Large scale control on the climate of Patagonia

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• Current climate of Patagonia supports glaciers, ice fields, rain forests, and massive rivers. Biodiversity hotspot

• Large area, complex terrain

• Mounting evidence of contemporaneous climate-driven environmental changes

• Numerous paleorecords (lakes, glaciers, tree-rings)

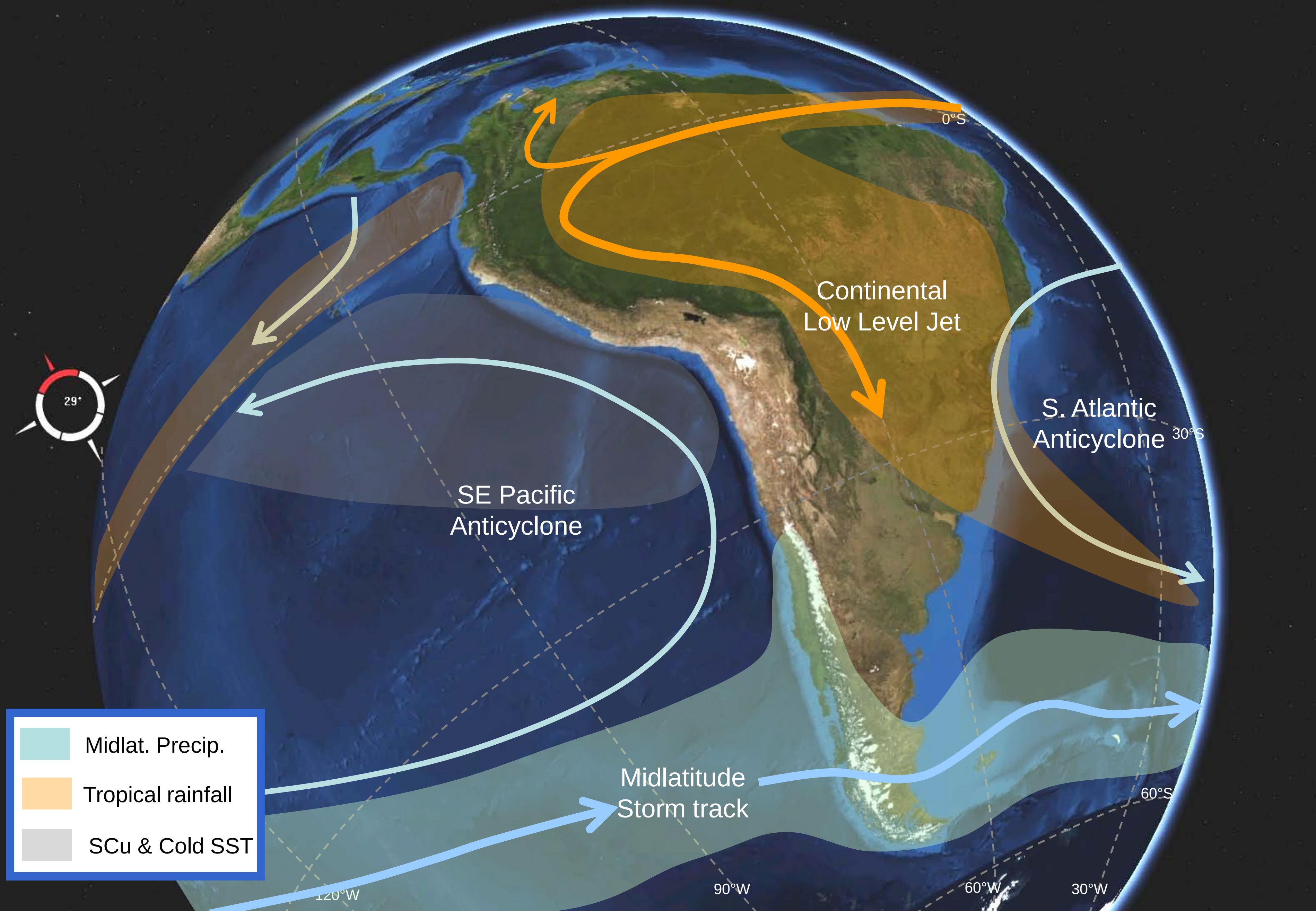
• Meteorological data clearly insufficient to address climate change/variability

Linking local climate variability (∂SAT and ∂P) with large-scale circulation anomalies (e.g., ∂U_{aloft}) will allow:

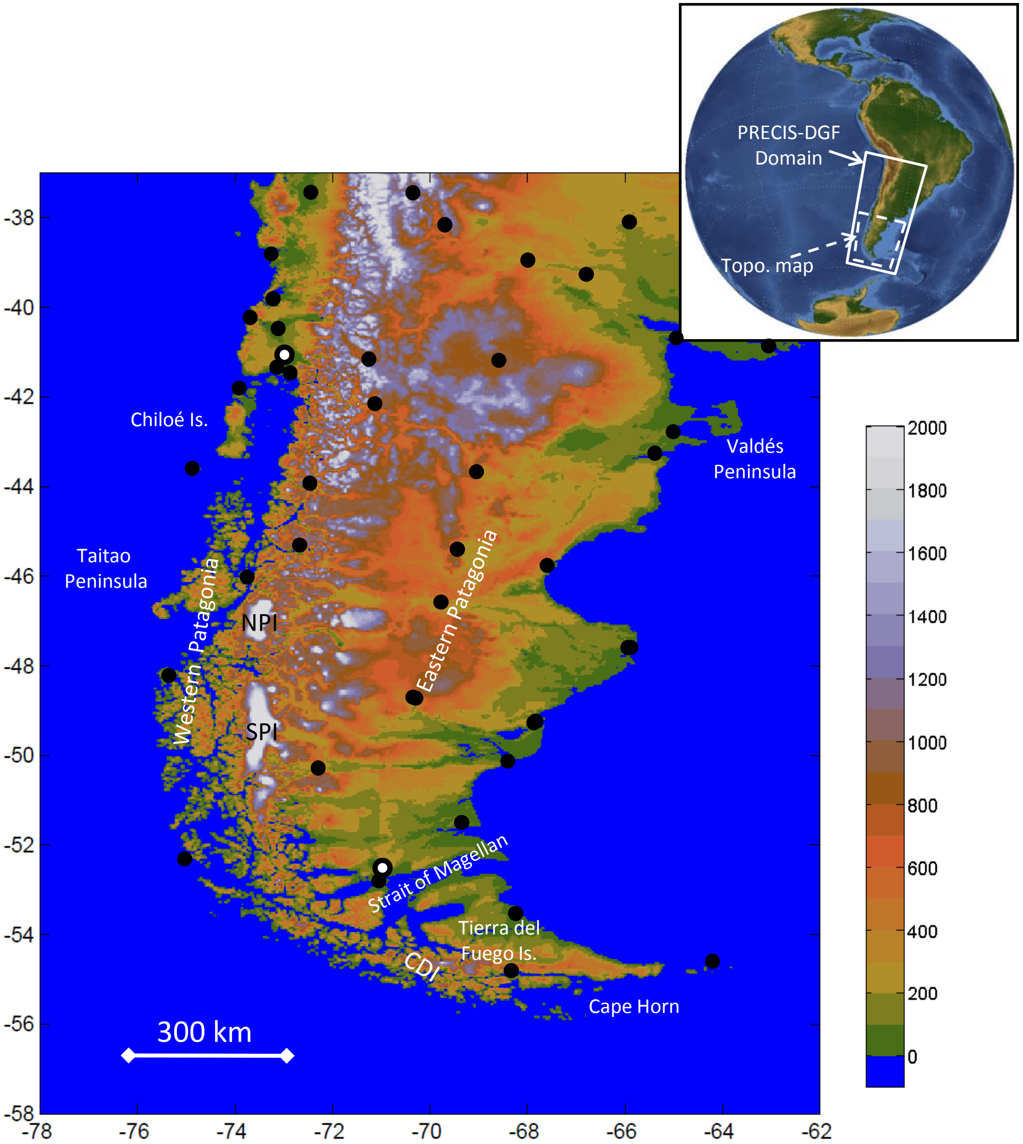
(a) downscale large-scale signals

(b) ***upscale*** local environmental changes.

The big picture

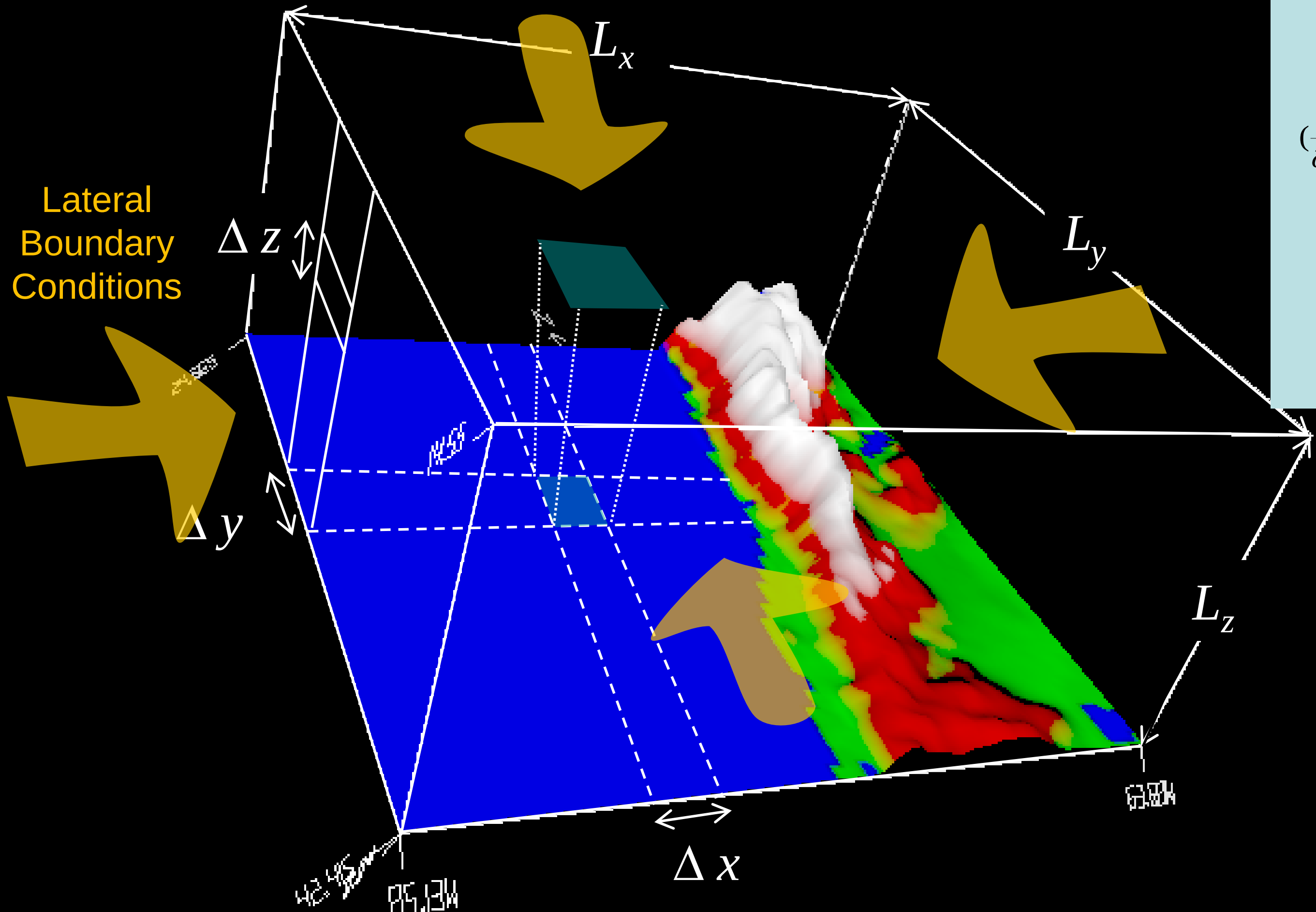


Geographical setting: Large, diverse and under-sampled



Regional Models (e.g., PRECIS; WRF)

Solve governing equation in a limited domain



$$\frac{d\vec{V}}{dt} + f\hat{k} \times \vec{V} = -\frac{1}{\rho}\nabla p - \vec{F}_R + g$$

$$\left(\frac{\partial}{\partial t} + \vec{V} \cdot \nabla\right)T - S_p\omega = Q_{RAD} + Q_{Conv} + Q_{Sfc}$$

$$\nabla \cdot \vec{V} + \frac{\partial \omega}{\partial p} = 0$$

$$\frac{\partial(gz)}{\partial p} = -\frac{RT}{p}$$

$\Delta x \sim \Delta y \sim$ 1-50 km $\quad \Delta z \sim$ 50-200 m $\quad \Delta t \sim$ seconds

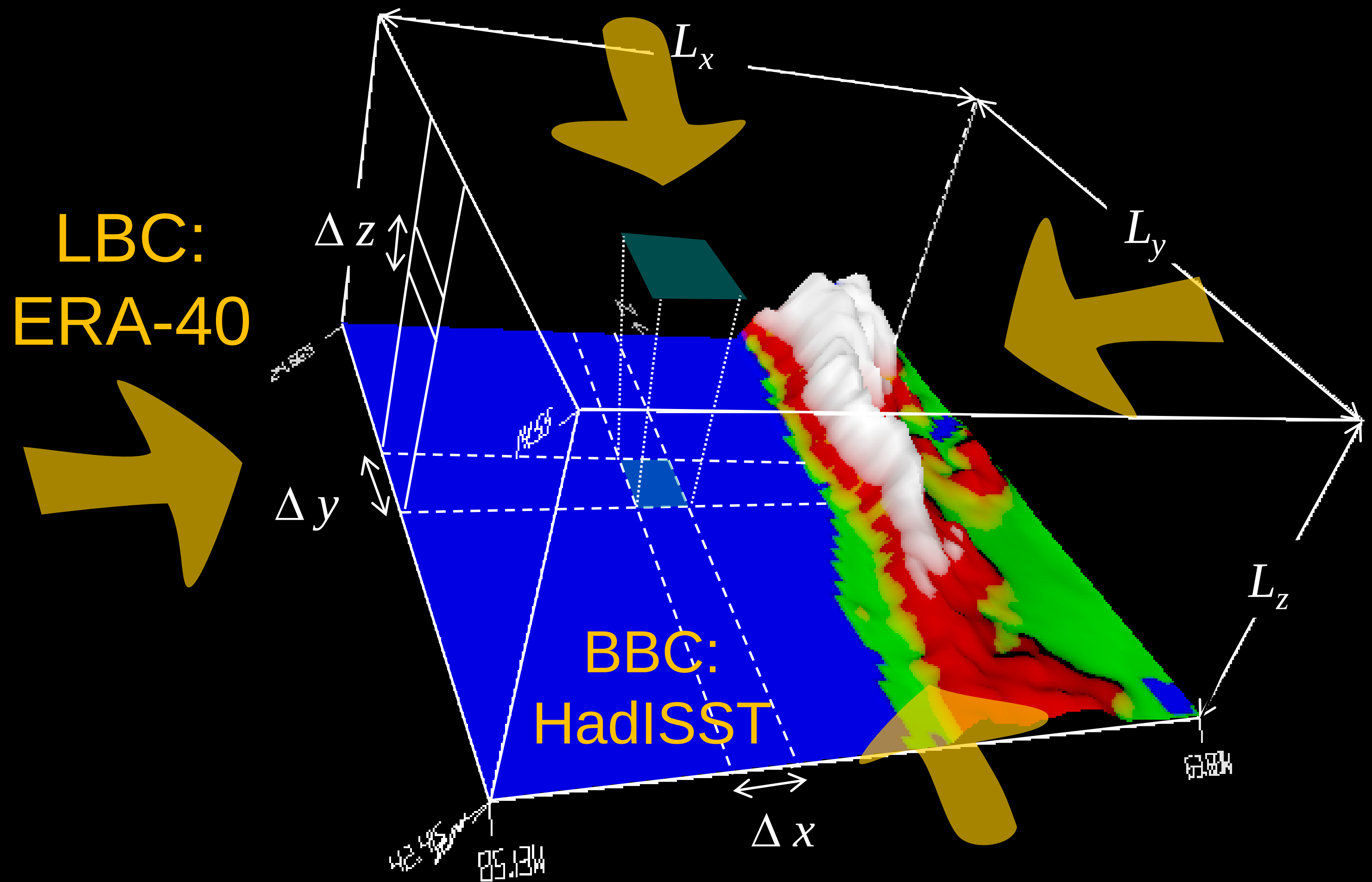
$L_x \sim L_y \sim$ 100-5000 km $\quad L_z \sim$ 15 km

PRECIS-DGF Simulation

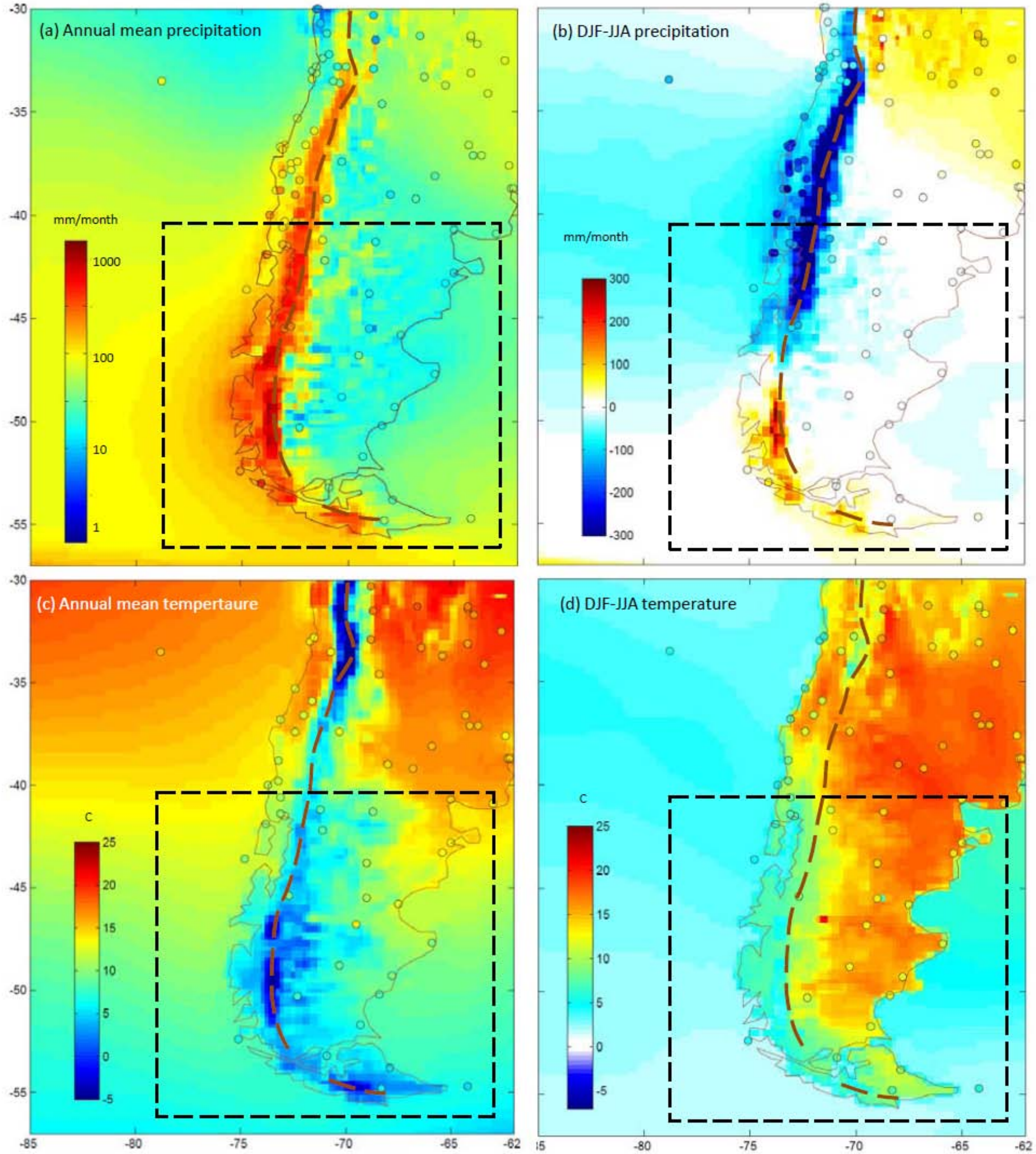
Period: 1978-2001 (avail: 1958-2001)

Hor. Resolution: 25 km

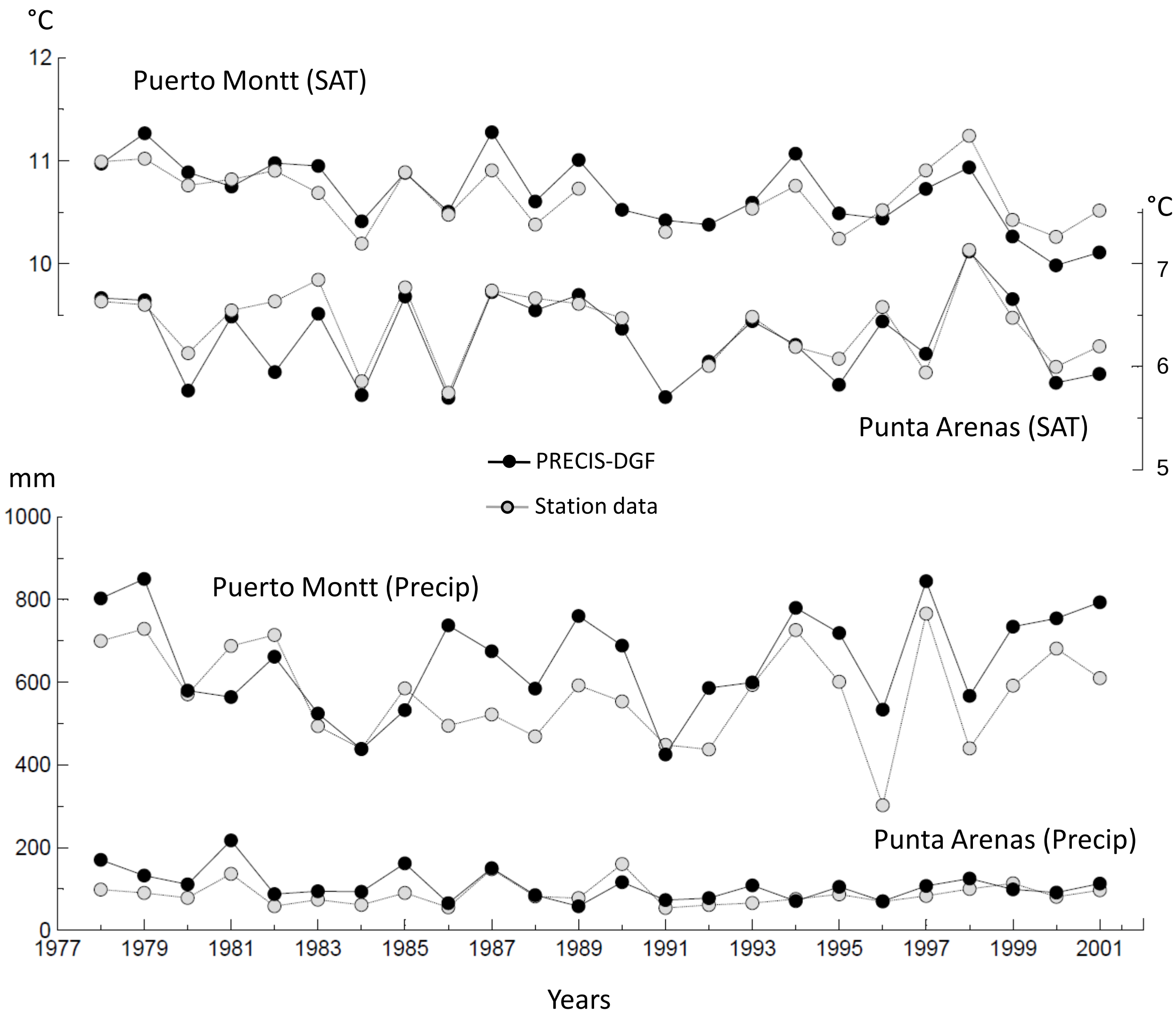
Area: Southern South America



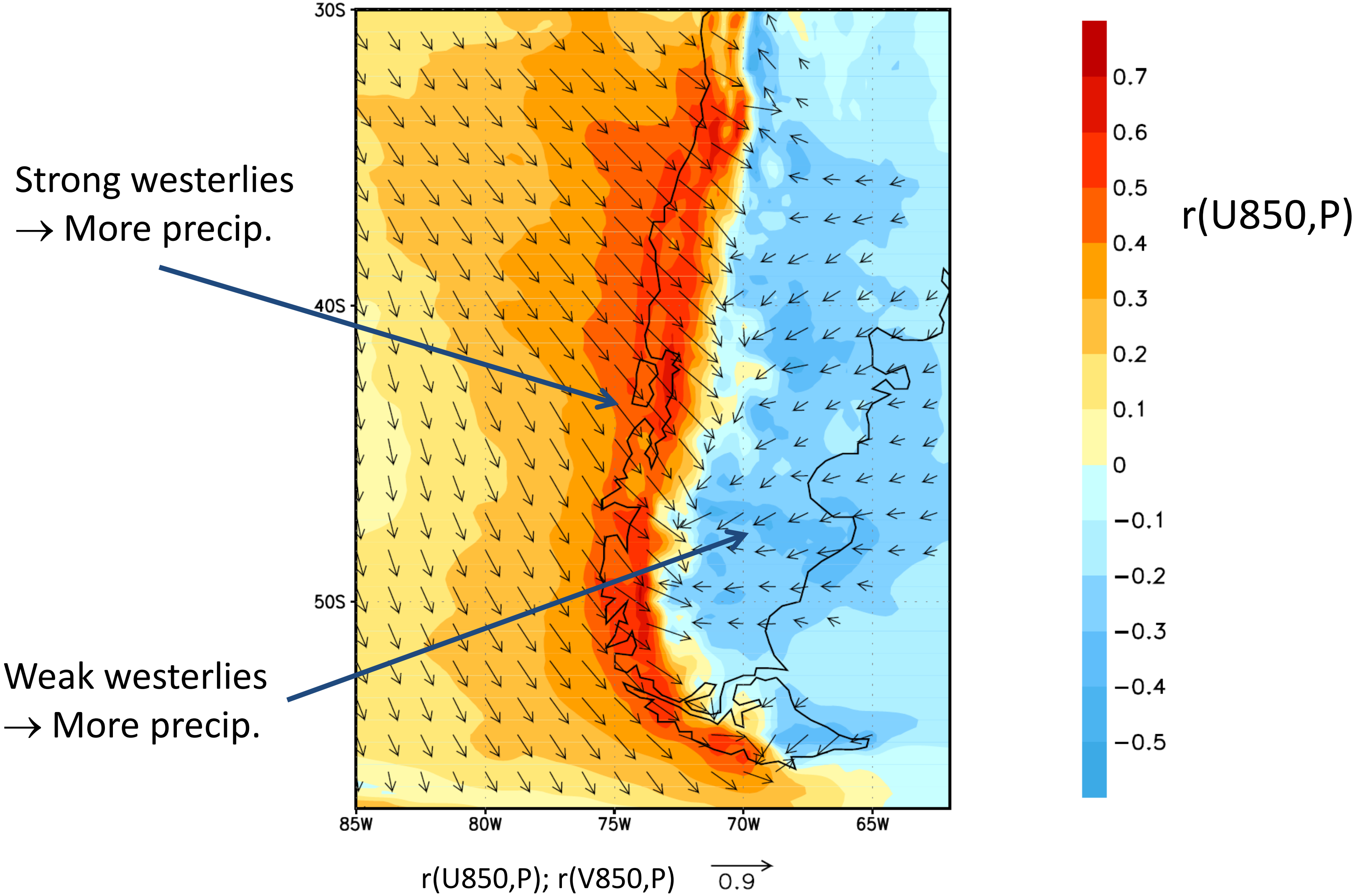
PRECIS-DGF mean state against observations…good enough



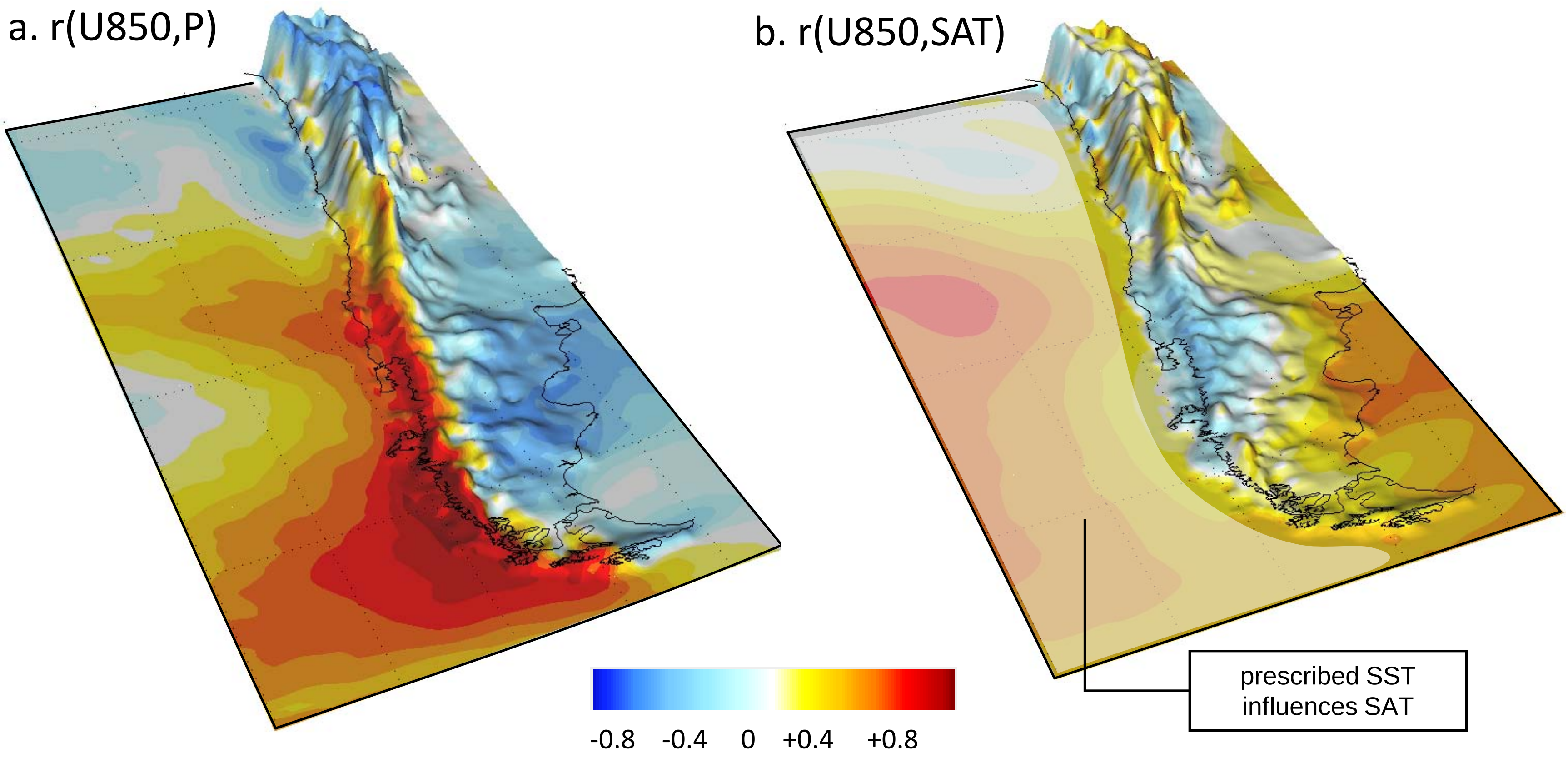
PRECIS-DGF variability against observations…good enough



Wind-precipitation covariability at daily timescale
Windward orographic enhancement and leeward rainshadow



Wind-precipitation and Wind-SAT covariability at annual timescale (year-to-year)



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

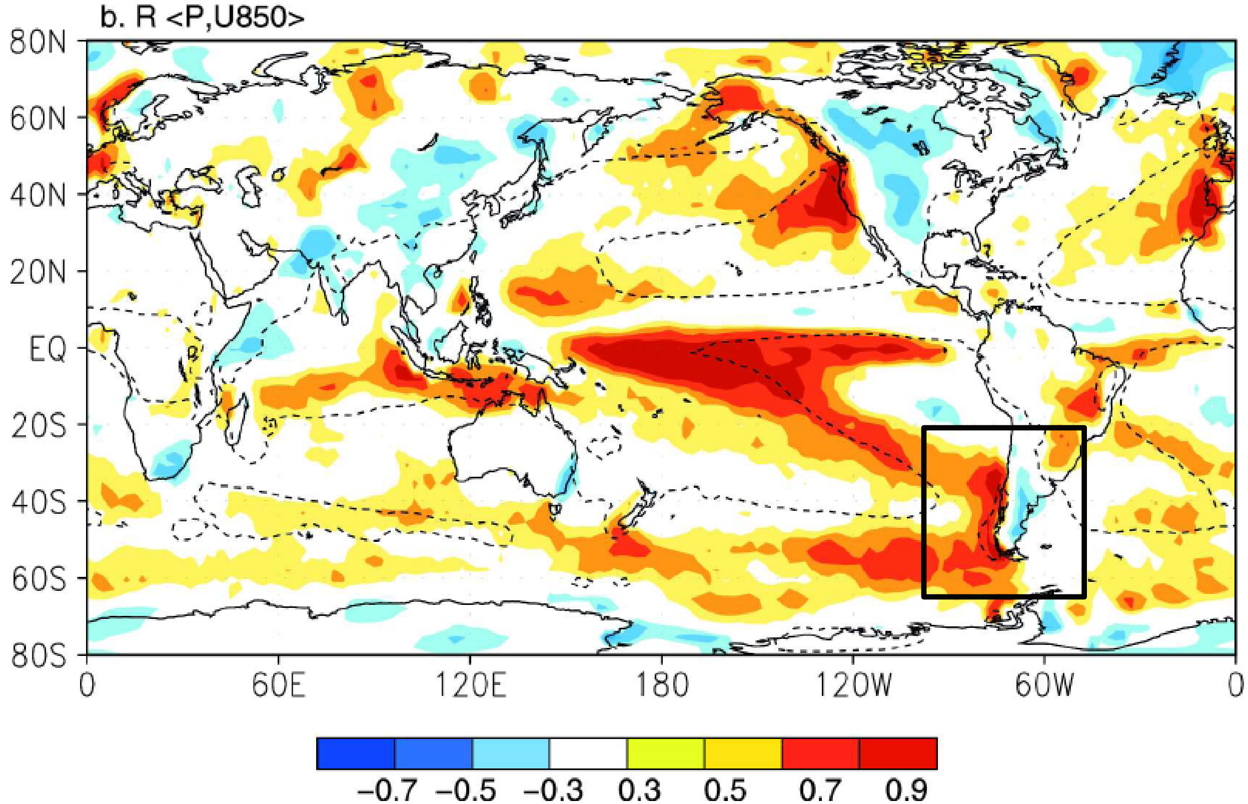
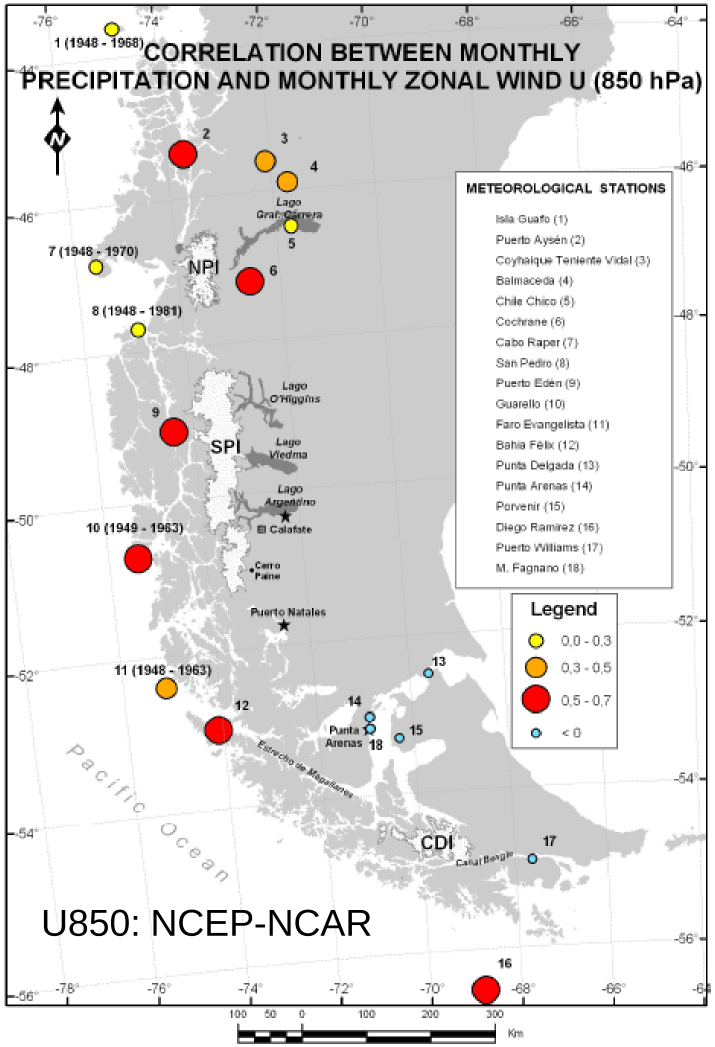


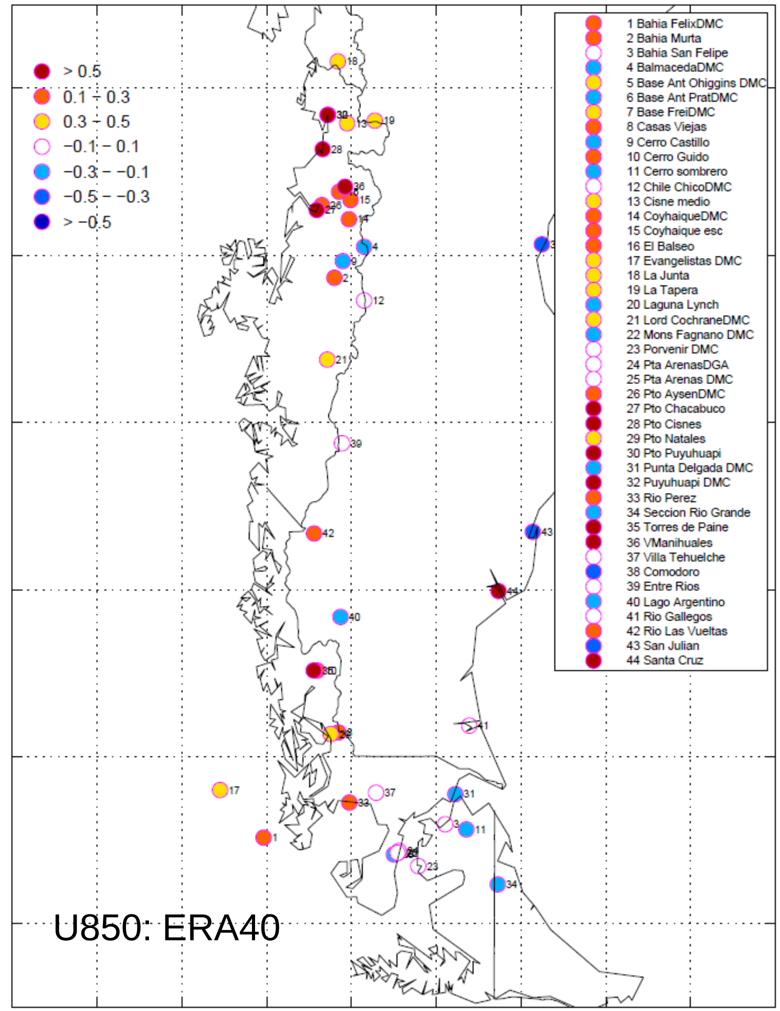
FIG. 2. (a) Map of local correlation between monthly anomalies of precipitation and 300-hPa zonal wind, scale at the bottom. Dashed lines outline regions where annual mean precipitation exceeds 1000 mm yr^{-1}. (b) Same as in (a) but for local correlation between monthly anomalies of precipitation and 850-hPa zonal wind.

Garreaud 2007
PAGES 2006

Co-variability of zonal wind and precipitation

Correlation between U850 (*NNR*) and precipitation (*station data*)

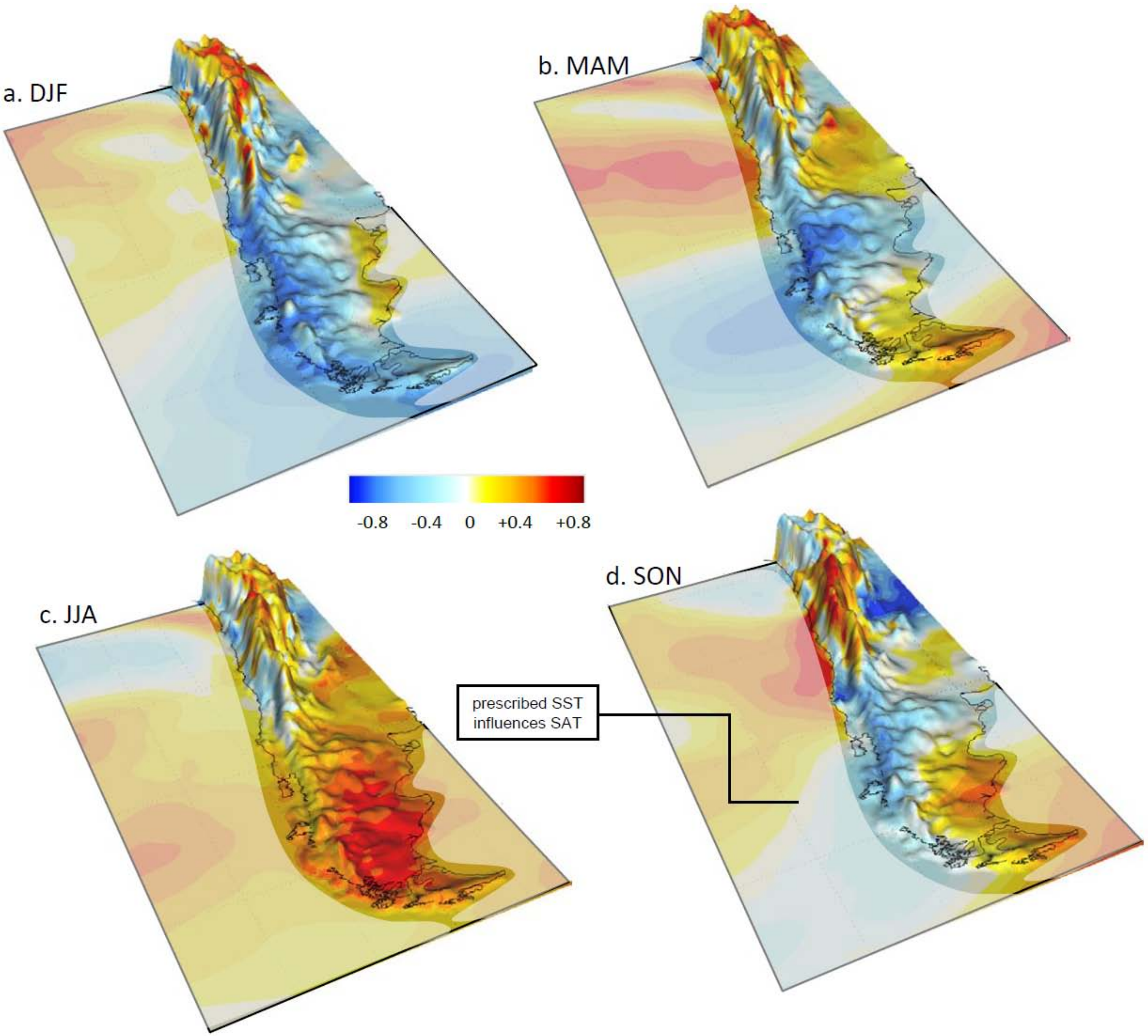




Wind-SAT covariability at annual timescale

Strong westerlies
→ cold summer

Strong westerlies
→ Warm winter

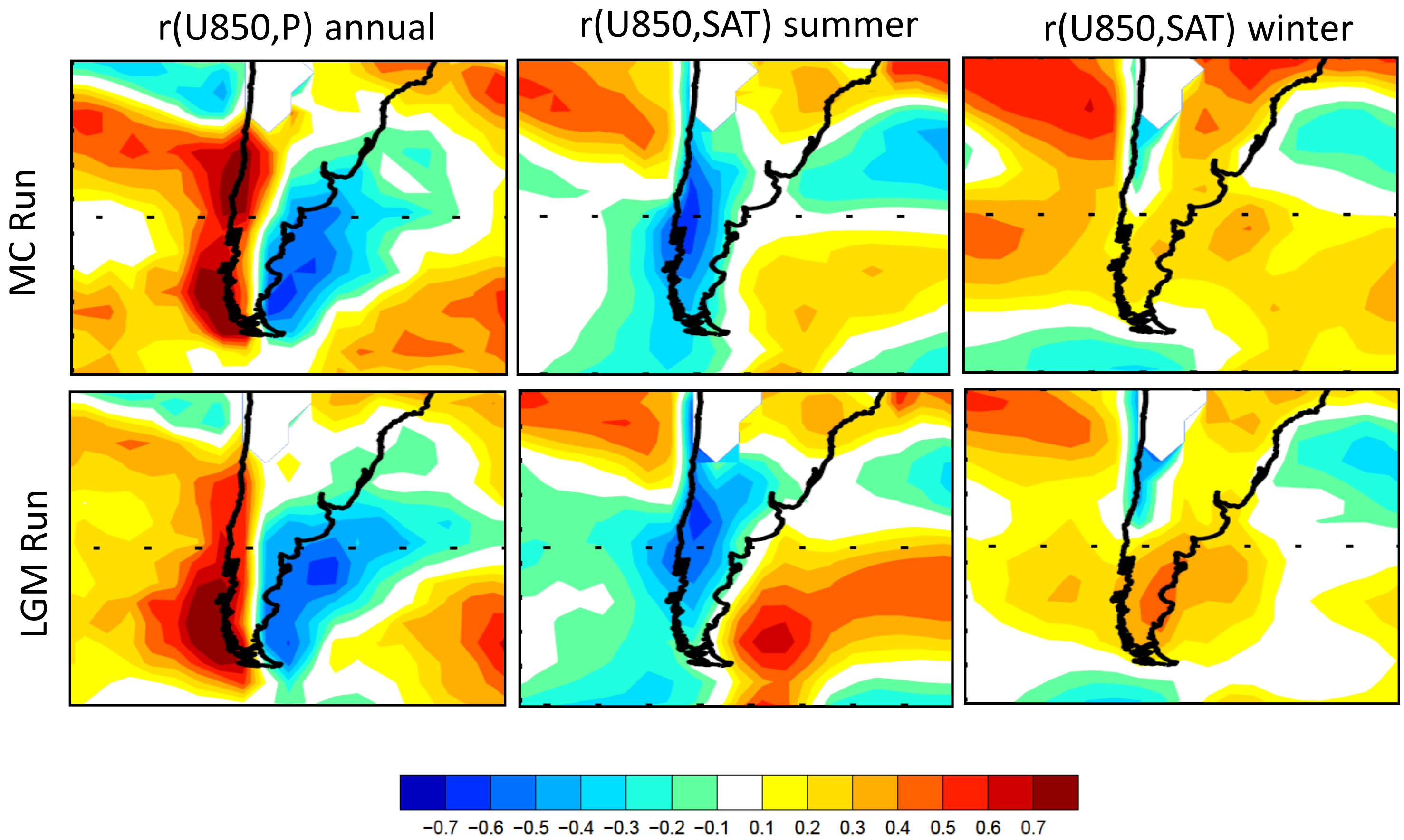


Let's consider windier (U' > 0) years (Stronger Westerlies)

	Western Patagonia	Eastern Patagonia
Winter	• Enhanced ascent: more humid (P'>0) • Strong advection of warm, maritime air • More clouds but little effect • Slightly milder conditions (T'>0)	• Enhanced subsidence: drier (P'<0) • Strong advection of warm, maritime air • Unfavorable for cold-air pool formation • Milder conditions (T'>0)
Summer	• Enhanced ascent: more humid (P'>0) • Strong advection of cold, maritime air • More clouds and less insolation • colder conditions (T'<0)	• Enhanced subsidence: drier (P'<0) • Strong advection of cold, maritime air • Slightly colder conditions (T'<0)
	More humid year round Decreased SAT seasonality	Drier year round Decreased SAT seasonality

Note: SAT also depends strongly on $T_{\text{low troposphere}}$

Stability of the Wind-P/SAT relationship
IPSL GCM



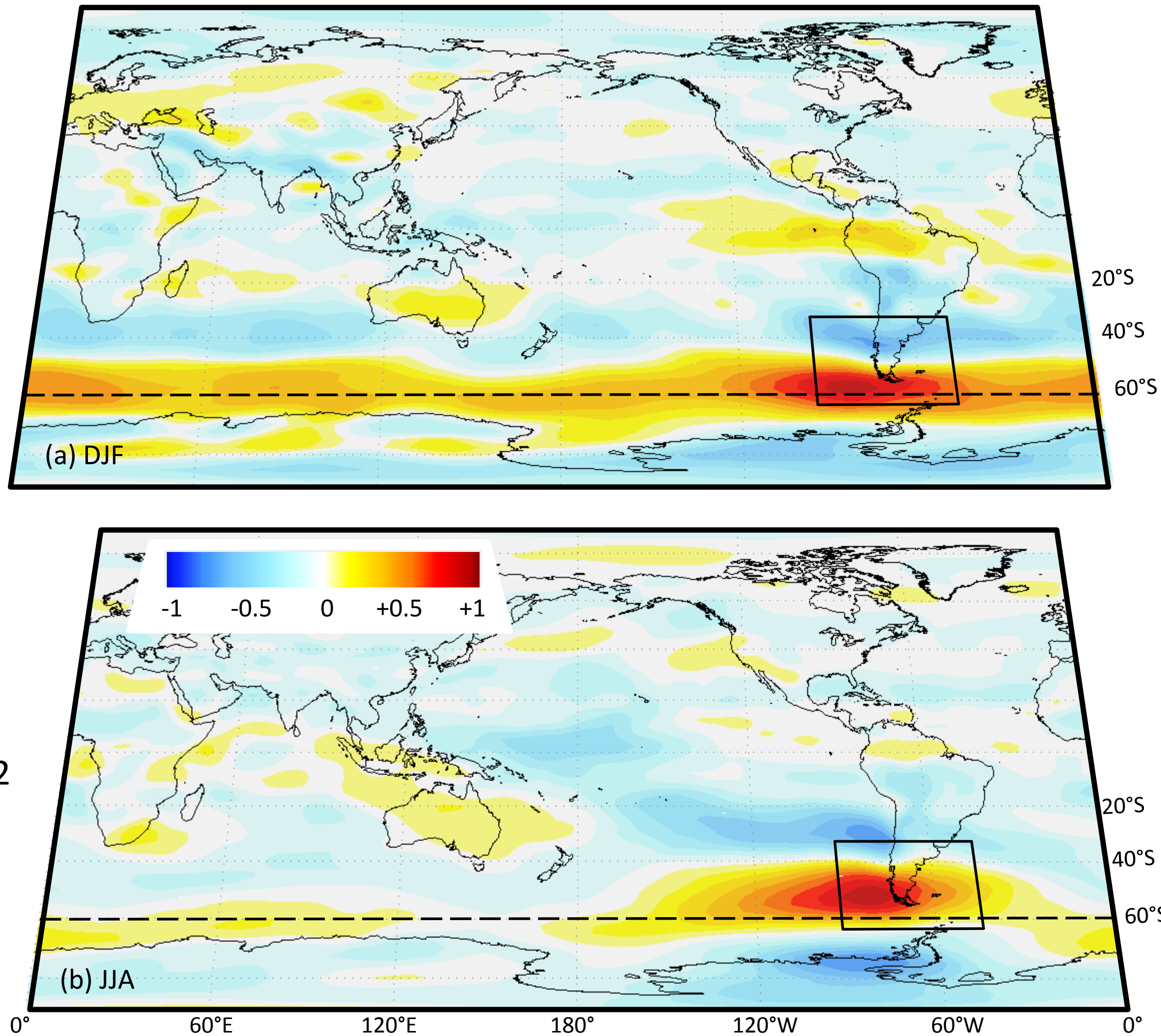
Leading modes of U850' interannual variability

EOF analysis performed each month using NNR & ERA40

First mode accounts for 40-50% of the variance

r(PC1,AAO) ~ 0.7

r(PC1,AAO) ~ 0.2



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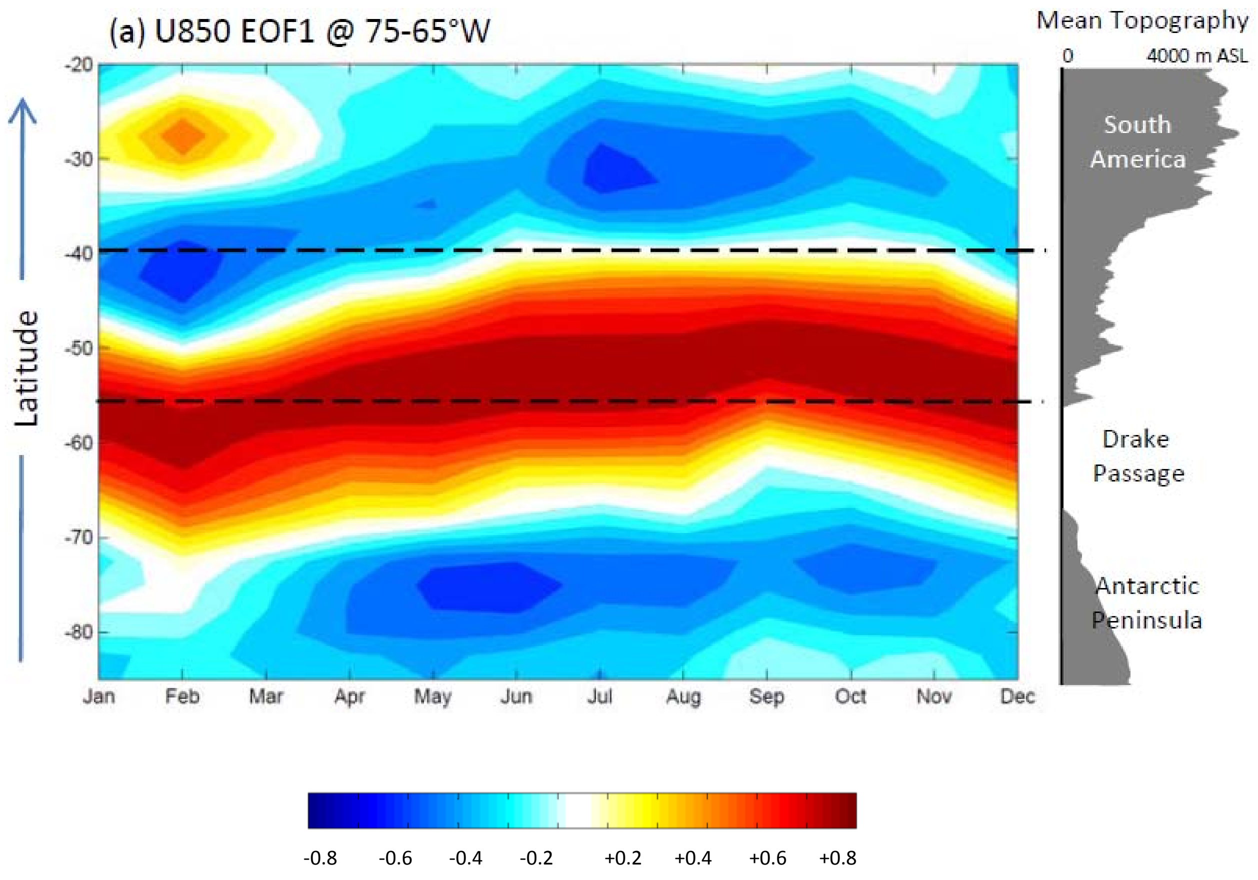
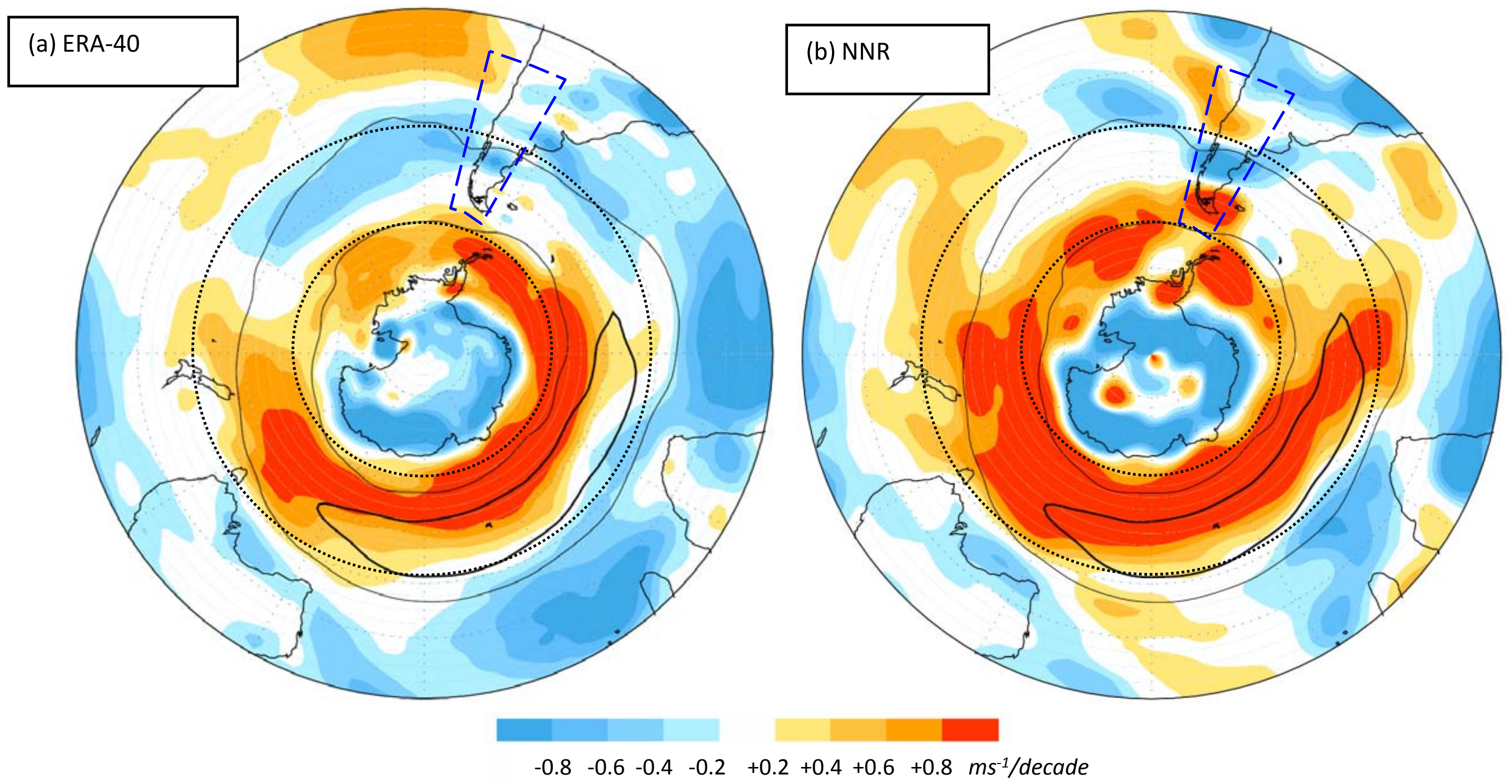
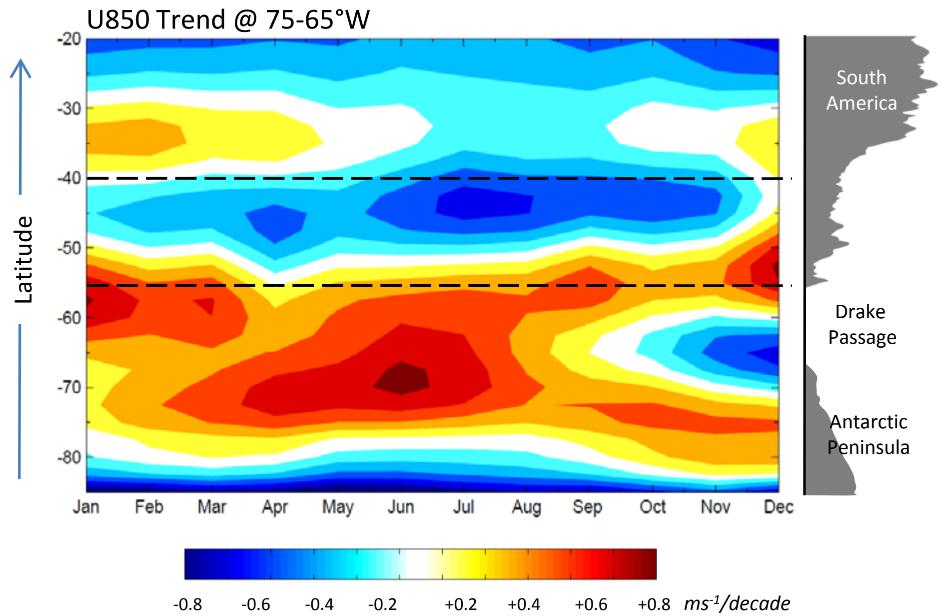


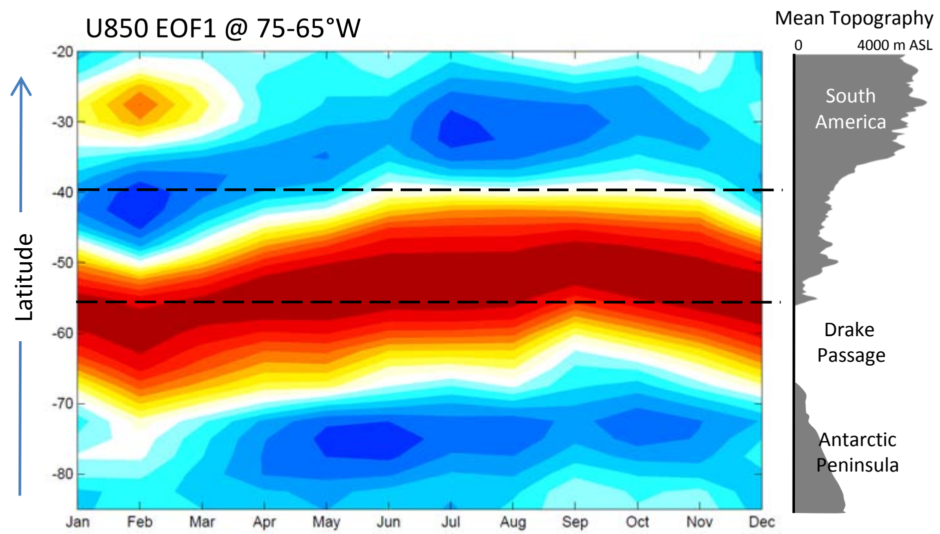
Downscale the U-P, U-SAT relationships



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

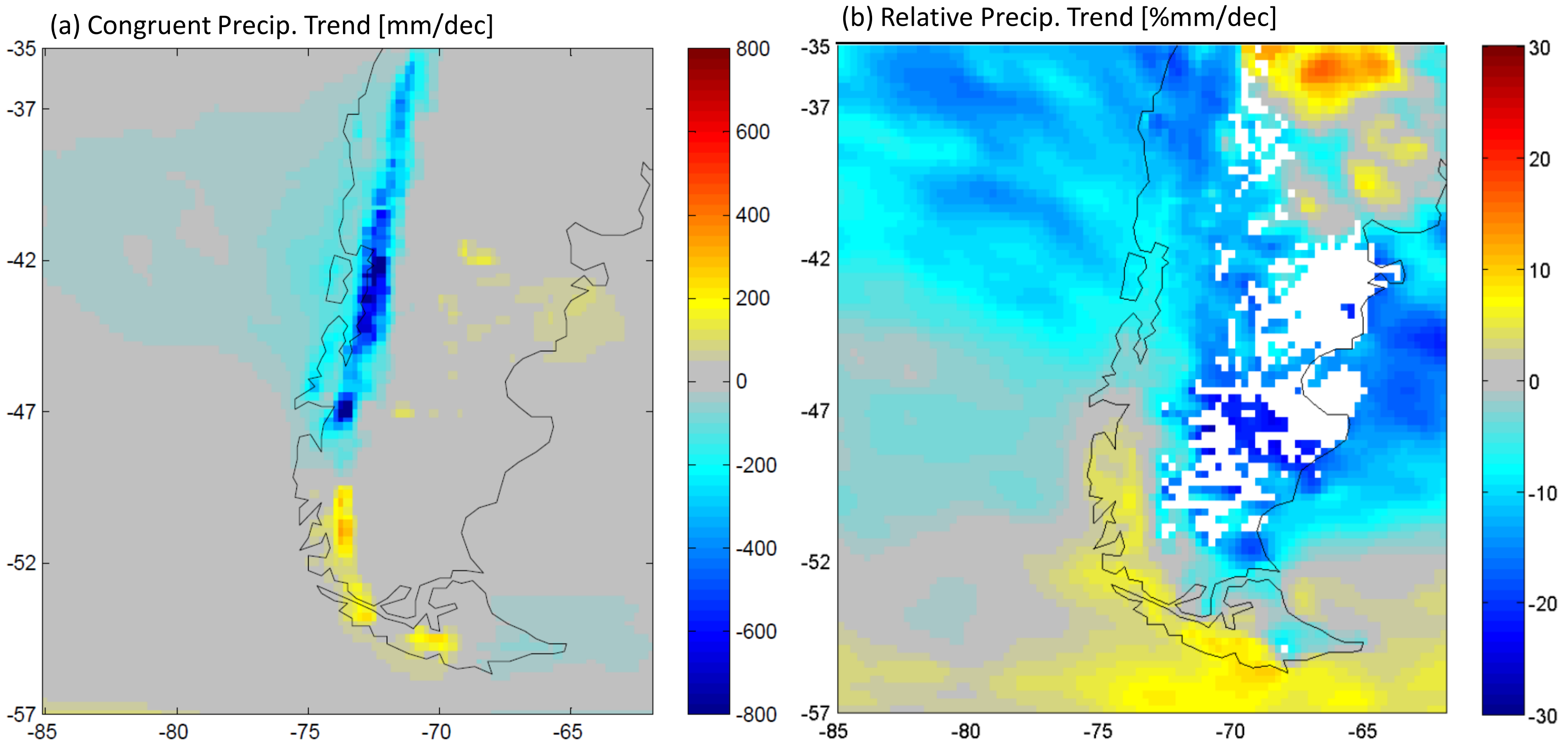
850 hPa zonal wind trend (1968-2001)





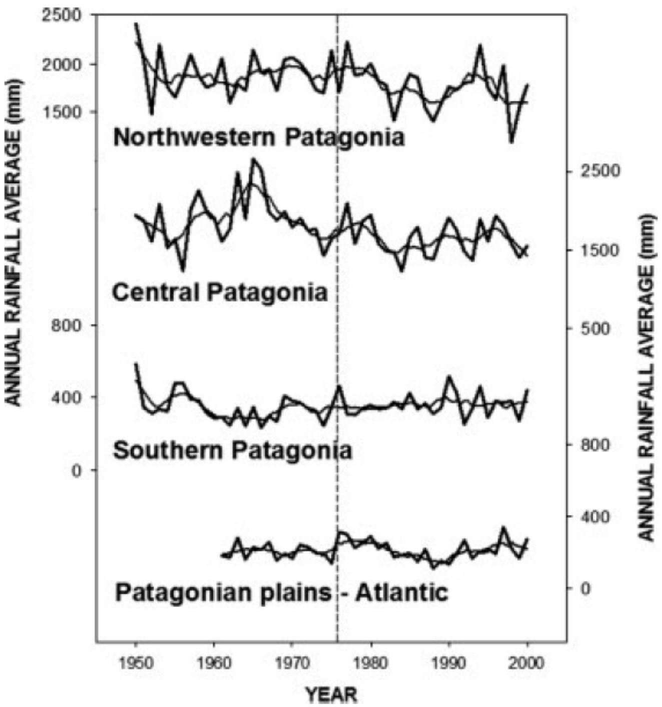
Wind-congruent precipitation trends(1968-2001)

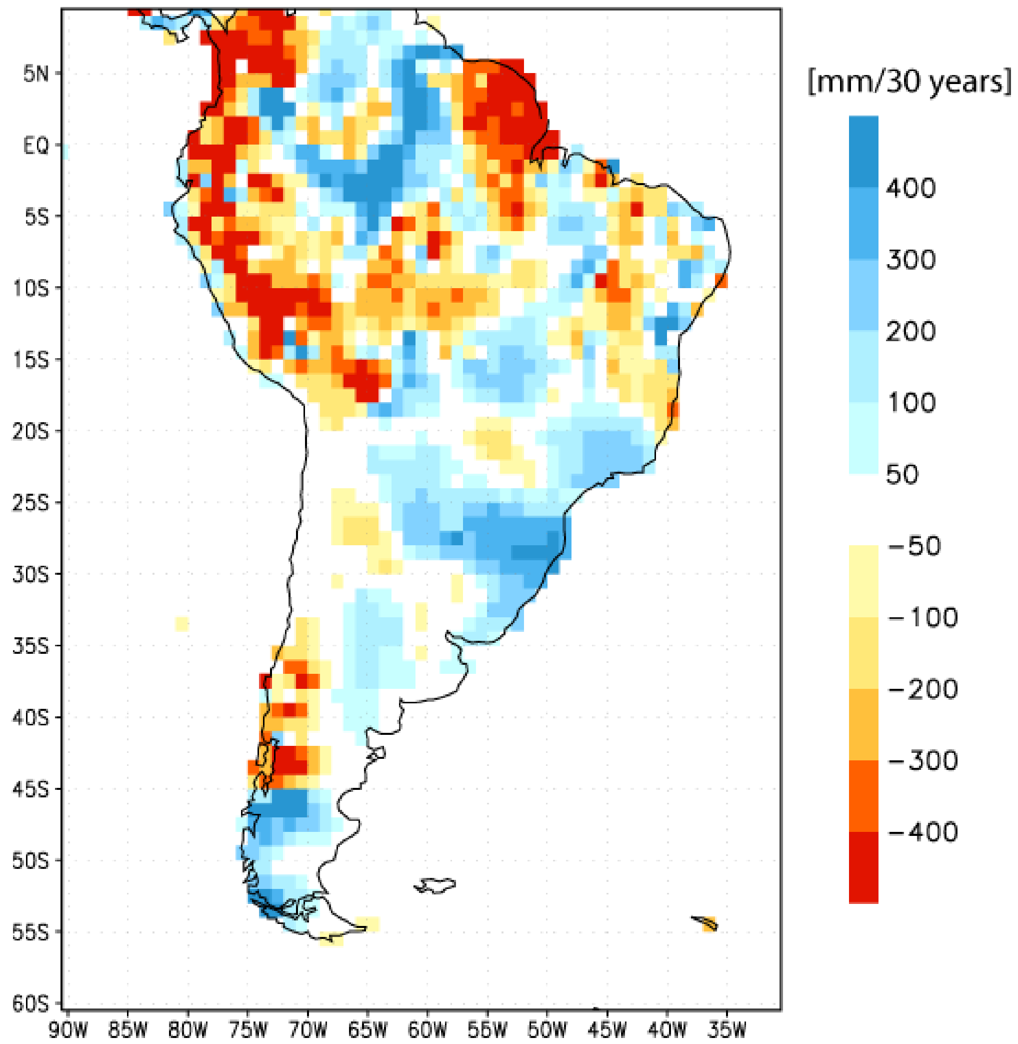
$$\Delta P^* = \beta \cdot \Delta U_{850}$$



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

Aravena & Luckman 2010

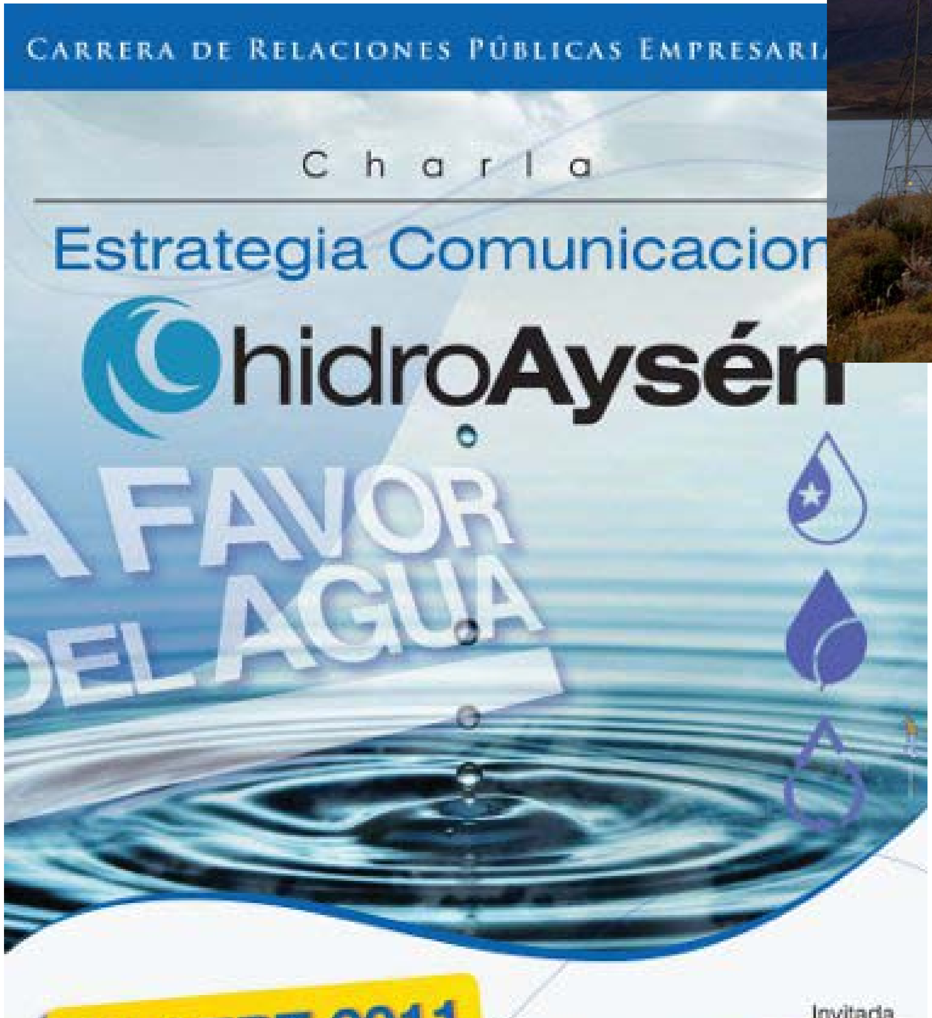




Conclusions

- Lower level (850 hPa) zonal flow strongly modulates precipitation and surface air temperature across Patagonia
- Substantial spatial and seasonal variability in correlations
- This approach can help to upscale local environmental records (and even select sites or proxy combinations) of past changes
- Likewise, it helps to reconstruct climate variability over the Patagonia during the last 50 years (downscaling)
- Wintertime monopole and summertime dipole in western Patagonia interannual variability and contemporaneous trend.

Todos aman la Patagonia…



Comparación entre la precipitación de Pto. Montt y el caudal del Río Puelo (Fuente: Antonio Lara, UACH)