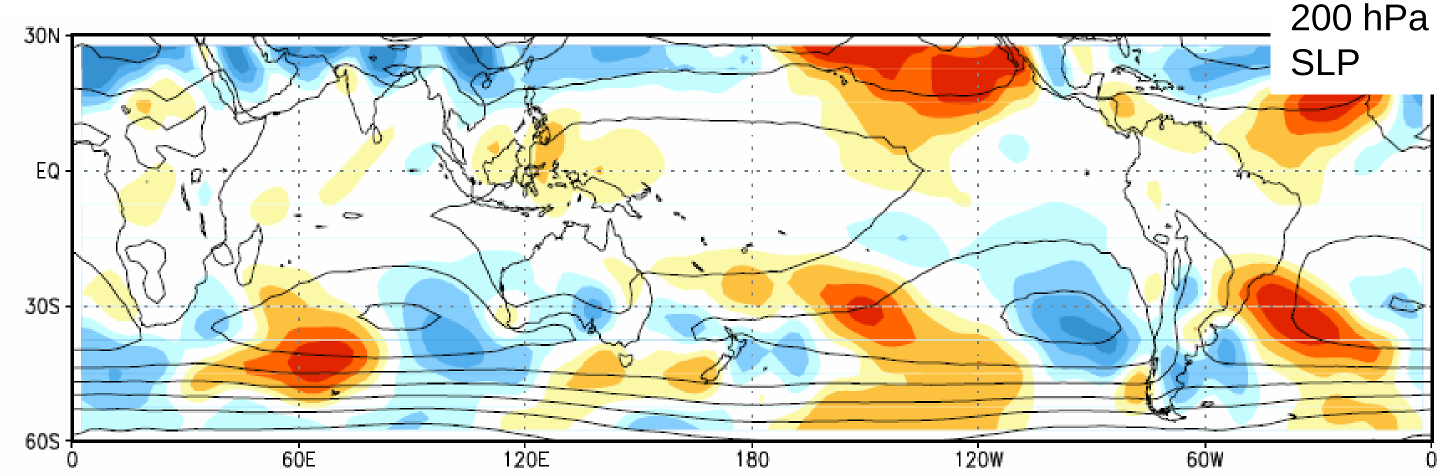
Efecto monsonal (Rodwell and Hoskins 2001)

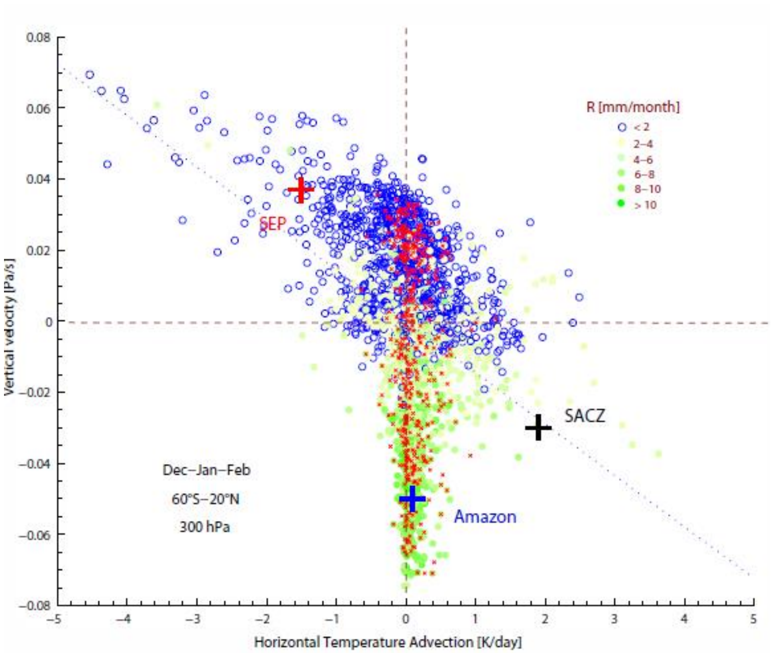
- Calentamiento diabático en zona de precipitación
- Expansión del calentamiento por ondas de Kelvin/Rossby
- Advección fría al Oeste del continente
- Incremento de la subsidencia sobre Pacifico SE



Efecto monsonal (Rodwell and Hoskins 2001)

200 hPa Hor Temp Adv
SLP

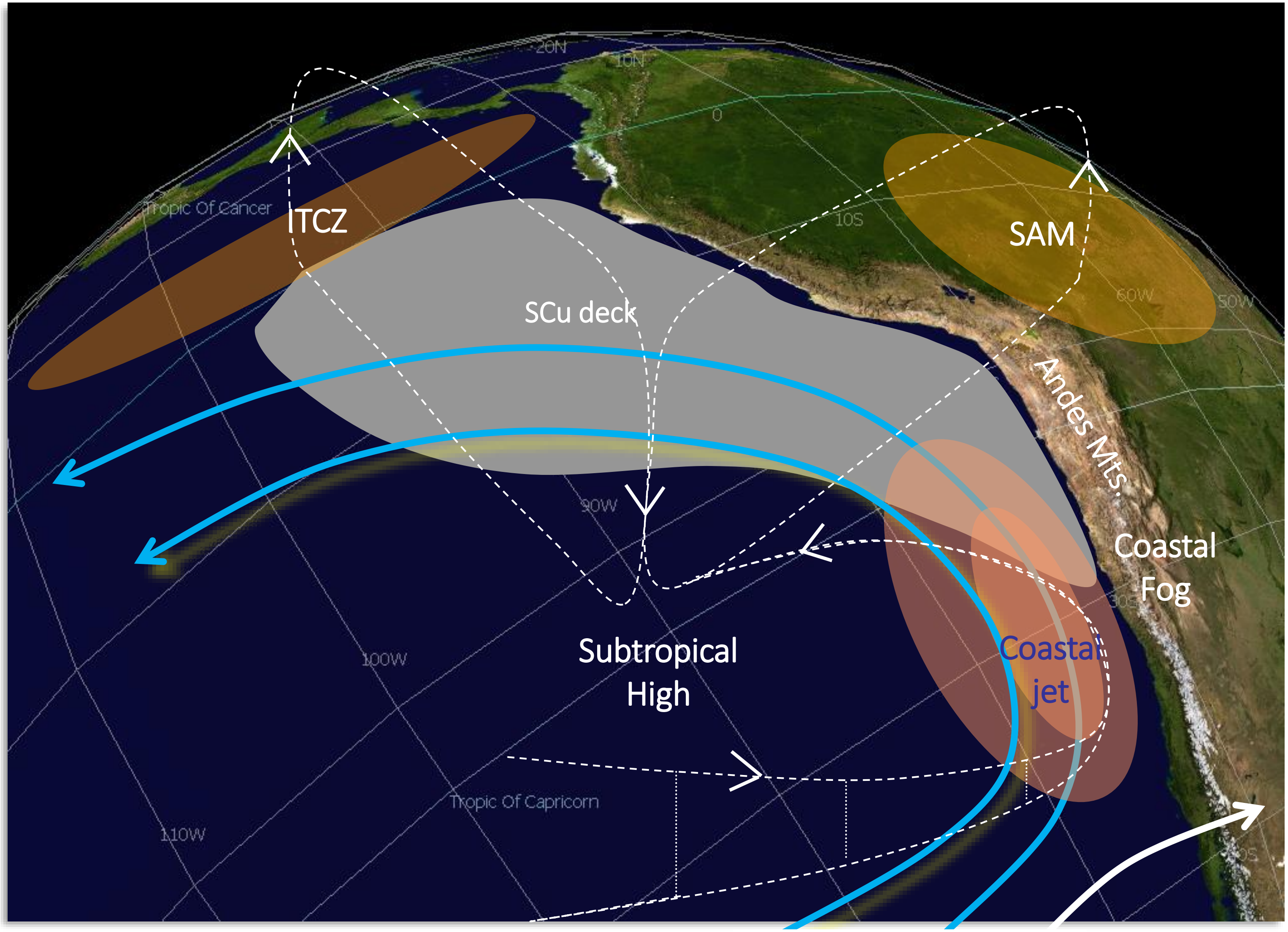


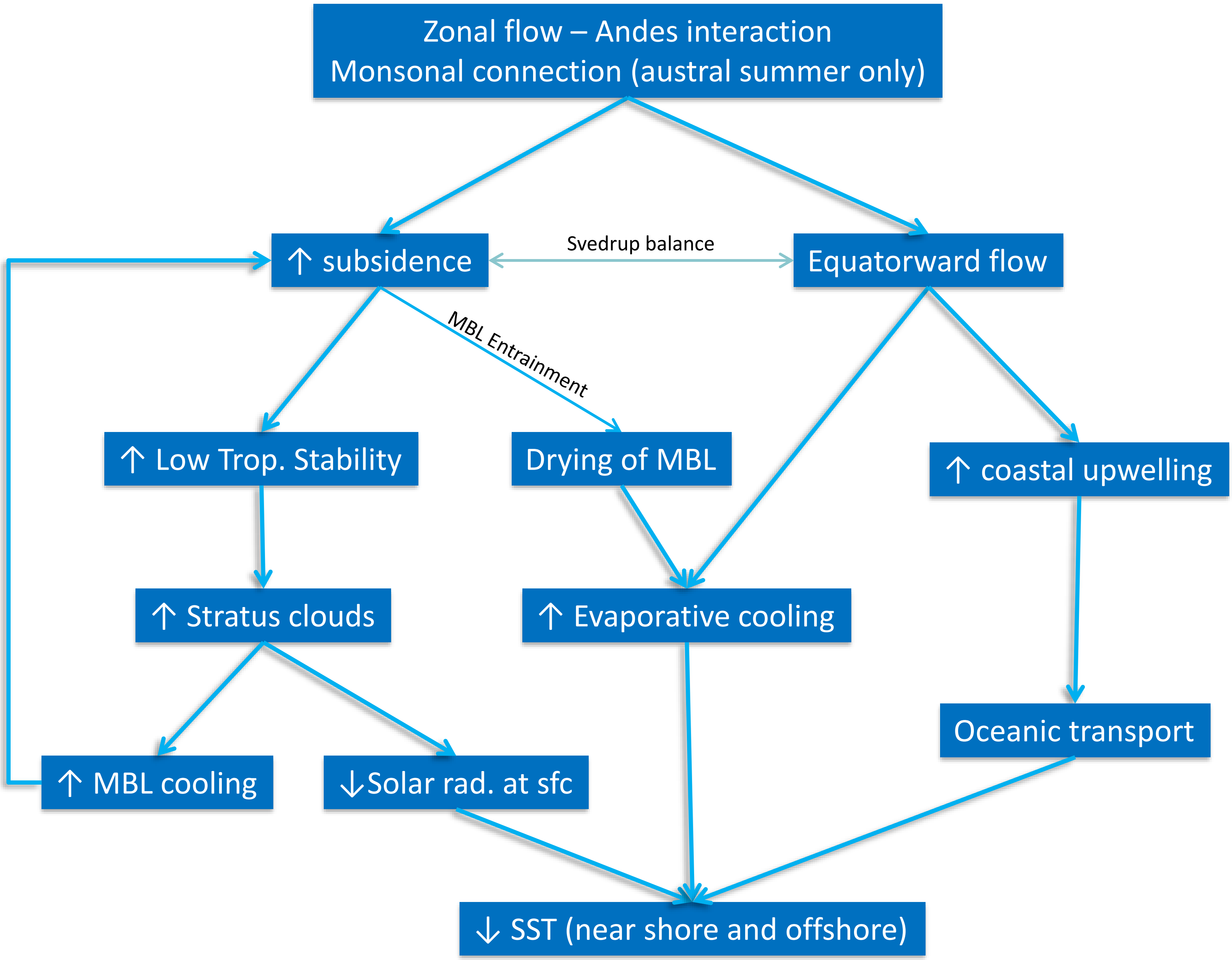


$$-\vec{v} \cdot \nabla T + S\omega \frac{\partial T}{\partial p} + \dot{Q} = \frac{\partial T}{\partial t} \approx 0$$

Sobre el SEP el calentamiento diabático es levemente negativo por lo que advección horizontal fría es compensada por subsidencia (calentamiento adiabático). Notar qué lo contrario ocurre en el SACZ. Sobre la Amazonia el balance es entre ascenso y calentamiento diabatico.

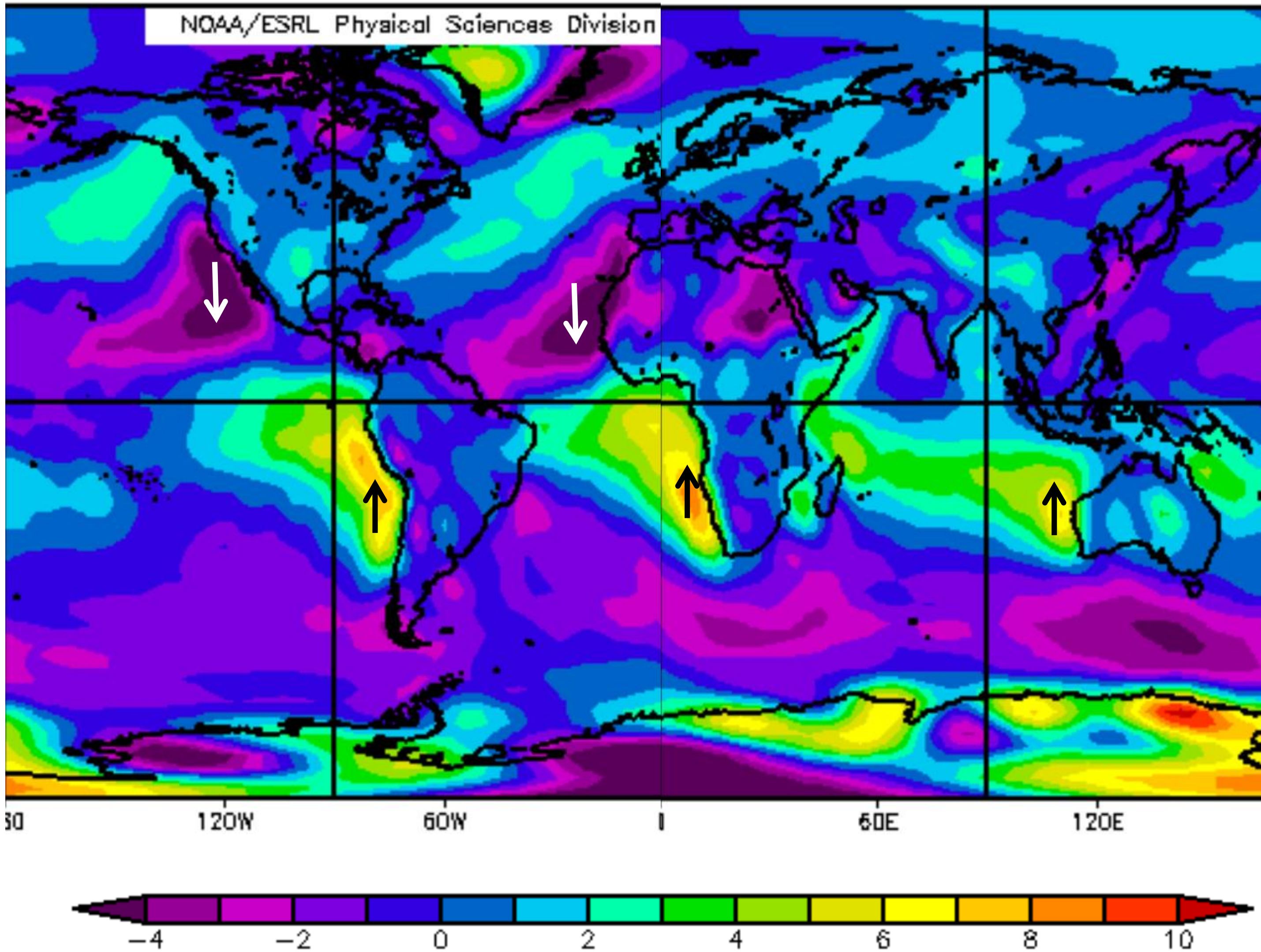
Key atmospheric features over the SEP




Zonal flow – Andes interaction
Monsonal connection (austral summer only)
↑ subsidence
Svedrup balance
Equatorward flow
MBL Entrainment
↑ Low Trop. Stability
Drying of MBL
↑ coastal upwelling
↑ Stratus clouds
↑ Evaporative cooling
Oceanic transport
↑ MBL cooling
↓Solar rad. at sfc
↓ SST (near shore and offshore)

Coastal Low Level Jets

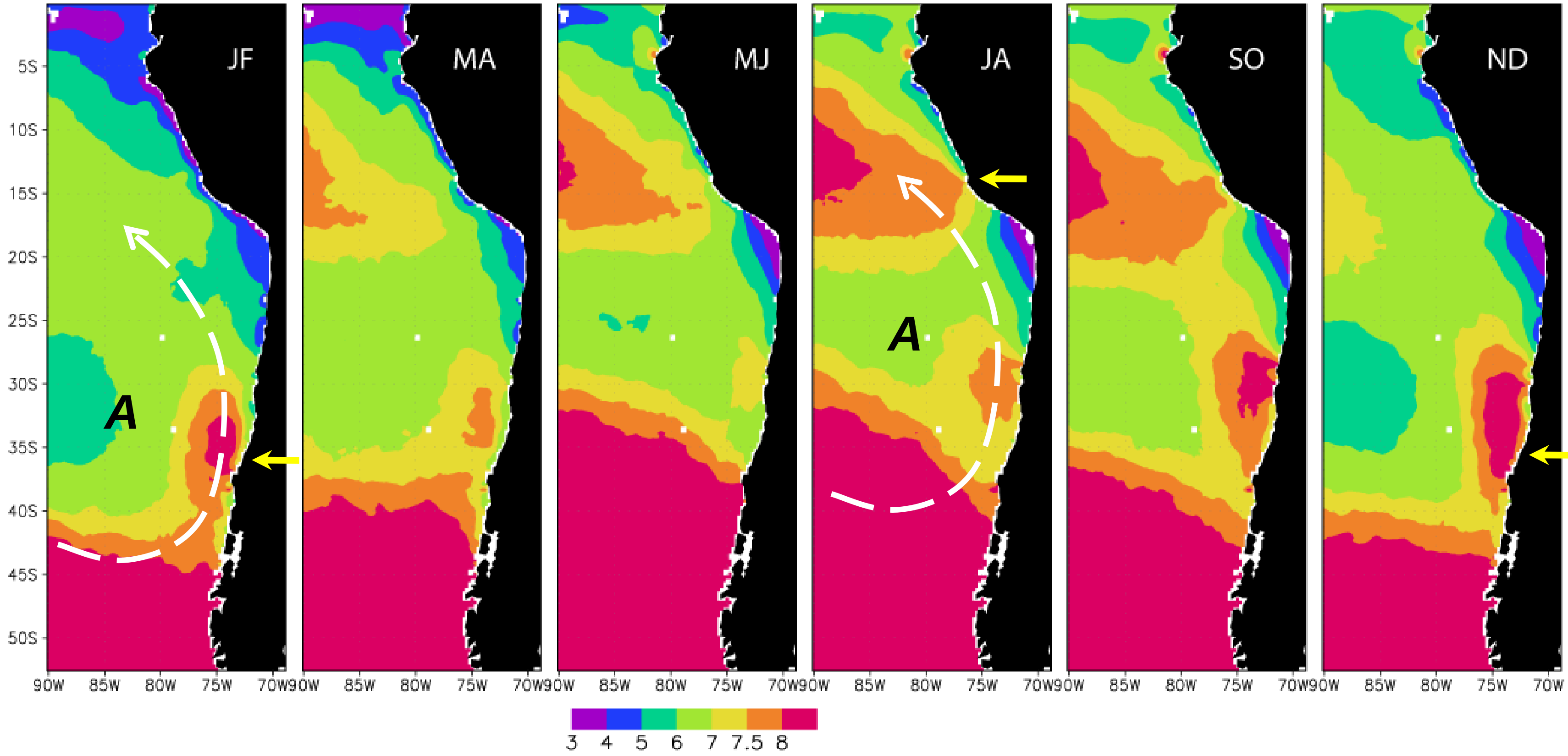
NCEP-NCAR Reanalysis, 1000 hPa meridional (NS) winds, annual long term mean



Surface wind speed & coastal jets

Jet costero (máxima magnitud) a lo largo de la costa
Variabilidad sinóptica y estacional dictada por ∂(SLP) / ∂y

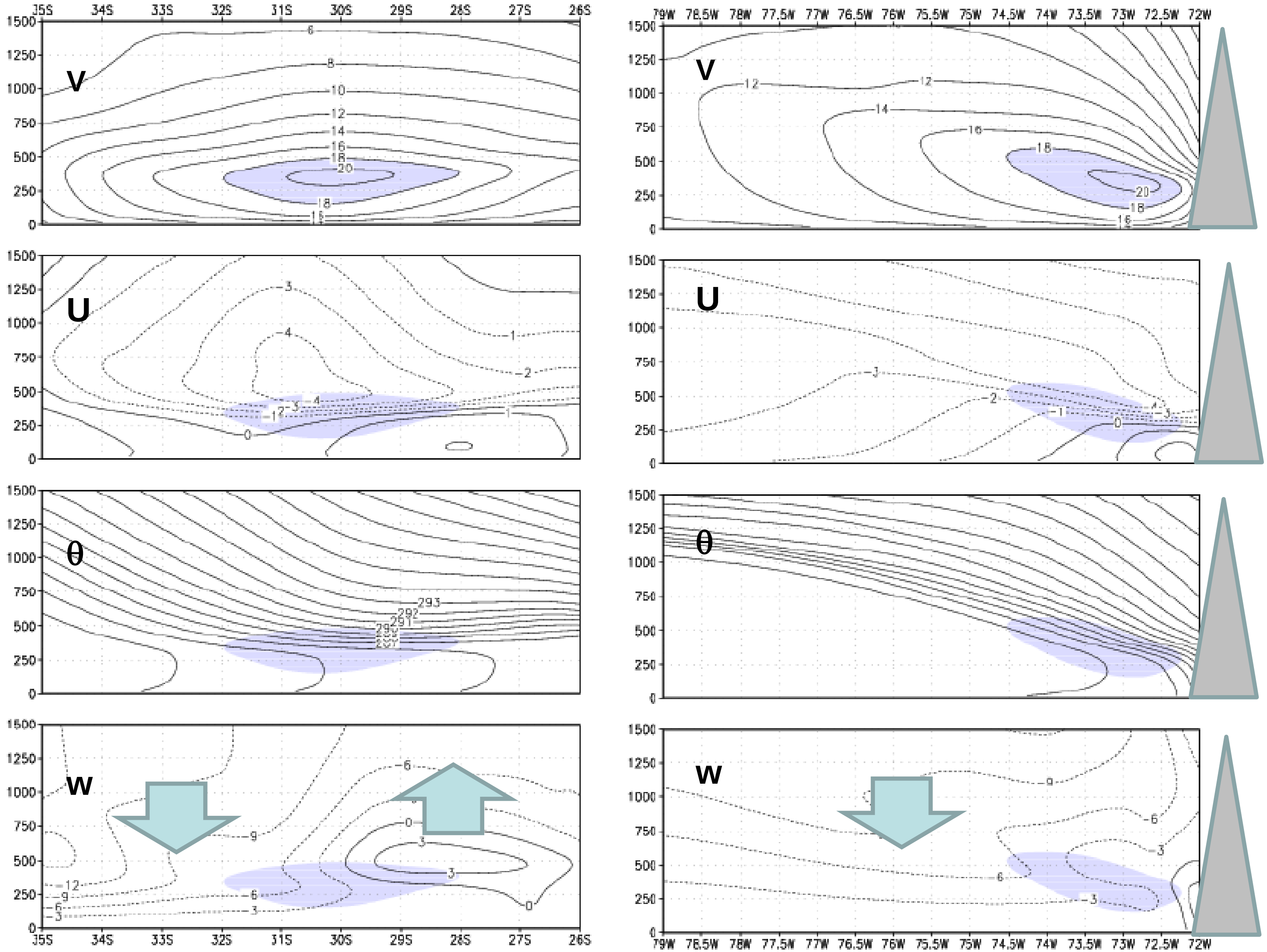
QuikScat surface wind speed climatology (2000–2005)



Simulated (MM5) structure of the coastal jet

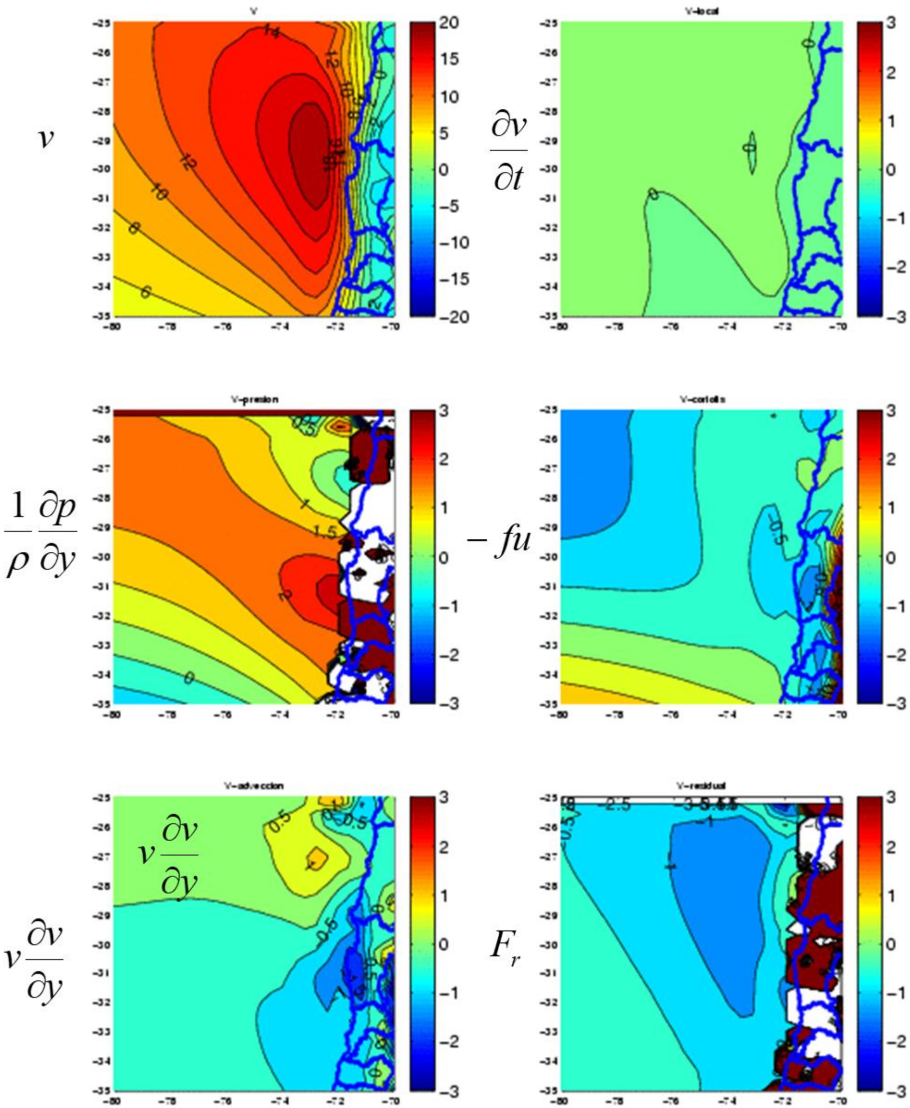
Along shore

Cross shore



V > 18 m/s

Garreaud & Muñoz 2006



Coastal jet dynamics

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{1}{\rho}\frac{\partial p}{\partial x}+fv-\frac{C_d}{H}u|\vec{v}|$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+fu-\frac{C_d}{H}v|\vec{v}|$$

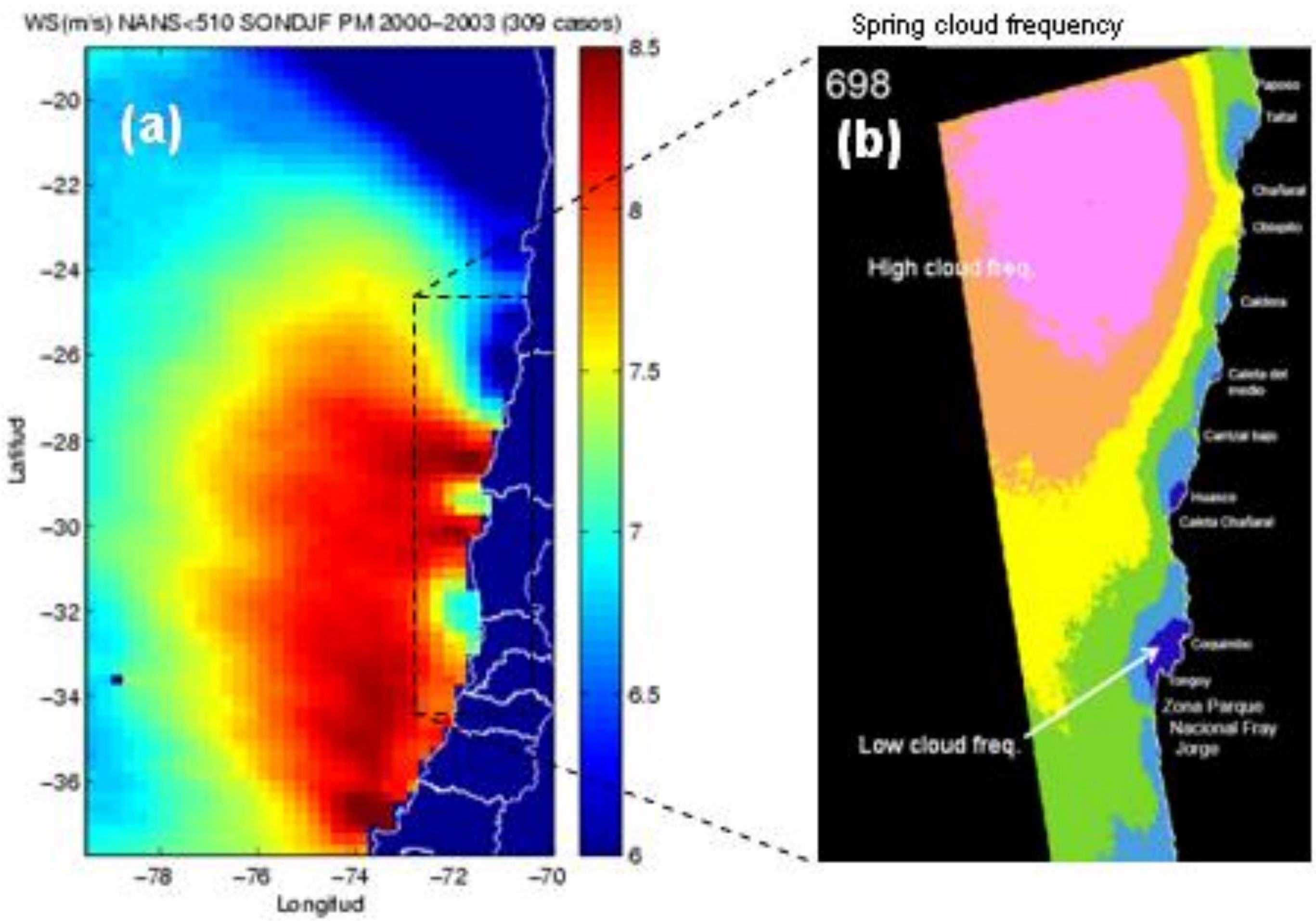
$$-\frac{1}{\rho}\frac{\partial p}{\partial y}=\frac{C_d}{H}v^2$$

Along-shore pressure gradient ~ friction

Garreaud & Muñoz 2006

Goals of Fondecyt 1090492 (Garreaud, Muñoz, Rutllant)

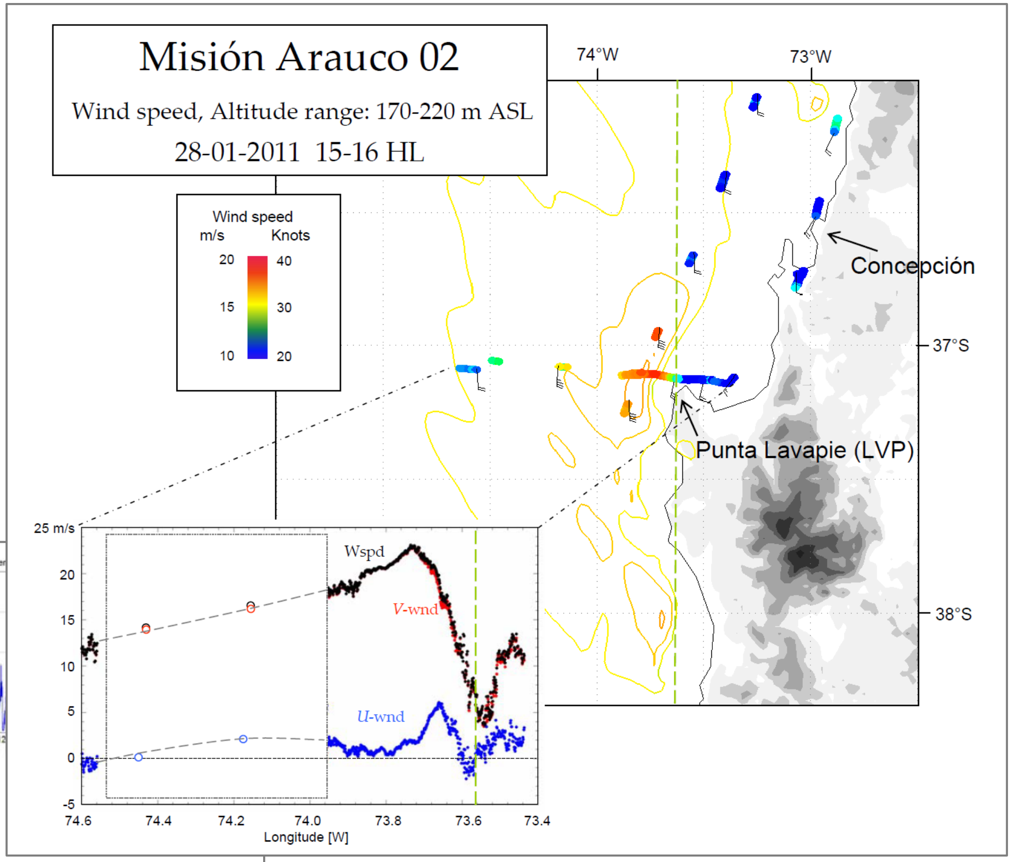
Understand the alongshore structure of the MBL and its diurnal cycle

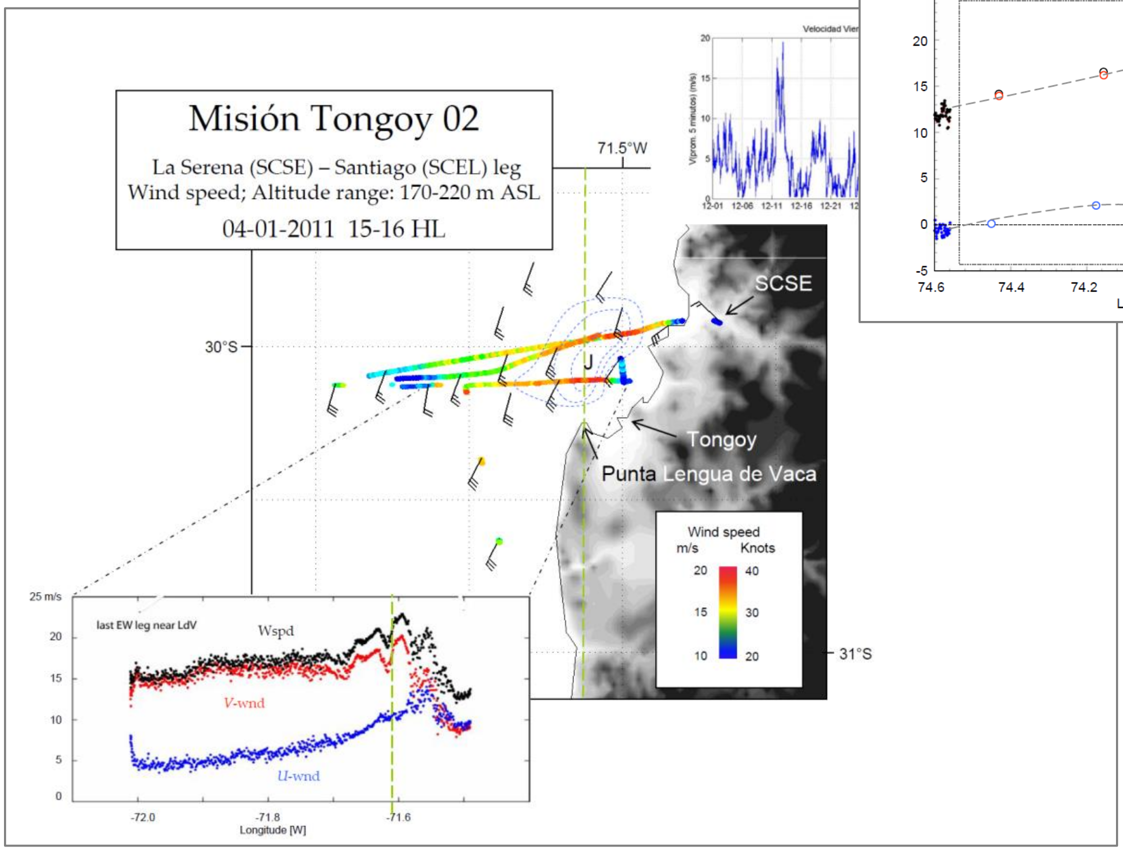


Coastal jets intensify downstream of major capes.

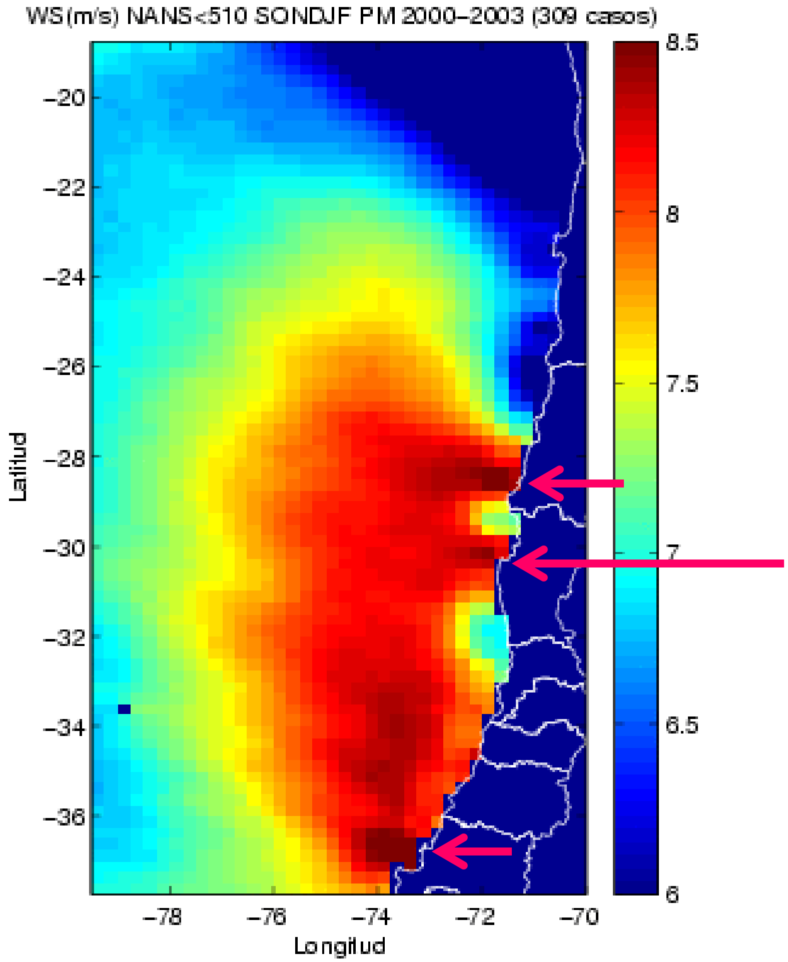
Upwelling maximum

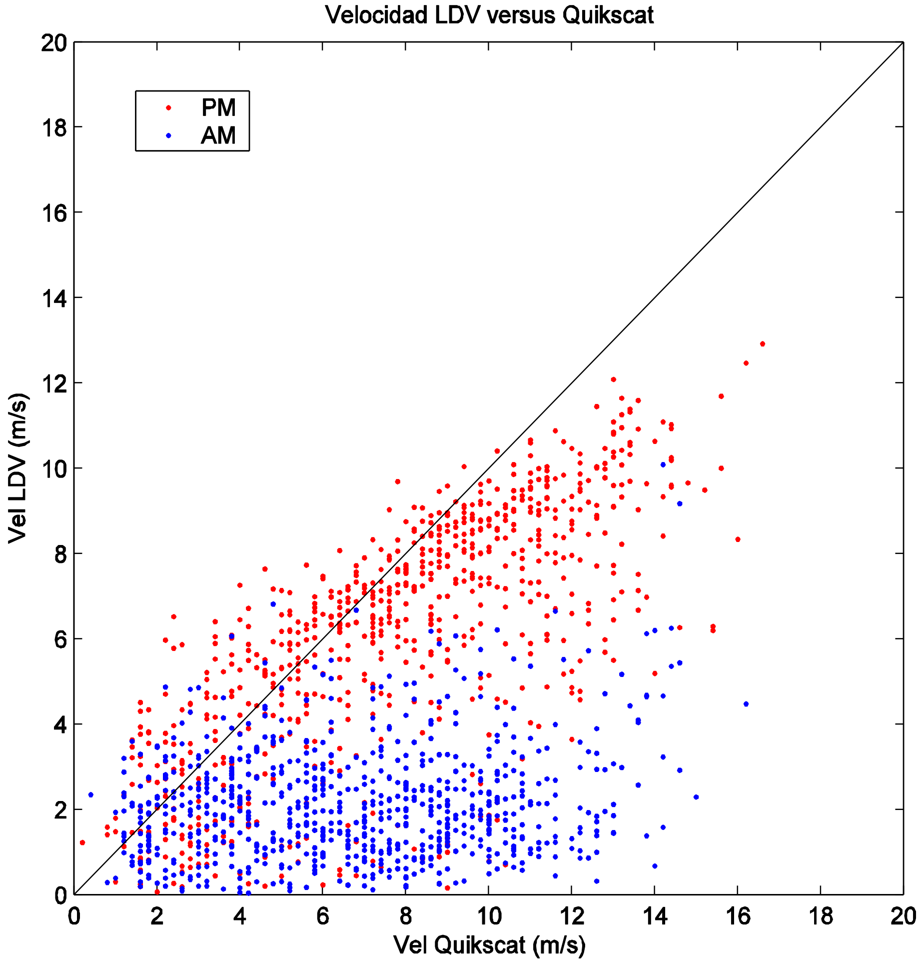
Cloud free





QSCAT also reveals some meso-scale details and insights on the diurnal cycle

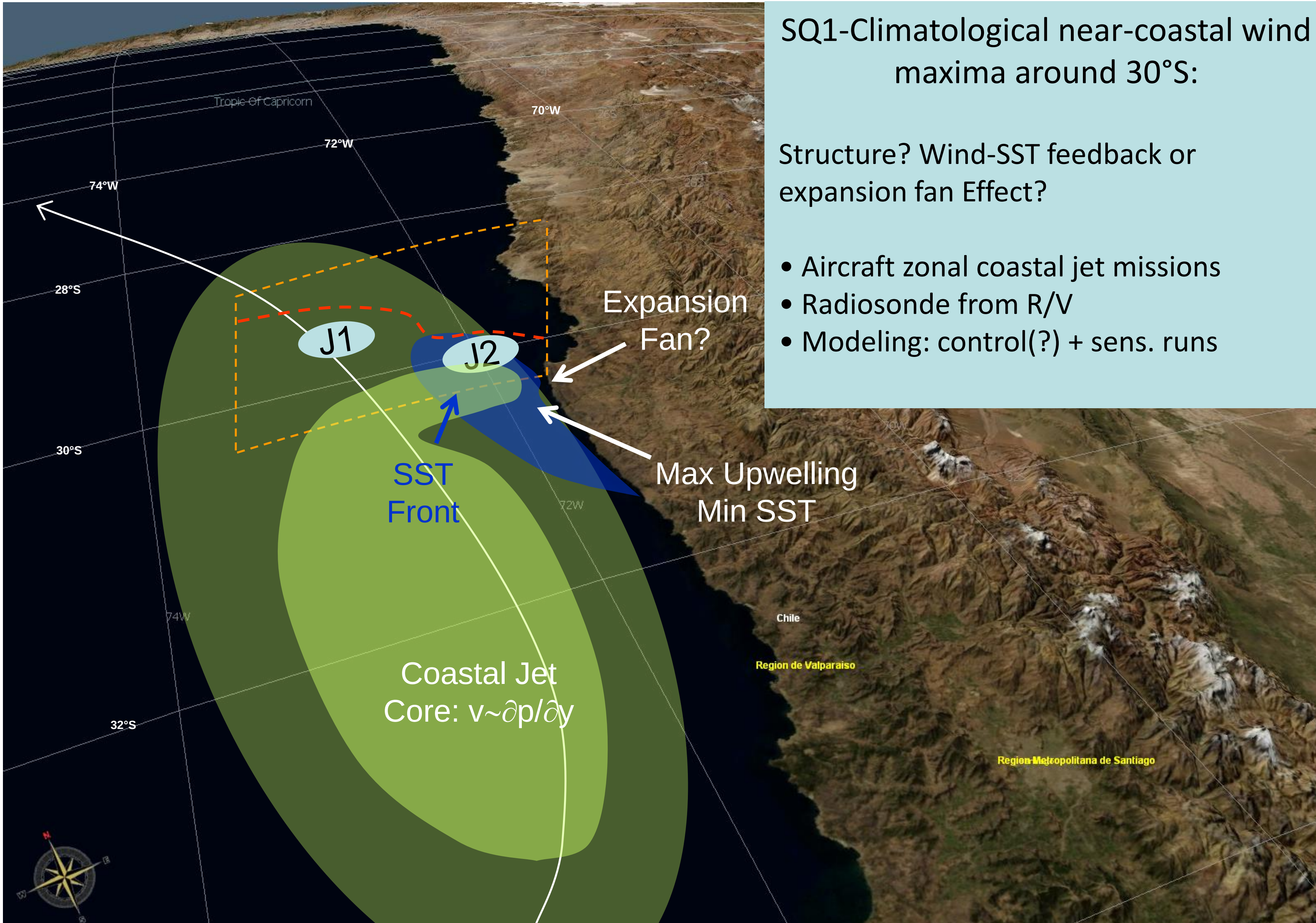




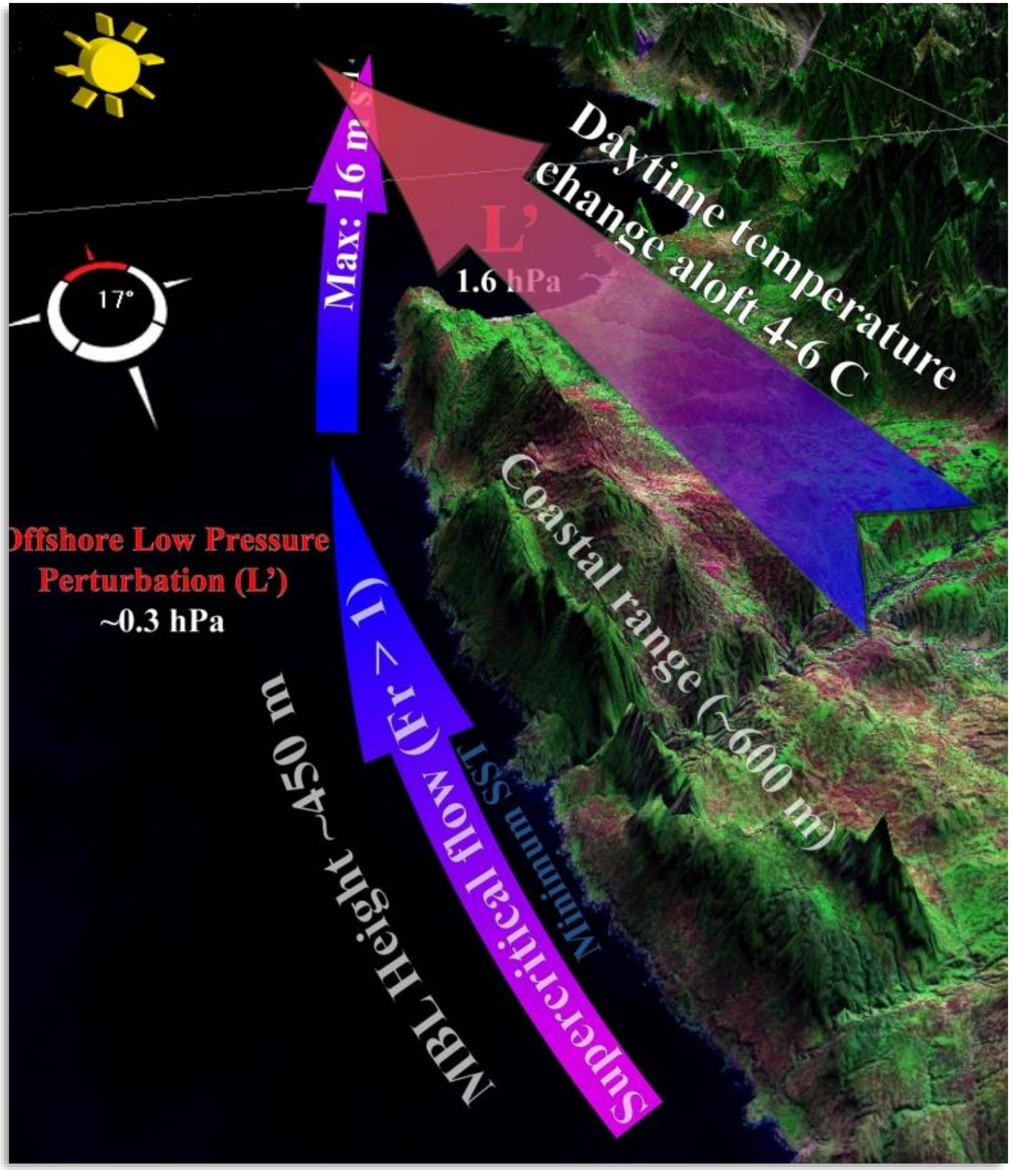
SQ1-Climatological near-coastal wind maxima around 30°S:

Structure? Wind-SST feedback or expansion fan Effect?

- Aircraft zonal coastal jet missions
- Radiosonde from R/V
- Modeling: control(?) + sens. runs

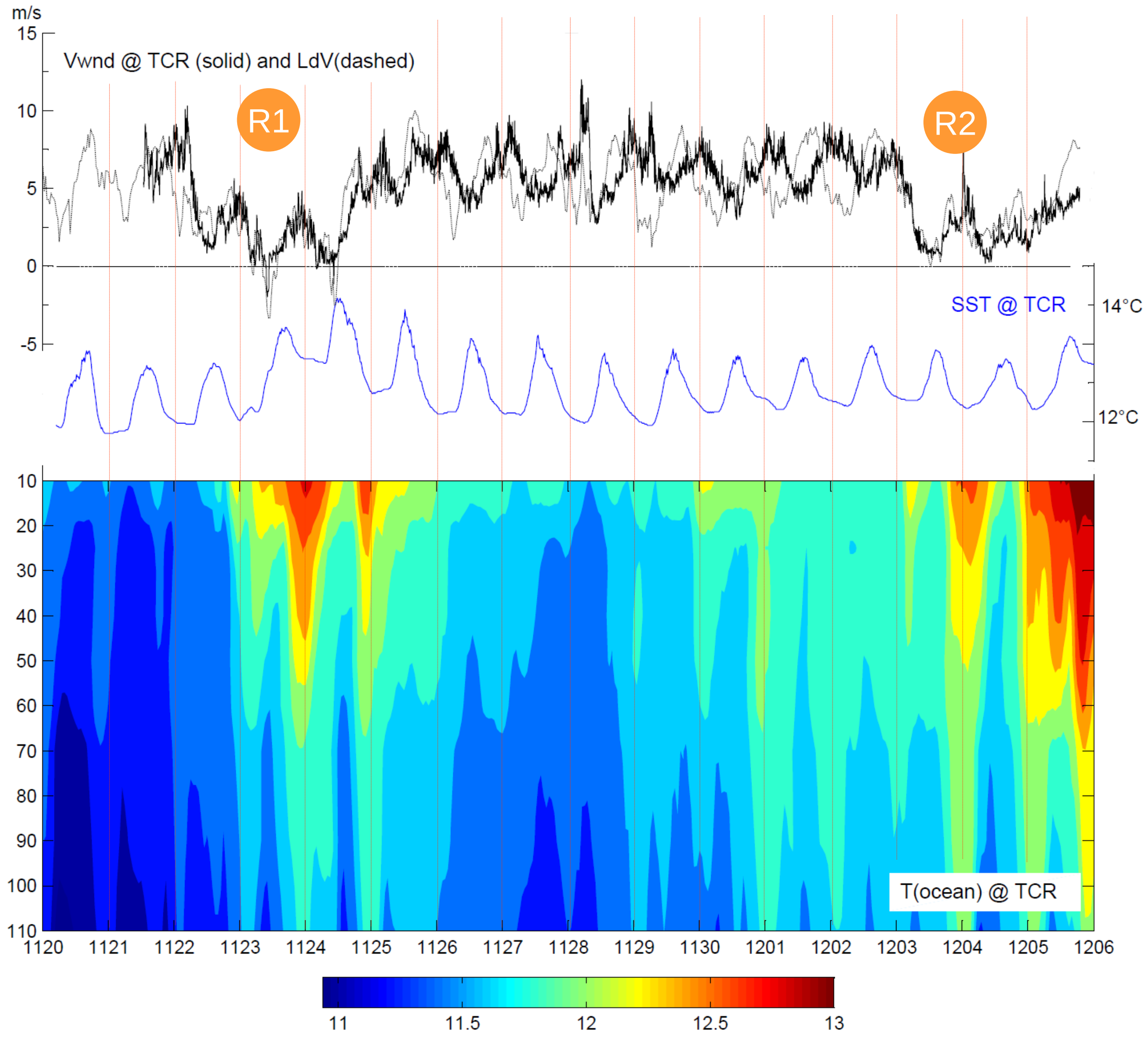


New Conceptual Model for Coastal Jet (30ºS)

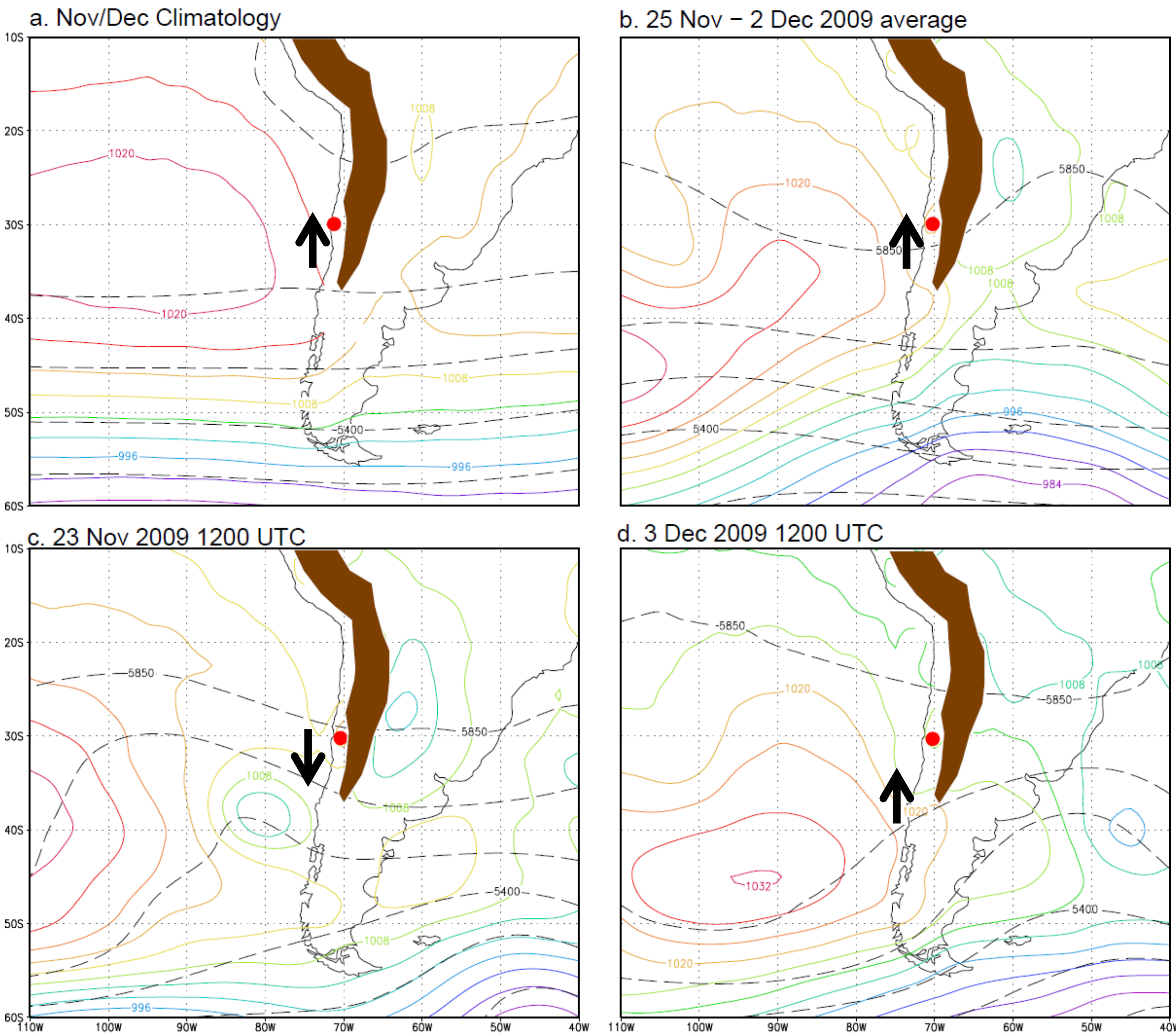


Rahn & Garreaud 2012

Synoptic variability during CUpEx: Local T(Ocean) & wind



Synoptic variability during CUpEx

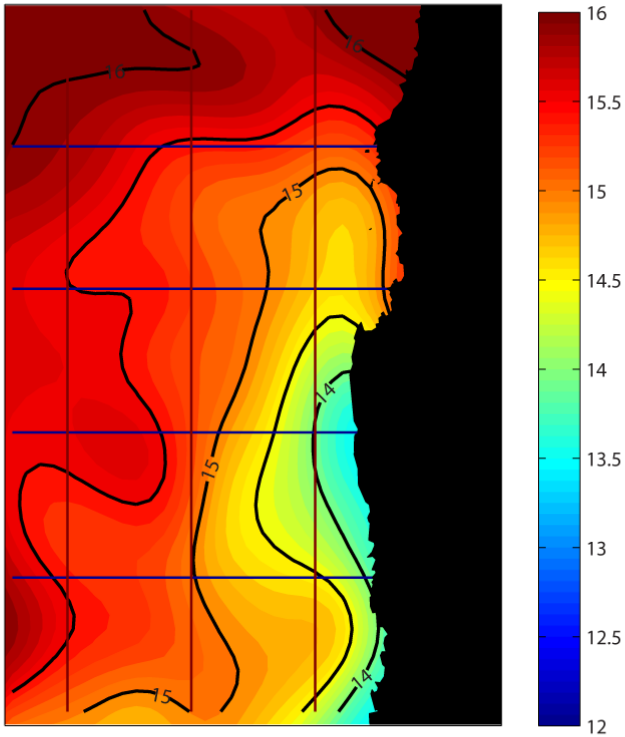


↑ PGF

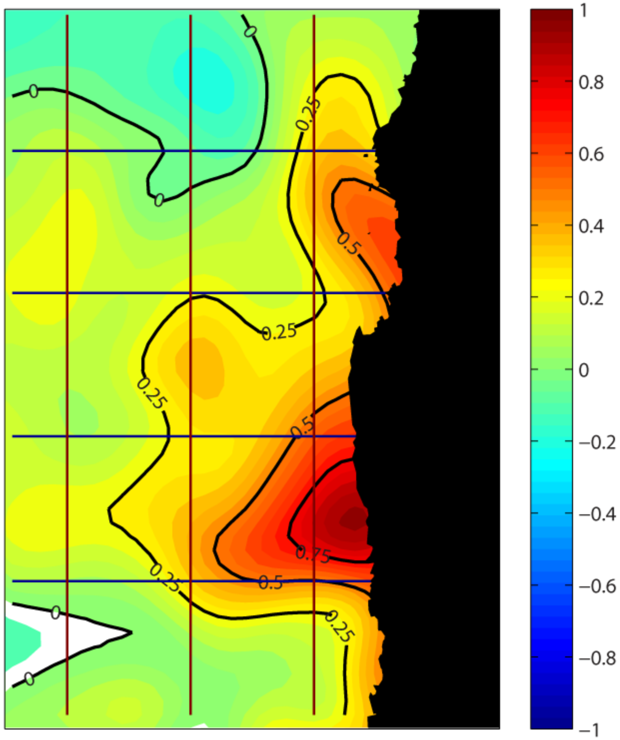
$$-\frac{1}{\rho}\frac{\partial p}{\partial y} = \frac{C_d}{H} v^2 \approx v$$

Synoptic variability during CUpEx: SSMI SST

High wind SST field [C]



Low - High wind SST field [C]



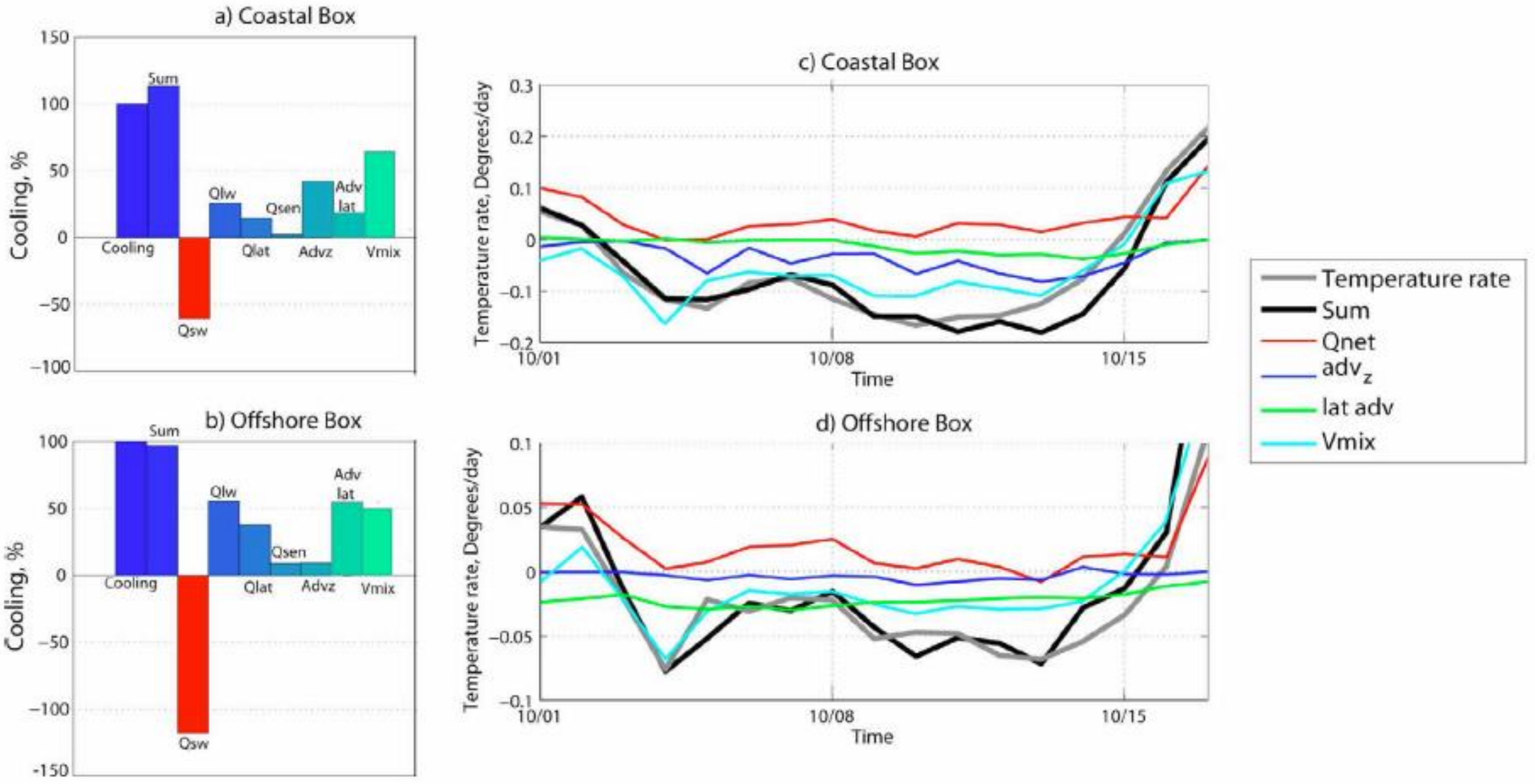
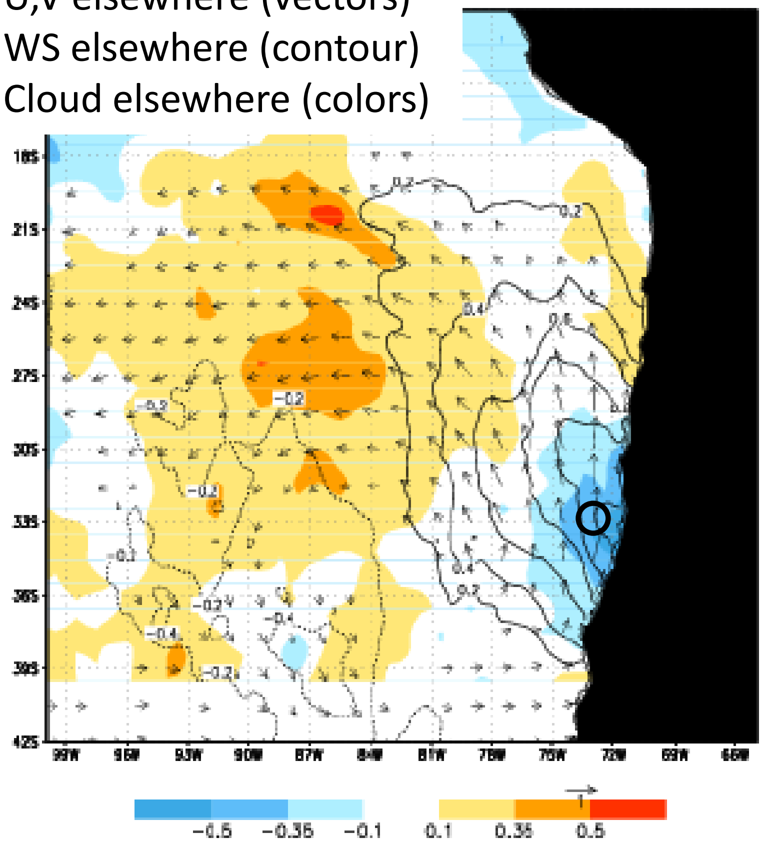


Figure 17. (a) Mean heat balance over the coastal box. Each bar represents the explained cooling percentage of the budget terms; from left to right: cooling tendency, budget residual (sum of all terms), surface flux terms (shortwave, longwave, latent heat, sensible), vertical advection, lateral advection, and vertical mixing. (b) Same as Figure 17a but for the offshore box. (c) Time series of heat budget terms in the coastal box (°C d^{-1}). (d) Same as Figure 17c but for the offshore box.

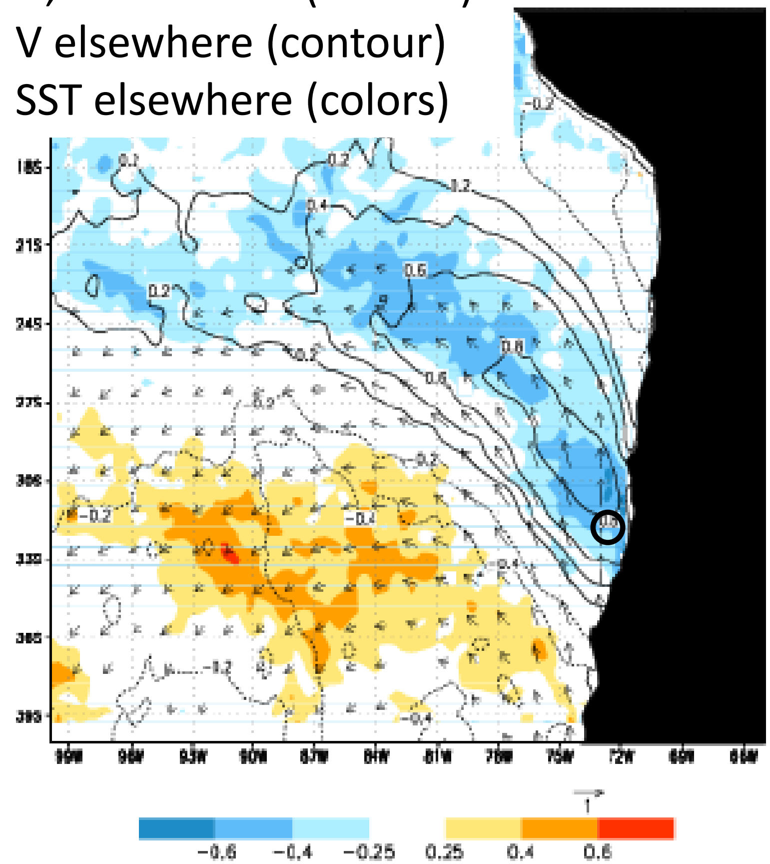
Synoptic variability of Coastal winds

1-Point correlation map. V(33S/73W) regresed upon

U,V elsewhere (vectors)
WS elsewhere (contour)
Cloud elsewhere (colors)

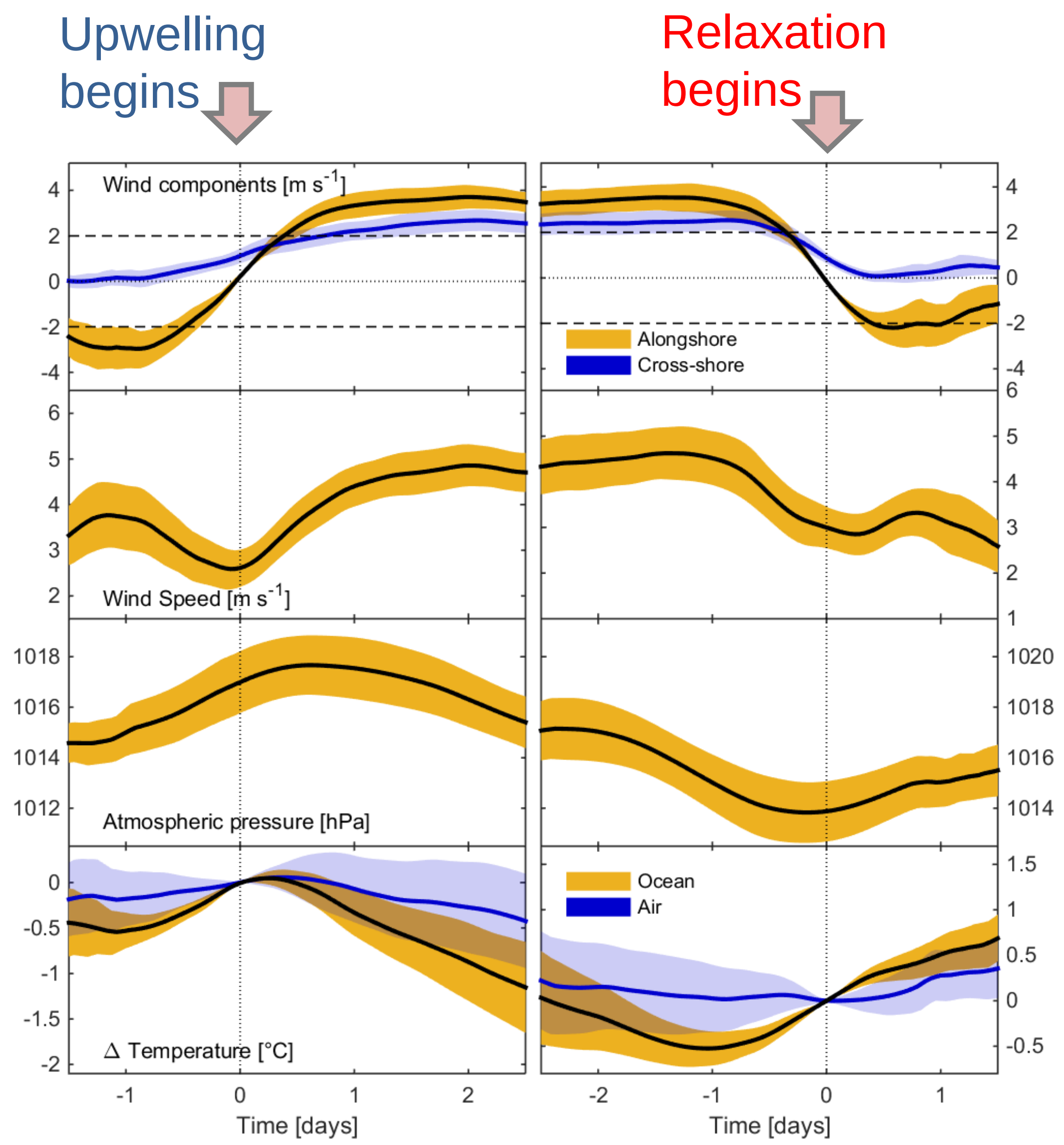


U,V elsewhere (vectors)
V elsewhere (contour)
SST elsewhere (colors)

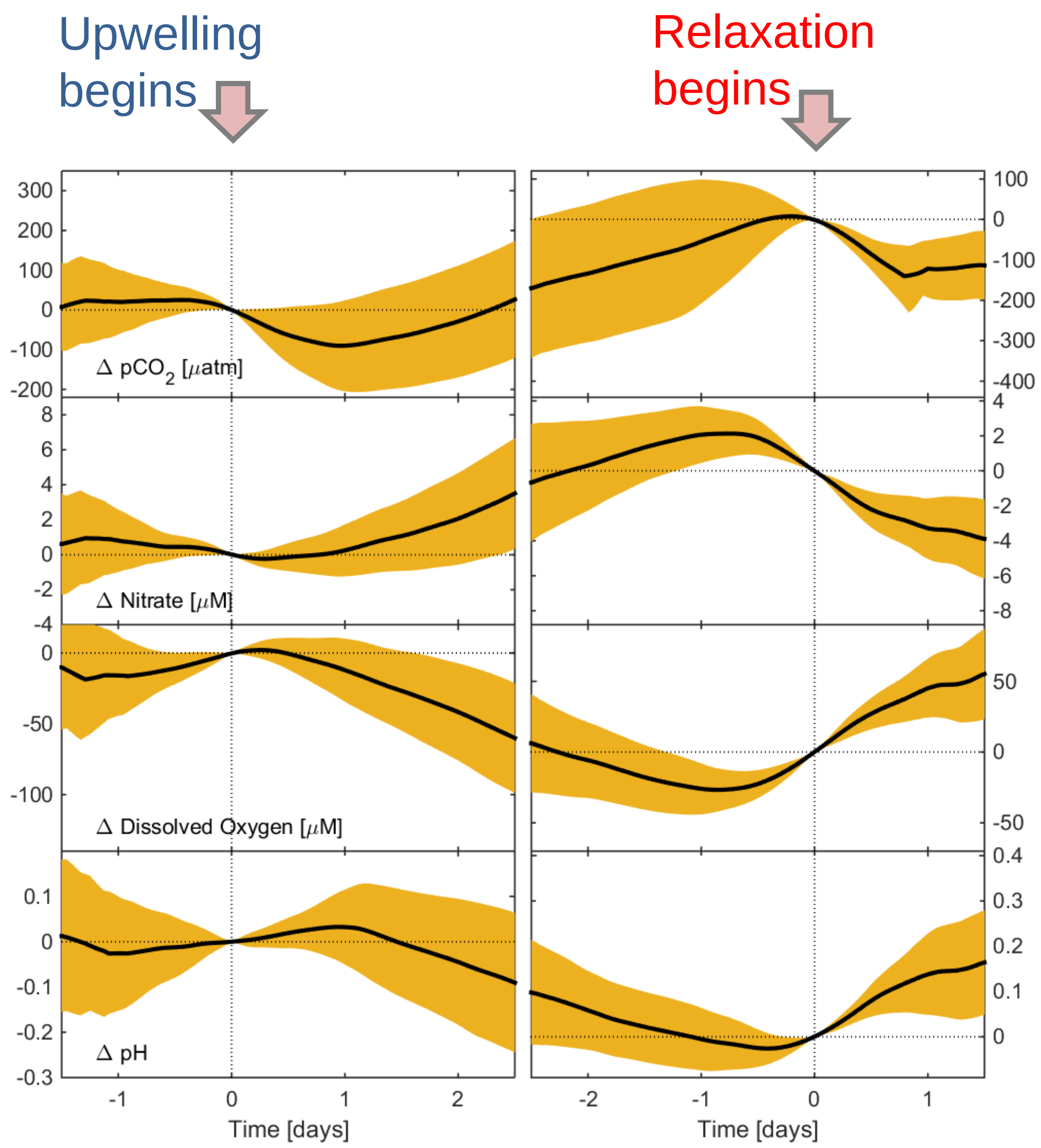


Jet events associated with: Stronger anticyclone / Reduced Sc near the coast / Increased Sc off the coast / Sea surface cooling at and downstream the jet

Composite upwelling events in near Concepción (37ºS, Chile)

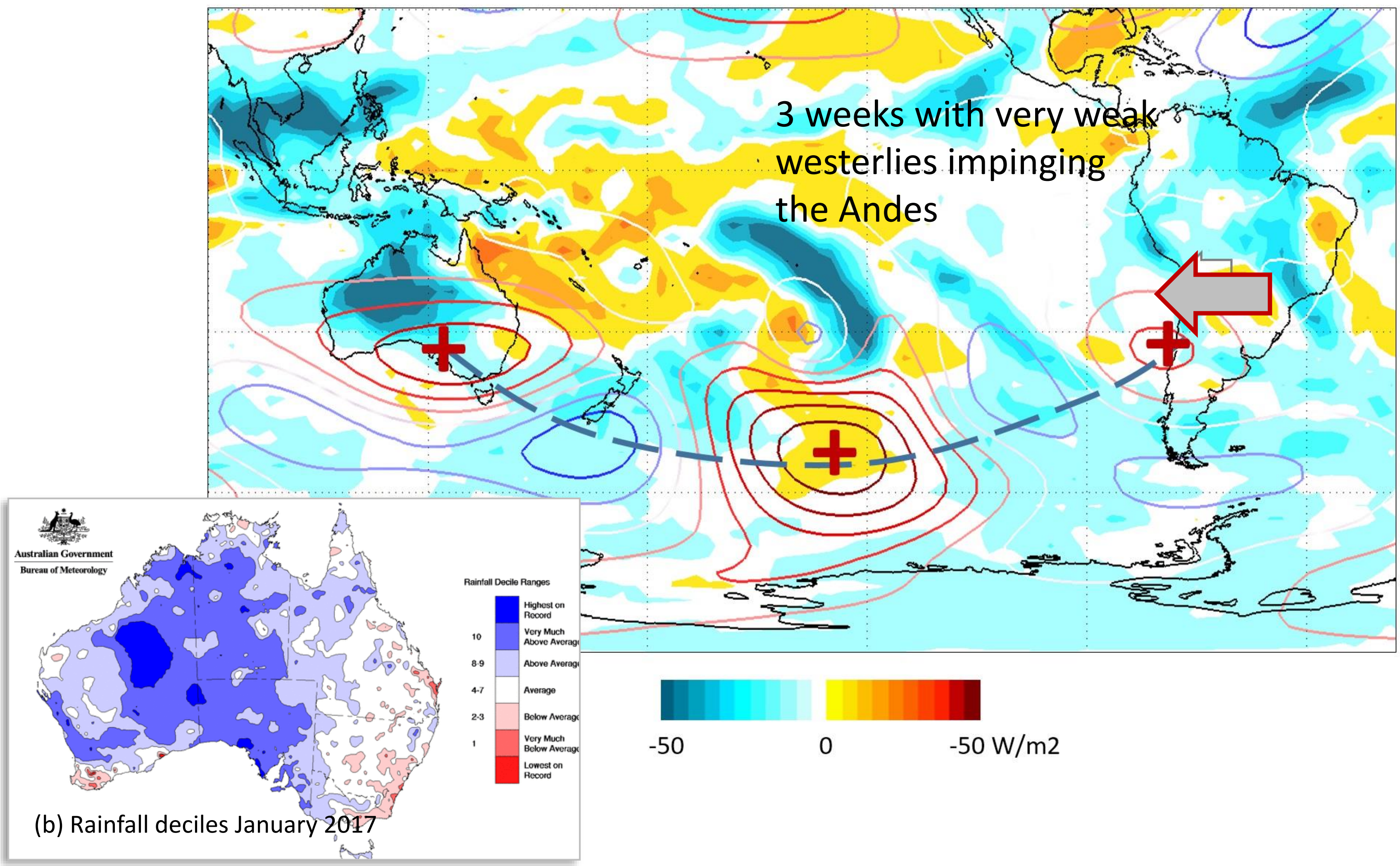


Composite upwelling events in near Concepción (37ºS, Chile)



Coastal El Niño 2017

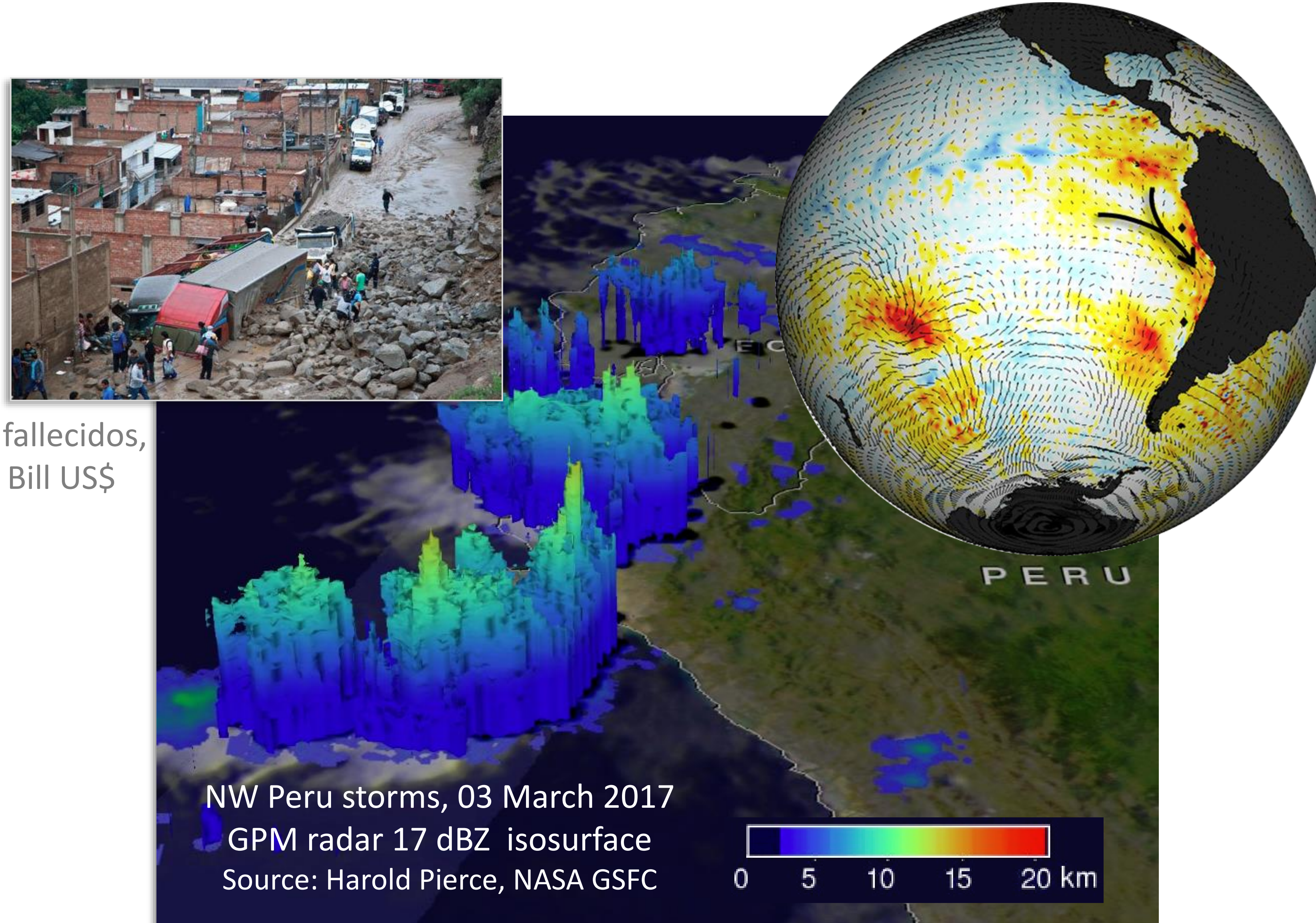
(a) 200 hPa height and OLR anomalies (15-30 January 2017)



(b) Rainfall deciles January 2017

Garreaud 2017

Coastal El Niño 2017

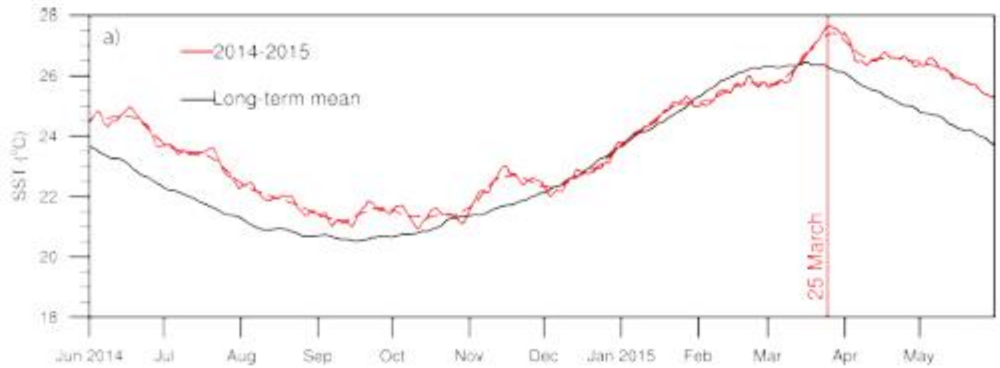


>200 fallecidos,
3.1 Bill US$

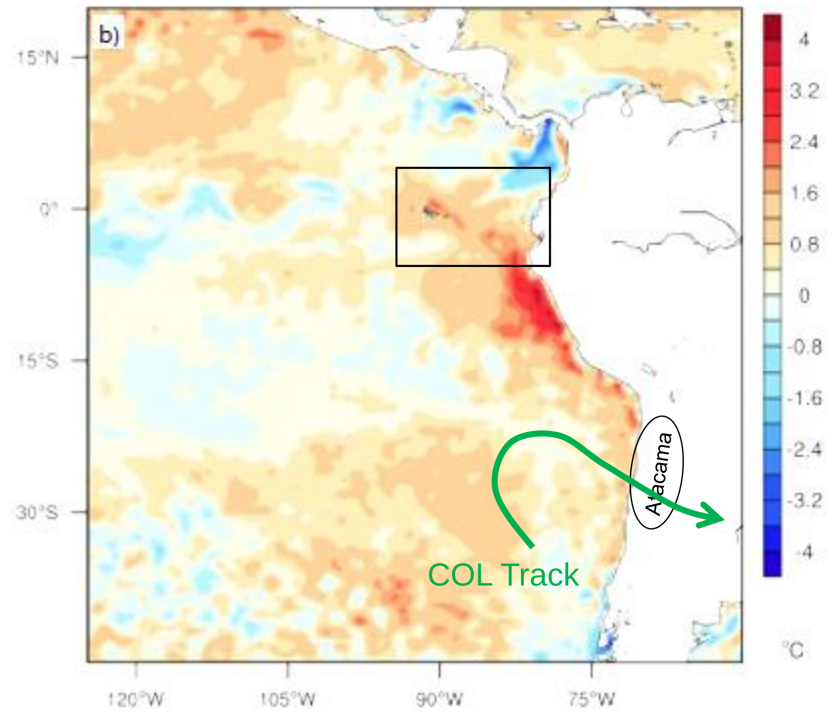
The March 2015 Atacama Storm. Three days of intense rainfall triggered landslides and widespread flooding. More than 80 causalities and major damage to public and private infrastructure. Most acute impact during the event but many problems (e.g. public health) in subsequent months.

Plausible suspect: marked, sudden SST warming off South America (EN 2015)
Destabilize the atmosphere and provide extra moisture

Niño 1-2
SST

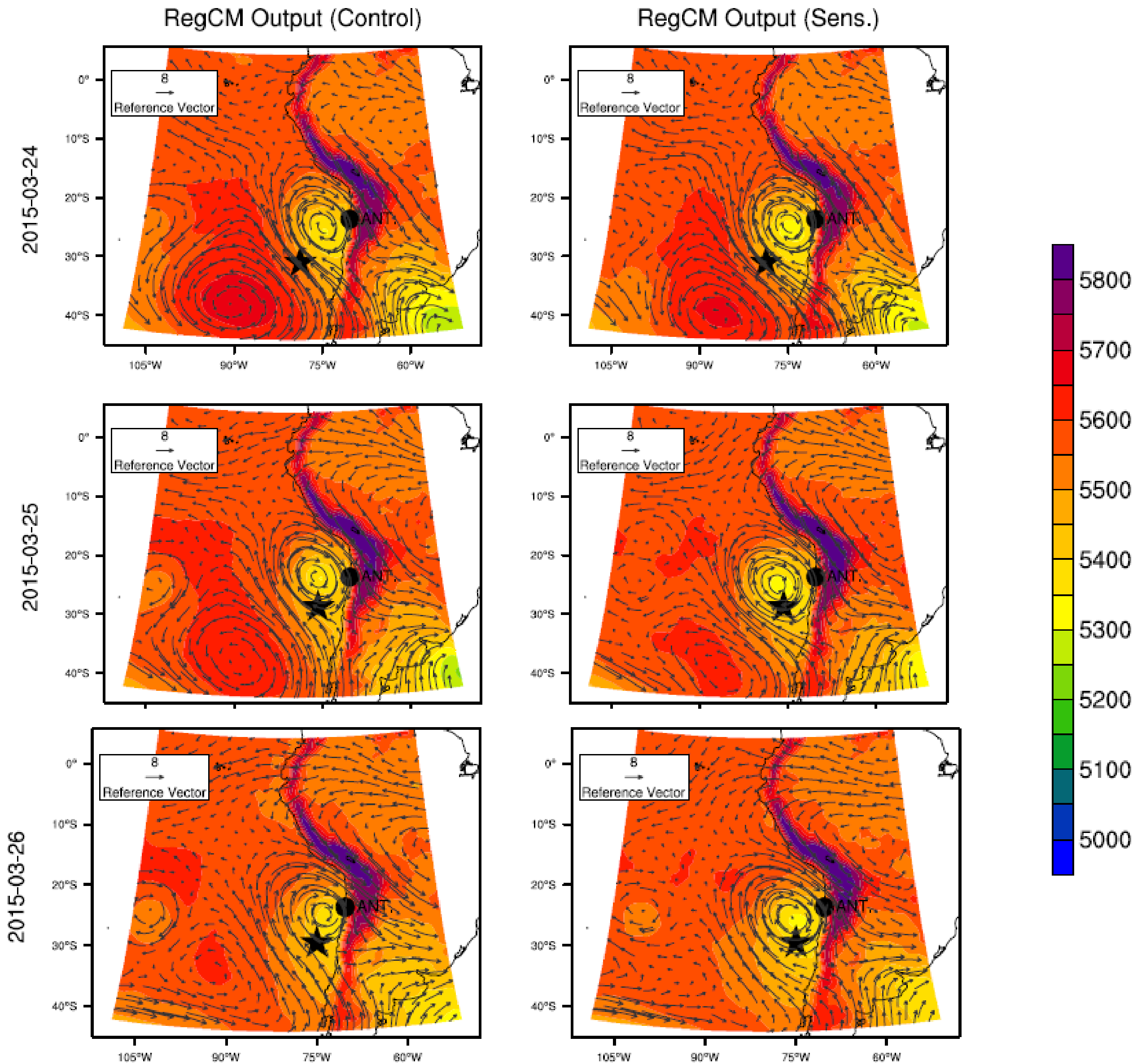


SST anomaly
23 March 2015

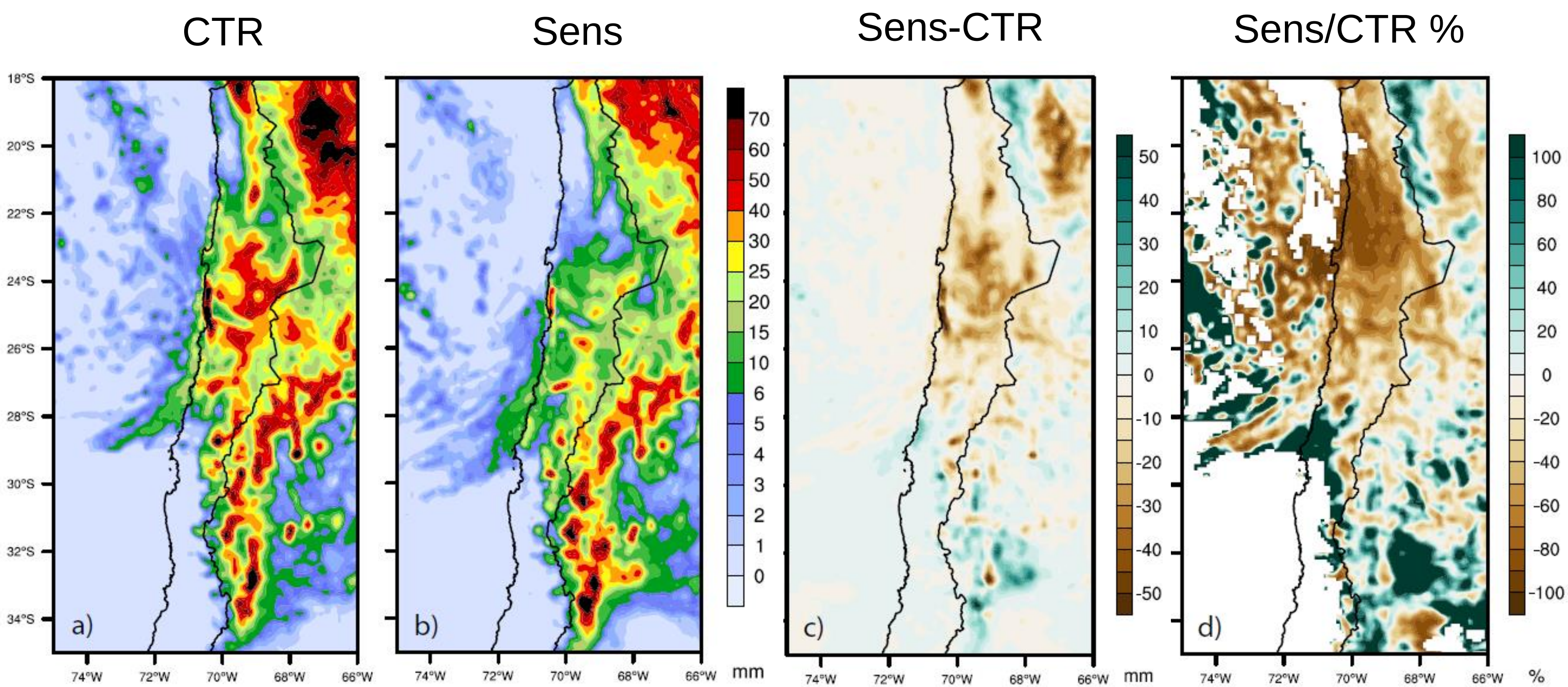


Numerical experiment using RegCM (forced by ERA)

In a sensitivity run the SST was keep equal to the field at March 10 (prior to the warming) thus causing a sfc BC cooler than the control run



RegCM simulated precipitation



CTR PW (contours) and SENS-CTR PW (colors)