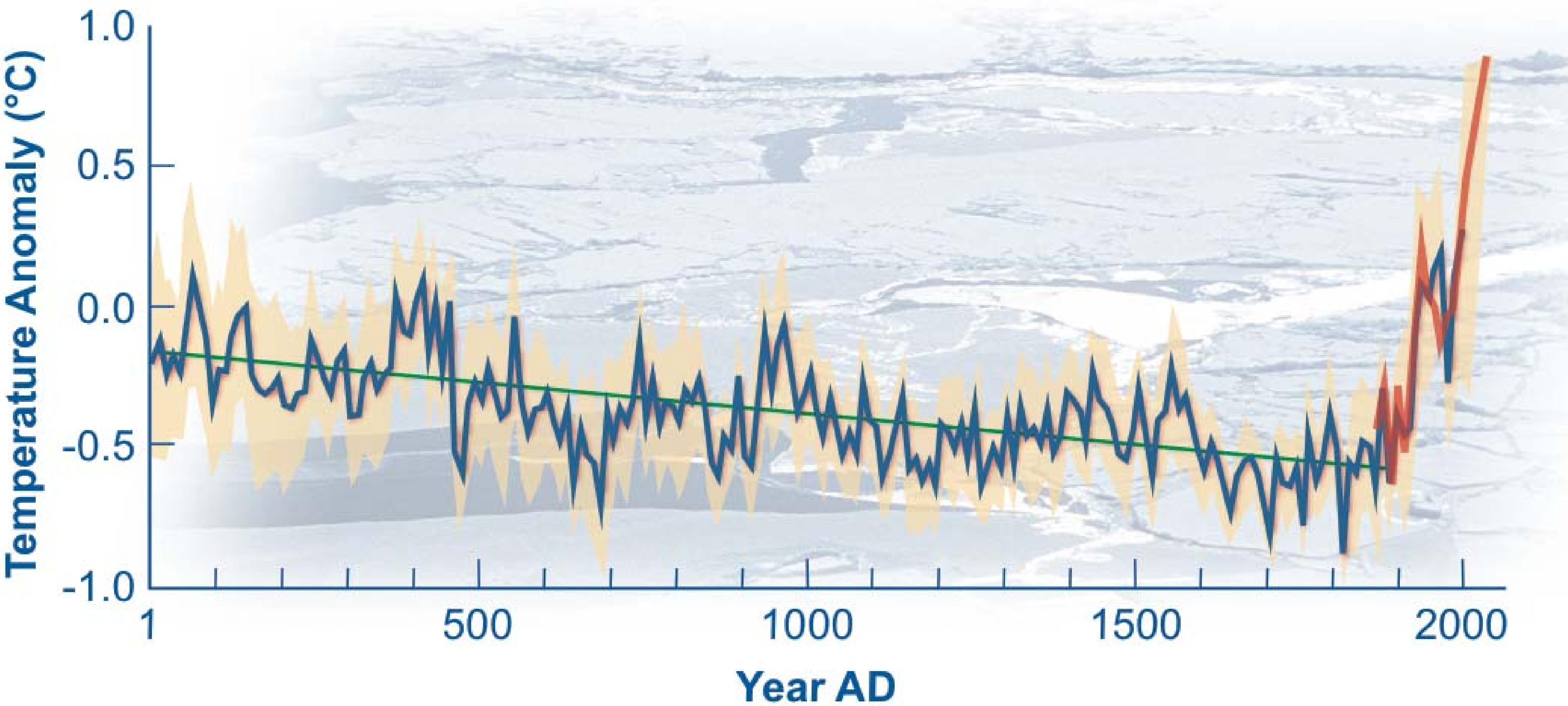
Summary of Past and Projected Climate Changes

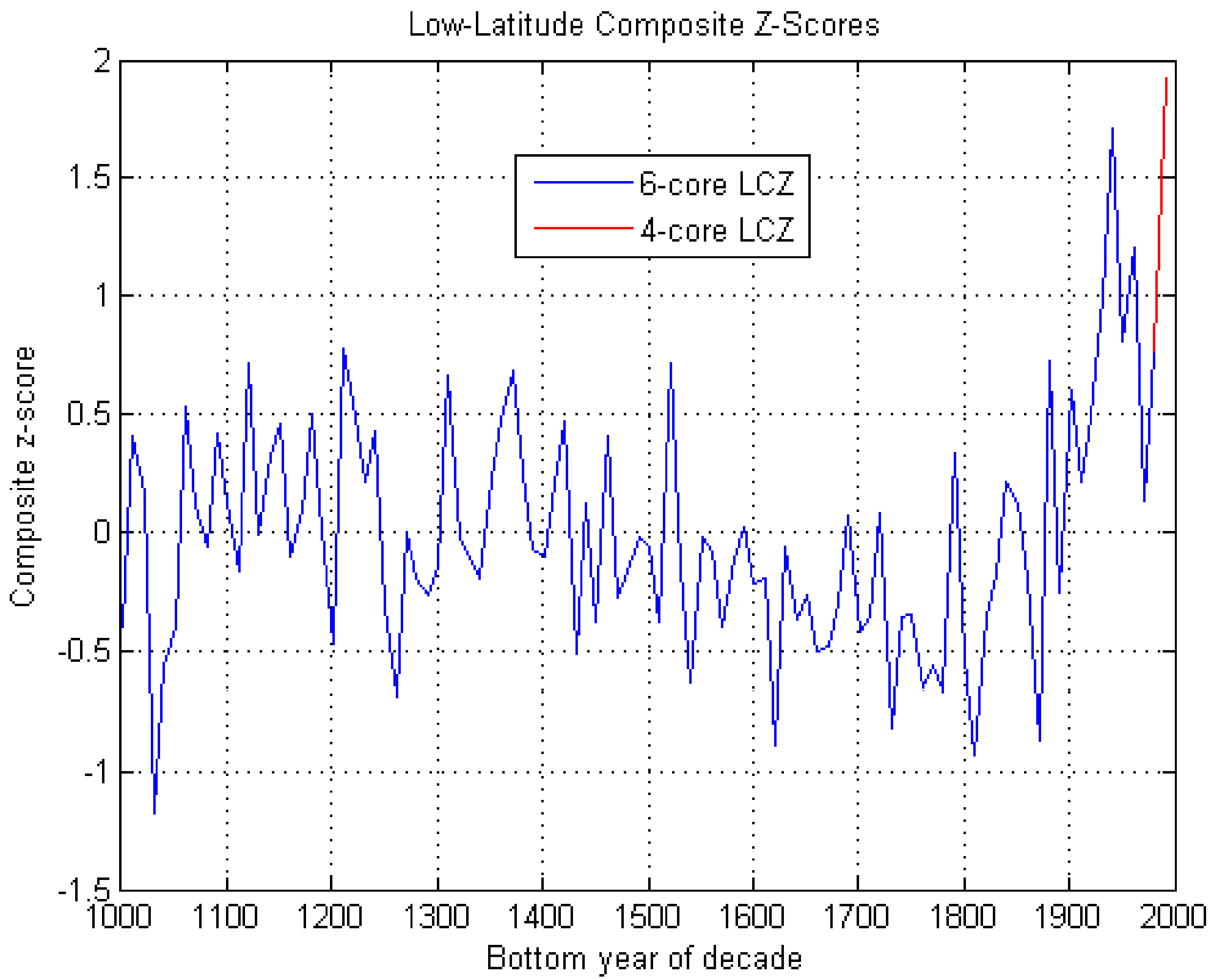
Summary of Evidence for Anthropogenic Climate Change

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."

- IPCC, 20007

Arctic air temperature change reconstructed (blue), observed (red)

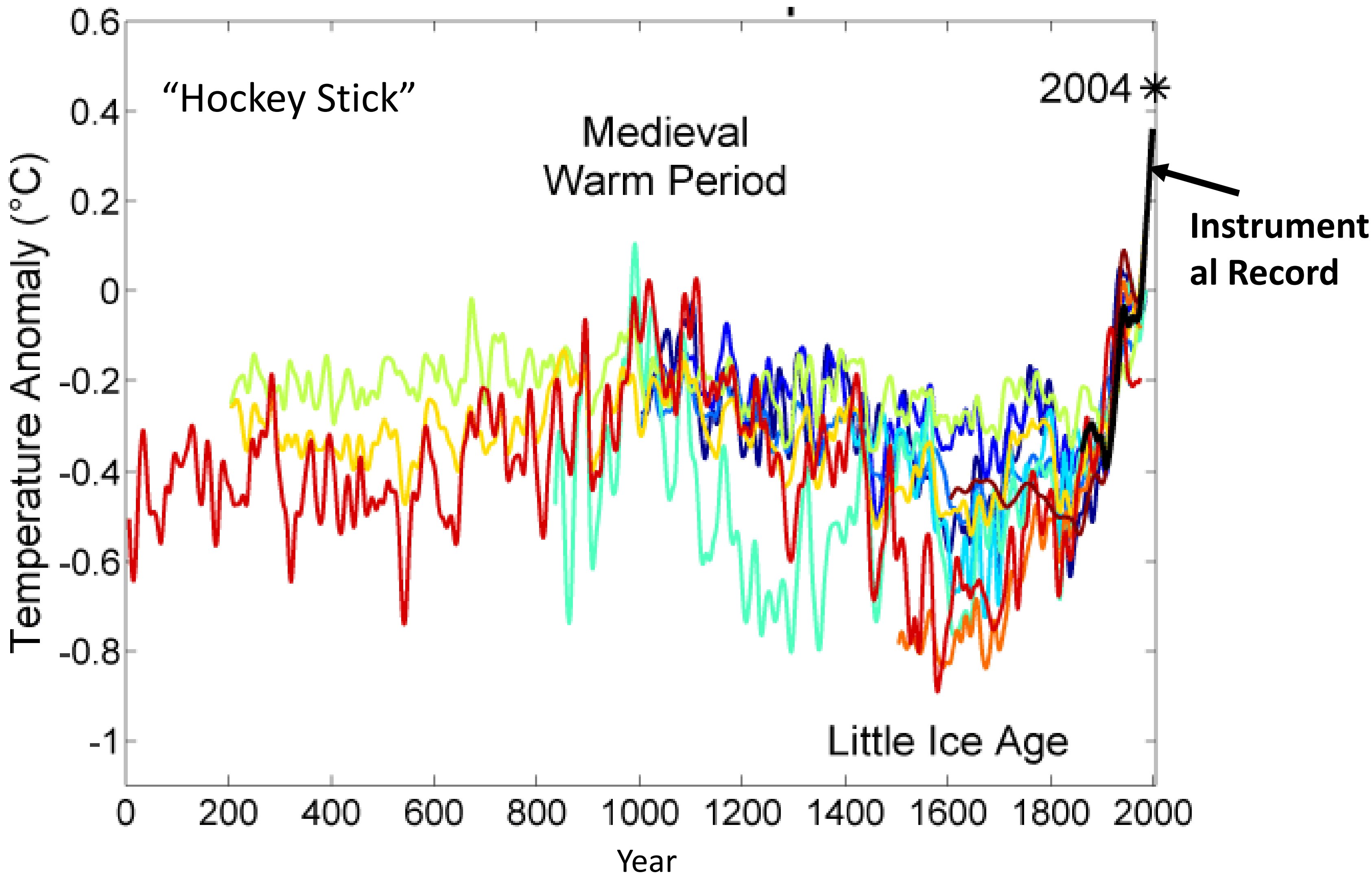




Low-latitude composite of Thompson (2003) data

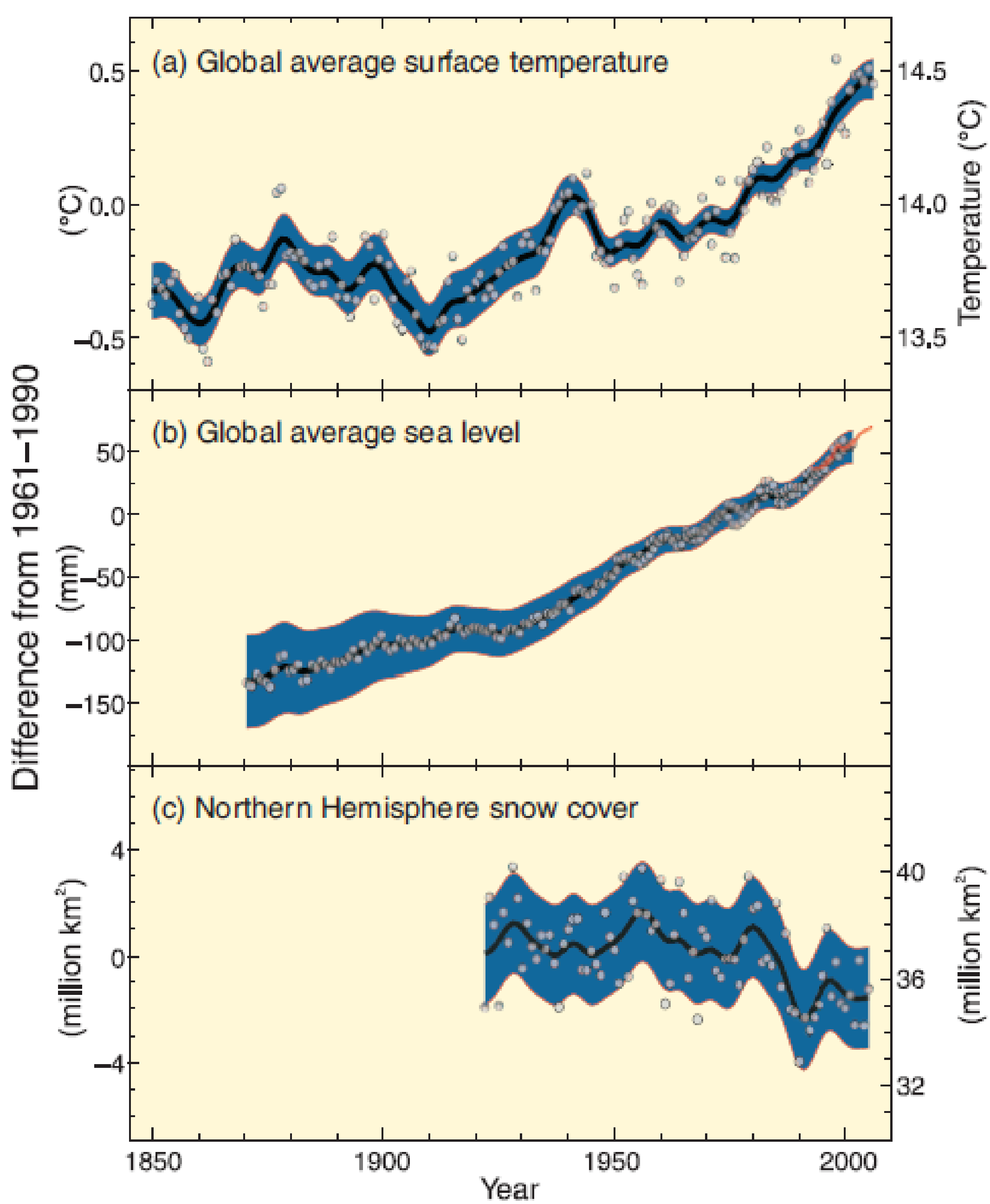
Oxygen isotopes in alpine glaciers

Paleo reconstructions of temperature change over the last 2000 years



Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data; and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).

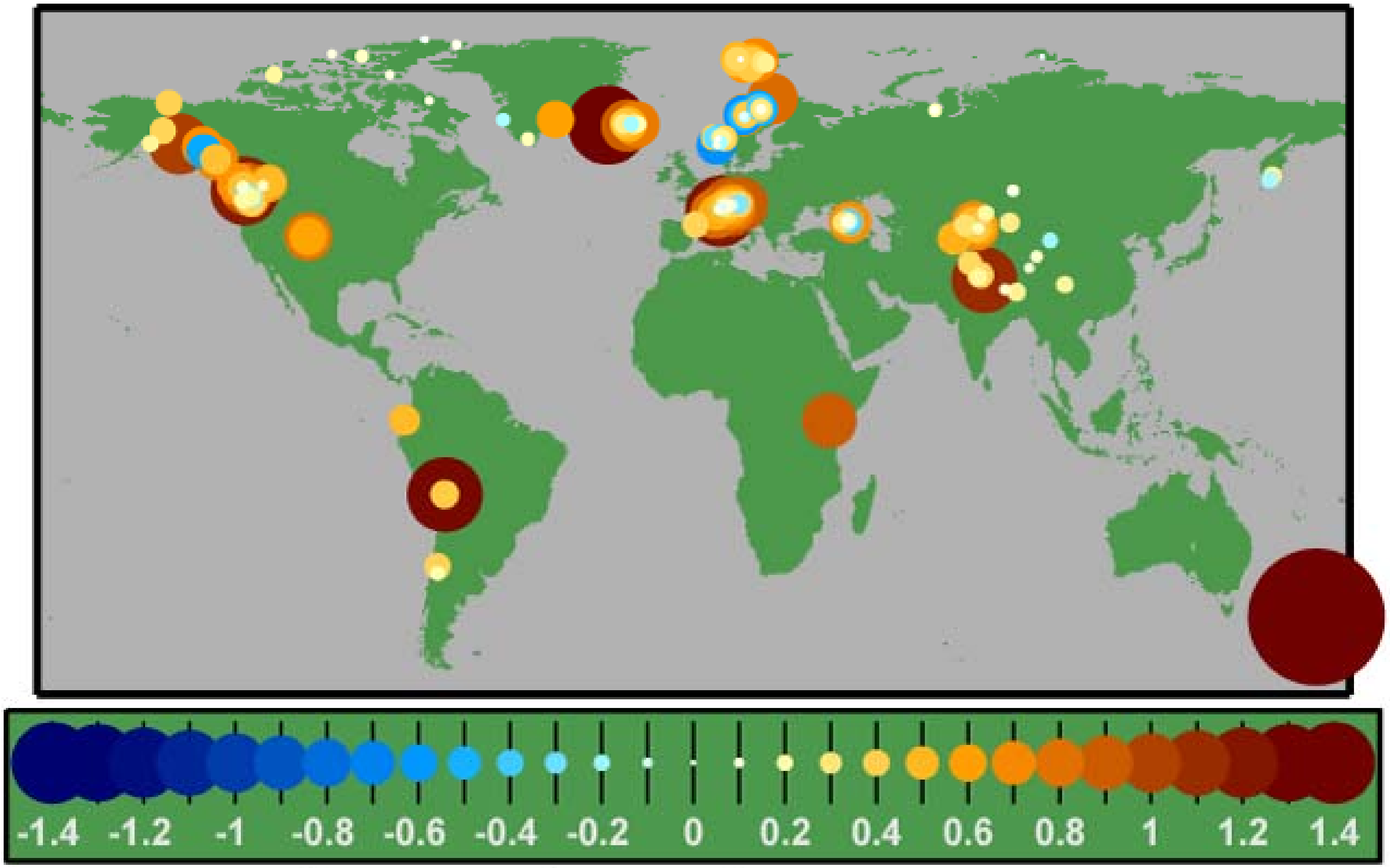
Changes in temperature, sea level and Northern Hemisphere snow cover



"Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1300 years."

-- IPCC, 2007

Mountain Glacier Changes Since 1970



Effective Glacier Thinning (m / yr)

Some extreme weather events have changed in frequency and/or intensity over the last 50 years:

- It is *very likely* that cold days, cold nights and frosts have become less frequent over most land areas, while hot days and hot nights have become more frequent.
- It is *likely* that heat waves have become more frequent over most land areas.
- It is *likely* that the frequency of heavy precipitation events *(or* proportion of total rainfall from heavy falls) has increased over most areas.
- It is *likely* that the incidence of extreme high sea level has increased at a broad range of sites worldwide since 1975.

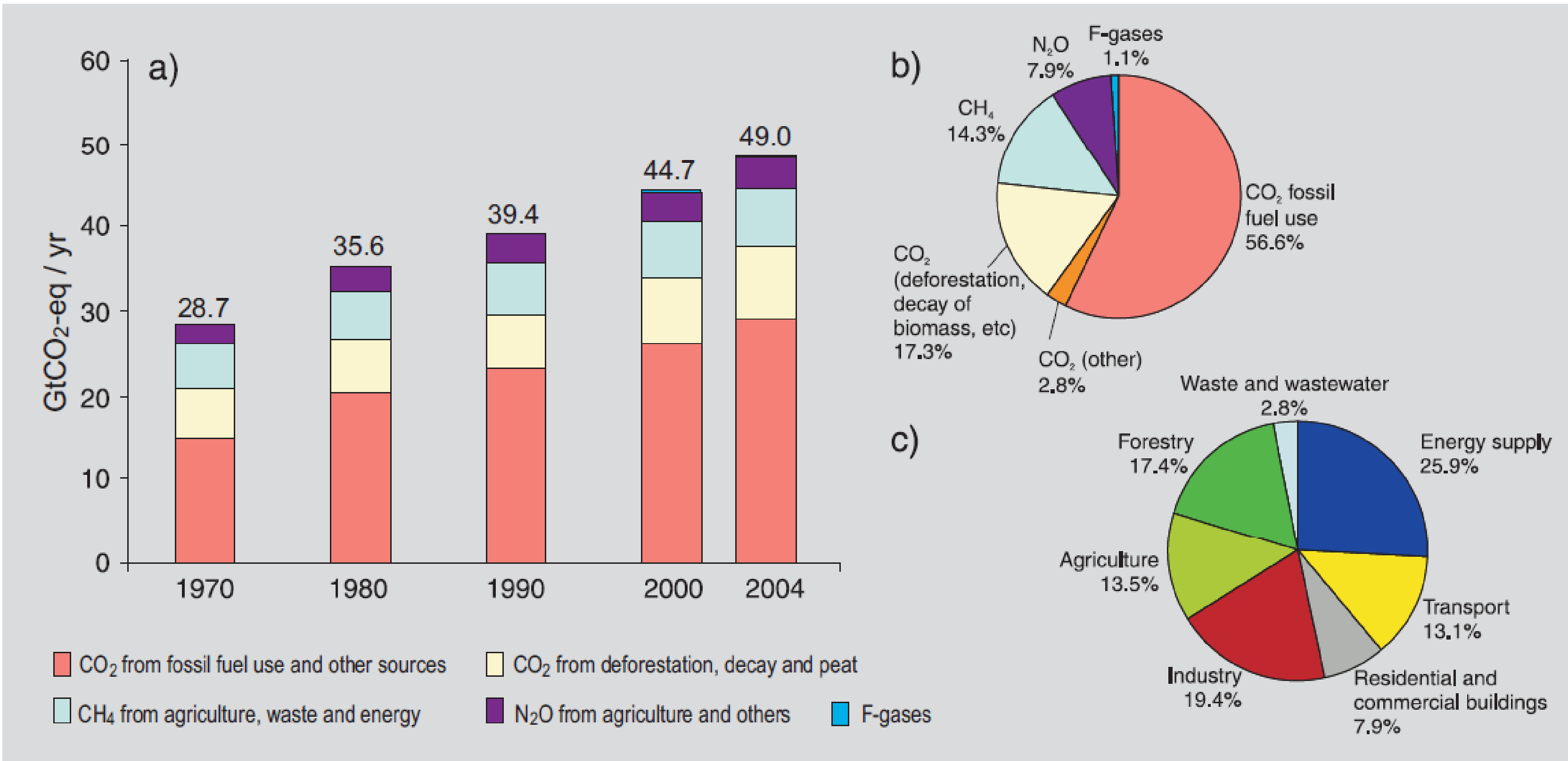
-- IPCC, 2007

“There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, and suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater”

-- IPCC, 2007

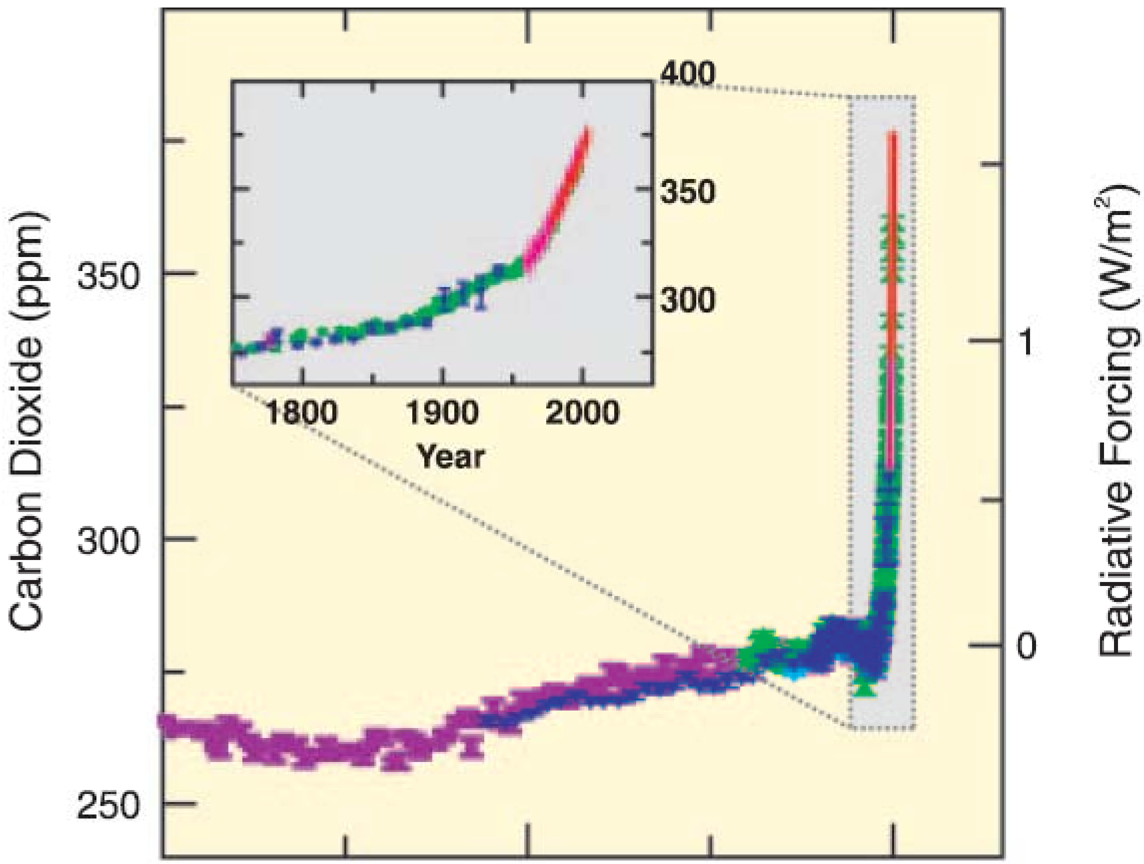
Causes of Recent Climate Change

Global anthropogenic GHG emissions



(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5 (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq. (Forestry includes deforestation.)

Changes in GHGs from ice core and modern data

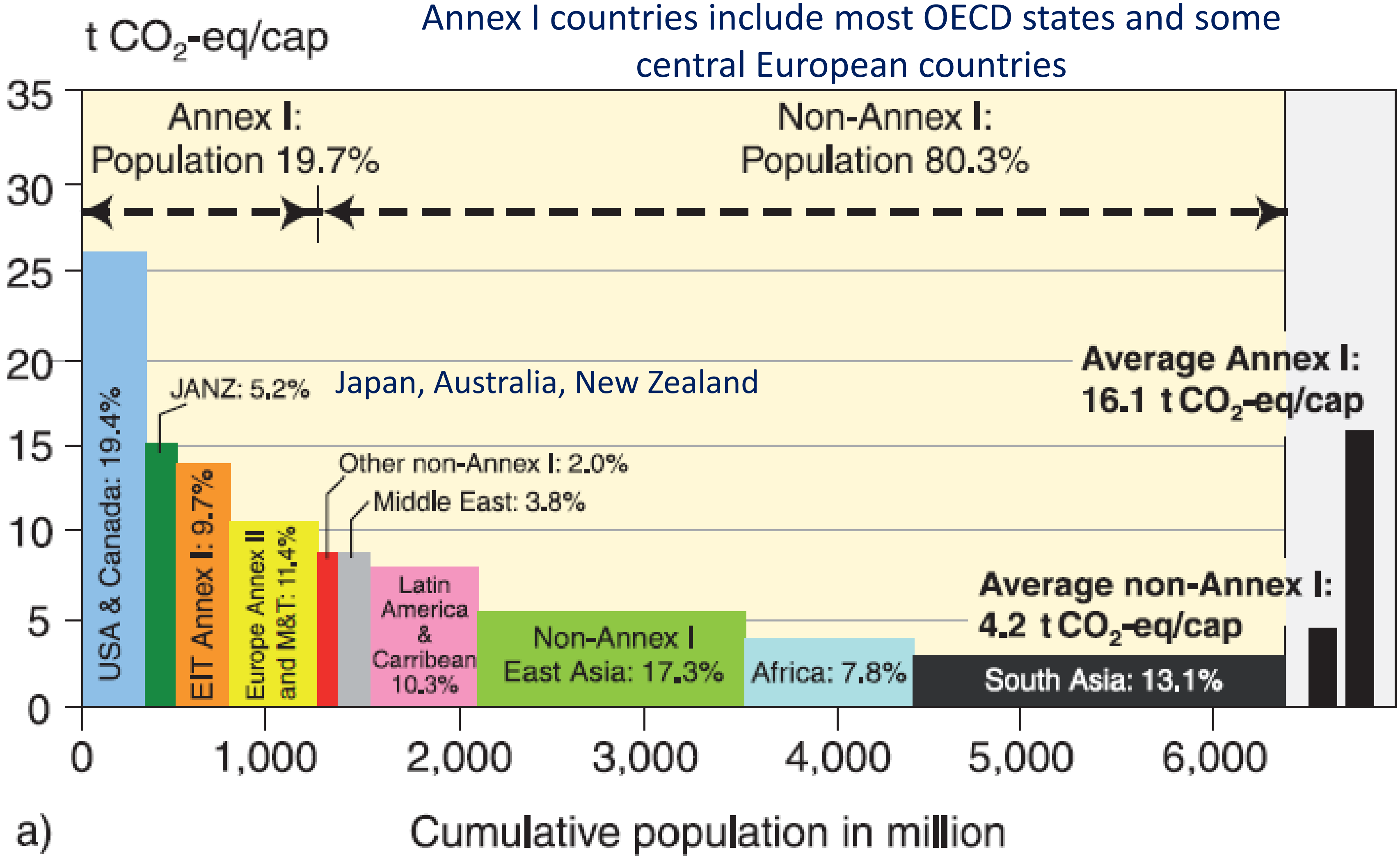


“Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The atmospheric concentrations of CO_2 and CH_4 in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. The increase in N_2O concentration is primarily due to agriculture.”

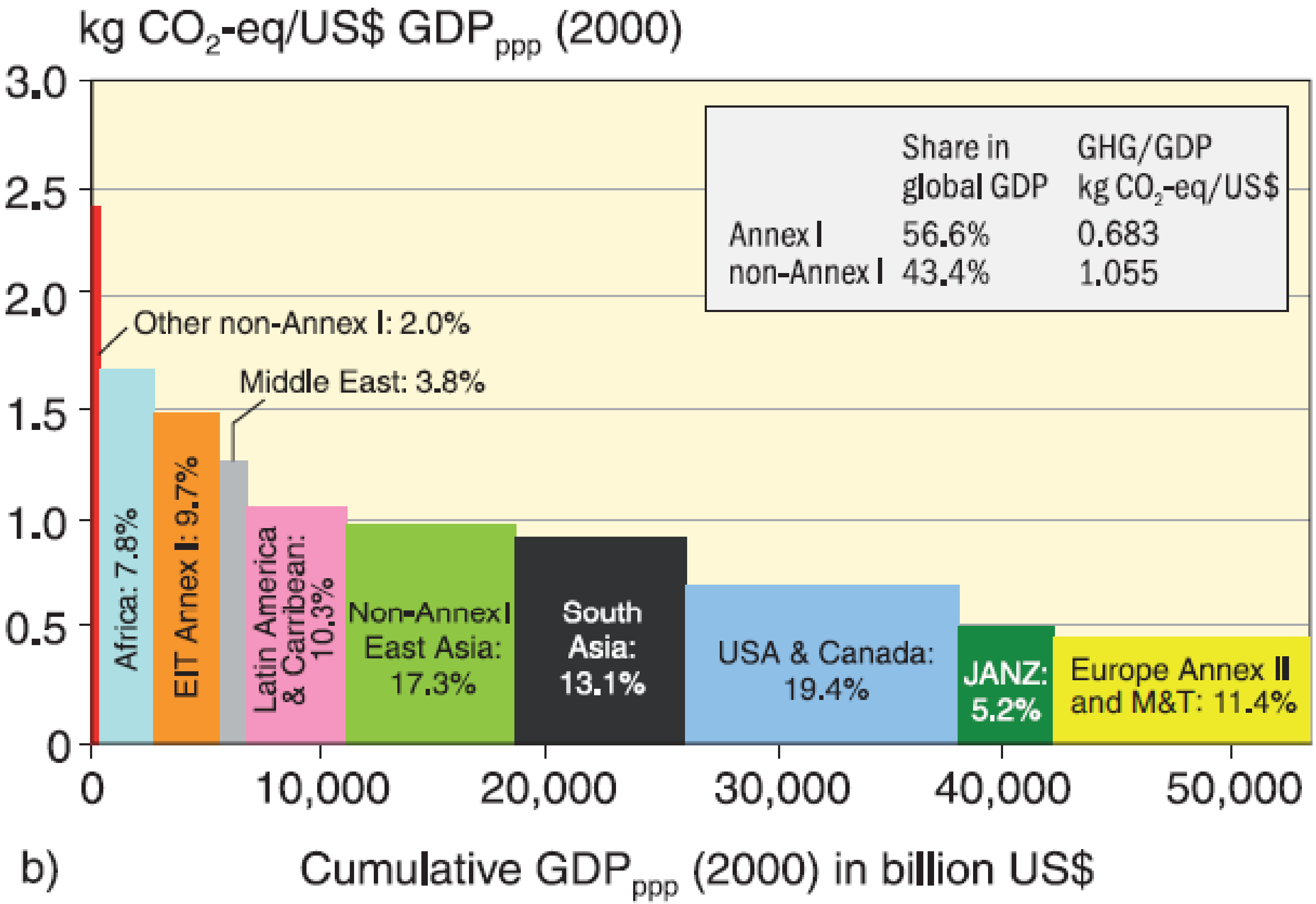
-- IPCC, 2007

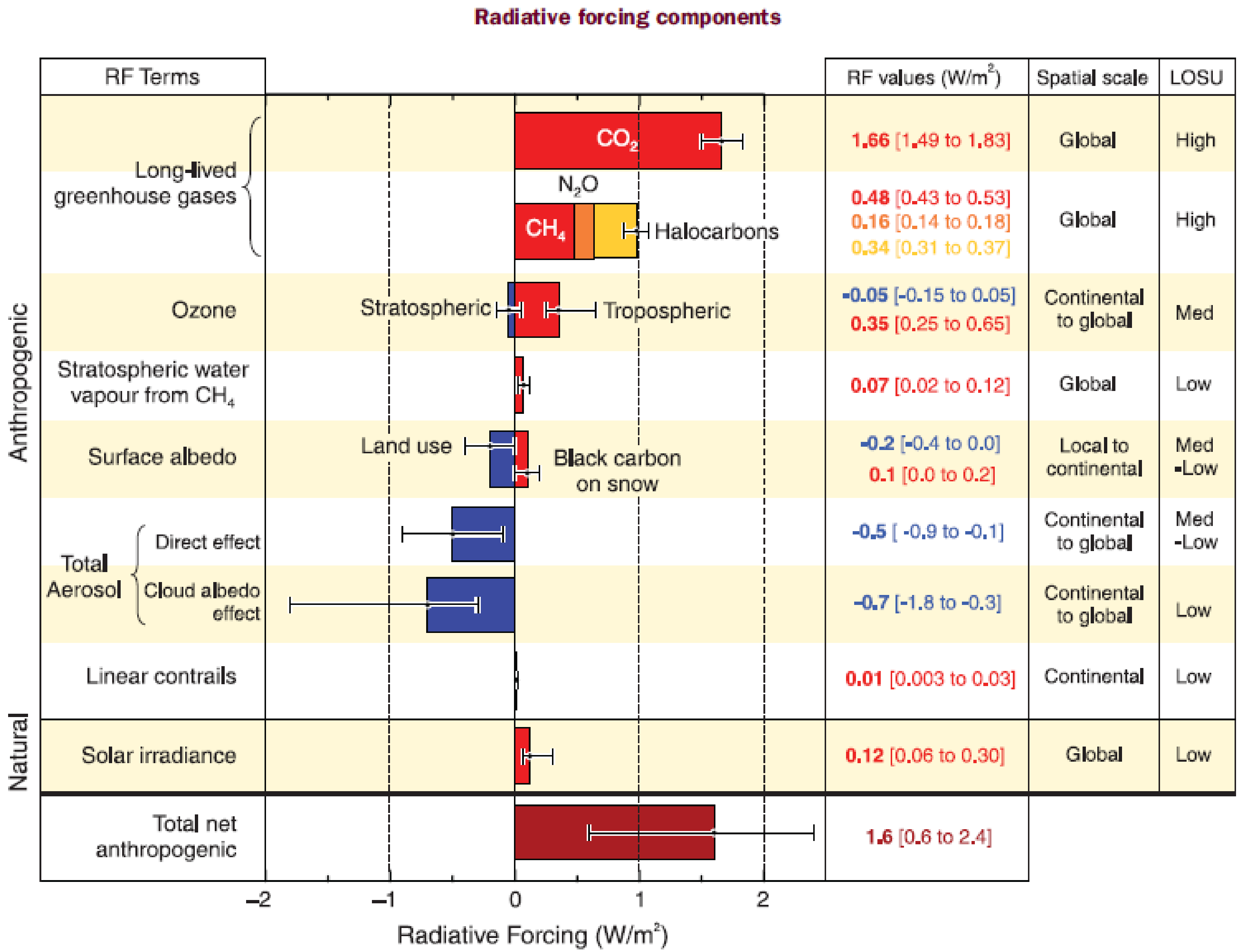
Per Capita GHG Emissions

Annex I countries include most OECD states and some central European countries



Per GDP GHG Emissions

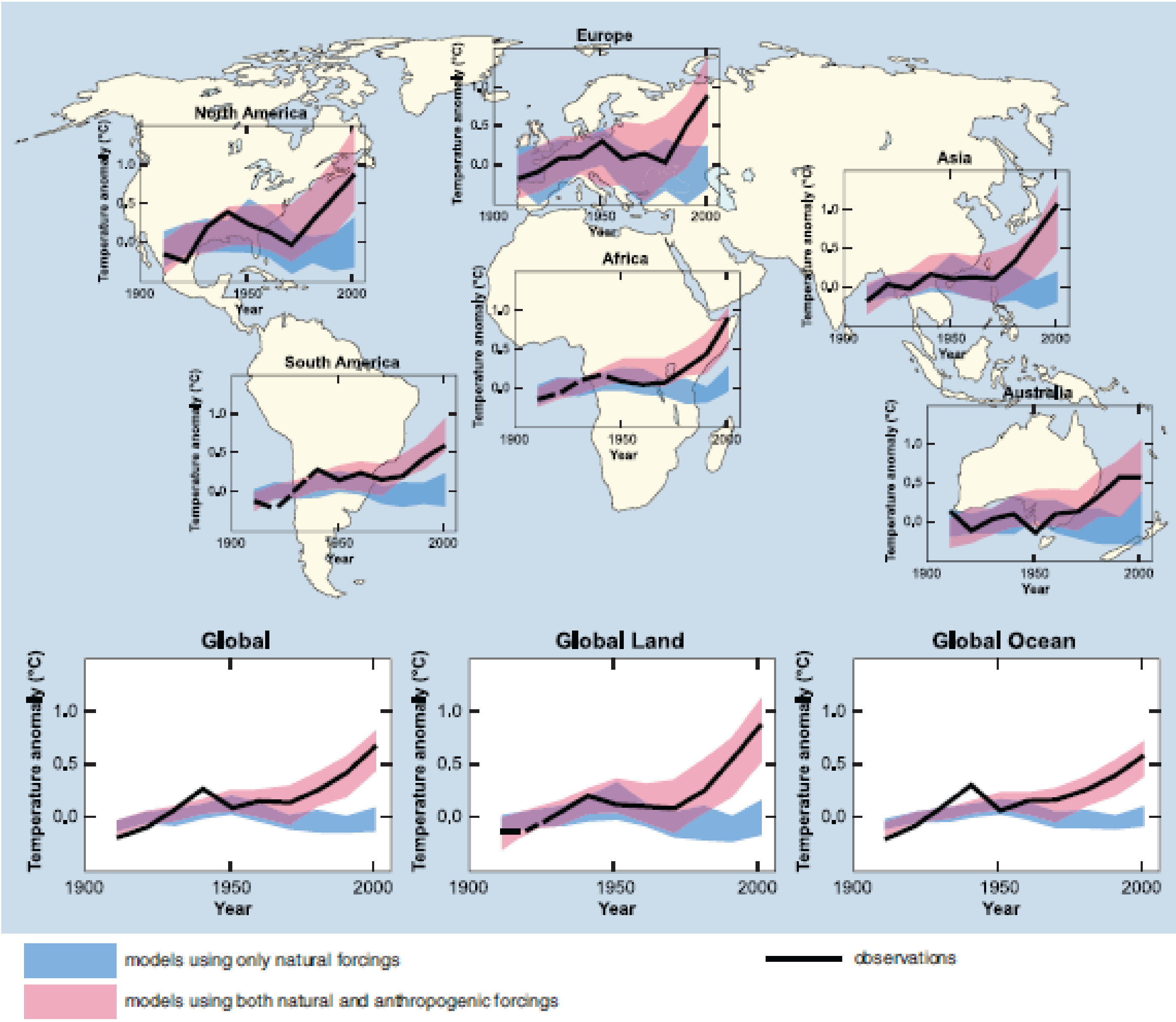



Radiative forcing components
RF Terms
RF values (W/m2)
Spatial scale
LOSU
Anthropogenic
Natural
Long-lived greenhouse gases
CO2
N2O
CH4
Halocarbons
1.66 [1.49 to 1.83]
Global
High
0.48 [0.43 to 0.53]
0.16 [0.14 to 0.18]
0.34 [0.31 to 0.37]
Global
High
Ozone
Stratospheric
Tropospheric
-0.05 [-0.15 to 0.05]
0.35 [0.25 to 0.65]
Continental to global
Med
Stratospheric water vapour from CH4
0.07 [0.02 to 0.12]
Global
Low
Surface albedo
Land use
Black carbon on snow
-0.2 [-0.4 to 0.0]
0.1 [0.0 to 0.2]
Local to continental
Med -Low
Total Aerosol
Direct effect
-0.5 [-0.9 to -0.1]
Continental to global
Med -Low
Cloud albedo effect
-0.7 [-1.8 to -0.3]
Continental to global
Low
Linear contrails
0.01 [0.003 to 0.03]
Continental
Low
Solar irradiance
0.12 [0.06 to 0.30]
Global
Low
Total net anthropogenic
1.6 [0.6 to 2.4]
–2
–1
0
1
2
Radiative Forcing (W/m2)

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations. This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is *likely* to have been due to the increase in GHG concentrations"

-- IPCC, 2007

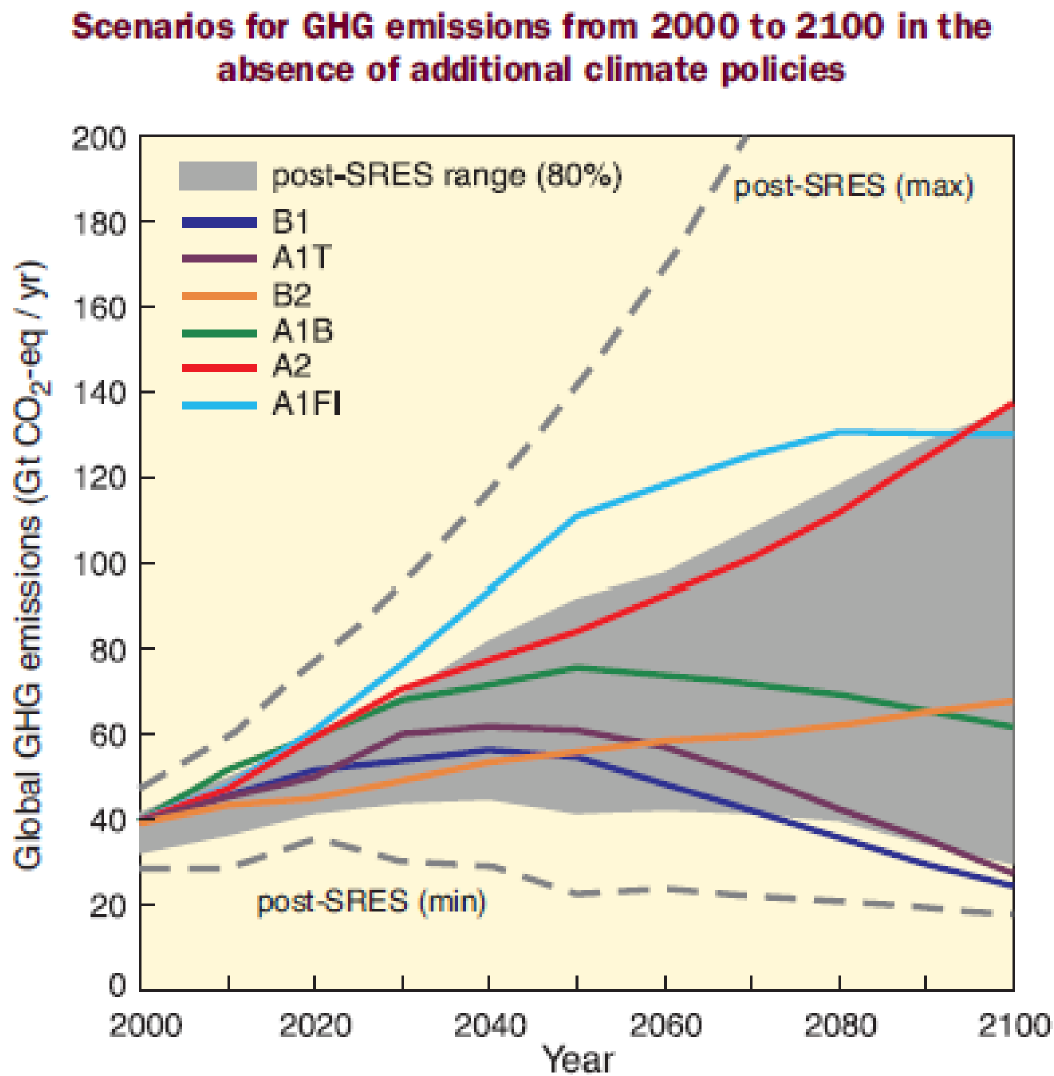
Global and continental temperature change



“It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) “

-- IPCC, 2007

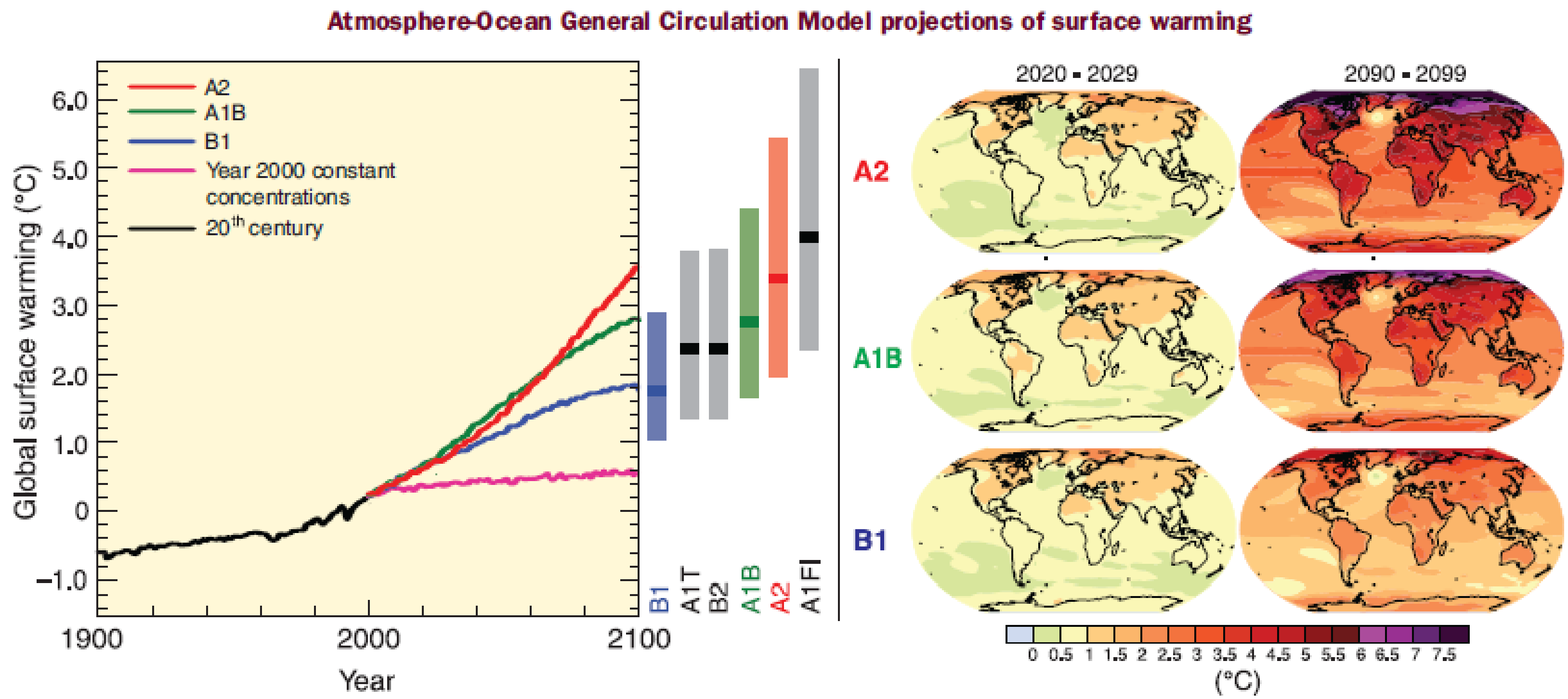
Projections



Global GHG emissions (in GtCO2-eq per year) in the absence of additional climate policies: six illustrative SRES marker scenarios (colored lines) and 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO2, CH4, N2O and F-gases.

“There is *high agreement* and *much evidence* that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. Baseline emissions scenarios published since the IPCC Special Report on Emissions Scenarios (SRES, 2000) are comparable in range to those presented in SRES.”

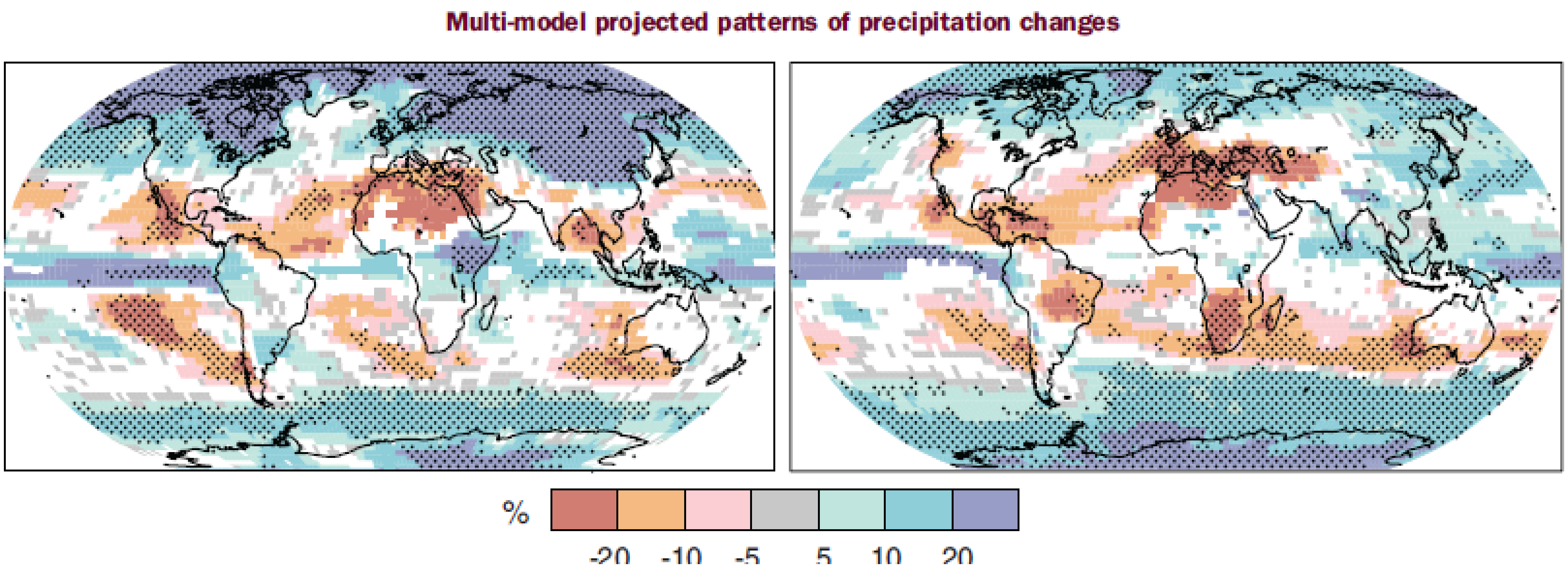
-- IPCC, 2007



Left panel: Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for the experiment where concentrations were held constant at year 2000 values. The bars in the middle of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099 relative to 1980-1999. The assessment of the best estimate and likely ranges in the bars includes the Atmosphere-Ocean General Circulation Models (AOGCMs) in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. ***Right panels: Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999. The panels show the multi-AOGCM*** average projections for the A2 (top), A1B (middle) and B1 (bottom) SRES scenarios averaged over decades 2020-2029 (left) and 2090-2099 (right).

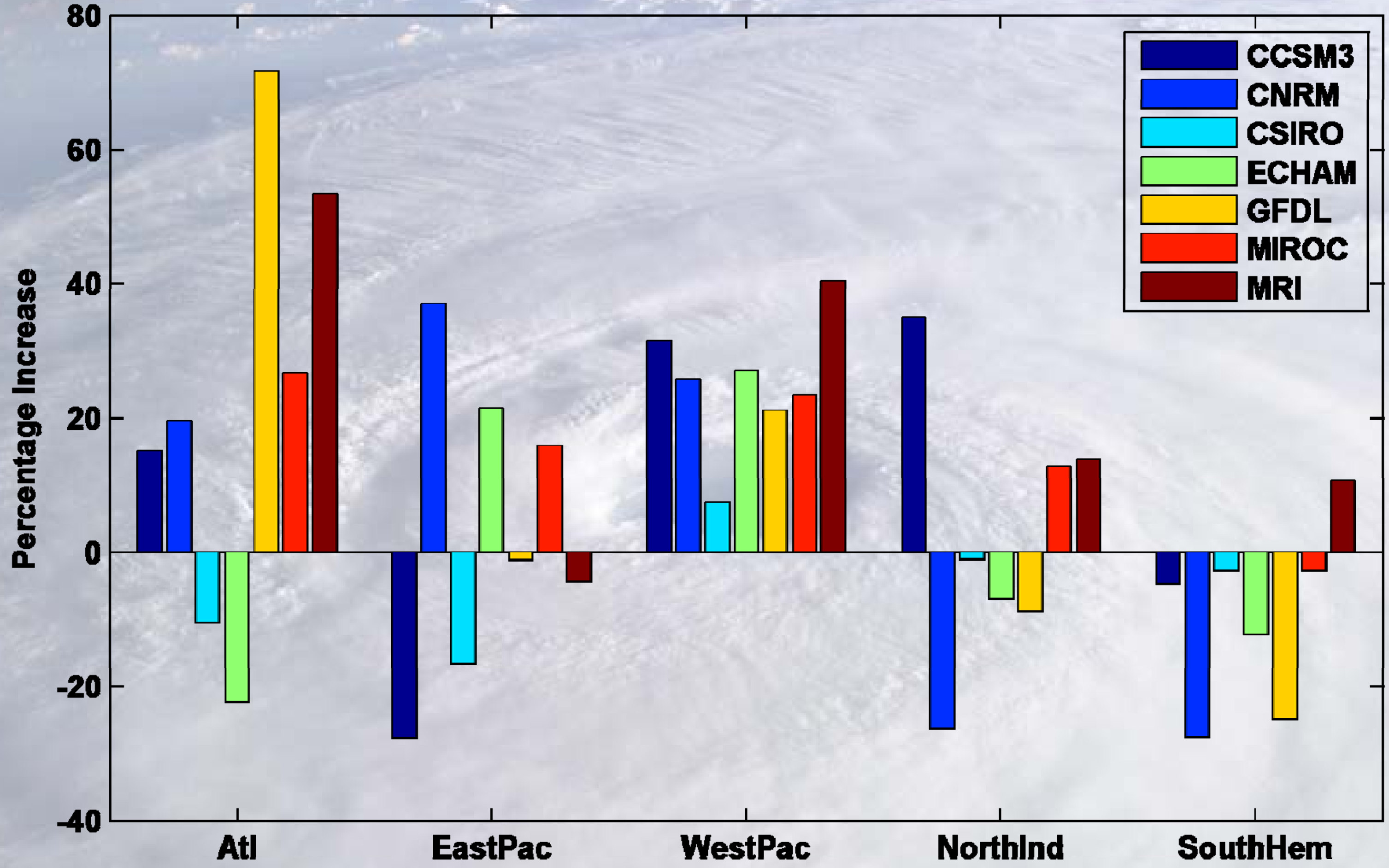
"For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios."

-- IPCC, 2007



Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change.

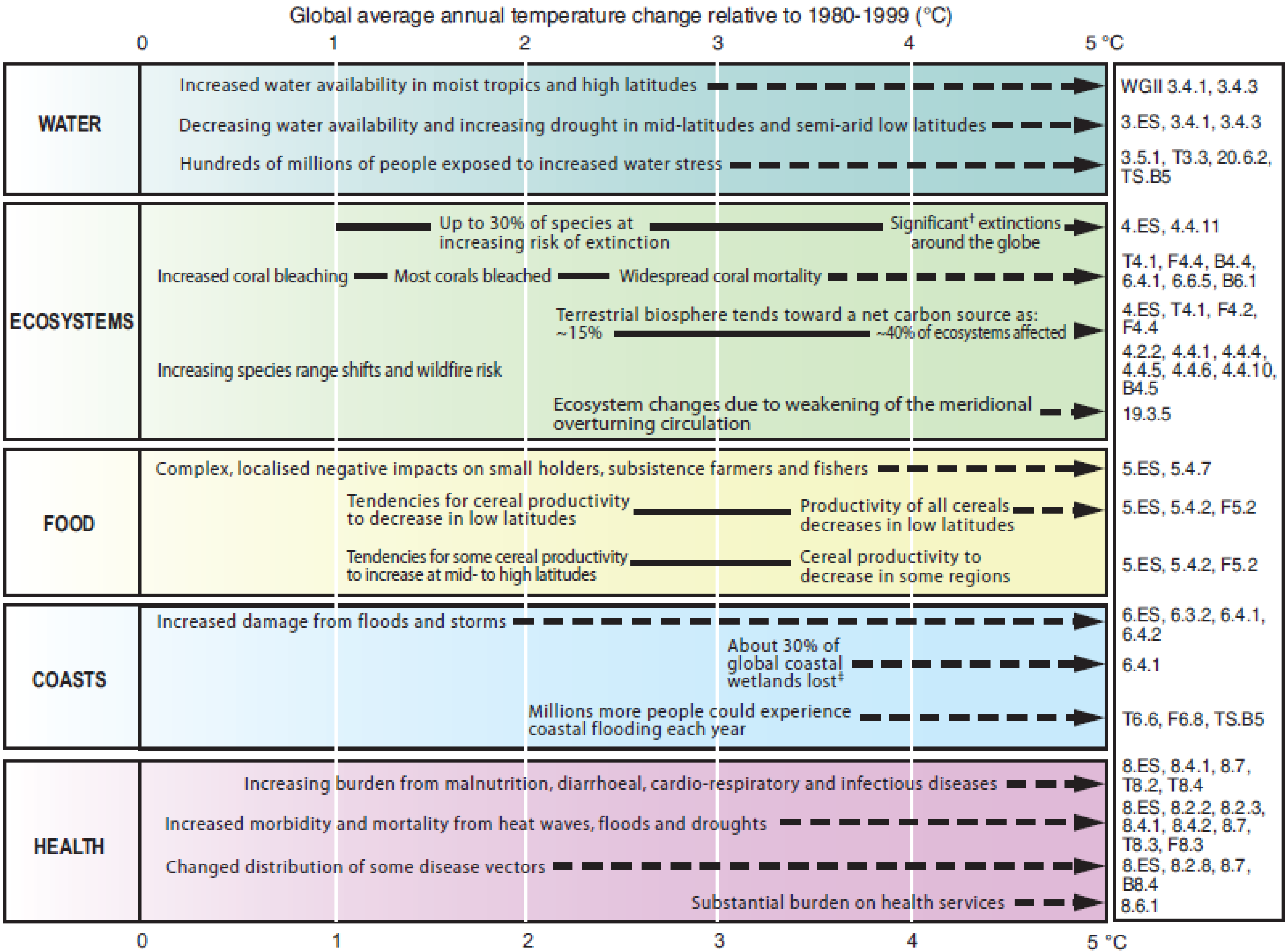
Basin-Wide Percentage Change in Power Dissipation



Different Climate Models

Projected Climate Impacts

Examples of impacts associated with global average temperature change
(Impacts will vary by extent of adaptation, rate of temperature change and socio-economic pathway)



† Significant is defined here as more than 40%. ‡ Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.

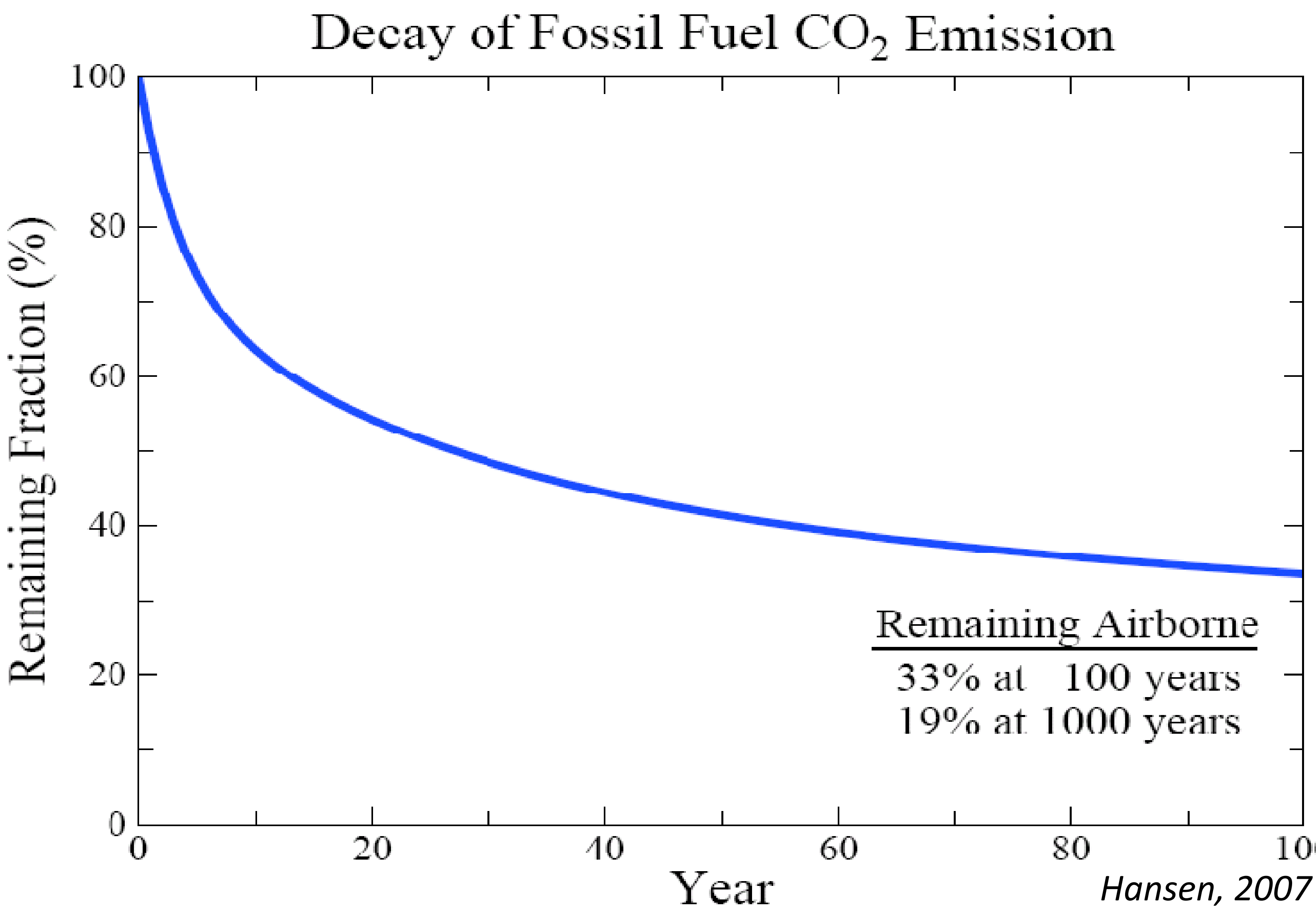
Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems *{WGII 4.4, 5.4}*	Water resources *{WGII 3.4}*	Human health *{WGII 8.2, 8.4}*	Industry, settlement and society *{WGII 7.4}*
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
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 shortage 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
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:

Dealing with Climate Change

- Winners and losers
- Difficult but necessary cost-benefit analysis
- Still large uncertainty in climate projections
- Small but difficult-to-quantify risk of major climate shifts (e.g. collapse of Greenland ice sheet)

Atmospheric lifetime of CO_2 is centuries long



Hansen, 2007

Summary of Possible Responses

- Mitigation
- Adaptation
- Geoengineering

Strategies

- **Reduce emissions**
  - gasification of coal—potential CO_2 capture
  - alternative sources– nuclear, wind, etc.
  - unlikely to effect major reductions
  - Fcous on non-CO_2 greenhouse gases
- **Carbon sequestration**
- **Other geoengineering**
  - technically feasible, $20-30 billion/year
  - Side effects, e.g. reduced precipitation
- **Adaptation**

“Responding to climate change involves an iterative risk management process that includes both mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity and attitudes to risk.”

-- IPCC, 2007

Adaptation

Adaptation

Sector	**Adaptation option/strategy**	**Underlying policy framework**	**Key constraints and opportunities to implementation** (Normal font = constraints; *italics = opportunities*)
Water {WGII, 5.5, 16.4; Tables 3.5, 11.6,17.1}	Expanded rainwater harvesting; water storage and conservation techniques; water reuse; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *integrated water resources management; synergies with other sectors*
Agriculture {WGII 10.5, 13.5; Table 10.8}	Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/ settlement (including coastal zones) {WGII 3.6, 11.4; Tables 6.11, 17.1}	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human health {WGII 14.5, Table 10.8}	Heat-health action plans; emergency medical services; improved climate-sensitive disease surveillance and control; safe water and improved sanitation	Public health policies that recognise climate risk; strengthen health services; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism {WGII 12.5, 15.5, 17.5; Table 17.1}	Diversification of tourism attractions and revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use); *revenues from 'new' attractions; involvement of wider group of stakeholders*
Transport {WGII 7.6, 17.2}	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy {WGII 7.4, 16.2}	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; energy efficiency; use of renewable sources; reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

Mitigation

WHAT ARE SOME LEADING RISKS WHOSE ODDS OR AMPLITUDES COULD BE LOWERED BY MITIGATION?

DEPLETION OF ARCTIC SUMMER SEA ICE?

Replacing reflecting with absorbing surface (2007 was 50% of 1979)

INSTABILITY OF GREENLAND & WEST ANTARCTIC ICE SHEETS?

7+5=12 meters of potential sea-level rise (Eemian sea level rise = 4-6 meters)

DEEP OCEAN CARBON & HEAT SINK SLOWED BY DECREASED SEA ICE & INCREASED FRESH WATER INPUTS INTO POLAR SEAS?

e.g. collapse if CO_2 >620 ppm and CLIMATE SENSITIVITY >3.5^{o}C (Scott et al)

INSTABILITY OF ARCTIC TUNDRA & PERMAFROST?

About 1670 billion tons of carbon stored in Arctic tundra & frozen soils (Tarnocai, GBC, 2009)

DELETERIOUS INCREASES OF OCEANIC ACIDITY?

pH drop exceeding 0.5 (>875 ppm CO_2) could decimate calcareous phytoplankton

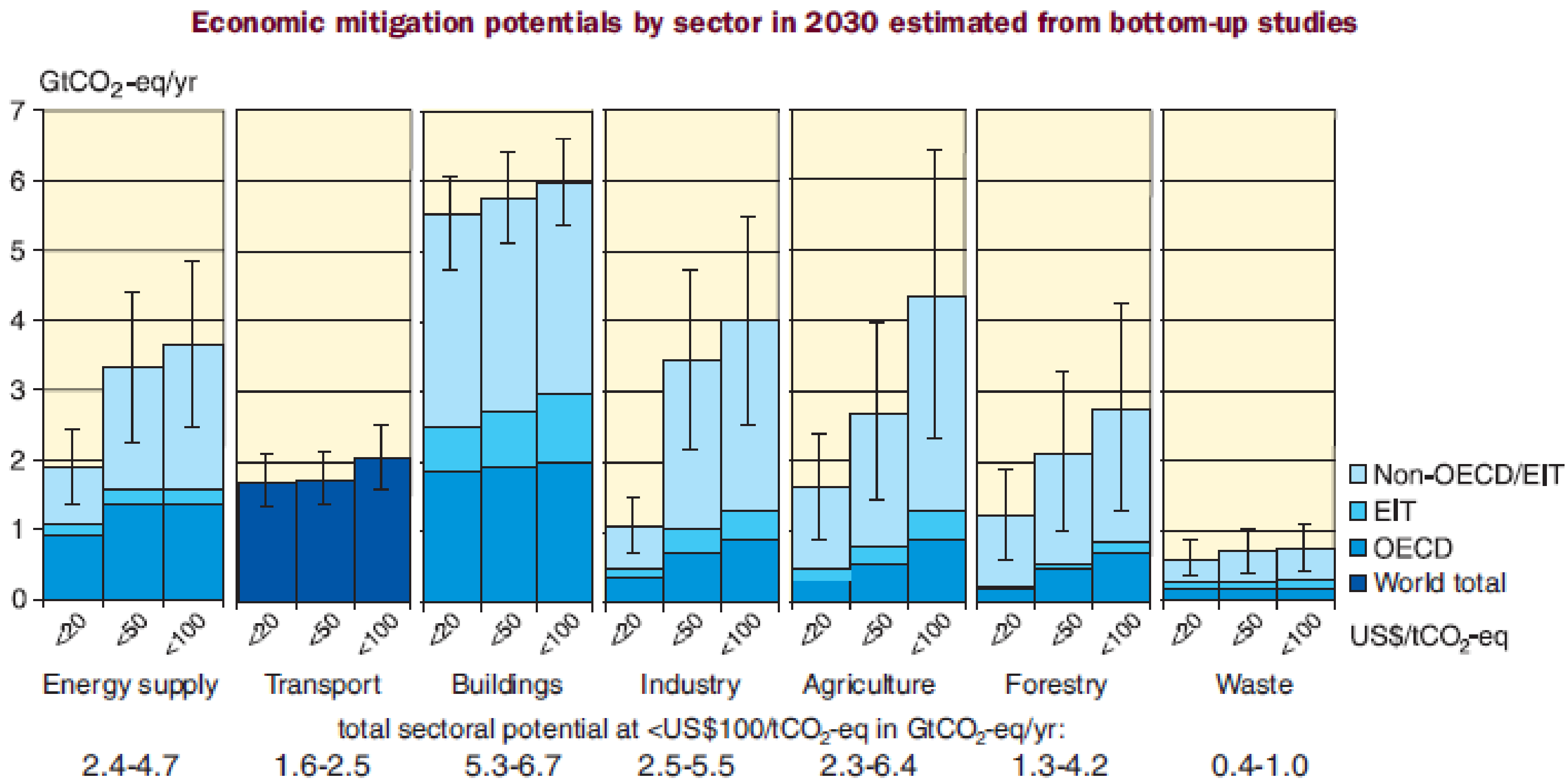
SHIFTING CLIMATE ZONES?

Maximum warming & % precipitation increase in polar regions?
More arid sub-tropics & lower mid-latitudes?

INCREASING DESTRUCTIVENESS OF TYPHOONS & HURRICANES?

Increased 2-3 times post-1960 and correlated with sea-surface warming? (Emanuel, 2005)

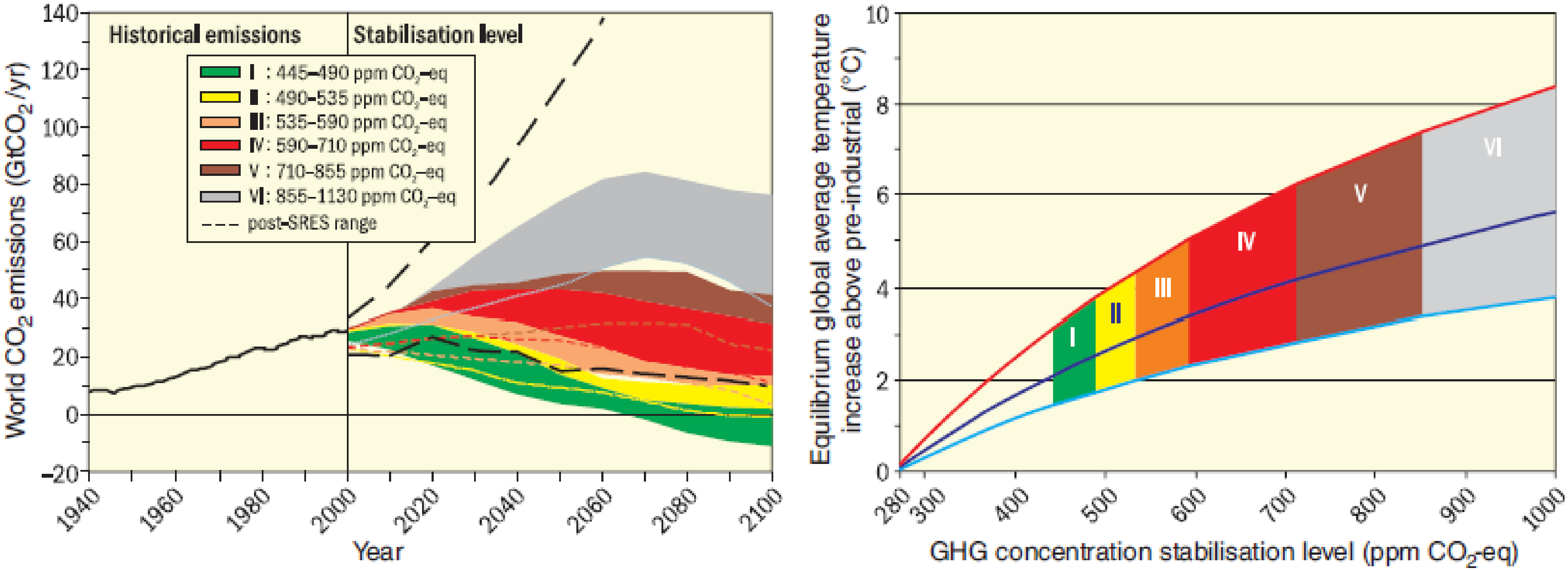
Mitigation



Estimated economic mitigation potential by sector and region using technologies and practices expected to be available in 2030. The potentials do not include non-technical options such as lifestyle changes.

Sector	**Key mitigation technologies and practices currently commercially available.** ***Key mitigation technologies and practices projected to be commercialised before 2030 shown in italics.***	**Policies, measures and instruments shown to be environmentally effective**	**Key constraints or opportunities** (Normal font = constraints; *italics = opportunities*)
Energy Supply {WGIII 4.3, 4.4}	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas); *CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics*	Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; renewable energy obligations; producer subsidies	*May be appropriate to create markets for low-emissions technologies*
Transport {WGIII 5.4}	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries*	Mandatory fuel economy; biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels; road and parking pricing	Effectiveness may drop with higher incomes
		Influence mobility needs through land-use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorised forms of transport	*Particularly appropriate for countries that are building up their transportation systems*
Buildings {WGIII 6.5}	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases; *integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar photovoltaics integrated in buildings*	Appliance standards and labelling	Periodic revision of standards needed
		Building codes and certification	*Attractive for new buildings.* Enforcement can be difficult
		Demand-side management programmes	Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	*Government purchasing can expand demand for energy-efficient products*
		Incentives for energy service companies (ESCOs)	*Success factor: Access to third party financing*
Industry {WGIII 7.5}	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies; *advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; performance standards; subsidies; tax credits	*May be appropriate to stimulate technology uptake.* Stability of national policy important in view of international competitiveness
		Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture {WGIII 8.4}	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertiliser application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; *improvements of crop yields*	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilisers and irrigation	*May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation*
Forestry/forests {WGIII 9.4}	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change*	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. *Can help poverty alleviation.*
Waste {WGIII 10.4}	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management	*May stimulate technology diffusion*
		Renewable energy incentives or obligations	Local availability of low-cost fuel
		Waste management regulations	Most effectively applied at national level with enforcement strategies

CO_2 emissions and equilibrium temperature increases for a range of stabilisation levels



Cumulative PROBABILITY OF GLOBAL AVERAGE SURFACE AIR WARMING from 1981-2000 to 2091-2100, WITHOUT (1400 ppm-eq CO_2) & WITH A 550, 660, 790 or 900 ppm-equivalent CO_2 GHG STABILIZATION POLICY

(400 forecasts per case. Ref: Sokolov et al, Journal of Climate, 2009)

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	ΔT > 2°C (values in red relative to 1860 or pre-industrial)	ΔT > 4°C	ΔT > 6°C
No Policy at 1400	100% (100%)	85%	25%
Stabilize at 900 (L4)	100% (100%)	25%	0.25%
Stabilize at 790 (L3)	97% (100%)	7%	< 0.25%
Stabilize at 660 (L2)	80% (97%)	0.25%	< 0.25%
Stabilize at 550 (L1)	25% (80%)	< 0.25%	< 0.25%

WITH THESE PROBABILITIES FOR WARMING EXCEEDING 2°C ABOVE PRE-INDUSTRIAL, HOW FEASIBLE IS A POLICY TARGET TO LIMIT WARMING TO LESS THAN 2°C?

Costs

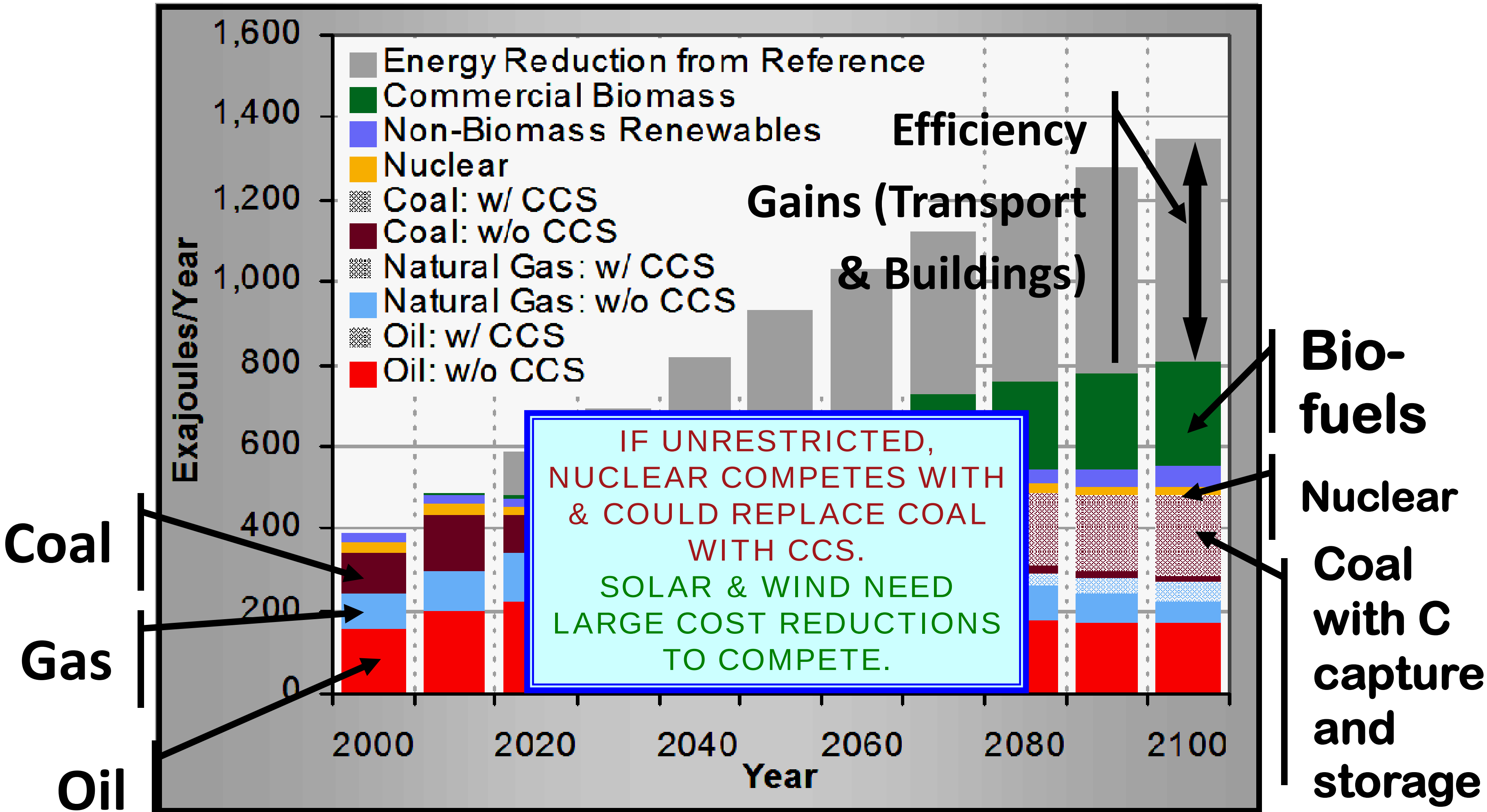
USING EPPA MODEL, WHAT IS THE PROBABILITY FOR GLOBAL MITIGATION COSTS (expressed as % WELFARE* LOSSES in 2050), WITH A 550, 660, 790 or 900 ppm-eq CO_2 STABILIZATION POLICY?

	ΔWL>1%	ΔWL>2%	ΔWL>3%
No Policy	-	-	-
Stabilize at 900	1%	0.25%	<0.25%
Stabilize at 790	3%	0.5%	<0.25%
Stabilize at 660	25%	2%	0.5%
Stabilize at 550	70%	30%	10%

*Approximately the total consumption of goods & services

USING EPPA MODEL, WHAT IS THE SCALE OF THE GLOBAL CHALLENGE?

e.g. Global Primary Energy for a 660 ppm CO_2-equivalent stabilization scenario with nuclear restricted.

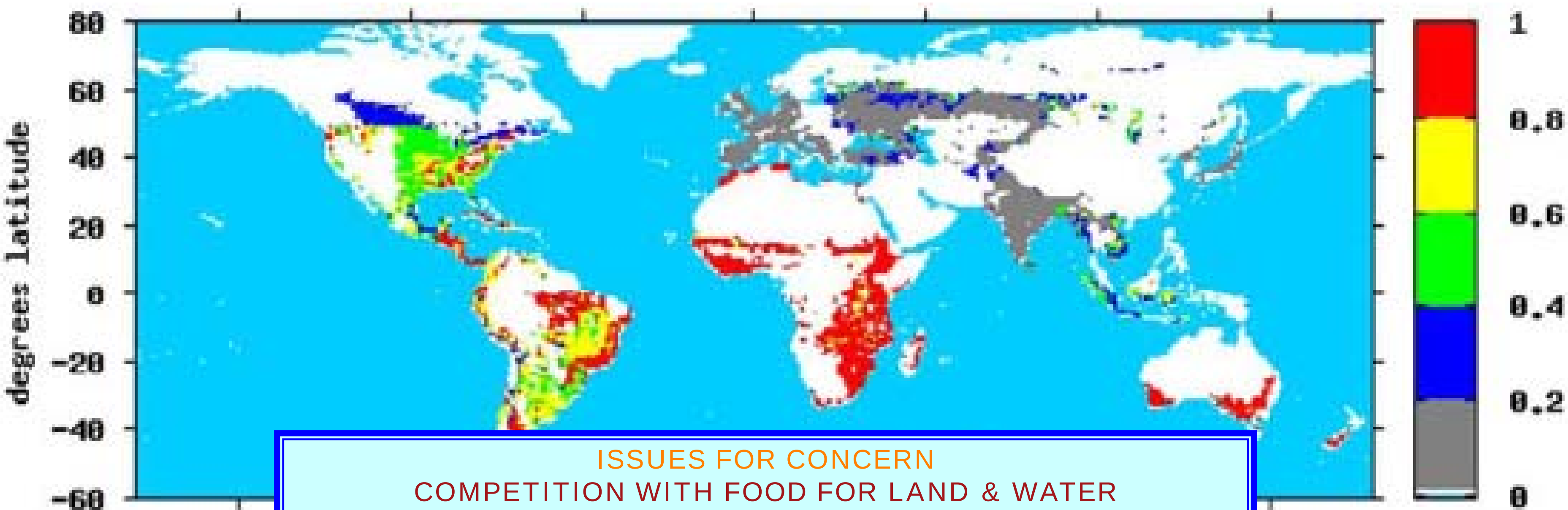


*Carbon price ~$1750/tonC in 2100

ARE THERE ISSUES REGARDING THE CONVERSION OF LAND FOR RENEWABLE ENERGY AT LARGE SCALES?

For bio-fuels to provide 240 EJ/year (7.5 TW or 60% of current demand or 18% of 2100 demand) requires more than 3.4 billion acres of land dedicated to crops producing ethanol, which is 8.5 times the total US cropland, assuming 40% efficiency in the conversion of the biomass (cellulose).

FRACTION OF LAND IN 2100 DEVOTED TO BIO-FUELS PRODUCTION for TRANSPORTATION, etc. WITH A 660 ppm CO_2-equivalent STABILIZATION POLICY & DEFORESTATION



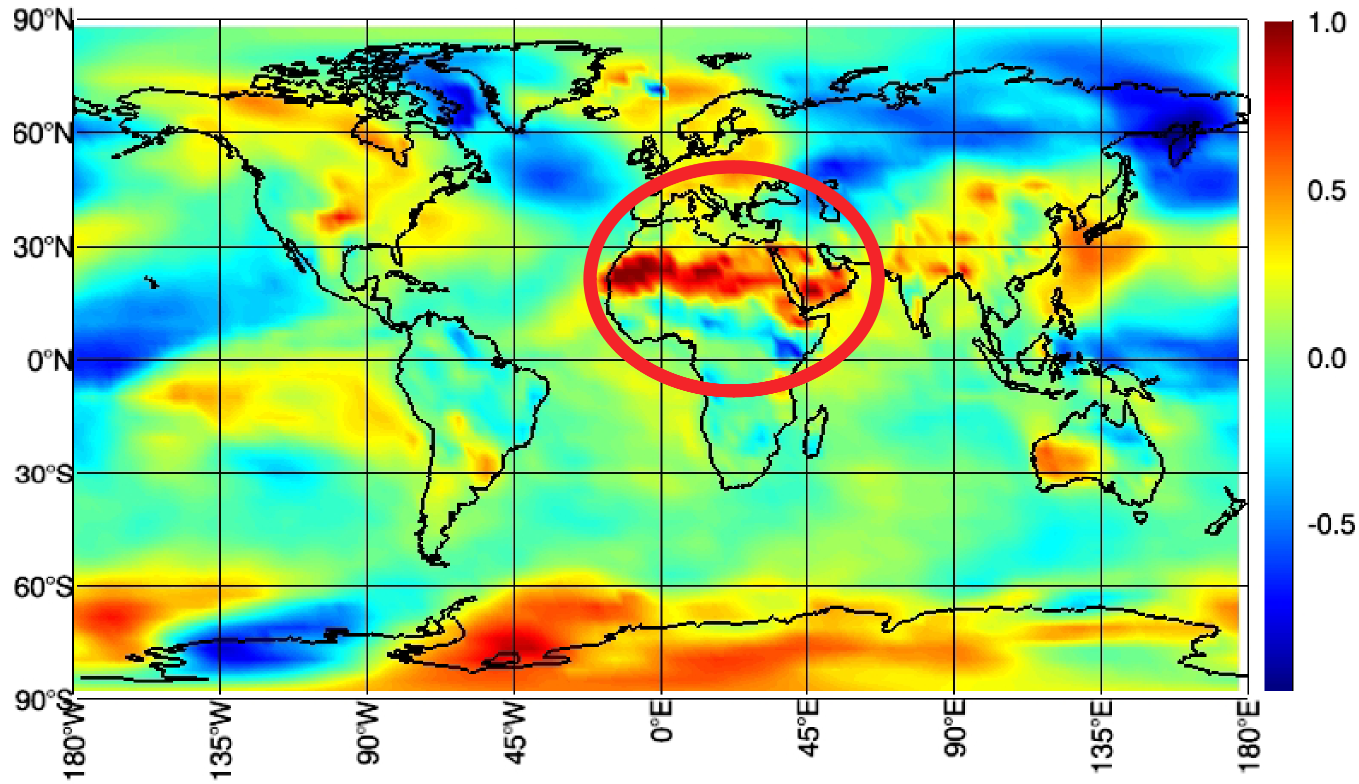
ISSUES FOR CONCERN
COMPETITION WITH FOOD FOR LAND & WATER
GREENHOUSE GAS RELEASE DURING LAND CONVERSION
LOSS OF NATURAL ECOSYSTEMS (TROPICAL FORESTS)
CLIMATE EFFECTS OF LAND CONVERSION

Ref: Melillo, et al, 2009

SOLAR PANELS WARM INSTALLED DESERT REGIONS & WARM/COOL ELSEWHERE

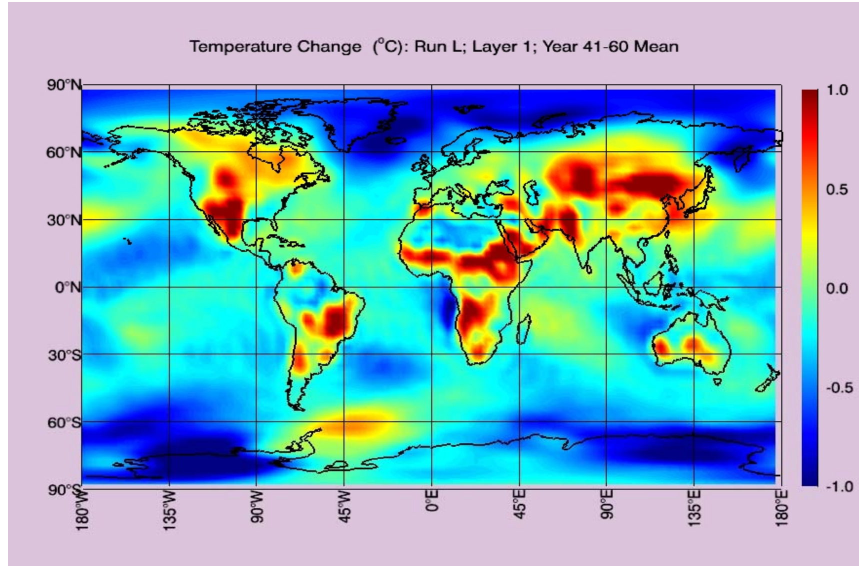
WHAT ARE EFFECTS OF SOLAR ARRAYS AT LARGE SCALES (5.3 TW OVER SAHARAN & ARABIAN DESERTS) ON SUNLIGHT ABSORPTION (W/m^2) AND SURFACE TEMPERATURE (^{o}C)? (Ref: Wang & Prinn, 2009)

Surface Air Temperature Change (K): Last 20 Year Mean



CAN AVOID THESE EFFECTS BY ADDING REFLECTORS TO THE ARRAY TO YIELD ORIGINAL REFLECTIVITY

WINDMILLS WARM INSTALLED LAND REGIONS & WARM/COOL ELSEWHERE

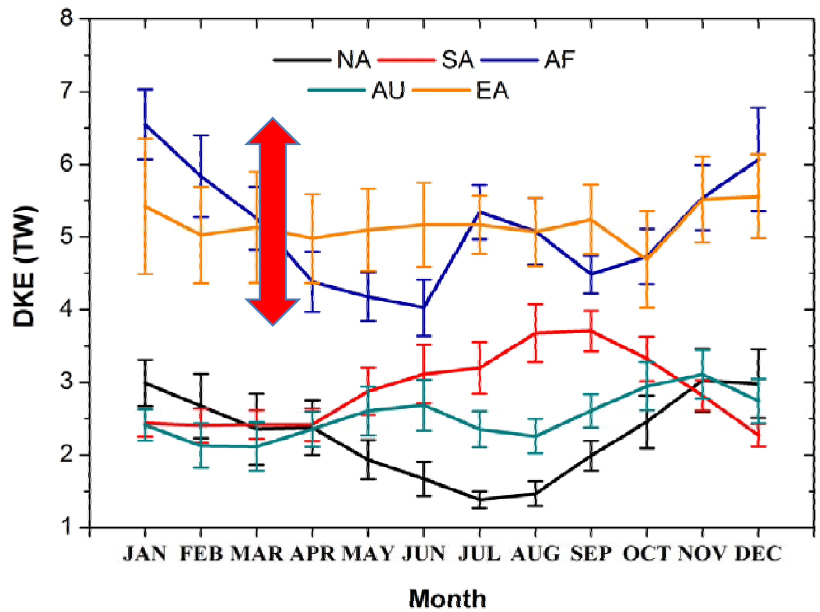


WHAT ARE EFFECTS OF WINDMILL ARRAYS AT LARGE SCALES ON SURFACE TEMPERATURE OVER SEMI-ARID LAND (L, 5TW, 58 million km^2) (Ref: Wang & Prinn, 2009)

LINEAR ARRAYS PERPENDICULAR TO WINDS FAVORED

INTERMITTENCY CHALLENGE: Twenty-year averages and standard deviations of the monthly mean wind power consumption (dKE/dt) by simulated windmills installed in: North America (NA), South America (SA), Africa and Middle East (AF), Australia (AU), and Eurasia (EA).

NEED BACKUP GENERATION CAPACITY, POSSIBLY INCLUDING ON-SITE ENERGY STORAGE



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