Impact of Crystal Shattering on Derived Microphysical Quantities: Implications for QUICR

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QUICR Breakout Session

Issues for QUICR

- **QUICR requires in-situ data on *N(D)*, *IWC*, β & N_T for developing & evaluating retrieval algorithms**

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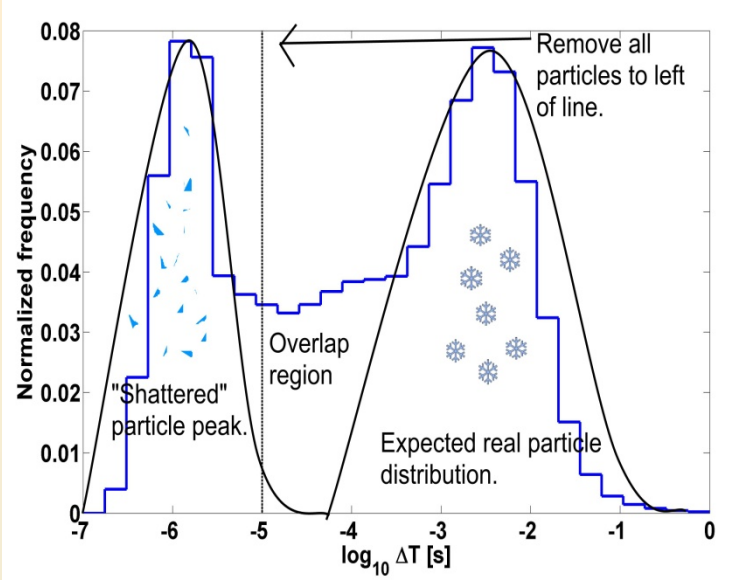
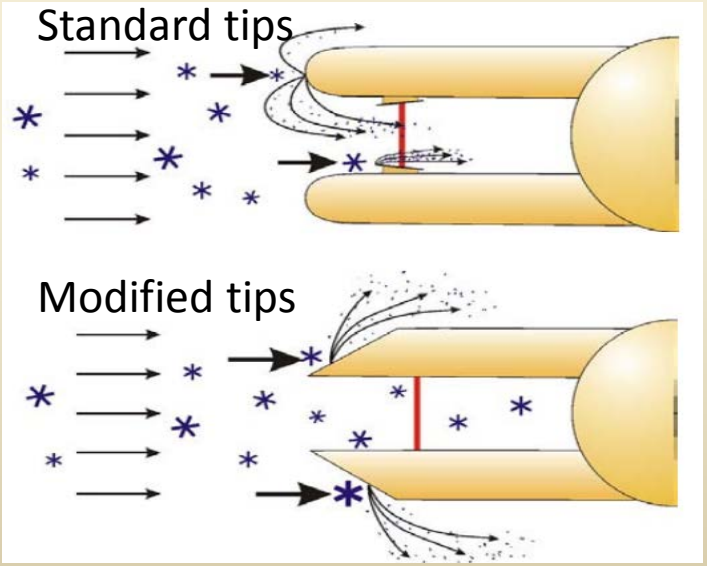
- **BUT,**
  1. **What is degree that new shatter-reducing tips & processing algorithms can mitigate shattered artifacts?**
  2. **What is uncertainty in derived bulk quantities from in-situ probes?**
  3. **Can past data sets be corrected to remove biases from shattered particles?**

Background

- **Ice crystal size distributions (SDs) from forward scattering and optical array probes (OAPs), like 2DC, may be biased by shattering**

- **Modified tips for OAPs & varying processing techniques based on particle interarrival distance (time) have been used to correct for artifacts**





Korolev and Isaac (2006)

Past Studies

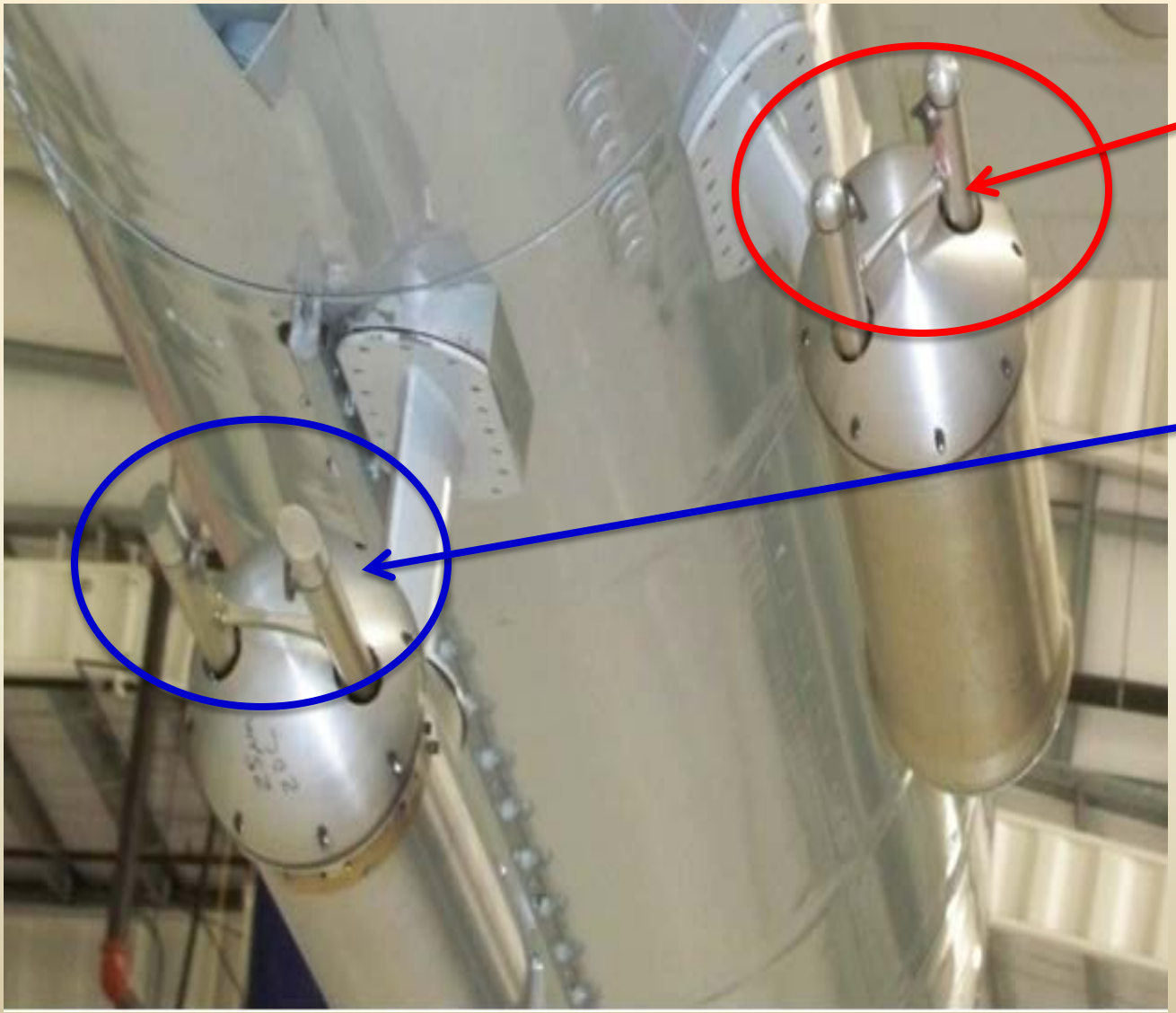
- **Studies differ on effect of modified tips and algorithms:**
  - **Modified tips remove more artifacts than algorithms for 2DC (Korolev et al. 2011) - impact of shattering on N(D) as large as D = 500 µm**
  - **Algorithms remove more artifacts than modified tips for 2D Stereo Probe (Lawson 2011)**
- **Little known about how use of tips and algorithms affect N(D) → may depend on cloud conditions (crystal habits/sizes, where probe mounted, angle of attack, etc.**

Current Work

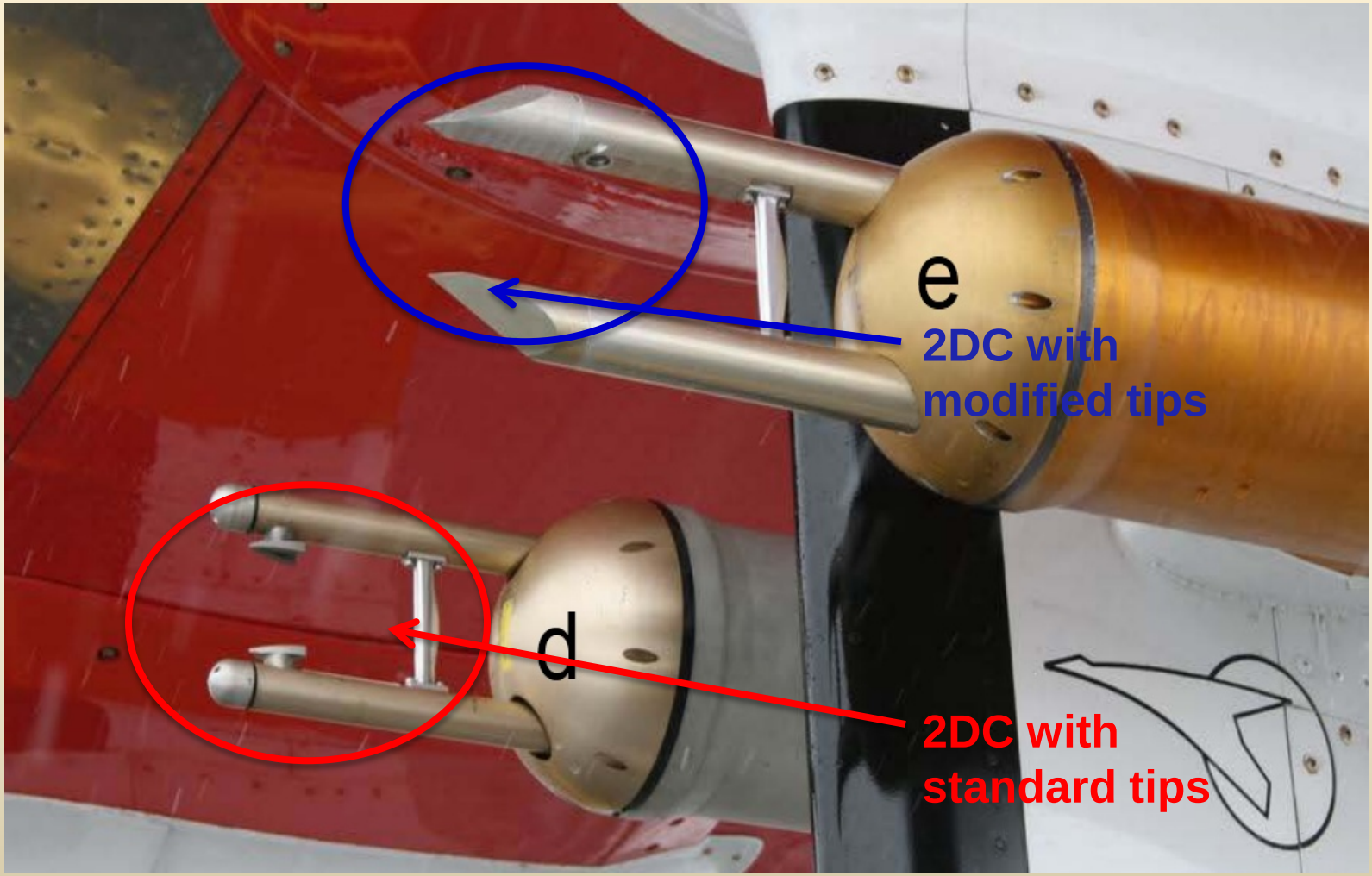
- **Use data from 2 campaigns with co-located standard & modified 2DCs to investigate:**
  - **What conditions are most conducive to shattering?**
  - **Ultimately what is the effect of shattering on bulk properties?**

Campaign	Platform	Time + Location
Instrumentation Development and Education in Airborne Science phase-4 (IDEAS)	National Center for Atmospheric Research C-130	Research flight 3 (25 October) and 4 - 1 November 2011 near Cheyenne, WY
Indirect and Semi-Direct Aerosol Campaign (ISDAC)	National Research Council of Canada Convair-580	30 April near Fairbanks, Alaska

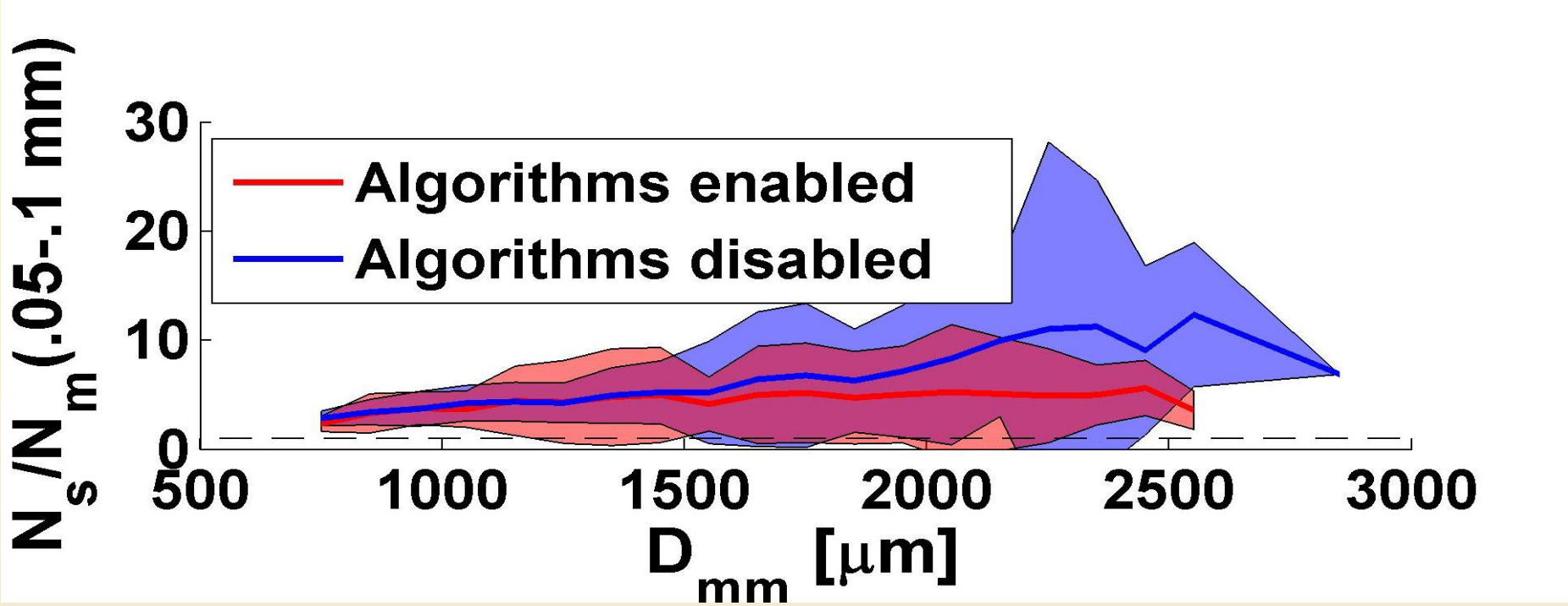
Probes with & without tips: IDEAS4



Probes with & without tips: ISDAC



Compare Standard & Modified 2DC



Compare numbers of particles from standard tips (Ns) with number of particles from modified tips (Nm) from IDEAS

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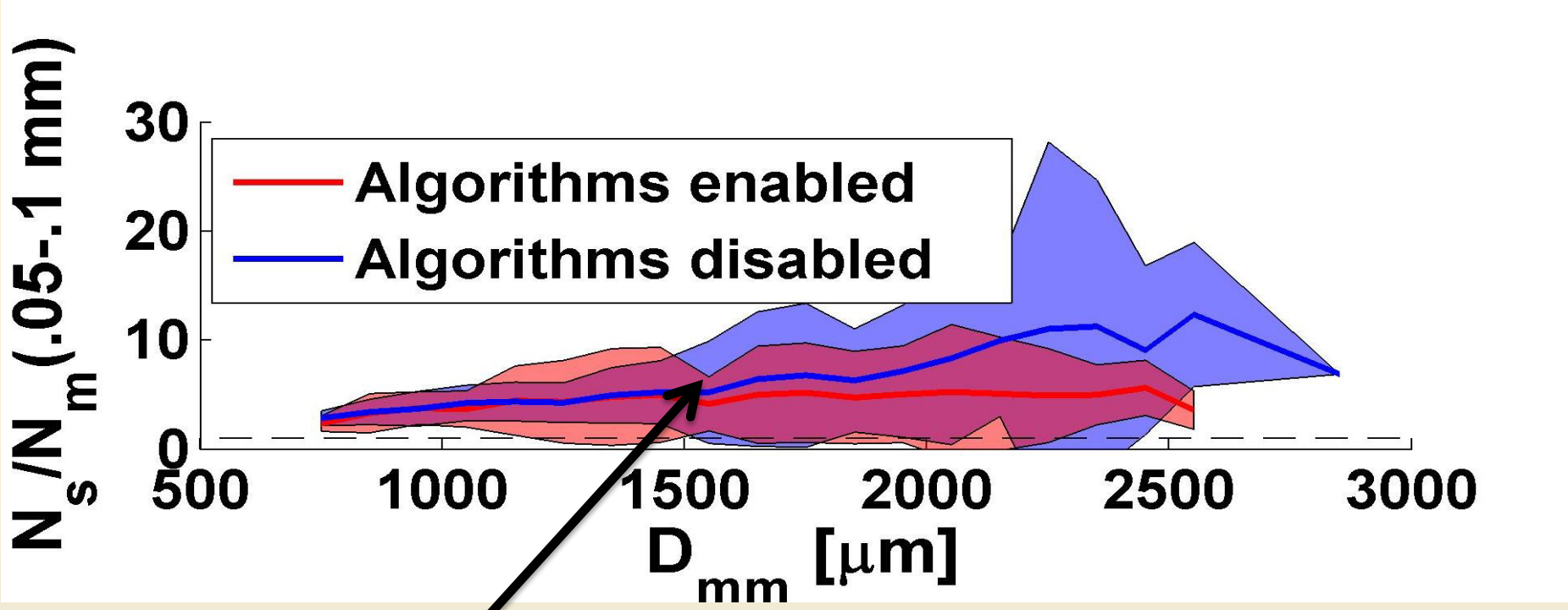

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Fewer shattered particles with algorithms enabled

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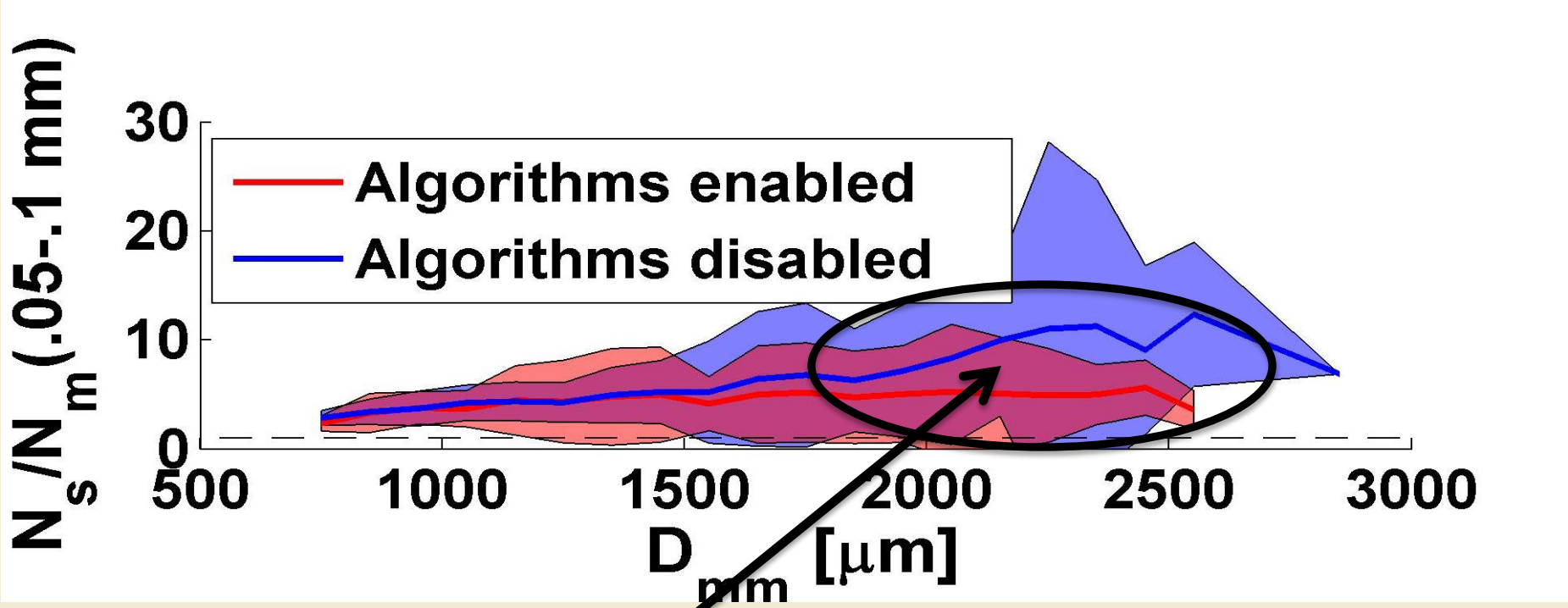

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Ratio of Ns/Nm increases with median mass diameter Dmm

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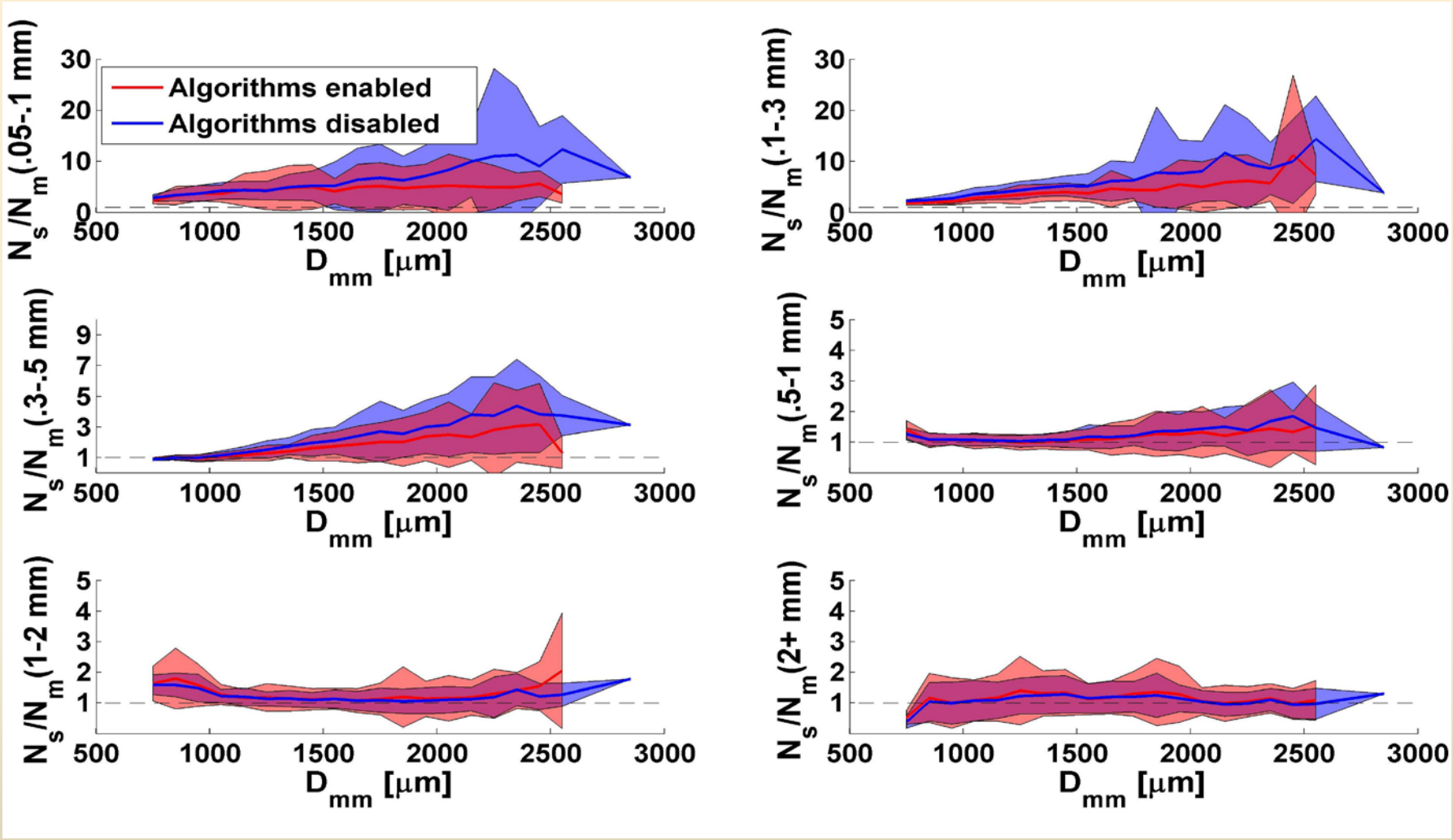
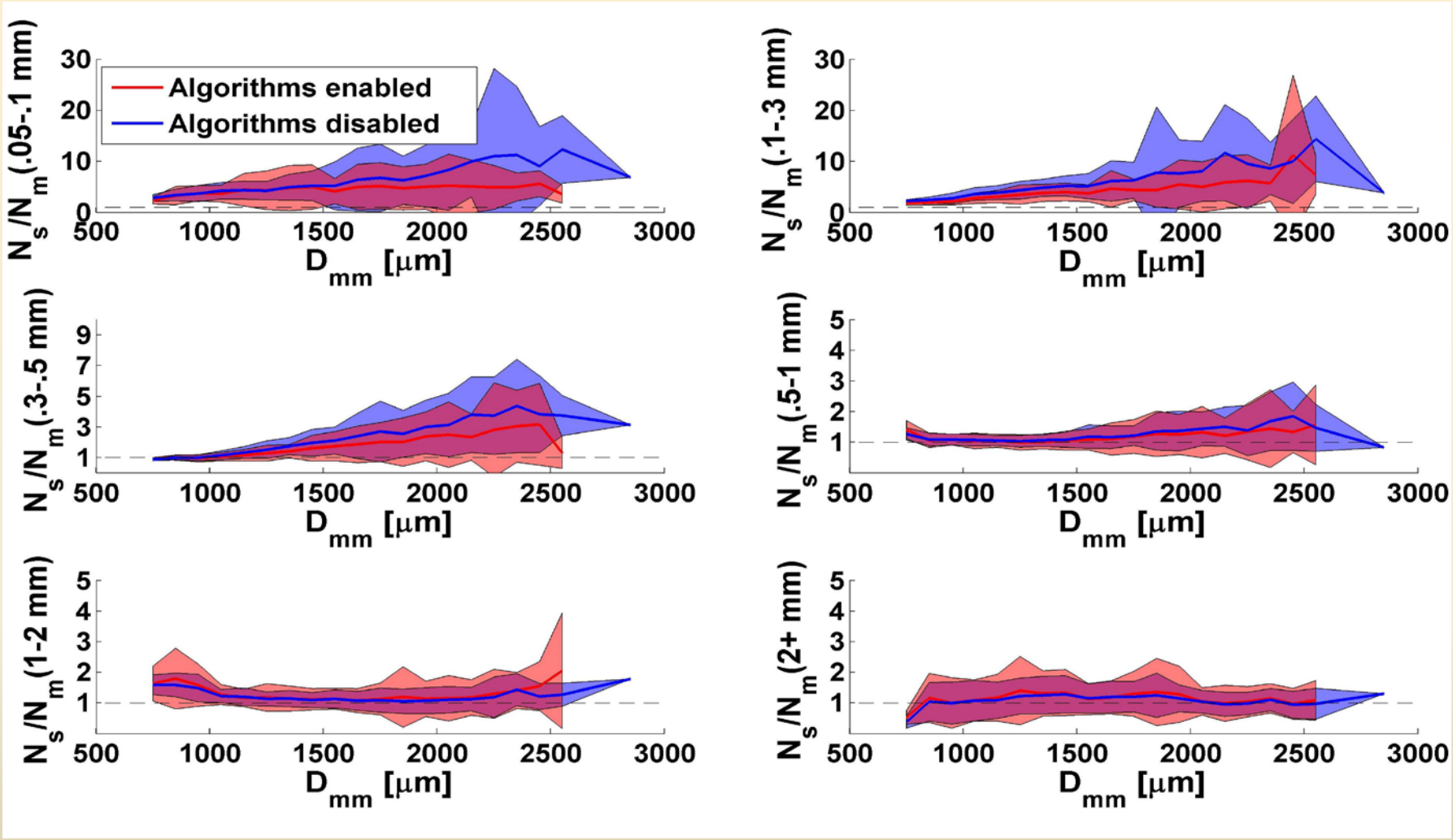


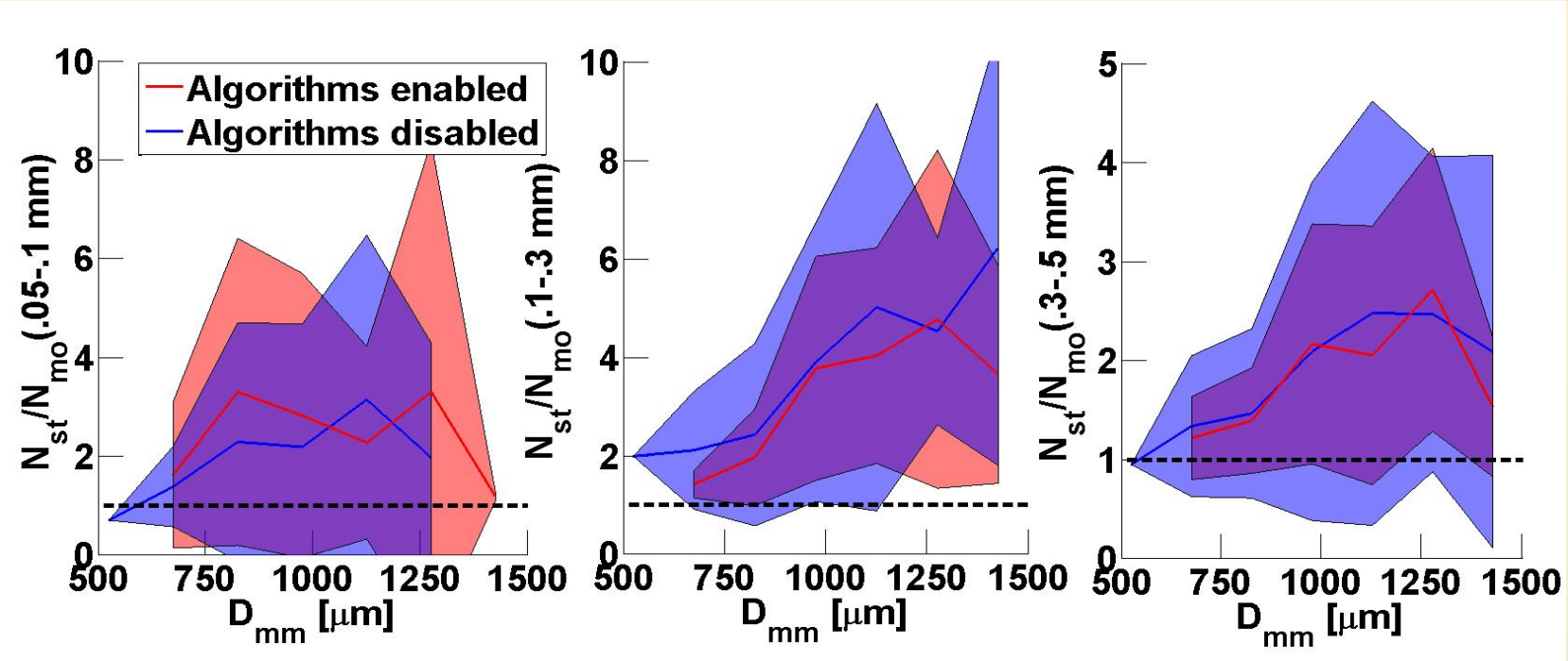
Look at ratio of Ns/Nm in six different size ranges

Compare Standard & Modified 2DC



Ns/Nm ratio well above 1:1 line for particles up to about 500 mm in size

Compare Standard & Modified 2DC



Similar comparisons made for ISDAC data

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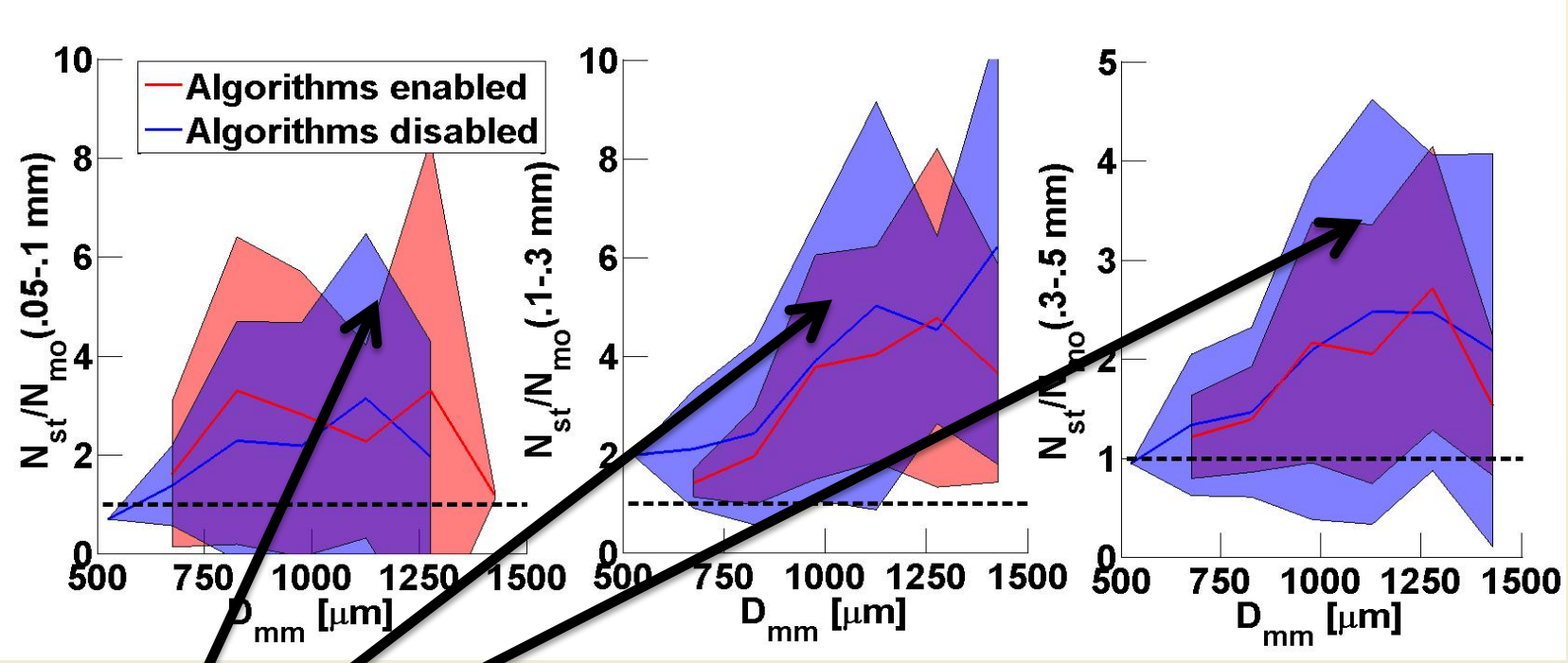

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Standard 2DC still overestimates concentration compared to modified 2DC

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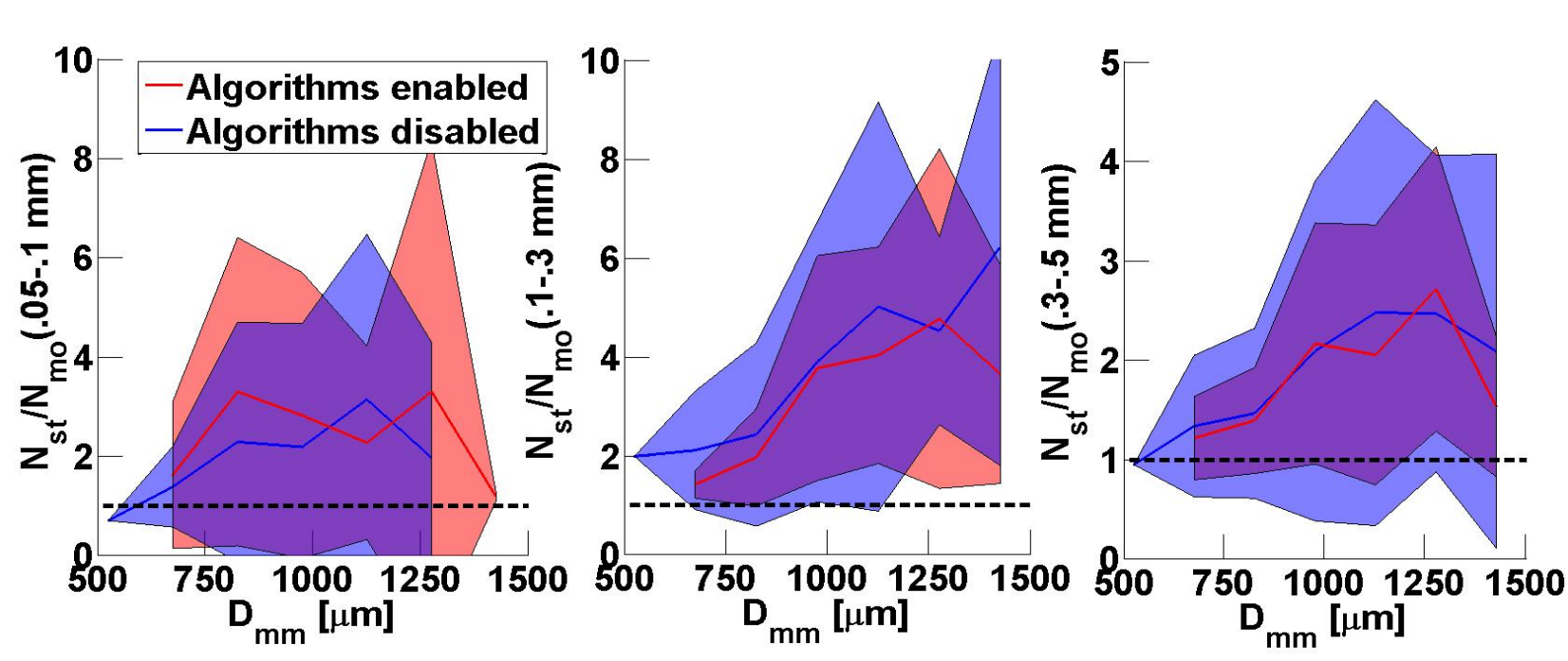

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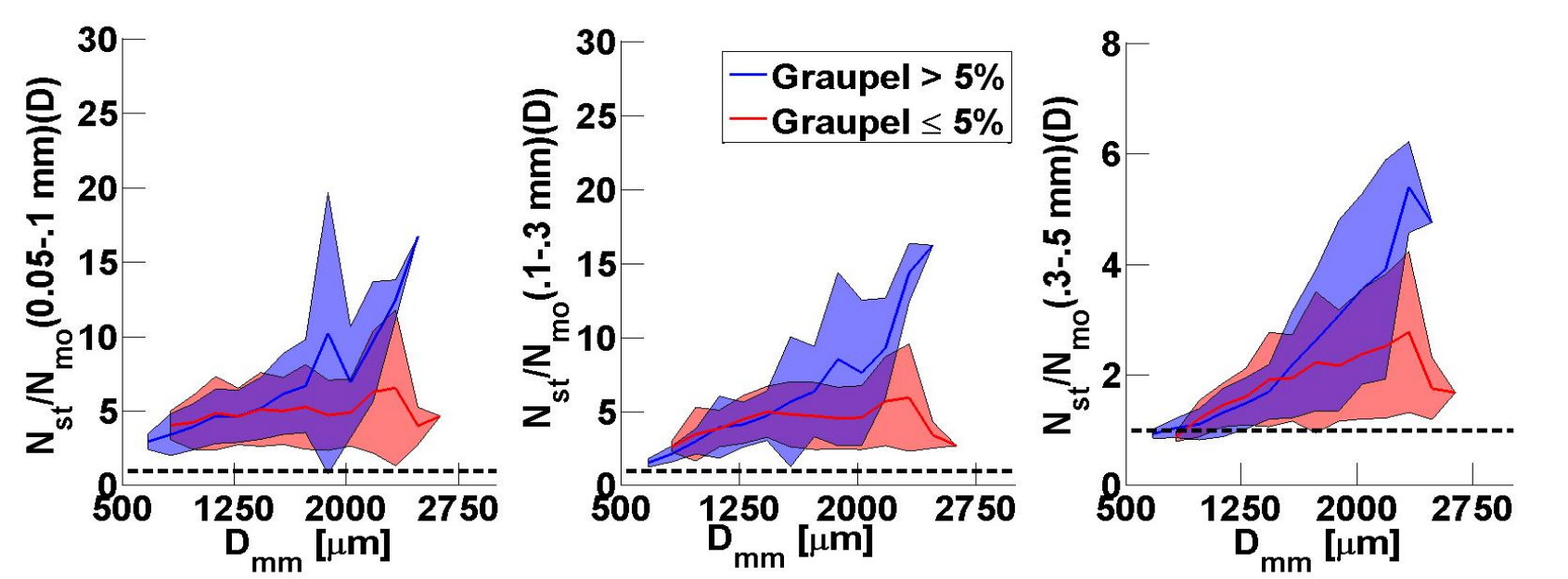
Need to take closer look at what amount of shattering depends on

Effect of Rimed Particles



Blue represents cases where > 5% of particles are graupel

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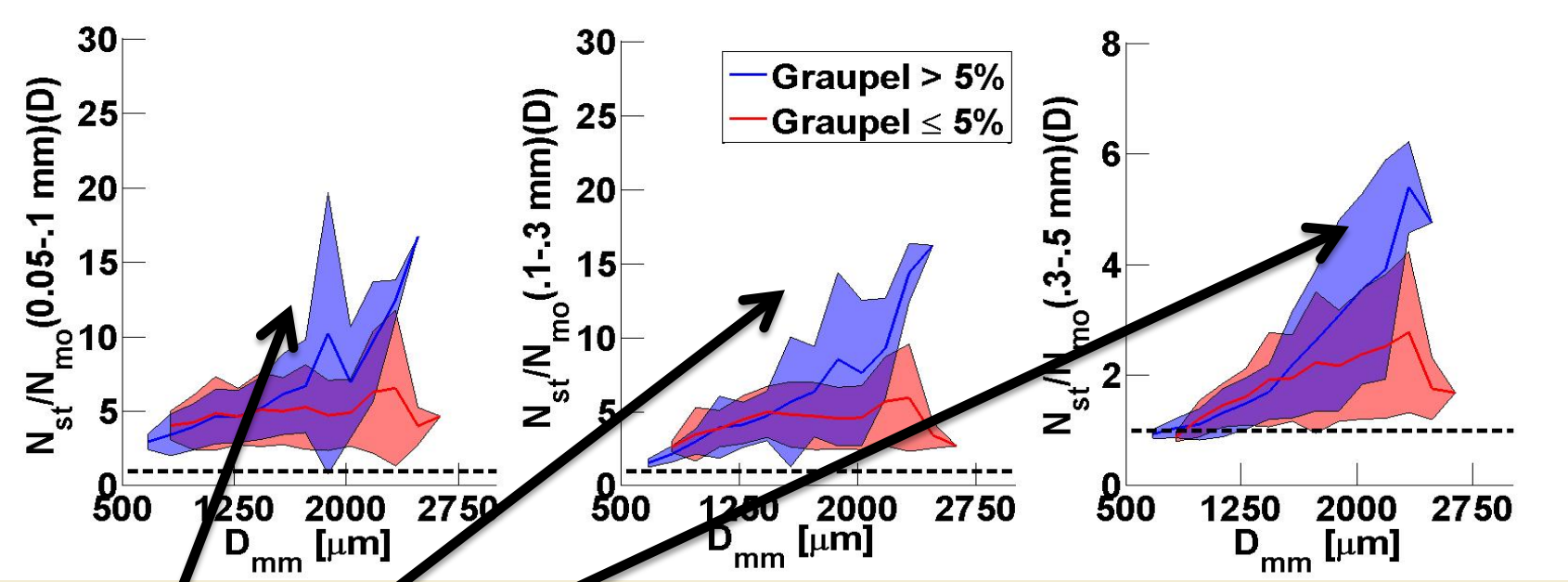

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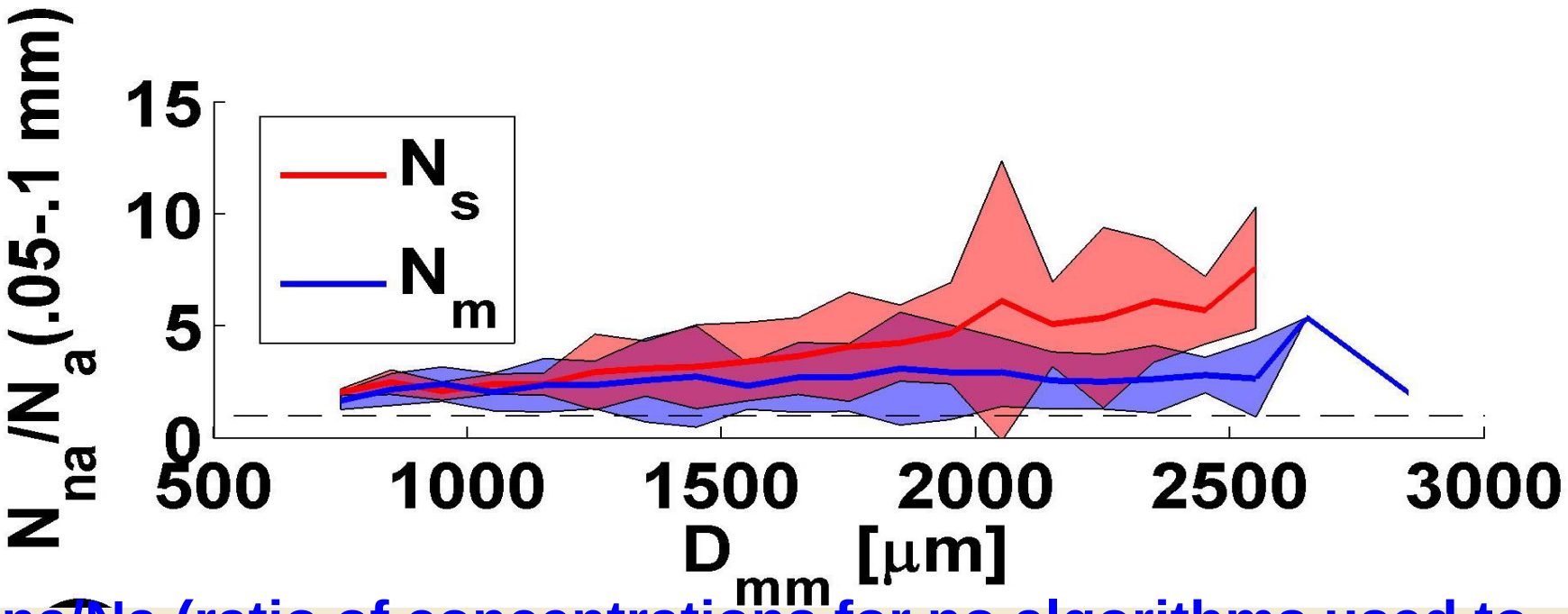
Large increase in ratios for Dmm > 2 mm when graupel present

Algorithms vs. Tips?



Nna/Na (ratio of concentrations for no algorithms used to when algorithms used for standard & modified probes

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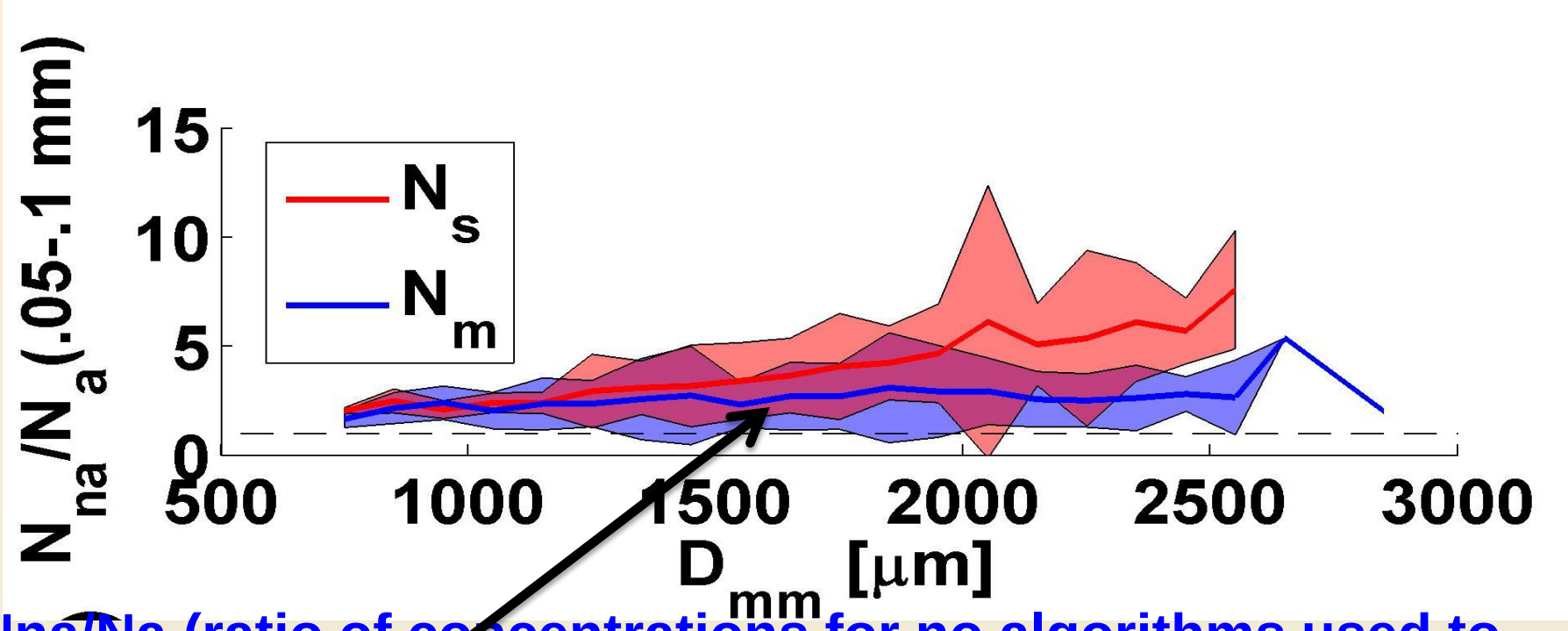

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Nna/Na > 1 for modified probes → modified tips do NOT remove all artifacts

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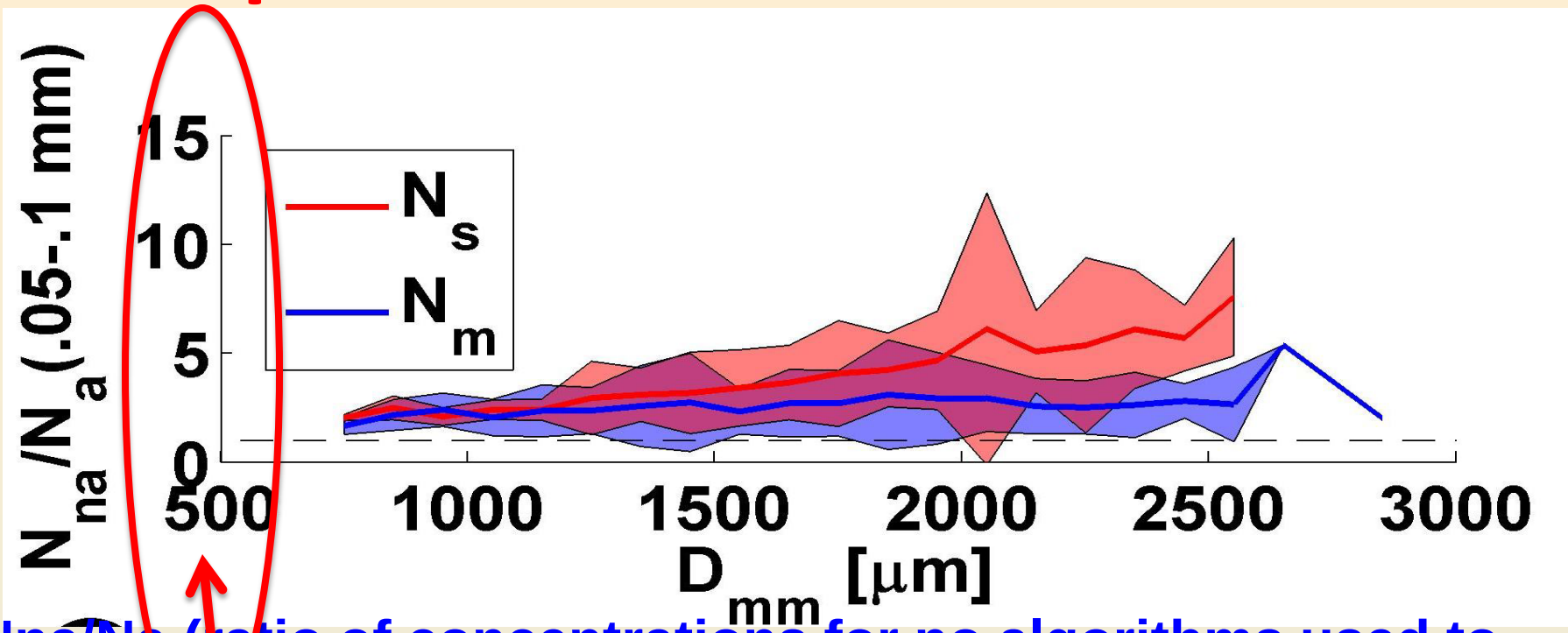
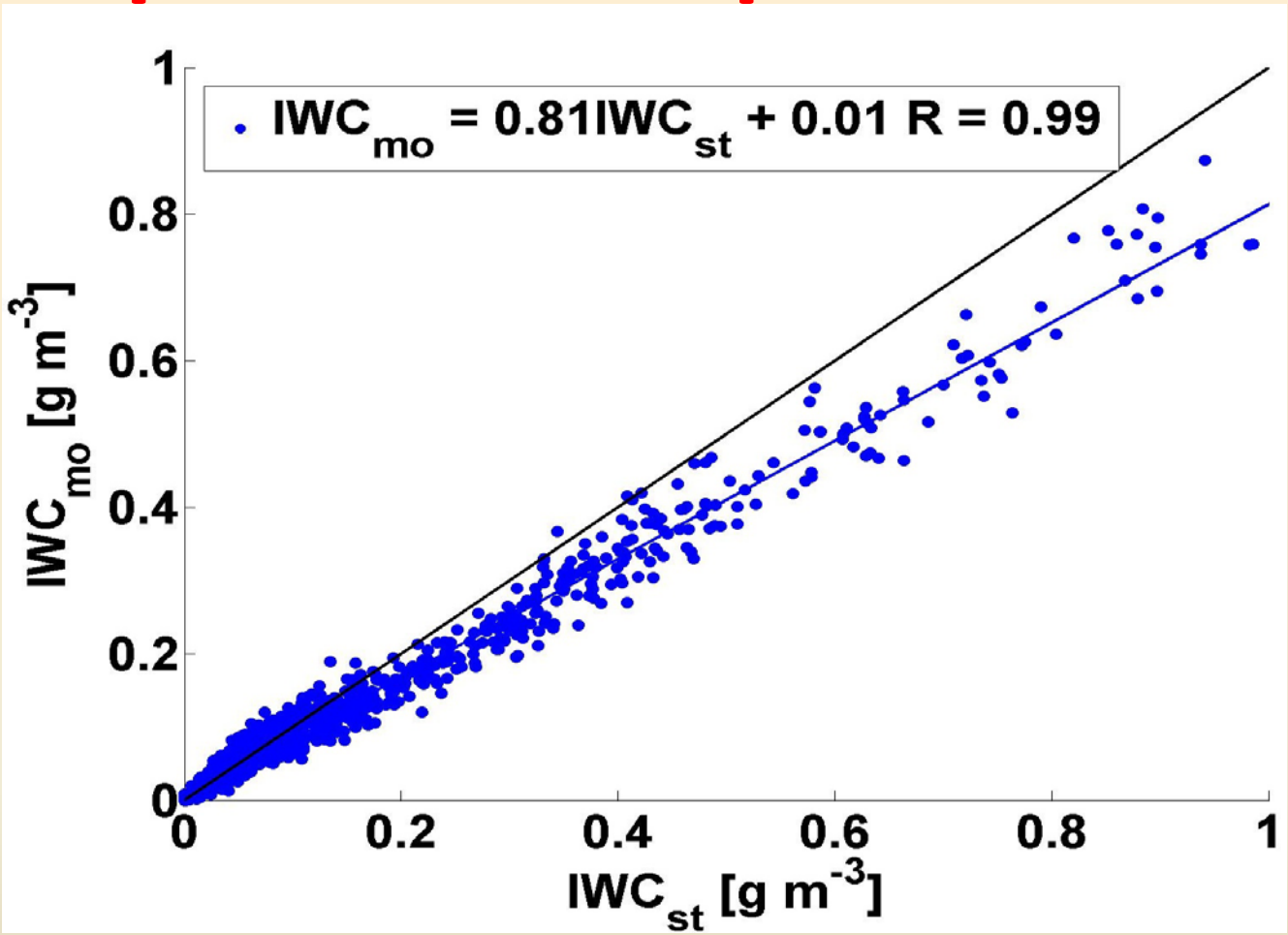


Nna/Na (ratio of concentrations for no algorithms used to when algorithms used for standard & modified probes

Nna/Na > 1 for modified probes → modified tips do NOT remove all artifacts

Nna/Na < Ns/Nm → tips more effective than algorithms at removing particles

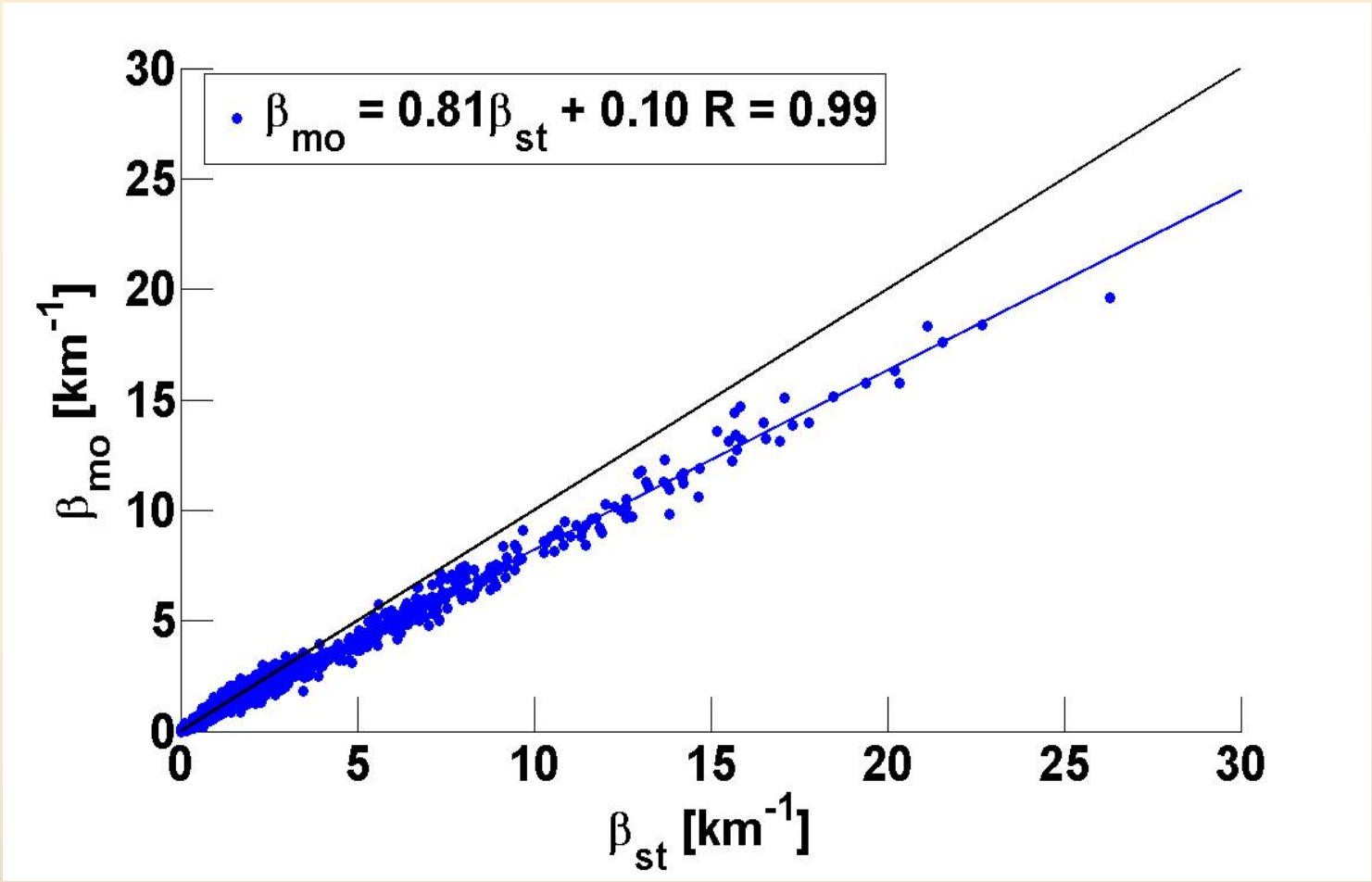
Impact on bulk parameters



IWC_{mo} vs. IWC_{st} for IDEAS+ISDAC shows ~20% difference, which is less than uncertainty in IWC due to m-D relation

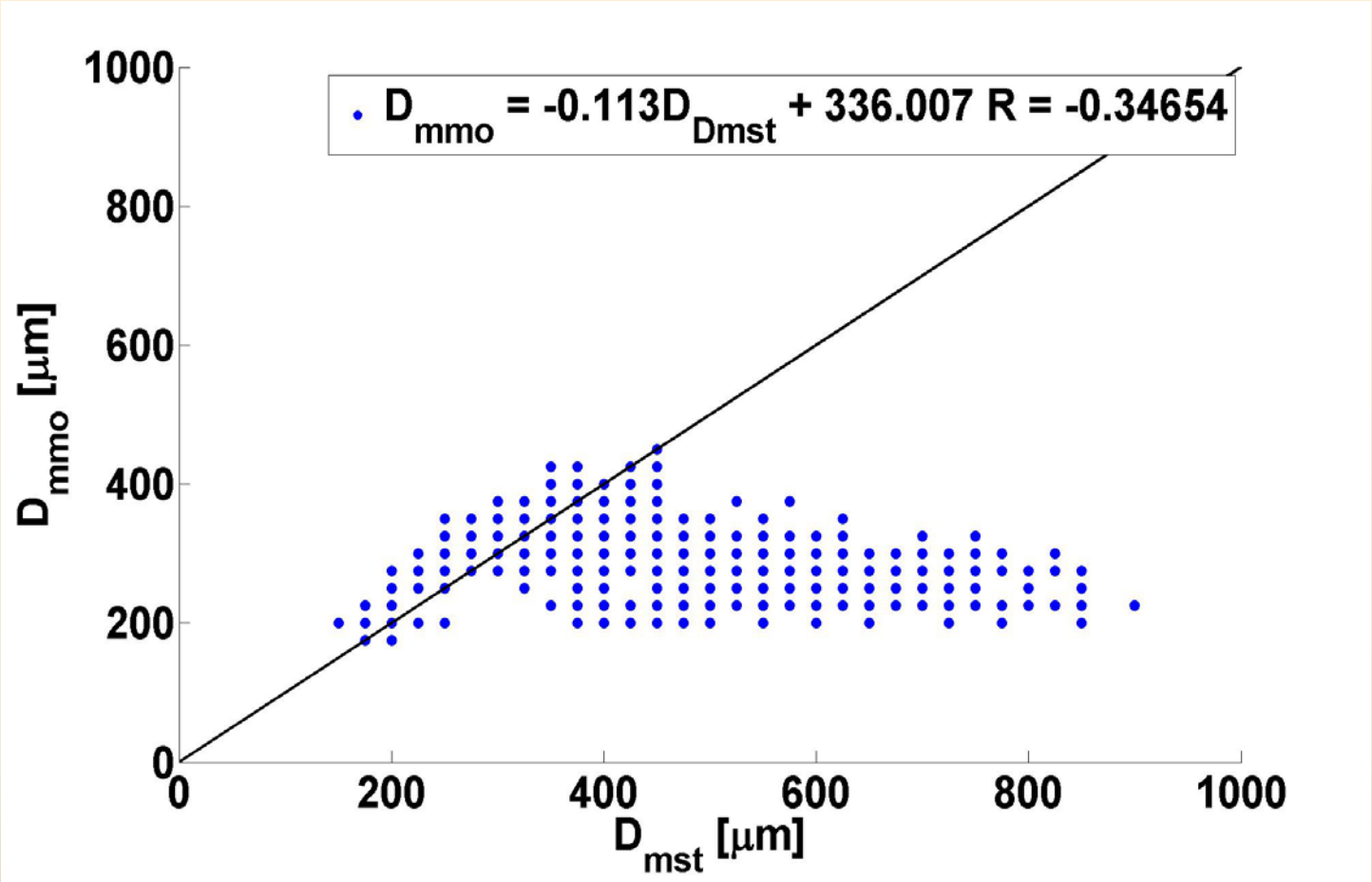
In –situ data provide reasonable IWC estimates

Impact on bulk parameters



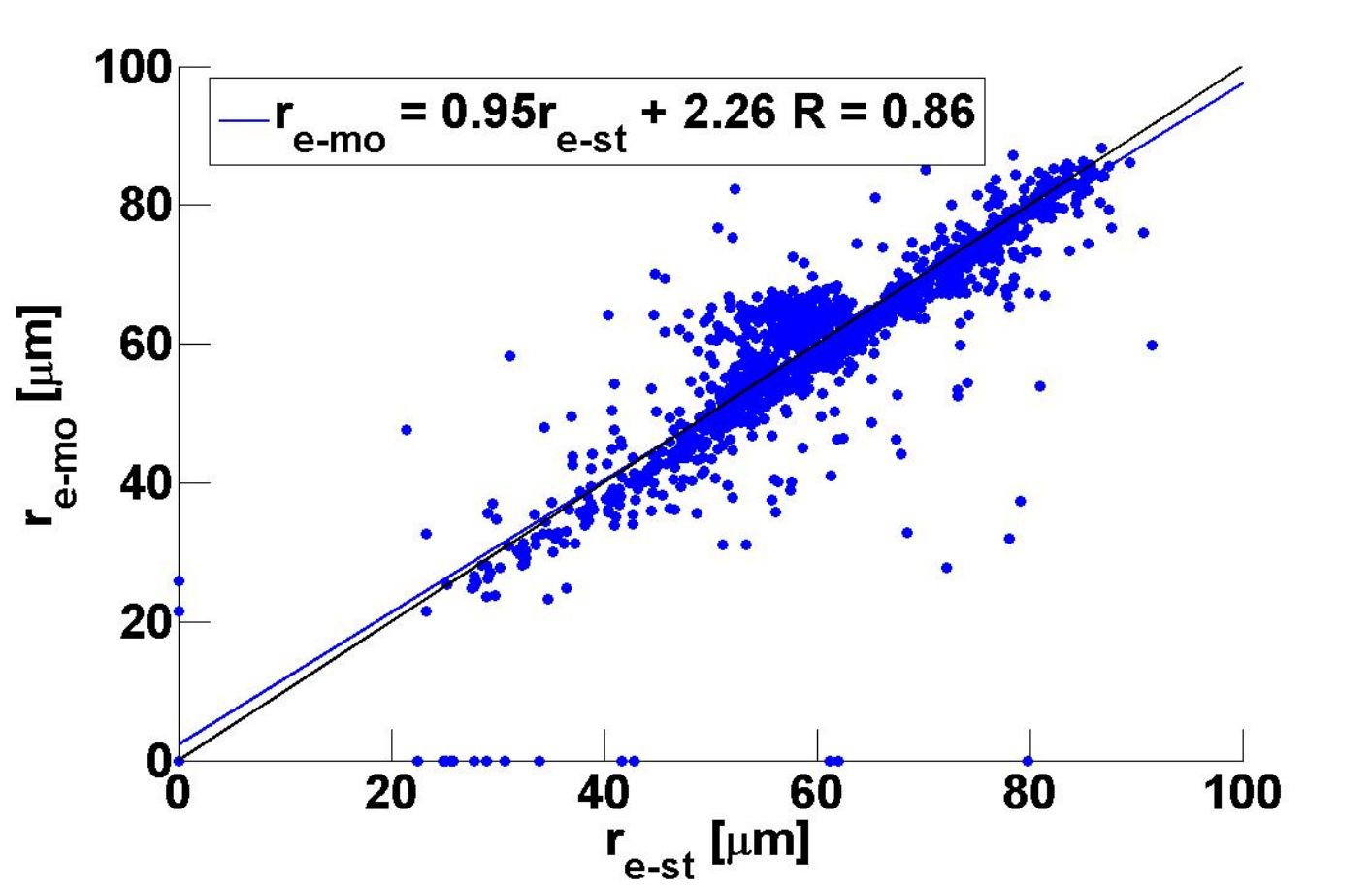
β_{mo} vs. β_{st} for IDEAS+ISDAC shows ~20% difference, but there will be more uncertainties due to shattering on forward scattering probes…. Need to investigate further

Impact on bulk parameters



Median mass diameters for IDEAS+ISDAC differ by factor of 4 depending on probe tips (and 67% difference on average)

Impact on bulk parameters



Effective radii show no systematic bias depending on whether from standard or modified tips

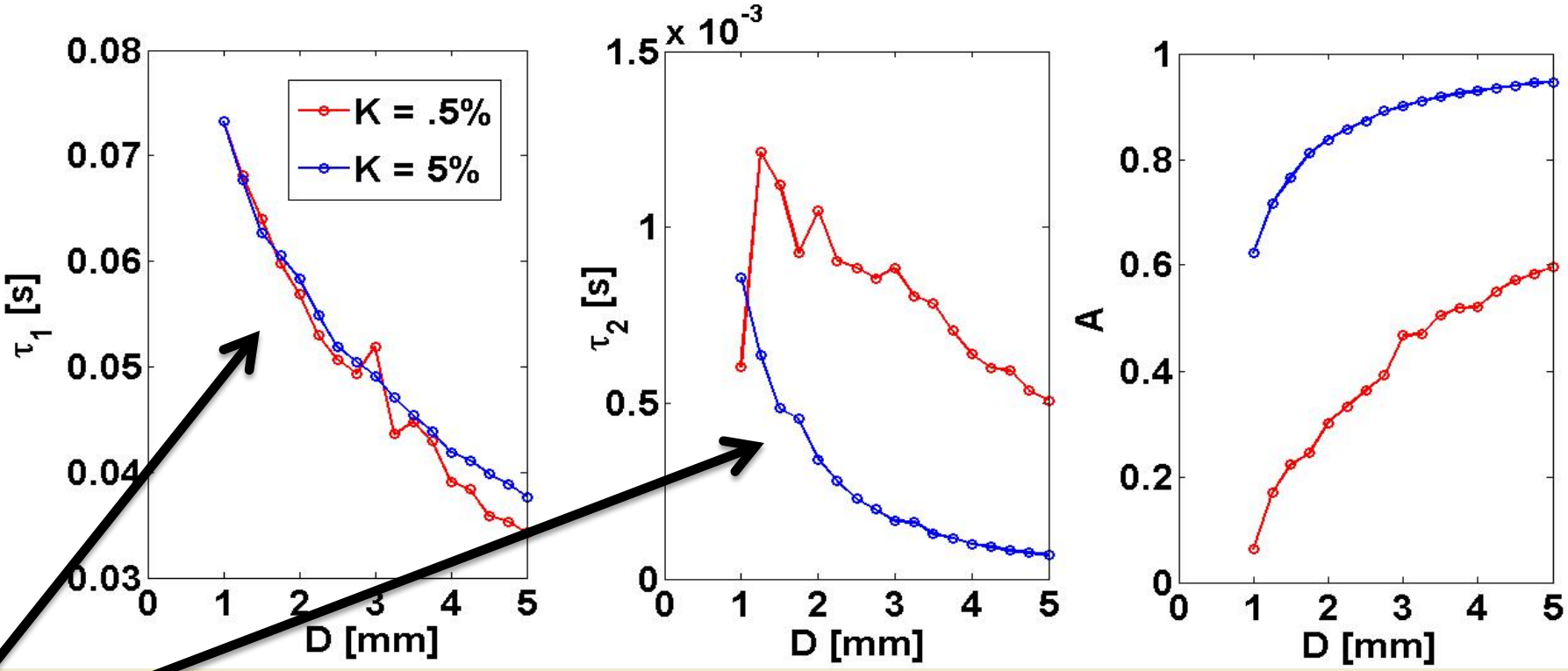
Conclusions

- Using modified tips reduces N(D < 0.5 mm) by factor > 2 for D_{mm} > 1 mm
- Larger D_{mm} & graupel best predictors of shattering
- Modified tips & processing algorithms combined best mitigate existence of shattered particles
- Modified tips reduce β, IWC by ~20%, no systematic bias in r_e
- Bias in D_m up to a factor of 4, 67% difference on average

Next Steps

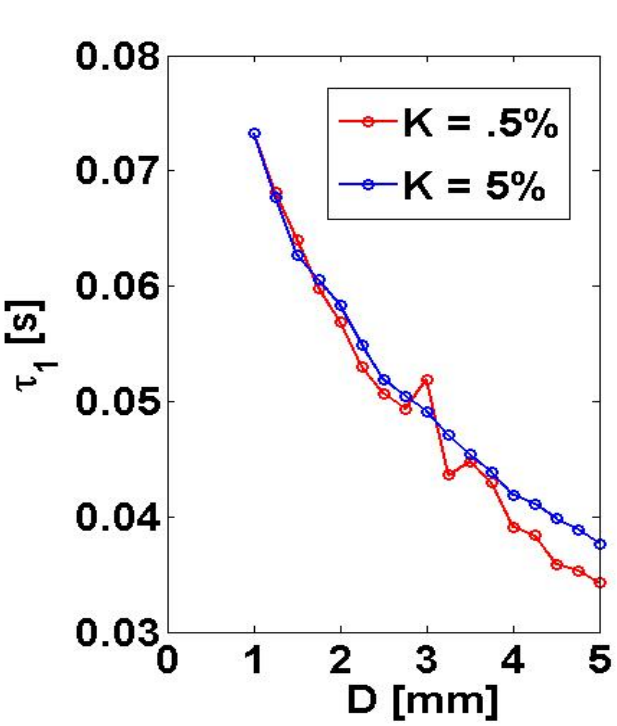
- **Continuing investigations:**
  - **Comparison of 2DC standard & modified probe data with 3VCPI & HOLODEC data**
  - **How shattering depends on cloud & aircraft parameters**
  - **Theoretical calculations on amount of shattering**
- **QUICR ramifications:**
  - **Level of uncertainty in bulk parameters different (determined on parameter by parameter basis)**
- **Next steps:**
  - **Modified probes do not eliminate shattered artifacts**
  - **investigate model of tips minimizing artifacts (dedicated field experiment?)**

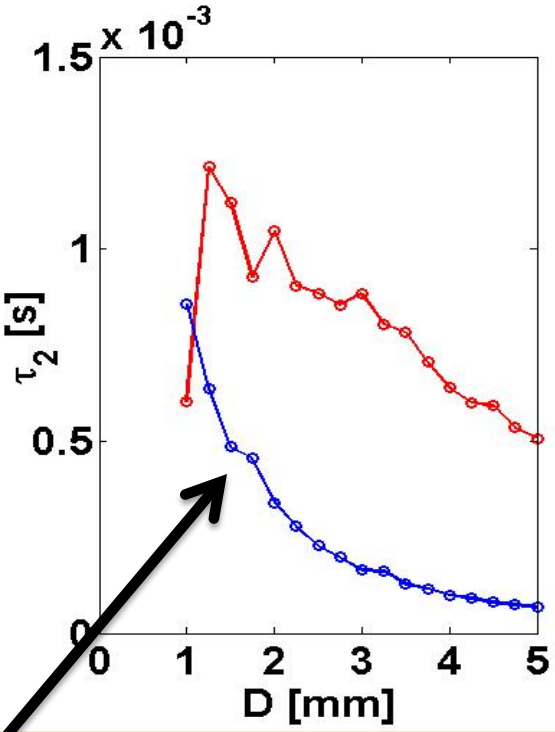
Theoretical calculations

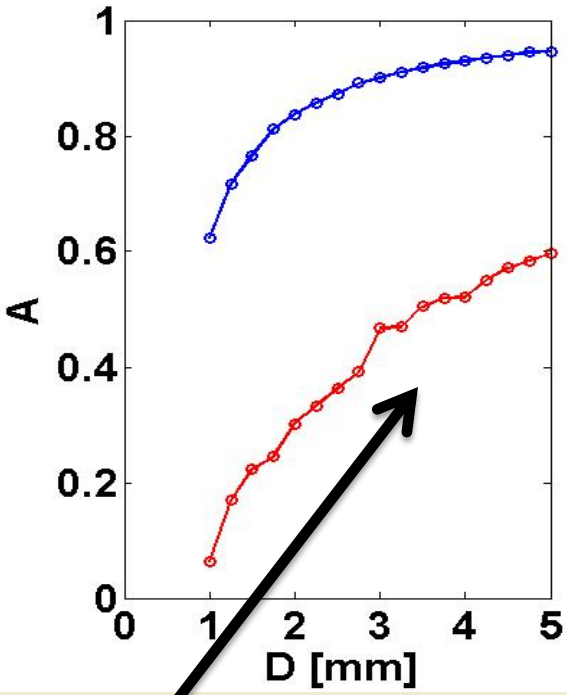


T_1 (mean interarrival time of real particles),
T_2 (mean interarrival time of shattered artifacts) strong function of particle maximum dimension D.

Theoretical calculations

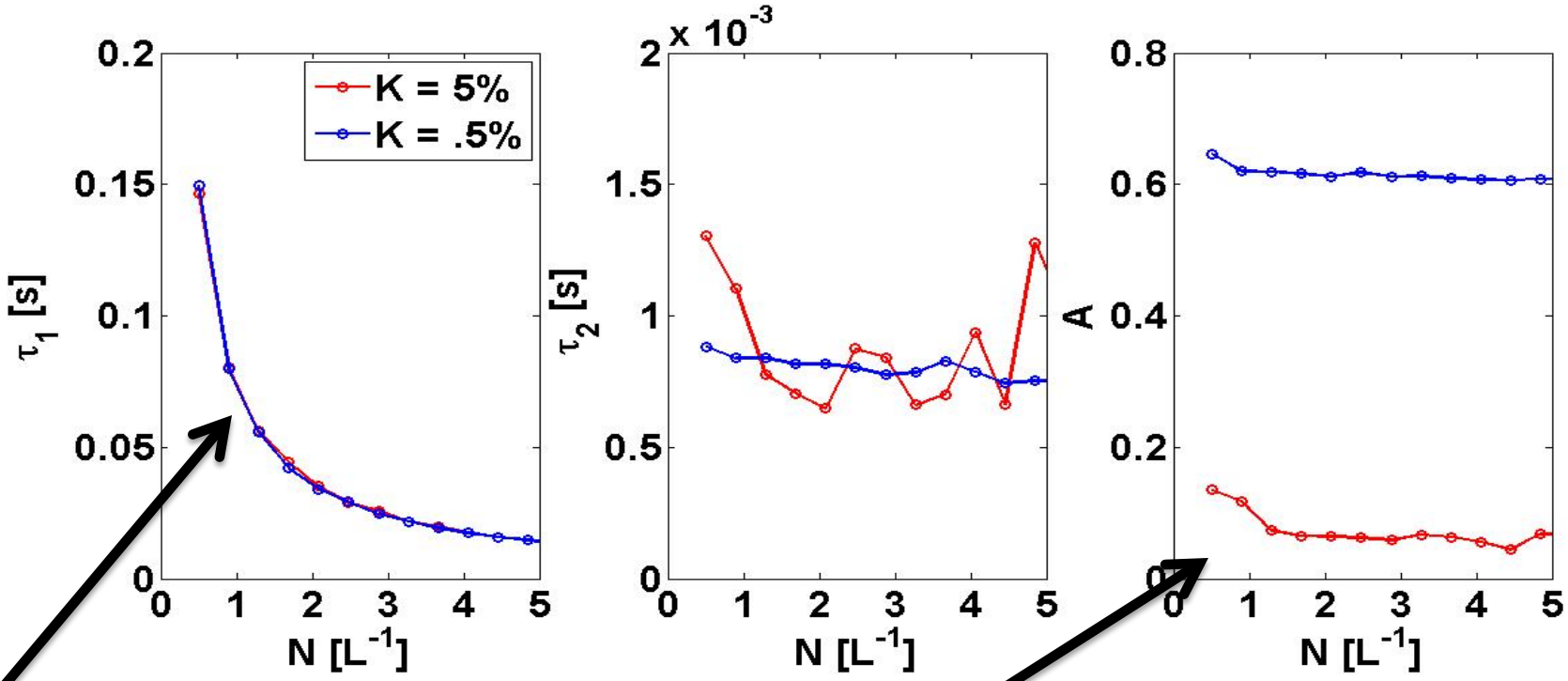






T_2, A (% contribution of shattered artifacts) strongly depends on D, K (probability that artifact enters sample volume)

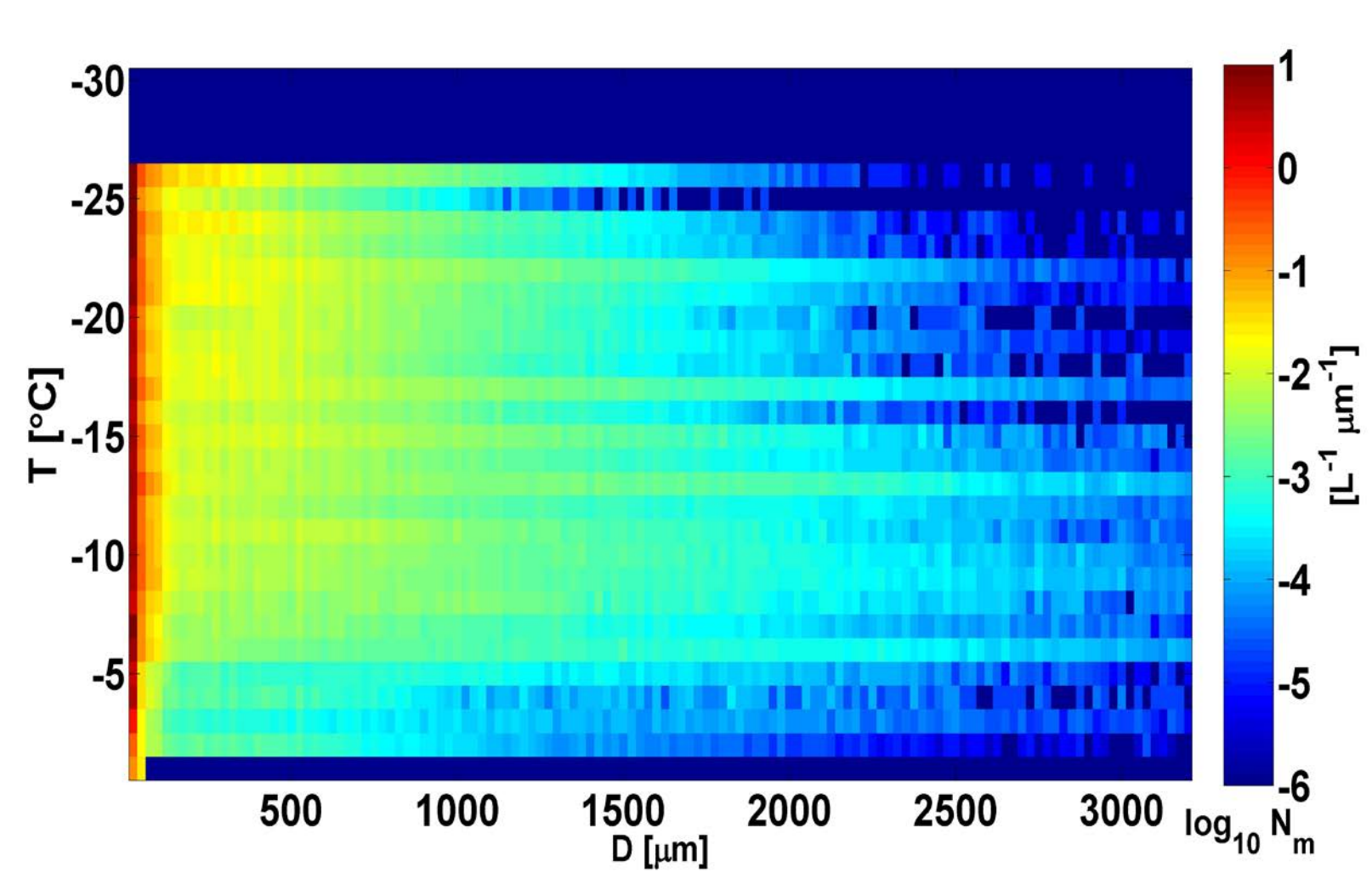
Theoretical calculations



T_1 depends on N (number concentration of real particles).

T_2, A do not depend on N.

Sample Data from IDEAS-4/ISDAC



Two 2DCs, 3V-CPI & HOLODEC flown in tandem during IDEAS ideal for investigating shattering: wide ranges of T & conditions sampled

Data in Arctic cirrus from 2DC with & without tips also available