The Golden Age of Weather Radar

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Supervisors

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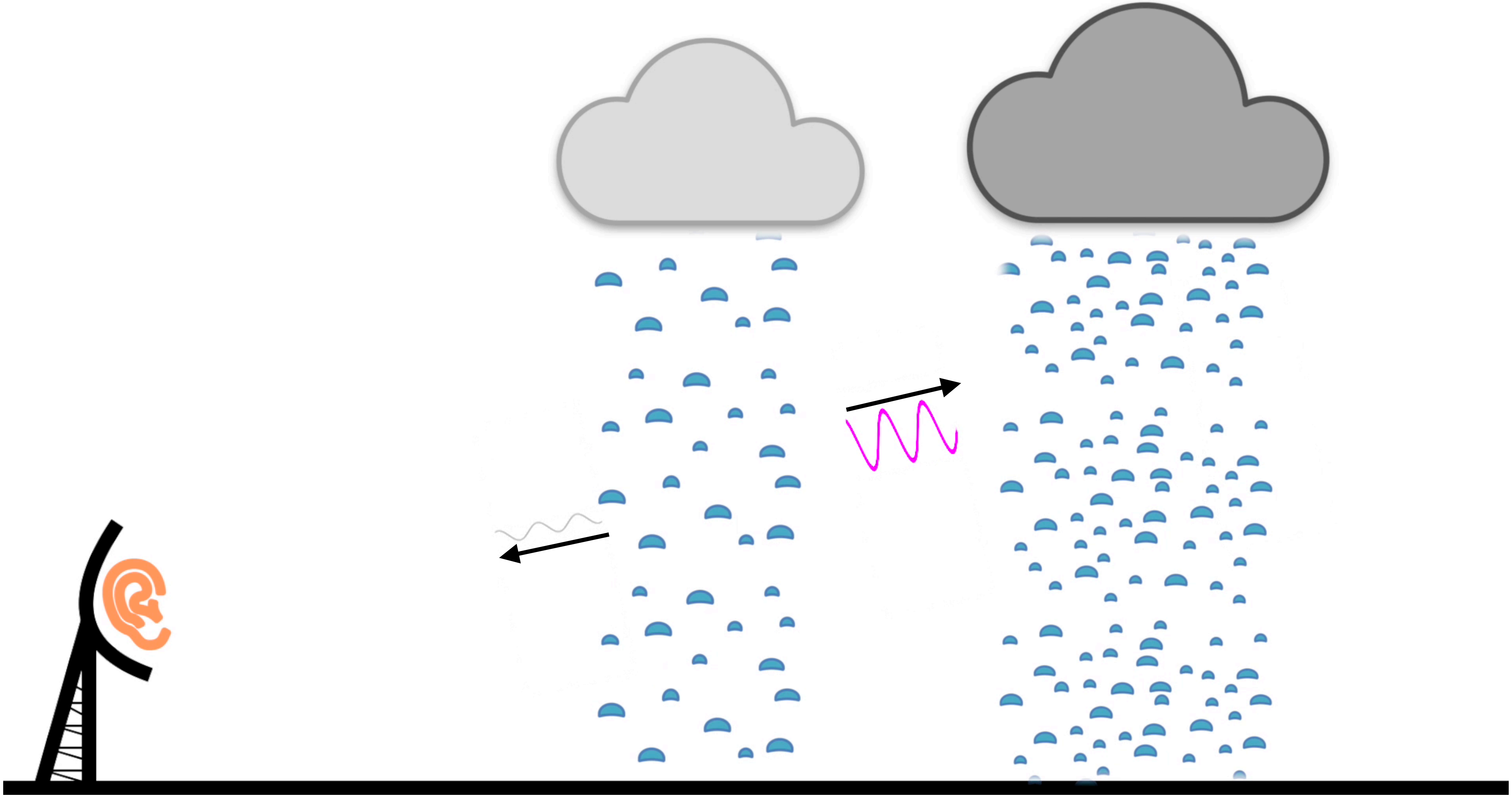
NERC SCIENCE OF THE ENVIRONMENT
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
RMetS Royal Meteorological Society
Met Office



Single-Polarisation Radar

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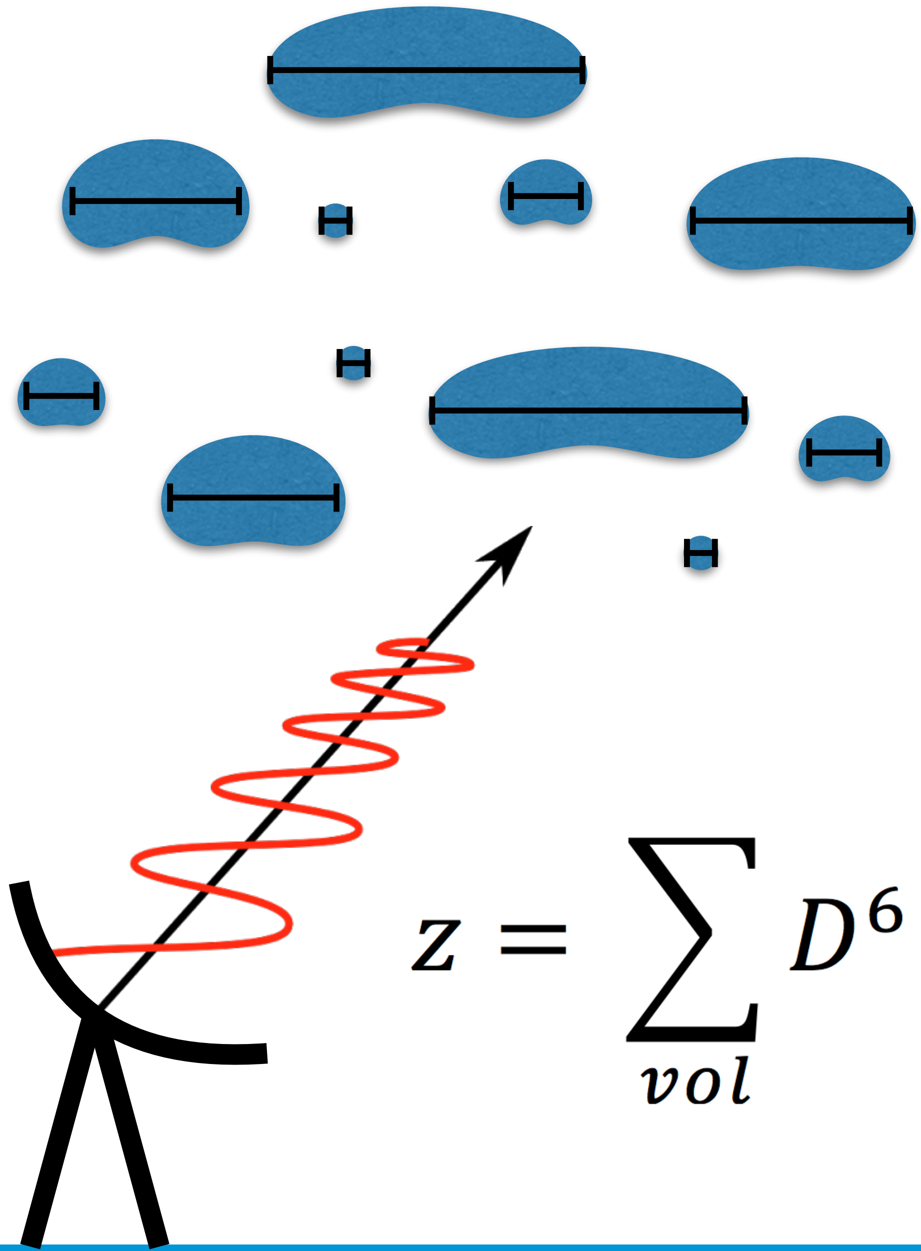
- Horizontally polarised beam.
- One output: Radar reflectivity factor, which is the sum of all raindrop diameters to the sixth power.
- However, lots of small liquid droplets can have the same reflectivity as a few large drops.
- Must assume all particles are liquid to convert to mm/hr.



$$z = \sum_{vol} D^6$$

Dual-Polarisation Radar

- Radar backscatter cross-sections are different for each polarisation.

- Several additional variables are derived from the Jones scattering Matrix

Rx

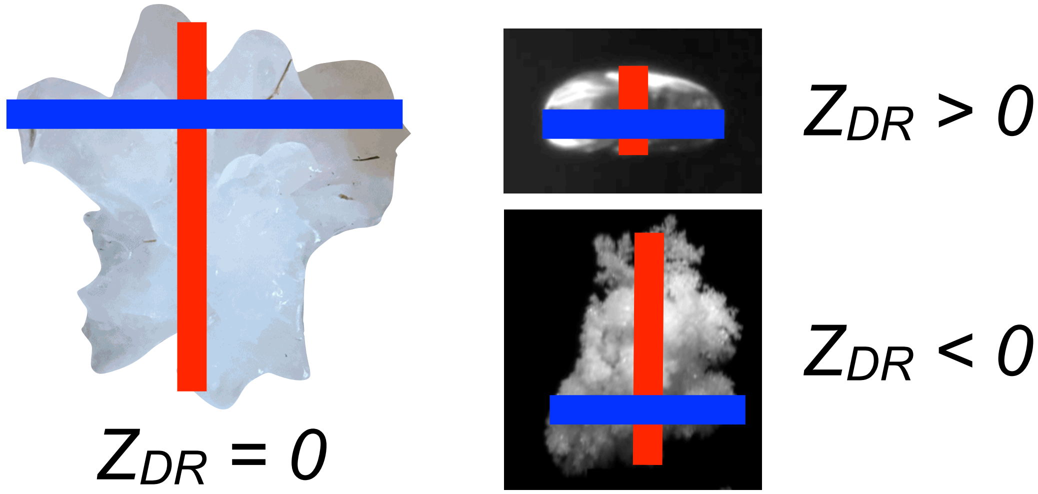
Tx	*h*	*v*
h	S_{hh}	S_{vh}
v	S_{hv}	S_{vv}

Fig 1. Jones Matrix power notation

1. Differential Reflectivity: Z_{DR}
2. Correlation Coefficient: ρ_{hv}
3. Specific Differential Phase: K_{DP}
4. Linear Depolarisation Ratio: LDR_{vh}

1. Differential Reflectivity: Z_{DR}

$$10log_{10}\frac{|S_{hh}|^2}{|S_{vv}|^2}$$



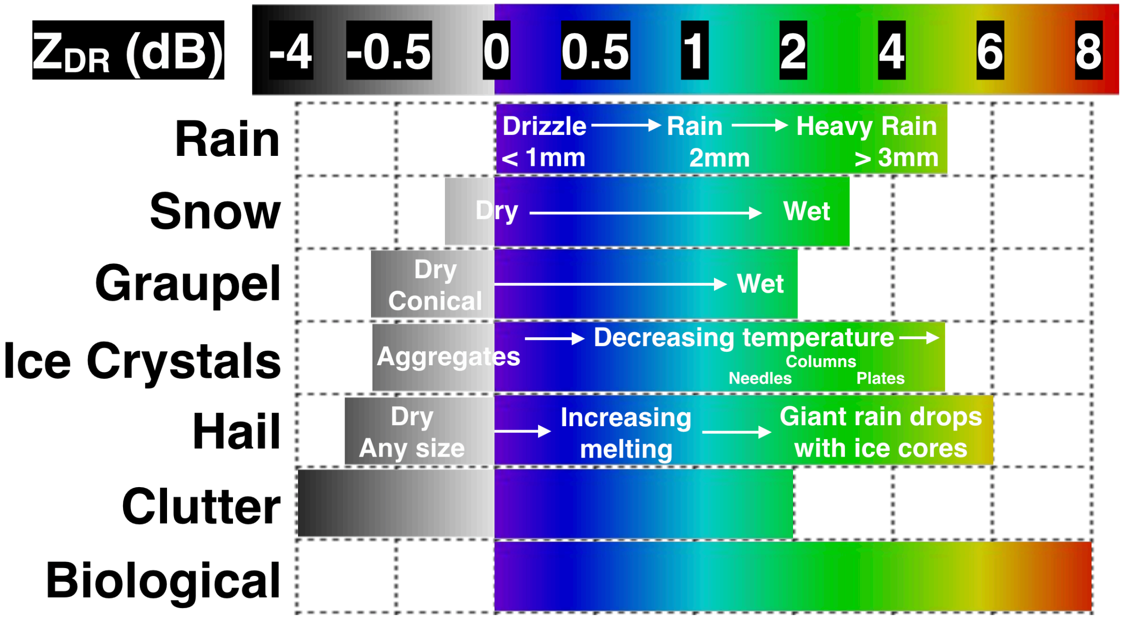


Fig 2. Typical values of Z_{DR}

Indicates shape of hydrometeors in the sample volume.

2. Correlation Coefficient: ρ_{hv}

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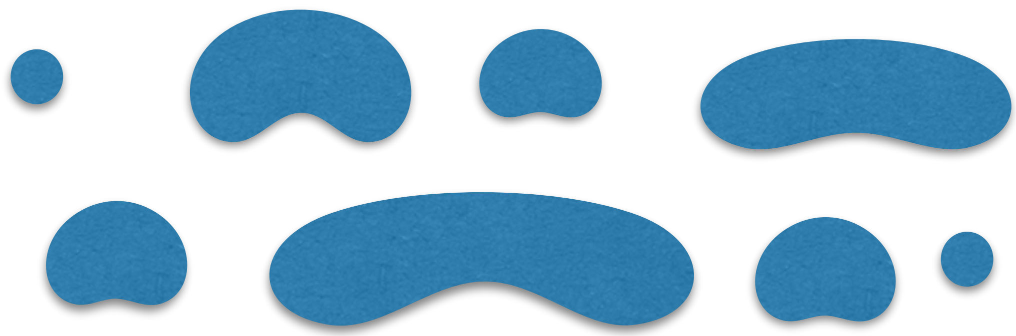
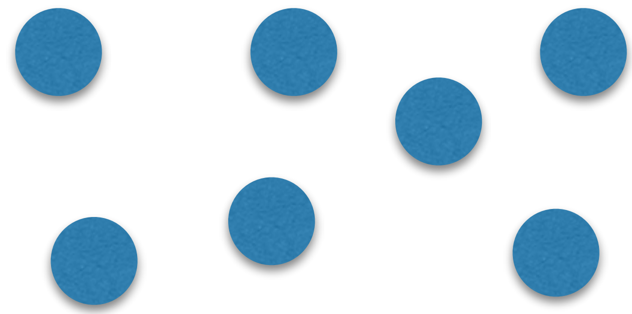


$\rho_{hv} < 1$



$\rho_{hv} = 1$

How similar the particles are to one another.

Equivalent to *r-value* in statistics.

$$\frac{|\langle n S_{hh} S_{vv} \rangle|}{(\langle n|S_{hh}|^2\rangle\langle n|S_{vv}|^2\rangle)^{1/2}}$$

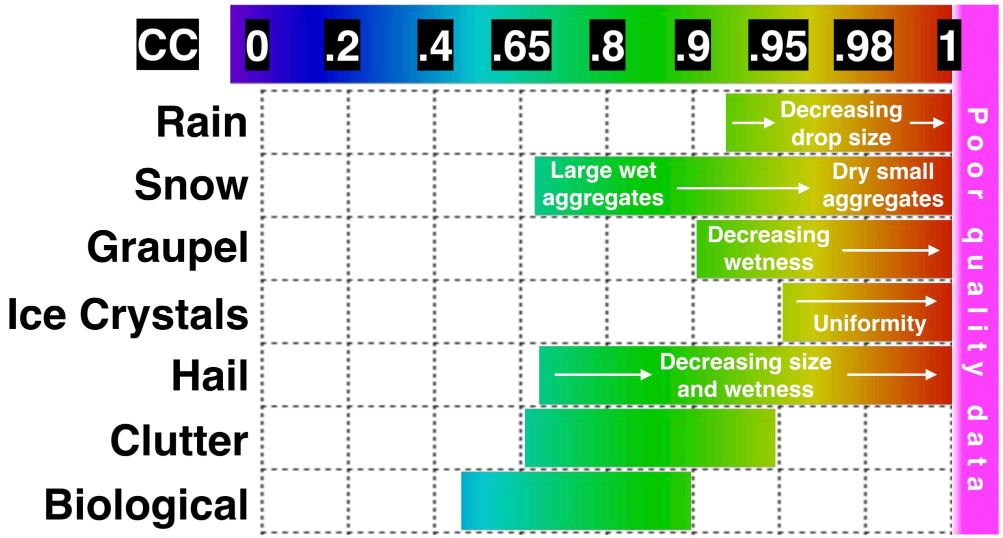


Fig 3. Typical values of ρ_{hv}

3. Specific Differential Phase: K_{DP}

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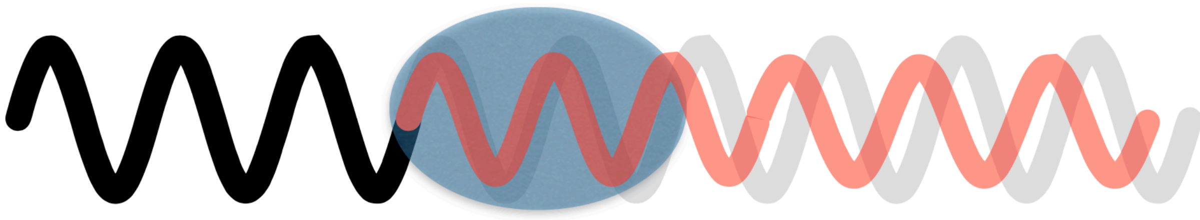
How much energy the beam lost & the orientation of particles.



$$\frac{1}{2}\frac{\partial(\Phi_{hh} - \Phi_{vv})}{\partial r}$$

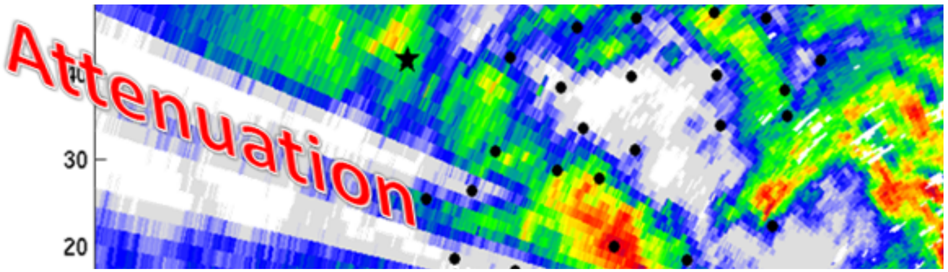


Fig 4. Attenuation shadow © Rob Thompson

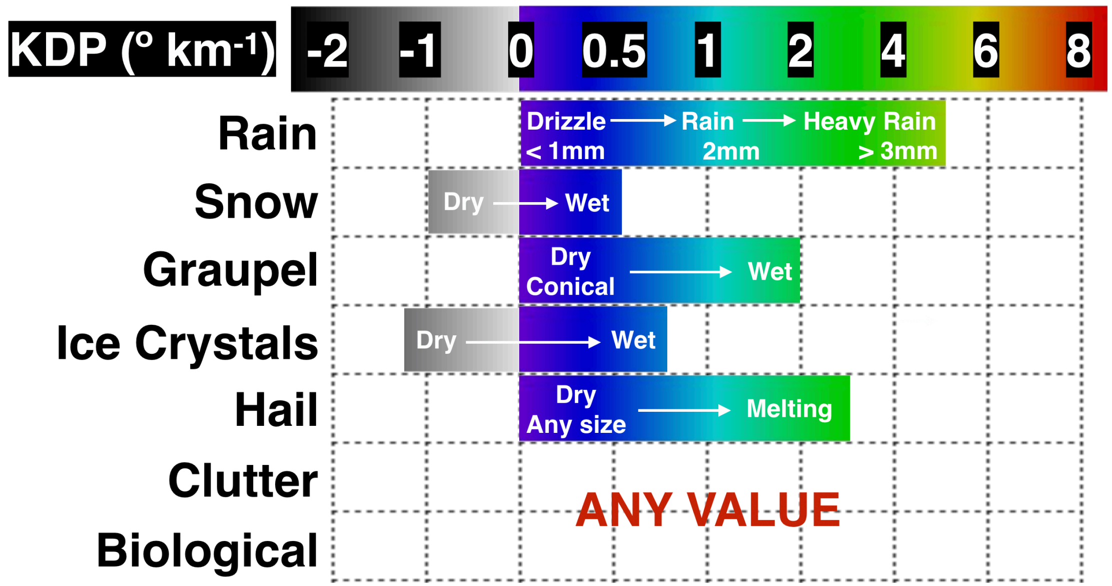


Fig 5. Typical values of K_{DP}

4. Linear Depolarisation Ratio: LDR_{vh}

How much energy switched from horizontal polarisation to vertical.

Indicates slanted, tumbling (hail) or wobbling (large droplets) objects.

Unique to Met Office.

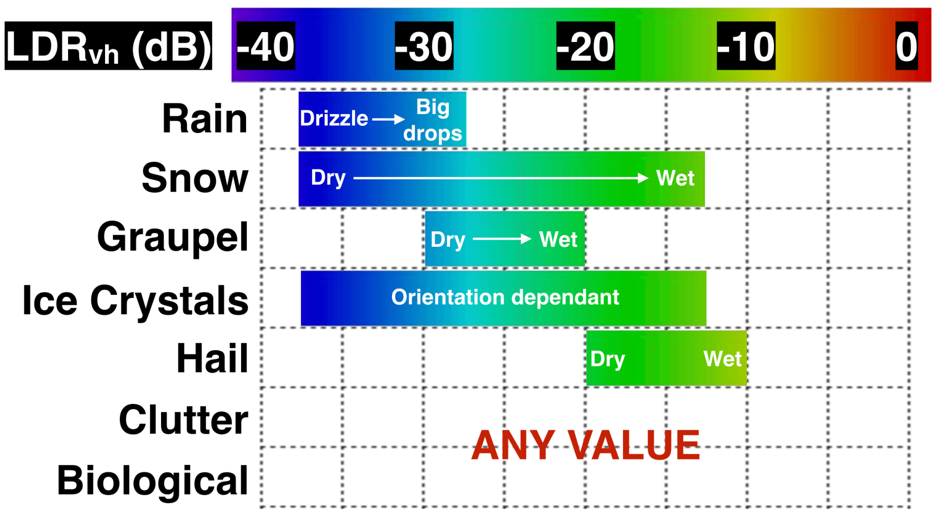
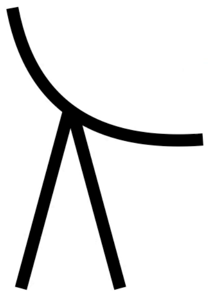
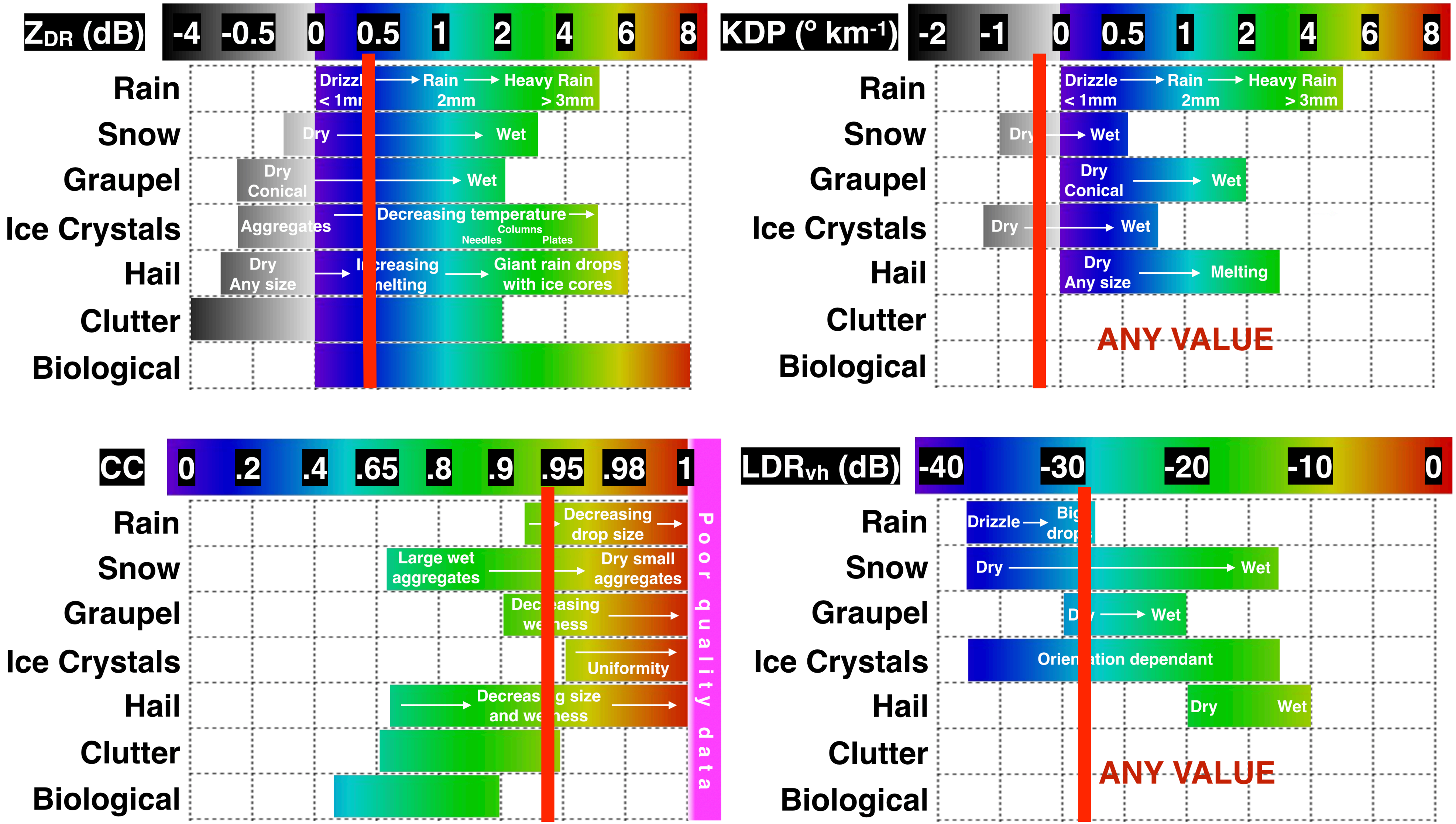


Fig 6. Typical values of LDR_{vh}



$$10log_{10}\frac{|S_{vh}|^2}{|S_{hh}|^2}$$

What precipitation type is being observed here?



Hydrometeor Classification Algorithms

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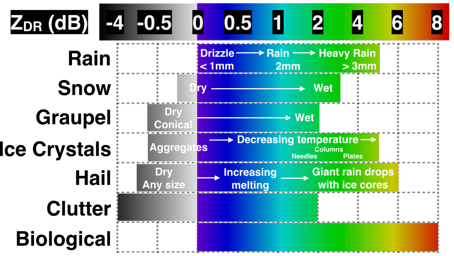
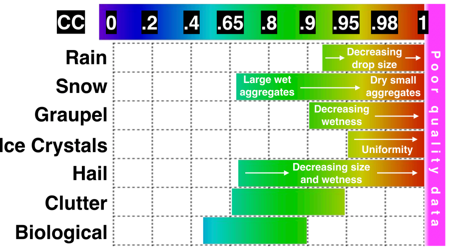
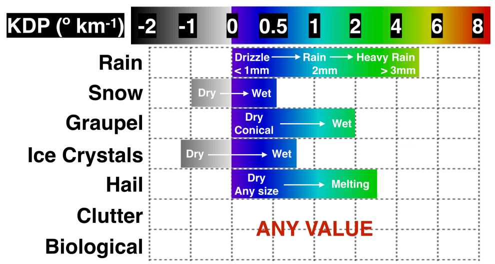
Z_{DR} →



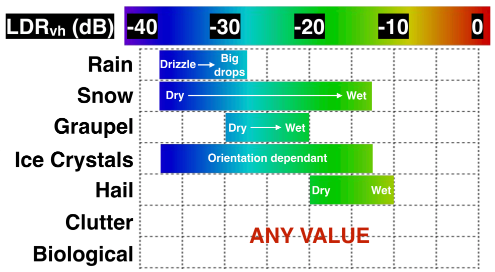
ρ_{hv} →



K_{DP} →



LDR_{vh} →



Rain	**3/4**
Snow	**4/4**
Graupel	**3/4**
Ice Crystals	**3/4**
Hail	**2/4**
Clutter	**4/4**
Biological	**3/4**

Output = Snow

HCAs combine observed values and knowledge of typical values to determine hydrometeor type

Why is Radar-Derived Hydrometeor Classification Important?

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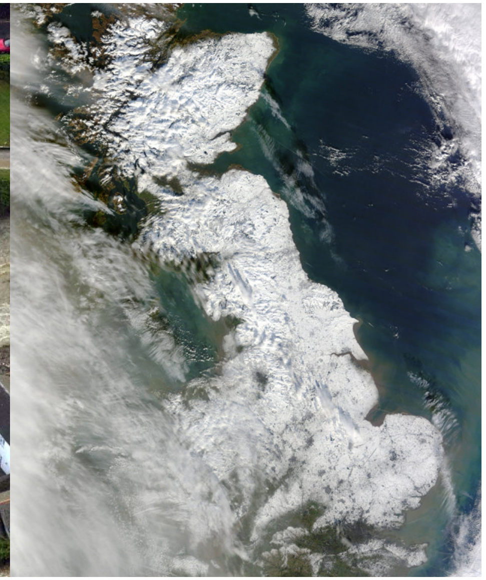
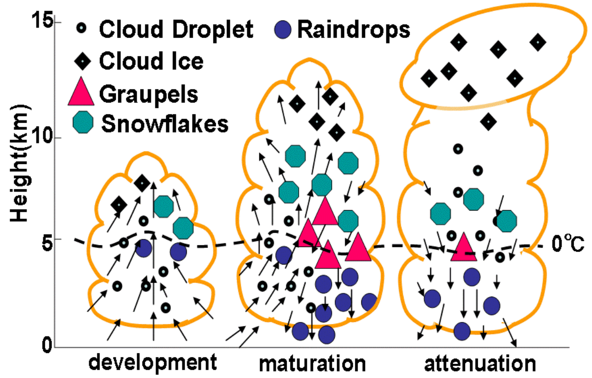
- Radar has excellent temporal (5 minute) and 3D spatial resolution (<1km, 5 tilts).
- More accurate precipitation rates
- Real time snow boundary.
- Flood forecast modelling.
- Input for NWP weather models.
- Reveals microphysical processes - lead to greater understanding of dynamics.

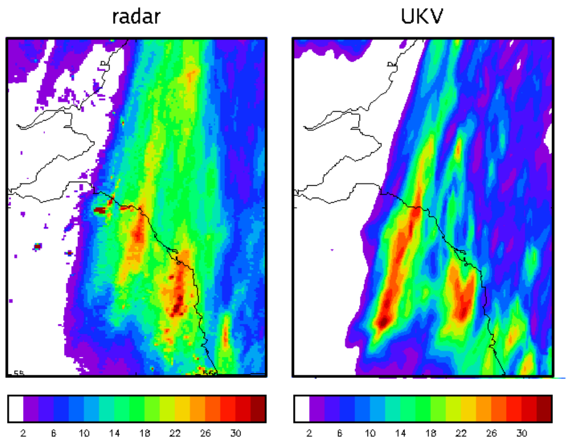
Environment Agency

HIGHWAYS AGENCY

SEPA Scottish Environment Protection Agency







UK Met Office Radar Network

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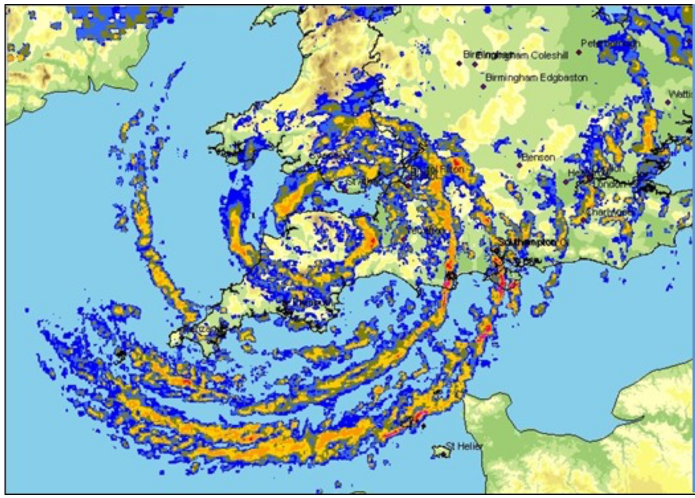
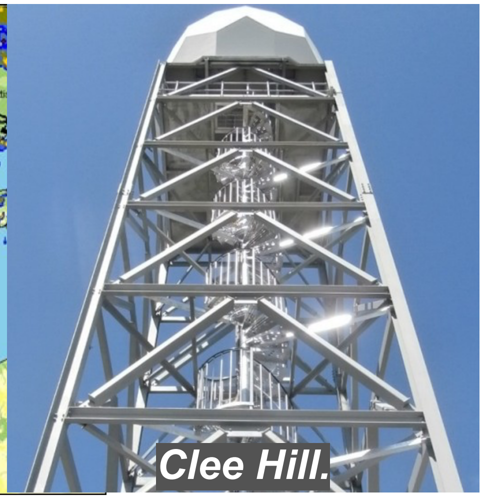
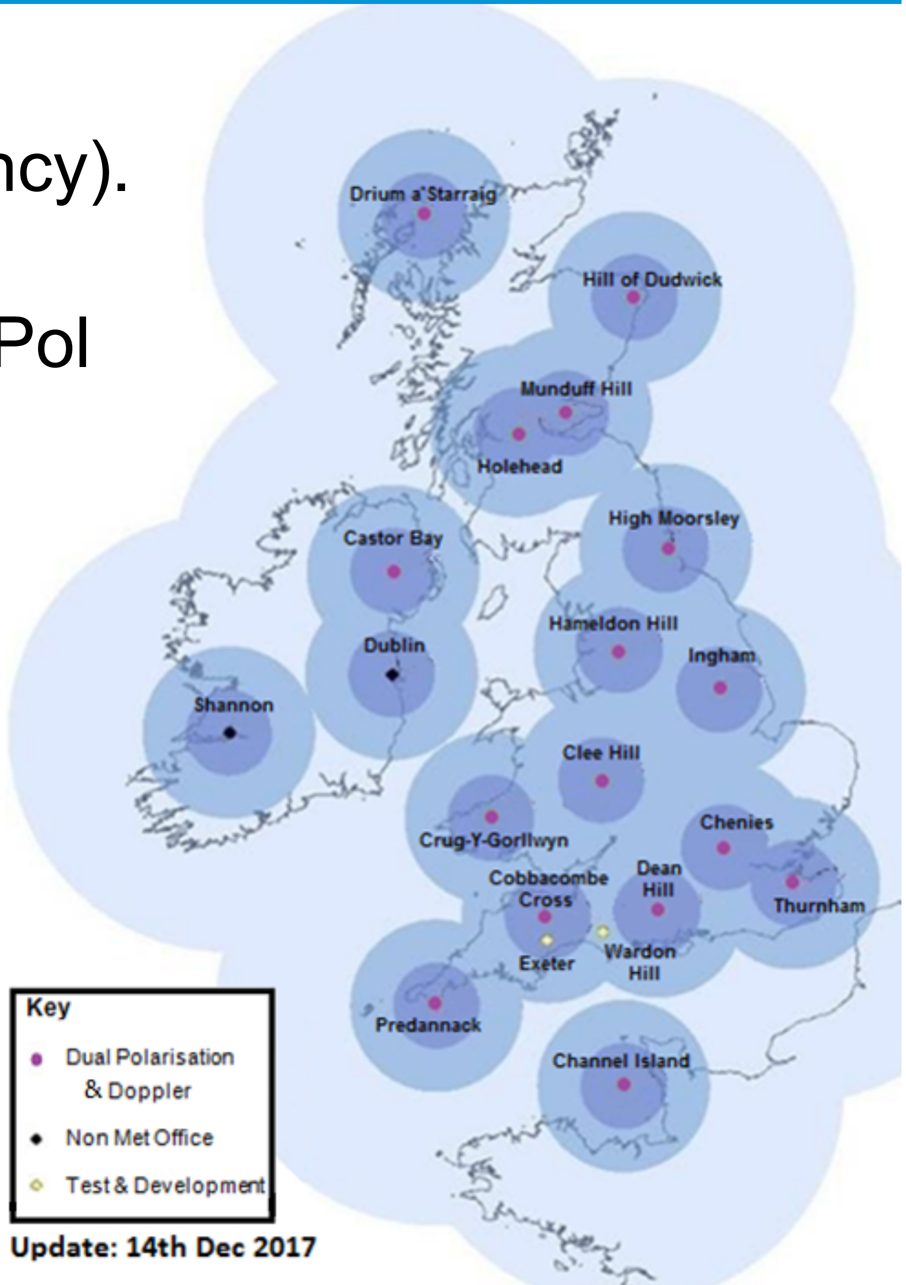
- 15 radars, C-band (5.6 GHz frequency).
- Met Office just completed the Dual-Pol upgrade to the radar network, in December 2017. Took 5 years.





MO surface rainfall, 10:30 29/11/09.



Project Questions

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Q1: What is the best method to evaluate the skill of hydrometeor classification and surface precipitation type products?

Q2: What is the uncertainty of current surface type products, using single-pol radar and NWP?

Q3: How much does dual-polarisation radar reduce the uncertainty in hydrometeor classification?

Q4: What is the impact of having improved skill in hydrometeor classification?

Existing Verification Data

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In-situ

(at beam-height)

1. FAAM aircraft

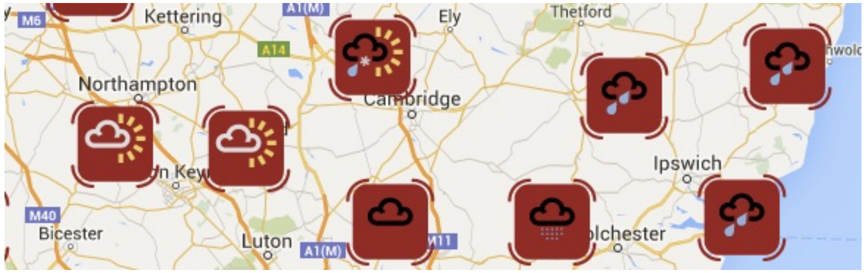
- Archived data since 1st UK DP radar.
- PICASSO campaign this winter, 12 flights estimated.
- Will not fly in > 35 dBz reflectivity.

Inferred

(at the surface)

1. Met Office surface station reports (SYNOP)

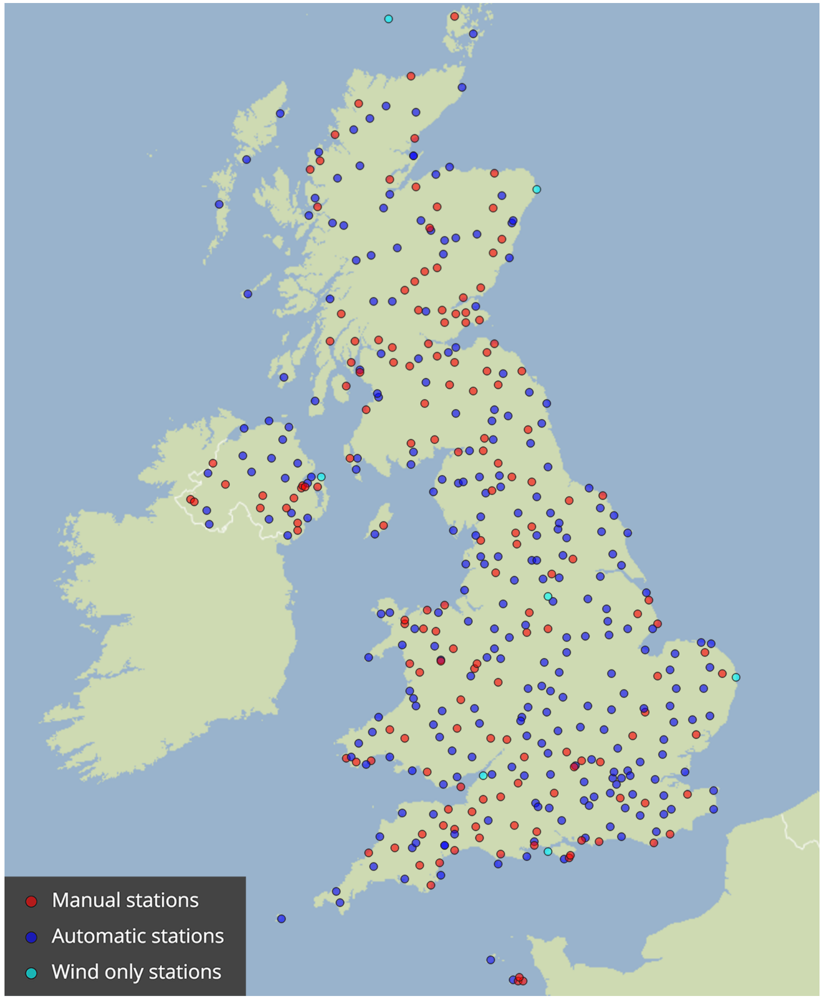
2. Crowdsourced: BBC Weather Watchers



Existing Verification Data

Inferred
(at the surface)

Met Office Surface Station (SYNOP)



- Report "present weather" every hour.
- Heavily relies on Visiometer to determine present weather.
- 100 present weather codes.

E.g. 'Thunderstorm in past hour, slight snow (or rain & snow, or hail)'

- Known visiometer issues.

Thies Laser Precipitation Monitor

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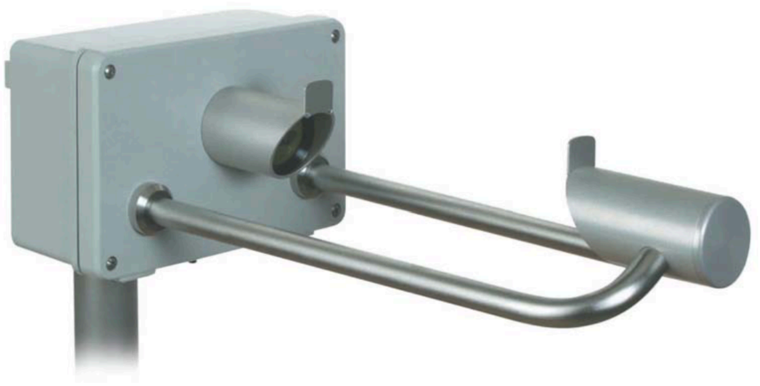
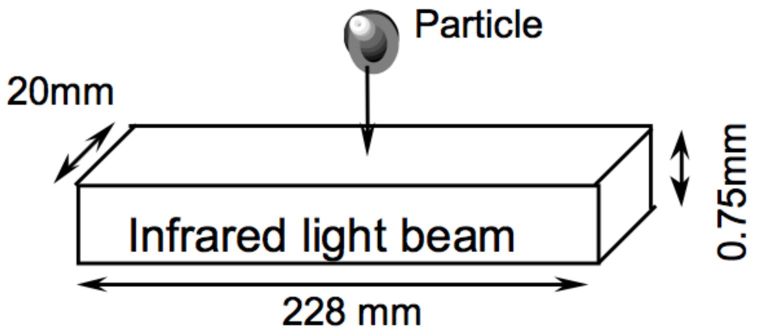
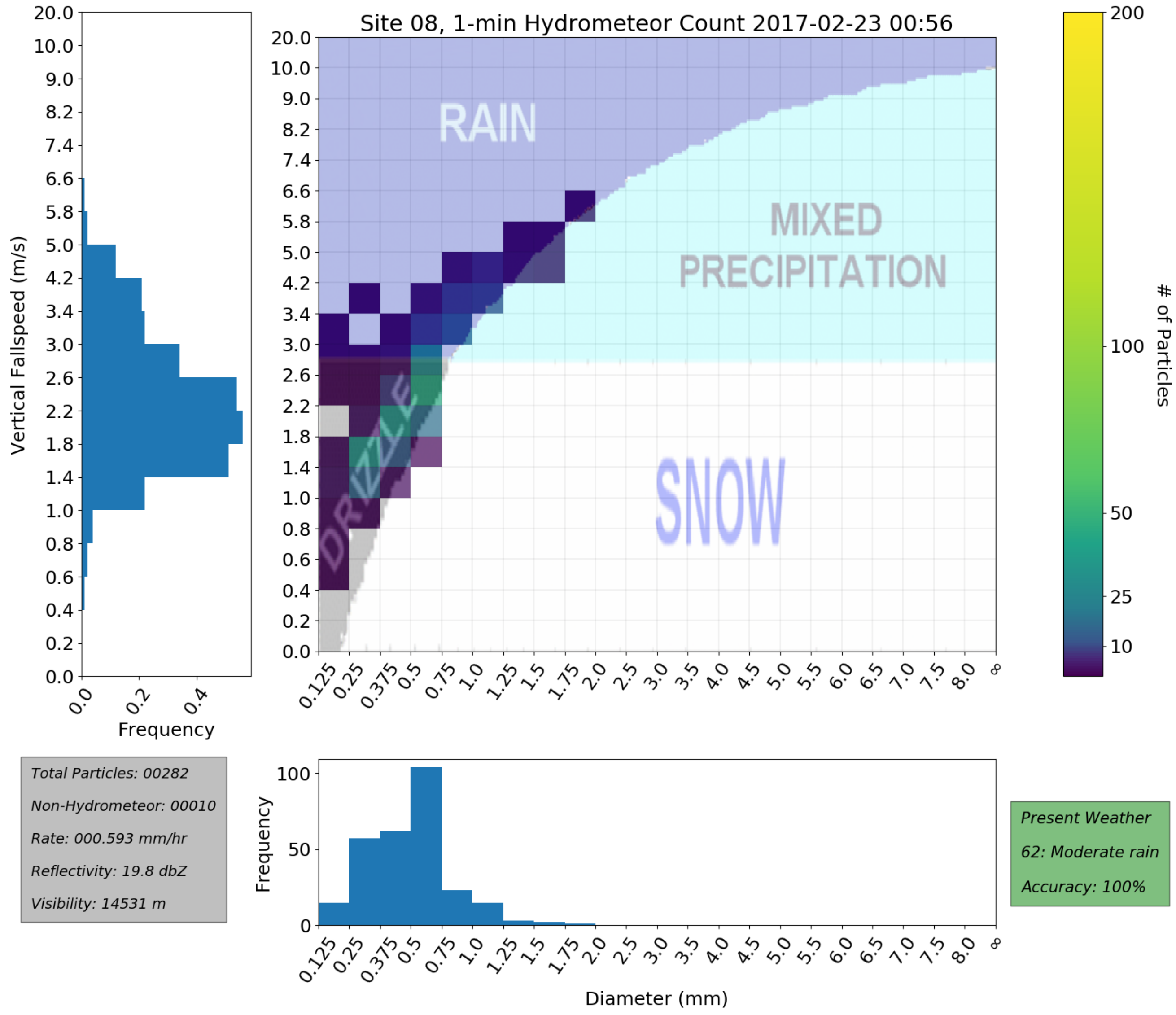




6 types:

drizzle, rain, snow,

“grains”, ice, hail



Output from the DiVeN disdrometer

Finding Host Sites

Coverhead Farm

University of Dundee

University of Cambridge

University of Essex

English Heritage

Aberystwyth MST

Chilbolton Observatory

University of Edinburgh

BT Tower (London)

University of Bristol

Weybourne AMF

University of Sheffield

Climatological Observers Link

Imperial College

MIWS (Galloway)

Leeds Farm

University of Manchester

University of Lancaster

Cairngorm Mountain

FAAM SkyLab (Cranfield)

RUAO (Reading)

Finding Host Sites

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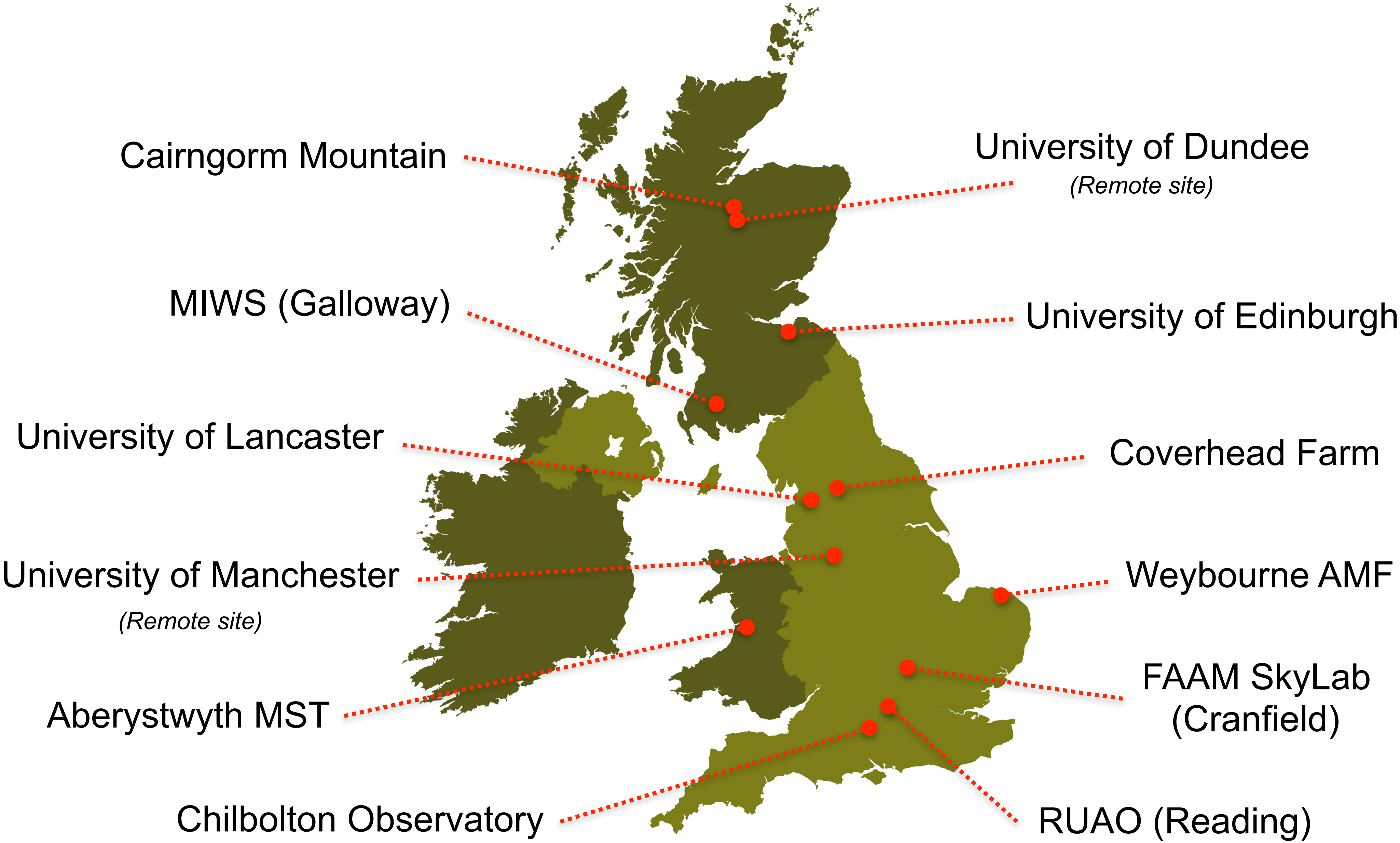

Installation Trip Video

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https://youtu.be/SZLJq_mT288

DiVeN Website

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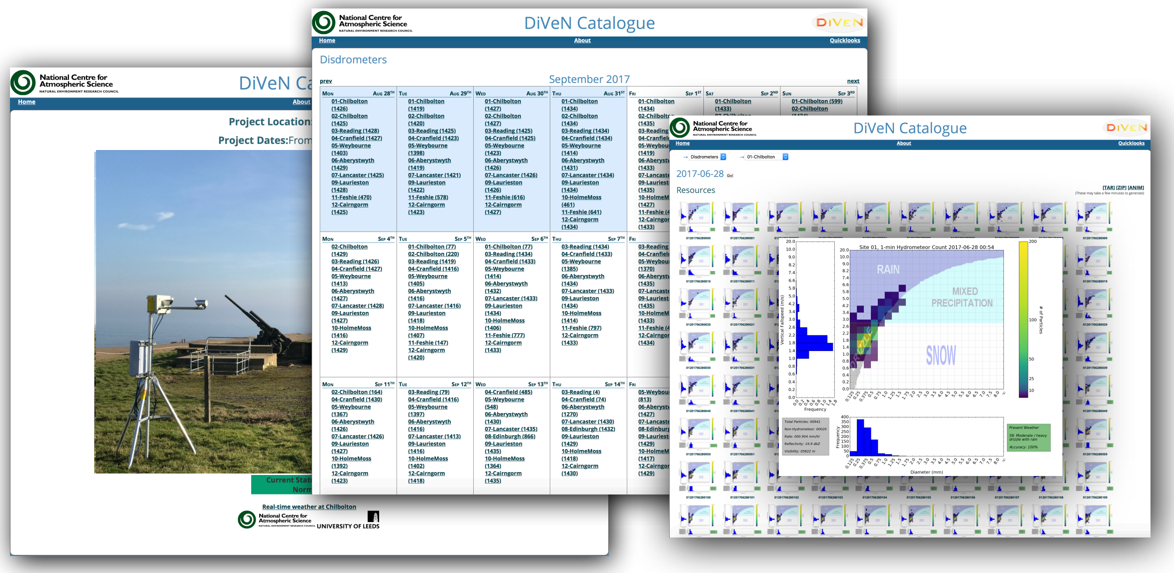
sci.ncas.ac.uk/diven



- Completely open to public.
- Daily image bundle downloads available.
- 60 second frequency data.
- Daily animated plots.
- 2–7 minute delay from real time.

Speed v Diameter Grid — Axial Histograms — Rainfall Rate (mm/hr, 3.d.p.) Precipitation Visibility (m) — Radar Reflectivity Factor (dBZ) — Hydrometeor Count (& non) — Present Weather Code (WMO 4680) — PW Accuracy (%)

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Summary of Ongoing Work

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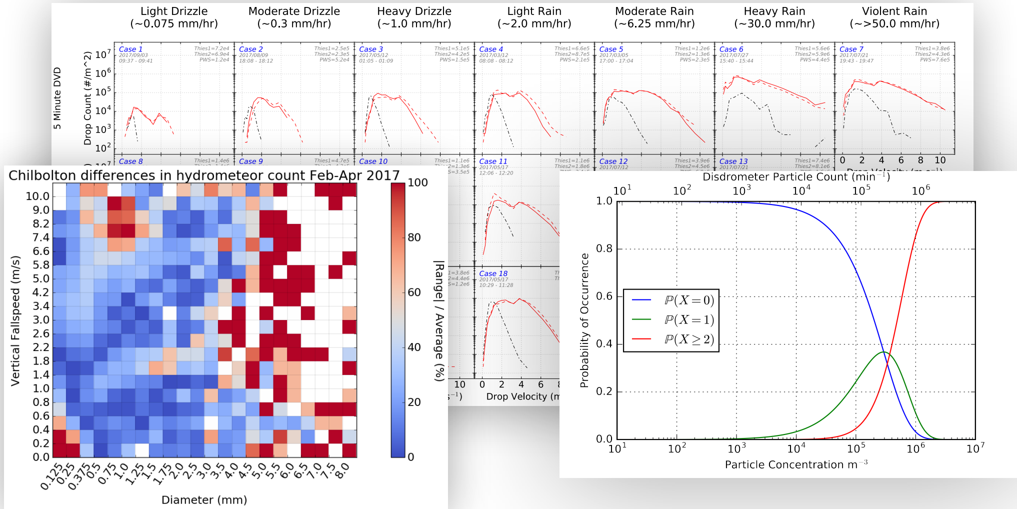
- DiVeN accuracy is being analysed and 2 papers currently being written, to be submitted "soon".

- Baseline products (single-pol radar + model temperatures) have been partially analysed. Skill seems to be poor.

- Methods used in single-pol verification will be applied to dual-pol verification in 2019. Added benefit of dual-polarisation to be quantified.



	FAAM	SYNOP	DiVeN	BBC WW
Surface Precipitation Type				
MeteoFrance Gridded PPI				
In-house Gridded PPI				
MeteoFrance RHI				
In-house RHI				

Why the Golden Age?

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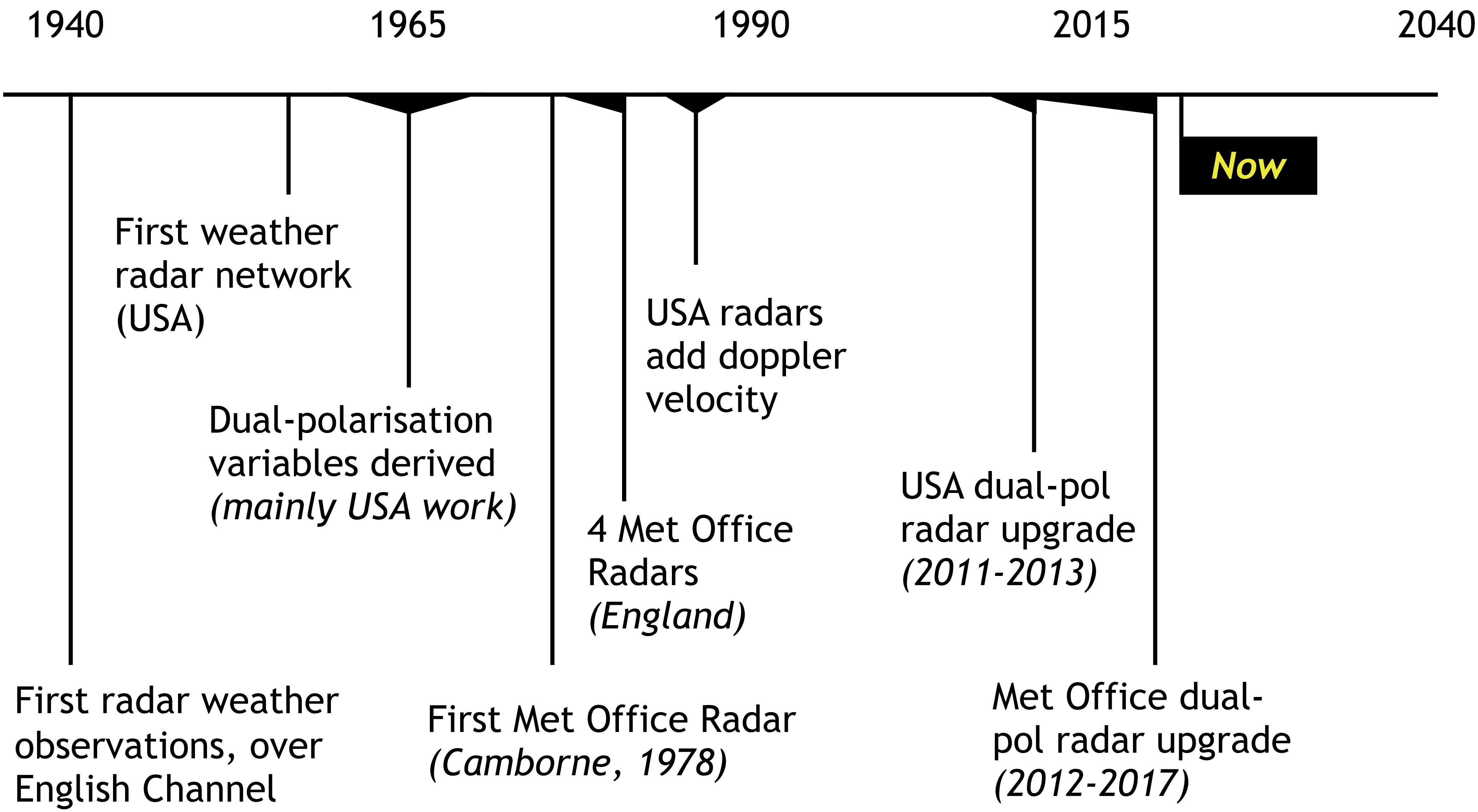

What Next?

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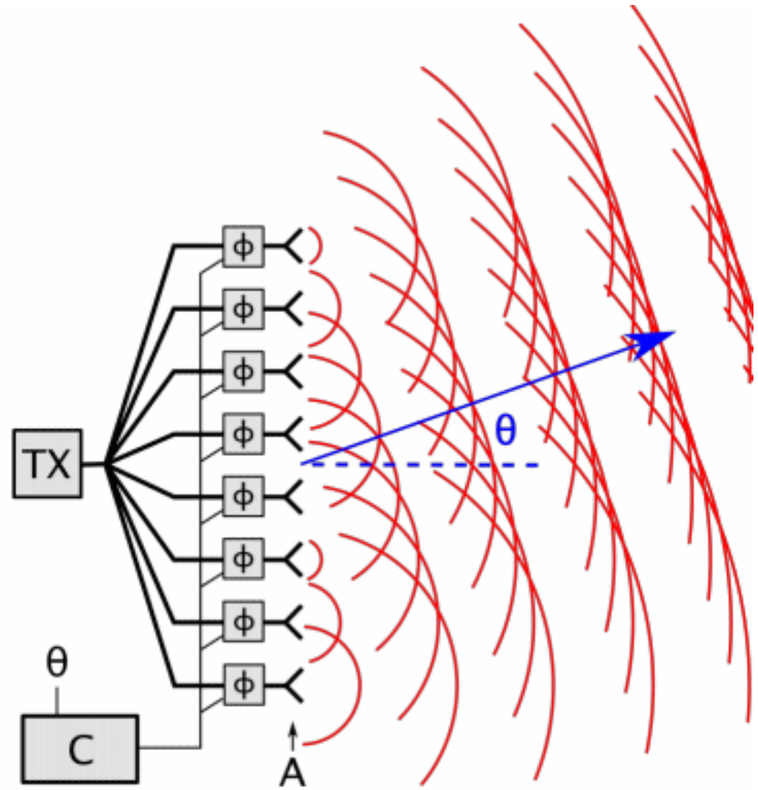
Phased Array Radar

- Numerous solid-state transmitters work cohesively to form a beam.
- Beam can be electronically steered (typically ± 60º).
- Radars could scan all directions simultaneously => faster updates.
- Widely used in military, only recently used in Meteorology. Several major faults currently being worked on.



What Next?

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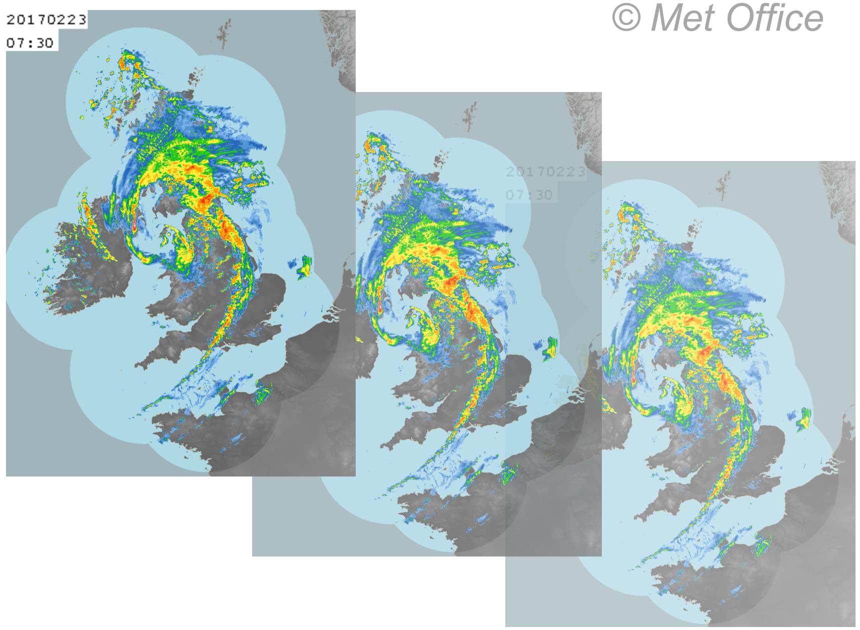
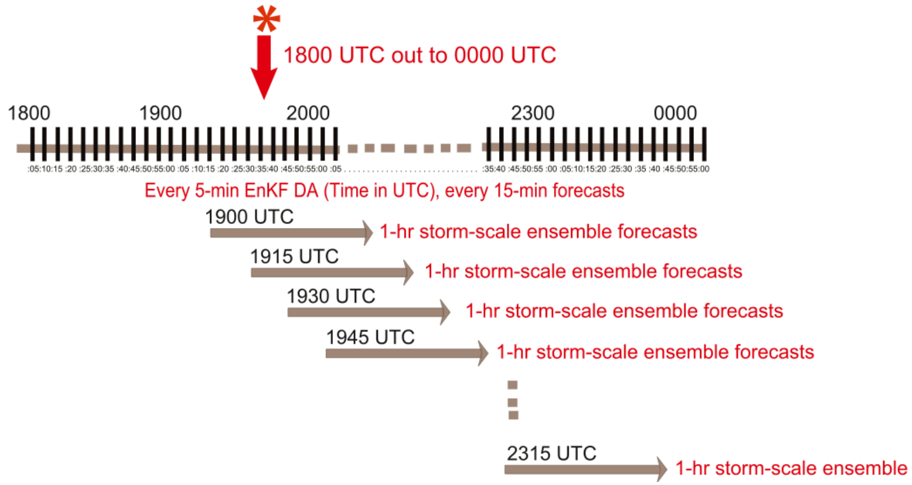
Data Assimilation

- Regional operational weather models are approaching radar resolution (1 km, 5 min).
- Radars can supply high resolution initial conditions.
- Problem is how to turn raw data into something the model can use.
- Research into assimilation of radar data is ongoing.





Yussouf et al. 2015

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