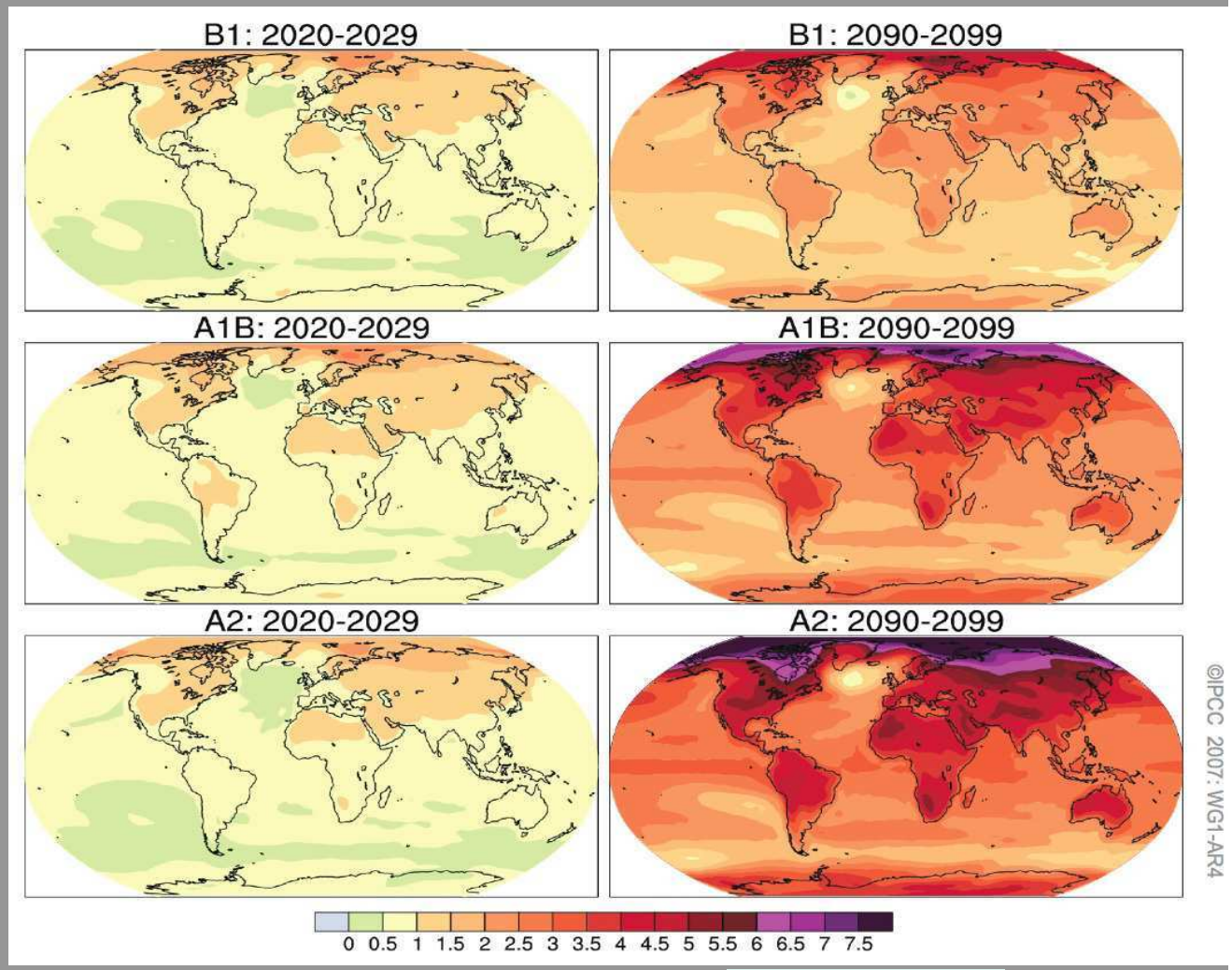
Proyecciones de cambios futuros en el clima

Mayor sobre tierra y en latitudes altas

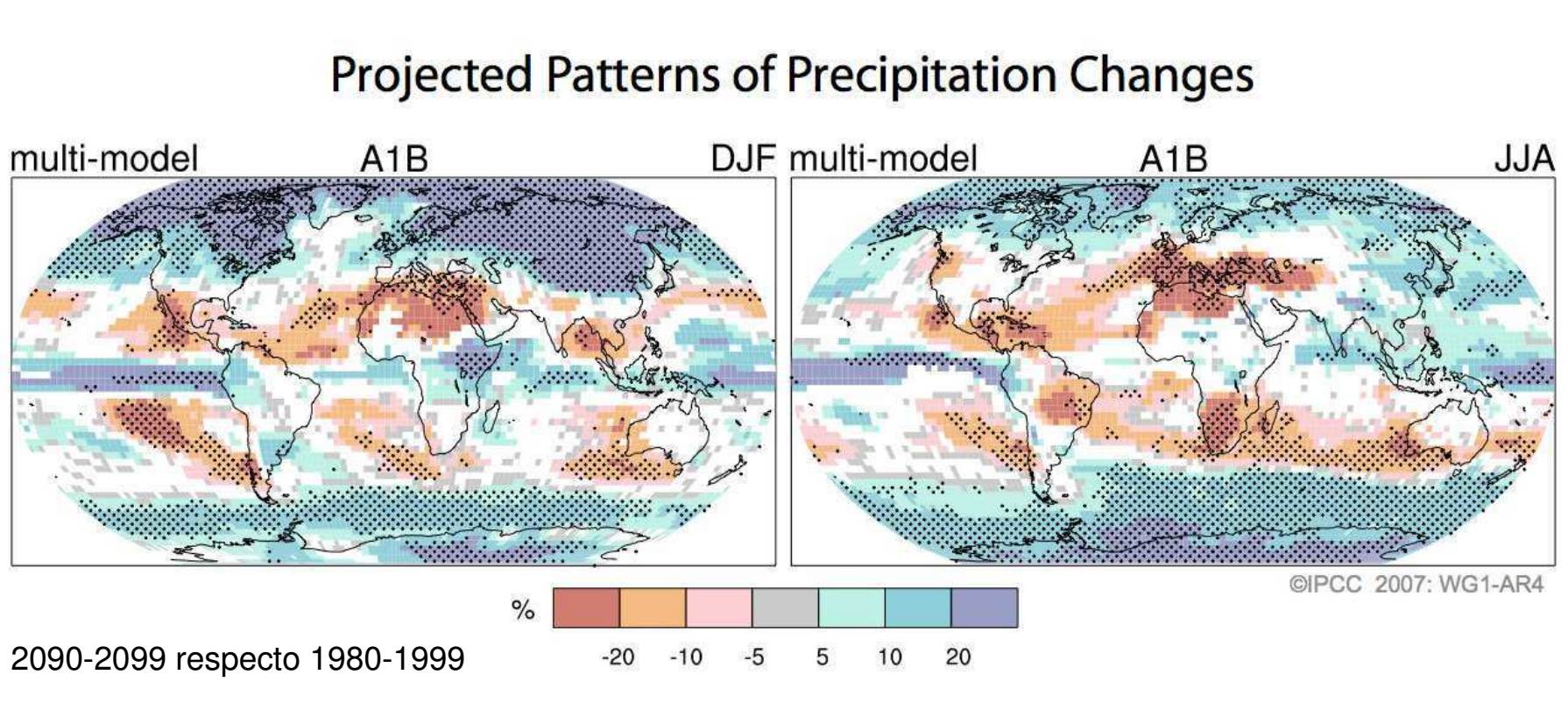
Proyecciones para las próximas décadas son insensibles a la elección del escenario

Proyecciones a largo plazo dependen del escenario y de la sensibilidad de los modelos climáticos



(AR4, 2007)

Proyecciones de cambios futuros en el clima



(AR4, 2007)

Precipitación aumenta muy probablemente in latitudes altas

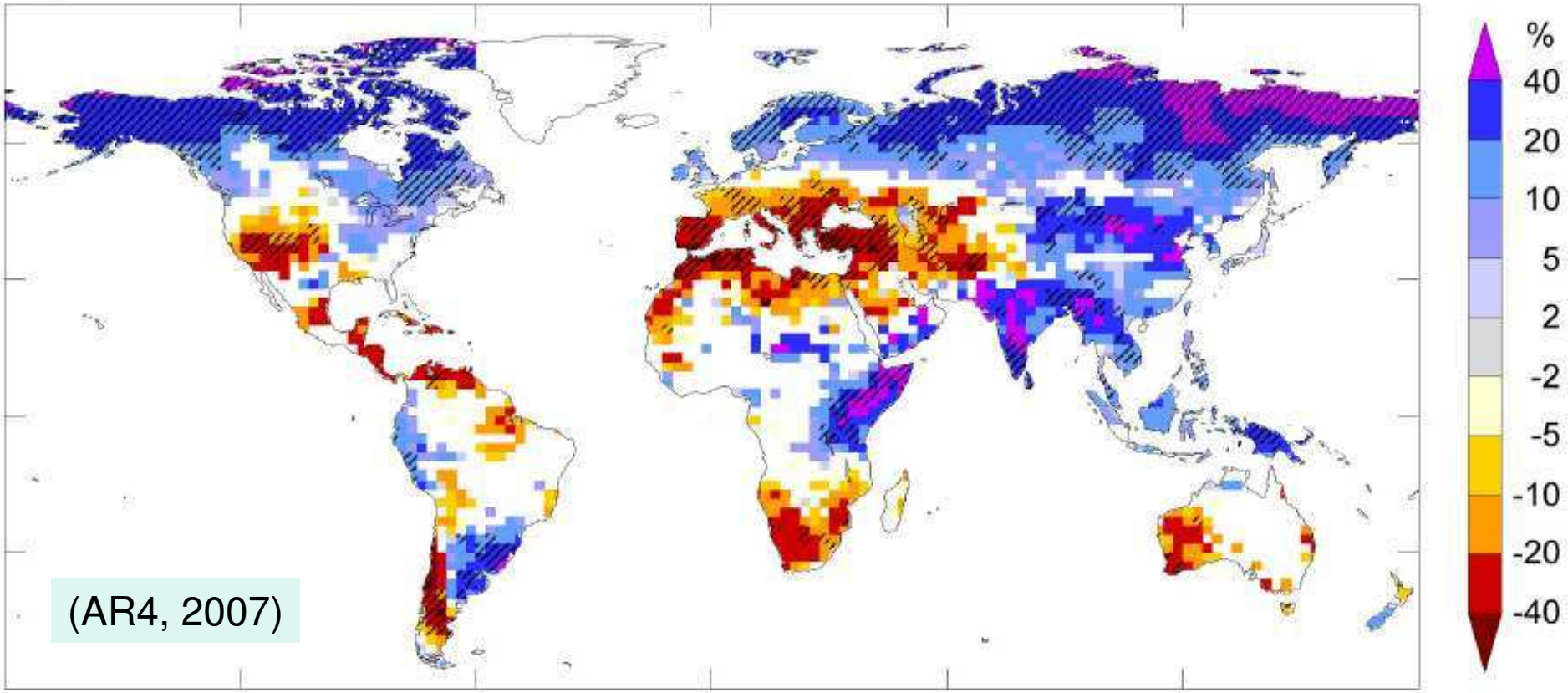
Decrece probablemente en la mayoría de las regiones terrestres subtropicales

Cambio (%) en escorrentía

[2090-2099 respecto a 1980-1999]

Ensemble basado en escenario SRES A1B

Projected relative changes in runoff by the end of the 21st century



(AR4, 2007)

La región Mediterránea parece mostrar una gran respuesta al cc

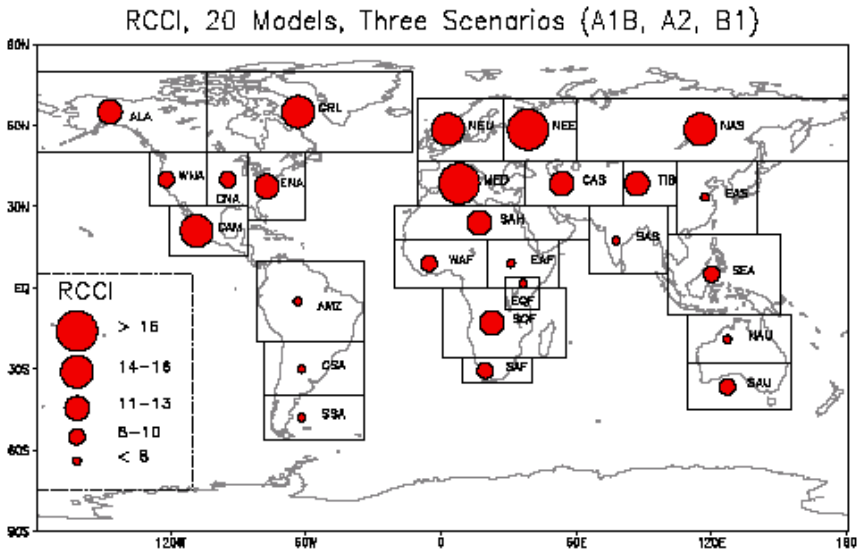
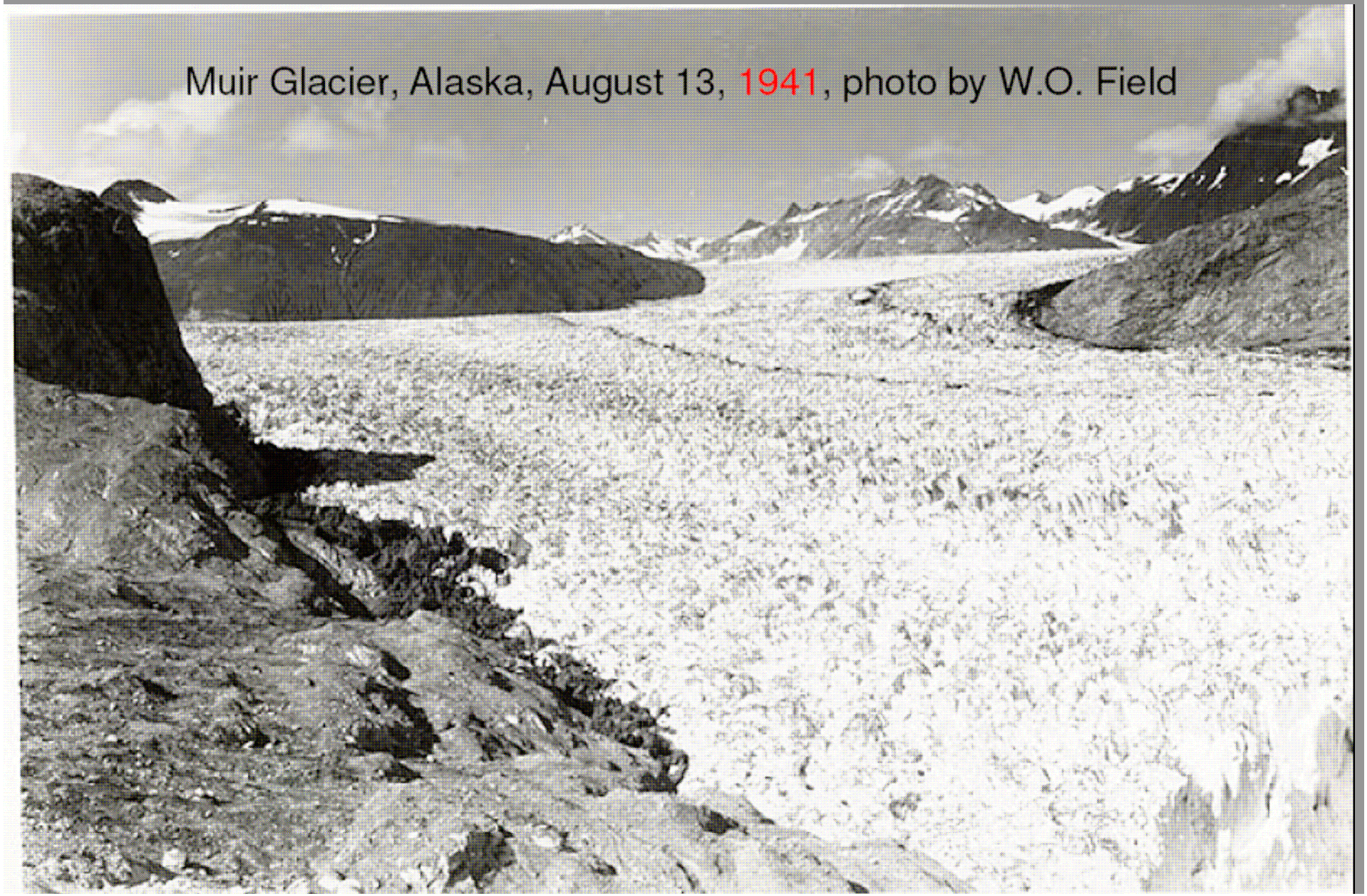


Figure 1. Regional Climate Change Index (RCCI) over 26 land regions of the World calculated from 20 coupled AOGCMs and 3 IPCC emission scenarios (A1B, A2, B1). The models used are BCCR-BCM2-0, CCMA-3-T47, CNRM-CM3, CSIRO-MK3, GFDL-CM2-0, GFDL-CM2-1, GISS-AOM, GISS-EH, GISS-ER, IAP-FGOALS, INMCM3, IPSL-CM4, MIROC3-2H, MIROC3-2M, MIUB-ECHO-G, MPI-ECHAM5, MRI-CGCM2, NCAR-CCSM3, NCAR-PCM1, UKMO-HADCM3. See also Table 1 of GB05a and http://www-pcmdi.llnl.gov.

- RCCI basado en cambio de T, RR y su cambio en variabilidad interanual

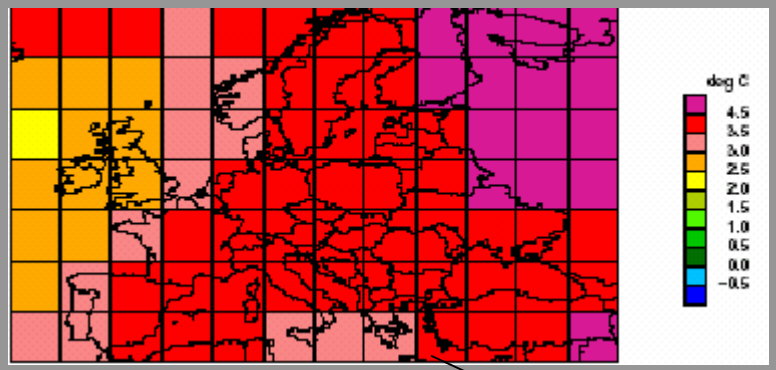
(Giorgi, 2006)

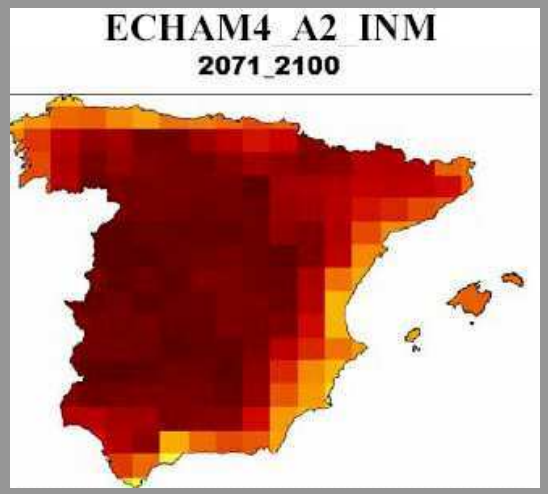

Muir Glacier, Alaska, August 13, 1941, photo by W.O. Field

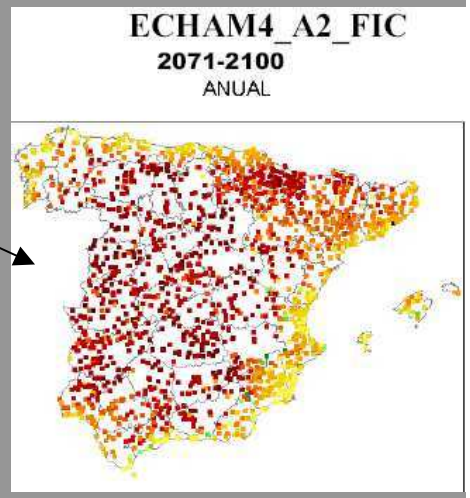
http://nsidc.org (National Snow and Ice Data Center)

Europe
Climate change hotspot
Amsterdam
Rotterdam
Rhine delta
London
Hamburg
Alps
Venice
Istanbul
Mediterranean basin
More precipitation
Less precipitation
Sea-level rise concerns and affected major cities
Malaria:
Possible extension by 2050
Permafrost:
Present permafrost
Permafrost in 2050
Negative agricultural changes
Changes in ecosystems
Forest fires
Impact on fisheries
Impact on mountain regions
Melting of glaciers
Source: IPCC, 2007; Klein et. al., 2002.

¿Qué necesita la comunidad de impactos al cambio climático?

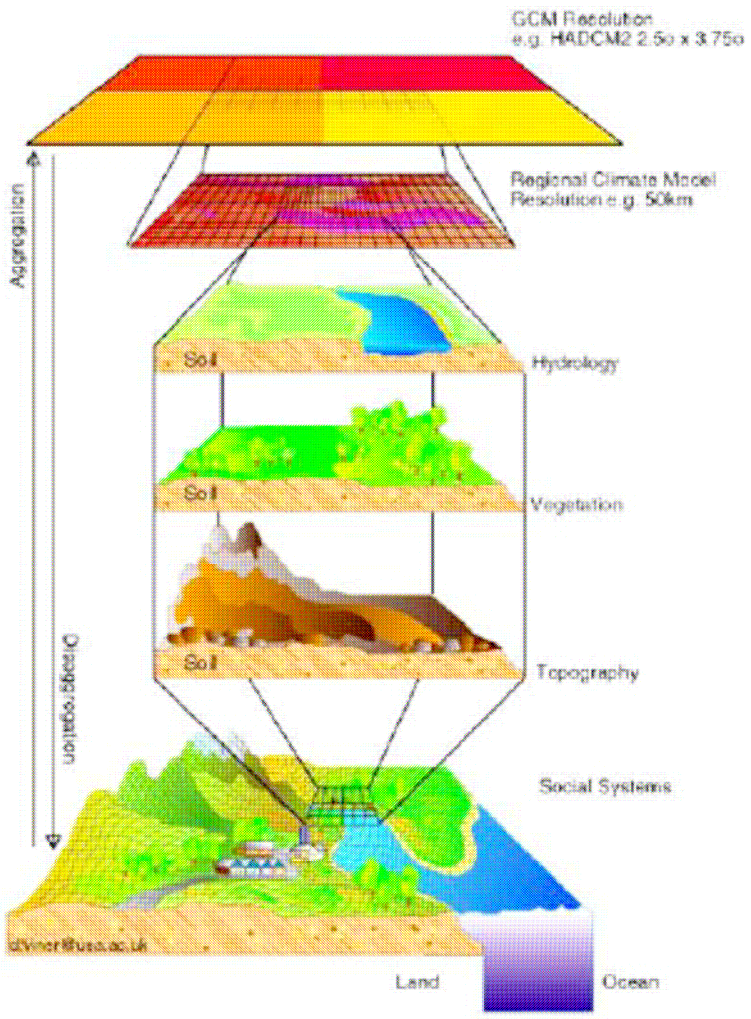






Proyecciones regionalizadas ajustadas a las necesidades específicas de cada sector (variables, resolución espacial/temporal, alcance, etc) con estimación de incertidumbres

¿Qué es la regionalización? (Top-down approach)



*** Las proyecciones directas de las variables superficiales a partir de los GCMs es difícil a escala subcontinental y a altas resoluciones temporales.**

*** Las técnicas de regionalización combinan salidas de GCMs con datos observacionales para mejorar la escala temporal y espacial de las proyecciones de cambio climático.**

*** Las técnicas de regionalización se conocen y se han aplicado desde los 70s y 80s en PNT:**

(i) LAMs
(ii) Técnicas de adaptación estadística basadas en regresiones lineales, p.e., MOS, Perfect Prog.

¿Por qué es necesaria la regionalización?

- **Variables de sup. adaptadas a características locales.**
- **Estimar extremos: AOGCMs "suavizan"**
- **Adaptar res. esp/temp a los modelos de impactos**

T max. (ºC) (2071-2100) SRES A2, HadAM3, INM

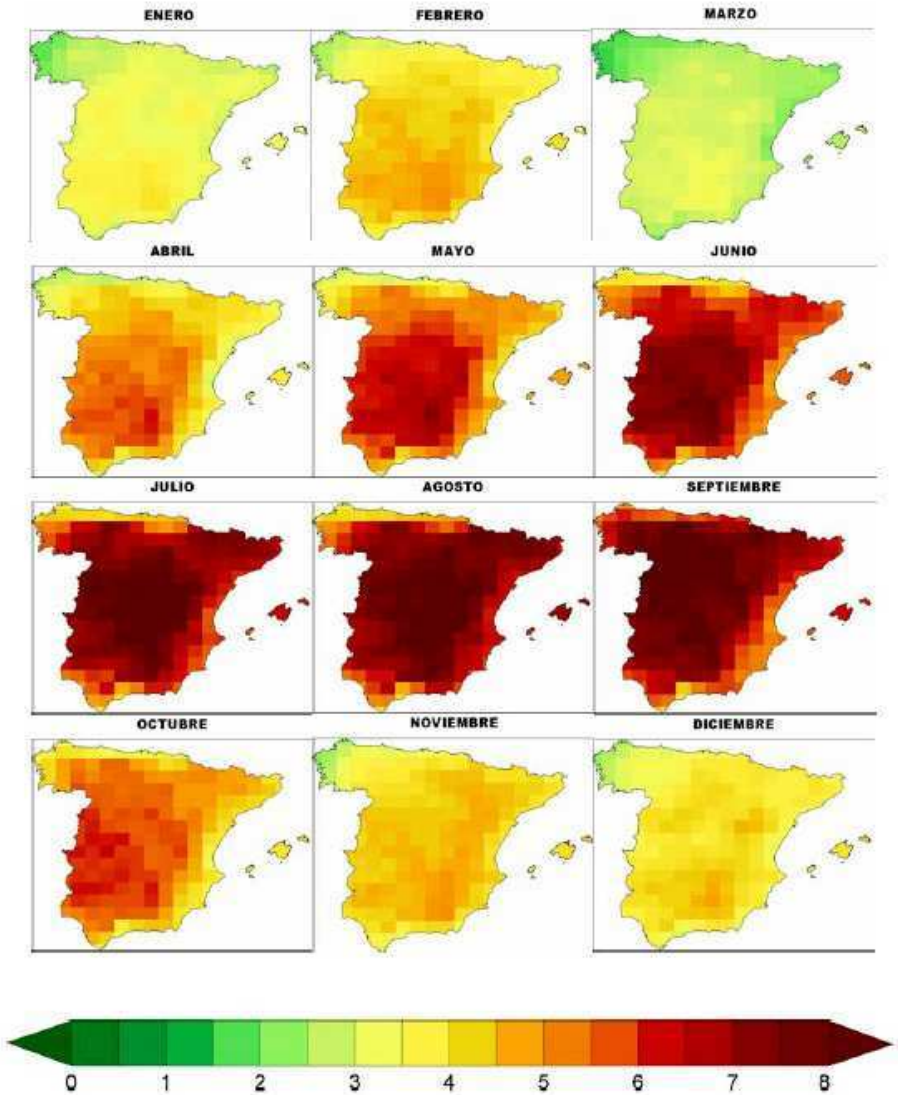


Figura 7.6.- Cambio medio mensual de temperatura máxima proyectado para el periodo (2071-2100) respecto al clima actual (1961-1990) por el modelo global HadAM3H y regionalizado con el método de análogos (INM) para el escenario de emisión A2.

(INM, 2007)

AEMET, Escenarios A2 y B2

ENSEMBLES, Escenario A1B

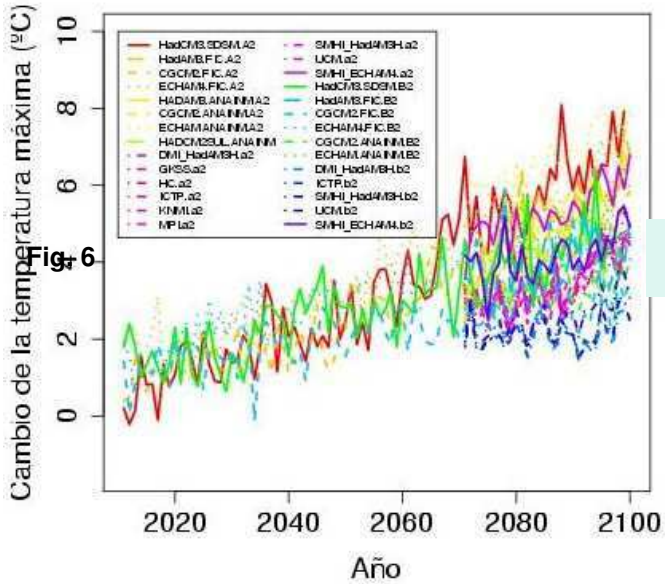
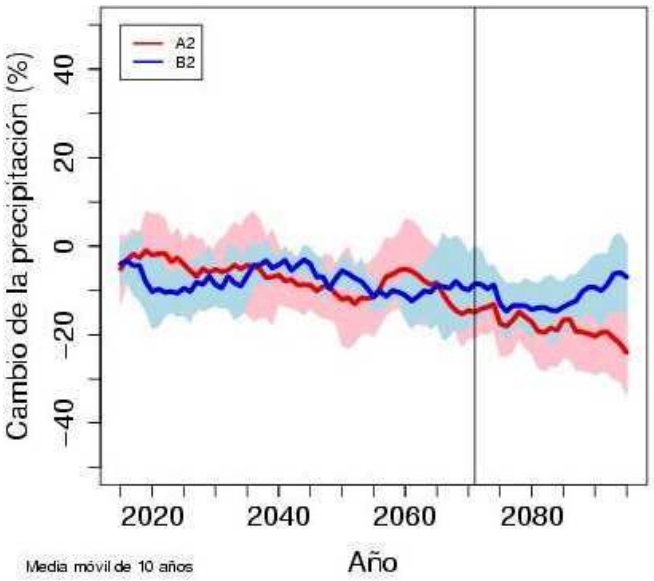
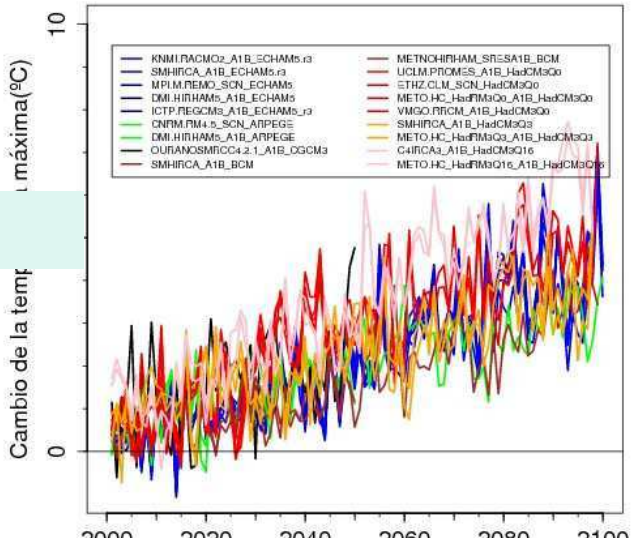
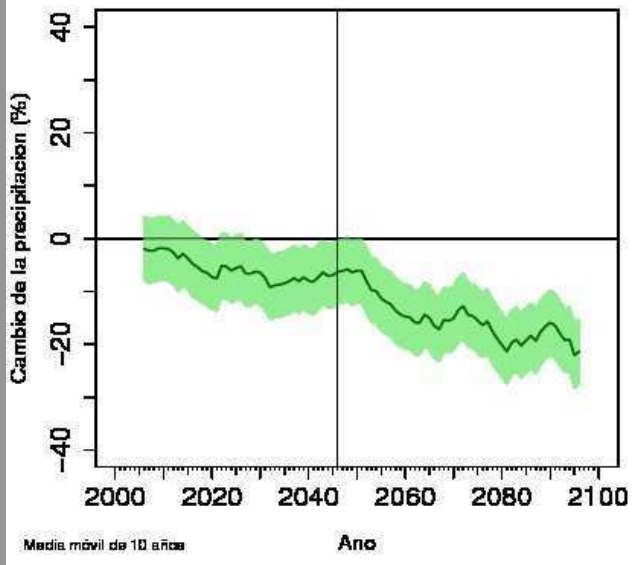


Fig. 6

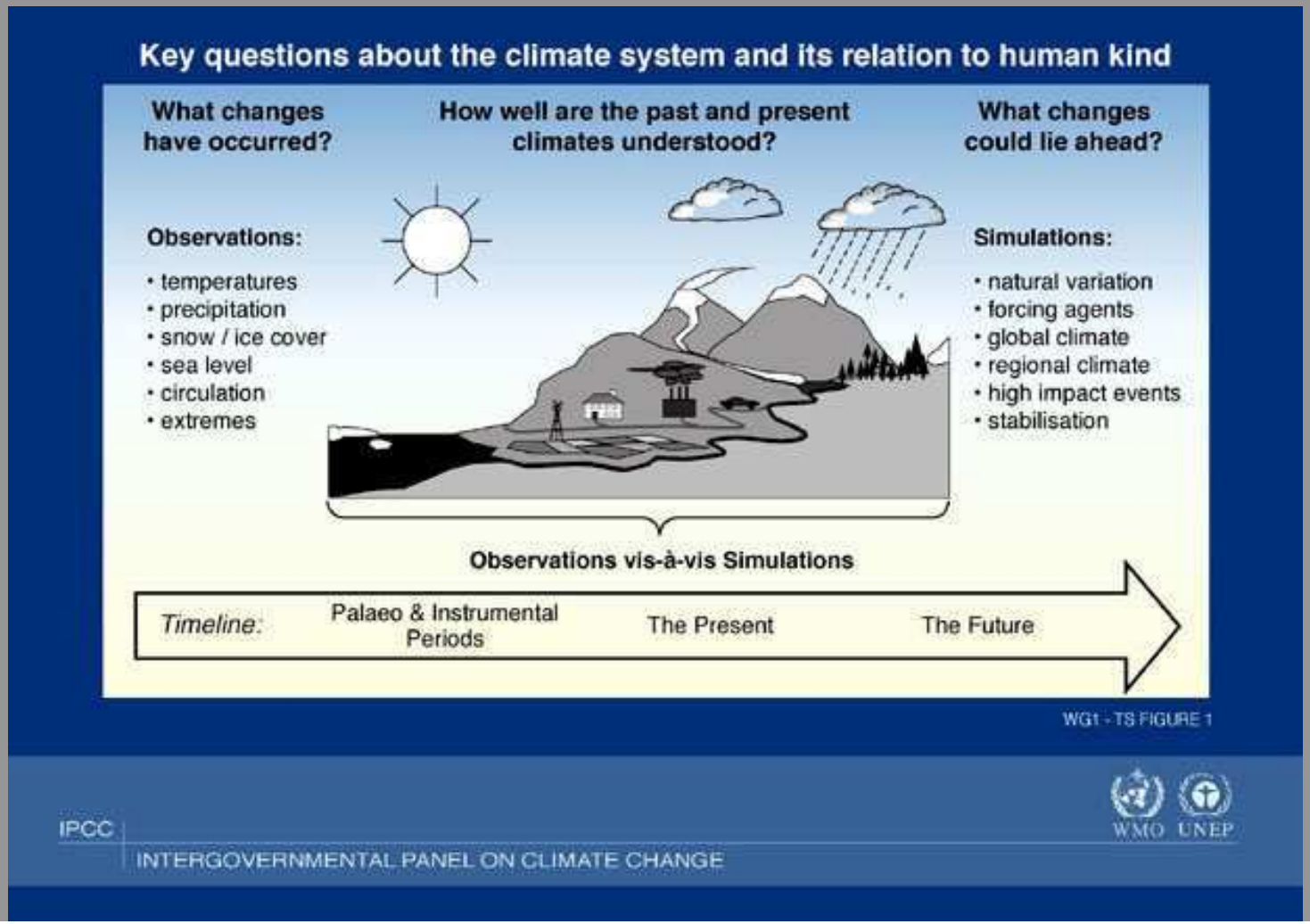
Más en http://www.aemet.es







What if? Simulations



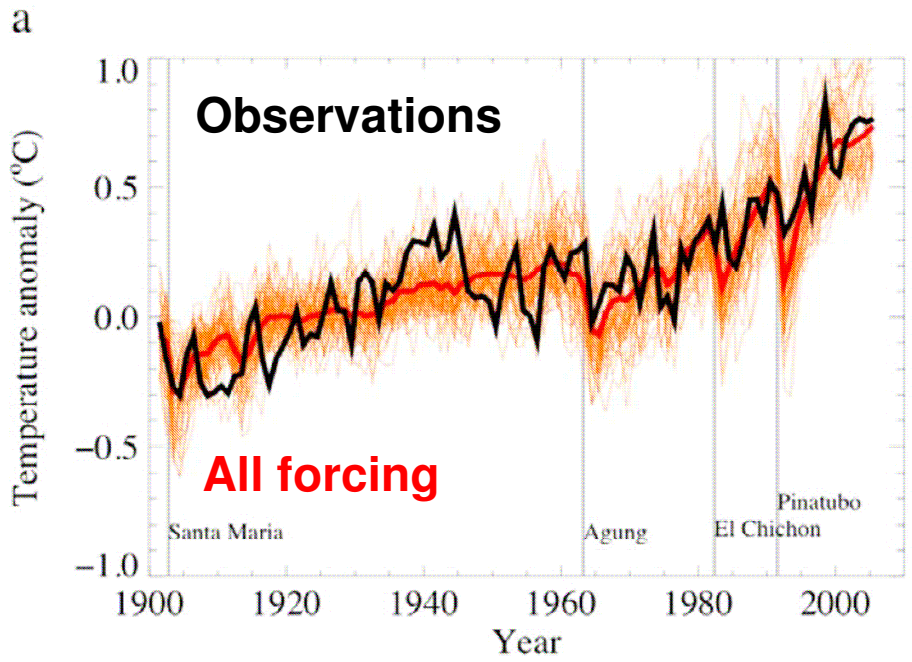
Attribution: cause(s) of global warming

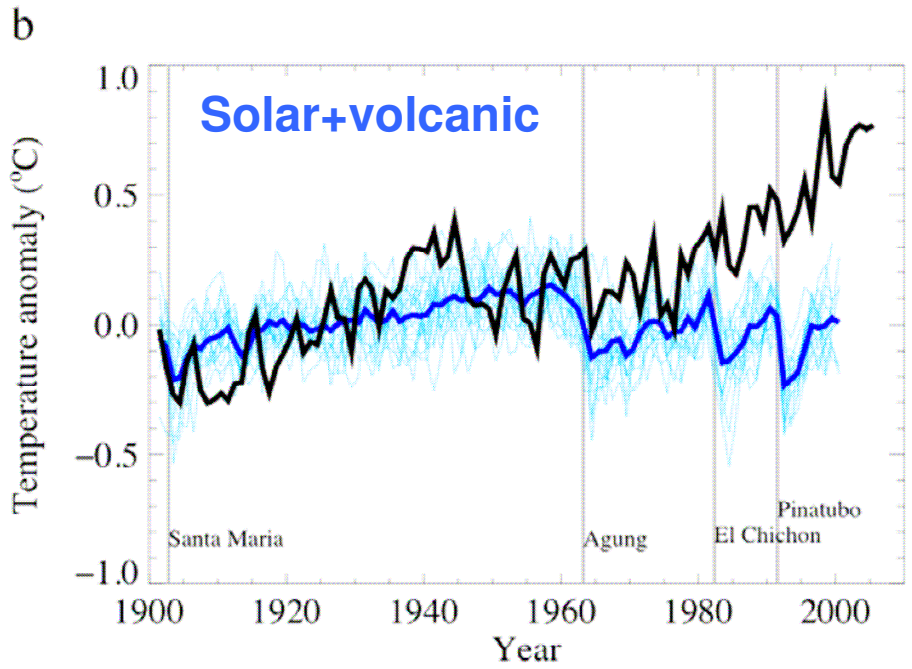
How reliable are the models?

- are observed changes consistent with

  expected responses to forcings

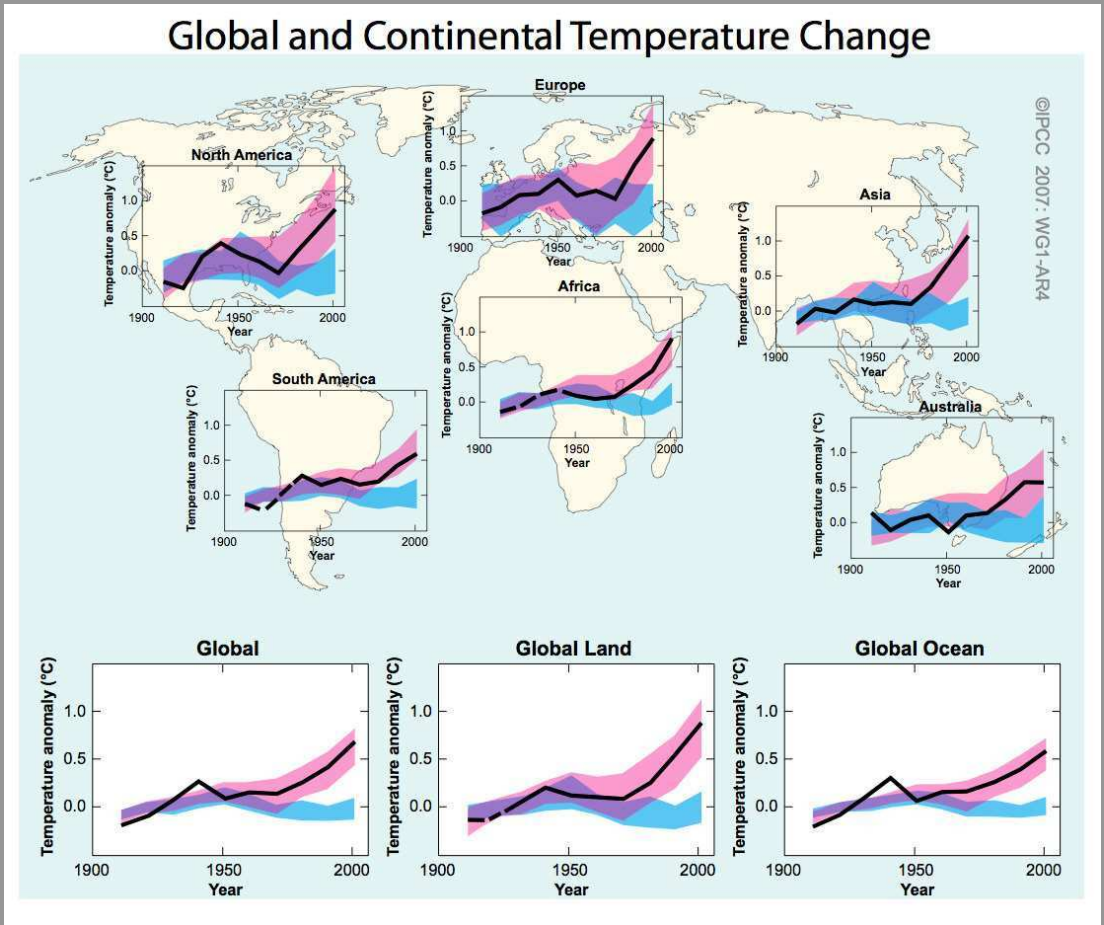
☒ inconsistent with alternative explanations



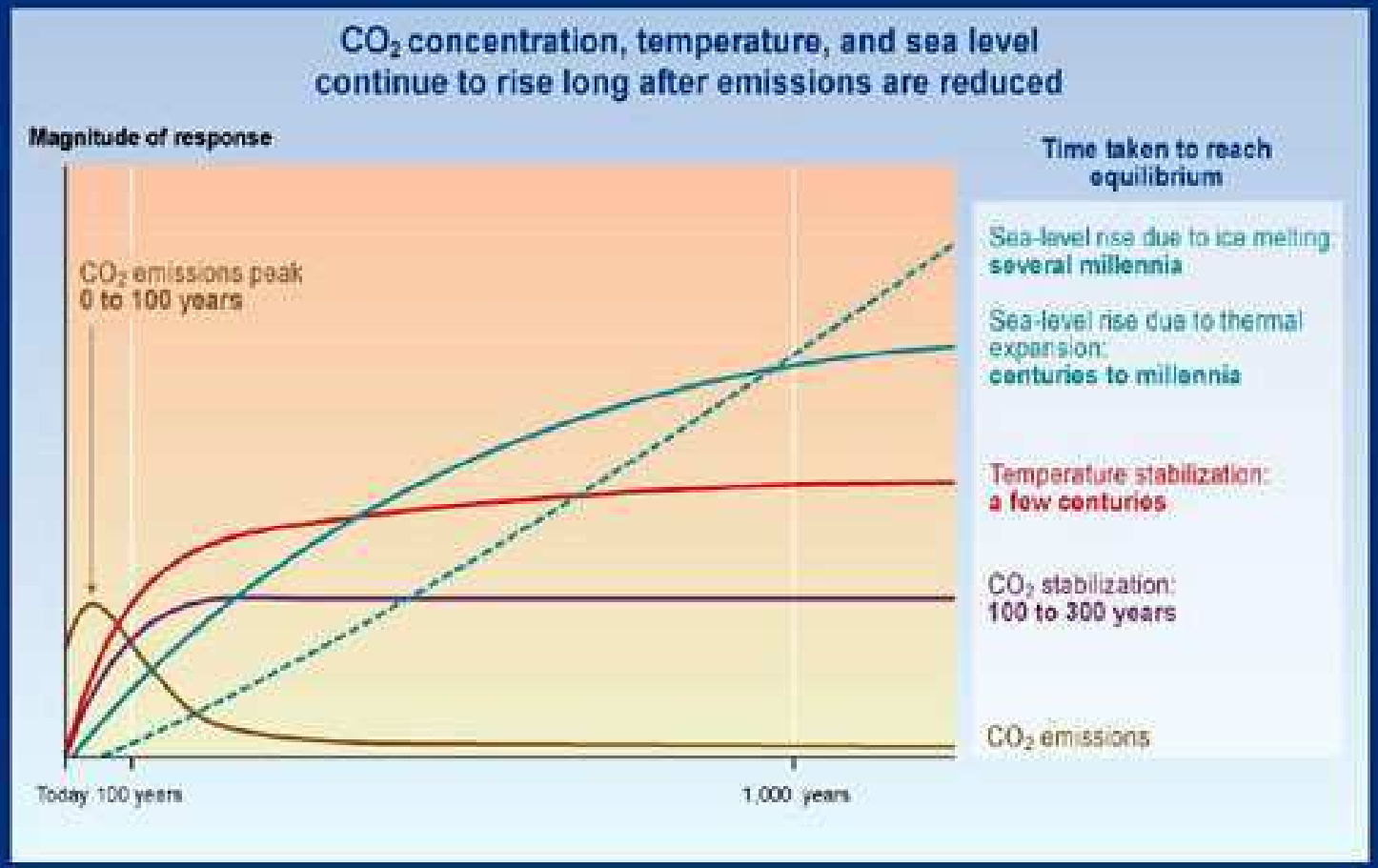


Understanding and Attributing Climate Change

Warming very probably (90%) of anthropogenic origin



Inercia del sistema climático



SYR - FIGURE 5-2

Necesidad de estrategias de adaptación!!

IPCC

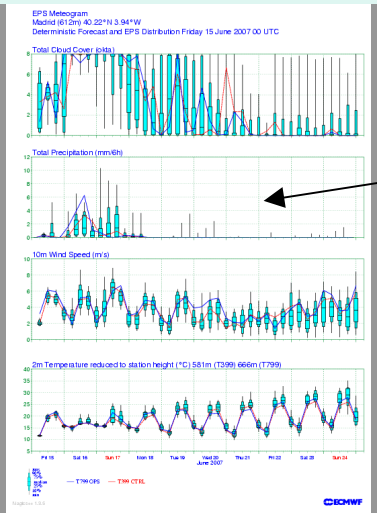
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

Uncertainties in climate change projections

- Natural forcing (sun, volcanoes)
- GHG emissions
- GHG concentrations
- AOGCM differences
- Internal variability (IC dependency)
- Downscaling techniques
- Tipping points

UNCERTAINTY DOESN'T MEAN TOTAL LACK OF KNOWLEDGE!!



- The uncertainty studies are something relatively new in atmospheric sciences. Only recently uncertainty (probabilistic approach) was introduced in our forecasts/projections
- Dealing with lack of knowledge and uncertainties a task for risk management

Cascade of uncertainties

Timothy D. Mitchell and Mike Hulme

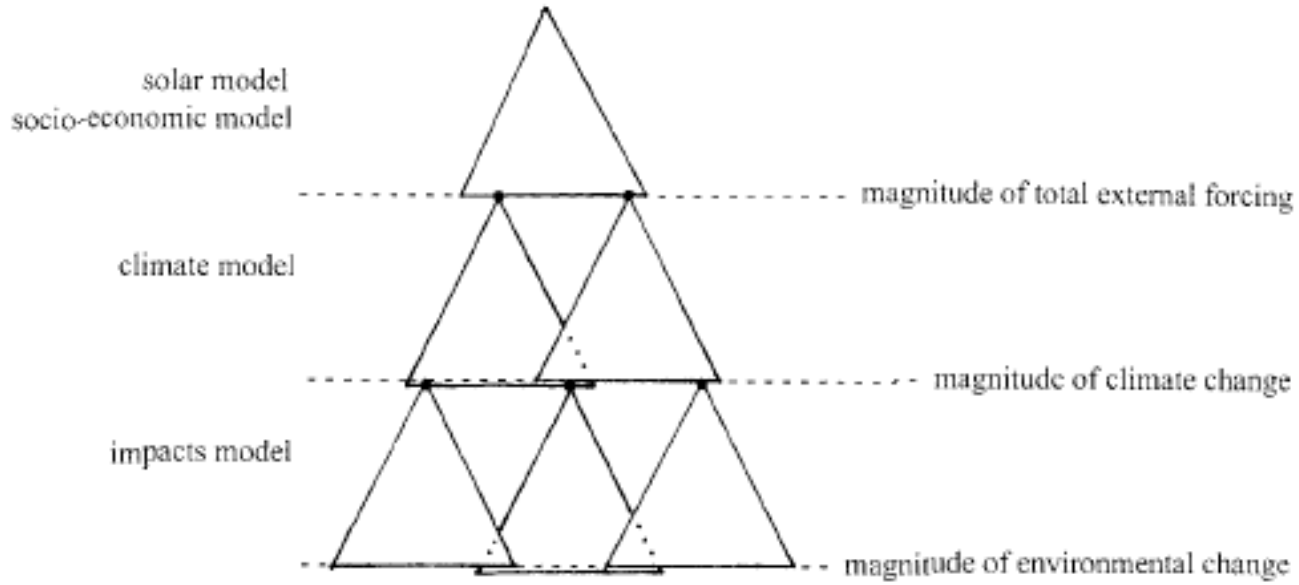
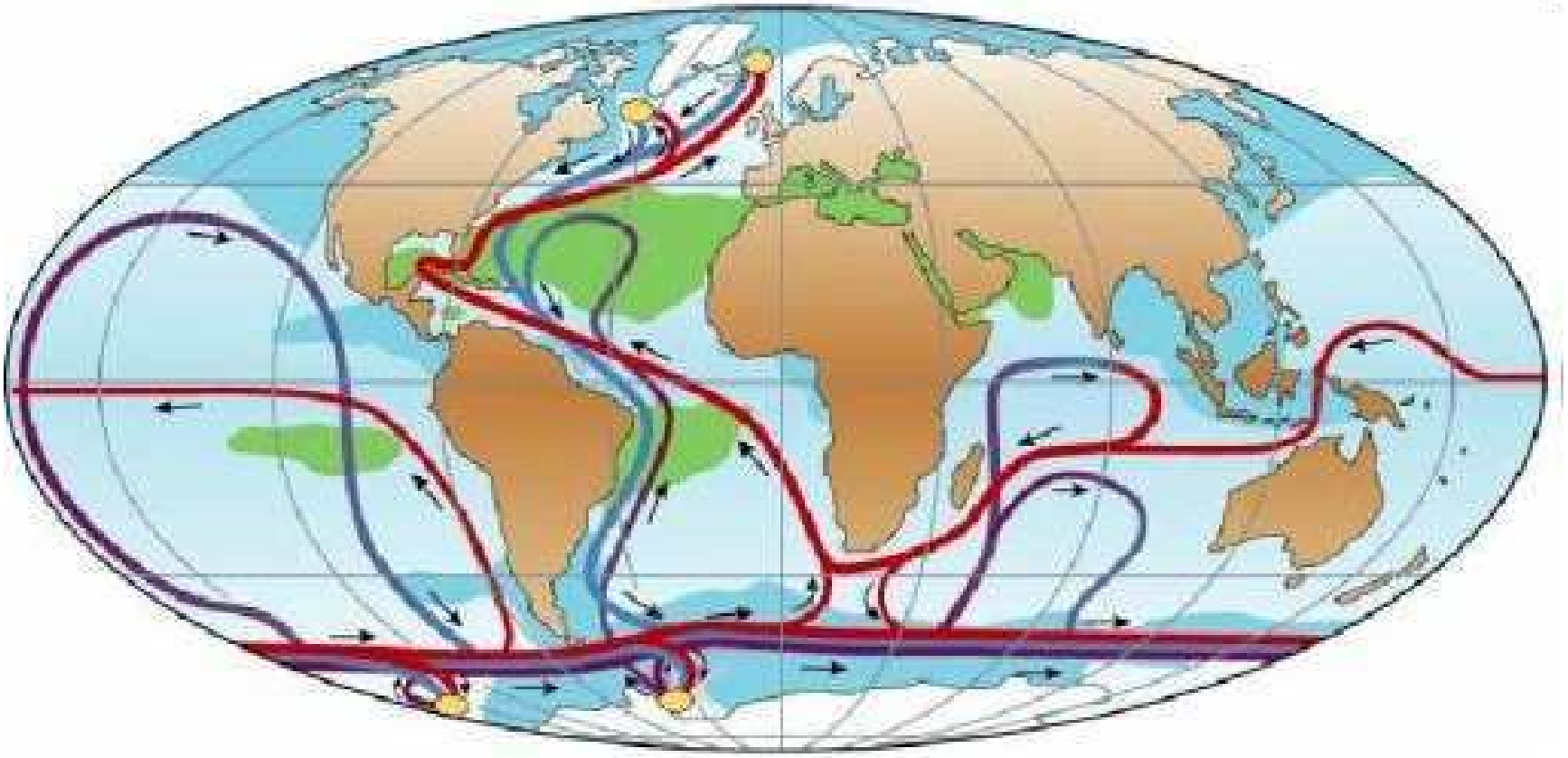


Figure 4 The magnitude of external radiative forcing is uncertain and so is presented as a range of possibilities in the top triangle. Two of these possibilities are selected as the starting points from which is presented the uncertainty concerning the magnitude of the climatic response. Thus we find that the cascade of uncertainties ultimately presents us with a wide variety of possible environmental futures at the base of the lowest triangles

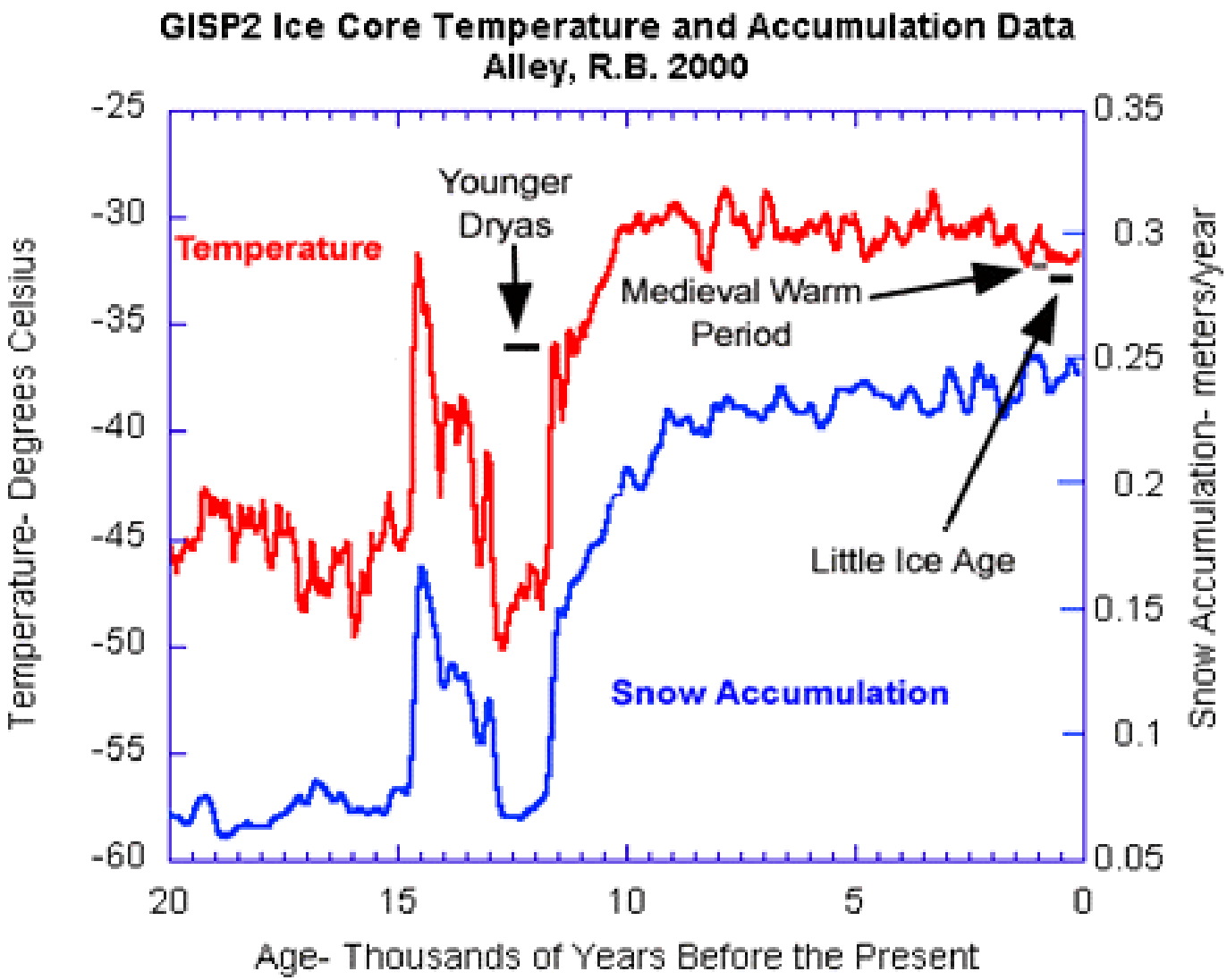
Wallace S. Broecker (1987)

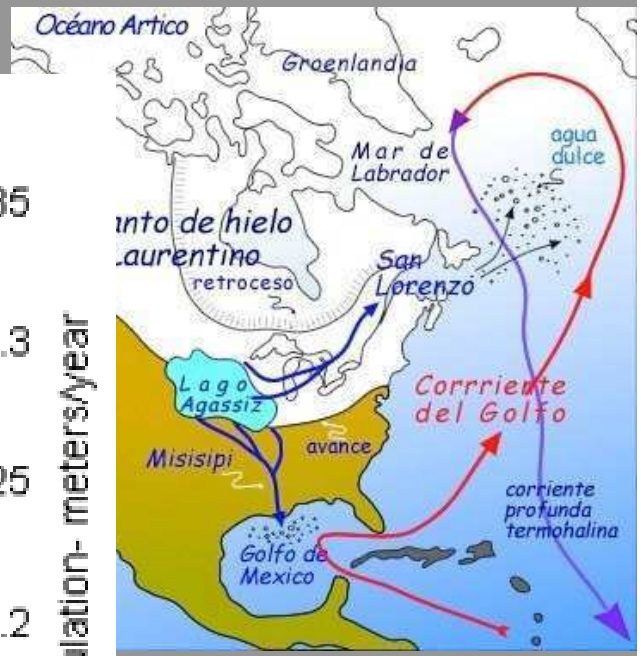
- He connected the evidence of relatively rapid changes in climate in the past to the possibility that anthropogenic climate change in the future might also trigger abrupt changes in aspects of the Earth's climate
- Ice cores records indicate that the Earth's climate responds in sharp jumps



(Rahmstorf, Nature 2002)

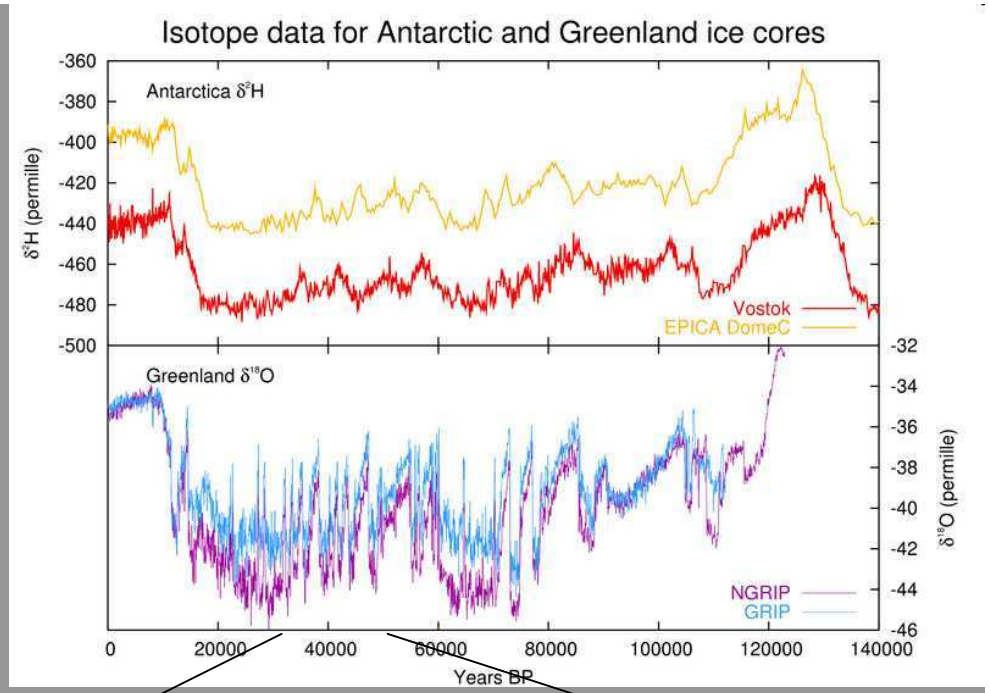
Younger dryas (12 900-11 500 BP)

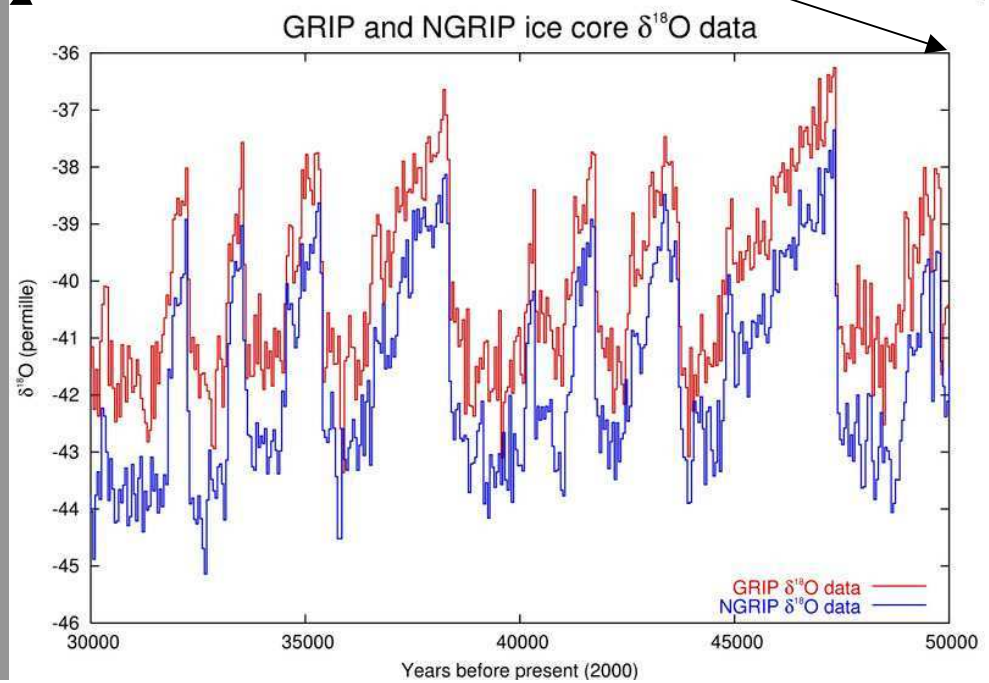


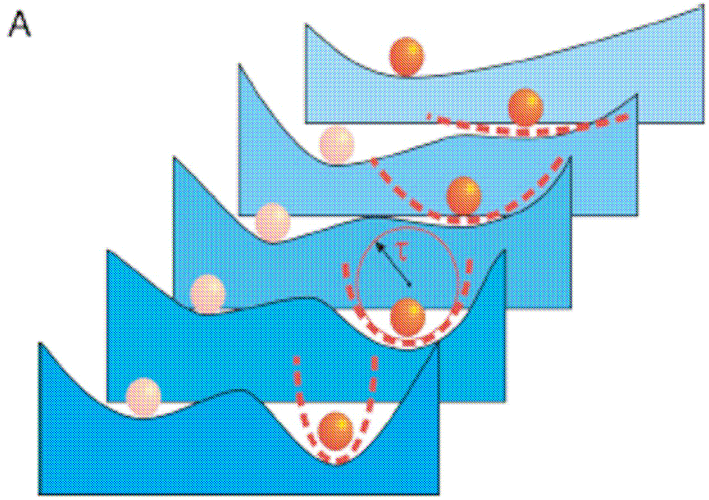


Dansgaard-Oeschger events

- 25 times during the last glacial period
- Events occur quasi-periodically with a recurrence time being a multiple of 1,470 years
- The best evidence remains in the Greenland ice cores.
- The events appear to reflect changes in the North Atlantic ocean circulation, perhaps triggered by an influx of fresh water





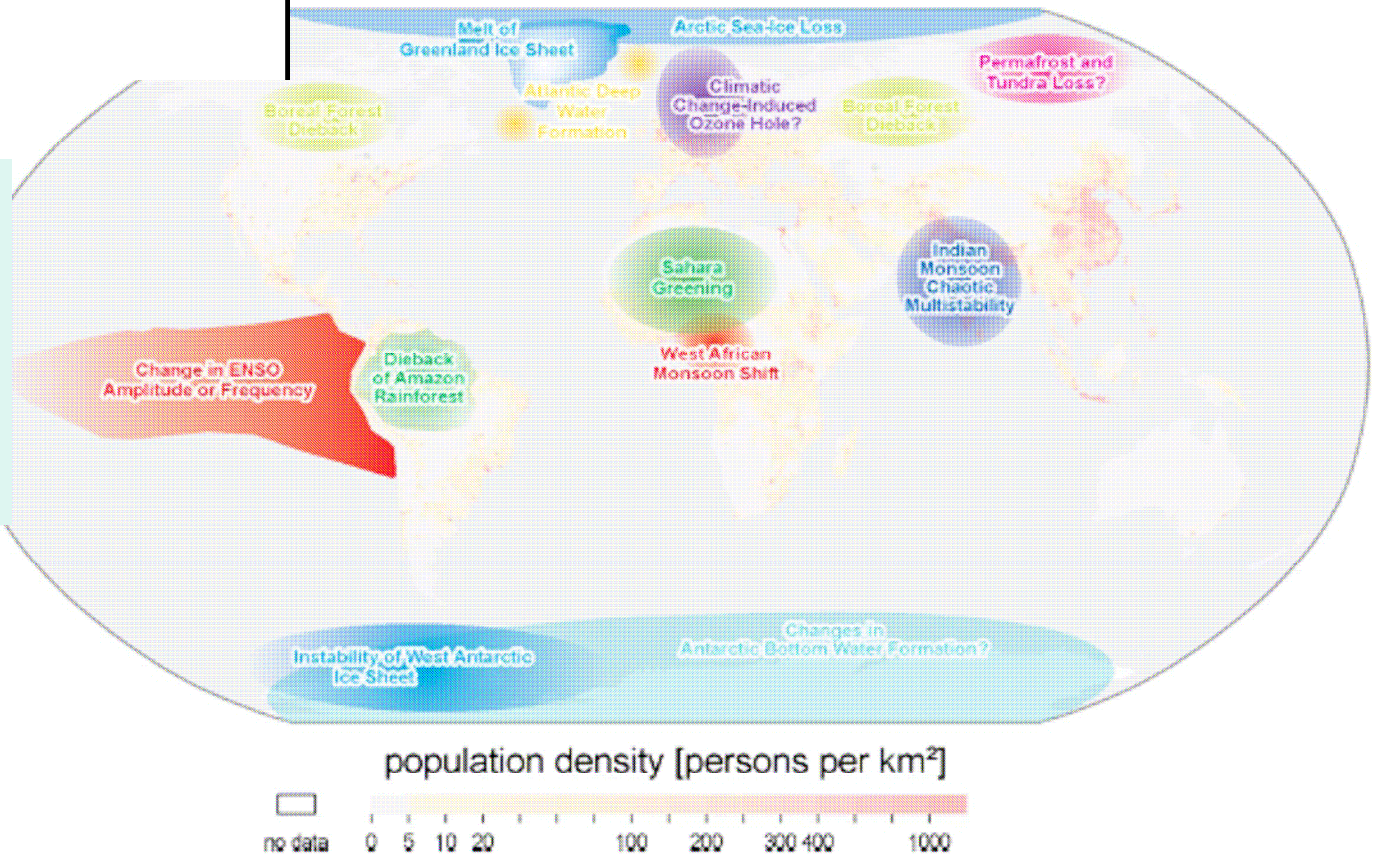


“Tipping points”

sobrepasables este siglo

Small changes can produce big long term effects

Ex.: forced convection!!



(Lenton et al., 2008)

Tipping points (II)

Tipping element	Feature of system, F (direction of change)	Control parameter(s), p	Critical value(s),† p_{crit}	Global warming†‡	Transition timescale,† T	Key impacts
Arctic summer sea-ice	Areal extent (−)	Local ΔT_{air}, ocean heat transport	Unidentified§	+0.5–2°C	~10 yr (rapid)	Amplified warming, ecosystem change
Greenland ice sheet (GIS)	Ice volume (−)	Local ΔT_{air}	+~3°C	+1–2°C	>300 yr (slow)	Sea level +2–7 m
West Antarctic ice sheet (WAIS)	Ice volume (−)	Local ΔT_{air}, or less ΔT_{ocean}	+~5–8°C	+3–5°C	>300 yr (slow)	Sea level +5 m
Atlantic thermohaline circulation (THC)	Overturning (−)	Freshwater input to N Atlantic	+0.1–0.5 Sv	+3–5°C	~100 yr (gradual)	Regional cooling, sea level, ITCZ shift
El Niño–Southern Oscillation (ENSO)	Amplitude (+)	Thermocline depth, sharpness in EEP	Unidentified§	+3–6°C	~100 yr (gradual)	Drought in SE Asia and elsewhere
Indian summer monsoon (ISM)	Rainfall (−)	Planetary albedo over India	0.5	N/A	~1 yr (rapid)	Drought, decreased carrying capacity
Sahara/Sahel and West African monsoon (WAM)	Vegetation fraction (+)	Precipitation	100 mm/yr	+3–5°C	~10 yr (rapid)	Increased carrying capacity
Amazon rainforest	Tree fraction (−)	Precipitation, dry season length	1,100 mm/yr	+3–4°C	~50 yr (gradual)	Biodiversity loss, decreased rainfall
Boreal forest	Tree fraction (−)	Local ΔT_{air}	+~7°C	+3–5°C	~50 yr (gradual)	Biome switch
Antarctic Bottom Water (AABW)*	Formation (−)	Precipitation–Evaporation	+100 mm/yr	Unclear¶	~100 yr (gradual)	Ocean circulation, carbon storage
Tundra*	Tree fraction (+)	Growing degree days above zero	Missing‖	—	~100 yr (gradual)	Amplified warming, biome switch
Permafrost*	Volume (−)	$\Delta T_{permafrost}$	Missing‖	—	<100 yr (gradual)	CH_4 and CO_2 release
Marine methane hydrates*	Hydrate volume (−)	$\Delta T_{sediment}$	Unidentified§	Unclear¶	10^3 to 10^5 yr (>T_E)	Amplified global warming
Ocean anoxia*	Ocean anoxia (+)	Phosphorus input to ocean	+~20%	Unclear¶	~10^4 yr (>T_E)	Marine mass extinction
Arctic ozone*	Column depth (−)	Polar stratospheric cloud formation	195 K	Unclear¶	<1 yr (rapid)	Increased UV at surface

(Lenton et al., 2008)

Tipping element	Feature of system, F (direction of change)	Control parameter(s), p	Critical value(s),† p_{crit}	Global warming††	Transition timescale,† T	Key impacts
Amazon rainforest	Tree fraction (–)	Precipitation, dry season length	1,100 mm/yr	+3–4°C	~50 yr (gradual)	Biodiversity loss, decrease rainfall

Effects of thermokarst on a railway track.
Photo: US Geological Survey

Tipping element	Feature of system, F (direction of change)	Control parameter(s), ρ	Critical value(s),[†] ρ_{crit}	Global warming[†‡]	Transition timescale,[†] T	Key impacts
Permafrost*	Volume (−)	$\Delta T_{permafrost}$	Missing[§]	—	<100 yr (gradual)	CH_4 and CO_2 release

No todos los “tipping points” muestran la misma sensibilidad e incertidumbre

Sensibilidad alta e incertidumbre pequeña

- Hielo marino ártico
- Hielo en Groenlandia

Sensibilidad baja e incertidumbre intermedia

- Circulación termohalina

Sensibilidad intermedia y alta incertidumbre sorpresas

- Hielo en Antártida Occ.
- Colapso bosques boreales
- Colapso selva amazónica
- ENSO
- Monzón África Occ.

¿Qué podemos hacer? (I)

- Inercia del sistema climático algunos cambios son inevitables **actuación sobre los efectos ADAPTACION**
- El calentamiento se produce por emisiones GEI a más emisiones, mayor calentamiento **actuación sobre las causas MITIGACION** (cambio modelo energético, usos de suelo (deforestación), demografía, desarrollo sostenible, …)
- Mejorar el conocimiento del sistema climático: **INVESTIGACION**

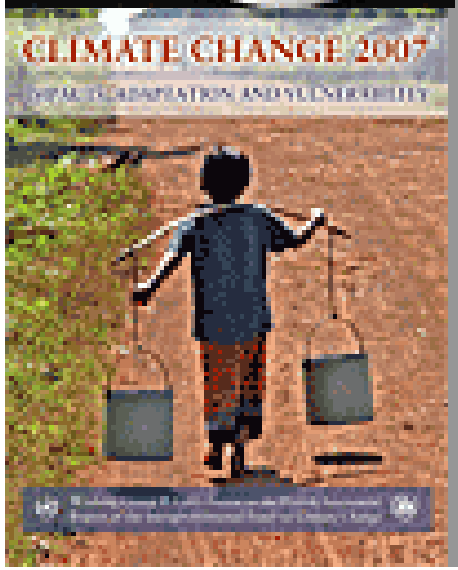
¿Qué podemos hacer? (II)

- **Actuación a diferentes niveles**: gobiernos, ciudades, individuos
- Aumentar el nivel de **concienciación del problema** Influencia en la acción de individuos, ciudades, gobiernos.
- El problema del cambio climático está íntimamente **ligado a otros problemas** de la humanidad en su conjunto:
  - pobreza (demografía),
  - desarrollo sostenible,
  - modelo energético,
  - patrones de producción y consumo,
  - comercio
  - etc

Conclusiones

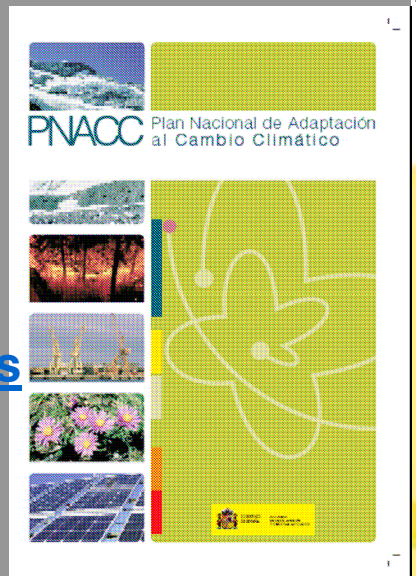
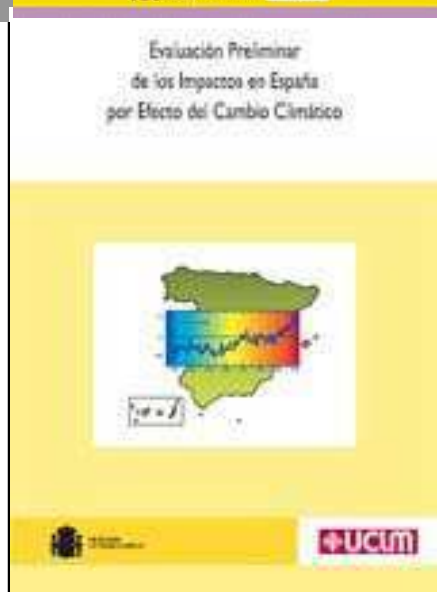
- Sistema climático es complejo y altamente no lineal modelos
- Inequívoco calentamiento global
- Proyecciones probabilísticas climáticas globales
  ensemble multi-modelo
- Causas: Emisiones por quema de combustibles fósiles + deforestación Uso de modelos
- Incertidumbres En cascada
- Posibles cambios abruptos monitorizar

Bibliografía básica



http://www.aemet.es

¡Gracias por su atención!

http://www.ipcc.ch

http://www.marm.es