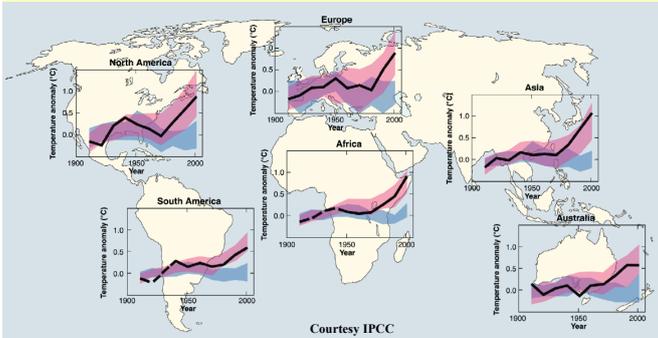


Climate Change & Global Warming

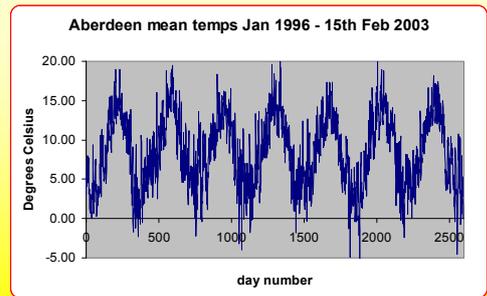


A topic of the times

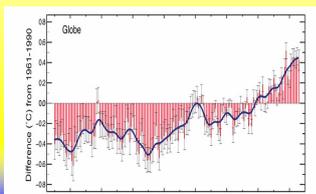
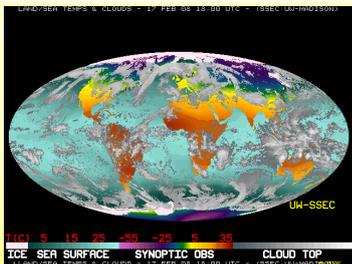


Do we notice Global Warming?

Daily events don't show up global warming



How do we find the facts?



- Satellites
 - past 30 years
- Temperature records
 - past 250 years
 - need well-calibrated data
- Proxies
 - further back

Courtesy: IPCC

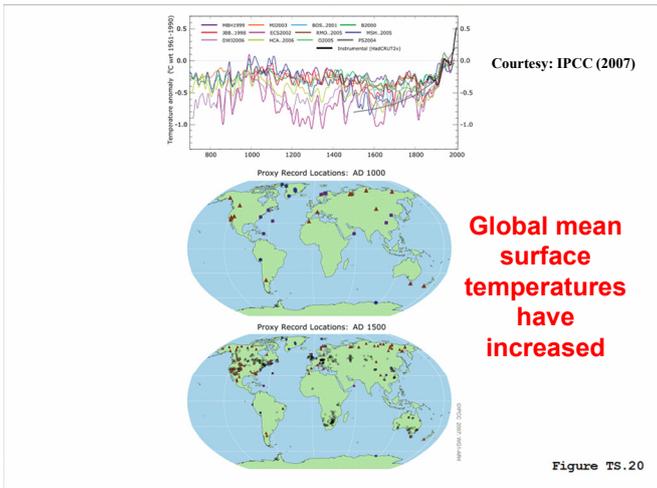
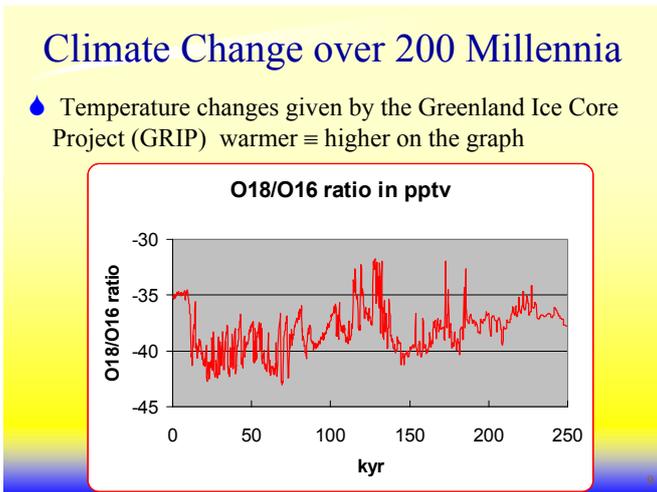
Proxies



- Proxies
 - plant growth (e.g. tree rings)
 - coral growth
 - relative abundance of species
 - relative abundance of isotopes in deposits
- Few proxies depend on temperature alone



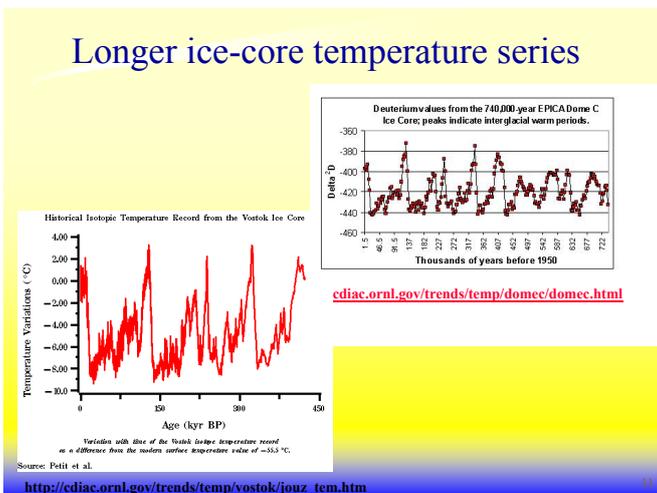
6

A Table of Climate Related Measurables from Ice Cores

Courtesy USGS →

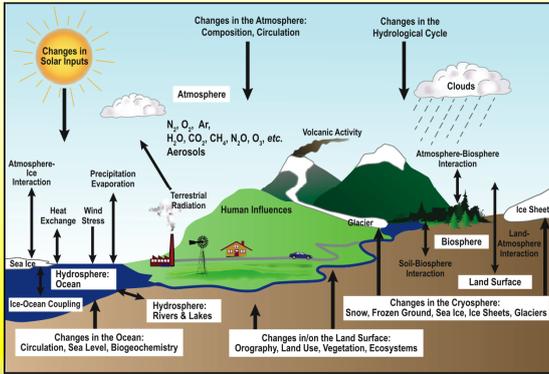
CO ₂ , CH ₄	Greenhouse gases
SO ₂ , ash	Volcanic eruptions
¹⁰ Be, ³⁶ Cl	Solar activity
¹⁸ O/ ¹⁶ O	Temperature
thickness	Precipitation
dust	Wind speed
anions/cations	Atmospheric circulation



Climate change conclusions

- There have been large fluctuations in global temperatures over very long timescales from natural causes
 - are there hidden patterns? Patterns point to causes. There are some patterns
- Some possible direct causes:
 - variation in the parameters of the Earth's orbit around the Sun (this variation does contribute definite climate patterns and is the strongest single effect changing climate)
 - the effect of plate tectonics and volcanoes on the climate
 - variation in the Sun's total output (this aspect is more subtle than you might think. Obvious light output of the Sun is astonishingly stable)

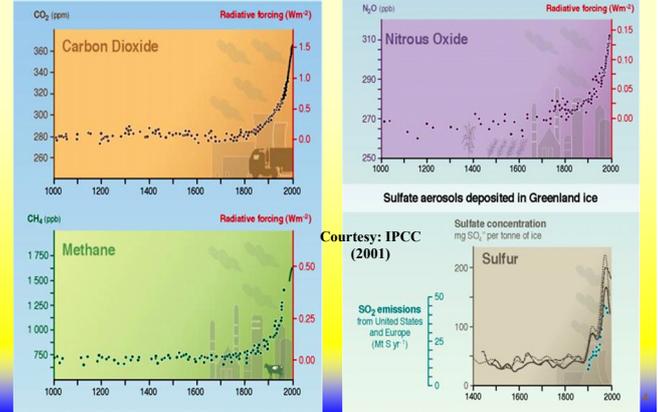
An overview of the climate system



Courtesy: IPCC 2007

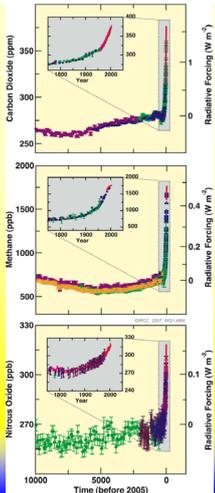
13

Human activities have changed the composition of the atmosphere since the pre-industrial era



Long-term greenhouse gas changes

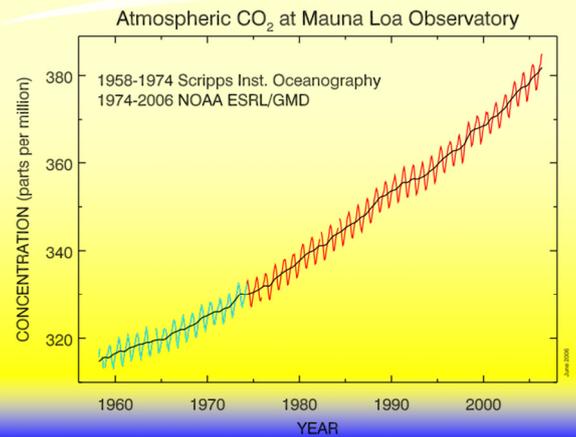
- 10,000 years of concentrations of CO₂ (carbon dioxide), CH₄ (methane) and NO (nitrous oxide) from ice-core measurements
- inserts show changes since 1750
- radiative forcings on right-hand side



Courtesy IPCC AR4

15

Focus on CO₂ trends

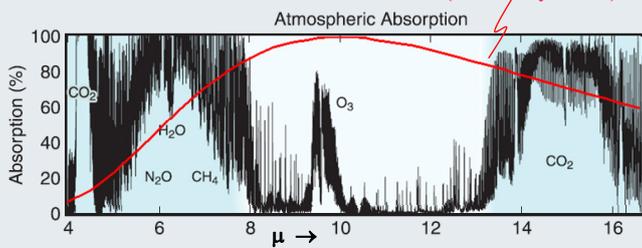


16

IR absorption spectra

- The peak emission of IR from the Earth is at about 10 μ wavelength

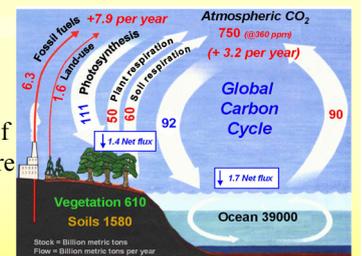
Earth's IR emission (blackbody 291 K)



17

The Carbon Cycle

- The natural exchange of CO₂ between atmosphere and biosphere is > 100 Gtonnes yr⁻¹
- this is known as the carbon cycle



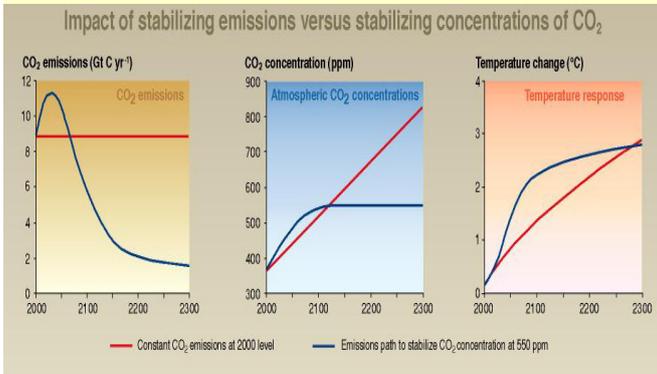
Courtesy http://www.globalchange.umich.edu/globalchange1/current/lectures/king/carbon_cycle/carbon_cycle_new.html

- Mankind's production of 8 G tonnes CO₂ per year is a small fraction
- about 5 G Tonnes yr⁻¹ is absorbed

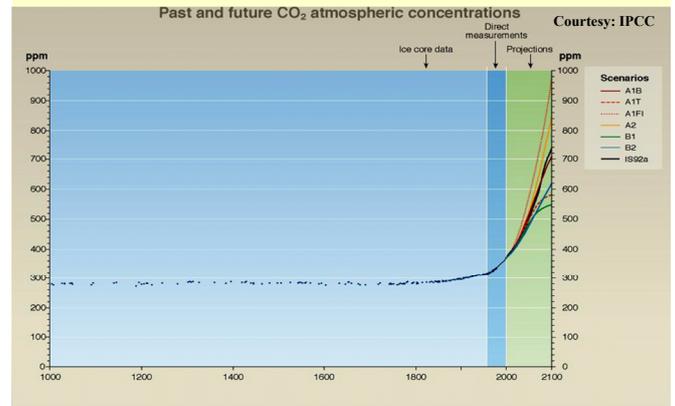
18

Constant emissions of CO₂ do not lead to stabilization of atmospheric concentrations

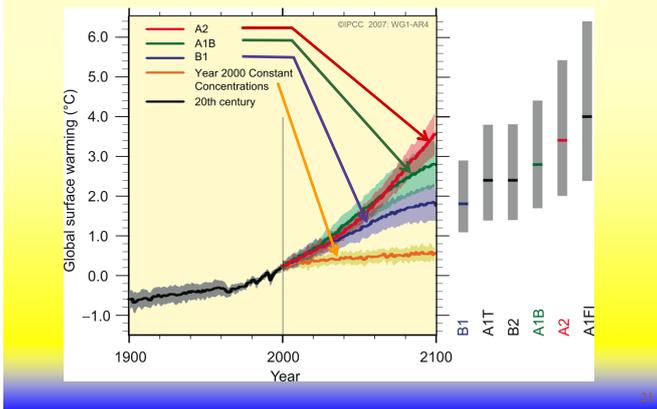
Courtesy: IPCC (2001)



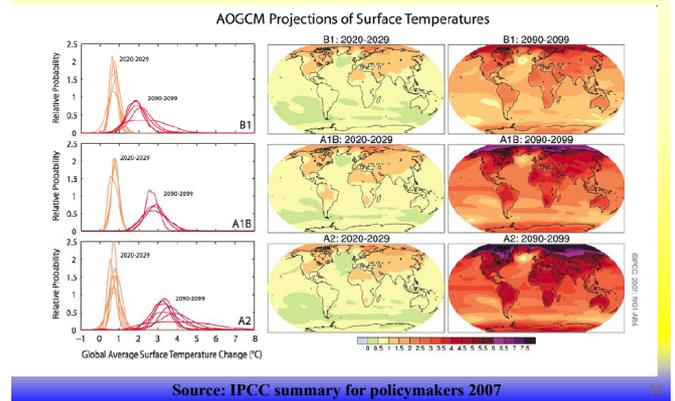
Projected concentrations of CO₂ during the 21st century are two to four times the pre-industrial level



Estimated global warming this century

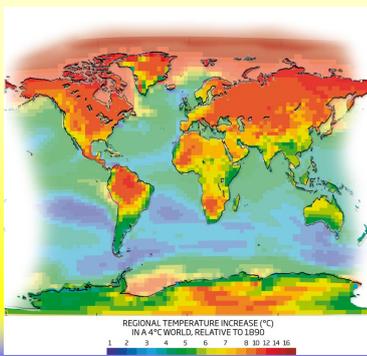


Temperature changes in 20 and 90 years



Best estimate of warming variation with an average rise of 4°C since 1890

- Climate modelling result
- When (if) depends on international policies
- Most land-masses will show a rise of much more than 4°C



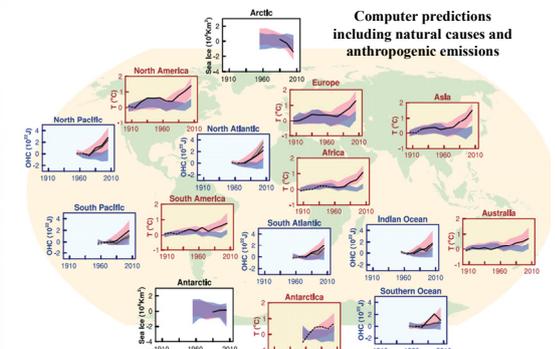
Met Office Hadley Centre/ New Scientist Oct. 2009

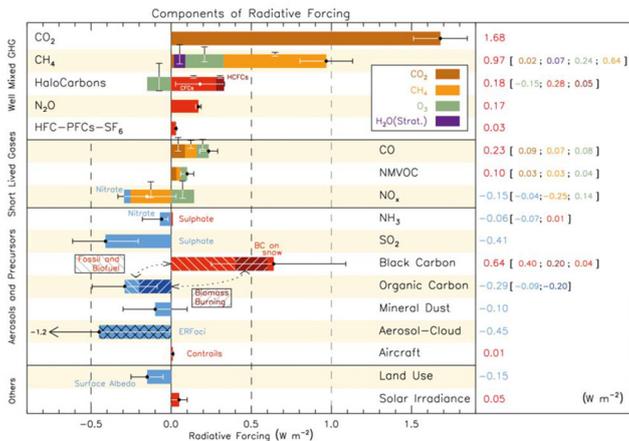
Anthropogenic forcing

Observed changes

Natural variation

+ mankind

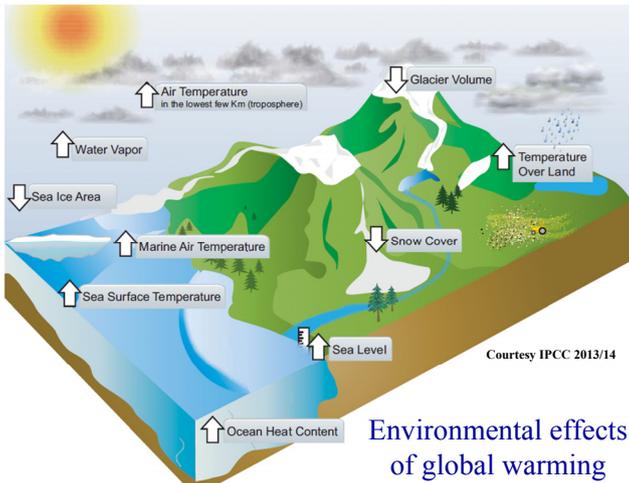
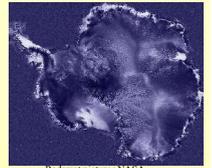




Courtesy: IPCC (2013) 25

Effects of global warming

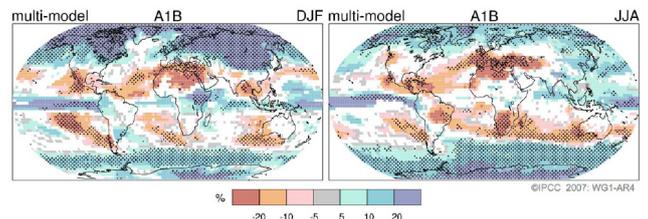
- Climate change
 - variable around world; generally wetter; some dry areas will get drier, some areas colder
- Raising of world sea level
 - thermal expansion of sea
 - melting of land-based ice
- Variation of ecosystems
 - population shifts and national economic changes
- Ocean current changes



Implications

- Rainfall and drought changes will have a major impact

Projected Patterns of Precipitation Changes



Some conclusions

- There is no 'stop' button for climate change
- The factors that affect global climate all interact
- We can't turn the clock back
 - every year we start from a different place
- We need to plan for global climate change



The Global Warming Sceptic

- 'Sceptics' have few credible arguments
 - they are fond of quoting each other rather than valid science, presenting opinion as fact, holding themselves up as misunderstood martyrs, pouring invective on their opponents, misrepresenting and not understanding the science
- Why don't global temperatures follow CO₂ trends?
 - see the notes
 - the balance of probabilities is against the sceptical position on global warming
 - scepticism as a principle is part of science



Sceptic, David Bellamy

From: <http://newsbusters.org/static/2007/10/2007-10-17GlobalWarming.jpg>

Future change

◆ Global problems need global solutions

- technology – infrastructure
- economics - legislation

