Discovering the Mechanisms Behind "Forecast Busts"

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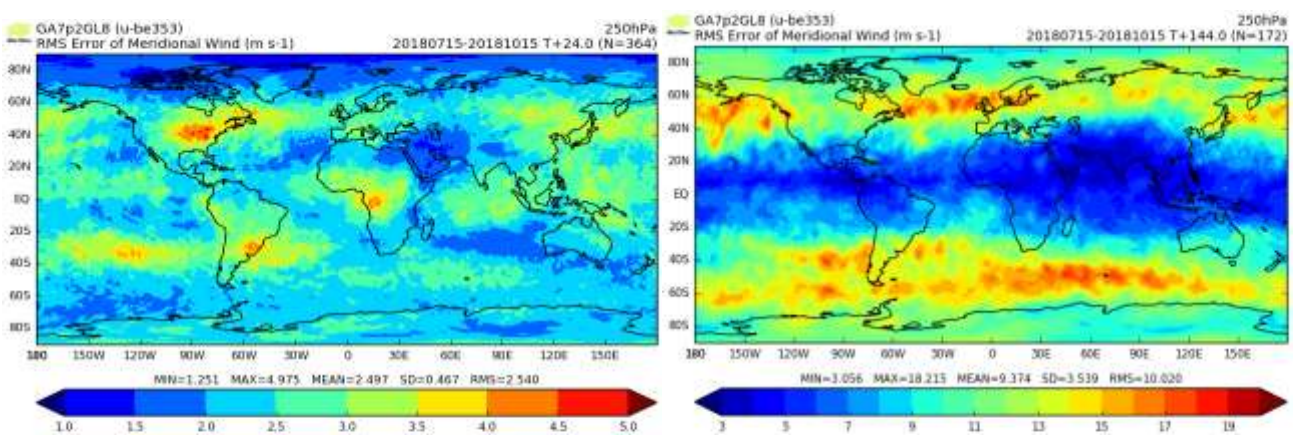
Numerical weather prediction (NWP) has become the essential forecasting tool that works well in the vast majority of cases. However, occasionally there are "forecast busts", in which the forecast skill at five- to six-day lead time drops to almost zero across the world's leading NWP centres. These occasional failures of our NWP systems present an important practical challenge and an intriguing multi-scale scientific problem.

Busts over northern Europe have been linked to a poor representation of Mesoscale Convective Systems (MCS) upstream over North America. An MCS is a long-lived and spatially organised system comprised of individual thunderstorms. Each thunderstorm is typically a few km across and the full MCS is several hundreds of km across. Crucially the MCS is no mere agglomeration of the thunderstorms. Rather it has a coherent dynamics of its own, which includes the formation of a large region of upper-level outflow around the level of the jet stream. That outflow in turn can couple to planetary-scale atmospheric waves, called Rossby waves, which impact on the weather systems over Europe several days later.



Root-mean-square wind error at 250 hPa (around the jet stream level) for forecasts over a summer season. Left for forecasts after 24 hours, and right after 144 hours. Errors develop initially over the central US. The errors amplify over time (note the change of colour scale), develop upscale (covering a wider area) and move downstream (from west to east in the middle latitudes). (Xavier, personal communication).

The formation and development of an MCS is challenging for numerical models to capture in detail as the treatment of convection has been identified as the leading source of systematic errors in weather and climate models. Global NWP models typically work with grid spacings of 10-20 km, small enough to capture the MCS but not small enough to capture explicitly its component convective storms. A key question motivating this project is why errors in the representation of an MCS can very often be relatively benign (multi-day forecasts over northern Europe are usually very good) and yet are occasionally catastrophic. What determines this difference – is it modelling errors in the representation of convection early in a forecast or physical and dynamical mechanisms active downstream later in the forecast that ultimately lead to the forecast busts? How important is an exact positioning of the MCS in relation to the planetary wave pattern? Answering these questions will provide insight into whether error growth in NWP systems depends on flow regimes.

The project will involve making detailed investigations of simulated cases and comparing situations that do and do not lead to busts. A key element will be understanding the development of errors in the forecast model and their propagation downstream towards Europe as they grow upscale. This will involve analyses and interpretations in the frameworks of potential vorticity (a very useful measure of the local stability and rotation of the atmosphere) and Rossby wave dynamics. Specialist diagnostics will be developed using diabatic tracers to unravel the contributions of different physical processes in the model and discover the mechanisms at play. The PhD student will themself run the simulations using the Met Office's weather forecast model, the Unified Model. This will include simulations with different representations of convection, such as the next-generation CoMorph parameterization which is currently being developed. Such changes to the forecast model are expected to lead to some significant changes at the MCS stage which may then alter the coupling to larger-scale weather patterns. Will new treatments and/or higher resolution solve the forecast bust problem, and why, or might they even make it worse? Answering these questions will likely help meet both society's need for improved predictions of convective events and extend the practical limits of predictability.

Training opportunities:
Full training and support will be given on the use of the forecast model, the Met Office Unified Model, and the student will have the opportunity to interact with various Met Office scientists as well as co-supervisor Roberts. The student will also have the opportunity to make a visit to the University of Oklahoma, to facilitate the interactions with Prof Parsons and his group, and to experience the convective systems of the central US.

Student profile:
The project would be suitable for students with a 1st or upper 2nd class degree (or equivalent) in meteorology, mathematics, physics or a closely related quantitative environmental or physical science
https://research.reading.ac.uk/scenario/