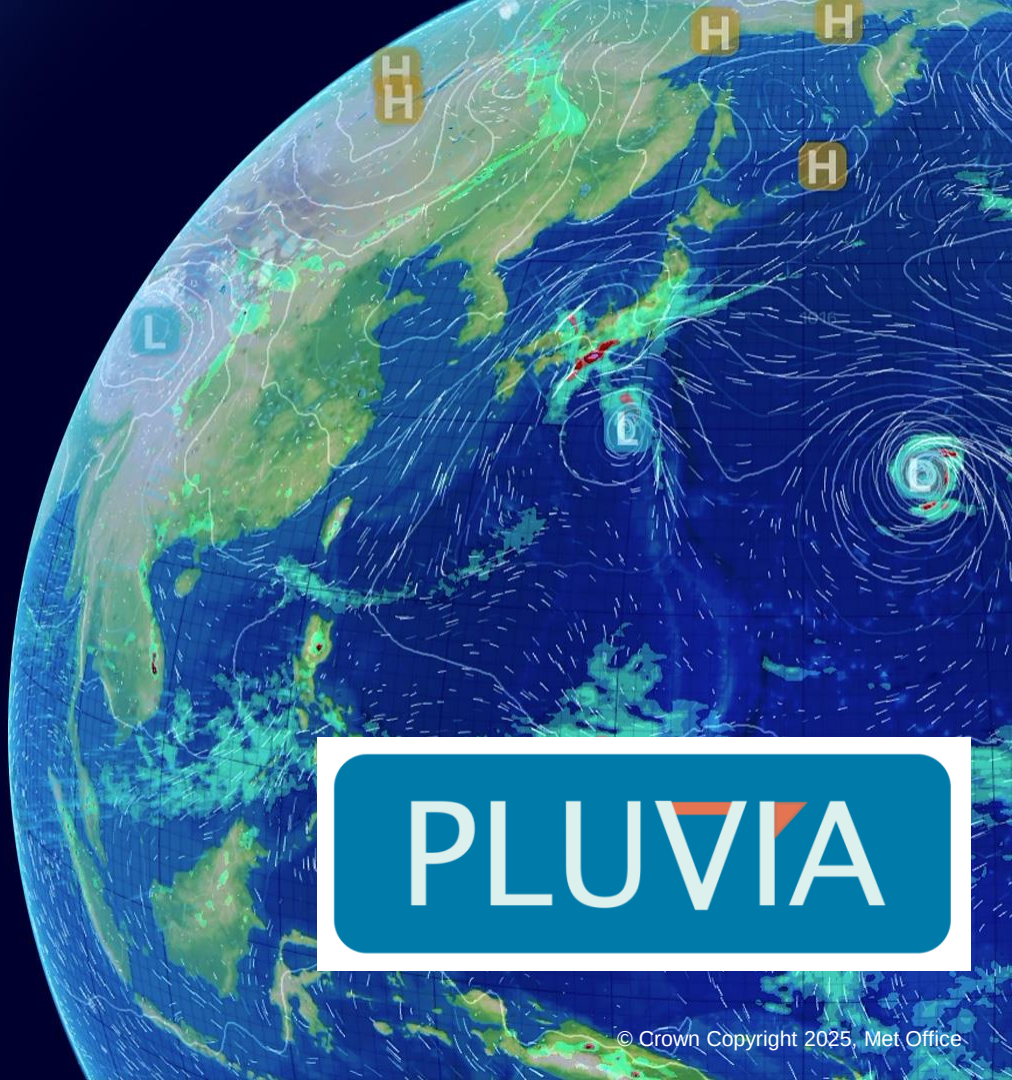
Nowcasting extreme rainfall over the UK

Katie Norman (she/her/hers)

Precipitation Processes - Estimation and Prediction, 20th March 2025

Matt Clark, Ed Pavelin, Andrew McNaughton, Anna Booton, Billie Mackenzie, Graeme Kelly, Brian Golding, Rosie Nation, Dan Suri, Will Rosling, Emma Hattersley



Overview

- Context for Nowcasting in the UK
- Overview of PLUVIA
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Rapid-onset flooding from intense rainfall

Flood Forecasting Centre: *“Rapid flooding is any flooding that starts within 6 hours of rain. It is caused by water getting trapped in urban low spots or overflowing drains and flow from small streams and rivers.”*

Kendon et al (2023) found that: *“a future intensification of short-duration rain in summer, with significantly more events exceeding the high thresholds indicative of serious flash flooding”*

2022	Good or Excellent Guidance	Poor or Very Poor Guidance
All weather warnings	80-85%	5-10%
Shower and Thunderstorm related warnings	40-45%	40-45%

Matt Clark

Analysis of surface water flooding events associated with deep moist convection in the UK

103 events 2015 – 2021

synoptic-scale, mesoscale and storm-scale environments explored using ERA5 reanalysis, satellite and radar.

Events distributed across a wide range of synoptic regimes. Most cases relate to **mesoscale features**.

It's a matter of "time" – flow aligned lines, slow cell advection velocities and back-building allow more rainfall to fall in one place.

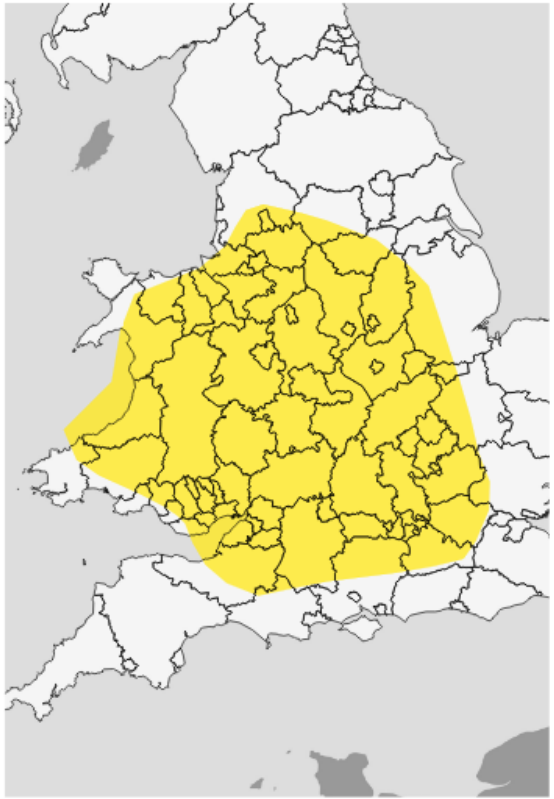
Most often occurs in relatively **low-CAPE, low-shear environments** (median values of MUCAPE and effective bulk wind shear of 561 J kg-1 and 13.8 knots, respectively).

Why nowcasting?

Thunderstorm warning issued at 10:00 BST Sun 11th June (about 24 hours ahead)

Yellow warning
Thunderstorm

Between
12:00 Mon 12 Jun 2023 and
21:00 Mon 12 Jun 2023



Thunderstorms and torrential downpours may bring disruption to parts of England and Wales during Monday.

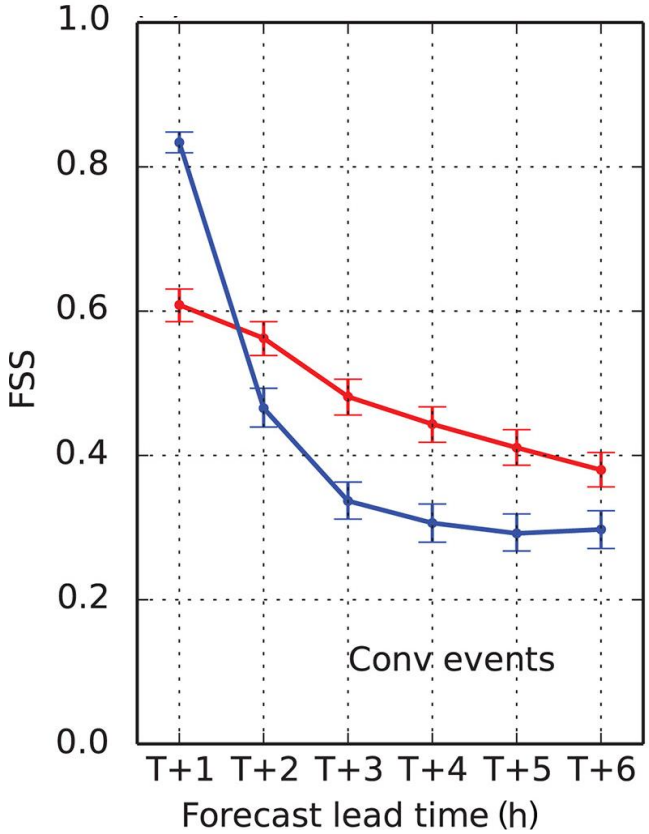
What to expect

- Flooding of homes and businesses could happen quickly, with damage to some buildings from floodwater, lightning strikes, hail or strong winds
- Spray and sudden flooding could lead to difficult driving conditions and some road closures
- Some communities might become cut off if roads flood
- Where flooding or lightning strikes occur, there is a chance of delays and some cancellations to train and bus services
- Power cuts might occur and other services to some homes and businesses could be lost
- Fast flowing or deep floodwater is possible, causing a danger to life

Why nowcasting?

The requirement for accurate 5-day forecasts makes it difficult to draw close enough to the observations assimilated to produce accurate very short-range forecasts.

Simonin *et al.* (2017): >1mm in an hour in convective events is forecast better by extrapolating rainfall radar (blue) than by NWP (red) 1.5 – 2 hours ahead.



Simonin *et al.* (2017) https://doi.org/10.1002/qj.3136

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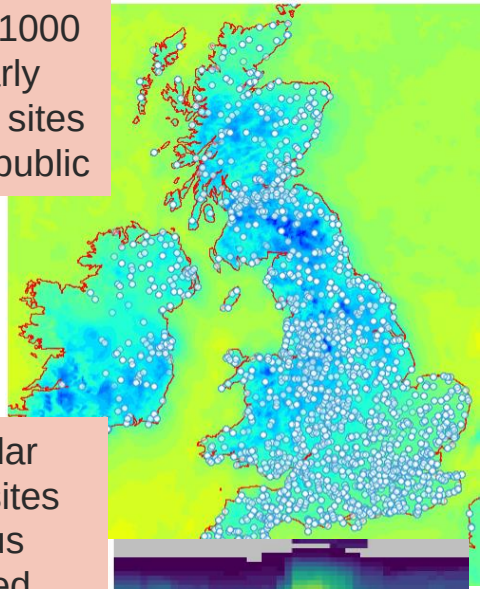
Met Office

PLUVIA

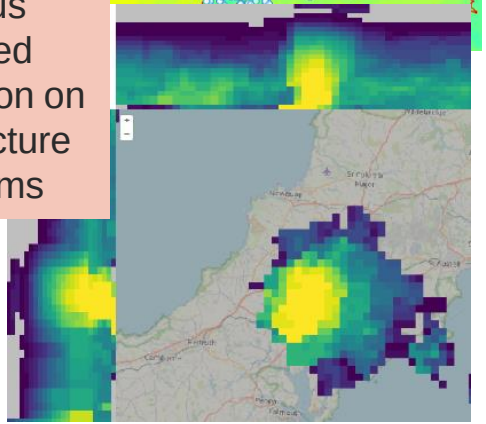
What is PLUVIA?

- Combines observations and NWP to produce **analyses** that can draw closer to observations than NWP.
- Uses alternatives to a physical simulation (e.g. Ensemble Forecast Adjustment, Kalman Filter) to generate **nowcasts** that have greater skill than NWP in the first few hours of the forecast.
- Developed to support the conceptual models used by Operational Meteorologists and Hydrometeorologists.

WOW > 1000 regularly reporting sites from the public



3D radar composites give us detailed information on the structure of storms

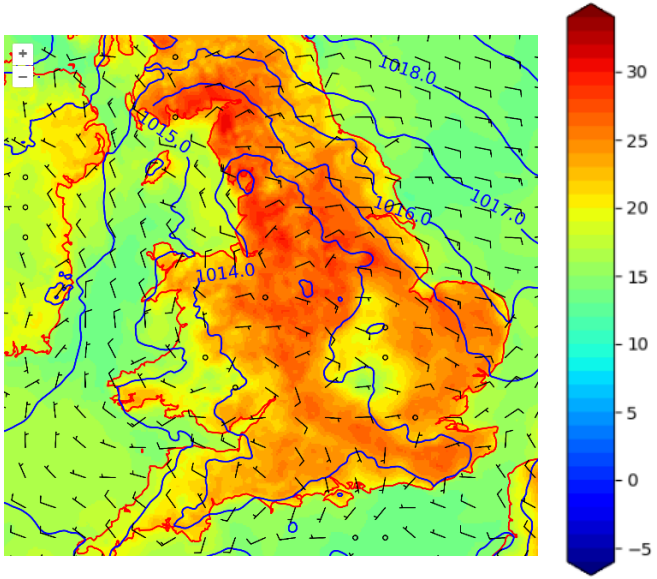


PLUVIA Mesoanalysis

Time-lagged 18-member ensemble NWP background from MOGREPS-UK

Combined with temperature, dewpoint, wind and pressure observations from WOW using Ensemble Optimal Interpolation (EnOI) to produce an analysis

Follows Lussana et al (2019)



Analyses of near-surface temperature, dewpoint, pressure, wind are much more timely than those from NWP, and draw more closely to the observations.

Currently hourly, **available at T+12 minutes**.

Allows an ingredients-based approach to be implemented by Operational Meteorologists, and the identification of mesoscale features.

Lussana et. al (2019): https://doi.org/10.1002/qj.3646

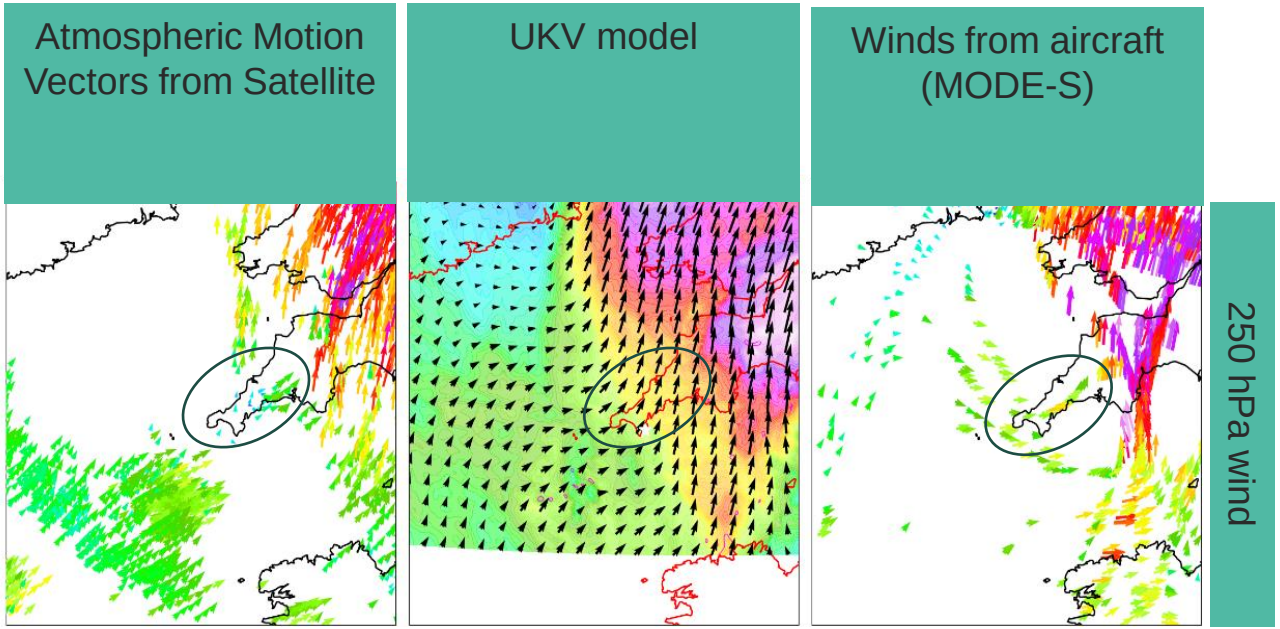
Ed Pavelin and Matt Clark

Extending to 3D

Flash flooding event in South-West England from a near-stationary storm.

Upper-level wind observations from satellite atmospheric motion vectors (left) and MODE-S (right) are much lower than the model (centre)

Convective cells likely to be slower-moving and associated with flooding impacts.



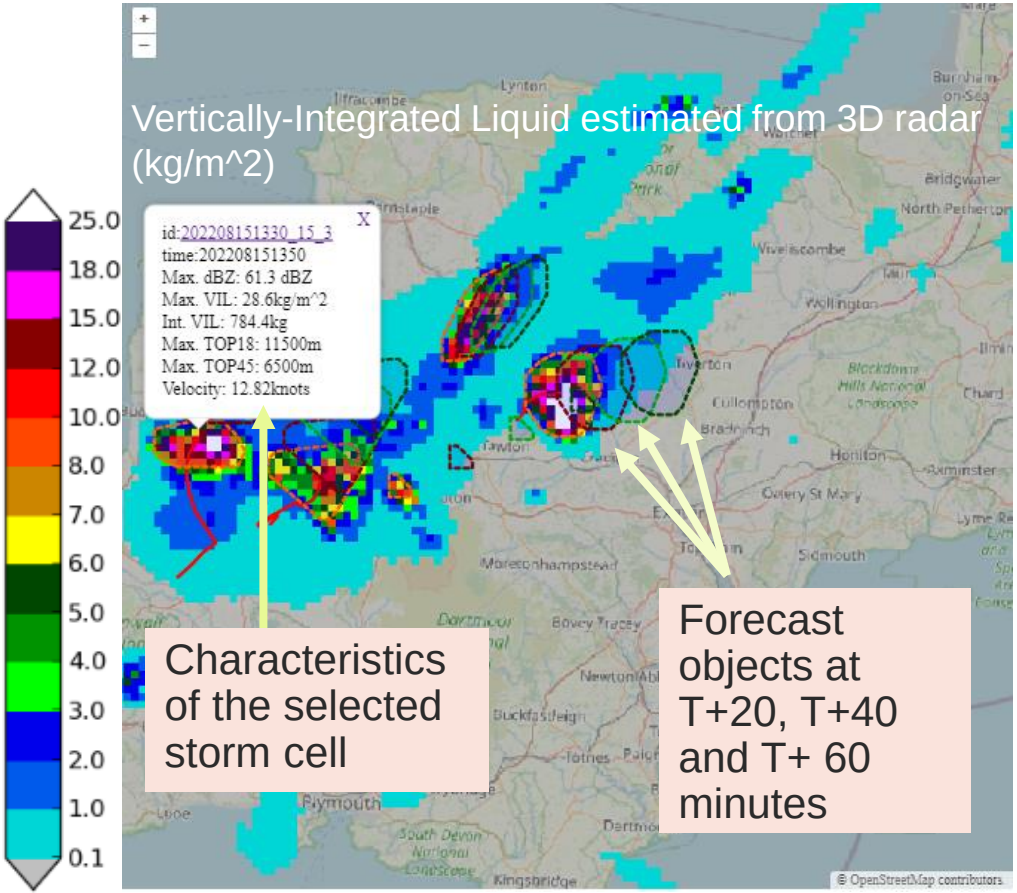
Andrew McNaughton

PLUVIA Cell Tracker

Convective cells are identified and tracked using a Vertically-Integrated Liquid (VIL) field derived from the 3D mosaic of radar reflectivity over the UK.

Optical Flow and an object-based Kalman Filter are used to forecast the trajectory of individual storms

Based on Muñoz et al (2018) with enhancements for probabilistic output.



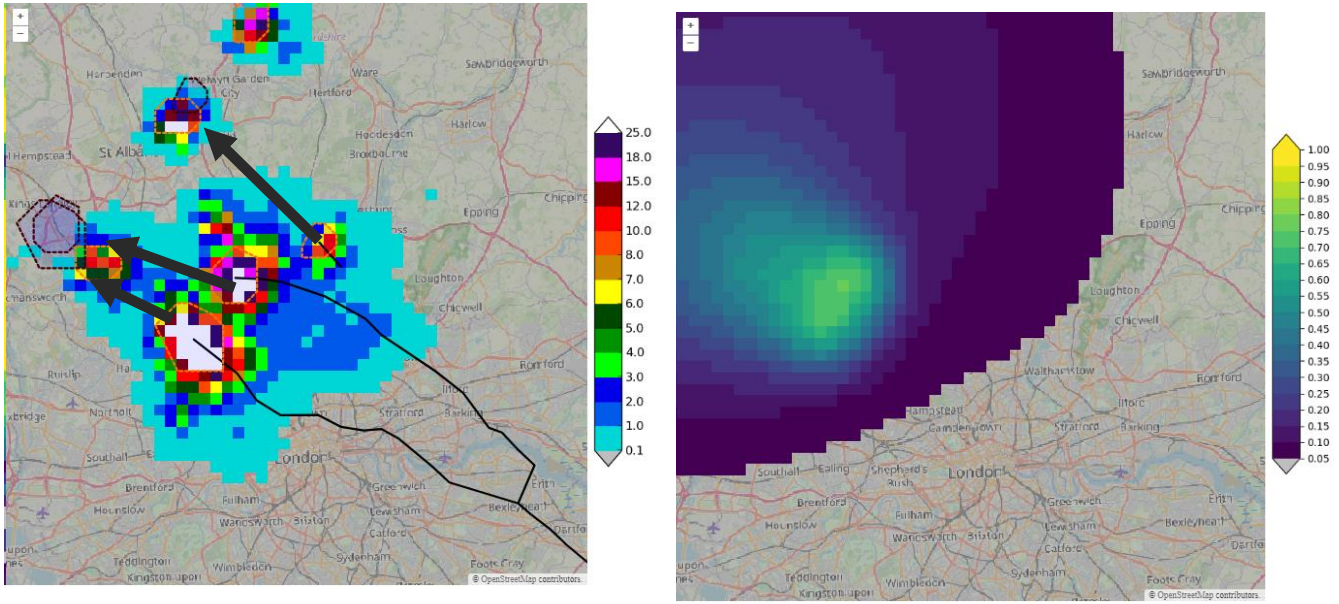
Muñoz et al (2018). Enhanced object-based tracking algorithm for convective rain storms and cells. Atmos. Res, 201, 144-158.

Andrew McNaughton

Introducing a Kalman Filter for Probabilistic nowcasts

Left: Vertically integrated liquid (kg/m3), with cells identified by dashed lines. Arrows connect identified cells with their forecast location in 30 minutes.

Right: New probabilistic forecast showing the probability of a storm passing in the next 60 minutes.



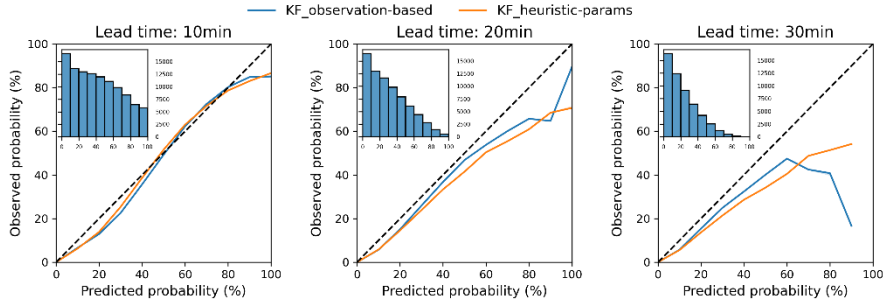
Wang et al (2024): Uncertainty Estimation For Convective Cell Nowcasting: A Kalman-filter Implementation Of Enhanced TITAN. ERAD 2024.

Met Office

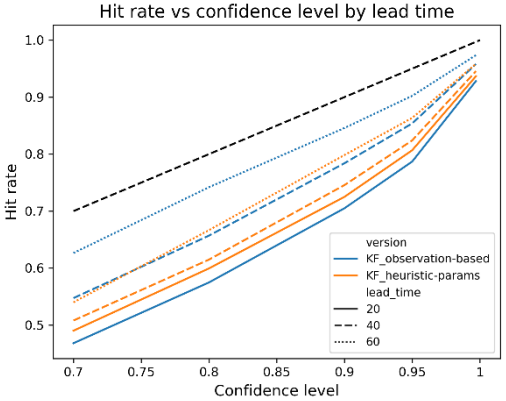
Probabilistic evaluation

- Reliability diagrams show good agreement between observed and predicted probabilities.
- Consistently positive Brier Skill Scores at all lead times show gain in skill from using probabilistic model over deterministic one.
- Observation based parameters show generally lower hit rates at shorter lead times than heuristic parameters but perform better at longer lead times.

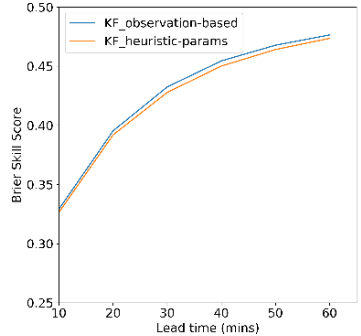
RELIABILITY DIAGRAMS



HIT RATES



BRIER SKILL SCORE



$$BSS = 1 - \frac{BS}{BS_{ref}}$$

Forecast centroid and confidence disc

1 Observed centroid = HIT

2 Observed centroid = MISS

Wang et al (2024): Uncertainty Estimation For Convective Cell Nowcasting: A Kalman-filter Implementation Of Enhanced TITAN. ERAD 2024.

Andrew McNaughton

Ed Pavelin

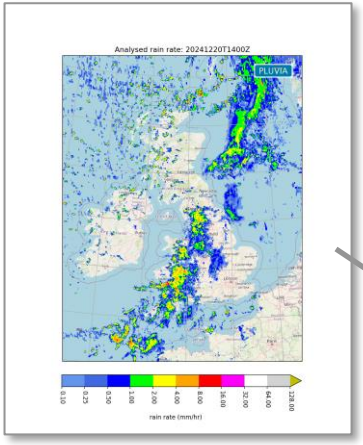
PLUVIA Precip

A framework for field-based rainfall analysis, nowcasting and verification.

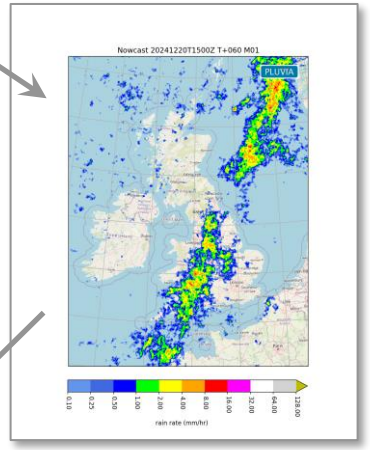
- **Analysis:** Currently uses radar and satellite. Ambition to extend to use WOW and possibly microwave links.
- **Nowcast:** Support for multiple nowcasting models, e.g.: Lagrangian Persistence, STEPS ensemble nowcasts and Machine Learning models.
- **Verification**

For skill in convection, we must go beyond rainfall-only inputs.

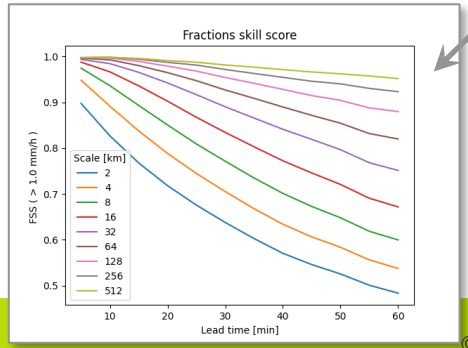
Analysis



Nowcast



Verification



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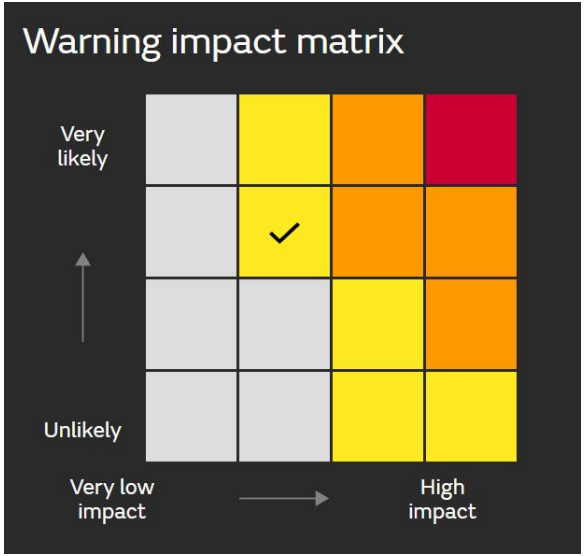
National Severe Weather Warning Service

Impact and likelihood-based warning matrix.

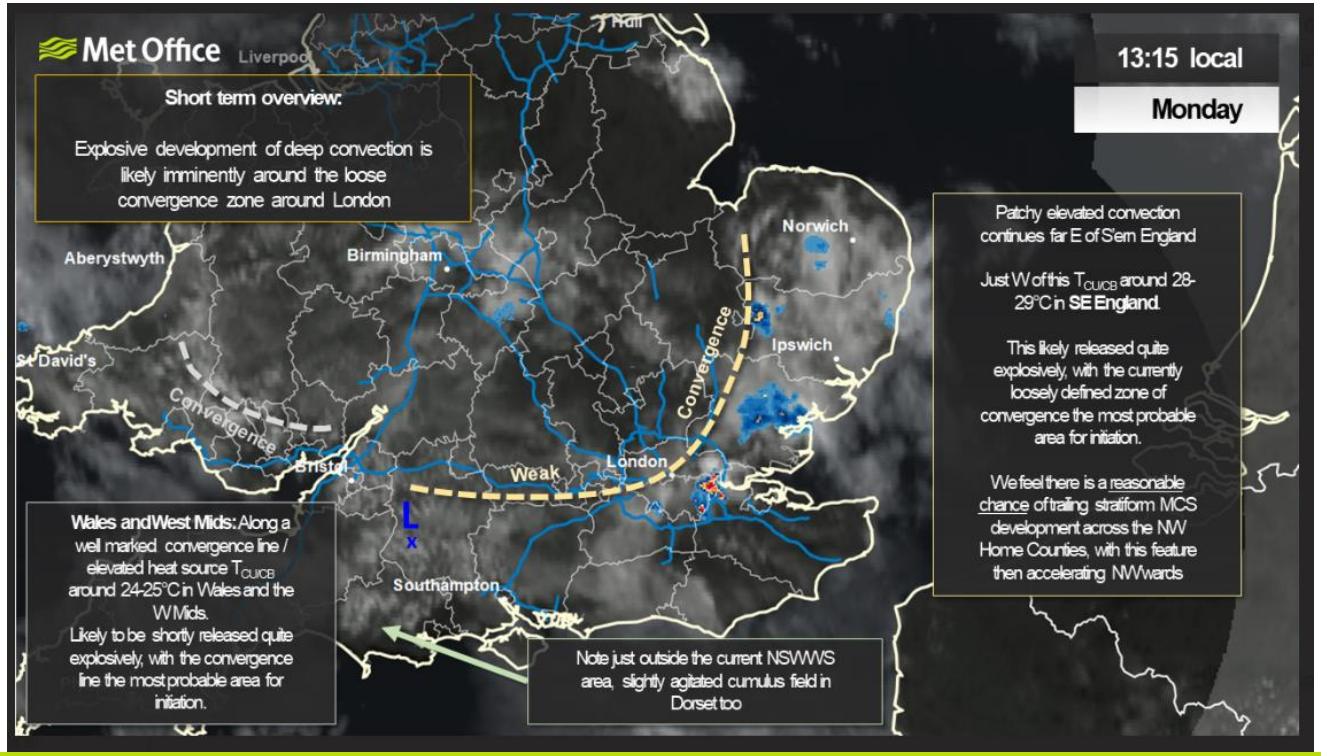
Warnings issued to the public and used by emergency responders for planning and response to severe weather

-> More localised and short-notice warnings for severe weather associated with summertime convection.



Improved nowcasting services during summertime convection

- Training
- PLUVIA nowcasting tools
- Observations
- Forecasts



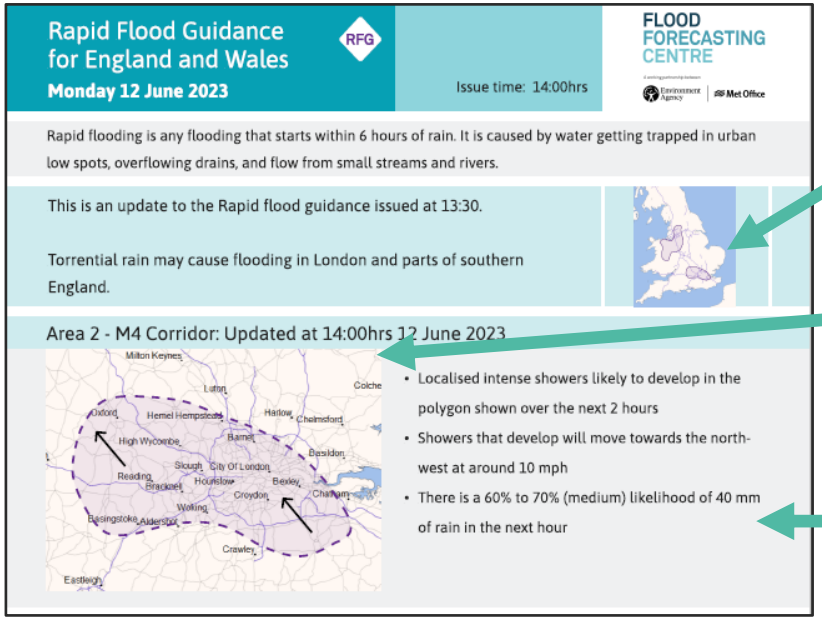
Met Office

FLOOD FORECASTING CENTRE

A working partnership between Environment Agency | Met Office

Rapid Flood Guidance

Flood Forecasting Centre delivered a trial Rapid Flood Guidance service for England during the Summer 2024.



Overview map showing areas affected.

More detailed map of one of the affected areas

Summary of meteorology and likelihood of high rainfall totals.

Matt Clark, Will Rosling, Emma Hattersley, Dan Suri, Rosie Nation, Brian Golding

Summer Nowcasting Testbed 2024

90 participants from 11 countries

5 weeks in June/July 2024

Nowcasting experiments each afternoon

Visualisation, surface water flood model evaluation, and warnings activities on different mornings.

Matt Clark, Will Rosling, Emma Hattersley, Dan Suri, Rosie Nation, Brian Golding

Summer Nowcasting Testbed 2024

Teams of 1 Operational Meteorologist, 1 Scientist, (both Met Office) and 1 or more participants from other organisations were set two tasks:

(1) Refining a warning polygon for a pre-defined convective hazard, through the afternoon to focus on the areas most impacted.

(2) Predicting point (grid box) one-hour rainfall totals for locations nowcast to be most impacted. (Golding et al (in prep)).

In addition to the polygons and point forecasts, teams were asked which tools were most useful for making their nowcasts.

Matt Clark, Will Rosling, Emma Hattersley, Dan Suri, Rosie Nation, Brian Golding

Summer Nowcasting Testbed 2024

Category	Mesoanalysis rated "Useful" or "Very Useful" (% responses)	Cell Tracker rated "Useful" or "Very Useful" (% responses)
Maritime convection advecting onto windward coasts, without significant overland/diurnal intensification	11	30
Marginal/weak and generally isolated convection within frontal zone invigorated by upper forcing/surface heating	25	29
Deep surface-based convection, banded showers forming along trough/convergence zone.	30	65
Surface-based convection along a surface front, e.g. line convection on a cold front	34	35
Scattered or widespread deep instability associated with surface heating and relatively cold air aloft	29	58
Widespread deep instability within a warm plume, possibly with Elevated Mixed Layer, typically ahead of weak/slow-moving front or within a warm sector	34	62

Summary

The PLUVIA Cell Tracker and Mesoanalysis have been developed to support Operational Meteorologists in nowcasting and warning for hazards associated with deep moist convection, in particular extreme rainfall.

Recent advances in science and operations have allowed the Flood Forecasting Centre to offer a new Rapid Flood Guidance Service.

PLUVIA has been evaluated in a testbed environment. We found that PLUVIA was most useful in situations where more intense convection was likely or present.

Thank you for your attention.

11th August 2024. North Devon. Photo credit: Matt Clark