Ensemble Sensitivity Analysis in the Operational Met Office in the UK Ensemble System

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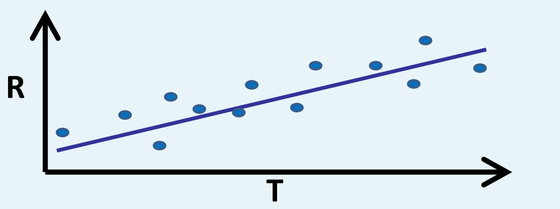
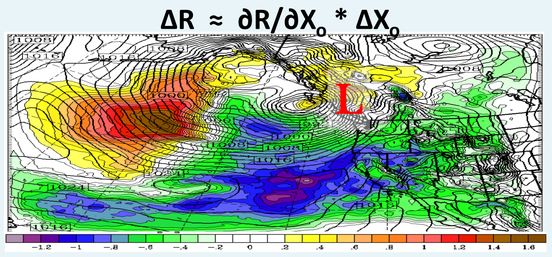
INTRODUCTION

The Met Office in the UK Ensemble Exploitation strategic action includes the development of forecasting tools that support a focus on their global ensemble system. Starting in summer of 2024, the use of ensemble sensitivity analysis to provide forecaster awareness of the key atmospheric features dynamically linked to high-impact forecast aspects has been tested in an operational environment. Through forecaster feedback and parallel research activities, this effort aims to both determine if ensemble sensitivity analysis can improve high-impact forecasts and provide the roadmap for further development of the technique.

ENSEMBLE SENSITIVITY ANALYSIS BACKGROUND



$\Delta R \approx \partial R/\partial X_0 * \Delta X_0$



SENSITIVITY OF 24-HR CYCLONE CENTRAL PRESSURE TO 00-HR SLP (mb/mb)

RAW ENSEMBLE SENSITIVITY

Linear Regression (SLOPE) = $\frac{COV(R,T)}{VAR(T)}$

→ Measures the growth of arbitrary perturbations to weather features that affect the response function R

STANDARDIZED ENSEMBLE SENSITIVITY

(Raw Sens) x (Ensemble Std Deviation)

→ Measures the growth of expected ensemble perturbations to weather features that affect the response function R

THE OPERATIONAL PROTOTYPE

Standardized sensitivity is calculated twice daily within the MOGREPS-G global ensemble to 7-day forecast time for the following response functions over the UK:

1) 600-meter wind speed > 20 m/s
2) 600-meter wind speed PCs 1 and 2
3) 95th percentile of 600-meter wind speed
4) Maximum 6-HR precipitation
5) Maximum 24-HR precipitation
6) Mean screen-level temperature
7) 95th percentile of screen-level temperature

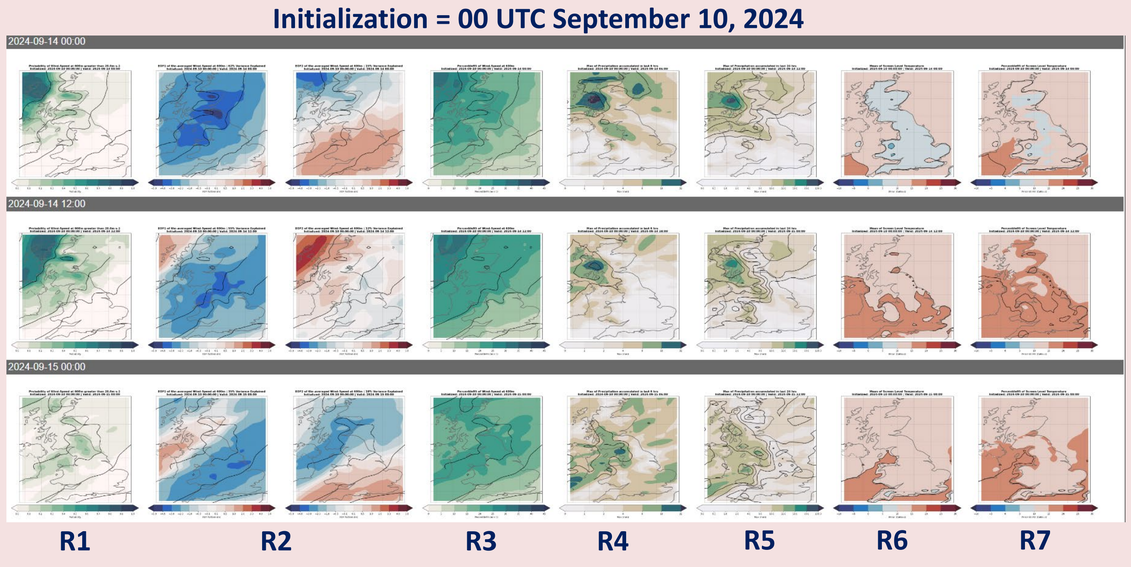
Sensitivity is calculated with a time-lagged ensemble including the current and prior initialization (36 total members) every 12 hours with respect to the following sensitivity variables backwards every 12 hours:

1) 300-hPa geopotential height
2) 500-hPa geopotential height
3) Sea-level pressure
4) 300-hPa wind speed
5) Pseudo water vapor imagery

Step 1: Identify High-Impact Forecast Response Functions

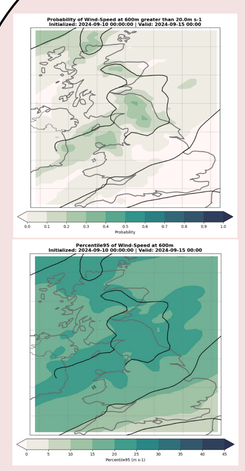
→ Response function diagnostics (e.g., probability of 600-meter wind speed exceeding 20 m/s) provided through postage stamps for all forecast times

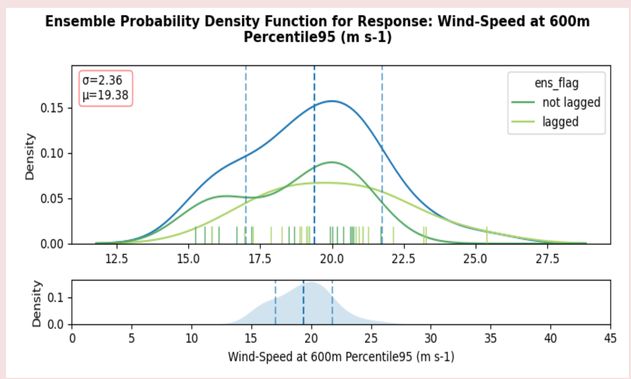
Initialization = 00 UTC September 10, 2024

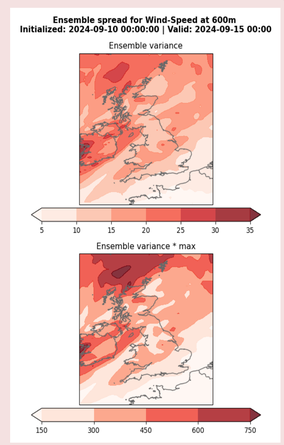


→ This postage stamp example shows a snapshot of three available forecast times

Step 2: Focus on a Specific Forecast Problem

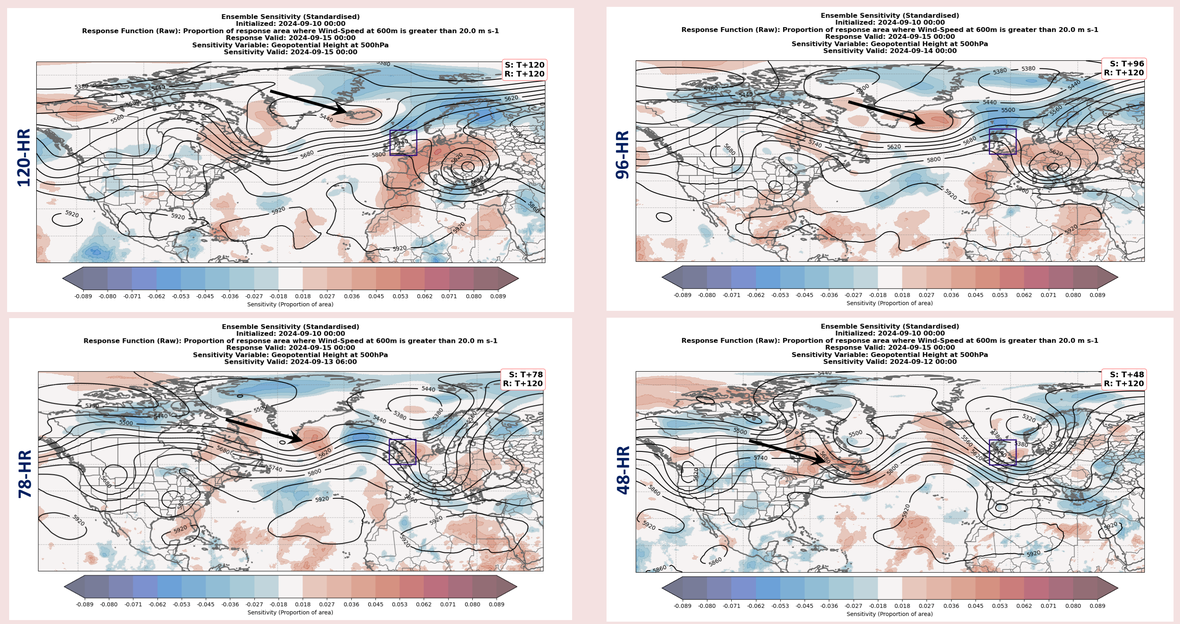




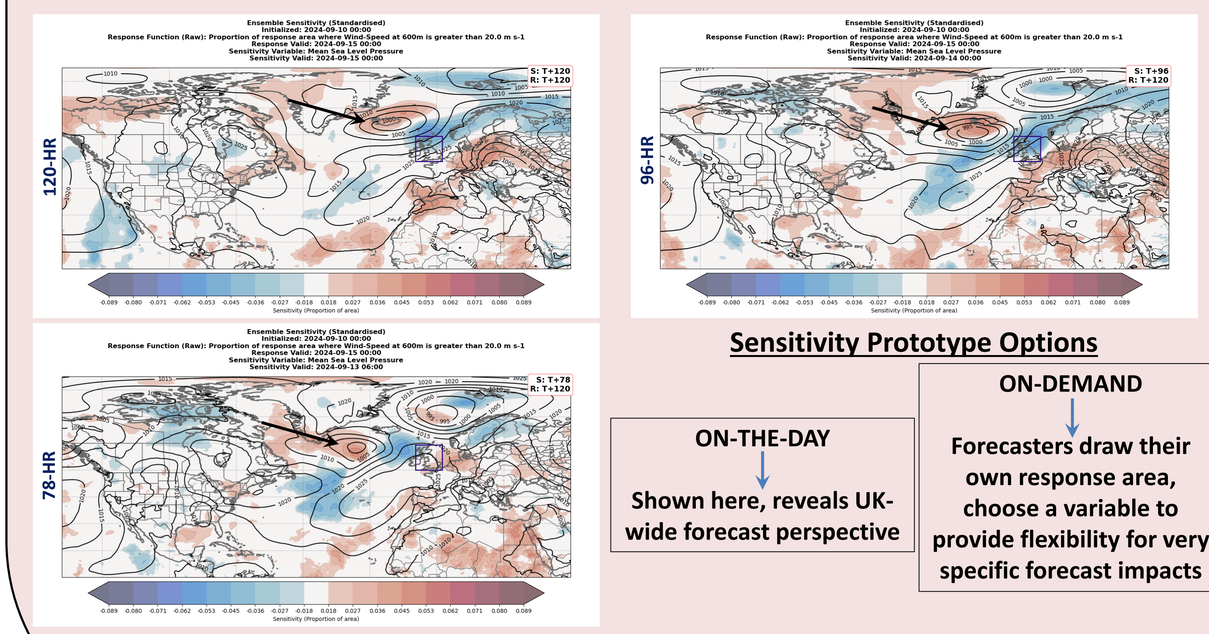


Hazard: 120-HR 600-meter wind speed

Step 3: Examine Sensitivity Fields to Understand the Features Relevant to the Predictability of Chosen Response



SENSITIVITY OF 120-HR HIGH WIND COVERAGE IN THE UK TO 500-HPA GEOPOTENTIAL HEIGHT



Sensitivity Prototype Options

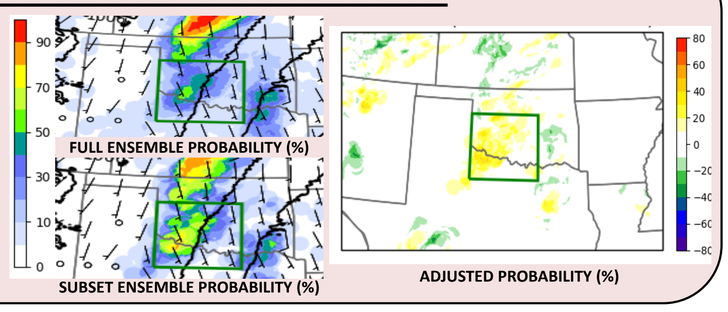
ON-THE-DAY → Shown here, reveals UK-wide forecast perspective

ON-DEMAND → Forecasters draw their own response area, choose a variable to provide flexibility for very specific forecast impacts

SENSITIVITY OF 120-HR HIGH WIND COVERAGE IN THE UK TO SEA-LEVEL PRESSURE

SENSITIVITY-BASED SUBSETTING

Can forecast probabilities be beneficially adjusted by favoring members with the smallest errors in sensitive regions early in the forecast window?



SUMMARY AND FUTURE WORK

The Met Office is testing ensemble sensitivity analysis to establish the value the technique has to operational forecasting. Initial feedback by forecasters and team members has already identified interesting questions including:

1) Why do sensitive areas change initialization to initialization?
2) Why do sensitive areas sometimes disappear during backwards integration?
3) How can sensitive areas exist so far from the chosen response function?
4) At what forecast lead times is ensemble sensitivity analysis most useful?

Answering these questions (and more), and using additional forecaster feedback regarding the sensitivity tool, is expected to pave the way forward for continued operational ensemble sensitivity analysis development at the Met Office.

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