Large scale control on the climate of Patagonia

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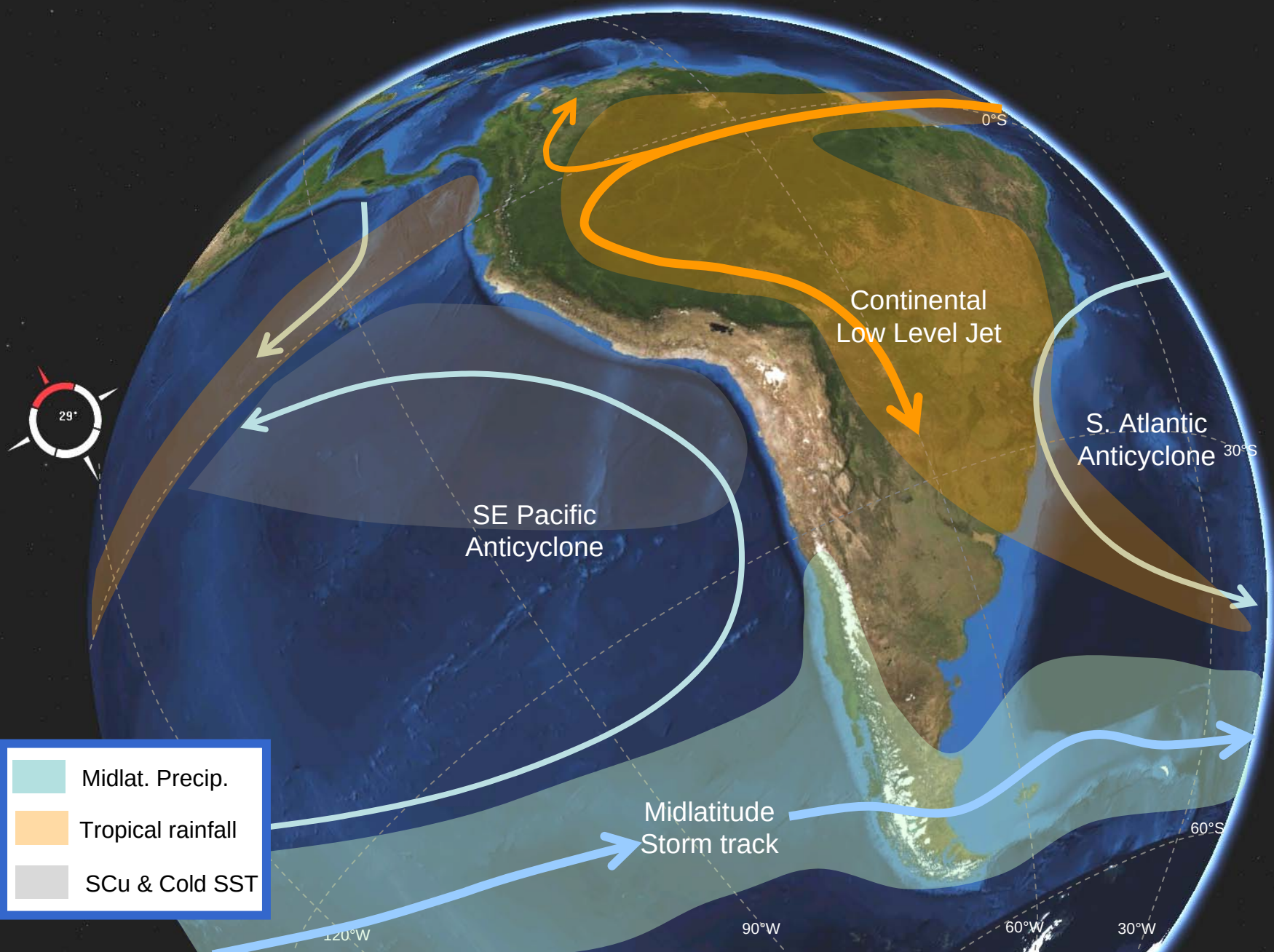
- Current climate of Patagonia supports glaciers, ice fields and massive rivers
- Biodiversity hotspot
- Large area, complex terrain
- Mounting evidence of contemporaneous climate-driven environmental changes
- Numerous paleorecords
- Meteorological data clearly insufficient to address climate change/variability

Linking local climate variability (∂SAT and ∂P) with large-scale circulation anomalies (e.g., ∂U_{aloft}) will allow: (a) ***downscale*** large-scale signals and (b) ***upscale*** local environmental changes.

The big picture



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

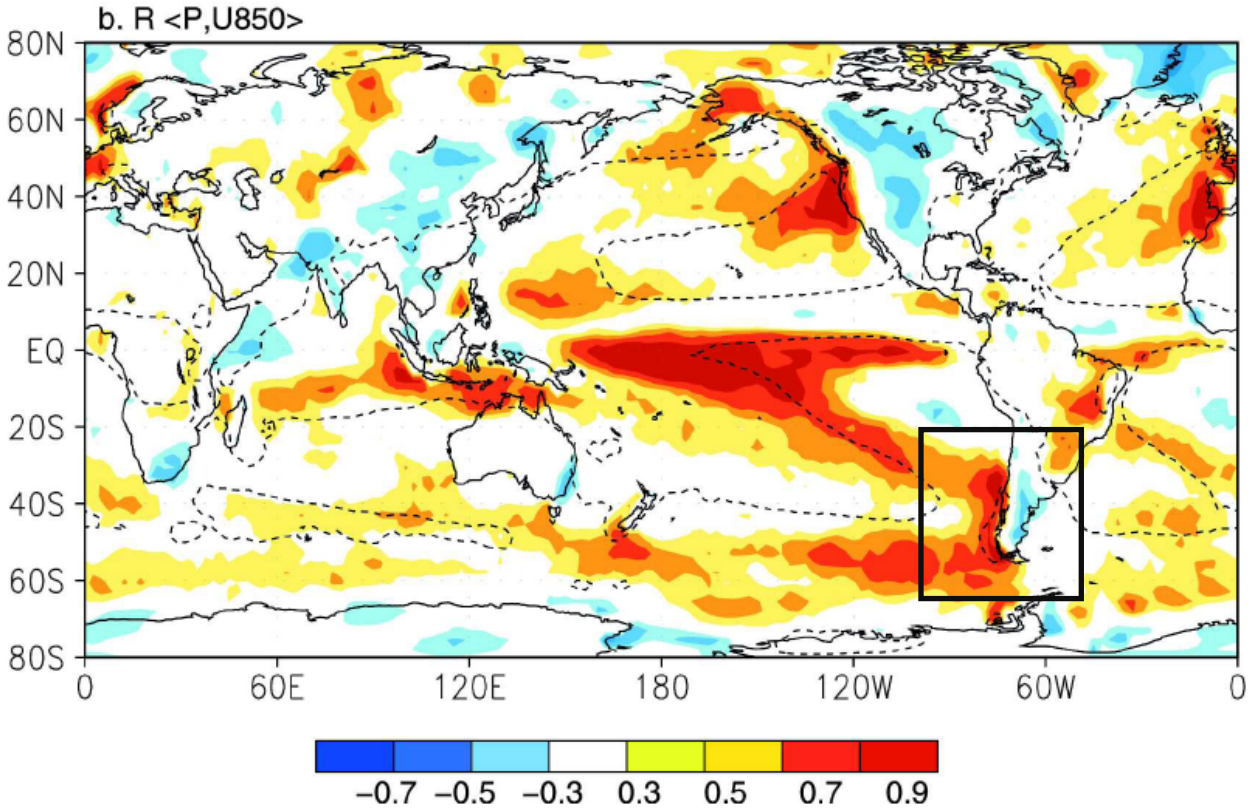
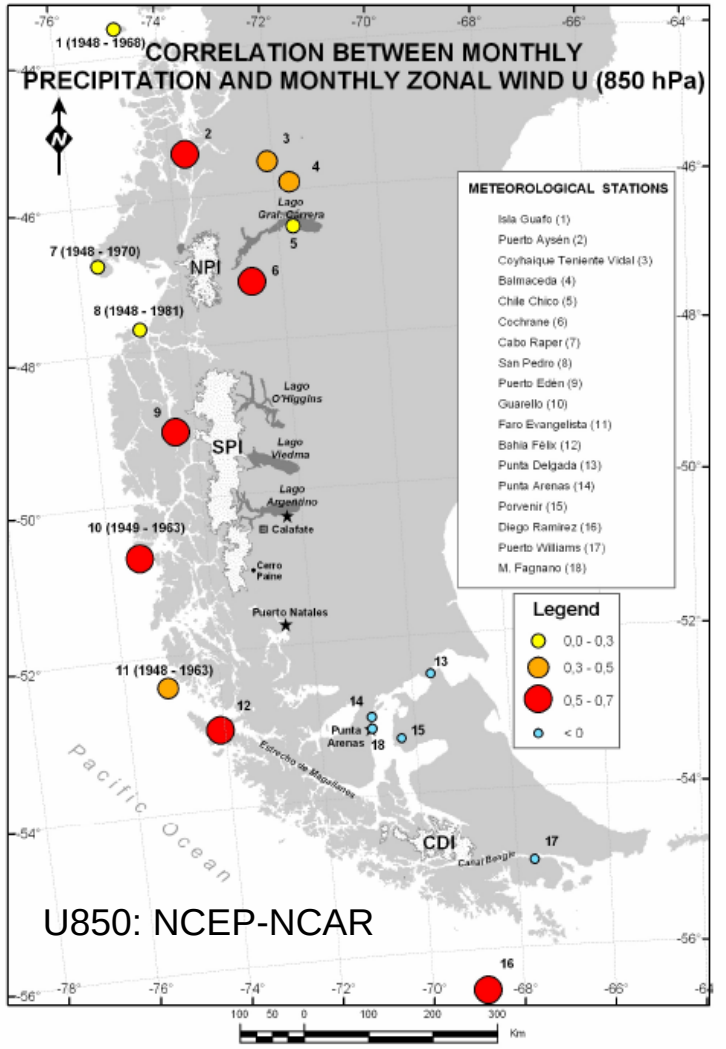


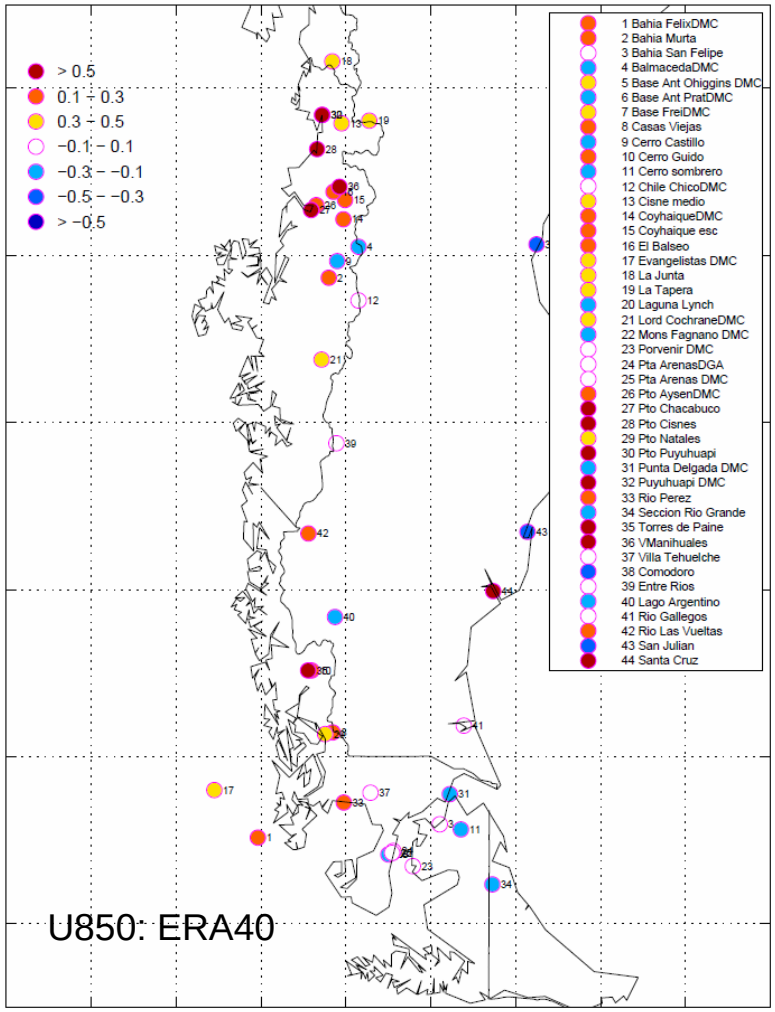
FIG. 2. (a) Map of local correlation between monthly anomalies of precipitation and 300-hPa zonal wind, scale at the bottom. Dashed lines outline regions where annual mean precipitation exceeds 1000 mm yr^{-1}. (b) Same as in (a) but for local correlation between monthly anomalies of precipitation and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

Garreaud 2007
PAGES 2006

Co-variability of zonal wind and precipitation

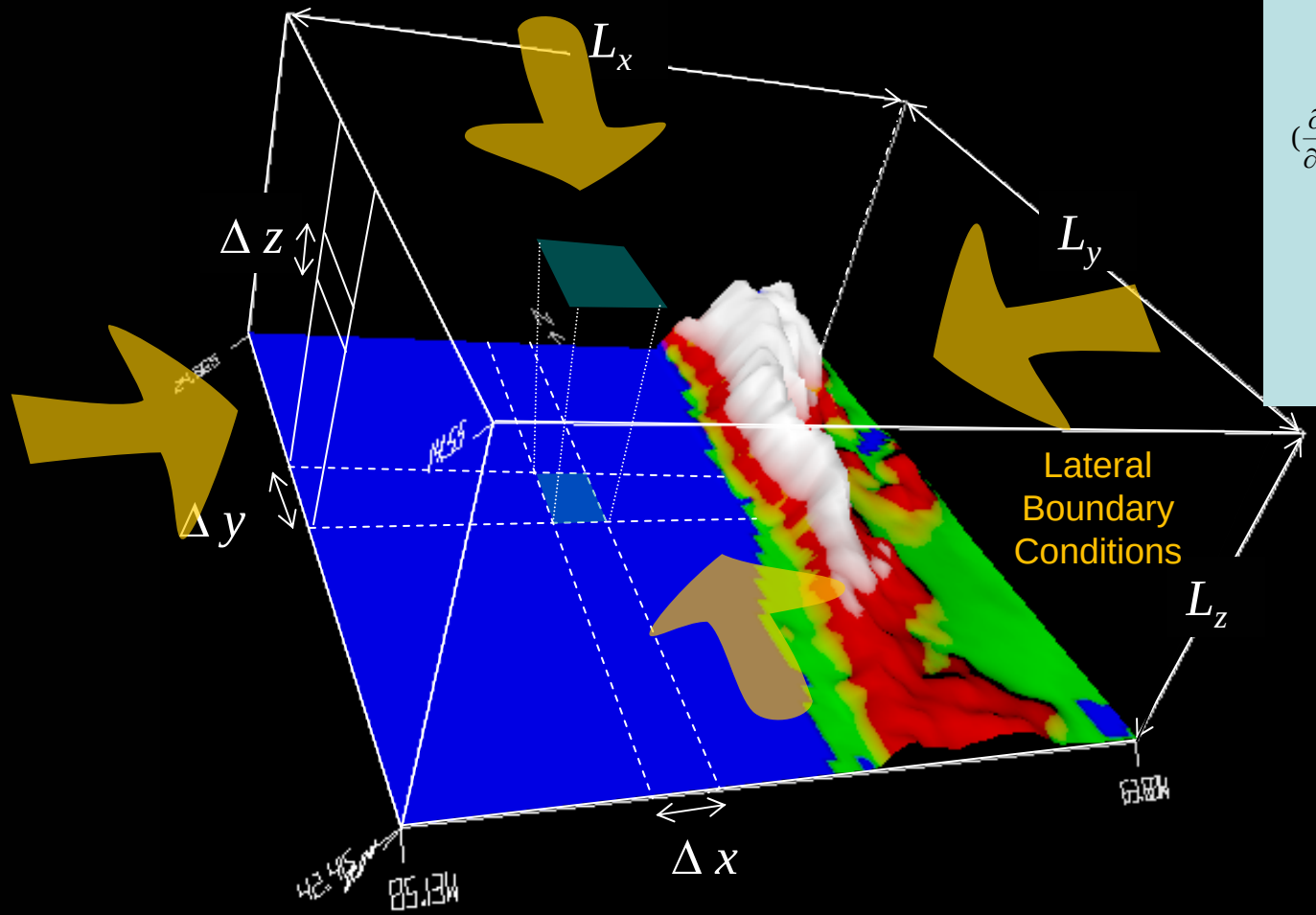
Correlation between U850 (*NNR*) and precipitation (*station data*)





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

Solve governing equation in a limited domain



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

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

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

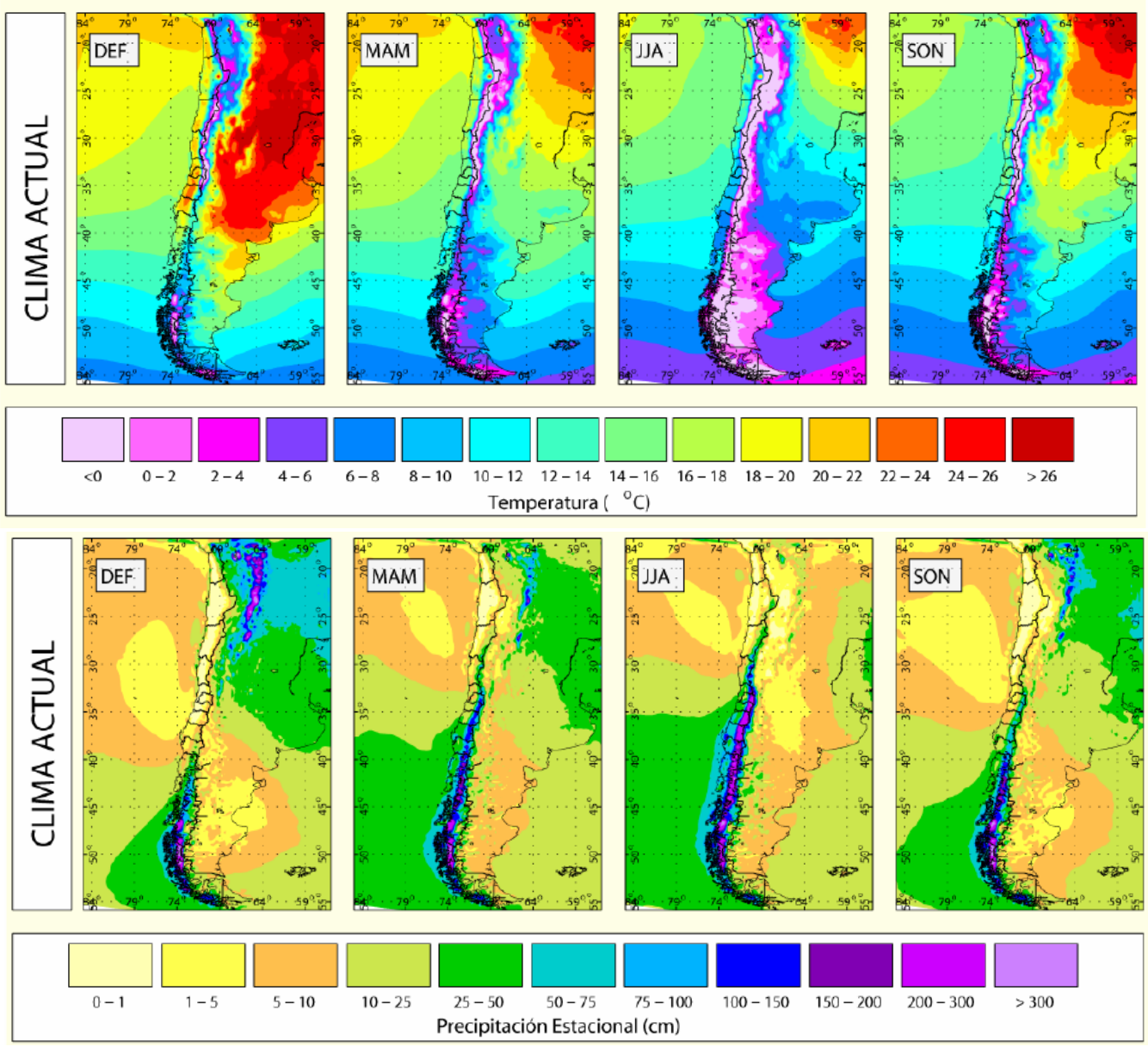
$$\frac{\partial(gz)}{\partial p} = -\frac{RT}{p}$$

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

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

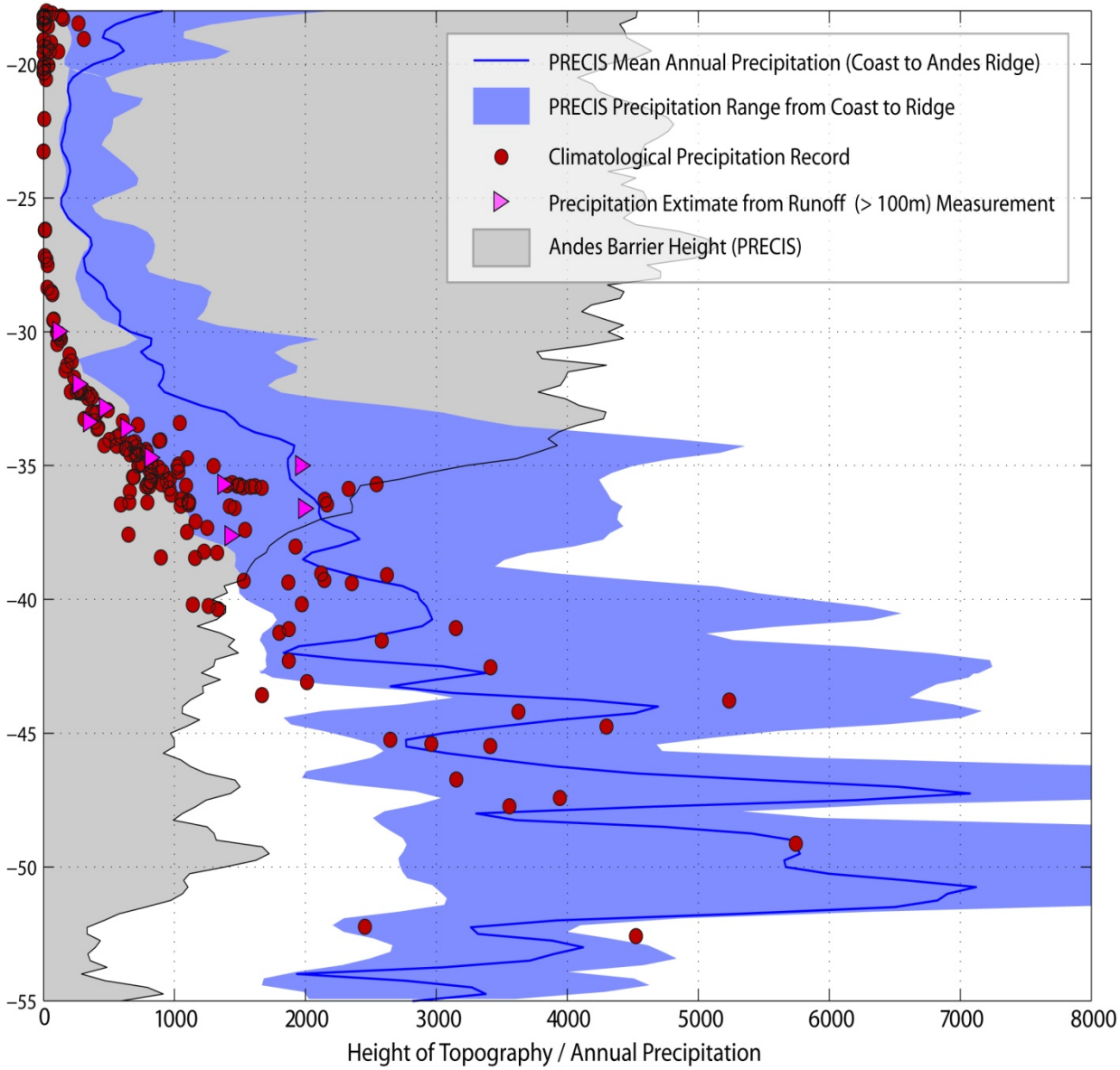
PRECIS-DGF Baseline (1960-1990) forced by ERA-40

Dynamical downscaling over complex terrain driven by observed BC



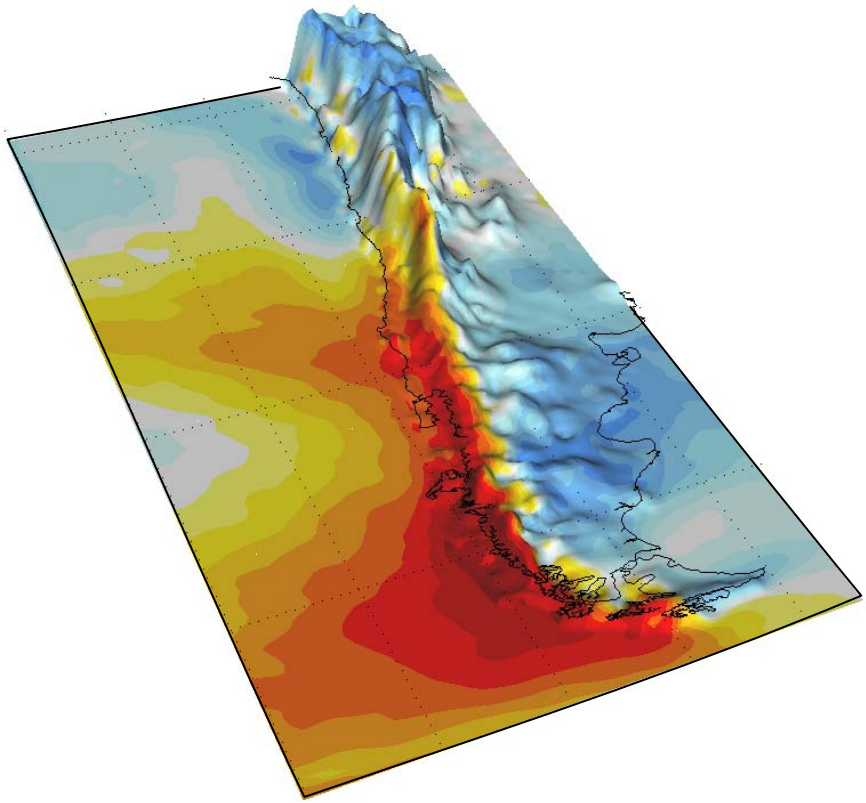
PRECIS-DGF Baseline (1960-1990) forced by ERA-40

Mean fields not perfect….but variability and internal dynamics Ok

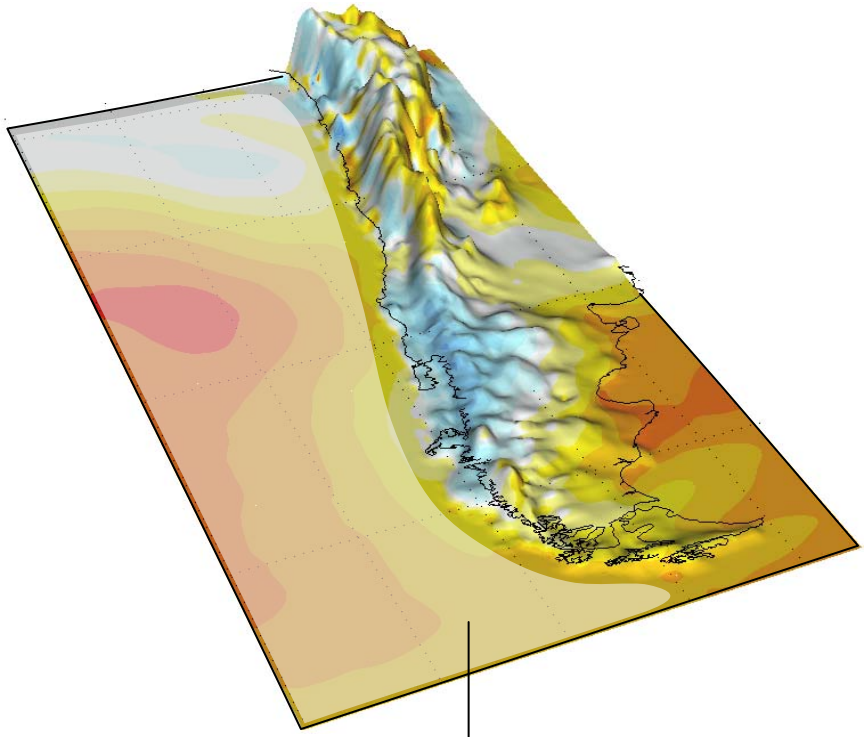


PRECIS-DGF Mean annual values, Control Run

ℜ(U850- Precipitation)



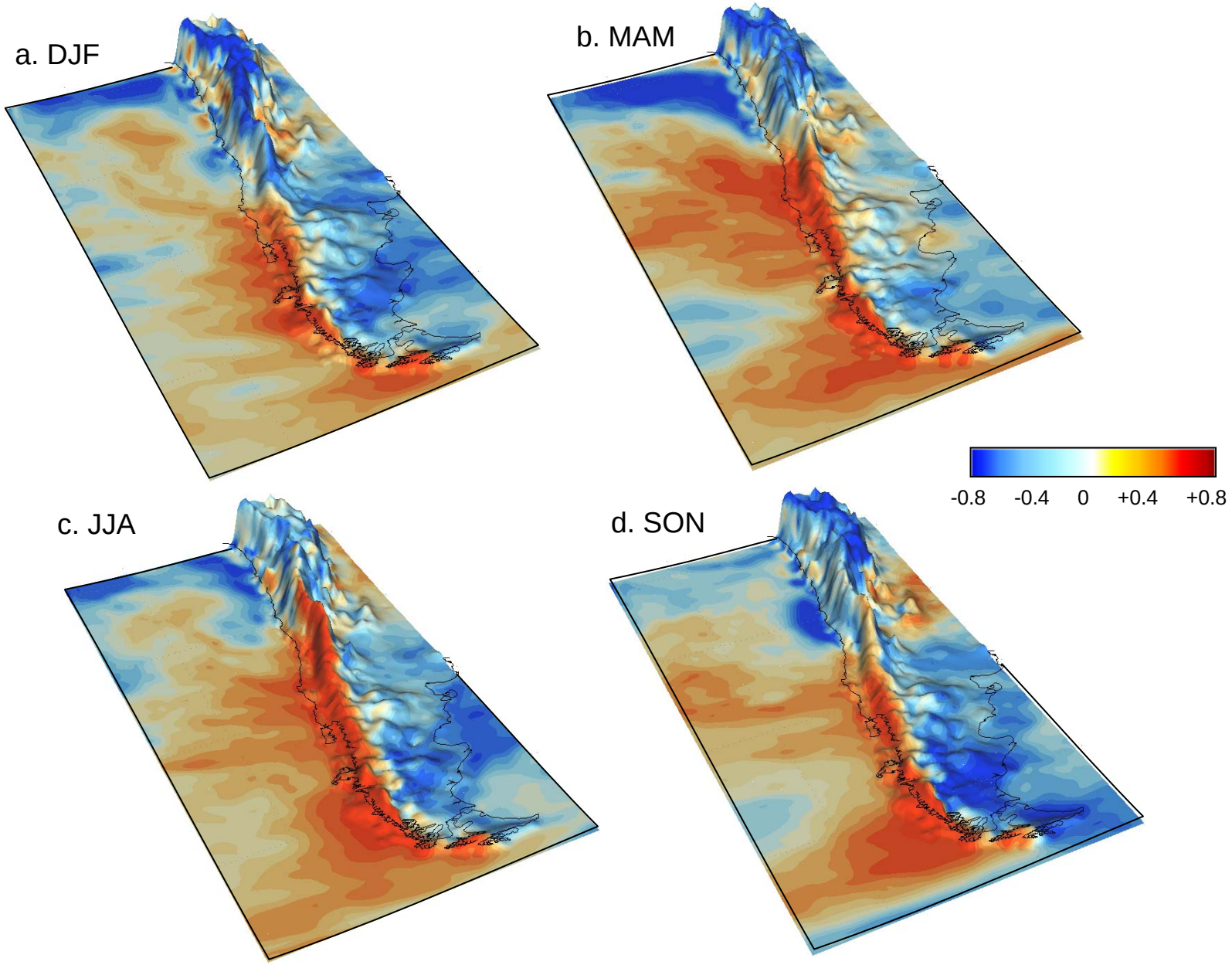
ℜ(U850- Surface Air Temp)



Warning!
prescribed SST
influences T2m

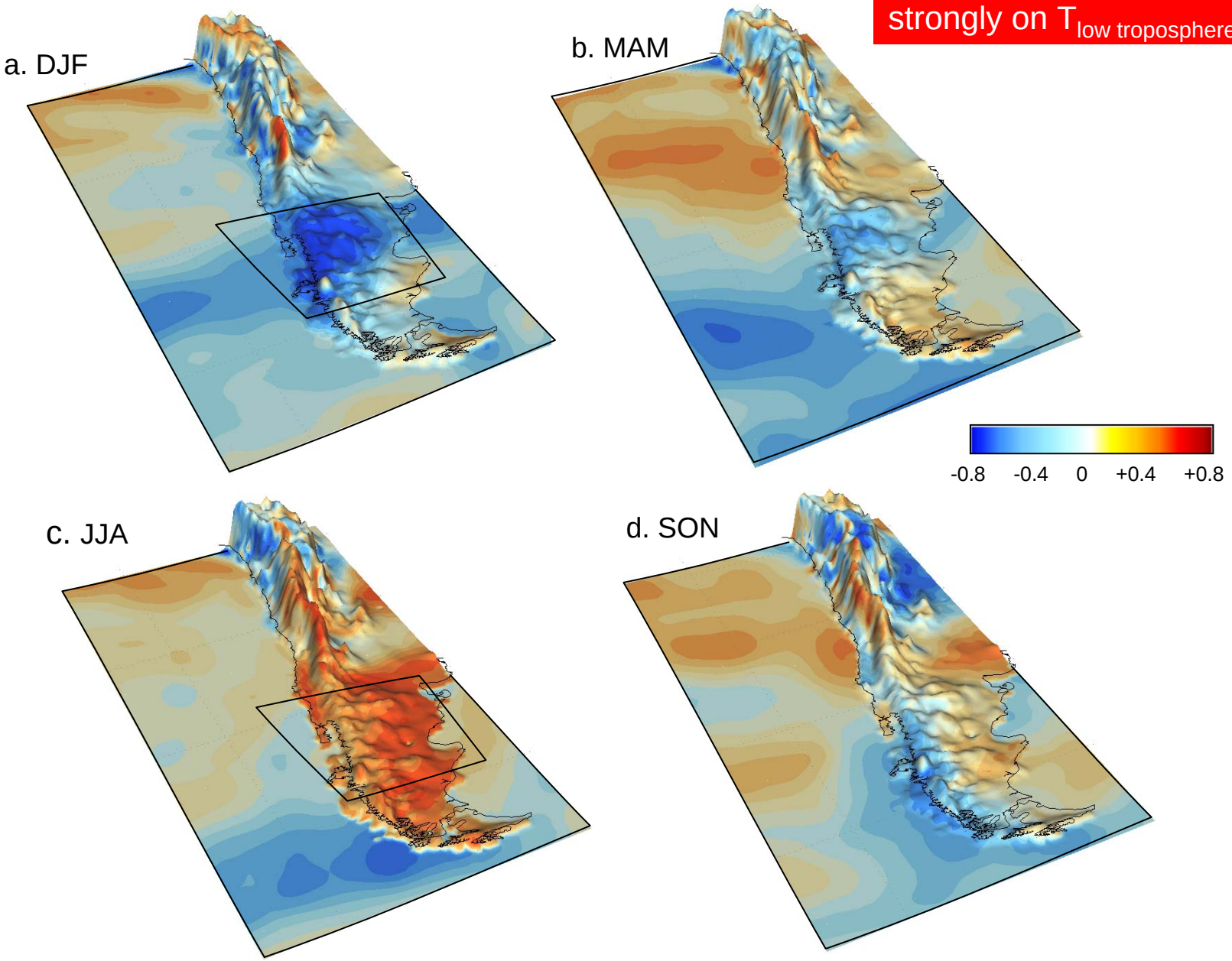
-0.8 -0.4 0 +0.4 +0.8

ℜ(U850 – Precipitation) Seasonal values



ℜ(U850 – SAT) Seasonal values

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



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

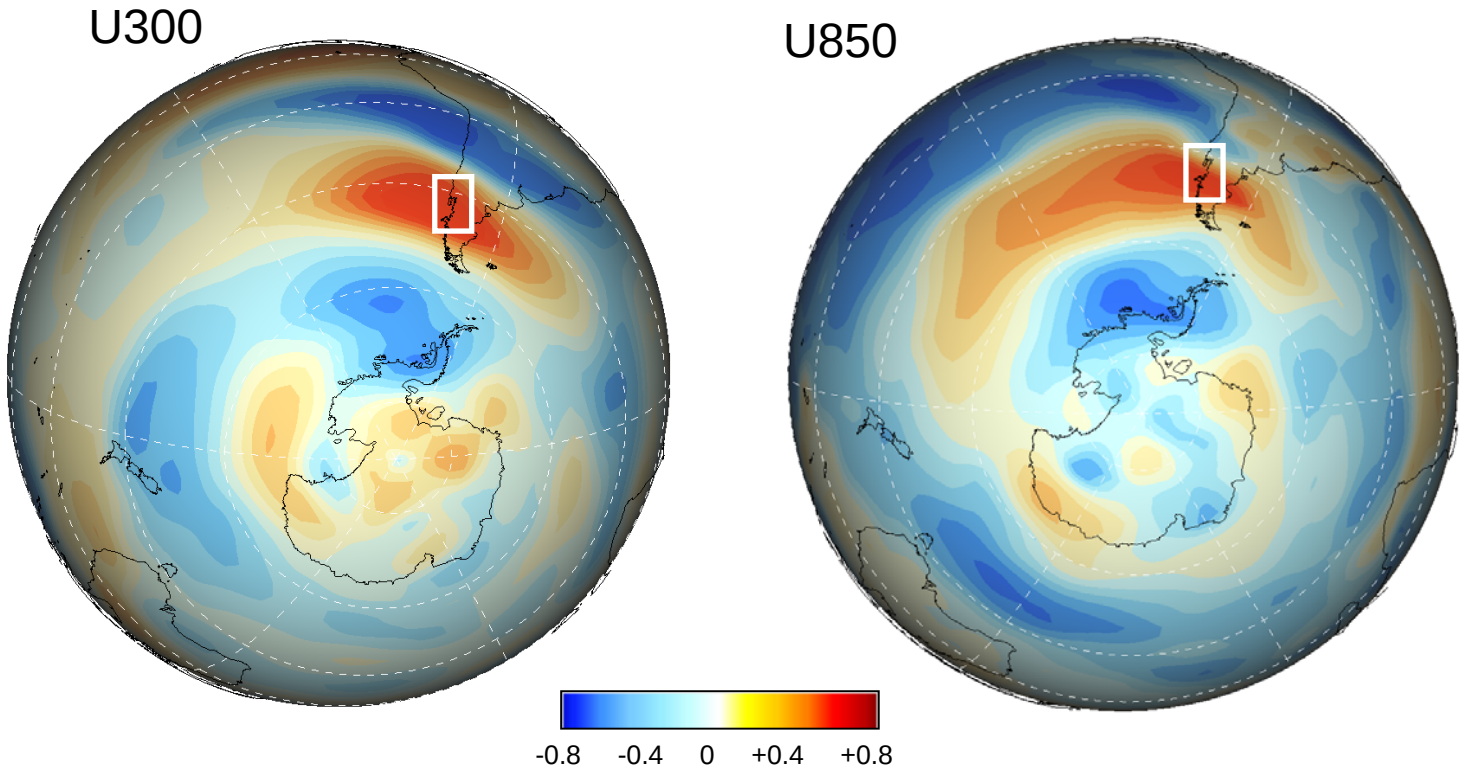
	Western Patagonia	Eastern Patagonia
Winter	• Enhanced ascent: more humid (P'>0) • Strong advection of warm, maritime air • More clouds but little effect • Slightly milder conditions (T'>0)	• Enhanced subsidence: drier (P'<0) • Strong advection of warm, maritime air • Unfavorable for cold-air pool formation • 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 $T_{\text{low troposphere}}$

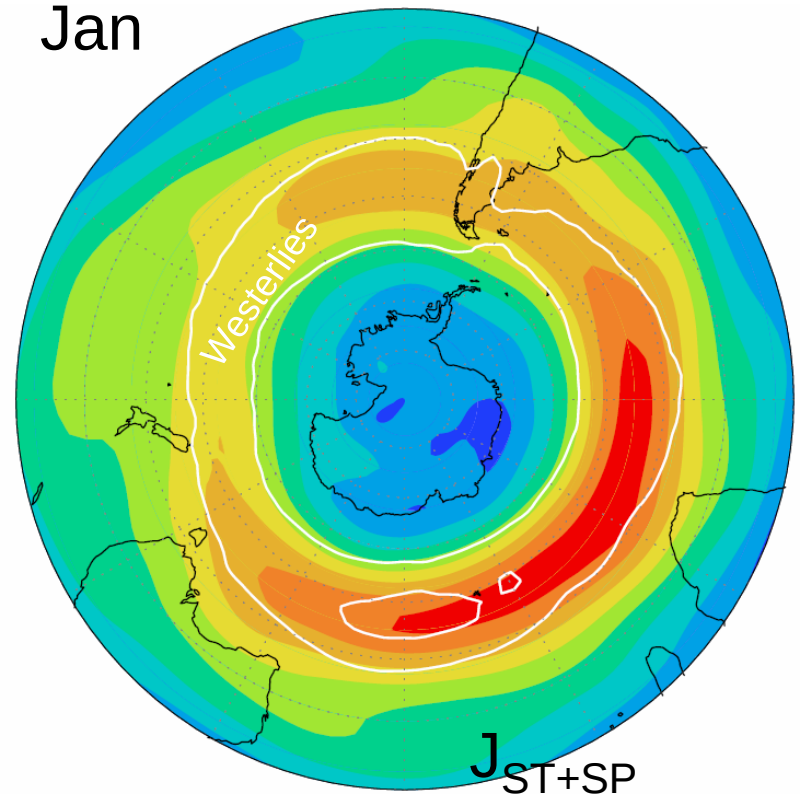
Upscale the U-P, U-SAT relationships

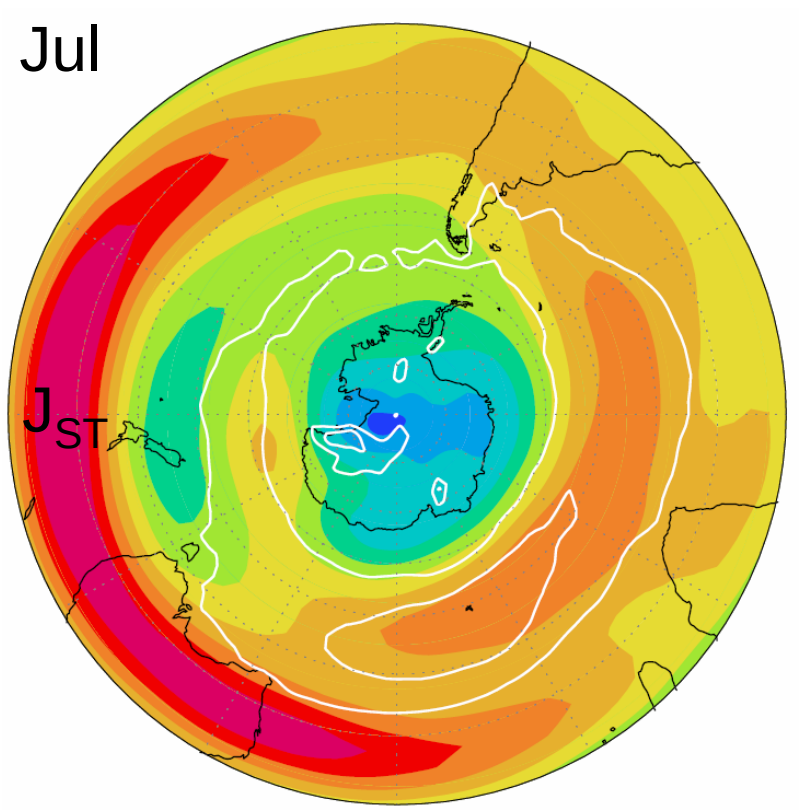
Let's suppose an environmental proxy suggest stronger than normal westerly flow over central Patagonia…what about the rest of the world? Specifically, stronger westerlies over the SH? Not sure yet…

1Point correlation map between U850(PAT) and…(annual means)



Real world general circulation
Surface wind (contours) & 300 hPa wind (colors)

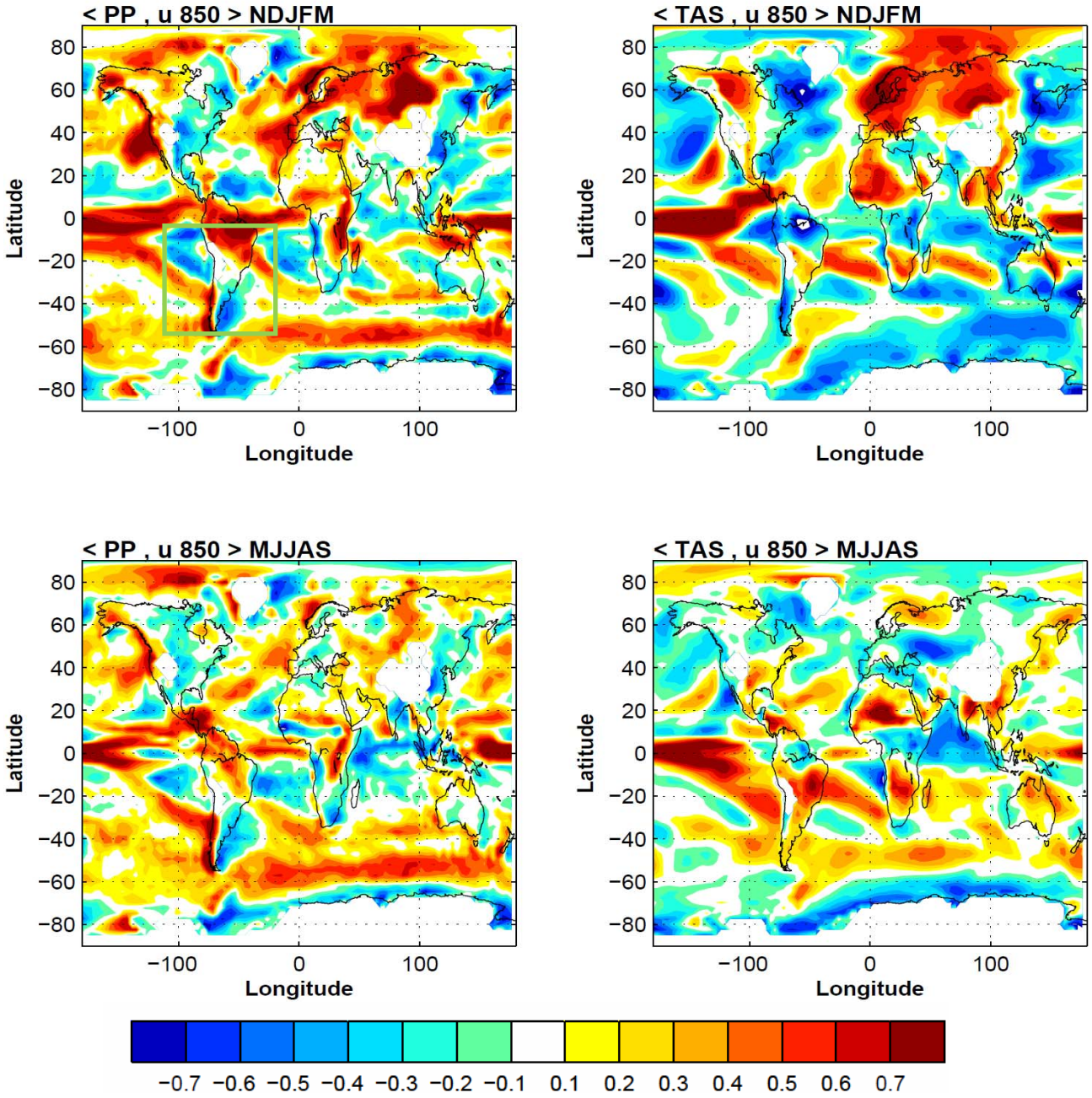




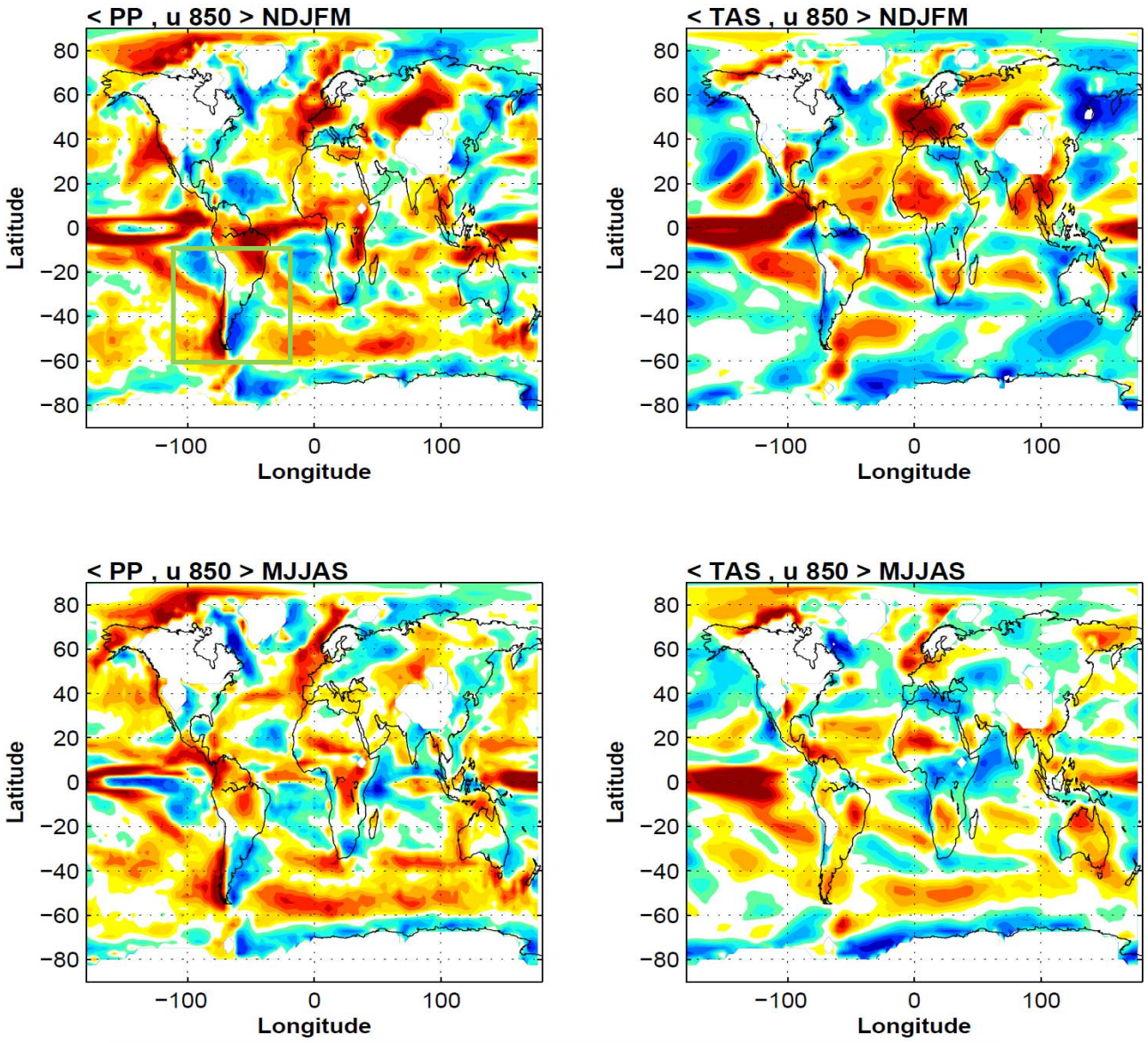
(Surface) Westerly belt is more continuous and stronger in austral summer than in winter. Stronger westerlies at surface not always under strong westerlies aloft....

How stable is the U-P & U-SAT relationship?

IPSL GCM
Control run
Modern Climate

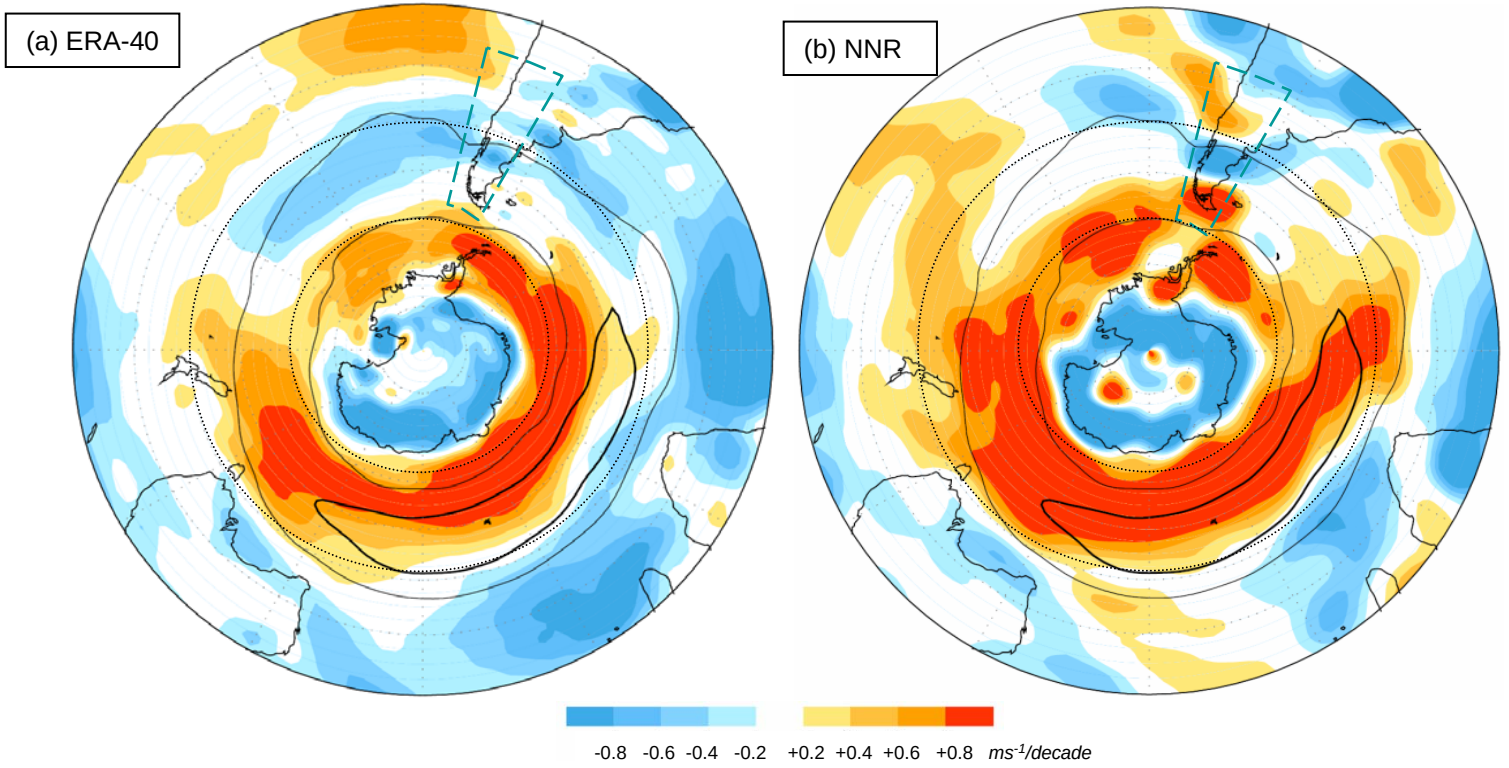


IPSL GCM
21 K run
LGM Climate

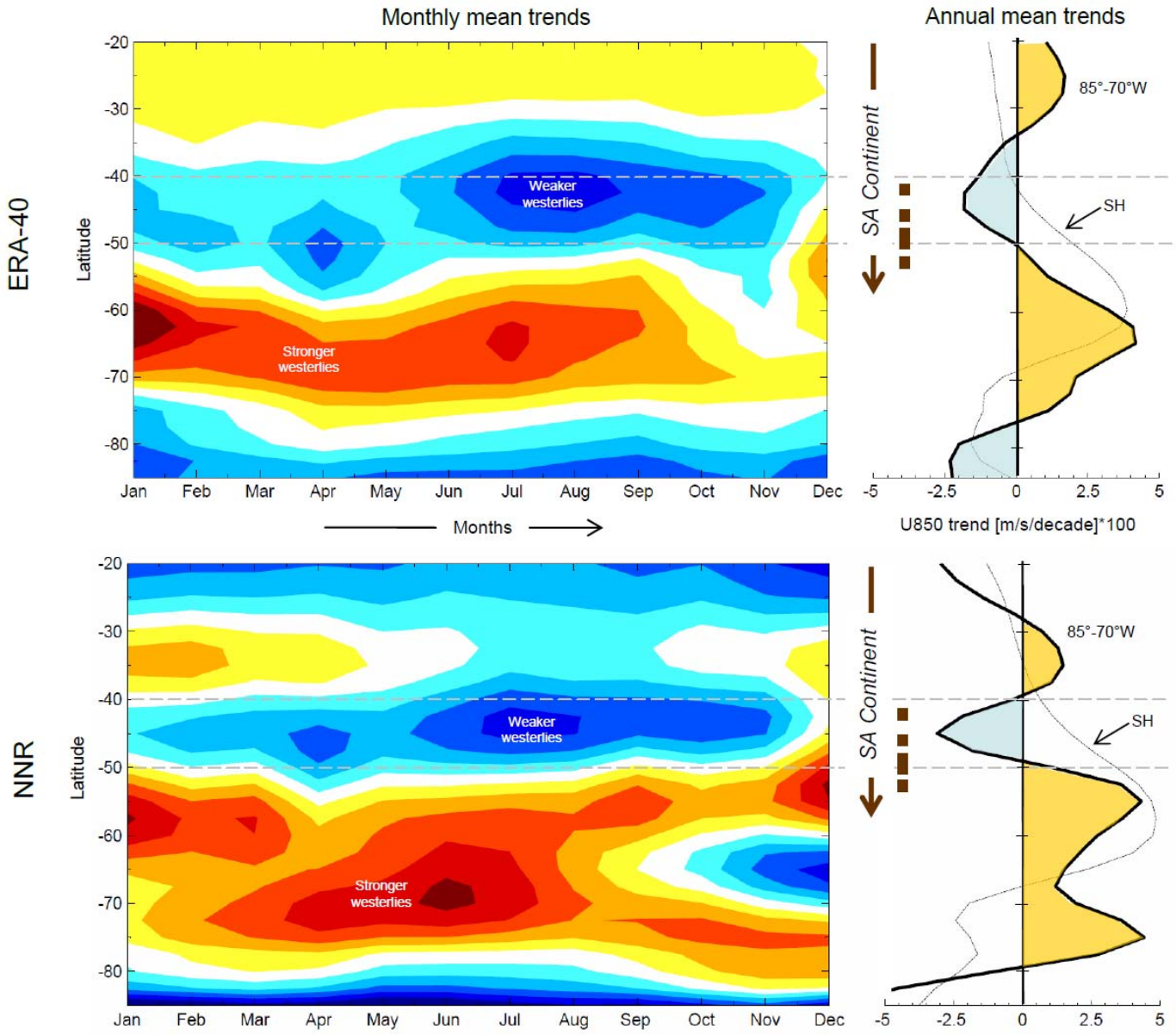


Downscale the U-P, U-SAT relationships

Let's use observed or projected changes in zonal wind to infer environmental changes in Patagonia (complement sparse observational network)



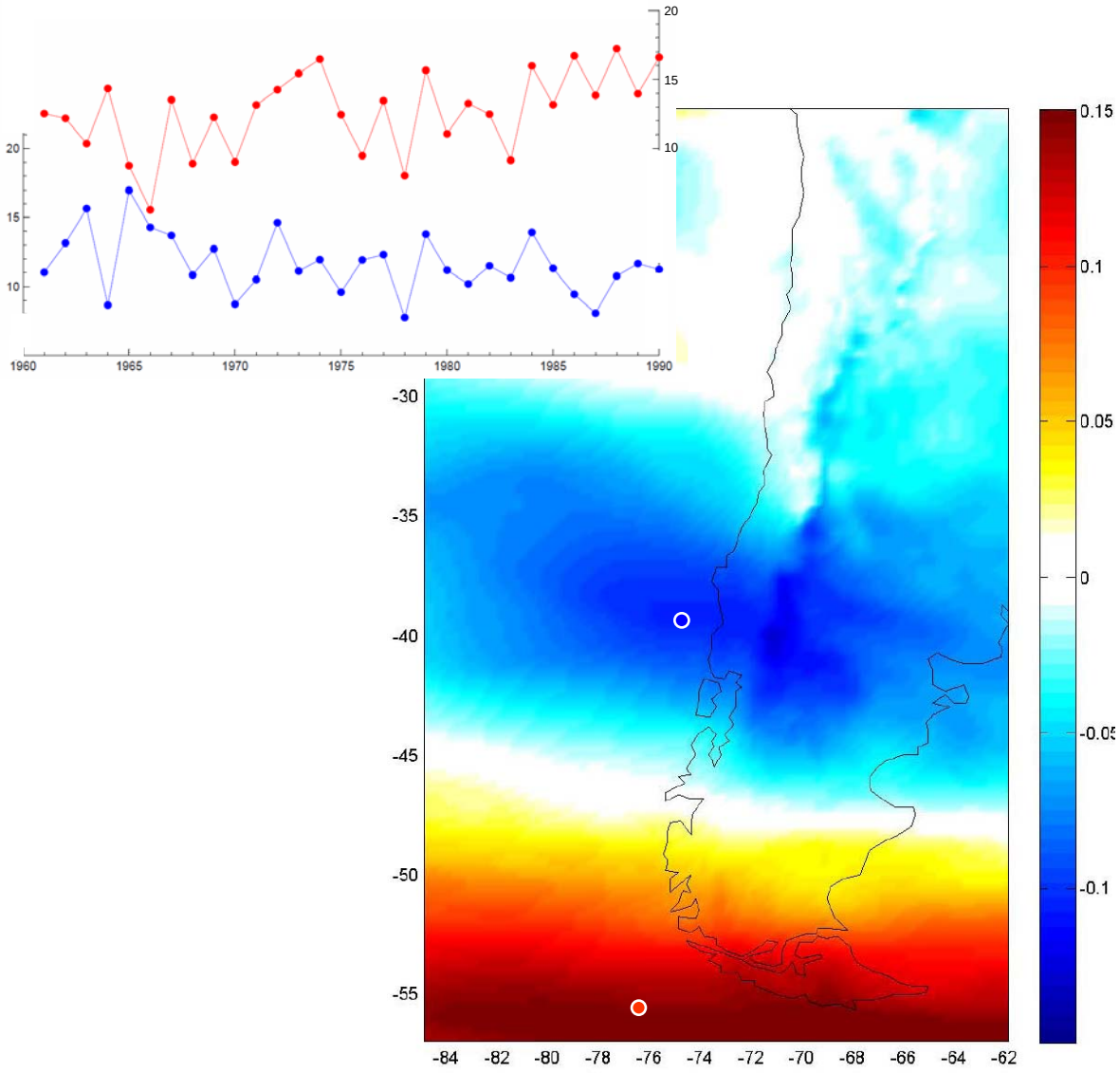
Linear trends in the annual mean zonal wind (E-W component) at the 850 hPa level using the (a) ERA-40 and (b) NCEP-NCAR reanalysis. Shading indicates the change between 1968 and 2001 of a linear least squares trend fit calculated at each grid-box



Linear trends (1968-2001) in zonal wind (E-W component) at the 850 hPa level averaged over southern South America using the ERA-40 and NCEP-NCAR reanalysis

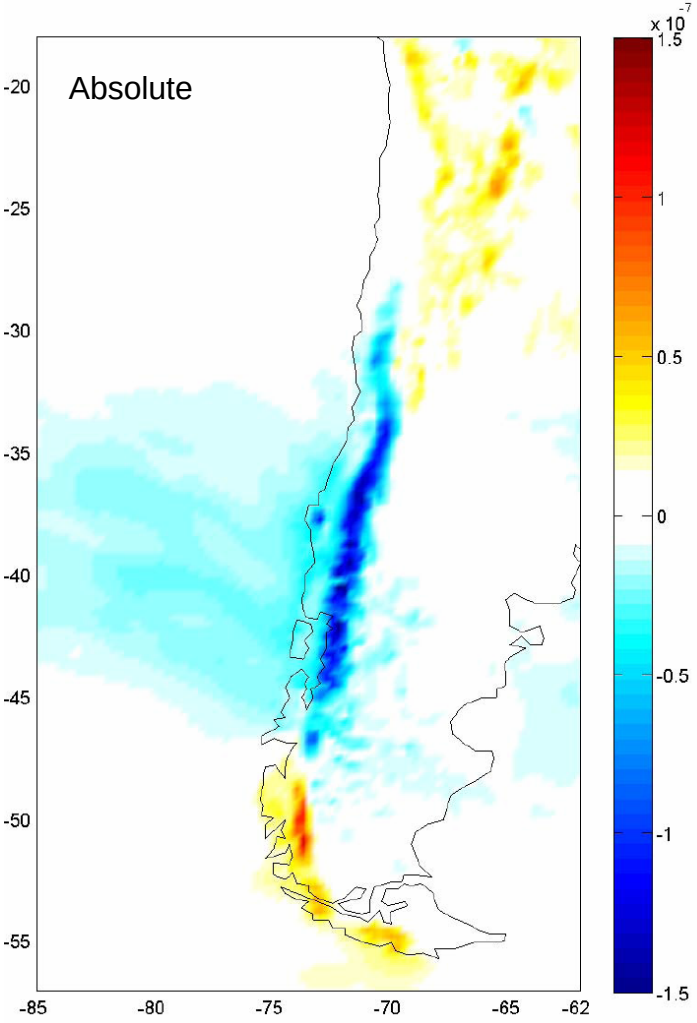
PRECIS BL-HadCM

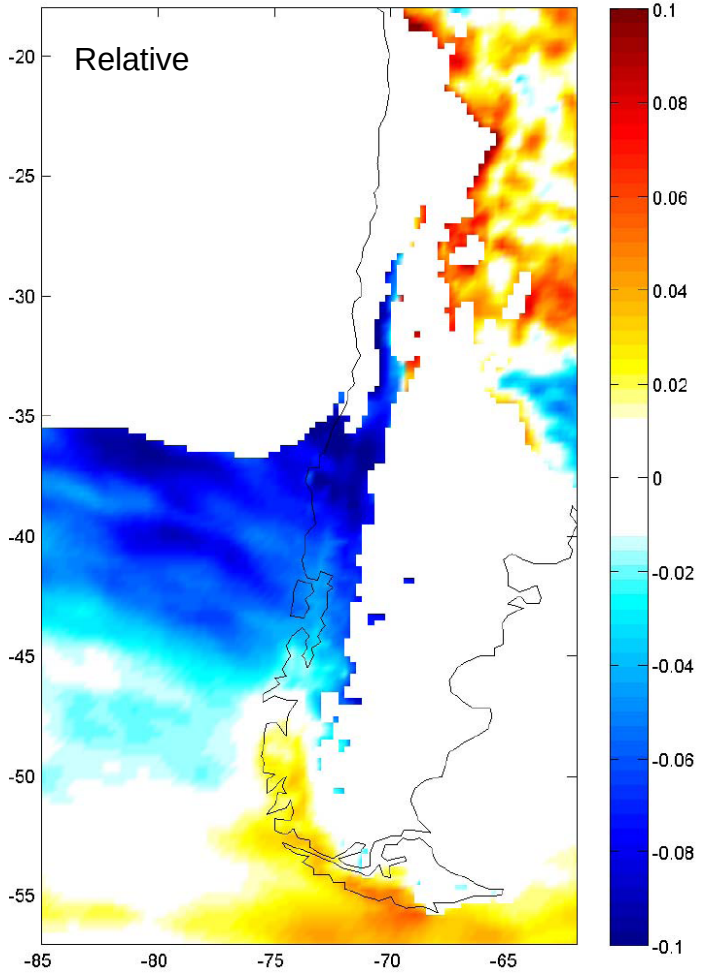
Mean annual U700 trend 1960-1990



PRECIS BL-HadCM

Mean annual precipitation trend 1960-1990



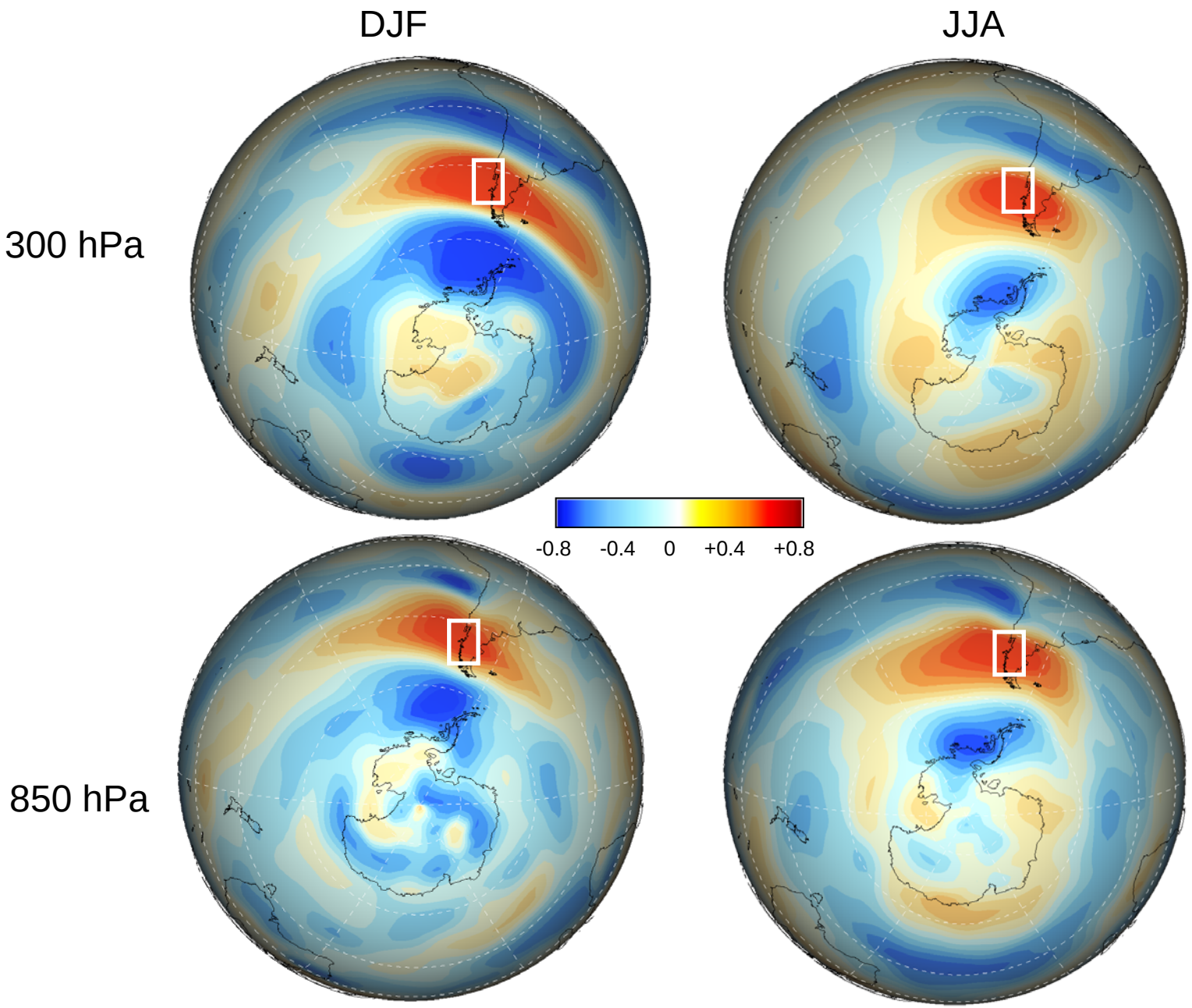


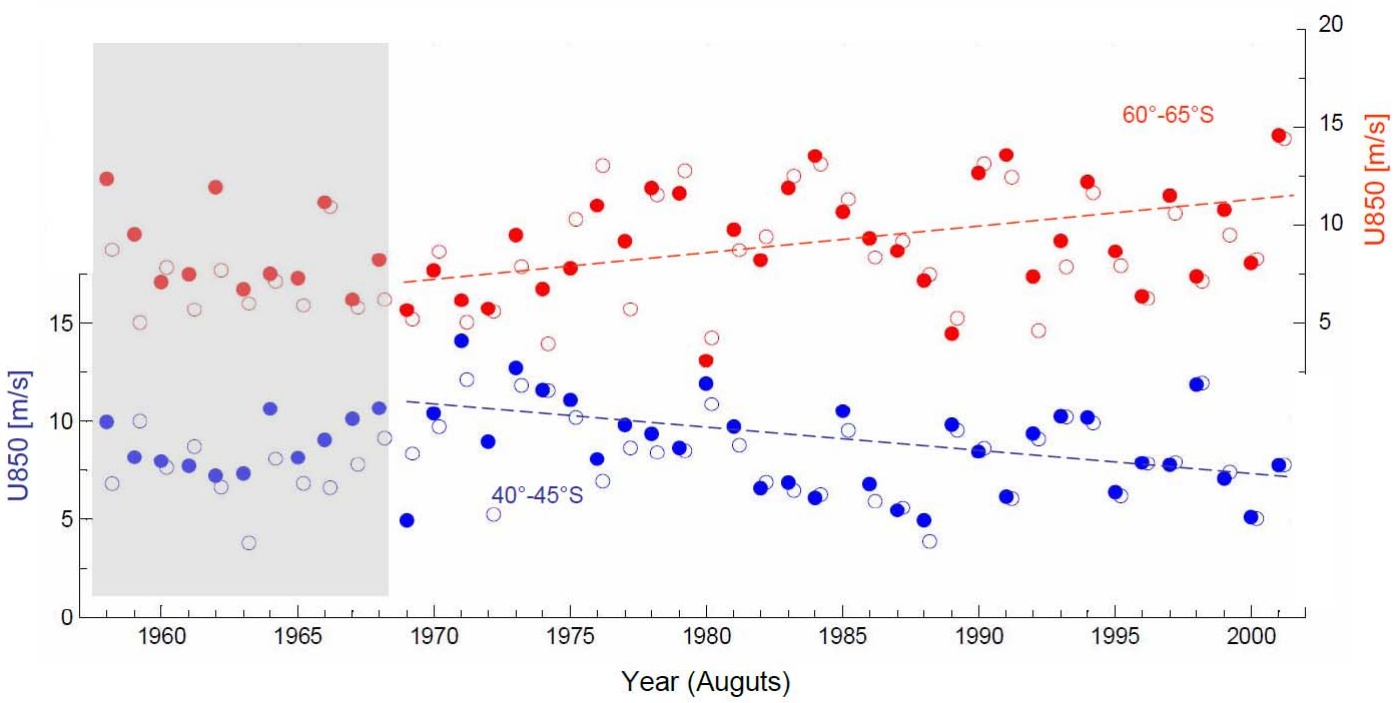
Conclusions

- 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, we plan to reconstruct climate variability over the Patagonia during the last 50 years (downscaling)

Supporting Material

1Point correlation map between U850(PAT) and…(seasonal means)





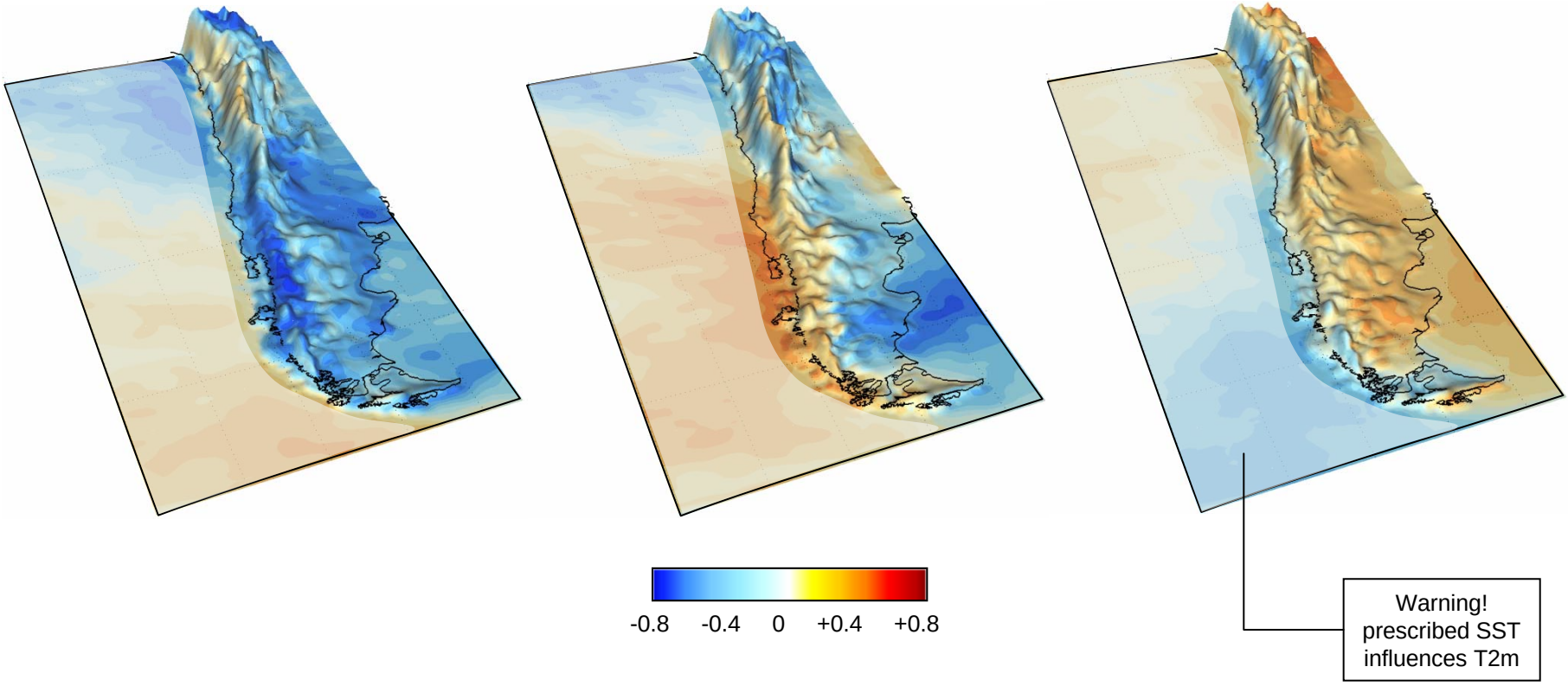
August mean of the zonal wind component at the 850 hPa level in the region [40°-45°S, 80-75°W] (blue circles) and [60°-65°S, 80-75°W] (red circles) from the ERA-40 (closed circles) and NCEP-NCAR reanalysis (open circles). The dashed lines indicate the linear least square trend fit between 1958 and 2001 using the ERA-40 values.

Additional diagnostics fields

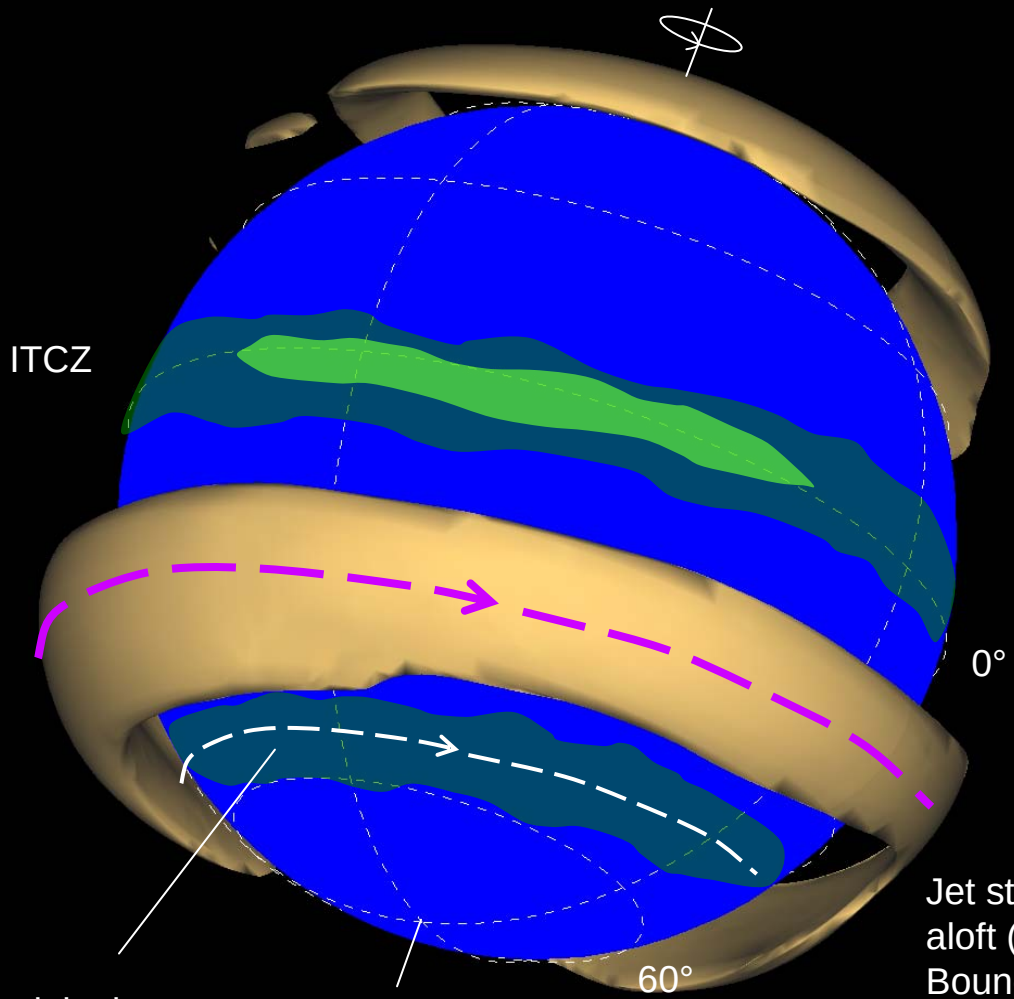
(a) $\Re(T_{2m}$- Prec) DJF

(b) $\Re(T_{2m}$- Prec) JJA

(c) $\Re(T_{2m}$- SWF) Annual



General circulation in an aqua-planet
Perpetual Equinox



Midlatitude precipitation maximum and westerly belt

Jet stream (westerly flow) aloft (10-12 km): long term mean. Boundary between subtropical and extratropical air masses