HOT TOPICS

If scientists are unable to forecast the next week's weather accurately, how can they predict the climate in the next 50 to 100 years?

Summary

Weather refers to the state of the atmosphere at a given time. It is highly variable due to the chaotic nature of the atmosphere over small time and space scales. This chaotic behaviour makes the weather difficult to predict more than a few days into the future.

Climate is often defined as the average weather. It is usually described in terms of the mean and variability of temperature, precipitation and wind over a period ranging from months to millions of years, but the period is typically 30 years. As Mark Twain said, "Climate is what we expect, weather is what we get." For example, it is easy to say that winter will be cooler than summer because the underlying process is understood and predictable. In contrast we cannot say with any confidence what weather will occur on a particular summer or winter day next year.

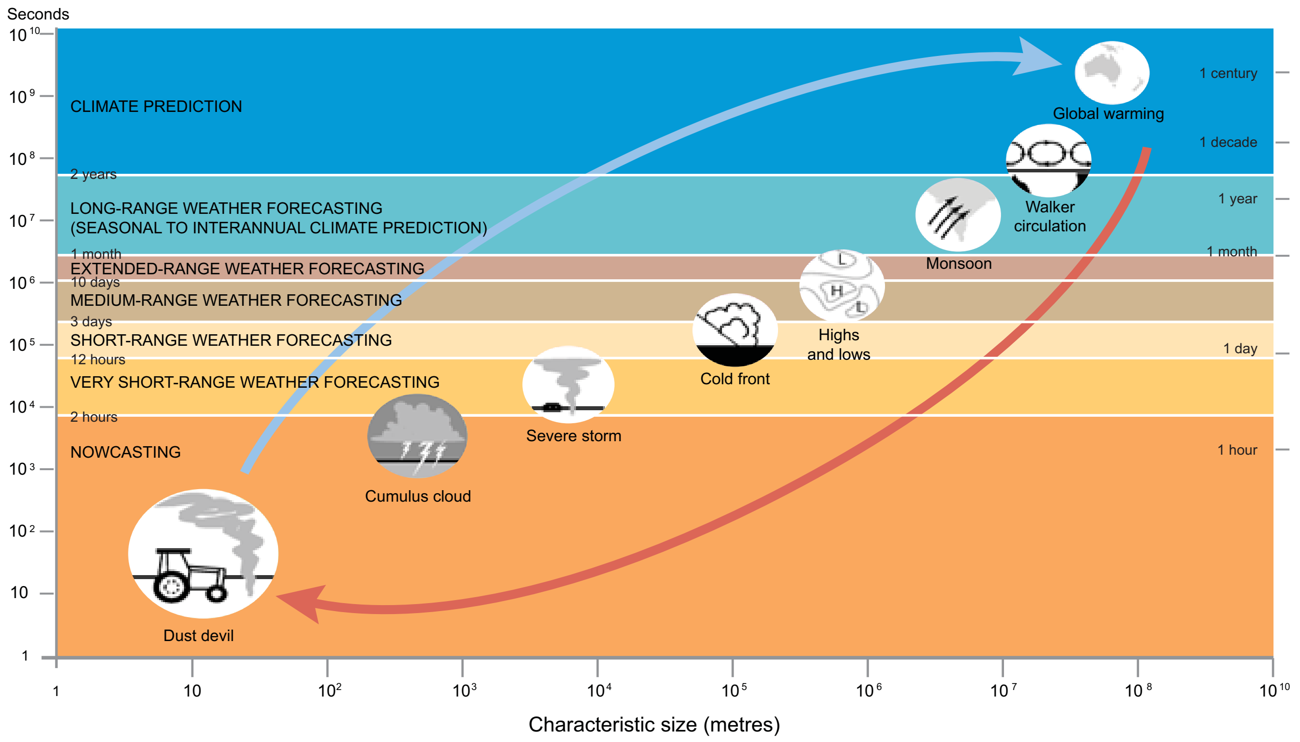
Climate evolves under the influence of internal dynamics and external factors called "forcings". External forcings include volcanic eruptions, solar variations, changes in vegetation and changes in atmospheric composition. The limitations in climate models' ability to forecast weather beyond a few days do not limit their ability to predict long-term climate changes, as these are very different types of prediction. If the likely future changes in external forcings are known, then climate can be projected a long way into the future regardless of the day-to-day fluctuations of the weather. However, uncertainties in some forcings and other feedback effects mean that projections cannot be precise.

Weather versus climate

Daily local weather is determined by large-scale factors such as global atmospheric circulation, and small, chaotic factors such as storm activity at a particular time and location (IPCC, 2007, FAQ 1.2). Because of the chaotic nature of the atmosphere,predictability of the weather decreases with time. If the initial values put into a weather forecast model are slightly wrong,the error will multiply and the accuracy of the forecast will decrease rapidly over the first days of the outlook. This is why it is difficult to predict weather conditions more than a few days in advance.

On the other hand, climate represents average weather. It is usually described in terms of the mean and variability of temperature, precipitation and wind over a period ranging from months to millions of years, but typically the period is 30 years (IPCC, 2007, FAQ 1.1). As Mark Twain said, "Climate is what we expect, weather is what we get." For example, it is easy to say that winter will be cooler than summer because the underlying process is understood and predictable – the amount of incoming solar radiation changes with latitude and time of year. In contrast we cannot say with any confidence what weather will occur on a particular summer or winter day next year.

Climate is driven by large-scale factors such as the level of radiation received from the Sun (which is affected by many factors including the Earth's orbit and tilt), the atmospheric composition (including greenhouse gases and aerosols), the landscape (especially its reflectivity), the distance from the ocean, movement of currents in the ocean and other atmospheric processes such as the El Niño Southern Oscillation. Many of these factors change gradually, and do so in a more predictable, less chaotic manner than those factors affecting our daily weather. Hence, the climate can be projected further into the future with more confidence (IPCC, 2007, FAQ 1.2).



Climate is traditionally viewed as the integration of discrete weather events and variables over time and space. Source: www.wmo.int/pages/publications/world_climate_news/documents/wcn18.pdf

Climate forcing

Climate evolves under the influence of internal dynamics and external factors called 'forcings'. External forcings include volcanic eruptions, solar variations, changes in vegetation and changes in atmospheric composition. Projecting changes in climate due to changes in external forcing is much easier than predicting the weather. If the likely future changes of these forcings are known, then climate can be projected a long way into the future regardless of the day-to-day fluctuations of the weather.

However, some future forcings are not well known. Since projected changes in greenhouse gas and aerosol forcings are partly dependent on uncertain human behaviour, a number of scenarios have been developed. These are based on different assumptions about future demographic changes, economic development and technological pathways (IPCC, 2000). In addition, there is uncertainty about feedback mechanisms in the climate system that can either amplify ('positive feedback') or diminish ('negative feedback') the effects of a change in climate forcing (IPCC, 2007, FAQ 1.1). For example, higher concentrations of greenhouse gases warm the Earth, leading to melting of snow and ice revealing darker land and water surfaces, which absorb more of the Sun's heat, causing more warming, and so on, in a self-reinforcing cycle. Other feedbacks, including cloud feedback and carbon cycle feedback, have ranges of uncertainty that must be included in climate projections, using computer models.

Climate models

The models used by climate scientists to predict the weather and to estimate future climate (long-term average weather) include most of the important physical, chemical and biological processes. These models use equations that describe the behaviour of the atmosphere, ocean, sea ice, snow cover, the land surface and other elements of the Earth system, based on the laws of physics. For more than 50 years scientists have developed more and more complex climate models, which are now among the most sophisticated tools ever created. A typical model might contain hundreds of thousands of lines of computer code, run on a powerful super-computer.

The limitations in climate models' ability to forecast weather beyond a few days do not limit their ability to predict long-term climate changes, as these are very different types of prediction (IPCC, 2007, FAQ 8.1). Weather forecasts are strongly influenced by information about the conditions at the start of the forecast period, and how these observations are assimilated into the modelling framework. Seasonal climate forecasts (for the next 1-3 months) are also sensitive to the initial conditions, such as the state of the El Niño Southern Oscillation. Multi-decadal climate forecasts are not very sensitive to the initial conditions and they do not include data assimilation, so they are not expected to simulate the exact sequence of historical, let alone future, climate fluctuations. Multi-decadal forecasts are designed to estimate general statistical properties of the climate, such as the mean and standard deviation of temperature or rainfall.

When climate models simulate the past 100 or more years, they have shown that they can replicate the observed global-average temperature – including the cooling impacts of volcanic eruptions – with a high level of accuracy. This gives scientists confidence in the ability of models to project future climates.[1]

When climate models project how the climate will change in future, averaged over several decades, the presence of natural climate variability (such as El Niño) means we know there will not be a perfect match between model simulations and the observed climate. To capture this natural variability, scientists use a range of climate simulations, each starting with slightly different initial conditions. The average (or 'ensemble') of these simulations is used to assess our future climate.

References

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[1] For more information see Hot Topic 'How reliable are climate models?' available online at www.climatechange.gov.au