1 Assessing climate change

Climate change is a complex area and there are many different sources of information on it. We need to ensure that our policy and programme work is based on the best available evidence and is informative and honest. This policy brief is an introductory guide to help WaterAid staff understand and use the best data to analyse how climate change affects our work.

Key messages

- There are many different interpretations of the term 'climate change'. It is vital to be clear whether you are referring to: climate; climatic variability; or climate change.
- It is difficult to attribute a particular event or trend to climate change rather than existing climatic variability. **The key issue is that climate change may exacerbate existing variability.**
- Practical steps for assessing climate change in a specific location are:
    1. Decide what climate information is relevant.
    2. Look at historical data.
    3. Look at future projections and trends.
    4. Identify uncertainties and make planning assumptions.
- There are many useful external sources of data that you can draw on.

What is climate change?

There is a clear **scientific** understanding of 'climate change' as any change in the mean state of the climate or in its variability[1].

However, official **political** understanding tends to use 'climate change' to refer to additional changes **caused by human activity** altering the global atmosphere[2], drawing a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Lastly, the **public** tends to use 'climate change' to refer to all variations in the mean state of the climate, as well as abnormal weather patterns or events.

WaterAid recognises that people and organisations use these terms differently, so we may need to be flexible in the exact language we use. However, we should always be clear what we are referring to and draw a distinction between:

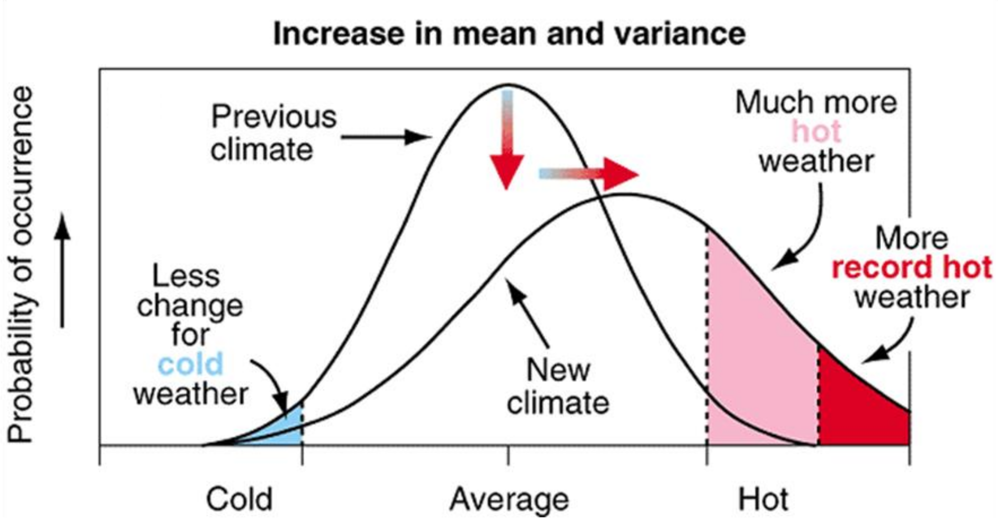
- **Climate** – the range of weather that a specific location experiences, represented by a mean (a single figure representing the 'average' conditions) and variance (a measure of how variable the conditions are). For example, September might 'normally' be wet.

- **Climatic variability** – the changeable nature of weather patterns or events within the bounds of the present climate. September might be more wet than ‘normal’ in one year, but drier than ‘normal’ in another.
- **Climate change** – long-term changes to the mean and variance of the climate, which may be natural or anthropogenic (caused by human activity). The average September over 40 years might be drier than ‘normal’ (change in mean).

Climate change affects existing climatic variability

The areas where WaterAid works all have highly variable climates. Climate change may change this underlying variability – increasing year-to-year variability (variance or standard deviation) and therefore extremes; as well as shifting long-term averages (mean). It is therefore difficult to attribute a particular event or trend to climate change rather than **existing** climatic variability. This is a very important distinction to make – **the key issue is that climate change may exacerbate existing variability.**

Figure 1 – Climatic variability vs climate change[3]



This illustrates the impact of an increase in variance and mean on extreme temperatures. If one summer we have hot weather (in the pink zone), then it is impossible to use this as evidence of climate change as this temperature could occur under the previous climate. However, if we had ten years’ worth of data (eg 2000-2010) and had more temperatures in the pink zone than in the ten years before (eg 1990-2000), then we can begin to demonstrate more clearly that the climate has changed (although not whether this was caused by human activity).

Useful data sources

- **National meteorological office** – most countries' meteorological offices will have data for various locations. This may be of varying quality, depending on how many working meteorological stations they have.
- **World Bank Climate Change Knowledge Portal** – information, data and reports, including downscaled historical data and scenarios.
- **CLIMWAT** – Food and Agriculture Organisation historical weather database.
- **Climate Systems Analysis Group (CSAG) Climate Information Portal** – an online portal showing historical data and future climate projections for many locations in Africa.
- **TAMSAT** – a 30 year satellite rainfall dataset for Africa. The data is hard to use, but they have pictures of every ten day period since 1980, plus the average climate across the continent.
- **Tropical Rainfall Measuring Mission (TRMM)** – a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA), designed to monitor and study tropical rainfall.

Understanding climate and climate change

There are many ways of understanding climate and climate change, but the following is a practical guide for assessing climate change in a specific location.

1. **Decide what information is relevant**
   The weather and climate can be measured in many ways. For example, you might record daily average temperatures, wind speeds, annual rainfall amounts, the number of extreme heat days per year. So it is important to decide what type of climate data is of relevance and interest to you. If you are interested in 'rainfall', you might need to know annual mean rainfall, growing season rainfall, dry season rainfall, or rainfall extremes. Try to be clear about exactly what information you need, why this data is useful, and what you would use it for – for example, understanding the distribution of rainfall across the seasons might help you to understand the variation across the year, and how much storage might improve access to water in the dry season.

2. **Look at historical data**
   To understand if or how the climate is changing, you have to start by understanding the current and past climate. Having identified the variables that you think are relevant, you now need to gather some historical data. For example, if you are interested in temperatures, then how have the average temperatures changed in the past? What is the current variability from year to year? What does the seasonal cycle look like? How often do you get extreme temperatures? Often, national meteorological agencies, research centres or internet portals hold historical climate information if you need access to data.

3 **Look at future projections and trends**
The next stage is to look at how things might change in the future as a result of climate change. This process involves the use of climate models. The future is inherently uncertain, so **it is important to treat future-oriented data as 'best-guess' rather than concrete fact**. There will be variations between different climate models and there will be variations depending on the different greenhouse gas emissions scenarios. Outputs from climate models give an 'envelope', or range, of possible futures. Finally, look at how both the mean **and** variance might change – what are the implications, eg for extreme weather?

4 **Identify uncertainties and make planning assumptions**
Climate is difficult to measure precisely, so it is important to be clear about where the data that you have may not be precise, where there is uncertainty, and how significant that is. For example, there may be conflicting views between climate models, or community perceptions of the past climate might be subject to memory bias. However, uncertainty doesn't mean inaction. Based on your assessment of uncertainty, it is useful to make some 'planning assumptions' – some practical assumptions that can then be used for planning purposes.

The above section gives an overview of the key issues in assessing climate change and is intended for senior management, team leaders and those short of time. The remainder of the briefing goes into more technical detail about analysing climate data and taking account of uncertainty. It is a guide for practical application of climate analysis and developing useful planning assumptions.

This policy briefing is one of a series on climate change, which complements the WaterAid position paper on climate change (entitled *Climate change and WaterAid*), the *Water security framework* and the *Disasters framework.* It should be cited as: Yeo D and Greatrex H (2013) *Policy briefing series: Climate change.1 Assessing climate change.* WaterAid, London, UK

Endnotes

[1] The Intergovernmental Panel on Climate Change (IPCC) defines climate change as: 'A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.'

[2] The UN Framework Convention on Climate Change (UNFCCC) defines climate change as: 'A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.'

[3] Adapted from Folland CK et al (2001) Observed climate variability and change. In: *Climate change 2001: The scientific basis. Contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change*, p155, Fig 2.32. Cambridge University Press, Cambridge, UK and New York, USA

Making sense of historical climate data

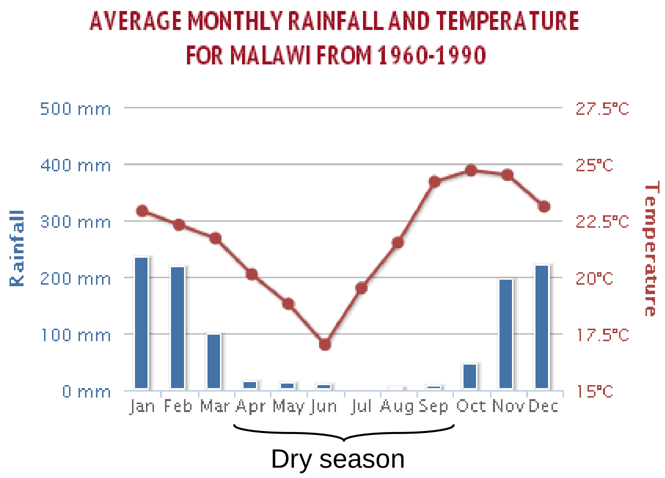
Climate data covers a wide range of variables over different timescales and levels of detail. Analysing and interpreting the data is not straightforward, and the specific analysis that you need depends on what you are interested in.

Intra-annual variability and climatologies

The mean annual rainfall is a good starting point for understanding how wet a country is, but the mean does not tell you much about how the rainfall is distributed across the year. To understand this variability **within** years (intra-annual*)*, rainfall data for a more appropriate span of time (eg growing season) is more useful. **Which period of the year is most critical in your context?**

The figure below is known as a climatology, and shows the mean monthly rainfall for Malawi from 1960-90. Across the entire year, the overall mean rainfall is 89mm a month, but this masks the pronounced dry season from April to September (with over 200mm a month) and a wet season from November to February (with less than 20mm a month).

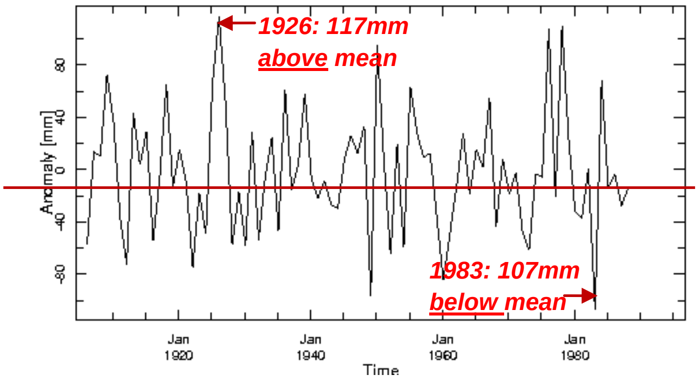
Figure 2 – Average monthly rainfall and temperature for Malawi, 1960-90[4]



Inter-annual variability and trends

Once you have identified which period of the year is most critical, it is important to know how your climate (for example the rainfall) has changed in the past. The easiest way to start studying this is to plot a time-series. There are several things to look for in these time-series:

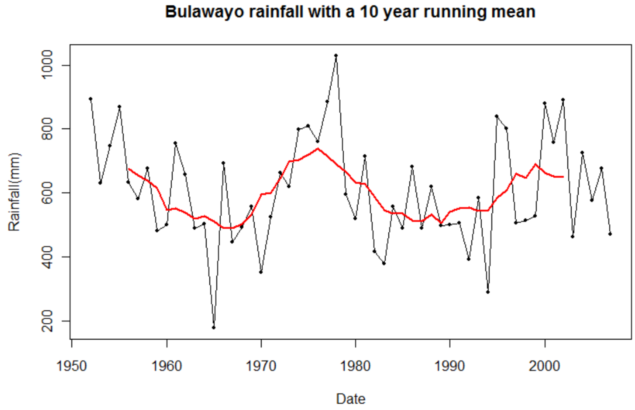
- **Inter-annual variability from year to year.** How much does the data change from year to year? Is it a smooth line, or a jagged time-series?
- **Multi-year variability (or cycles).** Can you see any cycles or patterns in the data? For example, sometimes there is a decadal cycle, or there might be a cycle every five years or so due to El Nĩno.
- **Underlying trends.** Is the average value rising? Or is the inter-annual variability increasing over time? Or decreasing?



Example 1 – Inter-annual variability

This example shows the January-March rainfall anomaly for Mangochi, Malawi, from 1900 to 2000 – ie how much the rain in January, February and March in each year varies from the mean across all years.

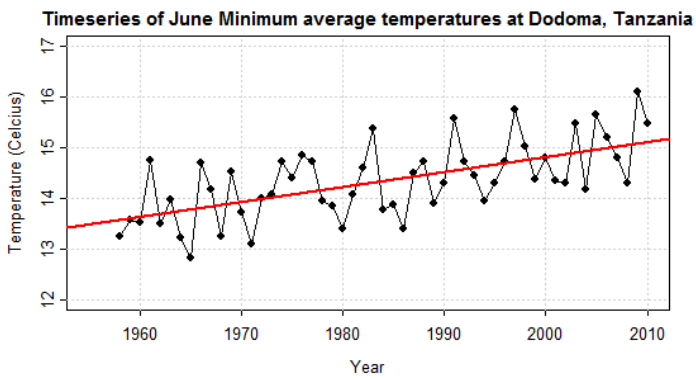
This is a good example of **inter-annual variability**, with a peak of 117mm above mean and a low of 107mm less than the mean. The standard deviation is 47mm, which means that in most years, rainfall will be within 47mm of the mean rainfall.



Example 2 – Multi-year variability (or cycles)

This shows the annual rainfall at Bulowayo, Zimbabwe. The ten year running mean was fitted to the data. This is the mean of the previous five years and the future five years at each point. It helps to smooth out the inter-annual variability to see underlying patterns.

This example clearly shows inter-annual variability, **plus a rainfall cycle** which repeats approximately every 20 years. **No underlying long-term trend can be seen.** Even though the data has been recorded since 1950, there is not enough data to see if this longer-term cycle is a real effect (eg that you would expect it to repeat in the future) or if it is simply something that has happened in the last 50 years.



Example 3 – Underlying trends

This shows the June minimum temperatures in Dodoma, Tanzania. A linear model was fitted to the data. This had a slope of 0.03°C per year (±0.005). So if this trend holds, in the last 100 years the average minimum temperature has increased between 2.5 and 3.5°C.

This final example shows inter-annual variability, but there is **a clear underlying trend** over the long-term, showing that average temperatures are increasing.

There is no right or wrong way to analyse climate data and you do not have to be a statistics expert to draw the conclusions made above. The aim is to get a sense for what has happened to the climate for your location using long-term data.

Putting it all together

The examples above show the three different aspects to the climate record. Each component represents a different aspect of climate process:

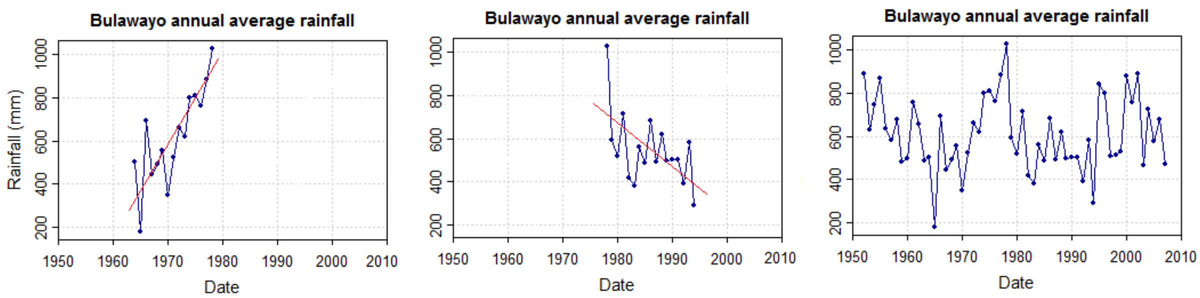
- **Inter-annual variability** – this indicates rapidly fluctuating process, **internal** to the climate system.
- **Multi-year variability or cycles** – represents slowly evolving processes, **internal** to the climate system.
- **Linear trend** – this represents the **anthropogenic influence** on climate.

These three components 'add up' to the total variability seen in the record.

Some points to bear in mind

- Normally (and in all of the examples above), this analysis is done for a specific location or a specific meteorological station. As the climate varies a lot from place to place, **these cannot be used to tell you about a whole country or region.** To do this, it might be better to look at the average of a lot of stations, or at satellite climate data.
- Sometimes trends can be misleading, especially if you have a short time-series, eg for the Bulowayo example, if you only had some of the data, then it would be easy to come to very different conclusions…

Figure 3 – Incomplete data can be misleading!



- Finally, you don't need to get caught up in statistics, even a quick hand drawn graph will give you a reasonable idea of what is happening!

Key point

Understanding climate change is complex; however, when considering the daily realities for communities, **inter-annual variability is often a much more significant and immediate issue than longer-term climate change.**

Climate change models

General circulation models (GCMs – sometimes also meaning 'global climate models') are very complex models of the oceans and the atmosphere that can be used to model the future climate.

They require a huge amount of computing power and cover the whole planet, so they can only provide a certain level of detail. The most recent climate model has a grid-size of about 100-200km. Therefore, each data point in the model covers at least 10,000km^2. This often means that there are only one or two gridboxes covering a country the size of Nepal, **so global climate models don't provide very meaningful data at a country or district level.**

To be more useful, global GCMs need 'downscaling', which is where the models are run again at a regional or national scale, using simplified assumptions for the rest of the world (based on 'boundary conditions'). The regional climate models (RCMs) have a much smaller resolution – for example, the PRECIS (Providing Regional Climates for Impacts Studies) model has a resolution of 25km. Another approach, called statistical downscaling, uses relationships between local weather conditions and the global climate to produce locally relevant projections.

However, it is important to remember that **no matter what resolution the model has, they are only models** – they are based on a set of assumptions about the state of the world, so **they are indications of possible futures and should not be treated as concrete forecasts**.

Climate change scenarios

There is a standard set of assumptions that are used for climate projections, known as the SRES[5] scenarios. They describe several greenhouse gas emissions scenarios that can be used to make projections of possible future climate change. SRES scenarios are grouped into families of individual scenarios with common themes. None of these scenarios are more likely to occur than others; therefore, none of the SRES scenarios represents a 'best guess' of future emissions. Note that none of these scenarios includes the effects of emissions reductions policies, such as the Kyoto Protocol, or other national policies or programmes.

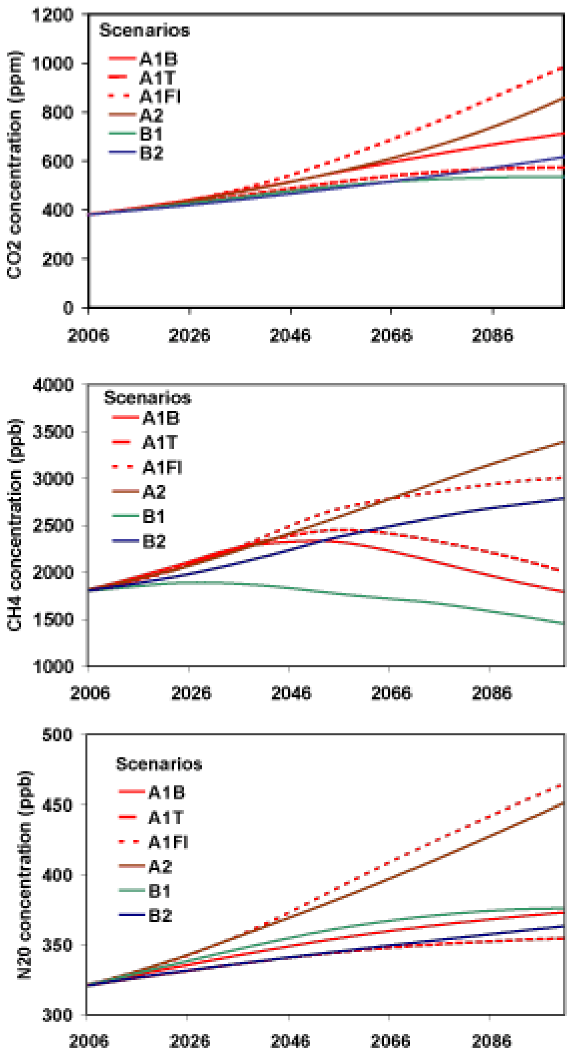
Key points

Global climate change models do not provide very meaningful data at a country or district level.

Climate change models are based on a set of assumptions so are only indications of **possible** futures and should not be treated as concrete forecasts.

Overview of the IPCC SRES scenarios

Figure 6 – The IPCC SRES scenarios



The **A1** scenarios are of a more integrated world. The A1 family of scenarios is characterised by:

- Rapid economic growth.
- A global population that reaches nine billion in 2050 and then gradually declines.
- The quick spread of new and efficient technologies.
- A convergent world – income and way of life converge between regions. Extensive social and cultural interactions worldwide.

There are subsets to the A1 family based on their technological emphasis:

- **A1FI** – An emphasis on fossil fuels.
- **A1B** – A balance of energy sources.
- **A1T** – Emphasis on non-fossil energy.

The **A2** scenarios are of a more divided world. The A2 family of scenarios is characterised by:

- A world of independently operating, self-reliant nations.
- Continuously increasing population.
- Regionally-oriented economic development.

The **B1** scenarios are of a world more integrated, and more ecologically-friendly. The B1 scenarios are characterised by:

- Rapid economic growth as in A1, but with rapid changes towards a service and information economy.
- Population rising to nine billion in 2050 and then declining as in A1.
- Reductions in material intensity and the introduction of clean and resource-efficient technologies.
- An emphasis on global solutions to economic, social and environmental stability.

The **B2** scenarios are of a world more divided, but more ecologically-friendly. The B2 scenarios are characterised by:

- Continuously increasing population, but at a slower rate than in A2.
- Emphasis on local rather than global solutions to economic, social and environmental stability.
- Intermediate levels of economic development.
- Less rapid and more fragmented technological change than in A1 and B1.

Uncertainties and planning assumptions

Understanding climate change is about understanding risk and uncertainty, so avoid statements that are not supported by evidence and make sure you are clear about where there is uncertainty. Even relatively small uncertainties can quickly add up and create large uncertainties. The following indicates some typical areas of uncertainty.

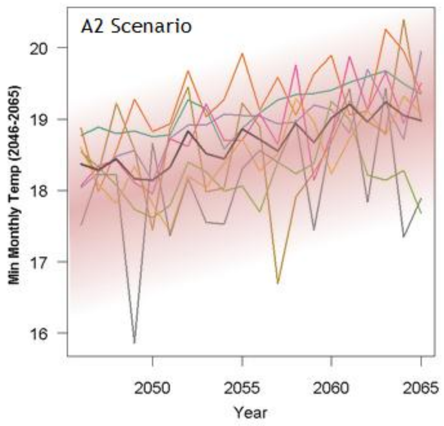
Historical data

The quality and accuracy of climate data can vary. Historical data is only available where there are working weather stations, but coverage in many countries is not very comprehensive. Therefore, weather station data will not give a full picture of the climate across a region or country. This is a particular challenge in geographically diverse countries that may have very different conditions across the country. In these cases, it might be better to use satellite data (although this is often hard to process) or one of the many country summaries from internet climate portals. In addition, there are often gaps or errors in historical weather data, so it is important to have an understanding of how reliable the historical data might be.

Models

Climate models are not predictors of the future, but indicators of possible future storylines. The outputs of a model depend on the assumptions made and the design of the model itself. To improve robustness, it is essential to compare across different climate models to see if there is agreement (using multiple models is known as an ensemble approach). Plus, the range of the model results is often more useful than the individual model output itself. For example, the diagram below shows the future temperature projections for Ethiopia for two climate scenarios.

Figure 7 – Different model outputs for Ethiopian average minimum temperature projections. Each line shows the output for a different model

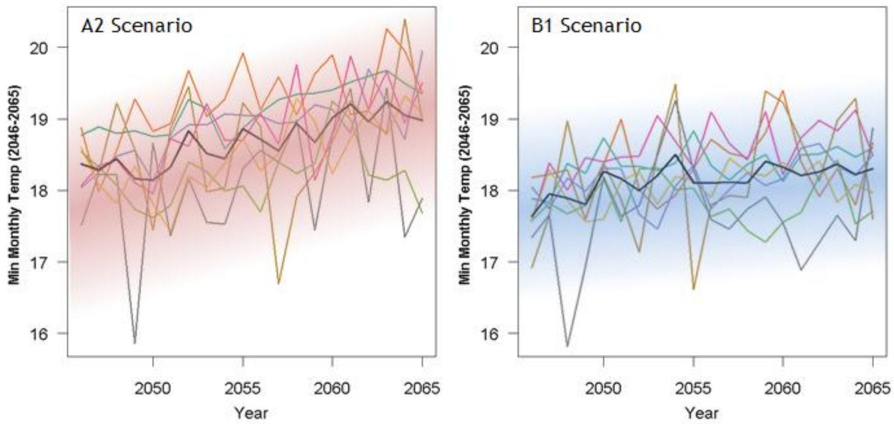


In this case, you might say that the average minimum temperature for Ethiopia is projected to be 18-20°C for the A2 scenario. This would be better than quoting the output from an individual model (only one coloured line). When using secondary data provided by someone else, ensure you understand the method and assumptions that they have used.

Scenarios

Models are based on scenarios – simulated futures based on a set of assumptions. Even if the model is perfect, the outputs are only as good as the input assumptions. This is particularly the case for the greenhouse gas scenarios, because they are trying to predict future population growth, government policy, economics and human behaviour. Therefore, it is important to treat scenarios as indicative rather than predictive. It is useful to look at a range of scenarios to assess sensitivity.

Figure 8 – Different model outputs for Ethiopian average minimum temperature projections. Each line shows the output for a different model. The left hand plot shows results for the A2 scenario and the right hand plot for the B1 scenario



In this case, you might say that the average minimum temperature for Ethiopia is projected to be 18-20°C for the A2 scenario, and between 17-19°C for the B1 scenario.

Qualitative data

WaterAid places a lot of emphasis on grassroots knowledge and community views in its work. Community perceptions of climate change and current/historical weather are important pieces of information, and are often key to instigating action. However, it is important not to use perceptions of climate change as the **only** piece of information – climate change is very difficult to detect on a human scale (it requires the sort of statistical analysis shown above) and community perceptions of climate change are subject to bias. At a human scale, climate change is often indistinguishable from normal variability. In addition, NGOs' and the media's focus on climate change tends to skew perceptions, with any variability being attributed to climate change. Local perceptions of change are incredibly valuable – but they need triangulation (comparison to other data sources).

Planning assumptions

Uncertainty should not prevent action. Having analysed the uncertainties, it is useful to make a set of planning assumptions – assumptions that you have chosen to make in the face of uncertainty in order to facilitate decision-making. It is important to be clear about what your planning assumptions are and where the uncertainties are, and to review the planning assumptions regularly.

Key points

Understanding climate change is about understanding risk and uncertainty, so avoid statements that are not supported by evidence and make sure you are clear about where there is uncertainty.

Uncertainty should not prevent action. Make some planning assumptions to facilitate decision-making, but review them regularly.

Written by Daniel Yeo and Helen Greatrex

February 2013

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Endnotes

[4] Generated by the World Bank Climate Knowledge Portal based on Climatic Research Unit data.
[5] The *Special Report on Emissions Scenarios (SRES)* is a report by the IPCC that was published in 2000.