Interactive discussion for amt-2018-302:

The Disdrometer Verification Network (DiVeN): a UK network of laser precipitation instruments

Response to Reviewer 2

The authors thank the reviewer for their time and consideration given to this manuscript.

The reviewer's comments have been listed below in **bold** and responded to individually in *red italics*.

* General comments:

The authors described and reported on the performance of a disdrometer network in the UK. I have found the work well written and without significant scientific flaws, as well as being of interest to precipitation researchers. For these reasons, I recommend publication after minor modifications.

* Specific comments

1) Page 3, line 22: "As of the time of writing this publication, operational net-works of disdrometers are uncommon". This may be true of optical disdrometer, but radar-based units have been used operationally for example in Canada to determine precipitation type from the early 1990s to about 2010 on all automatic stations. See https://journals.ametsoc.org/doi/full/10.1175/2007JTECHA957.1 and references therein.

The authors thank the reviewer for pointing this out and have added this to the paper as quoted below:

"As of the time of writing this publication, operational networks of disdrometers are uncommon, with the notable exceptions of Canada (Sheppard, 1990) and Germany. Networks of disdrometers solely for research purposes have been frequently deployed for short periods of time."

2) Page 4, line 32, or somewhere else: What is the quantitative meaning of the quality index? For example, what does an index of 90% mean, beyond being better than one of 80% and worse than 95%?

The manufacturers describe the quality index as an 'estimation' which has many inputs and again the details are not provided in the instrument manual. Through personal communication the manufacturer mentions the number of particles in each bin and the overlap between the empirical relationships used (which are not provided) in the determination of this index. The manufacturer then goes on to dismiss the usefulness of the index in personal communication, listed below. However, the case studies in the paper show that it has some ability to show when the Present Weather code assignment is less confident e.g. in Figure 13 and especially in Figure 8 where mixed phase present weather codes have reduced quality index.

The manufacturers supplied the following, in a personal communication on 20 Sep 2017: (Manufacturer comments in blue italics)

1: Is there a function or equation you can give me to show how measuring quality is calculated?

1: We do not issue this info. Reason:

The quality of the measurement results can only be estimated by the LPM disdrometer by means of the number of particles measured in the individual internal range classes and the ambient temperature. Further influences of the quality are to be expected with corresponding wind speeds (depending on the type of precipitation type) and with very dense fog (+ light wind).

Conclusion: in our opinion it makes no sense to use this estimated value without further consideration of the environmental conditions.

2. How many hydrometeors are required to get 100%? For "no precipitation" how many are required for 100% accuracy?

2. REMARK: it's only "our" ESTIMATION:

Example Hail: 2 particles ~ 50%

5 particles ~ 100%

Example No Precipitation 100%: max. 5 Drizzle-Particles

3. Does the disdrometer record the second highest probability class? E.g. if Snow is 87% and rain is 65%, can I see that, or does it just output the highest probability?

3. Prec-type classification is done according the WMO-codes.

E.g. if Rain and Snow is detected, the code 68(Rain AND Snow) is taken.

The so-called "measuring quality" value is not taken for this classification.

4. Can you tell me which speed/diameter bin is classified as each precipitation type? Where is the scientific evidence that those choices are correct? Is there an uncertainty on those classes?

4. For drizzle and rain we use the gunn-kinzer relation. The diameter/fall speed relation of hydrometeors are well measured, there are many scientific publications available. However, there are overlaps between some types of precipitation that lead to uncertainties in the measuring principle of this sensor.

3) Page 6, lines 9-11 : Given the simplicity of your assumptions (all drops measure 0.8 mm), I would reduce the reported accuracy of your probability of simultaneous occurrence to a single digit of precision, i.e., 0.09% and 7%. And at 0.8 mm, these are drops, not "droplets" (line 6).

This has been corrected in the text.

4) To what extent do you need Sections 3.2 and 3.3? I'll leave it to you to decide.

The authors wish to keep these technical details. The low-cost installation and continued low running costs of DiVeN are key aspect of its' success, and the network would not be possible were the costs higher. There has also been considerable attention within the atmospheric science community about "low cost" sensors and we hope to contribute to

this larger discussion. The authors leave the decision of the applicability of this material in an AMTD article to the Handling Associate Editor.

5) Page 11, line 26-27: "[The Doris event] will be a valuable case by which to compare the performance of radar hydrometeor classification schemes.". Yes and no: It depends on the altitude of radar measurements compared to your ground-level measurements. In such events, if melting occurs at too low altitude, the radar may be blind to it. There are hence two aspects to HCA performance: Accuracy at altitude, and representativeness of the assessment at altitude to surface conditions, both of which being two very different research projects.

The authors appreciate the comment made and will consider it going forward in future research which is primarily on the radar-derived surface hydrometeor type products. The text has been changed to specify radar-derived surface hydrometeor type products only.

6) Page 12, line 20, on the effect of wind: A strong surface wind would also often create strong surface turbulence that may affect drop vertical velocity in addition to worsening edge effects.

"The fall speed of hydrometeors measured by the disdrometer may be affected by the wind, in particular winds tangent to the disdrometer as was the case here (*N*-*S* oriented beam, westerly wind)."

changed to:

"A strong surface wind is associated with turbulent eddies which have some vertical component. The intermittent vertical wind acts to widen the drop velocity distribution. Furthermore, turbulence breaks up droplets thus skewing the drop size distribution. Finally, winds tangent to the beam (N-S oriented beam, westerly wind) as was the case here, increase the number of beam-edge hits which reduce the quality of the data."

* Technical corrections, typos, etc :

Page 5, line 4: Section 44.1 -> Section 4.1

This has been corrected in the text.

Page 5, line 30: 0.5 mm snow aggregate -> 0.5 mm ice crystal

This has been corrected in the text.

Page 6, line 13: Section 44.2 -> Section 4.2

This has been corrected in the text.

Page 11, line 26: its' -> its

This has been corrected in the text.

Page 12, line 10: Waldvögel -> Waldvogel

This has been corrected in the text.

Table 3 title: Disrometer -> Disdrometer

This has been corrected in the text.

Figure 13: Can you fix the alignment problem between the line plots (reporting on the minute mark) and the hydrometeor determination graphics (plotted in between the minute marks)?

The line plots on Figure 13 have been shifted forward by 30 seconds to indicate that a single point is valid across the minute labelled, thereby following the notation of the hydrometeor determination plot.

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Tracked changes to LaTeX file:

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78 79 80	<pre>\Author[1]{Ben S.}{Pickering} \Author[2]{Ryan R.}{Neely III}</pre>	
81 82	\Author[3]{Dawn}{Harrison}	
83 84 85	\affil[1]{Institute for Climate and Atmospheric Science, School of Earth and Environment, University of Leeds, Leeds, Yorkshire, UK. LS2 9JT} \affil[2]{National Centre for Atmospheric Science, 71-75 Clarendon Rd, Leeds, Yorkshire, UK. LS2 9PH} \affil[3]{United Kingdom Meteorological Office, Fitzroy Rd, Exeter, UK. EX1 3PB}	
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91 92	\runningtitle{TEXT}	
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95 96 97	<pre>\correspondence{Ben S. Pickering (eebp@leeds.ac.uk)}</pre>	
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139	Starting in mid-2012 and completing early-2018, every radar in the UK Met Office network was upgraded from single to dual-polarisation using in-house design and off-the-shelf components, re-using the pedestal and reflector from the original radar systems. To take advantage of the new information and to improve precipitation estimates, an operational HCA was developed within the Met Office, based on work at M\'et\'eo France \citep{Al-Sskta2013}. While significant amounts of literature have been published on the technical improvement of HCAs \citep{Chandrasekar2013}, the verification of HCA skill has not been discussed as widely. There is a need for more rigorous validation of HCAs and DiVeN was created specifically for the verification of the UK Met Office radar network HCA.	Added (FAAM) Mar 30, 2019 1:07 PM • You * Reject
140		all)
141	Typically in-situ aircraft are used to verify radar HCA \citep{Liu2000,Lim2005,Ribaud2016}. Instrumented aircraft flights such as the Facility for Airborne	Apr 8, 2019 3:31 PM • You
	Atmospheric Measurements (FAAM) take a swath volume using 20 Hz photographic disdrometer instruments \citep{abel2014}. However there is no fall speed	🗙 Reject 🛛 🗸 Accept
	information, which distinguishes hydrometeor type with high skill due to distinct particle density differences \citep{locatelli1974}. The lack of fall speed	Added , with the notable
	information on FAAM instruments means that the 1,200 images collected in every minute of flight must be visually analysed manually or with complex image	🔗 exceptions of Canada (show all)
	recognition algorithms. The major disadvantage with FAAM data is the sparsity of cases due to the expense of operating the aircraft.	Apr 22, 2019 4:52 PM • You
142		🗙 Reject 🛛 🗸 Accept
143	Therefore, in-situ surface observations must be utilised to expand the quantity of comparison data. A larger dataset allows bulk verification statistics to	 Changed However n to N
	be performed on radar HCAs. Here we introduce a new surface hydrometeor type dataset and examine the skill of the dataset, independently of any radar	Apr 22, 2019 4:54 PM • You
	instruments.	🗙 Reject 🛛 🗸 Accept
144		
145		Added -1
146		V Peiect Accent
147 -	(subsection(Precipitation Measurement with Disarometers)	
T40	A disurbancer is an instrument which measures the drop size distribution of precipitation over time. The drop size distribution (nenceforth obs) of	Changed Tonkawa, Oklahoma to
	precipitation is the function of arop size and arop frequency. (citeJameson2001) provides an in-depth discussion on the definition of a 050. Disdometers	Ponca City, Oklah (show all)
149	cypicarty record drop sizes into bins or nonrinearly increasing which due to the acturacy reducing with increasing values.	M Deject
150	The disdrometer is also a useful tool for verifying radar hydrometeor classification algorithms. Hydrometeor type can be empirically derived using	
200	information about the diameter and fall speed of the particle, which the Thies Laser Precipitation Monitor (LPM) instrument used in June is able to	Changed two to six
	measure. The Gunn-Kinzer curve \citep{Gunn1949} describes the relationship between raindrop diameter and fall speed. As diameter increases, the velocity of	 Apr 8, 2019 4:20 PM • You
	a raindrop increases asymptotically. Other velocity-diameter relations have been shown in the literature for snow, hail, and graupel which are well	🗙 Reject 🛛 🗸 Accept
	described in \cite{locatel]i1974}.	A Changed on to with
151		Apr 8, 2019 4:24 PM • You
152	As of the time of writing this publication, operational networks of disdrometers are uncommon, with the notable exceptions of Canada \citep{sheppard1990}	🗙 Reject 🛛 🗸 Accept
	and Germany. Networks of disdrometers solely for research purposes have been frequently deployed for short periods of time. From March 2009 to July 2010 (16	Changed attempts to subio
	months), 16 disdrometers were placed on rooftops within a 1 km by 1 km on the campus of the Swiss Federal Institute of Technology in Lausanne to study the	(show all) to demonstrates
	inter-radar pixel variability in rainfall \citep{Jaffrain2011}. Another example of research using networked disdrometers is the Midlatitude Continental	Apr 8, 2019 5:40 PM • You
	Convective Clouds Experiment (MC3E) \citep{jensen2016} which utilised 18 Parsive]-1 disdrometers and 7 ZDVDs (2-Dimensional Video Disdrometers) within a 6	🗙 Reject 🛛 🗸 Accept
	km radius of a central facility near Ponca City, Oklahoma. The project lasted for six weeks (22 April through 6 June 2011). Diven has an initial deployment	Channed a billiblica to data
	phase of 3 years with a high expectation of renewal, which enables unique long-term research to be conducted with the data.	Products
153		Apr 17, 2019 2:08 PM • You
154		🗙 Reject 🛛 🗸 Accept
155		Channel There exercise 111
150 -	\subsection(Paper structure)	 (show all) to These events will
121	In spaper describes Diven and demonstrates the data products of the intes LPM instruments being used. Ine first part of the paper provides a technical description of the did demonstrates used in the notice the location of the distruments of the theory of the theory of the technical determines and distruments in the notice of the distruments of the distrument of the distruments of the distruments of the distruments of the distrument of the distru	(show all)
	description of the discriments used in the network, the locations chosen to nost the instruments, and data management in the network, tase	Apr 22, 2019 2:46 PM & You
	security see sufficient of manyon operations are then discussed. The case studies include rain shew transitions in the 2017 named winter storm	Api 22, 2017 3.40 Pivi • Tou
	studies from the first 12 months of Diven observations are then discussed. The case studies include fain-show transitions in the 2017 named winter storm ports a convertive rainfall event and rained how the studies of the observations the being nordinged by all	× Reject ✓ Accept
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158	studies from the first 12 months of Diven observations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs.	★ Reject ✓ Accept Added describes a similar <i>I</i> Arstwell, (show all) Apr 8, 2019 3:52 PM • You
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158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. <pre>\section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 nm x 20 mm x 0.75mm, a total horizontal area of 45.6cm\$^25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-dioe and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometer is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometer is estimated by the duration of the signal reduction. Figure 1 in \cite{Ioffler-Mang2000} describes a similar instrument (Parsive]-1) with the same observing principle and is an excellent visualisation of the terphinue which is emolyced by the Thies Number Similar instrument (Parsive]-1) with the same observing principle and is an excellent visualisation of the terphinue which is enduced by the the signal reduction. Figure 1 in \cite{Ioffler-Mang2000} describes a similar instrument (Parsive]-1) with the same observing principle and is an excellent visualisation of the terphinue which is emolyced by the Thies Number Sime to cheare and is directed to the other of the other of the ot</pre></pre>	× Reject ✓ Accept Added describes a similar instrument (Parsivel(show all) Apr.8. 2019 3:52 PM • You × Reject ✓ Accept Apr.8. 2019 3:52 PM • You × Reject ✓ Accept Apr.8. 2019 3:52 PM • You × Reject ✓ Accept Apr.8. 2019 3:52 PM • You × Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM • You × Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM • You
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include fain-snow transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual discometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm\$x25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometer is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parsive]-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: The measured values are processed by a signal processing claims to detect and remove particles that fall on the edge of the beam: The measured values are processed by a signal processing claims to detect and remove particles that fall on the edge of the beam: The measured values are processed by a sional processor (DSP), and checked for nal</pre>	Apple 12:12:13:13:00 million ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL., (show all) Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Used to which is employed Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include fain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilizes an infrared (785 nm) beam with dimensions 228 nm x 20 nm x 0.75mm, a total horizontal area of 45.6cm\$>25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parsive]-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by manufacturer. The instrument is able to allocate individual hydrometeor is informed to signal box 20.2 m</pre>	Appl 11:1203 (South We Red ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Ab Deleted -messurement Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM × You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM × You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include fain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met office radar HCAs. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm\$^2\$. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parsive1-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$A(-1)\$.</pre>	Apple 12: 2017 Star Mer Rd ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to hydrometeor type Apr.8. 2019 4:01 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. <pre>\section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 nm x20 mm x 0.75mm, a total horizontal area of 45.6cm\$^25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and 0.75mm, a total horizontal area of 45.6cm\$^25. The infrared beam is emitted from one end of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000 describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is semployed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: ``The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits).'` No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$^{-1}\$ to \$>\$ 20 m s\$^{-1}\$.</pre></pre>	Apple 12, 1247 Jose Wei Kad ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept
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158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-snow transitions in the 2017 hamed winter storm poris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm%25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$A{-1}\$. The Thies disdrometer performs additional calculations on the incoming data which it attaches to the Telegram 4</pre>	Appl 11:1237 Jour Mer Kal ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL., (show all)) Apr. 2019 3:52 PM + You ★ Accept Ab Deleted -measurement Apr. 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr. 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr. 8, 2019 4:01 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to hydrometeor type Apr. 8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed Drecipitation typ (show all) to hydrometeor type Apr. 8, 2019 4:02 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-snow transitions in the 2017 named winter storm poris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met office radar HCAs. <pre>\subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies\texttrademark{Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm/S23. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: `The measured values are processed by a signal processor (OSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$A{-1}\$ to \$>\$ 20 m s\$A{-1}\$.</pre></pre>	Apple 12:1237 Journal of Mark ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -messurement Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8. 2019 4:02 PM + You ★ Reject ✓ Accept Changed such that to since Apr.8. 2019 4:02 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 - 163 - 164	<pre>studies from the first 12 months or biven observations are then discussed. The case studies include rain-snow transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met office radar HCAs. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in Diven (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm%25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeror is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometer is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler=Mang2000} describes a simil ar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$A(-1)\$ to \$>\$ 20 m s\$A(-1)\$. The Thies disdrometer performs additional calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \ref{Tab:var} provides de</pre>	Apple 12, 203 / 500 MM + Nd ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -messurement Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8, 2019 4:01 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to hydrometeor type Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed greetheteor type Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed greetheteor type Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept Apr.8, 2019 4:02 PM + You ★ Reject ✓ Accept
158 159 160 161 - 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-snow transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations these events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Divex. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section{Thies Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm\$^25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and theydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Infler-Mang2000} describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$> 8 mm, and 22 speed bins from \$> 0.2 m s\$4(-1)\$ to \$> 20 m s\${-1}\$. The Thies disdrometer performs additional calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \ref{Tabivar} provides details o</pre>	Apple 2019 000 MM + Kd ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL., (show all)) Apr 8, 2019 352 PM + You ★ Reject ✓ Accept Ab Deleted measurement Apr 8, 2019 352 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr 8, 2019 352 PM + You ★ Reject ✓ Accept Changed Used to which is employed Apr 8, 2019 352 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr 8, 2019 402 PM + You ★ Reject ✓ Accept Changed greecipitation typ (show all) to hydrometeor type Apr 8, 2019 402 PM + You ★ Reject ✓ Accept Changed such that to since Apr 9, 2019 330 PM + You ★ Reject ✓ Accept
158 159 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-snow transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. \section{These Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in Diven (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm525. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite{Loffler-Mang2000} describes a similar instrument (Parivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits)." No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$55 8 mm, and 22 speed bins from \$55 0.2 m \$5A(-1)\$ to \$55 20 m \$5A(-1)\$. The Th</pre>	Added describes a similar Added describes a similar instrument (ParsiveL., (show all)) Apr8, 2019 3:52 PM + You X Reject ✓ Accept Abb Deleted -measurement Apr8, 2019 3:52 PM + You X Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You X Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You X Reject ✓ Accept Changed precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You X Reject ✓ Accept Changed geschthat to since Apr9, 2019 3:30 PM + You X Reject ✓ Accept Changed des-not need to (changed des-not need to (changed des-not need to (changed des-not need to (changed des-not need to
158 159 160 161 - 162 163 - 164 165 166	<pre>studies from the first 12 months of Diven observations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within DiveN. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \subsection{Specification}\label{spec} The instruments used in DiveN (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{thies2011}. To make observations the instrument utilises an infrared (785 nm) beam with dimensions 228 mm x 20 mm x 0.75mm, at total horizontal area of 45.6mSv25. The infrared beam is emitted from one end of the instrument and is directed to theoter. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite(toffier-Man2000) describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particles that fail on the edge of the beam: "The massured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits)." No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 8 mm, and 22 speed bins from \$>\$ 0.2 m s\$A(-1)\$ to \$>\$ 20 m s\$A(-1)\$. The Thies disdrometer performs additional calculations on the incoming data</pre>	Apple 12:1237 Jose Wein Keil ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL(show all) Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed such-that to since Apr8, 2019 3:30 PM + You ★ Reject ✓ Accept Changed such-that to since Apr8, 2019 3:30 PM + You ★ Reject ✓ Accept Changed does not need to (show all) to is not Apr17, 2019 2:24 PM + You
158 159 160 161 - 162 163 - 164	<pre>studies from the first 12 months of Diven opervations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. \subsection{Specification}\label{spec} The instruments used in Diven (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in <cite{thies2011}. (785="" 20="" 228="" an="" beam="" dimensions="" infrared="" instrument="" make="" mm="" mm)="" observations="" the="" to="" utilises="" with="" x="" x<br="">0.75mm, a total horizontal area of 45.6mm\$x25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is unterred by the maximum amplitude of the signal processing claims to detect and remove particles that fall on the edge of the easa: The measured values are processed by a signal processor (OSp), and checked for plausibility (e.g. edge hits).''' No furth details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$>\$ 0 m s\$A{-1}\$. The Thies disdrometer performs additional calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \ref{Tab:var} provides details of the variables and the range of possible values that the instrument is capable of recording. The usation Monitor is capable of recording. The present weather code is encoded as a n</cite{thies2011}.></pre>	Apple 12:1237-0500 MM + Rd ★ Reject ✓ Accept Added describes a similar instrument (Parsivel(show all) Apr.8. 2019:352 PM + You ★ Reject ✓ Accept Ab Deleted -messurement Apr.8. 2019:352 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019:352 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019:401 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8. 2019:402 PM + You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019:3:30 PM + You ★ Reject ✓ Accept Changed des-not need to (show all) to is not Apr.17. 2019:2:4 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164 165 166	<pre>scueres rrum the rist 12 months of Diven observations are then discussed. The Case Studies include rain-snow trainsitions in the 2017 named winter storm Doris, a convective rainfall event, and graupel Observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. /section{Thies Clima Laser Precipitation Monitor}/label{instrument} /subsection{Specification}/label{spec} The instruments used in Diven (see Figure \ref[fig:weybourne]) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in /cite{Thies2011}. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.78mm, a total horizontal area of 45.6m5/23. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-idde and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in /cite{Loffler-Mang2000} describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processor (DSP), and checked for plausing claims to detect and renove particles that fail on the edge of the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$5 8 mm, and 22 speed bins from \$5 0.2 m s\$4(-1)\$ to \$5 2 0 m s\$4(-1)\$. The this disdrometer performs additional calculations on the incoming dat which it attaches to the Telegram 4 serial output. Table \</pre>	Apple 12, 123 - 0500 MM + Rd ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8. 2019 4:02 PM + You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:03 PM + You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:03 PM + You ★ Reject ✓ Accept Changed does not need to (show all) to is not Apr.17, 2019 2:24 PM + You ★ Reject ✓ Accept
158 159 160 161 - 162 163 - 164 165 166	<pre>scues rrum the rinst 12 months or Divem observations are then discussed. The Case studies include rain-snow transitions in the 2017 handed winter storm Doris, a convective rainfail event, and graupel observations. These events will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar MCAS. /section{Thies Clima Laser Precipitation Monitor}\label{instrument} /subsection{Specification}\label{spec} The instruments used in Divem (see Figure \ref{fig:weybourne}) are the Thies] Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detrichies2011. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm\$A25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle fails through the beam. The dimeter of the hydrometer is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometer is estimated by the duration of the signal reduction. Figure 1 in Loffler-Mang20000 describes a signal processor (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter of the S0 m S>6 20 m S>6 20 m S>6 20.2 m SA(-1) 5 to S>6 20 m S>(-1).</pre>	Added describes a similar Added describes a similar Instrument (ParsiveL., (show all)) Apr 8, 2019 3.52 PM × You X Reject ✓ Accept Added describes a similar Instrument (ParsiveL., (show all)) Apr 8, 2019 3.52 PM × You X Reject ✓ Accept Changed used to which is employed Apr 8, 2019 3.52 PM × You X Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr 8, 2019 4.01 PM × You X Reject ✓ Accept Changed genericitation typ (show all) to hydrometeor type Apr 8, 2019 4.02 PM × You X Reject ✓ Accept Changed genericitation typ (show all) to hydrometeor type Apr 8, 2019 4.02 PM × You X Reject ✓ Accept Changed genericitation typ (show all) to is not Apr 9, 2019 3.20 PM × You X Reject ✓ Accept Changed does not need to (show all) to is not Apr 17, 2019 2.24 PM × You X Reject <
158 159 160 161 - 163 - 164 165 166	<pre>scueics irom the irist 12 months or Divem observations are then discussed. The Case studies include rain-snow transitions in the 2017 handed winter storm Doris, a convective rainfail event, and graupel observations. These events will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. \section(Thies Clima Laser Precipitation Monitor)\label{instrument} \subsection{Specification}\label{spec} The instruments used in Divem (see Figure \ref{fig:weybourne}) are the Thies Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies201}. To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.78m, a total horizontal area of 45.6cm\$^25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intersum (Parsive1-D) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processing claims to detect and remove particle stat fall on the edge of the baam. The instrument is able to allocate individual hydrometeors into 20 diameter bits from 0.125 mm to \$5.8 mm, and 22 speed bits from \$5.0 .2 m s\$4(-1)5 to \$5.2 0 m s\$4(-1)5. The Thies disdometer performs additional calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \ref{Tab:var} provides details of the variables and the range of possible values that the instrument is capable of recording. The quantity, intensity, and type of precipitation (dirize), rai, snow, ice, grains, soft hall, hall a well as combinations of multiple types) are calculated. Mydrometeor type is precorded as a present weather code. Table \ref{Tab:war} of busible Values that the instrument is capable of recording. The quantity, intensity, and type of precipitation (dirize), rai,</pre>	Apple 12:1237 Jose Wein Keil ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr8, 2019 4:02 PM + You ★ Reject ✓ Accept Changed such that to since Apr8, 2019 3:30 PM + You ★ Reject ✓ Accept Changed design the You ★ Reject ✓ Accept Changed Jos Shat to since Apr8, 2019 3:30 PM + You ★ Reject ✓ Accept Changed does not need to (show all) to is not Apr17, 2019 2:24 PM + You ★ Reject ✓ Accept Changed fto with Marc Hilleb (show all) Ar8, 2019 3:27 PM + You ★ Reject ✓ Accept
158 159 160 161 - 163 - 164 165 166 167 168	<pre>scueres rrom the infsile work of gruppel observations are then discussed. The case studies native analysis of the observations hint within provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within proves. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAs. /section(Thies Clima Laser Precipitation Monitor)\label{instrument} /subsection(Specification)\label{spec} The instruments used in Divek (see Figure \ref(fig:weybourne}) are the Thies\texttrademark() Laser Precipitation Monitor (LFM), model number 5.4110.00.200, which are described in detail in \citeKinetiescoll). To make observations the instrument utilises an infrared (785 mg) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6cm%v25. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the isgnal reduction. Figure 1 in \citeL(offier-wang2000) describes a similar instrument (Parsivel-1) with the same observing principle and is an excellent visualisation of the ischnique which is melyosed by the Thies LFM. The signal Processing claims to detect and remove particles that fall on the edge of the beam: "The measured values are processed by a signal processor (DSP), and checked for plausibility (e.g. edge hits)." No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter birs from 0.125 mm to \$5.8 m, and 22 speed bins from \$5.0.2 m SA(-1)5. The thiss disdometer performs additional calculations on the incoming data which it att</pre>	Appl 21:237564/114 Accept Added describes a similar instrument (ParsiveL., (show all) Apr8, 2019:352 PM × You X Reject ✓ Accept Ab Deleted -messurement Apr8, 2019:352 PM × You X Reject ✓ Accept Changed used to which is employed Apr8, 2019:352 PM × You X Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019:401 PM × You X Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr8, 2019:320 PM × You X Reject ✓ Accept Changed such-that to since Apr8, 2019:320 PM × You X Reject ✓ Accept Changed desent need to (show all) to hydrometeor type Apr8, 2019:320 PM × You X Reject ✓ Accept Changed does not need to (show all) to is not Apr17, 2019:320 PM × You X Reject ✓ Accept Changed does not need to (show all) to is not Apr17, 2019:224 PM × You X Reject ✓ Accept Changed such that red tilleb (show all) Apr8, 2019:327 PM × You
158 159 160 161 - 162 163 - 164 165 166 167 168 169 170	<pre>scueres rrom the infsile work, and graupel observations are then discussed. The case studies include rain-show transitions in the 2017 named winter storm poris, a convective rainfail event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within Dives. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. /section(Thies Clima Laser Precipitation Monitor)\label{instrument} /subsection(Specification)\labelspec) The instruments used in DiveN (see Figure \ref[fig:weybourne]) are the Thies] Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite{Thies2011}. To make observations the instrument utilises an infrared (785 m) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6m5/23. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximum amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \citet(cliffle=radur2000) describes a similar instrument (Farsivel-1) with the same observing principle and is an excellent visualisation of the technique which is employed by the Thies LPM. The signal processory (DSP), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to 55 8 mm, and 22 speed bins from 55 0.2 m signal processory (DSP), and checked for plausibility (e.g. edge hits).'''. No further details are given by the manufacturer. The instrument is able to allocate individu</pre>	Apple 12: 123 - 0500 MM + Nd ★ Reject ✓ Accept Added describes a similar instrument (Parsivel (show all) Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted messurement Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8. 2019 4:02 PM + You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 4:02 PM + You ★ Reject ✓ Accept Changed des-not needto (show all) to hydrometeor type Apr.17. 2019 2:24 PM + You ★ Reject ✓ Accept Changed does not needto (show all) to is not Apr.17. 2019 2:24 PM + You ★ Reject ✓ Accept Changed r, to with Marc Hilleb (show all) Apr.8. 2019 3:27 PM + You ★ Reject ✓ Accept
158 159 160 161 - 163 - 164 165 166 166 166 168	<pre>scuere rrom the risk 12 months or Diven observations are then discussed. The Case Studies include rain-snow transitions in the 2017 hand winter storm Doris, a convective rainfall event, and grapel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within Divek. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section{These Clima Laser Precipitation Monitor}\label{instrument} \subsection{Specification}\label{spec} The instruments used in Divek (see Figure \ref[figureybourne)) are the Thies\texttrademark() Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite(Thies2011). To make observations the instrument ufilises an infrared (785 mg) beam with dimensions 228 mm x 20 mm x 0.77mm, a total horizontal area of 45.6cm\$25. The infrared beam is emitted from one end of the instrument and is afforced to ther. A photo-Idode and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximu amplitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the signal reduction. Figure 1 in \cite(Infler=Ama)OU describes a similar intrument (ArisVel-1) with the same observing principle and is an excellent visualisation of the instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$55 mm, and 22 speed bins from \$5.0.2 m s\$6(-1)5 to \$5 20 m s\$6(-2)5. The Thies disdometer performs additional calculations on the incoming data which it attaches to the relegram 4 serial output. Table \ref[Tab:var] provides details of the variables and the range of possible values that the instrument codes that the Thies Laser Foreipitation Monitor is capable of recording. The present weather code is</pre>	Added describes a similar Added describes a similar Instrument (ParsiveL., (show all)) Apr.8, 2019:352 PM × You X Reject ✓ Accept Added describes a similar Instrument (ParsiveL., (show all)) Apr.8, 2019:352 PM × You X Reject ✓ Accept Changed used to which is employed ✓ Accept Changed used to which is employed ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8, 2019:3019:401 PM × You X Reject ✓ Accept Changed genercipitation typ (show all) to hydrometeor type Apr.8, 2019:3:00 PM × You X Reject ✓ Accept Changed such that to since Apr.9, 2019:3:00 PM × You X Reject ✓ Accept Changed does not need to (show all) to is not Apr.17, 2019:2:24 PM × You X Reject ✓ Accept Changed _to with Marc Hilleb (show all) to is not Apr.8, 2019:3:27 PM × You X Reject ✓ Accept
158 159 160 161 - 163 - 164 165 166 167 168 169 170	<pre>studies rrom the inst 12 months or Diven observations are then discussed. The Case studies include rain-snow transitions in the 2017 hand winter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within Divek. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section(Thies Clima Laser Precipitation Monitor)\label{instrument} \subsection(Specification)\label(spec) The instruments used in Divek (see Figure \ref(figurewybourne)) are the Thies\texttrademark() Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite(Thies2011). To make observations the instrument utilises an infrared (785 mm) beam with dimensions 228 mm x 20 mm x 0.75mm, a total horizontal area of 45.6mx42. The infrared beam is emitted from one end of the instrument and is directed to the other. A photo-diode and signal processor determine the optical characteristics including optical intensity which is reduced as particle fails through the beam. The dimense of the hydrometeor is inferred by the maximum amplitude of the signal processing claims to detect and remove particles that fail on the edge of the beam: "The masured values are processed by a signal processing claims to detect and remove particles that fail on the edge of the manufacturer. The instrument is able to allocate individual hydrometeors into 20 diameter bins from 0.125 mm to \$55 8 mm, and 22 speed bins from \$55 0.2 m sis(-1)5 to 55 20 m 55(-1)5. The Thies disdrometer performs additional Calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \ref[Tabivar] provides details of the variables and the range of possible values that the instrument tis capable of recording. The quantity, intensity, and type of precipitation details of the variables</pre>	Apple 12:12:37:00:00 MM + Noi ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL., (show all)) Apr8, 2019:352 PM + You ★ Reject ✓ Accept Ab Deleted -measurement Apr8, 2019:352 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr8, 2019:352 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019:4:01 PM + You ★ Reject ✓ Accept Changed auch that to since Apr8, 2019:4:02 PM + You ★ Reject ✓ Accept Changed dusch that to since Apr8, 2019:3:02 PM + You ★ Reject ✓ Accept Changed dusch that to since Apr8, 2019:2:24 PM + You ★ Reject ✓ Accept Changed dusch that to since Apr8, 2019:2:24 PM + You ★ Reject ✓ Accept Changed dusch that to since Apr8, 2019:2:24 PM + You ★ Reject ✓ Accept Changed dusch that to since Apr8, 2019:3:27 PM + You ¥ Reject ✓ Accept Changed dusch that to since Apr8, 2019:3:27 PM + You ¥ Reject ✓ Accept Changed subch that to since Apr8, 2019:3:27 PM + You ¥ Reject ✓ Accept Deleted 'vef(case_studies) Mar:0:0:2019:2:22 PM + You ¥ Reject ✓ Accept
158 159 160 161 - 162 163 - 164 165 166 167 168 169 170	<pre>studies from the first 12 months of Diven Observations are then discussed. The Case studies include rain-snow transitions in the 2017 maned whiter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disconnecter instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar MCAs.</pre>	Added describes a similar Added describes a similar instrument (ParsiveL (show all) Apr8, 2019 3:52 PM + You Ab Deleted measurement Apr8, 2019 3:52 PM + You X Reject ✓ Accept Ab Deleted measurement Apr8, 2019 3:52 PM + You X Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You X Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You X Reject ✓ Accept Changed such that to since Apr8, 2019 4:02 PM + You X Reject ✓ Accept Changed desent need to (show all) to hydrometeor type Apr8, 2019 4:02 PM + You X Reject ✓ Accept Changed desent need to (show all) to is not Apr8, 2019 2:20 PM + You X Reject ✓ Accept Changed jco with Marc Hilleb (show all) to is not Apr8, 2019 3:27 PM + You X Reject ✓ Accept
158 159 160 161 - 162 163 - 164 165 166 167 168 169 170	<pre>studies from the first 12 months or Diven Observations are then discussed. The Case studies include rain-snow transitions in the 2017 maned whiter storm Doris, a convective rainfall event, and graupel observations. These events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar MCAS.</pre>	Apple 12: 123 - 0500 MM + Noi ★ Reject ✓ Accept Added describes a similar instrument (ParsiveL., (show all) Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Ab Deleted -messurement Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed used to which is employed Apr8, 2019 3:52 PM + You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr8, 2019 4:01 PM + You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr8, 2019 3:02 PM + You ★ Reject ✓ Accept Changed such that to since Apr9, 2019 3:30 PM + You ★ Reject ✓ Accept Changed desend need to (show all) to hydrometeor type Apr8, 2019 3:20 PM + You ★ Reject ✓ Accept Changed does not need to (show all) to is not Apr17, 2019 2:24 PM + You ★ Reject ✓ Accept Changed does not need to (show all) Apr8, 2019 3:27 PM + You ★ Reject ✓ Accept Apr8, 2019 3:27 PM + You ★ Reject ✓ Accept Changed such thar chilleb (show all) Apr8, 2019 3:27 PM + You ★ Reject ✓ Accept Ab Deleted Veffease_studies] Mar 30, 2019 1:227 PM + You ★ Reject ✓ Accept Ab Deleted Veffease_studies] Mar 30, 2019
158 159 160 161 - 162 163 - 164 165 166 167 168 169 170 171 172	<pre>suures runs use runs 12 months or piven observations are then discussed. The class studies includes influence train-show trainsitions in the 2017 named winter storm boris, a convective rainfall event, and grangel observations. Hese events will provide an illustrative analysis of the observations being produced by all the individual disdometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar HCAS. \section(Thies Clima Laser Precipitation Monitor)\label{instrument} \subsection(Specification)\label{spec}) The instruments used in Diven (see Figure \reff(figureybourne)) are the Thies/texttrademark() Laser Precipitation Monitor (LPM), model number 5.4110.00.200, which are described in detail in \cite(Thies/COLL). To make observations the instrument utilises an infrared (735 m) beam with dimensions 228 mm x 0.75mm, a total horizontal area of 45 GenX43. The infrared beam is mitted from one end of the instrument and is directed to the other. A photo-clide and signal processor determine the optical characteristics including optical intensity which is reduced as a particle falls through the beam. The diameter of the hydrometeor is inferred by the maximu applitude of the signal reduction and the speed of the hydrometeor is estimated by the duration of the estimal reduction. Figure 1 th. <cli>Cliff(figureybourne) describes a similar instrument Grassvel-1) with the sam observing principle and is an excellent visualisation of the lechnique with the simple of the signal processor (DS7), and checked for plausibility (e.g. edge hits).'' No further details are given by the manufacturer. The instrument is able to allocate individual hydrometors into 20 diameter bins from 0.125 mm to 35 m, and 22 speed bins from 53.0 m sS4-clifs. The files disdometer performs additional calculations on the incoming data which it attaches to the Telegram 4 serial output. Table \reff(Tab:var) provides details of the variab</cli></pre>	Apple 12: 237 5500 MM × Nod ★ Reject ✓ Accept Added describes a similar instrument (Parsivel. (show all) Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Ab Deleted messurement Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Changed used to which is employed Apr.8. 2019 3:52 PM × You ★ Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr.8. 2019 4:01 PM × You ★ Reject ✓ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8. 2019 4:02 PM × You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 4:02 PM × You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:30 PM × You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:32 PM × You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:32 PM × You ★ Reject ✓ Accept Changed such that to since Apr.9. 2019 3:32 PM × You ★ Reject ✓ Accept Ø Changed for with Marc Hilleb (show all) Apr.8. 2019 3:32 PM × You ★ Reject ✓ Accept Ø Deleted As with optical probes aboard aircraft w (show all) Apr.8. 2019 3:42 PM × You ★ Reject ✓ Accept
158 159 160 161 - 163 - 164 165 166 166 166 169 170 171 172 173	<pre>subset run up inst 2 months or piven observations are then discussed. The class studies includes influes rain-show transitions in the 2017 named winter storm poris, a convective rainfall event, and grangel observations. Hese events will provide an illustrative analysis of the observations being produced by all the individual disdrometer instruments within Diven. Enhanced scrutiny will be placed on the performance of the present weather code because this variable will be used to verify the Met Office radar MCAs.</pre>	Added describes a similar Added describes a similar Instrument (ParsiveL., (show all)) Apr 8, 2019 352 PM × You X Reject ✓ Accept Added describes a similar Instrument (ParsiveL., (show all)) Apr 8, 2019 352 PM × You X Reject ✓ Accept Changed used to which is employed Apr 8, 2019 352 PM × You X Reject ✓ Accept Changed Precipitation typ (show all) to Hydrometeor type Apr 8, 2019 4:01 PM × You X Reject ✓ Accept Changed genercipitation typ (show all) to hydrometeor type Apr 8, 2019 4:02 PM × You X Reject ✓ Accept Changed such that to since Apr 9, 2019 4:02 PM × You X Reject ✓ Accept Changed does not need to (show all) to is not Apr 17, 2019 2:24 PM × You X Reject ✓ Accept Changed 4:0 with Marc Hilleb (show all) to is not Apr 17, 2019 2:24 PM × You X Reject ✓ Accept Ab Dele

175	L	Deleted This paper focuses on
176	<pre>\cite{Tapiador2016} performed a physical experiment with 14 laser disdrometers (Parsive]-1) placed in close proximity (within 6 m\$^25) on the roof of a building in Toledo, Spain. Precipitation characteristics were calculated for one disdrometer's data, then for two instrument's combined data and so on until all 14 disdrometer's data were used. The aim was to test how many disdrometer's data were needed for the precipitation parameters to asymptote towards a stable value. It was found that a single disdrometer could underestimate instantaneous rain rate by 70\%. \cite{Tapiador2016} proposed that large drops contribute disproportionately to the rain rate and that instantaneous measurements have a lower chance of measuring large drops because they are sparsely populated. The DiVeN disdrometers have a shortest temporal resolution of 1 minute which alleviates some of the sampling issues by allowing time for larger droplets to be observed.</pre>	AB the hydrometeor ty (show all) Apr 8. 2019 3:11 PM • You X Reject
178 179 180 181	<pre>index index in the sample size of the instrument were larger and thus could count more particles at a faster rate, other limitations would occur. The instrument relies of speed observations. If two hydrometeor spet at the optical intensity which the signal processor must account for. Similarly for diameter, if two hydrometeor sample at a count of the sample area is thus limited to reduce the possibility of overlapping particles. The sample area is the user wave the sample area is the user wave the sample area is the user wave the particle in the user and the sample area is the user the user and the</pre>	Changed precipitation typ (show all) to hydrometeor type Apr.8.2019-402 PM × Vou ★ Reject ★ Accept Changed precipitation typ (show all) to hydrometeor type Apr.8.2019-402 PM • Vou ★ Reject ★ Accept Changed snow aggregate to ice crystal Mar 30, 2019 12:30 PM • You ★ Reject ★ Accept Changed lets to s Apr.8.2019-628 PM • You ★ Reject ★ Accept
182	Ayam, righte i millitetetetetetetetetetetetetetetetetete	· Deleted 2
183	The chance of two drops being in the disdrometer at the same time is unlikely except in extremely high precipitation rates. To examine this, a Poisson distribution test is applied using the sampling volume of the disdrometer with increasing drop concentrations. Figure \ref{fig:poisson_test} shows that precipitation rates of greater than 10,000 drops mins^{-1}s are required before the probability of simultaneous drops in the beam occurring becomes non-negligible. There is a 0.05% chance of 2 or more drops in the beam simultaneously for 105A45 drops mins^{-1}s observed by the disdrometer; 1 in every 1,075 drops. For a 105A55 drops mins^{-1}s observed by the disdrometer here is a 7% chance of 2 or more drops in the beam simultaneously; 1 in every 14 drops. For context, a drop count of 12,000 observed by the disdrometer located at NFARR Atmospheric observatory, chilbolton, England in March 2017 (see Section ref{violent_rain}) was equivalent to 22 mm hfs^{-1}s. Rain rates approaching 100 mm hfs^{-1}s would be necessary for the chance of 2 drops existing in the beam simultaneously to be non-negligible. Such rainfall rates are extremely rare in the UK.	Ab Deleted 3 Apr 8, 2019 6:28 PM • You X Reject ✓ Accept Ab Deleted -2 Apr 8, 2019 6:28 PM • You × X Reject ✓ Accept Ab Deleted -2 Apr 8, 2019 6:28 PM • You × X Reject ✓ Accept Ab Deleted -Yref(case_studies) Mar 30, 2019 12:31 PM • You ×
184		🗙 Reject 🛛 🗸 Accept
185 186 187 - 188 - 189	<pre>\section{Description of the Network}\label{description} \subsection{Diven Locations} Disdrometers have similar site specification requirements as other precipitation instruments. Ideally a flat site with no tall objects or buildings nearby that can cause shadowing, and steps taken to minimise the splash of liquid droplets from the surrounding ground into the instrument. To this end, Thies recommends that the instrument be mounted on a 1.5 m pole above a grassy surface. A grassy surface also minimises convective upwelling from solar heating of the ground - a particular problem for concrete surfaces - which can slow hydrometeor fall speeds and create turbulence. Turbulence from buildings should</pre>	
100	also be avoided if possible since it acts to break larger particles into smaller particles, resulting in skewed drop size distributions.	
190 191 192	The locations chosen for DiVeN cover a variety of geophysical conditions such as mountain peaks, valleys and flat regions, as well as inland and coastal sites. The locations also cover the full breadth of the climatology of precipitation totals and hydrometeor types in the UK \citep{Fairman2015} with sites in wetter (Wales) and drier (East Anglia) regions as well as sites in warmer (southern England) and colder (northern Scotland) climates.	Deleted Cairngorm Ski Centre is Ab situated in a va (show all) Apr 8, 2019 1:51 PM • You
193	The typical range at which the Met Office radar HCA product will need to perform is \$<\$ 120 km (maximum range used to produce surface rainfall rate composite). For the disdrometers to be representative when verification work is performed, the instruments in DiveN are located at varying ranges from Met Office radars. Figure \ref{fig:DiveN_Map} shows the DiveN site locations and the Met Office radar locations for comparison. Table \ref{Tab:locations} gives an overview of each site in DiveN, including the coordinates, height a.m.s.l. and terrain characteristics.	X Reject ✓ Accept Apr8, 2019 1:50 PM + You X Reject ✓ Accept
195		Deleted , which represent every
196 197	Two instruments are located 10 m apart at NFARR Atmospheric Observatory in Chilbolton. These two instruments form part of an extended observational period of 12 months where their performance will be assessed against several other precipitation sensors located at the same site. A separate paper will be produced to address the results of this dual-instrument study.	AB possible method (show all) Apr 8, 2019 1:50 PM • You
198		Apr 8, 2019 1:51 PM • You
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201 - 202	\subsection{Installation} The main installation campaign occurred in February 2017 for 9 instruments. The Holme Moss site was installed shortly after in March, followed by Cairngorm and Feshie in June 2017. Dunkeswell is a Met Office installed site which was added to the network via a Raspberry Pi with 3G dongle being appended in July 2017. The last instrument to be installed was at Coverhead Estate in the Yorkshire Dales in December 2017, as a collaboration with Water@Leeds \url{http://water.leeds.ac.uk}.	
203 204	Installation took around 2 hours at each site and consisted of: anchoring the tripod to the ground; attaching the disdrometer and data logging box; plugging the disdrometer cables into the power strip and the Raspberry Pi; cutting the power strip cable to length for the site. The installation was designed to be `as plug and play as possible'. Wiring of plugs, data and power cables onto the disdrometer and coding of the Raspberry Pi were all completed in a lab before arriving at the site.	
205 206 207 208 -	\subsection{DiVex Costs and Environmental Impact}	
209	Each site required the following components to support the disdrometer: Davis Instruments\textregistered tripod (\pounds100, \url{http://www.davisnet.com/product_documents/weather/manuals/07395-299_IN_07716.pdf]); IP67-rated box (\pounds25, \url{http://www.timeguard.com/products/safety/weathersafe-outdoor-power/outdoor-multi-connector-box}); Raspberry Pi 3 Model B (\pounds30, \url{http://www.timeguard.com/products/raspberry-pi-3-model-b/}) and a generic RS-485 to USB converter (\pounds12). Therefore the total cost per site for hardware was \pounds167. 200 m of power/data cable and tools required for the installation cost an additional \pounds270 and \pounds00 respectively. Some sites rely on a 3G dongle to upload data. The dongles themselves were free when purchased with a single-use data allotment. The total cost of hardware and equipment to build DiVeN amounted to \pounds2,500.	

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- 211 The Thies Clima instrument is power rated at a maximum of 750 mA @ 230 v. No typical usage has been measured but should the maximum be continuous, then the annual consumption would be 1,500 kwh per year, or \pounds190 p.a. at average UK electricity costs (valid March 2018). In reality the power consumed is subjectively known to be much less than the maximum rating.
- 212
- 213 Most sites use existing networks at their sites for uploading data to the NCAS server, but those with 3G dongles have an ongoing cost of \pounds75 per year for a yearly data plan. There are 8 sites using 3G dongles hence the ongoing annual cost is \pounds600.
- 214
- 215 The emissions from the first 2,300 mile journey in a diesel van were approximately 966 kg of COS_25 and 1.74 kg of NOS_X5 + PMs (nitrogen oxides + particulate matters). Ongoing power consumption for 13 sites (the Druim nam B0 (Feshie) site is powered off-grid by solar and wind) at the aforementioned maximum rating would be 7,150 kg of COS_25 annually (using the UK average of 0.367 kg kwh5^{-1}\$, valid October 2017). In reality the power consumption is less and the UK average kg kwh5^{-1}\$ is gradually decreasing over time. Computational energy consumed by DiveN is near-unquantifiable; the data hosting, processing and analysis were carried out on shared systems (National Centre for Atmospheric Science server, JASMIN server), so the fractional consumption is difficult to estimate.
- 216 217
- 218
- 219 \subsection{Data Acquisition and Management}\label{data_management}
- The disdrometer data is read through a serial port by a Raspberry Pi which executes a Python script to receive and digest the Telegram 4 format data. The Python code performs file management with timestamps taken from the Raspberry Pi internal clock (set over IP) and backs up files to a memory card into a directory specific to the date. Separate programming triggers the uploading of new files in the 'today' directory to an NCAS server every 5 minutes over SFIP. At 01 UTC each day, the Raspberry Pi attempts to upload any remaining files in the directory of the previous day. At 02 UTC each day, the Raspberry Pi attempts to upload files from the directory for 7 days ago as a backup command in the event that no connection could be made at the time. Only new files that do not already exist on the NCAS server are uploaded to avoid duplication. The entire directory of data for a single day is compressed using tar gunzip, 8 days after it is recorded. A support script exists to keep the processing and uploading scripts running and self-regulating. The support script checks that the processing script is running; if not, it will issue a command to start the processing script again. This means that the data acquisition script will be reattempted if an exit error occurs. In the event of a power loss the Raspberry Pi will startup and initiate all of the required scripts itself when power is restored, without user intervention.
- 221
- 222 Each disdrometer produces 3.2 MB of ASCII .txt files per day but this can be compressed significantly. 10 years of continuous minute-frequency disdrometer data (5.3 million minutes) can be compressed to as small as 400 MB.
- 223
- 224 225
- 226 \subsection{Open Access Website}
- 227 Data is uploaded to an NCAS server every 5 minutes. One minute after the upload, plotting scripts are initiated. An additional minute later, a <u>quicklook</u> system indexes the target directories for new images and displays them on the public website.
- The public website can be accessed here: \url{https://sci.ncas.ac.uk/diven/}. Data can currently be downloaded from NCAS upon request to the lead author. At the end of the first DiveN deployment phase (early 2020) all data collected by DiveN will be archived into netCDF at the Centre for Environmental Data Analysis (CEDA).
- 230
- 231

232 - \subsection{DiVeN Users}

- 233 Although the data from DiveN will be used for radar verification, there are many other uses for the data. Several stakeholders have used DiveN data. Met Office operational forecasters are able to see live hydrometeor type data and compare with numerical weather preciction forecasts to adjust their guidance. Second, there are some research projects at the University of Leeds being carried out. This includes research on DSD characteristics in bright band and non-bright band precipitation, calibration work with the NACAS X-band polarimetric (NXPO1) radar in Cumbria, England for the Environment Agency (EA) and flood forecasting research with the Water@Leeds project. Other institutions have used DiVeN data also; The University of Dundee and the Scottish Environment Protection Agency (SEPA) are conducting work on snow melt and the University of Reading may use DSD information from the Reading University Atmospheric Observatory (RUQO) disdrometer to study aerosol sedimentation rates. Finally, the wind turbine manufacturer Vestas have used annual DSD data to evaluate models of blade-tip drag to improve turbine efficiency. The applications of disdrometer data are broad and cover many fields. The authors intend that this publication combined with the open accessibility of data will inspire new uses of DiveN observations.
- 234 235
- 236
- 237 \subsection{Performance of DiVeN in the First Year}
- Figure \ref{fig:uptime} shows the uptime of each site in DiVeN in the order that they were installed. Generally the uptime of the network has been good for the period shown, with most sites uploading more than 95\% each day. A few sites have not been as good but this was mostly anticipated. In particular the Druim nam Bo site at 900m a.m.s.l. in the Scottish Highlands has poor upload percentages. 3G signal is weak at the site and a signal booster was added in January 2018. Furthermore the site is powered by a small wind turbine and solar panel, which became rimed in ice during the winter (Figure \ref{fig:rime}). Although these issues were anticipated, the site was still chosen because it can provide cases of solid hydrometeors nearly all year round, in a terrain which is notoriously difficult for radar performance. Radar hydrometeor classification will be particularly difficult at this location and thus the site will provide a `wost-case scenario' for radar HCA verification work.
- 239
- 240 Holme Moss is a remote site at relatively high altitude and uses satellite broadband which has been somewhat unreliable, however the amount of data stored on the Raspberry Pi may be higher than depicted in Figure \ref{fig:uptime} which was created based from data successfully uploaded to the NCAS server. Furthermore, the data is being archived on the University of Manchester's system at Holme Moss and this is known to be a much more complete dataset, which will be transferred to the NCAS servers in the future.
- 241
- 242 There were several unanticipated downtime periods. Weybourne had to be moved for construction work at the field site and was without power for approximately 1 month in March 2017. In late April 2017, the NGAS server blacklisted all disdrometer IP addresses and these had to be manually whitelisted. This was detected and resolved within 8 days. The 7-day backup upload filled in the majority of the missing data but the 8th day prior to the issue being fixed was never reattempted because of the design of the code discussed in Section \ref[data_management].
- 243
- 244 The largest unanticipated downtime occurred in September 2017. An issue arose with the disdrometers being unable to record any new data, in the order that they were installed. 2 GB of free space remained on the SD cards, however there was a (previously unknown) limit to the number of files that can be saved to certain card formats irregardless of the space remaining. The issue was fixed by the creation of a new script which merged old files together. The script had to be added to all of the Raspberry Pis in the network. The issue was detected after the first 4 DiveN disdrometer installations failed sequentially, so the failure of other sites in the network was anticipated and mitigated. This can be seen on Figure \ref{fig:uptime} as a stepped-failure starting with the chilbolton 1 instrument in September 2017.
- 245
- 246 Some further issues occurred which were avoidable. Laurieston was disconnected from power whilst closing the datalogger box after the installation which meant it was offline for the first 2 months until the site could be visited again. Similarly during the Dunkeswell installation in July 2017 the serial data cable was damaged which could not be fixed until November 2017. The Raspberry Pi at Lancaster was not reconnected after the aforementioned file number problem in September 2017.
- 247
- Although several problems have arisen with the Disdrometer Verification Network in the first 12 months, the network manager and site owners have been, on the whole, quick to respond to these issues which has minimised downtime. DiveN is in an ideal state for long-term data collection as it has been designed with few potential failure points and with several backup methods in place in the event of a failure.
- 250

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251		
252 - 253 254	\section(case Studies)\label{case_studies} The following sections subjectively analyse the skill of the disdrometer instrument for classifying hydrometeor type. Three types are discussed here: snow from named winter storm Doris; an intense rainfall event at NFARR Atmospheric Observatory and a graupel shower at the Reading University Atmospheric Observatory. NFARR Atmospheric Observatory instrument data were sourced from \cite{Chilbolton_JWD} and \cite{Chilbolton_PWS100}.	Changed precipitation typ (show all) to hydrometeor type Apr 8, 2019 4:02 PM • You X Reject Accept
255 - 256	\subsection{Rain-Snow Transition}\label{doris} During the first disdrometer installation trip in February 2017, the Met Office-named winter storm Doris impacted the UK. The disdrometer at Lancaster was installed on 22nd February, and Edinburgh was scheduled for installation on 24th February. Storm Doris was forecast to bring heavy snowfall to the central belt of Scotland on the morning of the 23rd. Therefore a decision was made to leave Lancaster early on the evening of the 22nd, to arrive in Gladhouse Reservoir before the expected snowfall. An opportunity arose to temporarily operate a disdrometer at Gladhouse Reservoir (55.7776, -3.1173). Observations began at 01:00 UTC, by which time light rain had begun precipitating.	
257		
258	The opportunistic observations made during storm Doris provide a unique dataset by which to evaluate the skill of the disdrometer for prescribing hydrometeor type. Several transitions between rain and snow occurred that were also observed by a qualified meteorologist. The following section compares the disdrometer present weather codes and the eyewitness observations taken by the lead author during the event. An important consideration is the fact that the disdrometer was setup in a suboptimal observing environment which had approximately 2005A{\circ}\$ of tall objects in close proximity. Figure \ref{fig:gladhouse_map} shows the instrument operating at cladhouse Reservoir. There were tall evergreen trees to the east and west, and a two-floor building to the south. Telecoms cables were also overhead and associated poles are visible to the NNE behind the disdrometer in Figure \ref{fig:gladhouse_map}. This was unavoidable given the impromptu circumstances of deployment.	
260	Despite the suboptimal observing conditions, the disdrometer performed well at diagnosing the correct present weather code during the storm Doris event. Table \ref{Tab:Doris_Dbs} and Figure \ref{fig:doris_HCA} show that the disdrometer correctly output a present weather code of rain initially, followed by an unverified `mixed precipitation' from 01:24 to 01:50. From 01:50 onwards a consistent snowfall PW code was observed, which agrees with visible observations made within 01:50-03:55. At 03:55 the precipitation became light and was described as drizzle by the disdrometer.	
262	From 06:00 onwards the precipitation intensified and the present weather code changed between drizzle and rain. By 06:45 the PW code was switching between only rain and a rain/snow mix. From 07:24 onwards the present weather code was constant snow, which continued with varying intensity until 15:28. The eyewitness observation at 15:39 is of individual ice crystals which the disdrometer perceived as low precipitation rates of 0.293 mm hr\$^{-1}5 misclassified as drizzle. Weak precipitation continued until 17:13 where no precipitation is observed by the disdrometer, concluding the IOP.	
264	Table \ref{Tab:Doris_Obs} shows that the Thies LPM has good skill with regard to determining the present weather type. Every disdrometer-diagnosed present weather code is in agreement with the eyewitness observations throughout the IOP, with the exception of 15:39. The difference in fall velocity between drizzle particles and individual ice crystals is small and as such the disdrometer struggled to identify the precipitation correctly.	
265	Figures \ref{fig:doris_hca_1} and \ref{fig:doris_hca_2} show the periods of constant hydrometeor type observed by the disdrometer in Figure \ref{fig:doris_HCA}, normalised for particle count. There are clear differences between rain, snow and rain/snow mix periods. Rain follows the curve shown by \cite{Gunn1949}. The rain/snow mix periods in b) and f) retain the Gun-Kinzer relationship but with additional, larger particles with slower fall velocities. The snow categories in c) and g) are markedly different with broader distributions of particle size and a shifted fall velocity distribution. The drizzle and ice crystal periods however, are very similar. Both are characterised by distributions of particle fall speed and diameter peaking at approximately 1.4 m s54-135 and 0.375 mm respectively. The distribution similarities of drizzle and pristine ice crystals on Figures \ref{fig:doris_hca_1} and \ref{fig:doris_hca_2} illustrates the difficulty in distinguishing between these two types by fall speed and diameter alone, without additional information. A temperature sensor added to the disdrometer may have aided the PW code classification. The misidentification described here is not a major concern since pristine ice crystal precipitation is a) uncommon in the UK and b) contributes negligible amounts to total rainfall as indicated during this	Changed precipitation typ (show all) to hydrometeor type Apr.8, 2019 4:02 PM + You X Reject Accept
267	event.	Ab Deleted ! Mar 30, 2019 12:36 PM • You
268	The present weather code quality index shown in Figure \ref{fig:doris_HCA} demonstrates that the Thies LPM is able to detect when recording conditions are challenging. The PW code quality index decreases, showing a poor quality measurement, during times of weak precipitation rates and in mixed precipitation phases.	× Reject ✓ Accept Added -derived surface Apr 8, 2019 6:37 PM • You
270	The opportunistic data collected in the storm Doris event is unusual in its number of transitional periods and will be a valuable case by which to compare the performance of radar-derived surface hydrometeor classification schemes.	× Reject ✓ Accept → Changed nominal to recorded
271 272 -	\subsection{Intense Convective Rainfall}\label{violent_rain}	Mar 30, 2019 12:13 PM • You
273	Storm Doris also brought an interesting event to another site; a high rainfall rate observed by the NFARR Atmospheric Observatory pair of disdrometers (Chilbolton 1 \& 2). The event was synoptically characterised by a narrow swath of intense precipitation oriented meridionally. The high intensity precipitation moved west to east across the UK, associated with a cold front originating from the low associated with named winter storm Doris. 30 km NE of NFARR Atmospheric Observatory in Stratifield Mortimer, a private weather station managed by Stephen Rurt also observed the intense precipitation of a constraint of the state o	Added of Mar 30, 2019 12:13 PM • You X Reject
	communication, 20th October 2017). A high-resolution Lambrecht gauge (recorded resolution of 0.01 mm) on the site observed a 75.6 mm hr\$^{-1}\$ rain rate over 10 seconds at 07:51 UTC. The 1-minute rain rate at 07:51 was 54.6 mm hr\$^{-1}\$ and the 5-minute rain rate ending 07:52 was 30.6 mm hr\$^{-1}\$. The event was described by a trained observer as ``rain ouickly became heavy then torrential''.	Ab Deleted 0 Mar 30, 2019 12:13 PM • You
274 275 276	The event was particularly outstanding from a DiVeN point of view due to the drop count measured by the Thies LPMs situated at NFARR Atmospheric Observatory, Chilbolton, which peaked at around 12,000 drops in a single minute (200 per second) at 07:39 UTC on 23rd February 2017. Both disdrometers observed a similar evolution of drop count over the short 26-minute rainfall event. This does not prove that the instruments are recording accurately; conversely it may be a signal of a systematic issue with the measurement technique used in every Thies LPM.	
277	Figure \ref{fig:heavy_DSD_DVD} shows an anomalously large left-tailed DSD from both of the Thies LPMs when compared against the Joss Waldwogel RD-80 and Campbell Scientific PWS100 disdrometers. A high concentration of small drop sizes suggests that splashing is occurring, where larger drops breakup on impact with either the instrument itself, or the surroundings. Earlier versions of the Thies LPM did not have shields on top of the sensor, which the manufacturer acknowledged were added because of splashing issues. It is possible that in very high rainfall rates, splashed droplets are still reaching the instrument beam and are being erroneously recorded. The drop velocity distribution (OVD) from the Thies LPM is also in disagreement with the PWS100. The PWS100 uses a similar optical technique to the Thies LPM with the addition of having 4 vertically stacked beams versus 1 on the Thies LPM, which should increase the accuracy of fall velocity measurements. Furthermore, the Thies LPM categorises the highest velocity particles into the smallest diameter particle bins, which is unphysical. Finally. The total drop court per metre is significantly bridner for both of the Thies LPM.	Ab Deleted ¥ Mar 30,2019 12:38 PM • You ★ Reject
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279	The DVD during the event is very wide. A noteworthy observation from the Stratfield Mortimer observatory is the wind characteristics. Marking the passage of the cold front at 07:45, winds became increasingly gusty and 10-minute wind mean ending 07:40 was 20 knots. A strong surface wind is associated with	Changed The fall speed of (show
280	turburent educes which have some vertical component. The intermittent vertical wind acts to when the drop vertical y distribution. Furthermore, turburence breaks up droplets thus skewing the drop size distribution. Finally, winds tangent to the beam (N-S oriented beam, westerly wind) as was the case here, increase the number of beam-edge hits which reduce the quality of the data.	All) to A strong surface (show all) Apr 22, 2019 5:04 PM • You X Reject
280	Figure \ref{fig:heavy_RR} shows that the two Thies LPMs have good agreement for rain rate from 07:25 to 07:35 where the rain rates are moderate, but that the Thies LPMs overestimate the rainfall during 07:35 to 07:40 where the rain rate is heavy. In total, Chilbolton 1 and Chilbolton 2 recorded 120% and 149% of the rainfall measured by the PWS100. The JWD is expected to underestimate slightly due to the range of observable diameters (0.3 mm to 5 mm) being smaller than true raindrop sizes, and smaller drop sizes being undetectable in the presence of large droplets due to sensor oscillation.	
282 283	It appears that in these conditions the hydrometeors were not correctly measured by the Thies LPM. However, the hydrometeor type is still correctly identified despite these shortcomings in rain rate, particle diameter and particle velocity.	
284 285 - 286	\subsection{Graupel Shower} Graupel (rimed ice crystals) are important signatures of convection for the UK, where hail is relatively uncommon. The Thies instrument does not have a graupel category because the category does not exist within the MMO Table 4680 which it uses to convey hydrometeor type. Codes 74, 75, 76 (light / moderate / heavy soft hail / ice grains) are presumed to be equivalent to what is commonly described as graupel.	Changed precipitation typ
287 288	On the 25th April 2017 a shower containing conical-shaped graupel passed over Reading University 'between 16:30 and 16:45 UTC' as observed by Dr Chris Westbrook (personal communication, 25th April 2017). Figure \ref{fig:ruao_HCA} shows the temporal evolution of hydrometeor type identified by the Diven Instrument during the event. The disdrometer observed only a single minute (16:36) of 'soft hail / ice grains' PW code (indicating graupel) during the entire 21 minutes of precipitation detected. Between 16:30 and 16:50 UTC inclusively, the following codes were also observed: 7 minutes of code 86 (moderate / heavy rain and / or drizzle with snow); 12 minutes of codes 61 / 62 (light / moderate rain); 1 minute of code 72 (moderate snow fall). Clearly the instrument struggled to diagnose graupel in this particular event.	Apr 8, 2019 4:02 PM + You ★ Reject ▲ Accept
289 290	Figure \ref{fig:ruao_grids} shows the particle size and velocity information grouped by hydrometeor type prescribed by the Thies LPM. Throughout the graupel shower the instrument observed a bimodal distribution in both velocity and diameter for all hydrometeor types which is indicative of both rain and graupel precipitating simultaneously. Furthermore in the rain/snow, snow, and graupel periods, a few hydrometeors exist below the Gunn-Kinzer curve which are misidentified as snow. Although the accumulated drop characteristics for the rain and rain/snow minutes are indicative of a rain/graupel mixture, in a single minute only a few particles may fall through the disdrometer beam versus several hundred raindrops. The ratio of rain to graupel may therefore be insufficient for the PW code to change to graupel. No PW code exists in the WMO Table 4680 for a rain/graupel mixture or rain/soft hail' mixture. The false detection of snow hydrometeors may be attributed to graupel particles bouncing off nearby surfaces or the instrument itself, slowing the fall velocity and thus appearing to the disdrometer as a lower density particle such as an ice aggregate.	
291 292 293	For future work with DiVeN data it is important to note 1-minute observations of `soft hail / ice grain' PW codes when longer time periods are being analysed. For example, radar hydrometeor classification will be performed with DiVeN data at 5-minute intervals. If in one of the five minutes soft hail or snow grains are observed, this must be highlighted. Graupel likely existed for longer than one minute but it was either not the dominant hydrometeor or the instrument was unable to correctly identify it.	
294 - 295 295	\section{Summary} The Disdrometer Verification Network is the largest network of laser precipitation measurements in the UK. Here we have fully described the network and discussed three specific observation cases to subjectively discuss the accuracy of the Thies LPM with a focus on hydrometeor type diagnosis.	
297	In summary, the instruments are able to correctly identify changes between snow and rain during storm Doris even with the suboptimal observing conditions. Snow is easily detected by the disdrometer and it is also able to accurately signal a mixture of hydrometeor types when transitioning between rain and snow.	Changed precipitation typ (show all) to hydrometeor type
298 299	Yet, the Thies LPM appears to have difficulty with measuring heavy rainfall events, where droplet breakup may be occurring due to instrument design. Distributions of drop size are skewed, such that small particle counts are significantly enhanced when compared with the Joss Waldv\"ogel RD-80 and the Campbell Scientific Pws100. The hydrometeor type variable was unaffected by the distribution discrepancies in the case studied.	Apr8,2019 4:02 PM • You ★ Reject ✓ Accept Changed precipitation typ
300 301 302	The Thies LPM also struggled to detect graupel in the event studied here. This shortcoming can be somewhat compensated for by flagging individual minutes of present weather codes 74, 75 and 76 within larger datasets but there will be graupel cases that the Thies LPM fails to detect entirely.	 ✓ (show all) to hydrometeor type Apr 8, 2019 4:02 PM • You ★ Reject ✓ Accept
303	A factor affecting the Thies LPM for hydrometeor classification is that empirical relationships do not account for instrument errors or the design of the instrument which may interfere with the precipitation being measured. The <u>hydrometeor type</u> signatures should be derived using data from the instrument to which they will be applied. Furthermore, by using the present weather code to describe hydrometeor type, the Thies LPM is restricted in it's ability to express the true nature of the observations being made, particularly noted in instances of graupel.	Changed precipitation typ (show all) to hydrometeor type Apr 8, 2019 4:02 PM • You
304 305	DiVeN offers open-access data in near-real-time at 5 minute updates. 1 minute frequency data is available upon request from the authors or via the Centre for Environmental Data Analysis (CEDA) from 2020. Data has been made publicly accessible in the hope that the Disdrometer Verification Network will be used for research beyond the original scope of the network.	x Reject ✓ Accept
306 307 308	%% The following commands are for the statements about the availability of data sets and/or software code corresponding to the manuscript. %% It is strongly recommended to make use of these sections in case data sets and/or software code have been part of your research the article is based on.	
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313	\dataavailability{Data plots are available in near-real-time here: \url{https://sci.ncas.ac.uk/diven/}. Original data is available upon request to the corresponding author and will be available through the Centre for Environmental Data Analysis (CEDA) in NetCDF format in 2019; } %% use this section when having only data sets available	Changed 2020 to NetCDF format in (show all) Apr 22, 2019 5:27 PM + You
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329	% \noappendix %% use this to mark the end of the appendix section	
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334	respective appendix sections. %% They will be correctly named automatically.	
336 337	%% option 2: If you put all figures after the reference list, please insert appendix tables and figures after the normal tables and figures. %% To rename them correctly to A1, A2, etc., please add the following commands in front of them:	
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357 -	\begin{acknowledgements}	
358	\textit{\\The lead author wishes to thank the following people and institutions for contributing to the creation of the Disdrometer Verification Network}	
359 360	\textit{The United Kingdom Meteorological Office for loaning the Thies LPM instruments used in DiVeN, Thies for advice and communication regarding the instrument, and the National Centre for Atmospheric Science (NCAS) for all other supporting hardware.}	
361		
362	\textit{Morwenna Cooper (Met Office), Dan Walker (NCAS), James Groves (NCAS) and Darren Lyth (Met Office) for technical advice regarding the data acquisition design of Diven.}	
363	The contacts at each site hosting a disdrometer for Diven. Judith Jeffery (NEARB) Andrew Lomas (University of Reading). Reherca Carling (Eacility	
501	for Atmospheric Measurements), Grant Forster (University of East Anglia), David Hooper (NFARR), James Heath (University of Lancaster), Richard Essery	
	(University of Edinburgh), Geeff Monk (Mountain Weather Information Service), Michael Flynn (University of Manchester), Louise Parry (Scottish Environment	
	Protection Agency), Jim confloot (Natural Retreats), Chris Taylor (Natural Retreats), Andrew Black (University of Dundee), Darren Lyth (Met Office), Megan	
265	Klaar (University of Leeds), Stephen Mawle (Coverhead Farm)}	
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368 369	\textit{Philip Rosenberg (NCAS) for advice on statistical tests.}	
370	Also: Stephen Best (Met Office), James Bowles (Met Office), Dave Hazard (NFARR), Darcy Ladd (NFARR), Stephen Burt (University of Reading), Chris Westbrook (University of Reading).}	
371	\end{acknowledgements}	
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410	<pre>A Diven Thies LPM located at Weybourne Observatory in Weybourne, East Anglia, UK, which is an Atmospheric Measurement Facility (AMF) site, part of the National Centre for Atmospheric Science (MCAS) } \label{fig:weybourne}</pre>	
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417	\includegraphics[width=8.3cm]{poisson_test.pdf}	
418	<pre>Probability of \$X\$ number of drops residing in within the disdrometer beam for a given drop concentration. If two or more drops are within the beam simultaneously, data quality can be reduced. More than 12,000 drops m\$^{-3}\$ (equivalent to 10,000 drops min \$^{-1}\$ recorded by the disdrometer*) are required before the probability of 2 or more drops occurring in the beam simultaneously becomes non-negligible. As such, any events with more than 10,000 drops observed per minute should be treated as less reliable. *Drops falling through the disdrometer beam assumes a 3 m s\$^{-1}\$ fall velocity, which from \cite{Gun1949} is a particle of approximately 0.8 mm diameter, typically the average size observed for a moderate rainfall event. Droplet breakup on the housing of the Thies LPM is not factored into this test.} \label{fig:poisson_test}</pre>	
419 420	\end{figure}	
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424 425	\includegraphics[width=8.3cm]{Diven_Map.png} Instrument locations that make up the Disdrometer Verification Network (Diven) as of September 2018. Grev icons are the operational Met Office	
426	radars as well as the Met Office research radar at Wardon Hill. Map data \textcopyright2018 GeoBasis-DE/BKG (\textcopyright2009), Google, Inst. Geogr. Nacional.}\label{fig:Diven_Map} \end{figure}	
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430 - 431	<pre>\trighters[t] \includegraphics[width=8.3cm]{Diven_Data_Flow.png}</pre>	
432	<pre>Flow chart of the sequence of data in the Disdrometer Verification Network. The instrument outputs a Telegram 4 format serial ping every minute, which is then captured by a Raspberry Pi (v3) running a Python script. The Python script then saves the file to the built-in SD card as an ASCII .txt. Separate BASH scripts upload the new files every 5 minutes (xx:05, xx:10, xx:15) to an NAS server, which JASMIM then reads to plot the data (xx:06, xx:11, xx:16). The website indexes for new images at xx:07, xx:12, xx:17 and so on. Thus the time taken for the xx:00 to xx:05 data to reach the website is 2 minutes.} \label{fig:Diven_Data}</pre>	
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439	\caption{Daily upload performance of DiVeN in the first 365 days of operation. Black indicates 100\% upload (1440 files in a day), and white indicates 0\% upload. } \label{fig:uptime}	
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445	<pre>\includegraphics[width=8.3cm]{rime.jpg}</pre>	
446	\caption{Disdrometer at Druim nam Bo, Scotland covered in rime in January 2018. The instrument was still receiving power and recording nullified (no beam received by optical diode) data which it interpreted as a `sensor error' (-1) present weather code.} \label{fig:rime}	
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451 - 452	\u00edrachics[width=8.3cm]{gladhouse_map.pdf}	
453	Maps, satellite images and ground images of the disdrometer location and setup for named winter storm Doris at Gladhouse Reservoir House, Scotland.	
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459	<pre>\includegraphics[width=20.5cm]{Doris_HCA_quality_RR.pdf}</pre>	
460	Caption(Rain rate, hydrometeor type, and present weather code quality index during the storm Doris event on 25rd February 2017, which occurred over approximately 16 hours at Gladhouse Reservoir, Scotland. Rain rate is liquid equivalent for periods of snow and is recorded by a Thies LPM disdrometer. Hydrometeor type is shown from both the disdrometer and impromptu from a trained meteorologist. The meteorologist observations at 05:00 and 07:00 UTC are	
461	approximate use to a fack of accurate time information. The disorometer mistoentified individual ice crystals at 15:39 as drizzie.} \rabel{fig:doris_HCA} \end{sidewaysfigure}	
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467	\caption{Accumulated particle information for each hydrometeor class period described in Figure \ref{fig:doris_HCA}. The centre grid shows particle counts	
	binned by size and fall velocity. The y-axis histogram shows particle velocity distribution (DVD) and the x-axis histogram shows particle size distribution (DSD) for the time period described, Since the time periods between each subplot are inconsistent in length, the color scale and histograms have been	
	normalised for the total precipitation over each period. The periods are as follows: a) 0055-0124 (Rain) b) 0124-0150 (Rain/Snow) c) 0150-0355 (Snow) and d)	
468	0355-0600 (Drizzle).} \label{fig:doris_hca_1} \end{figure}	
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<pre>visity during the set of a set of</pre>	481	Caption(urop characteristics of a neavy rain event at NEAK Atmospheric observatory, Childoton, England on the 2srd March 2017, Distributions are accumulated from 07:25 to 07:50 UTC inclusively for a 26 minute summation. The left panel shows drop osize distribution and the right panel shows drop	
<pre>bit indths. Total drop count is listed in the top "right of each plot. Both of the Thise LHB have a higher total drop count, as well as significantly higher counts of suall, fast mving droplets.) (Lakel(fig:have_JDDL_PK) indtreased counts of null, fast mving droplets.) (Lakel(fig:have_JDDL_PK) indtreased counts of null relations of the theorem indtreased by indtrease</pre>		velocity distribution. The Joss-Waldvogel RD-80 (JWD) does not provide drop velocity information. Each instrument has been normalised for sampling area and	
<pre>costs of sall and high velocity particles compare with the Peg and 100. The frame of the Thes LPM may be splashing droplets into the Beam leading to increased courts of sall. Task into version of the Peg and 100. The frame of the Thes LPM may be splashing droplets into the Beam leading to increased courts of sall. Task into version of the Peg and 100. The Per and Per and Per and Per and 100. The Per and 100. T</pre>		bin widths. Total drop count is listed in the top right of each plot. Both of the Thies LPMs have a higher total drop count, as well as significantly higher	
<pre>vertices of the set of the s</pre>		counts of small and high velocity particles compared with the PWS and JWD. The frame of the Thies LPM may be splashing droplets into the beam leading to	
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<pre>total accumulated rain depth over the 26 minutes for each instrument is as follows: oilbothon 1 (1.43 m); chiloblon 2 (1.847 ms); msilo (1.837 msilo (1.837 ms); msilo (1.837 msilo (1.837 ms); msilo (1.837 ms</pre>	488	Rain rate measured by 4 instruments during a heavy rain event at NFARR Atmospheric Observatory, Chilbolton, England on the 23rd March 2017. The	
<pre>bit device of frogles plashing from the instrument housing into the measuring beam.] \lue (fig:neary_AN) write(fig:neary_AN) write(fig:neary_</pre>		total accumulated rain depth over the 26 minutes for each instrument is as follows: Chilbolton 1 (1.481 mm); Chilbolton 2 (1.847 mm); PWSID0 (1.237 mm); JWD	
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wordffgure) wordffgure		evidence of droplets splashing from the instrument housing into the measuring beam. } \label{fig:heavy_RR}	
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524 %%% TABLES 525 %%% %%% The different columns must be seperated with a & command and should 526 %%% end with \\ to identify the column brake. 527 528 529 \clearpage 530 531 - \begin{table}[t] 532 \caption{Variables output from the Thies Laser Precipitation Monitor (LPM).}\label{Tab:var} 533 - \begin{tabular}{ccccrrcrc} 534 \hline\hline 535 Output & Units & Resolution & Range \\ 536 \hline Particle Diameter & 0.125 mm (max) & \$\geq\$ 0.125 \$-\$ \$>\$ 8 mm \\ 537 & mm Particle Velocity 538 & m s $^{-1}$ & 0.2 m s $^{-1}$ (max) & 5> 0 - 5> 20 m s $^{-1}$ \\ 539 Particle Count & Counts & 1 Count // 0000 2-2 0 3 & mm hr\$^{-1}\$ & 0.001 mm hr\$^{-1}\$ & 0.000 \$-\$ 999.999 mm hr\$^{-1}\$ \\ Rainfall Rate 540 Precipitation Visibility & m & 1 m & O \$-\$ 99999 m \\ 541 Radar Reflectivity Factor & dBZ & 0.1 dBZ & -9.9 \$-\$ 99.9 dBZ \\ 542 543 PW Code Quality Index & \% & 1 \% & 0 \$-\$ 100 \% \\ 544 \hline \end{tabular} 545 546 \end{table} 547 548 \clearpage 549 550 - \begin{table}[t] 551 \caption{world Meteorological Organization (WMO) synoptic present weather codes (Table 4680) output by the Thies Laser Precipitation Monitor (LPM) } \label { Tab: pw_codes } 552 - \begin{tabular}{ccccrrcrc} 553 \hline\hline 554 SYNOP (Tab.4680) & Description \\ 555 \hline -1 & Sensor error \\ 556 41 & Light / moderate unknown precipitation \\ 557 558 42 & Heavy unknown precipitation \\ 559 0 & No precipitation \\ 51, 52, 53 & Light / moderate / heavy drizzle \\ 560 57 & Light drizzle with rain \\ 561 562 58 & Moderate / heavy drizzle with rain $\backslash\backslash$ 563 61, 62, 63 & Light / moderate / heavy rain \\ 67 & Light rain and / or drizzle with snow \\ 564 565 68 & Moderate / heavy rain and / or drizzle with snow \\ 566 71, 72, 73 & Light / moderate / heavy snow fall \\ 567 74, 75, 76 & Light / moderate / heavy soft hail / ice grains \\ 568 77 & Snow grains \\ 89 & Hail \\ 569 570 \hline 571 \end{tabular} 572 \end{table} 573 574 \clearpage 575 576 - \begin{sidewaystable*} 577 \caption{Site location descriptions of disgrometers in the Disdrometer verification vetwork.}\label{Tab:locations} Added d Mar 30, 2019 12:41 PM • You 578 - \begin{tabular}{p{1.5cm}p{1.1cm}p{1cm}p{1.2cm}p{14cm}}%{ccccrrcrc} 579 \hline\hline 🗙 Reject 🛛 🖌 Accept 580 Site Name & Lat/Lon & Altitude (a.m.s.].) & Install Date & Description \\ Changed et to D 581 \hline Mar 30, 2019 12:39 PM + You Chilbolton & 51.1455,-1.4396 & 83 m & 10th Feb 2017 & NFARR Atmospheric Observatory. 2 instruments, 10 m apart. Land type: flat, agricultural fields for 582 🗙 Reject 🗸 Accept \$>\$ 500m in all directions. Nearby objects: 25 m diameter radar dish antenna 100 m ESE; 2-floor building 25 m SSW. \\ RUAO & 51.4415, -0.9376 & 63 m & 13th Feb 2017 & Reading University Atmospheric Observatory. Land type: open grass in vicinity; campus with lake and trees 🖉 Changed 🕶 to V 583 Mar 30, 2019 12:39 PM • You situated within a wider suburban area. Lake 100 m W-NW, 3-floor building 50 m SSE. Shed 30 m ENE. \\ 🗙 Reject 🛛 🗸 Accept 584 cranfield & 52.0744, -0.6252 & 105 m & 15th Feb 2017 & Facility for Airborne Atmospheric Measurements. Land type: 2-floor rooftop observatory within a cluster of buildings at a university airport. Nearby objects: stairwell NW, hangar ESE. Above most nearby buildings.\\ Changed n to N 585 Weybourne & 52.9505, 1.1218 & 8 m & 17th Feb 2017 & NCAS Atmospheric Measurement Facility. Land type: military base, mostly grass. Sandy beach and ocean Mar 30, 2019 12:41 PM • You 100 m NNE. Nearby objects: small 1-floor building ESE, 4-floor scaffold tower E. 🗙 Reject 🛛 🗸 Accept Aberystwyth & 52.4248, -4.0045 & 44 m & 20th Feb 2017 & NFARR / NERC (Natural Environment Research Council) Mesosphere-Stratosphere-Troposphere (MST) radar 586 site. Land type: agricultural fields in a WSW-ENE valley. Nearby objects: single tree and 1-floor building SSE, hedgerow N-SSE. \\ 587 Lancaster & 54.0138, -2.7749 & 94 m & 22nd Feb 2017 & Hazelrigg Weather Station, University of Lancaster. Land type: agricultural fields. Nearby objects: 100 m tall wind turbine 150 m WSW, meteorological mast 10 m NW. Road and trees 30 m E.\\ Edinburgh & 55.9217, -3.1745 & 105 m & 24th Feb 2017 & GeoSciences Weather Station, University of Edinburgh. Land type: roof of 6-floor James Clark Maxwell 588 Building. Urban campus W-N-E, with golf course S. Nearby objects: rooftop above all surrounding buildings. \\ 589 Laurieston & 54.9614, -4.0605 & 67 m & 28th Feb 2017 & Mountain Weather Information Service. Land type: rural village, undulating agricultural terrain beyond. Nearby objects: 1-floor buildings 10 m SE, trees 30 m S-W \\ Holme Moss & 53.5335. -1.8574 & 522 m & 10th Mar 2017 & Holme Moss transmitting station. Land type: hilltop moorland. Nearby objects: 228 m transmitting 590 mast 40 m SW with anchoring cables overhead. Cabin 10 m SW, wire mesh fence NW-N. \\ 591 Cairngorm & 57.1269, -3.6628 & 781 m & 12th Jun 2017 & CairnGorm Mountain Ski Resort with Scottish Environment Protection Agency (SEPA) collaboration. Land type: arctic tundra, frequently snow-covered valley, facing NM. Nearby objects: road and power outbuilding uphill (SE) 20 m.\\ 592 Feshie & 57.0063, -3.8550 & 882 m & 13th Jun 2017 & Druim nam Bo weather station owned by University of Dundee. Land type: arctic tundra, frequently snow-Covered, rounded mountain ridge oriented SW-NE, sloping SW. Nearby objects: weather station 10 m N.\\ 593 Dunkeswell & 50.8603, -3.2398 & 255 m & 14th Jul 2017 & Met Office official observatory at Dunkeswell Aerodrome. Land type: flat in all directions. Runway N-E-S with surrounding agricultural fields and forest SW-N. Nearby objects: 1-floor building 20 m NW. \\ Coverhead & 54.2038. -1.9849 & 316 m & 15th Dec 2017 & Coverhead Estate with Water@Leeds collaboration. Land type: NW slope of SW-NE valley, agricultural 594 fields. Nearby objects: mounted on a small outhouse facing S. Telegraph pole 10 m NW and trees E-SW. \\ 595 \hline 596 \end{tabular} \end{sidewaystable*} 597 598

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599 \clearpage
600
601 - \begin{table}[t]
602 \caption{Present Weather code evolution throughout the named winter storm Doris event on 23rd February 2017. All times in UTC.}\label{Tab:Doris_Obs}
603 - \begin{tabular}{p{1.9cm}p{4cm}p{1.9cm}p{3.1cm}}%{ccccrrcrc}
604 \hline\hline
605 Time & Disdrometer Present Weather Code & Time & Qualified Meteorologist Observation \\
606
     \hline
607
      00:55 to 01:24 & Rain & 00:30 to 01:05 & Rain \\
608
      01:24 to 01:50 & Rain or Mixed Precipitation & & \backslash\backslash
      01:50 to 03:55 & Snow & 02:31 to 02:40 & Snow \\
609
      03:55 to 06:00 & Light / Moderate Drizzle & Approx. 05:00 & Drizzle \\
610
      06:00 to 06:45 & Drizzle or Rain & & \\
611
612
      06:45 to 07:24 & Rain or Mixed Precipitation & Approx. 07:00 & Mixed Precipitation \\
613
      07:24 to 15:28 & Moderate / Heavy Snow & 09:49 to 14:31 & Moderate / Heavy Snow \\
      15:28 to 17:13 & Light / Moderate Drizzle & 15:39 & Pristine Ice Crystals \\
614
615 \hline
616 \end{tabular}
617 \end{table}
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665
    %%% MATHEMATICAL EXPRESSIONS
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    8
667 %%% All papers typeset by Copernicus Publications follow the math typesetting regulations
668 %%% given by the IUPAC Green Book (IUPAC: Quantities, Units and Symbols in Physical Chemistry,
669 %%% 2nd Edn., Blackwell Science, available at: http://old.iupac.org/publications/books/gbook/green_book_2ed.pdf, 1993).
670 ***
671 %%% Physical quantities/variables are typeset in italic font (t for time, T for Temperature)
    %%% Indices which are not defined are typeset in italic font (x, y, z, a, b, c)
672
    %%% Items/objects which are defined are typeset in roman font (Car A, Car B)
673
674
    XXX Descriptions/specifications which are defined by itself are typeset in roman font (abs, rel, ref, tot, net, ice)
    %% Abbreviations from 2 letters are typeset in roman font (RH, LAI)
675
676 %%% Vectors are identified in bold italic font using \vec{x}
677 %%% Matrices are identified in bold roman font
678 XXX Multiplication signs are typeset using the LaTeX commands \times (for vector products, grids, and exponential notations) or \cdot
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679 %%% The character * should not be applied as mutliplication sign

680 🕺 681 🕺 682 %%% EQUATIONS 683 * 684 %%% Single-row equation 685 🕺 686 %\begin{equation} 687 🕺 688 %\end{equation} 689 🕺 690 %%% Multiline equation 691 * 692 %\begin{align} 693 *%& 3 + 5 = 8*\\ 694 *%& 3 + 5 = 8*\\ 695 *%& 3 + 5 = 8* 696 %\end{align} 697 🕺 698 % 699 %%% MATRICES 700 % 701 %\begin{matrix} 702 %x & y & z\\ 703 %x & y & z\\ 704 %x & y & z\\ 705 %\end{matrix} 706 🕺 707 708 %%% ALGORITHM 709 🕺 710 %\begin{algorithm} 711 %\caption{...} 712 %\7abe7{a1} 713 %\begin{algorithmic} 714 %... 715 %\end{algorithmic} 716 %\end{algorithm} 717 🕺 718 🕺 719 %%% CHEMICAL FORMULAS AND REACTIONS 720 🔏 721 %%% For formulas embedded in the text, please use \chem{} 722 🕺 723 %%% The reaction environment creates labels including the letter R, i.e. (R1), (R2), etc. 724 % 725 %\begin{reaction} 726 %%% \rightarrow should be used for normal (one-way) chemical reactions 727 %3% \rightleftharpoons should be used for equilibria 728 %3% \leftrightarrow should be used for resonance structures 729 %\end{reaction} 730 % 731 🕺 732 %%% PHYSICAL UNITS 733 %%% 734 %%% Please use \unit{} and apply the exponential notation 735 736

737 \end{document} 738

Current file Overview