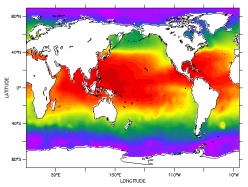




Climate Variability and Climate Change in the Arid Americas

Training Institute on Adaptive Management of Water Resources under Climate Change in Vulnerable River Basins

Dr. Francisco Meza

Objectives

- Review main features of the Climate in the Arid Americas
- Concept of Climate Variability
- Large scale factors that control climate in the region
  - ENSO
  - PDO
- Climate Change in the Arid Americas

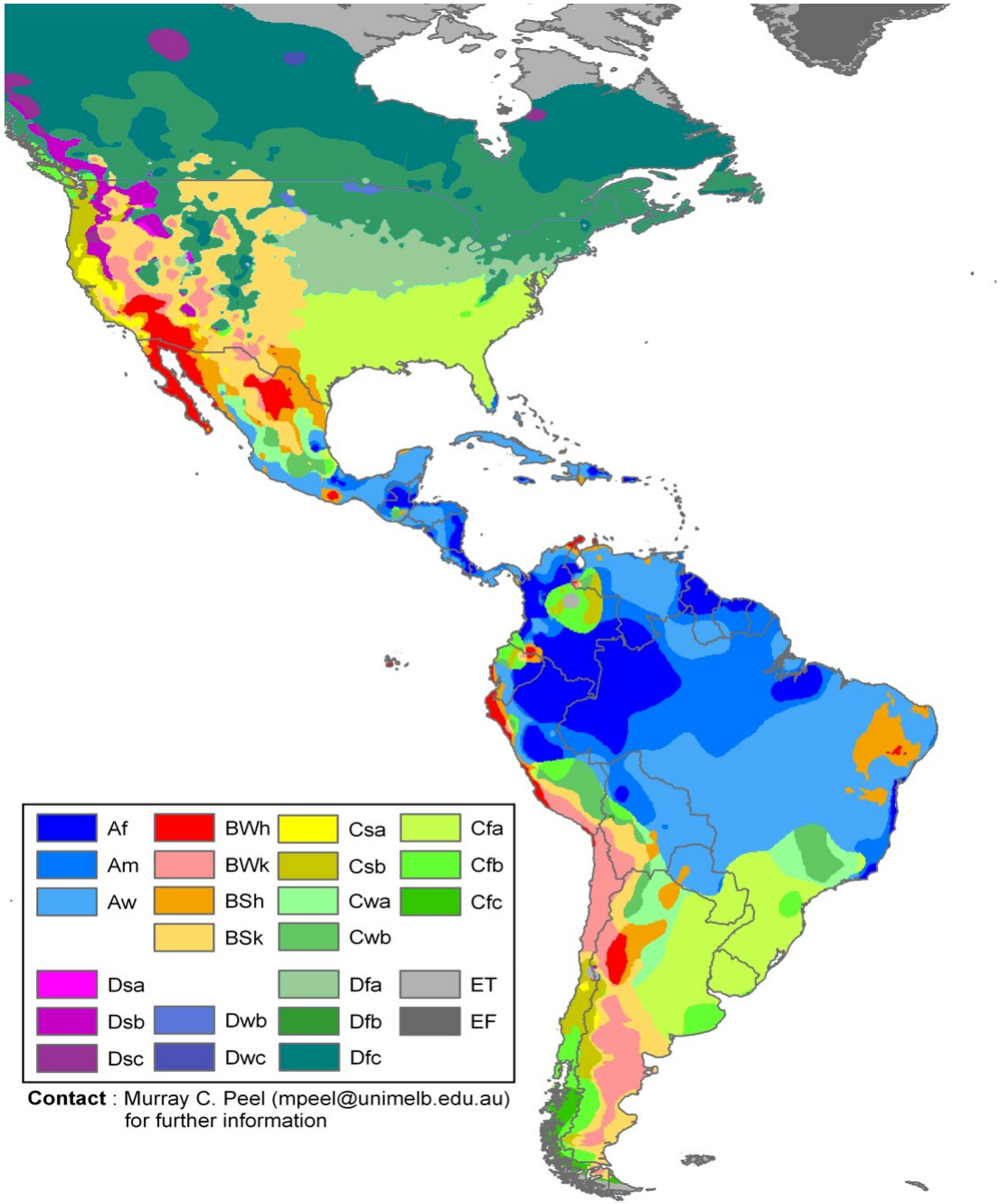
Readings

- Garreaud, R., M. Vuille, R. Compagnucci and J. Marengo, 2008: Present-day South American Climate. PALAEO3 Special Issue (LOTRED South America), 281, 180-195
- McDonald, G. 2010. Water, climate change, and sustainability in the southwest. PNAS.
- Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.
- Magrin, G., C. Gay García, D. Cruz Choque, J.C. Giménez, A.R. Moreno, G.J. Nagy, C. Nobre and A. Villamizar, 2007: Latin America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 581-615.

Challenges in the Arid Americas

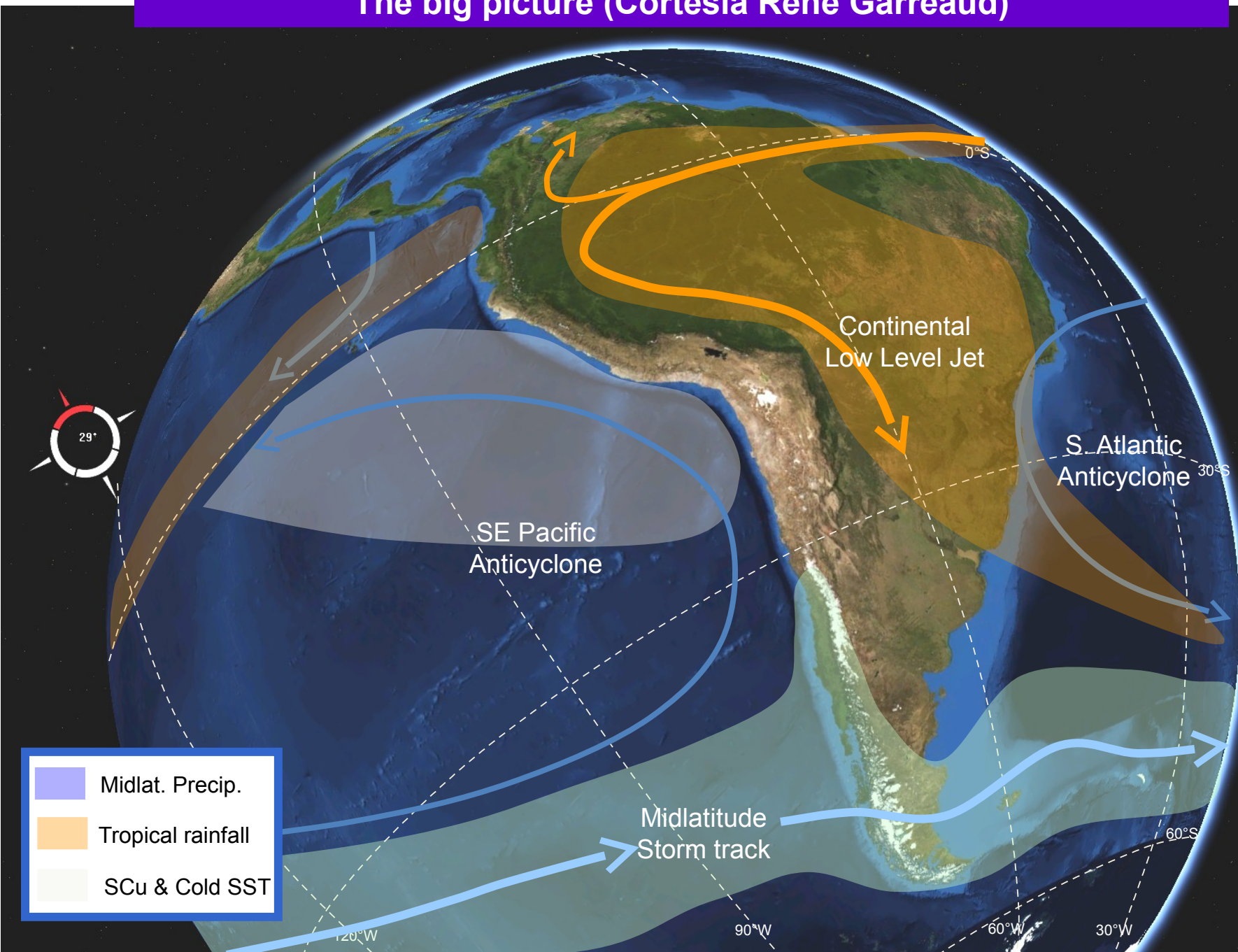
- Water scarcity
  - hydroclimatological
  - human use
- Energy insecurity
- Adaptation
  - science & policy
  - networks
- Governance
  - intersectoral
  - transboundary
  - cross-regional

Scott et al . Accepted

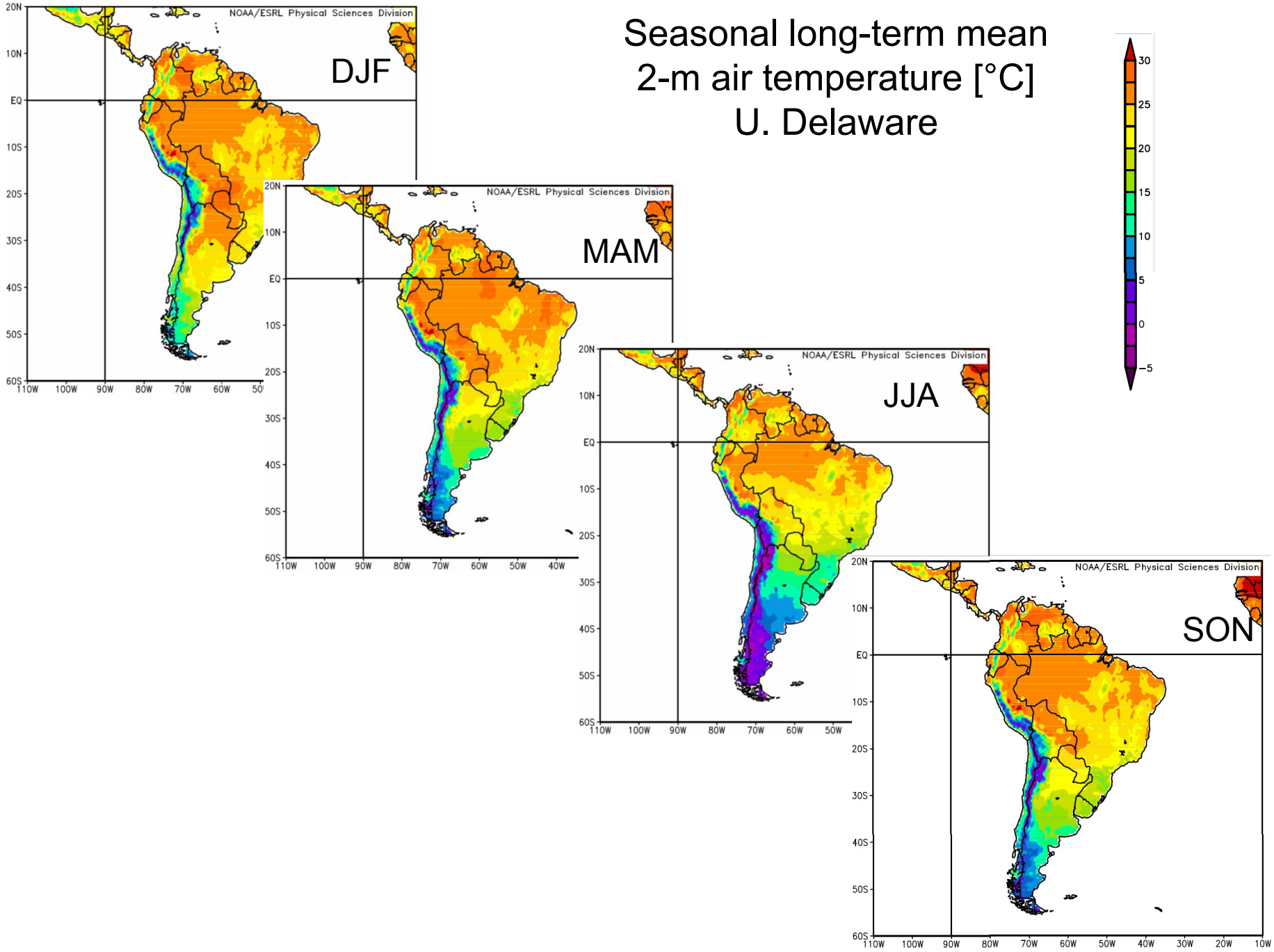


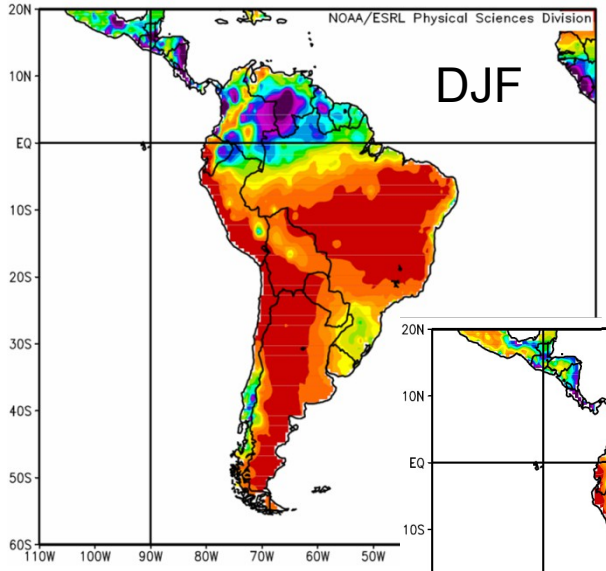
Contact : Murray C. Peel (mpeel@unimelb.edu.au)
for further information

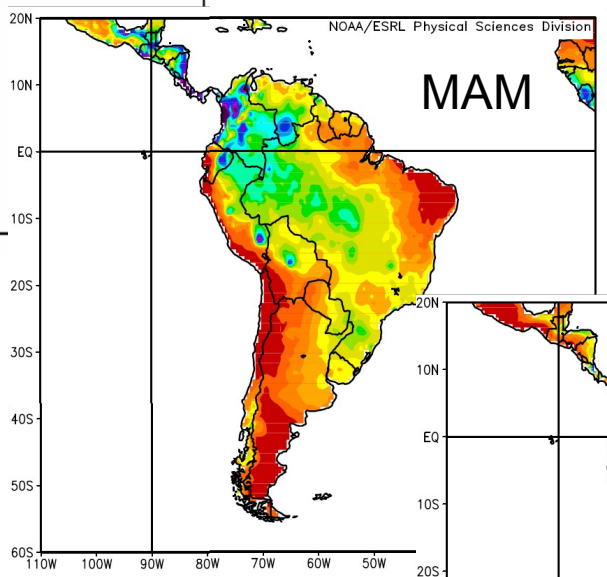
The big picture (Cortesía René Garreaud)

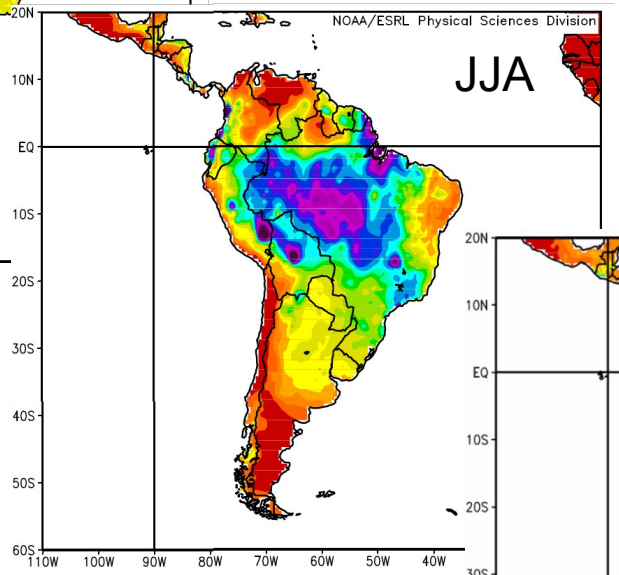


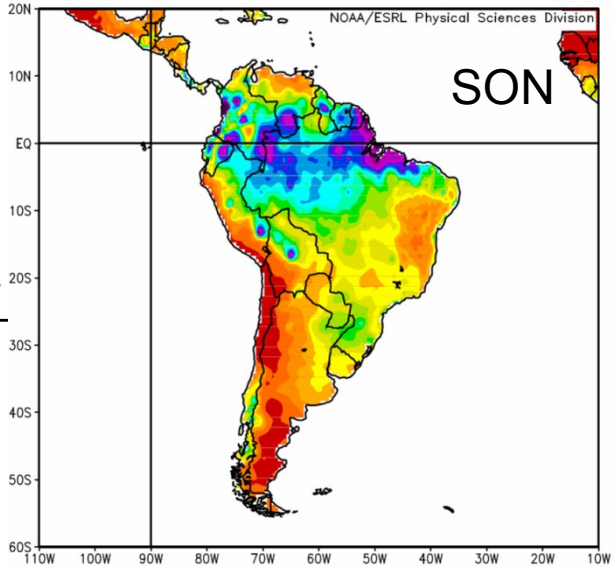
Seasonal long-term mean 2-m air temperature [°C] U. Delaware



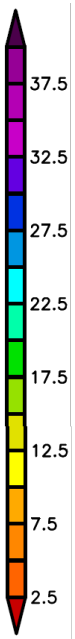




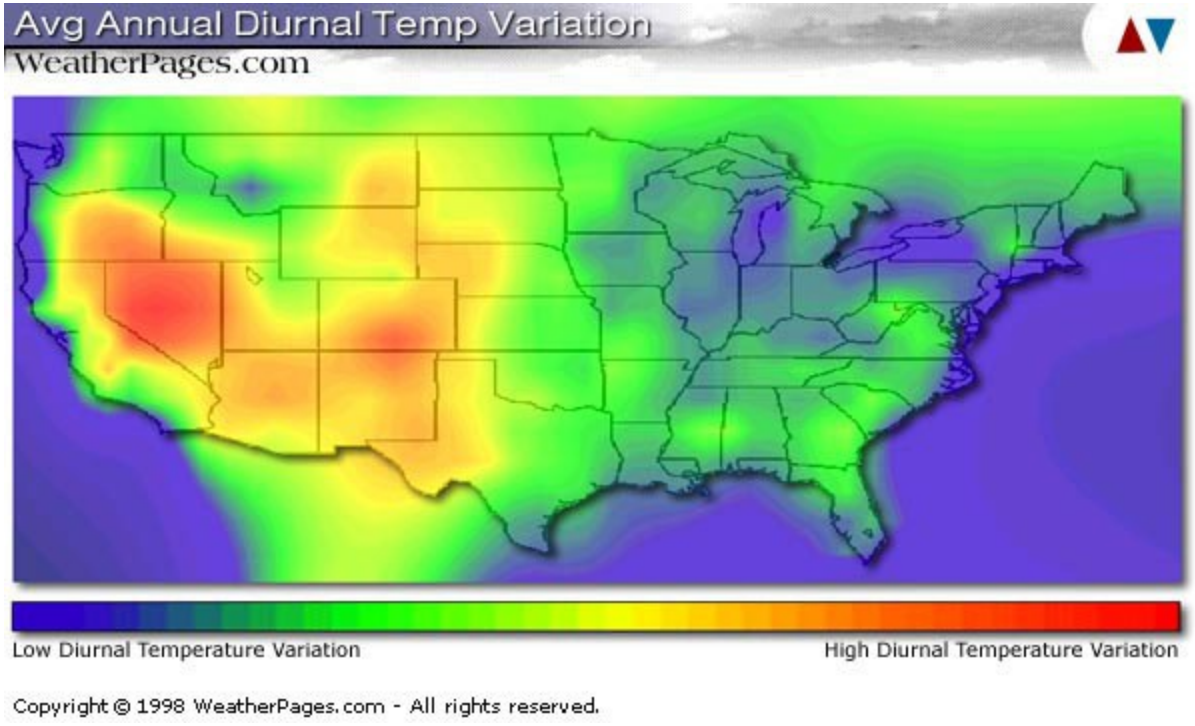




Seasonal long-term mean
Precipitation [mm/day]
U. Delaware



Diurnal Temp Variation (Southwest)



Precipitation (Southwest)

- Precipitation in the Southwest has two distinct seasons.
  - Summer thunderstorms characteristic of the monsoon season
  - Winter precipitation often involves large-scale frontal systems.
  - Where northern cold fronts and southern warm fronts meet, the jet stream flows as a current of swift-moving air high in the atmosphere.


PACIFIC OCEAN
L
Gulf of California
Moist air
Gulf of Mexico
Moist air


SPOTTY PM
WEDNESDAY
HUMID AIR
©2011 WWW.ACCUWEATHER.COM

Examples of Interannual Precipitation Variability

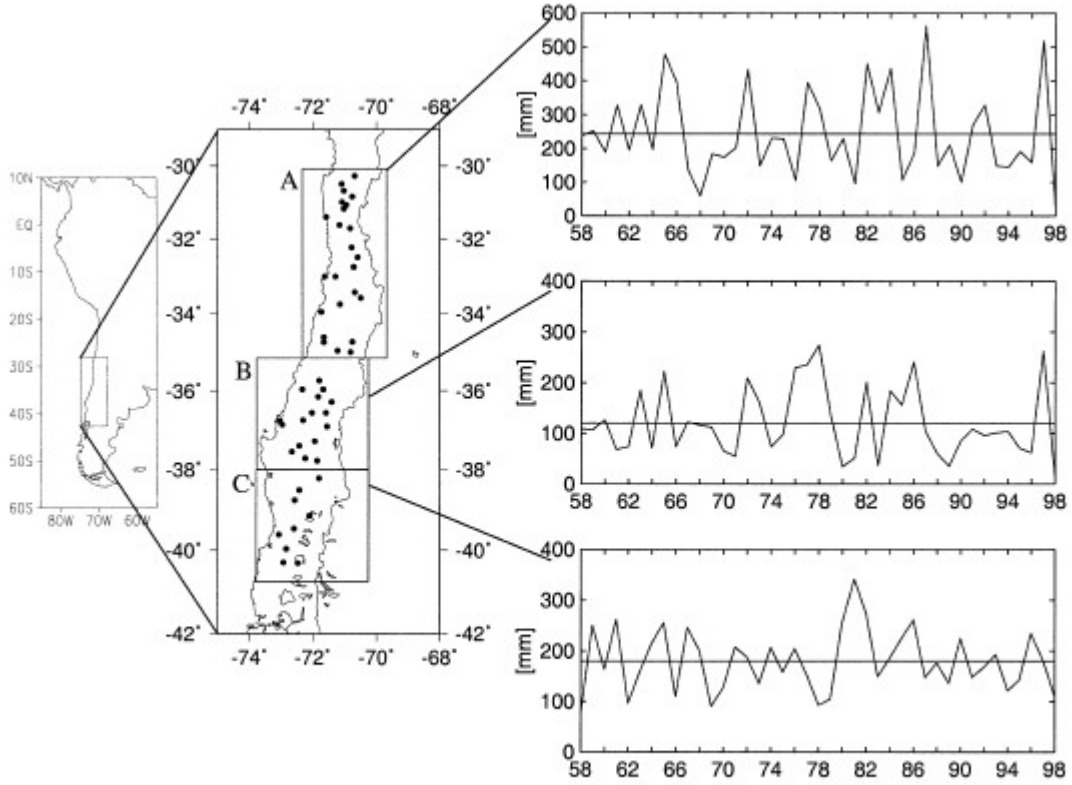
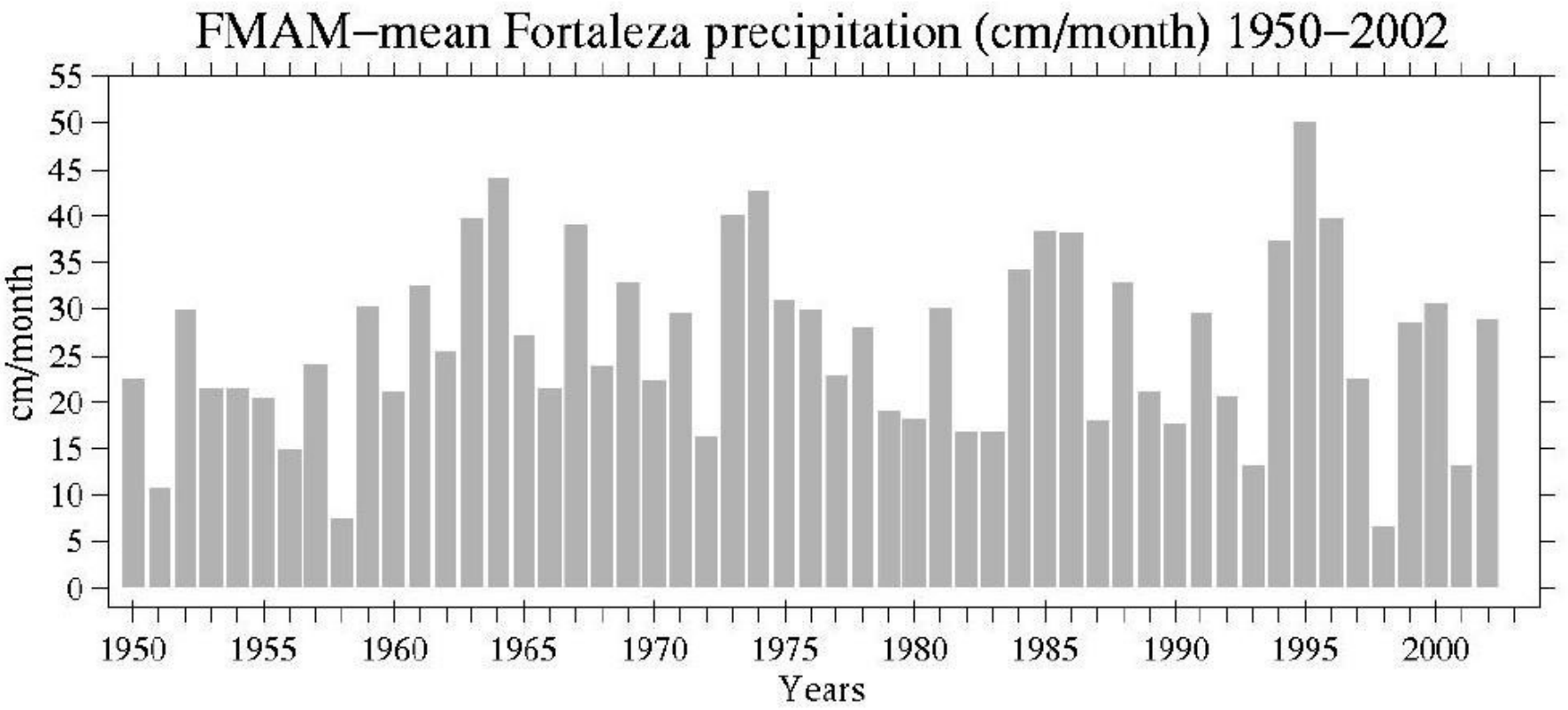


FIG. 1. Seasonal rainfall indices for central Chile (30°–41°S): (top) winter (JJA) in region A (30°–35°S), (middle) late spring (ON) in region B (35°–38°S), and (bottom) summer (JFM) in region C (38°–41°S). Spatial distribution of rainfall stations in each region is indicated.

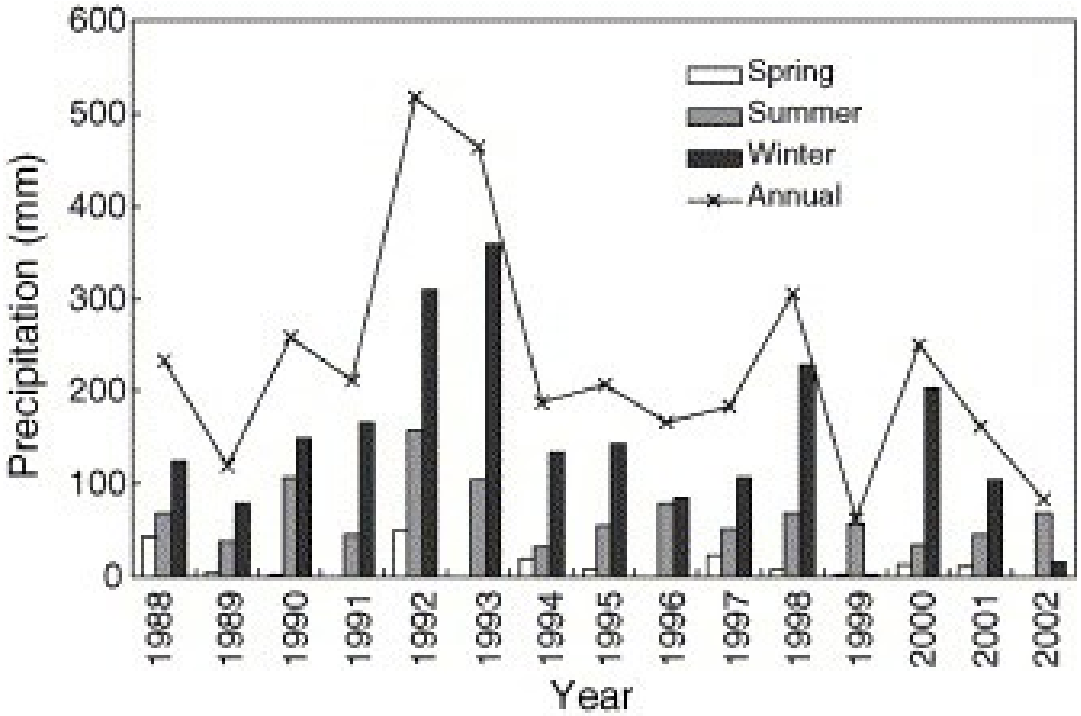
Aceituno and Montecinos 1993

Examples of Interannual Precipitation Variability



Data from University of Washington

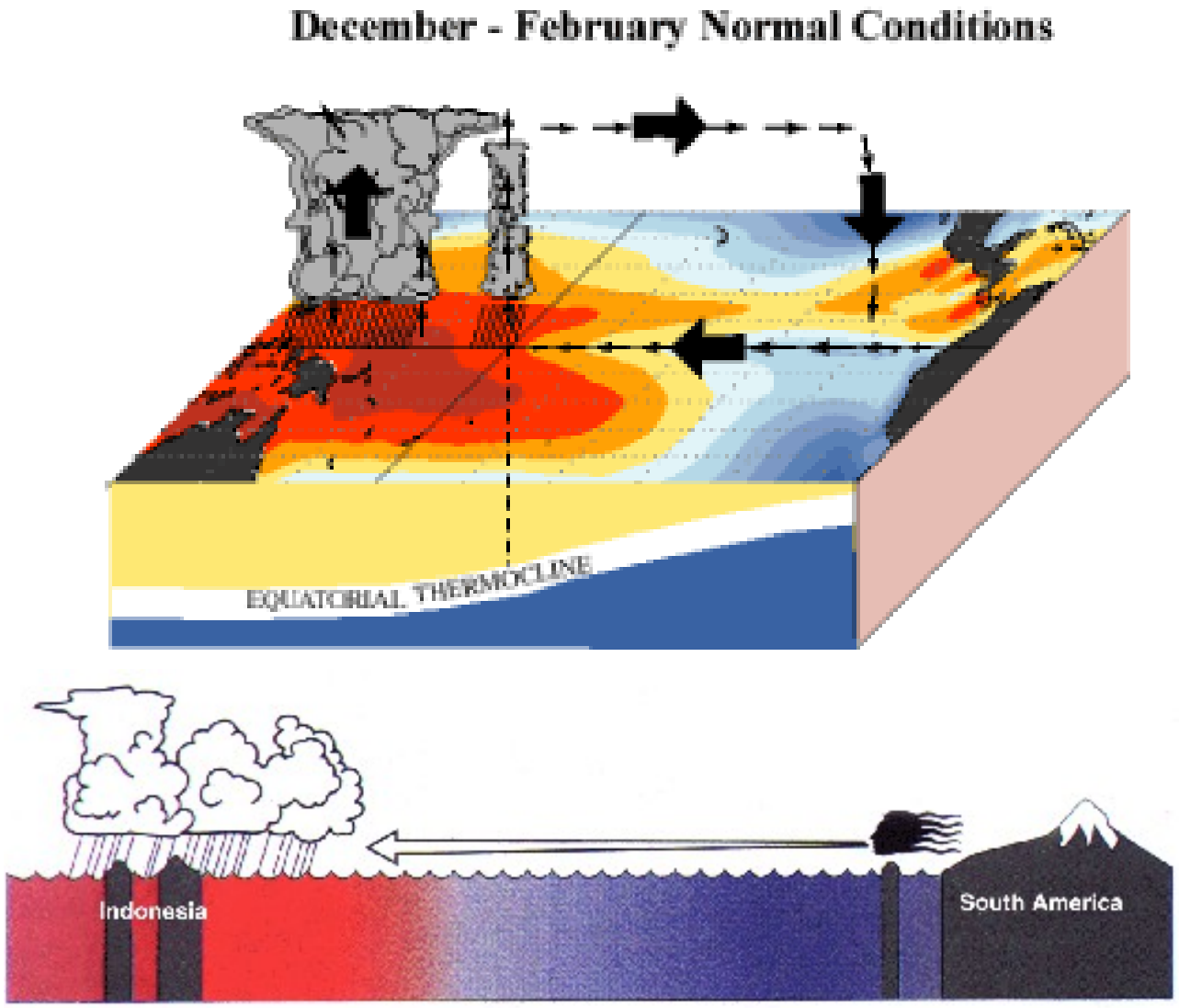
Examples of Interannual Precipitation Variability



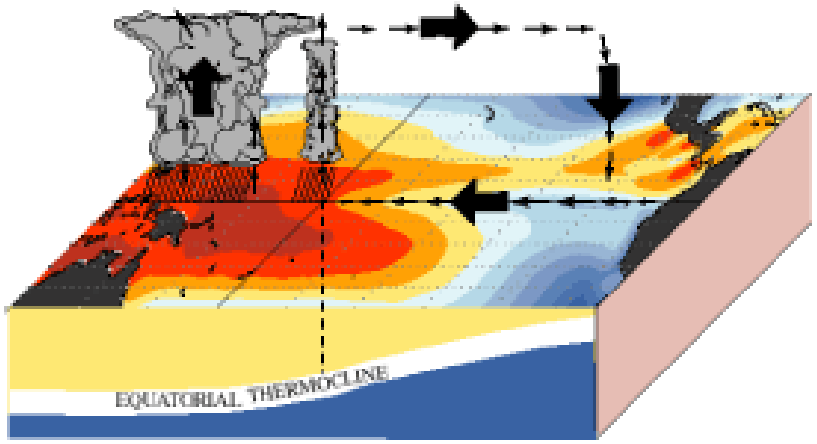
Seasonal distribution and amount of rainfall in the 15 years from 1988 to 2002 in the Sonoran Desert of Northwestern Phoenix. The three seasons are defined as: spring (April 1–June 31), summer (June 30–September 30), and winter (October 1–March 31). Shen et al,, 2005

ENSO BASICS

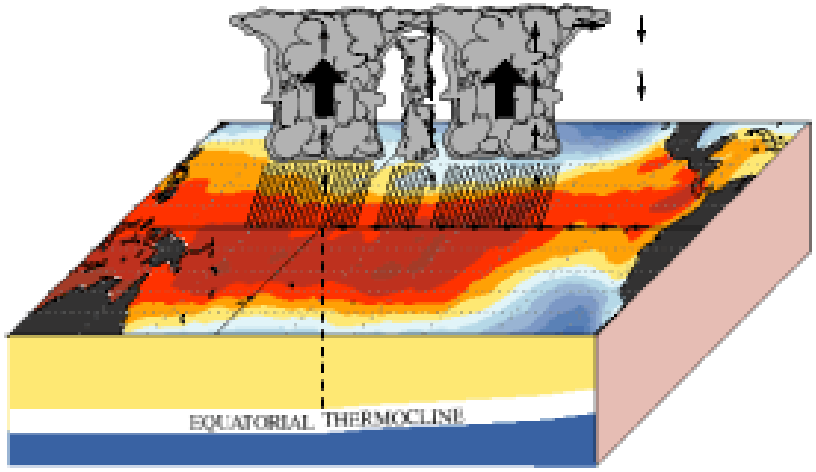
http://iri.columbia.edu/climate/ENSO/background/basics.html



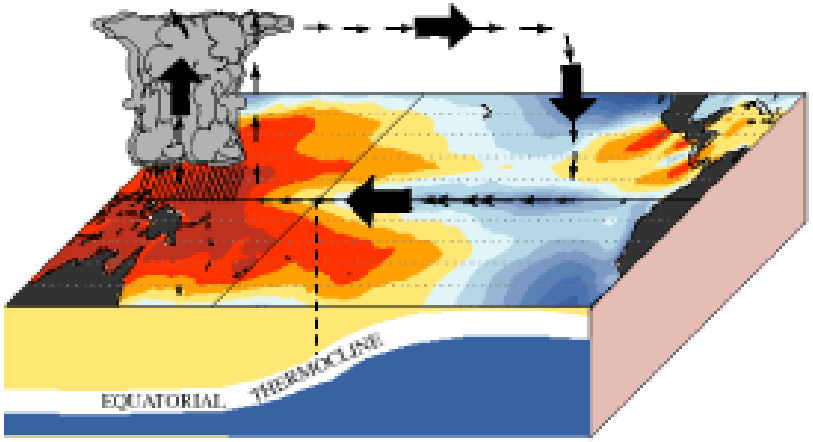
December - February Normal Conditions



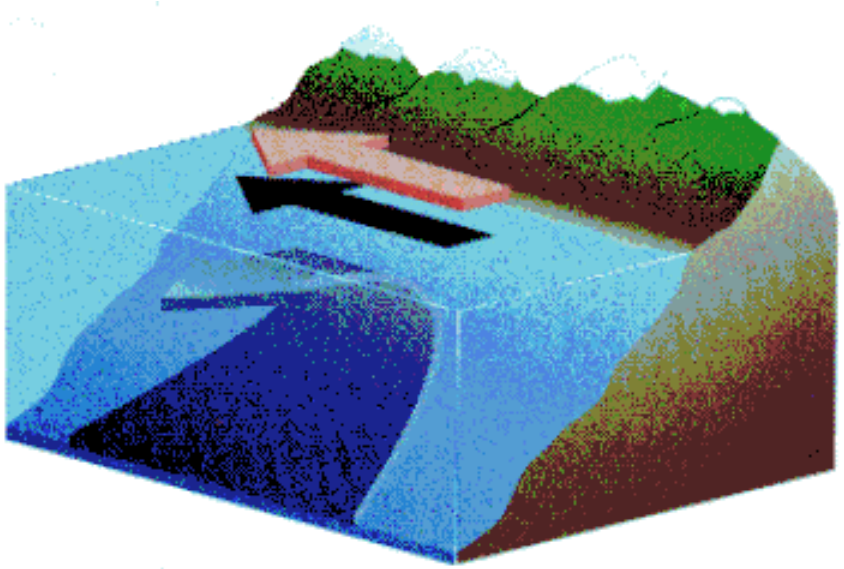
December - February El Niño Conditions



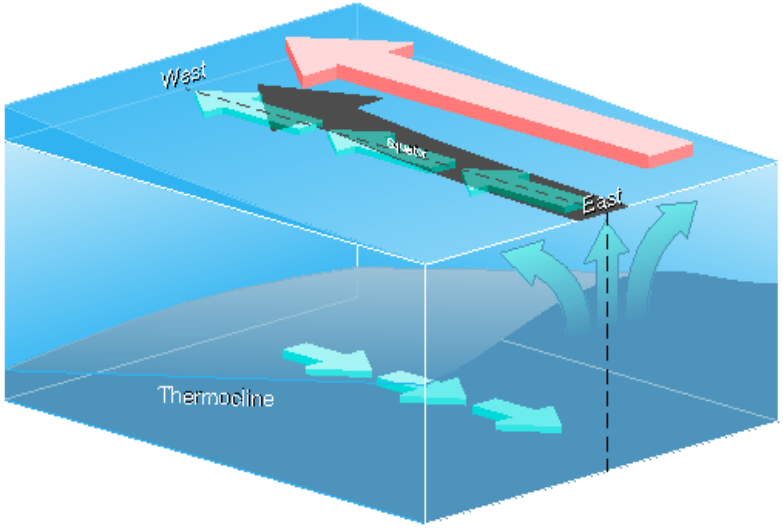
December - February La Niña Conditions



Surgencia: Afloramiento de aguas profundas (frías, ricas en O2 y nutrientes) por efecto del viento

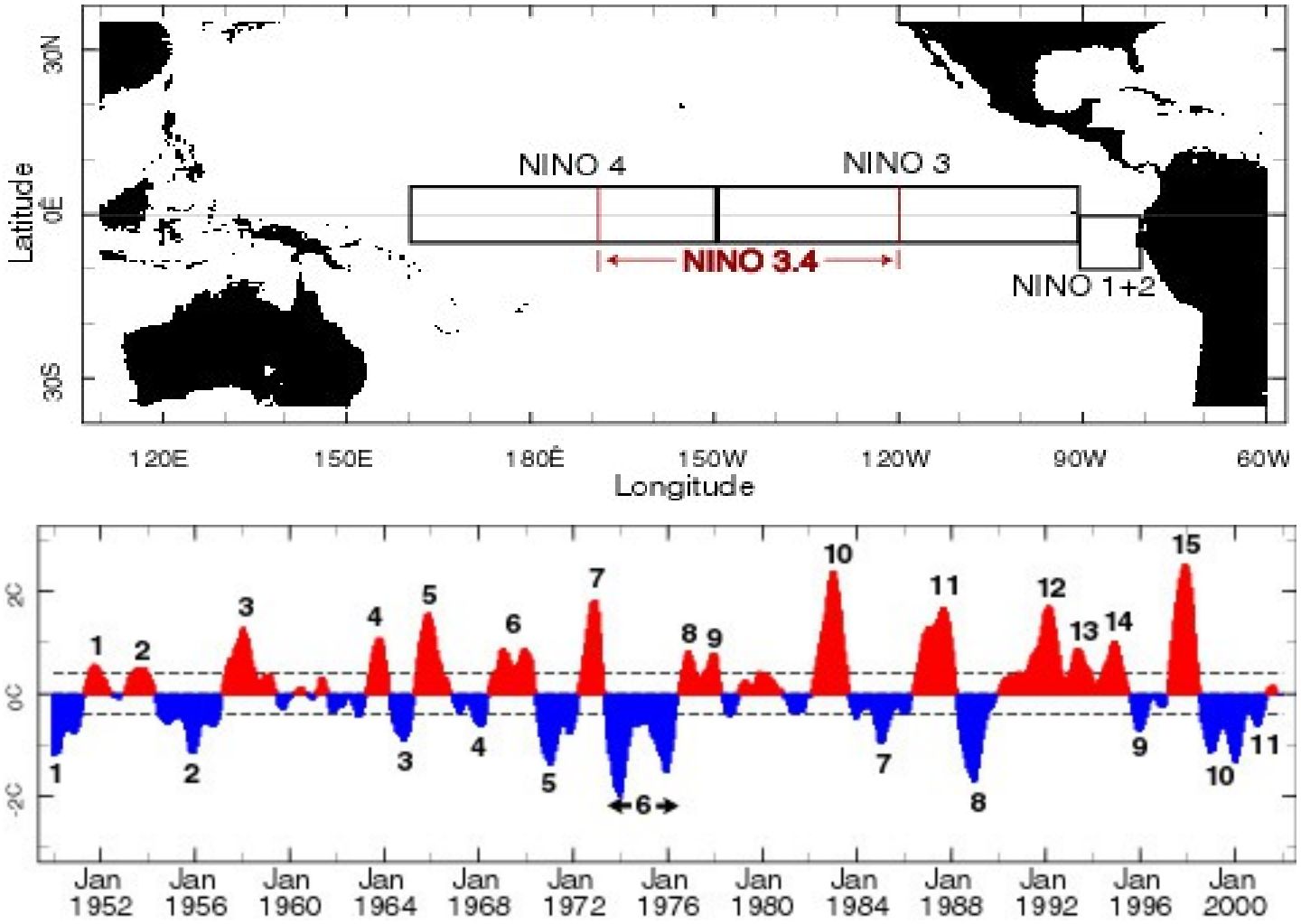


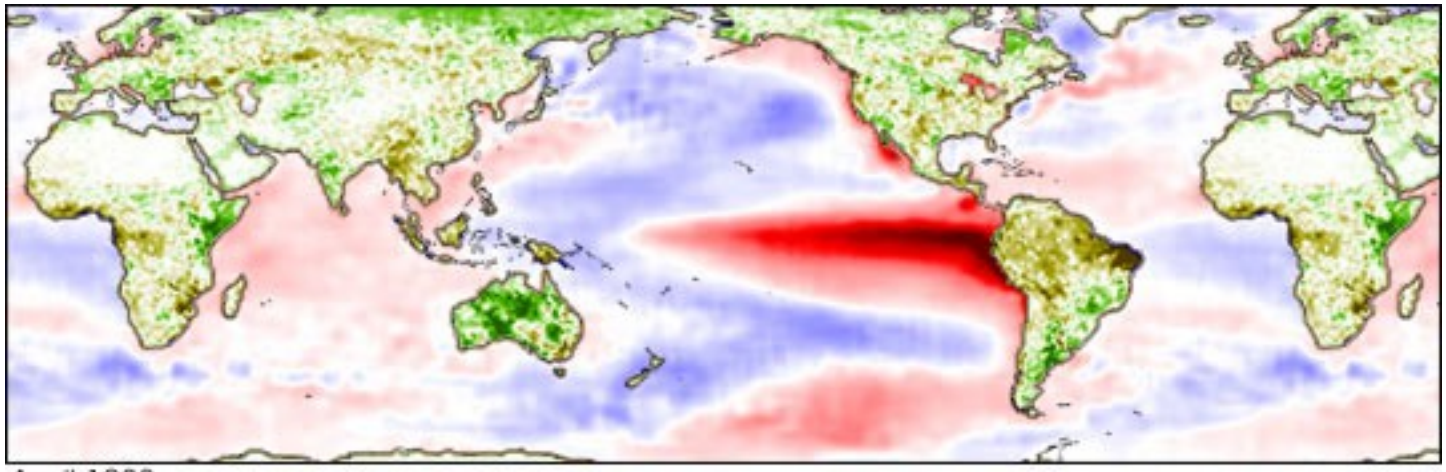
Surgencia costera



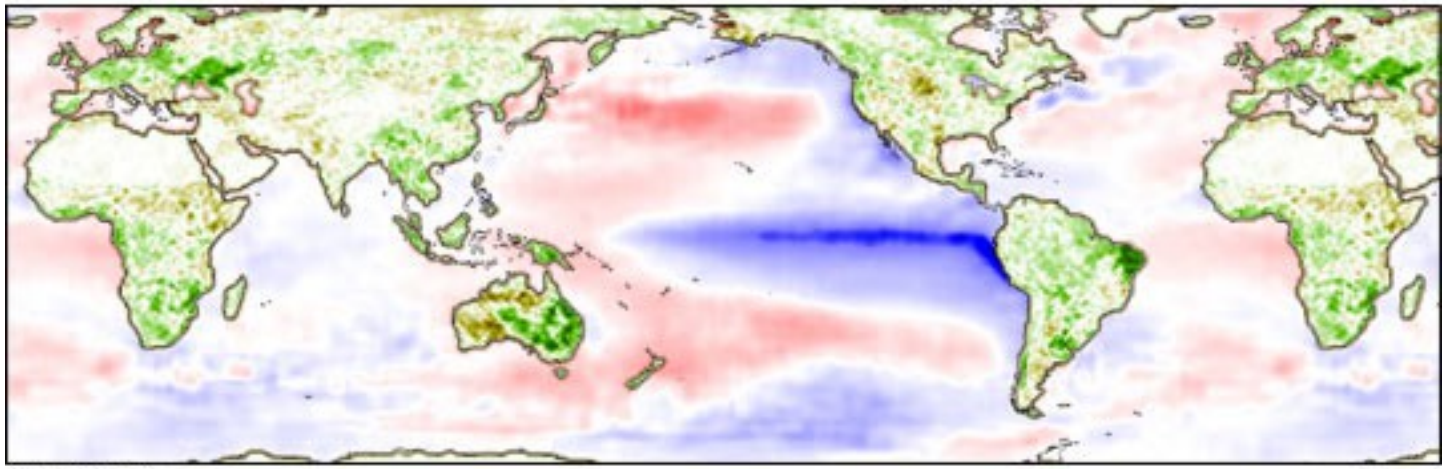
Surgencia ecuatorial

Periodicidad: 3-7 años, duración: 1-2 años, Amplitud ~1-2°C





April 1983



April 1989

SST Anomaly (°C)

-2.5 0 2.5

Vegetation Index Anomaly

-0.05 0 0.05

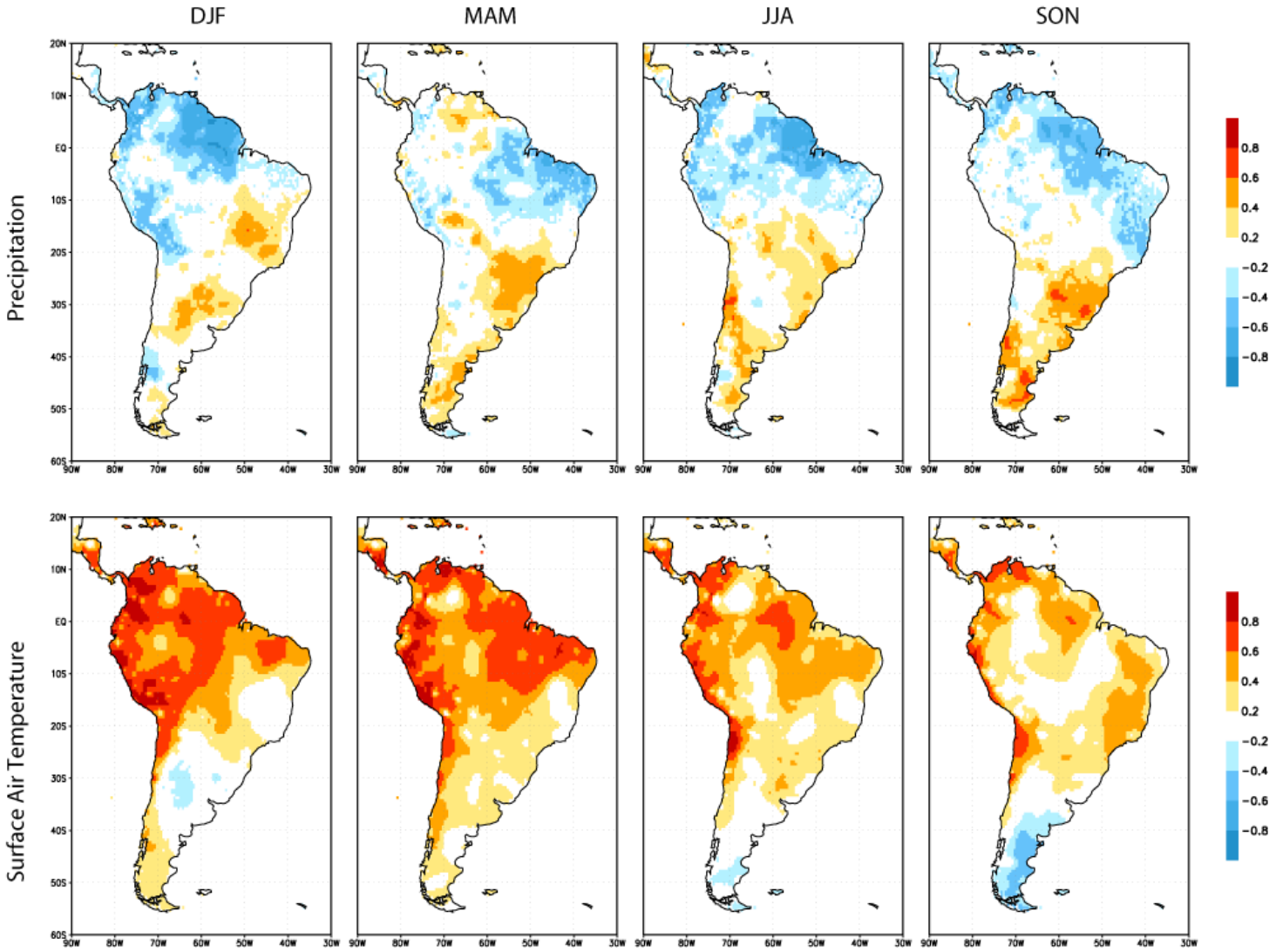
FENOMENO EL NIÑO

- Disminuye la presión frente a la costa de Ecuador, Perú y norte de Chile, y aumenta en el Pacífico occidental (fase negativa de la OS)
- Los vientos alisios se debilitan por menor gradiente de presión.
- Se debilita la surgencia a lo largo del Pacífico ecuatorial, como resultado del debilitamiento de los alisios
- Aumenta la temperatura superficial del mar debido a la menor surgencia. La zona de ascenso de la celda de Walker se mueve hacia el Este.
- Aumenta el nivel del mar en la costa de América del Sur, y disminuye en Oceanía.
- El contraste térmico E-W disminuye a lo largo del Pacífico ecuatorial
- Lo anterior favorece un reforzamiento de las anomalías de presión y de los efectos asociados.
- El fenómeno persiste ! !

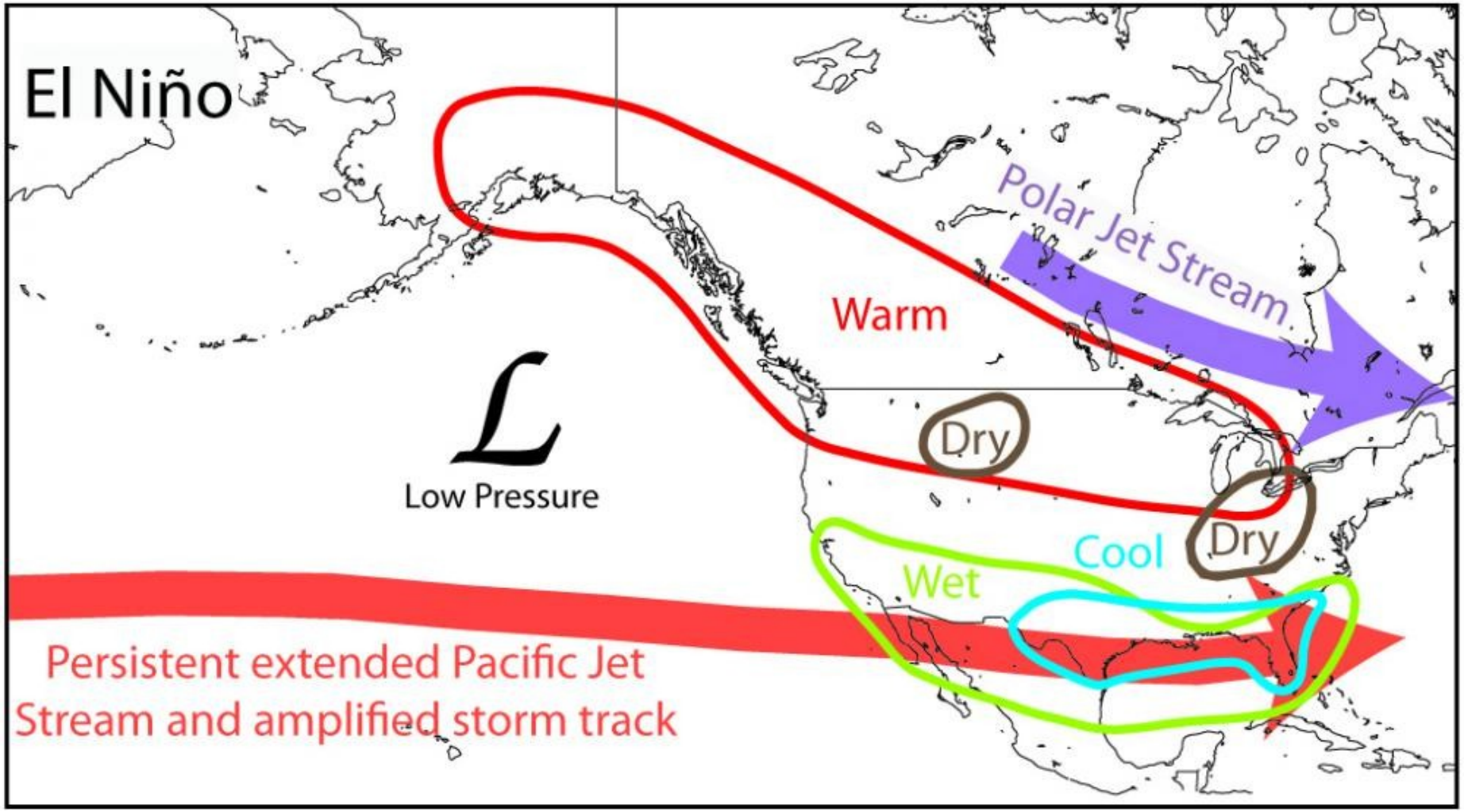
FENOMENO LA NIÑA

- Aumenta la presión frente a la costa de Ecuador, Perú y norte de Chile, y disminuye en el Pacífico occidental (fase positiva de la OS)
- Los vientos alisios se intensifican por el mayor gradiente de presión.
- Se fortalece la surgencia a lo largo del Pacífico ecuatorial, como resultado de la intensificación de los alisios.
- Disminuye la temperatura superficial del mar debido a la menor surgencia. La zona de ascenso de la celda de Walker se mueve hacia el Oeste.
- Disminuye el nivel del mar en la costa de América del Sur, y aumenta en Oceanía.
- El contraste térmico E-W aumenta a lo largo del Pacífico ecuatorial
- Lo anterior favorece un reforzamiento de las anomalías de presión y de los efectos asociados.
- El fenómeno persiste ! !

Seasonal correlation between Precip/SAT and Multivariate ENSO Index (50 years of data)

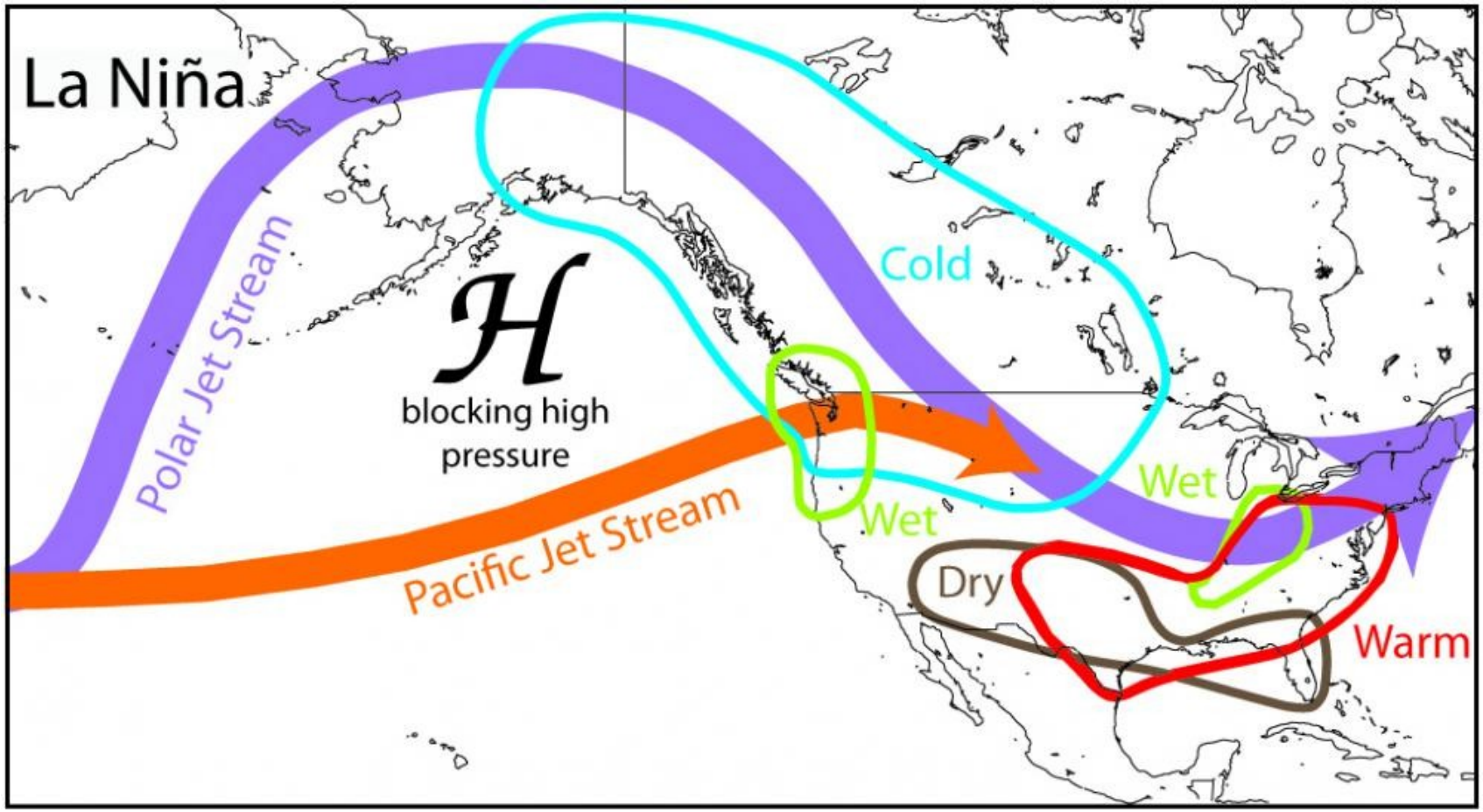


http://www.climas.arizona.edu/sw-climate/enso



El Niño events cause the winter path of the jet streams to move over Southwest, usually delivering more winter rain and snow in the region.

http://www.climas.arizona.edu/sw-climate/enso



The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño-like pattern of Pacific climate variability. While the two climate oscillations have similar spatial climate fingerprints, they have very different behavior in time. Causes for the PDO are not currently known.

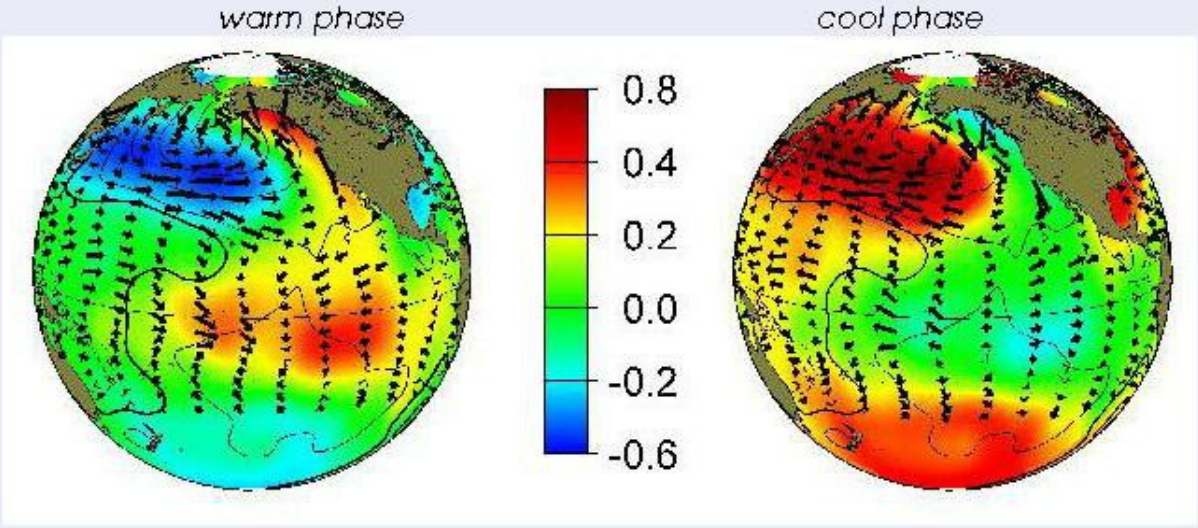
Two main characteristics distinguish PDO from ENSO:

1. 20th century PDO "events" persisted for 20-to-30 years, while typical ENSO events persisted for 6 to 18 months

2. The climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics and the SH - the opposite is true for ENSO.

Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990's.

PDO Basics


warm phase
cool phase
0.8
0.4
0.2
0.0
-0.2
-0.6

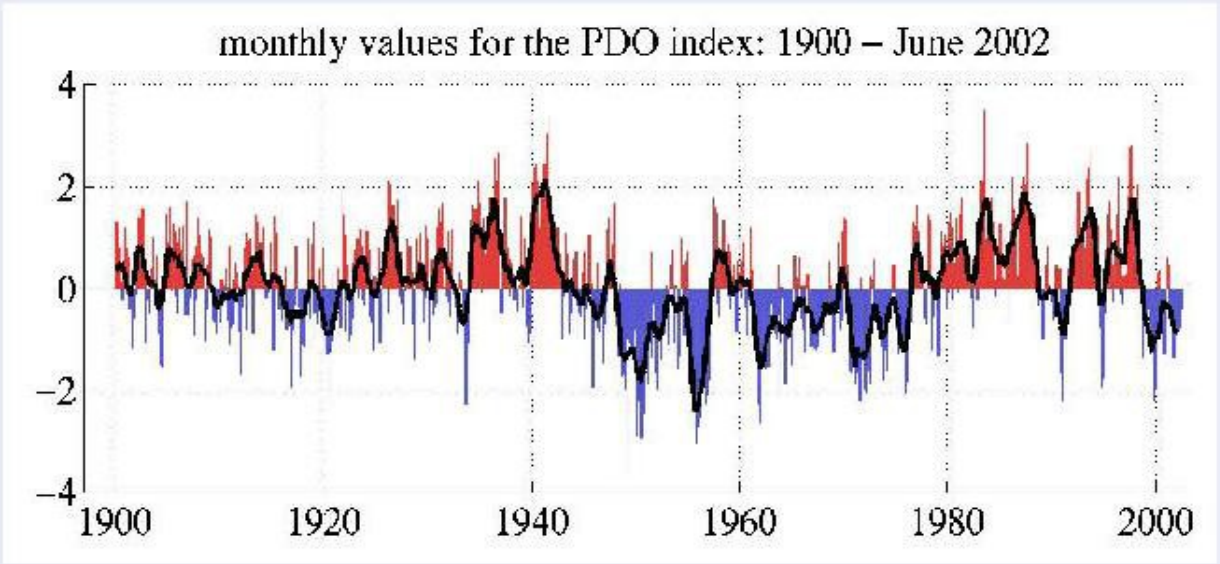
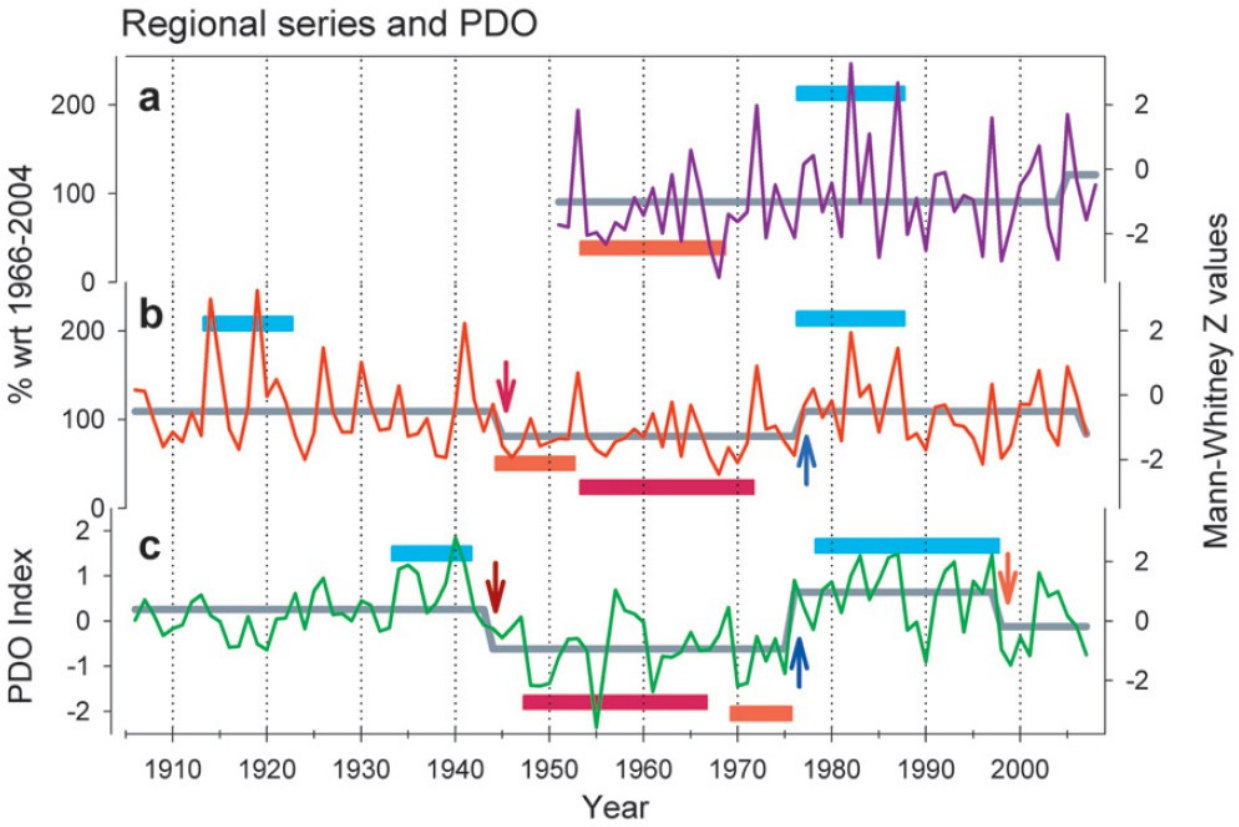

monthly values for the PDO index: 1900 – June 2002
4
2
0
−2
−4
1900
1920
1940
1960
1980
2000

Figure 2. Characteristics of the PDO phases.

PDO Phase	North Pacific Sea Surface Pressure	North Pacific Sea Surface Temperature	Influence on El Nino Conditions	Influence on La Nina Conditions
Positive	Low	Cold	Enhance	Weaken
Negative	High	Warm	Weaken	Enhance

Cambios observados de Precipitación (1960-2000)

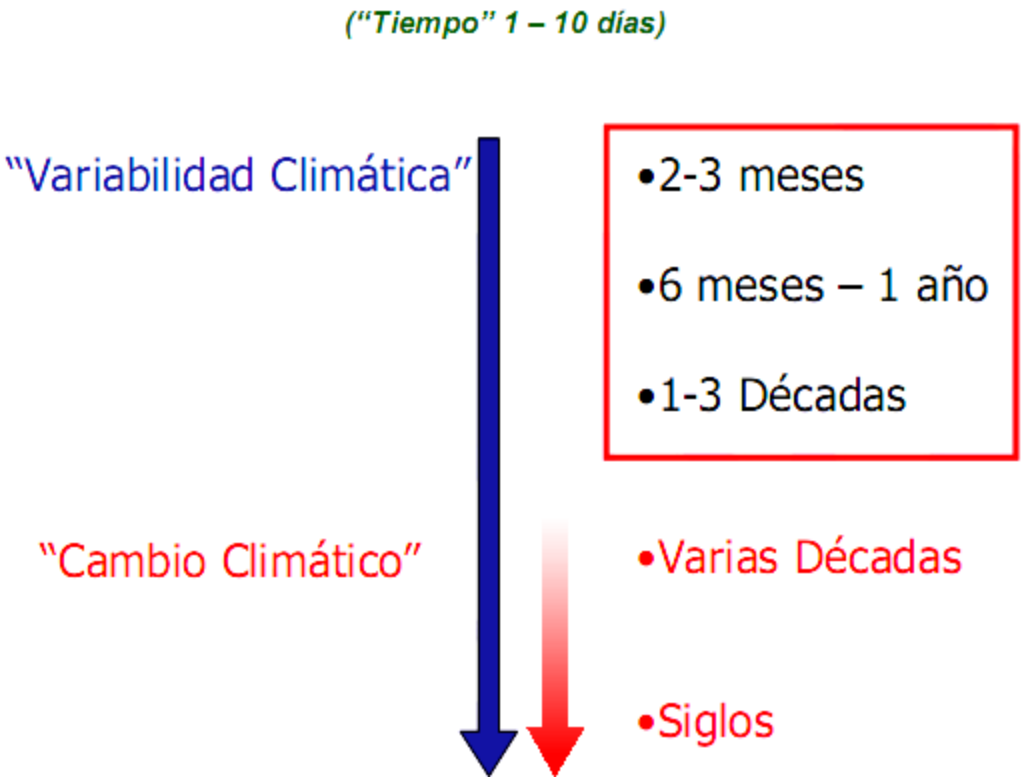


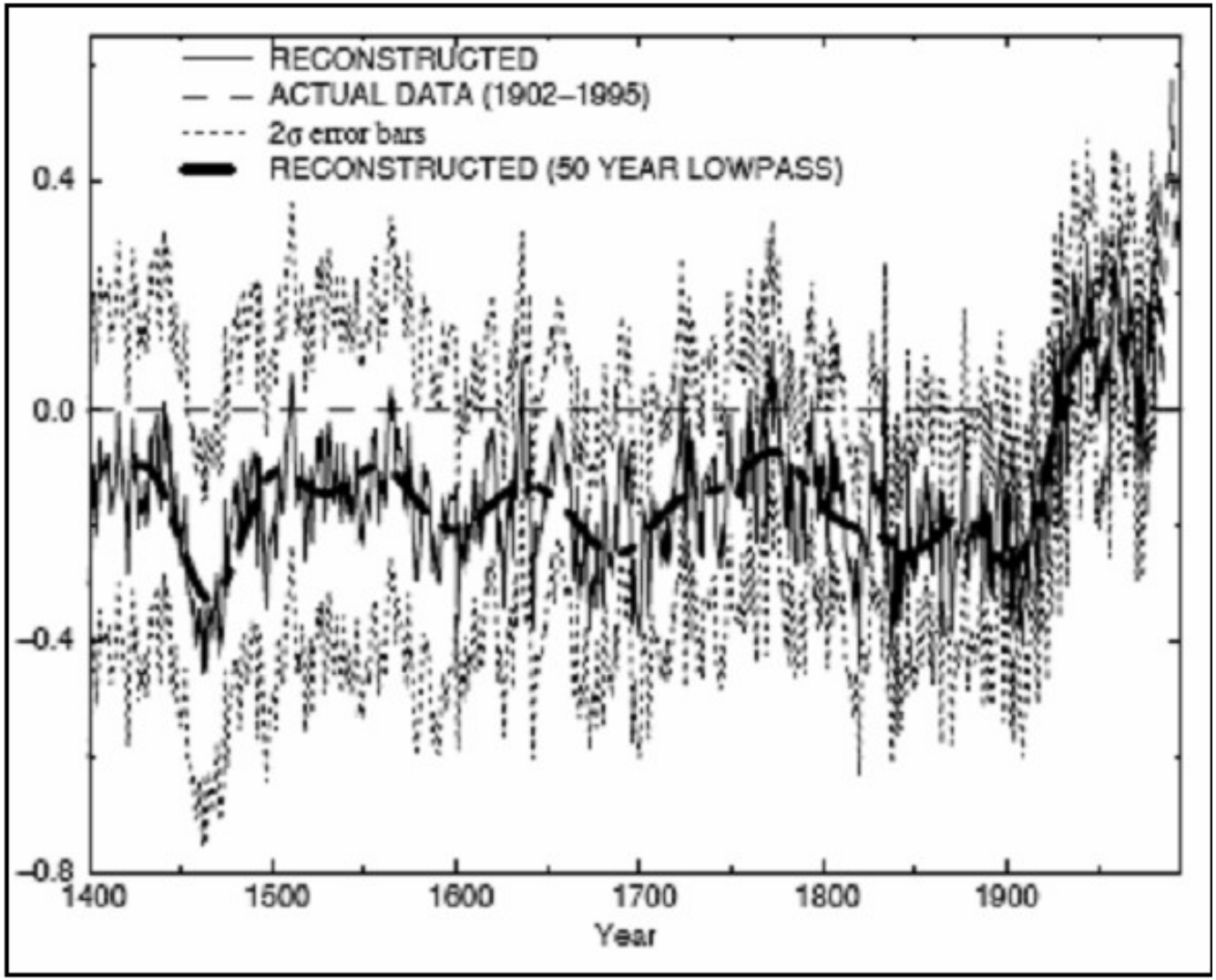
JOURNAL OF HYDROMETEOROLOGY

Intra- to Multidecadal Variations of Snowpack and Streamflow Records in the Andes of Chile and Argentina between 30° and 37°S

MARIANO H. MASIOKAS AND RICARDO VILLALBA

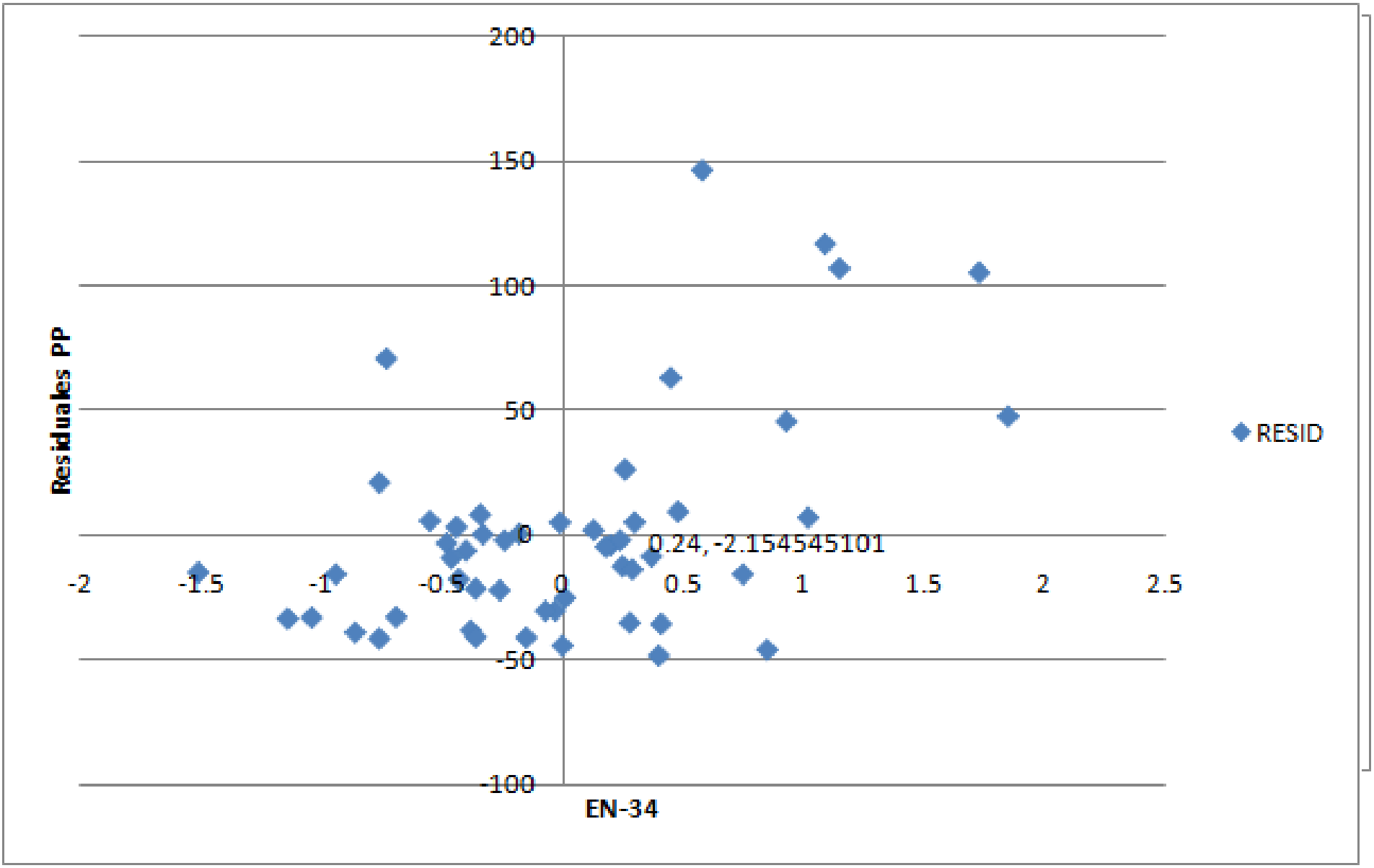
Variabilidad Climática (Cortesía de W Baethgen)



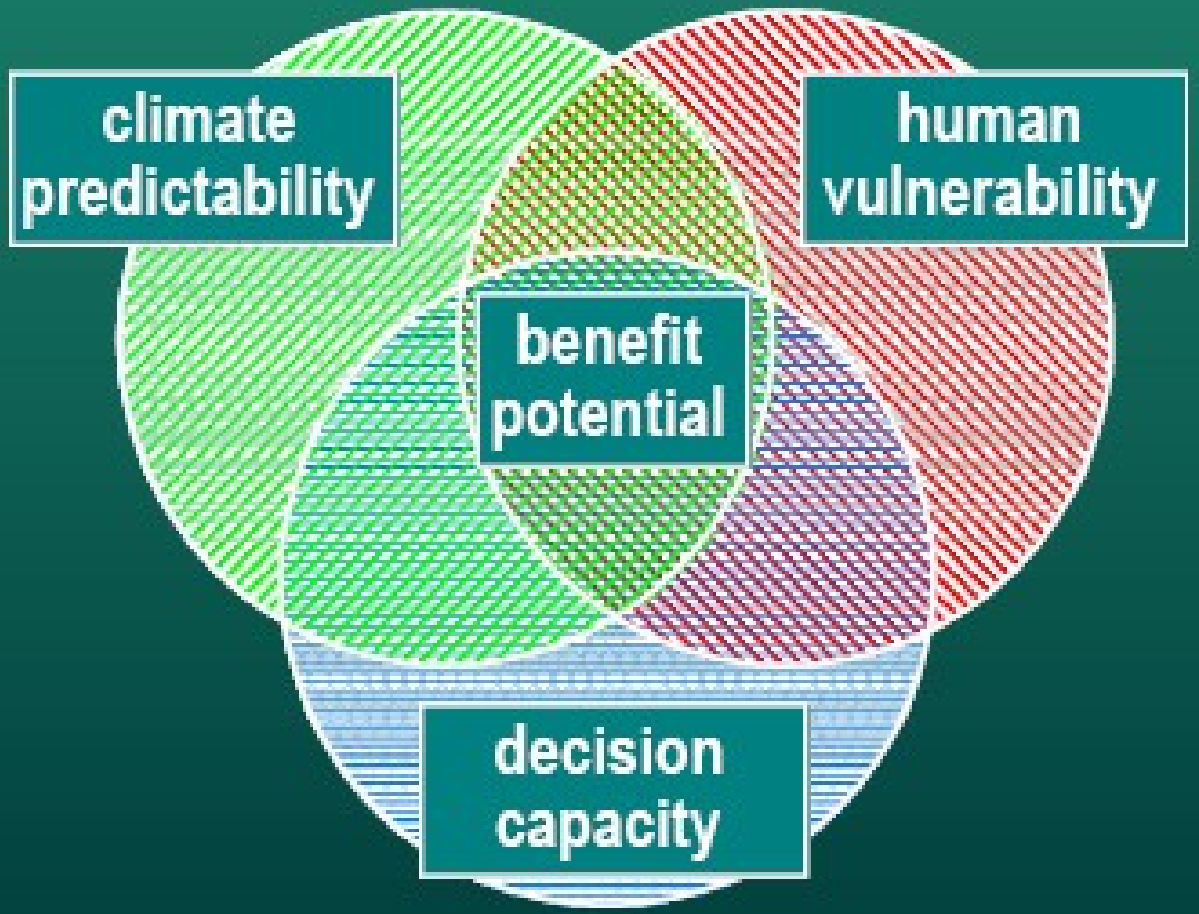

RECONSTRUCTED
ACTUAL DATA (1902–1995)
2σ error bars
RECONSTRUCTED (50 YEAR LOWPASS)
0.4
0.0
−0.4
−0.8
1400
1500
1600
1700
1800
1900
Year

Variabilidad Climática vs “Cambio Climático”

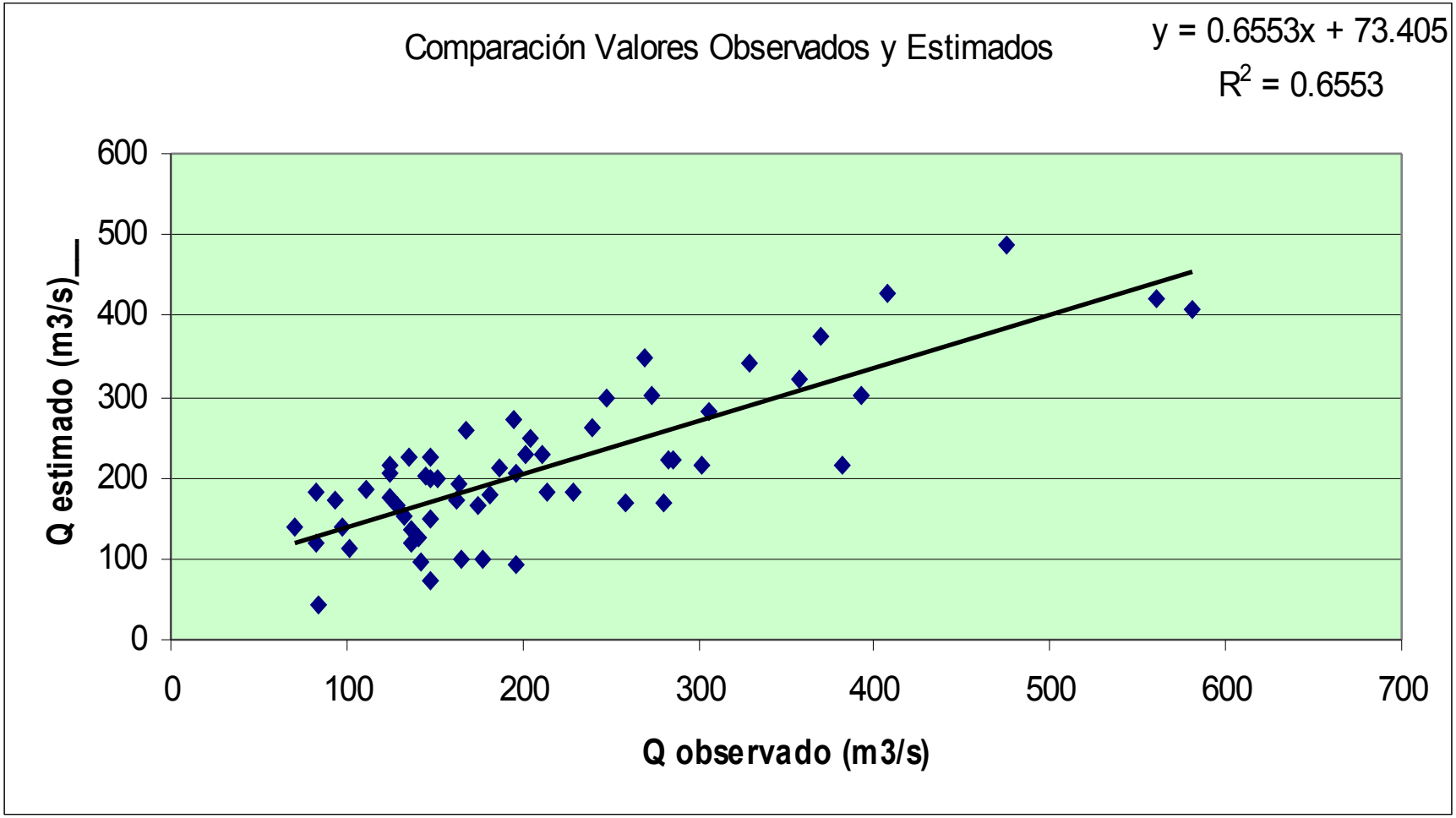
- Precipitaciones en Pudahuel-Quinta Normal (Agosto)
- Análisis histórico que no reconoce saltos ni cambios en regímenes mayores
- No es un sistema “óptimo”
- Busca descomponer las fuentes de la variabilidad


200
150
100
50
0
-50
-100
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
Residuales PP
EN-34
0.24, -2.154545101
RESID

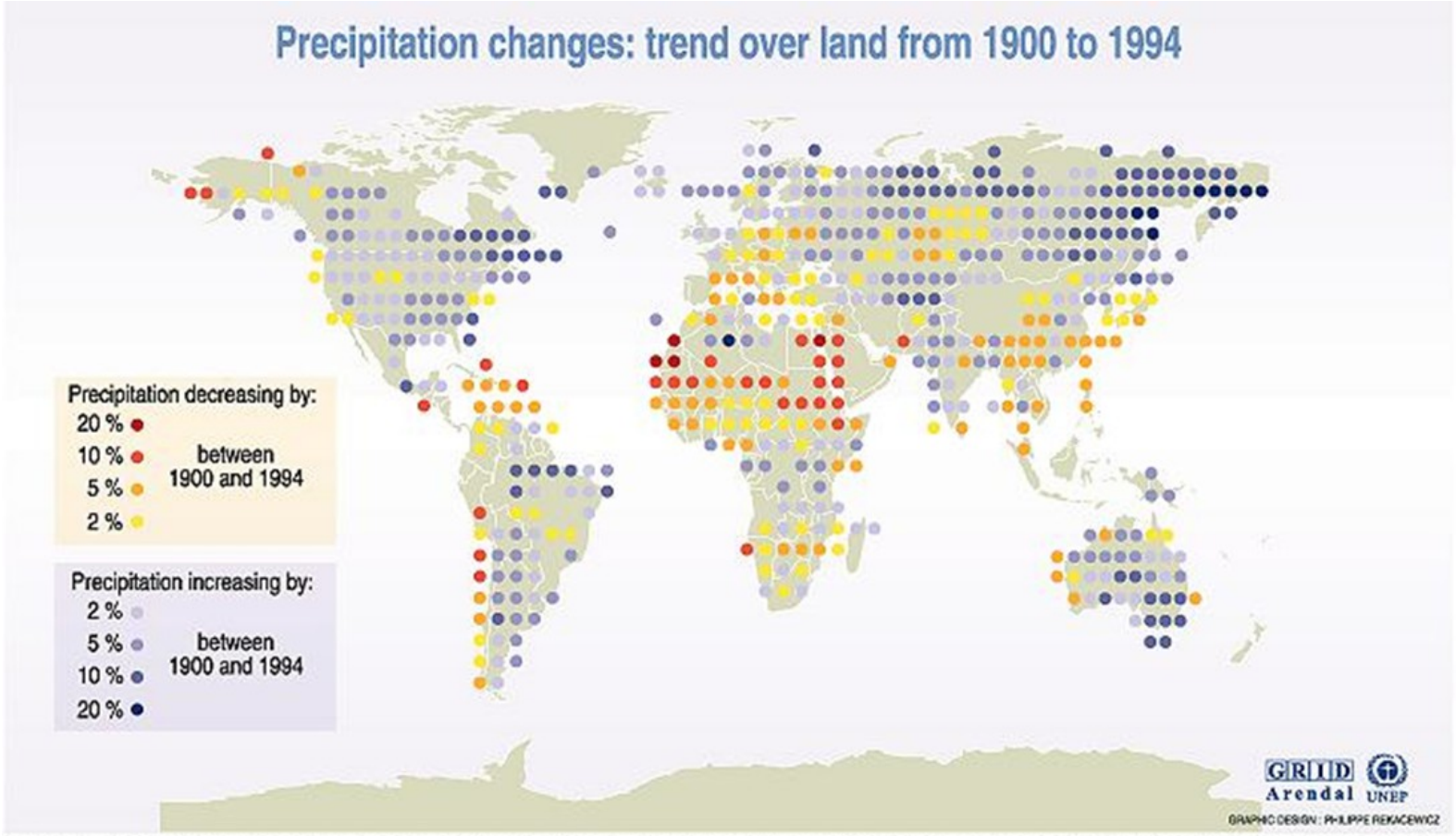
Prerequisites to Beneficial Use



Caudales en El Manzano (Enero)



Tendencias Observadas
Cambios en la Precipitación



Sources: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996; Hulme et al., 1991 and 1994; Global Historical Climate Network (GHCN), Vose et al., 1995 and Eischeid et al., 1995)

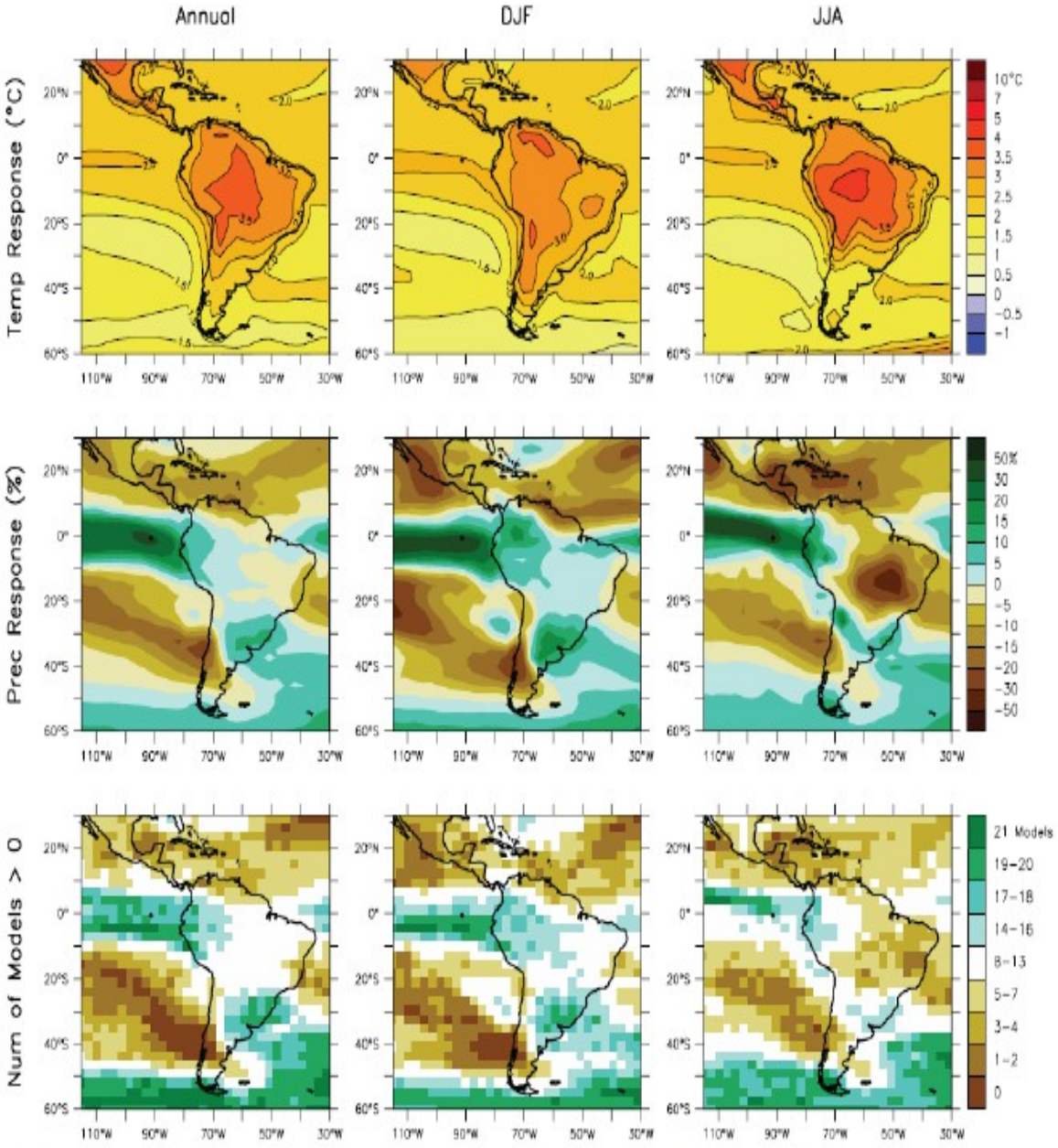
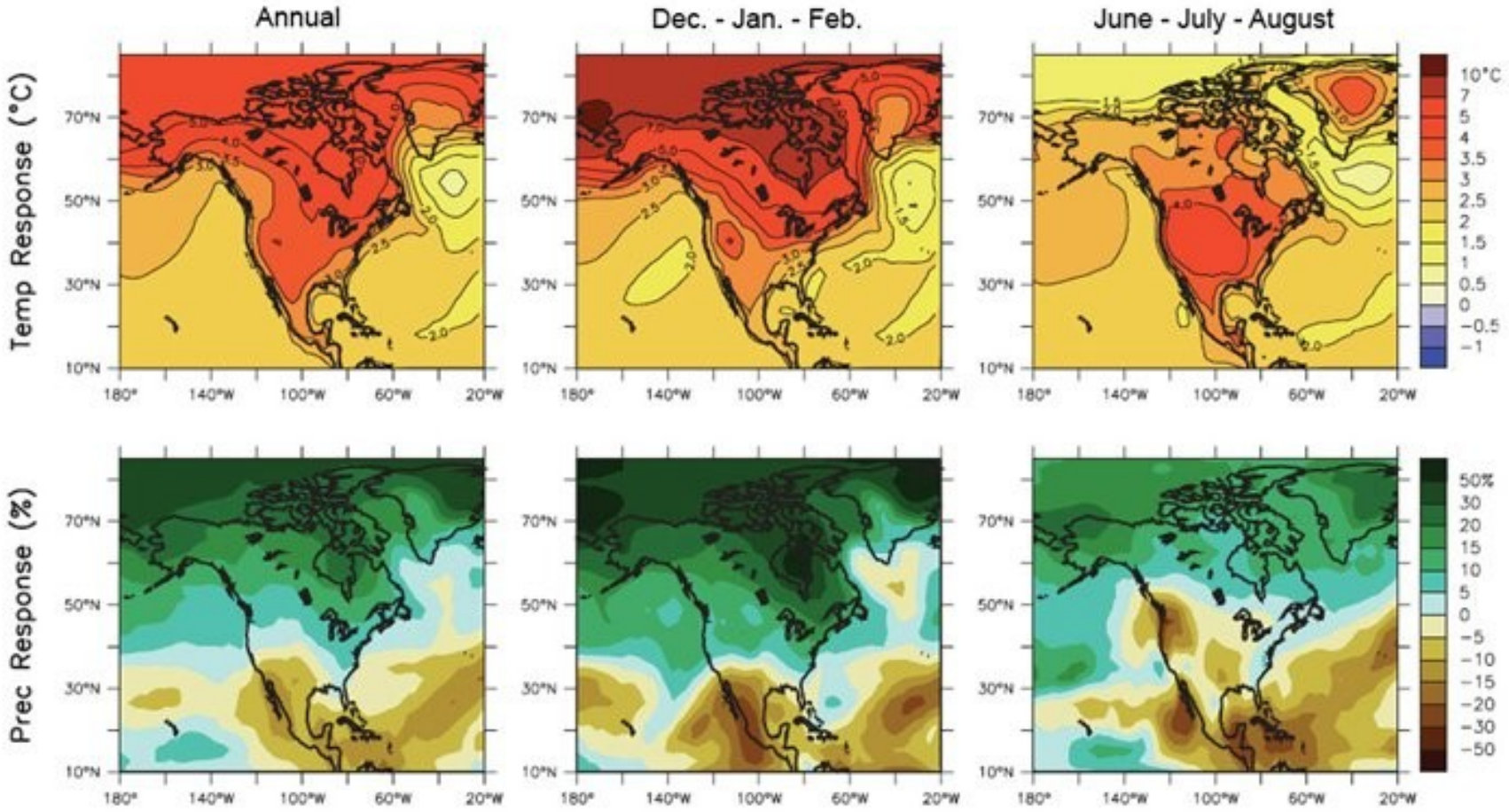
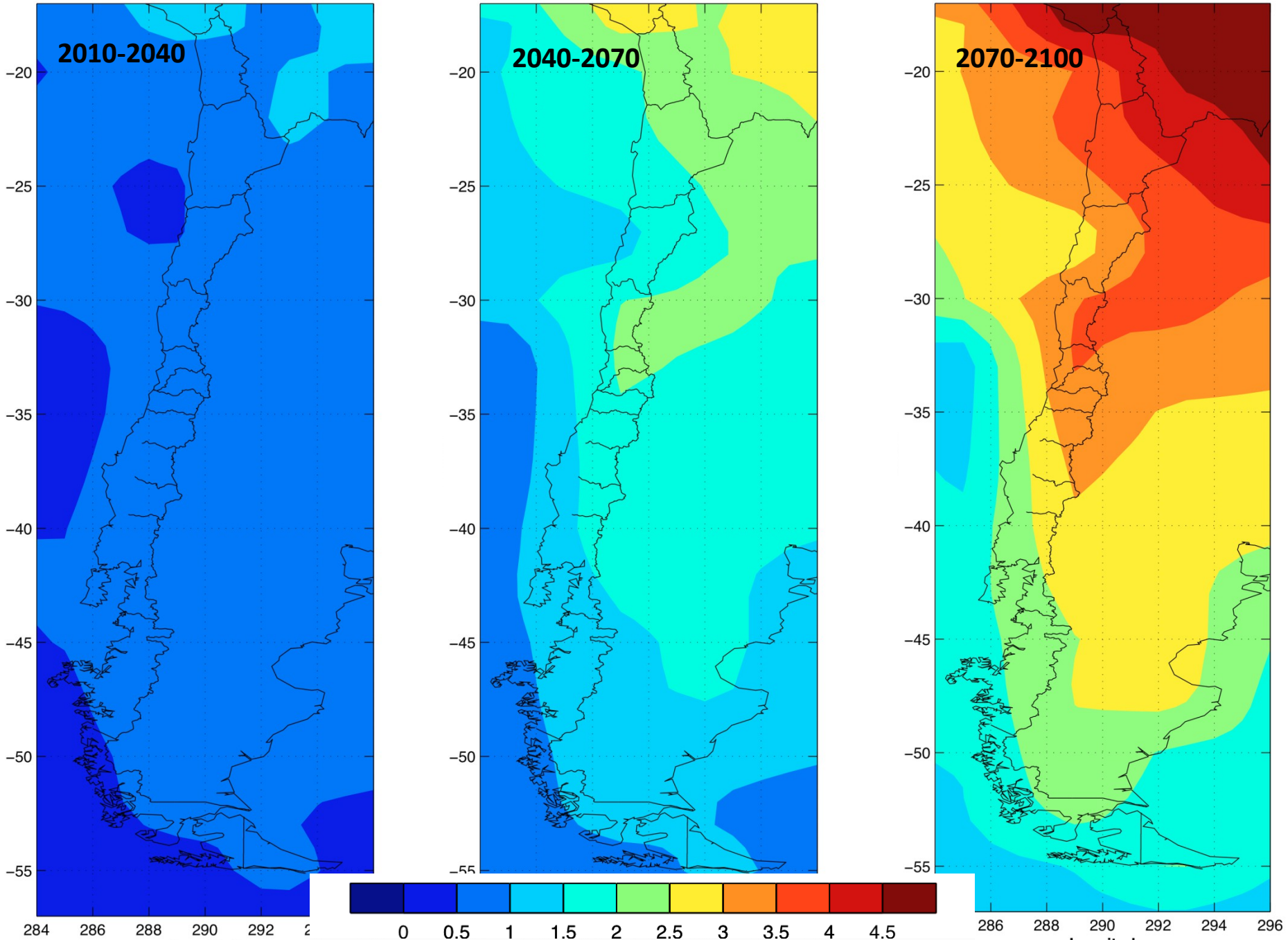


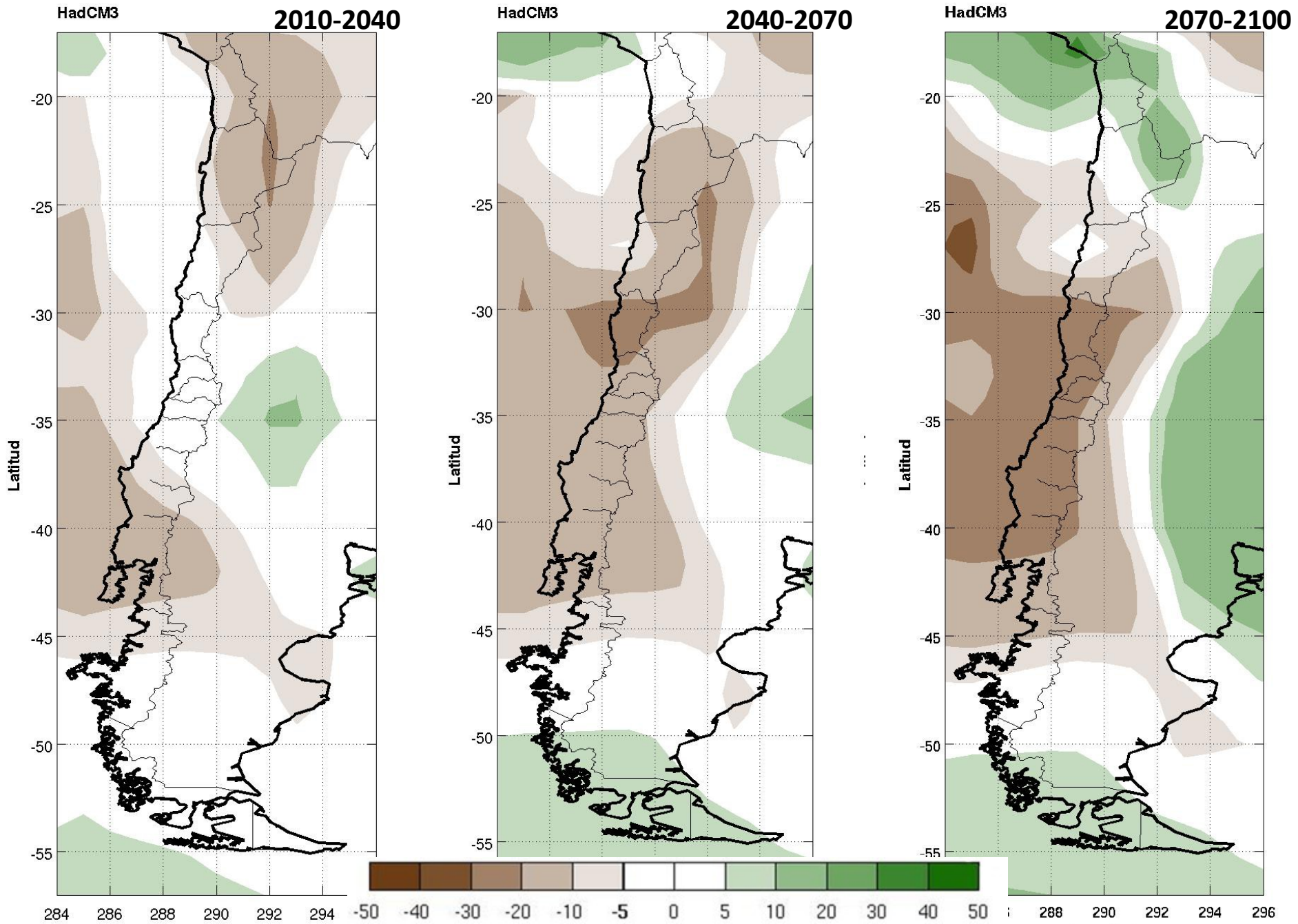
Figure 11.15. *Temperature and precipitation changes over Central and South America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.*


Annual
Dec. - Jan. - Feb.
June - July - August
Temp Response (°C)
Prec Response (%)
70°N
50°N
30°N
10°N
180°
140°W
100°W
60°W
20°W
10°C
7
5
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
50%
30
20
15
10
5
0
−5
−10
−15
−20
−30
−50

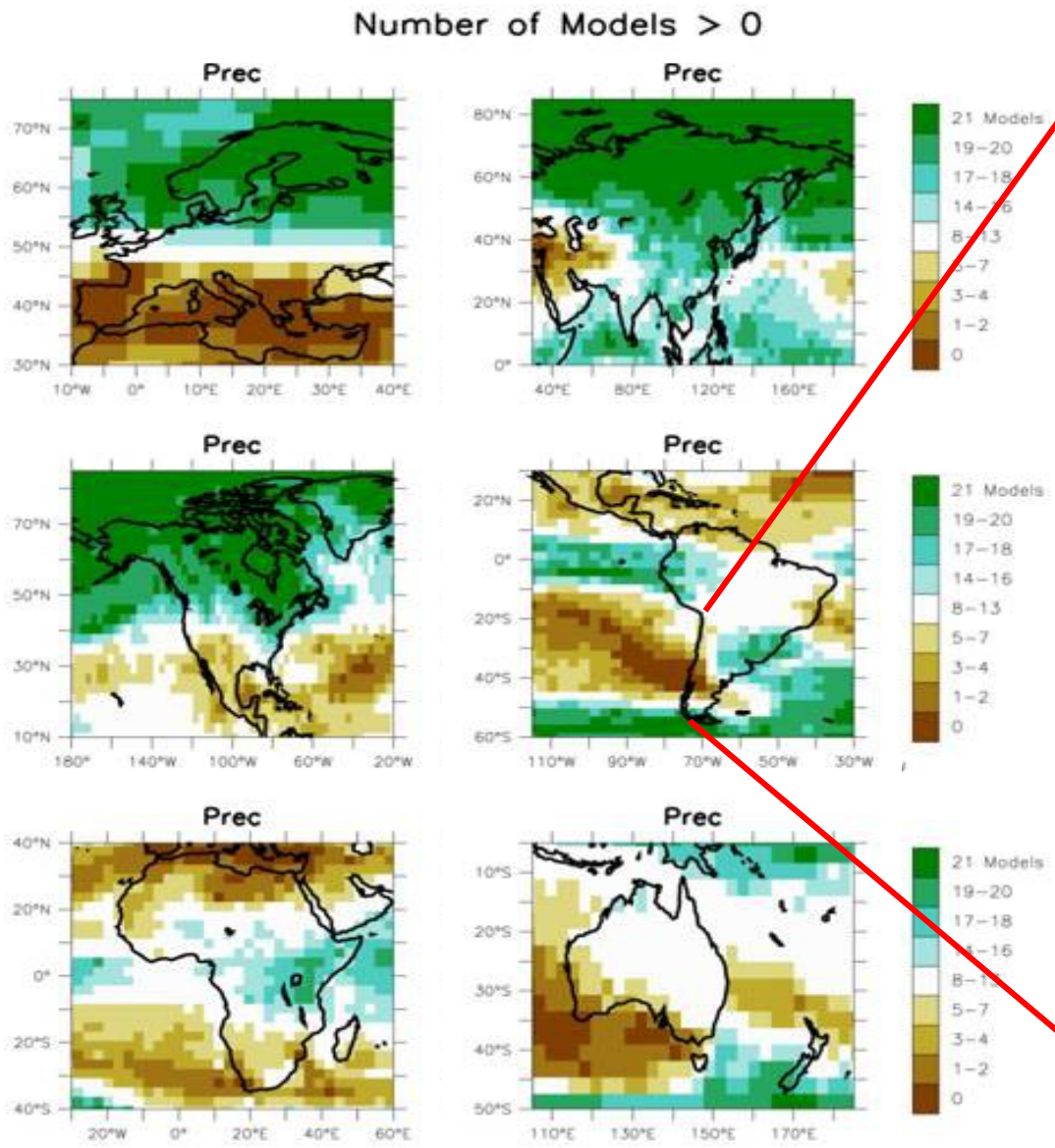
Proyecciones temperatura – HadCM3

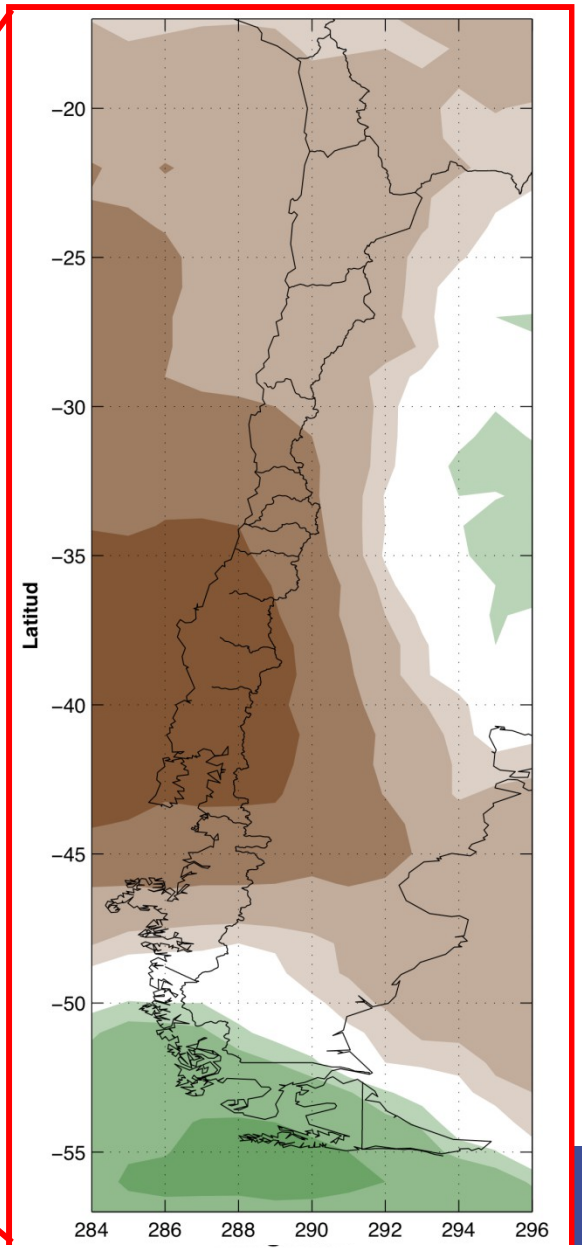


Proyecciones precipitación – HadCM3



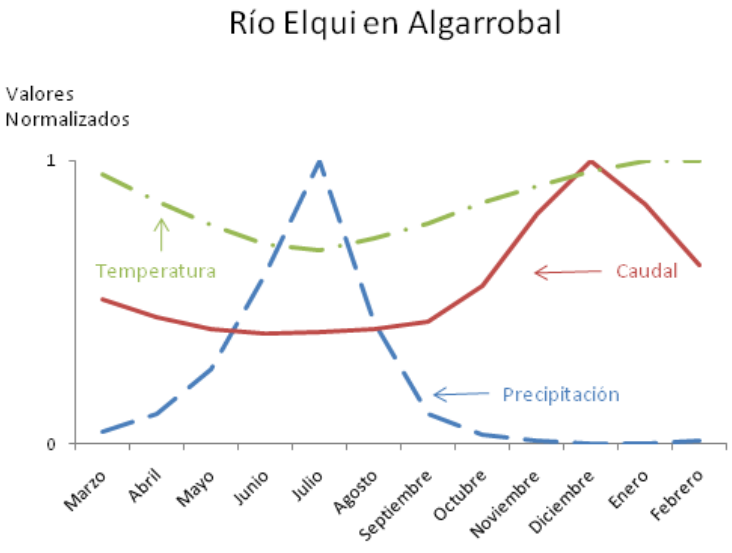
Incertidumbre precipitación Porcentaje modelos > 0



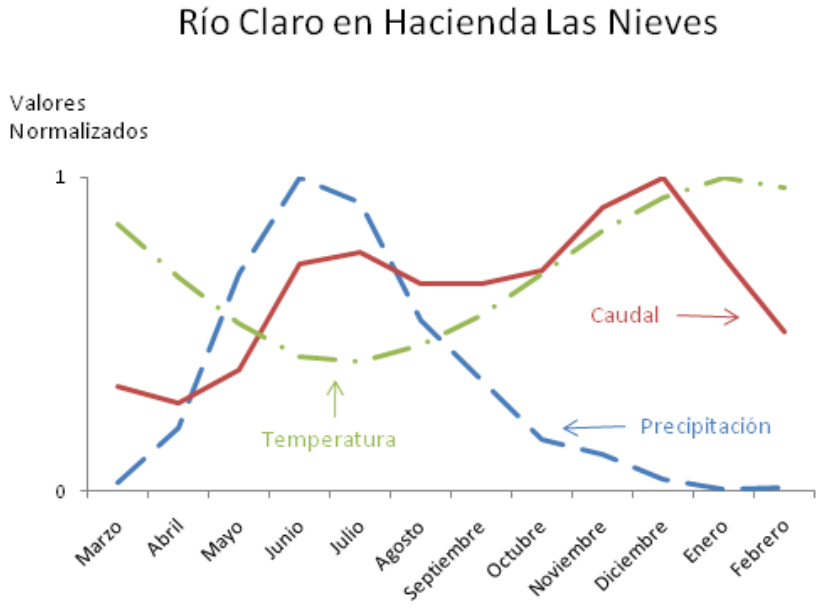


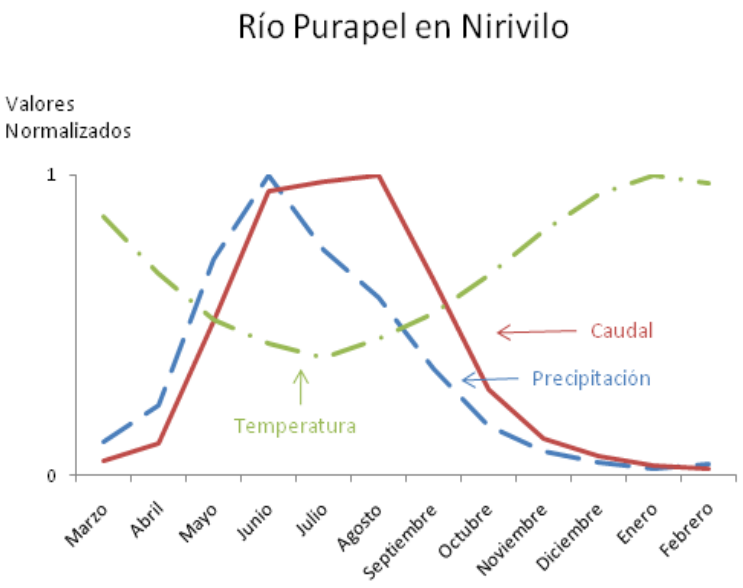
Hidrología en cuencas Mediterráneas en Chile

Fuente: Cruzat, 2010



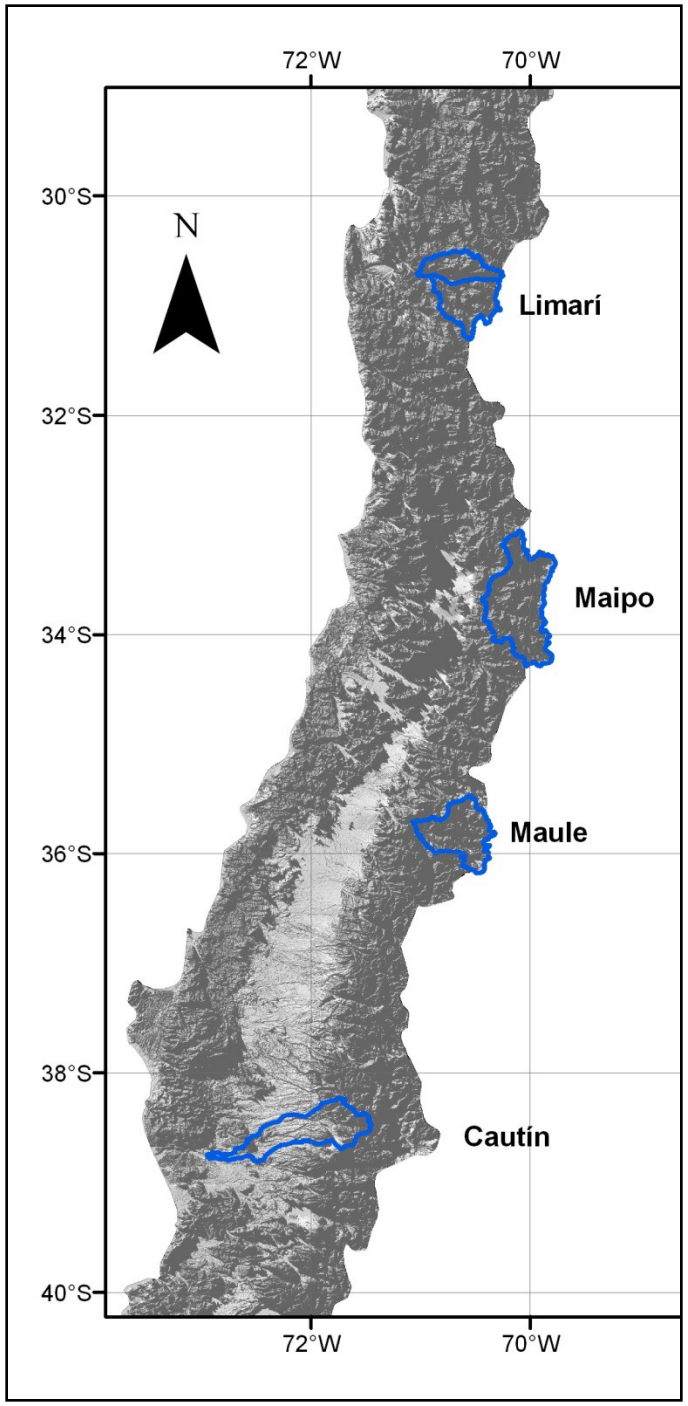
Régimen nival

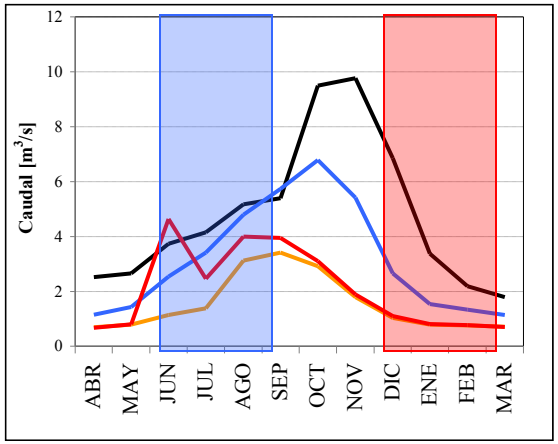


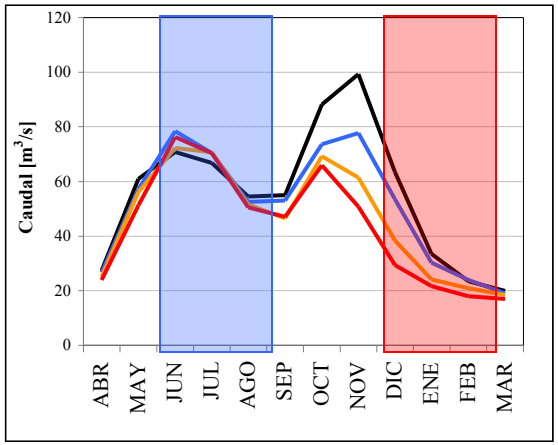


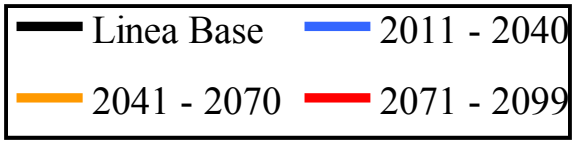
Régimen pluvial

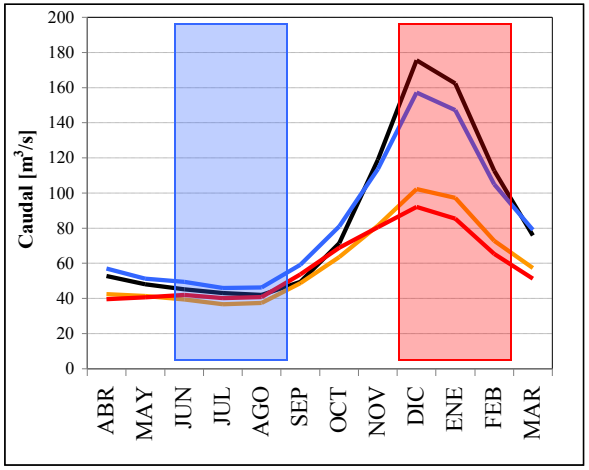
Régimen mixto

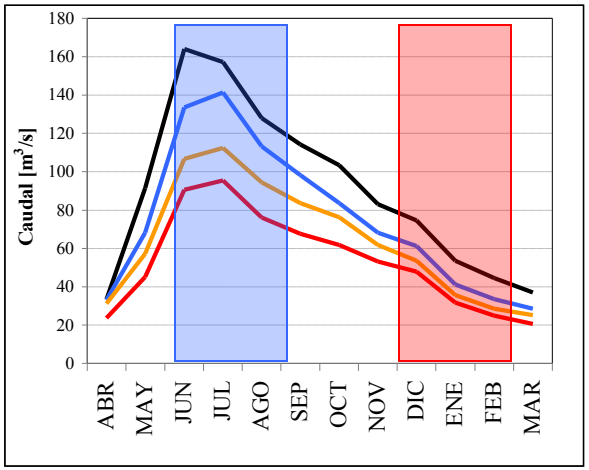












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