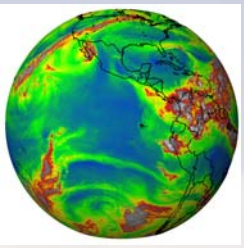
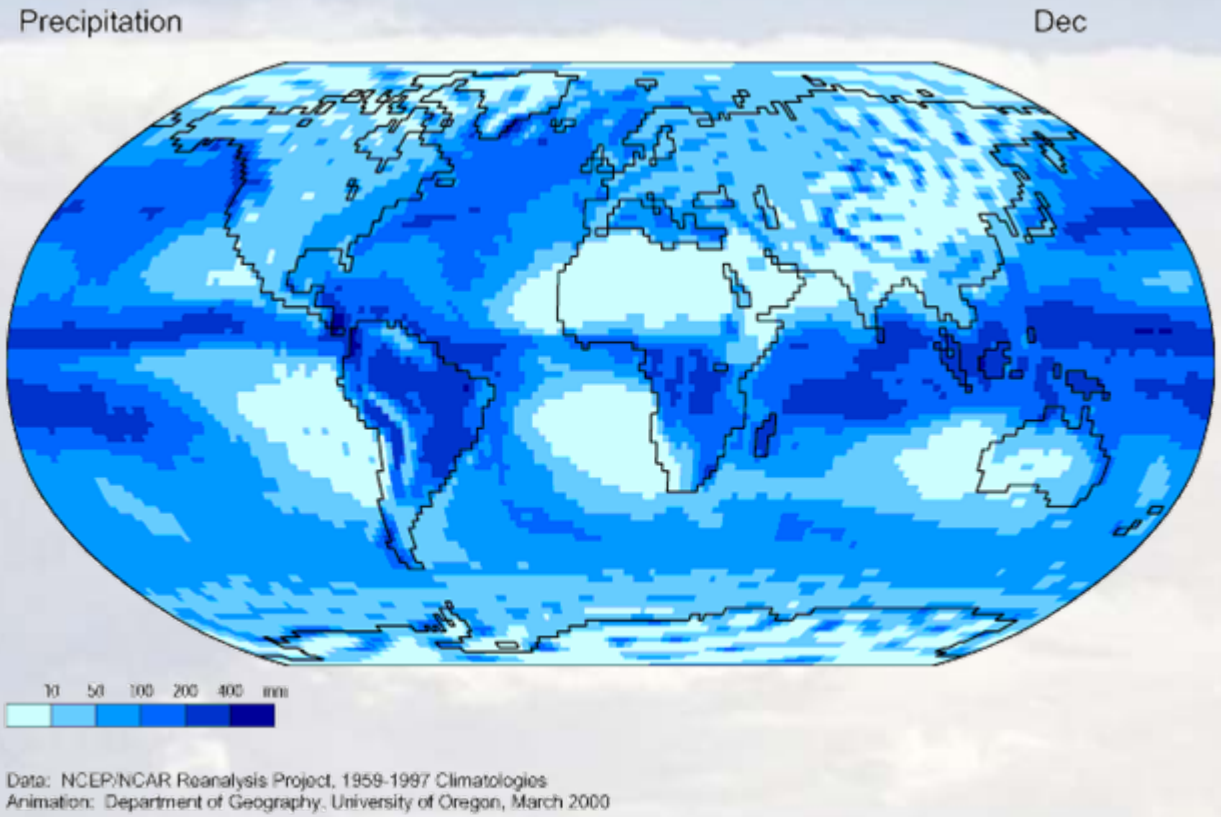


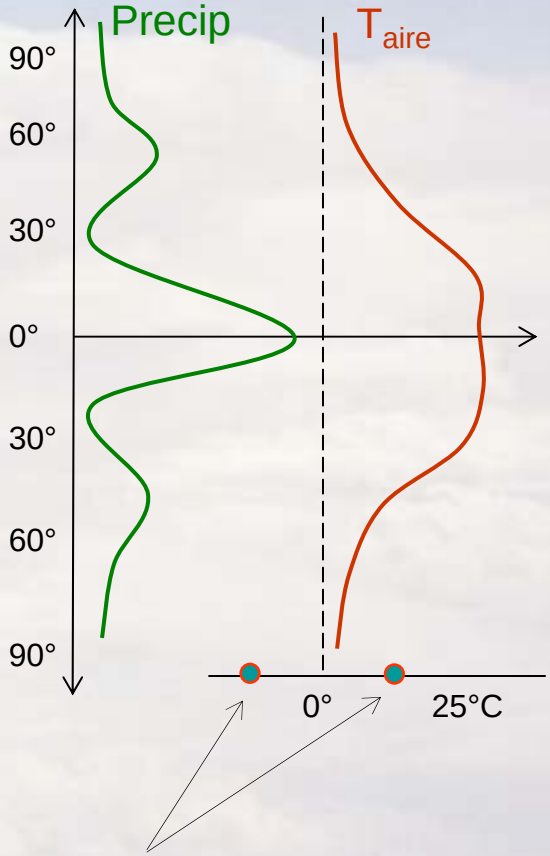


Tema 11

Variabilidad Climática II: Paleoclimas y Cambio Climático Global



Promedio Zonal y Anual

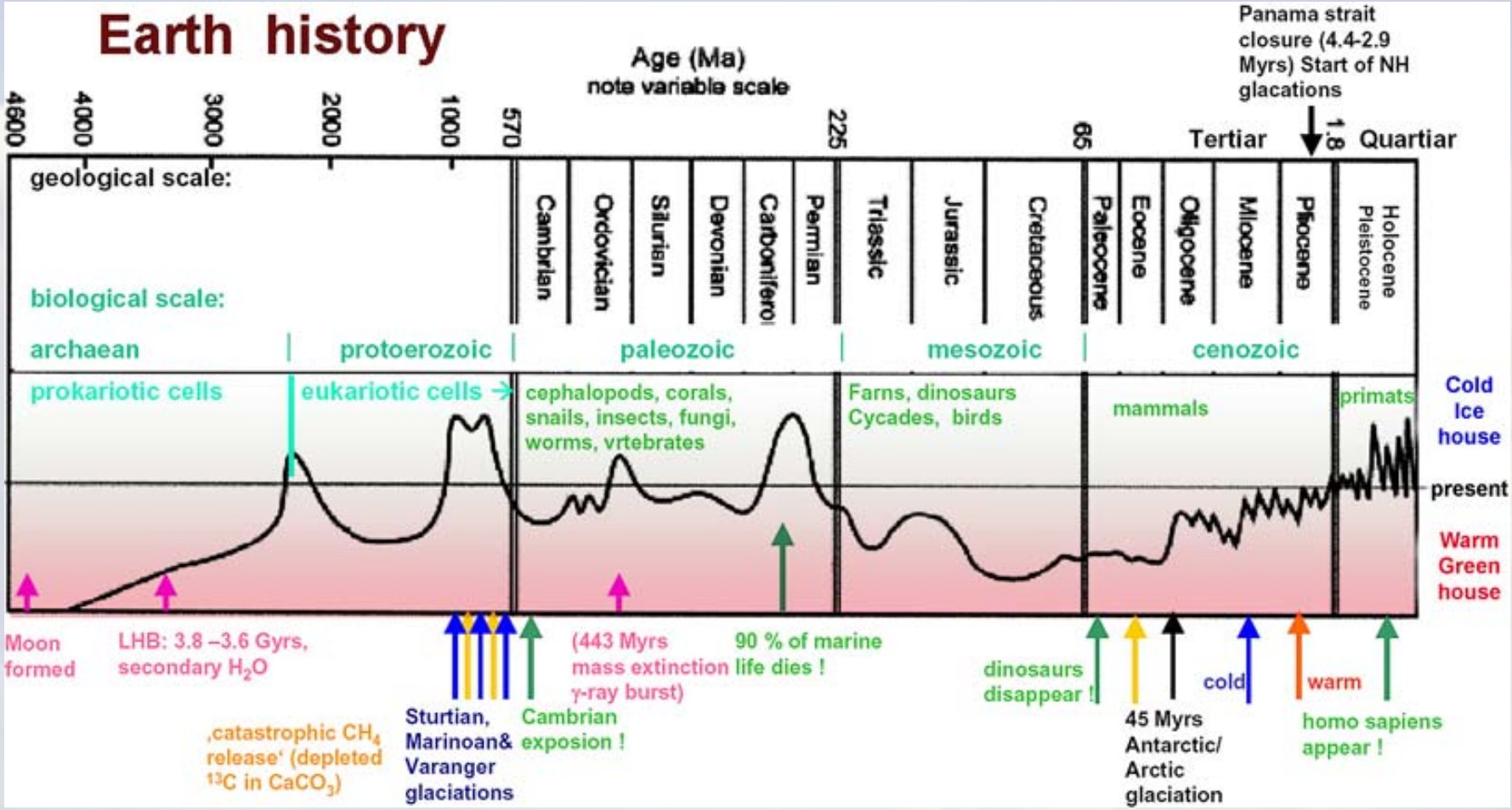


Efecto invernadero

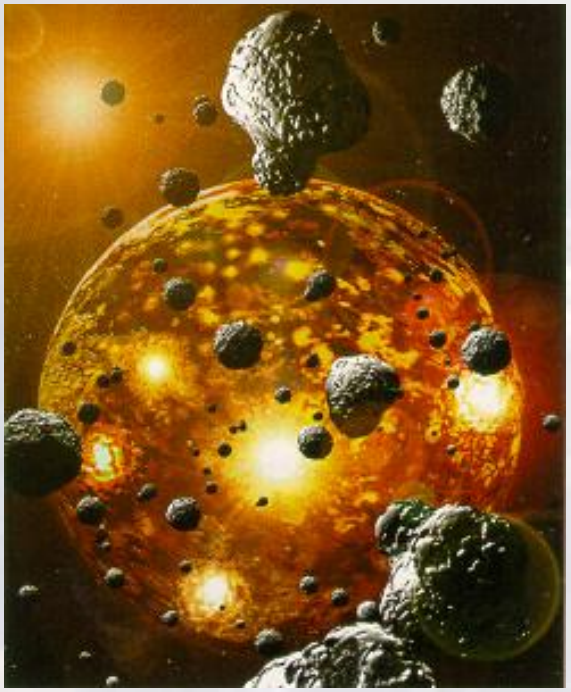
Elementos que pueden cambiar el clima

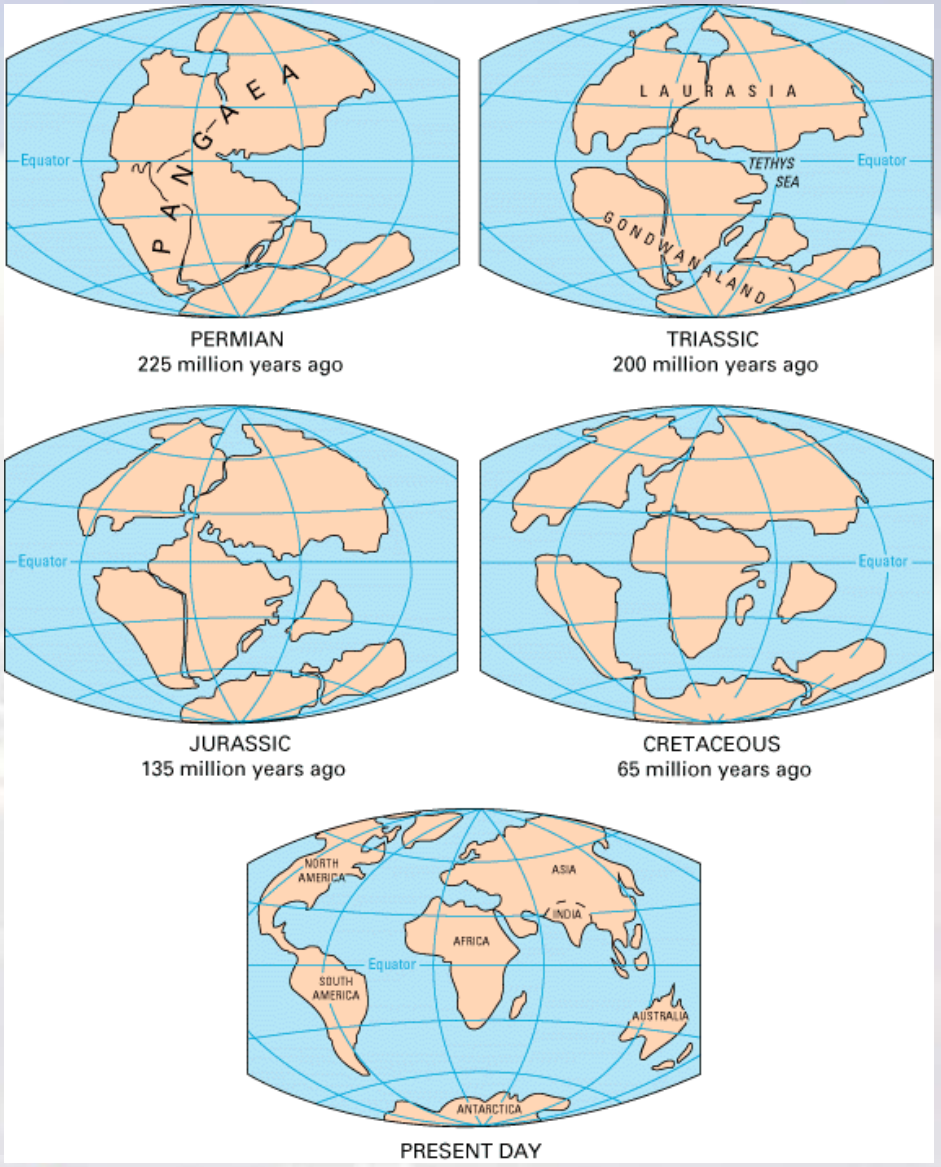
1. Energía solar
2. Tasa de rotación del planeta
3. Bombardeo de meteoritos
4. Energía interna del planeta
5. Posición de los continentes
6. Composición de la atmósfera

Atmósfera, tiempo y clima

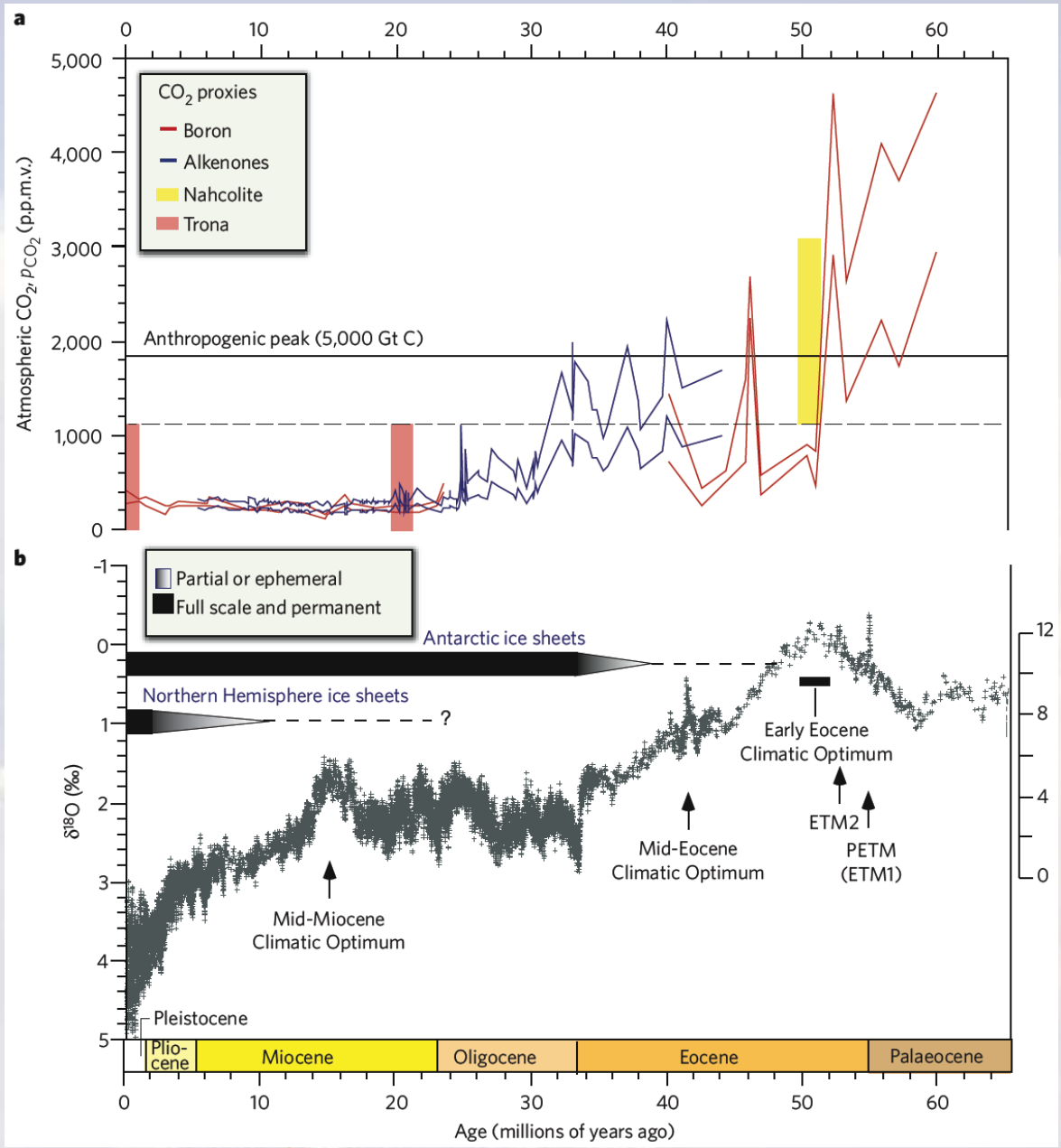


Factores de cambio climático a escala geológica





Atmósfera, tiempo y clima



James C. Zachos, Gerald R. Dickens & Richard E. Zeebe

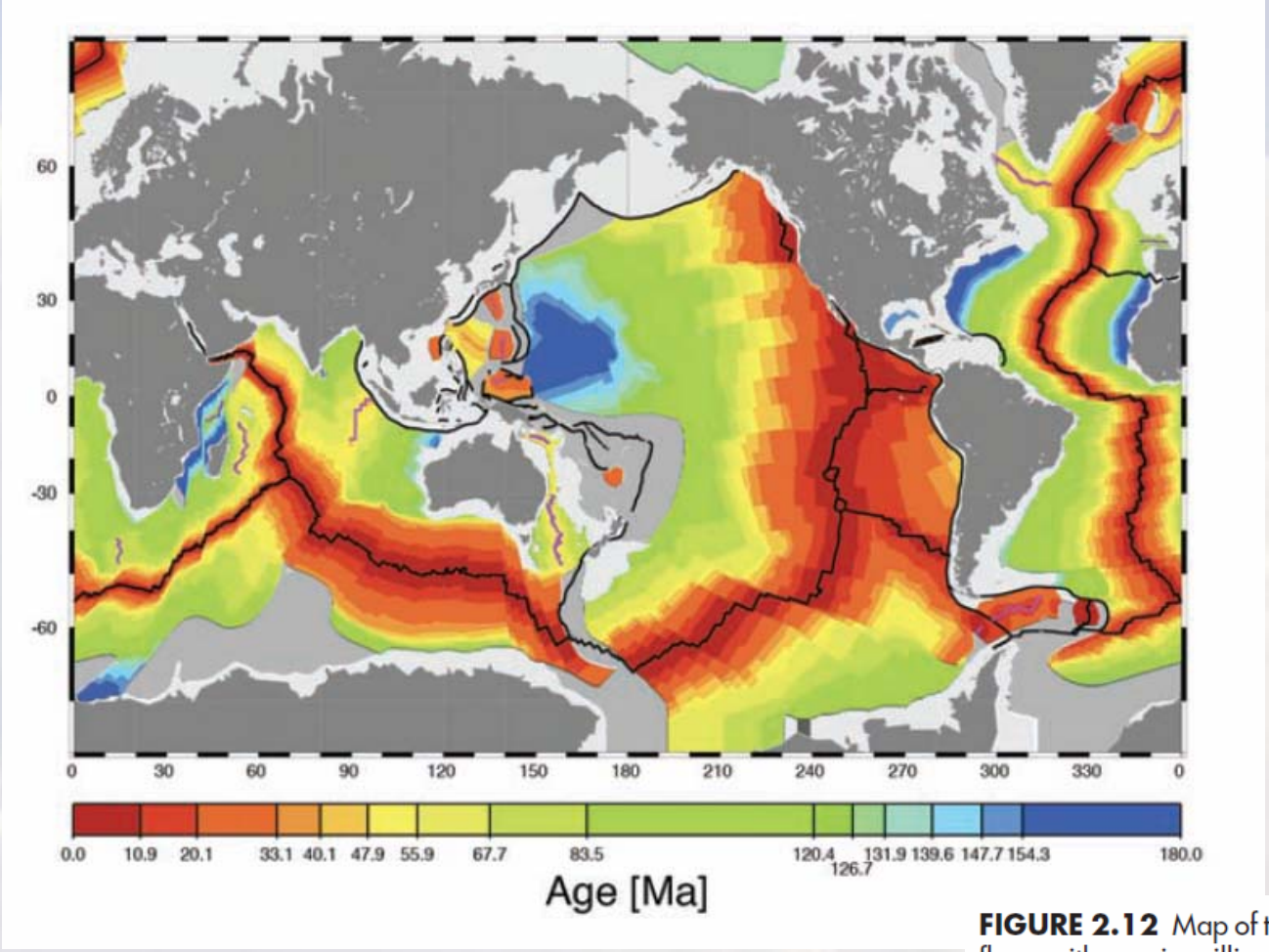
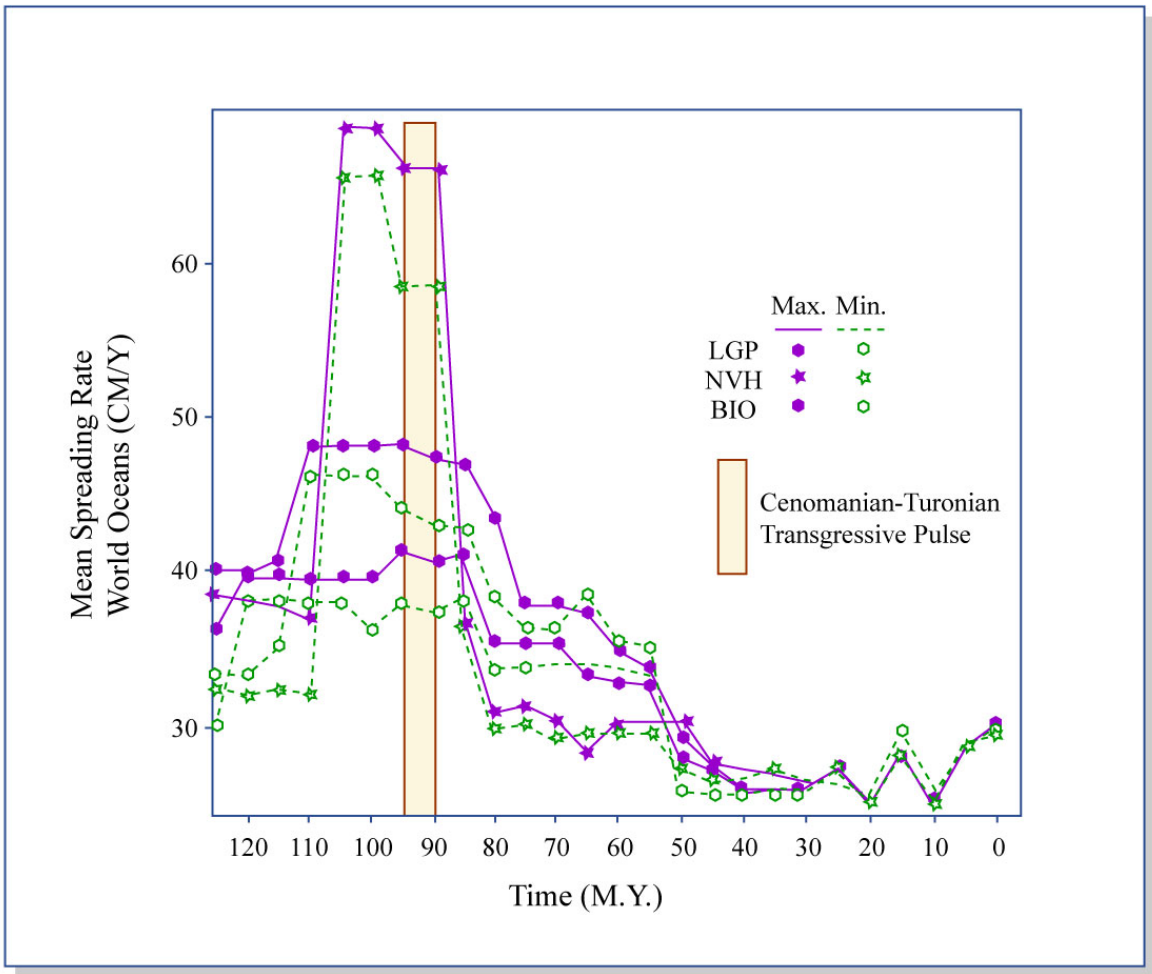
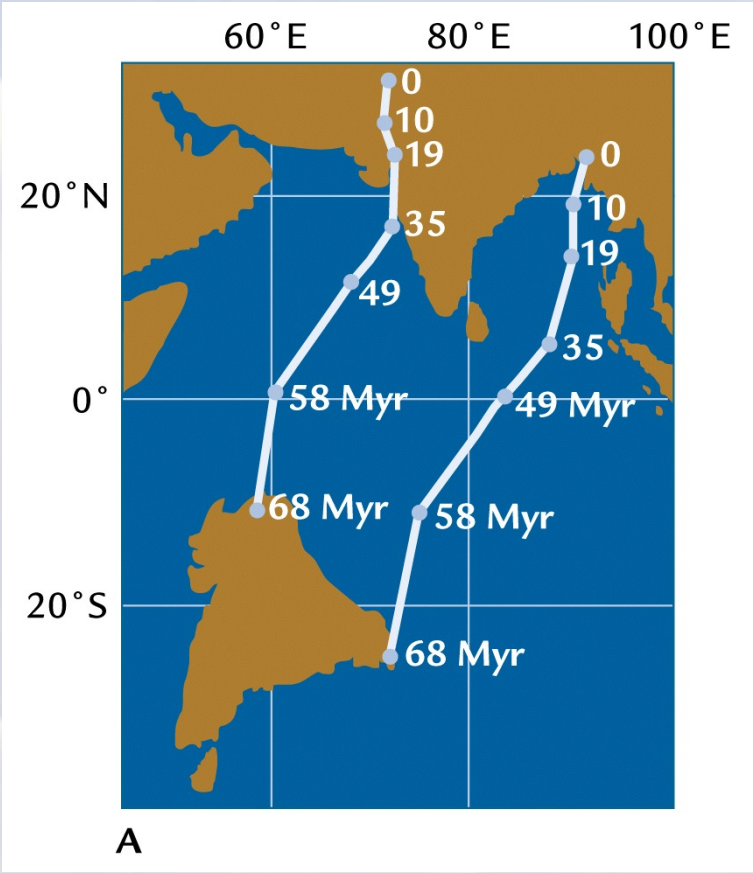


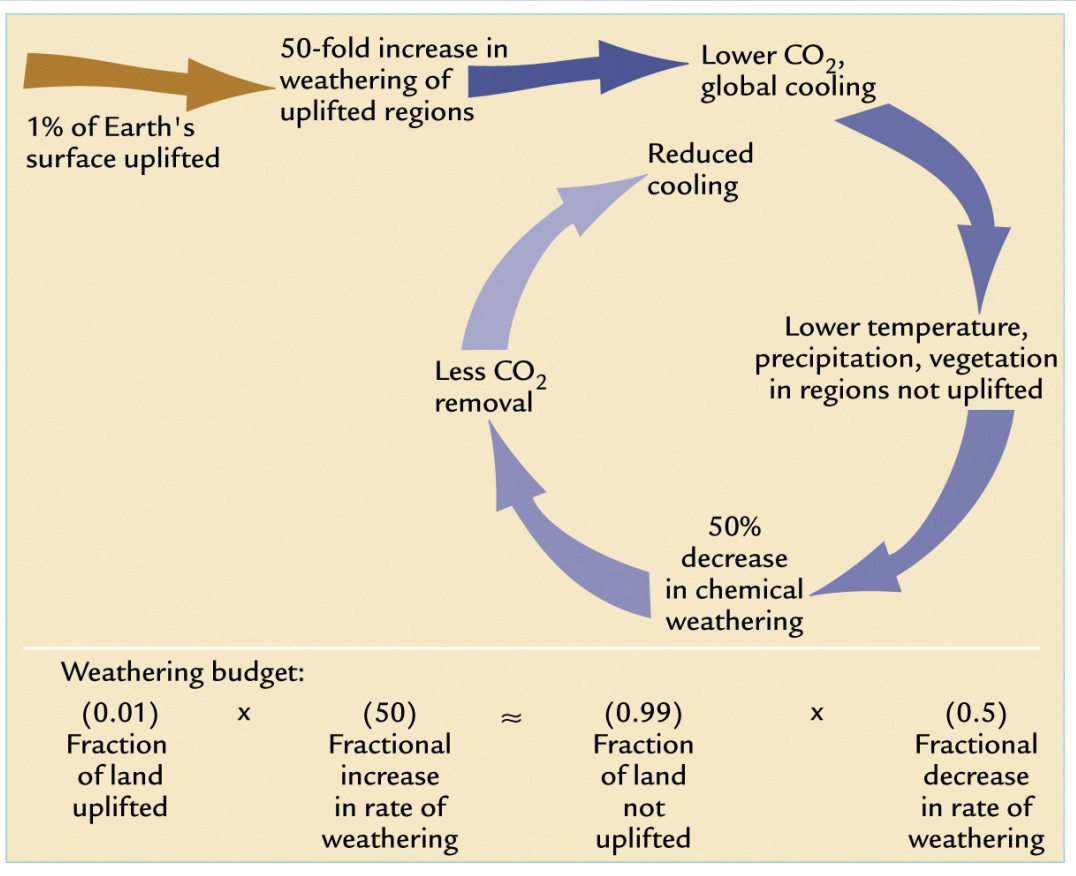
FIGURE 2.12 Map of the age of the ocean floor, with age in million years before present (Ma). Solid black lines are midocean ridges. SOURCE: Müller et al. (1997). Copyright 1997 American Geophysical Union. Reproduced with permission.

GF3004 Sistema Climático
Semestre Primavera 2009



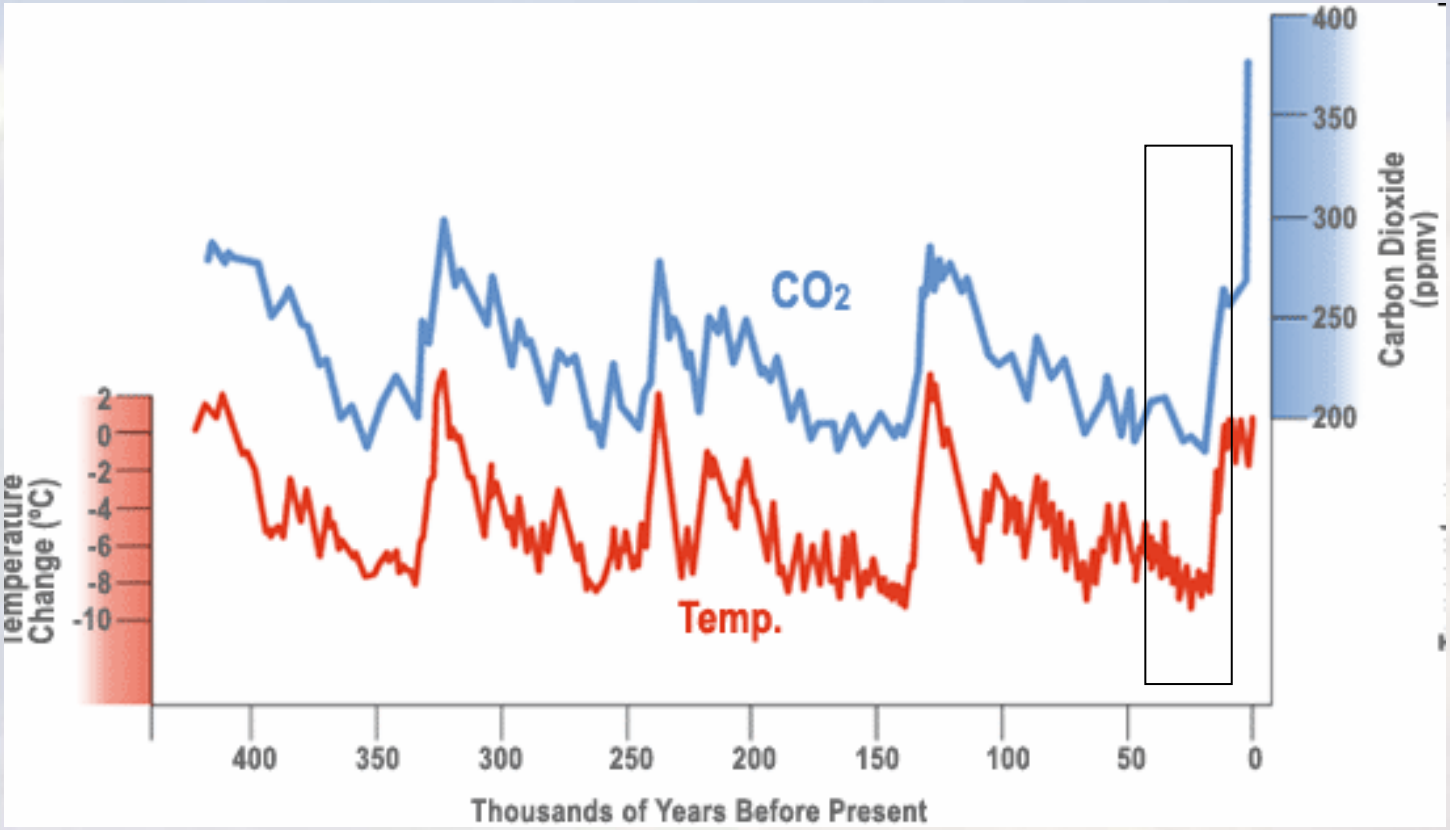
GF3004 Sistema Climático
Semestre Primavera 2009



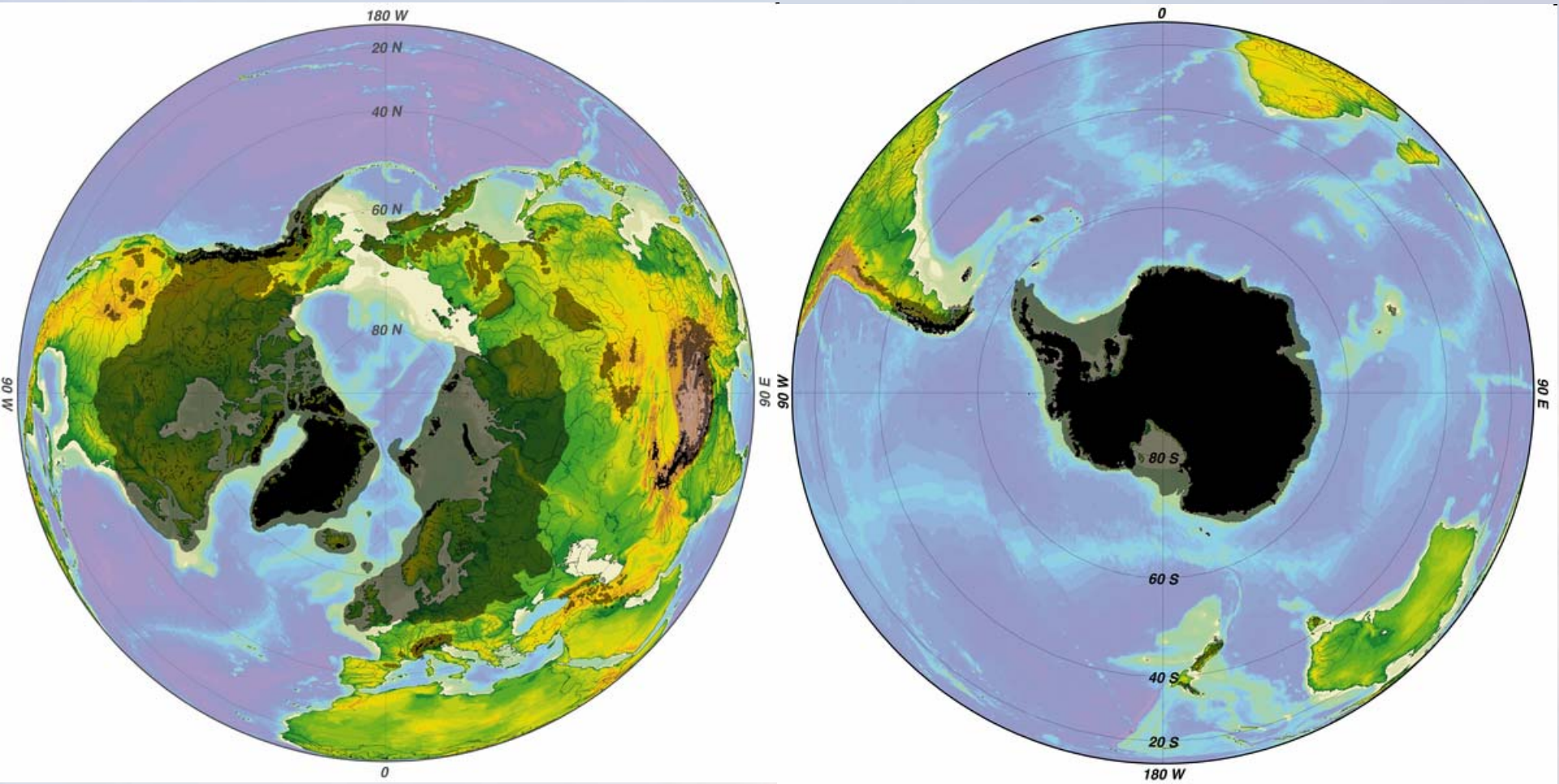


Ruddiman: Earth's Climate, Chapter 4

Entre mas reciente mas detalle...

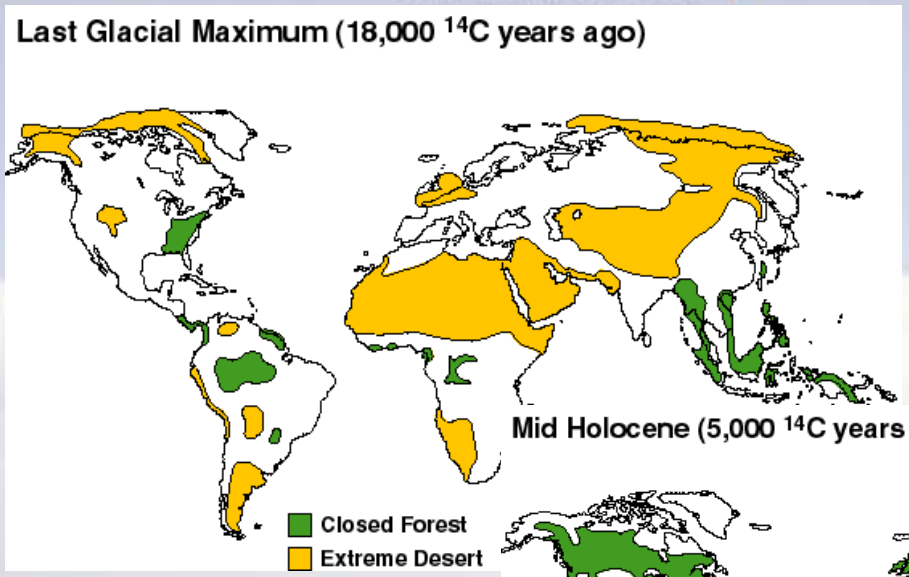


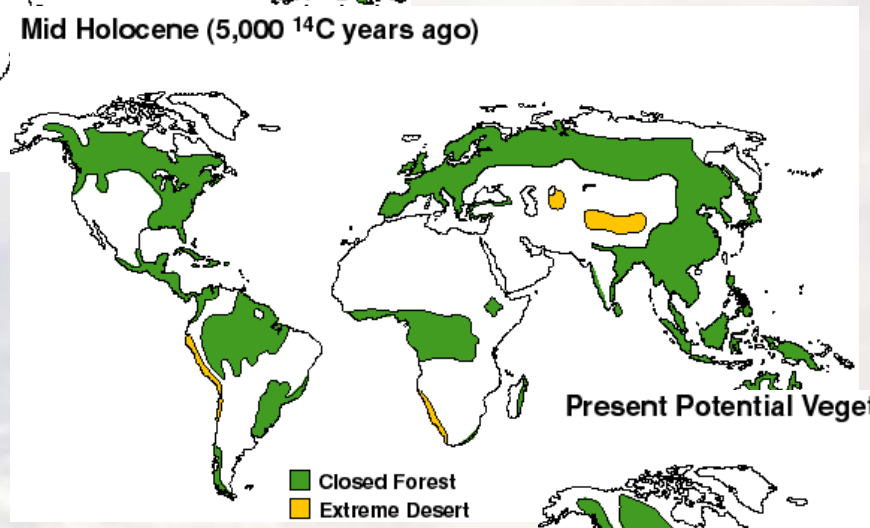
Cobertura de hielo durante LGM

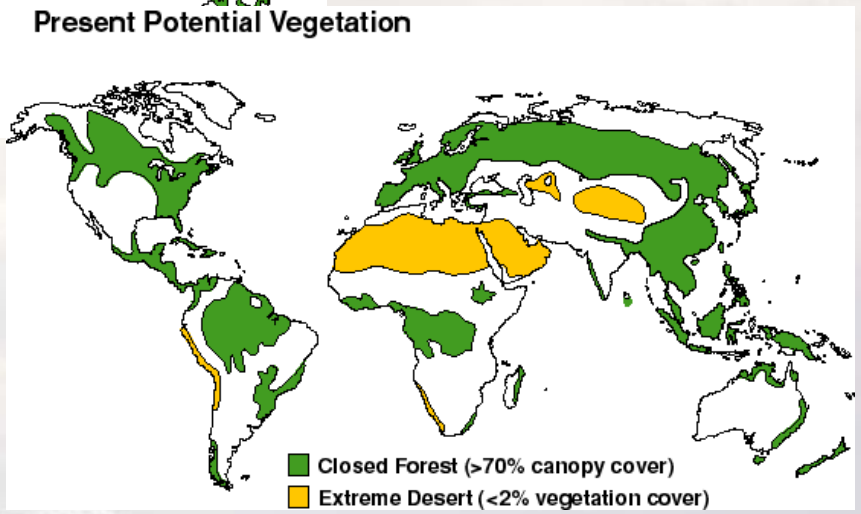


http://en.wikipedia.org/wiki/File:Iceage_south-intergl_glac_hg.png

Atmósfera, tiempo y clima

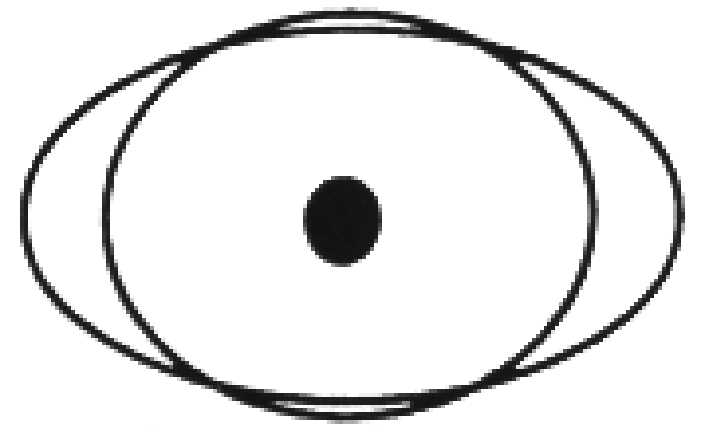


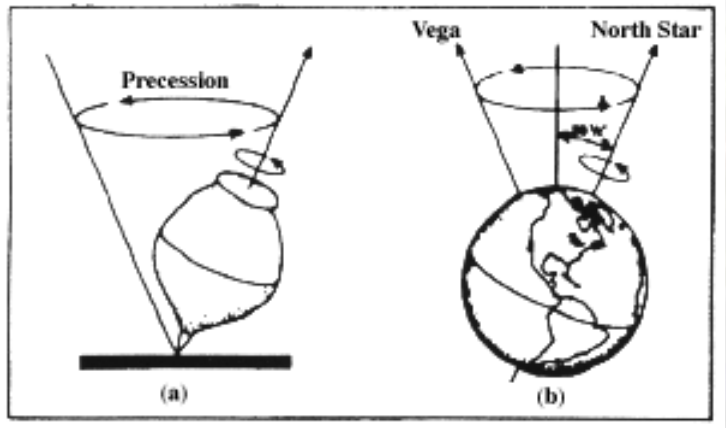


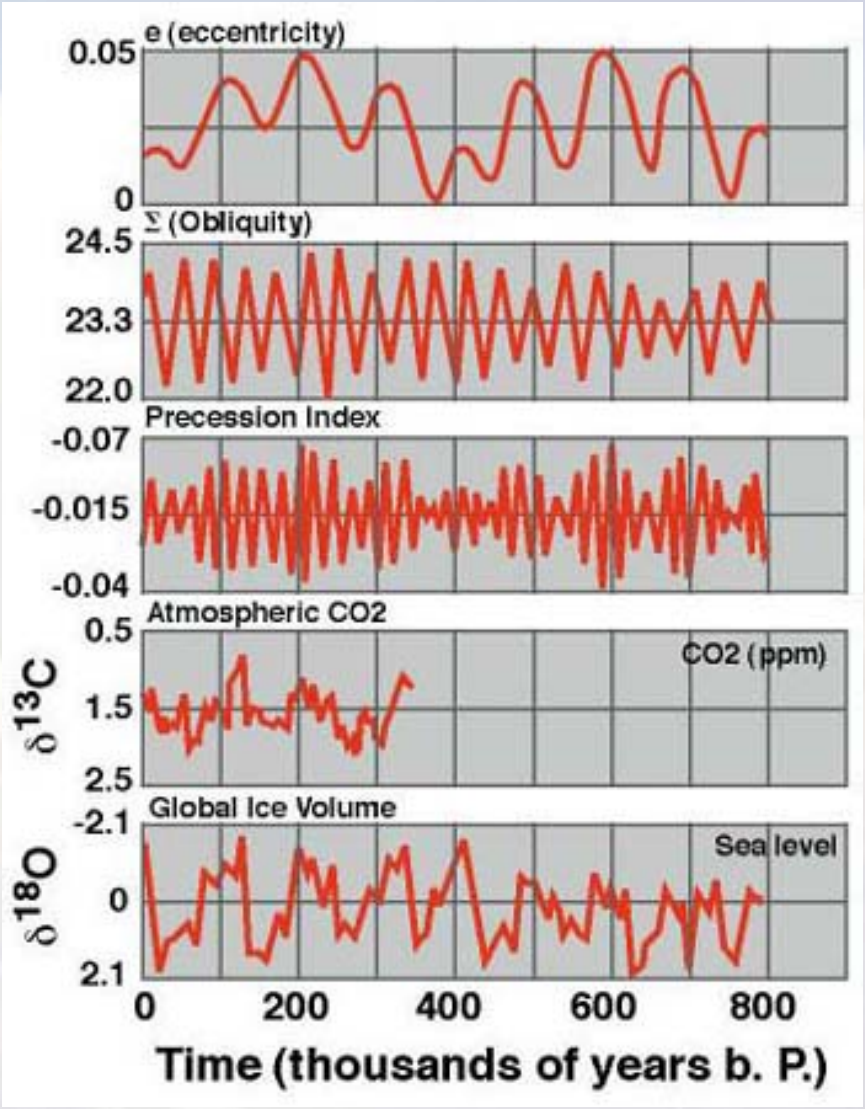


Entre mas reciente mas detalle...
Reconstrucciones de P y T

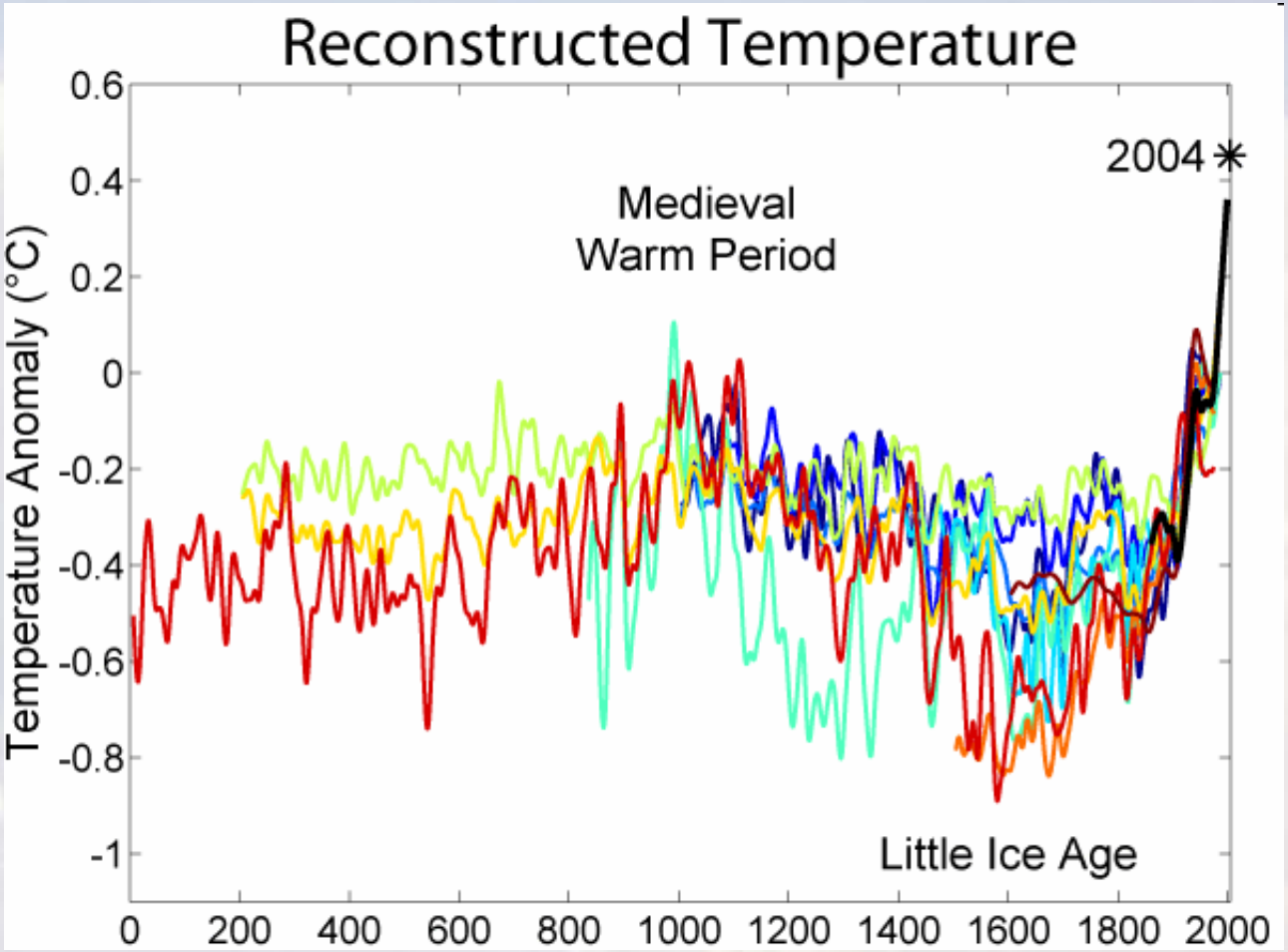
Cambios en Geometría Tierra-Sol → Cambios en energía dipsonible



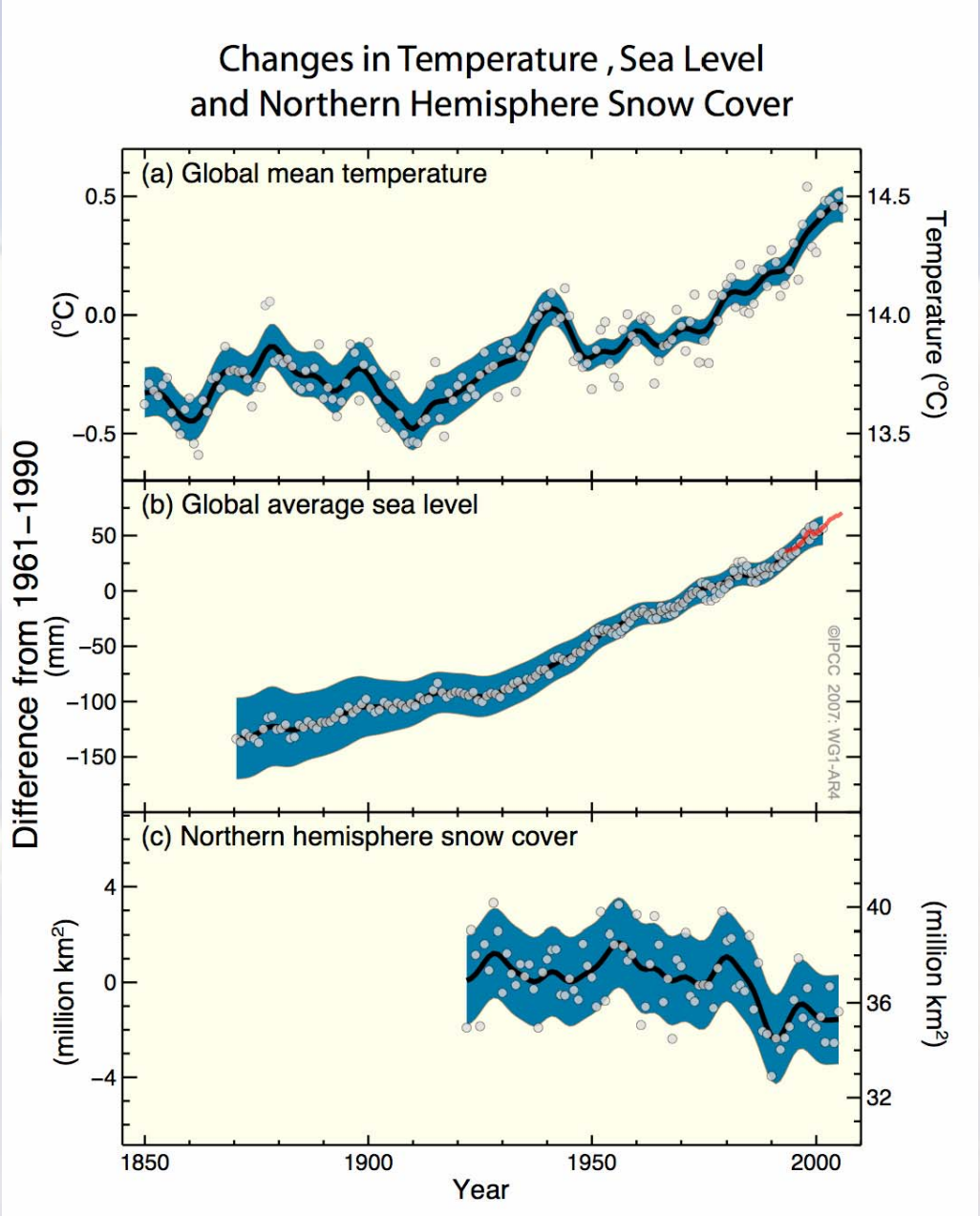




Entre mas reciente mas detalle...

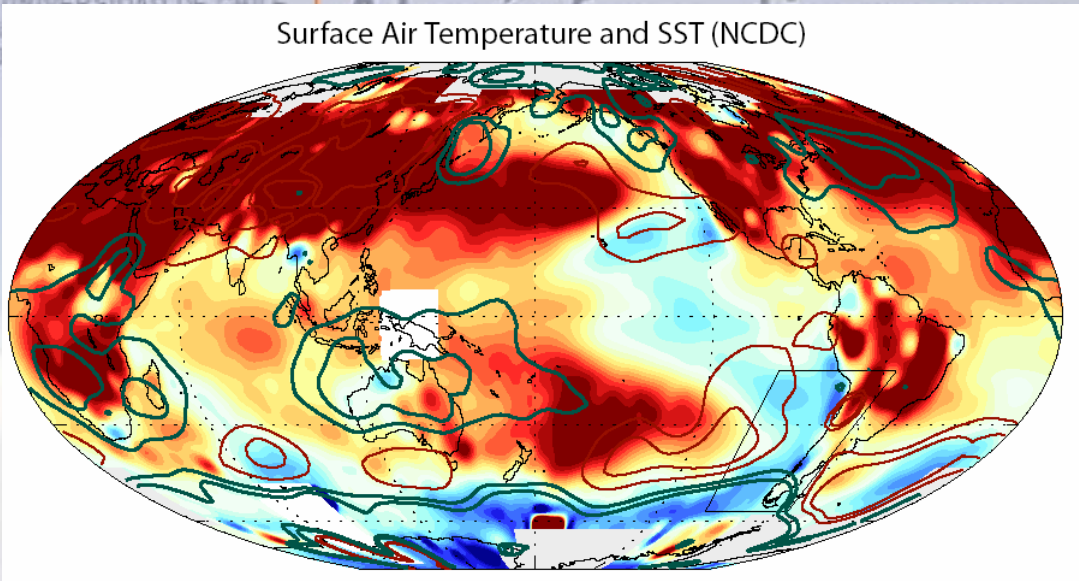


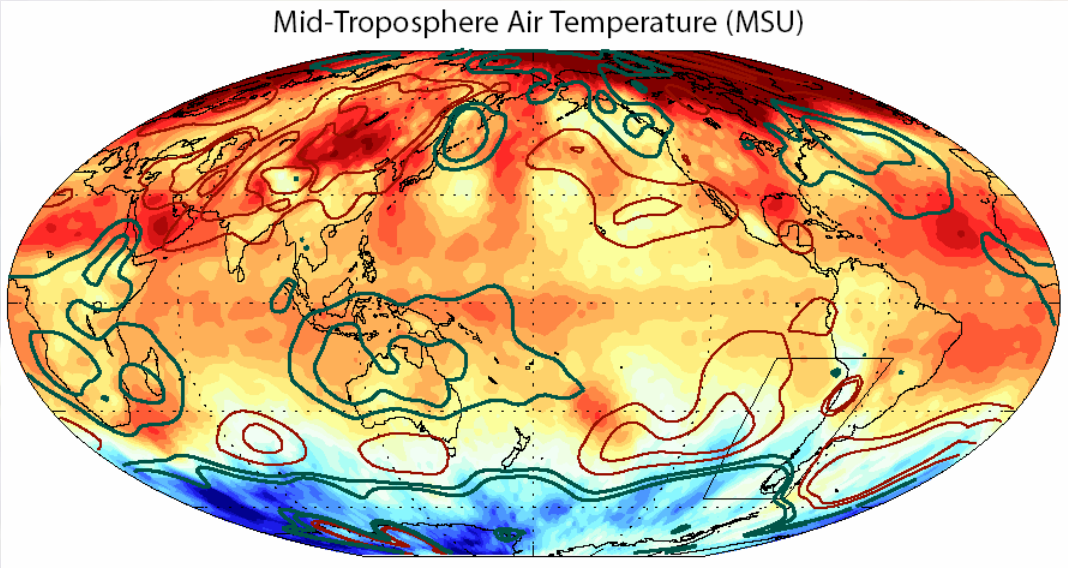
http://www.st-edmunds.cam.ac.uk/CIS/houghton/images/fig2.jpg

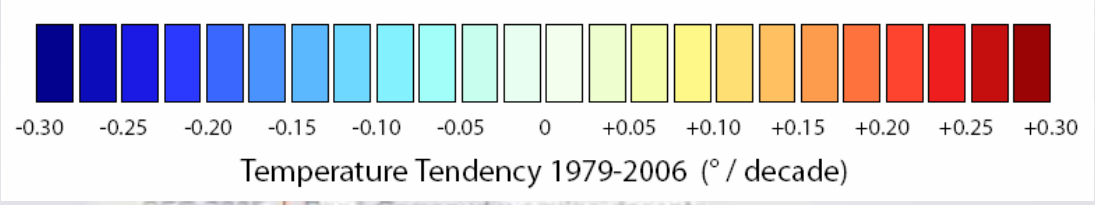


4th IPCC Report

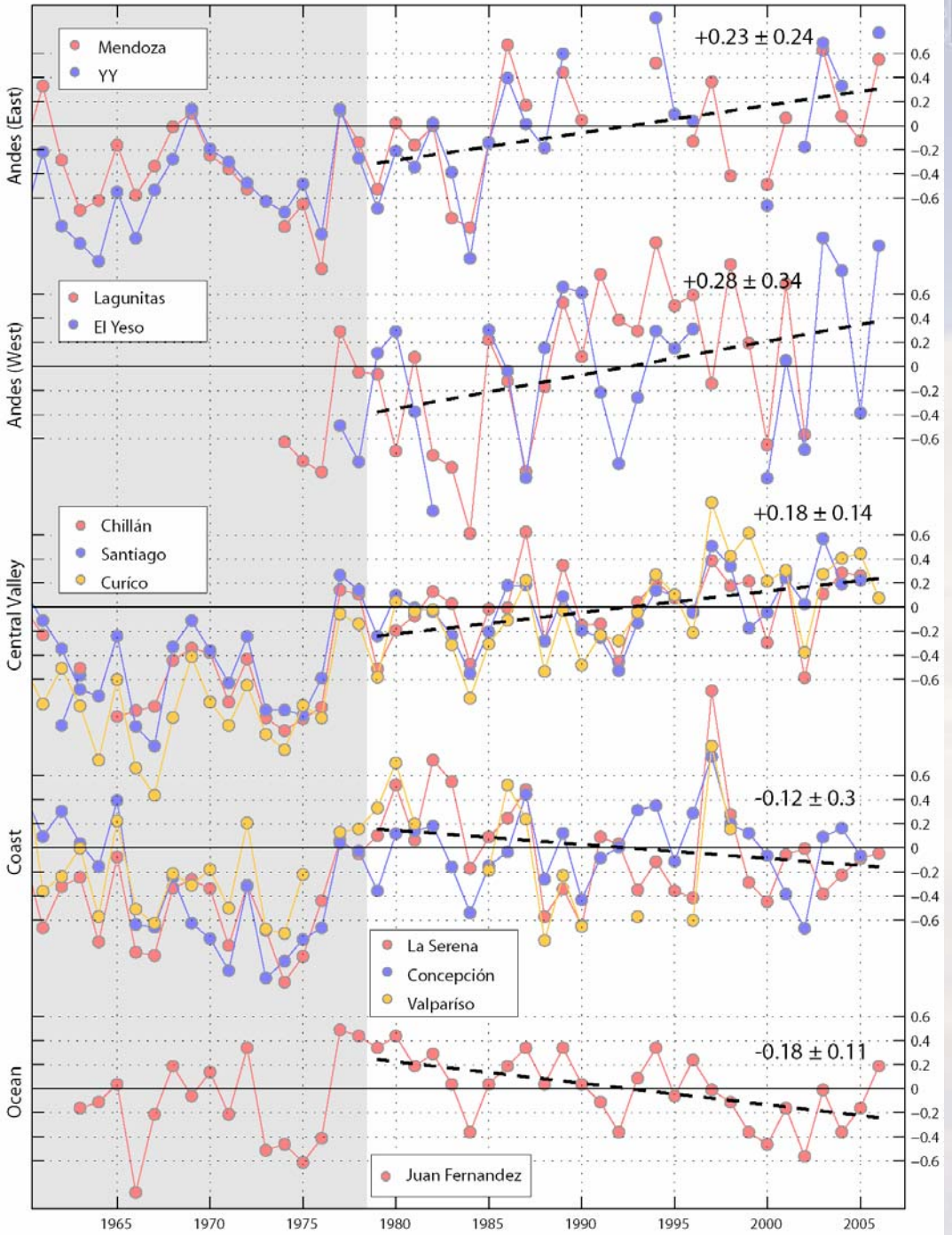
Global Temperature Change 1979-2006



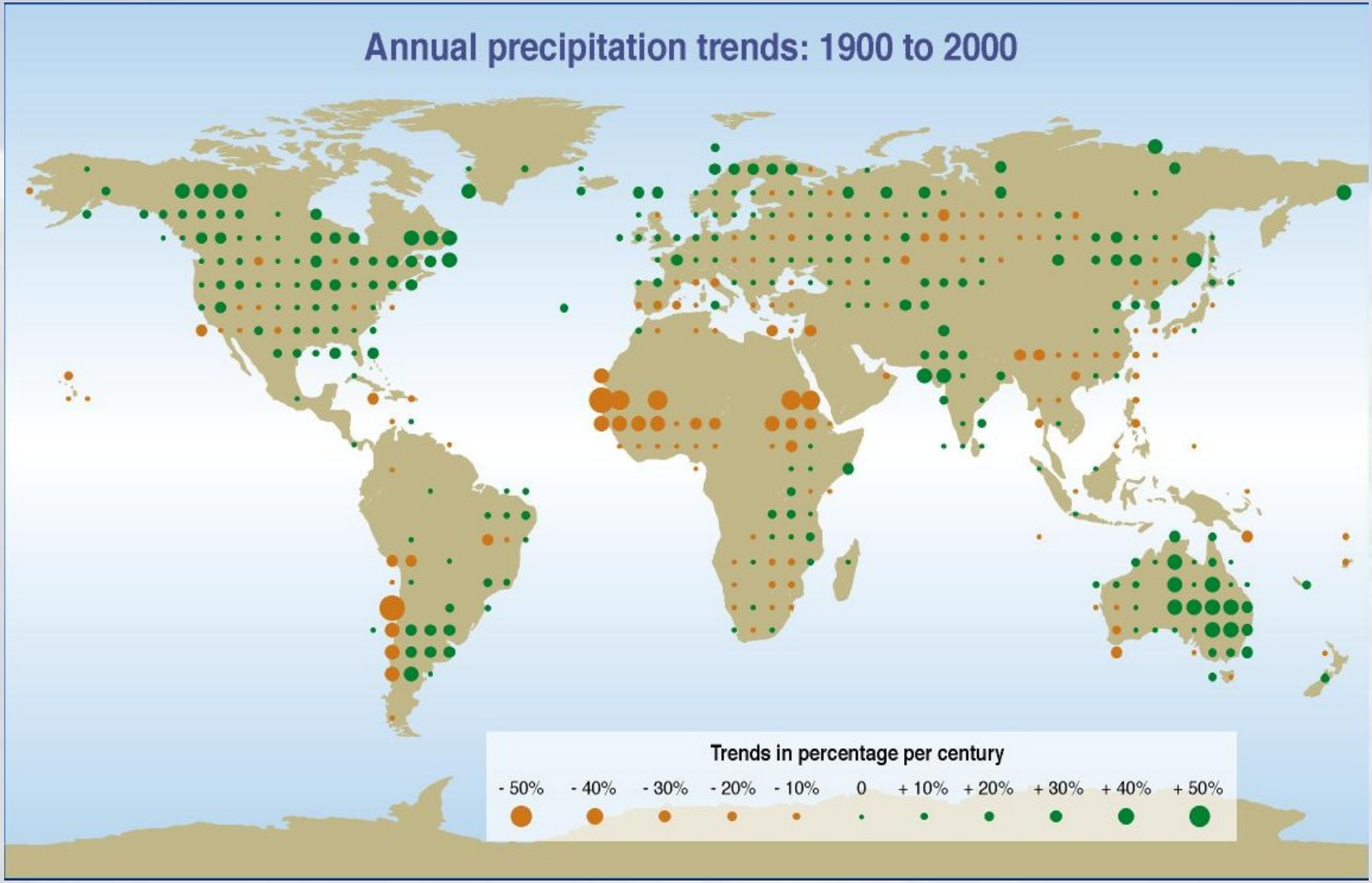




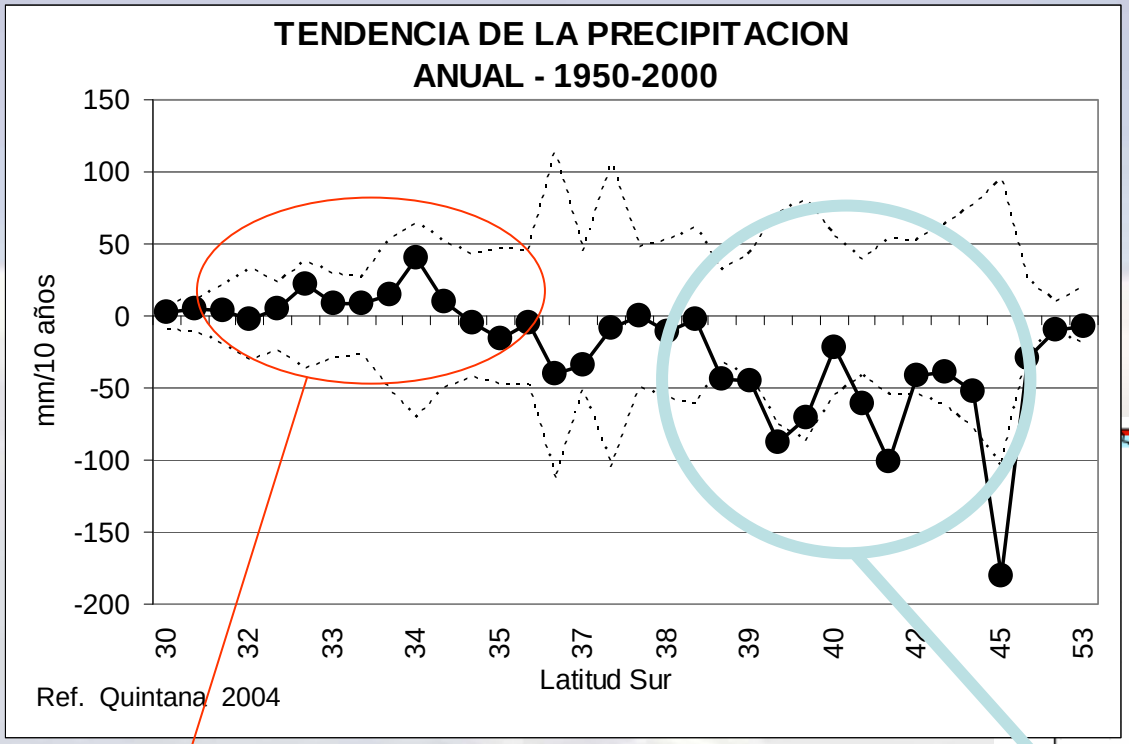
Temperature Changes in Central Chile

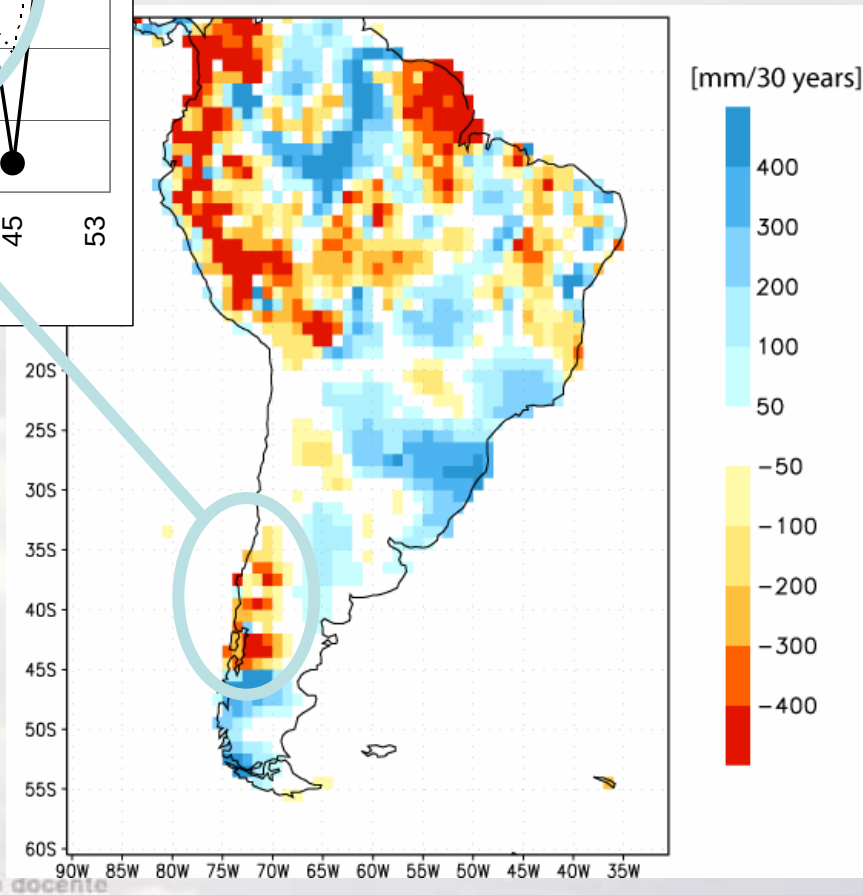


Atmósfera, tiempo y clima



Atmósfera, tiempo y clima

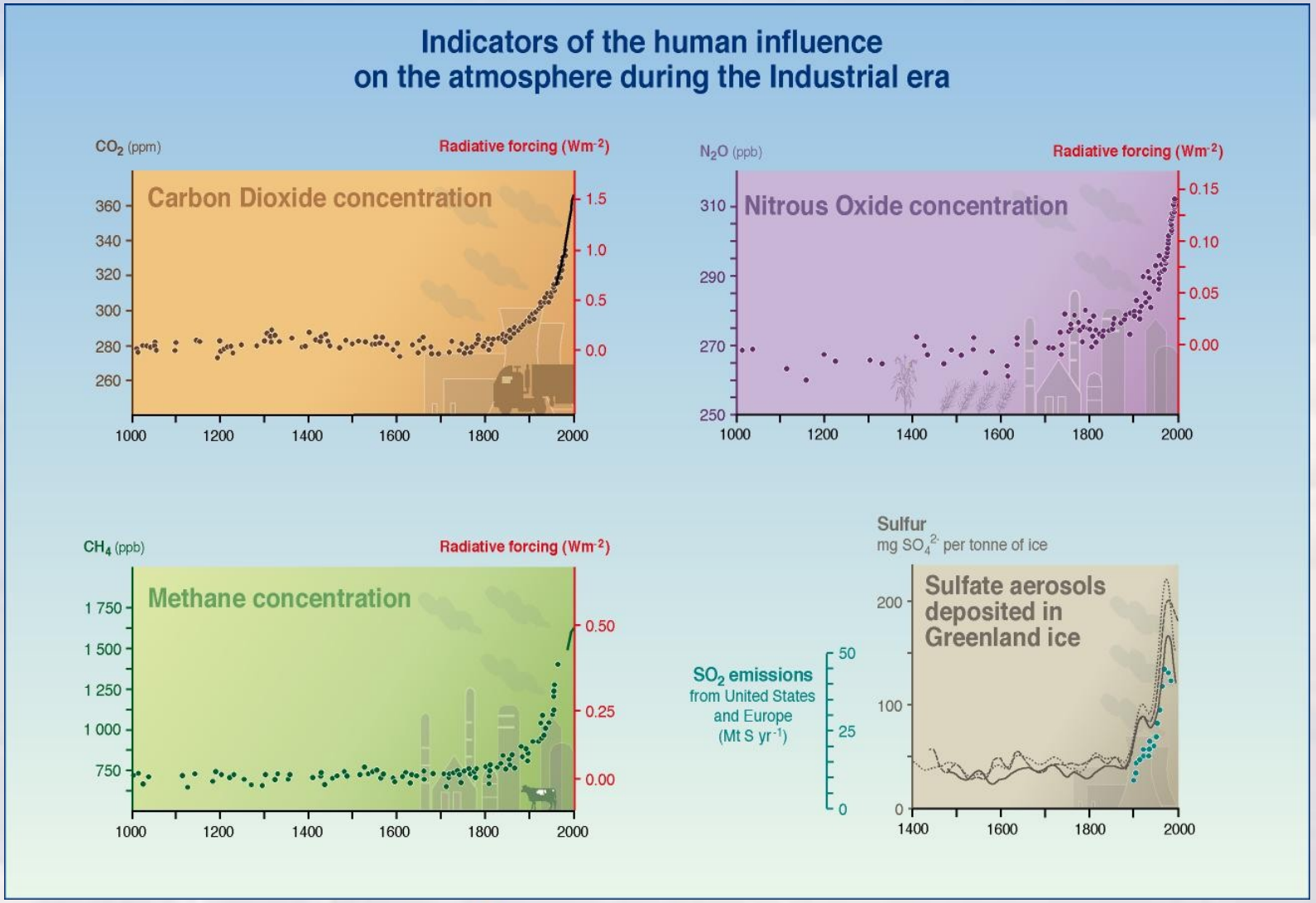


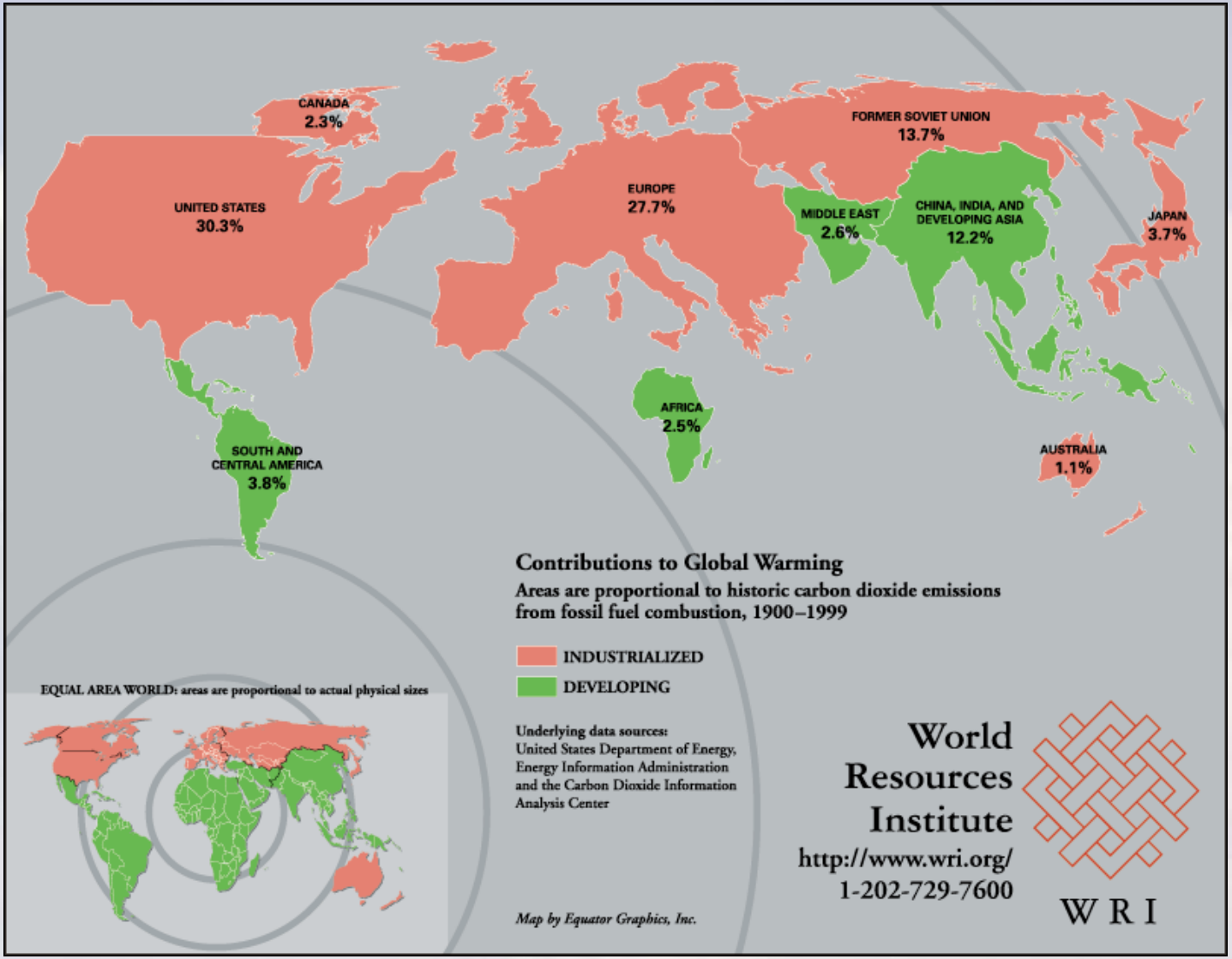


Semiarid climate
MAP ~ 30-500 mm
σ(IA)/MAP ~ 0.3 – 0.5
Strong ENSO Impact

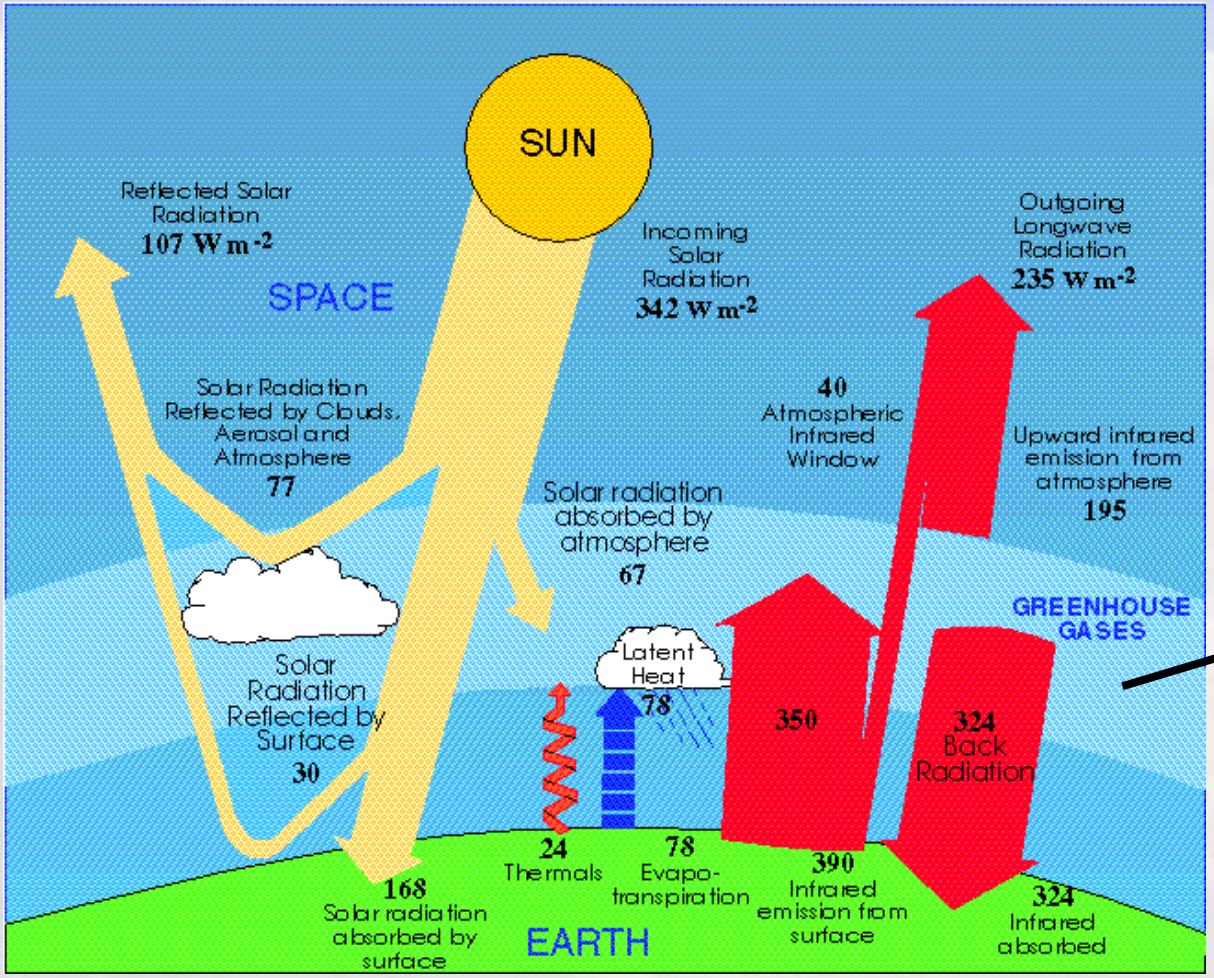
Factores de cambio climático contemporáneo (antropogénico)

Factores de cambio climático contemporáneo (antropogénico)




CANADA
2.3%
UNITED STATES
30.3%
EUROPE
27.7%
FORMER SOVIET UNION
13.7%
MIDDLE EAST
2.6%
CHINA, INDIA, AND
DEVELOPING ASIA
12.2%
JAPAN
3.7%
AFRICA
2.5%
SOUTH AND
CENTRAL AMERICA
3.8%
AUSTRALIA
1.1%
Contributions to Global Warming
Areas are proportional to historic carbon dioxide emissions
from fossil fuel combustion, 1900–1999
INDUSTRIALIZED
DEVELOPING
EQUAL AREA WORLD: areas are proportional to actual physical sizes
Underlying data sources:
United States Department of Energy,
Energy Information Administration
and the Carbon Dioxide Information
Analysis Center
Map by Equator Graphics, Inc.
World
Resources
Institute
http://www.wri.org/
1-202-729-7600
WRI

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

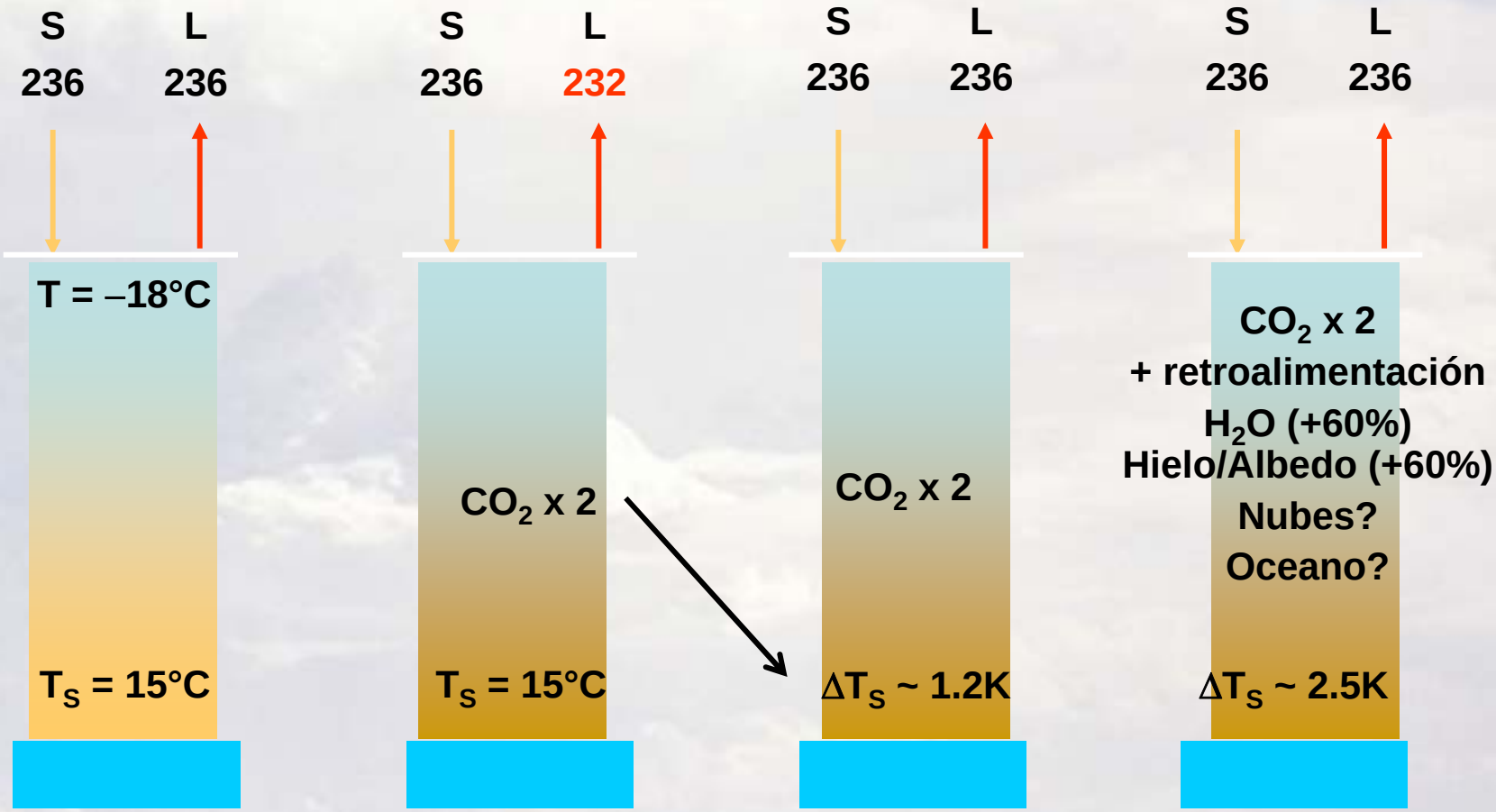


Gases Invernadero

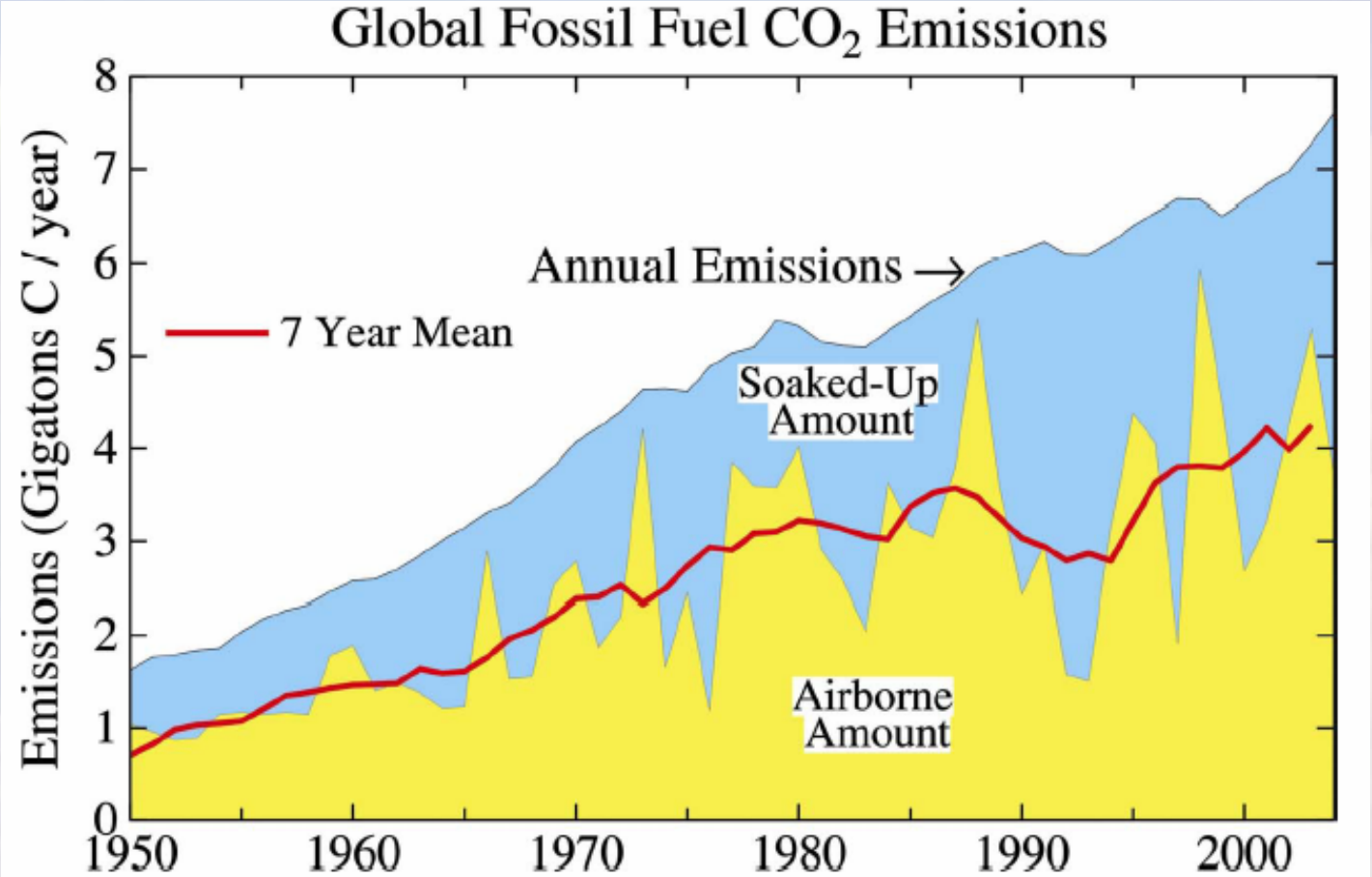
H_2O, CO_2, CH_4, N_20

Efecto invernadero antrópico

Sistema planetario intenta mantener un balance entre radiación recibida y radiación emitida



Durante el siglo XX el océano/biosfera ha capturado cerca del 40% del CO2 emitido…captura puede variar (± ?) con incremenento de T



Global fossil fuel CO_2 emissions with division into portions that remain airborne or are soaked up by the ocean and land.

Source: Hansen and Sato, *PNAS*, **101**, 16109, 2004.

5

Proyecciones climáticas para el siglo XXI:

Modelos numéricos de la atmósfera/oceano
Proyecciones de GEI (escenarios de desarrollo)

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

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

Momentum eqn.

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

Energy eqn.

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

Mass eqn.

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

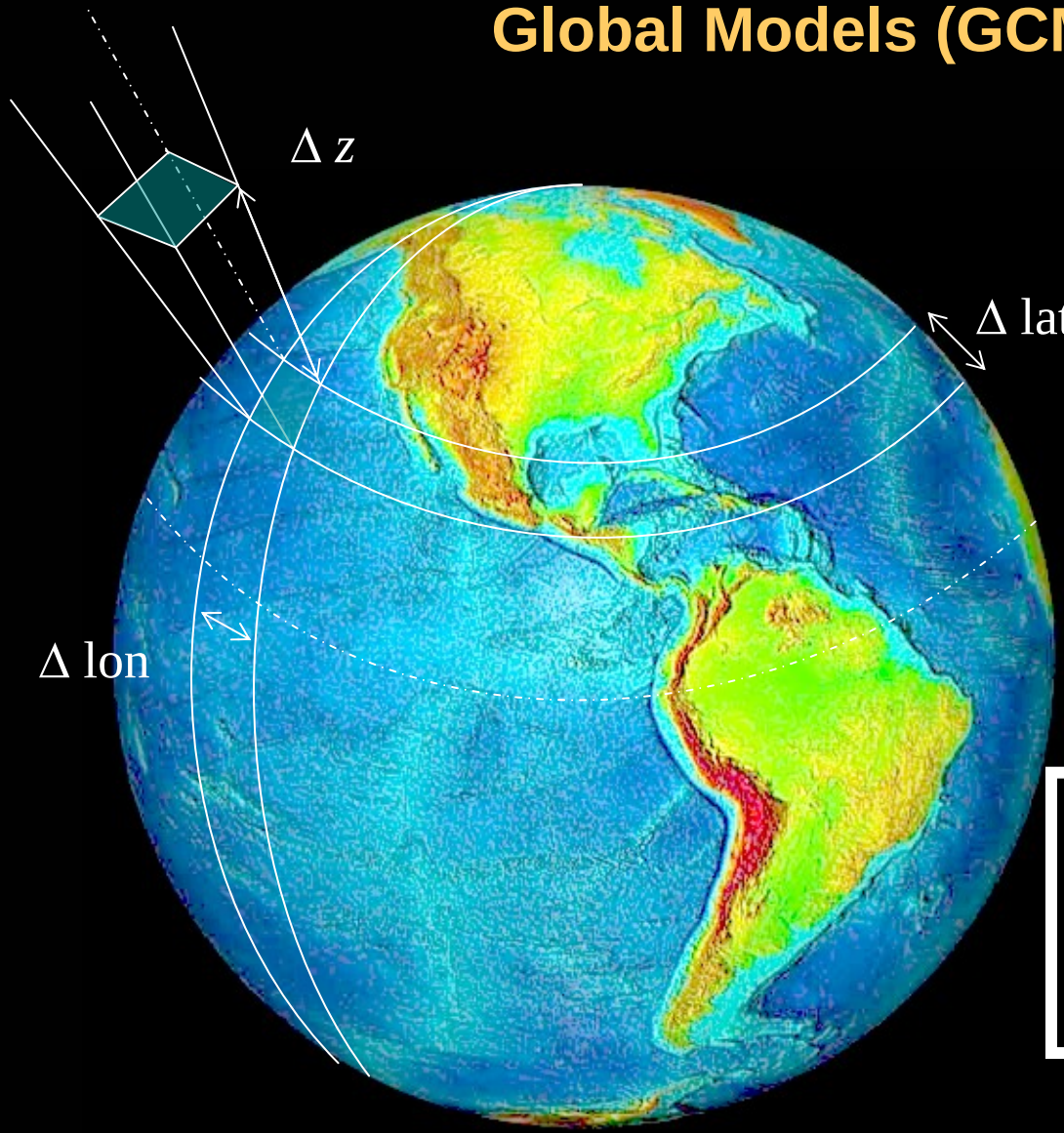
Idea gas law

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

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

Water substance eqns.

Global Models (GCM)

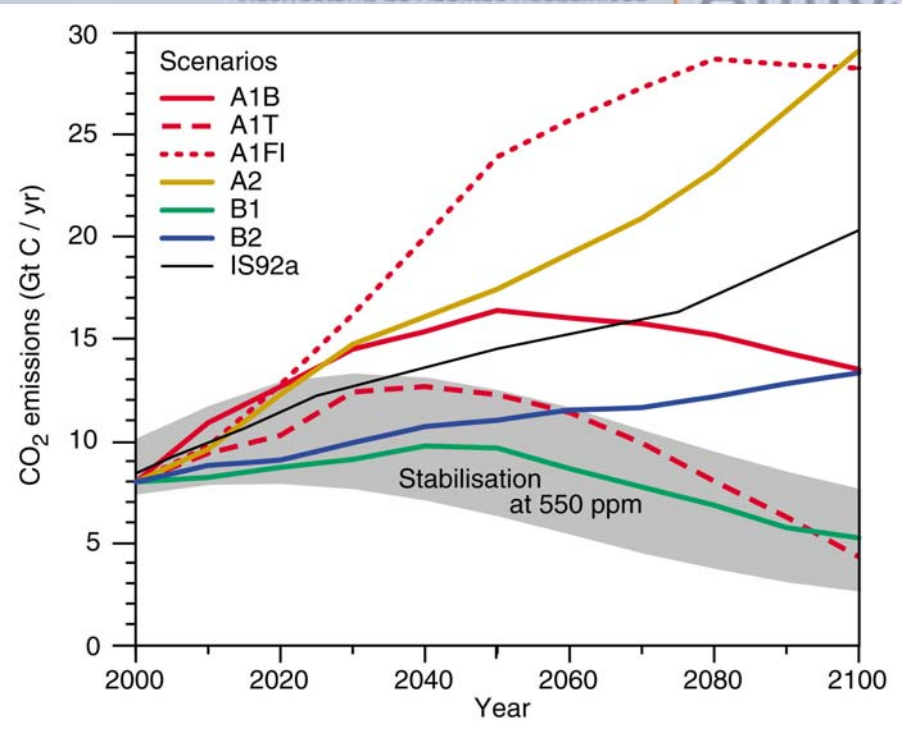


Concentración de CO_2 y otros GEI determinan las condiciones medias de la atmósfera

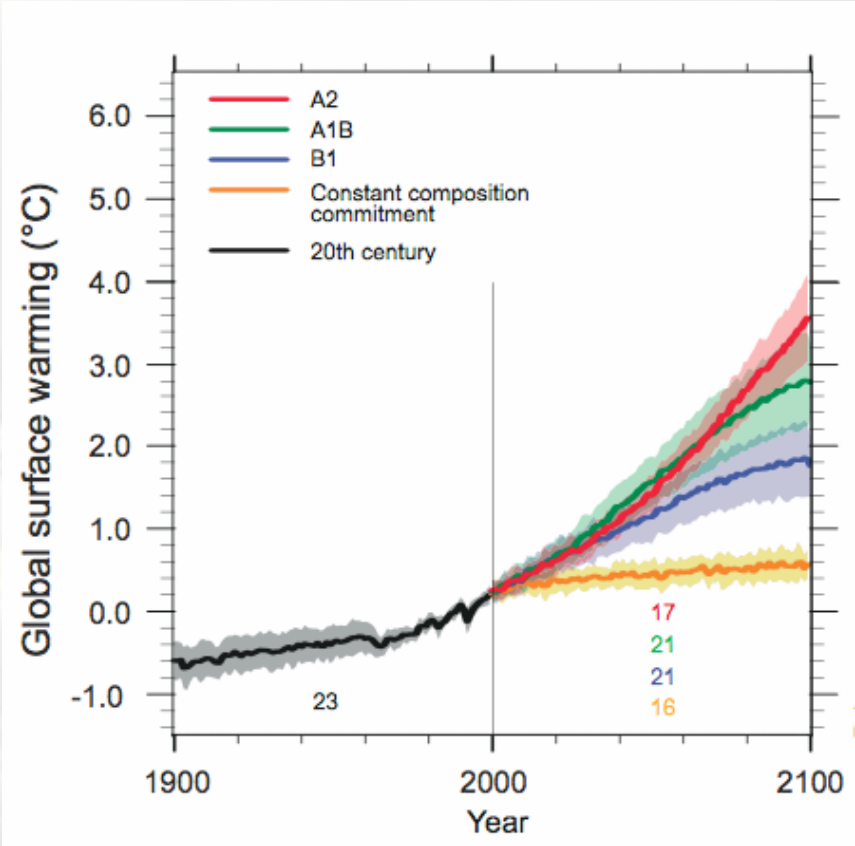
Δlat ~ Δ lon ~ 1° - 3° Δz ~ 1 km Δt ~ minutes-hours

Top of atmosphere: 15-50 km

Atmósfera, tiempo y clima



GCMs



Atmósfera, tiempo y clima

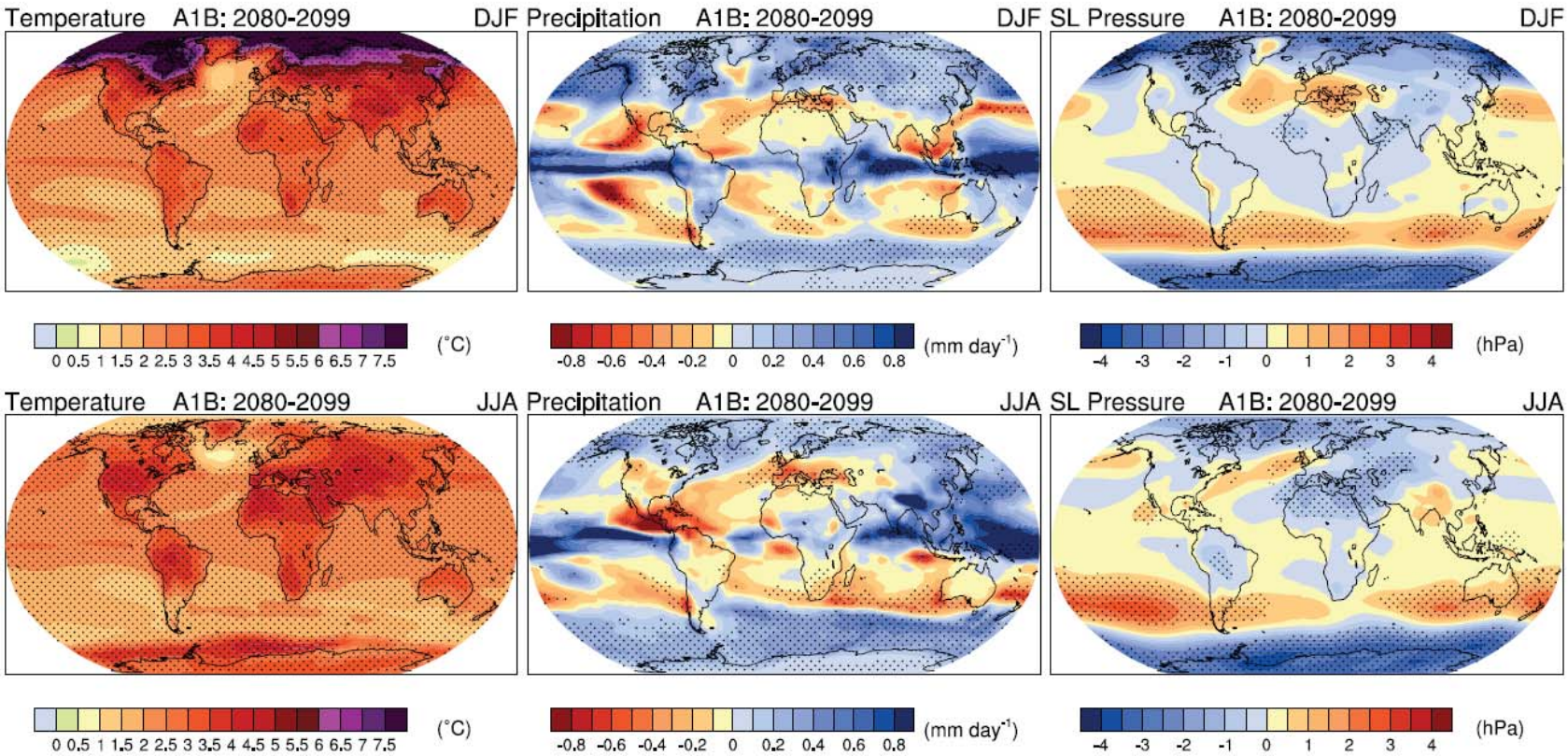
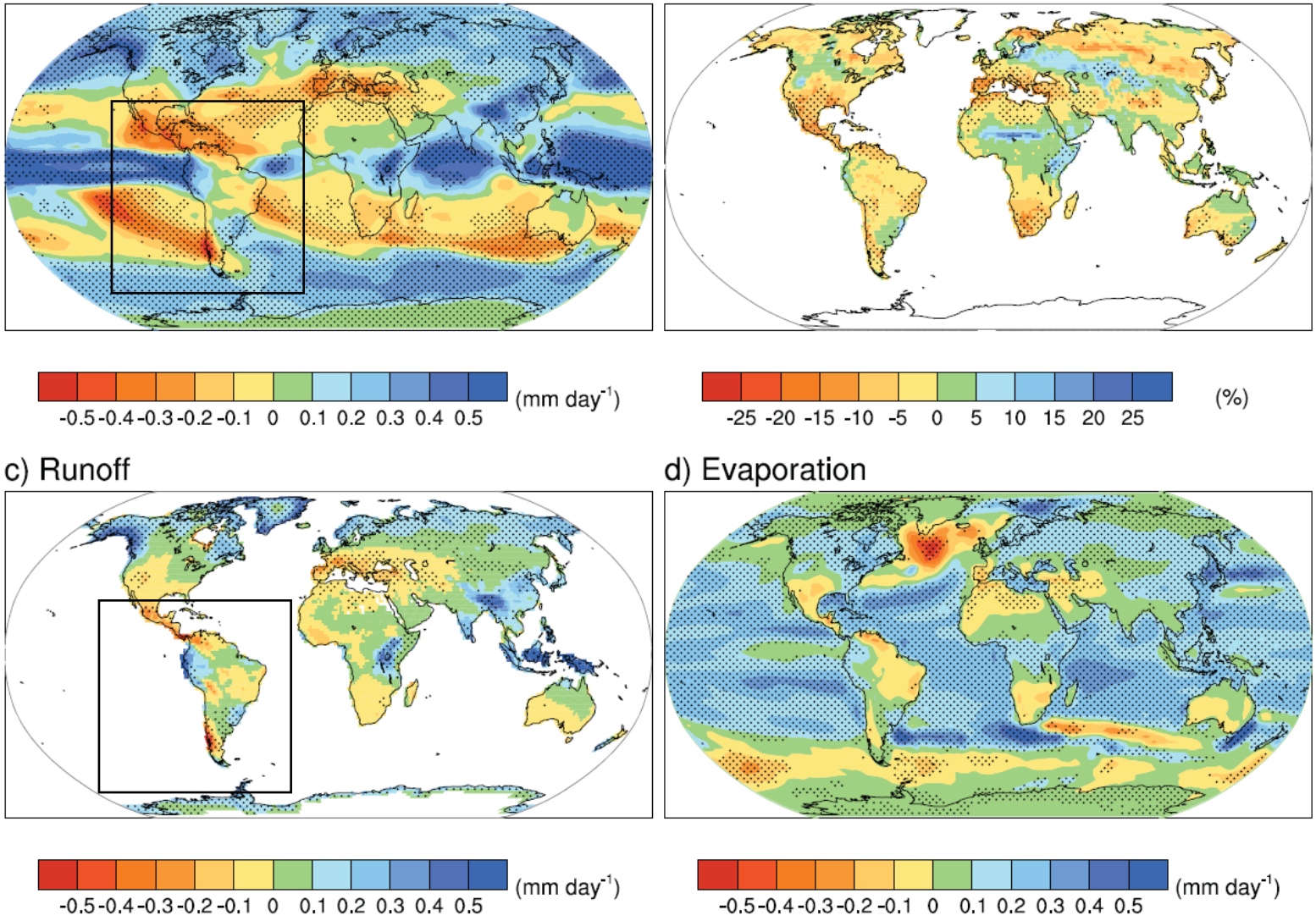


Figure 10.9. *Multi-model mean changes in surface air temperature (°C, left), precipitation (mm day⁻¹, middle) and sea level pressure (hPa, right) for boreal winter (DJF, top) and summer (JJA, bottom). Changes are given for the SRES A1B scenario, for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Results for individual models can be seen in the Supplementary Material for this chapter.*



ure 10.12. *Multi-model mean changes in (a) precipitation (mm day⁻¹), (b) soil moisture content (%), (c) runoff (mm day⁻¹) and (d) evaporation (mm day⁻¹). To indicate con-ncy in the sign of change, regions are stippled where at least 80% of models agree on the sign of the mean change. Changes are annual means for the SRES A1B scenario ne period 2080 to 2099 relative to 1980 to 1999. Soil moisture and runoff changes are shown at land points with valid data from at least 10 models. Details of the method results for individual models can be found in the Supplementary Material for this chapter.*

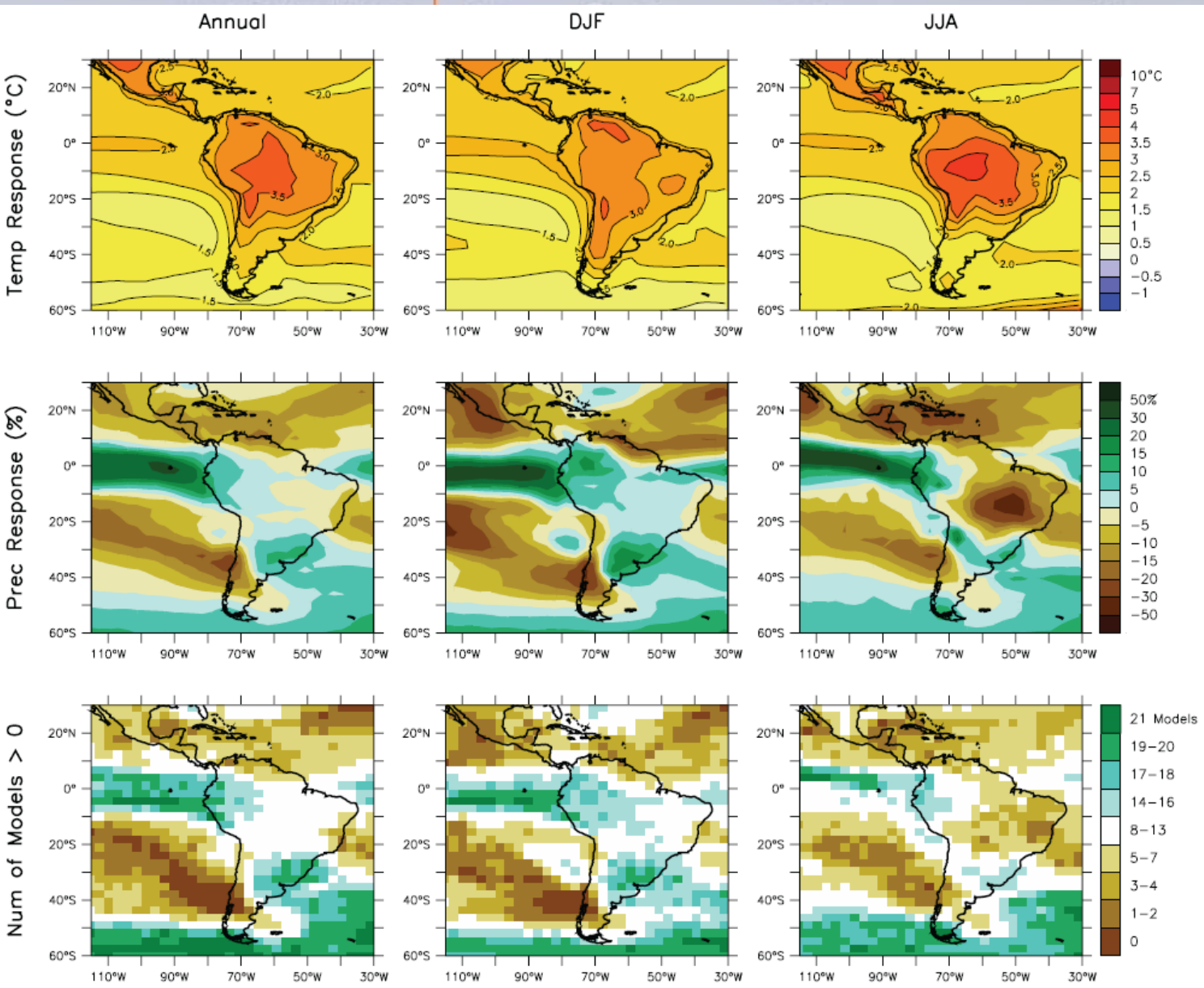
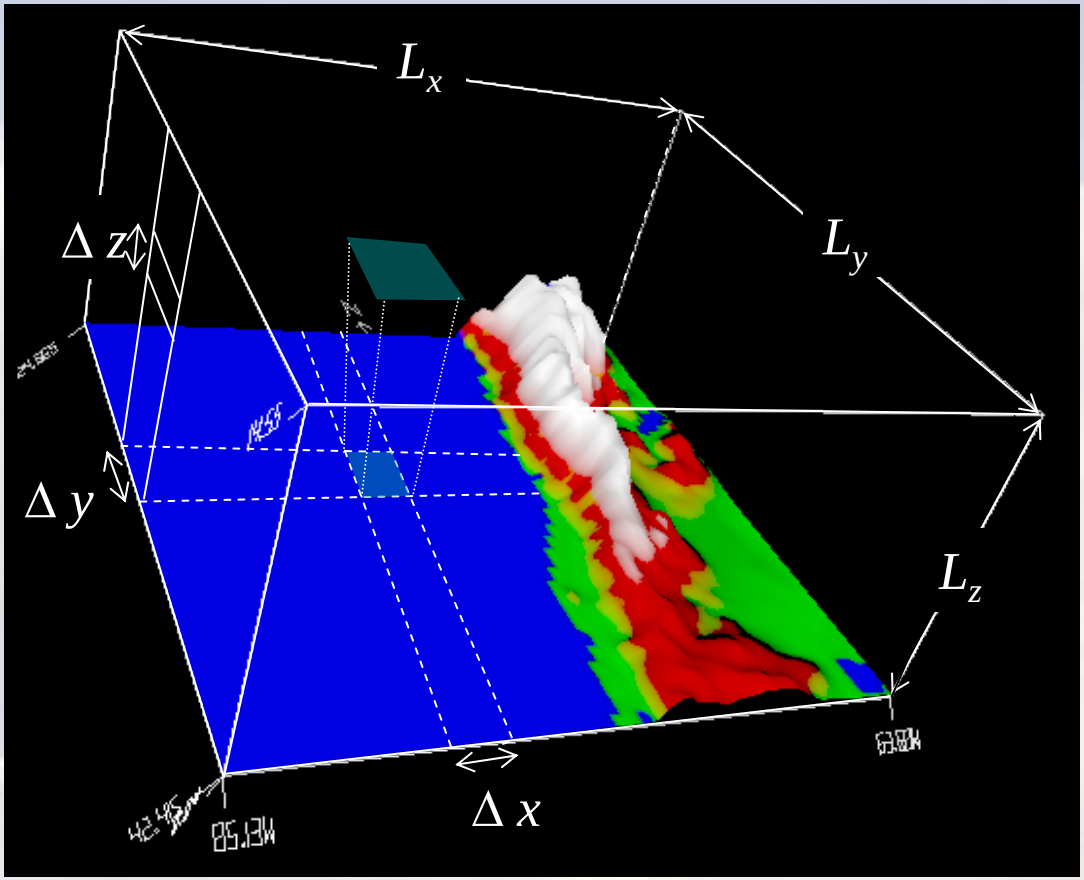


Figure 11.15. *Temperature and precipitation changes over Central and South America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom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

Regional Models (LAM, Mesoscale Models)



$\Delta x \sim \Delta y \sim$ 1-50 km $\quad \Delta z \sim$ 50-200 m $\quad \Delta t \sim$ seconds

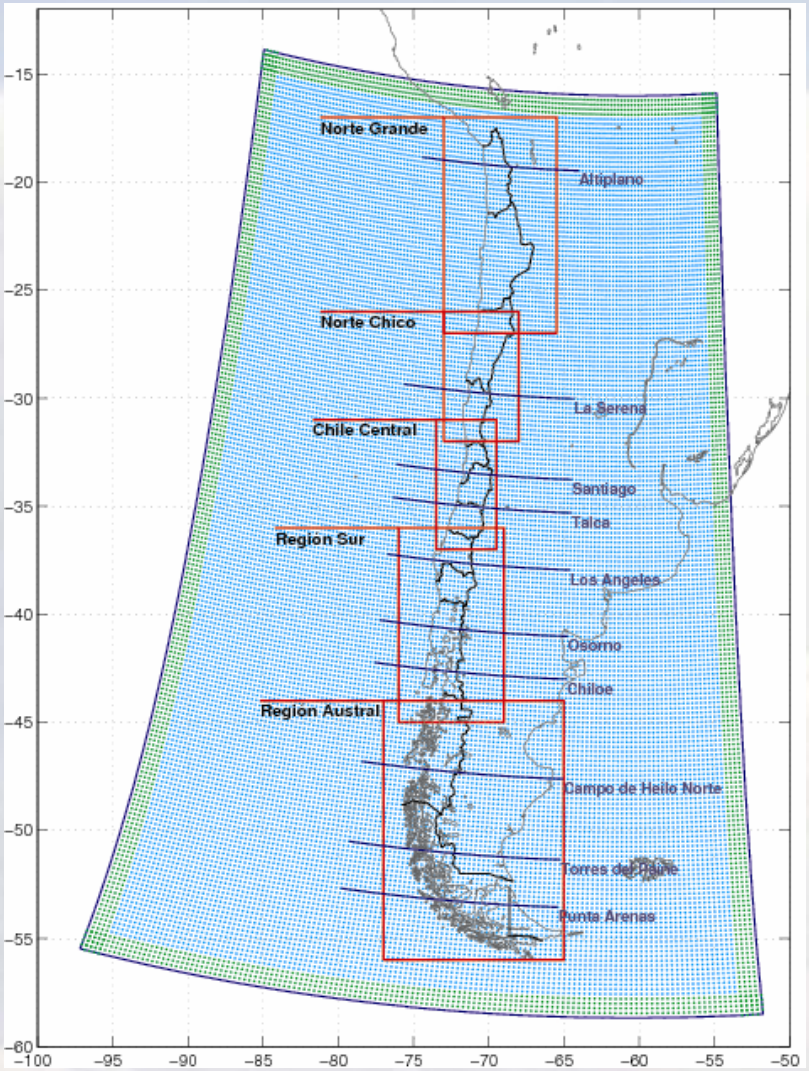
$L_x \sim L_y \sim$ 100-5000 km $\quad L_z \sim$ 15 km $\quad$ LBC from GCMs

Main Problem: Garbage in – Garbage out

Proyecto CONAMA – DGF/UCH

http://www.conama.cl/portal/1301/article-39442.html

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



Model:

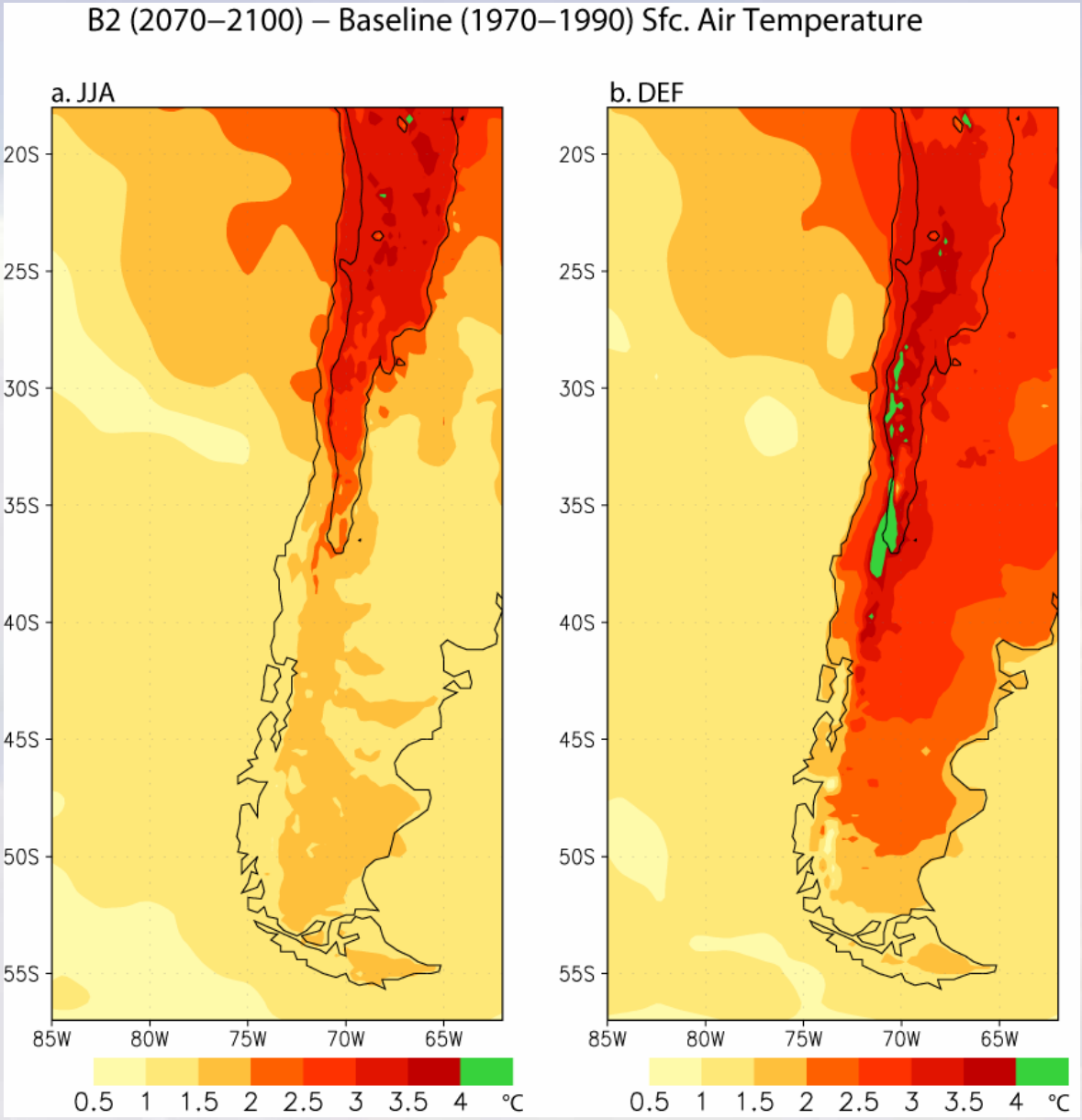
- PRECIS – UK

Single domain

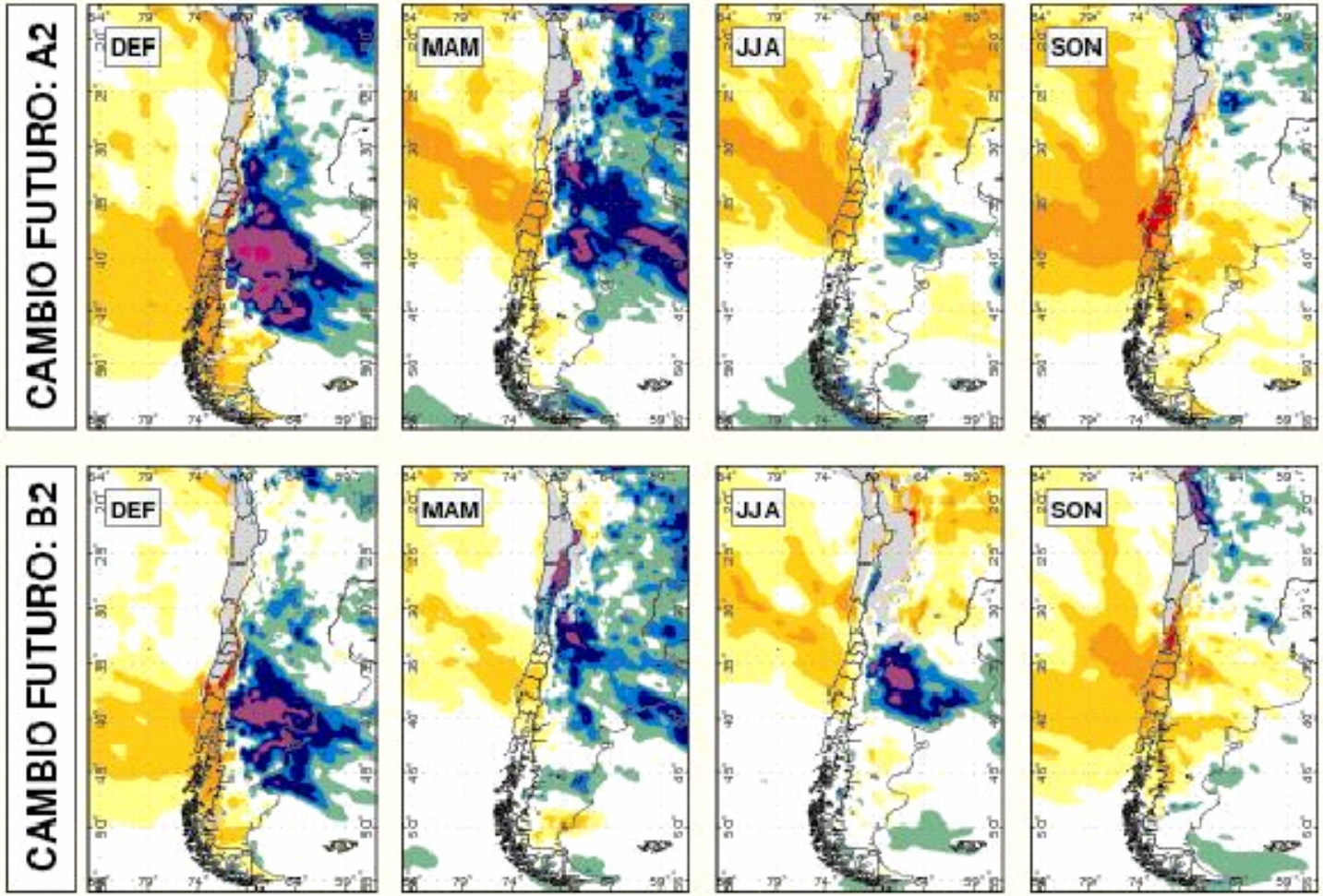
- Horiz. grid spacing. 25 km
- 19 vertical levels
- Lateral BC: HadAM every 6h
- Sfc. BC: HadISST1 + Linear trend

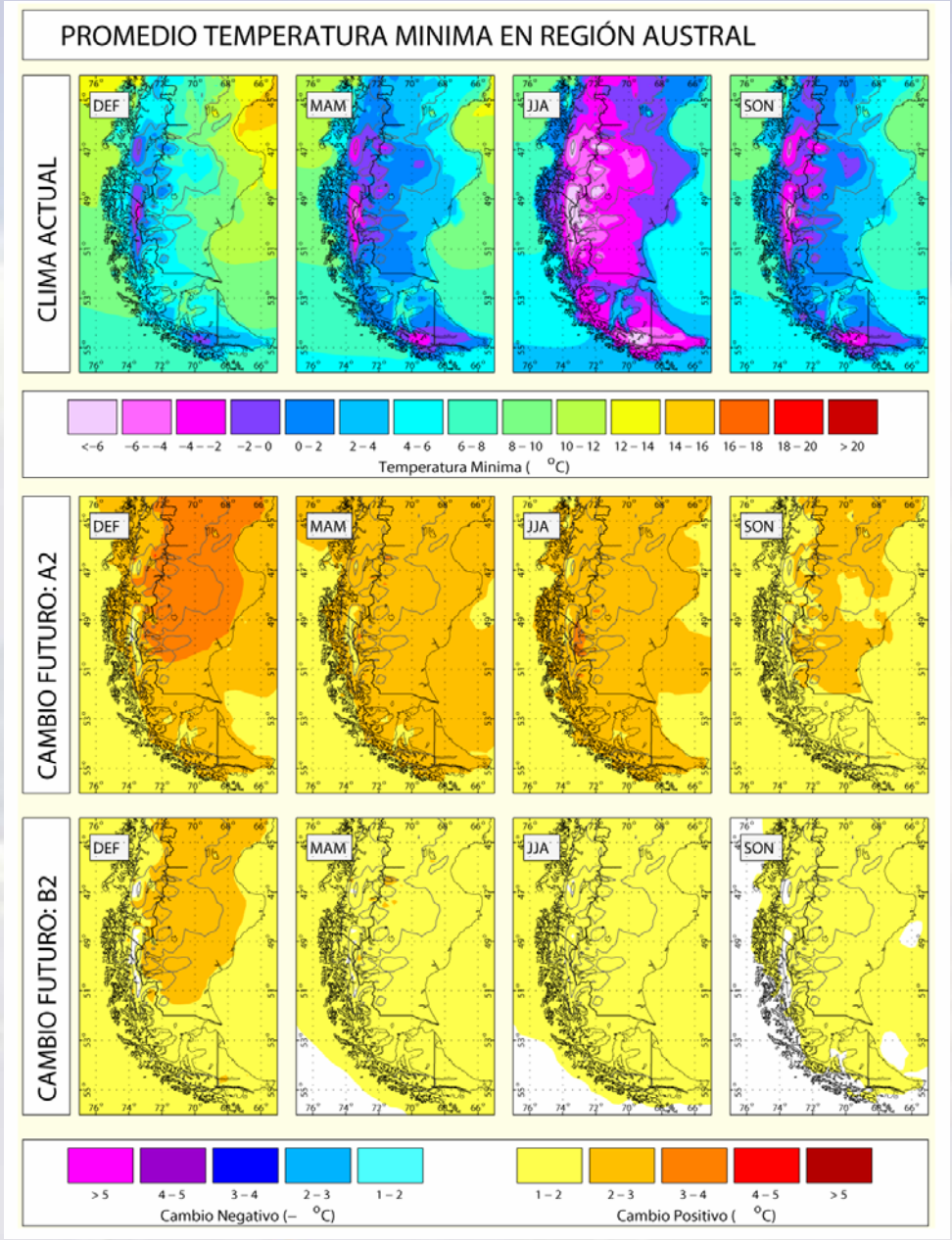
Simulations

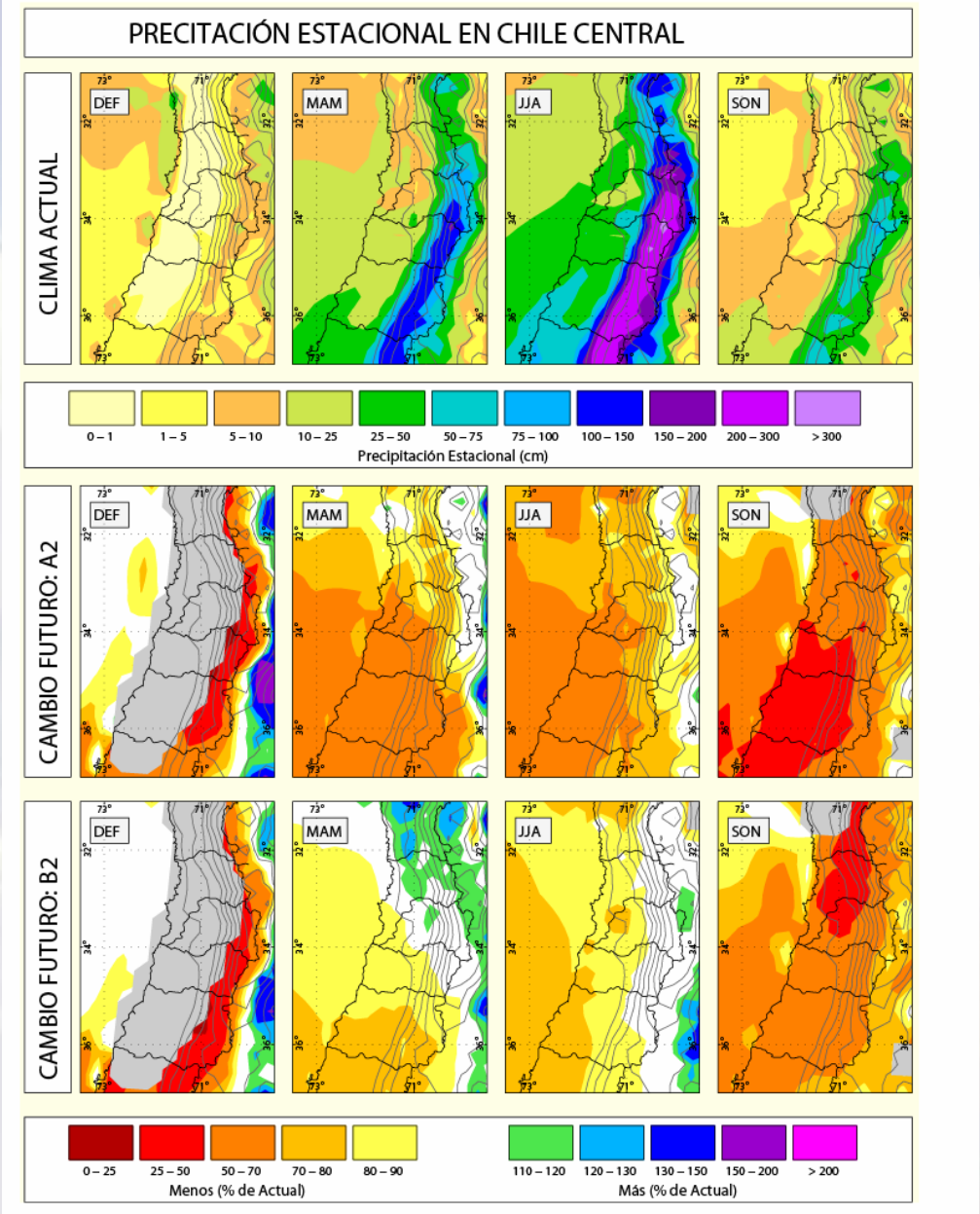
- 1961-1990 Baseline
- 2071-2100 SRES A2 y B2
- 30 years @ 3 min → 4 months per simulation in fast PC


B2 (2070–2100) – Baseline (1970–1990) Sfc. Air Temperature
a. JJA
b. DEF
20S
25S
30S
35S
40S
45S
50S
55S
85W
80W
75W
70W
65W
0.5 1 1.5 2 2.5 3 3.5 4 °C

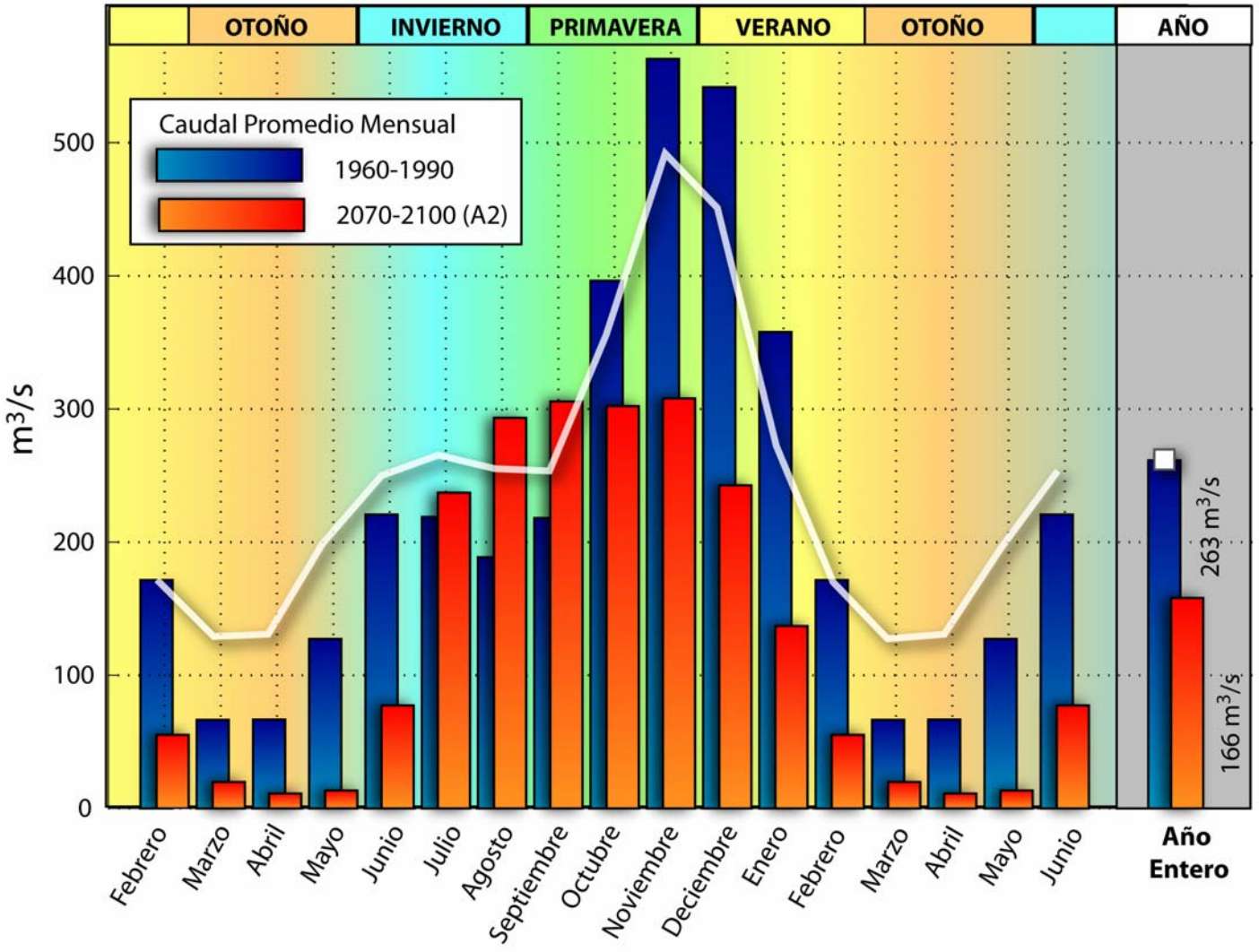
Atmósfera, tiempo y clima




PROMEDIO TEMPERATURA MINIMA EN REGIÓN AUSTRAL
CLIMA ACTUAL
DEF
MAM
JJA
SON
<-6
-6 – -4
-4 – -2
-2 – 0
0 – 2
2 – 4
4 – 6
6 – 8
8 – 10
10 – 12
12 – 14
14 – 16
16 – 18
18 – 20
> 20
Temperatura Minima (°C)
CAMBIO FUTURO: A2
CAMBIO FUTURO: B2
> 5
4 – 5
3 – 4
2 – 3
1 – 2
Cambio Negativo (– °C)
Cambio Positivo (°C)


PRECITACIÓN ESTACIONAL EN CHILE CENTRAL
CLIMA ACTUAL
DEF
MAM
JJA
SON
0 – 1
1 – 5
5 – 10
10 – 25
25 – 50
50 – 75
75 – 100
100 – 150
150 – 200
200 – 300
> 300
Precipitación Estacional (cm)
CAMBIO FUTURO: A2
CAMBIO FUTURO: B2
0 – 25
25 – 50
50 – 70
70 – 80
80 – 90
Menos (% de Actual)
110 – 120
120 – 130
130 – 150
150 – 200
> 200
Más (% de Actual)

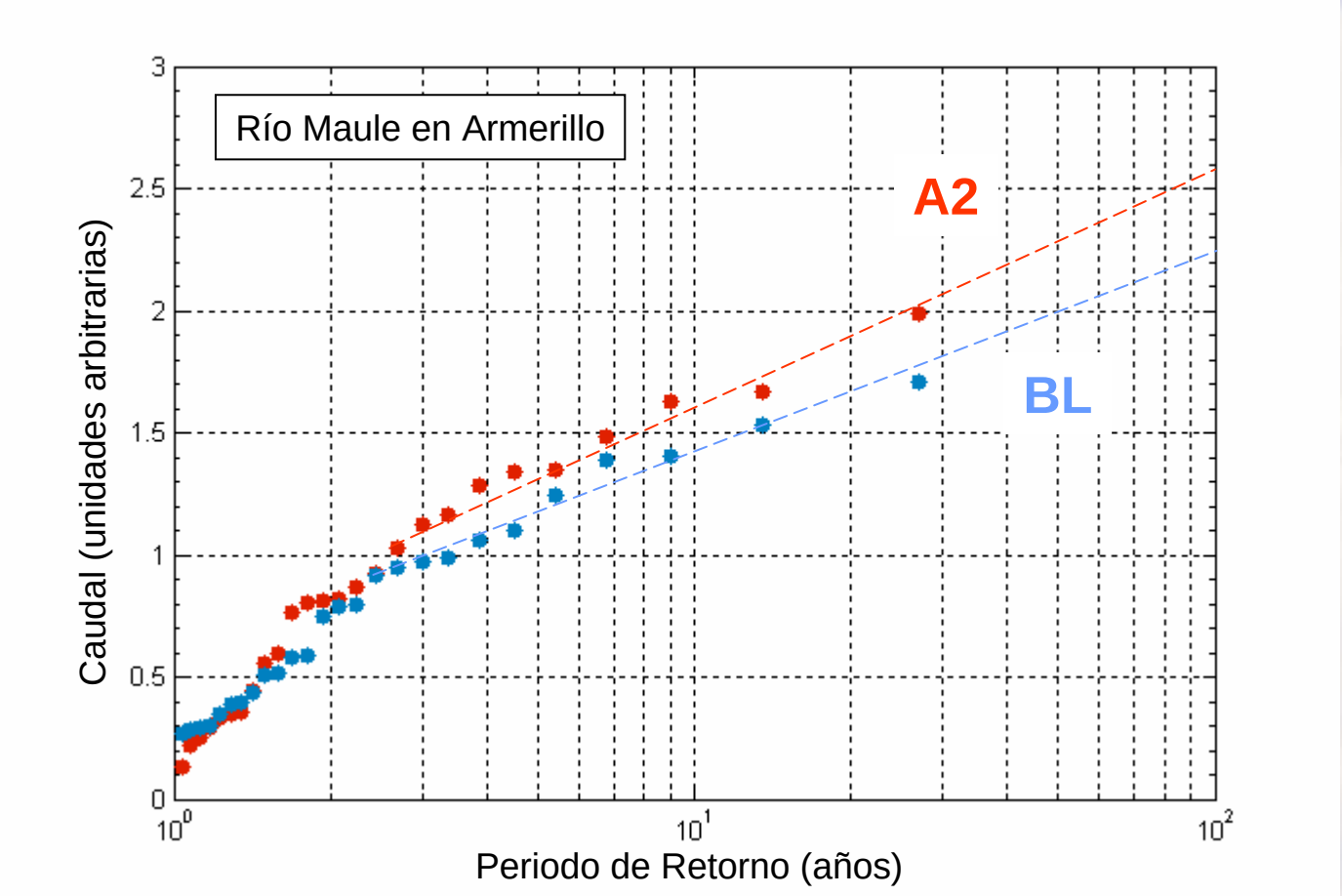
CAUDAL SIMULADO DEL RIO MAULE* - PRESENTE y FUTURO (A2)



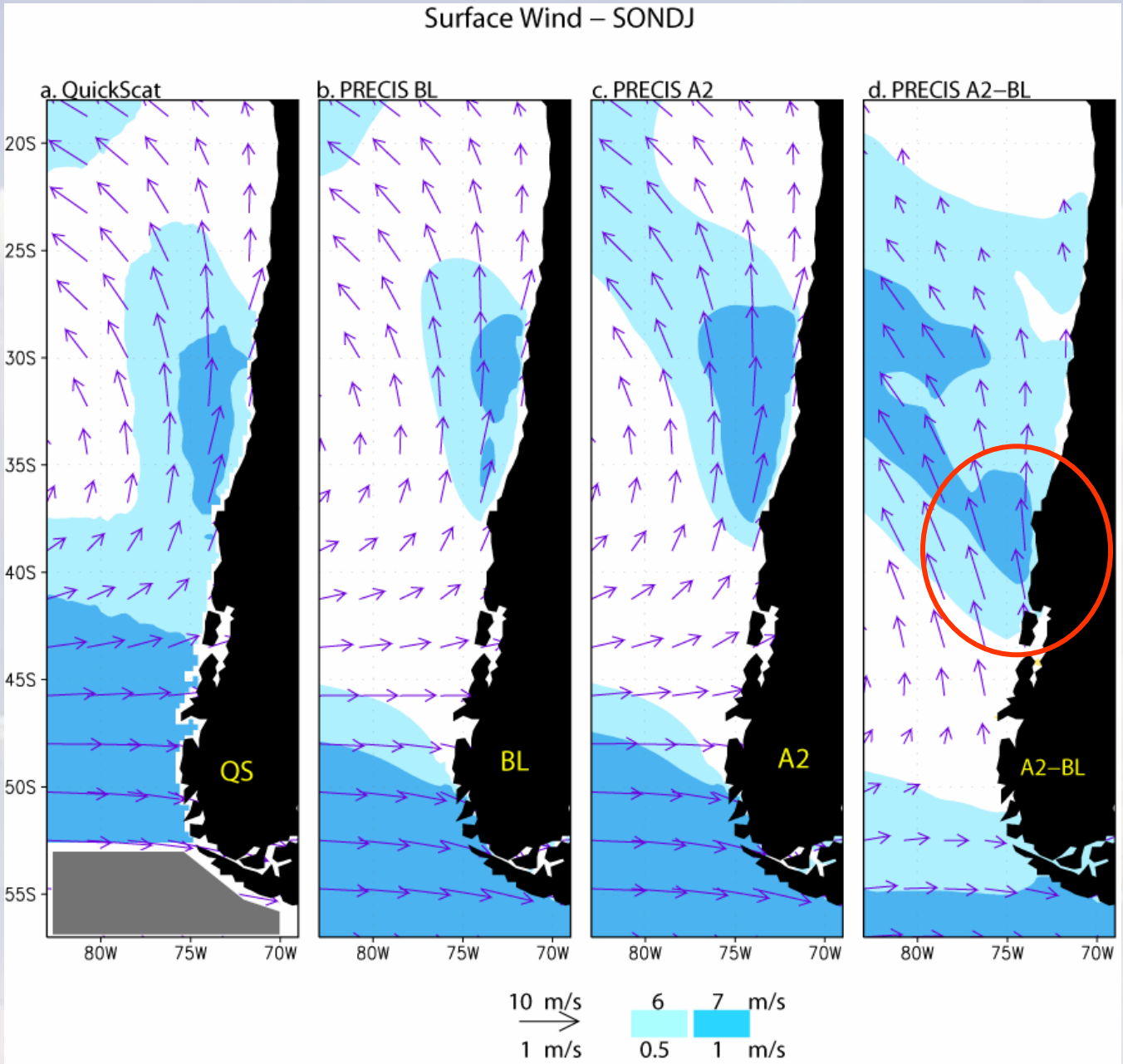
* Rio Maule en Armerillo - Pre-Cordillera

PRECIS-DGF - Eventos Extremos

Modelo hidrológico simple indica cierta disminución de **caudales extremos diarios** con bajo periodo de retorno pero un aumento de caudales extremos diarios con alto periodo de retorno



Resultados PRECIS: Viento Superficial



Consecuencias biológicas a través de cambio en la surgencia costera y turbulencia

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.

Recursos hídricos superficiales se verán afectados por disminución de precipitación y aumento de temperatura

Necesidad de evaluar los efectos “sectoriales” de un cambio climático asociado a los GI. Quienes ganan, quienes pierden?