Raghu Murtugudde

Can we model the earth in our laboratory? Can we make accurate and useful predictions of its future behaviour based on these models? H. J. Schellnhuber in his paper[1] quotes Alonso X of Castile: 'If the Lord Almighty had consulted me before embarking on the Creation, I would have recommended something simpler'.

There has been a move from 'individual science' made possible by the first Copernican revolution with the invention of optical magnification instruments, to 'collective science' ushered in by the second Copernican revolution with the advent of devices such as satellites. Raghu Murtugudde, in his talk at the Indian Institute of Science (IISc), Bangalore on 15 March 2010, spoke of how we could take advantage of this second Copernican revolution to understand our planet better, build better models and make better predictions.

Murtugudde is a Professor at the Department of Atmospheric and Oceanic Science, Earth System Science Interdisciplinary Centre in the University of Maryland, USA, and Executive Director of the Chesapeake Bay Forecast Project. He has a number of books, peer-reviewed publications and awards to his credit. He teaches 'Cycles in the Earth System', 'Introduction to the Blue Ocean' and 'Introduction to the Earth-Life System' at the University of Maryland. He also guides several students. The following is the essence of an interview with Murtugudde on 15 March at IISc.

About himself

I grew up in Dharwad, Karnataka and completed my high school and pre-university college studies there. Then I studied aeronautical engineering at IIT Bombay, after which I went to the US for my master's and then my Ph D in mechanical engineering.

Why did you shift from aeronautical to mechanical engineering?

I went to Columbia University for Ph D and they don't have aeronautical engineering there. Fundamentally, aeronautical and mechanical engineering are the same thing. Aeronautical and aerospace focus more specifically on using mechanical engineering and also electrical engineering and computer science to build aeroplanes and rockets.

I worked at NASA for a few years on environmental satellites, and then moved to climate modelling – the same fluid dynamics but different scales. While growing up in Dharwad, there was a serious water problem. So I always remembered that water is a big issue and wanted to do something on climate and water. I have been working with an NGO called BAIF on sustainable water and agriculture, and rainwater harvesting issues. So it's been about gathering knowledge and understanding in science and technology to apply it to climate and its impacts.

About his work

Basically I am an earth system modeller. So I model the atmosphere, the ocean, and how the ocean and atmosphere interact with each other. I model the biology, how the nutrients come into the ocean, how they sink, how they come up, how these affect phytoplanktons which are the algae that do the primary production, i.e. the energy at the bottom of the food chain determining how much carbon is taken up by the ocean. Then I see how that primary production gets converted into different kinds of fish and how much fish we can produce.

More lately, I've been doing regional earth system prediction where we are basically trying to see how the environment and human beings interact, and if we want to do sustainable management of the planet, what kind of information do we need and at what scale? For example, if I want to advise a hospital on old people living in that area who are affected by pollution or by certain seasonal changes, let's say they are asthmatic; then can I make information available in that region and say that the next three weeks are going to be hot? Pollution will be dangerous in combination with heat. So can we use that information to tell the old people to be careful, to close their windows, to use the fan or not to go outside? So it's about human health, agriculture, water, energy, transportation and industries. Can we produce information for everybody to perform day-to-day management of whatever they are trying to manage? That's what I work on.

And, for a country like India, can we make this data reliable? Can we make it usable for decision makers? How do we tell places like ISRO what kind of satellites to build to make this information more useful? Can we watch vegetation, biodiversity, fish and so on?

Does this work reach the person who actually needs the information?

Modellers used to produce a lot of information, put it on a website and hope that everybody used it. But what we are doing now is that we pay fishermen, persons who collect harmful algal bloom data, persons who collect pathogens in the water, persons who manage a river and persons who manage a forest, to use our forecasts and say whether they can use this to make a decision and if it was useful. If it was not, then how could it have been more useful? This gives us a better way to look at the skill of our forecasts.

On Earth System science

How has Earth System science changed over the years?

In the times of Socrates or Plato or Aristotle, people did everything – there were no disciplines. Then medicine evolved. And then when engineering evolved, it was called civil engineering as opposed to military engineering because a lot of the engineering was supported by military establishments for defence requirements; and then when you started building bridges and roads, it became civil engineering. Then it became obvious that you need mechanical engineering and electrical engineering. Slowly we evolved computer science.

From the 1920s, it became clear that physics and atmospheric physics are slightly different, like weather forecasting. So weather forecasting evolved. And then, after World War II, weather forecasting became more regular and routine. Then we started flying satellites. Atmospheric physics was seen as interdisciplinary research, and pure physicists looked down upon atmospheric physics! Then atmospheric chemistry and oceanography developed. By nature these are interdisciplinary.

Weather prediction was focused on two days, three days, five days. But the ocean, for example, has its own heat content, so much memory, and changes so slowly that it controls climate. So you can make climate predictions. Even though you may not be able to say what happens in 10 days, there are other ways to say what happens in one month, two months. People began to realize the difference between weather and climate. You can predict both of them. It soon became evident that climate actually depends on whether you have a forest, a city, grass or desert. You have phytoplanktons and fish in the ocean – so biology became a part of it. Earth rotates at changing speeds and angles, so the amount of sunlight and radiation coming in may change. So slowly everything began to evolve and it became fully multidisciplinary.

On prediction of the Indian monsoon

We are not able to predict the Indian monsoon accurately with the currently available climate models. . .

Monsoon is like fluid turbulence. Turbulence happens at molecular scales, but affects large-scale motions. People have studied this difficult topic for hundreds of years and sometimes at the end of the day, it feels like there is nothing new. Monsoon is similar. We know approximately what happens. But once it starts, a lot of things change in a day, in a week, and so on. Richard Feynman, the famous physicist who won the Nobel Prize, said that when we don't understand something that is difficult, it's like riding a bicycle – once you know it, it is very easy. So there are some fundamental processes of monsoon, like turbulence, that you don't understand. Right now, it's almost like a blind man touching different parts of an elephant and saying it's like a tree trunk or it's like a rope!

On global scale versus regional scale models

In the simplest sense, global scale models have very coarse resolution. They represent the atmosphere and ocean by, for example, 100 km blocks. When you look outside in monsoons for example, it could be raining one mile from here whereas it could be really dry here. Things happen on a very, very small scale. Regional models represent a region and can be run at a very high resolution, which allows addition of some new physics.

Nowadays we even have things like cloud resolving models or models which explicitly represent cloud microphysics. This cannot be done on a very coarse resolution model. It's like you have much better control when doing a family budget whereas on a national scale, it is not easy to track every little thing. But if some fundamental physics is missing, then just increasing the resolution does not improve monsoon predictions. However, we have evidence that we can improve physics and monsoons.

On data–model blend

How do you handle errors in input data?

Models represent reality in a certain way. They might be looking at winds, humidity, temperature or radiation. But people may measure something else. So sometimes they are not doing the same things. Plus, when you measure something by a balloon, radiosonde or aerosonde, you are measuring at one location whereas the model is representing, let's say, in 1 km blocks. Consequently, it is representing an average of 1 km.

So, sometimes you use the data to improve the model by some intelligent choice or you blend the model with the data so that the data tells the model 'you are going away from reality, so you should come back'. So they blend together. And that works. But these are all evolving. If you are making monsoon forecasts, for example, and you have data for today and want to say what happens in May, but you don't have data for May. In that case, you use available data to initialize the model, get the model to be as real as possible for today, and then you integrate forward. So data can be used in many different ways. You can use data to reconstruct past years, for example, to understand what the model did wrong and what it did right and so on. We have to collect data and build models, bring them together and make something useful from both of them.

How do you implement this?

It needs expert teams: engineers who can build accurate instruments, scientists who can use these to collect data and immediately talk to modellers, and modellers who can use the data to improve the parameters in the model or the physics of the model. There's something called process understanding: how does a cloud form? when does it rain? when does convection happen over Bay of Bengal versus Arabian Sea? There are different kinds of data that represent each of these processes. So you collect those data and do process understanding to improve models, and then you see whether you can increase predictive understanding of the models. And we have to make it much more precise, useful and relevant locally.

On the IPCC report on the Himalayan glaciers

IPCC is not creating new knowledge. What it is doing is to take existing knowledge that has been 'peer-reviewed' and synthesize the information that is relevant for climate variability and climate change. But somehow somebody slipped up, and some statement made by someone that glaciers may disappear by 2035 went into the report. Just yesterday it came out in the newspapers that it was actually supposed to be 2350 and got misprinted as 2035.

It is now clear that glaciers have huge mass. The Himalayas has several thousand glaciers; they cannot melt so fast. The Himalayas is so big that the front of the glacier may be melting but the centre of the glacier may be getting more snowfall and getting thicker. So these things point to how careful we have to be plus what kind of new observations we need. For example, can we design a satellite with laser altimetry to measure thickness of glaciers, extent of glaciers, precipitation on top of glaciers and so on?

How did they arrive at this 2350 number?

We have people who do ice dynamics. We have models that can use IPCC climate projections to try and estimate when a certain glacier might disappear. But this is very uncertain right now. The estimate 2350 is from one of those models. But again we have to be careful – 2350 is far enough that it immediately changes dynamics of water problems in India. It's a big difference saying 2350 versus 2035.

There are not enough people doing ice modelling. There are educational requirements, observational requirements to reduce uncertainty, and need for validation and skill for these models.

From 2035 to 2350: the attitude of people might change now. . .

Yes. We have a credibility problem. We have to make sure that we don't keep changing stories and that we communicate the uncertainty in our science very well because people are, every single day, making decisions based on uncertainties.

People's attitude could be: 'It's going to happen only in 2350, not 2035. So we can do whatever we want!

Absolutely! That's why water is the problem. Glacier melting was not the biggest problem. Ganga is already so polluted. Groundwater is already being depleted. The water table is at 200–300 feet due to irrigation. What will happen? That message was kind of lost by raising the red flag over glacier melting. Whatever happens, the main message is that water is still very crucial for survival, and we have to use it properly. So you are right, it is a dangerous situation if people think there is no problem anymore. So we had better learn to convey this message properly and positively.

On Copenhagen's success and failure

The whole IPCC outcome from Copenhagen should not be seen as a failure. The fact that people are coming to the table and discussing responses to climate change represents the complexity of the problem, and it represents the fact that everybody recognizes the importance of finding a solution. Obviously, it's very difficult. For the first time we are trying to do something together – that's the Second Copernican Revolution.

It was a major step because everybody agreed that a political solution is more important right now than a binding agreement because unless a political solution is found, a binding agreement cannot be made. Nothing is going to be perfect but it's a way forward and everybody is on board; so it is enormous progress.

On Earth System science as a cure for the Planet

Earth System science, for the first time, is what Edward Wilson called 'consilience'. We have knowledge from different fields which have to come together to treat this as one problem. And the question is, 'will we do it before something catastrophic happens?' Is there a catastrophic solution possible? Even that requires a system science. The question is not whether it can find a cure; it is how can it find a cure? There is just no choice. This is the only way forward. We cannot do it by being separate fields and doing separate things and not coming together to find a solution, because it's all combined.

1. Schellnhuber, H. J., *Nature*, 1999, **402**, C19–C23; www.iterations.com/protected/dwnload_files/earth_system.pdf

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