UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Impacts of varying small ice crystal shapes and concentrations on bulk scattering properties of tropical cirrus

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Outline

I. Motivation

II. Measurements from TWP-ICE

III. Small ice crystal models

IV. Results

V. Summary

I. Introduction

1. Motivation

Concentration

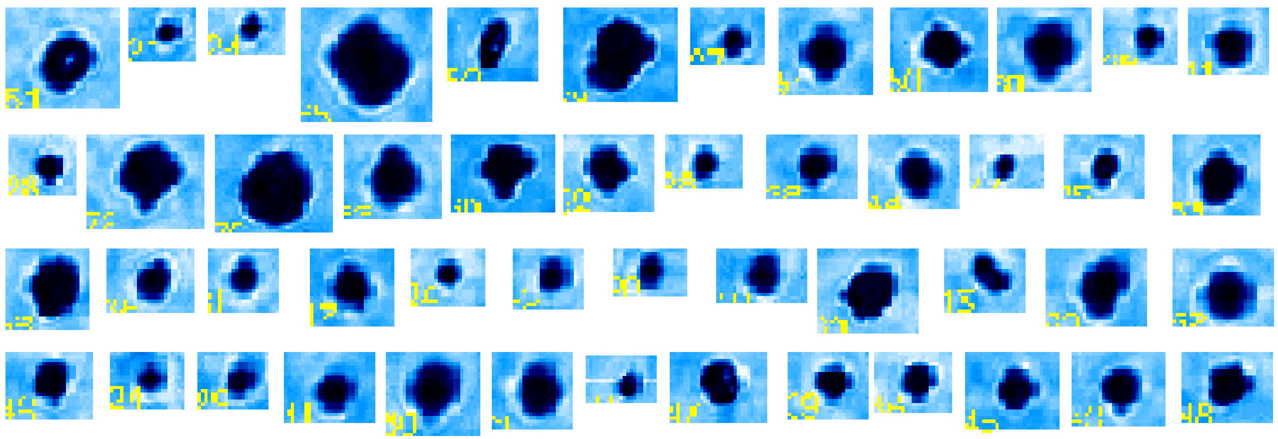
- ✓ Shattering of large ice crystals may enhance concentrations of small ice crystals (D < ~ 50 μm)

- ✓ GCM simulations with high concentration of small ice crystals
  +12% global ice cloud amount
  - 5 W m^{-2} cloud forcing in Tropics

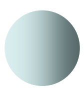
I. Introduction

1. Motivation

Small Ice Crystals



100 μm



Sphere (old studies)

Chebyshev particle (McFarquhar et al., 2002)

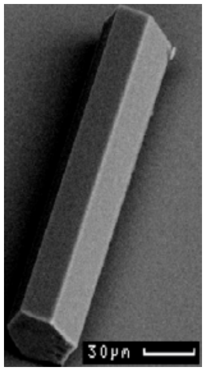
Droxtal (Yang et al., 2003)

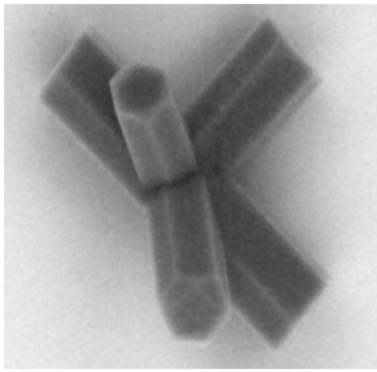
Gaussian random sphere (Nousiainen and McFarquhar, 2004)

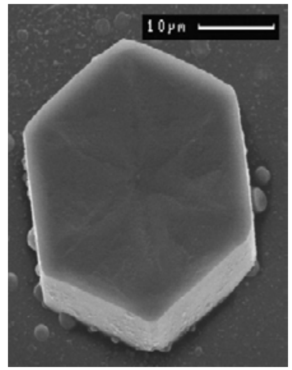
I. Introduction

1. Motivation

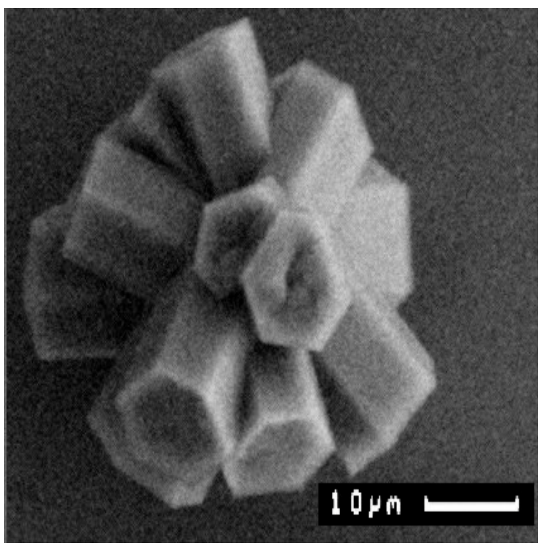
Ice Analogues





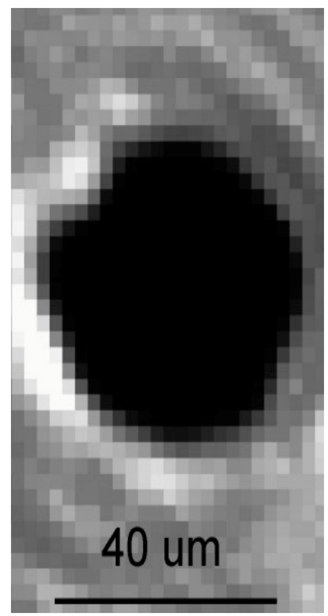


The ice analogues were crystalline particles of sodium fluorosilicate Na_2SiF_6 grown from solution on glass substrates

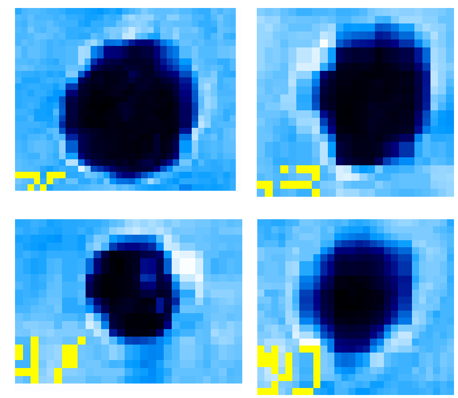


Electron microscopy image of ice analogue

CPI



Ulanowski et al. (2009)



Quasi-spheres ??

I. Introduction

1. Motivation

Shape

- ✓ **Several idealized models represent shapes of small ice crystals**
  - Chebyshev particle, droxtal, Gaussian random sphere

- ✓ **State-of-art cloud probes cannot distinguish shapes of small ice crystals**

- ✓ **98.45 % particles were 1 particle/frame in CPI, suggests shattering not responsible for observed small crystals on CPI during TWP-ICE**

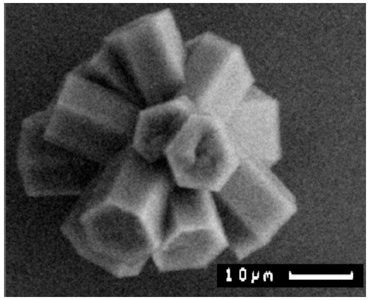
I. Introduction

1. Motivation

Q. What are impacts of small crystal shape and concentration on bulk scattering properties of cirrus?

II. Idealized models

Budding Bucky Ball (3B)



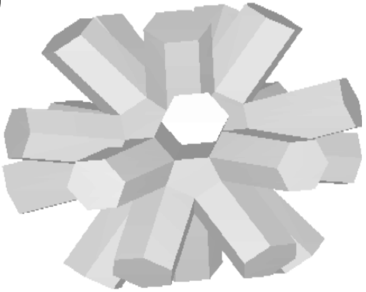
Ice Analogue

Idealized Model

a)

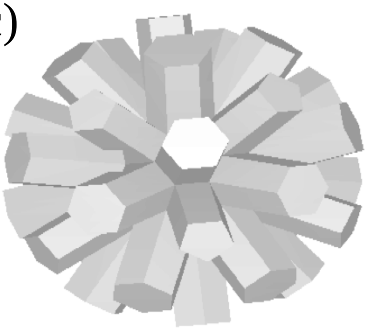
Core

b)



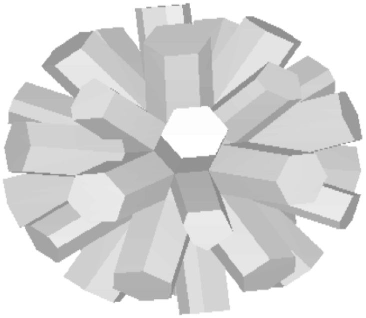
3B with 20 regular Hexagonal columns

c)



3B with 20 regular Hexagonal & 12 pentagonal columns

d)



3B with 20 regular & 12 irregular hexagonal columns

II. Idealized models

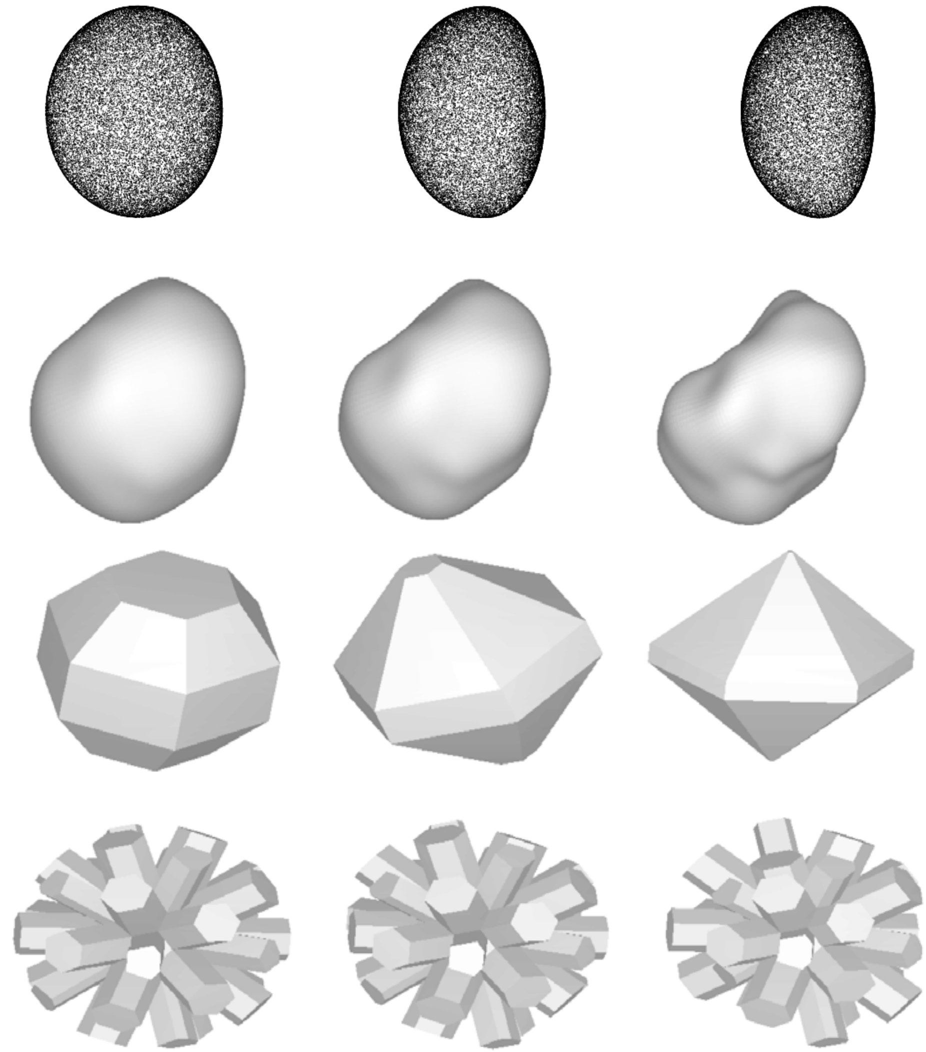
Area ratio	0.85	0.77	0.69

Chebyshev particles

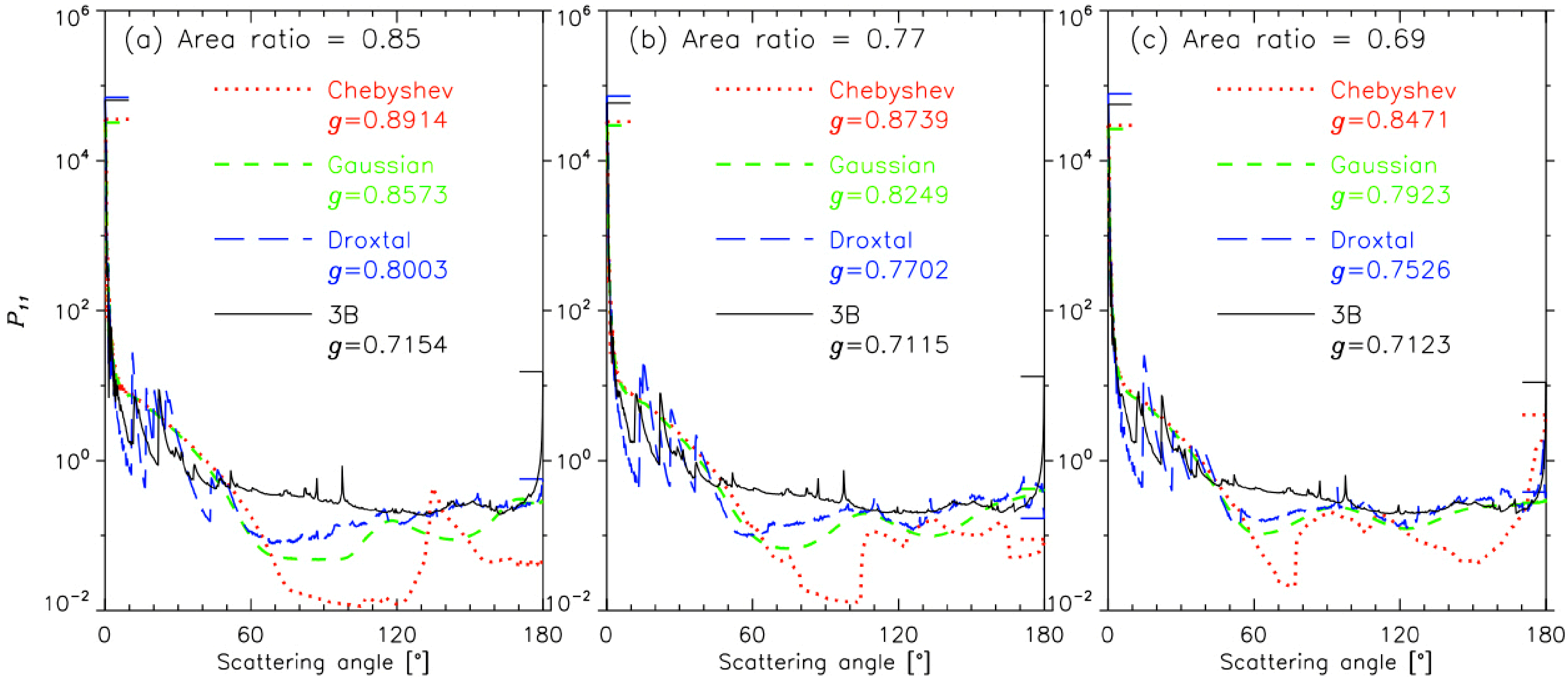
Gaussian random spheres

Droxtals

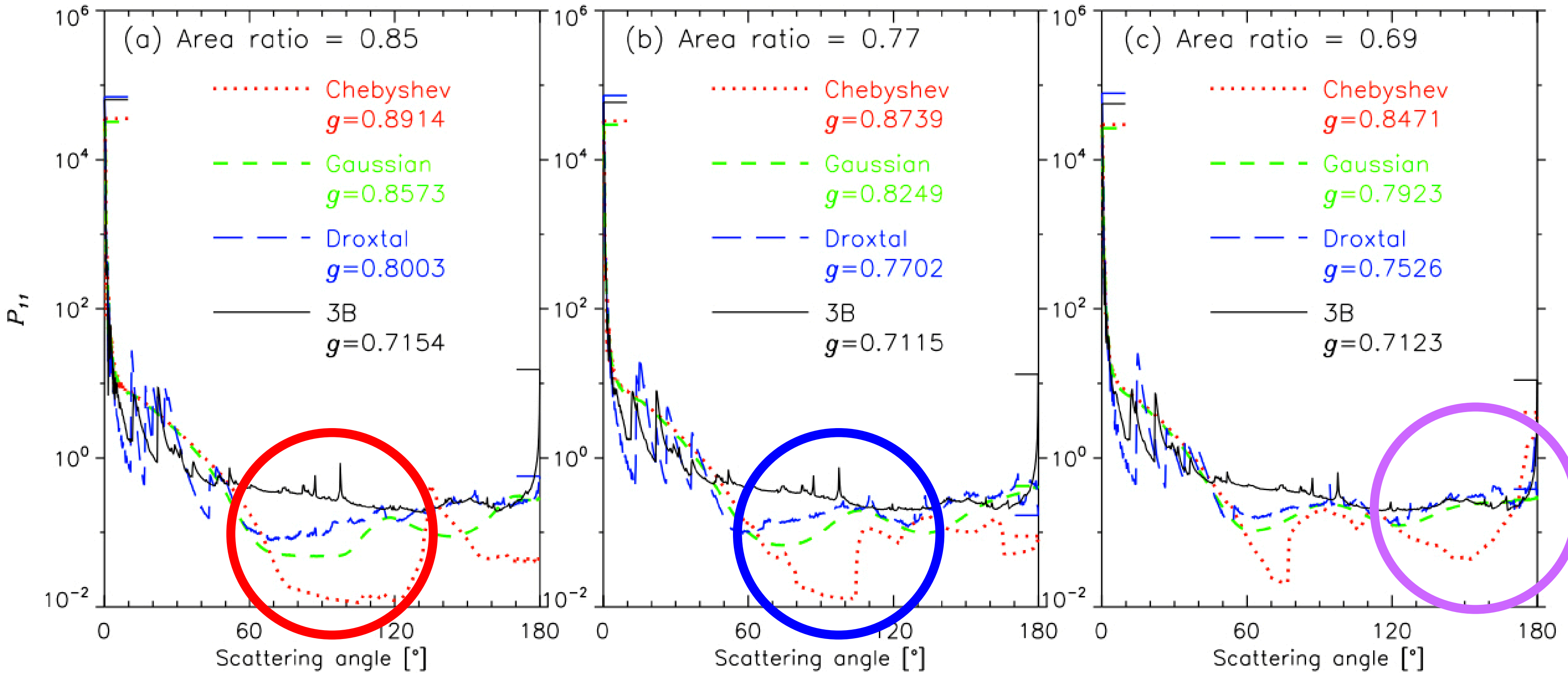
Budding Bucky ball (3B)



III. Single-scattering properties

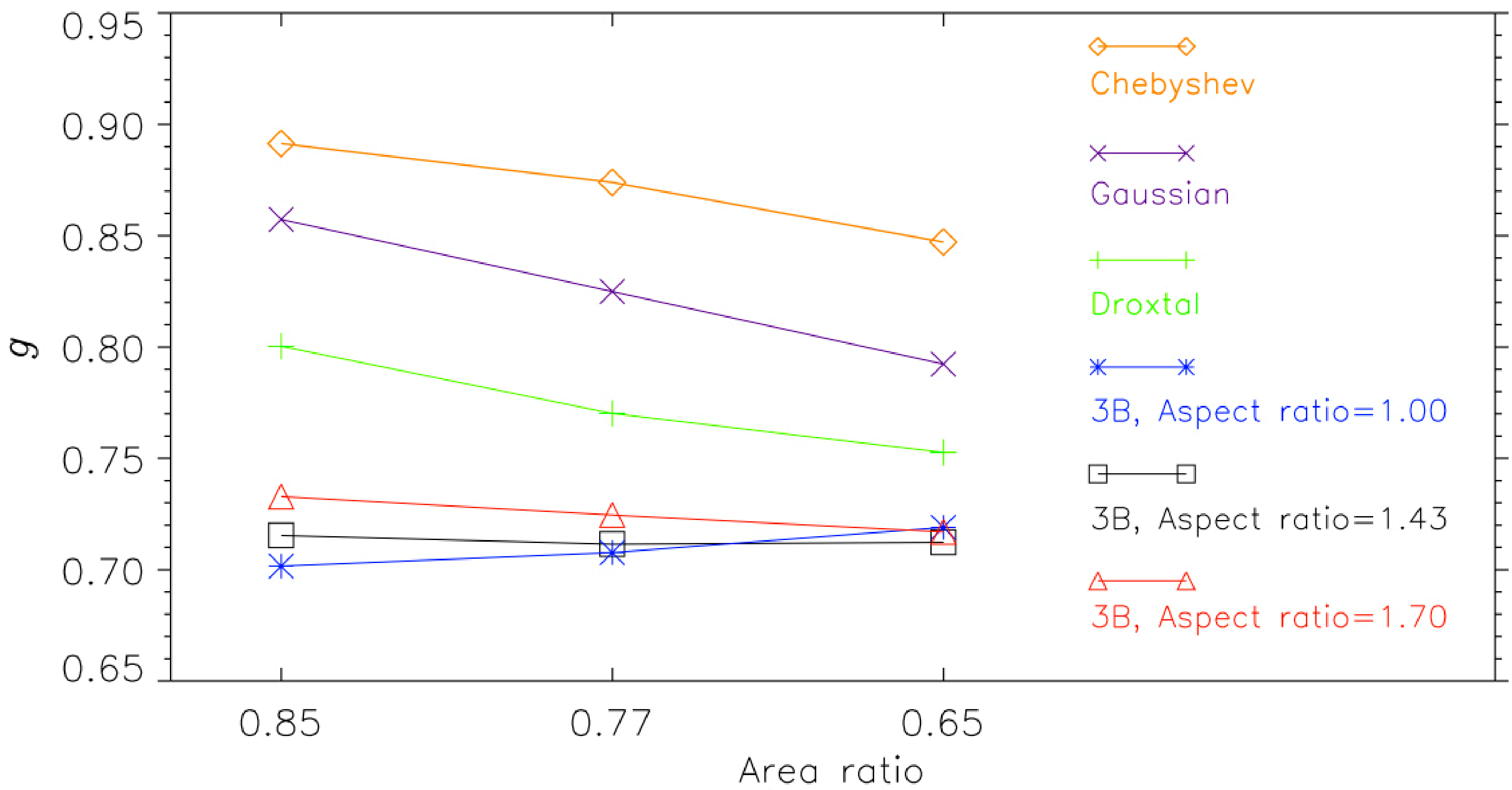


III. Single-scattering properties



- **For area ratio of 0.85, differences are 21.6%, 993.8%, and 131.7% in forward, lateral, and backward direction**
- **For area ratio of 0.77, differences are 20.2%, 509.8%, and 101.3%**
- **For area ratio of 0.69, differences are 16.1%, 146.5%, and 156.1%**

III. Single-scattering properties

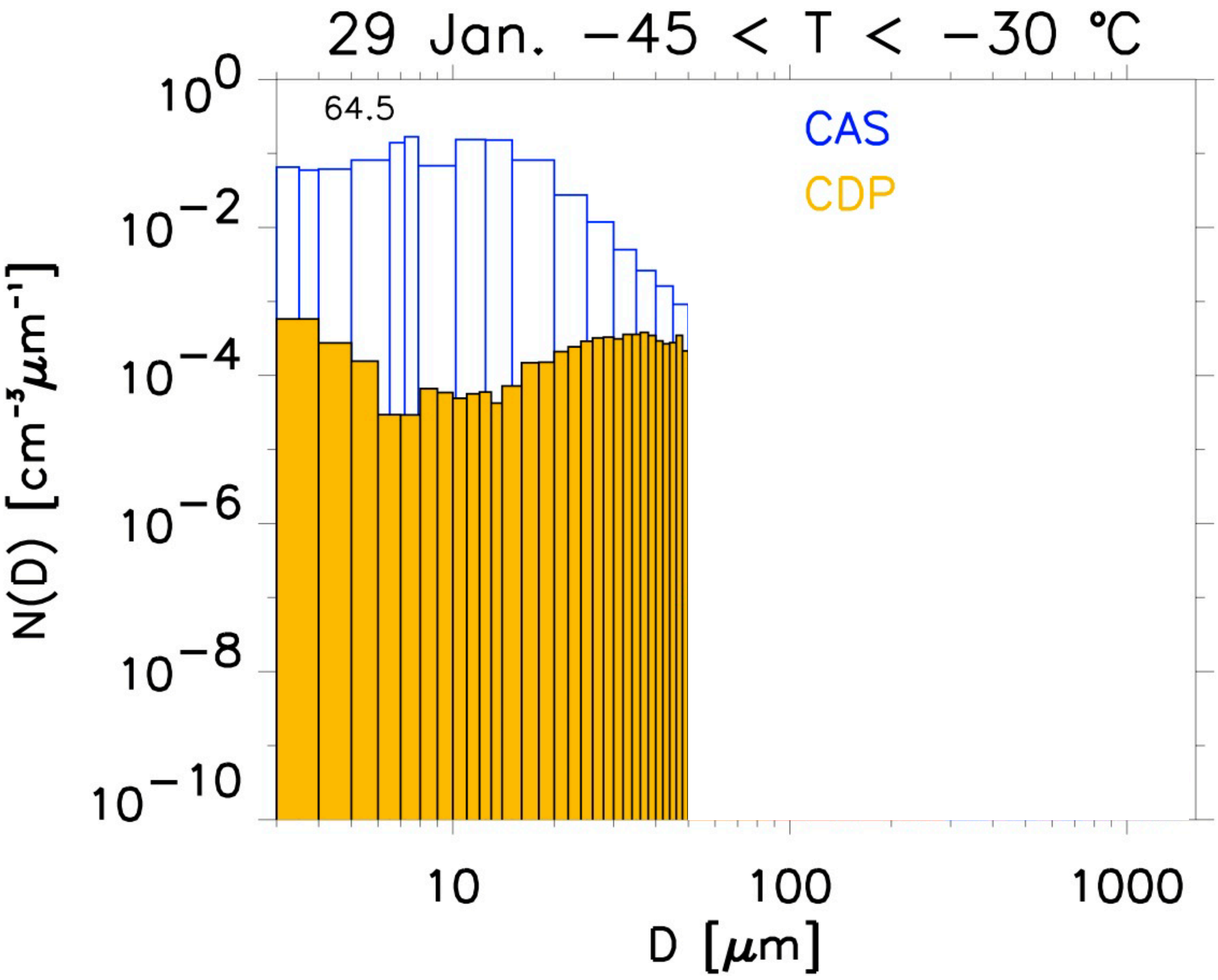


- **The g varies by up to 24.6%, 22.8%, and 18.9% for area ratio of 0.85, 0.77, and 0.69**

IV. Measurements

Size Distributions

D < 50 μm
CAS (upper bound),
CDP (lower bound),
or No small

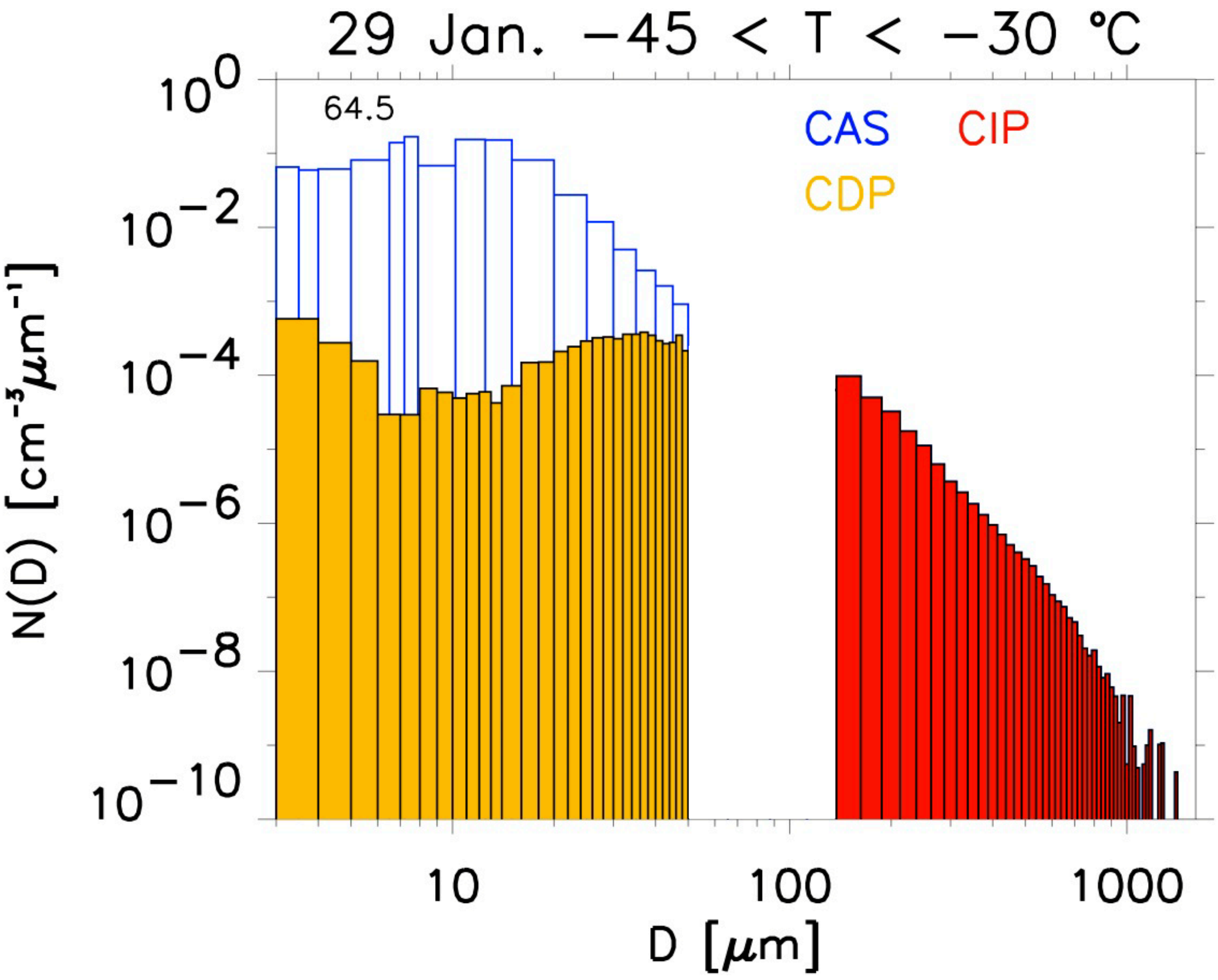


IV. Measurements

Size Distributions

D < 50 μm
CAS (upper bound),
CDP (lower bound),
or No small

D > 125 μm
CIP



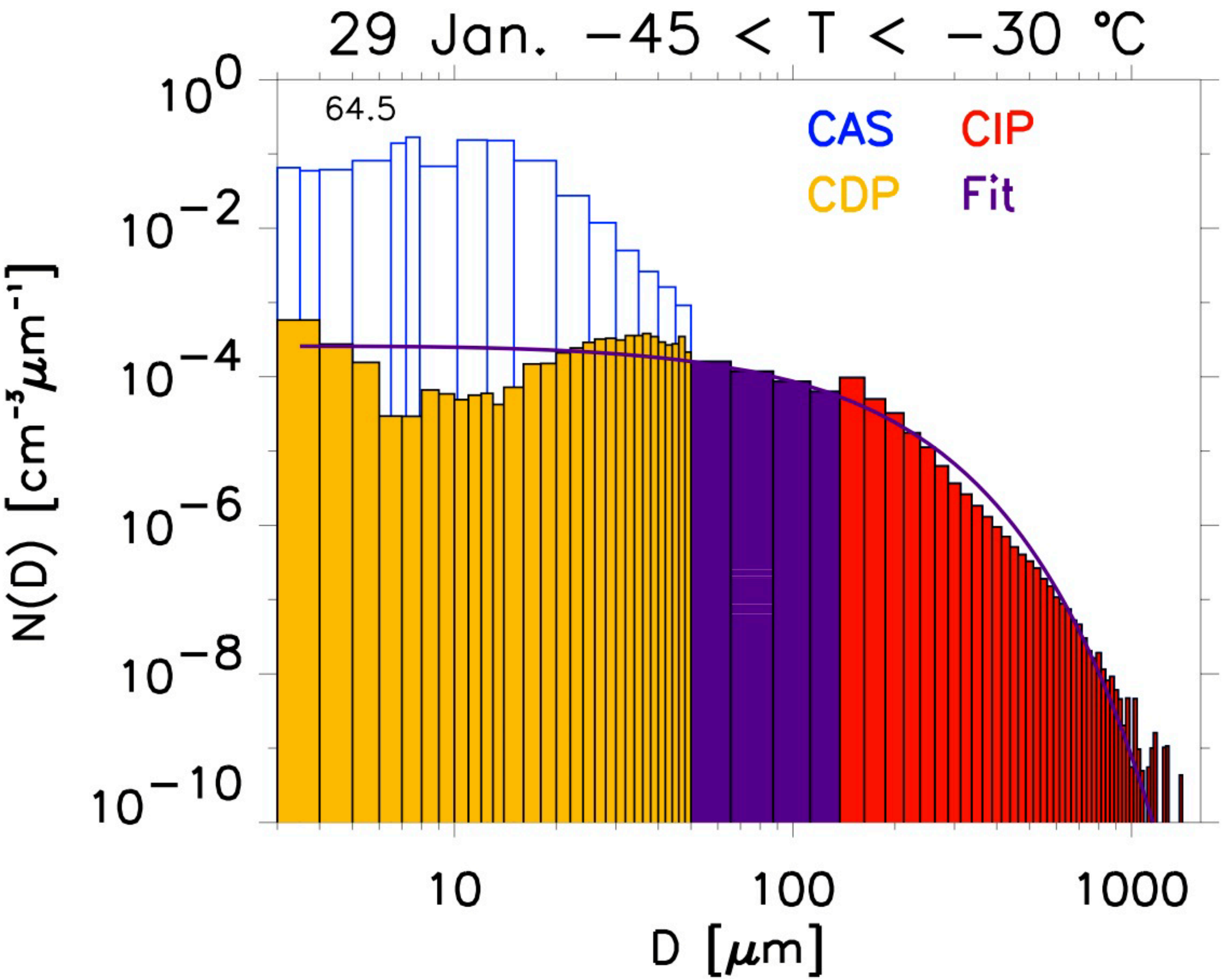
IV. Measurements

Size Distributions

D < 50 μm
CAS (upper bound),
CDP (lower bound),
or No small

D > 125 μm
CIP

50 < D < 125 μm
Fit



IV. Measurements

Size distributions: 3 representations

- ✓ CDP + FIT + CIP
- ✓ CAS + FIT + CIP
- ✓ FIT + CIP (no small)

V. Results

Mean P_{11}

[redacted]

DP+FIT+CIP

NS: No small ice crystals

SP: sphere

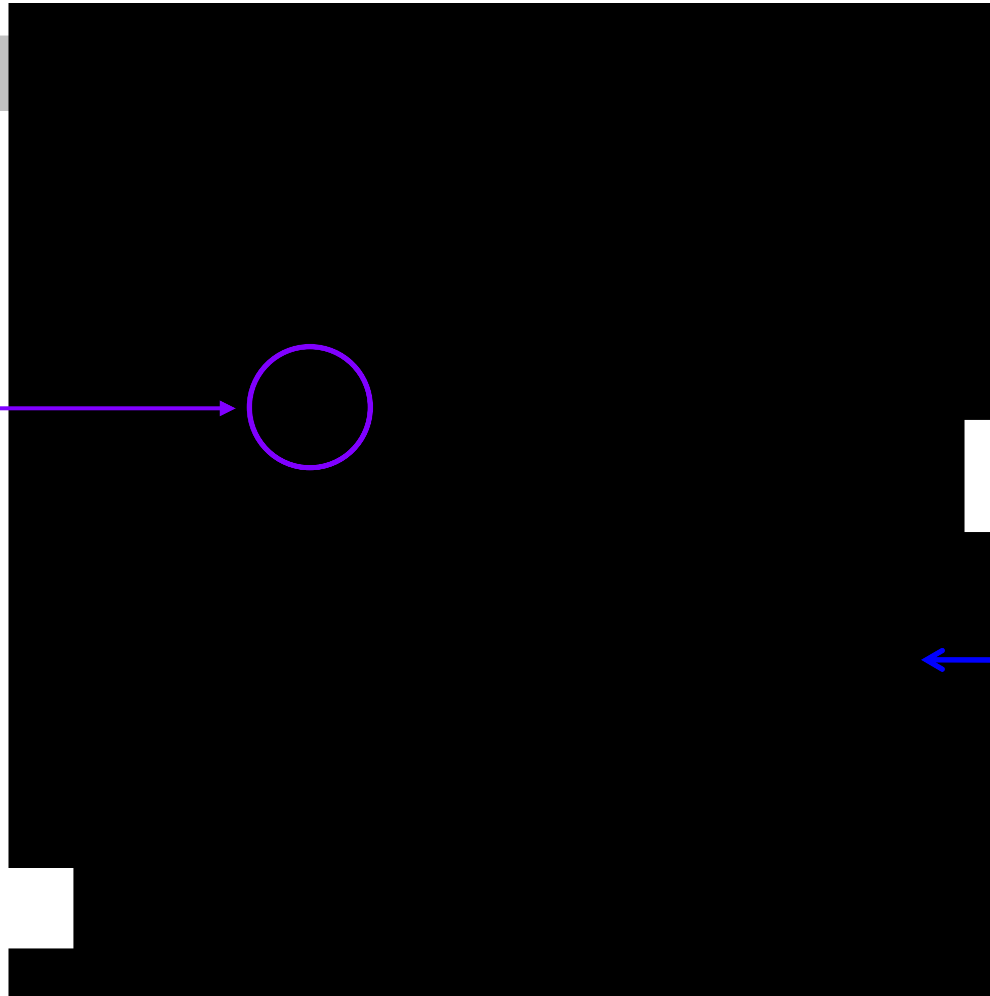
3B : Budding Bucky ball

DX: Droxtal

GS: Gaussian random sphere

V. Results

Mean P_{11}



CDP+FIT+CIP

Contributions of pristine ice crystals are larger

SP differs most from other models

NS: No small ice crystals

SP: sphere

3B : Budding Bucky ball

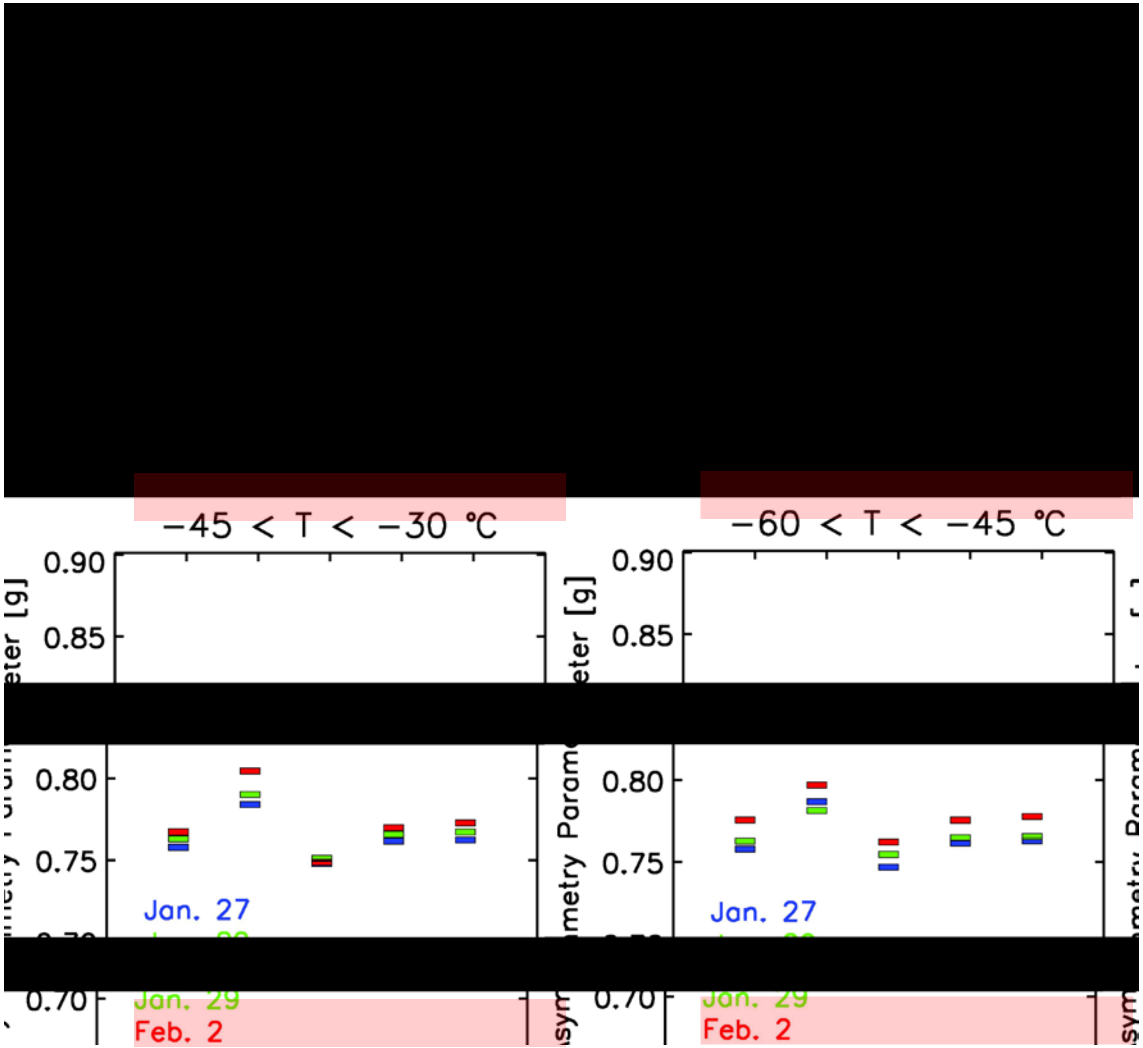
DX: Droxtal

GS: Gaussian random sphere

V. Results

Mean g

CDP+FIT+CIP



4 models
+
No small

V. Results

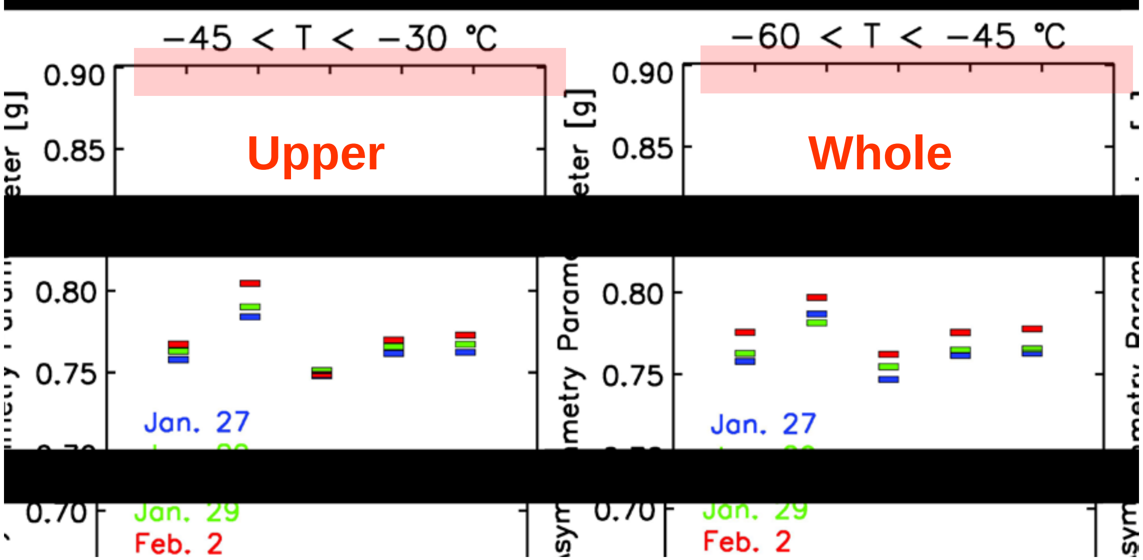
Mean g

CDP+FIT+CIP

[redacted]

Lower

Middle



Upper

Whole

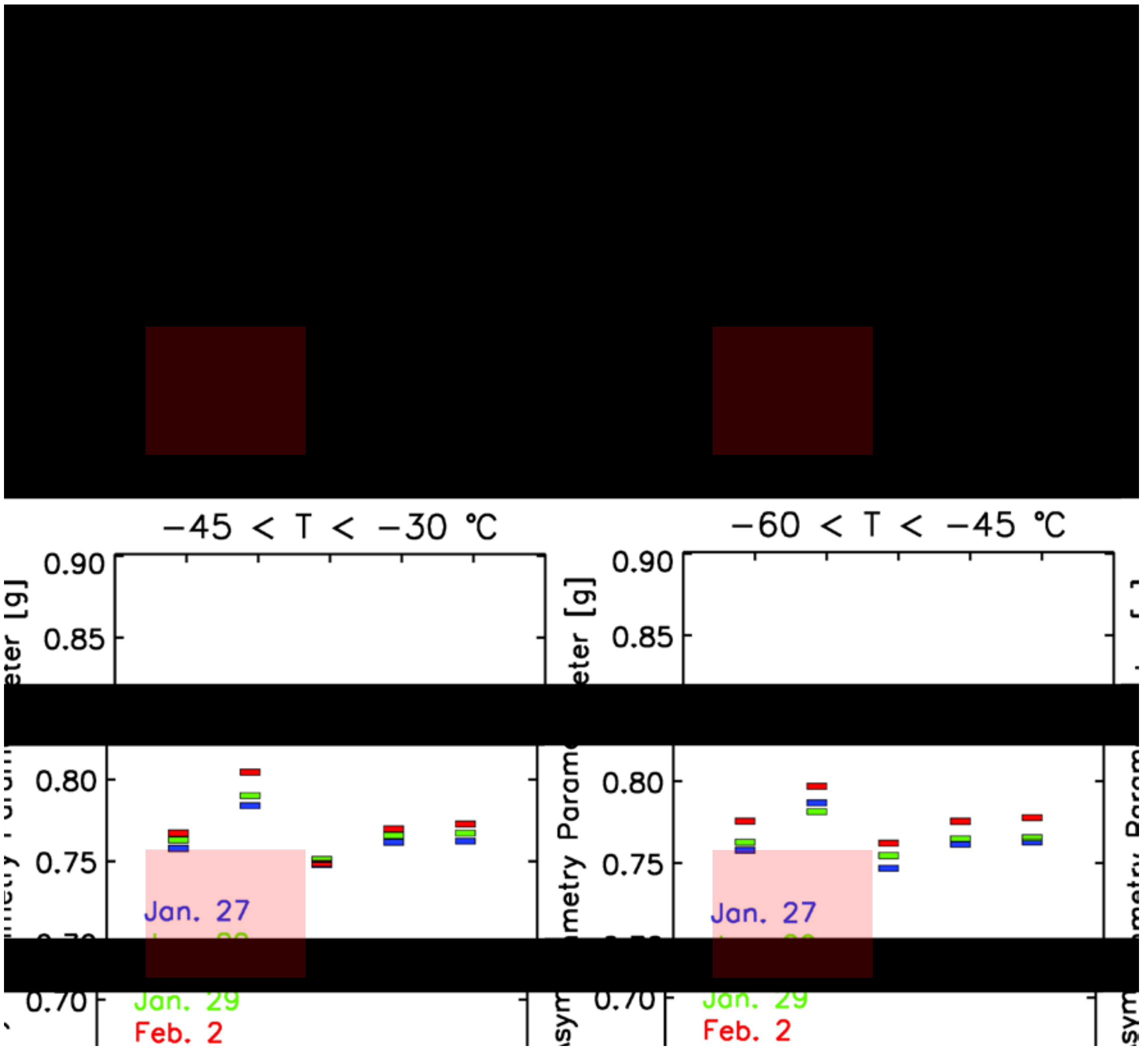
[redacted]

4 Temperature

V. Results

Mean g

CDP+FIT+CIP

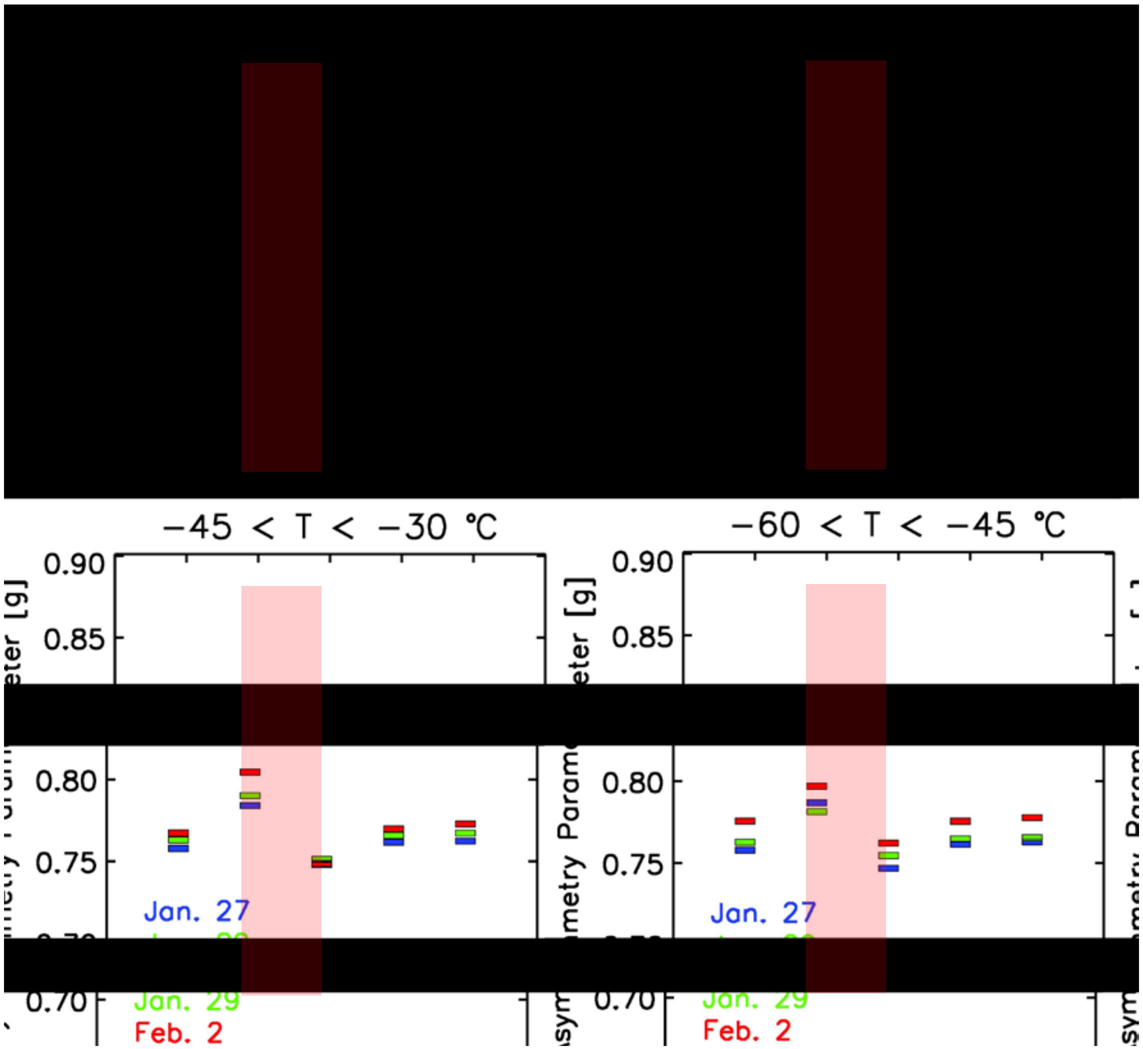


3 Days

V. Results

Mean g

CDP+FIT+CIP



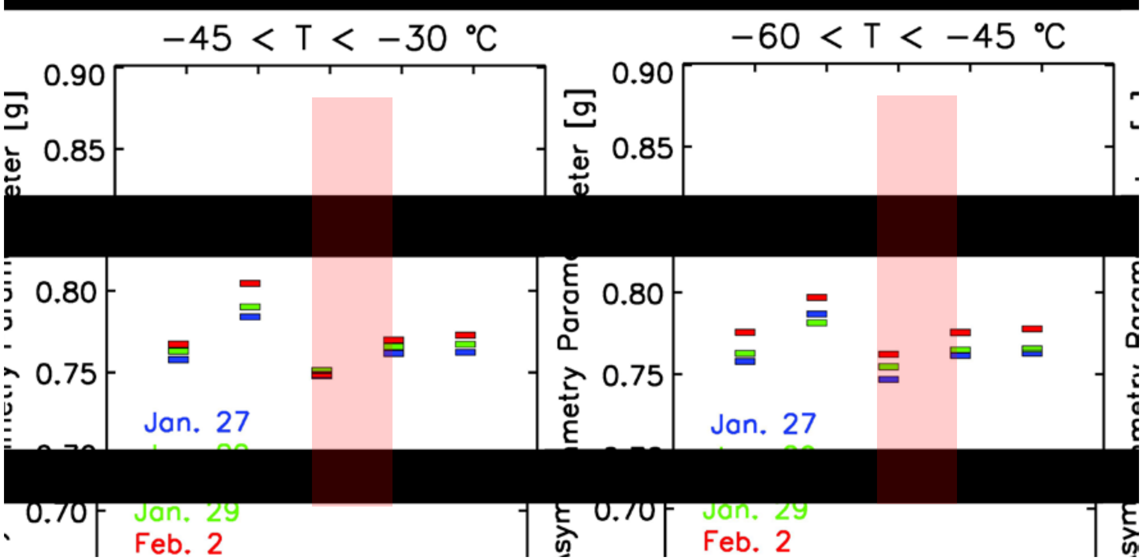
SP, highest g

IV. Results

Mean g

CDP+FIT+CIP

[redacted]

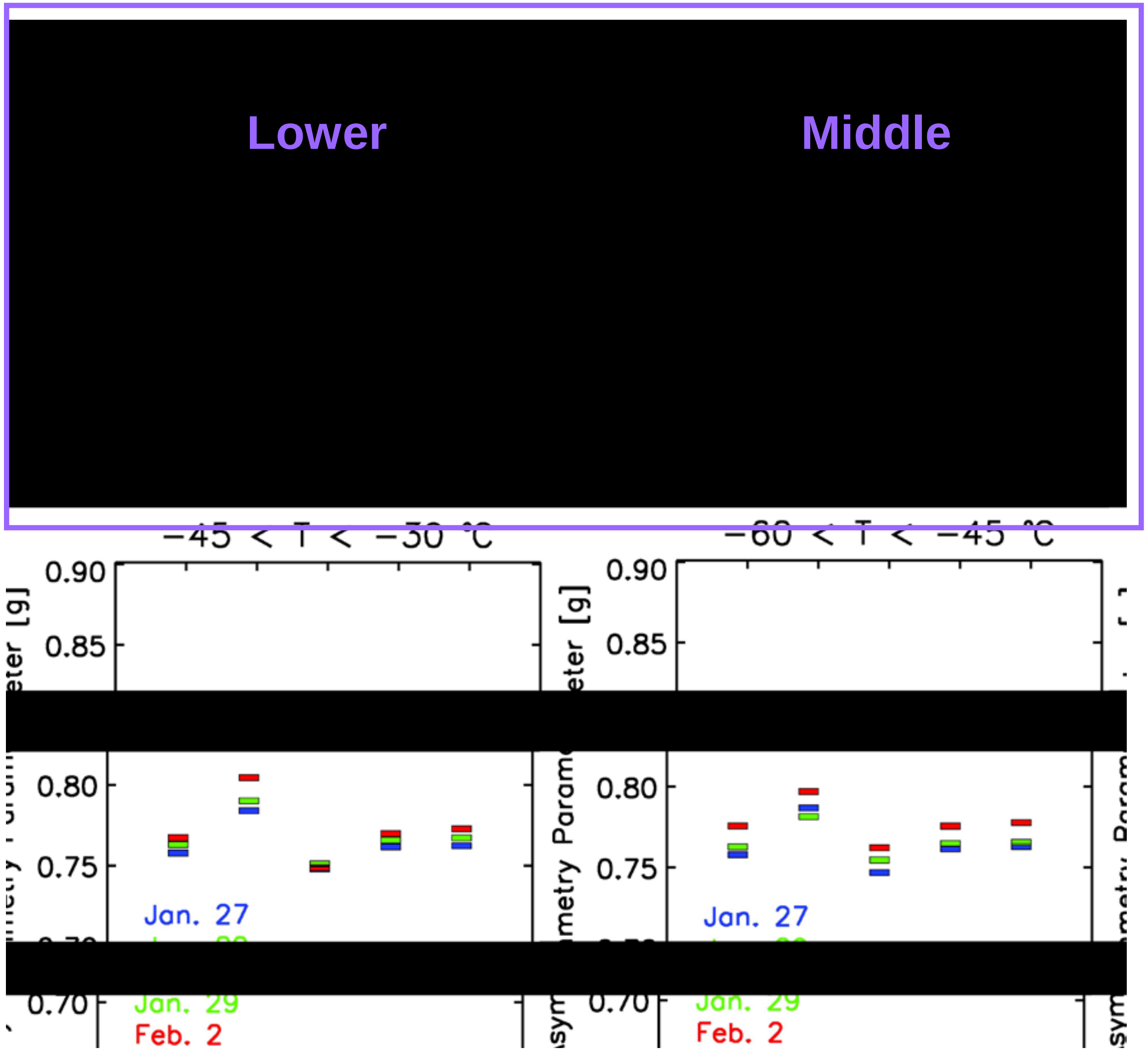


3B, lowest g

IV. Results

Mean g

CDP+FIT+CIP



Mean g for 2 Feb. Is larger

Contribution of small crystal are smaller

V. Results

Impact of Shape

✓ **Difference in mean g for different small crystal models using CAS+FIT+CIP larger than that using CDP+FIT+CIP:**

- 16.7 % (SP), 5.4 % (DX), 7.8 % (GS), Jan. 27

VI. Summary

- ✓ Up to 21.6% (993.8% and 156.1%) difference in forward (lateral and backward) direction
- ✓ Up to 24.6%, 22.8%, and 18.9% difference in g area ratios of 0.85, 0.77, and 0.69
- ✓ Up to 17% difference in mean g depending on shape and *N* of small ice crystals
- ✓ Impacts of different models largest at lower temperatures & higher concentrations of small ice crystals
- ✓ Impacts of enhanced *N* largest at higher temperatures
- ✓ Impacts on bulk scattering depend heavily on assumed models for small ice crystals
- ✓ Higher resolution cloud probe neede