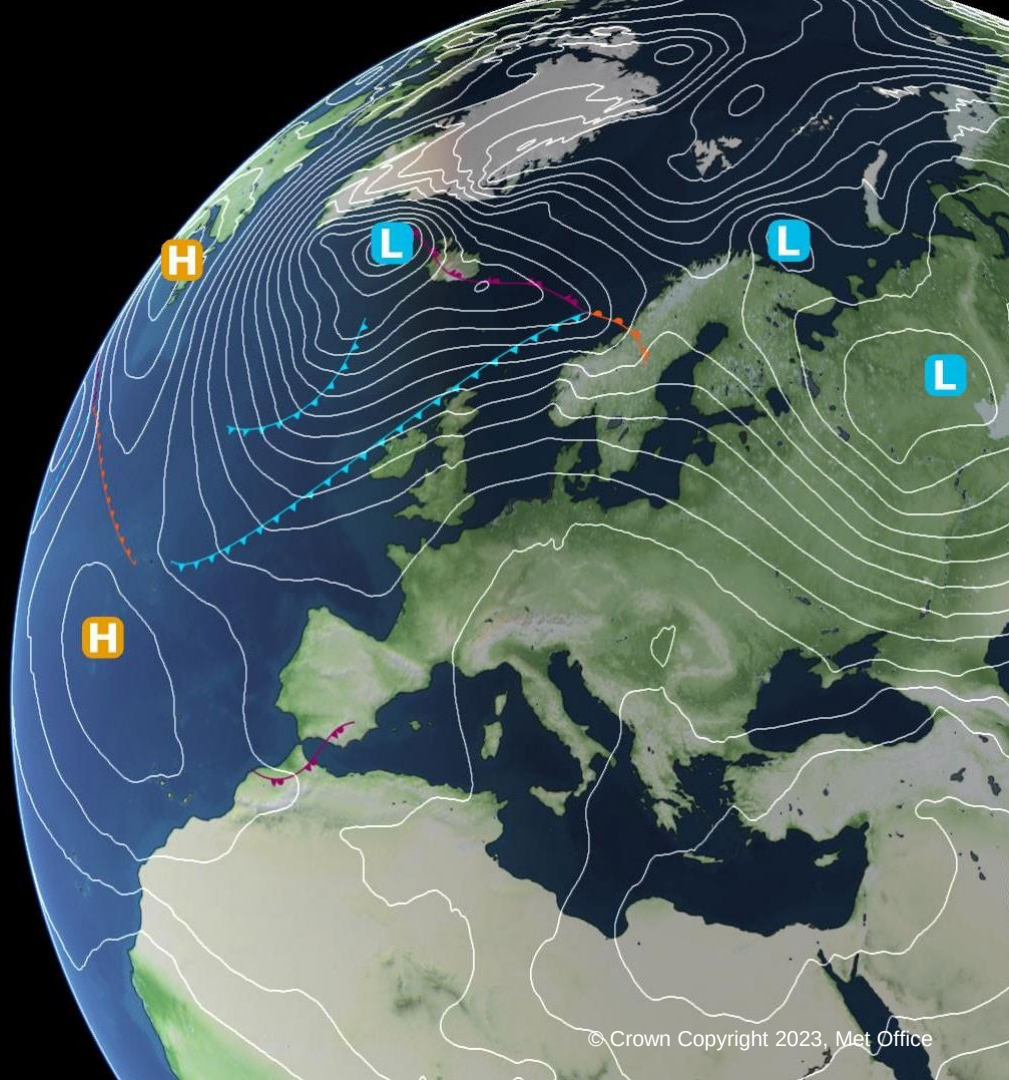
Use of ECMWF ensembles within a new seamless blended multi-model version of the Decider weather pattern forecasting tool

Robert Neal

With thanks to several colleagues from the Flood Forecasting Centre, Guidance Unit, Media Team and Science area of the Met Office.



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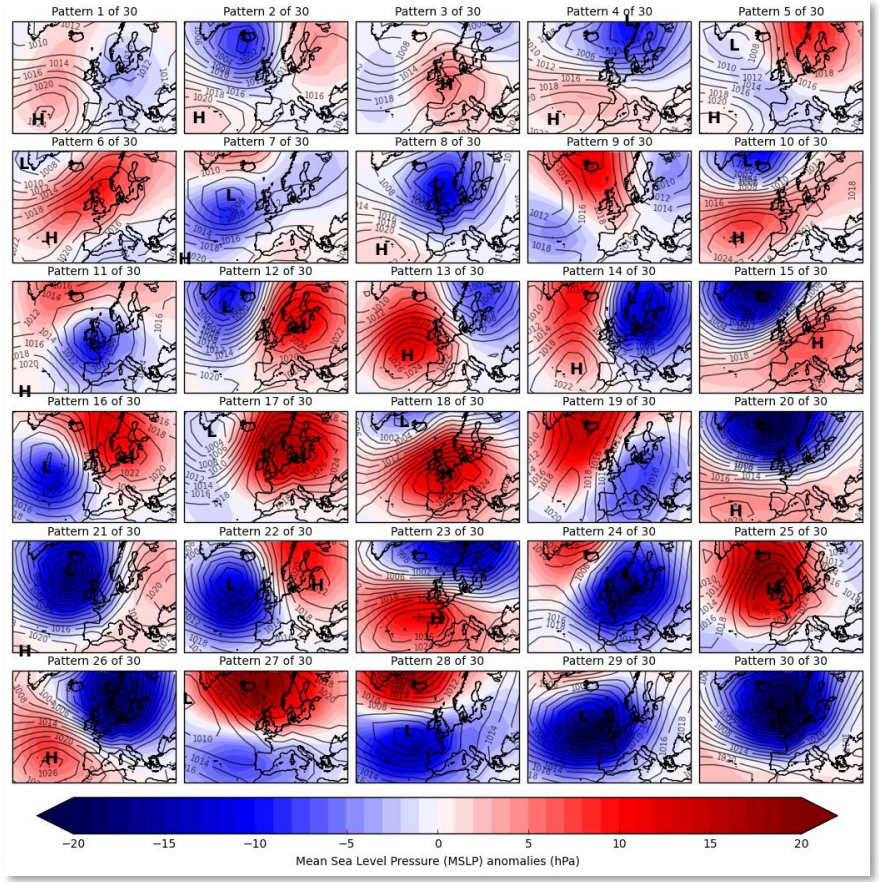
1. What is Decider?

What is Decider?

- 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.



Weather pattern definitions from Neal *et al.* (2016) in *Meteorol. Appl.*

2. New seamless blended multi-model weather pattern forecasts

Implemented operationally in July 2022

Multi-model configuration

seamless

One forecast which can be used out to any lead time (1 to 45 days)

blended

Models are blended in and out at different lead times

multi-model

Taking a weighted average of probabilities from several models

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

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Model weights

	MOGREPS-G (36 members)	ECMWF	GEFS	ECMWF extended-range	GLOSEA
Day 1	0.3333	0.3333	0.3333	0.0000	0.0000
Day 2	0.3333	0.3333	0.3333	0.0000	0.0000
Day 3	0.3333	0.3333	0.3333	0.0000	0.0000
Day 4	0.3333	0.3333	0.3333	0.0000	0.0000
Day 5	0.3333	0.3333	0.3333	0.0000	0.0000
Day 6	0.3000	0.3500	0.3500	0.0000	0.0000
Day 7	0.2250	0.3750	0.3750	0.0000	0.0250
Day 8	0.0000	0.4750	0.4750	0.0000	0.0500
Day 9	0.0000	0.4750	0.4750	0.0000	0.0500
Day 10	0.0000	0.4750	0.4750	0.0000	0.0500
Day 11	0.0000	0.4750	0.4750	0.0000	0.0500
Day 12	0.0000	0.4750	0.4750	0.0000	0.0500
Day 13	0.0000	0.4500	0.4500	0.0000	0.1000
Day 14	0.0000	0.4500	0.4500	0.0000	0.1000
Day 15	0.0000	0.4000	0.4000	0.1000	0.1000
Day 16	0.0000	0.0000	0.4000	0.3000	0.3000
Day 17	0.0000	0.0000	0.0000	0.5000	0.5000
Day 18	0.0000	0.0000	0.0000	0.5000	0.5000
Day 19	0.0000	0.0000	0.0000	0.5000	0.5000
Day 20	0.0000	0.0000	0.0000	0.5000	0.5000
Day 38	0.0000	0.0000	0.0000	0.5000	0.5000
Day 39	0.0000	0.0000	0.0000	0.5000	0.5000
Day 40	0.0000	0.0000	0.0000	0.5000	0.5000
Day 41	0.0000	0.0000	0.0000	0.5000	0.5000
Day 42	0.0000	0.0000	0.0000	0.5000	0.5000
Day 43	0.0000	0.0000	0.0000	0.5000	0.5000
Day 44	0.0000	0.0000	0.0000	0.5000	0.5000
Day 45	0.0000	0.0000	0.0000	0.5000	0.5000

- Models generally use equal weights
- Extended range models are slowly blended in
- ECMWF extended-range is blended in later to avoid duplication with its medium-range version*

** This will change at IFS Cycle 48r1*

Forecast probabilities

	Wed 17 May	Thu 18 May	Fri 19 May	Sat 20 May	Sun 21 May	Mon 22 May	Tue 23 May	Wed 24 May	Thu 25 May	Fri 26 May	Sat 27 May	Sun 28 May	Mon 29 May	Tue 30 May	Wed 31 May	Pattern Category	Historical frequency occurrences (April)	Historical frequency occurrences (May)	Historical frequency occurrences (June)
Pattern 1							4%	3%	2%	3%	5%	4%	5%	4%	4%	North-westerly variants	4.9%	7.9%	12.0%
Pattern 2								1%	6%	12%	9%	8%	3%	5%	5%	South-westerly variants	4.6%	6.8%	9.4%
Pattern 3										1%		2%				High pressure over UK	3.9%	6.5%	8.7%
Pattern 4								3%	2%	1%	4%	2%	1%	1%	2%	NAO+	4.5%	5.7%	6.7%
Pattern 5								1%	3%	11%	13%	12%	20%	11%	11%	Scandinavian high	4.4%	6.0%	7.0%
Pattern 6				2%	3%	23%	14%	7%	16%	21%	26%	24%	23%	25%	26%	NAO-	5.5%	6.8%	7.2%
Pattern 7																Low west of Ireland	4.7%	7.9%	9.3%
Pattern 8									1%	2%						NAO+	4.6%	5.4%	6.0%
Pattern 9													1%	5%	3%	NAO-	5.5%	8.0%	6.0%
Pattern 10	100%	99%	92%	98%	97%	71%	62%	68%	38%	22%	16%	14%	12%	11%	6%	Azores high extension	5.9%	4.9%	5.7%
Pattern 11									1%	1%	1%	1%	1%	2%	1%	NAO-	5.0%	6.1%	4.0%
Pattern 12									2%	3%	4%	1%	2%	2%	2%	South-westerly variants	3.7%	2.9%	2.6%
Pattern 13						6%	20%	2%	4%	2%	2%	2%	2%	3%	3%	North-westerly variants	5.0%	3.3%	3.1%
Pattern 14										2%					1%	North-westerly variants	3.8%	2.1%	1.6%
Pattern 15								3%	6%	3%	4%	5%	2%	2%		South-westerly variants	2.9%	1.9%	
Pattern 16										4%	2%	5%	5%	4%	7%	Scandinavian high	3.5%	2.7%	
Pattern 17											5%	10%	10%	6%	2%	Scandinavian high	2.2%	1.6%	
Pattern 18		1%	8%						2%	1%			2%	1%	2%	High pressure over UK	2.1%	1.1%	
Pattern 19										1%			4%	3%	6%	NAO-	3.1%	1.6%	
Pattern 20								3%	10%	4%	3%		1%	1%		NAO+	2.3%	1.4%	
Pattern 21											1%					South-westerly variants	2.2%	1.7%	
Pattern 22											1%	1%		2%		Scandinavian high	3.1%	2.0%	
Pattern 23								8%	5%				1%	1%		NAO+	2.2%	1.2%	
Pattern 24																North-westerly variants	2.0%	0.8%	
Pattern 25										2%			1%	6%	5%	NAO-	2.1%	0.8%	
Pattern 26										1%						NAO+	1.6%	0.8%	
Pattern 27									2%	3%	3%	8%	4%	6%	10%	NAO-	0.9%	0.5%	
Pattern 28															1%	NAO-	1.5%	0.7%	
Pattern 29																Low west of Ireland	1.7%	0.5%	0.4%
Pattern 30																NAO+	0.7%	0.4%	0.2%

Weather pattern probabilities from the seamless blended multi-model using the 09 UTC blend time on 17th May 2023

Models used in the blend:

- **MOGREPS-G** 00 UTC run on Wed 17 May 2023
- **ECMWF** 00 UTC run on Wed 17 May 2023
- **GEFS** 00 UTC run on Wed 17 May 2023
- **ECMWF extended-range** 00 UTC run on Mon 15 May 2023
- **GloSea** 00 UTC run on Tue 16 May 2023

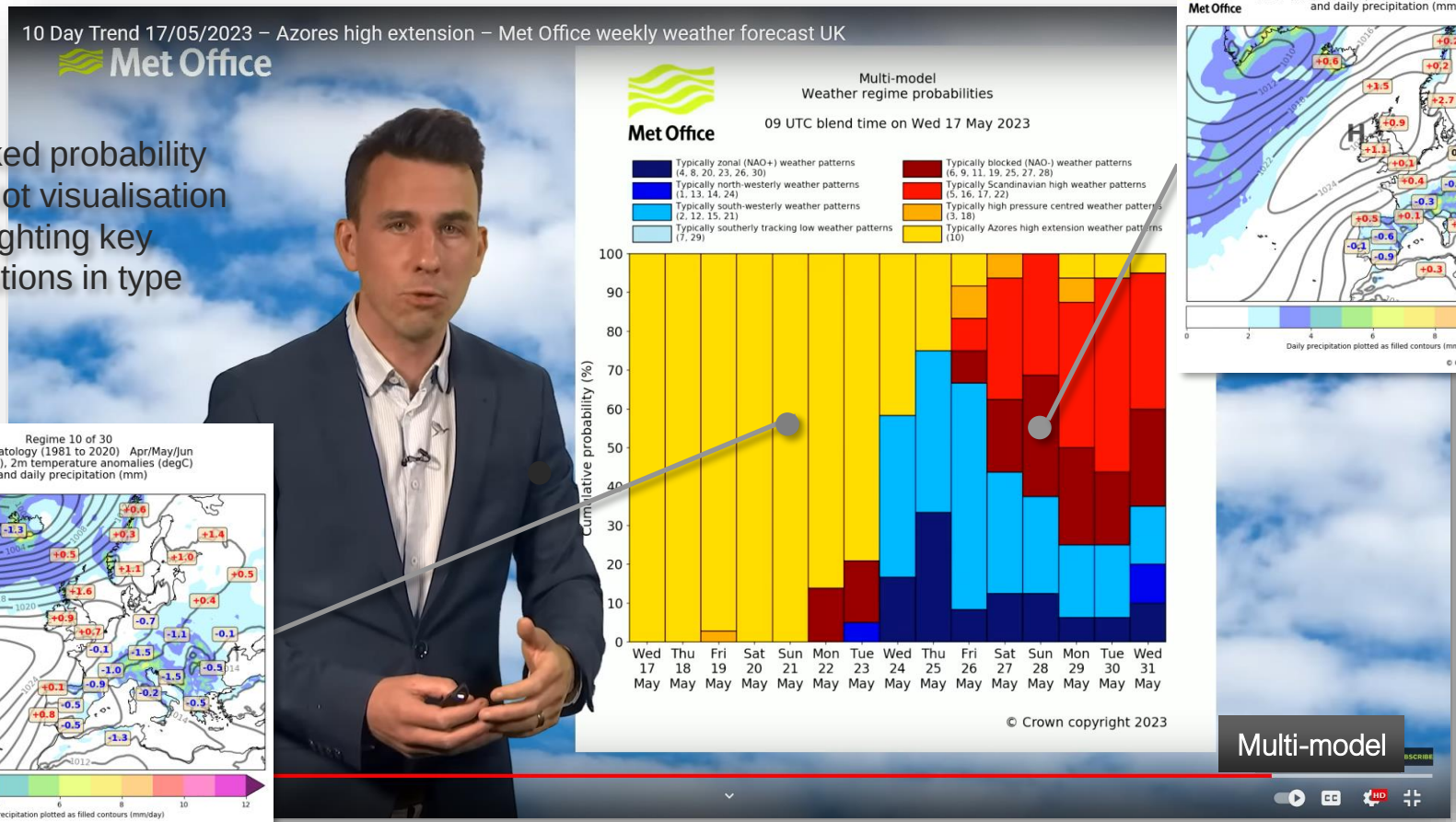
	Wed 17 May	Thu 18 May	Fri 19 May	Sat 20 May	Sun 21 May	Mon 22 May	Tue 23 May	Wed 24 May	Thu 25 May	Fri 26 May	Sat 27 May	Sun 28 May	Mon 29 May	Tue 30 May	Wed 31 May
Azores high extension	100%	99%	92%	98%	97%	71%	62%	68%	38%	22%	16%	14%	12%	11%	6%
High pressure over UK		1%	8%						2%	2%		2%	2%	1%	2%
Low west of Ireland															
NAO+								14%	18%	9%	7%	2%	2%	2%	3%
NAO-				2%	3%	23%	14%	7%	18%	27%	31%	33%	34%	47%	54%
North-westerly variants						6%	24%	6%	6%	6%	7%	7%	8%	7%	8%
Scandinavian high								1%	3%	15%	20%	27%	36%	24%	21%
South-westerly variants								4%	14%	18%	18%	15%	7%	9%	7%

Aggregated probabilities for the regime groups

The same forecast visualisation is also available out to 45 days

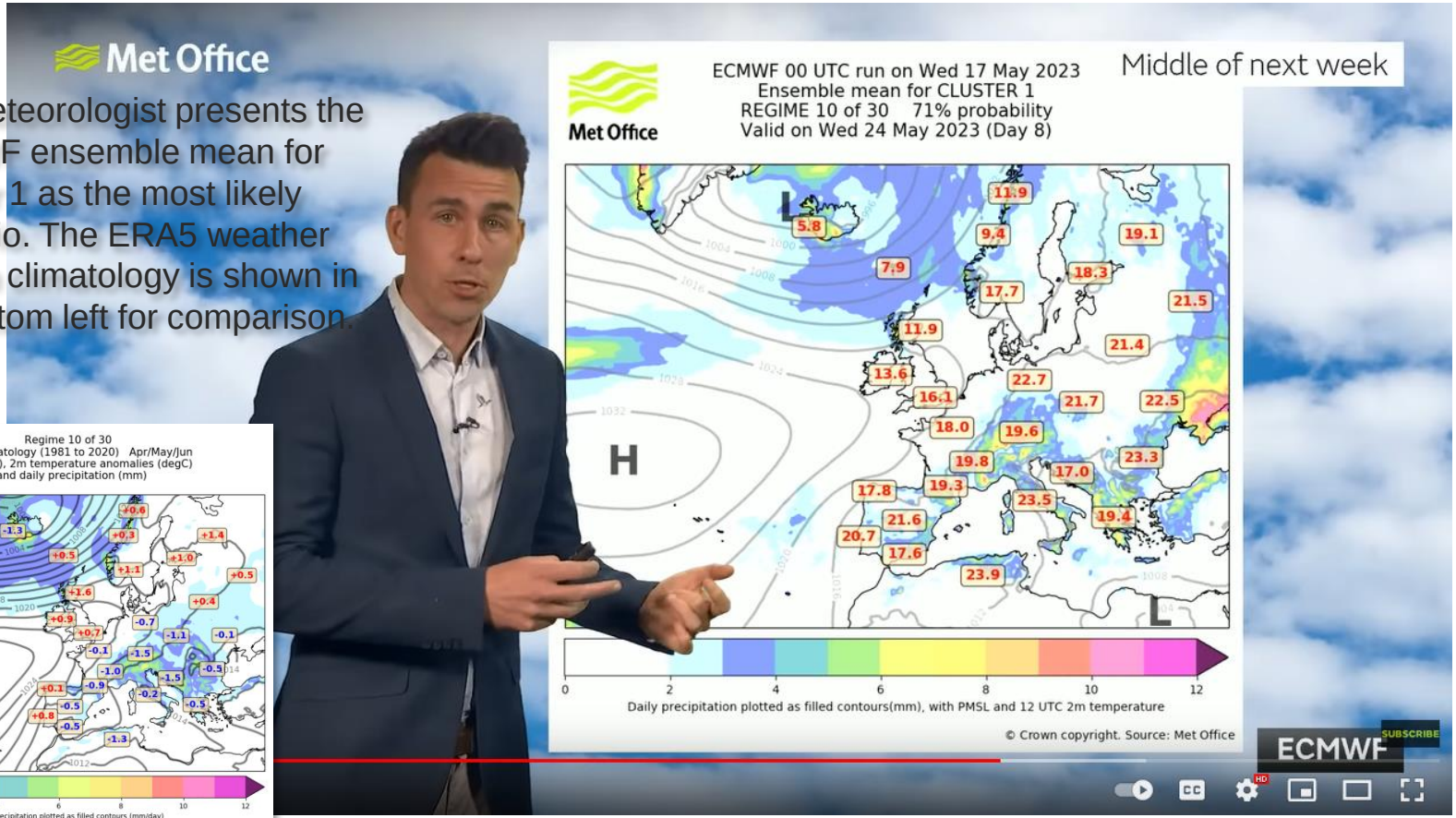
Forecast communication

Stacked probability bar plot visualisation highlighting key transitions in type



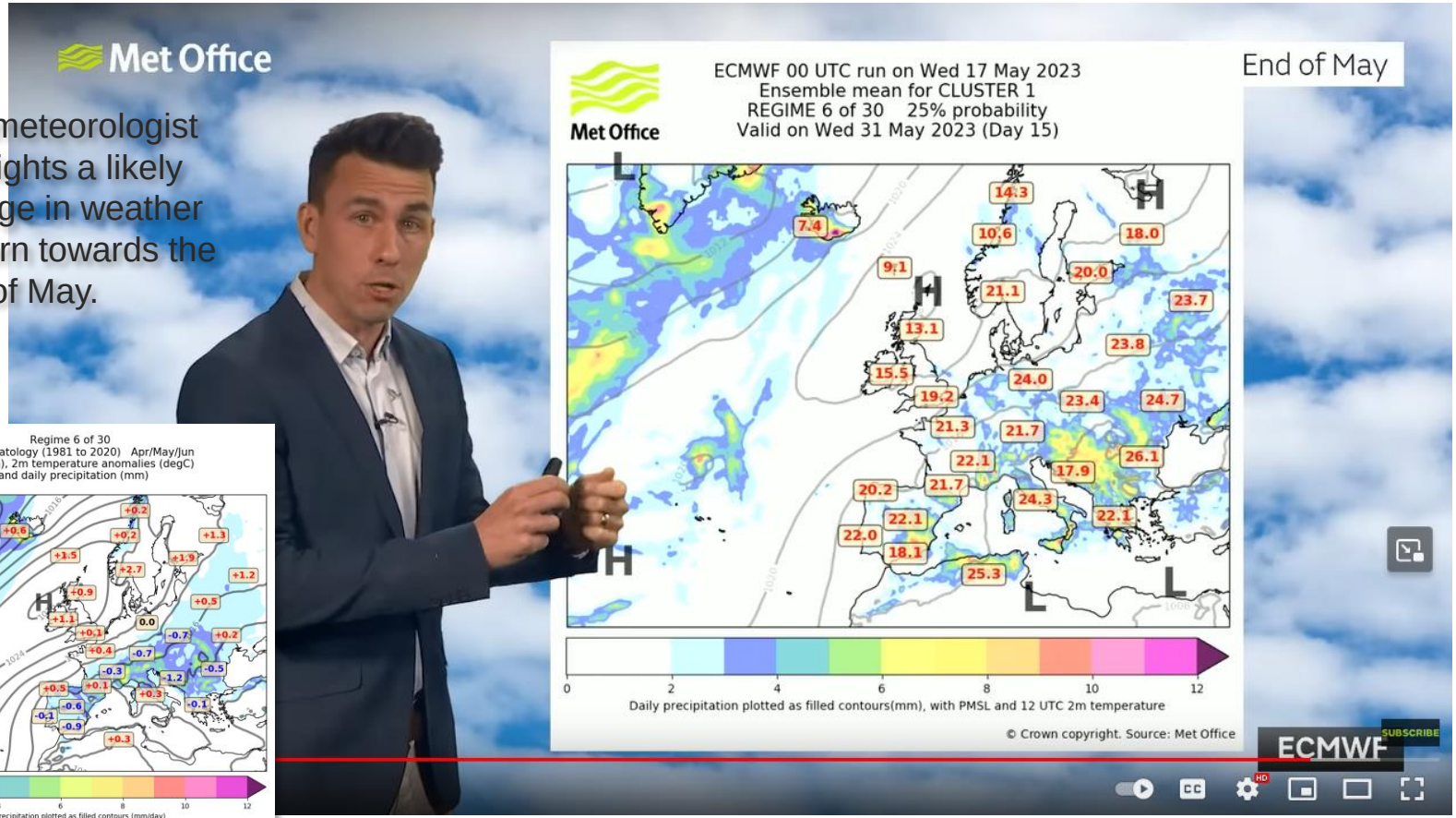
Forecast communication

The meteorologist presents the ECMWF ensemble mean for Cluster 1 as the most likely scenario. The ERA5 weather pattern climatology is shown in the bottom left for comparison.



Forecast communication

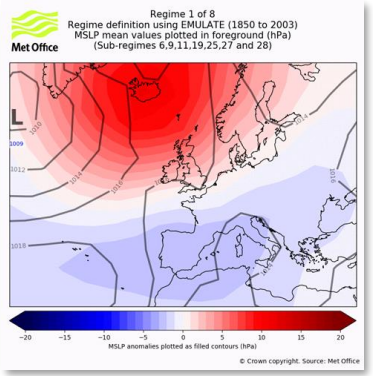
The meteorologist highlights a likely change in weather pattern towards the end of May.



3. Verification

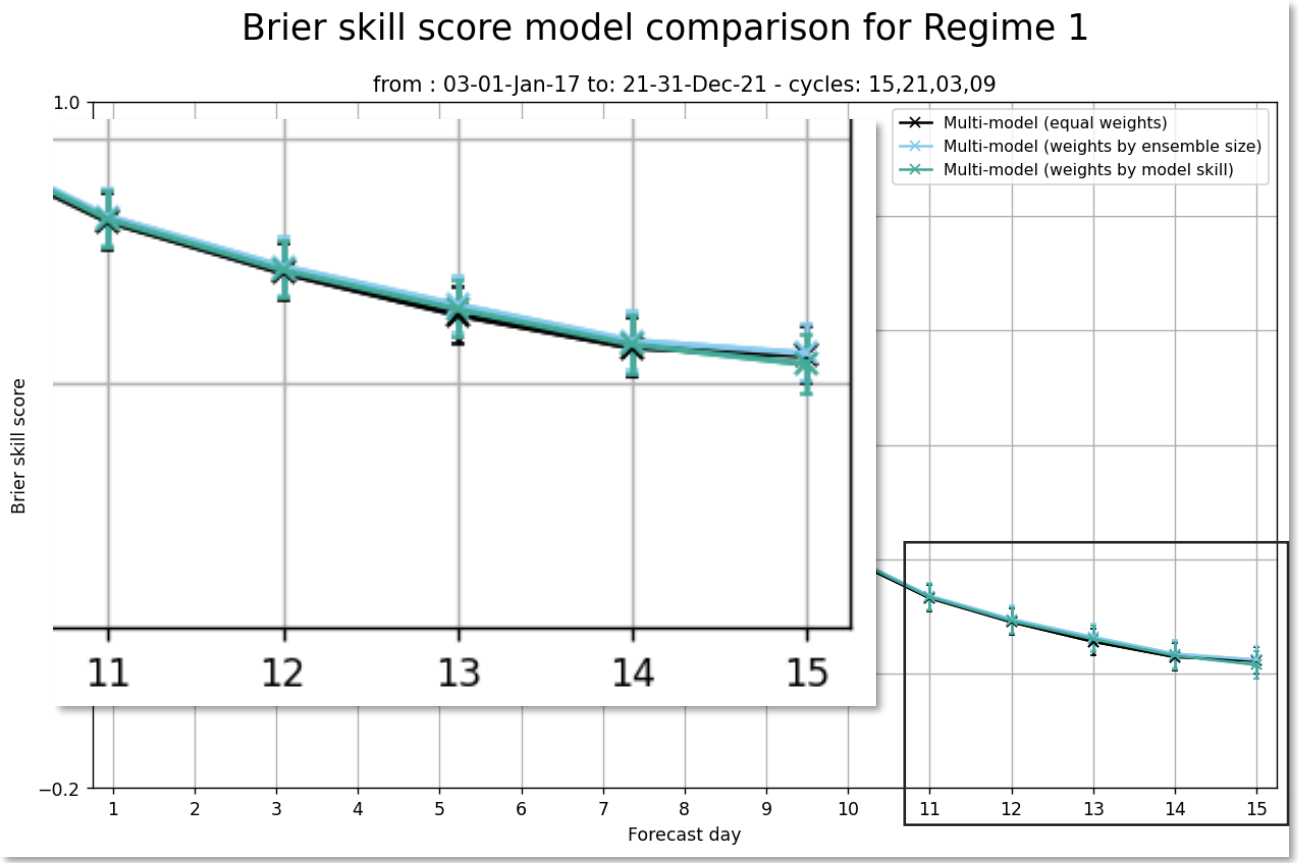
- Weather pattern forecast probabilities have been verified against observed weather patterns using ERA5
- 5-year period covering 2017 to 2021
- We focus on the BSS of different weather pattern groups (regimes) and look at the skill of the multi-model in comparison to individual models
- We also look at how varying model weights changes forecast skill

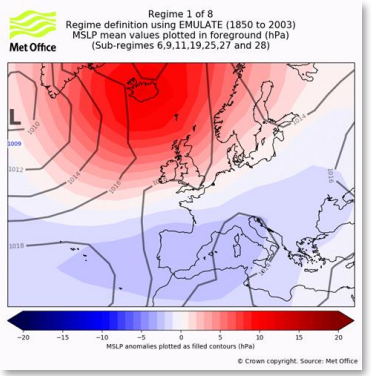
Regime 1 (NAO-) model comparison Using equal weights



- The multi-model has the best forecast skill for most lead-times, closely followed by ECMWF.

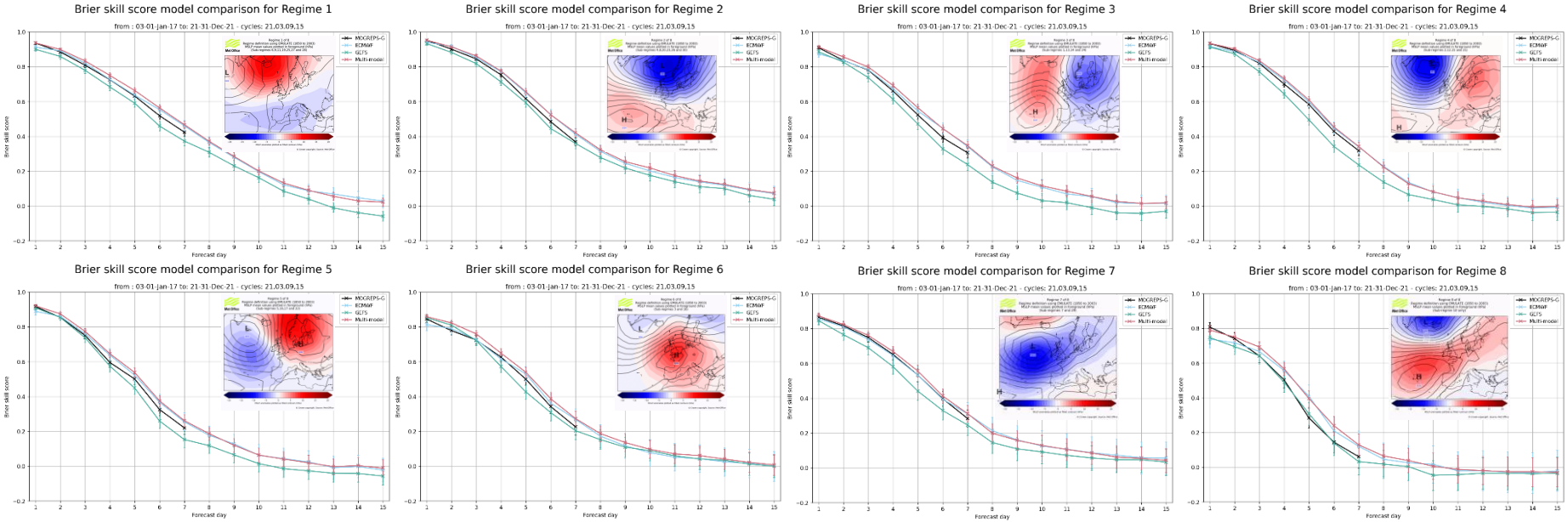
Regime 1 (NAO-)
Model weight comparison





- Weights by ensemble size marginally better at longer lead times.
- Overall there is very little in it.

Model comparison for each regime
Using equal model weights



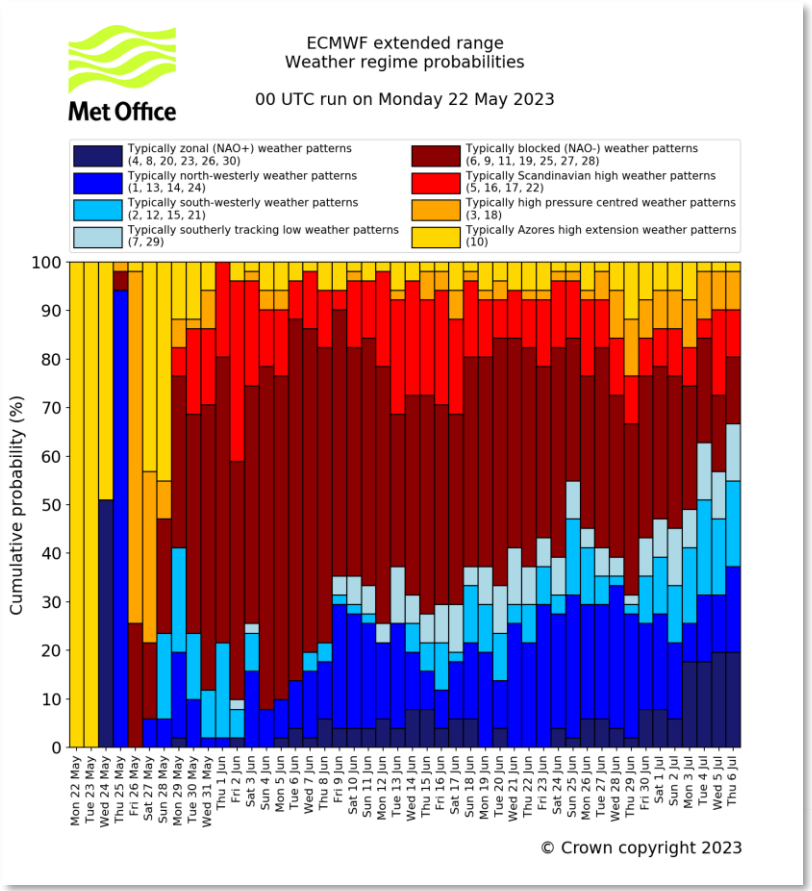
- Multi-model typically at least as good as, if not better than the best performing individual model
- Regime 2 (NAO+) has best forecast skill
- Regime 8 (Azores high) has the lowest forecast skill
- Skill is better in winter than summer (not shown)
- Skill close to climatology from day 15, however beyond this lead time different verification methods are more appropriate.

4. Future use of ECMWF's 101-member extended-range ensemble

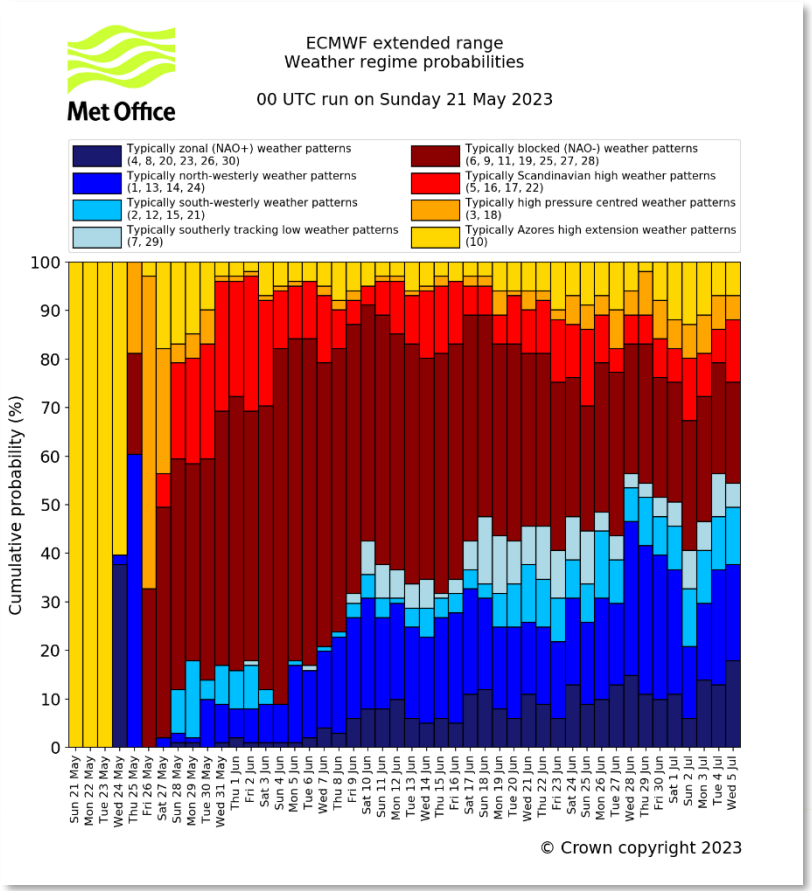
From IFS Cycle 48r1

51-member / 101-member comparison

51-member run on Monday 22nd May 2023



101-member run on Sunday 21st May 2023



Proposed new model weights

	MOGREPS-G (36 members)	ECMWF	GEFS	ECMWF extended-range	GLOSEA
Day 1	0.3250	0.3300	0.3250	0.0200	0.0000
Day 2	0.3200	0.3200	0.3200	0.0400	0.0000
Day 3	0.3100	0.3200	0.3100	0.0600	0.0000
Day 4	0.3050	0.3100	0.3050	0.0800	0.0000
Day 5	0.3000	0.3000	0.3000	0.1000	0.0000
Day 6	0.2900	0.3000	0.2900	0.1200	0.0000
Day 7	0.1450	0.3600	0.3550	0.1400	0.0000
Day 8	0.0000	0.4200	0.4200	0.1600	0.0000
Day 9	0.0000	0.4050	0.4050	0.1800	0.0100
Day 10	0.0000	0.3900	0.3900	0.2000	0.0200
Day 11	0.0000	0.3600	0.3600	0.2500	0.0300
Day 12	0.0000	0.3300	0.3300	0.3000	0.0400
Day 13	0.0000	0.2750	0.2750	0.4000	0.0500
Day 14	0.0000	0.2150	0.2100	0.5000	0.0750
Day 15	0.0000	0.1080	0.1920	0.6000	0.1000
Day 16	0.0000	0.0000	0.1500	0.7000	0.1500
Day 17	0.0000	0.0000	0.0000	0.8000	0.2000
Day 18	0.0000	0.0000	0.0000	0.8000	0.2000
Day 19	0.0000	0.0000	0.0000	0.8000	0.2000
Day 20	0.0000	0.0000	0.0000	0.8000	0.2000
Day 38	0.0000	0.0000	0.0000	0.8000	0.2000
Day 39	0.0000	0.0000	0.0000	0.8000	0.2000
Day 40	0.0000	0.0000	0.0000	0.7000	0.3000
Day 41	0.0000	0.0000	0.0000	0.6000	0.4000
Day 42	0.0000	0.0000	0.0000	0.5000	0.5000
Day 43	0.0000	0.0000	0.0000	0.4000	0.6000
Day 44	0.0000	0.0000	0.0000	0.3000	0.7000
Day 45	0.0000	0.0000	0.0000	0.2000	0.8000

- Main models generally use equal weights in first 2 weeks.
- ECMWF extended-range is now blended in from day 1 as no longer a duplication of the medium-range run.
- ECMWF extended-range is given a larger weight compared to GloSea at similar lead times.

101-member use within the blend

09 UTC blend time on Monday 22nd May 2023

Operational setup. Models used in the blend:

- MOGREPS-G (36 members) 00:00 UTC run on Mon 22 May 2023
- ECMWF 00:00 UTC run on Mon 22 May 2023
- GEFS 00:00 UTC run on Mon 22 May 2023
- ECMWF extended-range 00:00 UTC run on **Thu 18 May 2023**
- GloSea 00:00 UTC run on Sun 21 May 2023

	Mon 22 May	Tue 23 May	Wed 24 May	Thu 25 May	Fri 26 May	Sat 27 May	Sun 28 May	Mon 29 May	Tue 30 May	Wed 31 May	Thu 1 Jun	Fri 2 Jun	Sat 3 Jun	Sun 4 Jun	Mon 5 Jun	Pattern Category
Pattern 1							1%	2%	2%		1%		2%	4%	4%	North-westerly variants
Pattern 2							3%	4%	2%	3%	6%	1%	2%	1%	1%	South-westerly variants
Pattern 3						1%	8%	1%		4%	2%		1%	2%	3%	High pressure over UK
Pattern 4						2%	2%	1%				1%		1%	1%	NAO+
Pattern 5								4%	4%	6%	6%	14%	9%	9%	7%	Scandinavian high
Pattern 6					8%	9%	25%	47%	34%	25%	32%	28%	27%	28%	23%	NAO-
Pattern 7												1%	1%		1%	Low west of Ireland
Pattern 8																NAO+
Pattern 9									1%	6%	9%	10%	9%	10%	10%	NAO-
Pattern 10	100%	100%	44%		4%	39%	31%	13%	15%	6%		3%	3%	3%	3%	Azores high extension
Pattern 11										1%	1%			1%	2%	NAO-
Pattern 12							6%	8%	8%	4%	5%	1%	2%			South-westerly variants
Pattern 13				94%	6%	23%	14%	8%	4%	2%	3%	2%	8%	4%	6%	North-westerly variants
Pattern 14								1%						1%	2%	North-westerly variants
Pattern 15							2%	2%	2%			1%	1%			South-westerly variants
Pattern 16									1%	4%	4%	6%	3%	1%	2%	Scandinavian high
Pattern 17							1%	1%	10%	5%	5%	9%	6%	3%	3%	Scandinavian high
Pattern 18				9%	67%	20%	3%	3%	1%	4%			1%			High pressure over UK
Pattern 19							2%			1%		4%	4%	8%	16%	NAO-
Pattern 20																NAO+
Pattern 21																South-westerly variants
Pattern 22											1%	2%				Scandinavian high
Pattern 23			56%			4%										NAO+
Pattern 24																North-westerly variants
Pattern 25				2%	15%	2%		3%	15%	20%	14%	14%	19%	22%	11%	NAO-
Pattern 26																NAO+
Pattern 27									2%	8%	10%	2%	3%	2%	2%	NAO-
Pattern 28															1%	NAO-
Pattern 29																Low west of Ireland
Pattern 30																NAO+

Test setup. Models used in the blend:

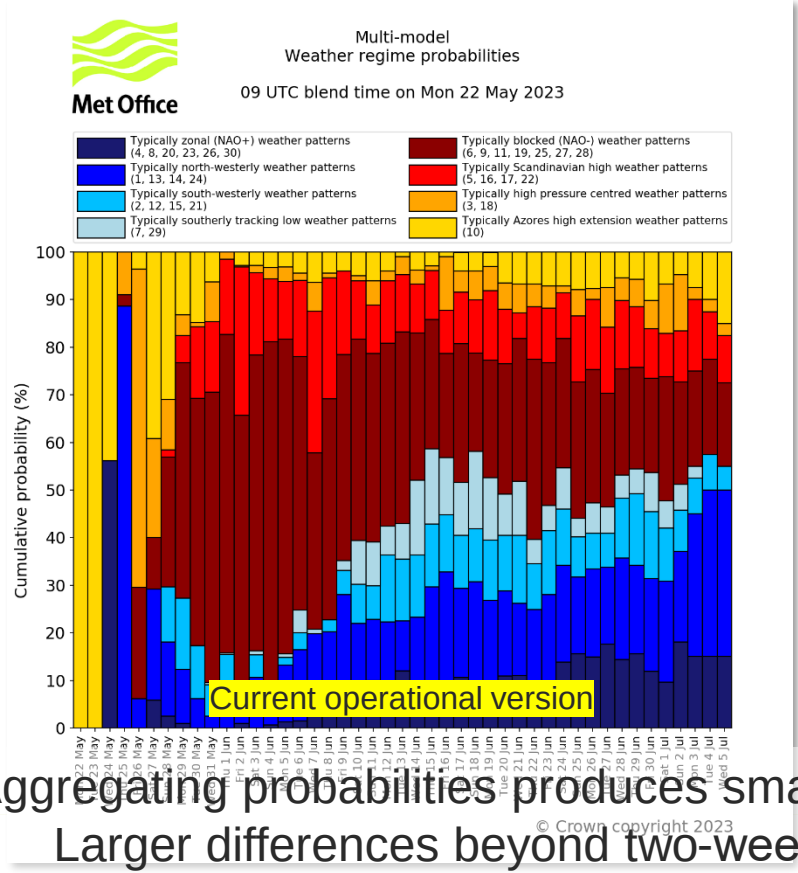
- MOGREPS-G (36 members) 00:00 UTC run on Mon 22 May 2023
- ECMWF 00:00 UTC run on Mon 22 May 2023
- GEFS 00:00 UTC run on Mon 22 May 2023
- ECMWF extended-range 00:00 UTC run on **Sun 21 May 2023**
- GloSea 00:00 UTC run on Sun 21 May 2023

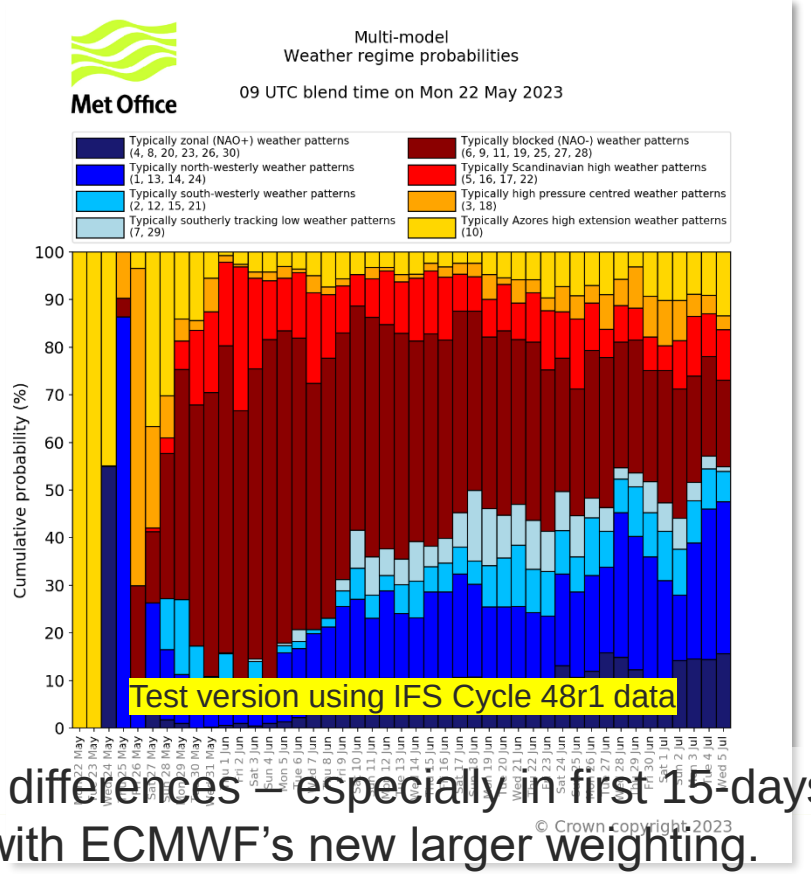
	Mon 22 May	Tue 23 May	Wed 24 May	Thu 25 May	Fri 26 May	Sat 27 May	Sun 28 May	Mon 29 May	Tue 30 May	Wed 31 May	Thu 1 Jun	Fri 2 Jun	Sat 3 Jun	Sun 4 Jun	Mon 5 Jun	Pattern Category
Pattern 1							1%	2%	2%	1%	2%	1%	4%	4%	7%	North-westerly variants
Pattern 2							3%	4%	2%	3%	6%	3%	1%		1%	South-westerly variants
Pattern 3						1%	6%	2%	1%	4%	1%		1%	1%	3%	High pressure over UK
Pattern 4						2%	2%	1%				1%		1%	1%	NAO+
Pattern 5							2%	5%	5%	8%	8%	16%	10%	8%	8%	Scandinavian high
Pattern 6					10%	13%	28%	45%	34%	26%	30%	26%	29%	35%	29%	NAO-
Pattern 7												1%	1%			Low west of Ireland
Pattern 8																NAO+
Pattern 9									2%	5%	10%	9%	9%	10%	9%	NAO-
Pattern 10	100%	100%	45%		4%	37%	30%	14%	14%	6%	1%	3%	4%	4%	3%	Azores high extension
Pattern 11										1%	2%	1%		1%	3%	NAO-
Pattern 12							6%	9%	7%	4%	4%	2%	2%		1%	South-westerly variants
Pattern 13				86%	6%	21%	14%	7%	5%	3%	3%	2%	6%	3%	6%	North-westerly variants
Pattern 14								1%						1%	2%	North-westerly variants
Pattern 15							2%	2%	1%			1%	1%			South-westerly variants
Pattern 16									1%	4%	4%	5%	4%	2%	2%	Scandinavian high
Pattern 17						1%	1%	1%	10%	4%	4%	7%	5%	2%	1%	Scandinavian high
Pattern 18				10%	67%	20%	3%	3%	1%	3%						High pressure over UK
Pattern 19							2%		1%	2%	1%	4%	4%	8%	11%	NAO-
Pattern 20																NAO+
Pattern 21																South-westerly variants
Pattern 22											1%	2%				Scandinavian high
Pattern 23			55%			4%										NAO+
Pattern 24																North-westerly variants
Pattern 25				4%	15%	2%		2%	13%	17%	12%	11%	14%	14%	9%	NAO-
Pattern 26																NAO+
Pattern 27									2%	8%	10%	5%	3%	3%	3%	NAO-
Pattern 28												1%	1%	1%	1%	NAO-
Pattern 29																Low west of Ireland
Pattern 30																NAO+

Some evidence of changing probabilities across the 30 patterns in the first 15 days

101-member use within the blend

09 UTC blend time on Monday 22nd May 2023





Aggregating probabilities produces smaller differences – especially in first 15-days.
Larger differences beyond two-weeks with ECMWF's new larger weighting.

Summary

Summary

- ECMWF ensemble data is used alongside other model output to form seamless blended multi-model weather pattern forecasts.
- This provides a single best output, which supplies all forecast visualisations and speeds up the decision-making process for forecasters.
- All multi-model variations generally perform as well as, if not better than the best performing individual model (ECMWF).
- Any benefits from flexing model weights is minimal. Therefore, equal weighting is chosen for simplicity.
- Changes have been prepared in order to incorporate the new ECMWF 101-member ensemble as soon as it becomes operational.

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Questions?

For more information please contact


www.metoffice.gov.uk/research/people/robert-neal


robert.neal@metoffice.gov.uk


0330 135 2166

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