Scenario
DOCTORAL TRAINING PARTNERSHIP

NERC
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Exploiting the benefits of convective-scale ensemble forecasts

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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. It's well recognised though that, 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 (perhaps only a few km across) 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%".

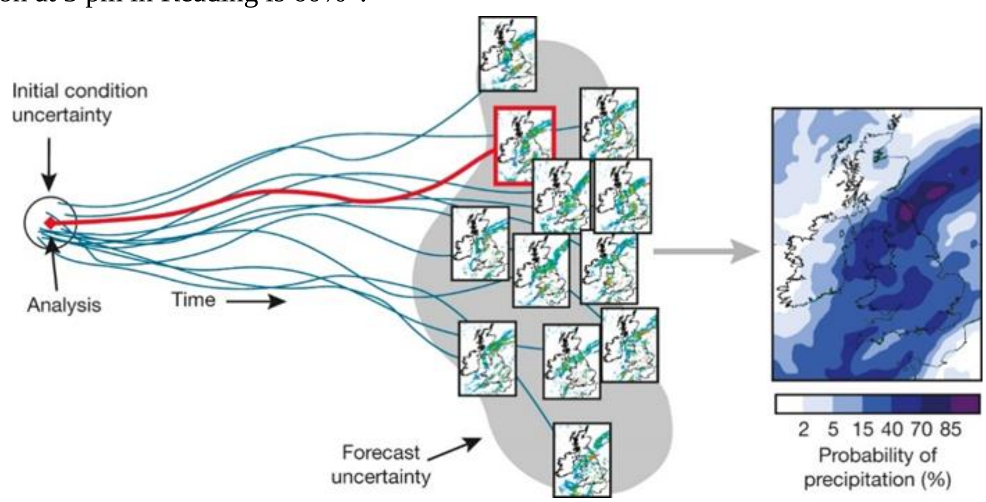

Figure: Schematic diagram of an ensemble forecast used to estimate the probability of precipitation over the UK. From Bauer et al. (2015)

Convection-scale ensemble forecasts are run in regional domains (e.g. covering the UK) and use much coarser resolution global domain forecasts to provide lateral boundary conditions. The individual ensemble members differ in their initial conditions, i.e. they start from initial conditions that, while different, are all consistent with current observations and previous forecasts, as well as in their boundary conditions and model physics. 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 still 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, in particular, is exploring new strategies for creating perturbed forecasts e.g. they have recently changed their convection-permitting ensemble forecasting system (known as MOGREPS-UK; Hagelin et al. (2017) 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.

Similar to convective-scale ensembles produced by most operational centres, MOGREPS-UK is under-spread e.g. the calculated probabilities of precipitation are too high when compared to the forecast error across many events. An optimal convective-scale ensemble should reproduce the large-scale errors as well as the low predictability of small-scale events. However, some types of perturbations may also 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 convection within a weather front. Forecasters do not exploit the use of ensembles 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.

In this project recently-developed metrics for evaluating ensemble spread and spatially-skilful scales will be applied. 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 and spend time at the Met Office headquarters in Exeter. 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 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.

Funding particulars:

This project has agreed CASE funding from the Met Office.

References:

Bauer, P, A. Thorpe and G Brunet (2015), The quiet revolution of numerical weather prediction, *Nature*, **525,** 47–55. doi:10.1038/nature14956

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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