Frequently Asked Questions

FAQ 11.1 | If You Cannot Predict the Weather Next Month, How Can You Predict Climate for the Coming Decade?

Although weather and climate are intertwined, they are in fact different things. Weather is defined as the state of the atmosphere at a given time and place, and can change from hour to hour and day to day. Climate, on the other hand, generally refers to the statistics of weather conditions over a decade or more.

An ability to predict future climate without the need to accurately predict weather is more commonplace that it might first seem. For example, at the end of spring, it can be accurately predicted that the average air temperature over the coming summer in Melbourne (for example) will very likely be higher than the average temperature during the most recent spring—even though the day-to-day weather during the coming summer cannot be predicted with accuracy beyond a week or so. This simple example illustrates that factors exist—in this case the seasonal cycle in solar radiation reaching the Southern Hemisphere—that can underpin skill in predicting changes in climate over a coming period that does not depend on accuracy in predicting weather over the same period.

The statistics of weather conditions used to define climate include long-term averages of air temperature and rainfall, as well as statistics of their variability, such as the standard deviation of year-to-year rainfall variability from the long-term average, or the frequency of days below 5°C. Averages of climate variables over long periods of time are called climatological averages. They can apply to individual months, seasons or the year as a whole. A climate prediction will address questions like: 'How likely will it be that the average temperature during the coming summer will be higher than the long-term average of past summers?' or: 'How likely will it be that the next decade will be warmer than past decades?' More specifically, a climate prediction might provide an answer to the question: 'What is the probability that temperature (in China, for instance) averaged over the next ten years will exceed the temperature in China averaged over the past 30 years?' Climate predictions do not provide forecasts of the detailed day-to-day evolution of future weather. Instead, they provide probabilities of long-term changes to the statistics of future climatic variables.

Weather forecasts, on the other hand, provide predictions of day-to-day weather for specific times in the future. They help to address questions like: 'Will it rain tomorrow?' Sometimes, weather forecasts are given in terms of probabilities. For example, the weather forecast might state that: 'the likelihood of rainfall in Apia tomorrow is 75%'.

To make accurate weather predictions, forecasters need highly detailed information about the current state of the atmosphere. The chaotic nature of the atmosphere means that even the tiniest error in the depiction of 'initial conditions' typically leads to inaccurate forecasts beyond a week or so. This is the so-called 'butterfly effect'.

Climate scientists do not attempt or claim to predict the detailed future evolution of the weather over coming seasons, years or decades. There is, on the other hand, a sound scientific basis for supposing that aspects of climate can be predicted, albeit imprecisely, despite the butterfly effect. For example, increases in long-lived atmospheric greenhouse gas concentrations tend to increase surface temperature in future decades. Thus, information from the past can and does help predict future climate.

Some types of naturally occurring so-called 'internal' variability can—in theory at least—extend the capacity to predict future climate. Internal climatic variability arises from natural instabilities in the climate system. If such variability includes or causes extensive, long-lived, upper ocean temperature anomalies, this will drive changes in the overlying atmosphere, both locally and remotely. The El Niño-Southern Oscillation phenomenon is probably the most famous example of this kind of internal variability. Variability linked to the El Niño-Southern Oscillation unfolds in a partially predictable fashion. The butterfly effect is present, but it takes longer to strongly influence some of the variability linked to the El Nino-Southern Oscillation.

Meteorological services and other agencies have exploited this. They have developed seasonal-to-interannual prediction systems that enable them to routinely predict seasonal climate anomalies with demonstrable predictive skill. The skill varies markedly from place to place and variable to variable. Skill tends to diminish the further the prediction delves into the future and in some locations there is no skill at all. 'Skill' is used here in its technical sense: it is a measure of how much greater the accuracy of a prediction is, compared with the accuracy of some typically simple prediction method like assuming that recent anomalies will persist during the period being predicted.

Weather, seasonal-to-interannual and decadal prediction systems are similar in many ways (e.g., they all incorporate the same mathematical equations for the atmosphere, they all need to specify initial conditions to kick-start

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FAQ 11.1 (continued)

predictions, and they are all subject to limits on forecast accuracy imposed by the butterfly effect). However, decadal prediction, unlike weather and seasonal-to-interannual prediction, is still in its infancy. Decadal prediction systems nevertheless exhibit a degree of skill in *hindcasting* near-surface temperature over much of the globe out to at least nine years. A 'hindcast' is a prediction of a past event in which only observations prior to the event are fed into the prediction system used to make the prediction. The bulk of this skill is thought to arise from *external forcing*. 'External forcing' is a term used by climate scientists to refer to a forcing agent outside the climate system causing a change in the climate system. This includes increases in the concentration of long-lived greenhouse gases.

Theory indicates that skill in predicting decadal precipitation should be less than the skill in predicting decadal surface temperature, and hindcast performance is consistent with this expectation.

Current research is aimed at improving decadal prediction systems, and increasing the understanding of the reasons for any apparent skill. Ascertaining the degree to which the extra information from internal variability actually translates to increased skill is a key issue. While prediction systems are expected to improve over coming decades, the chaotic nature of the climate system and the resulting butterfly effect will always impose unavoidable limits on predictive skill. Other sources of uncertainty exist. For example, as volcanic eruptions can influence climate but their timing and magnitude cannot be predicted, future eruptions provide one of a number of other sources of uncertainty. Additionally, the shortness of the period with enough oceanic data to initialize and assess decadal predictions presents a major challenge.

Finally, note that decadal prediction systems are designed to exploit both externally forced and internally generated sources of predictability. Climate scientists distinguish between decadal predictions and decadal projections. Projections exploit only the predictive capacity arising from external forcing. While previous IPCC Assessment Reports focussed exclusively on projections, this report also assesses decadal prediction research and its scientific basis.

for both externally forced and internally generated components of the potential predictability of decadal means of surface air temperature in simulations of 21st century climate in CMIP3 model data are analysed in Boer (2011) and results based on CMIP5 model data are shown in Figure 11.2. Potential predictability of 5-year means for internally generated variability is found over extratropical oceans but is generally weak over land while that associated with the decadal change in the forced component is found in tropical areas and over some land areas.

Predictability studies of precipitation on long time scales are comparatively few. Jai and DelSole (2012) identify 'optimally predictable' fractions of internally generated temperature and precipitation variance over land on multi-year time scales in the control simulations of 10 models participating in CMIP5, with results that vary considerably from model to model. Boer and Lambert (2008) find little potential predictability for decadal means of precipitation in the internally generated variability of a collection of CMIP3 model control simulations other than over parts of the North Atlantic. This is also the case for the internally generated component of CMIP3 precipitation in 21st century climate change simulations in Boer (2011) although there is evidence of potential predictability for the forced component of precipitation mainly at higher latitudes and for longer time scales.

11.2.1.4 Summary

Predictability studies suggest that initialized climate forecasts should be able to provide more detailed information on climate evolution, over a few years to a decade, than is available from uninitialized climate simulations alone. Predictability results are, however, based mainly on climate model results and depend on the verisimilitude with which the models reproduce climate system behaviour (Chapter 9). There is evidence of multi-year predictability for both the internally generated and externally forced components of temperature over considerable portions of the globe with the first dominating at shorter and the second at longer time scales. Predictability for precipitation is based on fewer studies, is more modest than for temperature, and appears to be associated mainly with the forced component at longer time scales. Predictability can also vary from location to location.

11.2.2 Climate Prediction on Decadal Time Scales

11.2.2.1 Initial Conditions

A dynamical prediction consists of an ensemble of forecasts produced by integrating a climate model forward in time from a set of observation-based initial conditions. As the forecast range increases, processes in the ocean become increasingly important and the sparseness, non-uniformity and secular change in sub-surface ocean observations is a challenge to analysis and prediction (Meehl et al., 2009b, 2013d; Murphy et al., 2010) and can lead to differences among ocean analyses, that is, quantified descriptions of ocean initial conditions (Stammer, 2006; Keenlyside and Ba, 2010). Approaches to ocean initialization include (as listed in Table 11.1): assimilation only of SSTs to initialize the sub-surface ocean indirectly (Keenlyside et al., 2008;