Seasonal forecasts: from science to services

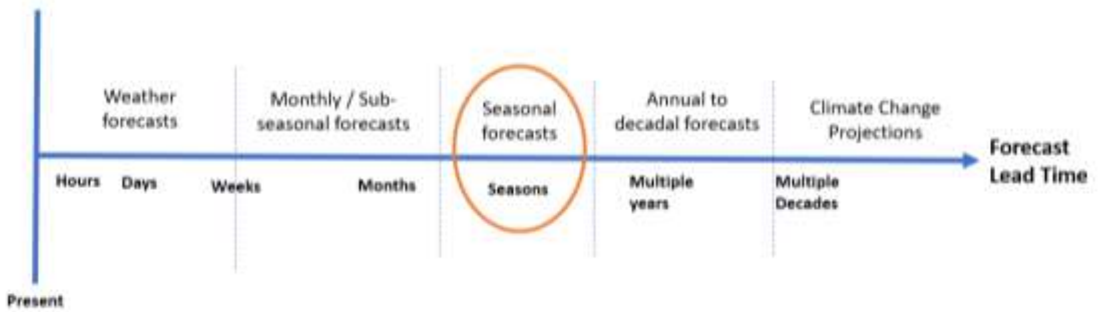
Video transcript

Links to the videos are included for each section within the transcript below.

Contents

Introduction

ALEX DEAKIN: Welcome along to this introduction video, part of a series of films about seasonal weather forecasting. Seasonal forecasts provide information on the general weather conditions, such as precipitation and temperature, over an upcoming season.



On the forecast timeline, seasonal forecasts sit after short-term weather forecasts and monthly to sub-seasonal forecasts and before annual, decadal and long-term climate projections. The seasonal timeframe is an important window for forward planning across many sectors, such as energy, agriculture and humanitarian work. Seasonal forecasts can help with questions like "will there be enough rain to sustain crops this season?"

As part of this brief introduction let's first think about what a season is. A season can be defined as a period of the year that has its own "typical" weather conditions which are distinct from the rest of the year. Around the world, seasons vary hugely in duration, timing and characteristics. For example, its winter now here in the UK, in which we experience much colder weather than other times of year. Meteorologists define winter in the northern hemisphere as the three-month period covering December, January and February.

Other places may experience distinct rainy or dry seasons, for example in India, the rainy season occurs during the summer monsoon between June and September.

So, if we already know the "typical" weather in a season – that is, the "climate", then why do we need a forecast? Well a season's characteristics naturally vary from one year to another;

for example, a mild and wet winter one year may be followed by a cold and dry winter the next. This is known as “climate variability”.

Climate variability and in particular “climate extremes” such as heat waves, droughts and floods, can pose many difficult challenges, particularly to the world’s most vulnerable. In many places, these extremes are already becoming more frequent and intense as a result of climate change.

Seasonal forecasts can be an extremely valuable tool for adapting to climate variability, giving communities more time to prepare for climate extremes.

Here at the Met Office, we work with a range of organisations in the UK and around the world to enhance the performance and communication of seasonal forecasts. This series of short videos is particularly inspired by our ongoing international collaborations in sub-Saharan Africa and South Asia.

In this series of short videos, scientists from the Met Office will explain the key steps of the seasonal forecast process, from the science to the services. In part 1, we explain exactly what we mean by a seasonal forecast. In part 2, we explain how seasonal forecasts are produced, then in part 3, how the forecast information is presented. Finally, in part 4, we look at the role of different organisations in creating and communicating seasonal forecasts, providing examples of how they are successfully used in practice.

These videos are aimed at those new to seasonal forecasts, so don’t worry if you have no prior knowledge of seasonal forecasting or climate science. Our aim is to improve your understanding, so that you can interpret and use seasonal forecasts more effectively.

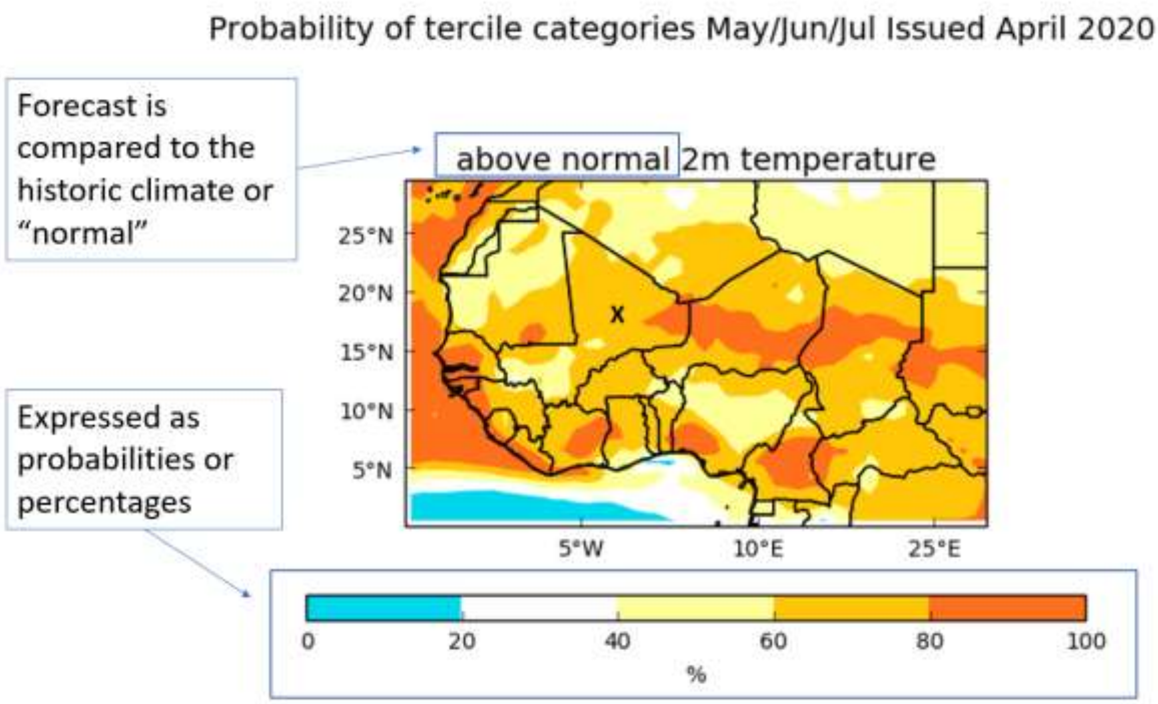
We hope you find these videos useful. For more information on the Met Office, our approaches to seasonal forecasting and international partnerships, please visit the Met Office website.

Met Office

Part 1: The science behind seasonal forecasts

ALEX: In this video, Joe Daron - science manager in the International Climate Services team - will help to explain what a seasonal forecast is, what it isn't, and the fundamental reasons why seasonal forecasts are possible. Joe, first, please can you explain what a seasonal forecast actually is, and how it's different to say a weather forecast?

JOE: A seasonal forecast is a prediction of the long-term behaviour of weather, typically over a 3 to 6-month period. Forecasts are first made several months ahead of a season and then updated regularly as the season approaches. A seasonal forecast can provide information on, for example, the average temperature over the winter, or total rainfall over the summer. Crucially, the forecasts do not attempt to predict day-to-day changes, like a weather forecast, since these can't be predicted accurately beyond about a week or 10 days. This is because our atmosphere is what we call a 'chaotic system'. As first shown in the 1960s by the scientist Edward Lorenz, who is famous for his work on chaos theory and the butterfly effect, tiny errors at the beginning of a weather forecast spread rapidly and grow larger with time. This is why the atmosphere is so difficult to predict the further we look into the future.



Because the atmosphere is chaotic, on seasonal timescales, it's not only impossible to accurately forecast day-to-day weather within a season, but we also can't provide accurate forecasts for a specific location, such as a village or area postal code. That's why seasonal forecasts are predictions for a large spatial area – typically an area covering the size of a country or several countries.

Finally, seasonal forecasts are expressed using probabilities. Typically, the probability of how the next season will compare to average, or 'normal', conditions for that season. Again, this contrasts with short-range weather forecasts where there is more certainty and often only the most likely outcome is given, such as forecasting a maximum daily temperature of 15 degrees Celsius or heavy rainfall expected in the afternoon. Rather a seasonal forecast will tell us, for example, the chances of a warmer or colder than average season.

You might think of a seasonal forecast as a blurry photograph, you can't quite pick out the details of exactly who's in the picture or where it is, but you still have more information than no photograph at all!

ALEX: So, given that accurate weather forecasts are only possible for several days into the future, how is it possible to predict conditions several months into the future, as we do with seasonal forecasts?

JOE: Well to help answer that question, we first need to understand what factors control the long-term climate of a region. And then, most importantly, which of these factors influence the year-to-year variability from that long-term climate.

A region's climate can be classified into different categories, such as tropical or temperate.

A location's climate is largely controlled by factors that are fixed, like where it is on the planet. For example, places close to the equator typically experience a warm tropical climate, and places close to the poles experience a much colder polar climate, mainly due to the amount of solar radiation received at the surface throughout the year.

Other fixed factors that influence climate conditions include the presence of mountains or oceans. In seasonal forecasting, it is the factors that vary that we are interested in, as these are the ones that can cause variability in a season from one year to the next. These factors are commonly referred to as "climate drivers".

ALEX: Can you tell us what you mean by 'climate drivers'?

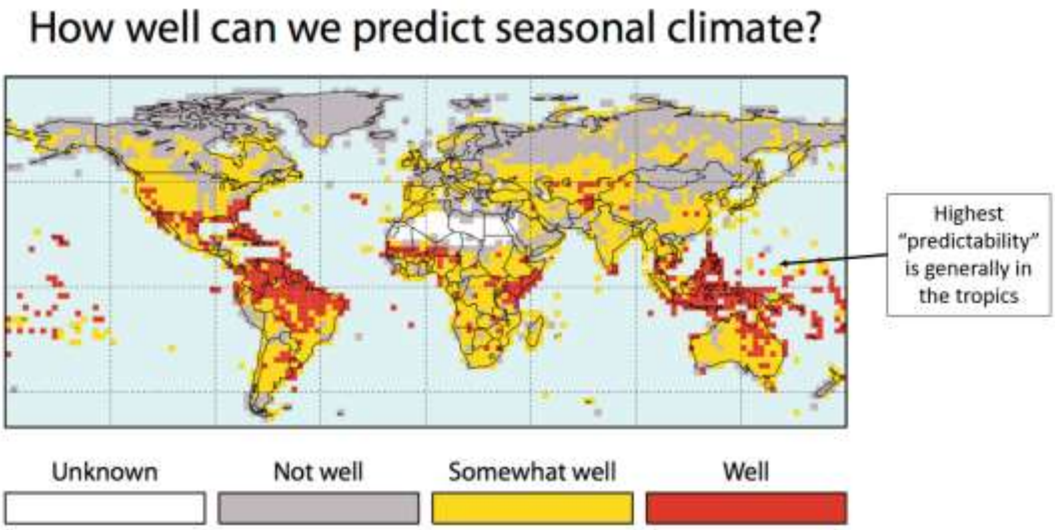
JOE: Climate drivers are those elements of the climate system that vary, but do so more slowly than fast-moving processes in the atmosphere that control day-to-day weather. A particularly important climate driver is the ocean.

As you can see in this animation, the ocean heats up and cools down much more slowly than the atmosphere, making it possible to predict aspects of the ocean's behaviour several months ahead. And if a large area of the ocean's surface is warmer or cooler than normal, it will affect the air above it. This can influence large scale atmospheric circulation and weather patterns around the world. Other climate drivers include changing conditions of sea ice at the poles, snow cover over land and moisture conditions of the soil.

These climate drivers, in particular the ocean, are the fundamental reason why seasonal forecasting is possible. But we need to understand how these different drivers affect the region we're interested in. This can be done by relating past weather observations in that region with observed patterns of the key climate drivers. And by using knowledge of how the drivers affect weather patterns, and representing these relationships in forecast models, we can make predictions several months into the future.

ALEX: So, you mean when we have a wet summer here in the UK, that can be linked to a climate driver somewhere else in the world?

JOE: Yes, though it's not always entirely straightforward. Seasonal forecasts perform best where there is a strong connection with predictable climate drivers. These regions are referred to as having higher "predictability". In some places, climate drivers have much less of an effect, and in these places there is lower predictability, meaning seasonal forecasts will not be as accurate.

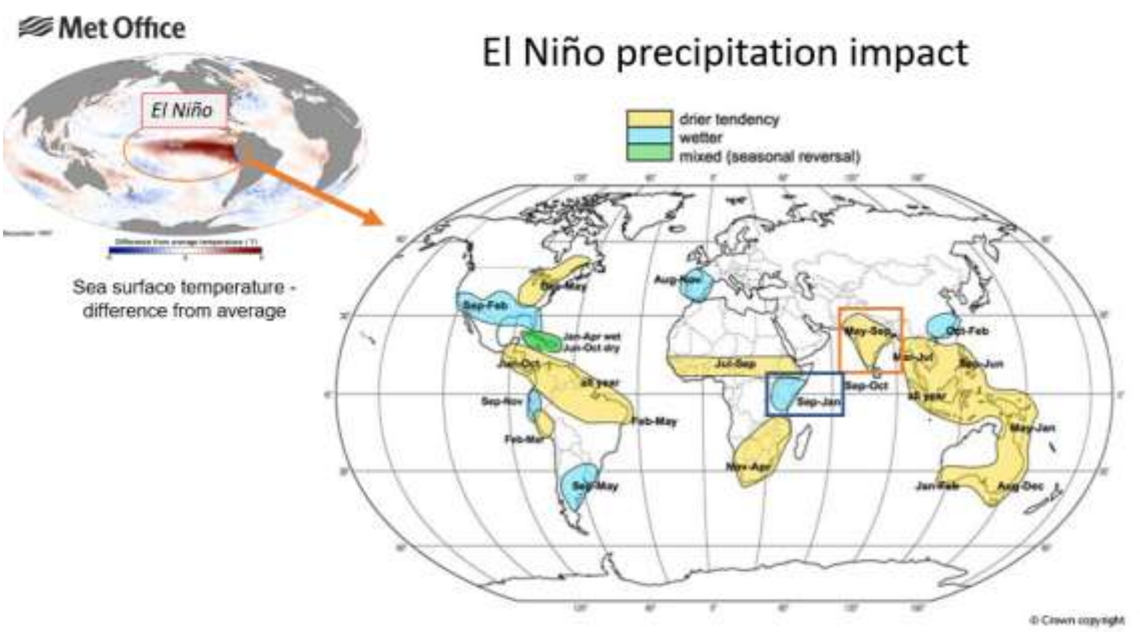


This map shows where seasonal forecasts perform well and not so well. You can see that seasonal forecasts typically perform better in the tropics, because it is here that relationships between the ocean and the atmosphere are usually strongest.

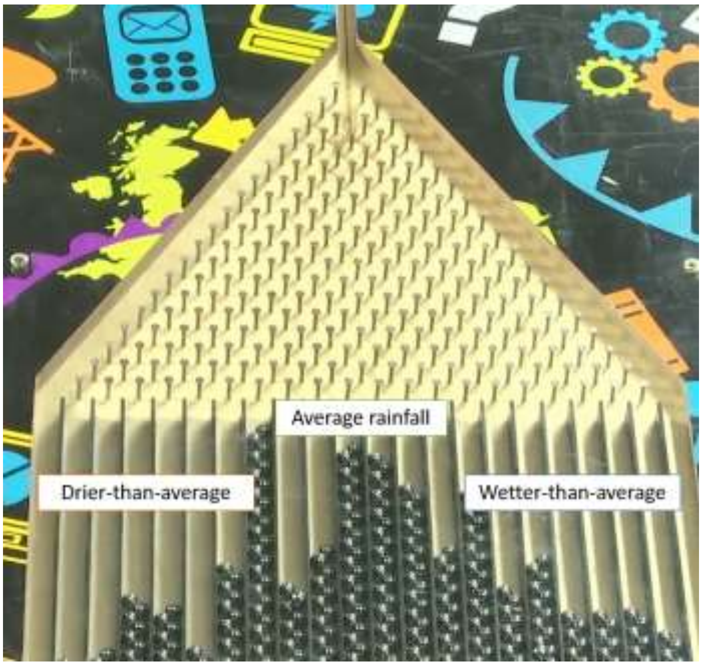
ALEX: Would El Nino be an example of one of these relationships?

JOE: Yes, that's right, the "El Niño Southern Oscillation" or "ENSO" for short, is probably the most well-known of these relationships.

ENSO is a phenomenon involving changes in the ocean and atmosphere over the tropical Pacific, with changes happening as part of a 2-7 year cycle. The warm phase, "El Niño", and the cool phase, "La Niña", can disrupt weather patterns across many parts of the world, but especially in the tropics and sub-tropics.



For example, El Niño events have been linked to drier than average conditions in South Asia during the summer monsoon, and wetter than average conditions over east Africa between September and January.



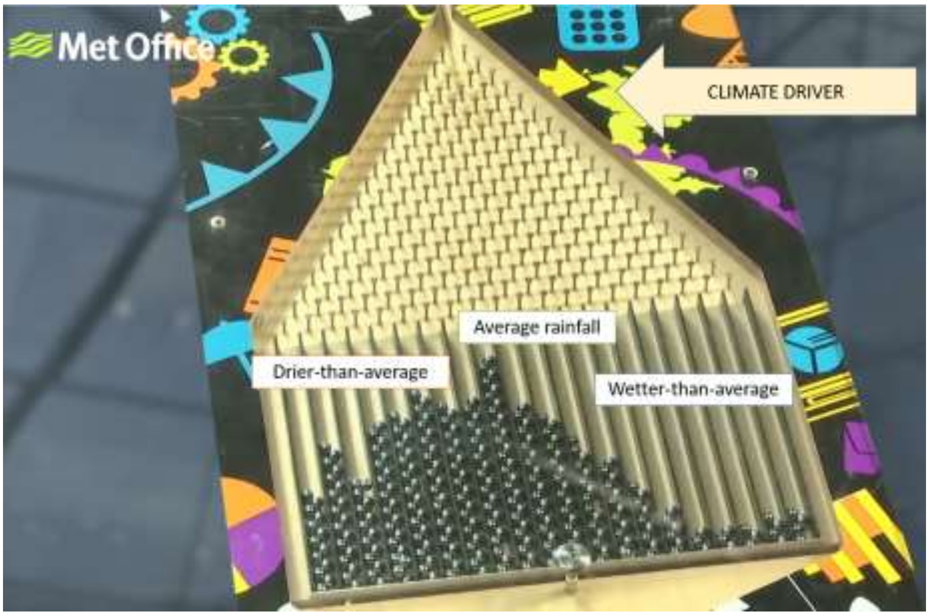
To help understand how climate drivers influence a region's climate, we can use an analogy. This is a Galton board. If I drop a ball into the top, it hits each pin with a roughly equal chance of falling either left or right, eventually landing at the bottom.

If I repeat this, where do you think the next ball will land? We can't tell for sure, since slight changes in its starting position will change the way the ball bounces through the pins, and we can't predict its final location precisely. This is similar to the natural chaos within our climate system - the butterfly effect mentioned earlier. But, if we repeat this experiment and drop more and more balls in, a distribution forms at the bottom.

What we can see is that a ball is more likely to land near the centre, with a lower chance of it landing near the edges. The resulting distribution resembles many climate distributions; for example, you can think of the centre as representing the average temperature for a region, and either side would be drier or wetter than average.

ALEX: So, if a climate driver, like El Nino, is known to influence a region, would this distribution change?

JOE: Yes exactly. The climate driver would effectively act to tilt the board. This means the balls are more likely to fall to one side, shifting the distribution and changing the probabilities, so that a drier or wetter season is now more likely.



Now let's imagine an El Niño event is forecast. We know, for example, that El Niño is typically associated with drier-than-average conditions in India during the summer monsoon. Whilst we still can't tell exactly where the ball will fall, we can say that the distribution of possible outcomes would be shifted towards drier-than-average, noting that wetter-than-average conditions are still possible, just less likely. So even though chaos is still present, climate drivers give us a source of predictability which make seasonal forecasts possible.

Of course, the climate system is not as simple as this. Often there are several climate drivers interacting with one another, so it's not always clear which way the board will tilt or to what extent, adding additional uncertainty to the forecast.

ALEX: Thank you Joe. So, to summarise, Joe has explained how seasonal forecasts are predictions of long-term weather, typically for a 3-6 month period, over a large spatial area. They do not predict day-to-day changes in weather or provide detailed information for a specific location. Forecasts are usually expressed as probabilities of how the forecast conditions compare to average conditions. And the fundamental reason they are possible is thanks to slow-moving 'climate drivers', like ocean temperatures.

In our next video, we will learn about how we use our understanding of the climate system to generate seasonal forecasts.

Links to further information

- BRACED seasonal forecast toolkit: http://www.braced.org/resources/i/practical-guide-seasonal-forecasts
- El Nino Southern Oscillation: https://www.metoffice.gov.uk/weather/learn-about/weather/oceans/el-nino

Part 2: Seasonal forecast production

ALEX: In this video, we have the two Phil's with us, climate scientist Dr Philip Bett and scientific software engineer Dr Philip Davis from the Monthly To Decadal Variability and Prediction team, to tell us about the main method for producing seasonal forecasts and how we deal with the uncertainty that exists in the forecast process.

First, Phil can you tell us more about how seasonal forecasts are usually generated?

PHIL: The most common approach to producing seasonal forecasts is to use so-called "dynamical methods" requiring large supercomputer systems. Dynamical models attempt to represent the many physical processes within the climate system that drive seasonal variability. Seasonal forecast models work in a similar way to those used in weather forecasts and climate projections and use our knowledge of the physics of the atmosphere and ocean to simulate processes in the climate system.

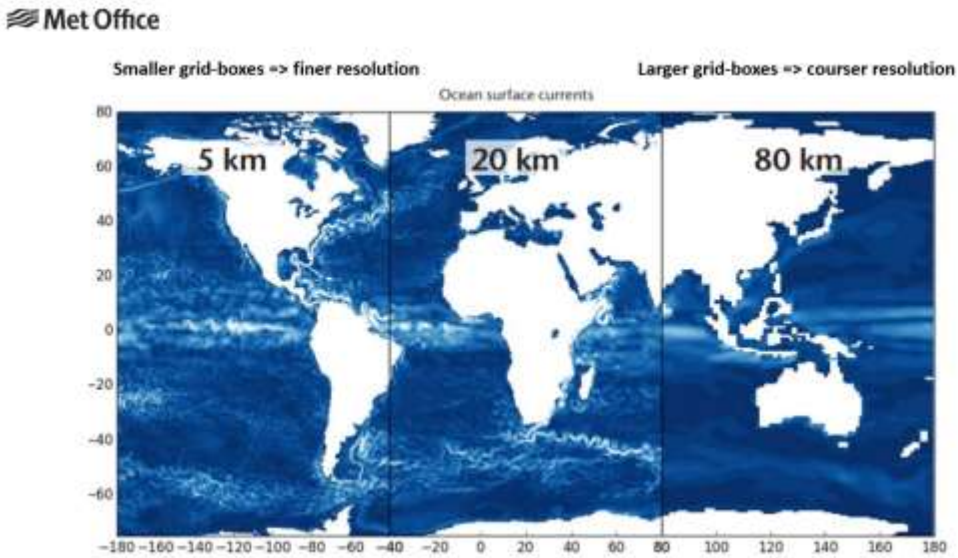
To do this, the models use a 3-D grid covering the entire globe, reaching from the depths of the ocean to the top of the atmosphere. This can be imagined as many thousands of cubes, or grid-boxes, on and above the earth's surface and beneath the oceans. The model solves mathematical equations that describe basic physical processes to predict how the atmosphere and ocean in each of these grid-boxes will change in the future and how processes in one grid-box interact with processes in its neighbouring grid-boxes. These equations require millions of calculations using supercomputers. Before the model can be run, it must be set up so that winds, temperature and humidity in all of the cubes resemble, as closely as possible, those observed in the real climate system at the forecast start time. These are known as the "starting conditions" or "initial conditions". An estimate of the initial conditions across the world is produced using observations from a variety of sources such as satellites, weather stations and ocean buoys. After the model run is complete, its output is processed and analysed.

ALEX: So, what are the advantages and disadvantages of this approach?

The big advantage of the dynamical approach is that the predictions are based on simulating the many complex interactions that occur in the real world, between the atmosphere, ocean, land and ice. These sophisticated models have been improved over several decades and continue to improve. Nonetheless, although remarkably realistic, they remain imperfect and model errors are inevitable. Running dynamical models is also very data intensive and expensive due to the need for supercomputers and significant human resources.

At the time of making this video, there are 13 centres across the world designated by the World Meteorological Organisation, or WMO, as 'Global Producing Centres' of seasonal forecasts. A list of the seasonal forecast models and their characteristics are listed on the WMO lead centre website (https://www.wmolc.org/).

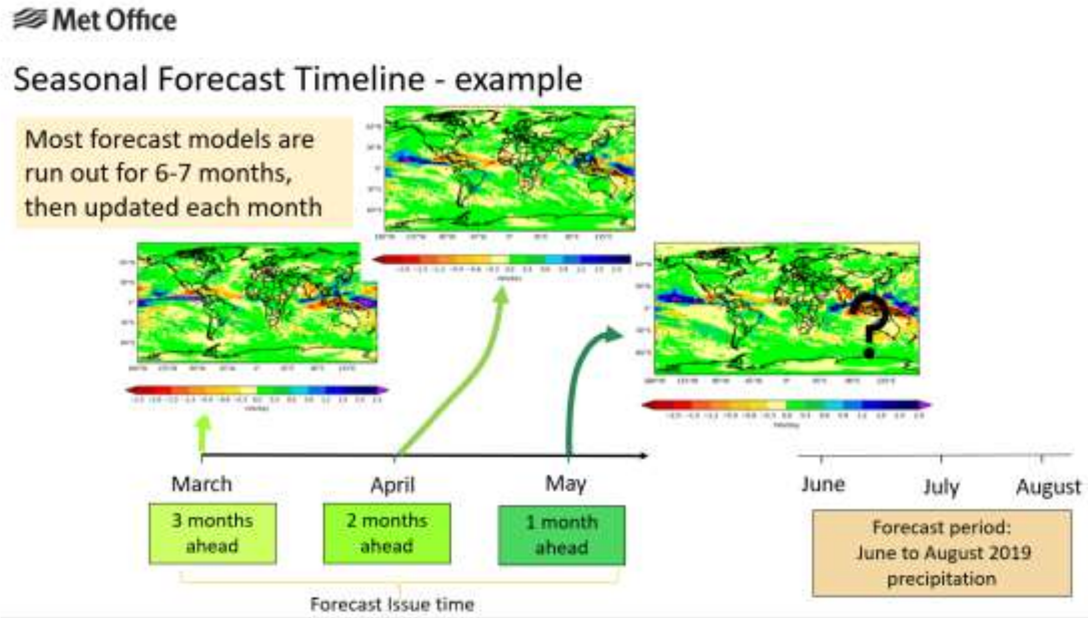
The characteristics of the models from the 13 centres varies, and therefore so does the forecast output. For example, some models only simulate the atmosphere, whilst other more advanced models also simulate the ocean, sea ice and land surface – the most advanced models are known as "coupled Earth-system models". Earlier we spoke about the grid-boxes that models use to cover the earth; the size of these boxes determines the "model resolution", and this also varies between models.



For example, here is the model's representation of ocean currents and different resolutions. The output on the right uses larger 80 km grid boxes – a relatively low resolution, the output on the left uses smaller, 5 km grid-boxes, and so has a higher resolution. You can see that much more detail is captured in the high-resolution case, just like a high-resolution television or photograph. The downside of higher resolution models is that they take up even more computing power and do not necessarily provide a more accurate forecast.

ALEX: So how do you know which model to use?

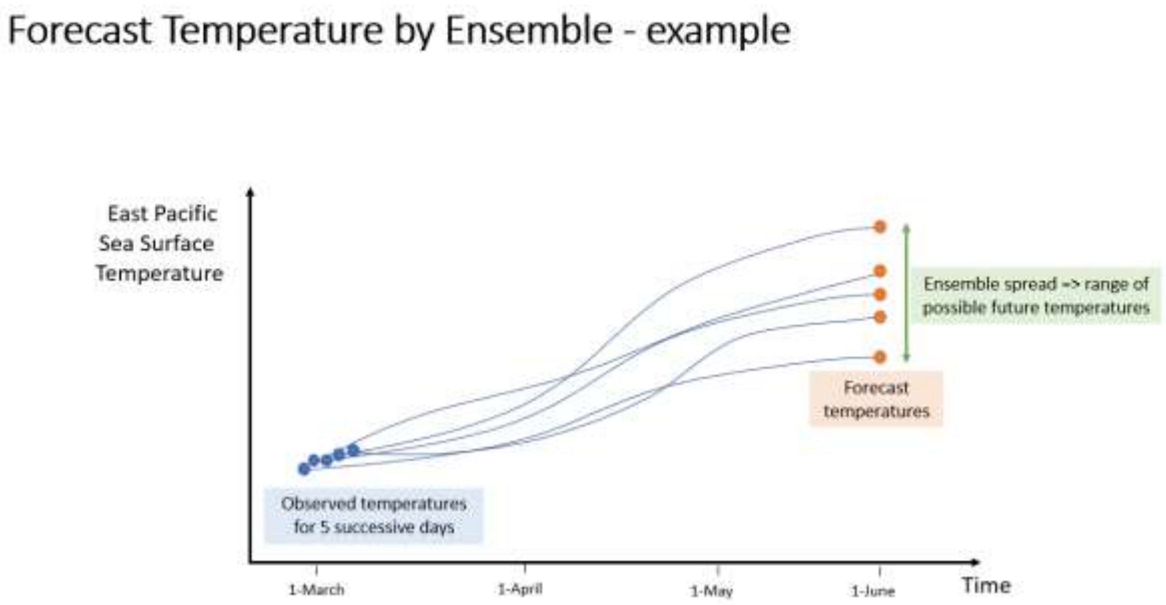
PHIL: That's a good question, and we talk about different ways to assess a model's performance in the next video. It's important not to rely on one individual model but rather look at output from a variety of models. There are online data portals which allow you to compare and combine multiple models, and we talk about these in the final video.



Most centres run their models to cover the next 6- to 7-month period and this is repeated each month. Therefore, the seasonal forecast for the June, July and August season, would first be available in March. It would be updated in April and then again in May.

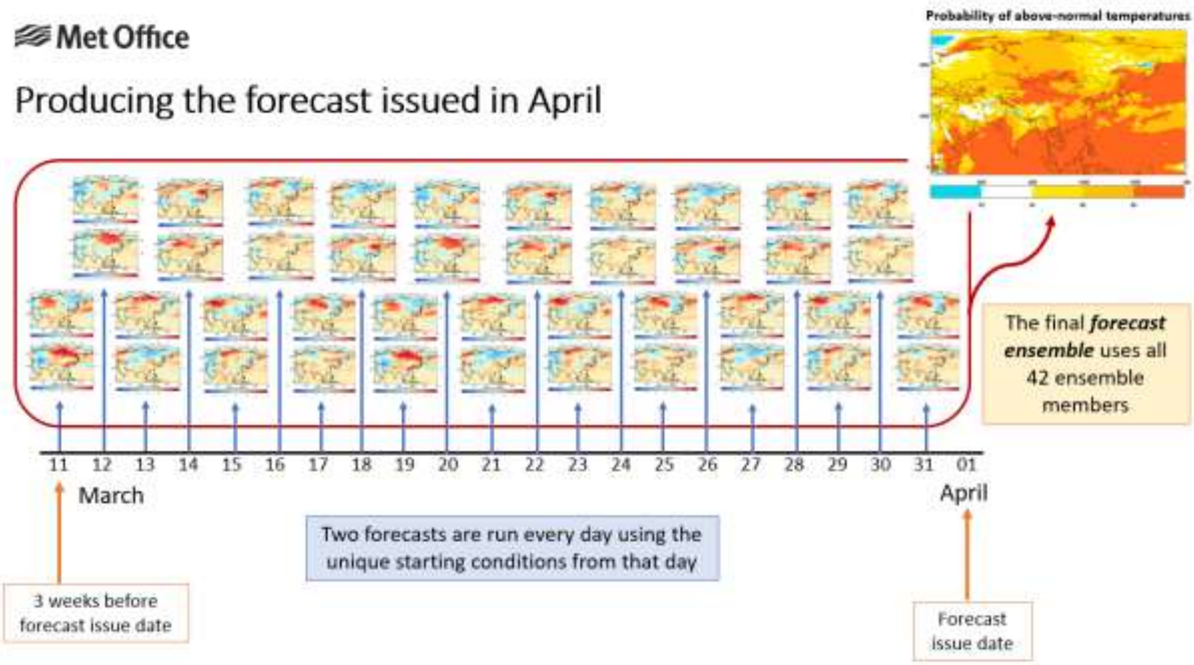
ALEX: As we mentioned earlier, running a forecast this far into the future is associated with considerable uncertainty, how is this dealt with by the models?

PHIL: Yes, it is very important to account for and measure this uncertainty, which is done using an approach called 'ensemble forecasting'. The model is run several times, but with tiny variations applied to the system each time, carefully designed to represent the uncertainties in the starting conditions and the models. This results in a number of different individual forecasts forming the 'forecast ensemble', with each forecast known as an 'ensemble member'. As with the Galton Board analogy earlier, doing the experiment with multiple balls builds up a distribution of plausible landing positions; ensemble forecasting works in a similar way, giving us a range or distribution of possible futures.



Here is a temperature forecast for the East Pacific Ocean using an ensemble with 5 members. Each ensemble member has slightly different starting conditions, taken here as the conditions measured on five successive days. As the model simulation runs forward in time, the spread of the ensemble increases, providing a range of possible future temperatures for the forecast period.

Global producing centres use different approaches to set up their ensembles, but all aim to represent the uncertainties in the forecast process. Here at the Met Office, our global seasonal forecast model, GloSea-5, uses a 'lagged' approach.



Two forecasts are run each day using the starting conditions of that day; each run with slight variations to its physical processes. The changes in atmosphere and ocean from day-to-day give another source of uncertainty in the starting conditions. For the seasonal forecast for 1st

April for example, we pool together the past 3 weeks of forecasts, giving us an ensemble of 42 members, where each forecast is considered to be equally likely over the forecast period. Further information on the GloSea-5 system can be found on the Met Office website.

ALEX: So, once you have the forecast ensemble for the coming season, what comes next?

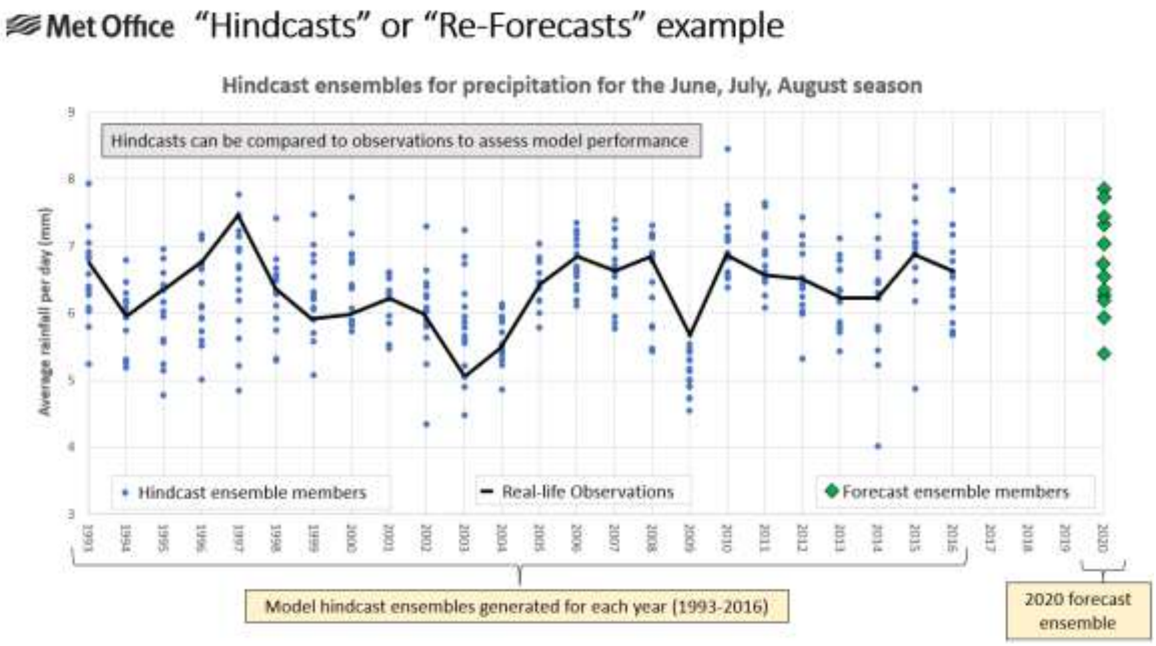
PHIL: Next, we need to calculate how the forecast compares to the average for that season, “wetter or drier than average” for example. To do this, the forecast must be compared with the model’s long-term representation of the same season and lead time, which we will refer to as “model climatology”.

ALEX: So, the model climatology is different from the observations?

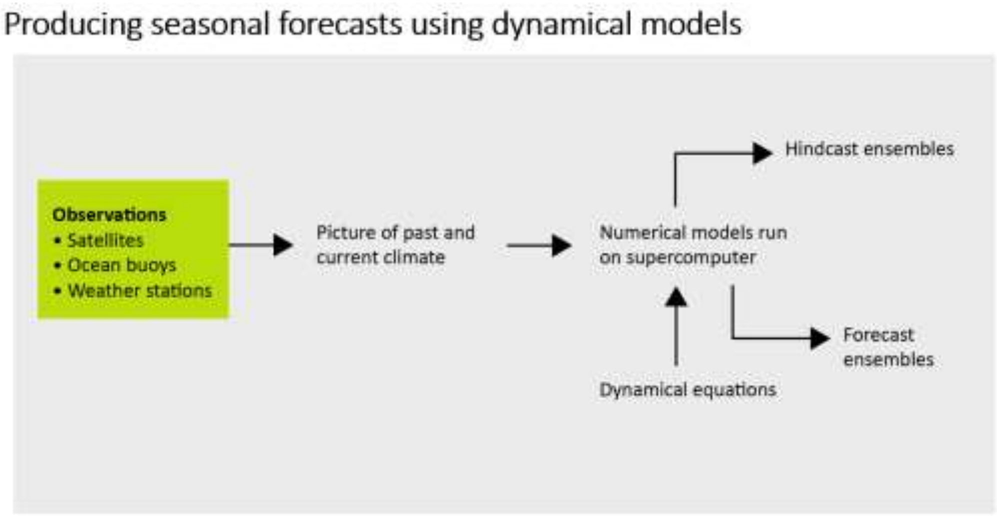
PHIL: Yes, it is. Remember, because of imperfections in the model, the model’s climatology will differ slightly from the observed climatology, as shown in this example. Therefore, the model forecast must be compared with the model climatology for a fair like-for-like comparison.

ALEX: I see, so how do you determine the model climatology?

PHIL: The model is run over a period in the past, typically 20-30 years; in the Met Office Glosea-5 model this is done for the period 1993 to 2016.



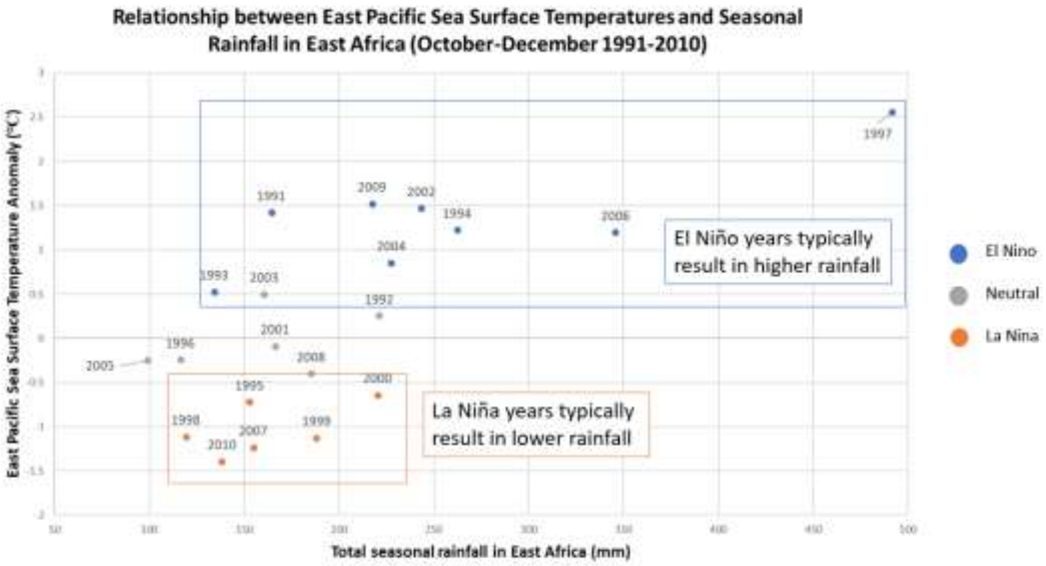
These historical forecasts are known as ‘hindcasts’ or ‘re-forecasts’. Hindcast runs are produced throughout each past year, allowing a hindcast ensemble to be made to match any forecast ensemble, in terms of lead time and forecast season. This allows a fair like-for-like comparison between hindcasts and forecasts. Hindcasts are useful for comparing with the observations of the real climate to see how well the model captures climate variability from year-to-year; we will speak more about model performance in our next video.



As a recap, here is a flow diagram reminding us of the process of producing seasonal forecasts using dynamical methods. First, observations are used to paint a picture of the current global climate system. This picture is projected forward in time using dynamical equations built into a numerical model run on the super-computer. These models produce both hindcast ensembles and forecast ensembles.

ALEX: So far, we have spoken about producing seasonal forecasts using dynamical methods. Are there any other ways to produce seasonal forecasts?

PHIL: Yes, before the development of these sophisticated computer models, the only way to produce seasonal forecasts was using “statistical methods”, some of which are still used today. Statistical methods use observational records to determine relationships between weather conditions and pre-season climate drivers, such as global patterns in sea surface temperatures. By knowing the current sea surface temperatures, and using the identified relationship, a seasonal forecast can then be produced.



This figure compares seasonal rainfall totals over East Africa with sea surface temperatures in the eastern Pacific, over the past 20 years. The data shows that, in general, higher temperatures in the east Pacific, as occur during El Nino events, are usually associated with higher rainfall amounts over East Africa. This statistical relationship allows us to make seasonal forecasts over this region, although other sea surface temperature drivers in the Indian Ocean are also important to consider.

One of the main advantages of using statistical methods is that, unlike dynamical methods, they are relatively quick to calculate and don't require too much computing power. The main disadvantage is that they only use statistical relationships, and so do not benefit from our knowledge of the many physical processes within the climate system. They also require long records of past observations and assume that the relationships we see in the past will work in the future – which might not be true in a changing climate.

ALEX: Thanks to both the Phils for that great summary! We've come to the end of this section, and we have covered a lot! We've learnt how statistical methods work by identifying relationships between local weather patterns and global climate drivers, whereas dynamical models use numerical methods to represent the complex physical processes in the Earth system. Dynamical models attempt to capture the uncertainty by generating multiple forecasts and hindcasts, known as "ensemble forecasting". Hindcasts are forecasts run for a period in the past and used to calculate the "model climate".

In the next video, we'll explain how seasonal forecast output is presented and how to assess forecast accuracy and skill.

Links to further information

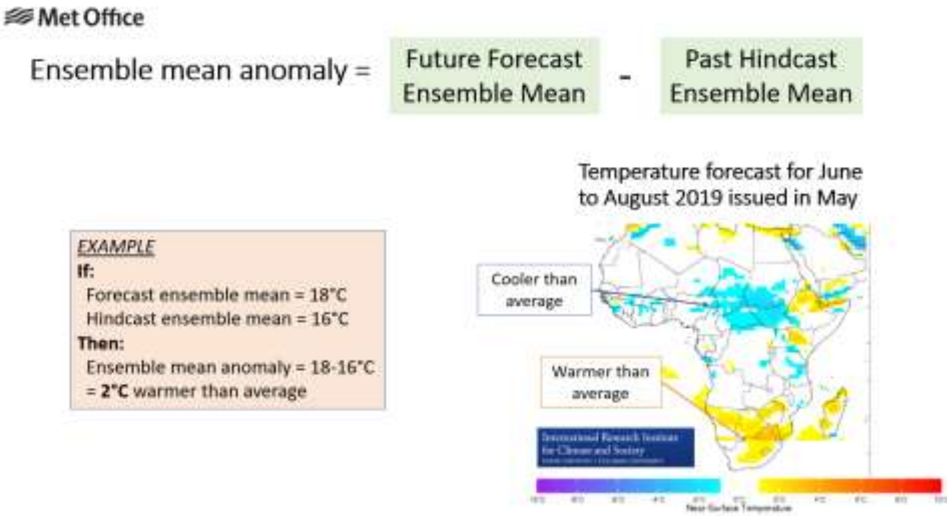
- Ensemble Forecasting: https://www.metoffice.gov.uk/research/weather/ensemble-forecasting/what-is-an-ensemble-forecast
- Met Office monthly to decadal prediction: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/
- Met Office seasonal prediction system: https://www.metoffice.gov.uk/research/approach/modelling-systems/unified-model/climate-models/glosea5
- Met Office seasonal output: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/

Part 3: Seasonal forecast analysis and presentation

ALEX: In this section, scientist Tammy Janes will explain some common approaches to presenting seasonal forecast information and show how these are calculated. Then, we will talk about how we can assess the accuracy and skill of seasonal forecasts. Some parts of this video are quite technical, but they are important to understand so it's worth taking your time.

In the previous video, we explained how seasonal forecasts are produced using an ensemble approach. Each ensemble member is a forecast for the same season and the range of different outcomes describes uncertainty in the forecast. Then we also have hindcast ensembles, which use a similar approach, with the model run over a 20- to 30-year period in the past, to calculate the model climatology. As previously mentioned, the Met Office GloSea-5 model produces 42 different forecast ensemble members. That's a lot of data! Tammy can you tell us how we process and display all of this information to make it useful?

TAMMY: One common method is to take the average, or mean, of the forecast ensemble members for a particular climate variable, like temperature. This "ensemble mean" is a simple central estimate of the forecast. The difference between particular conditions and the long-term climatology is called an anomaly. In our case, we are interested in the difference between the forecast ensemble mean, and the model's climatological mean as calculated from the hindcasts. This difference is known as an "ensemble mean anomaly". This can be calculated at each grid-box in the model to produce a map like this one.



This forecast shows the ensemble mean anomaly of surface temperatures averaged over June to August, from an ensemble forecast issued in May 2019. Here the output suggests that, for this season, much of Africa is forecast to be around average. Although parts of central Africa are forecast to be cooler than average by about 2 to 3 degrees, and parts of South Africa are forecast to be up to 2 to 3 degrees warmer than average. Remember, that this is just the average of the forecast ensemble members. Some members can be very different; therefore, the spread of possible forecast outcomes is also important to consider.

Another common way to display seasonal forecasts is to compare the distribution of ensemble members to categories representing the long-term climate. For example, a common approach is to divide the historical climatology data into three equal categories or "terciles", representing above average, near average, and below average.

ALEX: So how would we calculate tercile categories for a region?

TAMMY: First, we consider the climatology over the historical period. For producing dynamical seasonal forecasts, we use the model climatology determined by the hindcasts. The process of categorising the climatology can be explained with an analogy.

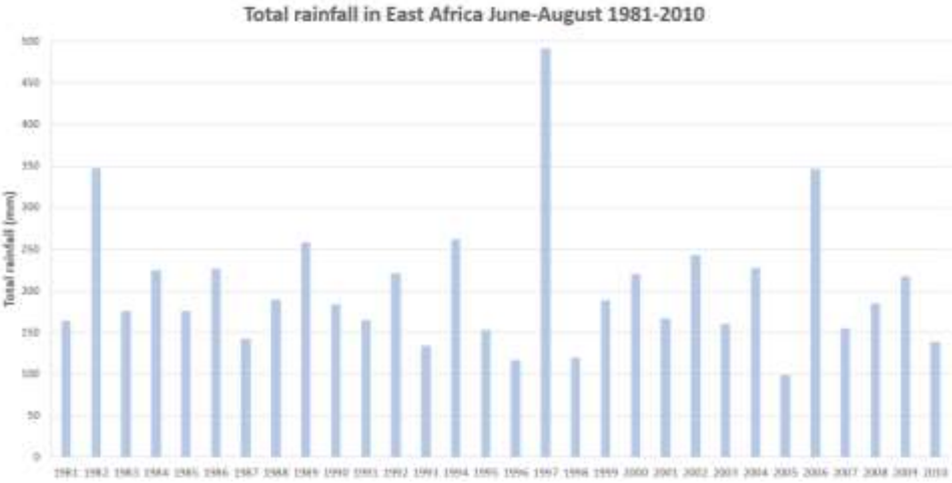
Here is a group of 15 people and we want to categorise them by their height. There is variability in the group's height, so one way to help organise this information is to sort them by height order.

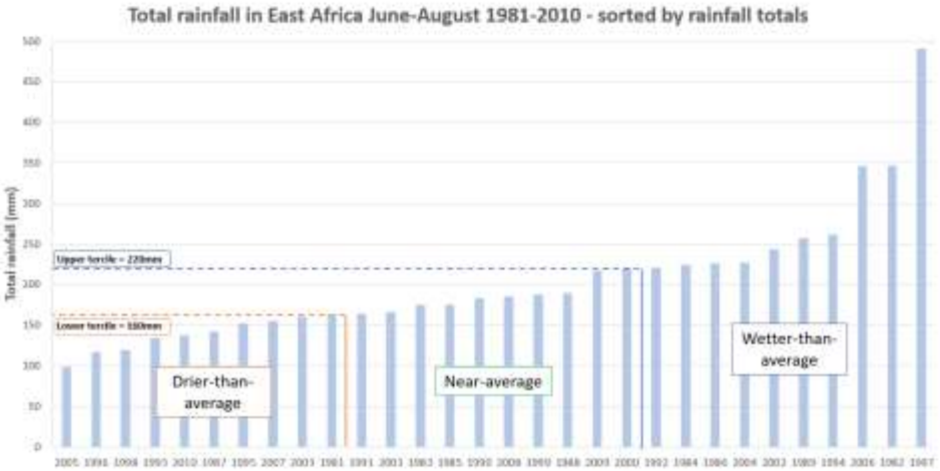
Now, to group them into terciles, we need to split them into three equal groups, with 5 people per group. One group includes the shortest 5 people – or the 'below-average' tercile, another includes the tallest 5 people - the 'above-average' tercile, and the remaining people are in the 'near-average' tercile. Each tercile category includes exactly one third or about 33% of the total group.

We could also split our data in other ways. For example, splitting the group into 5 equal groups, known as "quintiles". In this analogy, splitting the line into 5 groups gives us 3 people in each, or 20% of the total group. This helps us identify the more 'extreme' heights, such as the very tallest. Splitting the data into quintiles might be especially useful when dealing with seasonal climate data, if we're interested in understanding the probability of more extreme conditions, that could be linked to droughts or flooding, for example.

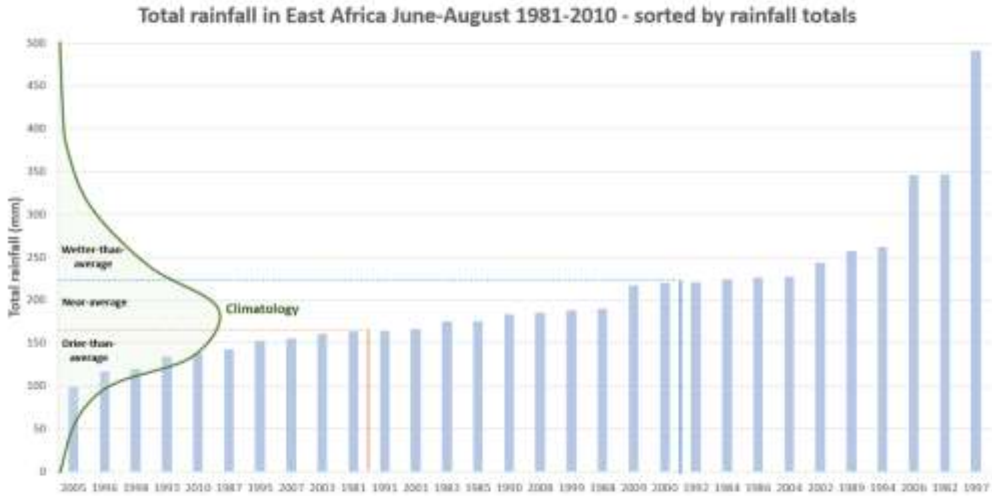
ALEX: So, in this analogy, you sorted people into height order and split them into 3 equal groups to determine the terciles, would you do the same with climate data?

TAMMY: Yes, we could imagine that each person's height represents the total seasonal rainfall for a particular year, for example, and categorise the rainfall data in the same way. Let's take a look at some real data.

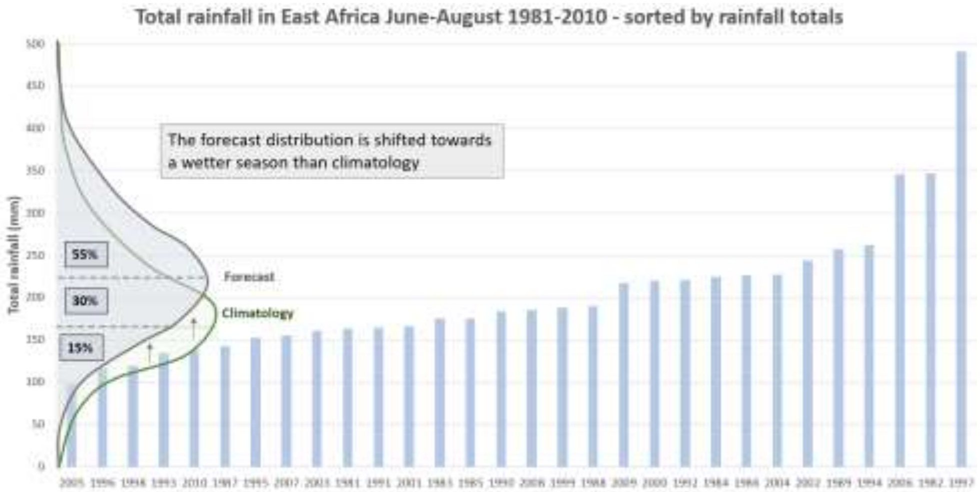




Here are 30 years of rainfall totals for East Africa from 1981 to 2010, representing the climate of the region. There is natural year-to-year variability, with some wetter years and some drier years. Let's now rank these years from the driest on the left to the wettest on the right. The data can then easily be grouped into terciles; we'll label the 10 driest years as "drier-than-average", the 10 wettest years as "wetter-than-average" and the middle 10 years as "near-average". This allows us to define rainfall thresholds between each of the tercile categories. When we construct terciles using dynamical model data, we use the same process but with hindcast data using multiple ensemble members, instead of observations.



We can also construct a frequency distribution from the data *3giv* – producing a curve showing the likelihood of a particular amount of rainfall, based on our past data. *3gv* The area under the curve for each tercile is 1/3 or about 33% of the total area and each tercile category has occurred one third of the years in this period.



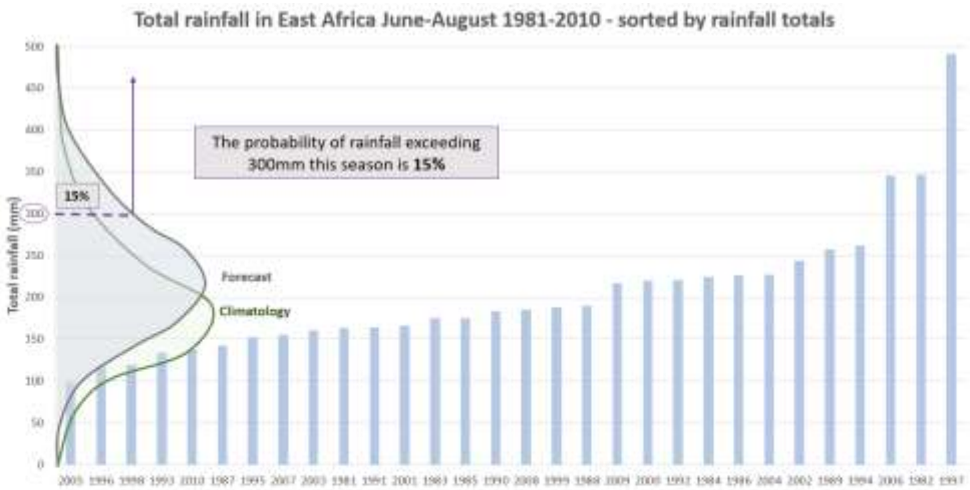
Now let's imagine we have just generated our forecast by running our dynamical model. Each ensemble member has given us a different seasonal rainfall total for the next season. Using the ensemble output we can construct a forecast probability distribution, and see how many ensemble members fall into each historical tercile category.

ALEX: So, the forecast distribution is shifted towards higher rainfall totals?

TAMMY: Yes, you can see that just over half of the ensemble members forecast rainfall above the historical upper tercile threshold. There are only a few in the lower tercile category and the remainder are in the middle. Therefore, the probabilistic forecast from the ensembles suggests that the next season is 55% likely to experience above-average-rainfall, 30% likely for near-average and 15% likely for below-average rainfall.

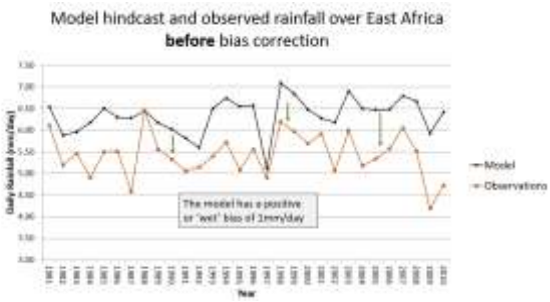
ALEX: With a 55% chance that this season will be wetter than average, we can be quite confident that we'll have a wet season, is that right?

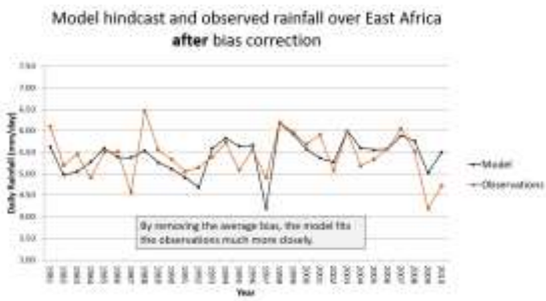
TAMMY: Well not necessarily, we must remember that even though it seems from this forecast that above-average rainfall is more likely than not, it's important to recognise that there is still a 45% chance of near-normal or below-normal rainfall. The context for using such information might therefore alter how the forecast should be communicated.



As well as terciles, there may be specific, fixed, trigger values or thresholds that are important for decision makers. The output of seasonal forecasts can be processed to display the probability of those thresholds being exceeded. In our example, let's imagine that seasonal rainfall over a threshold of 300mm may lead to damaging impacts on crops. The forecast shows there is a 15% chance of reaching that threshold in the next season, which is more likely than average.

Before using and trusting the output from a seasonal forecast, it is important to understand how well forecasts have performed in the past. This can be done using the hindcasts to determine the extent of any 'model bias'. Looking back at the flow diagram, this is done by comparing the hindcasts with the observed climatology of the same region and period.



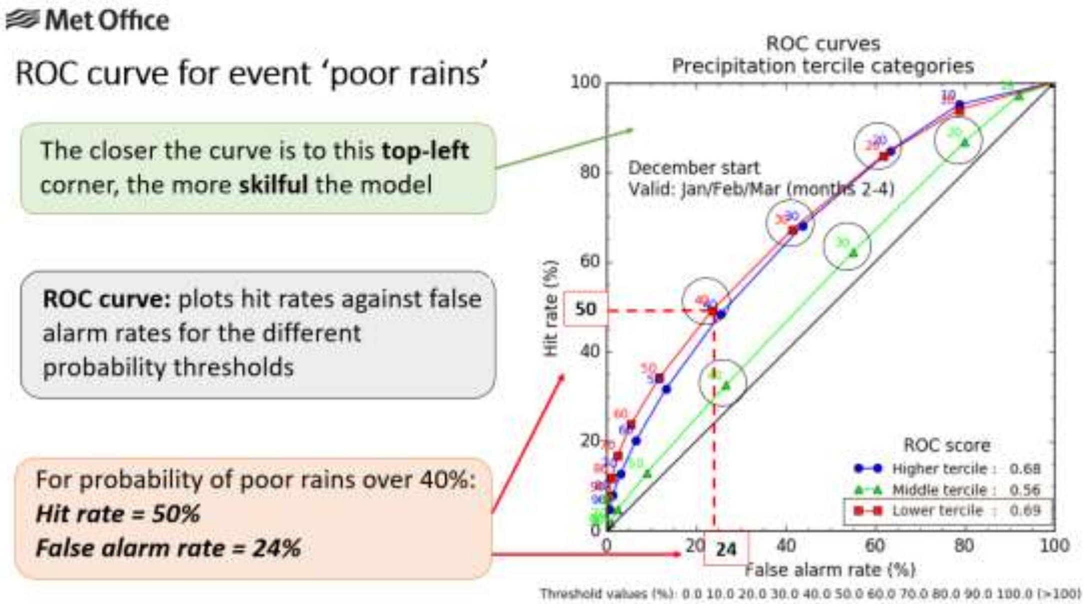


For example, here is the model hindcast in black and observations in orange over east Africa in the 30-year period from 1981 to 2010. You can see the model has a wet bias, as it has predicted more rainfall than was observed. The average bias over this period is calculated to be about 1 mm/day from all points. We can remove this bias by subtracting 1 mm/day, and then the hindcast fits the observations much more closely. Future forecasts can then be adjusted in the same way accounting for the model's average wet bias. Removing the bias in dynamical models is known as model 'calibration' and is done using much more sophisticated statistical techniques.

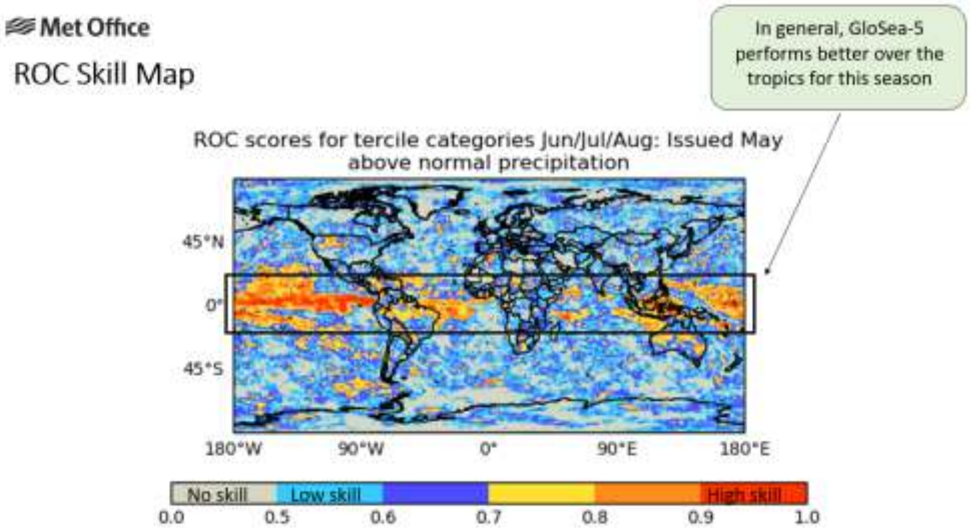
ALEX: It's already been mentioned a few times how important it is to assess the performance of seasonal forecasts. Can you tell us more about how this is done?

TAMMY: That's right, when considering the seasonal forecast output, assessing the performance or 'skill' of that forecast in the past is very important. Forecast skill can vary over time and space, and there are many different ways to define and measure skill. Ideally all methods require datasets over long periods, typically 20-30 years. One common method to assess forecast skill is the 'relative operating characteristic', or 'ROC' diagram which compares the number of forecast 'hits' against the number of 'false alarms' for a particular event, such as above normal rainfall.

For example, let's say that advisories are sent to farmers if the forecast probability of poor rains (for example the probability of being in the drier than normal tercile category) is 40% or more. If an advisory is issued and then the poor rains occur, it's a "hit"; otherwise it's a "false alarm". By looking at many cases, a hit rate and false alarm rate for the advisory statements can be calculated to measure forecast performance.



Plotting the hit and false alarm rates against one another is called a 'ROC curve'. In this example, when the probability of poor rains, or the lower tercile represented by the red line, is 40%, the hit rate is 50%, and false alarm rate is 24%. This can be repeated for other probability thresholds, forming a curve. For a skilful forecast, 'hit' rates must exceed 'false alarm' rates, so when the curve is closer to the top left corner, this indicates a more skilful forecast model. The total area under the curve is a summary statistic of overall performance, called the ROC score. In this example the ROC score is 0.69.



ROC scores can also be displayed as maps, by calculating the scores at each grid point. The skill can vary considerably depending on season and location. This map shows the ROC scores for the GloSea-5 system for the above-average precipitation tercile category in the June to August season. In general, you can see that for this season the model performs better over places in the tropics, such as South Asia.

Before communicating or using a seasonal forecast, it is very important to understand its skill, but we know it can be confusing. There are many other skill available, such as reliability diagrams and the Brier Skill Score. For more information on ROC scores and reliability diagrams, you can look at the user guidance provided on the Met Office website.

TAMMY: In this video we have discussed some common approaches to displaying forecast data, including the ensemble mean anomaly, which is the difference between the forecast ensemble mean and the model climate. Another approach is to categorise them based on the historic climate; the most commonly used categories are terciles (3 groups) and quintiles (5 groups). We have discussed the importance of hindcasts, which allow us to identify model bias and forecast skill for your area and season of interest.

In our next video, we will explain some of the uses of seasonal forecasts and give some examples of how they are being used in real life.

Links to further information

- BRACED seasonal forecast toolkit: http://www.braced.org/resources/i/practical-guide-seasonal-forecasts
- Relative Operating Characteristic (ROC): https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/user-guide/interpret-roc
- Reliability and sharpness diagrams: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/user-guide/interpret-reliability

Part 4: Seasonal forecast delivery and services

ALEX: In the previous videos we have explained how seasonal forecasts are produced, analysed and presented.

In this final section, scientist Jessica Stacey from the International climate services team will tell us about where to access seasonal forecasts, the role different organisations play in the creation and communication of seasonal forecasts, and finally two Met Office scientists will talk about projects they have been involved in to develop seasonal forecast services.

Jess, first can you tell us about where to start when using seasonal forecast information?

JESS: Yes, a good place to start would be to contact your own "national met service", also referred to as a "National meteorological and hydrological service", who can provide you with weather, climate and sometimes hydrology information for your country.

The role of a national met service can vary significantly from country to country; typically they produce daily weather forecasts and are responsible for collecting and archiving weather observations. A growing number of national met services provide seasonal forecasts, and some even work alongside customers to co-produce seasonal products and services.

Some national met services, including the Met Office, have the capacity to produce their own seasonal forecasts by running models on high-performance supercomputers, as discussed earlier in part 2. These centres are known as "global producing centres" or "GPCs", and the seasonal forecasts they produce are usually made freely-available on their own websites. Some universities and research organisations also generate their own seasonal forecasts. For example, the European Centre of Medium range Weather Forecasting or ECMWF are also known as a GPC.

ALEX: In part 2, we learnt there are 13 GPCs around the world, that's a lot of information, are there places where we can find all the seasonal forecasts in one place?

JESS: Yes, fortunately, there are various useful online portals which make it easy to access and compare different seasonal forecasts in one central place.

The portals we recommend using are the IRI data portal, the Copernicus Climate Data Store and the World Meteorological Organisation, or WMO, Lead Centre. Both the Copernicus and WMO Lead Centre portals even combine some of these models to make their own 'multi-model ensemble' forecast.

"Regional Climate Centres" also play an important part in the science to services seasonal forecast chain. These have been established in many regions of the world by the "WMO" to provide support to all the national met services in the countries within that region.

They are either hosted at a national met service or formed from a network of organisations across a region. In South Asia, this is the India Meteorological Department.

Regional climate centres have defined roles within the WMO framework, including building regional climate services and co-ordinating regional climate outlook forums.

ALEX: Can you tell us more about these forums?

JESS: "Regional Climate Outlook Forums", abbreviated to "RCOFs", first began in the late 1990s. They bring together national, regional and international climate experts on a regular basis to co-produce a consolidated seasonal forecast for the region.

This is done by assessing the different seasonal forecast output we have been discussing through this video. In the tropics, RCOFs usually occur twice a year, typically some weeks ahead of the rainy seasons. An example is the South Asian seasonal climate outlook forum, known as SASCOF.

DR PAI: From 2010, every April all south Asian countries meet in place and other invited global experts from GPCs, WMO and regional climate centres, based on input from different models provided by GPCs, we take all forecasts together and prepare consensus forecast. We also have training capacity building workshops prior to SASCOF meeting, and after preparing forecast outlook in each SASCOF, also have a user forum from sectors like water, agriculture, energy, media etc.

JESS: As well as producing the regional seasonal forecast, RCOFS often have training capacity building workshops for meteorologists in the region. They also provide an opportunity for forecast providers to interact with decision-makers using the seasonal forecasts. Sharing information helps the forecast providers understand the implications of the seasonal outlooks on different socio-economic sectors, such agriculture, energy and water resources.

Following the RCOF, most countries in the region hold National Climate Outlook Forums, also known as NCOFs.

Usually this will involve adapting the regional seasonal forecast produced in the RCOF, to make it more country-focused, as well as engaging with user communities to reach a wide range of stakeholders.

ALEX: Thanks Jess. There has always been a great interest in forecasts on seasonal timescales, as it is important for planning decisions in key government sectors, industry, and for individuals such as farmers. Here at the Met Office, we are working to increase the use and effectiveness of seasonal forecasts. Through the process of co-production, we work with organisations and end-users to strengthen the science to services chain. Now let's hear of examples from a couple of Met Office scientists on work they've been doing. Kathrin Hall is from the international development team and has been involved in work in Africa.

KATHRIN: Seasonal forecasts have been used in parts of Africa for decades. The Met Office works closely with many organisations in the region to co-produce actionable seasonal forecasts for different sectors. Scientists from the Met Office regularly run seasonal forecast training workshops for both producers and end-users.

One example of how seasonal forecasts have added value occurred in West Africa. The regional climate centre issued the regional forecast ahead of the rainy season. It highlighted an enhanced risk of wet conditions. In response, the Red Cross increased their relevant emergency stocks. Widespread heavy flooding then affected much of the region. Having had the advanced warning meant that the Red Cross were well prepared to help those in need.

ALEX: Next, we hear from scientist Dr Philip Bett, who has been working on a project in China.

PHIL: For the last few years, we have been working on a project to develop seasonal forecast services in China. Alongside organisations in the region, we have co-produced a forecast service for the Yangtze River basin, providing information on the likelihood of the summer being wetter or drier than average. Our colleagues at the China Meteorological Administration use it to communicate these risks to stakeholders along the river, such as at the Three Gorges Dam. They can then use the forecast to support decisions on how much water to release from the dam before and during the season. This in turn helps to ensure there is enough water to produce hydroelectric power, but also reduces the risk from flooding to cities and farmland downstream.

ALEX: As discussed in this video, there is a wealth of seasonal forecast information available to use, but it can be tricky to fully understand and use, even for the experts! If you are new to using seasonal forecasts, we recommend contacting your National Meteorological Service who can provide guidance and may be able to recommend the most appropriate information and how to interpret it for application in your own decisions. They may also be interested to get an insight into your operations and how you think seasonal forecasts can help you. Over time, two-way communication may even open up opportunities to co-develop bespoke seasonal forecasts tailored to your requirements, like the examples given, allowing you to translate seasonal forecast information directly into an action plan.

So, to recap for part 4. We've learnt that seasonal forecasts can be accessed either through global producing centre websites, or via online portals such as the WMO, Copernicus and IRI portals. Regional and national climate outlook forums bring together climate experts and decision makers to produce a seasonal forecast whilst promoting its uptake and usability. And finally, we looked at examples of how seasonal forecasts are being successfully implemented into long-term planning strategies.

Closing summary

ALEX: This brings us to the end of this series of videos which has stepped through the seasonal forecast process, from the science, to the production, analysis and finally the development of services. All elements within this process are continually evolving, including the science that goes into improving the models, and the way in which forecasts are communicated. Despite this, seasonal forecasts will always have their limitations and should be interpreted with caution.

Decisions based on seasonal forecasts should also be reviewed alongside forecasts with shorter lead times as they become available. Sub-seasonal forecasts are usually available with a 1-month lead time and weather forecasts should always be monitored for details on day-to-day variability. When seasonal forecasts are used appropriately, they can provide valuable information to support risk-based decision-making and reduce the impacts of climate extremes.

We hope you found these videos useful. For more information about seasonal forecasting and the range of work we're doing with partners in the UK and around the world, please visit the Met Office website.

Links to further information

- BRACED seasonal forecast toolkit: http://www.braced.org/resources/i/practical-guide-seasonal-forecasts
- Copernicus: https://cds.climate.copernicus.eu/#!/home
- IRI Data Portal: https://iri.columbia.edu/
- Met Office international work: https://www.metoffice.gov.uk/services/government/international-development
- Met Office Applied Science: https://www.metoffice.gov.uk/research/applied
- WMO Lead Centre: https://www.wmolc.org/
- WMO Regional Climate Centres: https://public.wmo.int/en/our-mandate/climate/regional-climate-centres
- WMO Regional Climate Outlook Forums (RCOFs): https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products