# Why do numerical models have so much difficulty predicting elevated convection?

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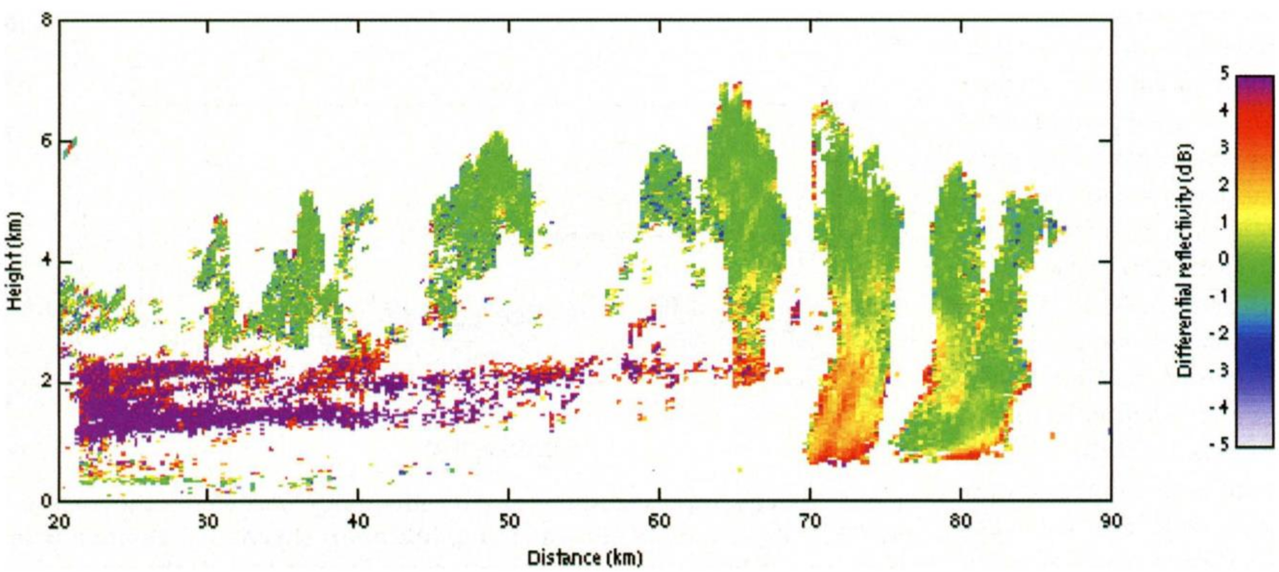


A distance/height scan from the high-resolution 3 GHz Chilbolton radar, showing differential reflectivity (ZDR); the red/purple out to around 60 km shows a stably stratified layer up to about 2 km. Above this are convective towers initiating away from the surface, eventually (70 km on) precipitating to the surface and destroying the stable layer. From Browning et al, 2007.

Convective clouds are responsible for the heaviest rain as well as strong winds, downdraughts and other high-impact weather. They are often generated as air near the ground is warmed by solar heating. However, sometimes they occur in air separated from the ground by several kilometers. Such elevated convection can occur day or night and can result in the development of some of the most severe thunderstorms. However, it remains one of the largest challenges to numerical weather prediction (NWP) systems even with modern, convection-permitting configurations. In the UK, poor representation of elevated convection is the number two model problem on the current Operational Forecast Evaluation Group (OFEG) list in the Met Office. It has also been identified as a priority area by the international Met Office Unified Model Partnerships' convection working group (the group of operational forecasting centres that use the Met Office's weather forecast model).

While the basic environmental characteristics favouring elevated convection are known, at least in some cases, the mechanisms leading to triggering are poorly understood, and there has been little observational work apart from *ad hoc* studies and one relatively recent US field campaign. Poor predictability may arise because local variations in e.g. convergence or humidity that cause initiation are harder to constrain in numerical models than those in layers close to the ground directly influenced by surface topography. It is also possible that models have systematic errors that are important for these clouds. This project aims to answer the question of which factor is more important, primarily through making use of the Met Office's operational convection-permitting ensemble forecast system combined with ensemble sensitivity techniques to understand the sensitivity of the representation of elevated convection to different factors in the analysis or model formulation and resulting predictability issues.

Lower-resolution NWP and climate models cannot resolve convective clouds – they are smaller than the numerical grid. Their effects on resolved scales have to be estimated using 'parametrization' schemes. The Met Office is developing a new parametrization called COMORPH, that has made many improvements over its predecessors. However, poor representation of elevated convection is also a major deficiency in the performance the new parametrization. It is anticipated that the new understanding that arises from this project will therefore have broader impact through improving these models.

The student will initially study cases of elevated convection over the UK using available observational (radar, satellite etc.) and model data, with a view to understanding of deficiencies in the representation of elevated convection in convection-permitting km-scale models, such as the Met Office's deterministic and ensemble high-resolution systems (UKV and MOGREPS-UK, respectively). The ensemble forecast system, in which many perturbed versions of the flow are generated, will then be used with techniques such as ensemble sensitivity analysis and spatial ensemble spread techniques to help deduce the nature of the predictability of elevated convection given particular environmental conditions. The option will be considered of extending the study to elevated convection events in other regions of the world, particularly where the Met Office runs convection-permitting forecasts. This includes the USA, where the model is run for the NOAA Hazardous Weather Testbed, or over India or China, where it is run for the Climate Science for Service Partnership programmes.

**Training opportunities:**

This project will build on proven expertise in Reading in these areas along with ongoing Met Office based work to address the forecasting problem. The CASE award supports up to 3 months working within Met Office HQ, with close involvement of operational (Met Office) meteorologists (mentored by one of the Deputy Chief Meteorologists) who will provide training in the practical application of forecasts even the customer applications of them. As part of the project the student will:

- Develop considerable understanding of what NWP models are, why they are run and how they are used.
- Develop analysis skills as well as use of large datasets to gain insight into fundamental physical processes.
- Gain understanding of the nature of predictability and hazardous weather and the practical application of forecasts and, through extended visits to the Met Office HQ, even the customer applications of them.
- Develop communication skills with knowledgeable users through interaction with operational meteorologists.
- Development of software skills – coding in Python for data analysis and FORTRAN within model.
- Gain expertise in the implementation and use of state-of-the art convection-permitting

modelling systems.

**Student profile:**

This project would be suitable for students with a degree in physics, mathematics or a closely related environmental or physical science. Students with no meteorological background are expected to undertake relevant training with the MSc programme.

**Funding particulars:**

The project has been approved for CASE funding by the Met Office under the Met Office Academic Partnership.

**References: (optional)**

Keith A. Browning *et al*, 2007: The Convective Storm Initiation Project. *Bull. Amer. Meteor. Soc*. **88** (12): 1939–1956.

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https://research.reading.ac.uk/scenario/