The Impact of Varying Definitions of Particle Maximum Dimension on Calculations of Cloud Properties from Optical Imaging Probes

Wei Wu, Greg McFarquhar

Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign

1. Introduction

- Parameterization of ice crystal size distributions (SDs):
  - used in numerical models and retrieval schemes
  - impact latent heat release & radiative heating
  - based on in-situ observations represented as number concentration function N(D) as function of maximum dimension (D)
- Many definitions of D exist for non-spherical particles
- New definition based on the Computational Geometry Algorithm Library (CGAL) is proposed
- Dependence of SDs and calculated bulk properties on definition of D examined

2. Method and Dataset

Method

The following definitions of Ds are used in this study:

- Smallest-circle diameter (D_S) determined from linear time algorithm of CGAL
- Maximum dimension in time direction (D_T) of photodiode array
- Maximum dimension in photodiode direction (D_P)
- $D_A = (D_T + D_P)/2$
- $D_L = \max(D_T, D_P)$
- $D_H = \sqrt{D_T^2 + D_P^2}$

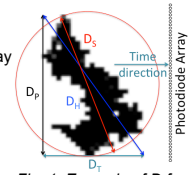

Fig. 1. Example of D for non-spherical particles

Field campaign and data

- Data collected on 20 May 2011 with probes in Table 1 installed on UND Citation during spirals and constant-altitude flight legs during MC3E.
- Using closure and consistency tests, composite SDs defined from 2DC and HVPS, with breakpoint of 1 mm

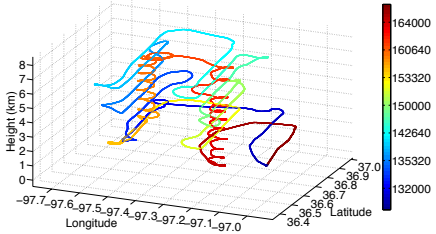

Fig. 2 Flight track of UND Citation, color denoting time

Probe	2DC	HVPS
Resolution	25 um	150 um
# Diodes	32	128
Nominal Range	25 - 800 um	150 - 19200 um
Photos		

Table 1. Description of Microphysical probes installed on UND Citation

3. Size Distributions

- Average SDs in 3 different temperature ranges examined using different definitions of D
- SDs could vary up to an order of magnitude depending on definitions of D
- N(D) differs more when D farther away from mode D of 300 to 500 μm

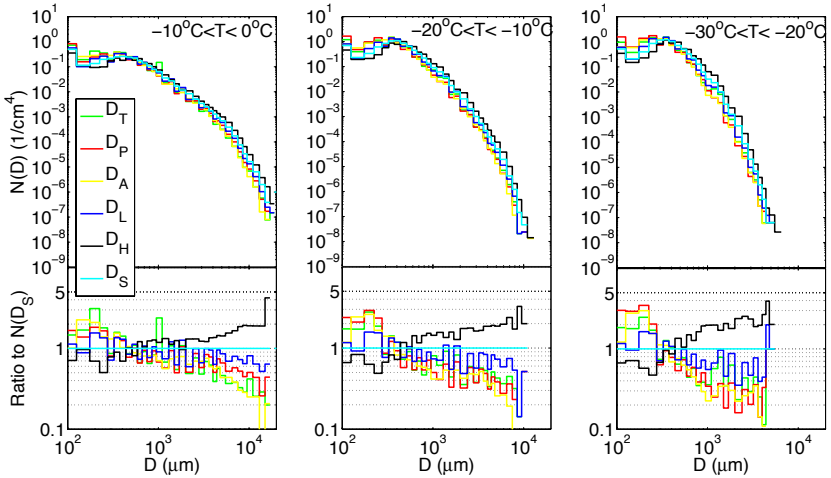

Fig. 3 Number concentrations with different definitions of Ds (upper) and their ratio to N(D_S) (lower) shown for different temperatures.

4. Bulk Properties

Ice water content

- IWC calculated using habit-dependent m-D relations according to different definitions can result in 2-4 times differences (Fig. 4).

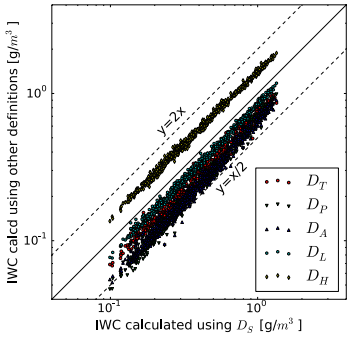

Fig. 4 IWC Calculated using D_S in m-D relations against IWC calculated using other definitions of D

Mass-weighted terminal velocity

- Calculated mass-weighted terminal velocity (V_m) varies up to 5 times according to definition of D.

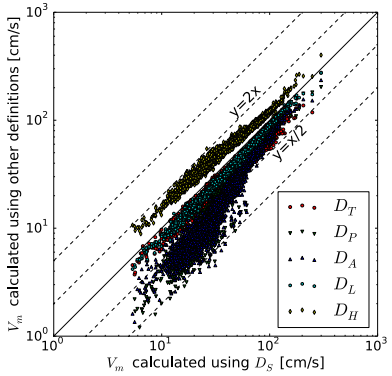

Fig. 5 As in Fig. 4, but for V_m

5. Precipitation rate

Calculated precipitation rates using different definitions of D can vary by up to one order of magnitude.

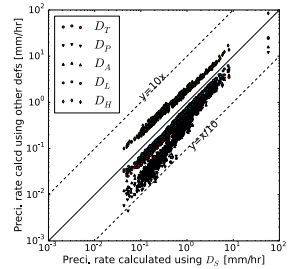

Fig. 6 As in Fig. 4 but for precipitation rate

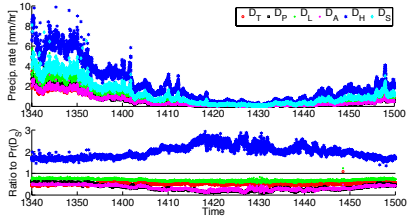

Fig. 7 Precipitation rate change for constant altitude legs using different definitions of D

6. Conclusions

The use of a consistent definitions of D is important because:

- N(D) differ up to 1 order of magnitude
- IWC by 2-4 times
- Terminal velocity up to 5 times
- Precipitation rate by up to 1 order of magnitude

Based on this study, it is recommended to use D_S as the maximum dimension.

7. Acknowledgments

The work was supported by the office of Biological and Environmental Research (BER) of the U.S. Department of Energy (DE-SC0001279 and DE-SC0008500). Data obtained from the ARM program archive, sponsored by the U.S. DOE Office of Science, BER, Climate and Environmental Sciences Division.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ASR Atmospheric System Research

U.S. DEPARTMENT OF ENERGY