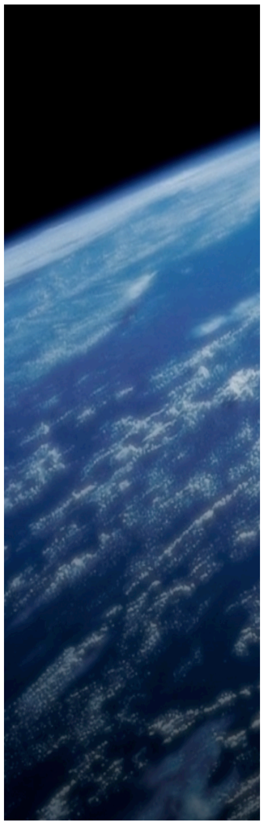

IPCC AR5 Chapter 10:

Detection & Attribution of Climate Change: from Global to Regional

November 20, 2013

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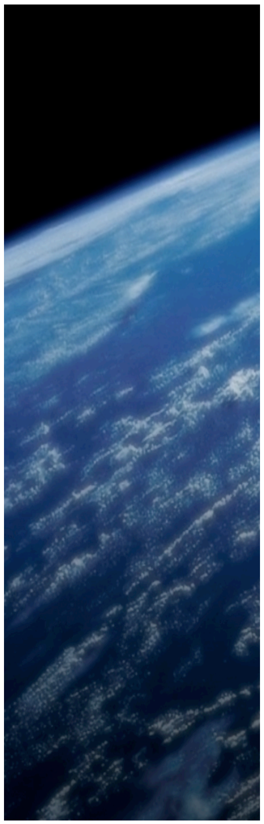


Introduction

Introduction

This chapter assesses the causes of the observed climate changes

FAQ

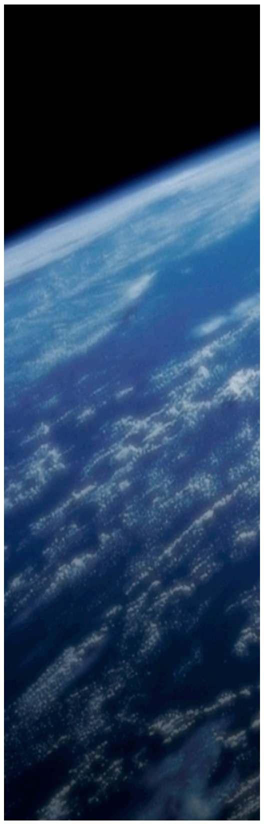
Climate is always changing. How do we determine there is obvious change and the causes of it?

Introduction

This chapter assesses the causes of the observed climate changes

The observation datasets have been improved and a new set of models is available

Keyword: Coupled Model Intercomparison Project (CMIP), a great number of atmosphere-ocean general circulation models that are used



Evaluation of Detection and Attribution Methodologies

Detection and attribution

Detection: the process of demonstrating that the climate has changed in some statistical sense

Attribution: the process of evaluating the relative contributions of multiple factors to a change or event

Observations, estimate and analysis

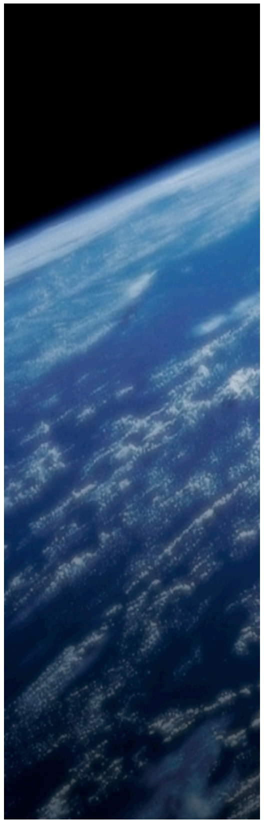
Common methods in this chapter

Time series: separating signal from noise or spatial pattern

Optimal Fingerprinting: use climate model simulation, generalized multi-variate regression

Single-step & multi-step attribution

Null hypothesis and statistic test



Atmosphere and Surface

Temperature

The global surface temperature (GMST) warmed at most regions compared with 1901

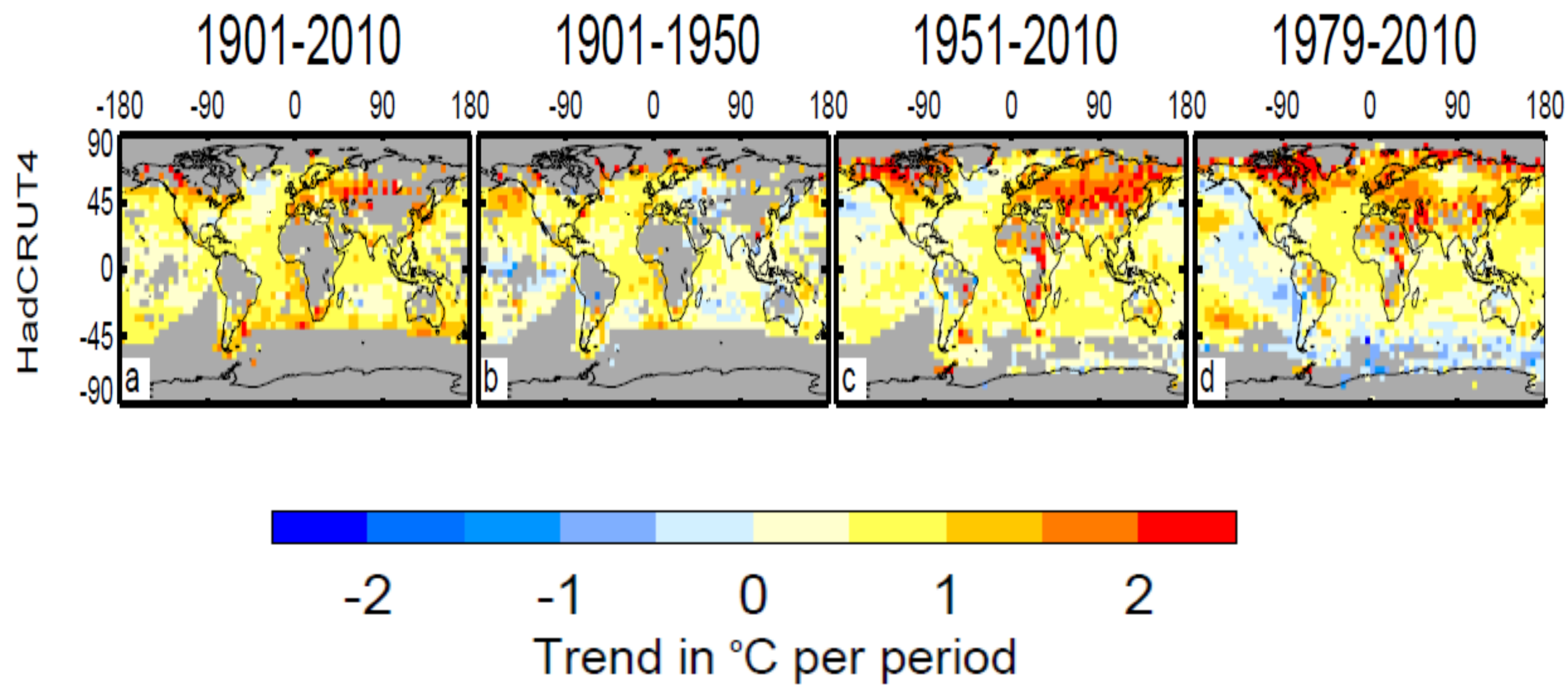


Figure 10.2

Temperature

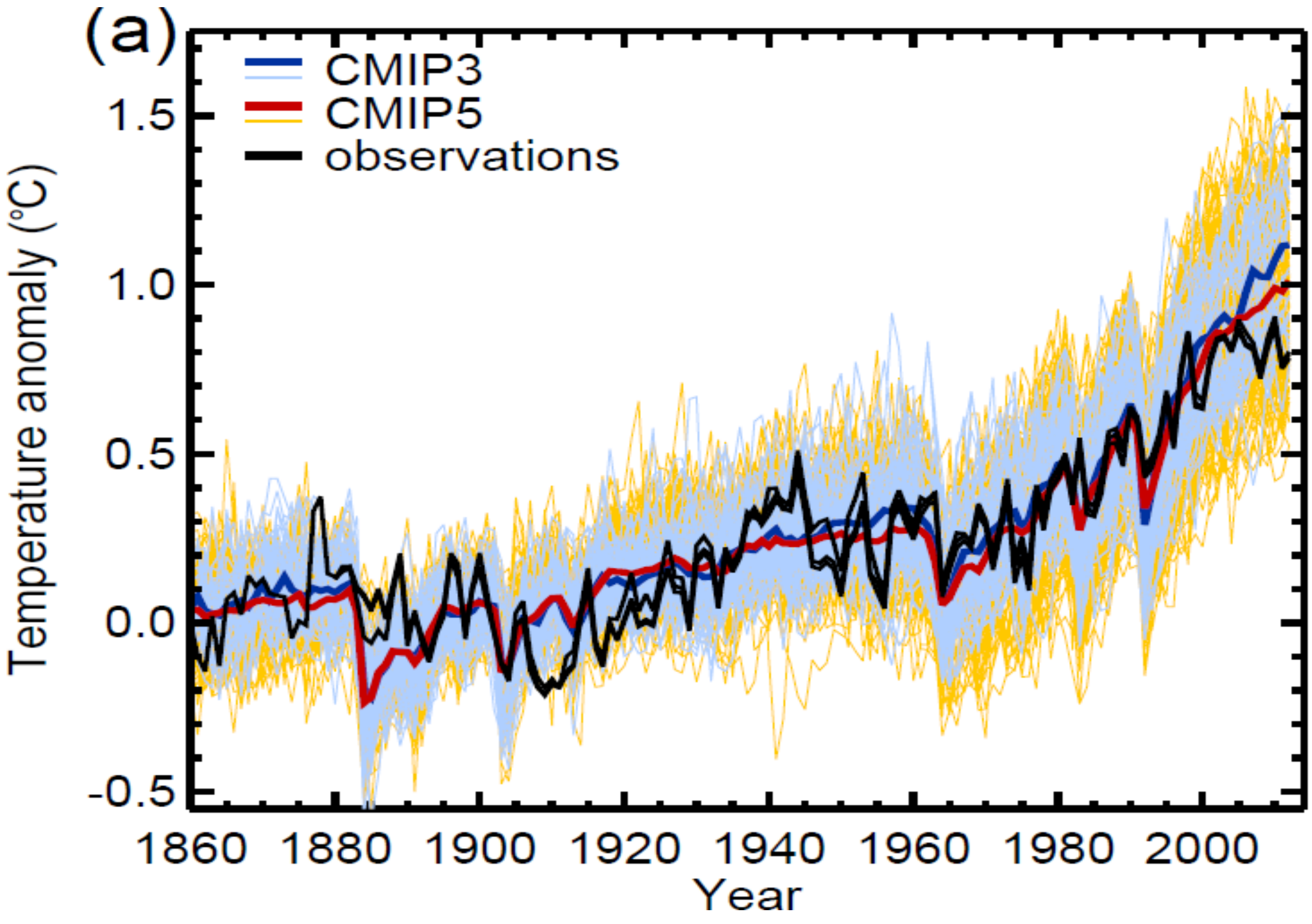


Figure 10.1

Attribution of global temperature changes

- Green house gas: 0.5 to 1.3°C
- Combine anthropogenic forcing: 0.6 to 0.8°C
- Natural forcing: -0.1 to 0.1°C
- Internal Variability: -0.1 to 0.1°C

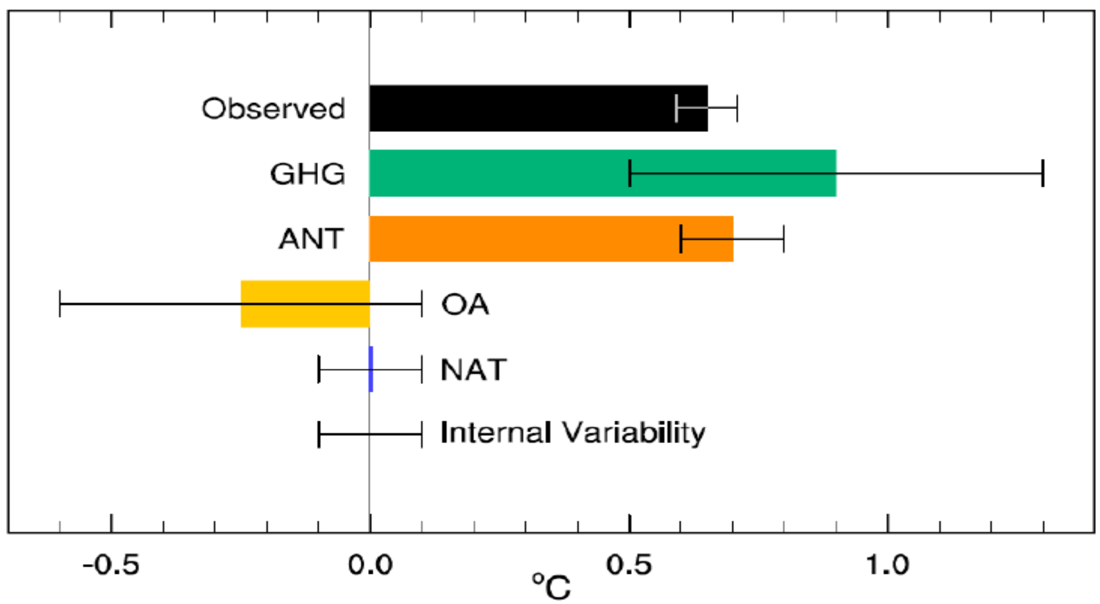


Figure 10.5

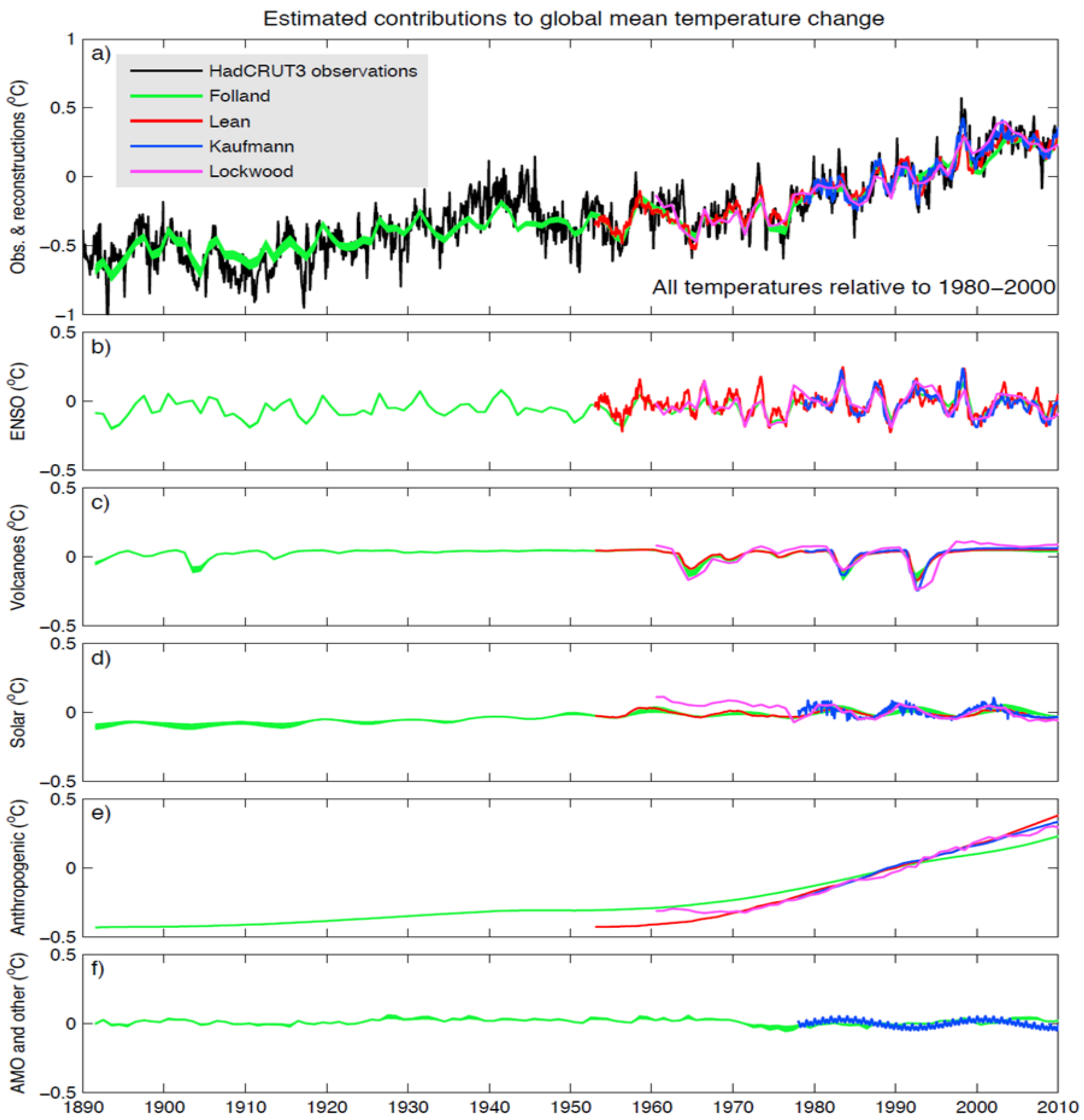

Estimated contributions to global mean temperature change
a)
HadCRUT3 observations
Folland
Lean
Kaufmann
Lockwood
All temperatures relative to 1980–2000
Obs. & reconstructions (°C)
b)
ENSO (°C)
c)
Volcanoes (°C)
d)
Solar (°C)
e)
Anthropogenic (°C)
f)
AMO and other (°C)
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Figure 10.6

Attribution of regional temperature changes

- Detection and attribution at continental and smaller scales is more difficult
- The conclusion is anthropogenic forcing has substantial contribution to each continent except Antarctica since 1950

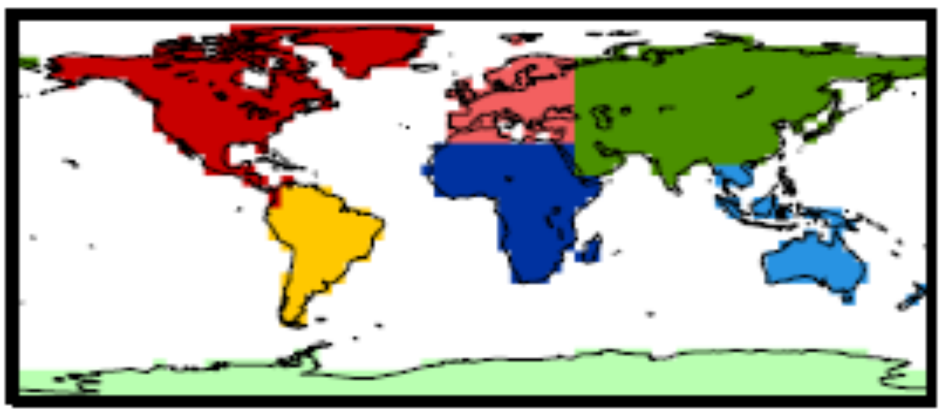


Figure 10.7

Free atmosphere

The troposphere is warming while the stratosphere is cooling

The warming troposphere is due to increasing greenhouse gases and the cooling is due to stratospheric ozone depletion

The models (CMIP5) simulation verify this conclusion

Lower stratosphere

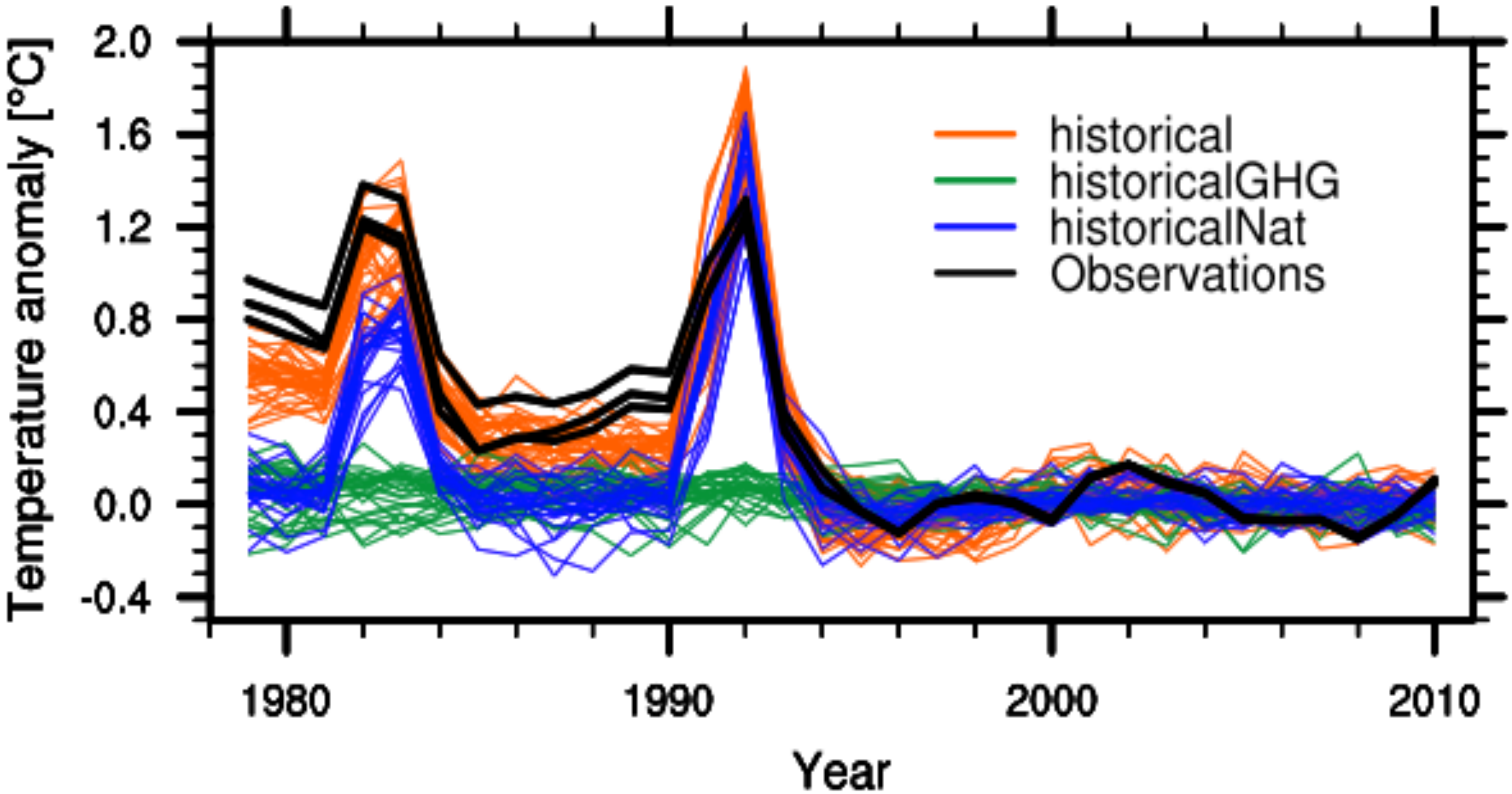


Figure 10.9

Water cycle

The work is challenged by simulating hydrologic variables, medium confidence

Specific humidity increasing near surface is found

Large scale precipitation pattern over land is changed

Stream flow and evapotranspiration are only studied in limited regions and use a few models

Atmospheric circulation and patterns of variability

Tropical circulation: Hadley cells widen, but magnitude is uncertain, the ozone depletion should contribute to this

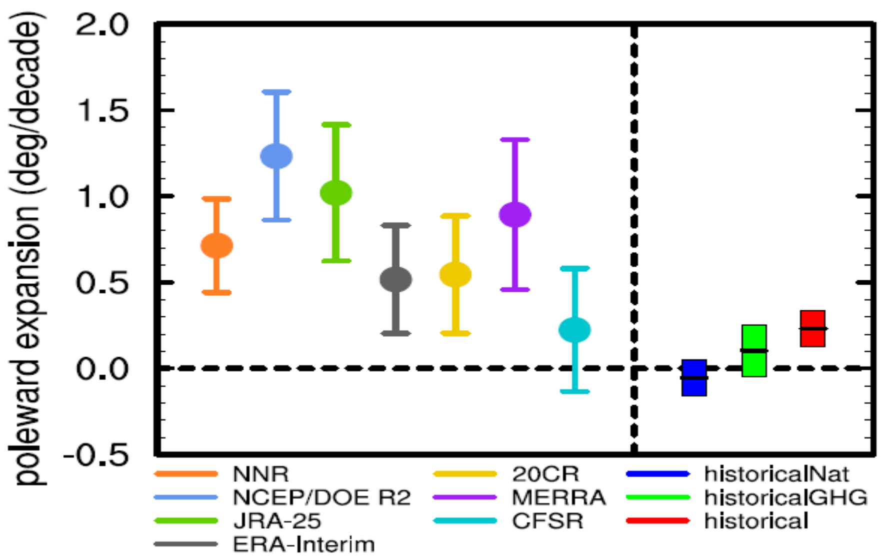
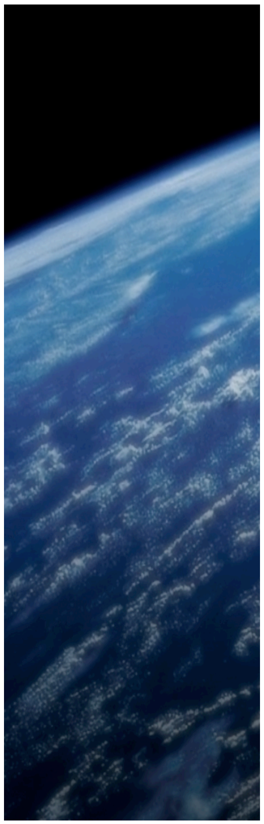


Figure 10.12



Changes in Ocean Properties

Ocean temperature and heat content

"It is *very likely* that anthropogenic forcings have made a substantial contribution to upper ocean warming (>700 m) observed since the 1970s"

- Observations are consistent with climate model simulations that include anthropogenic and volcanic forcings
- Regional heat changes are less certain

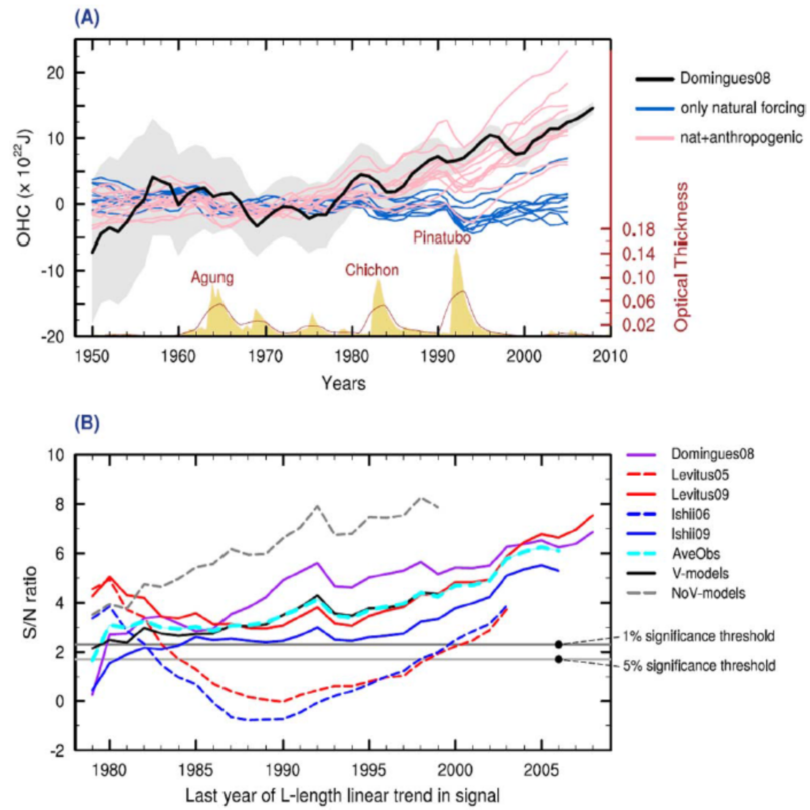


Figure 10.14

Ocean salinity & freshwater flux

"It is *very likely* that anthropogenic forcings have made a contribution to surface and subsurface oceanic salinity changes since the 1960s"

- 40+ studies show patterns consistent with understanding of anthropogenic changes

  "Fresh surface waters get fresher, and salty waters get saltier"

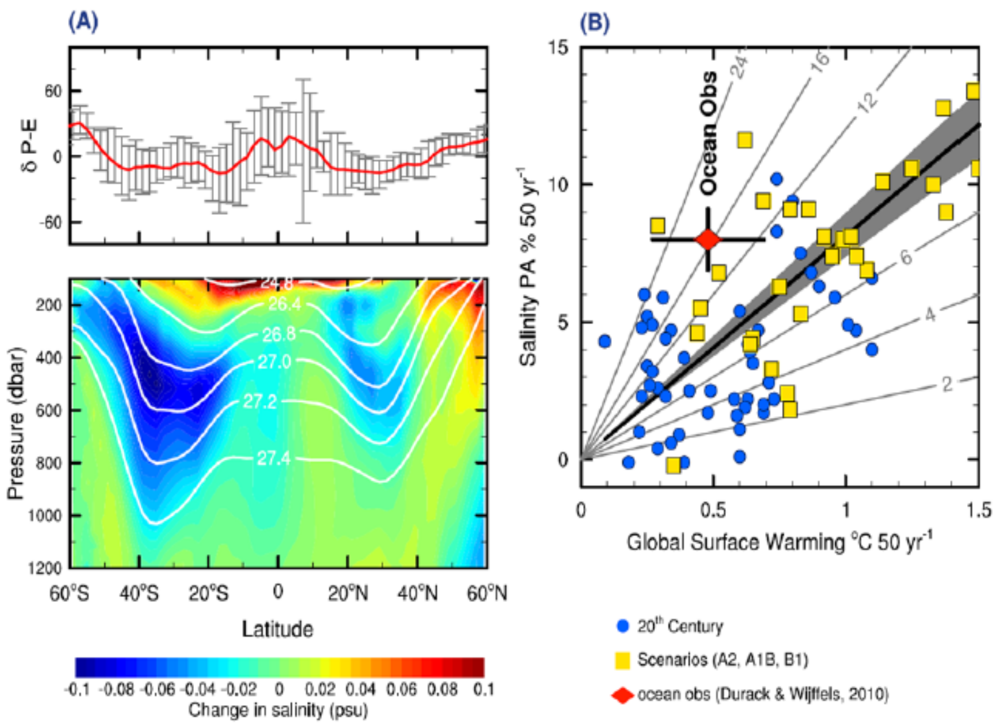
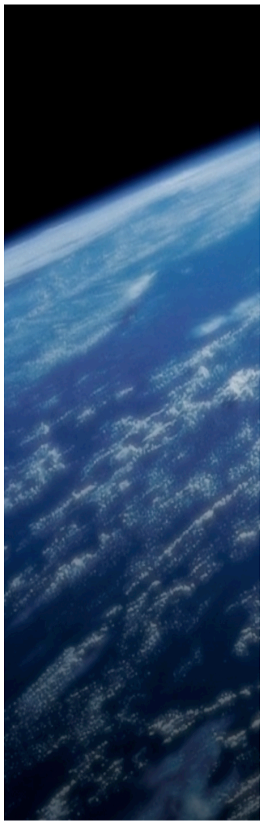


Figure 10.15



Cryosphere

Sea ice

"Anthropogenic forcings are *very likely* to have contributed to Arctic sea ice loss since 1979…[and] there is low confidence in the scientific understanding of the observed increase in Antarctic sea ice extent"

- "Arctic Amplification": surface temperatures in the Arctic are increasing faster than anywhere else in the world
  - Ice albedo feedback plus a positive ice insulation feedback from additional ocean heat storage in areas previously covered by sea ice, and pole-ward heat transport

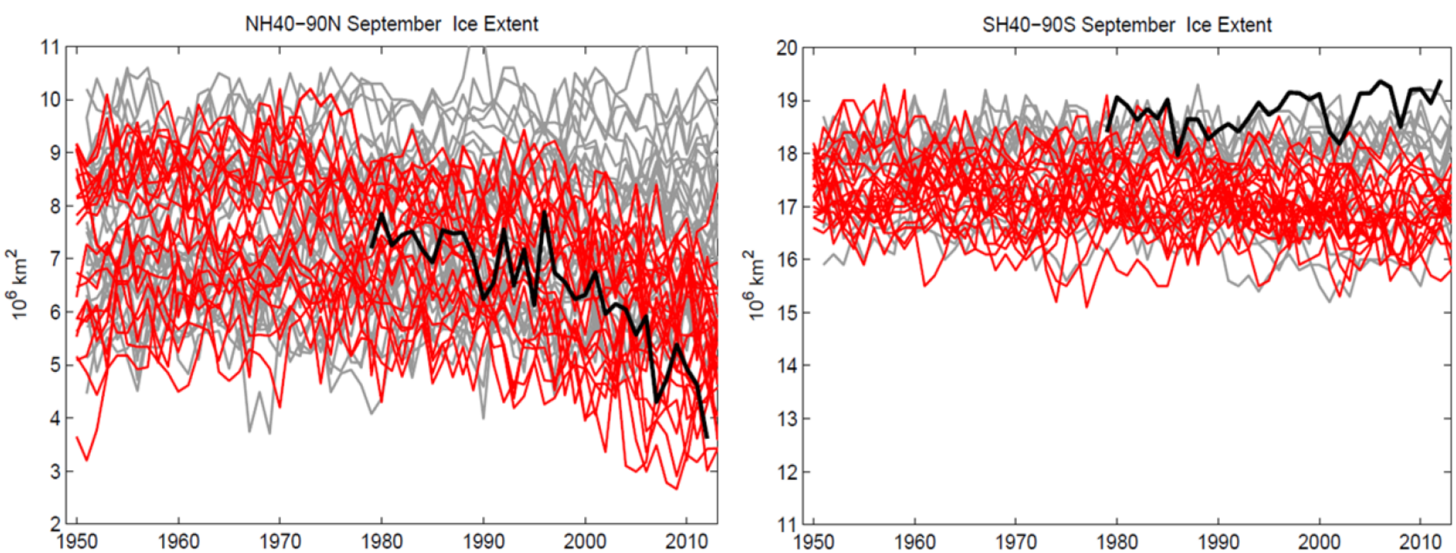
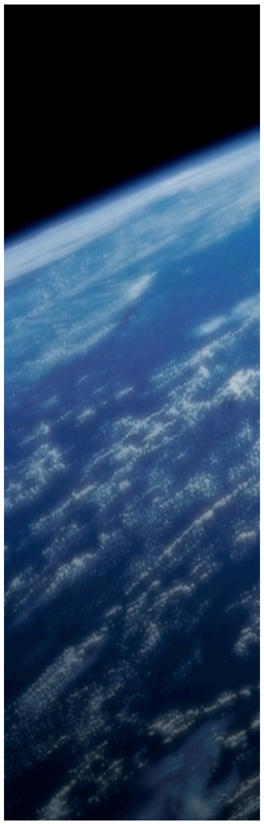


Figure 10.16

Ice sheets/shelves and glaciers

"Ice sheets and glaciers are melting, and anthropogenic influences are *likely* to have contributed to the surface melting of Greenland since 1990 and to the retreat of glaciers since the 1960s"

- Greenland and Antarctic ice sheet:
  - Important to regional and global climate because they cause a polar amplification of surface temperatures, are a source of fresh water to the ocean, and a source of potentially irreversible change to the state of the earth system
  - Attribution of change is difficult as ice sheet and glacier changes are local
- Glaciers:
  - There is robust evidence of internal climate variability impacting glacier mass and length
  - There is *high confidence* that a substantial part of the mass loss of glaciers is *likely* due to human influence



Extremes

Attribution of changes in frequency/intensity of extremes

Human influence has *very likely* contributed to the observed changes in frequency and intensity of daily temperature extremes, there is *medium confidence* that anthropogenic forcing has contributed to increasing heavy precipitation, and there is *low confidence* that changes in tropical cyclone activity are due to human influence

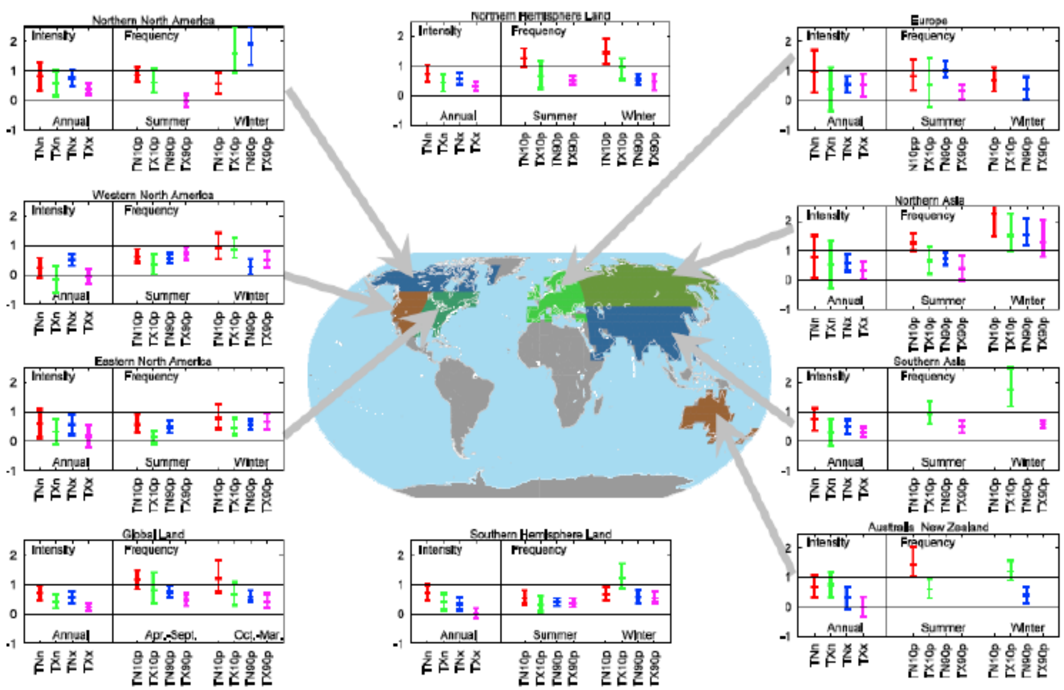


Figure 10.17

Attribution of weather and climate events

Two methods to assess the impact of external drivers:

- “Attributable risk” considers the event as a whole and asks how the external drivers have influenced the probability of occurrence of an event of similar magnitude
- “Attributable magnitude” considers how different external factors contributed to the event or how they may have increased the scale of an event of comparable occurrence probability

- Measuring the absolute risk/probability of an extreme event in the absence of human influence is difficult
  - You cannot extrapolate from the distribution of less extreme events as extreme events occur because of self-reinforcing processes

- There is considerable uncertainty in quantifying changes in probabilities
  - For individual events with return-times greater than the time-scale over which the signal of human influence is emerging (such as 50 years), it is impossible to observe a change in occurrence frequency

Attribution of weather and climate events

Multi-step assessment of attributable risk using various model types

- Including the influence of anthropogenic ghg warming increases flood risk (~factor of 2)
- A reduction in snow-melt-induced flooding in the spring led to the increased precipitation-induced flood risk in the fall

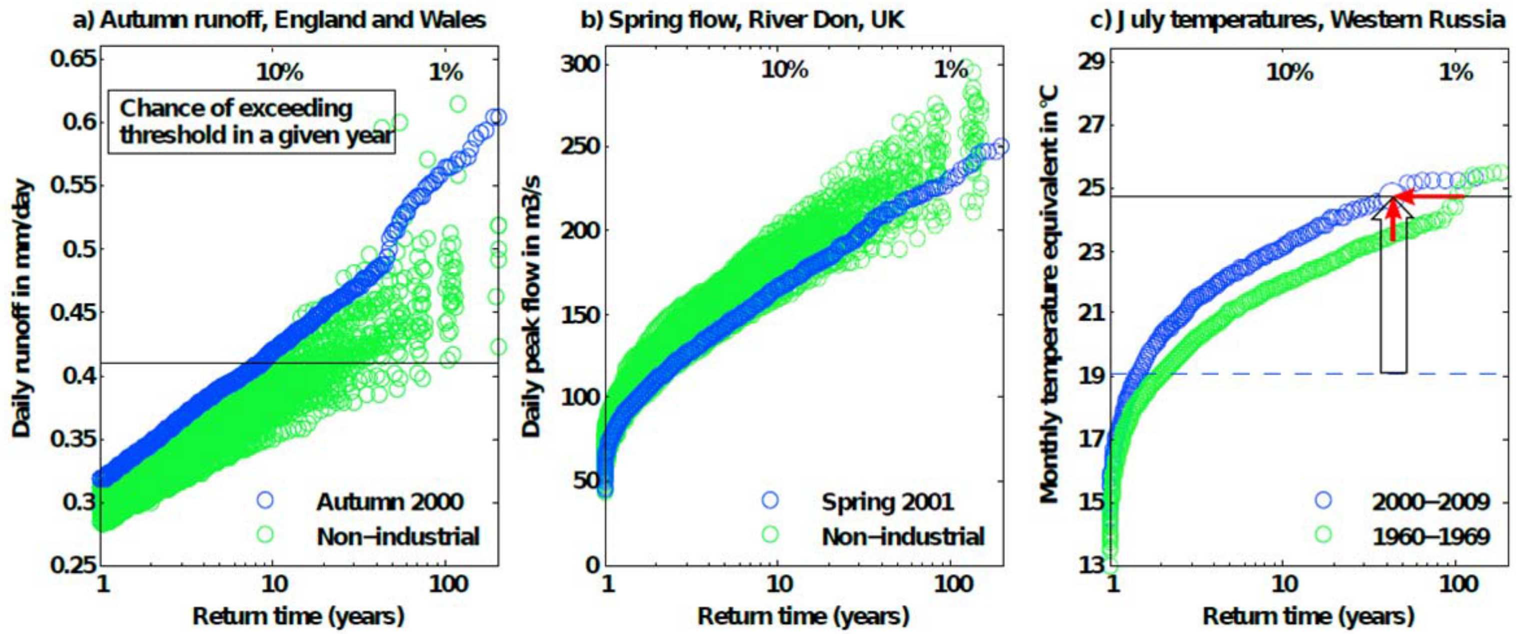
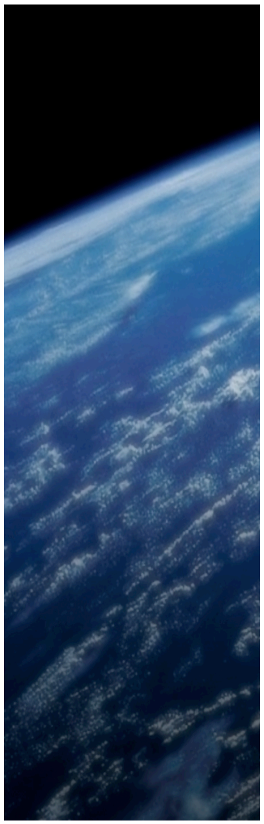


Figure 10.18



Implications for Climate System Properties and Projections

Transient climate response

- TCR: determines the global temperature change to any gradual increase in radiative forcing, normalized to the forcing due to doubling CO_2 (transient climate sensitivity)
- Focuses on the short/medium-term response (constrained by recent observations)
- With new evidence, TCR is *likely* to lie in the range 1°C-2.5°C, and *extremely unlikely* to be greater than 3°C.
- Greater confidence to exclude high values due to better estimates of past forcing

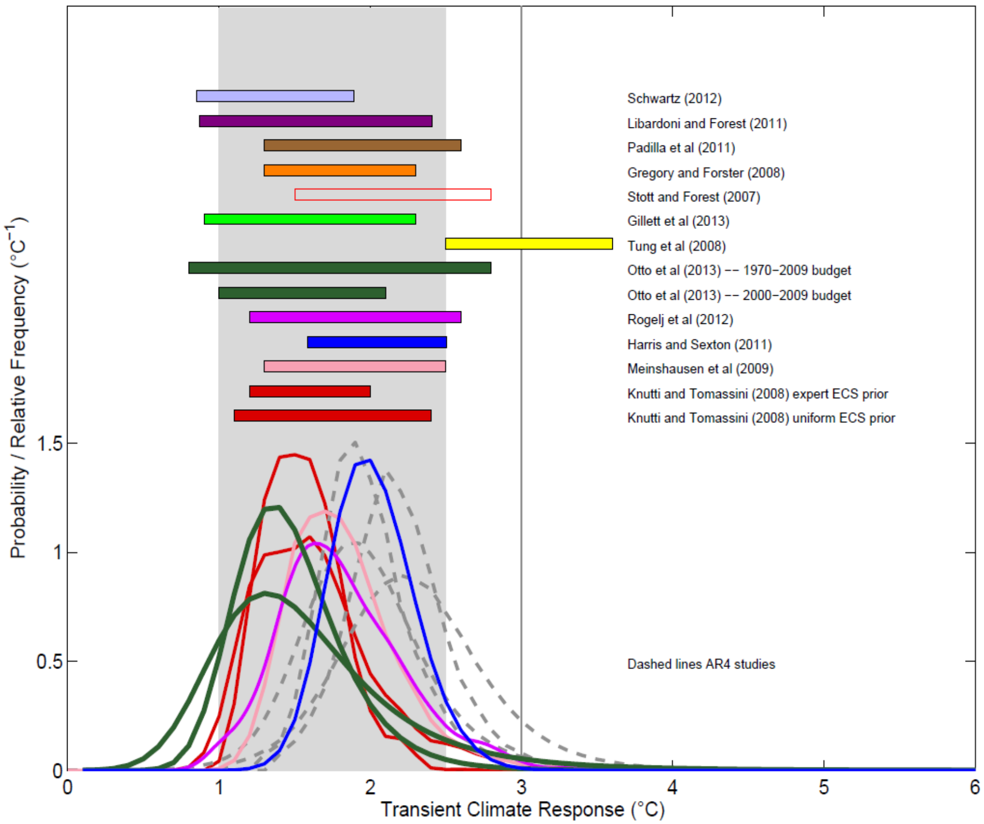


 Figure 10.20

Equilibrium climate sensitivity

- ECS: the warming response to a sustained doubling of CO_2 in the atmosphere, relative to pre-industrial levels (with equilibrium of the ocean-atmosphere system)

- There is *high confidence* ECS is *extremely unlikely* to be less than 1°C and *medium confidence* that the ECS is *likely* 1.5°C - 4.5°C, and *very unlikely* greater than 6°C

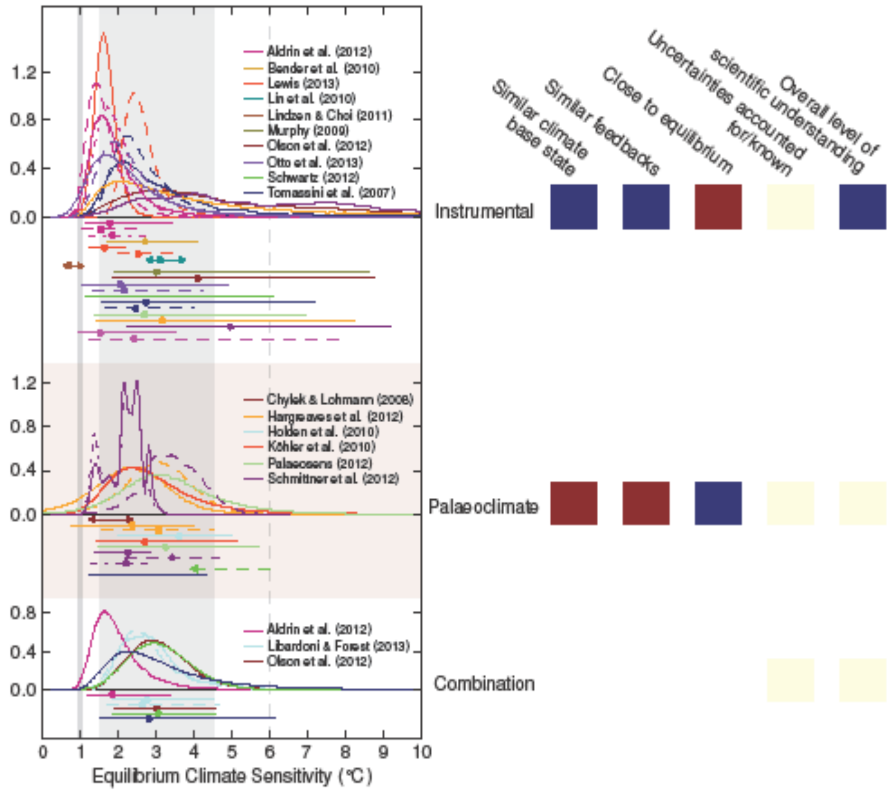
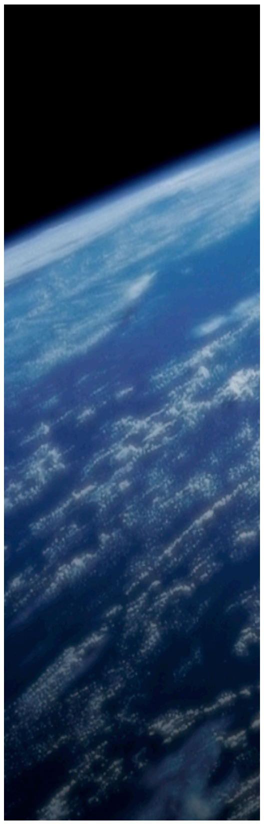


Figure 10.20

Transient climate response to cumulative CO_2 emissions

- TCRE: the ratio of CO_2 induced warming realized by a given year to cumulative carbon emissions up to that year
  - May be estimated from observations by dividing an estimate of warming to date attributable to CO_2 by historical cumulative carbon emissions
  - The strongest predictor of peak warming is cumulative emissions to 2200
  - Global warming response to CO_2 is primarily determined by total cumulative emissions, irrespective of the time of the emissions

- The TCRE is *likely* to be between 0.8°C - 2.5°C per 1000 PgC.
  - Implies that, for warming due to CO_2 emissions alone to be *likely* less than 2°C at the time CO_2 emissions cease, total cumulative emissions from all anthropogenic sources over the entire industrial era would need to be limited to ~1000 PgC



Synthesis

Multi-variable approaches

"Multi-variable attribution studies potentially provide a stronger test of climate models than single variable attribution studies"

- Give a more comprehensive view of the climate system
- May potentially have greater power to discriminate between forced changes and internal variability
- There may be sensitivity to weighting of different components of the multi-variable fingerprint
- Analyses typically yield stronger signals on the climate than looking at one variable alone

Whole climate system

“From [the] combined evidence it is *virtually certain* that human influence has warmed the global climate system”

- There is strong evidence that **human influence** has been identified in the major assessed parts of the climate system: temperature changes near the earth’s surface, atmosphere, and oceans; changes in the cryosphere, the water cycle, and extreme events; rather than solar forcing, volcanoes, and internal variability

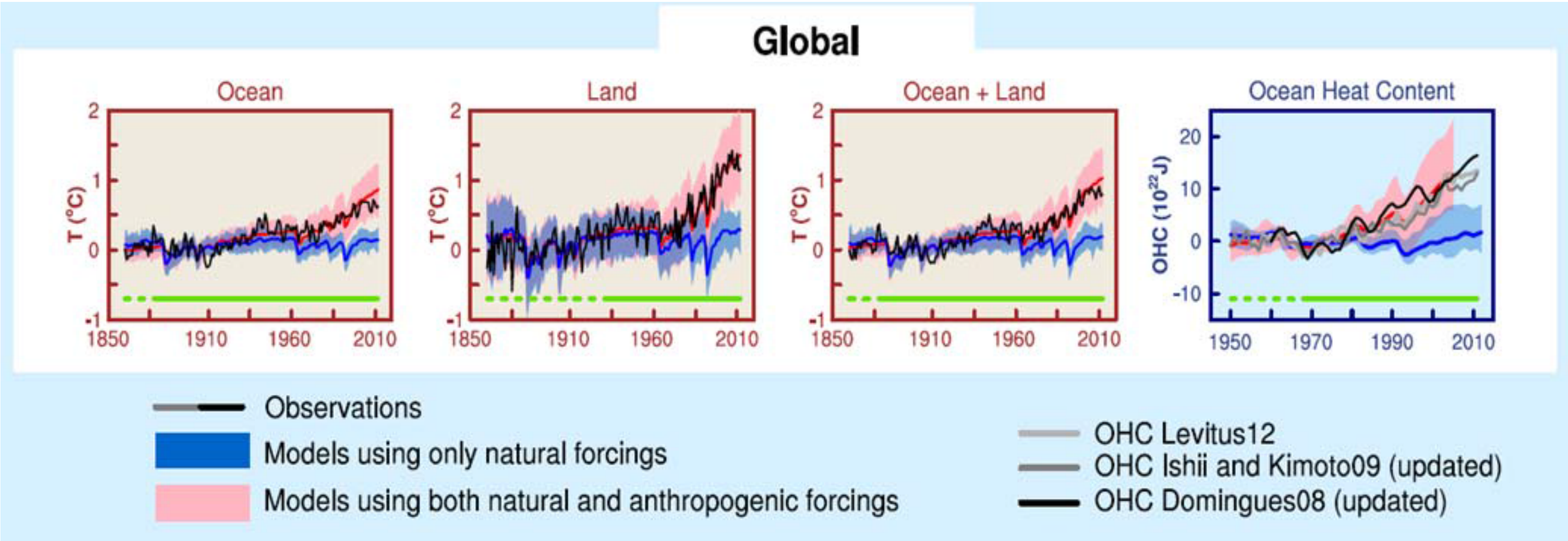
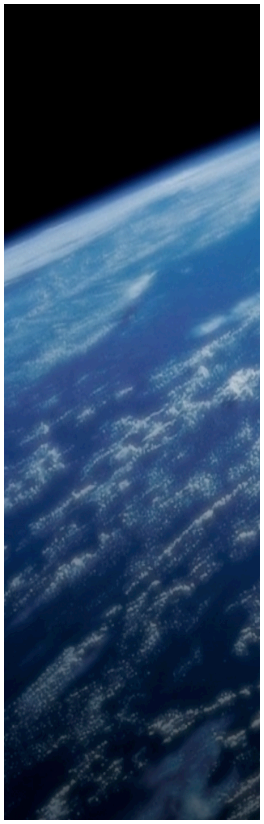


Figure 10.21



Questions?