Testing the Drop-Size Distribution Based Separation of Stratiform and Convective Rain using Radar and Disdrometer data from a Mid-latitude Coastal Region

M. Thurai[1], V. N. Bringi[1], D. Wolff[2], D. Marks[2,3], and C. Pabla[3]

[1]Colorado State University, Fort Collins, CO 80523, USA
[2]NASA GSFC Wallops Flight Facility, Wallops Island, Virginia, USA
[3]Science Systems and Applications, Inc., Lanham, MD, USA

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Background

- Stratiform and convective rain are associated with different microphysical processes and generally produce drop size distributions (DSDs) with different characteristics.

- Identification of these two rain types is also important for estimating rainfall rates from ground-based polarimetric radars as well as spaceborne radars.

- In earlier studies, an empirically-derived DSD-based separation method was tested in:
  - Darwin, AU …. a tropical coastal location
    using JOSS disdrometer data with dual-freq. profiler and C-band dual-pol. radar
  - Huntsville, Alabama, USA … a sub-tropical continental location
    using 2D video disdrometer (2DVD) data and UHF profiler observations
  - Greeley, Colorado, USA … a mid-latitude continental location with semi-arid climate
    using 2DVD + MPS data & CSU-CHILL S-band dual-pol radar

- Here we test the separation technique using data+observations from:
  - Delmarva peninsula, USA …. a mid-latitude coastal region
  - using DSD data from 2DVD + MPS and S-band polarimetric radar observations
  - 3 events are considered

Outline

- Instrumentation and Observations
- Separation technique + Examples
- DSD-based classification versus radar observations
  … for the 3 events
- Application of the method for radar data
- Conclusions

Instrumentations and Observations

At WFF:

Network of instruments, including 2DVDs,
MPS (Meteorological Particle Spectrometer)
inside DFIR double wind-fence,
MRR, Pluvio, plus many others

38 km NNE:

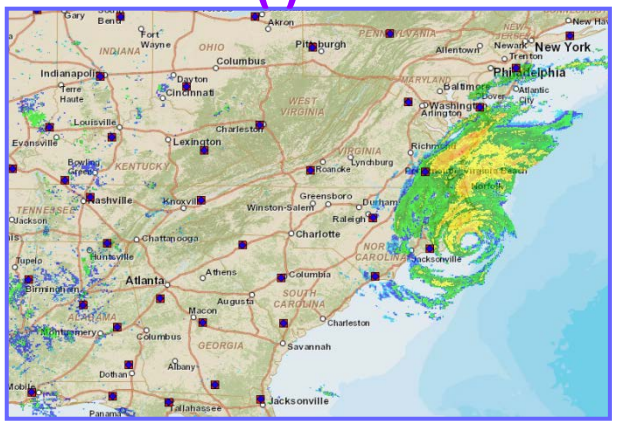
S-band polarimetric radar, NPOL
Regular scan sequence includes
RHI scans over the disdrometer site

Three events considered here:

i. A category-1 Hurricane event (Dorian) whose rain-bands on 06 September 2019.
ii. A squall-like event with an 'ill-defined' line convection which occurred on 14 Oct. 2019;
iii. A more widespread event with small embedded convective cells on 16 October 2019.

Instrumentations and Observations

(i)



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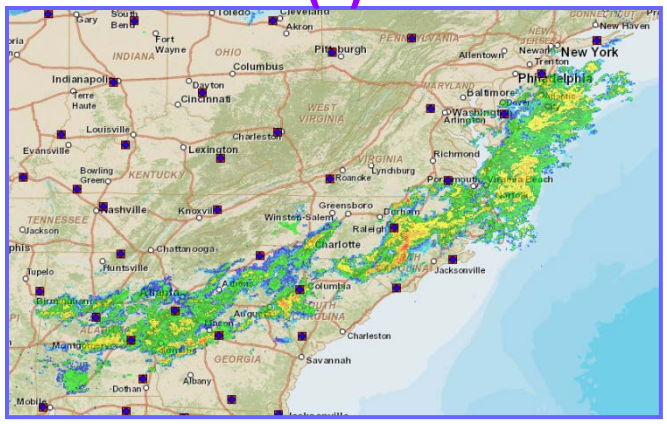

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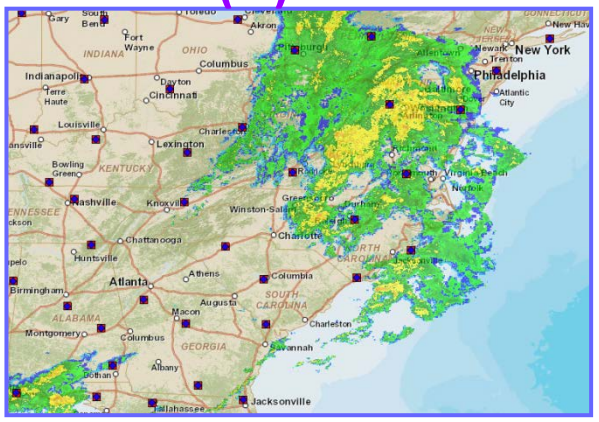

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i. A category-1 Hurricane event (Dorian) whose rain-bands on 06 September 2019.
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iii. A more widespread event with small embedded convective cells on 16 October 2019.

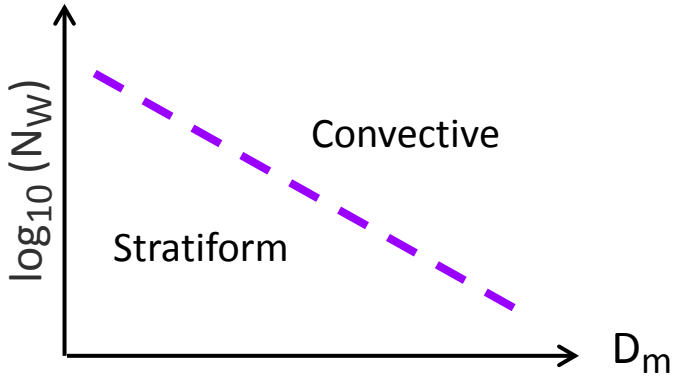
Separation Technique + Examples

Data and Observations from Darwin, AU, + Huntsville, Alabama, USA showed that

⇨ Two main parameters governing the DSDs can be used to separate the two rain types

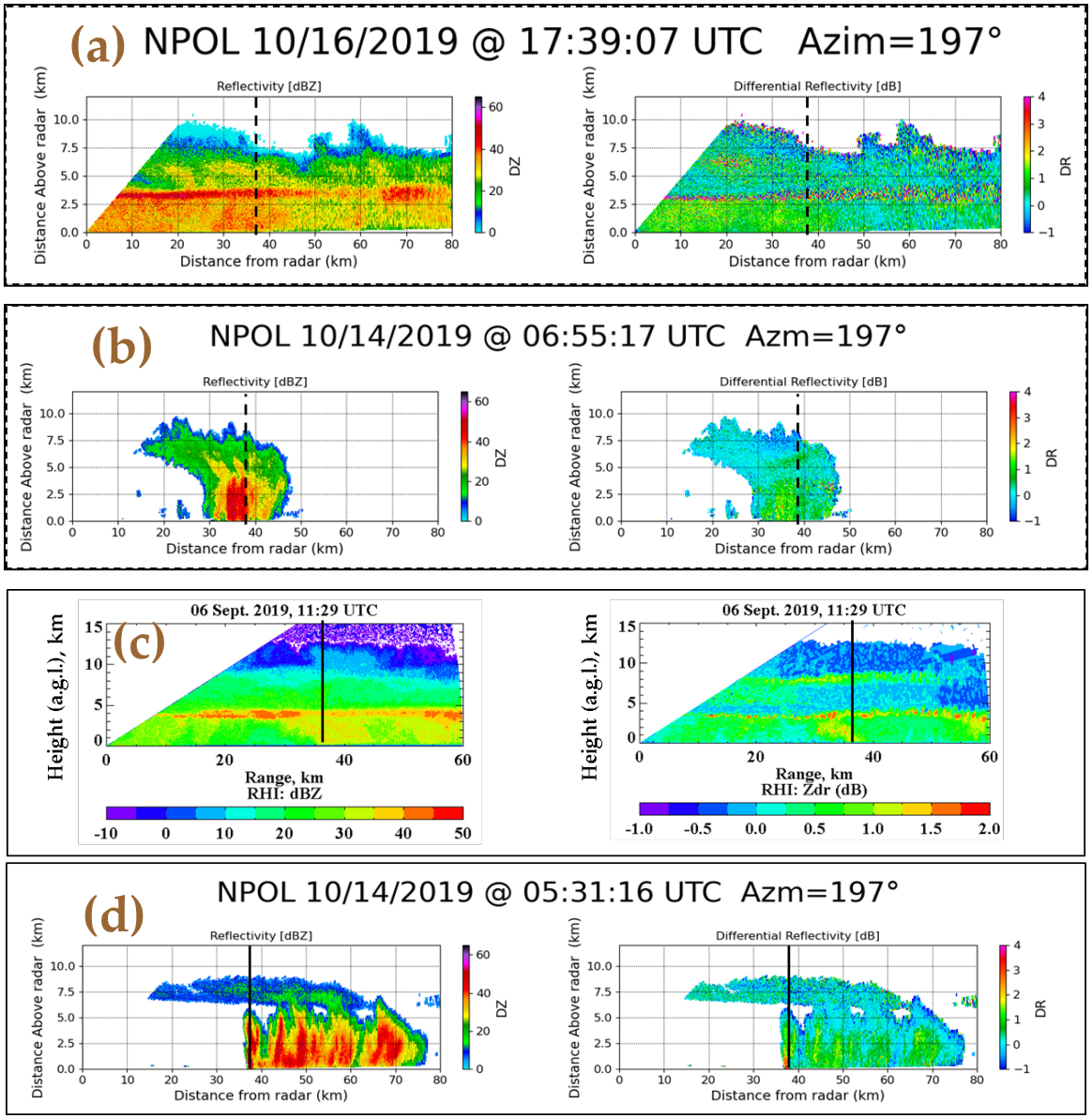
⇨ Separation in the $N_W - D_m$ space … where D_m is the mass-weighted mean diameter and N_W is the normalized intercept parameter

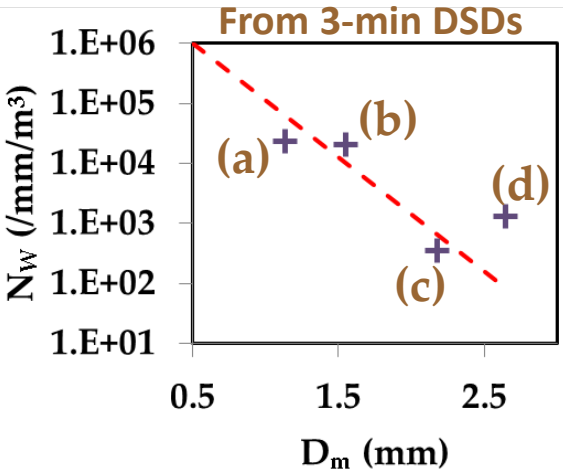
⇨ Separation line: $\log_{10}(N_W{}^{sep}) = c_1 D_m + c_2$



- Determine N_w and D_m from 1- 3 min DSDs from the ground-based disdrometers
- Compare with NPOL RHI scans over the disdrometer site

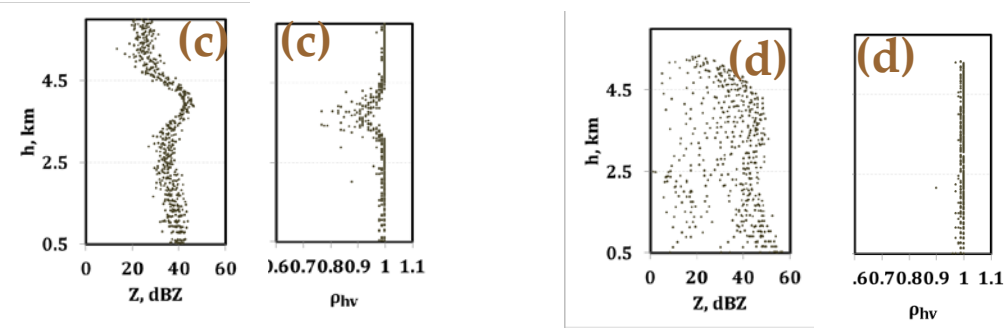
Separation Technique + Examples





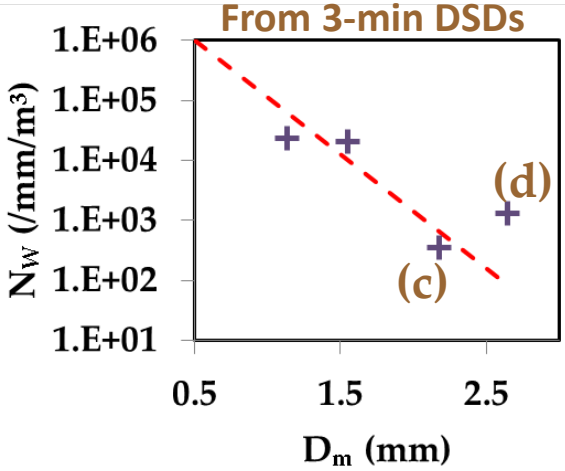
Vertical lines are at and above the disdrometers

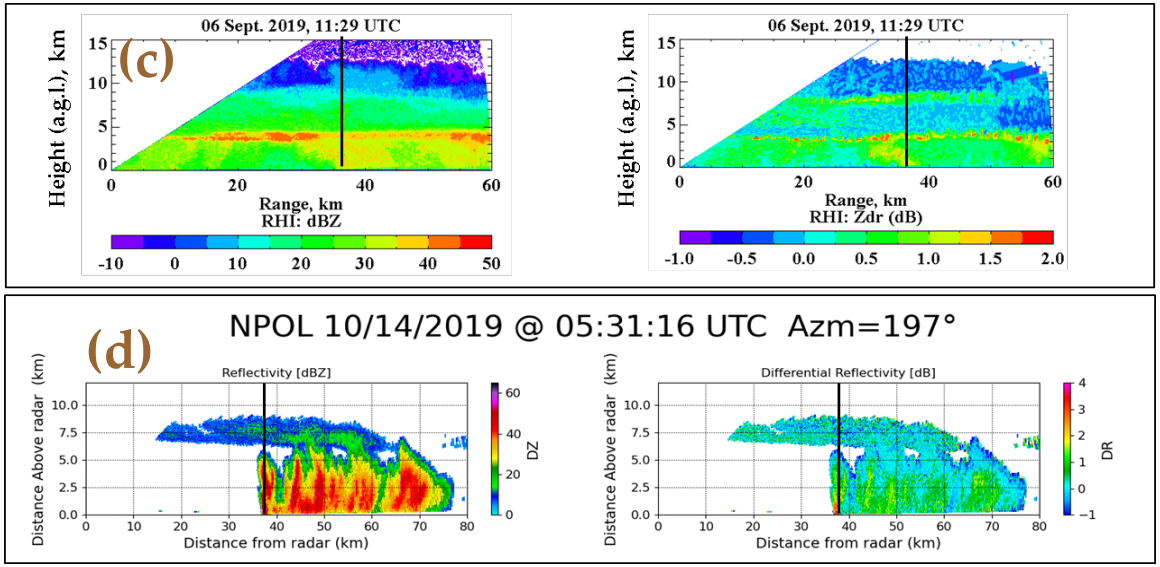
Separation Technique + Examples



(c) Shows Clear melting layer in height profiles of Z_h and ρ_{hv}

(d) Shows no melting layer from the height profiles



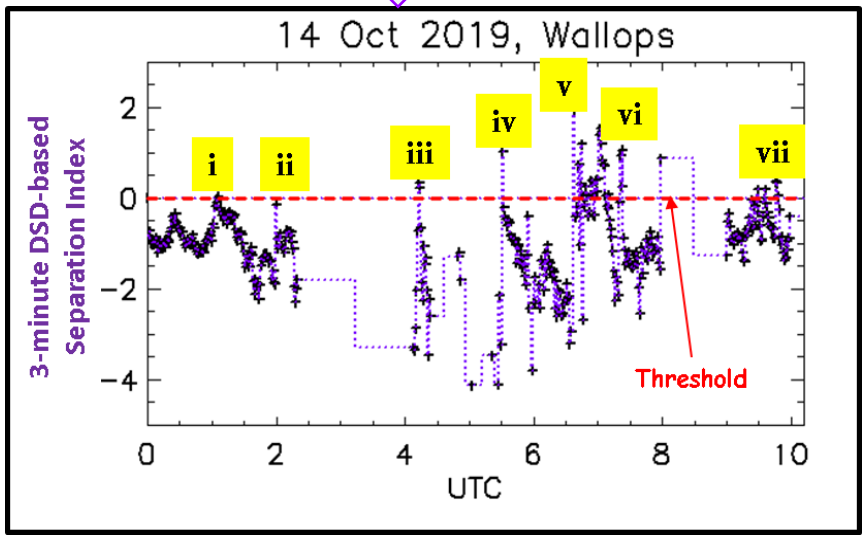


Vertical lines are at and above the disdrometers

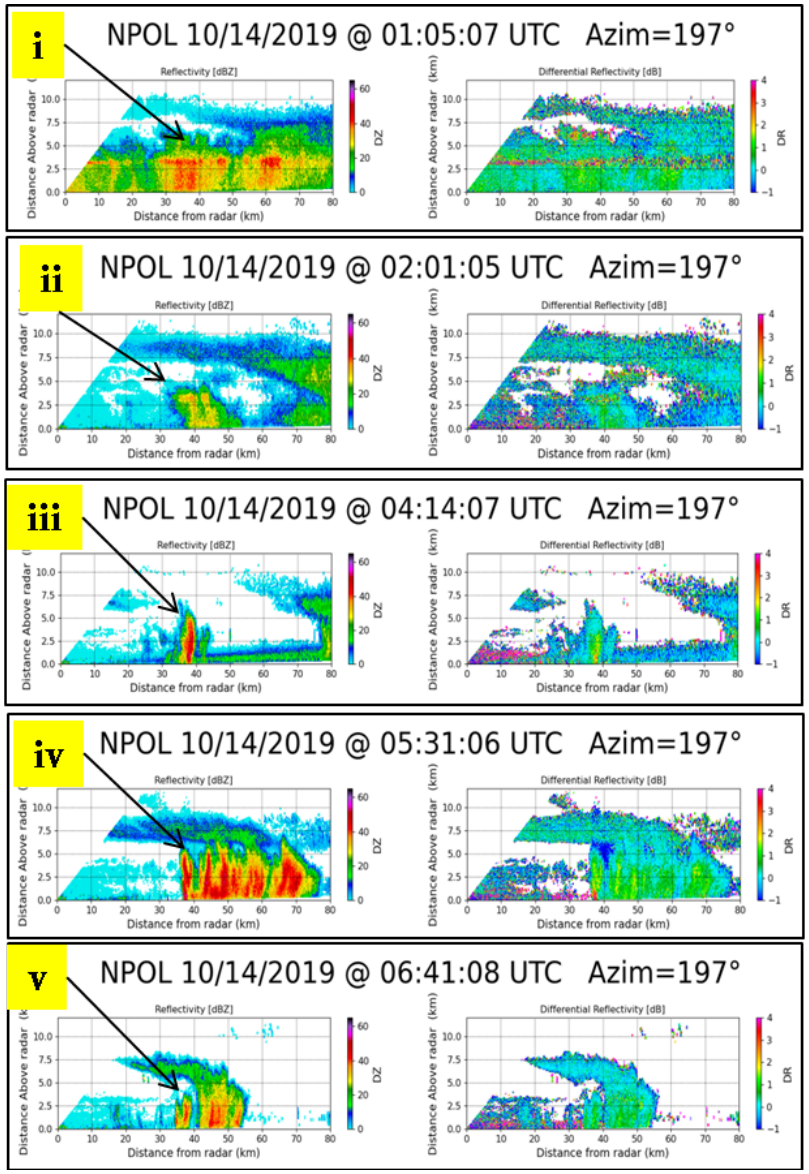
DSD-based Classification versus Radar Observations

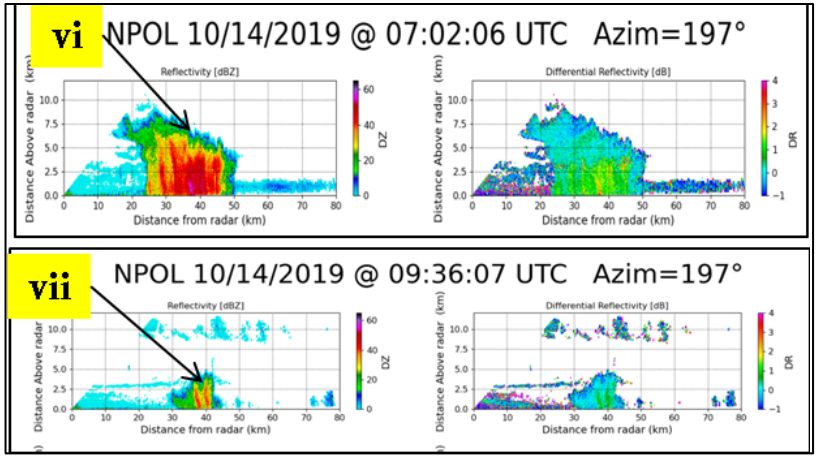
Use an 'index, ***i***, to indicate whether N_W vs. D_m points lie above or below the separation line .....

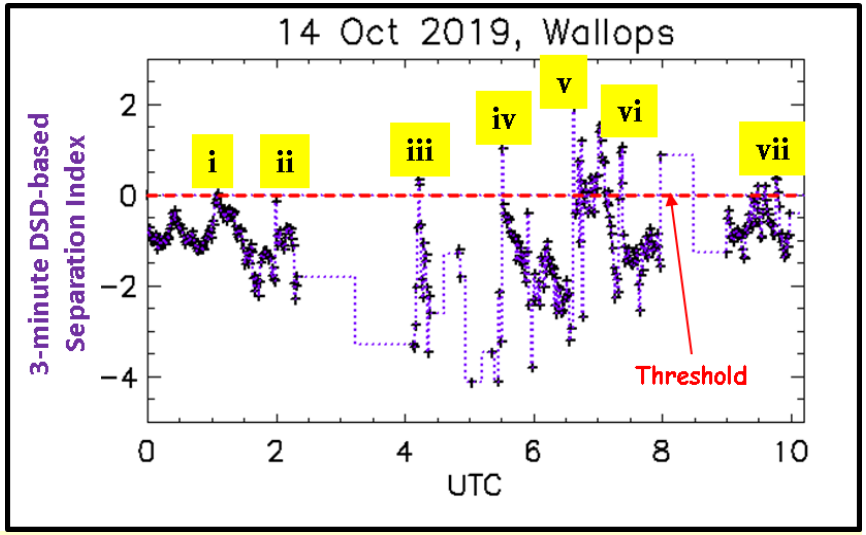
For the 14 Oct 2019 event .. 7 time periods shows ***i*** close to or above the 0 threshold.



DSD-based Classification versus Radar Observations

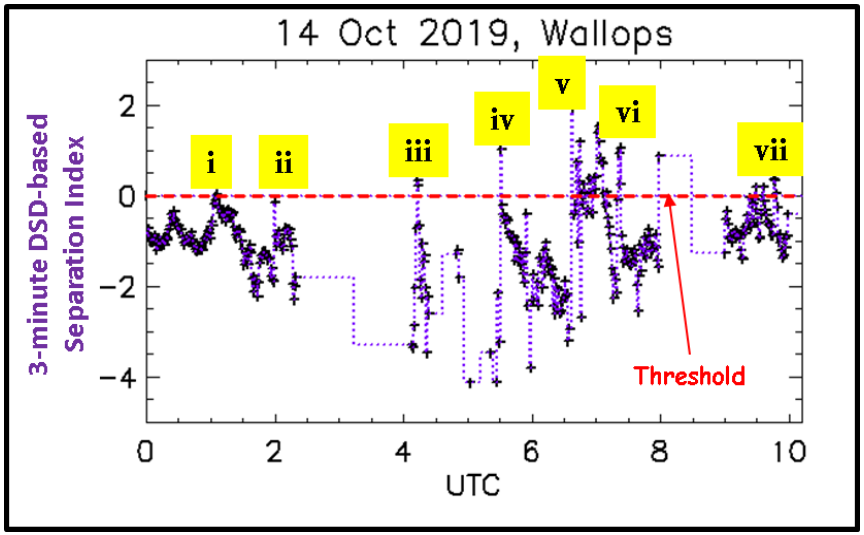






(i) and (ii) are associated with thick bright band
(iii) Modest convection
(iv), (v) and (vi) are Convection
(vii) Shallow (ish) convection

DSD-based Classification versus Radar Observations



So, for the 14th Oct. 2019 event:

i reaches 0 threshold for thick bright-band cases

i goes positive during convective rain periods

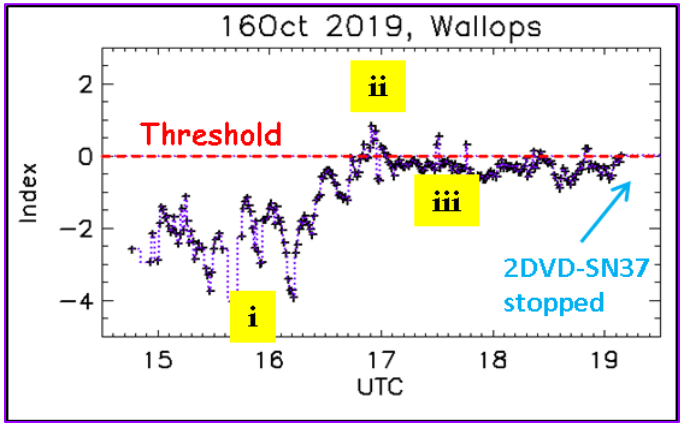
i close to 0 for shallow convection

i is negative for the remaining time periods,
(NPOL scans showed stratiform rain)

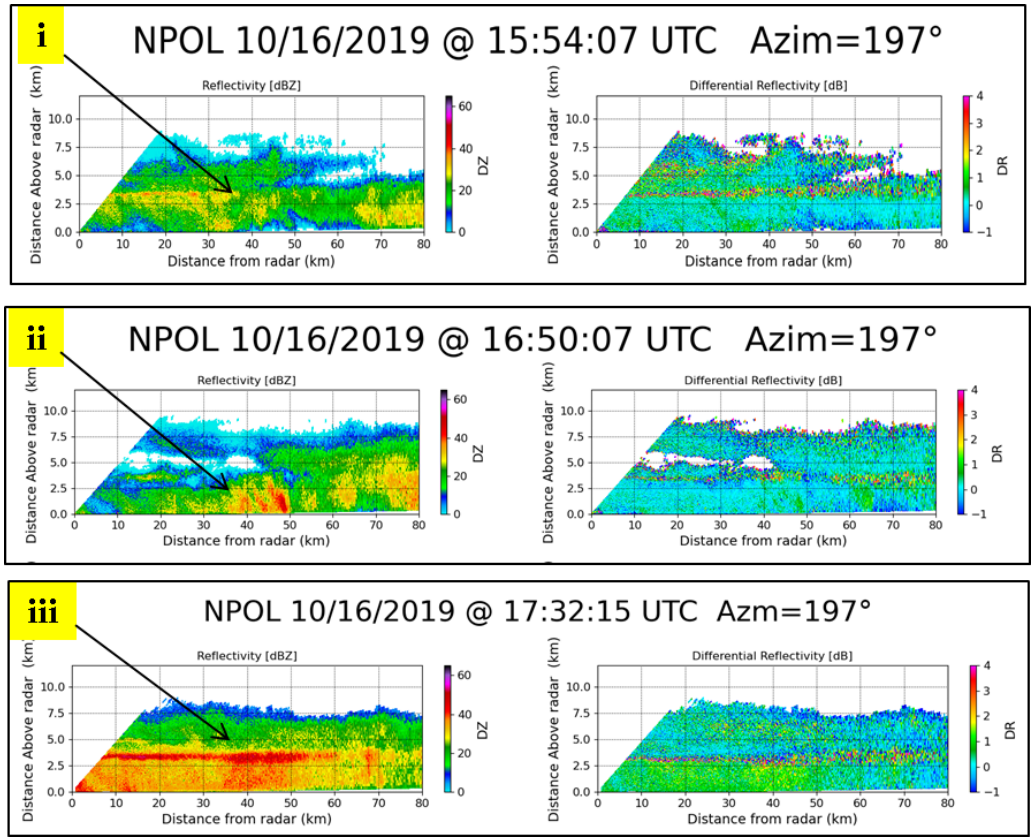
(i) and (ii) are associated with thick bright band
(iii) Modest convection
(iv), (v) and (vi) are Convection
(vii) Shallow (ish) convection

DSD-based Classification versus Radar Observations

Next event: 16 Oct 2019



3 time periods are marked



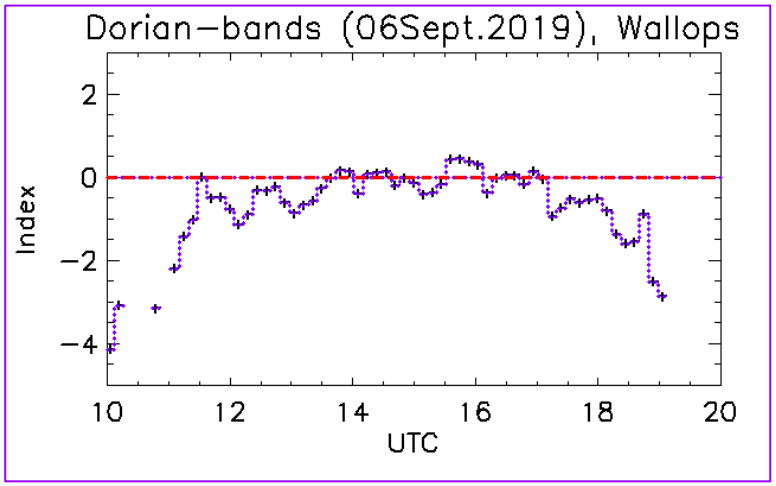
(i) has negative i ⇨ RHI shows stratiform rain

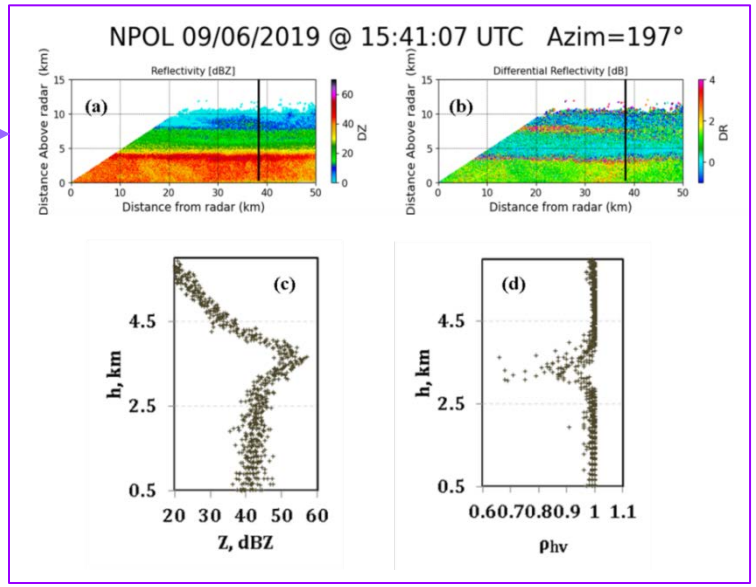
(ii) has positive i ⇨ RHI shows modest convection

(iii) i close to zero ⇨ associated with thick bright band

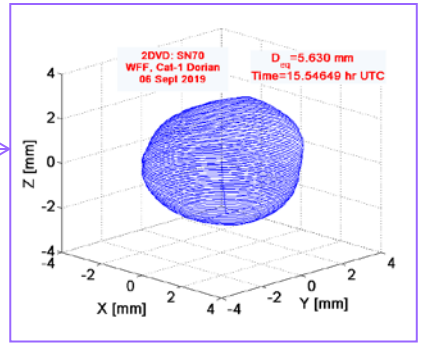
DSD-based Classification versus Radar Observations

Next event: Dorian rain-bands





- DSD-based classification indicates mostly stratiform ⇨ Confirmed by NPOL RHI's
- Except for between 15:30 – 16:00 UTC
  - ⇨ NPOL RHI showed very thick bright-band
  - ⇨ And large drops measured by 2DVD



Application of the Method for Radar Data

- The DSD based separation technique can also be used to identify stratiform and convective rain regions from NPOL radar scans.

- First step ⇨ the estimation of N_W and D_m
  … *but use an intermediate parameter, D_m'*
  which depends on two (chosen) reference DSD moments.
  Here we use 3rd and the 6th moments.

- Scattering (T-matrix) calculations using 3-minute DSD spectra used to derive the retrieval equations.

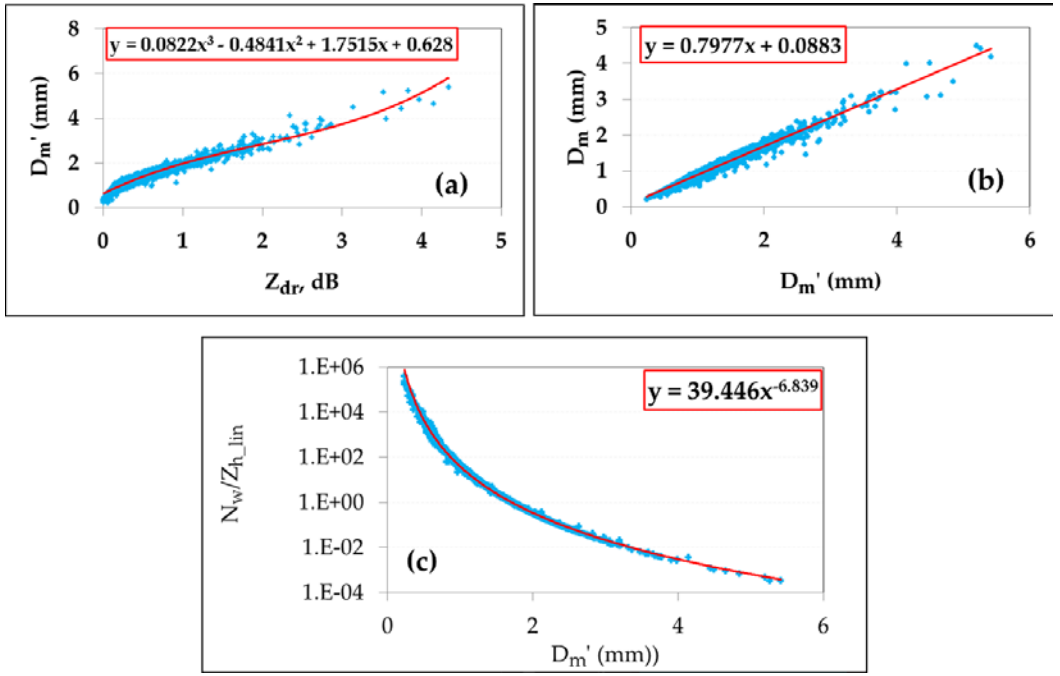
Application of the Method for Radar Data

From scattering simulations:

(a) D_m' with the S-band Z_{dr}

(b) D_m with D_m'

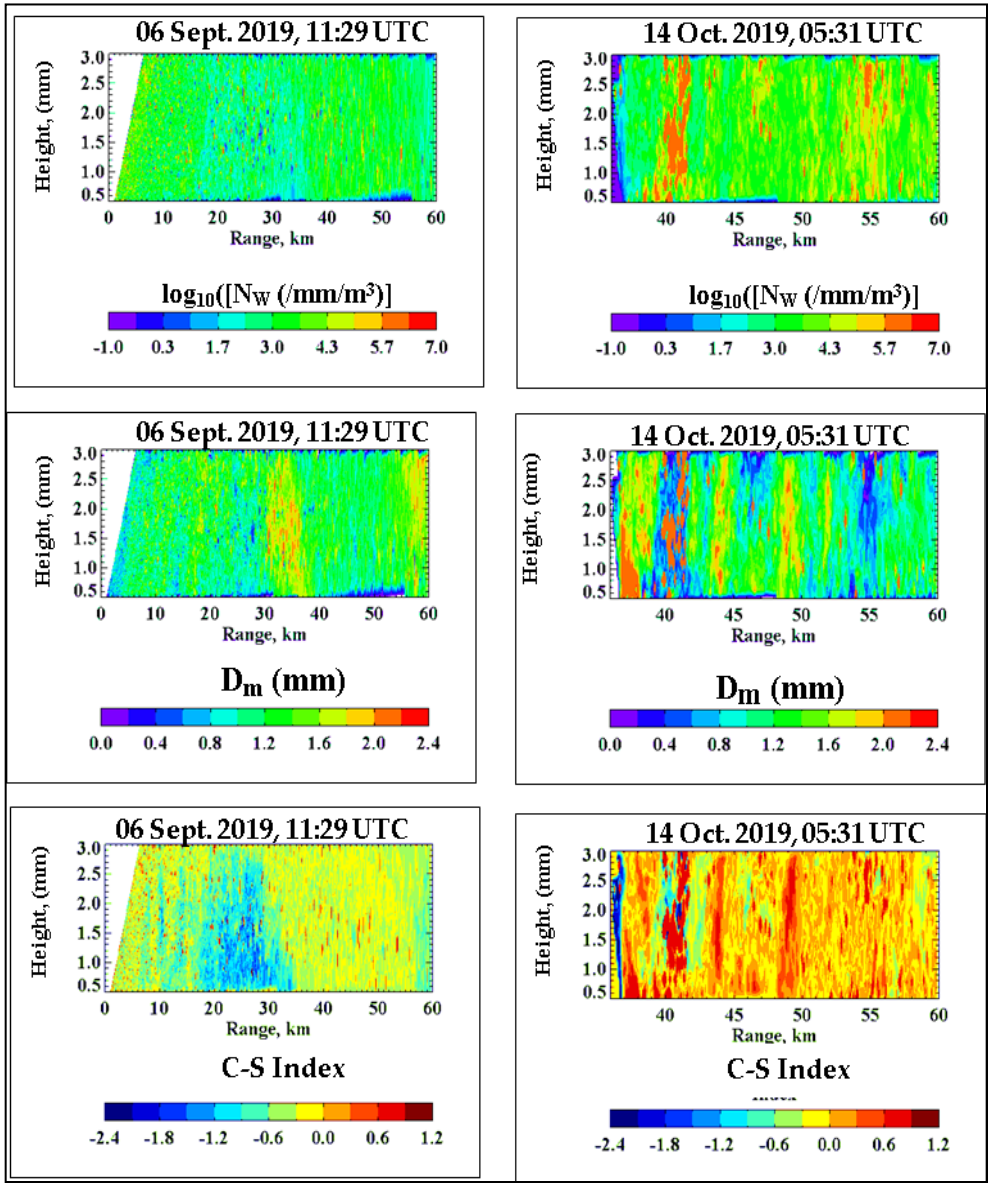
(c) N_W/Z_h(linear) versus D_m'

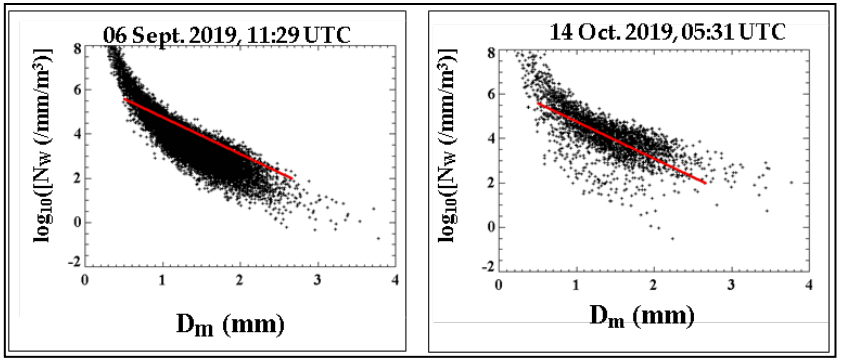


Now apply these equations to NPOL RHI scans

'Zoom in' to the rain region (eg. < 3 km height)

Application of the Method for Radar Data





For 06 Sept. 2019 @ 11:29 UTC

- N_W more uniform
- D_m not so high
- Index ***i*** mostly negative
- $N_W - D_m$ points lie below the separation line

For 14 Oct. 2019 @ 05:31 UTC

- N_W shows more variation
- D_m > 2 mm in some regions
- Index ***i*** mostly positive
- $N_W - D_m$ points lie above the separation line

Summary / Conclusions

- DSDs from disdrometer measurements have been used to separate stratiform and convective rain events at Wallops.
- Testing was done for three long duration events.
- NPOL-RHI scans confirm classification for most cases.
- For a 30 minute period during the Dorian rain-bands event
  ⇨ wrong classification…. but large drops were measured during this time, and RHIs showed very thick bright band
- The separation technique can also be applied directly to NPOL scans; N_w, D_m retrievals have been developed.
- Two cases show promising results

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Examples of available data from other locations also show this separation to be valid

		Site (Disdrometer type)	$<D_m>$ mm	Std dev. of D_m in mm	Log $<N_W>$	Std dev. of log N_W
Tropical	**Conv**	Darwin (Joss)	1.68	0.385	4.1	0.36
		SCSMX (Joss)	1.76	0.326	4.03	0.312
		Papua New Guinea (2DVD)	1.47	0.32	4.15	0.327
		Florida (2DVD)	1.74	0.49	4.25	0.52
		TOGA-COARE (from airborne data)	1.6	0.34	4.33	0.4
Continent	**Conv**	Graz (2DVD)	2.12	0.53	3.39	0.45
		Sydney(Joss)	2.29	0.51	3.3	0.34
		Arecibo (Joss)	2.36	0.17	3.15	0.27
		Colorado (2DVD)	2.45	0.58	3.43	0.38
All	**Strat**	Darwin (Joss)	1.37	0.31	3.72	0.4
		SCSMX (Joss)	1.34	0.28	3.73	0.35
		Papua New Guinea (2DVD)	1.22	0.31	3.94	0.52
		Florida (2DVD)	1.48	0.34	3.5	0.48
		TOGA-COARE (from airborne data from Testud)	1.3	0.28	3.49	0.5
		Colorado(2DVD)	1.58	0.3	3.28	0.24