

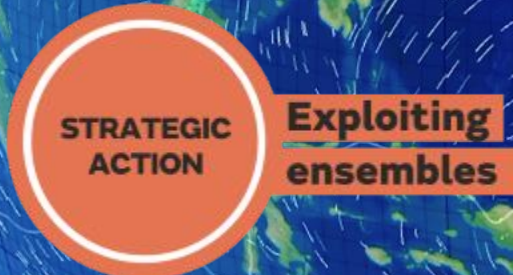
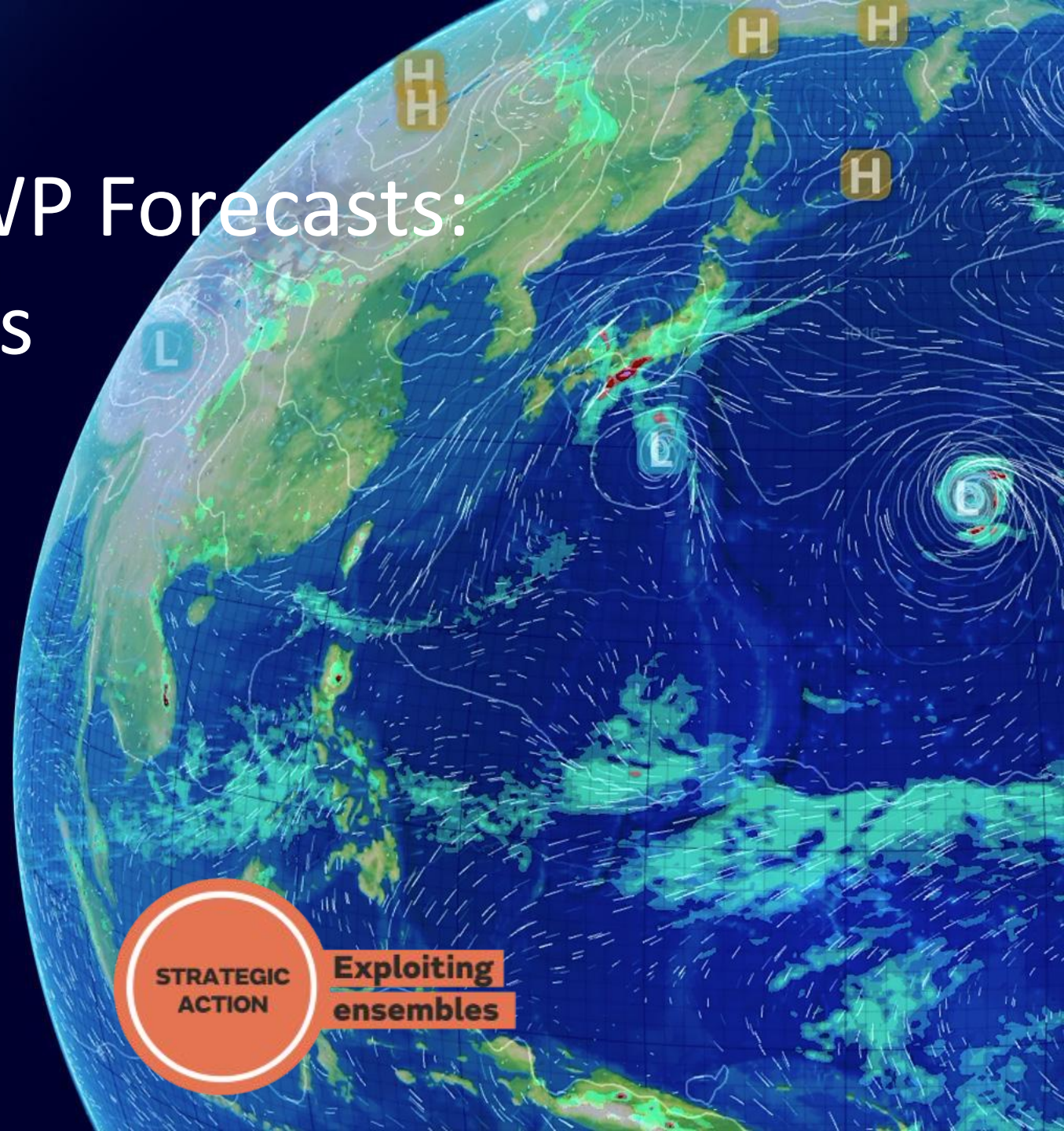
Exploiting Ensemble NWP Forecasts: From Science to Services

Rosa Barciela

Strategic Head of Ensembles Exploitation

*Paul Davies, John Petch, Mike Gray, Teil Howard, Ken Mylne,
Chiara Piccolo, Nigel Roberts, Patrick Sachon, David Walters,
Oak Wells, Keith Williams, Steve Willington, Rose Jones*


with thanks to several colleagues from the Programmes,
Markets, Media and Enterprise Design areas of the Met Office

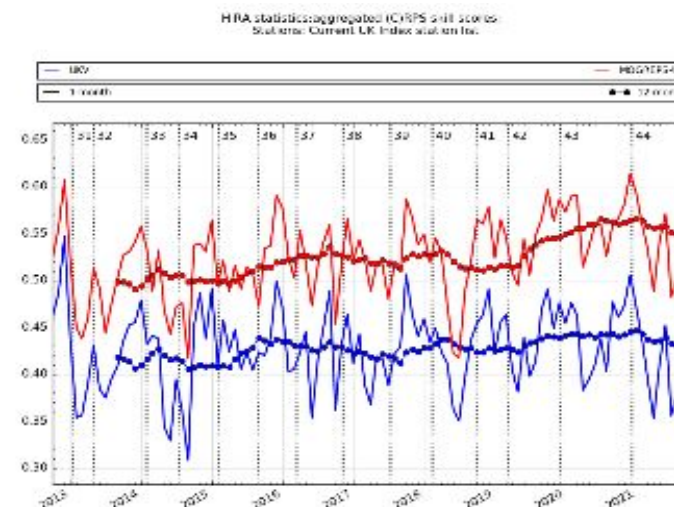
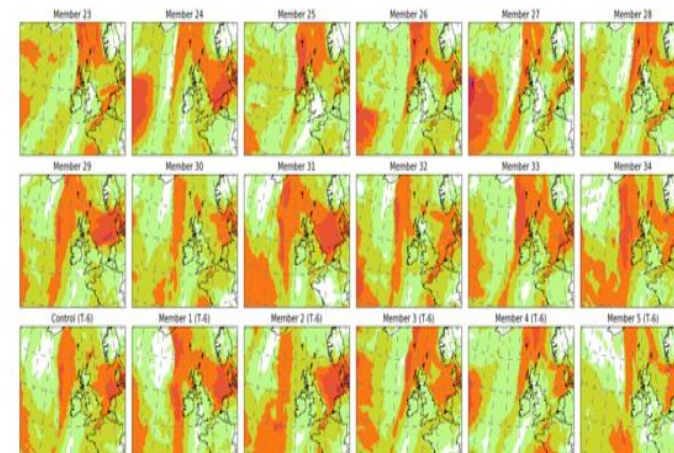


Contents

1. Background
2. The challenge to exploit ensemble prediction
3. The ensembles exploitation strategic action
4. Early successes
5. The 2023 UK summer testbed
6. Summary

30 years of ensembles!

- Thanks to the pioneering efforts of NCEP and ECMWF in the 1990's.
- Met Office followed with:
 - ✓ MOGREPS-Regional in 2005.
 - ✓ MOGREPS-UK convective scale in 2012. 
 - ✓ IMPROVER blended post-processing.
 - ✓ DECIDER weather regimes.
- Significant investment in HPC.
- Verification shows **ensembles** provide greater skill than **deterministic**.



Met Office The challenge to exploit ensemble predict

"The public don't understand probabilities"

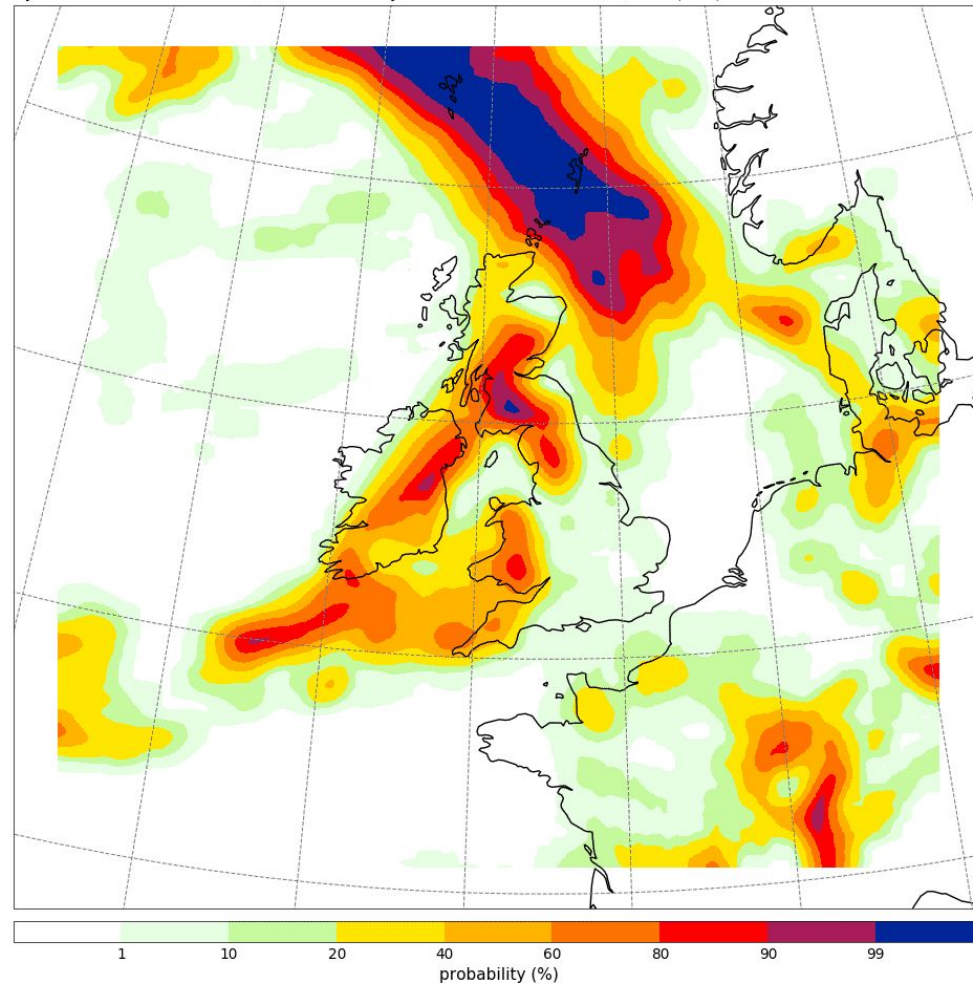
"Uncertainty is too difficult to communicate"

"There's too much data"

"I just need to make a decision"

"Just tell me what will happen"

Unknown Model probability_of_rainfall_rate > 0.03 mm/hr
Cycle Time: 11 UTC on Thu 06/12/2018 Validity Time: 11 UTC on Thu 06/12/2018 (T+0)



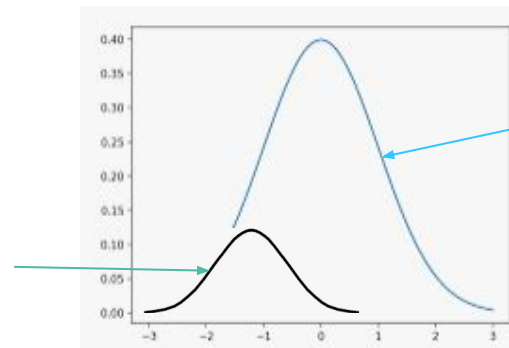
Example: Probability of Precipitation

Met Office **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!

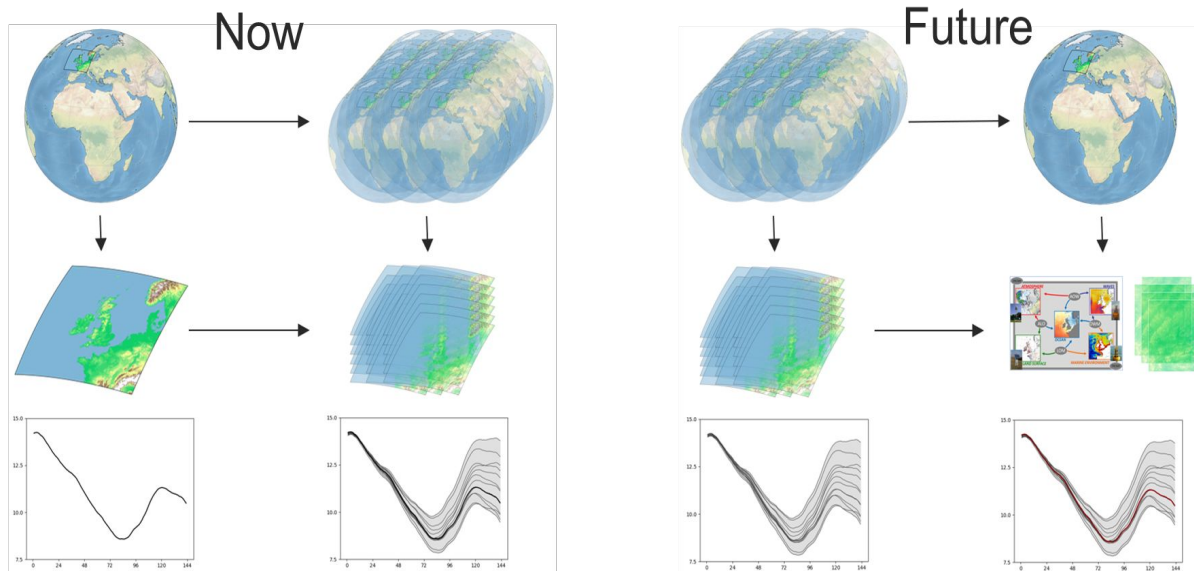
Ensemble Exploitation

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.

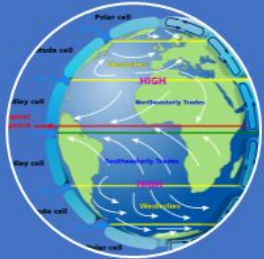
We are **already using ensembles** but want to **fully exploit and extract maximum value** from our **NWP-based ensemble systems**, for underpinning all our **services**, in order to support users and customers in their **decision-making**, particularly in terms of **risk** of high **impact** weather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

Ensembles at the heart of what we do



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.*

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

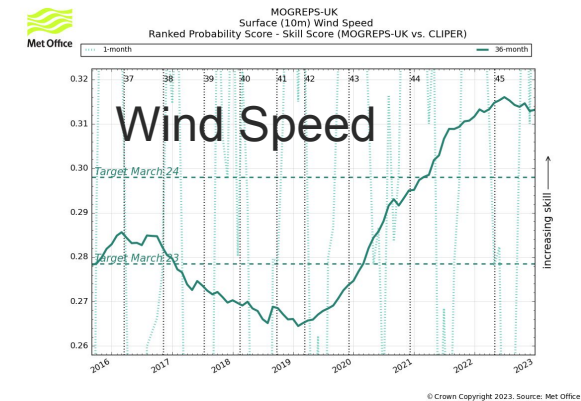
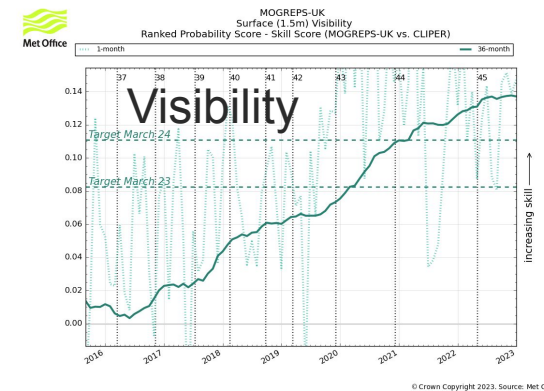
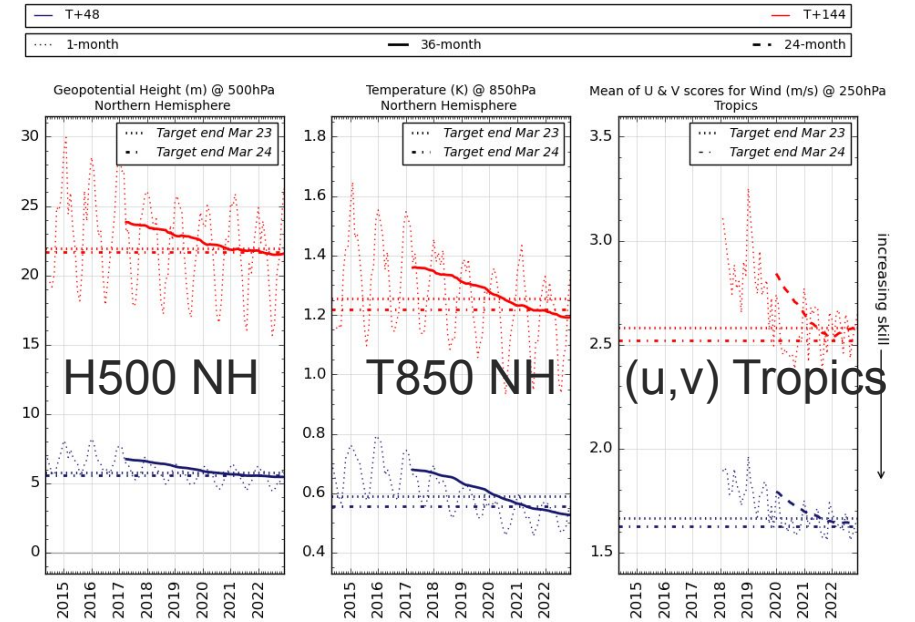
WP3: Mike Gray & Ken Mylne

WP4: Teil Howard & Patrick Sachon

WP5: Oak Wells & David Walters

Area	Component	202211		202212	
		T+48 (2 days)	T+144 (6 days)	T+48 (2 days)	T+144 (6 days)
NH	GPH @500hPa	0.3	0.46	0.3	0.41
	Temp @850hPa	0.06	0.06	0.06	0.06
TR	Temp @850hPa	0.07	0.1	0.07	0.1
	(u,v) Wind @250hPa	0.02	0.0	0.02	-0.0
SH	GPH @500hPa	0.38	0.77	0.38	0.76
	Temp @850hPa	0.05	0.04	0.05	0.04

- Corporate Key Performance Indicators for forecast accuracy now based on ensembles.
- Global MOGREPS CRPS to WMO standards.
- UK HiRA scores for 6 surface weather components.



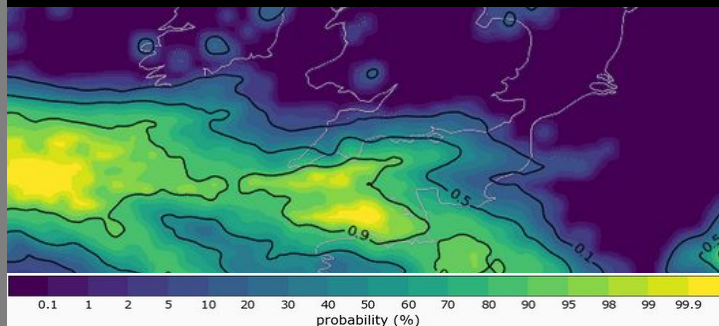
Classes of use cases for ensembles

1) Use cases for ensemble stats

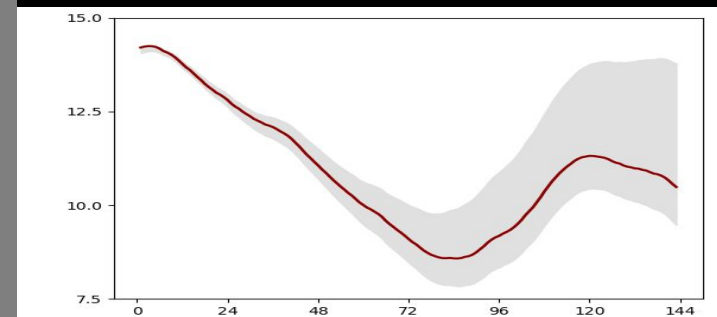
1a. Best estimated values

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

1b. Probability distributions

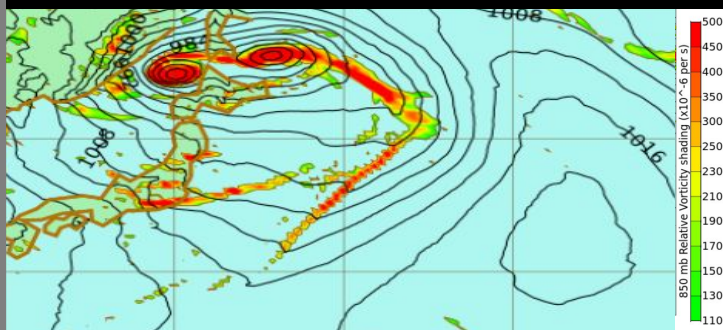


1c. Ranges of uncertainty

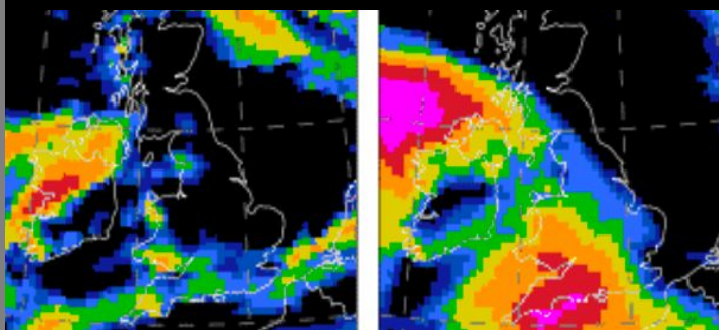


2) Use cases for 1 or more members

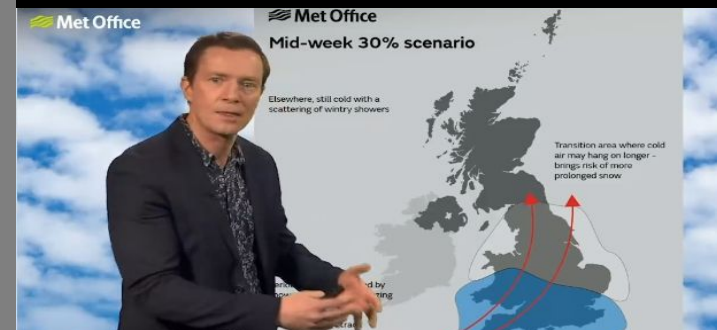
2a. Representative member



2b. Realistic low-prob. extremes

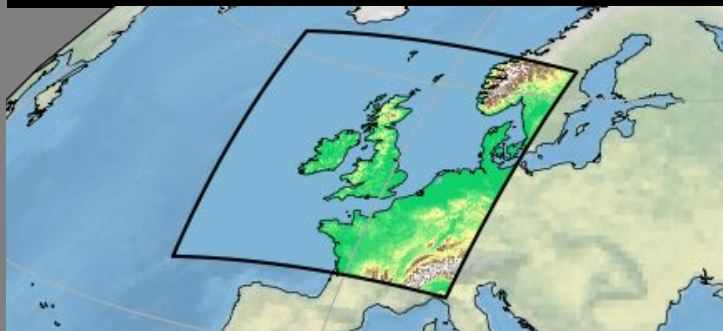


2c. Probable "storylines"



3) Use cases for all members

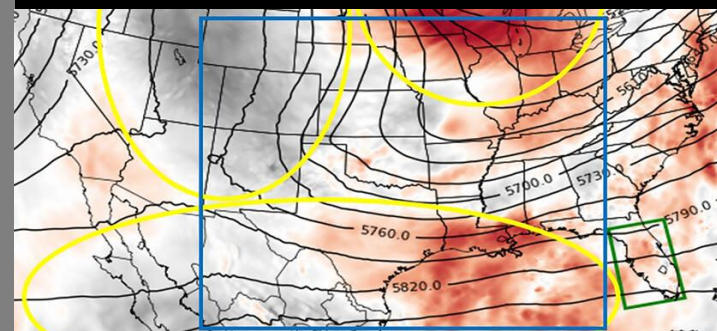
3a. Driving downstream models



3b. Correlated prob. distribution



3c. Extra ensemble processing



What is IMPROVER?

IMPROVER

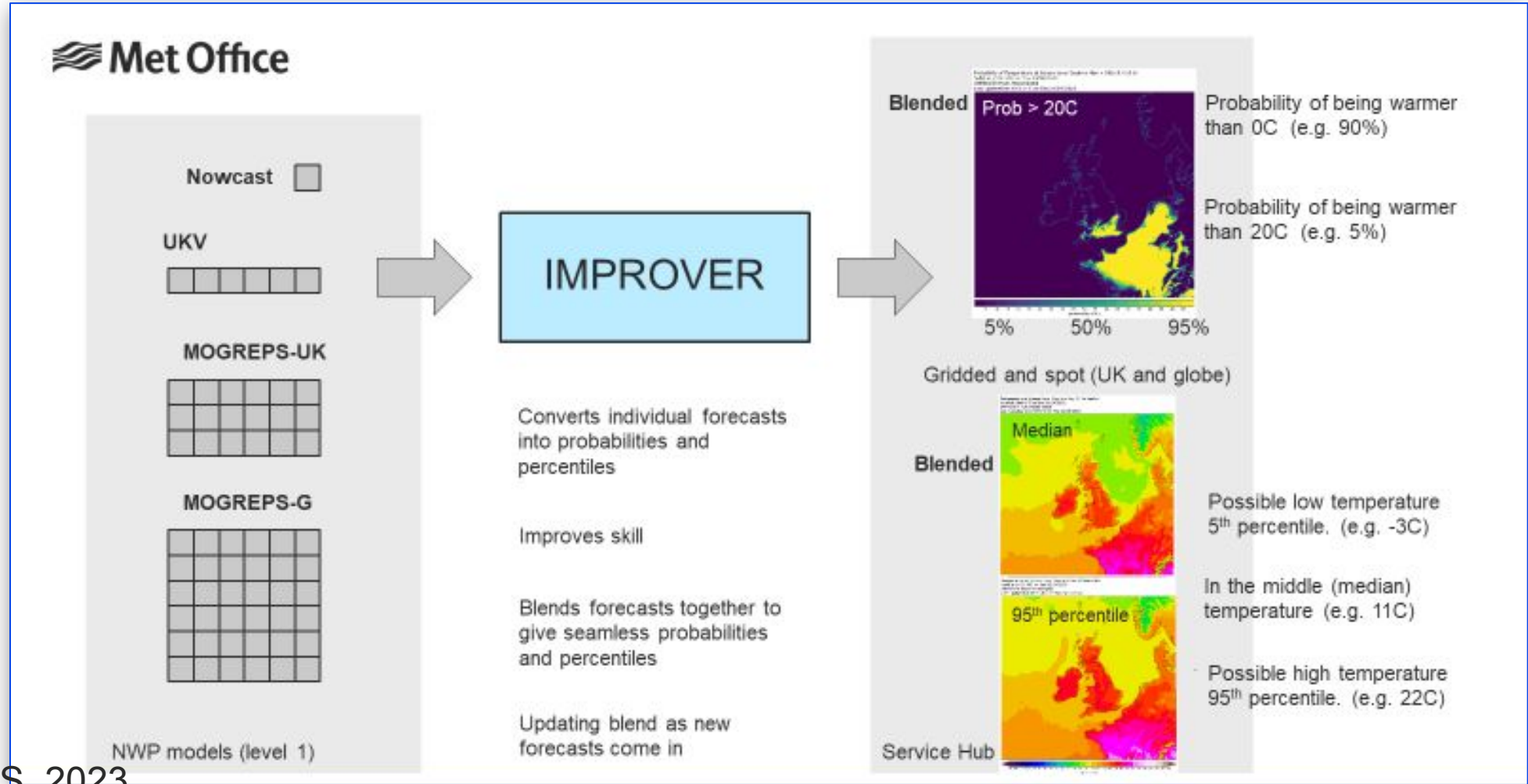
serves use case 1
– ensemble stats

Includes:

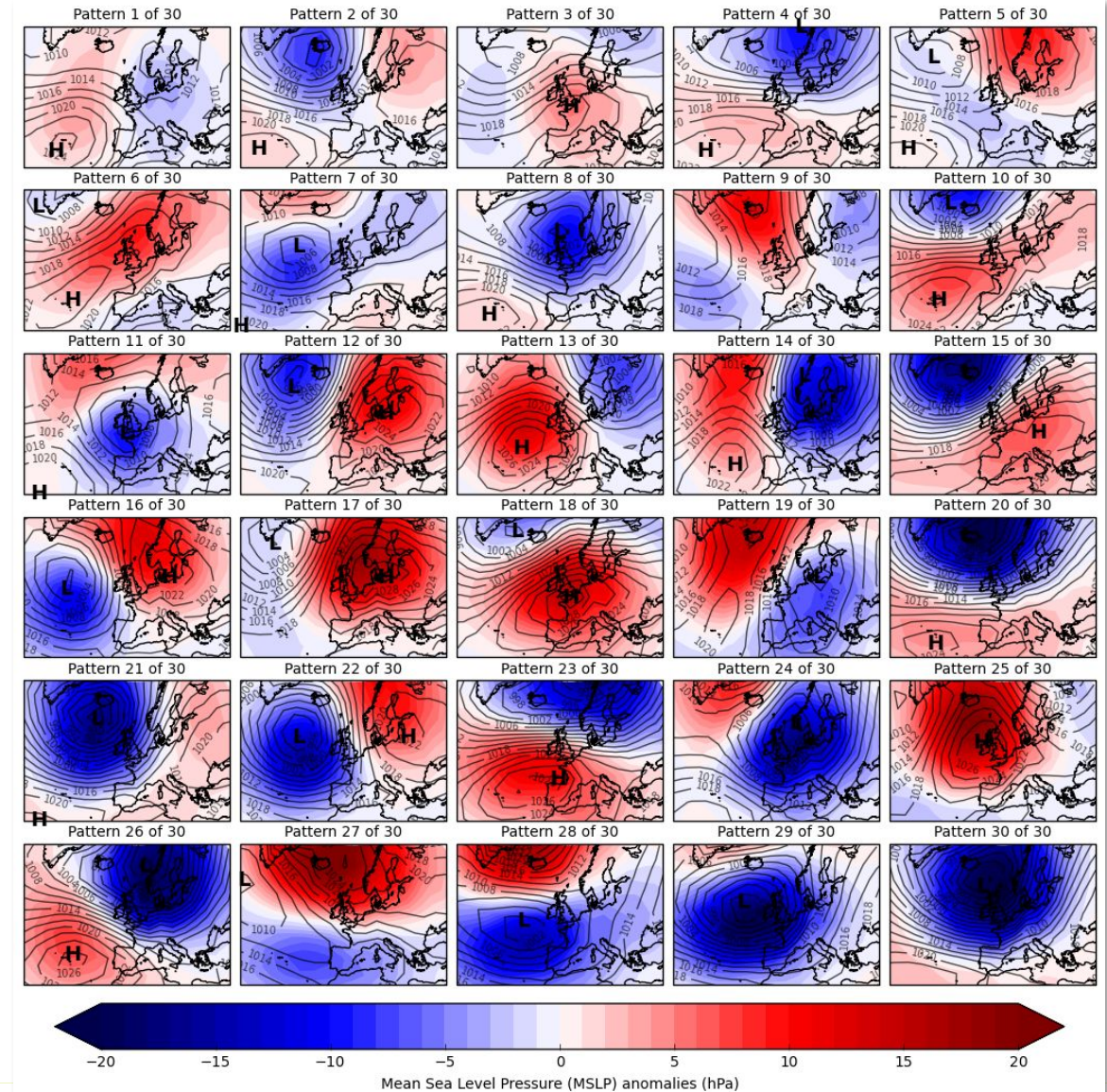
- **Most likely**
- **Extremes**
- **Reasonable worst case**

...but on a local
point-by-point
basis

See Roberts et al, BAMS, 2023



- A medium- to extended-range probabilistic weather pattern forecasting tool, which summarises key aspects from the large volumes of data ensembles provide.
- Based on a set of 30 weather pattern definitions.
 - Can be merged into 8 groups.
 - Daily historical classifications available from 1850 to present.
- A new seamless blended multi-model provides a single, best output.
 - Combines probabilities from MOGREPS-G, ECMWF, GEFS and GloSea6.
 - Output supplies all forecast visualisations and downstream applications
 - Single best output, which speeds up the decision-making process for forecasters



Early successes

Met Office Heatwave Warnings

National Severe Weather Warning Service

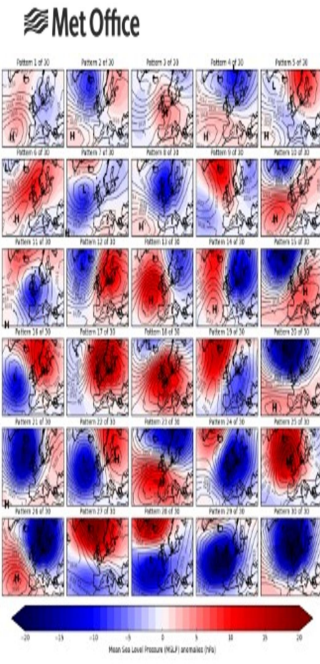
- Extreme Heat Summer 2022
- UK temperature record of 40.3C set 19 Jul 2022

Red warning Extreme Heat
 00:00 Mon 18 Jul 2022 and
 23:59 Tue 19 Jul 2022

An exceptional hot spell on Monday and Tuesday leading to widespread impacts on people and infrastructure.

What to expect

- Population-wide adverse health effects experienced, not limited to those most vulnerable to extreme heat, leading to serious illness or danger to life. Government advice is that 999 services should be used in emergencies only; seek advice from 111 if you need non-emergency health advice.
- Substantial changes in working practices and daily routines will be required
- High risk of failure of heat-sensitive systems and equipment, potentially leading to localised loss of power and other essential services, such as water or mobile phone services
- Significantly more people visiting coastal areas, lakes and rivers, leading to an increased risk of water safety incidents
- Delays on roads and road closures, along with delays and cancellations to rail and air travel, with significant welfare issues for those who experience even moderate delays



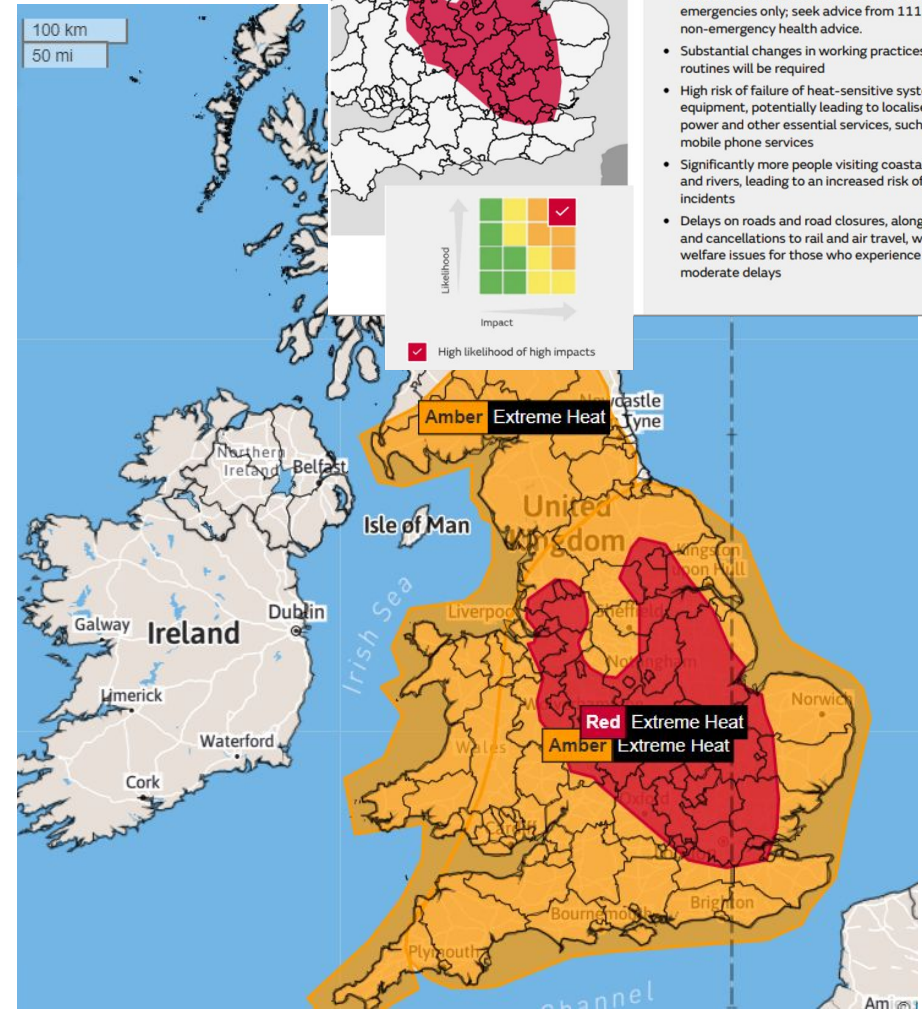
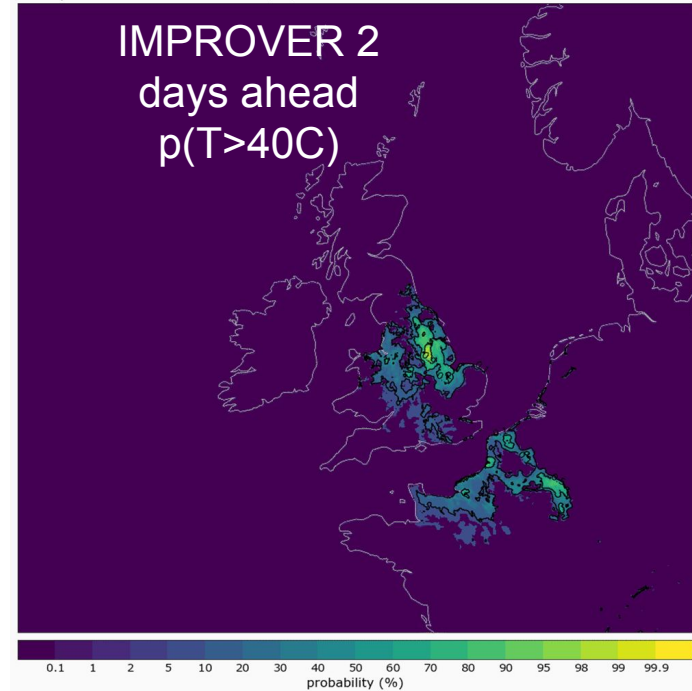
Day	Month	Weather pattern	Day	Month	Weather pattern
1	July	10	1	August	2
2	July	10	2	August	2
3	July	10	3	August	4
4	July	13	4	August	13
5	July	13	5	August	13
6	July	13	6	August	18
7	July	13	7	August	6
8	July	18	8	August	6
9	July	18	9	August	12
10	July	6	10	August	10
11	July	12	11	August	6
12	July	10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

Predominantly high-pressure dominating types throughout July with no sudden transitions in large-scale regime

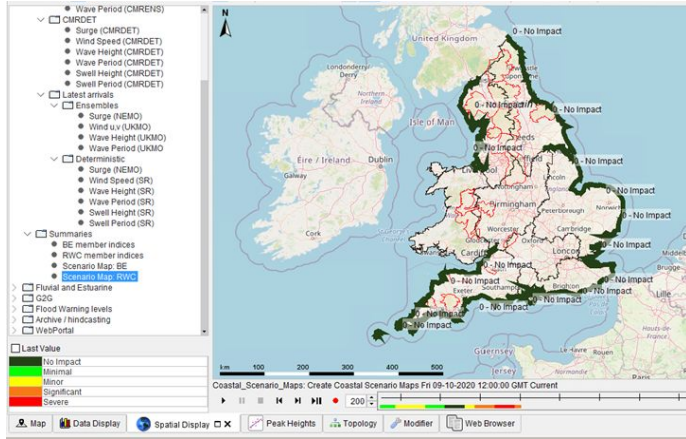
Temporary transition to more unsettled types in mid-August

Easterly dominating high-pressure types at the end of August

Probability of Temperature at Screen Level Daytime Max > 40 °C 12 hr
 Valid at 2100 UTC on Tue 19/07/2022
 IMPROVER Multi-Model Blend
 Last Updated at 0715 UTC on Sun 17/07/2022

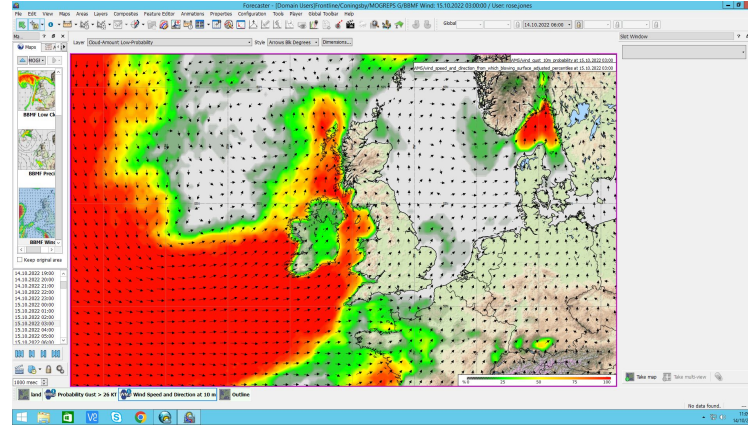


Observed weather patterns in July and August
 (Based on the 1200 UTC Met Office Global Model analysis)



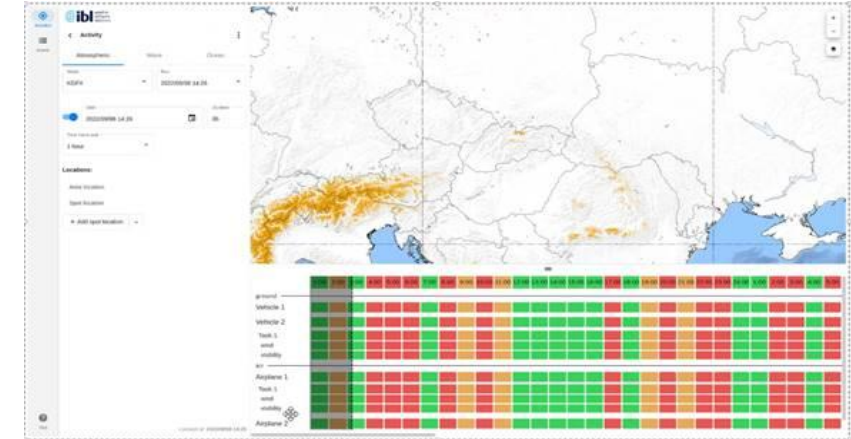
Ensemble-driven flood impacts decision tools

- Likelihood and impact of coastal flooding across a 7 day period
- Uses MOGREPS-G & Nemo Surge (driven by MOGREPS G) data.
- Alert for local authorities with increased notice, to trigger action to keep the public safe.



Ensemble-driven planning products

- Red Amber Green probability of occurrence of a customer specified threshold
- Used for planning military flying of fragile WW2 aircraft.
- Product re-designed (from a deterministic, manually-created risk table, to automated MOGREPS-UK feed with great success. [p(gust>26kt)]



Newly developed tools to exploit ensembles

- Military MetOc Visualisation Hub (MMVH)
- A web-based tool developed for the British military to ensure access to meteorological data, despite data volumes, even with bandwidth limitations.
- It has allowed us to developed novel ways to display and utilise ensembles.

2023 UK Summer Testbed

*Aurore Porson, Rosie Jones, Dan Suri (Met Office)
Simon Peatman (University of Leeds)*

- Proven concept for accelerating the development of new tools and forecasting techniques.
- Inter-disciplinary and cross-organisational teams: researchers, developers and users (including the Met Office Operational Centre) from Met Office, NOAA and Met Office Academic Partnership universities.
- Aims: (i) accelerating the operational use of ensembles and (ii) determining the strengths of ensembles *versus* deterministic modelling.
- Focus on severe convection.
- A typical day at the test bed: daily situational awareness & scene setting by OpMet, followed by scheduled activities.
- Six activities: Forecasting Denial Experiment, IMPROVER, WesCon, Post-event Ensemble Evaluation, Post-event Surface Water Flooding and Sub-km ensemble modelling.
- Inspired by NOAA Hazardous Weather Testbed.

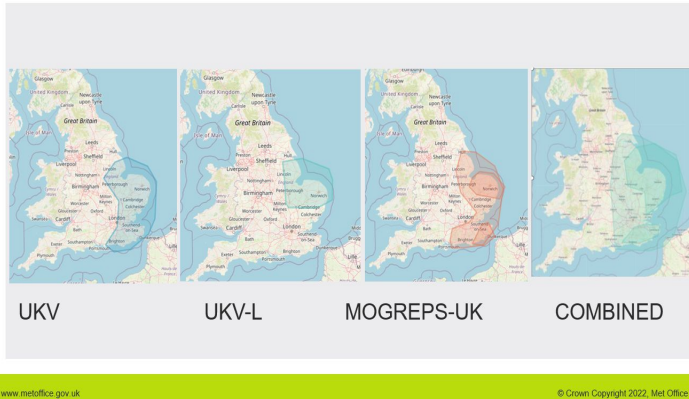
Met Office

Schedule



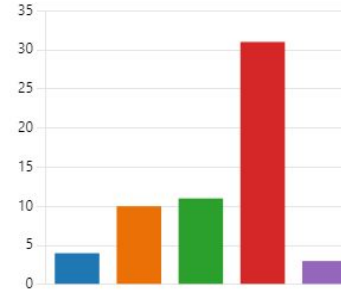
FDE-based forecasts

Met Office All 3 groups of polygons issued- Monday 17th July 2023

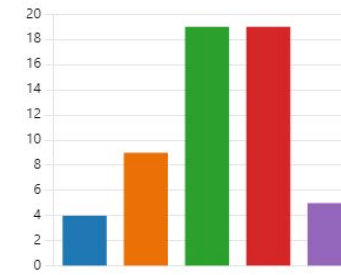


How useful was IMPROVER compared to your previous source of forecasting data?

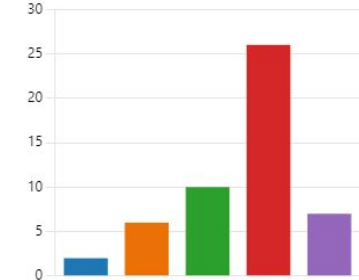
Shower location



Shower intensity



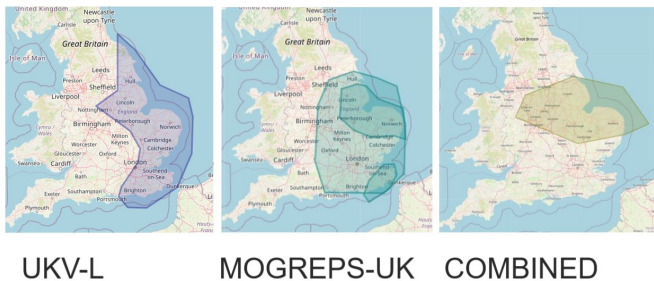
Lightning



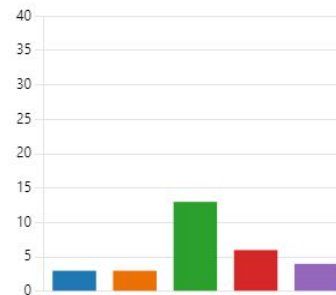
IMPROVER-based forecasts

Met Office

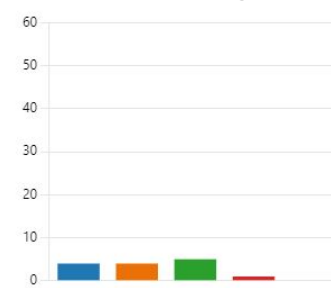
All three groups IMPROVER polygons issued 17th July 2023



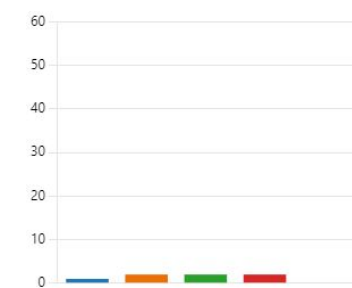
Hail



Wind speed/gust



Max .Temperatures



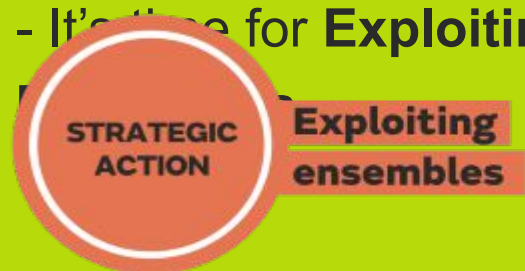
(1 not useful, 5 very useful)

After the FDE, same groups of participants use IMPROVER data and assess whether this new information would make them re-issue the forecast polygons initially drawn without IMPROVER data.

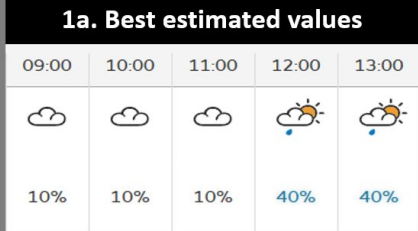
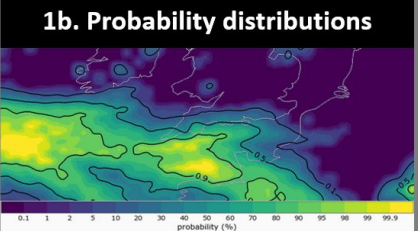
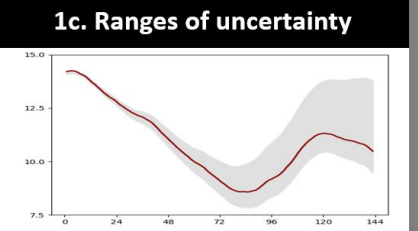
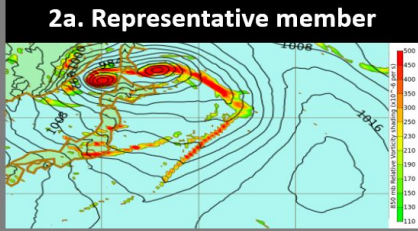
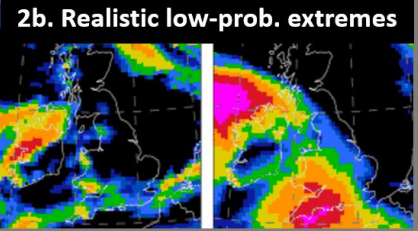

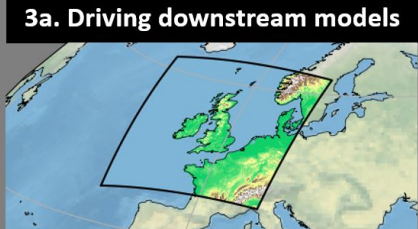

Thank You!

rosa.barciela@metoffice.gov.uk

- The full value of ensemble prediction remains to be exploited and achieved.
- Science is proven.
- Potential benefits are demonstrated ...with good examples of use cases.
- It's time for **Exploiting**



Classes of use cases for ensembles

1) Use cases for ensemble stats	1a. Best estimated values 	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? 