

Cambio Climático Global Bases Físicas e Impactos en Chile(*)

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Temario

1. La Evidencia
 - Paleo-cambios
 - Cambios en el siglo XX: Global /Regional
2. Bases Físicas del Cambio
3. Pronóstico para mañana

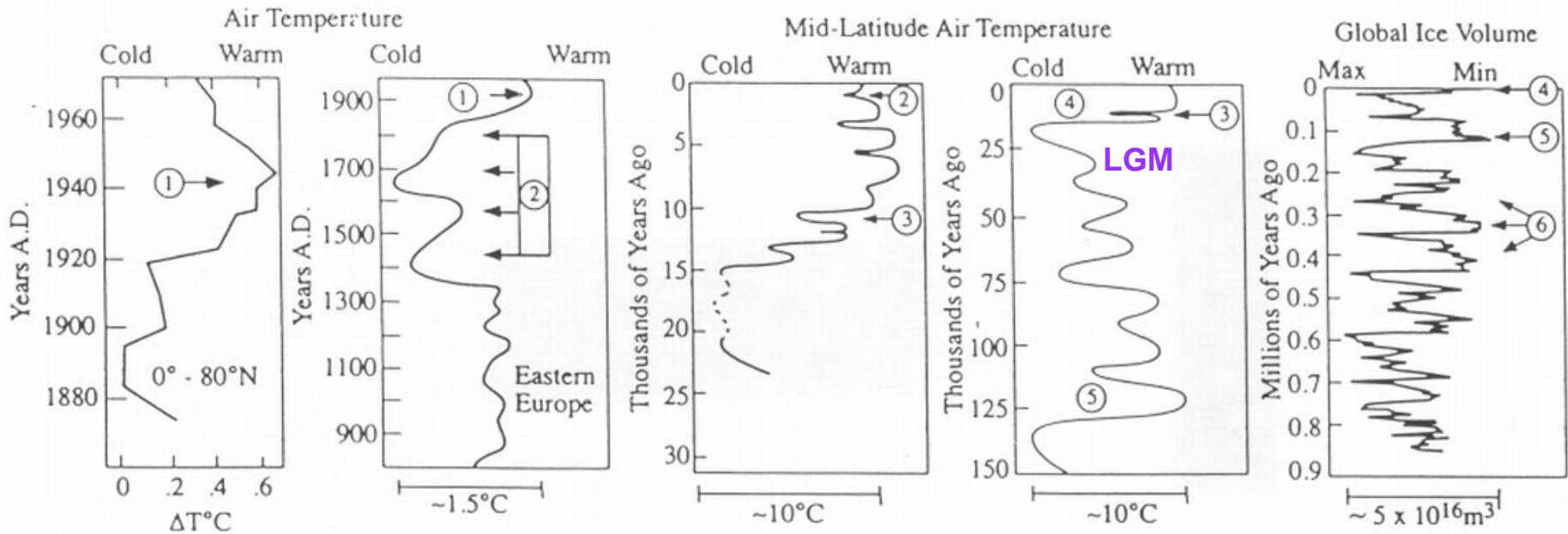
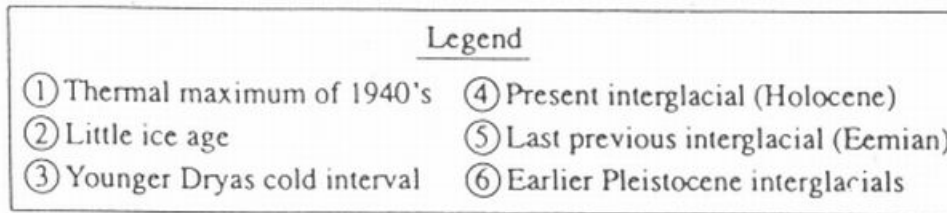
La evidencia



Paleoindicadores: indirecta estimación de Temp. y Precip.



Entre mas reciente mas detalle...



Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover

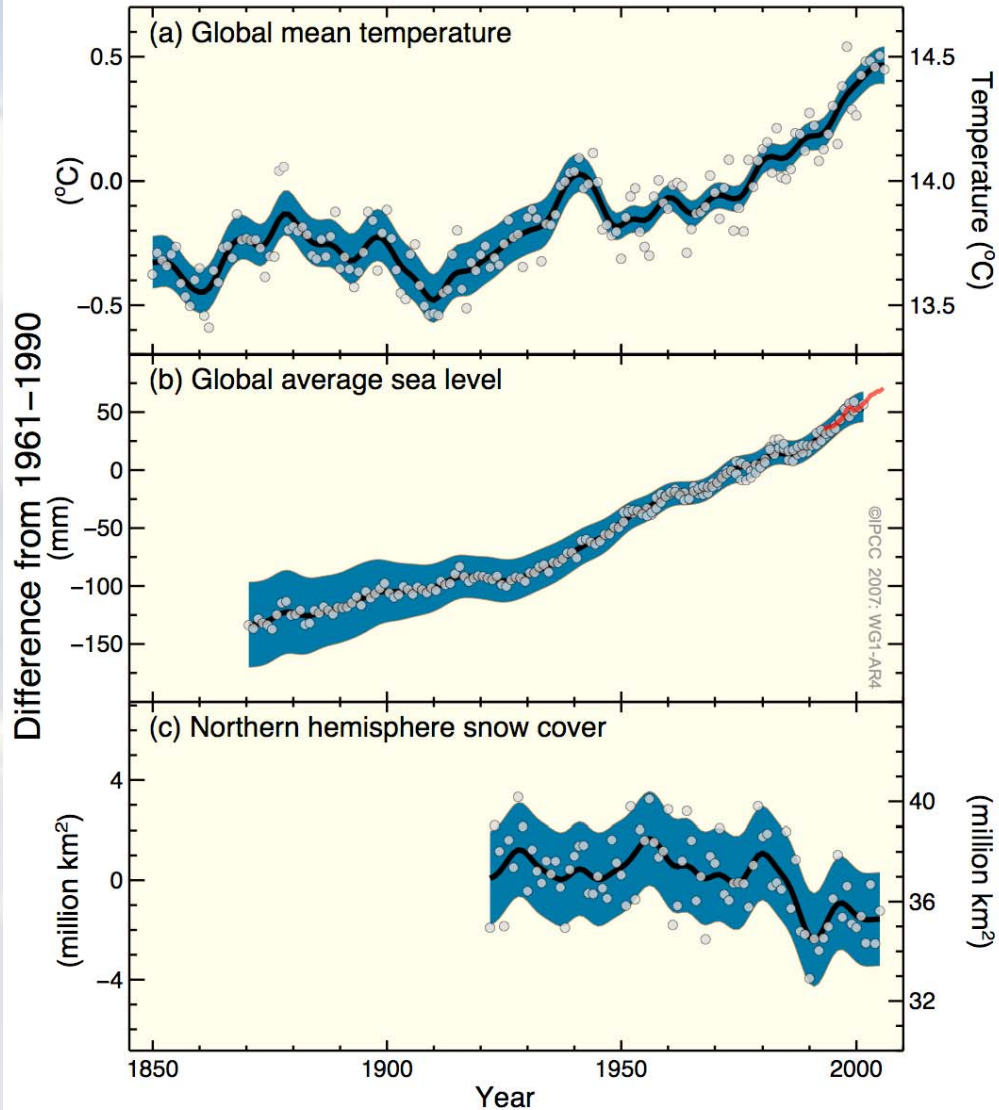
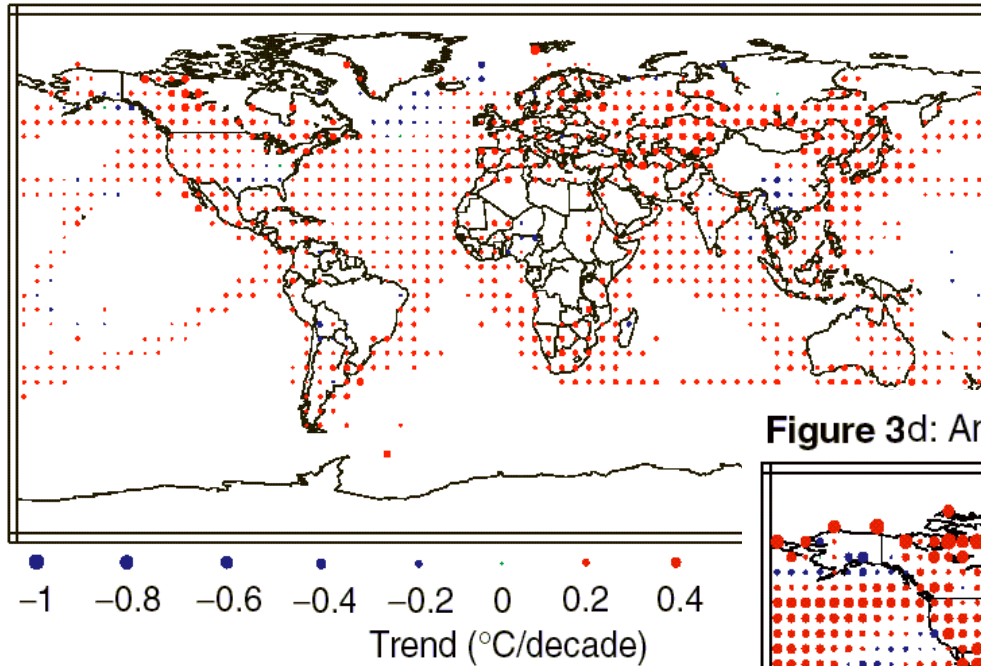
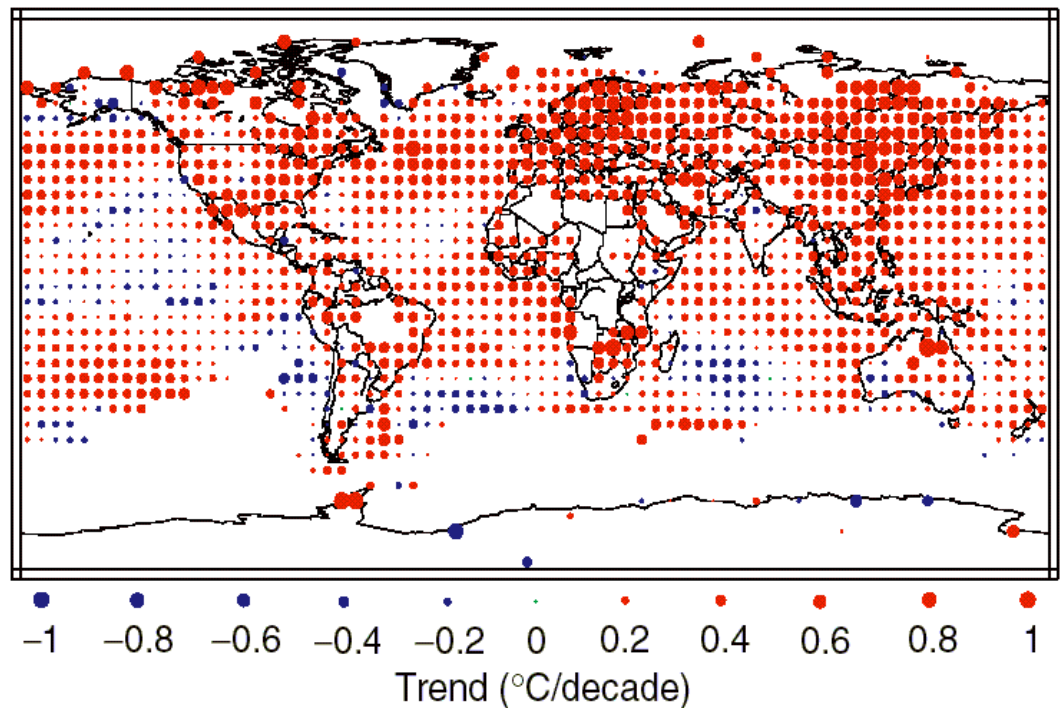


Figure 3a: Annual temperature trends, 1901 to 2000

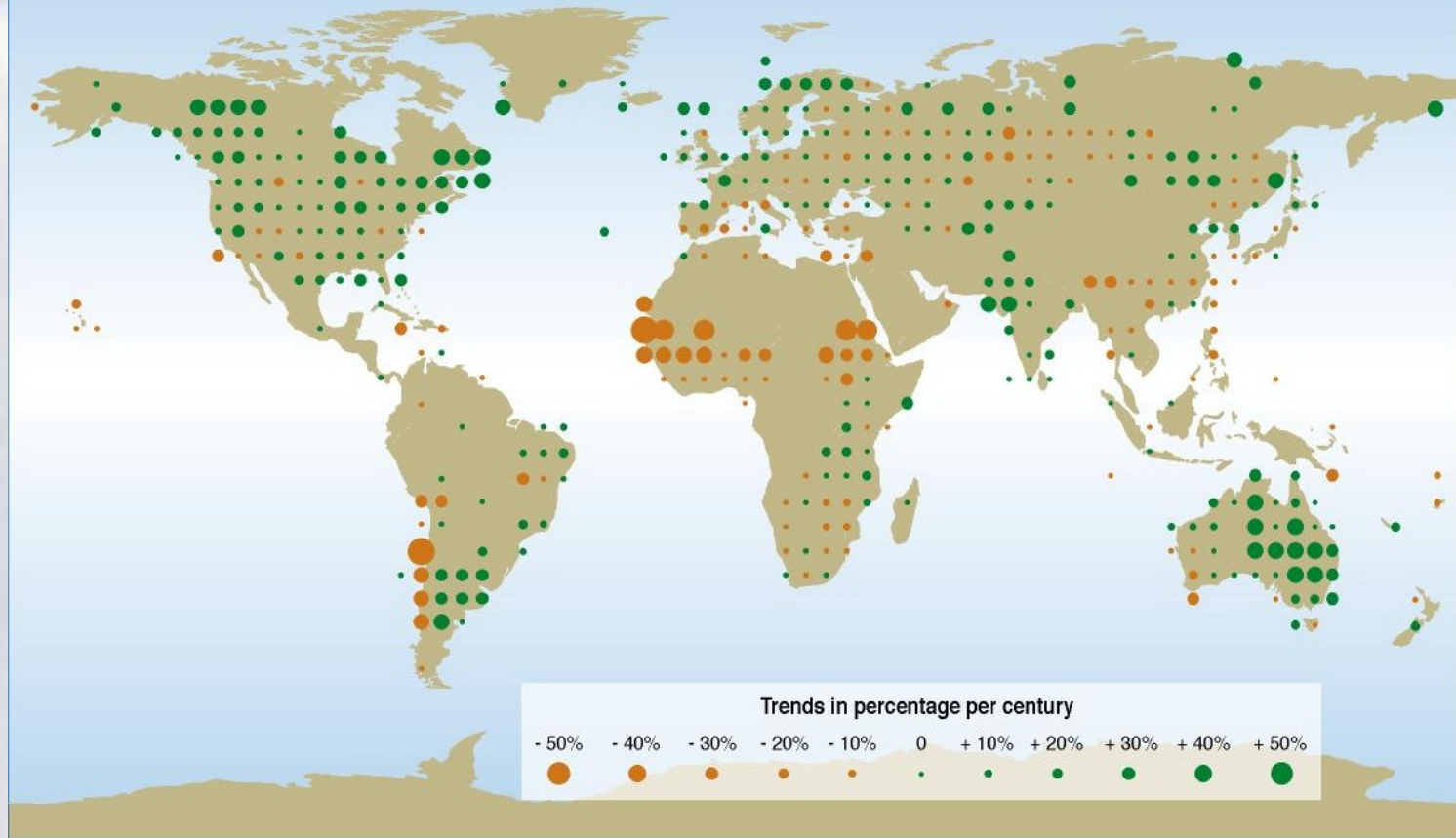


**Calentamiento global
NO es uniforme ni en el
tiempo ni el espacio**

Figure 3d: Annual temperature trends, 1976 to 2000

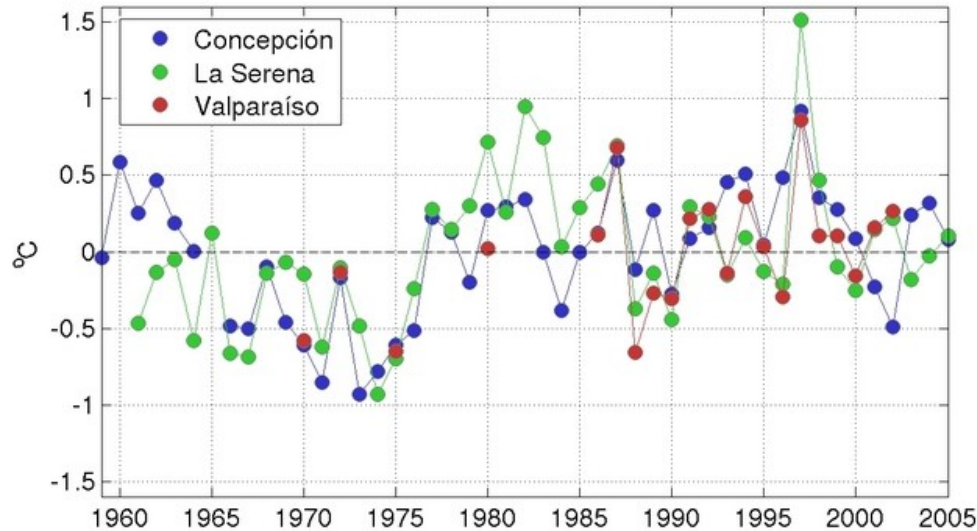


Annual precipitation trends: 1900 to 2000





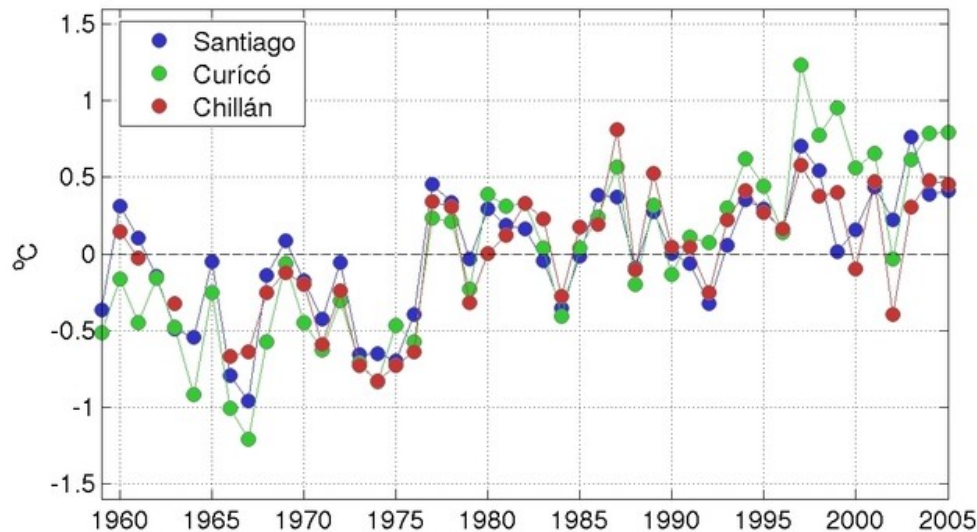
Estaciones Costeras



1977-2005:

$\Delta T \sim 0^\circ\text{C/decade}$

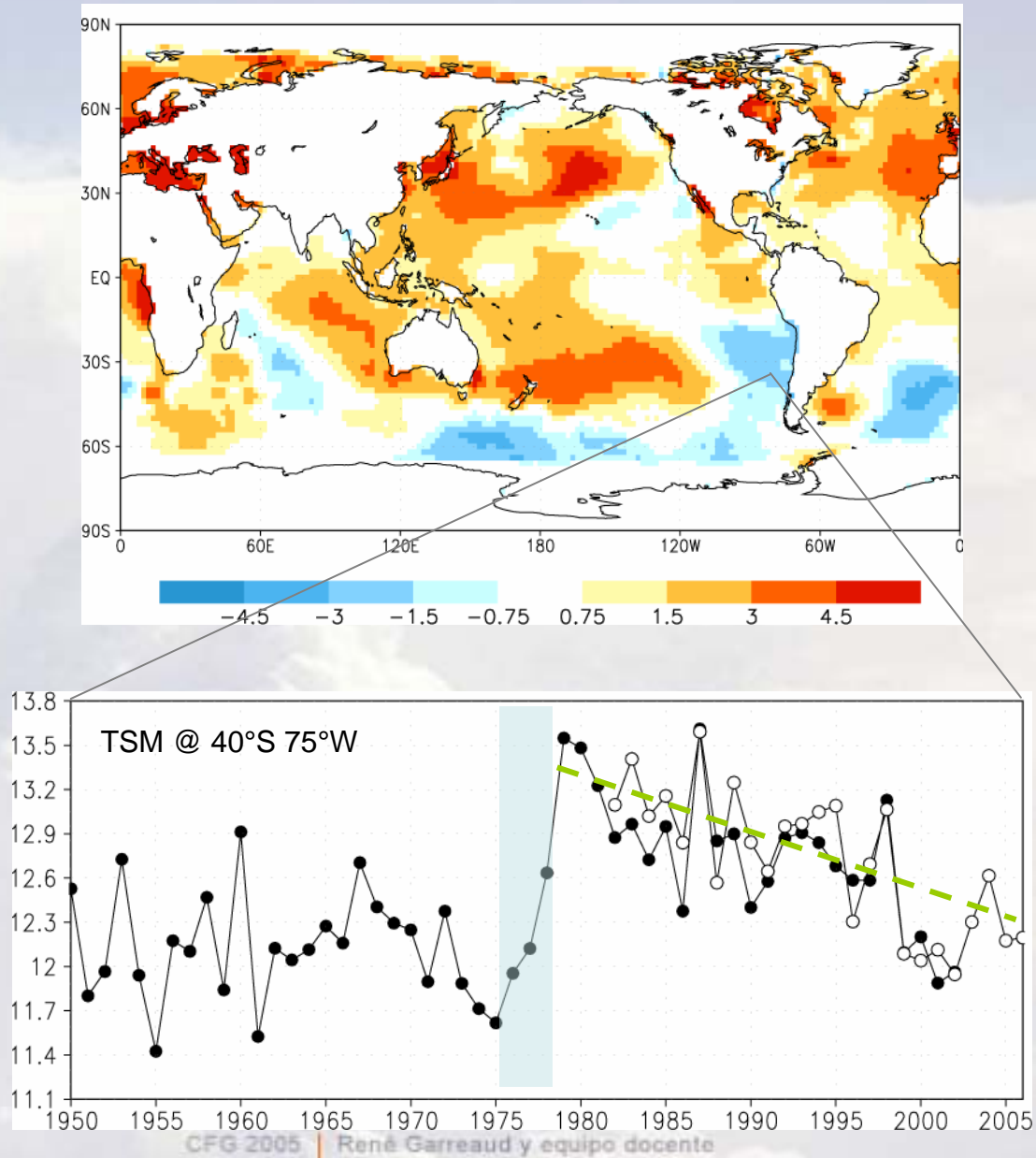
Estaciones Valle Central



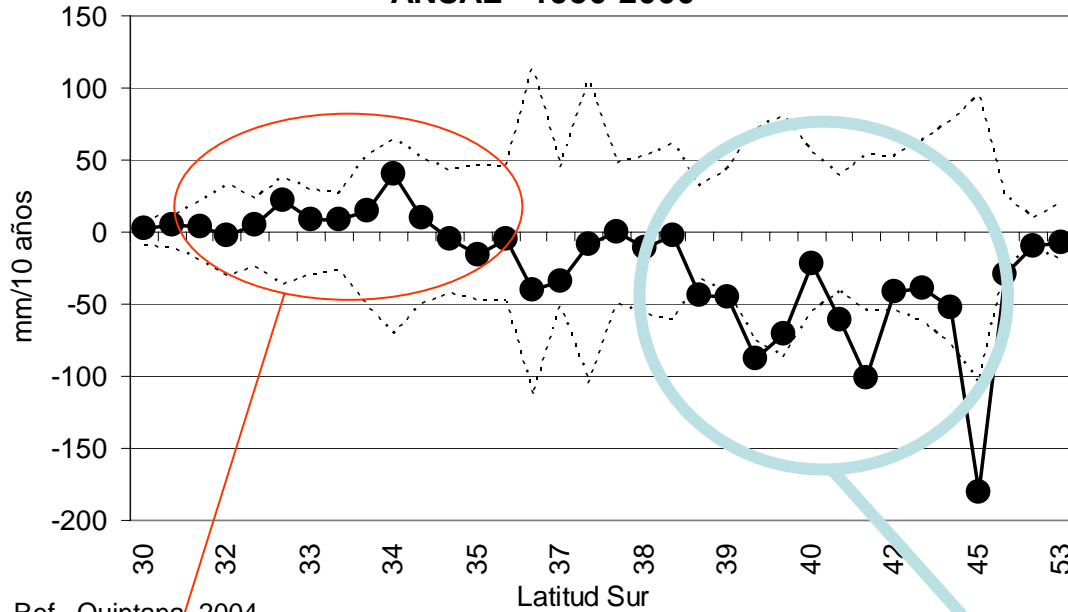
$\Delta T \sim 0.25^\circ\text{C/decade}$

$\Delta T \sim 2.50^\circ\text{C/century}$

Figura 5: Tendencia de la temperatura superficial del mar ($^{\circ}\text{C}/28$ años) en el periodo 1978-2004

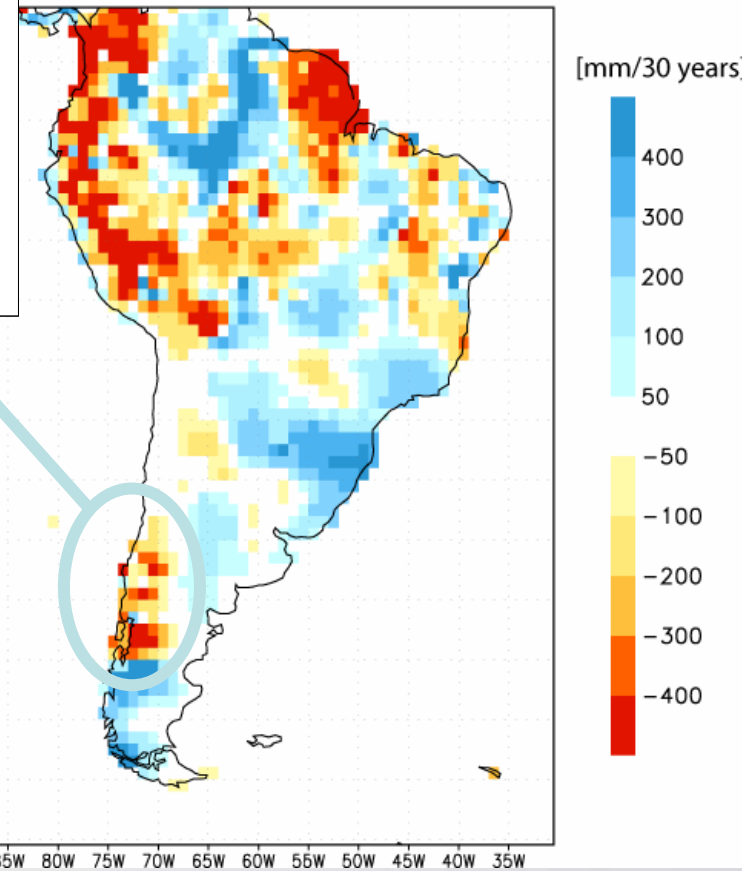


TENDENCIA DE LA PRECIPITACION ANUAL - 1950-2000



Ref. Quintana 2004

Semiarid climate
MAP ~ 30-500 mm
 $\sigma(\text{IA})/\text{MAP} \sim 0.3 - 0.5$
Strong ENSO Impact



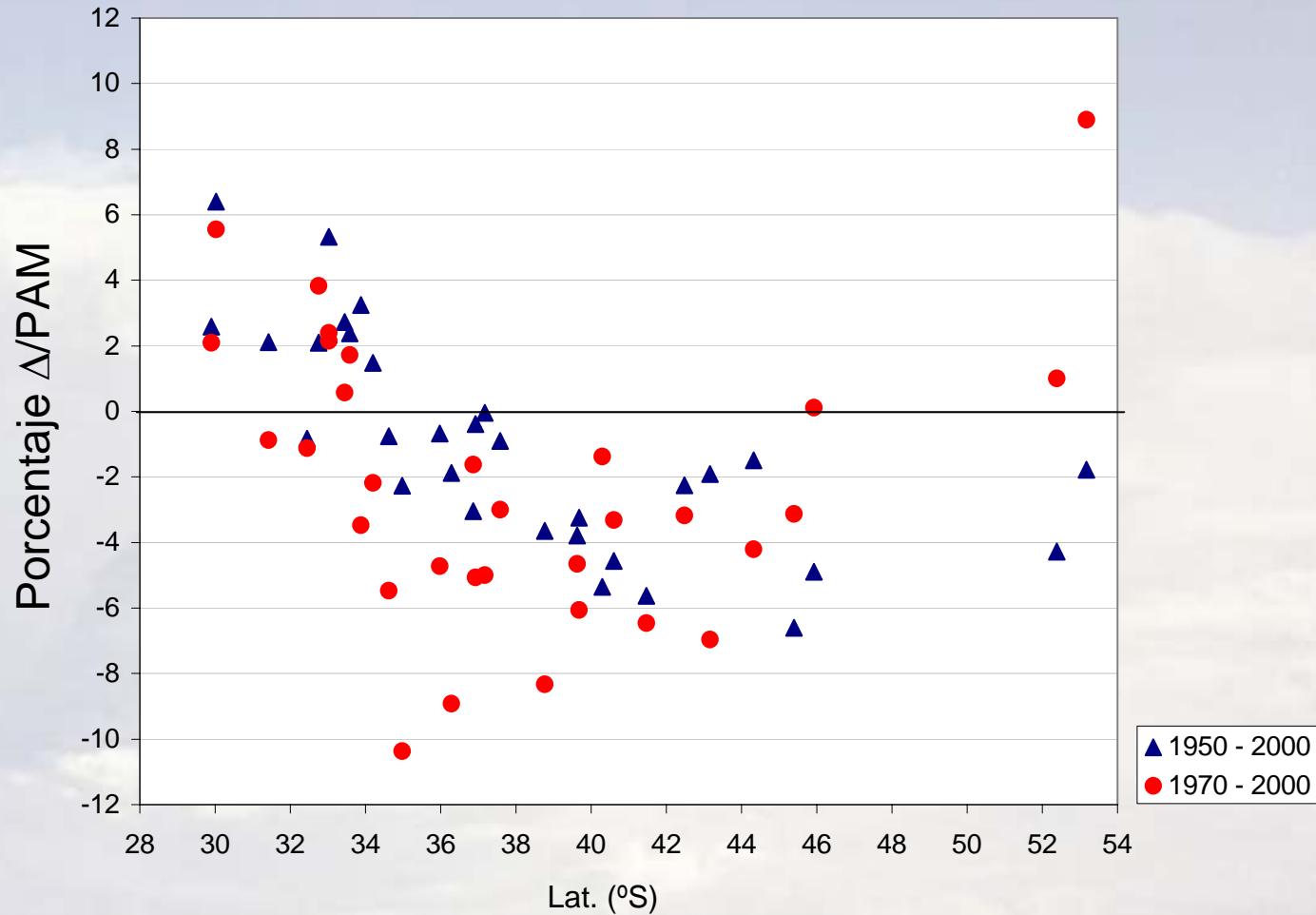


Figura 2. Tendencia de la precipitación anual expresada como el cambio porcentual por década (el porcentaje se evalúa con respecto al promedio de precipitación durante el periodo respectivo).

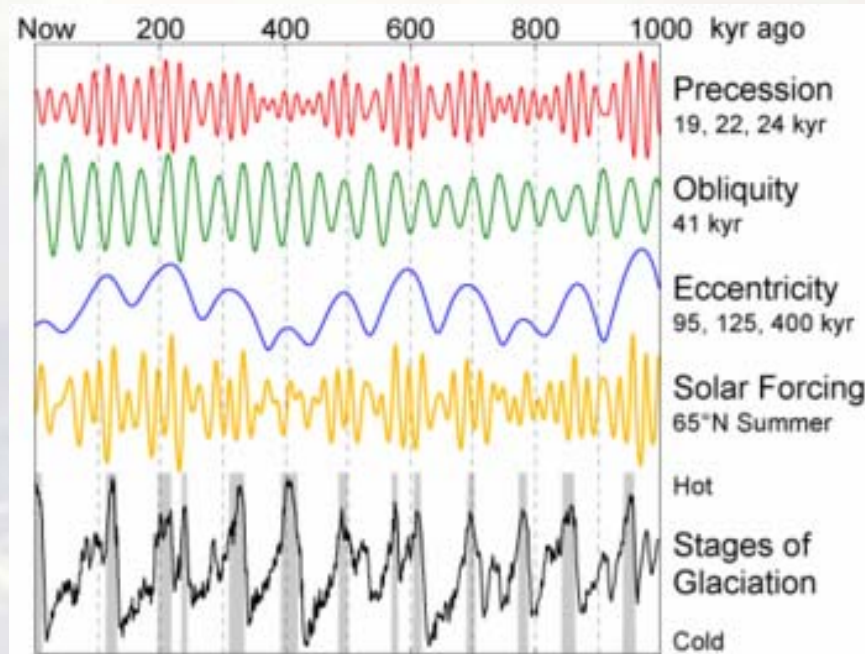
Factores de cambio climático

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



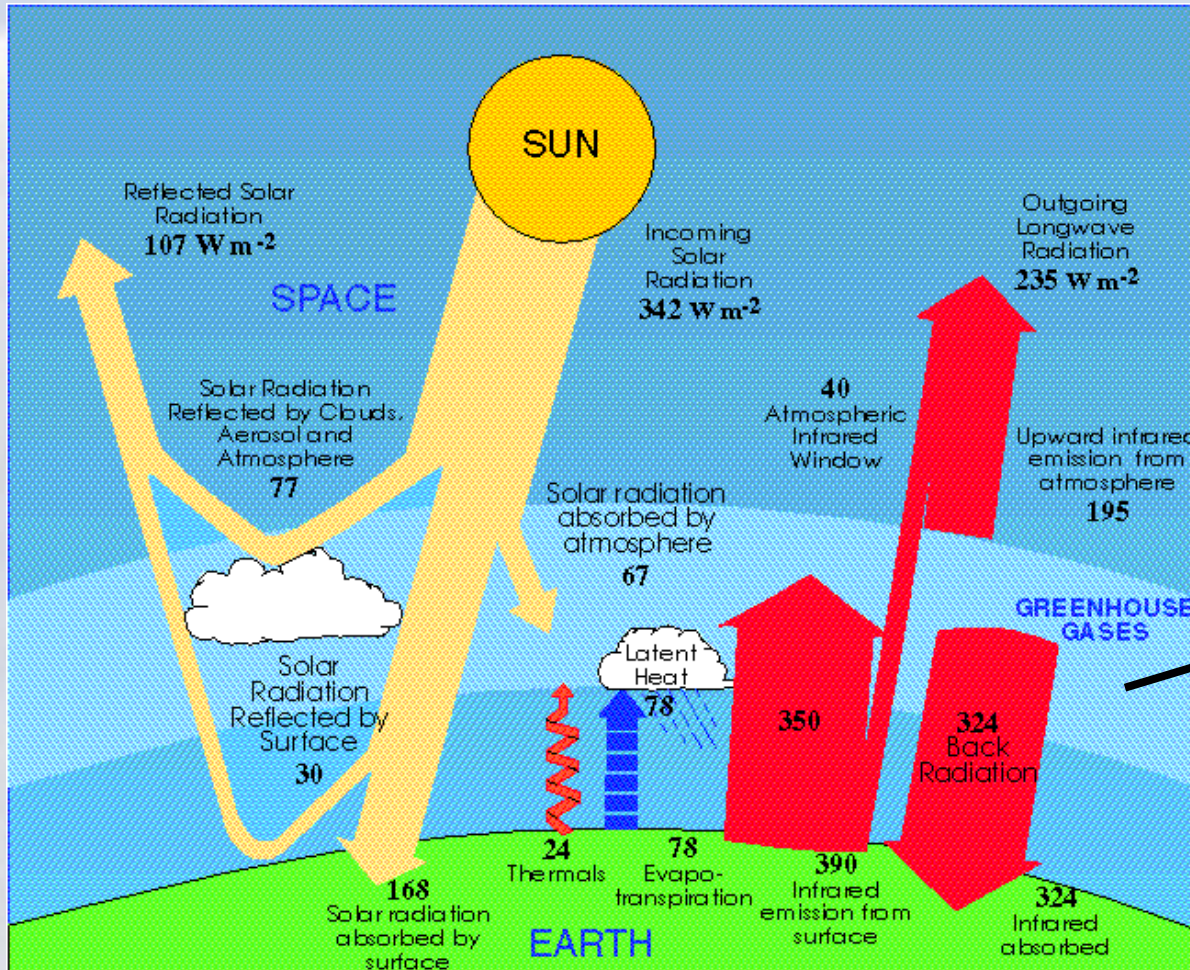
Teoría de Milankovish

**Cambios en Geometría Tierra-Sol → Cambios en energía disponible
→ “Gatillo” para cambios climáticos globales...**



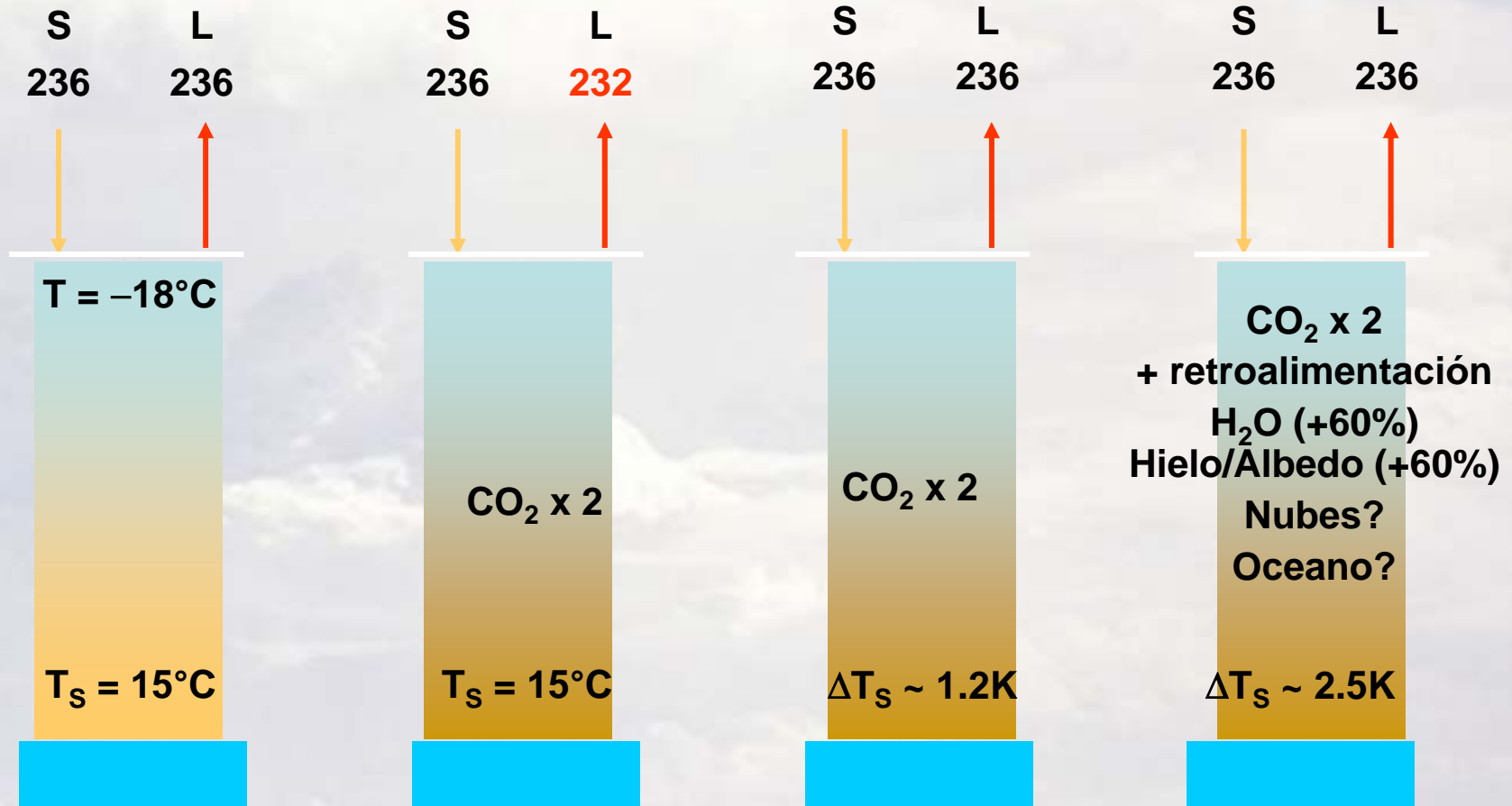
An often-cited 1980 study by Imbrie and Imbrie determined that "Ignoring anthropogenic and other possible sources of variation acting at frequencies higher than one cycle per 19,000 years, this model predicts that the long-term cooling trend which began some 6,000 years ago will continue for the next 23,000 years."^[4]

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

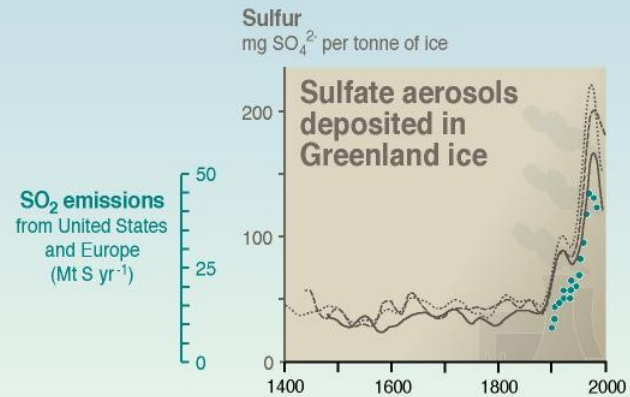
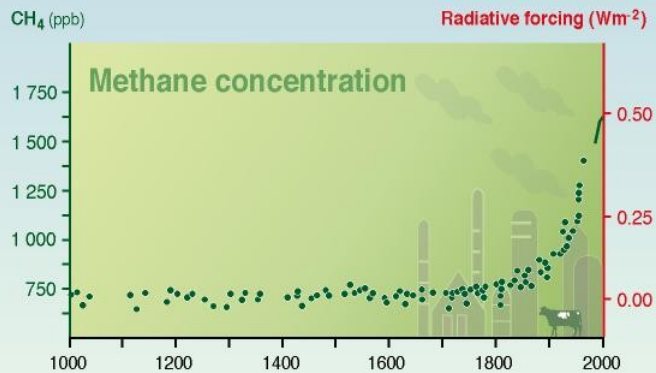
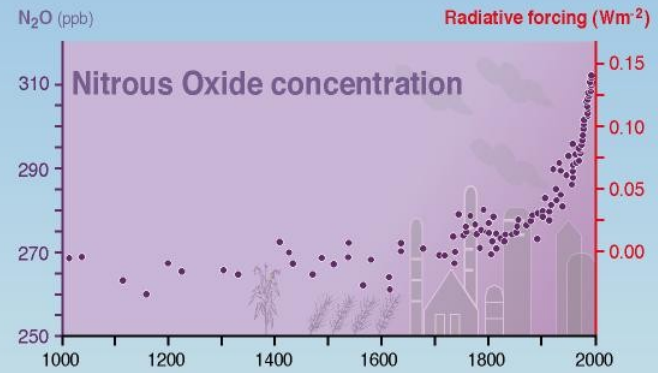
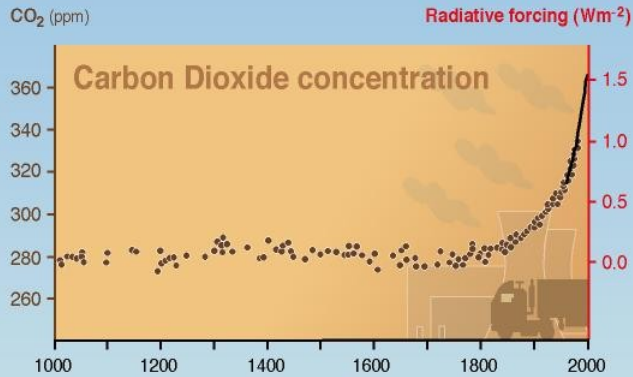


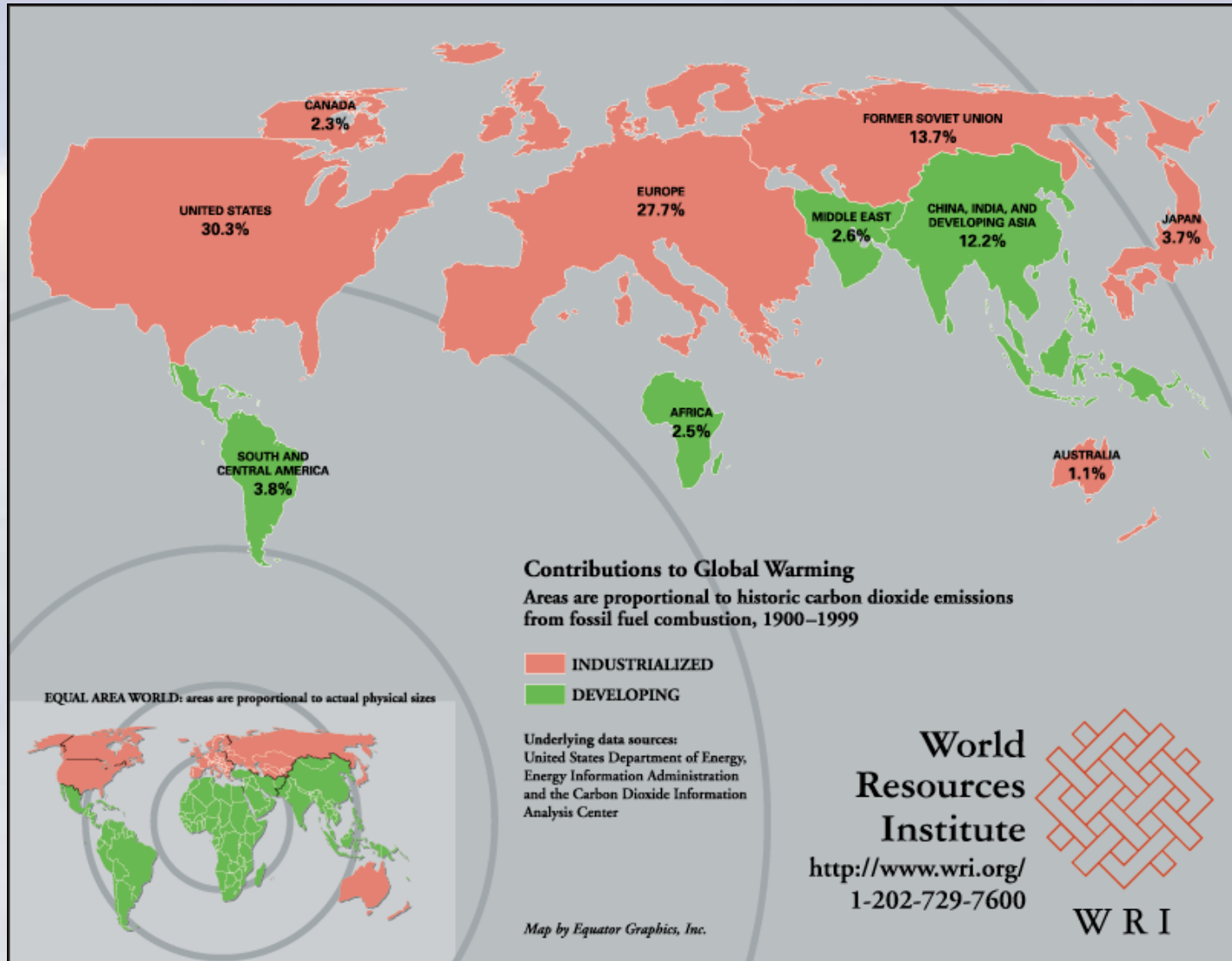
Gases Invernadero
 H_2O , CO_2 , CH_4 , N_2O

Efecto invernadero antrópico

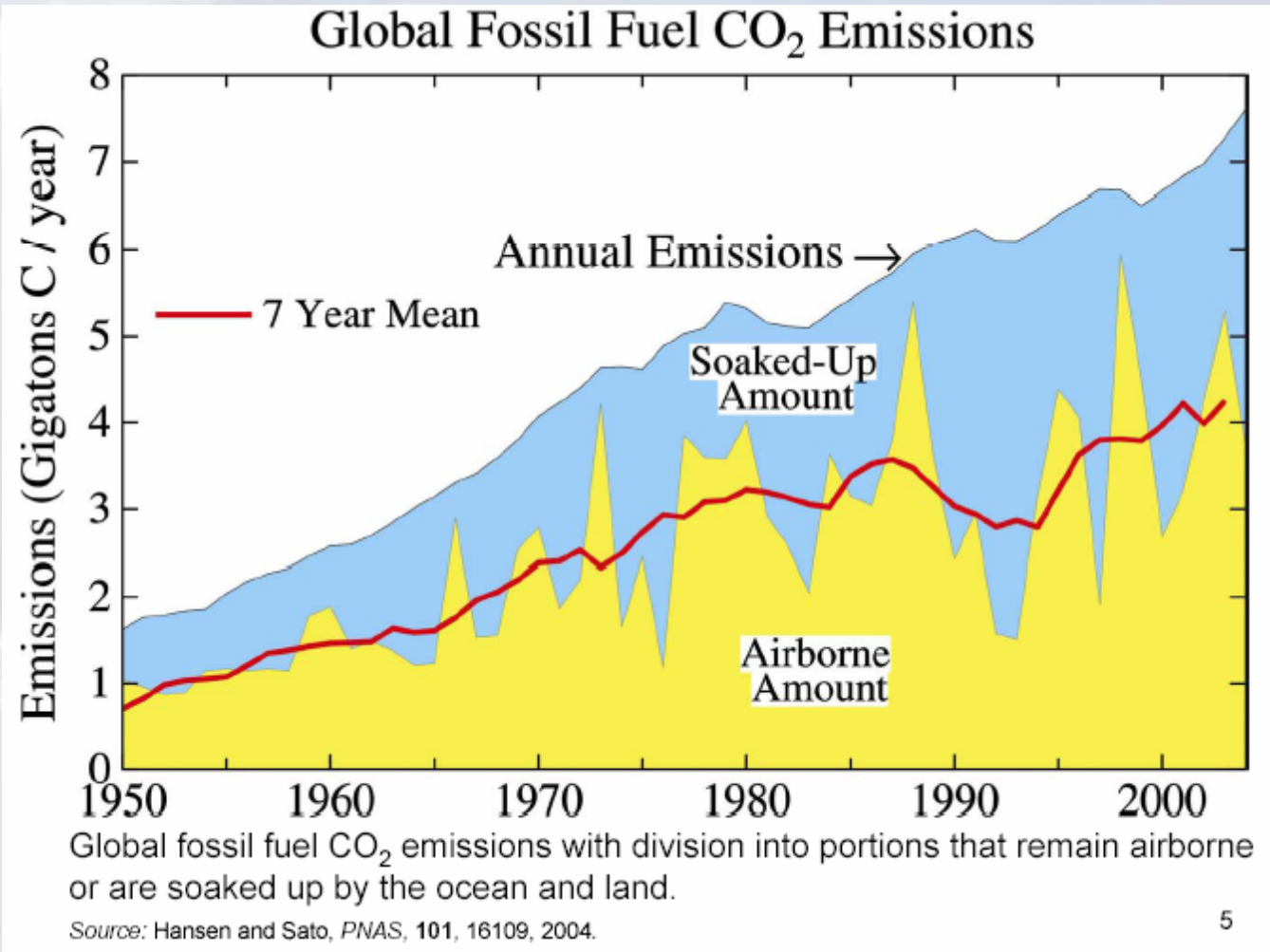


Indicators of the human influence on the atmosphere during the Industrial era





Durante el siglo XX el océano/biosfera ha capturado cerca del 40% del CO₂ emitido...captura puede variar (\pm ?) con incremento de T



Proyecciones climáticas para el siglo XXI



My first toy model

A system of coupled, non-linear algebraic equations

$$X_{(t)} = A \cdot X_{(t-1)} \cdot Y_{(t)} + B \cdot Z_{(t-1)} + \varepsilon_x$$

$$Y_{(t)} = C \cdot X_{(t-1)} \cdot Y_{(t-1)} + B \cdot Z_{(t)} + \varepsilon_y$$

$$Z_{(t)} = D \cdot Z_{(t-1)} \cdot Y_{(t)} + E \cdot X_{(t-1)} + \varepsilon_z$$

$$\varepsilon_x = \varepsilon_y = \varepsilon_z = 0$$

X, Y, Z: Time-dependent variables

Pressure, winds, temperature, moisture,....

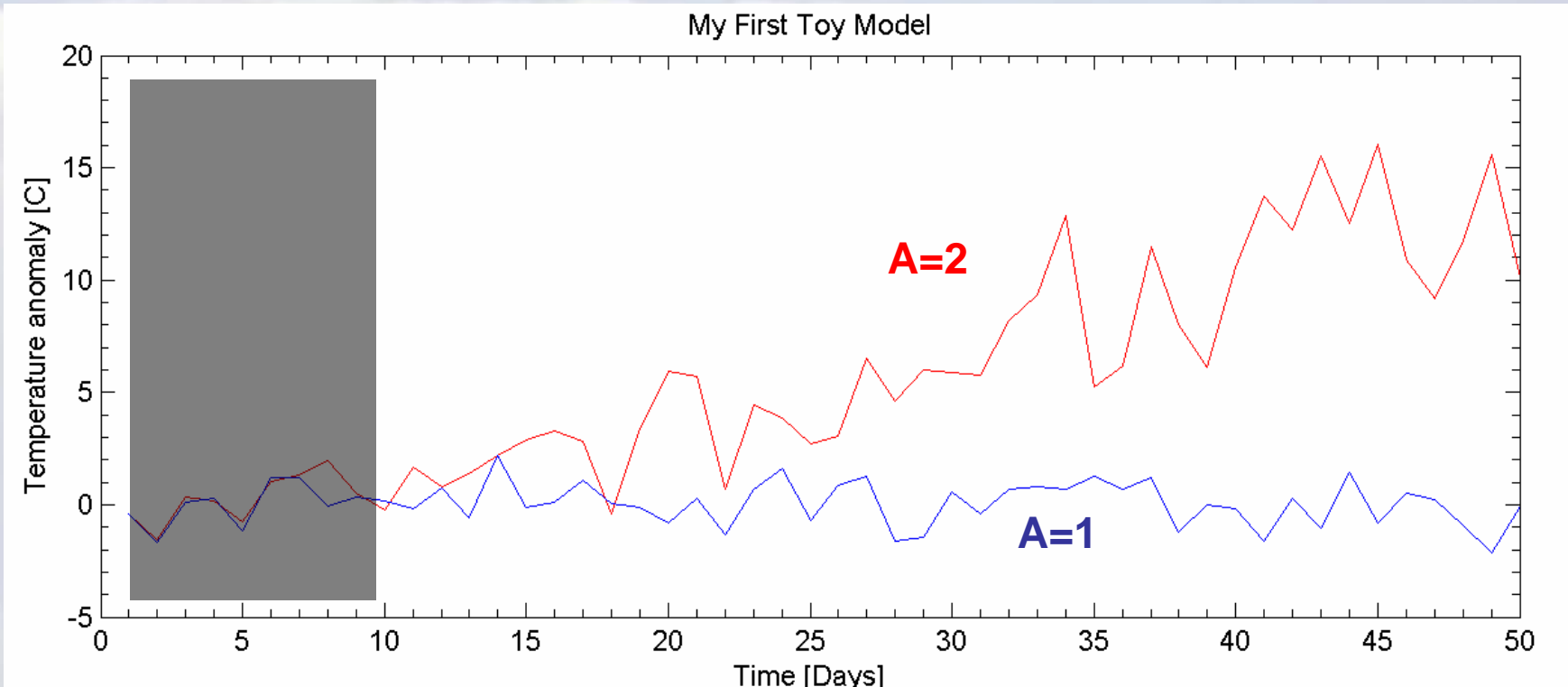
A, B, C, D: External parameters

Orbital parameters, CO₂ Concentration, SST (AGCM), Land cover

ε_x ε_y ε_z **Random errors**

Set to zero → Deterministic model

Model results departs from reality after two-weeks because of “butterfly effect” (uncertainty in initial conditions) but they are still useful in a climatic perspective and highly dependent upon external parameters



Two runs of the model, everything equal but parameter A
Note the “Climate Change” related to change in A

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Vicerrectoría de Asuntos Académicos

Atmósfera, tiempo y clima

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.

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

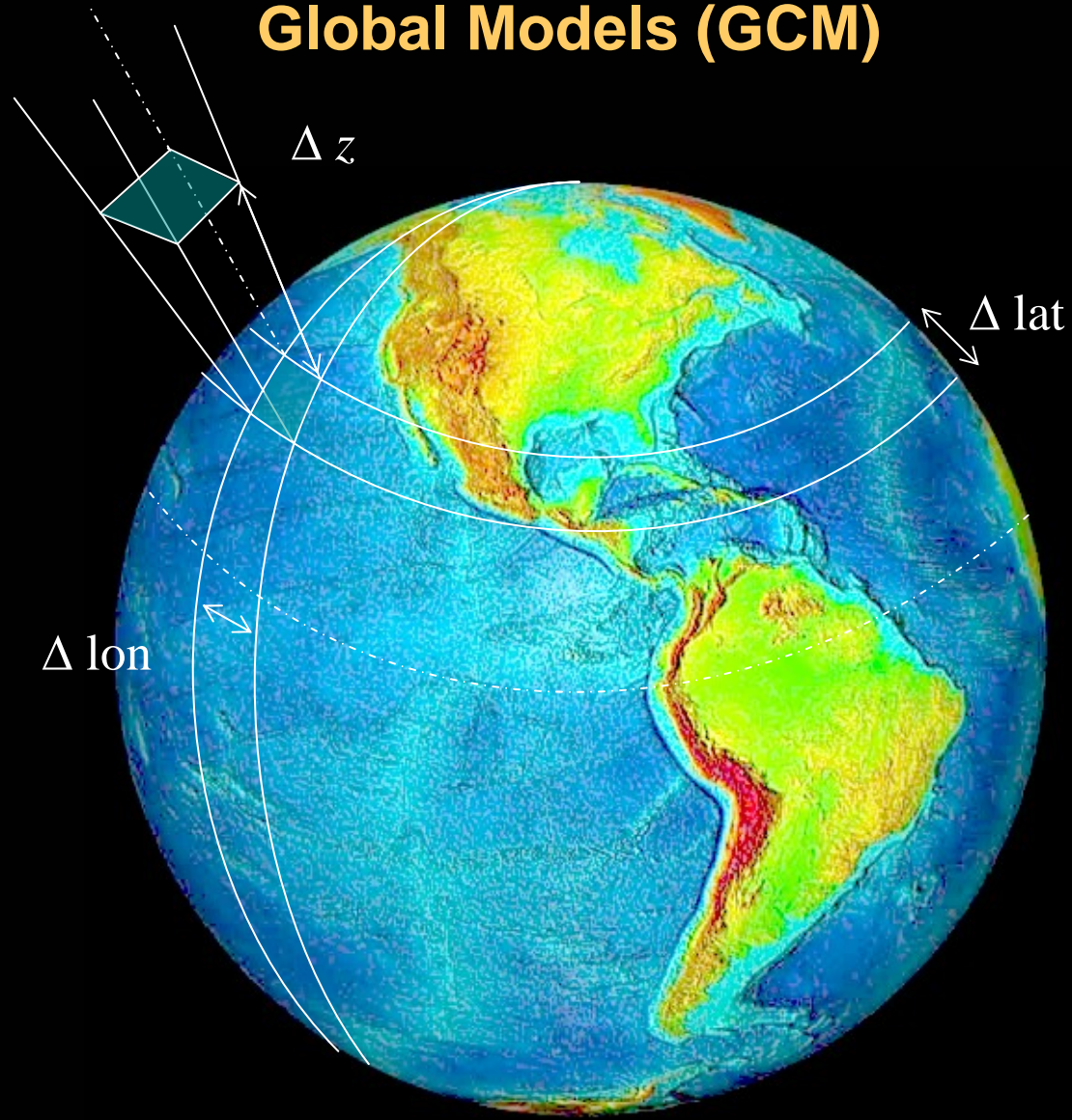
Idea gas law

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

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

Water substance eqns.

Global Models (GCM)

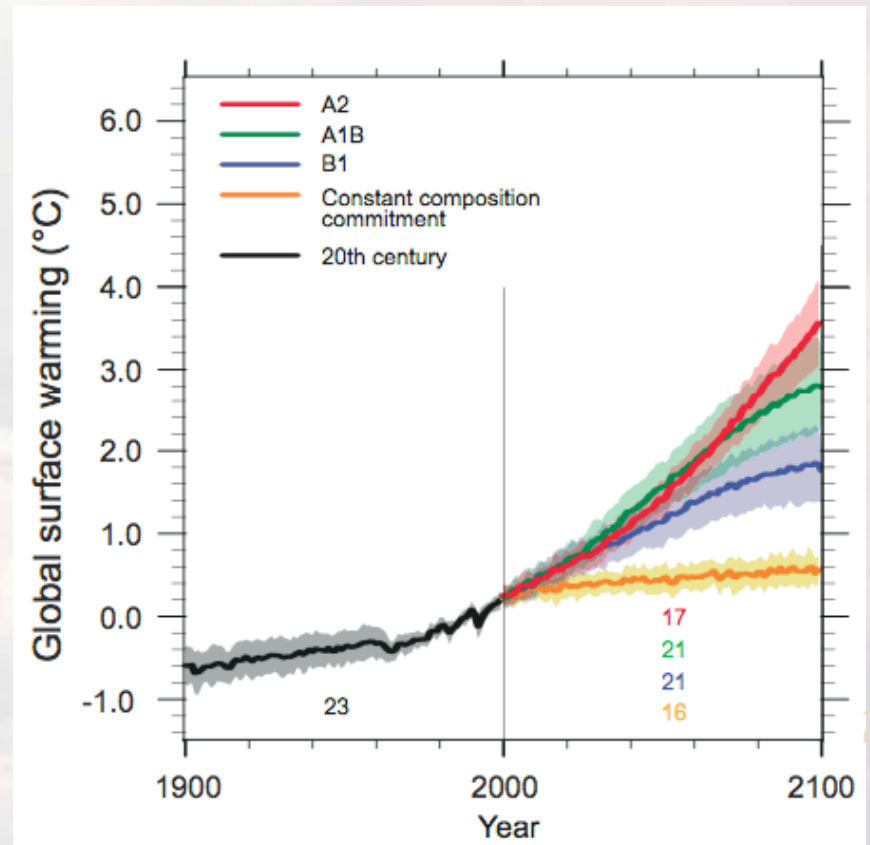
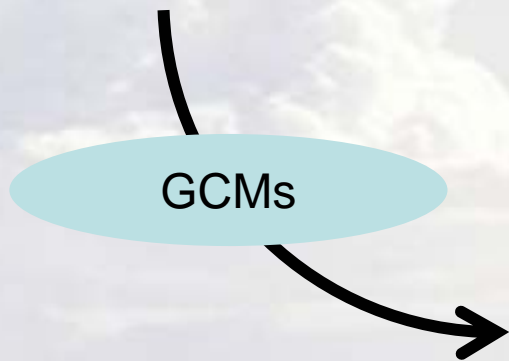
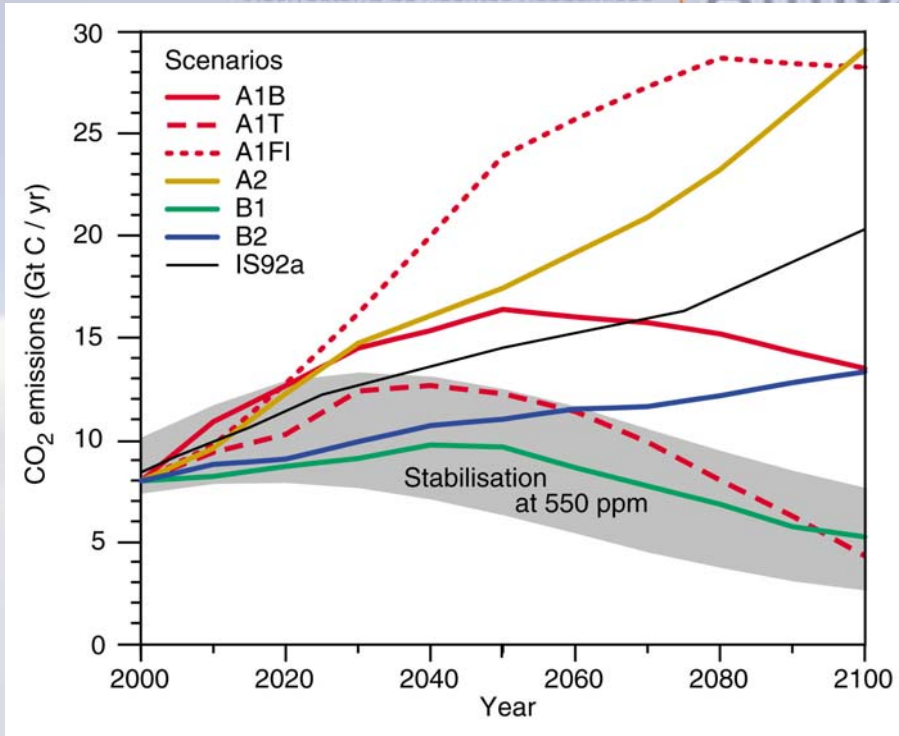


$\Delta \text{lat} \sim \Delta \text{lon} \sim 1^\circ - 3^\circ$

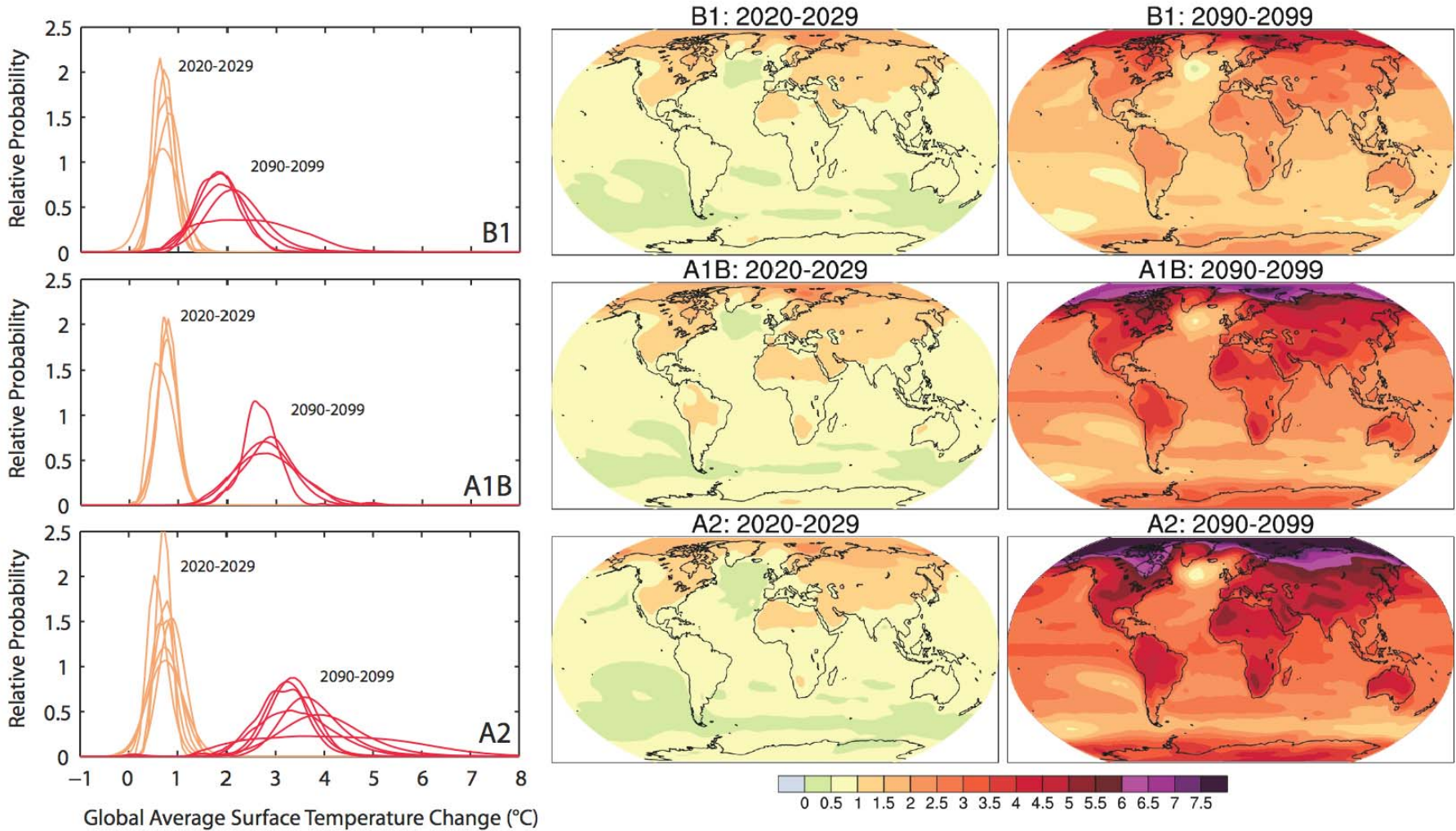
$\Delta z \sim 1 \text{ km}$

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

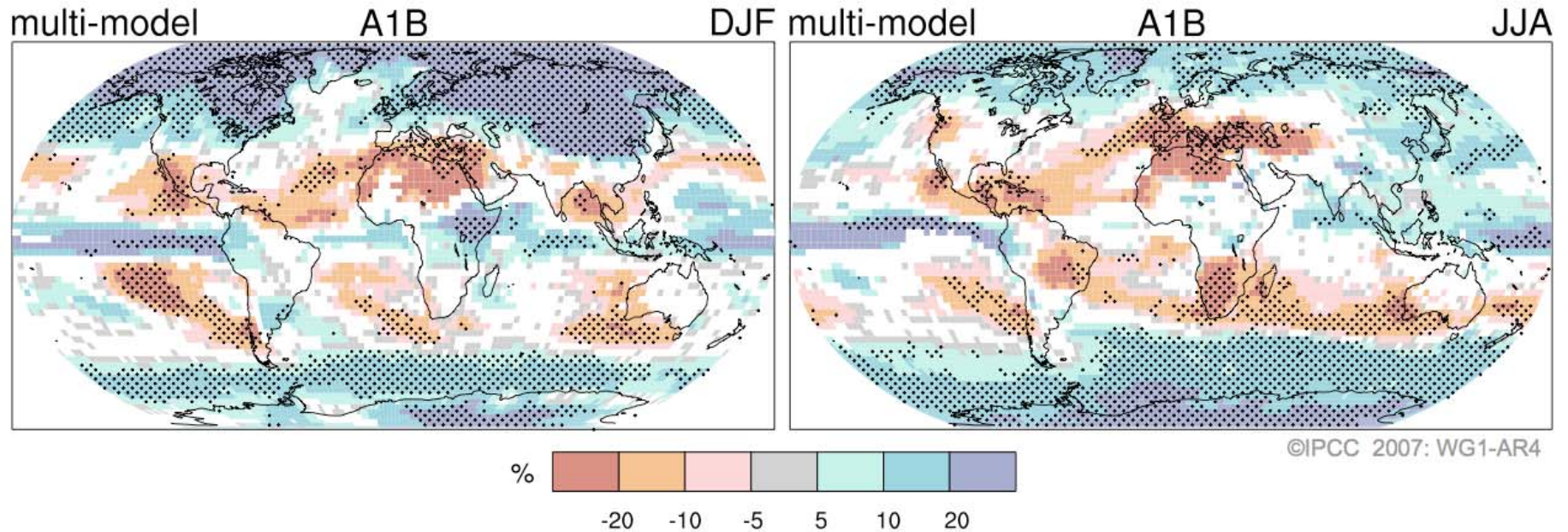
Top of atmosphere: 15-50 km

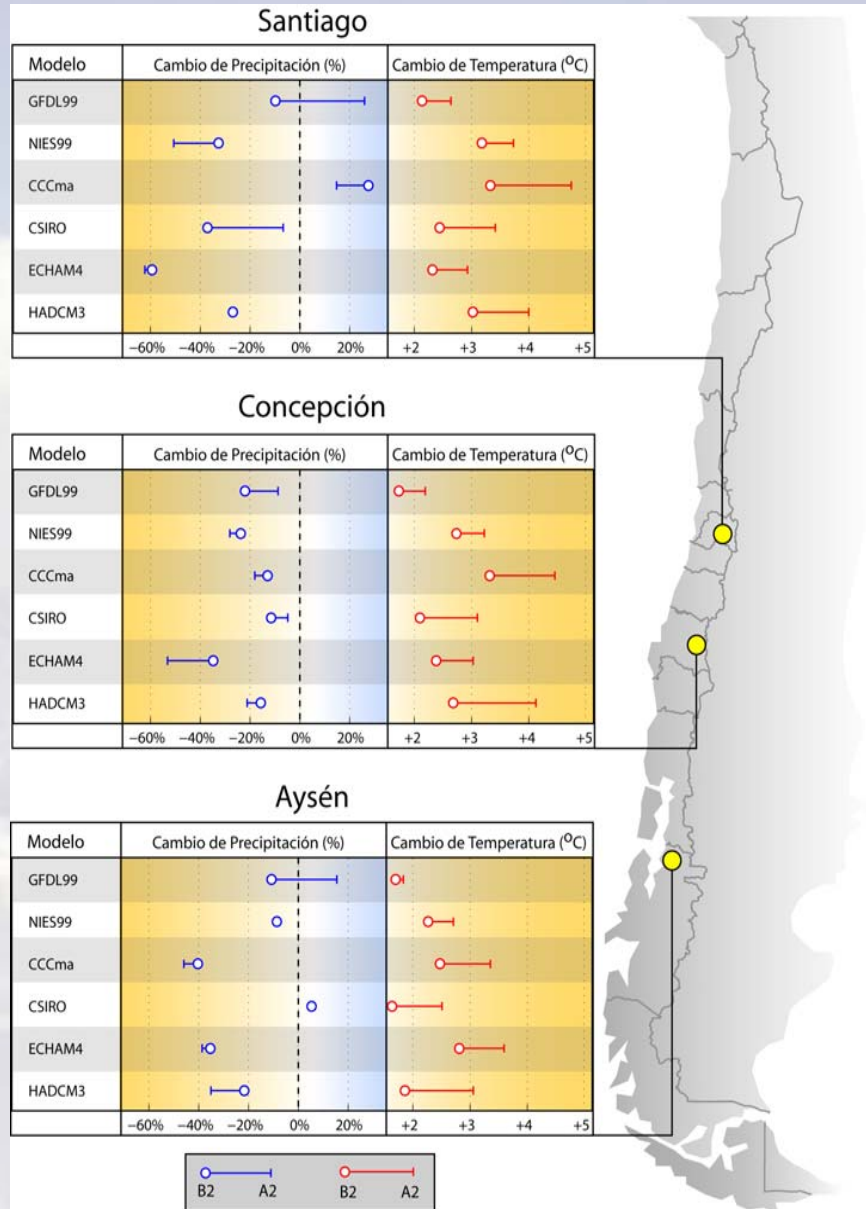


AOGCM Projections of Surface Temperatures

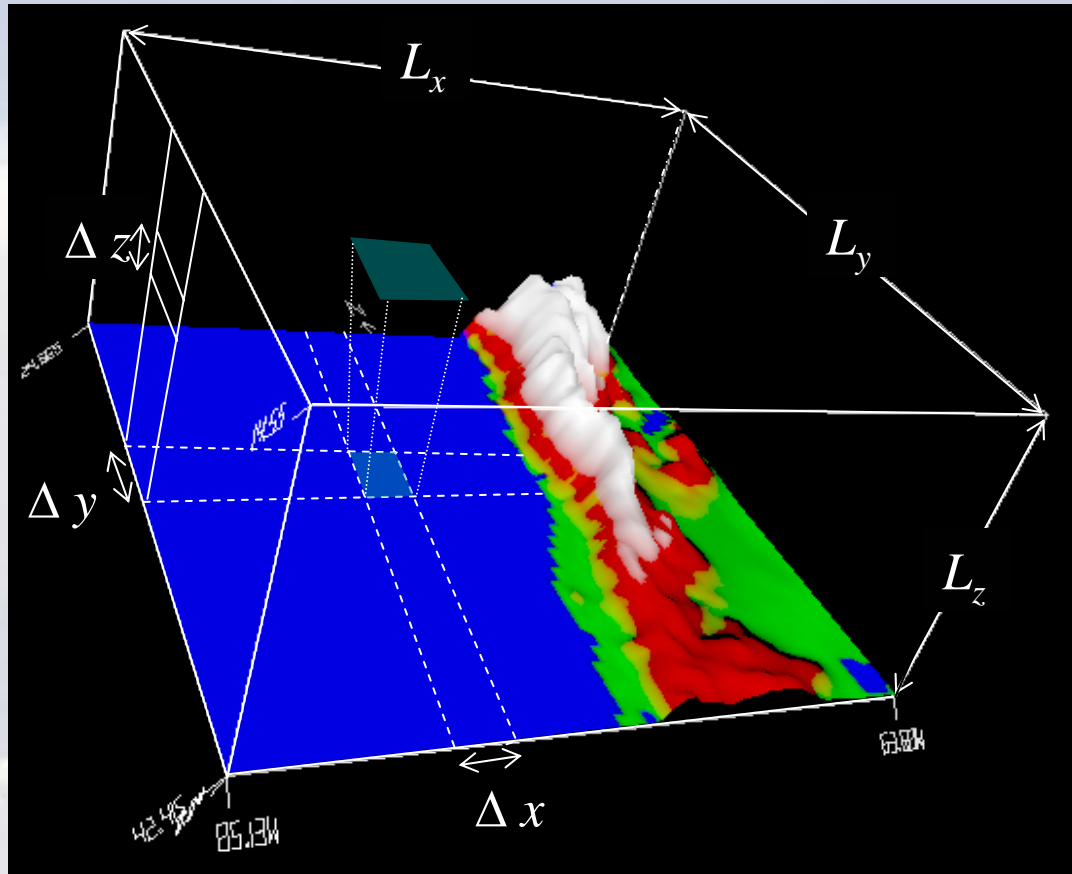


Projected Patterns of Precipitation Changes





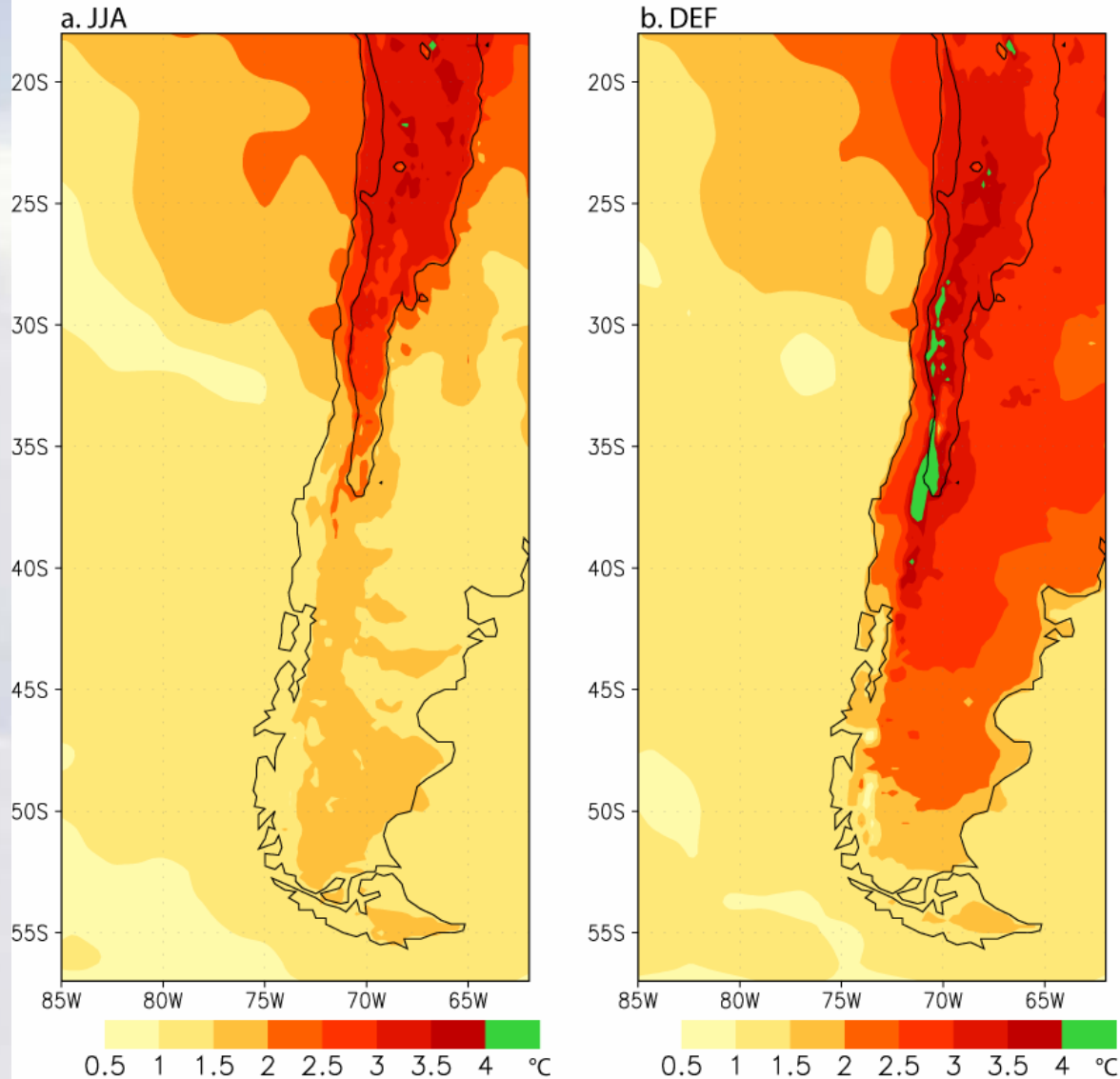
Regional Models (LAM, Mesoscale Models)



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

Main Problem: Garbage in – Garbage out

B2 (2070–2100) – Baseline (1970–1990) Sfc. Air Temperature



A2-Baseline (from GCM and RCM)

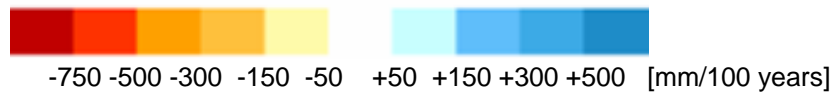
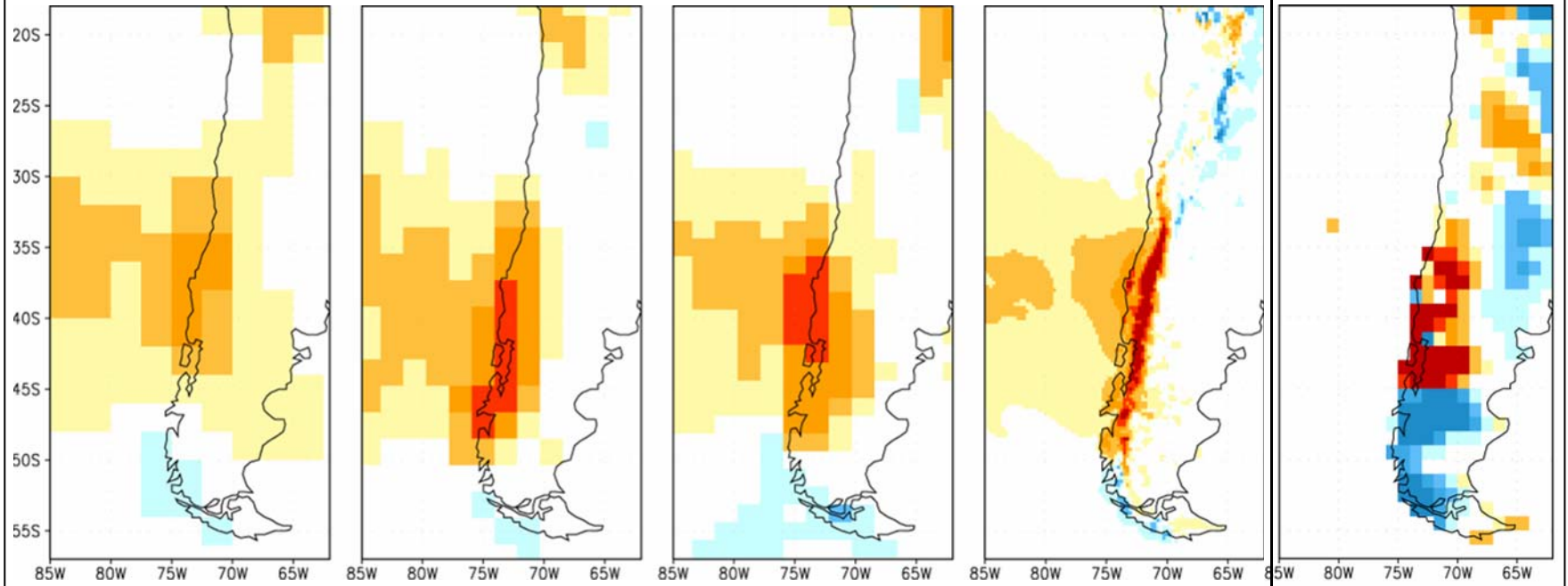
Observed
2000-1960

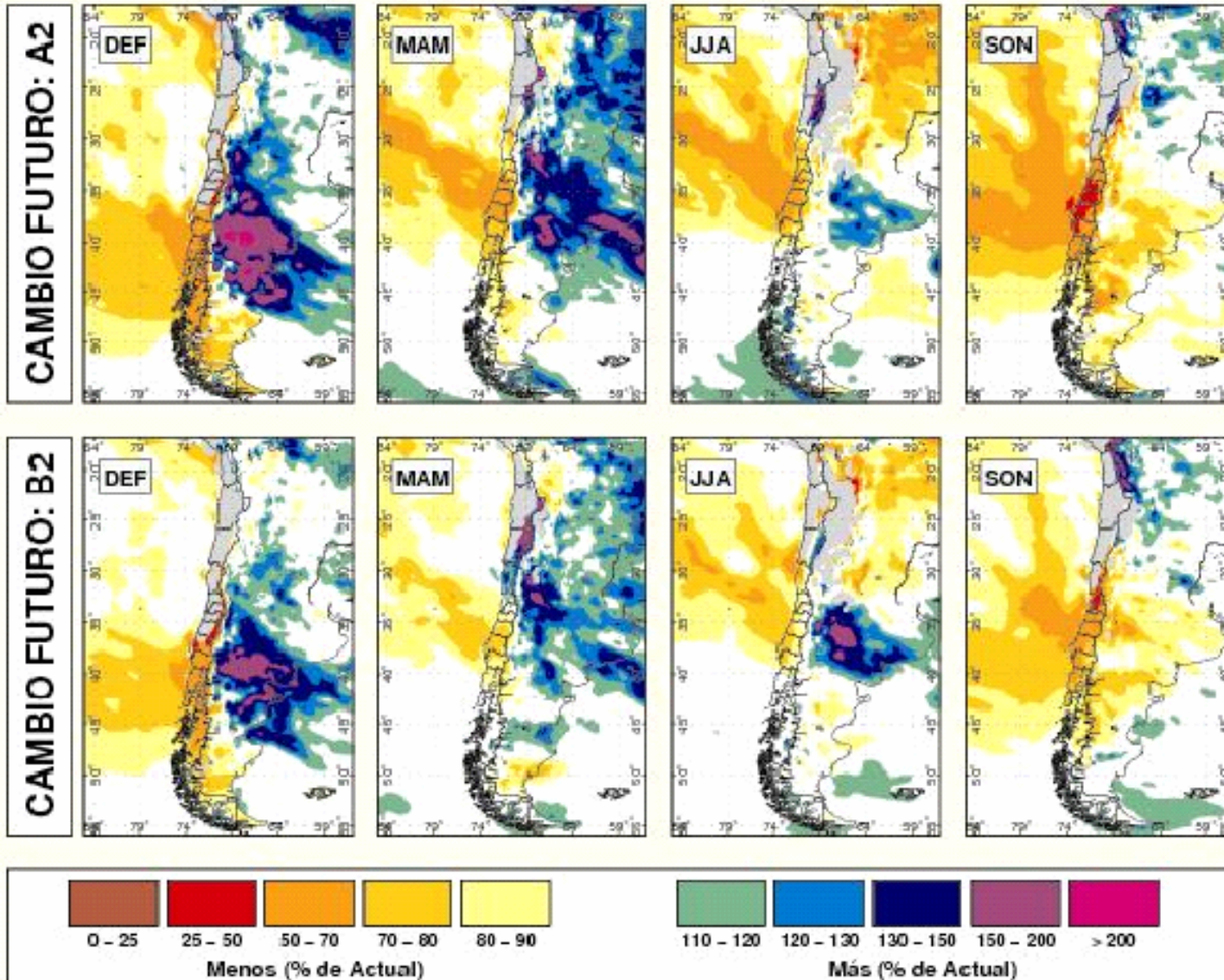
GFDL

ECHAM

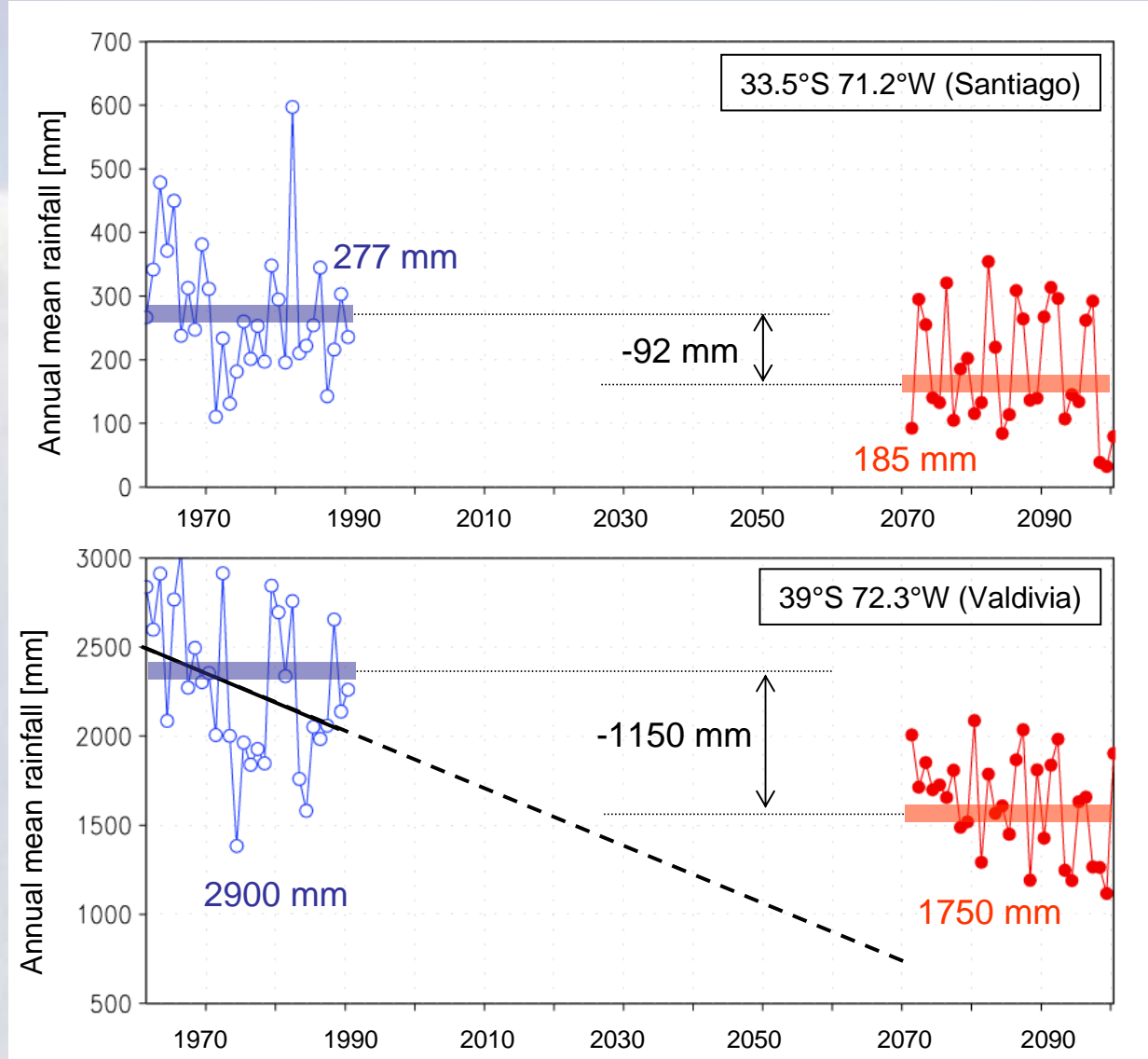
HADAM

PRECIS





Projected Changes v/s Observed changes



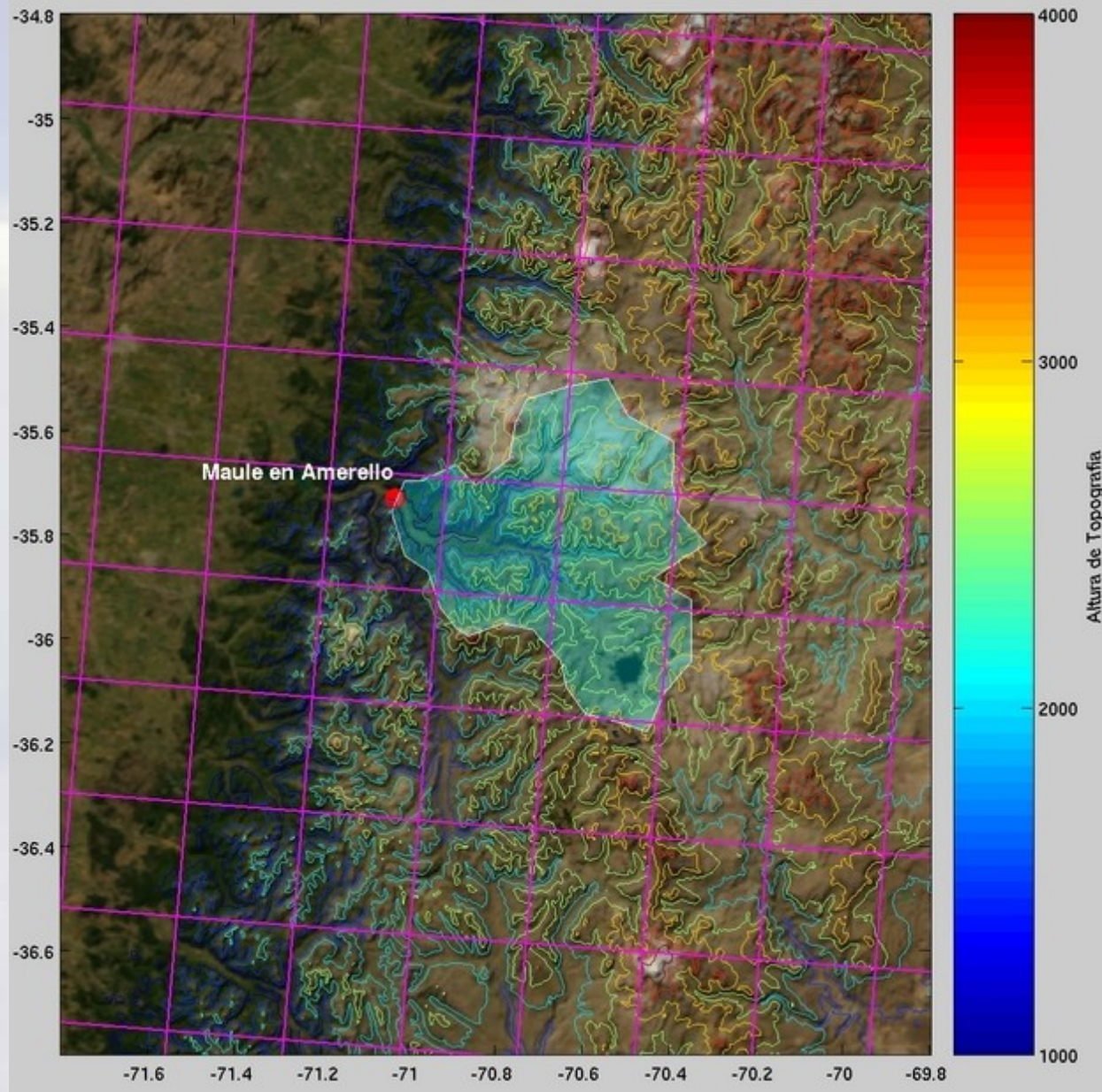
Observed:

$\sigma(IA) \sim 100$ mm

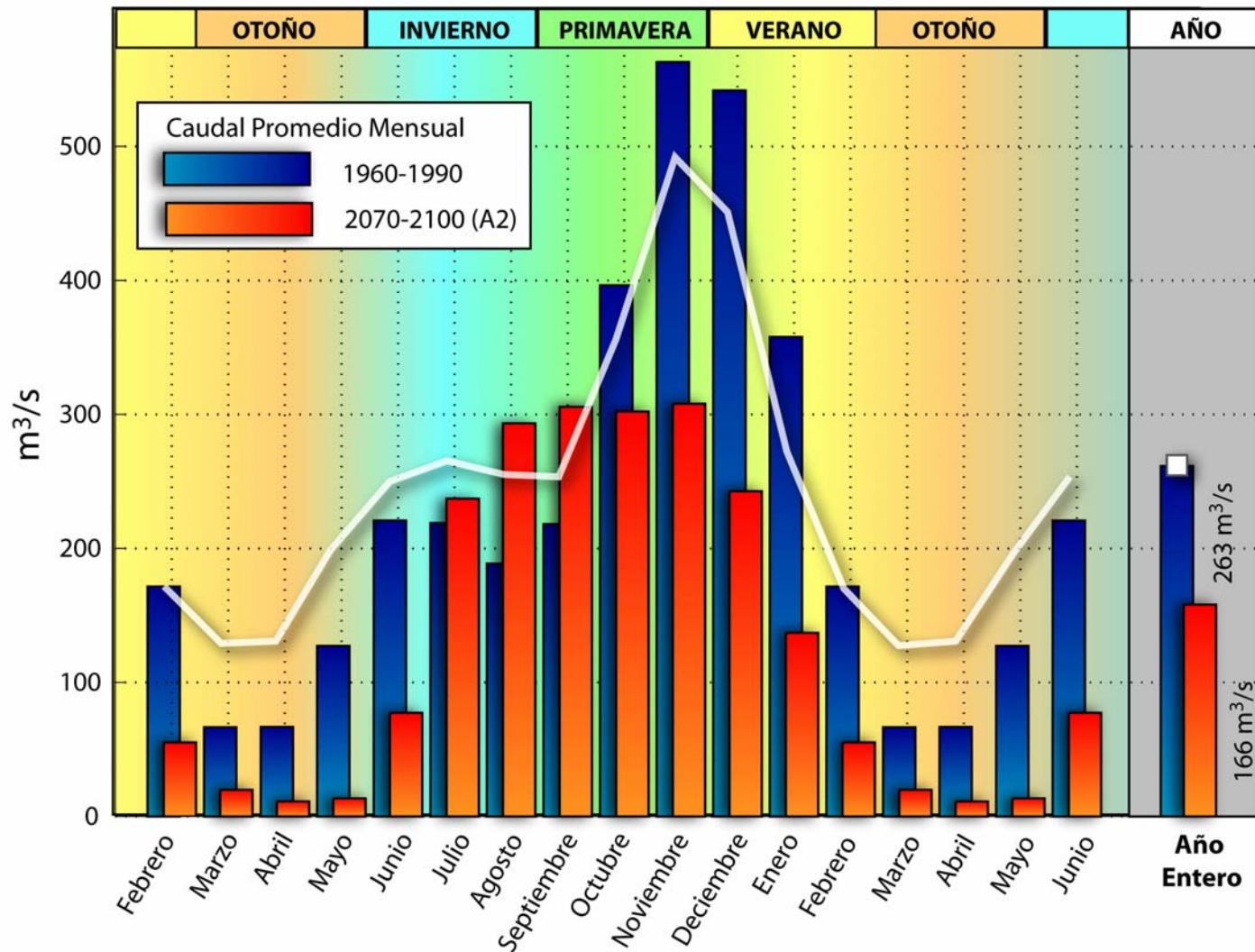
MAP Range: 100-700 mm

Observed:

Trend ~ 150 mm/decade



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



* Rio Maule en Armerillo - Pre-Cordillera

Preguntas

Como se comparan los cambios proyectados con la variabilidad observada en la actualidad (Siglo XX) y el pasado cercano (1500-2000)?

Existen manifestaciones del cambio climático asociado a los GI en las últimas décadas?

Cuales son los efectos “sectoriales” de un cambio climático asociado a los GI? Quienes ganan, quienes pierden?



FIN