Chapter 5

'Attributing' the climate variations observed

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Building a road to exploit timber in West Papua New Guinea, Indonesia.
Deforestation is an important factor in climate warming caused by human factors.

In 25 years, the dominant share of the warming measured in the atmosphere and the sea since the beginning of the industrial era is now attributed to anthropic emissions and not to the natural variability of the climate. In successive IPCC reports, the responsibility of human activities changed from uncertain (1990) to possible (1995) and then probable (2001), very probable (2007) and then extremely probable (2013). These scientific certitudes are the fruit of long work on the 'attribution' of climate variations to determine the share of anthropic forcings, natural forcings and natural variability.

The components of climate variations

The share of anthropic forcings

Confirmation of the mainly anthropic cause of climate change at global and regional scales is based on the one hand on the observation networks of climate warming and on the other on increasingly elaborate climate modelling. The models reproduce the temperature trends observed under the effect of an increase in the concentration of greenhouse gases. The influence of human activities is also detected

Eruption of the volcano Cotopaxi (Quito, Ecuador) in August 2015.
Volcanic dust and gas emissions in the upper atmosphere contribute to natural climate variability.

using other indicators such as changes in the global water cycle, the retreat of snow and ice, the rise in average sea level, the amplification of heatwaves in certain regions, etc.

The share of natural forcings

However, natural forcings (solar radiation, volcanic eruptions) also affect the variability of the climate system. According to satellite measurements available since 1978, the solar energy reaching the earth can be modulated by about 0.1% by variations in the activity of the sun itself in cycles lasting approximately 11 years. Volcanic eruptions also modify the amount of solar energy reaching the earth, especially when they occur in the tropics and when the eruption column contains considerable quantities of gases rich in sulphur at a sufficiently high altitude to reach the stratosphere. The fine particles of volcanic aerosols formed in the stratosphere can cover the entire world in a few months and disturb solar radiation because of their reflective quality.

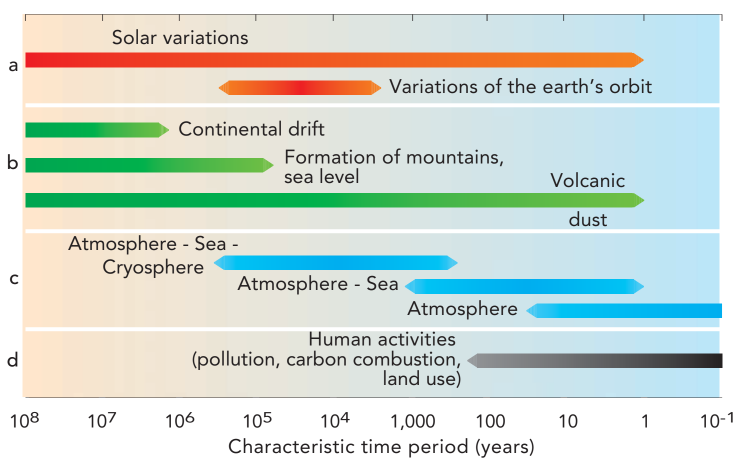


Figure 12.
Anthropic forcings have been added to natural forcings for a century.
At levels a and b distinction is made between forcings that are external to the climate system; c indicates variations that are internal to the system and d indicates anthropic effects.
Source: Bard, 2006.

The share of natural variability

Finally, the internal variability of the climate system—which is chaotic by nature—is always operating and may mitigate or strengthen the effects of anthropic and natural forcings. Within this internal feature, modes of variability such as the El Niño phenomenon have strong impacts especially in the tropics. For example, this variability can result in a cooling of the Pacific. Indeed, modulation of **Pacific Decadal Oscillation** (PDO) was responsible to a considerable degree for the slowing of the global atmospheric warming observed from 1998 to 2012 by greater heat transfer from the surface to the sub-surface of the tropical Pacific Ocean. This slowing was highlighted by climate sceptics to contest the anthropic causes of climate change. In fact, warming is not steady in time. After the slowing observed in the last 15 years, it will probably accelerate in the coming decades as a result of the return to the atmosphere of part of the excess heat stored in the sea.

Changes are difficult to attribute at local scales

In this context, the difficulty is that of being able to attribute a change observed—especially at the local scale—either to the impact of the anthropic greenhouse effect, to natural forcings, to natural internal climate variability or to more local anthropic activities such as deforestation for example. The generic 'detection-attribution' approach thus

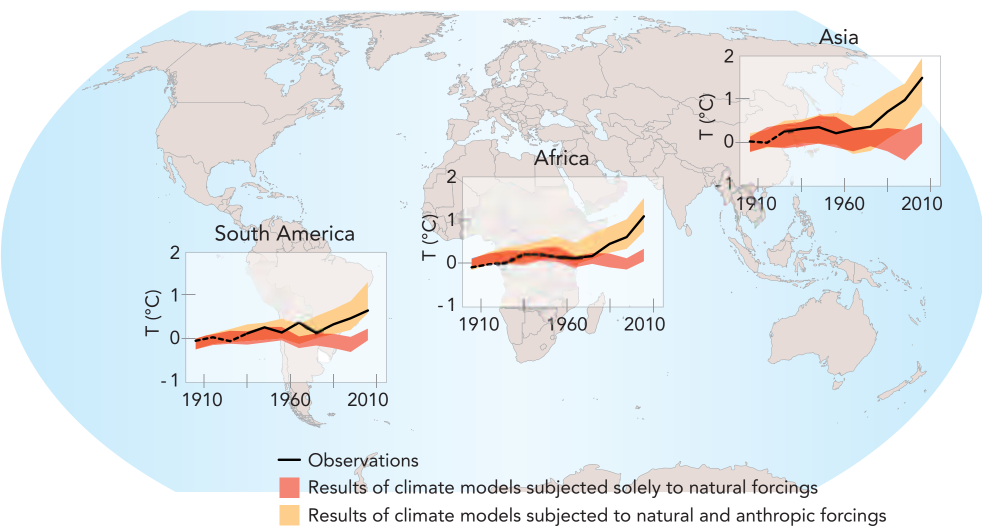


Figure 13.
Example of a method of attribution of observed climate warming.
The gap between the trajectory of the red and orange curves shows the forcing effect of greenhouses gases. The trajectory of the observations is part of the simulations including anthropic forcings, confirming the anthropic impact on the increase in temperature.
Source: 2013 IPCC report.

combines observations and simulations to determine whether an observed change can be explained by one or more external forcings and in what proportions, and then to validate the coherence of observations and the results of climate simulations.

Climatic variability in the tropics

Interpretation of climate variations at the regional scale is complex, especially for the tropics where certain modes of variability have a strong impact. These modes are on different time scales: intra-seasonal (like the Madden-Julian oscillation), interannual (like the El Niño phenomenon) and multi-decadal (the Atlantic Multi-decadal Oscillation and the Pacific Decadal Oscillation). Indeed, climate variations or fluctuations take place according to preferential variability modes according to the dynamic regional context of the ocean and the atmosphere.

The El Niño phenomenon

Because of its global impact, the El Niño phenomenon—also called the El Niño Southern Oscillation (ENSO)—is the main mode of variability of the global climate. In the tropics, El Niño features in particular substantial warming of the equatorial sea surface water in the eastern Pacific Ocean every 2 to 7 years. These warm episodes are sometimes followed by cold events (La Niña). During the hot periods of this mode of variability, the trade winds (easterly winds blowing in the tropics) are weaker than during normal periods. Ocean-atmosphere interactions enable this type of situation to last for a year or longer with repercussions throughout the Pacific basin (forming almost half of the world's surface). For example, El Niño causes drought periods in Indonesia and strong precipitations in Peru. It also affects the Atlantic and Indian Ocean basins and can cause periods of drought or lasting flooding throughout the tropical monsoon systems (Fig. 14).

Decadal ocean oscillations

At the scale of a decade, alternate hot and cold phases similar to those caused by El Niño are also observed in the Pacific Ocean. Compared to El Niño, the Pacific decadal oscillation (PDO) has a broader spatial signal in the tropical Pacific and oscillates on a 20 to 30-year time scale.

The increase in the number of long series of observations in the north Atlantic region resulted in the identification of another mode of variability: the Atlantic Multi-decadal Oscillation (AMO) with oscillations over much longer, pluri-decadal periods. This mode alternates between the warming and cooling of the entire North Atlantic from the equator to the tip of Greenland.

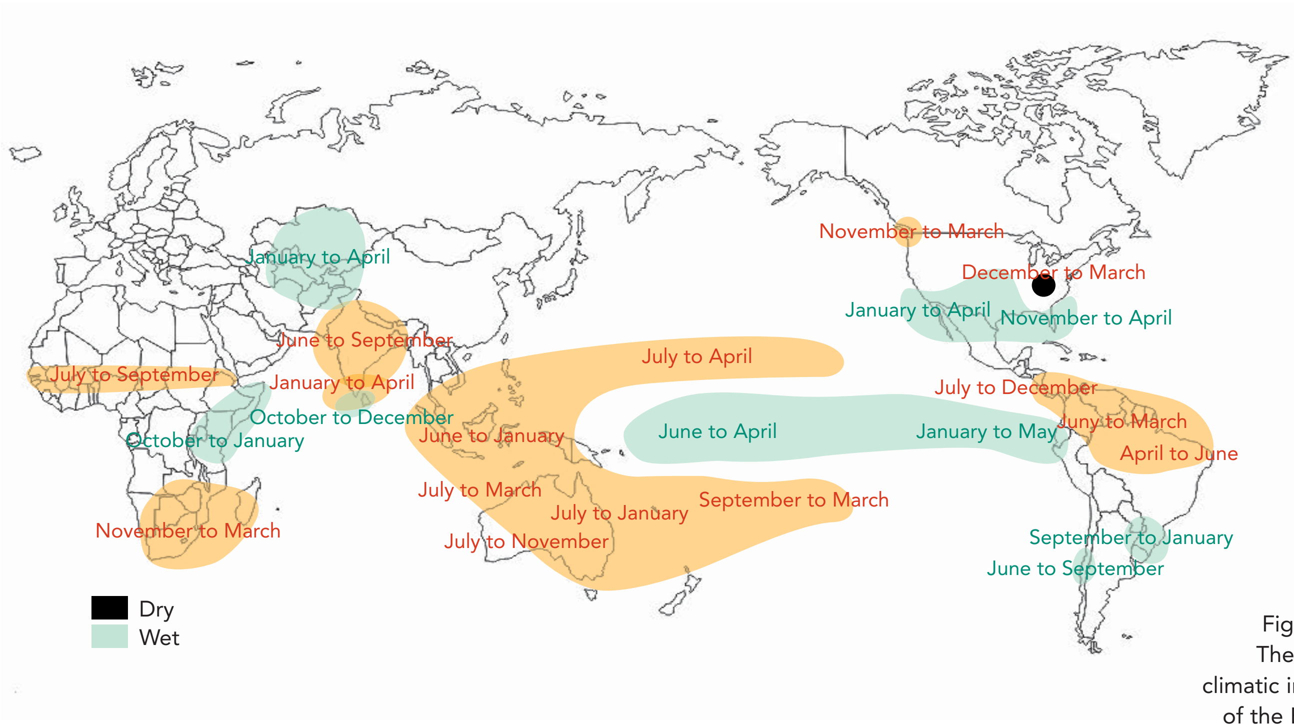
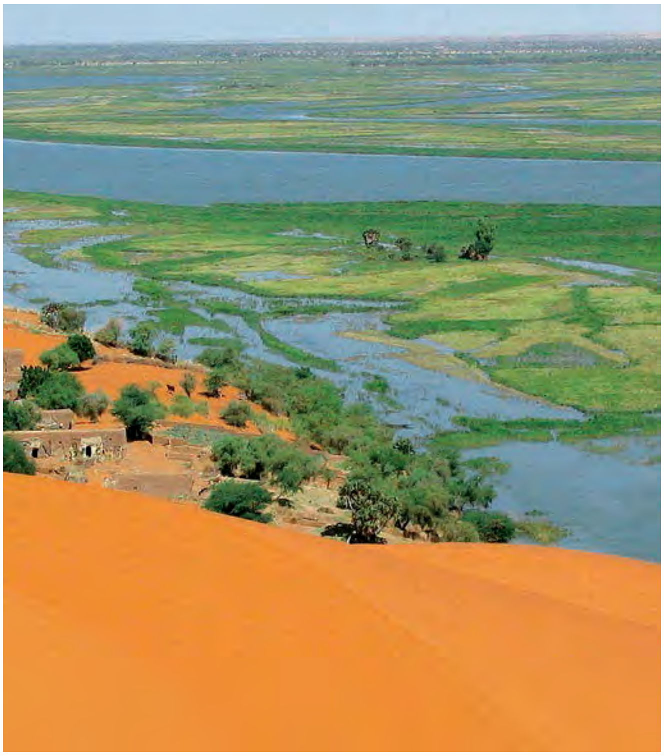


Figure 14.
The global climatic impacts of the El Niño phenomenon.
Source: ROPELEWSKI and HALPERT, 1989

2012 flood in Peru.
Upstream of the town of Iquitos, the Rio Ucayali, one of the main feeders of the Amazon, has eroded about 100 metres of bank and flooded the surrounding villages.



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Flooded rice fields in the bed of the Niger. Gao Dune, Mali.
It is difficult to forecast precipitation in the Sahel, while the population depends on rainfall more than elsewhere.

All these interannual to decadal variability modes in the Pacific and Atlantic oceans have a significant effect on the decadal variations of the precipitation regime in South America and the Sahel. However, they also affect the frequency of cyclones in the tropical Atlantic and even the climate of Europe in the summer. It is therefore difficult to separate the roles of these variability modes from that caused by global climate warming (of both land and oceans) in the climate changes observed in the tropics since 1850.

The role of internal climate variability in the return of rainfall in the Sahel

Can the partial return of rainfall in the Sahel from the 1990s onwards be attributed to climate change or is it still within the framework of internal climate variability? Observations covering the 20th century and the beginning of the 21st show that the transition is driven mainly by the Atlantic Multi-decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO). More precisely, the return of rainfall corresponds to phase reversals in the Atlantic (from negative to positive) and the Pacific (from positive to negative). The positive phase of AMO, that is to say the warming of the north Atlantic, is favourable for rainfall in the Sahel and the positive phase of PDO, that is to say a warming of the Pacific, is unfavourable for rainfall. The signal of the global warming of the oceans, which is unfavourable for rainfall in the Sahel, starts to compete with AMO and PDO, the two other modes, without exceeding them. Simulations using an atmospheric climate model and taking the three modes into account confirm their impact on rainfall in the Sahel and their competitive feature.

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A squall line on the move during the monsoon season in Niger.

The influence of global climate change on variability modes

These different variability modes are comparatively well represented in climate models. Natural or anthropic forcings can affect their trends by preferentially stimulating one or other of the modes. This major influence has been documented over the past 150 years, a period for which numerous meteorological and oceanographic instrument observations are available. It has been studied using statistical detection and attribution methods and a set of climatic simulations with different forcings.

Although it is less well documented, the longer period of the last 1,000 years also provides a relevant temporal framework for investigating the interactions between external forcings and internal climate dynamics. Research teams are currently developing climate simulations of the last millennium and numerous reconstructions of the variations of these modes of variability. They make it possible in particular to evaluate the share of non-forced natural variability in comparison with those related to human activities since the beginning of the industrial era.

Thus although it has been shown that climate change does exist, in the current phase in which anthropic forcing is still moderate scientists remain very careful not to make excessive attributions of any new climatic anomaly to human activities.

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