Exploiting the benefits of convective-scale ensemble forecasts

Lead Supervisor: Suzanne Gray, University of Reading, Department of Meteorology
Email: s.l.gray@reading.ac.uk

Co-supervisors: Tom Frame (University of Reading); Aurore Porson (MetOffice@Reading); Marco Milan (Met Office)

Accurate weather forecasts save lives and livelihoods and are important to a host of industries from energy to agriculture and retail. They also, theoretically at least, help us to get our washing dry and plan our visit to the beach. However, while large-scale weather systems such as winter storms can be forecast several days in advance, it is unlikely that the exact timing and location of individual convective clouds will ever be predictable more than a few hours ahead. Consequently, most operational weather forecasting centres, including the Met Office, produce so-called "ensemble forecasts": multiple equally-likely forecasts that allow predictions of the probability of events such as heavy rainfall to be made (see Figure) e.g. "the chance of precipitation at 3 pm in Reading is 60%". This project provides an opportunity for a student to collaborate with leading operational forecast centres and work at the forefront of convective-scale ensemble design.

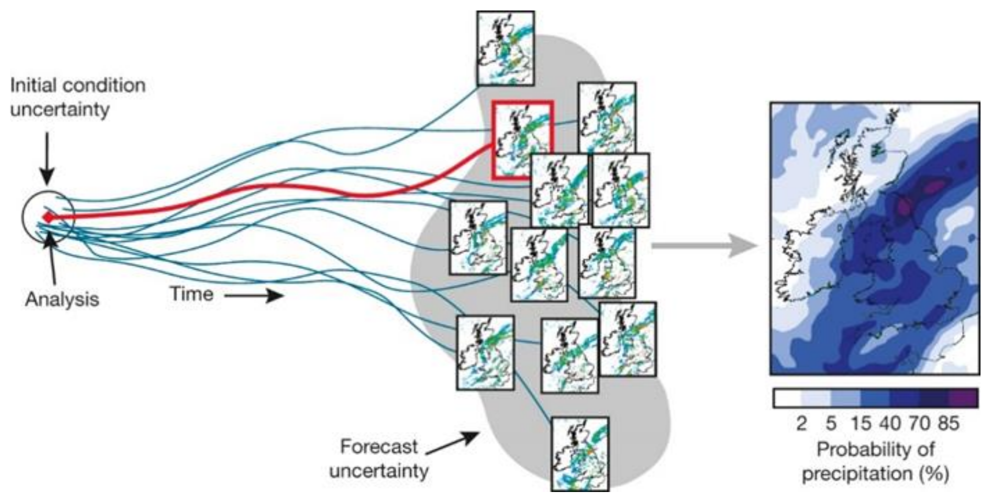

Figure: Schematic diagram of an ensemble forecast used to estimate the probability of precipitation over the UK. From Bauer et al. (2015)

Convective-scale ensemble forecasts are run with fine model resolution (grid boxes ~2 km across) in regional domains (e.g. covering the UK) and use much coarser resolution parent forecasts to provide lateral boundary conditions. The individual ensemble members are perturbed so that their initial conditions differ, i.e. they start from initial conditions that, while different, are all consistent with current observations, previous forecasts, and their errors. These forecasts diverge from each other (known as "spread") as the forecast length increases, indicating increasing forecast uncertainty.

The project aim is to investigate the factors controlling the spread of convective-scale ensembles at multiple spatial scales and under different flow regimes, and so improve the skill of short-range weather forecasts.

While their production is now routine, the techniques for initialising the multiple convective-scale forecasts are not firmly established. Most of our knowledge on the growth of forecast uncertainty with forecast length has been generated for global forecasts of longer than a few days, where larger-scale atmospheric processes dominate. The Met Office is exploring new strategies for creating perturbed forecasts e.g. they have recently changed their convective-scale ensemble forecasting system to take new observations into account, through so-called data assimilation, every hour instead of every six hours with multiple forecast start times. Their aim is to both provide more timely forecasts by reducing the time between assimilation cycles and forecast availability, and to increase the spread of the ensemble by taking into account additional perturbations coming from successive assimilation cycles. They are also collaborating with other European centres to enable comparison of convective-scale ensemble systems.

Like convective-scale ensembles produced by most operational centres, the Met Office ensemble (Hagelin et al. 2017) is under spread e.g. the calculated probabilities of rain are too high when compared to the forecast error across many events. An optimal convective-scale ensemble should reproduce the more predictable large-scale phenomena as well as the less predictable small-scale events. For this reason, the Met Office is also investigating the importance of large-scale dynamics in its convective-scale model using a spectral nudging approach. Some types of ensemble perturbations may lead to unwanted spread and convective-scale ensemble behaviour is likely to depend on the weather regime e.g. scattered convective showers will behave differently to organised frontal convection. Forecasters do not exploit ensemble output as much as they would like as the ensemble does not provide them with the additional information they need: the ensemble forecasts are too close to the unmodified forecast and do not cover the range of possibilities. New and ongoing developments in convective-scale ensemble design provide us with the opportunity to investigate the response of the ensemble spread and skill to these changes. The Met Office strategy is to exploit the use of ensembles as a main research priority.

This project will exploit recently developed metrics for evaluating ensemble spread and spatially skilful scales. The consistency of spread interpreted from different metrics (including also standard objective verification metrics of the ratio of spread to skill and spectral analysis) and different model output fields (precipitation, wind etc.), and for different weather regimes, will be determined. The long-term goal is to optimally design convective-scale ensembles in terms of perturbation type, ensemble size and verification metrics with emphasis on the assessment of spread at small scales. Use of such ensembles should improve forecasts of convective-scale hazardous weather.

Training opportunities:
The student will be able to work closely with Met Office supervisors. He or she will spend time at the Met Office headquarters in Exeter working with research groups, including the research-to-operations and data assimilation groups depending on research direction, as well as meeting with the supervisor working within the MetOffice@Reading (and so based in the Meteorology Department). As the use of ensembles is rapidly developing across the Met Office partnership, regular meetings (through videoconference or based at Exeter) take place to coordinate the latest research and developments. The student will join a research team facing new challenges in the way that the Met Office seeks to exploit convective-scale ensembles. The candidate may thus be asked to disseminate their research to operational and research centres across the world.

Student profile:
We are seeking a student with a degree in physics, mathematics or a closely related environmental or physical science and with an interest in atmospheric processes and forecasting. Knowledge of statistical methods and computer programing as well as experience of working with large gridded datasets is desirable, but not essential.

Funding particulars:
This project has agreed CASE funding from the Met Office.

References:
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Hagelin, S., J. Son, R. Swinbank, A. McCabe, N. Roberts and W. Tennant (2017), The Met Office convective-scale ensemble, MOGREPS-UK. *Q.J.R. Meteorol. Soc.,* **143,** 2846-2861. doi:10.1002/qj.3135

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