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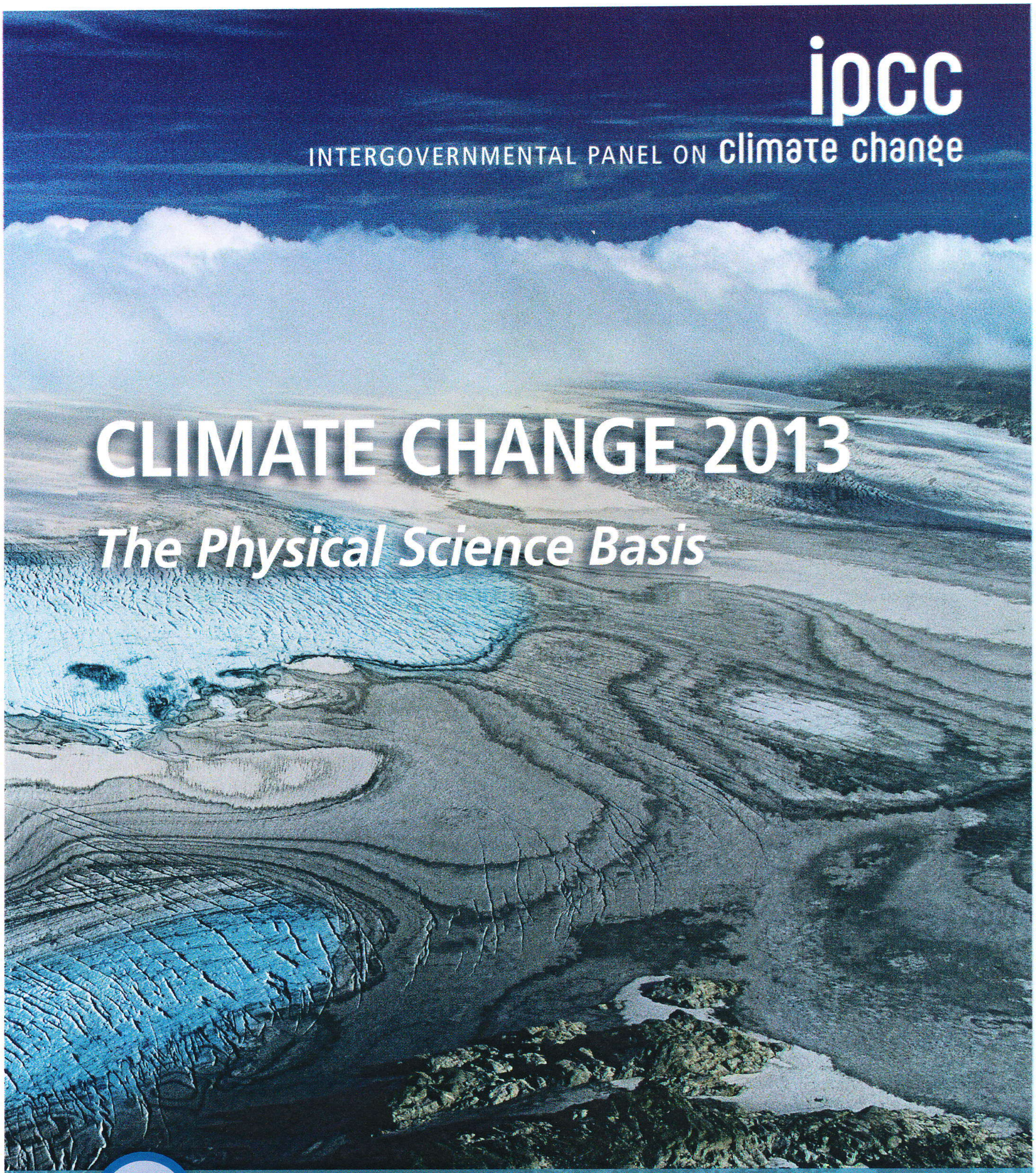
INTERGOVERNMENTAL PANEL ON climate change

# CLIMATE CHANGE 2013

## *The Physical Science Basis*



WG I

**WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE**

WMO UNEP

# Climate Change 2013
# The Physical Science Basis

## Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change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Cover photo:
Folgefonna glacier on the high plateaus of Sørfjorden, Norway (60°03′ N - 6°20′ E) © Yann Arthus-Bertrand / Altitude.

scenarios but those model results may also account for historical emissions analyses. The recent observed trends in $CO_2$ concentrations tend to be in the middle of the scenarios used for the projections (Figure 1.5).

As discussed in Dlugokencky et al. (2009), trends in $CH_4$ showed a stabilization from 1999 to 2006, but $CH_4$ concentrations have been increasing again starting in 2007 (see Sections 2.2 and 6.3 for more discussion on the budget and changing concentration trends for $CH_4$). Because at the time the scenarios were developed (e.g., the SRES scenarios were developed in 2000), it was thought that past trends would continue, the scenarios used and the resulting model projections assumed in FAR through AR4 all show larger increases than those observed (Figure 1.6).

Concentrations of $N_2O$ have continued to increase at a nearly constant rate (Elkins and Dutton, 2010) since about 1970 as shown in Figure 1.7. The observed trends tend to be in the lower part of the projections for the previous assessments.

### 1.3.3 Extreme Events

Climate change, whether driven by natural or human forcings, can lead to changes in the likelihood of the occurrence or strength of extreme weather and climate events such as extreme precipitation events or warm spells (see Chapter 3 of the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX); Seneviratne et al., 2012). An extreme weather event is one that is rare at a particular place and/or time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations (see also Glossary in Annex III and FAQ 2.2). By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. At present, single extreme events cannot generally be directly attributed to anthropogenic influence, although the change in likelihood for the event to occur has been determined for some events by accounting for observed changes in climate (see Section 10.6). When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season). For some climate extremes such as drought, floods and heat waves, several factors such as duration and intensity need to be combined to produce an extreme event (Seneviratne et al., 2012).

The probability of occurrence of values of a climate or weather variable can be described by a probability density function (PDF) that for some variables (e.g., temperature) is shaped similar to a Gaussian curve. A PDF is a function that indicates the relative chances of occurrence of different outcomes of a variable. Simple statistical reasoning indicates that substantial changes in the frequency of extreme events (e.g., the maximum possible 24-hour rainfall at a specific location) can result from a relatively small shift in the distribution of a weather or climate variable. Figure 1.8a shows a schematic of such a PDF and illustrates the effect of a small shift in the mean of a variable on the frequency of extremes at either end of the distribution. An increase in the frequency of one extreme (e.g., the number of hot days) can be accompanied by

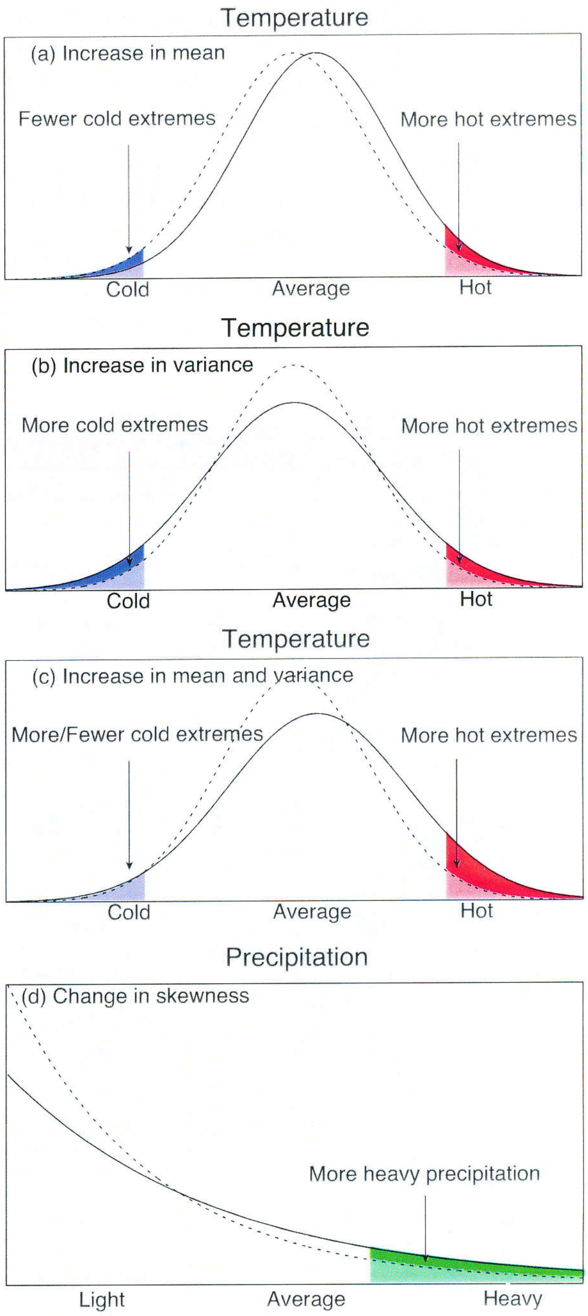


Figure 1.8 | Schematic representations of the probability density function of daily temperature, which tends to be approximately Gaussian, and daily precipitation, which has a skewed distribution. Dashed lines represent a previous distribution and solid lines a changed distribution. The probability of occurrence, or frequency, of extremes is denoted by the shaded areas. In the case of temperature, changes in the frequencies of extremes are affected by changes (a) in the mean, (b) in the variance or shape, and (c) in both the mean and the variance. (d) In a skewed distribution such as that of precipitation, a change in the mean of the distribution generally affects its variability or spread, and thus an increase in mean precipitation would also imply an increase in heavy precipitation extremes, and vice-versa. In addition, the shape of the right-hand tail could also change, affecting extremes. Furthermore, climate change may alter the frequency of precipitation and the duration of dry spells between precipitation events. (Parts a–c modified from Folland et al., 2001, and d modified from Peterson et al., 2008, as in Zhang and Zwiers, 2012.)

a decline in the opposite extreme (in this case the number of cold days such as frost days). Changes in the variability, skewness or the shape of the distribution can complicate this simple picture (Figure 1.8b, c and d).

While the SAR found that data and analyses of extremes related to climate change were sparse, improved monitoring and data for changes in extremes were available for the TAR, and climate models were being analysed to provide projections of extremes. In AR4, the observational basis of analyses of extremes had increased substantially, so that some extremes were now examined over most land areas (e.g., rainfall extremes). More models with higher resolution, and a larger number of regional models have been used in the simulation and projection of extremes, and ensemble integrations now provide information about PDFs and extremes.

Since the TAR, climate change studies have especially focused on changes in the global statistics of extremes, and observed and projected changes in extremes have been compiled in the so-called 'Extremes'-Table (Figure 1.9). This table has been modified further to account for the SREX assessment. For some extremes ('higher maximum temperature', 'higher minimum temperature', 'precipitation extremes', 'droughts or dryness'), all of these assessments found an increasing trend in the observations and in the projections. In the observations for

| Changes in Phenomenon | Uncertainty in observed changes (since about the mid-20th century) | | | Uncertainty in projected changes (up to 2100) | | |
|---|---|---|---|---|---|---|
| IPCC Assessment Report | TAR | AR4 | SREX | TAR | AR4 | SREX |
| Higher maximum temperatures and more hot days | *Likely* over nearly all land areas | *Very Likely* over most land areas | *Very Likely* at a global scale | *Very Likely* over nearly all land areas | *Virtually Certain* over most land areas | *Virtually Certain* at a global scale |
| Higher minimum temperatures, fewer cold days | *Very Likely* over nearly all land areas | *Very Likely* over most land areas | *Very Likely* at a global scale | *Very Likely* over nearly all land areas | *Virtually Certain* over most land areas | *Virtually Certain* at a global scale |
| Warm spells/heat waves. frequency, length or intensity increases | - | *Likely* over most land areas | *Medium Confidence* in many regions | - | *Very Likely* over most land areas | *Very Likely* over most land areas |
| Precipitation extremes | *Likely*[1], over many Northern Hemisphere mid- to high latitude land areas | *Likely*[2] over most areas | *Likely*[3] | *Very Likely*[1] over many areas | *Very Likely*[2] | *Likely*[2,4] in many land areas of the globe |
| Droughts or dryness | *Likely*[5], in a few areas | *Likely*[6], in many regions since 1970s | *Medium Confidence* in more intense and longer droughts in some regions, but some opposite trend exists | *Likely*[5], over most mid-latitude continental interiors (Lack of consistent projections in other areas) | *Likely*[6] | *Medium Confidence*[7] that droughts will intensify in some seasons and areas; Overall *low confidence* elsewhere |
| Changes in tropical cyclone activity (i.e. intensity, frequency, duration) | Not Observed[8], in the few analyses available | *Likely*[9], in some regions since 1970 | *Low confidence*[10] | *Likely*[8], over some areas | *Likely*[9] | *Likely*[11] |
| Increase in extreme sea level (excludes tsunamis) | - | *Likely* | *Likely*[12] | - | *Likely* | *Very Likely*[13] |

1 More intense precipitation events
2 Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases
3 Statistically significant trends in the number of heavy precipitation events in some regions. It is *likely* that more of these regions have experienced increases than decreases.
4 See SREX Table 3-3 for details on precipitation extremes for the different regions.
5 Increased summer continental drying and associated risk of drought
6 Area affected by droughts increases
7 Some areas include southern Europe and the Mediterranean region, central Europe, central North America and Mexico, northeast Brazil and southern Africa
8 Increase in tropical cyclone peak wind intensities
9 Increase in intense tropical cyclone activity
10 In any observed long-term (i.e., 40 years or more) after accounting for past changes in observing capabilities (see SREX, section 3.4.4)
11 Increase in average tropical cyclone maximum wind speed is, although not in all ocean basins; either decrease or no change in the global frequency of tropical cyclones
12 Increase in extreme coastal high water worldwide related to increases in mean sea level in the late 20th century
13 Mean sea level rise will contribute to upward trends in extreme coastal high water levels

**Figure 1.9** | Change in the confidence levels for extreme events based on prior IPCC assessments: TAR, AR4 and SREX. Types of extreme events discussed in all three reports are highlighted in green. Confidence levels are defined in Section 1.4. Similar analyses for AR5 are discussed in later chapters. Please note that the nomenclature for confidence level changed from AR4 to SREX and AR5.