Met Office

Improvements to direct assimilation of radar reflectivity in the Met Office UKV, including use of French and German radars

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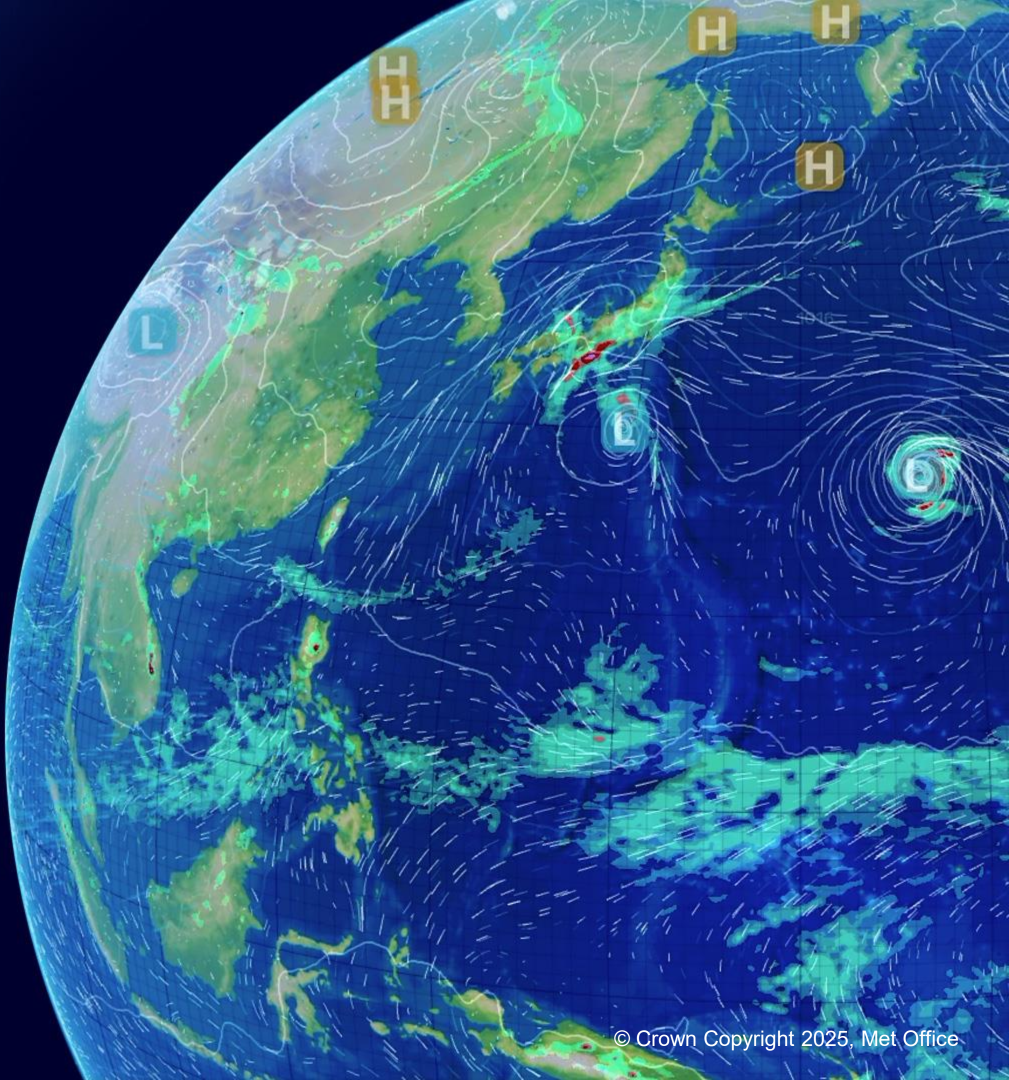


Content

- Operational usage of radar in Met Office UKV
- Retirement of LHN and updates to direct reflectivity assimilation
- Porting observation processing code to JEDI

Improved direct reflectivity assimilation at the Met Office

• Radar data usage in Met Office regional NWP

Operationally assimilated

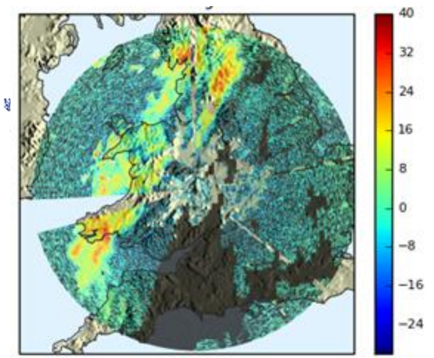
Radar data	Use in assimilation
Met Office generated European rainrate composite	• Latent Heat Nudging • Every 15 minutes
UK short pulse scans (75m / 100km)	• Doppler winds • 4D-Var • Every 10 minutes • Correlated obs errors
UK & Ireland long pulse scans (600m / 250km)	• Reflectivity • 4D-Var • T-30, T-15, T0

Next upgrade (PS47, Jan 2026)

Radar data	Use in assimilation
Met Office generated European rainrate composite	• Retired
UK short pulse scans (75m / 100km)	• Doppler winds • 4D-Var • Every 10 minutes • Correlated obs errors
UK & Ireland long pulse scans (600m / 250km)	• Reflectivity • 4D-Var • T-30, T-15, T0
France & Germany 3 lowest elevation scans	

Reflectivity observation & QC

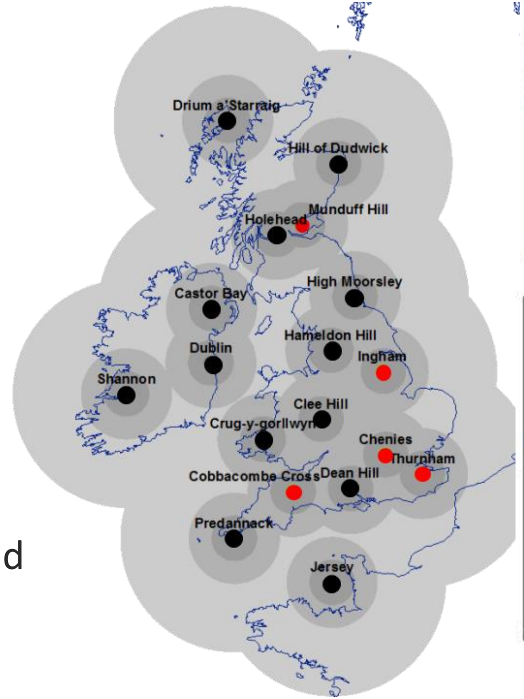
A replacement for the Met Office latent heat nudging method to assimilate a radar derived surface precipitation product (over 25 years)

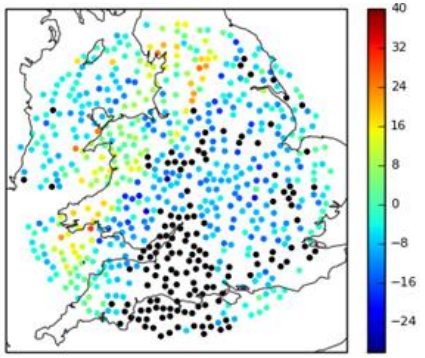


General information

- 4DVar hourly cycle / UKV.
- Total water control variable.
- 3 volumes scans (0, 15, 30 minutes)
- Both dry and wet observations are used.
- Initially applied to UK & Ireland radar.

  → Outside the UK & Ireland use LHN





Quality control

- reject non-hydrometeorological echoes
- reject obs where background T < °3C, to avoid bright band melting layer.

[Hawkness-Smith & Simonin (2021)](#)

Plan to remove LHN: preparing for Next Generation Modelling System (NGMS)

- Switch off LHN

>25 year old code in the UM (which will be replaced by LFric)

Method inconsistent with and separate to that used for all other atmospheric observations

Not ported to NGMS

- Switch reflectivity from GRIB2 to HDF5

Technical change to enable use of European radar data

- Include French and German reflectivity observations
- Improve coverage of directly assimilated reflectivity observations
- Retune observation operator and errors

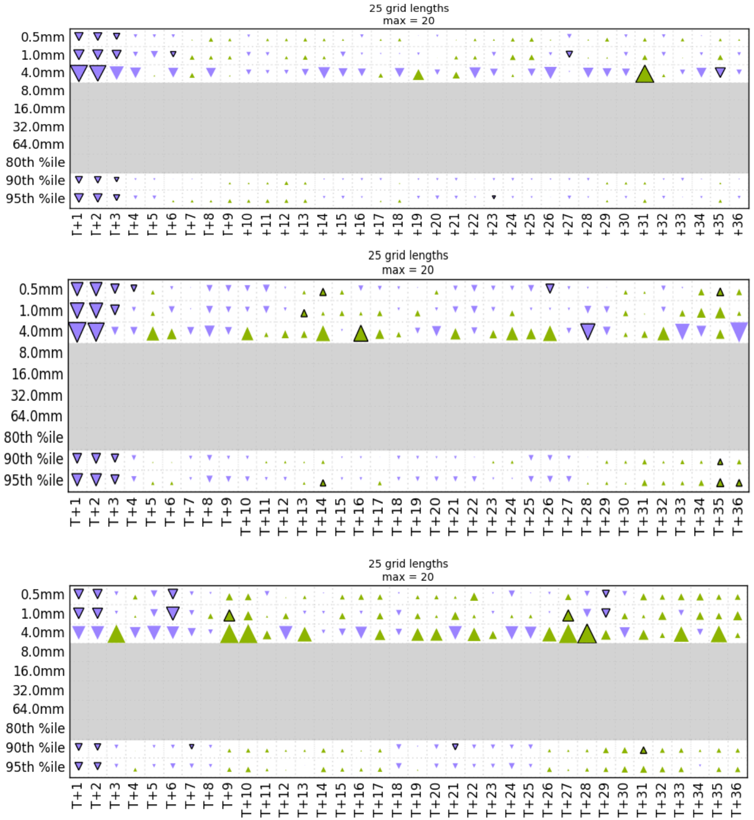
Improved direct reflectivity assimilation at the Met Office

Test switch off LHN

Winter 2019/20

Summer 2020

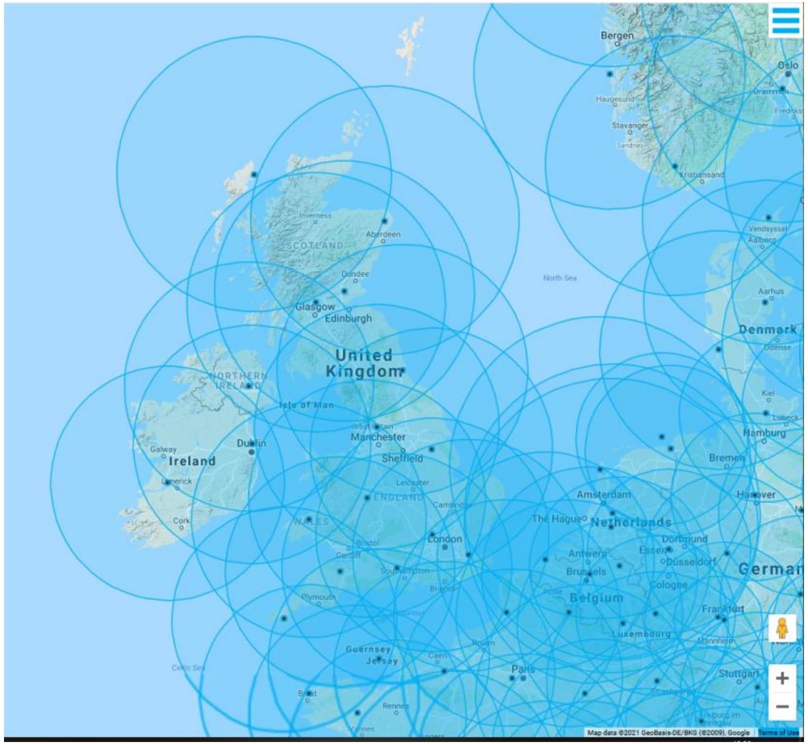
Spring 2020



- Switching of LHN over UK/Ireland is detrimental for FSS in first few hours of forecast
- Can we compensate with the inclusion of continental European radar scans & better usage of UK radar scans?

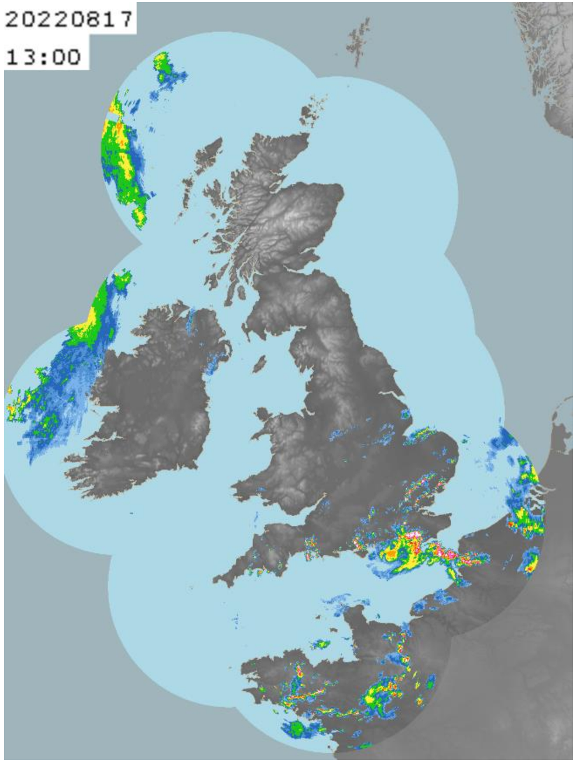
European reflectivity data

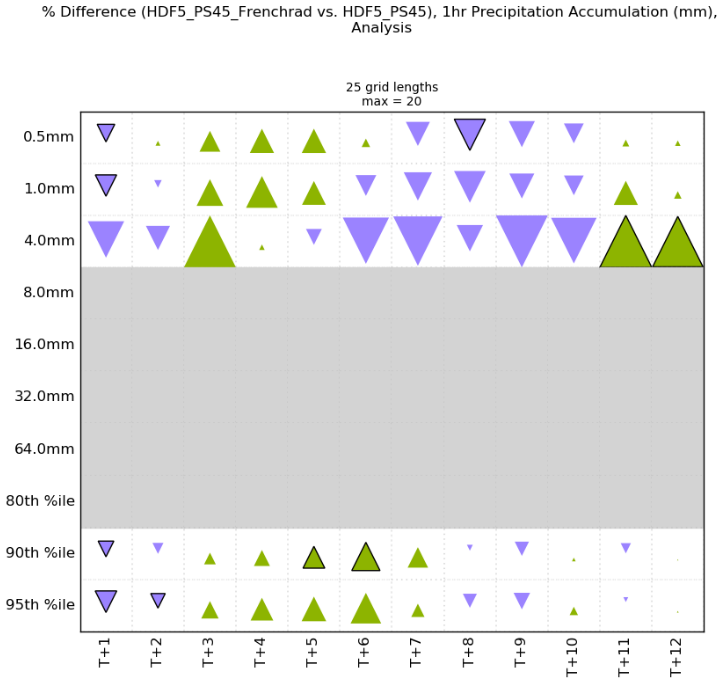
- Single-site scans taken directly from CIRRUS/STRATUS and processed internally
- New MO-ODIM format, extension to ODIM HDF5. Allows standard extraction and processing, including extra QC information where available.
- A lot of work with data teams to enable timely and stable extractions (using `wget`)
- A lot more work to match observation selection and QC between formats…



Improved direct reflectivity assimilation at the Met Office

Short test trial 14 – 21 August 2022





Fractions Skill Score impact of including French radar

Improvements to direct assimilation scheme

- Include lowest 3 elevation scans from MÉTÉO-FRANCE and DWD radars in the domain
- Reject pixels classified as ‘wet snow’ by dual-pol scheme
- Remove rejection of obs where T<3°C where dual-pol classification available
- Remove superob variance test which led to spurious rejection of obs where background was near zero
- Retune operator to reduce bias with respect to model background (using trial data from new Physics scheme)

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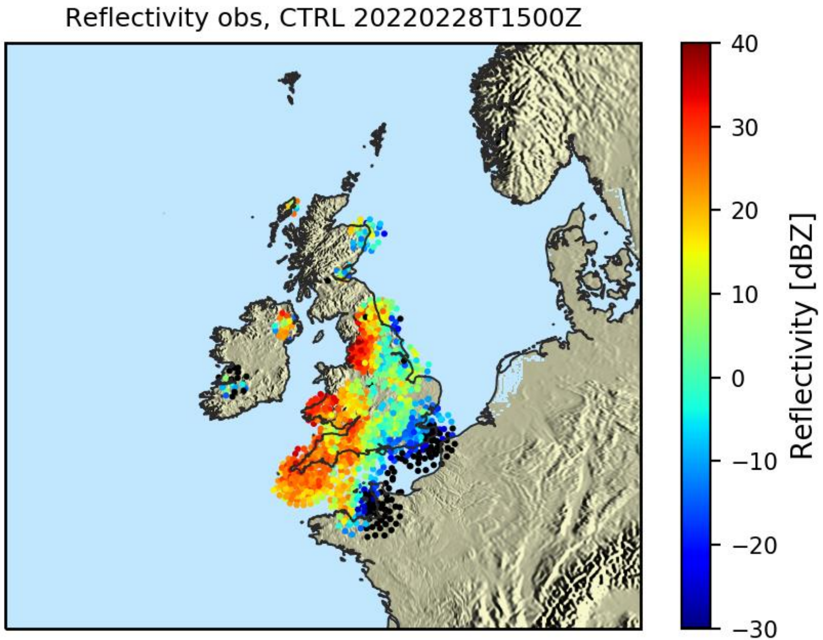
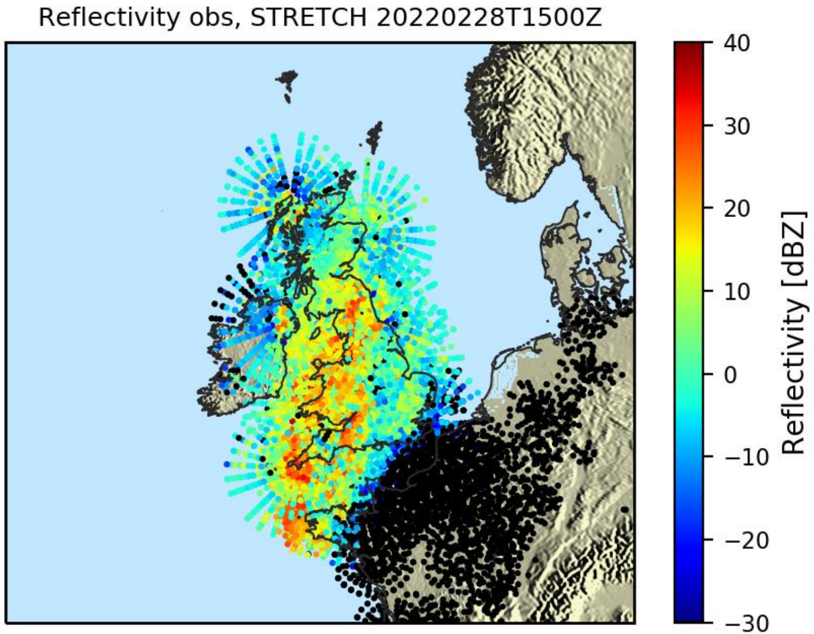
Example of change in coverage of Reflectivity observations



Operational Control



Improved reflectivity experiment

Experiments run for convective week in August 2022

- Test reduced azimuthal size of superobservation (from 12° to 6°)
- Test increasing and reducing observation error
- All tests except increasing the observation error quickly looked detrimental
- Subjective and objective verification performed for two viable configurations:

REFL and REFL4 (as REFL with 50% increase in obs error)

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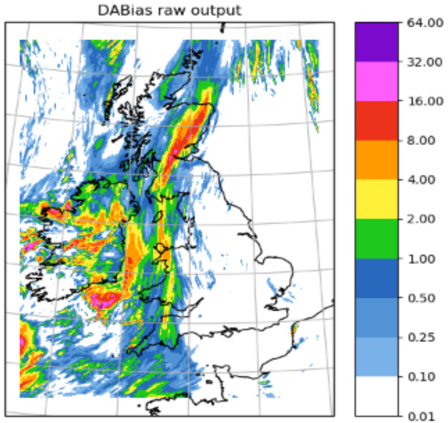
Summary of verification of reflectivity experiments

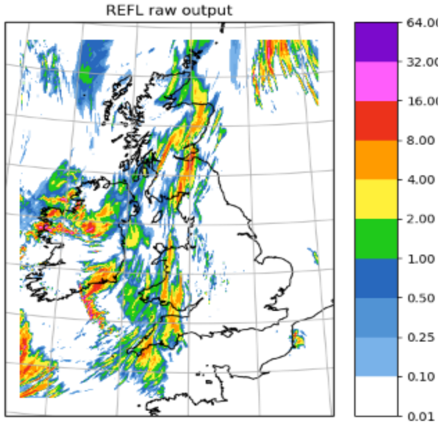
- Concerning large differences in the first 2 days (particularly between the DA Bias package and REFL; somewhat smaller differences between the DA Bias package and REFL4)
- Overall, no preferred configuration but slight edge for REFL4
- **REFL4 selected for Conservative Final Package**

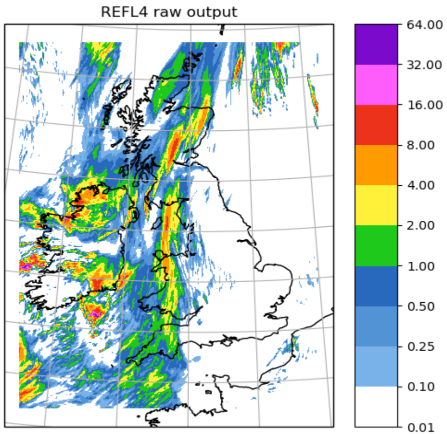
Rainfall investigation plots 20220815T00Z T+6H

DABias (mibg278) vs REFL (mibg291)

NO THRESHOLD PLOTS







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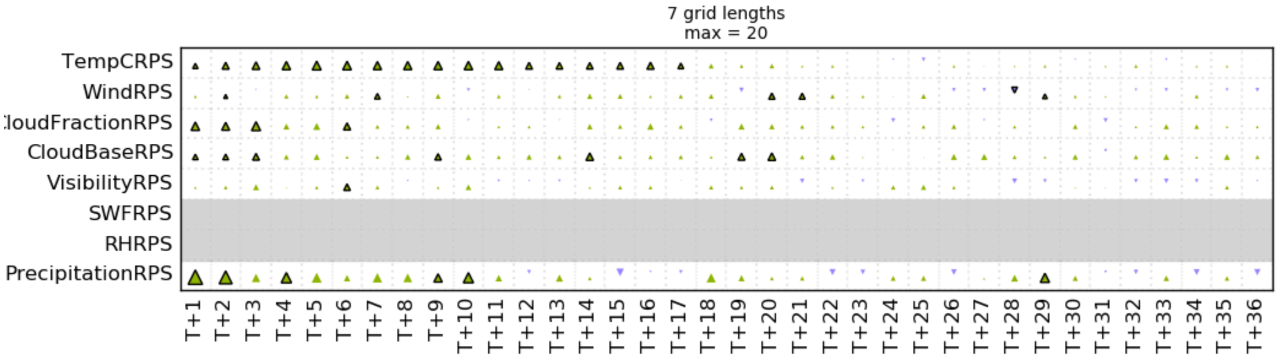
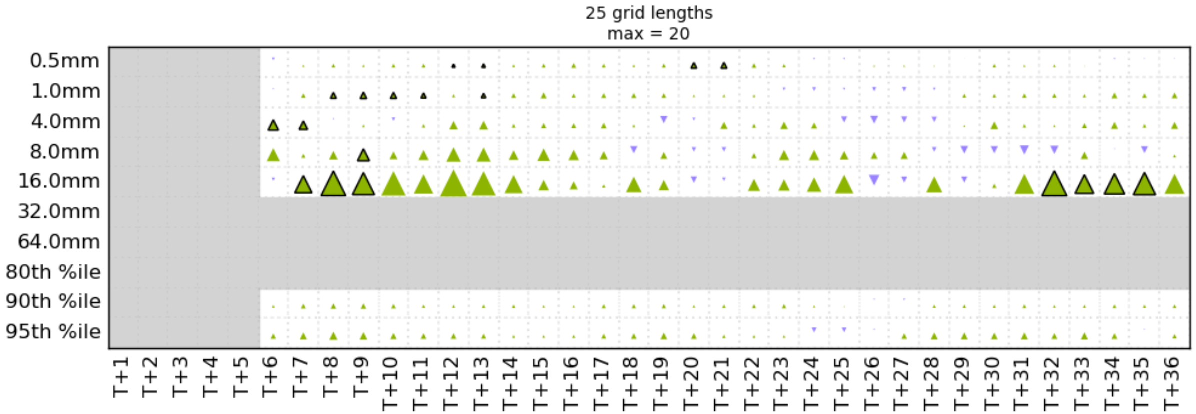
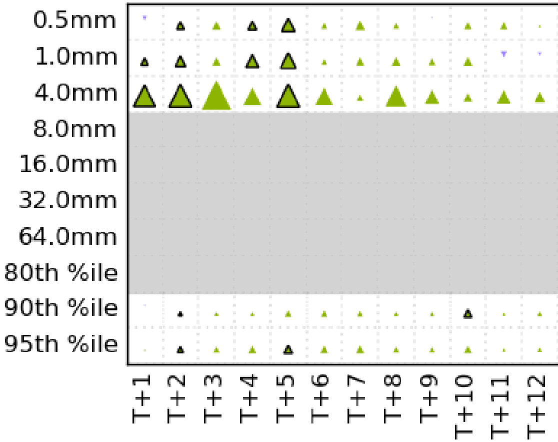
Incremental impact of REFL4 package, Summer 2022



- REFL4 beneficial for Precipitation RPS and FSS, and cloud and temperature RPS in first few hours





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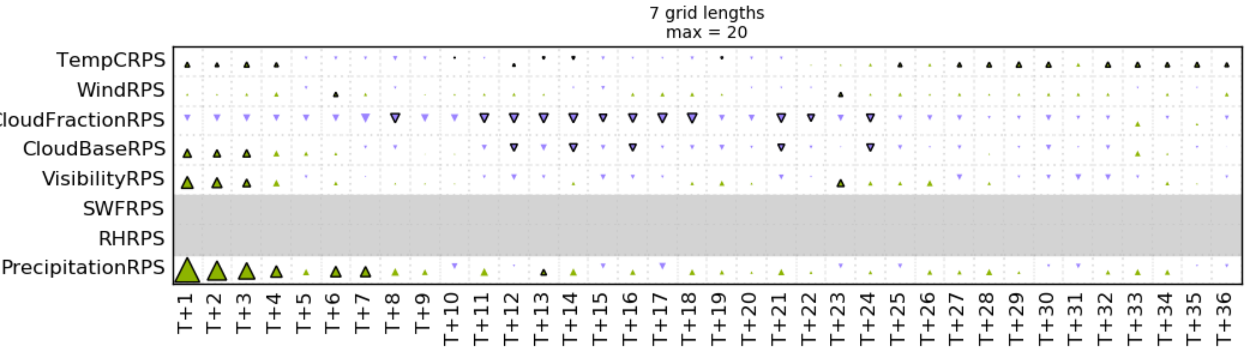
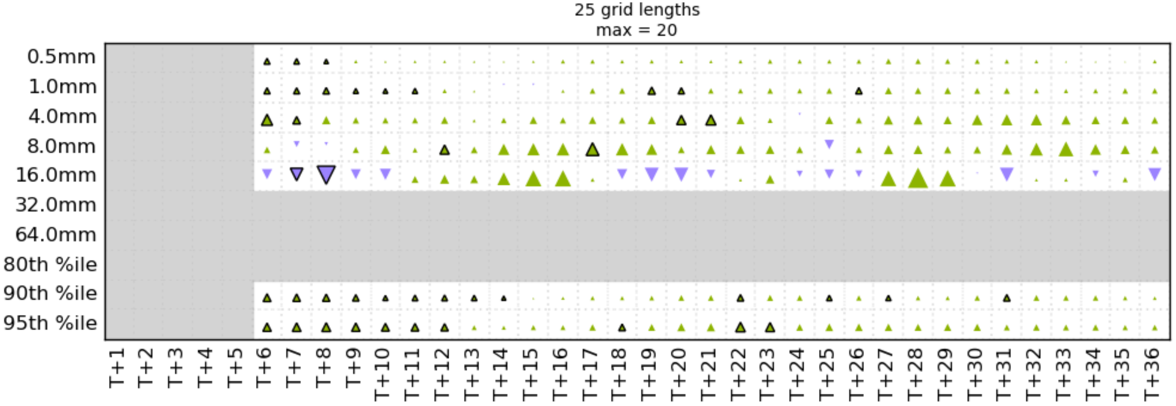
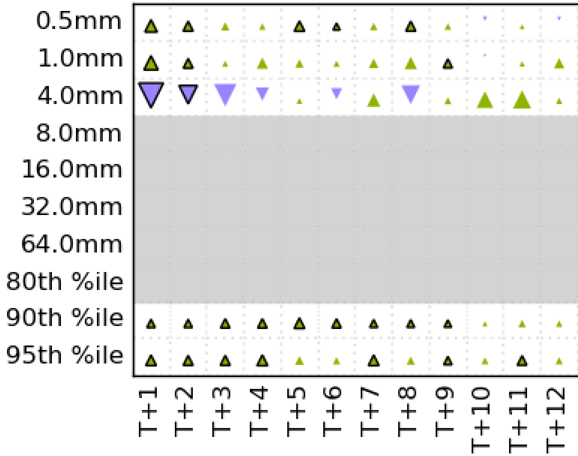
Incremental impact of REFL4 package, Winter 21



- REFL4 largely beneficial for Precipitation RPS and FSS in first few hours





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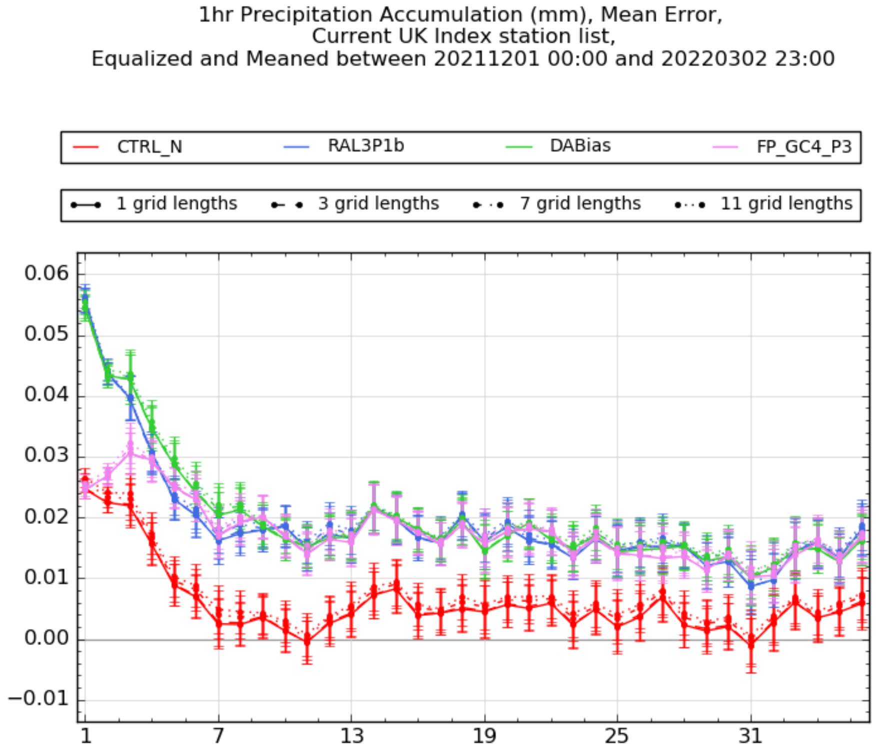
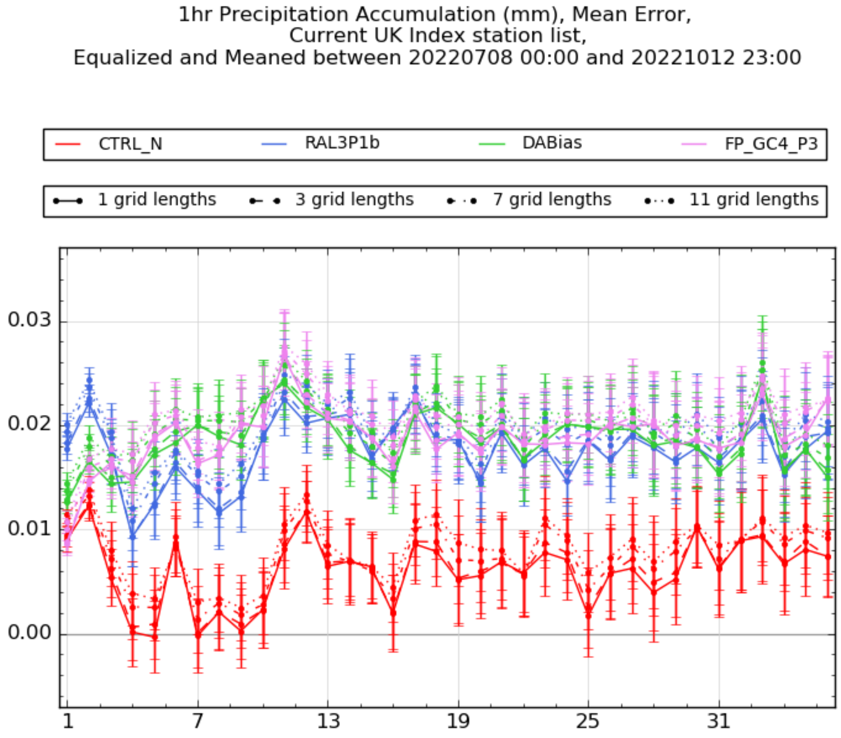
Mean error in precipitation accumulation



Winter 2021



Summer 2022

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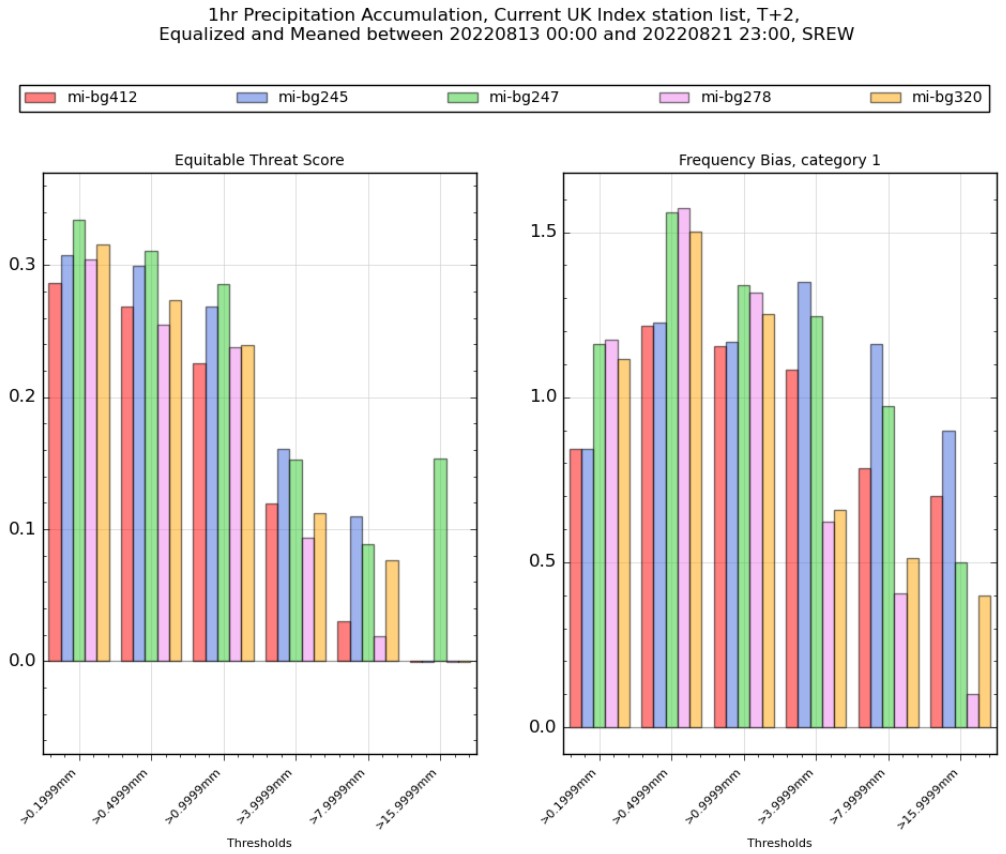
Reminder: Brier scores and Frequency Bias for wet August week



mi-bg412 = CTRL – LHN
mi-bg245 = CTRL
mi-bg247 = RAL3 (New Physics Package)
mi-bg278 = DA Bias Package
mi-bg320 = REFL4 or conservative package

- Introduction of RAL3 physics and removal of LHN both reduce heavy rain at short lead-times
- REFL4 package gives some (limited) compensation

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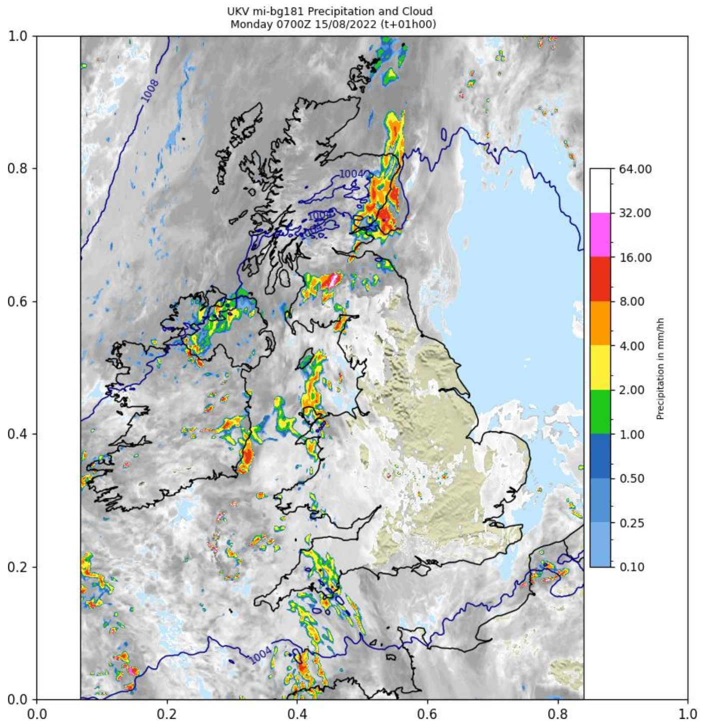
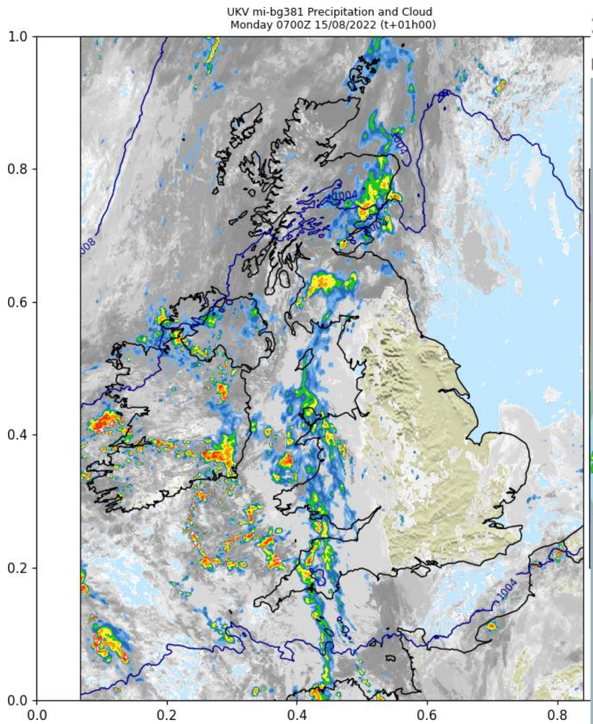
15 Aug 2022 07UTC (T+1)

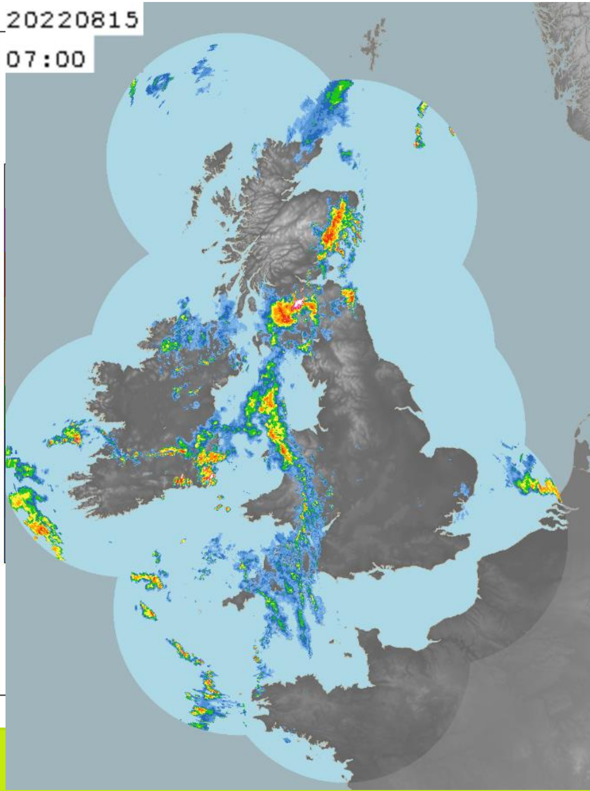
Control



Final Conservative GC4



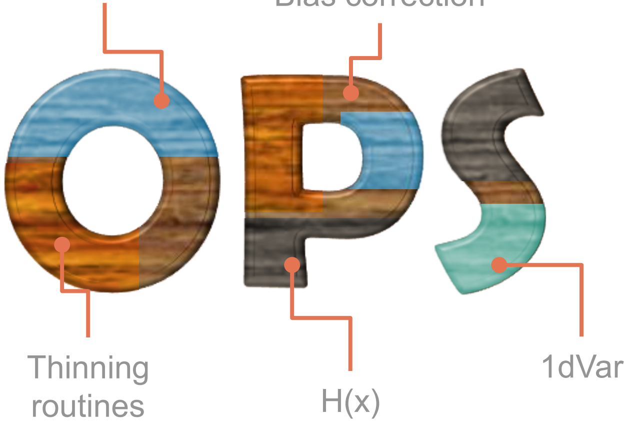
Radar composite



Re-code all observation processing: Joint Effort for Data assimilation Integration (JEDI)

Current system…

In our current system, the logical chain of processing applied to the observations is "**static**".



JOPA | JADA

The logical chain of processing is applied "**dynamically**".

→ <u>Code free of any science</u>

Collection of bricks

functions, methods, classes, procedures

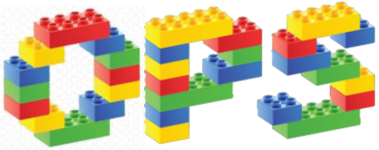
Configuration file

```
window_begin: 2018-
04-14T21:00:00Z
window_end: 2018-04-
15T03:00:00Z
LinearObsOpTest:
coefTL: 0.1
toleranceTL: 1.0e-13
toleranceAD: 1.0e-11
Observations:
ObsTypes:
- ObsOperator:
name: VertInterp
VertCoord:
air_pressure
```

Assemble the bricks using modern computation techniques

Instructions

how to assemble the bricks.



Radar in JOPA
(JEDI-based Observation Processing Application)

- Port radar processing from OPS to JOPA using a selection of filters and observation operators
- Processing of Doppler winds and reflectivity have features in common
  - Highly dense observations
  - **Thinning** and **superobbing** play a key role each time

Observation operators

- Doppler wind

$$H(x) = \mathbf{u}\sin(\varphi)\cos(\theta) + \mathbf{v}\cos(\varphi)\cos(\theta) + \mathbf{w}\sin(\theta)$$

φ = azimuth, θ = tilt

- `RadarDopplerWind` operator
- Fully C++

- Reflectivity

$$H(x) = f(\mathbf{qrain}) + g(\mathbf{qice})$$

Empirical relationships between mixing ratios and reflectivity. Transform to **square-root reflectivity** for numerical stability.

- `RadarReflectivity` operator
  - Generic code allows for different algorithms
  - `Met Office reflectivity` algorithm

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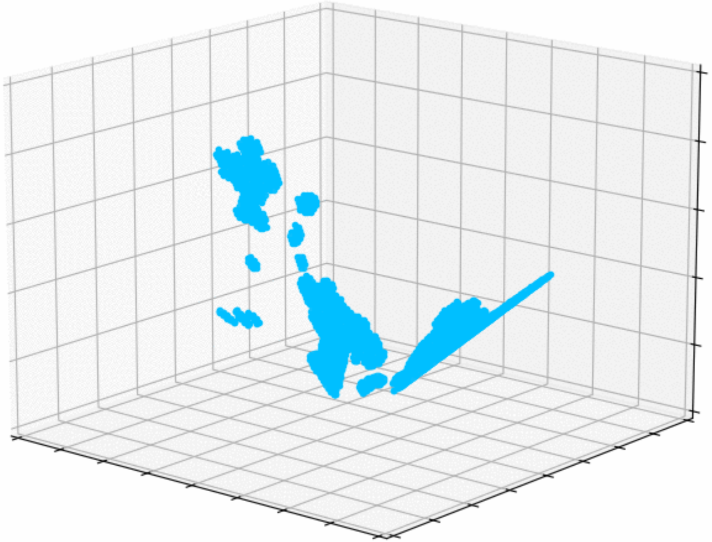
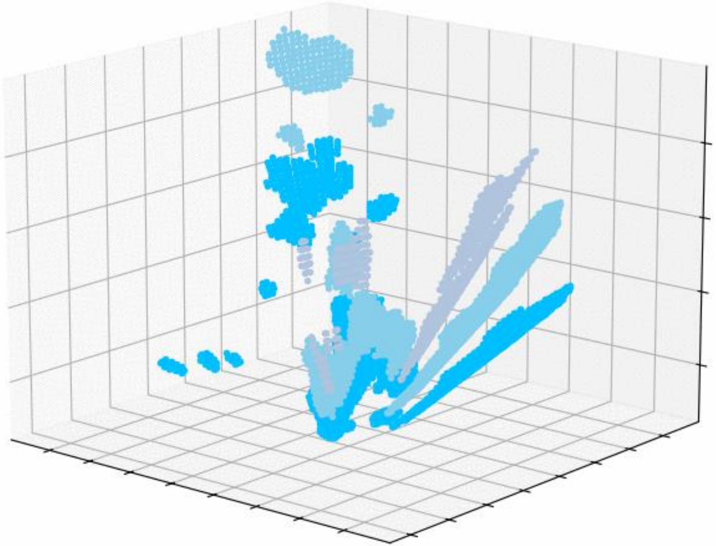
Doppler wind scan

- 4, 6, 9 degree tilt (exaggerated here)



Preliminary QC

- 3 < gateRange < 100 km
- |O – B| < 10 ms^{-1}
- Remove noisy edges from scans
- Reflectivity:
  - Remove hail contamination
  - Reject bright-band observations

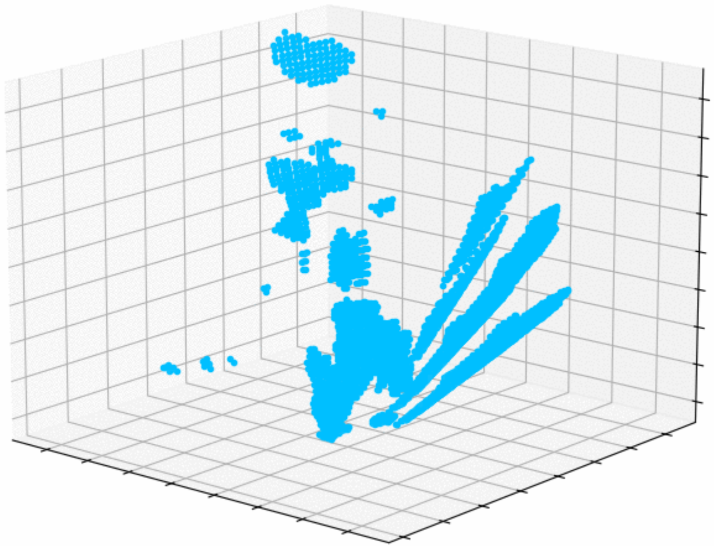


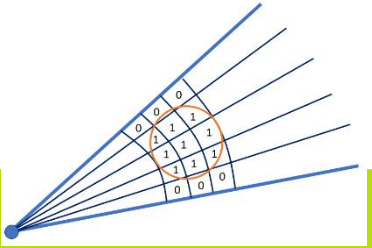
Accepted observations
Rejected observations

Met Office

Superobbing

- Reduce obs spatial density
- Avoids problems from misspecified **R**
- Mean O – B in a region added to B at a chosen point in that region
- `SuperOb` filter
  - Choice of algorithm
  - `radar` algorithm used here

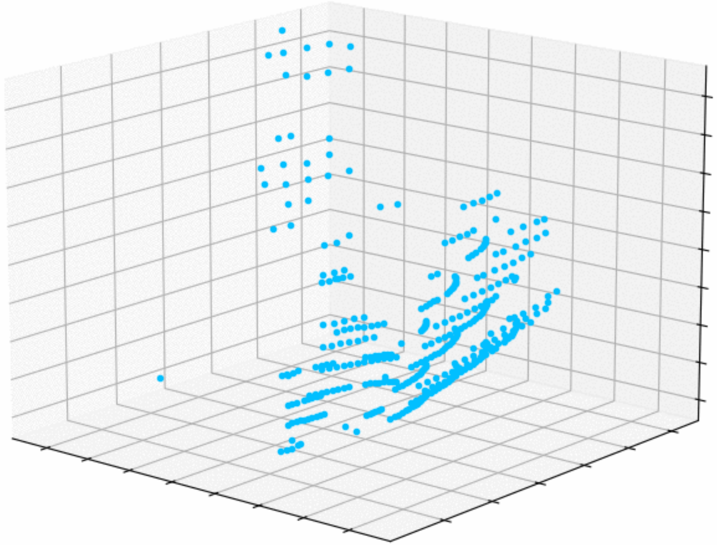




Accepted observations
Rejected observations

Thinning

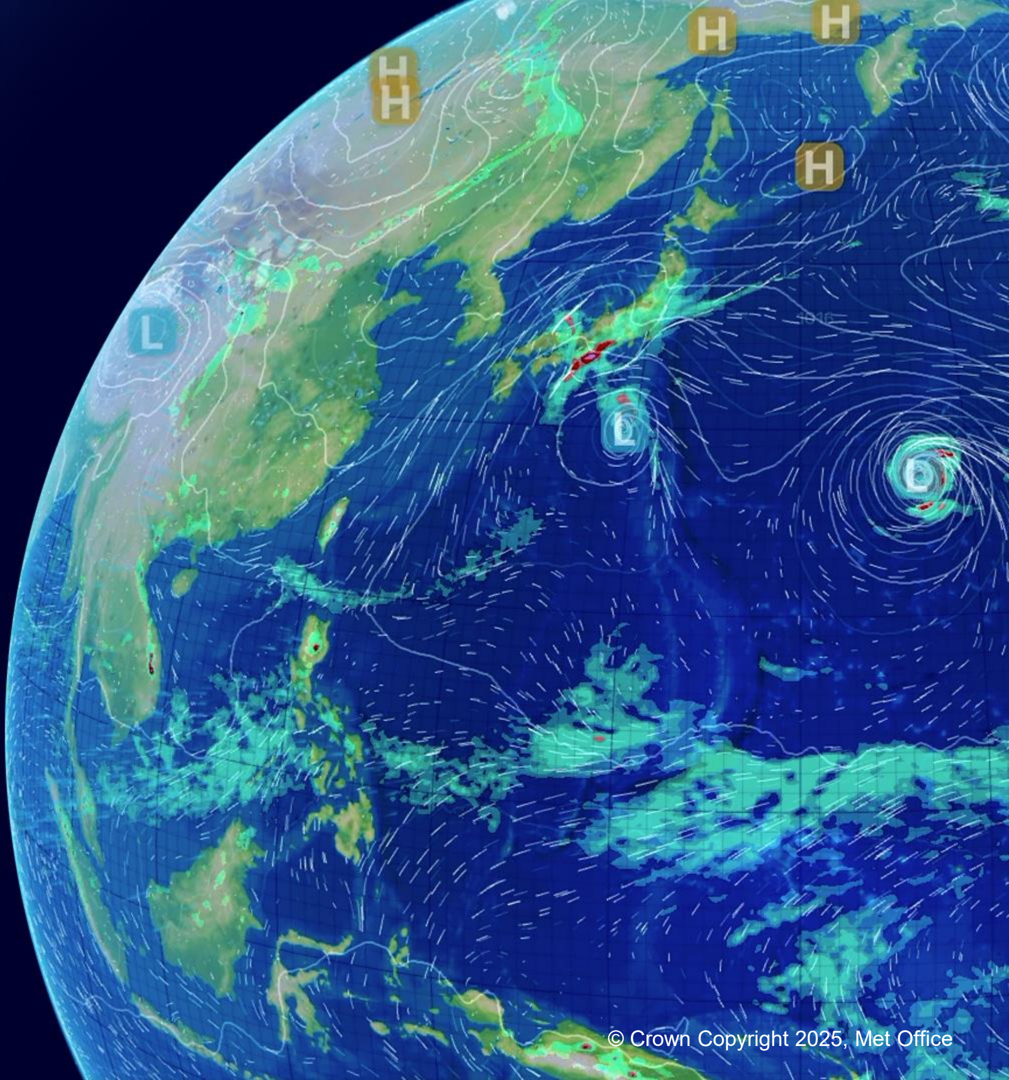
- Additional density reduction
- `Poisson Disk Thinning` filter
  - Select one observation in a chosen region
  - Random component
- Reflectivity QC performs additional **height** thinning to further reduce vertical density



Accepted observations
Rejected observations

Met Office

Tack!



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Improved direct reflectivity assimilation at the Met Office

Observation operator

Current operator uses:

- Interpolation to a point – No beam broadening
- A simple Z-q_r relation for rain (no ice assimilation):

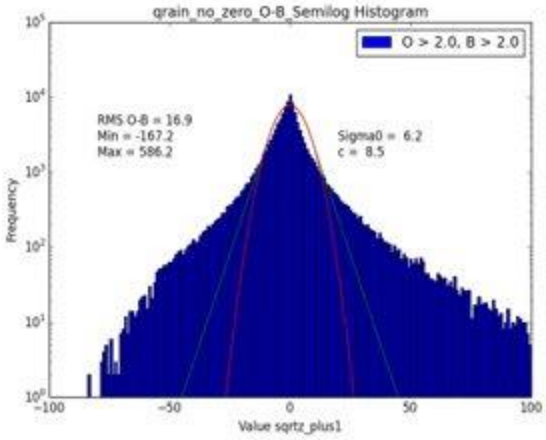
$$Z_R = 4x10^3 q_r^{2.1}$$

- Fixed non-zero dZ/q_r where $q_r < q_{r\_CRIT}$ and precip observed
- Unit of reflectivity are transformed from ZR [mm6 m-3] to $\sqrt{Z_R + 1}$

  → Compress the range and scale with the water mass.

Super-Observation and Poisson thinning

- Super-Observation size: 15^o by 15km
- Thinning: 15km for precip - 30km Dry obs.
- Vertical thinning currently set to 15km → single layer



Large Innovations:

- Reweight with Huber norm

Observation error:

- 30 $[\sqrt{Z_R + 1}]$ (Use ½ (O-B) from first trials for precip.)