Derivation of Ice Parameters Relevant to ASR Modeling Efforts & Quantification of Uncertainties

G. McFarquhar[1], J. Um[1], T.-L. Hsieh[1], M. Freer[1], B. Jewett[1], J. Mascio[1], K. Yaffe[1], T. Nousiainen[2], J. Tiira[2], H. Lindqvist[2], A. Schwarzenboeck[3] and A. Delplanque[3]

[1]University of Illinois, Urbana, IL

[2]University of Helsinki, Helsinki, Finland

[3]Université Blaise Pascal, Clermont-Ferrand, France

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Overall Objective of Proposed ICEPRO Focus Group

- **Better characterize ice physical properties & processes by establishing linkage between observed ice properties (means, distributions) & models (covering variety of scales) used to investigate how cloud radiative properties change with environmental conditions**

- **ICEPRO focuses on**
  1. **Establishing how uncertainties in ice properties affect associated process rates & model results**
  2. **Quantifying uncertainties from in-situ data that serve as basis for model parameterizations of mass-based ice crystal properties**

Available Data on Ice μphysics

- Large databases exist with varying accuracies
  - Not known how properties vary by location, cloud type, formation mechanism, vertical motion, dynamics, meteorology, etc.
  - Such knowledge needed for process-oriented understanding & parameterization development
- Additional data in variety of conditions needed
  - properties of individual crystals & global populations
  - Need uncertainties associated with properties
  - Need to investigate optimal representations in models with variety of scales

Representations of ice μphysics

- **Single-particle properties:**
  - Aspect ratios, masses, areas of ice crystals
  - Surface roughness and its effect on optics
  - Fall velocities, scattering properties
- **Particle distributions**
  - M-D & A-D relations used in μphysics & optics
  - Size distributions, $N(D)=N_0 D^{\mu} e^{-\lambda D}$
  - Habit distributions, Effective diameter, mass-weighted velocity, scattering properties, process rates, etc.
- **How do uncertainties cascade to larger scales?**
- **How do properties vary by location, cloud type, vertical motion, dynamics, meteorology, etc.**

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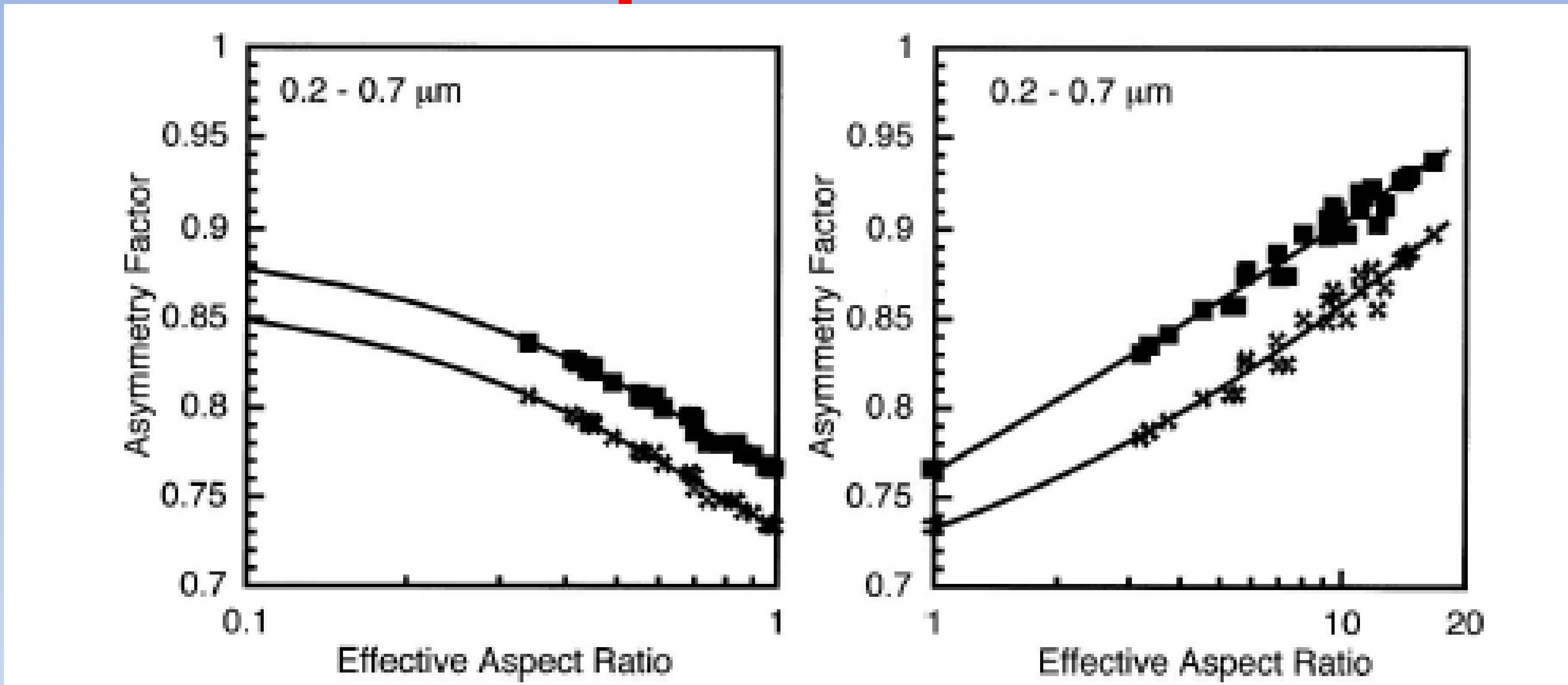
Aspect Ratios



- **Fu (2007): Aspect ratio α is key parameter for determining g for solar radiation (along with effective size)**

  → Need more data on a for single particles and controls of its variance

Aspect Ratios

- **α for pristine habits (columns, bullets, bullet rosettes) can be determined from 2.3 μm resolution CPI images**

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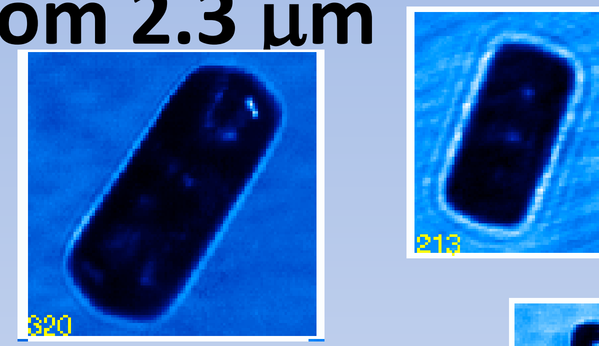

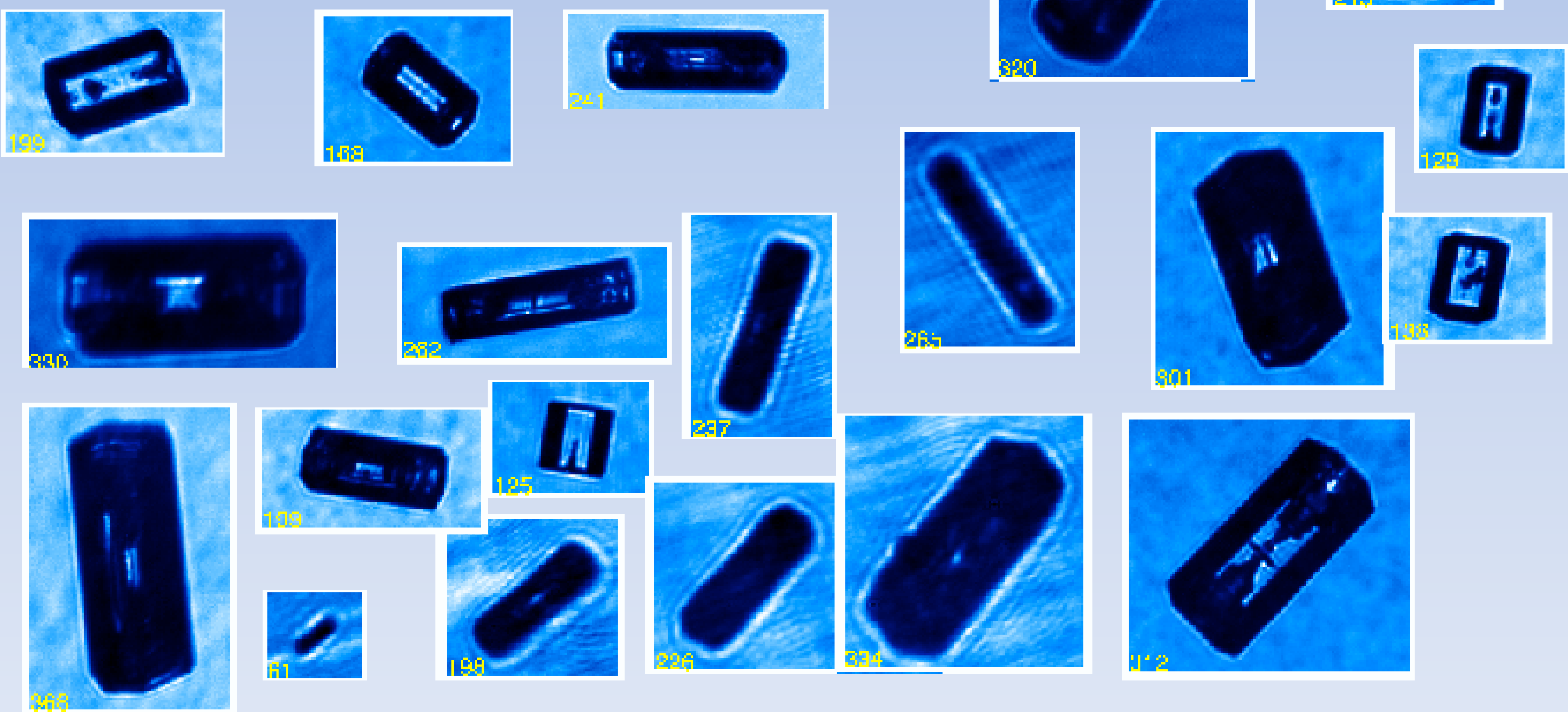

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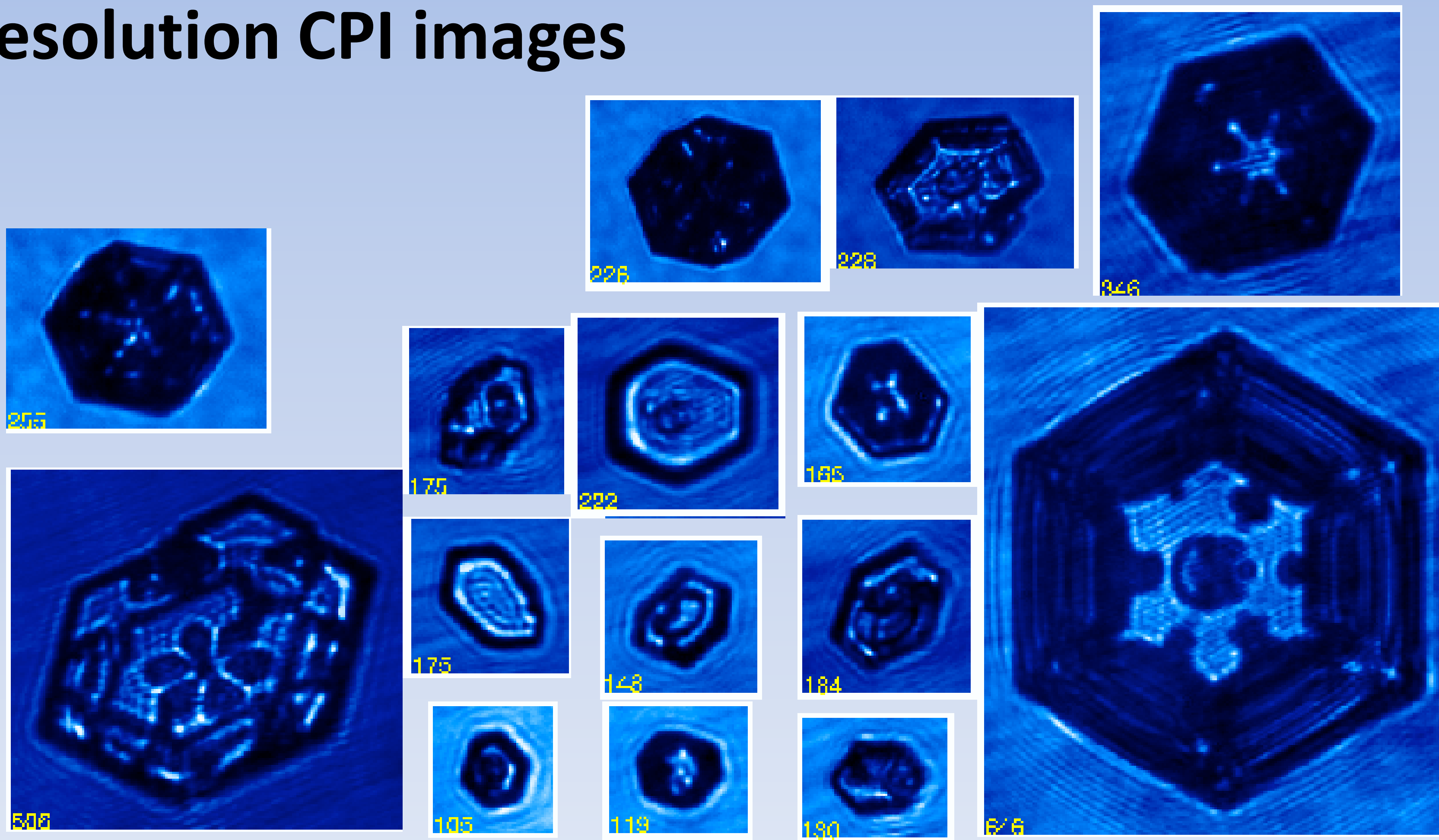

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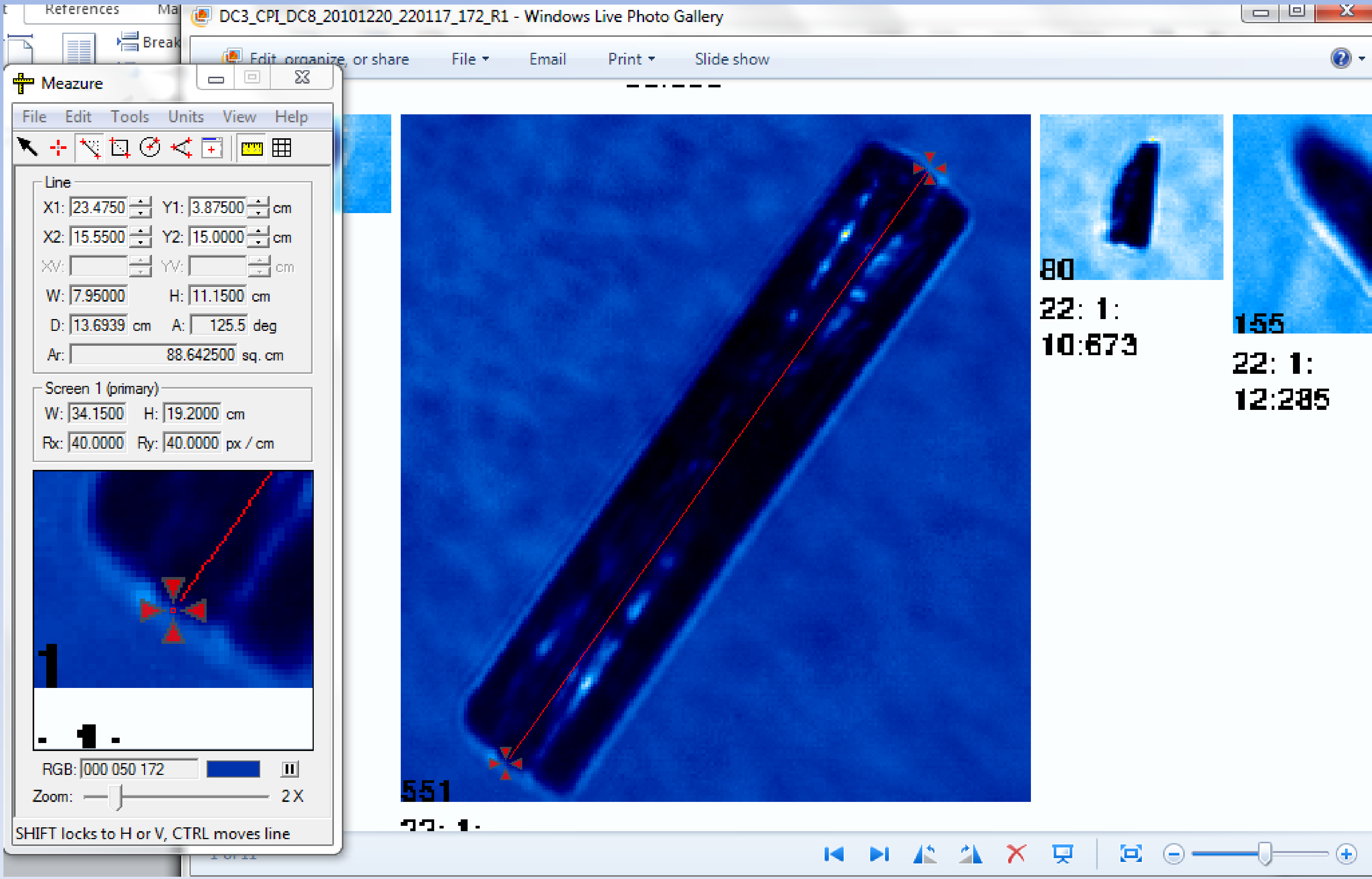
Aspect Ratios

- **Harder to get α for more complex crystal habits**

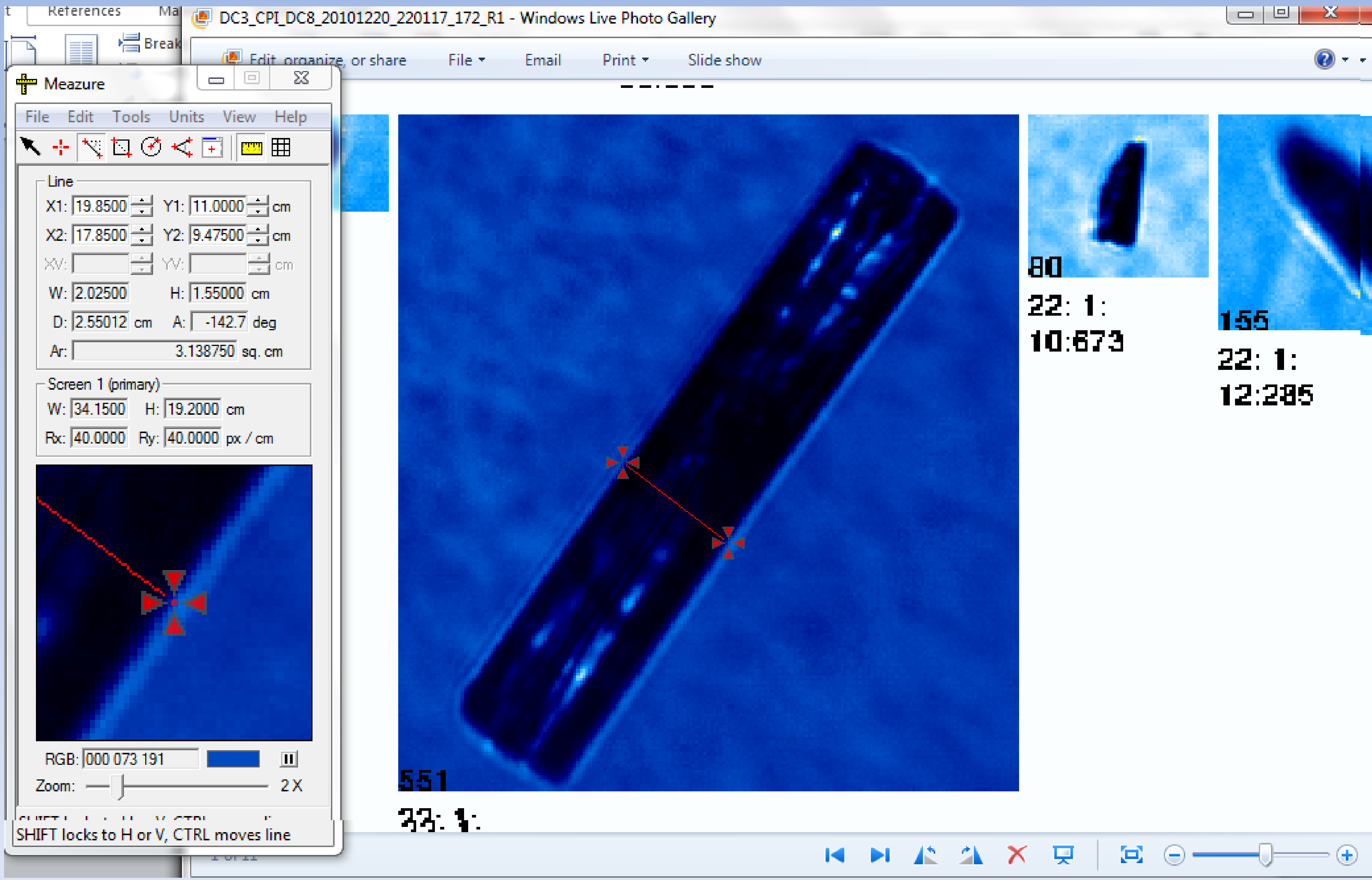
Aspect Ratios

- α for pristine habits (columns, bullets, bullet rosettes) can be determined from 2.3 μm resolution CPI images
- Note, variety of aspect ratios caused by variation in crystals and fact we are looking at 2-d silhouettes of 3-d particles
- How can we get data base on aspect ratios?

Determining Aspect Ratios



Determining Aspect Ratios



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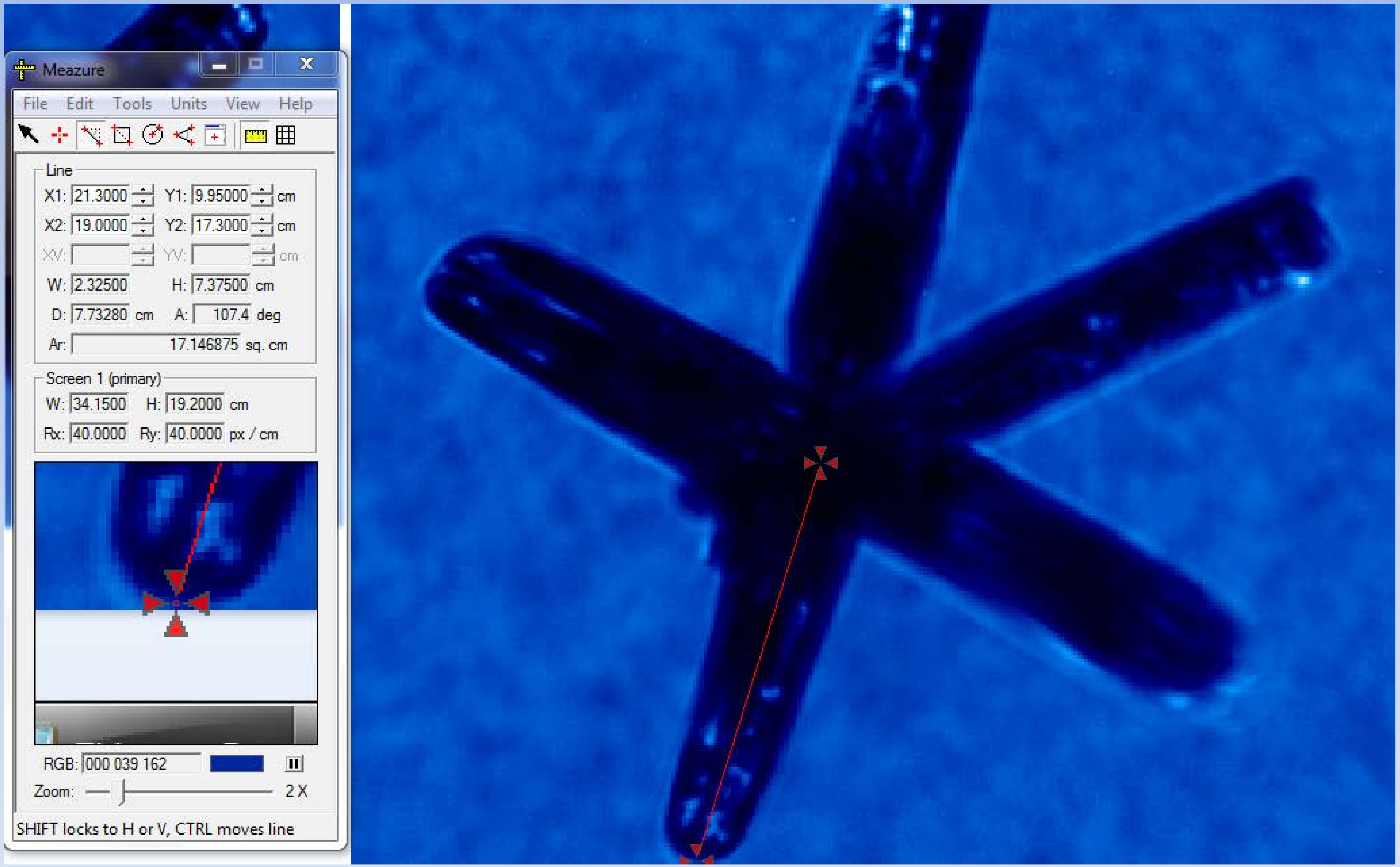

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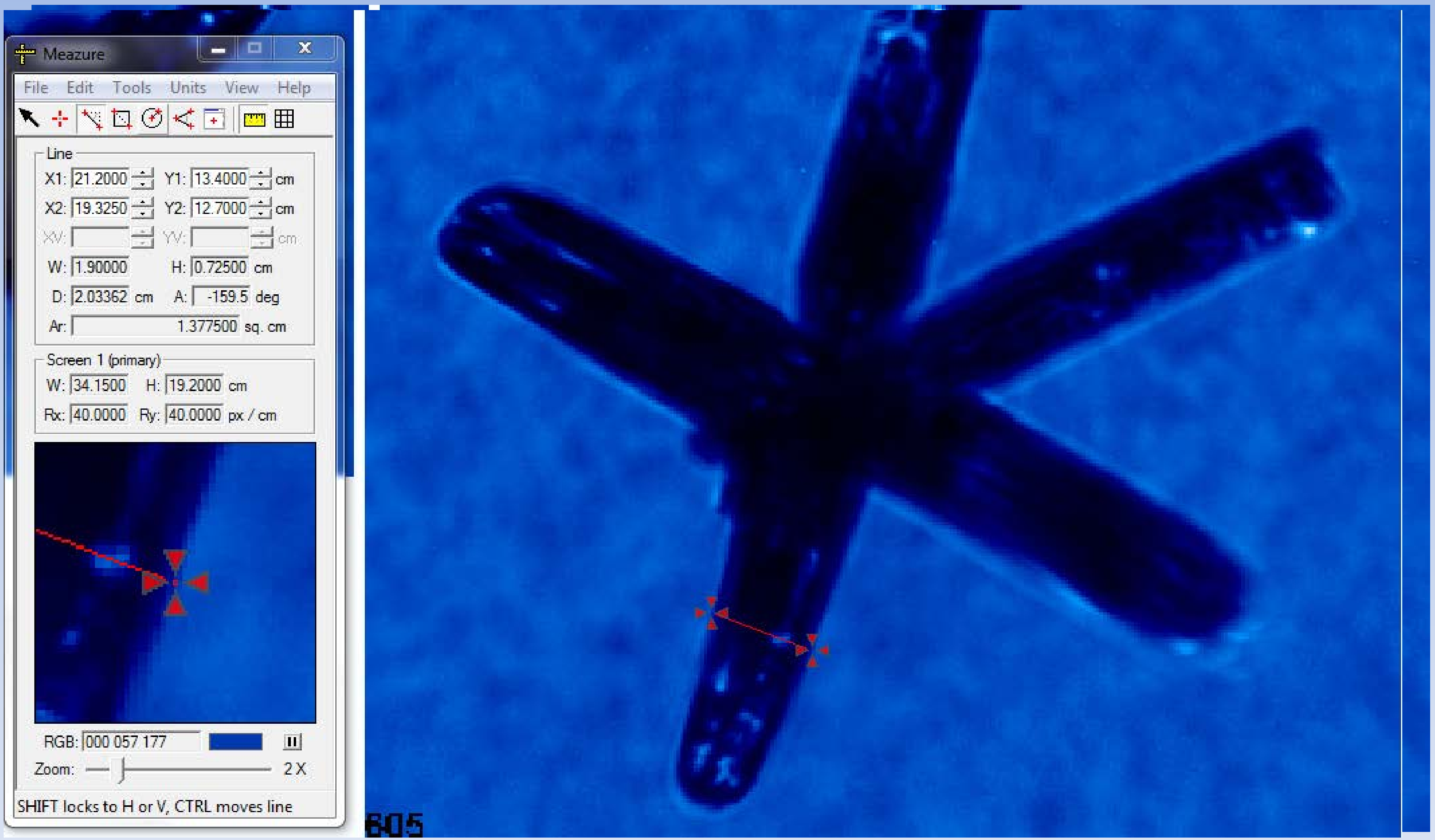

Uncertainties

- **Determining precise edges or centers of the crystals**

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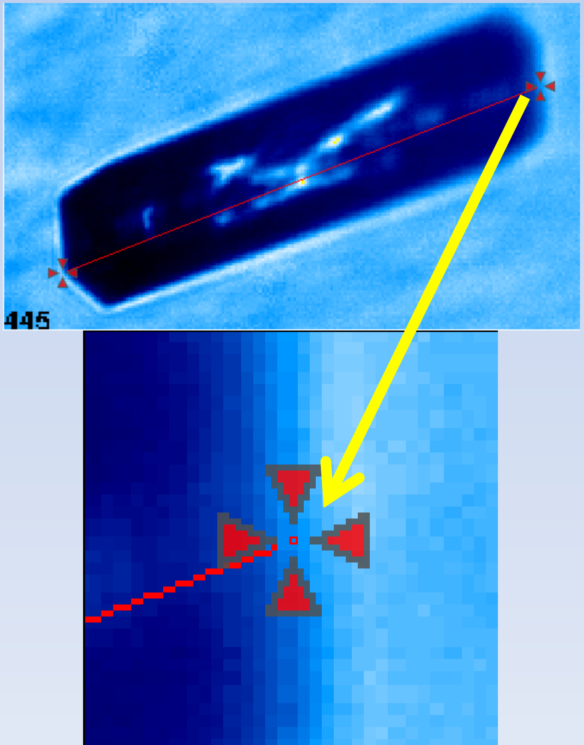

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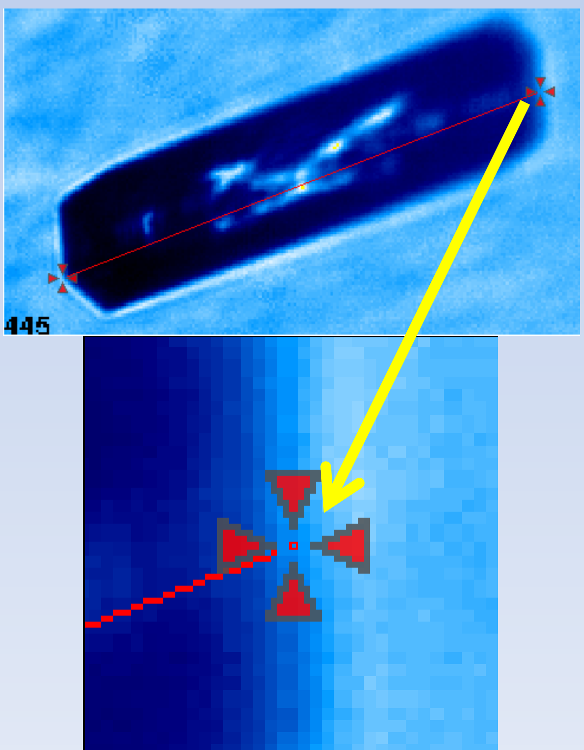
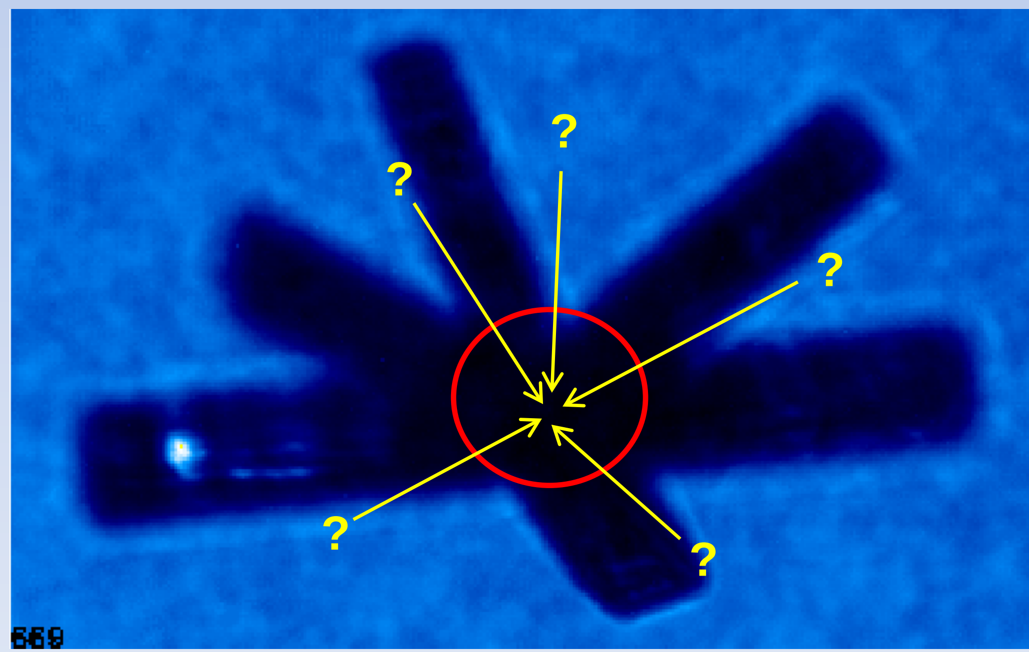
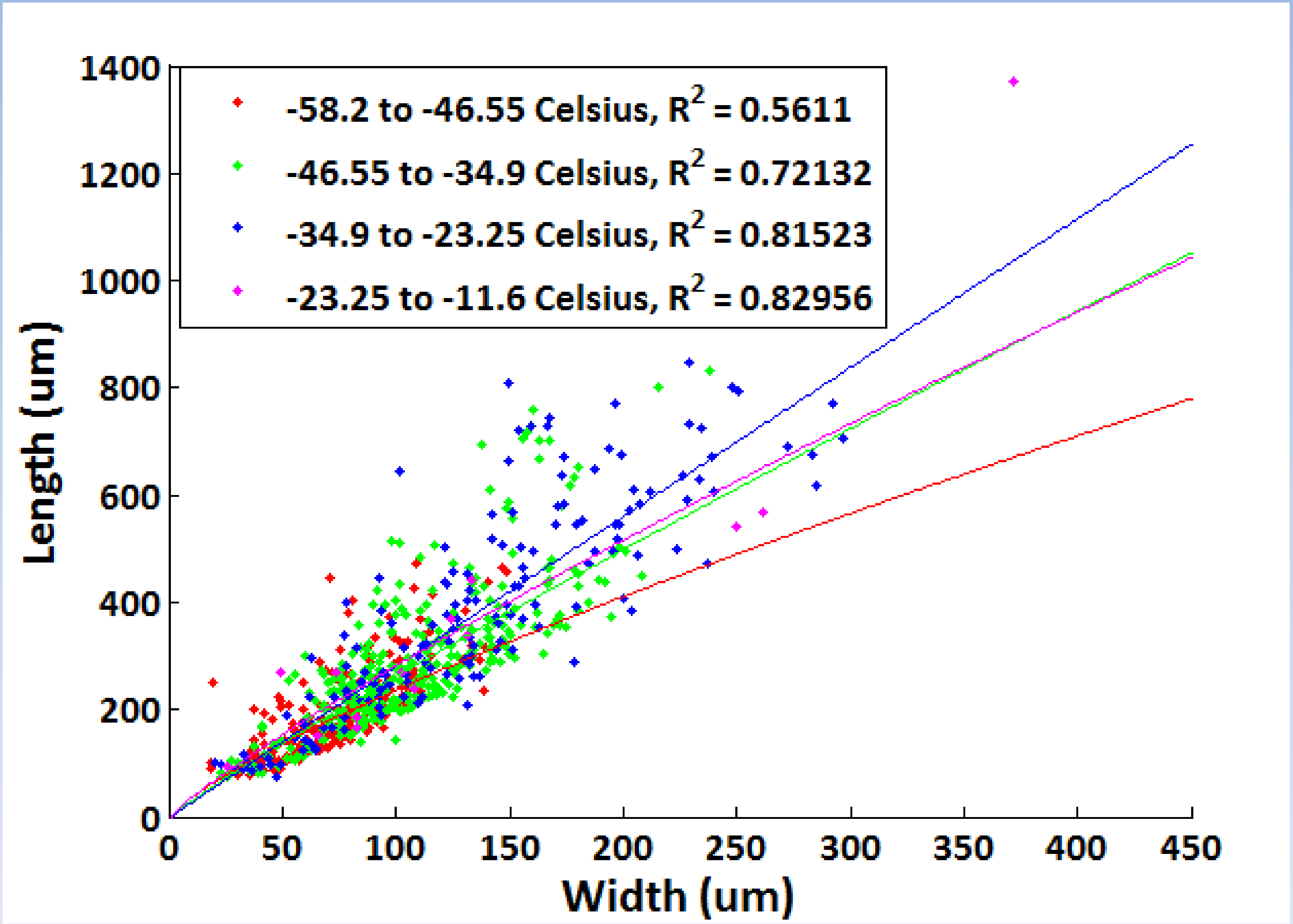
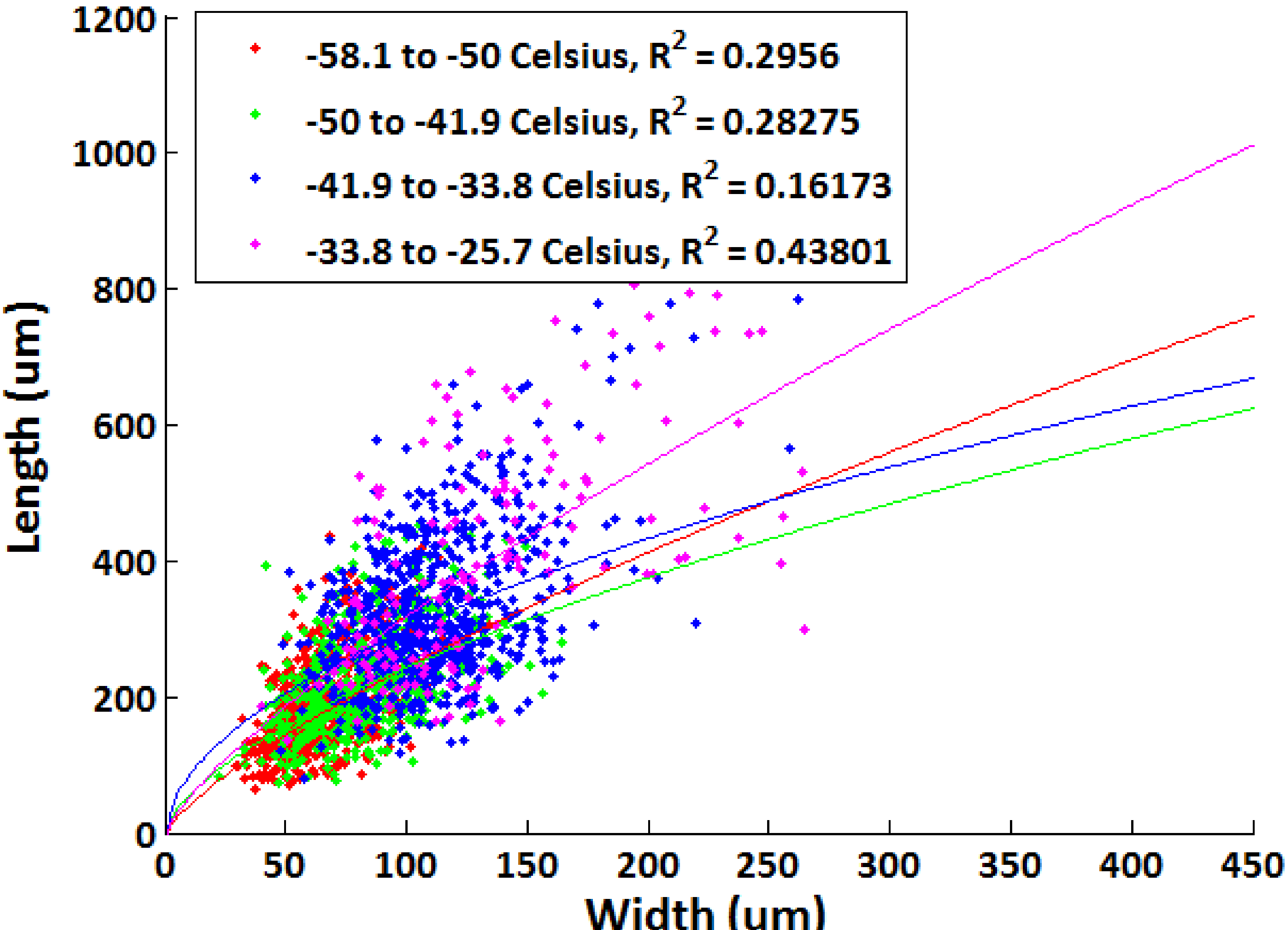




Column Aspect Ratios - Temperature



Bullet Rosette Aspect Ratios – Temperatures



Relationship between L and w:

- Observed relation between L' and w' is for 2-d silhouettes rather than actual crystals. To get relation between actual L/W or crystal
  - Make first guess of $L=a\ w^b$
  - Get multiple random orientations of crystals following this relation
  - Use resulting silhouettes to derive new relation between L'/w'
  - Use iterative procedure with new a/b until have L'/w' from silhouettes within 2 μm of those observed (Um and McFarquhar 2007)
  - Get surface of possible a/b values if permit acceptable solutions within some threshold

Gamma Distribution:

Mathematical Representation of Size Distributions

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$

- N(D) = Number Distribution Function
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- μ = shape
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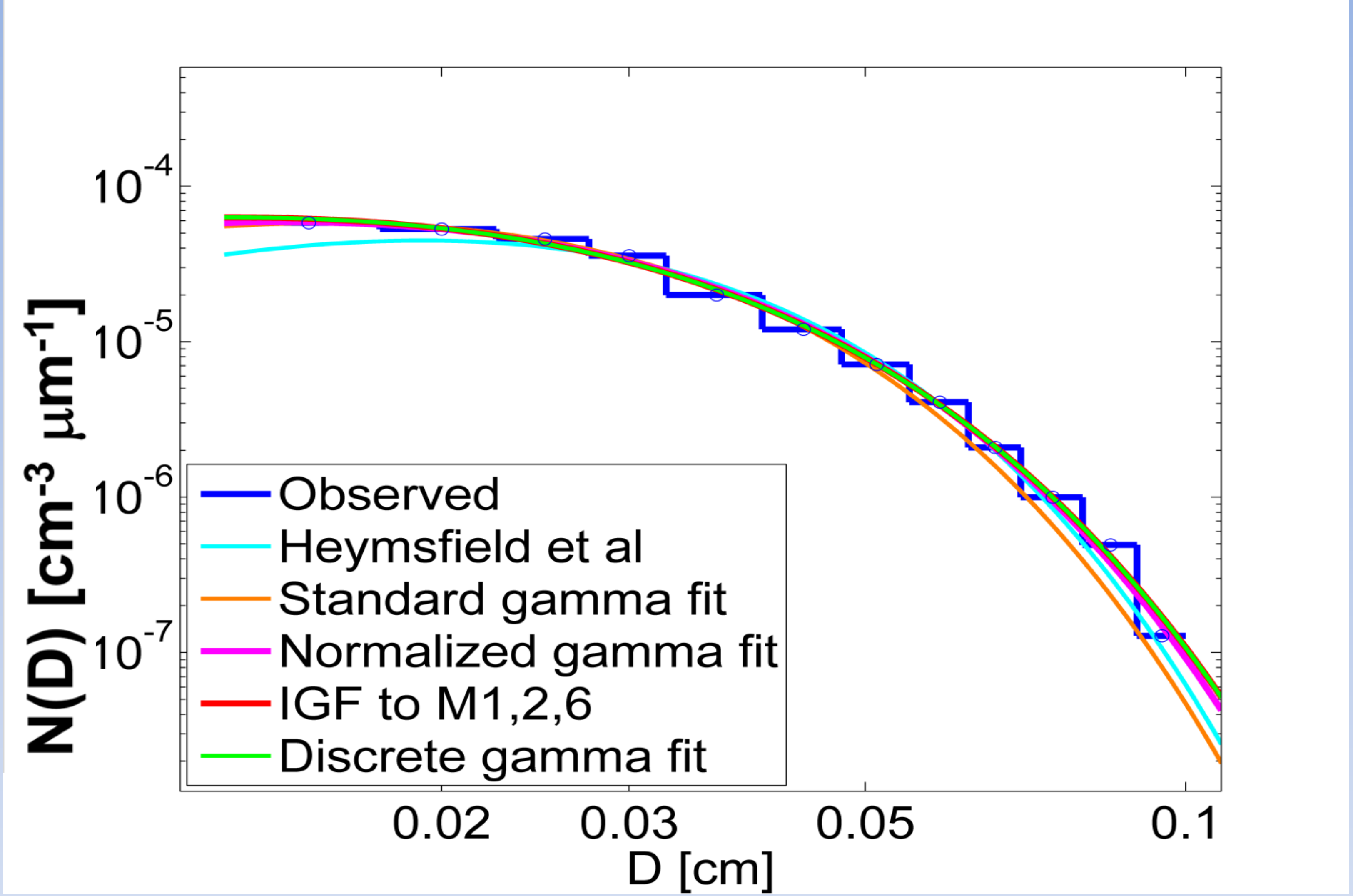
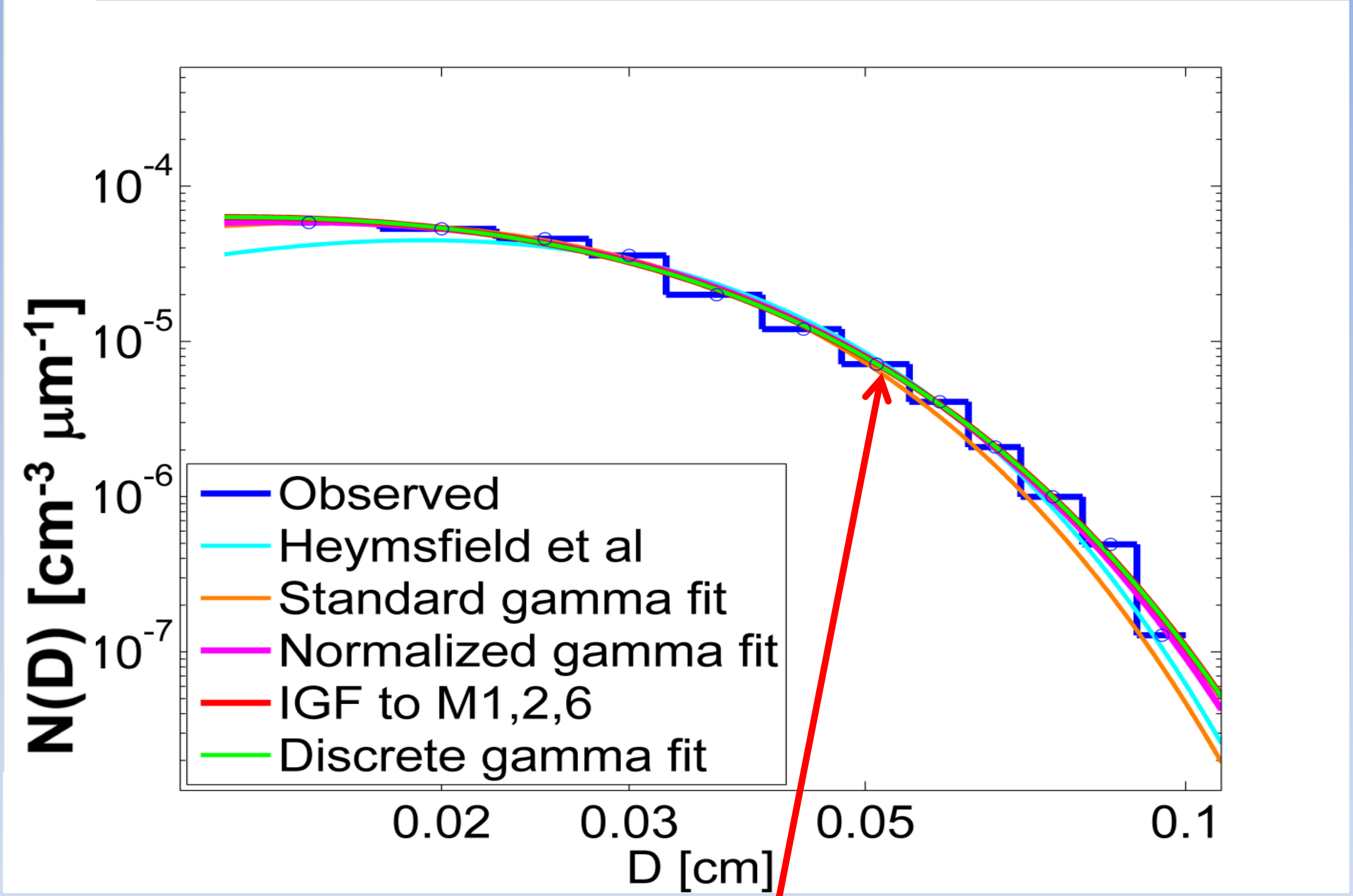
How do N_0, μ, and λ depend on meteorological and cloud conditions?

How well are N_0, μ, and λ known?



Even though fits all look quite good, there can be huge range in N_0, λ and μ



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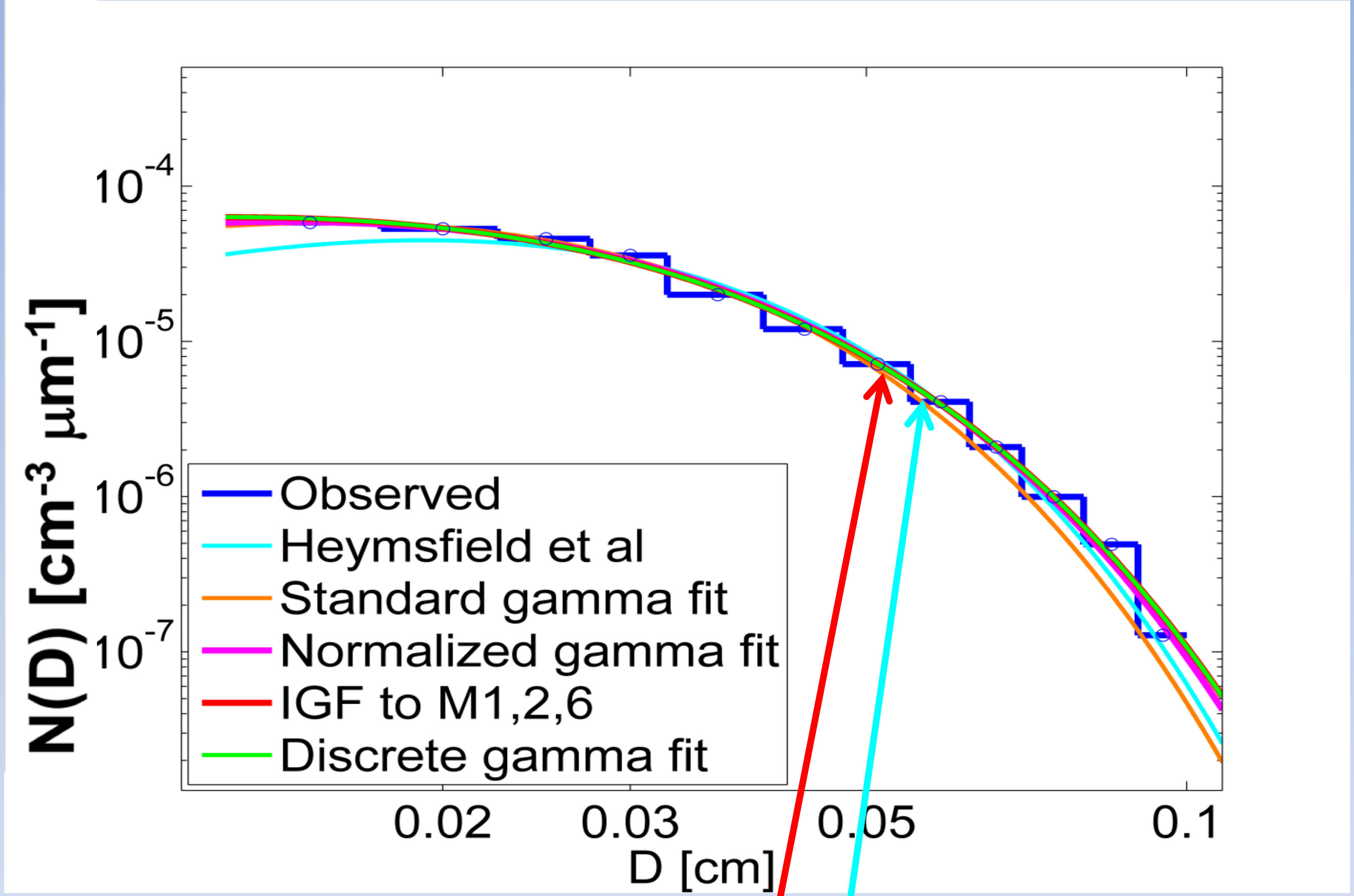
IGF: N_0 $6.3\text{x}10^{-1}$ μ=1.86; λ =$1.1\text{x}10^{2}$



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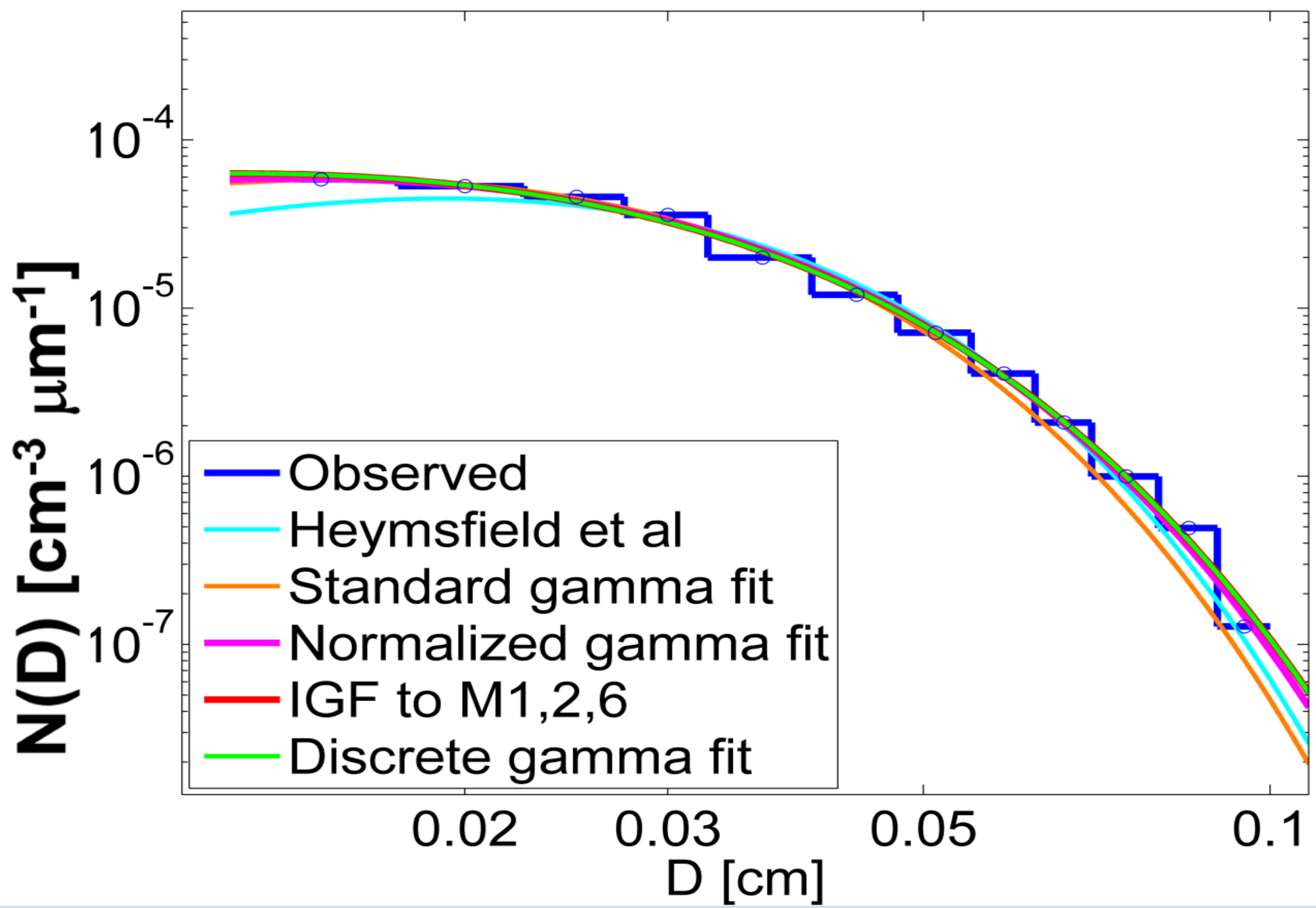
IGF: N_0 6.3×10^{-1} $\mu = 1.86$; $\lambda = 1.1 \times 10^{2}$

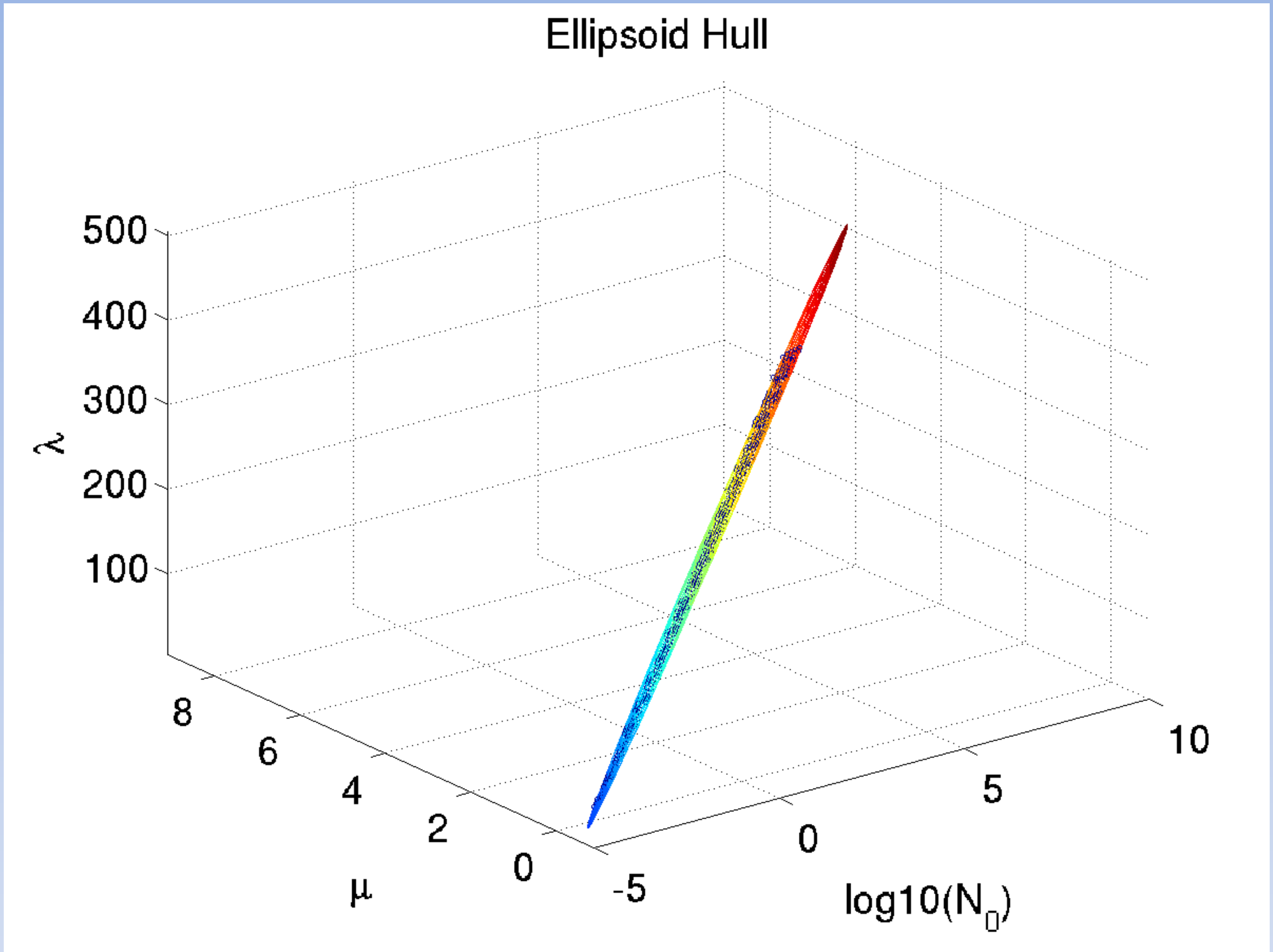
Hey: N_0 7.3×10^{1} $\mu = 2.97$; $\lambda = 1.4 \times 10^{2}$



There is broad range of $N_0/\mu/\lambda$ that fit SD well

$N_0/\mu/\lambda$ determined depend on tolerance allowed

→ Can't represent by single $N_0/\mu/\lambda$ value



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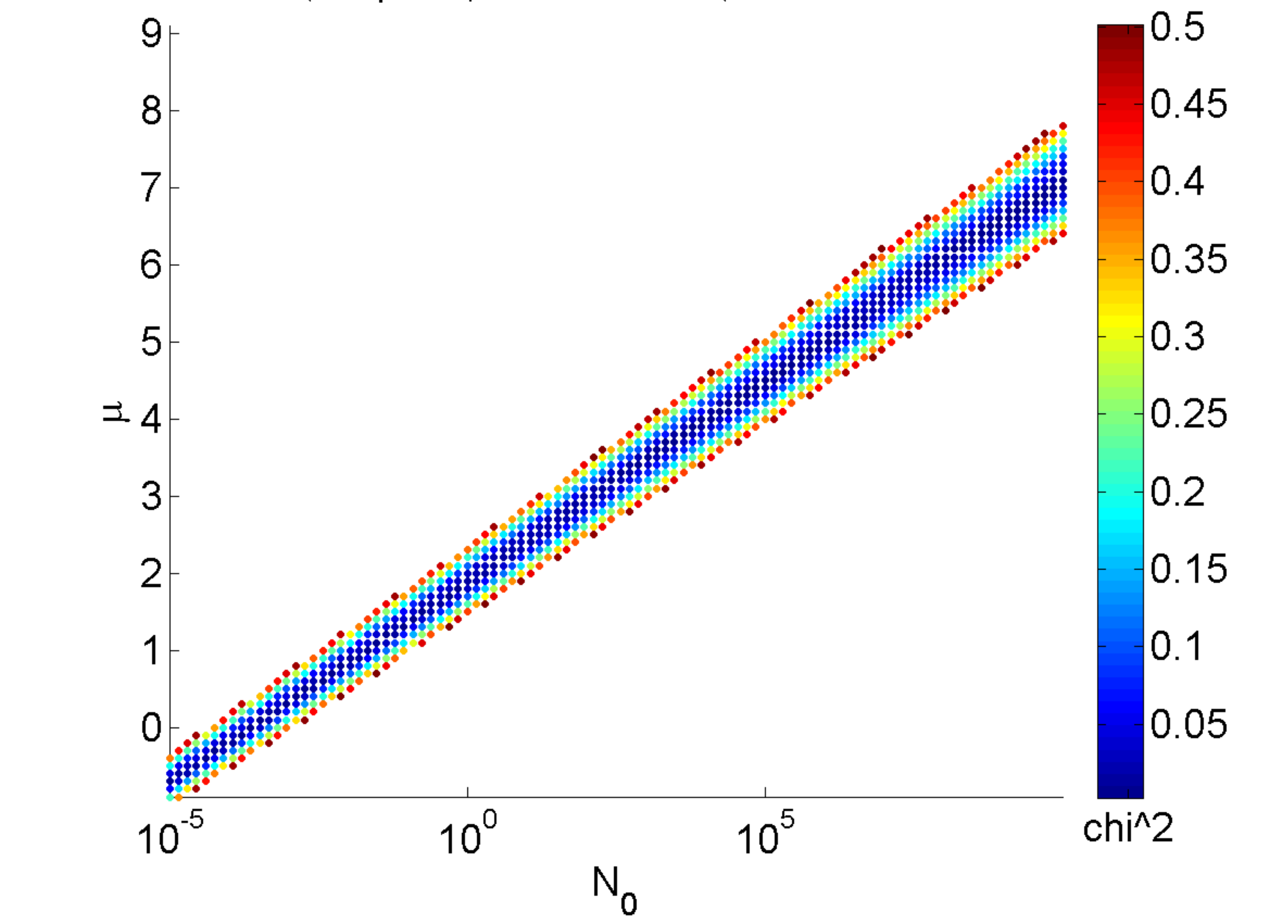
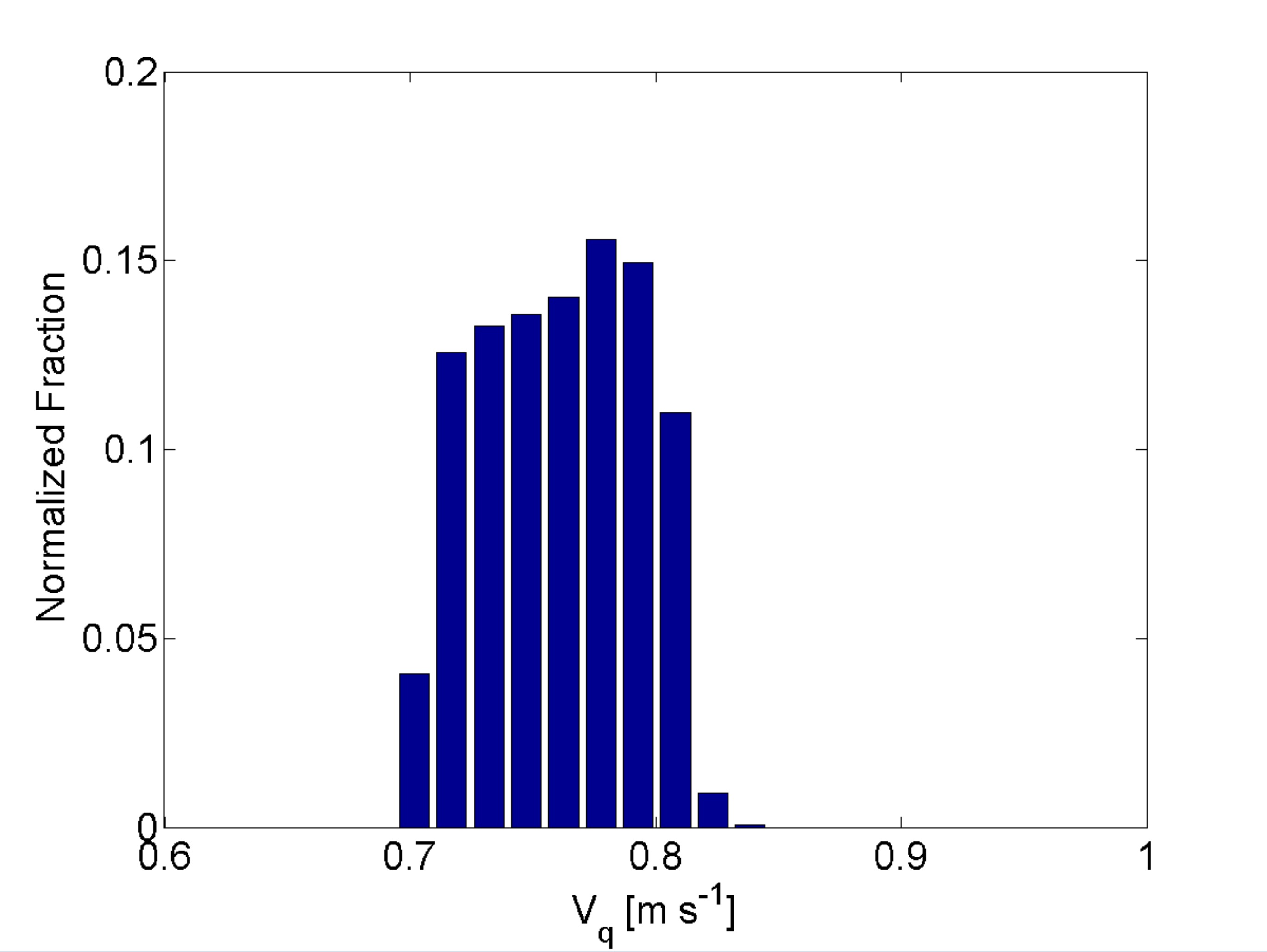
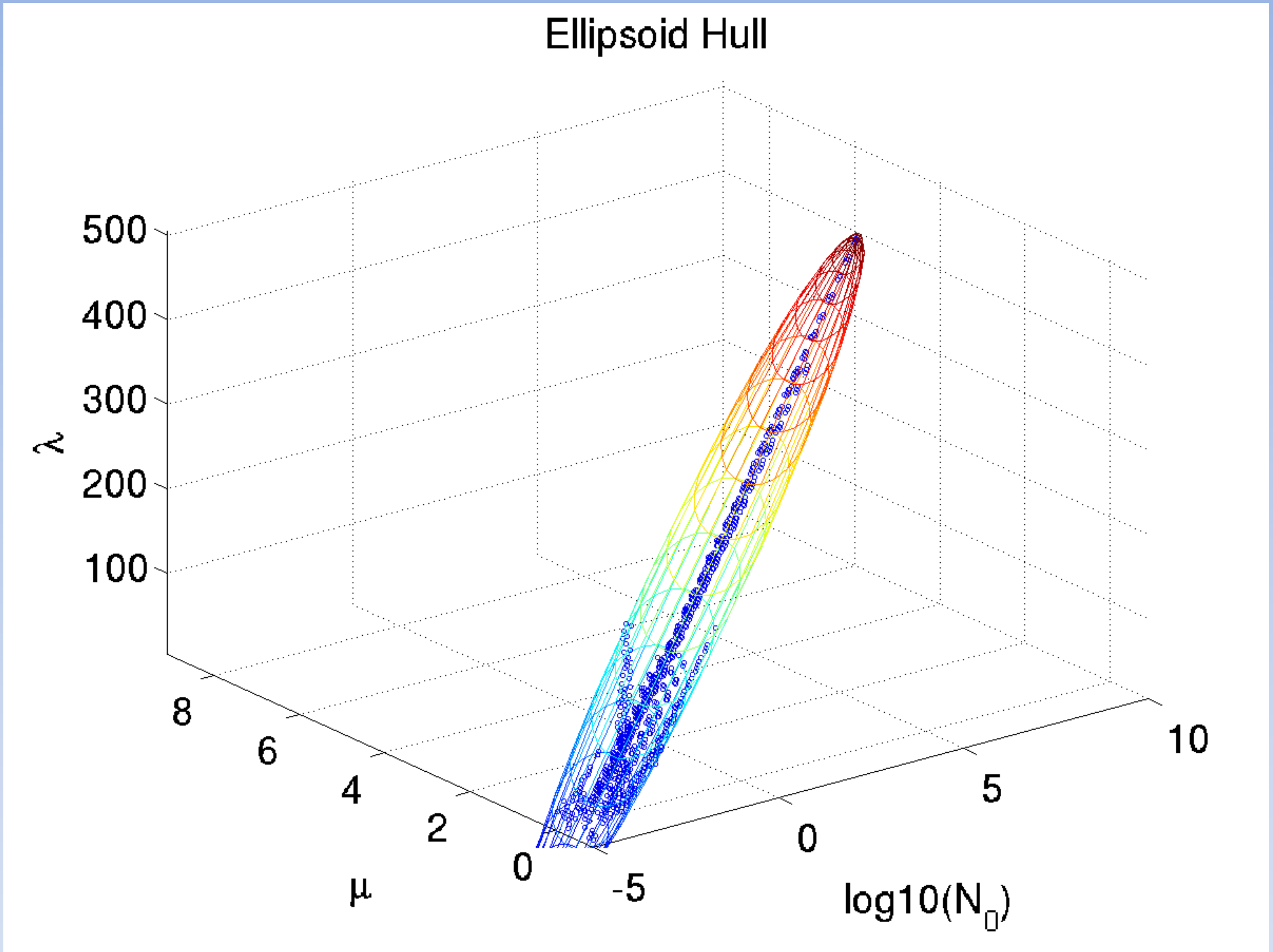


Surface of equally realizable solutions with $\Delta\chi^2 = 0.5$ of χ_{min}^2

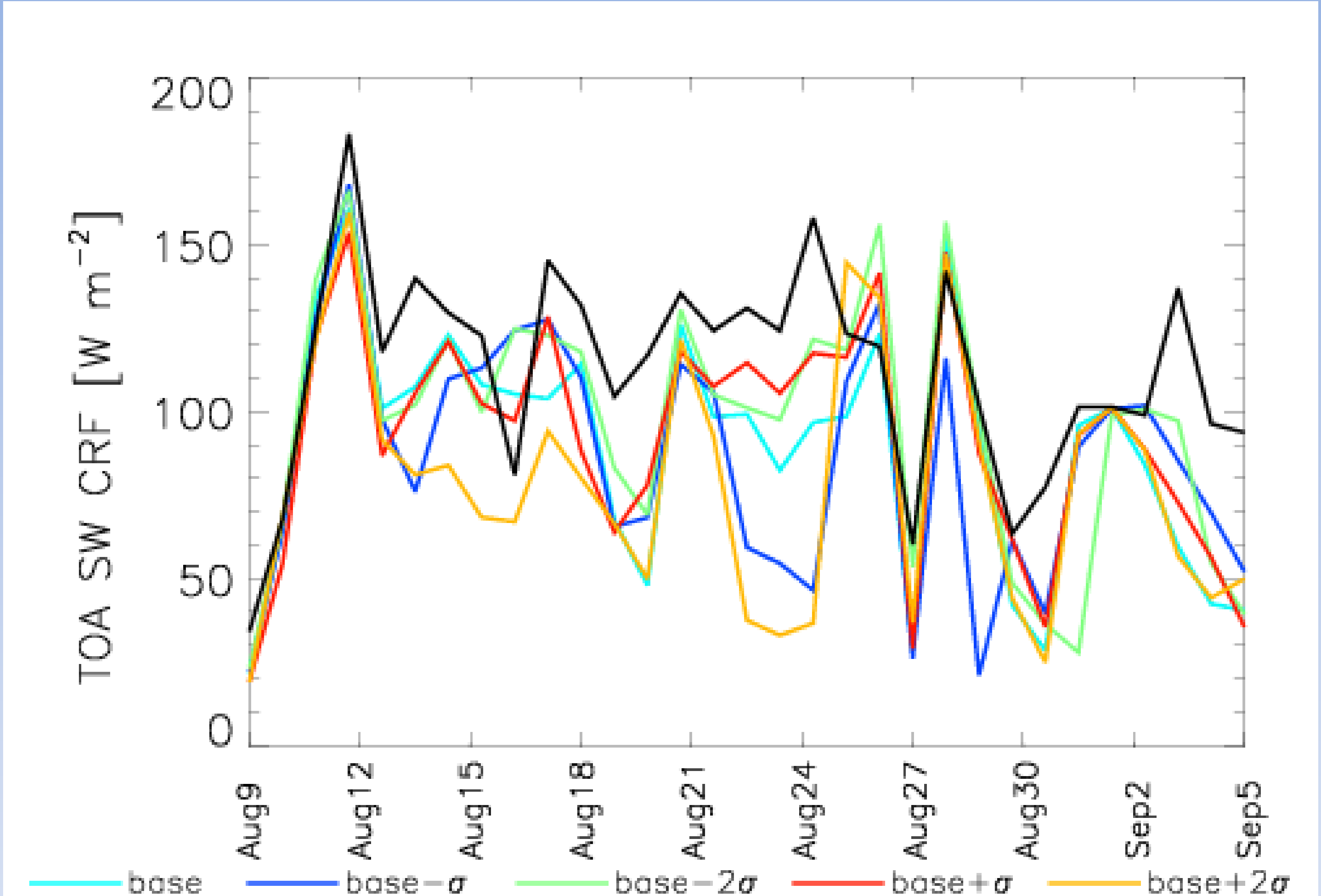
Implications



Depending on choice of $N_0/\lambda/\mu$ within surface, mass-weighted fall speed can vary by about 10%



In addition, we look at % of SDs for which N_0/μ within $\Delta\chi^2 = 0.5$ of minimum χ^2
Need to determine how these surfaces vary with meteorology
Mathematical representations of ellipse allow this to be implemented in model: use random values from surface in parameterization



- **TOA SW CRF accounting for uncertainty in r_e parameterization**
- **18 W m^{-2} maximum average difference** **(McFarquhar et al. 2003)**

Effect of r_e variability

- Choose r_e randomly at each time ± 1 or 2 σ of mean from surface of realizable solutions, examine impact on CRF

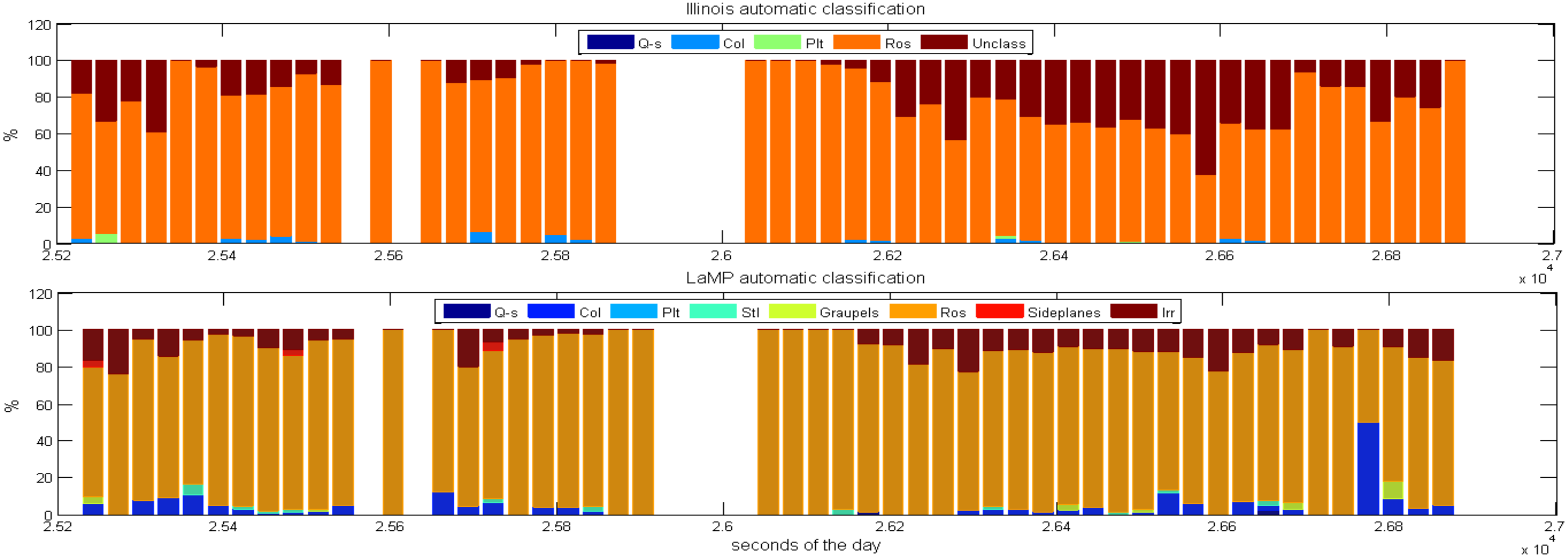
CASE	SW TOA CRF [W m^{-2}]
$r_{e,best}$	-88.8
$r_{e,best}\pm 1\sigma$	-92.0±4.7
$r_{e,best}\pm 2\sigma$	-93.7±4.5
$r_{e,best}\pm\Delta q,\Delta t$	-88.5±4.4

- Average of simulations not simulation of averages!
- Chaotic nature of model does not affect results
- IMPORTANT TO CONSIDER UNCERTAINTIES IN PARAMETERIZATION DEVELOPMENT

Habit Classifications

- **How well can we identify particle habits from CPI images?**
  - **Compare schemes from LaMP, Illinois, and Helsinki**
- **3 cases :**
  - **2 Tropicals : TWP-ICE campaign (2006):**
    - **One aged cirrus case : January, 29th ;**
    - **One fresh anvil case : February, 2nd.**
  - **1 Arctic case : ISDAC (2008) :**
    - **Low cloud : April, 25th.**
- **Look at contributions of particles with D > 200 μm**

Time serie TWP-ICEcirrus, D>=200μm, 7h00'29"-7h28'05", Focus > 30



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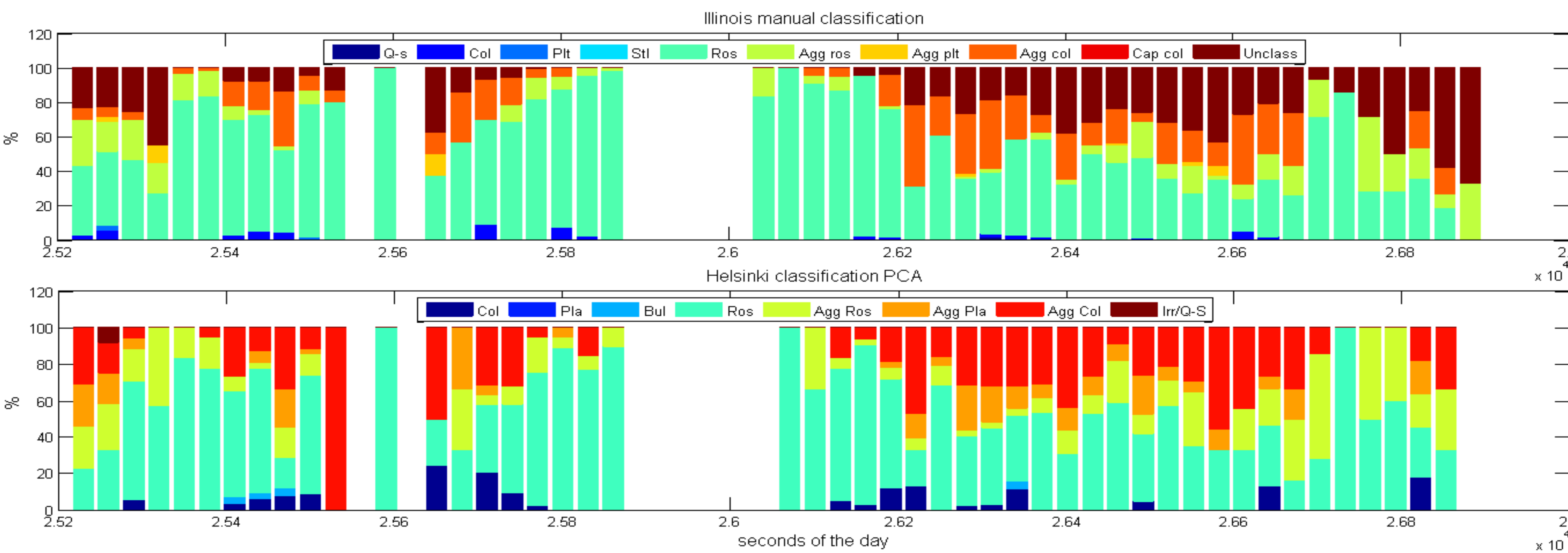


Main Points

GOOD POINTS :

- **Aggregates of rosettes, aggregates of plates, and rosettes classified correctly compared to Illinois semi-manual scheme.**

BAD POINTS :

- **A lot of particles classified as aggregates of columns by Helsinki are classified as other shapes by Illinois semi-manual treatment (aggregates of plates, irregulars, etc.)**
- **Columns overestimated**

Mission Statement of IcePro

1. Characterize ice physical processes represented in climate models & processes depending on them
2. Establish link between observations characterizing ice particle properties & models investigating how cloud & radiative properties change with environmental conditions
3. Focus not only on mean & statistical distributions of ice properties, but also their uncertainties and consequences for process rates, parameterizations & model results

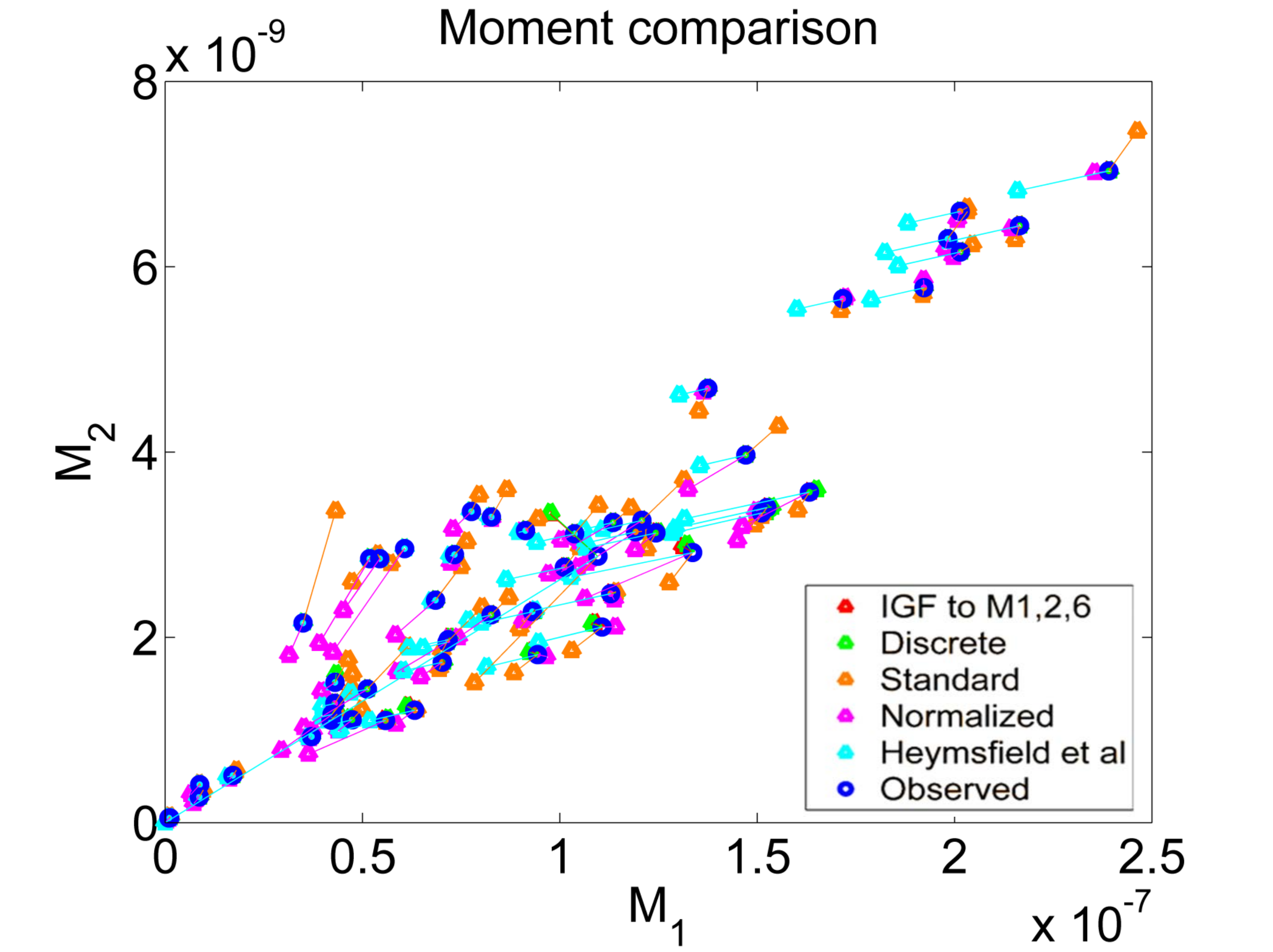
Approaches of IcePro

1. Use in-situ observations to derive statistical databases (individual crystals & populations)
2. Utilize new ground-based scanning radar to develop retrieval techniques for crystal habits
3. Conduct spectral radiative closure to constrain ice particle physical & optical properties
4. Conduct model studies to assess sensitivity of modeled cloud properties to representation of ice properties

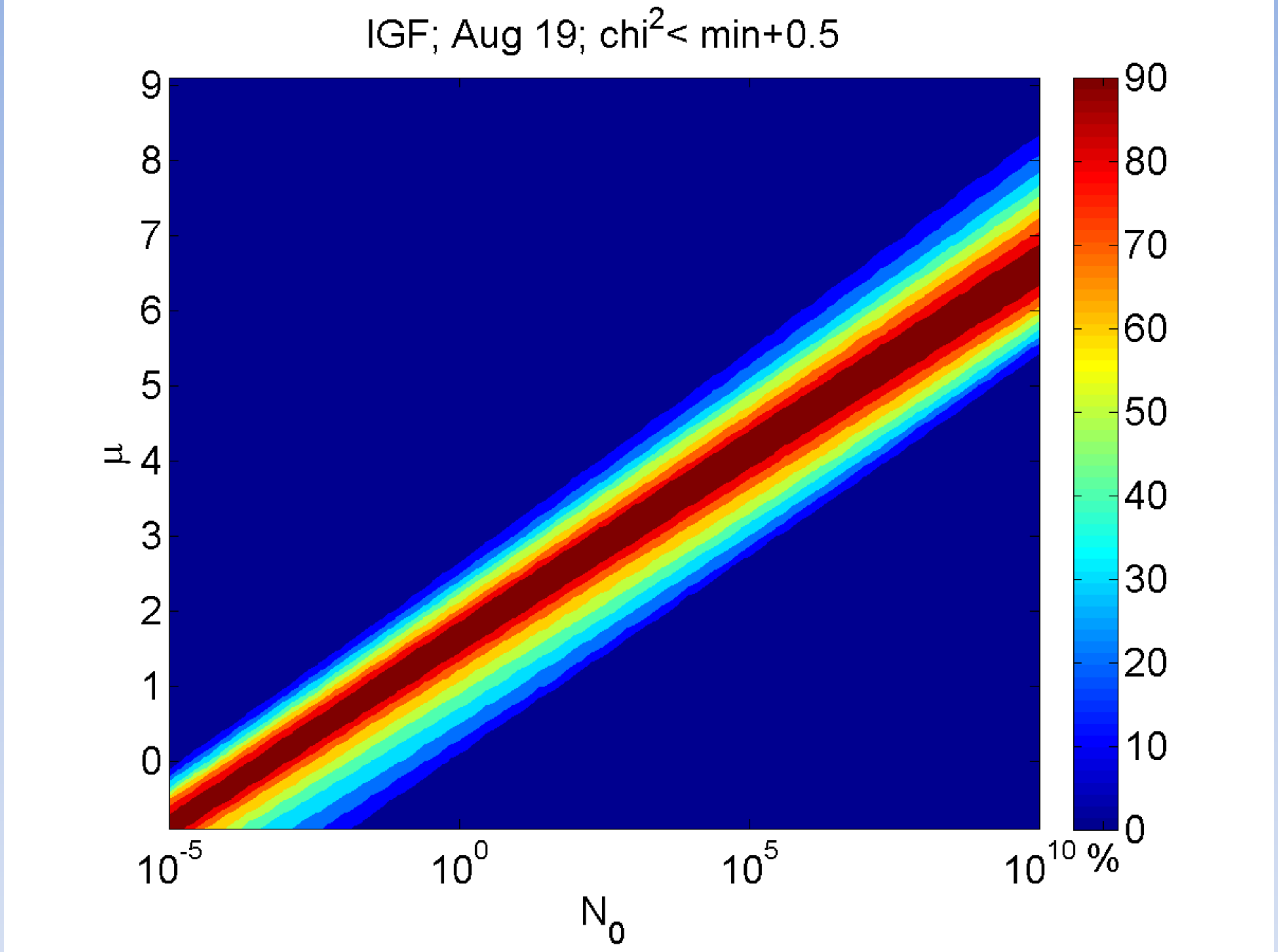
UNCERTAINTY IMPORTANT FOR ALL ACTIVITIES

Today’s Objectives

1. Further focus ICEPRO science questions
2. Identify specific model needs & deficiencies guiding future research
3. Prioritize areas of science focus, datasets, and/or geophysical parameters that are needed (and other modeling/observational resources)
4. Establish plans to coordinate research efforts addressing programmatic objectives (need to be explicitly identified in next white paper draft)



Comparison of observed & fit moments for some SDs: IGF better matches observed moments



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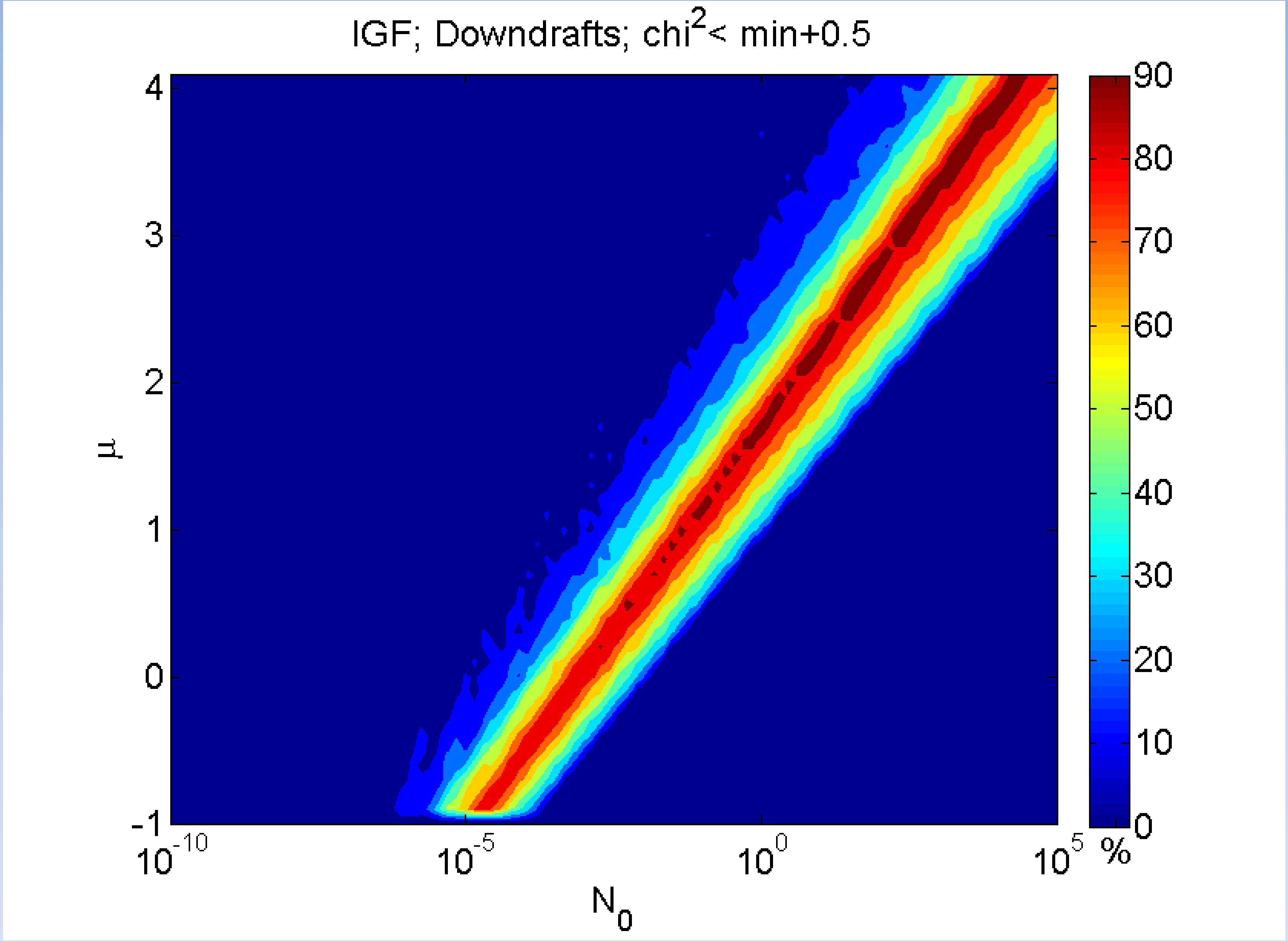
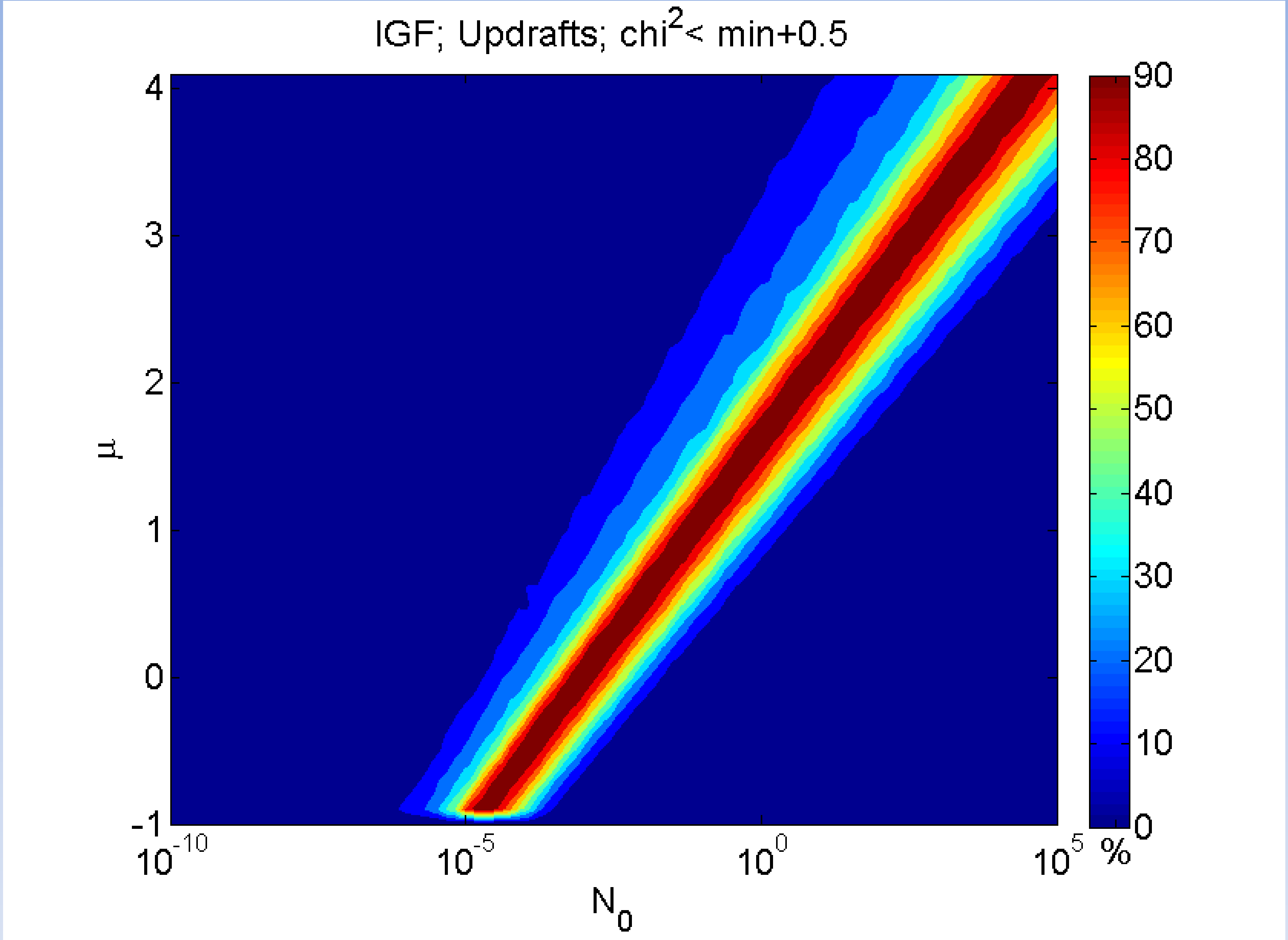


Compare surface describing fits when downdrafts are present compared to when updrafts are present



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