Rebecca: (00:09)
I think the research that we've done as part of the PICSEA project (Predicting the Impacts of Cyclones in South-East Africa) project will help forecasters at the national weather services to increase their understanding of the NWP models and the way they work and the skill and the uncertainty associated with each different model. If you're forecasting a tropical cyclone and you're presented with several different forecasts, this should give you an idea of which is the mostskillful model to look at under certain conditions.

Rebecca: (00:36)
The highlight of the project for me was definitely working with all of the national meteorological services in Mozambique, Madagascar, and the Seychelles, and being able to visit each of the national weather services. I learned so much from the forecasters that we spoke to out there and about their knowledge of meteorology in the region, which definitely helped our research as well.

Nick: (00:58)
So error is the difference between what we forecast either the average of an ensemble or the single deterministic run and what actually happens. And when you accumulate those errors, when you take those errors over a long period of time, many, many forecasts together, you can derive the bias of the model, which is basically the average error over many forecasts. Uncertainty just is our lack of understanding of the range of possible outcomes, that our forecast might have, and ensembles attempt to capture some of this uncertainty, both in the model's forecast of how the weather will evolve, but also uncertainty in the initial conditions of the forecast. So ensembles attempt to span the range of uncertainty, although they often don't.

Rebecca: (01:52)
So while it's not possible to know how accurate a forecast is, while you're looking at an operational forecast, one of the things to take into account is ensemble or probabilistic forecasts that are designed to take into account as much uncertainty in the forecast as possible to give you a range of potential forecast scenarios. Another aspect you can take into account is whether we have large-scale circulation conditions, for example, certain phases of the MJO, which might give you more confidence in the forecast because they tend to provide more skillful, more accurate forecasts than when you have other large-scale atmospheric conditions.

Rebecca: (02:26)
Another way of accounting for this is to look at forecasts from various different forecasting models. And this can give you an idea of the uncertainty across different forecast models and whether they tend to be in agreement giving you more confidence in the forecasts, or whether they tend to tell different stories of the tropical cyclone's evolution, perhaps indicating more uncertainty in the forecasts.

Rebecca: (02:51)
So if you're looking at the track forecasts from the UK, Met Office and ECMWF models. For the first one to one-and-a-half days of lead time, very short lead times, the UK Met Office tends to have slightly more accurate tropical cyclone forecasts than ECMWF. At that lead time,we're kind of looking at 75 to 100 kilometres as the average error in the track forecast of a tropical cyclone. Beyond one and a half days ahead, the errors in the Met Office model tend to increase much more quickly with lead times than the ECMWF forecasts. So we say that ECMWF provides slightly more accurate forecasts beyond one-and-a-half days ahead. And by the time you get to three days ahead,

you're looking at an average error in the ECMWF forecasts of about 200 kilometres.

Rebecca: (03:35)
In terms of the intensity forecasts, ECMWF does tend to provide slightly more accurate intensity forecast for tropical cyclones. In terms of the wind speed, we're looking at about 20 kilometres an hour underestimation in the wind speeds of a tropical cyclone at the maximum wind speeds. And in the Met Office, it's about 25 kilometres per hour underestimation. So slightly more accurate in the ECMWF forecasts.

Rebecca: (04:12)
The accuracy of tropical cyclone forecasts can vary in different parts of the Southwest Indian Ocean. We know that in terms of forecasting, the track of tropical cyclones, this tends to be more difficult when tracks are re-curving. And this tends to happen towards the edges of the basin, more commonly, and that's more difficult to predict than for example, a tropical cyclone which travels in more of a straight line.

Rebecca: (04:34)
In terms of the intensity of tropical site cyclones, because we typically tend to underestimate the intensity of tropical cyclones, the forecasts tend to be less accurate where the storms are strongest, which tends to be in the centre of the basin and to the east of Madagascar.

Nick: (04:52)
So in Numerical Weather Prediction we are working with models that work with a limited resolution of finite resolution. We cover the earth in tiny little grid squares, and we make those grid squares as small as we possibly can, but we can't make them as small as we'd like, because we're limited by computing resources. So a key source of error for representing tropical cyclones is the limited resolution of our models. Today, leading centres like ECMWF and the Met Office are running forecasts at about 10 kilometre resolutions. So those grid boxes are 10 kilometres wide. But the processes that give tropical cyclones their intensity are much smaller scale than that. And so the key source of errors is our limited resolution, our limited ability to resolve the convectivemotions , within tropical cyclones.

Nick: (05:39)
Other sources of error include the fact that we have to parameterize many processes and models.So by parameterize, I mean that we have to try to represent statistically those processes that are happening at sub-grid scale. And that leads to the growth of errors in our forecast because we represent those processes inaccurately.

Nick: (05:58)
Other sources of error. So we have errors in the initial conditions. We don't represent perfectly the initial state of the atmosphere that goes into making these forecasts at all times everywhere. Andso when the models are run, even if we had a perfect model, because we have errors in our initial conditions, we would have errors in our weather forecast.

Rebecca: (06:23)
So while a lot of the evaluation we've done looks at the average errors across a large number of tropical cyclones. It's important to remember that these are average statistics and the errors for each individual site cyclone can vary quite considerably. This is one of the reasons it's important totake

into account the forecast from various different forecasting models and from ensemble forecasts to give an account of the uncertainty in the forecasts.

Nick: (06:56)
An ensemble forecast, the main advantage is that it gives you a range of outcomes, a range of probabilities. An ensemble is many forecasts started from either the same or similar initial conditions, forecasting for the same period. So if you look at different members of the ensemble, different forecasts, you'll get different, probable outcomes. If you take many ensemble members together, you can construct a range of scenarios of how the weather might evolve. The disadvantage of an ensemble is that because we're trying to run many forecasts and we have a finite amount of time in which to try to run that forecast so we can get the forecast issued. The ensemble members are often run at a lower resolution, a coarser resolution than the high-resolution deterministic forecast. And this means that for things like tropical cyclones, the ensemble will be worse for intensity forecasts of tropical cyclones than the high resolution deterministic.

Nick: (07:54)
Today, if I had to choose between two different deterministic models or a single deterministic model and it's ensemble, I would choose the two different deterministic models for tropical cyclins. First, because we know that tropical cyclone intensity is much better represented in high resolution deterministic forecasts. And secondly, because we know that today, the spread of our ensembles is often not sufficient to represent the uncertainty in tropical cyclone tracks or intensity.So we measure this by comparing the error in the ensemble being forecast to the ensemble spread. And the ensemble spread is typically much smaller than the error, which means that the real trajectory of the tropical cyclone often lies outside of the model ensemble. So ensembles for tropical cyclone track and intensity forecasts, I think I'd rather have two different models giving me two different representations of that high resolution intensity and the high resolution track forecasts.

Nick: (08:52)
Over the next 10 years or so, we expect to see a number of developments in Numerical Weather Prediction. We expect that our models will be able to run an increasingly high resolution, and that includes both the deterministic and the ensembles, which we're currently under-predicting the intensity of cyclones. Being able to have higher resolution ensemble members would give us a better probabilistic forecast, of tropical cyclone intensity. Numerical Weather Prediction centres are also considering how the atmosphere interacts with the ocean. It's something that's done in seasonal forecasts, or even in sub-seasonal forecasts, but for short range, NWP, many centres are still running just models of the atmosphere and not considering how the atmosphere interacts with the ocean. Increasingly, centres like ECMWF are starting to couple their atmosphere and their ocean models together for NWP. And this is something that we expect to become more widespread over the next 10 years or so. We also hope to see other upgrades to model physics as we go to increasingly high resolution. We should be able to start to disable some of those sub-grid scale parameterizations and remove some of those sources of error and bias that those parameterizations introduce. Particularly parameterizations of convection, is the most important one for the tropics. And one, that when we get down to kilometre scale NWP, we should start to be able to disable some of them.

Nick: (10:25)
PICSEA (Predicting the Impacts of Cyclones in South-East Africa) as a project developed from some similar work that we'd done in the west Pacific working with national meteorological agencies in the Philippines and in Vietnam as well. And also from conversations that we had with project partners at

the Red Cross about the value that this kind of tropical cyclone forecast analysis would bring to the South-Eastern African region, in terms of the value of the project. So I think the real advance has been our ability to interrogate quantitatively, archives of tropical cyclone forecasts from ECMWF and the Met Office. Two leading forecast centres whose forecasts we know are being used quite widely throughout the region. And also from the collaborations that we've had with our project partners, being able to visit these regions, being able to talk with forecasters, understand the challenges that they're facing and try to integrate some of those challenges into the analysis that we've done. Being able to make those visits at an early stage in the project and being able to then integrate those challenges, those questions that forecasters have, into our analysis, to be able to show which model performs best for which region at which times, for which types of cyclones, to be able to then give that advice back to forecasters working operationally in the area.