Climate change in Patagonia

What we should expect in the next 50 years ?

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Departamento de Geofísica Universidad de Chile
Centro del Clima y Resiliencia

Global change at basin and fjord scale and future water management challenges in Patagonia

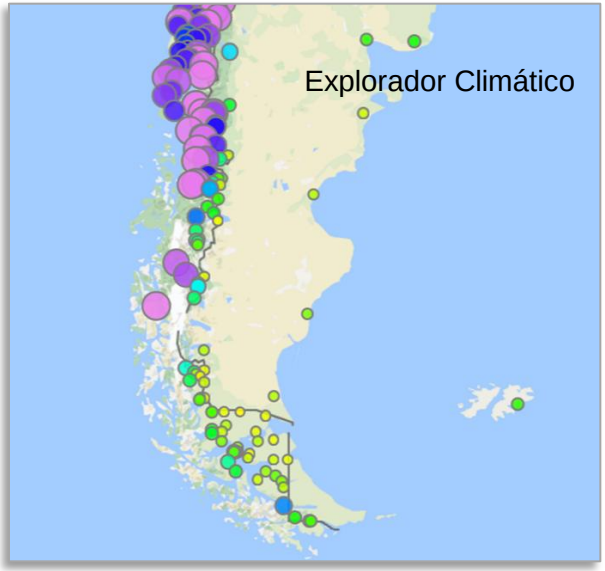
Coyhaique, 7-9 Nov 2018

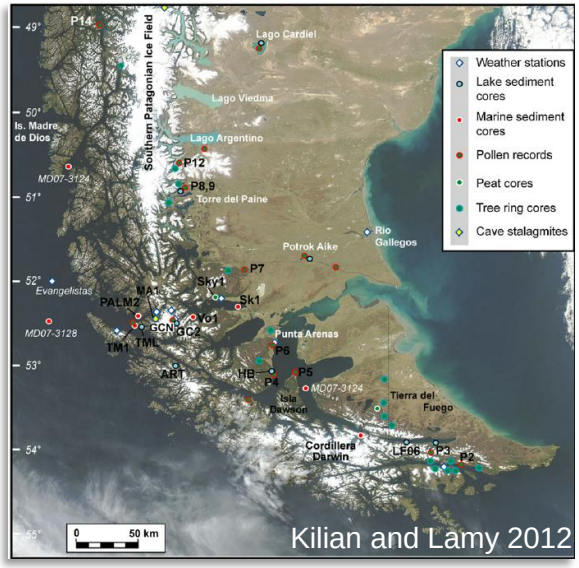
Outline

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

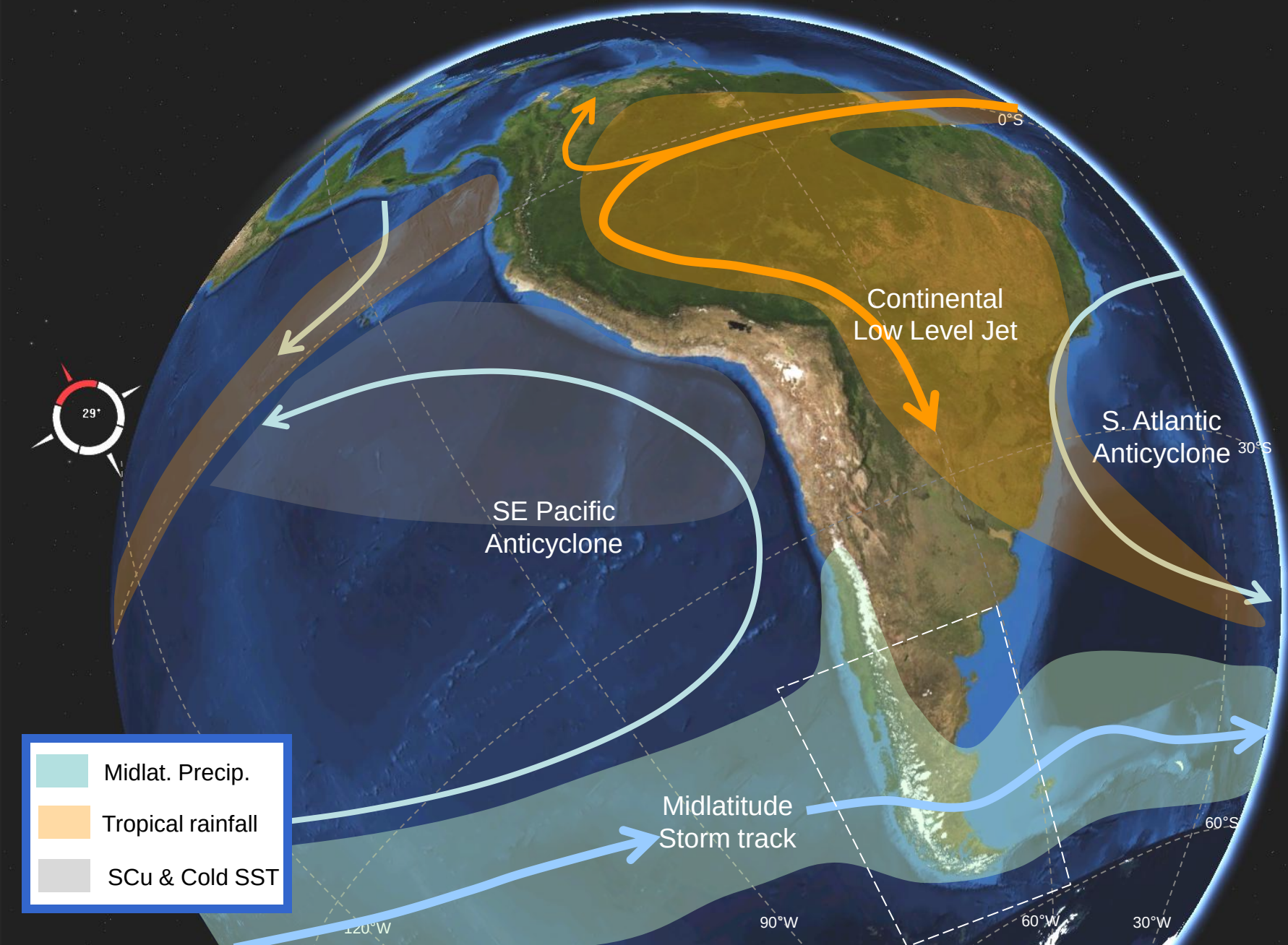
We all love Patagonia…..

- 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



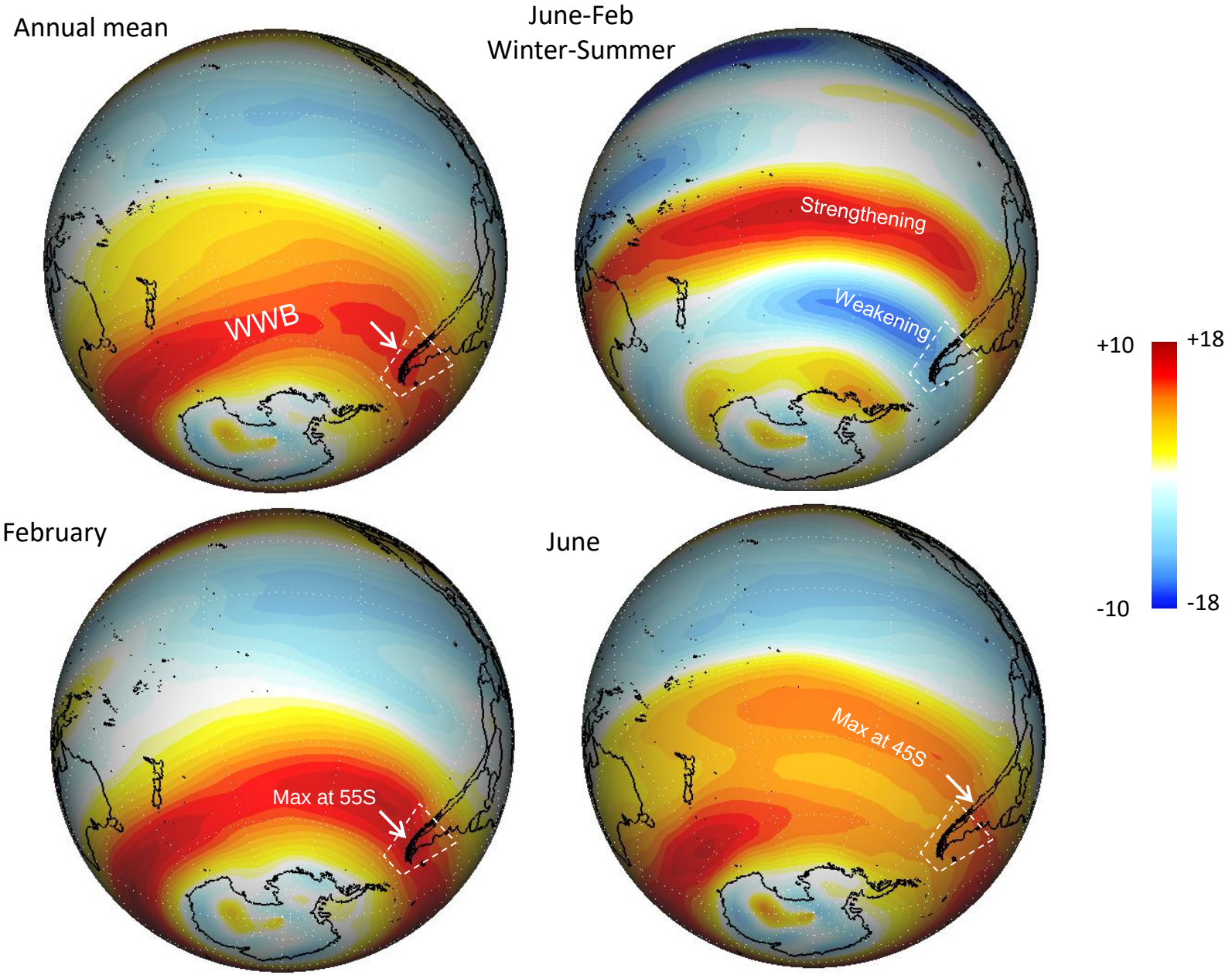


The big picture



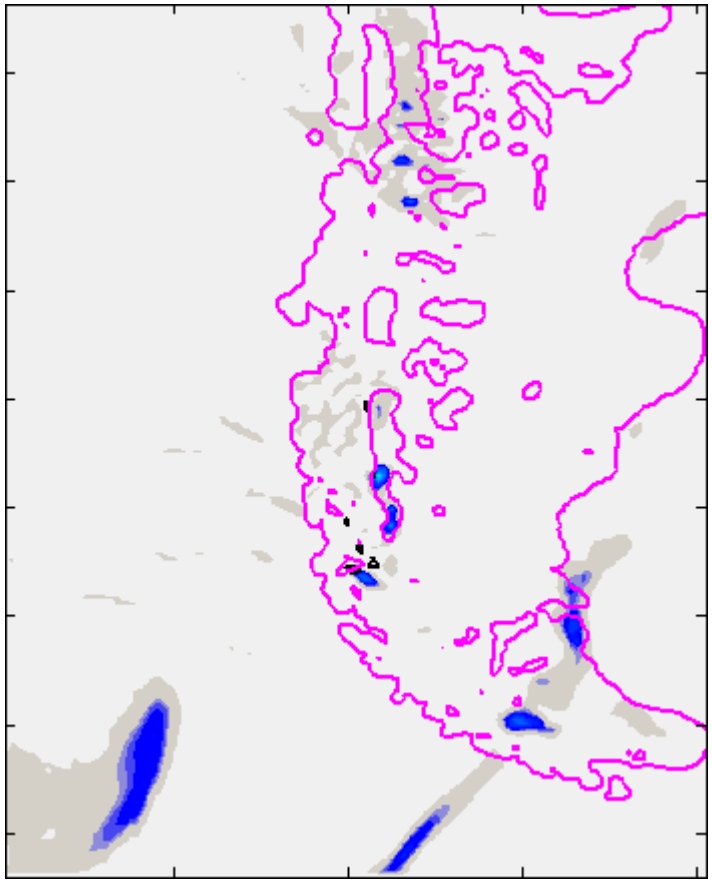
Long term mean zonal wind at 700 hPa

(best predictor of precipitation over the extratropical Andes)



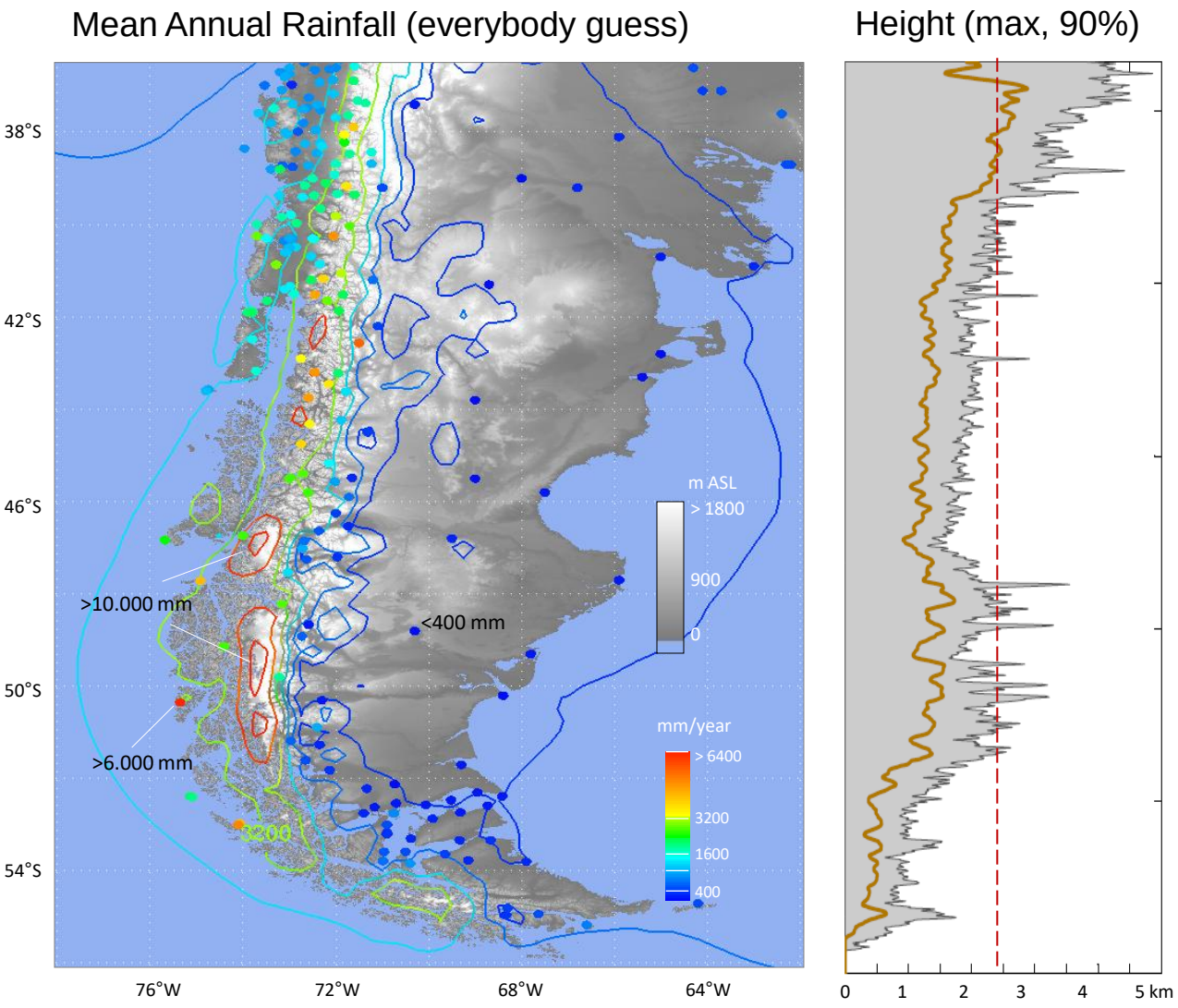
One (typical) storm simulation (WRF)

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

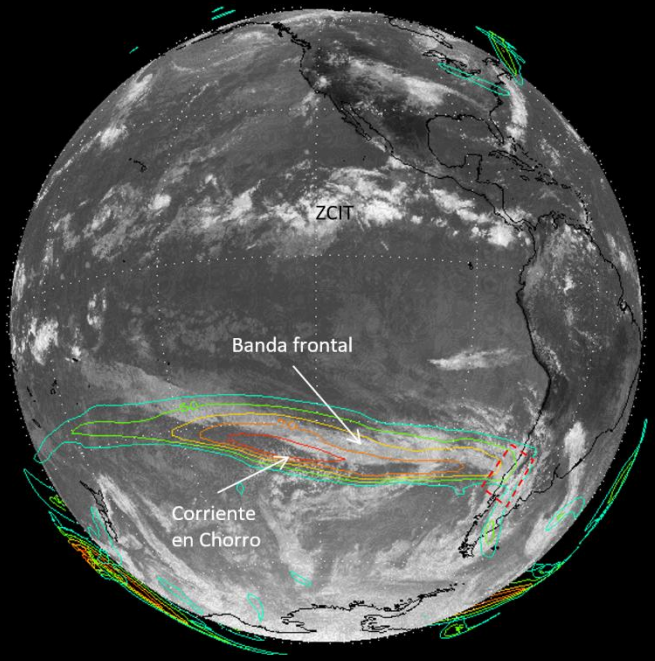


Salient features: Rainfall enhancement over the Andes windward slope, Rain shadow, Convective rainfall along the coast

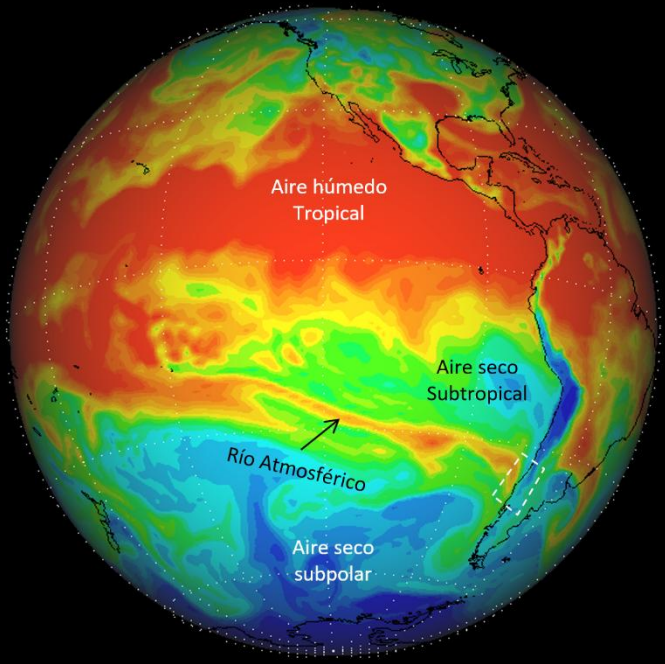
Patagonia 101: Precipitation



Atmospheric Rivers landfalling on Patagonia

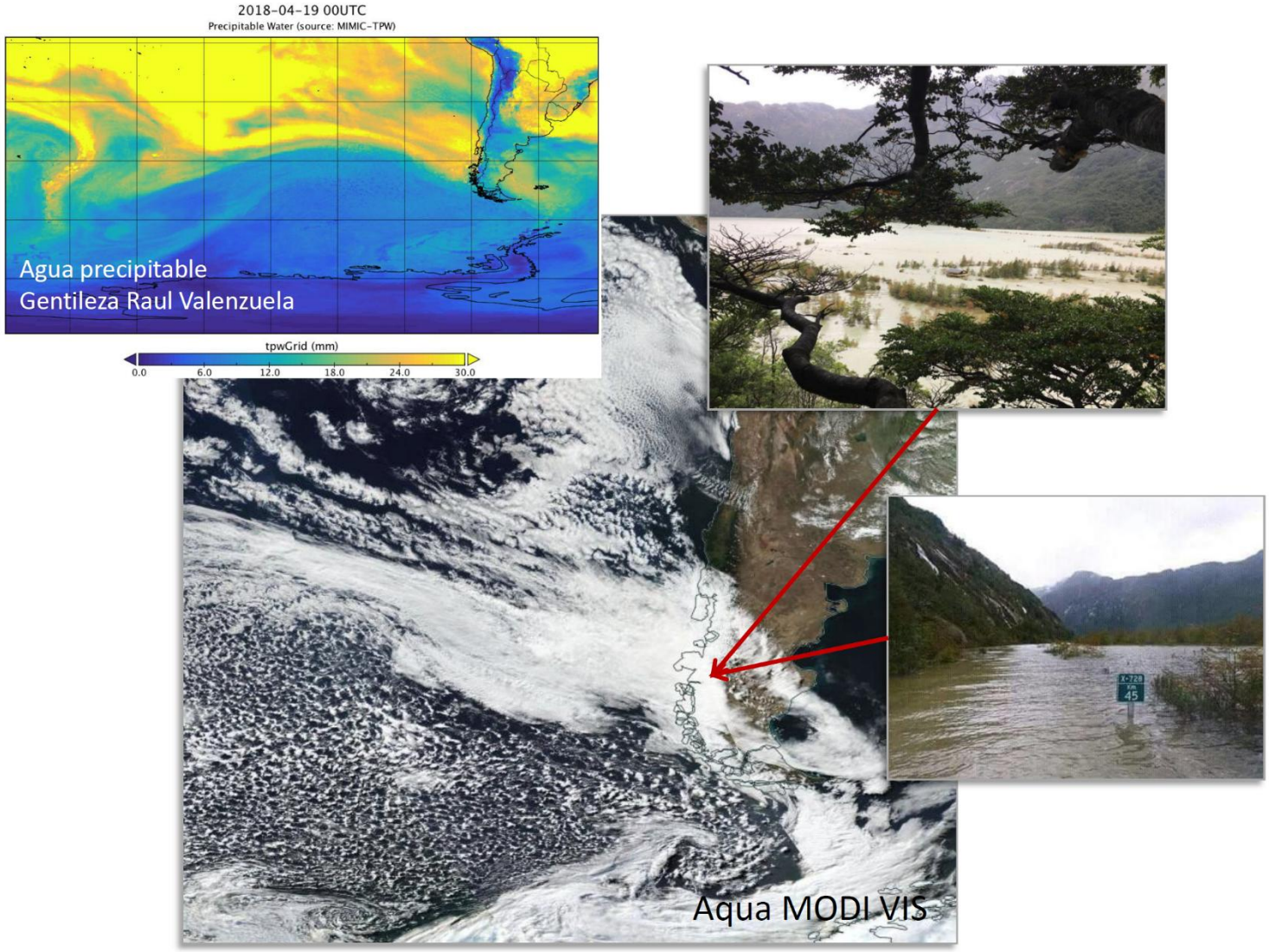


Clouds and upper level winds



Precipitable water

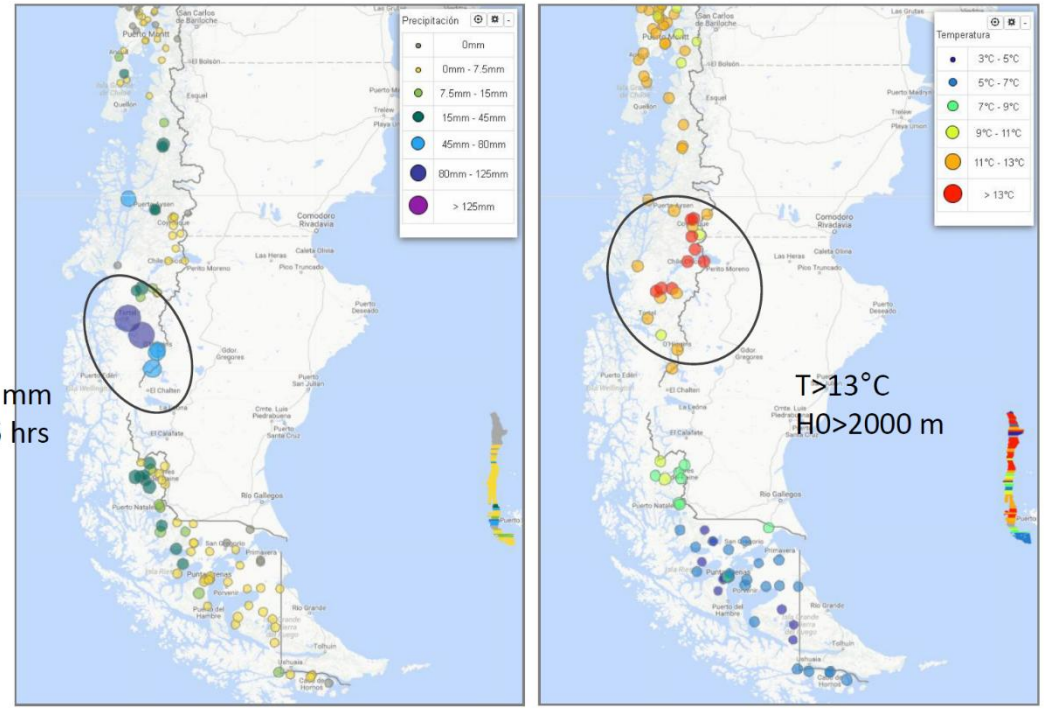
Atmospheric Rivers landfalling on Patagonia



Atmospheric Rivers landfalling on Patagonia

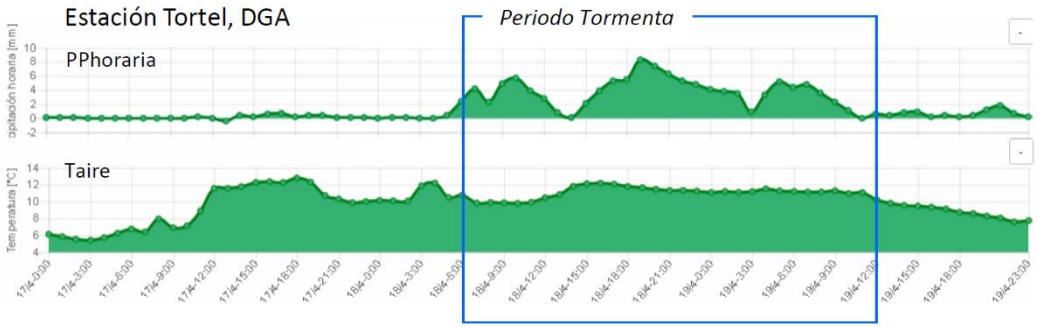
Precipitación acumulad tormenta

Temperatura media tormenta



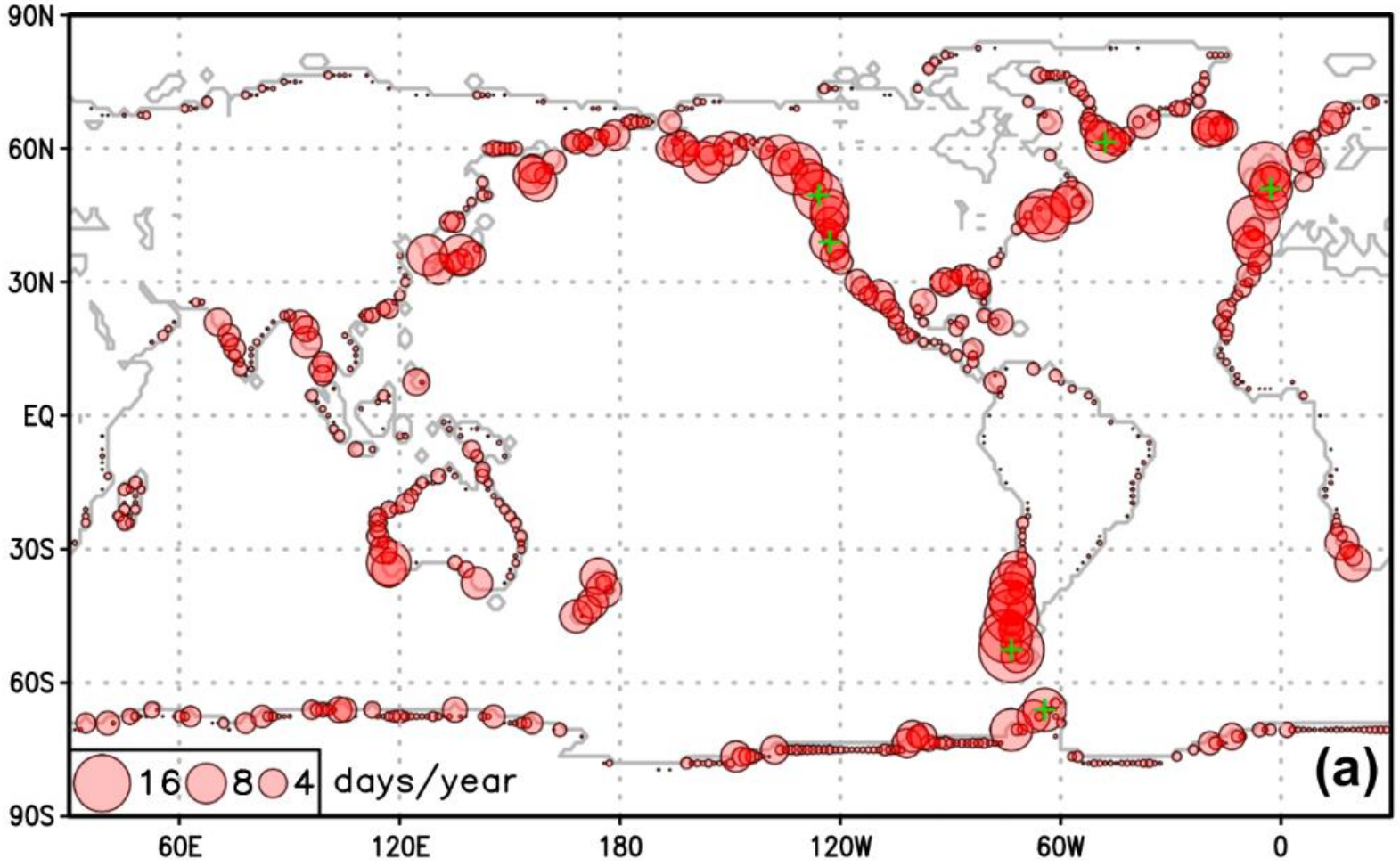
>100 mm
en 36 hrs

T>13°C
H0>2000 m



0 HL 18 Abril –12 HL 19 Abril

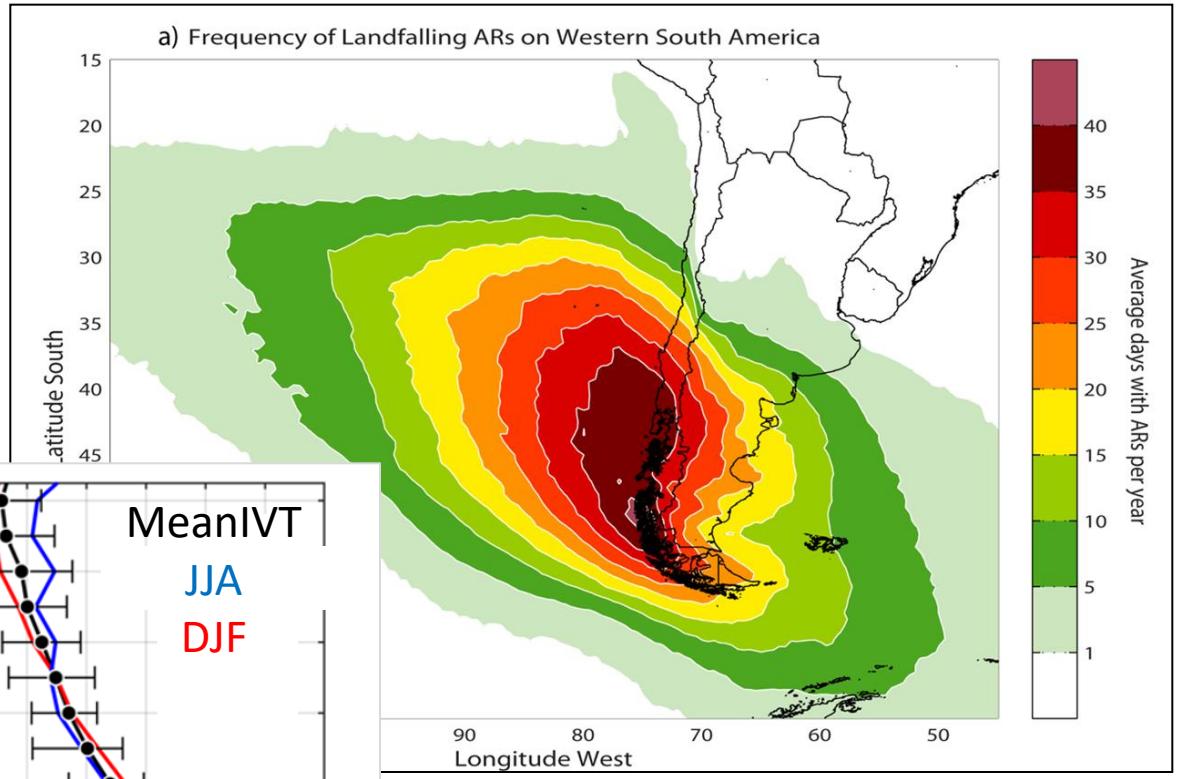
Landfalling AR – Global Survey

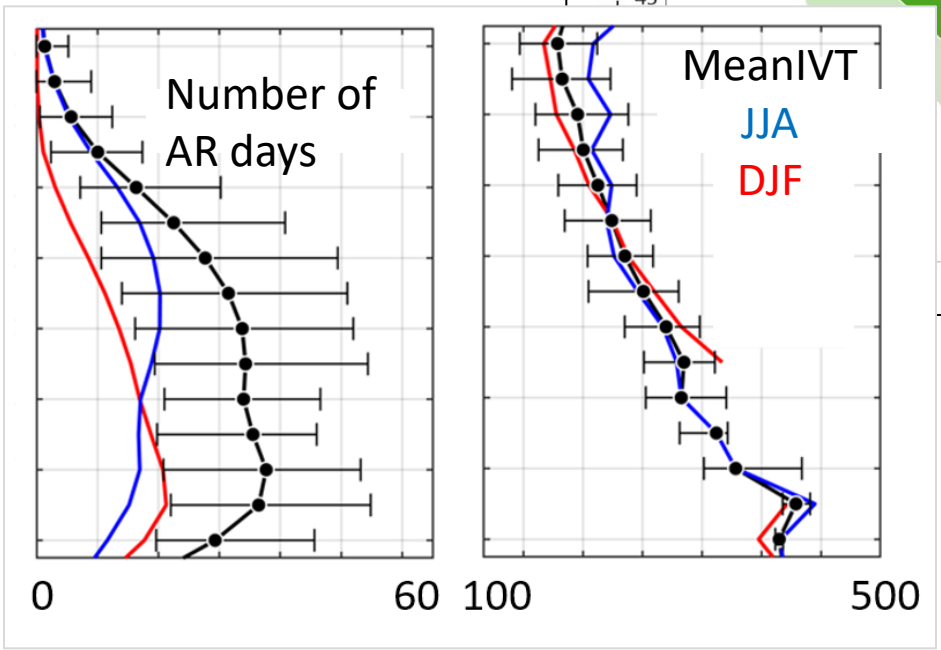


Modified Guan and Waliser (2015)

15 year landfalling AR climatology

Viale et al. 2018

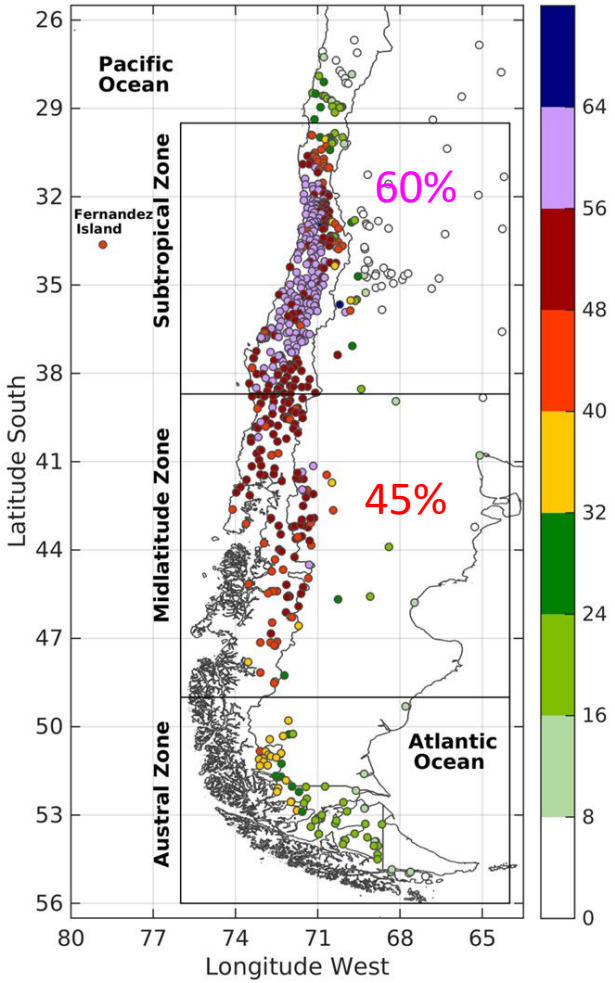




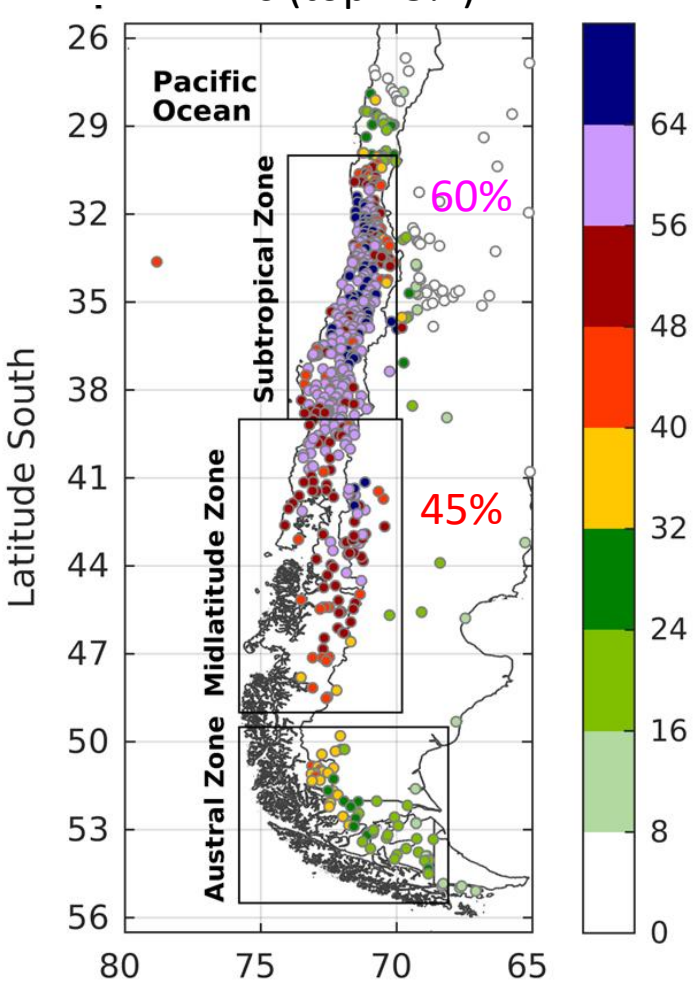
15 year landfalling AR climatology

Viale et al. 2018

AR contribution to annual rainfall



Fraction of AR-related EPEs (top 25%)

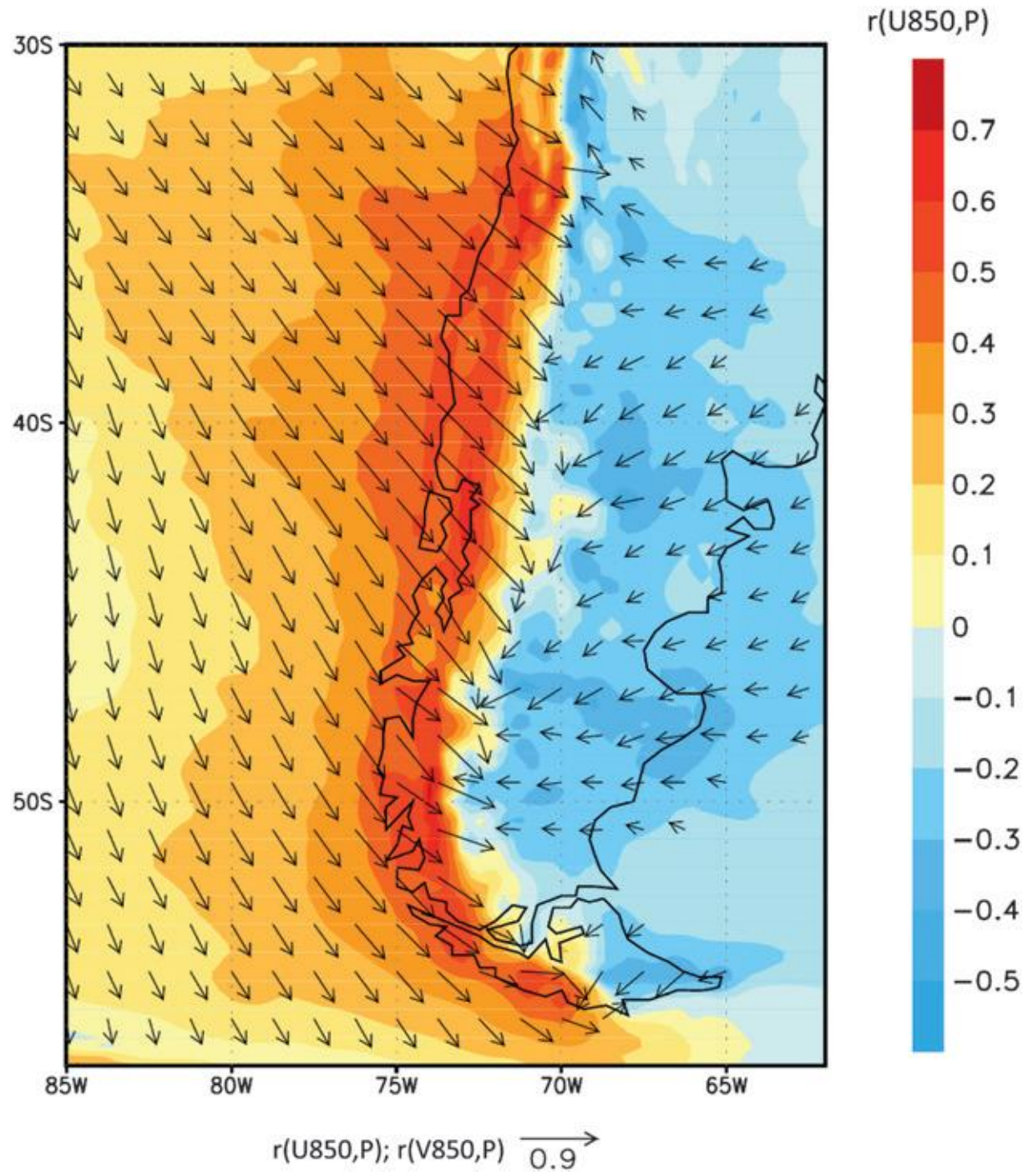


Large scale control of regional climate

(Garreaud 2007; Garreaud et al. 2013)

Linking U with P/SAT we can:

* Downscale large-scale signals
* Upscale local-scale records



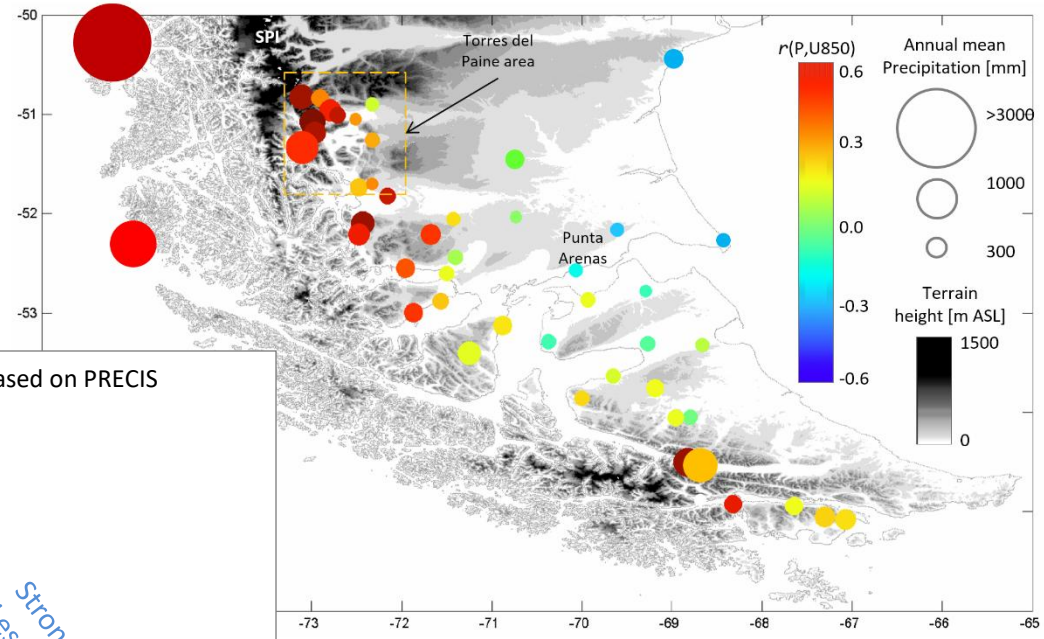
Local (point-to-point) **correlation map between daily precipitation (P) and 850-hPa zonal and meridional wind components (U850; V850)** using PRECIS-DGF results from 1980–90. At each grid point the correlation was calculated for the sample of days with P >1 mm.

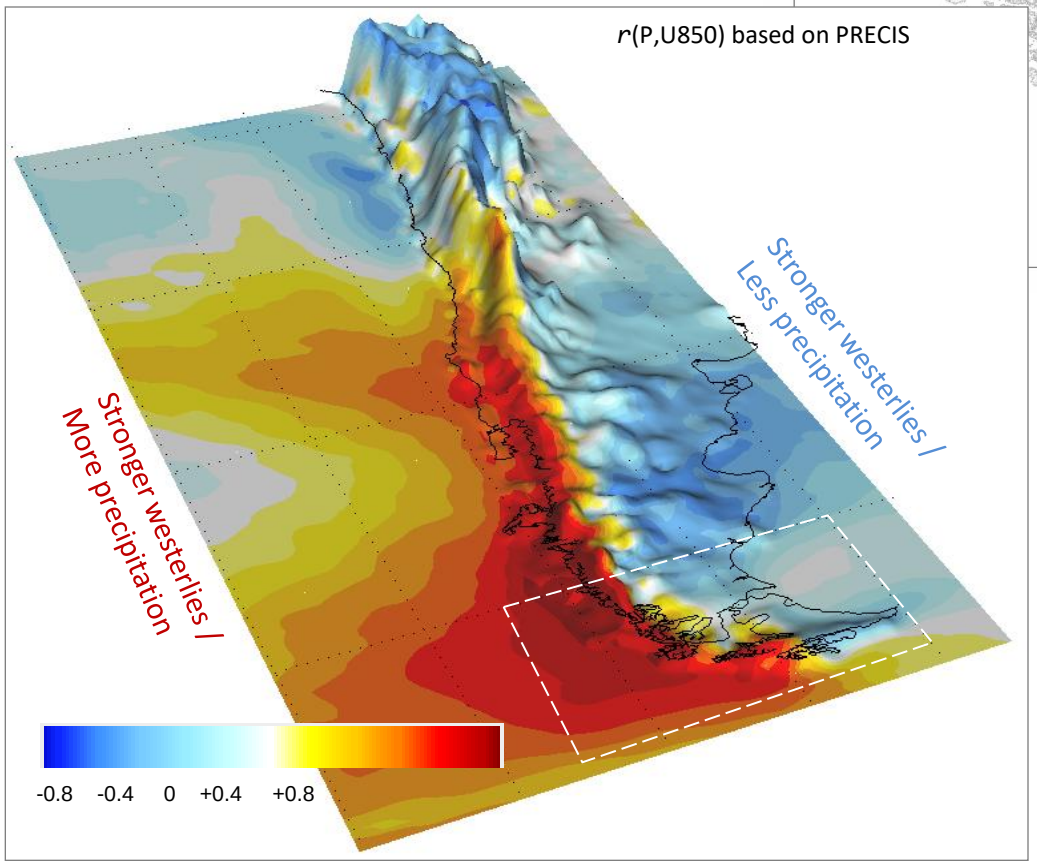
Colors indicate the P–U850 correlation.

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

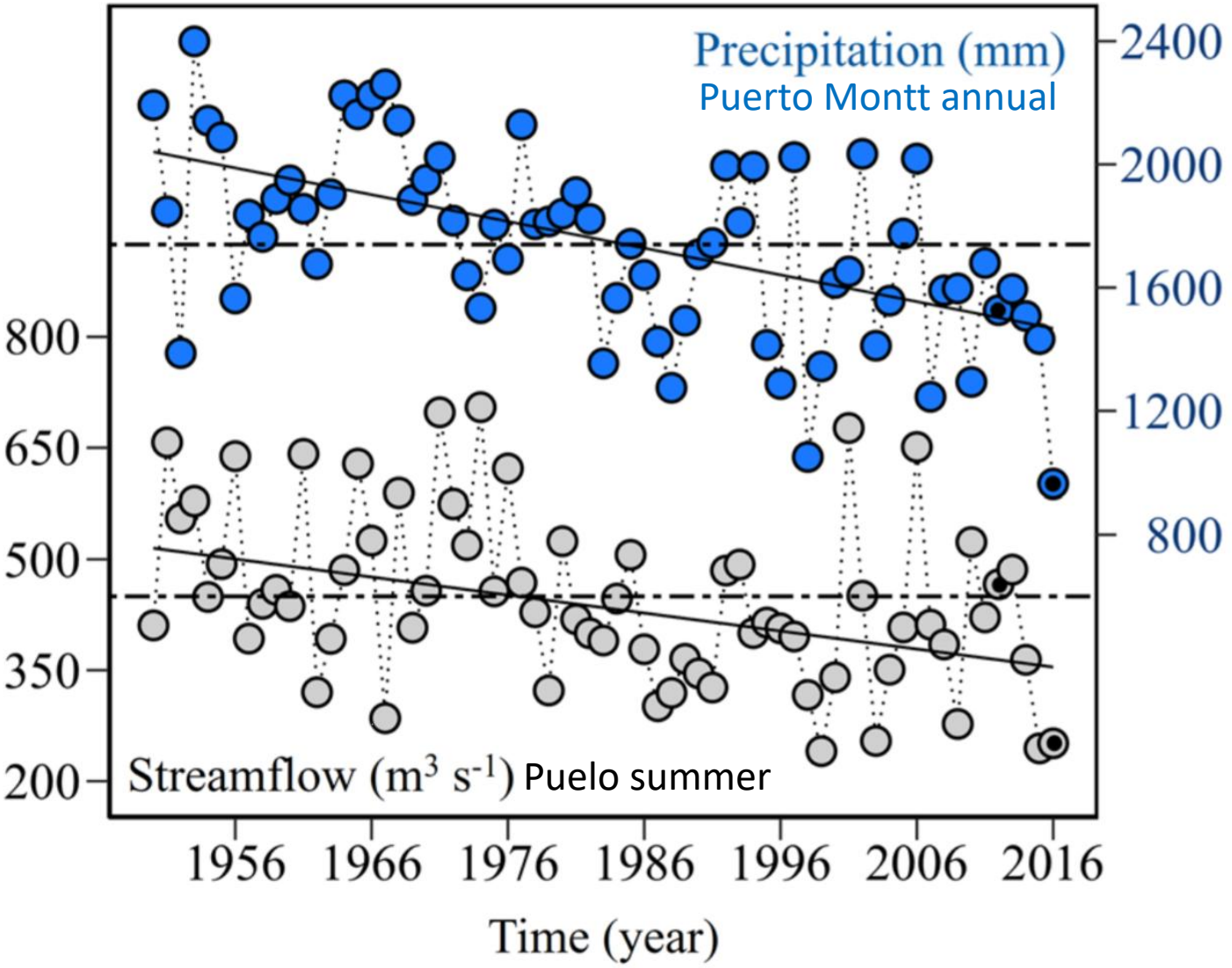
Wind-precipitation covariability at annual timescales (year-to-year)



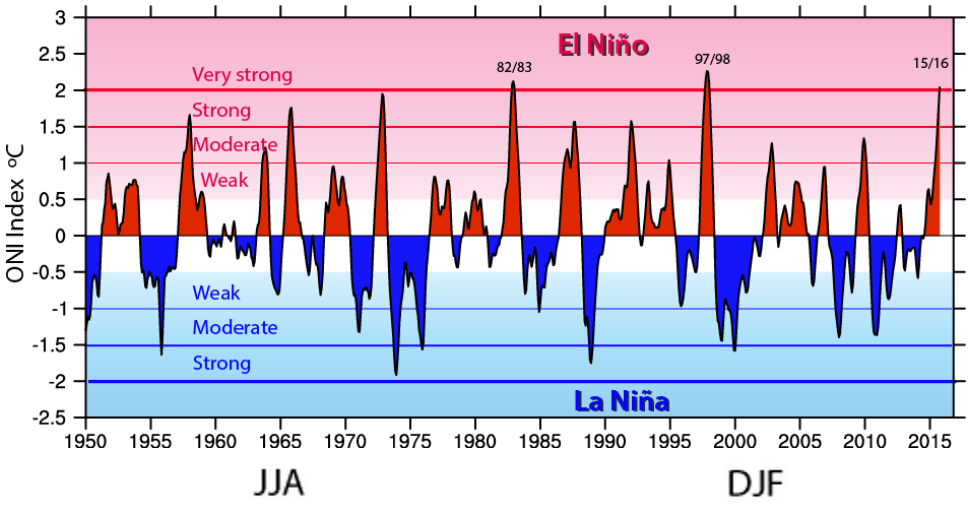


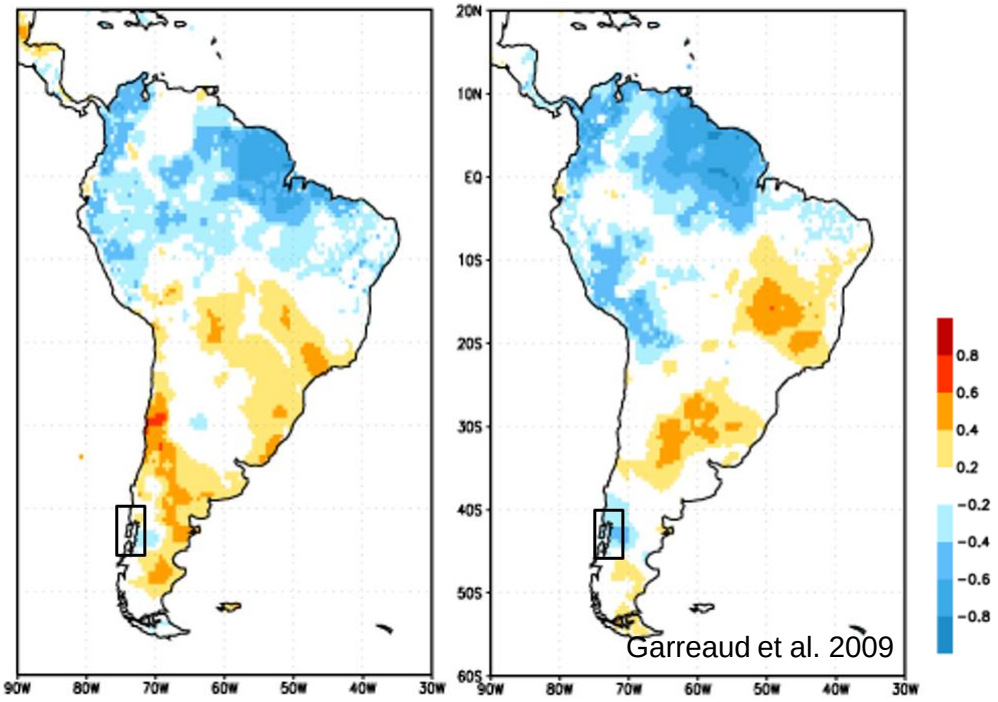
Stronger westerlies / More Precip. up to 50 km downstream of the Mnts.

Trend and Variability



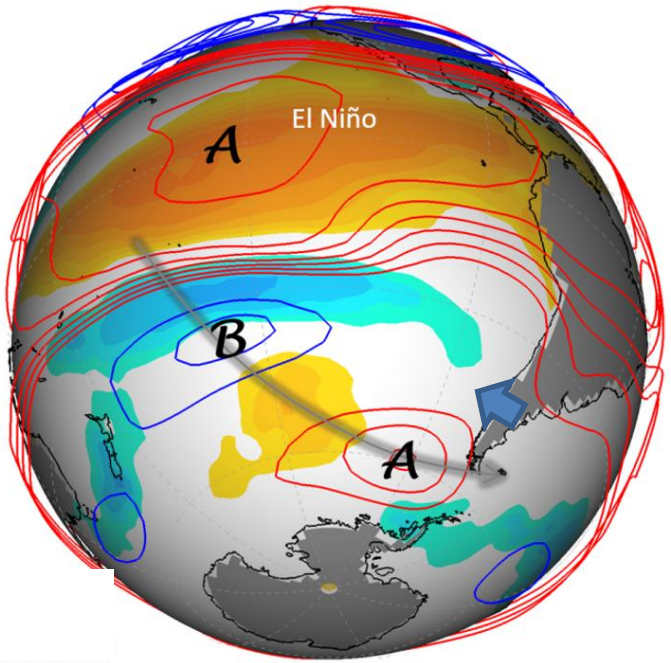
ENSO impacts on Patagonia





Garreaud et al. 2009

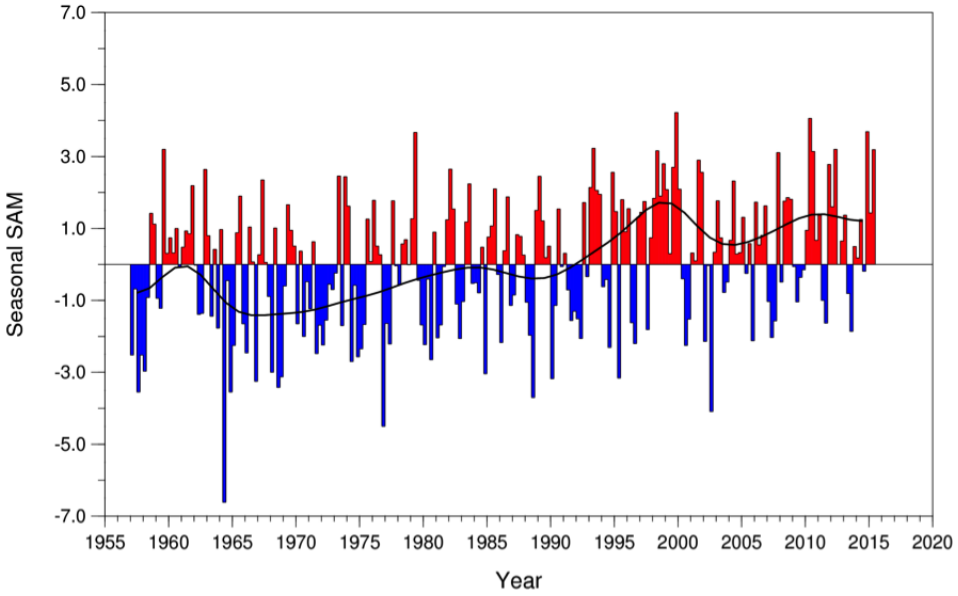
El Niño Composite JFM



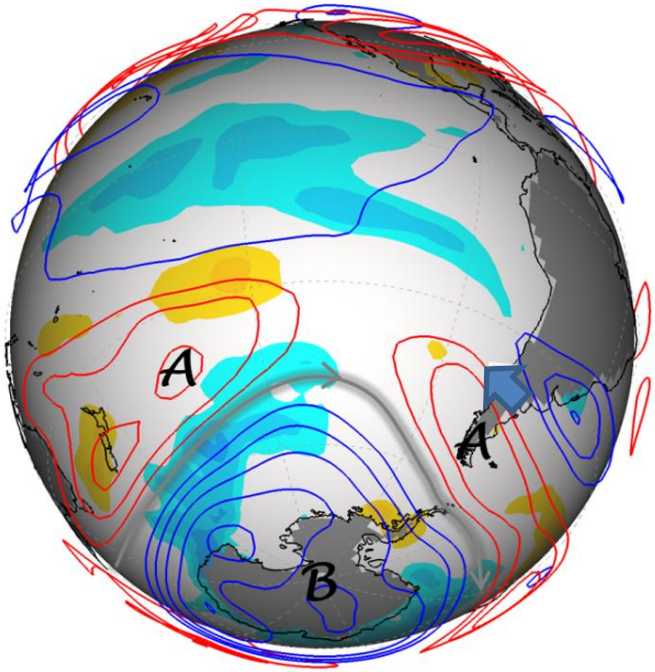
Colors: SST anomalies
Contours: Z300 anomalies

← Correlación estacional ONI-PP

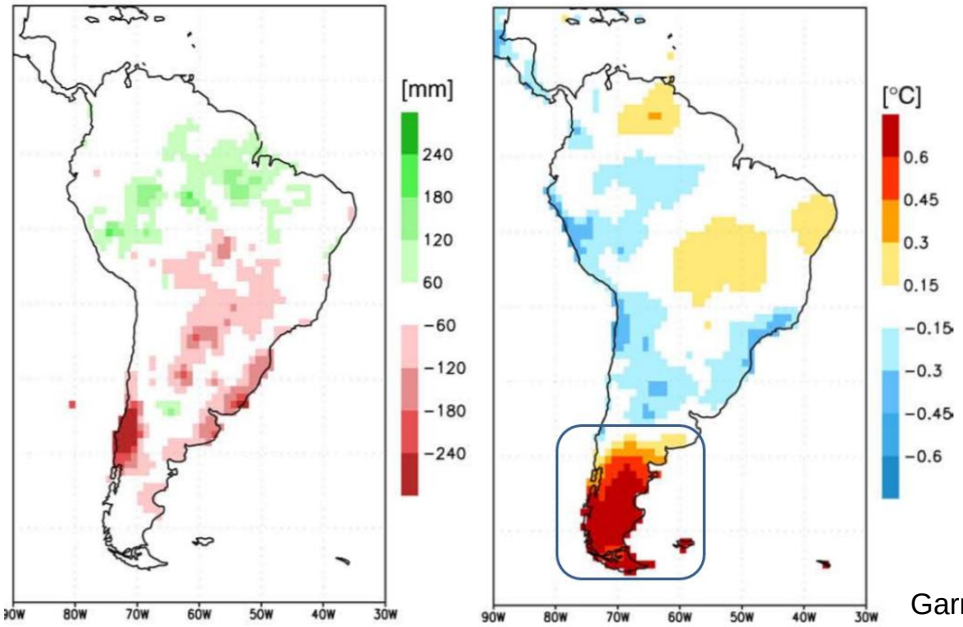
SAM impacts on Patagonia



SAM+ Composite



Colors: SST anomalies
Contours: Z300 anomalies



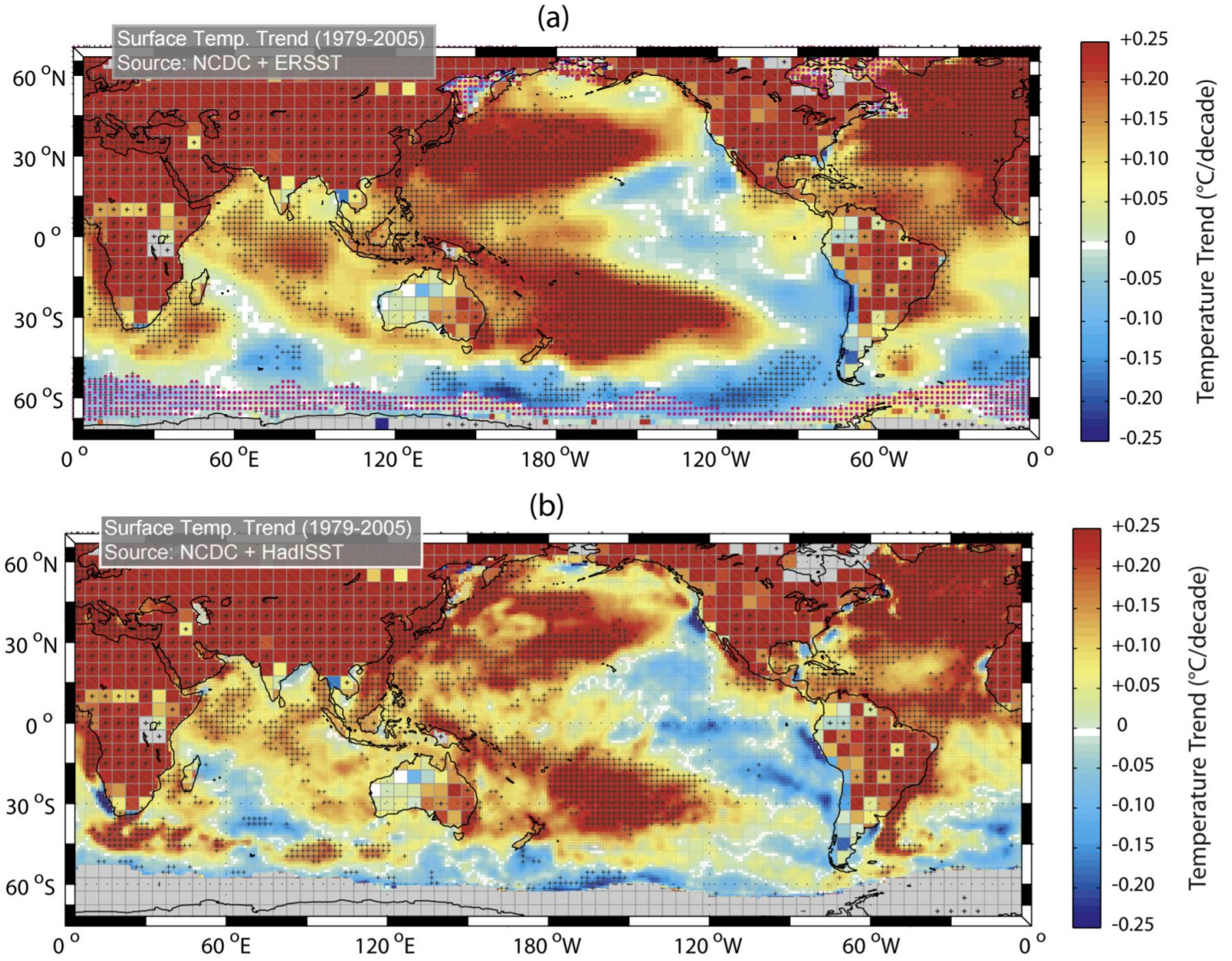
← Regresión annual SAMI-PP,T

Garreaud et al. 2009

Contemporaneous climate change

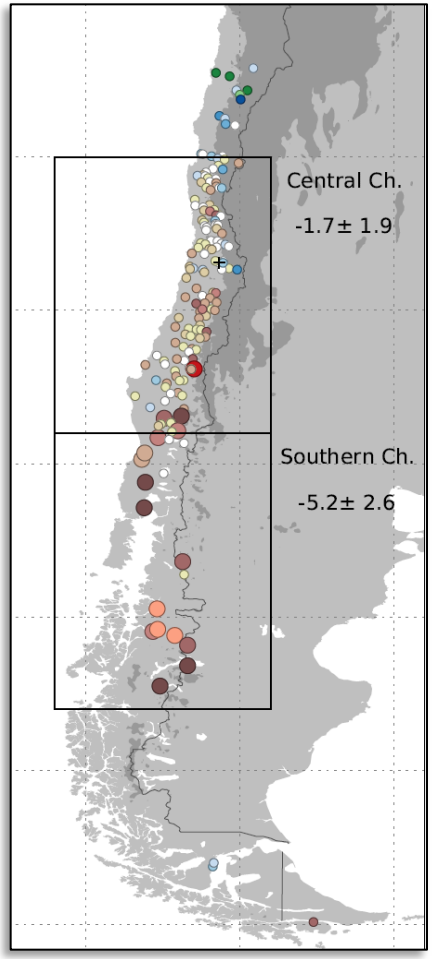
Recent past and near future

Weak temperature trends



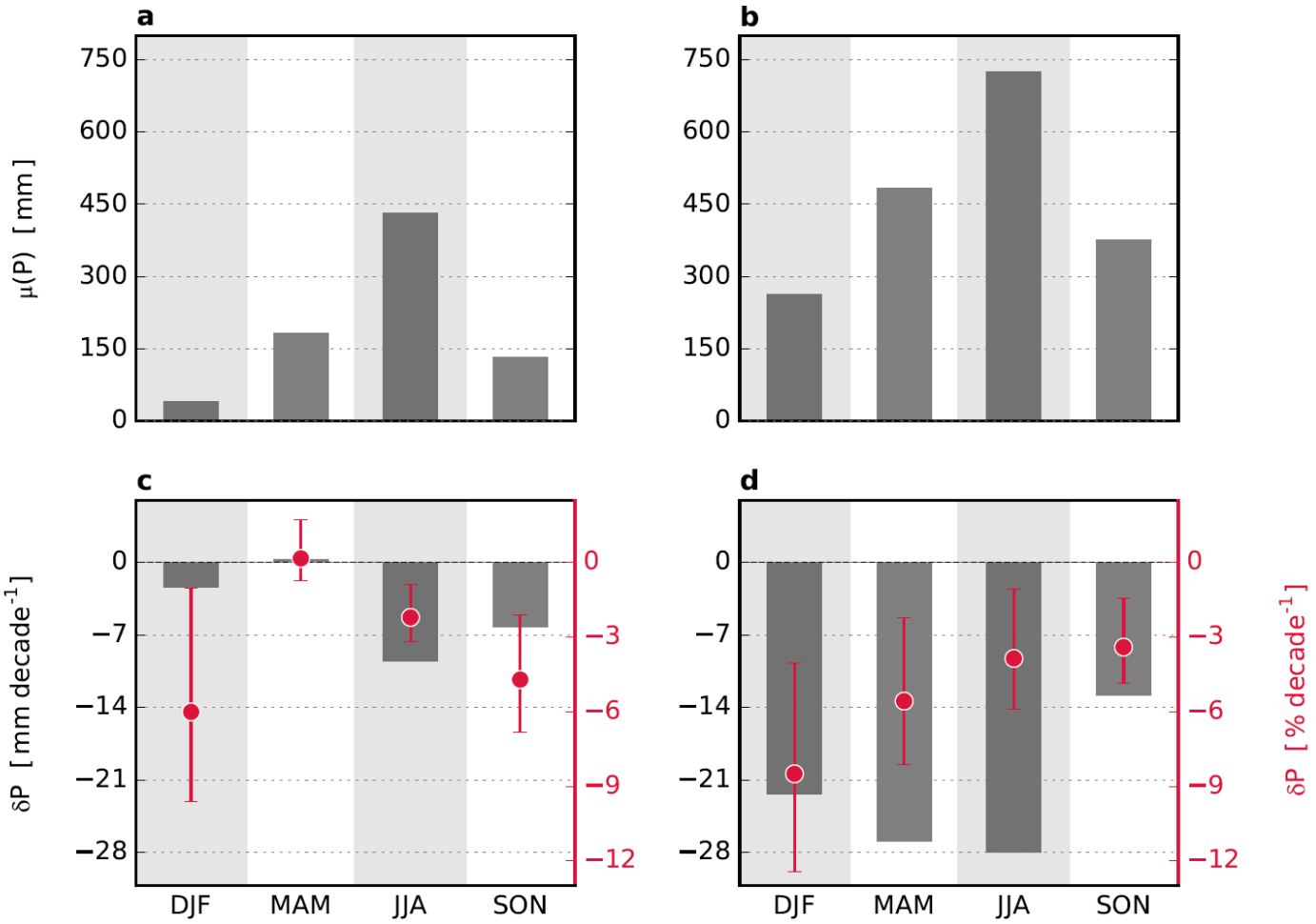
Heterogeneous precipitation trends

Annual rainfall trends
(1960-2016)



Central Chile

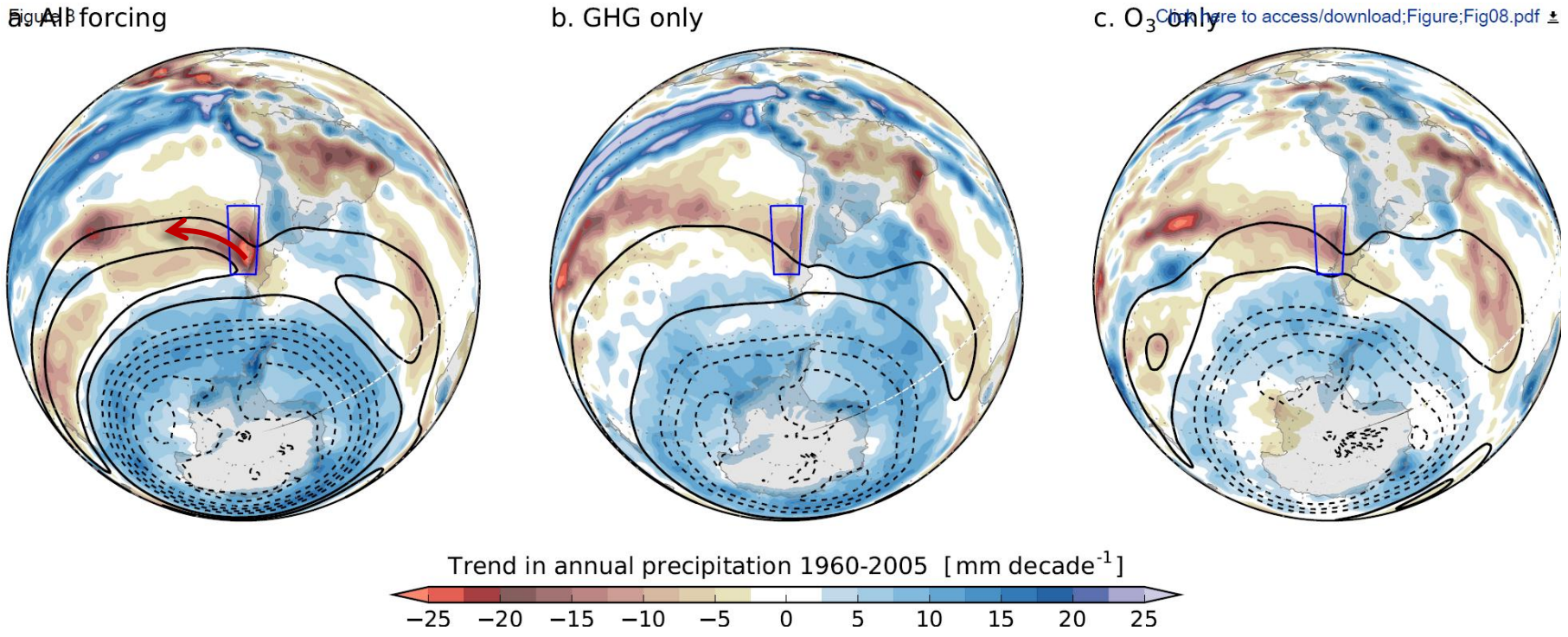
Southern Chile



Boisier et al. 2018, *Elementa*

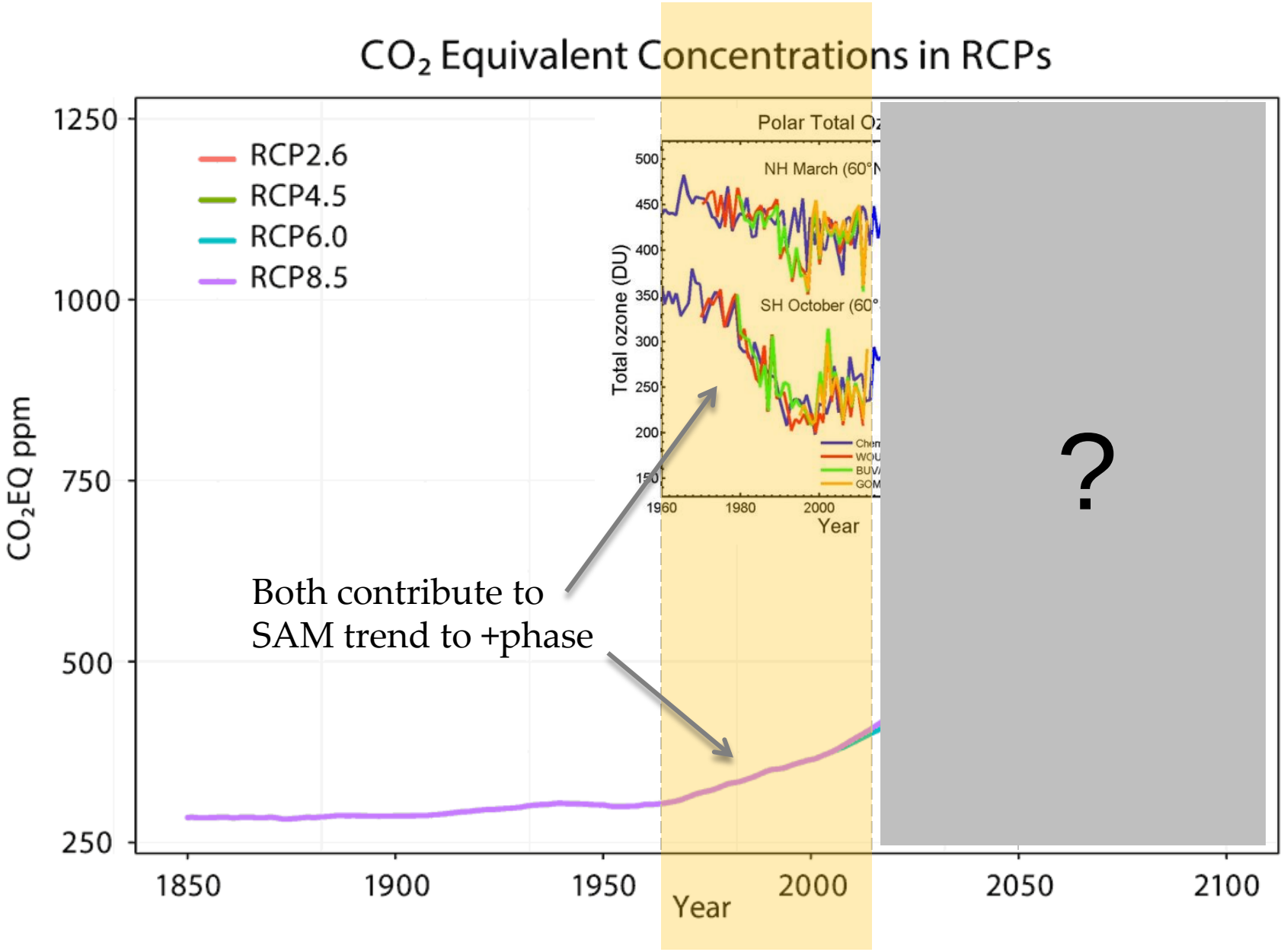
Precipitation trends 1960-2005: Attribution

Both O3 depletion and GHG increase, but O3 effect dominates in summer



Boisier et al. 2018, *Elementa*

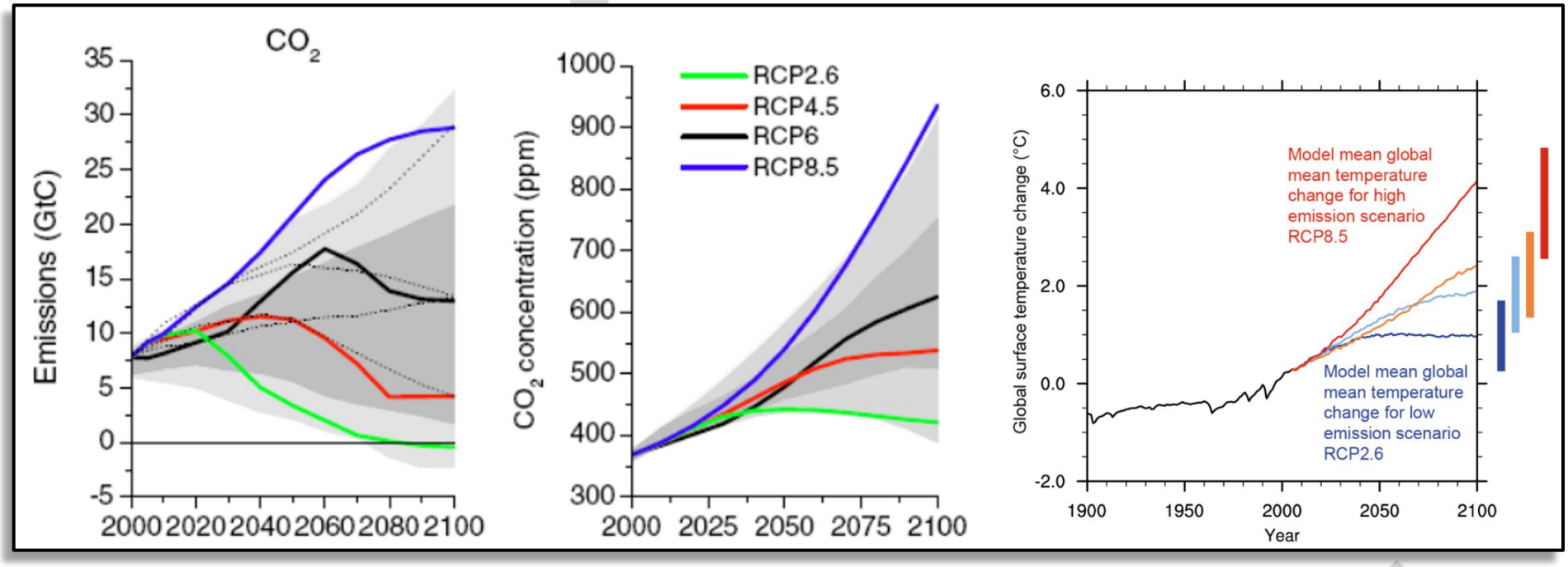
Greenhouse gases and Ozone: the main drivers of climate change



How much CO2 will be emitted in the future ?

Socio-economic development pathways

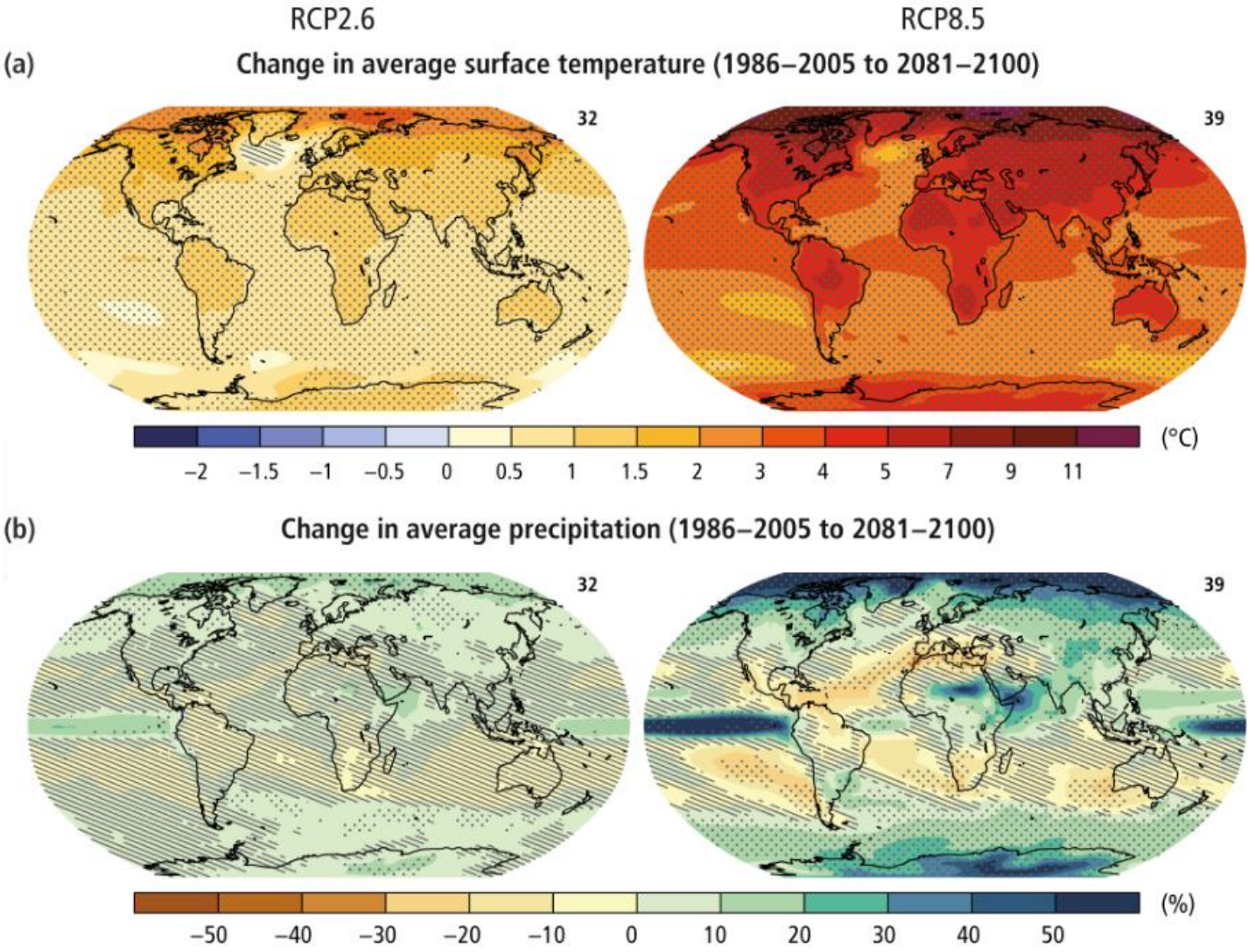
Climate Scenarios



Balance
De Masa

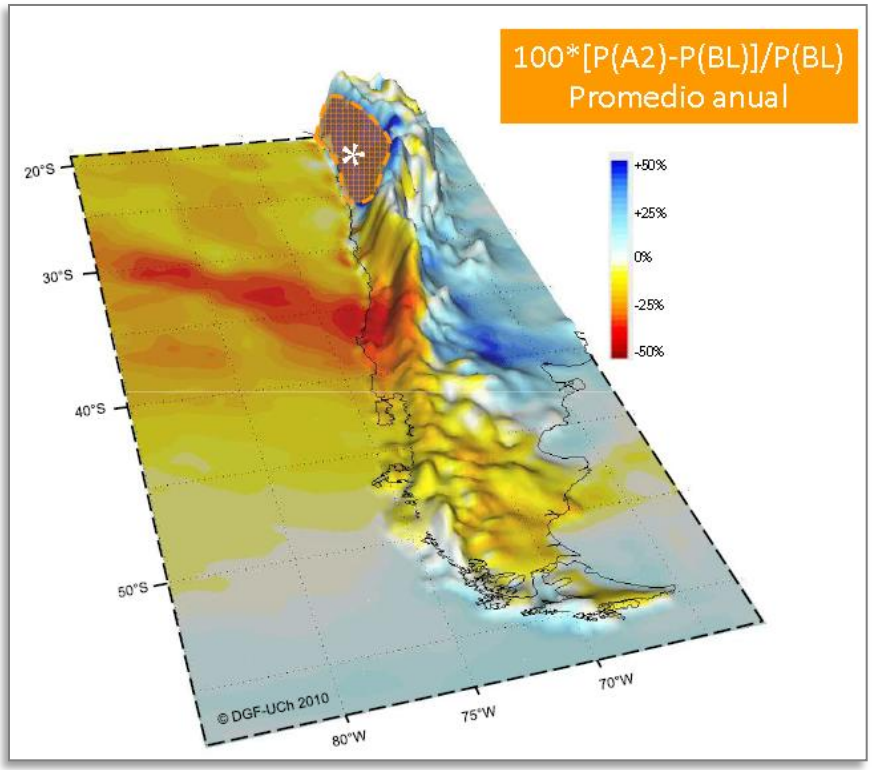
GCMs (more than 40)

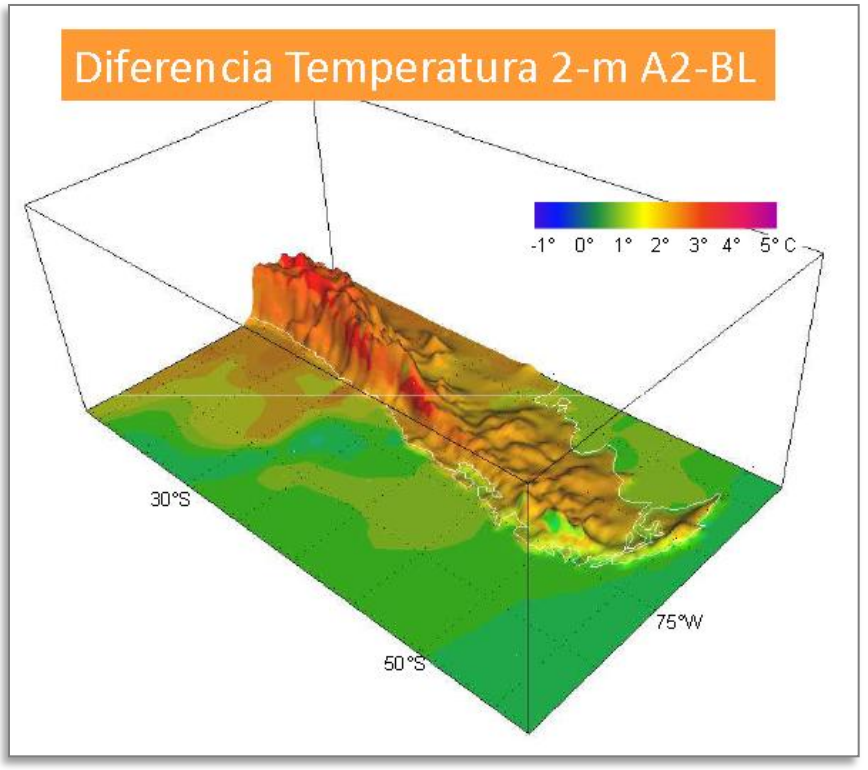
Proyected climate change



Southern SA Climate Change Projections

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



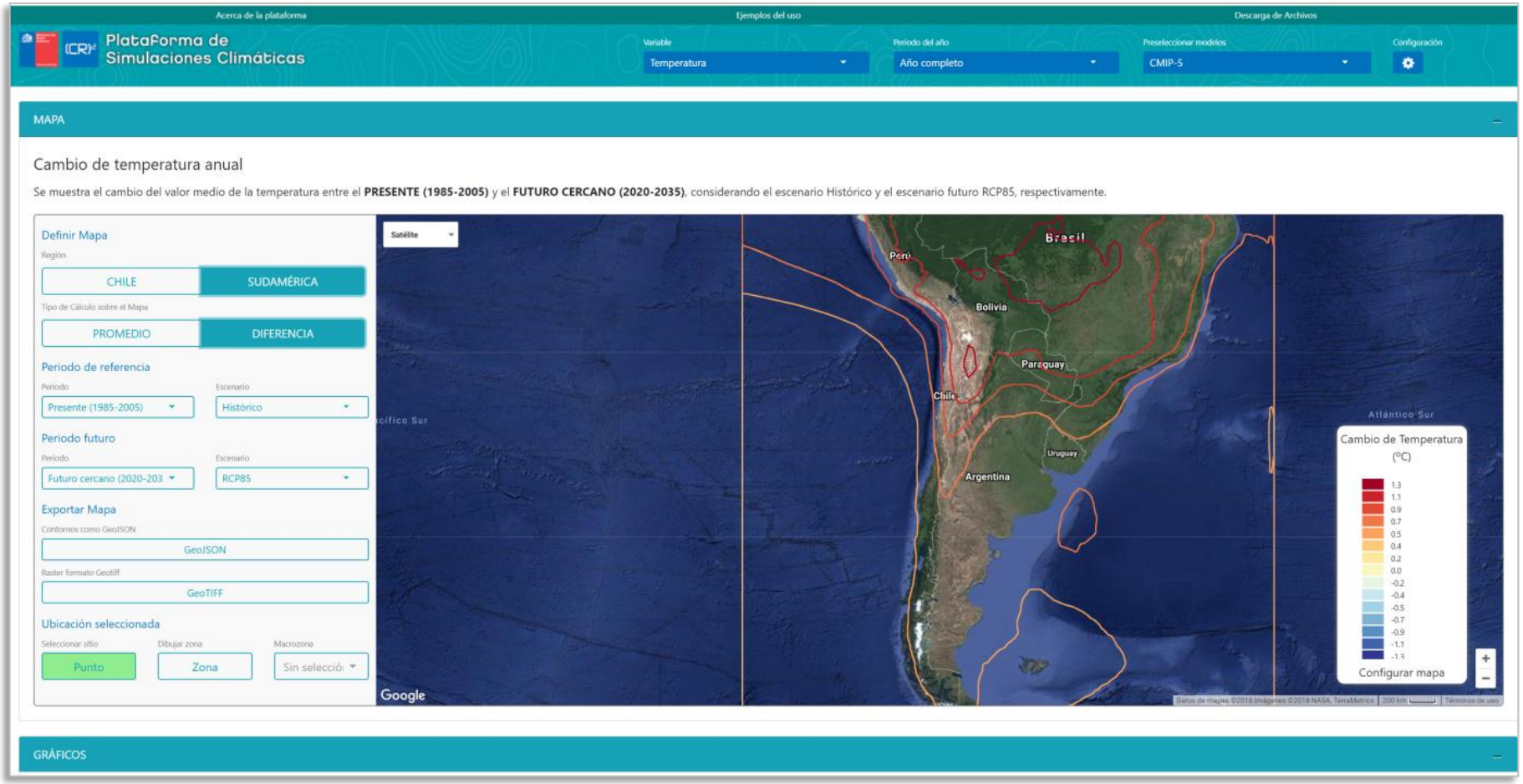


Estudio DGF/UCh-CONAMA 2007 empleando PRECIS

Programa de Capacitación

FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE

Simulaciones Climáticas Regionales y Plataformas de Visualización



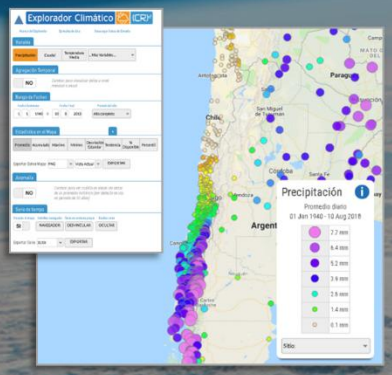
Servicios Climáticos CR2

¿Qué pasó?

→ Explorador Climático

Datos históricos diarios, mensuales y anuales en estaciones en Sud América

`http://explorador.cr2.cl/`

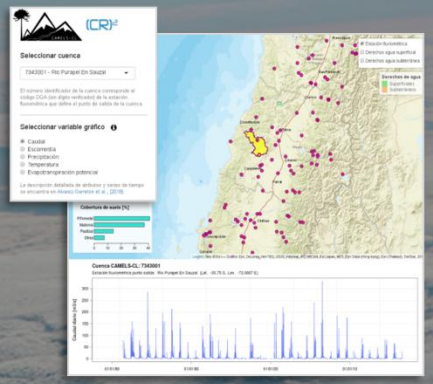


¿Qué pasó?

→ Camels CL

Explorador hidrológico en cuencas de Chile

`http://camels.cr2.cl/`

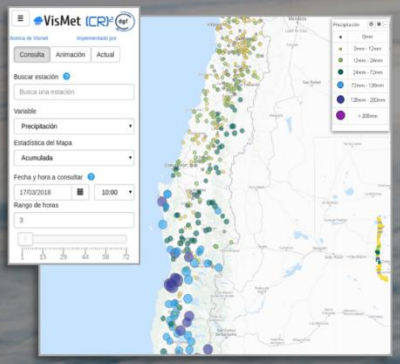


¿Qué esta pasando?

→ VisMet

Registros horarios en tiempo real en estaciones en Chile

`http://vismet.cr2.cl/`



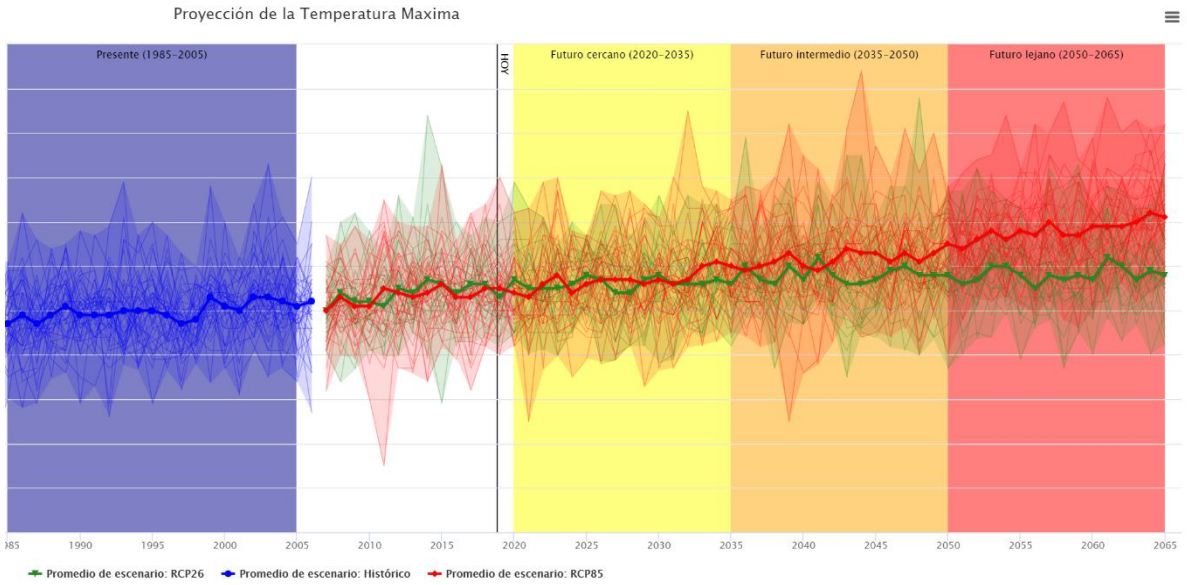
¿Qué pasará?

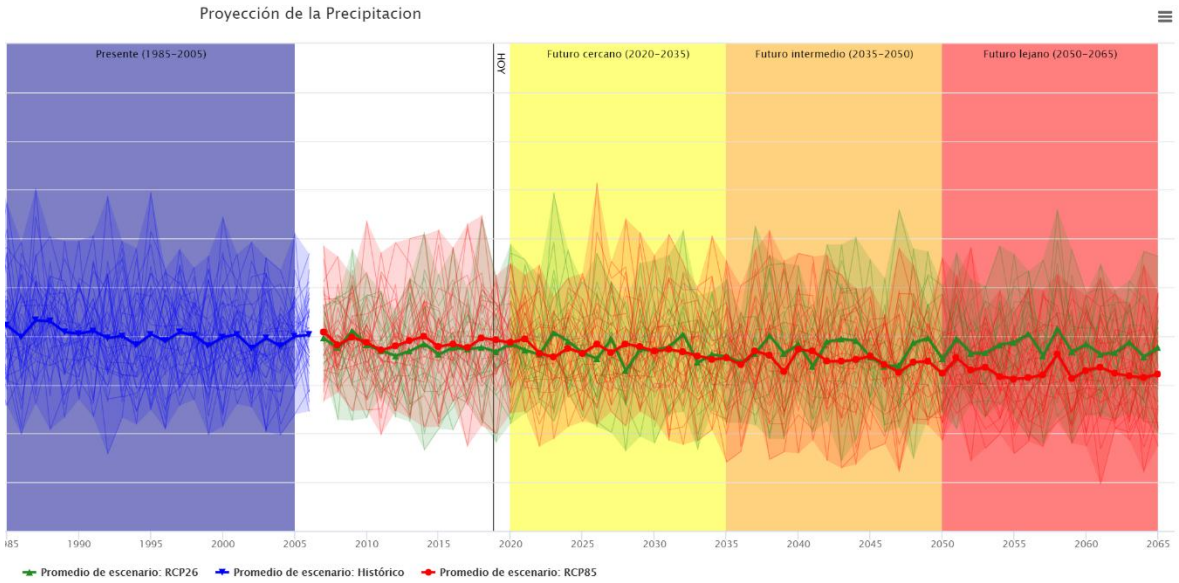
→ Plataforma Simulaciones

Resultados de modelos climáticos globales y regionales para el siglo XXI

`http://simulaciones.cr2.cl/`

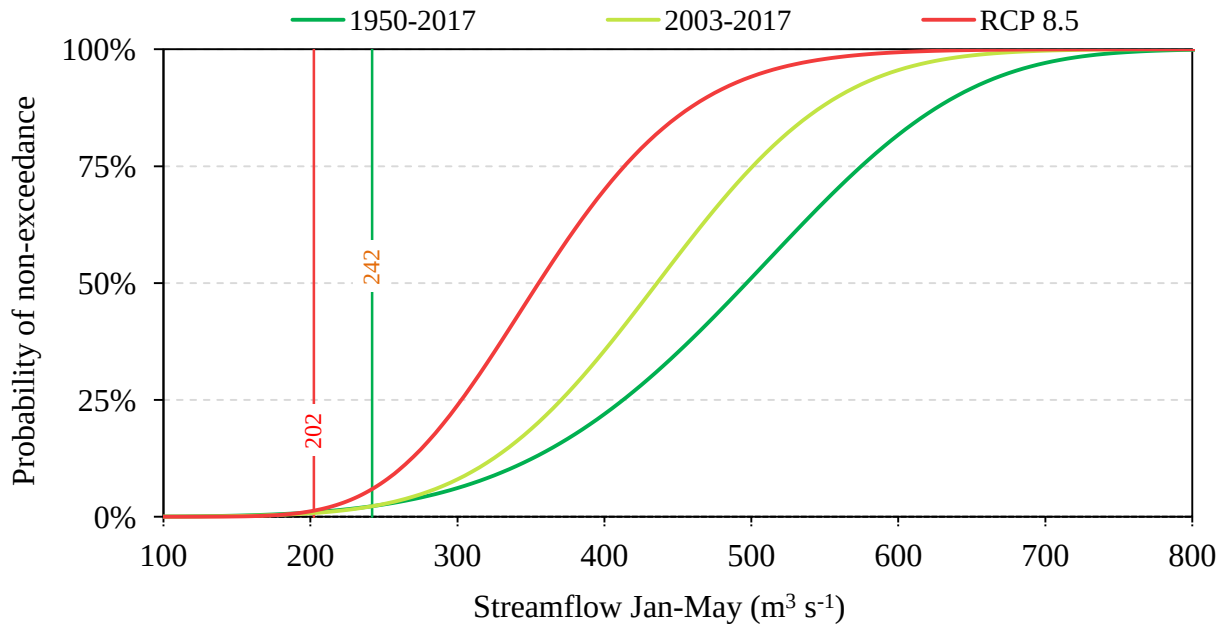
Projected Changes for Chaiten – Summer (DJF)
Explorador Climatico CR2



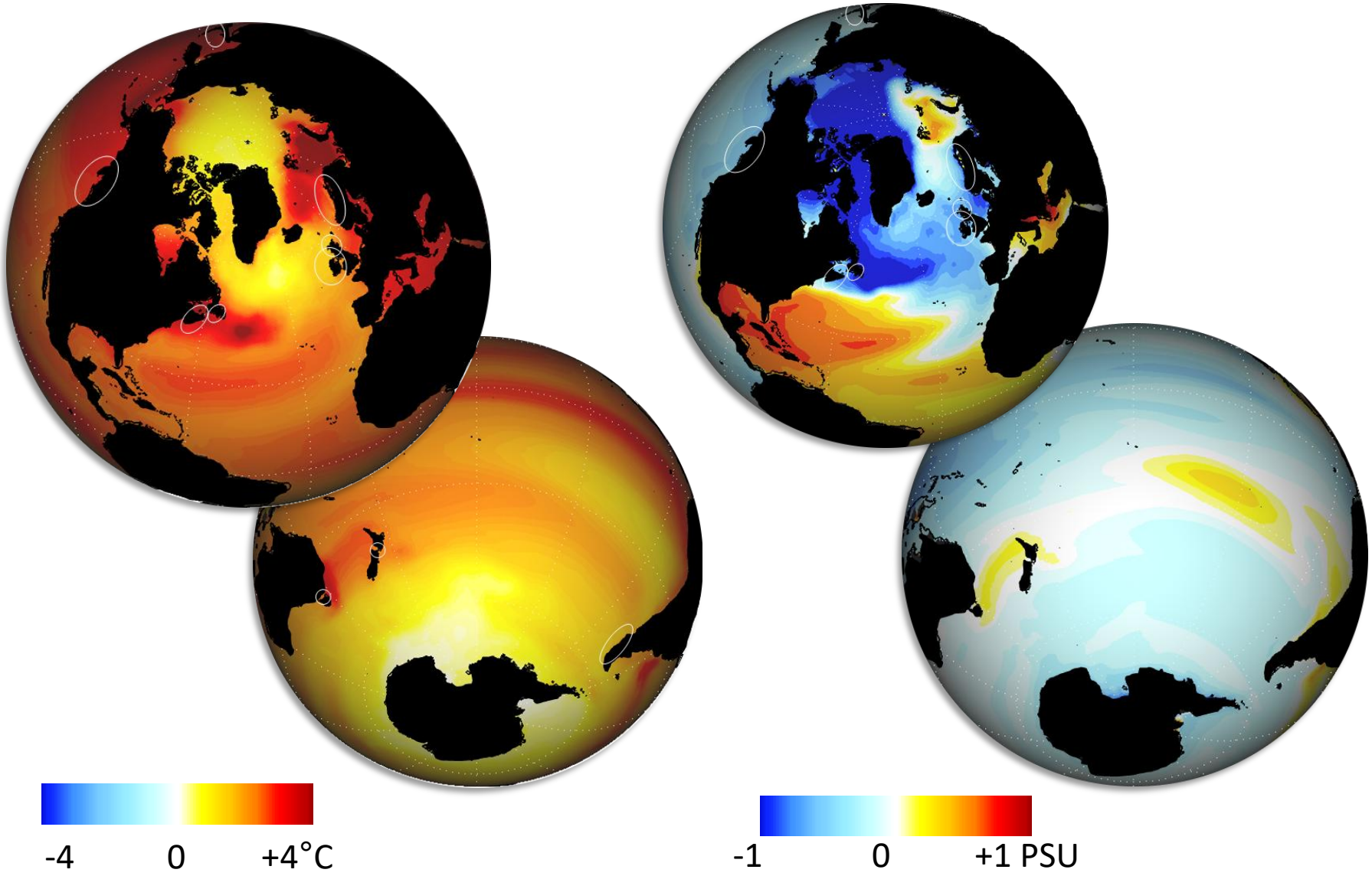


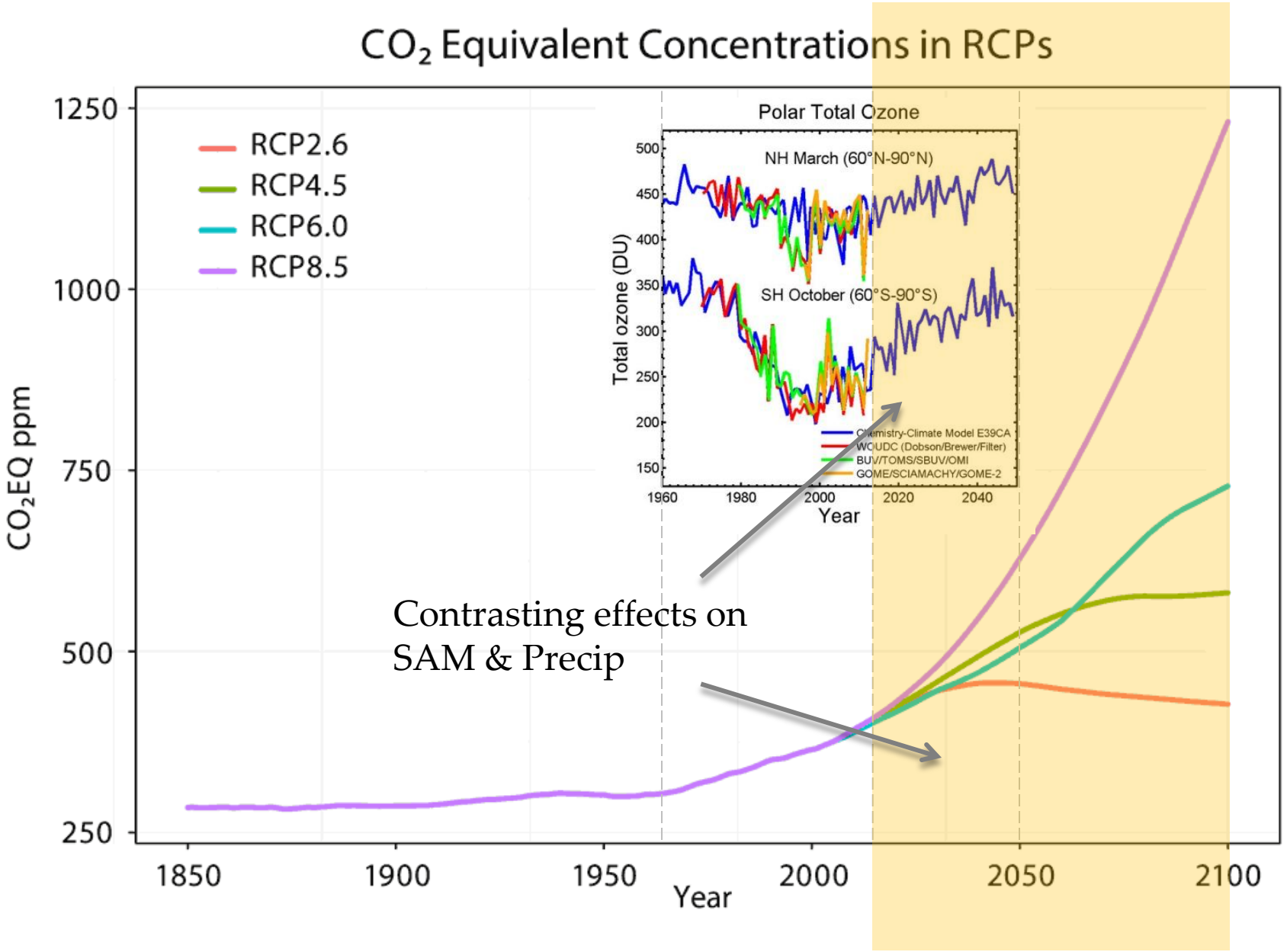
The Glass Half-Empty: Climate Change Drives Shortage in Freshwater Inputs from a Trans-Andean Basin to the Coastal System of Chilean Northern Patagonia

Rodrigo Aguayo[1], Jorge León-Muñoz[2,3]*, José Vargas-Baecheler[1], Aldo Montecinos[4,5], René Garreaud[6,7], Mauricio Urbina[8,9], Doris Soto[3], José Luis Iriarte[10,11]



SST and Salinity changes under RCP8.5

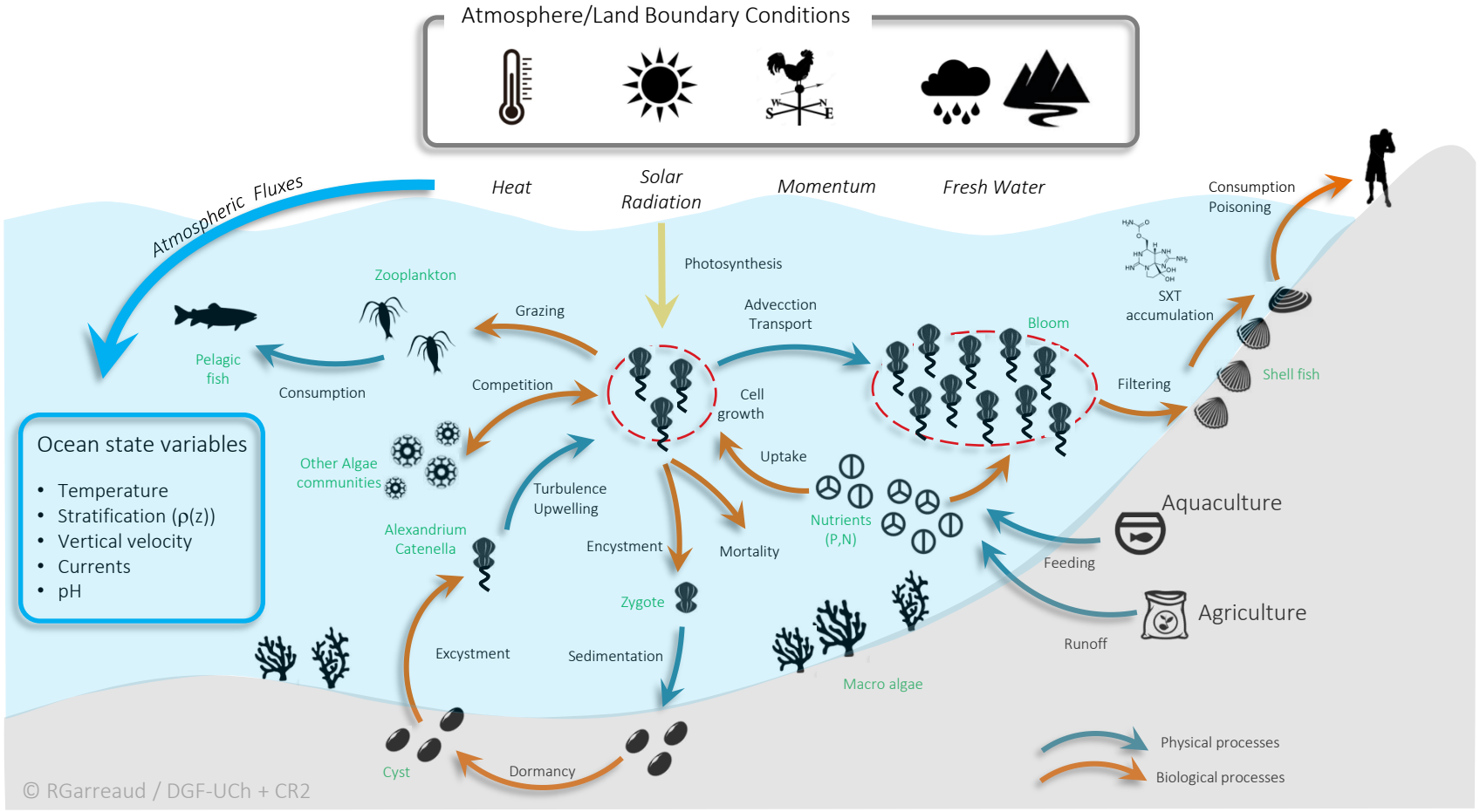



CO2 Equivalent Concentrations in RCPs
RCP2.6
RCP4.5
RCP6.0
RCP8.5
CO2EQ ppm
1250
1000
750
500
250
1850
1900
1950
2000
2050
2100
Year
Polar Total Ozone
NH March (60°N-90°N)
SH October (60°S-90°S)
Total ozone (DU)
500
450
400
350
300
250
200
150
1960
1980
2000
2020
2040
Year
Chemistry-Climate Model E39CA
WOUDC (Dobson/Brewer/Filter)
BUV/TOMS/SBUV/OMI
GOME/SCIAMACHY/GOME-2
Contrasting effects on
SAM & Precip

What about

Extreme Events?

The awful 2016



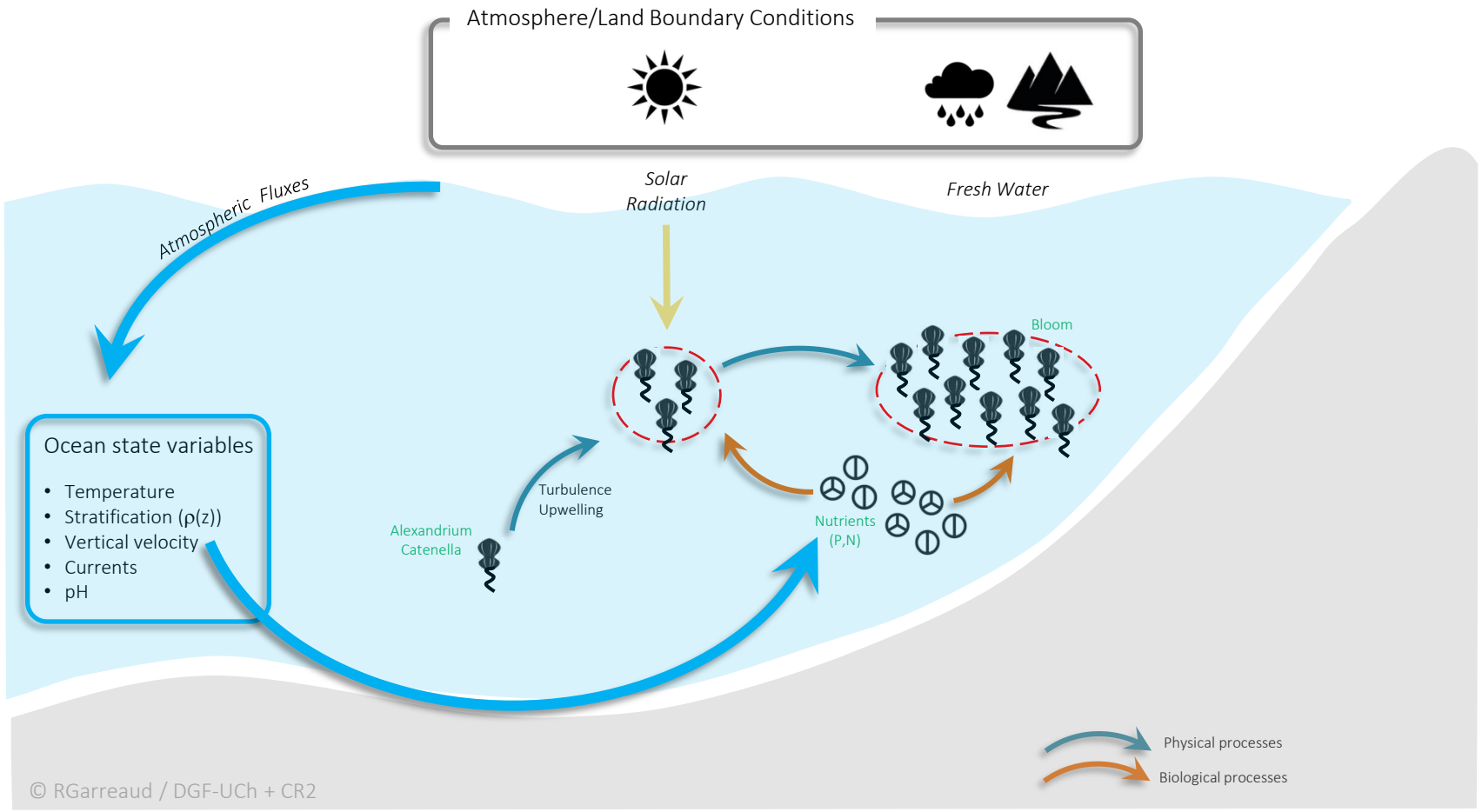
SCIENTIFIC REPORTS

OPEN

Hydroclimatic conditions trigger record harmful algal bloom in western Patagonia (summer 2016)

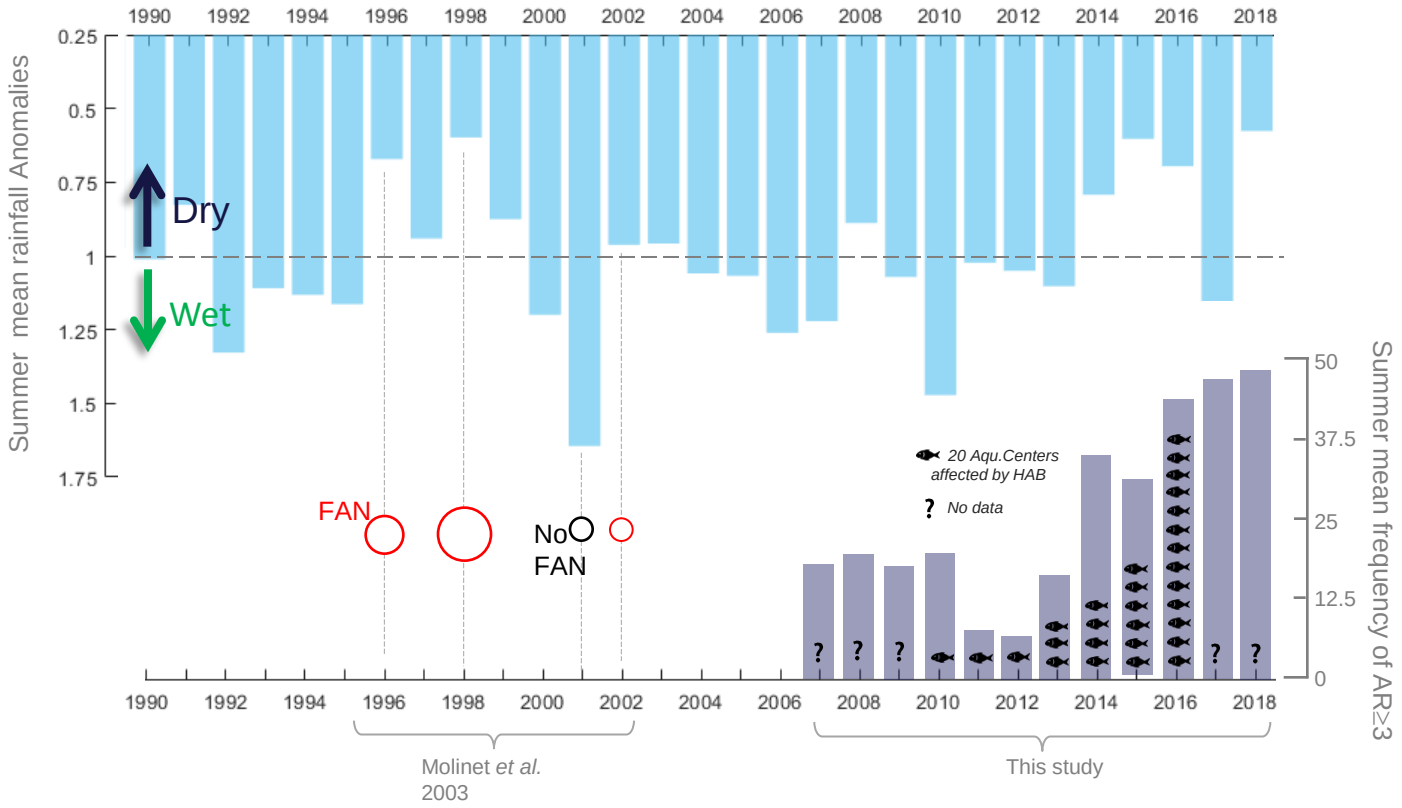
Jorge León-Muñoz[1], Mauricio A. Urbina[2], René Garreaud[3,4] & José Luis Iriarte[5,6,7]

: 26 April 2017

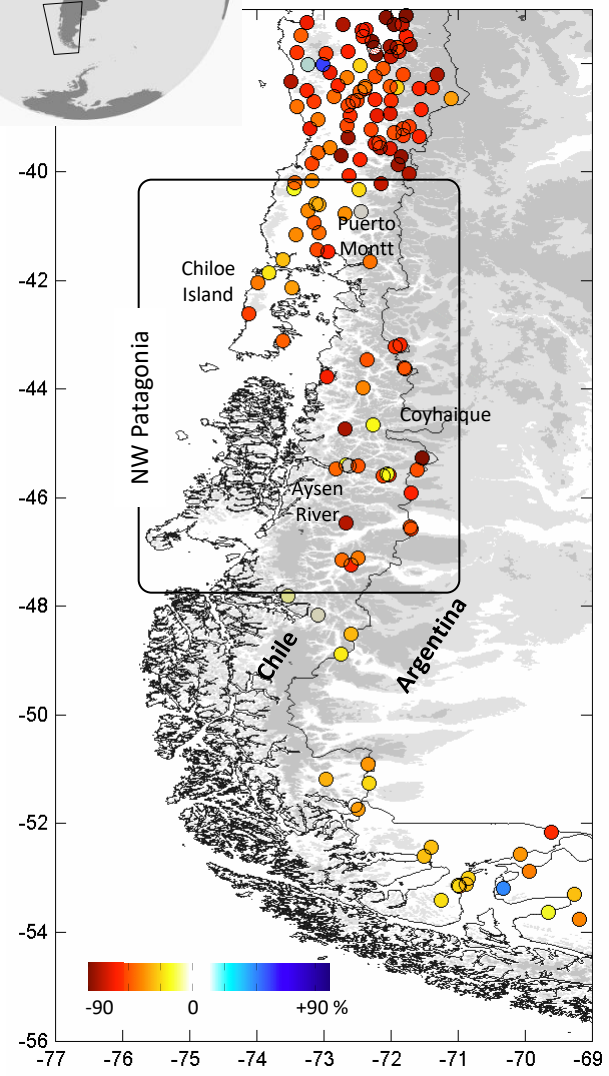

Atmosphere/Land Boundary Conditions
Atmospheric Fluxes
Solar Radiation
Fresh Water
Ocean state variables
• Temperature
• Stratification (ρ(z))
• Vertical velocity
• Currents
• pH
Alexandrium Catenella
Turbulence Upwelling
Bloom
Nutrients (P,N)
Physical processes
Biological processes
© RGarreaud / DGF-UCh + CR2

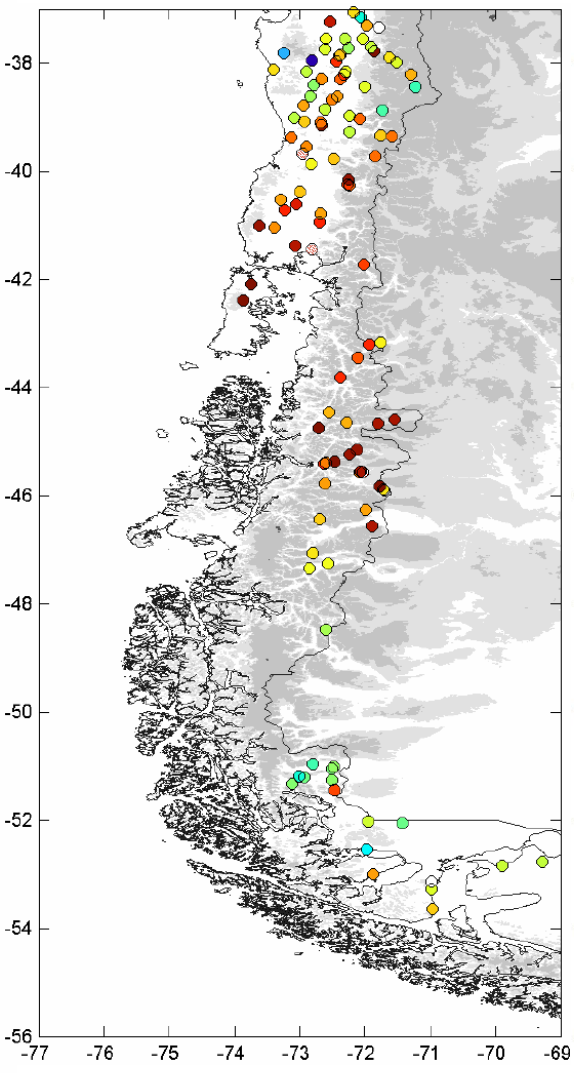
Climate Control of HABs in Patagonia

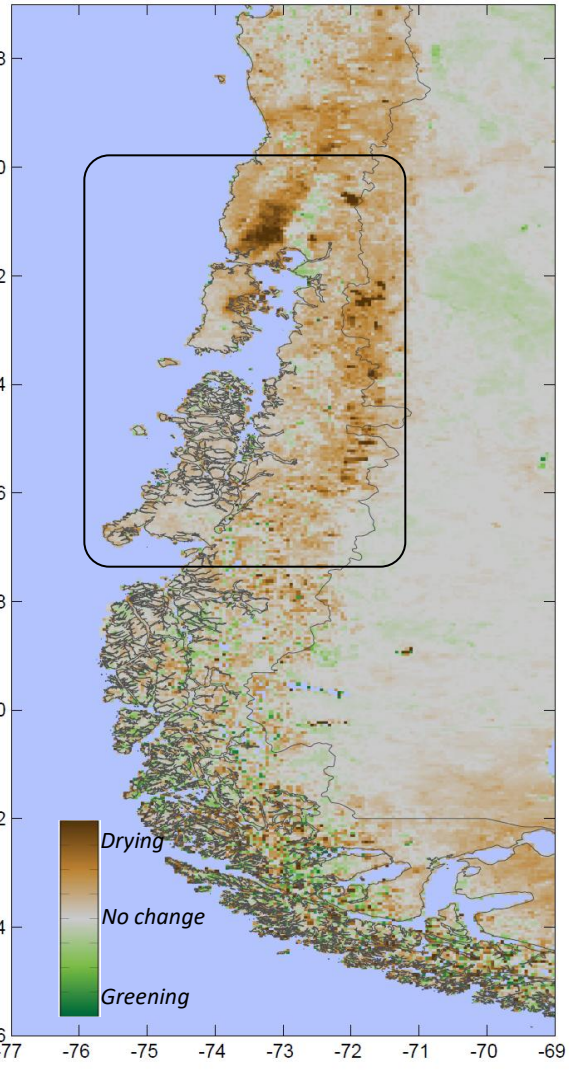
Garreaud, Massoti et al. 2019?



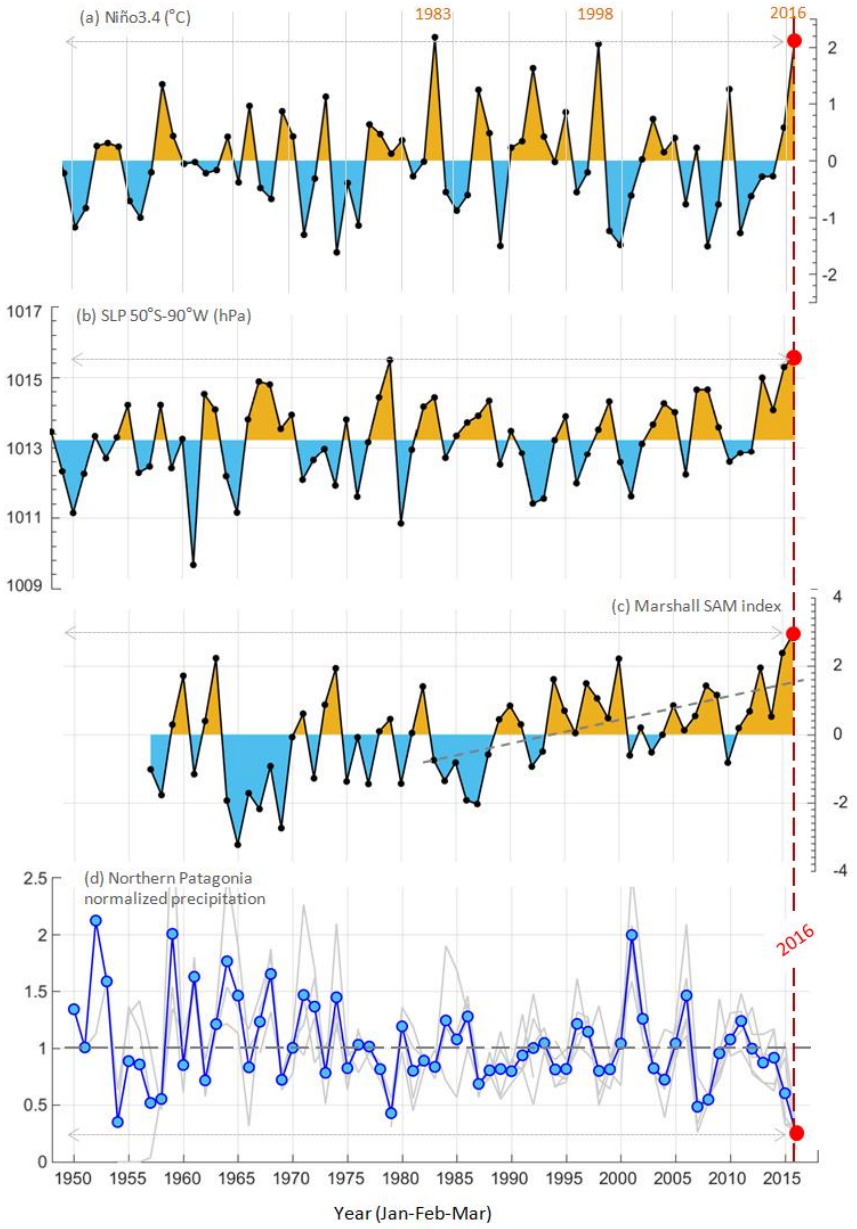
The awful 2016







Large scale conditions JFMA 2016



El Niño!
Natural….

r = -0.2

SAM!
Antrophogenic

Garreaud 2017

Conclusions

* Climate anomalies (wet/dry) accounted by changes in westerly wind impinging the austral Andes. Drivers of Temperature?

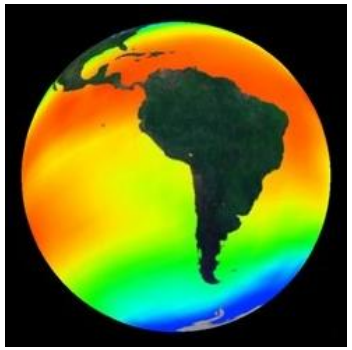
* Large scale circulation anomalies modulated by ENSO (Natural) and SAM (anthropogenic: GHG+O3)

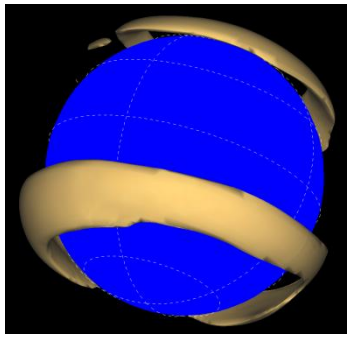
* Robust changes in precipitation, not so clear in temperature. Local scale? Hydrological response?

* Climate projections: drying in central Patagonia + warming, superimposed on natural variability. Uncertainty? Extreme events (ARs, severe droughts)? Other drivers?

Environmental extremes and change
→ Social tensions

Local activities





Climate variability
Climate change