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A shortened summary of IPCC AR5 WG1: "The Physical Science Basis"

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Headlines

- The climate system has warmed in the last century
- It is *extremely likely*[i] that human influence has been the dominant cause of the observed warming since the mid twentieth century
- Warming and associated changes in the ocean and global land and ice will continue in the 21st century
- The extent of future warming is determined by cumulative greenhouse gas emissions.
- Limiting climate change will require substantial reductions in emissions.

Observed Change

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.

Temperature: Globally, surface temperatures increased by 0.85^{o}C in the period 1880–2010. Regionally, there was warming in the period 1901–2012 over all regions in which data is available except the central North Atlantic where a small cooling occurred. Care must be taken when examining shorter (one or two decade) records, since natural variability may disguise or amplify the longer-term trend.

Rainfall: Rainfall over northern hemisphere mid-latitude land areas, including Scotland, has increased since 1901 (medium confidence). In other areas there is low confidence in long-term changes, due to a lack of data.

Extremes: Changes in temperature and precipitation extremes have been observed since around 1950. These are consistent with the above trends; very likely reductions in cold days and increases in hot days globally; likely more frequent heat waves in parts of Europe, Asia and Australia, and likely increases in heavy precipitation in Europe and North America.

Ice and Snow: In the last two decades there has been a large reduction in ice mass in Greenland and Antarctica, in glacier mass worldwide, in Arctic sea ice and northern hemisphere snow cover. In Antarctica, a small increase in sea ice extent has been observed; this is much smaller than the decrease in extent seen in the Arctic and the trend varies by region, and the cause is uncertain (see section "Uncertainties").

Ocean: Ocean warming accounted for more than 90% of the increase in energy in the climate system[ii] between 1971 and 2010. Between 1901 and 2010 global mean sea level rose by between 0.17 and 0.21 m. This is a rate of 1.7 mm/yr and there is high confidence that this is larger than the mean rate over the past 2000 years. Around 75% of sea level rise since the 1970s is due to expansion of the ocean as it warms, and to added water from glacial mass loss. The remainder is from ice sheet melt and decreases in land water storage, particularly groundwater depletion linked to human activity.

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Carbon Cycle: Current levels of carbon dioxide (CO^2), methane, and nitrous oxide - all greenhouse gases - in the atmosphere exceed levels for the last 800,000 years as estimated from ice cores. Recent rates of increase are higher than those seen since the last glacial maximum (22,000 years ago). Emissions are from fossil fuel combustion, cement production, and deforestation and other land use change. Of total CO2 emissions since 1750, approximately 40% have been taken up by the atmosphere, 30% by the ocean, and 30% by natural land ecosystems. The take up of CO2 by the ocean has caused ocean acidification.

Links to human activity

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

Possible drivers of change: Substances or processes which alter the balance of energy entering and leaving the Earth system, and therefore its temperature, are known as 'forcings'. Forcings include both natural processes (changes in the incoming radiation from the sun, emissions from volcanoes) and human behaviour (emission of gases and aerosols and changes to the land surface).

Improved tools for understanding: Climate models have improved since AR4. Models reproduce global and continental scale temperature patterns and changes over the last century. Internal variability, which is a natural element of the climate system and not driven by any of the forcings described above, is high on timescales of one to two decades. This causes much of the difference in trends between the model and observations at these timescales *(medium confidence).*

Understanding recent change: Alongside physical understanding, climate model simulations allow changes to be **detected** in observations and **attributed** to a particular forcing, such as greenhouse gases. Human influence has been identified in recent changes in surface temperatures, upper ocean heat content, northern hemisphere snow and ice reductions, sea level rise, and some changes in climate extremes. For example, changes in surface temperature since around 1960 cannot be explained by natural forcing (the sun and volcanoes) alone (Figure 1).

In summary, it is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century. Improved climate models and longer observational records since the previous IPCC report give increased evidence for human influence in this newer report.

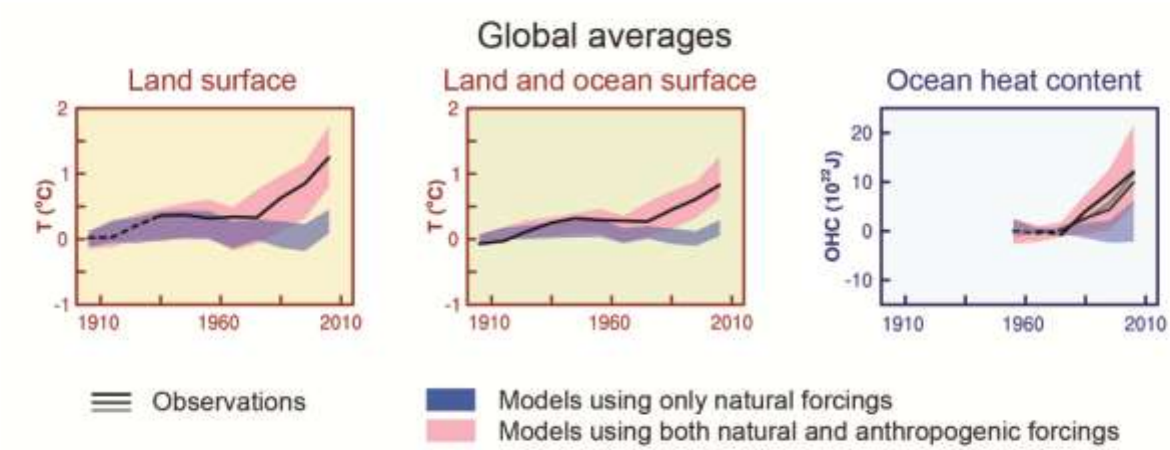

Figure 1: adapted from Figure SPM.6 (lower panel, with global changes only, is shown here. Full caption at end of document.) Comparison of observed (black) and simulated (coloured) trends in the atmosphere and ocean. Simulated trends are from multi-model ensemble, with shaded bands containing 90% of model projections. Anomalies are given relative to 1880–1919 for surface temperatures, and 1960–1980 for ocean heat content. All time-series are ten-year averages, plotted at the centre of the decade. Dashed lines show poorer observational data coverage.

Climate Sensitivity: Various measures are used to represent the magnitude of the climate system's response to greenhouse gas emissions under certain conditions. Model estimates of equilibrium climate sensitivity, defined as the long-term response to a doubling of atmospheric CO_2, give a *likely* range of 1.5 –4.5°C. This is similar to the range in the previous assessment report although the low-end estimate is reduced.

Expected Future Change

Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions

Temperature The increase in global mean surface temperature relative to 1850—1900 is *more likely than not* to exceed 2°C under all but the weakest scenario of human forcing. Global mean surface warming is largely determined by cumulative emissions of CO_2. Keeping warming below 2°C above pre-industrial (late 19th century) conditions would require substantial reductions in emissions.

Rainfall There will be regional variations in changes in the water cycle in the 21st century. In general, the contrast between wet and dry regions and seasons will increase.

Ice and Snow: Global glacier mass will continue to decrease, and it is *very likely* that northern Hemisphere snow and sea ice cover will continue to decline.

Ocean: There will be a continued warming of the ocean in the 21st century. The rate of sea level rise is *very likely* to increase, and ocean acidification will increase.

Longer term changes: Even if emissions drop to zero, climate change will not be reversed or even stopped; surface temperatures will remain at an increased level for several centuries, and ocean warming and sea level rise will continue.

Uncertainties

Despite the improvements since AR4, uncertainties remain. In particular:

- There is relatively *low confidence* in some past changes - in particular changes in precipitation, tropical cyclones, tropospheric warming, and changes in Antarctica - generally due to a lack of data.
- There is a lack of understanding regarding aerosol effects on clouds, which leads to uncertainty in the total human contribution to observed warming.
- There is a lack of understanding of feedbacks between the climate and the carbon cycle (the movement of carbon between the atmosphere, ocean and land). For example, warming caused by CO_2 affects how the land/ocean system takes up carbon, so more may remain in the atmosphere.
- It is challenging to attribute the causes of observed change in the water cycle and in regional or sub-continental climate change. This challenge arises because internal variability is relatively large compared to forced responses in the water cycle and at regional scales.
- There is still a range of projections for: short term climate; the effect of methane and thawing permafrost; changes in tropical storms; changes to systems such as El Nino; and ice sheet melt. Future changes in these areas are therefore uncertain.

Many of the above questions are addressed by five World Climate Research Program (WCRP) grand challenges. These are **Clouds, Circulation and Climate Sensitivity**; **Melting Ice and global consequences**; **Climate Extremes**; **Regional Sea-Level change and coastal impacts; and Water Availability.** Within Scotland, work addressing these challenges includes ongoing work into understanding climate sensitivity and climate variability, the carbon cycle, and the stability of the Greenland Ice Sheet (at Edinburgh University alone).

Further Information

The above information is taken from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). In particular it draws on the Summary for Policymakers (SPM) from the Working Group 1 contribution, which focuses on the Physical Science Basis for climate change. The previous report, the fourth assessment report (AR4) was published in 2007; AR5 benefits from a larger body of evidence, such as publications and observational data, and improved climate models. In particular there is increased evidence for human influence on recent changes.

In addition to the SPM for each Working Group, the IPCC provides a synthesis summary, "Climate Change 2014 Synthesis Report: Summary for Policy Makers". This resource covers all three working groups (Physical Science, Adaptation and Impacts, and Mitigation) and is recommended for further details on the above information. Quotations are taken from one of the above two documents.

When past records use a specific set of years, it is based on availability of reliable data. Future changes are calculated under four Representative Concentration Pathways (RCPs), which are four different scenarios of human emissions and land use. These include a mitigation scenario (RCP2.6), two stabilisation scenarios (RCP4.5 and RCP6) and a very high emissions scenario (RCP8.5). All RCPs have higher atmospheric CO_2 concentrations in 2100 than at present.

The information on uncertainties is drawn from the IPCC WG1 Technical Summary. Information on the WCRP grand challenges and UK efforts to address uncertainties is taken from institutional websites.

Likelihood and Confidence

This report adopts the IPCC uncertainty language for likelihood and confidence.

For likelihood, *extremely likely* indicates >95% probability; *very likely* >90% probability; *likely* >66% probability; and *more likely than not >50% probability.*

Where appropriate the IPCC also qualifies its statements with a level of confidence ('*very low' ,'low', 'medium', 'high'* and *'very high*') based on the level of agreement in the scientific community and the amount of evidence.

The following caption from the original of Figure 1 is included to comply with IPCC restrictions on use of graphics:

Full caption, Figure SPM.6: **| Comparison of observed and simulated climate change based on three large-scale indicators in the atmosphere, the cryosphere and the ocean: change in continental land surface air temperatures (yellow panels), Arctic and Antarctic September sea ice extent (white panels), and upper ocean heat content in the major ocean basins (blue panels). Global average changes are also given. Anomalies are given relative to 1880–1919 for surface temperatures, 1960–1980 for ocean heat content and 1979–1999 for sea ice. All time-series are decadal averages, plotted at the centre of the decade. For temperature panels, observations are dashed lines if the spatial coverage of areas being examined is below 50%. For ocean heat content and sea ice panels the solid line is where the coverage of data is good and higher in quality, and the dashed line is where the data coverage is only adequate, and thus, uncertainty is larger. Model results shown are Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model ensemble ranges, with shaded bands indicating the 5 to 95% confidence intervals. For further technical details, including region definitions see the Technical Summary Supplementary Material. {Figure 10.21; Figure TS.12}**

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[i] Text in italics indicates use of IPCC uncertainty language for likelihood and confidence; details are given under 'Further Information'

[ii] The total energy in the climate system increased during this period due to natural and human-driven forcings; see section 'Possible Drivers of Change'