This Digest is a faithful summary of the leading scientific consensus report produced in 2013 by the Intergovernmental Panel on Climate Change (IPCC): Climate Change 2013: The Physical Science Basis.

IPCC 2013 report on Climate Change

Level 1 summary of Part 1 -*The Physical Basis*

Context

"Climate Change 2013: The Physical Science Basis" is a comprehensive assessment of the physical aspects of climate change, which puts a focus on the elements that are relevant to understand past, document current and project future, climate change. The report covers observations of changes in all components of the climate system and assess the current knowledge of various processes of the climate system. Direct global-scale instrumental observation of the climate began in the middle of the 19th century, and reconstruction of the climate using proxies such as tree rings or the content of sediment layers extends the record much further in the past.

The present assessment uses a new set of new scenarios to explore the future impacts of climate change under a range of different possible emission pathways.

1. How are uncertainties handled by the IPCC?

Although both the body of knowledge on the climate system and the confidence in projections are growing, there are still many uncertainties in climate science. An integral element of the IPCC 5th Assessment Report (AR5) is the use of a specific uncertainty language to reflect accurately the strength of each statement.

Where appropriate, findings are formulated as statements of fact, but when a qualifier is needed, there are two systems that are applied.

The first one is **the level of confidence** in the validity of a finding. It is based on the type, amount, quality and consistency of evidence (e.g. data, mechanistic understanding, theory, models, expert judgment), and on the degree of agreement. This goes from low agreement – limited evidence to high agreement –robust evidence. The second one is **the level of likelihood** of a finding, which express the quantified measures of uncertainty as a probability.

When confidence or likelihood terms are used in this summary, these are indicated *in italics*.

Likelihood terms used in this report	
Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability
* Additional terms (*extremely likely*: 95–100% probability, *more likely than not*: >50–100% probability, and *extremely unlikely*: 0–5% probability) may also be used when appropriate.	

OBSERVATIONS

2. What have been the observed climate changes in the last centuries?

2.1 It is *certain* that the global mean surface temperature of the earth has increased since the beginning of the instrumental record. This warming has been about 0.85°C from 1880 to 2012 with an increase of about 0.72°C from 1951 to 2012. Each of the last three decades has successively been the warmest on record. They also have *very likely* been the warmest in the last 800 years and *likely* the warmest in the last 1400 years even if the rate of warming over the last 15 years is smaller than the rate since the 1950s..

The upper ocean (above 700 m) has warmed over the course of the 20th century (*certain*), the ocean warmed between 700 and 2000 m *(likely),* and from 3000 m to the bottom (*likely)*, but no significant trend was observed between 2000 m and 3000 m.

Since at least circa 1970, the planet has been in energy imbalance, with more energy from the sun entering than exiting the top of the atmosphere (this is what is called "radiative forcing") and the warming of the oceans accounts for most (93%) of the increase in energy capture.

2.2 On the global scale, it is *not clear* if there were changes in **precipitation and cloud cover**, in part because there is insufficient data. The humidity of the lower atmosphere has *very likely* increased since the 1970s, but it is *not clear* what changes in precipitations this has led to.

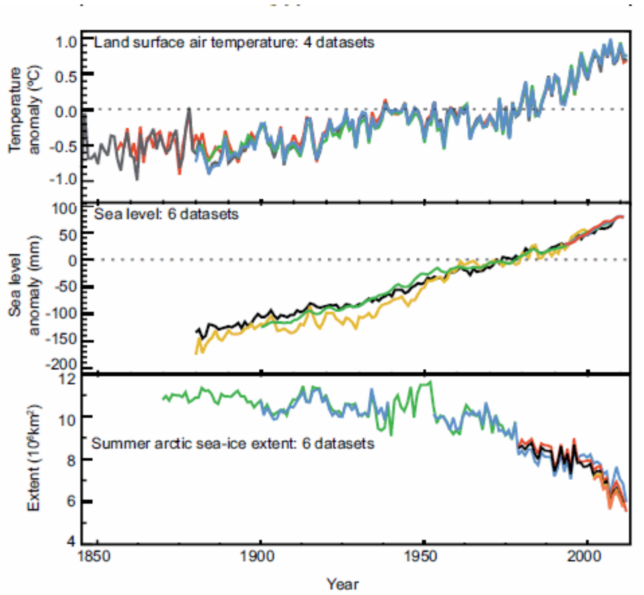

Figure TS.1 : Indicators of climate change
Source: IPCC WGI – Technical summary

2.3 Changes have been observed in **ocean properties** (warming, changes in salinity, increase in carbon content and acidity, decrease in oxygen concentration) during the past forty years. The observed patterns of changes are *consistent* with a response to climate change.

2.4 There is *very high* confidence that the **Arctic sea ice** extent has decreased over the period 1979–2012. By contrast, it is *very likely* that the Antarctic sea ice extent increased between 1979 and 2012, due to a decrease in the percentage of open water within the ice pack. There is *high confidence* that parts of Antarctica floating ice shelves are undergoing substantial changes.

There is *very high* confidence that terrestrial glaciers have shrunk world wide in the last decades and that they will continue to melt. Permafrost has also been warming all around the globe. In the Northern Hemisphere, snow cover has decreased.

2.5 It is *virtually certain* that the rate of global **mean sea level rise** has accelerated from relatively low rates in the order of tenths of mm per year in the past millennia to the present rates in the order of mm per year. More specifically, the global mean sea level has risen by 0.19 [0.17 to 0.21] m over the period 1901– 2010. The current rate of global mean sea level is, with *medium confidence*, unusually high in the context of the last two millennia.

2.6 It is *very likely* that the number of **cold days and nights** has decreased and the number of **warm days and nights** has increased on the global scale. Globally, the length and frequency of **warm spells and heat waves** has increased since the middle of the 20th century. It is *likely* that since 1950 the number of **heavy precipitation events** over land has increased in more regions than it has decreased. It is *virtually certain* that the frequency and intensity of **storms** in the North Atlantic have increased since the 1970s although the reasons for these increases are debated. Changes in **droughts and floods** are more variable from region to region.

2.7 In 2011, the atmospheric concentrations of the **greenhouse gases** carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), exceed the range of concentrations recorded in ice cores, and their rate of rise also exceeds what is known from ice cores. The main source of CO_2 is the burning of fossil fuels and the production of cement. About half of this carbon ends up in the atmosphere and the rest is taken up by plants or by the oceans.

DRIVERS
3. What makes the climate change?

3.1 Changes in climate are due to an imbalance between the energy from the sun received by the earth and the energy that is radiated back to space (this imbalance is called 'radiative forcing').

3.2 Over the period of the industrial era, since 1750, solar and volcanic forcings are the two dominant natural contributors to global climate change. **There is a *high confidence* that solar forcing is much smaller than the forcing caused by greenhouse gasses**. The impact of volcanic particles is now well understood and there is a large negative forcing for a few years after major volcanic eruptions such as the eruption of Mount Pinatubo in 1991.

3.3 Human activity leads to change in the atmospheric composition either directly (via emissions of gases or particles) or indirectly (via atmospheric chemistry). **Anthropogenic emissions have driven the changes in greenhouse gas concentrations during the industrial era (since 1750).** Over the last 15 years, CO_2 has been the dominant contributor to greenhouse gases, the main others being methane, nitrous oxide and halocarbons. The contribution of each gas is usually expressed in terms of Global Warming Potential (GWP) or of Global Temperature change Potential (GTP). On the one hand, the GWP compares a greenhouse gas to CO2 and is expressed as an equivalent amount of CO2. The GTP, on the other hand estimates the temperature change caused by a specific gas, and includes the response of the climate system.

Aerosols are tiny liquid droplets or particles (such as dust from volcanoes) that are in suspension in the atmosphere. Overall, aerosols cause a cooling of the atmosphere, but with a *large range of uncertainty,* there is a *high confidence,* however, that **aerosols have offset a substantial portion of the forcing due to greenhouse gases**. There is *robust evidence* that anthropogenic land use changes, such as deforestation, has affected the albedo (the reflectivity of the solar radiation), which is different in a darker green forest than in a paler field, and thus, the energy balance. Persistent contrails from aviation also contribute to warming.

3.4 Feedback mechanisms also play an important role in determining (future) climate change. For example:
Snow and ice albedo feedbacks: the warmer it gets the less snow there is, the darker and hotter the ground is, the warmer it gets.
There can also be feedbacks in cloud cover, although there are still large uncertainties attached to their importance and influence.

UNDERSTANDING
4. How do we study the climate system?

4.1 Understanding of the climate system results from combining observations, theoretical studies of mechanisms and feedback processes, and model simulations. Compared to the 4th assessment report published in 2007, more detailed observations and improved climate models now enable the attribution of the observed climate changes to human influences in more components of the climate system.

It is *extremely likely* that human activities caused more than half of the observed increase in global average surface temperature from 1951 to 2010, with greenhouse gases contributing a warming between 0.5°C and 1.3°C over this period.

4.2 The observed **global-mean surface temperature** (GMST) has shown a much smaller increase over the past 15 years than over the past 30 to 60 years. Changes in radiative forcings between decades show that for the period 1998-2011 forcing was indeed two thirds of what it had been for the 1984-1998 period. Globally, it is *very likely* that over that period the climate system has continued to accumulate energy, for instance in the form of increasing ocean heat. However, since some data show a slowing, and some do not, whether there has been a slowdown in that recent period remains *unclear*.

4.3 The most convincing way of establishing the credibility of the models used in climate change science is arguably the **verification of their projections**. It appears that results of projected changes in CO_2, global mean surface temperature and global mean sea level from previous IPCC assessment reports are in general agreement with the observed trends.

4.4 Various oceanic parameters have been monitored and modelled in terms of their response to climate change**.** It is *very likely* that human influence made a substantial contribution to the upper ocean warming (the upper 700m layer) that has been observed since the 1970s. This warming has in turn contributed to a global sea level rise through thermal expansion. **It is estimated that most of the energy that has been added to the climate system has been absorbed by the oceans.** Likewise, changes in salinity, oxygen content and acidity can also be attributed to human influence.

4.5 The reductions in **Arctic sea ice extent** and Northern hemisphere **snow cover extent**, as well as the widespread **glacier reduction** (retreat)- and the increased surface melt of Greenland are all *evidence* of overall changes in snow and ice linked to increased radiative forcing of anthropogenic origin.

4.6 The possibility of **irreversible changes**, the rate and magnitude of global climate changes is determined by radiative forcings, climate feedbacks and storage of energy by the climate system. For some elements of the climate system, there is a point where an abrupt change might happen once a threshold is reached. These abrupt changes can be irreversible – meaning that it takes a lot longer for the system to recover than it takes to shift to the new state – transitions to different states of the climate system.
For example:
Changes in the Atlantic meridional overturning circulation (AMOC) could produce abrupt climate changes at global scale and on the climate of Europe and North America.
In a warming climate, the thawing of permafrost could lead to the release of carbon accumulated in frozen soils, leading to increased atmospheric CO_2 and methane concentrations, and to further warming.
Since the growth of the ice sheets is a very slow process, any increase in the loss of ice, either through melt or ice outflow would be irreversible.

PROJECTIONS
5. What changes are projected in the climate system in the future?

5.1 Projections of changes in the climate system are made using a range of climate models that simulate changes based on a set of scenarios of anthropogenic forcings. A new set of scenarios, the *Representative Concentration Pathways (RCPs),* was used for the climate model simulations carried out for this assessment. These scenarios typically include economic, demographic, energy and simple climate components. The scenarios used in this assessment that explore what those emissions might be, have different targets in terms in radiative forcings by 2100, which range from a 'strong mitigation' scenario to a scenario of continuing growth in emissions.

5.2 Between 2012 and 2100, depending on the scenario, Earth System Models (ESM) results imply cumulative **fossil fuel emissions** ranging between 270 and 1685 gigatonnes of carbon.

5.3 In the absence of major volcanic eruptions—which would cause significant but temporary cooling—and, assuming no significant future long term changes in solar irradiance, it is *likely* that the global mean surface temperature will be **higher by 0.3°C to 0.7°C,** during the period 2016–2035 compared to 1986–2005(*medium confidence*). Global mean temperatures will continue to rise over the 21st century under all of the scenarios. From around the mid-21st century, the rate of global warming begins to be more strongly dependent on the scenario: the *likely* global-mean surface temperatures increases are projected as 0.3 to 4.8°C

Ocean temperatures will *very likely* continue to increase over the course of the 21st century. In some regions by the end of the century, **ocean warming is projected to exceed 0.5°C to 2.5°C** in the top few hundred meters and 0.3°C to 0.7°C at a depth of about 1 km. The sea level are also projected to continue rising, to between 0.26 to 0.81 m before the end of the 21st century. It is virtually certain that sea level rise will continue beyond 2100, and go on for centuries to millennia.

A nearly ice-free Arctic Ocean (sea ice extent less than 1000 000 km2) in September is *likely* before mid-century under the highest emission scenario, with *medium confidence*. It is very *likely* that there will be further shrinking and thinning of Arctic sea ice cover, and decreases of northern high-latitude springtime snow cover and near surface permafrost, as global mean surface temperature rises.

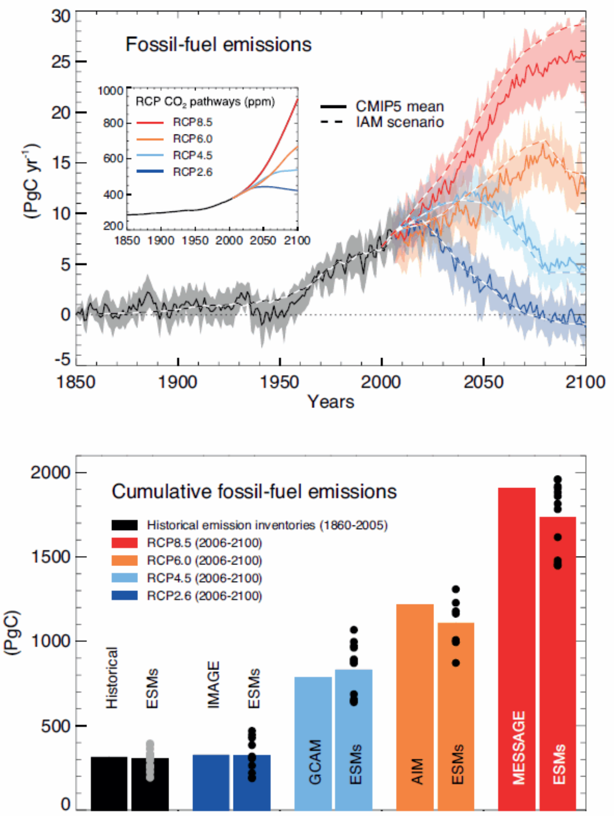

Figure TS.19 : Simulated fossil fuel emissions for the four RCP scenarios
Source: IPCC WGI – Technical summary

5.4 As regards the potential for **stabilizing the climate**, such climate stabilization can mean in practice :

- to stabilize of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, which is the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) ;
- to limit the global temperature increase.. The most widely discussed being 2°C above pre industrial levels;
- to return the level of atmospheric CO_2 below 350 ppm.

One approach to reach climate stabilization is geo-engineering, defined as the deliberate large-scale intervention in the Earth system to counter undesirable impacts of climate change on the planet, such as large-scale carbon capture and storage, or solar radiation management through the injection of aerosols in the atmosphere.

5.5 Assessing changes in **climate extreme** events poses unique challenges, not just because of the rare nature of these events, but because they invariably happen in conjunction with disruptive conditions. For the near- and long-term, scenario's projections confirm a *clear tendency* for increases in heavy precipitation events, although with large regional variations. For extreme events such as floods, droughts, and cyclones there are still a *lot of uncertainties* when it comes to establishing a trend of change, or establishing projections.

UNCERTAINTIES

6. What are the main uncertainties regarding climate change?

Human influence has been detected in nearly all of the major assessed components of the climate system. Taken together, the combined evidence increases the overall level of confidence in the attribution of observed climate change, and reduces the uncertainties associated with assessment based on a single climate variable. The coherence of observed changes with simulations of anthropogenic and natural forcing in the physical system is remarkable. However, *a series of uncertainties remain*. Understanding of the sources and means of characterizing uncertainties in long-term large-scale projections of climate change has not changed significantly since the previous report, but new experiments and studies have continued to work towards a more complete and rigorous characterization.

6.1 The ability of climate models to simulate surface temperature has improved in many ways, but there are still a number of uncertainties when it comes to specific elements of the observed changes in the climate system.

6.2 Uncertainties in how aerosols interact with clouds remain the main contributor to the uncertainty on man-made climate change.

6.3 In some aspects of the climate system, including droughts, tropical cyclone activity, Antarctic warming, sea ice extent, and glacier mass balance, the *confidence remains low* in attributing changes to human influence due to modelling uncertainties and low agreement between scientific studies.

6.4 There are also several areas in which projections of climate change remain difficult: the projections of global and regional climate change and precipitation, a pole ward shift of the position and strength of Northern Hemisphere storm tracks, the trends in tropical cyclone frequency and intensity in the 21st century, the changes in soil moisture and surface run off, the magnitude of carbon emissions to the atmosphere from thawing permafrost and methane emissions from natural sources such as wetlands or gas hydrates.

• There is also medium confidence on how ice sheets will affect sea level during the 21st century, and low confidence in model projections of sea level rise, and no consensus in the scientific community about their reliability.

• Eventually, there is low confidence in projections on many aspects of regional climate change.

This summary was peer-reviewed by a climate expert from academia.

You can find this summary, along with a more detailed one on the GreenFacts website at:
www.greenfacts.org/en/climate-change-ar5-science-basis/index.htm
The source document for this summary can be found on the IPCC website:
www.ipcc.ch/report/ar5/wg1/

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