Climate variability in Chile: Present and Future

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Overview

1. Climate regional elements and timescales
2. Climate modes and impacts
3. Observed long-term trends
4. Climate projections
5. Conclusions

Workshop Internacional Encuentro Alumni DAAD 2012 en la Universidad de Concepción

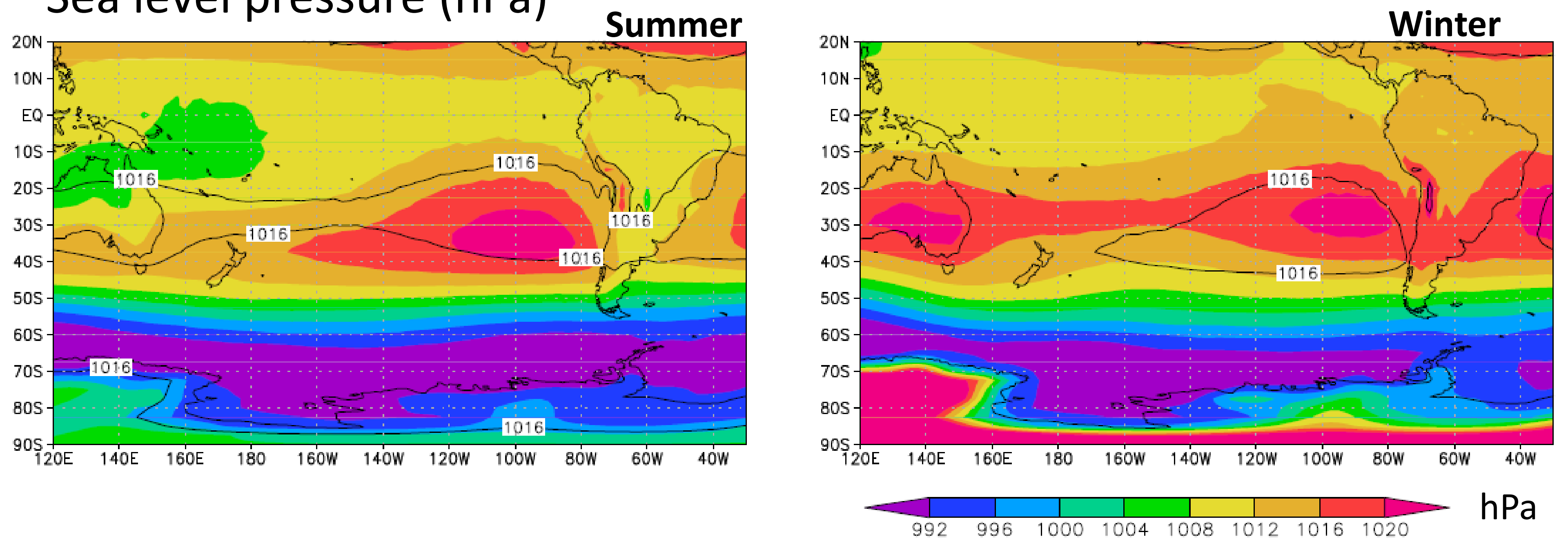
GEOCIENCIAS Y ENERGÍAS

DESARROLLO Y PERSPECTIVAS DE LA COOPERACIÓN CHILENO-ALEMANA

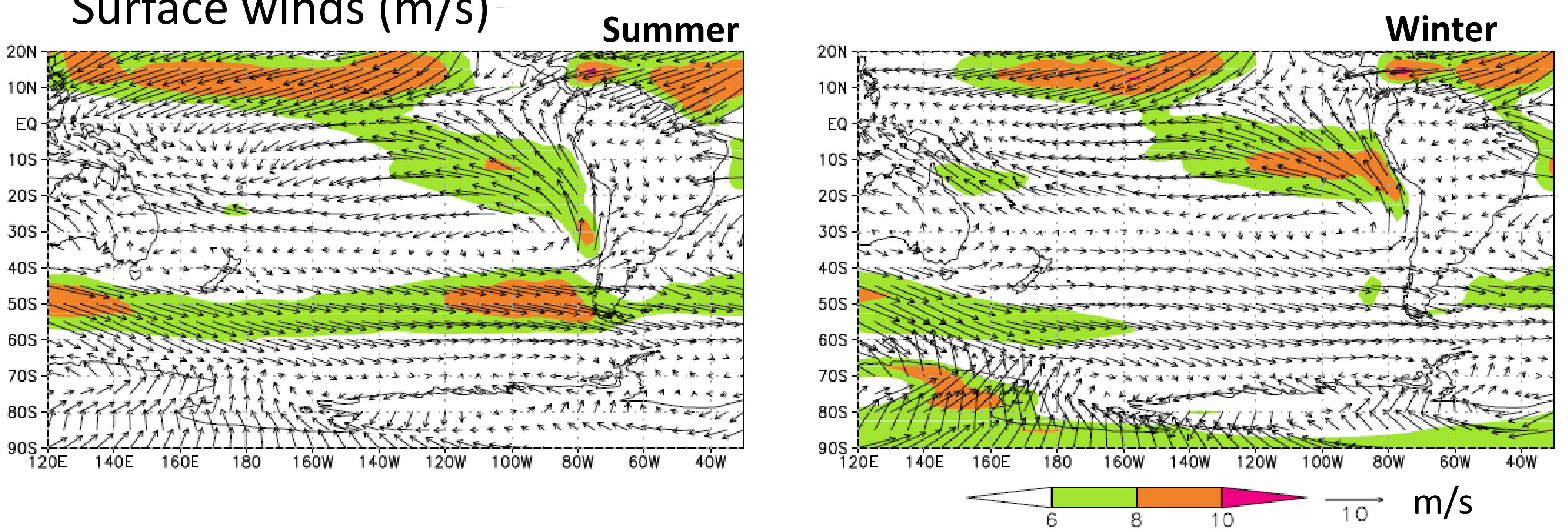
18-21 de enero de 2012

Regional climate elements and timescales

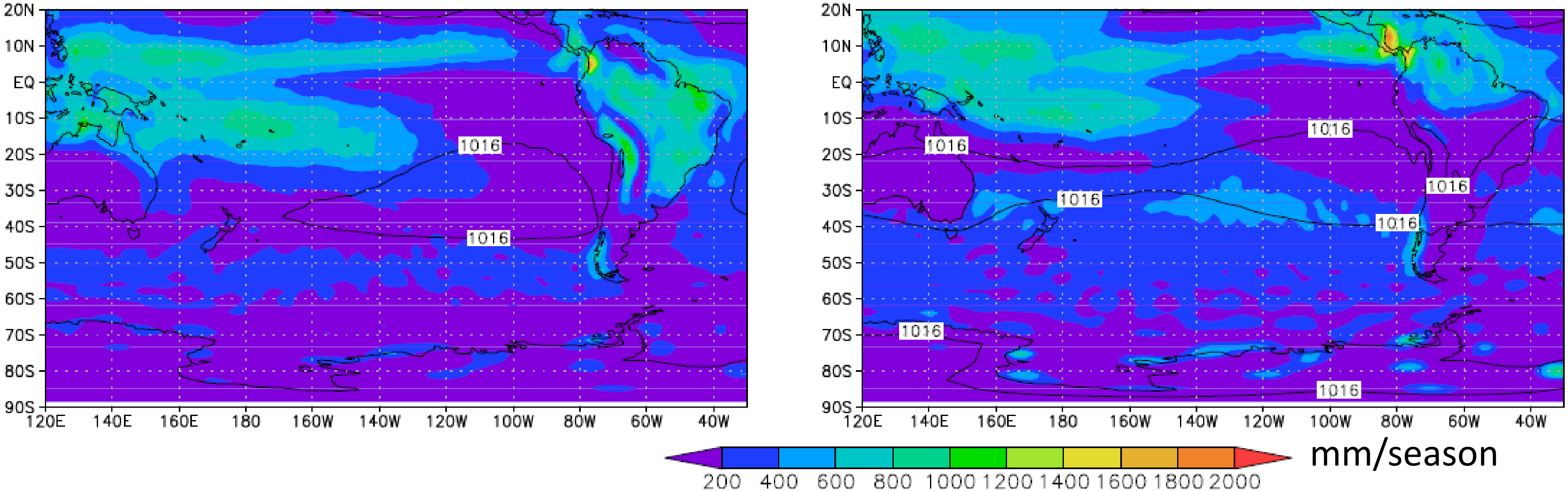
Sea level pressure (hPa)



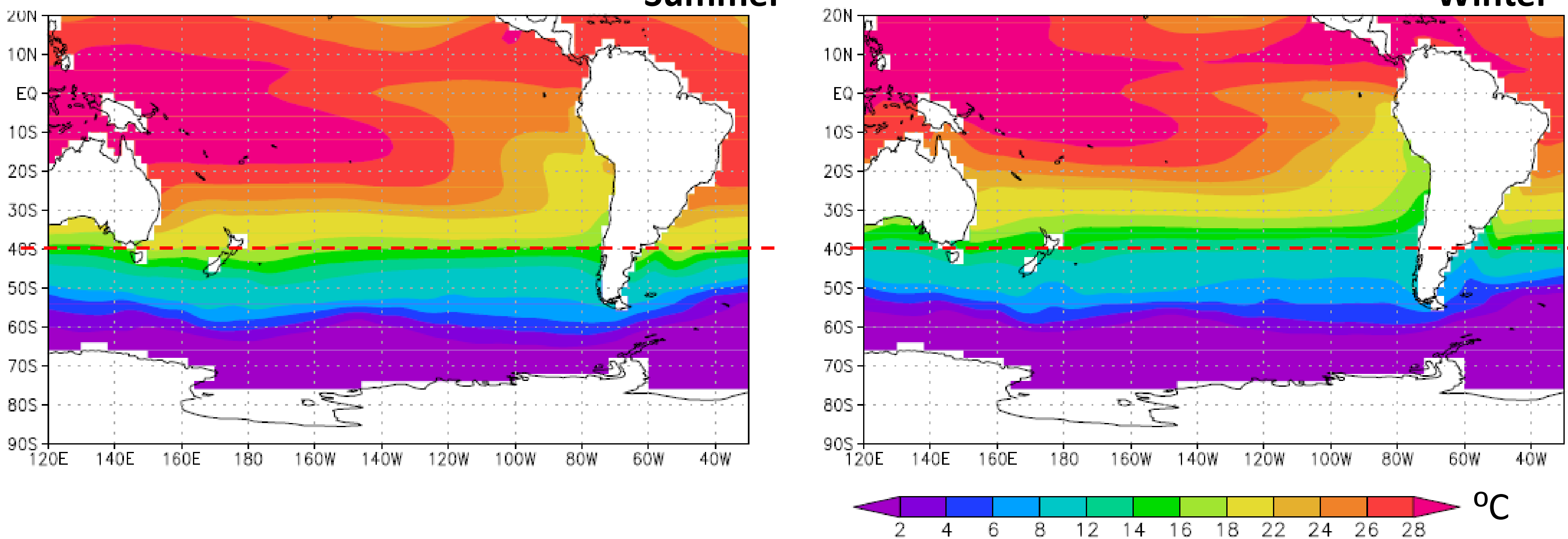
Surface winds (m/s)

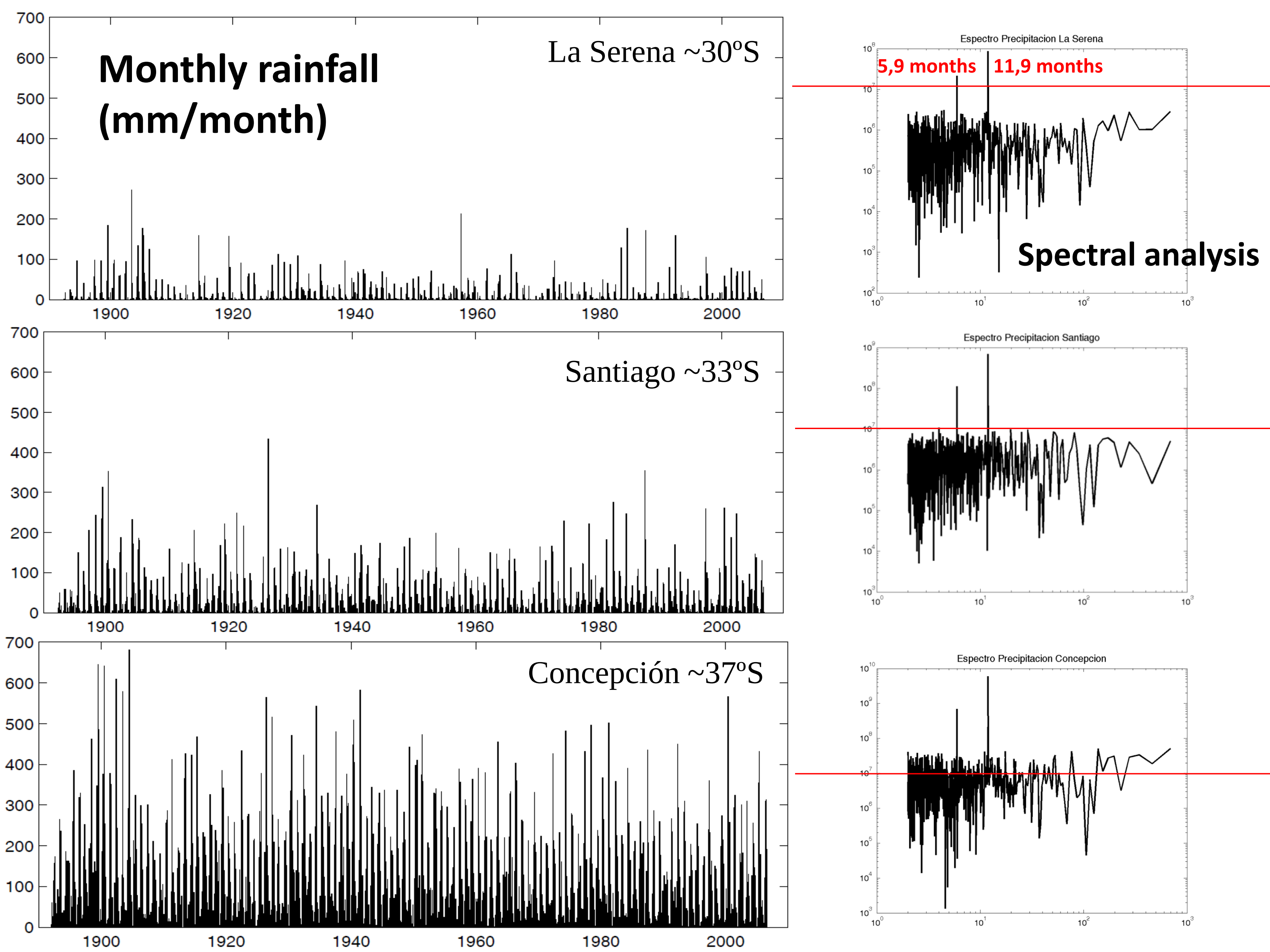


Rainfall (mm/season)

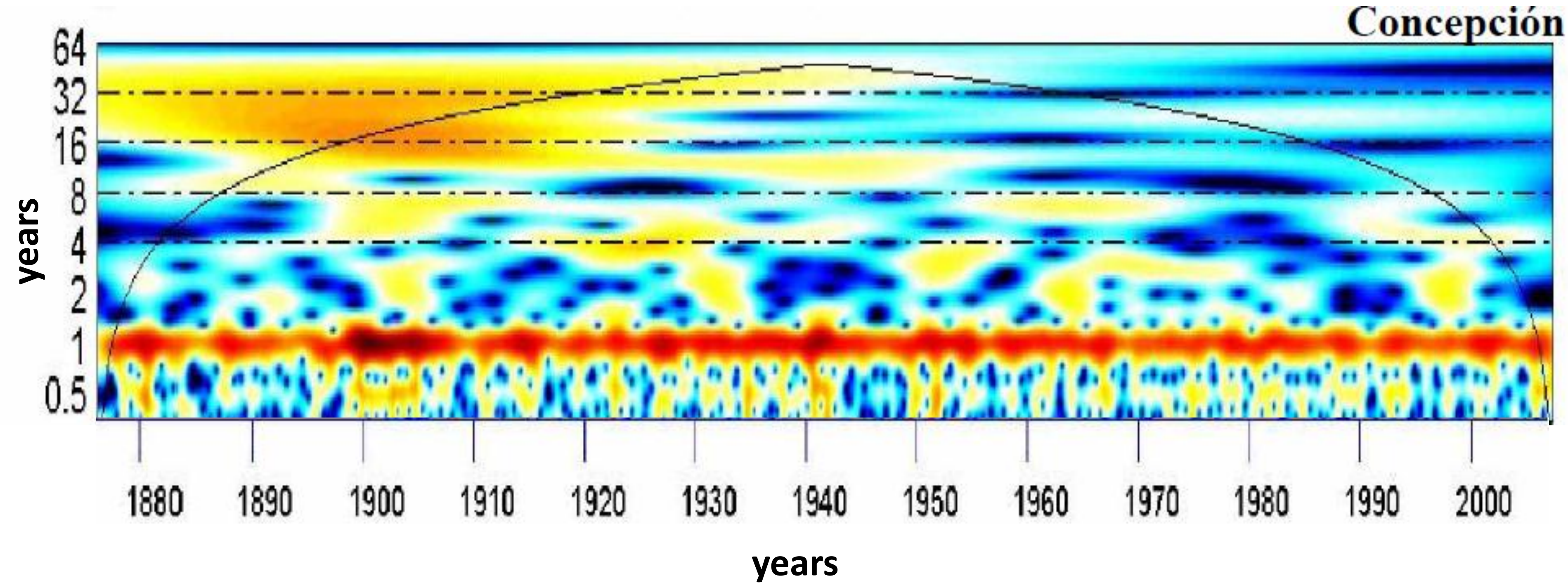


Sea surface temperature (ºC)



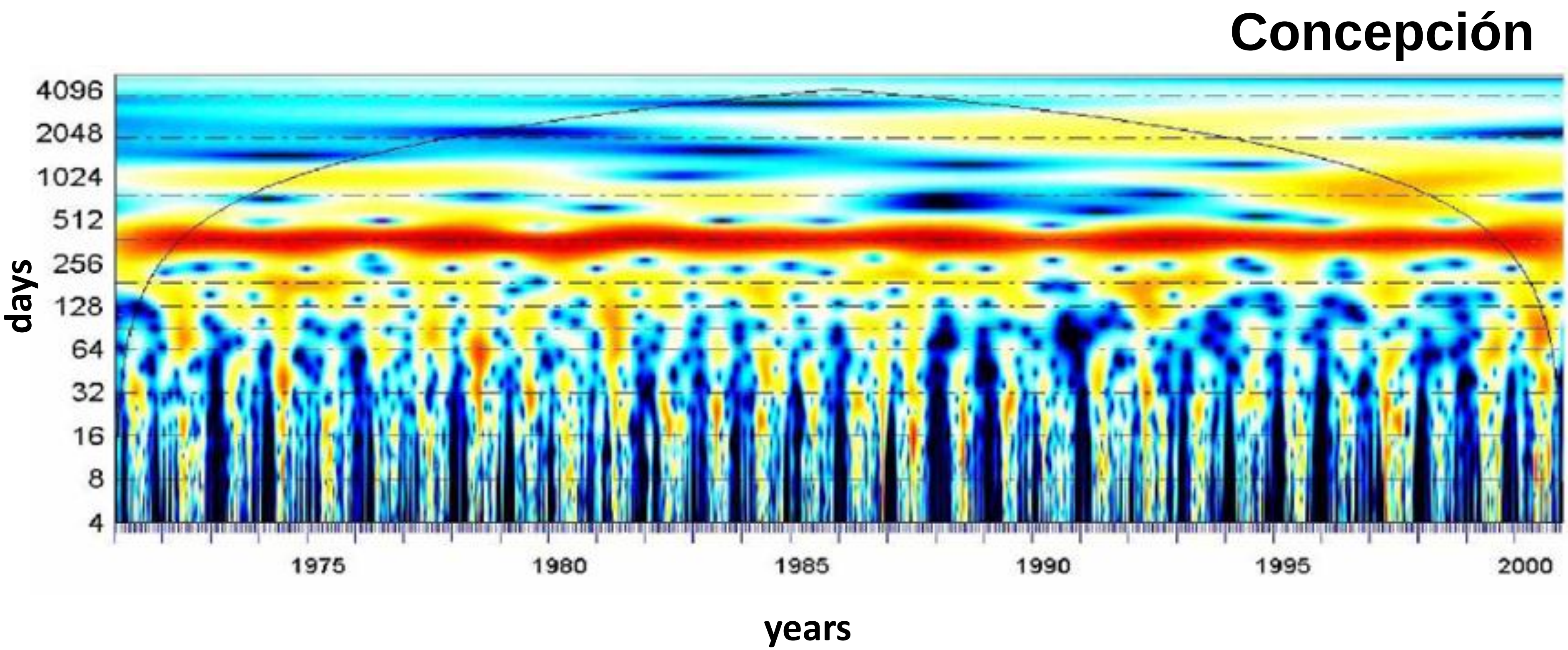

Monthly rainfall (mm/month)
La Serena ~30ºS
Santiago ~33ºS
Concepción ~37ºS
Espectro Precipitacion La Serena
5,9 months
11,9 months
Spectral analysis
Espectro Precipitacion Santiago
Espectro Precipitacion Concepcion
1900
1920
1940
1960
1980
2000

Wavelet analysis of monthly rainfall



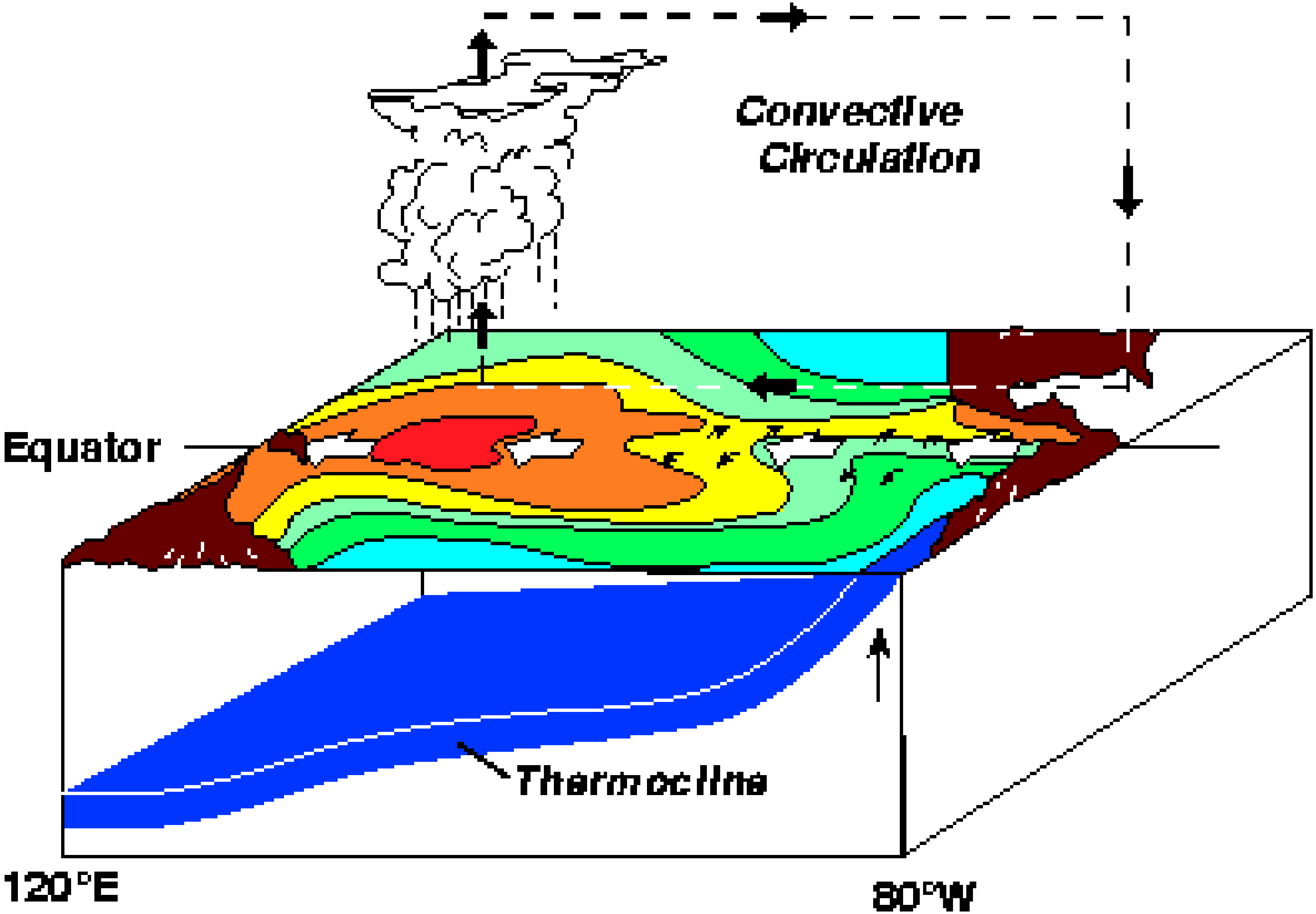
Semmi-annual, annual, interannual, interdecadal

Wavelet analysis of daily rainfall



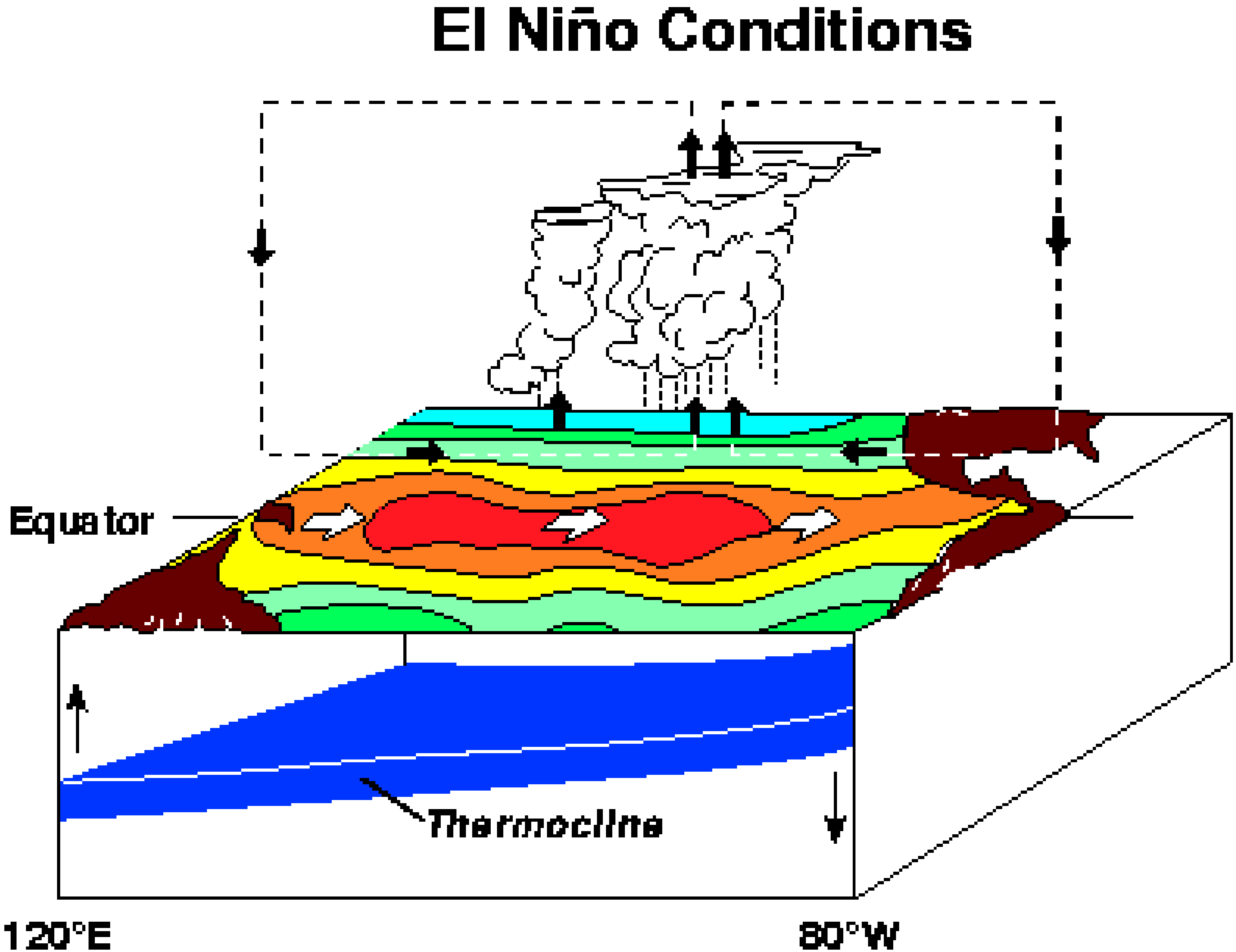
Climate modes and impacts

Normal Conditions



http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

El Niño-Southern Oscillation (ENSO) cycle



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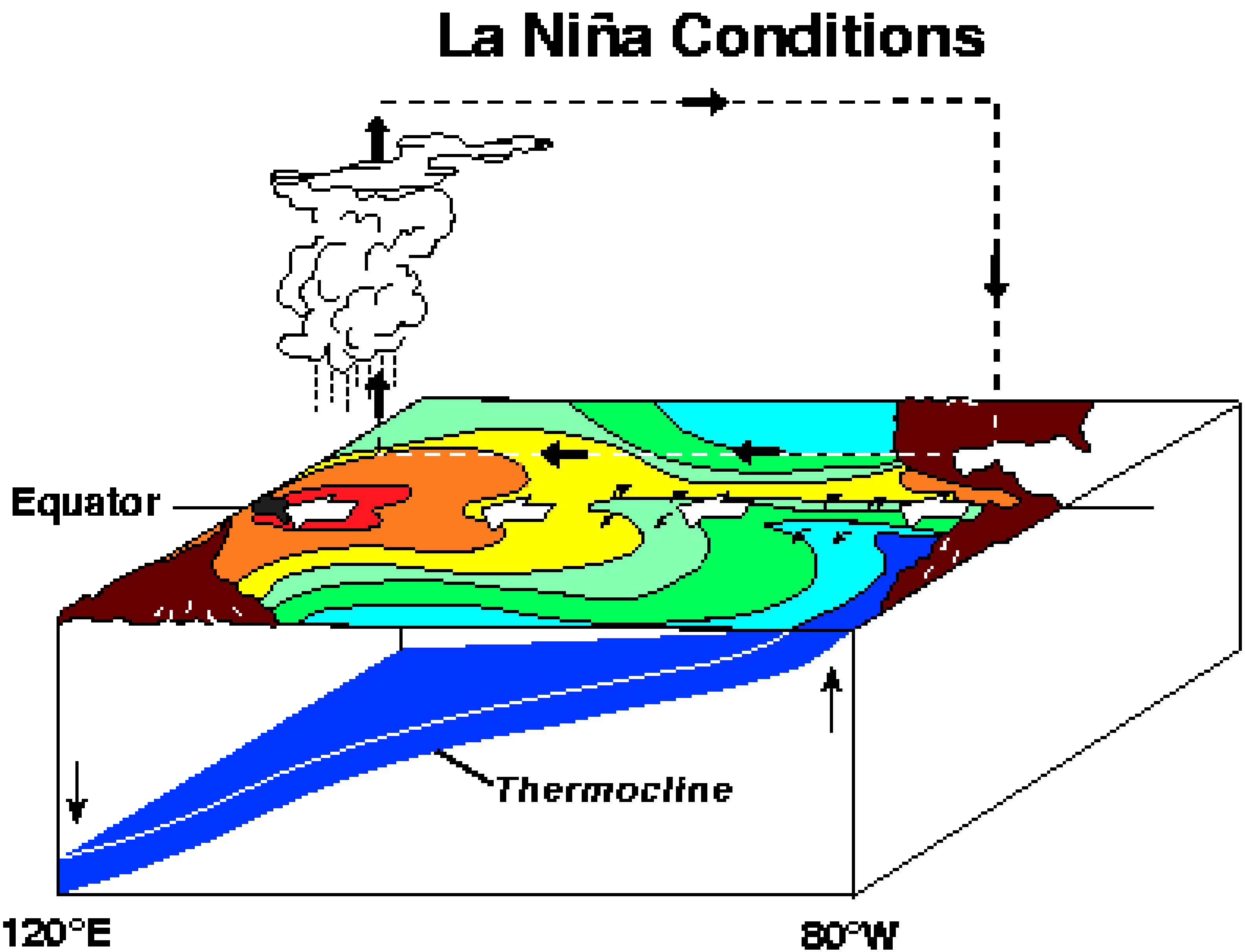
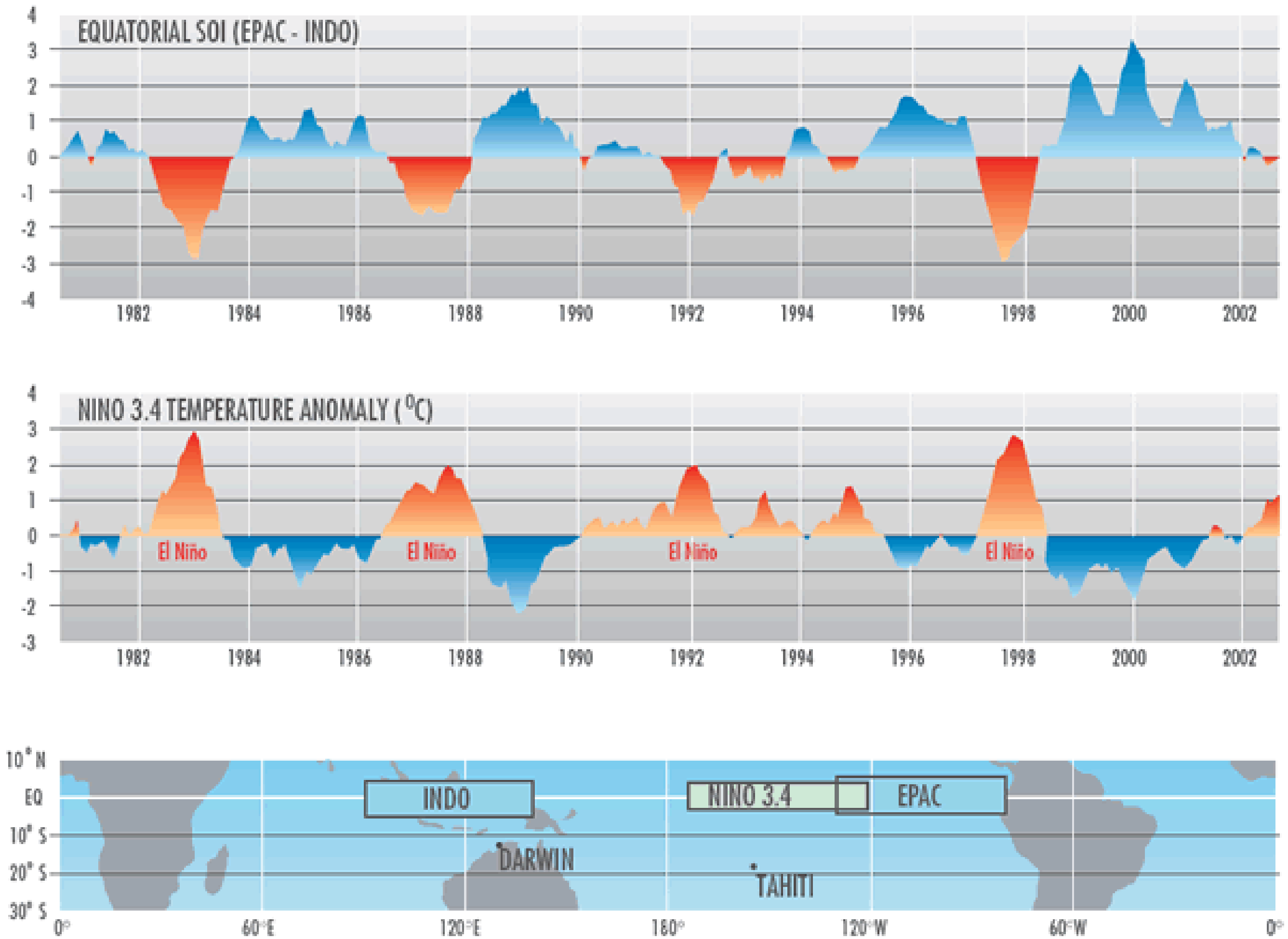
El Niño-Southern Oscillation (ENSO) cycle

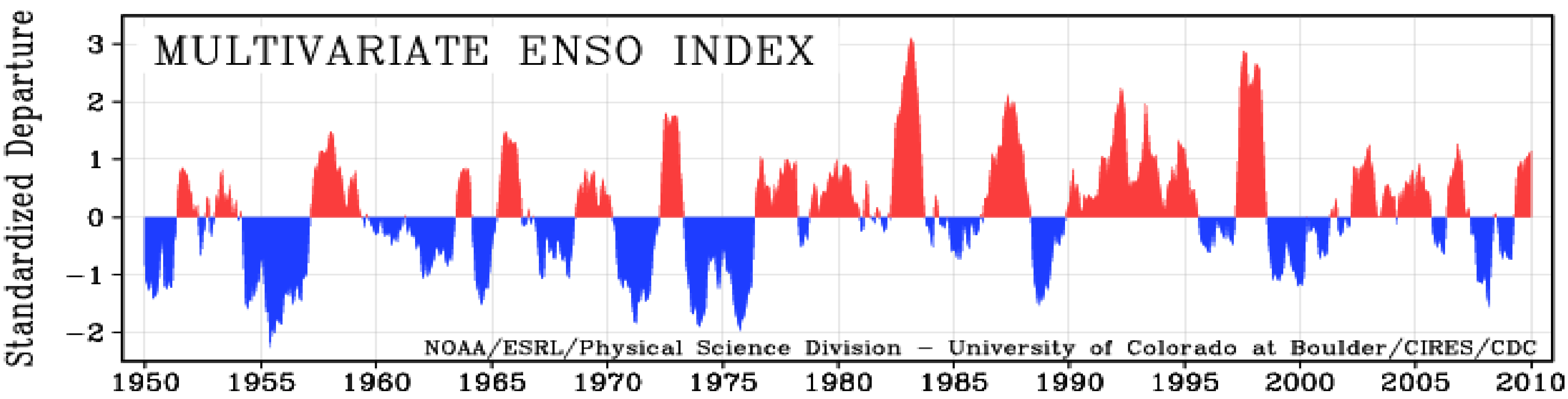


http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

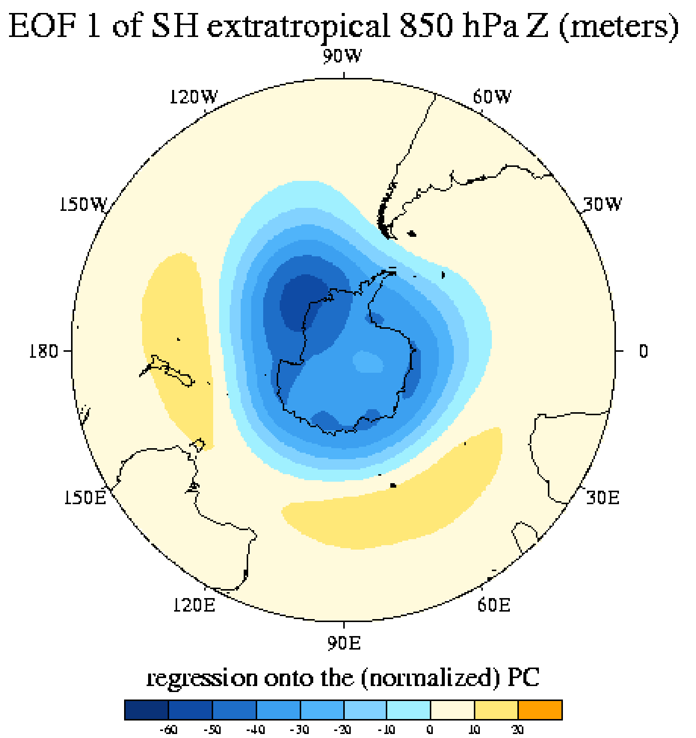
ENSO indices

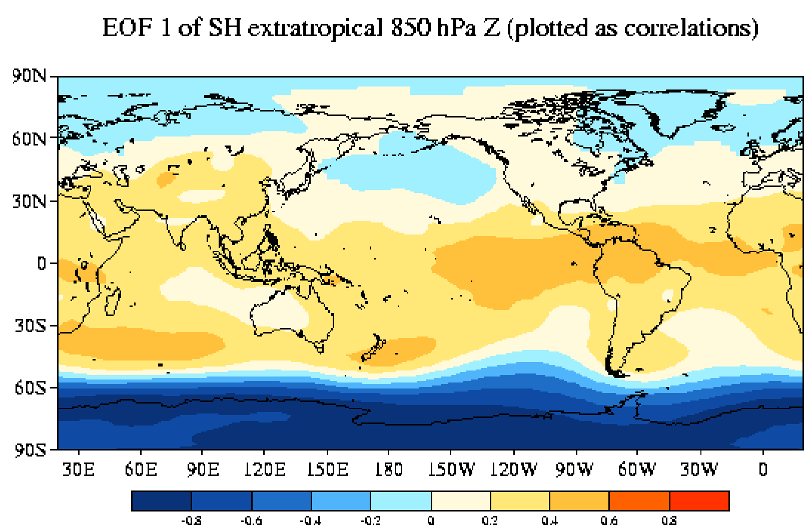


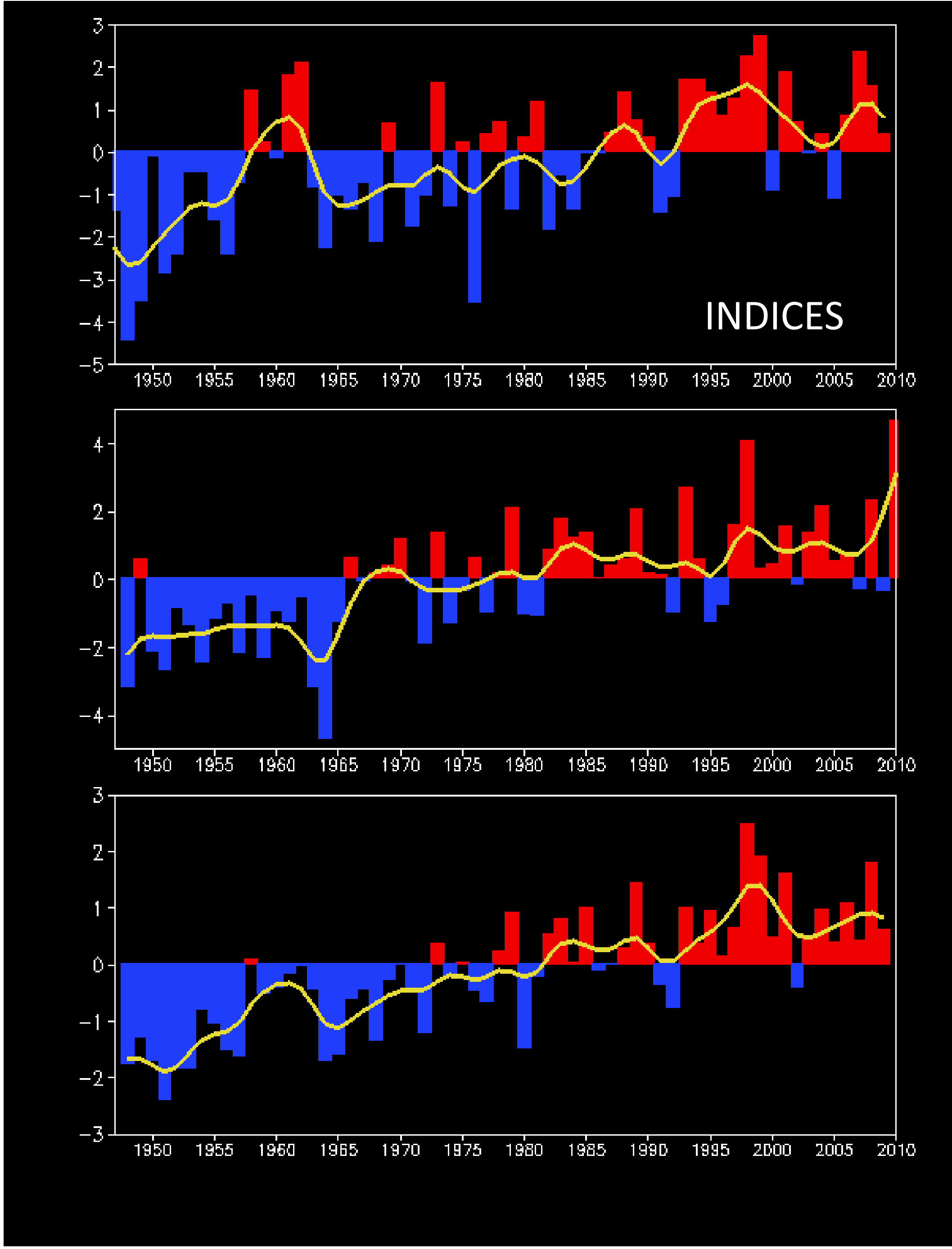
MEI



Antarctic Oscillation (AAO)







http://www.jisao.washington.edu/aao/

Interdecadal Pacific Oscillation (IPO, PDO, ENSO-like)

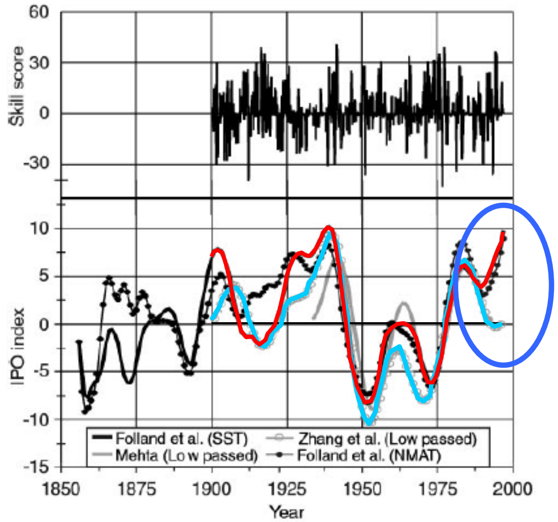


Fig. 1 a The temporal evolution of a skill score (Potts et al. 1996) averaged over eastern Australia for the rainfall prediction scheme (Zhang and Casey 1992; Casey 1998) from 1900 to 1997, using a jack-knife (Wilks 1995), cross validation procedure. The scheme was applied every month during this period to "predict" (hindcast) rainfall anomalies for the following three month block. **b** The temporal evolution of four indices of observed, coherent patterns of sea-surface temperature (SST) variability from various sources (Folland et al. 1998; Zhang et al. 1997; Mehta 1998) and one of night-time marine air temperature (Folland et al. 1998, labelled *NMAT*). The longest two time series (Folland et al. 1998) represent annual totals of seasonal records and are derived from EOF analyses of near-global data sets. The second shortest (based on a time-series calculated by Zhang et al. 1997, *grey line* and *circles*) was filtered using a low pass spectral filter with an 13 y cut-off (see Power et al. 1998a for further details on the filtering process), after combining monthly data into annual totals. It is derived from monthly SST data for the North Pacific. The shortest time series is based on an EOF analysis of annual SST data for the North Pacific (Mehta 1998). It has been multiplied by 15 to facilitate comparison. For the purposes of this study the amplitude is essentially arbitrary. The correlation coefficients between the indices depicted vary between 0.8 and 0.95. Further details given in the text.

SST

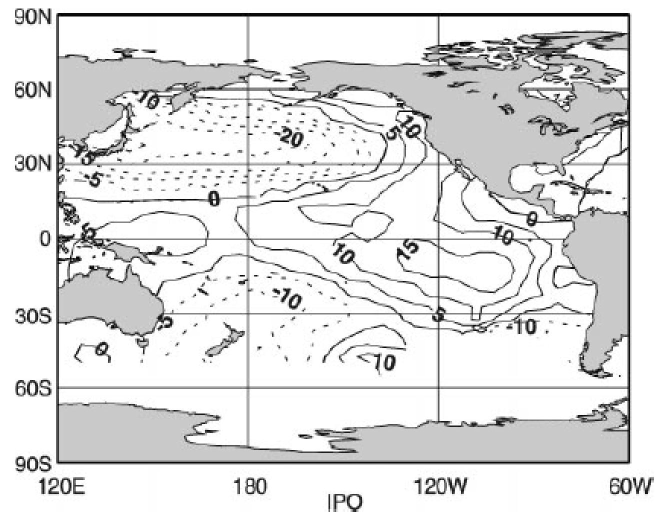


Fig. 2 The SST signature of the IPO during its warm tropical Pacific phase (i.e. when the IPO Index is positive). This particular plot is based on an analysis of near-global SST data for 1911–1995 by Folland et al. (1998). Only the Pacific is shown here. It represents the third unrotated EOF of low frequency SST variability. A 13 y cut-off was used. It accounts for approximately 13% of the low frequency variability and 3% of the total variability (Folland et al.'s 1988 equivalent figure for the interannual El Niño mode is 16% of the total variability). The first EOF in the same analysis represents global warming, while the second represents out-of-phase temperature fluctuations between the Northern and Southern Hemispheres.

Warm tropical phase of IPO.

… a basin-wide interdecadal oscillation

Power et al. (1999)

ENSO-like

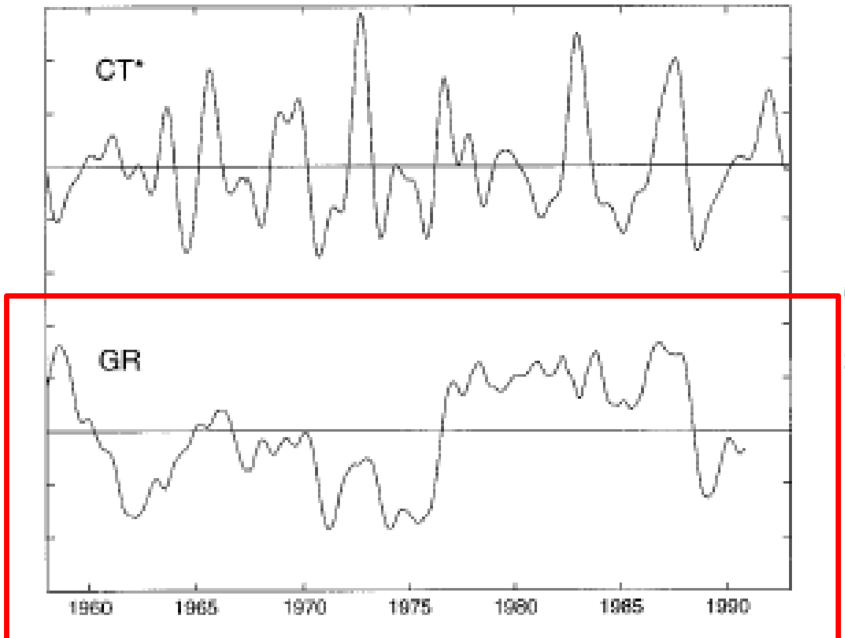
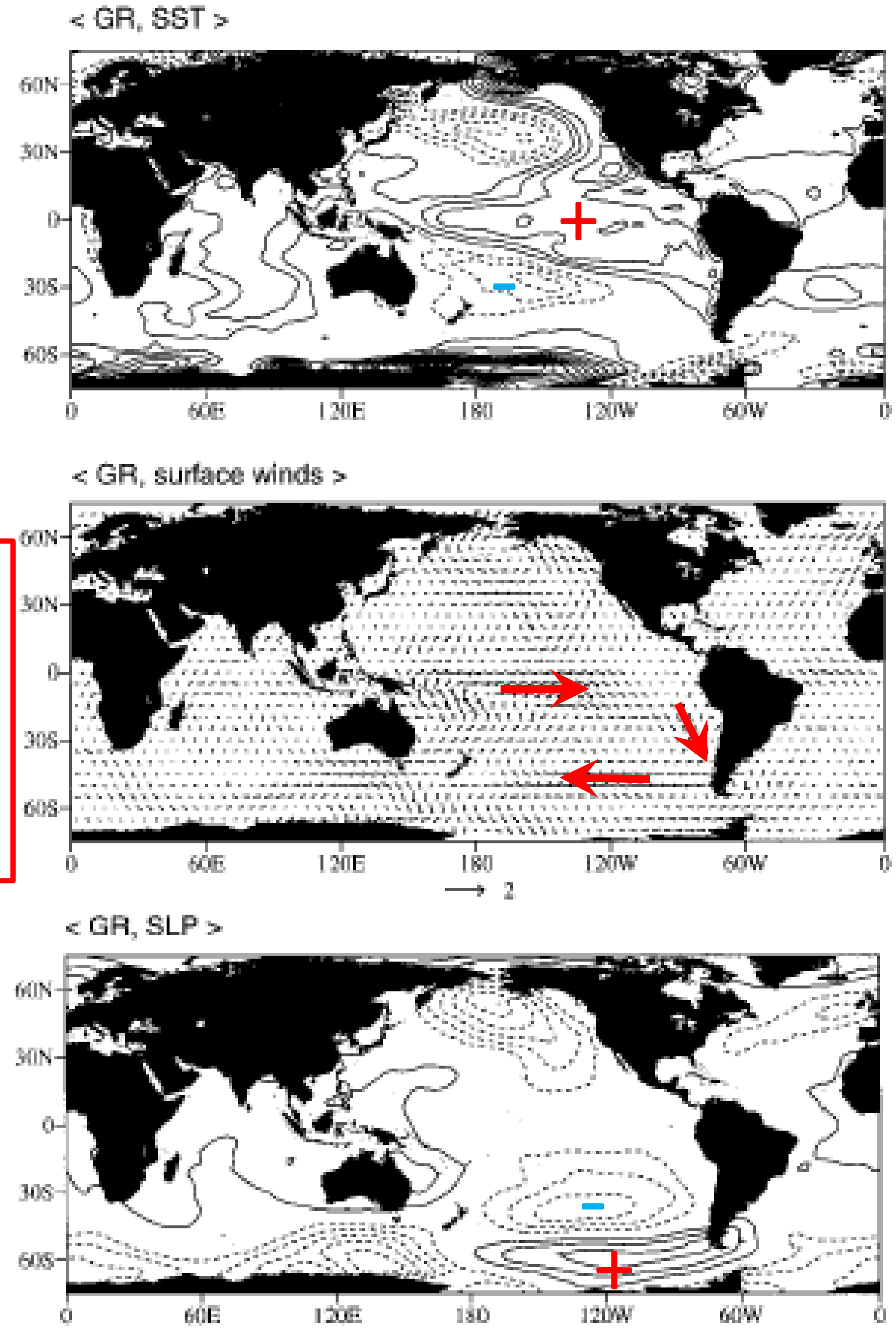
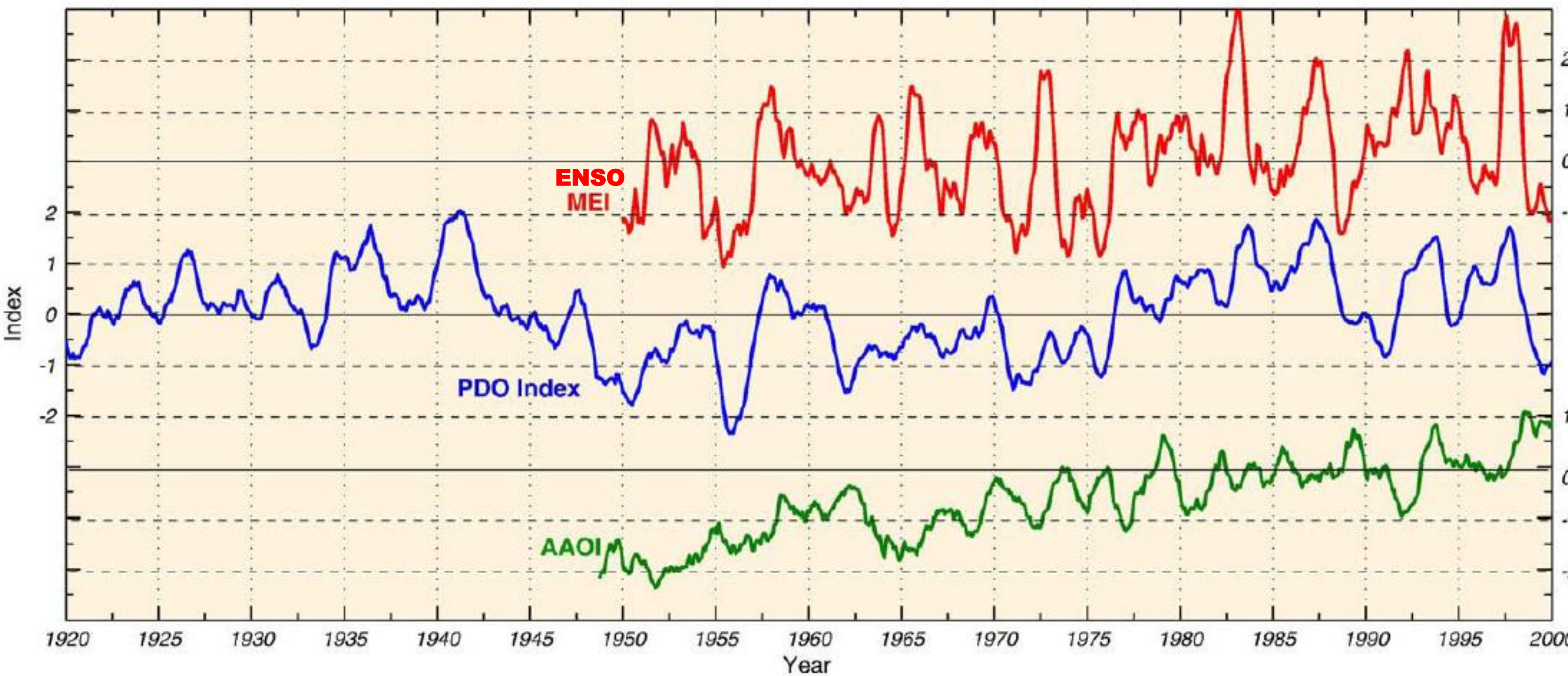


FIG. 1. Normalized time series of the 6-yr high-pass filtered cold tongue index (CT*) and global residual (GR). The interval between tick marks is 1.0 std dev.



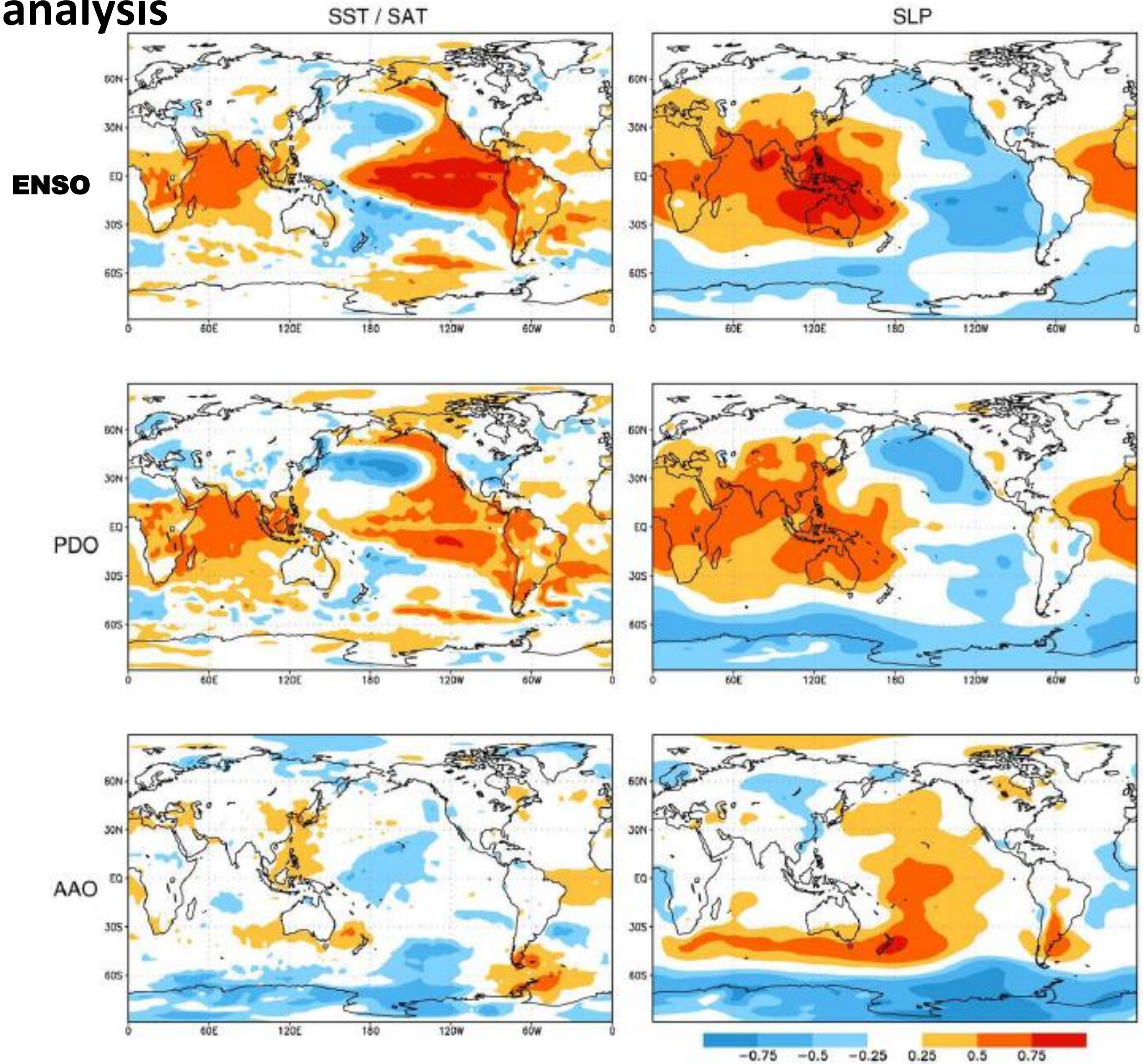
Zhang et al. (1997), Garreaud and Battisti (1999)

Main climate modes



Garreaud et al. (2008)

Correlation analysis

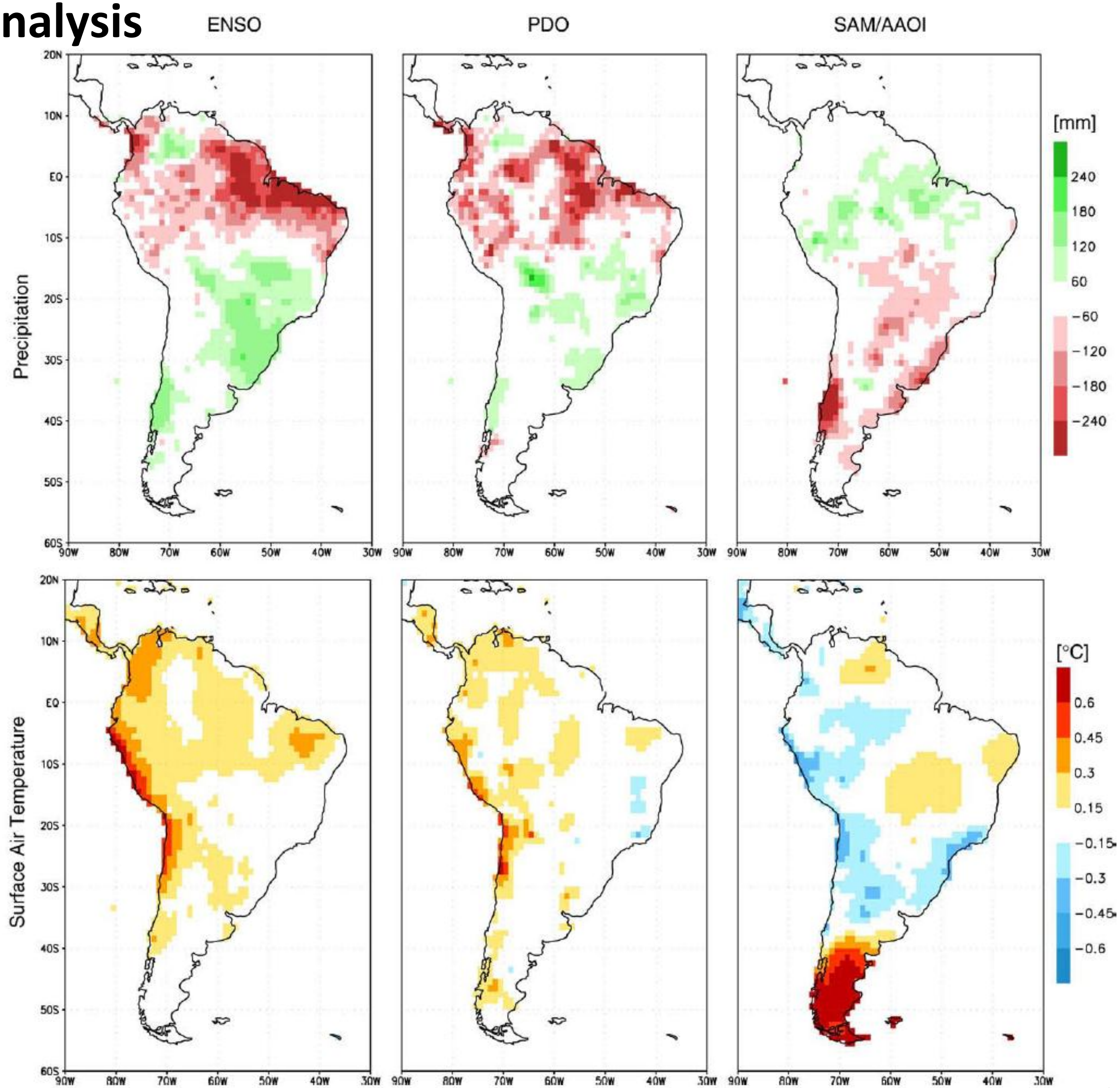


Garreaud et al. (2008)

Regression analysis

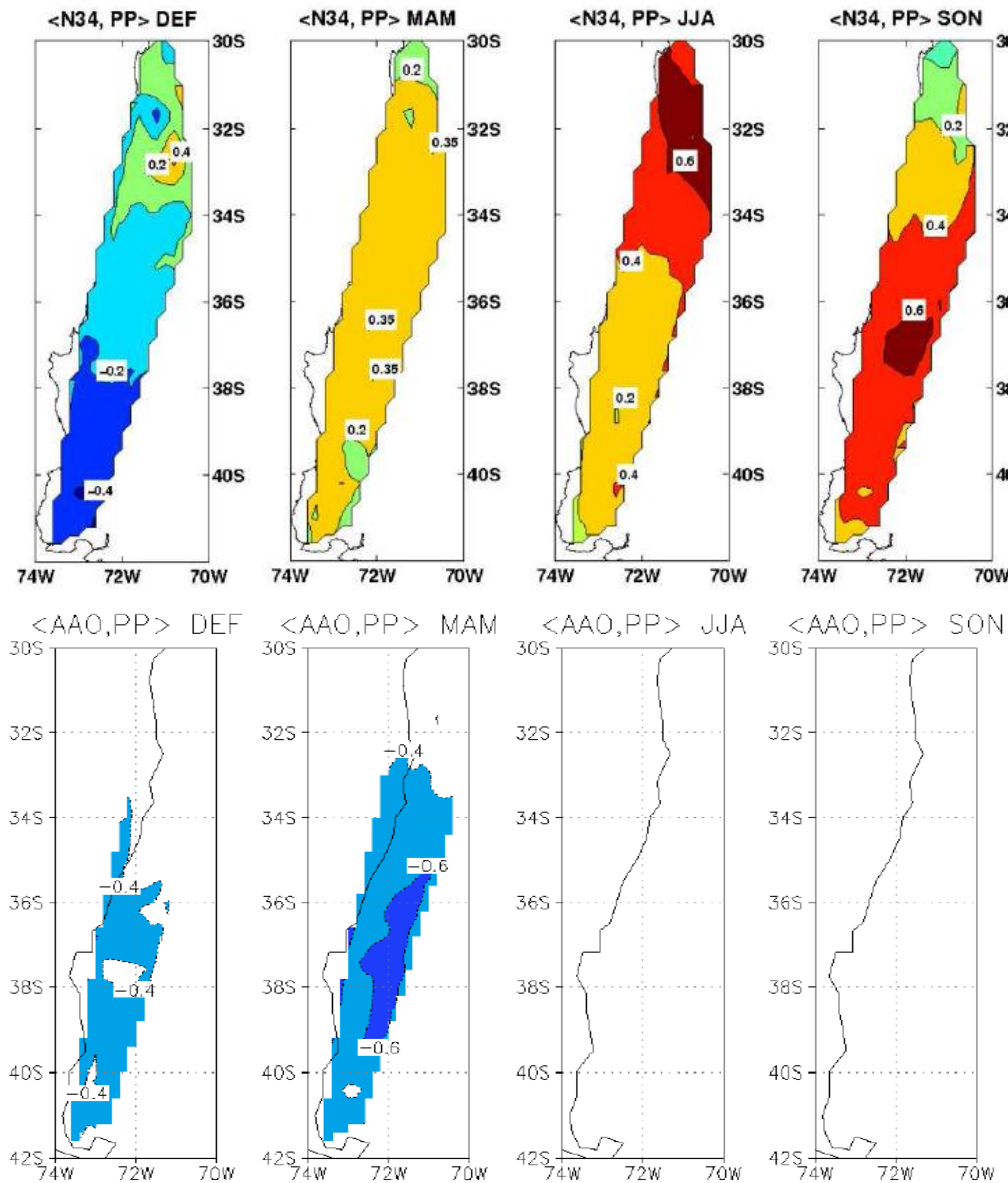
Annual rainfall

Annual air temperature



Garreaud et al. (2008)

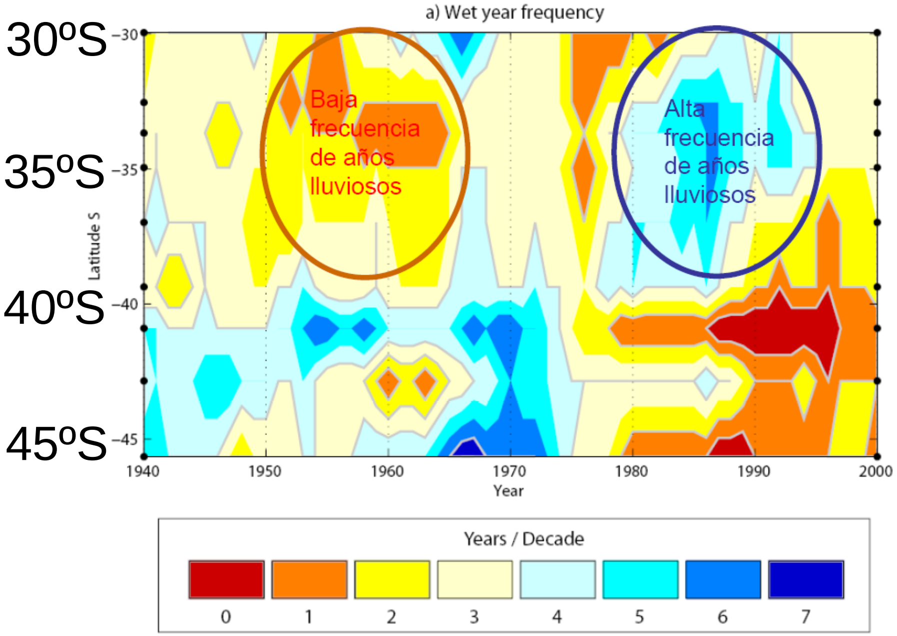
Correlation analysis
Seasonal rainfall



ENSO
(tropical forcing)

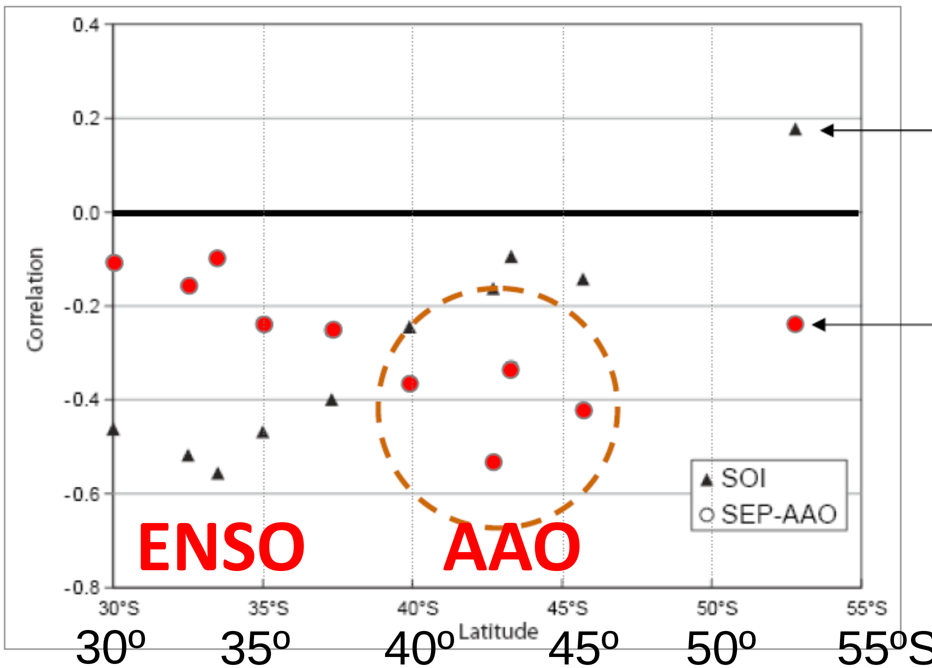
AAO
(extratropical forcing)

Muñoz and Montecinos (2009)



Wet years frequency by decades

Correlation analysis (Annual rainfall)

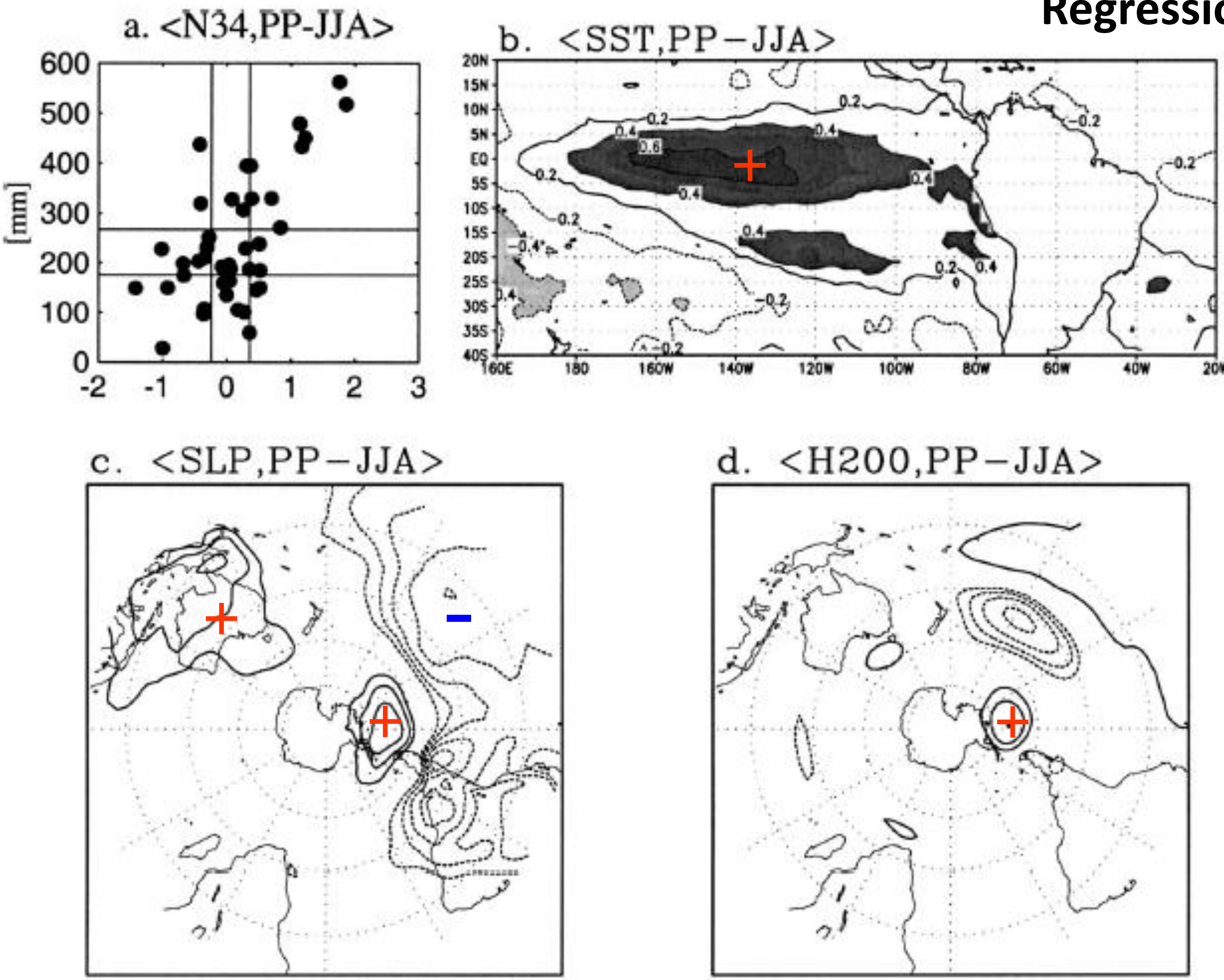


Correlación entre el Indice de Oscilación del Sur y la precipitación anual

Correlación entre el Indice de la Oscilación Antártica en el Pacífico Suroriental y la precipitación anual

Quintana and Aceituno (2008)

Regression analysis



Montecinos and Aceituno (2003)

Annual rainfall in Antofagasta (23° 26'S)

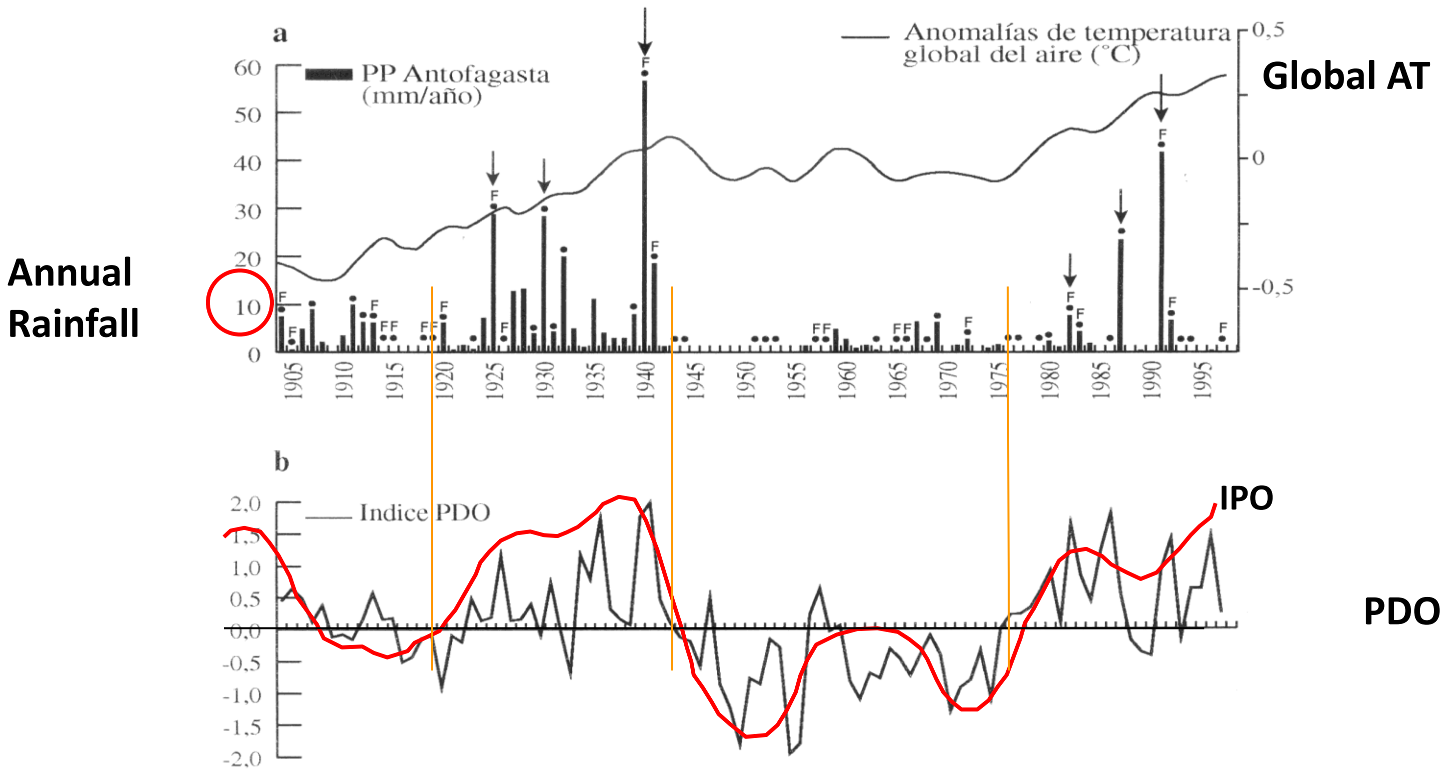
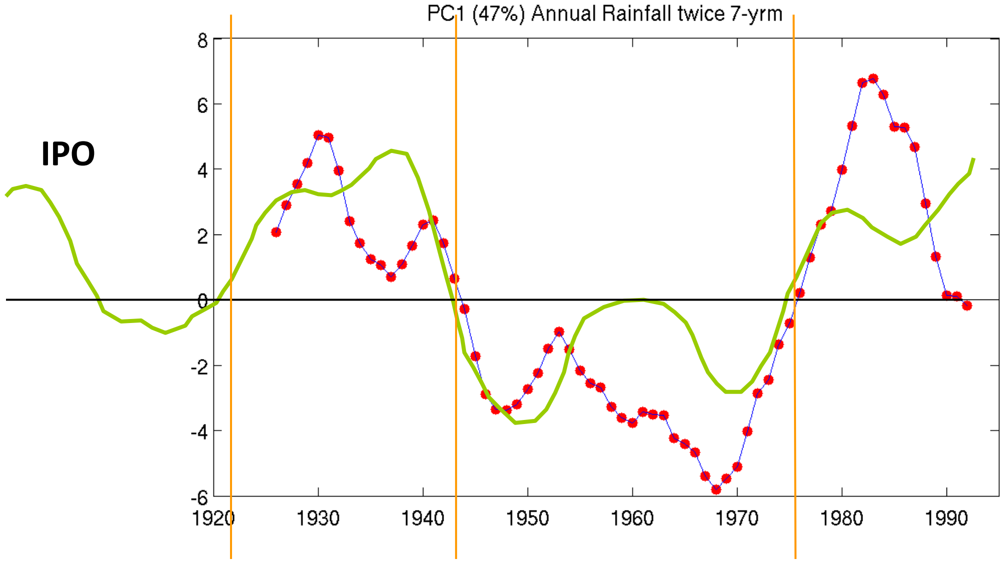
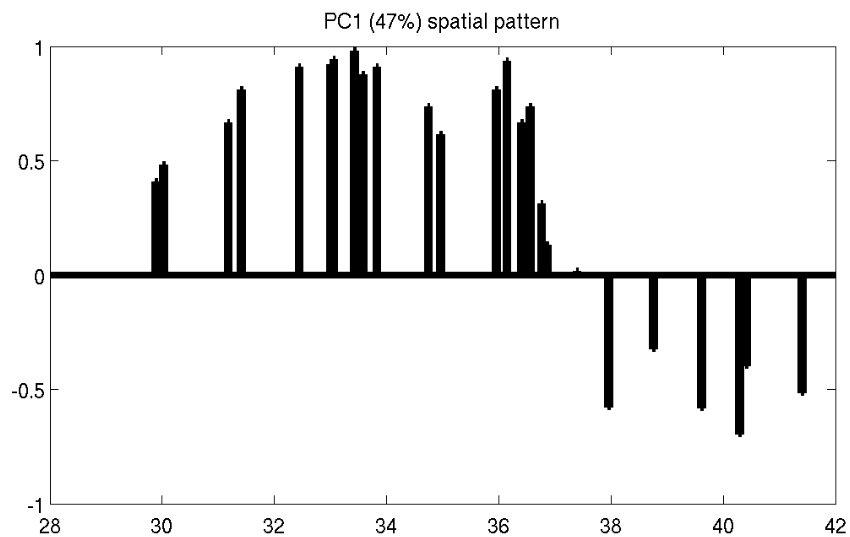


FIG. 9. Totales anuales de precipitación en Antofagasta durante el siglo XX, en relación a la ocurrencia de años El Niño y variaciones interdecadales así como tendencias globales de la temperatura del aire y de la superficie del mar. Los eventos ENOS de intensidad moderada se señalan mediante puntos negros, mientras que los eventos ENOS fuertes a muy fuertes se indican con punto negro y letra 'F' (según Quinn (1993), y revisado según Trenberth (1997) para los eventos posteriores a 1950. Se indican, además, los años en que ocurrieron aluviones o inundaciones en la ciudad (flechas negras) (1904-1913 y 1919-1967: datos estación Portezuelo. 1914-1918: carencia de información. 1968-1998: datos de la estación de la Universidad Católica del Norte). PDO: Pacific Interdecadal Oscillation Index.

Vargas et al. (1999)

PC1 of annual rainfall along Chile (30°-40°S), 45%





Spatial pattern
(as correlation)

30°S 37°S 42°S

ENSO-rainfall stability

Correlation analysis

Fig. 1 - Localización de las estaciones pluviométricas y del lago Titicaca.

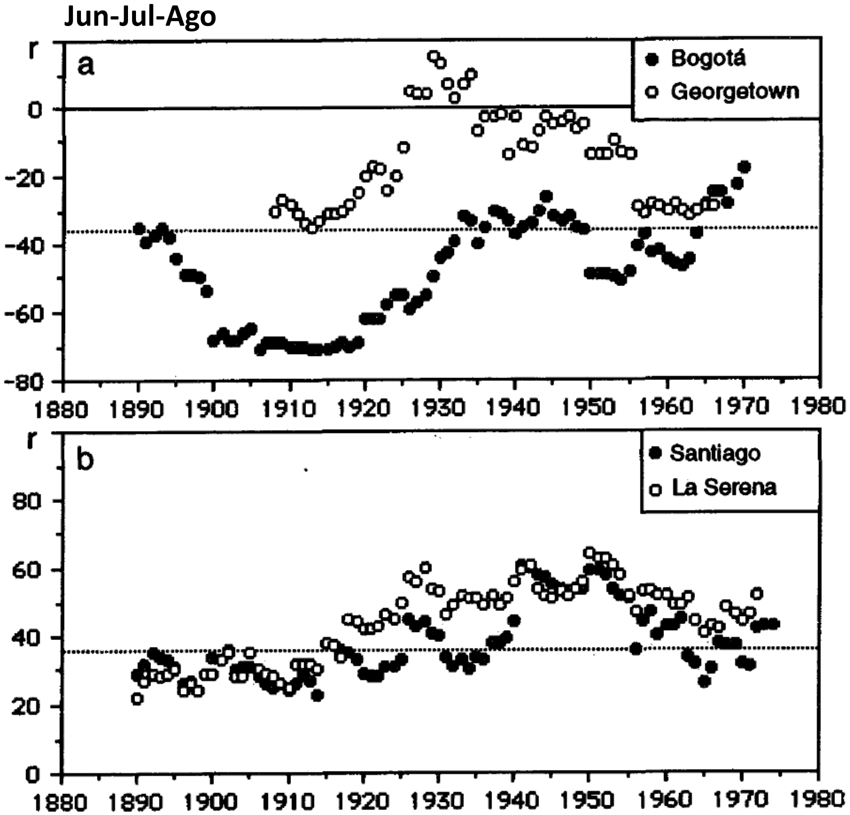
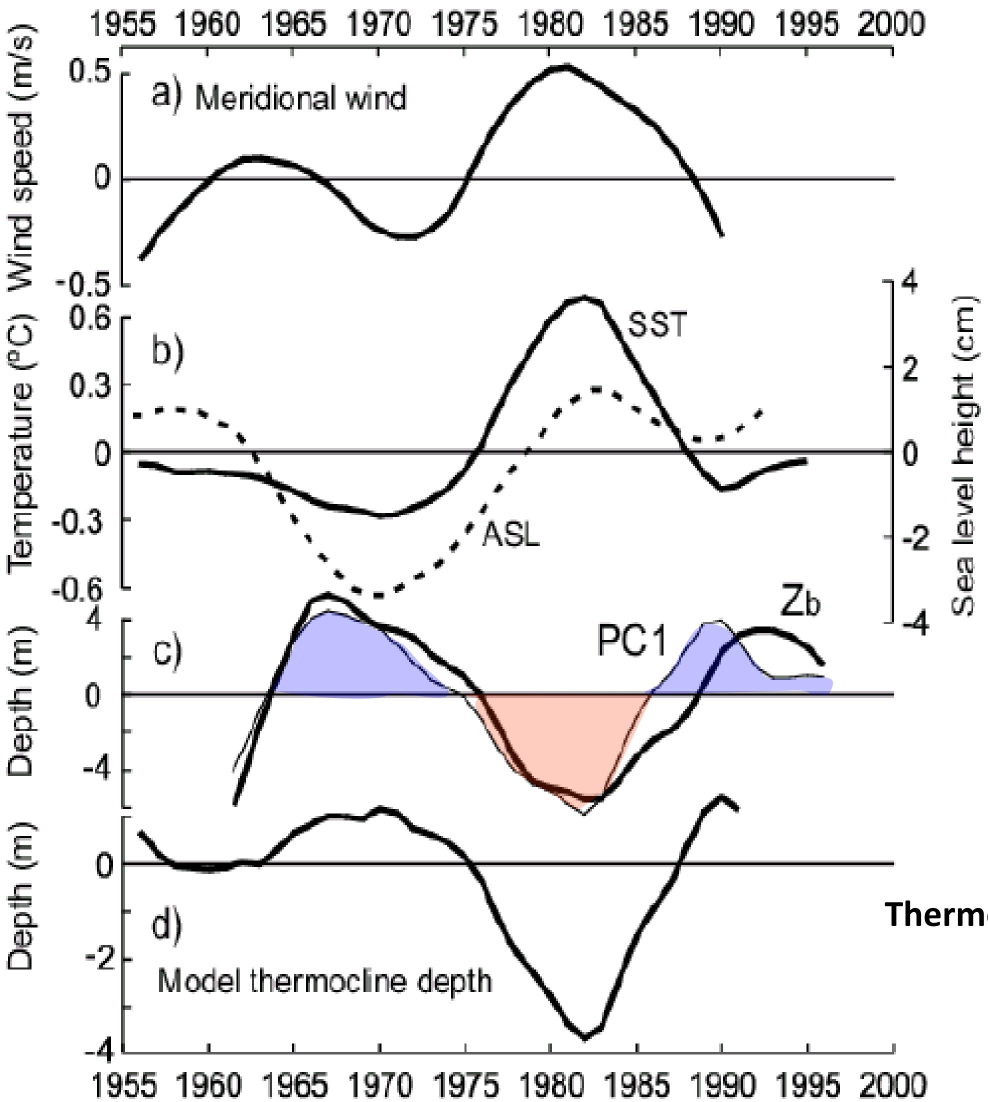


Fig. 3 - Correlación móvil entre la presión media en Darwin y la precipitación en la estación indicada, durante Jun-Jul-Ago, considerando períodos de 30 años: a) Bogotá y Georgetown; b) Santiago y La Serena. Los valores, expresados en centésimos, se asignan al año número 15 del período correspondiente de 30 años. La línea horizontal punteada señala el nivel de significancia de 95%. La localización de las estaciones se indica en la Fig. 1.

Aceituno and Montecinos (1993)

Coastal alongshore thermocline, SST, SLH, meridional wind

ANTOFAGASTA (23ºS)



Meridional wind (14 hl)

SST

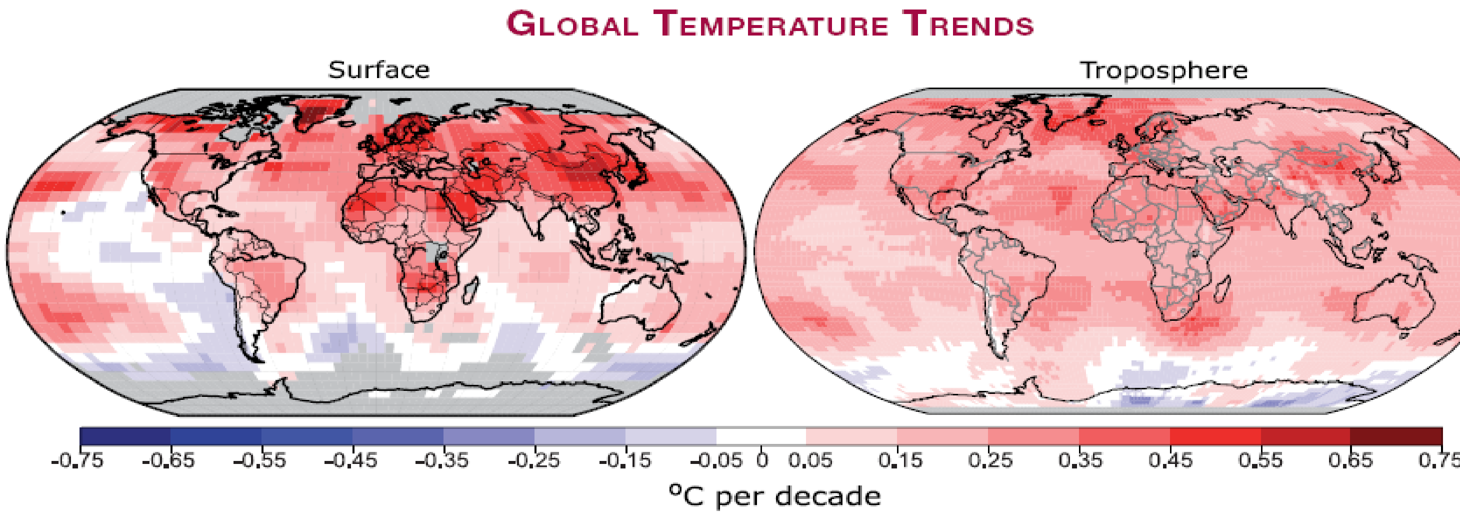
Sea level height

Thermocline depth (Z_b)

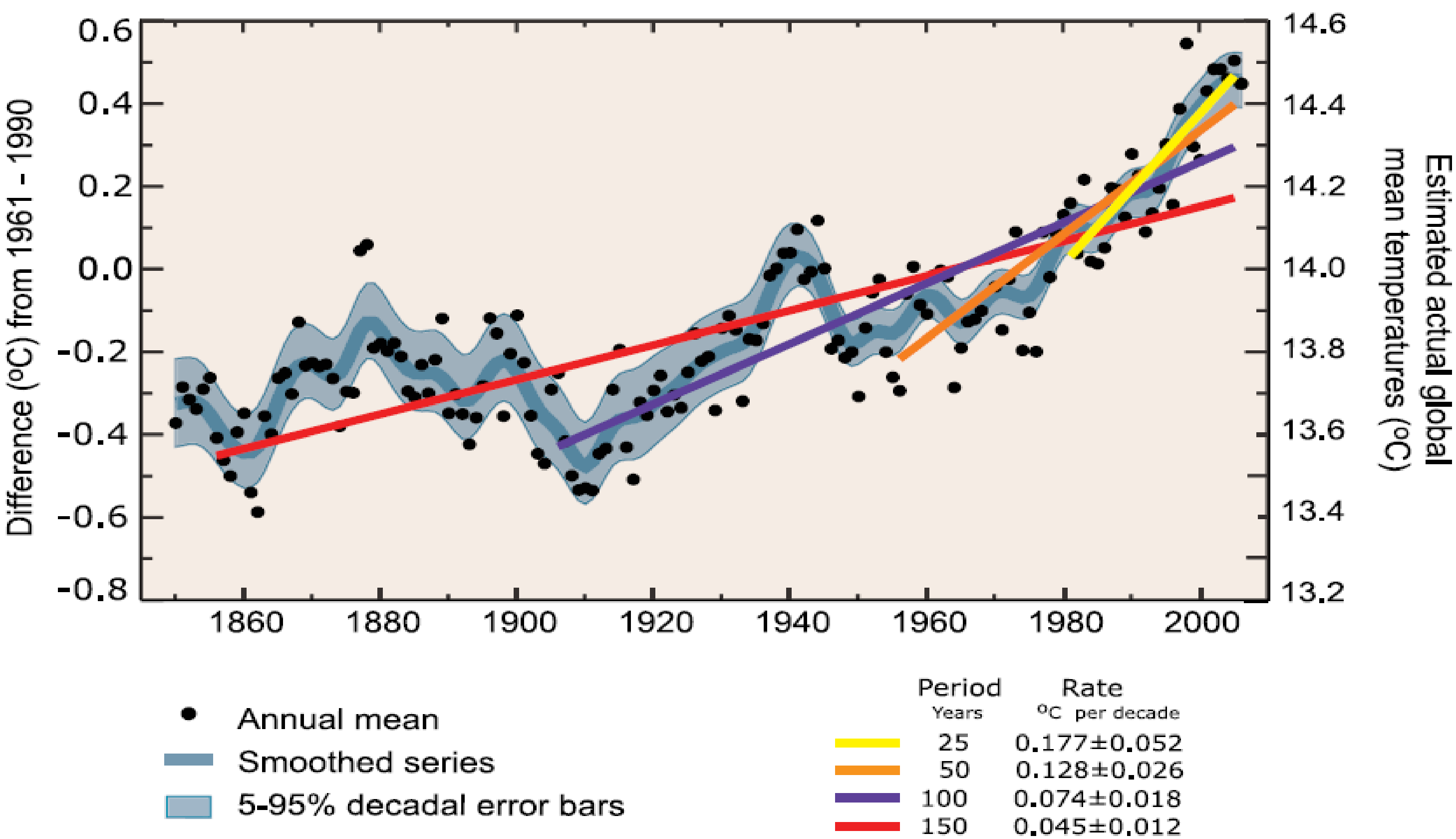
Thermocline depth estimated with equatorial winds

Pizarro y Montecinos (2004)

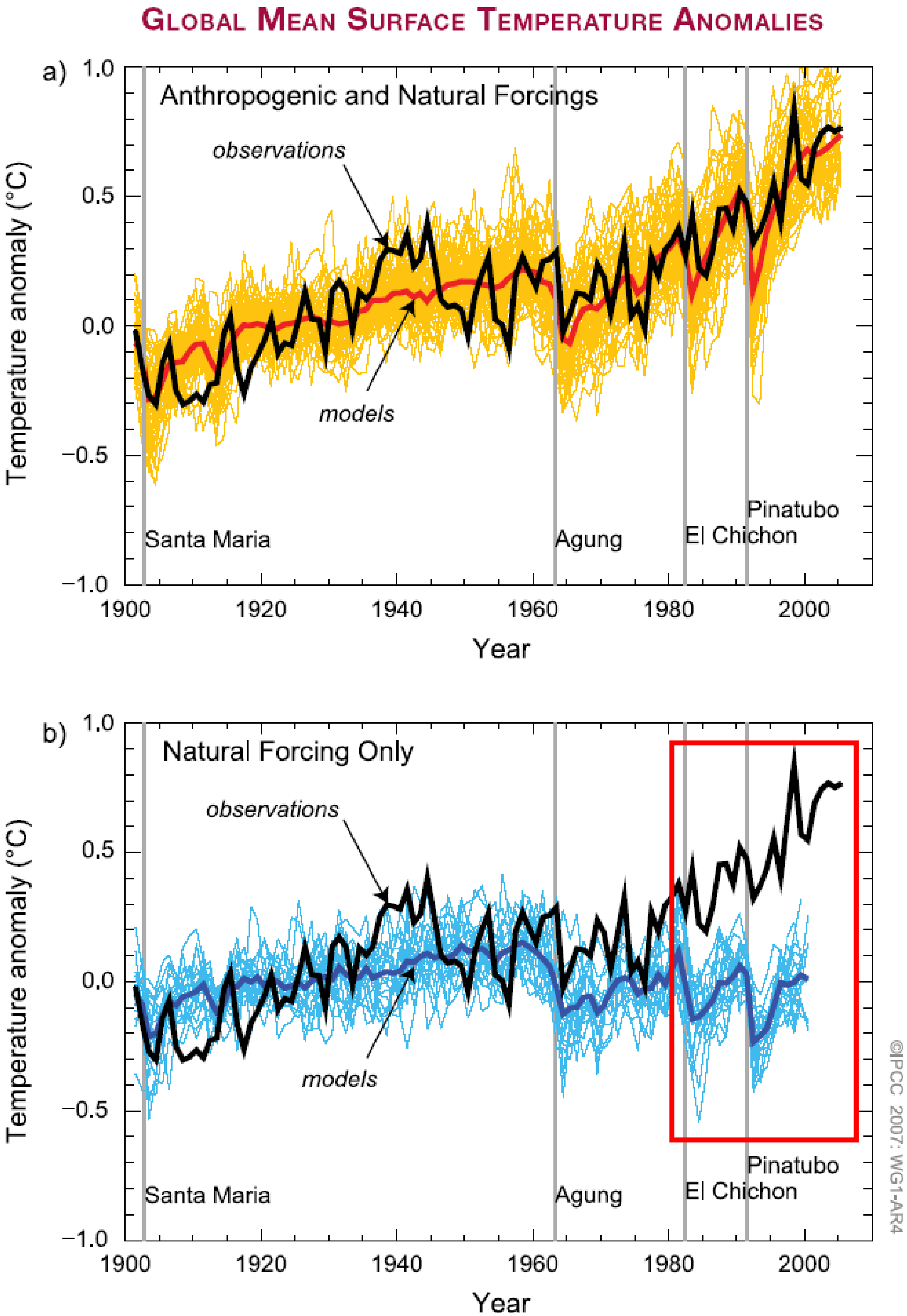
Observed long-term trends



1979-2005



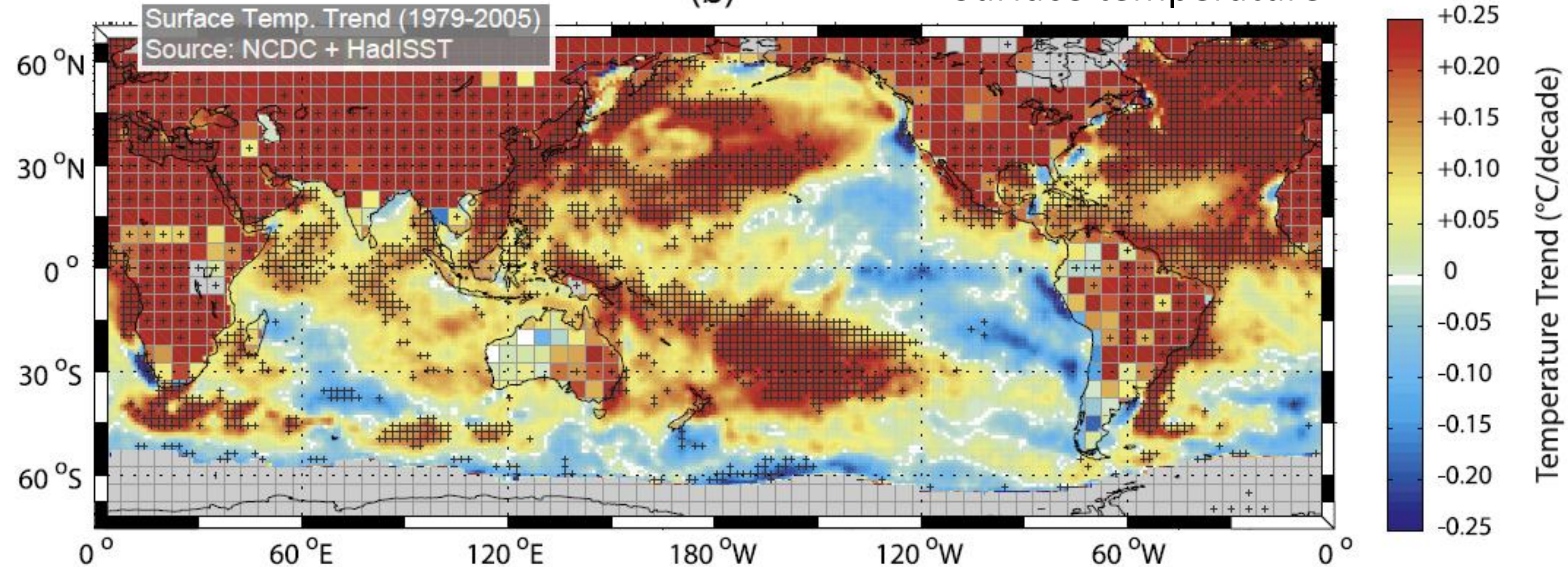
IPCC (2007)



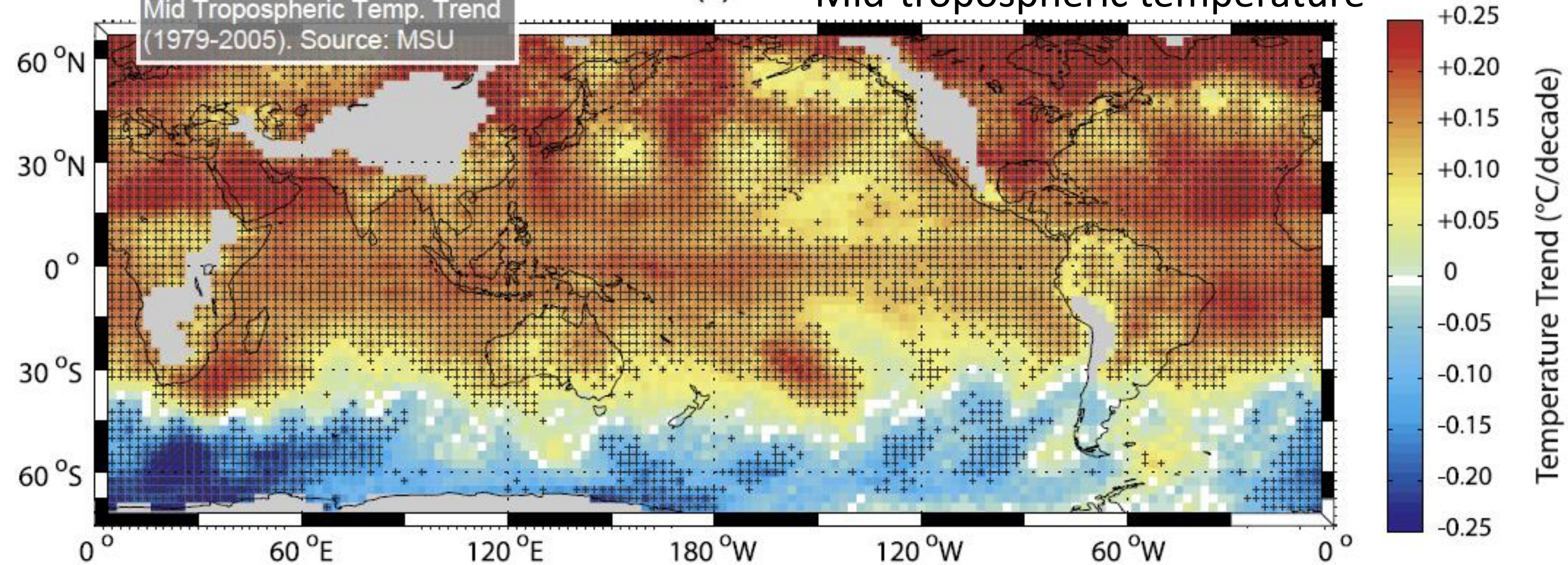
According to global climate models, since 1980s the global warming is mainly forced by anthropogenic radiative forcing.

IPCC (2007)

(b) Surface temperature

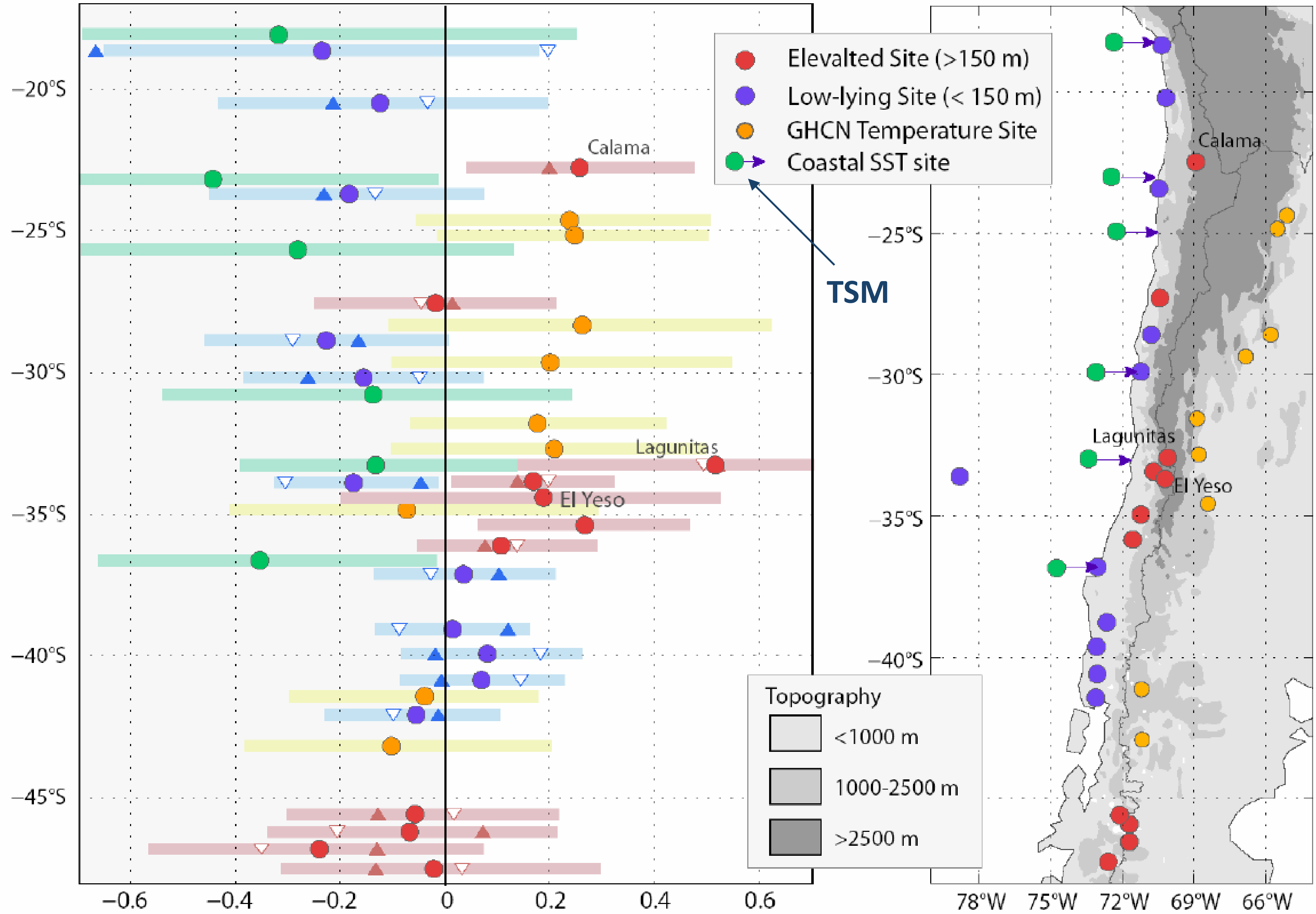


(c) Mid-tropospheric temperature



Falvey y Garreaud (2009)

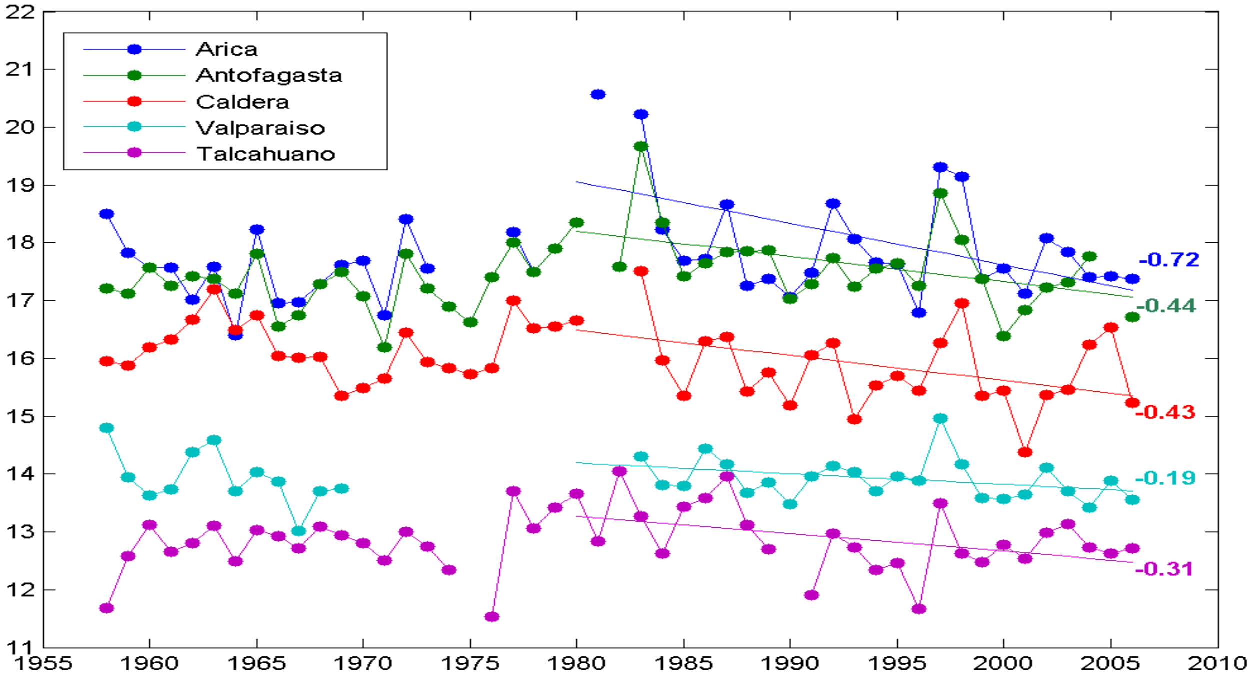
1979-2006 Surface air temperature



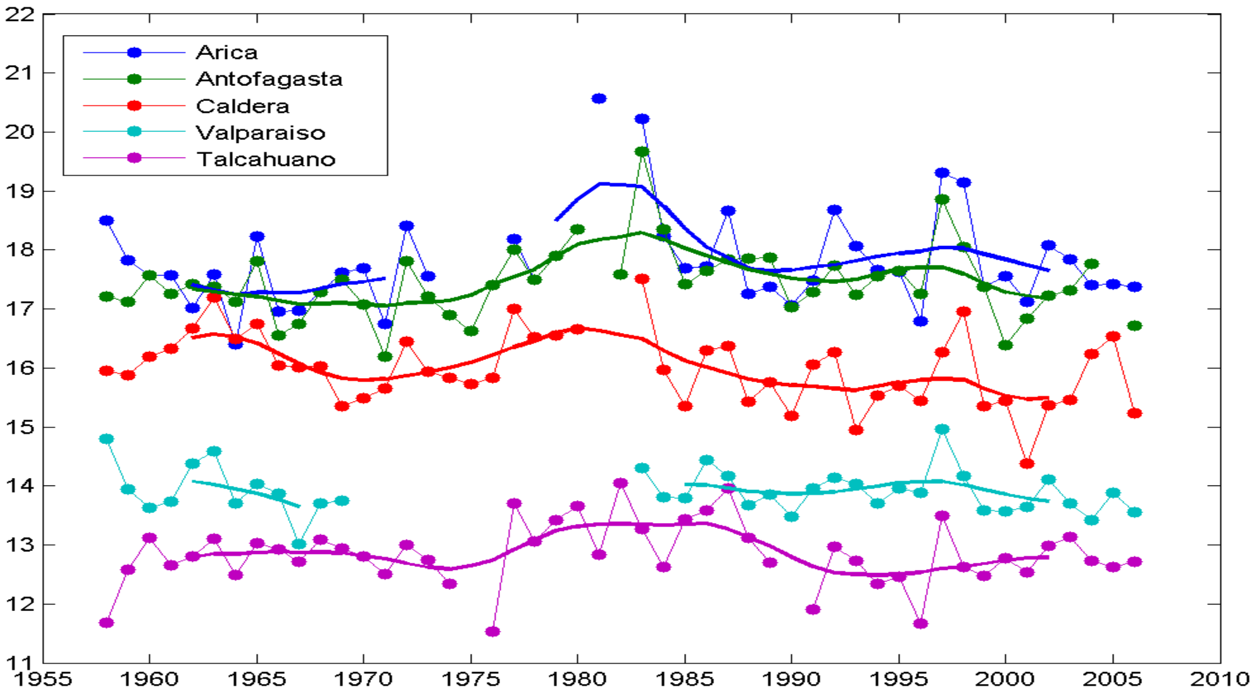
Falvey y Garreaud (2009)

Coastal SST

Long-term trend

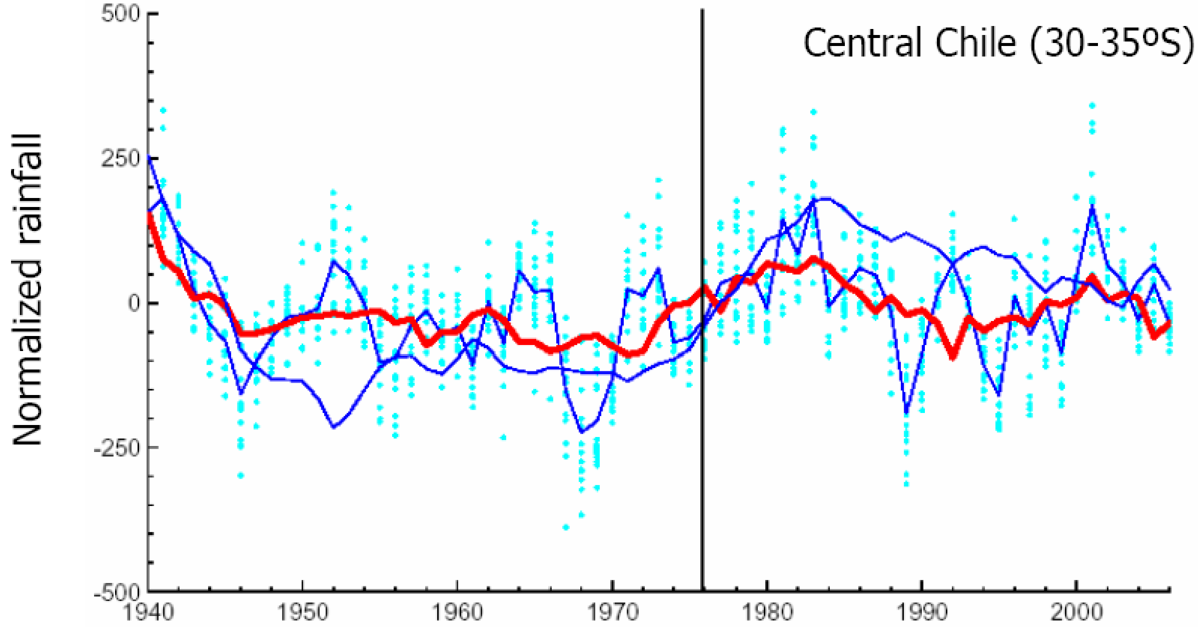


Interdecadal

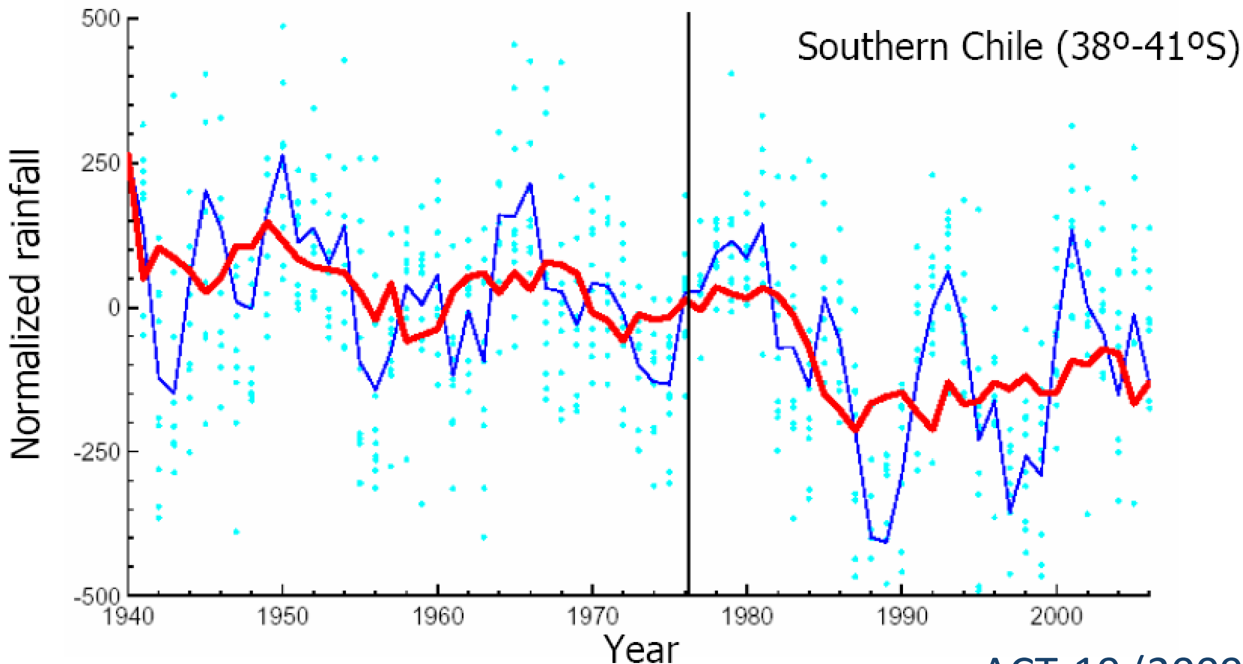


Annual rainfall

30º-35ºS

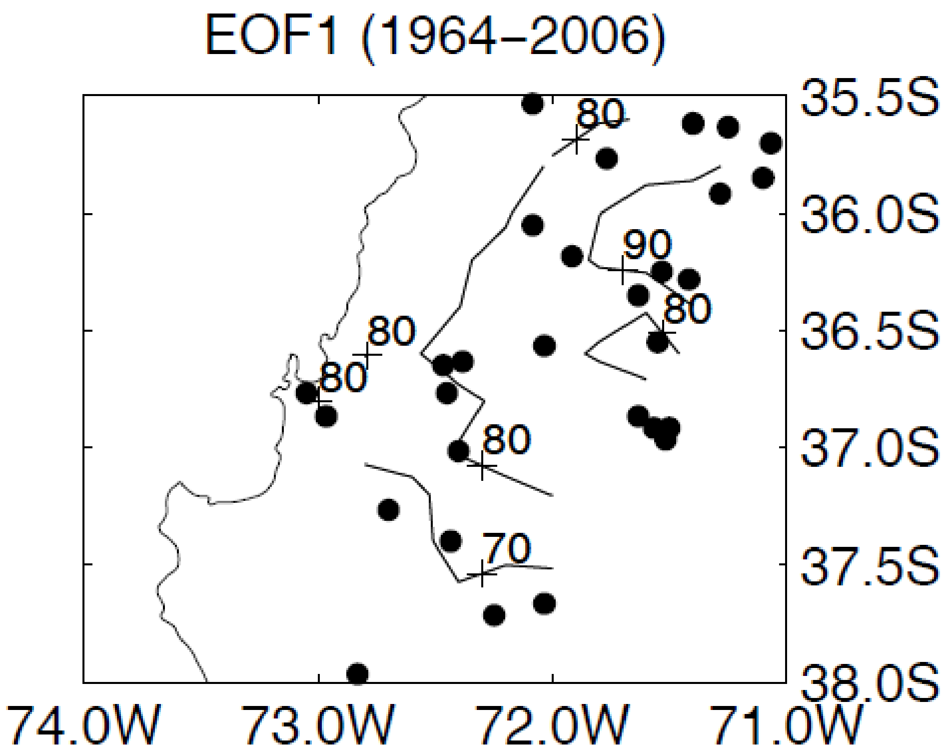


38º-41ºS

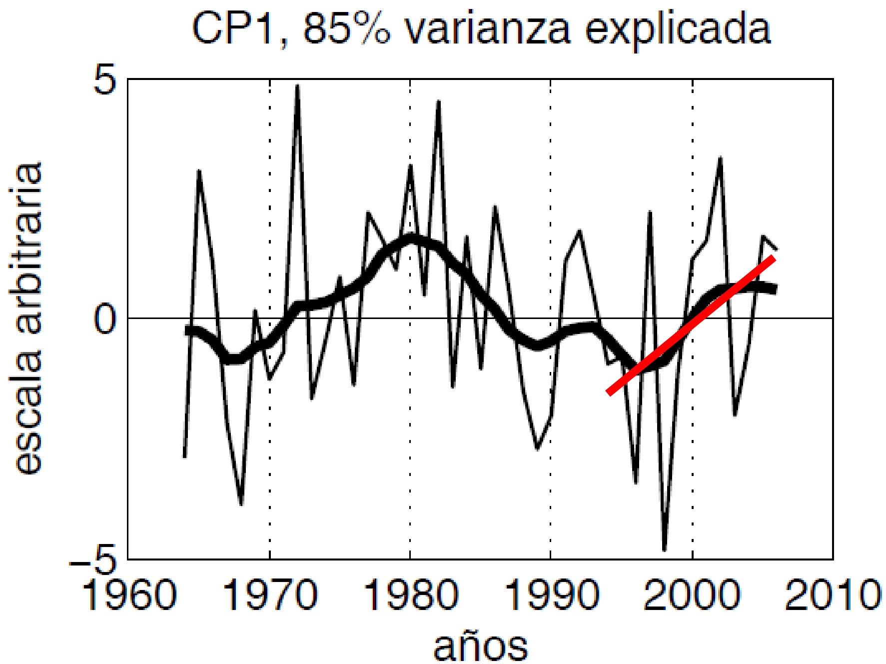


ACT-19 (2009)

Annual rainfall



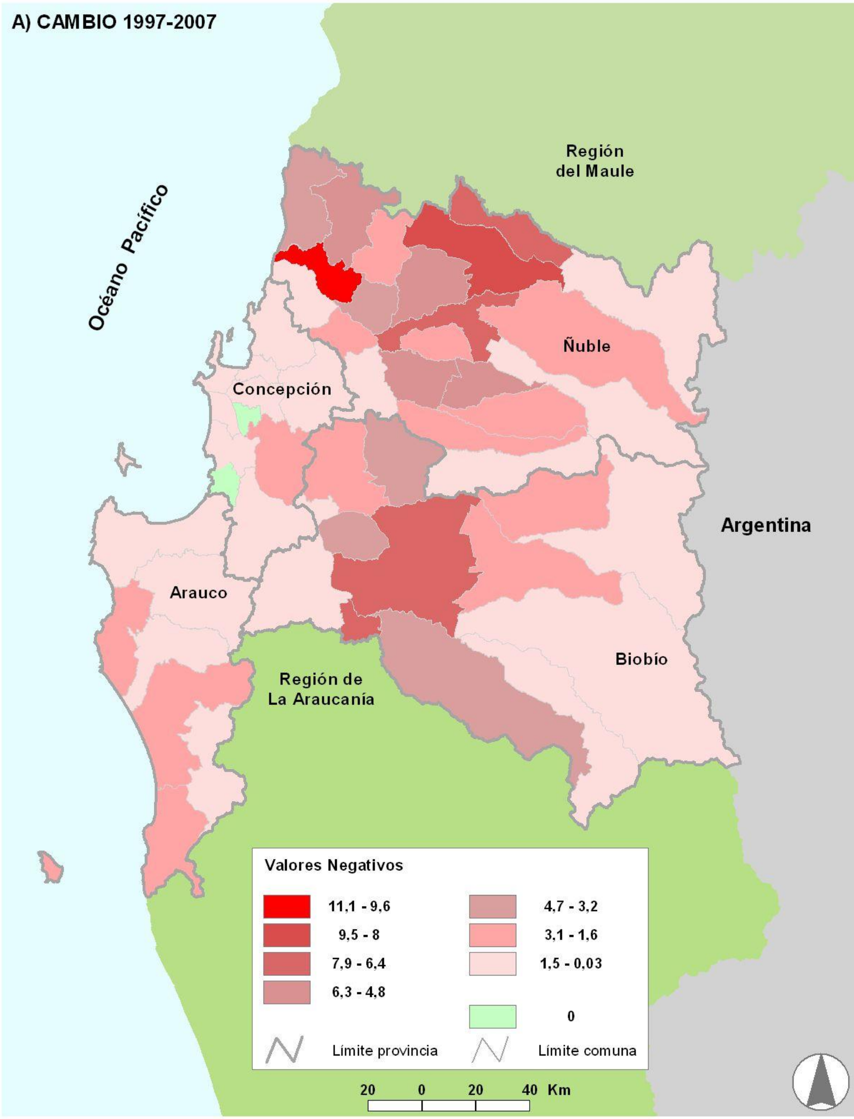
35º-38ºS



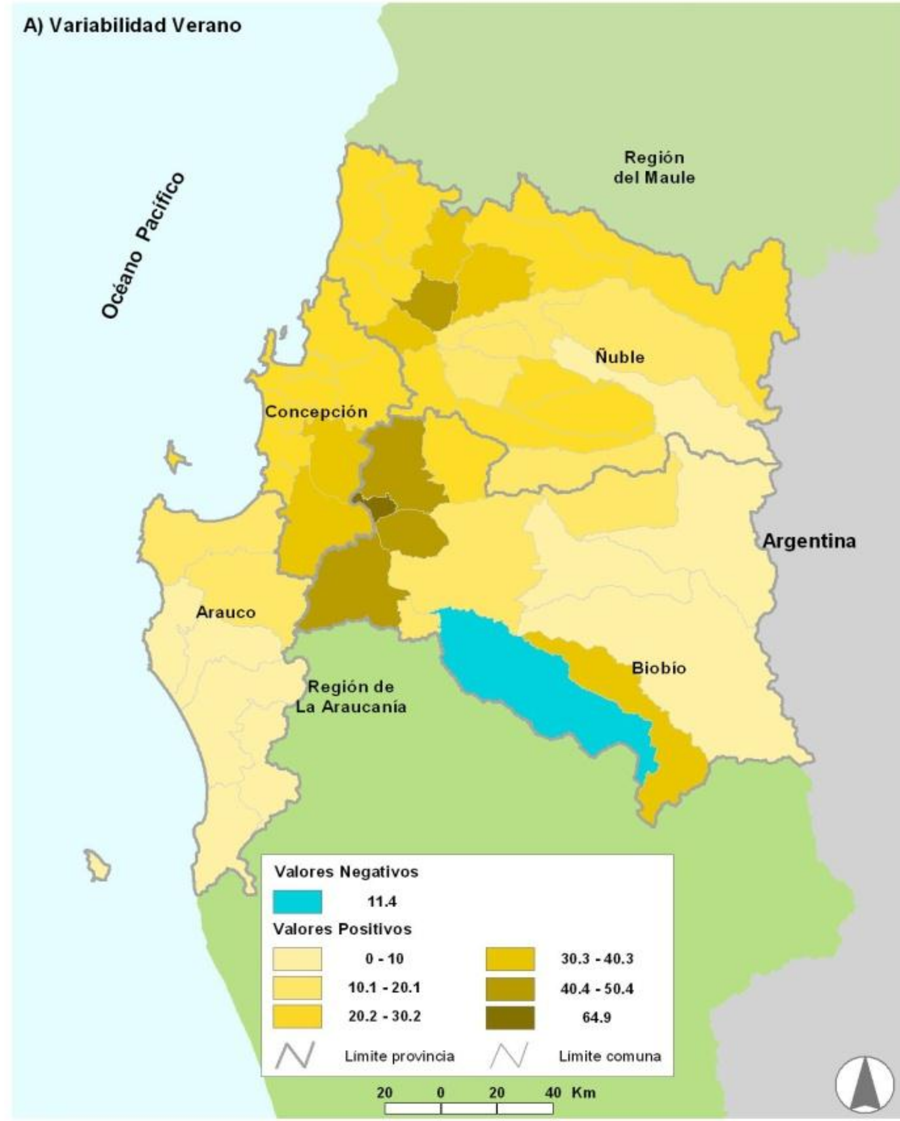
Montecinos (2011), SOC-28

2007-1997, CULTIVATED AREA

Summer (oct-mar) rainfall change



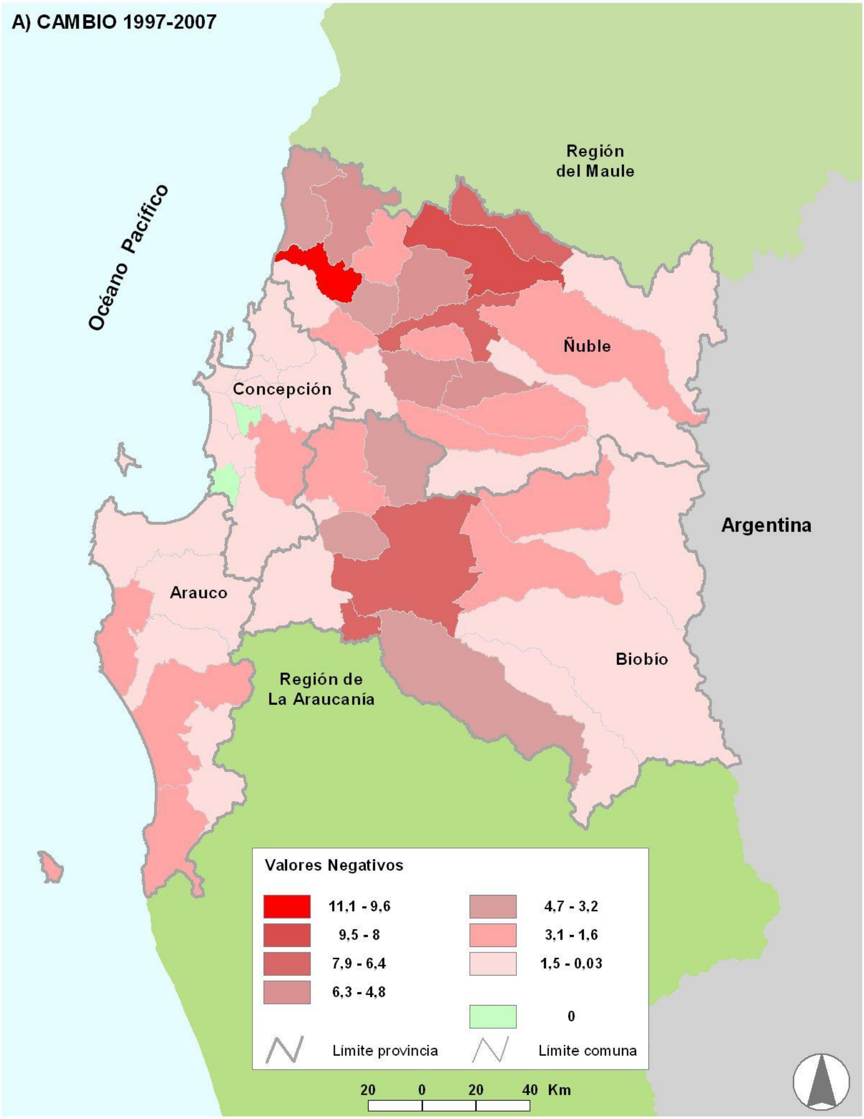
Negative changes



positive changes

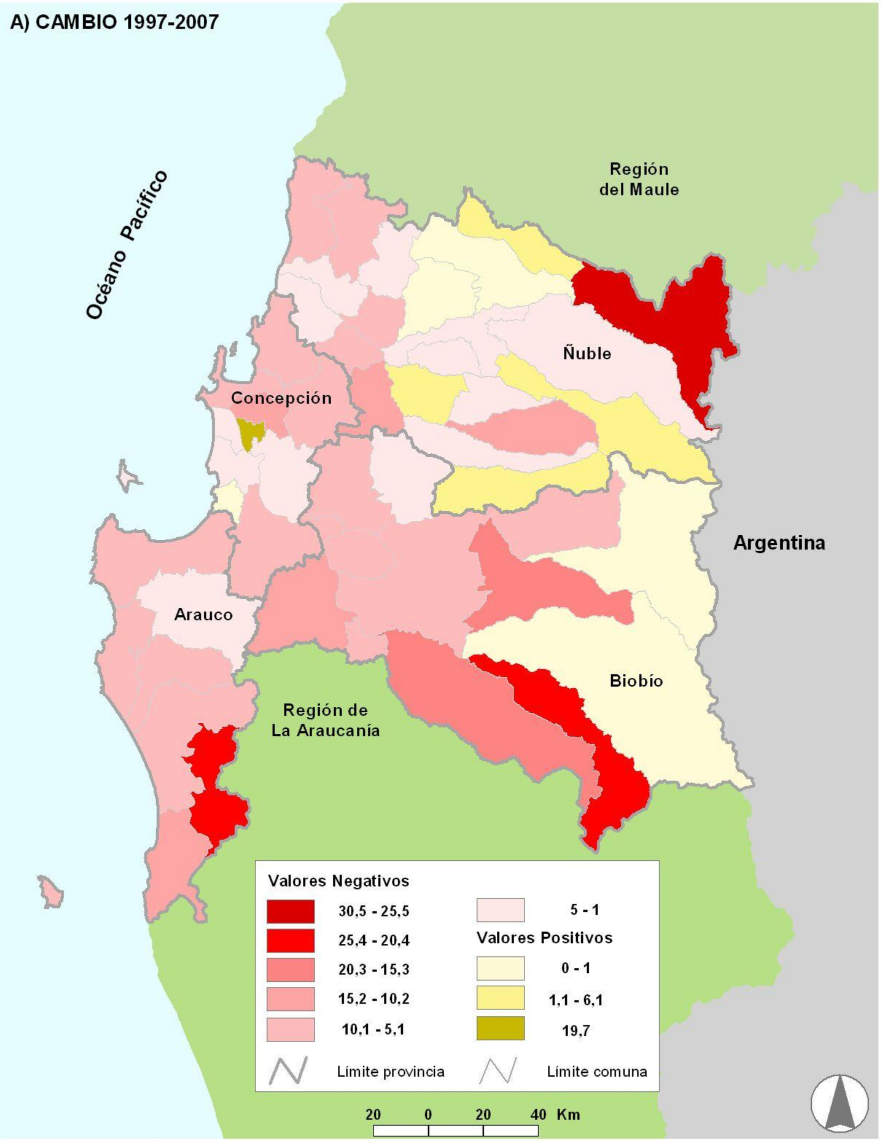
Azocar et al. (2011), SOC-28

2007-1997, CULTIVATED AREA



Negative changes

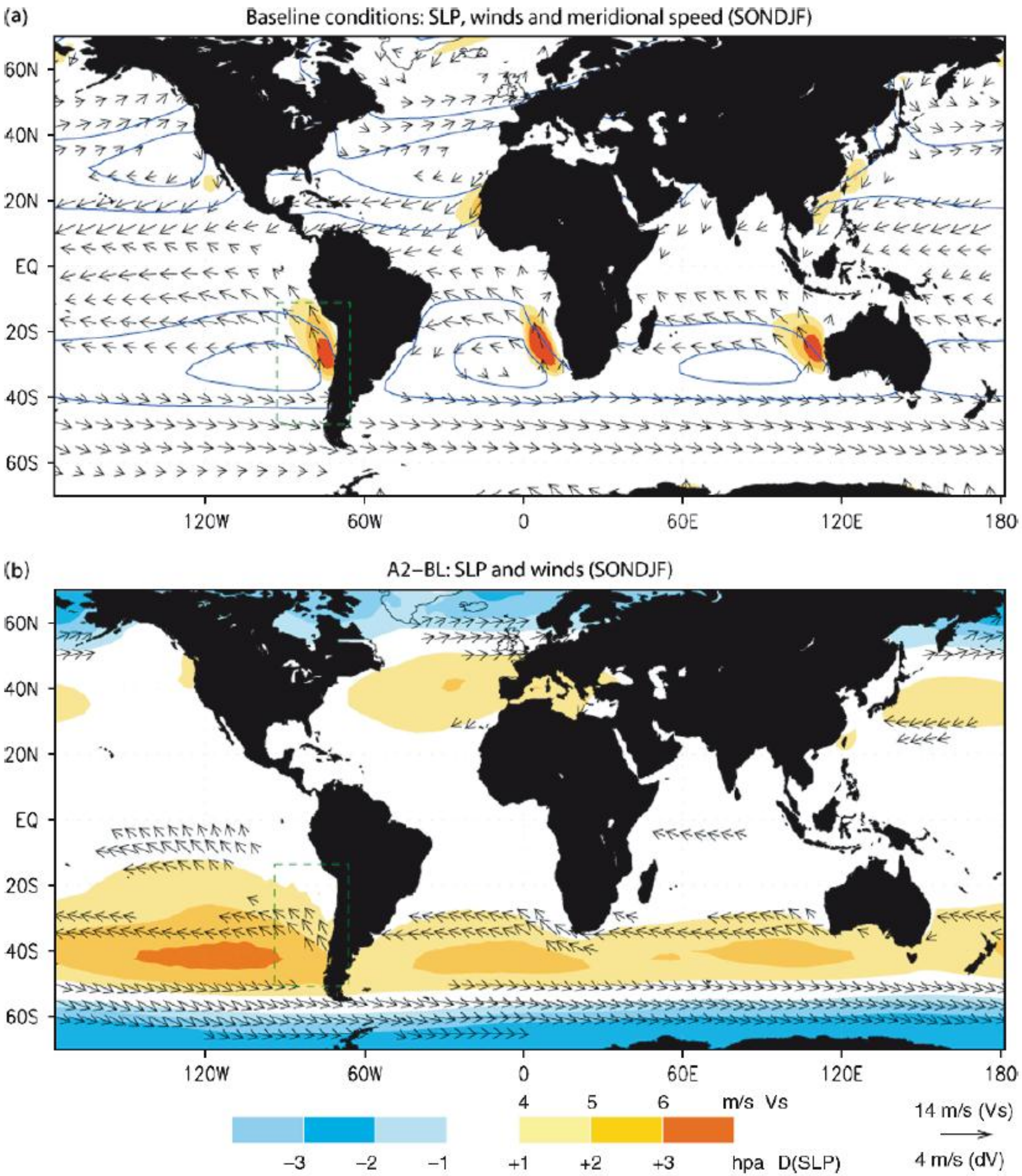
2007-1997, NATURAL FOREST



Negative changes

Azocar et al. (2011), SOC-28

Climate projections



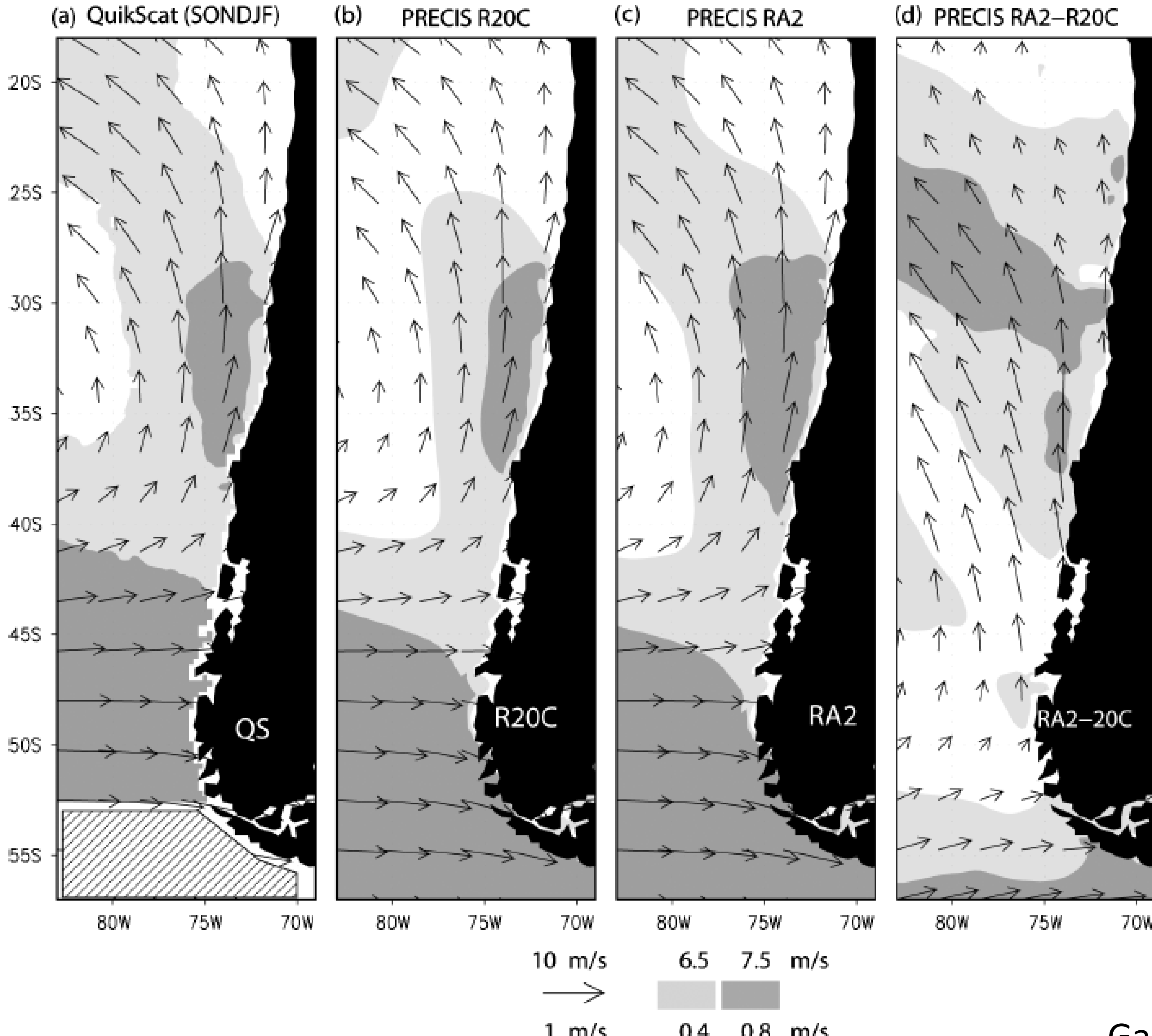
Climatology (CLIM): SLP, winds and meridional speed SPRING-SUMMER

Using IPCC GCMs

2071-2100 - CLIM
A2 scenario

Garreaud y Falvey (2009)

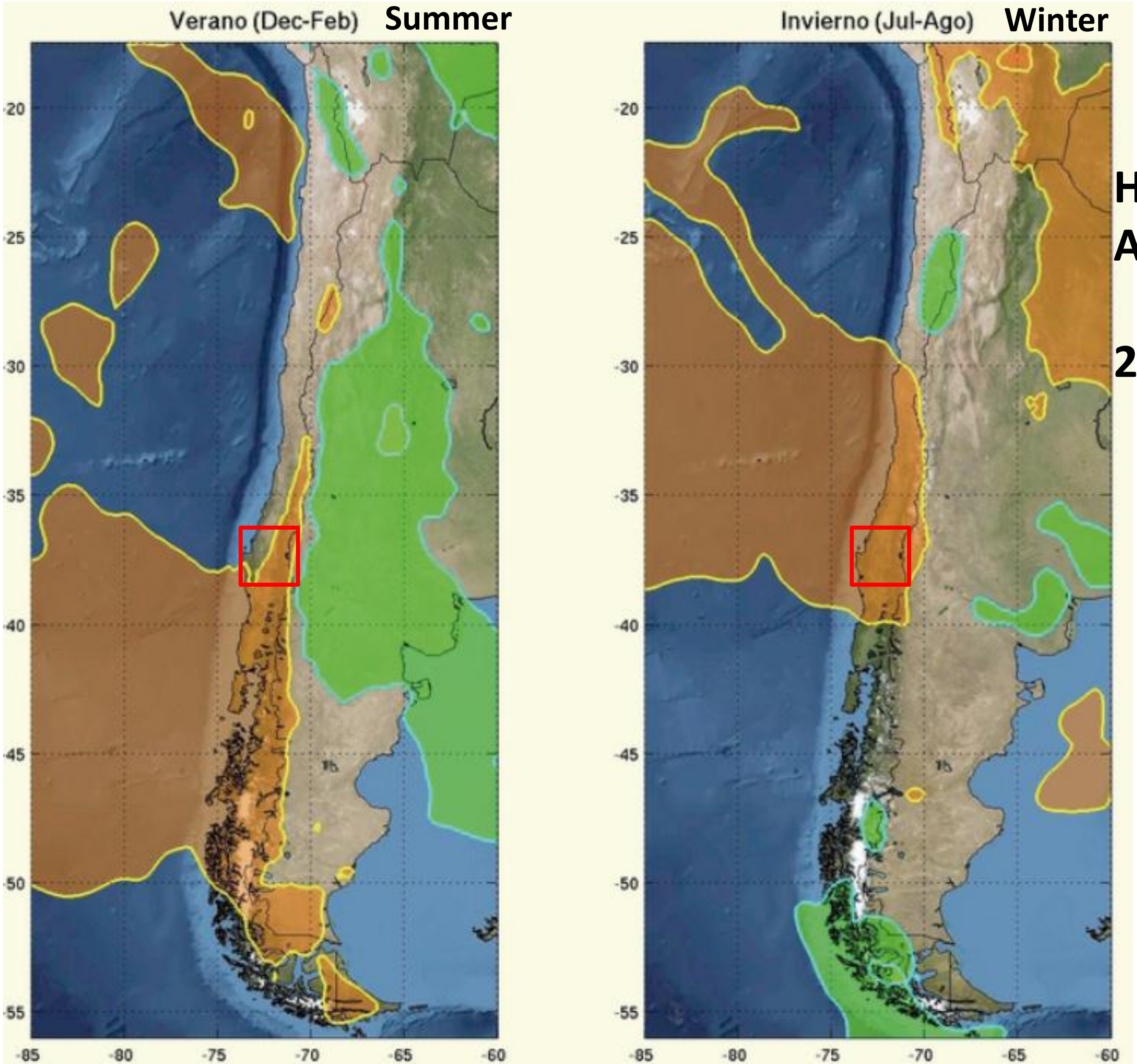
Surface winds



HADCM3-PRECIS
A2 scenario
SPRING-SUMMER

2071-2100

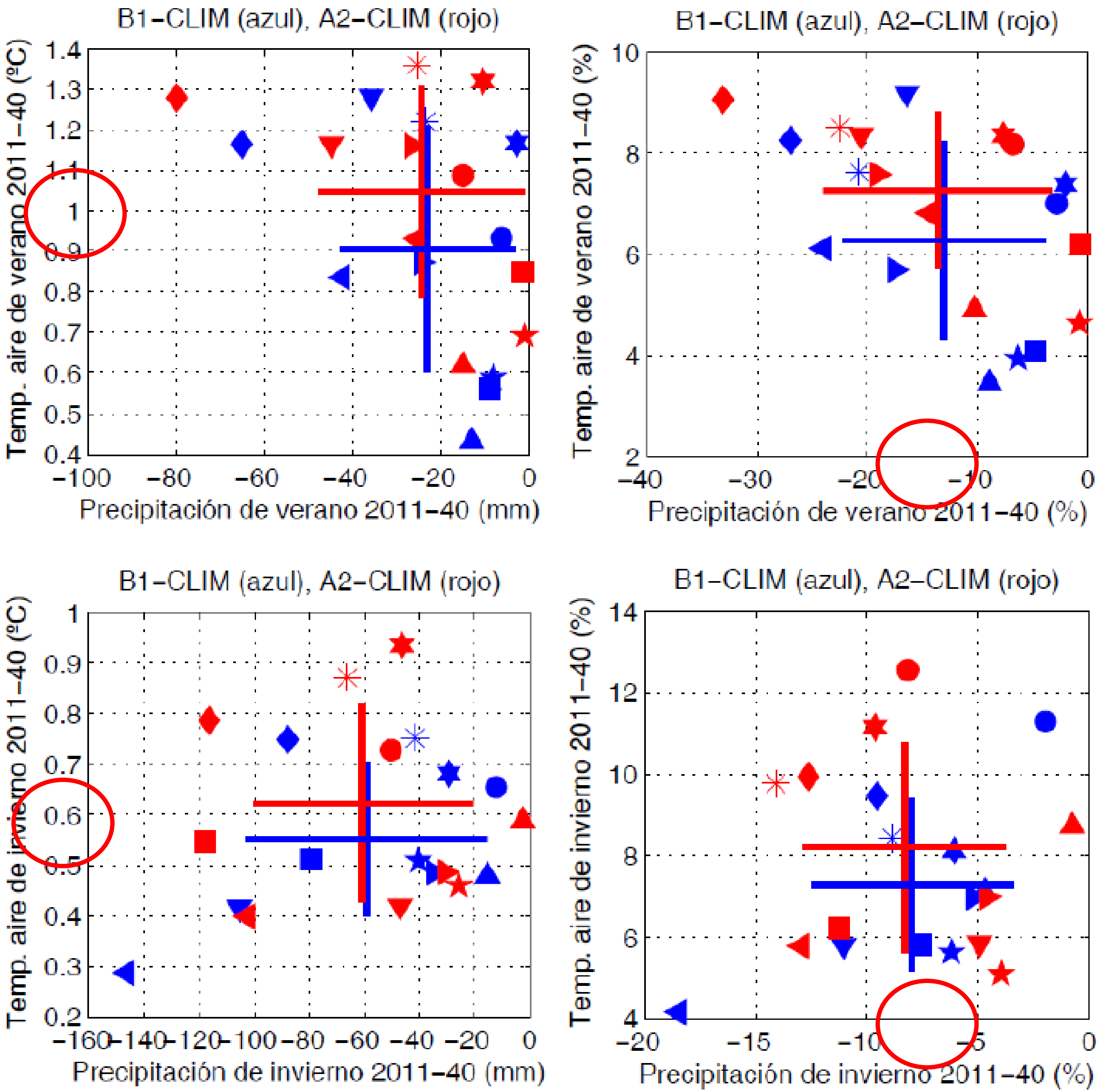
Garreaud y Falvey (2009)



HADCM3-PRECIS A2 SCENARIO

2071-2100

DGF (2007)



OCTOBER-MARCH

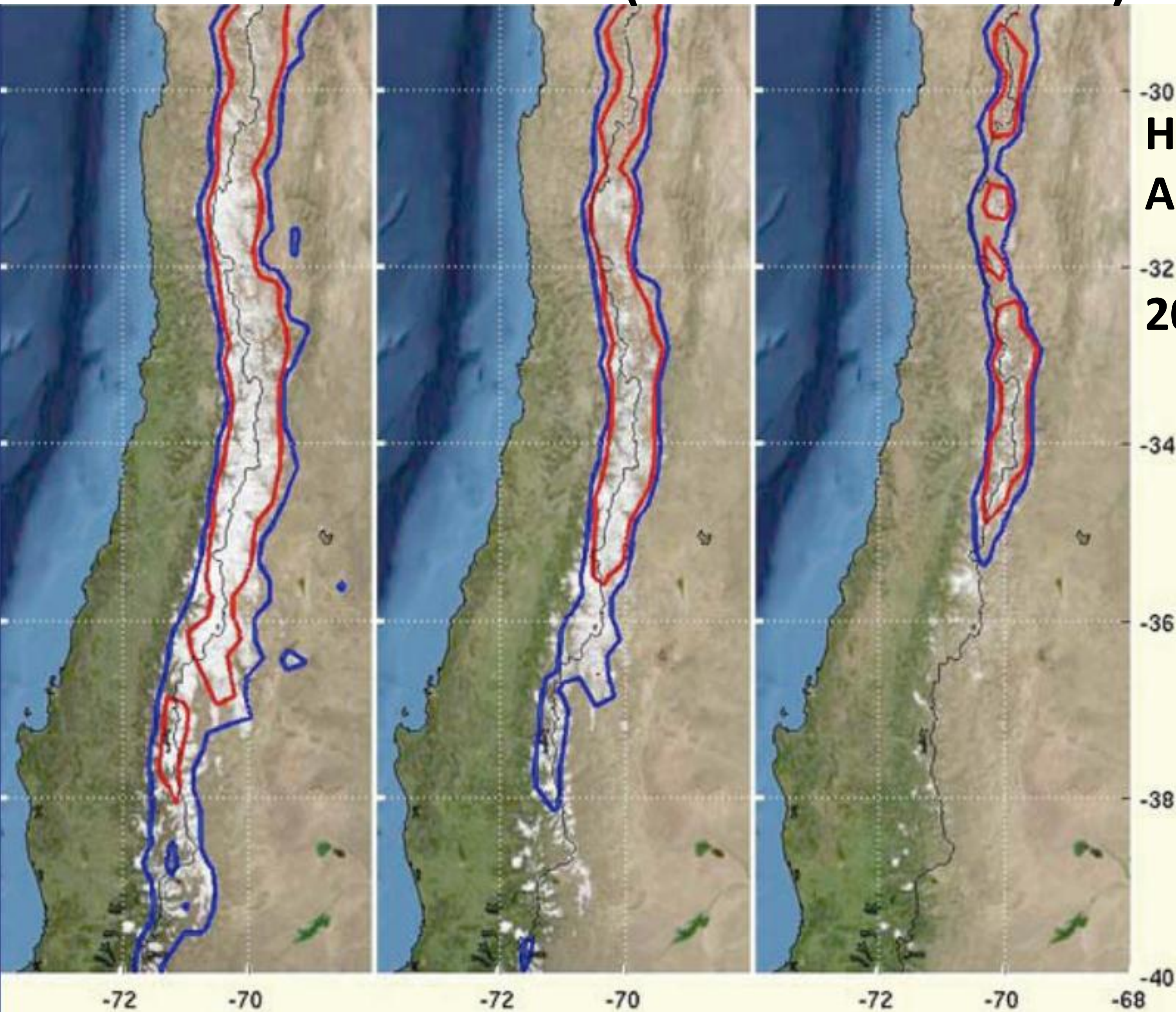
A2 & B1 SCENARIOS

2011-2040

APRIL-SEPTEMBER

Azocar et al. (2011), SOC-28

0ºC ISOTHERM HEIGHT (snow accumulation)



HADCM3-PRECIS
A2 SCENARIO
2071-2100

CLIM
2071-2100

JULY-AUGUST SEPTEMBER-OCTOBER NOVEMBER-DECEMBER

DGF (2007)

Conclusions

Conclusions

- **Strong observed interannual-to-interdecadal variability, superimposed to a weak (?) long-term trend.**

- **The negative SST trend during the last 30 years is not simulated by models.**

- **The most consistent observed long-term trends and projections are related to the increase of sea level pressure along mid-latidudes (AAO positive phase and/or La Niña-like condition): negative rainfall trend and positive alongshore winds in central Chile.**

- **The mid-tropospheric temperature positive trend would impact water availability.**