Climate Predictability at Decadal Scale in Chile

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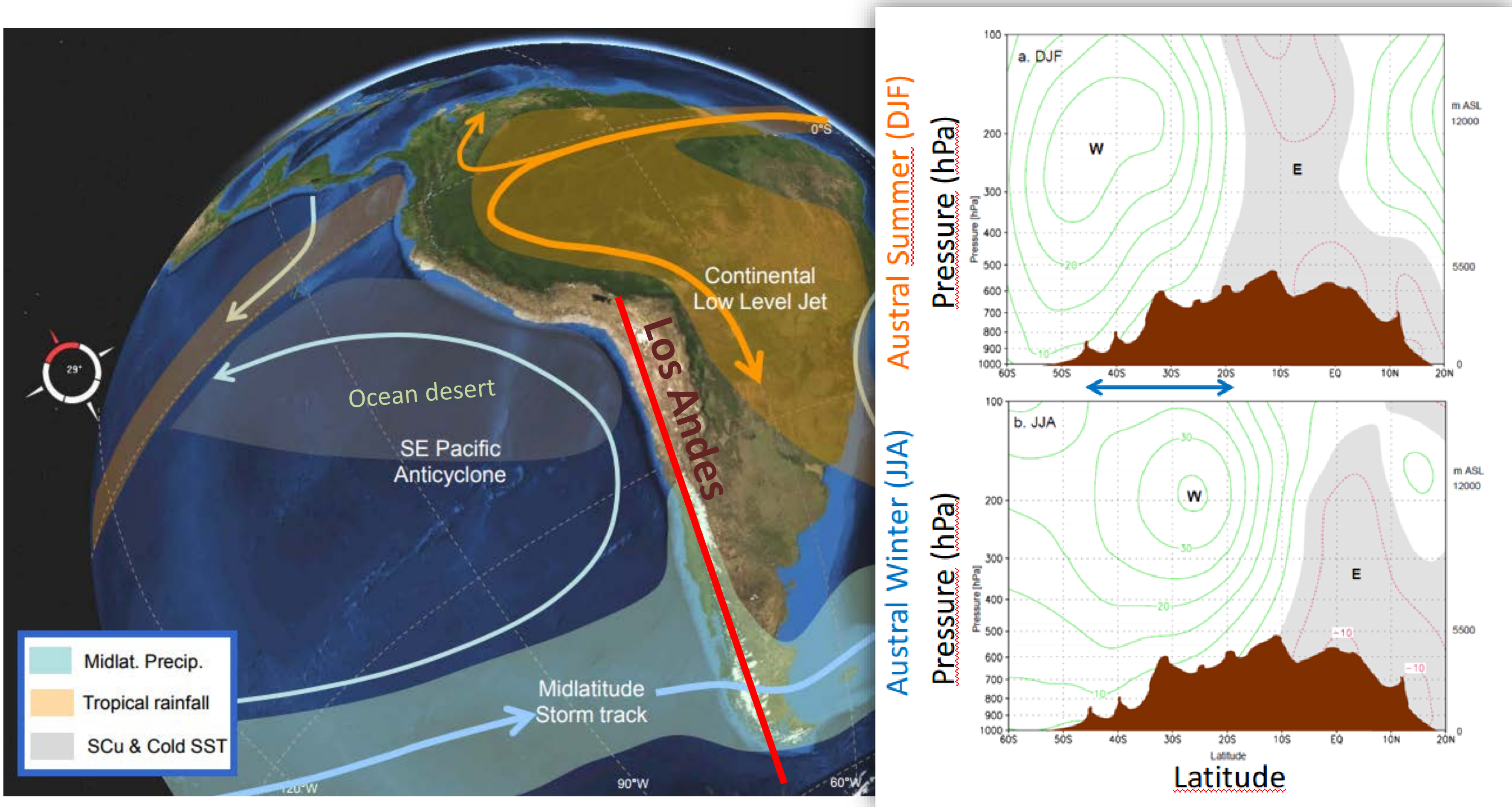
General overview of climate features in Chile

- Southern Hemisphere, west coast of South America
- Bound by the Andes mountain range to the east and Pacific Ocean to the west
- Long and narrow country, most of the population in central zone
- Differents climate patterns along and across (height, proximity to the sea and insolation)

General overview of climate features in Chile

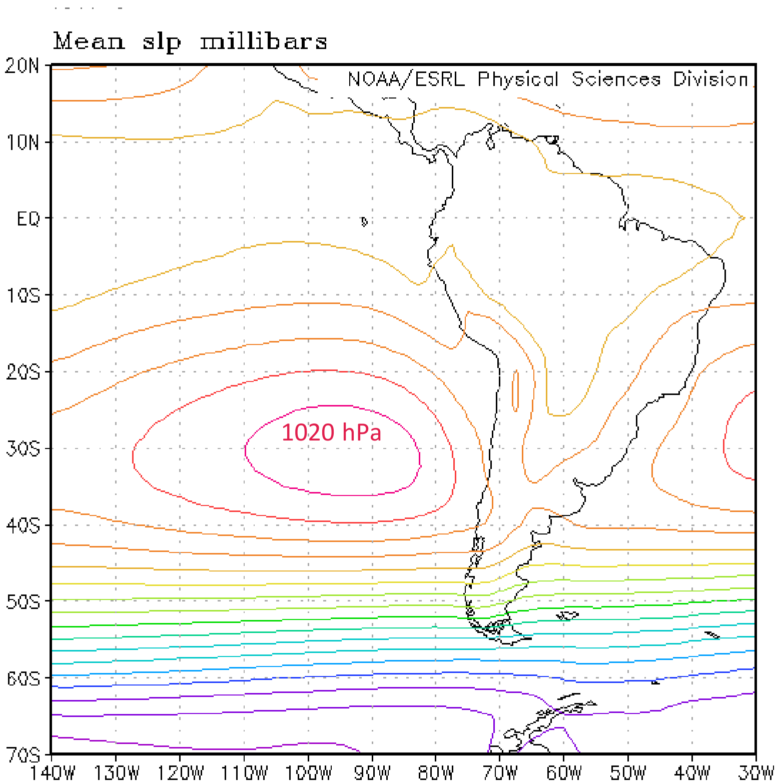


Modificadas de Garreaud (2009) and Barrett *et al*. (2011)

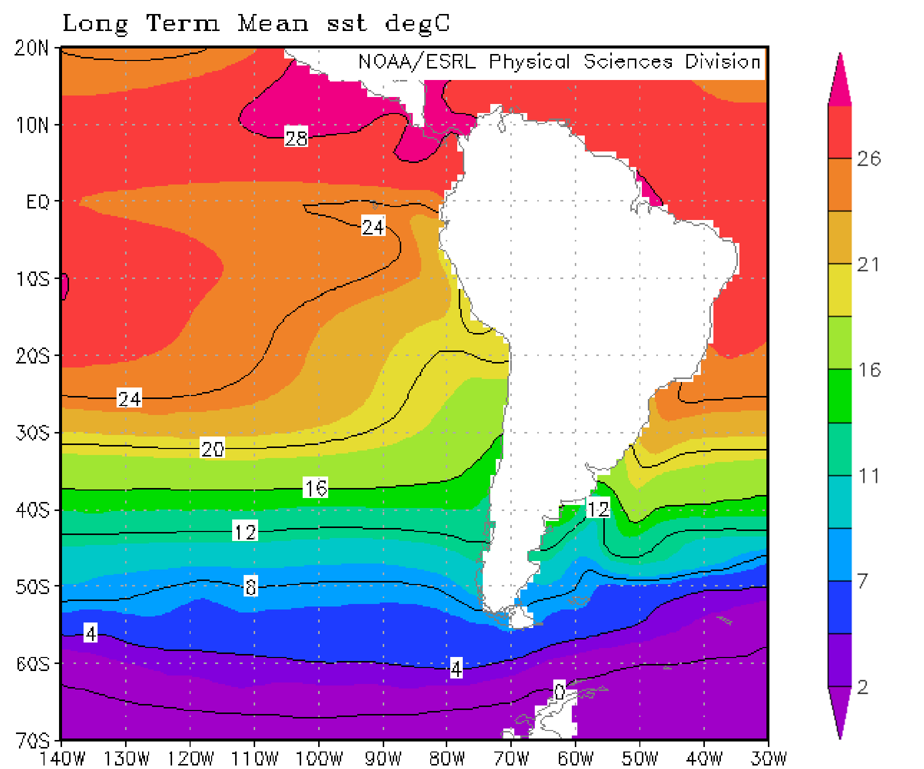
General overview of climate features in Chile

<u>Main Los Andes efects:</u>

- Anticyclone location (enhanced subsidence)
- Cold tongue SST

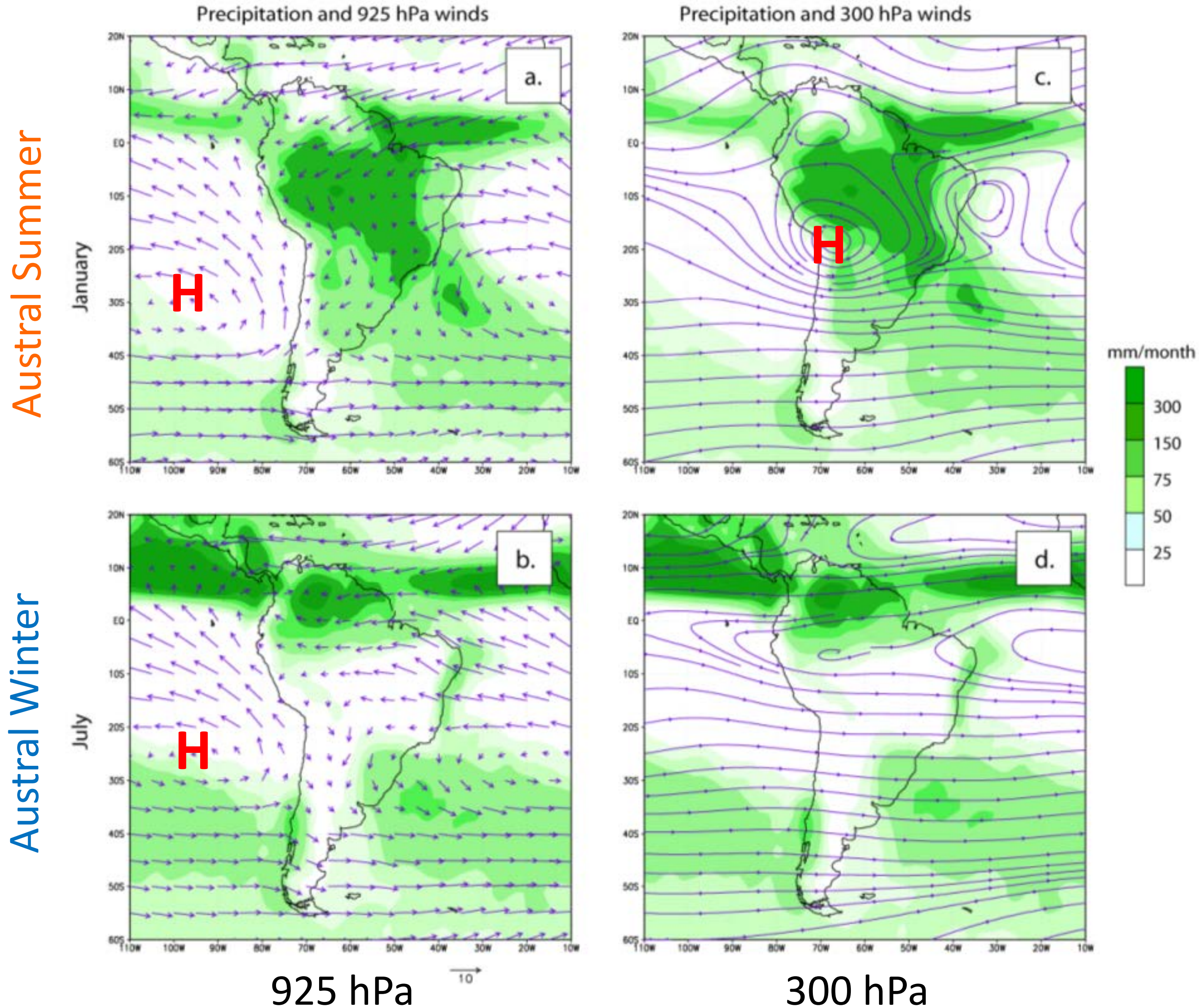


SLP long term mean - *NCEP Reanálysis*



SST long term mean – NOAA Optumum Interpolation (OI)

General overview of climate features in Chile



Main Los Andes efects:

- Southeast Pacific Subtropical Anticyclone (SPSA)
- Seasonal Changes of SPSA
- Precipitation Assymetry (zonal and meridional)
- Bolivian High modulate precipitation over the Chilean Altiplano, only for summer season (DJF).

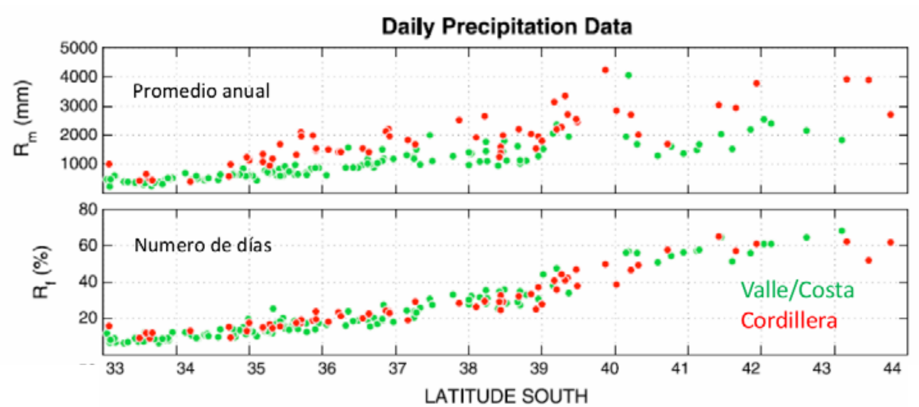
Garreaud *et al.*, 2007

General overview of climate features in Chile

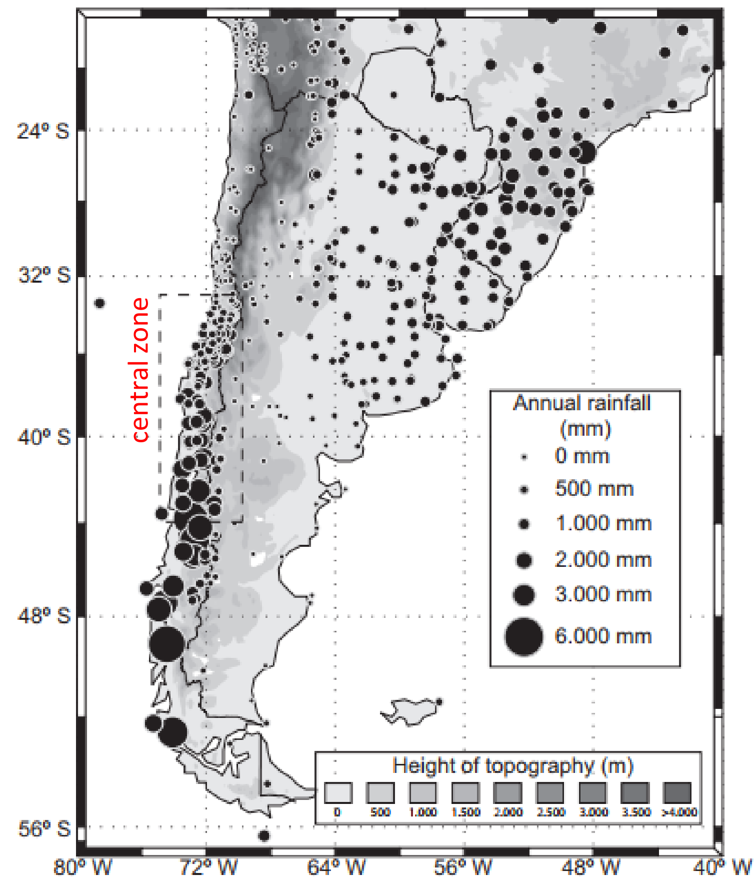
- Maximum precipitacion over Austral zone (NS assymetry), related to storm track position and SPSA.

- Zonal assymetry for topography effect

TP = Extratropical cyclons **+** orographic precipitation

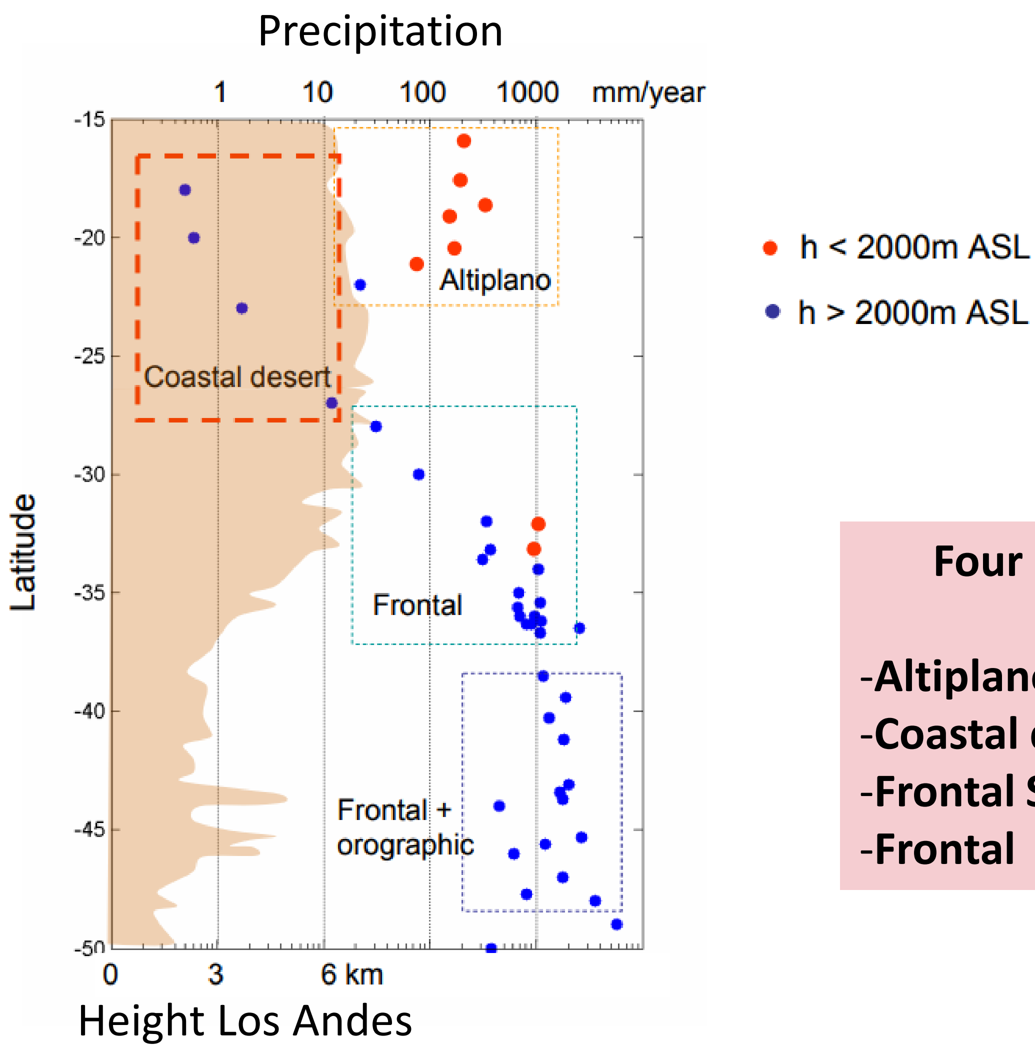


Viale y Garreaud, *2015*



Quintana y Aceituno, *2011*

General overview of climate features in Chile



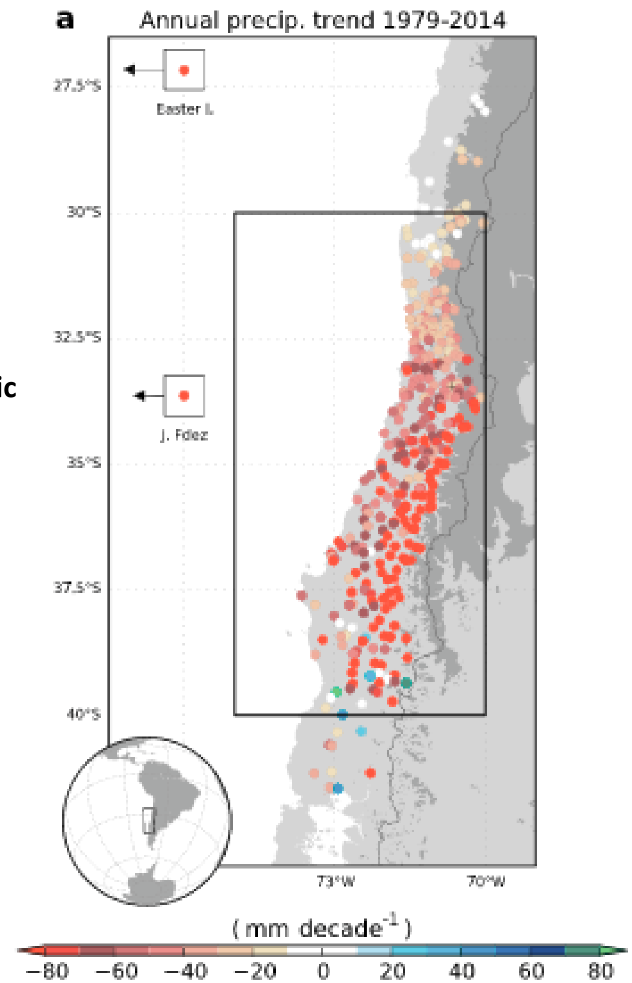
Four precipitation patterns

-Altiplano
-Coastal desert
-Frontal Systems
-Frontal Systems + Orographic

Garreaud, 2005 (http://www.dgf.uchile.cl/rene/PRES/Concord_DGF.pdf)

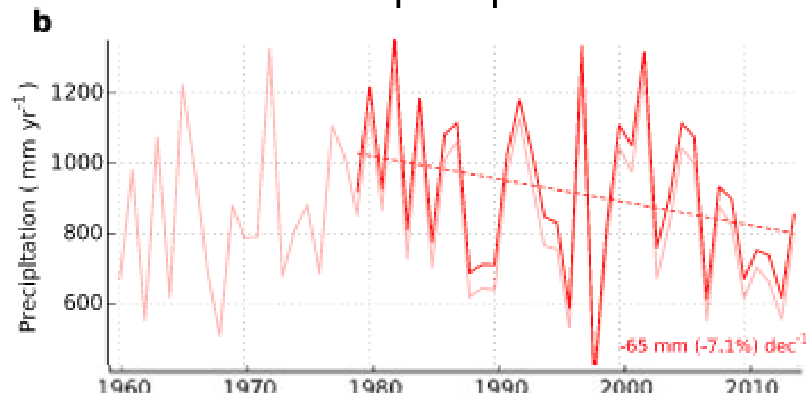
General overview of climate features in Chile

Frontal + orographic



Trend 1979 - 2014

Central-south precipitation mean



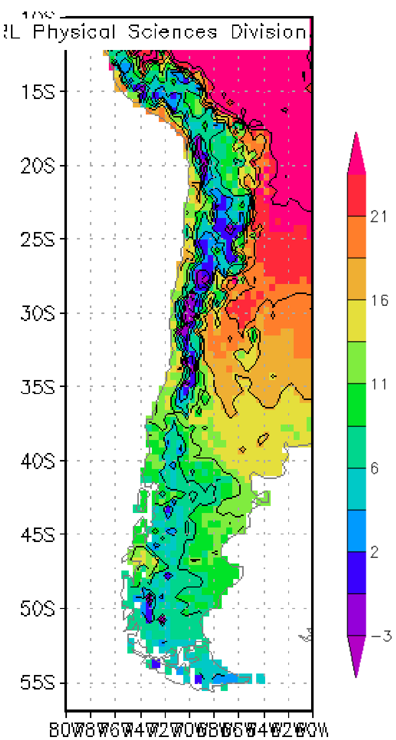
Internal / natural variability or external forcings?

First let's see the temperature!

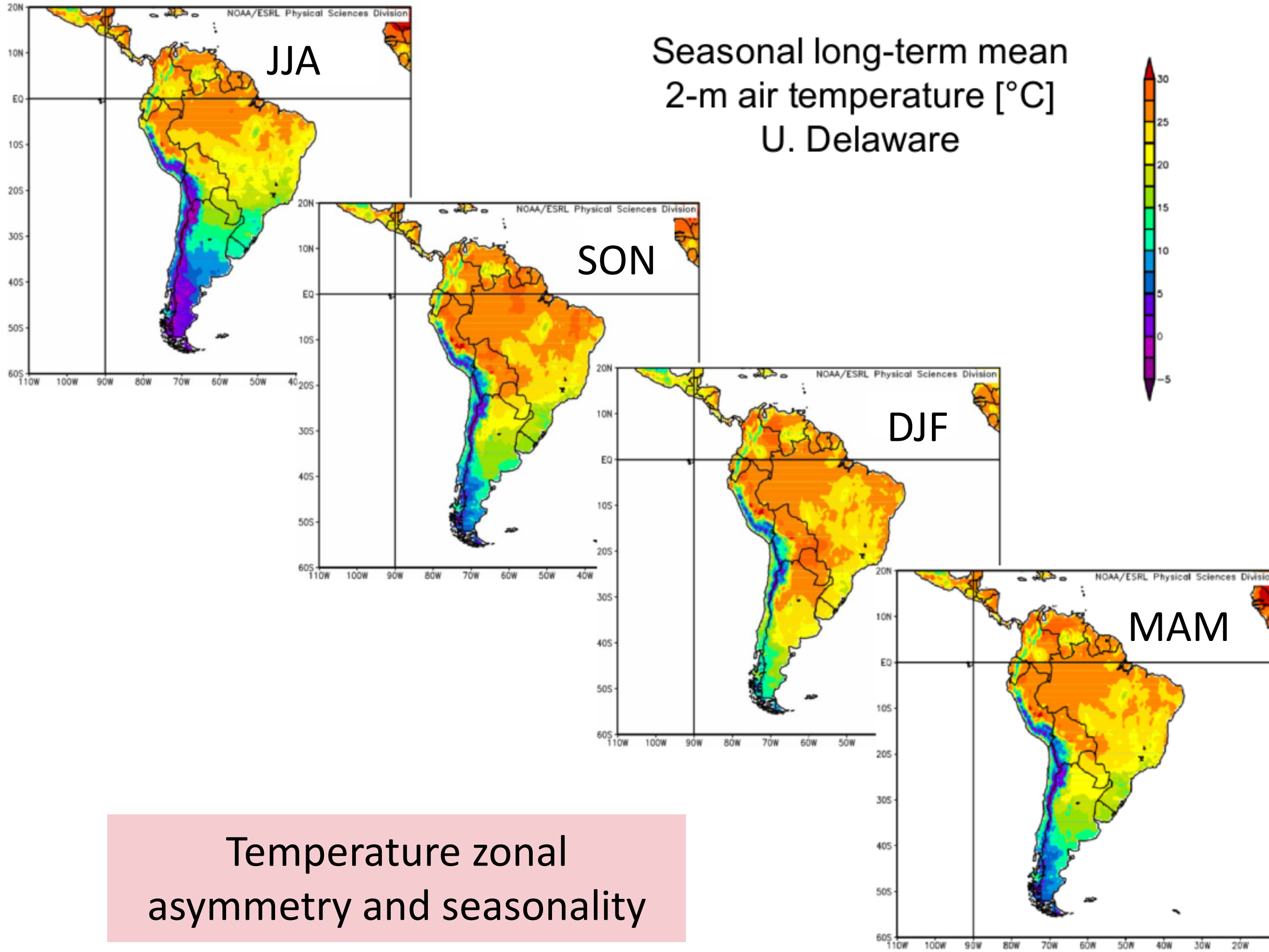
Boisier *et al., 2016*

General overview of climate features in Chile

Temperature patterns over SA



Seasonal long-term mean
2-m air temperature [°C]
U. Delaware



Temperature zonal asymmetry and seasonality

General overview of climate features in Chile

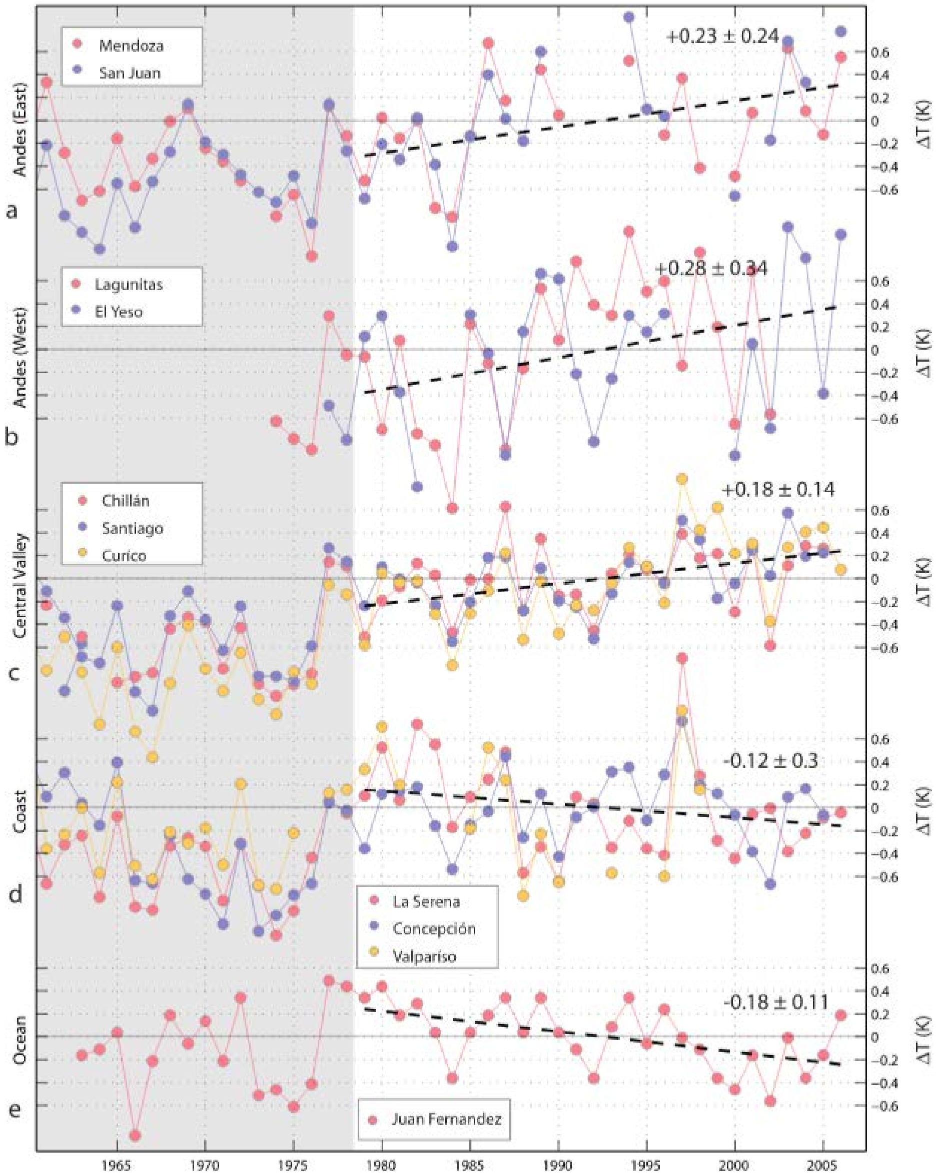
Andes (East)

Andes (West)

Central Valley

Coast

Ocean



Years

Changes in local temperature.

Andes (east and west) and central valley are warming

Coast and South-East Pacific Ocean is cooling

Andes warming is strongest

Internal / natural variability or external forcings?

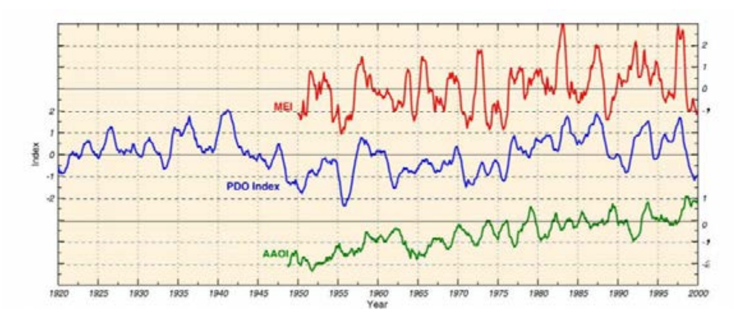
Falvey y Garreaud, *2009*

Influence of internal and external climate variability

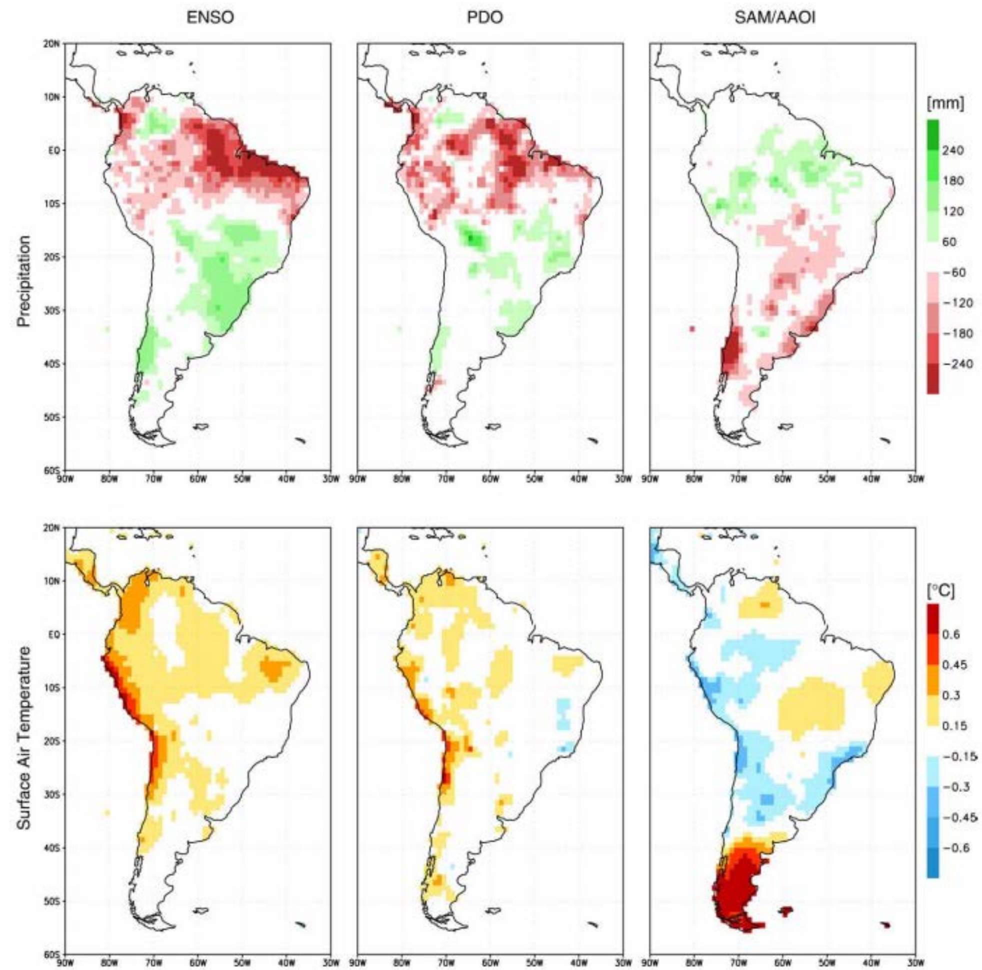
Internal/natural variability

Precipitation
Central-south zone

Temperature
South (SAM) and coastal north zone (PDO and ENSO)



ENSO – PDO – AAO/SAM

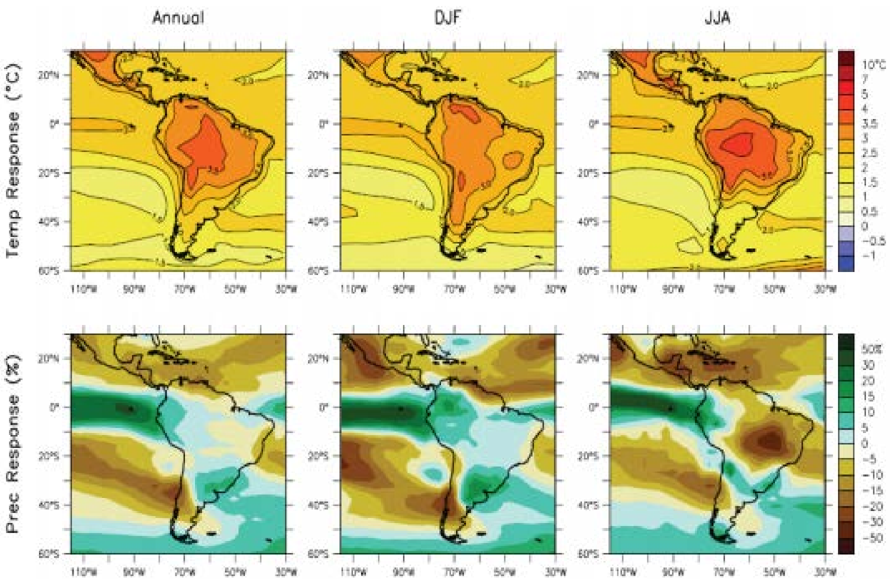


Annual mean Precip/SAT regressed upon index of large-scale modes (50 years of data)

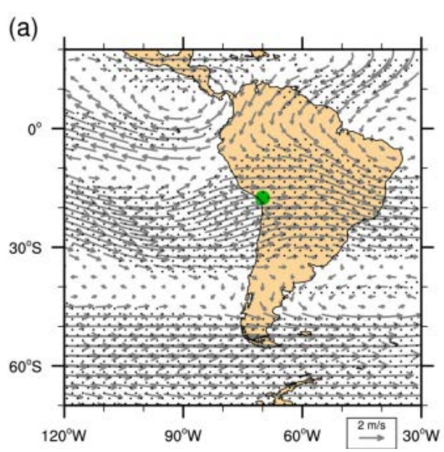
Garreaud et al. 2002

Influence of internal and external climate variability

External forcing variability

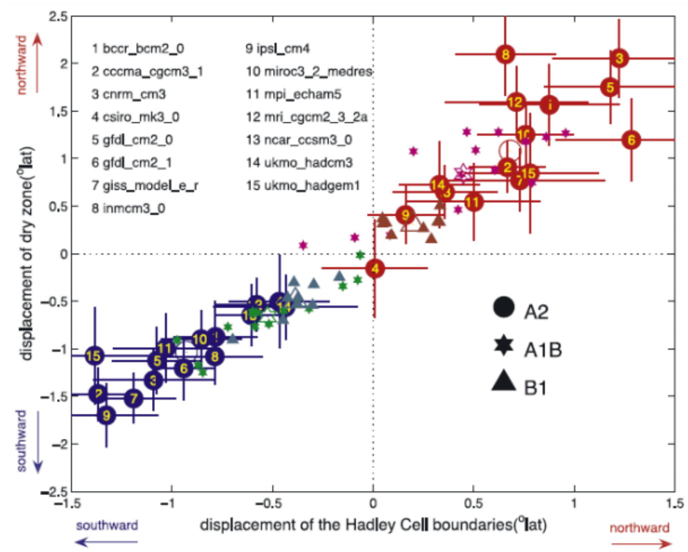


IPCC 2007: WG1-AR4 (2007) (A2 - BL)



200 hPa wind, summer

Less precipitation and higher temperature is consistent with the Hadley expansion



Lu *et al., 2009*

Influence of internal and external climate variability

¿Internal variability vs external forcing?

ENSO PDO/IPO SAM	Hadley cell expansion Strengthening of SPSA Increase of upwelling

Both!

Let's see an example…

The current Mega Drought

Is the future now?

• Uninterrupted sequence of 8 dry years (25-45% anomalies)
• Reached farther south than previous droughts
• Warm decade anomaly in central Valleys (~1°C)

Central-southern Chile :

- Most important cities are there
- About 9 millons inhabitants
- Agricultural and wine industry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The 2010–2015 megadrought in central Chile: impacts on regional hydroclimate and vegetation

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Geophysical Research Letters
RESEARCH LETTER
10.1002/2015GL067265

Key Points:
• Evidence of an anthropogenic contribution to the drying trend in central Chile
• Anthropogenic forcing explains about a quarter of the 2010–2014 drought in central Chile
• Major PDO effect on the recent large-scale circulation and South Pacific precipitation trends

Supporting Information:
• Text S1, Table S1, and Figures S1–S4

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Citation:
Boisier, J. P., R. Rondanelli, R. D. Garreaud, and F. Muñoz (2016), Anthropogenic and natural contributions to the Southeast Pacific

Anthropogenic and natural contributions to the Southeast Pacific precipitation decline and recent megadrought in central Chile

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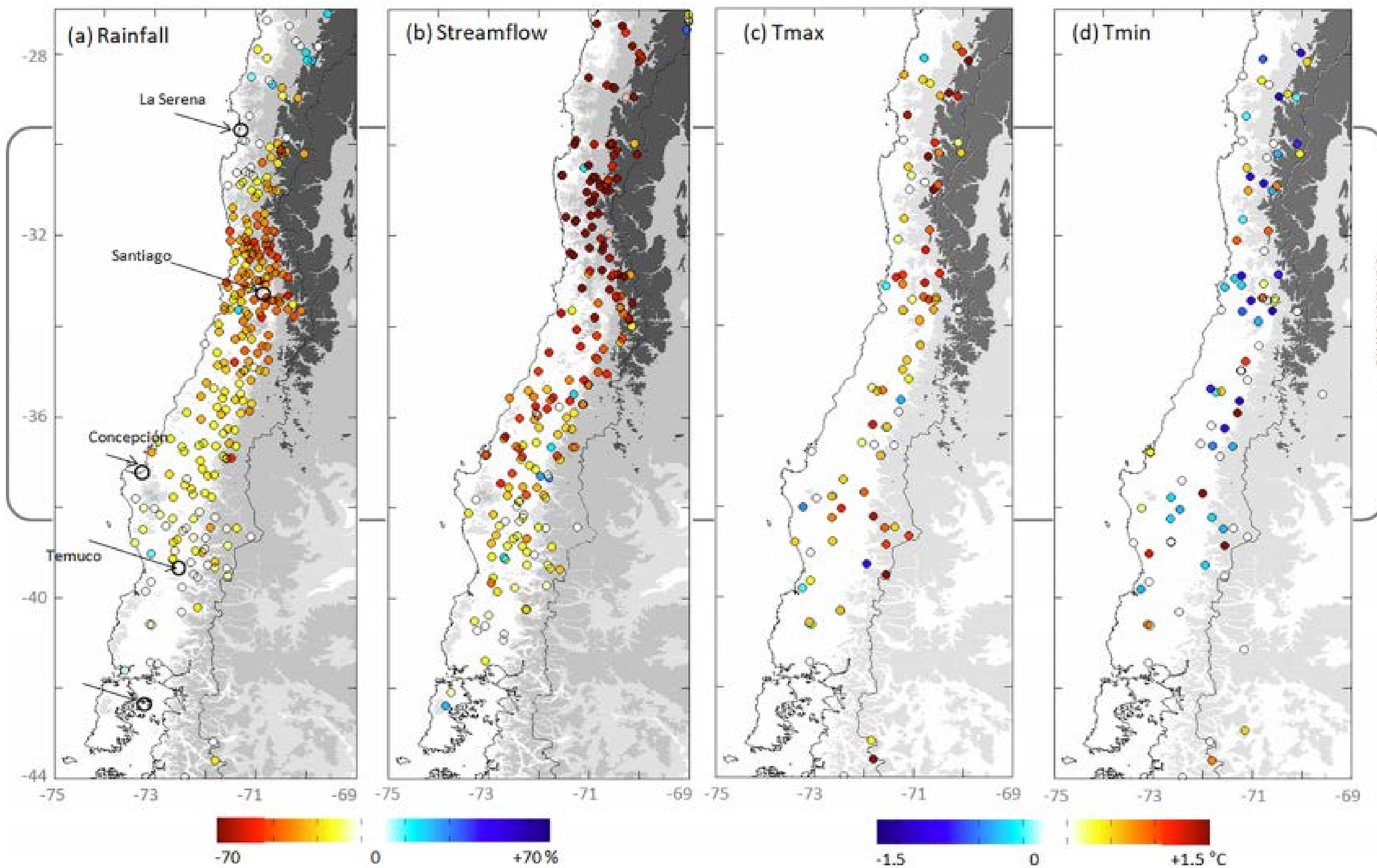
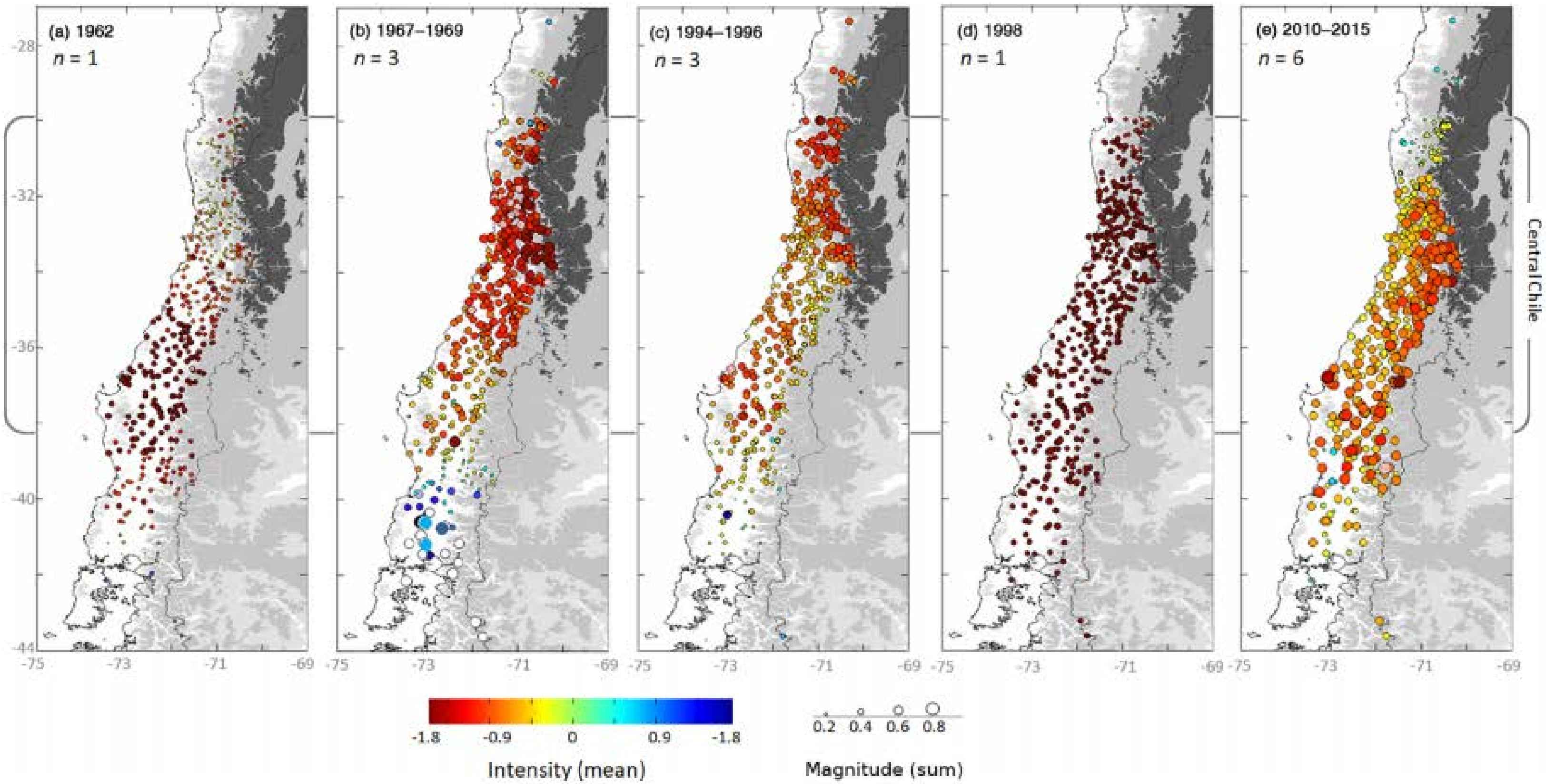
Abstract Within large uncertainties in the precipitation response to greenhouse gas forcing, the Southeast Pacific drying stands out as a robust signature within climate models. A precipitation decline, of consistent direction but of larger amplitude than obtained in simulations with historical climate forcing, has been observed in central Chile since the late 1970s. To attribute the causes of this trend, we analyze local rain gauge data and contrast them to a large ensemble of both fully coupled and sea surface temperature-forced simulations. We show that in concomitance with large-scale circulation changes, the Pacific Decadal Oscillation explains about half of the precipitation trend observed in central Chile. The remaining fraction is unlikely to be driven exclusively by natural phenomena but rather consistent with the simulated regional effect of anthropogenic climate change. We particularly estimate that a quarter of the rainfall deficit affecting this region since 2010 is of anthropogenic origin. An increased persistence and recurrence of droughts in central Chile emerges then as a realistic scenario under the current socioeconomic pathway.

The current Mega Drought



Garreaud et al. 2017

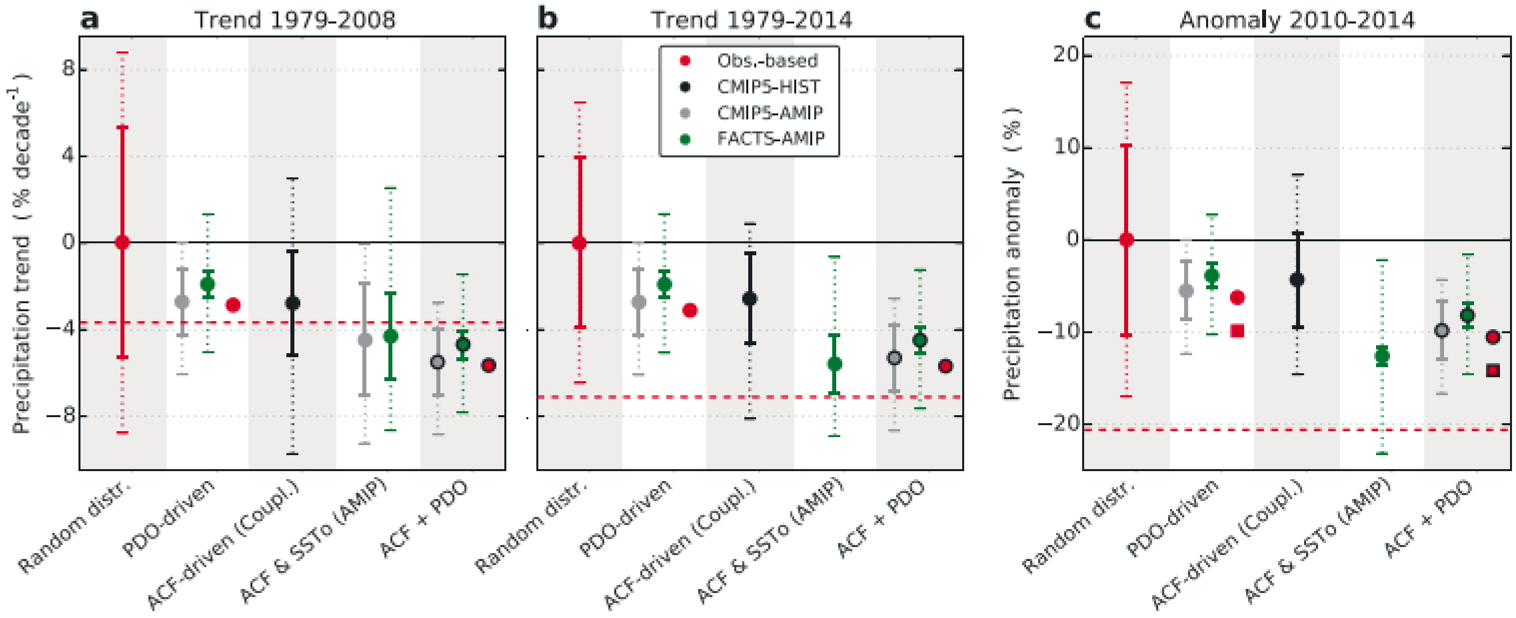
The current Mega Drought



Garreaud et al. 2017

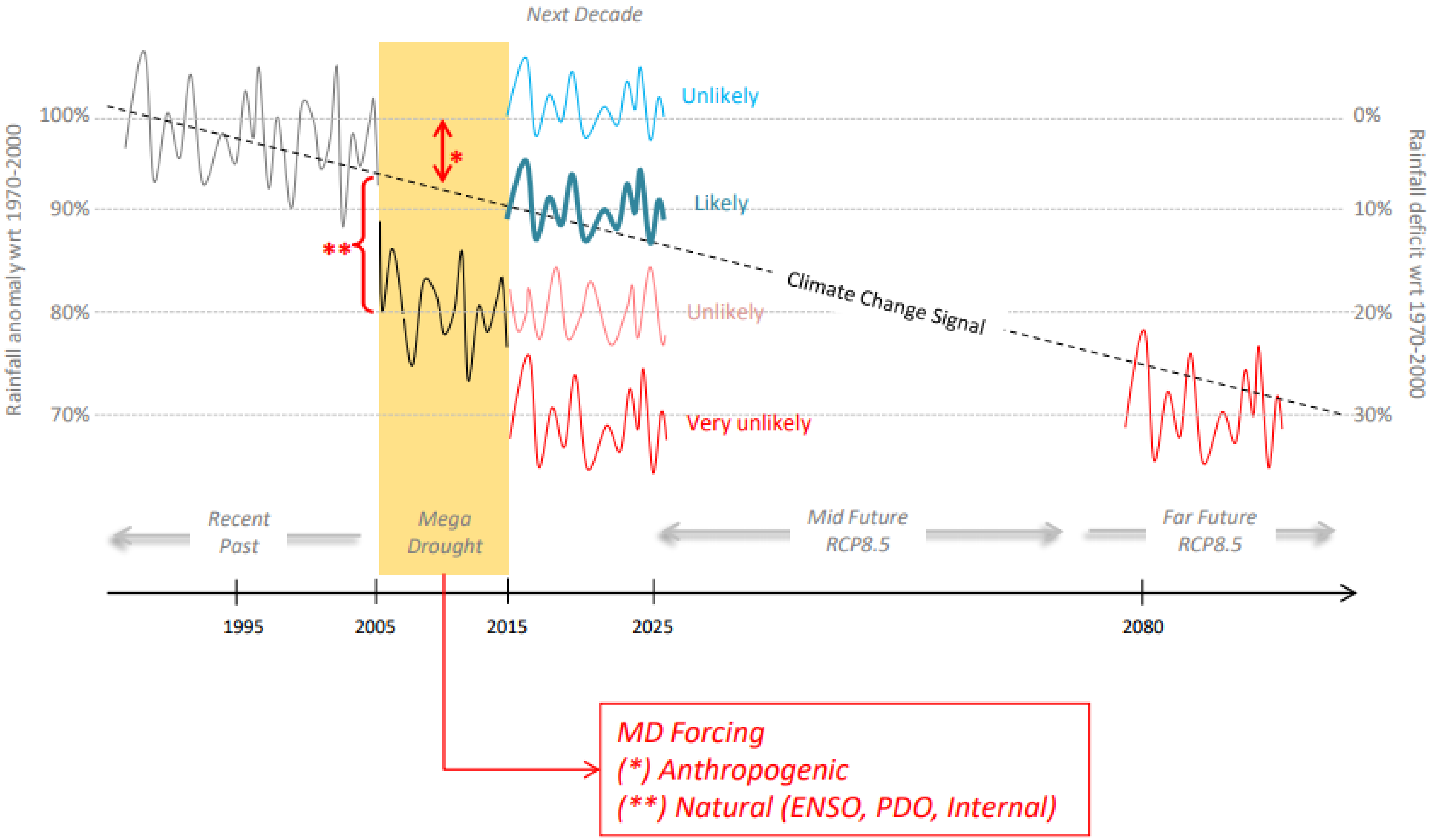
The current Mega Drought

Natural variability (PDO) ¼ + Antropogenic Climate Forcing ¼ = ½ Megadrought



Boisier et al., 2015

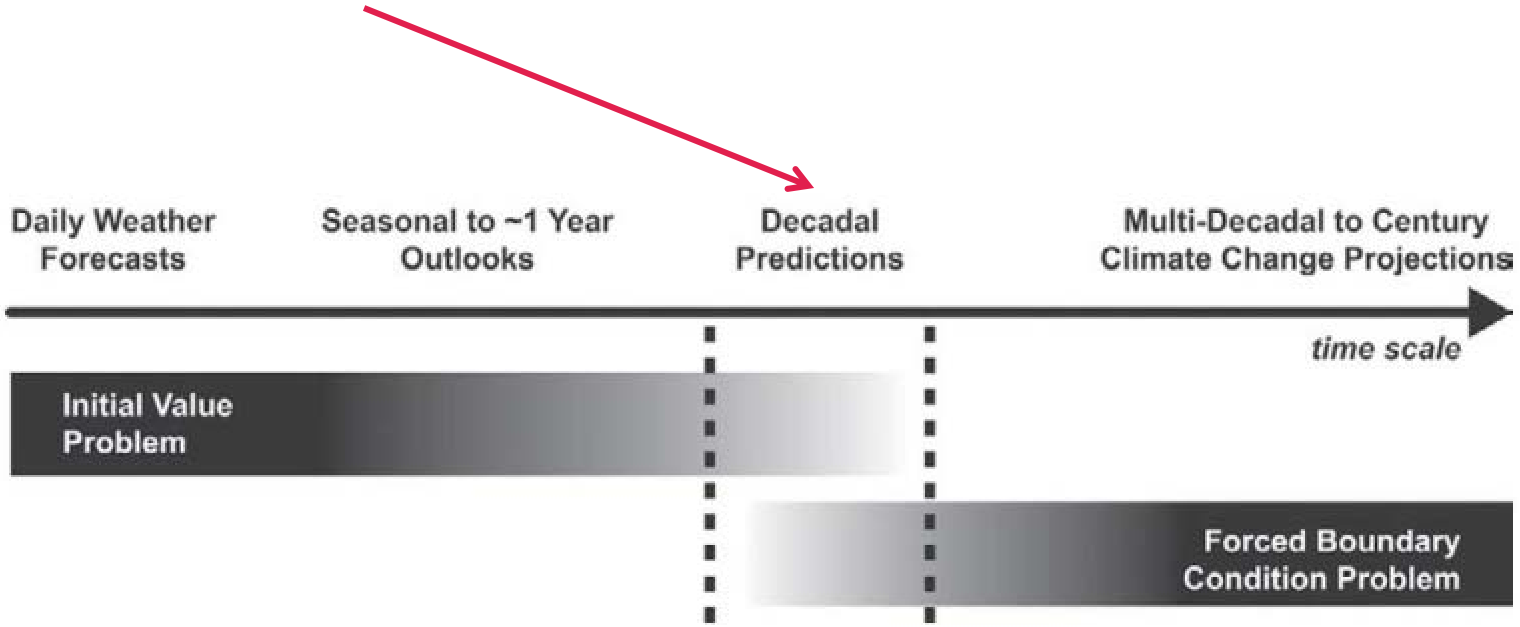
The current Mega Drought



Why decadal predictions?

How can it help?

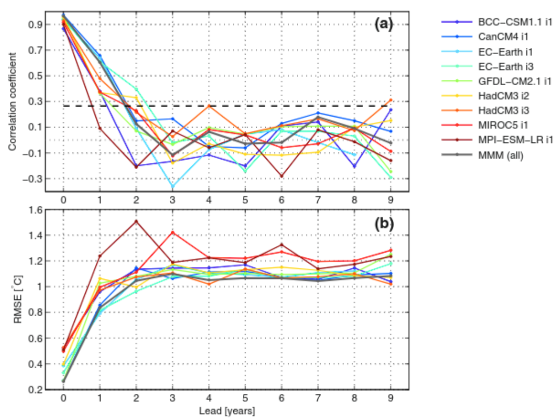
Predictability of Chilean Climate = External forcings + Natural variability



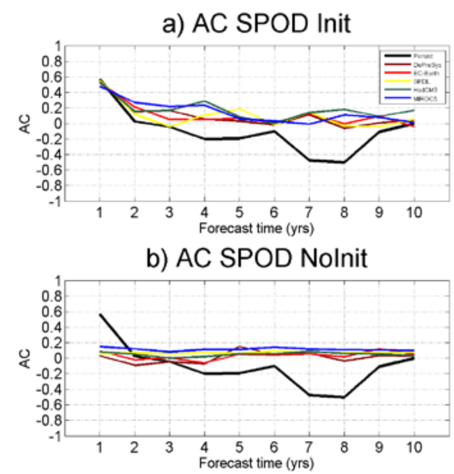
Meehl et al., 2009

Why decadal predictions?

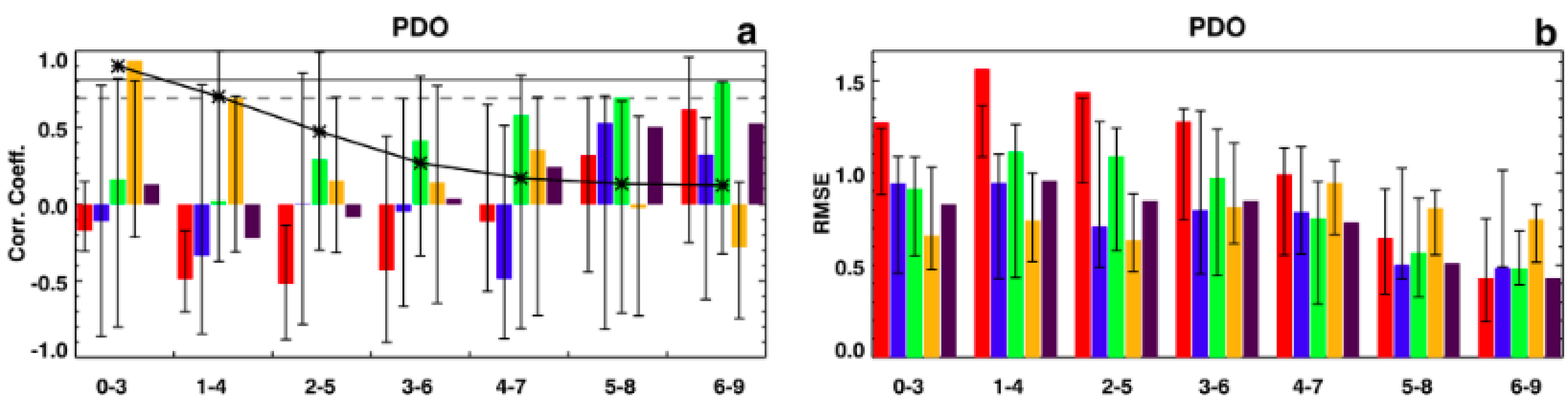
Decadal prediction in South America



Gonzalez and Goddard*, 2015*



Saurral *et al., 2018*



Mehta *et al., 2018*

Introduction: Objectives of my work

Main objective

Examine the predictability of temperature and precipitation at decadal scales in Chile.

Specific objectives

- Evaluate the performance of historical simulation to represent typical climate patterns in Chile.

- Evaluate the impact of the initialization of the models comparing the forecast quality of historical simulations with decadal predictions.

- Apply predictability analysis on Chile: temperature and precipitation.

- Predictability of the mega-drought (2010-2015).

Contents

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a) Climate features: where does Chile stand?
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e) **Objectives of my work**

2. **Data and methodologies**

a) Data and models
b) Forecast quality assessment: temperature and precipitation

3. Preliminary Results
a) External forcing in Chilean Climate

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Data and models

Models (CMIP5)

Variables	Nombre CMIP5	Modelo	Resolución	# Ensambles DP	# Ensambles Históricos	Disponibilidad temporal
Temperature Precipitation Sea level pressure Sea surface temp. Zonal wind 200 hPa Geopotential 500 hPa	tas, pr, psl, tos, ua (200hPa) y zg (500 hPa)	bcc-csm1-1	2.79° x 2.81°	4	3	1960-2006
		CanCM4	2.79° x 2.81	10	10	1960-2009
		EC-EARTH	1.12° x 1.12°	10	10	1960-2006
		HadCM3	2.50° x 3.75°	10	10	1960-2009
		MIROC5	1.40° x 1.40°	6	5	1960-2009

Observations

Reanalysis	Gridded products	Meteorological Stations
ERA40 (1961 - 1978) and ERAinterim (1979-2016)	**GPCP, GHCN and ERSST**	**DGA and Meteochile**

Servers

(CR)2 Center for Climate and Resilience Research

BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Forecast quality assessment: temperature and precipitation

Direct	Indirect
Comparison between decadal predictions, historical (non-inicializated) and observations • Deterministic: ACC and RMSE. • Probabilistic: BS, RCP and CRPS	Use relations with other variables for evaluate the quality assessment of the prediction of temperature and precipitacion • Sea level pressure • Geopotential 500 hPa (SAM) • Zonal wind 200 hPa • SST (ENSO, PDO, IPO)

Compare with estándar forecast systems: persistence and climatology

Quantify the added value of initialize the models for get temperature and precipitation in Chile

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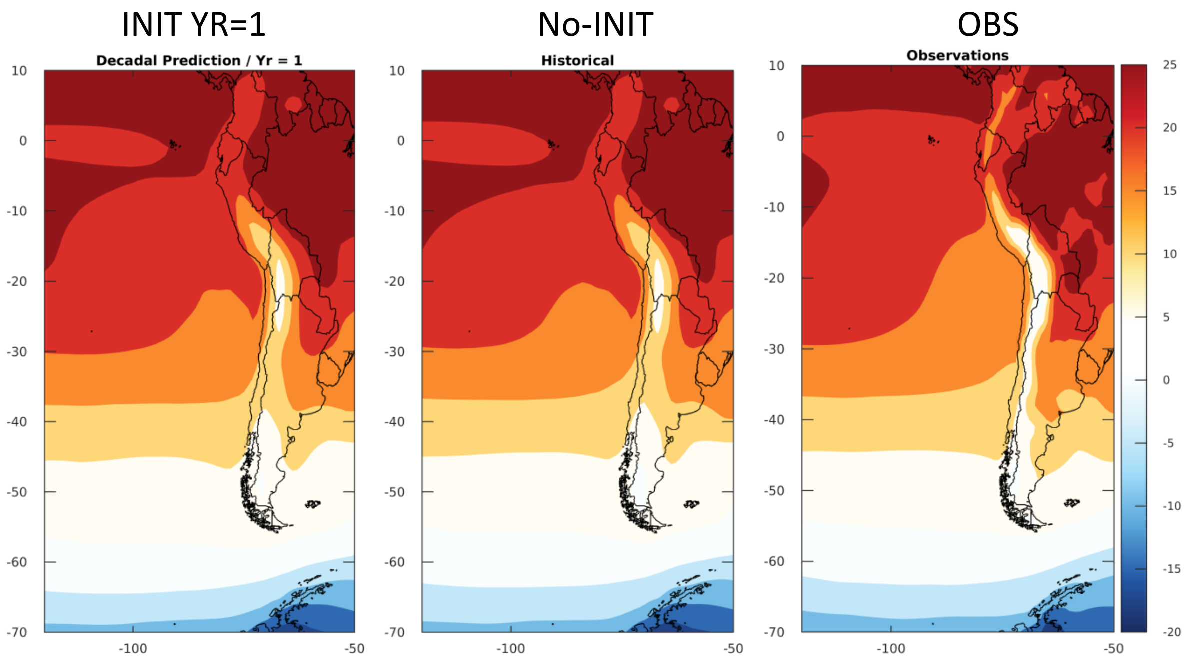
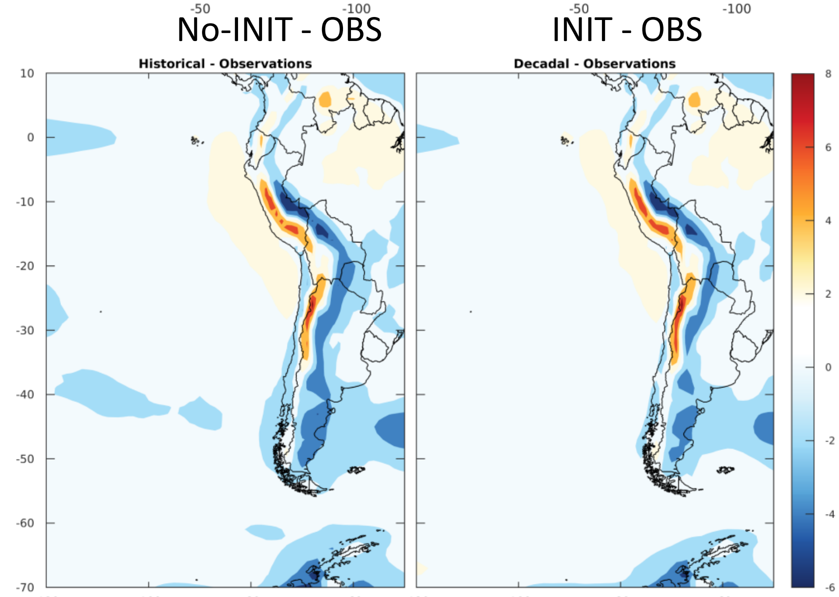
External forcing in Chilean Climate: Temperature



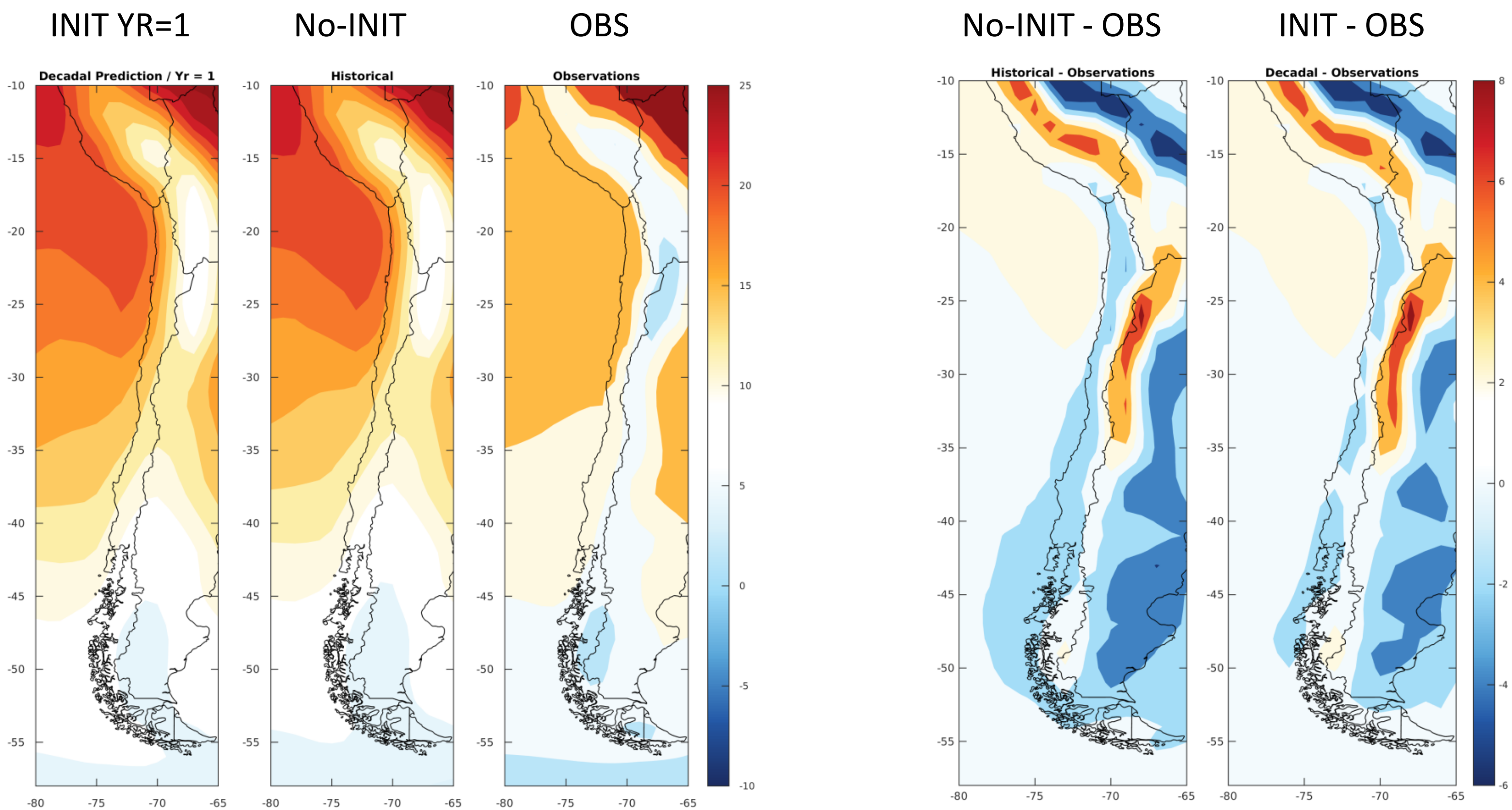


Climatologies
1961 – 2006

Multimodel
Ensemble Mean

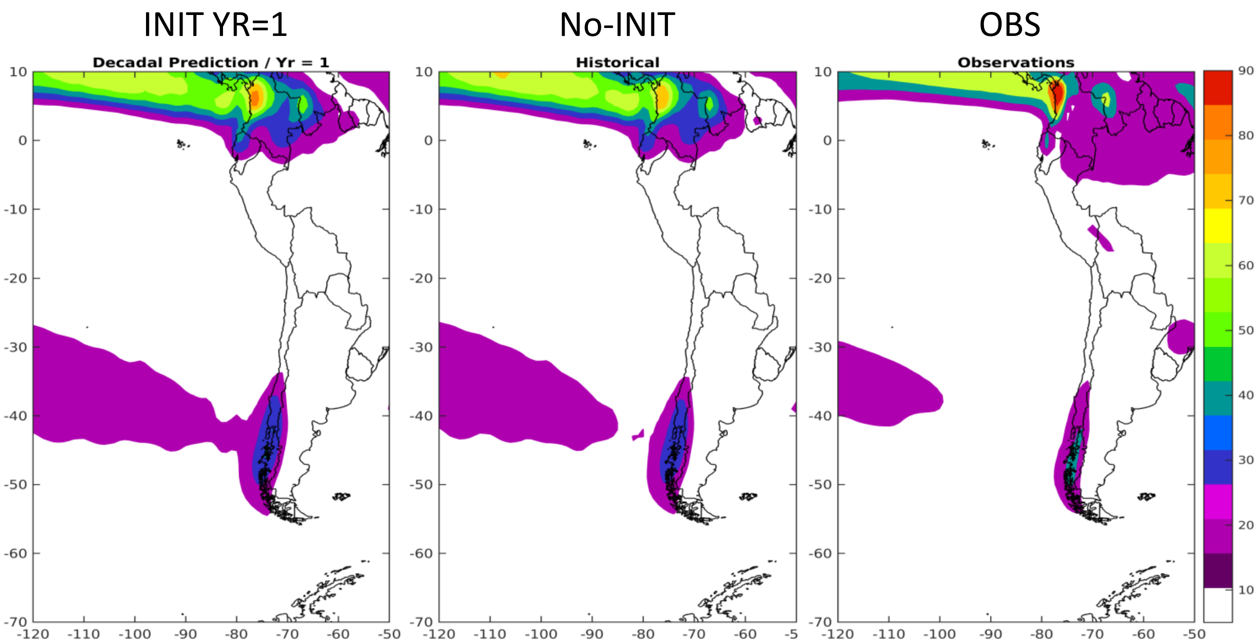
- INIT and No-INIT overestimate the SST in Pacific Ocean in front of Chile y Perú

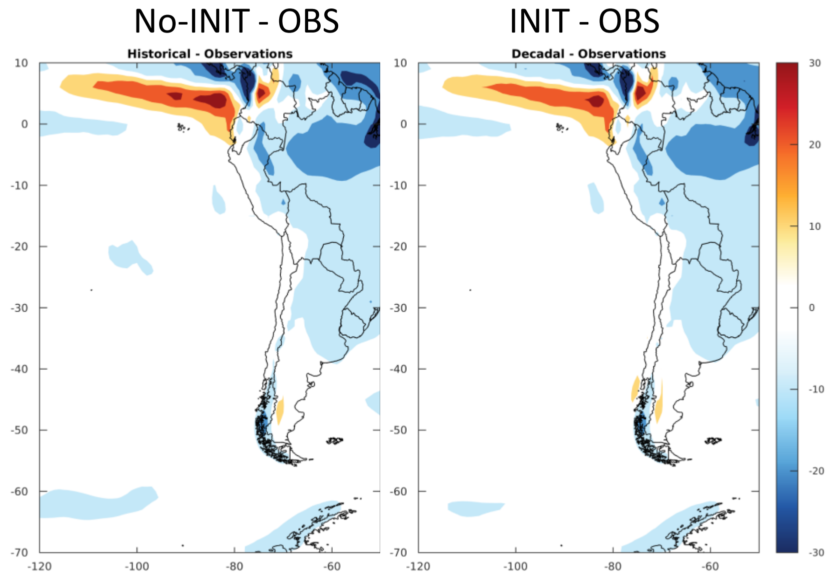
External forcing in Chilean Climate: Temperature - Chile



- Models underestimate temperature over coast and valleys
- Models overestimate temperatures over Los Andes
- Problems in the Altiplano

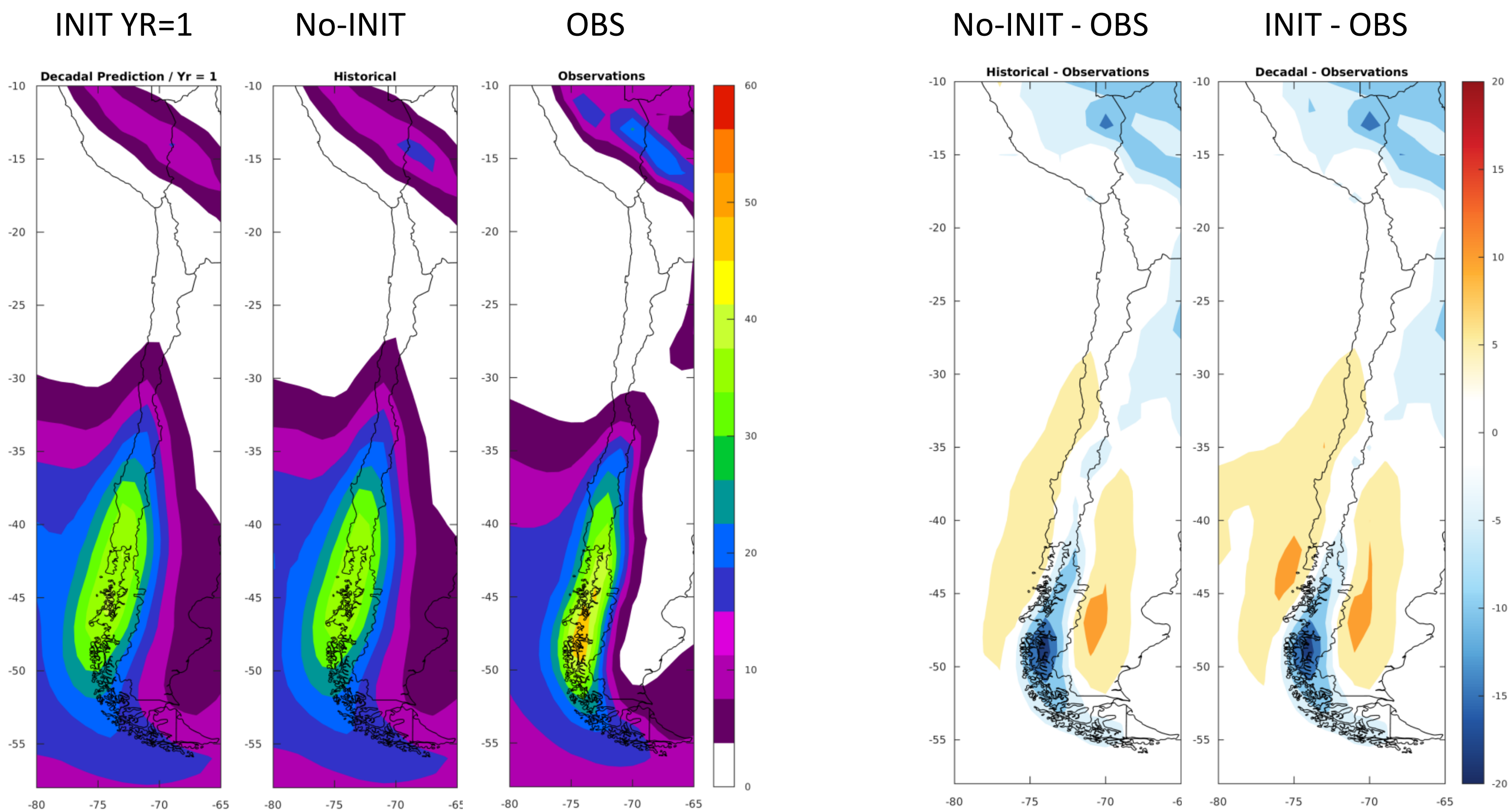
External forcing in Chilean Climate: Precipitation





- Big differences in tropics
- Altiplano and Southern Chile differences

External forcing in Chilean Climate: Precipitation - Chile



- INIT and No-INIT underestimate precipitation over Altiplano
- Problems with orographic precipitation

Conclusions

• The main characteristic of temperature and precipitation over Chile are decently reproduced with both INIT and No-INIT simulations.

• Models have problems with orographic precipitations and stratocumulus cloud cover.

• Is difficult for models to identify changes in temperature and precipitation for Los Andes Mountais.

Gracias!

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