Clima de Sudamérica y Chile

Cambio Climático

Curso Biogeografía de Chile
Instituto de sistemas complejos de Valparaíso
20 octubre 2009

Introduction

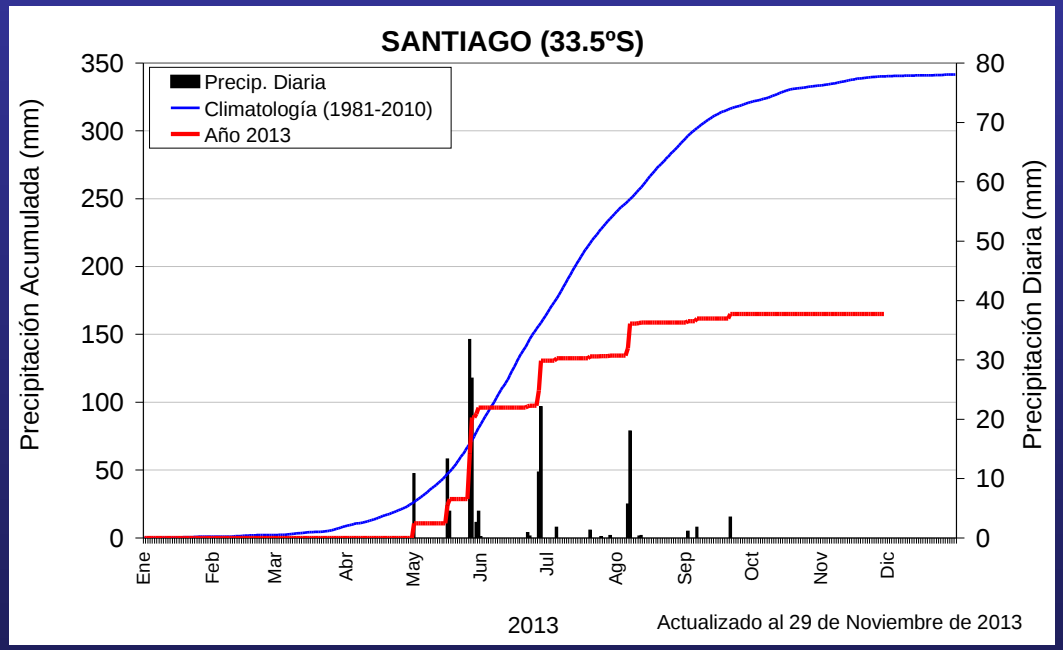
- The 2013 rainfall regime in central Chile
- The “future” of global surface temperature at four times in the past

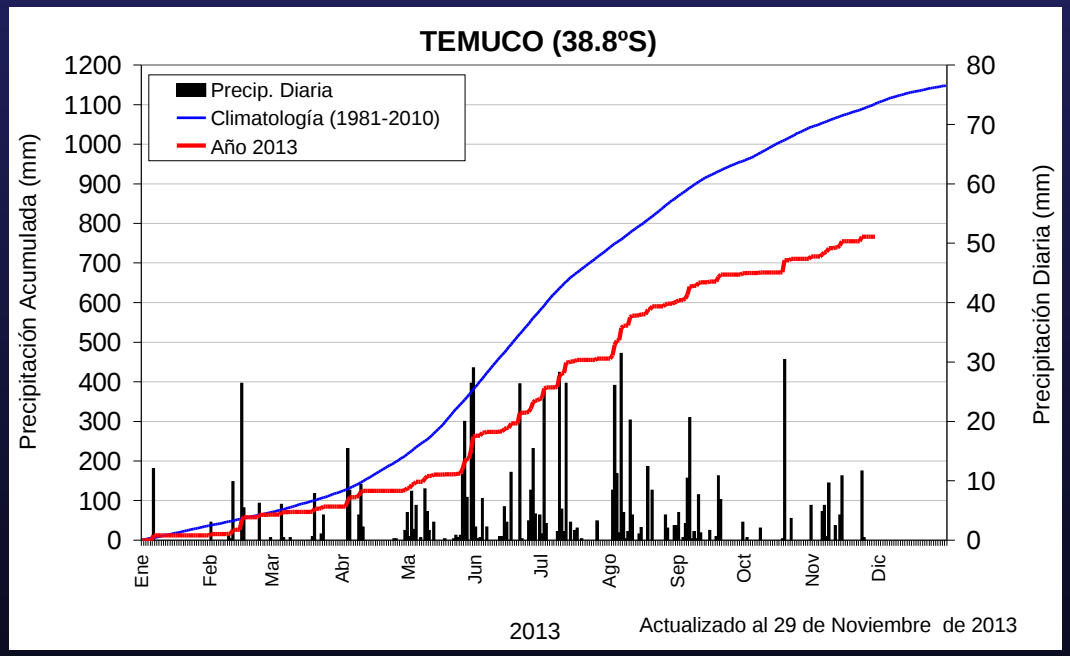
Rainfall regime 2013

Blue: accumulated (climatology)

Red: accumulated 2013

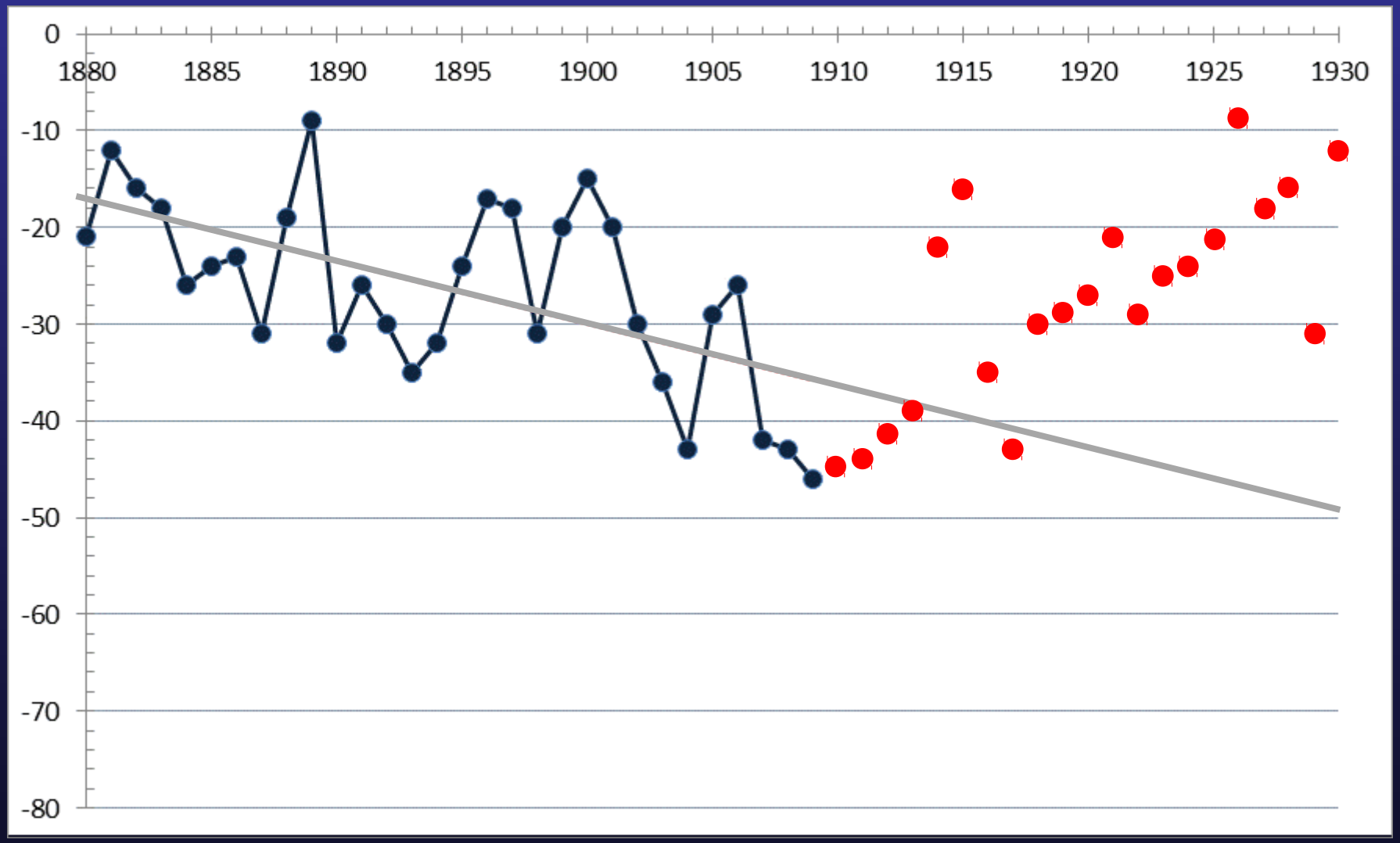
Black: rainfall episodes





Global land-ocean surface temperature anomalies (Ref.: 1951 – 1980 mean)

°C x 100



Data source: Goddard Institute por Space Studies - NASA

Global land-ocean surface temperature anomalies (Ref.: 1951 – 1980 mean)

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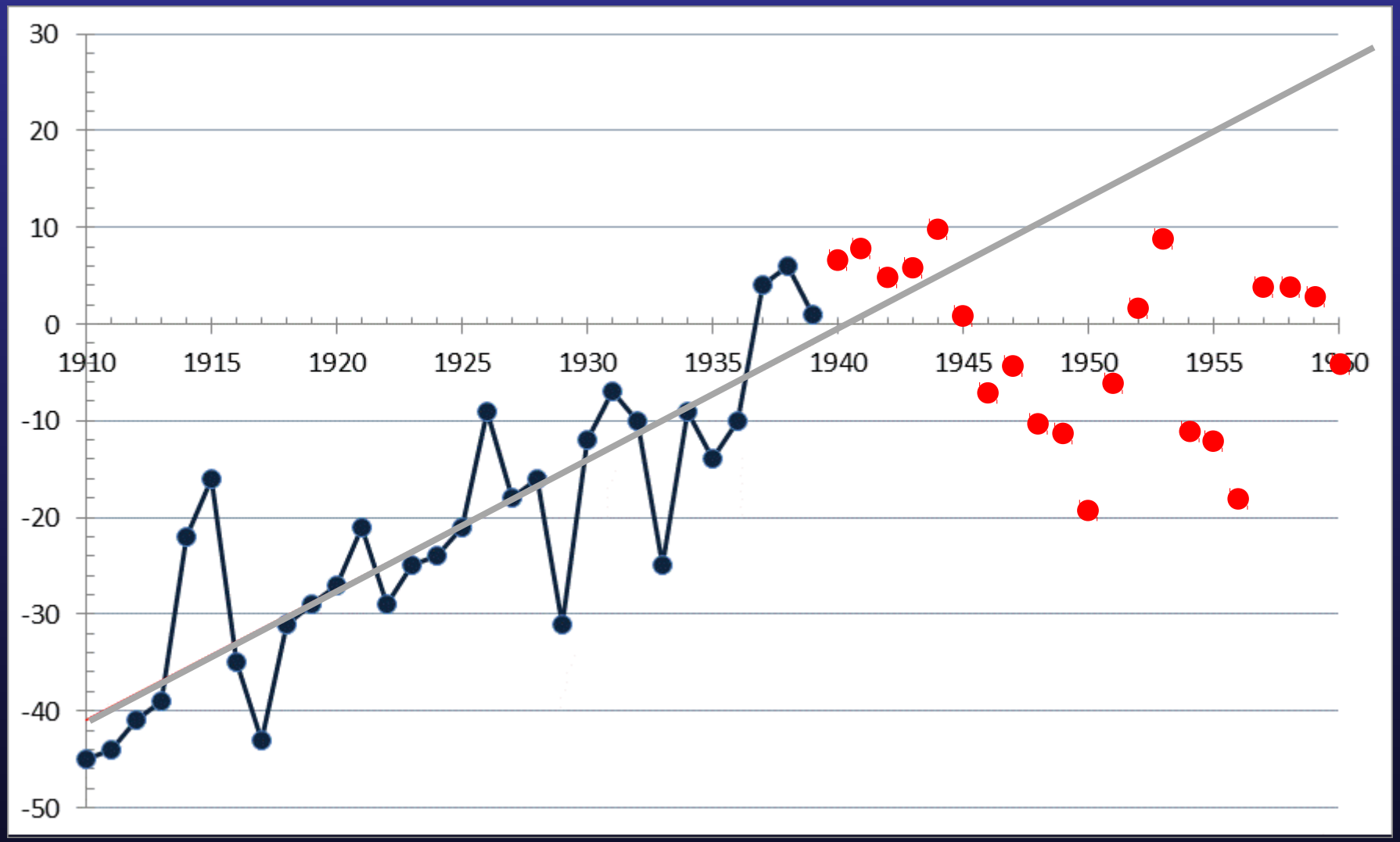

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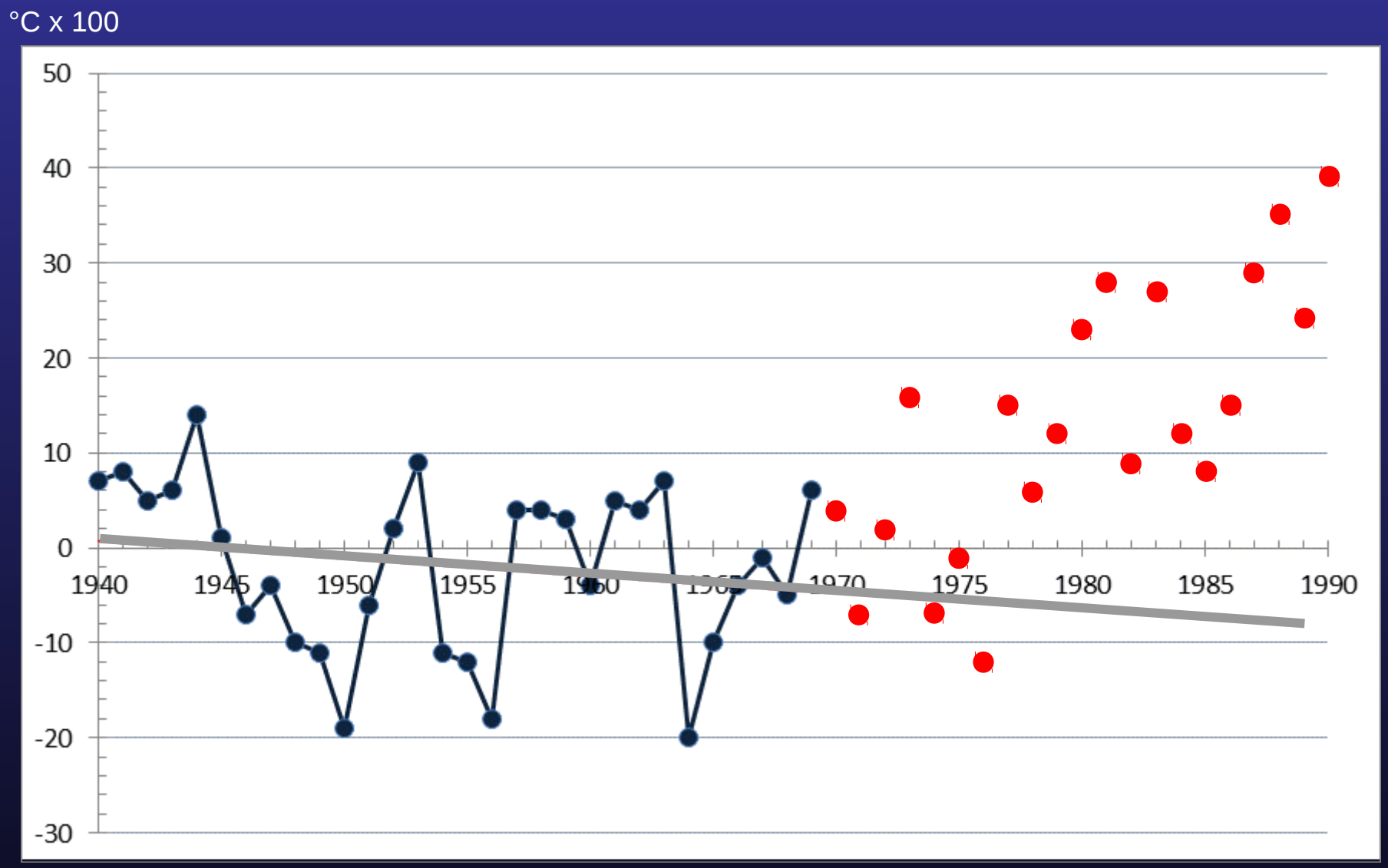

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Global land-ocean surface temperature anomalies (Ref.: 1951 – 1980 mean)

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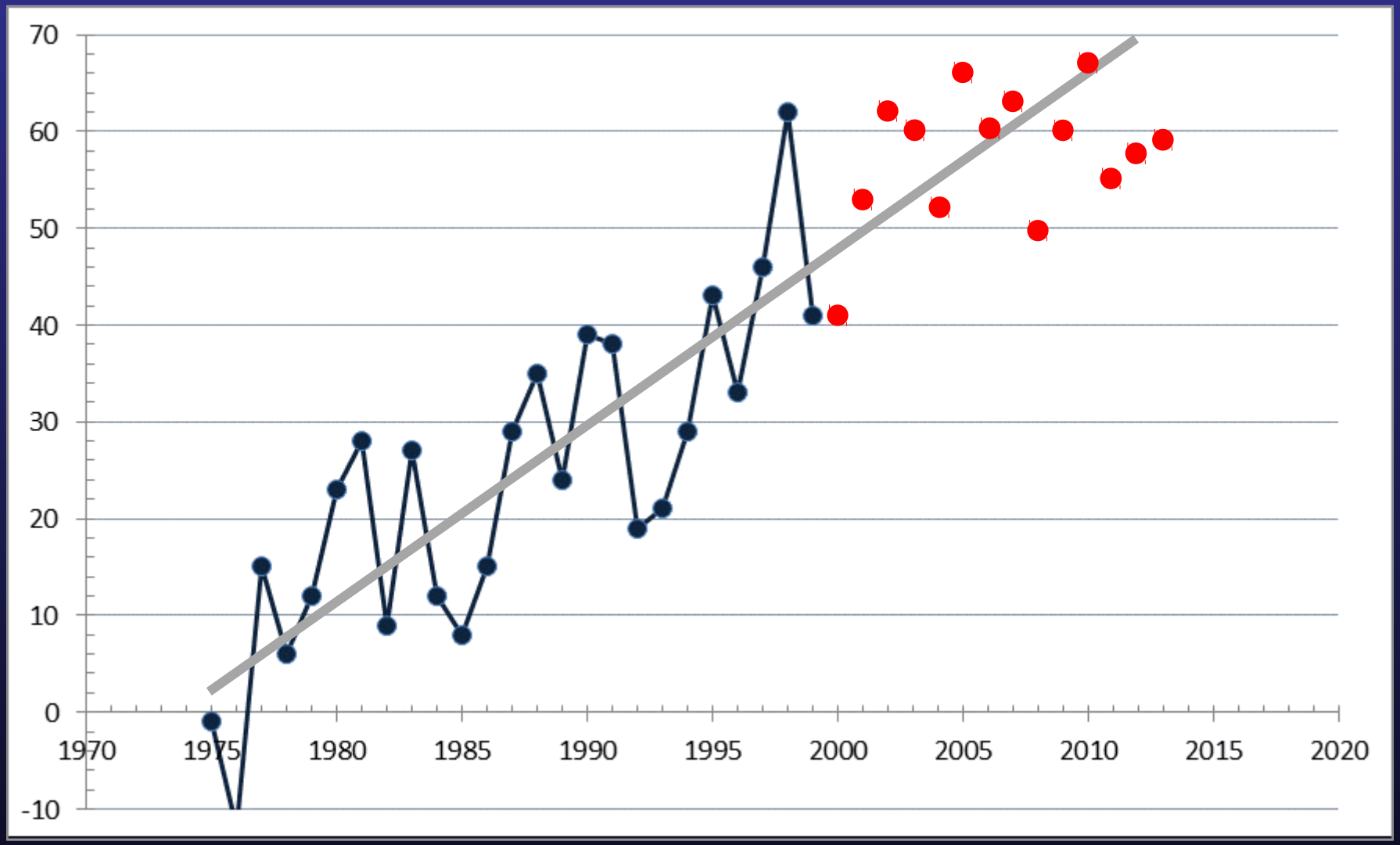

Data source: Goddard Institute por Space Studies - NASA

Global land-ocean surface temperature anomalies (Ref.: 1951 – 1980 mean)

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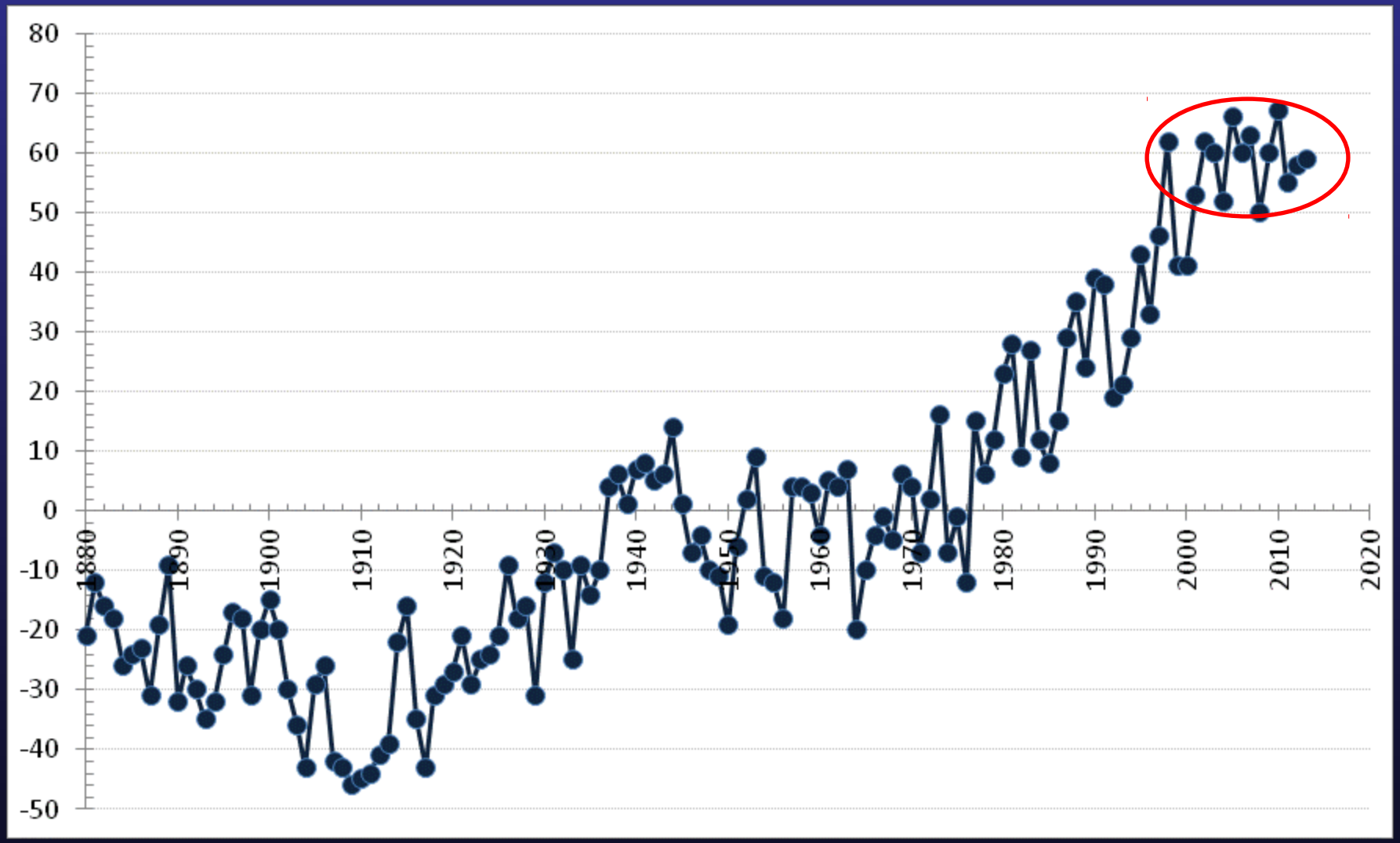
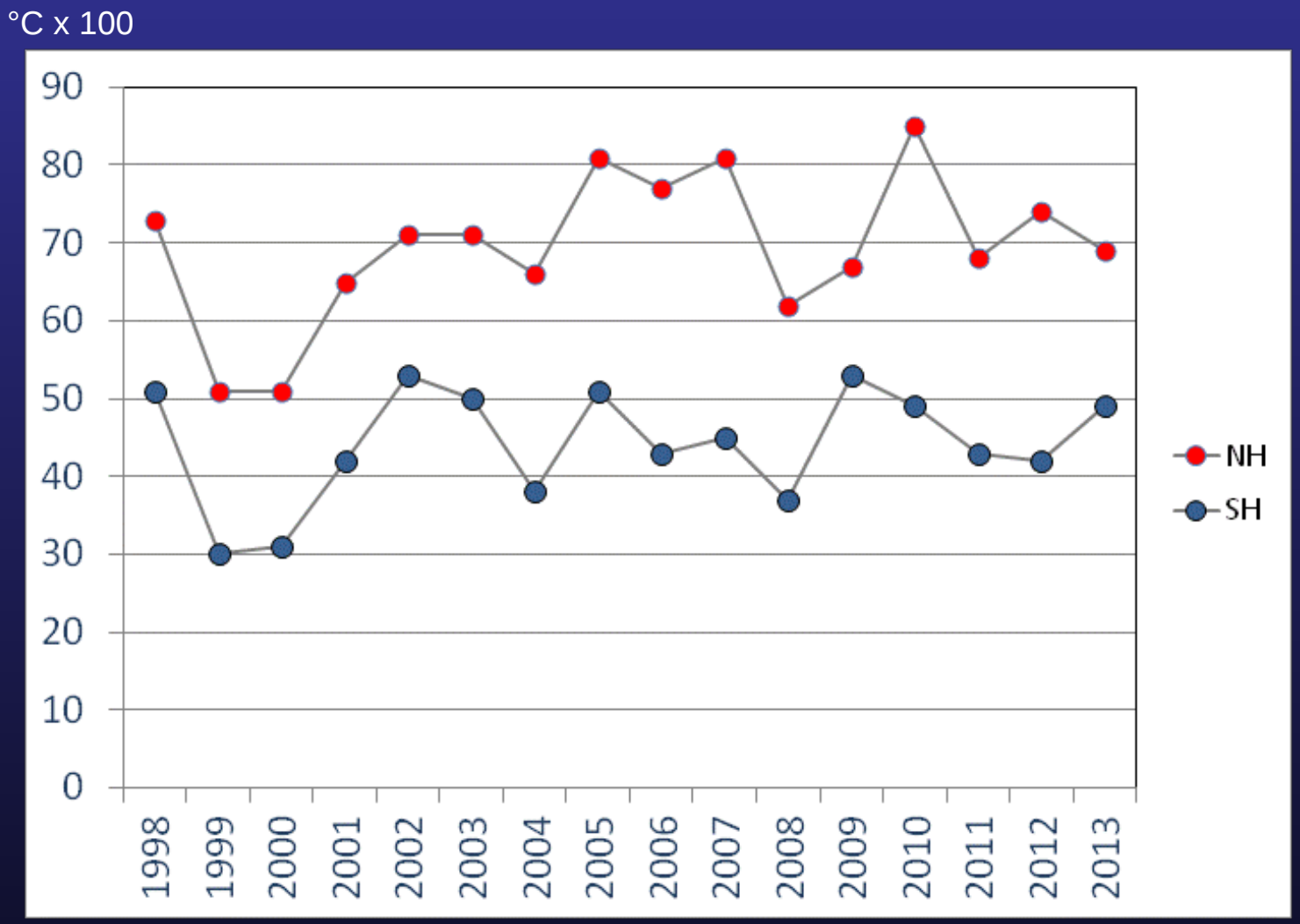


Data source: Goddard Institute por Space Studies - NASA

“Cimate hiatus” in the evolution of land-ocean surface temperature anomalies in the Northern (NH) and Southern (SH) Hemispheres during the period 1998 - 2013



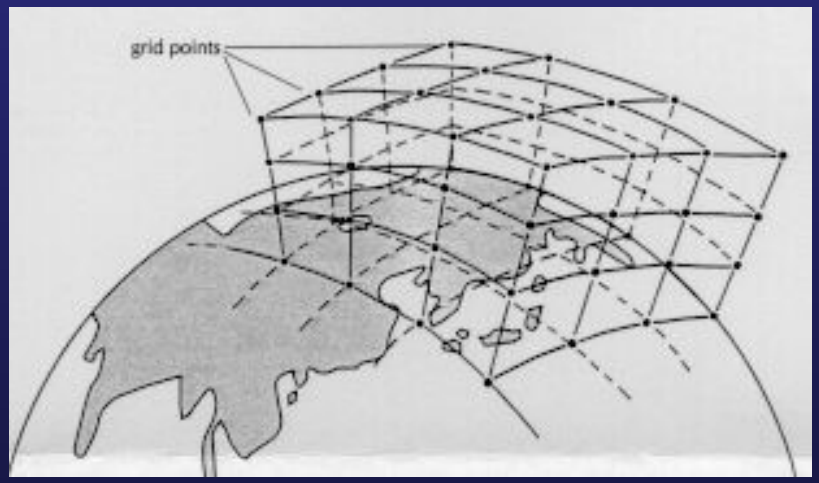
Source: Goddard Institute por Space Studies – NASA http://data.giss.nasa.gov/gistemp/

Anomalies calculated from the corresponding 1951-1980 means.

2. Future climate scenarios in Chile (2071 – 2100)

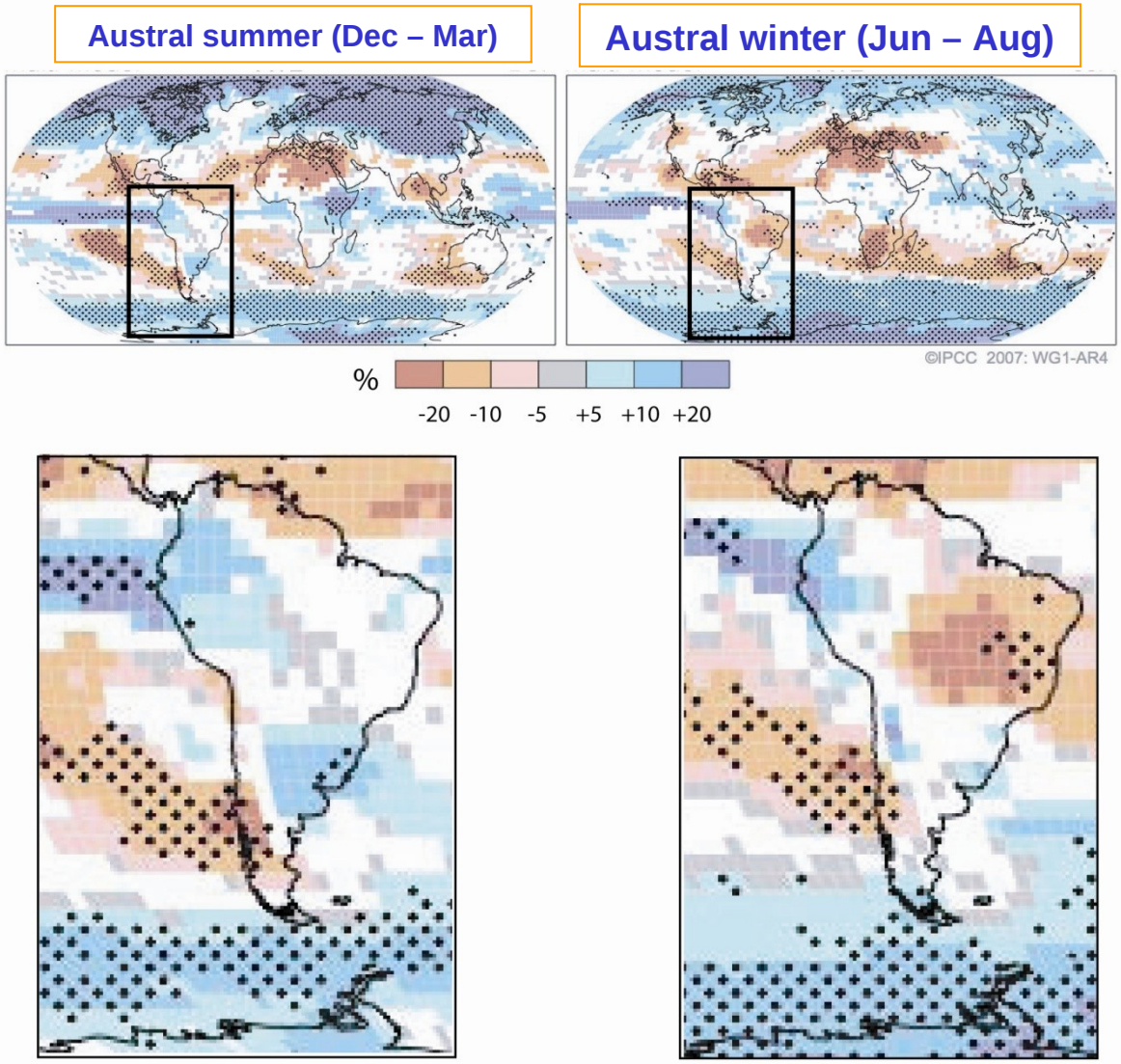
Fundamental tool to project global climate in the future

AOGCM : Atmosphere – Ocean General Circulation Model



Future global climate scenarios are built using mathematical models (Atmosphere – Ocean General Circulation Models) that simulate the dynamic and thermodynamic behaviour of the atmosphere and oceans in response to an intensification of the greenhouse effect due to anthropogenic factors.

Changes in rainfall projected by AOGCM's for the last part of 21st century



Dots indicate regions where more than 90% of the models agree.

Source: IPCC 2007 executive summary

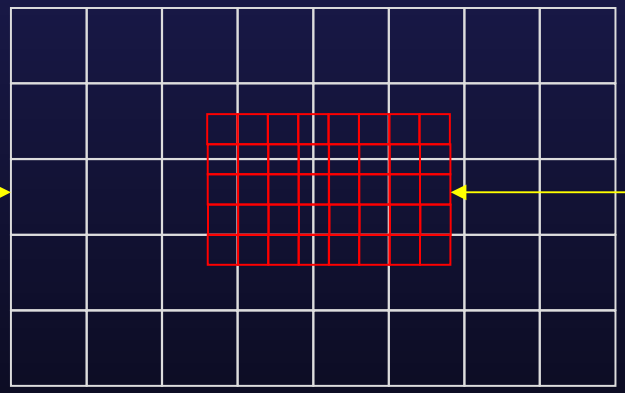
Simulation of Regional future climate scenarios

Regional climate models (RCM's) are used to improve the spacial resolution. Border conditions are prescribed by the output of a global climate model (AOGCM).

In the 2006 study by the Department of Geophysics (U. de Chile) for the National Comission for the Environment (CONAMA) it was used the RCM PRECIS, developed by the Hadley Center (UK – Meteorological Office).

AOGCM
Hadley Centre Coupled Model, v 3 (HadCM3)

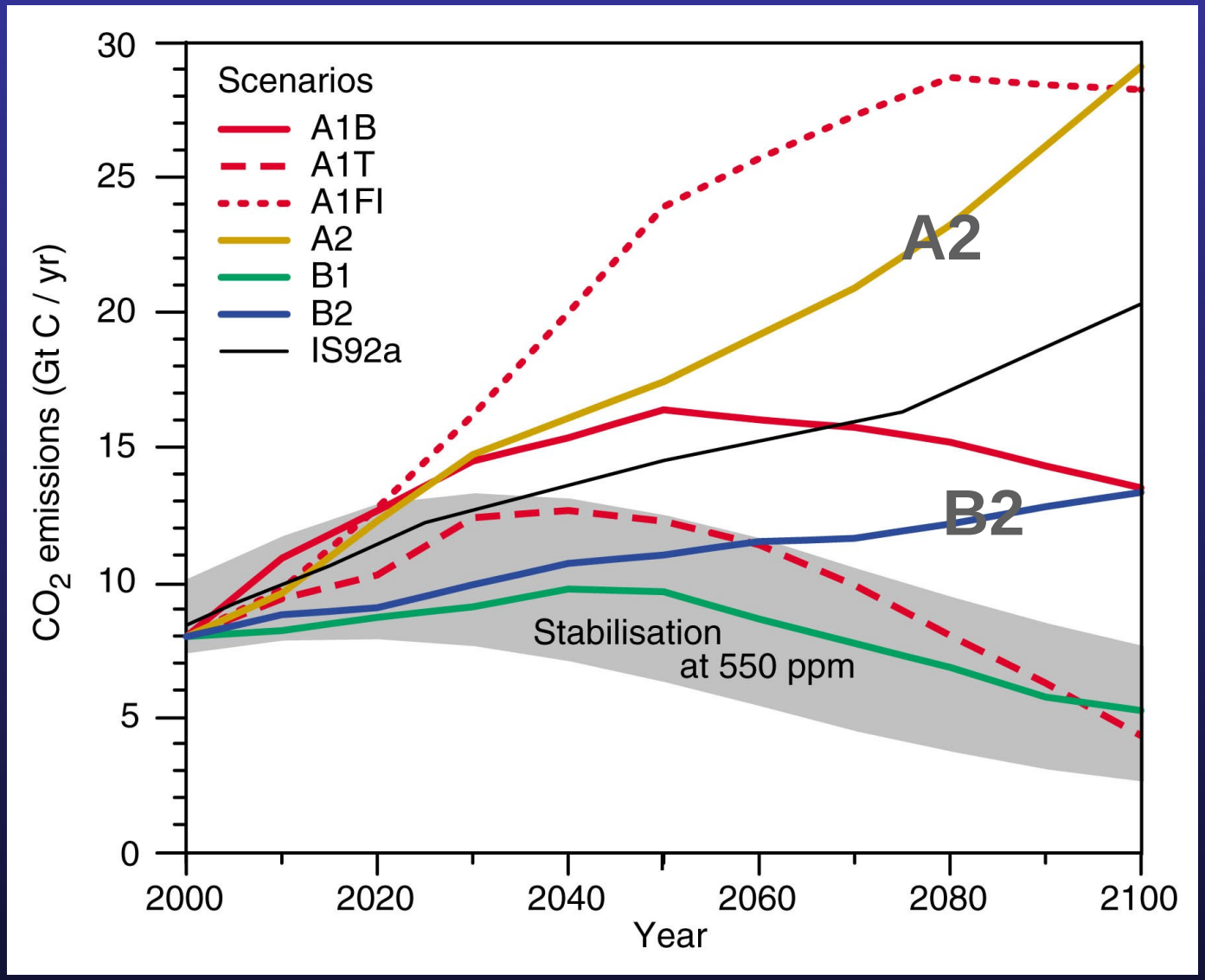
Hadley Centre
UK – Met. Office



RCM

Model PRECIS

Hadley Centre
UK – Met. Office



Global emissions of CO2 projected for the XXI century, associated to several scenarios of global development (Source: IPCC Report, 2006)

Spacial domain of the RCM PRECIS applied for the definitions of future climate scenarios in Chile

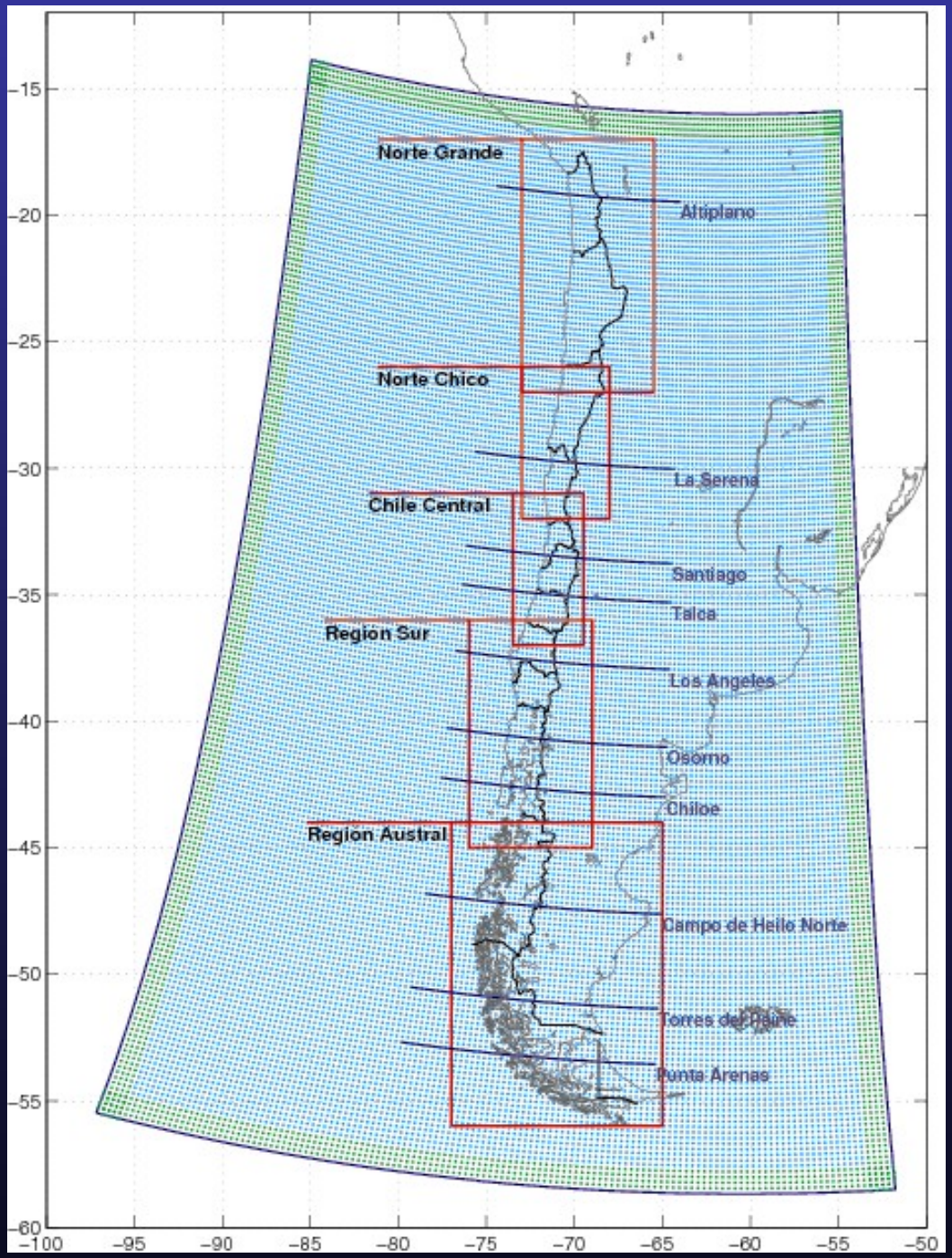
Resolution: 25 x 25 km

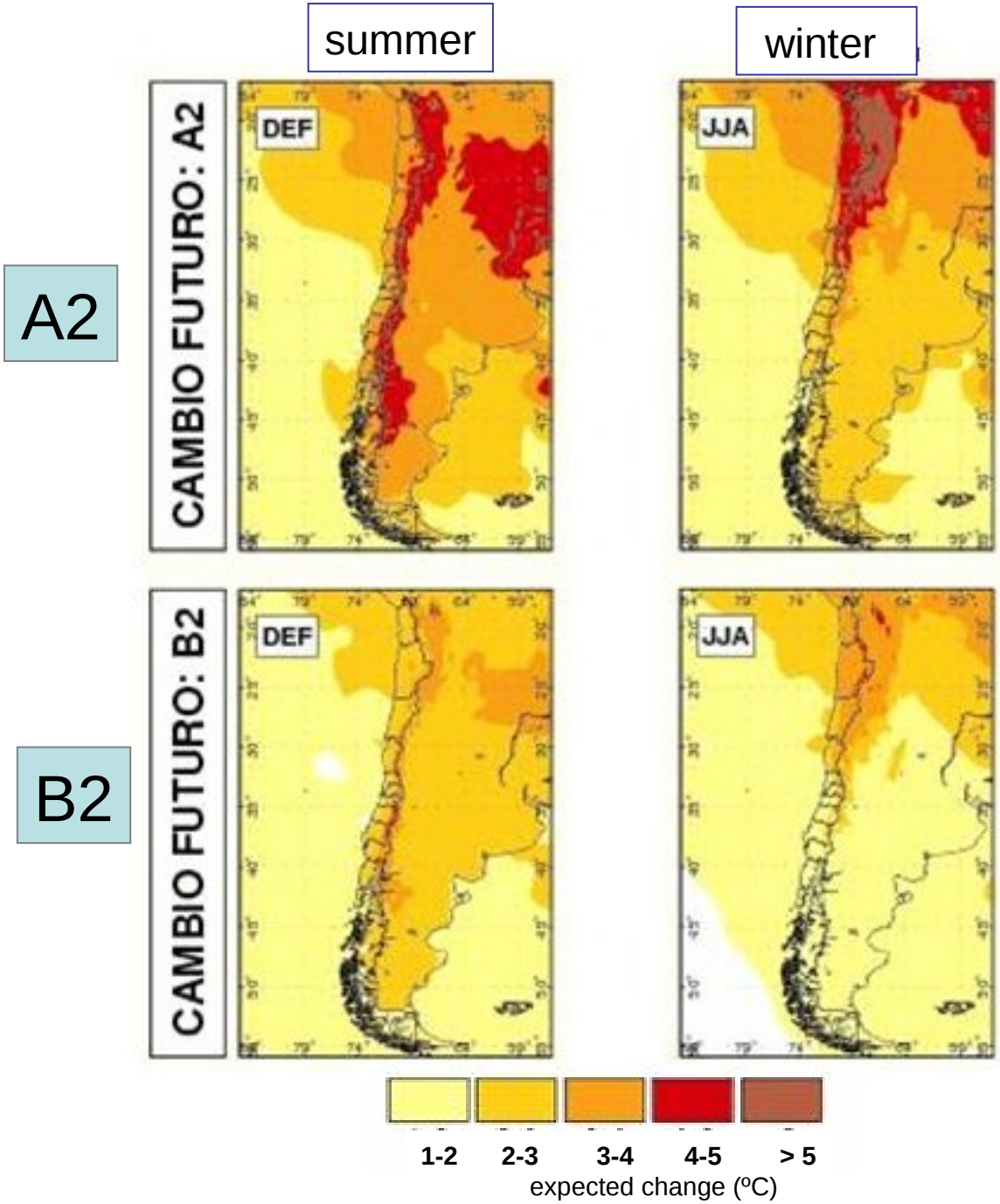
Source: DGF – U. de Chile. Report to CONAMA.

Methodology

The regional climate was simulated for the period 1961 – 1990 (to represent the current climate) and for the period 2071 – 2100 (to represent future conditions associated to an intensified greenhouse effect).

The difference (or the quotient) between the two simulations was calculated at each grid point.





Expected changes in surface air temperature precribed by the RCM PRECIS for the period 2071 - 2100 with respect to conditions during 1961 - 1990.

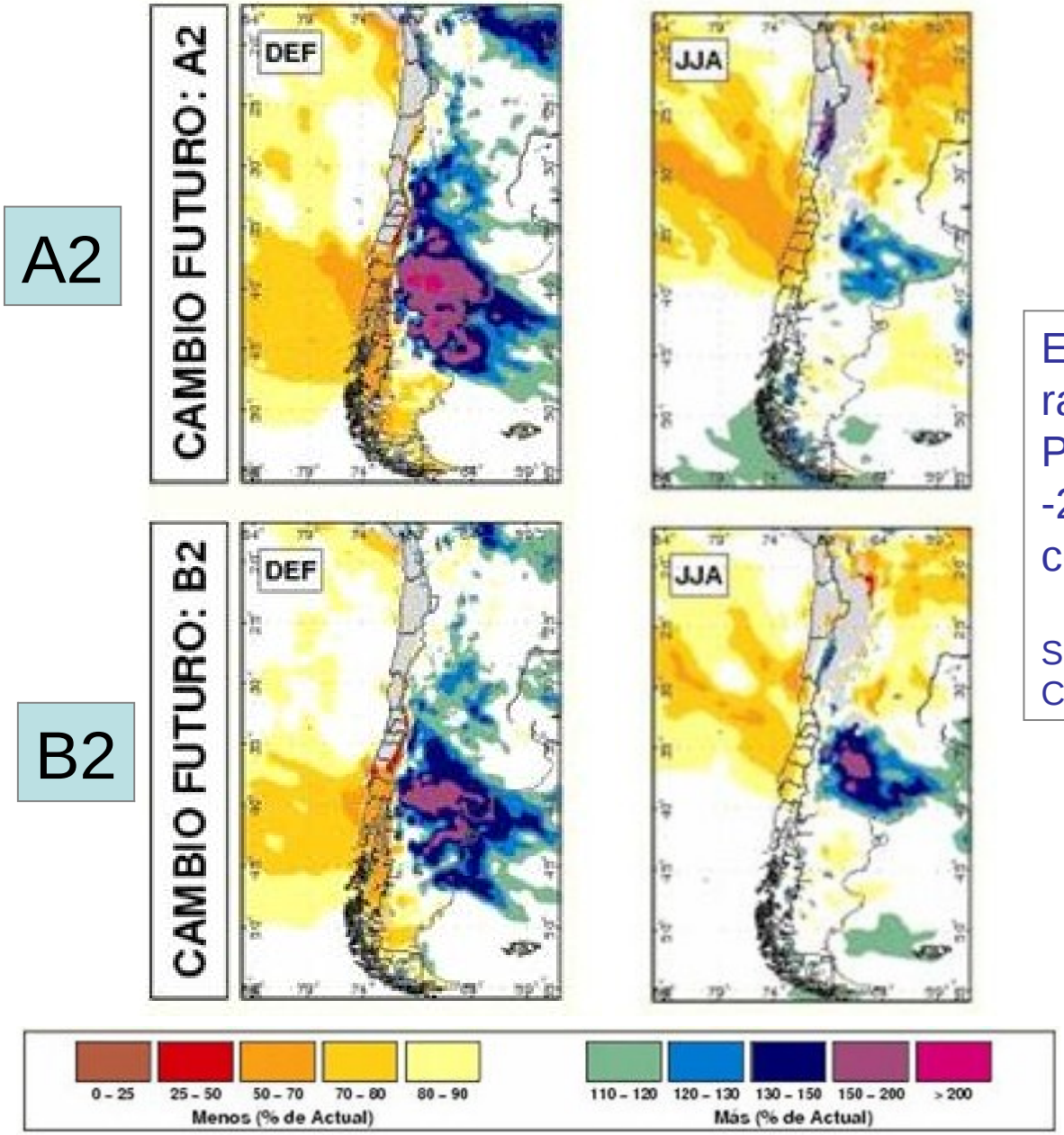
Source: DGF – U. de Chile. Report to CONAMA.

Summer (DJF)

Winter (JJA)

A2

B2



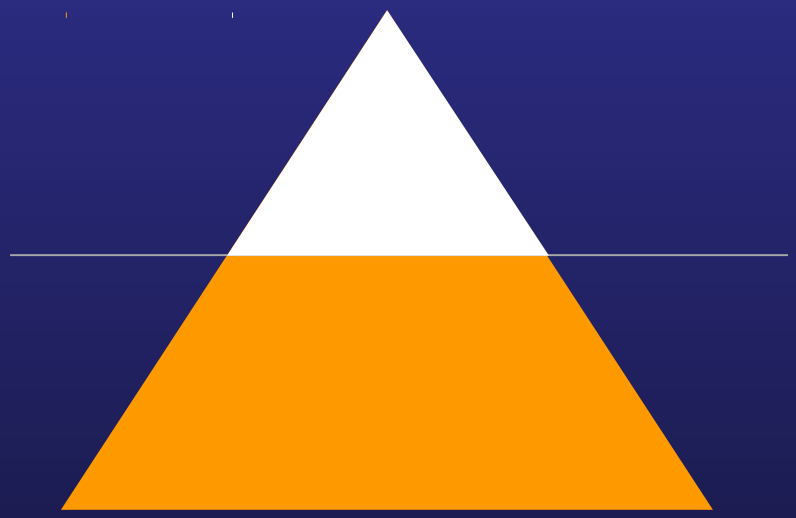
Expected changes in seasonal rainfall prescribed by the RCM PRECIS for the period 2071 -2100 with respect to conditions during 1961 - 1990.

Source: DGF – U. de Chile. Report to CONAMA.

Expected changes in hydrological regimes of Andean basins in central Chile

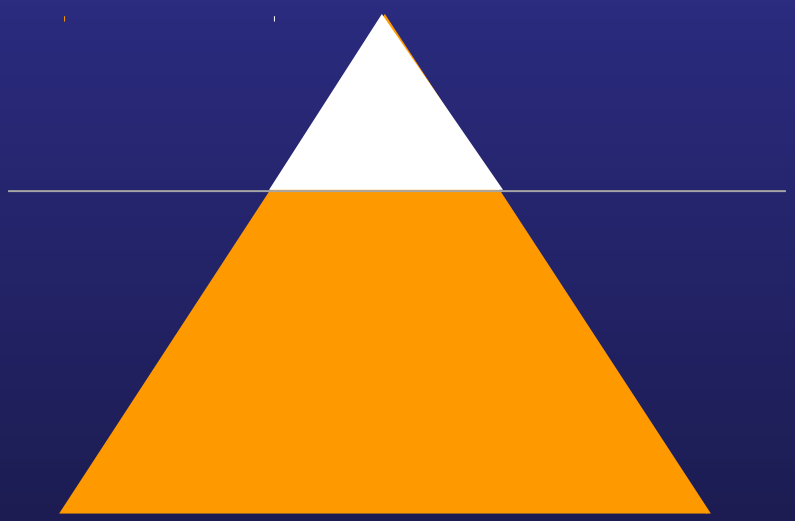
WINTER CONDITIONS

Present Climate



H 0°C

Future Climate

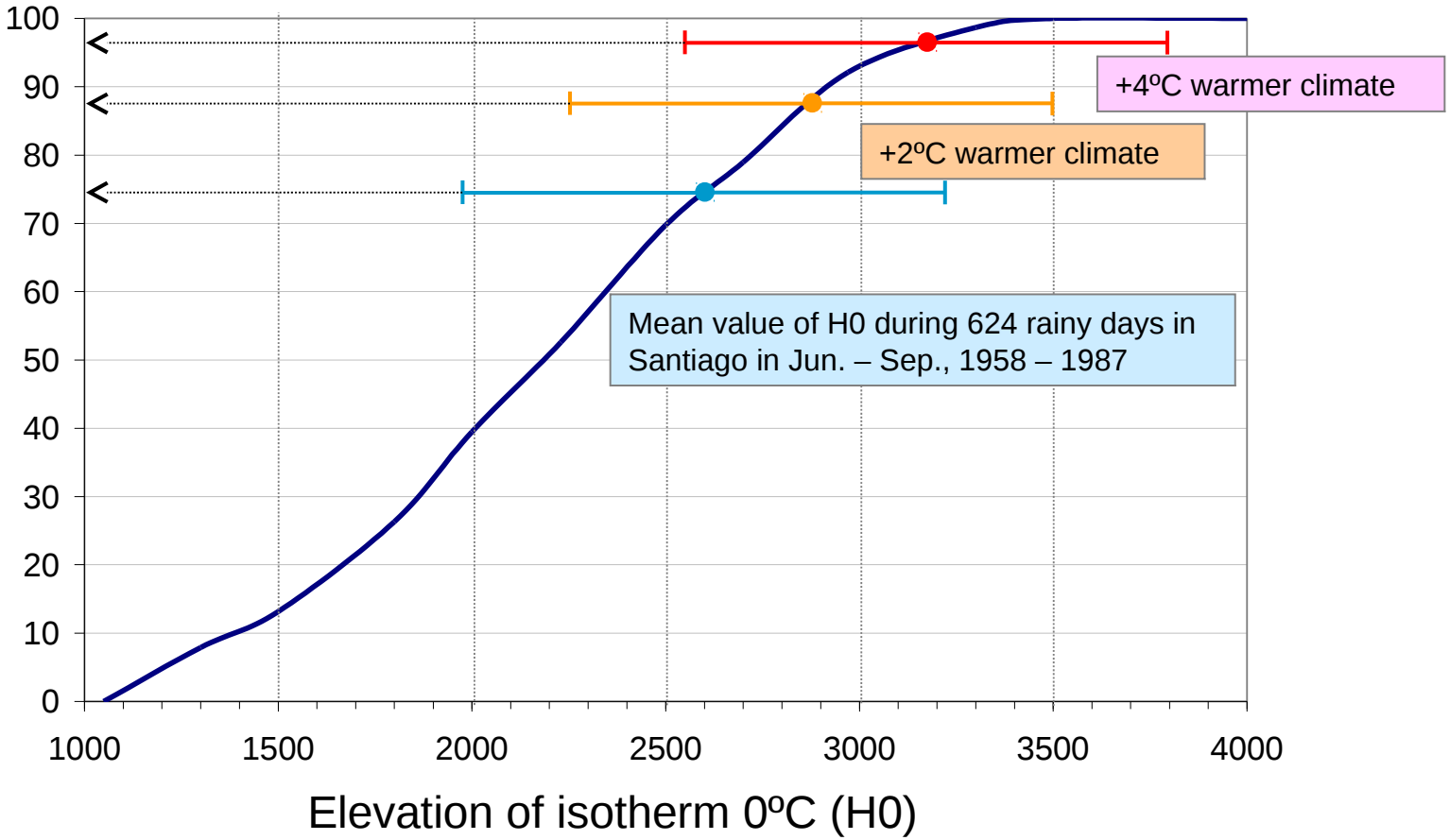


Future climate

- Overall warmer and drier conditions in central Chile
- Higher elevation of isotherm 0°C
- Area receiving rainfall will increase
- Snow accumulation over mountains will decrease

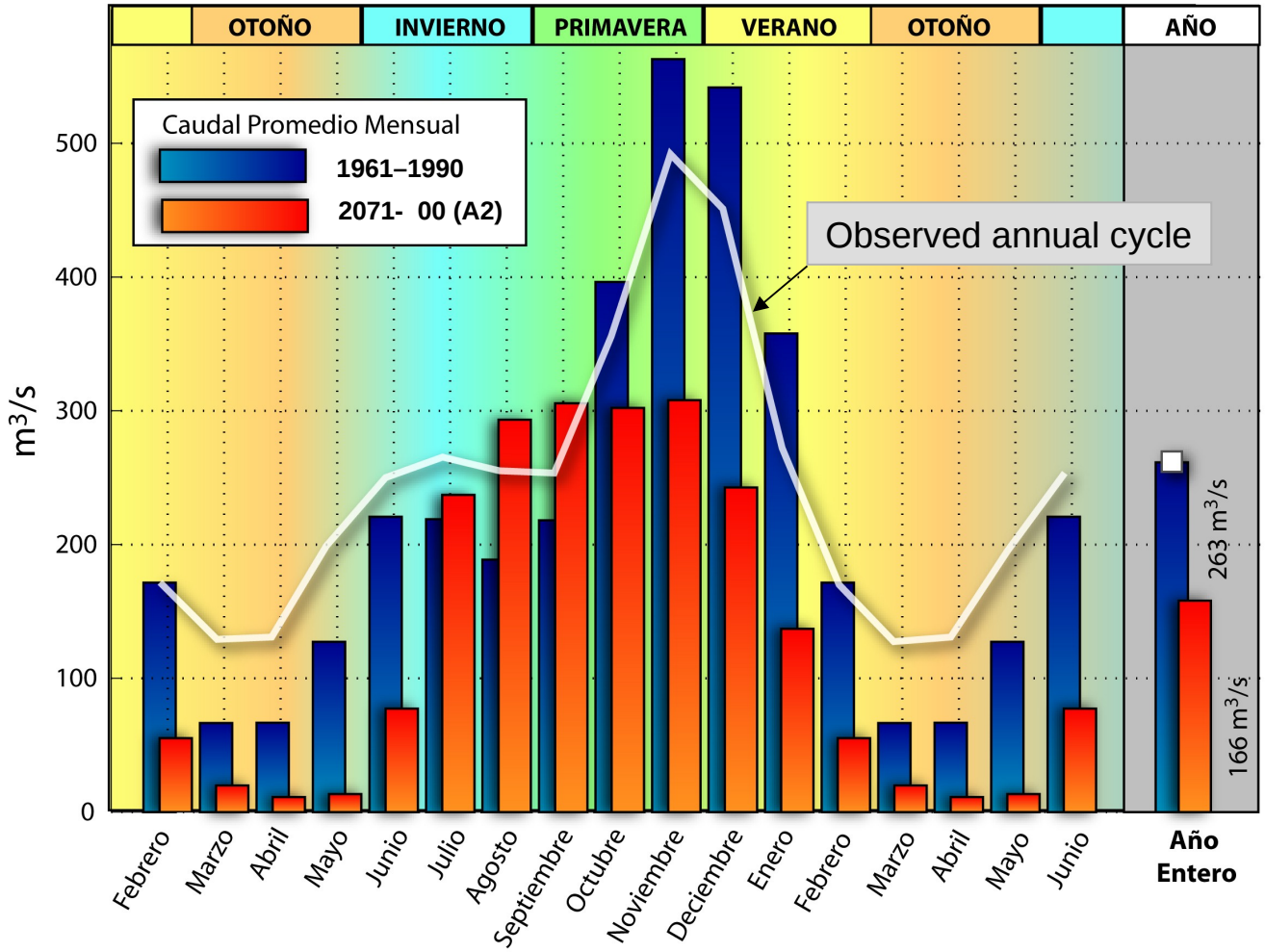
Basin: San Ramón – Santiago (33.5ºS) Area: 38 km2

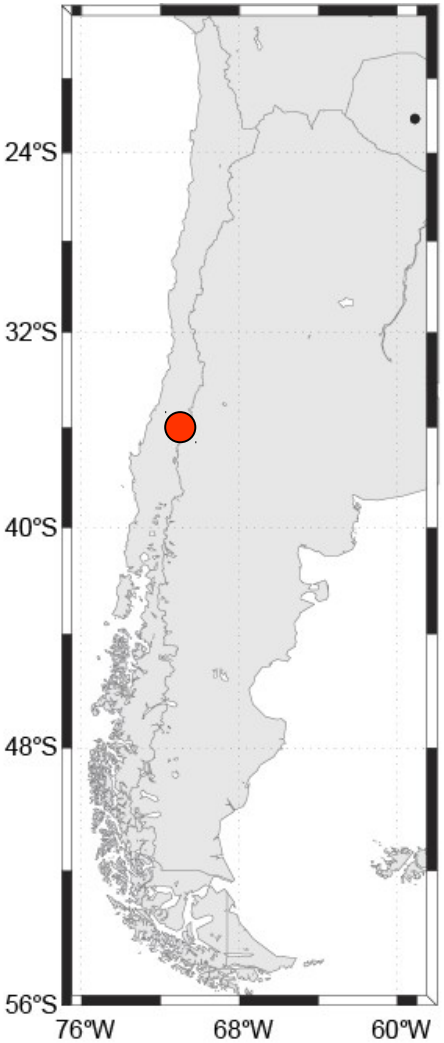
Percentage of the total basin area receiving rainfall (instead of snowfall) during winter storms, depending of the elevation of isotherm 0ºC (H0)



SIMULATING DISCHARGE OF RIVER MAULE IN CENTRAL CHILE

In the A2 scenario, PRECIS anticipates significant changes in the discharge of river Maule, both in the annual mean and in the seasonality, due to reduction of the area covered with snow in winter.



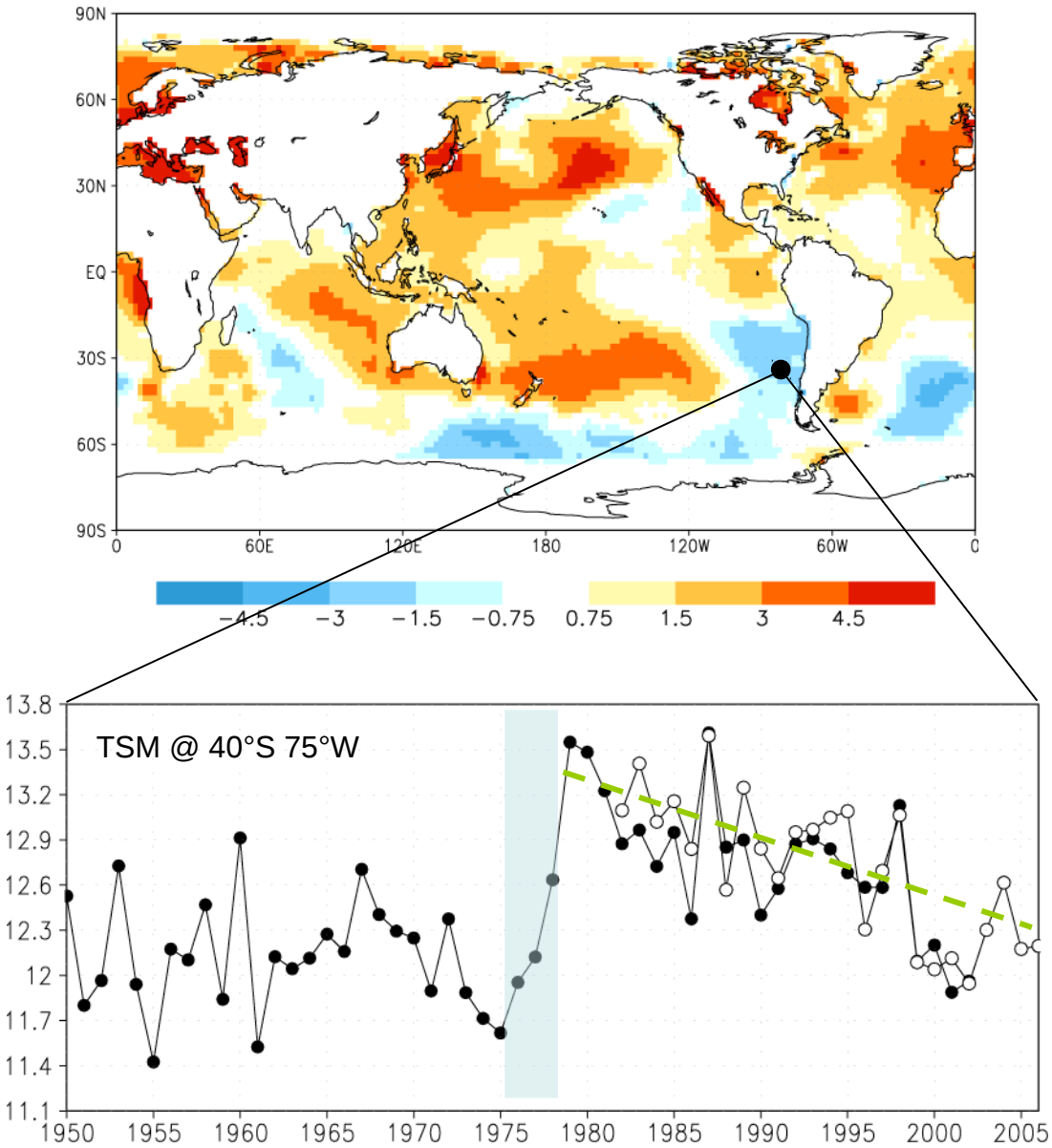


* Rio Maule en Armerillo - Pre-Cordillera

3. How is the climate changing in Chile

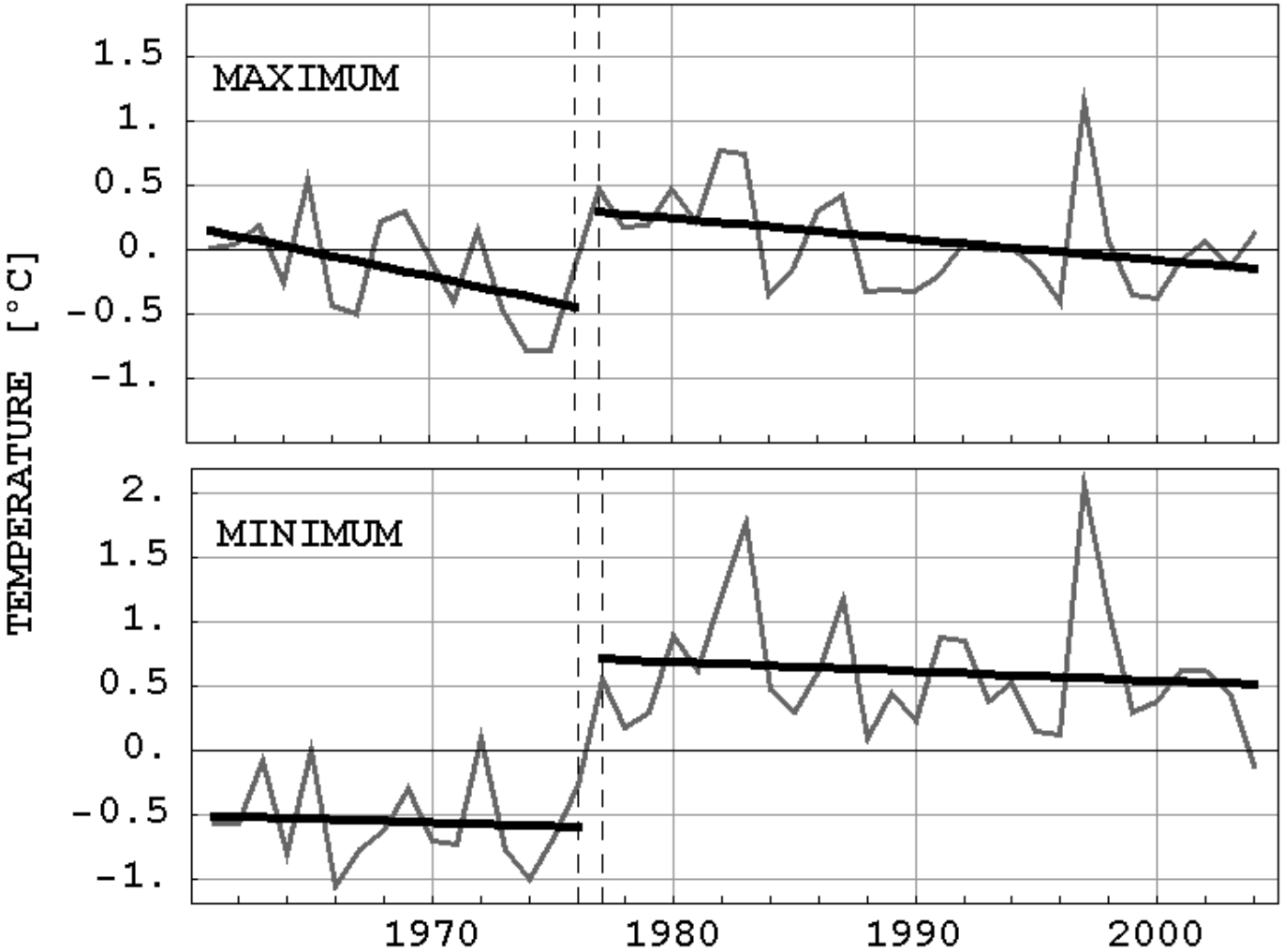
Climate trends…

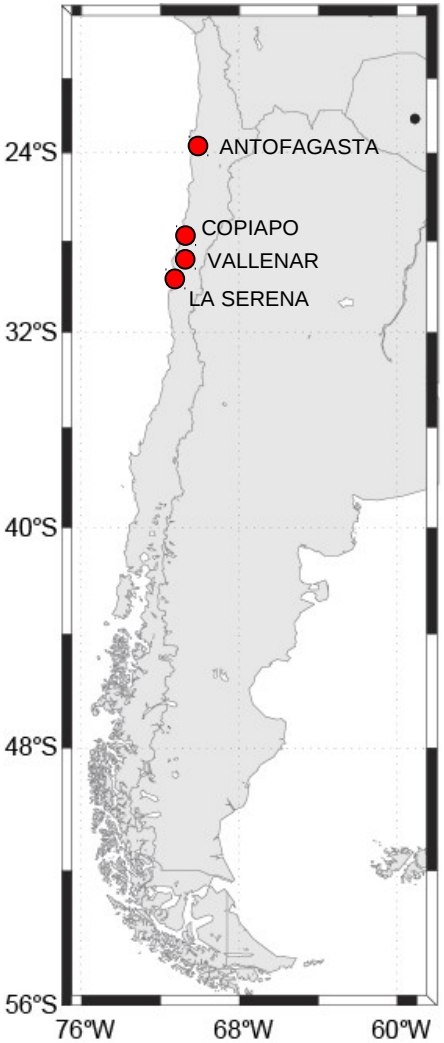
Linear trend in SST (ºC/28 años) during the period 1978-2004



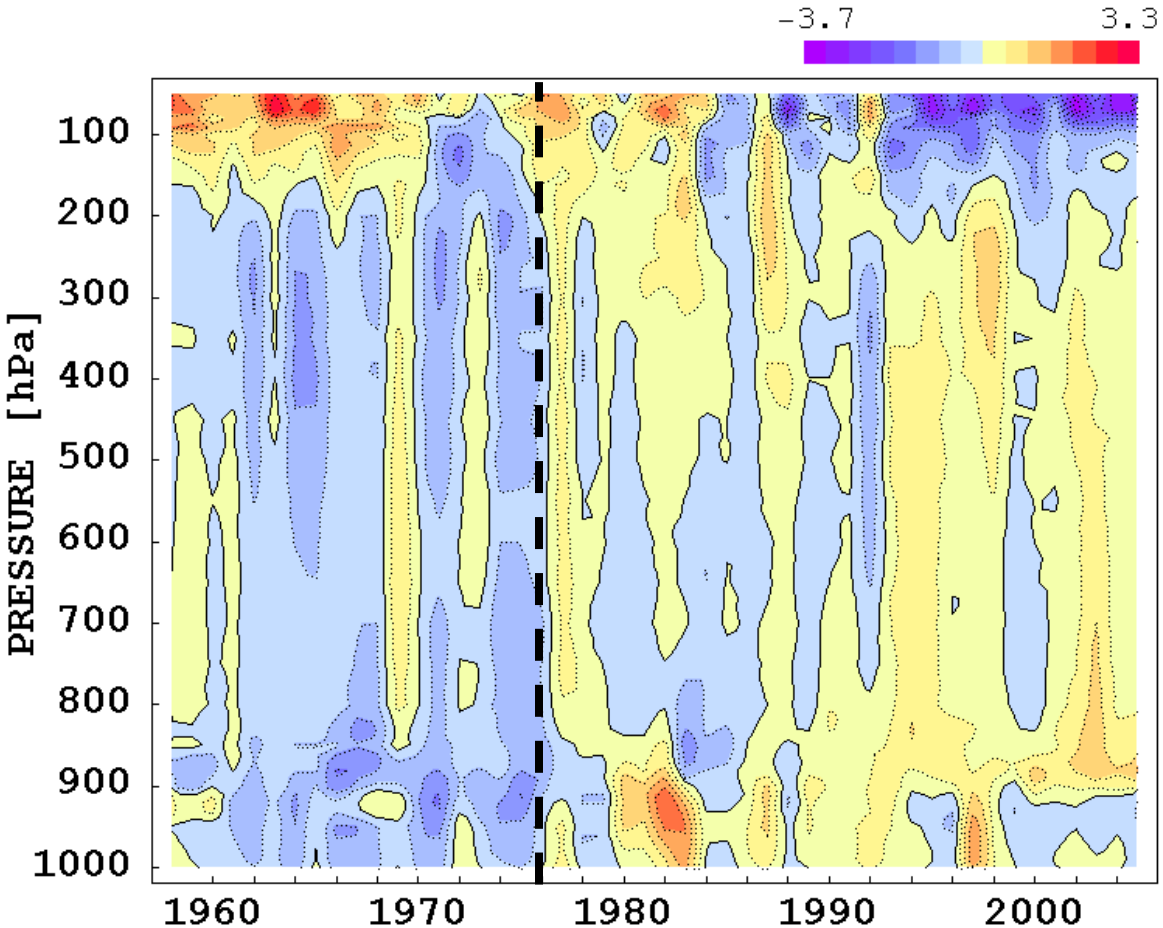
Ref: Garreaud y Falvey, 2008

Composites of annual mean anomaly of daily maximum and minimun temperature at stations Antofagasta, Copiapó, Vallenar y La Serena (1961 – 2004), in northern Chile.

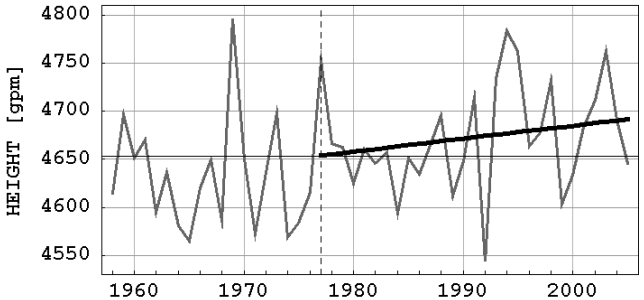




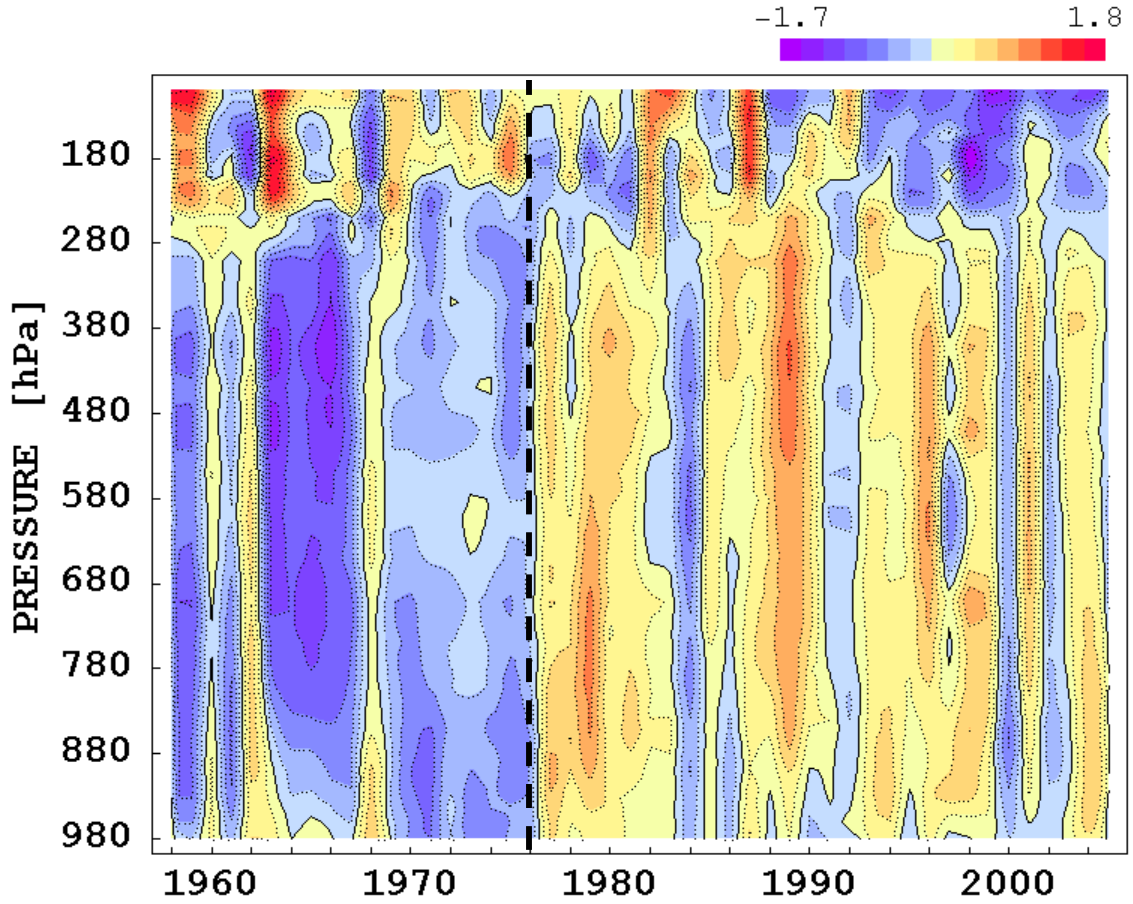
Vertical cross-section of the annual temperature anomaly in Antofagasta (23.6º S) from 1958 to 2004



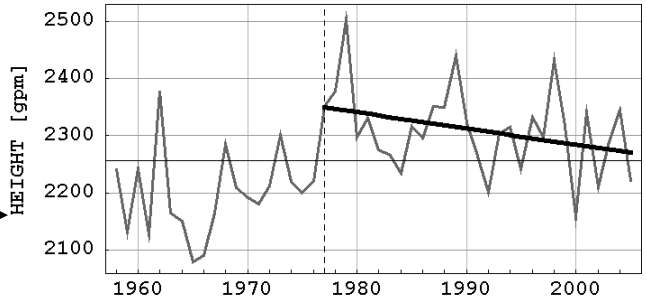
Height (a.s.l) of isotherm 0ºC →



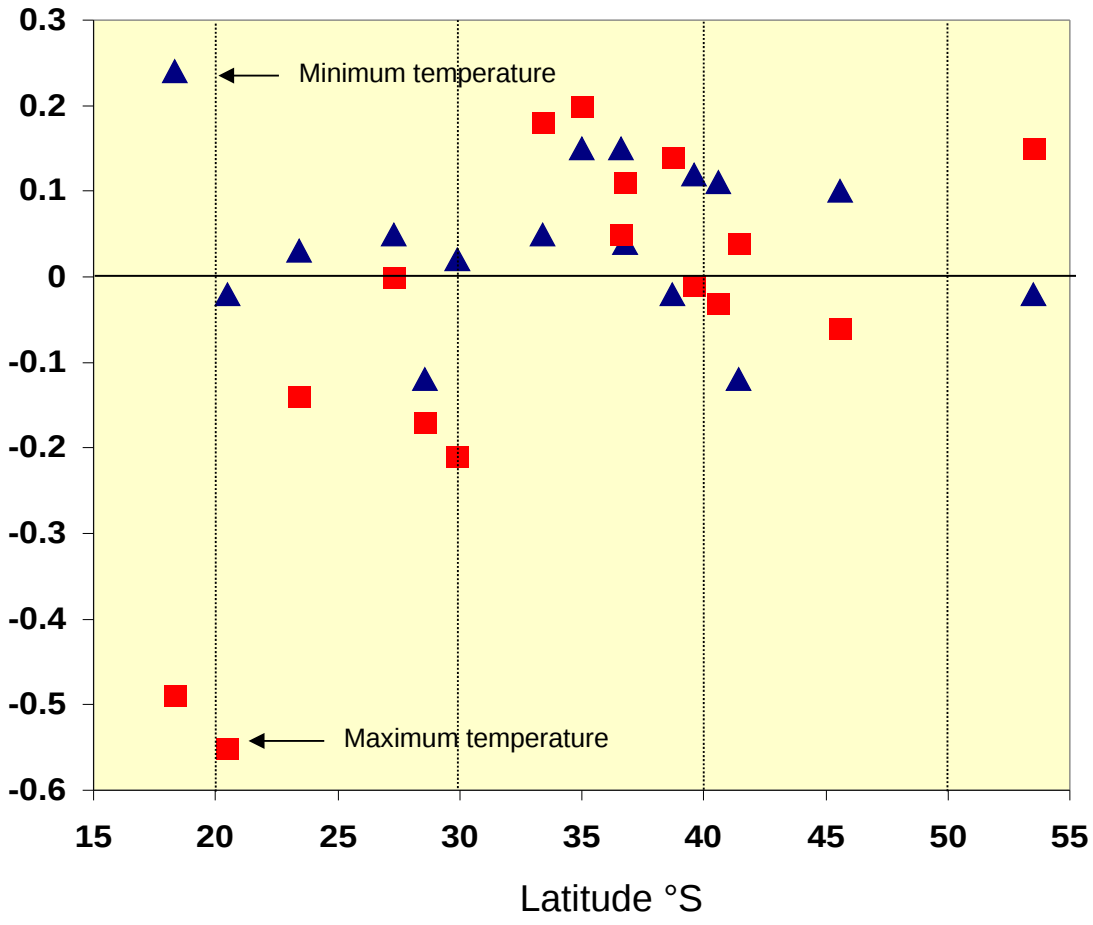
Vertical cross-section of the annual temperature anomaly in Puerto Montt (42ºS) from 1958 to 2004.



Height (a.s.l) of isotherm 0ºC

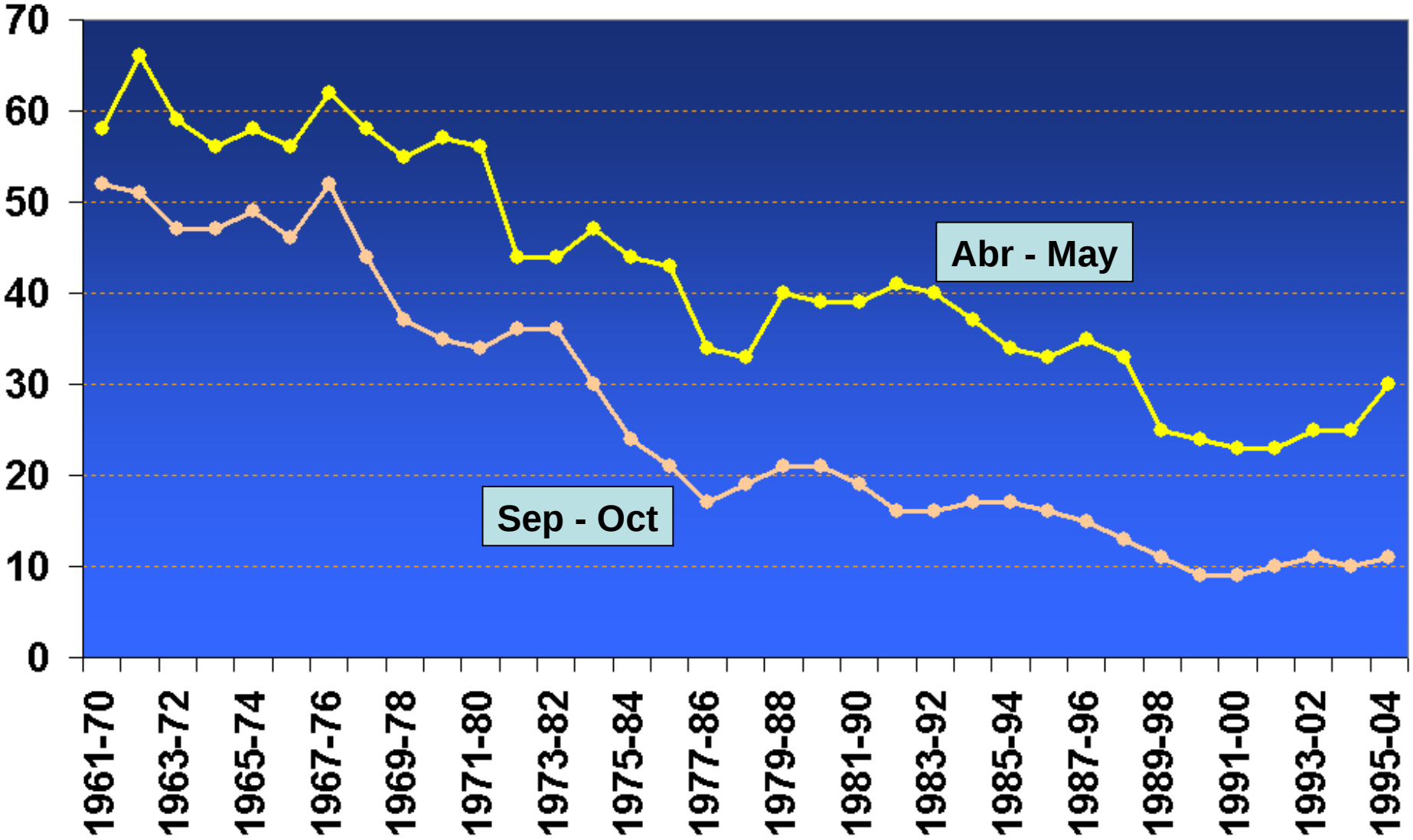


Trend (°C/decade) in the mean annual values of daily maximum and minimum temperature from 1976 to 2003.

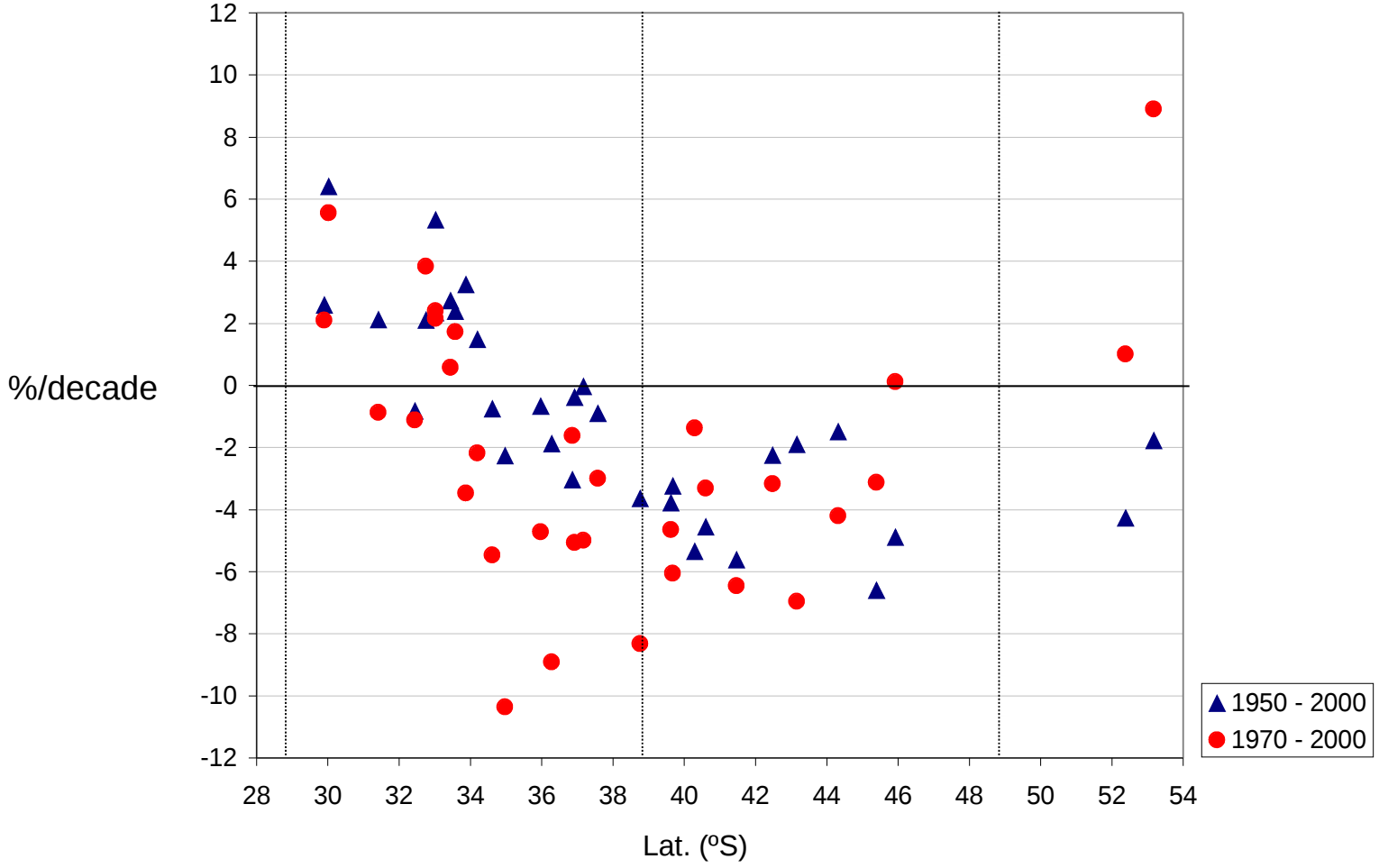


Data source: Chilean Weather Service (DMC)

CURICO (35°S).
Número de heladas de otoño y primavera en periodos móviles de 10 años

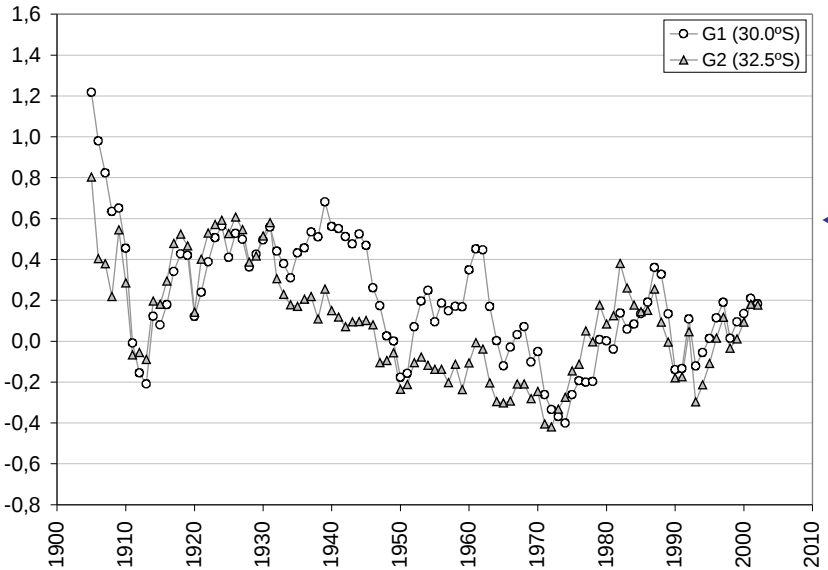


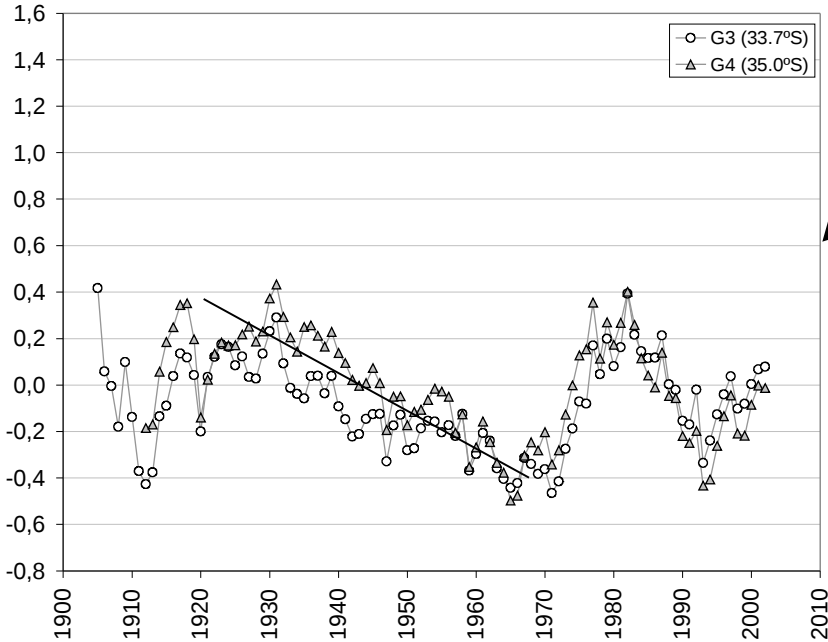
Trend in **annual rainfall** expressed as percentual change per decade

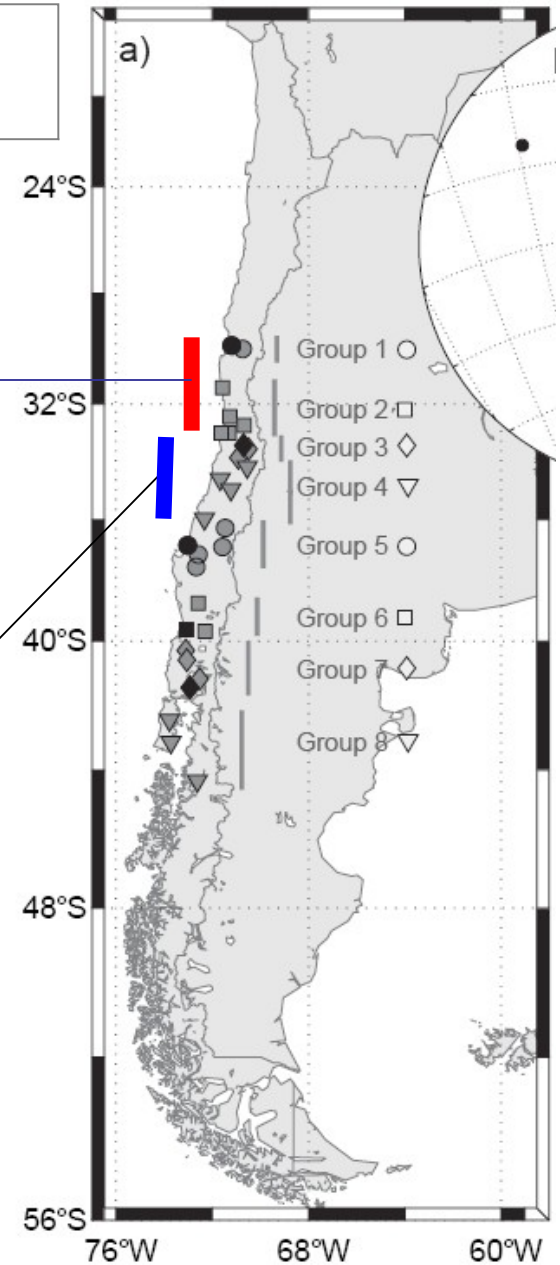


Source: Quintana & Aceituno, 2008

11-years moving averages of standardized regional rainfall indices (ref. 1971 – 2000)

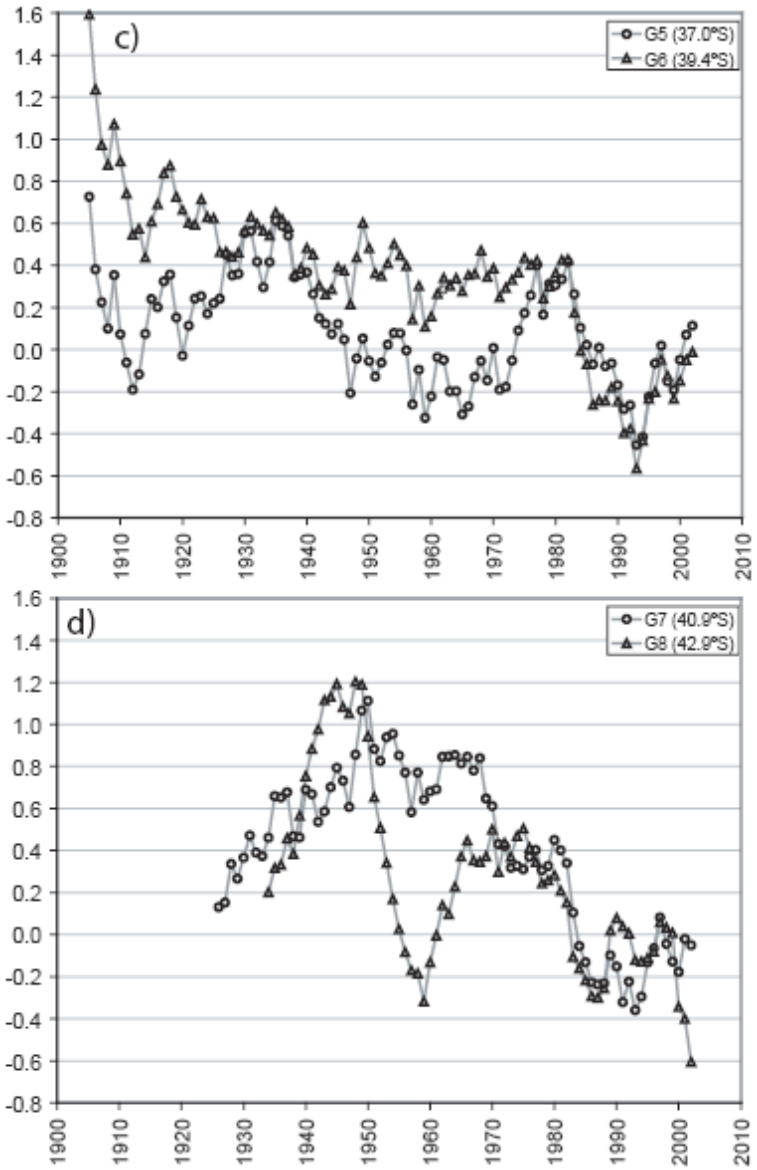


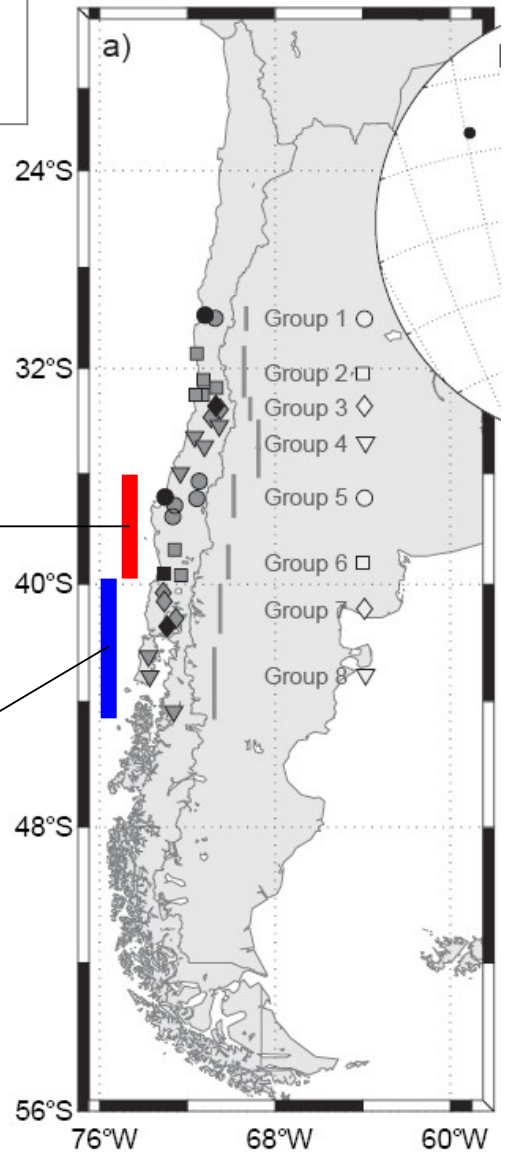




Ref: Quintana & Aceituno, 2009

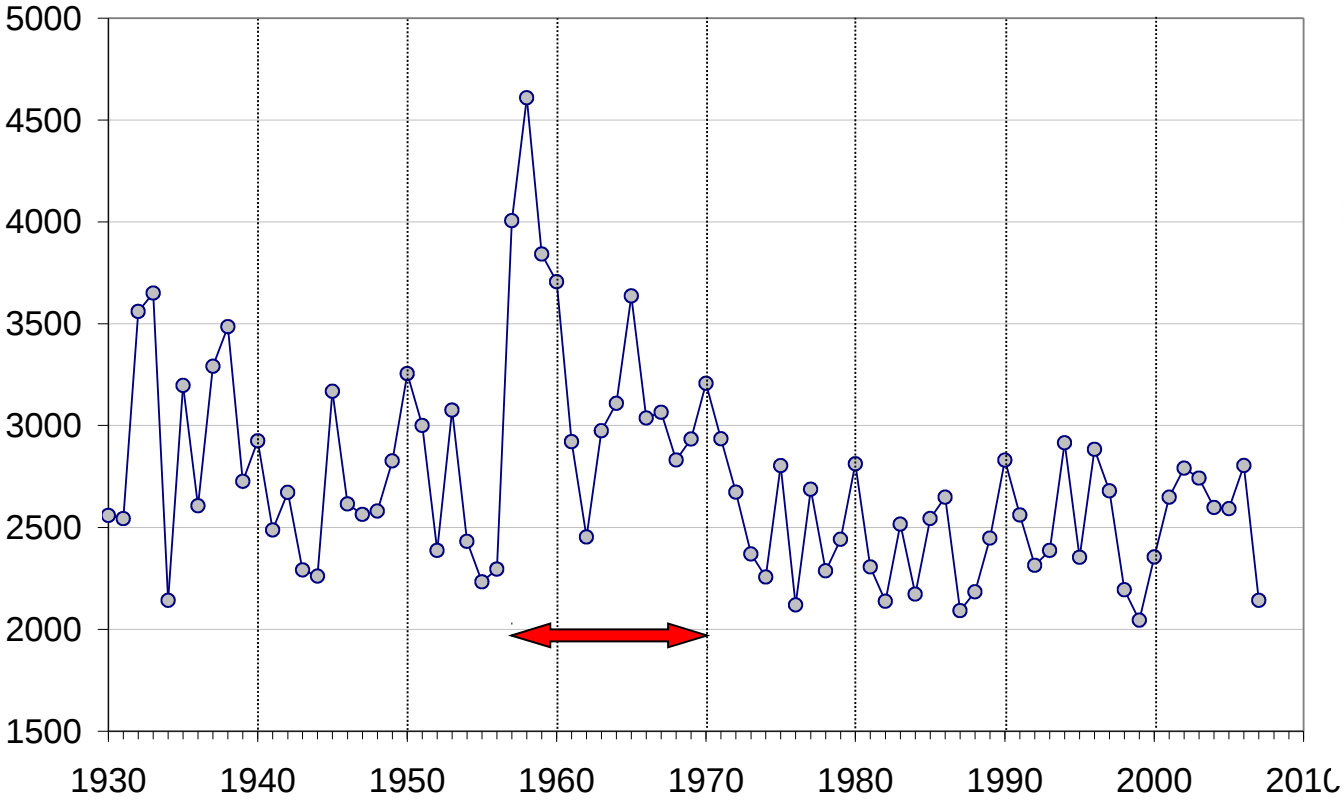
11-years moving averages of standardized regional rainfall indices (ref. 1971 – 2000)

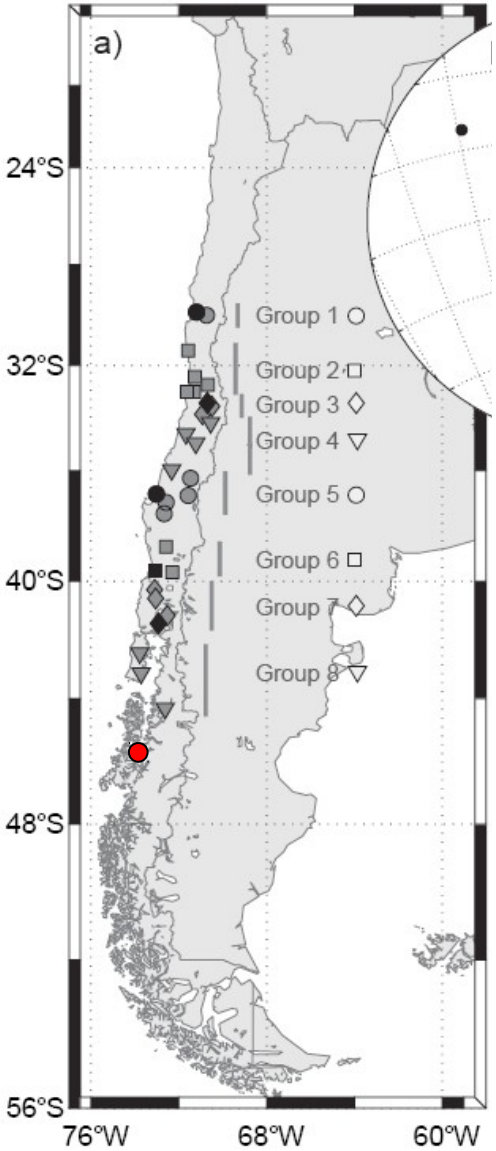




Ref: Quintana & Aceituno, 2009

Annual rainfall at Puerto Aysen (1930 – 2007)

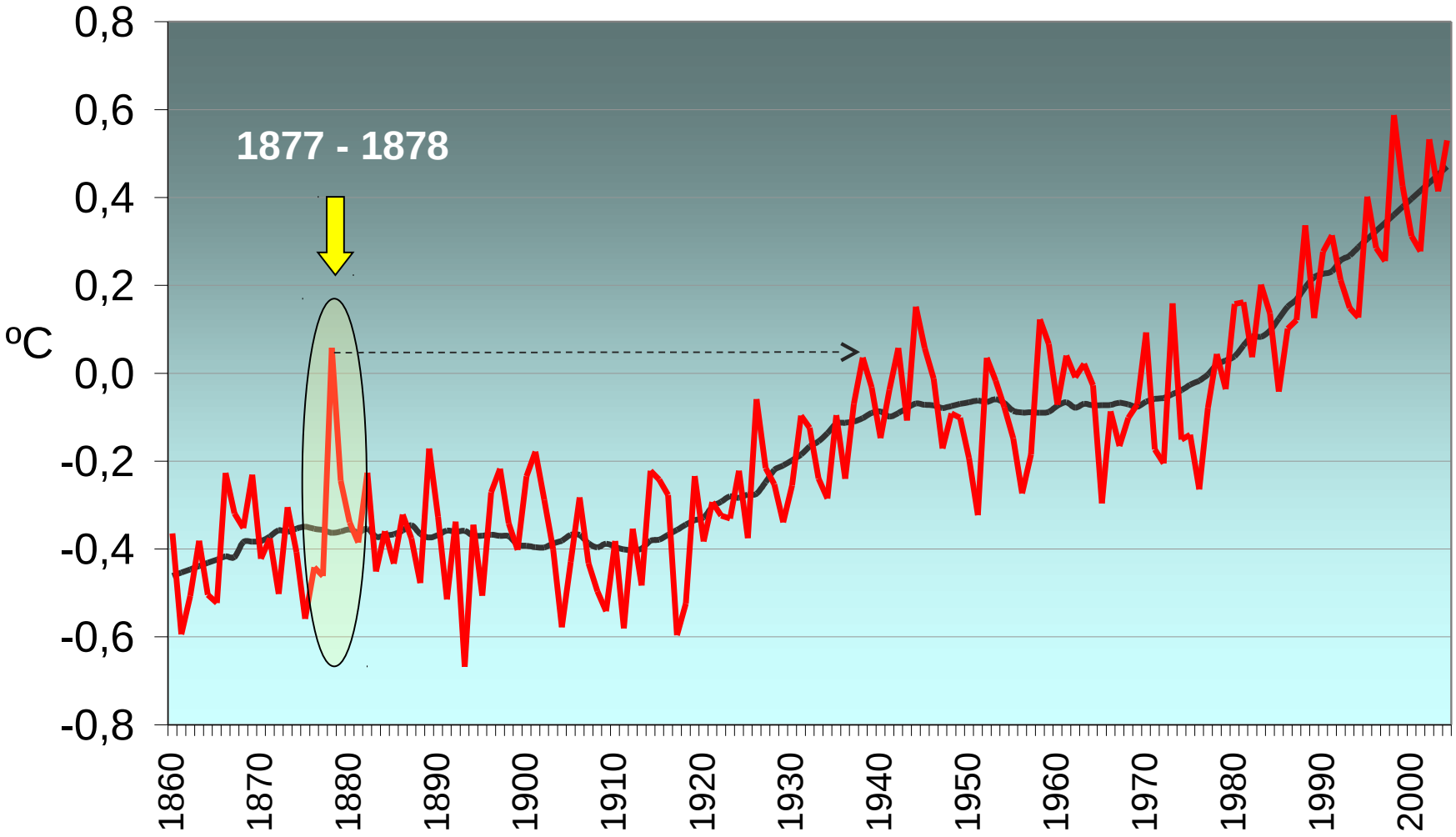




4.- Looking backward: the 1877-78 global climate anomaly

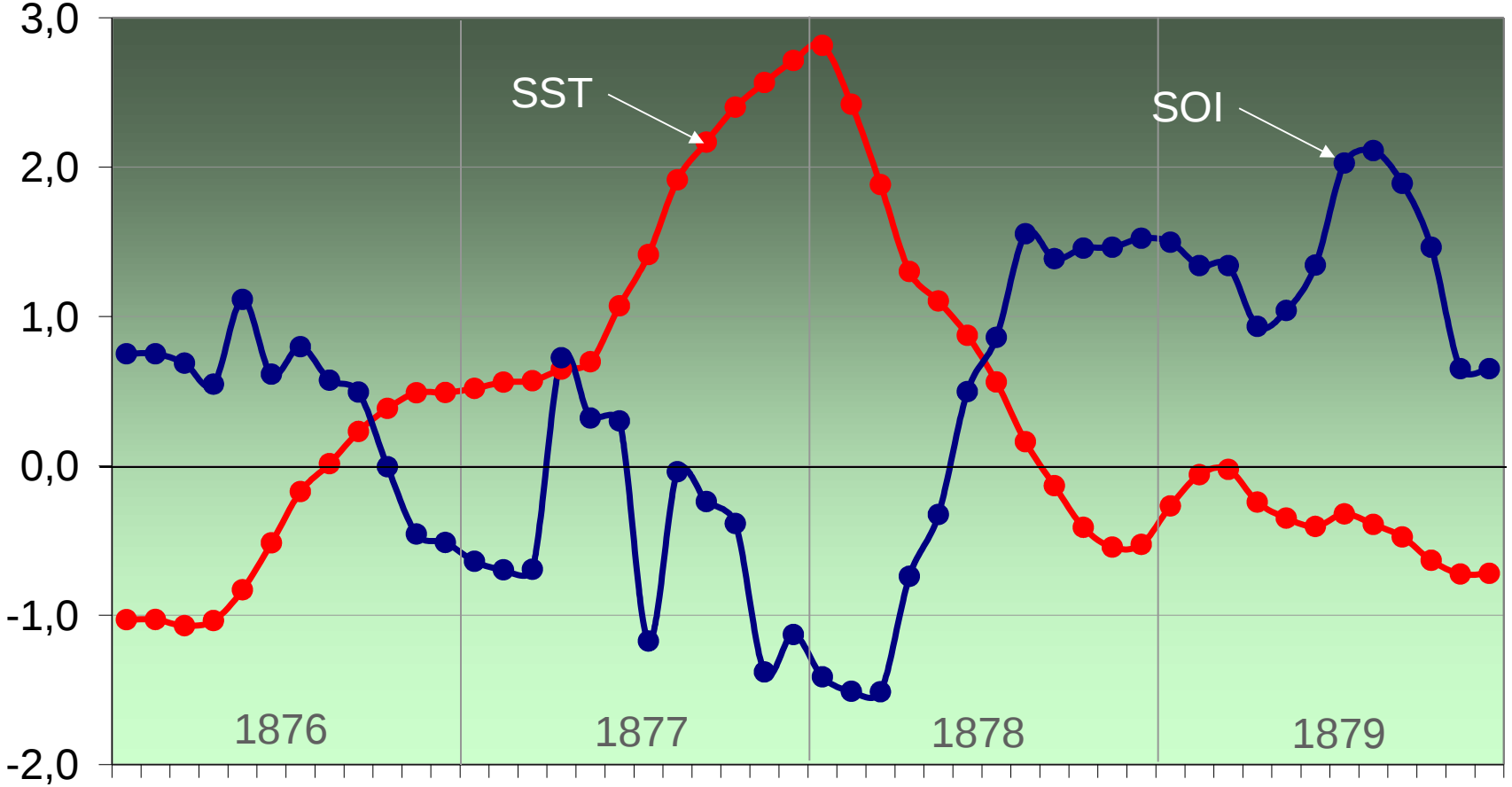
Source: Aceituno et al., 2009

Mean global temperature anomaly for October – March
Ref: 1961 - 1990



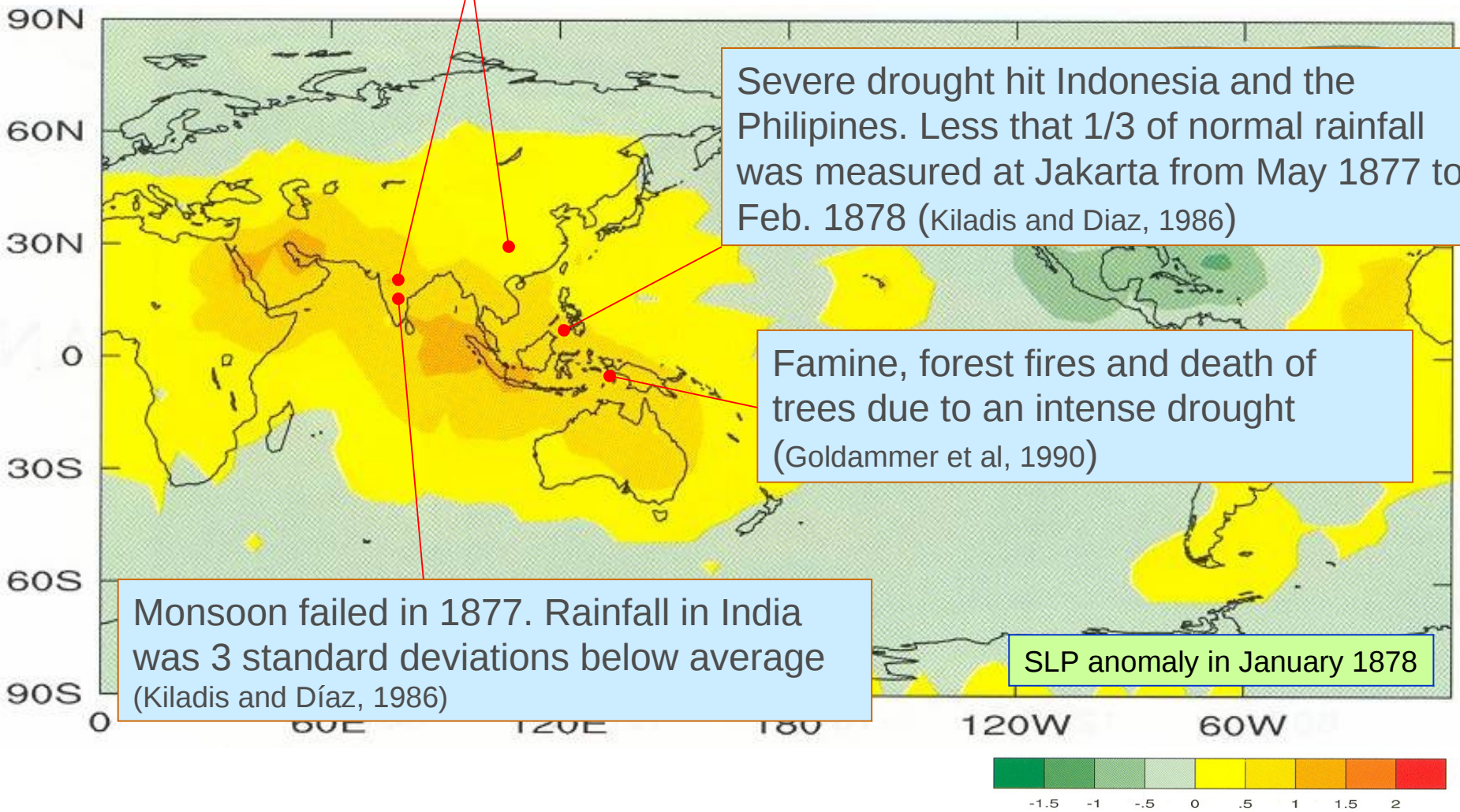
Source: Climate Research Unit. University of East Anglia

Southern Oscillation Index (SOI) and sea surface temperature (SST) anomalies in the Niño 3 region (3 – month averages)



Sources: SOI: Bureau of Meteorology – Australia; SST: Hadley Center

15 – 25 million people died in India and northern China during the period 1877-79, as result of drought and associated diseases. By 1879 one third of the population had died in the Shanxi province in N. China (Davis, 2001)



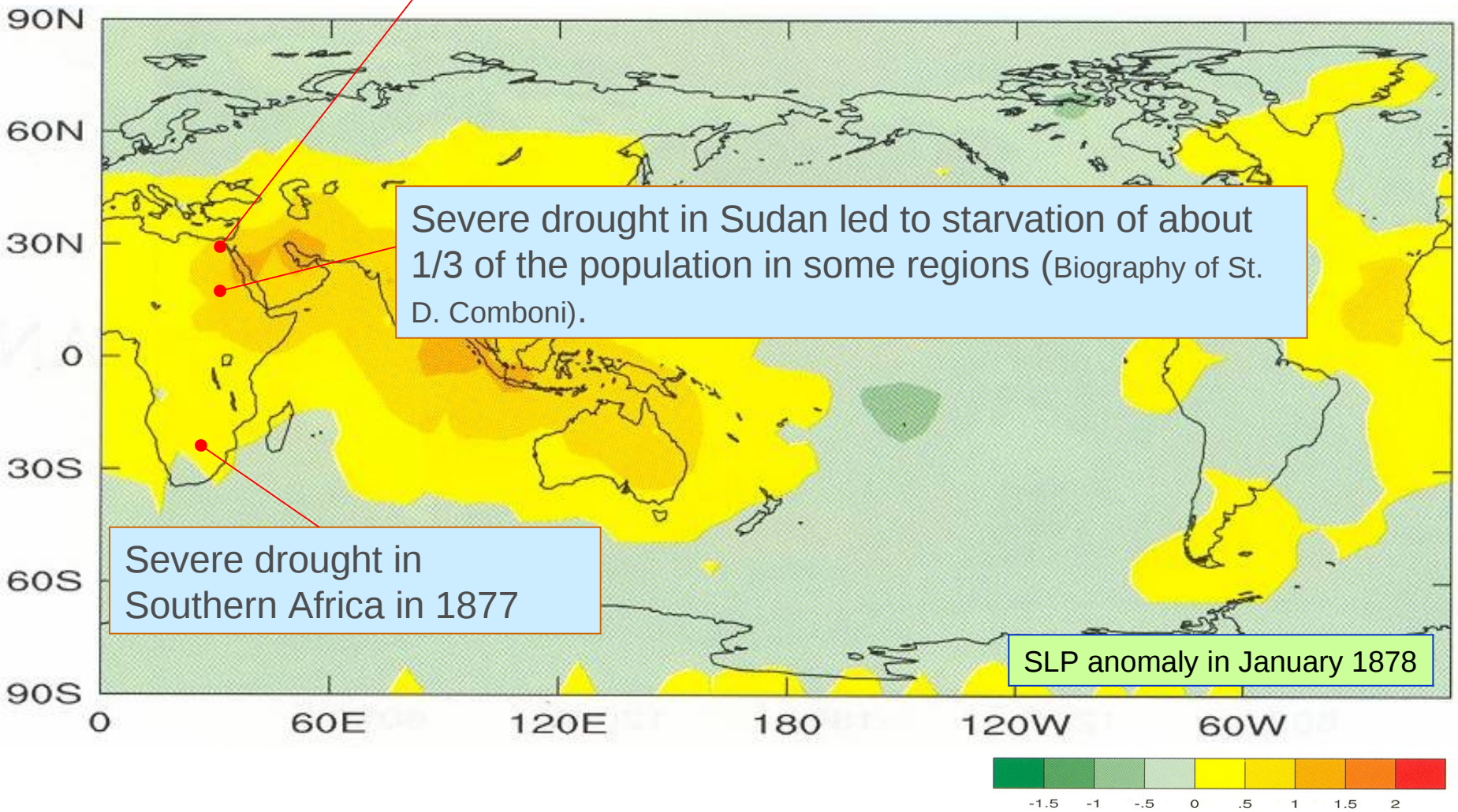
Severe drought hit Indonesia and the Philipines. Less that 1/3 of normal rainfall was measured at Jakarta from May 1877 to Feb. 1878 (Kiladis and Diaz, 1986)

Famine, forest fires and death of trees due to an intense drought (Goldammer et al, 1990)

Monsoon failed in 1877. Rainfall in India was 3 standard deviations below average (Kiladis and Díaz, 1986)

SLP anomaly in January 1878

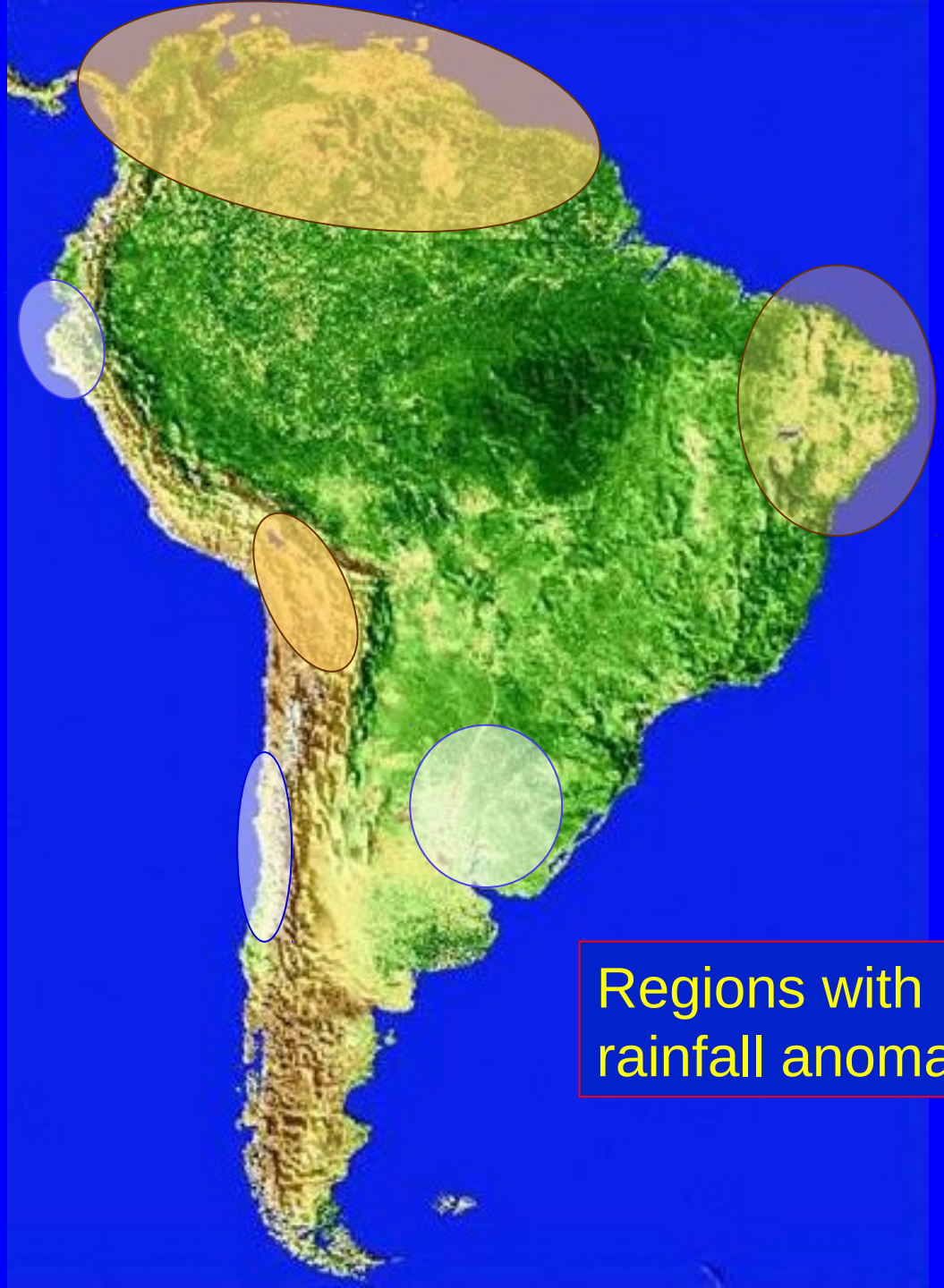
Anomalously low level reported for the Nile river in 1877 (Mossman, 1914). Food shortage in Egypt.



Severe drought in Sudan led to starvation of about 1/3 of the population in some regions (Biography of St. D. Comboni).

Severe drought in Southern Africa in 1877

SLP anomaly in January 1878



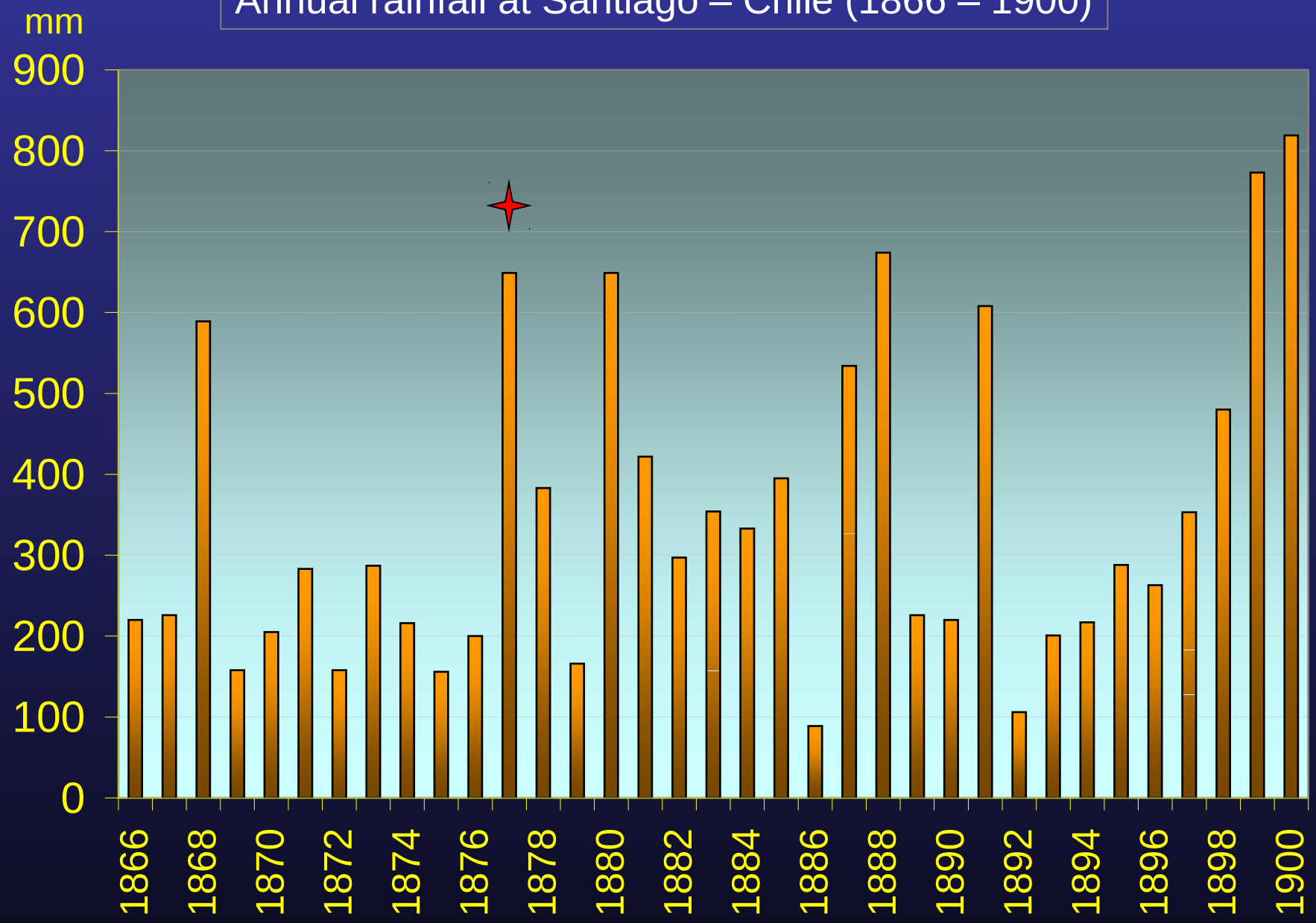
Regions with ENSO-related rainfall anomalies

Sources for information on climate anomalies in 1877 - 1878

- Direct information from rainfall measurements
- Indirect information from newspapers, historical reports, and other sources

Central Chile

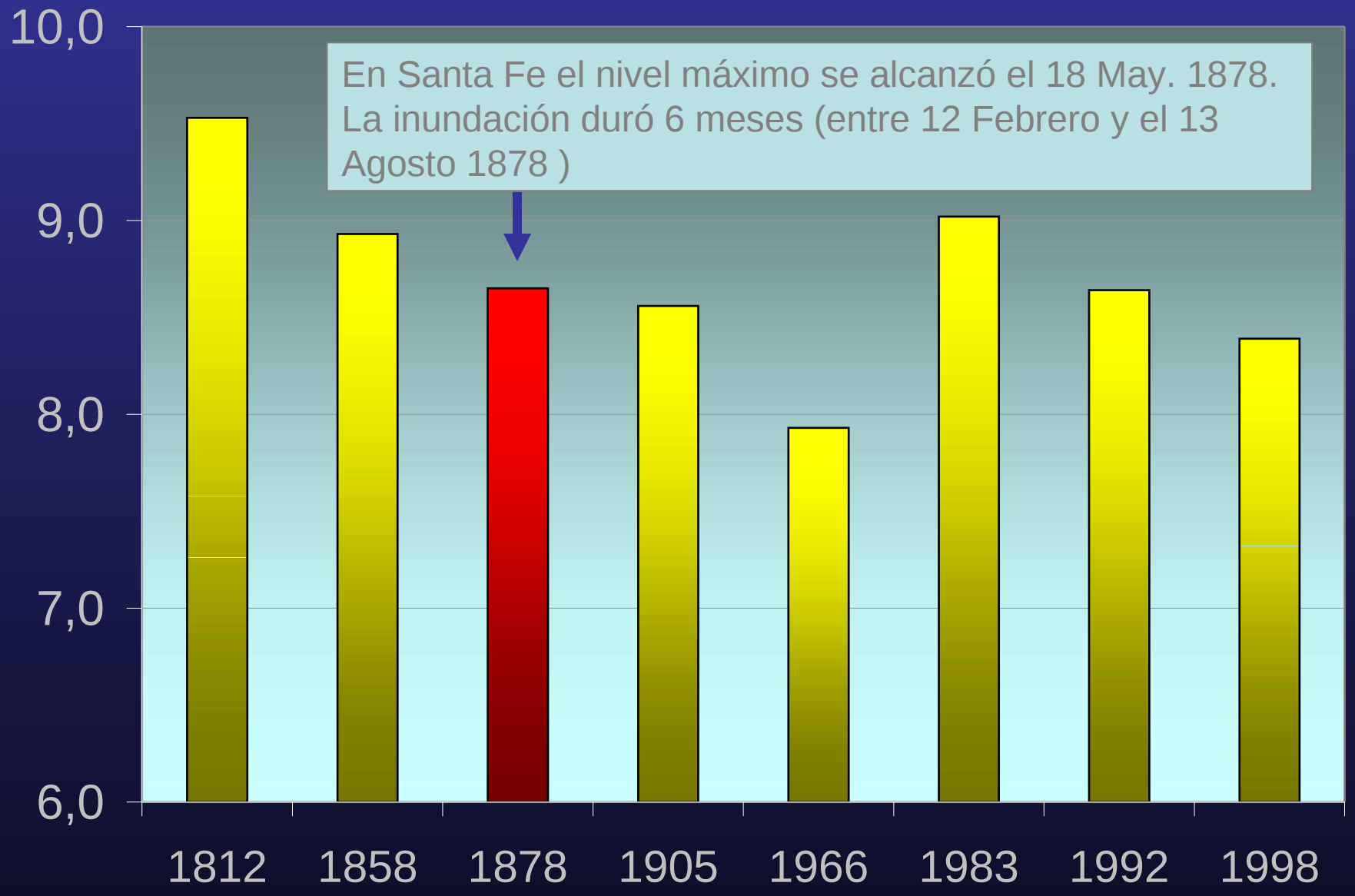
Annual rainfall at Santiago – Chile (1866 – 1900)




SE of South America
Paraguay river
Paraná river
Paraguay
Asunciòn
Corrientes
Uruguay river
Santa Fe
Chile
Rosario
Uruguay
Argentina
Buenos Aires
Average discharge of Parana river at Corrientes = 18,500 m3/s

Floods in SE South America during El Niño episodes

Mayor floods of the Paraná River. Maximum water level at Corrientes (m)



Sources: Subsecretaría de Recursos hídricos, Argentina and Depettris and Rohrmann, 1998

Altiplano

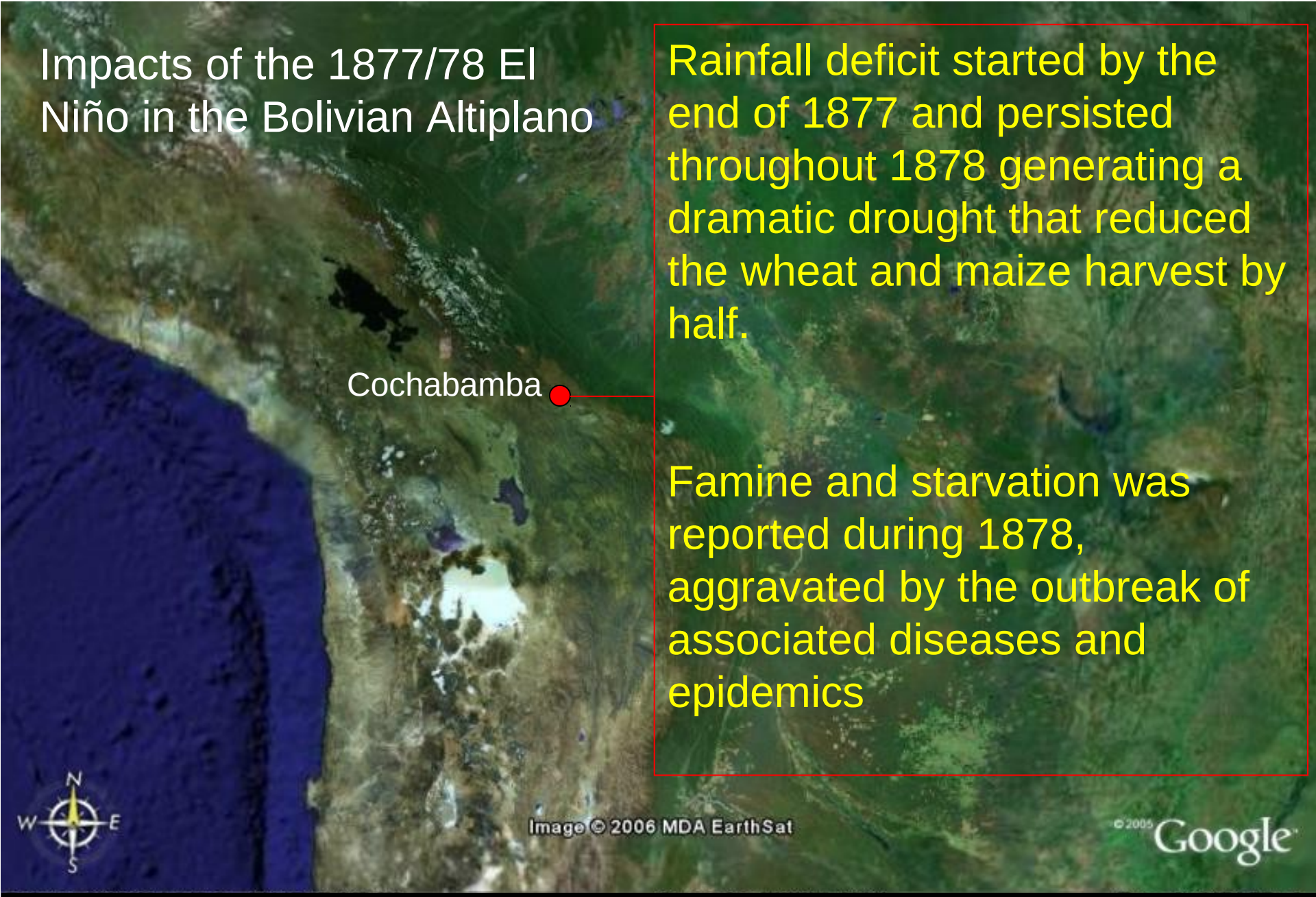
Puno: *La falta de aguaceros ha causado un daño irreparable a la agricultura, así que las cosechas serán malas, habrá mortandad en la ganadería y el año será de una escasez abrumadora*
El Comercio, Lima, 13 Abril 1877

Impacts of the 1877/ 78 El Niño in the Peruvian Altiplano

Puno: *Va a terminar el malhadado 77 dejando un reguero de penurias y sufrimientos, que tienen visos de prolongarse indefinidamente… la ganadería en decadencia, los empleados muriéndose de hambre y un malestar en todas las clases sociales son los caracteres bien acentuados del año que va a concluir.*
Published in a local newspaper in Dec. 1877 and reproduced by El Comercio, Lima, in 2 January 1878

Fuente: Información recopilada por Alejandra Martínez (Inst. Geofísico del Perú)

Impacts of the 1877/78 El Niño in the Bolivian Altiplano

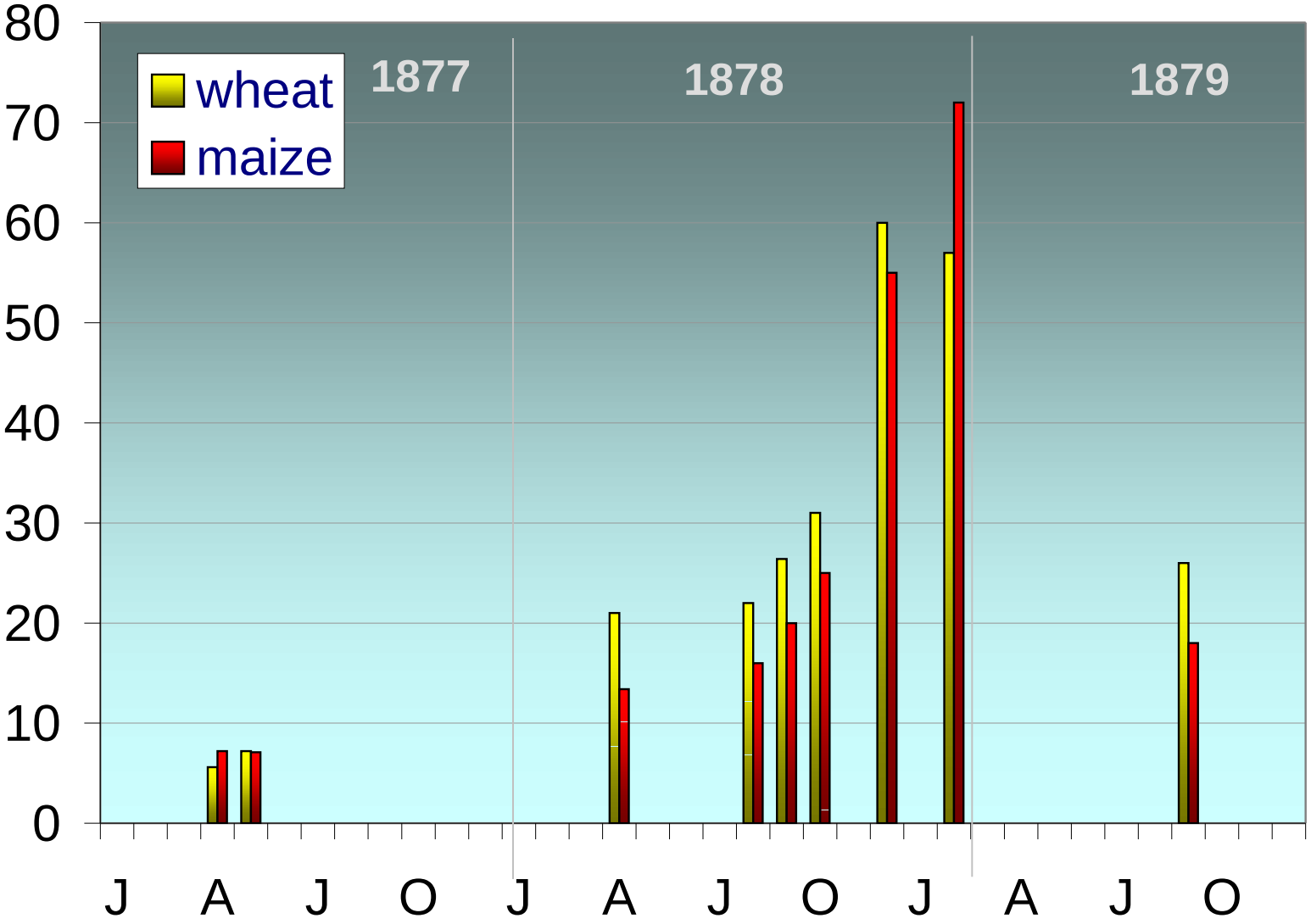


Rainfall deficit started by the end of 1877 and persisted throughout 1878 generating a dramatic drought that reduced the wheat and maize harvest by half.

Famine and starvation was reported during 1878, aggravated by the outbreak of associated diseases and epidemics

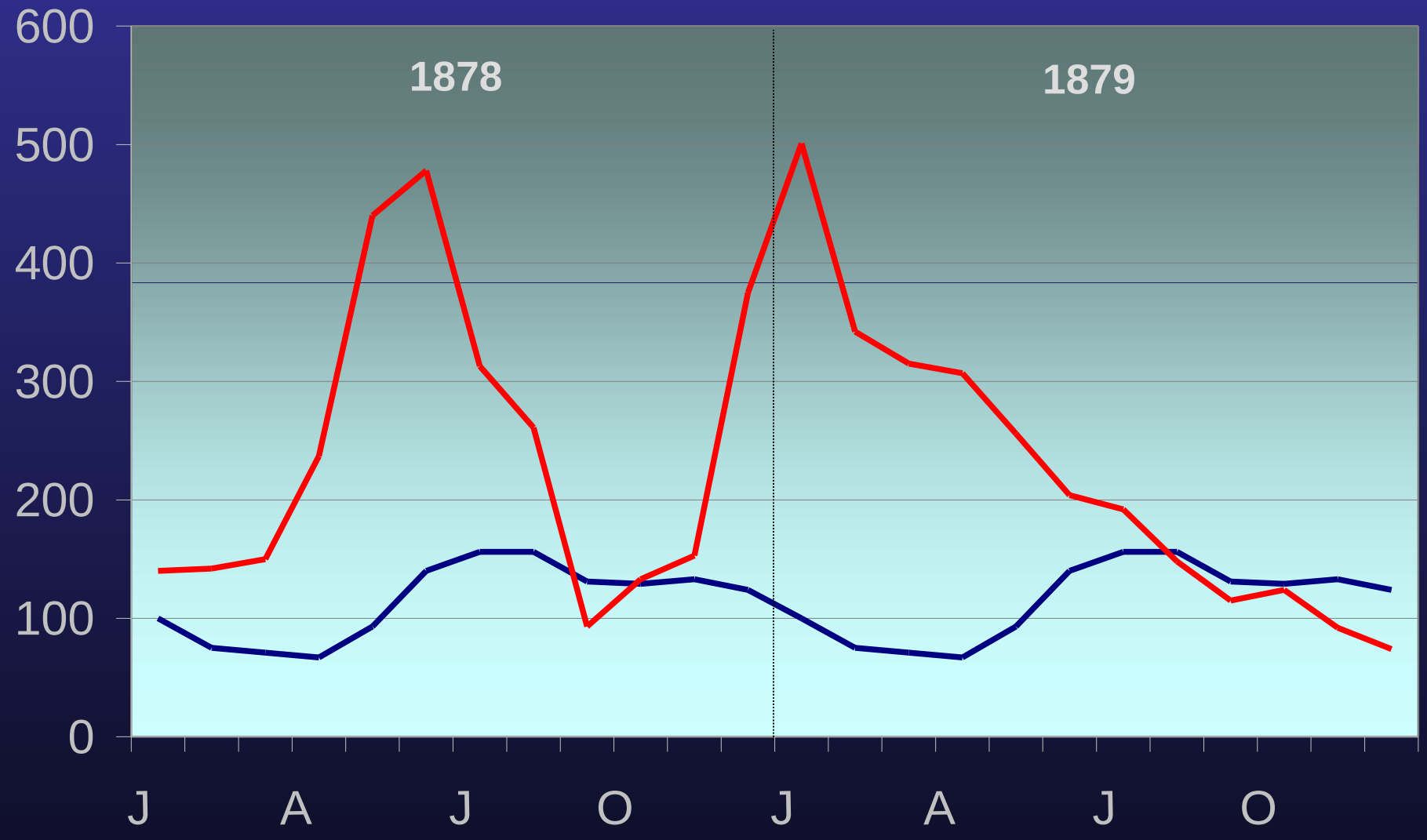
Source: Pentimalli and Rodríguez. Las razones de la multitud (hambruna, motines y subsistencia: 1878-78 in *Estado y Sociedad*, 1988, La Paz – Bolivia, FLACSO

Precio de cereales (pesos/fanega) en Cochabamba - Bolivia



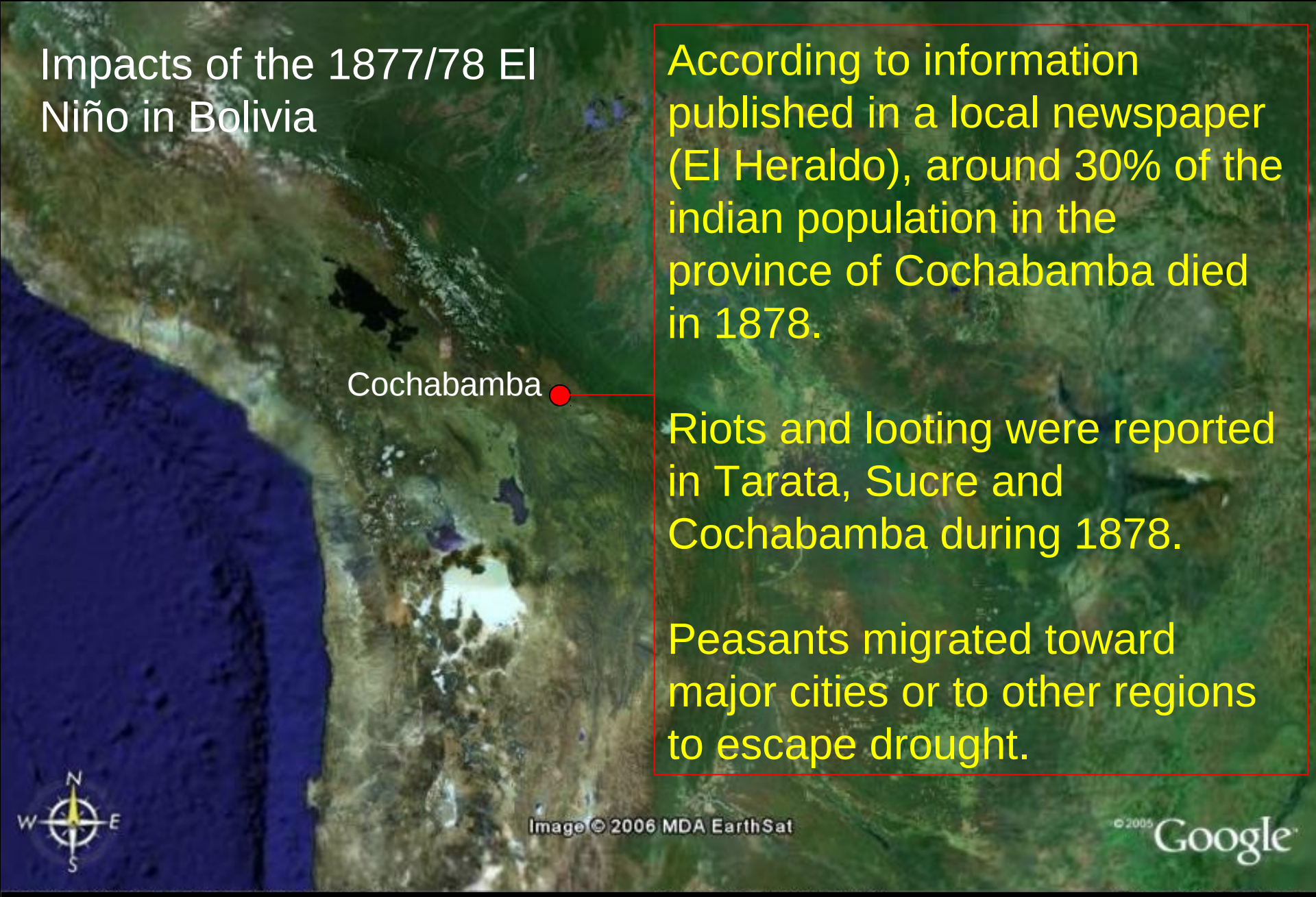
Source: El Heraldo, Cochabamba, citado por Pentimalli and Rodriguez (Estado y Sociedad, 1988, La Paz – Bolivia, FLACSO

Registered monthly deaths at Cochabamba – Bolivia during 1878 and 1879



Source: El Heraldo, Cochabamba (12 Dic. 1879), citado por Pentimalli and Rodriguez en *Estado y Sociedad*, 1988, La Paz – Bolivia, FLACSO

Impacts of the 1877/78 El Niño in Bolivia



According to information published in a local newspaper (El Heraldo), around 30% of the indian population in the province of Cochabamba died in 1878.

Riots and looting were reported in Tarata, Sucre and Cochabamba during 1878.

Peasants migrated toward major cities or to other regions to escape drought.


Brazil Nordeste

Annual mean rainfall over Northeast Brazil

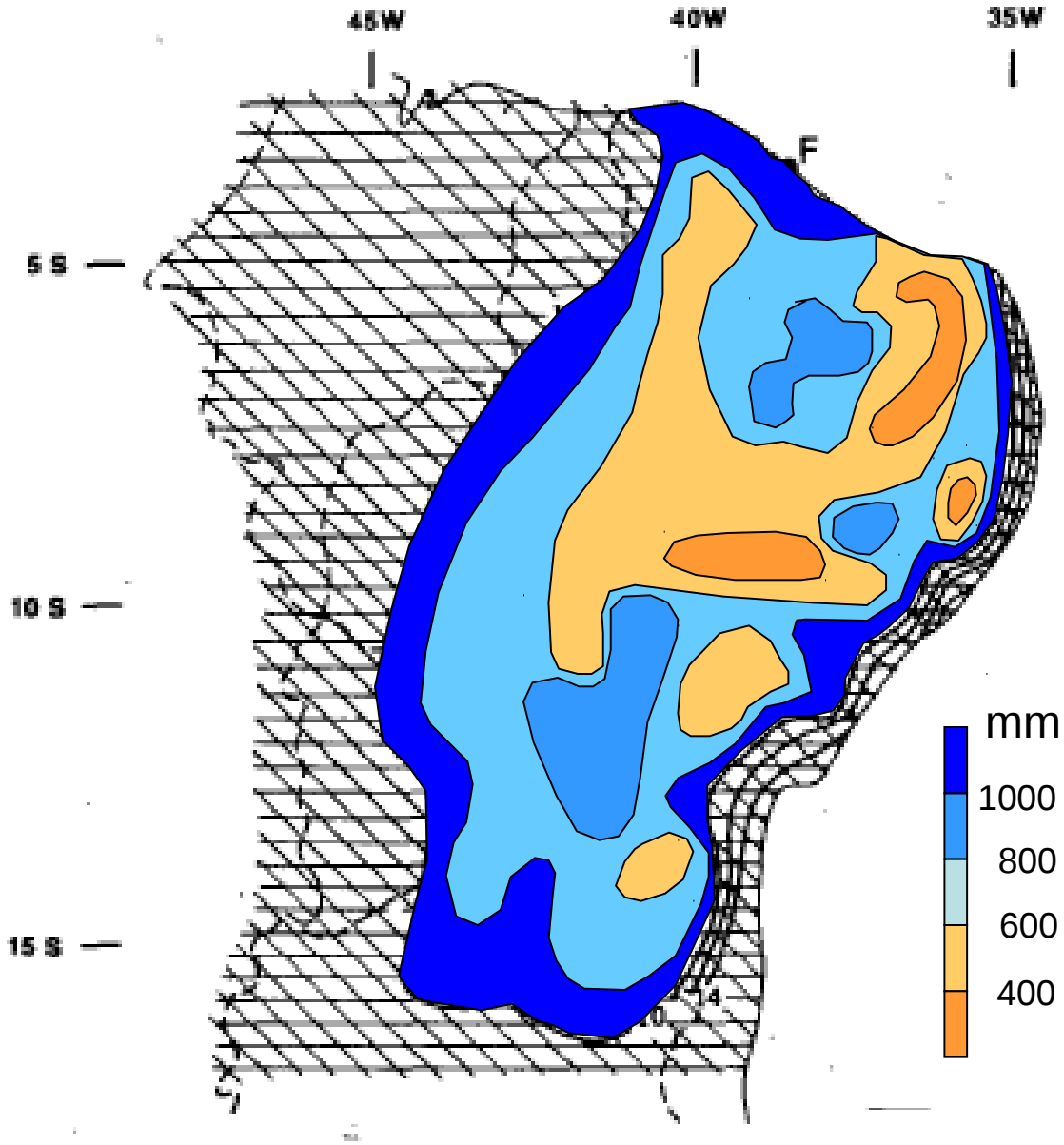
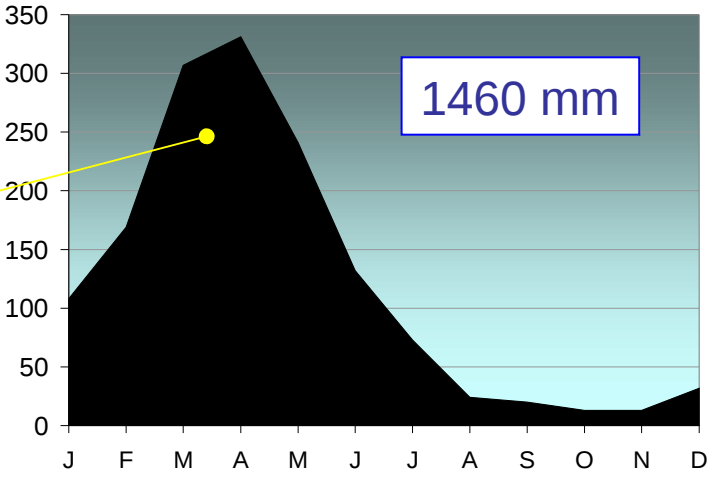
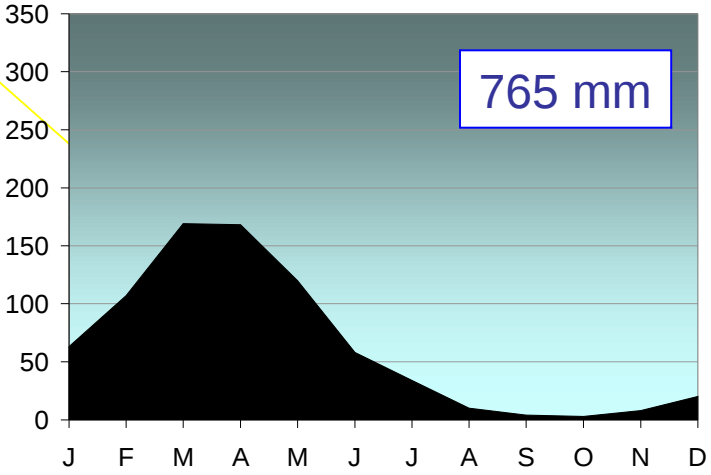


FIG. 1. Annual mean precipitation (10^2 mm) over Northeast Brazil (from Kousky and Chu, 1978).

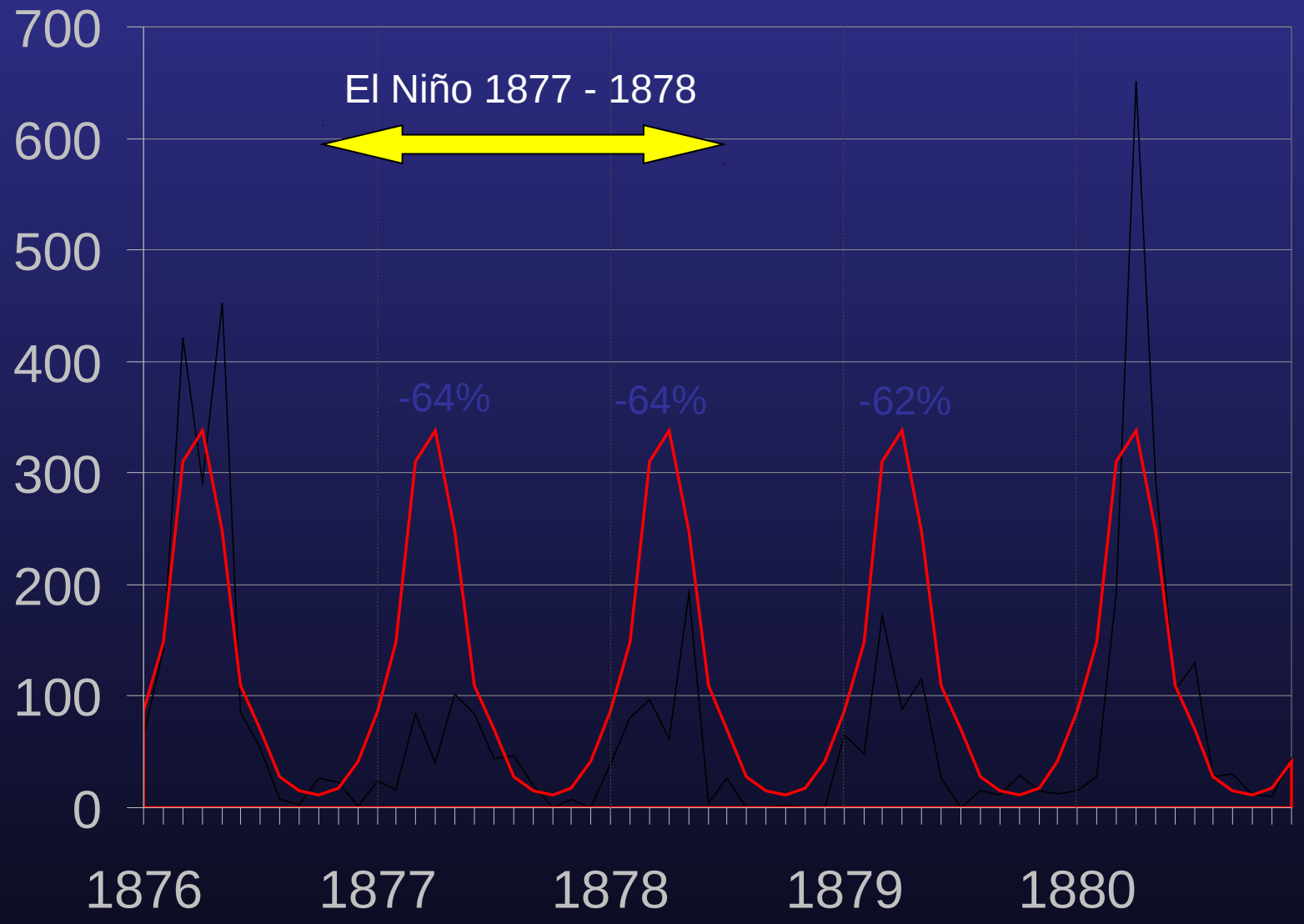
Ref: Moura and Shukla, 1981

Annual rainfall regime in Northeast Brazil





Monthly rainfall at Fortaleza (Ceara – Brazil) from 1876 to 1880



The 1877-79 drought in NE. Brazil…

Source: Villa M.A., 2000: Life and death in the Sertao: History of Nordeste droughts during the XIX and XX centuries (in portuguese).

By the end of 1877 around 2 million people ("*retirantes*" or "*flagelados*") had fled the dry interior (*Sertao*) creating a huge social and sanitary crisis in coastal cities (looting, increased prostitution, corruption, food black market.. etc.).

For those that remained in the interior, the hunger was so extreme that some cases of cannibalism were reported.

In September 1878, of the 130.000 inhabitants in Fortaleza, 110.000 were "*retirantes*".

A smallpox epidemic started in September 1878 killing around 30.000 people

1877 – 78 drought, Ceara - Brazil (J.A. Correa)

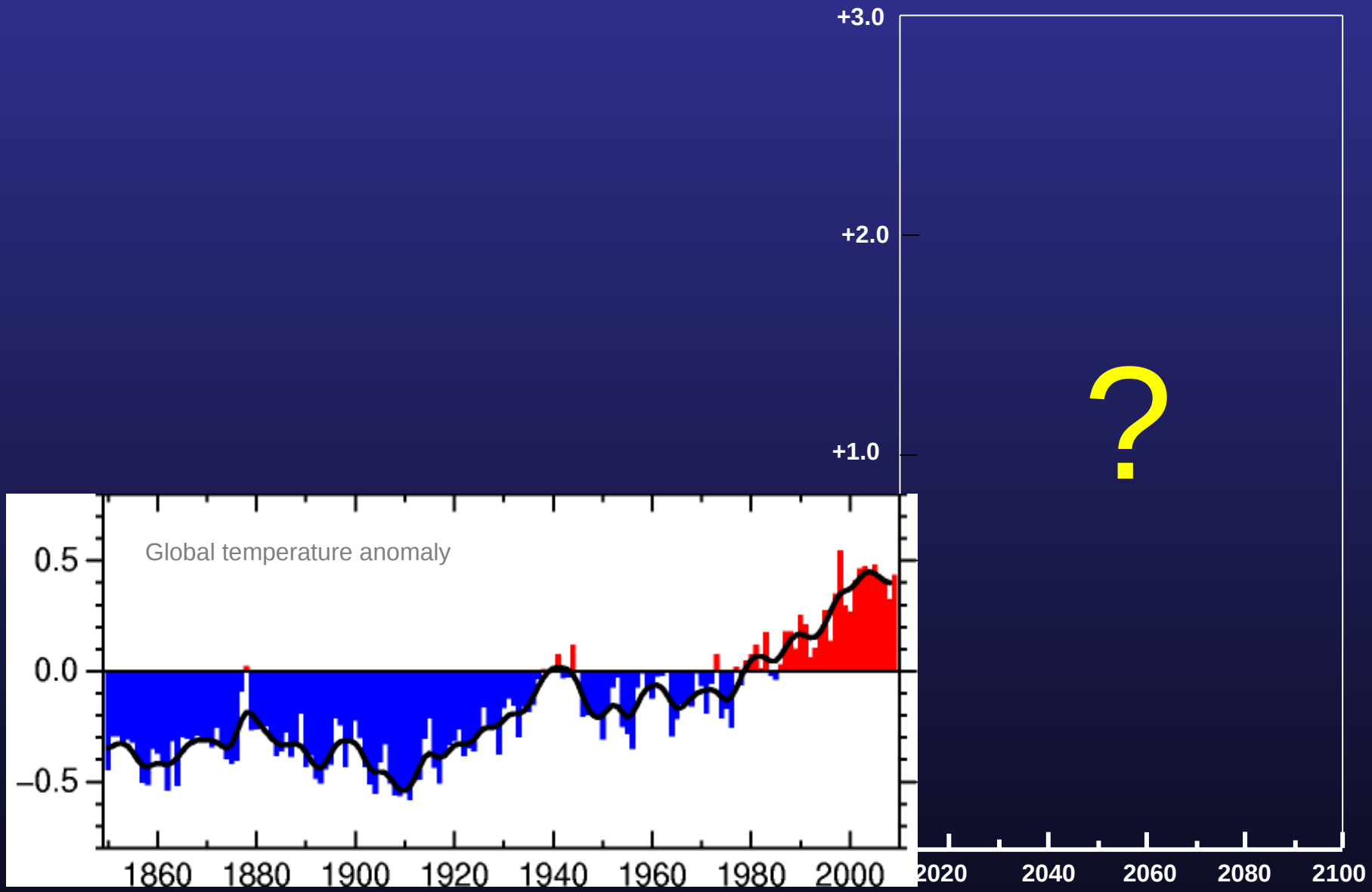
The 1877-79 drought in NE. Brazil…

Thousands of people migrated toward the Amazon attracted by the flourishing rubber industry, initiating a migratory pattern that intensified in forthcoming droughts, although mainly directed towards major cities in the South (Rio de Janeiro and Sao Paulo)

The local economy experienced some permanent changes. Drought resulted in livestock (cattle) losses in the hundreds of thousands, and the cotton industry collapsed.

It is estimated that when the drought was over in 1880, around 500.000 people had died of starvation and associated diseases (5% of the Brazilian population).

Fuente: Villa M.A., 2000: Life and death in the Sertao: History of Nordeste droughts during the XIX and XX centuries (in portuguese).


+3.0
+2.0
+1.0
?
Global temperature anomaly
0.5
0.0
−0.5
1860
1880
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100