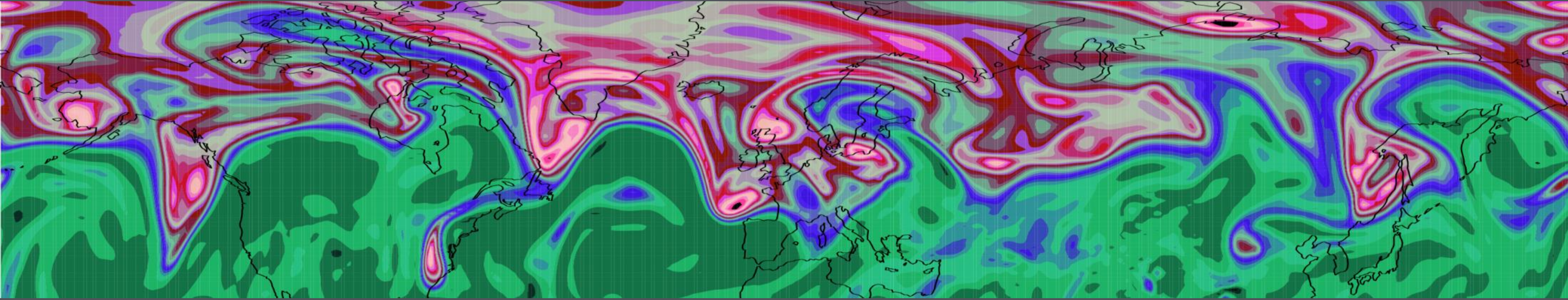
Department of Meteorology

University of Reading

CAPRI – Cyclones, coupled Atmosphere-surface Processes and Risk of Impacts



John Methven, Suzanne Gray, Helen Dacre, Len Shaffrey, Oscar Martínez-Alvarado, Ben Harvey, **U. Reading**;
Ian Renfrew & Xiaoming Zhai, **UEA**; Doug Parker & Andrew Ross, **U. Leeds**; Jennifer Catto, **U. Exeter**;
Justin Langridge, Duncan Ackerley, Segolène Berthou, Huw Lewis, **Met Office**;
David Lavers & Linus Magnusson, **ECMWF**.

CAPRI – Focus on 3 weather impacts

Cyclones are most intense in winter and impacts include:

i. Damaging winds

ii. Extreme ocean waves affecting coastlines and offshore infrastructure

iii. Catchment-scale heavy precipitation and flooding

Aim of CAPRI is to observe, understand and model the atmosphere and coupled hazards at the scales where impacts are felt, from ~200 km down to ~20 m.

Quantify elevated risk with climate change of these 3 weather impacts.

CAPRI – Science questions

Overarching science question:

How do atmosphere-surface interactions affect cyclone impacts on the UK?

1. *Coupling with BL: momentum transfer downwards and downscale*
    - *How are severe wind footprints and damage generated?*
2. *Coupling at ocean interface*
    - *How does coupling with ocean affect cyclone impacts?*
3. *Coupling moisture transport with heavy precipitation*
    - *How well are moisture uptake and precipitation mechanisms represented?*
    - *Focus on turbulent fluxes near fronts and precip efficiency for ARs over orography.*

CAPRI – Multi-scale processes

Phenomena bringing severe winds (B, T) and precipitation (U, P)

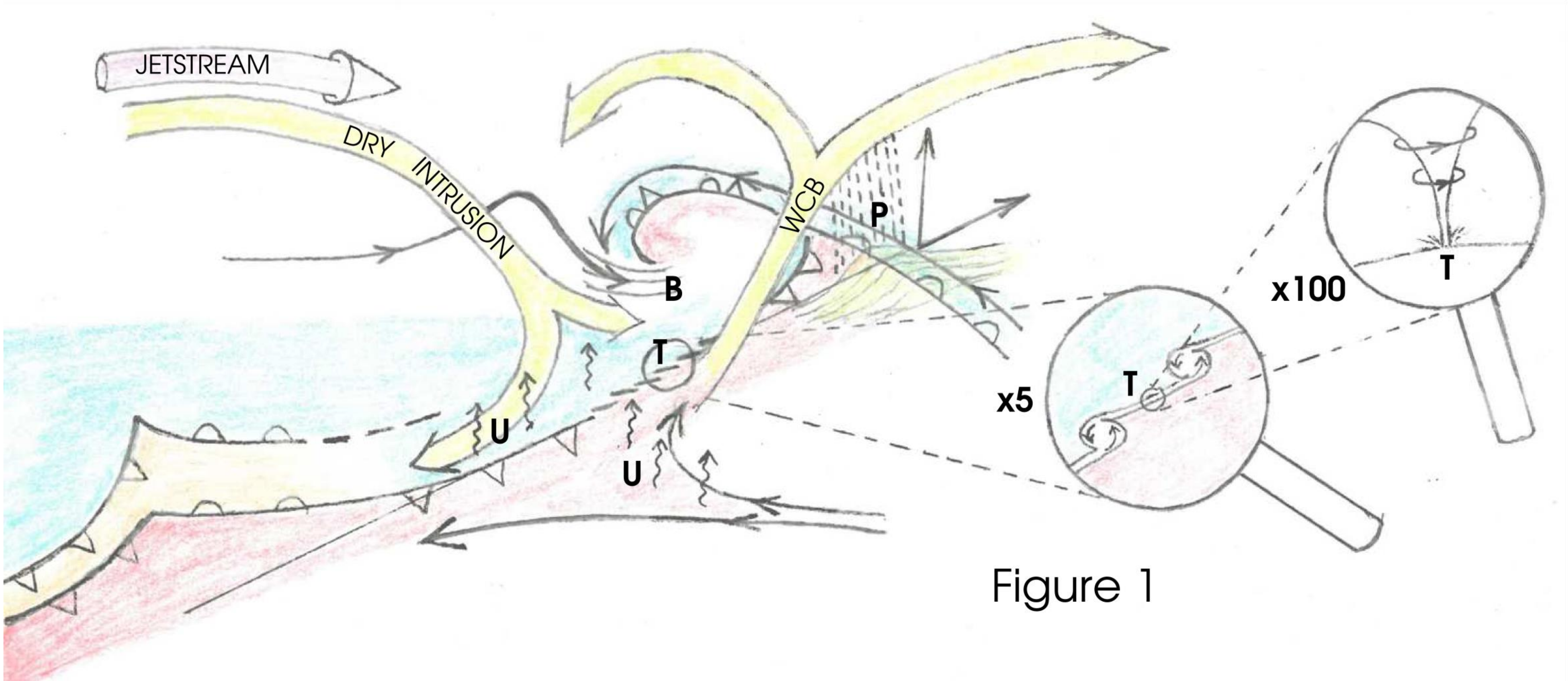


Figure 1

Observational capabilities

FAAM aircraft and UK ground networks

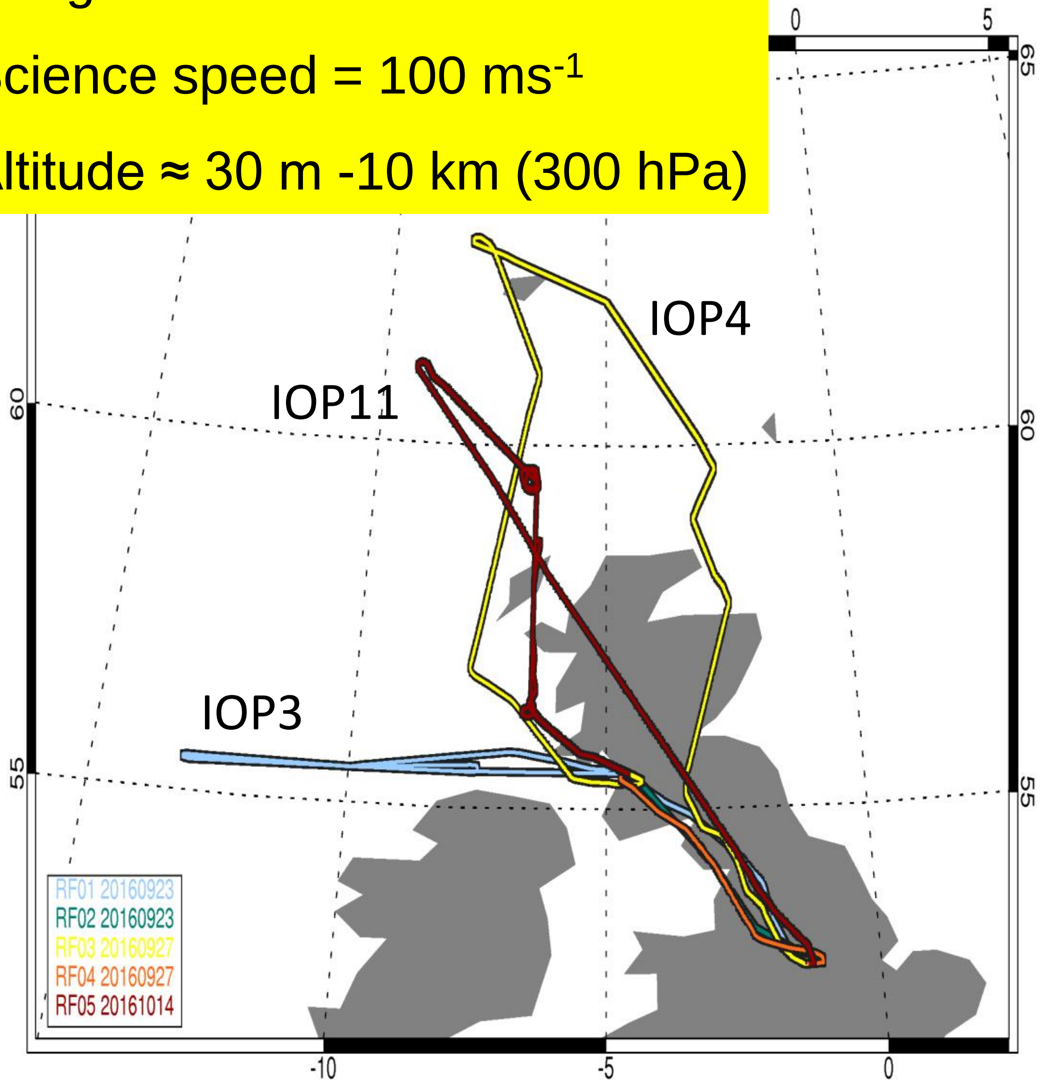
FAAM aircraft from NCAR C130 during RICO. *Courtesy of Bjorn Stevens*

FAAM research aircraft capability

Range ~ 4.5-5 hrs

Science speed = 100 ms^{-1}

Altitude ≈ 30 m -10 km (300 hPa)



FAAM: Mid Life Upgrade Project

Mid Life Upgrade (MLU): major refit to aircraft and instruments (funded £50M).

It will be equipped for service until 2040.

- Turbulence probe upgrade (heated and not heated)
- Cloud microphysics probes upgraded
- **New wind and aerosol lidars**
- Laser altimeter *possible* (measurements of surface height including ocean waves)
- 3-channel Doppler radar *(but unlikely to be ready by 2026)*

Timeline: MLU is scheduled to complete in March 2026.

Last new instruments due to be fitted in autumn 2025.

Therefore, NAWDIC will still be during testing phase for some instruments.

Ground-based instruments

Radars:

Chilbolton S-band (3 cm) Doppler, dual-polarisation radar

FGAM Mobile X-band (10 cm) Doppler, dual-polar radar

Met Office network Doppler C-band (4-8 cm) radars.
Dual-polarisation providing radial wind component.

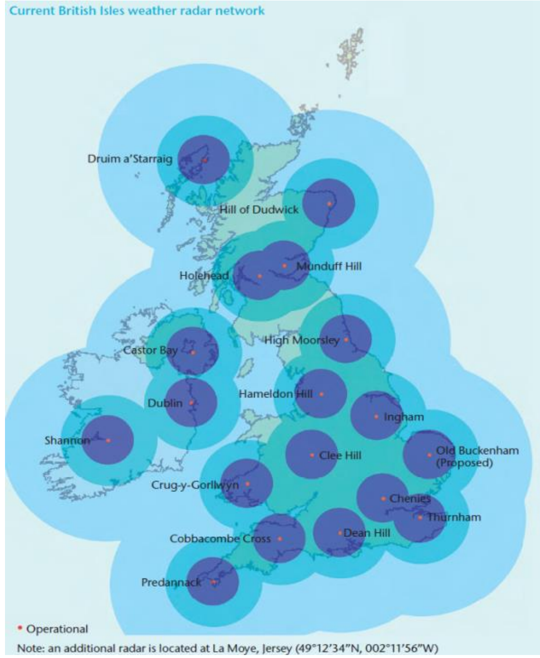
Wind Profilers:

MST, Aberystwyth (Wales). ST, South Uist (Scotland)

Radiosonde stations:

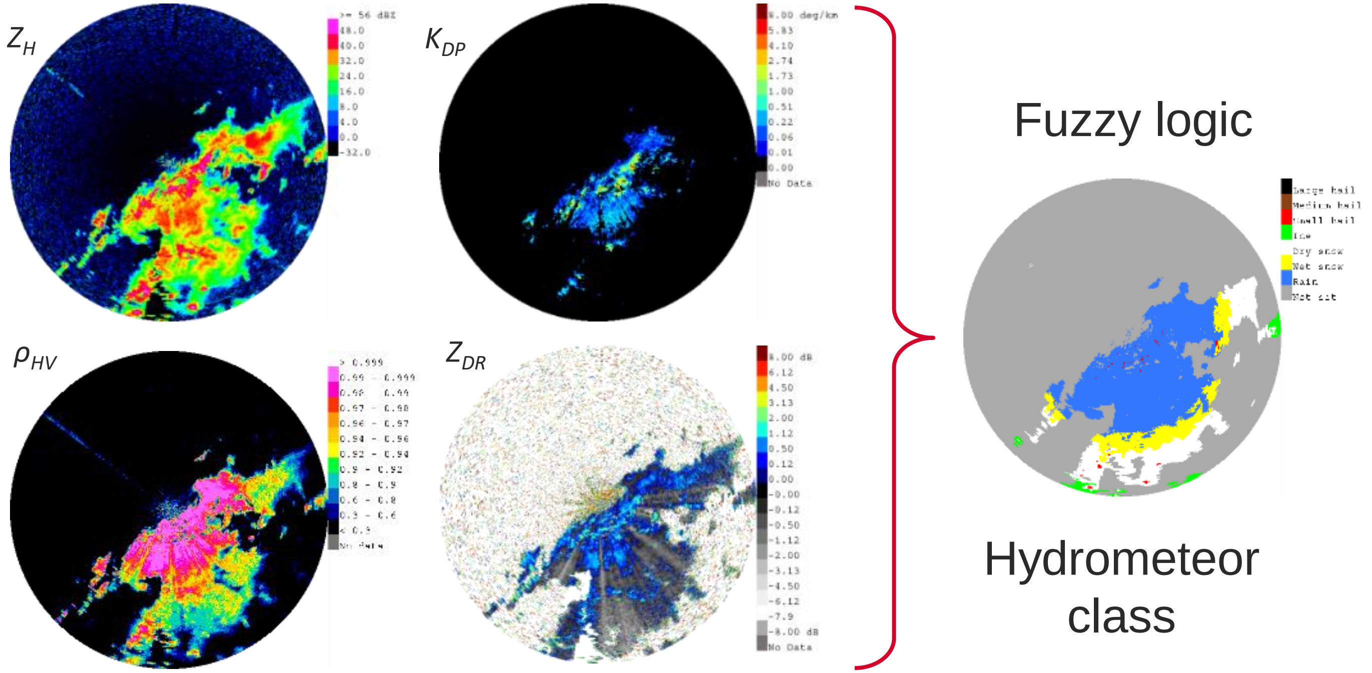
6 operational GTS sites + additional from Aberystwyth

FGAM mobile radar with the large Chilbolton radar.

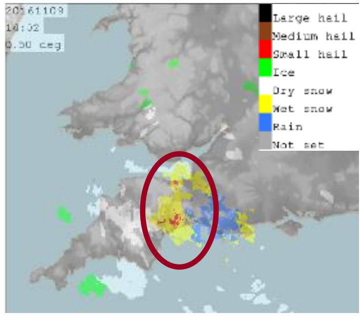


Met Office network radars

Dual polarisation radar network
Improved hydrometeor classification

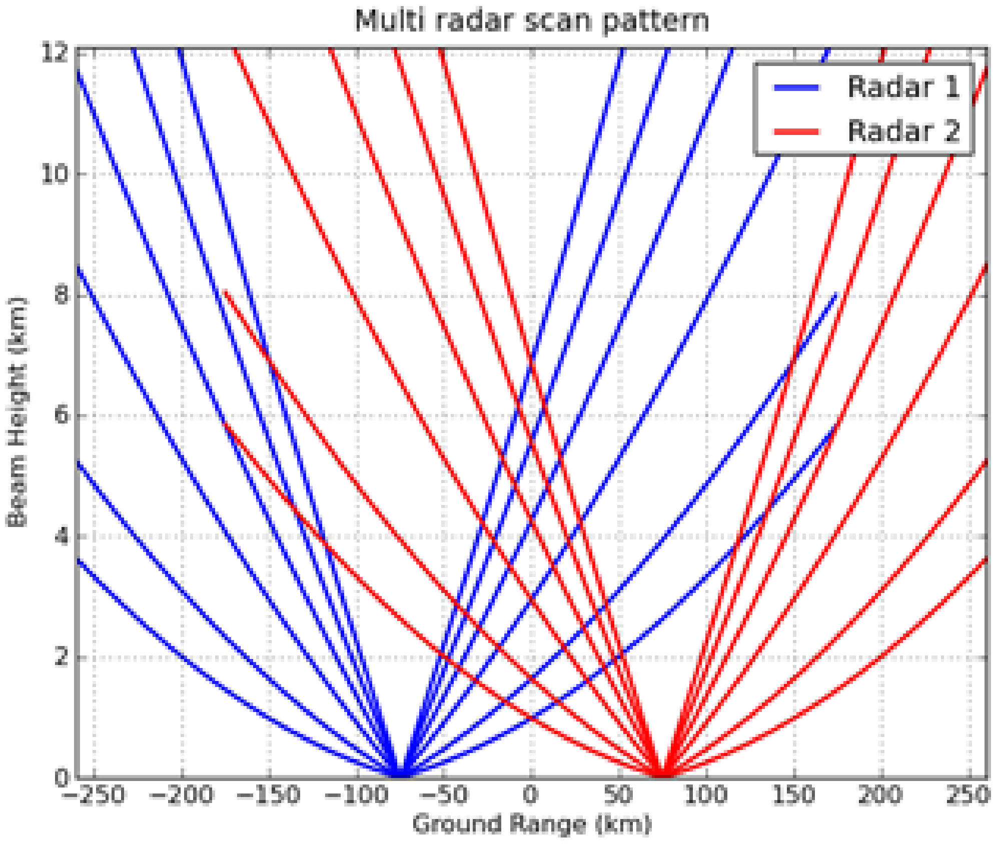


Tim Darlington,
Met Office



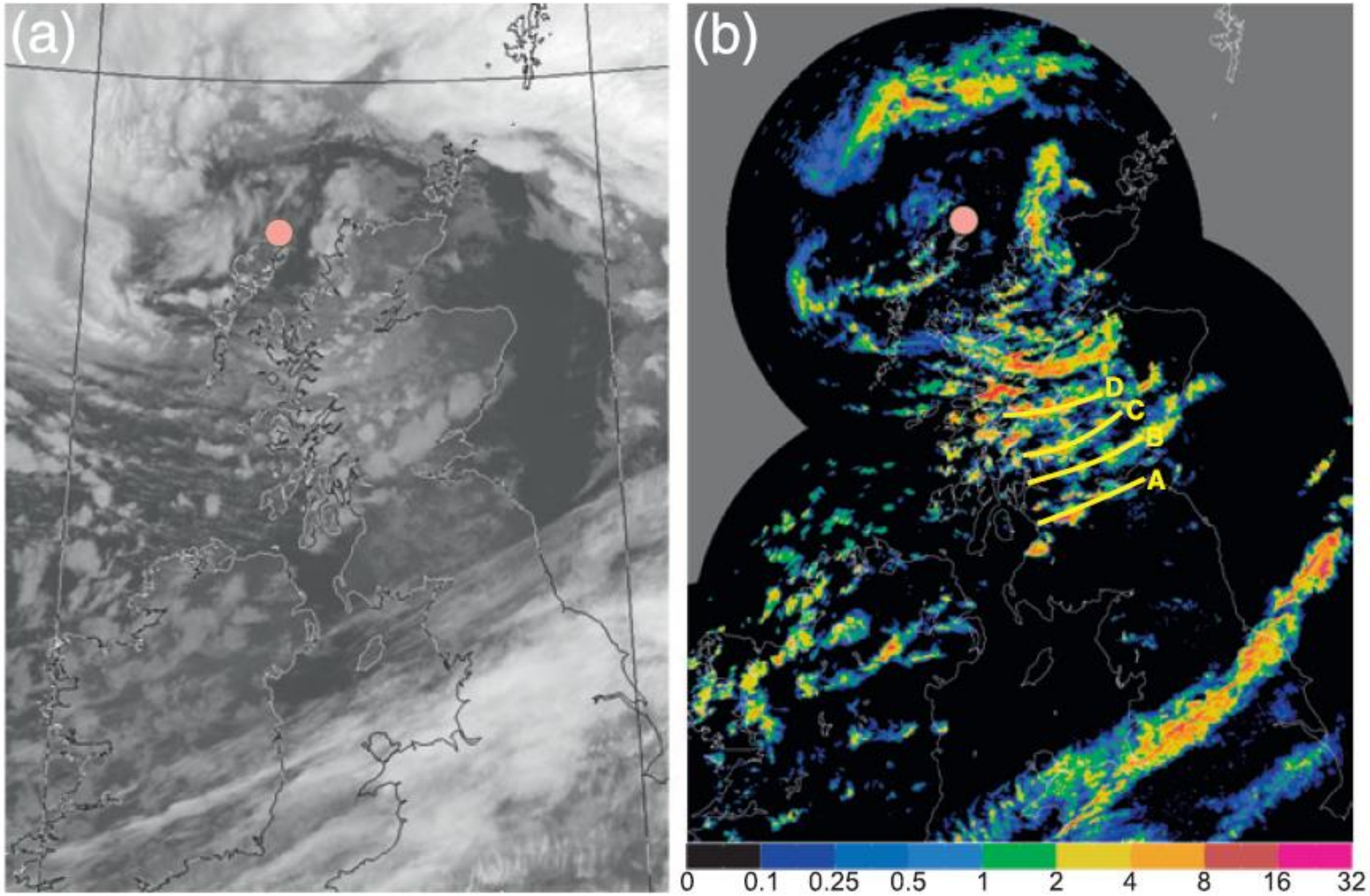
3-D radar retrieval for severe weather prediction

- By using multiple scan data from multiple radars we can generate a 3D view of the precipitation above the UK
- The additional information from the 3D structure data is particularly useful for aviation and severe weather forecasting
- Additional products such as Probability of severe hail, vertically integrated water, vertically integrated ice, max height of reflectivity



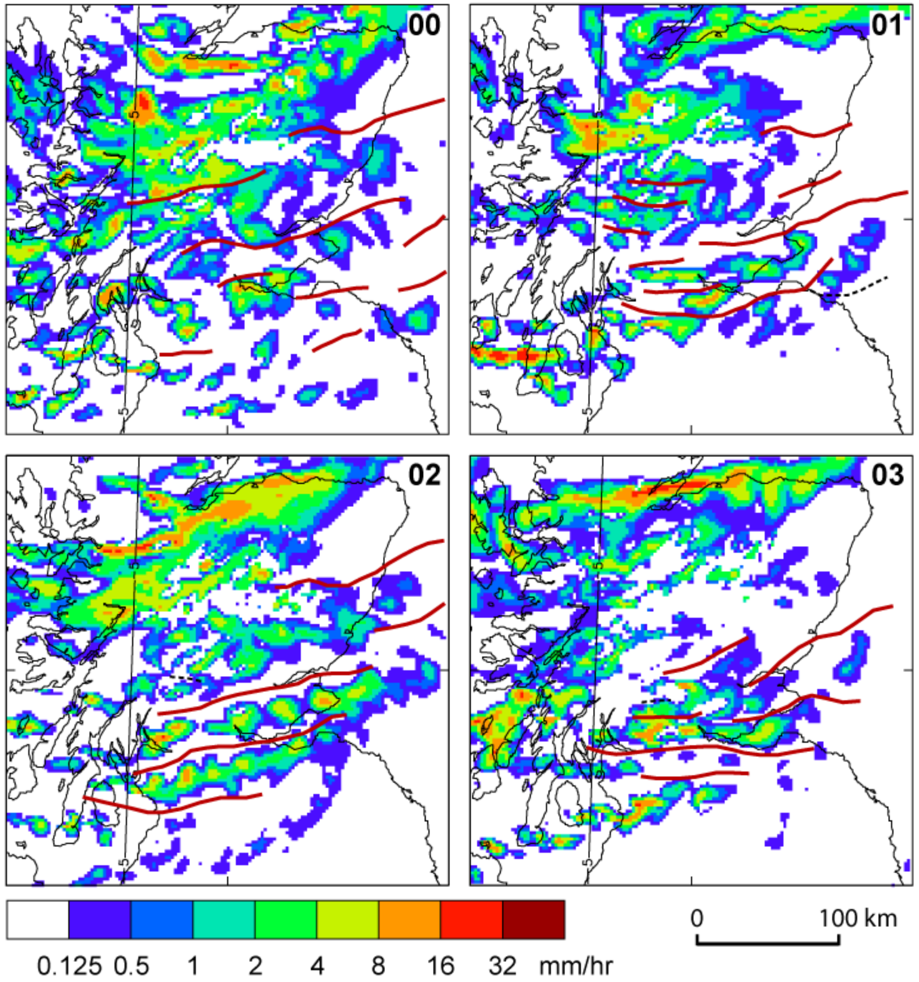
Topic 1: Damaging winds (e.g., mesoscale banding)

Friedhelm – sting jet cyclone - DIAMET IOP-8



Vaughan *et al*, *BAMS* (2015)

Banding in high resolution ensemble forecast

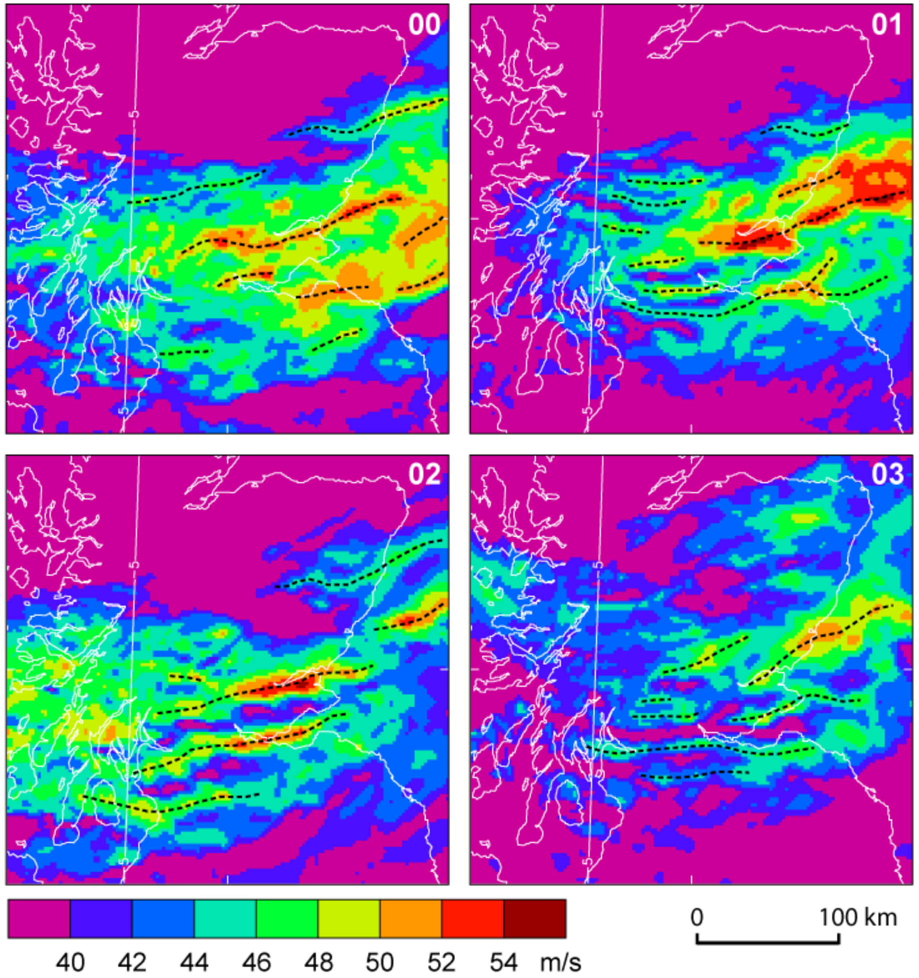


Precipitation rate from 4 ensemble members of a high resolution forecast for the IOP8 cyclone.

Trial of Met Office MOGREPS-UK ensemble (2.2km grid)

Vaughan, Methven *et al*, *BAMS*, 2015

Banding in high resolution ensemble forecast



Wind speed (850 hPa) from the same 4 ensemble members.

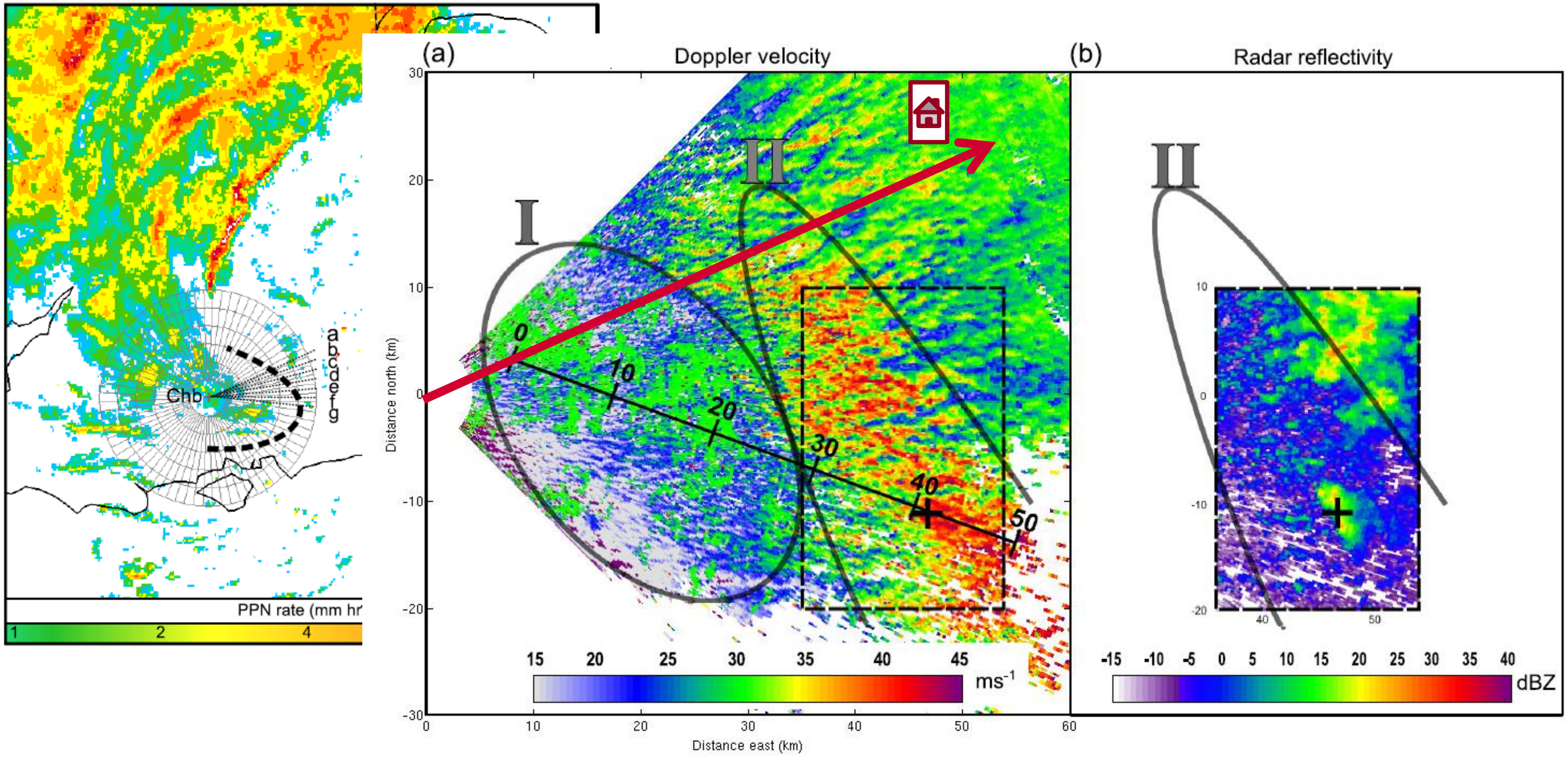
Strongest winds occur between the precip bands.

Seen at surface stations but no Doppler radar network in 2011

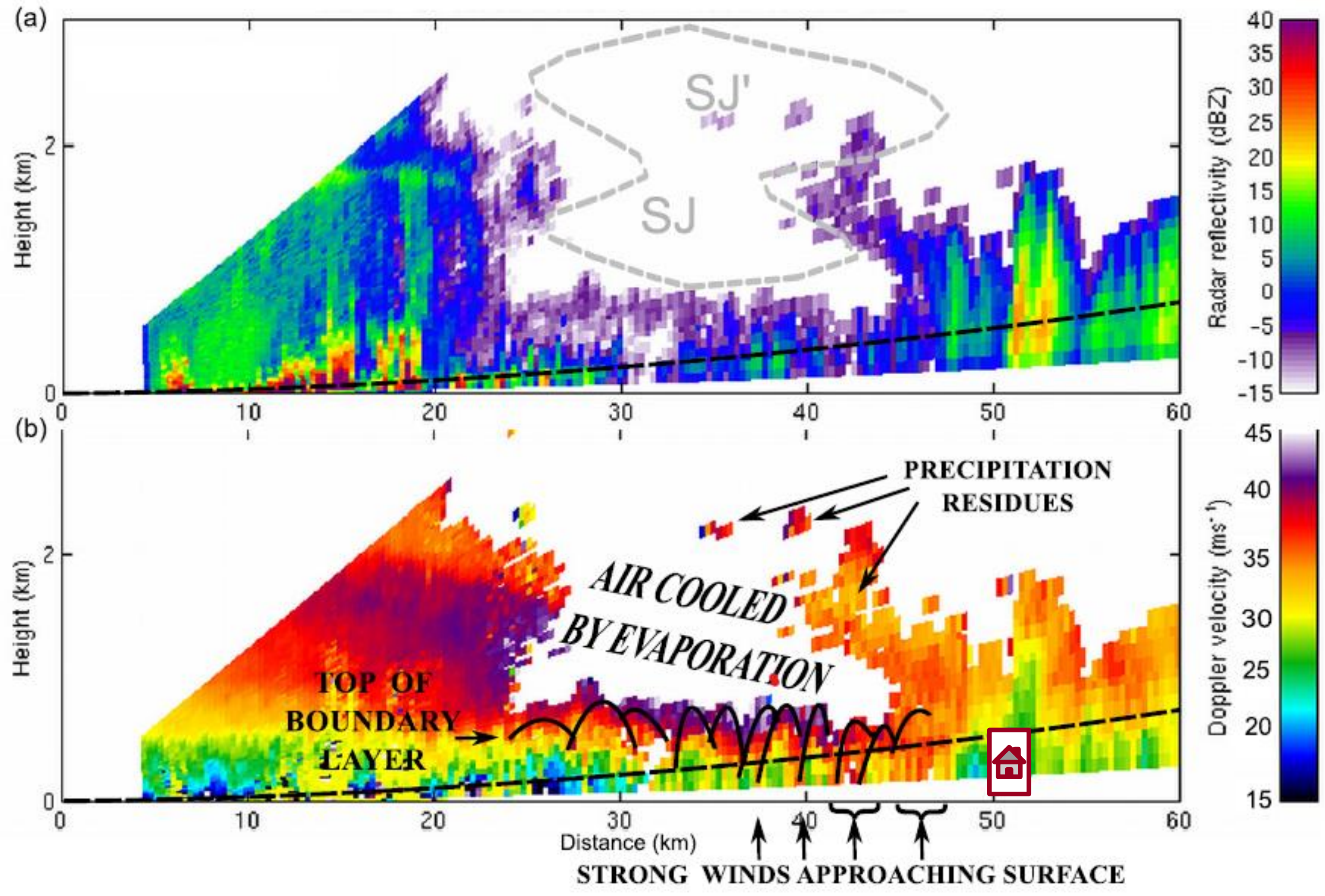
Implications for predictability of wind damage in intense cyclones.

Vaughan, Methven *et al, BAMS*, 2015

St Jude's storm, Oct 2013 (Browning *et al, QJ*, 2015)

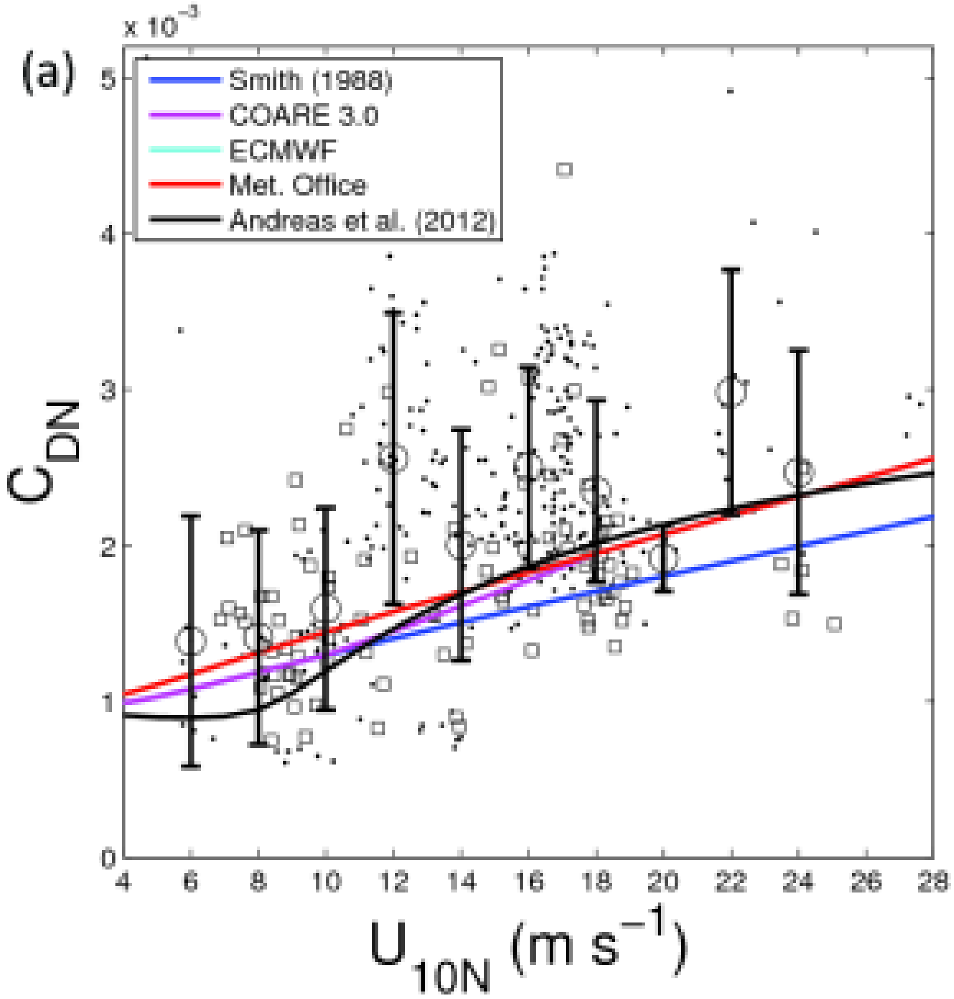


RHI scan – Chilbolton radar



Topic 2: Air-sea interaction. Turbulent surface layer fluxes in the marine BL in high wind speed conditions

Using data from FAAM low level legs over sea near the UK, 2007-2012



Momentum exchange coefficient obtained from turbulence probe measurements from 26 flights.

Stronger wind dependence than in current parameterisations.

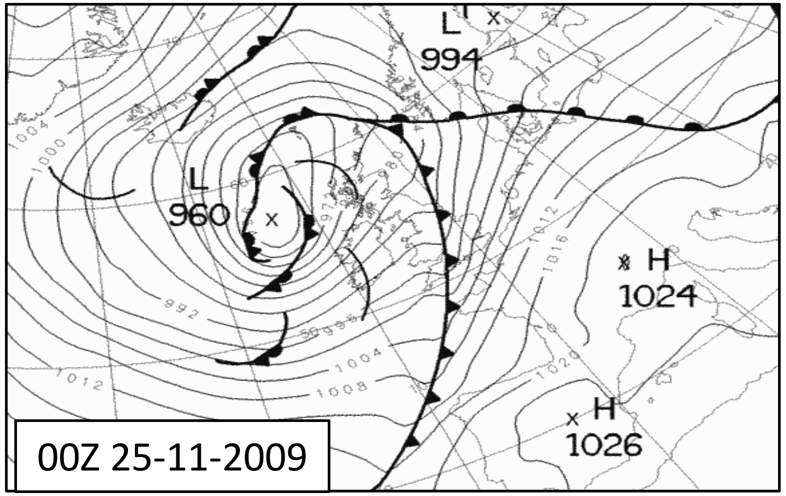
Requires straight legs at z=30-50m ASL.

Wind direction important.
Higher C_D for cross-wind legs.
Evidence for anisotropy in turbulence.

Cook and Renfrew, *QJRMS*, 2013

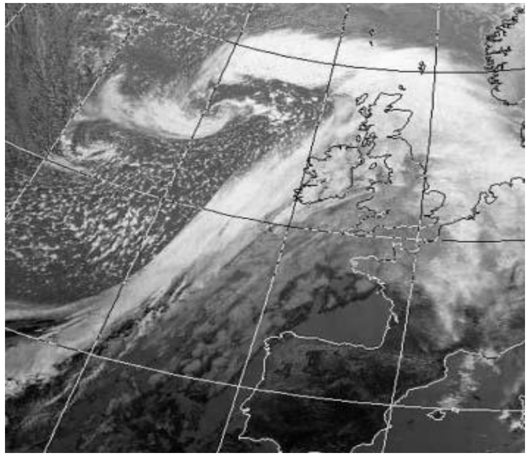
Topic 3a: Moisture uptake into ARs

e.g., T-NAWDEX Pilot, flight 3



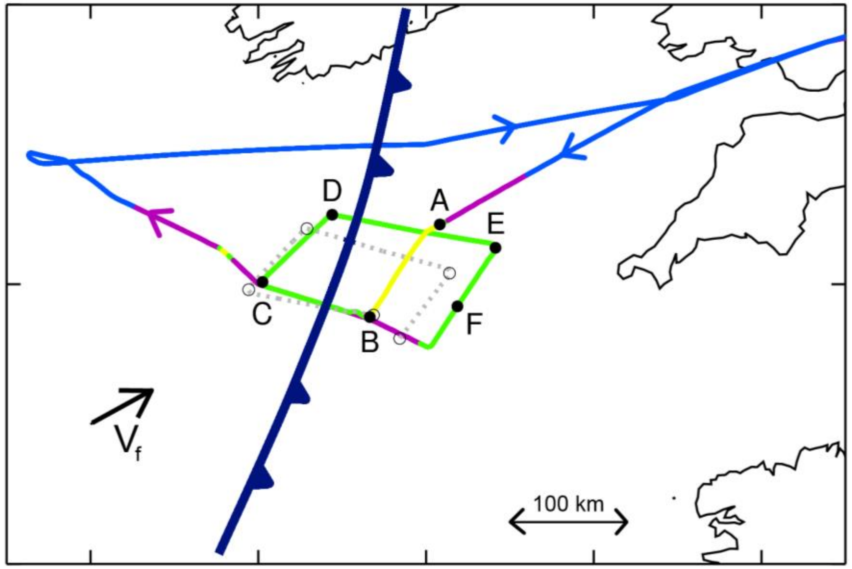
- FAAM BAe146
- 24th November 2009
- Intense trailing **cold front** approaching UK

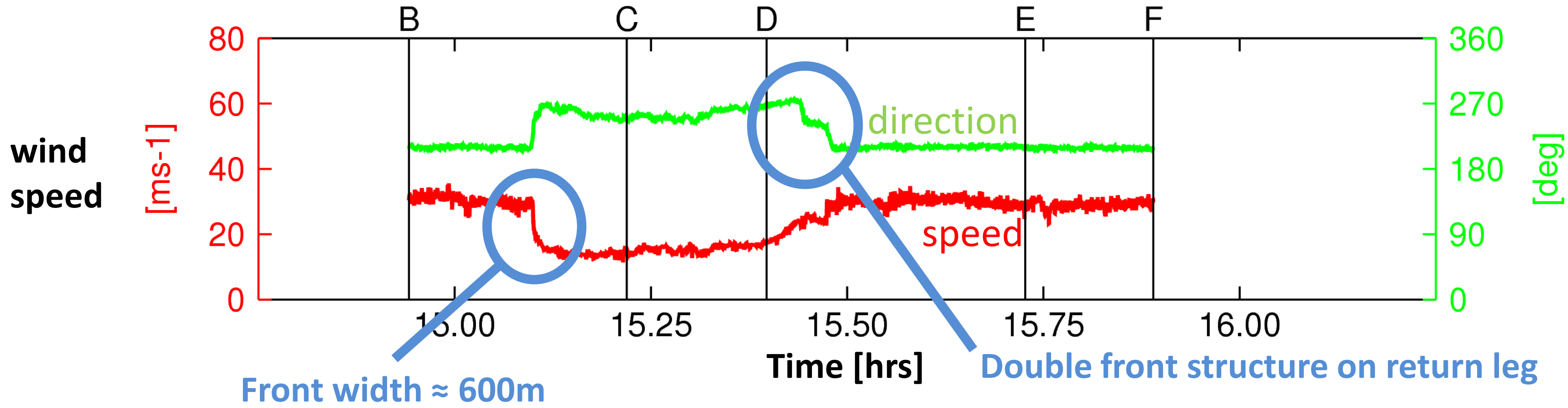
Knippertz *et al.*, *Weather* (2010)



Observations

- Timing of circuit: **14:56-15:53 UTC**
- Altitude: **300 m**, air speed: **100 m/s**
- Flight track (nearly) a **closed circuit in a system-relative sense**

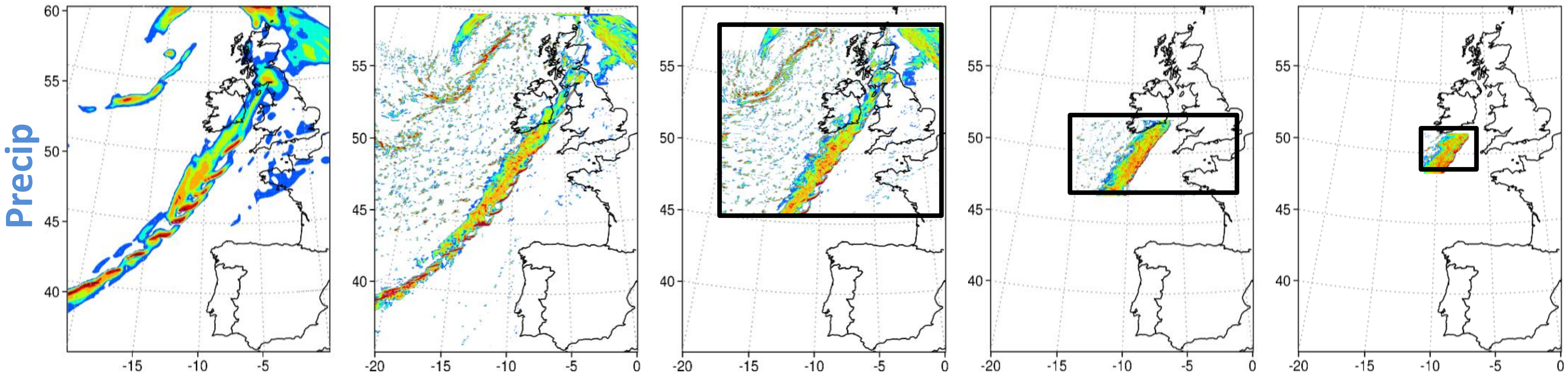




Simulations

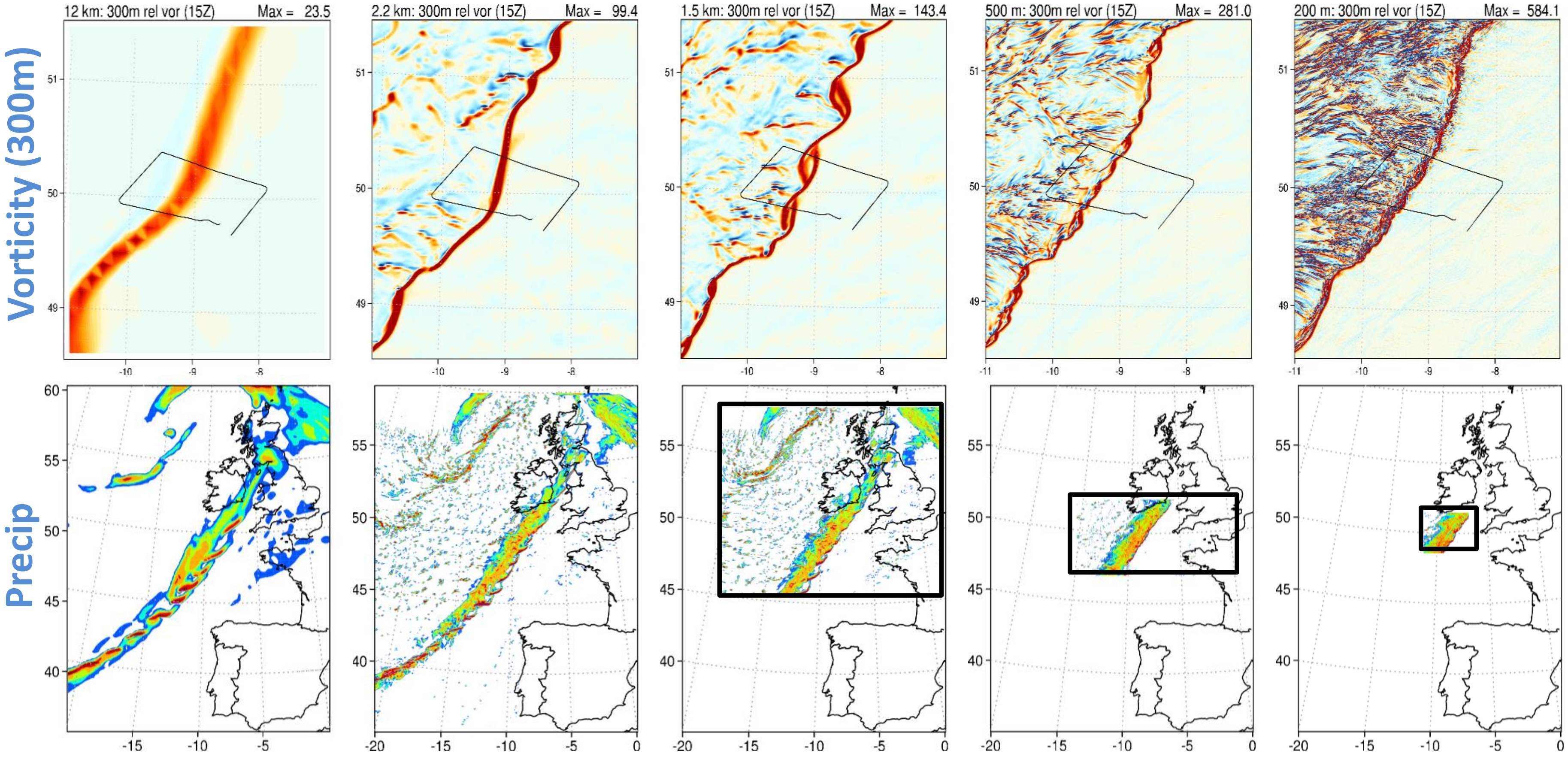
UM8.4 (“New Dynamics”)

12 km	2.2 km	1.5 km	500 m	200 m
L38	L70	L70	L140	L140
Conv scheme ON	Conv scheme OFF			
1-d BL scheme	1-d BL with 2-d Smagorinsky		3-d Smagorinsky	



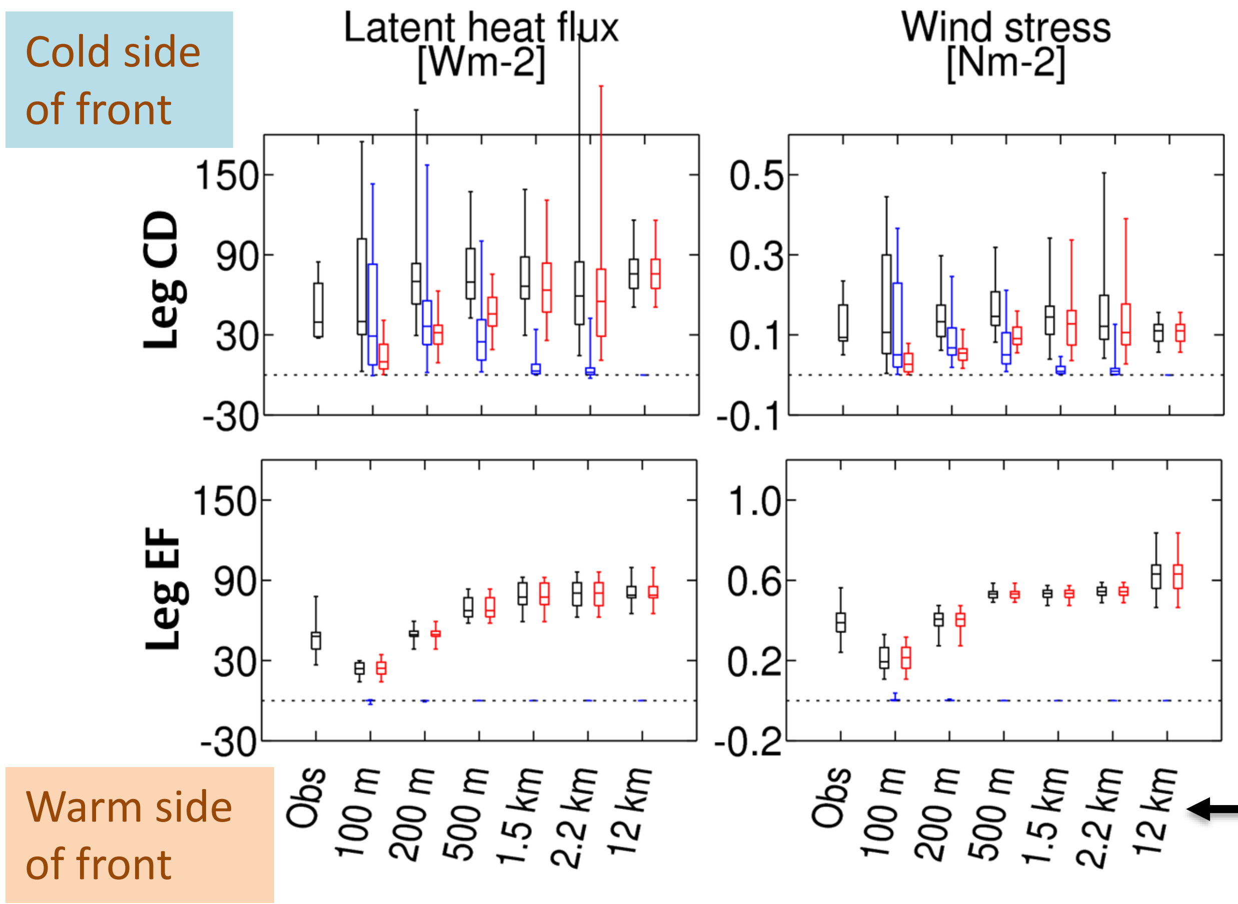
12km 2.2km 1.5km 500m 200m

Simulations UM8.4 (New Dynamics)



12km **2.2km** **1.5km** **500m** **200m**

Representation of turbulent fluxes



- **Left bar** – ***observed turbulent fluxes*** *using eddy correlation from probe along 2-minute legs (64 Hz data)*
- Blue – resolved fluxes (covariance of model data along aircraft legs)
- Red – fluxes from model's sub-grid parametrization
- Black – total flux from model

Model grid scale

CAPRI – Science questions

Observational focus for UK component of NAWDIC

1. *Coupling downwards and downscale*
    - *Mesoscale phenomena coupling with BL to bring severe winds to surface*
    - *High res, 3-D wind obs spanning UK plus aircraft*

2. *Coupling at ocean interface*
    - *Effect of coupling with ocean on cyclone impacts - including ocean current and waves & impact on offshore infrastructure*

3. *Moisture uptake, transport and precipitation efficiency*
    - *Surface fluxes in the warm sector ahead of cold fronts and moisture uptake. Precipitation mechanisms from ARs over orography (UK) – Helen’s talk.*

FAAM instrumentation used in NAWDEX

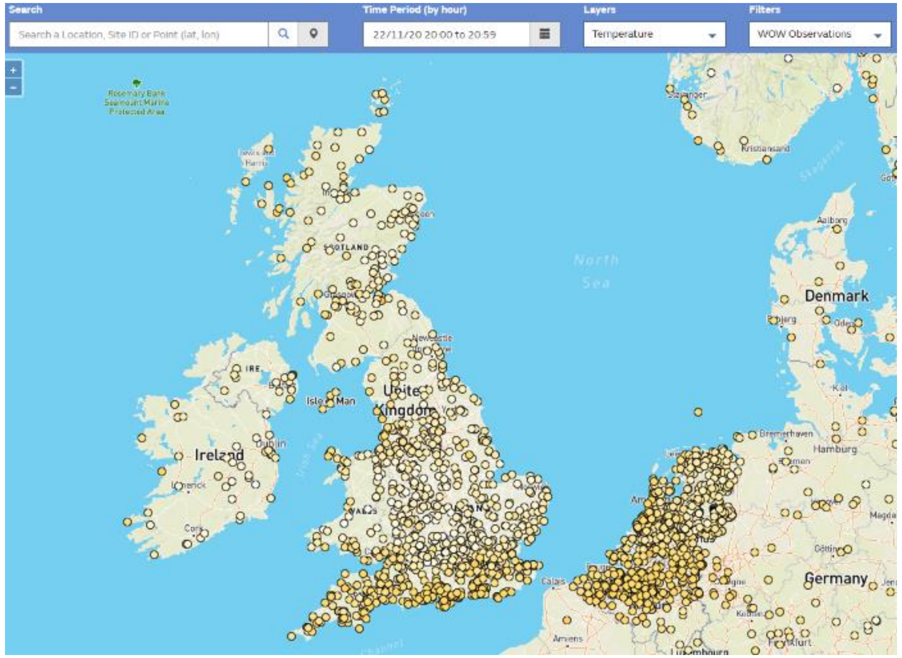
- Dropsondes: Vaisala RD94 – p, T, q, wind
- De-iced and non-deiced temperature
- Humidity: Buck CR2 and General Eastern dew/frost point, WVSS-2 TDL absorption
- Winds: turbulence probe on nose + AIMMS probe on wing (32 Hz)
- Cloud particles: PCASP, CDP (scattering), CIP-15, CIP-100 (imaging) cover 2 µm – 6 mm diameter
- Ice/Liquid water content: Nevzorov hot wire probe
- Chemistry – O_3, CO, CH_4
- LIDAR (cloud top, aerosol)

Mid Life Upgrade (MLU) project: major refit to aircraft, science infrastructure and instruments (funded £50M).

It will be equipped for service until 2040.

WOW Observations

- Amateur automated observing stations can submit their data to the Met Office Weather Observations Website (WOW)
- Through QC and bias correction using the high-quality Met Office observing network a high resolution, improved quality surface analysis is generated
- Mean sea level pressure, temperature, dewpoint temperature, wind speed and wind direction are currently analysed



WOW submitted temperature observations 22/11/20 20:00-20:59

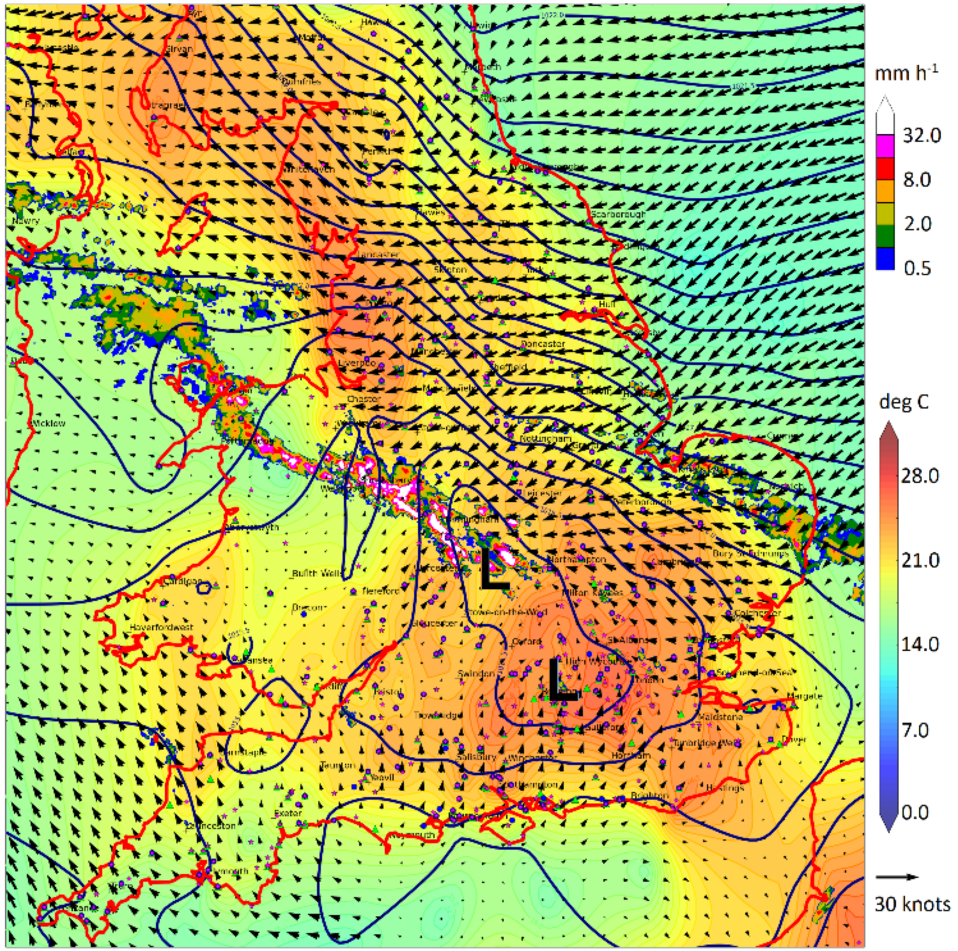
University of Reading

WOW Analysis

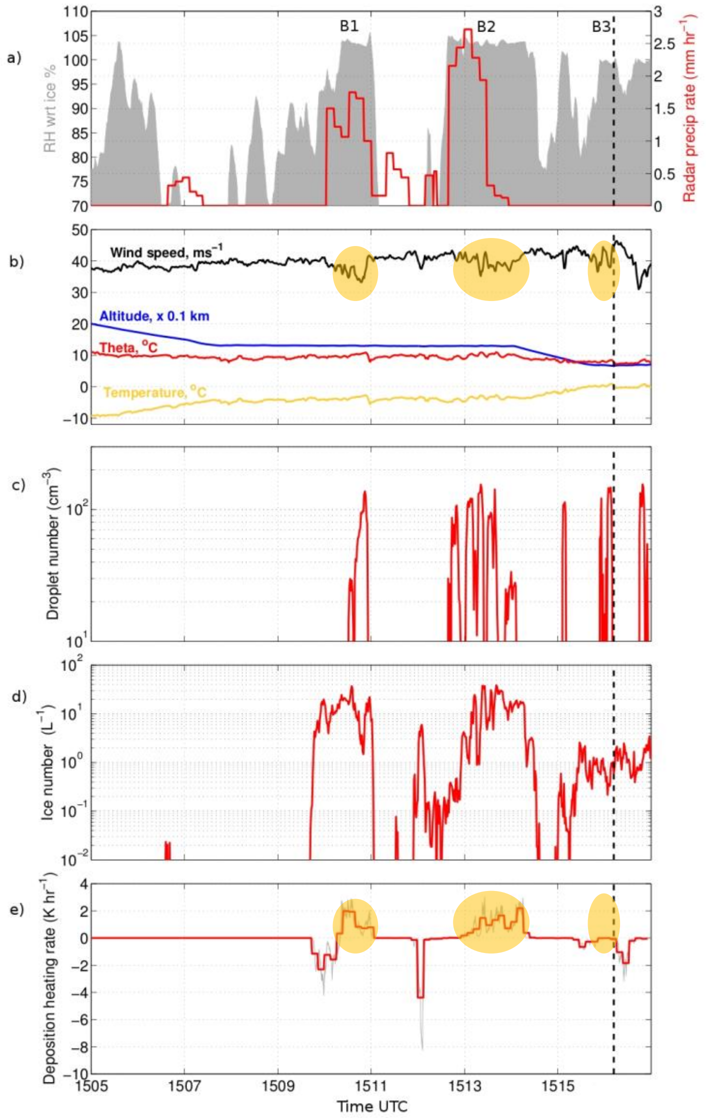
Temperature (shading),
wind vectors (arrows) and
mean sea level pressure
(contours at 0.5 hPa intervals)
from bias corrected WOW data.

Composite radar rainfall data
overlaid

1600 UTC 27 May 2018.



Aircraft obs across bands in strong wind region
plus estimate of diabatic heating from cloud microphysics obs



Cloud bands contain mixed phase

Heating by deposition onto ice within bands, but evaporational cooling inbetween

Wind speed lower within bands

Both a signature of mesoscale circulations?