30 years Exploiting Ensemble Weather Forecasts at the Met Office

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Met Office

ECMWF | 50

ECMWF's pioneering medium-range ensemble forecasts in 1992 grew out of earlier work on monthly predictions by Tim Palmer and James Murphy at the Met Office, and the two organisations have developed and exploited ensembles in partnership, more or less, ever since. Last year ECMWF brought the ensemble resolution up to the same as its deterministic "hi-res" forecast and is phasing out the latter. In 2026 the Met Office will do the same with both its MOGREPS global and UK convective-scale ensembles. Ensembles have gone from being an interesting supplement to deterministic models, to being the core of operational NWP.

Inspired by the early ECMWF ensemble forecasts while working as a forecaster in the 1990s, the author of this poster went on to lead the development of MOGREPS and applications of ensemble forecasts at the Met Office. The ECMWF 50th Anniversary provides a good opportunity to reflect on 30 years of ensemble prediction.

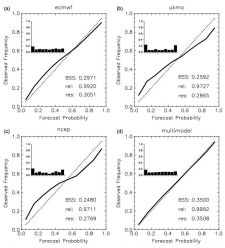
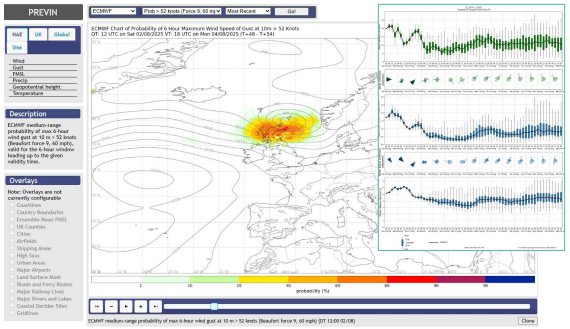


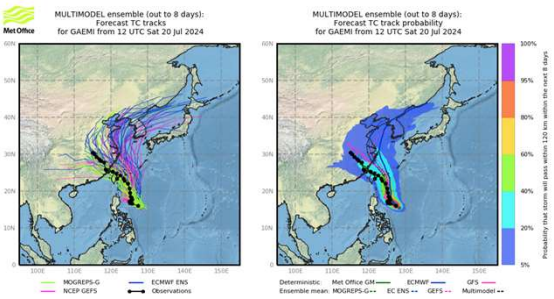
Figure 8. Reliability and sharpness diagrams for 2 m temperature greater than the climatological mean, at T + 240. The bias-corrected single-model ensembles for (a) ECMWF, (b) Met Office, (c) NCEP and (d) the bias-corrected multimodel ensemble are shown. The data are verified globally for period 1 January 2006–29 April 2006.

From: Johnson, C. and Swinbank, R. (2009). Medium-range multimodel ensemble combination and calibration. *Q.J.R. Meteorol. Soc.*, 135: 777-794.

Early Met Office research explored the potential benefits of multi-model ensembles (e.g. Mylne *et al* 2002, QJRMS **128**: 361-384). This work was developed under the THORPEX programme and the TIGGE project (left) which continues to support research in ensemble applications. While individual ensembles have continued to improve, the Met Office sees benefits in combining multi-model ensembles, for example for tropical cyclone tracks (right). The IMPROVER post-processing system (Roberts *et al* 2023, BAMS **104** E680–E697) is designed to blend ensemble data from multiple sources, including AI models. ECMWF data are now being blended in IMPROVER to extend forecasts into Week 2 – see UEF 2025 presentation by Mylne and Ayliffe.



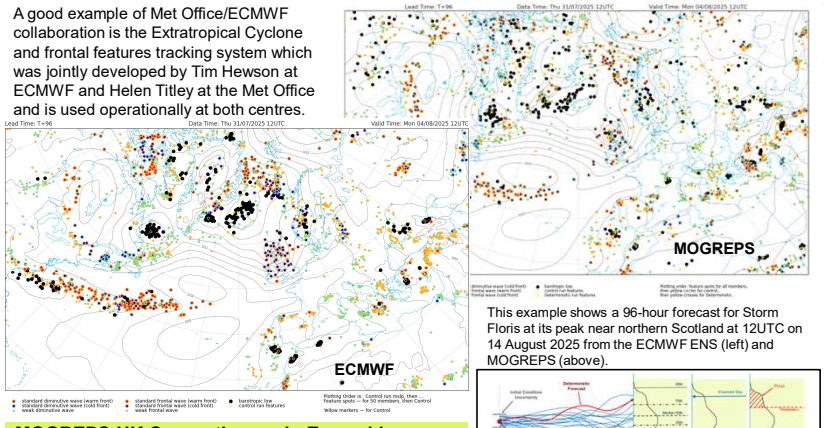
The Met Office developed its *Previn* system (above) to visualise ECMWF ensemble forecasts long before development of ecCharts. Site meteograms based on ECMWF ENS and wave ensembles (above right) have been in production for offshore customers for about 25 years!



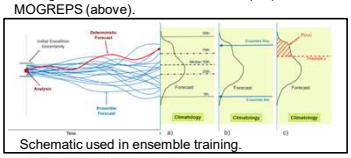
Multi-model ensembles are also used in:

- Decider regime-based clustering for medium to long range
- Global Hazard Map to identify high-impact risks globally

A good example of Met Office/ECMWF collaboration is the Extratropical Cyclone and frontal features tracking system which was jointly developed by Tim Hewson at ECMWF and Helen Titley at the Met Office and is used operationally at both centres.



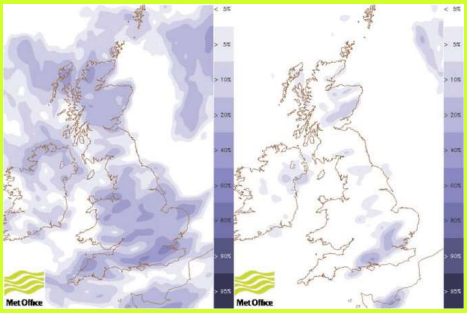
This example shows a 96-hour forecast for Storm Floris at its peak near northern Scotland at 12UTC on 14 August 2025 from the ECMWF ENS (left) and MOGREPS (above).



Schematic used in ensemble training.

An early forecast from MOGREPS-UK during the London 2012 Olympic Games.

Probability of rain rate exceeding 16mm h^{-1} anytime in the period 0600–2400 UTC 29 July 2012 from a forecast initiated at 1500 UTC on the previous day (left) and Probability of 16mm h^{-1} in the period 1300–1400 UTC from a forecast initiated at 0300 UTC on the same day



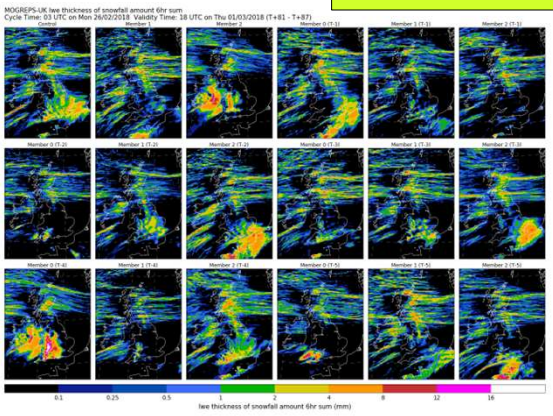
From Golding et al (2014) *BAMS* **95**, No. 6, 3104–3127

MOGREPS-UK Convective-scale Ensemble Development

MOGREPS was conceived in 2002 as a short-range ensemble to complement the ECMWF ensemble used for medium-range forecasting. Initially MOGREPS-R ran over the N. Atlantic and Europe with 24 members and a 24km grid-length and parametrized convection. The global MOGREPS-G existed mainly to provide boundary conditions, although was later extended to 15 days (at ECMWF) for the THORPEX experiments in multi-model ensembles. Despite kind offers from ECMWF to help develop singular-vector based perturbations, the Met Office chose the ETKF approach of Bishop *et al* (2001; MWR **129,** 420-436) which we considered more suitable for short-range prediction.

MOGREPS-R demonstrated improved forecasts of high-impact weather but the development of convection-allowing models introduced rapid error growth on timescales of hours and the need for a convective-scale ensemble. MOGREPS-UK, using the new non-hydrostatic UK model with 12 members on a 2.2km grid-length, was introduced in time to be demonstrated at the London 2012 Olympic Games. A major upgrade in 2019 increased ensemble size to 18 members with time-lagging (6 hourly cycles of 3 members, centred around hourly 4D-Var analyses). MOGREPS-UK runs to 5 days ahead, providing downscaling of the potential intensity of convection as well as resolved, orographically-forced local weather. The IMPROVER post-processing system, which drives the Met Office web and app forecasts, takes MOGREPS-UK as its only input between 12h and 4.5 days ahead.

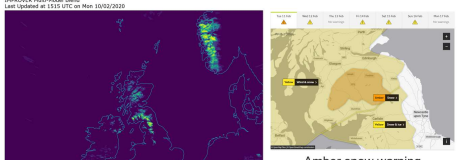
From 2026 MOGREPS-UK will be upgraded to 1.5km horizontal grid-length and become the primary NWP for the UK. **Ensemble forecasting is no longer a supplement, but the core of operational NWP.**



MOGREPS-UK Postage stamp charts (below) for a 3-day forecast of 6-hour snowfall for the "Beast from the East" storm of 1st March 2018. Contrast the high confidence for heavy snow showers near NE coasts with large uncertainty for heavy snow in SW England. A Yellow warning for low likelihood of high impact was issued for the SW at this time, later upgraded to a Red warning as uncertainty reduced.

IMPROVER: Probability 6 hour snow > 4 cm

Providing a several hour lead time of an amber snow warning being issued



Amber snow warning

MOGREPS-UK post-processed with IMPROVER offers hi-res detail to support issue of severe weather warnings.

In preparation for ensemble-only NWP, the Met Office ran a 2-year strategic action on ***Exploiting Ensembles*** (2022-24) :

- Developed a new forecasting process
- Development of training materials for ***all staff***
- Research on techniques including Ensemble Sensitivity Analysis, sub-setting and feature-based clustering
- New operational tools and visualisation
- Classification of Ensemble Use cases (BAMS, https://doi.org/10.1175/BAMS-D-24-0183.1)
- Reviewed research on public understanding of probability (DOI: https://doi.org/10.62998/bwjw5735)
- Testbed experiments with focus on ensembles
- Model system development process aligned to ensembles
- Review of Products and Services for candidate products to better exploit ensembles, and prototypes

The future – some thoughts

Just as ensembles become core NWP, AI ensembles are the next revolution. Potential is exciting but good headline scores are not everything.

- IMPROVER provides an ideal tool for blending AI models and ensembles with conventional NWP and testing the benefits – and in operations if successful.
- Optimisation of CRPS is exciting and should drive good probabilities and quantiles
  - Can we support all ensemble use cases, e.g. meteorologically consistent scenarios, coupled hydrology?
- Potential for much larger ensembles –
  - need to test spread-skill relationship and performance for extremes
  - how to manage and process data volumes
- Beyond ERA5 – new training sets required to support convective-scales and local surface weather, including precipitation
- Conventional convective-scale ensembles such as MOGREPS-UK face continued challenges of insufficient spread
  - Scope for more multi-model combination (where domains overlap), including with AI ensembles
  - Use of alternative boundary conditions (e.g. ECMWF-driven members in MOGREPS-UK, perhaps AIFS members)

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As I approach retirement, ensembles have transformed NWP and I have seen the start of a step-change in their application to support better decision-making. AI offers exciting potential but blend it carefully – don't throw away the physical ensembles too quickly!