# A model approach

## Reflections on 50 years of weather and climate research

**The Met Office also celebrates a 50th anniversary this year – their first numerical weather prediction was in 1965. Their chief scientist Dame Julia Slingo shares her perspective on developments in weather, climate and environmental-change research since then.**

That first numerical prediction at the Met Office began the transformation of weather and climate science from an area concerned with theory and observations to one increasingly centred on computational models. These would become our laboratories for helping us understand the Earth's weather and climate, and the tools we would use to predict the future on all timescales from hours to centuries ahead.

Since then the transformation of weather and climate science has been profound. Fifty years ago there was no Earth observation to tell us what was happening to the atmosphere, the oceans, the land surface, the polar regions, and so on. We had only a crude understanding of the energy balance of the planet, of how the atmosphere and oceans move heat, momentum and water around the climate system, and how water and its phase changes are fundamental to the general circulation and patterns of regional weather and climate.

When I joined the Met Office in 1972, climate modelling was in its infancy, and the possibility of human-induced global warming was only just entering the debate. At that time there were other concerns, such as the climatic effects of waste heat from nuclear reactors and whether we were entering the next ice age! We were using models to understand fundamental processes and interactions, such as how much heat is transported by the oceans versus the atmosphere, whether changes in soil moisture could be a driving factor in drought, and what a world without Arctic ice might look like.

As in many branches of science, technological advances have opened the door to whole new areas of investigation. Space-based observation and supercomputers have revolutionised weather and climate science. Where we could only forecast one day ahead with any skill when I started my career, now we can often say with a high degree of confidence what the weather will be like five days ahead. That enables us to provide much earlier warnings of severe weather and increasingly of its impacts too.

This has come about because the models we use for simulating the weather and climate have become more and more sophisticated as our knowledge of atmosphere and ocean physics has grown – knowledge accrued through a combination of theory, field experiments, Earth observation and process-based models.

As our models became more sophisticated they became ever better at assimilating increasing volumes of observations from different sources. Rooted in complex mathematics, this discipline of data assimilation is critical for providing the forecasting process with the best possible description of the current state of the atmosphere and increasingly the oceans too.

Year-on-year increases in computing power have allowed us to increase the spatial resolution of our global models from a few hundred to a few tens of kilometres in the horizontal, and from less than ten to approaching one hundred levels in the vertical. Every increase in resolution enables weather systems and ocean currents to be represented with greater fidelity, but every increase comes with a considerable increase in the required computational resources.

Alongside model development, pioneering work at the European Centre for Medium-range Weather Forecasts (ECMWF) demonstrated the importance of capturing forecast uncertainty arising from 'the flap of the seagull's wings' or the 'butterfly effect', which describes how a small change in initial conditions can produce large differences in outcome. Now probabilistic approaches – which consider the likelihood of a number of different outcomes – are deeply embedded in all our forecast systems from a few hours ahead to century-scale climate change.

The nesting of much higher resolution regional models within the global system has revolutionised local weather forecasting. The introduction of the UK kilometre-scale model in 2009 meant that, for the first time, forecasters had access to detailed predictions

> As in many branches of science, technological advances have opened the door to whole new areas of investigation.

Susannah Ireland / eyevine

of intense thunderstorms, damaging strong winds and other local hazards. Our resilience and preparedness for natural hazards, such as flash flooding, storm surges and damaging winds, is greater than it's ever been, thereby saving lives and livelihoods and protecting critical infrastructure.

Arguably the biggest transformation of climate science occurred in the 1980s when climate change emerged as a political, social and economic issue as well as a science challenge. In 1990 Margaret Thatcher opened the Hadley Centre for Climate Prediction and Research in the Met Office, and the First Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) was published. From there on the development of climate modelling was strongly driven by the need for answers on whether human activities were indeed changing the climate, how much global warming was possible under particular emission scenarios, and what the regional implications would be.

It became very clear at an early stage that the oceans were likely to play a critical role in climate change, so general circulation models began to be transformed into global models that combined data about the oceans and the atmosphere. Today, the models we use for IPCC are essentially models of the whole Earth system that include atmospheric chemistry, the carbon cycle, ocean biogeochemistry, ice sheets and so on. The scale of this multi-disciplinary endeavour is such that NERC and the Met Office now work in close partnership to produce the next generation Earth System Model (UKESM) for future climate-change assessments.

It would be wrong, however, to assume that climate science has been taken over by climate change. Many climate scientists, including myself, are deeply interested in natural climate variability, such as El Niño; during my time at NERC's National Centre for Atmospheric Science (NCAS) we sought to understand these variations, to see if the models could capture them, and whether we could predict them. Now we appreciate more and more that natural climate variability, and its interaction with climate change, will be fundamental in determining our future exposure to hazardous weather and climate extremes.

When I joined the Met Office in 1972, weather and climate science was confined to a few small pockets of excellence in the academic community. Since then the sustained investment in weather and climate science and model development at the Met Office has delivered a world-leading national capability to the UK science community. By the time I returned to the Met Office as chief scientist six years ago, weather and climate science was thriving across a broad network of universities and NERC research centres. It is now inconceivable that the Met Office could deliver its science and services without the research partnerships we now enjoy with NERC, through the Joint Weather and Climate Research Programme, with leading universities in the Met Office Academic Partnership and beyond.

There is much still to do together. The UK with its wealth of expertise is uniquely placed to work at the leading edge of issues related to environmental hazards and environmental change, so that we can all contribute to managing the risks we face in the days and decades ahead.

**i** Dame Julia Slingo has had a long career in climate modelling and research. She became chief scientist at the Met Office in 2009, taking responsibility for scientific research and development. Previously she was director of climate research at NERC's National Centre for Atmospheric Science at the University of Reading, where she is still a professor of meteorology. In 2006 she founded the Walker Institute for Climate System Research at Reading, to address the cross-disciplinary challenges of climate change and its impacts.