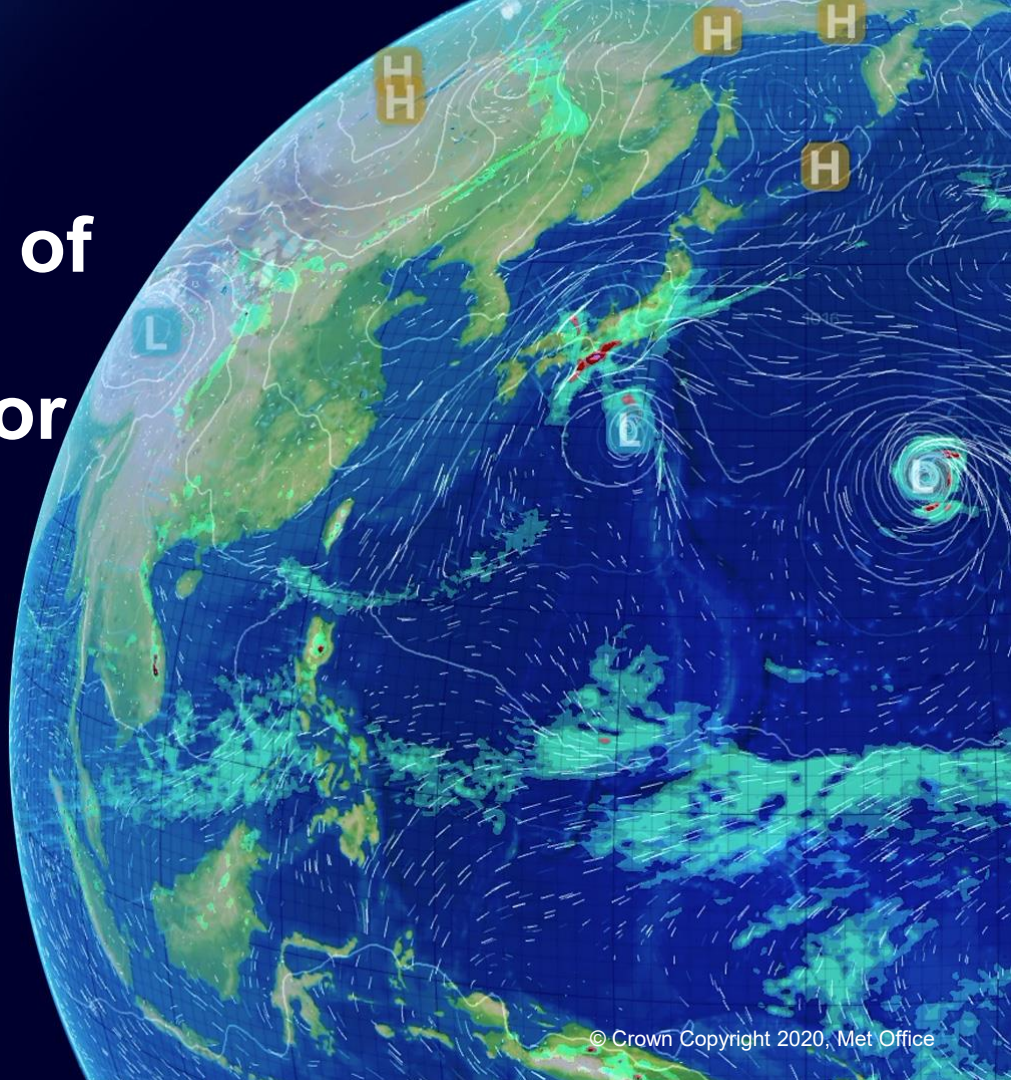
Exploring the potential of MTG-IRS to diagnose convective instability for nowcasting and situational awareness

Ruth Taylor

EUMETSAT Fellow Day

2nd March 2026



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Diagnosis of convective instability from hyperspectral soundings

- targeting **nowcasting and situational awareness**: using observations faster than NWP can
- improving forecasting of convective activity, localised heavy precipitation and potential for surface-water flooding
- exploiting **MTG-IRS** to build on a legacy of geostationary imager products
- combining hyperspectral sounding capability with ability to monitor a developing situation
- intended to be generally applicable

Met Office

Research Fellowship aims to extract the maximum available information from hyperspectral MTG-IRS

Proof-of-concept forecasting tool

1D-Var (optimal estimation) retrievals

- how to complement other retrievals (EUMETSAT, NWC-SAF)?
- rôle of background information

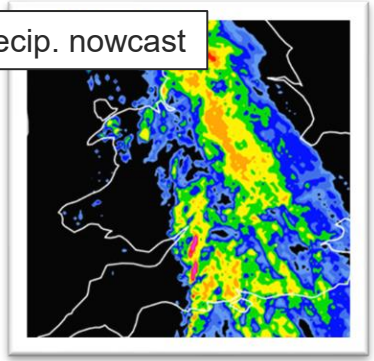
Potential for machine-learning approaches

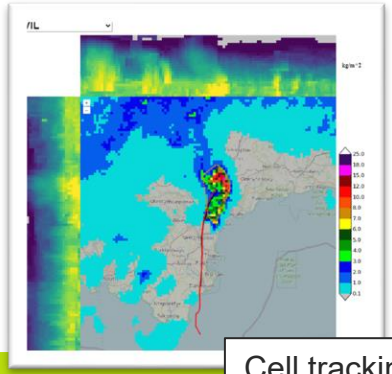
Verification/validation

case studies vs statistics

how to deal with triggering?

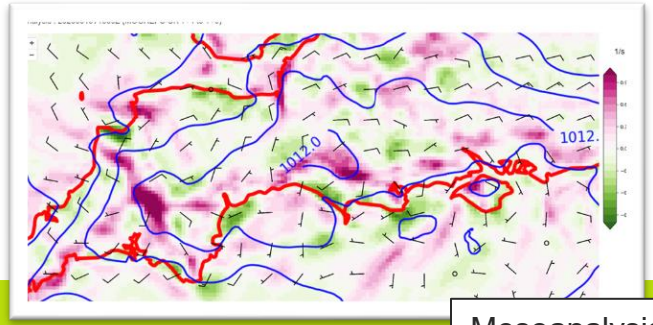
Sounder-derived profile information will complement existing nowcasting tools


Precip. nowcast


Cell tracking

Met Office Nowcasting R&D team's PLUVIA suite:

- **Radar precipitation nowcasting** (optical flow + probabilistic ensemble NWP post-processing)
- **Radar cell tracking** (tracking cells in 3D radar data using Kalman Filter)
- **Mesoanalysis** – Rapid analysis combining recent observations and NWP



Mesoanalysis

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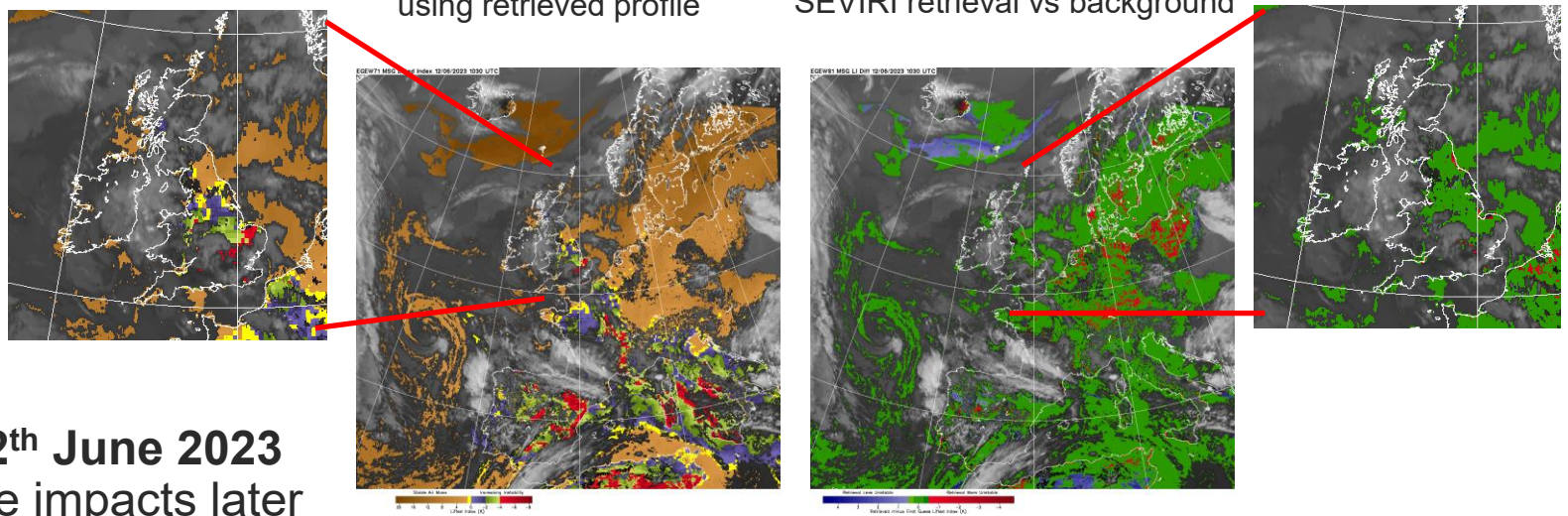
Lifted Index
using retrieved profile

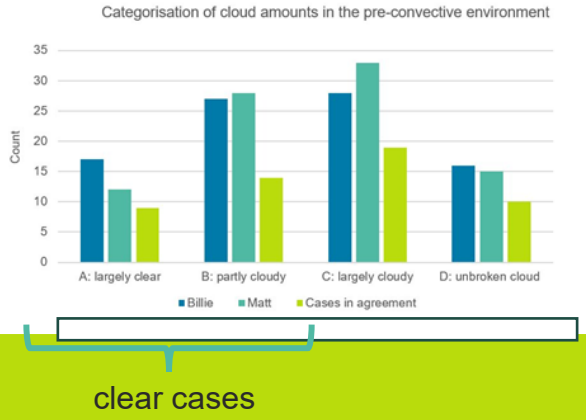
Δ(Lifted Index)
SEVIRI retrieval vs background



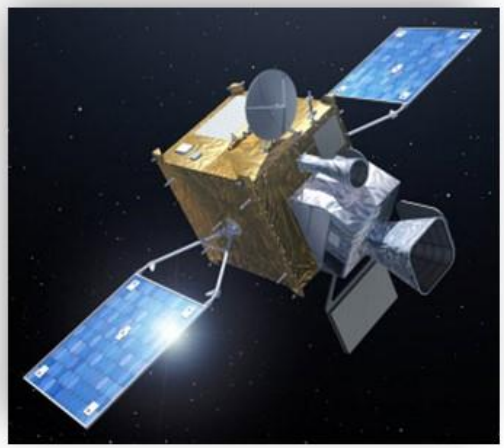
1030Z, 12th June 2023
convective impacts later over UK

Our current products use MSG-SEVIRI radiances to **add information to NWP,**

targeting the **pre-convective** environment



Hyperspectral sounders will improve vertical profiling of temperature and humidity



MTG-IRS : hyperspectral sounder in geostationary orbit

Spatial resolution 4km – slightly lower than SEVIRI

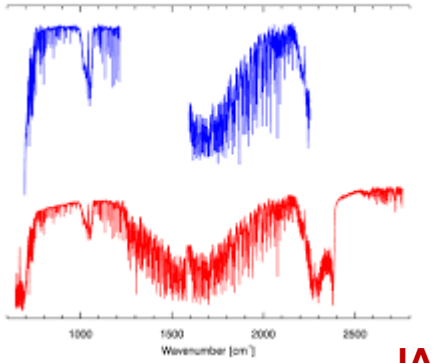
Temporal frequency up to 30 minutes

Successfully launched July 2025

IASI as a proxy:

- MetOp-B and –C have overpasses between 0930 and 1200 local time
- Spectral resolution slightly higher than MTG-IRS and more complete spectral coverage
- Lower spatial resolution 12km

MTG-IRS



IASI

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Our 1D-VAR retrievals of T and q combine observed radiances with a background from operational NWP.

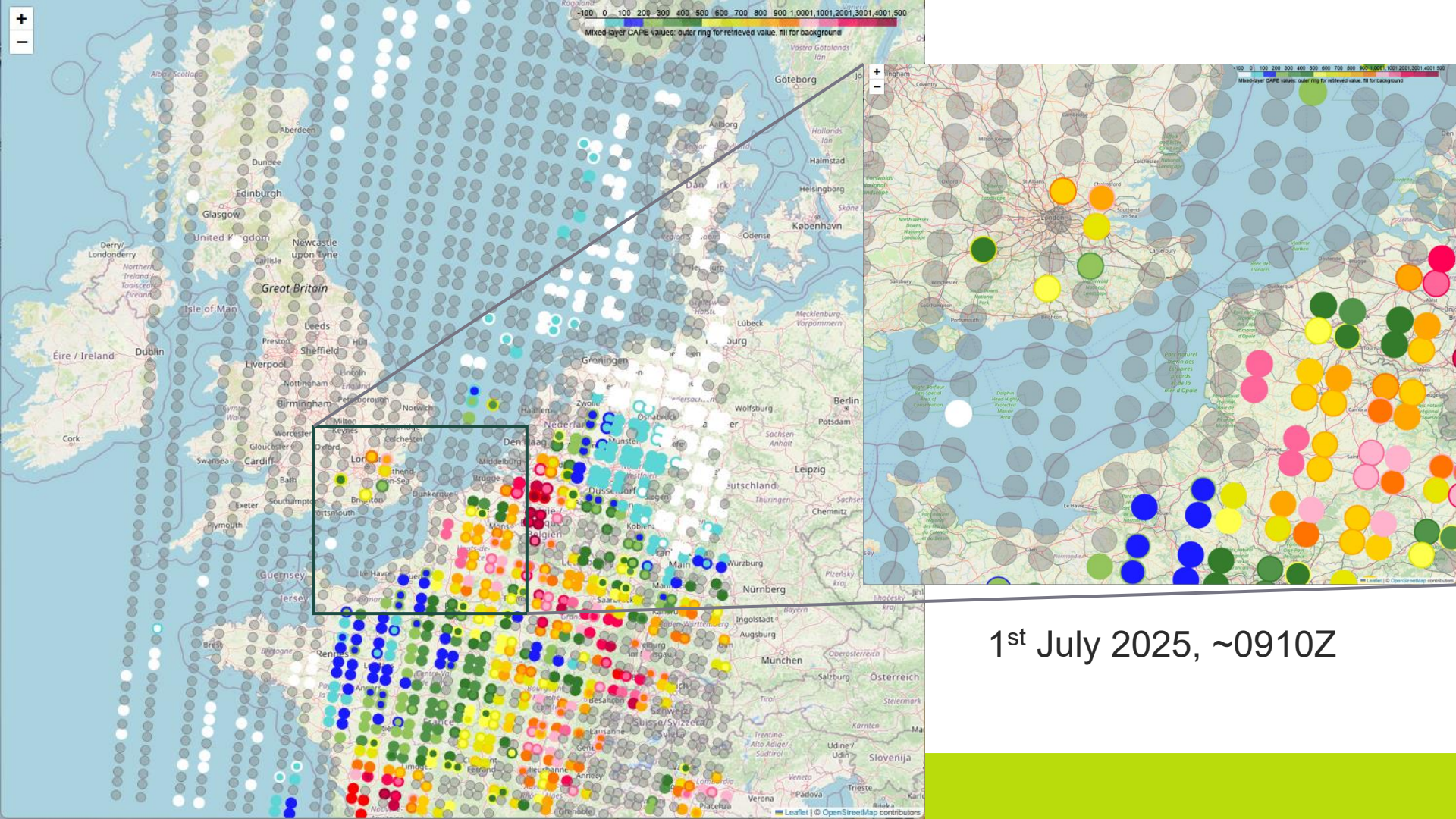
- Optimal estimation technique
- Locally-archived 314 **channel subset** – ***increase number?***
- **Background** is a short-range Global forecast – ***use ensemble***
- **Background errors are static**
  - ***scaling tests performed;***
  - ***introduce flow dependence***
- uncorrelated **observation error matrix** – ***alternatives available***
- includes single-layer grey cloud & uses cloud-free profiles
- **bias correction** from operational NWP – ***try an alternative?***

Met Office

CAPE & TCWV for forecasters.

- Calculate values for forecast and model, and present as a departure
- Sign of departure is useful (more than accurate magnitude)

- Proof of concept …

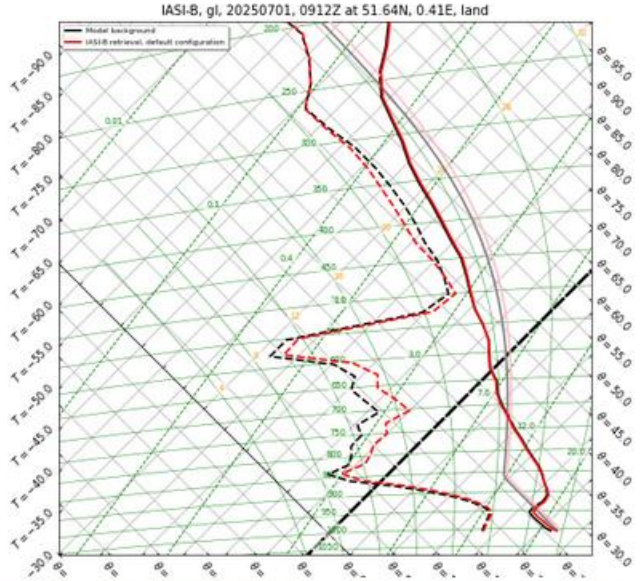


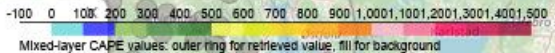
1st July 2025, ~0910Z

Met Office

1st July 2025, ~0910Z

Retrieved Value Background Value Difference (retr - back)			
SBCAPE (J / kg)	1457.40	1293.31	164.08
MLCAPE (J / kg)	979.31	809.49	169.82
MUCAPE (J / kg)	1457.40	1293.31	164.08





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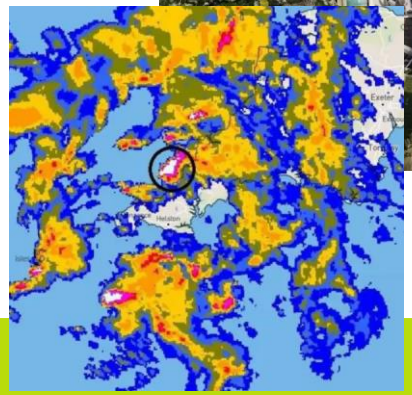
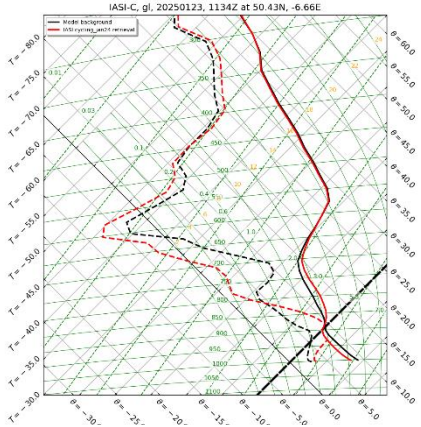
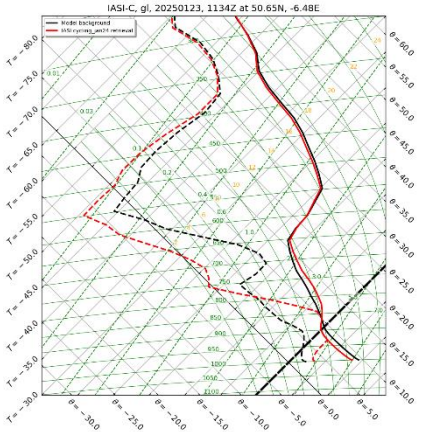
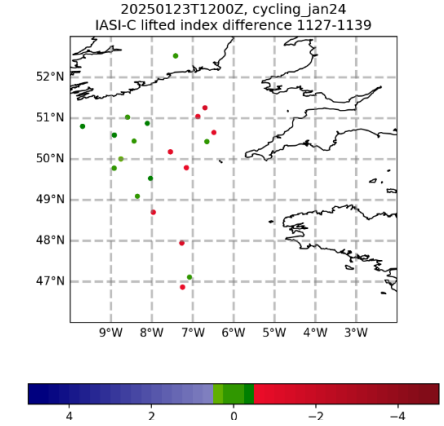
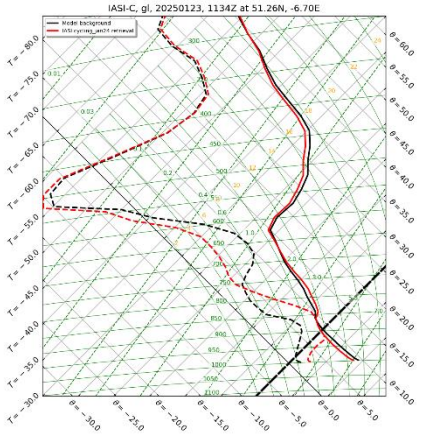
'Carnage' as mini-tornado tears through village





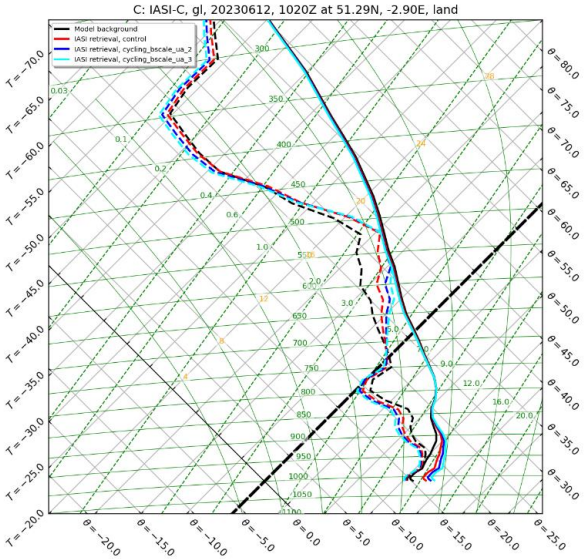




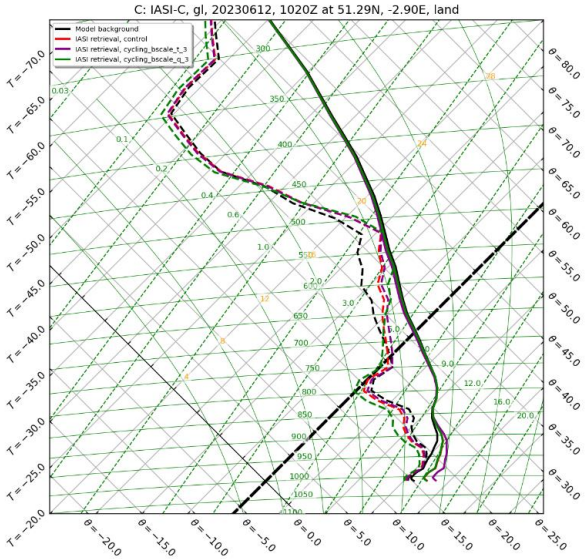


23rd January 2025

Scaling background error B matrix (12th June 2023)

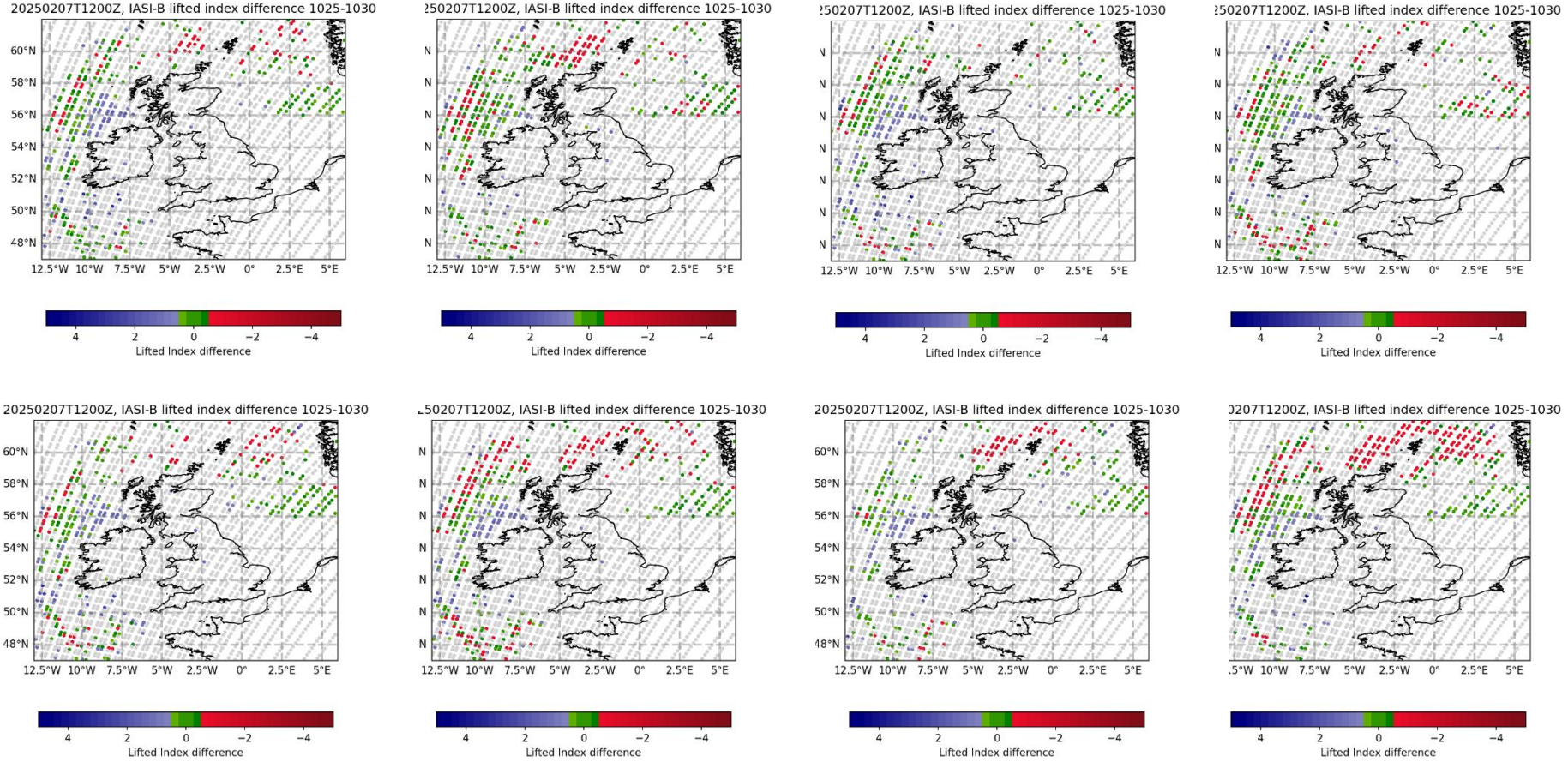


(all elements, factors of 2 and 3)

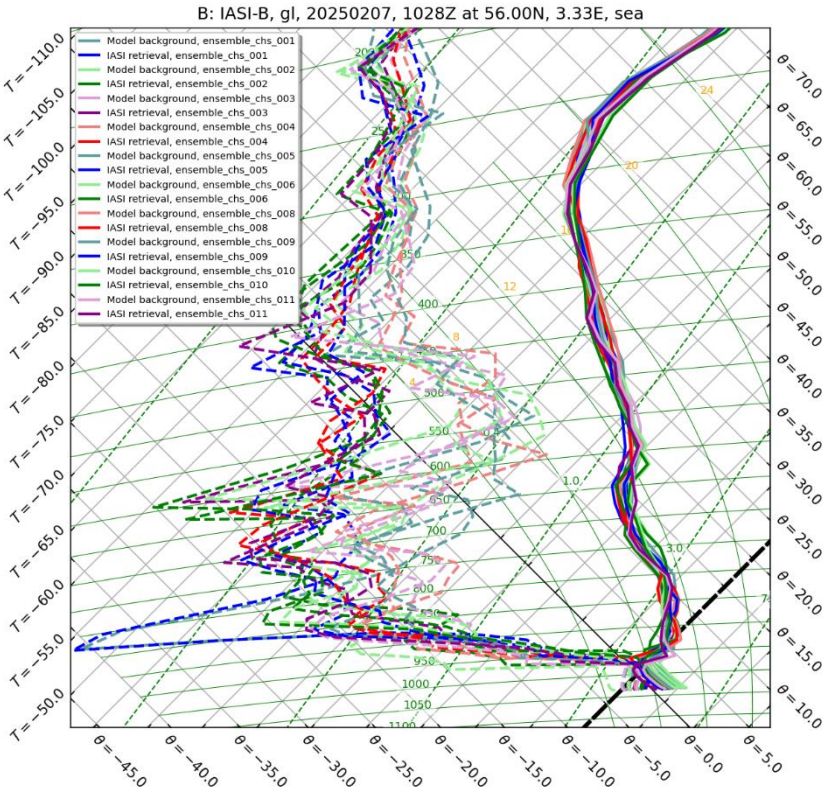


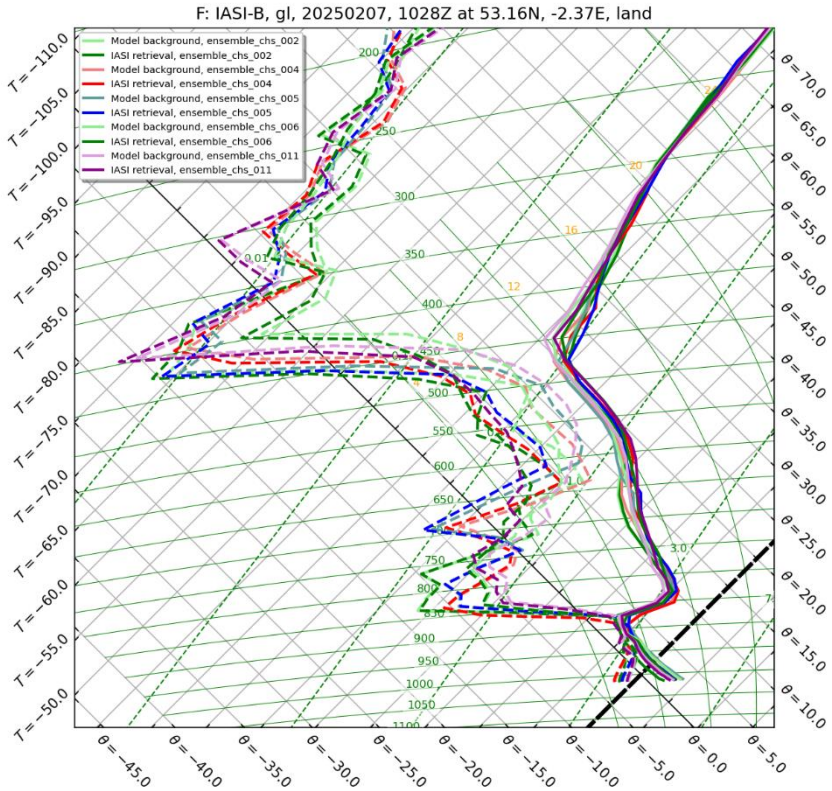
(temps scaled by 3 vs q scaled by 3)

Compare terms in the uncertainty estimate: $\mathbf{A^{-1} = B^{-1} + H^T R^{-1} H}$



Ensemble members, 7th February 2025





Ensemble members, 7th February 2025

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Sounder-derived products need validation and verification data …
… which could also serve as ML training data

- radiosonde ascents and other direct observations (including field campaign data)
- analyses
- rainfall cell-tracker data / lightning / other satellite products
- catalogues of severe storm events
- catalogue of “model busts”

Important to keep the “real-time model verification” context in mind!

Met Office

(extra slides)

Met Office

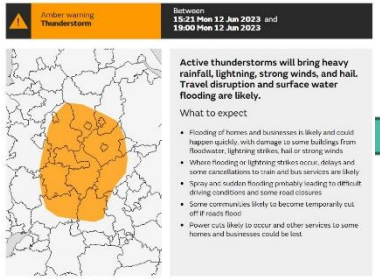
Routine index generation using IASI:

- compare with background profiles – where are we adding information?
- understand the sensitivities of each index
- baseline for changes to the retrieval
- how common are false positives?

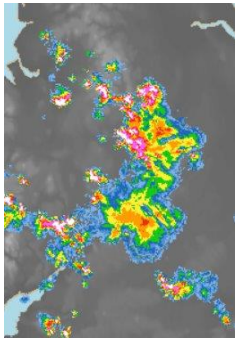
5-week Testbed activity, June-July 2024,
working with Operational Meteorologists on forecast production

Case study analysis, e.g. 12th June 2023

Yellow warning
10:00 BST
Sun 11th June



Amber warning
15:21 BST
Mon 12th June



Radar rainfall rate
18:00 BST, Mon 12th June

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Analysis variables

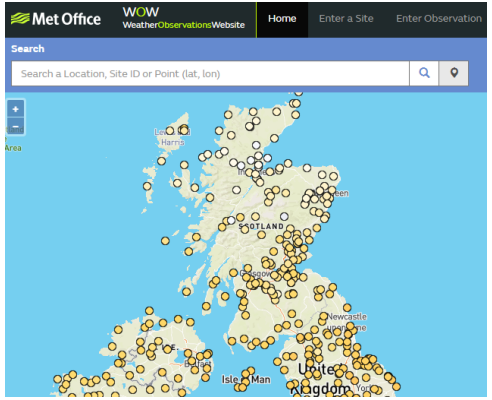
In principle, can analyse any variable for which an NWP field is available

Variable	Obs. available	Typical obs. error	Typical bgd. error	Localisation radius	Inflation factor	Smoothing radius (gridboxes)	Notes
2m temperature	Y	0.5 °C	0.5 °C	25	2.0	2	
2m dew point	Y	0.5 °C	0.5 °C	25	2.0	2	
PMSL	Y	0.2 hPa	0.4 hPa	50	2.0	3	
x/y wind at 10m	Y	1 m/s	0.6 m/s	25	2.0	2	
Visibility at 2m	Y	35 %	23 %	25	2.0	2	Limited observations
SBCAPE	N	N/A	N/A	25	1.0	2	Not directly observed
SBCIN	N	N/A	N/A	25	1.0	2	Not directly observed

Analyses are on a 2 km grid over UK/IRL area

2D Surface Mesoanalysis

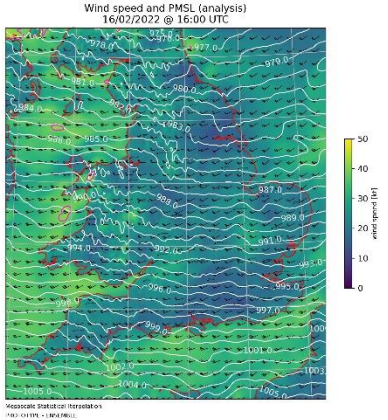
- Produce timely **2D analyses of surface variables** for situational awareness and nowcasting
  - 2 km grid over UK domain
- Exploit **high-density surface observations**
  - Use **data from private weather stations** (Met Office WOW network)
  - Also uses other surface observations
  - Approx. 2000 surface observations used per cycle
- **Incorporates ensemble NWP information** and allows for uncertainties
- Uses data assimilation methodology:
  Ensemble Optimal Interpolation (EnOI) (like EnKF)
- **Can use any observation for which an observation operator is available**
- Aims to produce analysis products
  within 15 minutes of observation time
- Distinct from NWP analysis (UKV 4D-Var):
  - Uses more recent observations and is optimised for close fit to observations



Home weather stations

From this…

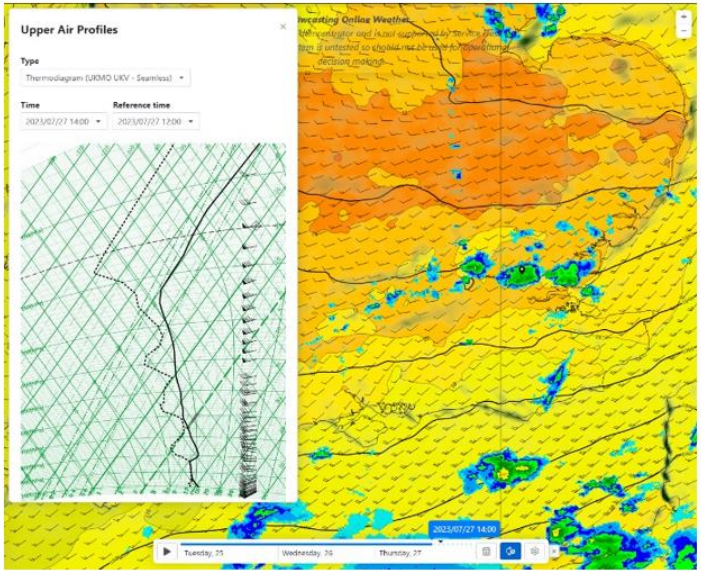
….to this



(Ed Pavelin, Nowcasting group)

Plans for 3D mesoanalysis

- **Mesoanalysis system will be extended to a 3D domain**
- Allow analysis of **vertical thermodynamic and wind profiles**
- Aim to incorporate upper-air observations and **satellite data**
  - **AMV winds (MSG/MTG)**
  - **Infra-red sounding data from MTG-IRS**
  - MODE-S aircraft data
- Allow forecasters to plot vertical profiles and cross-sections through near-real-time analyses
- Wind profile information is important for understanding:
  - Cell motion
  - Mode of convection



3D mesoanalysis visulisation concept incorporating horizontal fields, vertical profiles and radar overlay

Combine diverse observations in a single analysis
- Reduce the need to look at separate products

Retrieve a profile using the radiances. Then …

Lifted Index

- find LCL then follow a moist isentrope to 500 hPa; index is temperature difference
- correlates well to surface-based CAPE
- more negative value => greater instability

Potential wet-bulb index

- $\Theta_{w,500} \_ \Theta_{w,850}$
- negative value => greater instability

K index

- $T_{850} - T_{500} + T_{d,850} - (T_{700} - Td_{,700})$
- increasing positive value => greater instability
- useful to diagnose high precipitation