Assessing Uncertainty in Mass-Dimensions Estimates Using 3D Synthetic Particles

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Outline

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- Methods and Data
  - Synthetically Constructed Particles
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- Conclusions

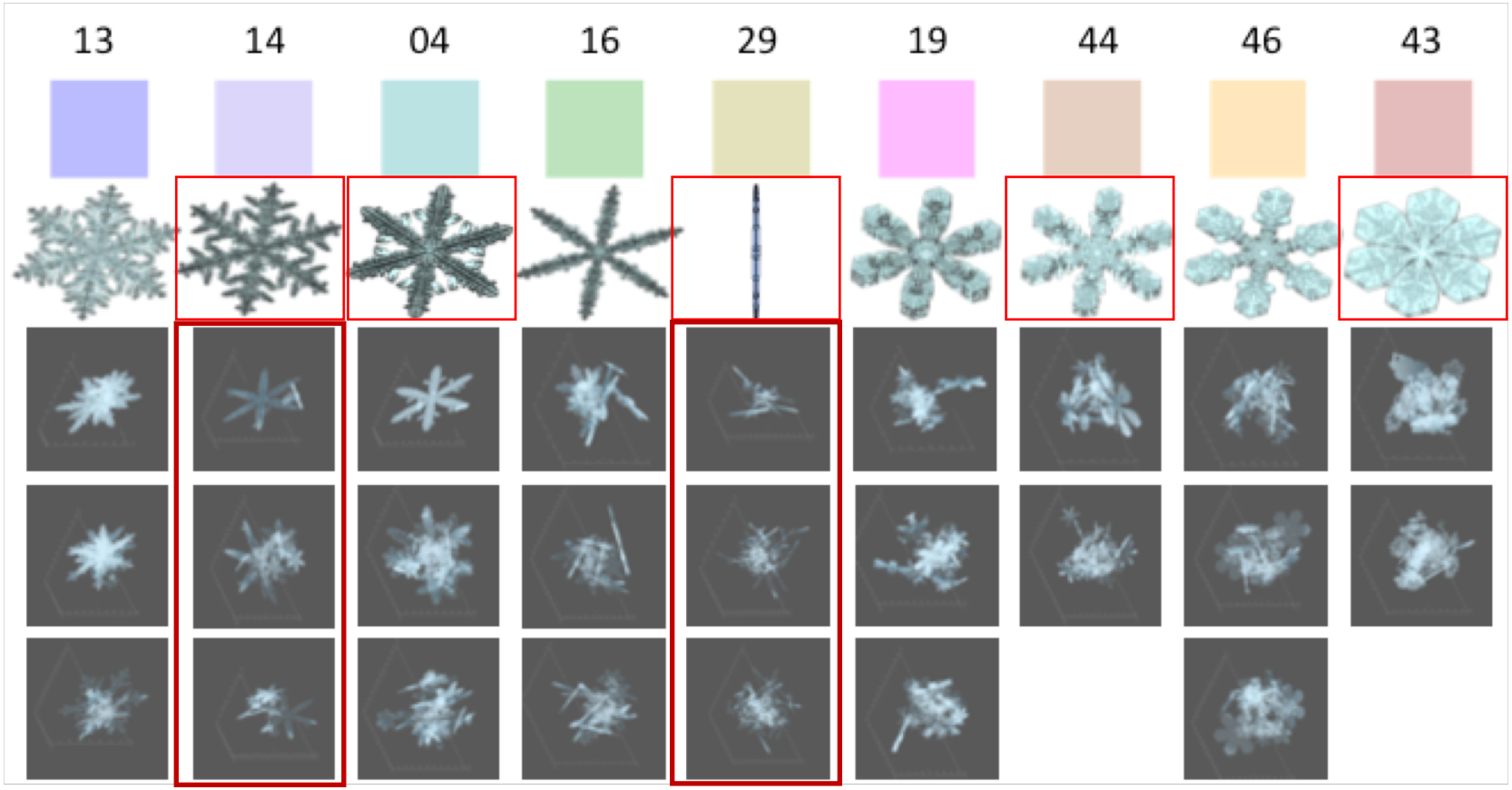
Introduction

- Mass-Dimension (m-D_{max}) Relation
  - A power-law relation relating the mass of the particle to its maximum dimension (D_{max})
  - Estimated using particle probe observations
    - Estimating mass is easier
    - Maximum dimension is estimated based on 2D projection(s)
  - It is used to constrain the particles used in forward radiative transfer modeling, which in turn is used for retrieval
  - Uncertainty in D_{max} leads to uncertainties downstream.

Methods and Data

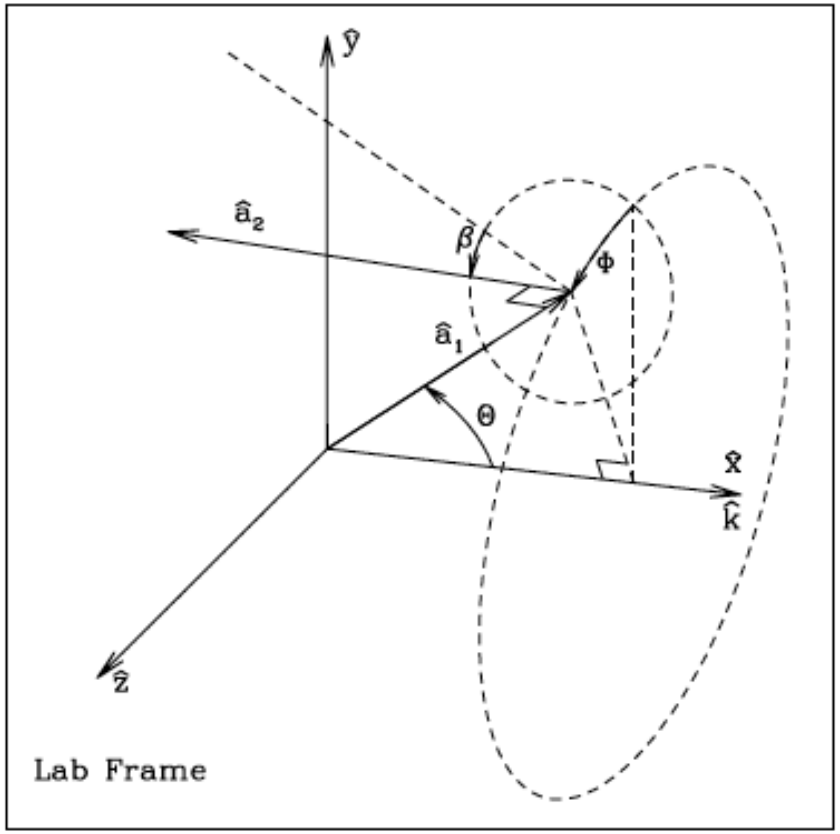
- Synthetically Constructed Particles
  - Pristine particles are ”grown” using the *Snowfake* model pioneered by Gravner and Griffeath (2009)
  - Aggregate particles are constructed using (mono-habit) pristine particles, using a heuristic approach.
  - Described in Kuo et al (2016)
    - The Microwave Radiative Properties of Falling Snow Derived from Non-spherical Ice Particle Models. Part I: An Extensive Database of Simulated Pristine Crystals and Aggregate Particles, and Their Scattering Properties. *J Appl Meteorol Clim*, **55**, 691–708, doi:10.1175/JAMC-D-15-0130.1.

Samples of Synthetical Particles

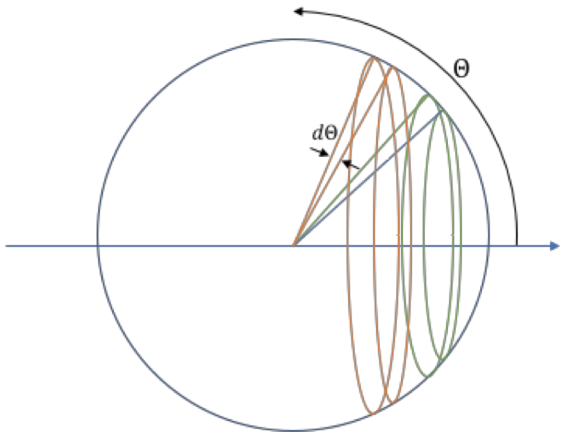


Methods and Data

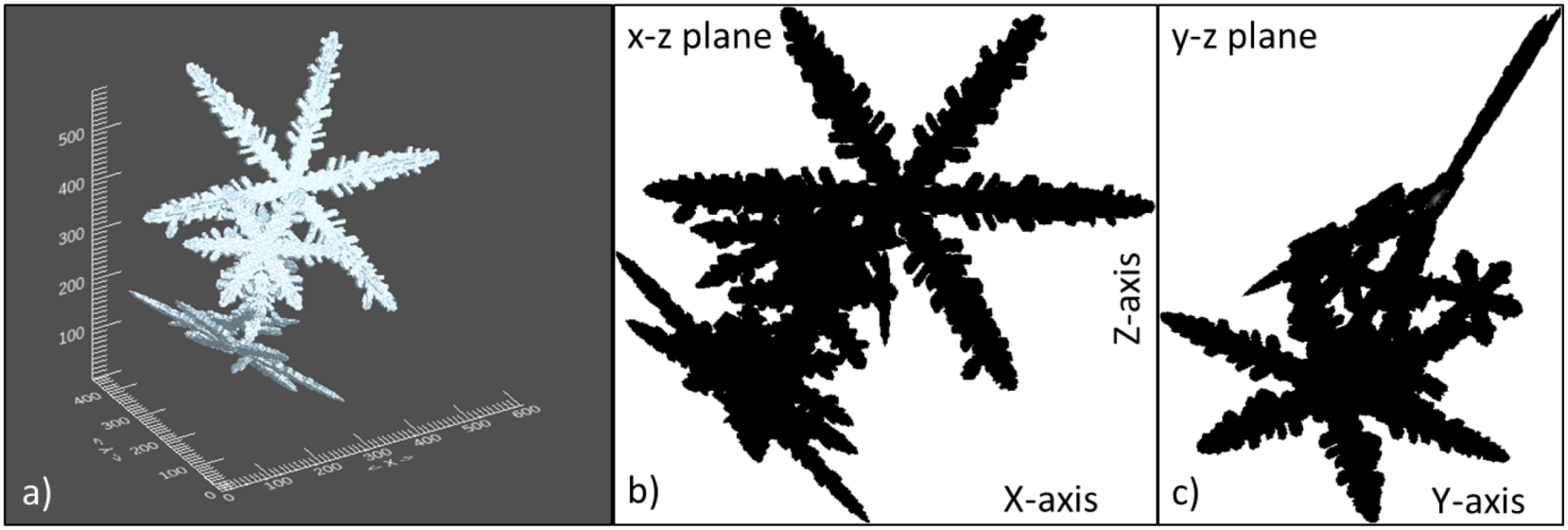
- Orientation Convention



$$
\begin{aligned}
\hat{\mathbf{a}}_1 &= \hat{\mathbf{x}}_{\mathrm{LF}} \cos\Theta + \hat{\mathbf{y}}_{\mathrm{LF}} \sin\Theta \cos\Phi + \hat{\mathbf{z}}_{\mathrm{LF}} \sin\Theta \sin\Phi \\
\hat{\mathbf{a}}_2 &= -\hat{\mathbf{x}}_{\mathrm{LF}} \sin\Theta \cos\beta + \hat{\mathbf{y}}_{\mathrm{LF}} [\cos\Theta \cos\beta \cos\Phi - \sin\beta \sin\Phi] \\
&\quad + \hat{\mathbf{z}}_{\mathrm{LF}} [\cos\Theta \cos\beta \sin\Phi + \sin\beta \cos\Phi] \\
\hat{\mathbf{a}}_3 &= \hat{\mathbf{x}}_{\mathrm{LF}} \sin\Theta \sin\beta - \hat{\mathbf{y}}_{\mathrm{LF}} [\cos\Theta \sin\beta \cos\Phi + \cos\beta \sin\Phi] \\
&\quad - \hat{\mathbf{z}}_{\mathrm{LF}} [\cos\Theta \sin\beta \sin\Phi - \cos\beta \cos\Phi]
\end{aligned}
$$



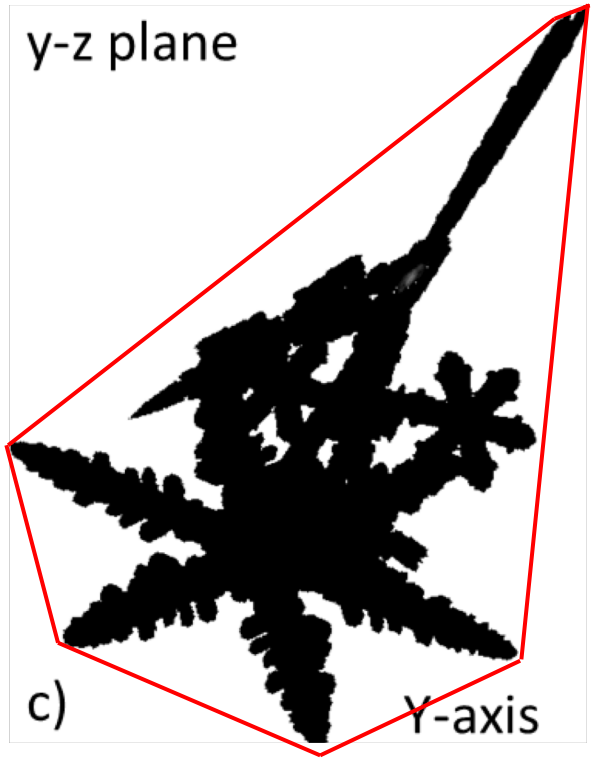
An Example



Orienting The Particles

- It is a rotation
- Maximum dimension needs to be found after each rotation
  - It is not easy!
  - Finding the convex hull of the particle and use the bounding points is more efficient

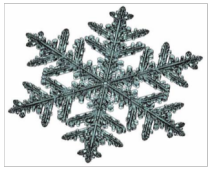
Example of a 2D Convex Hull



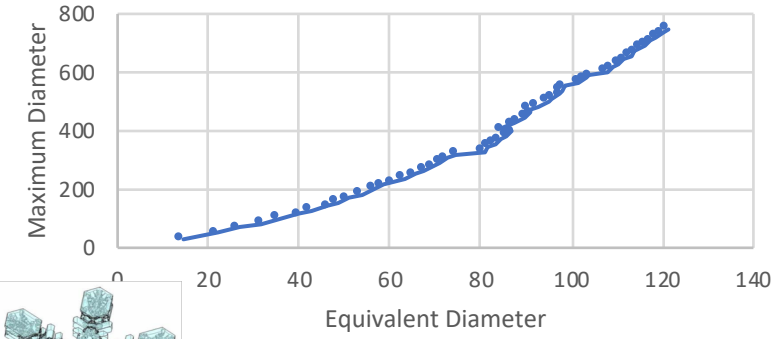
Results

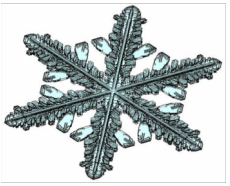
- Statistics are derived from 100 uniformly random orientations
- Numbers are dimensionless, i.e. number of cells
- The comparison between 2D and 3D maximum dimensions are done with their ratios.

Results – Pristine Particles

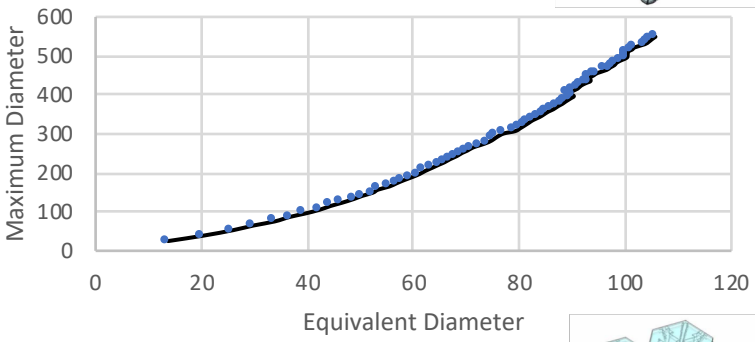


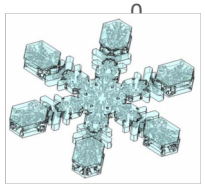
m-D Relation (p-14)



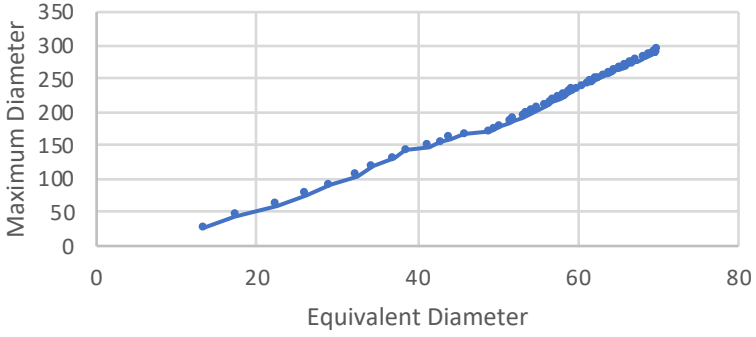


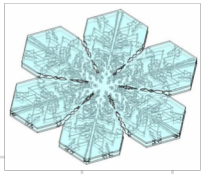
m-D Relation (p-04)



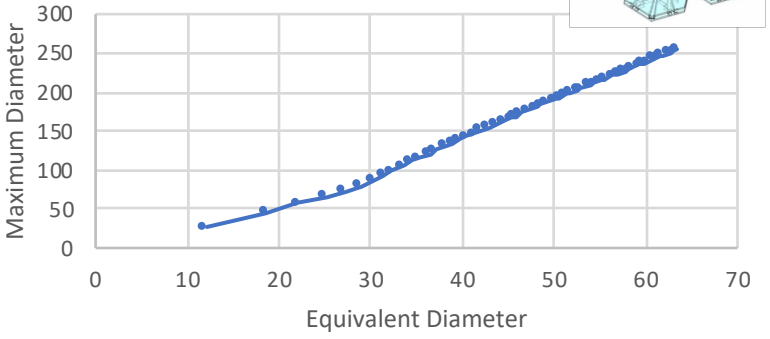


m-D Relation (p-44)

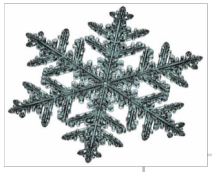


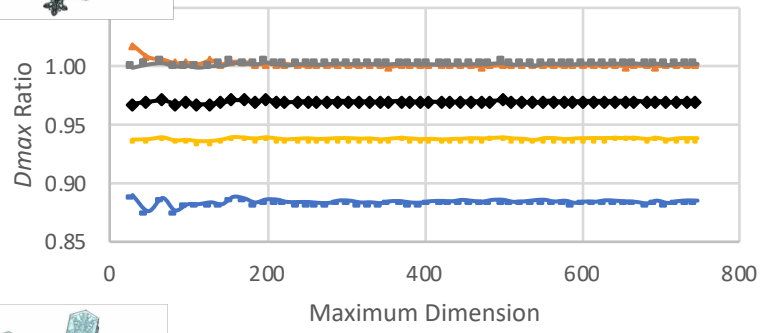


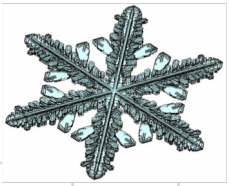
m-D Relation (p-43)

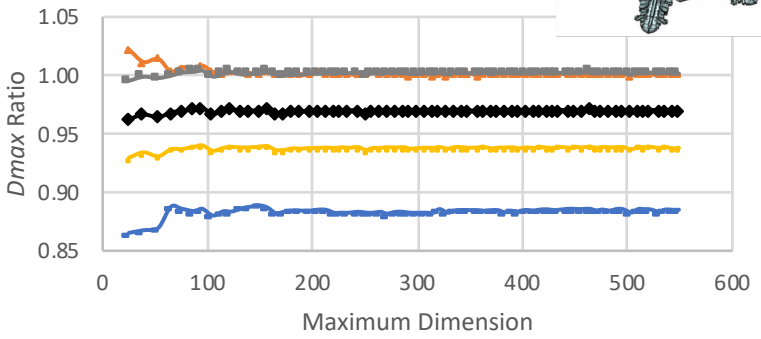


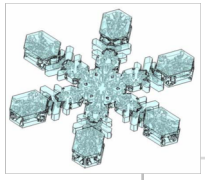
Results – Pristine Particles

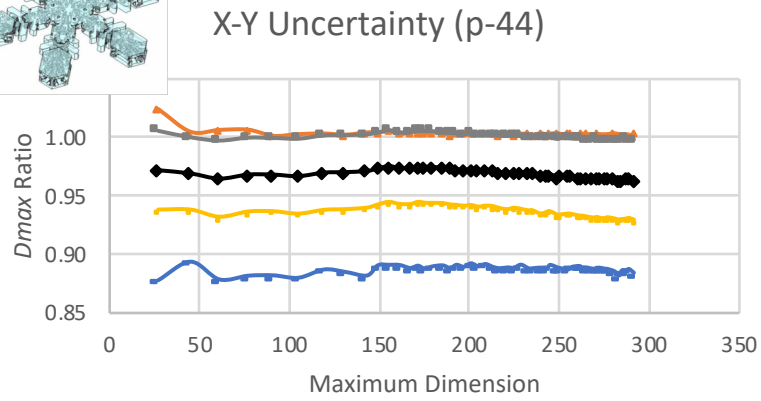


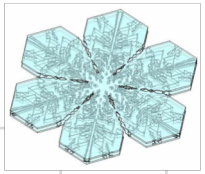


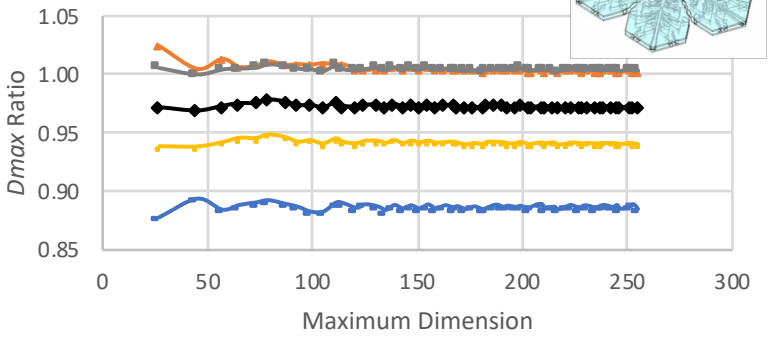




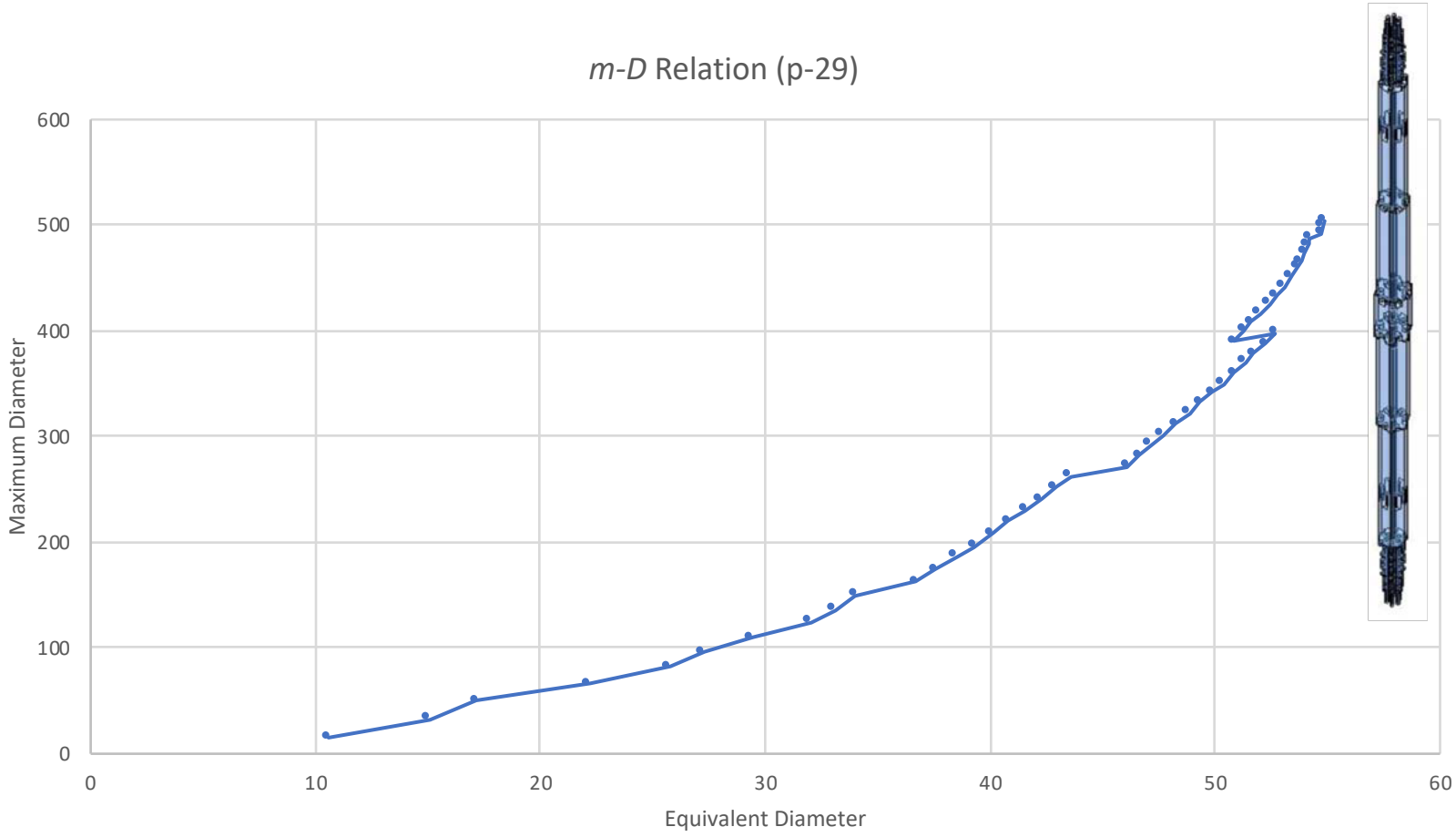








Results – Pristine Particles



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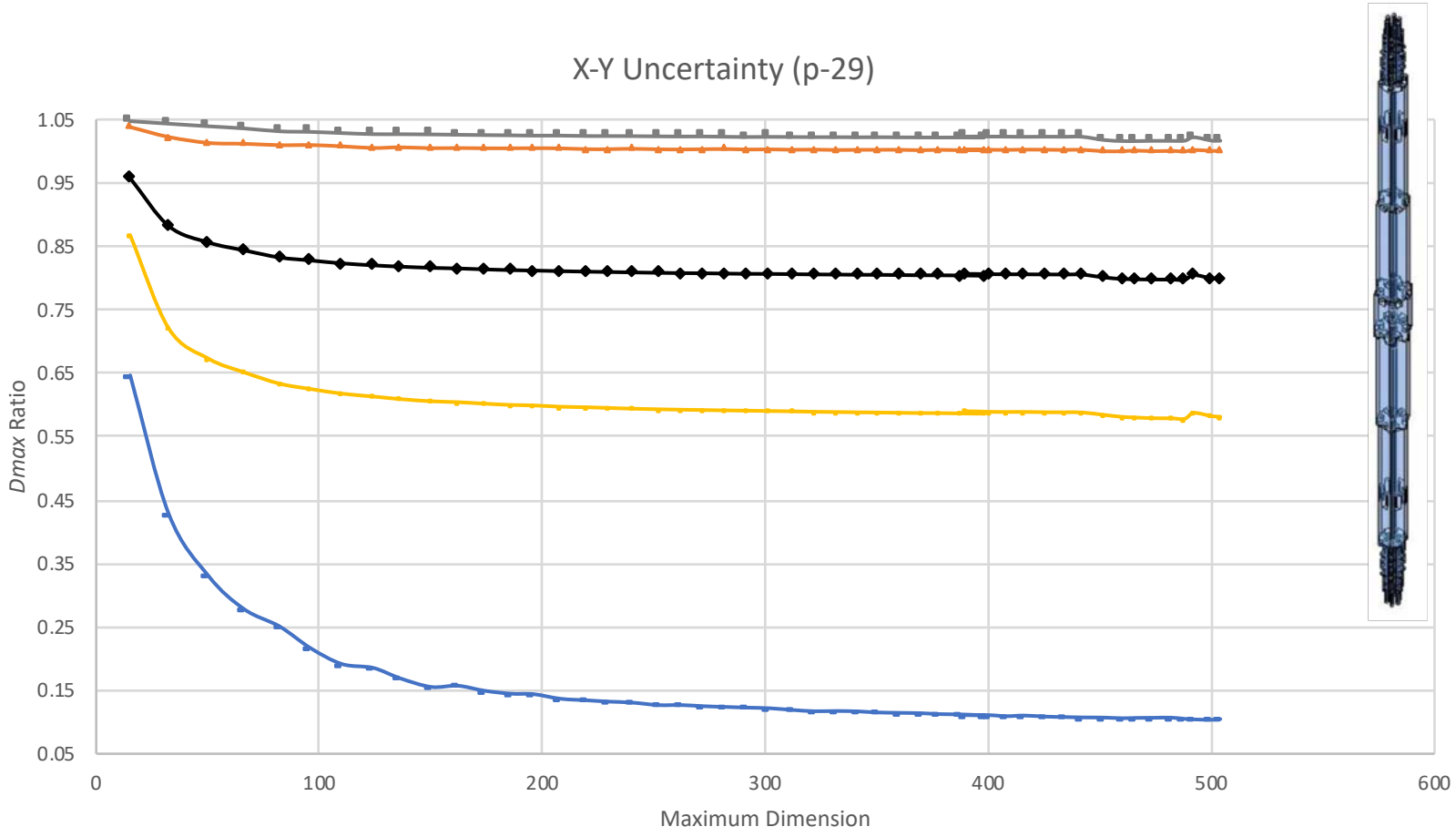

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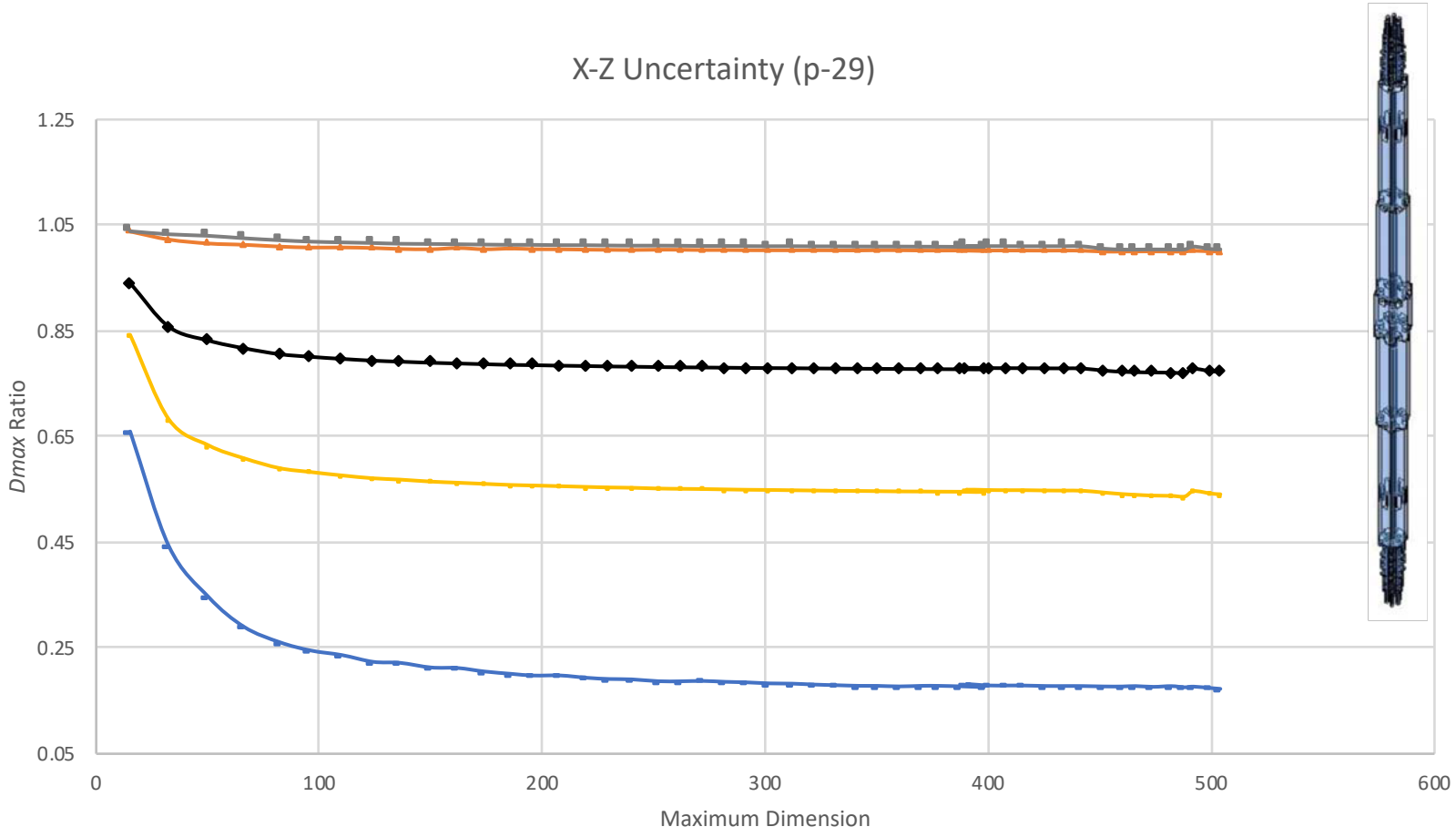
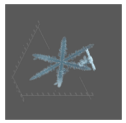
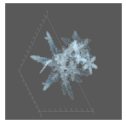
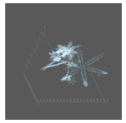
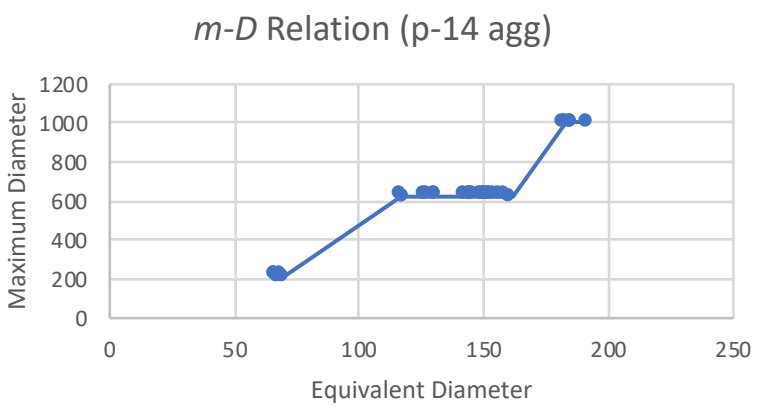


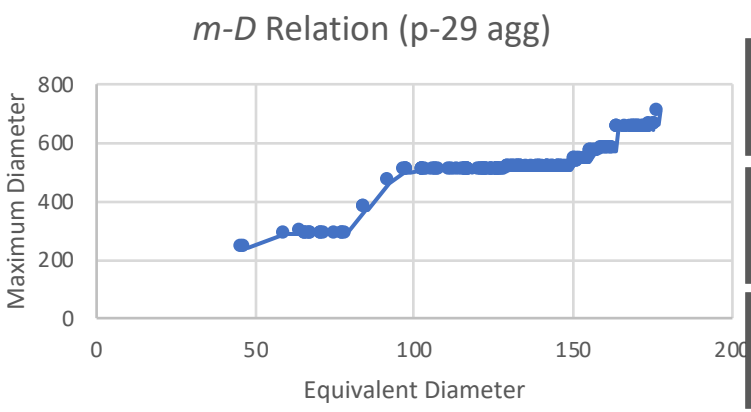
Results – Aggregates

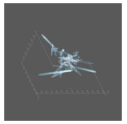


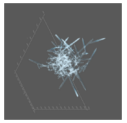


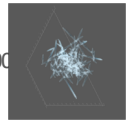


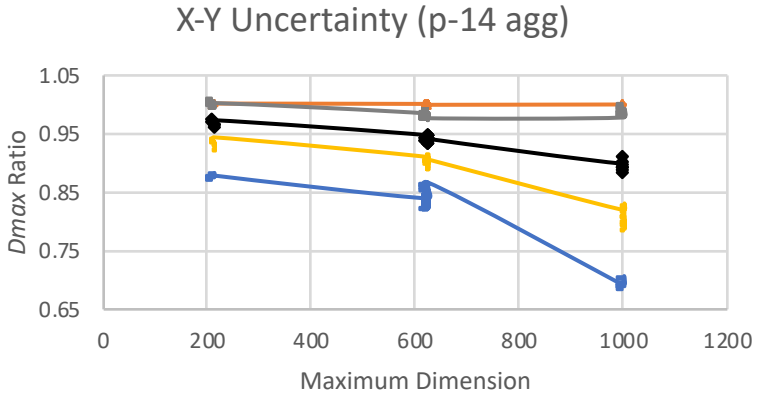


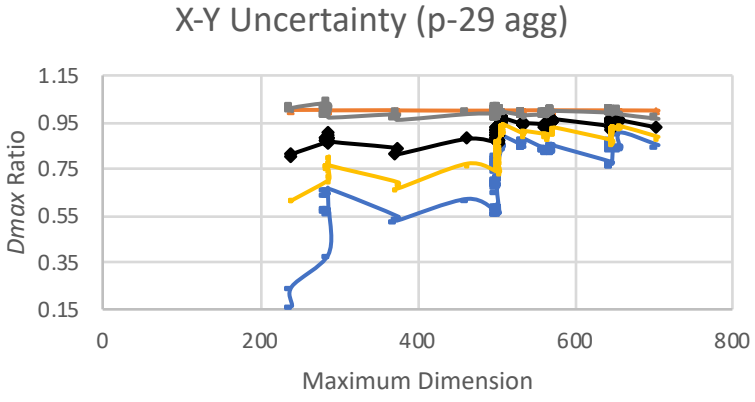












Conclusions

- Remember: Uniformly randomly oriented
- The 2D D_{max} uncertainty depends on particle morphology and size, but not severely.
- For pristine dendrites and sector plates, the uncertainty is generally within 5% (average over 100 orientations).
- For pristine needles, the uncertainty can be quite large (obviously).
- Uncertainty for Aggregates depends more on size.
- Further and more comprehensive investigation is needed.
- Preferentially randomly oriented.

Acknowledgement

- NASA Precipitation Measurement Missions program