Application of the Generalized Gamma Model to Represent the Full DSD Spectra

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Background

Measurement campaigns conducted in:

- Greeley, Colorado (April – Oct 2015)
  2DVD, MPS, Pluvio, all inside DFIR, plus POSS
  CSU-CHILL radar (13 km range)

- Huntsville, Alabama (From Feb 2015)
  2DVD, MPS, inside DFIR plus POSS,
  Another 2DVD outside DFIR and ARMOR (C-band)

Reference:

Thurai, M. P. Gatlin, V. N. Bringi, W. Petersen, P. Kennedy, B. Notaroš, and L. Carey, 2017: "Toward Completing the Raindrop Size Spectrum: Case Studies Involving 2D-Video Disdrometer, Droplet Spectrometer, and Polarimetric Radar Measurements", J. Appl. Meteor. Climatol., 56 (4), 877–896.

Background

- DSD spectra down to 0.15 mm
- Our new results pointed to the need for additional work on modeling the full DSD spectra.
- In this paper, we consider the generalized gamma DSD with the 4 parameters: N_0', D_m' and c and μ

References for G-G Representation

1. *Lee, G., I. Zawadzki, W. Szyrmer, D. Sempere-Torres, and R. Uijlenhoet, 2004: 'A general approach to double-moment normalization of drop size distributions', J. Appl. Meteor., 43, 264–281.*
2. *Auf der Maur, A. N., 2001: Statistical tools for drop size distribution: Moments and generalized gamma. J. Atmos. Sci., 58, 407–418.*
3. *Raupach, T.H. and A. Berne, 2017: Invariance of the Double-Moment Normalized Raindrop Size Distribution through 3D Spatial Displacement in Stratiform Rain. J. Appl. Meteor. Climatol., 56, 1663–1680.*
4. *Field, P. R., R. J. Hogan, P. R. A. Brown, A. J. Illingworth, T. W. Choularton, and R. J. Cotton, 2005: Parametrization of ice-particle size distributions for mid-latitude stratiform cloud. Quart. J. Roy. Meteor. Soc., 131, 1997–2017.*

Model Testing

$$N(D) = N_0' \; h_{GG(i,j,\mu,c)}(x) \qquad (1)$$

where $N_0' = M_i^{(j+1)/(j-i)} M_j^{(i+1)/(i-j)}$ and $D_m' = (M_j / M_i)^{1/(j-i)}$

and $$h_{GG(i,j,\mu,c)}(x) = c\, \Gamma_i^{\frac{(j+c\mu)}{(i-j)}} \Gamma_j^{\frac{(-i-c\mu)}{(i-j)}} x^{c\mu-1} exp\left[-\left(\frac{\Gamma_i}{\Gamma_j}\right)^{\frac{c}{(i-j)}}\right] x^c$$

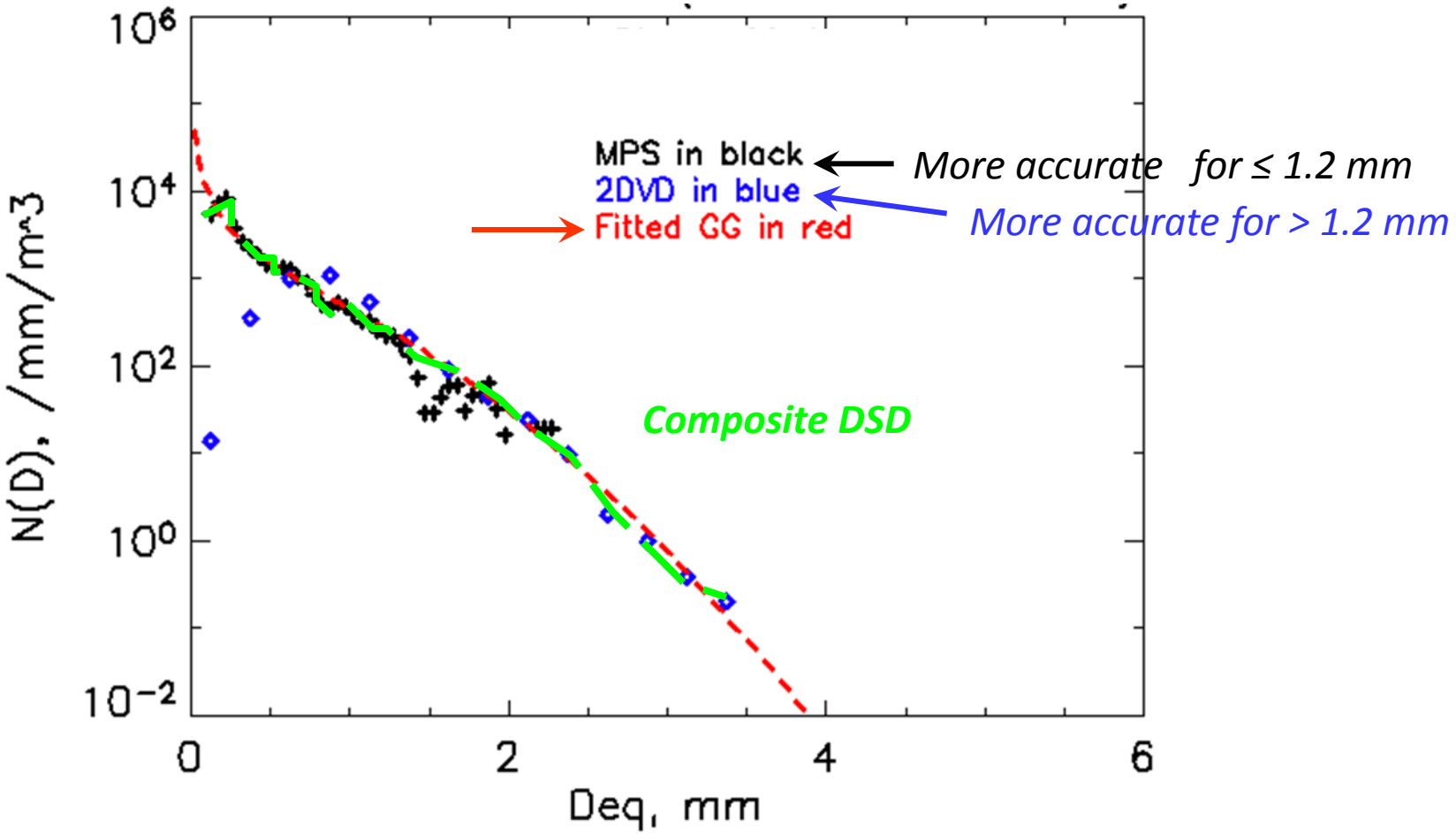
$$\Gamma_i = \Gamma\left(\mu + \frac{i}{c}\right) \text{ and } \Gamma_j = \Gamma\left(\mu + \frac{j}{c}\right)$$

$$x = \left(\frac{D}{D_m'}\right)$$

For example:
Lee et al, 2004

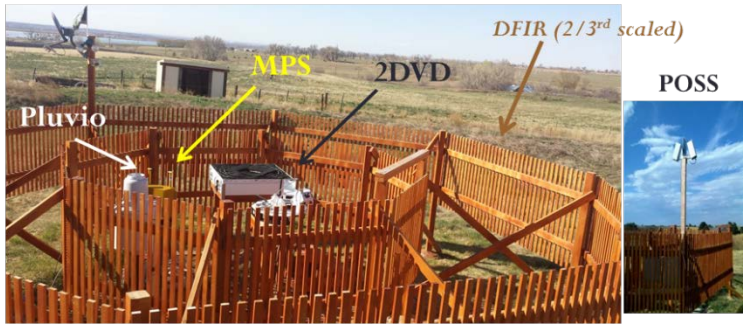
Note: μ is allowed to go -ve

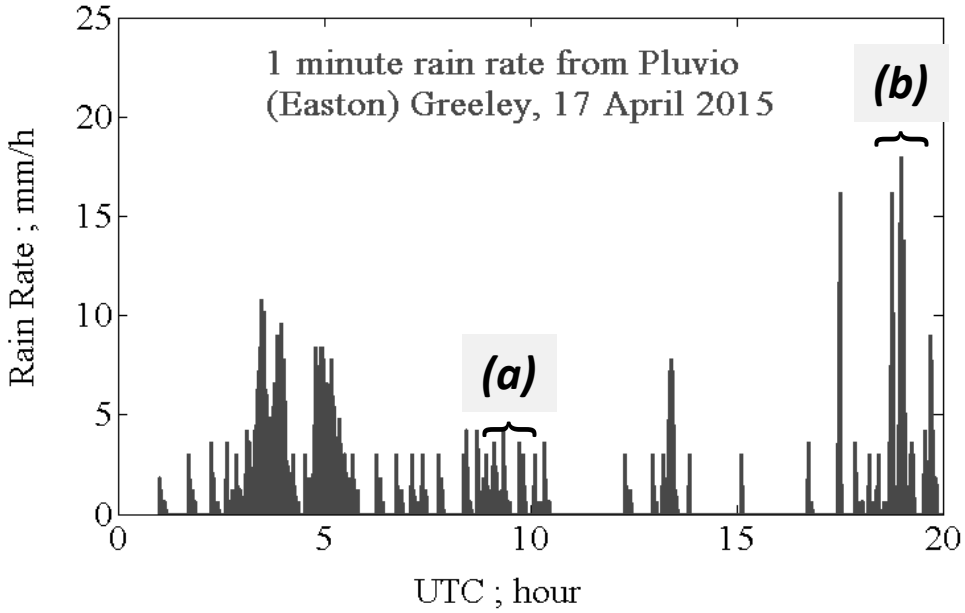
Data & Fitting



Data & Fitting

Near Greeley, Colorado

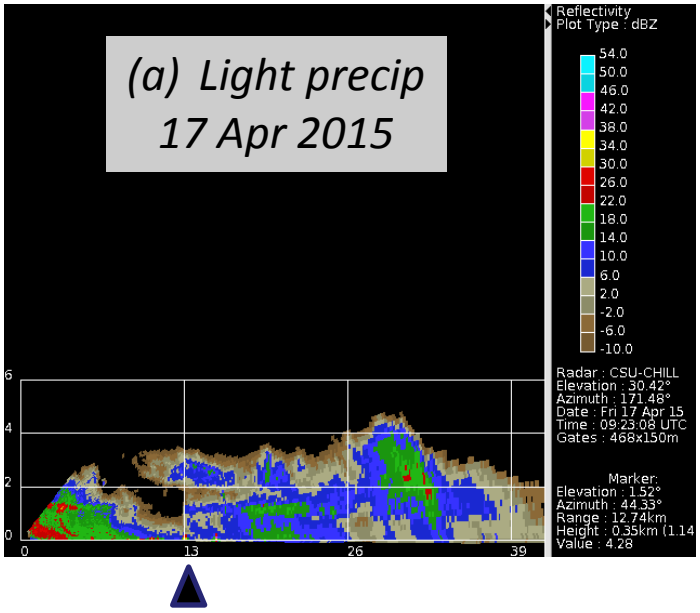


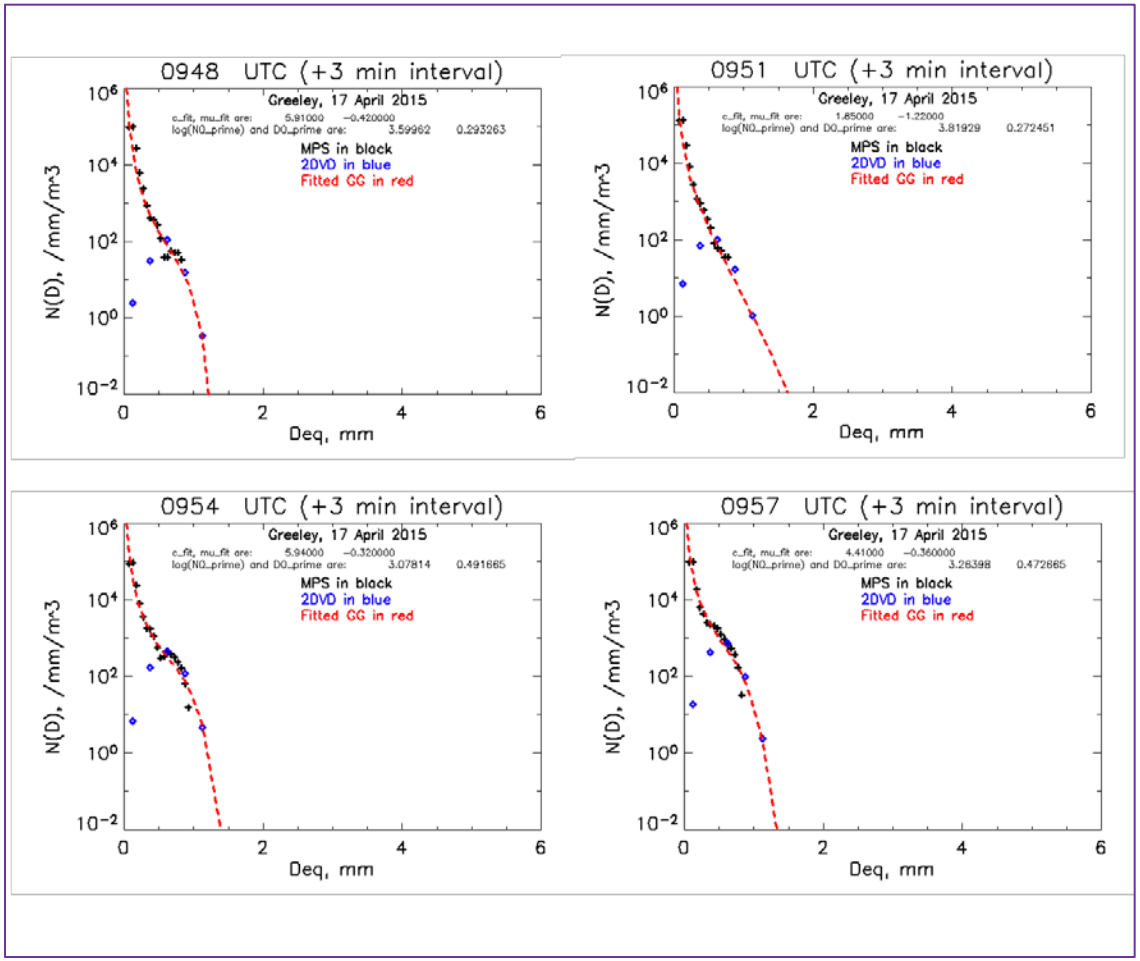


2DVD, MPS, Pluvio, inside DFIR, Plus POSS

Data & Fitting

Near Greeley, Colorado





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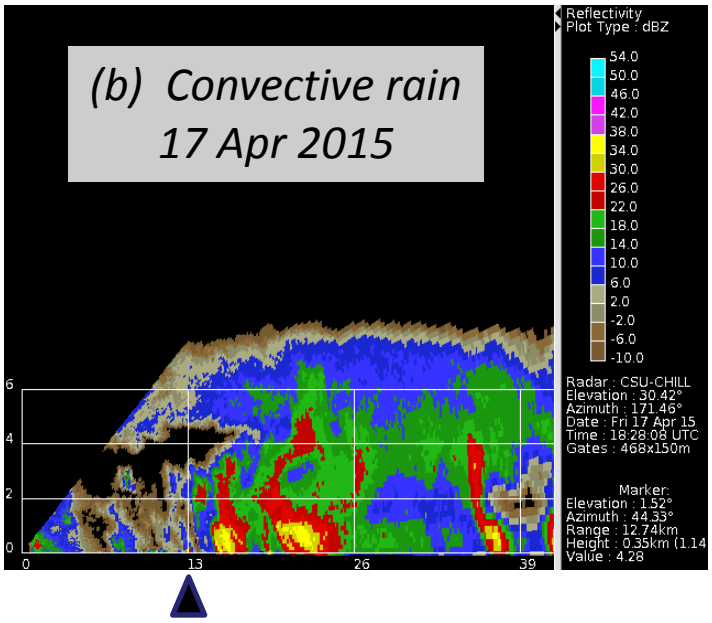
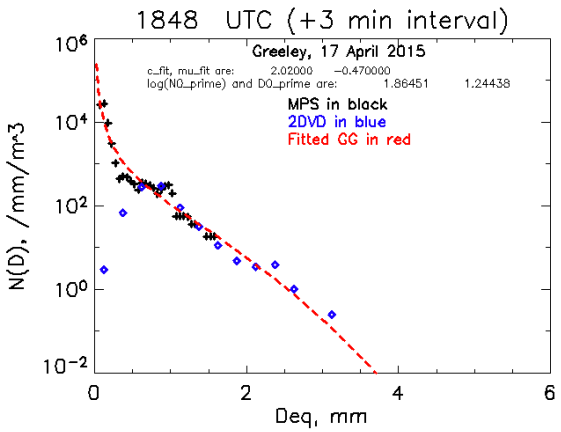
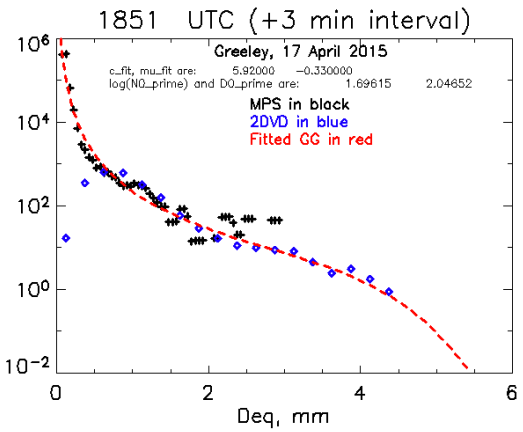
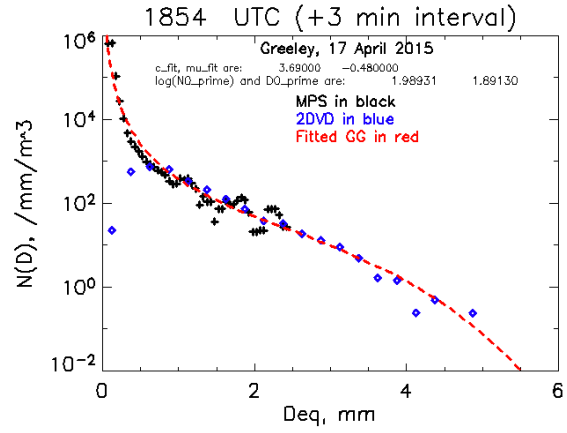
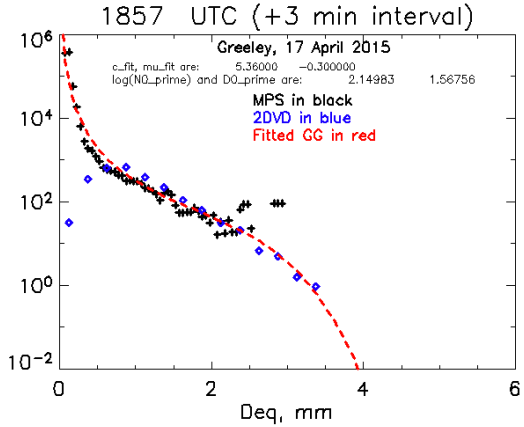


Instrumention site









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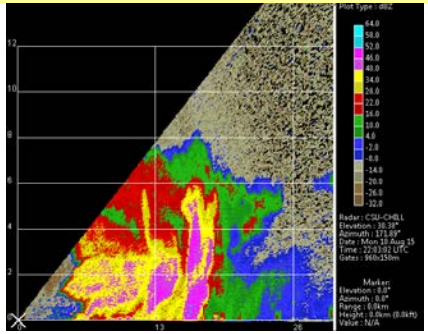
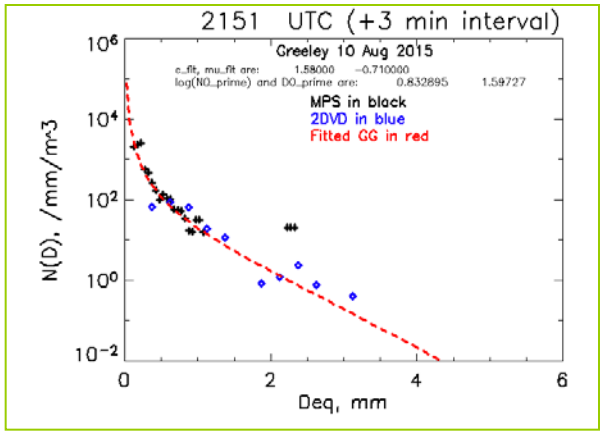
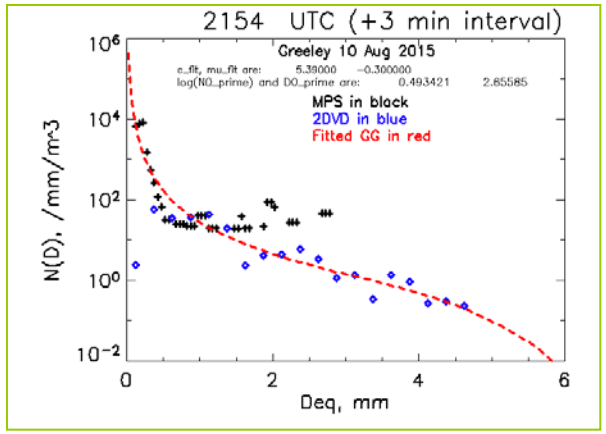
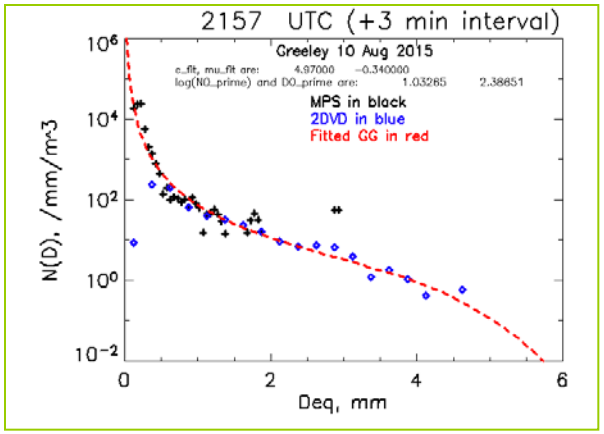
Near Greeley, Colorado

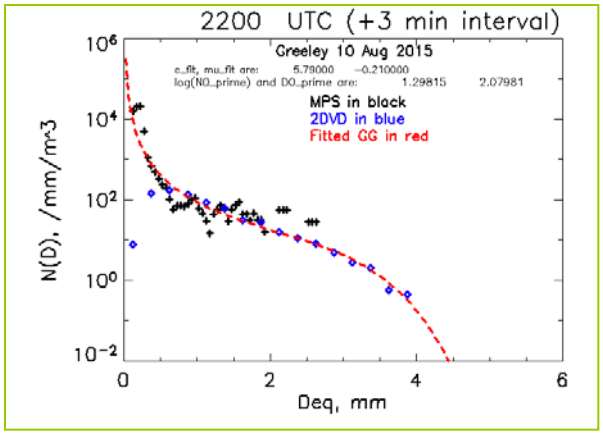


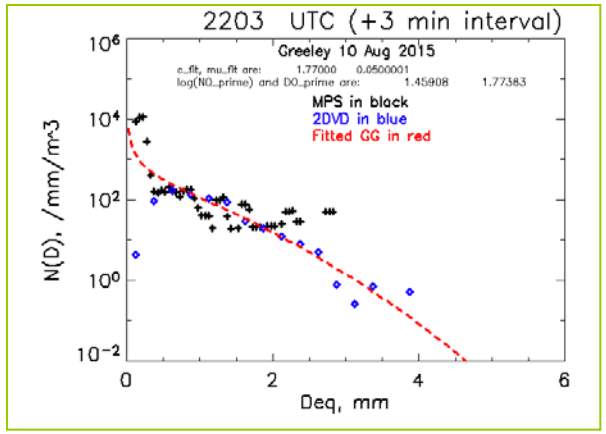
10 Aug 2015: large drops

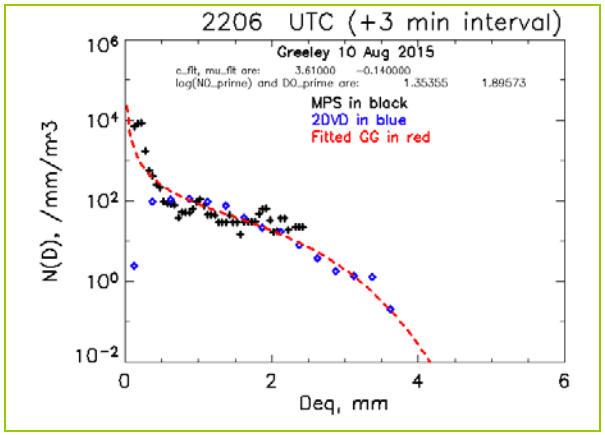




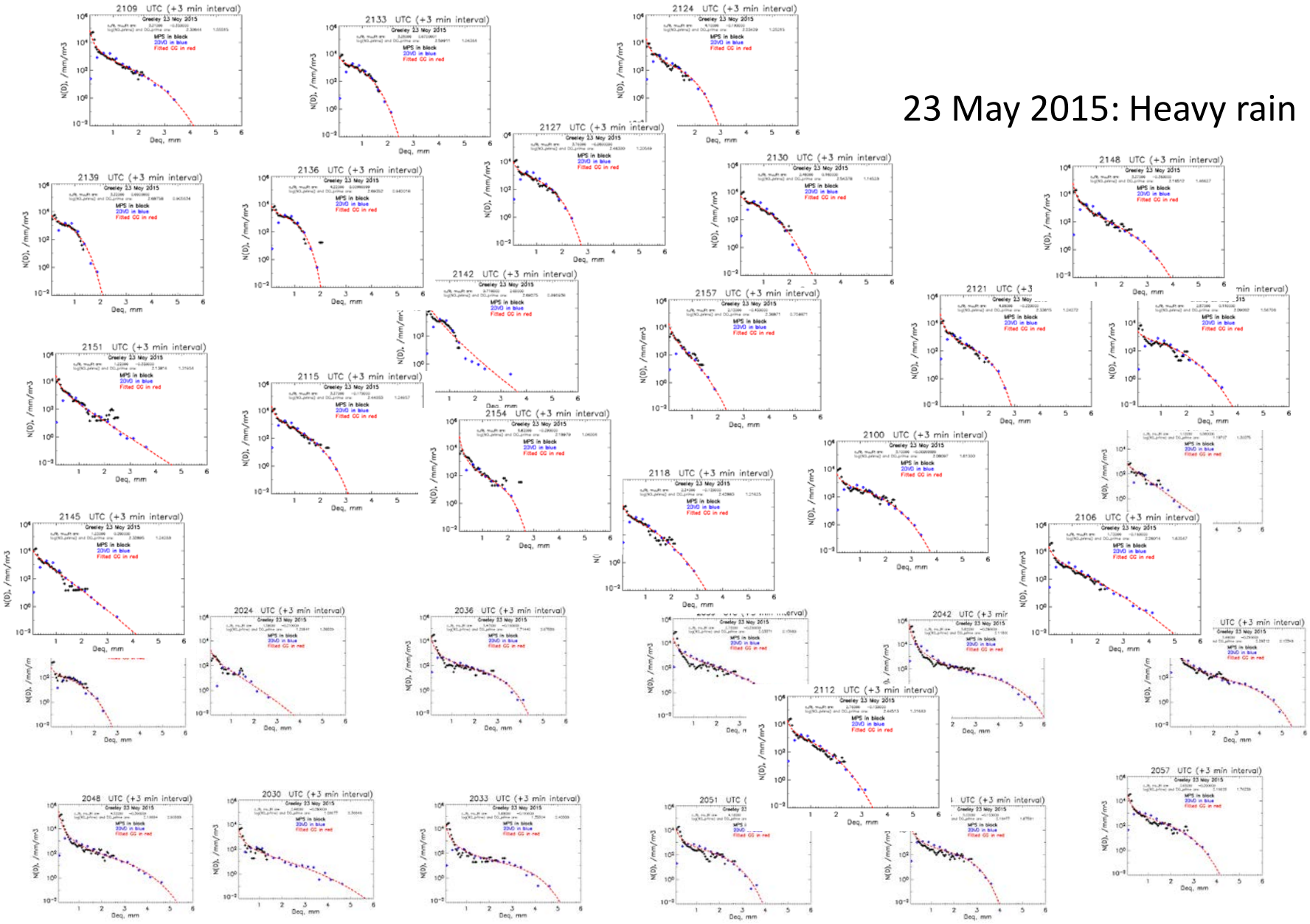






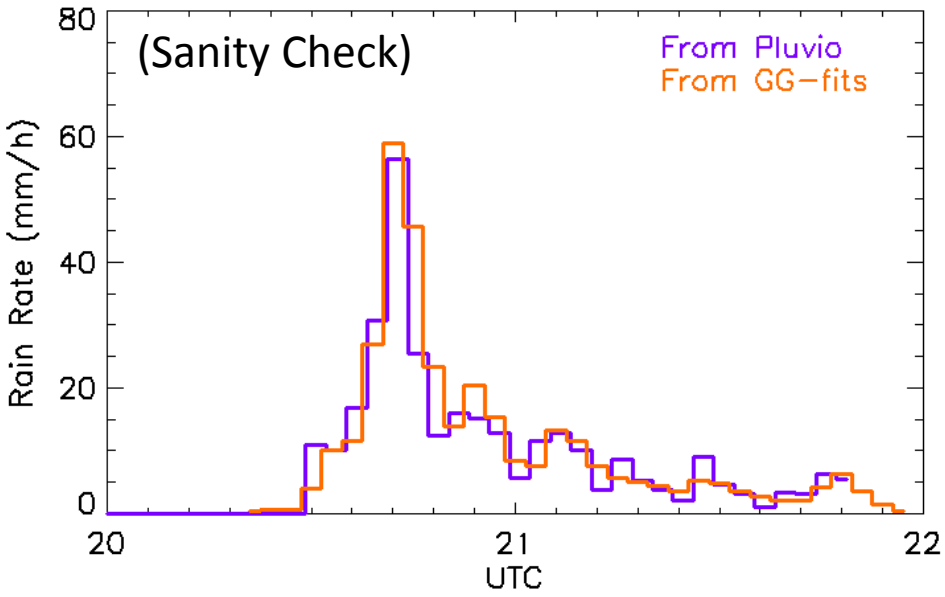


Data & Fitting

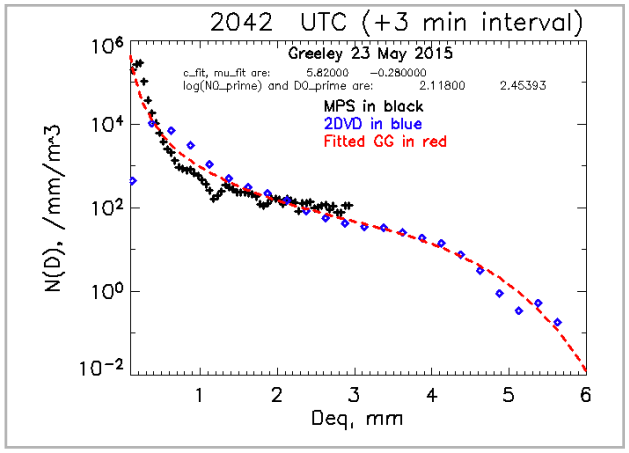


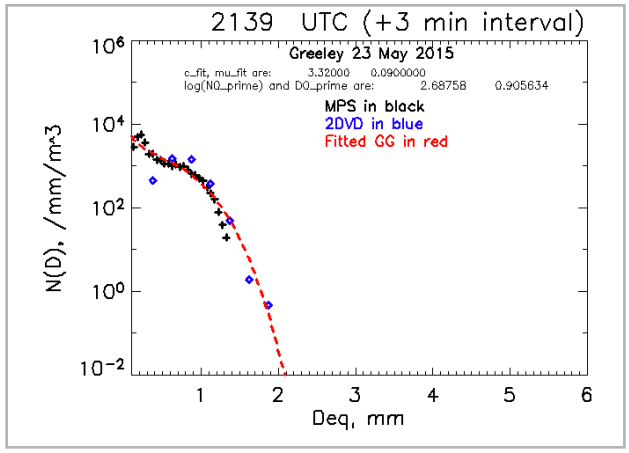
23 May 2015: Heavy rain

Data & Fitting



23 May 2015: Heavy rain





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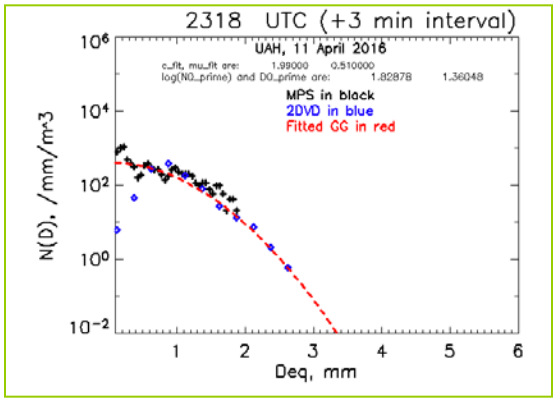
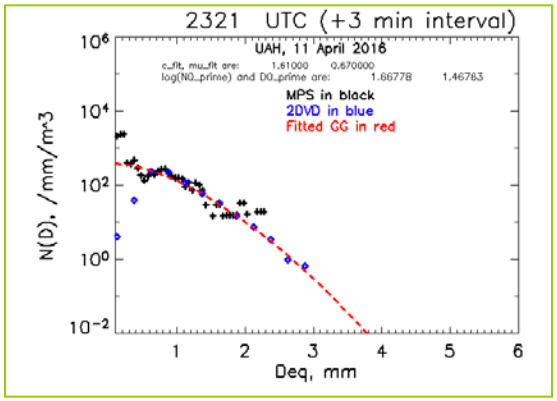
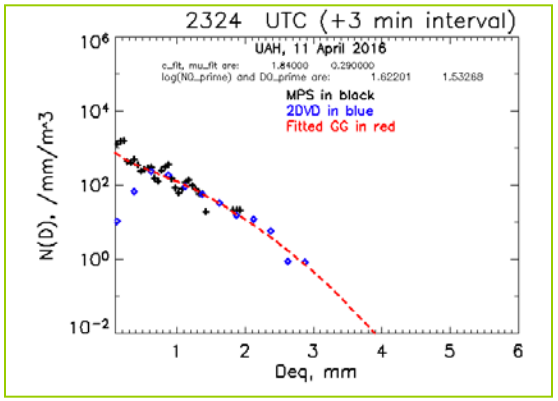
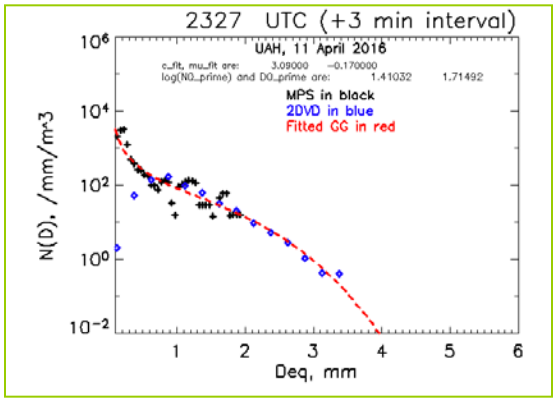
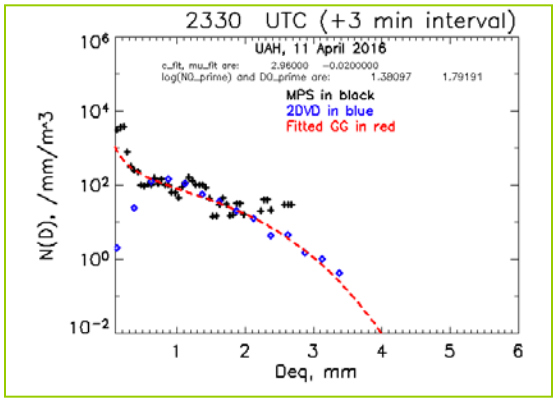
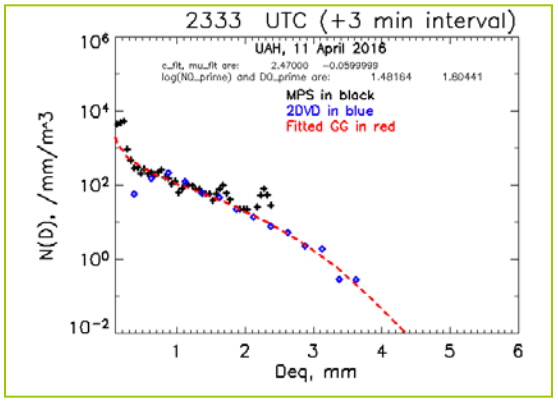




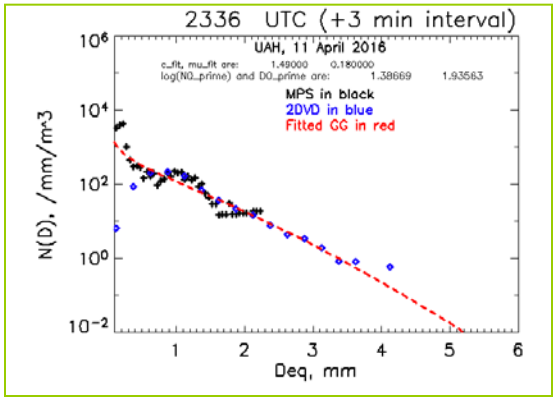


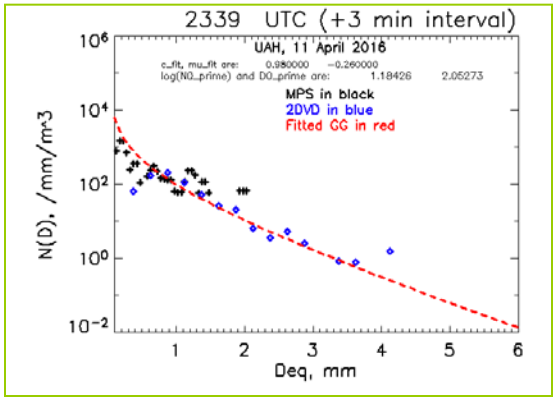




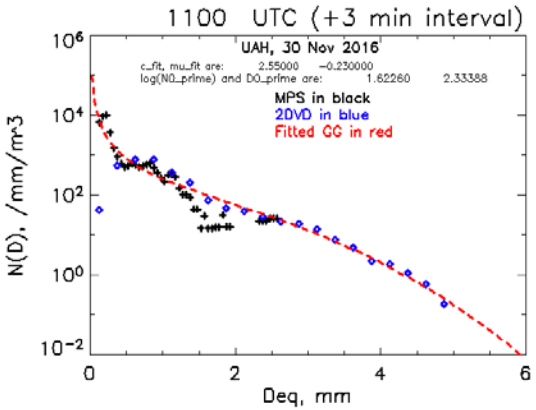


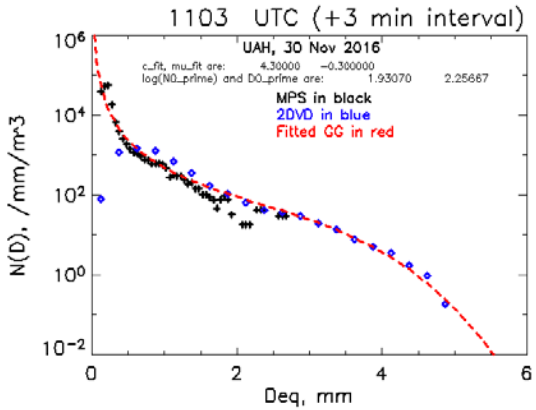
11 Apr 2016, UAH

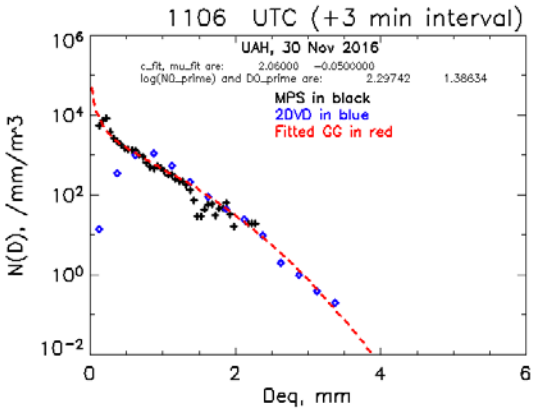


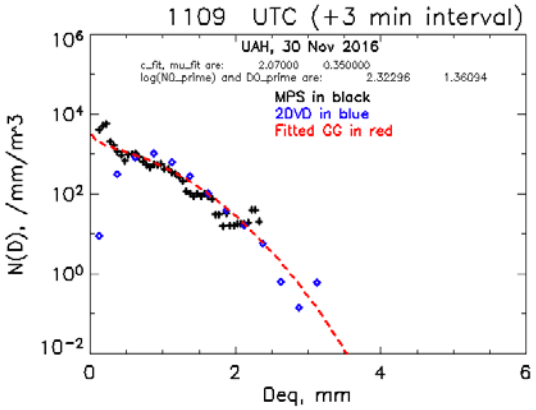


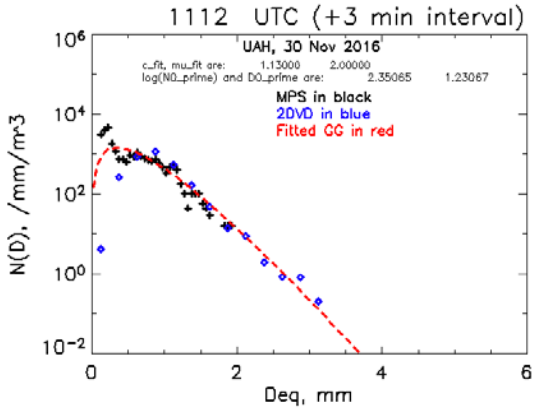
Data & Fitting

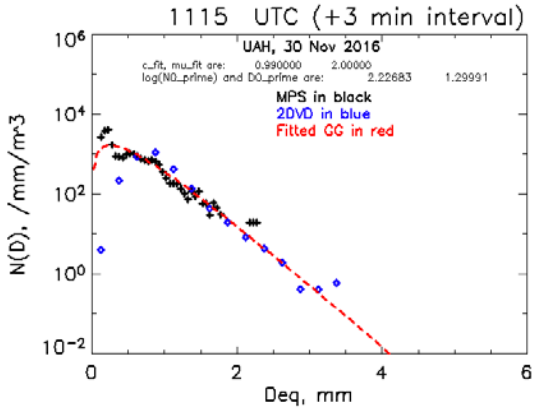


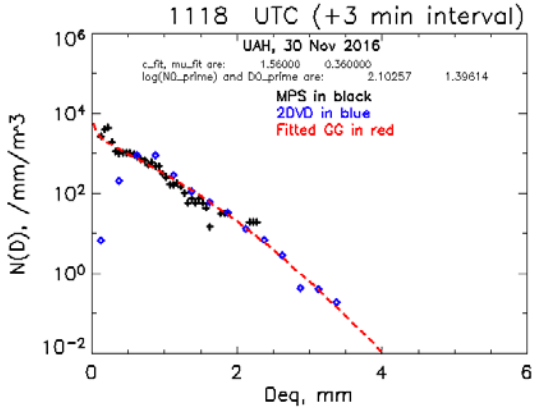


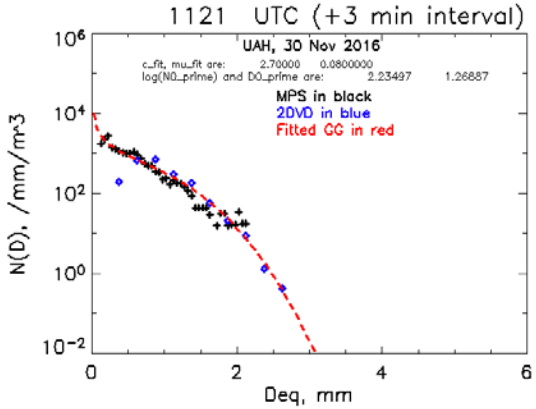






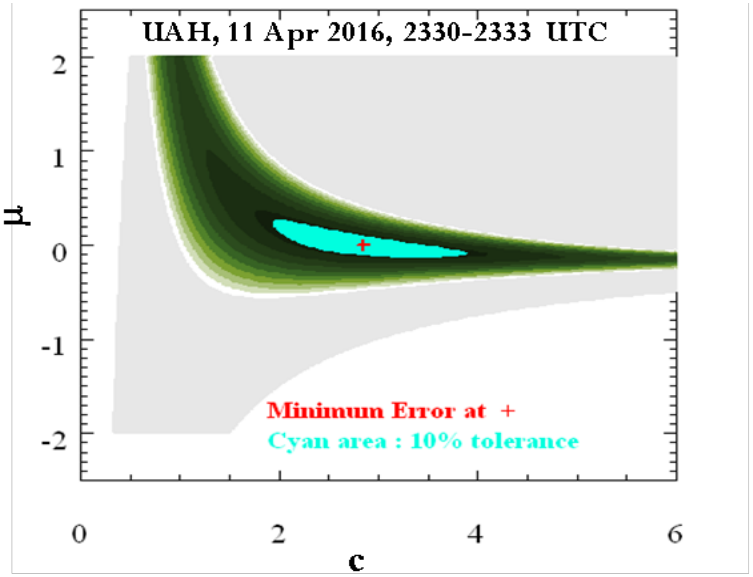


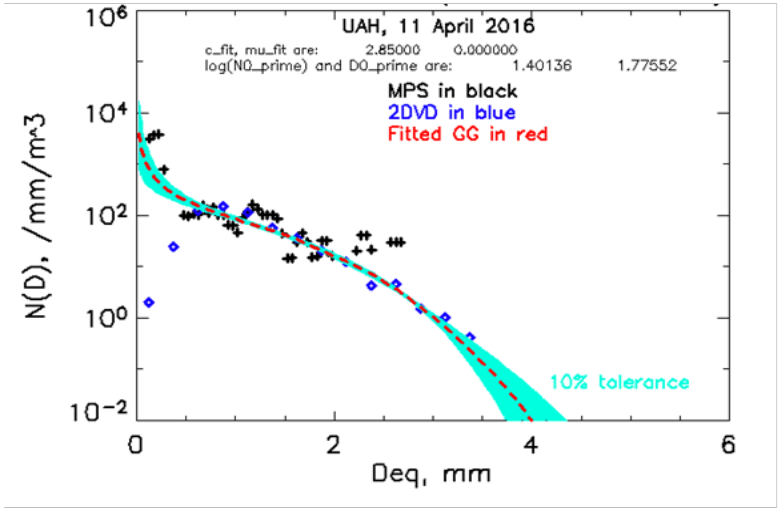


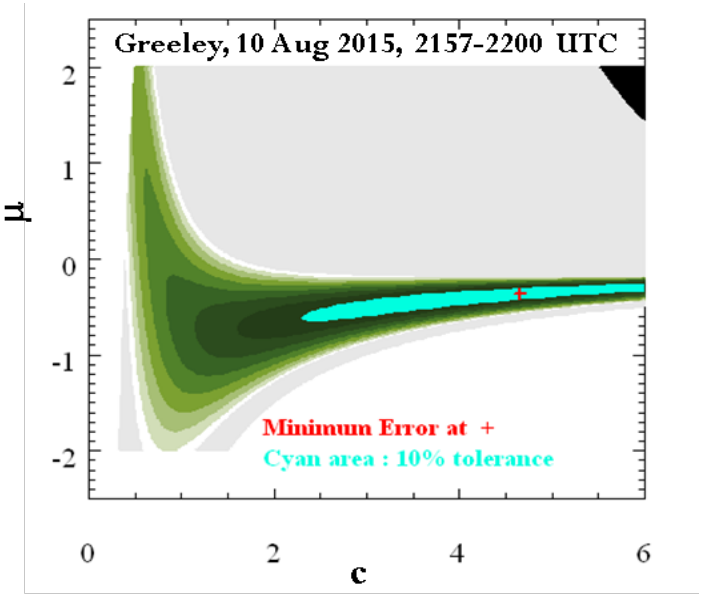


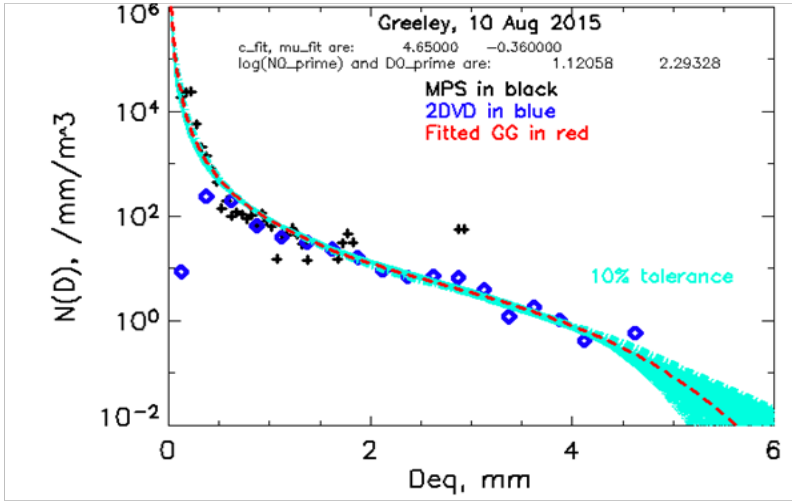
30 Nov 2016, UAH

Error Residuals

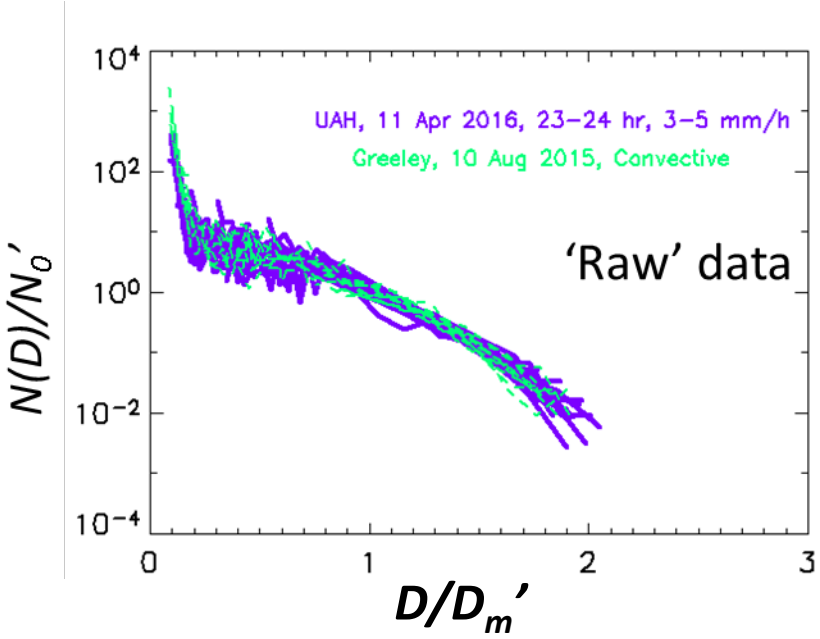


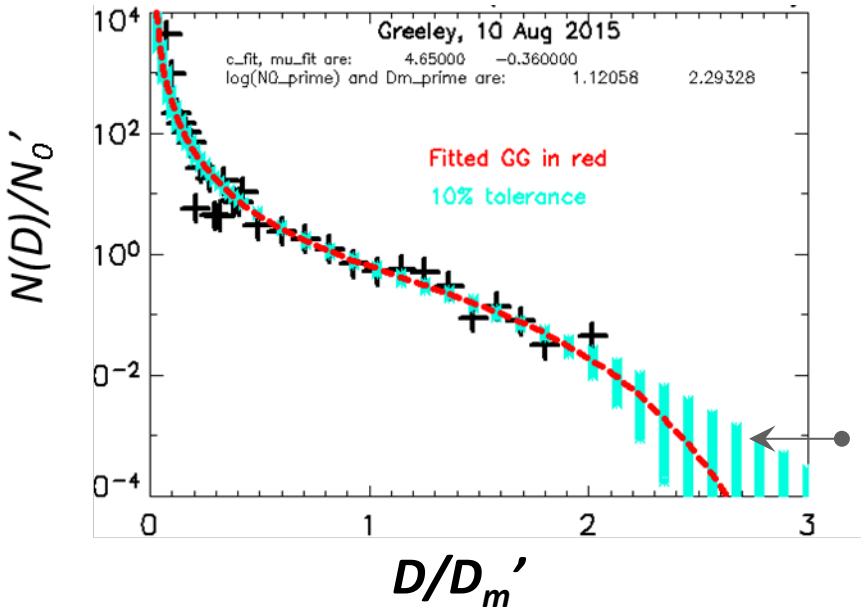






Normalized DSDs





Invariant/stable ..?

Probably

Note: the flare

Conclusions

- Testing of the G-G model against our datasets of the composite MPS-2DVD DSDs has **highlighted** its suitability to represent the full spectra.

- Analysis of error residuals has indicated that although minim error can be reached in the c - μ domain, if one allows 10% error tolerance, then c can vary over a significant range.

- μ on the other hand appears to be more sensitive, and lies within a narrow range.

- Normalized DSDs appear to be stable, to a large extent

Our thanks to ..

- Pat Kennedy (CSU-CHILL) for performing CHILL radar scans for selected events during the Greeley campaign (April to Oct 2015)

- Patrick Gatlin, Larry Carey, Walter Petersen, for hosting the MPS and the 2DVD instruments at the UA Huntsville site, and for the helpful discussions.

- Wonbae Bang (c/o Prof. G. Lee at KNU, Daegu, ROK) for some initial help with the fitting procedure.

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Family of curves