Spreading the scope of convection models

Dr Jun-Ichi Yano, Chair of the Core Action on Convection, highlights a major challenge for climate and weather forecasters, and explains how his team are working to improve modelling techniques in Europe

Firstly, can you outline the context from which the Core Action on Convection (COST Action ES0905) emerged?

This COST Action group materialised from a core group of scientists scattered throughout Europe who have realised a need for fundamental theoretical investigations on the parameterization problem in weather forecast and climate modelling. This core group began to organise themselves in 2008 by agreeing to meet for workshops and discussions. The activity has been funded by the COST Office since 2010, which transformed it into an official Action.

What are the challenges associated with weather and climate modelling? In general terms, how does parameterization address some of these challenges?

Parameterization is a method commonly adapted by weather forecast and climate models to represent the physical processes that cannot be directly described with first physical principles. Clearly, this is the weakest point in our current models so particular attention is required. Unfortunately, little fundamental theoretical research has been performed on this problem in previous years.

Why do current approximations used in convection parameterization not work with new generation models?

We are approaching a new phase of weather forecast model developments, in which these convective variabilities have started to be resolved thanks to an increase in the resolution of models – but not yet perfectly. In other words, we are entering into a 'grey zone', where convection is only partially resolved. Under the most pessimistic scenario, that will not happen until the forecast-model resolution increases by a hundredfold. Such an increase of model resolution is unlikely to be realised in the foreseeable future.

Could you outline the type of information that weather and climate models communicate to users?

Accurate precipitation prediction is indispensable for running any hydrological models to predict events such as the overflow of rivers and landslides. Because a substantial part of atmospheric precipitation is of convective origin, successful precipitation prediction strongly hangs on a successful performance of convection parameterization.

What would you regard as the Action's biggest success since its inception last year?

Our biggest success so far is the fact that it is actually running. The recognition of the importance of our theories by the COST Office is significant – that in itself is unusual. Next, the wide range of participants should be emphasised. All major operational and climate research centres from Europe have contributed to our Action. A number of theoretical physicists have also joined. The contributions of hydrologists must also be counted. In short, cross-border infusions are now actually taking place, and we are all working together.

Have you used significantly different approaches for short-term weather forecasting models and longer-term climate models, or is it a case of ensuring the parameterization concept is sufficiently scalable?

One of our major scientific goals is to propose a unified approach for parameterization in atmospheric modelling. Many current parameterizations are developed for specific models and they are also tuned for these. Tuning naturally involves adaptation for a particular resolution of a model, and parameterization must be re-tuned every time a model resolution is increased. The goal here is to achieve a unification and universality, which naturally includes a scalability of a parameterization by a change in the model resolution. A major obstacle for achieving this goal is the fact that current parameterizations are generally developed in an empirical manner without much theoretical reflection. The highest priority of our COST Action is to identify clear physical principles that can lead to a unification and universality.

How will the Action's work benefit the Intergovernmental Panel on Climate Change (IPCC) and who else will this work benefit? What long-term impact do you hope to achieve with this Action?

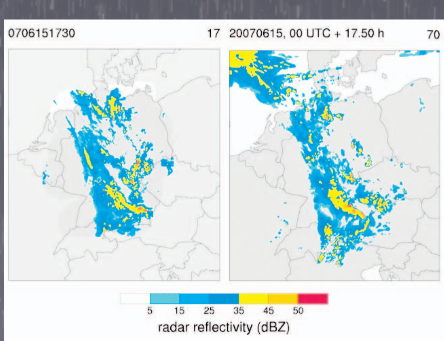
An important issue in climate projection that has never been fully addressed theoretically is uncertainty in climate projection itself. As currently presented in IPCC reports, the uncertainty in climate prediction is usually substituted by a spread of ensemble model predictions, but it is not necessarily reflecting the true physical uncertainties. One of the major factors defining the latter is an influence of small-scale processes, such as the impact of convection on global-scale climate variability in the long term. Such an uncertainty measure must be built-in as a part of convection parameterization. This is a particular domain that the present Action would like to address. We plan to seriously address both probabilistic and stochastic approaches for this reason.

An unpredictable atmosphere

Climate change and unpredictable weather patterns are a major challenge for meteorologists throughout the world. Producing models that are sufficiently reliable and flexible is a goal that still eludes researchers, but this may be about to change thanks to the novel approach proposed by the **Core Action on Convection**

ACCURATE PREDICTION OF the weather and climate is incredibly difficult due to the sheer complexity of these dynamic phenomena, yet in the present era it has become increasingly important to be able to do so successfully. Failure to forecast severe weather events can have devastating effects, and as these might occur with greater frequency due to climate change, policy makers have awoken to the need for improved predictive models to enable effective strategic planning.

Weather is influenced by a myriad of small-scale or complex processes, such as convection, boundary layer turbulence, and radiation. In numerical weather prediction and climate projection, these are replaced by mathematical processes using a method known as parameterization. This involves putting the combined effects of the different processes together within each grid box using calculus, then plotting it back as a grid value. All these are hard wired as a part of a numerical code of the model. However, this approach encounters some critical problems when attempting to determine variability (eg. of precipitation rates) at smaller scales. In order to compensate for these errors, forecasters 'tune' the parameters using various technical assumptions, which are tantamount to a best guess and hence prone to error. Additionally, tuning must be repeated every time the resolution of the model is changed.



CURRENT AFFAIRS

Convection is a key driver of atmospheric circulation, as it transports masses of heat from the Earth's surface to the atmosphere, generating precipitation in the process. Variability in convection is notoriously difficult to determine, and use of parameterization to predict events such as summer afternoon thunderstorms often falls short, with the onset of rainfall usually occurring later than forecast, while maximum rainfall is frequently underestimated. On a larger scale, monsoon in tropical and subtropical regions, which is marked by a sudden onset, is profoundly influenced by convective rain, and is very difficult to forecast. To confound matters further, the monsoon season itself experiences intermittent active and break phases. This makes management of water resources and agriculture challenging in these volatile areas, making the reliability of convection parameterization even more crucial.

'Core Action on Convection: Basic Concepts for Convection Parameterization in Weather and Climate Models' (COST Action ES0905) is an initiative dedicated to developing deeper understanding of the process of convection, and in doing so formulate enhanced methods of parameterization that are independent of scale and thus not reliant on current tuning techniques. This will require a fundamental shift in methodology, as Dr Jun-Ichi Yano, the chair of this Core Action on Convection explains: "Many of current operational convection parameterizations were developed in the 70s and 80s. Clearly, we are facing the need for an overhaul of those parameterizations". This overhaul also includes a thorough analysis of current parameterization approaches used by operational weather and climate research centres, and the subsequent establishment of a standardised technique that is suitably flexible and fit for purpose.

A CONSORTIUM BORN OF STORMY WEATHER

In order to overcome the numerous challenges of effective parameterization, the Core Action on Convection team need to enhance their understanding of the fundamental theoretical physics of convection when applied to weather systems. This involves a heady mixture of scientists from disciplines including statistical mechanics, theoretical physics (eg. quantum field theory), applied mathematics, computer modelling, hydrology, and meteorology – coming from a number of operational centres and research institutions from across the EU, as well as from Australia and the U.S. This international multidisciplinary collaboration is absolutely vital to achieve the COST Action's lofty goals,

INTELLIGENCE

CORE ACTION ON CONVECTION – COST ACTION ES0905

Basic Concepts for Convection Parameterization in Weather Forecast and Climate Models

OBJECTIVES

To provide clear theoretical guidance on convection parameterizations for climate and numerical weather prediction models.

PARTNERS

Please see website for Management Committee details. Participating countries at the time of publication are:

Austria, Belgium, Croatia, Czech Republic, Finland, Germany, Hungary, Israel, Italy, The Netherlands, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland, UK

Countries with intentions to accept the MoU:

France

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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

as Yano elaborates: "Parameterization is a very tough problem, where we desperately need strong infusions of the ideas from theoretical physics and applied mathematics. Of course, these theoretical studies must be performed in response to urgent operational needs, because otherwise they would be useless in practice. That is why we need to develop cross-border collaborations in order to know what must be done, and what can be done".

Unsurprisingly, bringing together modellers and theoreticians is no small feat and has presented a number of obstacles. Research techniques differ, as well as the basic scientific language used by each of the groups, the methods used to form hypotheses, and even their basic knowledge. In response to this, a series of annual workshops has been organised since March 2008, which allow the involved parties to get together and exchange ideas and knowledge. This has already enabled some potentially rewarding avenues to be explored. For example, the group have discussed the renormalisation group theory, which is well established in quantum field theory and statistical mechanics, but relatively unknown in operational forecasting circles despite its usefulness in understanding and predicting convective organisation. Another example of successful collaboration was demonstrated during a Short-Term Scientific Mission (STSM – a COST Action scheme enabling scientific visits to a partner institution), when the cellular automaton model of describing crystal growth was applied to precipitation field forecasting. The cooperation is ceaseless, with communication via e-mail a staple fixture between team members.

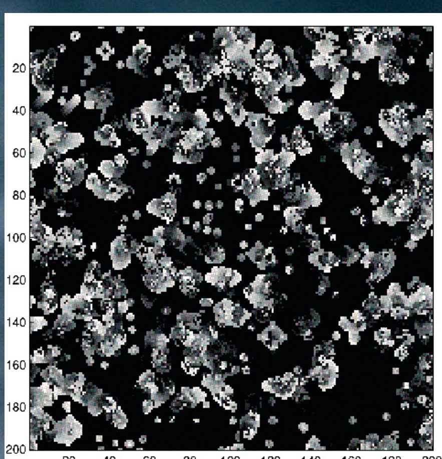

Figure 2. A realisation from an idealised model (cellular automaton) for a horizontal pattern of atmospheric convection.

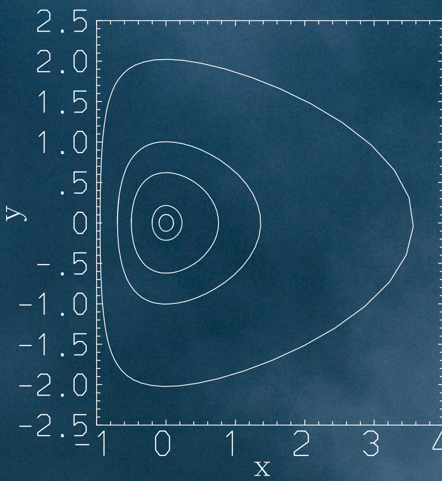

Figure 1. An idealised representation of periodic cycles of convection. The horizontal axis is a measure of convective activity. The vertical axis is a measure of a potential energy. The periodic solutions turn clockwise.

KNOWLEDGE IS POWER

The Core Action on Convection team aims to disseminate their findings in a timely and logical manner. Relevant papers and reports generated from workshops and STSMs will be published in peer-reviewed journals of atmospheric sciences and theoretical physics. The website will also contain this information, as well as updates on current progress. Their novel parameterization techniques will be presented to model developers and end-users to allow a smooth transition from theory to practice, and on a larger scale, the results of their study will be translated into specific recommendations targeted at highly influential global institutions, such as the GWEX Cloud System Study (GCSS) and the Intergovernmental Panel on Climate Change (IPCC).

The research team are committed to opening up their research to a much wider audience, especially early-stage researchers. To further this aim, they welcome the input of postdoctoral students and offer tutorials to guide them through the minefield of their ongoing work. They will be also inviting a broader spectrum of participants to their annual workshops, while their final Training School will be aimed at disseminating their findings in a more educational fashion. They anticipate a high level of participation from early-stage researchers at this event, which will include a significant number of PhD students and researchers from other backgrounds. This inclusive approach will surely prove invaluable in solving one of nature's big puzzles.