PHY392S
Physics of Climate

Lecture 1

Introduction

Some Definitions

Weather

- the fluctuating state of the atmosphere around us, characterized by the temperature, wind, precipitation, clouds and other weather elements

Climate

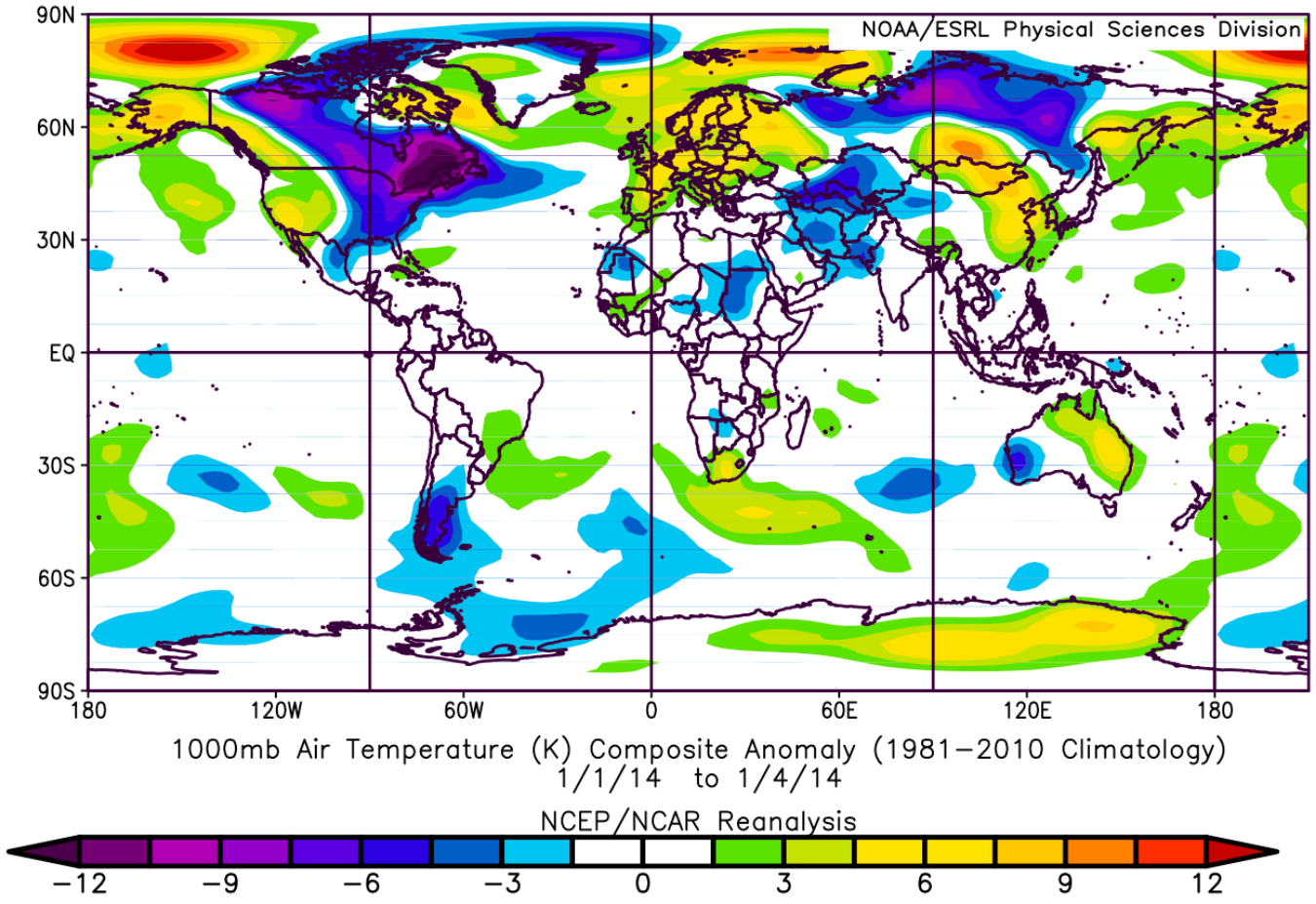
- the average weather in terms of the mean and its variability over a certain time-span and a certain area

"Climate is what we expect, weather is what we get." Mark Twain

Climate change

- statistically significant variations of the mean state of the climate or of its variability, typically persisting for decades or longer

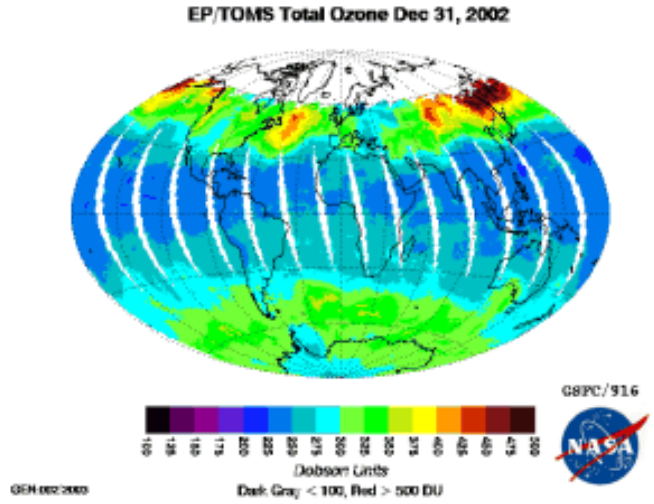
Jan 1-4, 2014, Surface Temperature Anomalies

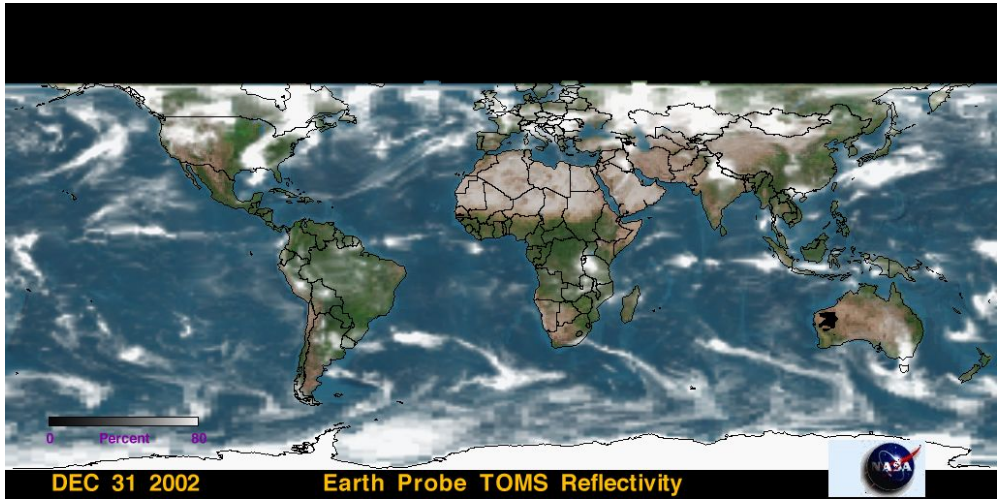


[http://www.esrl.noaa.gov/psd/data/composites/day/]

The Climate System

- The climate system is an interactive system forced or influenced by various external forcing mechanisms, the most important of which is the Sun.
- The atmosphere is the most unstable and rapidly changing part of the system.
- The climate of the Earth as a whole depends on factors that influence the radiative balance, such as for example, the atmospheric composition, solar radiation or volcanic eruptions.





The Composition of the Atmosphere

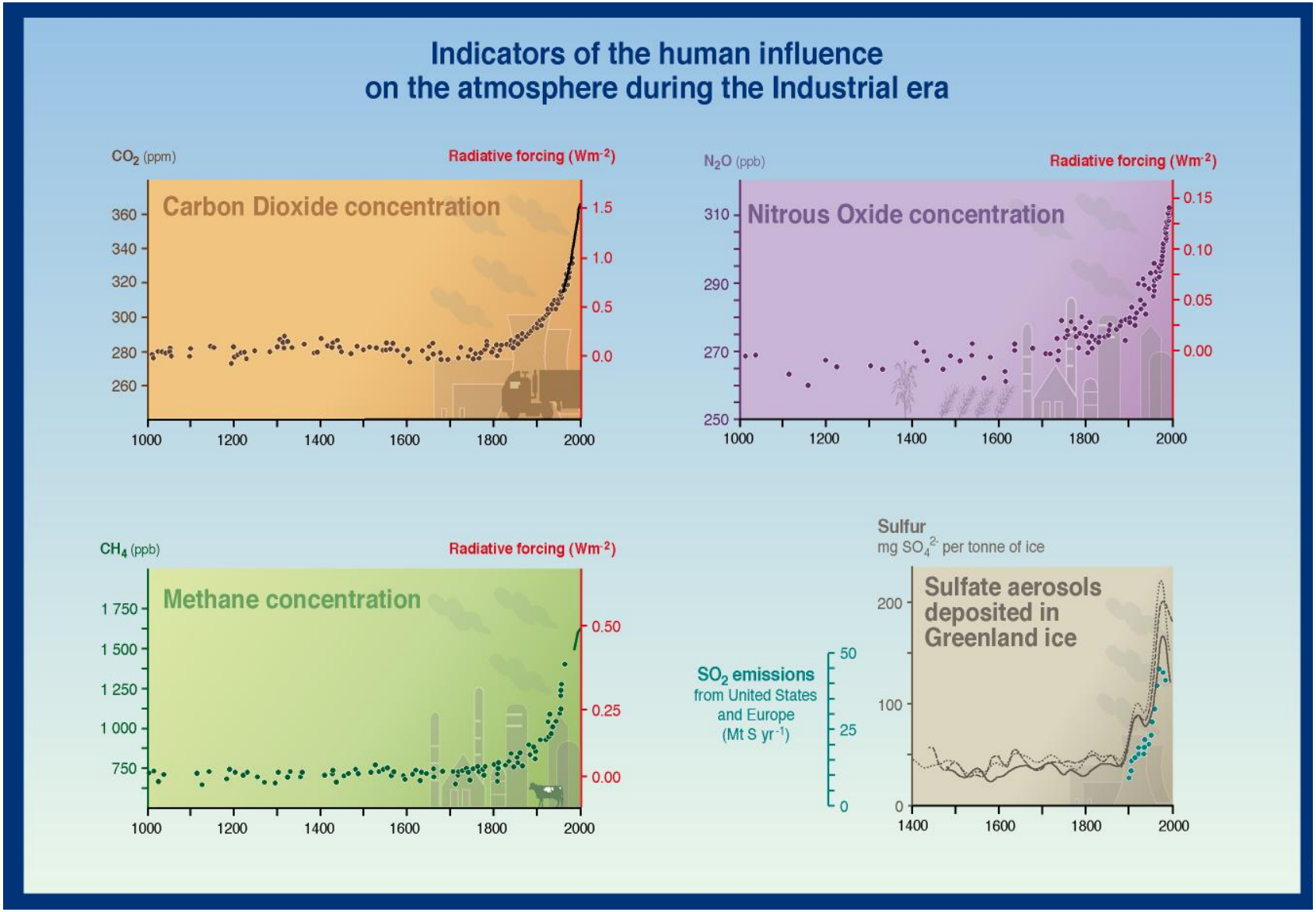
For Dry Air

Gas	Abundance (%)
Nitrogen (N_2)	78
Oxygen (O_2)	21
Argon (Ar)	0.93
Carbon Dioxide (CO_2)	0.04
Neon (Ne)	0.00182
Ozone (O_3)	< 0.001
Helium (He)	0.00052
Methane (CH_4)	0.00018

} 99.93% of the atmosphere

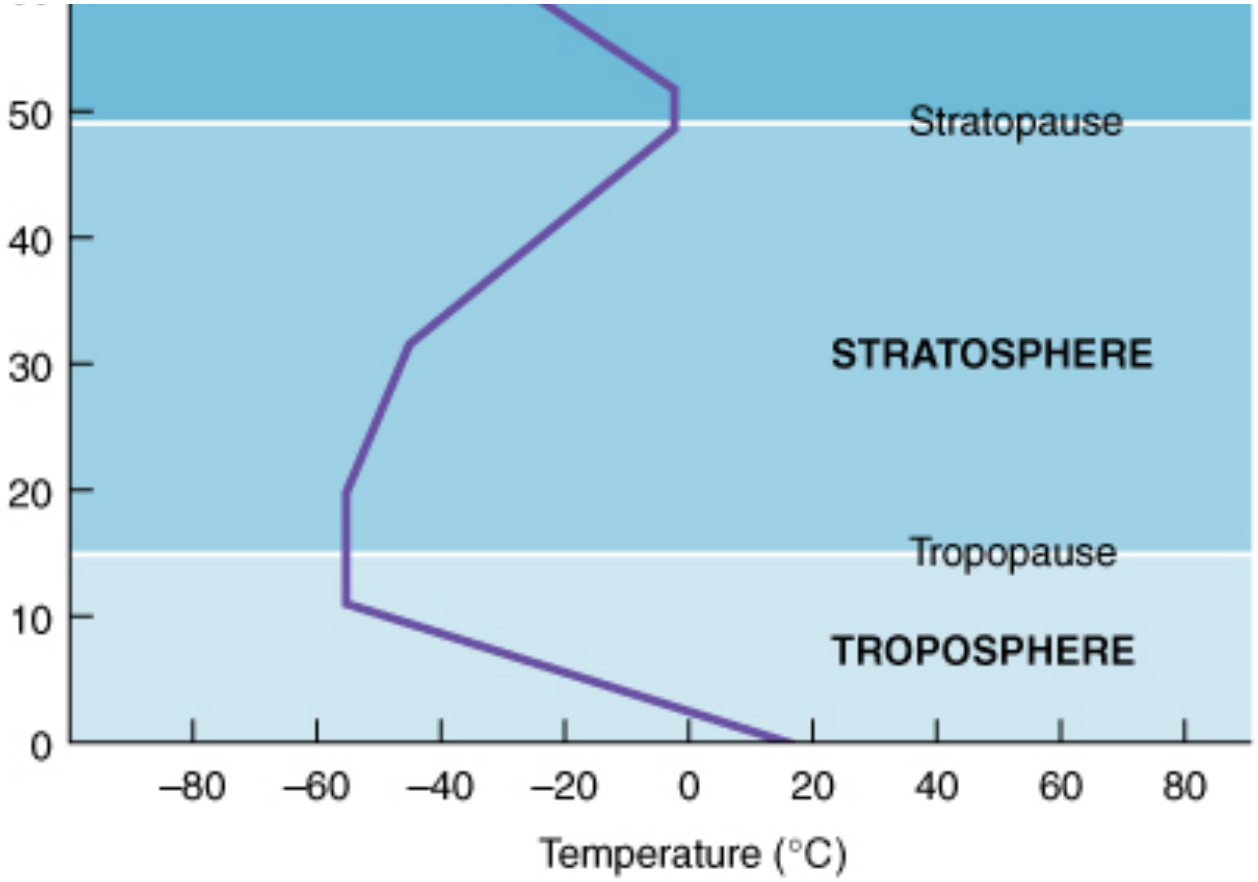
The abundance of most gases in the atmosphere is quite low and so they are called *trace gases*

Indicators of change: greenhouse gases



[Intergovernmental Panel on Climate Change, 2001]

The Vertical Structure of the Atmosphere



Weak vertical motions in the stratosphere

strong overturning motion (convection) in the troposphere

The layers of the atmosphere are defined by the variation of temperature with altitude:

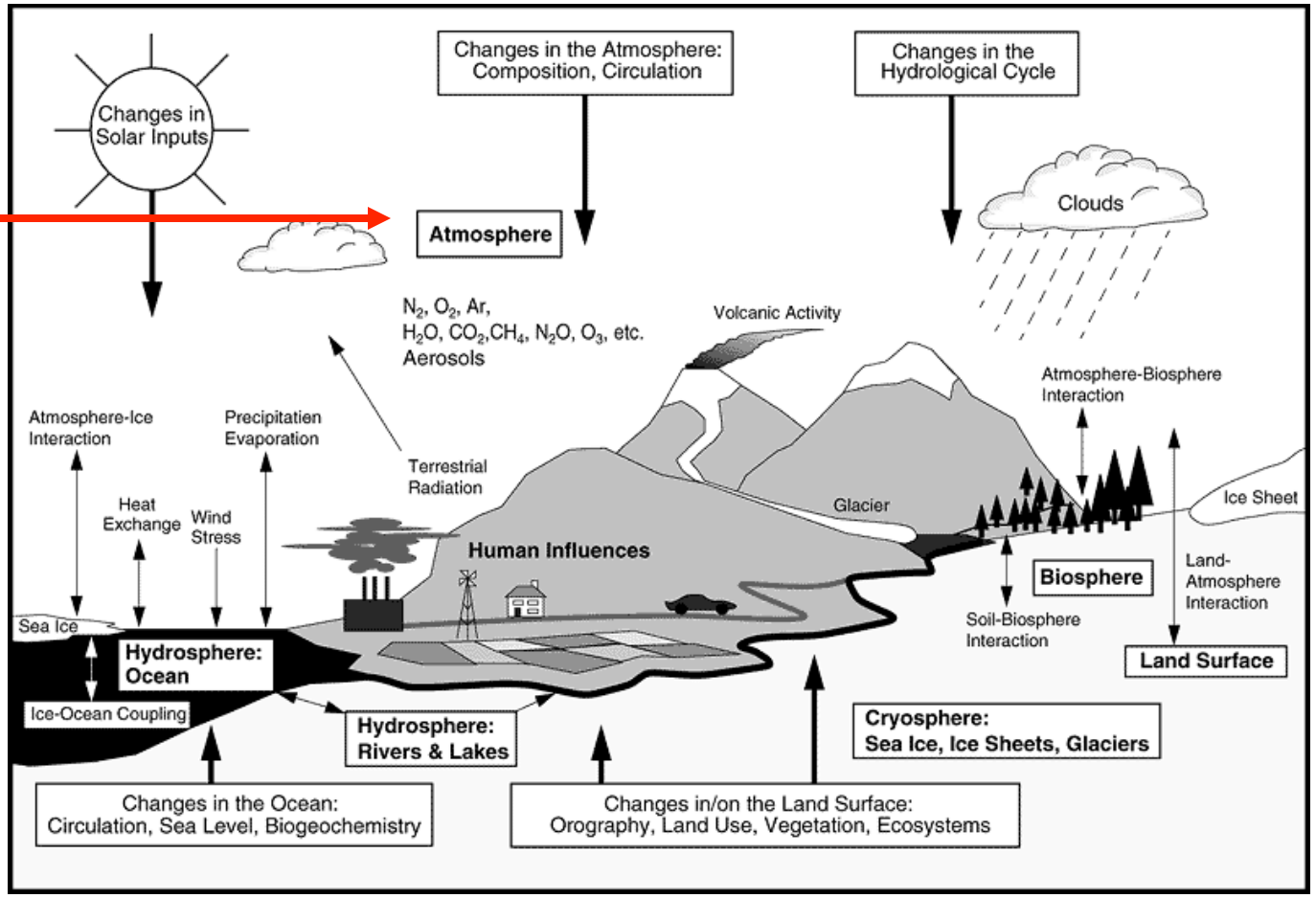
Troposphere: temperature decreases with altitude

Stratosphere: temperature increases with altitude

The Climate System

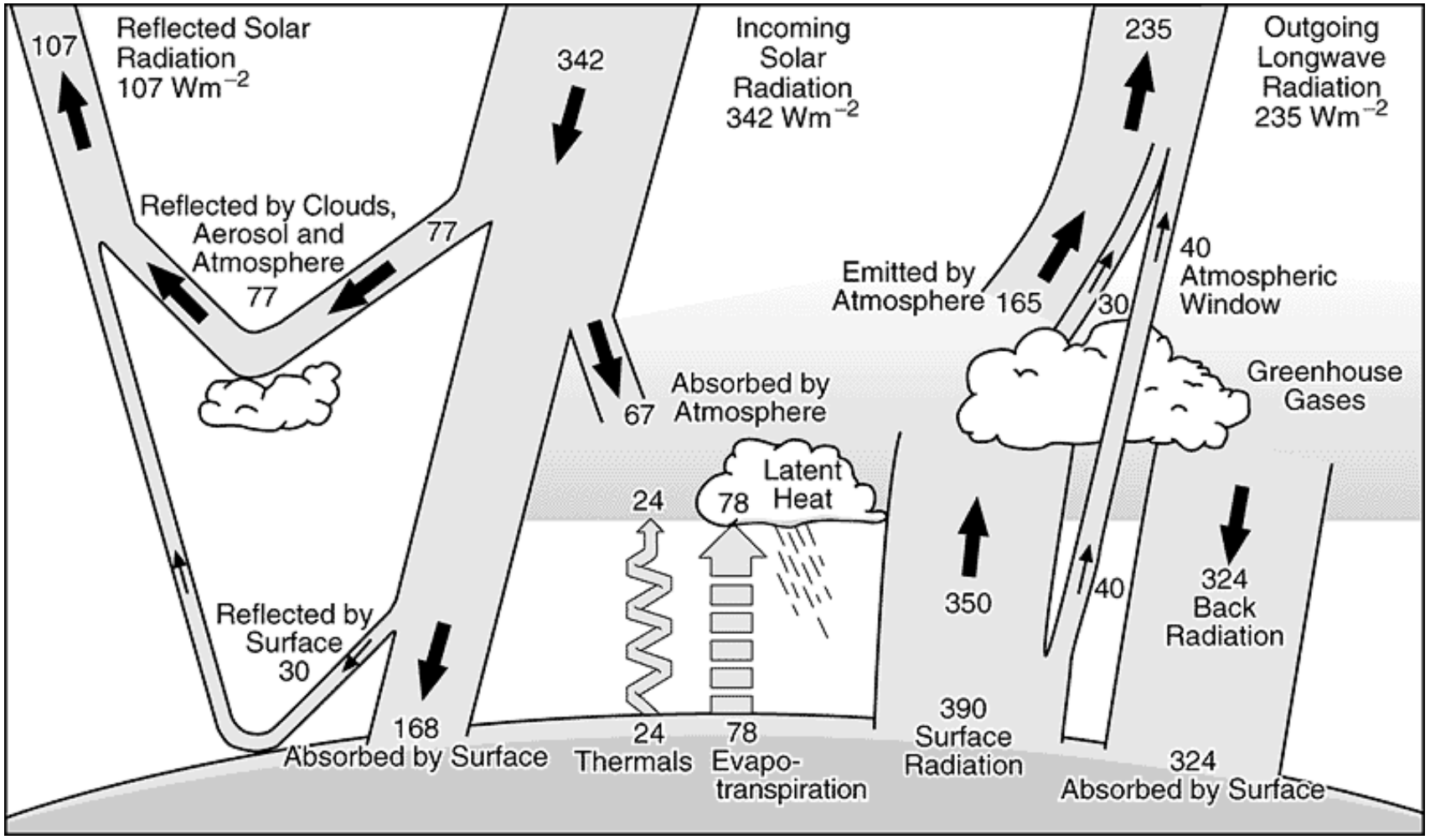
Climate system:

- Atmosphere
- Hydrosphere
- Cryosphere
- Land surface
- Biosphere



Schematic view of the components of the global climate system (bold), their processes and interactions (thin arrows) and some aspects that may change (bold arrows). http://www.grida.no/climate/ipcc_tar/wg1/index.htm

Earth's Energy Budget

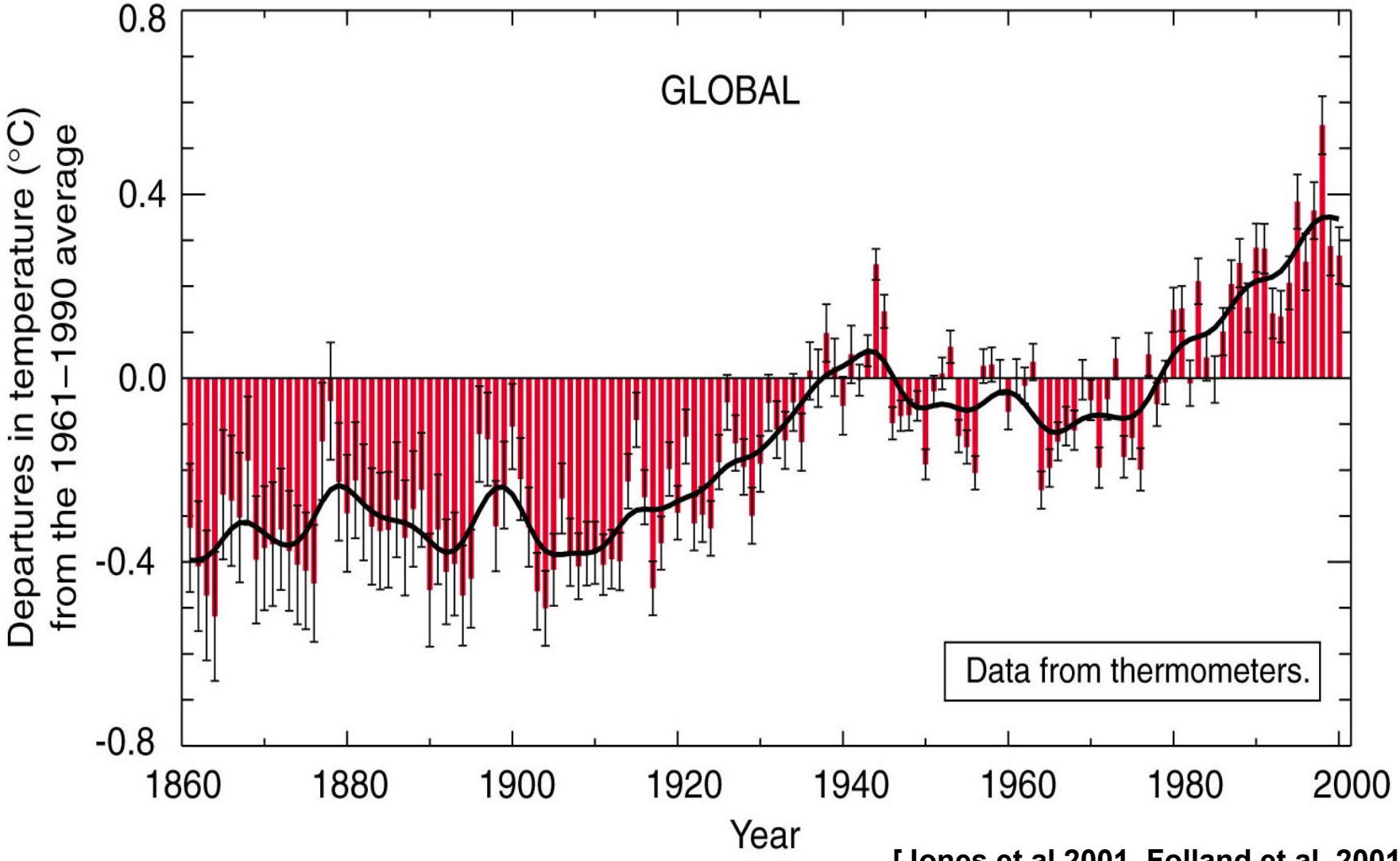


Source: Kiehl and Trenberth: Earth's Annual Global Mean Energy Budget, Bull. Am. Met. Soc. 78, 197-208, 1997.

Radiative Forcing

- Radiative forcing is a first-order measure of the relative climatic importance of different agents.
- It has been employed to denote an externally imposed perturbation in the radiative energy budget of the Earth's climate system.
- Such a perturbation can be brought about by:
  - changes in the concentrations of radiatively active species (e.g., CO_2, aerosols),
  - changes in the solar irradiance incident upon the planet, or
  - other changes that affect the radiative energy absorbed by the surface (e.g., changes in surface reflection properties).
- This imbalance in the radiation budget has the potential to lead to changes in climate parameters and thus result in a new equilibrium state of the climate system.

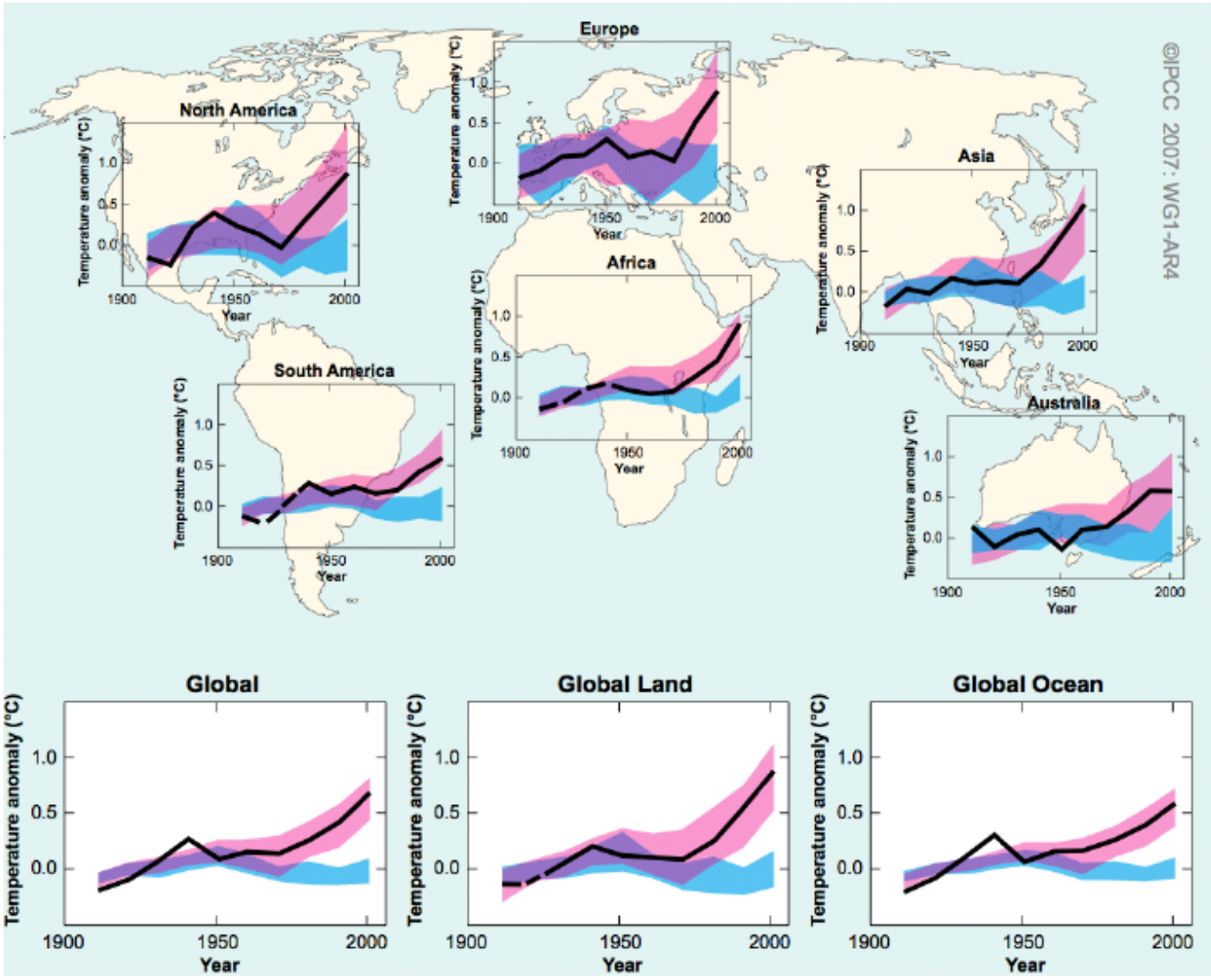
How have global surface temperatures changed over the last 150 years?



[Jones et al 2001, Folland et al. 2001]

IPCC 2007 Figure SPM.4
Changes in Surface Temperature

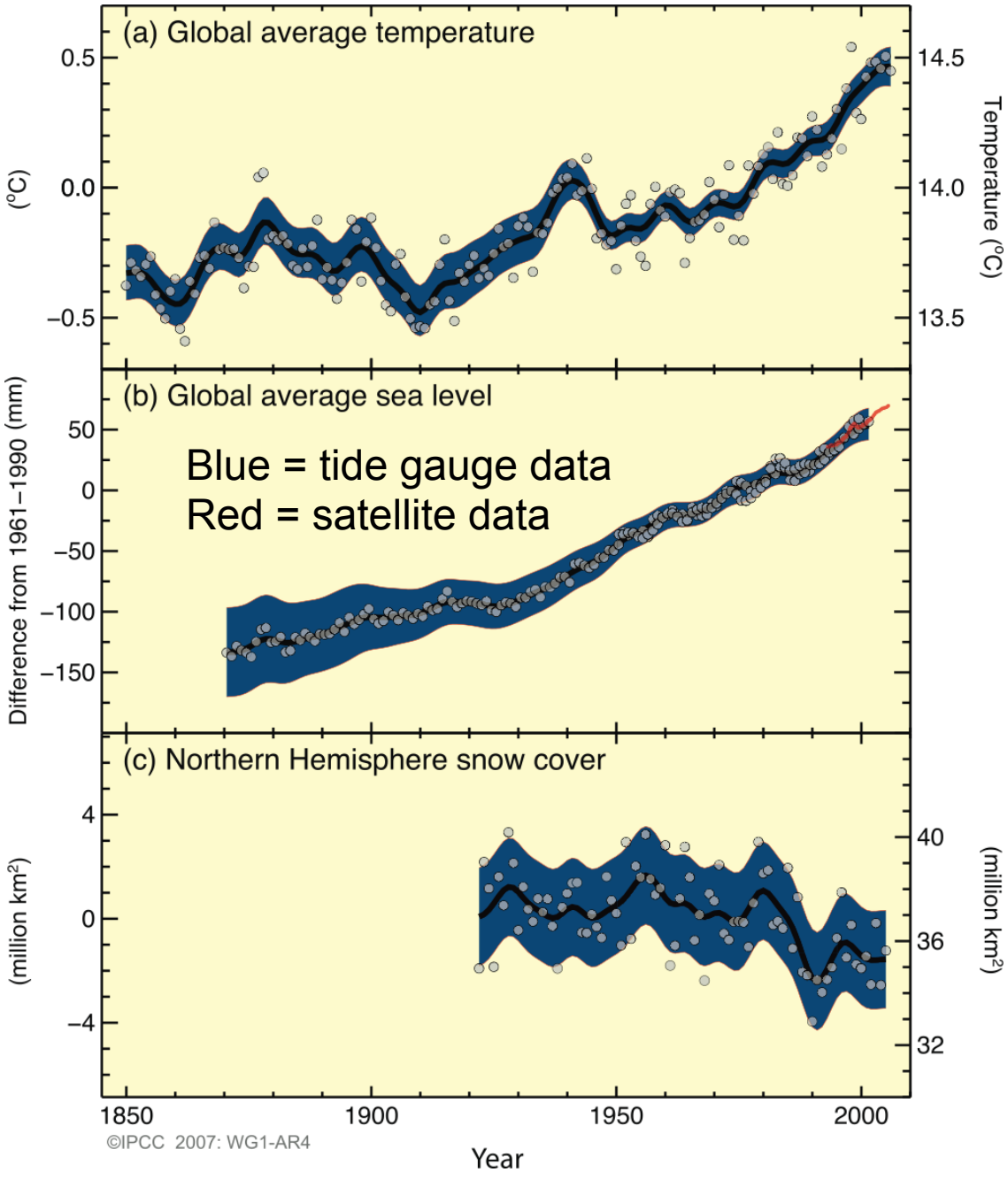
Figure SPM.4
Changes in surface temperature.
Black line = decadal averages of observations for 1906-2005 relative to 1901-1950. Blue shaded bands = 5-95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands = 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings.



IPCC 2007

Figure SPM.3

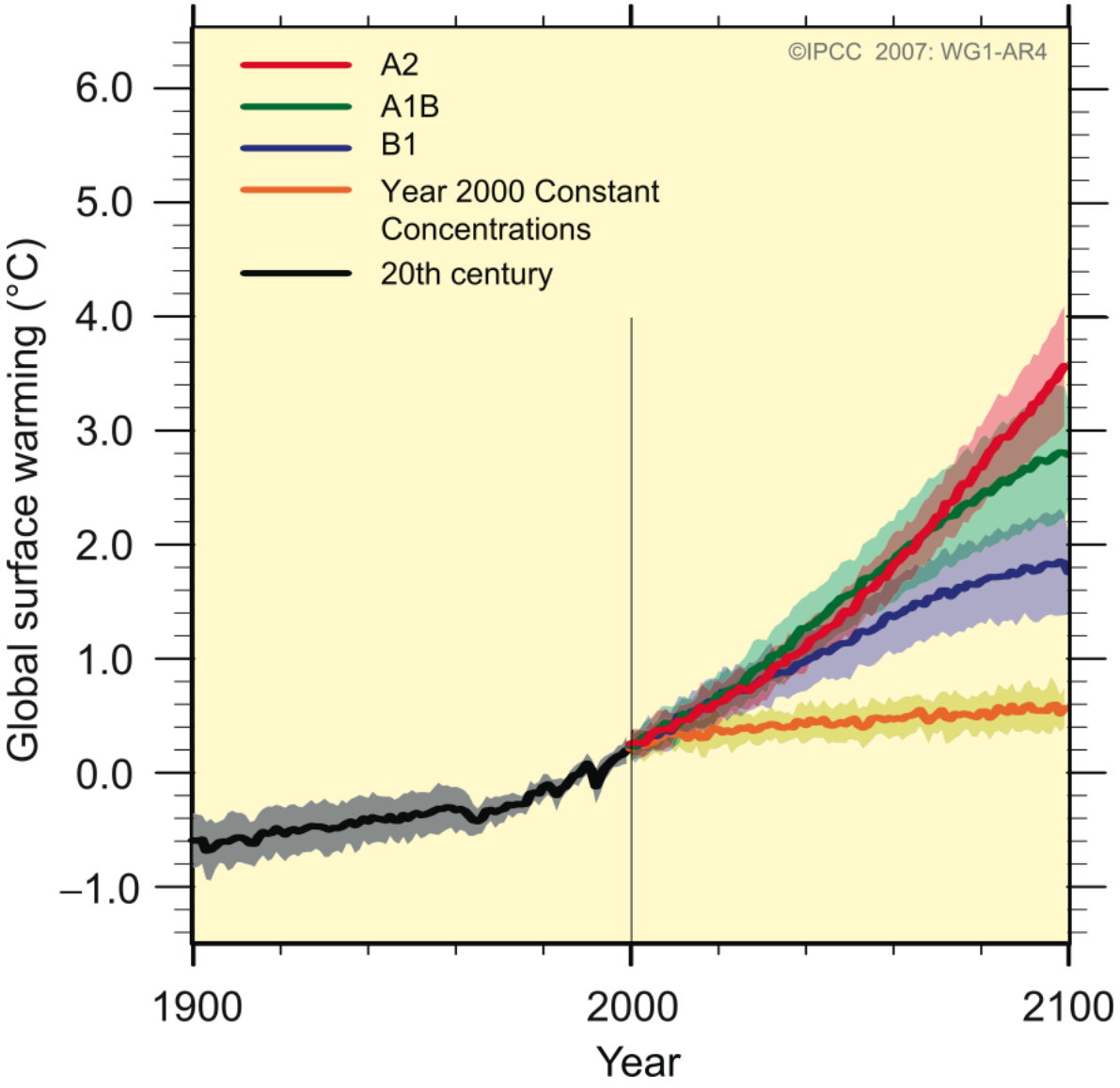
- Observed changes in (a) global average surface temperature, (b) global average sea level, (c) NH snow cover for March-April.
- All changes are relative to 1961–1990.
- Smoothed curves are decadal average values while circles show yearly values.
- The shaded areas are the uncertainty intervals.



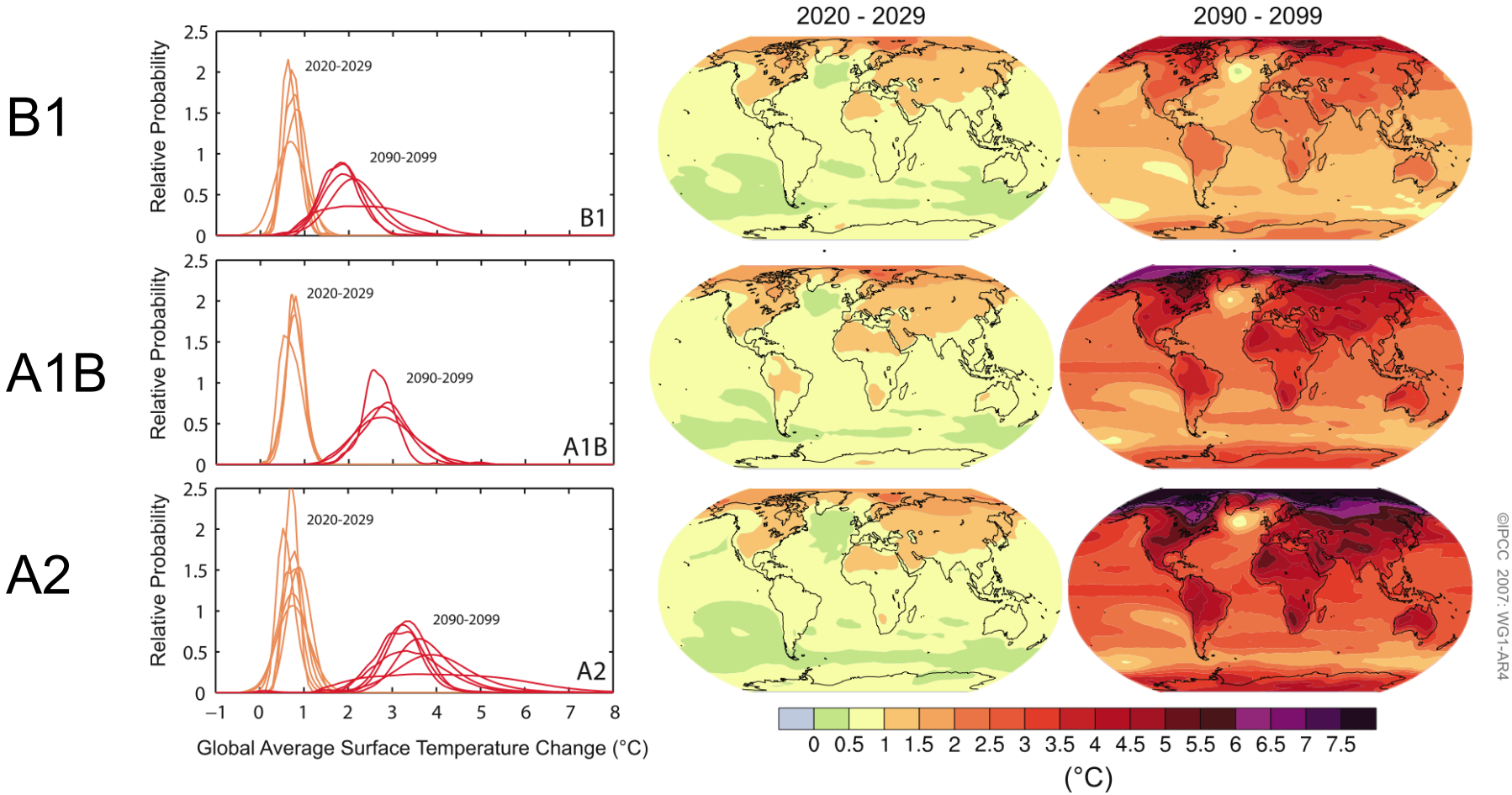
IPCC 2007 Figure SPM.5
Predicted Surface Warming

Figure SPM.5

- Multi-model global averages of surface warming, relative to 1980-1999.
- Shading denotes the ±1 standard deviation range of individual model annual averages.



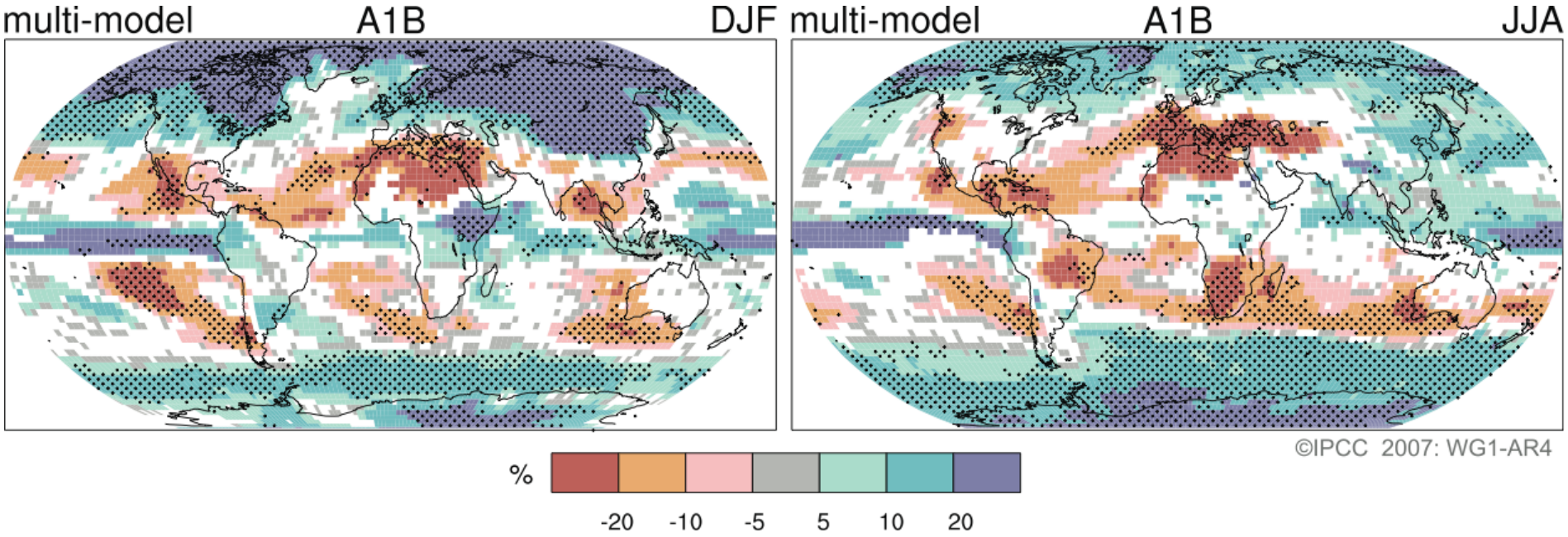
IPCC 2007 Figure SPM.6
Projected Temperature Changes



Projected surface temperature changes for the early and late 21st century relative to 1980-1999.

- Central and right panels show multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) scenarios averaged over 2020-2029 (center) and 2090-2099 (right).
- Left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different model studies for the same periods.

IPCC 2007 Figure SPM.7
Projected Precipitation Changes



- Relative (%) changes in precipitation for 2090-2099, relative to 1980-1999.
- Values are multi-model averages based on the 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.

Discussions on climate change are often heated...

Why?

- There is a broad consensus in the scientific community that global warming is underway.
- The impacts of a steadily warming planet, with rising global average temperatures, are starting to be felt in many areas:
  - agricultural production, water availability, health, sea ice, the mere subsistence of low-lying islands and coastal zones
- Climate change has been attributed to an increase of greenhouse gases in the atmosphere.
  - These gases are a result of activities in our everyday life: the use of energy from fossil fuels (coal, oil, gas), flying or driving, using electric equipment at home. Greenhouse gases also come from industrial processes, agricultural production and deforestation.
- The economic stakes are high on all sides: the economic impact of climate change may be large, and taking measures to reduce emissions will affect economic activity.

The Scientific Basis: IPCC Reports

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation.

- Four reports have been published: 1990, 1995, 2001, 2007
- The Fourth Assessment Report (AR4) was released in 2007
  - Working Group I - The Physical Science Basis
  - Working Group II - Impacts, Adaptation, and Vulnerability
  - Working Group III - Mitigation of Climate Change
- Oslo, 10 December 2007 - The IPCC and Al Gore were awarded of the Nobel Peace Prize *"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".*

Climate Change – The Response

- Scientific evidence of human interference with the climate first emerged in the international public arena in 1979 at the First World Climate Conference.
- In 1988 the United Nations General Assembly adopted resolution 43/53, proposed by the Government of Malta, urging: "… protection of global climate for present and future generations of mankind."
- The United Nations and its member states have been engaged in action to deal with the issue of Climate Change at a global level.
- In 1992, most countries joined an international treaty: the United Nations Framework Convention on Climate Change (UNFCCC), to begin to consider what could be done to reduce global warming and to cope with whatever impacts result.

The Kyoto Protocol

- The Kyoto Protocol is an addition to the UNFCCC treaty, and has more powerful (and legally binding) measures.
  - Commits countries to reduce their emissions of greenhouse gases, and allows trading of pollution credits, on the basis that the impact on the global atmosphere will be the same.
- The text of the Protocol was adopted in Kyoto, Japan, on 11 December 1997.
- The Kyoto Protocol entered into force on 16 February 2005.

- Have a look: http://unfccc.int/kyoto_protocol/items/2830.php

The Kyoto Protocol

- *"Depending on who you talk to, the Kyoto Protocol is either*
  a) an expensive, bureaucratic solution to fix a problem that may not even exist; or
  b) the last, best chance to save the world from the "time bomb" of global warming."
  (CBC - http://www.cbc.ca/news/background/kyoto/index.html)
- These are the extreme positions in the worldwide debate between governments, consumers, environmental groups, scientists, and industry.
- The impacts of climate variability and the threat of future changes are issues brought to our attention on an almost daily basis.
- A fundamental question is the level of confidence we have in our knowledge of what controls Earth's climate and what changes will happen in the future.
  - **This the topic of our course - the physics of climate.**