Capacity building to develop and review climate resilient policies

JAPAN
Official Development Assistance

Environment - Mauritius

UNDP

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Climate change science, current developments and what it means for Small Island Developing States

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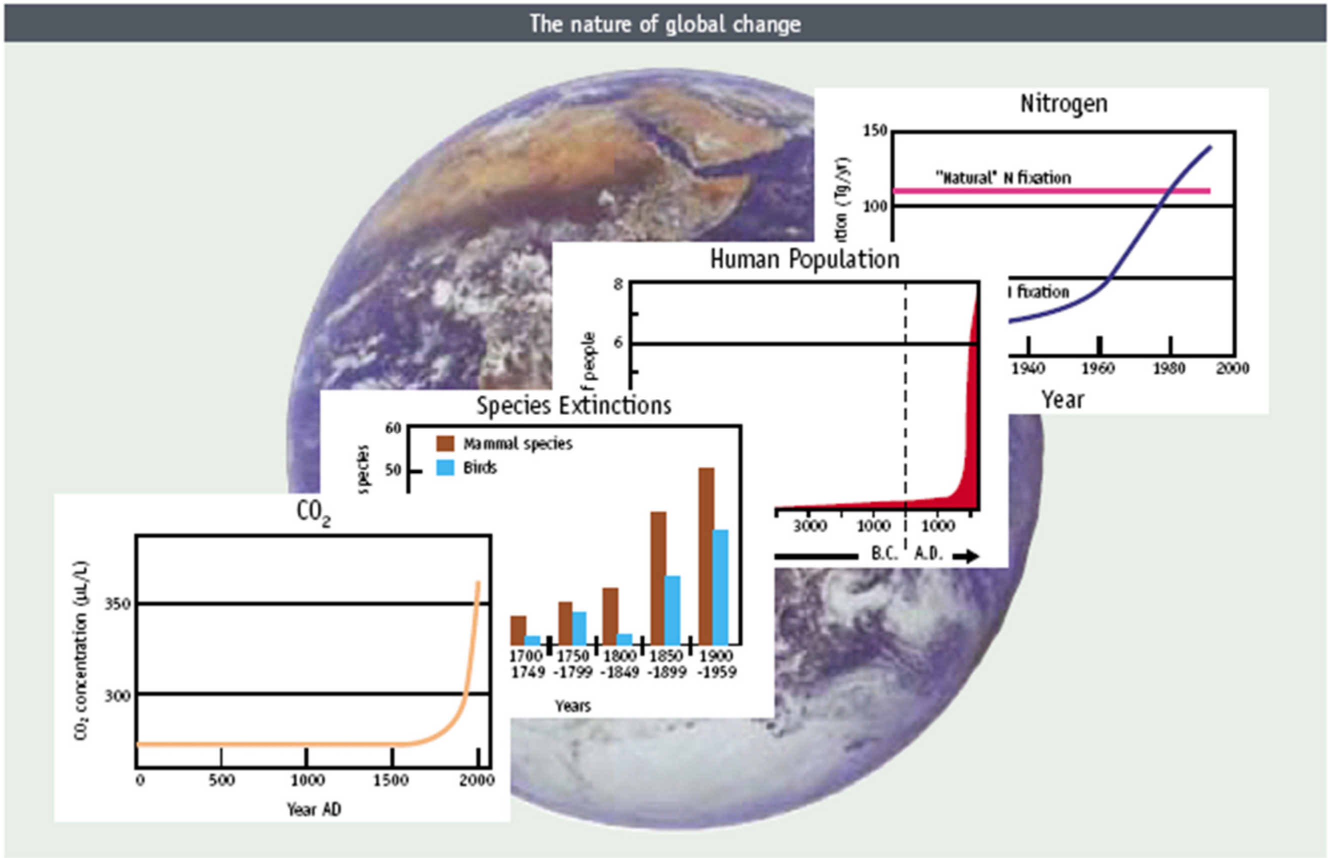
Overview

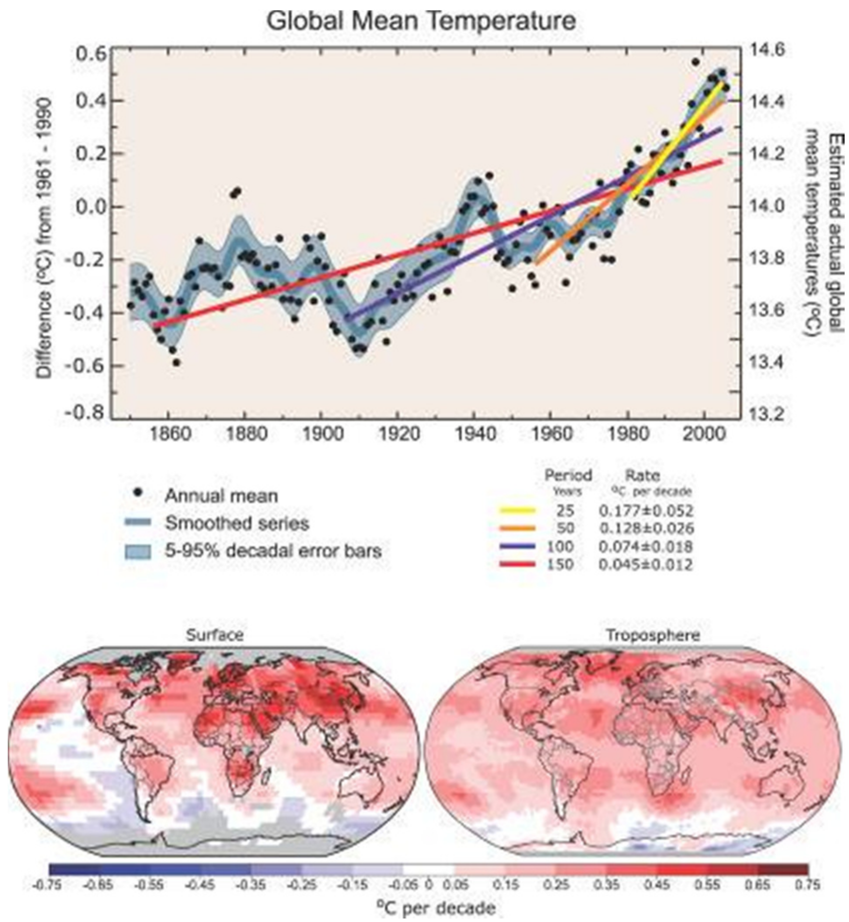
- Climate change science
- Understanding climate change
- Some local experiences/perspectives
- What's in a number?
- Summary of implications for Small Island Developing States
- Climate change in Mauritius

Global change



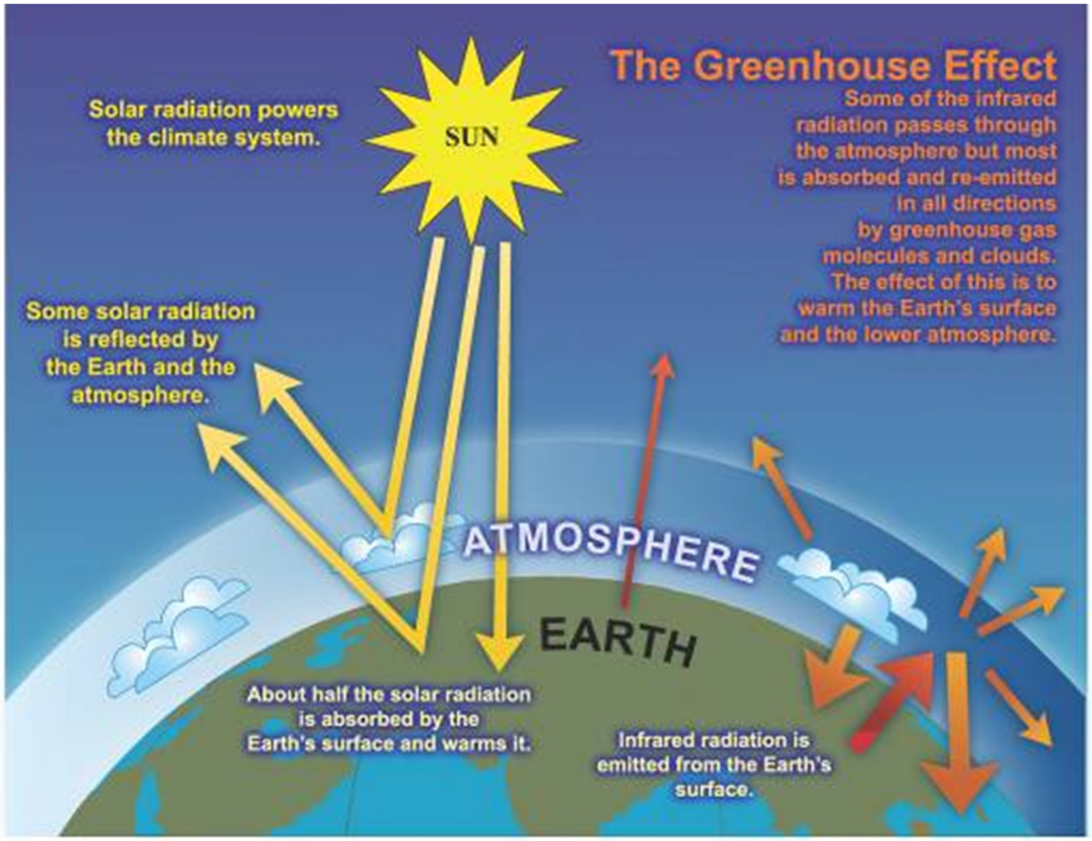
Source: www.igbp.kva.se

Climate change



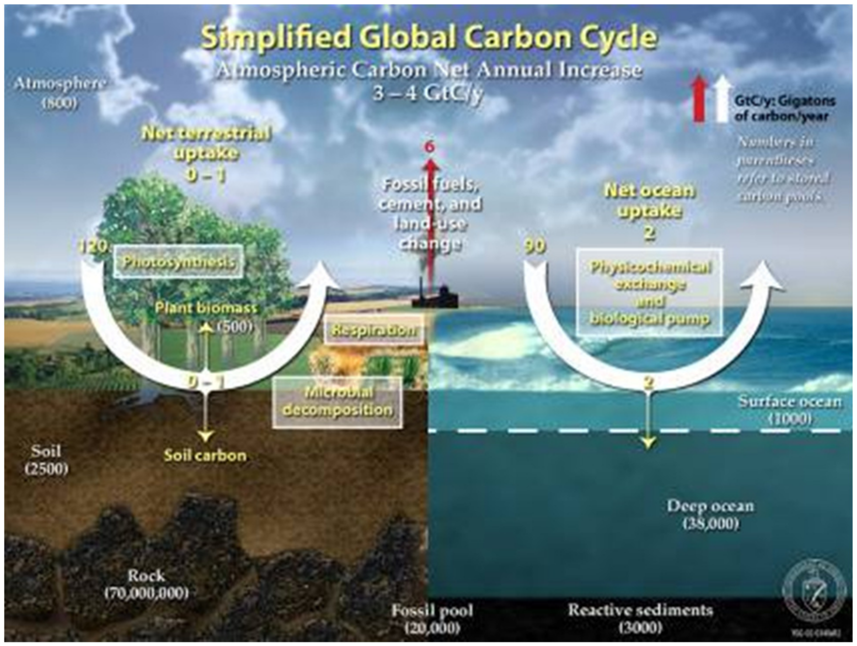
Source: FAQ 3.1, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

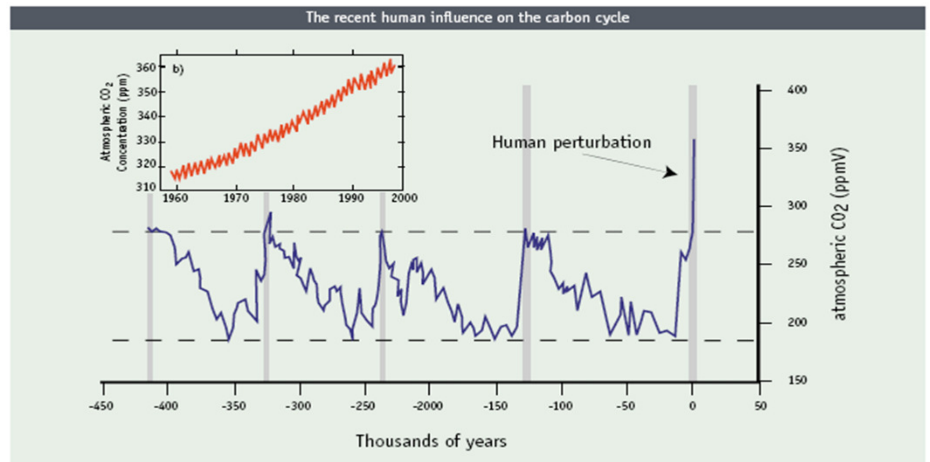
The Greenhouse Effect



Source: FAQ 1.3, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

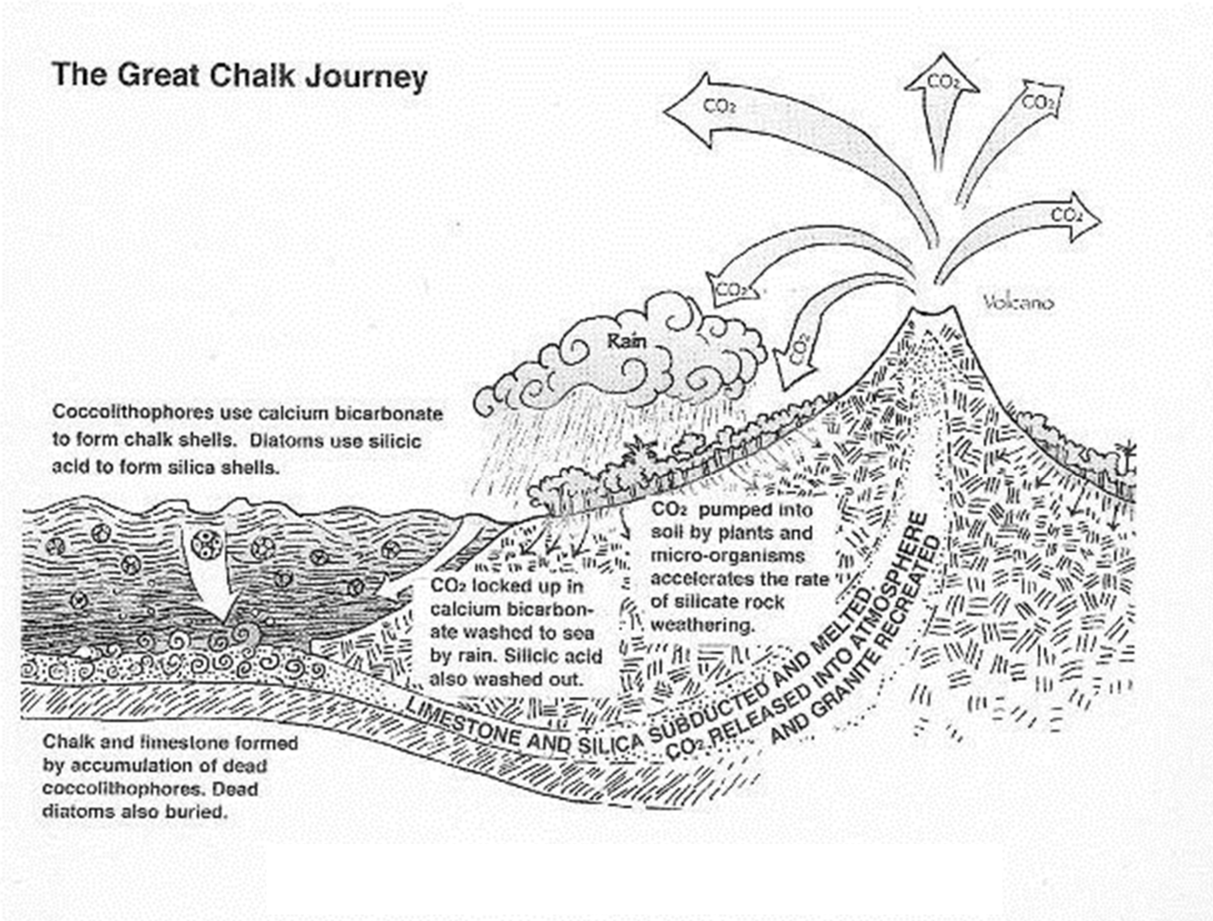
The carbon cycle





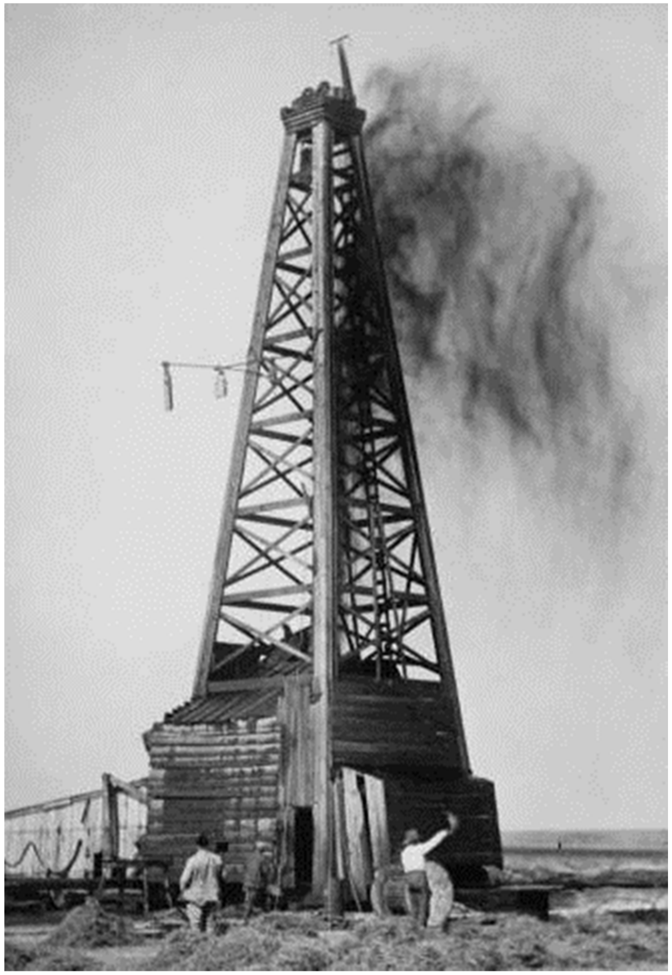
Source: www.igbp.kva.se

Carbons longest journey

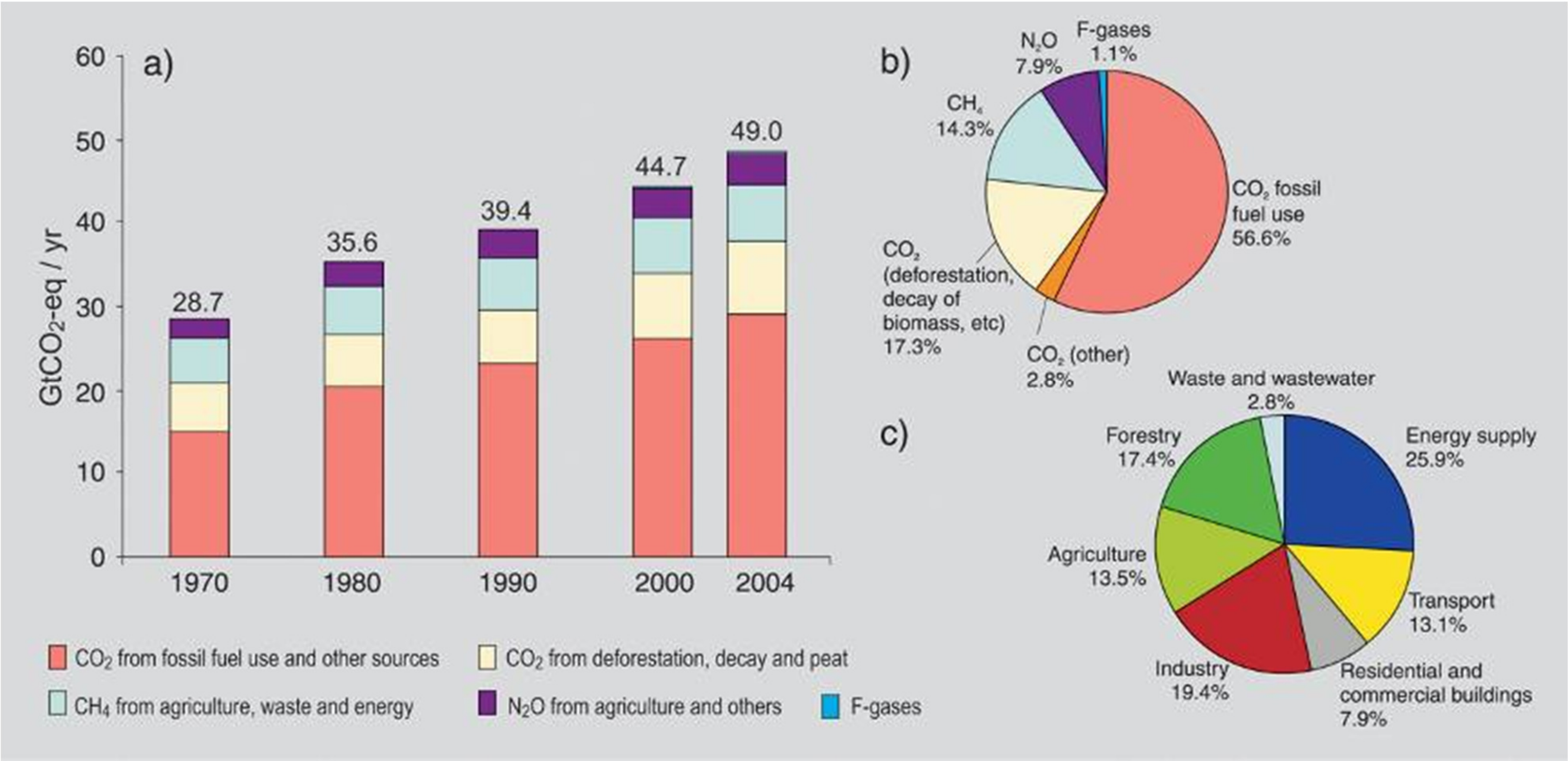


Source: Stephan Harding, *Animate Earth: Science, Intuition and Gaia*, Green Books, 2006

Human influence

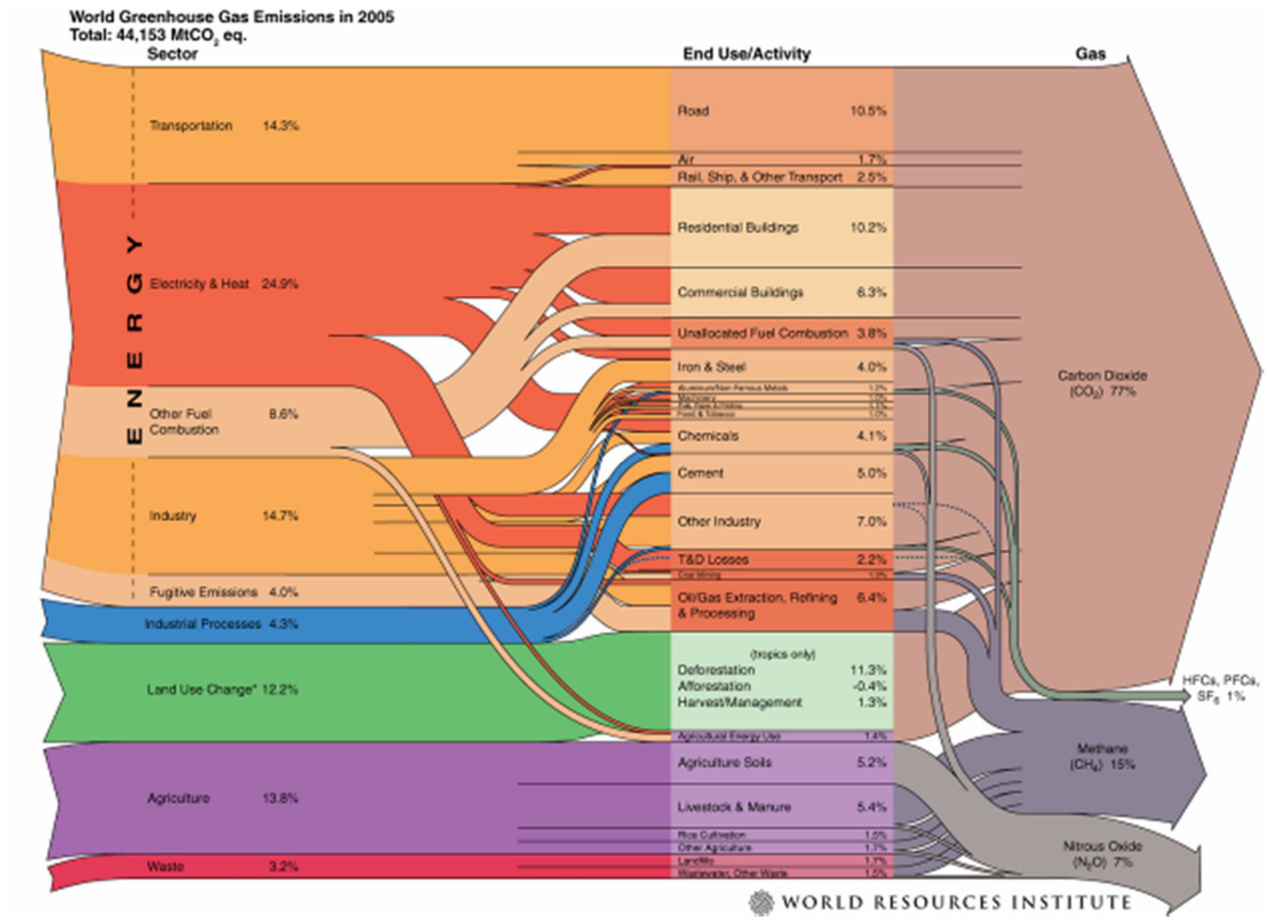


Global greenhouse gas emissions

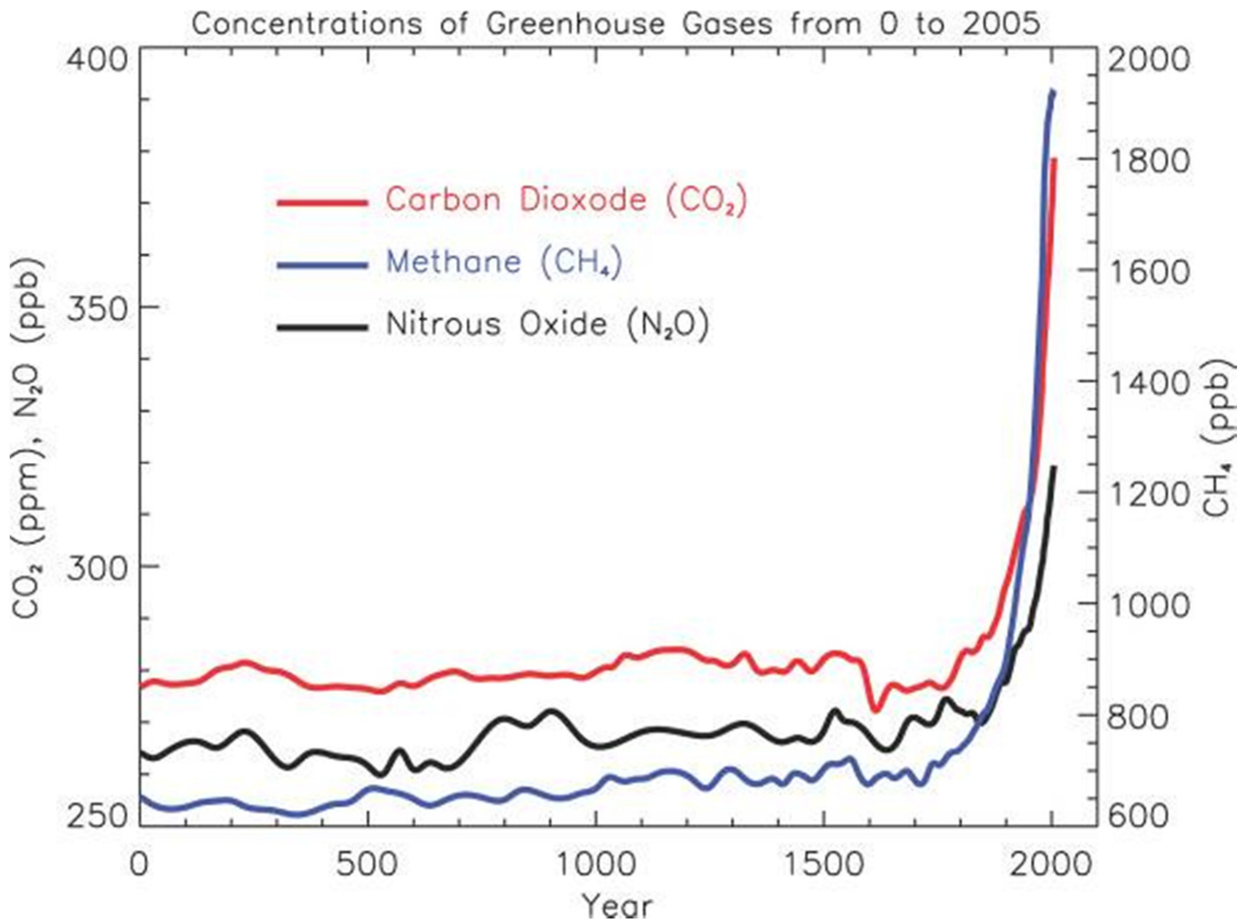


Source: Figure 2.1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Global greenhouse gas emissions

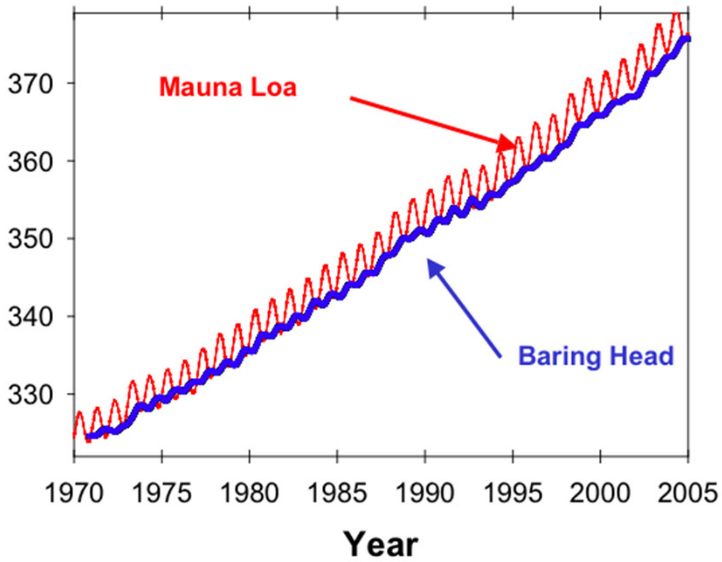


Changes in Greenhouse Gases



Source: FAQ 2.1, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Globally, greenhouse gas concentrations are increasing



Carbon dioxide, ppm
(CO_2 379ppm, CH_4 1780ppb, N_2O 319ppb)

- Since 1750
  - carbon dioxide increase 35%
  - methane increase 150%
  - Nitrous oxide increase 18%
- Human activities emit annually ~7,000,000,000 tonnes of carbon dioxide
- About half of this stays in the atmosphere
- Present carbon dioxide concentrations highest for 650,000 years, likely 20 My.

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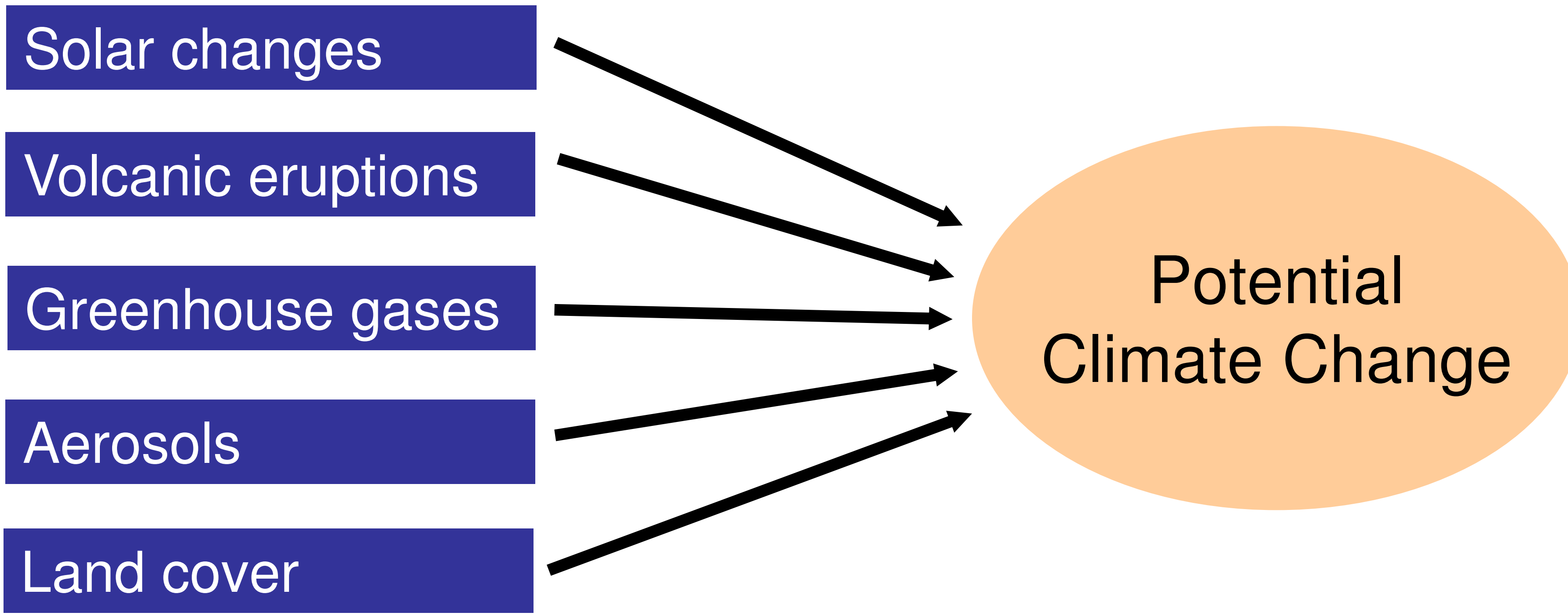
… and increasing

Canadian Tarsands, Source: National Geographic

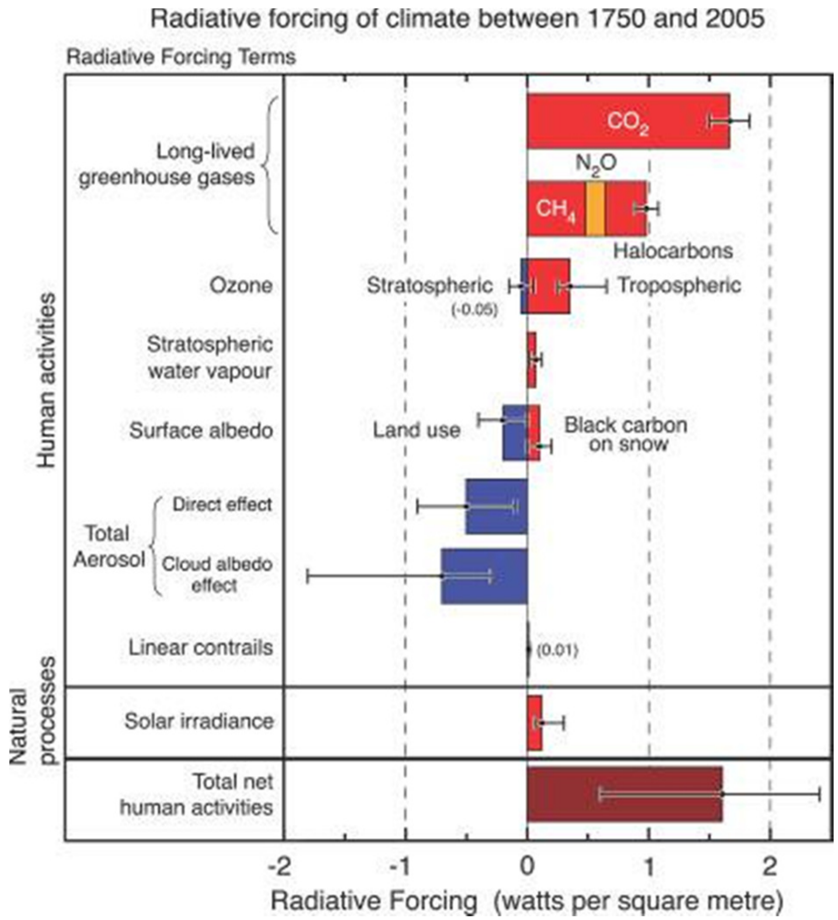
Causes of Change



There are both natural and anthropogenic drivers of climate change.

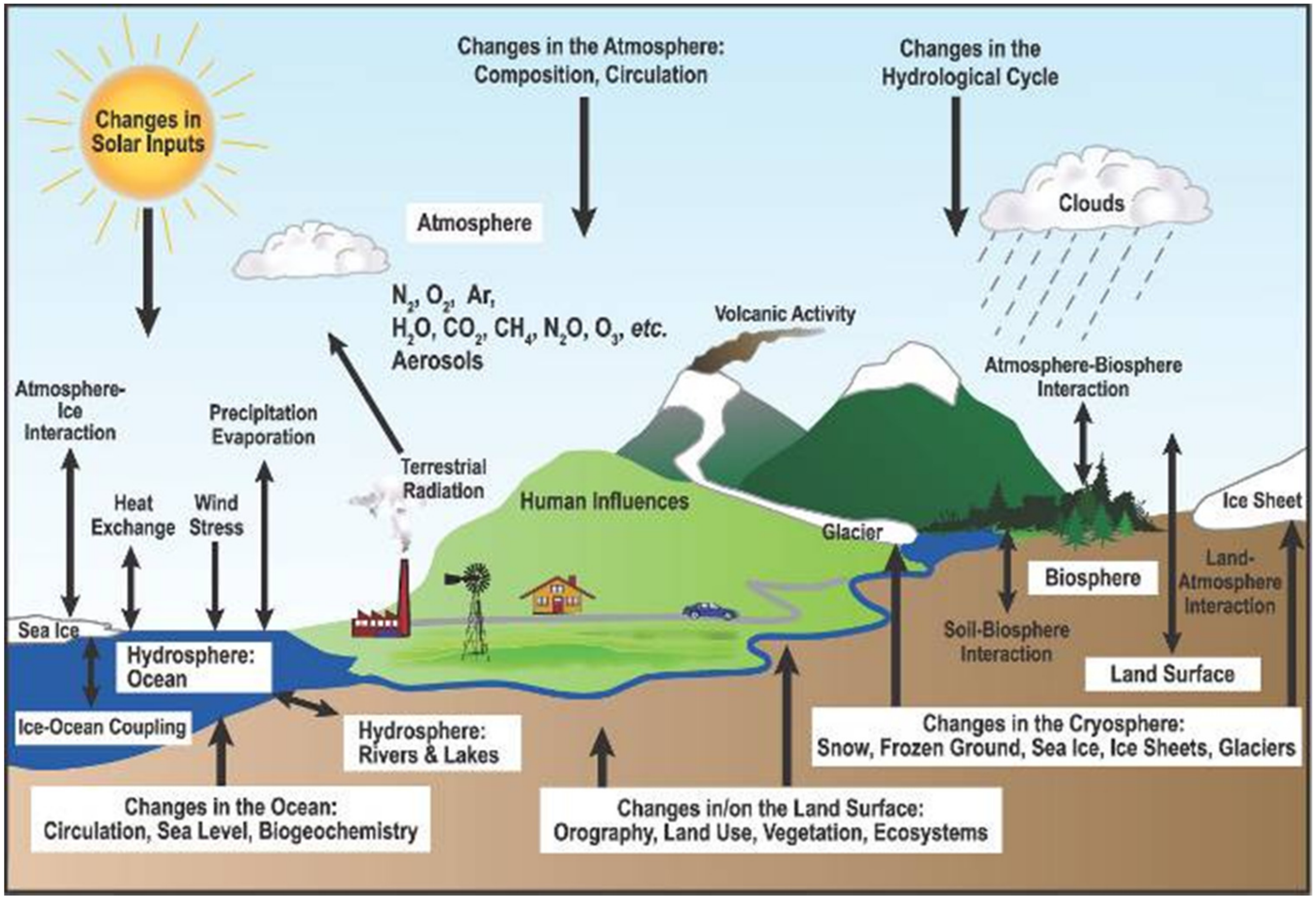
There will always be natural variability superimposed on long-term trends.

Radiative Forcing



Source: FAQ 2.1, Figure 2, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

The Climate System

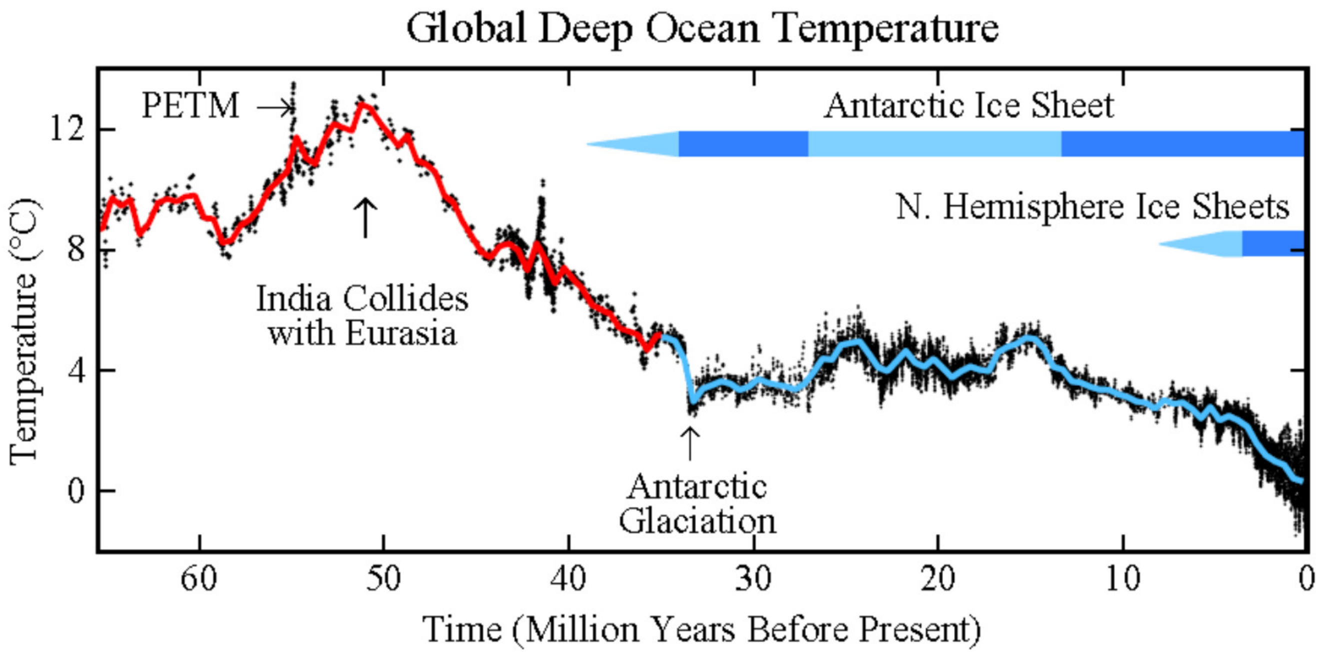


Source: FAQ 1.2, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Understanding climate change

- Paleoclimate history
- On-going global observations
- Climate models

Cenozoic Era



50 million years ago (50 MYA) Earth was ice-free.
Atmospheric CO_2 amount was of the order of 1000 ppm 50 MYA.
Atmospheric CO_2 imbalance due to plate tectonics ~ 10^{-4} ppm per year.

Source: Jim Hansen http://www.columbia.edu/~jeh1/

Cenozoic Era compared to now

1. Dominant Forcing: Natural ΔCO_2

- Rate ~100 ppm/My (0.0001 ppm/year)
- Human-made rate today: ~2 ppm/year

Humans Overwhelm Slow Geologic Changes

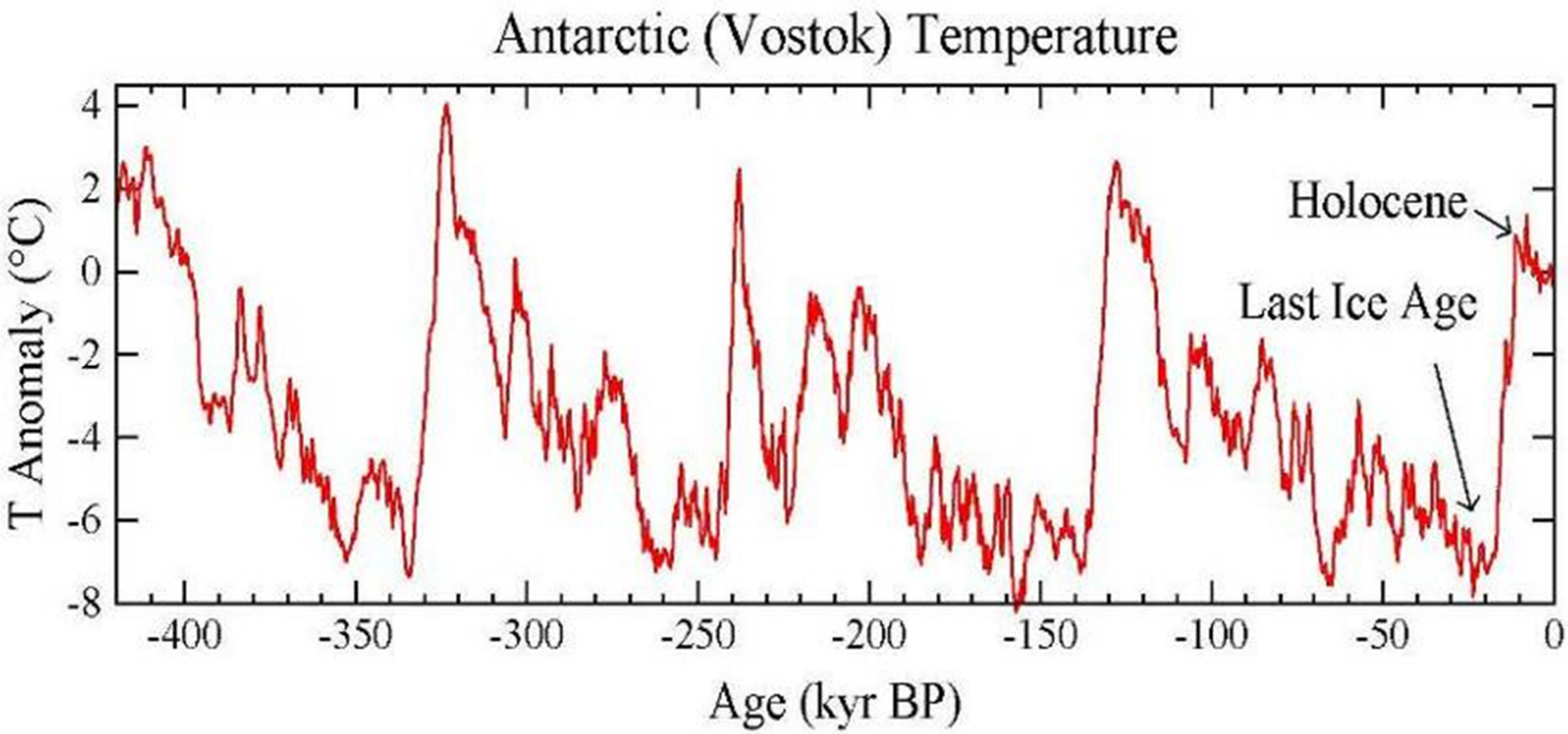
2. Climate Sensitivity High

- Antarctic ice forms if CO_2 < ~450 ppm
- Ice sheet formation reversible

Humans Could Produce "A Different Planet"

Source: Jim Hansen http://www.columbia.edu/~jeh1/

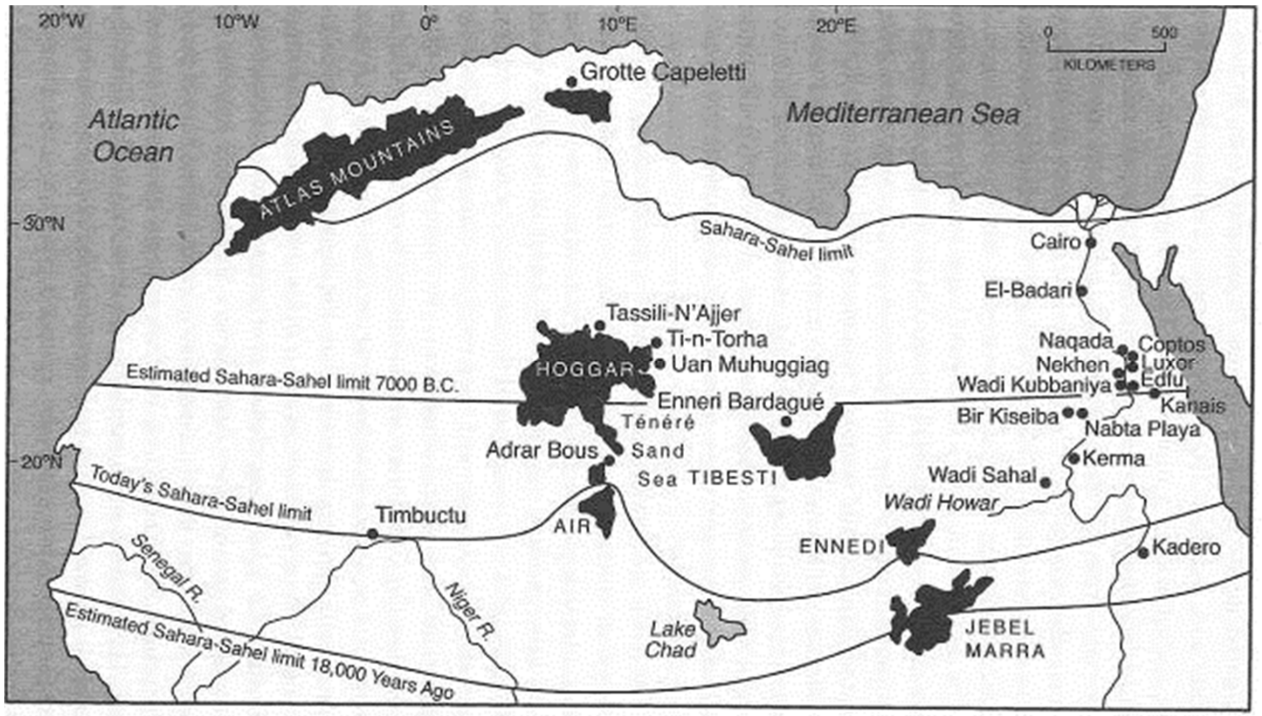
Vostok ice core records



Earth's history provides important information on global warming. Recorded human history occurs within the Holocene warm period.

Source: Jim Hansen http://www.columbia.edu/~jeh1/

Climate shifts



Source: Brian Fagan, *The Long Summer: How Climate Changed Civilization*, Basic Books, 2004

Holocene changes

	Climate Events Vegetation Zones		Human Events	Climate Triggers
3000 B.C.		ALTITHERMAL	Unification of Egypt	
	Sub-Boreal		Towns appear in Egypt Cities develop in Mesopotamia	Major aridification in the Sahara, Egypt, and Mesopotamia
4000 B.C.			Ertebolle culture in Scandinavia	Warm, moist conditions in Europe
			Cattle herded in the Sahara	Drought in American West
5000 B.C.				
	Atlantic		Linearbandkeramik farmers move into Central Europe	Euxine lake flooded Sea level rise
6000 B.C.	Mini Ice Age *(colder, drier)*		First settlement of southern Mesopotamia Farmers in the Balkans	Laurentide ice sheet collapses–Atlantic circulation slows
7000 B.C.				
8000 B.C.			Farming spreads rapidly in Southwestern Asia	
	Boreal		"Broad-spectrum hunter-gatherers" in Northern Europe	Atlantic circulation resumes
9000 B.C.	Pre-Boreal			

	Climate Events Vegetation Zones	Human Events	Climate Triggers
A.D. 2003	Little Ice Age	Industrial Revolution	Warming after A.D. 1860 Cooler, more volatile climate–many cold periods
		Ancestal Pueblo dispersal Collapse of Tiwanaku Collapse of Maya civilization in the southern lowlands, Yucatán	Major droughts in western North America, Central and South America
A.D. 1000	Medieval Warm Period Drought of A.D. 910 in Central America Event of 536	Avar empire in eastern Europe Decline of Rome	? major volcanic event causing cooling
A.D. 1		Caesar conquers Gaul Celtic migrations Biskupin	Drought on eastern steppes
	Sub-Atlantic *(cooler, wetter in Europe)*		Abrupt cooling (A.D. 850)
		Shaugh Moor, England, in use	
1000 B.C.	Drought event in eastern Mediterranean	Collapse of Hittite, Mycenaean civilization Uluburun shipwreck	Major drought episode– ? El Niño events
		Egypt reunified (2046 B.C.) Old Kingdom Egypt ends in crisis	Major El Niño event?
2000 B.C.	Drought event in eastern Mediterranean	Akkadian empire	300-year drought in eastern Mediterranean after 2200 B.C.
	Sub-Boreal	Old Kingdom Egypt	
		Sumerian civilization	
3000 B.C.			

Source: Brian Fagan, *The Long Summer: How Climate Changed Civilization*, Basic Books, 2004

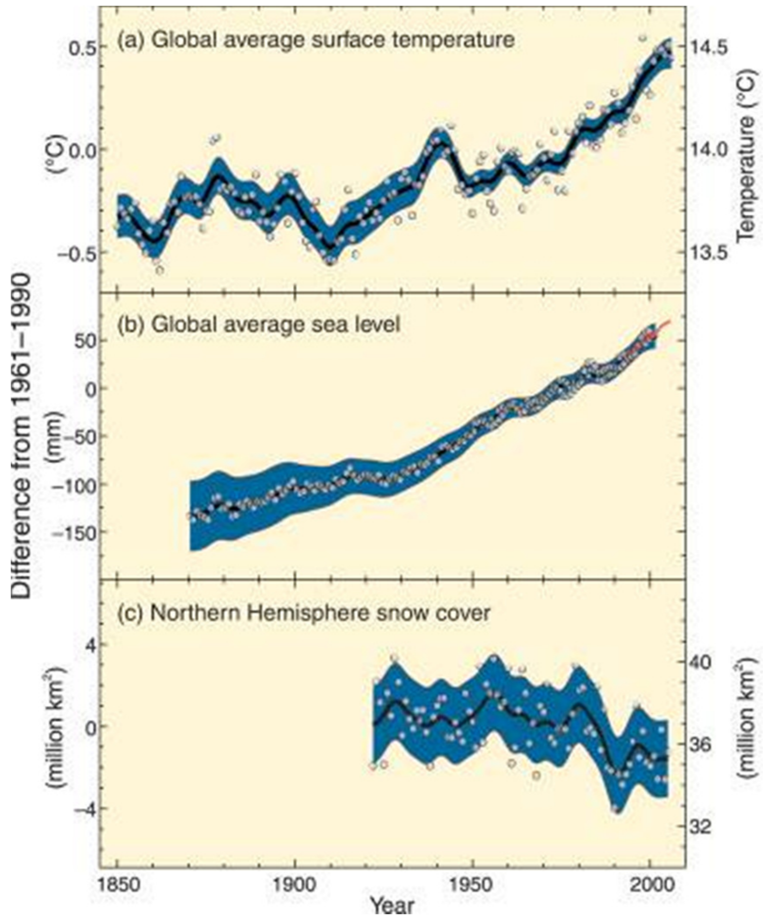
Holocene changes

- 8000-9000BC
  - Hunter gatherers in northern Europe
  - Atlantic circulation resumes
- 3000BC
  - Towns appear in Egypt. Cities develop in Mesopotamia
  - Major aridification in Sahara, Egypt and Mesopotamia
- About 2000BC
  - Old kingdom Egypt ends in crisis
  - 300 year drought in eastern Mediterranean after 2200BC
- 1000AD onwards
  - Medieval warm period followed by Little ice age
  - Eric the Red, decline of Rome, collapse of some native American civilisations

Buzz groups (5 mins)

- What are the key messages from the presentation so far?

Observed climate changes



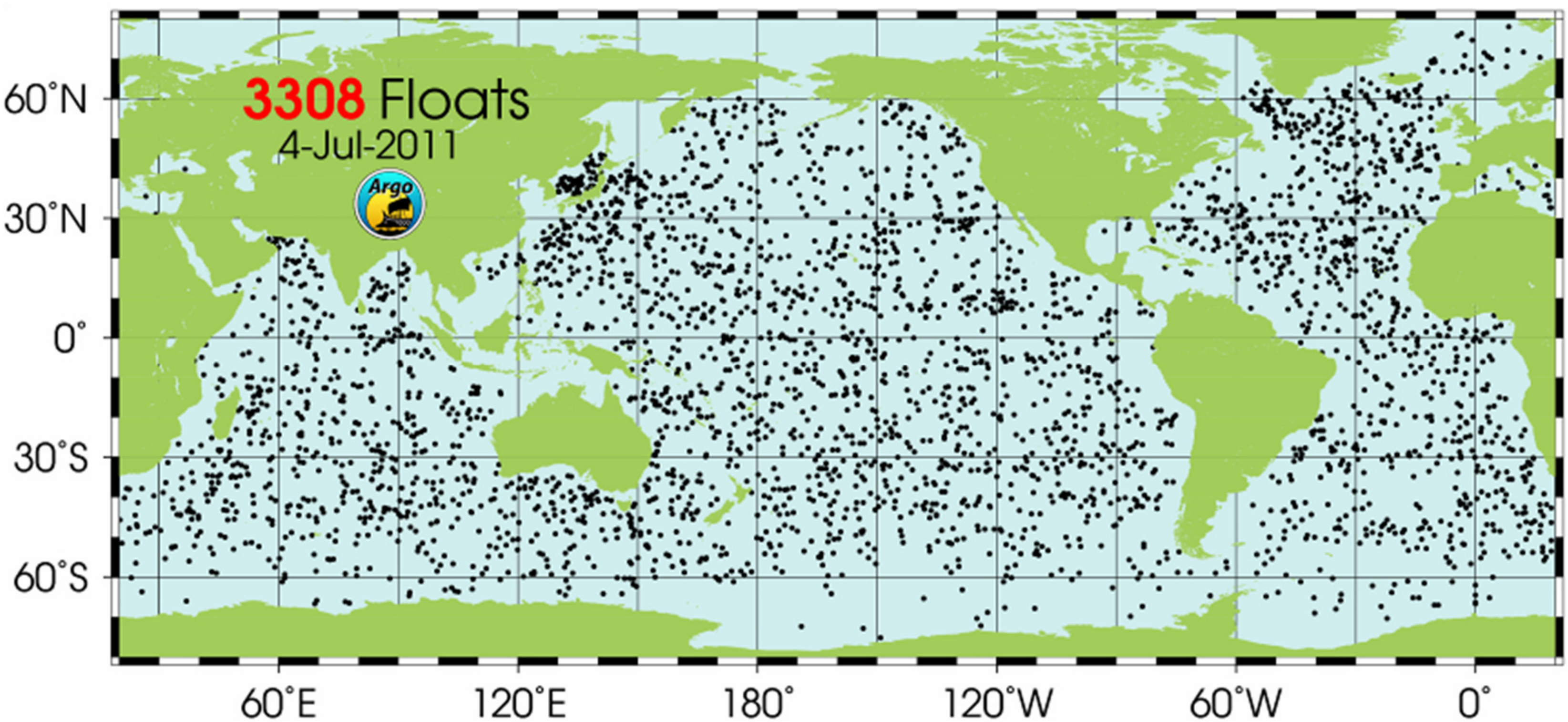
Source: Figure 1-1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Consistency of observations

- Surface temperatures increasing
- Atmospheric water vapour content increasing
- Ocean heat content increasing …
- … now directly linked to sea level rise
- Greenland and Antarctic Ice Sheets losing mass
- Glaciers and snow cover declined
- Arctic sea ice extent decreasing
- More intense and longer droughts
- More frequent heavy precipitation events over land
- Tropical cyclone intensity increasing (North Atlantic)

ARGO

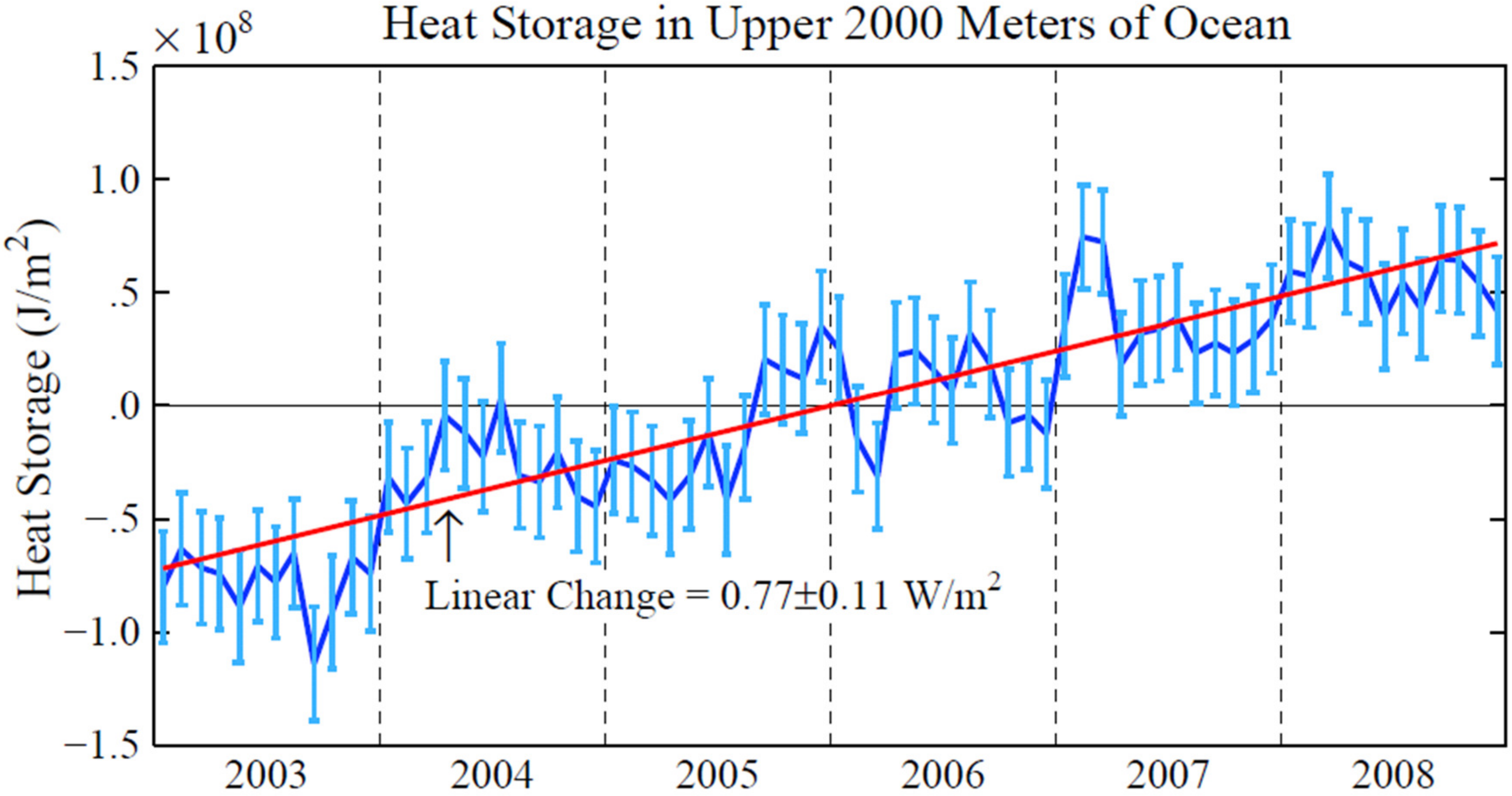
http://www.argo.ucsd.edu



What is Argo?

Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000m of the ocean.

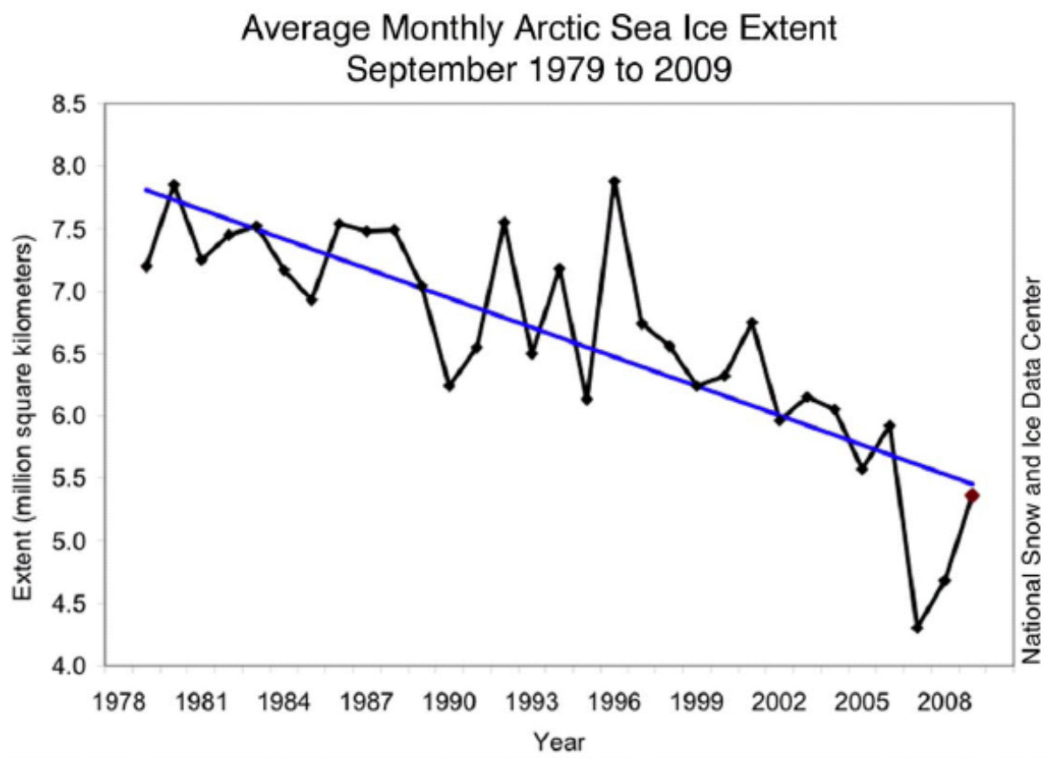
ARGO data

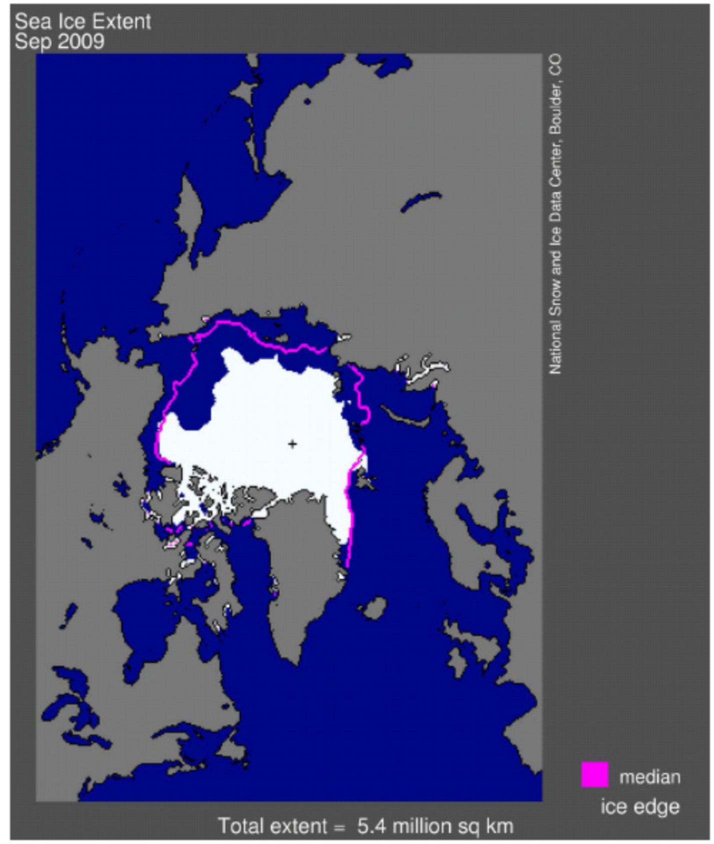


Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009, doi:10.1029/2008JC005237

Arctic sea ice area at warm season minimum

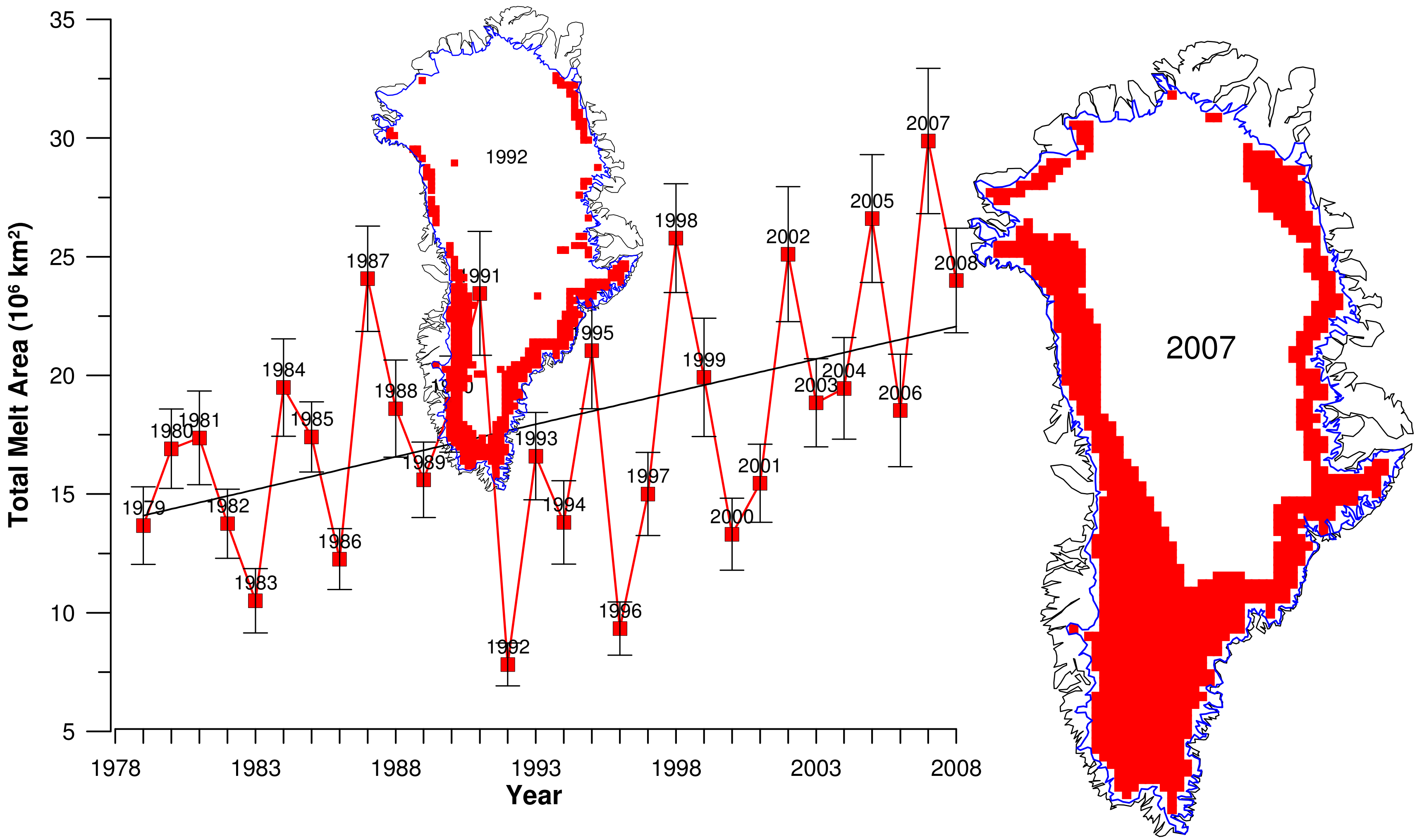




September sea ice extent based on satellite microwave observations

Data source: National Snow and Ice Data Center

Greenland total melt area



Source: Jim Hansen http://www.columbia.edu/~jeh1/ Graph credit: Konrad Steffen, Univ. Colorado

Surface Melt on Greenland

Melt descending
into a moulin,
a vertical shaft
carrying water
to ice sheet base.

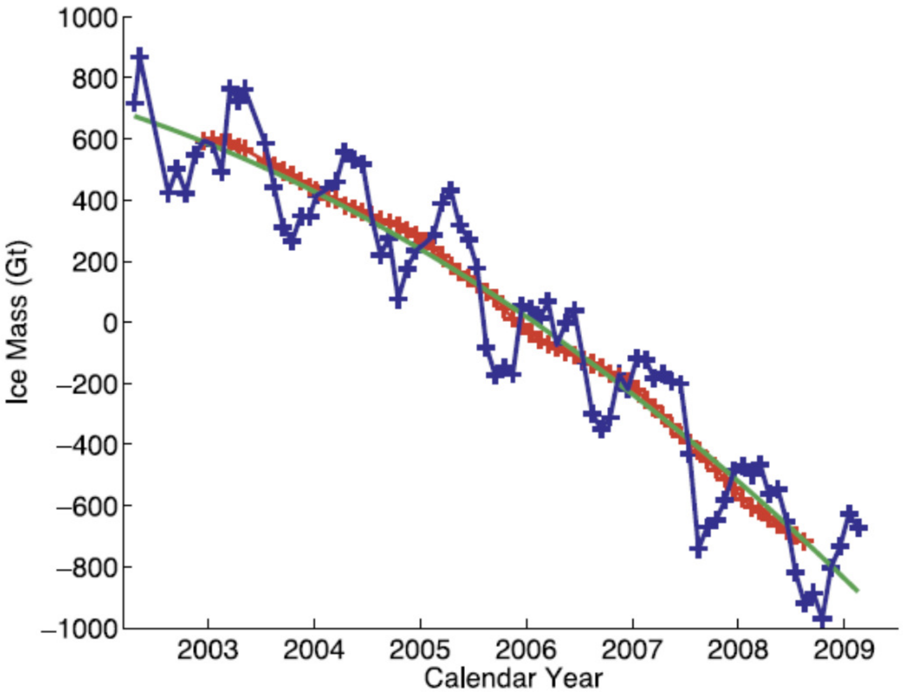
Source: Roger Braithwaite, University of Manchester (UK)

Jakobshavn Ice Stream in Greenland

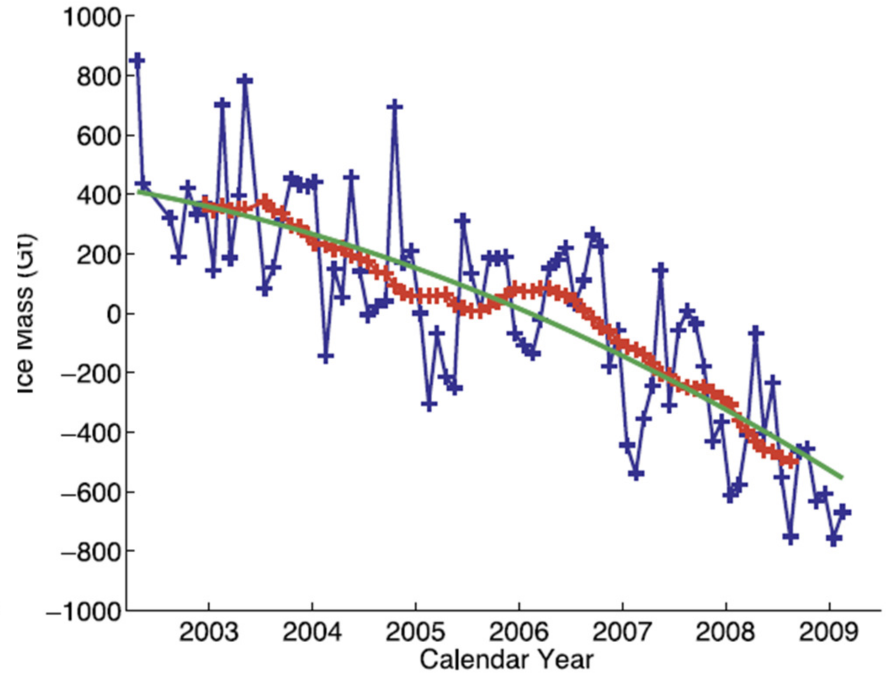
Discharge from major Greenland ice streams is accelerating markedly.

Source: Prof. Konrad Steffen, Univ. of Colorado

Gravity Satellite Ice Sheet Mass Measurements



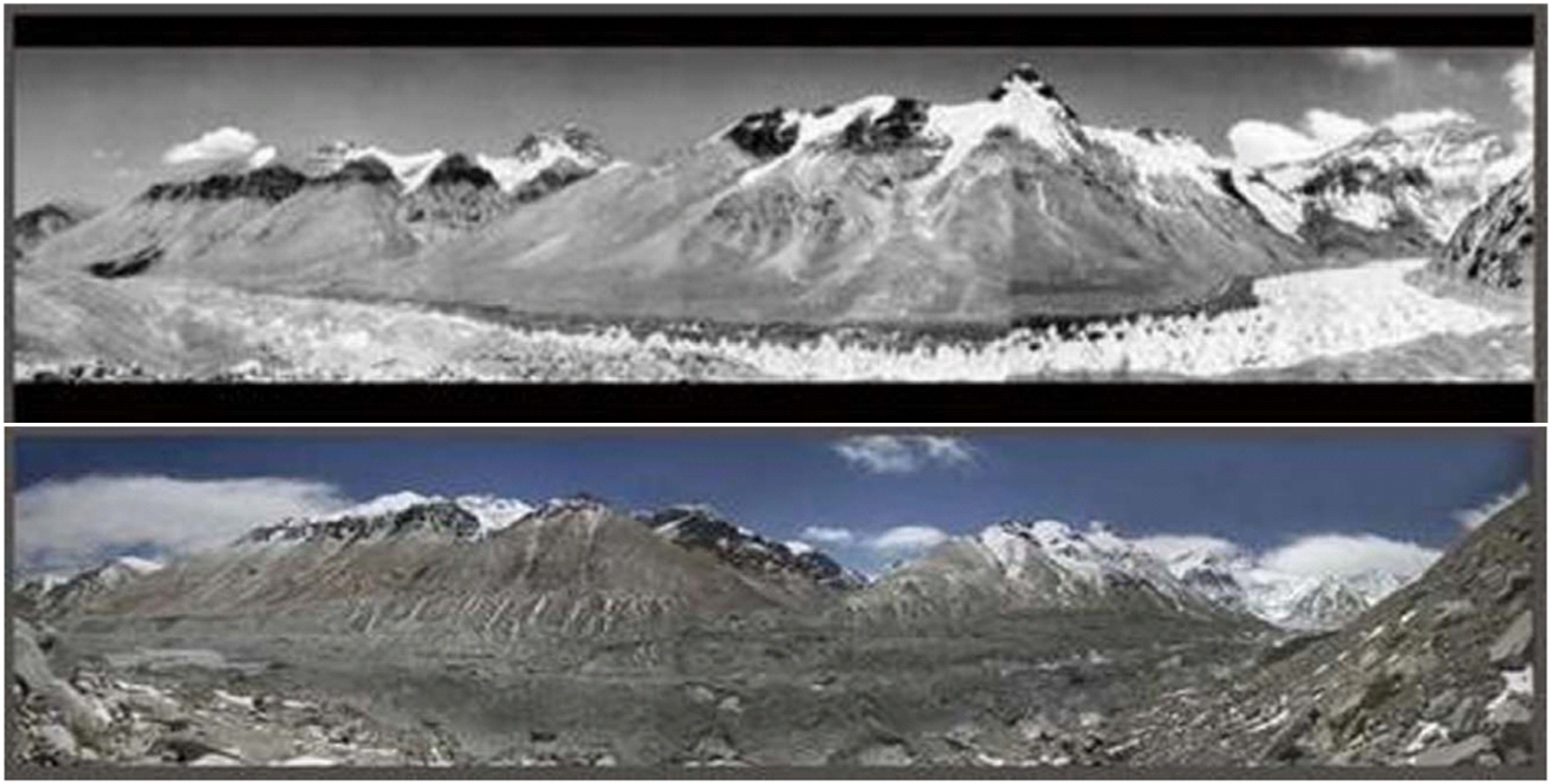
Greenland Ice Sheet



Antarctic Ice Sheet

Source: Velicogna, I. *Geophys. Res. Lett.*, 36, L19503, doi:10.1029/2009GL040222, 2009.

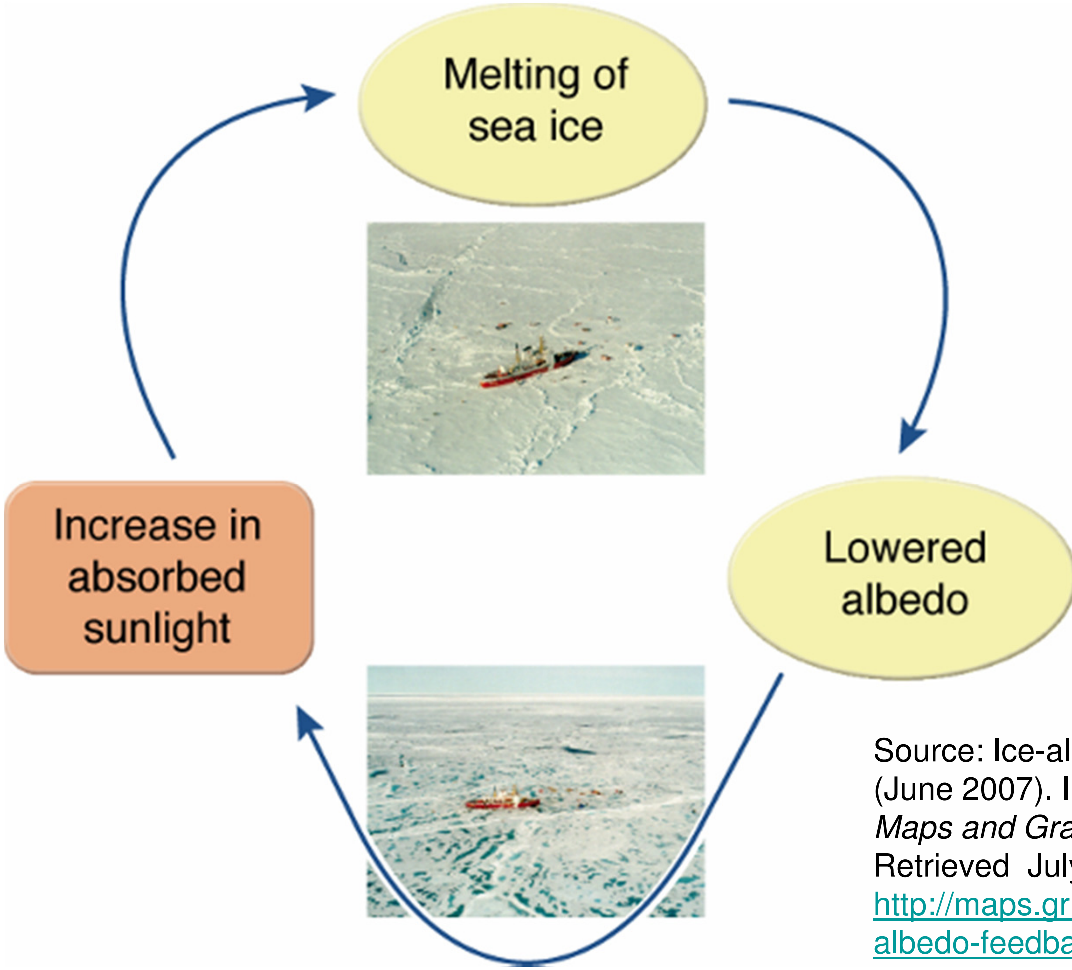
Himalayan (Rongbuk) Glacier



Rongbuk, the largest glacier on Mount Everest's northern slopes, in 1968 (top) and 2007.
Glaciers are receding rapidly world-wide, including the Rockies, Andes, Alps, Himalayas.
Glaciers provide freshwater to rivers throughout the dry season and reduce spring flooding.

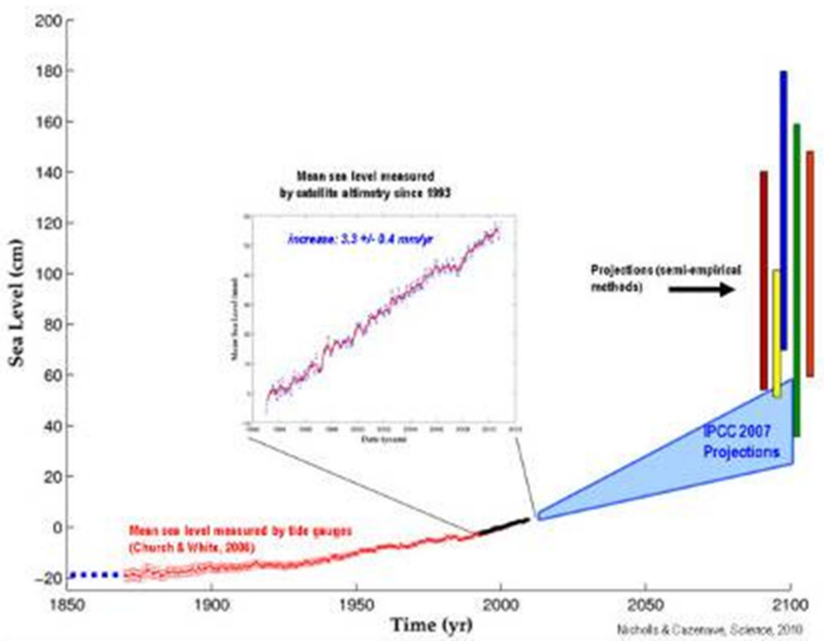
Photos: Chinese Academy of Sciences and Greenpeace/John Novis

Positive feedback



Source: Ice-albedo feedback process. (June 2007). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved July 6, 2011 from http://maps.grida.no/go/graphic/ice-albedo-feedback-process

Sea level rise



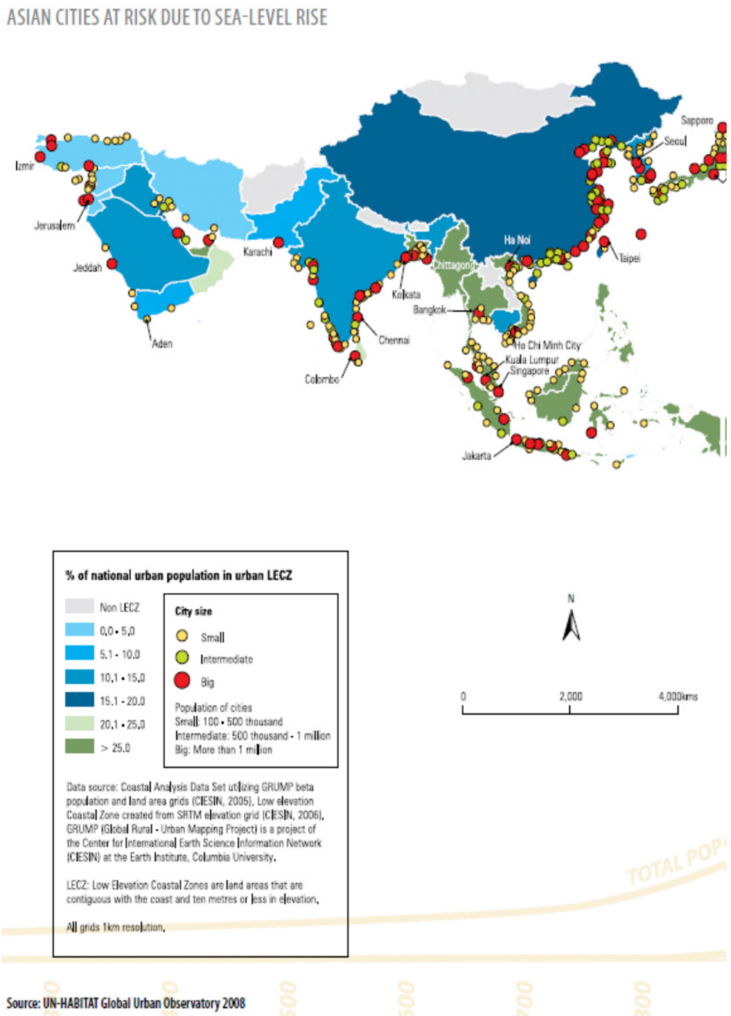
- IPCC 2007 projects 0.18 to 0.59 m sea level rise by 2100
- A further 0.1 to 0.2 m rise possible from increased ice sheet discharge
- An even larger contribution from ice sheets cannot be ruled out

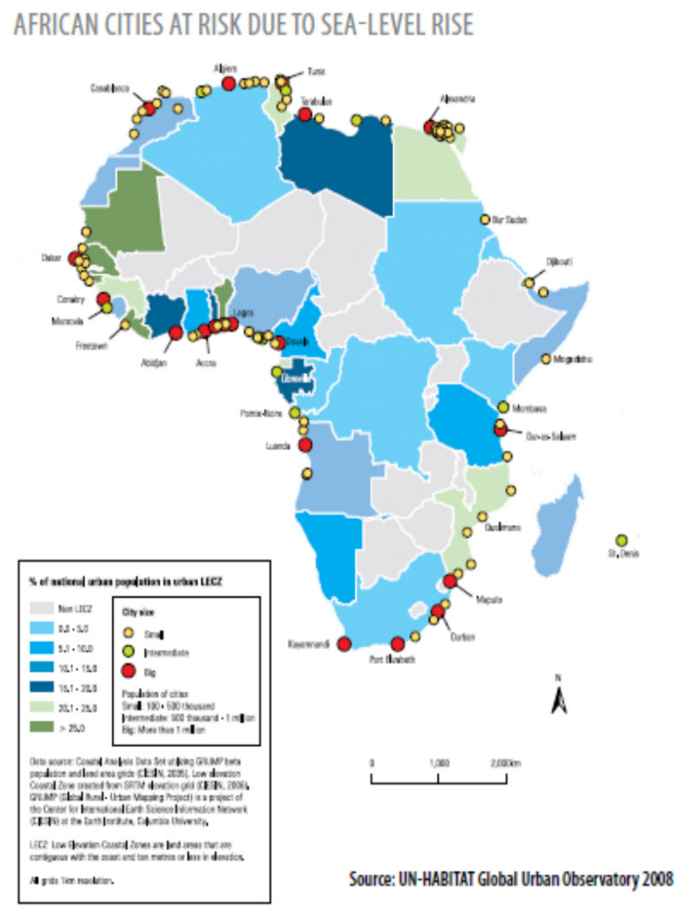
The Arctic as a Messenger of Global Processes, May 2011

- "Arctic snow and ice are melting much faster than expected. This warming has local and global consequences, especially for global sea level rise which is now expected to be greater than previously projected (0.9-1.6 m by 2100)."

http://amap.no/Conferences/Conf2011/programme.html

Cities at risk from sea level rise





Stresses on Coral Reefs

Coral Reef Fiji

Photo credit: Kevin Roland

More drought

Special report: Catastrophic drought in the Amazon
The Independent, 4/2/2011

A widespread drought in the Amazon rainforest last year caused the "lungs of the world" to produce more carbon dioxide than they absorbed, potentially leading to a dangerous acceleration of global warming.

The wrath of 2007: America's great drought, The Independent, 11/6/2007

America is facing its worst summer drought since the Dust Bowl years of the Great Depression. Or perhaps worse still.

Ministers call emergency summit as drought looms
The Independent, 15/5/2011

One of the driest springs on record has sparked fears for agriculture and wildlife, while crews 'work to the point of exhaustion' to battle forest fires

UN warns of severe food crisis in Horn of Africa
The Independent, 29/6/2011

The worst drought in 60 years in the Horn of Africa has sparked a severe food crisis and high malnutrition rates, with parts of Kenya and Somalia experiencing pre-famine conditions, the UN said yesterday.

Drought Stricken Area (1934), Alexandre Hogue.

More floods

Record floods put 20,000 at risk
The Independent, 21/6/2011

More than 40 miles of dykes are in danger of being breached in an eastern Chinese province where floods have caused $1.2bn in losses, authorities said yesterday, as the country neared a critical point in battling seasonal rains.

Residents flee ahead of Mississippi floods, The Independent, 9/5/2011

Residents of Memphis have begun to abandoning low-lying homes as the dangerously surging Mississippi River threatens to crest in coming days just shy of a 48.7ft record set by a devastating flood in 1937.

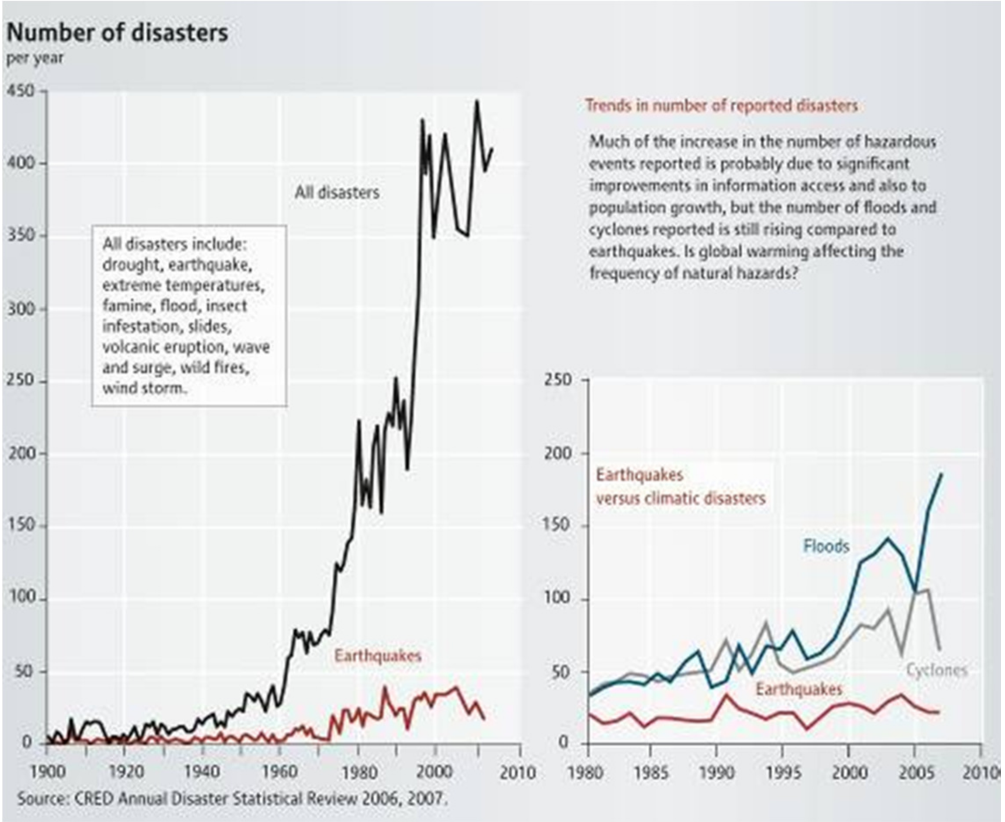
Flooding hits southern Thailand, The Independent, 2/11/2010

Thailand's prime minister today called flooding in the south that has displaced thousands of people "one of the worst natural calamities" to hit the country.

UN: Pakistan floods ravage lives of millions, The Independent, 3/8/2010

The worst floods in memory in Pakistan have devastated the lives of more than three million people, a UN spokesman said today while outrage over the unpopular government's response to its people's plight spreads.

Number of reported disasters

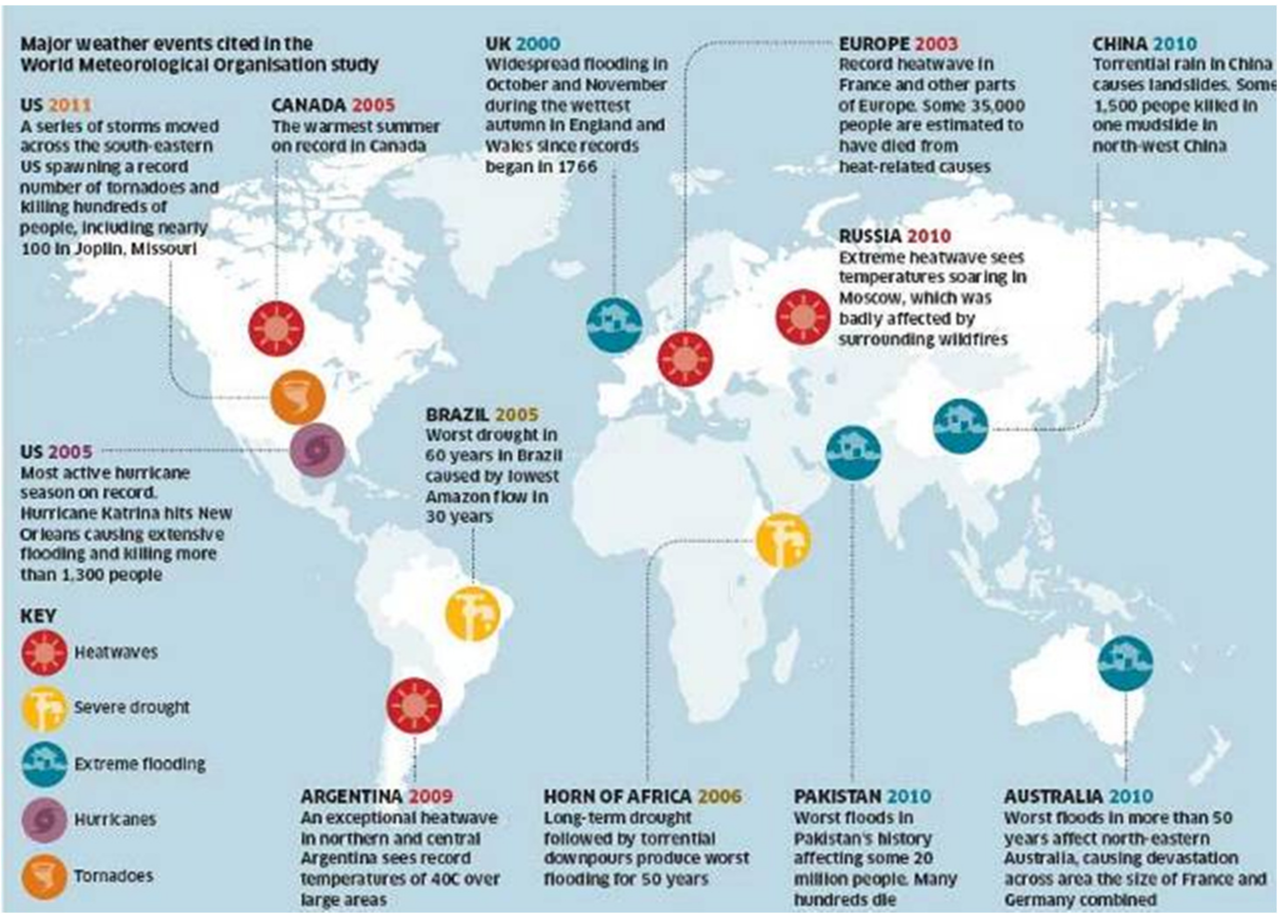


Possible Causes:

- Climate change
- Increased exposure
- Increased reporting

Source: Number of Disasters per Year. (2009). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved July 6, 2011 from http://maps.grida.no/go/graphic/number-of-disasters-per-year.

Extreme weather link 'can no longer be ignored'



Scientists are to end their 20-year reluctance to link climate change with extreme weather – the heavy storms, floods and droughts which often fill news bulletins – as part of a radical departure from a previous equivocal position that many now see as increasingly untenable.

The Independent, 1/7/2011

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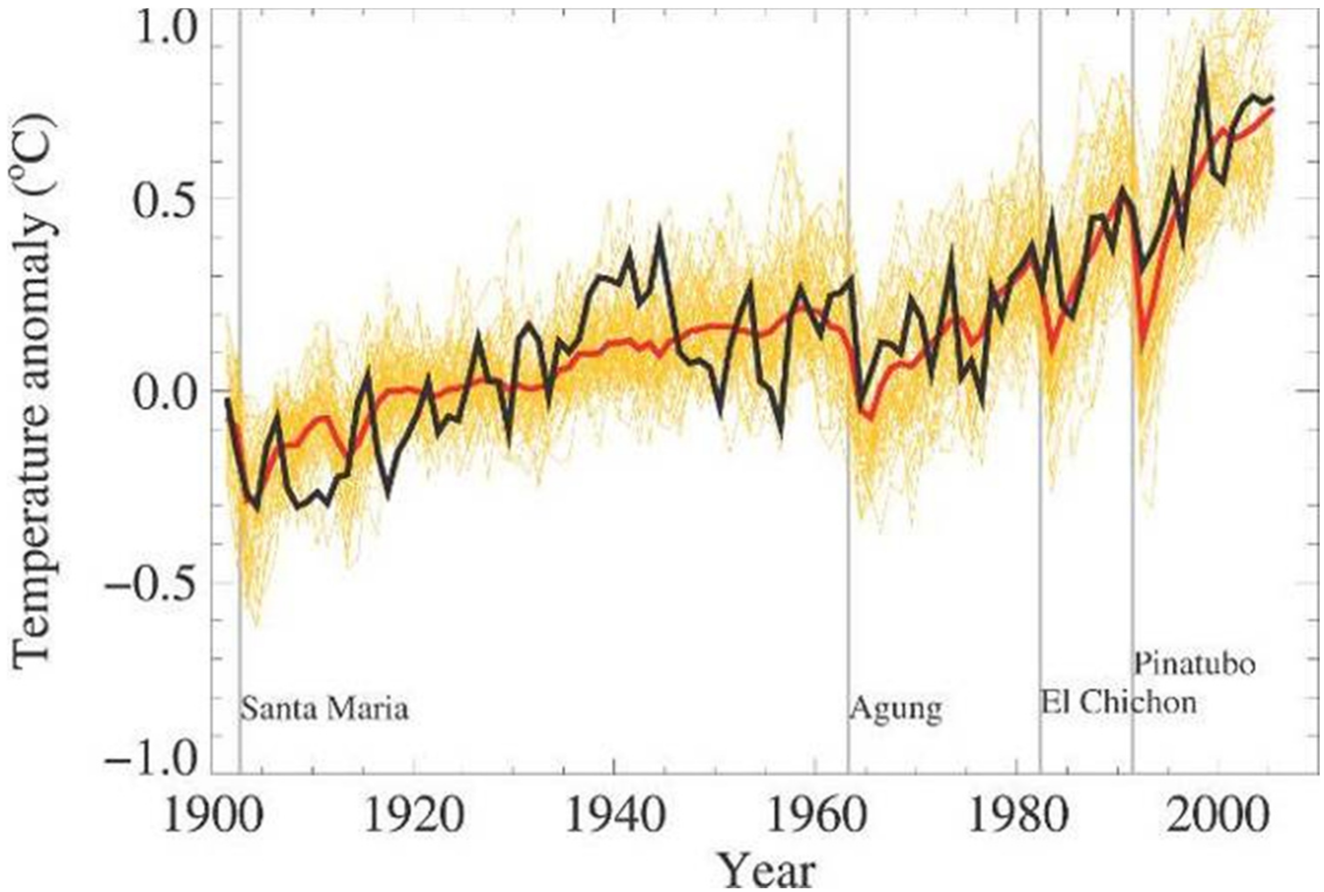
Buzz groups (5 mins)

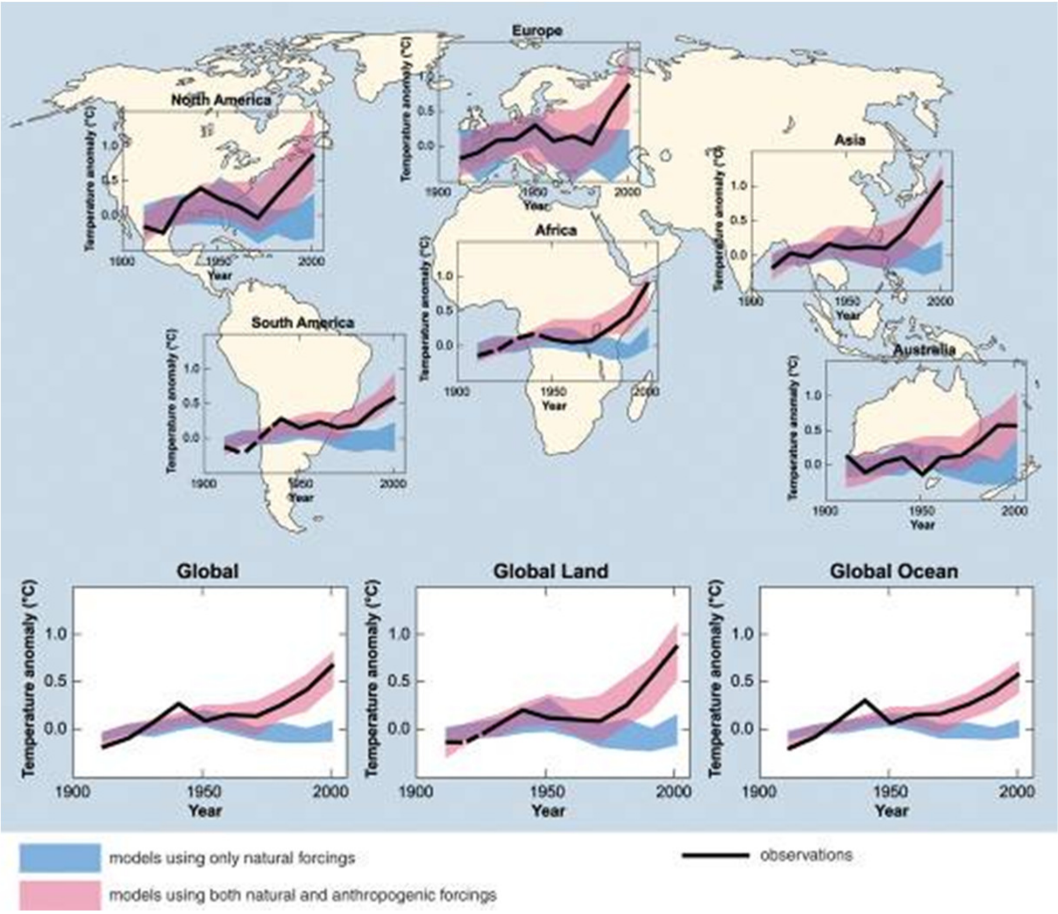
- What climate changes have you observed/experienced, or are aware of?

Reliability of climate models



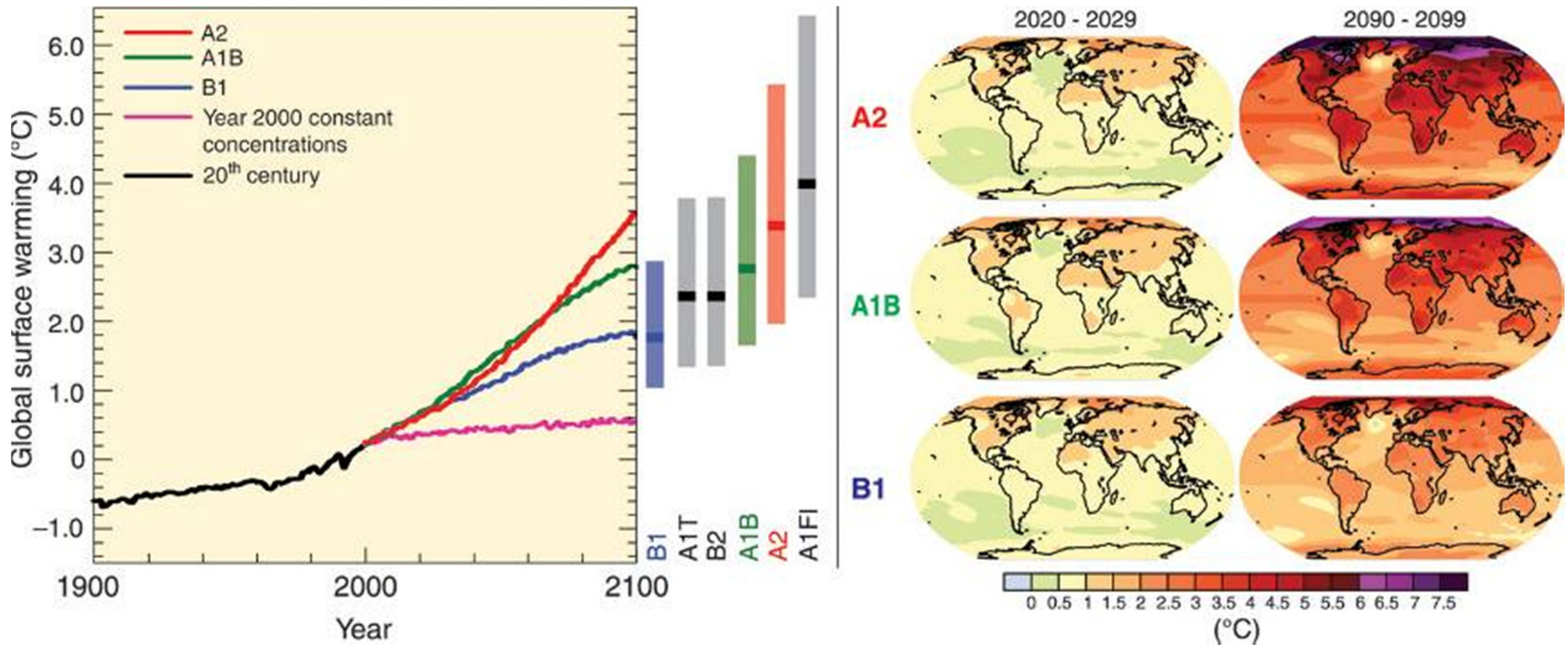
Source: FAQ 8.1, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Is warming due to natural variability?



Source: FAQ 9.2, Figure 1, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

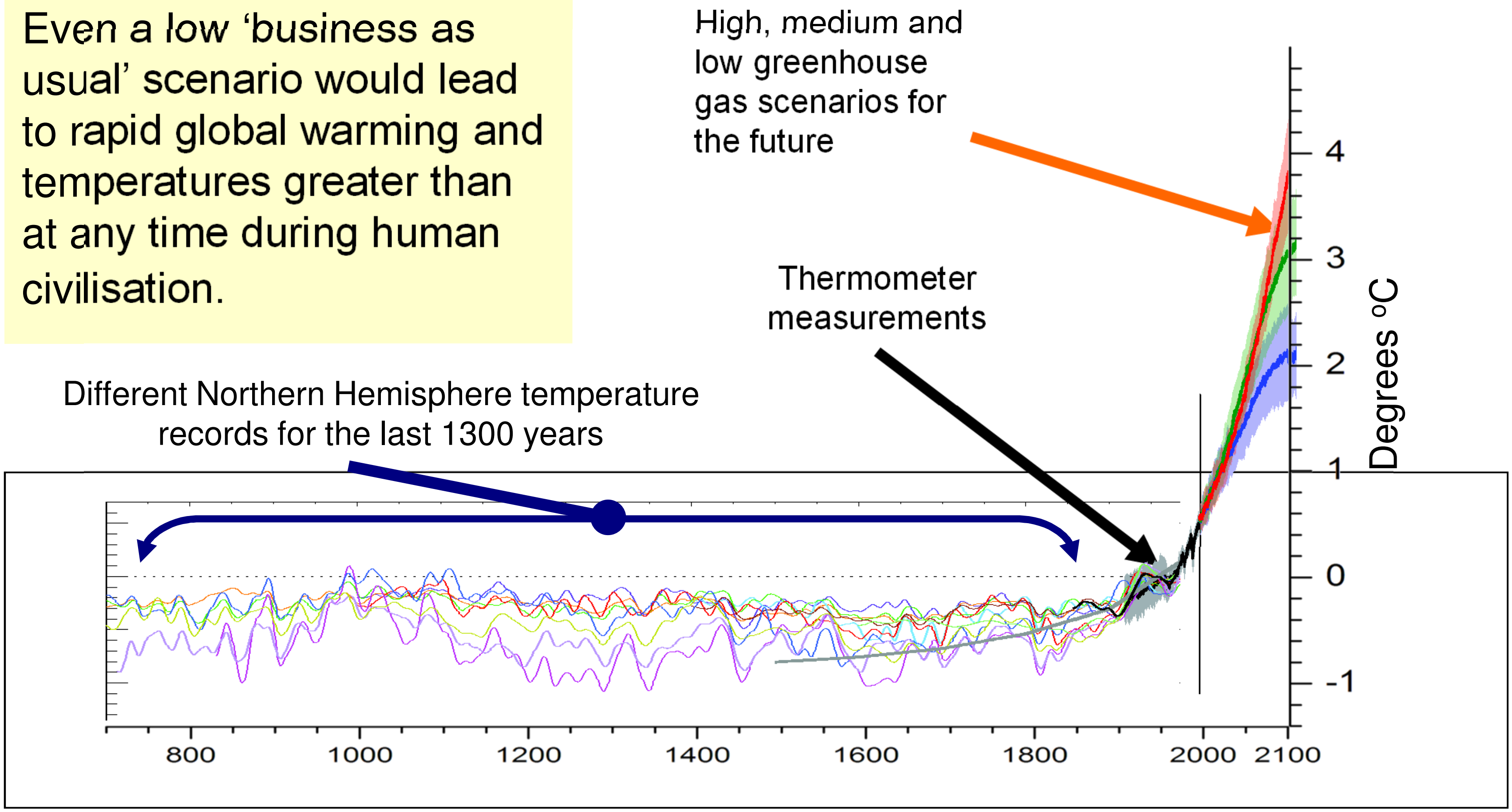
IPCC Projections



Source: Figure 3.2, IPCC Fourth Assessment Report, Climate Change 2007, Cambridge University Press

Future warming in historical context

Even a low 'business as usual' scenario would lead to rapid global warming and temperatures greater than at any time during human civilisation.



Source: Andy Reisinger

Local experiences

A Buddhist Monk stands in front of the Everest Mountain in the Himalayan mountain range.
He holds an empty bucket, symbolizing the loss of water from the region. The Pu Mai village depends on the water source from the Rongbuk Glacier Mount Everest (Qomolangma).

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Preeca Siri, Thailand

He said he has heard about the global warming and climate change because he goes to many meetings about the environment. But his village and himself work on environmental protection so he think that the cause of global warming is human beings.

Luu Chi Kien, Viet Nam

The main reason for higher temperatures is the forest destruction and also because of the mining of coal.

Sonam Chhering Gurung, Nepal

When I was 10 or 12 years old the lake near the Gangapurna Glacier was very small, the glacier was a massive chunk of ice. But now everything is gone. The lake has enlarged massively. The receding of the glacier is progressing leaving the bare rocks behind.

Alfredo, Italy

I want to believe that maybe for the generation for my son, maybe some change. Maybe one day some change. The human race is not stupid like that and maybe one day say ‘stop it’… and some change…

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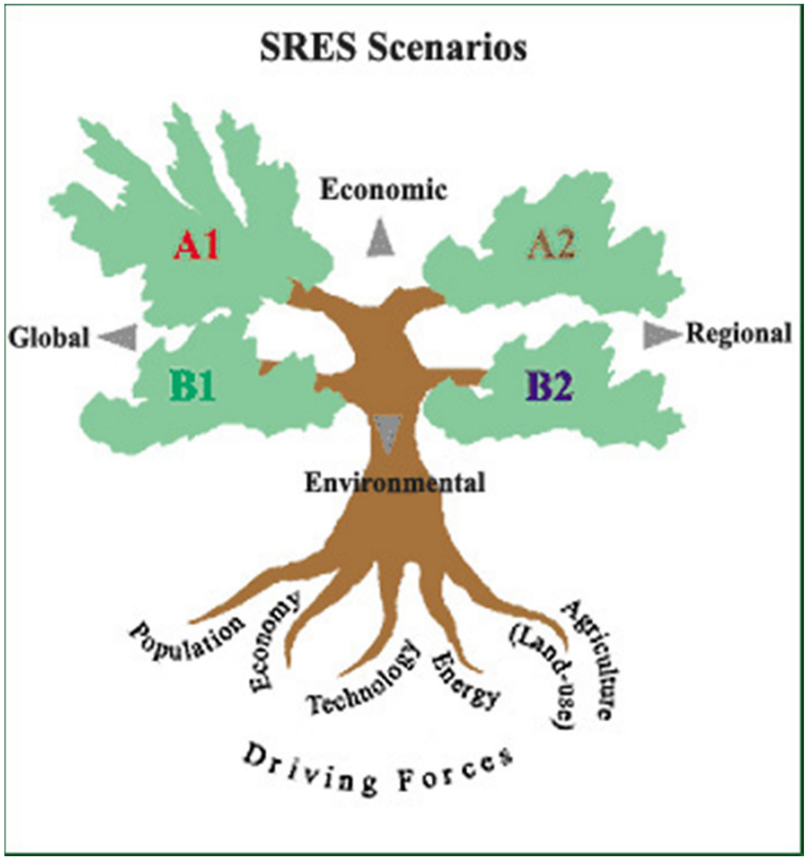
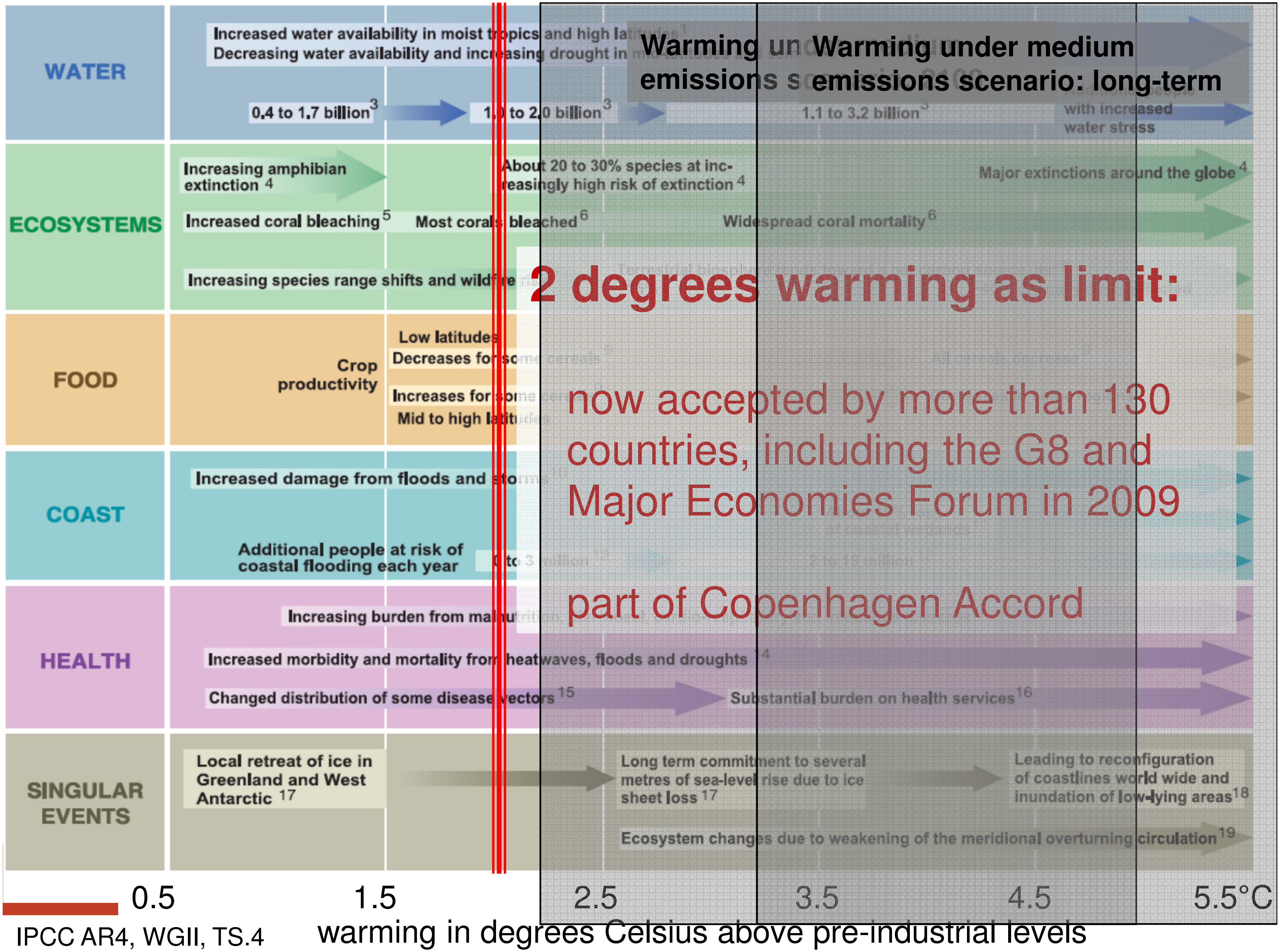
What’s in a number: 350ppm or 450ppm?



Source: IPCC



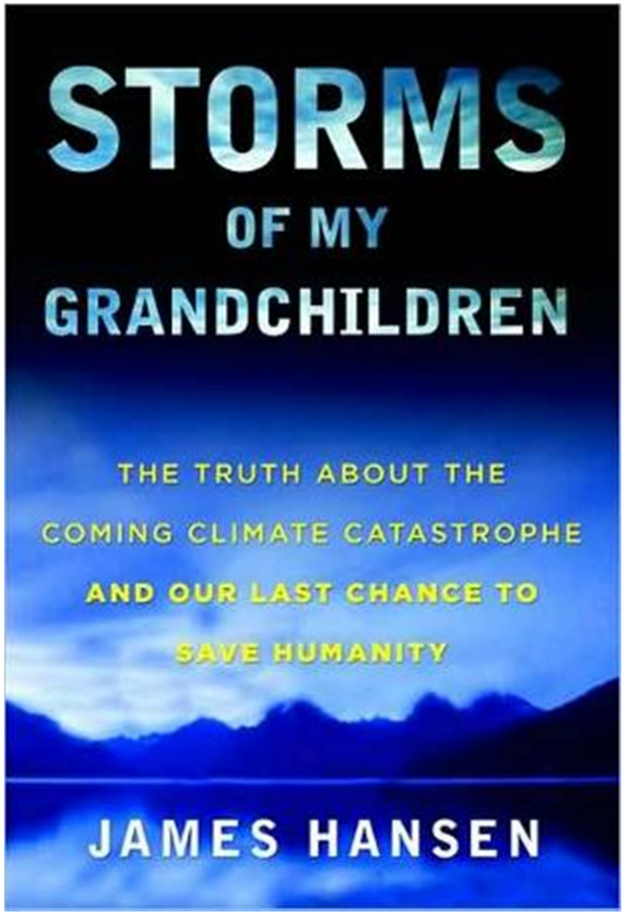
IPCC AR4, WGII, TS.4

Concentration targets

What concentration of GHGs gets us to 2°C?

- 450ppm CO_2-equivalent concentrations result in warming of 2°C as the best estimate …
- … but climate science is uncertain: 450ppm could result in warming between 1.4 and 3.1°C …
- … so there is a roughly 50% chance that warming could exceed 2°C even if we stabilise concentrations at 450ppm

Jim Hansen



- Heads the NASA Goddard Institute for Space Studies in New York City
- Since the late 1970s, he has focused his research on Earth's climate, especially human-made climate change
- Designated by Time Magazine in 2006 as one of the 100 most influential people on Earth

Jim Hansen's assessment

Assessment of Target CO_2

Phenomenon	Target CO_2 (ppm)
1. Arctic Sea Ice	300-350
2. Ice Sheets/Sea Level	300-350
3. Shifting Climatic Zones	300-350
4. Alpine Water Supplies	300-350
5. Avoid Ocean Acidification	300-350

→ Initial Target CO_2 = 350* ppm

*assumes CH_4, O_3, Black Soot decrease

Jim Hansen's assessment

Target CO_2:

< 350 ppm

To preserve creation, the planet on which civilization developed

What it means for SIDS

- A 450ppm target gives a high chance of significant impacts on SIDS
- Global sea-level rise of above 1m by 2100 is increasingly a possibility
- More extreme events
  - Extreme rainfall
  - Extreme temperatures/drought

Climate change in Mauritius

The current state of knowledge

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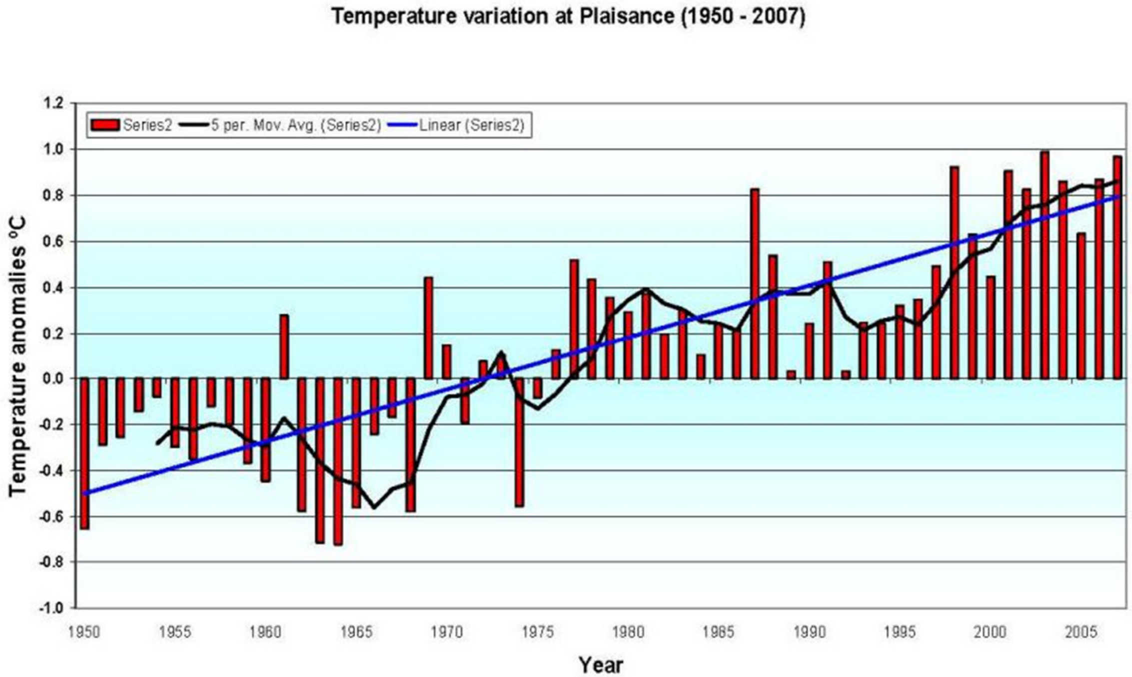
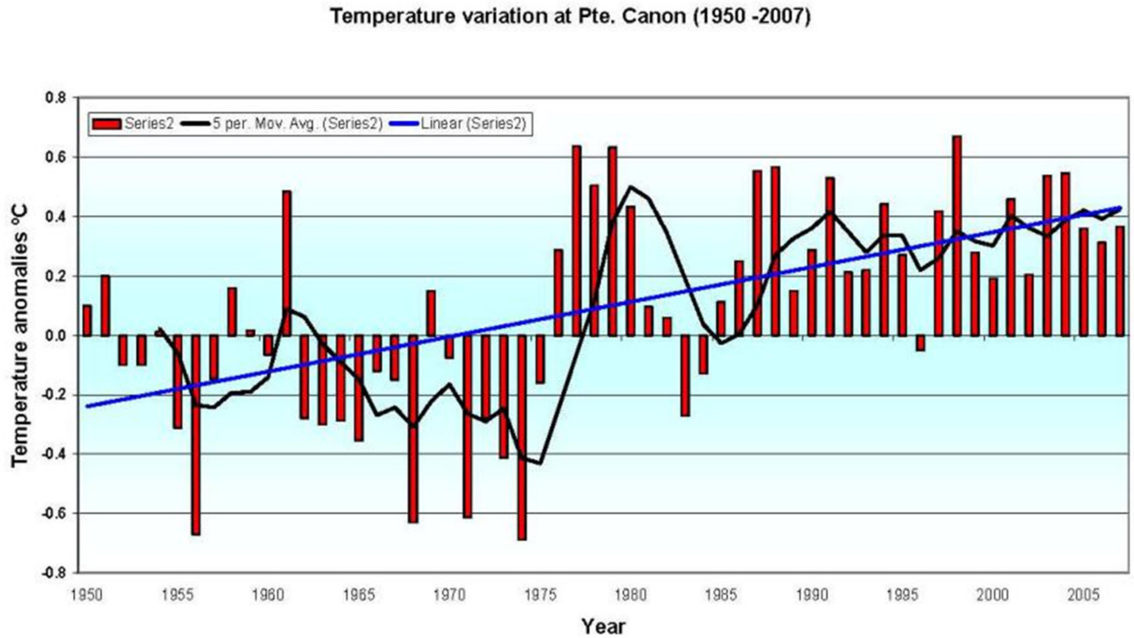
Recorded temperature changes



Average temperature at Vacoas and Plaisance during the last ten years (1998-2008) was higher than that of the decade 1951- 60 by 0.74 and 1.1 ˚C respectively.

Source: Meteorological Services, Mauritius

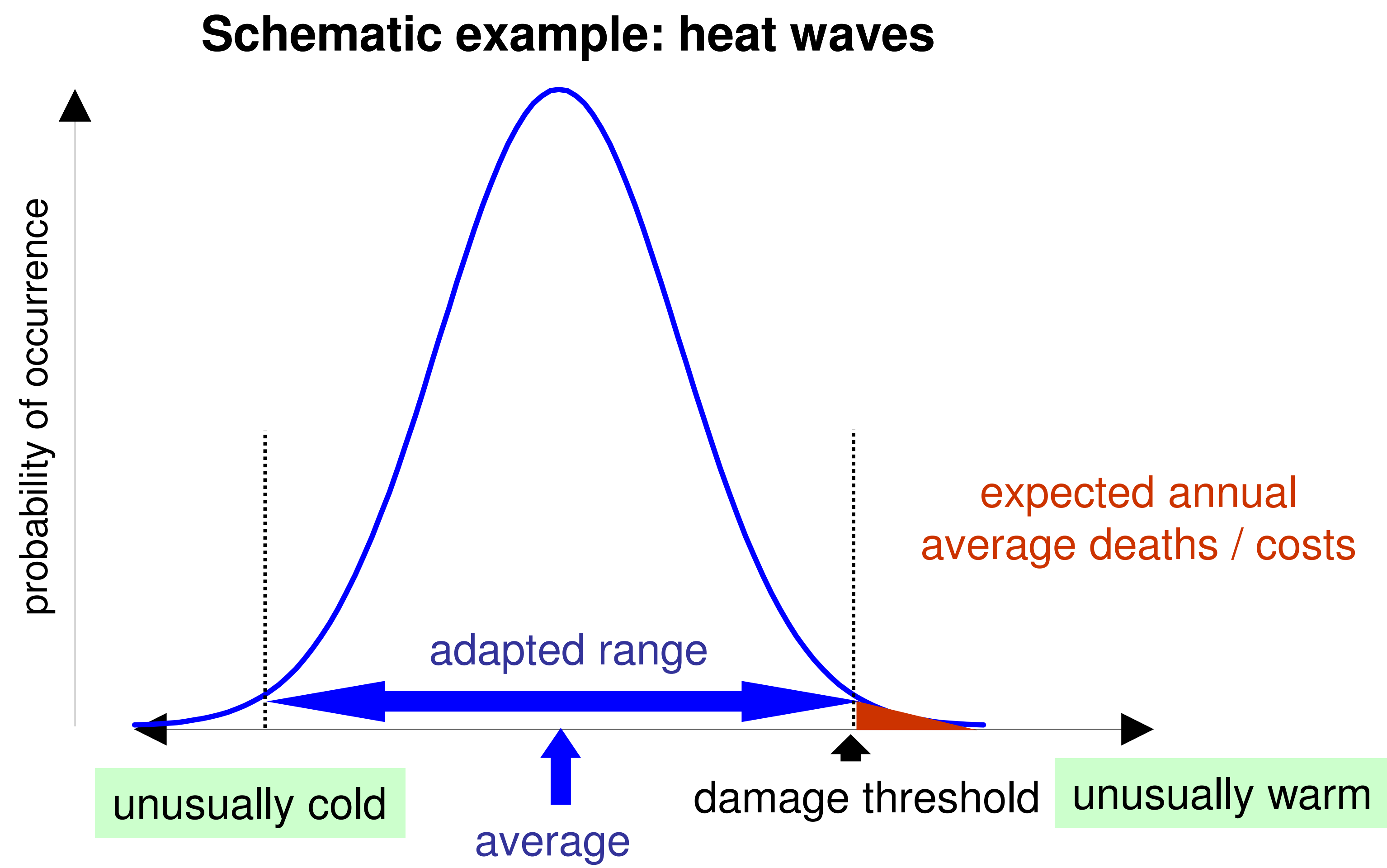
Recorded temperature changes



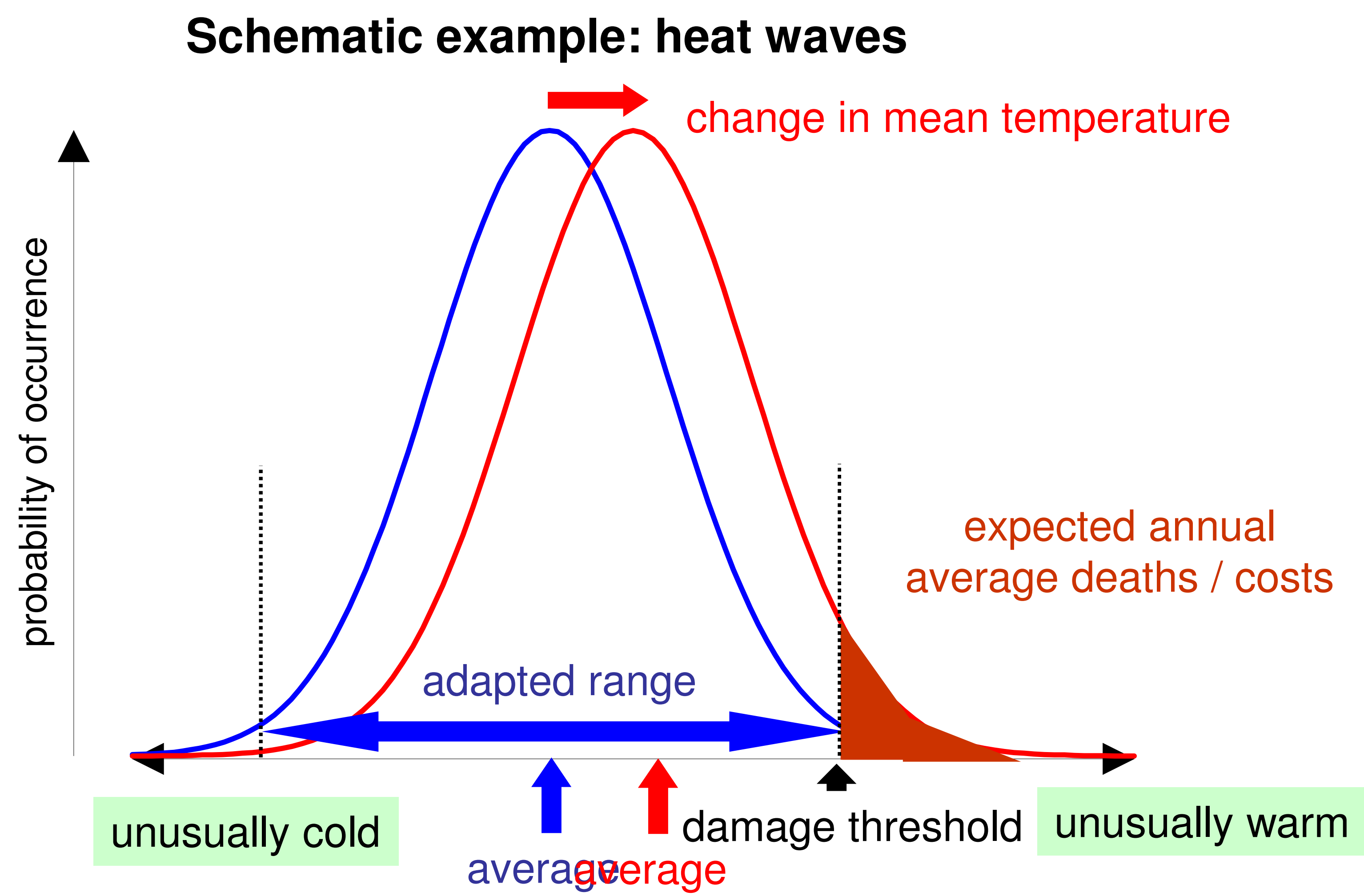
Similar warming trends were also observed at Rodrigues, St Brandon and Agalega, where the temperature rise is in the range of 0.5 to 1.0 ˚C

Source: Meteorological Services, Mauritius

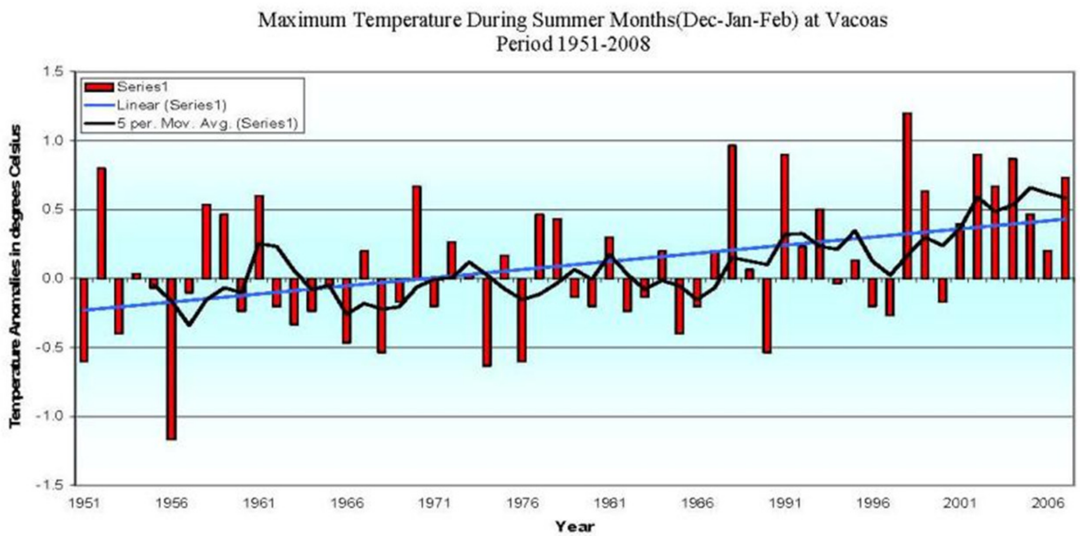
Changes in averages and extremes



Changes in averages and extremes



Changes in extremes



At Vacoas during the last ten years summer maximum temperatures became warmer by an average of 1.0 ˚C. By all comparisons of temperatures the summer of 2008 – 2009 was a unique one: day time maxima stayed between 33 – 34 ºC almost continuously for weeks.

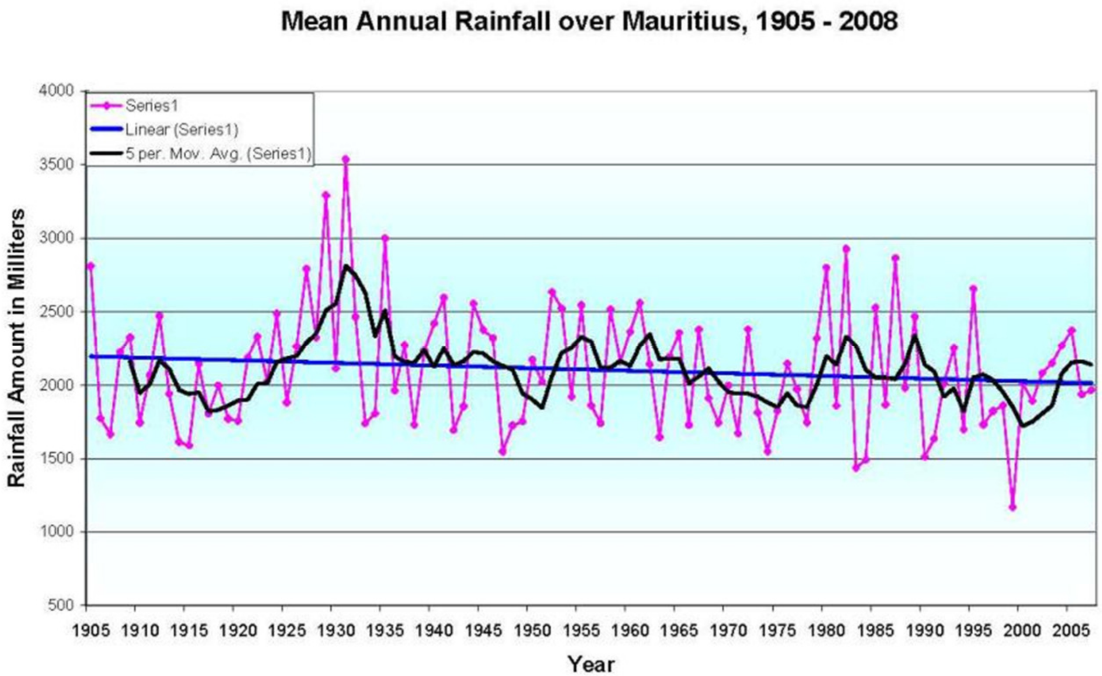
Source: Meteorological Services, Mauritius

Sea level rise

The mean sea level rise during the past decade (1998-2007) was 2.1 mm/yr at Port Louis. Tide gauge data from Rodrigues gives values of the same order of magnitude. Although these findings are consistent with IPCC conclusions, longer period of measurements are necessary for reliable conclusions.

Source: Meteorological Services, Mauritius

Rainfall changes



Long-term time series of rainfall amount over the past century (1905 to 2008) show a decreasing trend in annual rainfall over Mauritius.

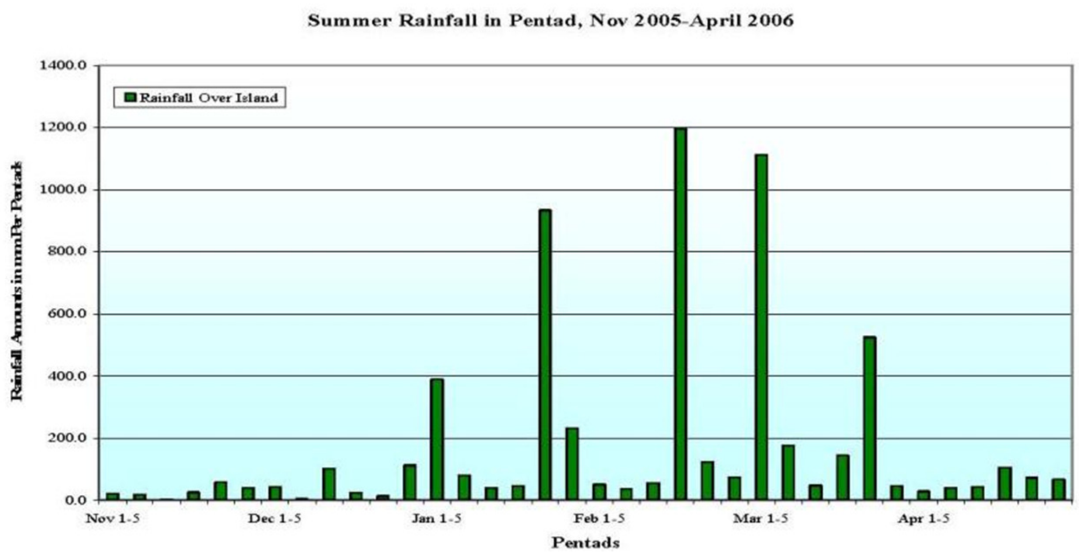
Source: Meteorological Services, Mauritius

Duration of dry months

The duration of the intermediate dry months, the transition period between winter and summer, is becoming longer.

Photo: http://www.valley-ae.com

Rainy days and rainfall intensity

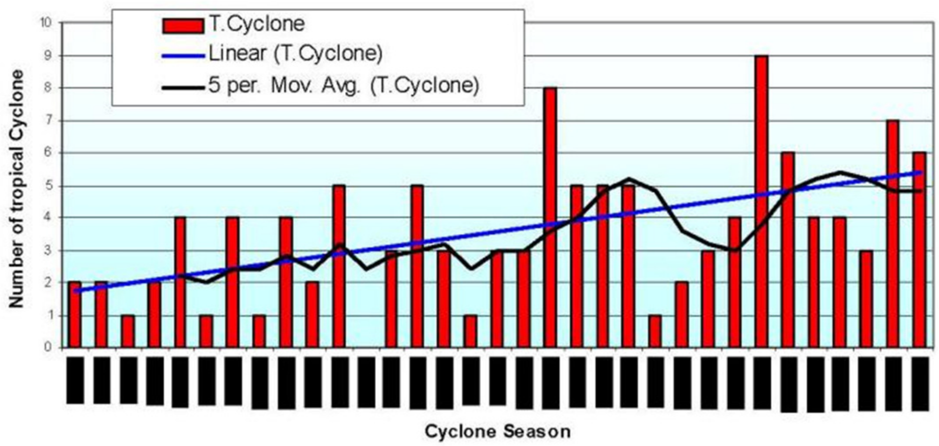


The number of rainy days has decreased but the frequency of heavy rainfall events has increased.

While in the old days, most of the summer rains resulted from cyclones, since the past five or so years summer rains have been harvested outside cyclones.

Source: Meteorological Services, Mauritius

Tropical cyclones



Analysis of data from Mauritius Meteorological Services does not show any increase in the number of storms in the South West Indian Ocean basin (SWIO).

However, decadal plot of the number of storm formations over the last 32 years (1975- 2008) clearly shows the increasing trend in the number of intense cyclone (winds above 165 km/hr).

Source: Meteorological Services, Mauritius

Recent climate trends
UNDP Climate Change Country Profile

Temperature

- Mean annual temperature has increased by 0.6℃ since 1960, an average rate of 0.13℃ per decade.
- This increase in temperature is most rapid in JFM (0.16℃ per decade) and least rapid in OND (0.10℃ per decade).
- There is insufficient daily temperature data available from which to determine trends in daily temperature extremes.

Source: McSweeney et al. UNDP Climate Change Country Profile

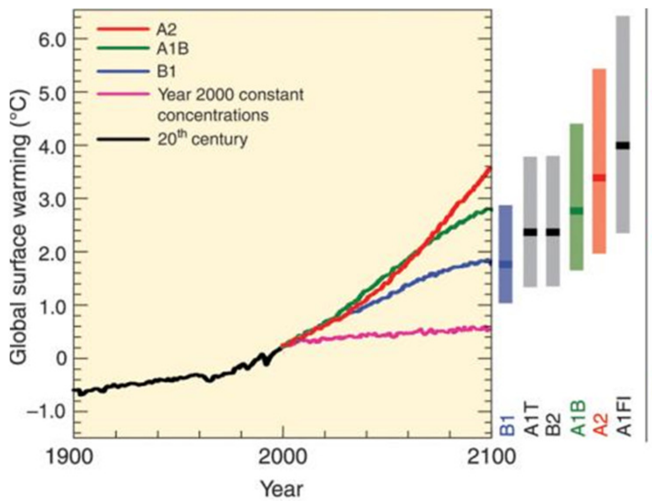
Recent climate trends
UNDP Climate Change Country Profile

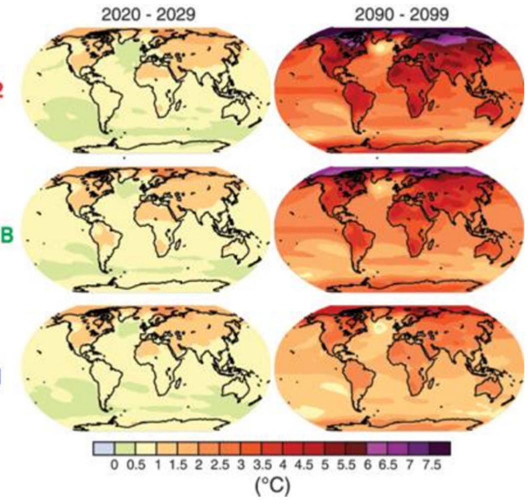
Precipitation

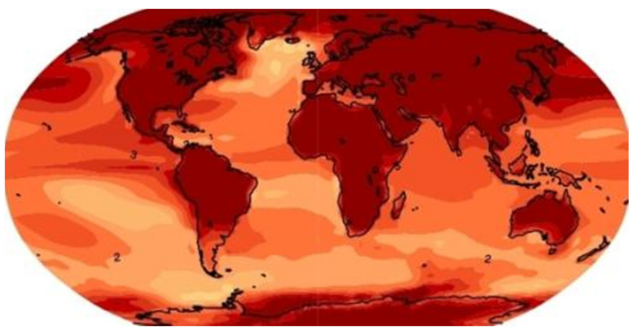
- The large inter-annual and inter-decadal variations in rainfall in this part of the world mean that it is difficult to identify long term trends. Whilst there is no evident trend in annual rainfall, OND rainfall has declined over the period 1960 to 2006, at an average rate of 7.7mm per month (8.7%) per decade.
- There are insufficient daily rainfall observations available to identify trends in daily rainfall extremes.

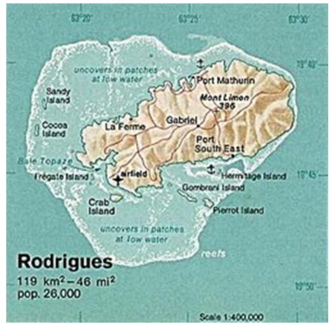
Source: McSweeney et al. UNDP Climate Change Country Profile

Projected changes

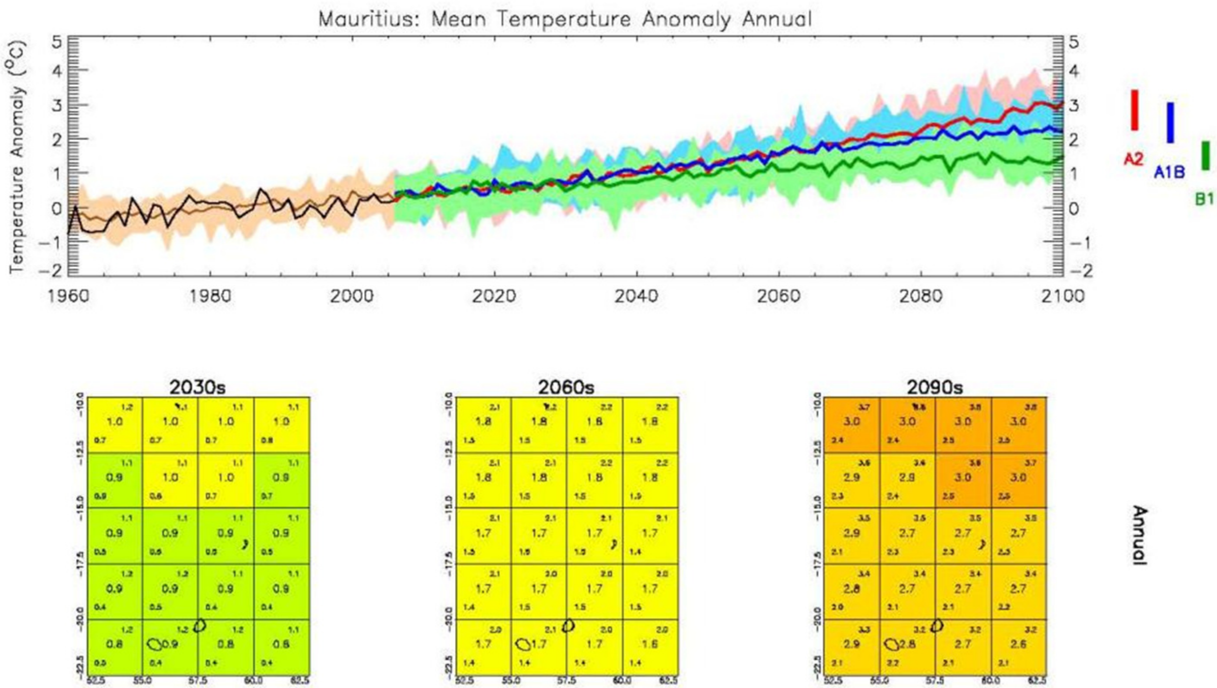








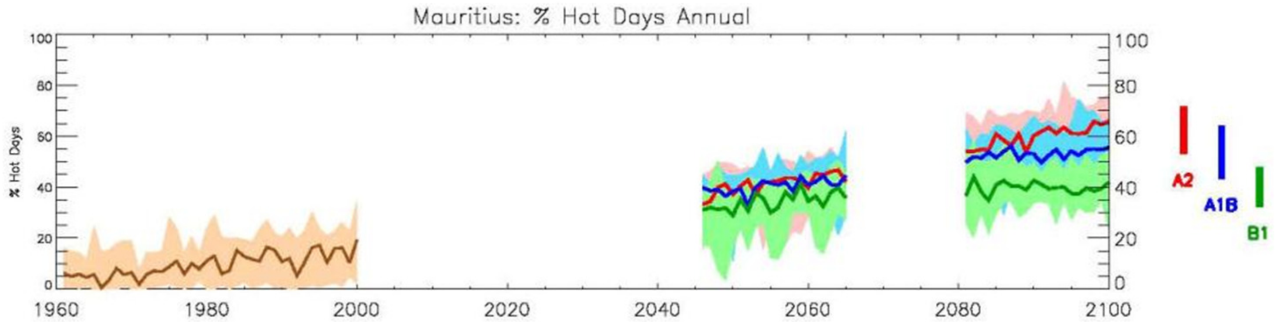
Projected temperature changes



- The mean annual temperature is projected to increase by 1.0 to 2.0℃ by the 2060s, and 1.1 to 3.4℃ by the 2090s.
- The range of projections by the 2090s under any one emissions scenario is 1.0-1.5℃.

Source: McSweeney et al. UNDP Climate Change Country Profile

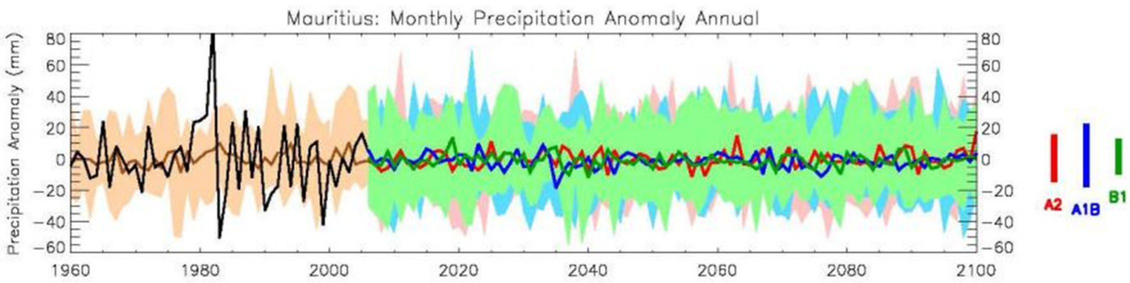
Projected changes in ‘hot’ days



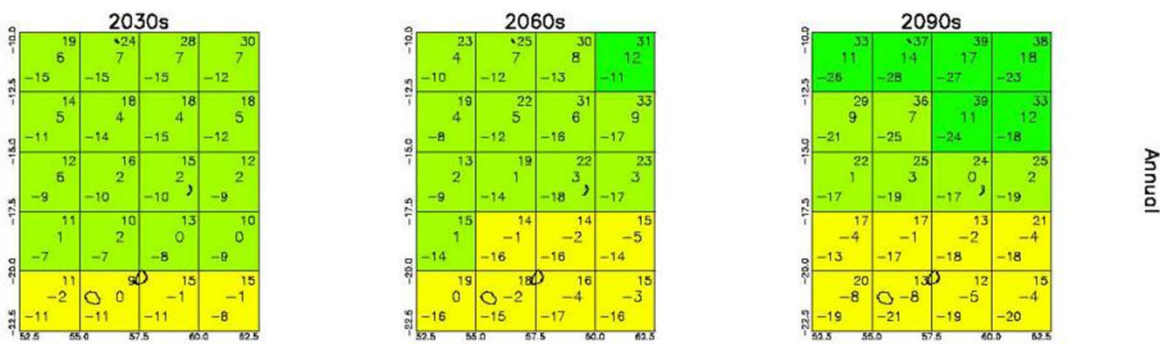
- All projections indicate substantial increases in the frequency of days and nights that are considered ‘hot’ in current climate.
- Annually, projections indicate that ‘hot’ days will occur on 29-48% of days by the 2060s, and 33-71% of days by the 2090s. Days considered ‘hot’ by current climate standards for their season are projected to occur on up 100% of days in JFM and JAS by the 2090s.

Source: McSweeney et al. UNDP Climate Change Country Profile

Projected rainfall changes

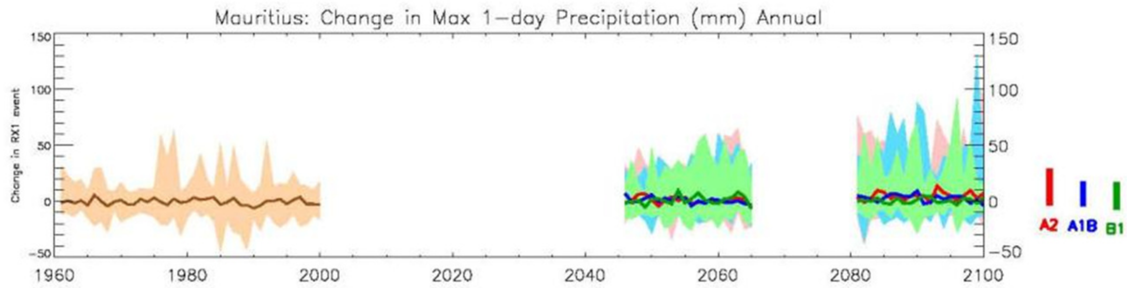


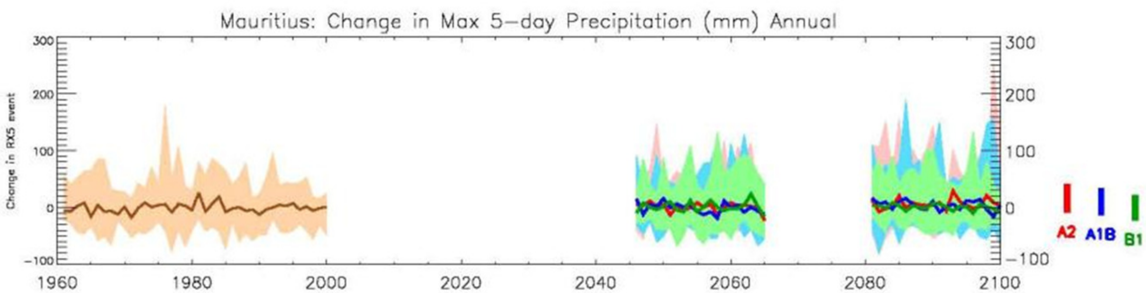
The range of projections in mean annual rainfall from different models is large and straddles both negative and positive changes (-20% to +24%), with ensemble median changes close to zero.



Source: McSweeney et al. UNDP Climate Change Country Profile

Projected changes in rainfall extremes





- The projections of change in the proportion of rainfall that falls in heavy events range between both increases and decreases.
- The models are broadly consistent in indicating overall increases in 1- and 5-day rainfall maxima by the 2090s.

Source: McSweeney et al. UNDP Climate Change Country Profile

Projected changes in tropical cyclones

- Tropical cyclones are poorly captured by GCMs and thus potential changes in intensity and tracks of tropical cyclones in the future are very uncertain.
- The uncertainty in potential changes in tropical cyclones contributes to uncertainties in future wet-season rainfall.

Source: McSweeney et al. UNDP Climate Change Country Profile

Projected sea-level rise

- Sea level in this region is projected by climate models to rise by the following levels by the 2090s, relative to 1980-1999 sea level:

  0.13 to 0.43m under SRES B1

  0.16 to 0.53m under SRES A1B

  0.18 to 0.56m under SRES A2

Source: McSweeney et al. UNDP Climate Change Country Profile

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Projected sea-level rise caveat

- The possibility of a sea level rise of up to 1m, or possibly even more, by 2100 cannot be excluded based on current evidence
- This is due to continued uncertainty regarding the West Antarctic and Greenland ice sheets

Climate changes – summary

- More frequent heat waves in summer
- Milder winters
- Uncertain changes in average rainfall
- The possibility of increased frequency of heavy precipitation events
- The possibility of increased duration of dry spell
- Uncertainty regarding changes with tropical cyclones
- Storm surges, flooding and inundation as a result of sea-level rise