The current Mega Drought in Central Chile: Natural Variability or Climate Change?

(Is the future now?)

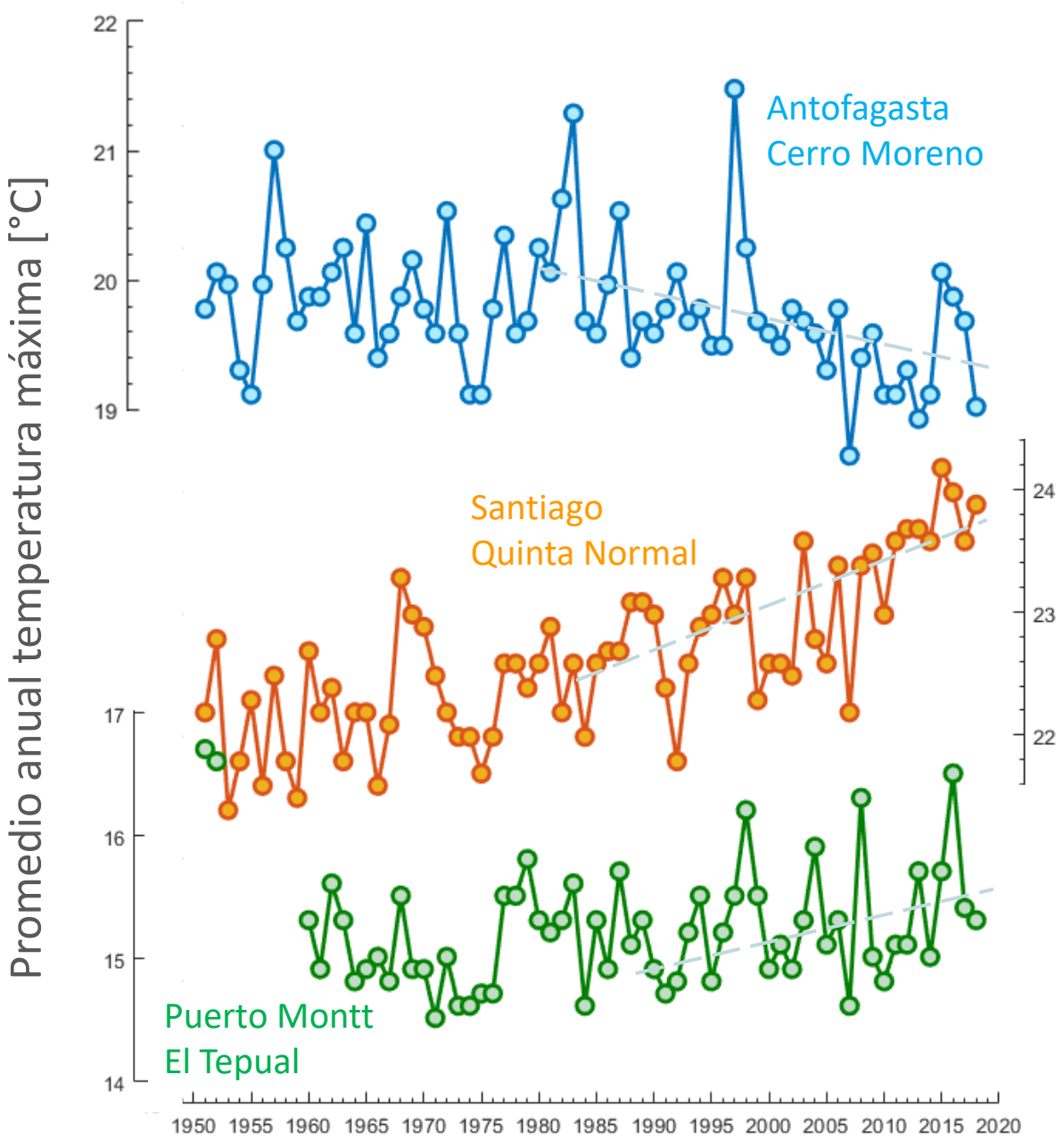
René D. Garreaud and MD group….
Department of Geophysics, Universidad de Chile
Center for Climate and Resilience Research, CR2

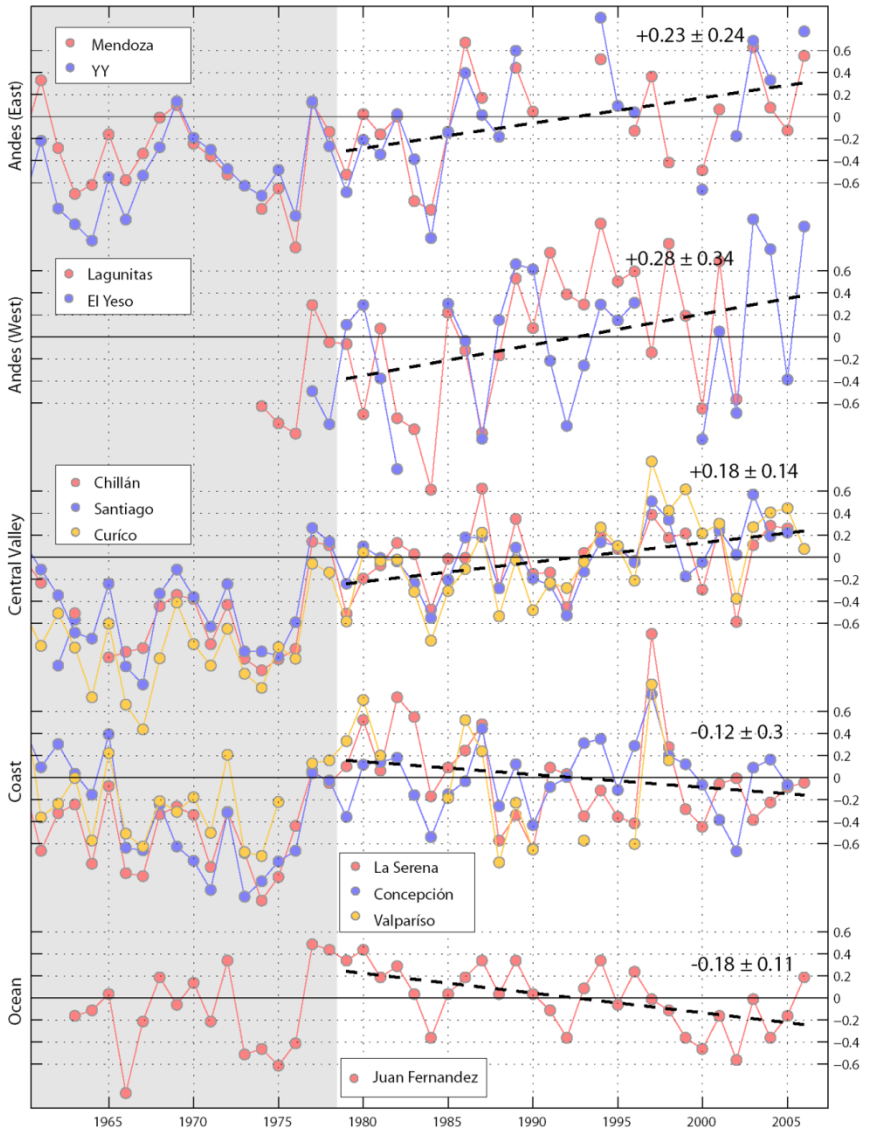
Outline

- Where is Chile? Megadrought???
- Historical context
- The current Mega drought
- Dynamical analysis: CC+PDO?

(CR)² Center for Climate and Resilience Research www.CR2.cl

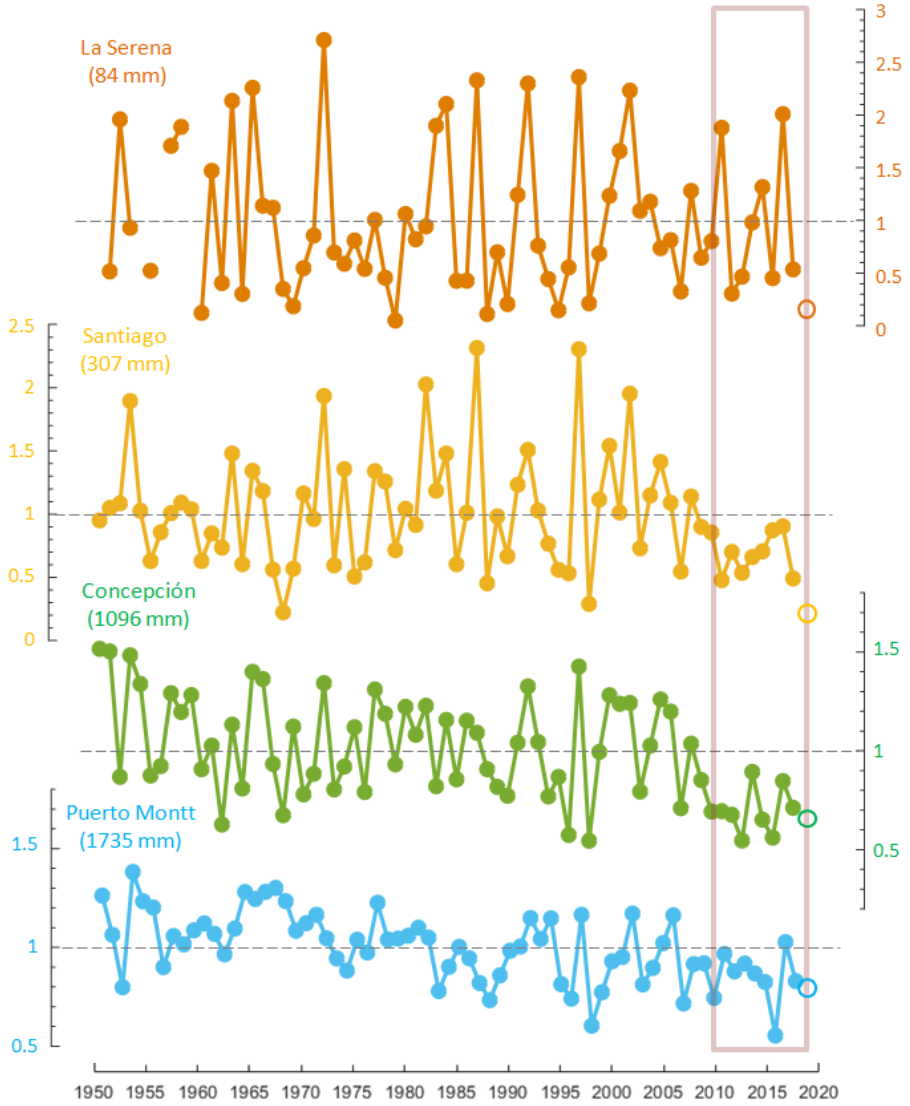
Calentamiento en Chile?

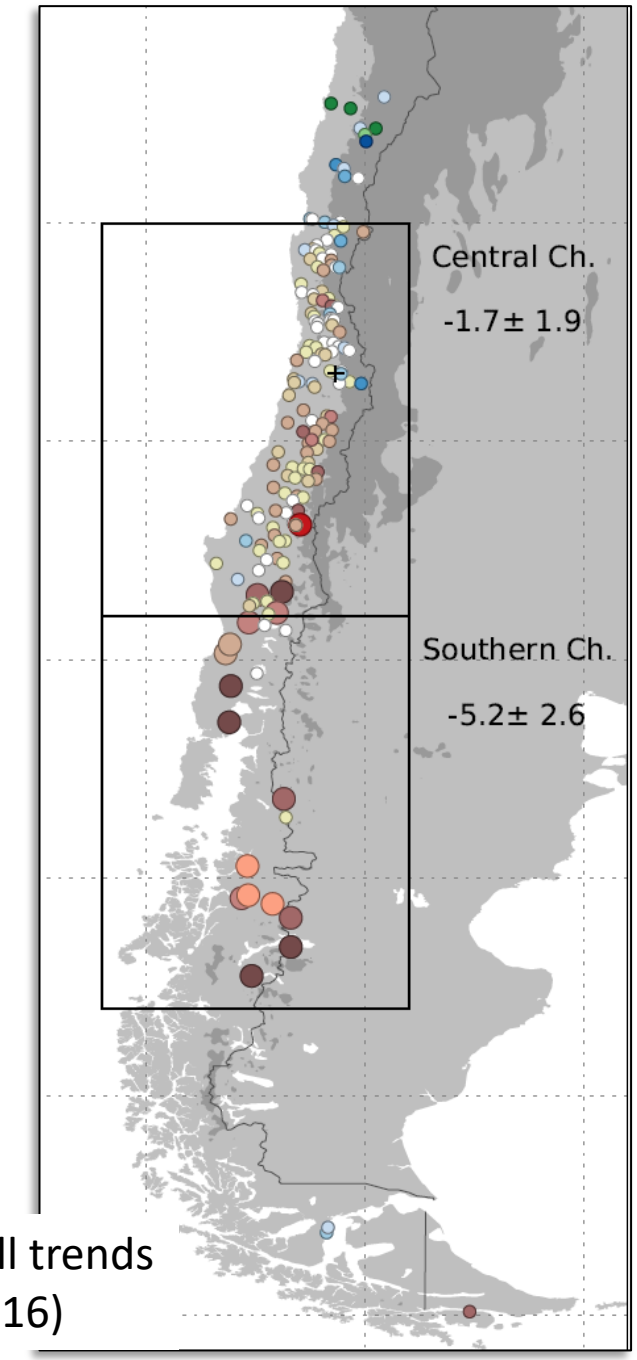




Falvey & Garreaud 2009

Y que pasa con la precipitación?

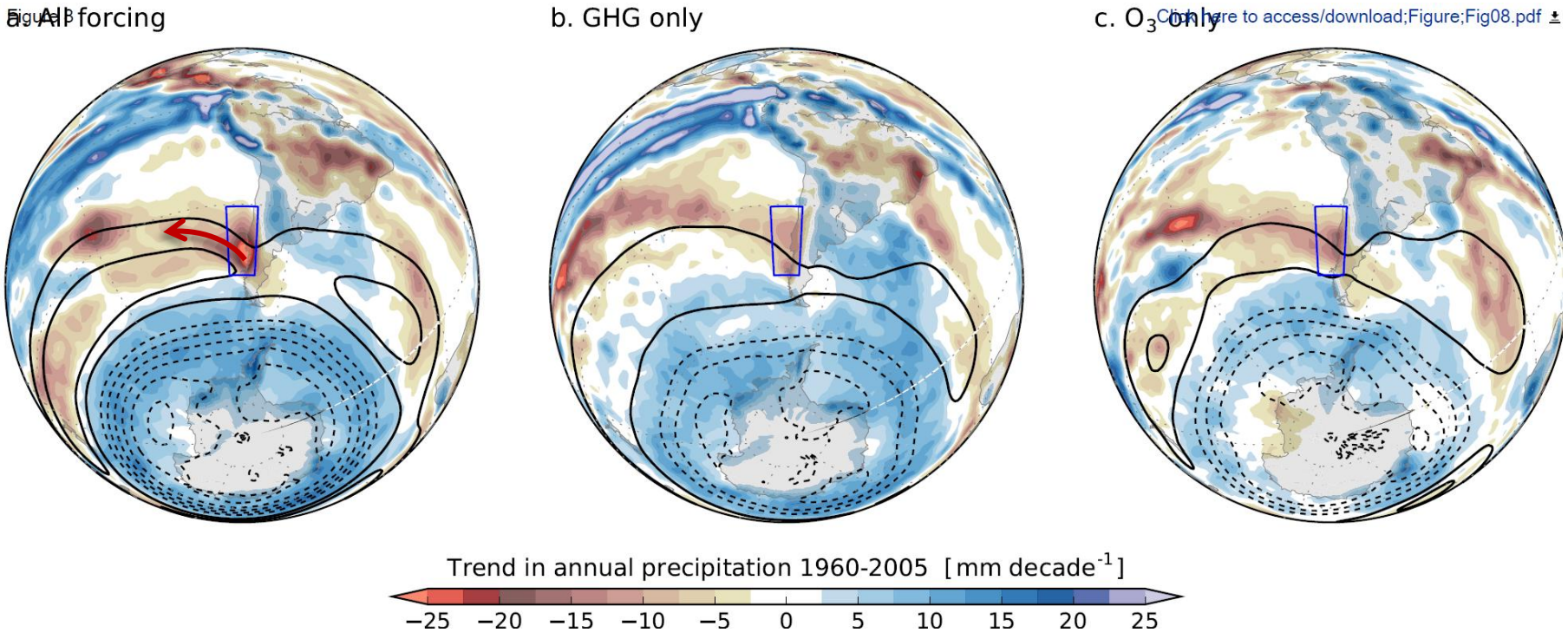




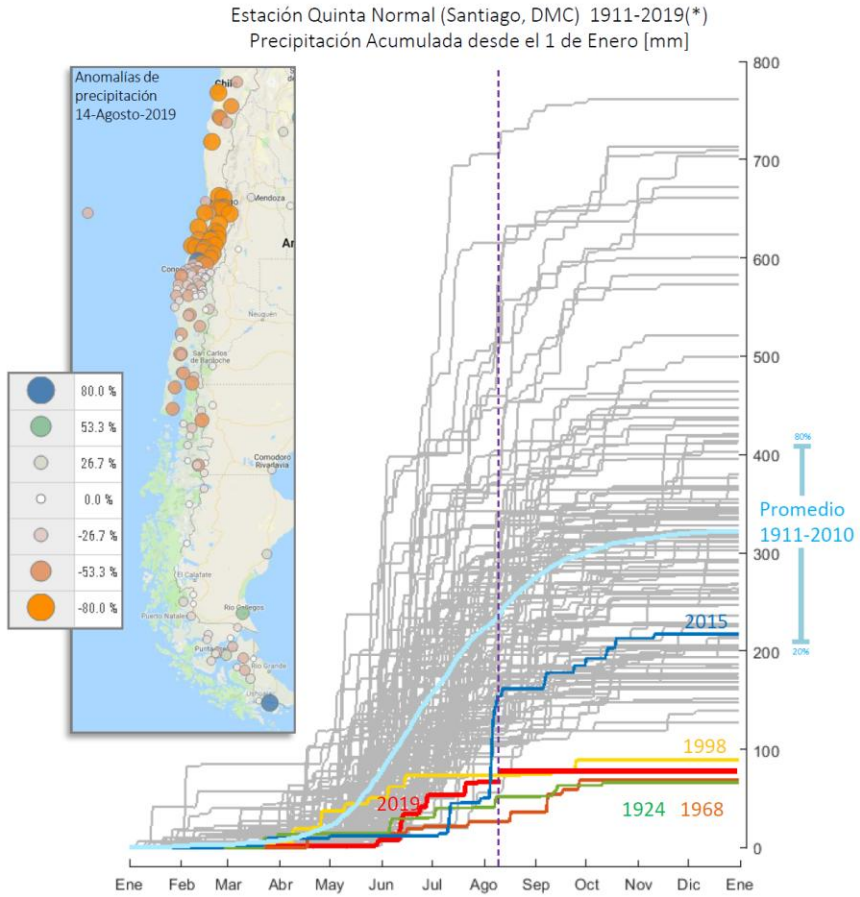
Annual rainfall trends
(1960-2016)

Precipitation trends 1960-2005: Attribution

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

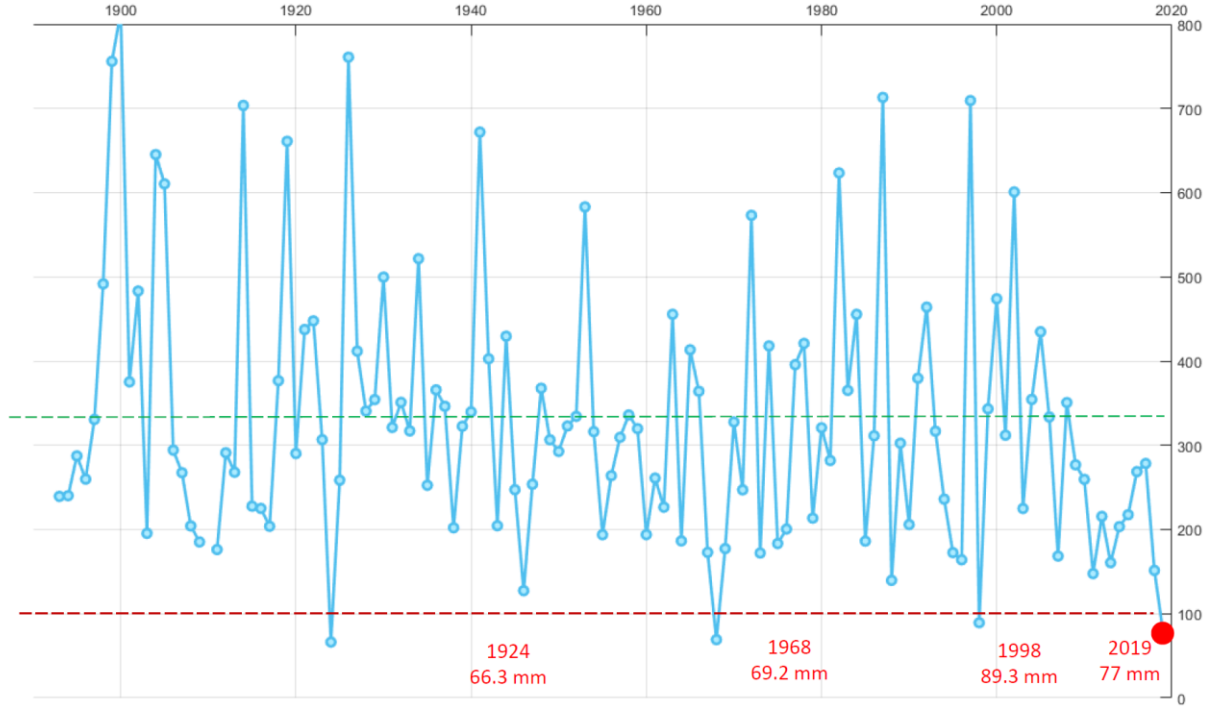


Boisier et al. 2018, *Elementa*



El régimen pluviométrico de Chile central

Precipitación Anual Quinta Normal - Santiago

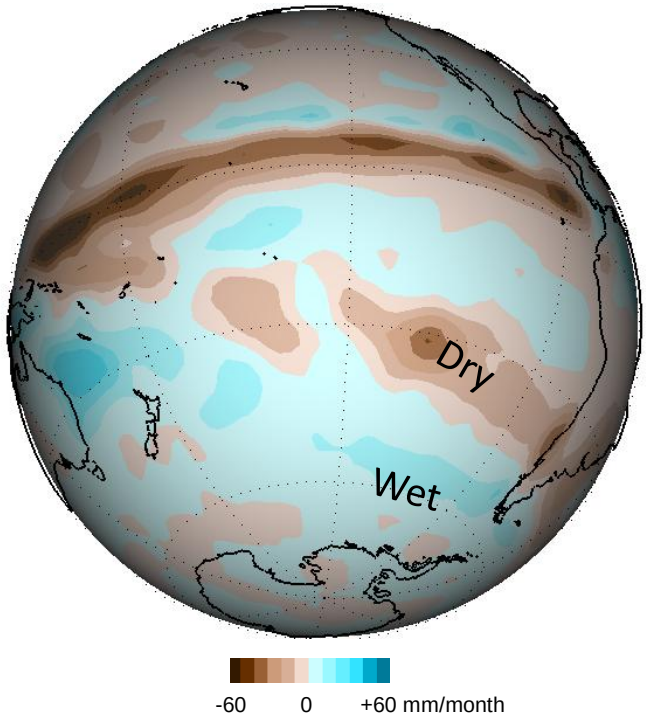


Large-scale context for central Chile droughts

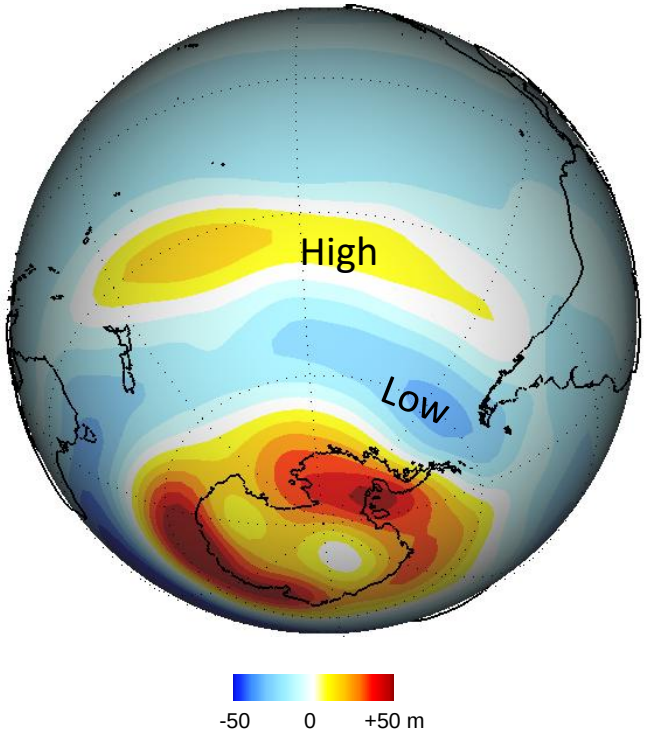
Drought Composite

1967,68,64,73,76,85,96,99,03,07

Rainfall anomalies

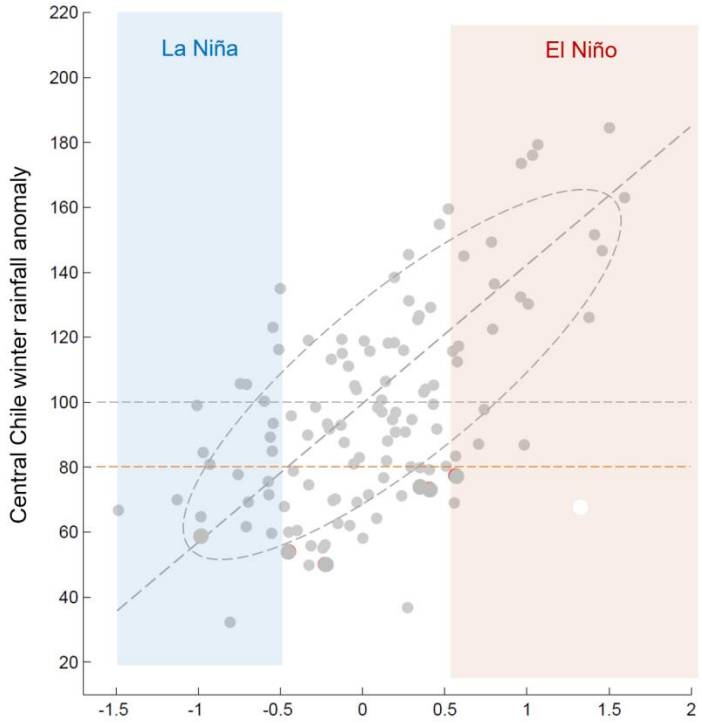


Z500 anomalies



ENSO Modulation

1911-2000



The 2010-2018 mega drought in Central Chile

Unprecedented length in 20th century - Few analogs in last 1000 years

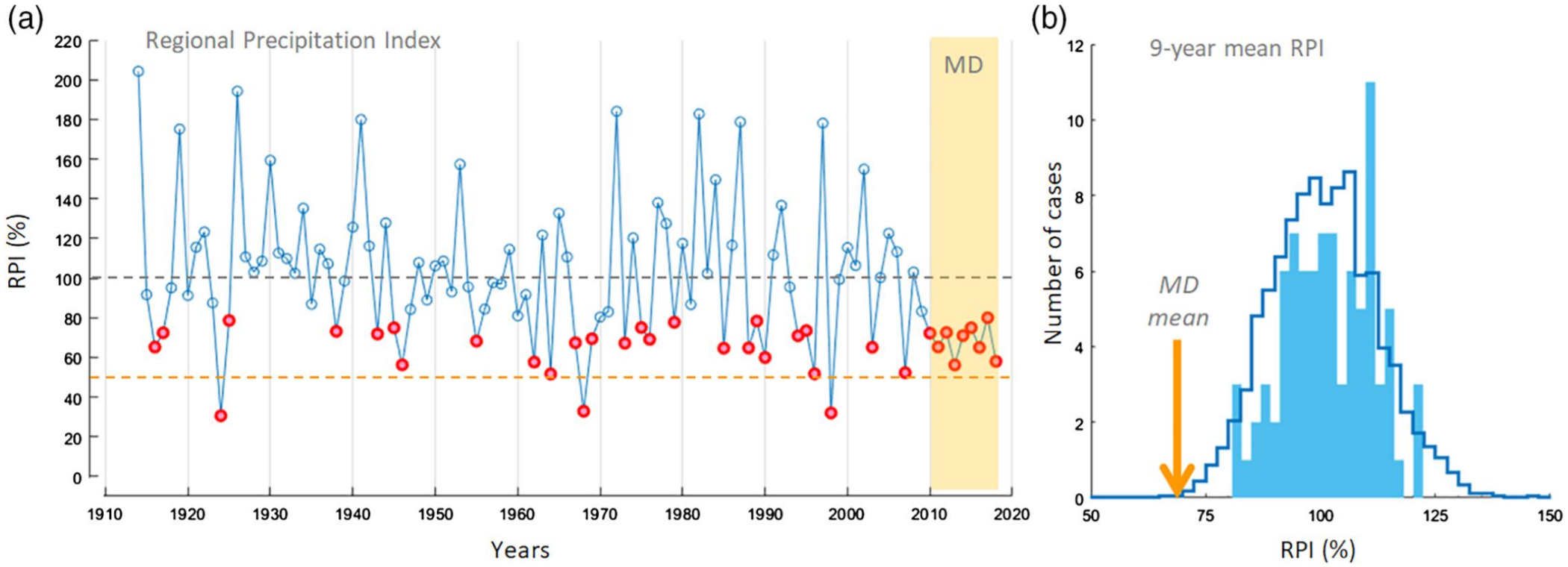
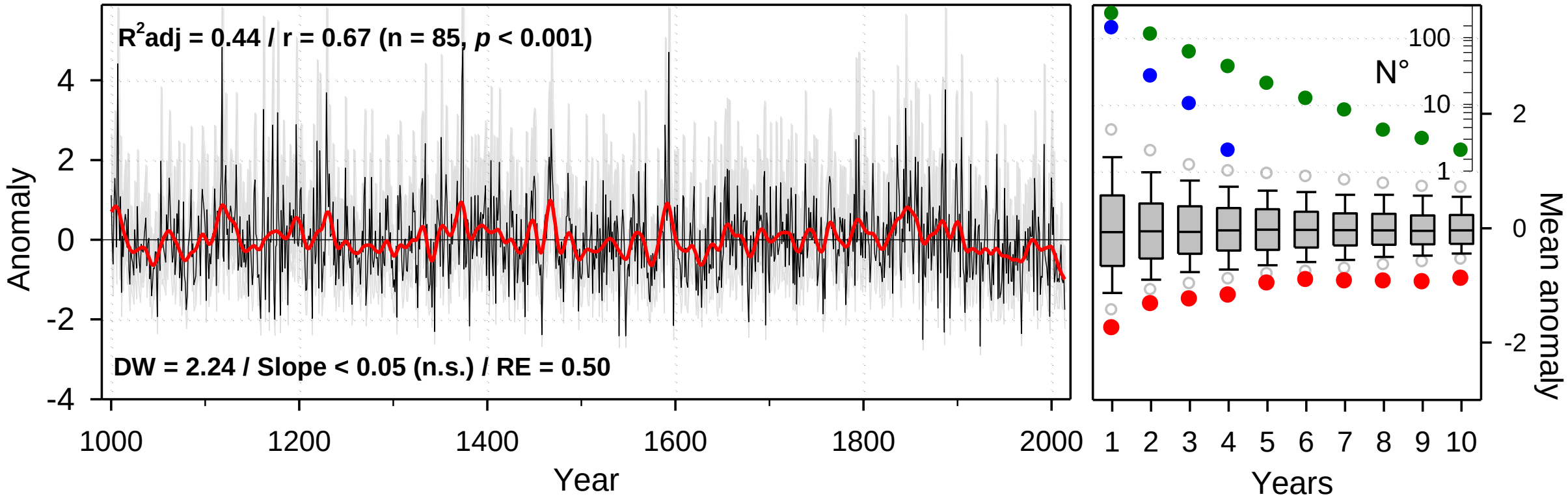


FIGURE 2 (a) Annual series of Central Chile regional precipitation index (RPI). Droughts, defined as years with RPI < 80%, are identified by the red circles. (b) Histogram of 9-year average of RPI for the period 1915–2009. The light blue bars show the observed frequency, considering a 9-year sliding window throughout the 1915–2009 record. The blue thick line is the distribution obtained from 5,000 randomly selected 9 years from the historical period. The orange arrow indicates the RPI averaged during the MD (2010–2018) [Colour figure can be viewed at wileyonlinelibrary.com]

Contexto de largo Plazo

Reconstrucción dendro-climática (1000-2000 años d.C.) de
la precipitación en Chile central (LeQuesne et al. 2012)



Hydrol. Earth Syst. Sci., 21, 6307–6327, 2017
https://doi.org/10.5194/hess-21-6307-2017

Hydrology and Earth System Sciences
Open Access
EGU

The 2010–2015 megadrought in central Chile: impacts on regional hydroclimate and vegetation

René D. Garreaud[1,2], Camila Alvarez-Garreton[3,2], Jonathan Barichivich[3,2], Juan Pablo Boisier[1,2], Duncan Christie[3,2], Mauricio Galleguillos[4,2], Carlos LeQuesne[3], James McPhee[5,6], and Mauricio Zambrano-Bigiarini[7,2]

[1]Department of Geophysics, Universidad de Chile, Santiago, Chile
[2]Center for Climate and Resilience Research (CR2), Santiago, Chile
[3]Laboratorio de Dendrocronología y Cambio Global, Instituto de Conservación Biodiversidad y Territorio, Universidad Austral de Chile, Valdivia, Chile
[4]Faculty of Agronomic Sciences, Universidad de Chile, Santiago, Chile
[5]Department of Civil Engineering, Universidad de Chile, Santiago, Chile
[6]Advanced Mining Technology Center, Universidad de Chile, Santiago, Chile
[7]Department of Civil Engineering, Faculty of Engineering and Sciences, Universidad de La Frontera, Temuco, Chile

Correspondence: René D. Garreaud (rgarreau@dgf.uchile.cl)

Received: 31 March 2017 – Discussion started: 26 April 2017
Revised: 8 September 2017 – Accepted: 5 November 2017 – Published: 13 December 2017

Abstract. Since 2010 an uninterrupted sequence of dry years, with annual rainfall deficits ranging from 25 to 45 %, has prevailed in central Chile (western South America, 30–38° S). Although intense 1- or 2-year droughts are recurrent in this Mediterranean-like region, the ongoing event stands out because of its longevity and large extent. The extraordinary character of the so-called central Chile megadrought (MD) was established against century long historical records and a millennial tree-ring reconstruction of regional precipitation. The largest MD-averaged rainfall relative anomalies occurred in the northern, semi-arid sector of central Chile, but the event was unprecedented to the south of 35° S. ENSO-neutral conditions have prevailed since 2011 (except for the strong El Niño in 2015), contrasting with La Niña conditions that often accompanied past droughts. The precipitation deficit diminished the Andean snowpack and resulted in amplified declines (up to 90 %) of river flow, reservoir volumes and groundwater levels along central Chile and westernmost Argentina. In some semi-arid basins we ongoing warming in central Chile, making the MD one of the warmest 6-year periods on record, may have also contributed to such complex vegetation changes by increasing potential evapotranspiration. We also report some of the measures taken by the central government to relieve the MD effects and the public perception of this event. The understanding of the nature and biophysical impacts of the MD helps as a foundation for preparedness efforts to confront a dry, warm future regional climate scenario.

1 Introduction

Droughts have been recognized as a major climate hazard in many regions worldwide (e.g., Mishra and Singh, 2010; Seneviratne et al., 2012). Depending on its duration and intensity, a lower-than-average precipitation condition (i.e., a meteorological drought) can lead to a substantial decrease

Received: 17 January 2019 | Revised: 23 May 2019 | Accepted: 27 June 2019
DOI: 10.1002/joc.6219

RESEARCH ARTICLE

International Journal of Climatology
RMetS

The Central Chile Mega Drought (2010–2018): A climate dynamics perspective

René D. Garreaud[1,2] | Juan P. Boisier[2] | Roberto Rondanelli[1,2] | Aldo Montecinos[3,4] | Hector H. Sepúlveda[3] | Daniel Veloso-Aguila[3]

[1]Geophysics Department, Universidad de Chile, Santiago, Chile
[2]Center for Climate and Resilience Research, Universidad de Chile, Santiago, Chile
[3]Department of Geophysics, Universidad de Concepción, Concepción, Chile
[4]Centro de Recursos Hídricos para la Agricultura y Minería, Universidad de Concepción, Concepción, Chile

Correspondence
René D. Garreaud, Blanco Encalada 2002, Santiago, Chile.
Email: rgarreau@dgf.uchile.cl

Funding information
CONICYT Chile, Grant/Award Numbers: FONDAP 15110009, FONDECYT 1170286

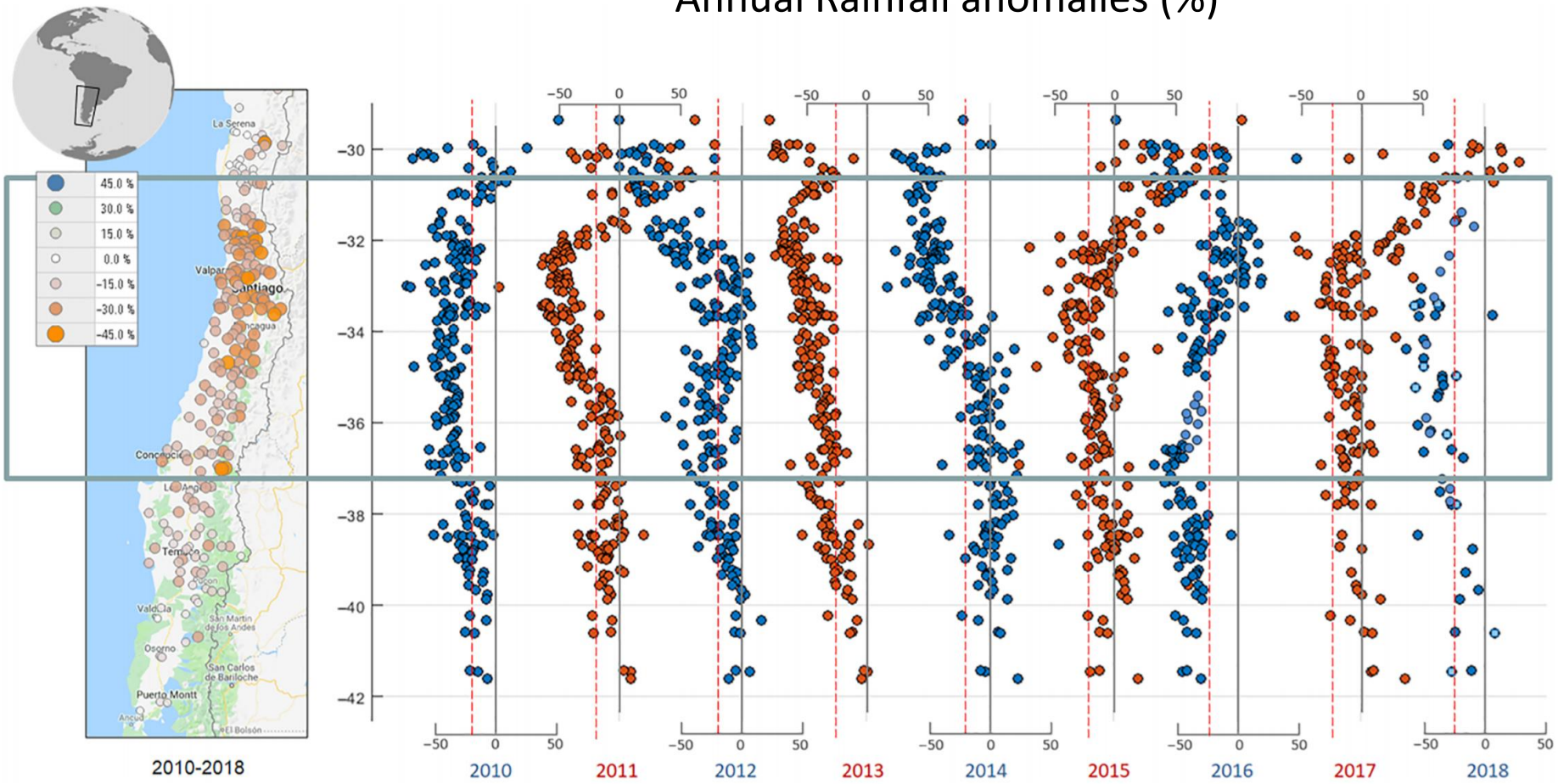
Abstract

Central Chile, home to more than 10 million inhabitants, has experienced an uninterrupted sequence of dry years since 2010 with mean rainfall deficits of 20–40%. The so-called Mega Drought (MD) is the longest event on record and with few analogues in the last millennia. It encompasses a broad area, with detrimental effects on water availability, vegetation and forest fires that have scaled into social and economical impacts. Observations and reanalysis data reveal that the exceptional length of the MD results from the prevalence of a circulation dipole-hindering the passage of extratropical storms over central Chile—characterized by deep tropospheric anticyclonic anomalies over the subtropical Pacific and cyclonic anomalies over the Amundsen–Bellingshausen Sea. El Niño Southern Oscillation (ENSO) is a major modulator of such dipole, but the MD has occurred mostly under ENSO-neutral conditions, except for the winters of 2010 (La Niña) and 2015 (strong El Niño). Climate model simulations driven both with historical forcing (natural and anthropogenic) and observed global SST replicate the south Pacific dipole and capture part of the rainfall anomalies. Idealized numerical experiments suggest that most of the atmospheric anomalies emanate from the subtropical southwest Pacific, a region that has experienced a marked surface warming over the last decade. Such warming may excite atmospheric Rossby waves whose propagation intensifies the circulation pattern leading to dry conditions in central Chile. On the other hand, anthropogenic forcing (greenhouse gases concentration increase and stratospheric ozone depletion) and the associated positive trend of the Southern Annular Mode also contribute to the strength of the south Pacific dipole and hence to the intensity and longevity of the MD. Given the concomitance of the seemingly natural (ocean sourced) and anthropogenic forcing, we anticipate only a partial recovery of central Chile precipitation in the decades to come.

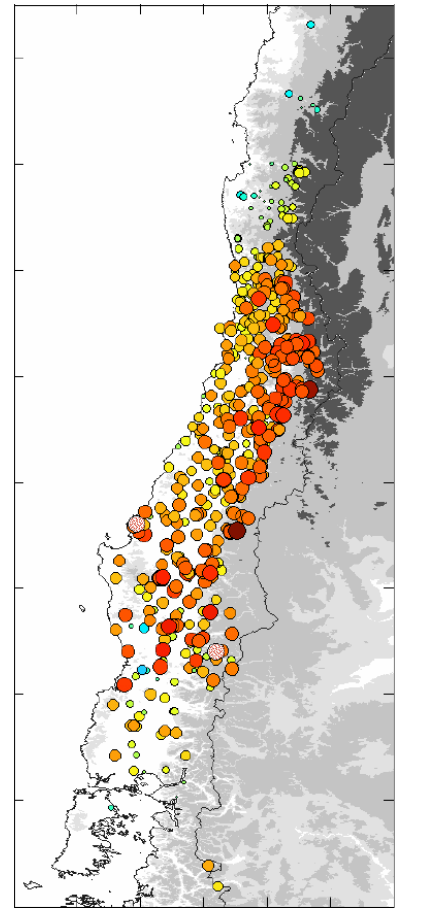
KEYWORDS
Chile, climate change, drought, ENSO, PDO, SAM, South America

Regional features

Annual Rainfall anomalies (%)



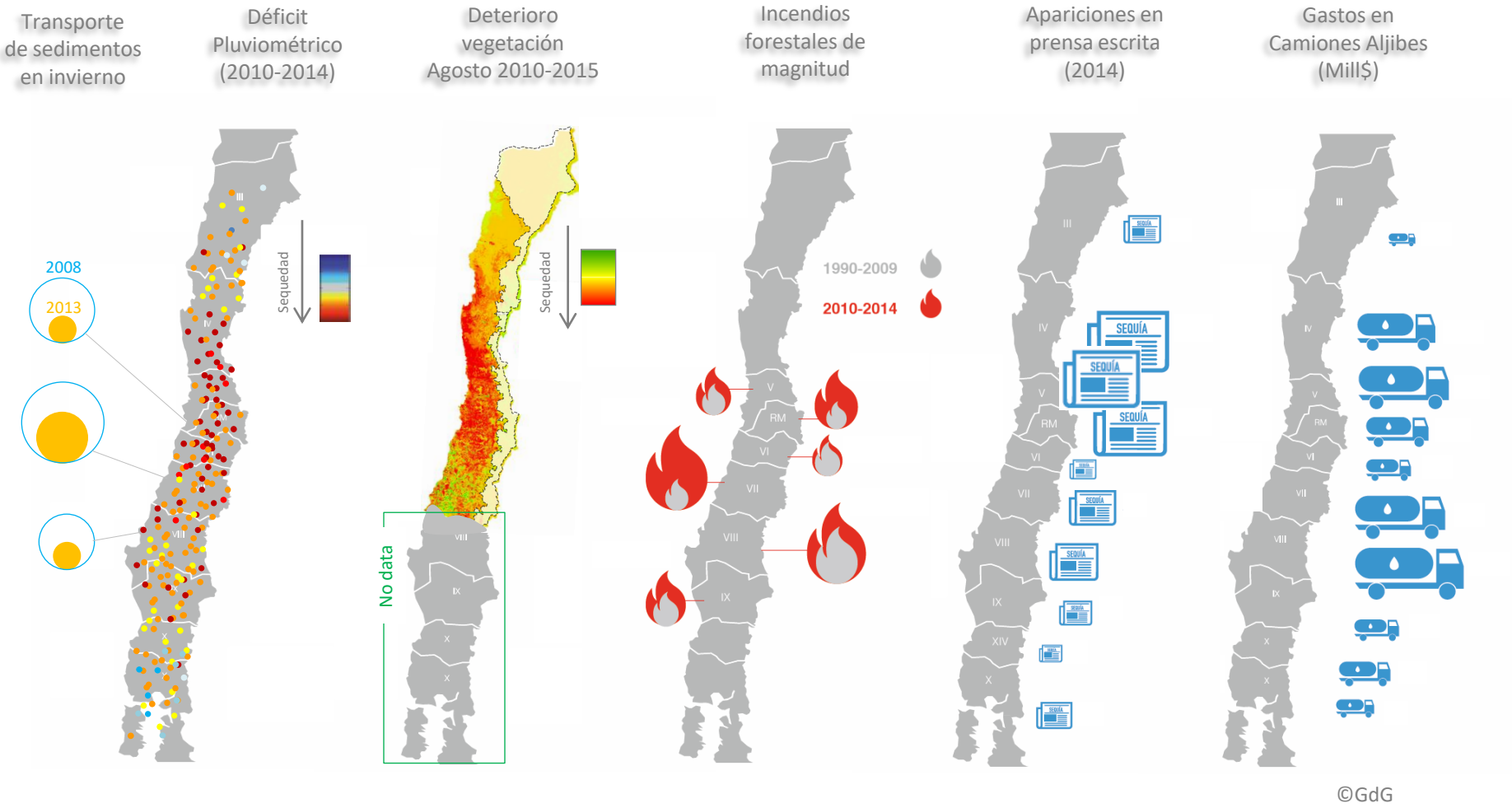
SPI-12 average 2010-2017



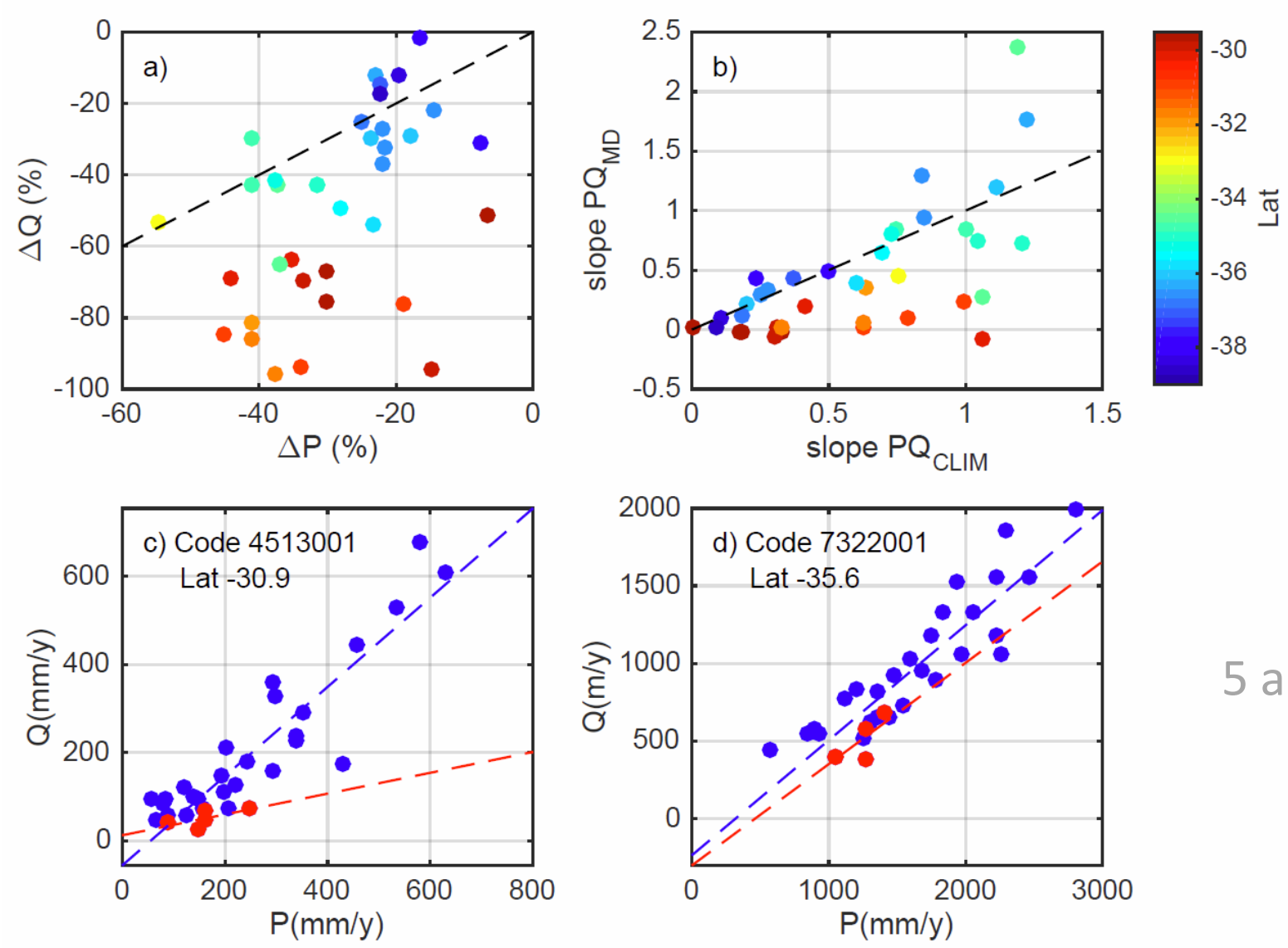
The 2010-2018 mega drought in Central Chile

Individual year rainfall deficit were not extreme

But MD length has caused major ecological and social impacts

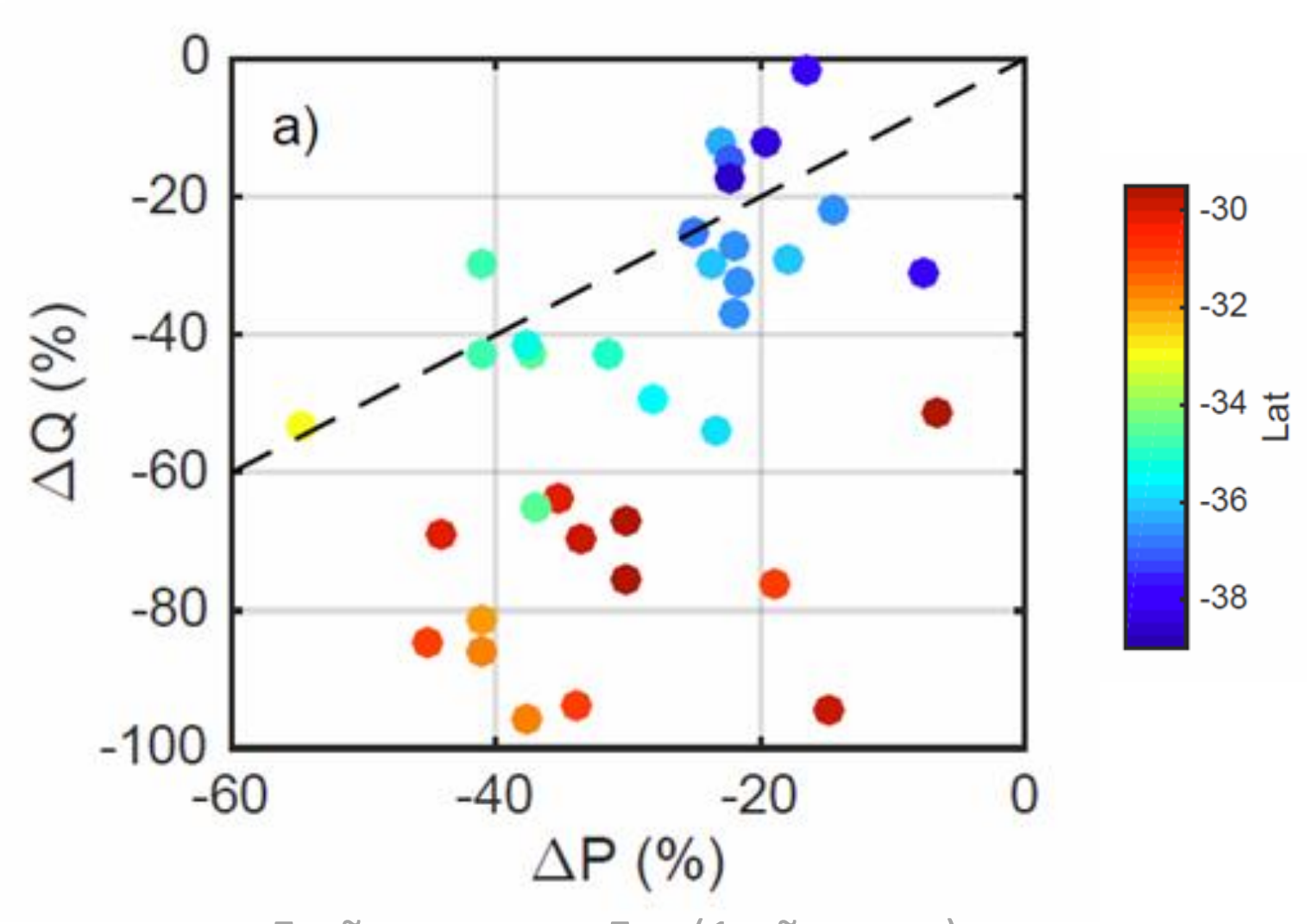


Impactos en Hidrología



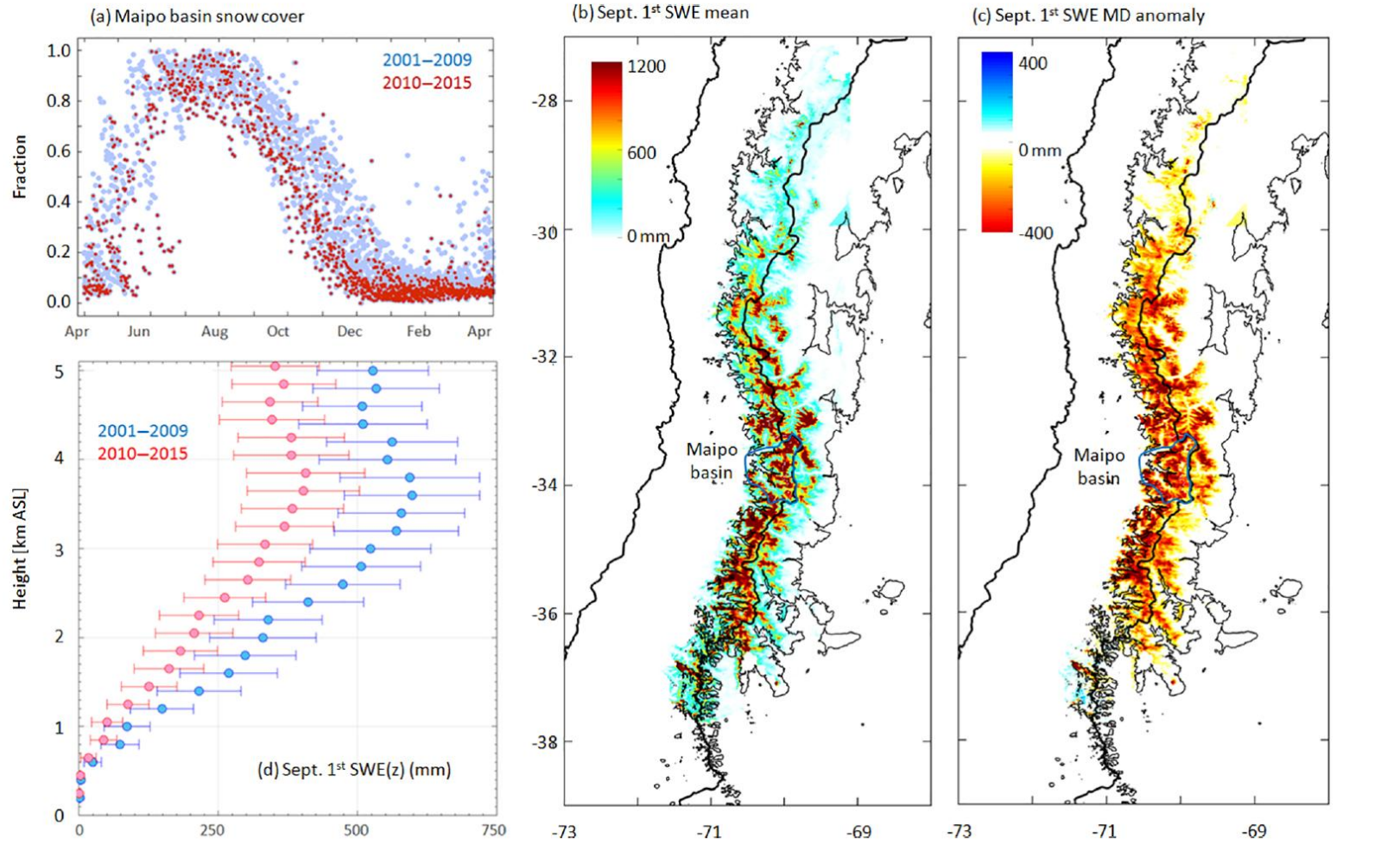
5 años secos ≠ 5 × (1 año seco)

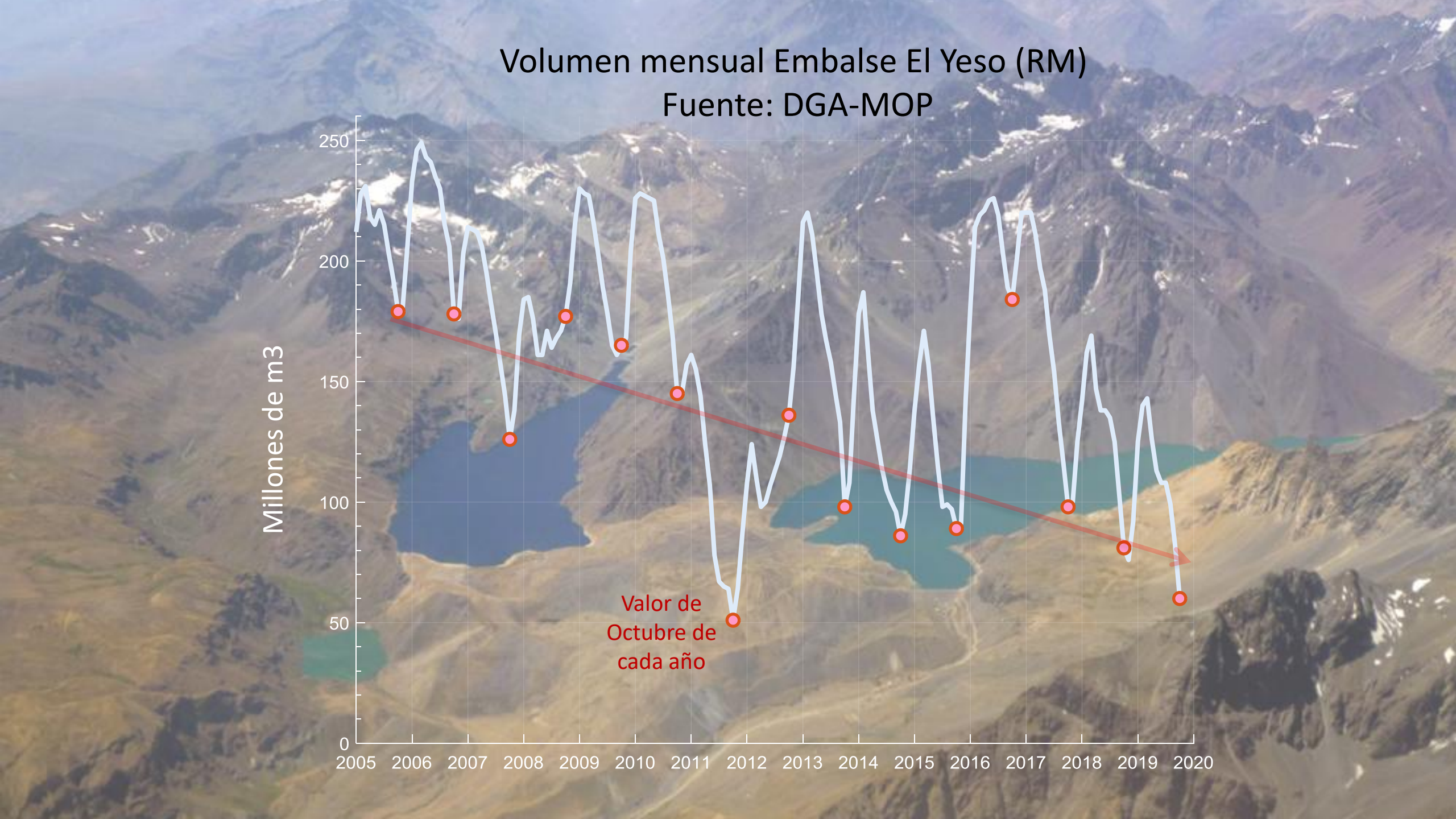
Impactos en Hidrología



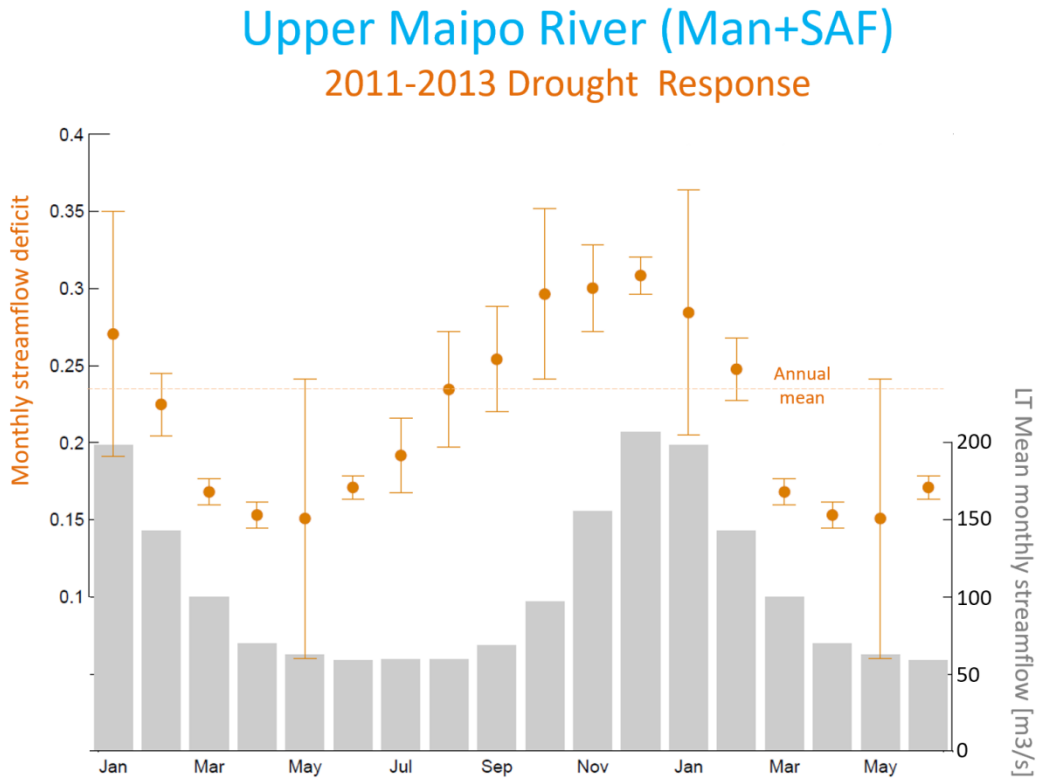
5 años secos ≠ 5 × (1 año seco)

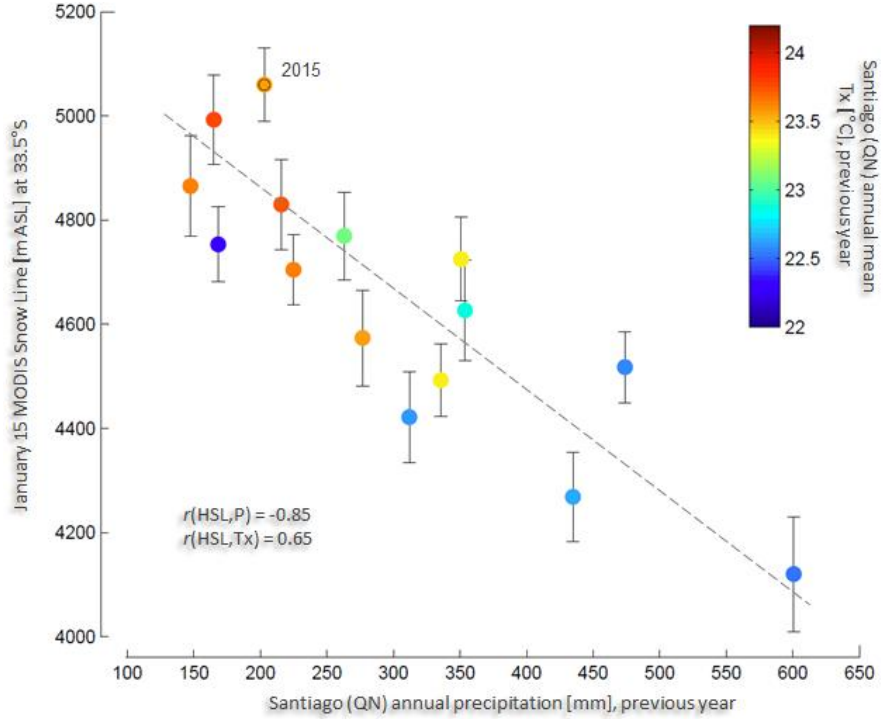
Impactos en Hidrología




Volumen mensual Embalse El Yeso (RM)
Fuente: DGA-MOP
Millones de m3
250
200
150
100
50
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Valor de
Octubre de
cada año

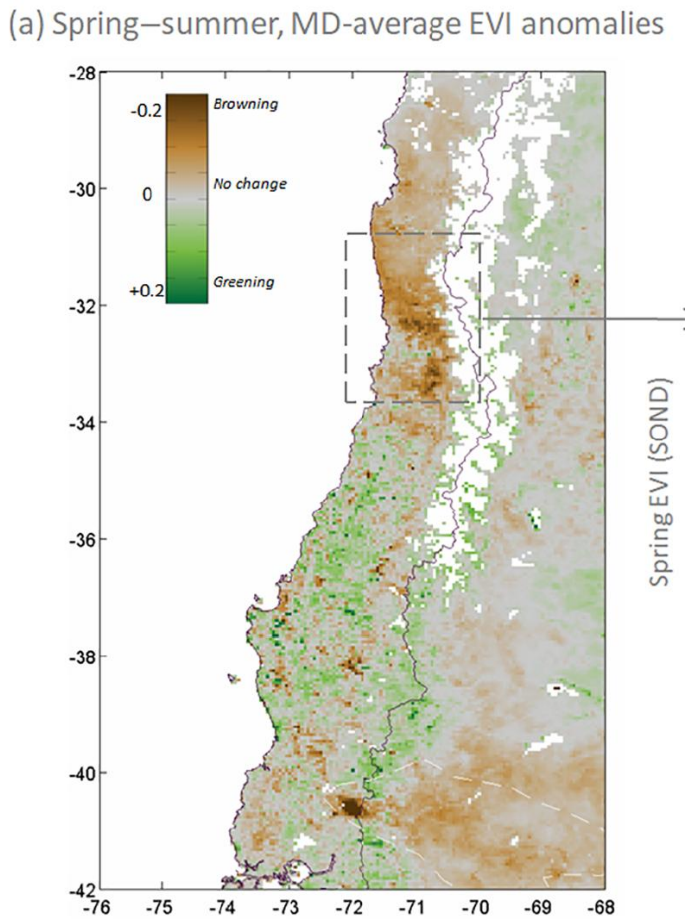
Impactos en Hidrología

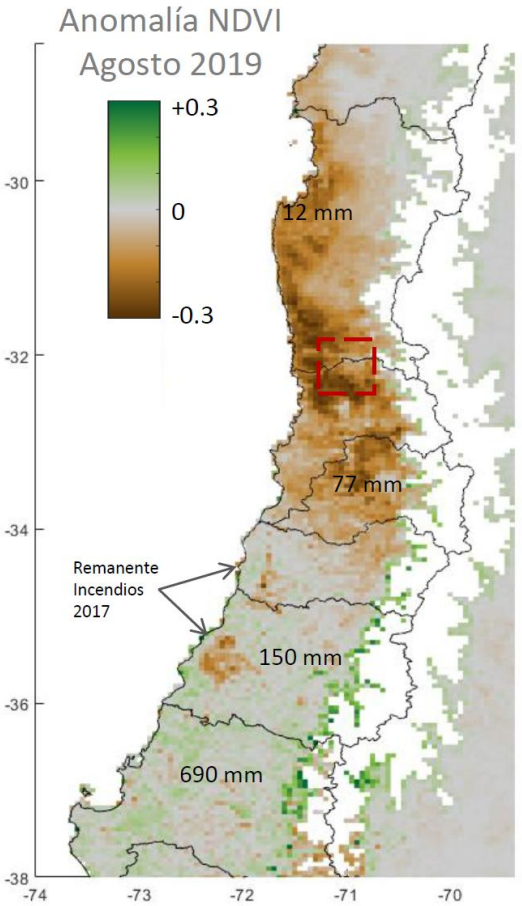


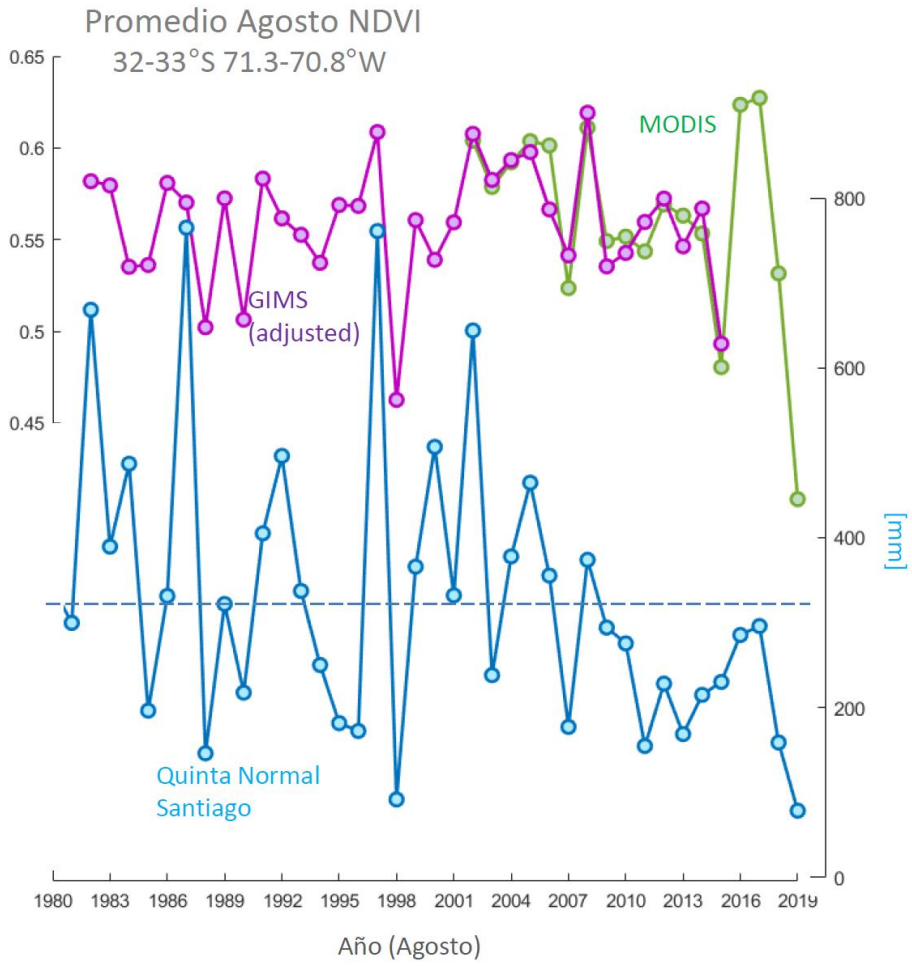


During the 2011-2013 drought the streamflow in the upper Maipo river decreased by 23% relative to the long-term mean value. The streamflow reduction was significantly larger during the spring-summer months (up to 33%) compared with fall (15%). The base flow seems more resistant to the precipitation deficit.

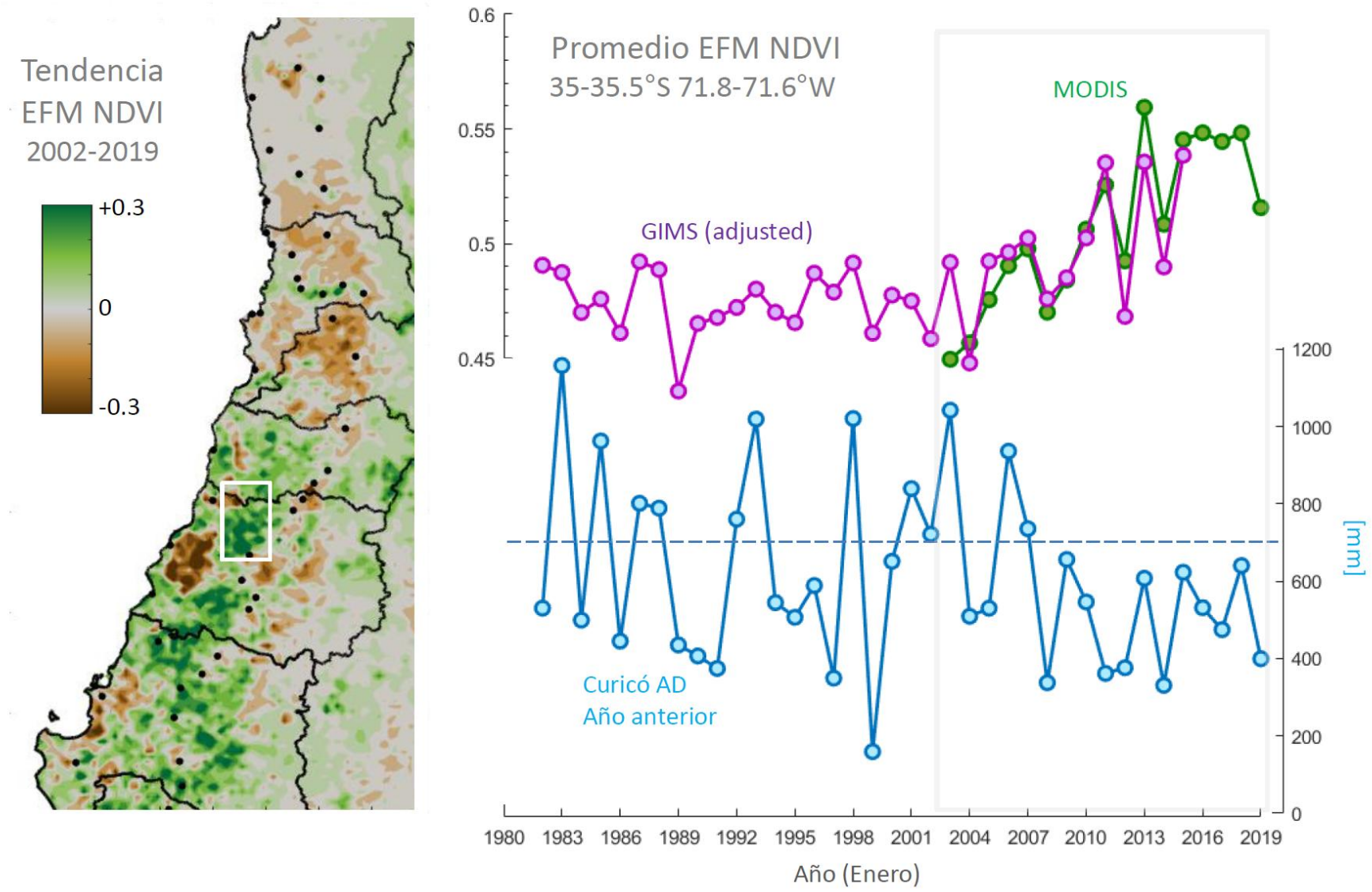
Impactos en Vegetación



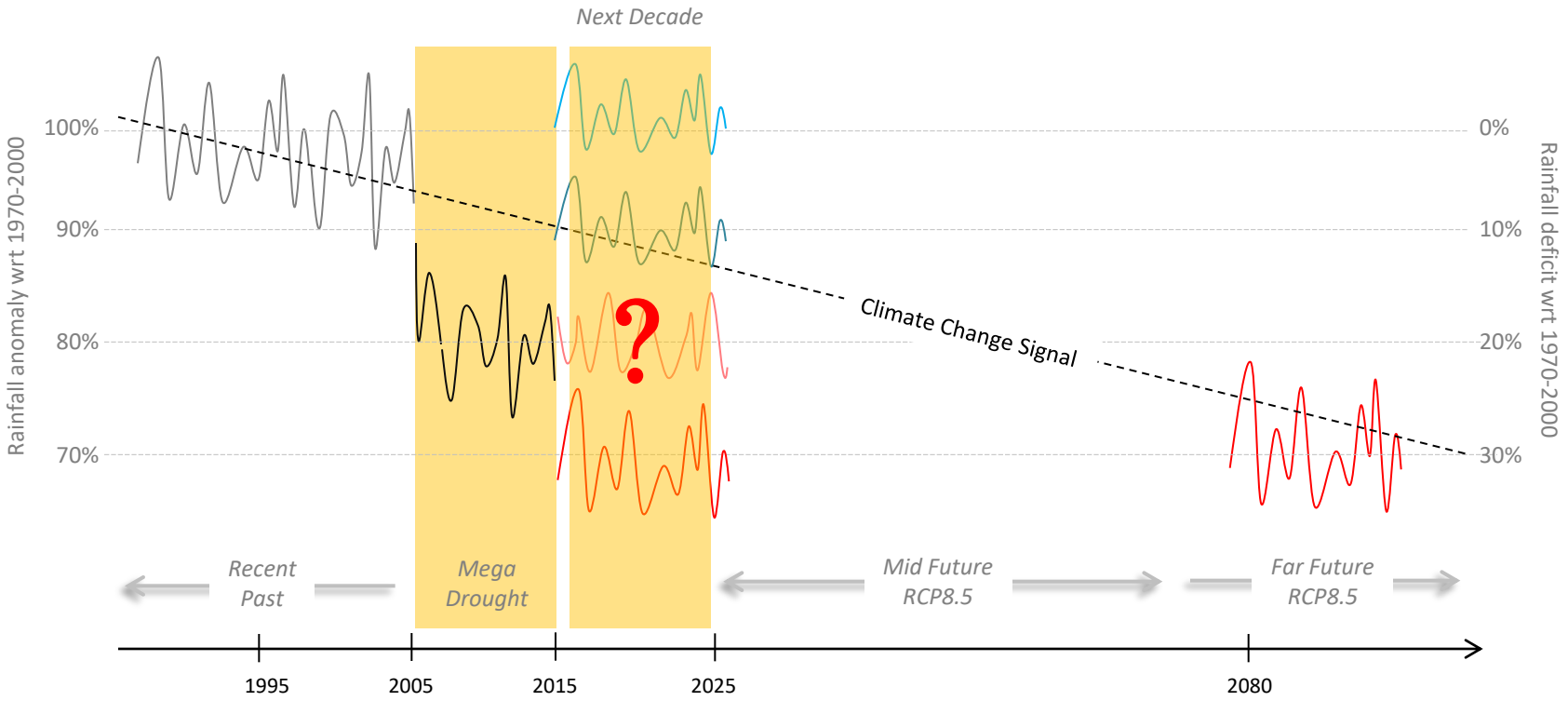




Impactos en Vegetación

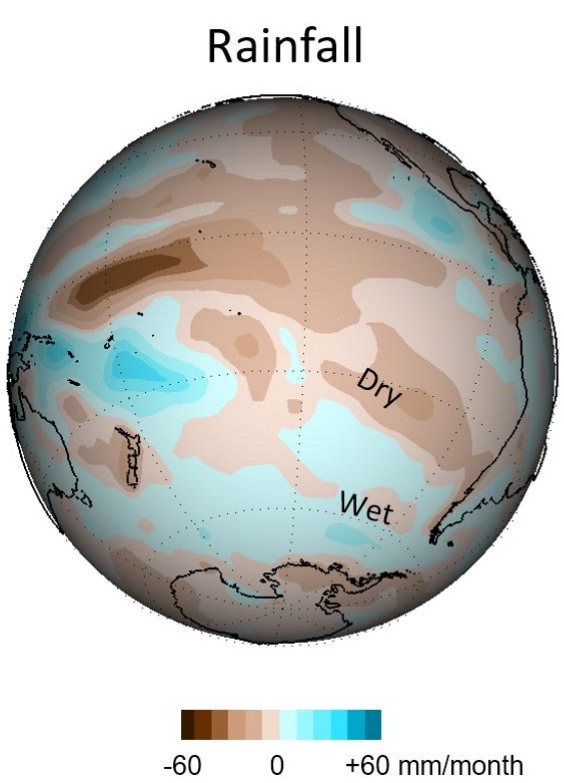


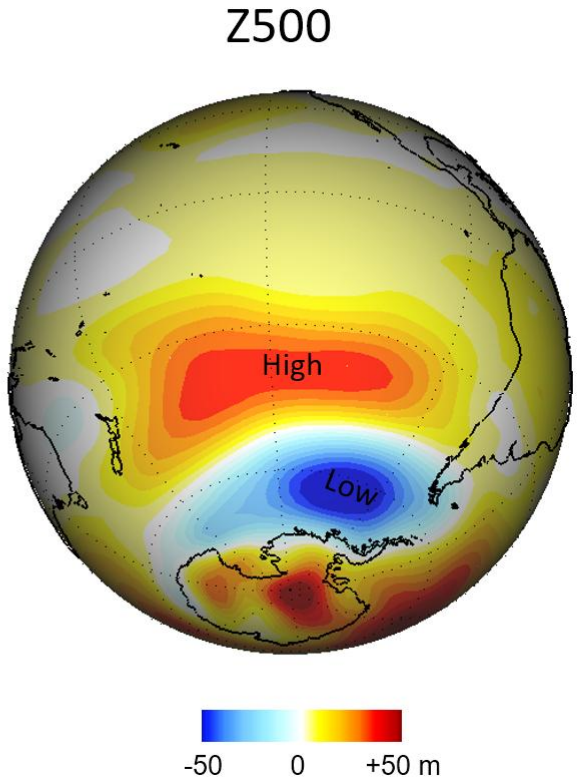
Precipitación en Chile Central
El desafío de la próxima década

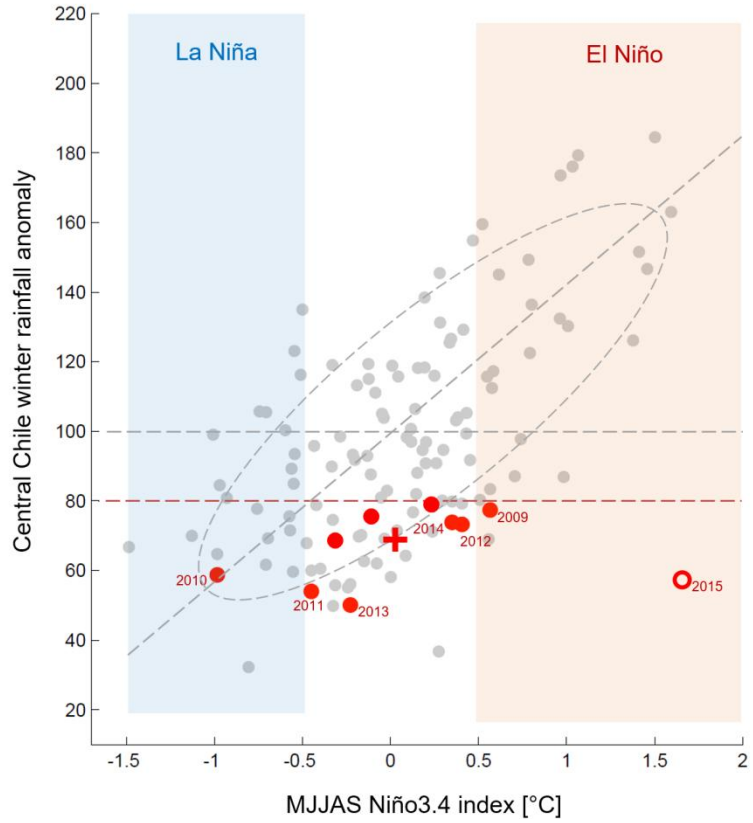


The 2010-2018 mega drought in Central Chile

Mostly ENSO neutral!

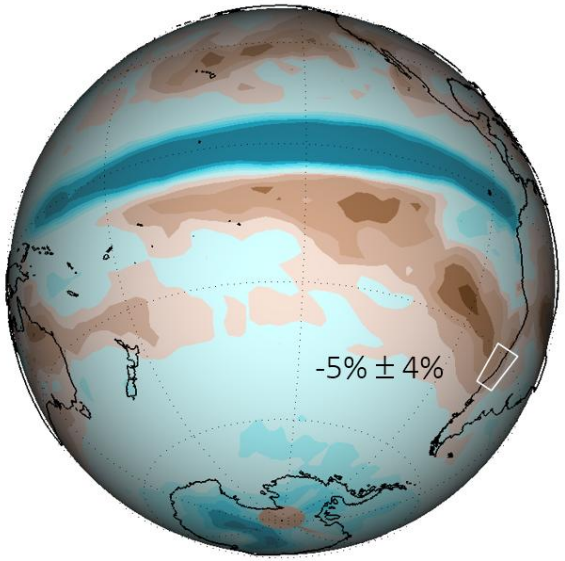




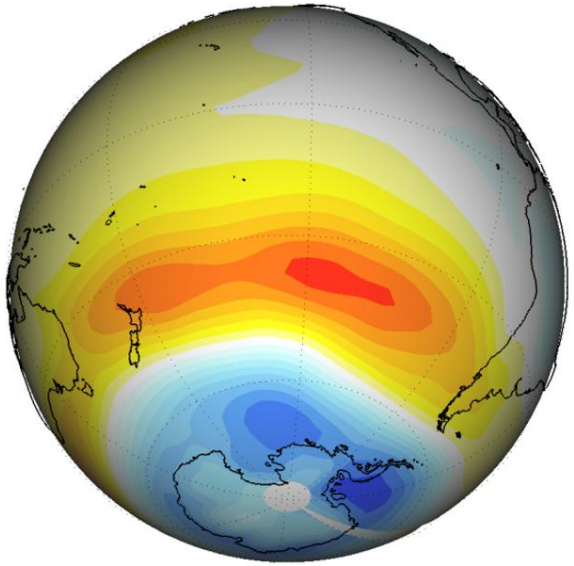


CMIP5 Models: Present (2010-2020)
minus recent past (1970-2000, HIST)

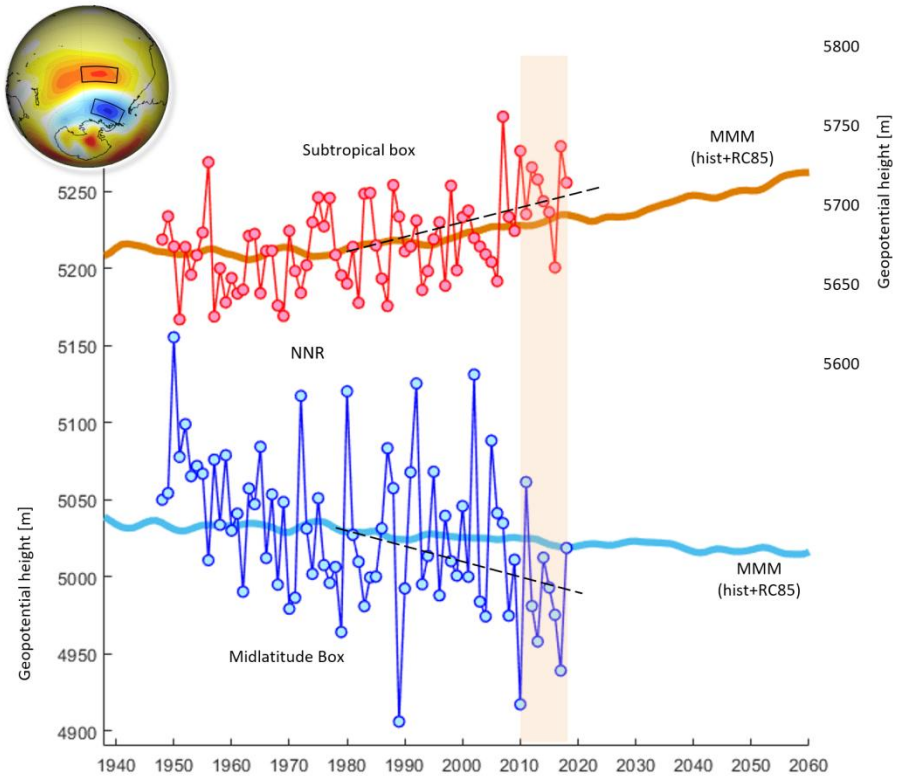
Precipitation Anomalies (%)



SLP Anomalies (hPa)



Multi model mean
(43 models)



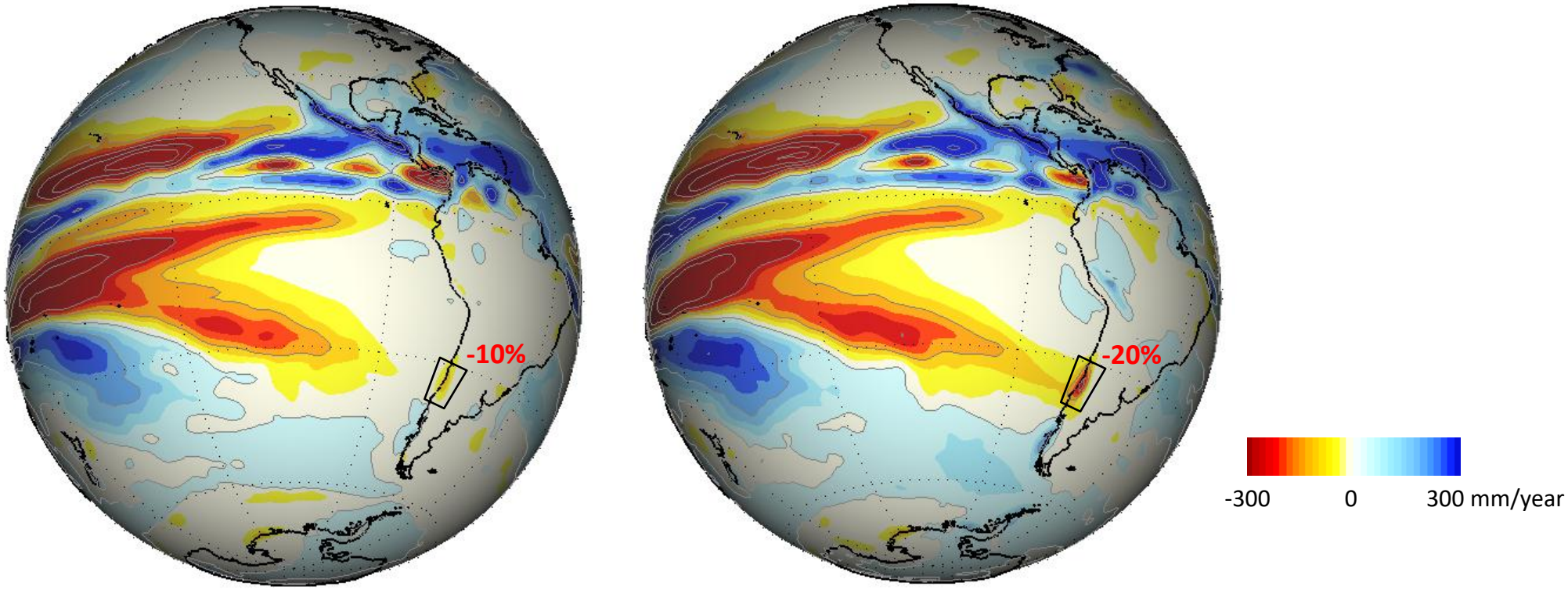
Ok…MD is climate change! (SAM: O3 + GHG)

Wait a second….signal is too small

Winter (MJJAS) rainfall anomaly 2010-2017
LBNL CAM 5.1 AMIP simulations (50 runs)

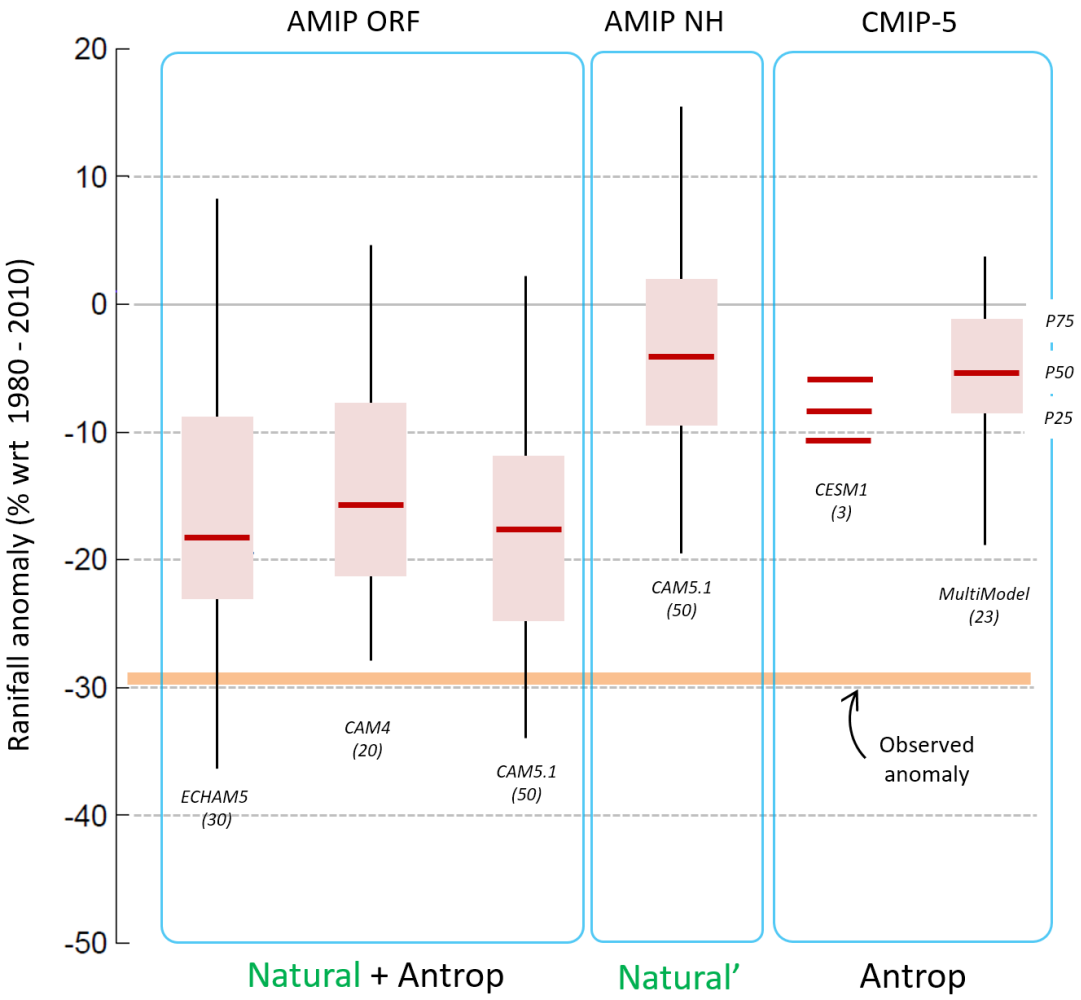
(a) Nat-Hist forcing / Obs SST

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



So…natural variability (PDO) also plays a role

Central Chile (33-36°S) winter (MJJAS) rainfall anomalies during mega drought (2010-2017)



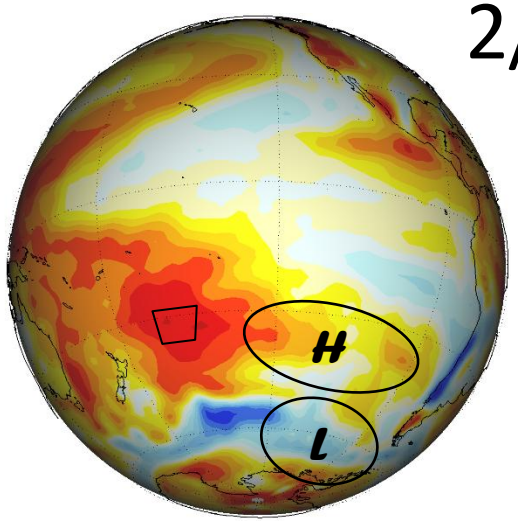
Final message:

Both anthropogenic forcing (1/3) and ocean sourced (natural) decadal variability (2/3) contribute to maintain the central Chile Mega Drought

Boisier et al. 2016; Boisier et al. 2018; Garreaud et al. 2017; Garreaud et al. 2019(?)

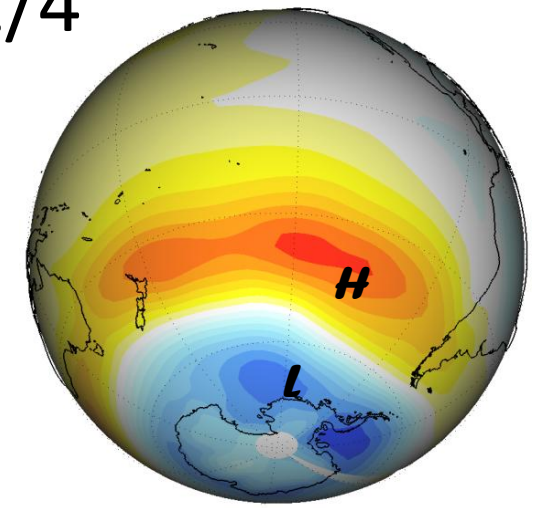
Causas de la Mega Sequía 2010-2019

2/3



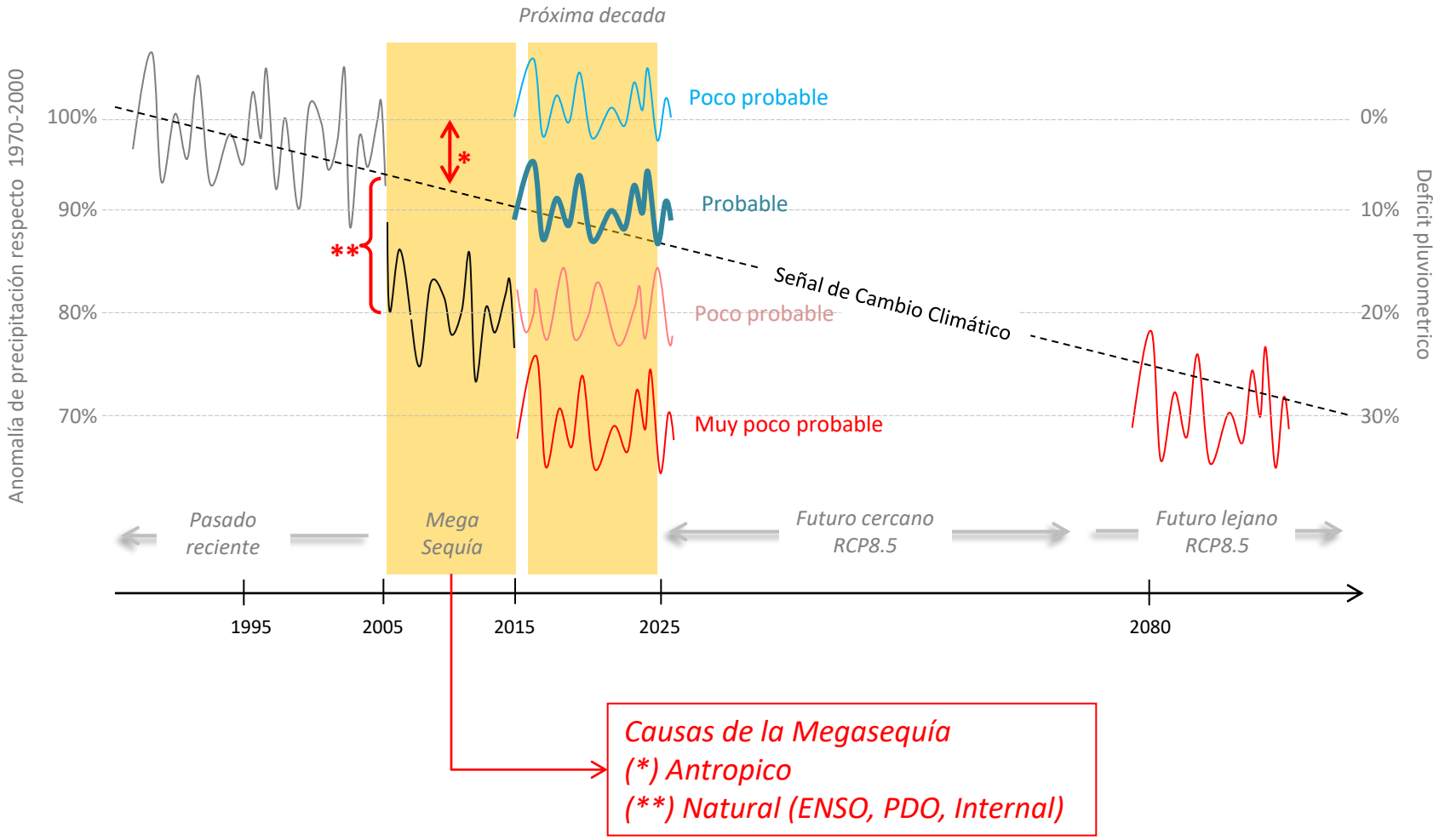
Observed SST Anomalies (°C)
Natural (?)

1/4

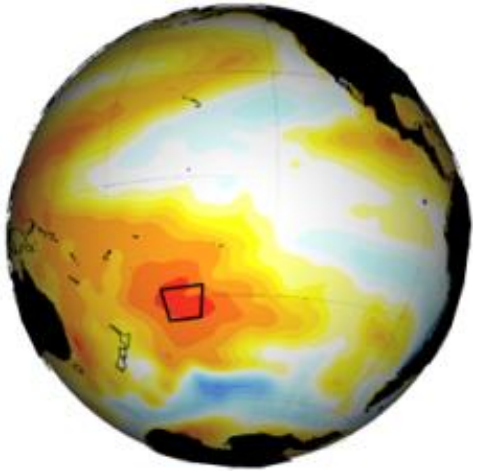


SLP Anomalies (hPa)
Antropoghenic

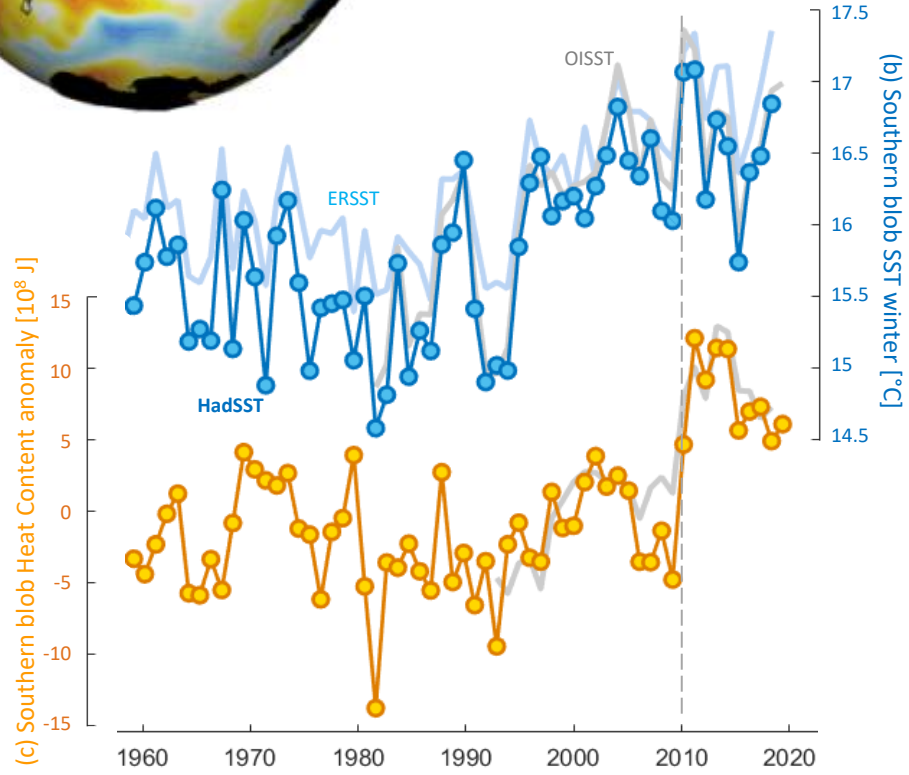
Precipitación en Chile Central
El desafío de la próxima década

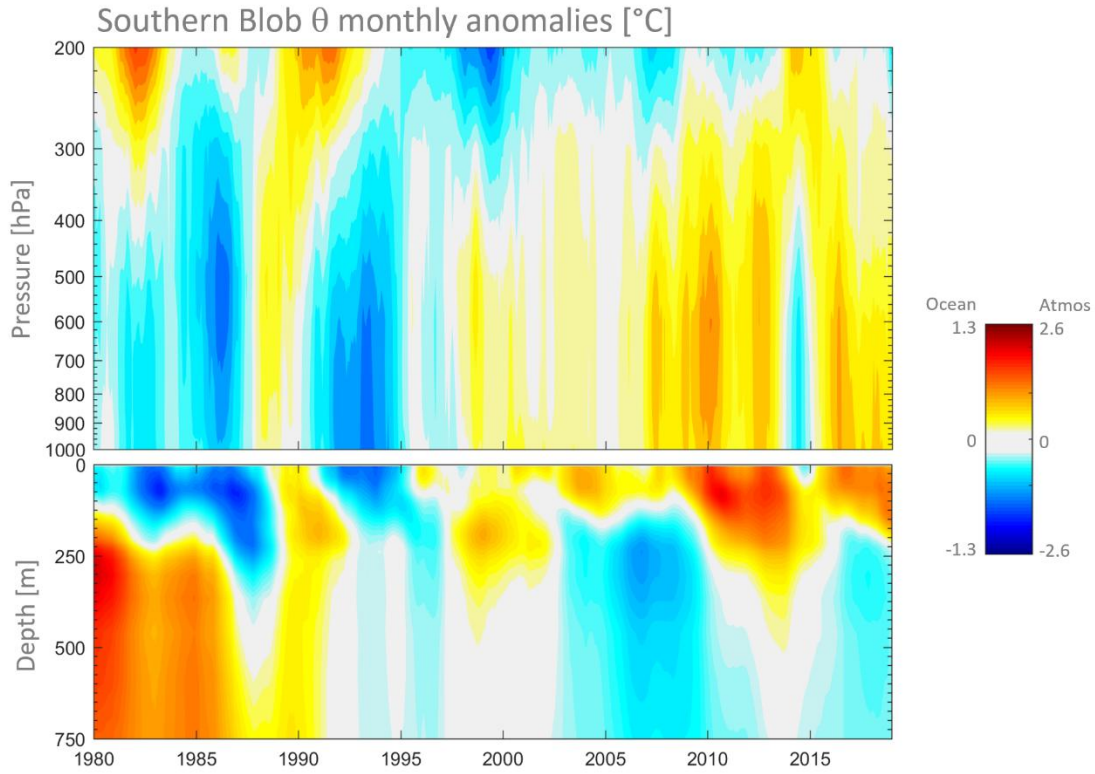


An emergent research topic… **the Southern Blob**



(a) OISST 1979-2018 trend [°C]

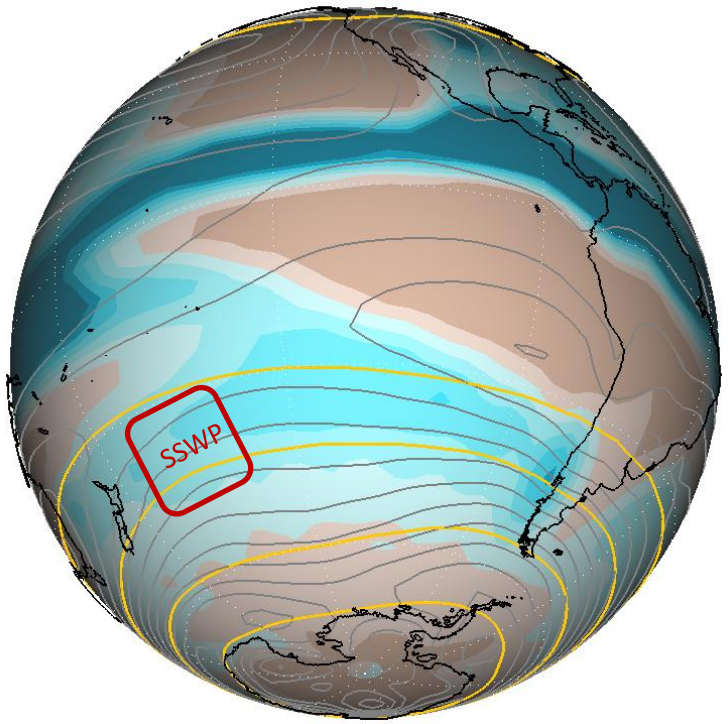




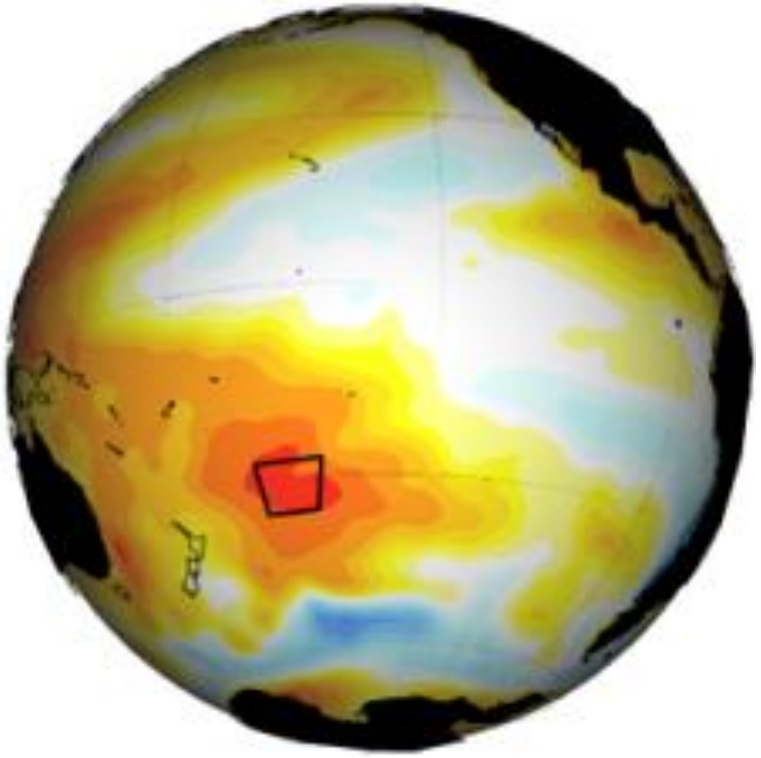
The relevance of the Southern Blob

Simulations using SPEEDY, a simple GCM

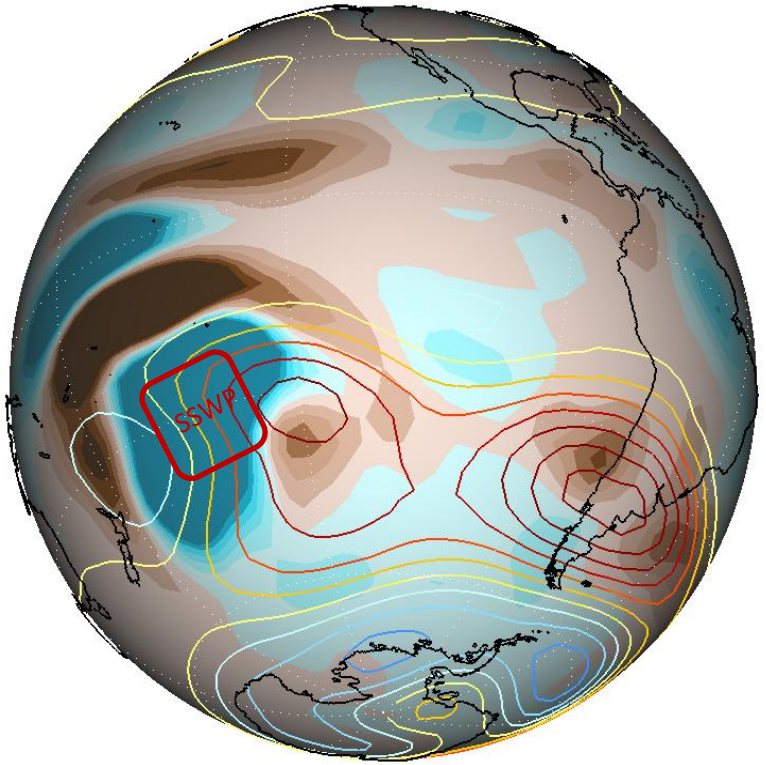
(a) Control Simulation (CTR)
Precip – SLP – Z500



(b) Observed SST trend



(c) SSWP+2.5 minus CTR
Precip – Z500

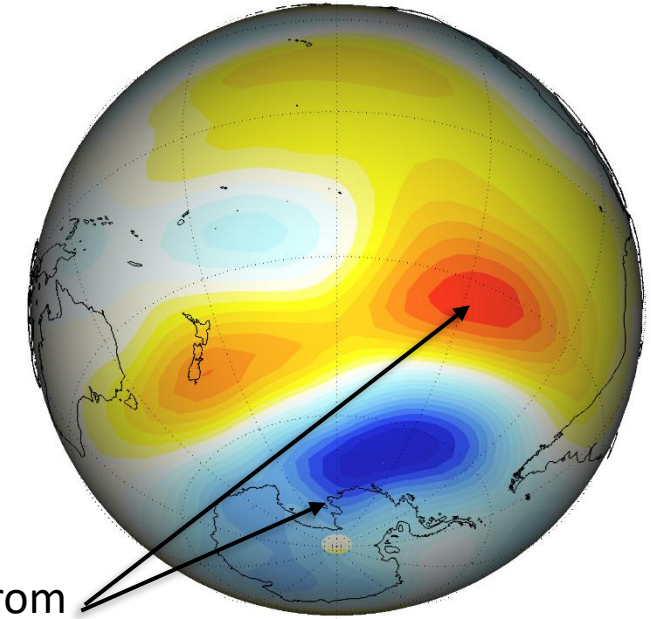


The relevance of the Southern Blob

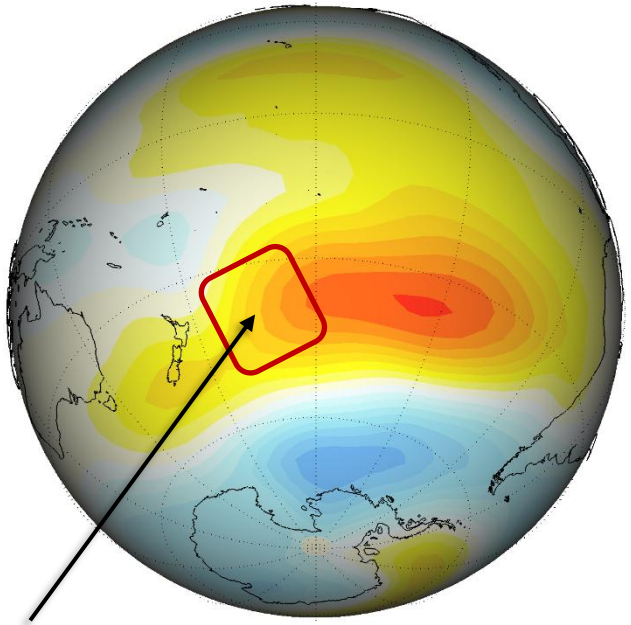
Simulations using SPEEDY, a simple GCM

SLP Trend 1980 – 2015

Control (Full SST)



No Southern Blob



SLP trends not far from reality and conducive to dry conditions in central Chile

Constant SST (no warming)

Key SLP trends much reduced, central Chile drought is reduced. What remains due to SST trends in the equatorial Pacific.