The Disdrometer Verification Network (DiVeN): A low-cost installation of 13 laser precipitation sensors in the UK.

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Supervisors

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NERC SCIENCE OF THE ENVIRONMENT

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

Further Acknowledgements

Morwenna Cooper (MO) · Dan Walker (NCAS Leeds)

Stephen Best (MO) · James Groves (NCAS Leeds) · James Bowles (MO)

Judith Jeffery · David Hazzard · Darcy Ladd (Chilbolton) · Andrew Lomas Rosy Wilson · Stephen Burt · Roger Brugge (Reading)

Jamie Trembath (FAAM) · Grant Forster (UEA, AMF Weybourne)

David Hooper (CFARR Aberystwyth) · James Heath (Lancaster)

Richard Essery (Edinburgh Uni) · Geoff Monk (Laurieston)

Michael Flynn (Manchester, Holme Moss) · Megan Klaar (Leeds)

Stephen Mawle (Coverhead Farm) · Louise Perry (SEPA)

Jack Giddings (UEA) · Ashley Nelis · Scott Duncan · Daniel Page

Why was DiVeN Created?

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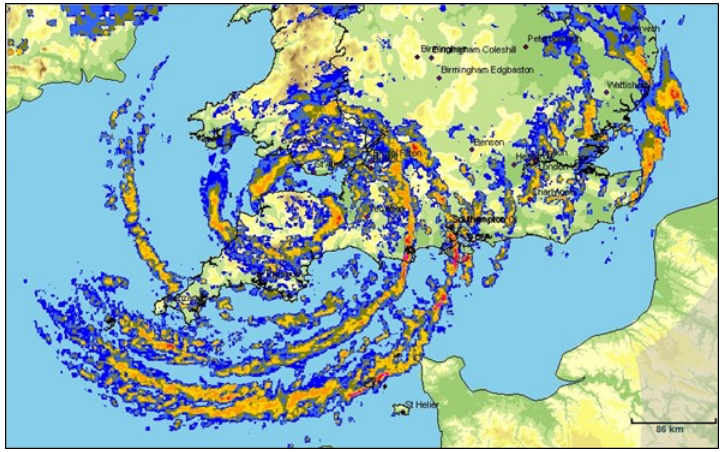
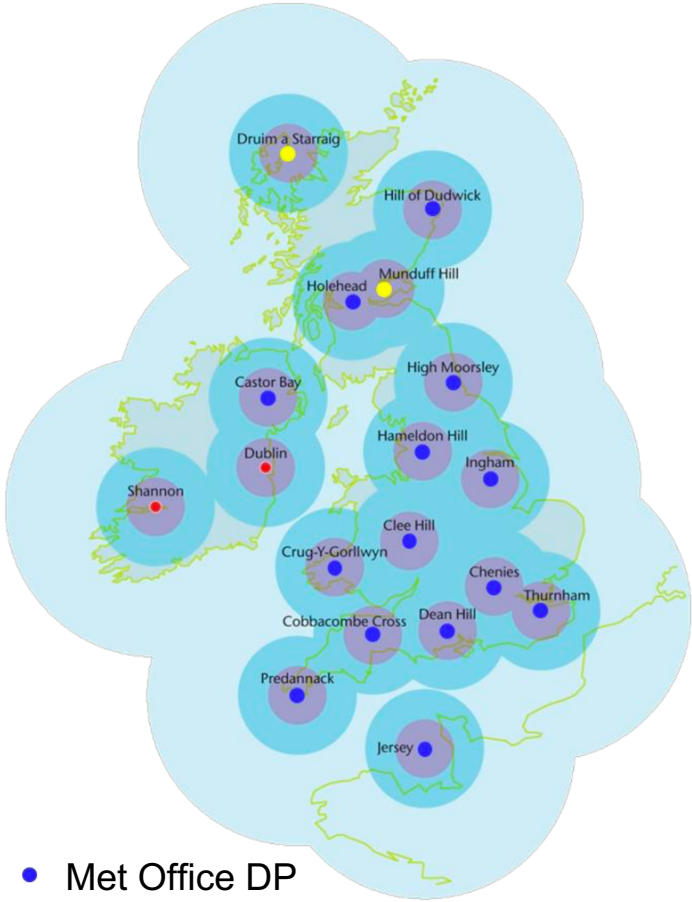
- Met Office is about to complete the Dual-Pol upgrade to the radar network.
- Incremental upgrade to DP began in 2012. Scheduled to complete November 2017. 2 radars left and in progress. 5 years total.
- From this we can estimate precipitation type from radar for the first time in the UK. My PhD project is to verify radar observations of precipitation type.



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

Clee Hill (DP).



Met Office radar network status as of June 2017. Circles indicate resolution.

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)

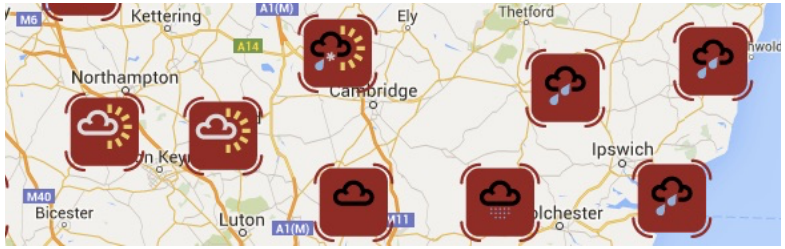
1. FAAM aircraft

- 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

2. Crowdsourced: BBC Weather Watchers



Existing Verification Data

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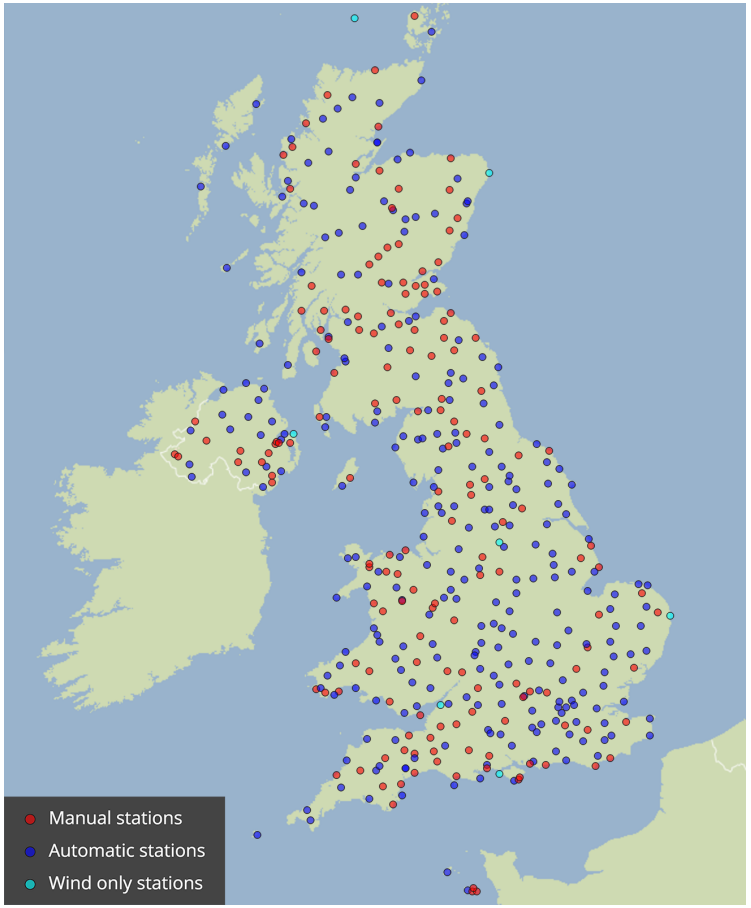
Inferred
(at the surface)

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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- 14 originally purchased for Met Office trial in 2008. In storage until 2017.
- To replace Visiometers for improved present weather codes from automatic stations.
- 1 at RAF Dunkeswell; data card changed monthly.
- Remaining 13 given to University of Leeds for this PhD project in 2016.

THE WORLD OF WEATHER DATA - THE WORLD OF WEATHER DATA - THE WORLD OF WEATHER DATA

Thies CLIMA

Instruction for Use
021341/07/11

Laser Precipitation Monitor
5.4110.xx.x00
V2.5x STD

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY WITH
OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

ADOLF THIES GmbH & Co. KG
Hauptstraße 76 37083 Göttingen Germany
Box 3536 + 3541 37025 Göttingen
Phone +49 551 79001-0 Fax +49 551 79001-65
www.thiesclima.com info@thiesclima.com

Thies Laser Precipitation Monitor

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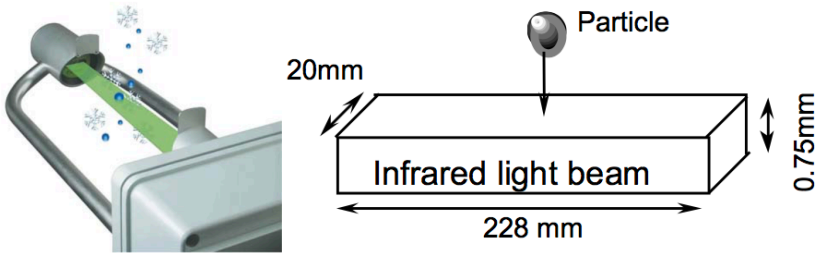
- Infrared beam measuring 20mm x 228mm x 0.75mm.
- 22 diameter bins; 20 speed bins.
- Non-linear bins weighted towards smaller particle sizes.
- 21 PW codes with 6 types (drizzle, rain, snow, grains, ice, hail).
- Visibility (m), rain/snowfall rate (mm to 3.d.p), radar reflectivity factor (dBZ)



Particle diameter class		
Class	Diameter [mm]	Class width [mm]
1	≥ 0.125	0.125
2	≥ 0.250	0.125
3	≥ 0.375	0.125
4	≥ 0.500	0.250
5	≥ 0.750	0.250
6	≥ 1.000	0.250
7	≥ 1.250	0.250
8	≥ 1.500	0.250
9	≥ 1.750	0.250
10	≥ 2.000	0.500
11	≥ 2.500	0.500
12	≥ 3.000	0.500
13	≥ 3.500	0.500
14	≥ 4.000	0.500
15	≥ 4.500	0.500
16	≥ 5.000	0.500
17	≥ 5.500	0.500
18	≥ 6.000	0.500
19	≥ 6.500	0.500
20	≥ 7.000	0.500
21	≥ 7.500	0.500
22	≥ 8.000	∞

Particle speed class		
Class	Speed [m/s]	Class width [m/s]
1	≥ 0.000	0.200
2	≥ 0.200	0.200
3	≥ 0.400	0.200
4	≥ 0.600	0.200
5	≥ 0.800	0.200
6	≥ 1.000	0.400
7	≥ 1.400	0.400
8	≥ 1.800	0.400
9	≥ 2.200	0.400
10	≥ 2.600	0.400
11	≥ 3.000	0.400
12	≥ 3.400	0.800
13	≥ 4.200	0.800
14	≥ 5.000	0.800
15	≥ 5.800	0.800
16	≥ 6.600	0.800
17	≥ 7.400	0.800
18	≥ 8.200	0.800
19	≥ 9.000	1.000
20	≥ 10.000	10.000

Disdrometer class binning of diameter and speed.(Table 6, p48 from manual)

Thies Laser Precipitation Monitor

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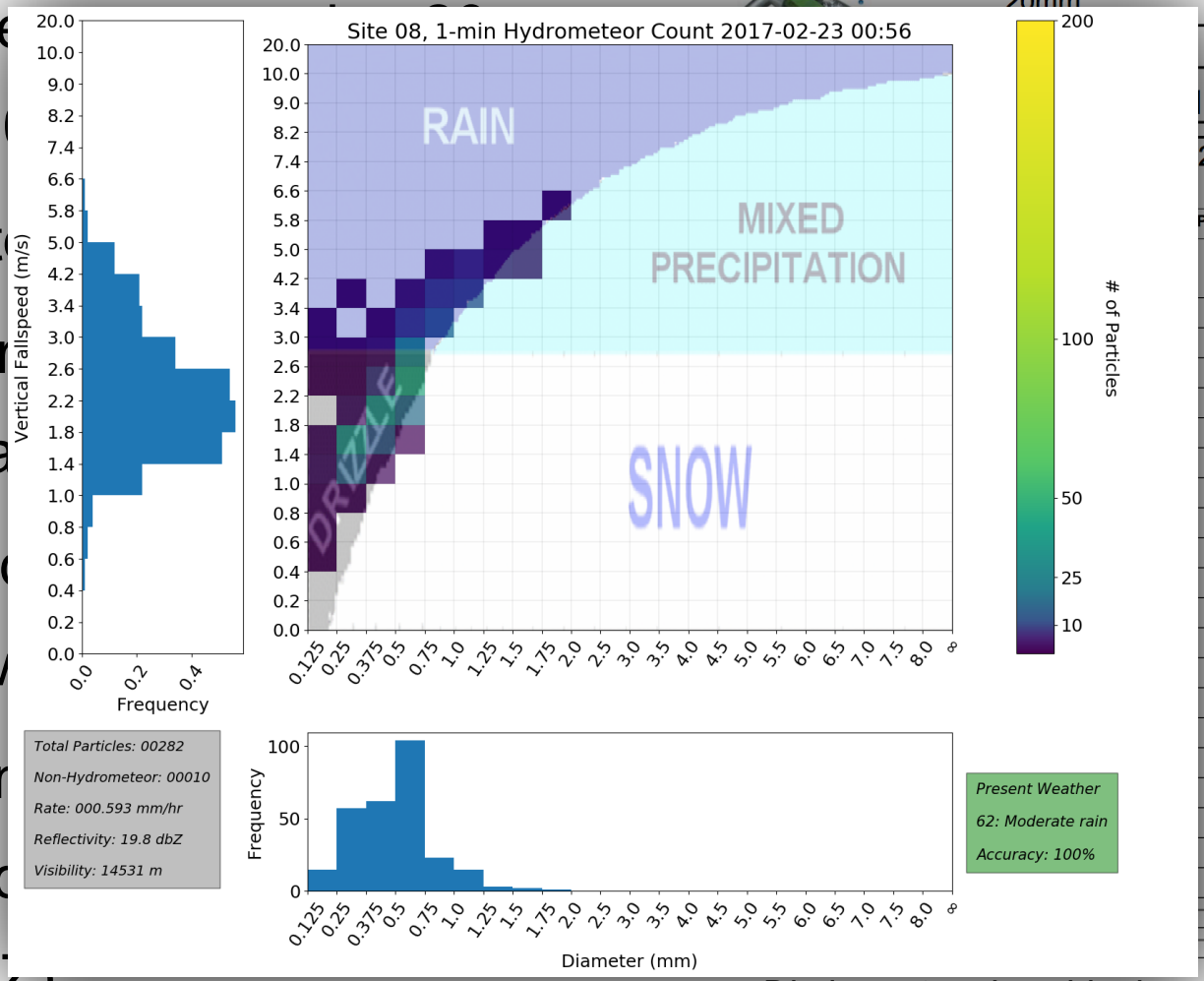
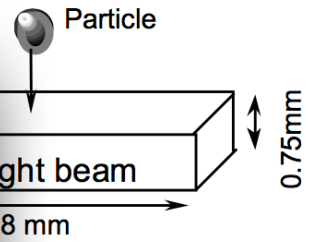
- Infrared be
  228mm x
- 22 diamet
- Non-linear
  smaller pa
- 21 PW co
  rain, snow
- Visibility (r
  (mm to 3.
  factor (dBZ)





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≥ 1.000	0.400
≥ 1.400	0.400
≥ 1.800	0.400
≥ 2.200	0.400
≥ 2.600	0.400
≥ 3.000	0.400
≥ 3.400	0.800
≥ 4.200	0.800
≥ 5.000	0.800
≥ 5.800	0.800
≥ 6.600	0.800
≥ 7.400	0.800
≥ 8.200	0.800
≥ 9.000	1.000
≥ 10.000	10.000

Disdrometer class binning of diameter and speed.(Table 6, p48 from manual)

Finding Host Sites

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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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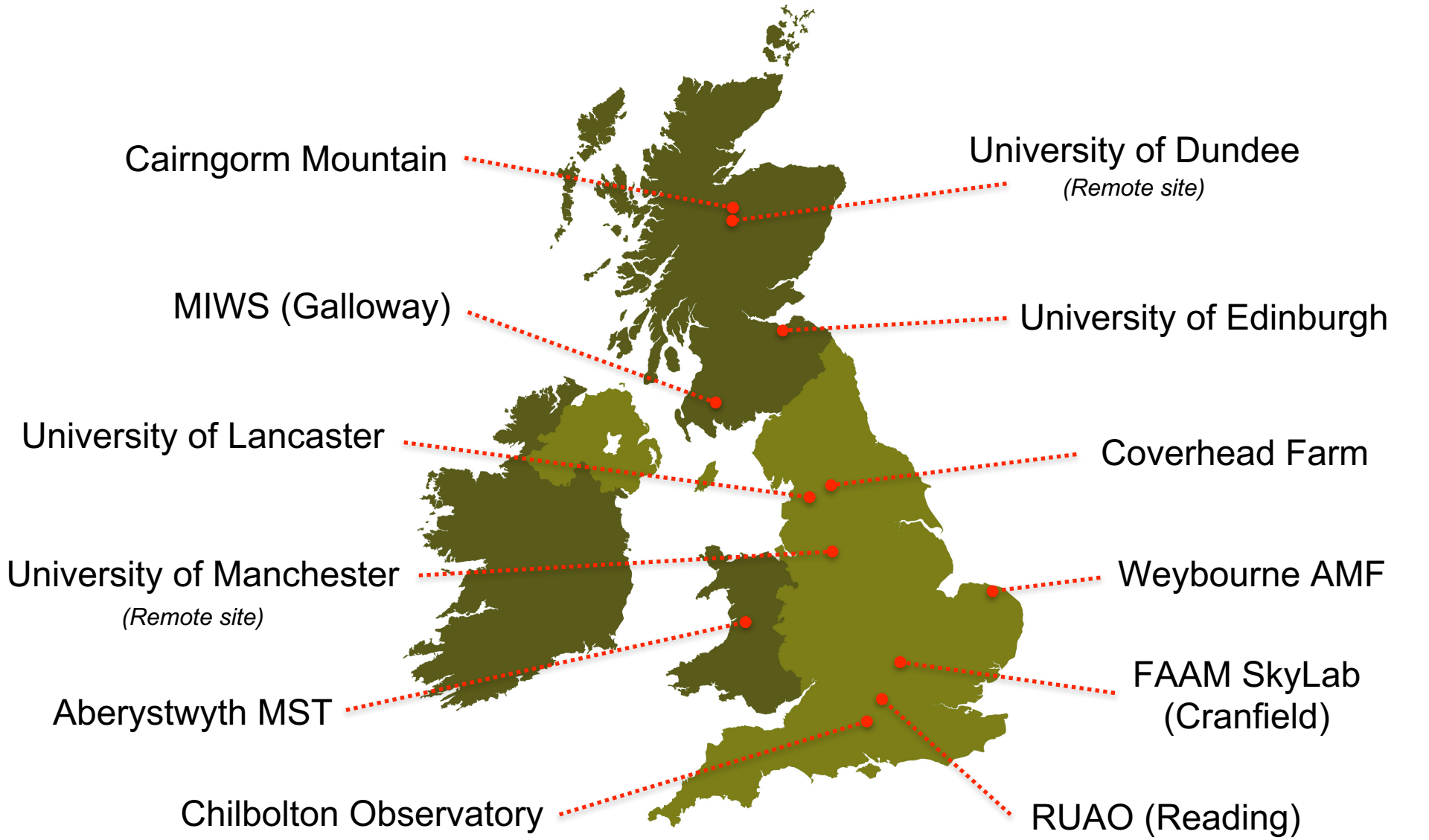

Installation Trip Video

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Installation Campaign video at:
https://youtu.be/SZLJq_mT288

Datalogger Components

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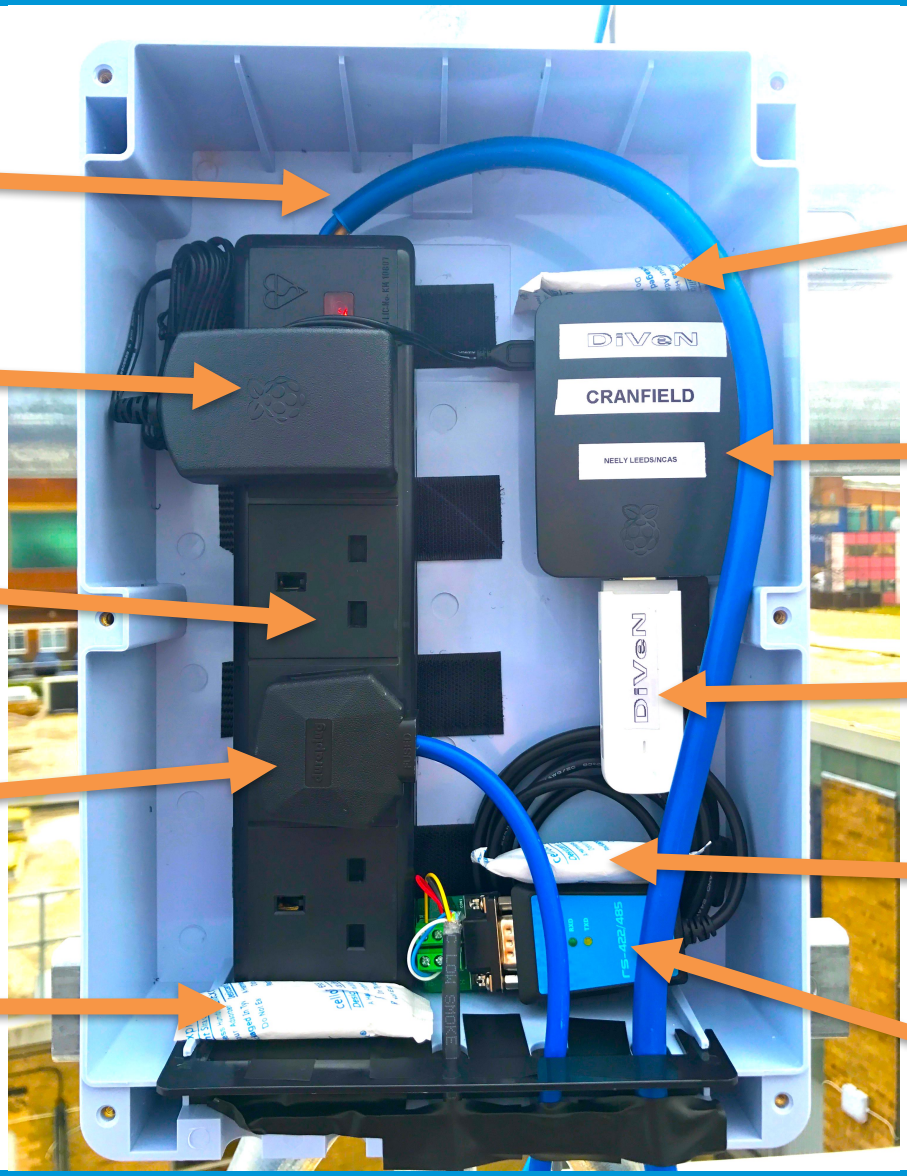

240v 13A Input

Pi Power

Simple Household Power Strip

Disdrometer Power

Silica Gel

More Silica Gel

Raspberry Pi

3G Dongle

Bonus Silica Gel

Serial to USB converter

Cost Breakdown I

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Site Equipment Costs

Item	Cost	Comments
Thies Disdrometer	*Free**	*On loan from the Met Office for 3 years. True cost ~£2400 each*
Raspberry Pi	*£30 each*	*13 sites + one development/testing unit*
Ubuntu Mate OS	*Free**	*Donations welcomed*
Serial to USB	*£12 each*	
Weatherproof Box	*£25 each*	*IP65 rating, 3 minutes to open/close w/ screws*
Davis Tripod	*£100 each*	*Difficult to source a supplier*
Electrical Cable	*~£1 / m*	*Arctic grade*
Tools	*~£60*	*For entire installation*
TOTAL:	~ £180 each	~ £2500 for entire network

Total cost for each site in equipment is approx. *£180* per site.

Cost of just the data collection equipment is £67 per site.

Cost Breakdown II

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	Raspberry Pi System	Campbell Scientific *Estimates based on Leeds University weather station setup for the Isle of Arran field trip.*
Initial Cost	Pi £30, Serial2USB £12, Box £25, 3G dongle free† = **£67**	Logger £820, Software £460, Box £225, 3G £280 ≈ **£1,785**
Initial Setup Time	2-4 weeks (**£554-1,200** staff time cost)*	2 days (**£280** for a knowledgeable technician)
Re-Deployment Setup Time	30-60 mins (**£4-8** staff time cost)*	*Similar*
Ongoing Costs	†**£80** for 3G p.a. Electricity **£170** p.a.	*Similar*
Longevity	*3 Years = 4 GB (non-compressed)* *No warranty*	*3 years = 72 GB* *3 year limited warranty*
Tech Support	*StackOverflow* *NCAS I.T. Team*	*Dedicated support line over phone or email during working hours.*
Maintenance	*Bugs from own coding abilities…*	*Expected to be more reliable.* *12 months free repair/replace.*

* Staff cost is for a PhD student (low paid) — cost would be significantly more for a Senior Researcher/Professor. Solution: get students to code for you.

Cost Breakdown III

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T&S Costs

Item	Cost	Comments
Hire Van + Fuel	~£500	2300 miles ≈ £350 of fuel + £150 van hire
Accomodation	~£500	Stayed with friends and family to reduce costs.
Sustenance	£600	£25 per diem
TOTAL:	£1600	*The costs to uninstall the network at the end of the project in 3 years time should be identical.*

Continuing Costs

Item	Cost	Comments
3G Data	£80 per year	6 sites have free internet (WiFi/Ethernet)
Electricity	Free*	*Most sites. True cost max £170 per year
TOTAL:	£640	

Data Journey

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Telegram 4
Serial Port

Serial to USB converter

Telegram 4
USB 2.0

Raspberry Pi v3

Python script to capture incoming data each minute

ASCII
SD Card

2 - 7 minutes for website to show data

crontab script to upload to NCAS server every 5 minutes

ASCII
3G / WiFi

crontab to plot images every 5+1 minutes using JASMIN server

PNG
JASMIN

"Quicklooks" website to index new images onto website every 5+2 minutes

DiVeN Website

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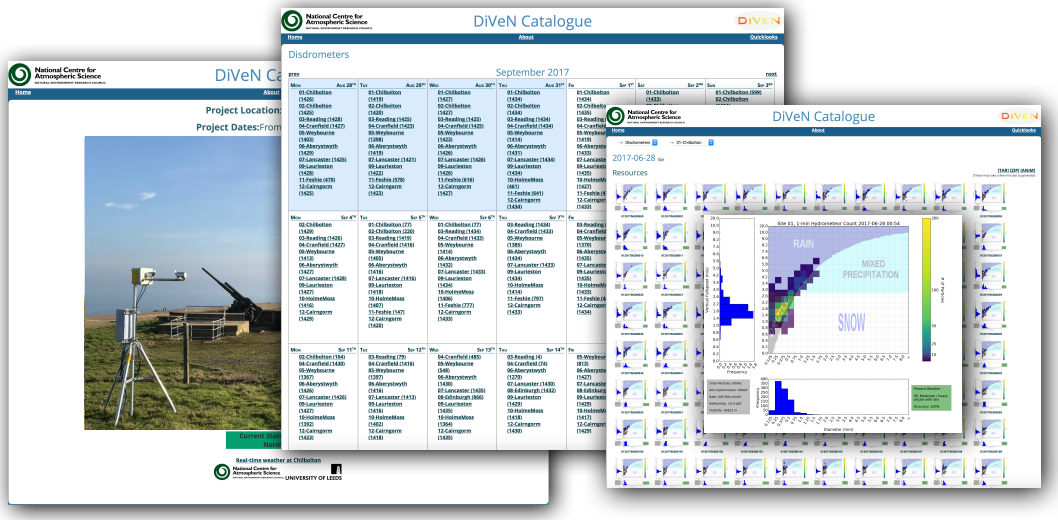
sci.ncas.ac.uk/diven



- 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 (%)

ben.pickering@ncas.ac.uk | @wx_radar

DiVeN Website

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Demo of website video at:
https://youtu.be/tb0Elkt3GH8

Challenges and Issues

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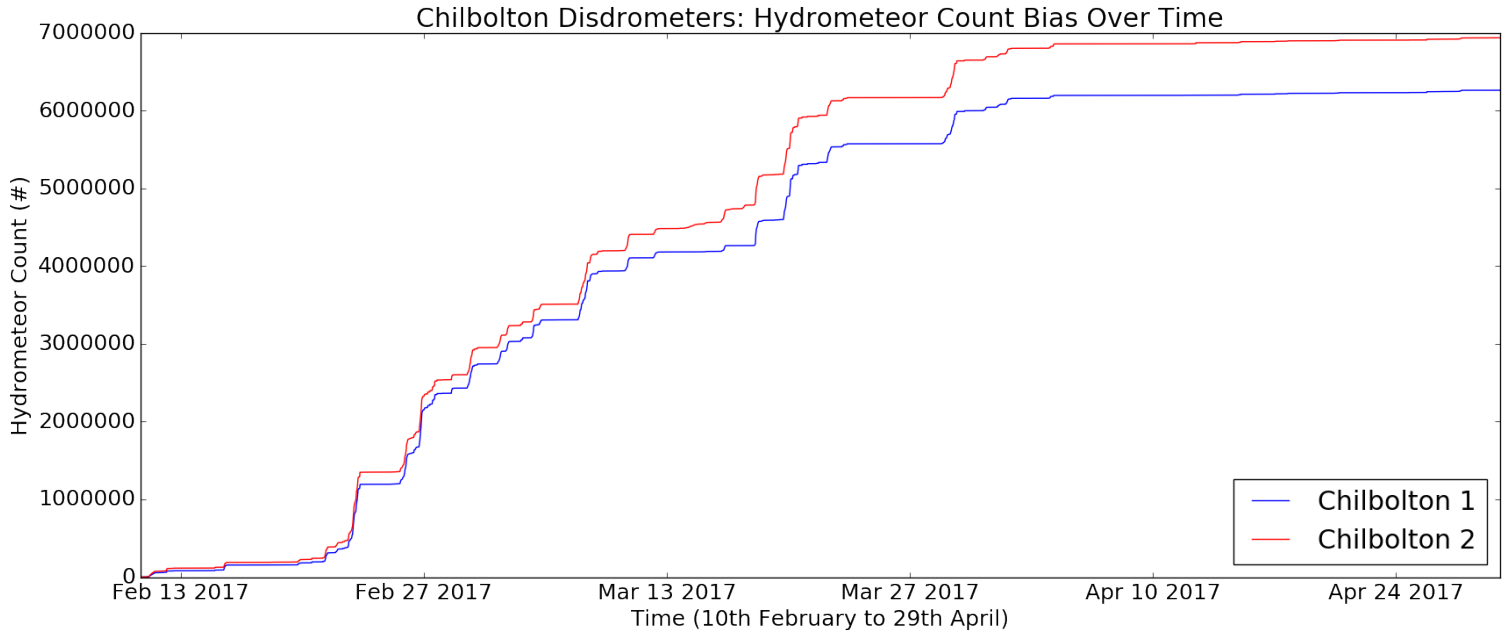
- I needed a lot of help writing the scripts for the Pi to communicate with the server through BASH & SFTP.
- Raspberry Pi file format (EXT4) has limit of 479,000 files on card. After 7 months (Early September 2017) Pi could not write new files. Code had to be sent to each site owner to fix the issue - some sites are still down because of it.
- 3G signal is patchy in some areas, especially one site in Scotland - signal booster needed there at extra cost.
- Unable to remotely SSH into the Raspberry Pi on a 3G dongle or WiFi because IP address is non-static.
- Longevity - project only expected to run for 3 years, unknown if the Raspberry Pi or other components will fail before then.

Chilbolton: Consistency

- 7 million hydrometeors measured in 3 months.
- 10% difference in total count.



Chilbolton: Consistency

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10% higher total count from Chilbolton #2:

- 8% from general bias
- 2% from "zero events"

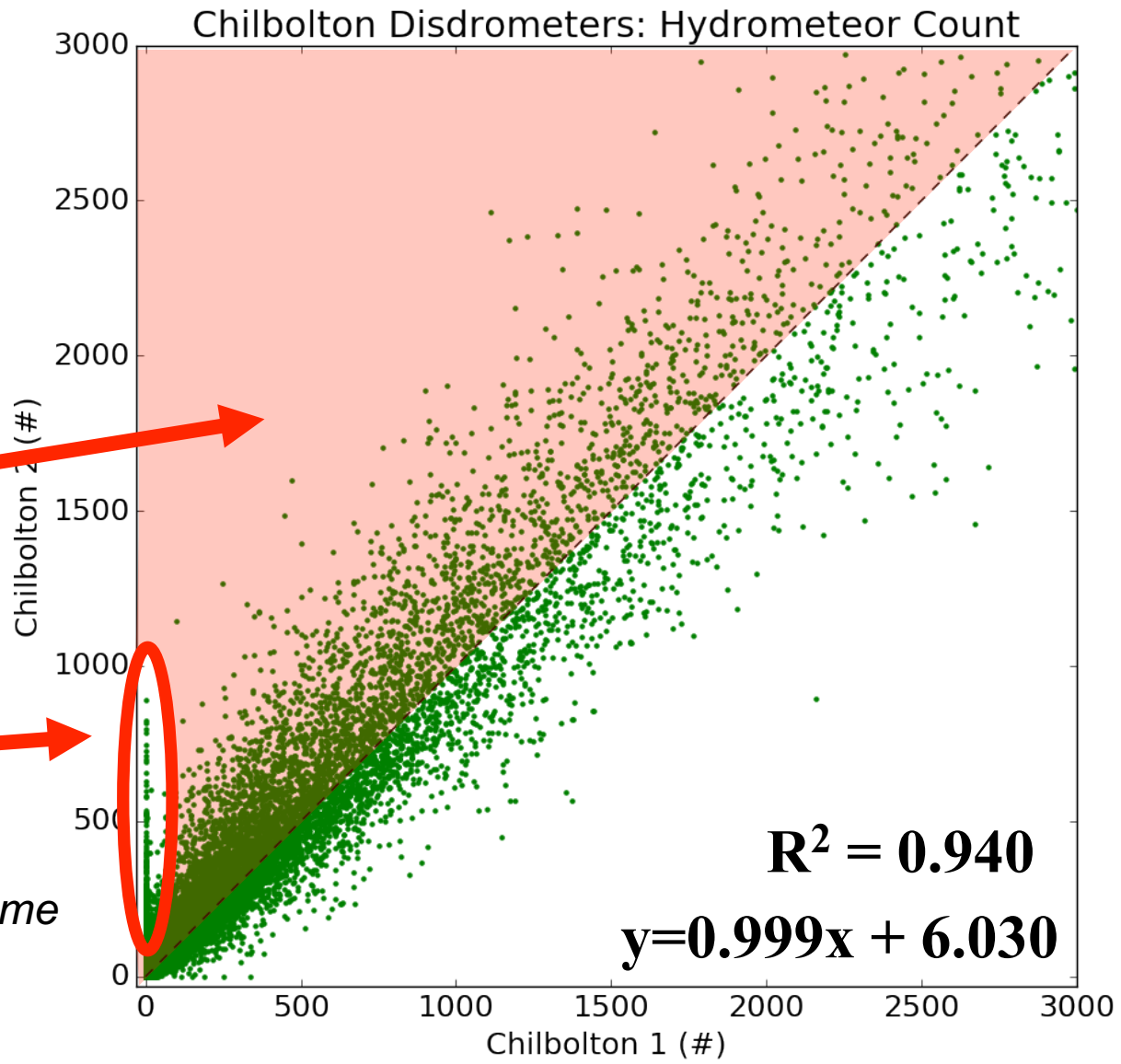

Figure zoomed in - some extreme values at 12,000 drops are skewing the correlation.

Biological Interference

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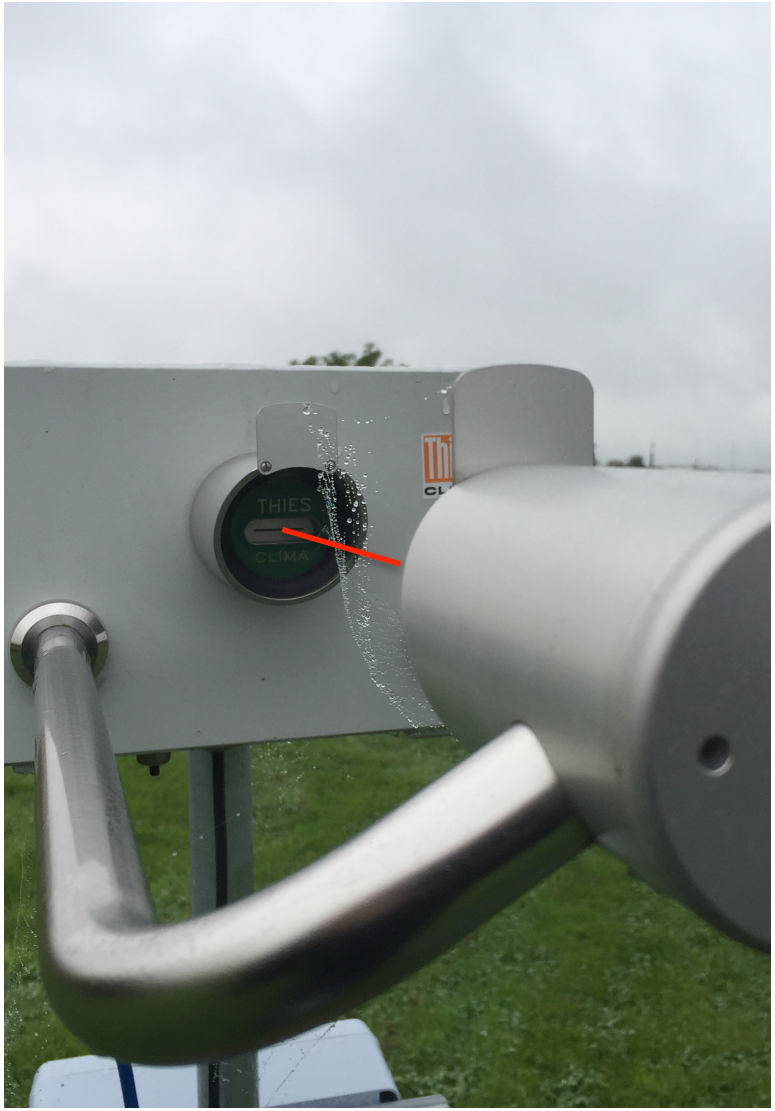

Chilbolton: Extreme Event

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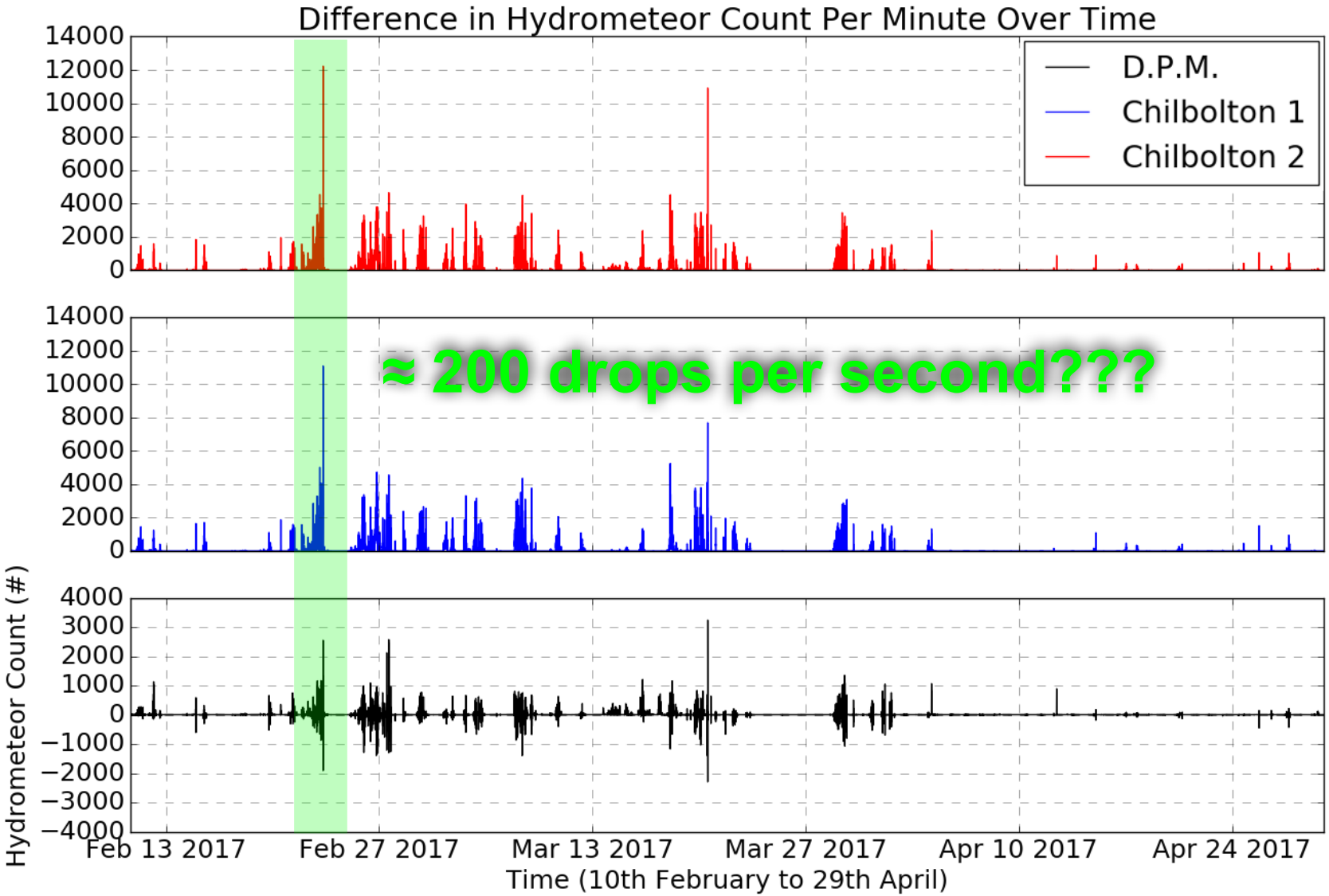
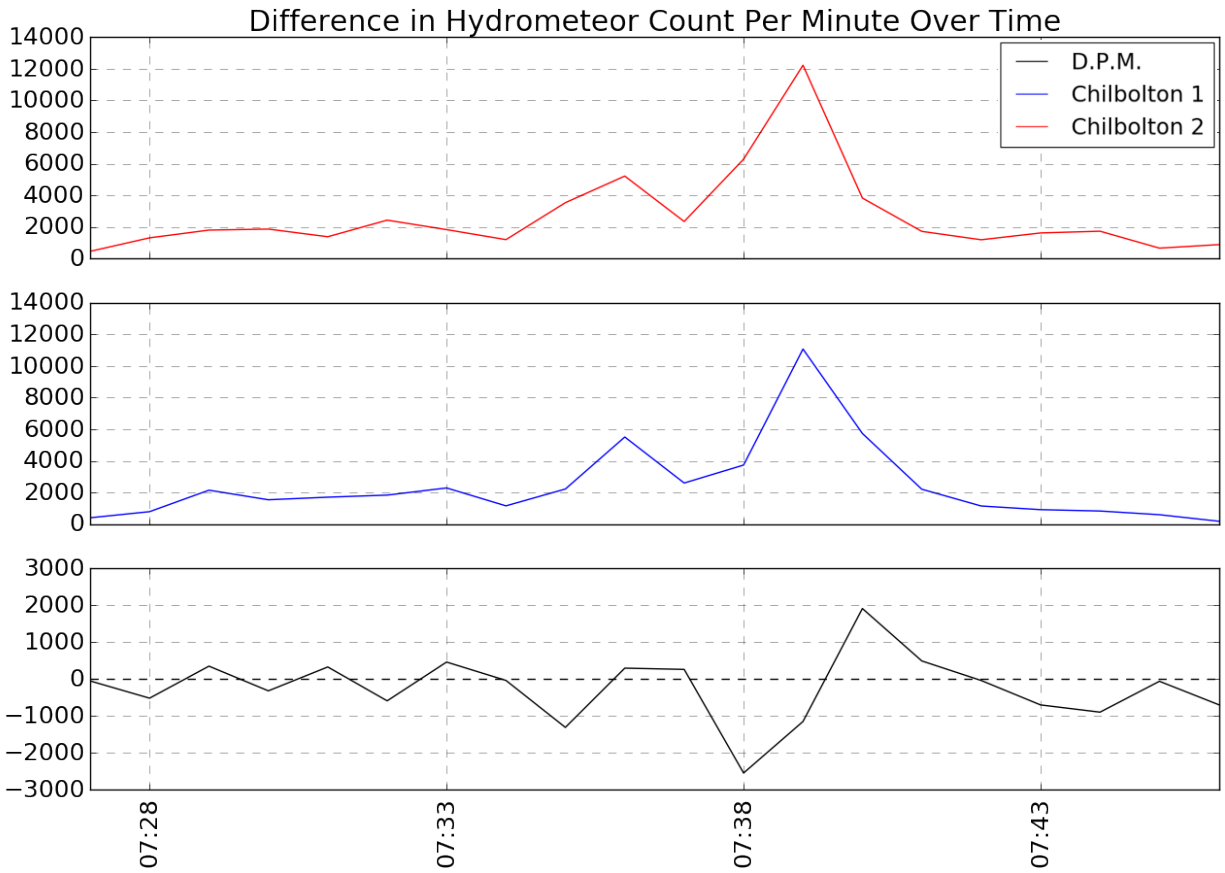


Chilbolton: Extreme Event

UNIVERSITY OF LEEDS



Both instruments broadly follow the same count.

Both instruments ‘ramp up’ to 12,000 particles.

Difference fluctuations suggest 1-min period is asynchronous. 5-min average = reduced anomaly

Chilbolton: Extreme Event

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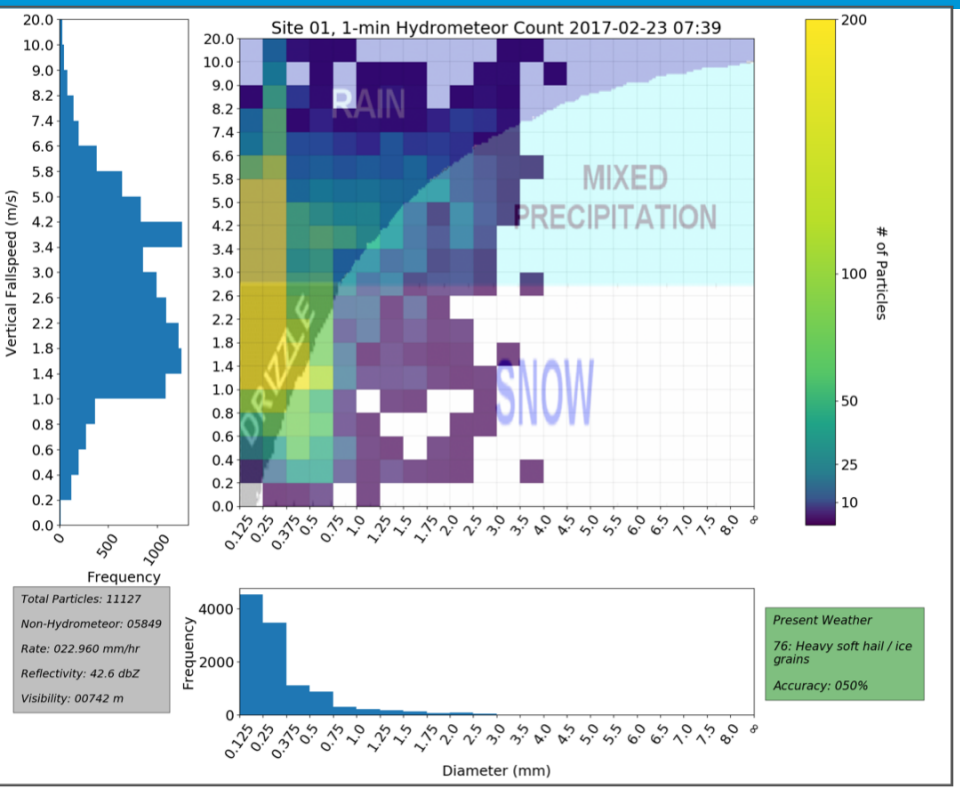
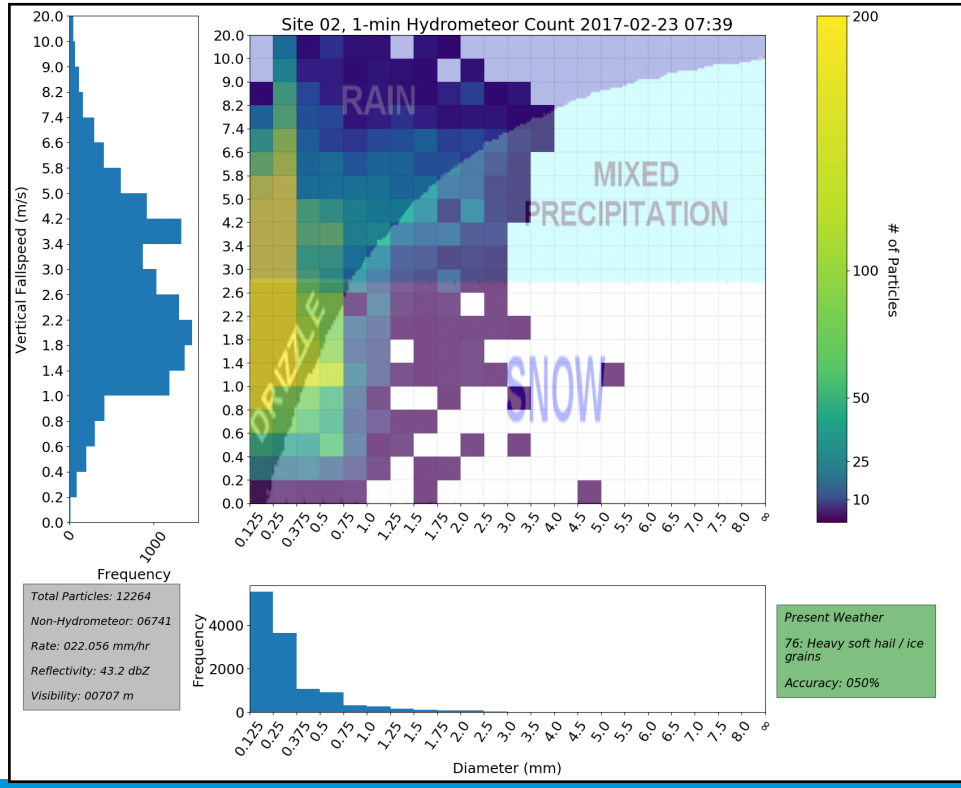


Chilbolton 1

Chilbolton 2



Chilbolton: Extreme Event

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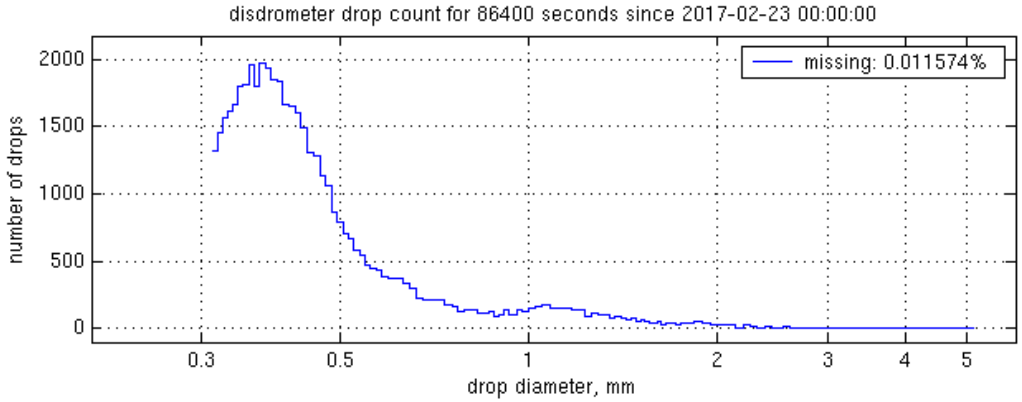

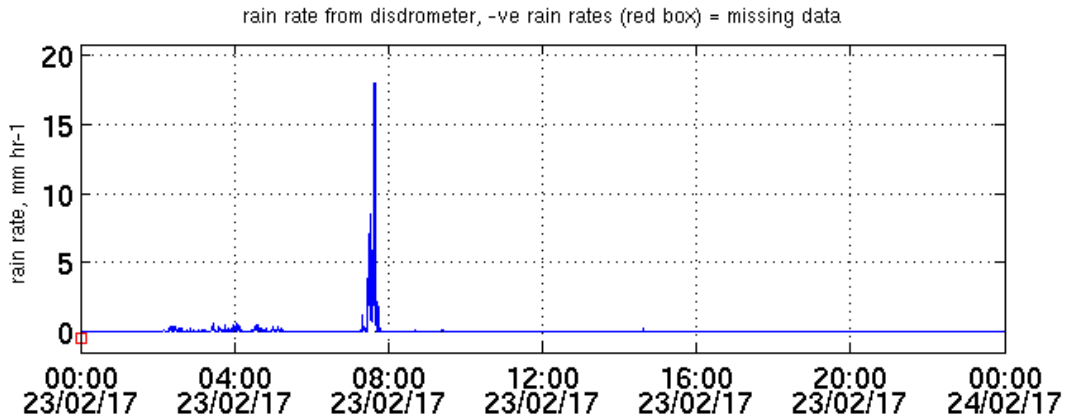

JOSS impact disdrometer 50m away.

One rainfall event in the day, peak 18mm/hr

Integral of the drop size distribution is ~55,000.

Both DiVeN disdrometers also record 50-60k hydrometeor counts for the day. Thus… 200 drops per second is happening for 18mm/hr rain rate?

Summary & Future Work

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- DiVeN is the largest drop precipitation monitoring network in the UK, measuring at 60 second frequency.
- The data is available on a near-real-time website (5 min updates) and available for download upon request.

- Use DiVeN to verify UK radar hydrometeor classification algorithm.
- Supervise an MRes student at Leeds using the DiVeN data to study precipitation with and without a bright band signature.
- Paper in progress, aiming for AMT submission by the end of 2017.