Climate Change: Science Summary

IPCC Third assessment report (TAR)

- What do the observations show?
- How quantitative is our understanding?
- What is the current ability to simulate?
- What is the human influence?
- What could the possible climate future be?

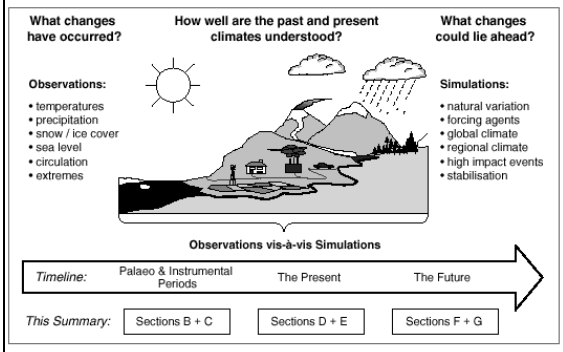


Figure 1: Key questions about the climate system and its relation to humankind. This Technical Summary, which is based on the underlying information in the chapters, is a status report on the answers, presented in the structure indicated.

Overall Picture

- Increasing body of evidence for warmer world and other climate changes
  - Surface temperature has increased over 20th century by about 0.6 C Temp change 140-1000yrppt
  - Temperature has risen during last four decades in lowest 8 km of atmosphere (troposphere) annual temp changesppt
  - Snow cover and ice extent have decreased
  - Global sea level has risen and heat content has increased sea level changesppt

Other changes

- Precipitation likely to have increased 0.5 – 1% per decade in 20th century
- Likely increase over 20th century in mid-latitude of frequency of heavy precipitation
- Likely increase 25% in cloud cover over 20th century over land areas
- Since 1950 very likely reduction in frequency of extreme low temperatures

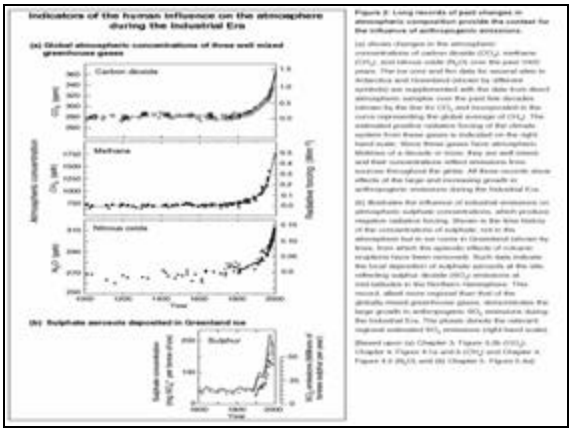
Other changes

- Warm El Nino have been more frequent and persistent
- Small increase in more areas experiencing more severe draught or severe wetness
- Increase in frequency of draughts

No change in some climate aspects

- A few areas have not warmed (Southern oceans and part of Antarctica)
- No significant trend in Antarctic sea ice?
- Changes in tropical and extra-tropical storm intensity and frequency dominated by inter-decadal to multi-decadal variability
- No systematic change in tornadoes, thunder days or hail

Emission of greenhouse gases and aerosol due to human activities continue to alter the atmosphere in ways that are expected to affect climate



Concentration of atmospheric greenhouse gases (GHG)

- CO_2 past CO2 concentration changes.ppt
  - concentration has increased 31% since 1750 (exceeded past 420,000y and likely past 20 my), unprecedented increase over past 20,000
  - ¾ of CO_2 emission is anthropogenic due to fossil fuel burning
  - Ocean and taking up ½ anthropogenic CO_2 emissions
  - Rate of increase 1.5 ppm per y over past 2 decades but variable (0.9 –2.8) over 20th century

Greenhouse gases

- CH4 CH4 concentration increase.ppt
  - Concentration has increased by 1060 ppb
  - Present concentration not been exceeded over past 420,000 y
  - Annual growth slowed down
  - Slightly more than ½ emissions are anthropogenic (fossil fuel use, cattle, rice agriculture and land fills)

Greenhouse gases

- N2O
  - Concentration has increased 46 ppb since 1750
  - Present concentration not been exceeded during at least past thousand years
  - 1/3 emissions are anthropogenic
- Halocarbon gases (CFCs) – ozone depleting and Greenhouse gases
  - Increasing more slowly or decreasing (Montreal protocol)
  - Concentration of substitutes that are also Greenhouse gases are increasing

Greenhouse Radiative Forcing

- Radiative Forcing = Imposed perturbation to energy balance – expressed in Wm^{-2}
- Allows to compare effect of different gases
- Total forcing = 2. 5 Wm^{2}
  - CO_2 forcing = 1.5 Wm^{-2}
  - CH4 forcing = 0.48 Wm^{-2}
  - Halocarbons forcing = 0.34 Wm^{-2}
  - N_2O forcing = 0.15 Wm^{-2}

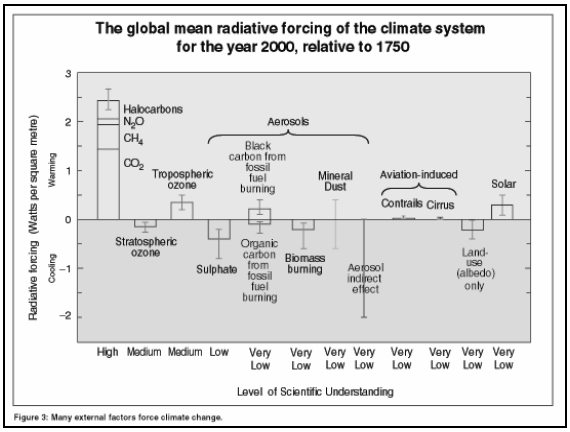


Figure 3: Many external factors force climate change.

Ozone (O_3) Radiative Forcing

- Observed ozone depletion in stratosphere 1979 –2000 => negative radiative forcing
- Total O_3 in troposphere has increased by 36% since 1750 due to anthropogenic emission of several 0_3-forming gases => positive forcing

Anthropogenic aerosol

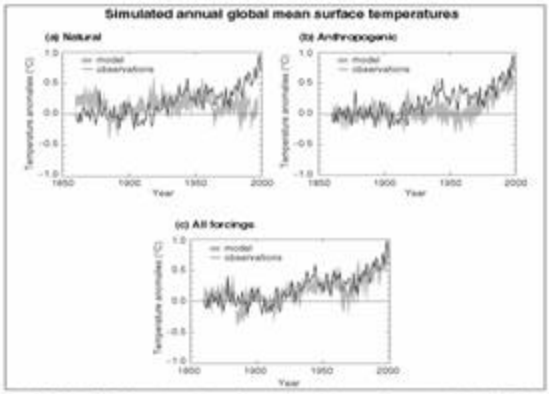
- Short lived
- Mostly producing negative forcing
- Major source anthropogenic aerosol = fossil fuel and biomass burning
- Better characterization of direct radiative role
  - -0.4 Wm^{-2} for sulphate
  - -0.2 for biomass burning
  - -0.1 for fossil fuel organic carbon
  - +0.2 for black carbon
- Much less confidence for quantifying total direct effect
- Indirect effect ???

Natural Factors have had a small contribution over past century

- Radiative effect due to solar irradiance change since 1750 ~ 1.3 Wm^{-2} mostly during first half of 20th century
- Stratospheric aerosol from volcanoes lead to negative forcing that lasts for a few years (e.g., Mt Pinatubo 1990s)
- Combine effect probably negative for the past 2-4 decades

Confidence in models to predict

- Has increased but still uncertain
- Water vapor, sea ice dynamics and ocean heat transport representation better
- Estimates of natural and anthropogenic effects on changes of temperature closer to observations
- Some aspects of model simulations of El Nino, monsoon, NAO have improved

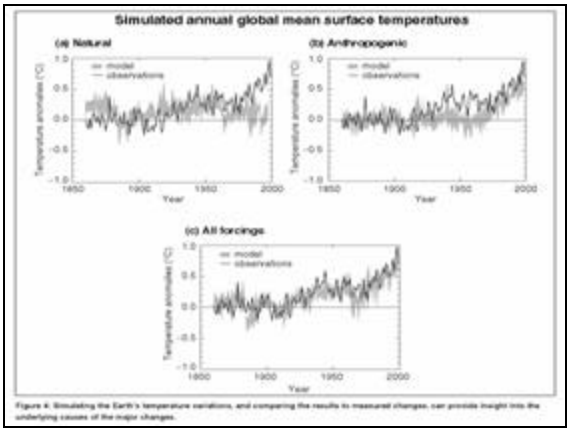


New and stronger evidence: most observed warming (last 50 y) is anthropogenic

- Longer and better temperature records
- Warming over past 100 y very unlikely due to internal variability alone
- New estimates of climate response and new detection techniques
- Simulation of natural forcing (solar and volcanic) alone cannot explain warming. But small contribution 1st half of 20th century
- Anthropogenic warming over last 50y can be identified despite uncertainties in forcing due to sulphate aerosols and natural factors

New and stronger evidence…

- Uncertainties in response to climate forcing and those due to climate sensitivity are now included
- Estimated rate similar to that observed
- Best agreement between model simulations and observations when natural and anthropogenic effects are taken into account



Future

- Predictions with models
- Use IPPC SRES scenarios based on projected changes in:
  - Population
  - Economic and technologic development
  - Energy use

Human Influence will continue

- Greenhouse gases
  - CO_2 emissions will dominate first part of 21st century
  - Ocean and land will take up decreasing fractions => increase in atm. concentration
  - Projections 2100 CO_2 concent. 540-970ppm (SRES scenarios)
  - Changing land use could affect CO_2 concent.
  - Non- GHG concentrations vary considerably across scenarios
  - Reductions in GHG emissions and their precursors necessary

Human Influence will continue

- Aerosols
  - different possibilities depending on extent of fossil fuel use and policies to abate polluting emissions
  - Natural aerosols (sea salt, dust and emissions leading to sulphate and carbon aerosols) projected to increase as a result of climate change

Global Temperature and sea level projected to rise under all scenarios

- Temperature
  - Globally 1.4 – 5.8 C from 1990 –2100
  - Rate of warming>>during 20th century
  - By 2100 large differences among models
  - Anthropogenic effect likely 0.1 – 0.2 C per decade
  - Likely that land will warm up more rapidly than global average particularly N.America and N. and central Asia
  - Recent trends in Surface temperature more like El Nino

Global temperature and sea level projected to rise…

- Precipitation
  - Water vapor and precipitation projected ot increase
  - Large year-to-year variations in precipitation
- Extreme events
- El Nino: likely to lead to greater extremes of drying and heavy rainfall
- Monsoons: increase in precip. Variability
- Thermohaline circulation – potential weakening

Global temperature and sea level projected to rise…

- Snow and ice
  - NH snow cover and sea-ice extent projected to decrease
  - Glaciers and ice caps projected to retreat
  - W. Antarctic ice sheet concerns about stability
- Sea level projected to rise 0.09 - .88 m from 1990 –2100
  - Thermal expansion
  - Loss of mass from glaciers

Future research needed to address remaining gaps

- Systematic observations and reconstructions
  - Reverse decline in monitoring system
  - Sustain and expand observation network
  - Enhance development of reconstructions of past
  - Improve observation spatial distribution GHG
- Modeling and process studies
  - improve understanding of processes and feedbacks
  - Improve methods to quantify uncertainties in projections and scenarios
  - Improve integrated hierarchy of models
  - Link physical climate models with biogeochemical system and human activities