The Climate of Patagonia: From the recent past to the near future

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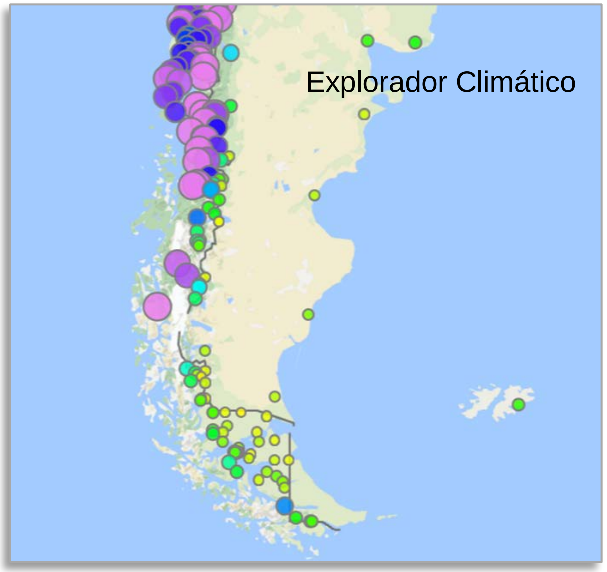
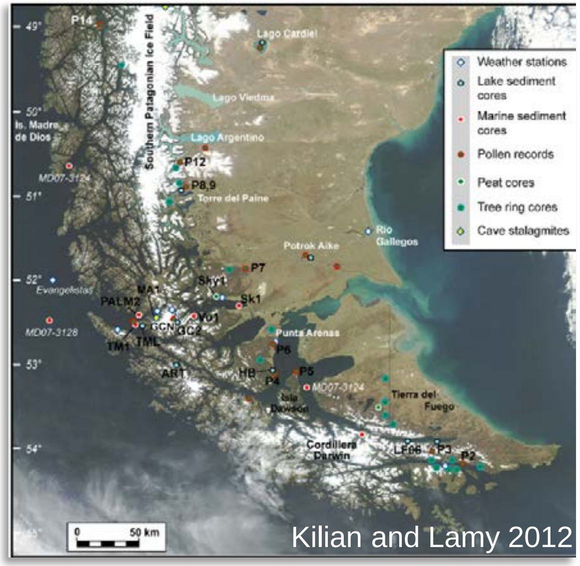
Outline

- Patagonia 101: Basic aspect
- Large scale control of regional climate (U-P, U-T)
- Climate variability and change
- The awful 2016

We all love Patagonia.....

- Large, complex territory, high biodiversity
- Ice fields, glaciers, major rivers in the west
- Hydrocarbons, wind and dinosaurs to the east
- Climate and environmental changes
- Multiple paleo-records but few climate stations

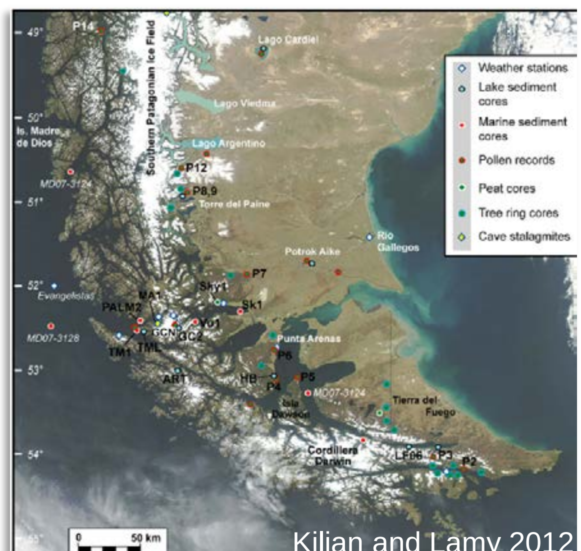




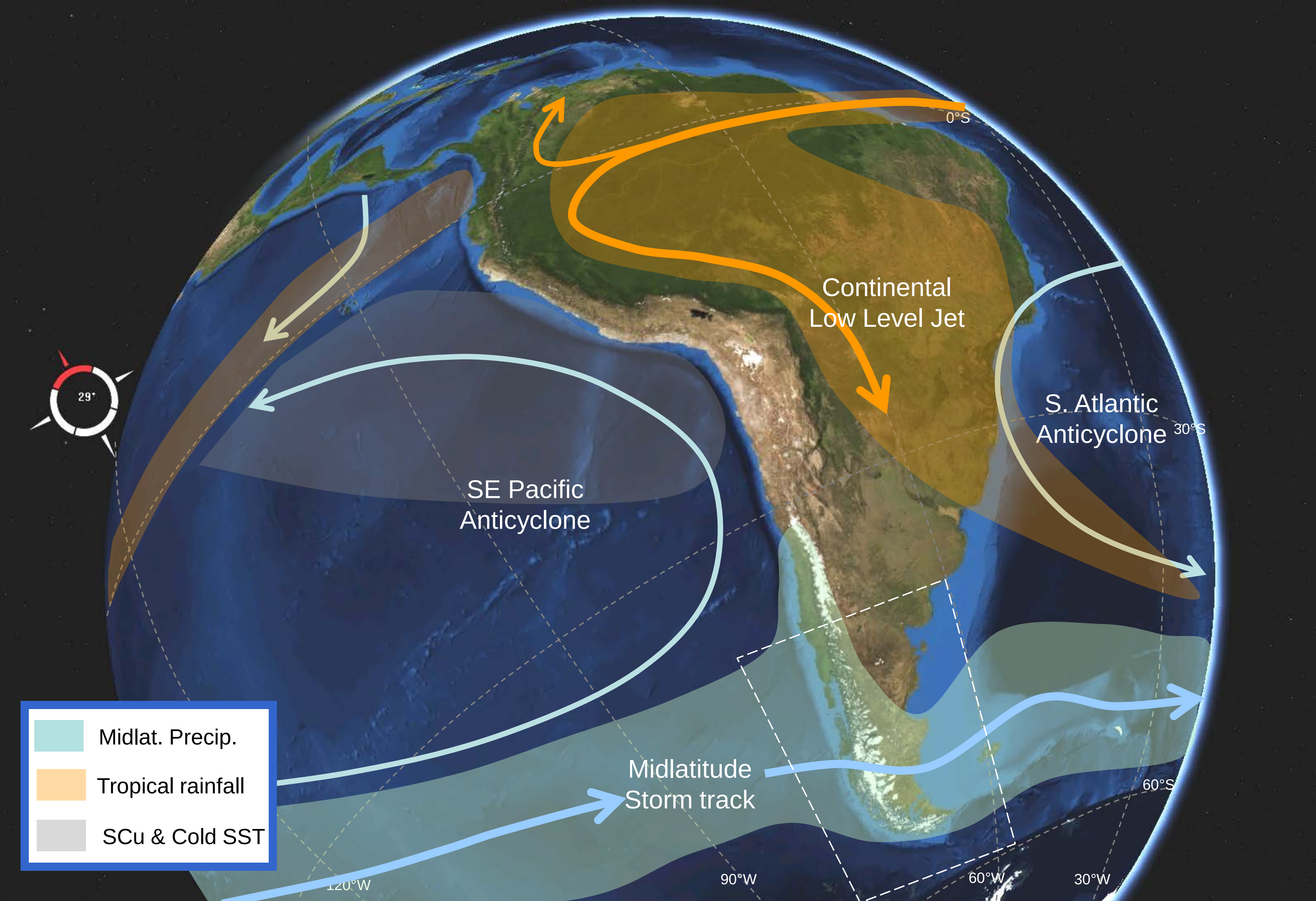
Kilian and Lamy 2012

We all love Patagonia…..

- Conferences began Sunday 8 AM

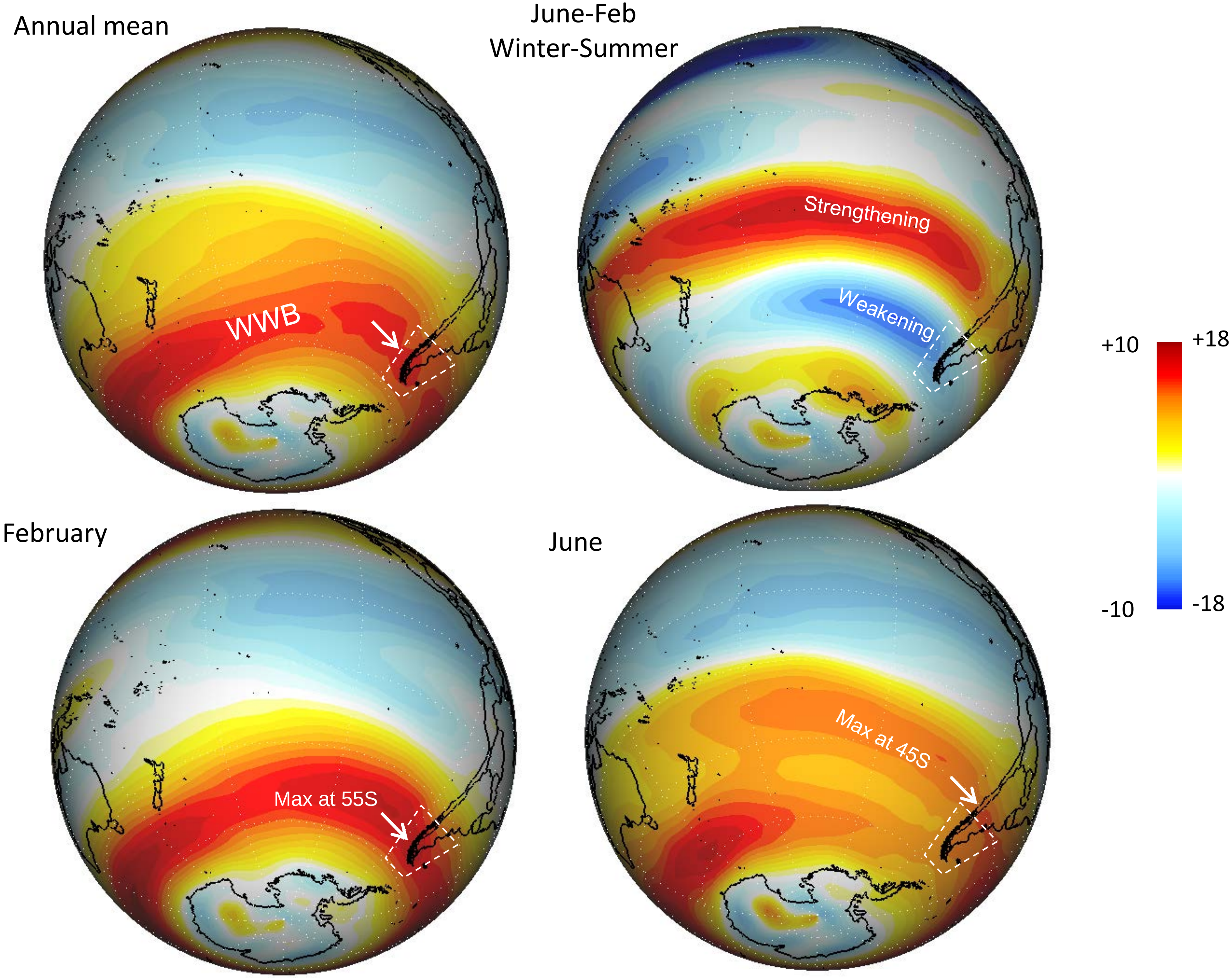


The big picture



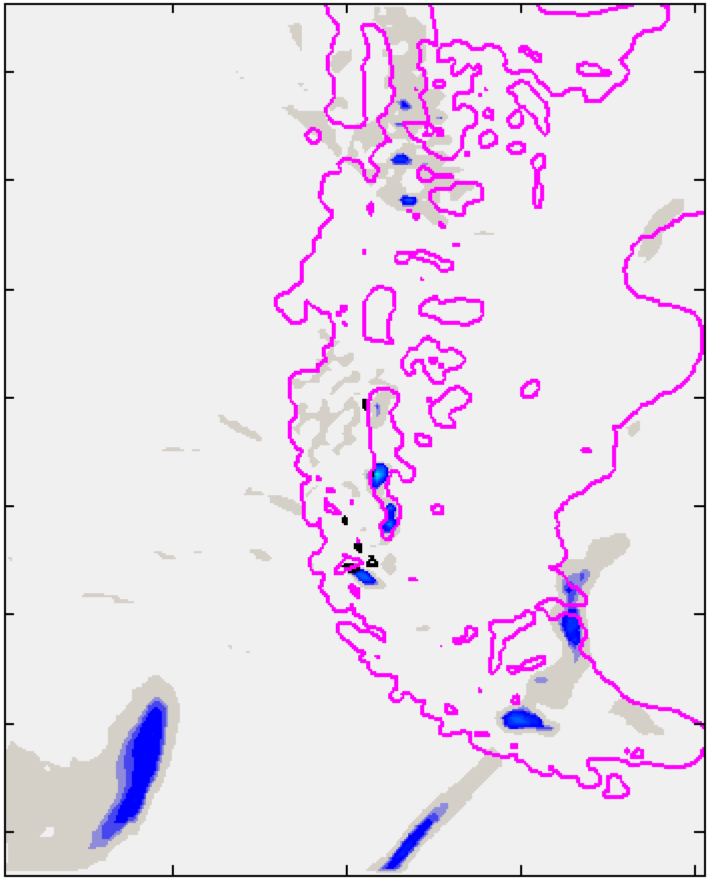
Long term mean zonal wind at 700 hPa

(best predictor of precipitation over the extratropical Andes)



One (typical) storm simulation (WRF)

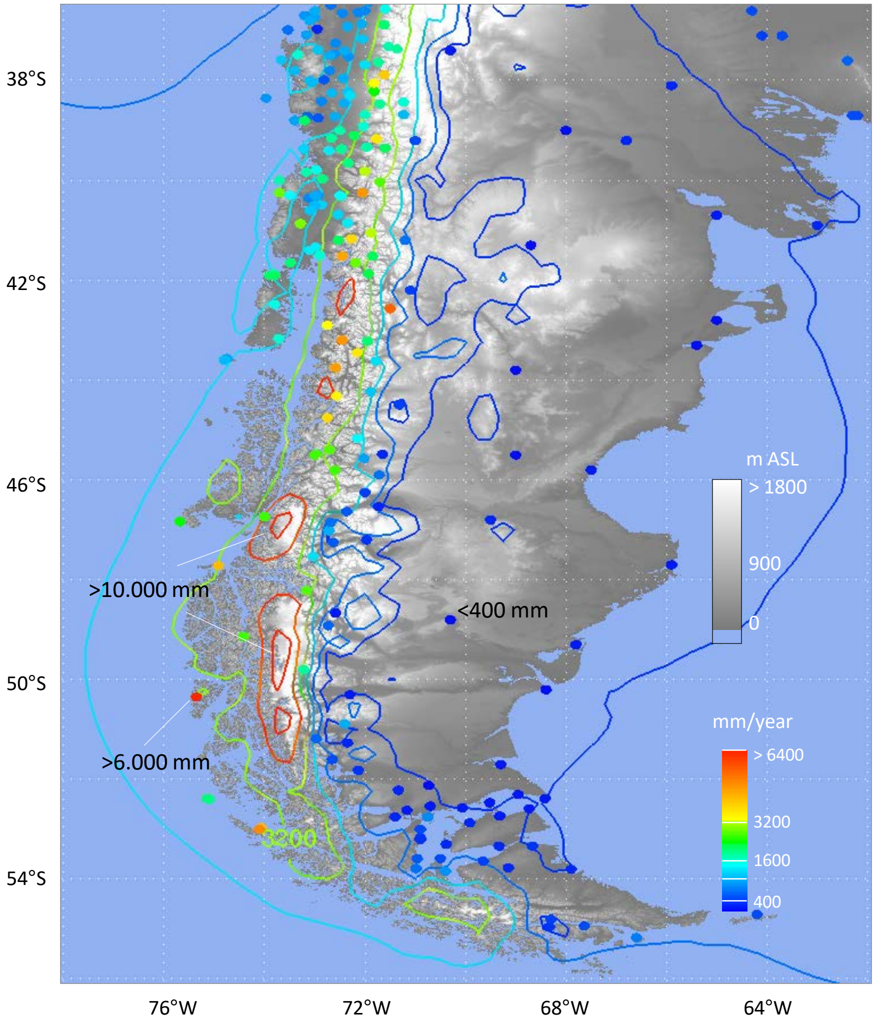
Hourly results during a 3 day period. Resolved precipitation (colors), Convective rainfall (contours) and topography



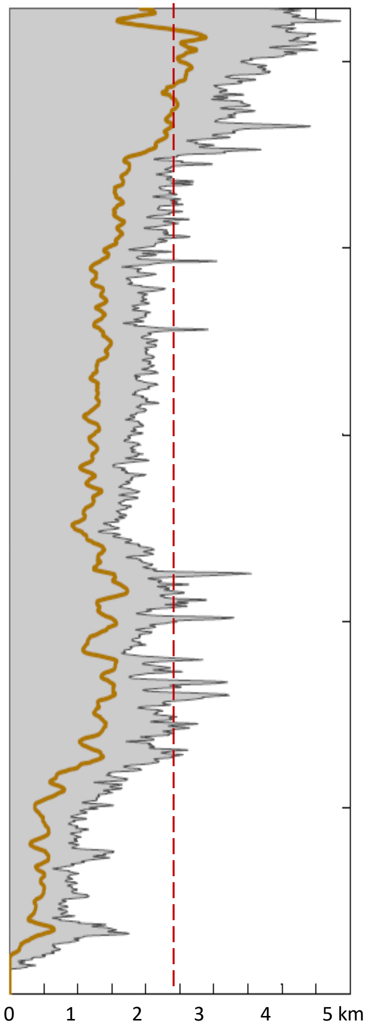
Salient features: Rainfall enhancement over the Andes windward slope, Rain shadow, Convective rainfall along the coast

Patagonia 101: Precipitation

Mean Annual Rainfall (everybody guess)

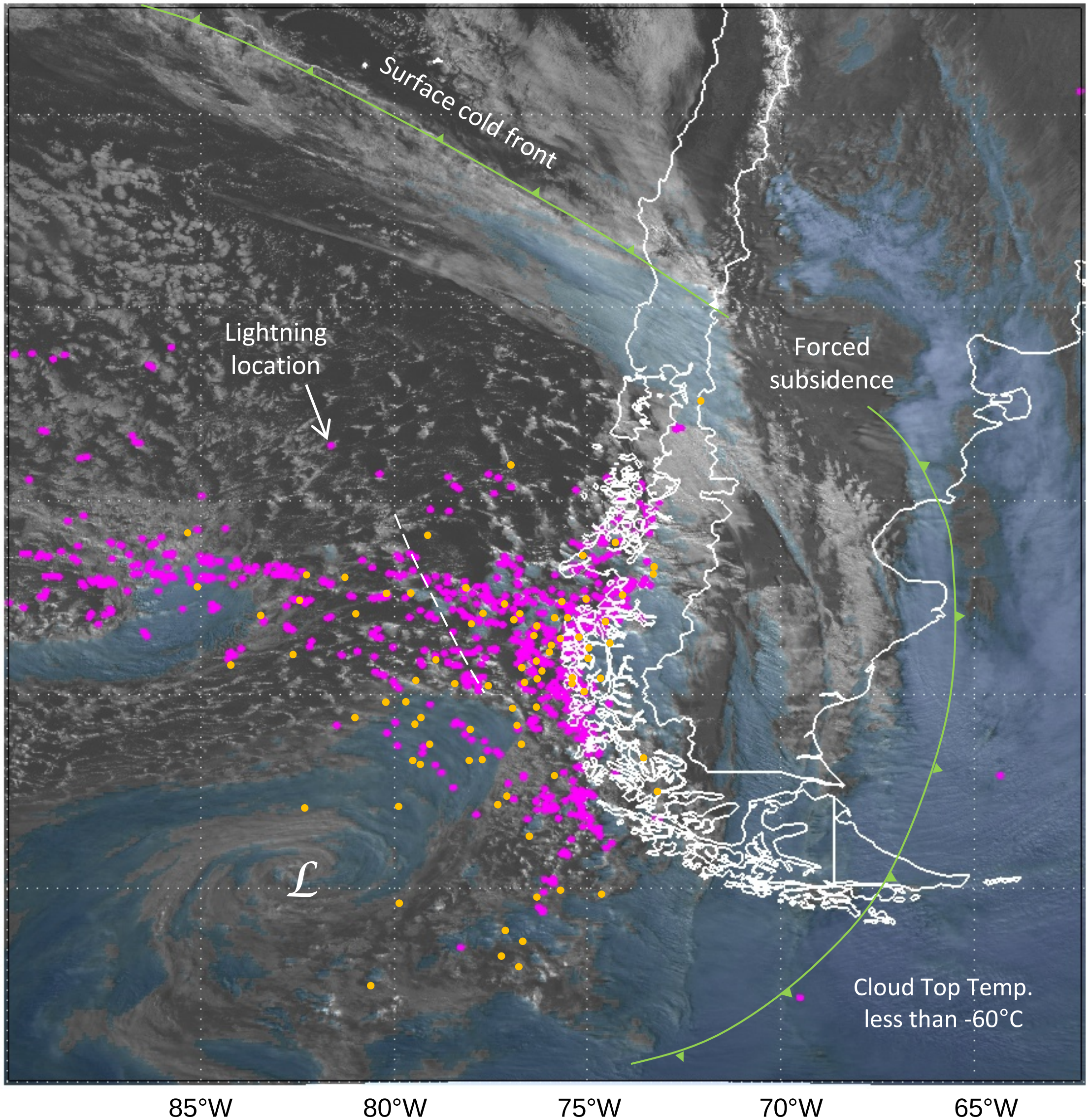


Height (max, 90%)



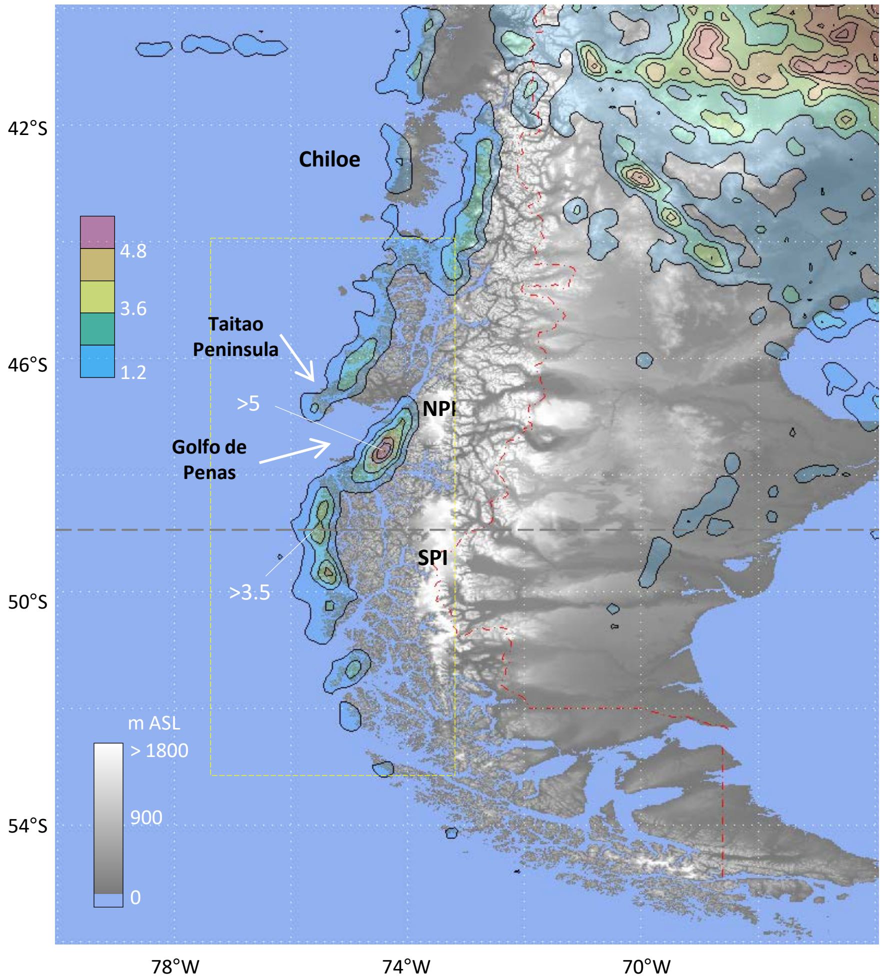
April 30, 2012 – 1800 UTC

GOES-13 Visible (BW) and IR4 (light shading) + WWLLN Lighting (dots) + Starnet

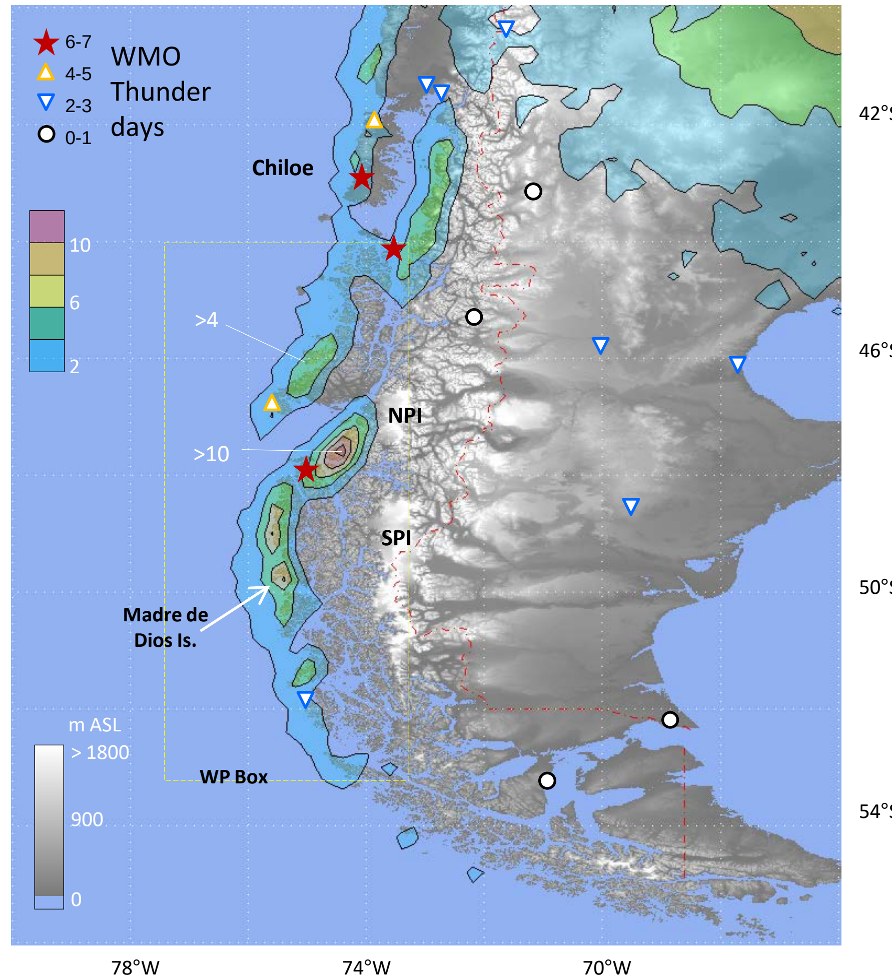


Spatial Distribution (2008-2012)

Lightning density, 0.1×0.1 lat-lon boxes



Number of lightning-days, 0.2×0.2 lat-lon boxes



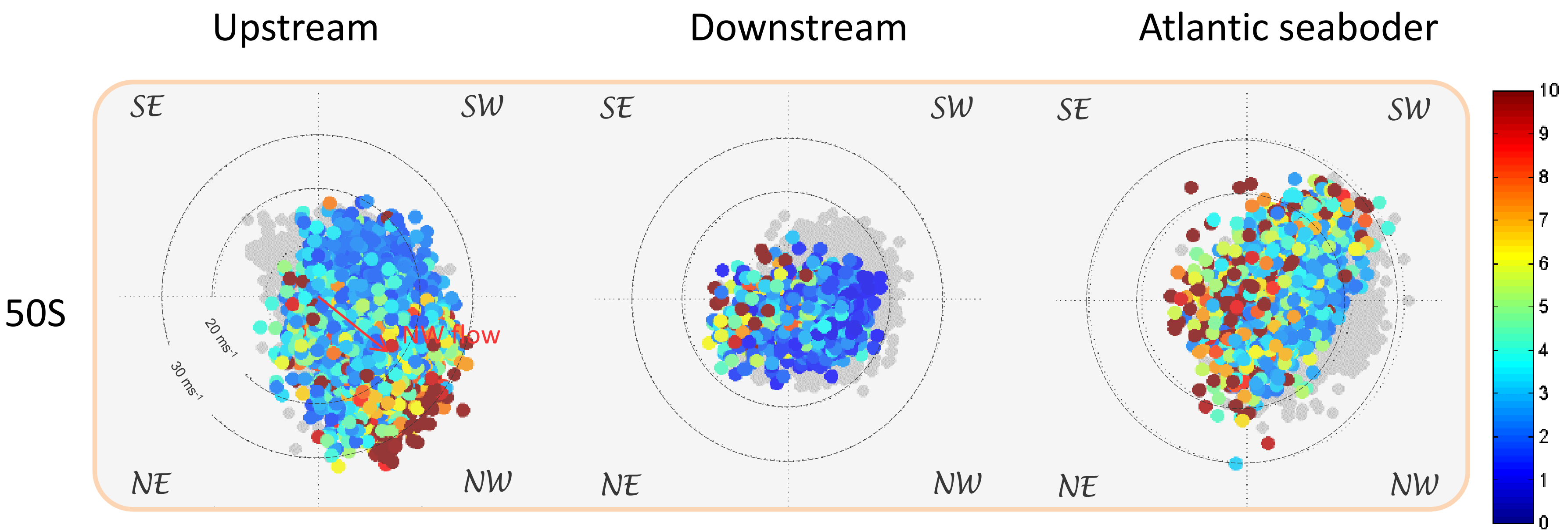
Garreaud, Nicora et al. 2014

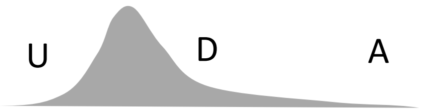
Large scale control of regional climate

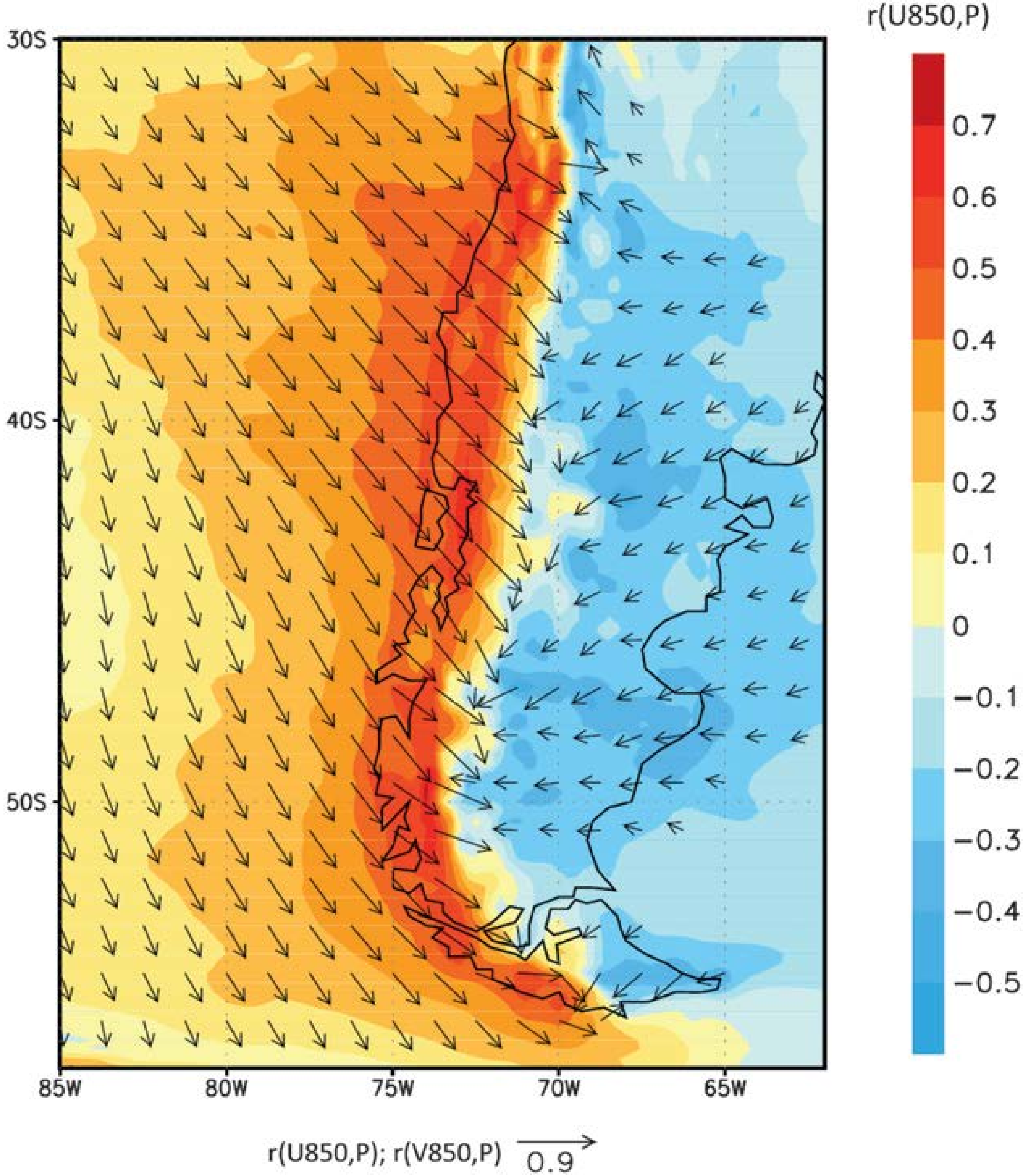
(Garreaud 2007; Garreaud et al. 2013)

Linking U with P/SAT we can:
* Downscale large-scale signals
* Upscale local-scale records

850 hPa (1500 m ASL) Wind roses for all days (grey) and rainy days (color) at selected locations in Patagonia







Local (point-to-point) **correlation map between daily precipitation (P) and 850-hPa zonal and meridional wind components (U850; V850)** using PRECIS-DGF results from 1980–90. At each grid point the correlation was calculated for the sample of days with P >1 mm.

Colors indicate the P–U850 correlation.

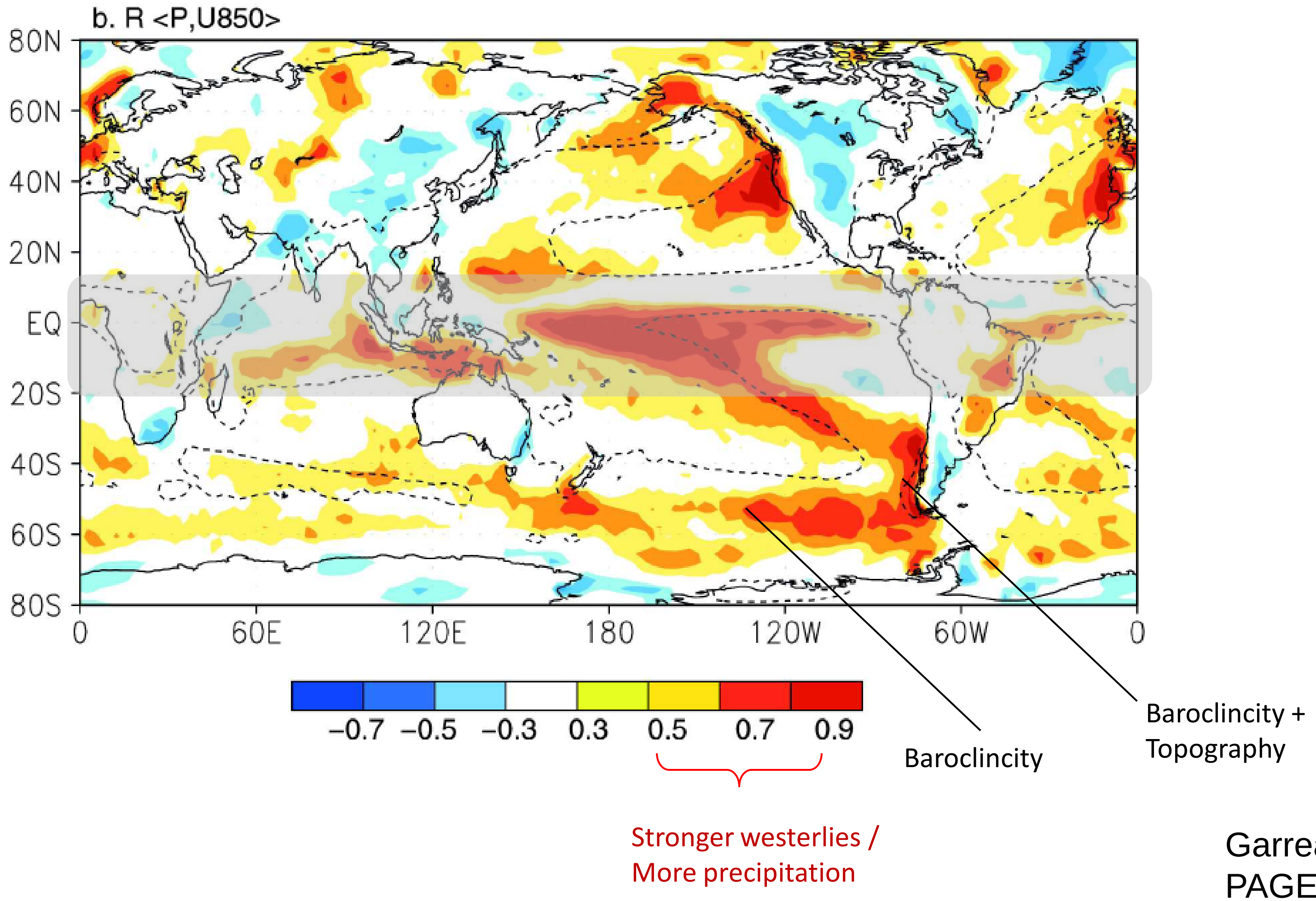
Vectors are constructed using r(P, U850) and r(P,V850) (scale at the bottom) and only shown where absolute value exceeds 0.3.

Garreaud et al. 2013

Co-variability of zonal wind and precipitation

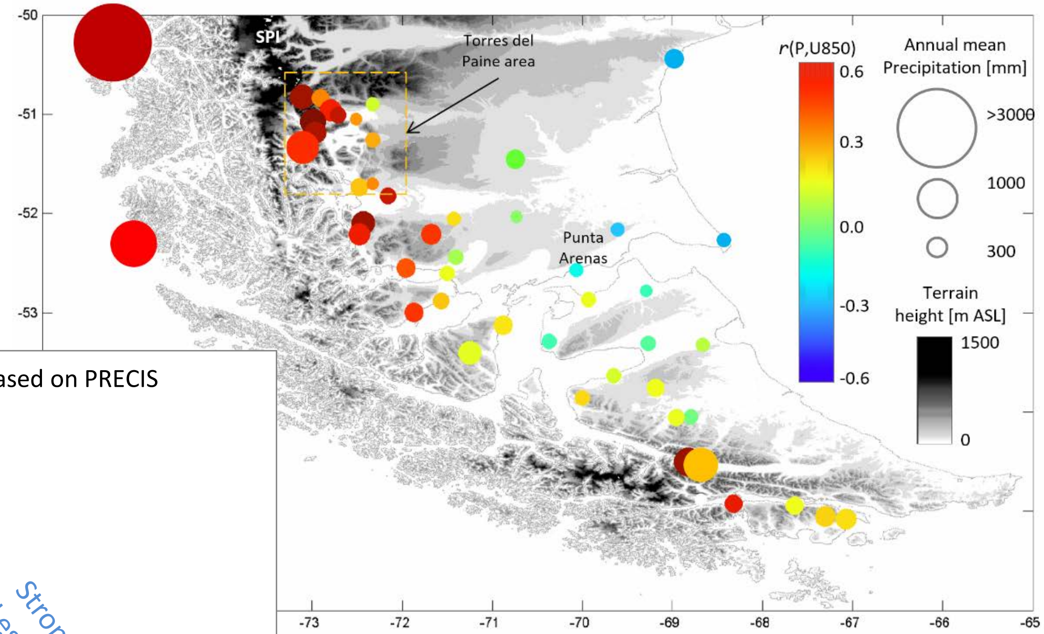
Point-to-point correlation between U850 (*NNR*) and precipitation (*CMAP*)

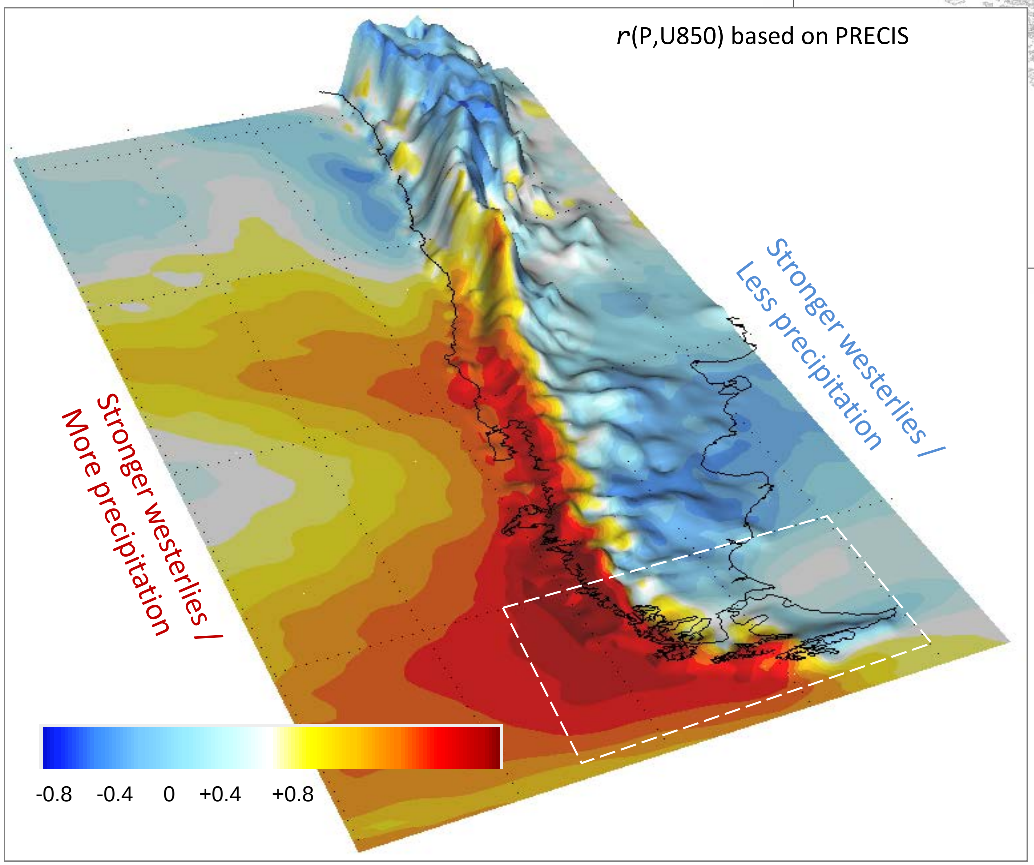
Both data sets 2.5º×2.5º lat-lon, **annual means, 1979-2005**



Garreaud 2007
PAGES 2006

Wind-precipitation covariability at annual timescales (year-to-year)

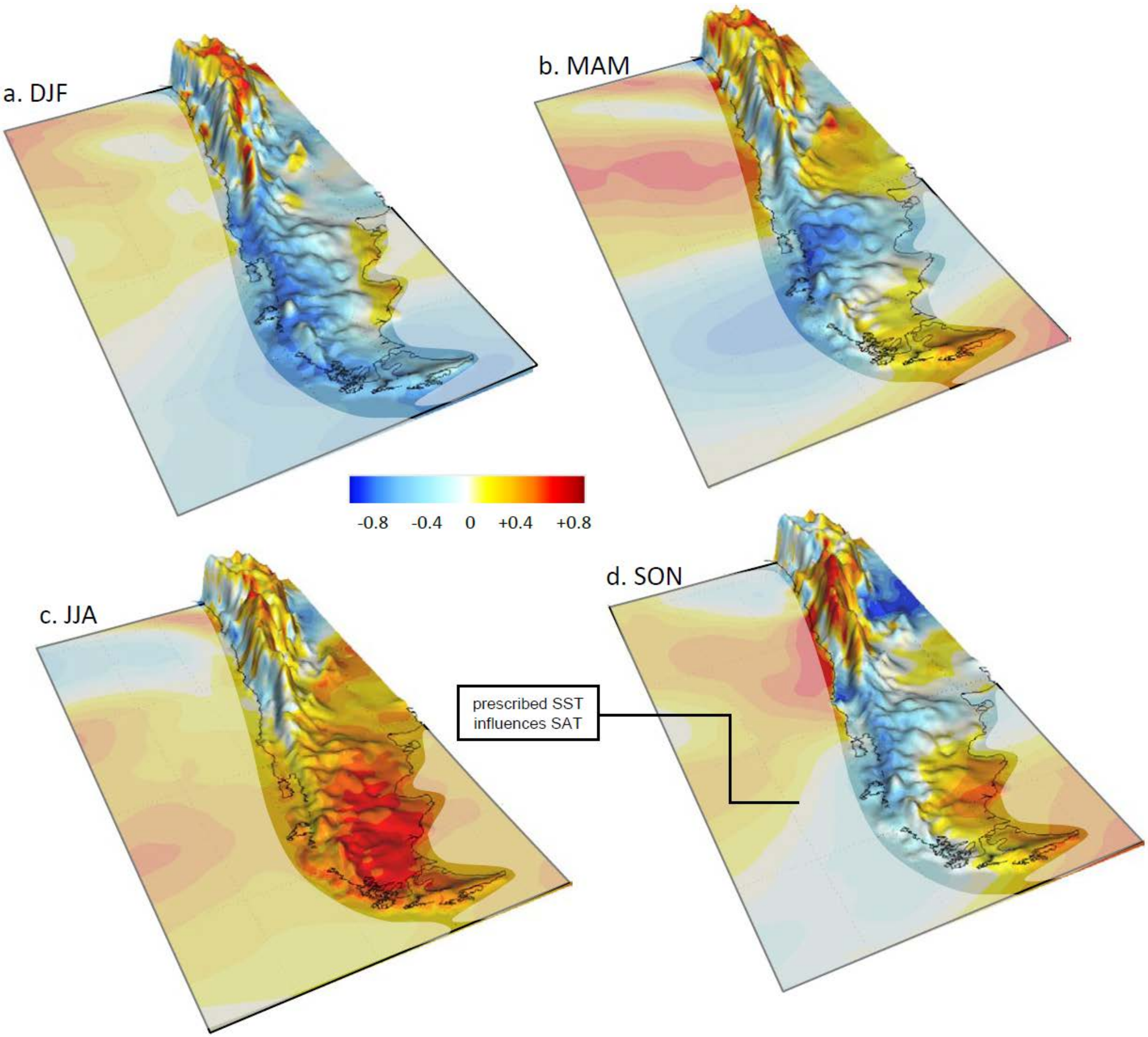




Stronger westerlies / More Precip. up to 50 km downstream of the Mnts.

Wind-SAT covariability at annual timescale

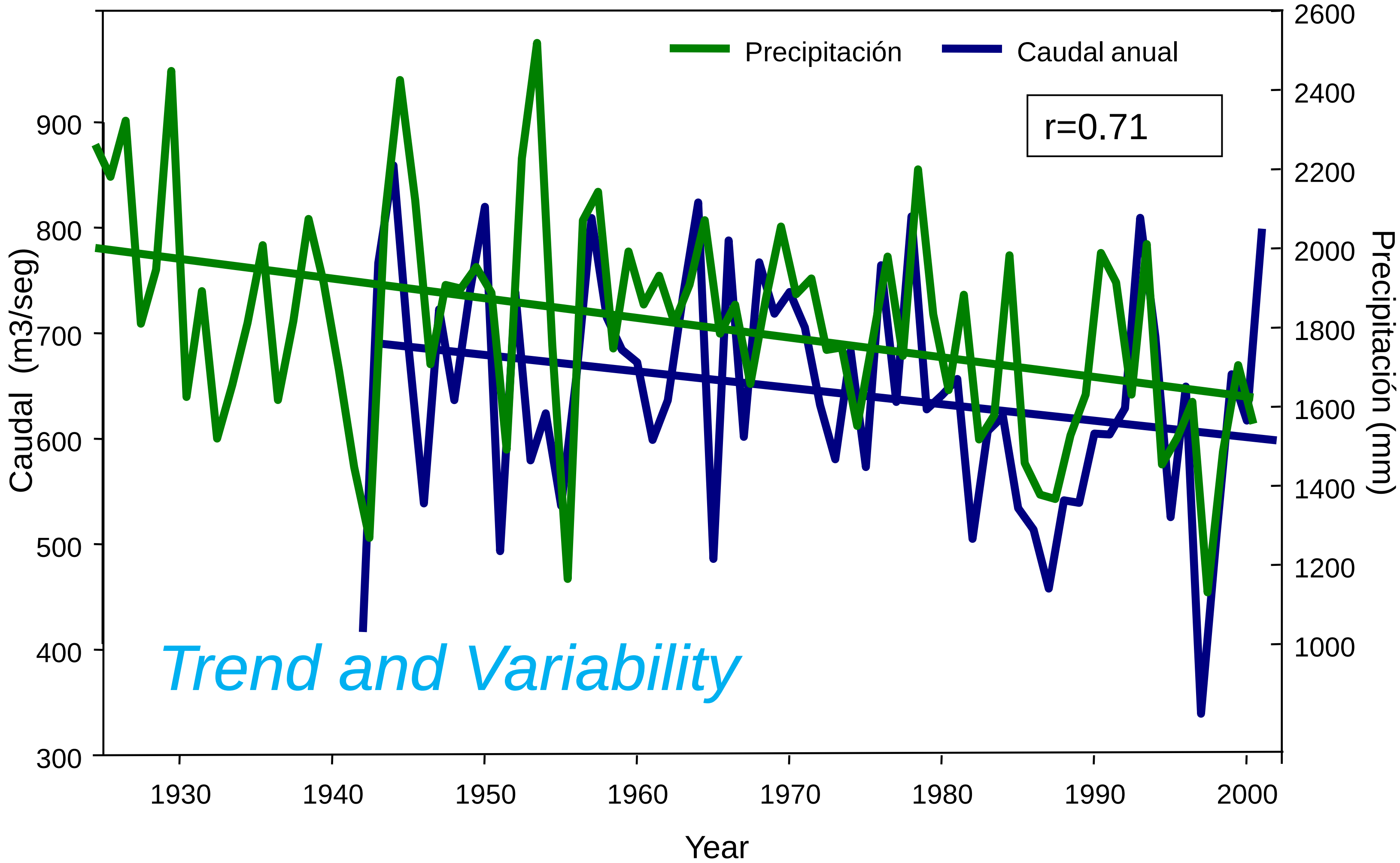
Strong westerlies
→ cold summer



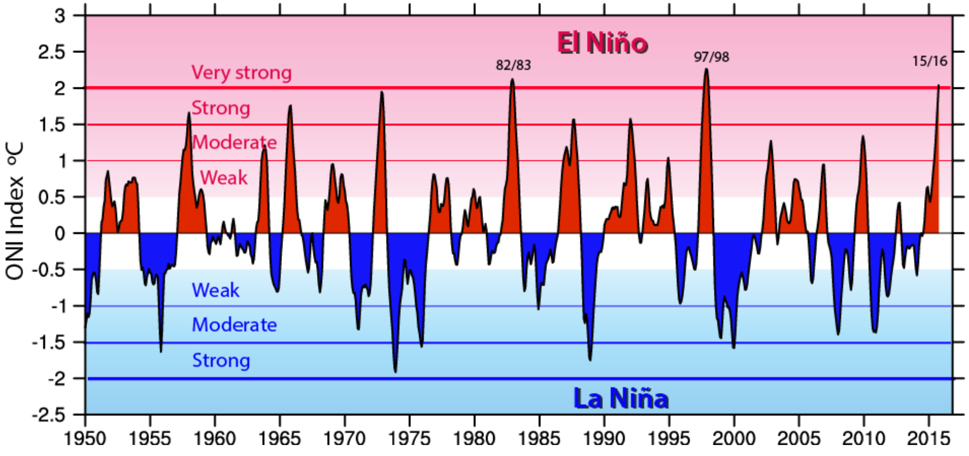
Strong westerlies
→ Warm winter

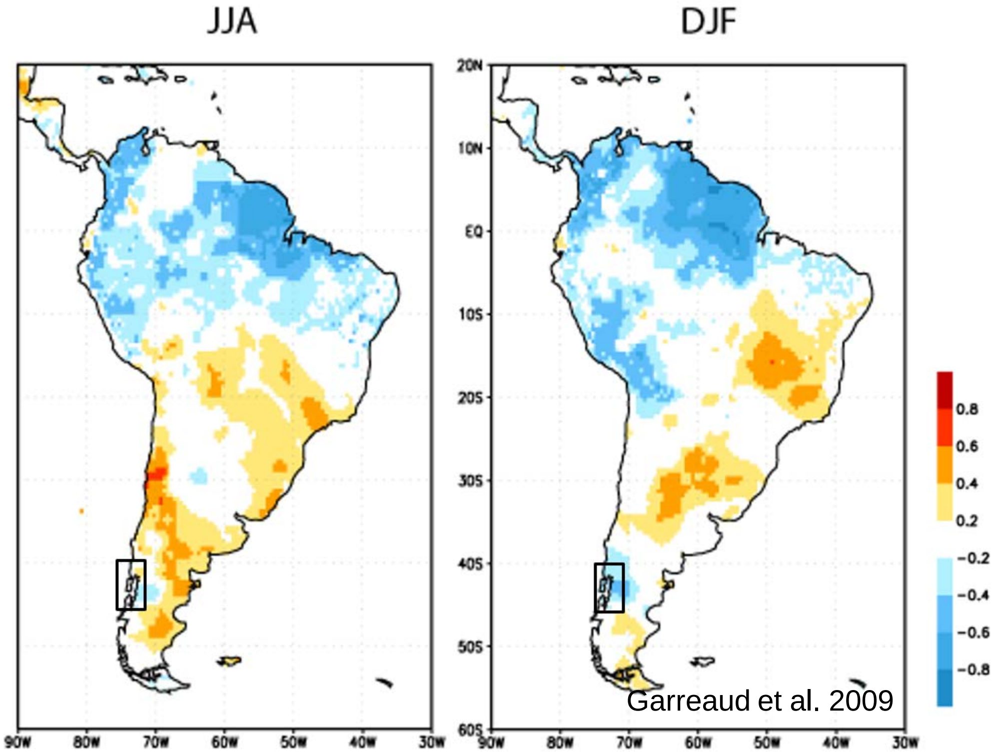
Puerto Montt annual rainfall and Puelo mean discharge

(Fuente: Antonio Lara, UACH)

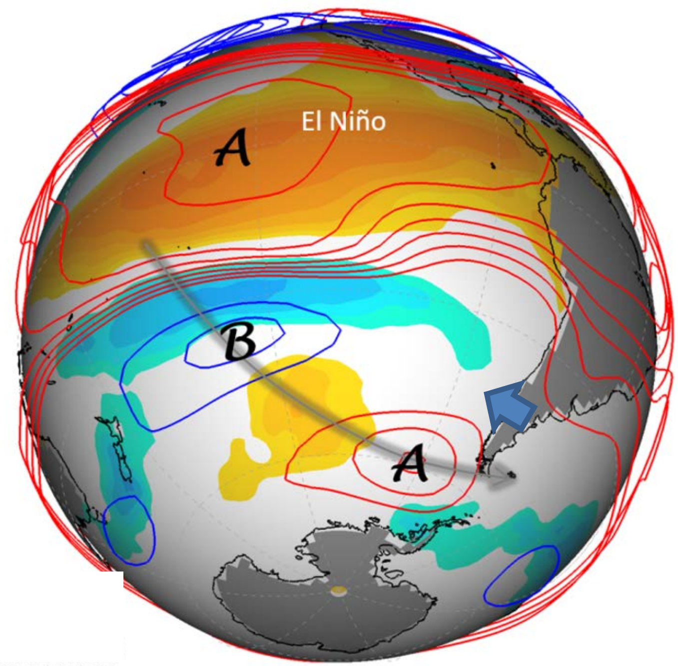


ENSO impacts on Patagonia





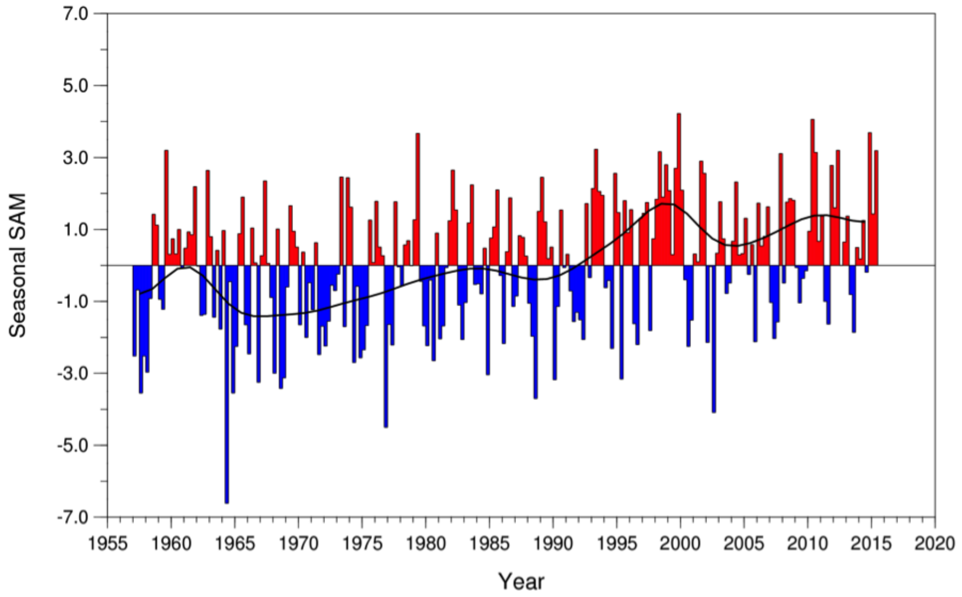
El Niño Composite JFM



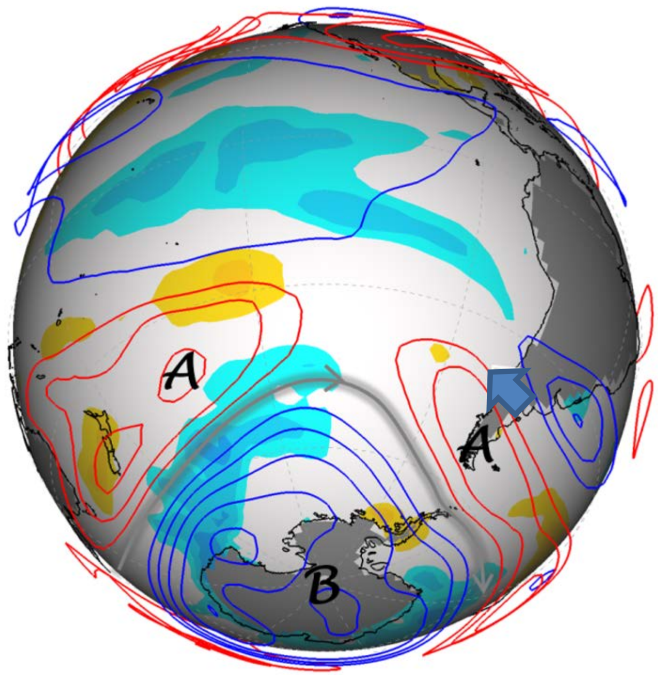
Colors: SST anomalies
Contours: Z300 anomalies

← Correlación estacional ONI-PP

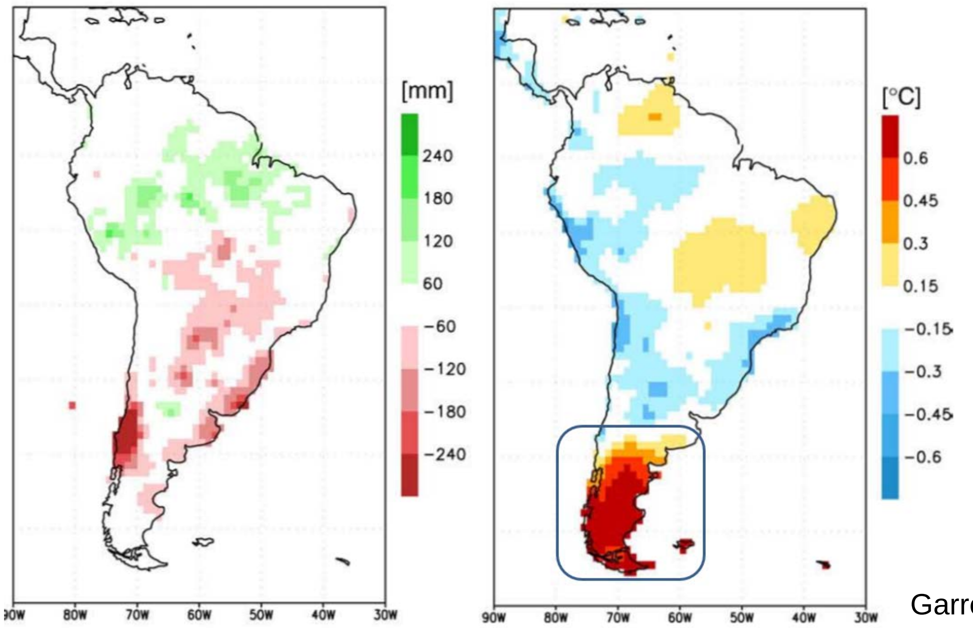
SAM impacts on Patagonia



SAM+ Composite



Colors: SST anomalies
Contours: Z300 anomalies



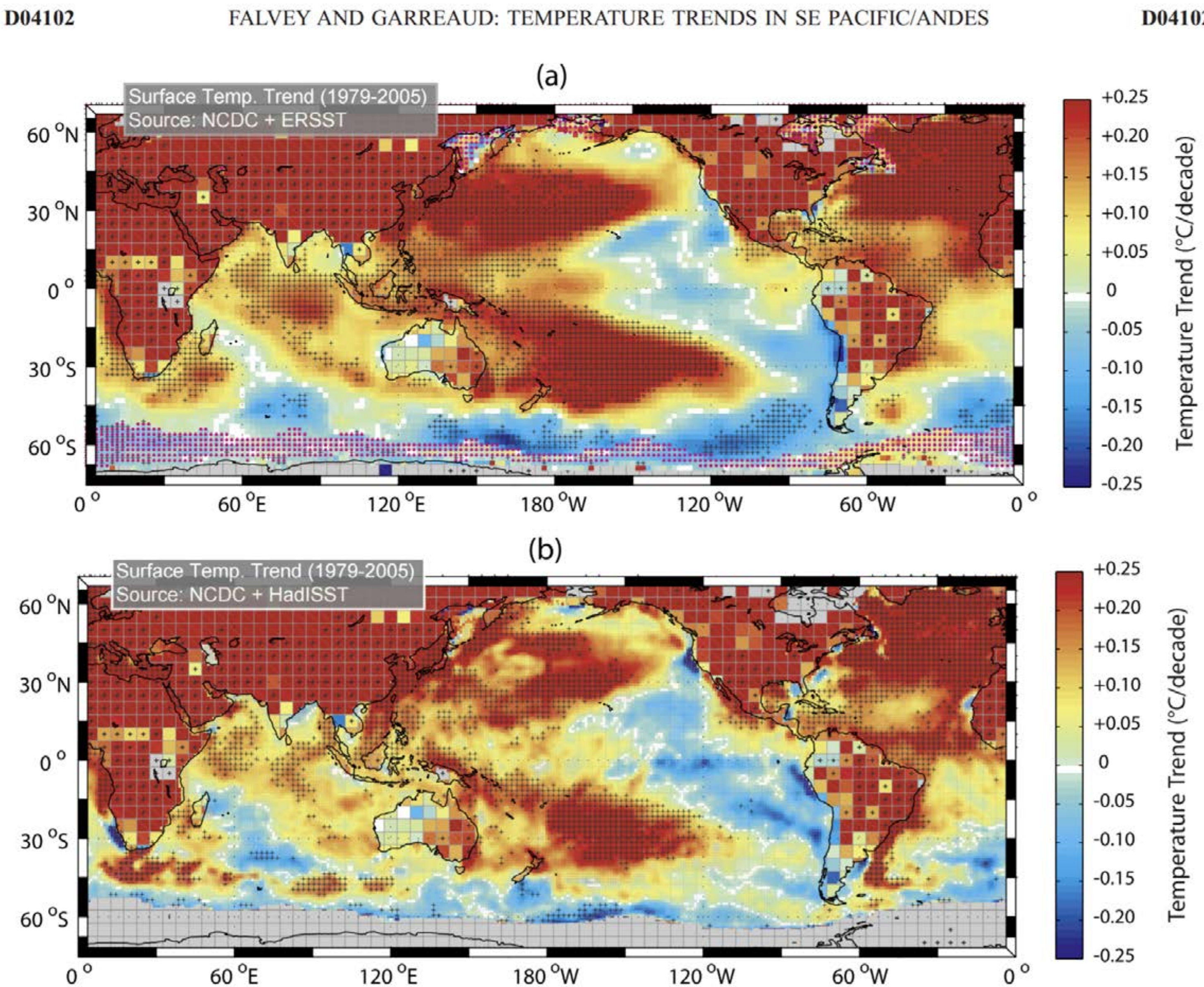
← Regresión annual
SAMI-PP,T

Garreaud et al. 2009

Contemporaneous climate change

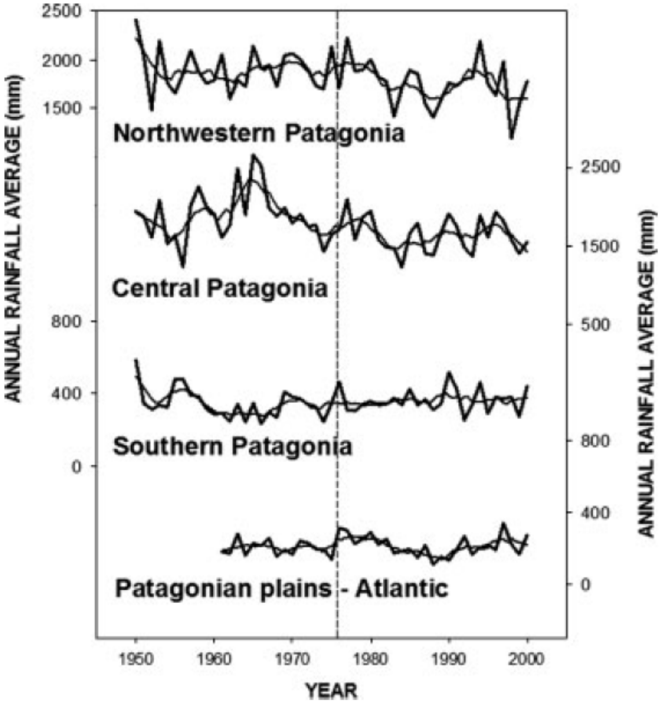
Recent past and near future

Weak temperature trends

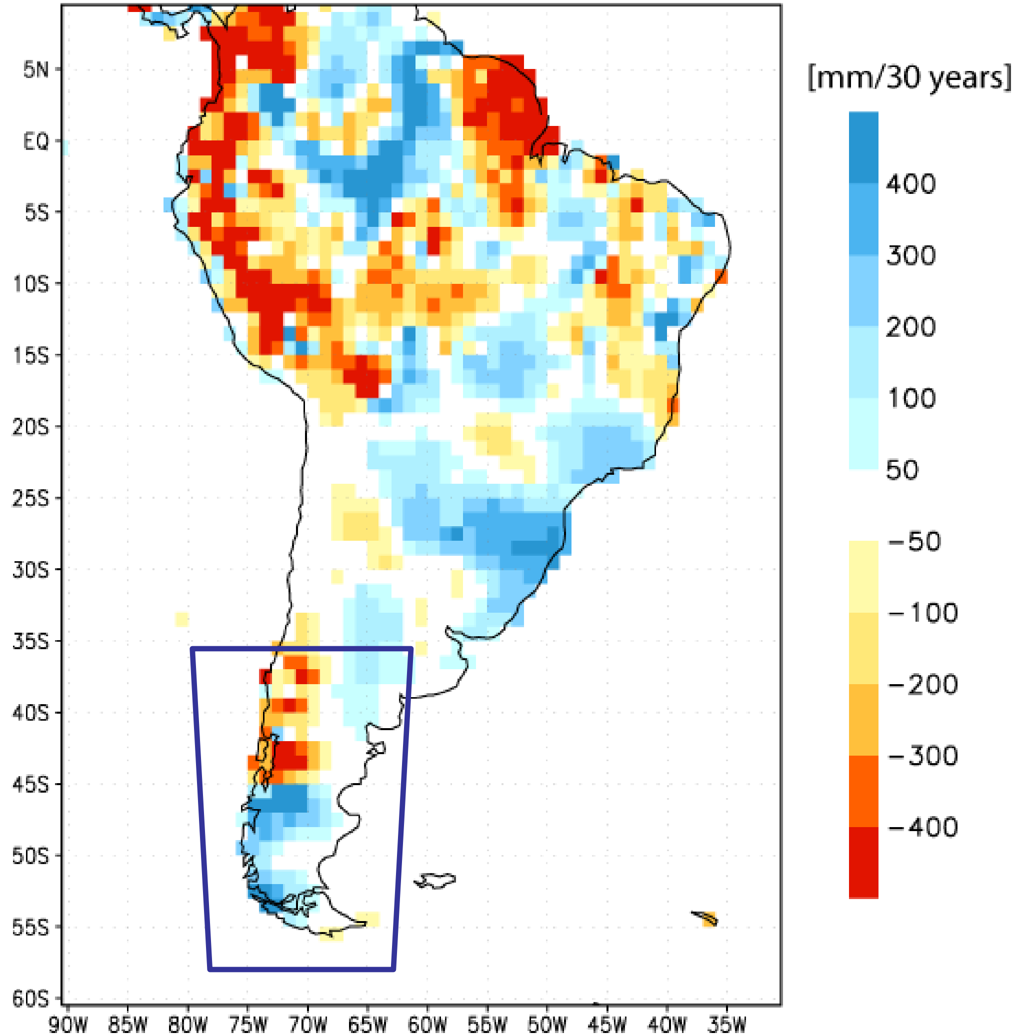


Heterogeneous precipitation trends

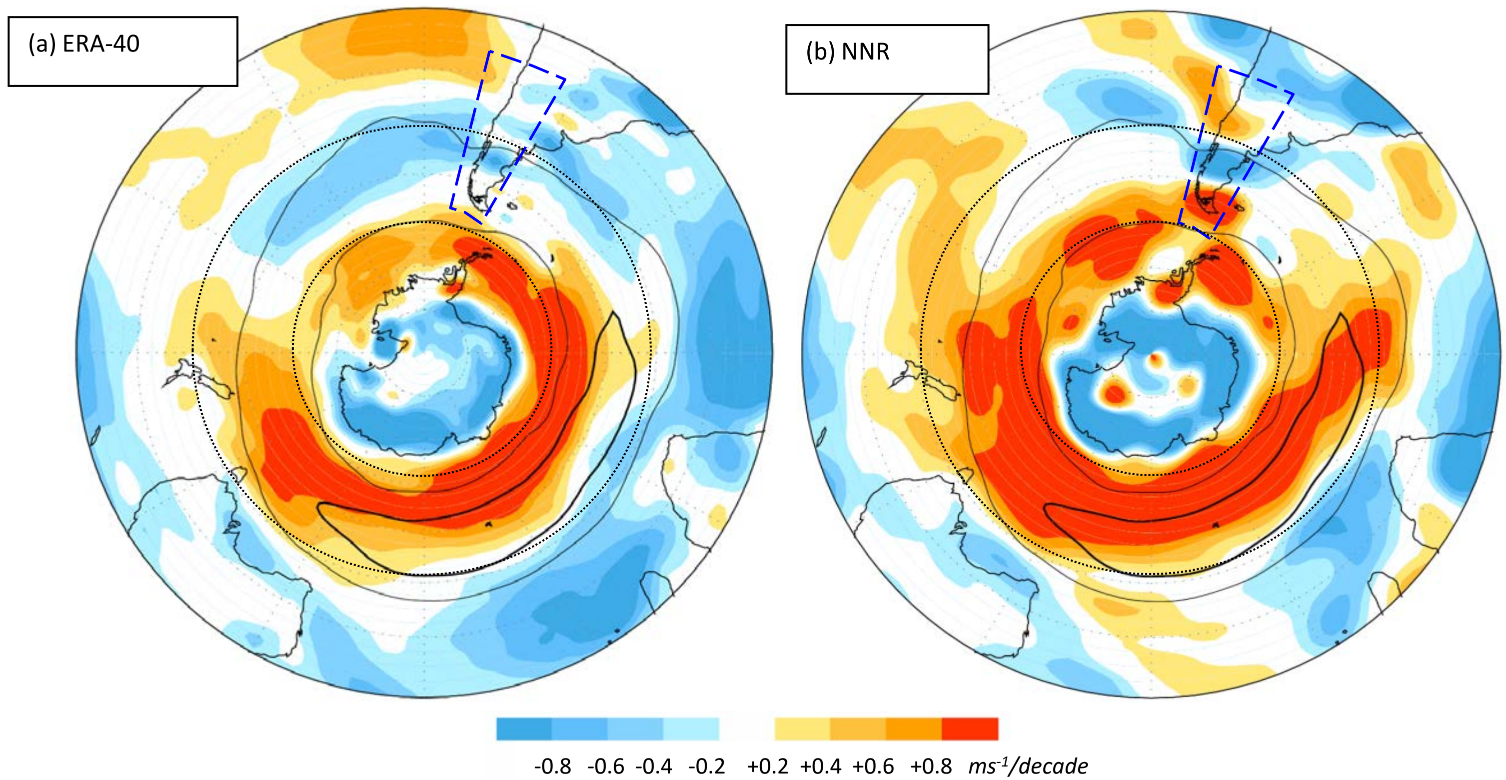
Aravena & Luckman 2010



Observed (U.Delaware) Precip trend (1960-2000)



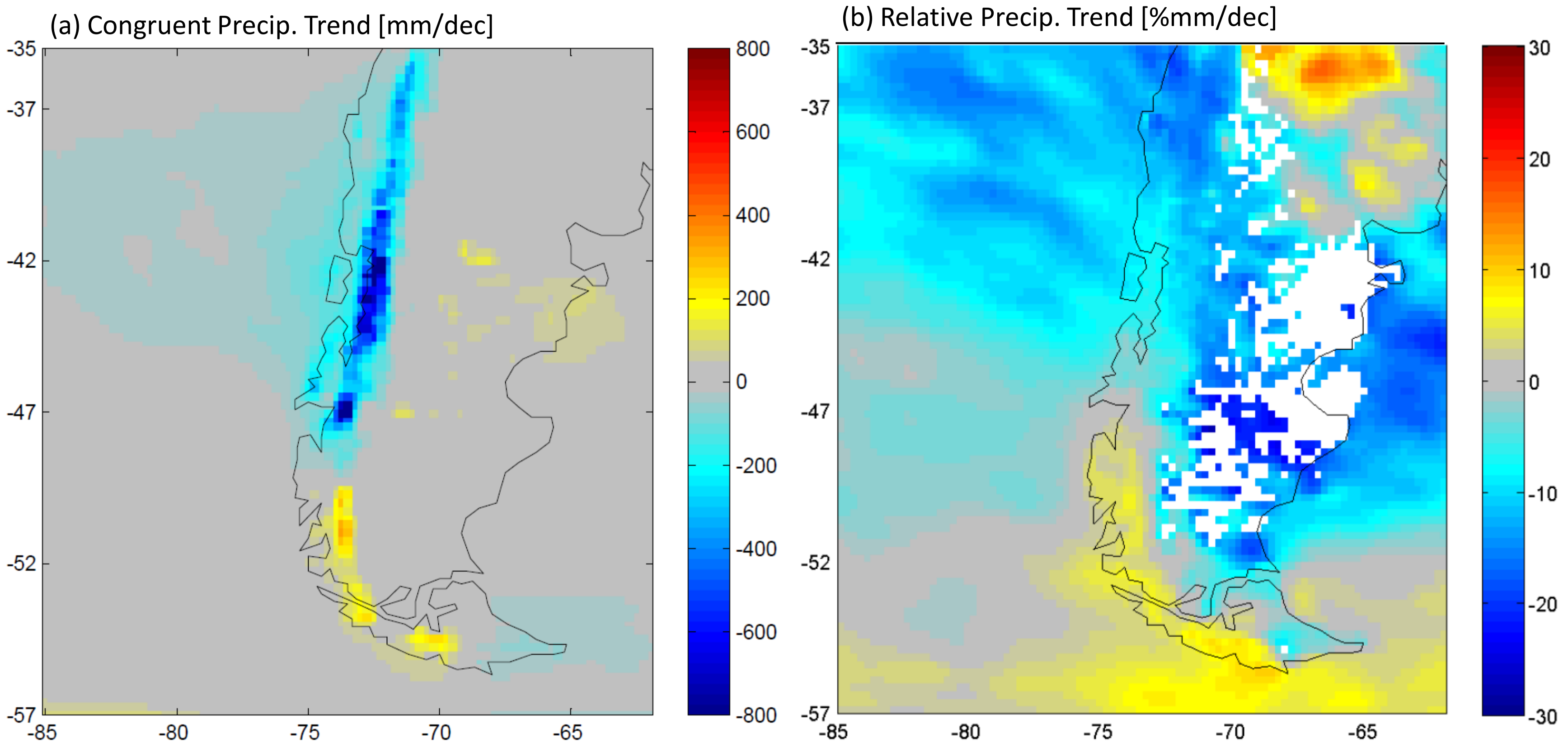
Downscale the U-P, U-SAT relationships



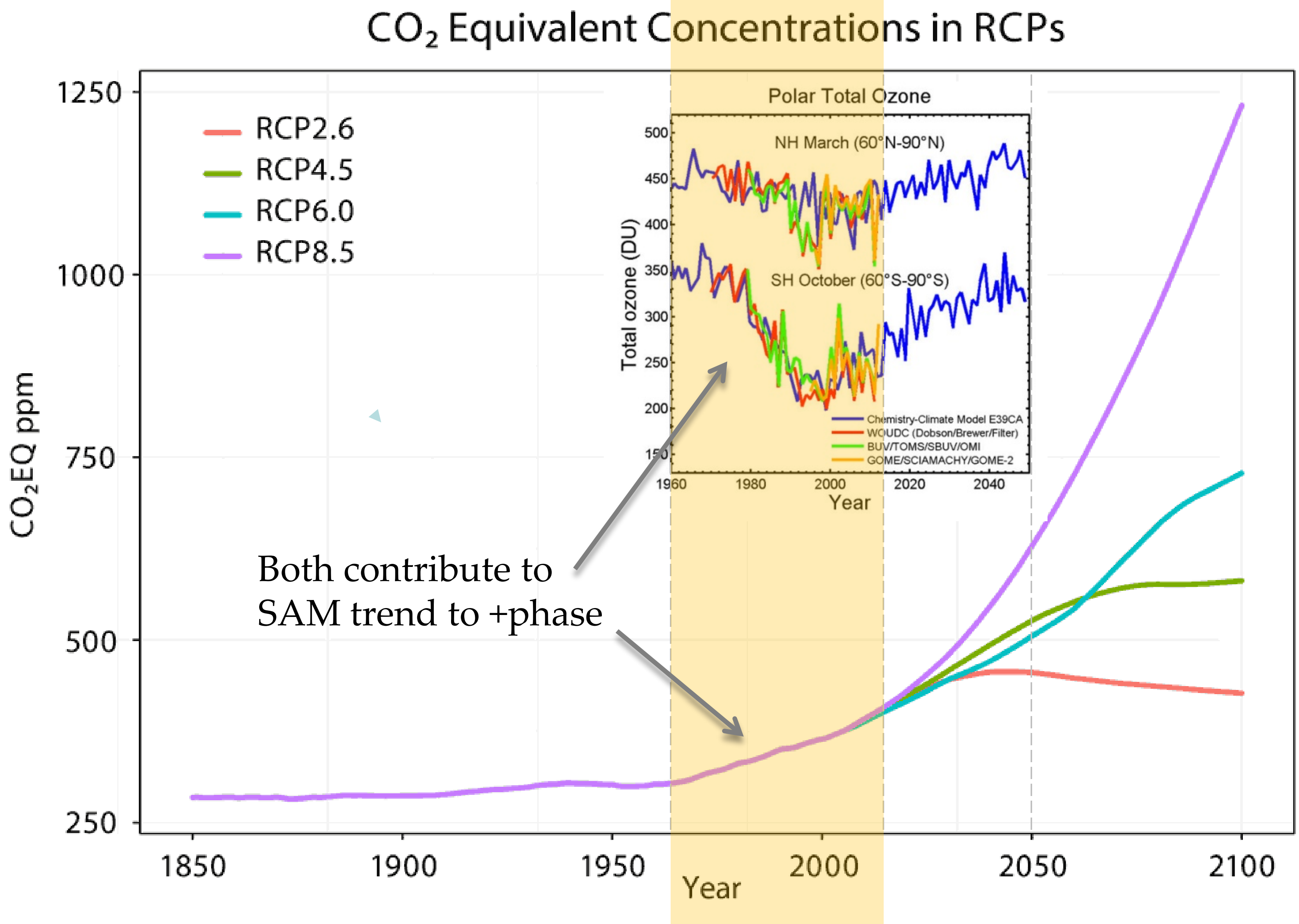
Linear trends in the annual mean zonal wind at the 850 hPa level using the (a) ERA-40 and (b) NCEP-NCAR reanalysis. **Shading indicates the change between 1968 and 2001 of a linear least squares trend fit calculated at each grid-box**

Wind-congruent precipitation trends(1968-2001)

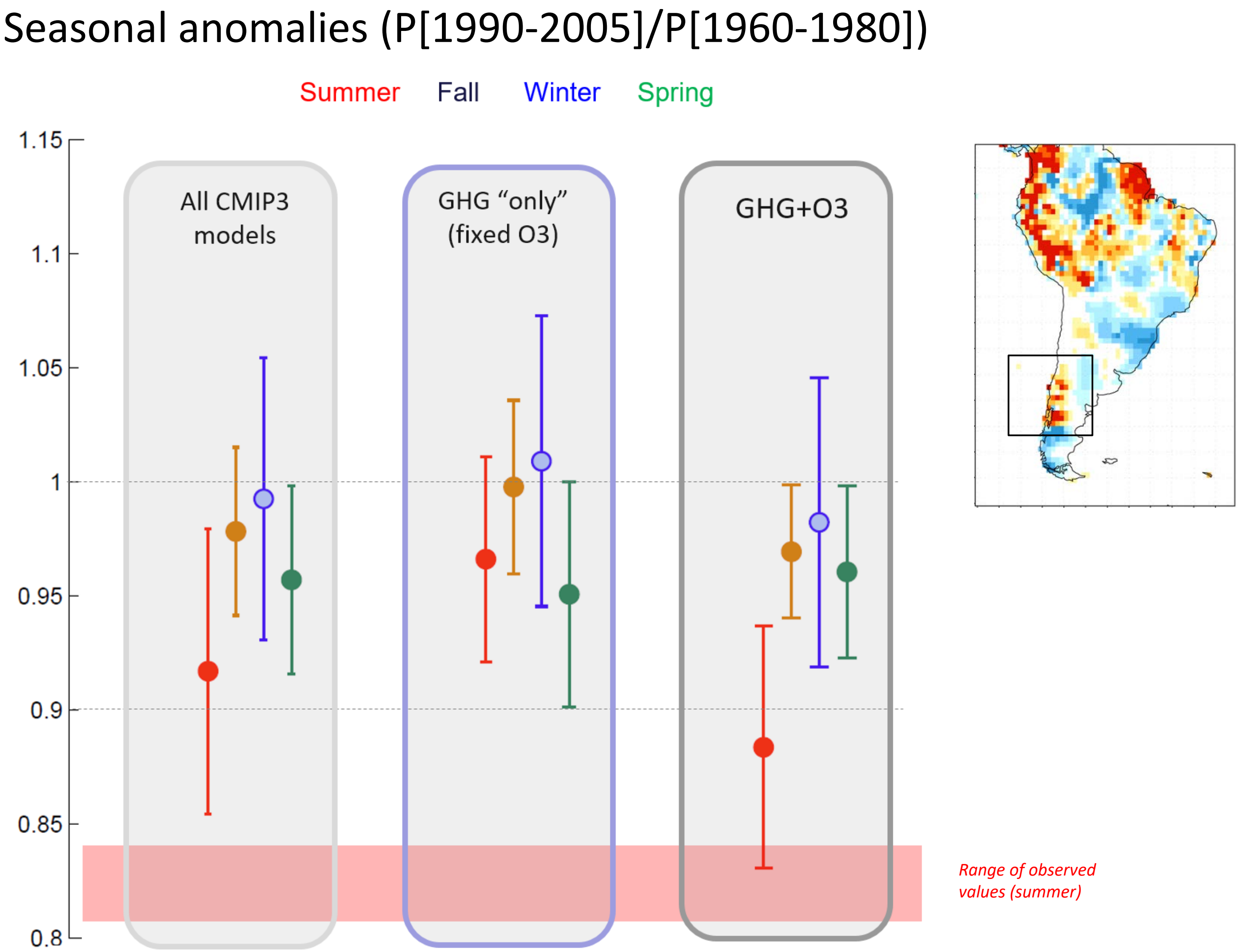
$$\Delta P^* = \beta \cdot \Delta U_{850}$$



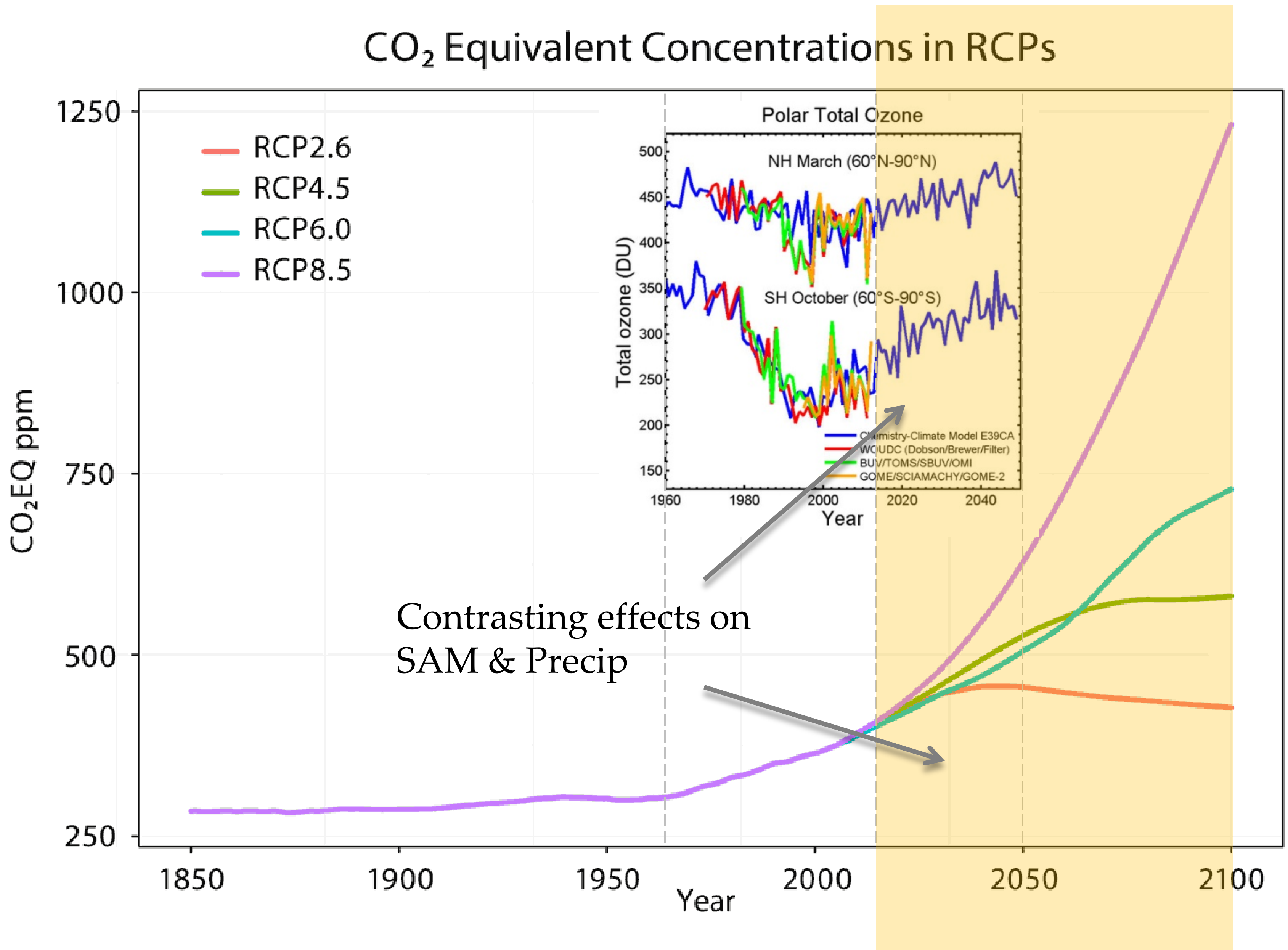
Greenhouse gases and Ozone: the main drivers of climate change



Precipitation trends 1960-2005: Attribution

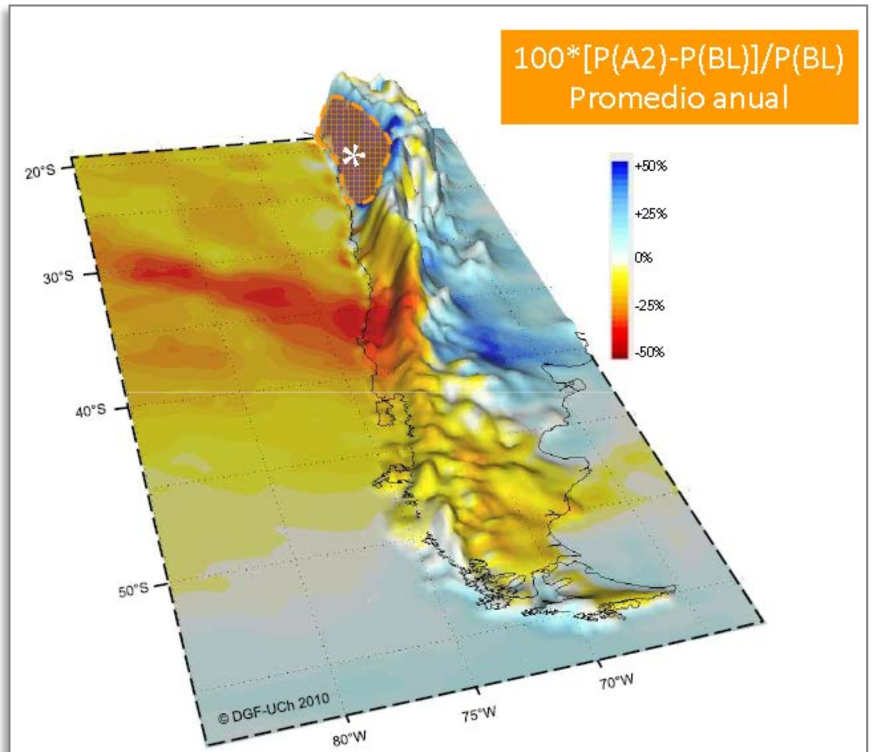


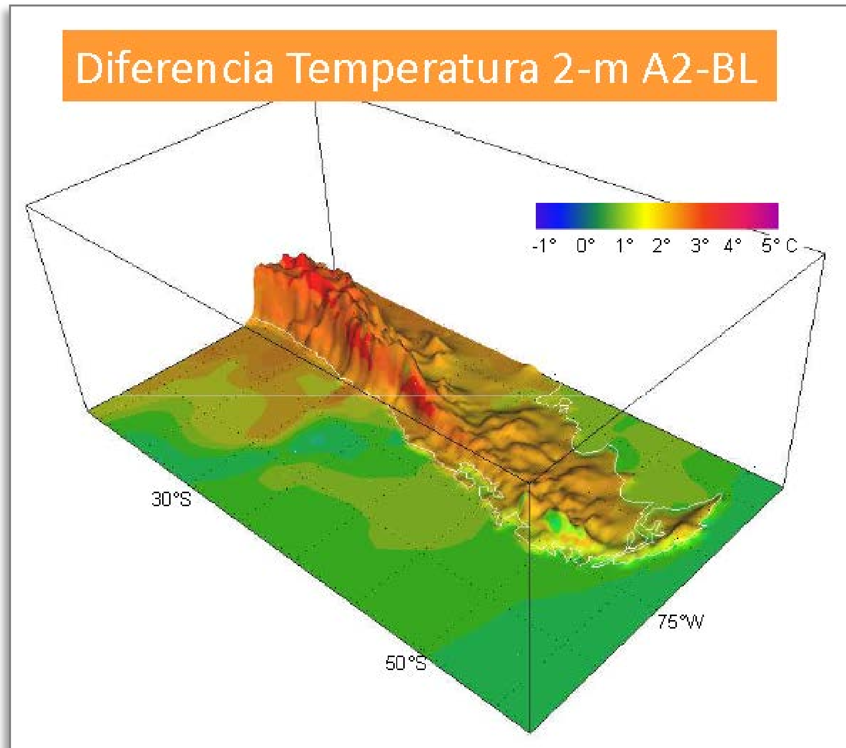
Greenhouse gases and Ozone: the main drivers of climate change



Southern SA Climate Change Projections

Towards the end of century under A2 (RCP8.5)

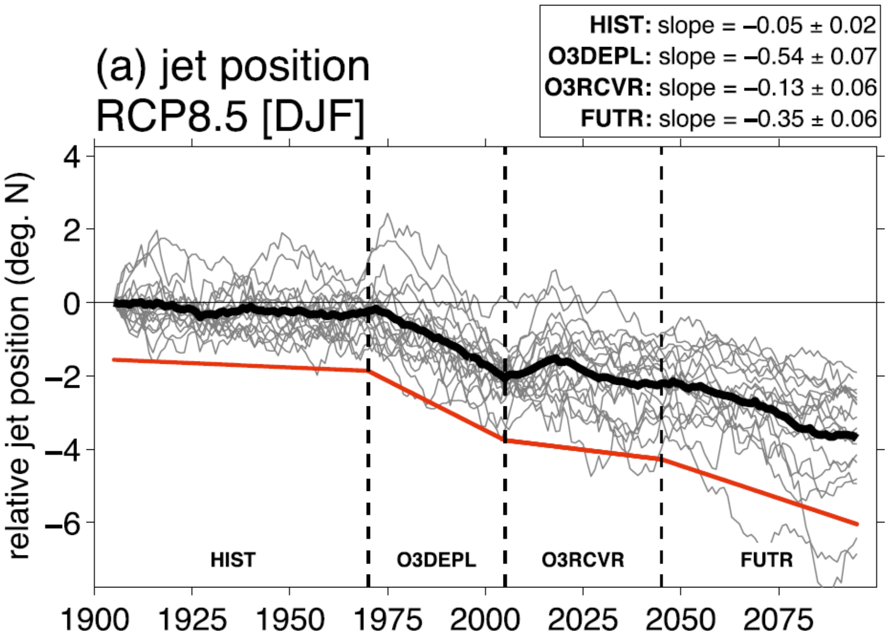


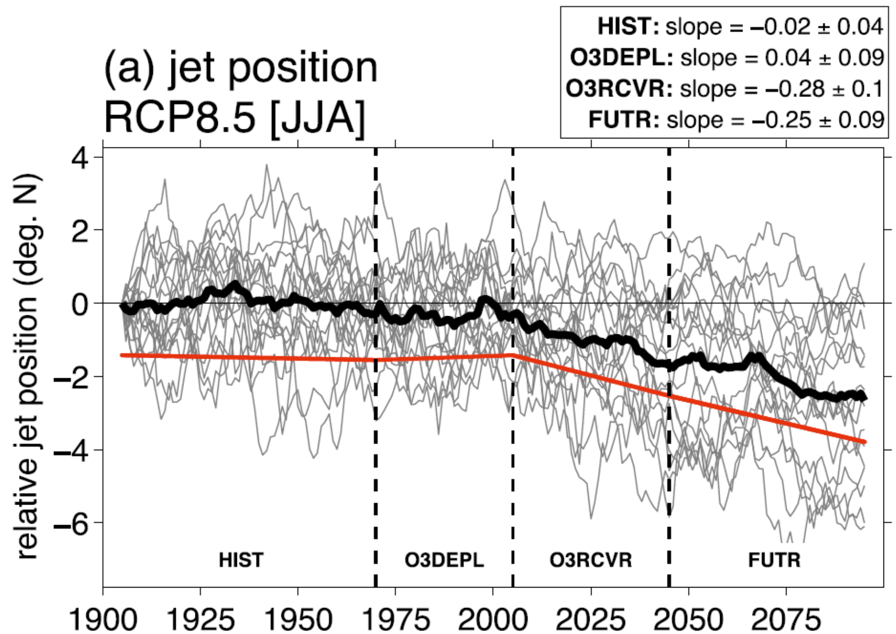


Estudio DGF/UCh-CONAMA 2007 empleando PRECIS

Projections of Jet Position

Implications for Patagonia hydro climate



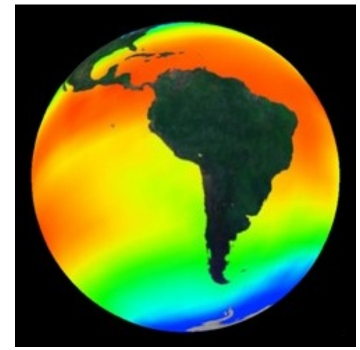


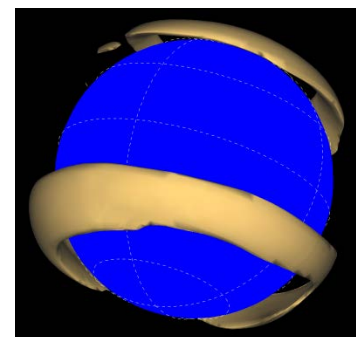
Delayed Southern Hemisphere Climate Change Induced by Stratospheric Ozone Recovery, as Projected by the CMIP5 Models

ELIZABETH A. BARNES

The awful 2016

Environmental extremes and change
→ Social tensions



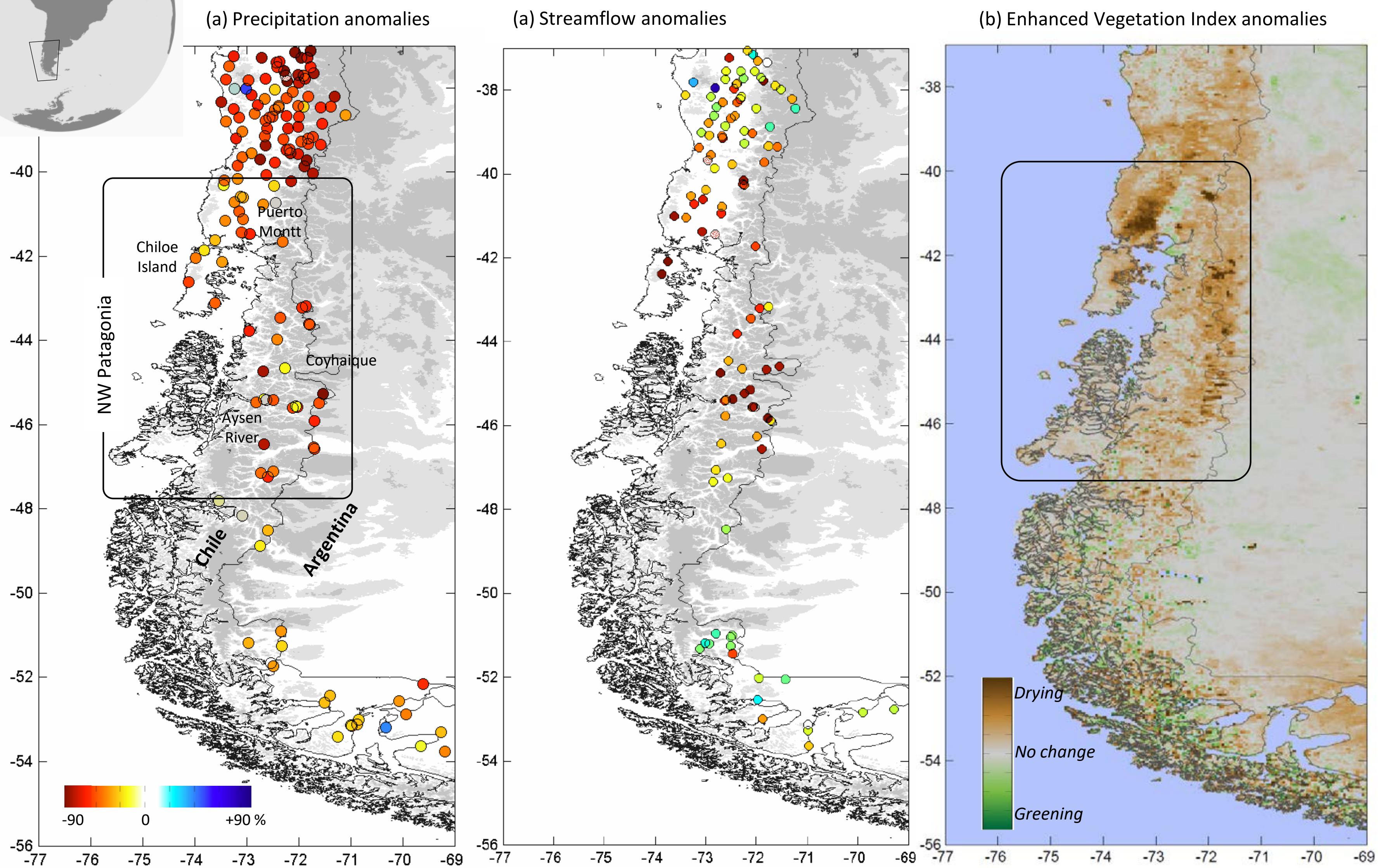


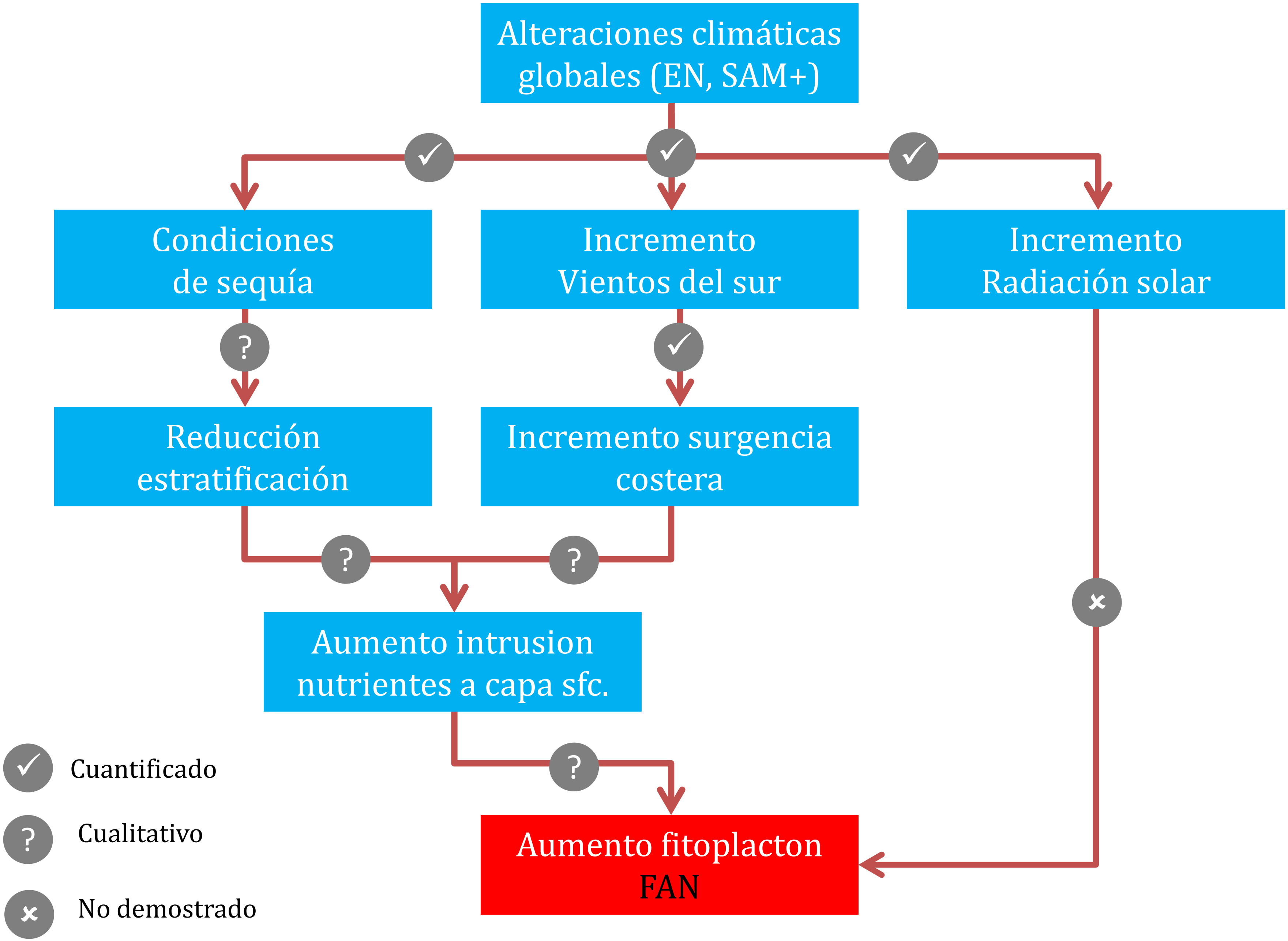
Local activities

Climate variability

Climate change

The awful 2016

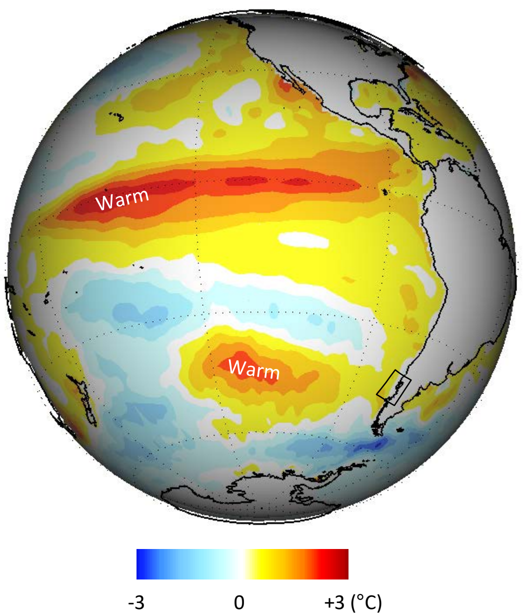




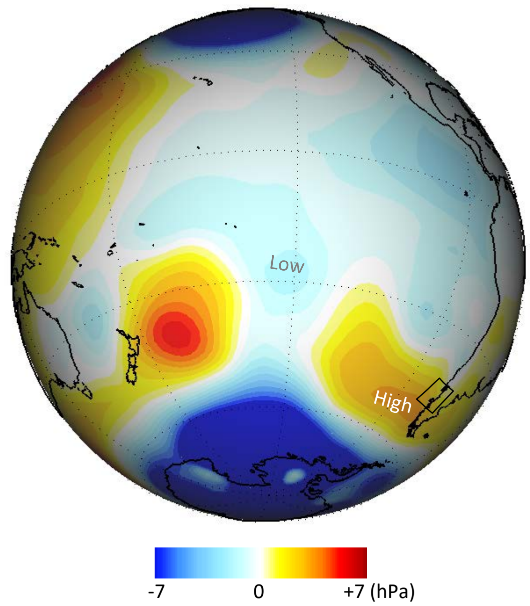
Leon et al. submitted

Large scale conditions JFMA 2016

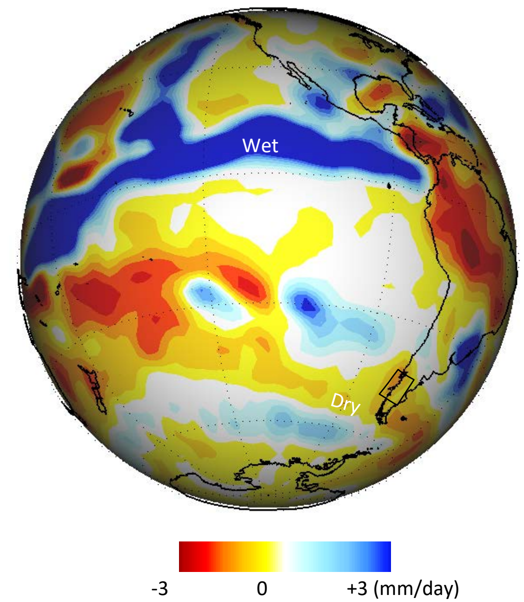
(a) SST (NOAA OI)



(c) SLP (NNR)

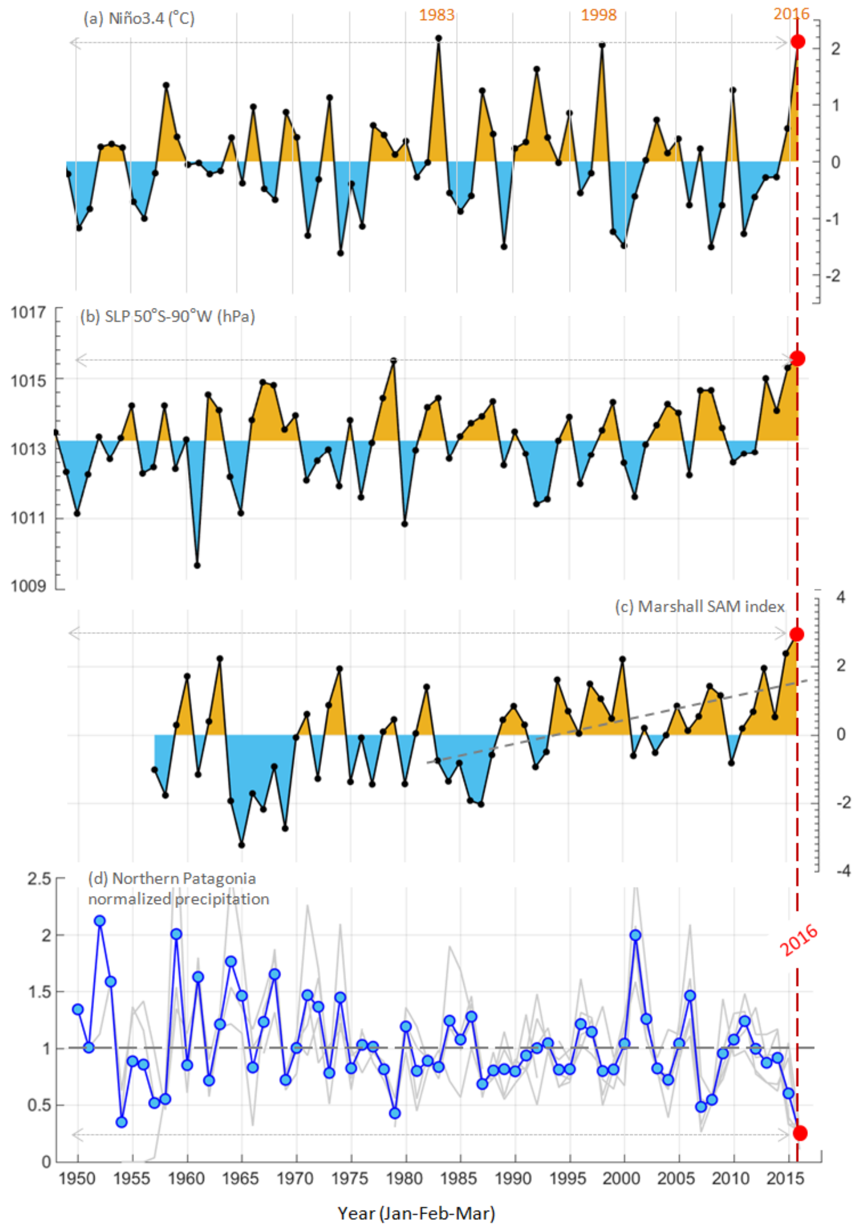


(b) Precipitation (CMAP)



Garreaud 2017

Large scale conditions JFMA 2016



El Niño!

Natural….

r = -0.2

SAM!

Antrophogenic

Garreaud 2017

Conclusions

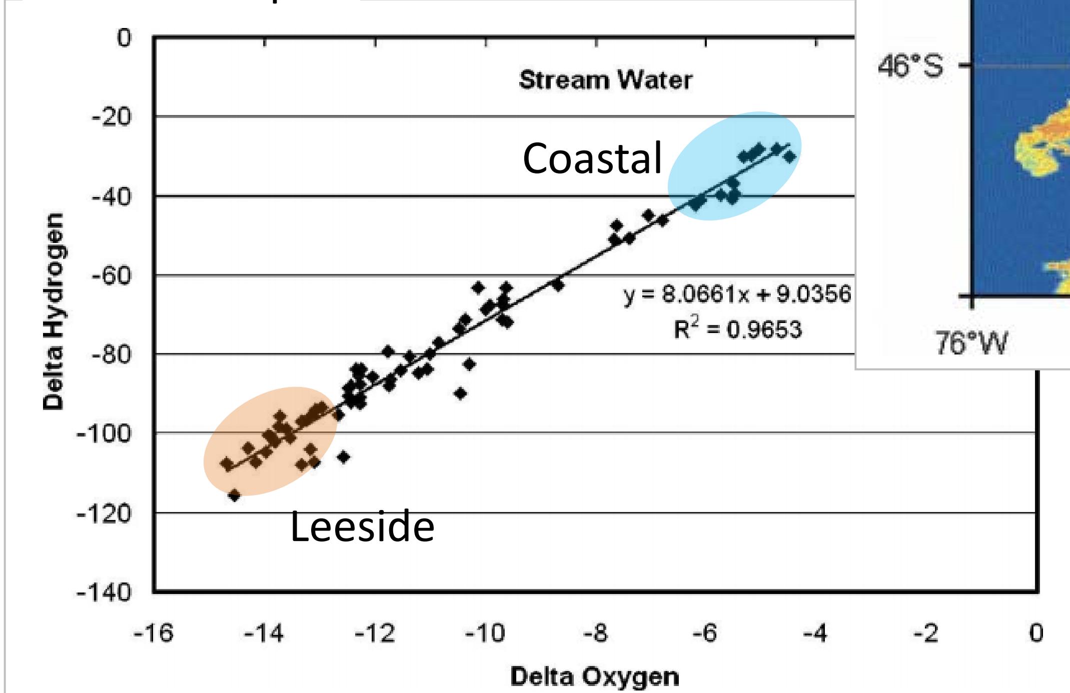
* High impact climate anomalies (wet/dry) accounted by changes in westerly wind impinging the austral Andes

* Large scale circulation anomalies modulated by ENSO (Natural) and SAM (anthropogenic: GHG+O3)

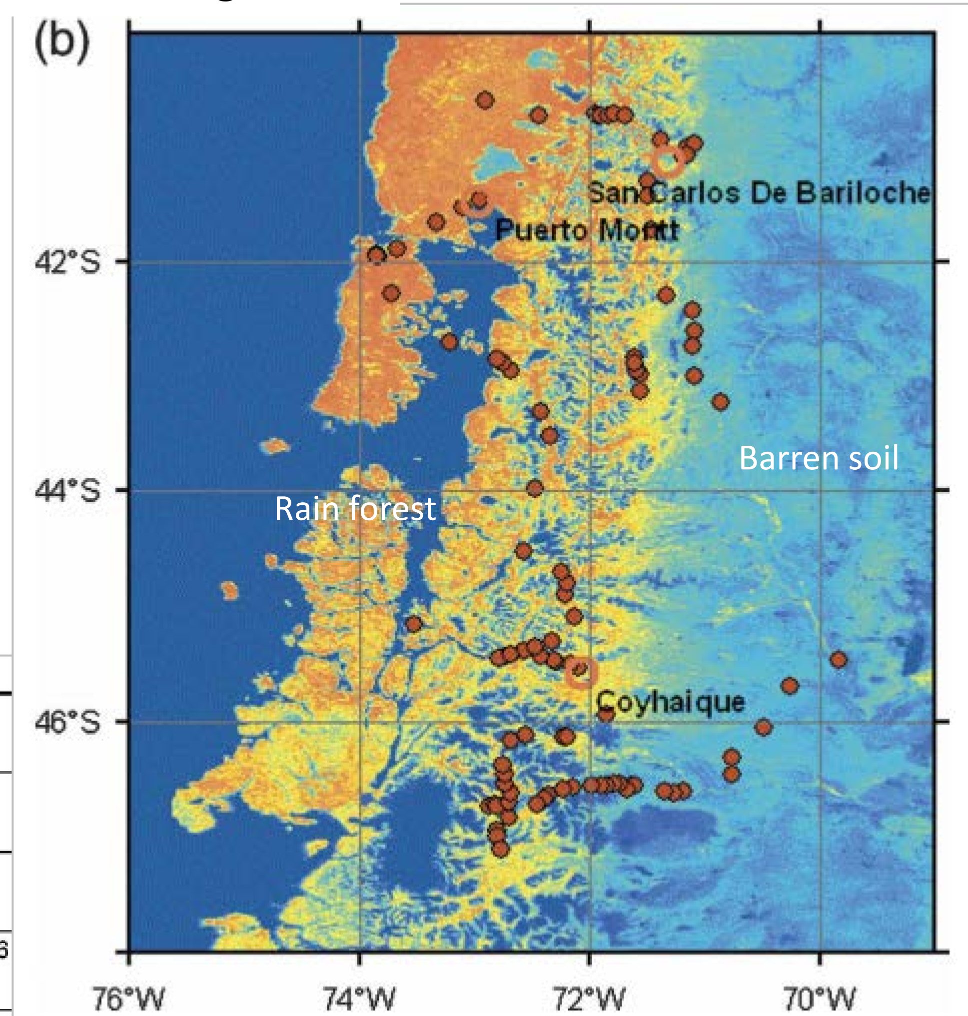
* Climate projections: drying in central Patagonia + weak warming, superimposed on natural variability

Precipitation gradient leads to other two biophysical contrasts: vegetation and isotopes

Stable isotopes



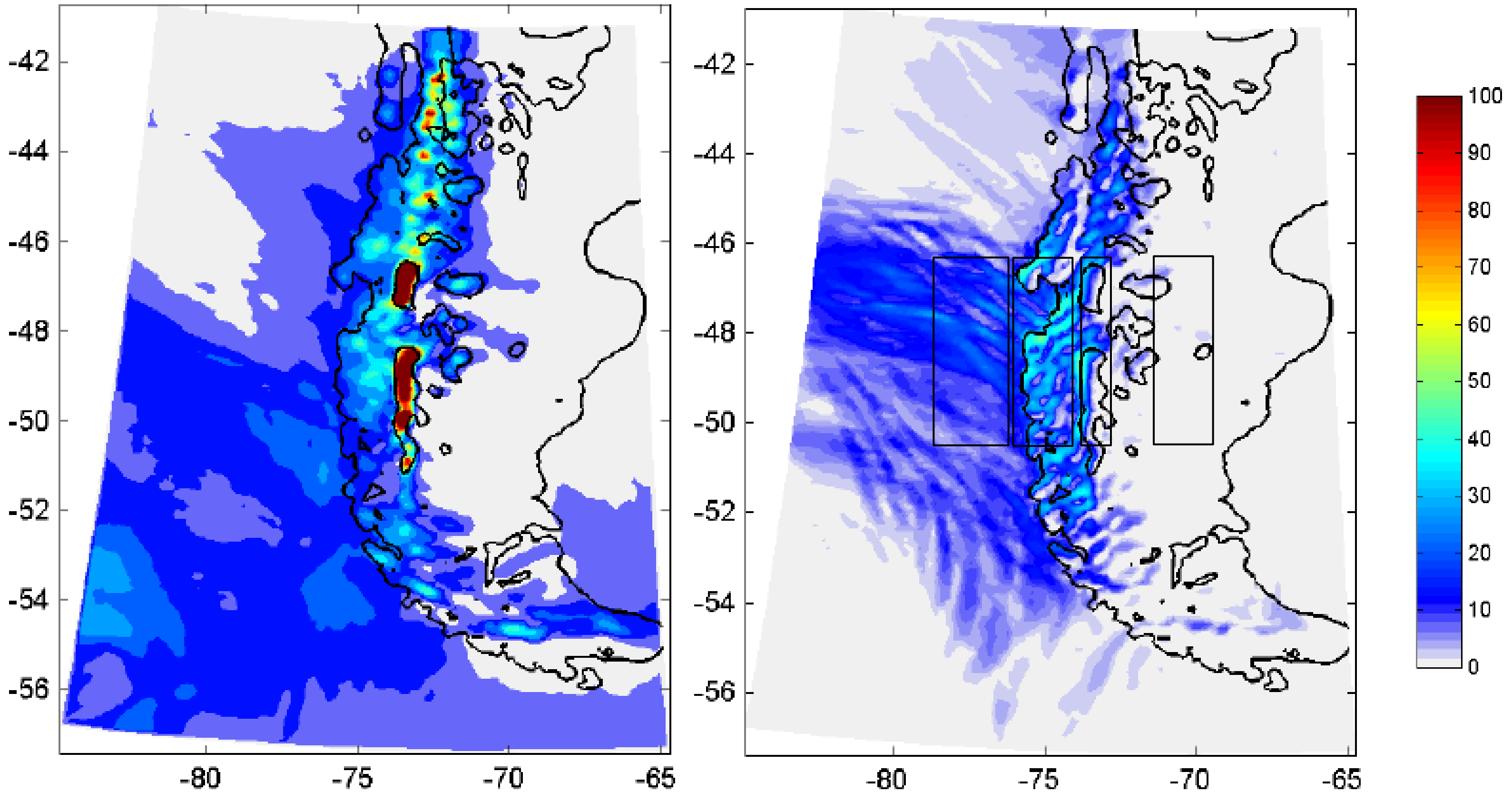
MODIS Vegetation



Smith and Evans 2007

Topographic control
(relevant on geological time scales)

48 hr Accumulated Precip - Control Simulation

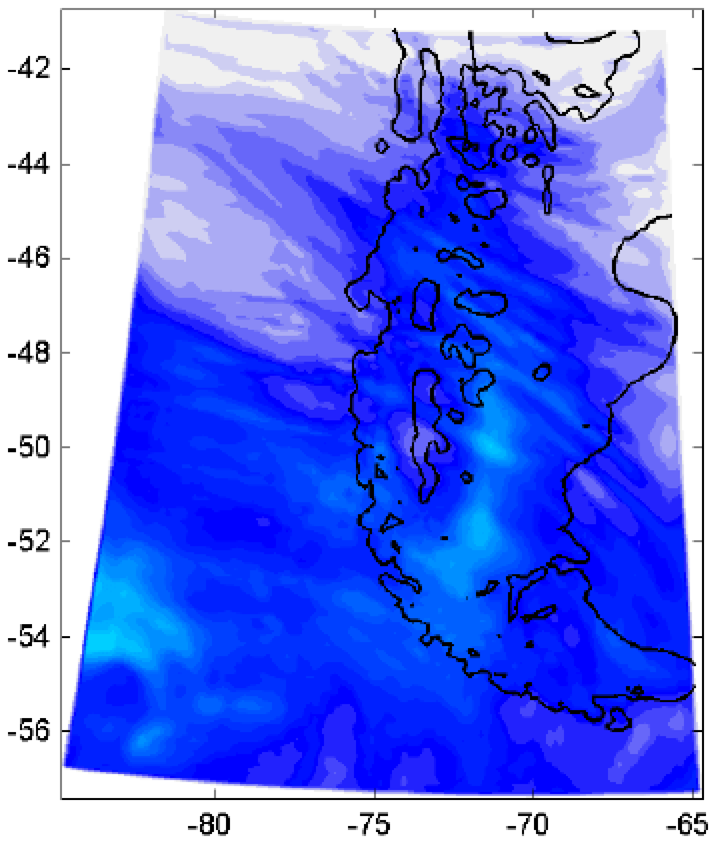


Resolved

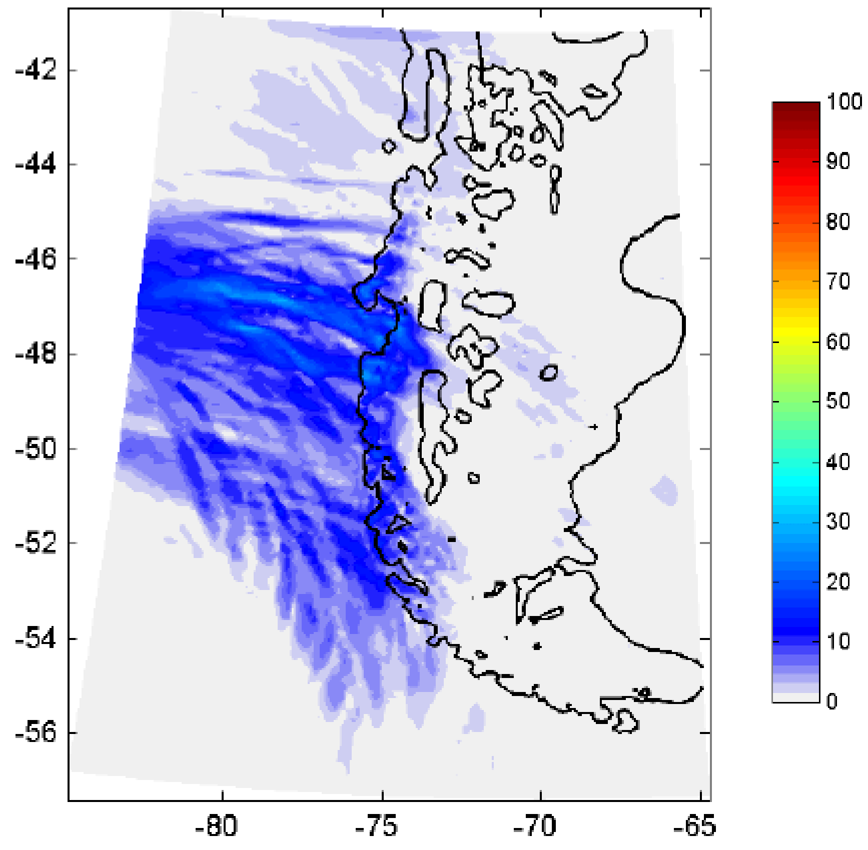
Convective

Topographic control
(relevant on geological time scales)

48 hr Accumulated Precip – No Topo Simulation



Resolved



Convective

GFS-0.25 Valido @ 29-Oct-2017, 12 UTC

Agua precipitable y viento a 850 hPa