

Cambio Climático Global Bases Físicas e Impactos en Chile

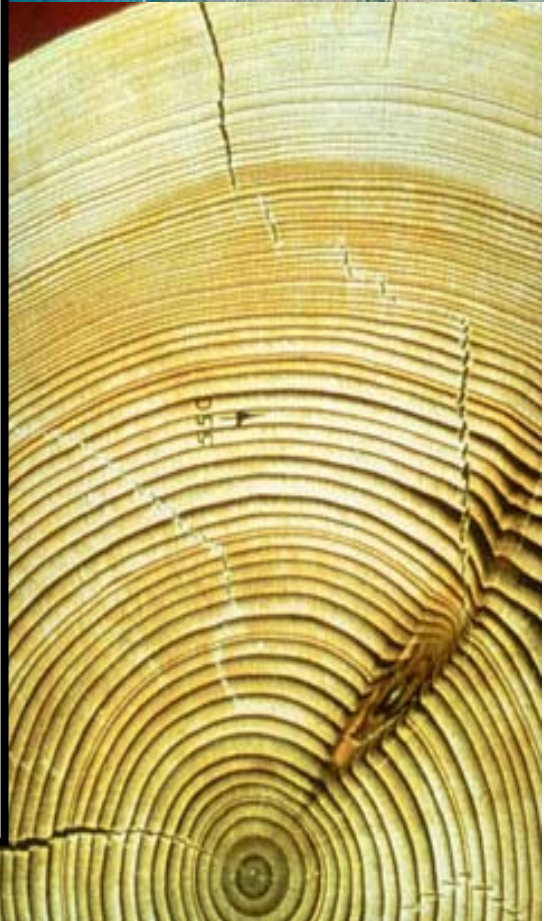
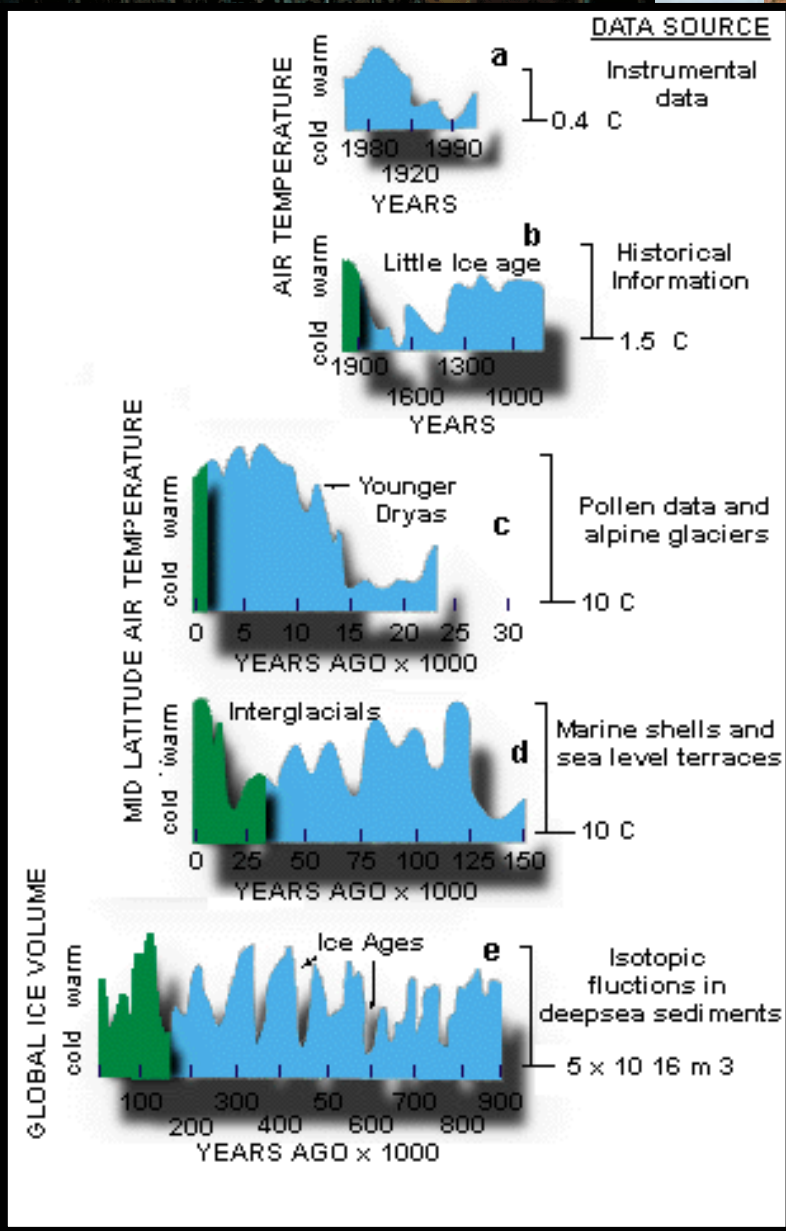
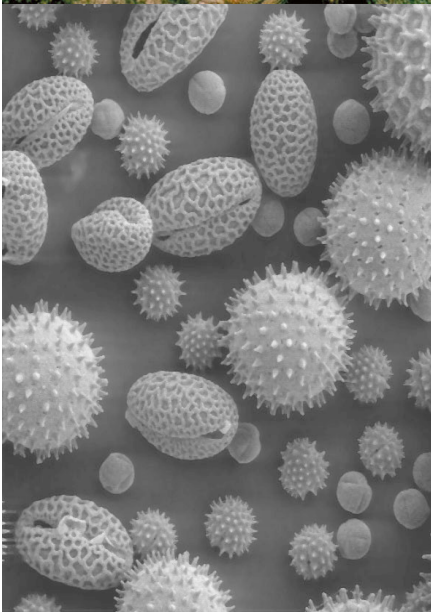
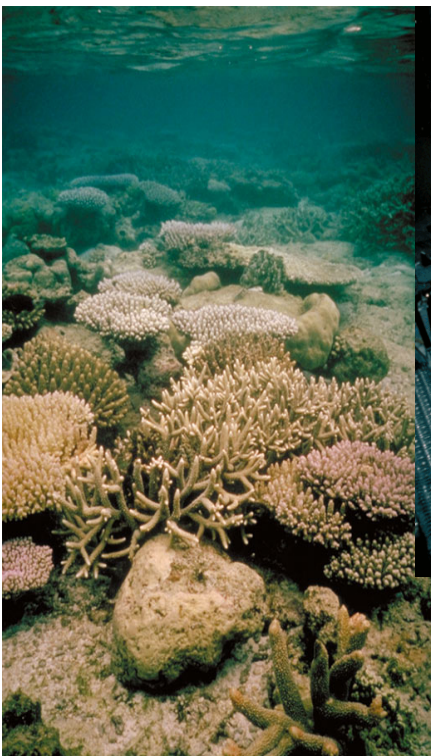
XXII Silvotecnica-CORMA
Noviembre 2007

René D. Garreaud

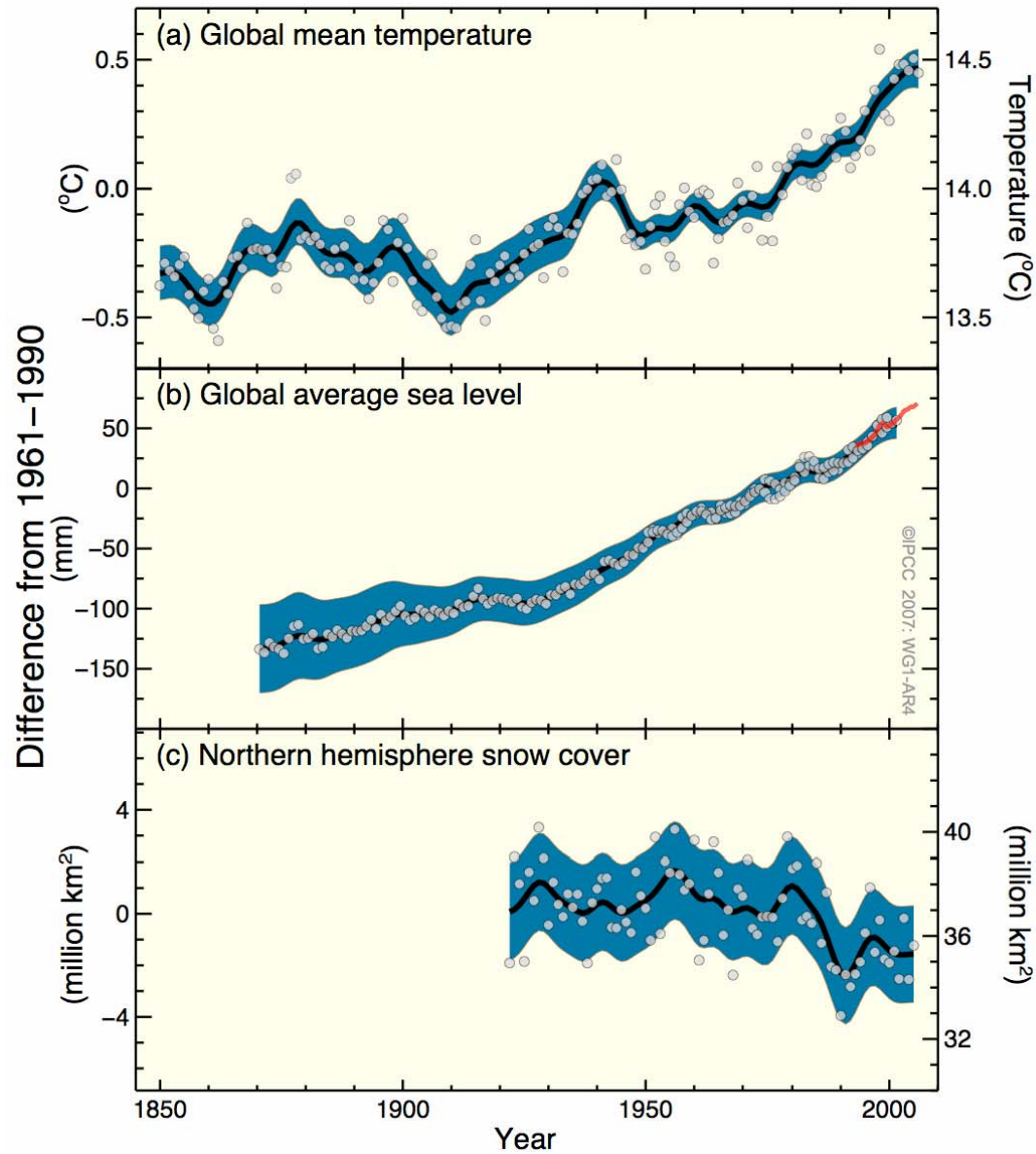
*Departamento de Geofísica
Universidad de Chile*

Temario

1. Cambios en el siglo XX: Global /Regional
2. Bases Físicas del Cambio Climático
3. Pronóstico para mañana



Changes in Temperature , Sea Level and Northern Hemisphere Snow Cover



$$\partial T_{sfc} / \partial t$$

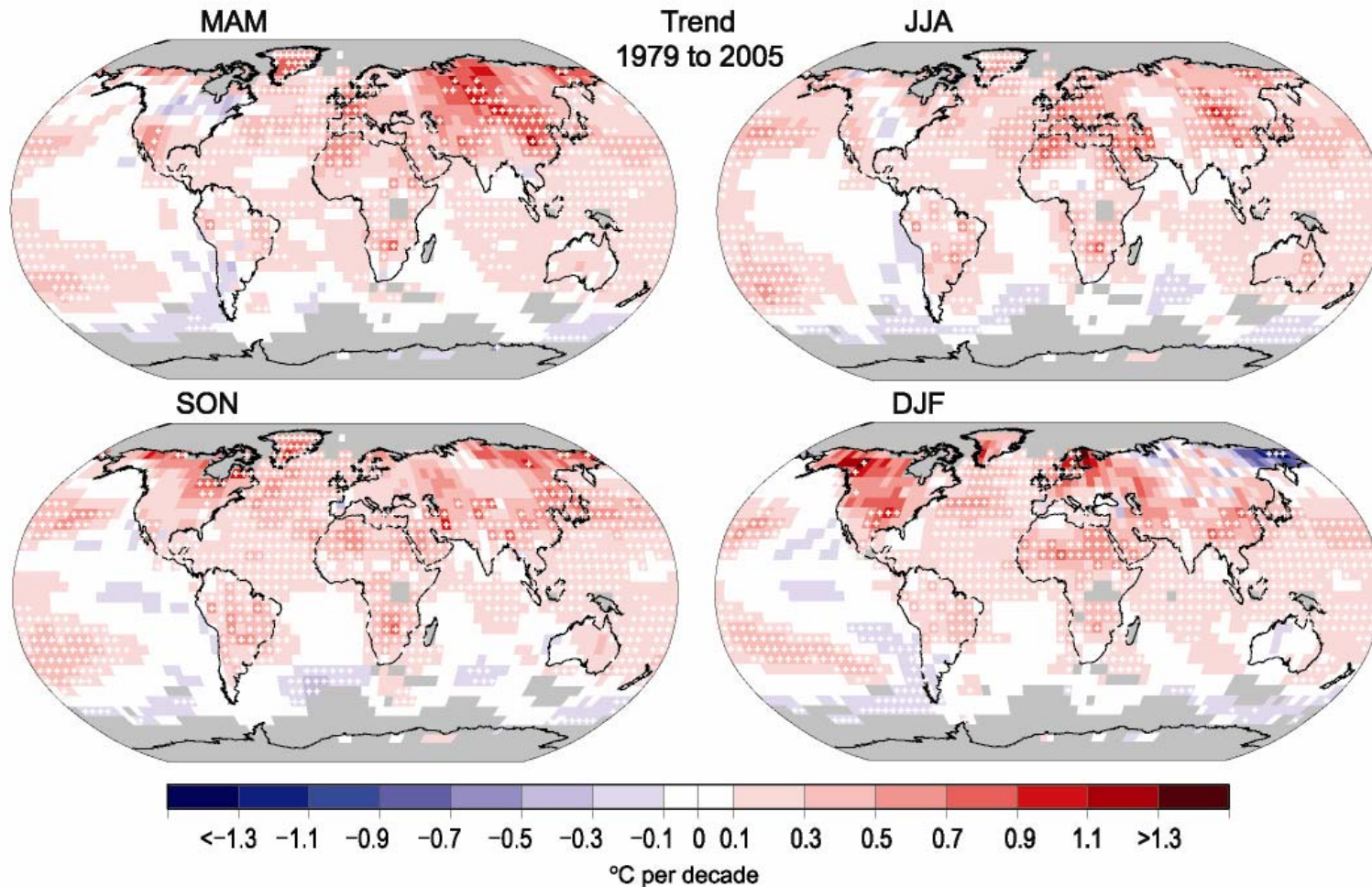
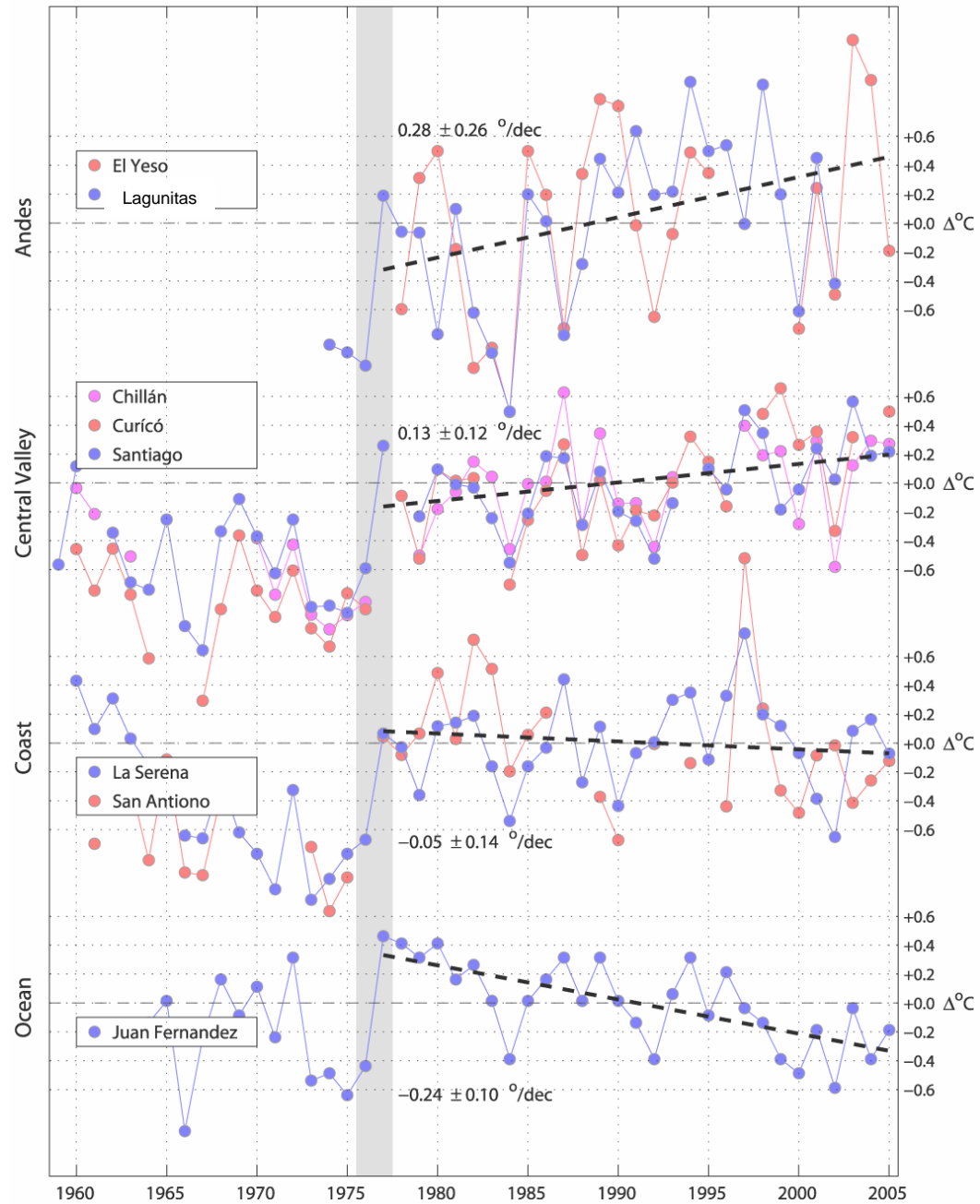


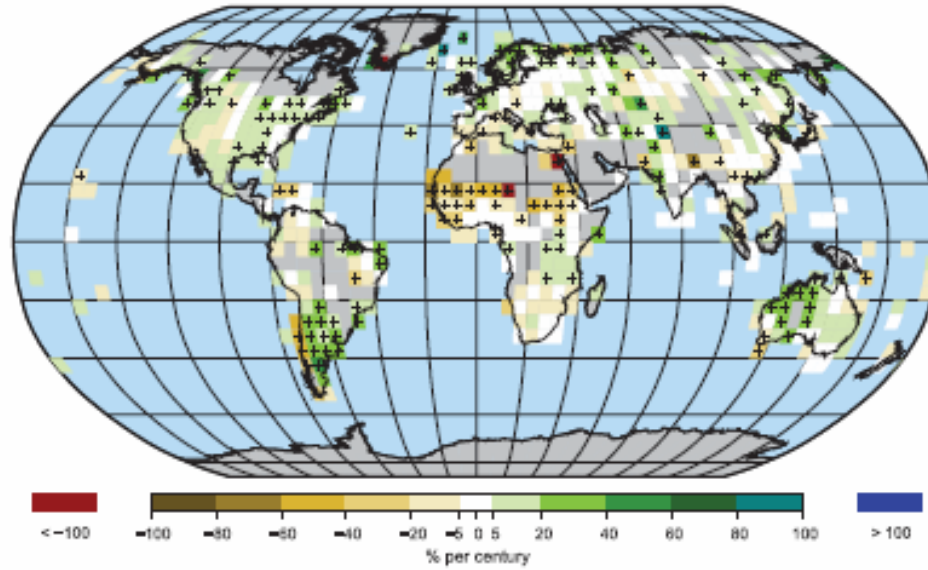
Figure 3.10. Linear trend of seasonal MAM, SON and DJF temperature for 1979 to 2005 (°C per decade). Areas in grey have insufficient data to produce reliable trends. The minimum number of years required to calculate a trend value is 18. A seasonal value is available if there are two valid monthly temperature anomaly values. The data used was produced by NCDC from Smith and Reynolds (2005). Trends significant at the 5% level are indicated by white + marks.

Central Chile Temperatures

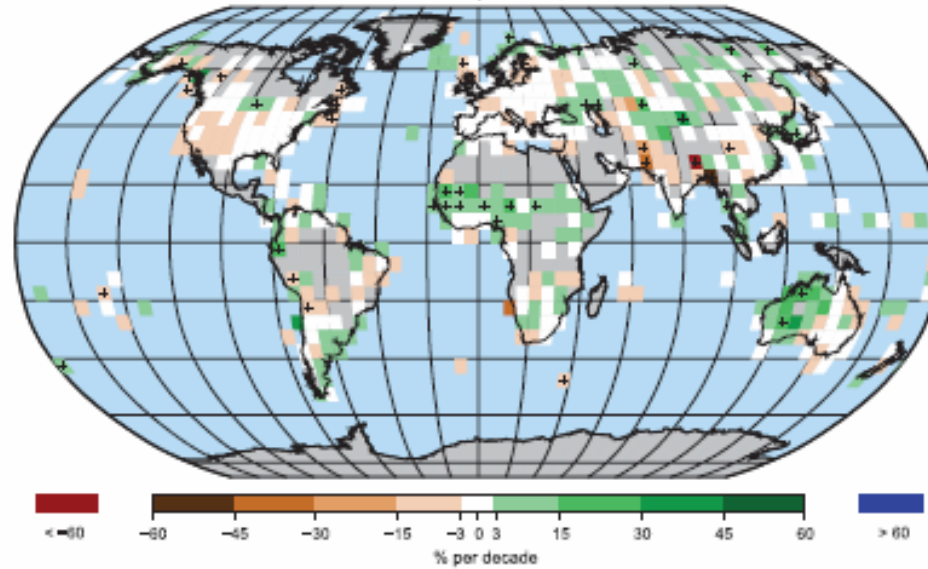


$$\partial R / \partial t$$

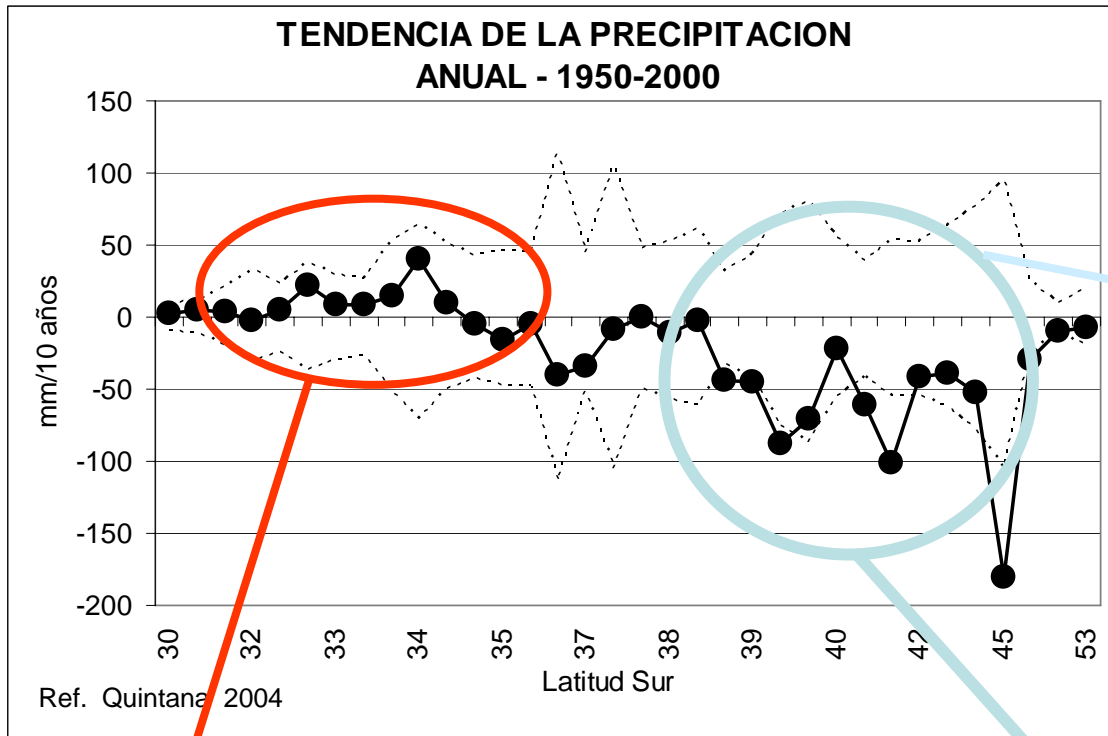
Trend in Annual Precipitation, 1901 to 2005



Trend in Annual Precipitation, 1979 to 2005

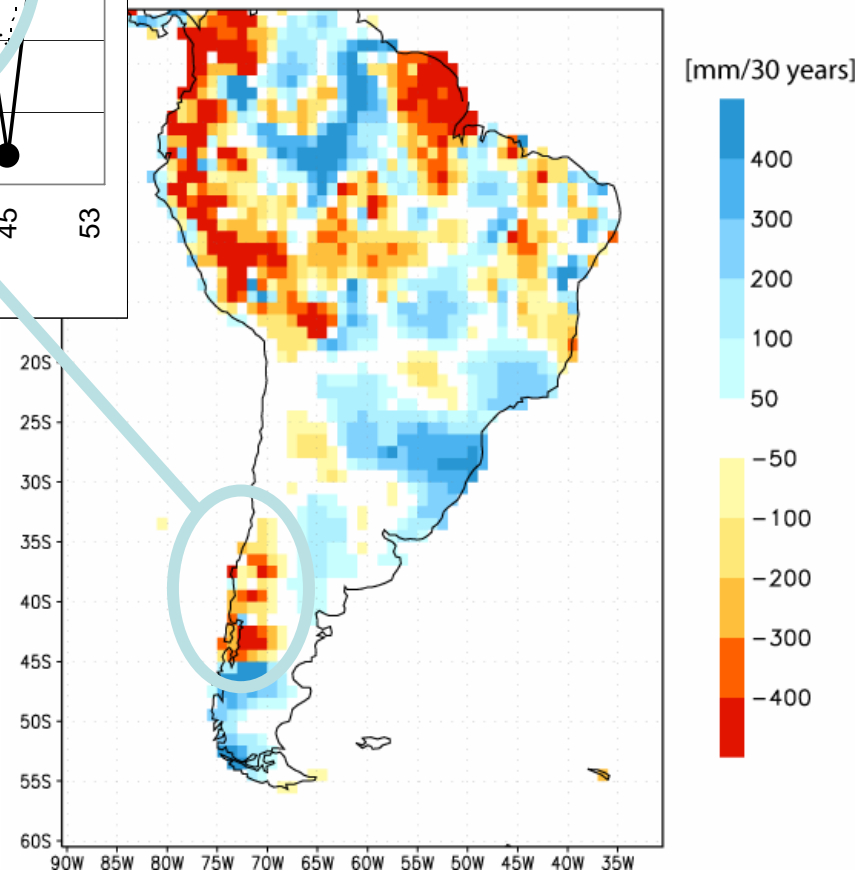


Cambios absolutos en precipitación

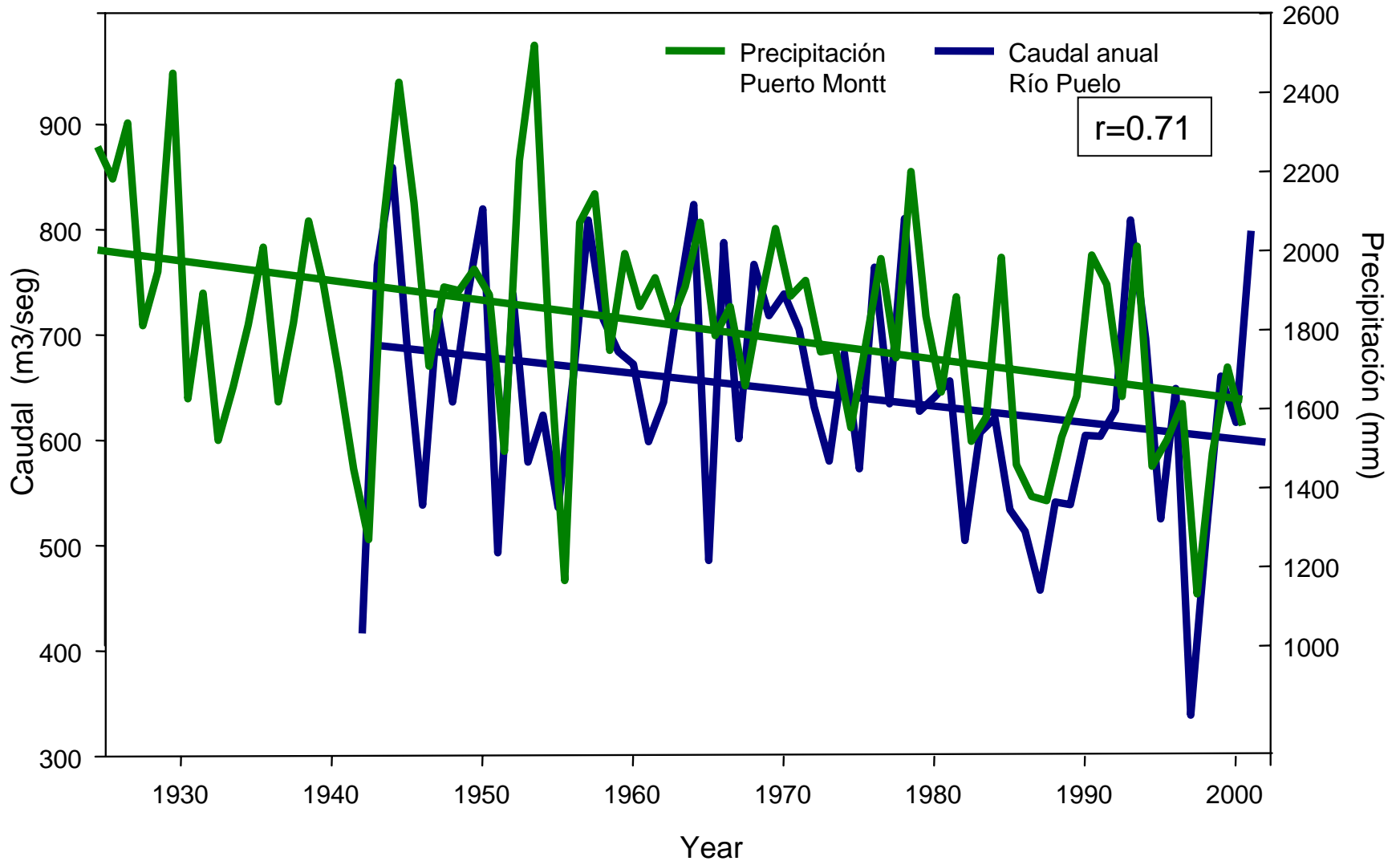


- Rainy climate
- MAP ~ 1000-3000 mm
- $\sigma(\text{IA})/\text{MAP} \sim 0.1$
- Weak ENSO Impact
- Significant drying trend

- Semiarid climate
- MAP ~ 30-500 mm
- $\sigma(\text{IA})/\text{MAP} \sim 0.3 - 0.5$
- Strong ENSO Impact
- No significant trend



PP Puerto Montt y Q en río Puelo

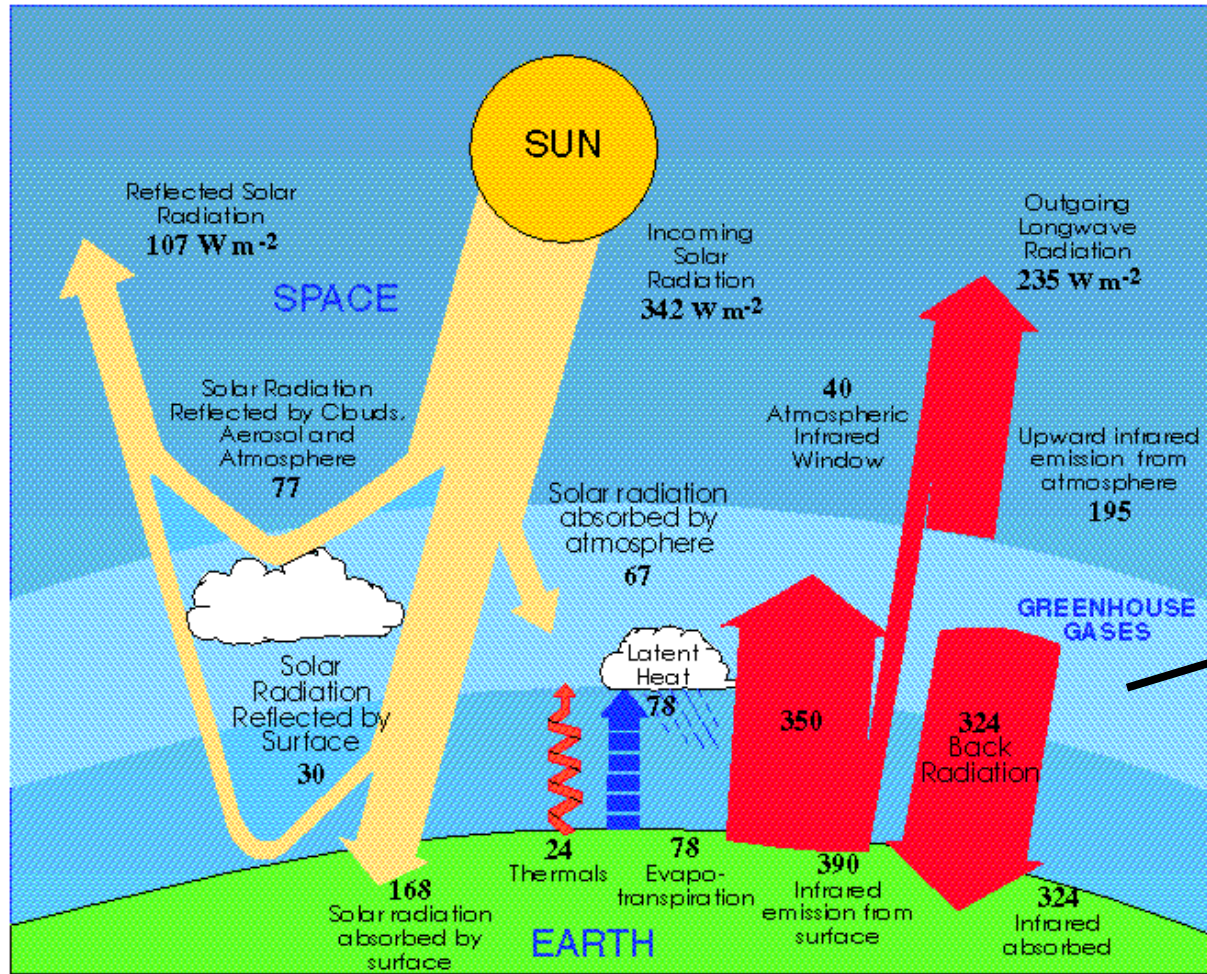


Factores de cambio climático

- Factores internos: tectónica, volcanismo,...
- Factores externos: actividad solar, meteoros,....
- Factores antropogénicos: Cambios en la composición de la atmósfera terrestre, uso de suelo, etc.

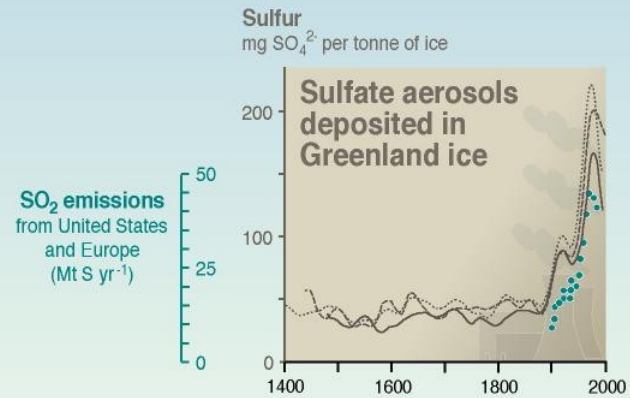
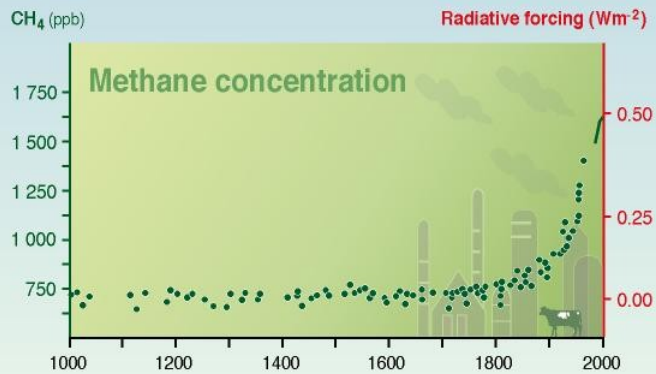
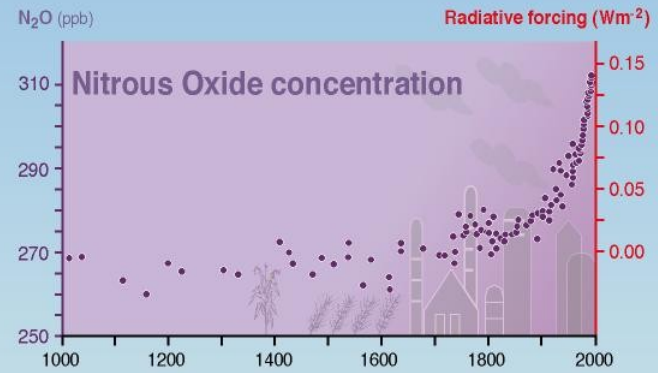
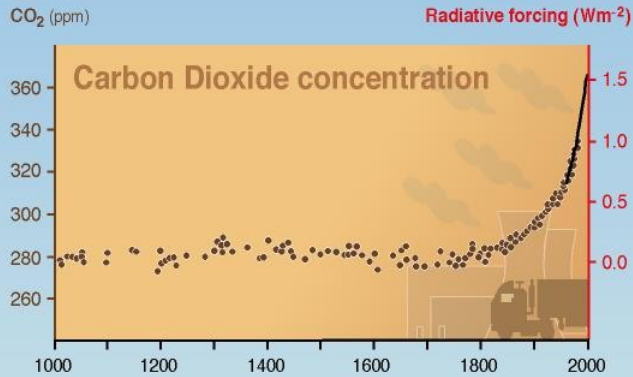


Balance Global de Energía del Planeta Tierra (promedio en latitud y longitud)



Gases Invernadero
 H_2O , CO_2 , CH_4 , N_2O

Indicators of the human influence on the atmosphere during the Industrial era



Proyecciones Climáticas para el siglo XXI

- i. Resultados Modelos Globales
- ii. Resultados Modelos Regionales

Atmospheric circulation is governed by fluid dynamics equation + ideal gas thermodynamics

$$\frac{d\vec{V}}{dt} + f\hat{k} \times \vec{V} = -\frac{1}{\rho} \nabla p - \vec{F}_R + \vec{g}$$

Momentum eqn.

$$\left(\frac{\partial}{\partial t} + \vec{V} \cdot \nabla\right)T - S_p \omega = Q_{RAD} + Q_{Conv} + Q_{Sfc}$$

Energy eqn.

$$\nabla \cdot \vec{V} + \frac{\partial \omega}{\partial p} = 0$$

Mass eqn.

$$\frac{\partial(gz)}{\partial p} = -\frac{RT}{p}$$

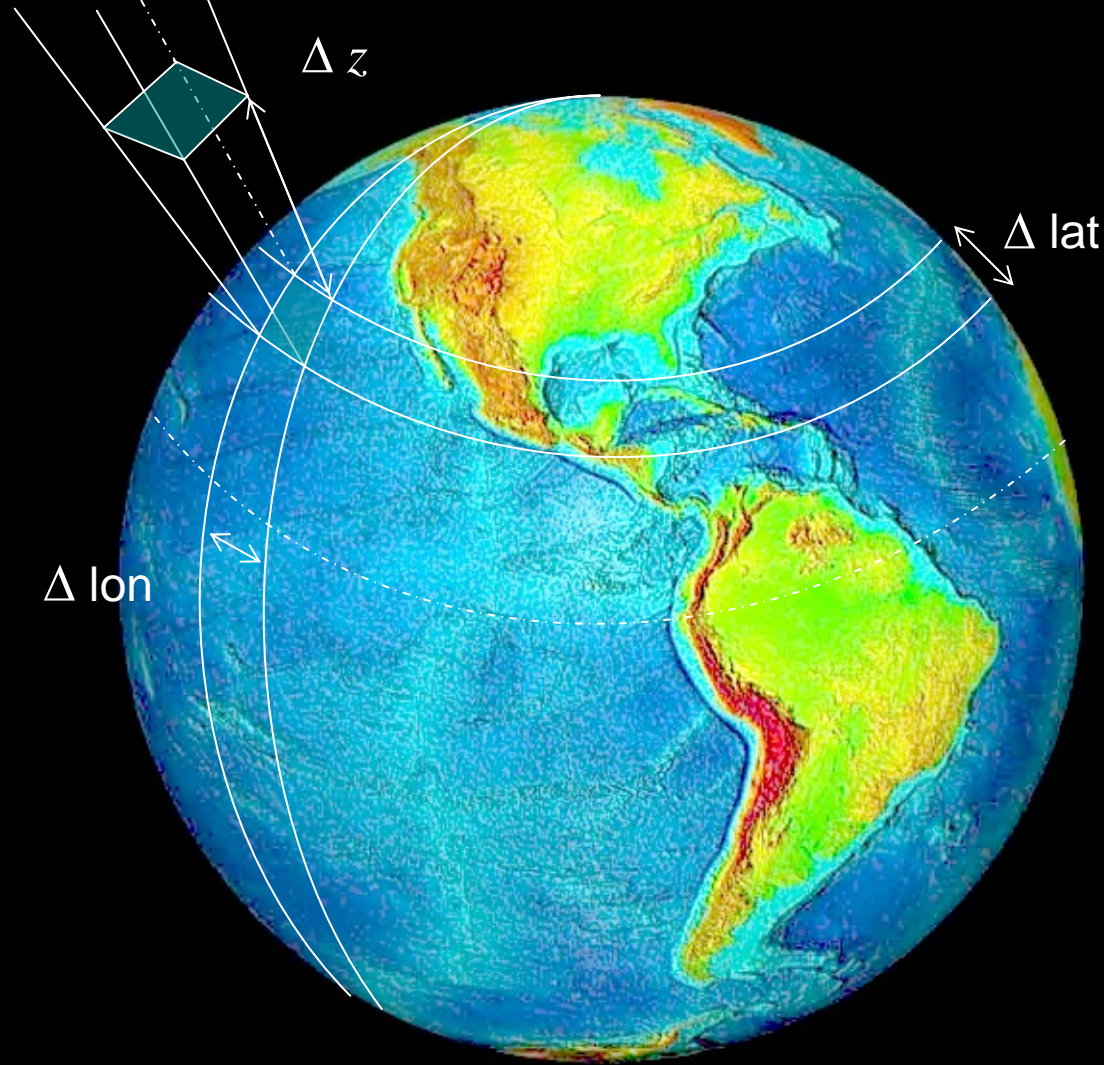
Idea gas law

$$\frac{dq_v}{dt} = -C + E$$

$$\frac{dq_r}{dt} = +C - E + S_r$$

Water substance eqns.

Global Models (GCM)

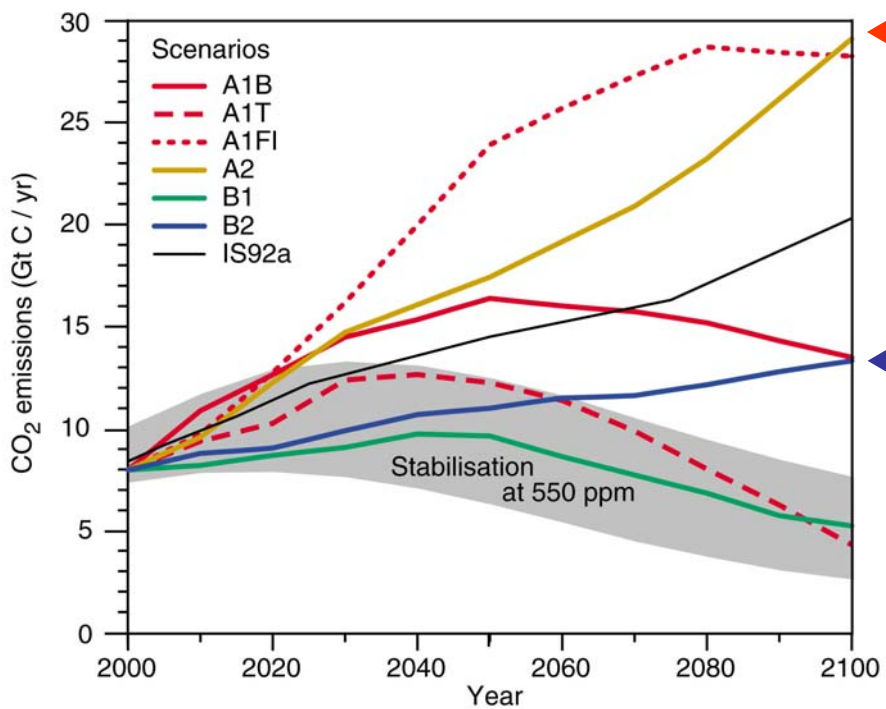


$\Delta \text{lat} \sim \Delta \text{lon} \sim 1^\circ - 3^\circ$

$\Delta z \sim 1 \text{ km}$

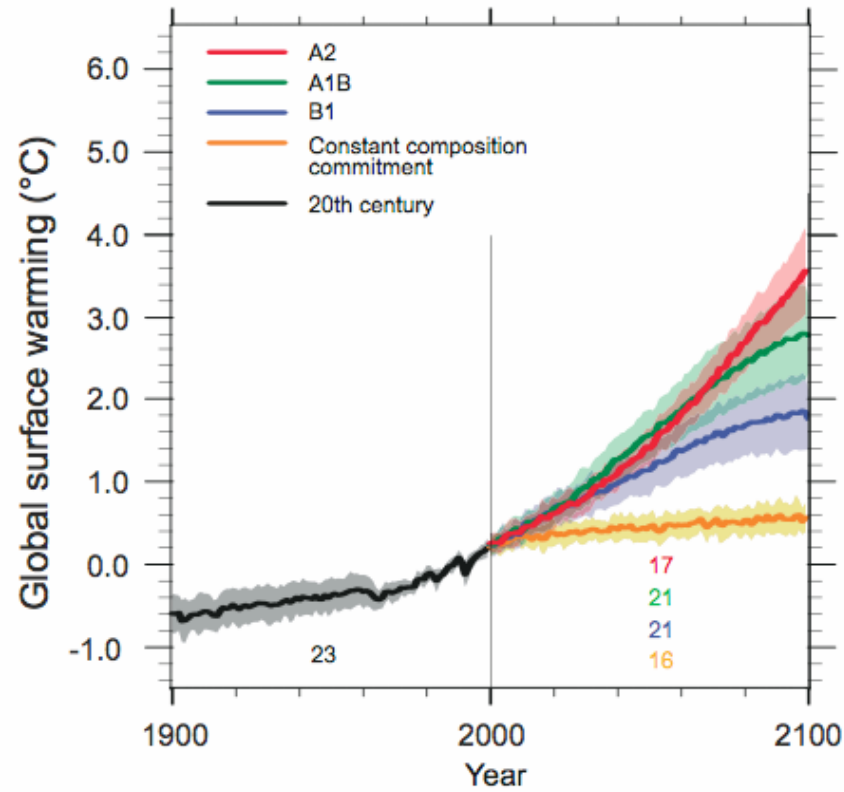
$\Delta t \sim \text{minutes-hours}$

Top of atmosphere: 15-50 km

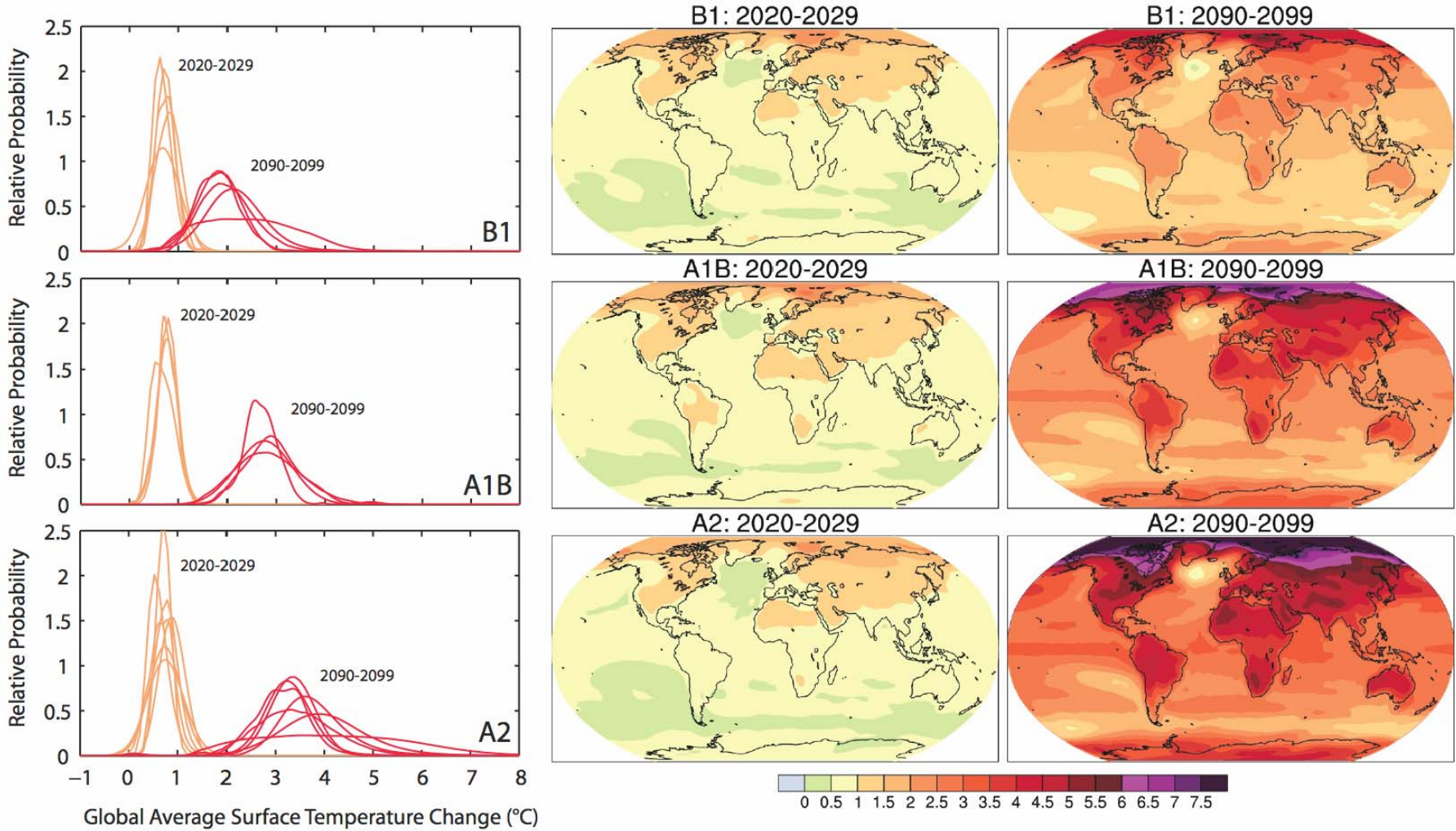


Escenarios Desarrollo
Economico-Social

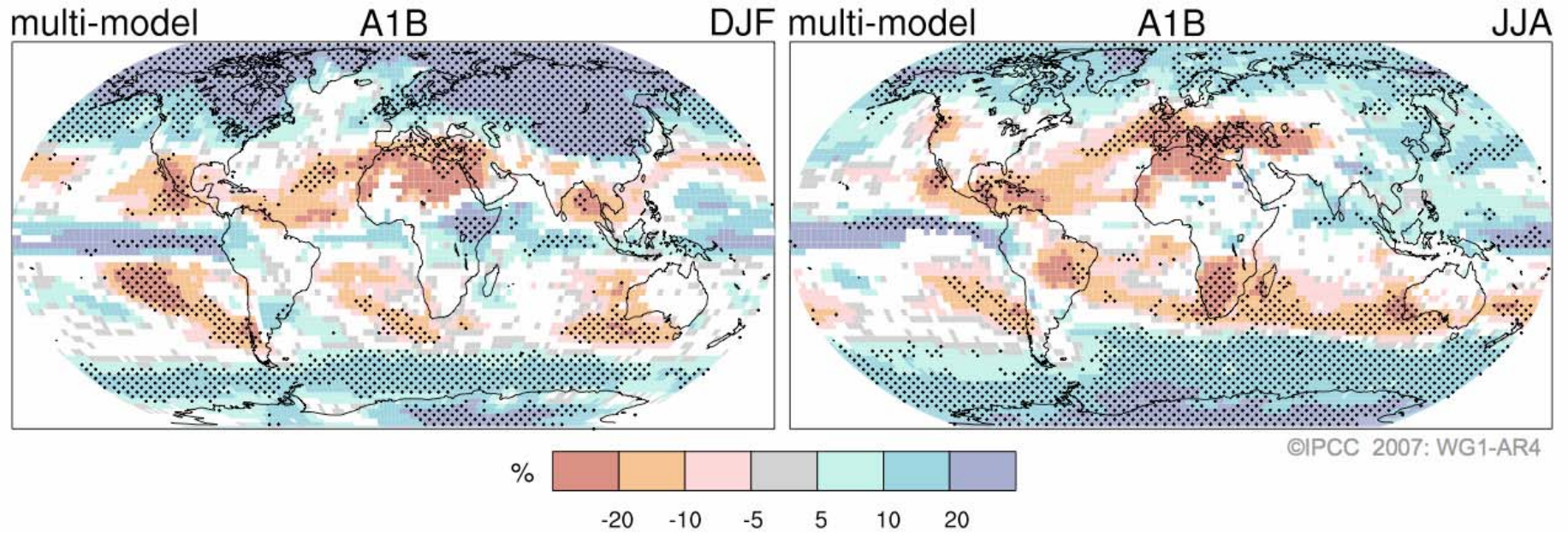
GCMs



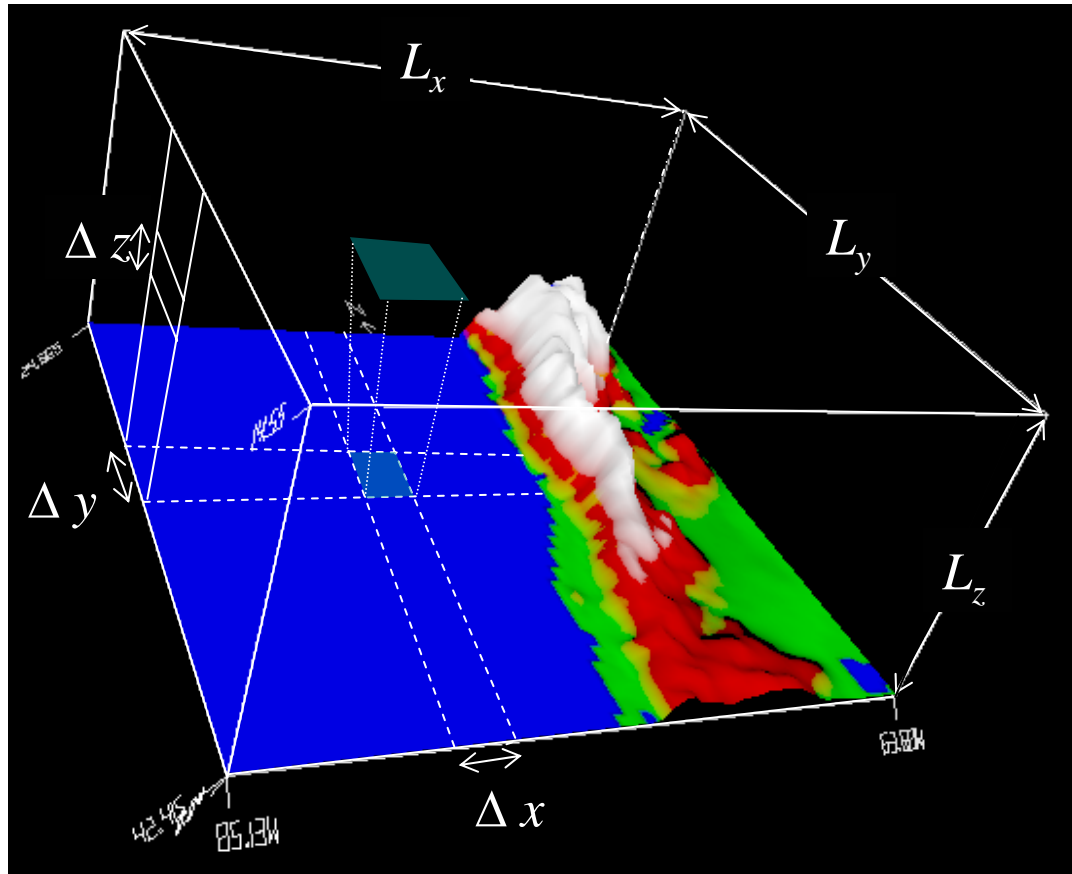
AOGCM Projections of Surface Temperatures



Projected Patterns of Precipitation Changes



Regional Models (LAM, Mesoscale Models)

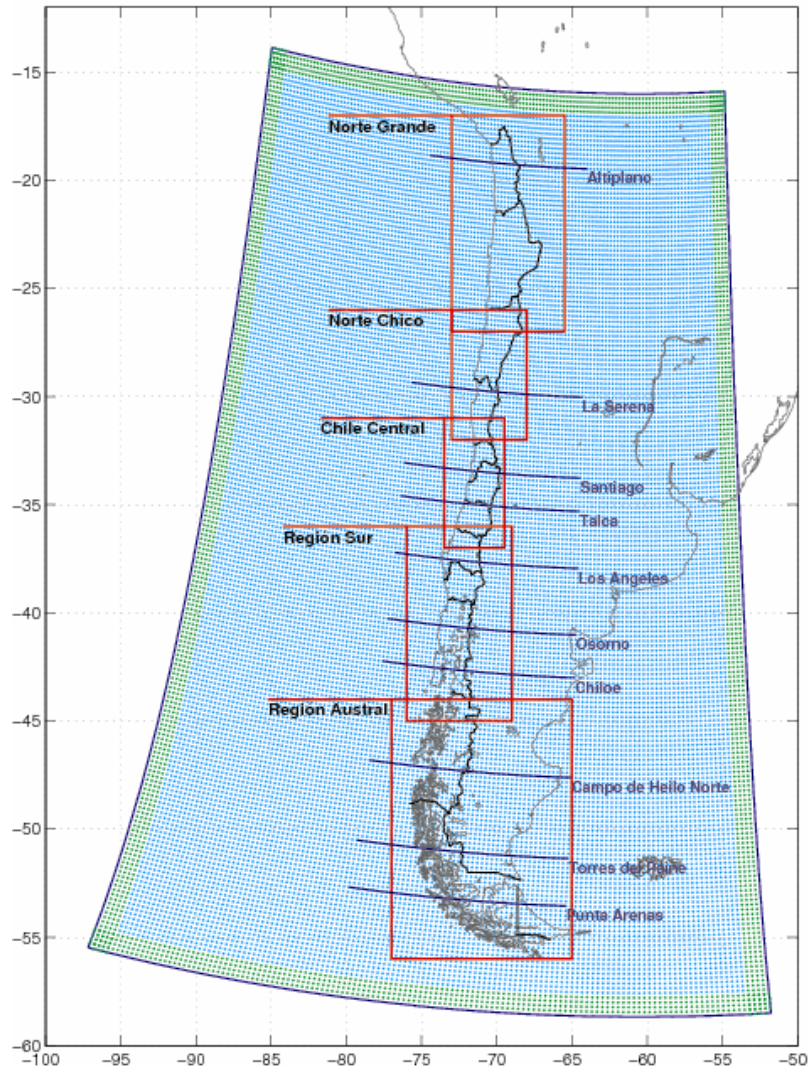


$\Delta x \sim \Delta y \sim 1-50 \text{ km}$ $\Delta z \sim 50-200 \text{ m}$ $\Delta t \sim \text{seconds}$
 $L_x \sim L_y \sim 100-5000 \text{ km}$ $L_z \sim 15 \text{ km}$ LBC from GCMs

Main Problem: Garbage in – Garbage out

Proyecto CONAMA – DGF/UCH

<http://www.dgf.uchile.cl/PRECIS>



Model:

- PRECIS – UK

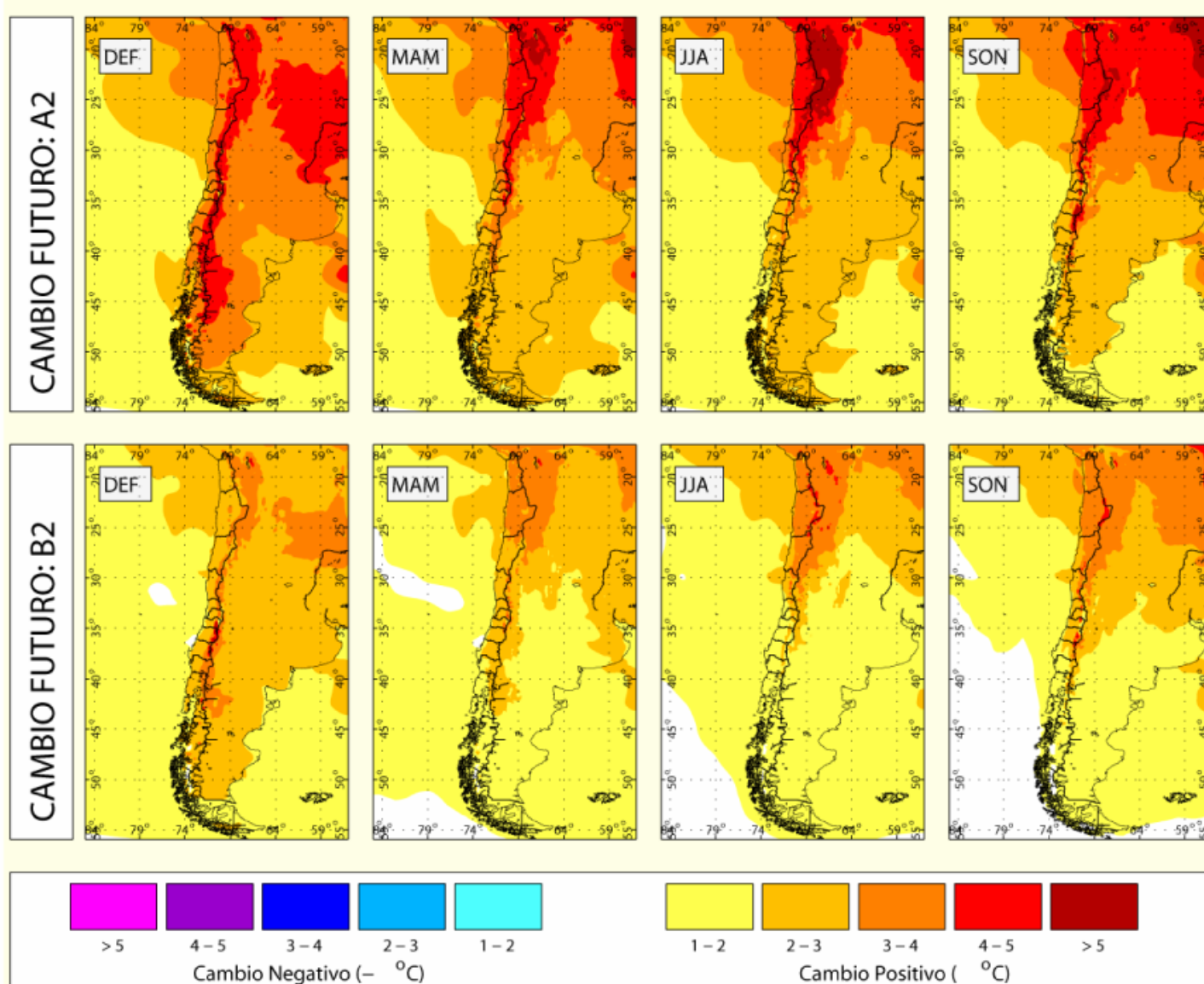
Single domain

- Horiz. grid spacing. 25 km
- 19 vertical levels
- Lateral BC: HadAM every 6h
- Sfc. BC: HadISST1 + Linear trend

Simulations

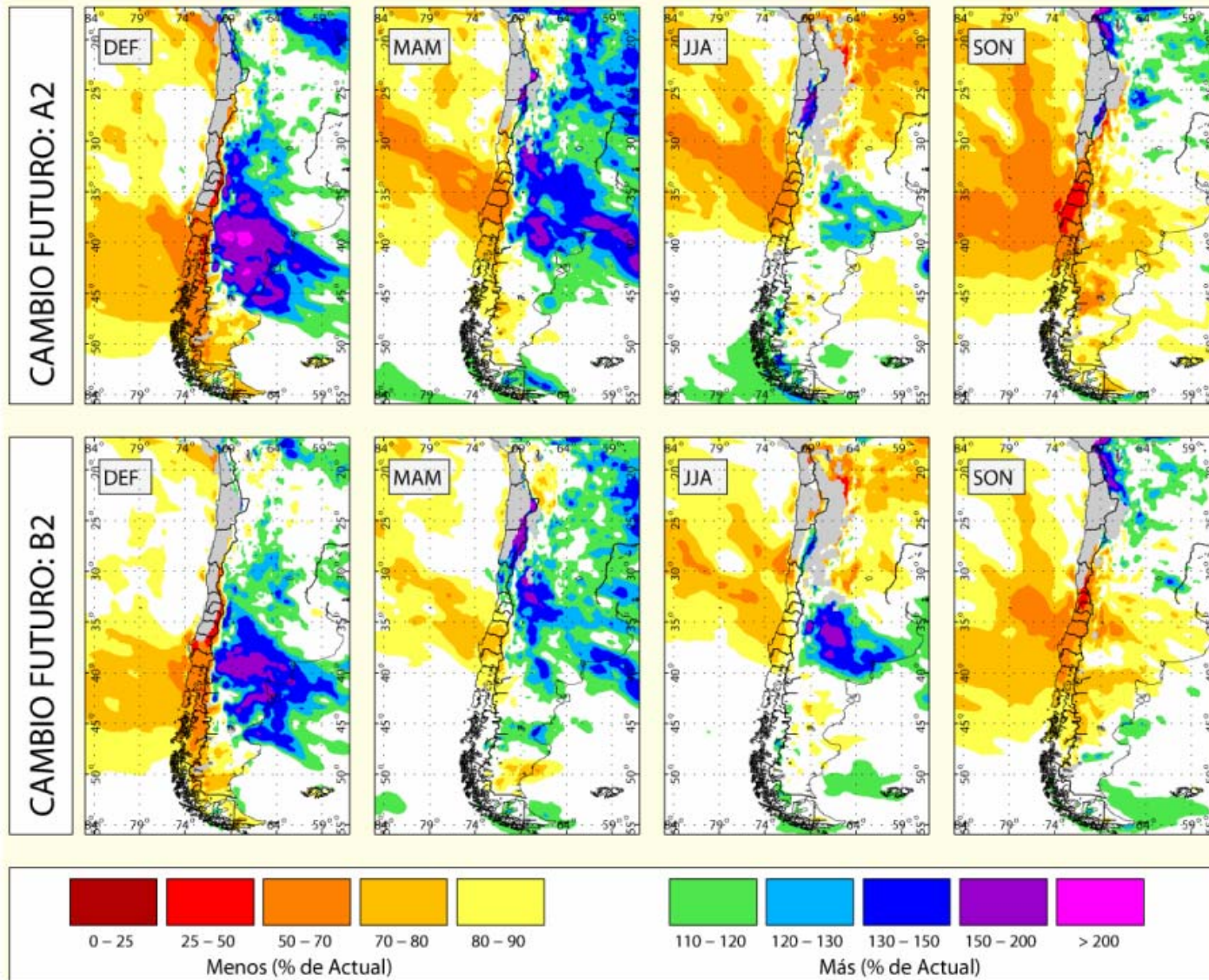
- **1961-1990 Baseline**
- **2071-2100 SRES A2 y B2**
- 30 years @ 3 min → 4 months per simulation in fast PC

PRECIS-DGF $T_{\text{futuro}} - T_{\text{presente}}$



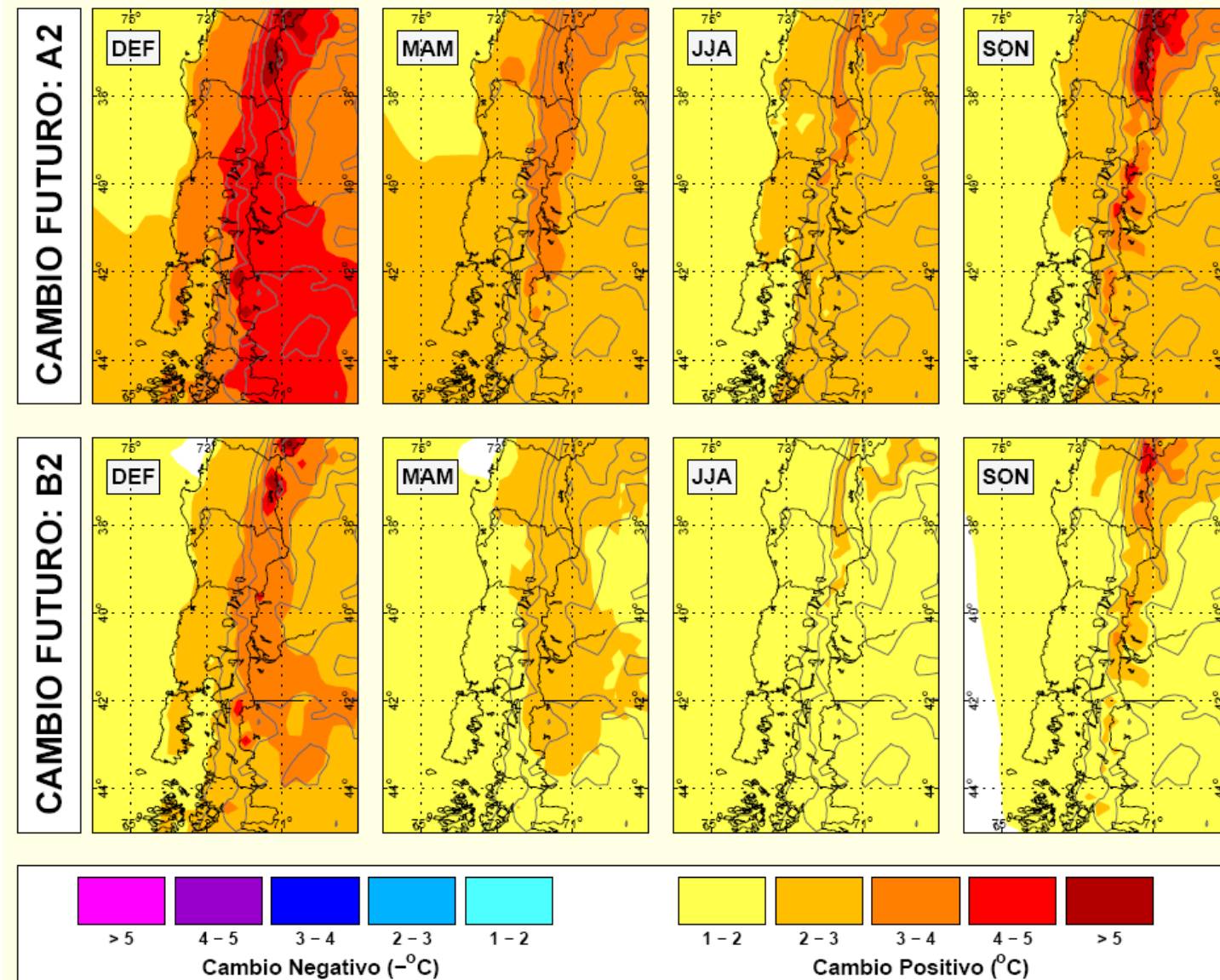
Futuro: 2071-2100 / Presente: 2071-2100

PRECIS-DGF $R_{\text{futuro}} / R_{\text{presente}}$



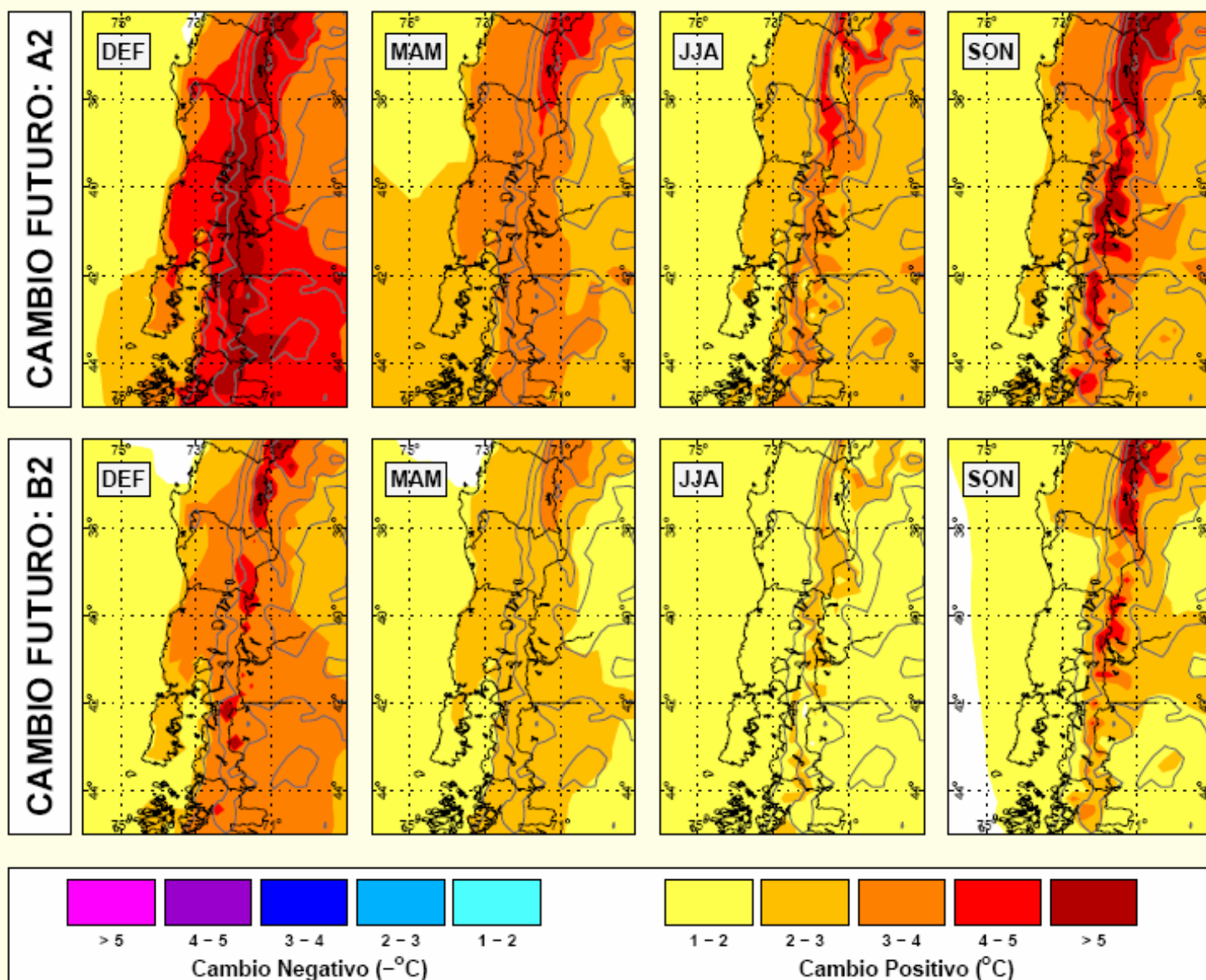
Futuro: 2071-2100 / Presente: 2071-2100

PRECIS-DGF $TM_{\text{futuro}} - TM_{\text{presente}}$



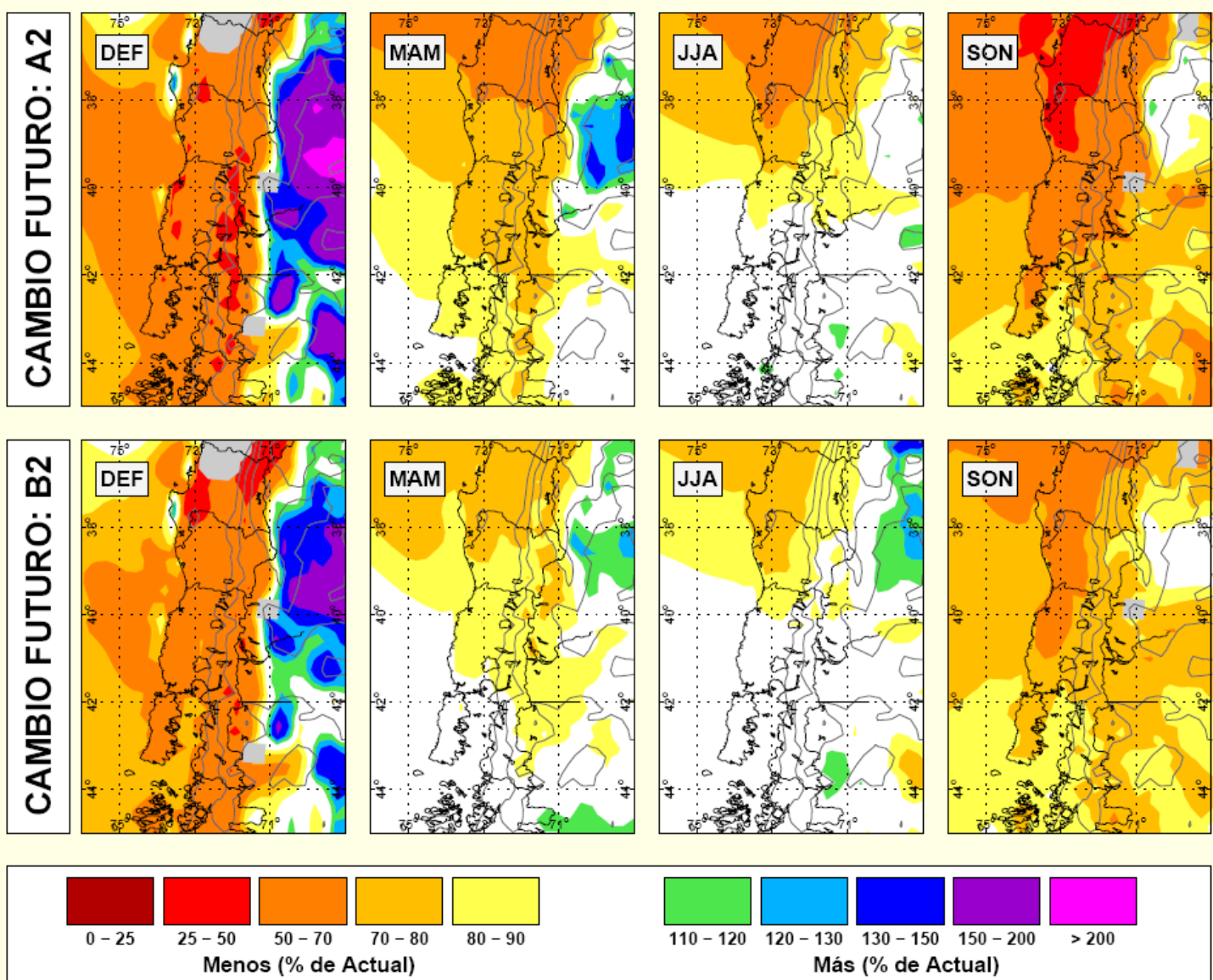
Futuro: 2071-2100 / Presente: 1961-1990

PRECIS-DGF $TX_{\text{futuro}} - TX_{\text{presente}}$



Futuro: 2071-2100 / Presente: 1961-1990

PRECIS-DGF $R_{\text{futuro}} / R_{\text{presente}}$

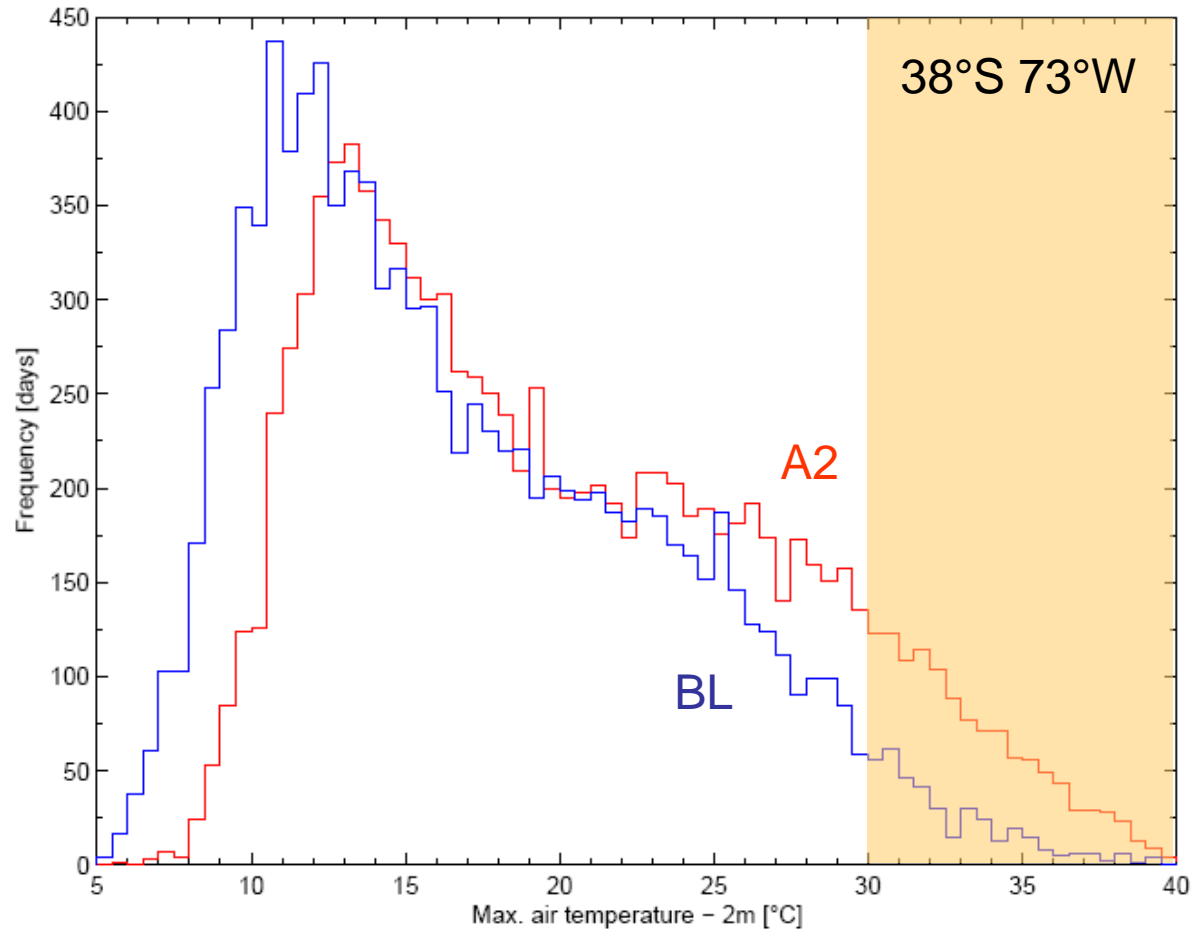


Futuro: 2071-2100 / Presente: 1961-1990

PRECIS-DGF

Probabilidad de días cálidos ($T_x > 30^\circ\text{C}$, Nov-Mar)

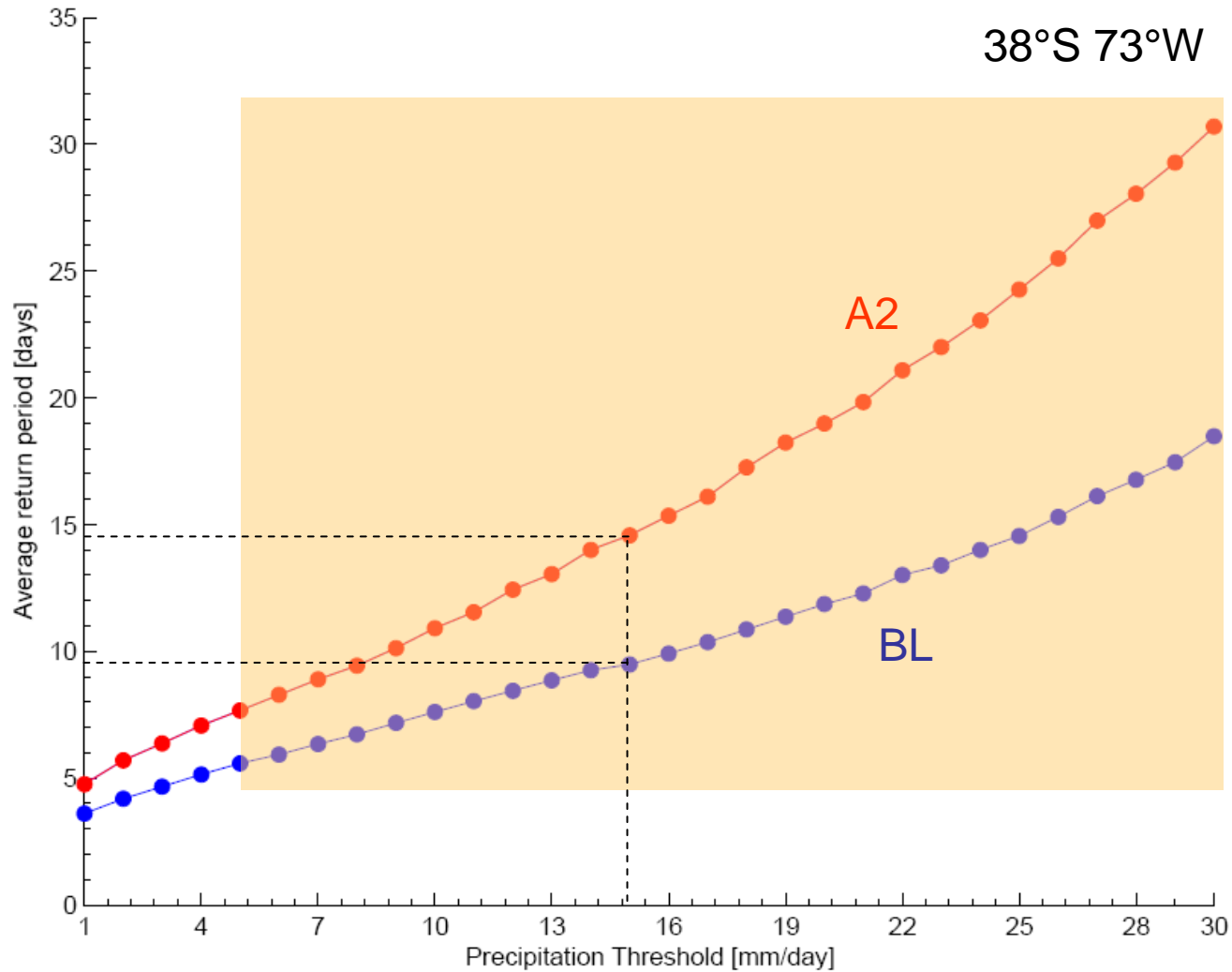
A2: 28% , BL: 8%



Futuro: 2071-2100 / Presente: 1961-1990

PRECIS-DGF

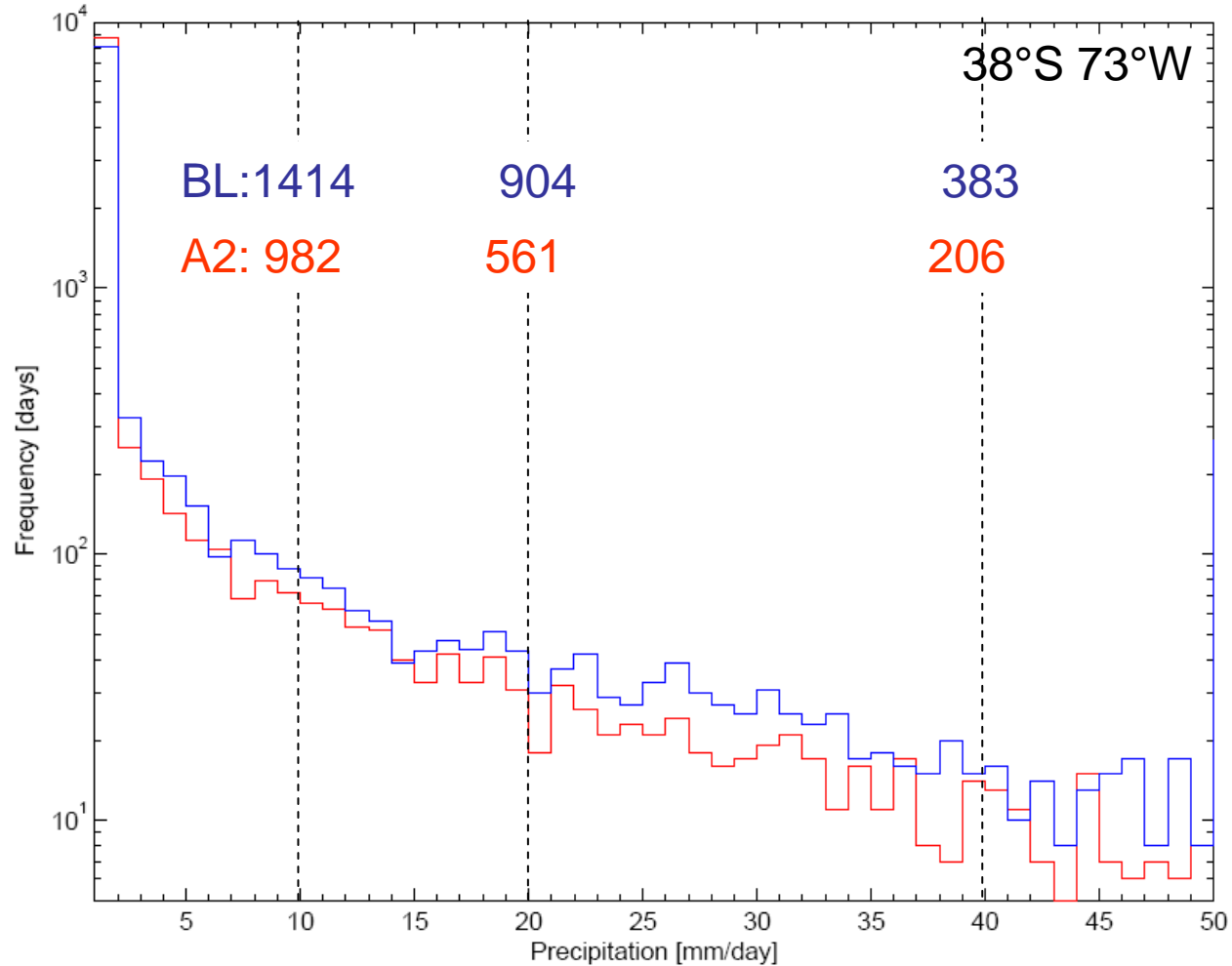
¿Cuanto tiempo transcurre entre episodios de precipitación?
e.g.: PP=15 mm: 9 días clima actual, 15 días clima A2



Futuro: 2071-2100 / Presente: 1961-1990

PRECIS-DGF

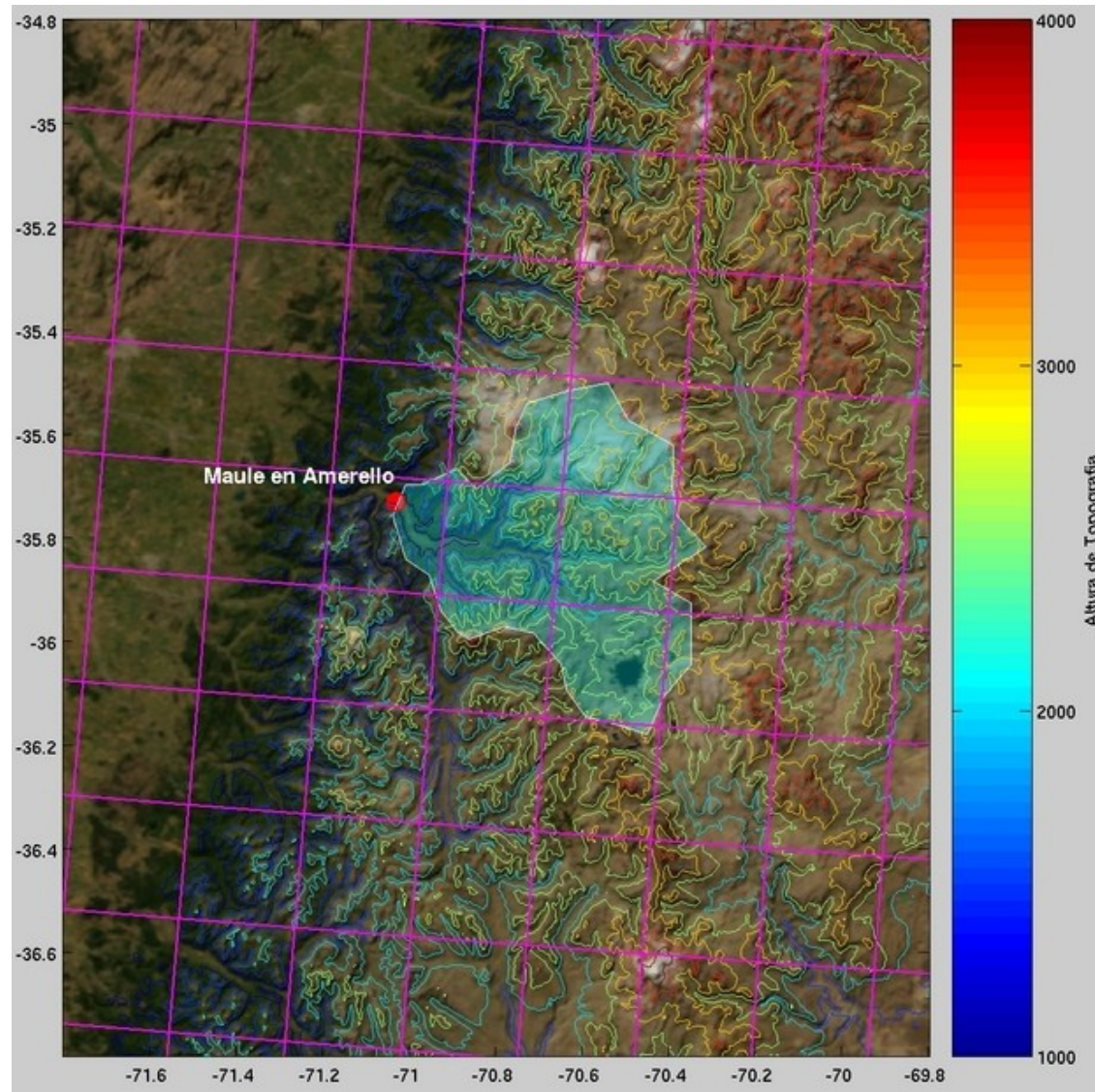
Probabilidad de días lluviosos



Futuro: 2071-2100 / Presente: 1961-1990

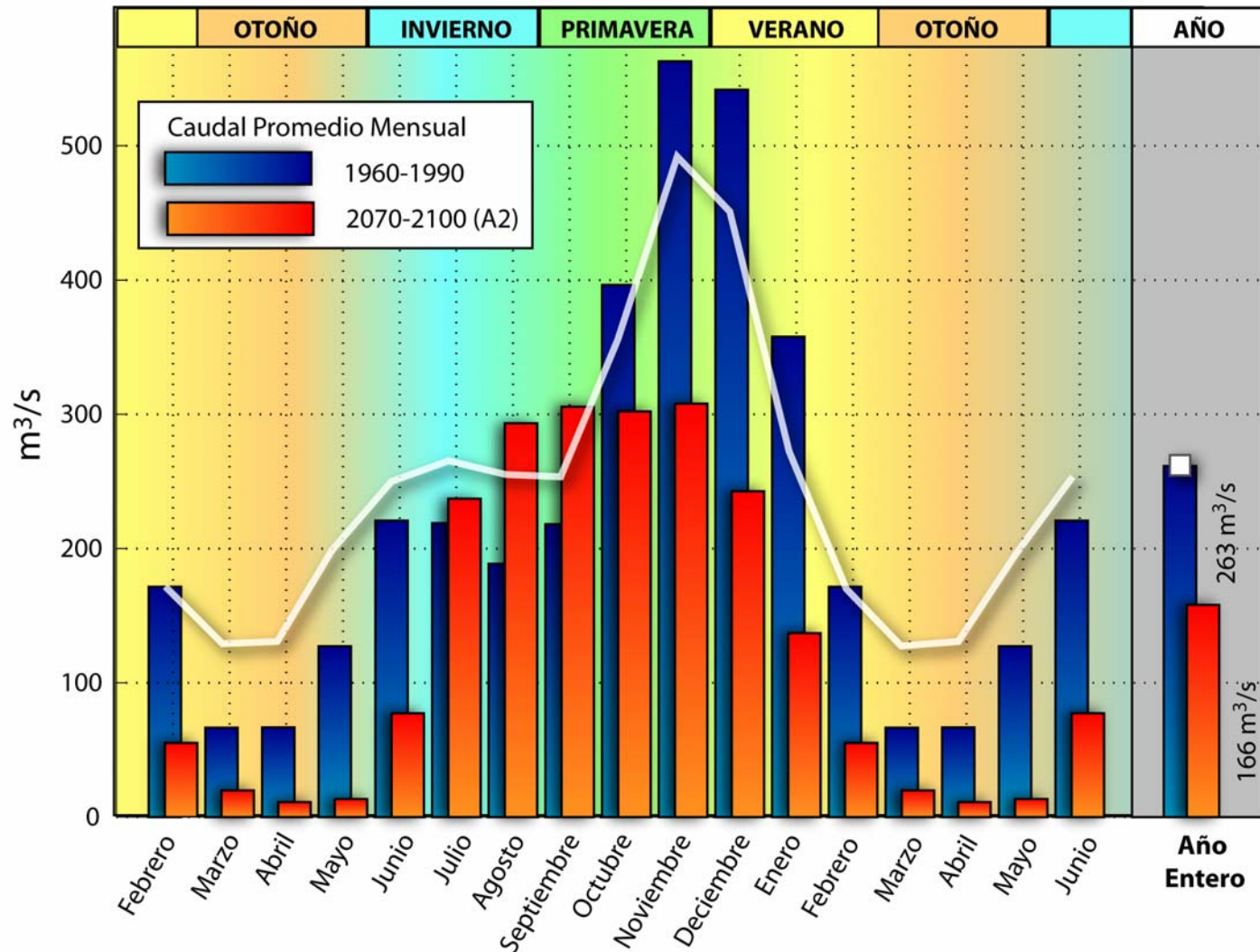
PRECIS-DGF

Acomplamiento con modelos hidrológicos.



PRECIS-DGF Acomplamiento con modelos hidrológicos.

CAUDAL SIMULADO DEL RIO MAULE* - PRESENTE y FUTURO (A2)



* Rio Maule en Armerillo - Pre-Cordillera

Conclusiones

Existen manifestaciones del cambio climático asociado a los GI en las últimas décadas a lo largo del país.

Cambios proyectados son en algunos casos similares en magnitud y signo a los observados en las últimas décadas.

Zona centro sur afectada por disminución de precipitación (especialmente en primavera, $\sim 1/2-3/4$ actual) y aumento de temperatura (especialmente T_x , $\sim + 2-4^\circ\text{C}$)

PRECIS-DGF es una buena base de datos para análisis sectoriales, pero solo un comienzo....