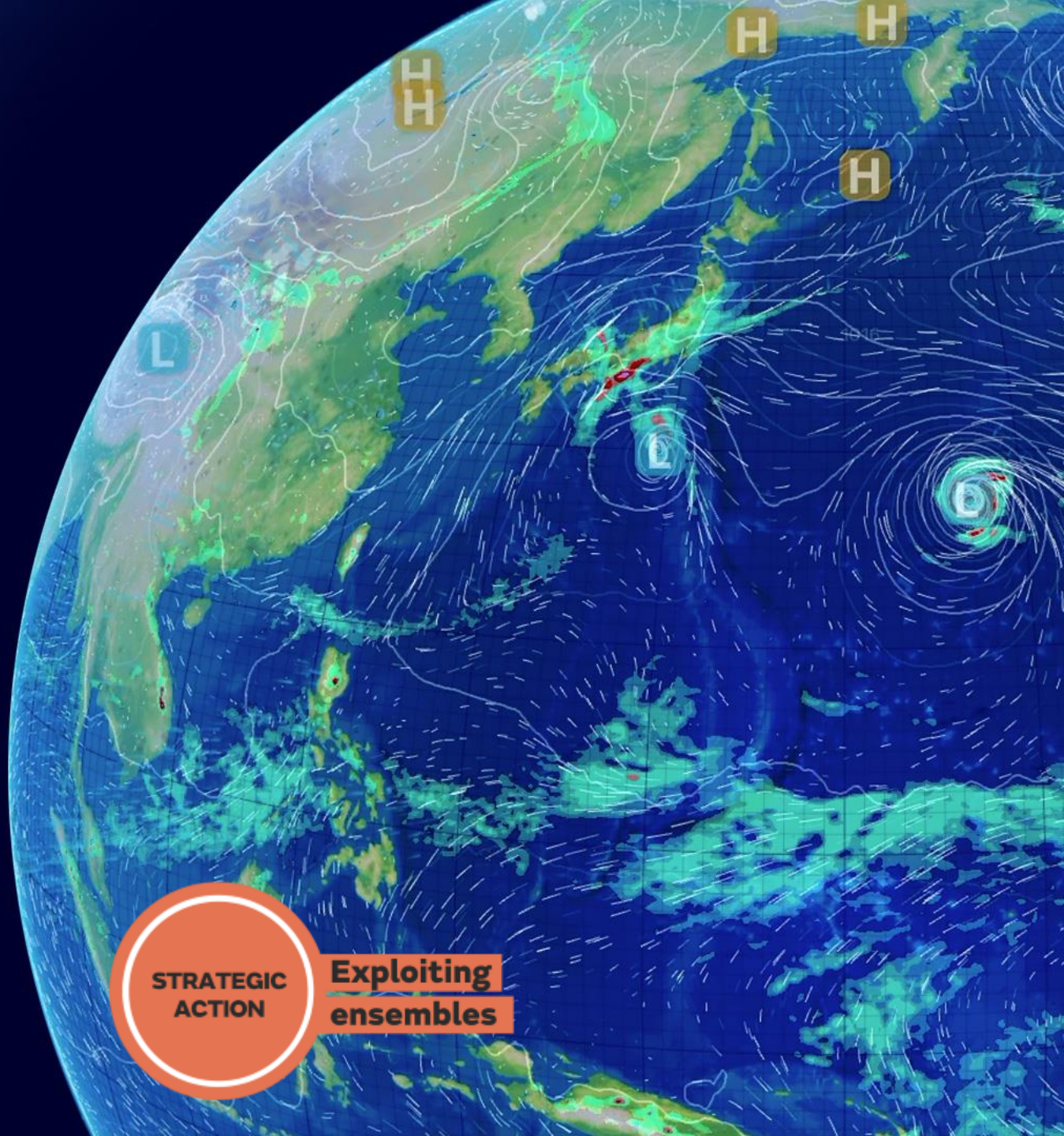
Met Office

Ensemble Exploitation and development

Nigel Roberts & David Walters

Special thanks to
Rosa Barciela, Steve Willington

and
Paul Davies, John Petch, Mike Gray, Teil Howard, Anne Mccabe, Ken Mylne, Chiara Piccolo, Aurore Porson, Patrick Sachon, Oak Wells, Keith Williams, Rose Jones



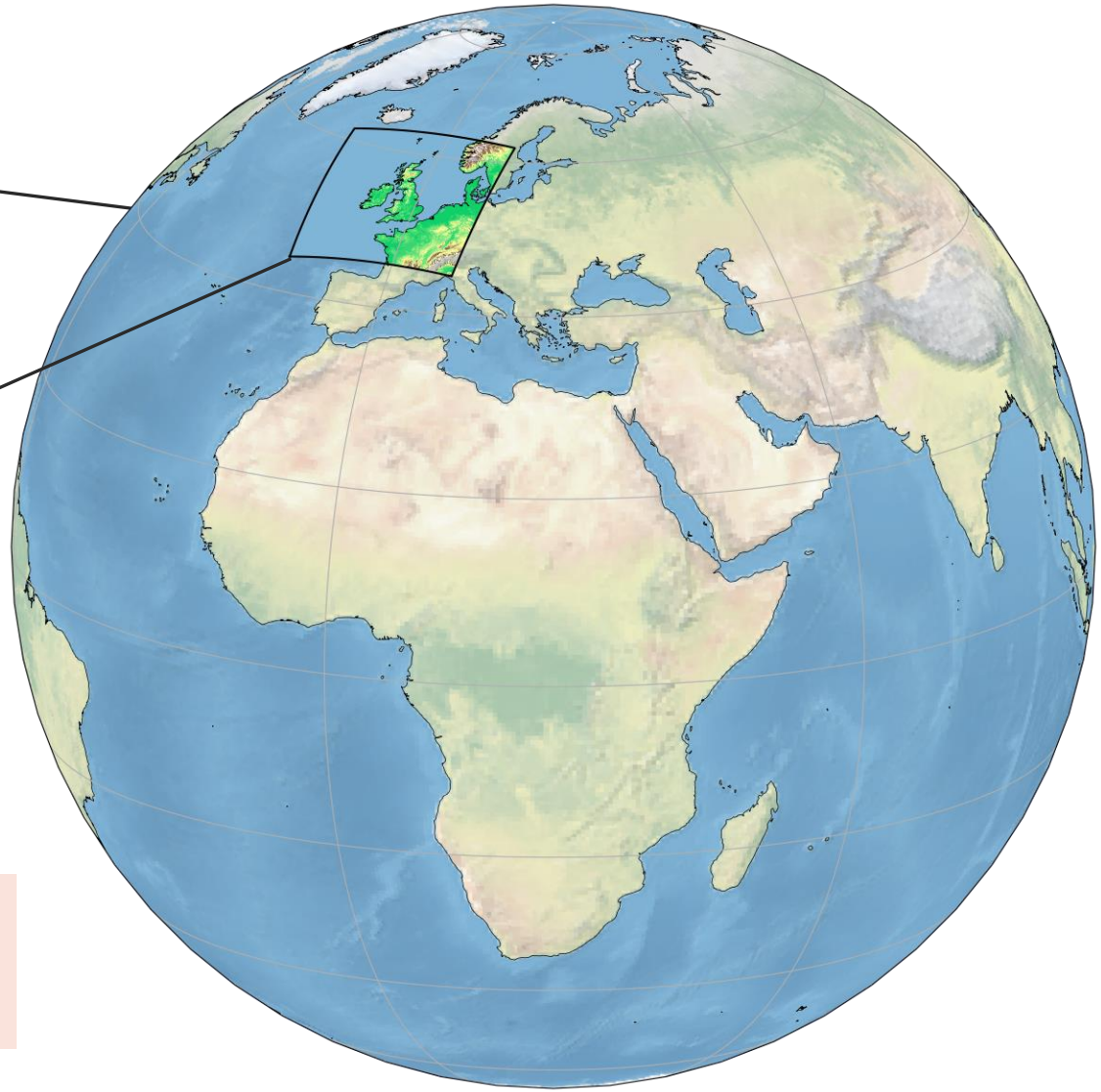
2023 Operational NWP (OS45)

Global NWP:

- 10/20km deterministic/ensemble
- Both coupled to ORCA025 (0.25˚) ocean
- 70 vertical levels (80km top)
- Hybrid 4DVar/En-4DEnVar Data Assimilation (DA)
- Forecasts to T+54 or T+192hr every 6 hours

UK NWP:

- 1.5/2.2km deterministic/ensemble
- 70 vertical levels (40km top)
- Hourly 4DVar DA
- Forecasts to T+12 - 120hr every hour
- Hourly updating ensemble (up to T+120hr)



GM + UKV	~ 25% cost of OS45
MOGREPS-G + UK	~ 43% cost of OS45

David Walters

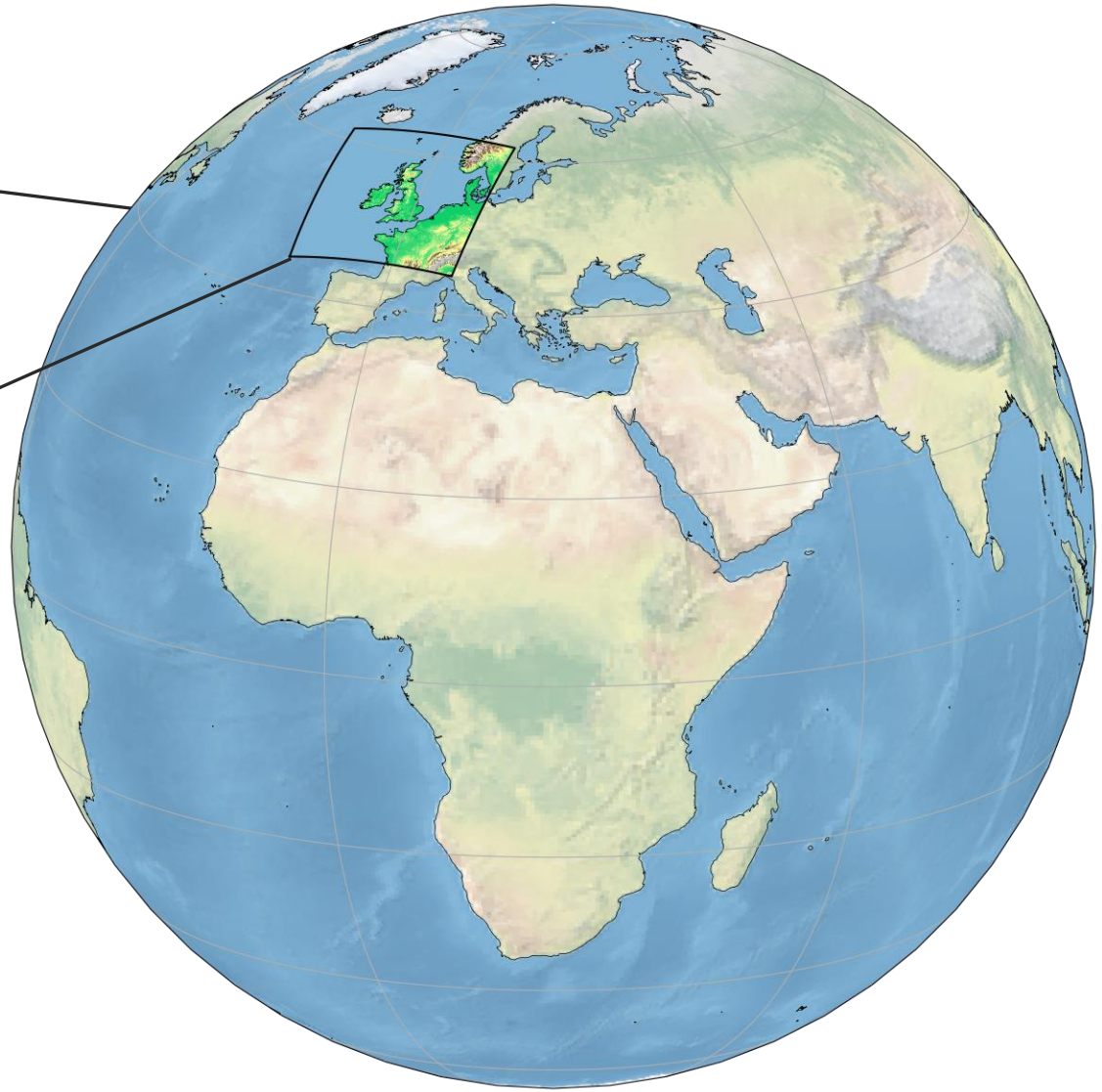
2025/6 Operational plans (PS48)

Global NWP:

- Horizontal resolution 10km in wk 1
  resolution 20km in wk 2
- Retire deterministic GM forecast
- Hybrid 4D-Var GM becomes control member

UK NWP:

- Horizontal resolution to 1.5km
- Retire deterministic UKV forecast (beyond T+12)
- Hourly 4D-Var UKV becomes control member



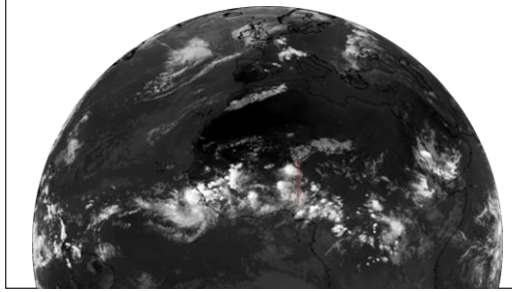
David Walters

Future capabilities: “trailblazer” systems

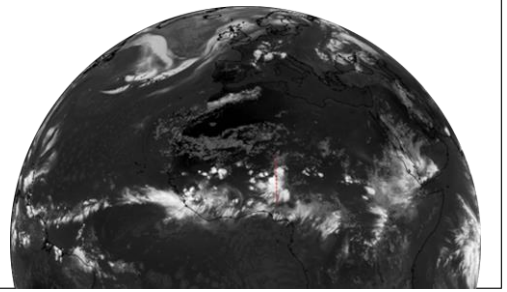
Global km-scale trailblazer

- 5km atmosphere/10km ocean
- Exploring convective greyzone (with new Comorph convection scheme)
- Ahead of km-scale global ensemble

MSG satellite



5km UM simulation



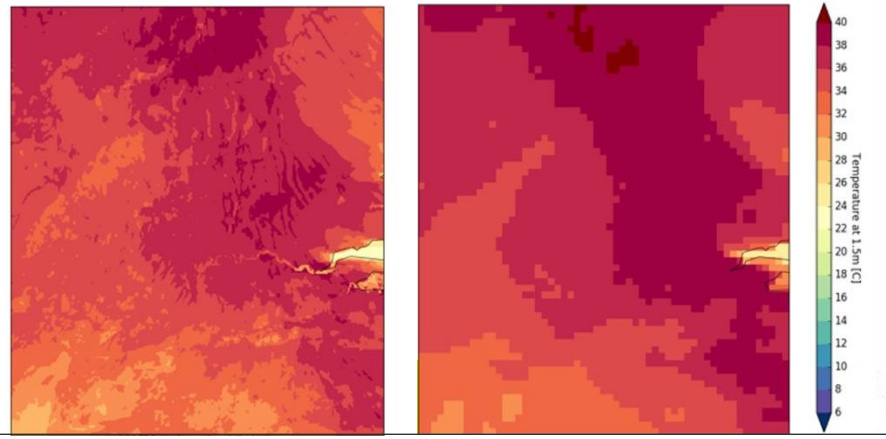
Lorenzo Tomassini

Urban-scale trailblazer

- 300m London ensemble
- Additional detail/urban processes

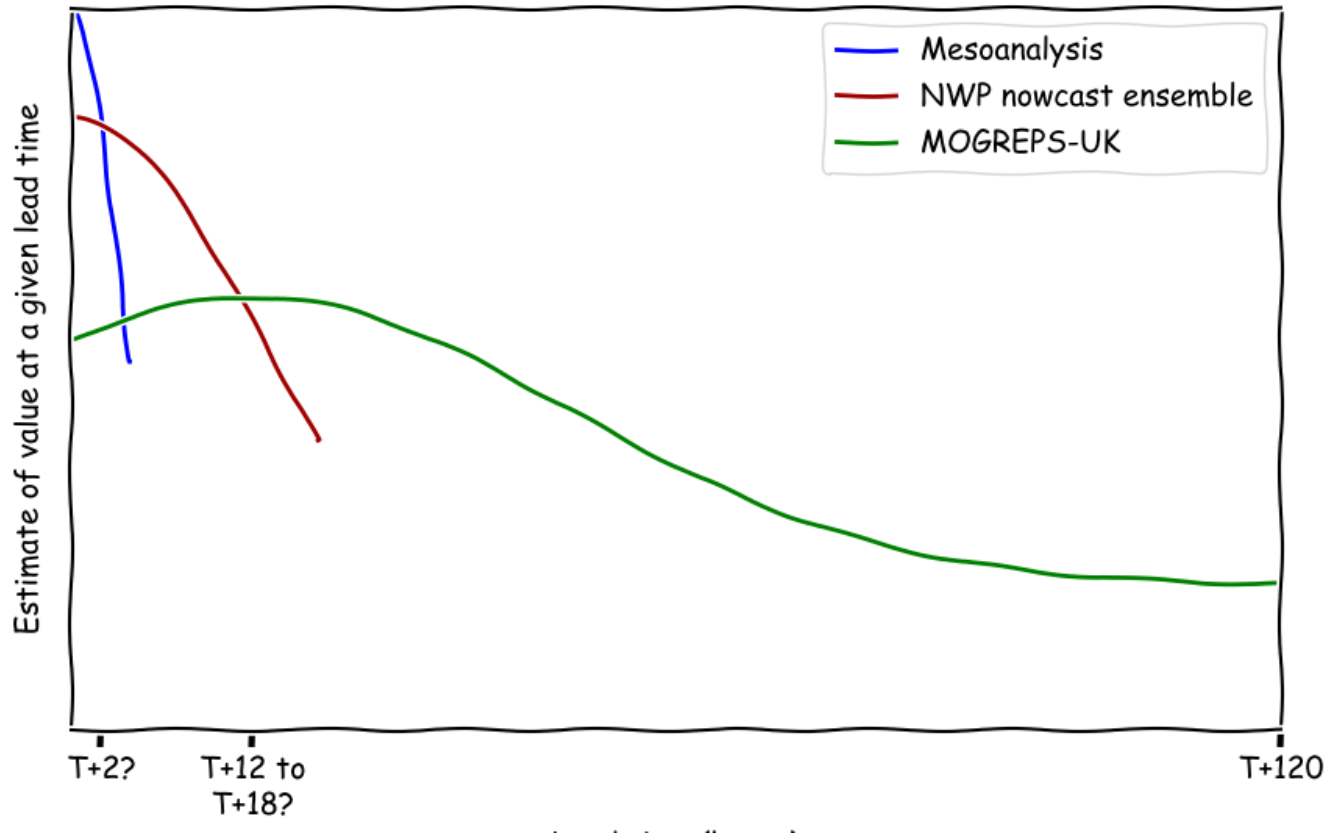
300m control

2.2km control



19th July Heatwave: Kirsty Hanley, Humphrey Lean

Long-term plan for UK NWP/DA



Current plan (in dev.):

- NWP nowcast/very short-range forecast ensemble using rapid-cycling EDA
- T+120 forecast ensemble likely warm-starting from MOGREPS-G ensemble

Early stage, current plan, work not started

David Walters

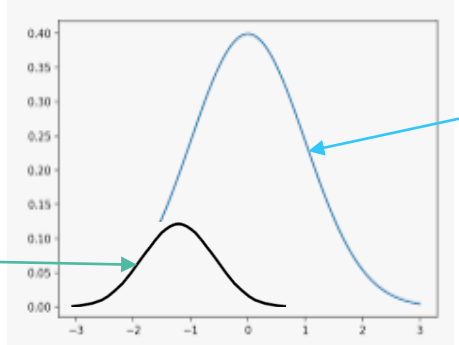
The Operational Meteorologist Perspective

- Lack of suitable tools, visualisation and products severely restricts use and take up.
- No tools to extract synoptic information to aid decision-making and increase value.
- Focus historically is on average scores and not verifying when it matters to an OpMet.

- Information not presented to compliment Op Mets “top down” working processes – decisions made before ensembles enter the process.
- Low probability extremes matter! Op Mets main challenge.

Can we identify an emerging event?

Eventual outcome lies in here!



Full ensemble distribution

- Only 5% of Met Office automated products use ensemble data - untapped benefit!

The challenge to exploit ensemble prediction

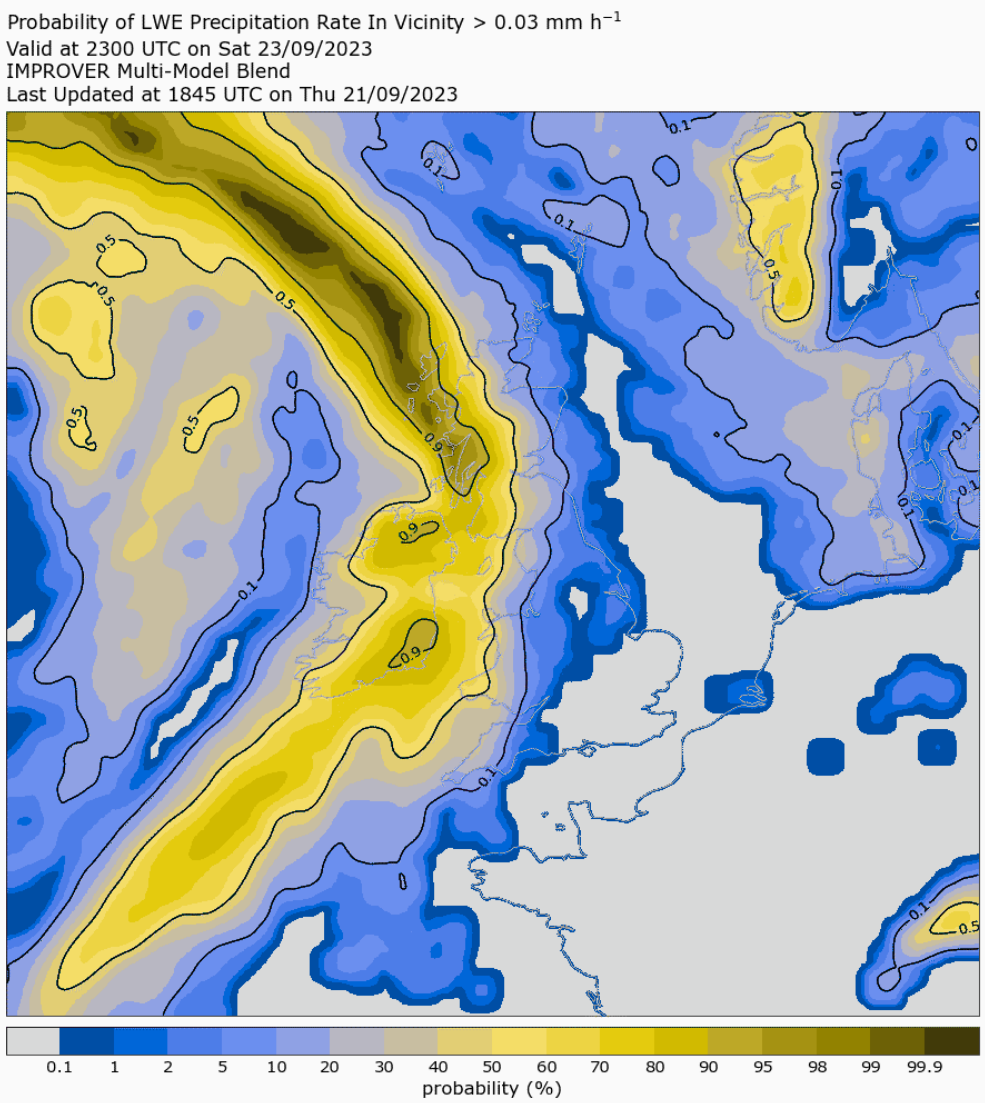
"The public don't understand probabilities"

"Uncertainty is too difficult to communicate"

"There's too much data"

"I just need to make a decision"

"Just tell me what will happen"



Example: Probability of Precipitation

Met Office

STRATEGIC ACTION Exploiting ensembles

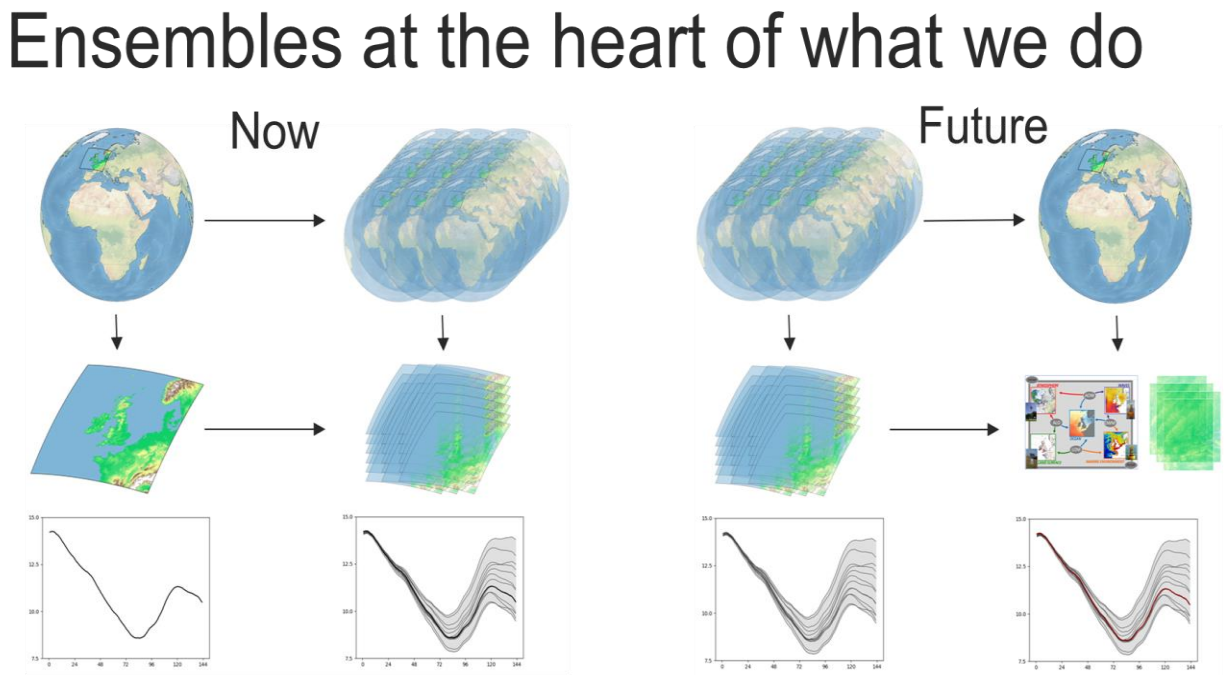
Ensemble Exploitation

A Met Office wide strategic action to accelerate and ensure **all our products and services are underpinned by our ensemble forecasting systems**.

- Forecast process based on ensembles first.
- Ensure we are developing our forecasting systems recognising how ensembles are used.
- Make better use of ensembles across our advice and services, particularly in terms of risk of high impact weather.
- Ready for retiring the deterministic models in 2026 (still have a control).

Vision

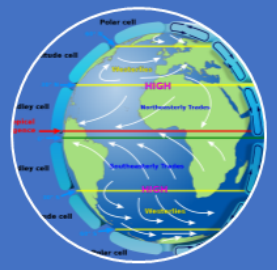
*We are **already using ensembles** but want to **fully exploit and extract maximum value** from our **NWP-based ensemble systems,** for underpinning all our **services,** in order to support users and customers in their **decision-making**, particularly in terms of **risk** of high **impact** weather events by …*



1. *Increase the number of forecasts products and services exploiting ensembles.*
2. *Engage with customers to exploit, and make more use of, our ensembles.*
3. *Develop new ways to exploit our ensembles.*
4. *Develop our models recognising how ensembles systems are being used.*
5. *Provide a common language and change the culture.*

Met Office

5. Communicating our work and thought leadership



2. Ensemble Development

3. Developing our tools, processes and people

4. Engaging and supporting our users

1. Underpinning research

WP1: Nigel Roberts & Steve Willington **WP2:** Chiara Piccolo & Keith Williams **WP3:** Mike Gray & Ken Mylne

WP4: Teil Howard & Patrick Sachon **WP5:** Oak Wells & David Walters

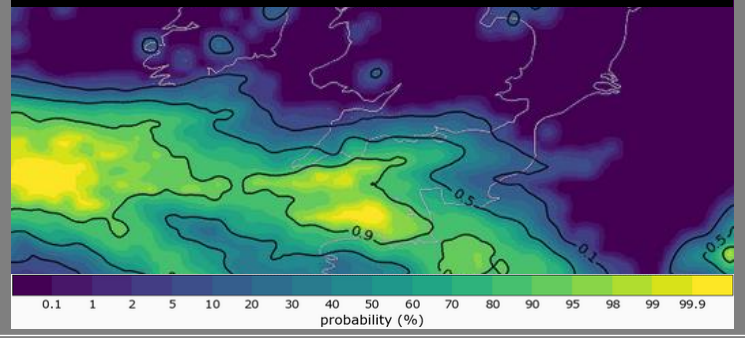
Classes of use cases for ensembles

1) Use cases for ensemble stats

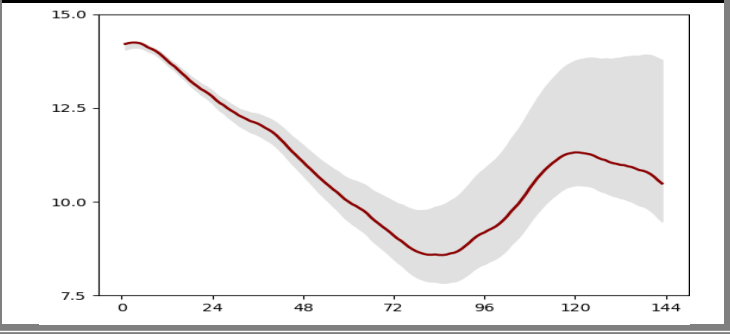
1a. Best estimated values

09:00	10:00	11:00	12:00	13:00
10%	10%	10%	40%	40%

1b. Probability distributions

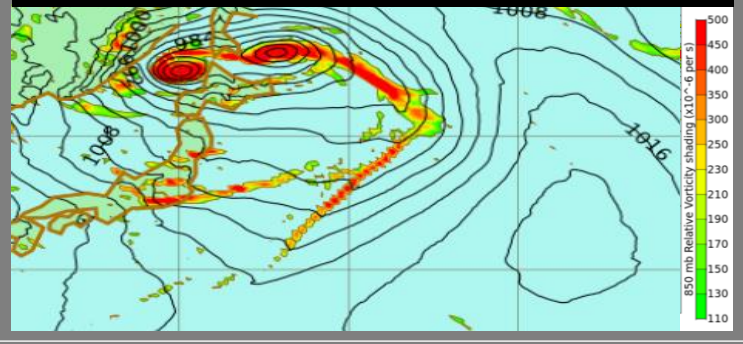


1c. Ranges of uncertainty

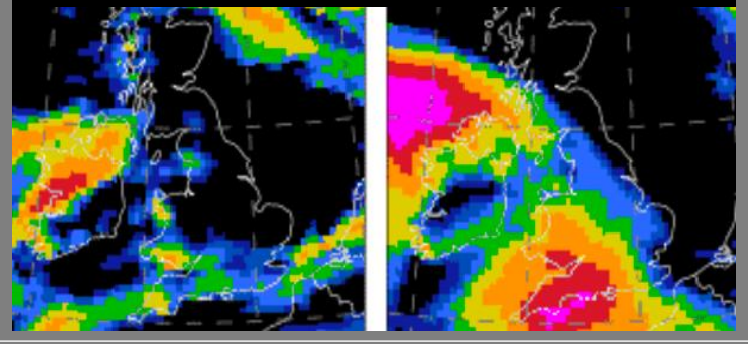


2) Use cases for 1 or more members

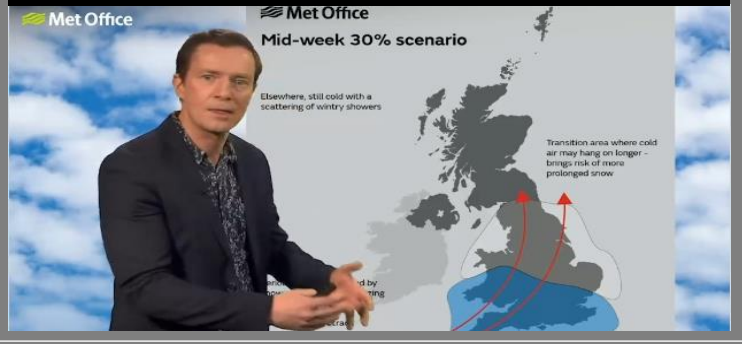
2a. Representative member



2b. Realistic low-prob. extremes

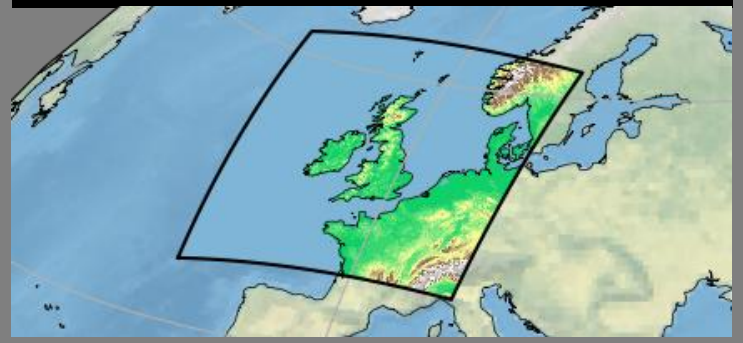


2c. Probable "storylines"



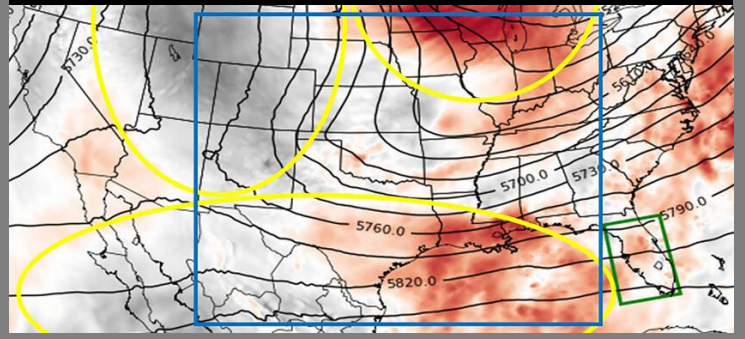
3) Use cases for all members

3a. Driving downstream models



3b. Correlated prob. distribution

3c. Extra ensemble processing



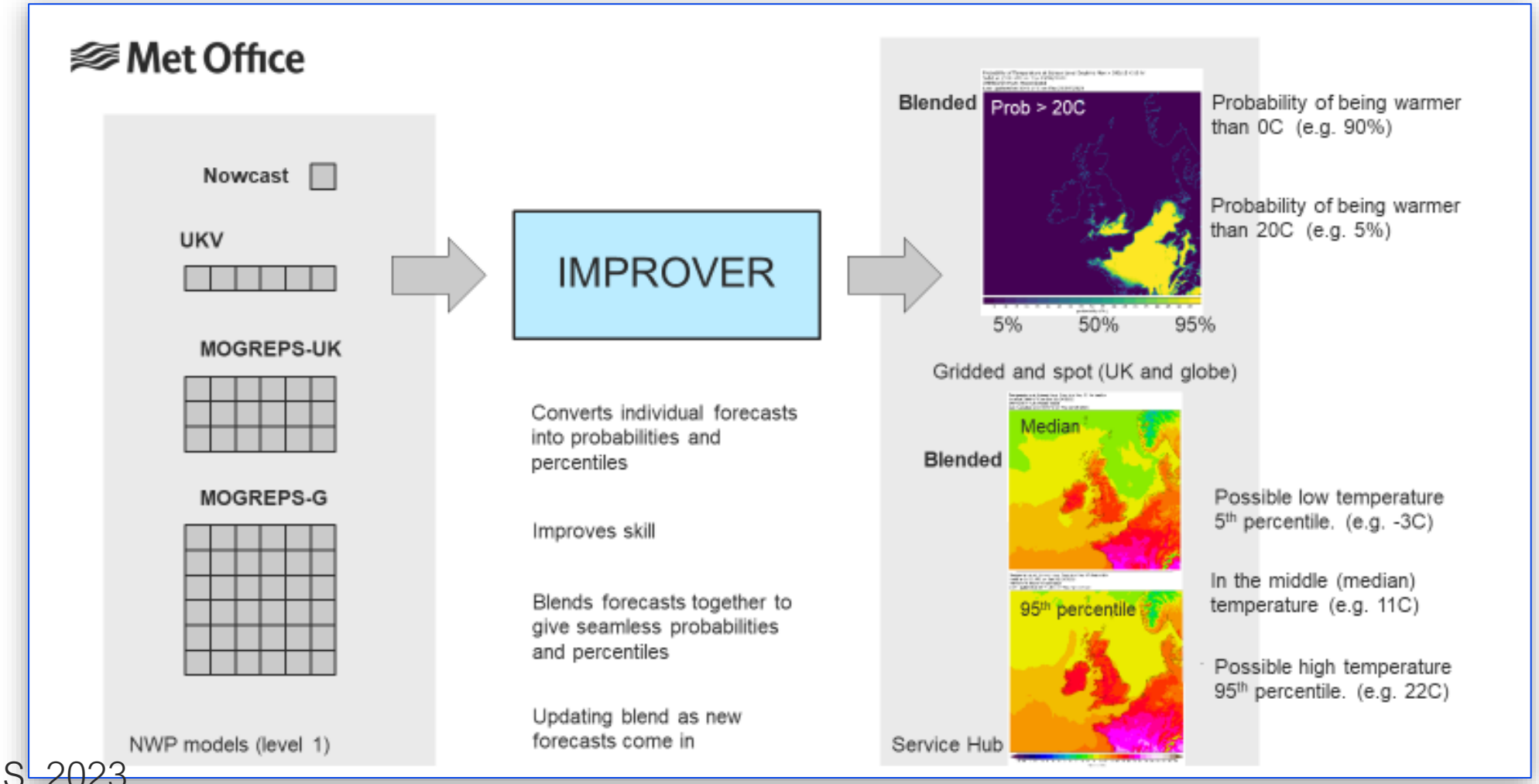
IMPROVER post processing Class 1

IMPROVER serves use case 1 – ensemble stats

Includes:

- *Most likely*
- *Tails*
- *Reasonable worst case*

…but on a local point-by-point basis



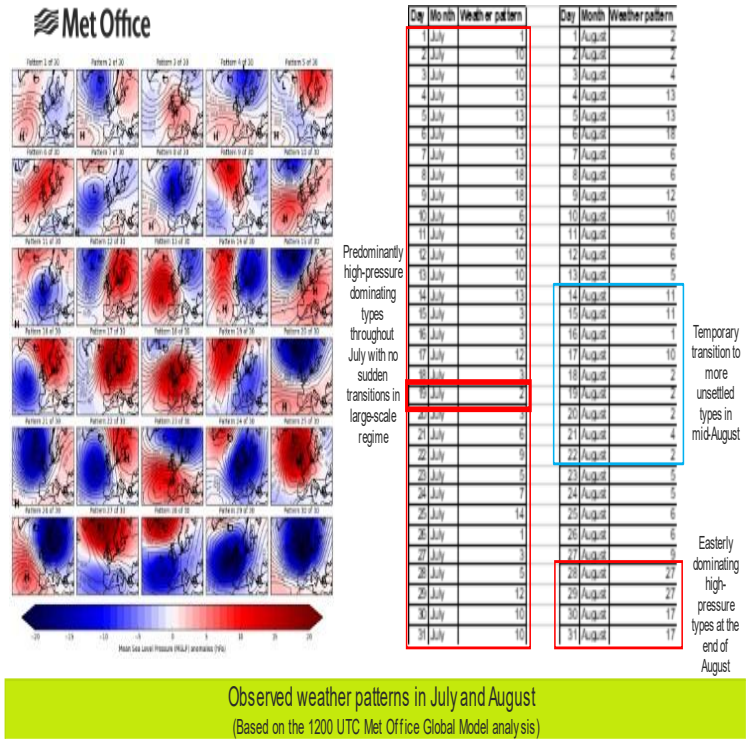
See Roberts et al, BAMS, 2023

Heatwave Warnings

National Severe Weather Warning Service

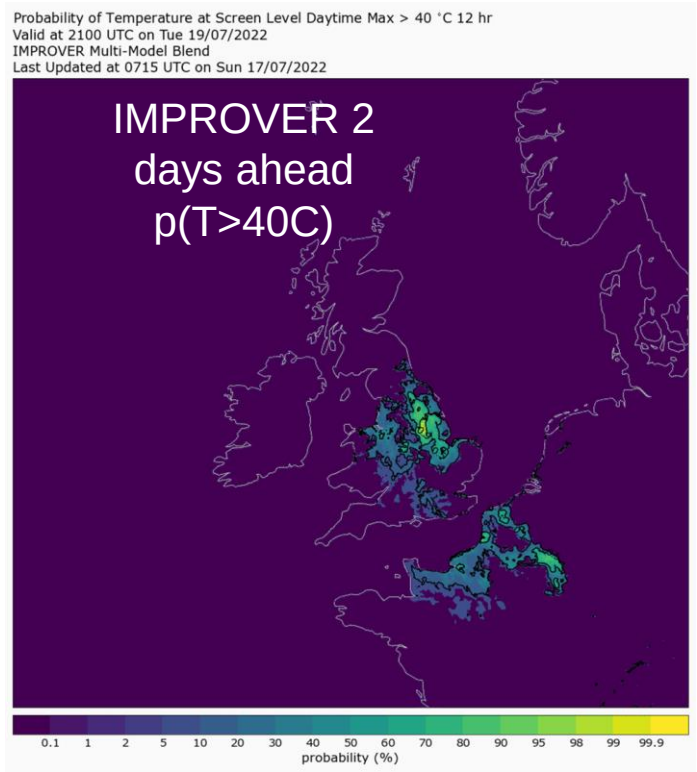
Extreme Heat Summer 2022

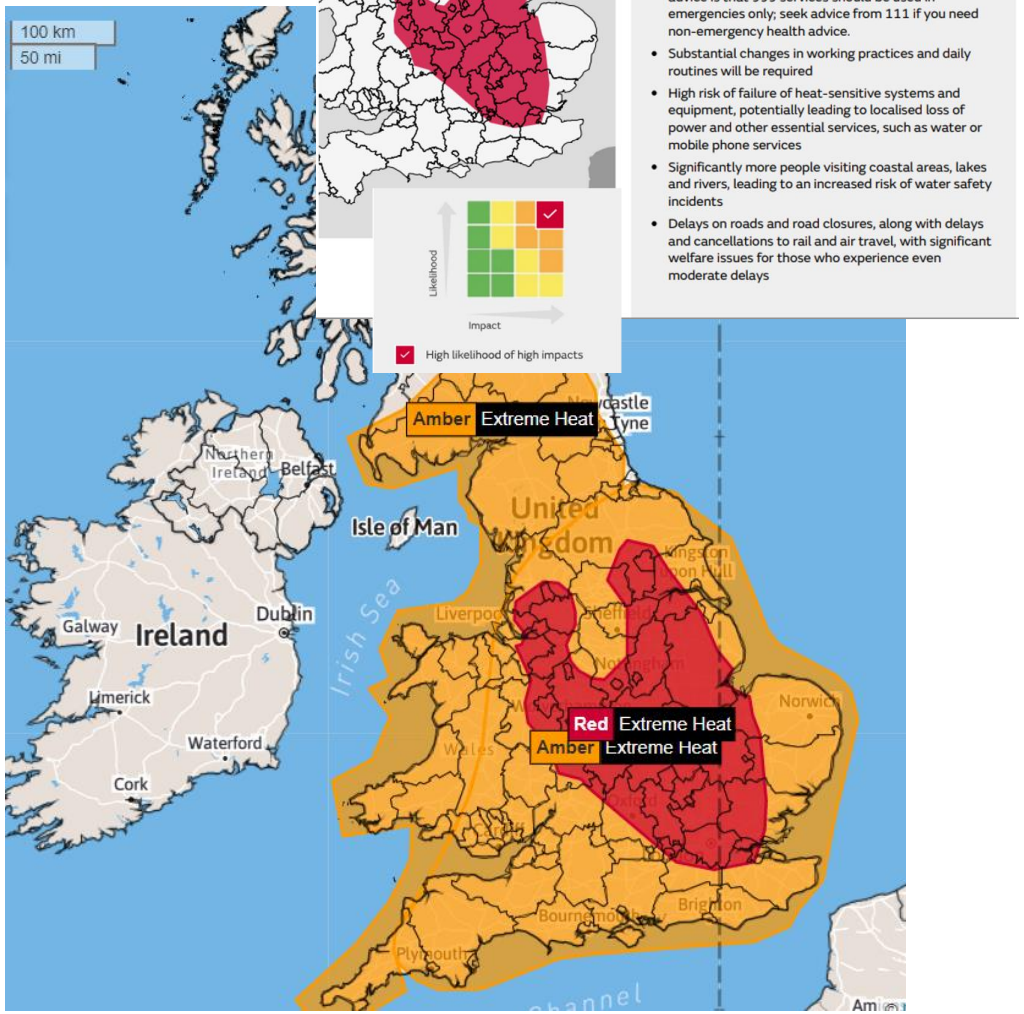
UK temperature record of 40.3C set 19 Jul 2022



Day	Month	Weather pattern	Day	Month	Weather pattern
1	July	1	1	August	2
2	July	10	2	August	2
3	July	10	3	August	4
4	July	13	4	August	13
5	July	13	5	August	13
6	July	13	6	August	18
7	July	13	7	August	6
8	July	18	8	August	6
9	July	18	9	August	12
10	July	6	10	August	10
11	July	12	11	August	6
12	July	10	12	August	6
13	July	10	13	August	5
14	July	13	14	August	11
15	July	3	15	August	11
16	July	3	16	August	1
17	July	12	17	August	10
18	July	10	18	August	2
19	July	2	19	August	2
20	July	3	20	August	2
21	July	6	21	August	4
22	July	6	22	August	2
23	July	5	23	August	5
24	July	7	24	August	5
25	July	14	25	August	6
26	July	1	26	August	6
27	July	3	27	August	6
28	July	5	28	August	27
29	July	12	29	August	27
30	July	10	30	August	17
31	July	10	31	August	17

Observed weather patterns in July and August
(Based on the 1200 UTC Met Office Global Model analysis)





More specific research

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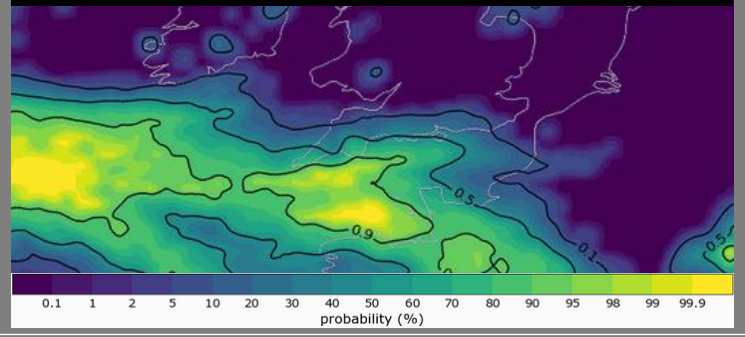

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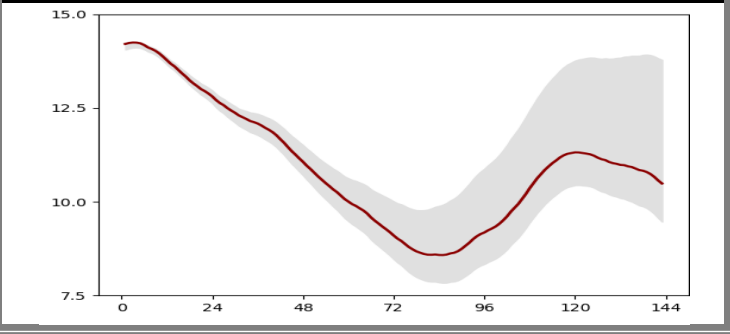

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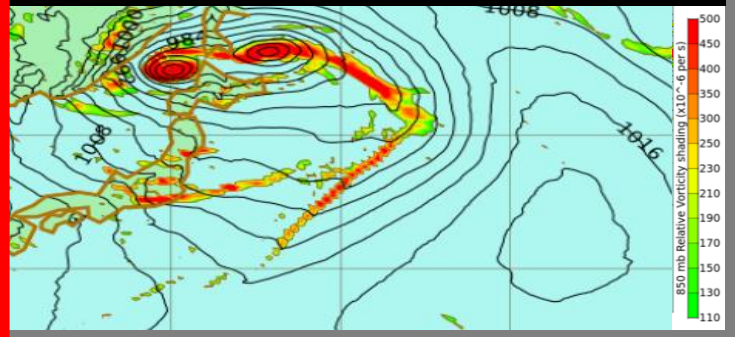

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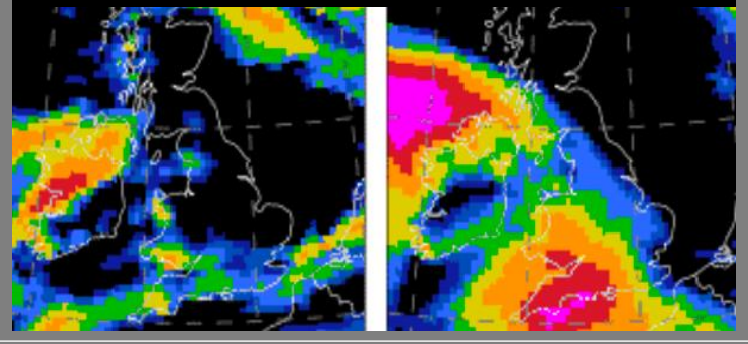

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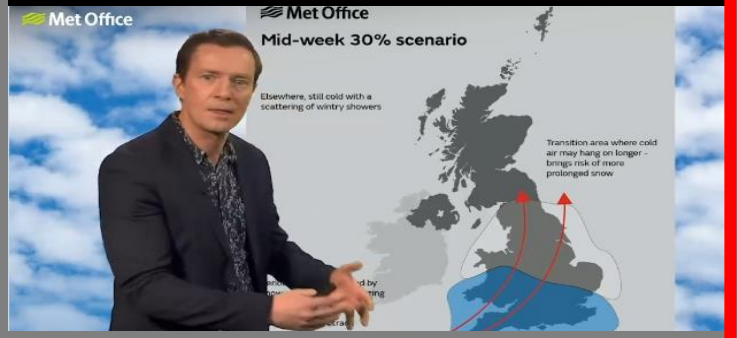

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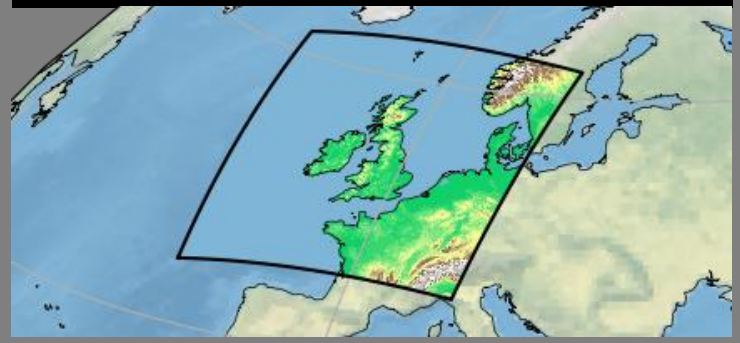

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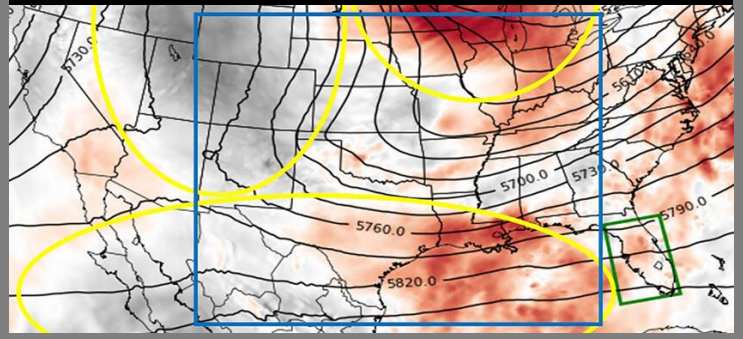


Clustering Class 2

Require methods to extract salient members from the full ensemble

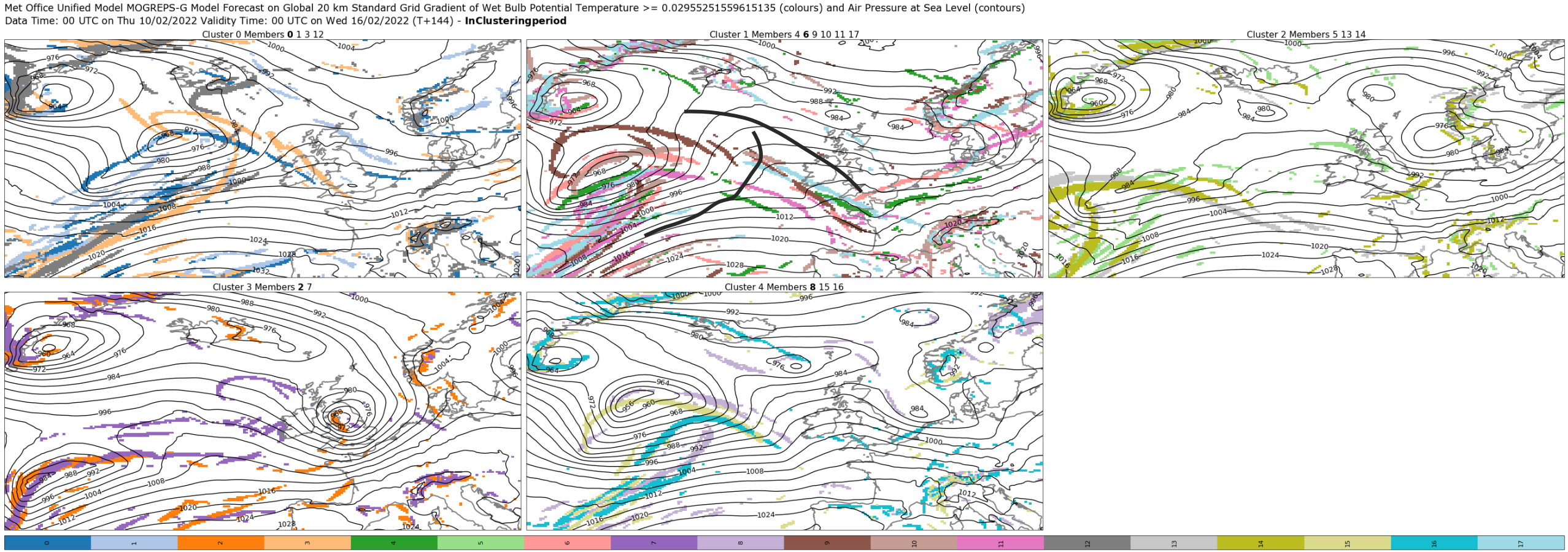
Essential to reduce information overload and allow scrutiny of forecasts or products that require a central member or scenarios

Even more important with higher resolution and more members

Conventional clustering (PCA, k-means, 500H) won't work for kilometre-scale

Can cluster on the distance between objects (e.g. fronts, precipitation etc) (Kris Boykin PhD University of Reading with Met Office)

Clustering based on distance between objects



Wet-bulb potential temperature gradient objects (fronts)

Kris Boykin

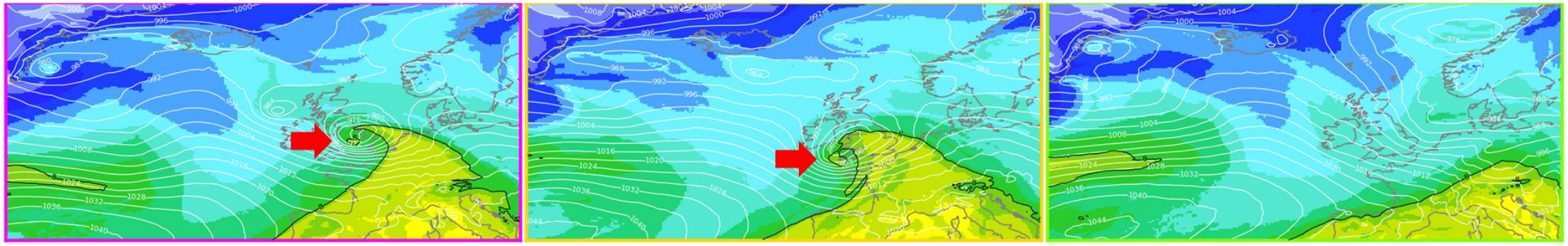
5 day forecast clusters for Storm Eunice

18th Feb 2022

Cluster 0
Members 0, 20, 27, 28, 32

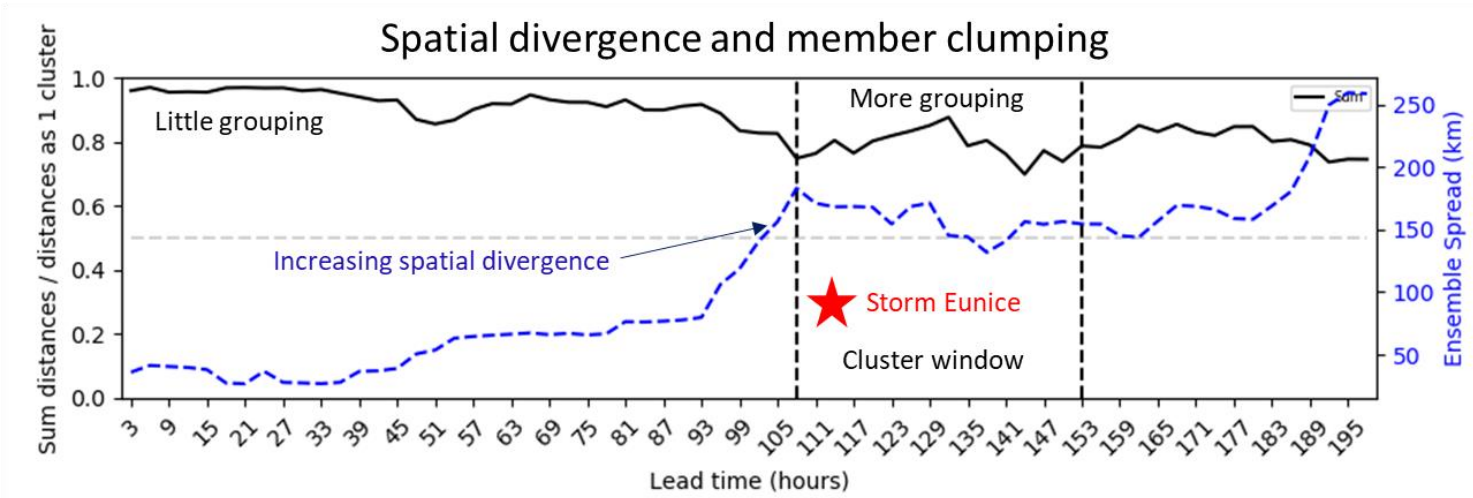
Cluster 1
Members 19, 23, 24, 26, 30,31,33,34

Cluster 2
Members 18, 21, 22, 25, 29



Wet-bulb potential temperature 850 hPa

Spatial divergence and member clumping



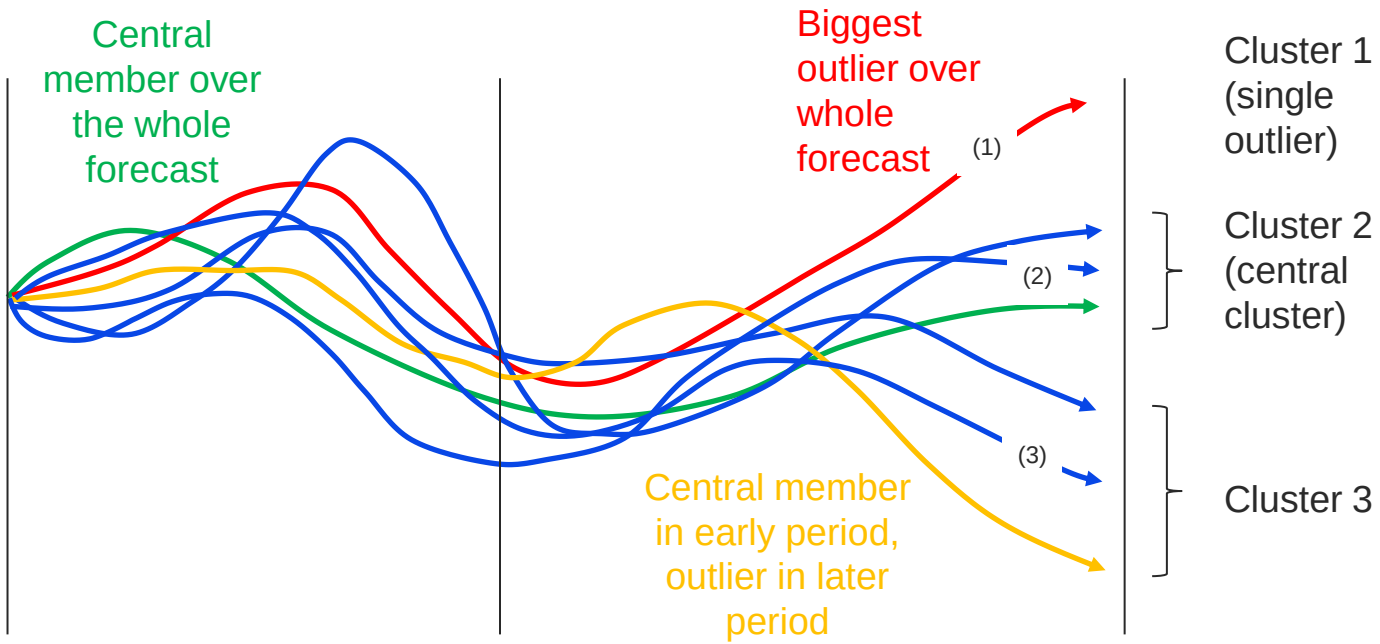
Kris Boykin PhD
John Methven, Tom Frame
University of Reading
Nigel Roberts, Stephen Moseley
Met Office

Forecast scenarios based on spatial clustering using wet-bulb potential temperature gradient objects

Different to traditional point-by-point methods

Clustering and scenarios

- Create objects defining the flow pattern or weather of interest
- Apply spatial agreement algorithm
- Find spatial spread
- Identify central member
- Identify outliers
- Identify clusters & coherence
- Identify scenarios



- Pick out salient forecasts to examine first
- Identify members that best represent the full ensemble (e.g. (1), (2), (3))
- Use alongside DECIDER
- Use alongside Ensemble Sensitivity Analysis & sub-setting

Nigel Roberts & Steve Willington
Working with Rob Neal
Working with Data Triage
Kris Boykin PhD

Met Office

Thanks for listening