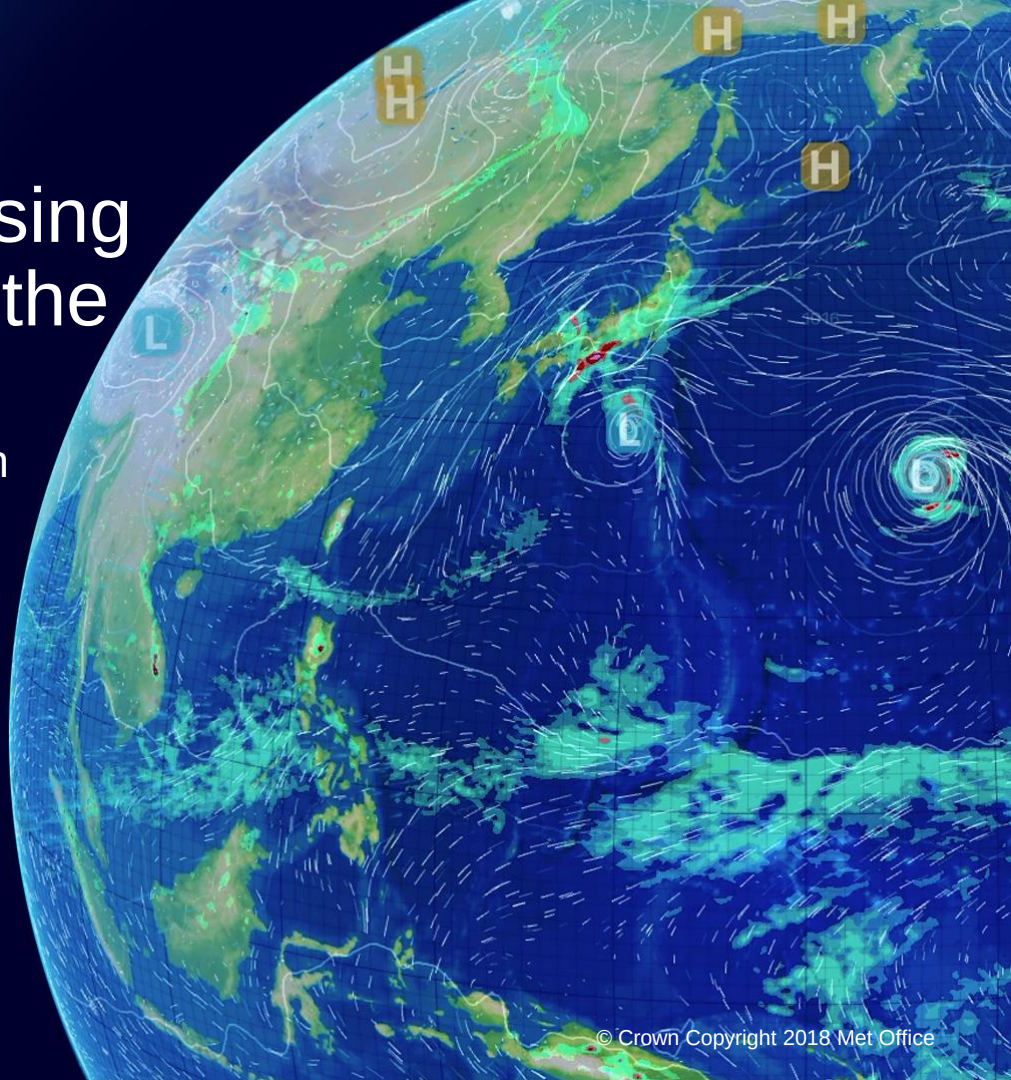
Creating a probabilistic, multi-model post-processing system (IMPROVER) at the Met Office

Gavin Evans, Nigel Roberts and Jonathan Flowerdew

European Meteorological Society Conference, Budapest 2018

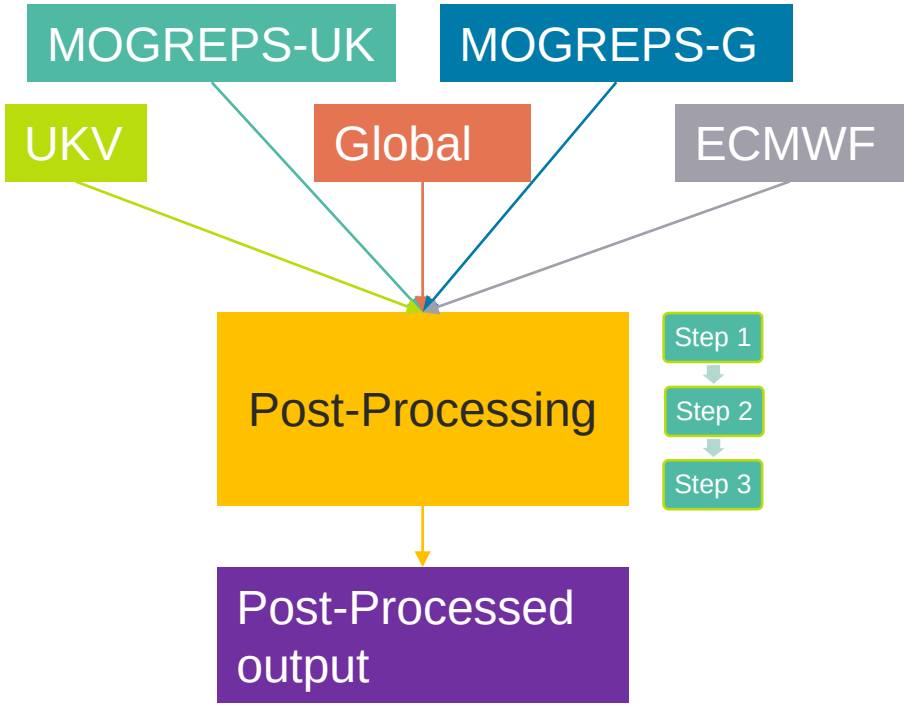
With thanks to the whole team including:
Ken Mylne, Bruce Wright, Ben Fitzpatrick, Simon Jackson, Fiona Rust, Ben Ayliffe, Caroline Jones, Stephen Moseley, Caroline Sandford, Anna Booton, Paul Abernethy, Tomek Trzeciak, Aaron Hopkinson, Laurence Beard, Katie Howard, Mark Baker, Mark Worsfold, Eleanor Smith, Clare Bysouth, Roger Harbord, Ric Crocker, Marion Mittermaier, Daniel Brierley



Motivation

- Multiple forecasts from different models
  - Difficult for a user or operational meteorologist to keep track
- Consistency between gridded and spot forecasts
- Exploit convection-permitting ensemble forecasts more effectively

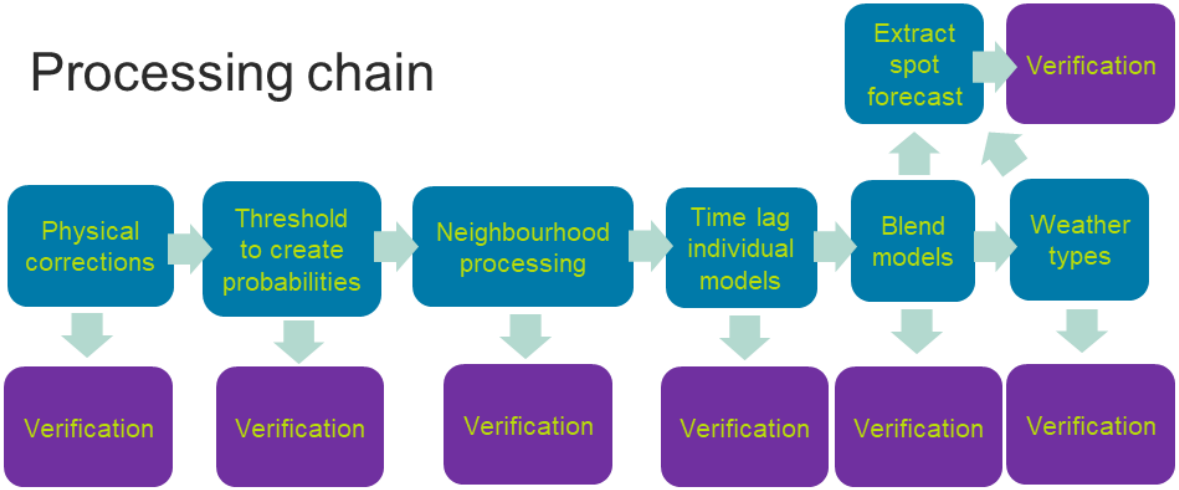
	UK	Global
Deterministic	UKV	Global
Ensemble	MOGREPS-UK	MOGREPS-G



Strategy

IMPROVER: Integrated Model post-PROcessing and VERification

IMPROVER Science

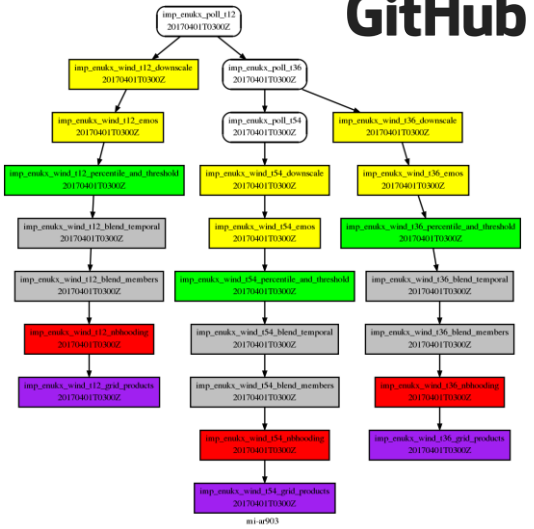


- **Single, integrated, modular processing chain, grid-based and probabilistic**
- **Sequential application of 'physical', 'statistical' and 'neighbourhood' processing**
- **Probabilistic at the core – forecasts blended using probabilities**
- **Consistent spot and gridded forecasts**
- **Fully integrated verification to measure the benefits of each stage of processing**

IMPROVER Technology

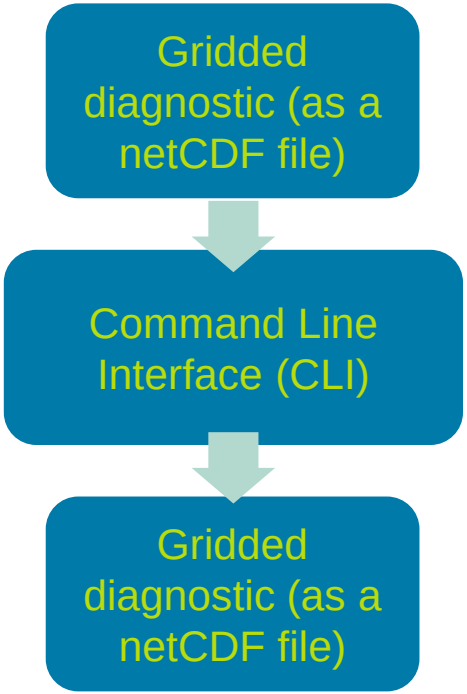
Adoption of existing standards:

- **Python-based, with use of Iris, numpy, etc**
- **CF-compliant netCDF4 data format**
- **Cylc suites, command line interfaces, pure Python**
- **Modular, unit-tested code**
- **Open source on GitHub**
- **Explore other open source tools in image processing, machine learning**



Using IMPROVER

Example usage



- Command line interfaces (CLIs) available in: https://github.com/metoppv/improver/tree/master/bin

- Example CLI call:
- `>>> improver CLI input.nc output.nc`

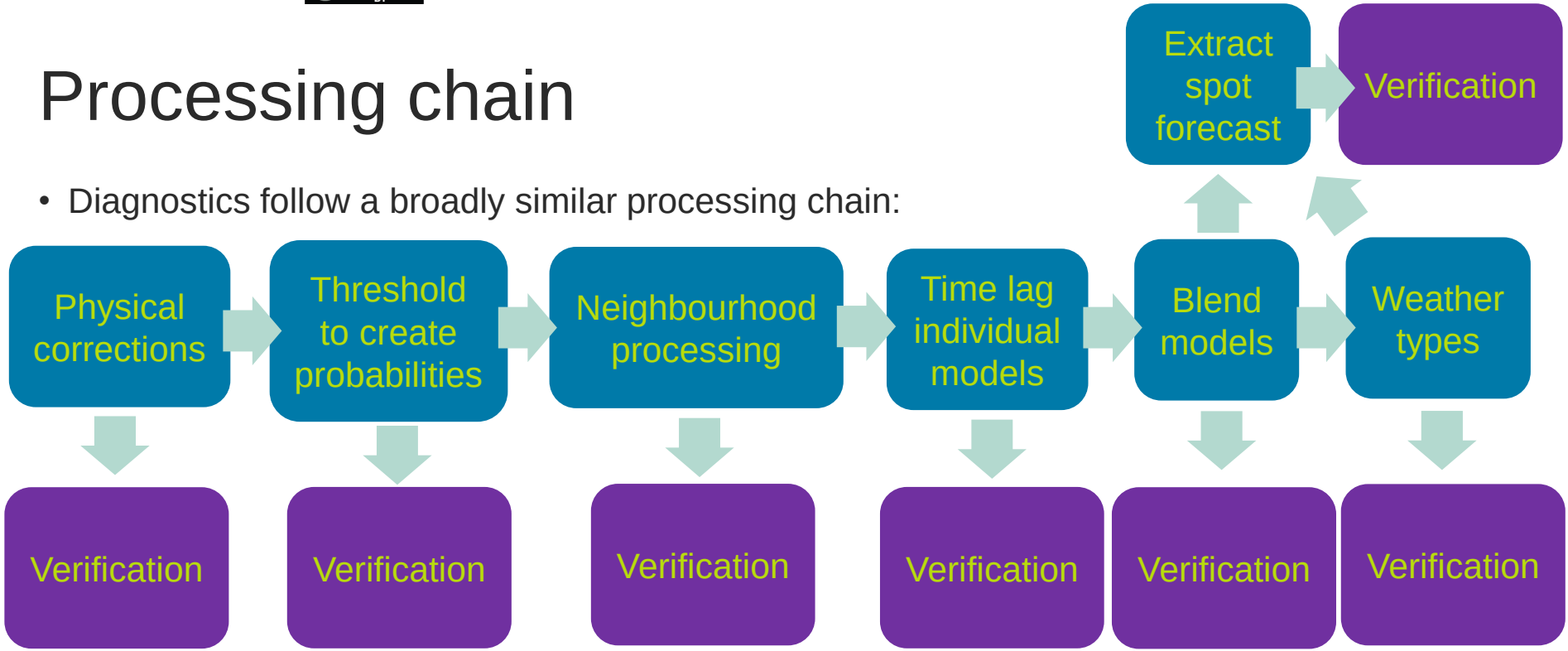
- Example CLI call for threshold CLI:
- `>>> improver threshold input.nc output.nc 10 –threshold_units m/s`

Current status

Last year's status:

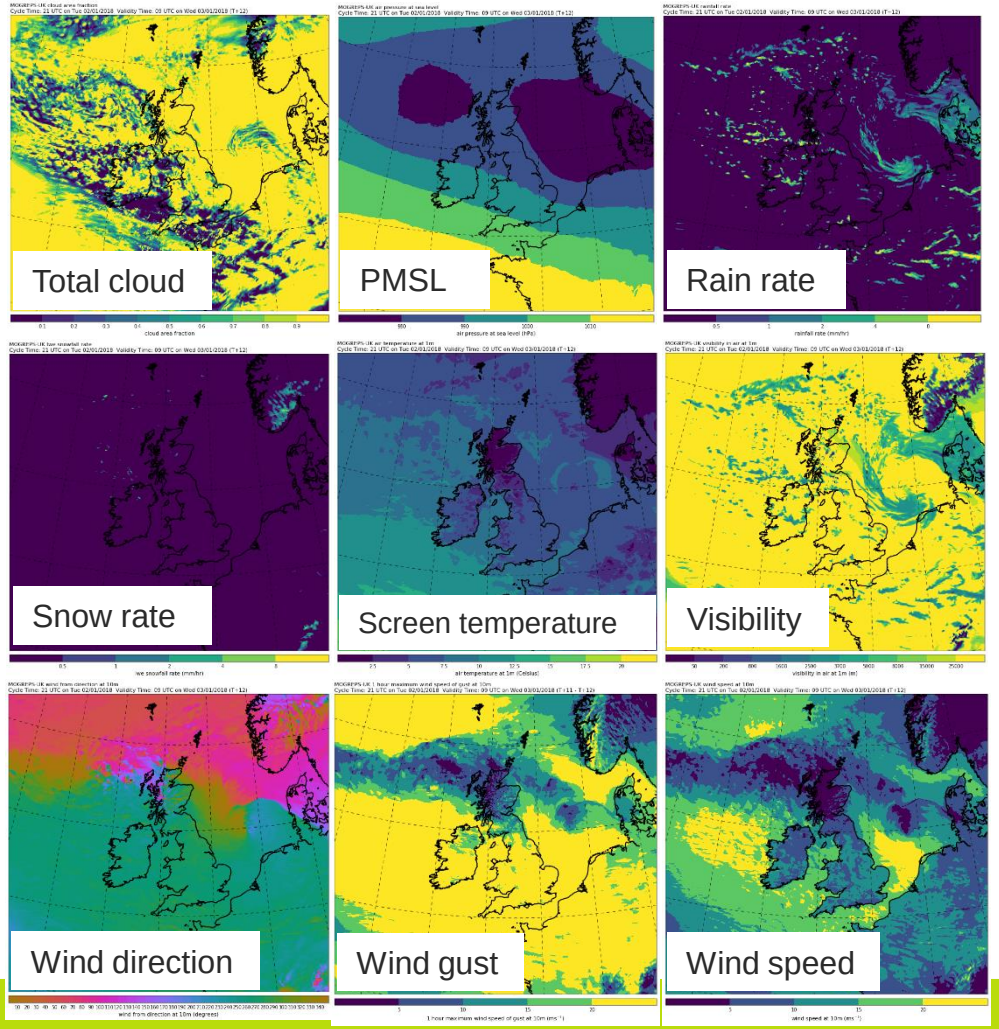
Processing chain

- Diagnostics follow a broadly similar processing chain:



Diagnostics

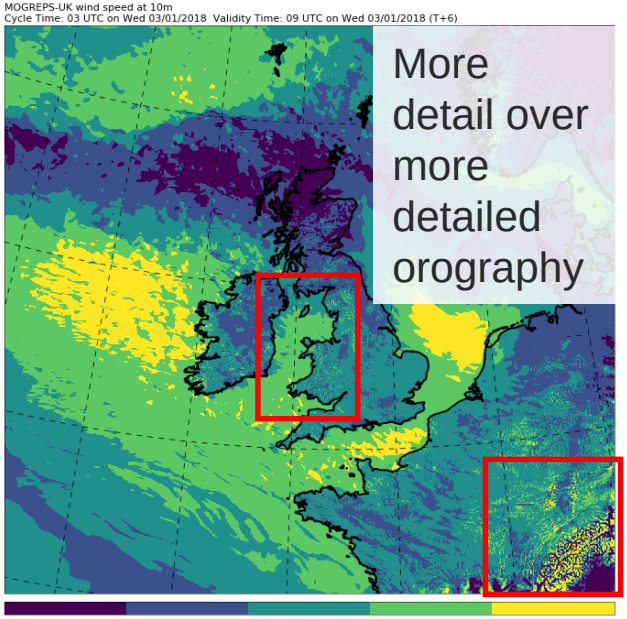
- Primarily single-level quantities:
  - Screen temperature, 10m wind speed, rain, snow, cloud, visibility
- We will add more diagnostics in the future



Physical corrections

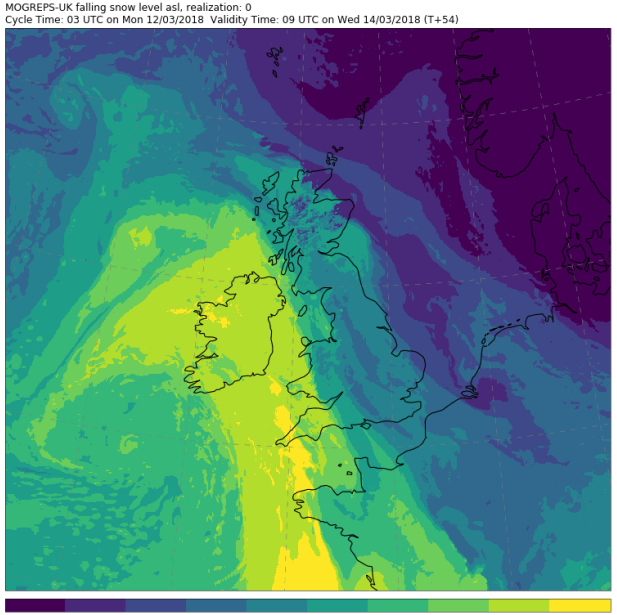
Wind downscaling

- Roughness correction
- Height correction

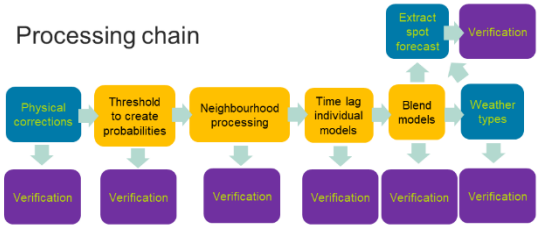


Snow falling level

- Does snow reach the surface?



Courtesy of Nigel Roberts, Fiona Rust, Caroline Jones, Stephen Moseley, Ben Ayliffe, Aaron Hopkinson



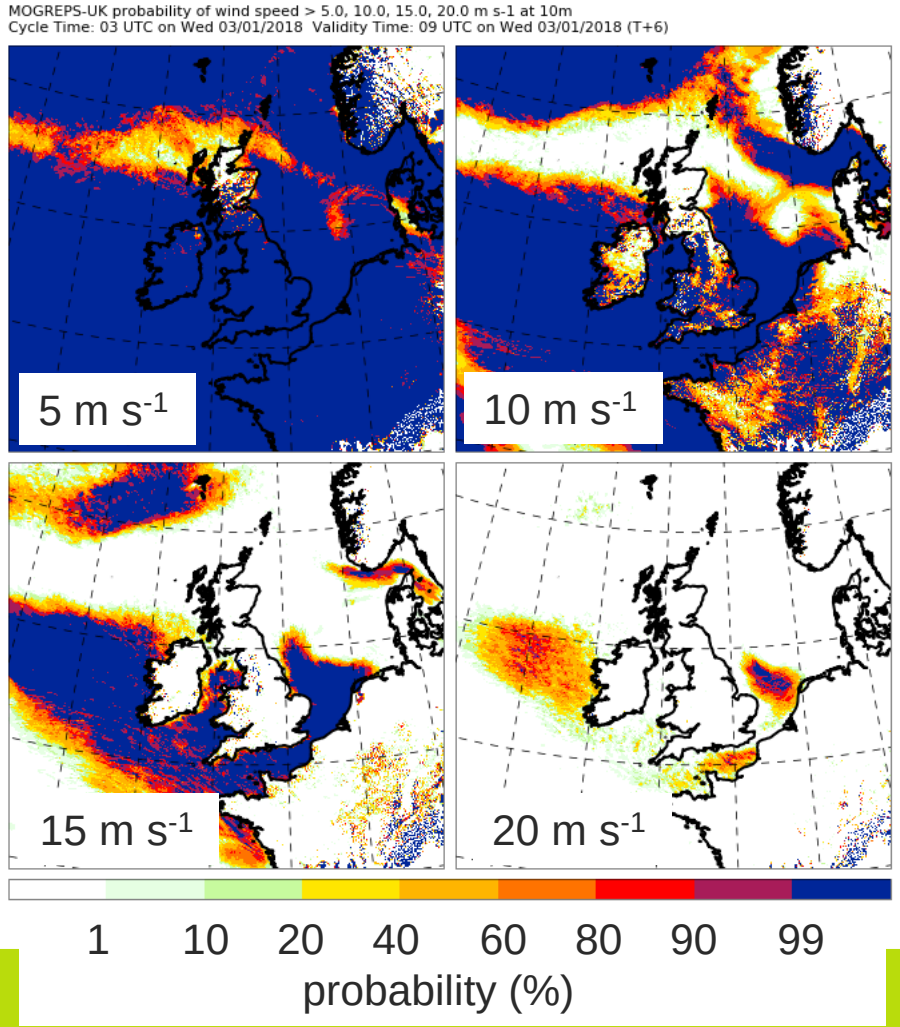
Probabilistic processing steps

Images on following slides from:

- UK ensemble (MOGREPS-UK) from 21Z on 2 January 2018
- Validity time: 3 January 2018 at 03Z (T+6)
- Storm Eleanor

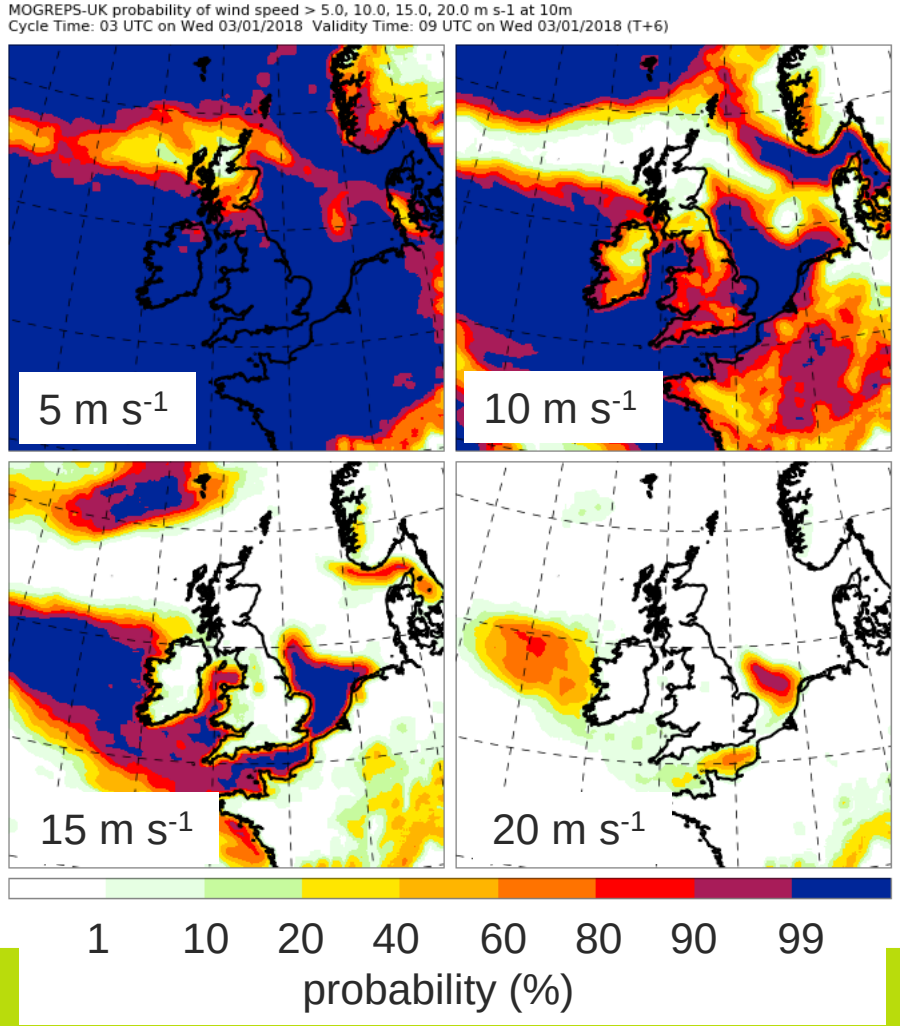
Threshold to create probabilities

- Thresholding the ensemble members creates probabilities of whether a given probability has been exceeded.
- Threshold need to be sufficiently fine to avoid information loss.



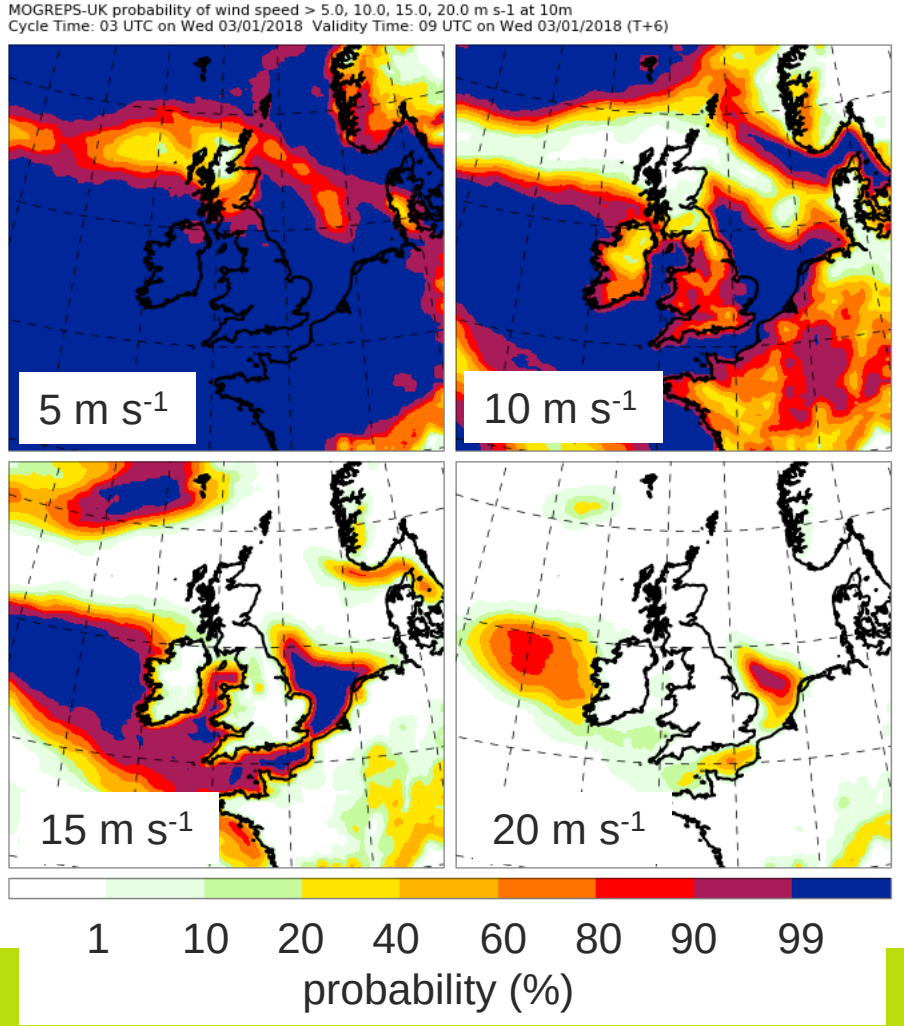
Neighbourhood processing

- Assume neighbouring grid points are equally likely forecasts for a central grid point.
- Find mean within the neighbourhood.
- Extensions: Topographic neighbourhood processing (See Fiona Rust's follow-on presentation)



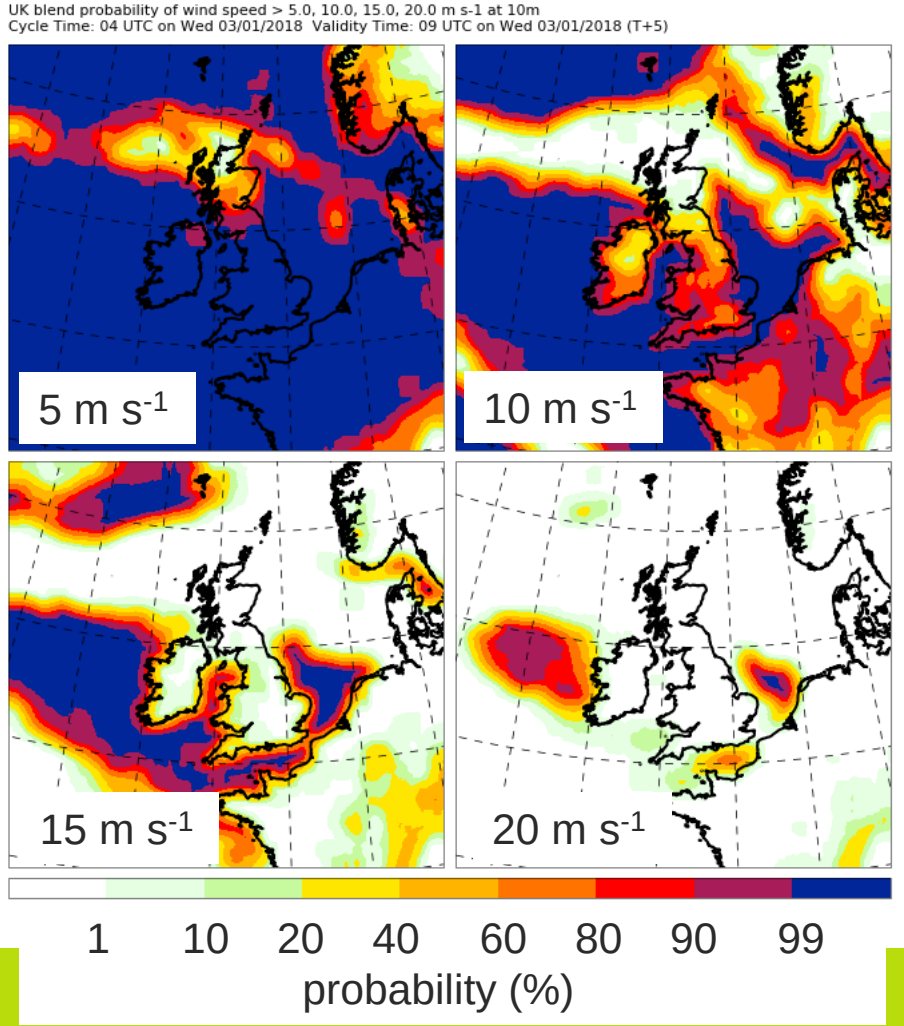
Time-lagging

- Combine two cycles with equal weights at all grid points



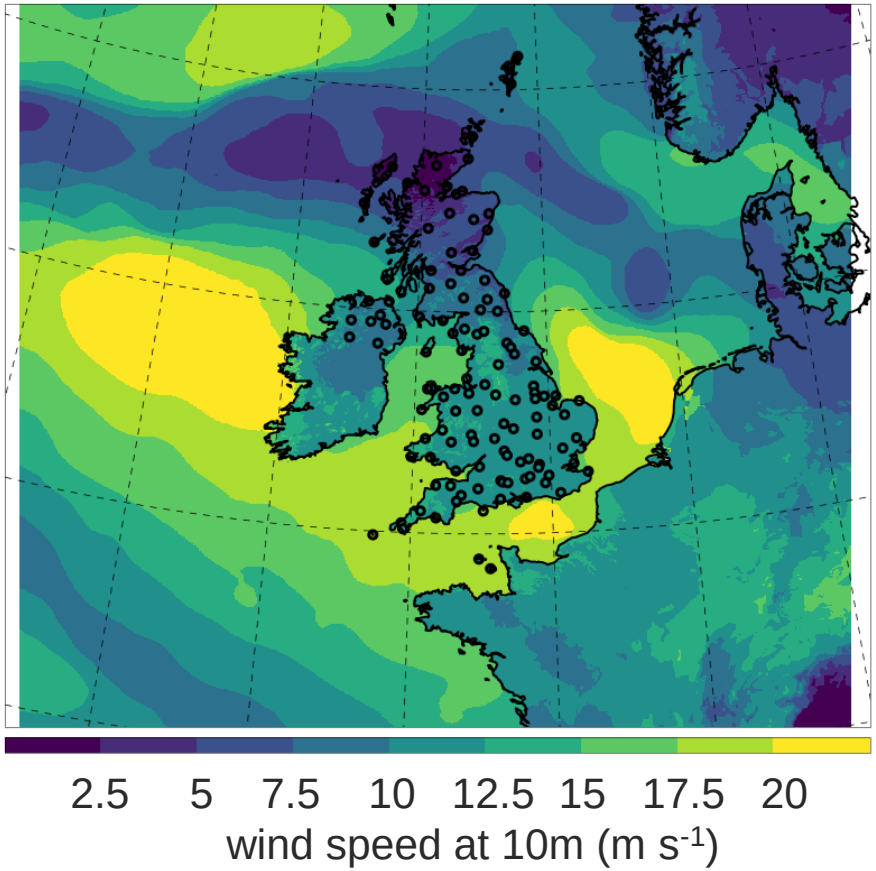
Multi-model blending

- Combine time-lagged UK ensemble and time-lagged UK deterministic



Gridded and spot consistency

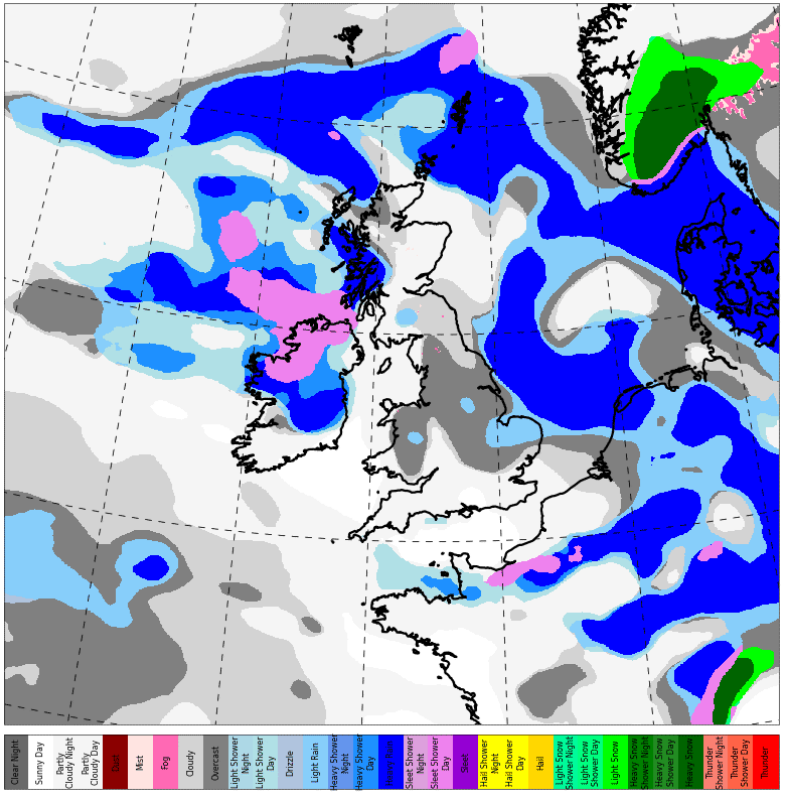
- Spot forecasts extracted directly from gridded fields, with limited site-specific post-processing, to ensure consistency.

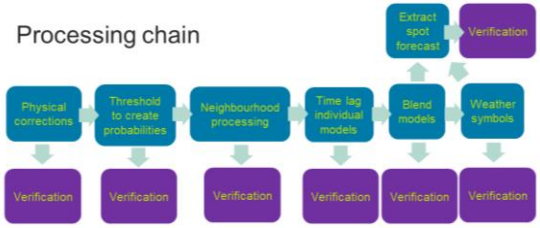


Weather types

- The weather types are calculated from multiple gridded fields.

Dark blue – heavy rain
Dark grey – overcast
Lighter grey – cloudy
Pink – sleet shower day

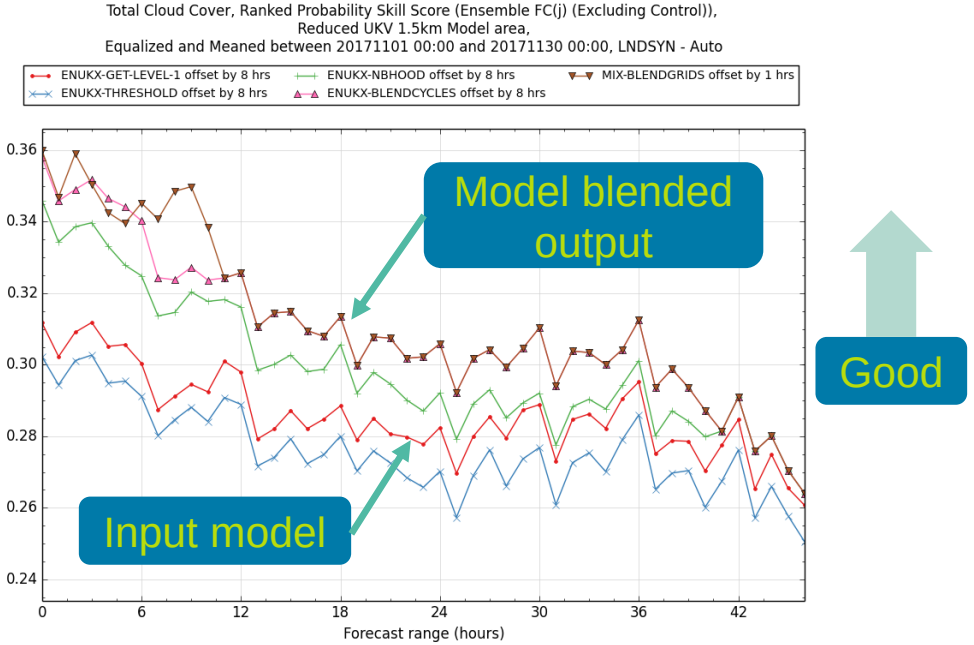




Verification at every step

Example for total cloud

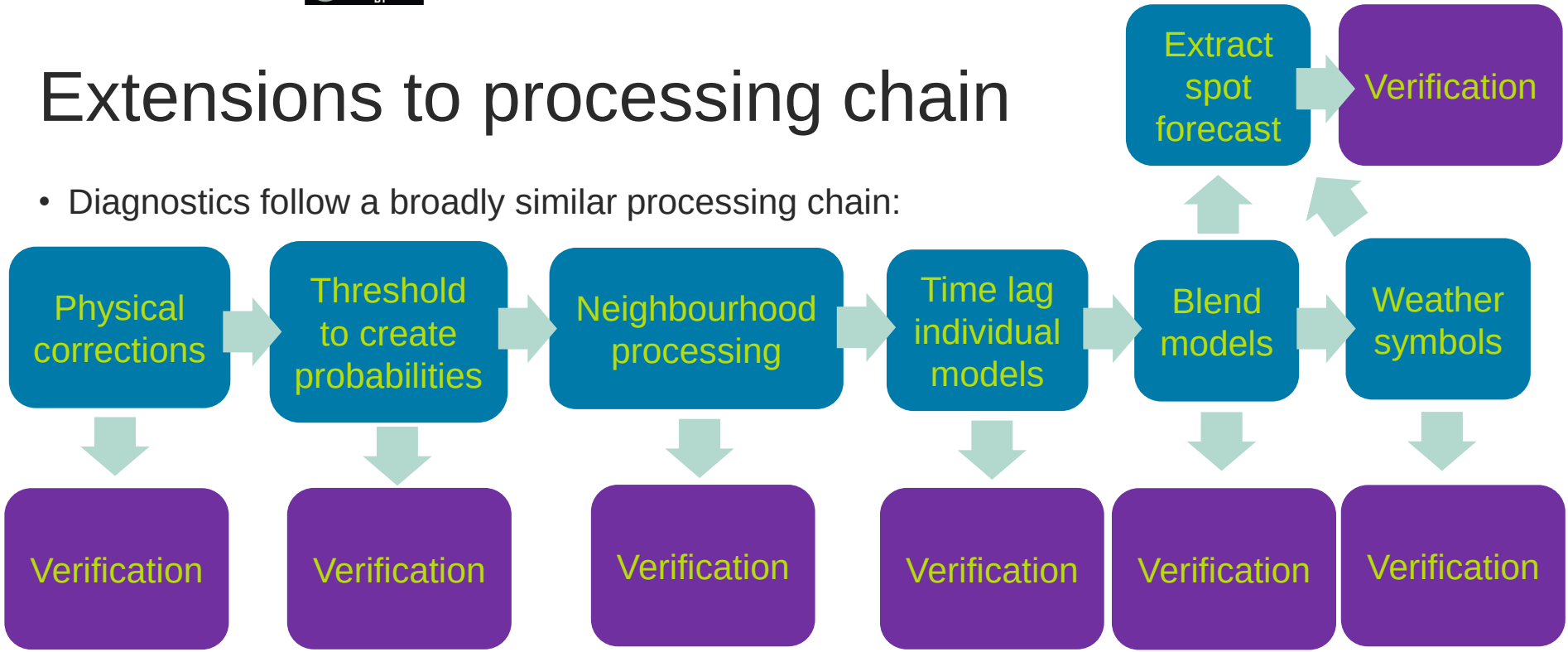
- Ranked probability skill score for total cloud exhibits some improvement.
- Converting members into probabilities by thresholding leads to some degradation, however, this skill is recovered by the subsequent steps.

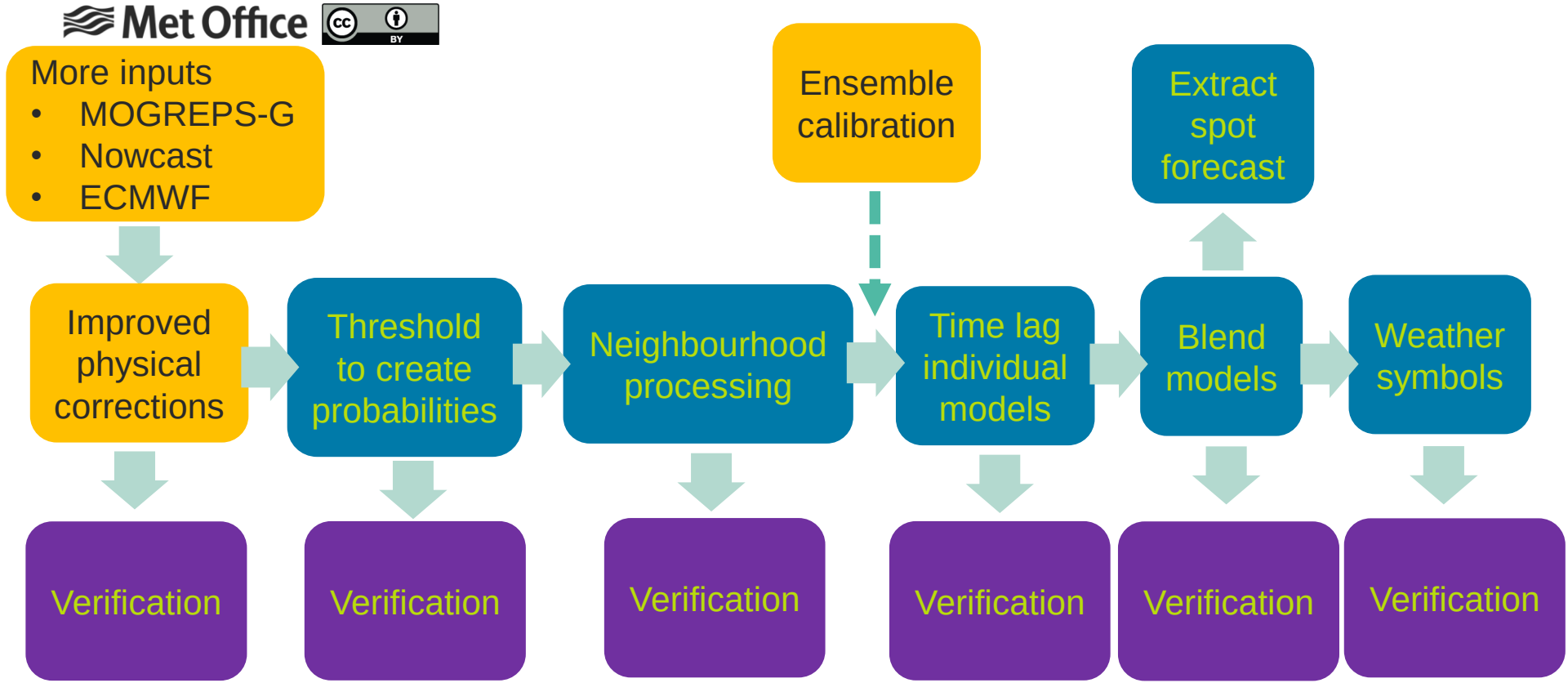


Next steps

Extensions to processing chain

- Diagnostics follow a broadly similar processing chain:




More inputs
• MOGREPS-G
• Nowcast
• ECMWF
Improved physical corrections
Threshold to create probabilities
Neighbourhood processing
Ensemble calibration
Time lag individual models
Blend models
Extract spot forecast
Weather symbols
Verification
Verification
Verification
Verification
Verification
Verification

Next steps

- Post-Processing of global models (e.g. MOGREPS-G) to support longer range forecasts beyond T+5 days.
- Longer trials to test science and technical infrastructure.
- Improve science, for example, by extending the range of diagnostics produced to include e.g. feels like temperature, UV index.
- More intelligent spot extraction.
- Improve technical infrastructure.
- Operationalise during the 2019/2020 financial year.

Summary

- Open-source codebase: https://github.com/metoppv/improver. New contributors encouraged!
- Easy to use framework for post-processing, including probabilistic post-processing.
  - Easily plugged into standardised output from a raw ensemble and verified.
- Leveraging modern technologies to ensure latest computing developments are included.

Questions?

For more information please contact

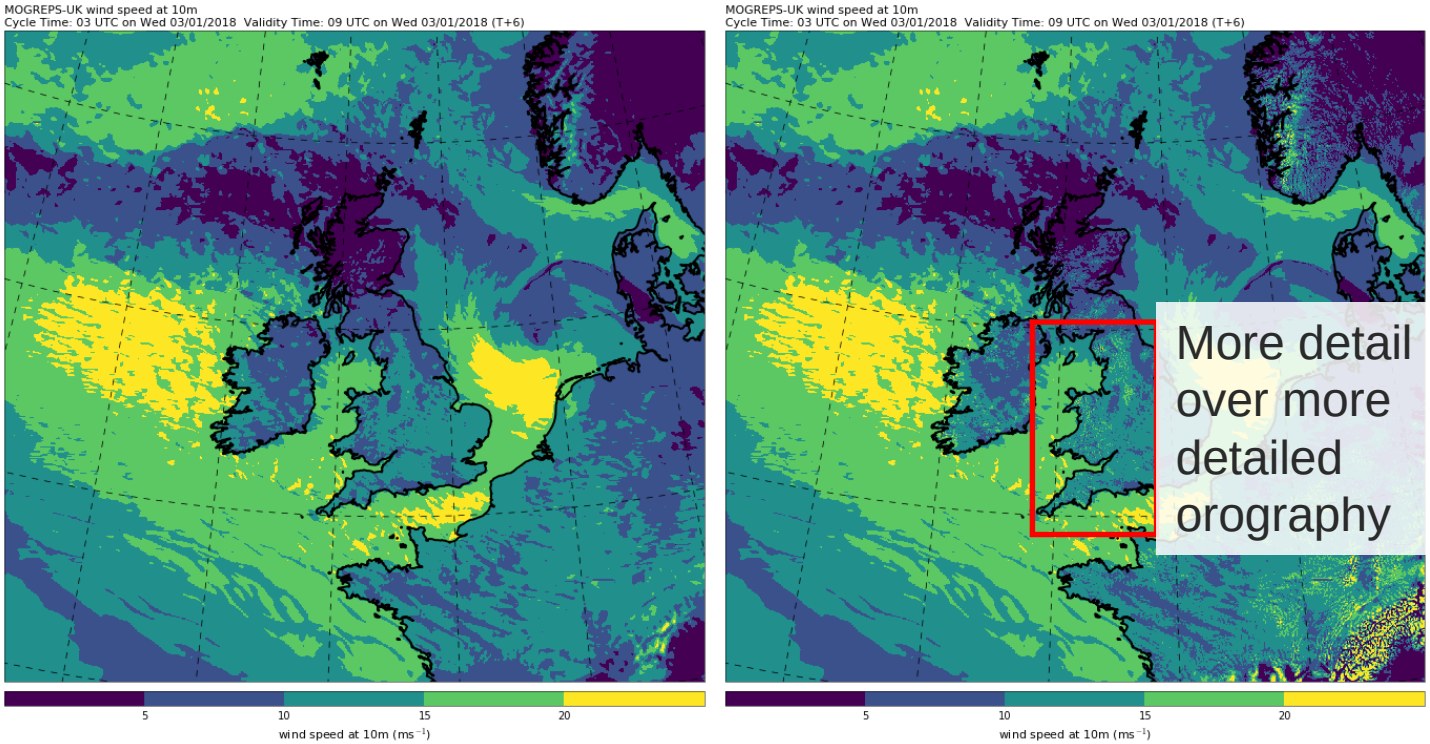
www.metoffice.gov.uk

gavin.evans@metoffice.gov.uk

Incorporating existing science: Wind downscaling

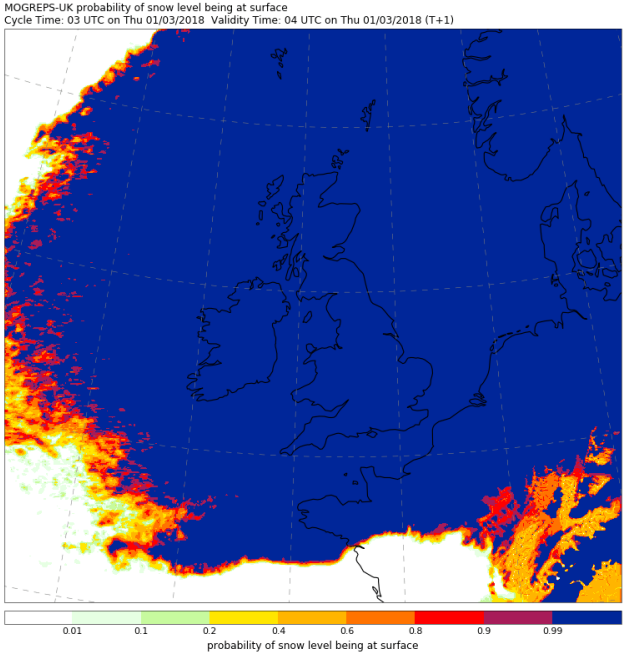
- Roughness correction – as the model's orography is smoother than the actual orography it doesn't have enough drag.
- Height correction – speed-up caused by unresolved hills within the model's orography.

Incorporating existing science: Wind downscaling



Developing new science: Snow falling level

- Is it snowing?
- At what level is it snowing?
- Focus on diagnosing the height of the rain/snow transition and whether this intersects with ground level.



Courtesy of Nigel Roberts, Fiona Rust, Caroline Jones, Ben Ayliffe, Aaron Hopkinson

Stepping through the processing

- Threshold
- Neighbourhood processing
- Time lag individual models
- Blend models