Current climate trends in the Southeast Pacific
Natural and anthropogenic contributions

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Current climate trends in the Central Chile
Natural and anthropogenic contributions

Why bothering with a study on climate change in Chile? After all, there is widespread warming (perhaps more rapid at high elevations) and, because of its substantial variability (ENSO), we can't discern any trend in rainfall. (Garreaud, 2012)

Well, one can be wrong….

Outline

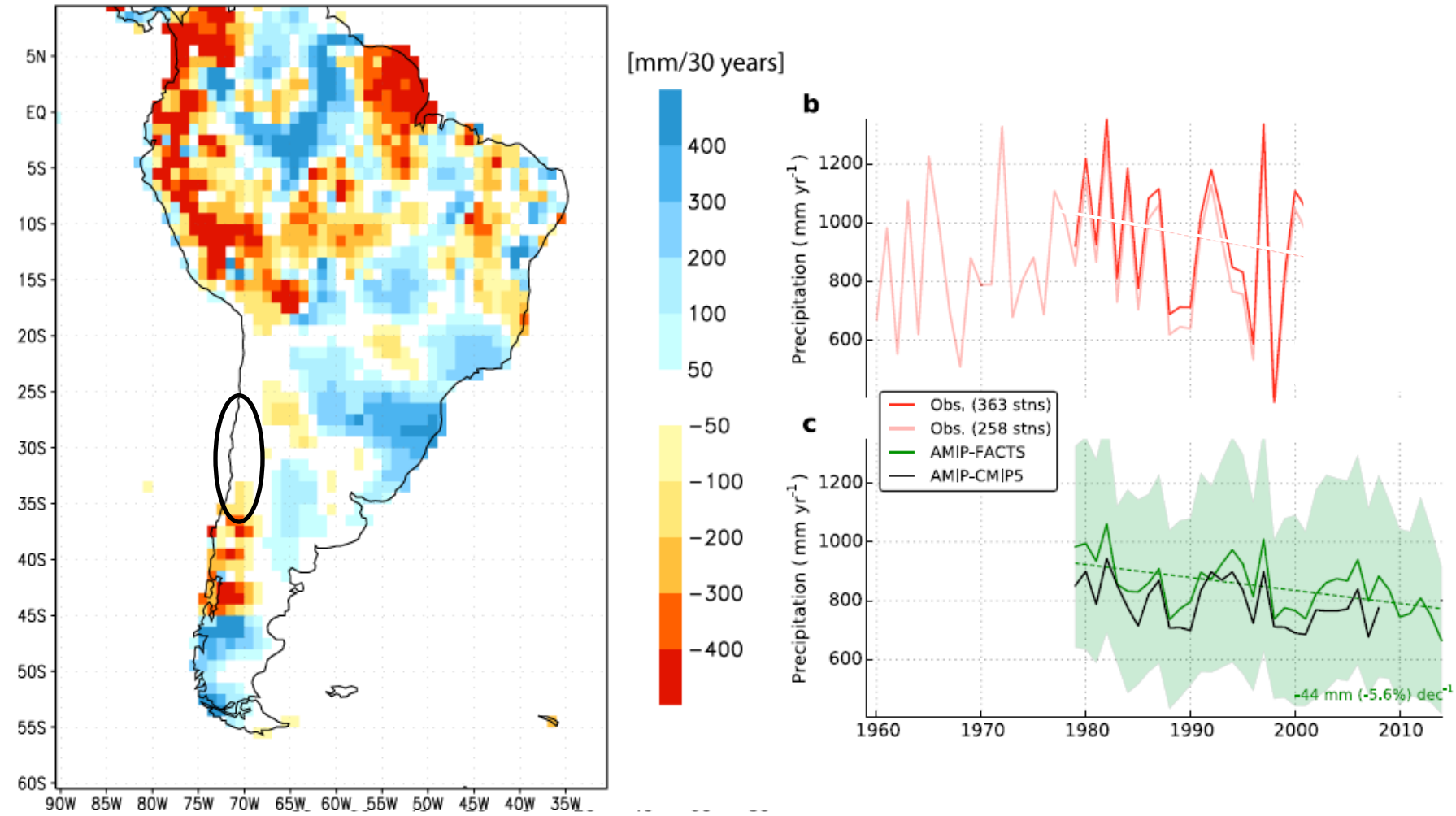
Part I

- Precipitation trends
- Current (mega) Drought
- Drought dynamics
- Attribution and projection

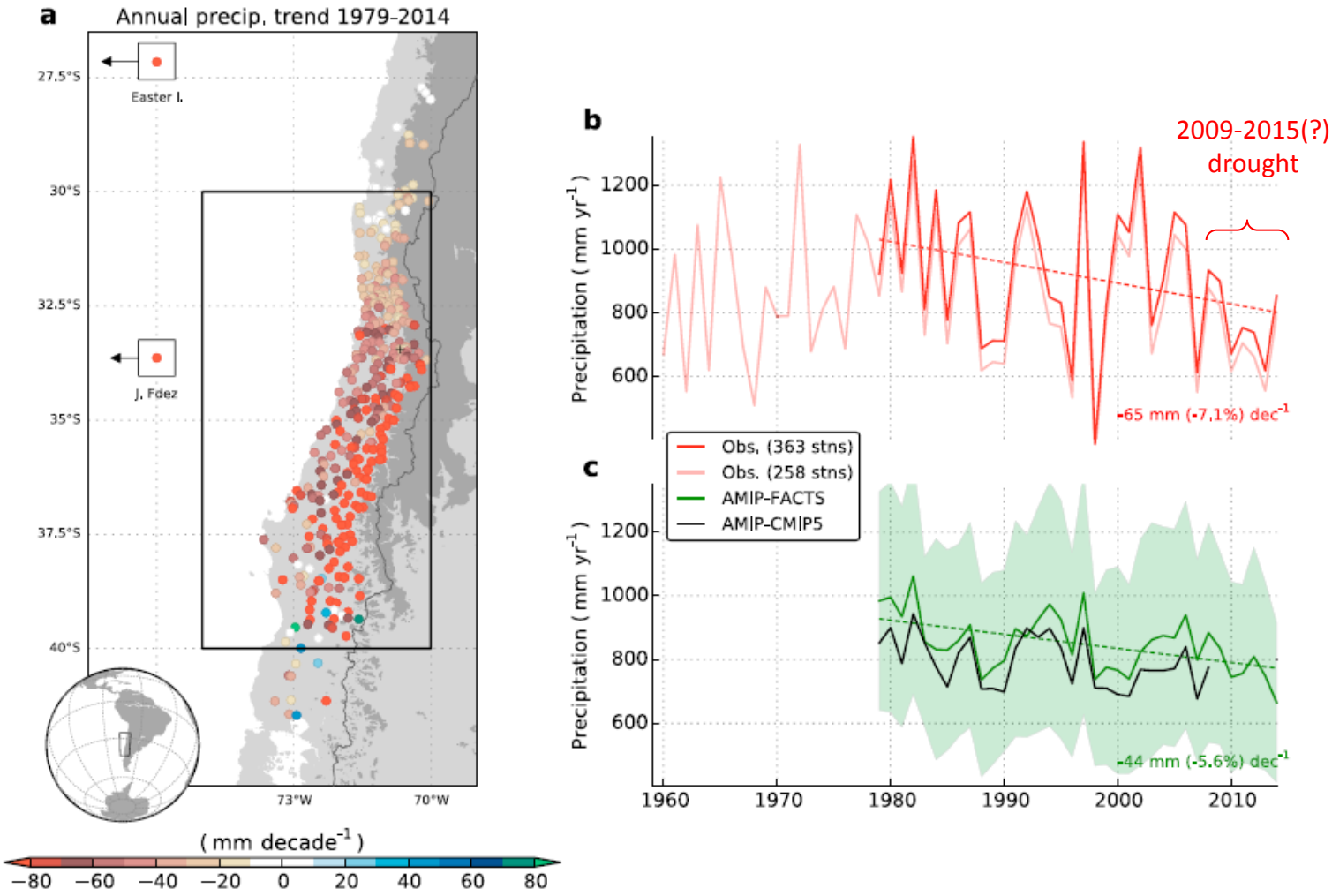
Part II

- Cooling ocean, Land Warming (COWL)
- Global warming hiatus and PDO
- Role of SAM (midlatitudes)
- Projections

Contemporaneous rainfall trends in central Chile (1960-2000)

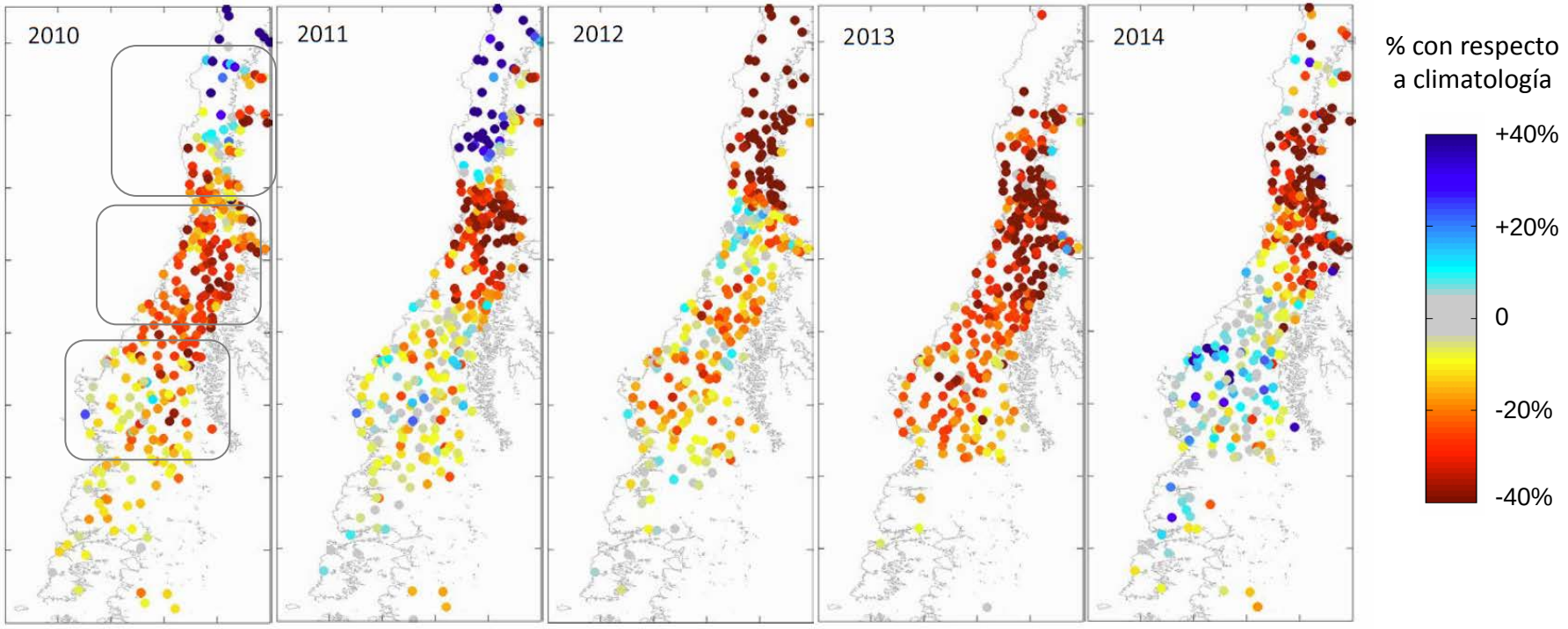


Contemporaneous rainfall trends in central Chile (Updated)



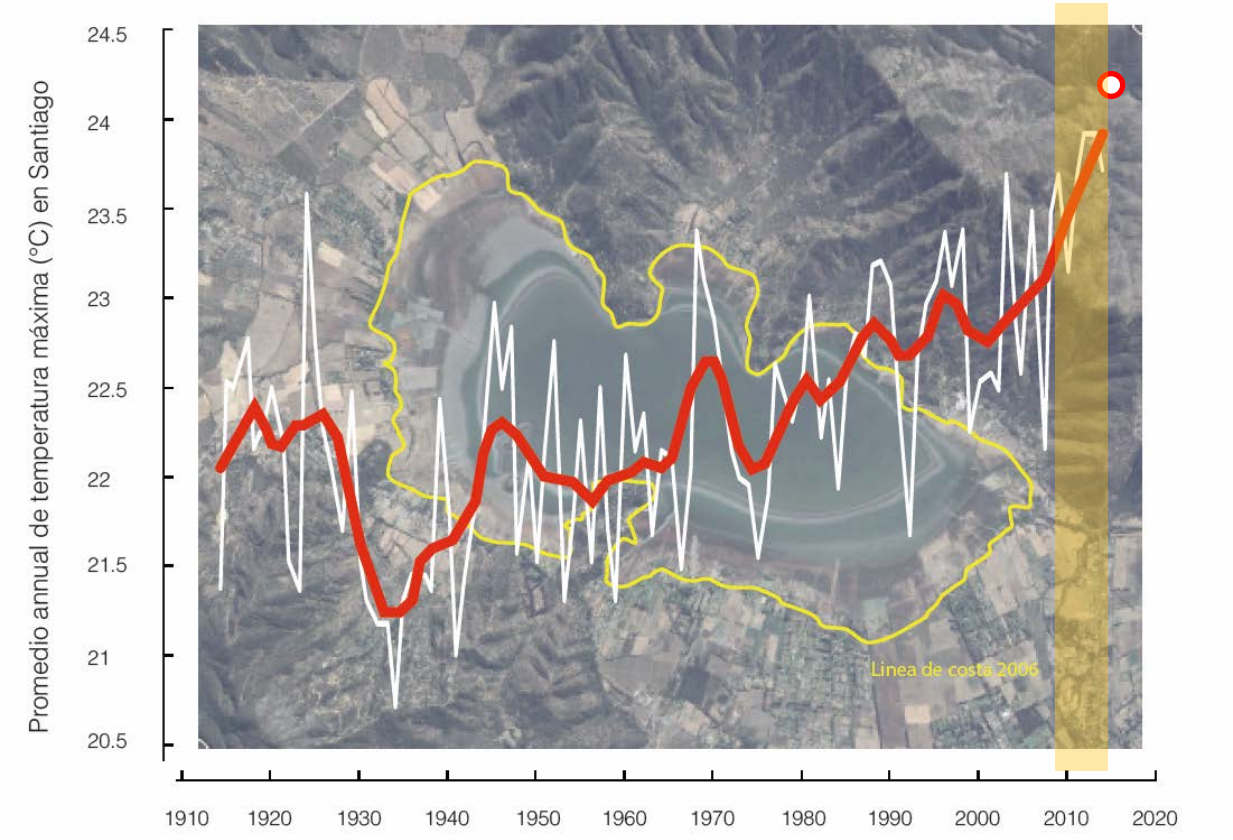
Bosier et al. 2016

Central Chile Mega Drought



	Norte Chico	Centro	Centro-sur
Return Period of driest year within MD	7	15	>30
Recurrence of a sequence of 4+ dry years	4-6	2-3	1?

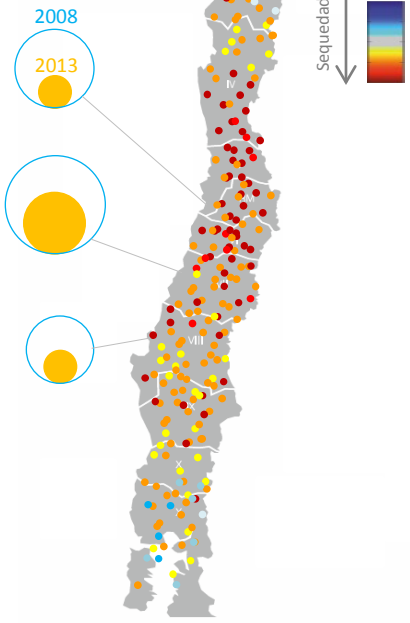
Dry and warm



Promedio anual de la temperatura máxima en Santiago (DMC)

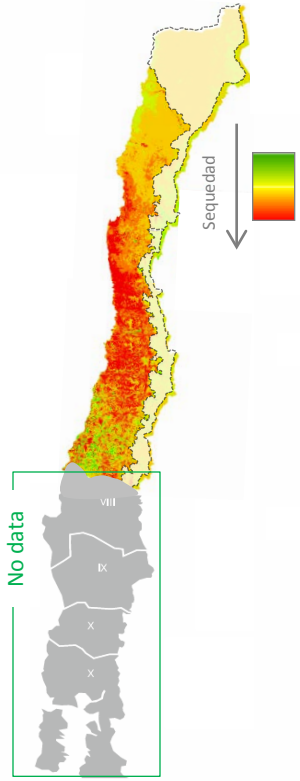
La Megasequía 2010-2015

Transporte de sedimentos en invierno

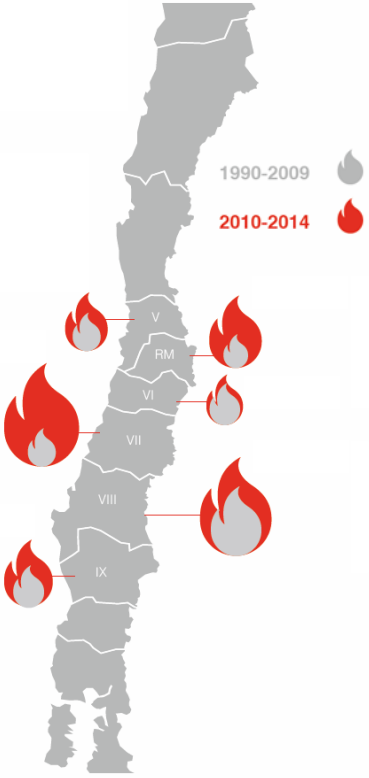


Déficit Pluviométrico (2010-2014)

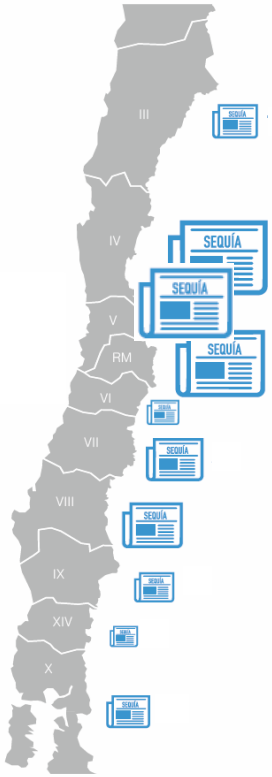
Deterioro vegetación Agosto 2010-2015



Incendios forestales de magnitud



Apariciones en prensa escrita (2014)

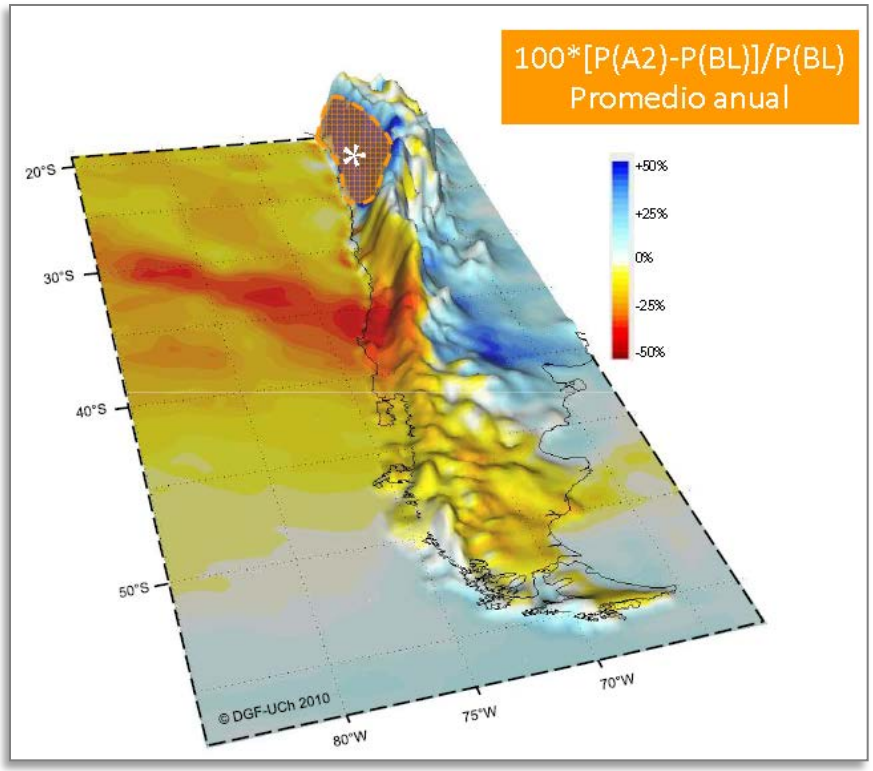


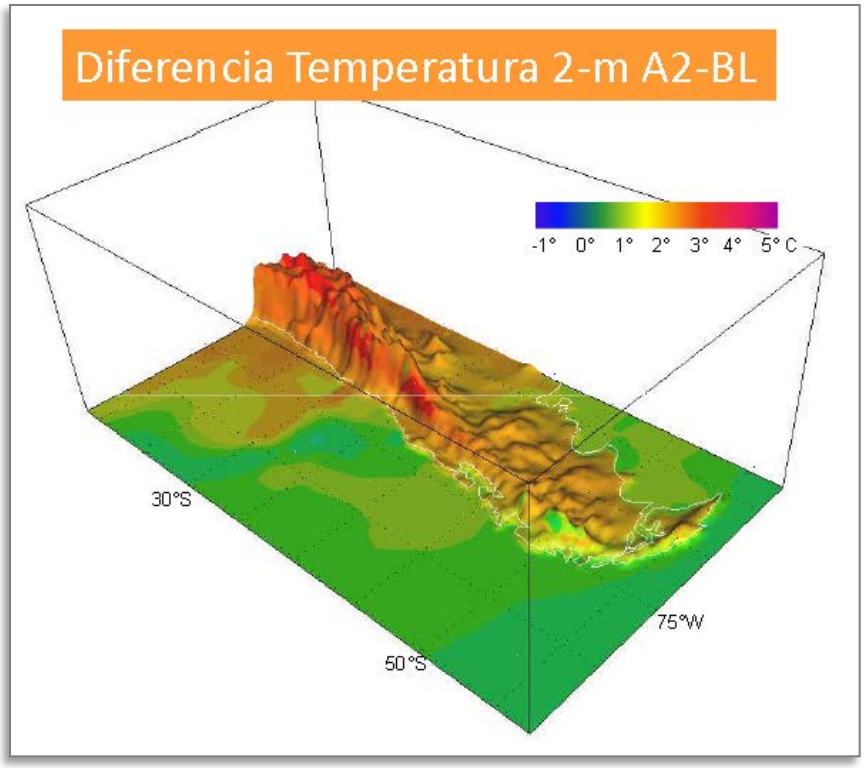
Gastos en Camiones Aljibes (Mill$)

Central Chile Climate Change Projections

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

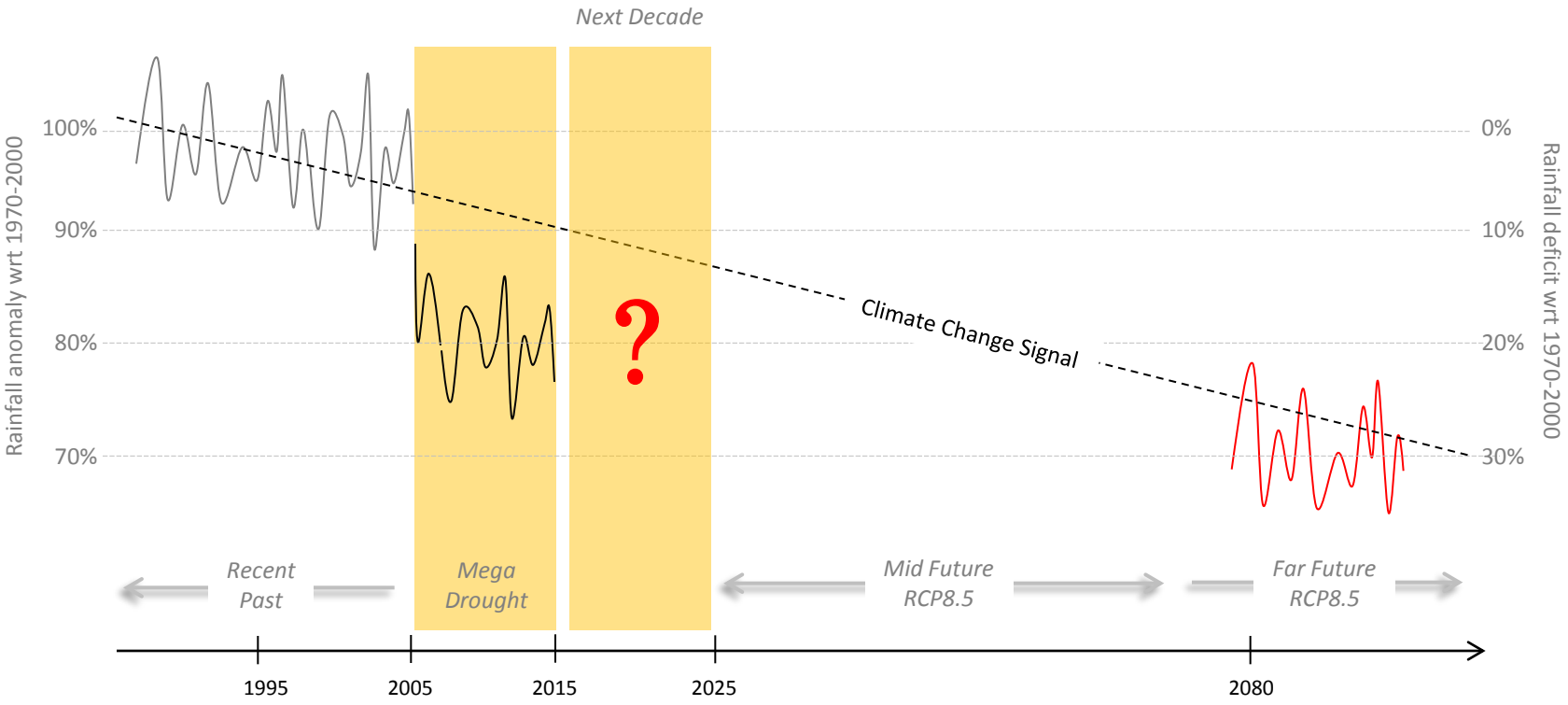
- Temperature increase 2.5-3.5ºC
- Rainfall decline 25-35%





Estudio DGF/UCh-CONAMA 2007 empleando PRECIS

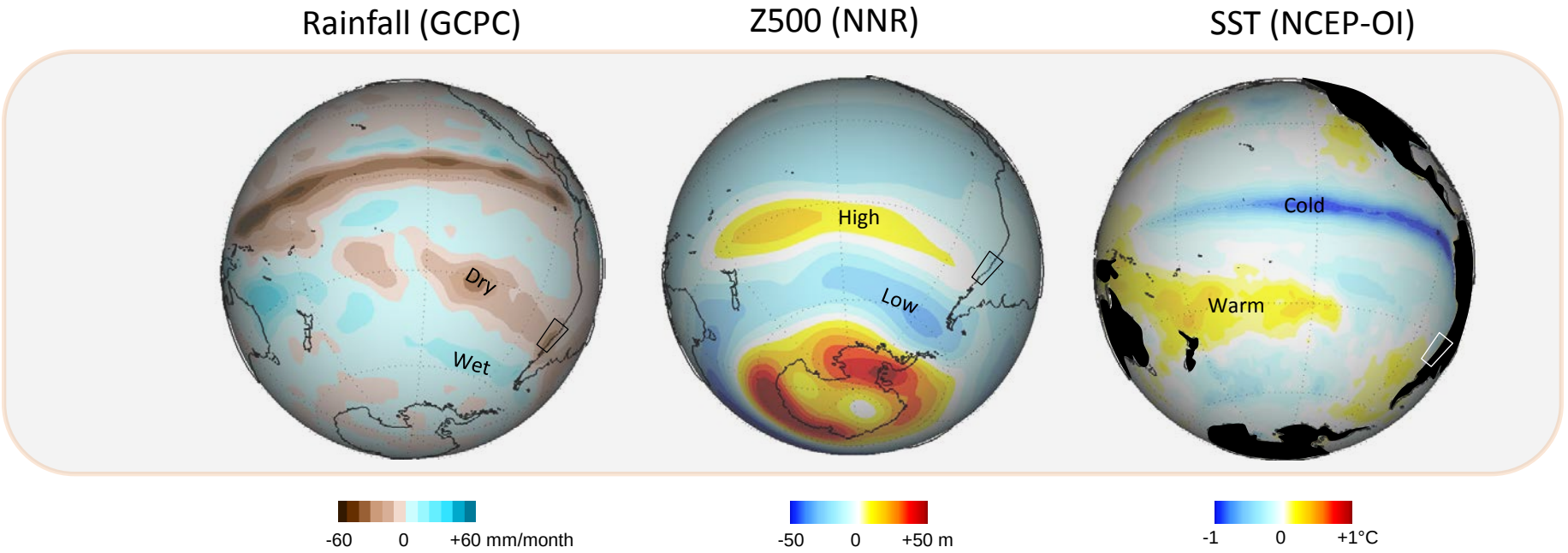
Central Chile Rainfall
The next decade chalenge



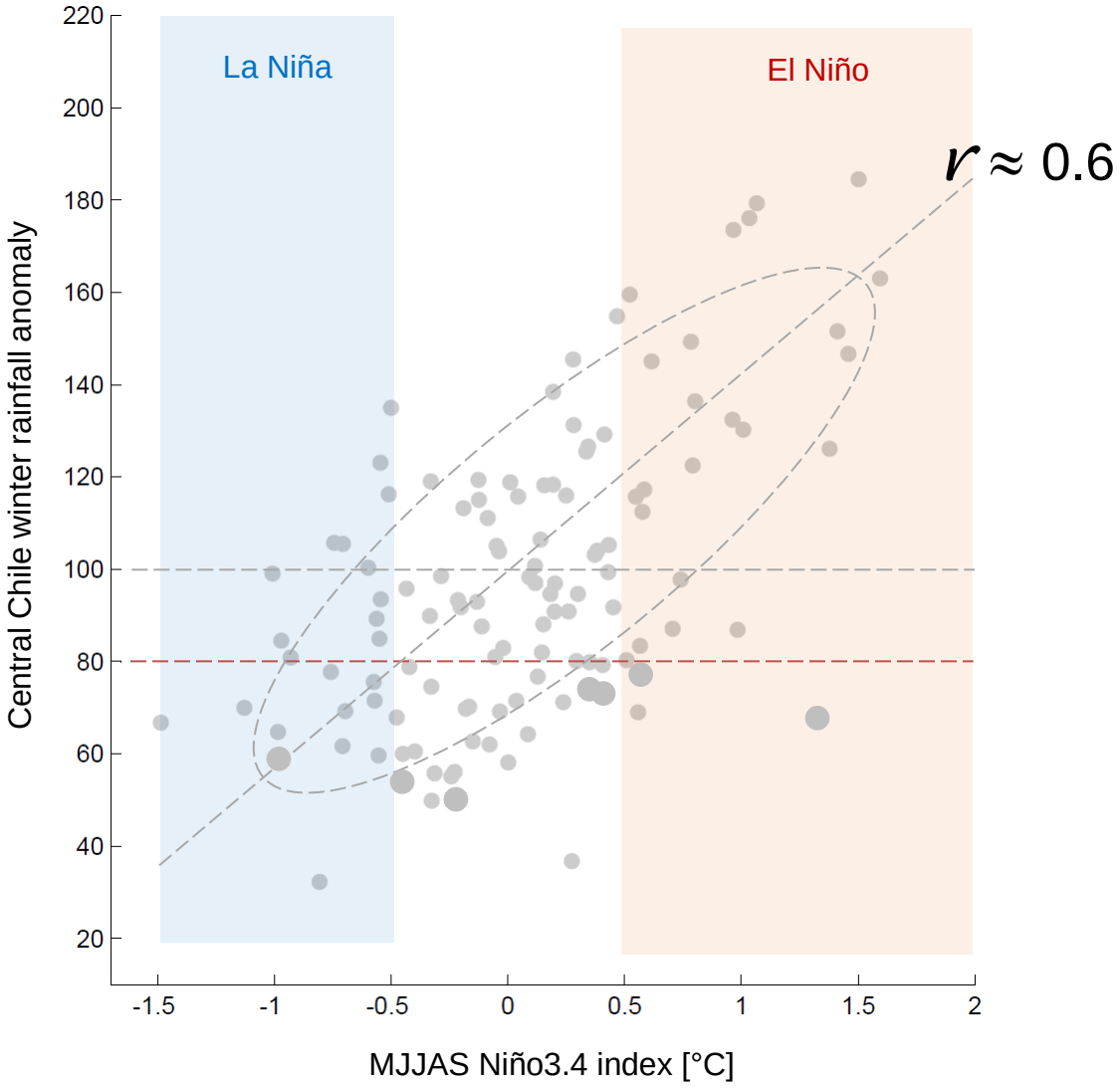
Large-scale context for central Chile droughts

Drought Composite

1967,68,64,73,76,85,96,2003,2007



Large-scale context for central Chile droughts



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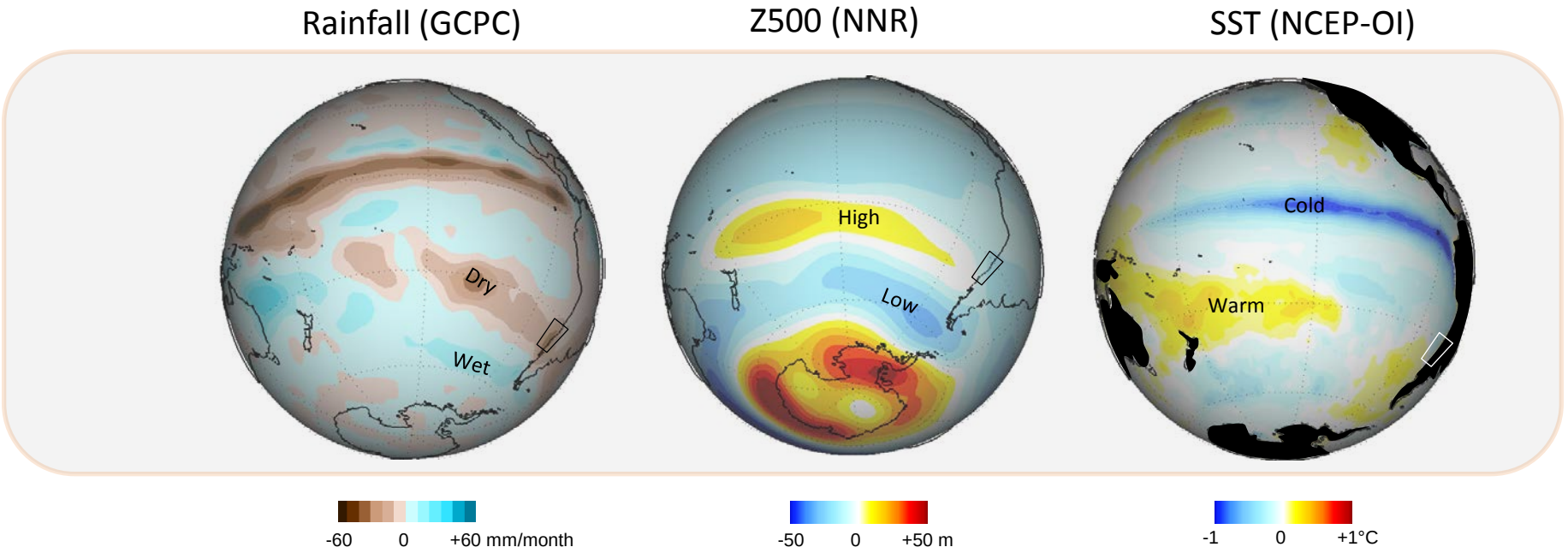

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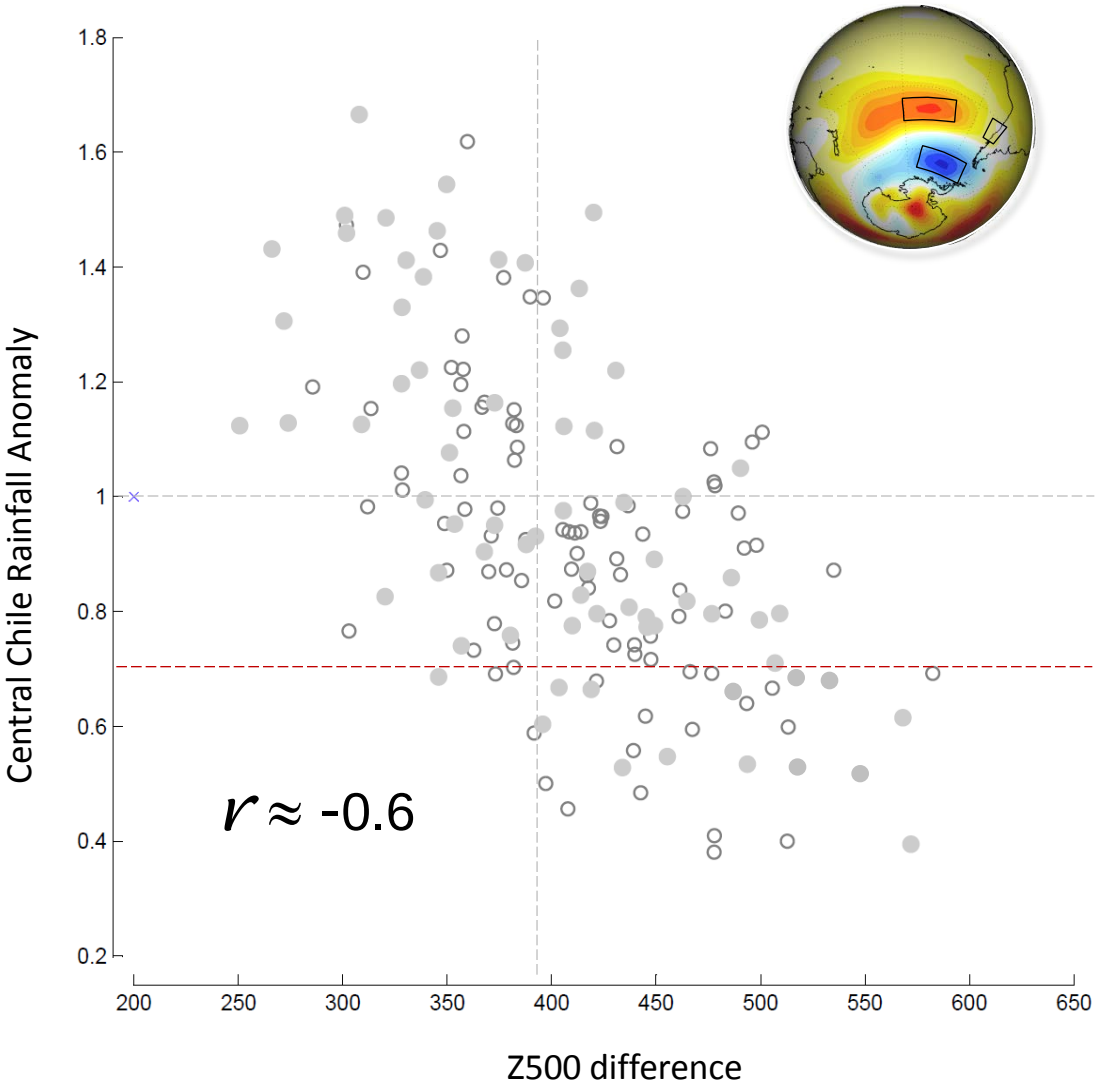
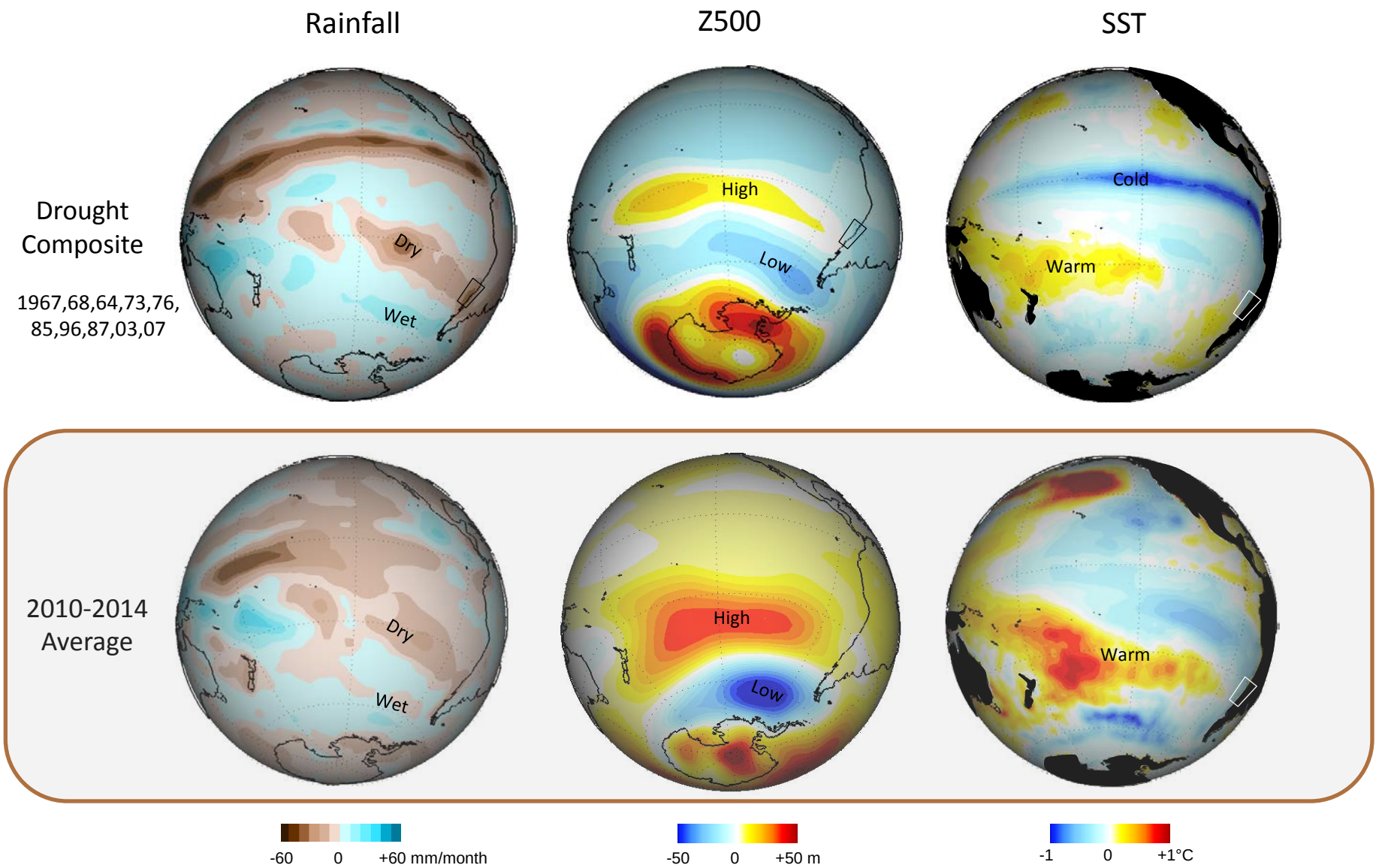
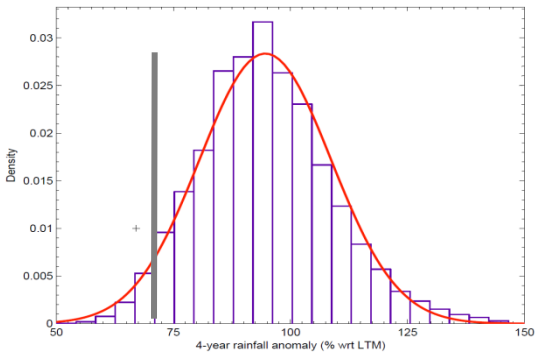


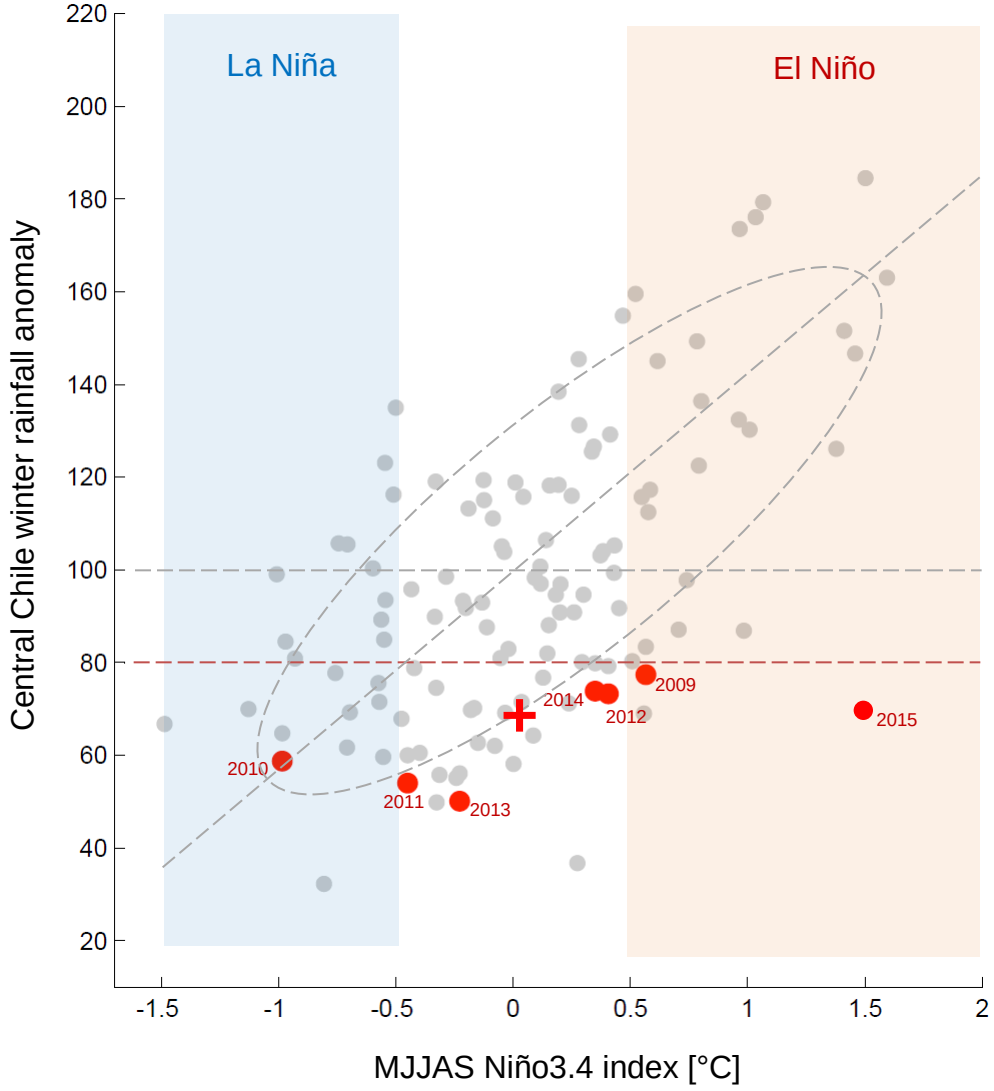
The 2010-2015 drought in Central Chile



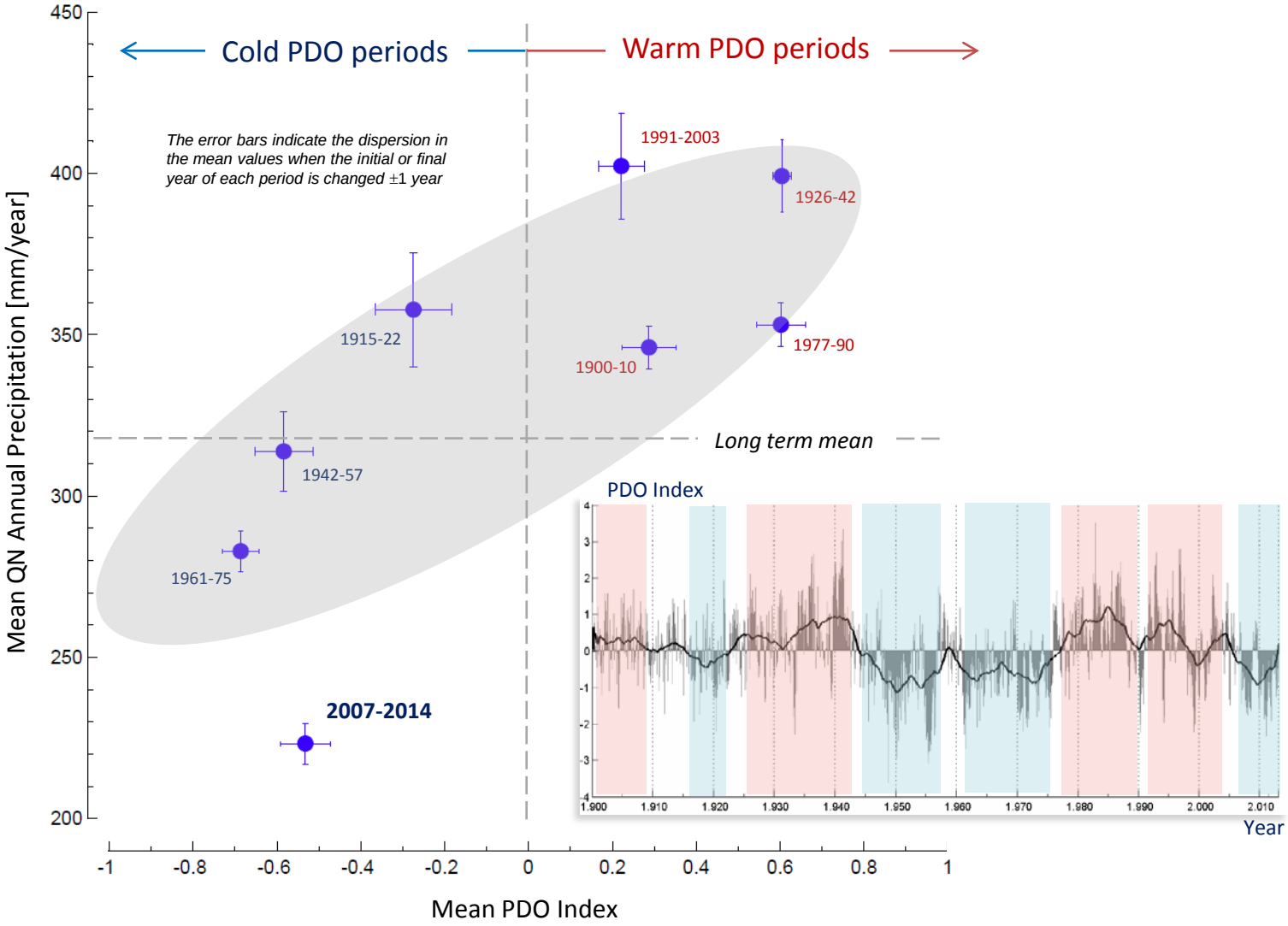
The 2010-2015 drought in Central Chile: ENSO

Monte Carlo Experiment:
5000 samples of 4 randomly chosen ENSO-neutral years

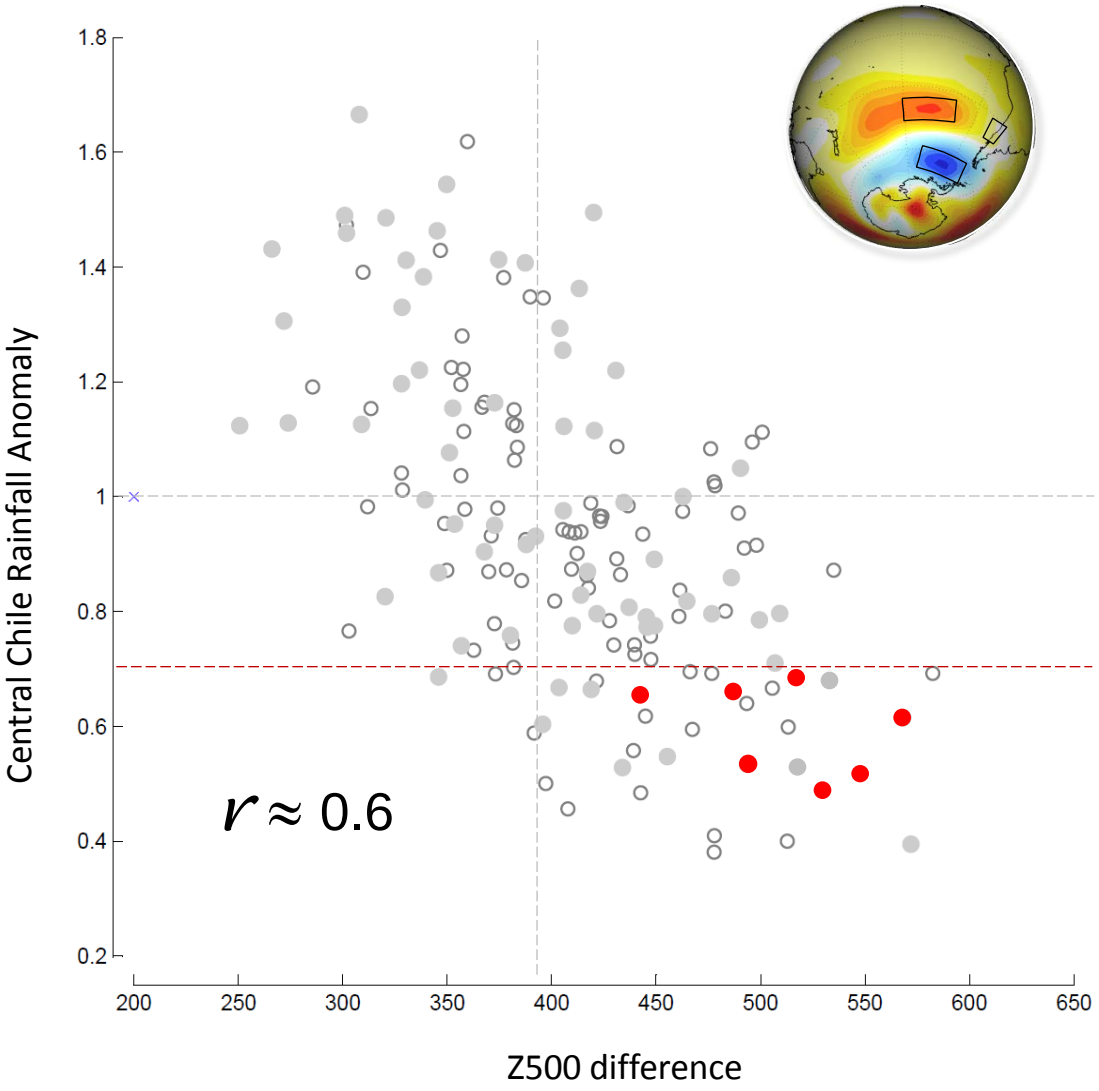




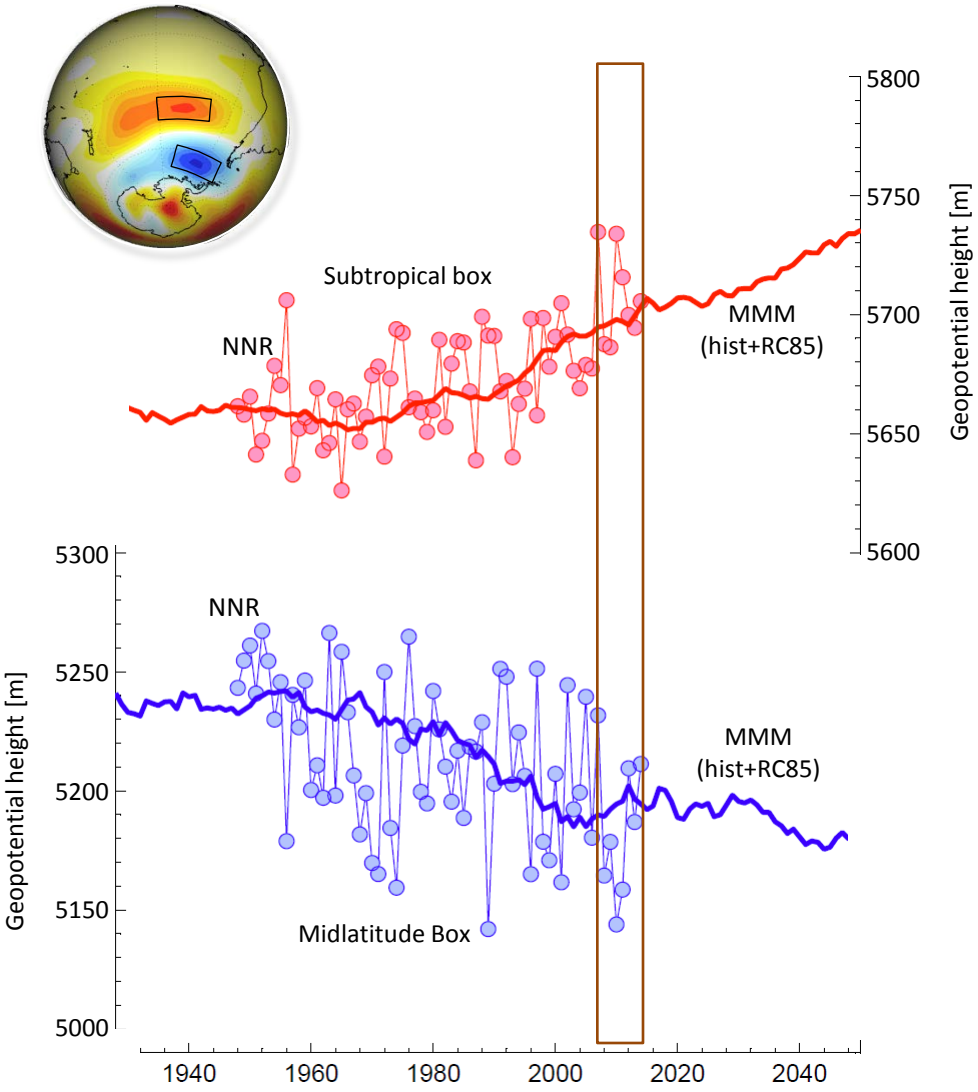
The 2010-2015 drought in Central Chile: PDO



The 2010-2015 drought in Central Chile



The 2010-2015 drought in Central Chile



Attribution of the 2010-2015 mega drought

AMIP-X simulations: Atmospheric Global Circulation Model (AGCM) forced by

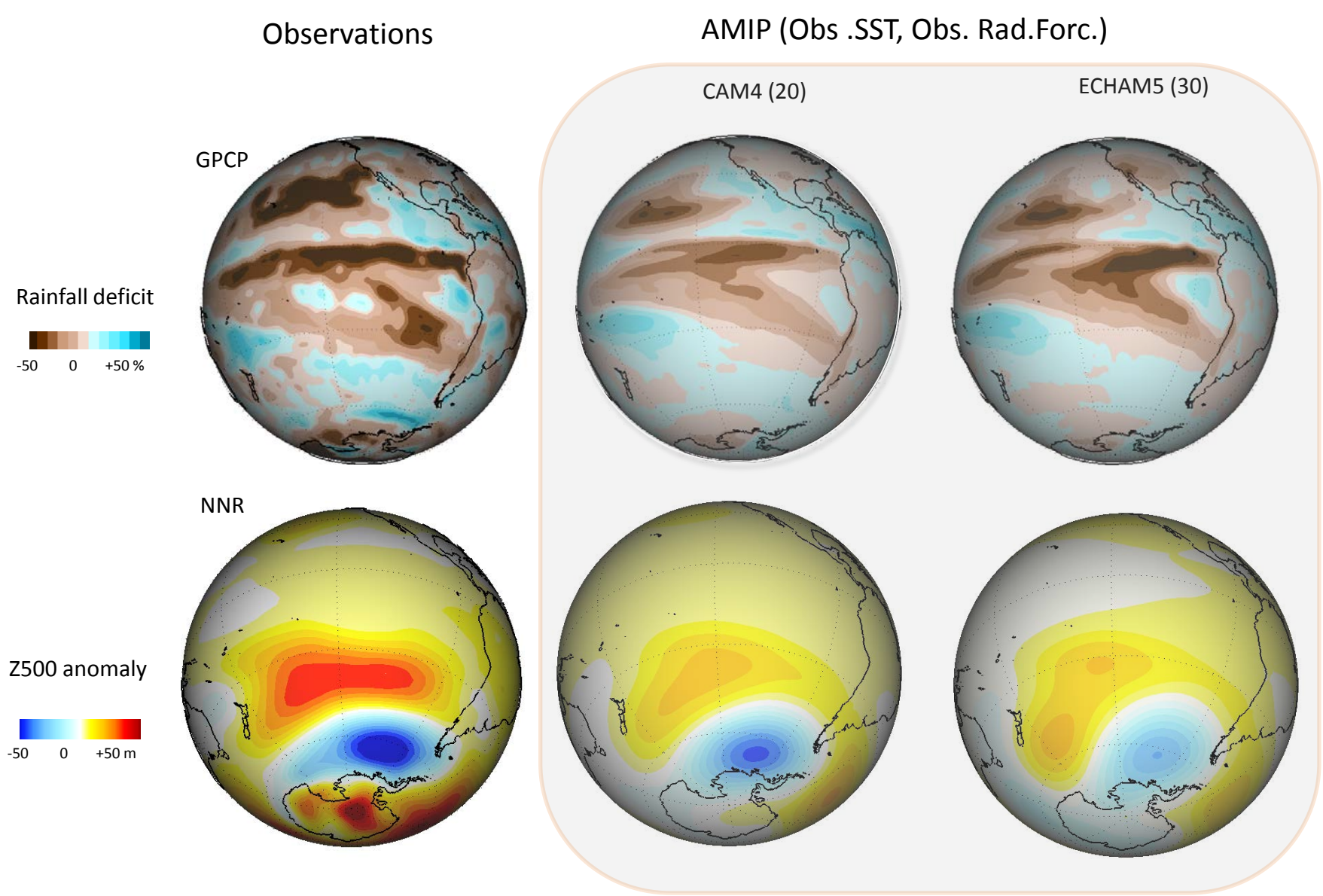
- Observed SST & Sea Ice Distribution
- Observed Radiative Forcing (CO2, aerosols, O3,…)
- Special AMIP simulations with natural-historical RF (1900')

- 10-30 "runs" of several decades long with slightly different initial conditions
- Ensemble mean reveals the "natural" SST forced response
- Ensemble spread reveals impact of internal variability (weather)
- Ensemble mean with NH-RF excludes *direct* anthropogenic impact

CMIP-X simulations: AO oupled Global Circulation Model (AOGCM) forced by

- Observed or projected RF (CO2, aerosols, O3,…)
- Multi-model, multi-run mean reveals the RF forced response

May-September, 2010-2014

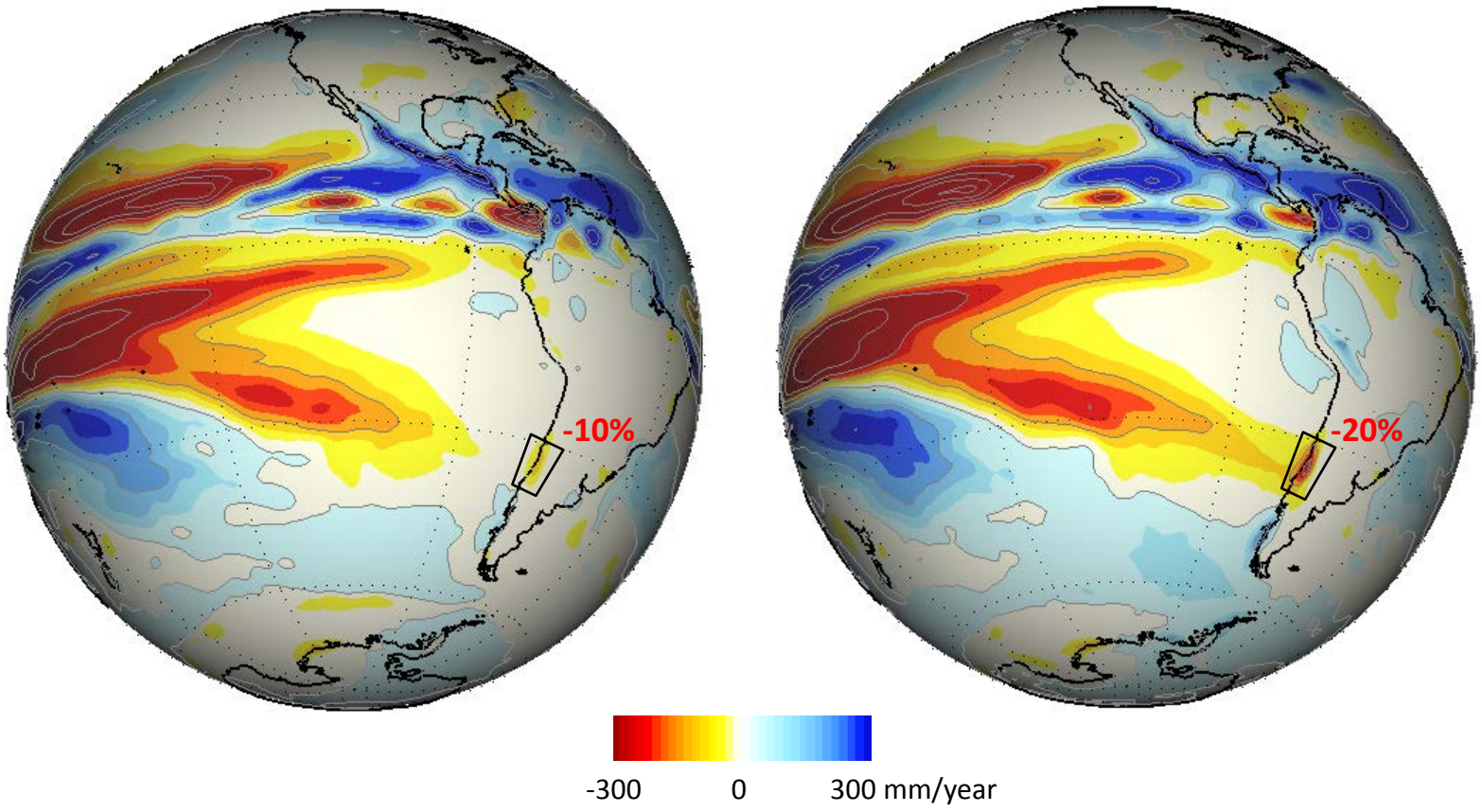


SST variability + Obs. Rad. Forcing during 2010-2014 accounts about half of the observed Z and P anomalies. Remaining anomaly can due to “bad luck”

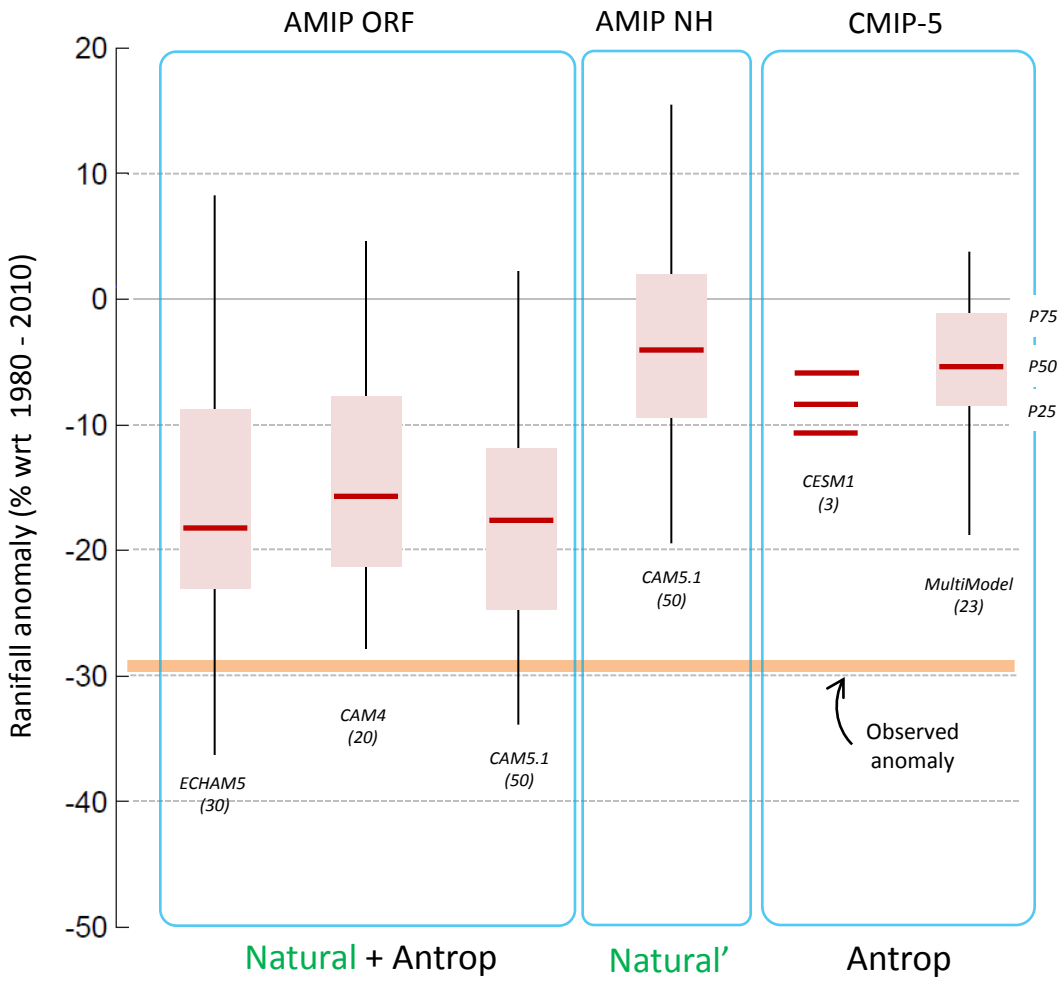
Winter (MJJAS) rainfall anomaly 2010-2014
LBNL CAM 5.1 AMIP simulations (50 runs)

(a) Nat-Hist forcing / Obs SST

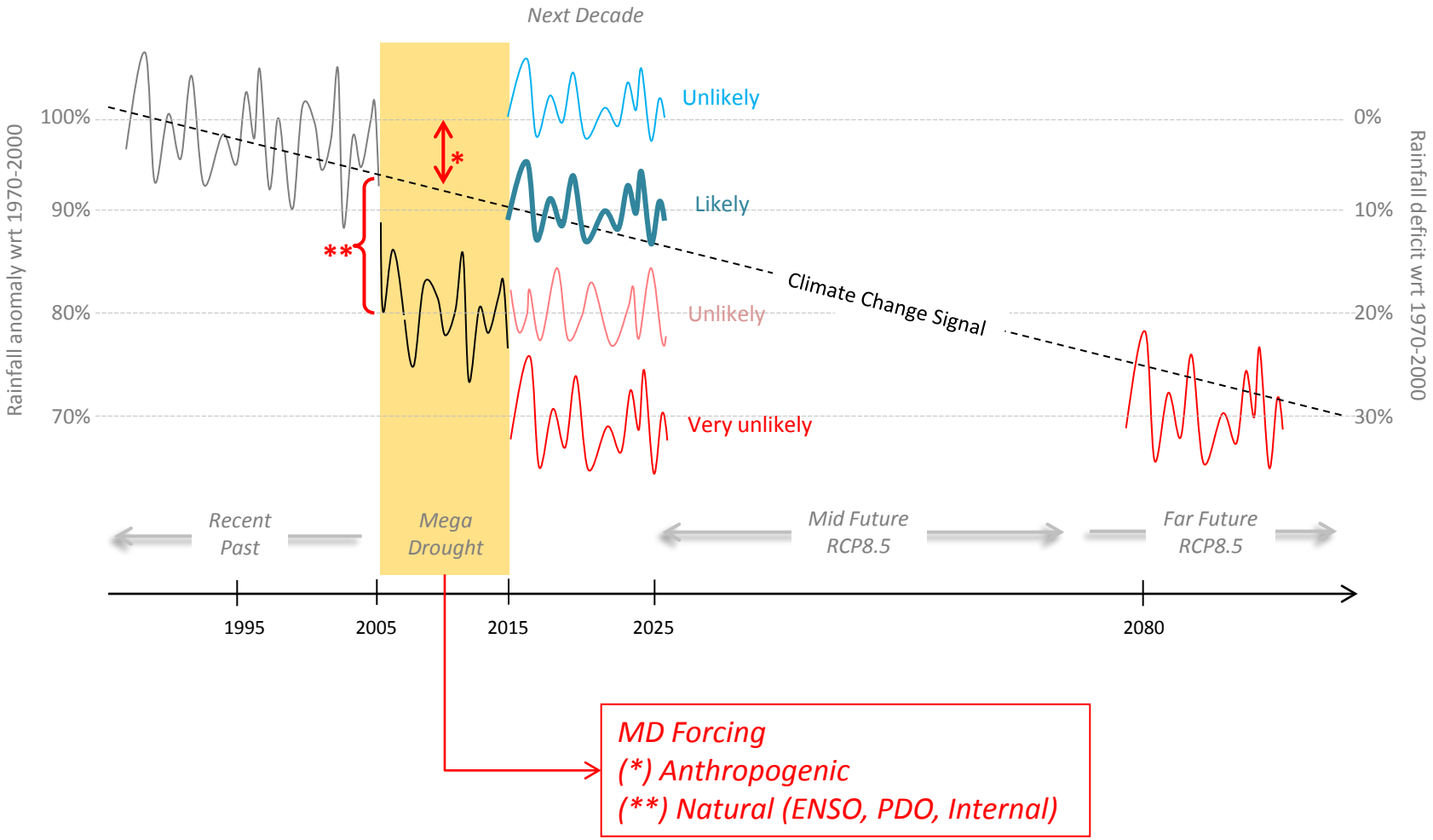
(b) Obs. Rad. Forcing / Obs. SST



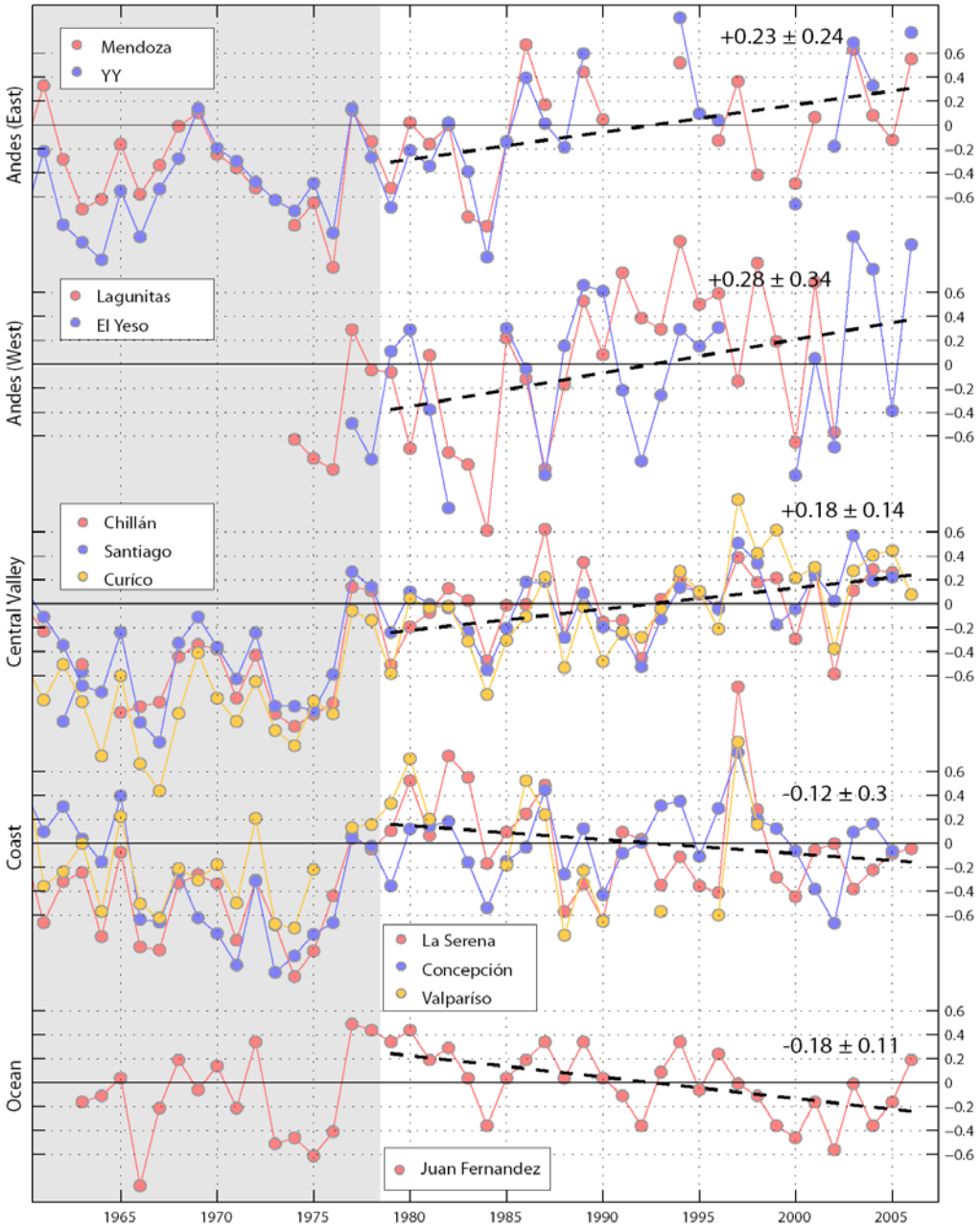
Central Chile (33-36°S) winter (MJJAS) rainfall anomalies during mega drought (2010-2014)



Conclusions for part I
(The Next Decade Challenge)



Surface Temperature Change



Falvey and Garreaud 2007

∂T/∂t along the western slope of the subtropical Andes

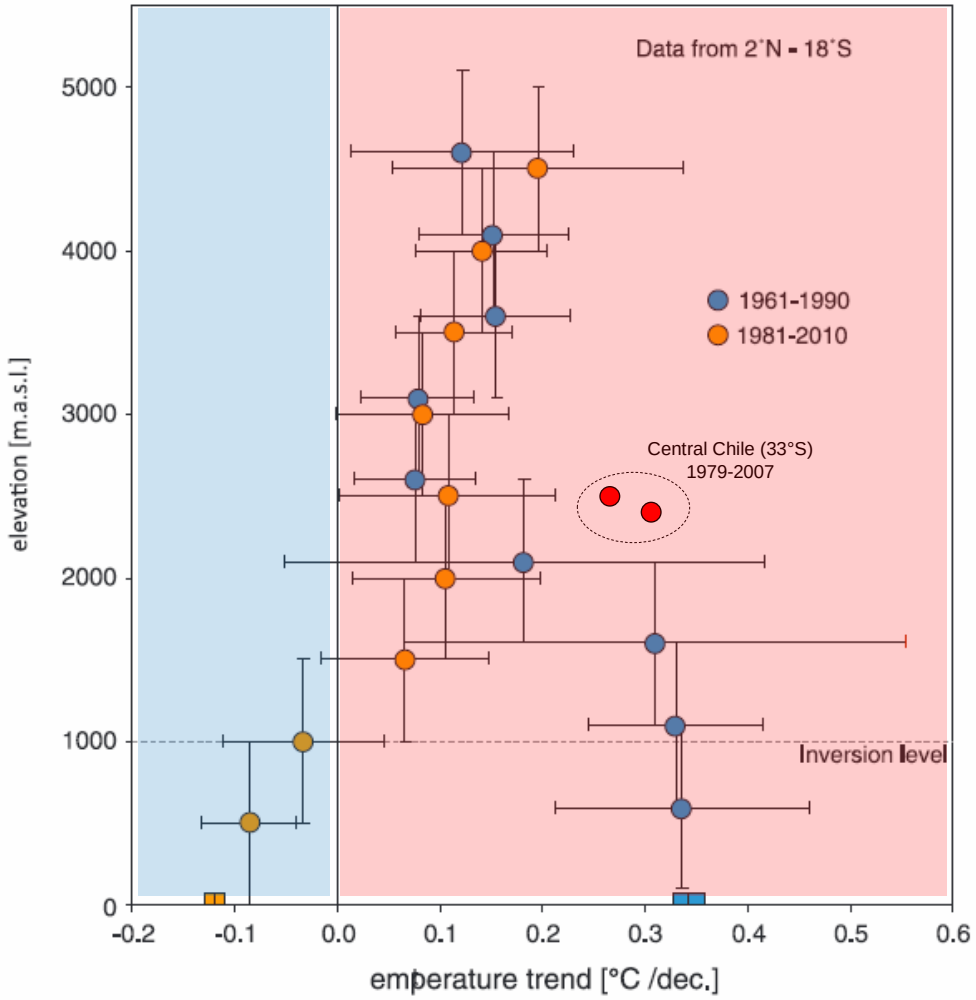


Figure 5. Temperature trends versus altitude along western tropical Andean slopes (2°N–18°S) for 1961–1990 (blue circle) and 1981–2010 (orange circle). The horizontal bars represent 95% confidence limits

Vuille et al. 2015. *JGR*

East Pacific Cooling

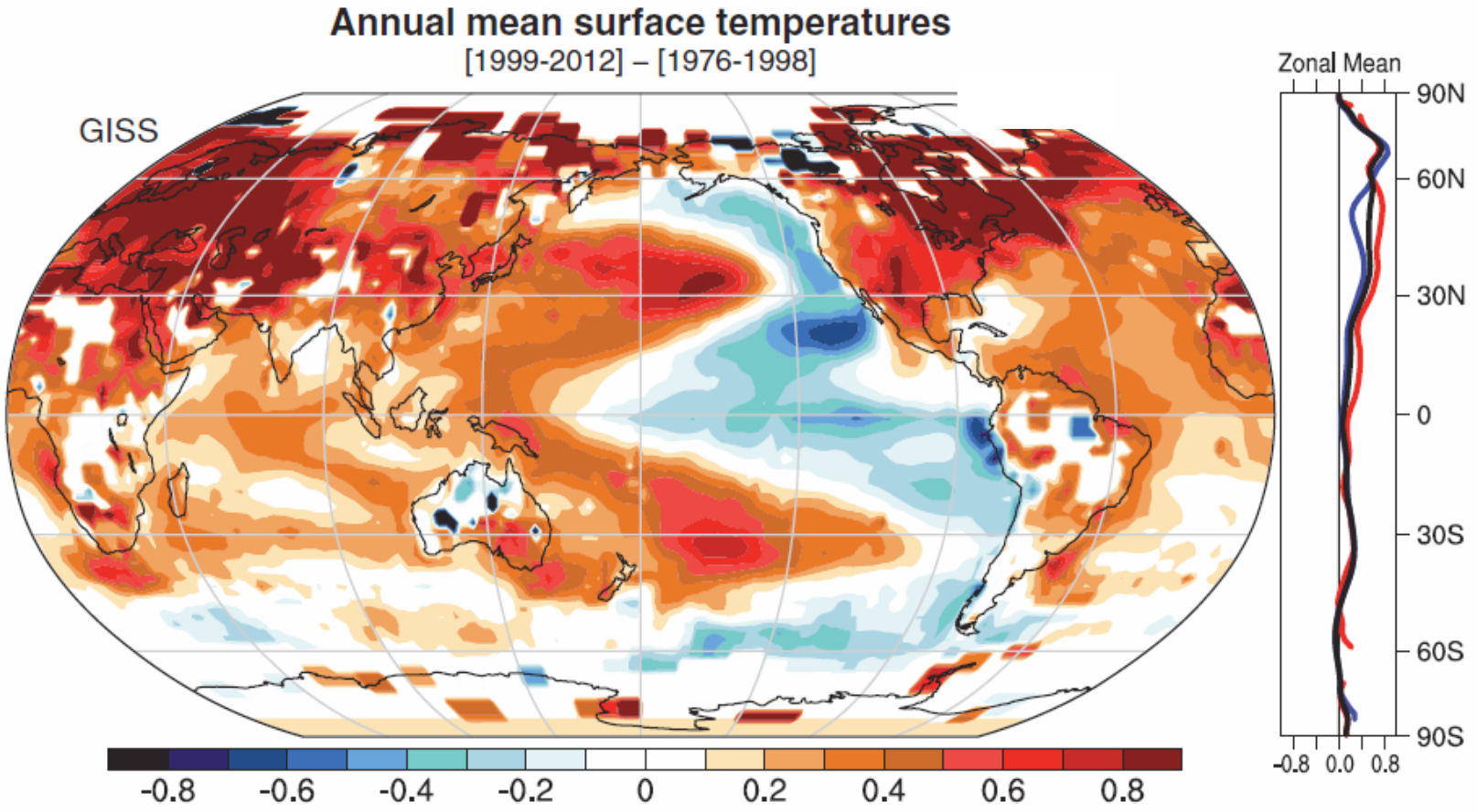
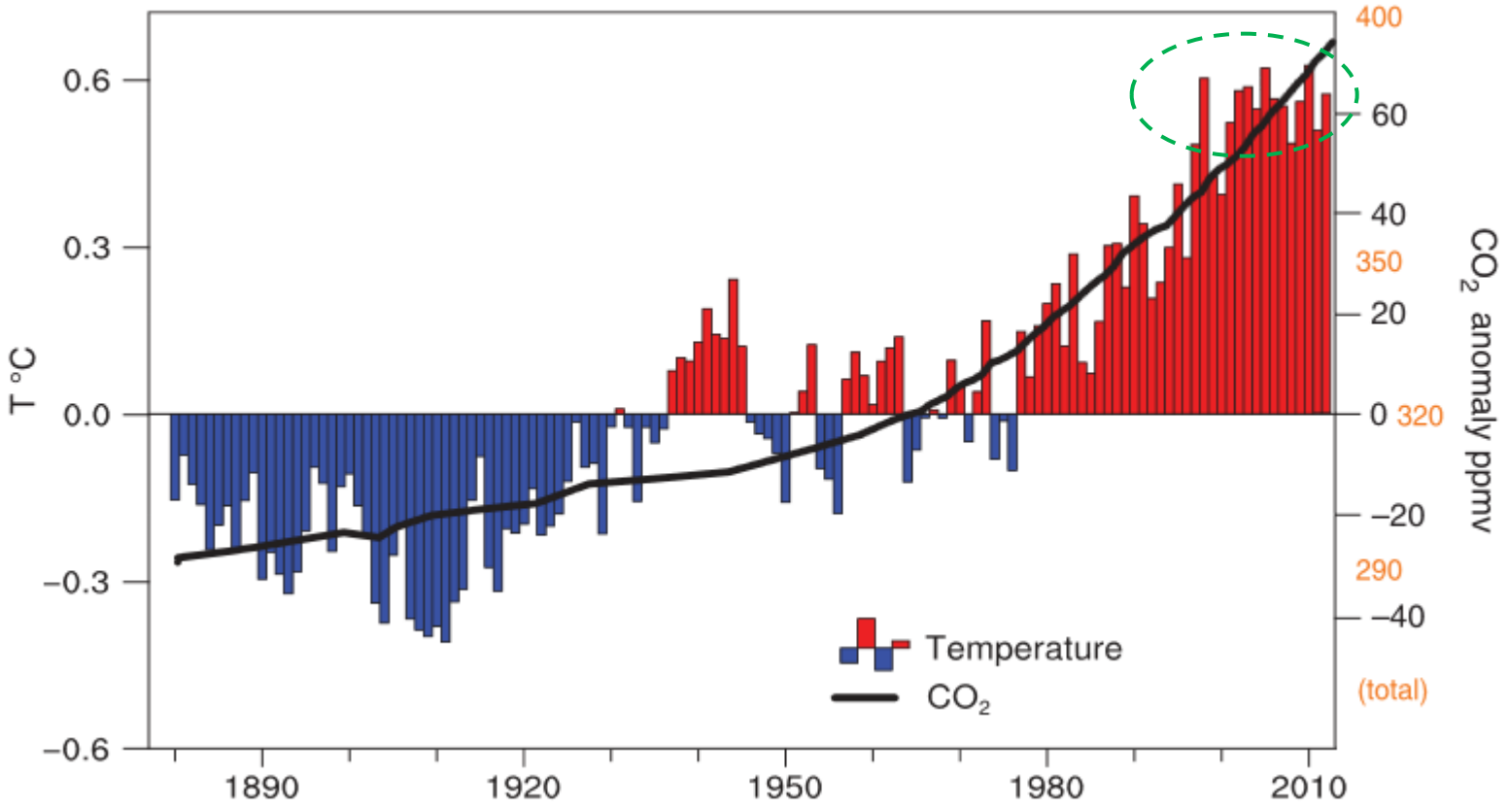


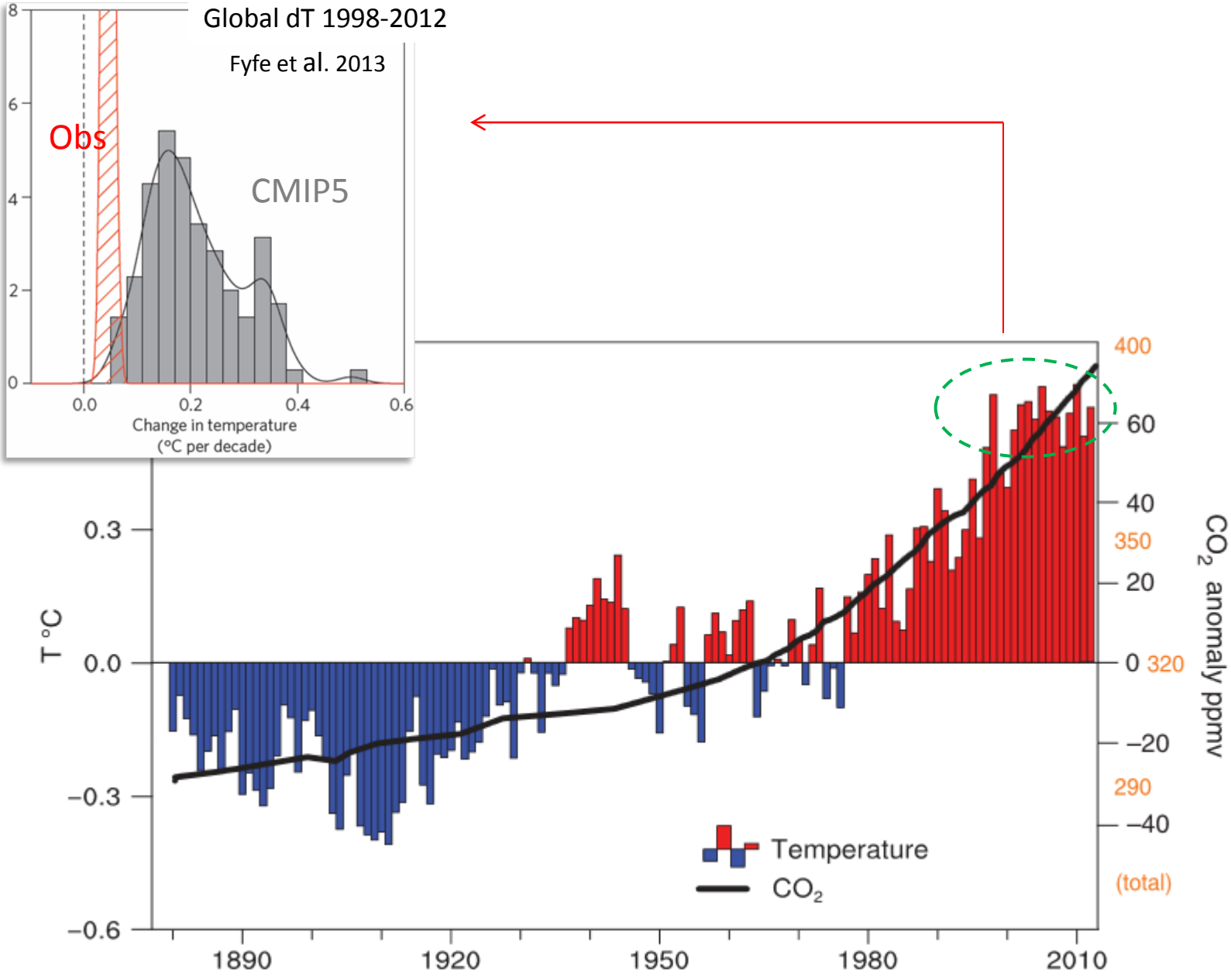
Figure 9. Mean annual surface temperature differences from GISS for 1999–2012 and 1976–1998 in °C, with zonal means at right for ocean (blue), land (red), and zonal mean (black).

Trenberth and Fasullo 2013.

Warmest decade on record but temperature increase has slowed down (**Global warming Hiatus**) in spite on monotonic rice in GEI and TAO radiative imbalance…



Trenberth and Fasullo 2013



Trenberth and Fasullo 2013

Main Suspect: Pacific Decadal Oscillation (PDO)

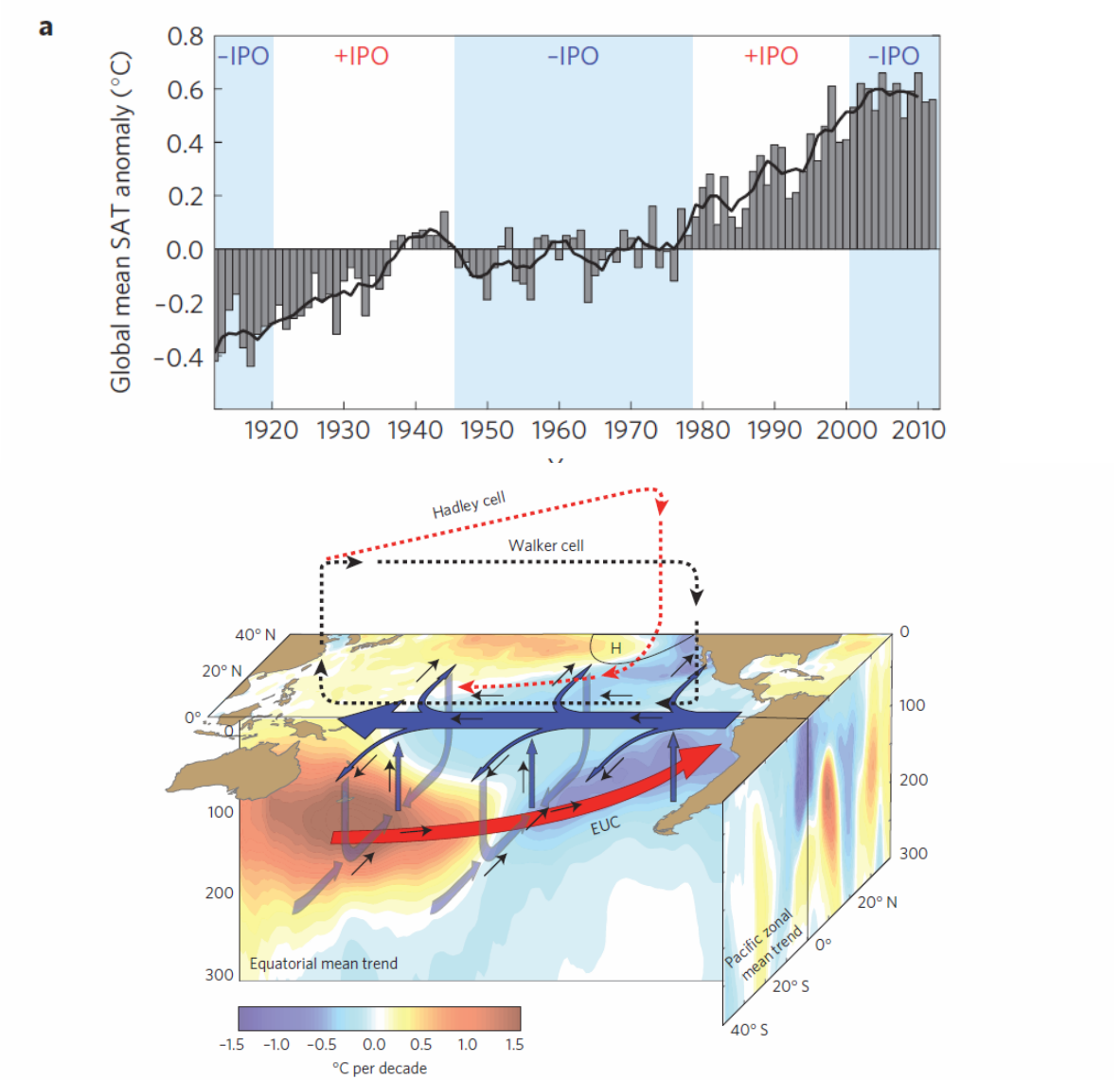
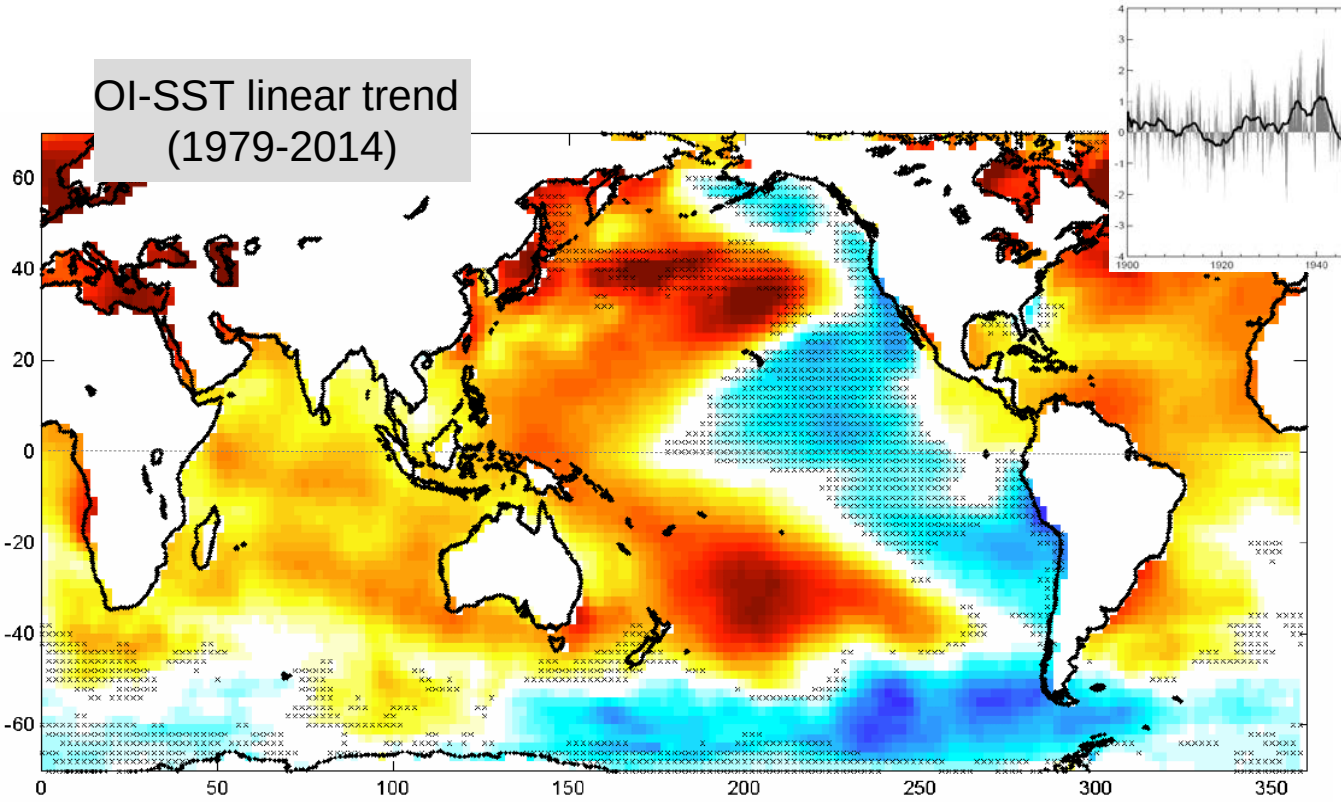
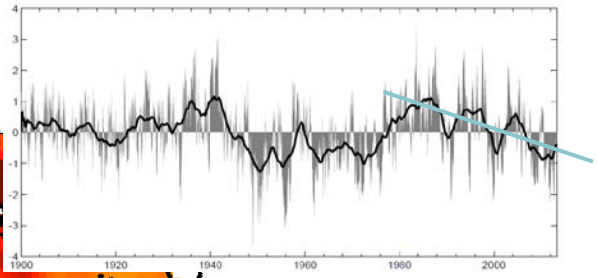


Figure 3 | Schematic of the trends in temperature and ocean–atmosphere circulation in the Pacific over the past two decades. Colour shading shows

England et al. 2014

Over the SE Pacific, PDO-congruent trend explains less than 50% of the observed cooling…something else is going on.

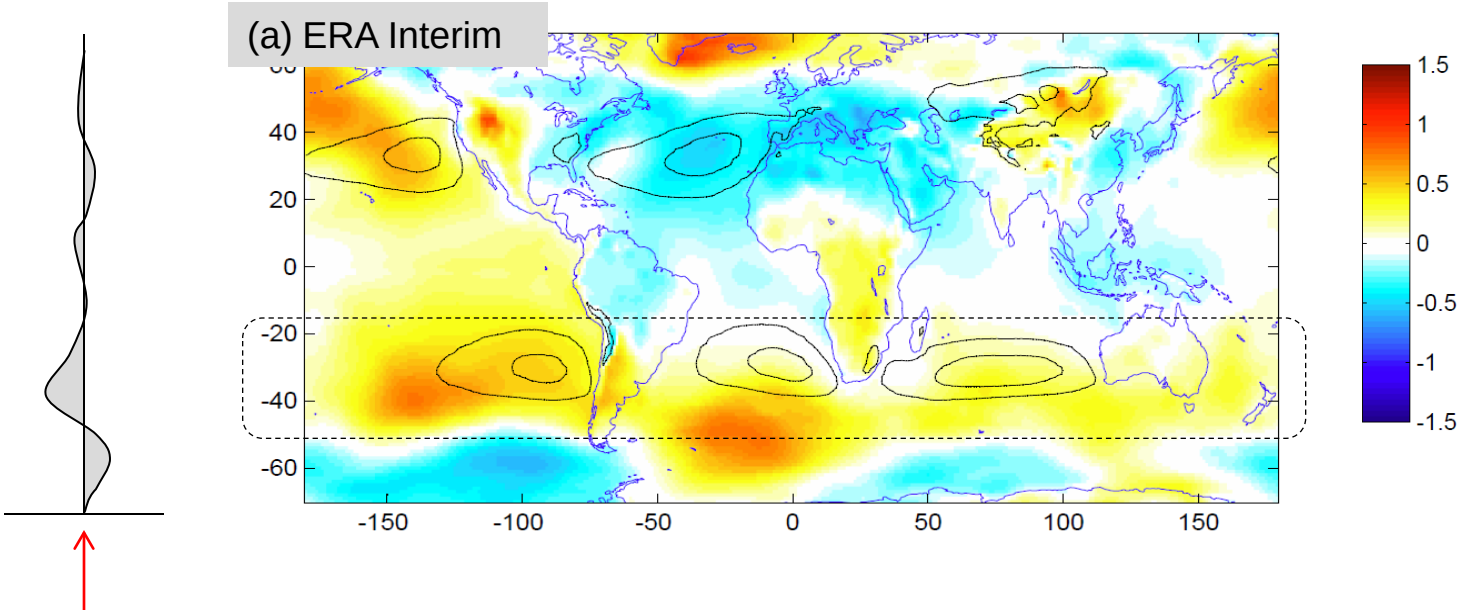




PDO time series

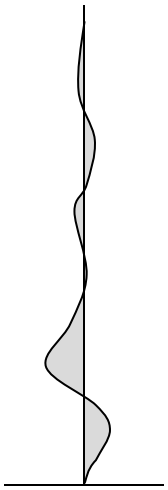
×: [δSST congruent with PDO] / [δSST observed] ≥ 0.5

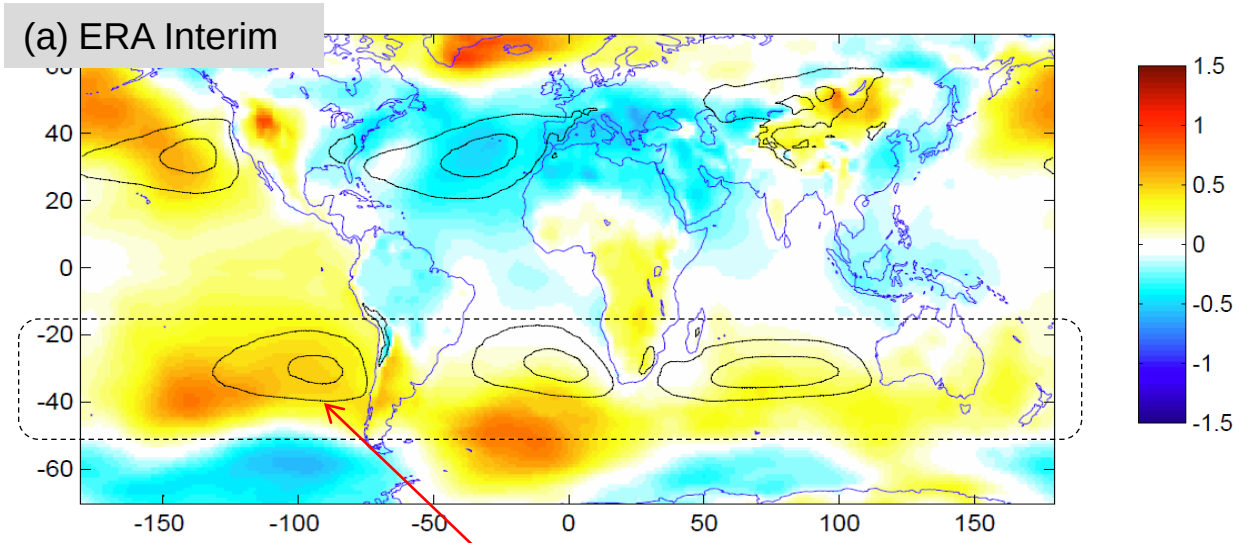
Observed SLP trends 1979-2005

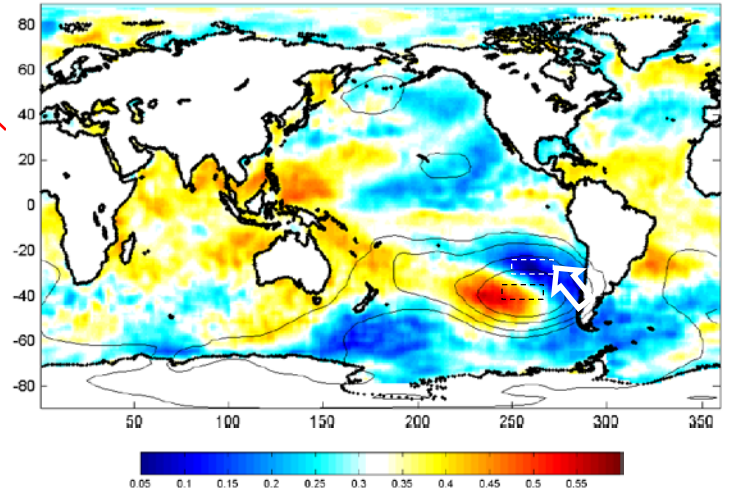


Zonally symmetric component:
increase centered at 40ºS and decrease
at higher latitudes…SAM-like pattern

Observed SLP trends 1979-2005





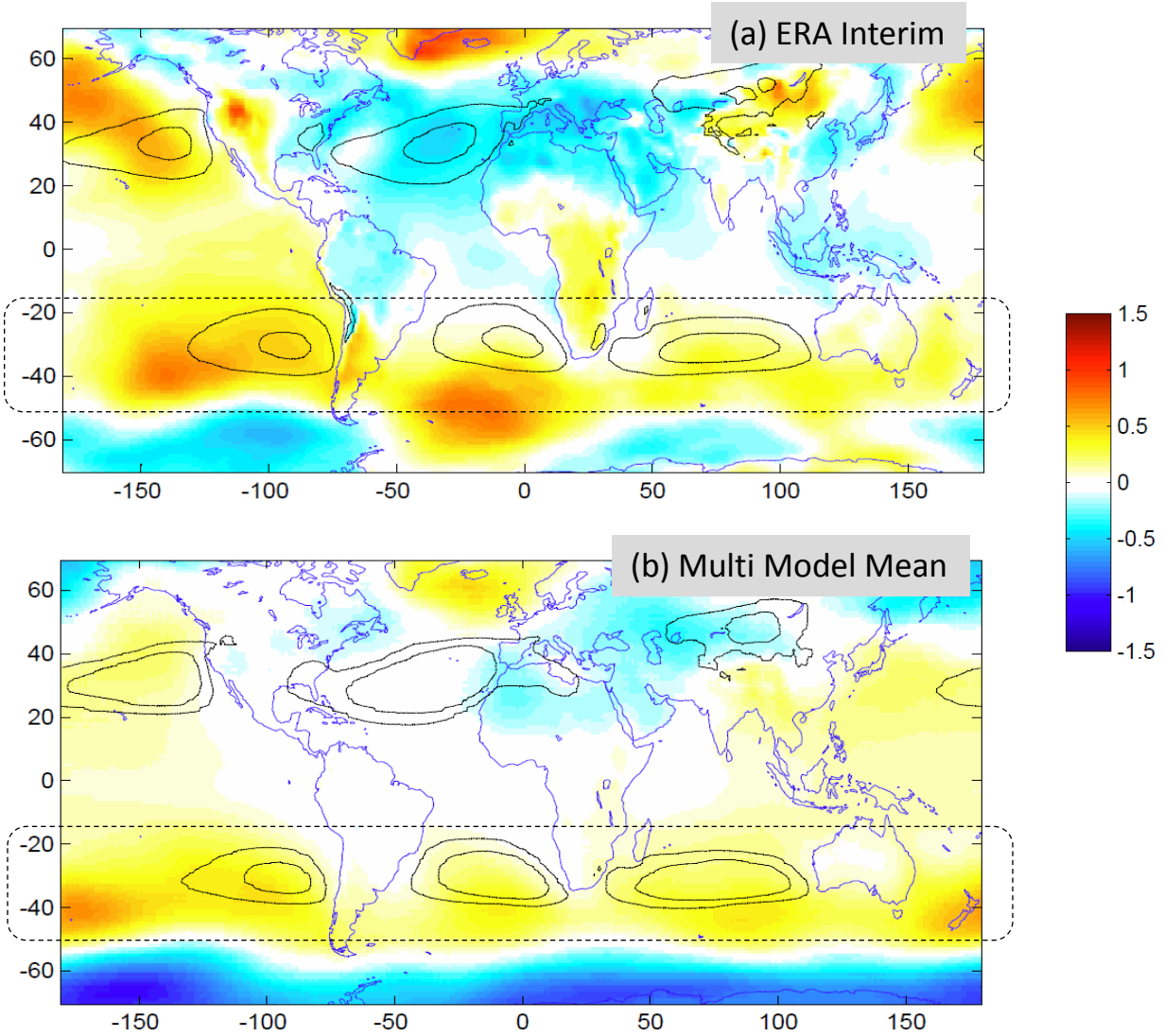


Correlation coefficients AI-OISST (colors) and AI-SLP (contours) .

Observed & CMIP-5 Simulated SLP trends 1979-2005

SAM-like trend in CMIP-5 models (RF response) projects in the observed trends, but over the SE Pacific account for about ½ of the observations

Observations: Nat. Var + RF

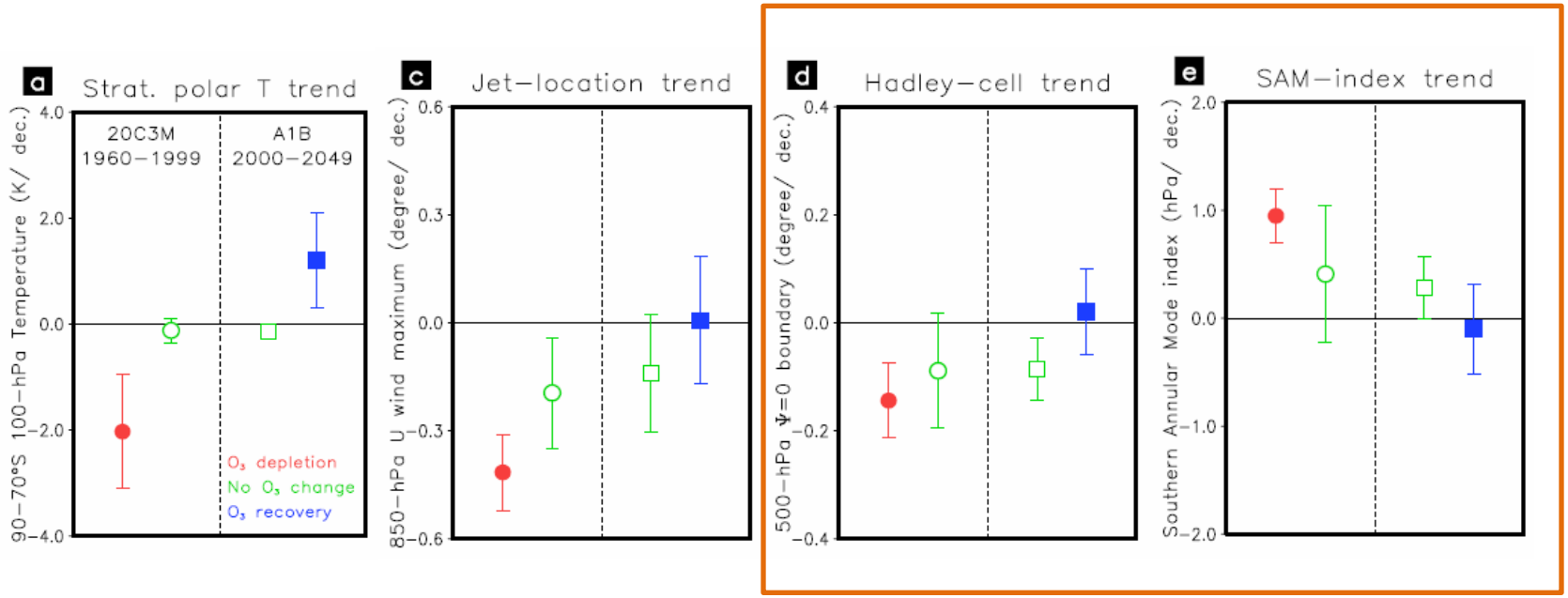


CMIP5 Multi-model mean:
Forced responce

Hadley cell expansion / SAM positive trend

Forced by GEI increase and O3 depletion.

Simulated in the recent past and near future



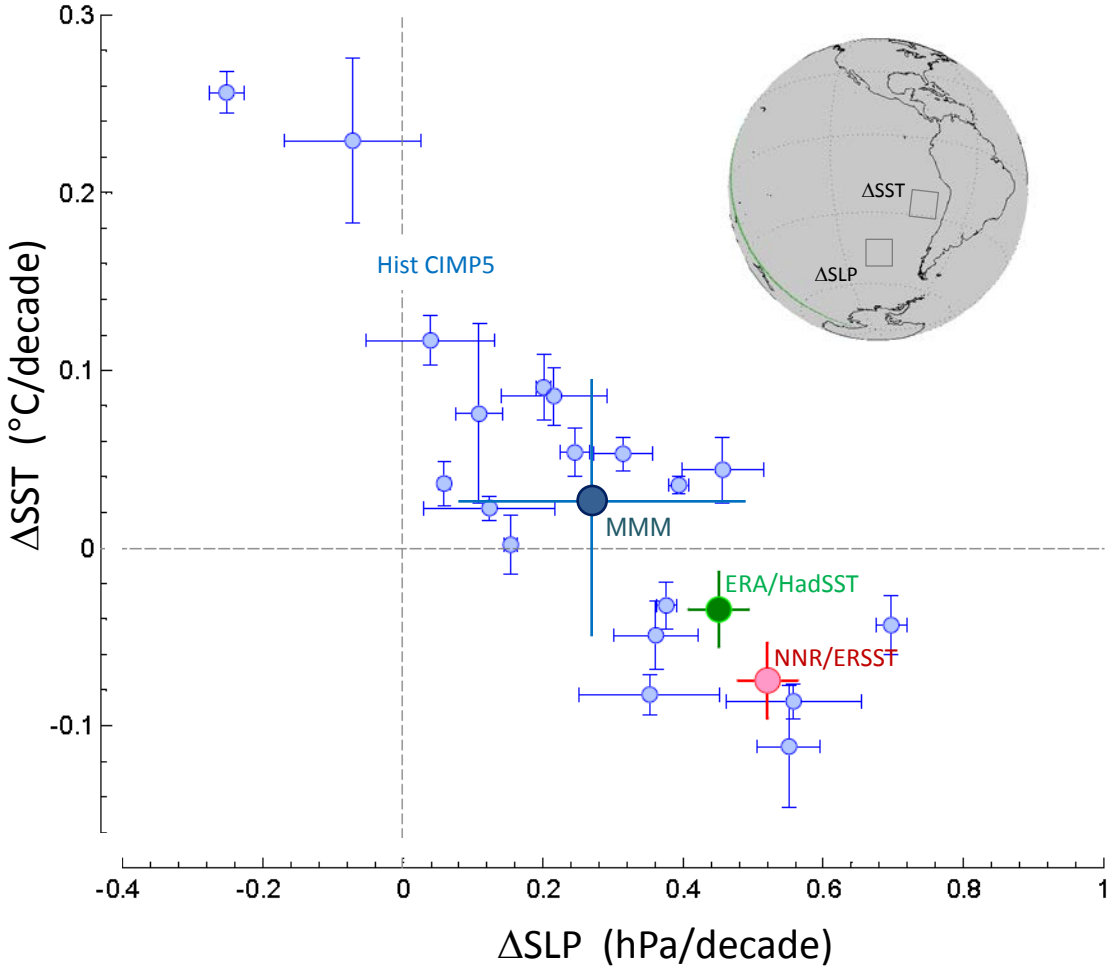
denote poleward shift in westerly jet and poleward expansion of the Hadley cell. The linear trends are computed for the time period of 1960–1999 in the 20C3M integrations (circles) and for the time period of 2000–2049 in the A1B scenario integrations (squares), and separately shown for models with (red, blue) and without time-varying stratospheric ozone (green).

Son et al, 2009. *GRL*

and many others…

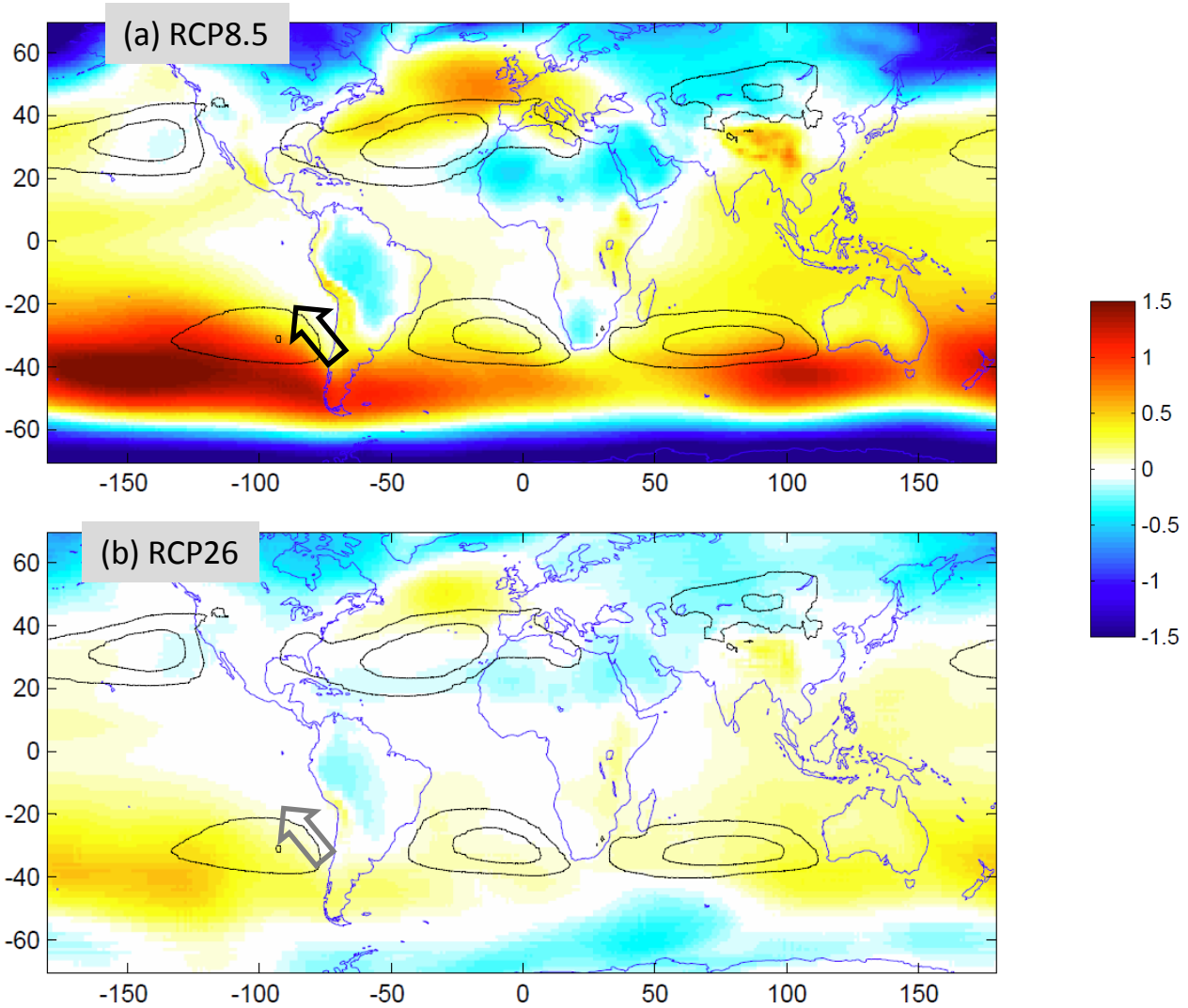
Observed and CMIP-simulated trends (1979-2005) in midlatitude ridging and SE Pacific cooling

In average, models don't get SEP cooling but…



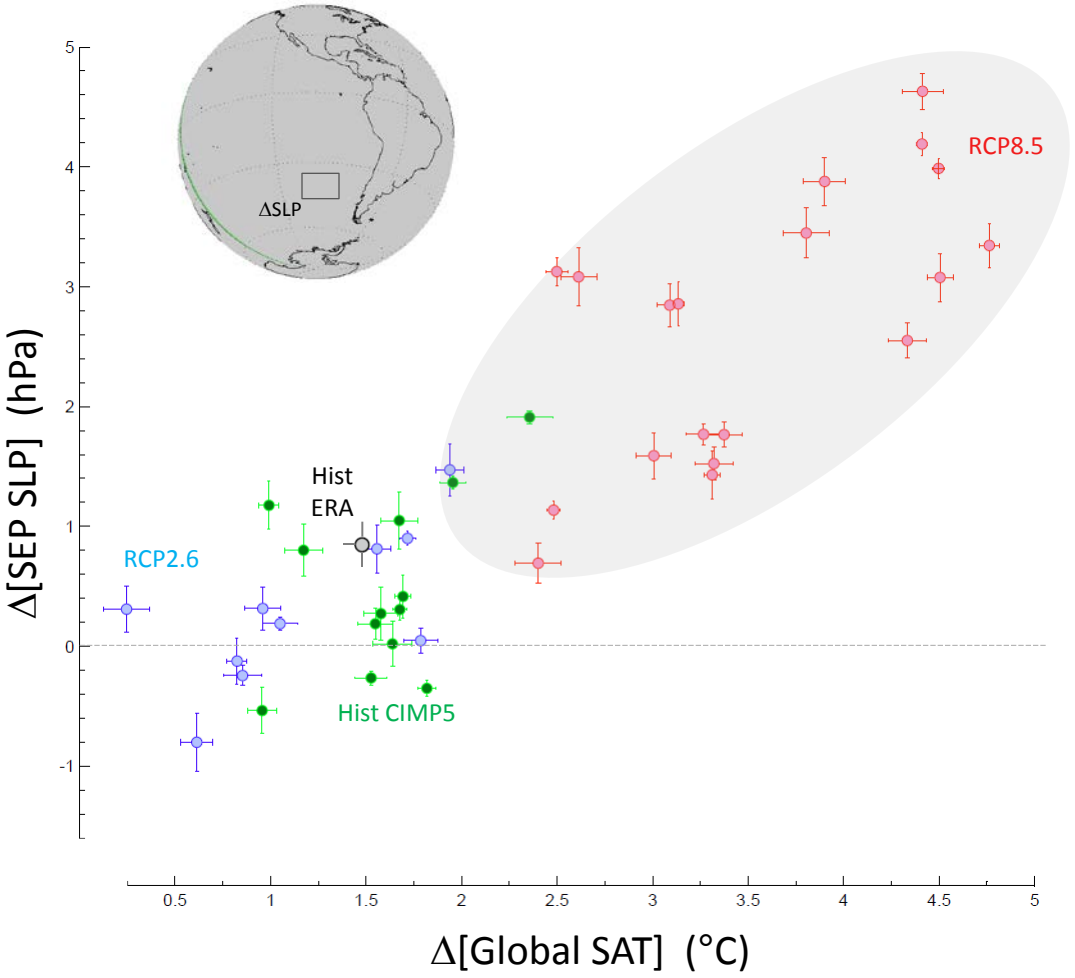
So, what's next?

Multi model mean change in SLP between end of the century and current climate



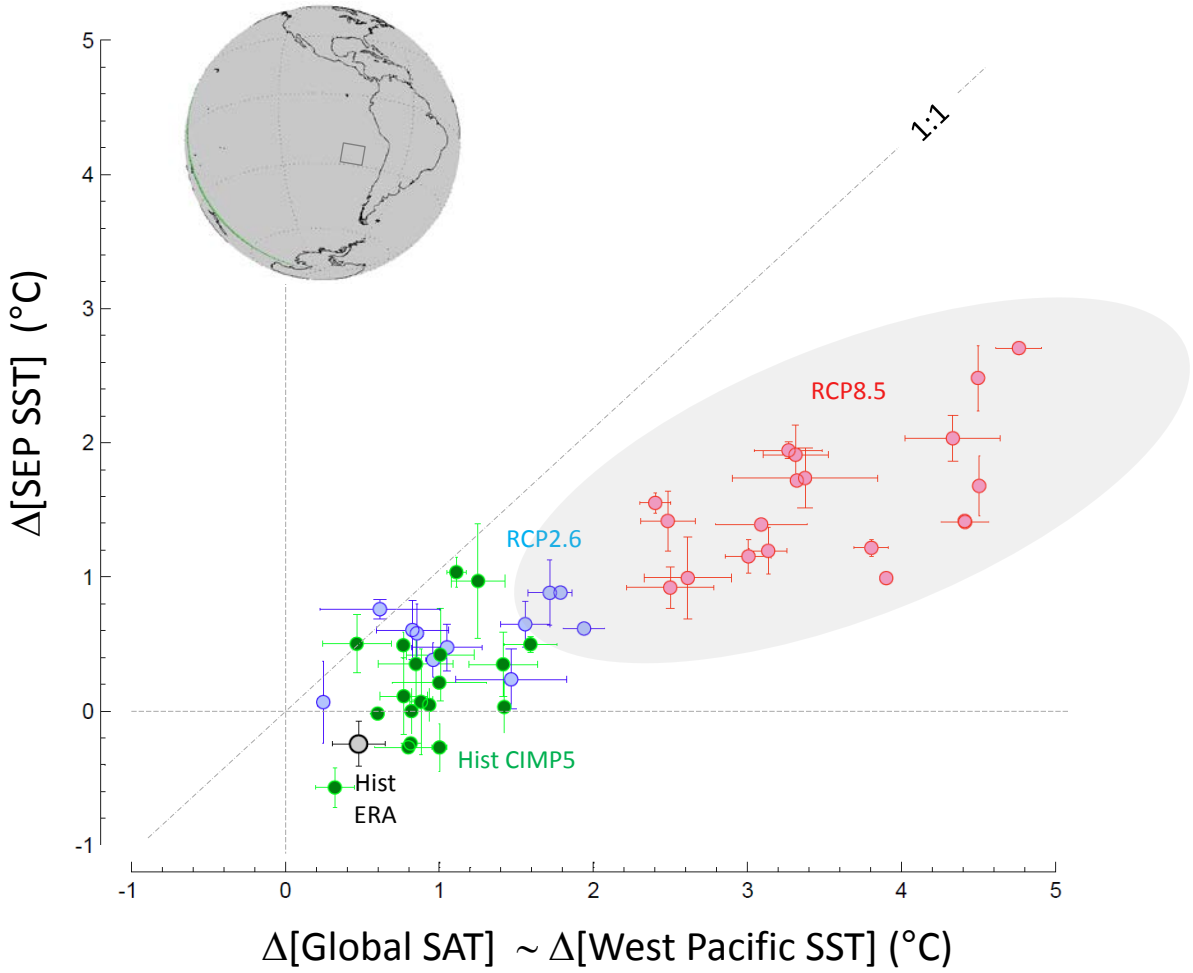
Ridging over the south Pacific increases in a warmer world

Δ= Ave(2080-2100)-Ave(1980-2000)



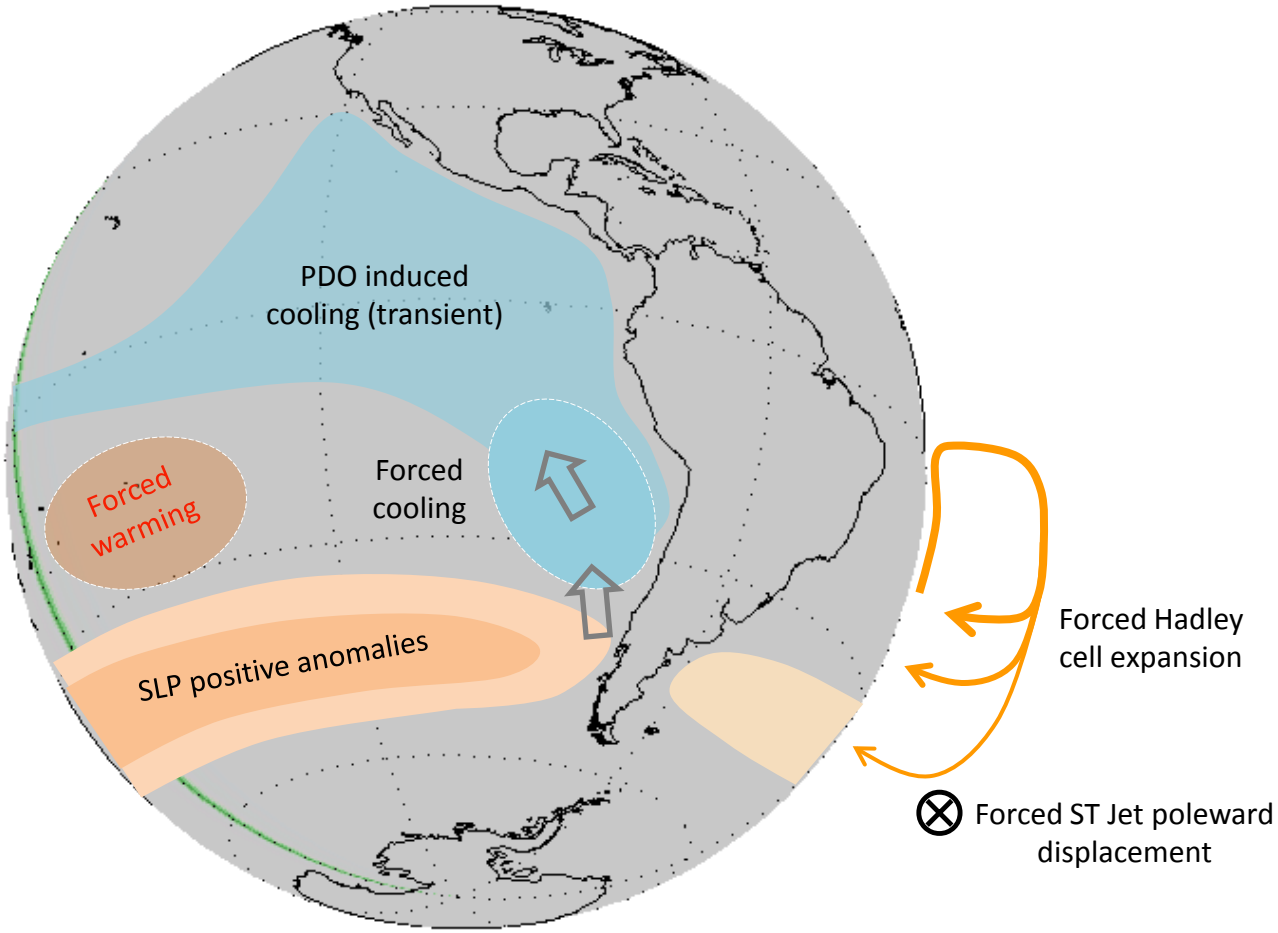
SE Pacific “less-warming” (regional cooling) continues to the end of the century

Δ= Ave(2080-2100)-Ave(1980-2000)



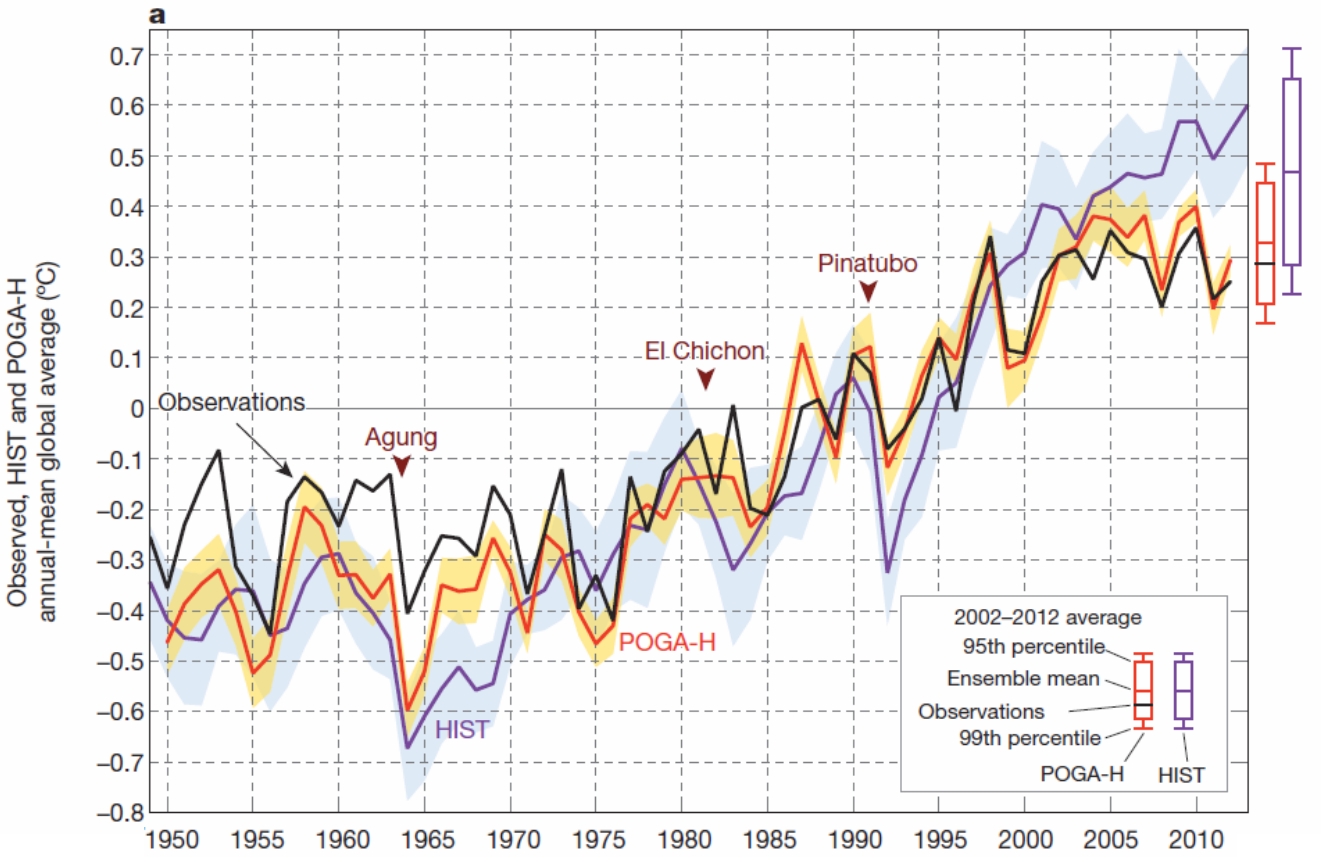
Conclusions Part II

Current cooling trend in the SE Pacific (and west coast of South America) caused by increased equatorward flow (upwelling + evaporation), which in turn results from the superposition of PDO cold phase (transient) and radiative forcing (permanent)



El golpe final…

En simulación POGA-H se prescribe SST en Pac. Central ecuatorial (8% del planeta) + forzamiento radiativo (GEI)



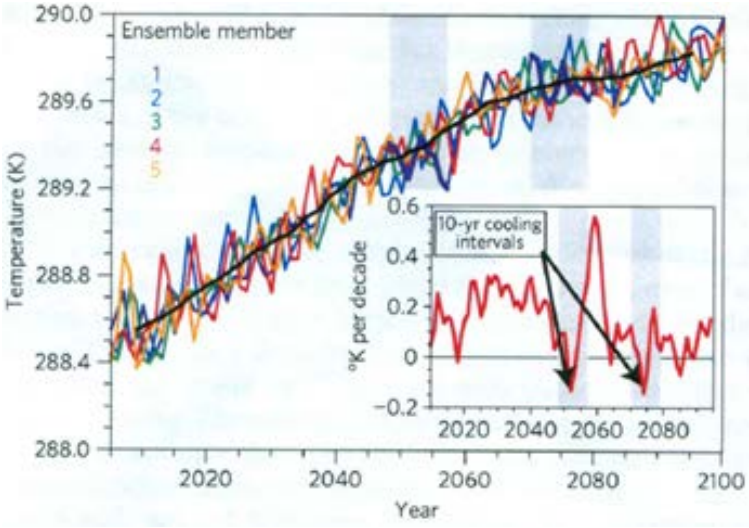
Kosaka and Xie, 2013. *Nature Climate Change*

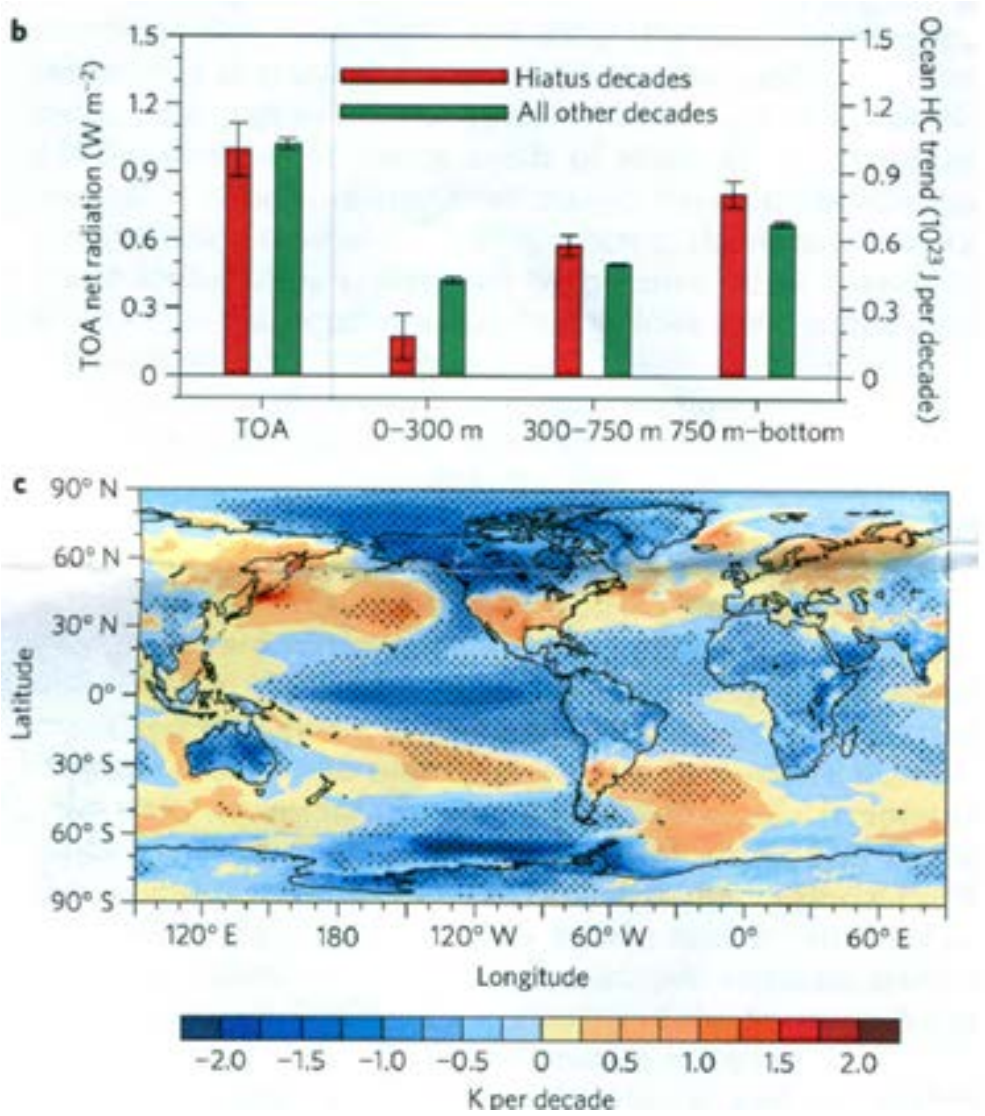

AZZARA
CHILE
RED


Fly
Emirates

Hiatos en los modelos de clima futuro

Future climate model simulation:
Look for Hiatus decade…



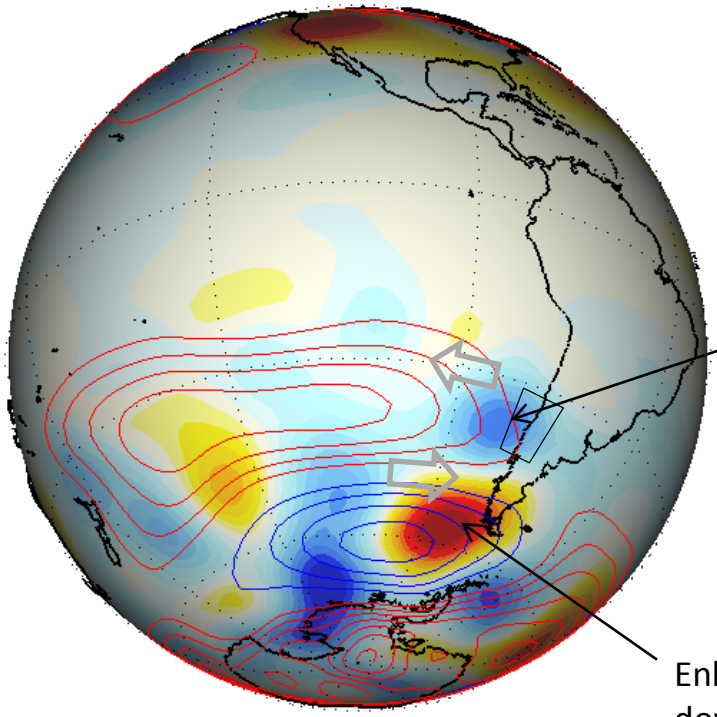


Meehl et al. 2011. *Nature Climate Change*

Large-scale context for central Chile droughts

Drought composite

Mean Z500 anomalies (contours)
Std Z500 anomalies (colors)



Reduced variability downstream of anomalous ridge

Enhaned variability downstream of anomalous trough