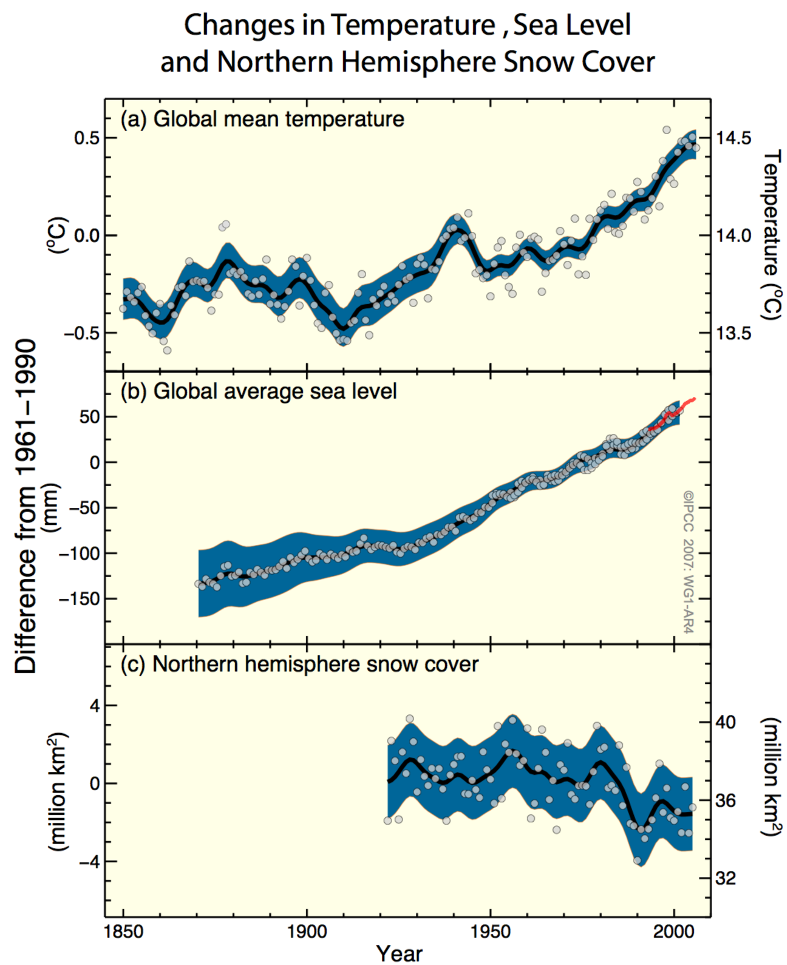
Climate change, its impacts and how to solve it

Warming is unequivocal…..

Global mean temperature

Sea level

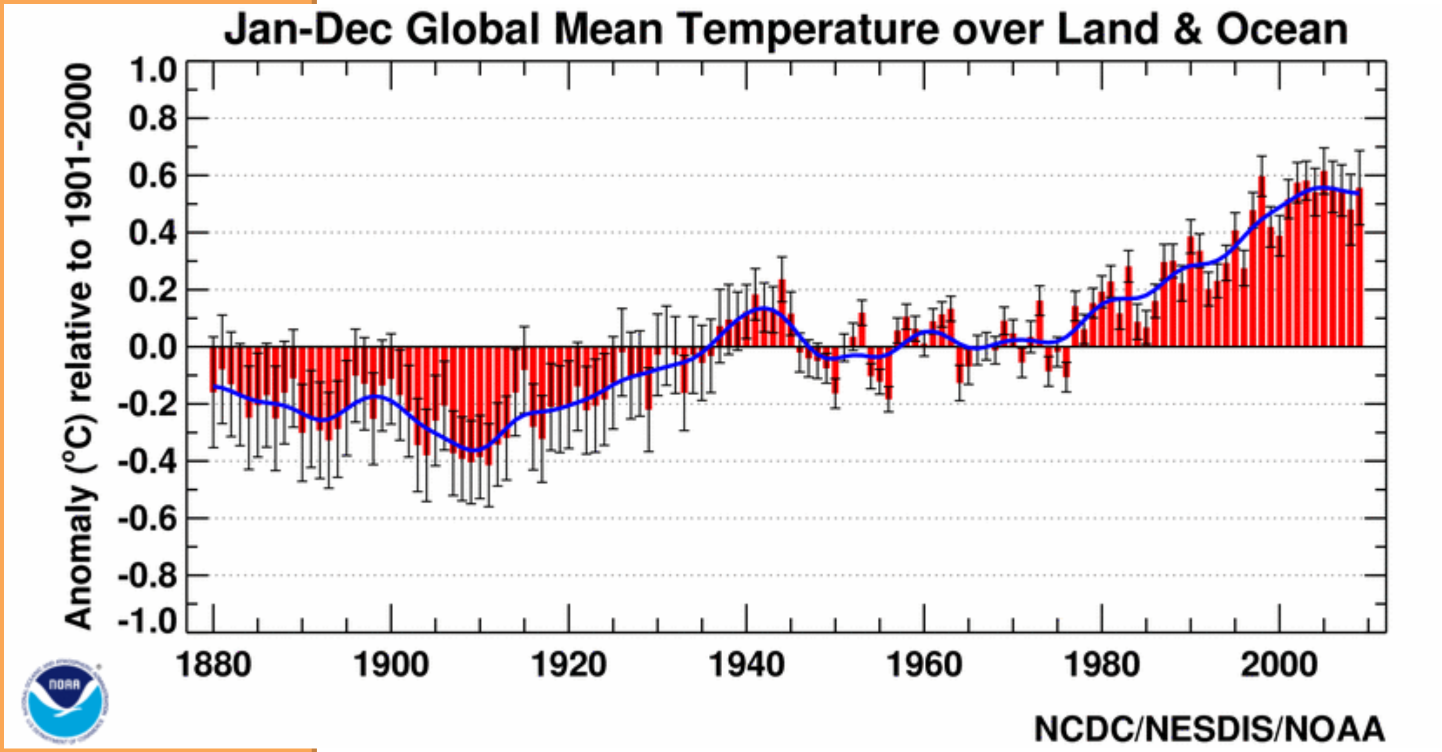
Northern Hemisphere snow cover



Global mean temperature

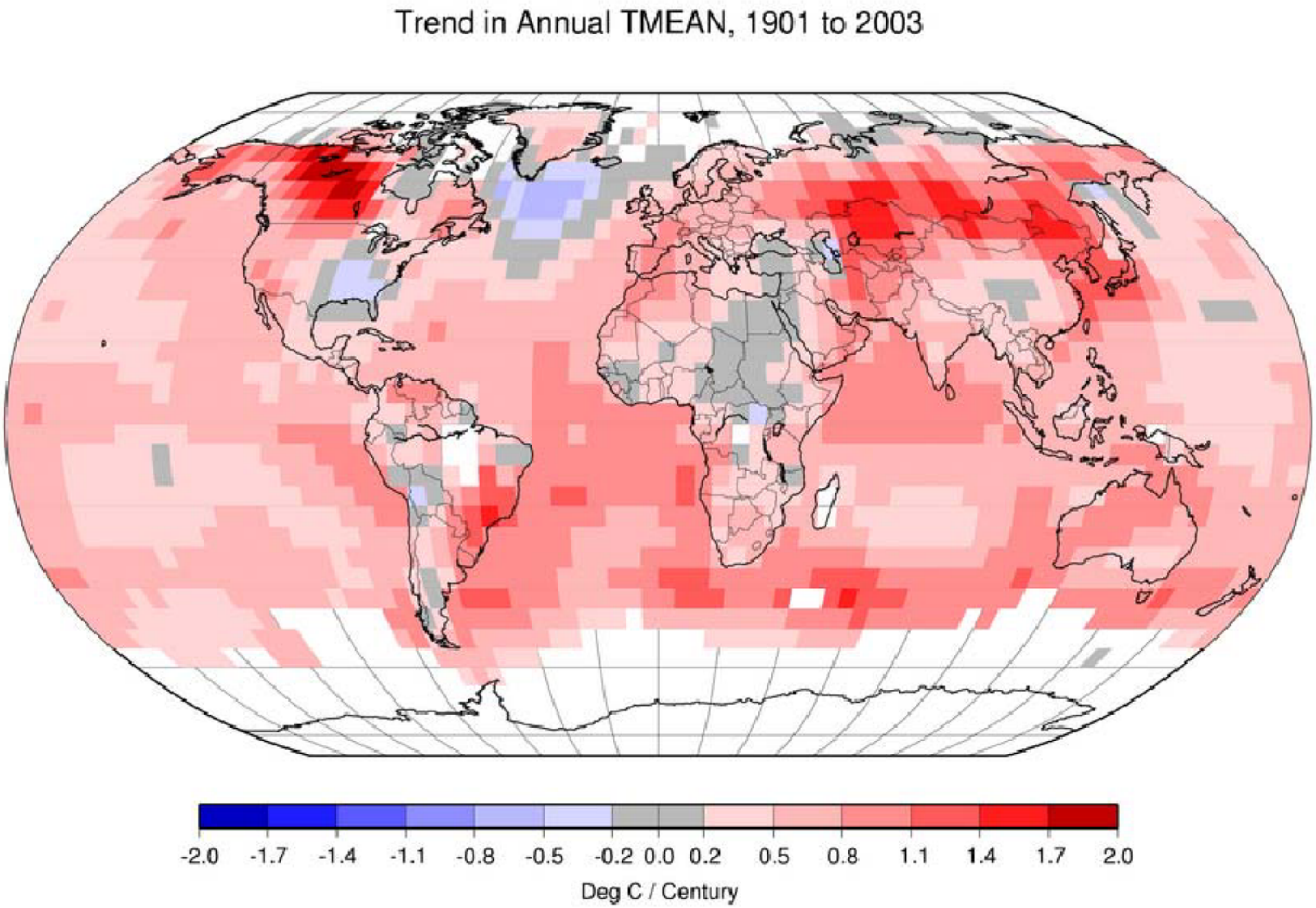
10 warmest years
(°C above mean 20^{th} cent)

2010	0.62
2005	0.62
1998	0.60
2003	0.58
2002	0.58
2009	0.56
2006	0.56
2007	0.55
2004	0.54
2001	0.52

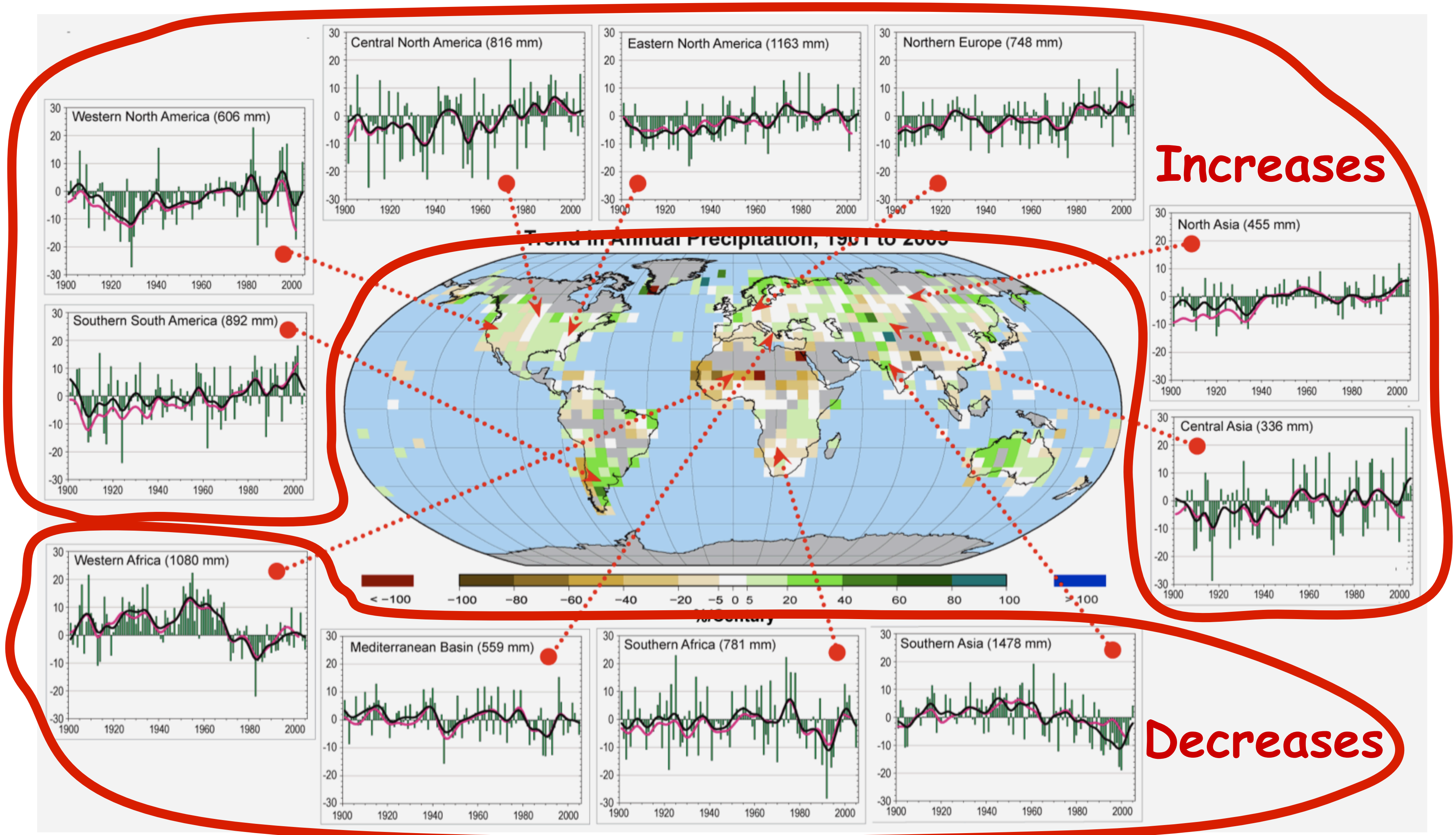


2001-2010: warmest decade ever
(0.56 °C above 20^{th} cent mean)

Observed Warming

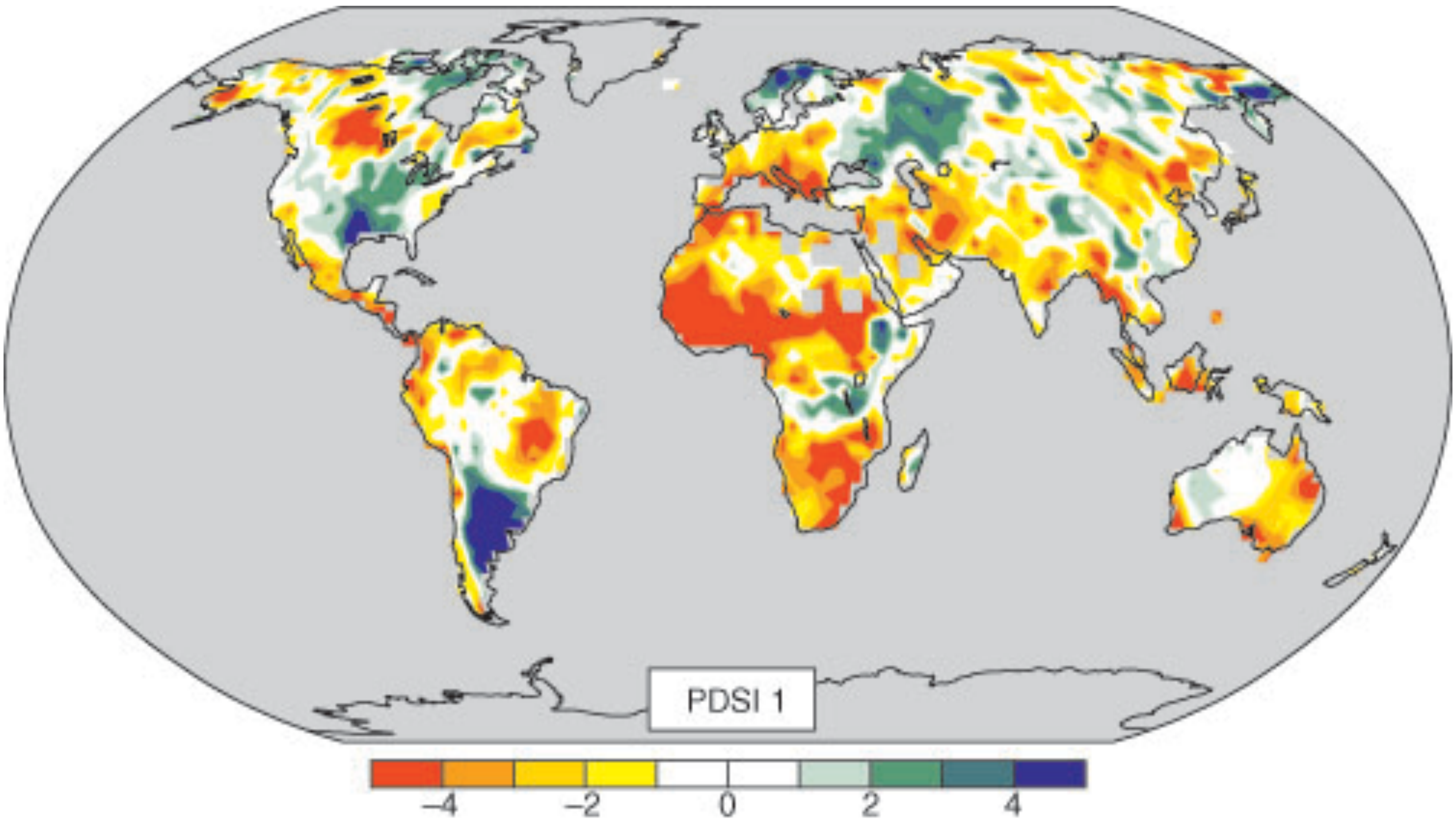


Land precipitation is changing significantly over broad areas



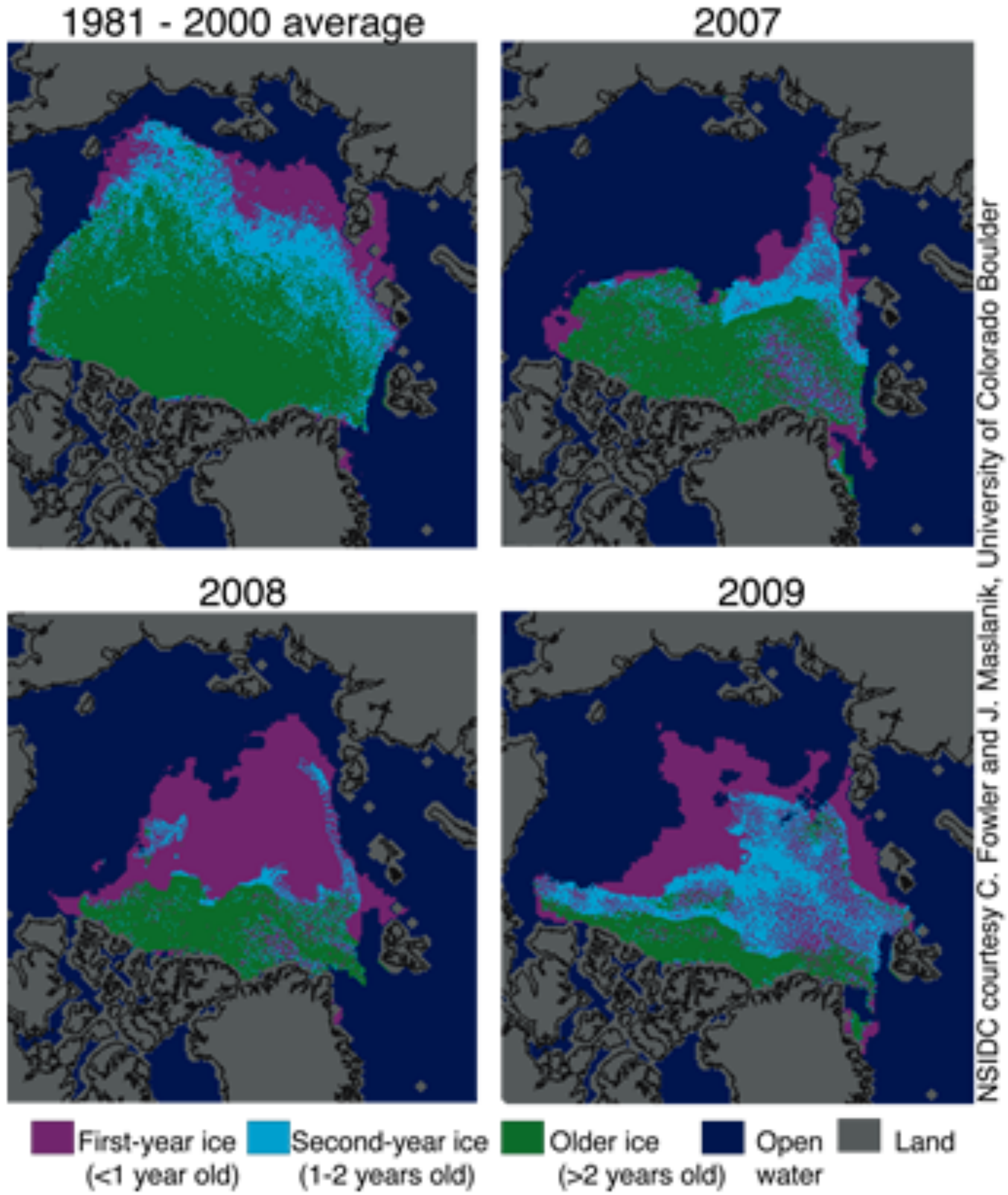
Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

Drought index change between 1900 and 2002

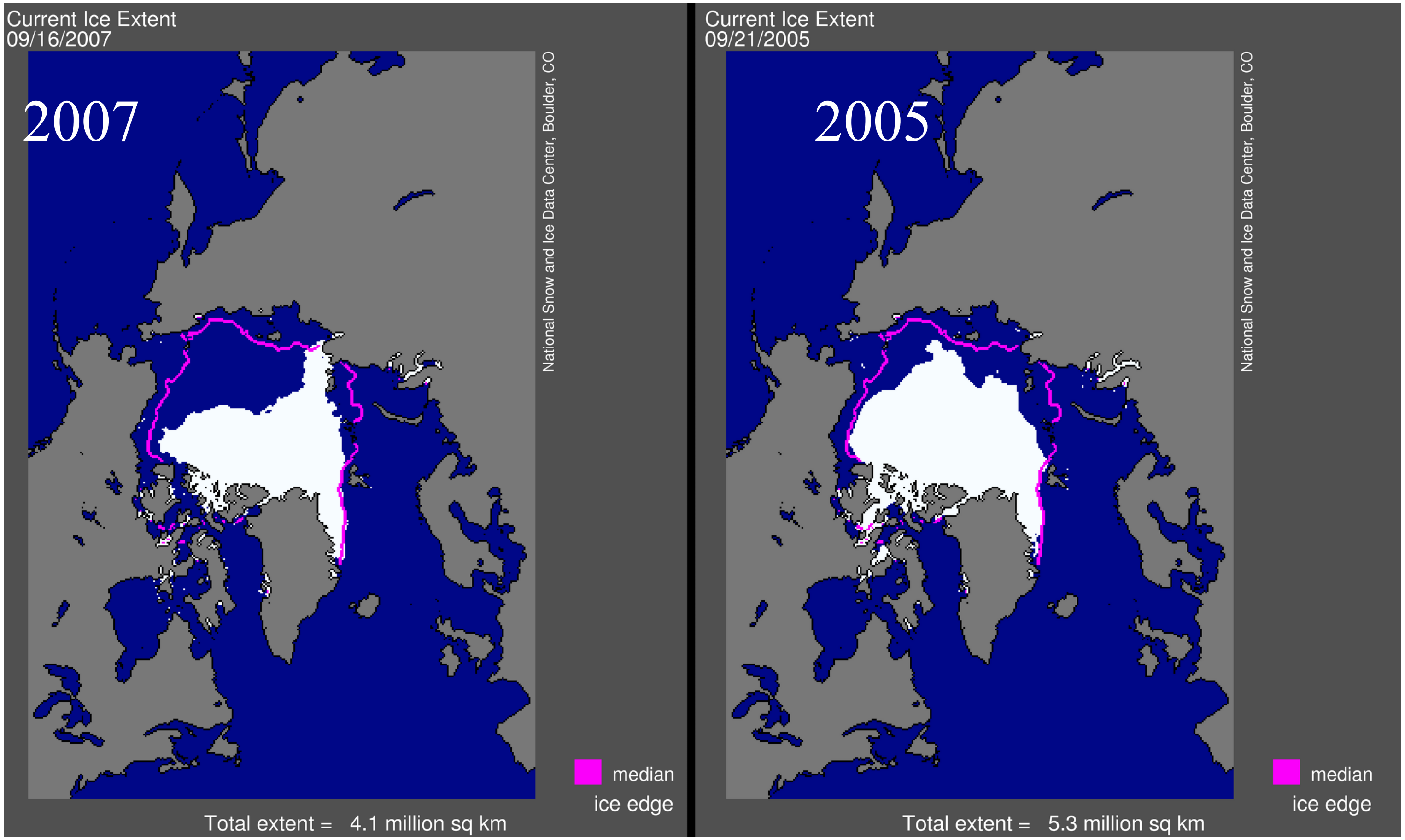


More drought

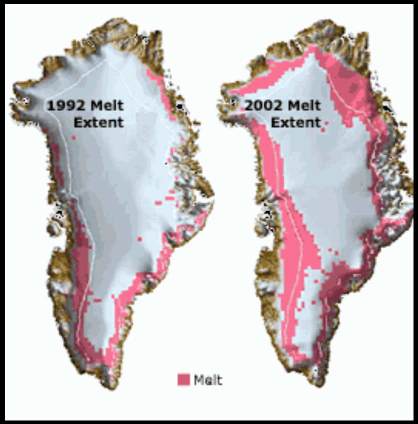
Arctic sea ice age at the end of the melt season

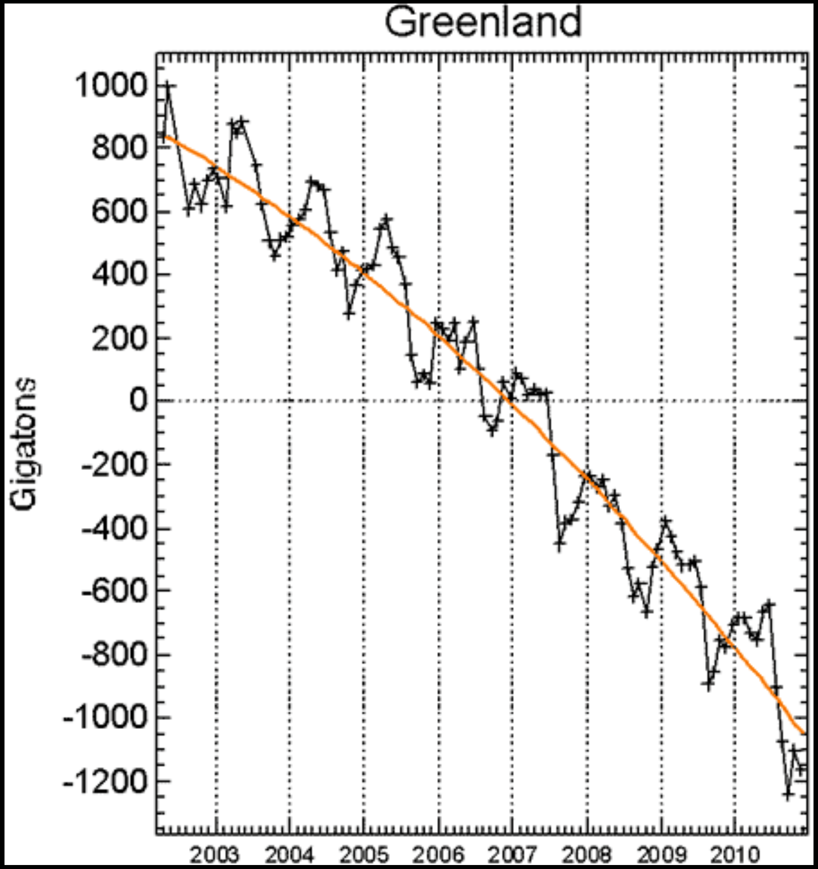


Arctic sea-ice is disappearing



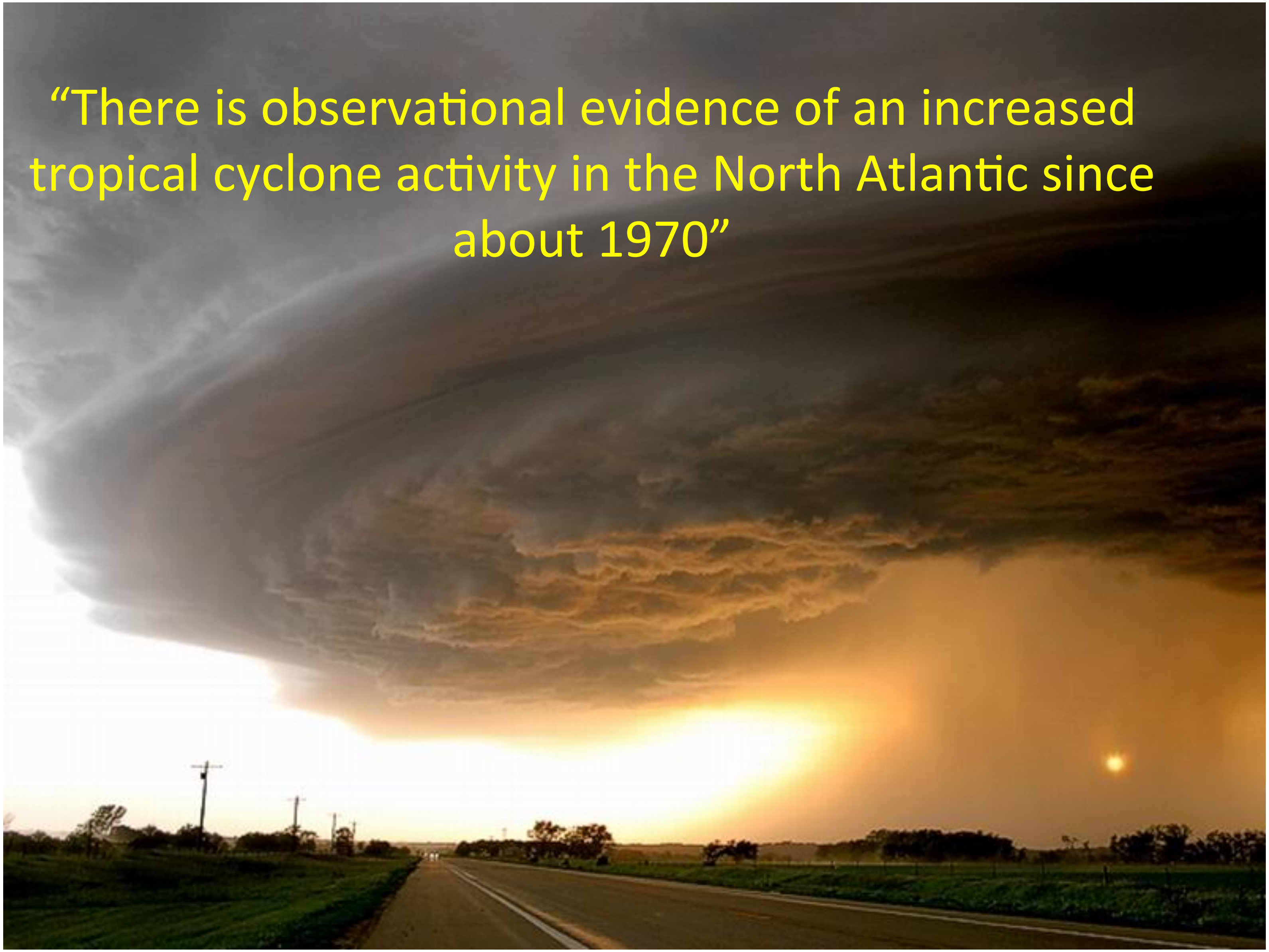
Greenland Ice Sheet



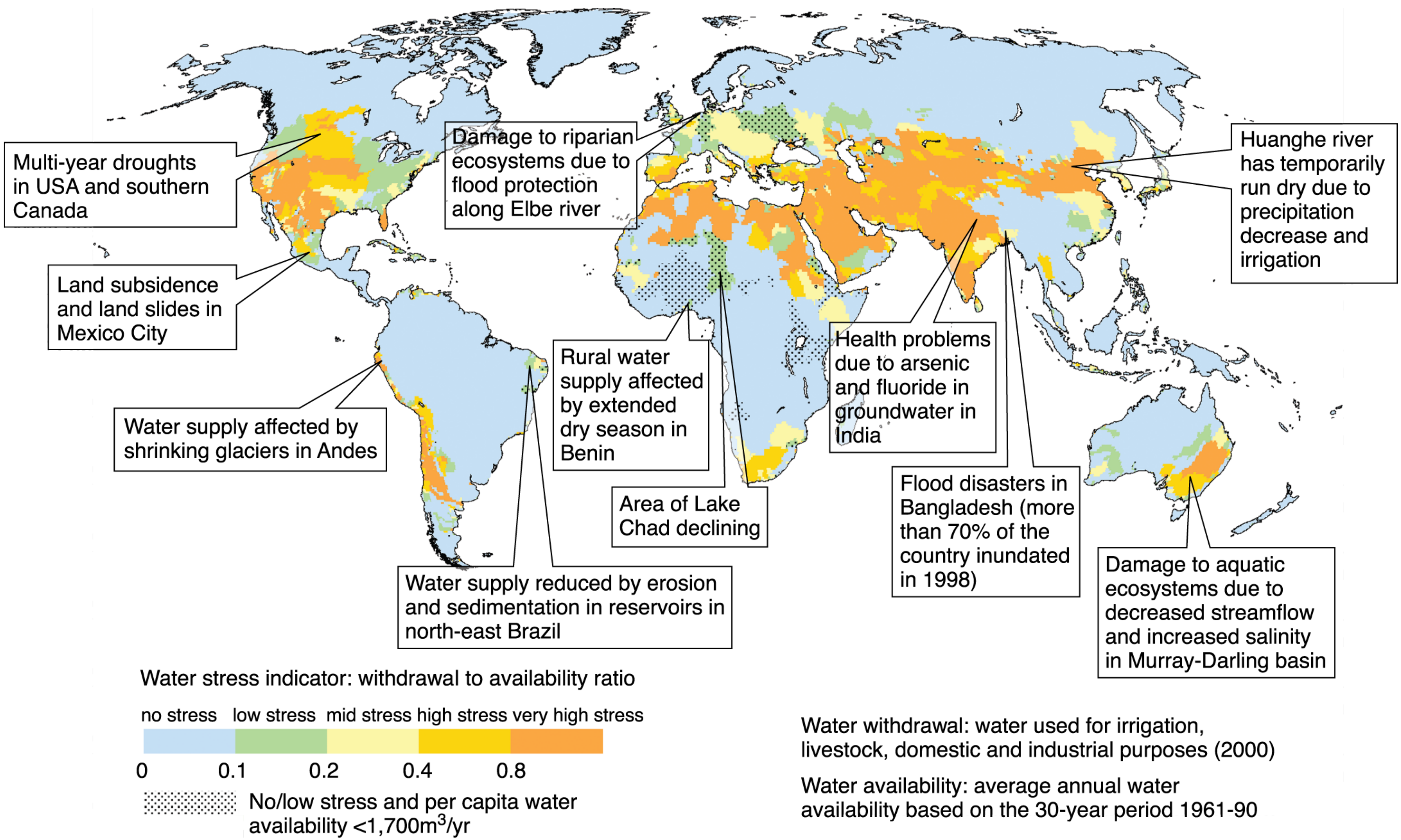


Greenland is now losing 20 percent more mass than it receives from new snowfall each year.

NASA Earth Observatory

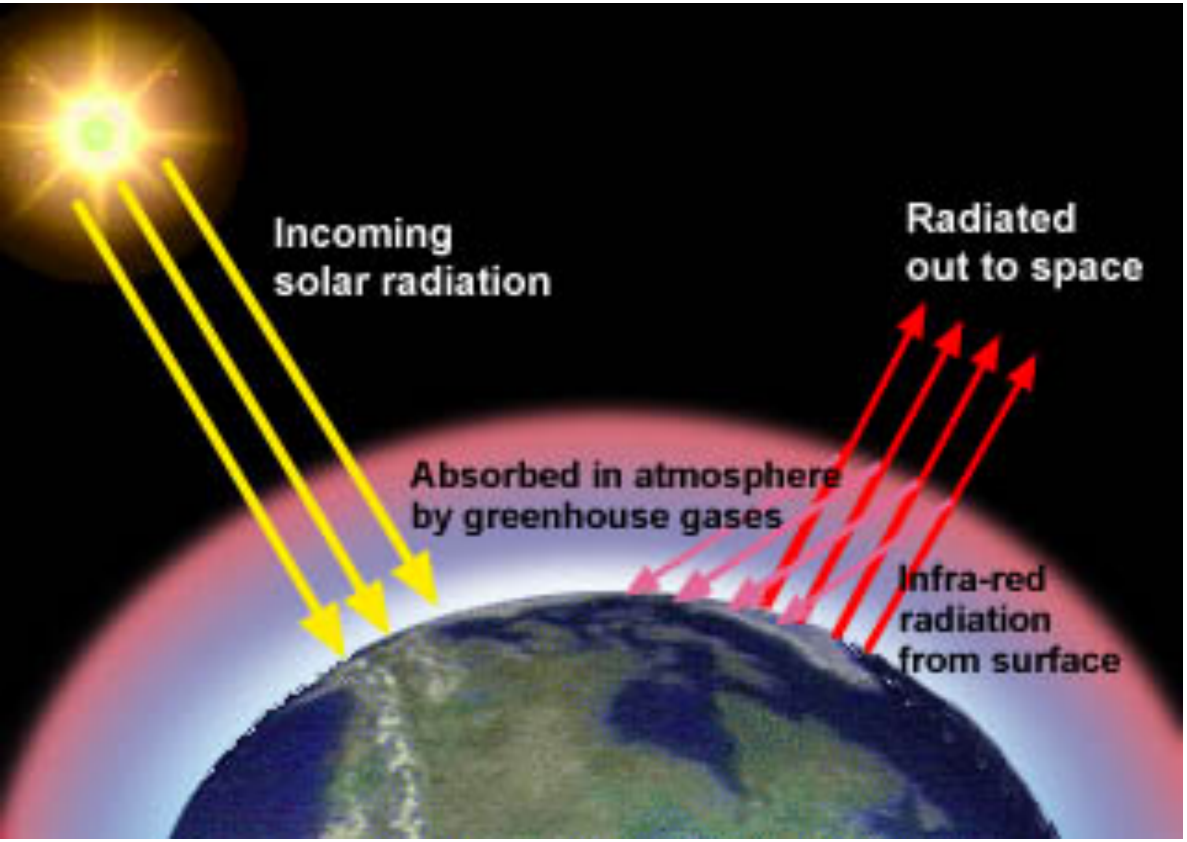

"There is observational evidence of an increased tropical cyclone activity in the North Atlantic since about 1970"

Current impacts of changing precipitation and glacier melt

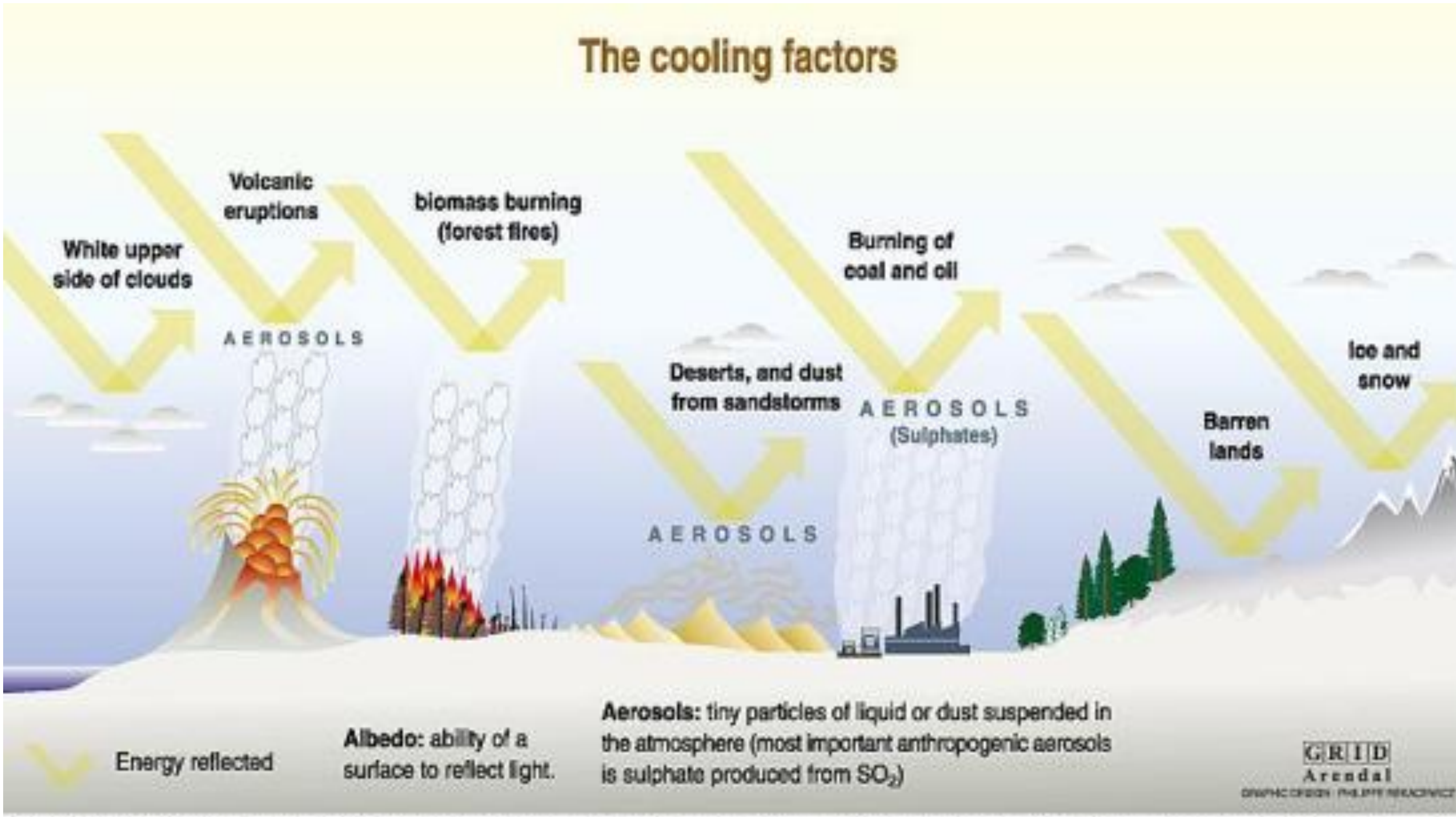


Source: IPCC TP Water

The greenhouse effect

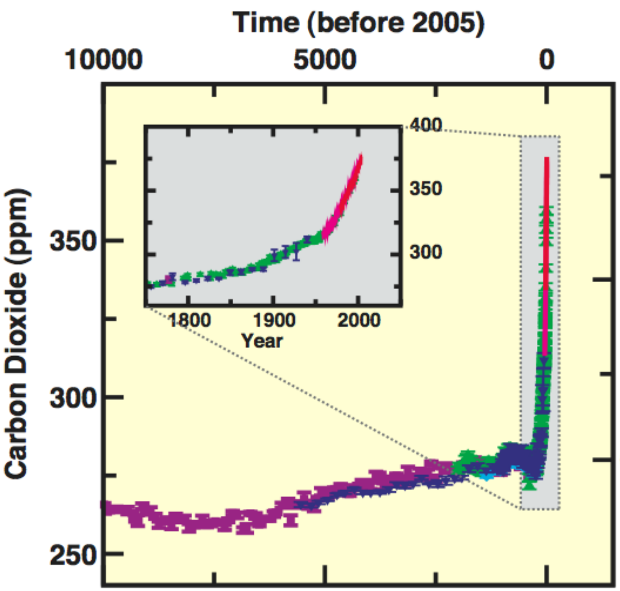


With no greenhouse effect, Te ≈ -18°C . We'd be frozen.
The real average temperature is +15°C, due to the Earth's natural greenhouse effect.
(see IPCC (1990).

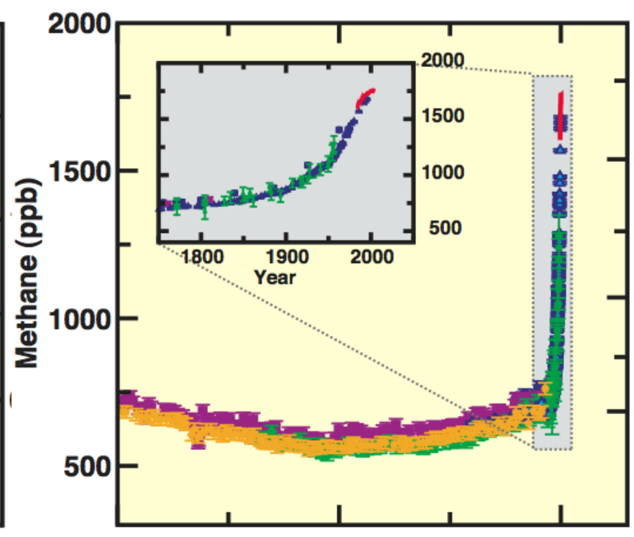


Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP; L.D. Danny Harvey, Climate and global environmental change, Prentice Hall, pearson Education, Harlow, United Kingdom, 2000.

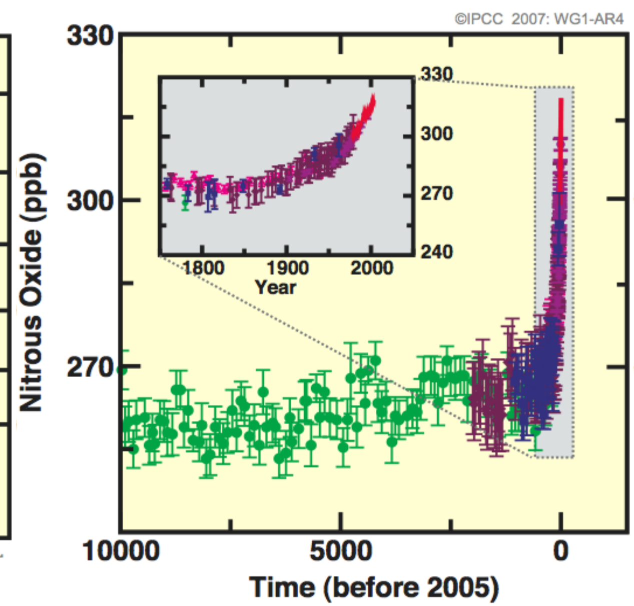
Greenhouse gases in the atmosphere



Carbon Dioxide

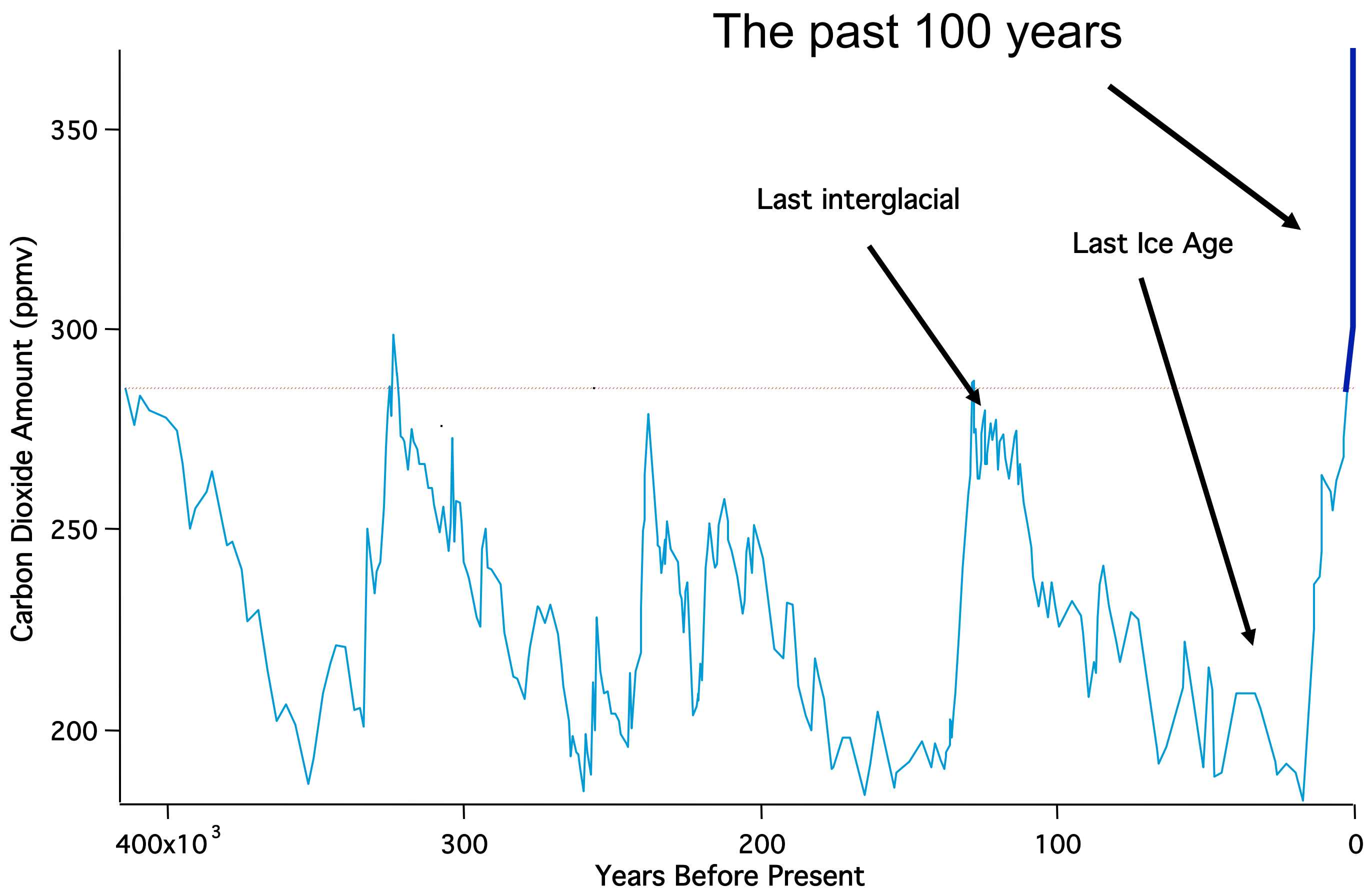


Methane



Nitrous oxide

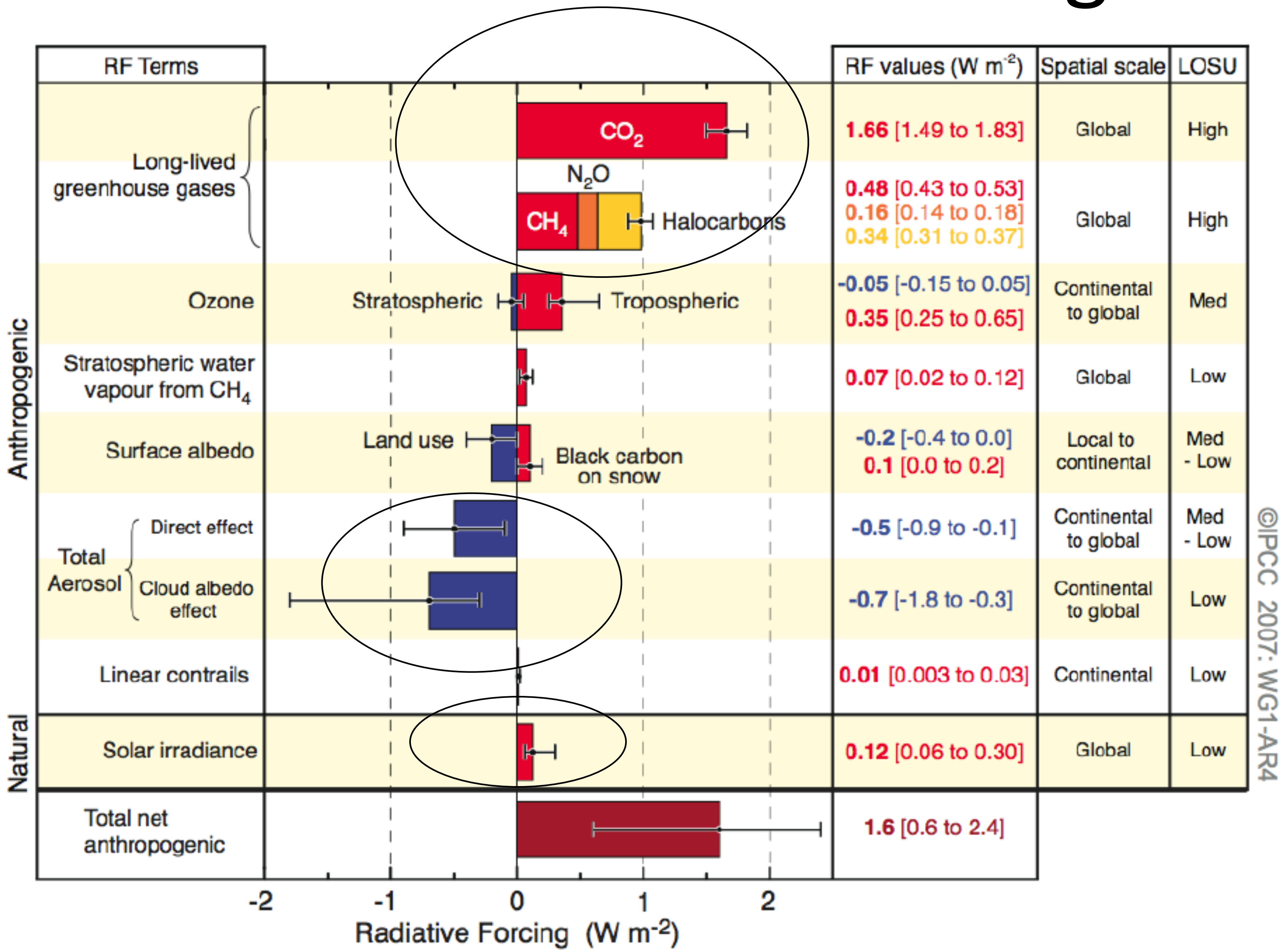
Some information about carbon dioxide changes through four past ice ages (from ice cores), and in the modern era (from global data)



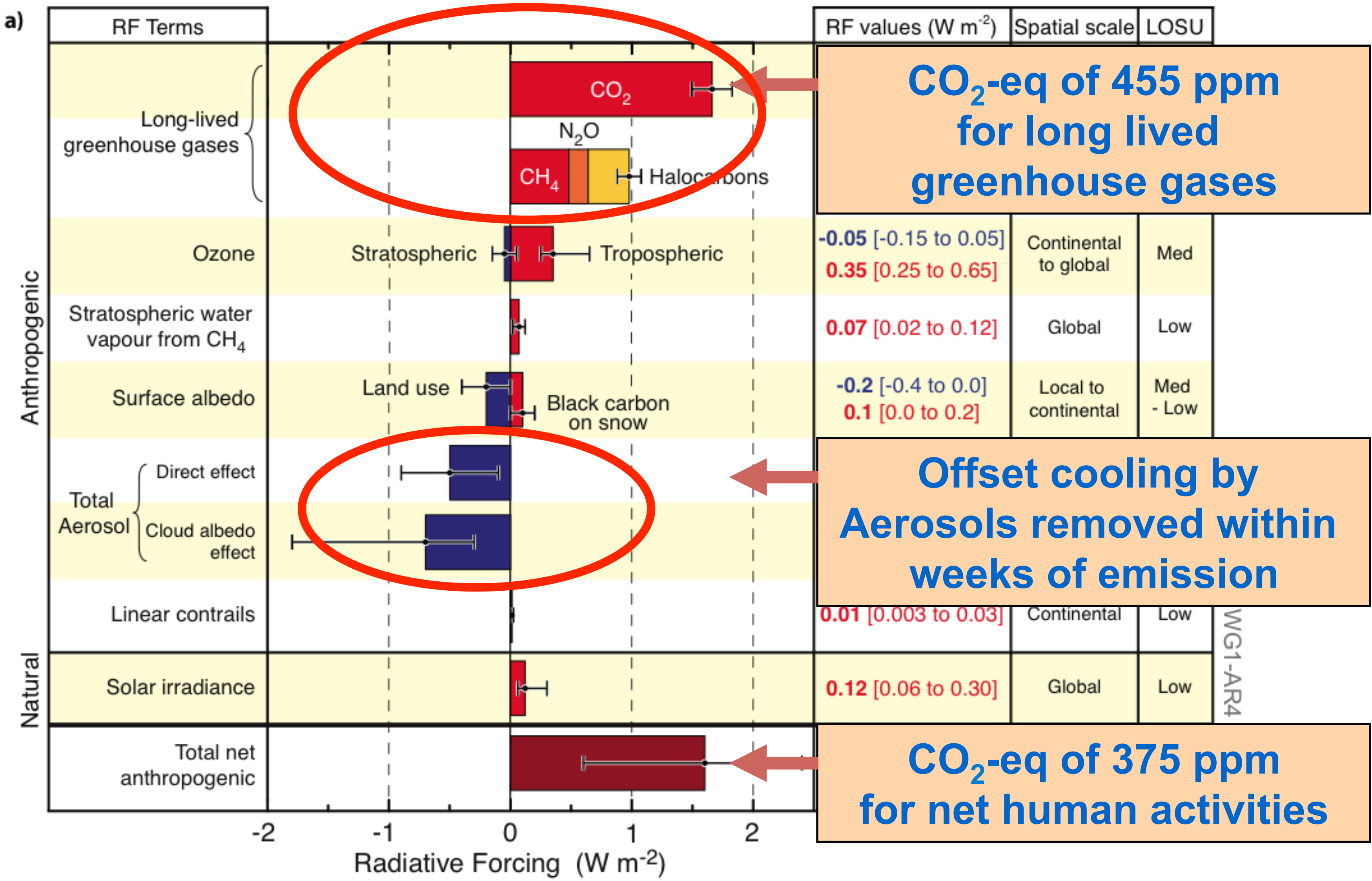
Ice ages are 'forced' by earth's orbital clock….

It is well established that there is more carbon dioxide in the atmosphere today than there has been in at least 650,000 years. **(Figure by S. Solomon)**

Contribution to warming



Contribution to warming

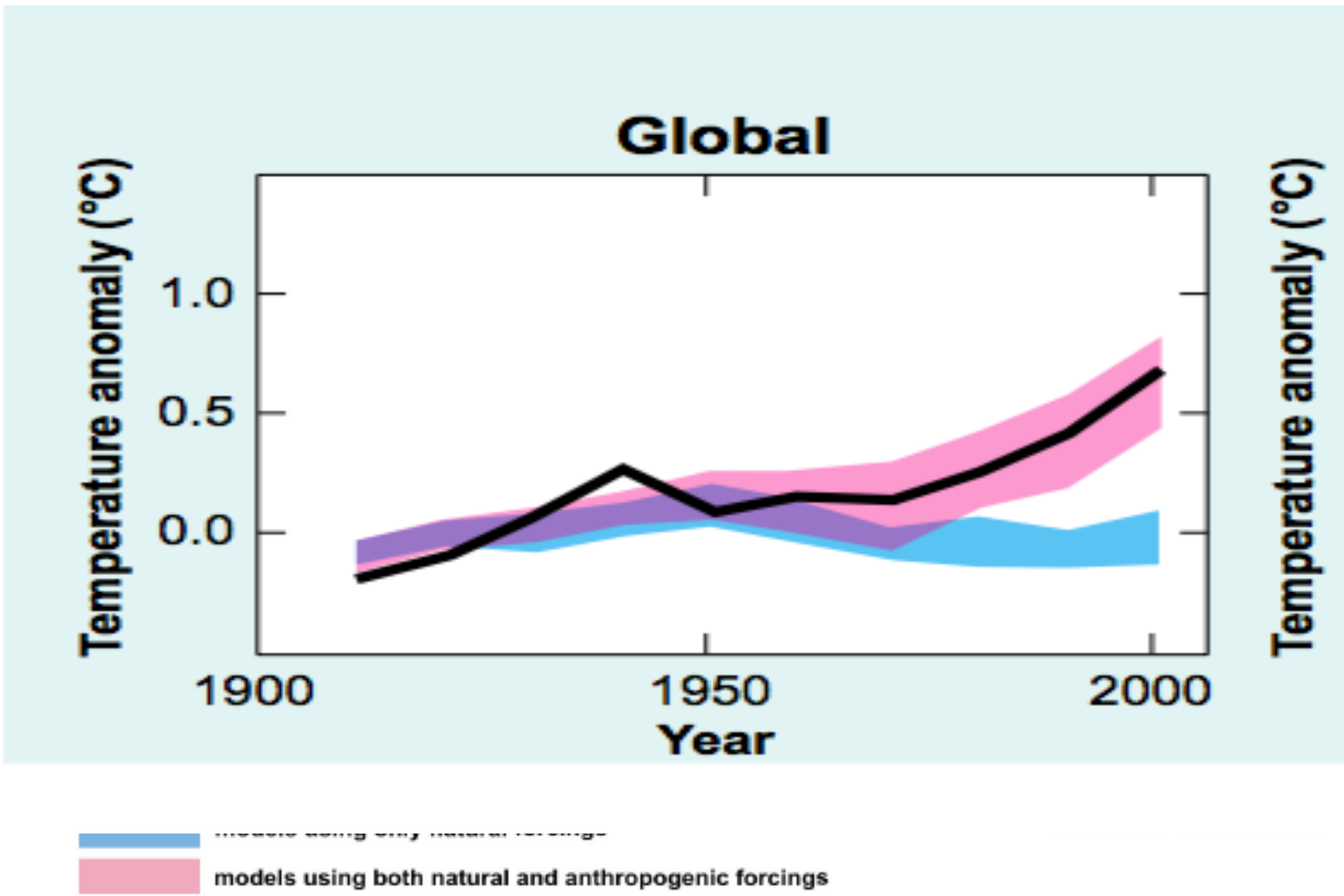


Global Warming Potential

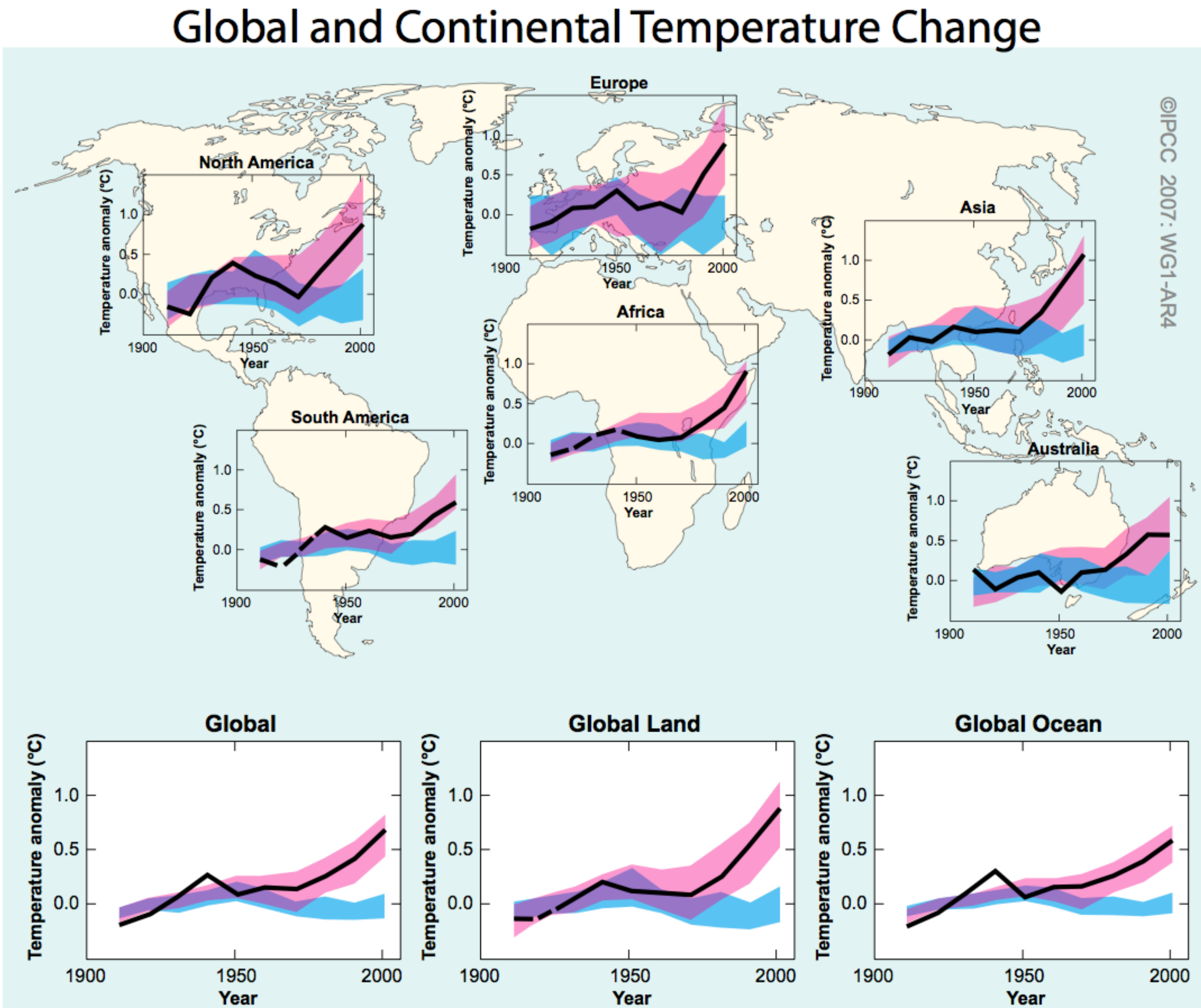
= time integrated radiative forcing for 1 kg compared to CO_2

Gas	Life time	GWP (20)	GWP (100)	GWP (500)
CH_4	12	72	25	7.6
N_2O	114	289	298	153
HFC23	270	12000	14800	12200
HFC 134a	14	3830	1430	435
SF_6	3200	16300	22800	32600

Most of the observed increase in global average temperature since mid 20th century is *very likely* due to increase in anthropogenic GHG concentrations



Anthropogenic warming is likely significant averaged over each of the inhabited continents

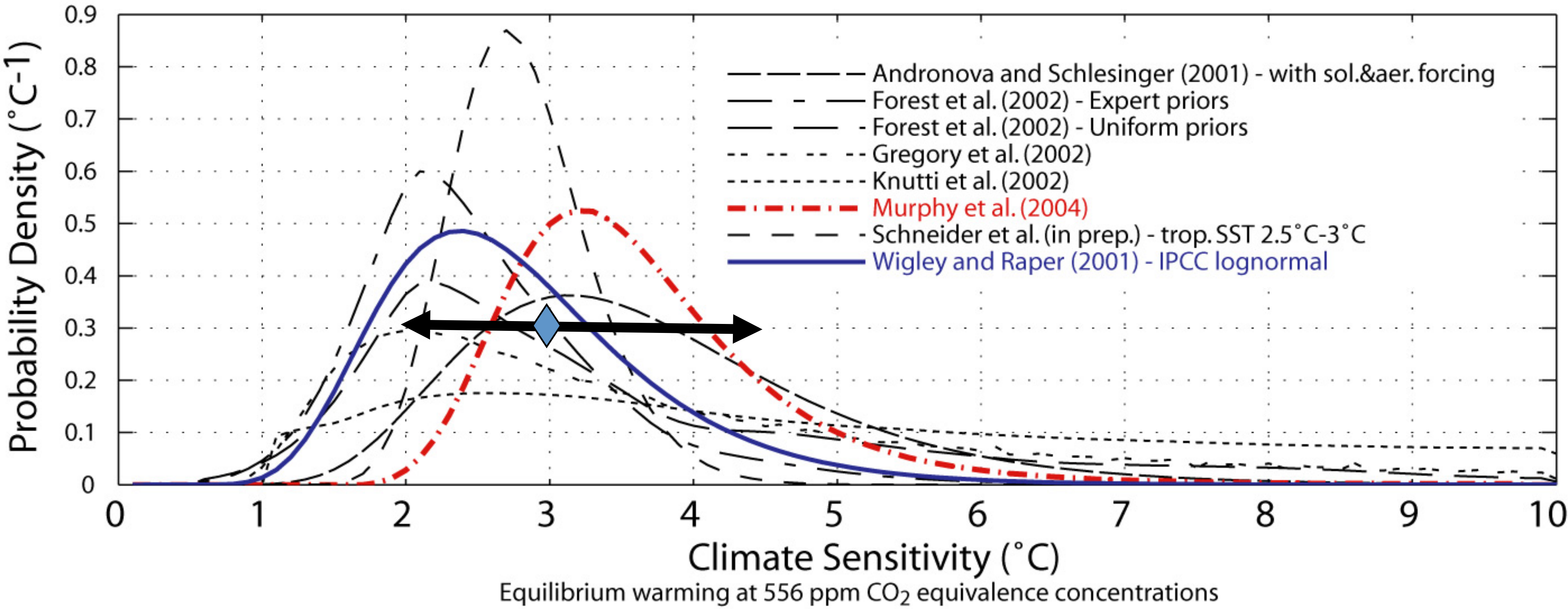


Climate models

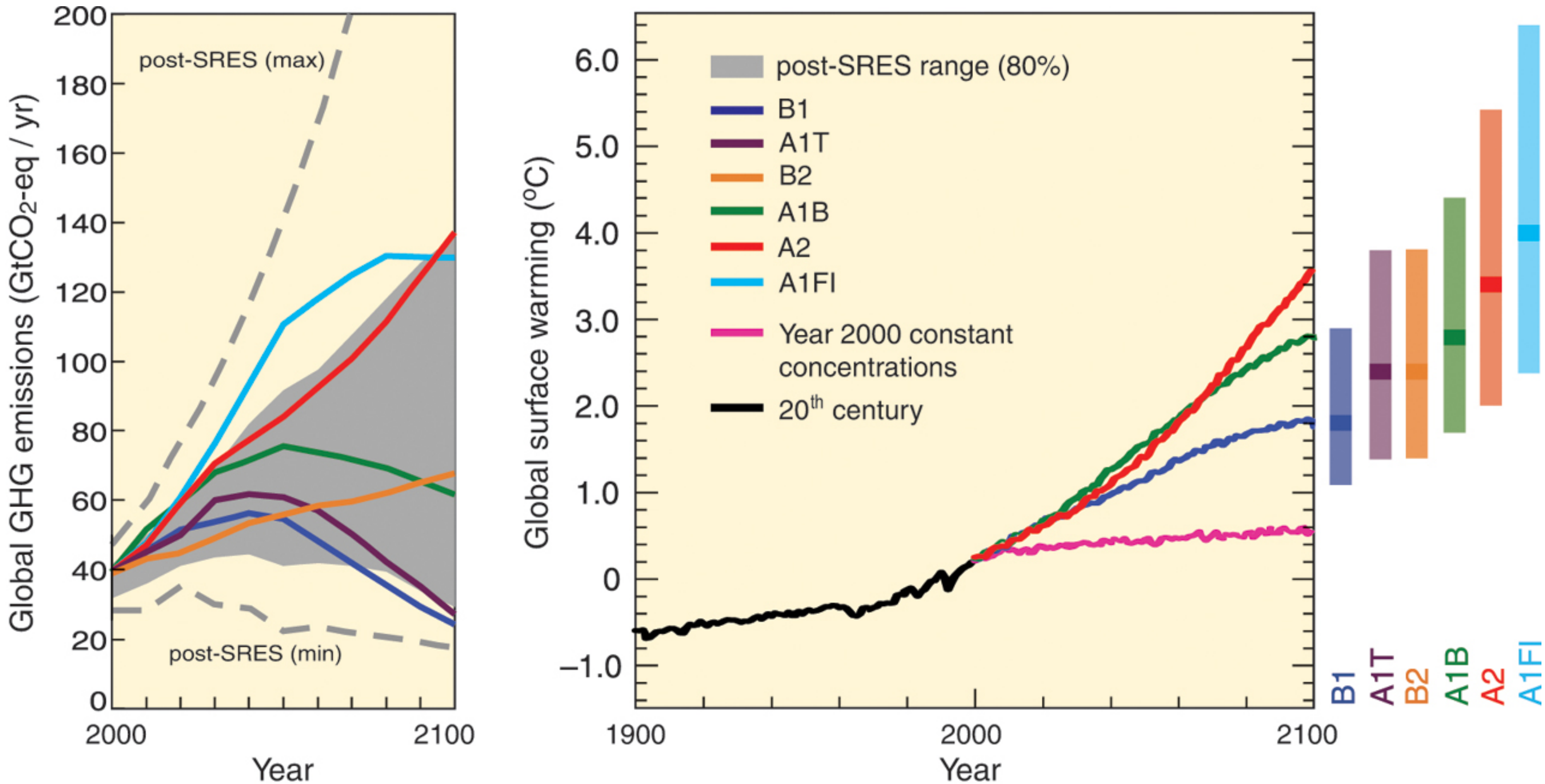
- Can reproduce historic climate pretty well
- Confidence?
  - Average temperature> average precipitation
  - Global average > continental average> regional average > local average
  - Average > extremes
  - Climate >> weather

Climate sensitivity: 2-4.5 (66% probability) with likely value of 3 (increased from 2.5)

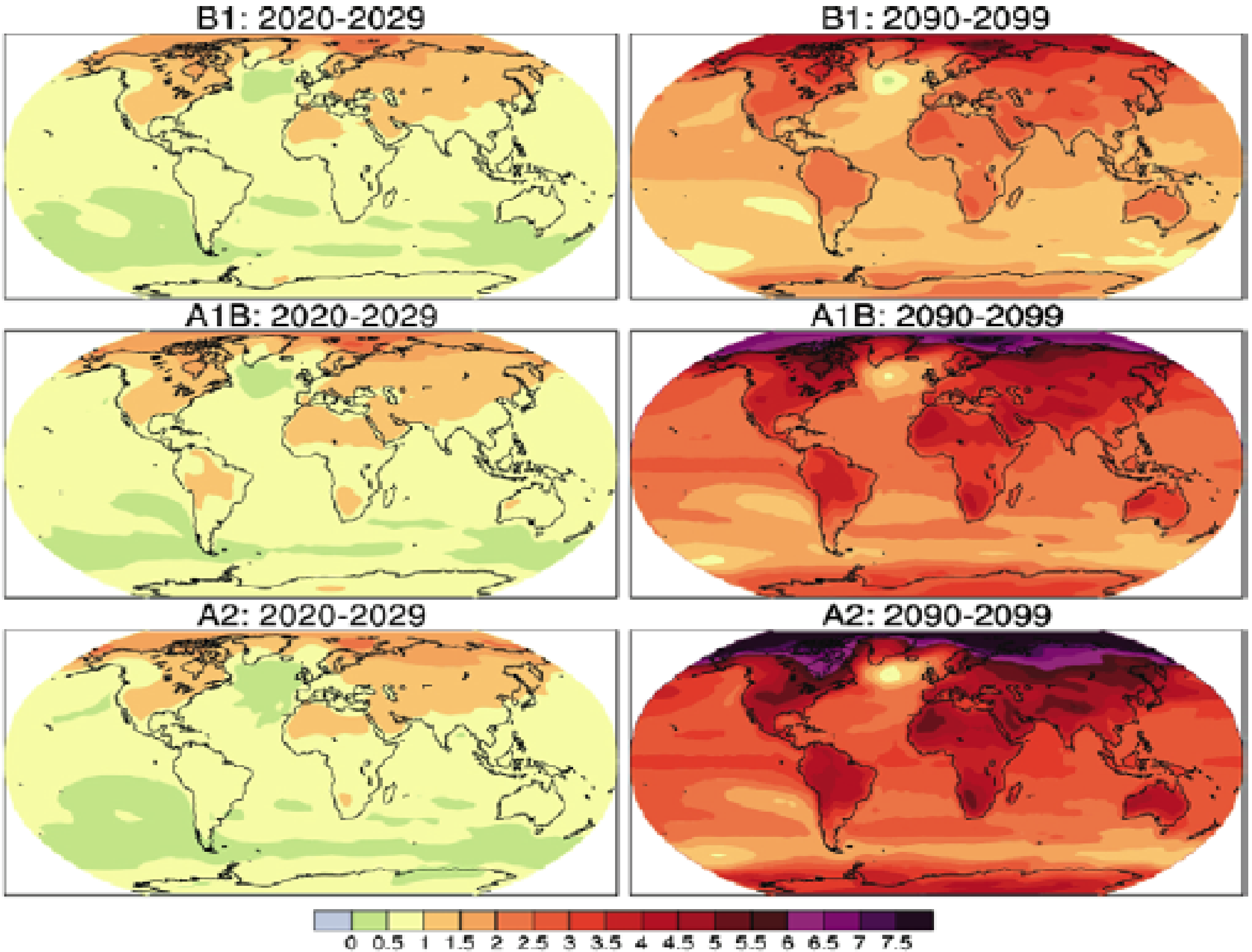
(Hare & Meinshausen, 2004)



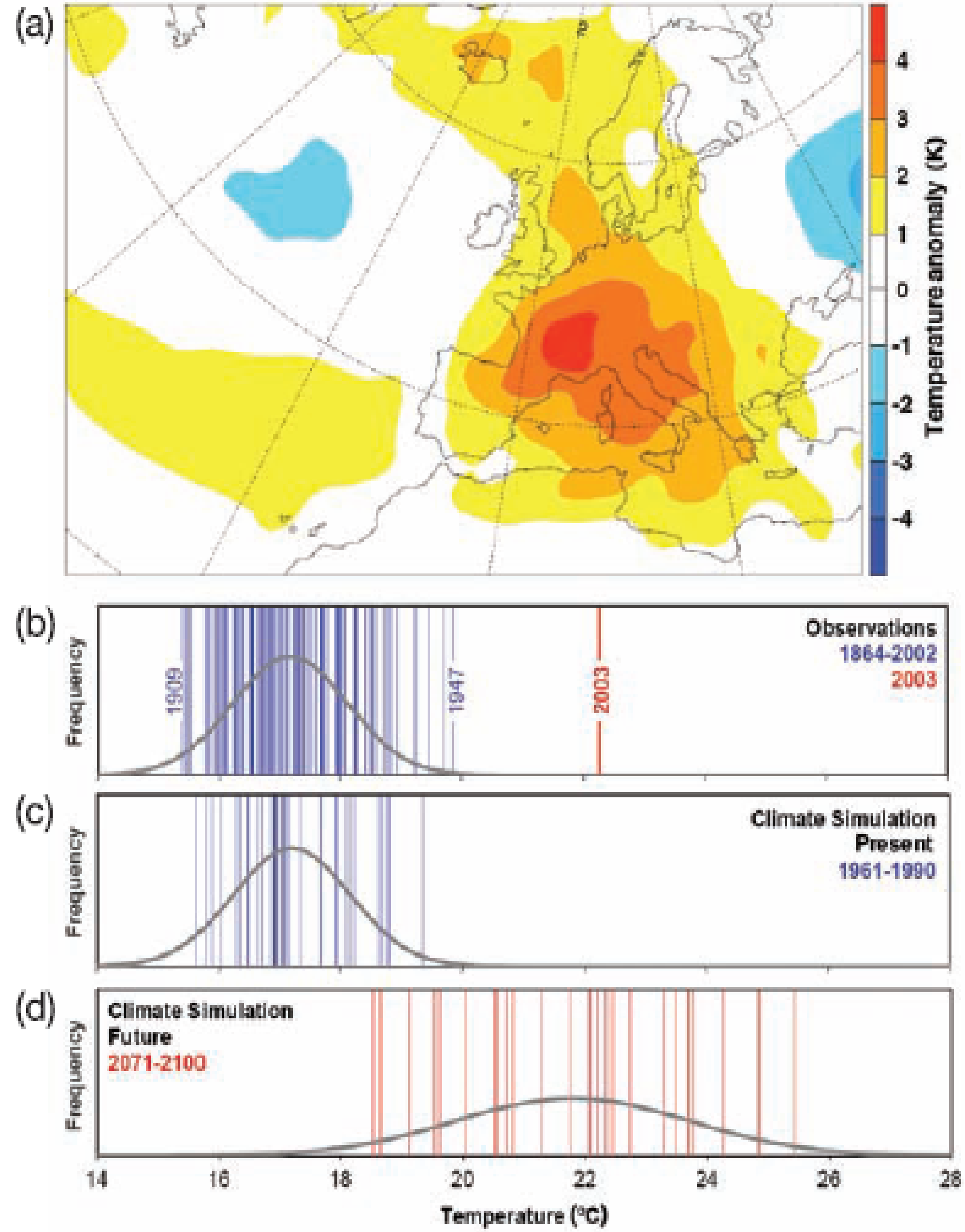
Projected climate change



Warming wil not be the same everywhere: three different scenarios



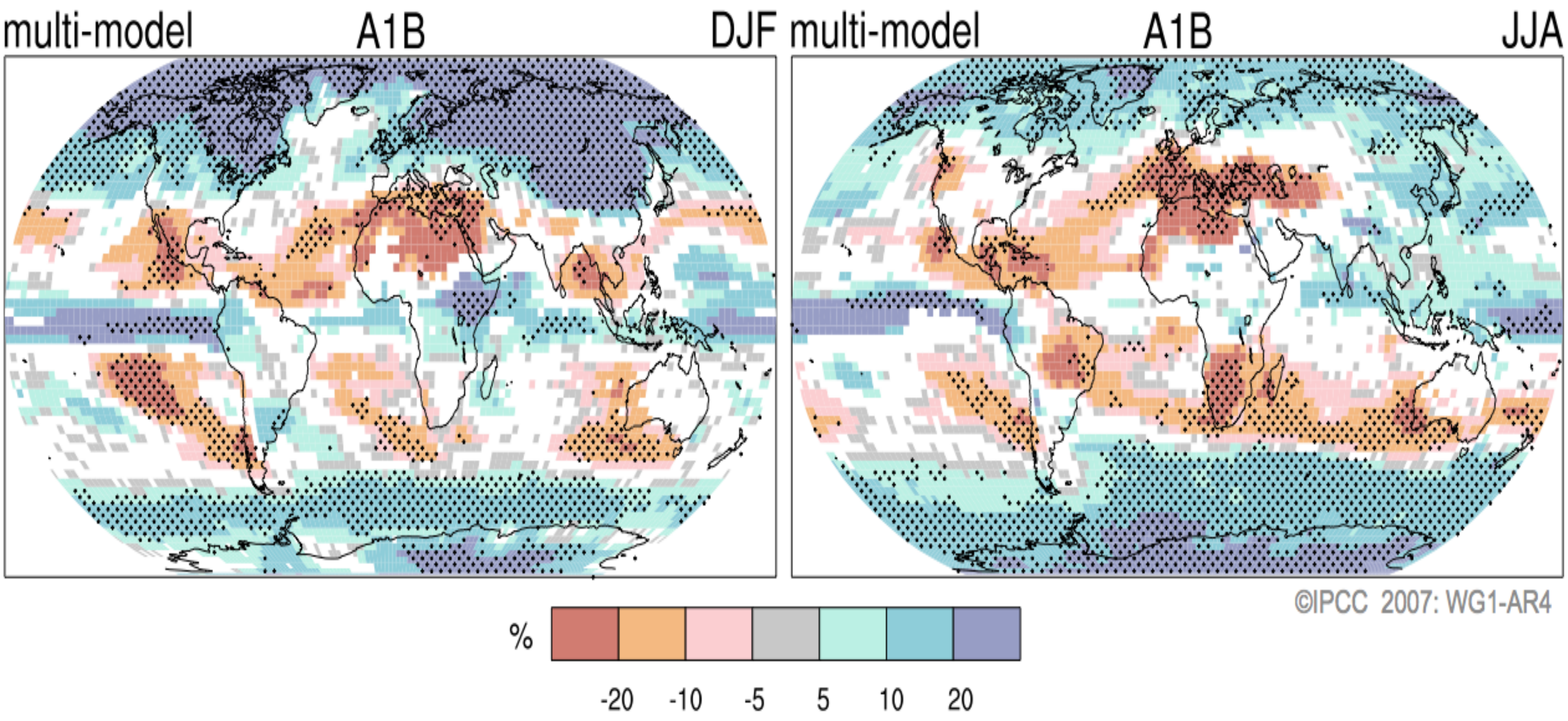
Summer 2003 heat wave in Europe projected to be common by 2070-2100



Are current extreme weather phenomena caused by climate change?

- Nature, February 16, 2011:
  - “ Likelihood of extreme rainfall may have been doubled by rising greenhouse-gas levels” >> role of climate change confirmed
  - “ Increased flood risk linked to global warming”

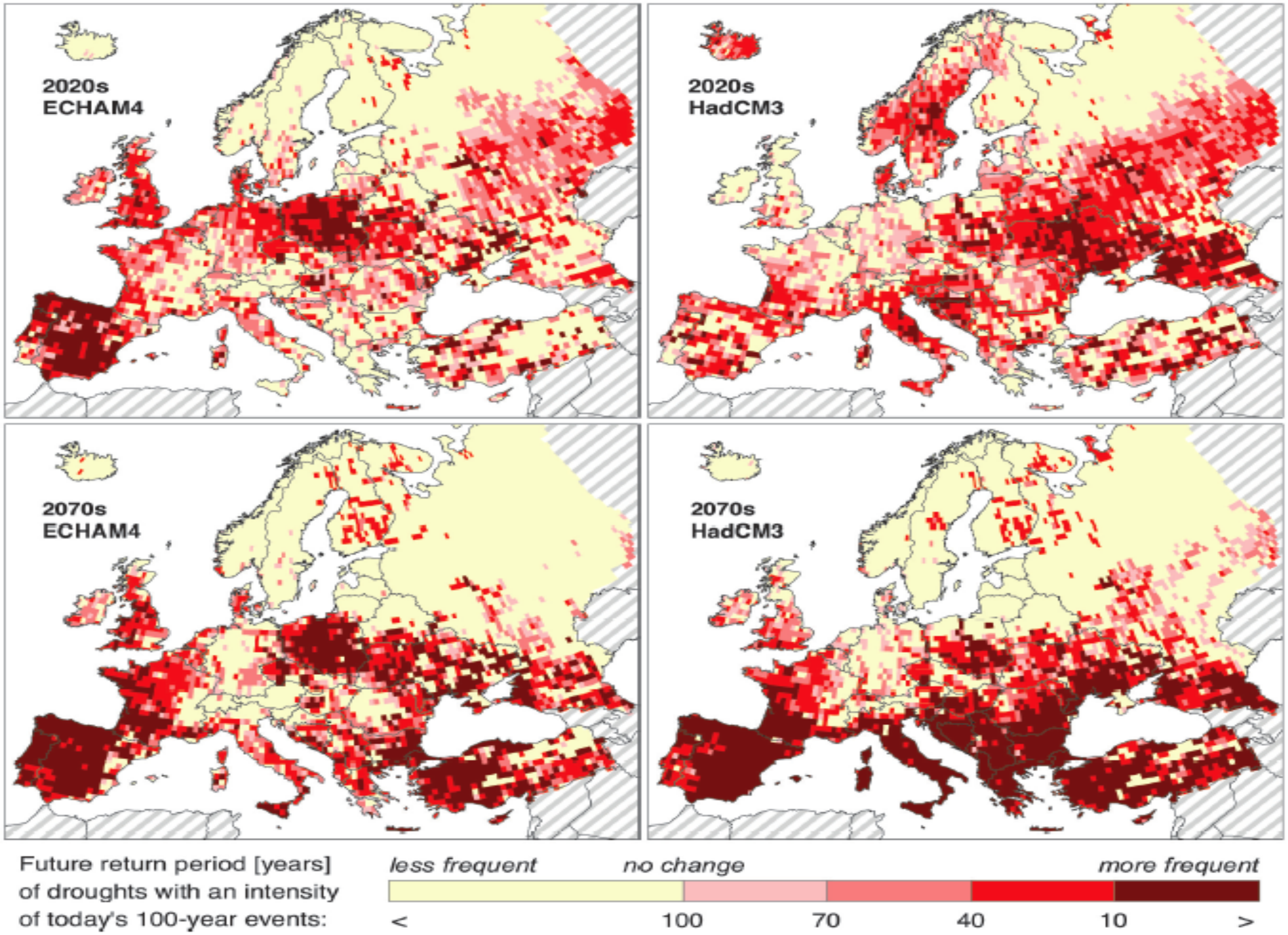
Some regions will become wetter, others drier



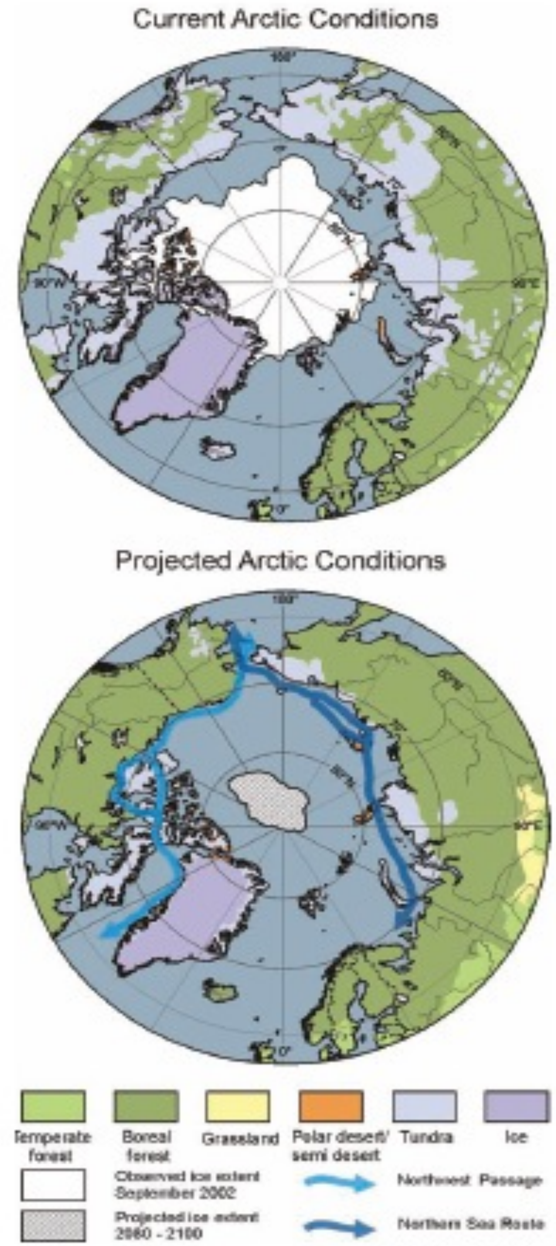
Checkered: models agree

More droughts AND more floods

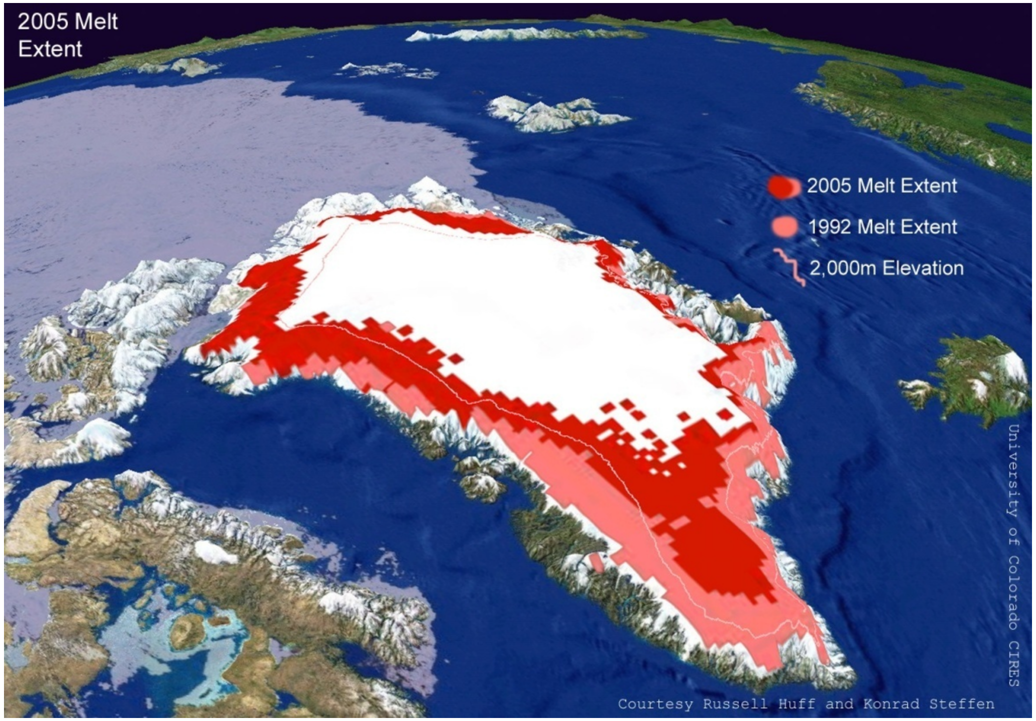
Drought frequency



Projected changes in Arctic sea ice 2090-2100



Long-term Sea Level: Ice Sheets

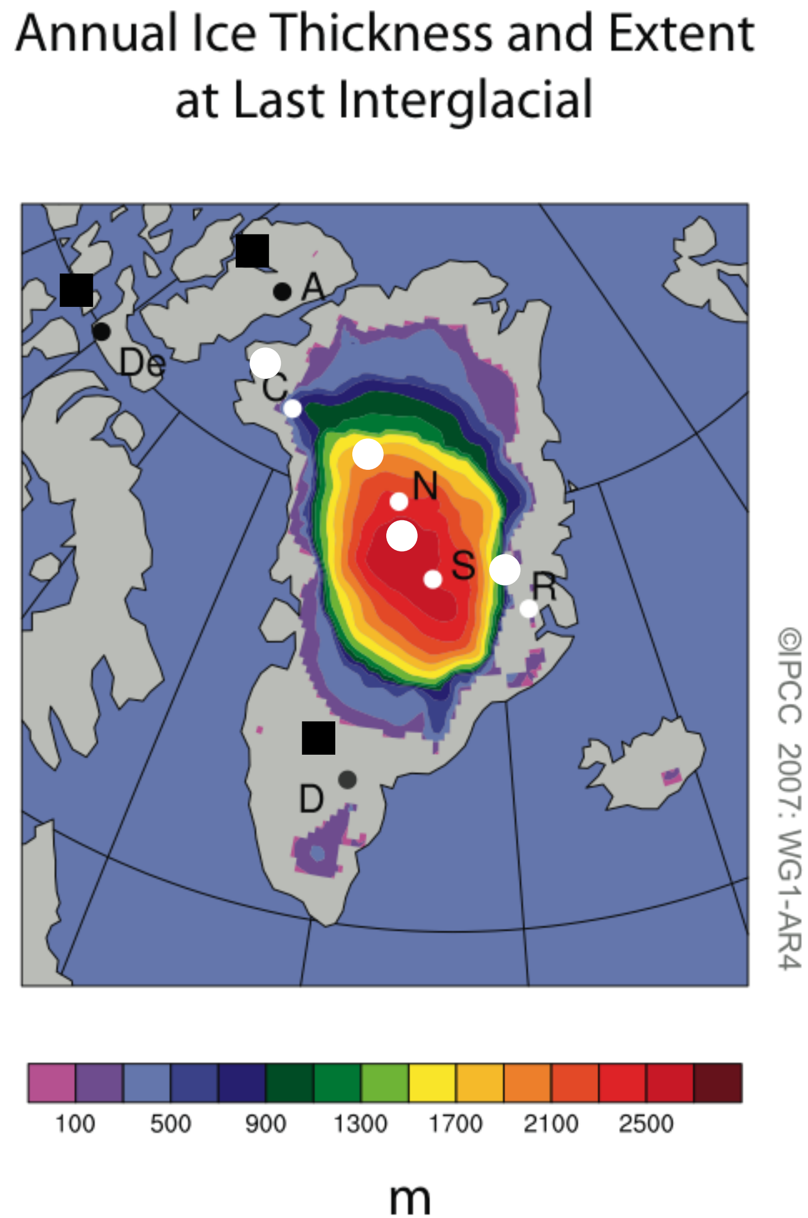


Volume: 2.8×10^{15} m^3 = 7 meters of sea level

Ice sheet response time : centuries to millenia

Greenland ice sheet 125,000 years ago

- •Contours are from average of 3 ice sheet models.
- •White dots show drill sites that had ice.
- •Black squares show sites that did not have ice.
- •The last time polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise.



So what will be the impacts?

- Water
- Food
- Nature
- Coasts/ human settlements
- Health
- Extreme events
- Large scale irreversible events

Drinking water

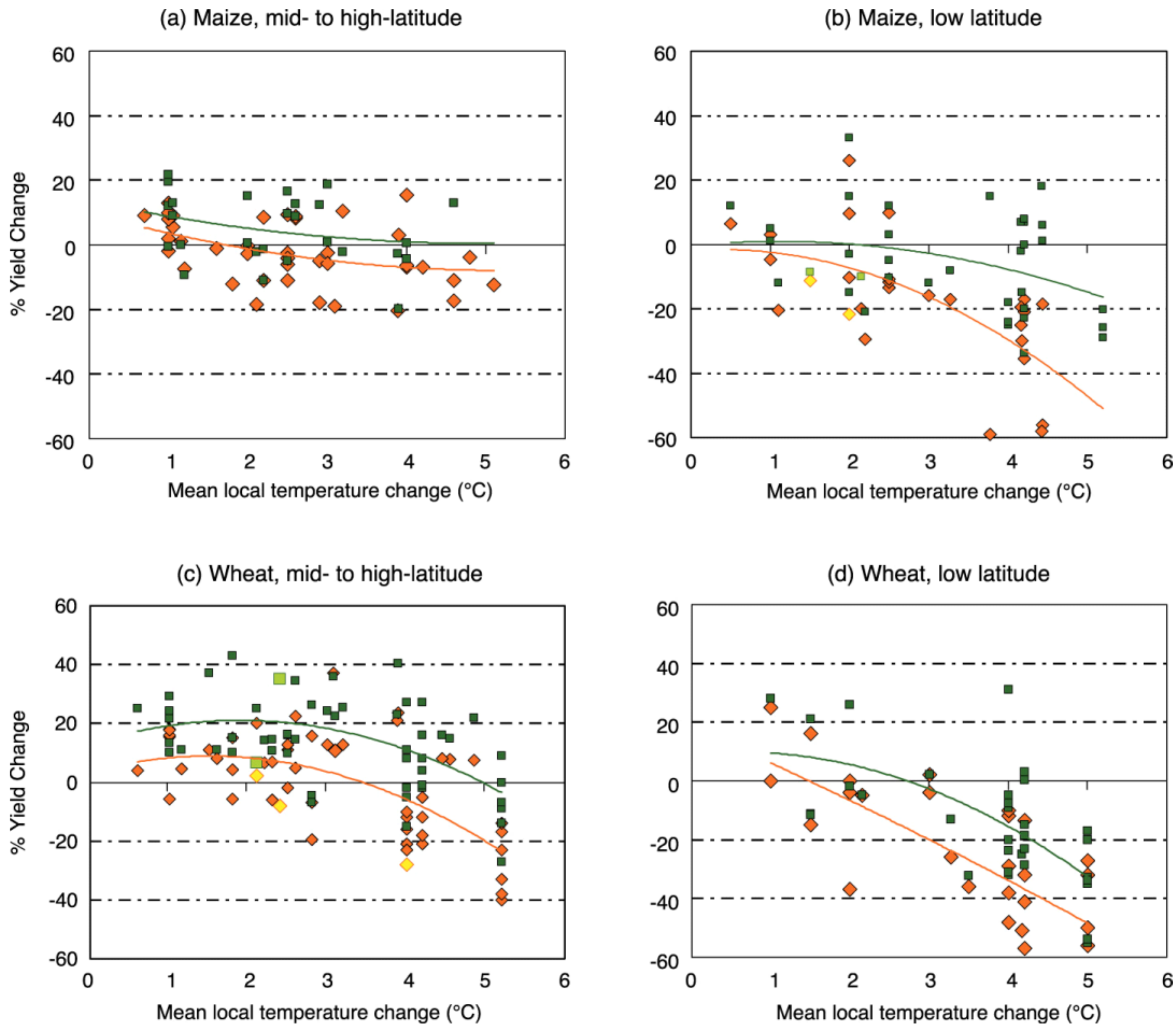
- By 2020 75-250 million people exposed to incresed water stress in Africa
- By 2050 fresh water availability in many parts of Asia is projected to decrease

Food production threatened

- Grain productivity in tropics goes down at any warming;
- Rainfall patterns change and risk of drought increases (particularly in dry areas)
- By 2020, in some countries, 50% reduction of yield possible

- In temperate areas productivity of some crops increases with moderate warming;
- With more than 3 degrees warming also there a decline

Figure TS.7. Sensitivity of cereal yield to climate change



Nature seriously threatened

Temp increase above 1980- 1999

1 2 3 4 5

Coral: bleaching already happening; dying at 1-3 degrees warmer water

Biodiv hotspots threatened

20-30% of species threatened with extinction at 1,5-2,5 degrees warming

Eastern Amazone turns into savanna by 2050

Alpine flora: in 2080 60% threatened with extinction

Extensive extinction of species

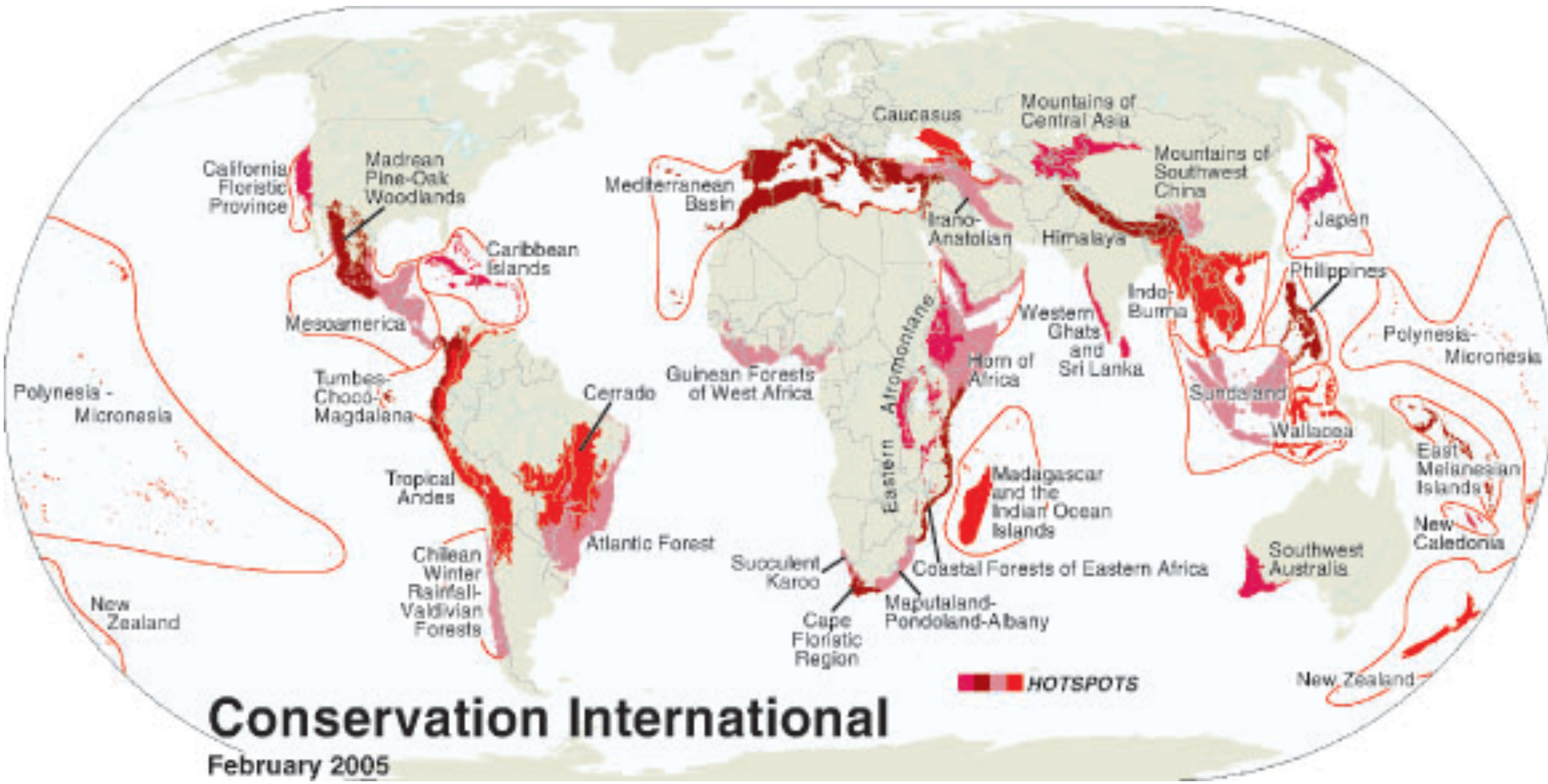
Threatened species

Extensively bleached community of corals near Great Keppel Island on the southern Great Barrier Reef in March 2002 at low tide.

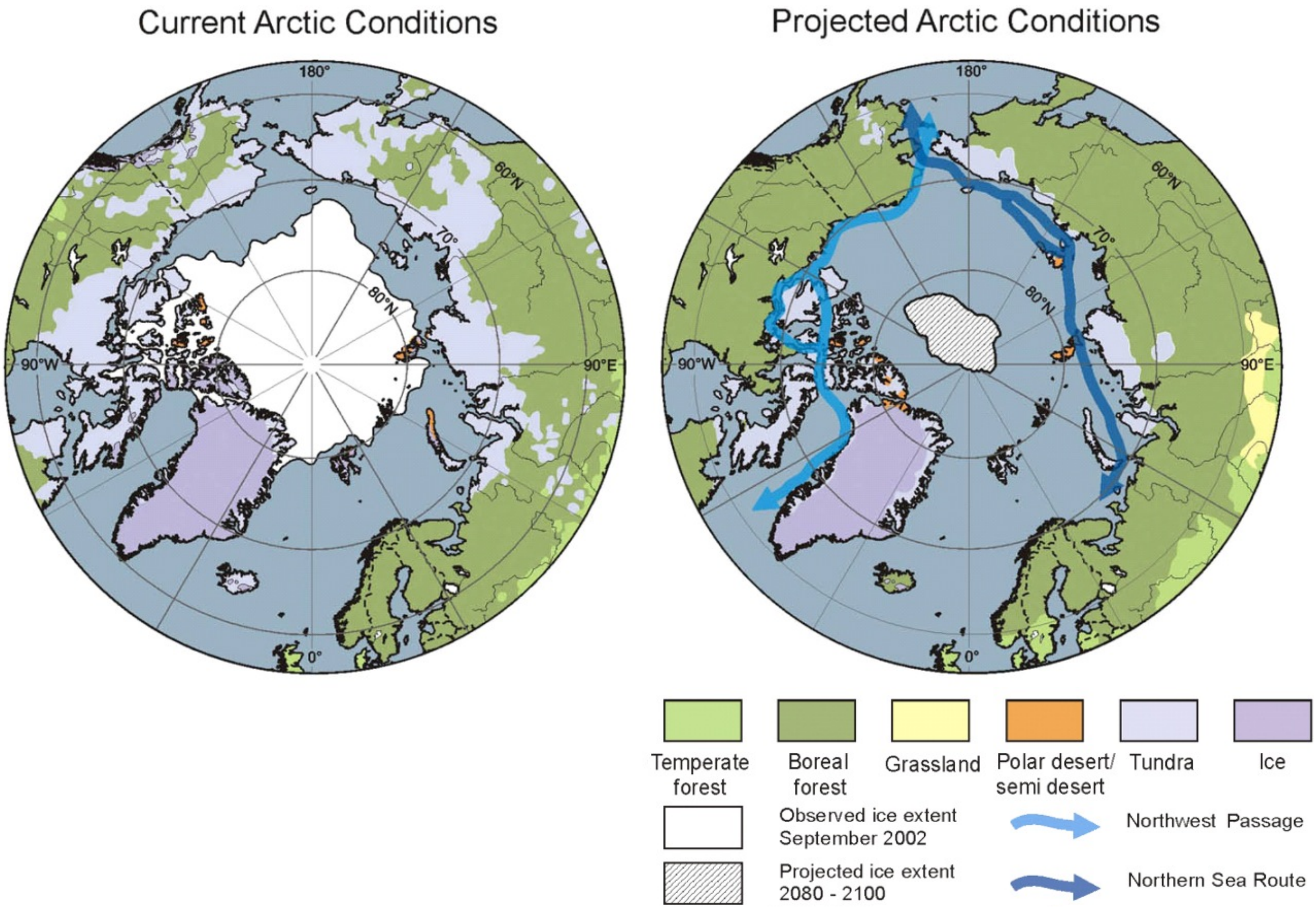
Photo Ove Hoegh-Guldberg, Univ. of Queensland

Polar bears have recently been listed as vulnerable due to climate change by IUCN (Wiig, 2005; Schiebe et al., 2006) and also proposed as endangered species on U.S. list of endangered species (Eilperin, 2006; Heilprin, 2006; Roach, 2006)

Biodiversity hotspots threatened

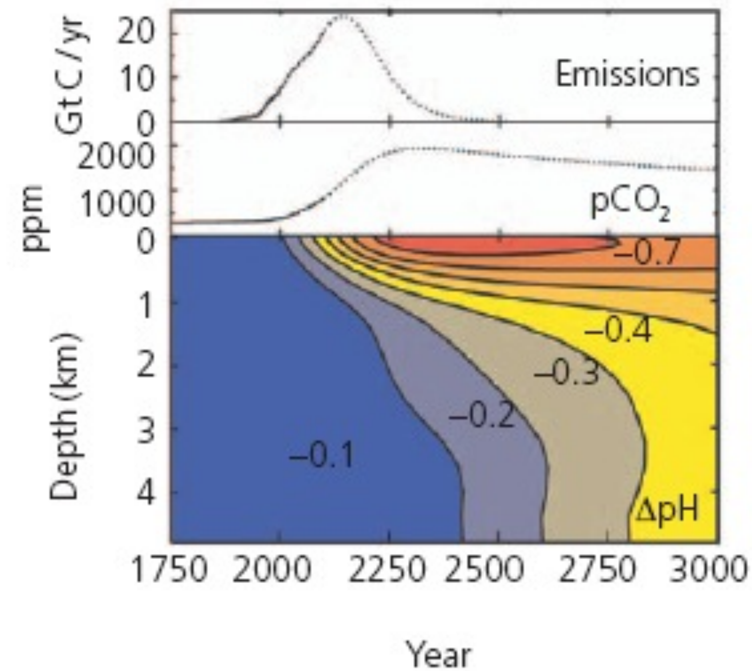


Vegetation of the Arctic: current conditions and projected changes under the IS92a scenario for 2090-2100



Ocean acidification

- Already happened (0.1 pH drop)
- Projected 0.4-0.5 drop by end of century
- Affects wide range of organisms forming (aragonite) carbonate skeletons (coral reefs, plankton, shellfish)
- Will have impact on food webs, ecosystems
- (Aragonite) coral reefs could be weakened/ eroded by end of century



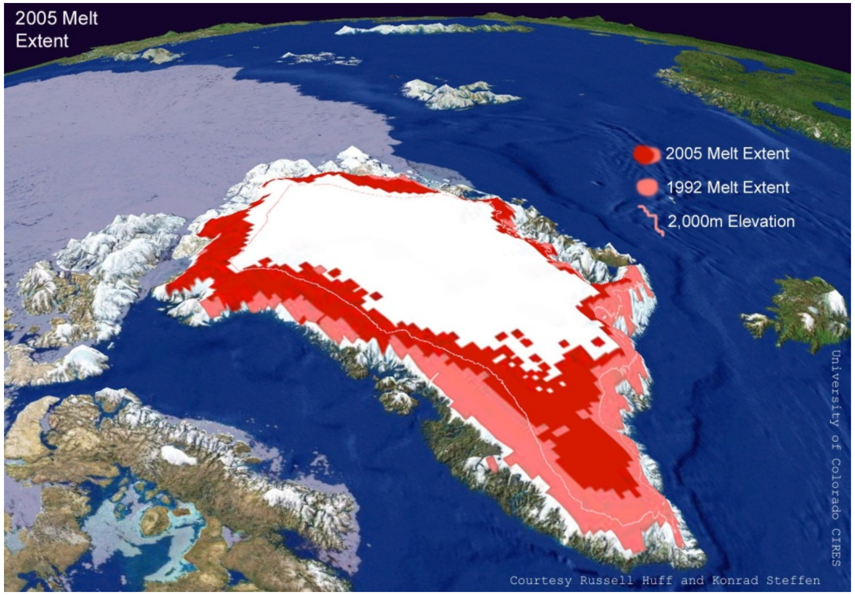
Threatened deltas

Relative vulnerability of coastal deltas as indicated by the indicative population potentially displaced by <u>current</u> sea-level trends to 2050 (Extreme $\geq$ 1 million; high 1 million to 50,000; medium 50,000 to 5,000)

Sea level rise unstoppable

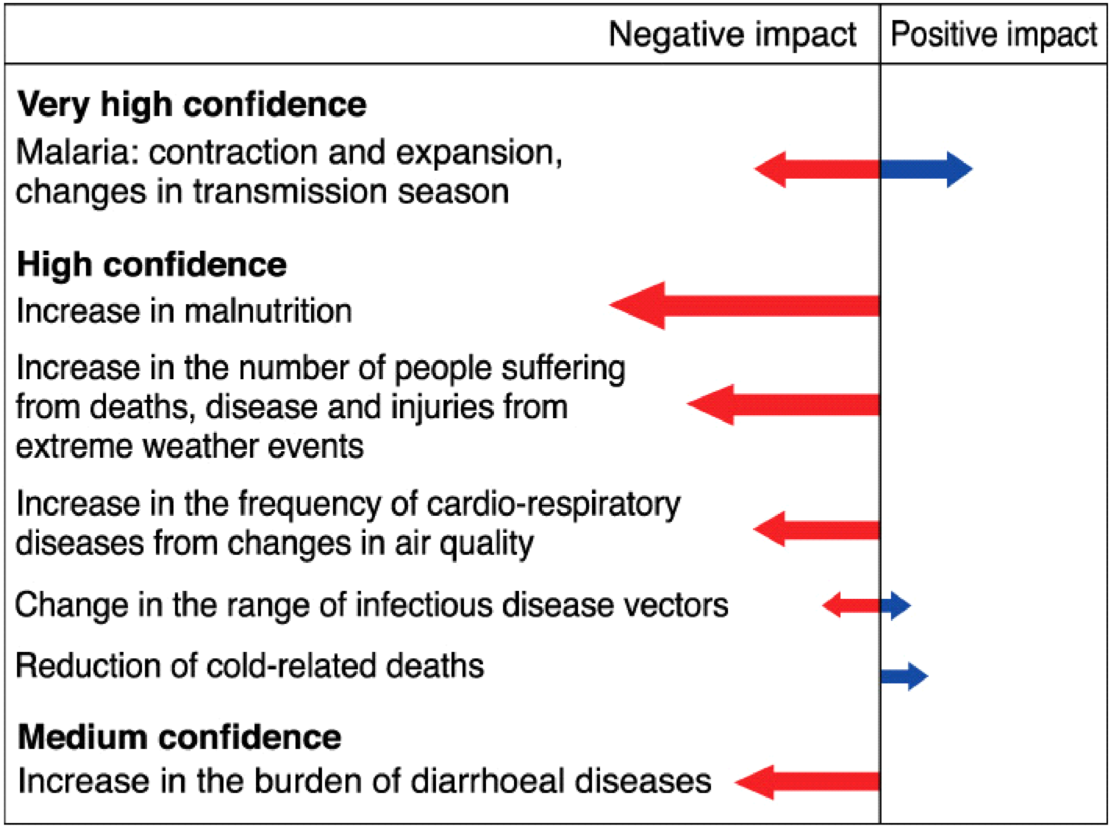
- 2100: 20 -60 cm
- Many centuries: several meters

  (WITHOUT melting Greenland/ Antarctica ice sheets)



- 1.5 to 4°C warmer for several centuries/ thousands of years: up to 7m increase from melting Greenland ice sheet (like 125,000 years ago)

Direction and magnitude of change of selected health impacts of climate change



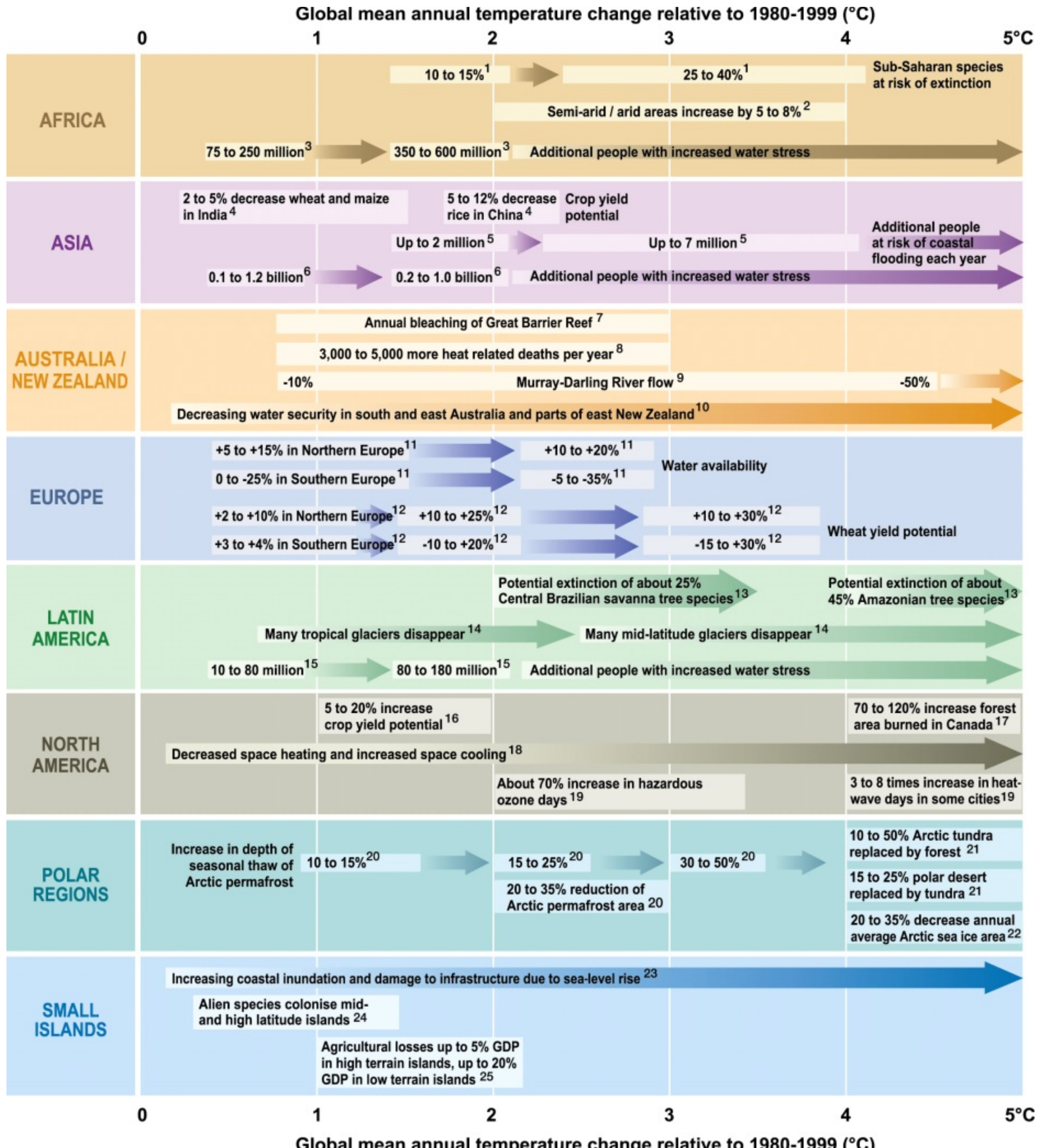
Extreme events

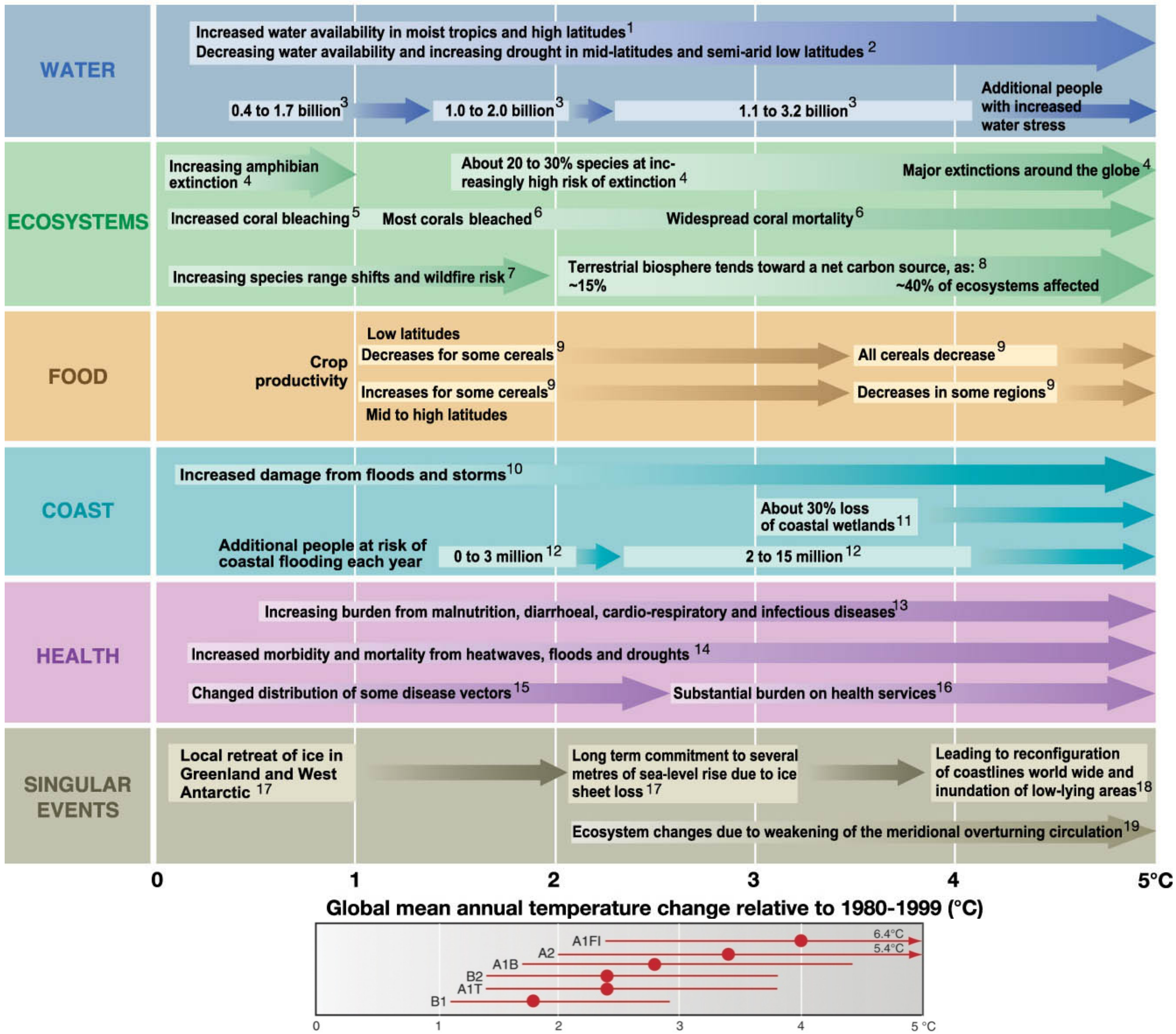
Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	Water resources [3.4]	Human health [8.2]	Industry, settlements and society [7.4]
Heavy precipitation events: frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property

The most vulnerable people and places can now be identified

- **Most vulnerable regions**:
  - Africa, Asian mega-deltas, small islands, the Arctic
- **Most vulnerable sectors**:
  - water in the dry tropics
  - agriculture in low latitudes
  - human health in poor countries
  - ecosystems at the margins: e.g. tundra, boreal, mountains or already stressed: e.g. mangroves, coral
- **Most vulnerable people**:
  - In all countries, even those with high incomes, some are especially at risk: the poor, young children, the elderly

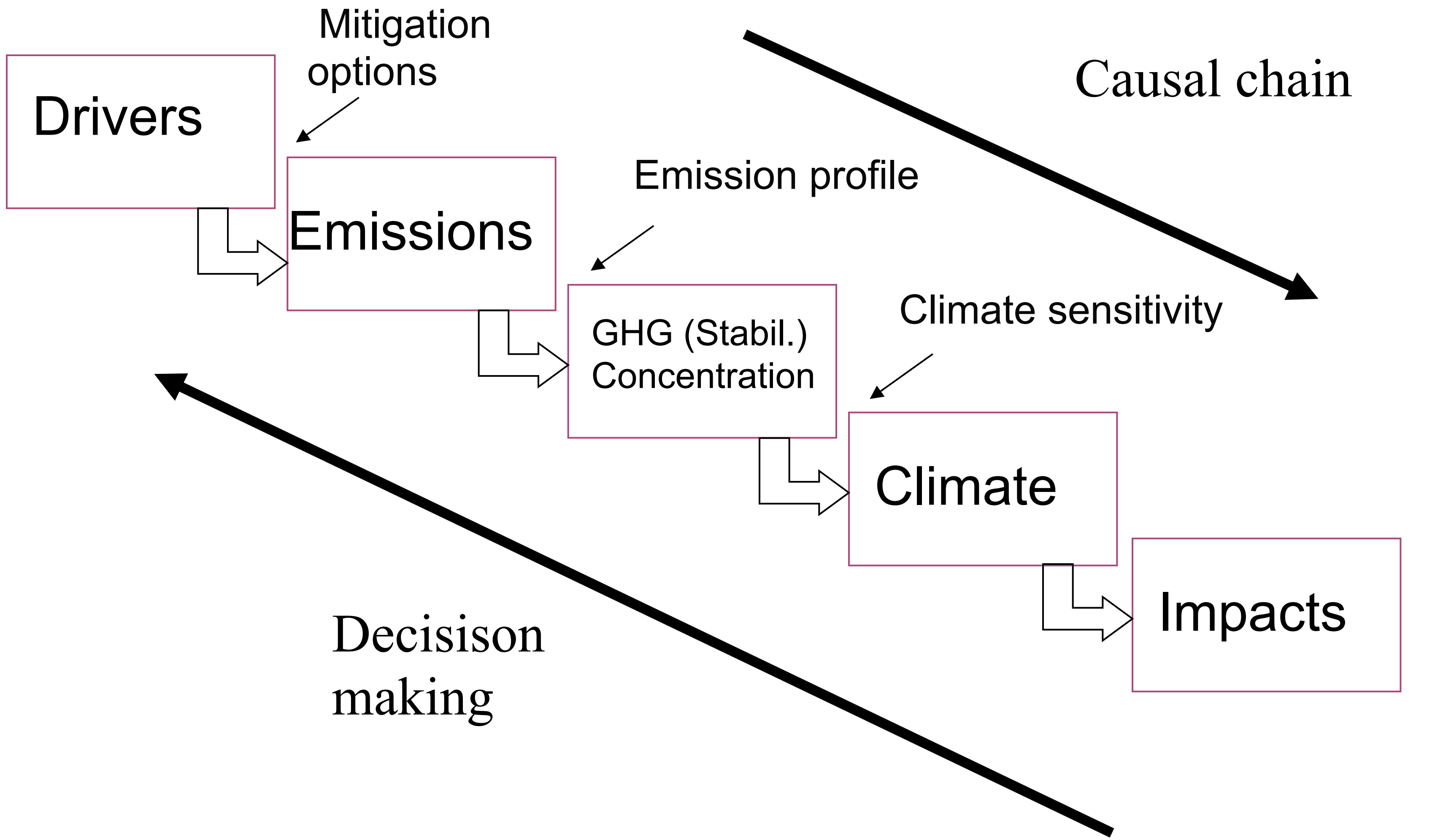
Examples of regional impacts



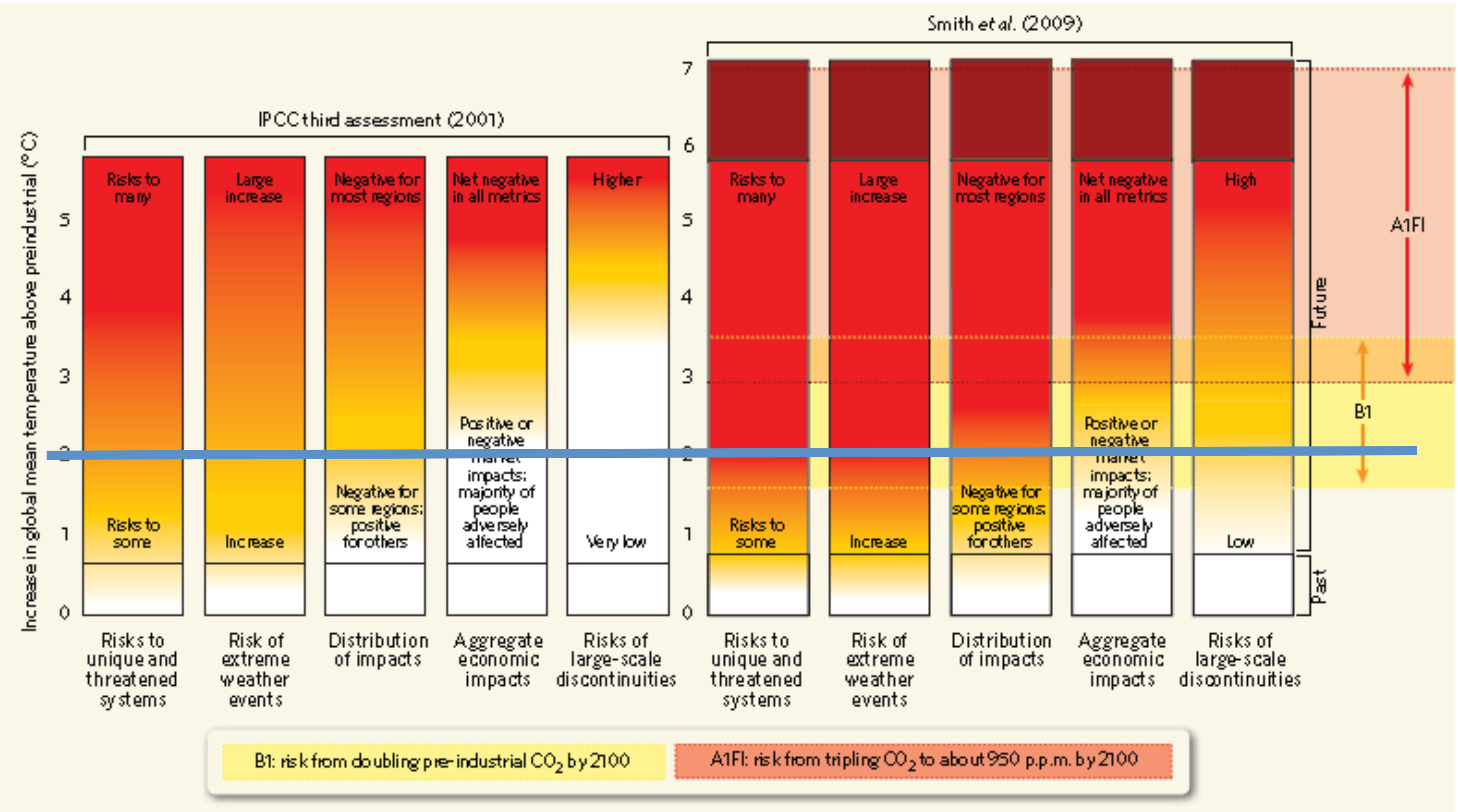

WATER
Increased water availability in moist tropics and high latitudes 1
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes 2
0.4 to 1.7 billion 3
1.0 to 2.0 billion 3
1.1 to 3.2 billion 3
Additional people with increased water stress
ECOSYSTEMS
Increasing amphibian extinction 4
About 20 to 30% species at increasingly high risk of extinction 4
Major extinctions around the globe 4
Increased coral bleaching 5
Most corals bleached 6
Widespread coral mortality 6
Increasing species range shifts and wildfire risk 7
Terrestrial biosphere tends toward a net carbon source, as: 8
~15%
~40% of ecosystems affected
FOOD
Crop productivity
Low latitudes
Decreases for some cereals 9
All cereals decrease 9
Increases for some cereals 9
Decreases in some regions 9
Mid to high latitudes
COAST
Increased damage from floods and storms 10
About 30% loss of coastal wetlands 11
Additional people at risk of coastal flooding each year
0 to 3 million 12
2 to 15 million 12
HEALTH
Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases 13
Increased morbidity and mortality from heatwaves, floods and droughts 14
Changed distribution of some disease vectors 15
Substantial burden on health services 16
SINGULAR EVENTS
Local retreat of ice in Greenland and West Antarctic 17
Long term commitment to several metres of sea-level rise due to ice sheet loss 17
Leading to reconfiguration of coastlines world wide and inundation of low-lying areas 18
Ecosystem changes due to weakening of the meridional overturning circulation 19
0
1
2
3
4
5°C
Global mean annual temperature change relative to 1980-1999 (°C)
A1FI
A2
A1B
B2
A1T
B1
6.4°C
5.4°C
0
1
2
3
4
5 °C

Economic impacts

- Developing country economies most affected:
  - climate sensitive economie sensitive economies (agriculture, fishery)
  - low incomes
  - vulnerable infrastructure
  - threatens poverty eradication
- Global GDP :
  - 1-5% loss (4 degrees warming)
  - Upto 10% loss(6 degrees warming)
  - Stern: 5-20% loss (per capita consumption; 7-9 degrees warming)
  - Developing countries higher than average
  - Catastrophic events big one-time losses

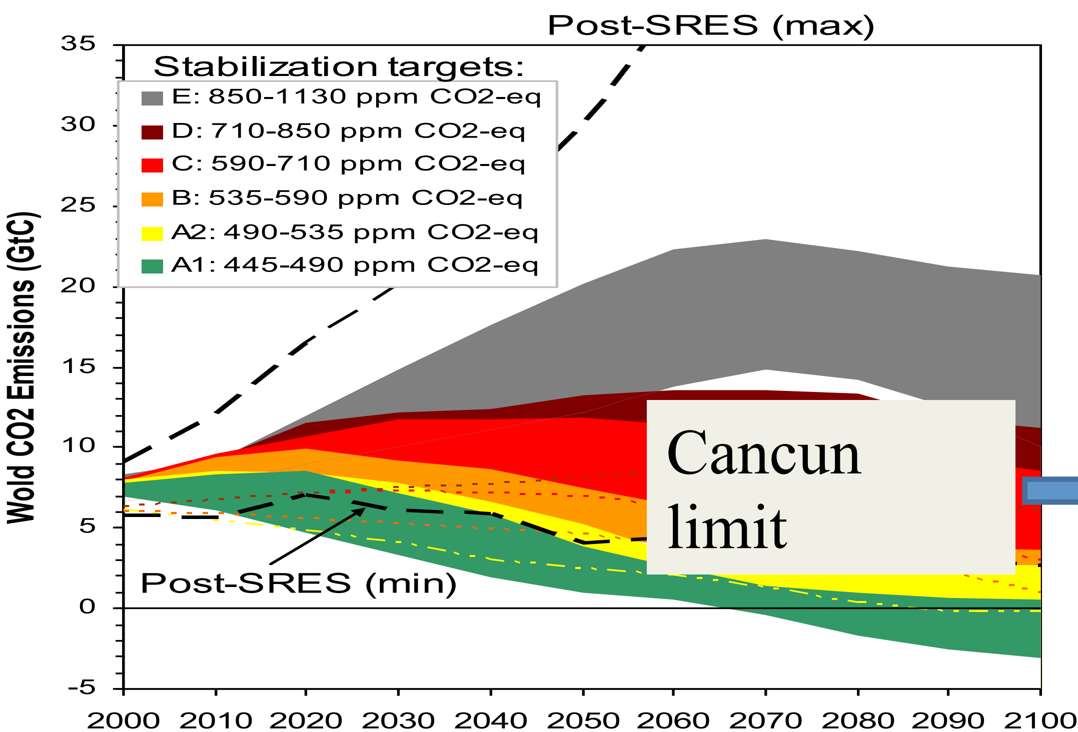

Mitigation options
Drivers
Emissions
Emission profile
GHG (Stabil.) Concentration
Climate sensitivity
Climate
Impacts
Causal chain
Decisison making

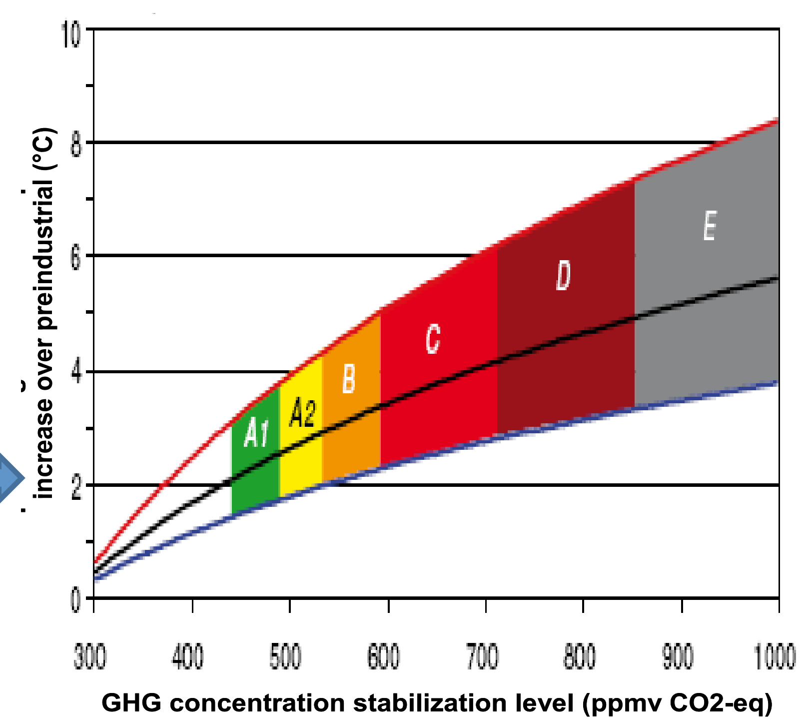
Climate change risks now seen as more serious



From Schneider, S., Nature, vol 458, April 30 2009, p 1104-1105

Where to draw the line and what that implies for GHG emissions?





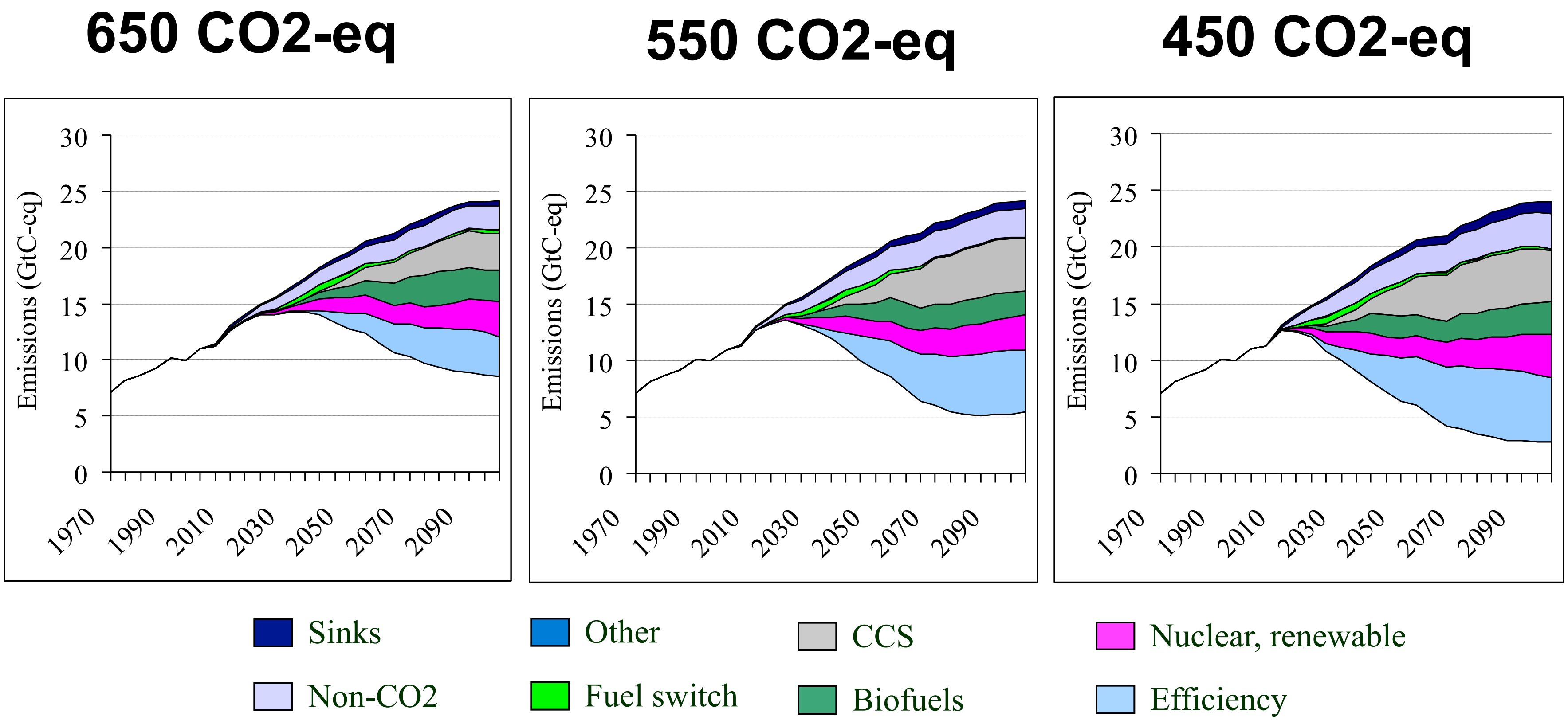
Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels

Stababilization level (ppm CO_2-eq)	Global Mean temperature increase at equilibrium (ºC)	Year global CO_2 needs to peak	Year global CO_2 emissions back at 2000 level	Reduction in 2050 global CO_2 emissions compared to 2000
445 – 490	2.0 – 2.4	2000 - 2015	2000- 2030	-85 to -50
490 – 535	2.4 – 2.8	2000 - 2020	2000- 2040	-60 to -30
535 – 590	2.8 – 3.2	2010 - 2030	2020- 2060	-30 to +5
590 – 710	3.2 – 4.0	2020 - 2060	2050- 2100	+10 to +60
710 – 855	4.0 – 4.9	2050 - 2080		+25 to +85
855 – 1130	4.9 – 6.1	2060 - 2090		+90 to +140

Table 5.1. *Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.*[a] *{WGI 10.7; WGIII Table TS.2, Table 3.10, Table SPM.5}*

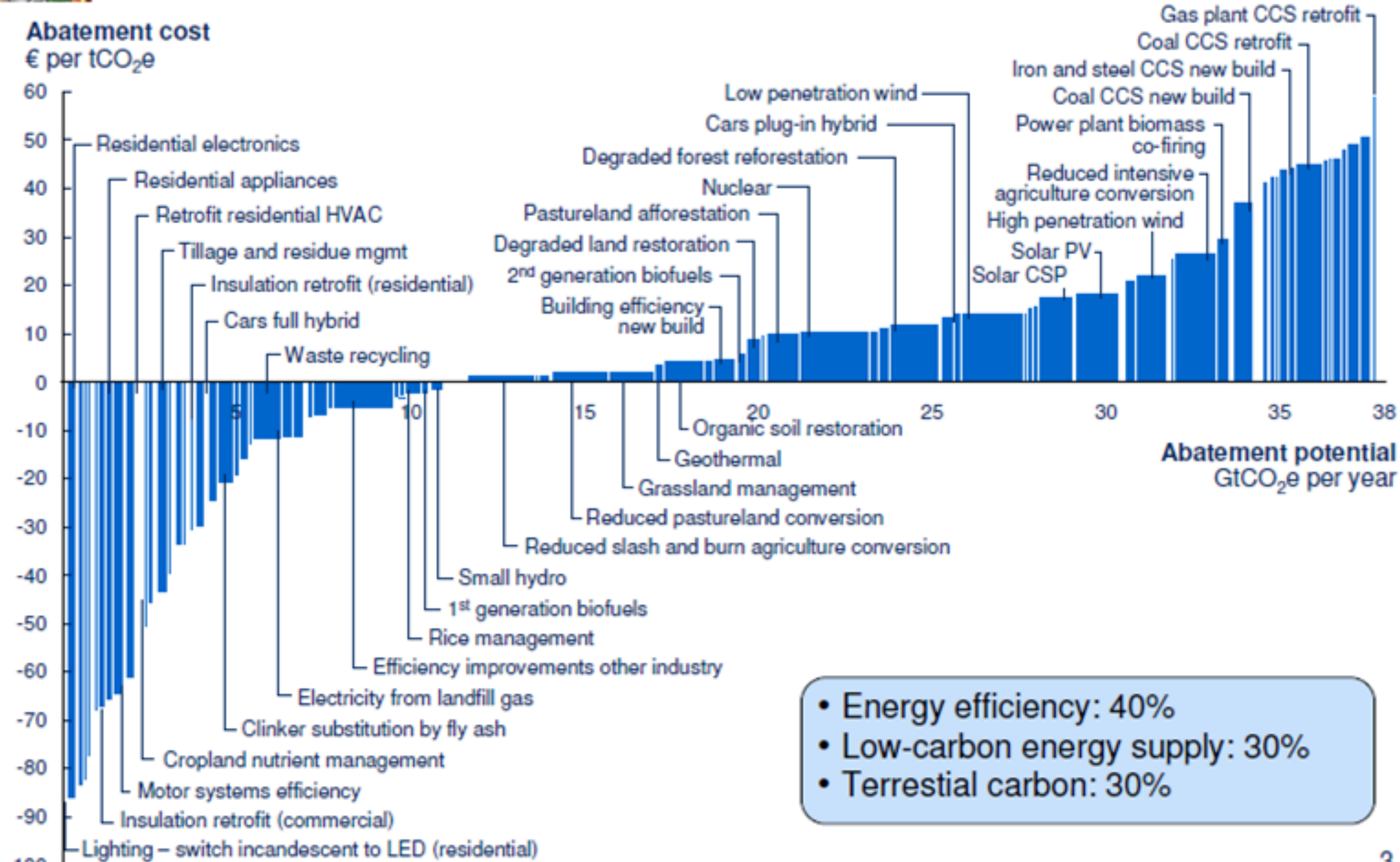
Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

How to get to low emissions?
Indicative distribution of options



Van Vuuren et al. Stabilising GHG emissions.

Global GHG abatement cost curve beyond business-as-usual – 2030

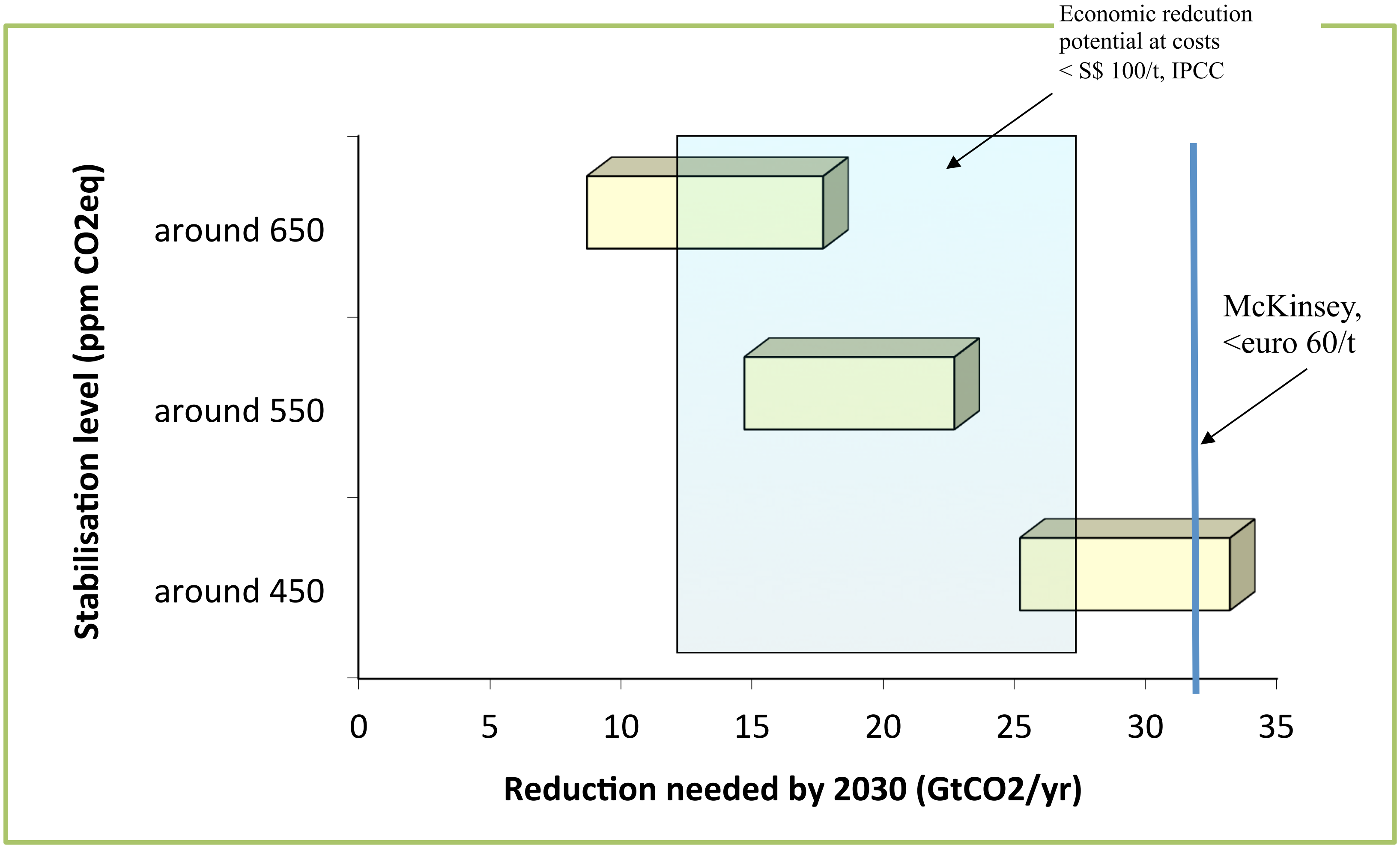


- Energy efficiency: 40%
- Low-carbon energy supply: 30%
- Terrestial carbon: 30%

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60/tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

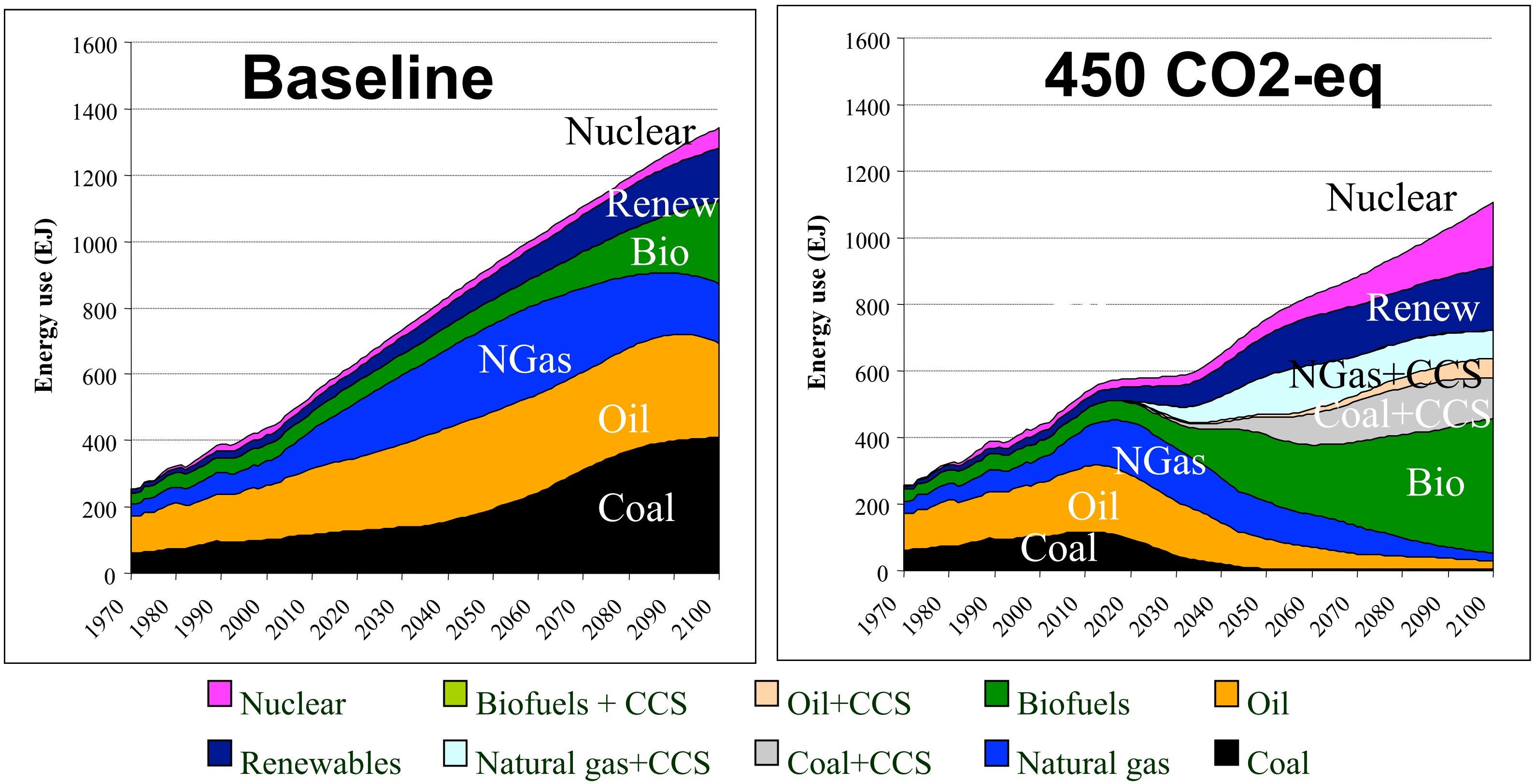
McKinsey&Company

Available and needed reduction potential 2030 (at < $100/tCO2e)



How to get to low emissions?

Indicative energy system changes

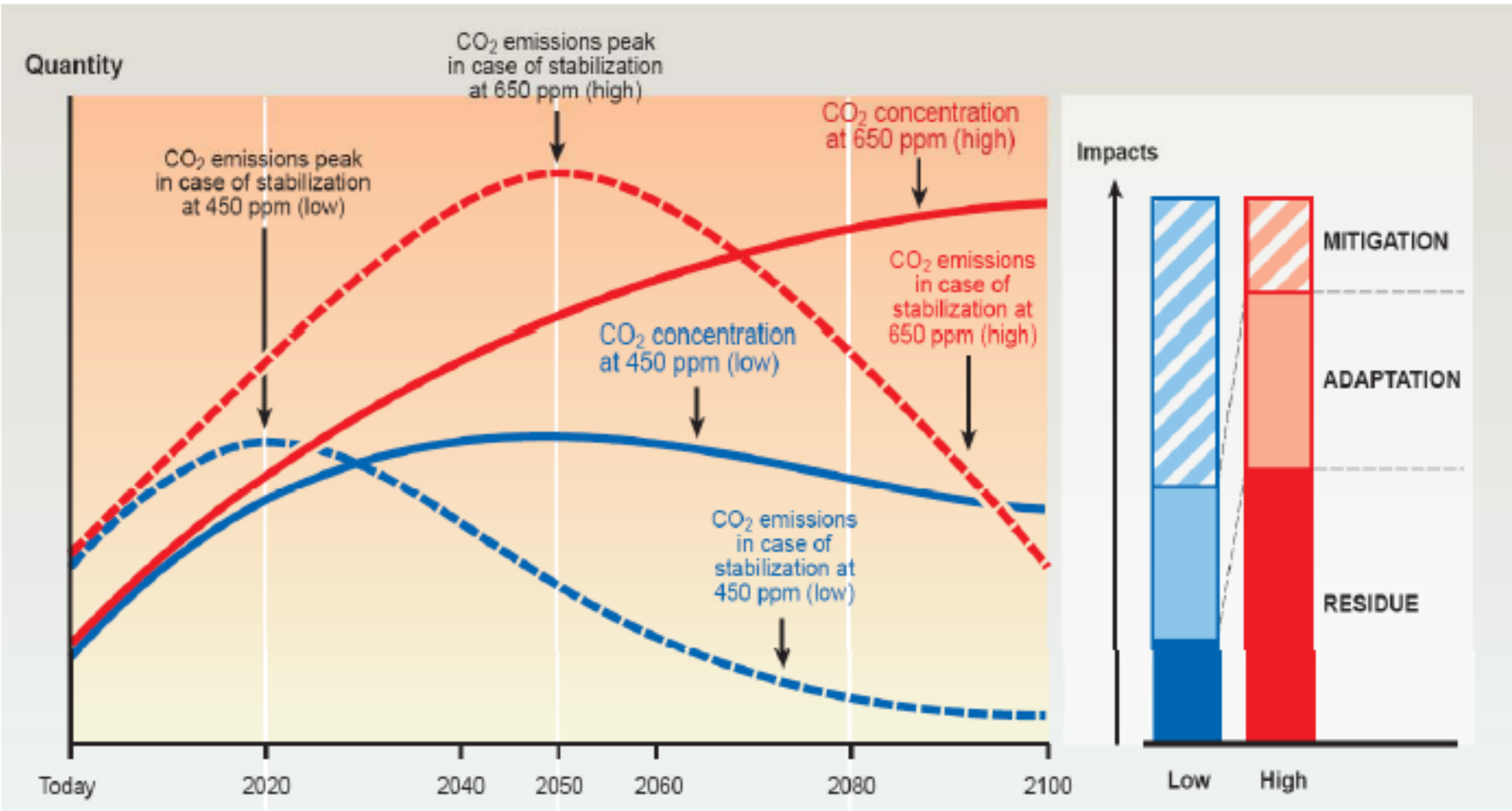


Source: Van Vuuren et al. Stabilising GHG emissions.

Neither adaptation nor mitigation alone can avoid all climate change impacts

- They can complement each other and together can significantly reduce the risks of climate change.
- Adaptation necessary as impacts would occur also at lowest stabilization scenarios, BUT
  - Certain risks can not be reduced
  - More serious impacts go beyond adaptive capacity
  - There are costs and they are hardly known
- Unmitigated climate change likely to exceed the capacity to adapt

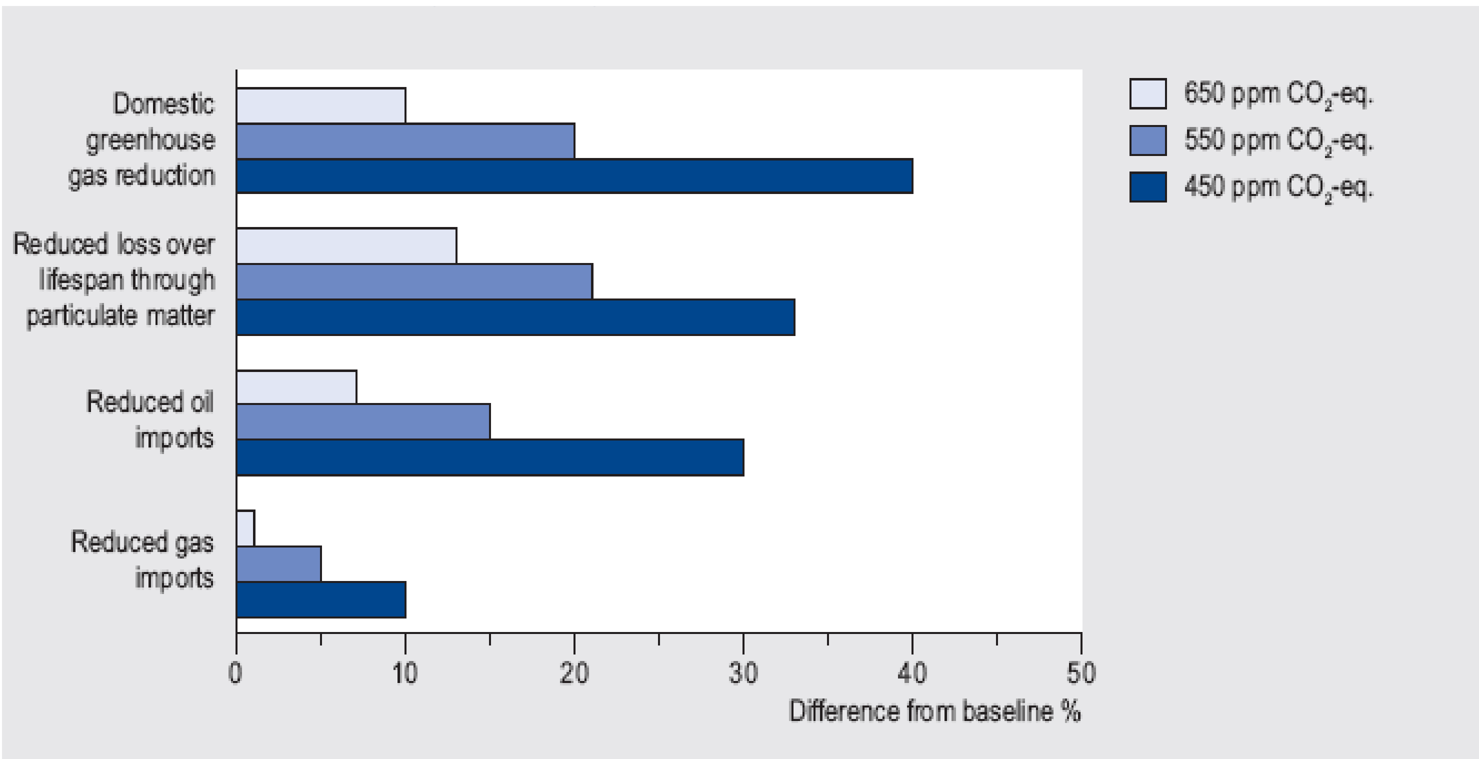
The role of adaptation



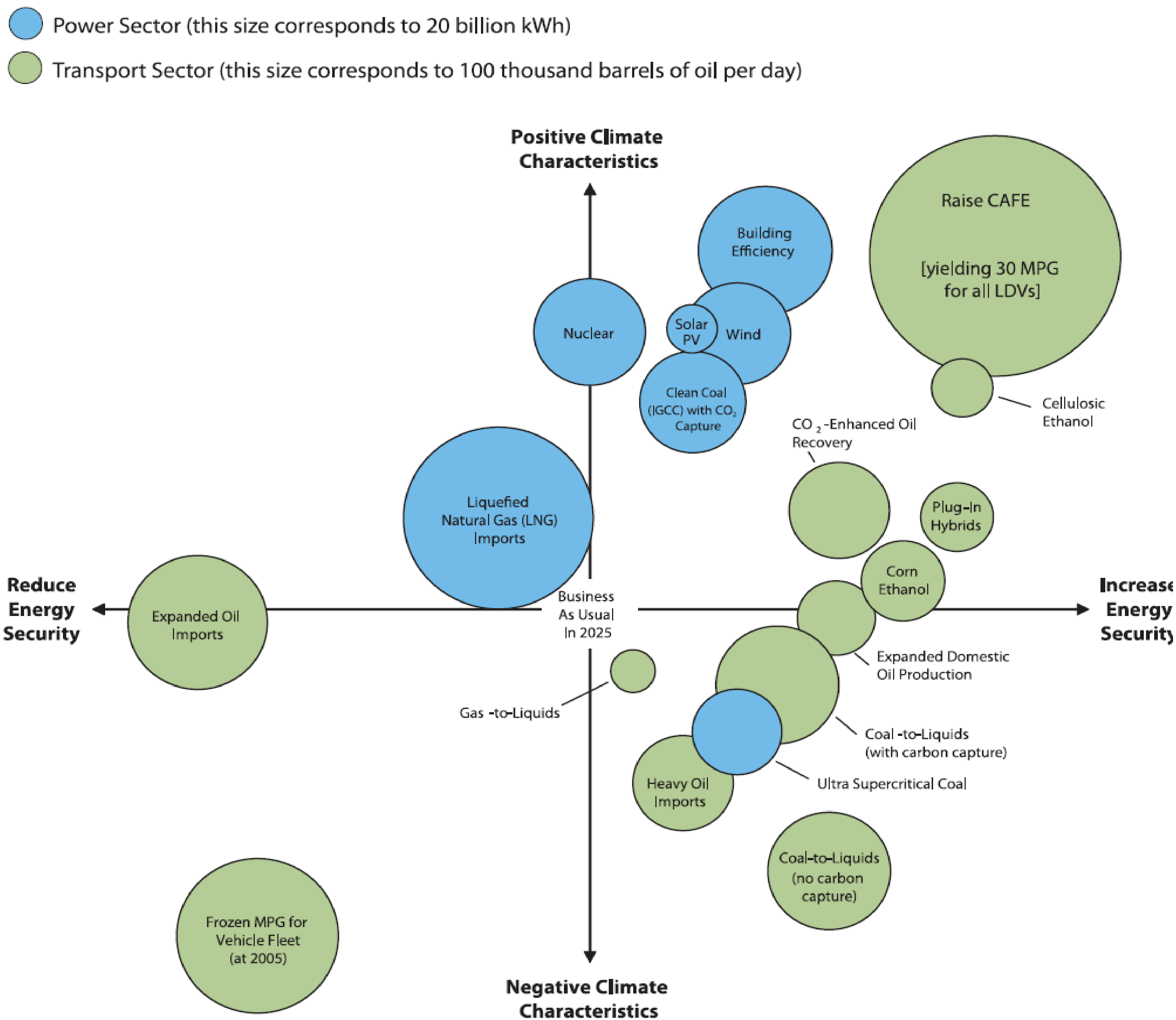
Co-benefits of mitigation

- Near–term *health benefits* from reduced air pollution may offset a substantial fraction of mitigation costs
- Mitigation can also be positive for: *energy security, balance of trade improvement, provision of modern energy services to rural areas, sustainable agriculture* and *employment*
- Land-use measures positive for improving resilience to climate change and carbon storage

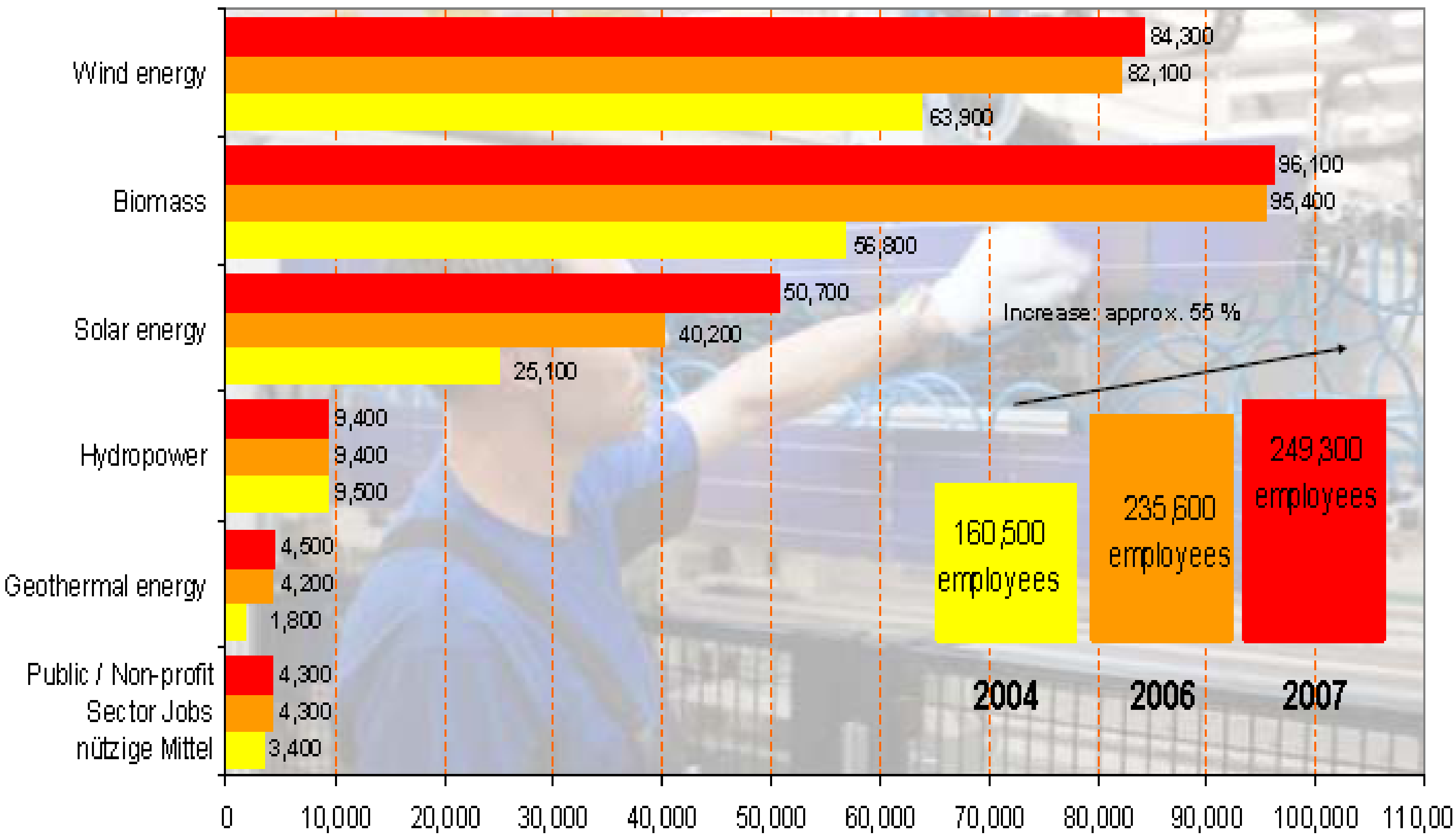
Co-benefits of climate change mitigation in Europe, 2030



Source:Netherlands Environmental Assessment Agency, 2007


Power Sector (this size corresponds to 20 billion kWh)
Transport Sector (this size corresponds to 100 thousand barrels of oil per day)
Positive Climate Characteristics
Negative Climate Characteristics
Reduce Energy Security
Increase Energy Security
Business As Usual In 2025
Building Efficiency
Raise CAFE
[yielding 30 MPG for all LDVs]
Nuclear
Solar PV
Wind
Clean Coal (IGCC) with CO_2 Capture
Cellulosic Ethanol
CO_2-Enhanced Oil Recovery
Liquefied Natural Gas (LNG) Imports
Plug-In Hybrids
Corn Ethanol
Expanded Oil Imports
Expanded Domestic Oil Production
Gas-to-Liquids
Coal-to-Liquids (with carbon capture)
Heavy Oil Imports
Ultra Supercritical Coal
Coal-to-Liquids (no carbon capture)
Frozen MPG for Vehicle Fleet (at 2005)

German renewable energy sector employment

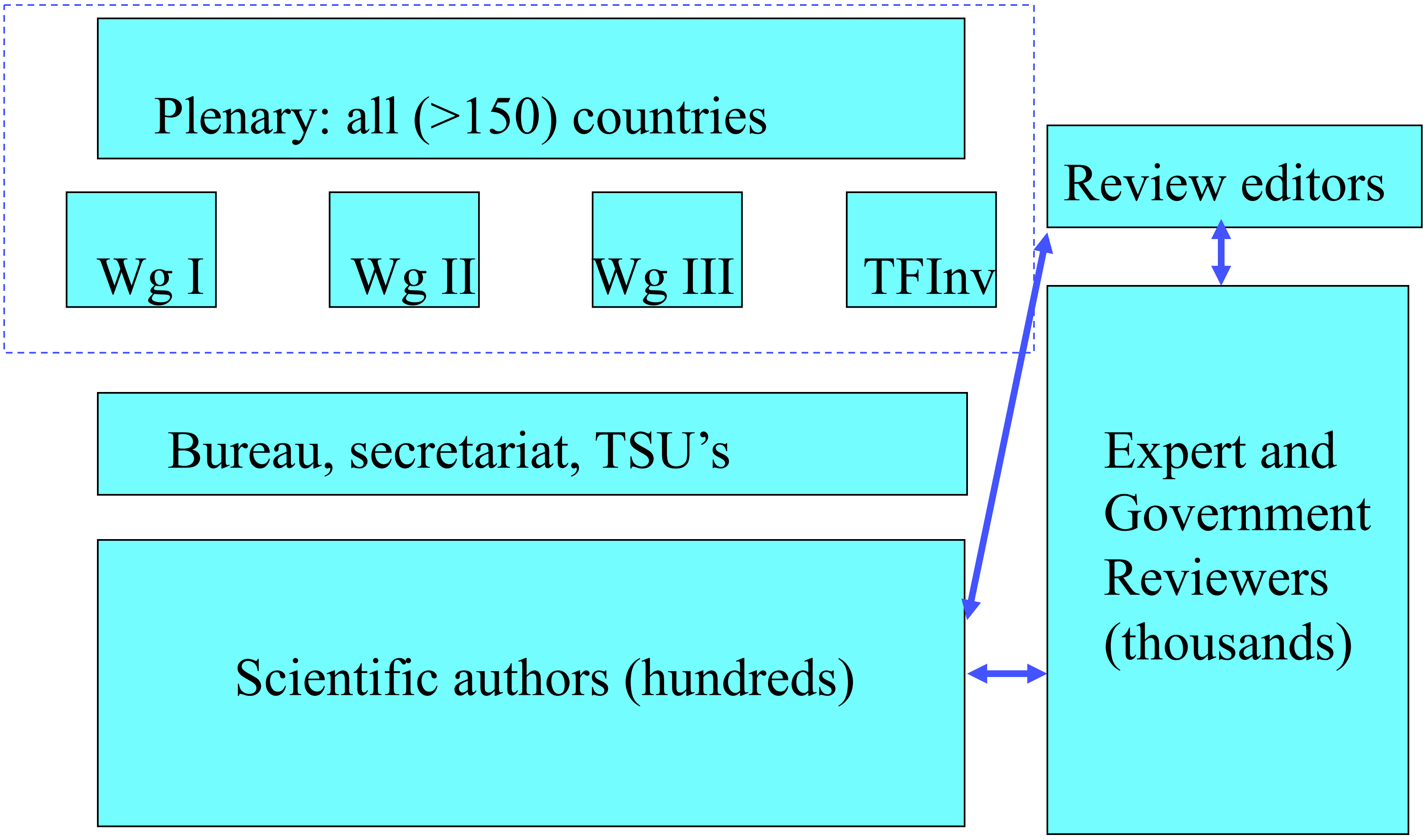


Source: BMU Projekt "Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt", KIII (interim report March 2008

What is IPCC?

- Intergovernmental Panel on Climate Change
- United Nations body, established in 1988 by WMO and UNEP to assess state of knowledge related to climate change
- Periodically assess published scientific, technical and socio-economic information on climate change, impacts and options for adaptation and mitigation (peer reviewed papers and quality “grey litarature”)
- No new research
- Independent of, but supporting, United Nations Framework Convention on Climate Change (UNFCCC)
- 2007 Nobel Peace Prize

Structure and operation of IPCC



Strength of IPCC publications

- World-wide effort to provide balanced assessments of all relevant scientific and technical information (3000 pages, 18000 references)
- Broad involvement of best scientists in writing and review
- Extensive review process
- Report: independent, owned by authors
- Summary for Policymakers: owned by governments, based on consensus

The criticism on IPCC

Valid claims:

- *Mistake on Himalayan glaciers:* erroneous statement of high chance of disappearance by 2035 in Asia chapter WG 2
- *Area under sea level The Netherlands*: quote from wrong statement in Dutch government report copied in WG 2 report
- *African crop yields*: in summarising section in WG2 report in Synthesis Report, nuances and qualifications were lost

Invalid claims:

- Link between warming and natural disasters
- Risk of Amazon forest dieback (40% at risk at reduced precipitation)
- Improper behaviour of UK scientists: “suppressing counterevidence”
- Many others

Reviews:

- Netherlands Env. Assessment Agency: no mistakes in main conclusions WG2
- UK Parliament/ University of East Anglia: no improper behaviour
- IAC Panel recommendations for improved procedures (http://reviewipcc.interacademycouncil.net/)