Amazonian Clouds microphysical profiles measured by HALO

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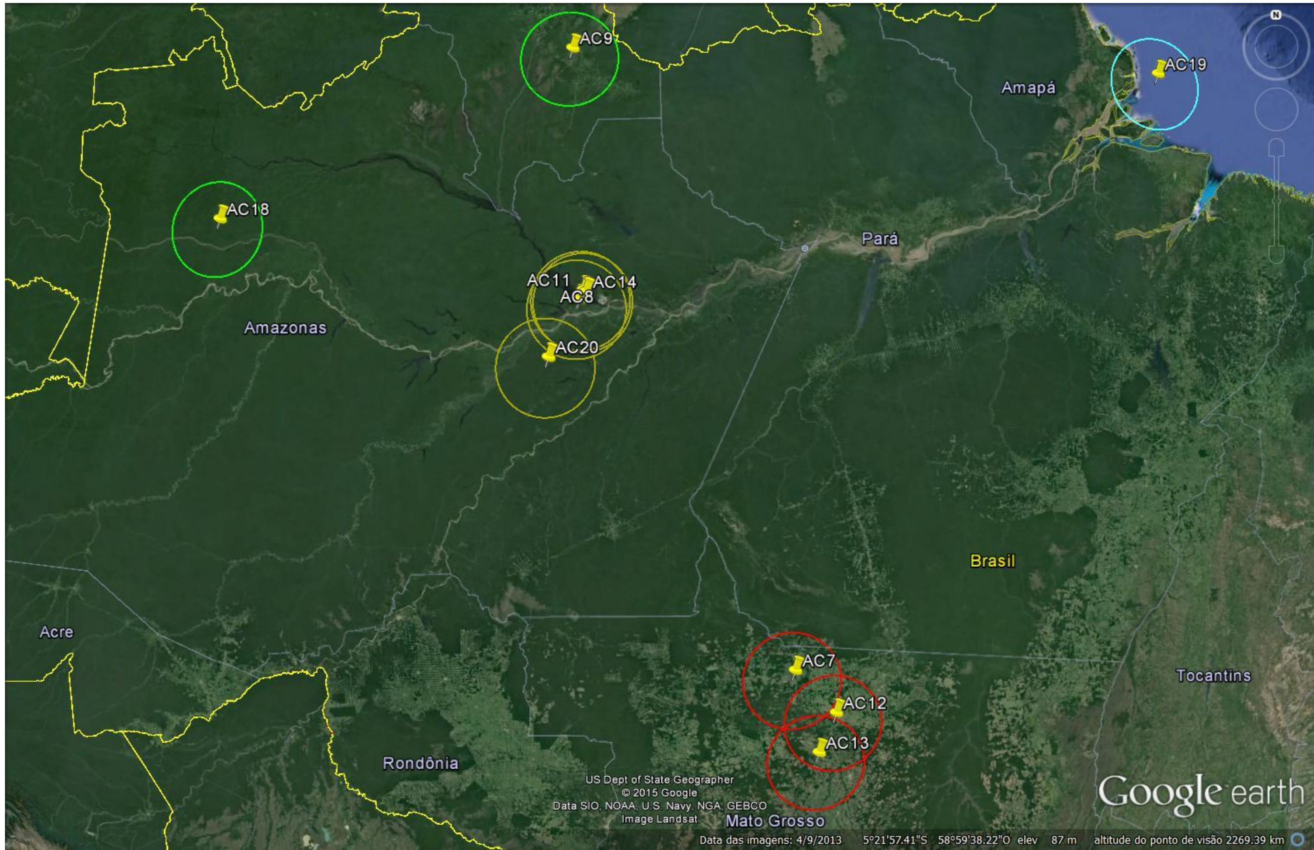
Motivation

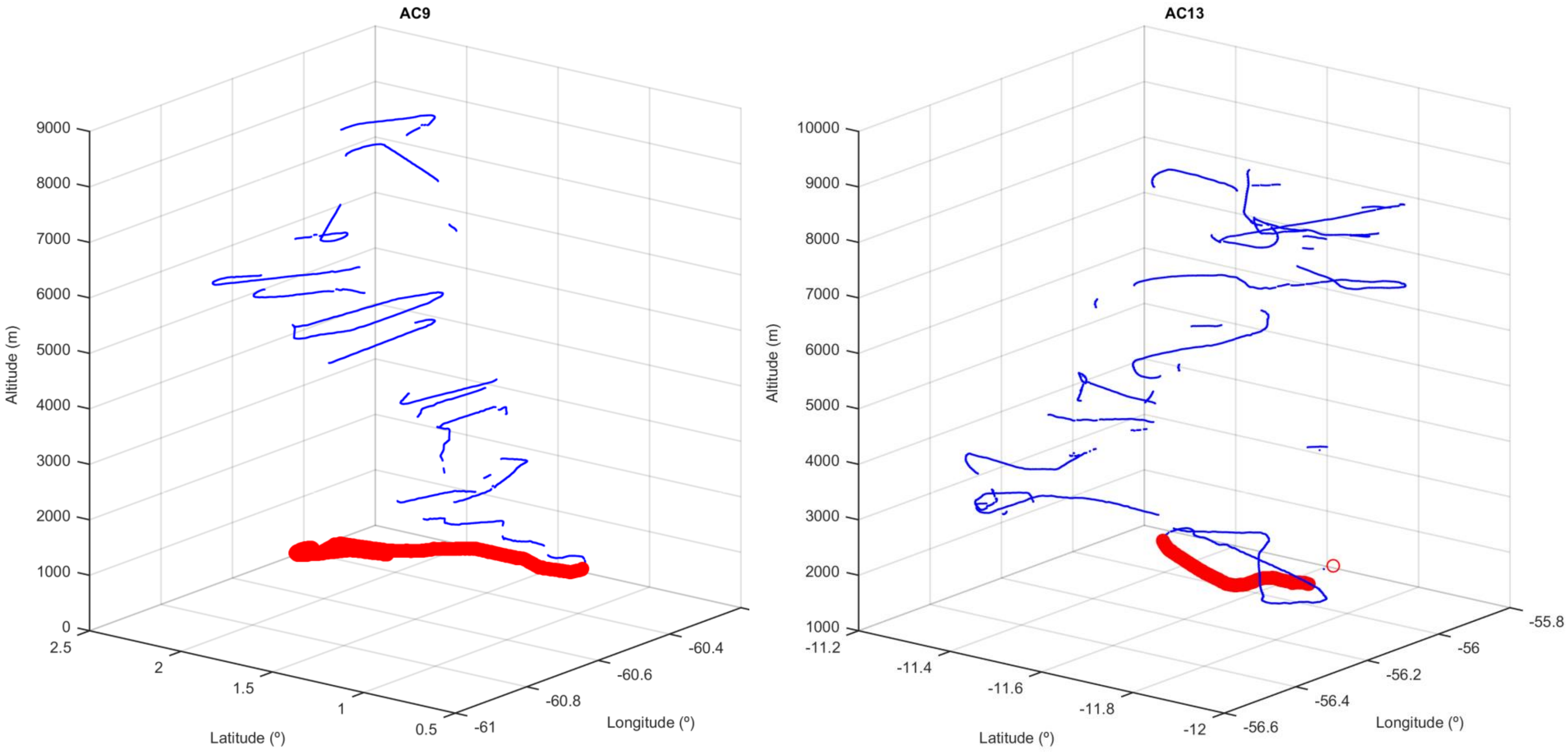
- Need for microphysical characterization of tropical convective clouds
- Bulk microphysical models, commonly used in numerical models, frequently rely on observations
- Important to analyze aerosol effects on cloud vertical evolution in order to understand its impacts on climate
  - How to reproduce observations in models?

Methodology

- All HALO cloud profiles were identified and classified



-> Selected level legs (vertical acceleration ≤ 4 m/s^2)
-> Identified "aerosol leg" (under clouds)
-> Calculated mean CN for aerosol leg



Methodology

- Combined CDP, CIP, PIP DSDs
  - Weights for overlapping D based on bin widths (inversely proportional)
- Filtering:
  - $NC_{D<50} > 80\ cm^{-3}$
  - $NC_{D>50} > 0.05\ cm^{-3}$
  - Only spherical hydrometeors (NIXECAPS)
- Relative altitude
  - 0% for cloud base
  - 100% for $H_{D\sim28}$ (estimated)

Flight	Cloud Base (m)	$H_{0°C}$ (m)	$H_{D\sim28}$ (m)
AC7	1768	4774	8000
AC8	762	5120	5200
AC9	1098	4816	5100
AC11	1372	4489	7500
AC12	1677	4759	8500
AC13	1890	4850	8400
AC14	1524	4823	4500
AC18	1436	4689	6100
AC19	518	4337	2700
AC20	1677	5148	8600

-> All DSDs measured

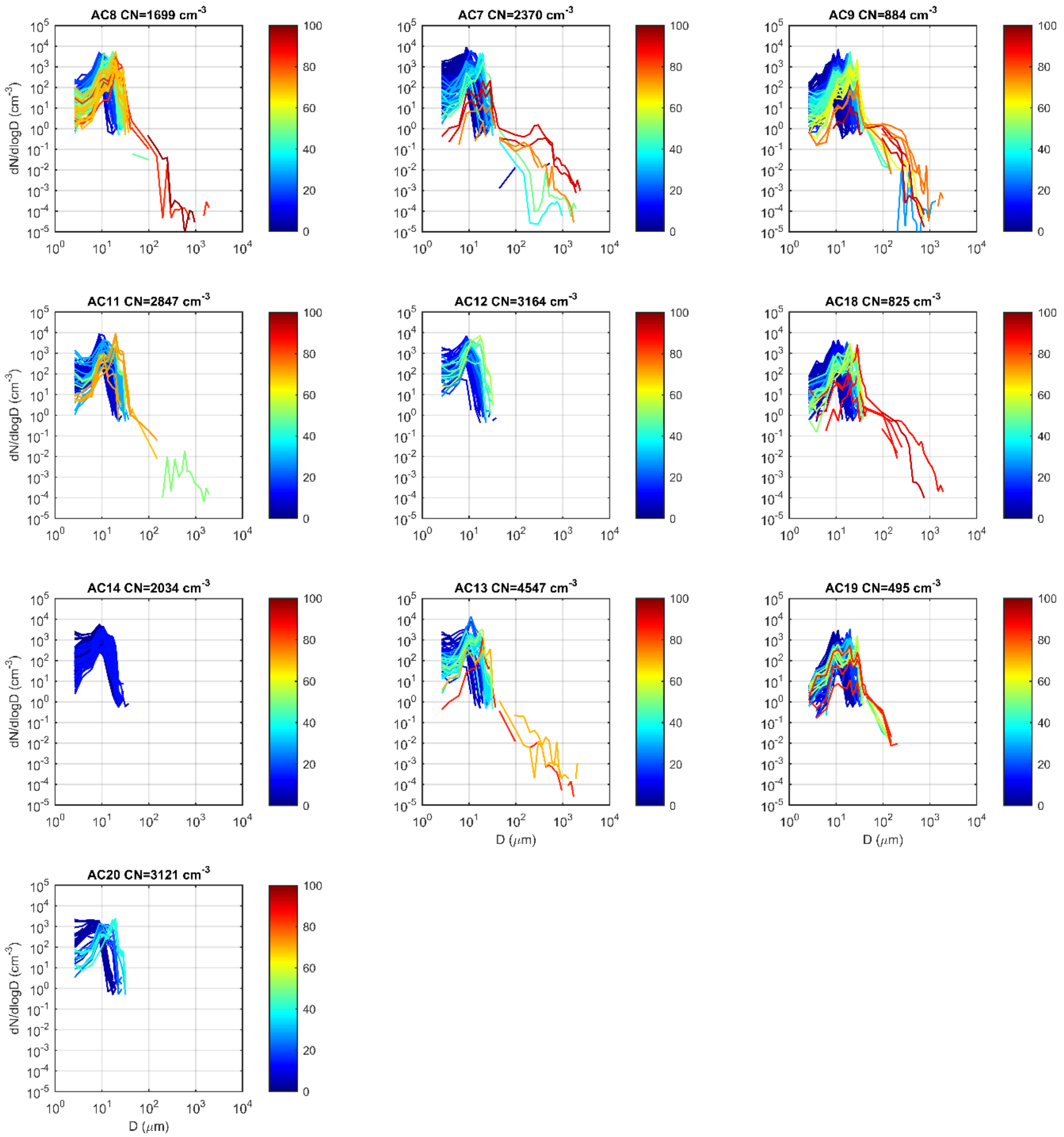
- Colors are relative altitude

-> Cloud-DSDs vertical profiles are directly related to aerosols

- Earlier second mode on background clouds

-> Relatively few observations of precipitation-DSDs

- Consistent with systems at their initial stages



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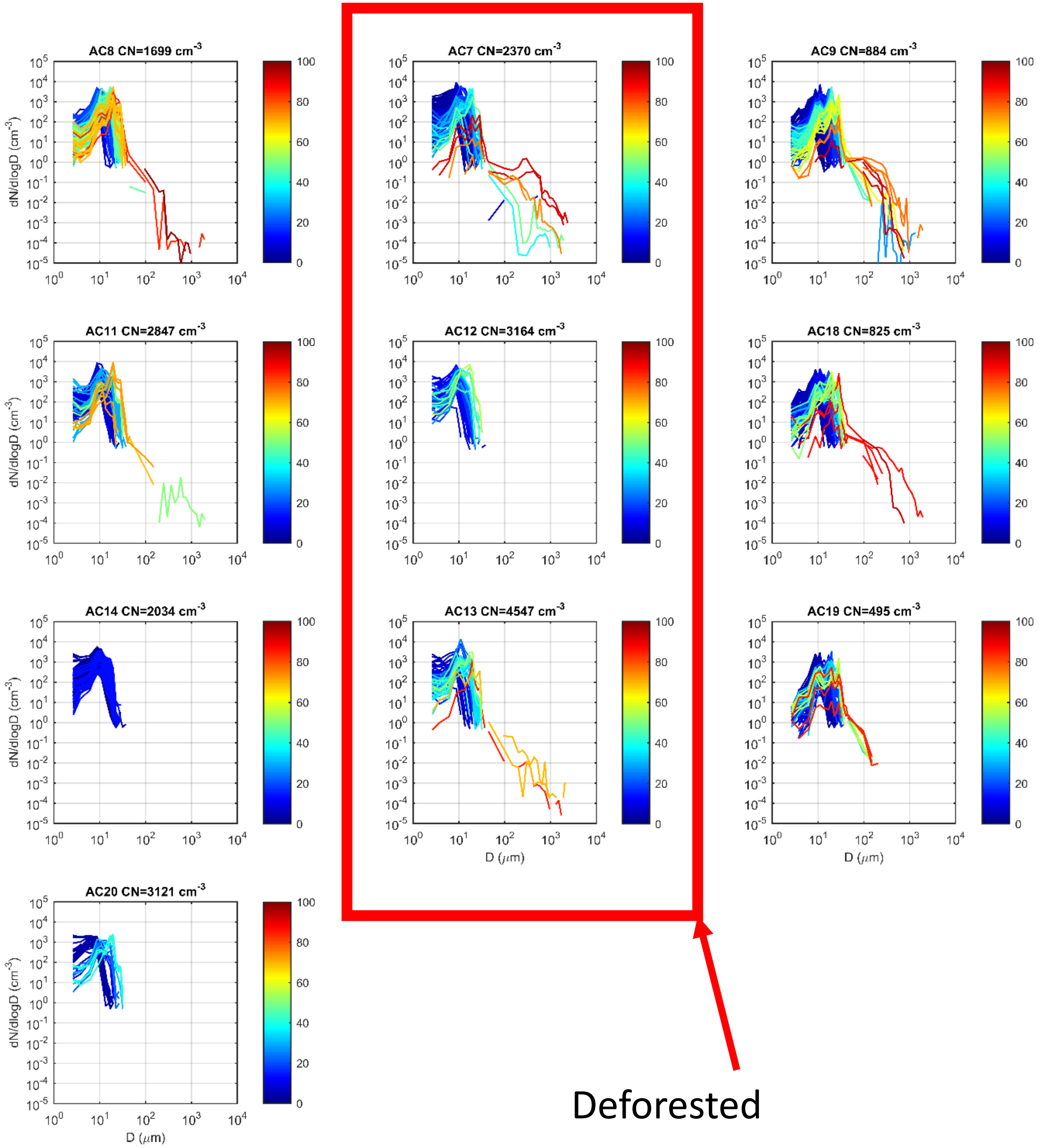

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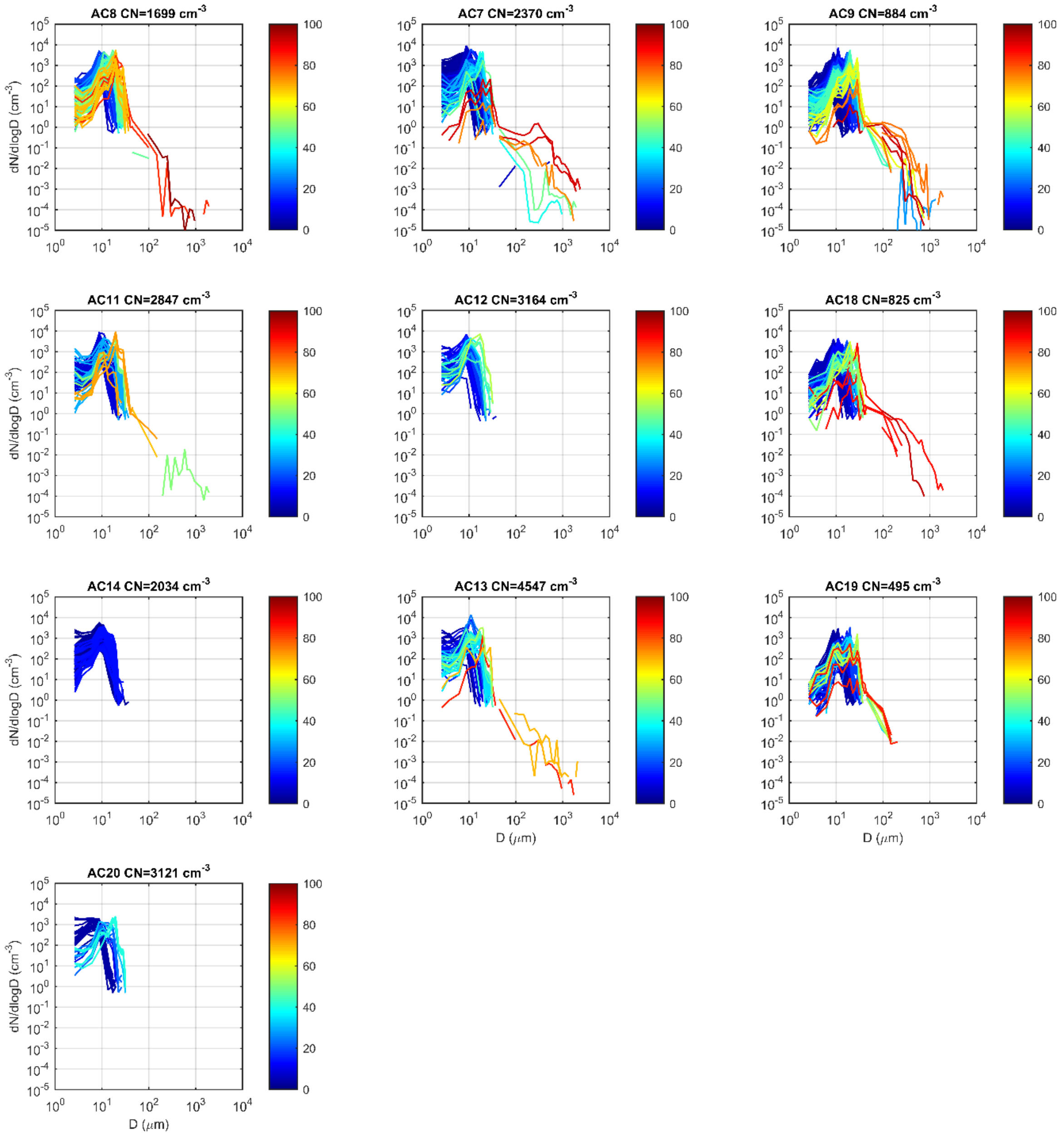

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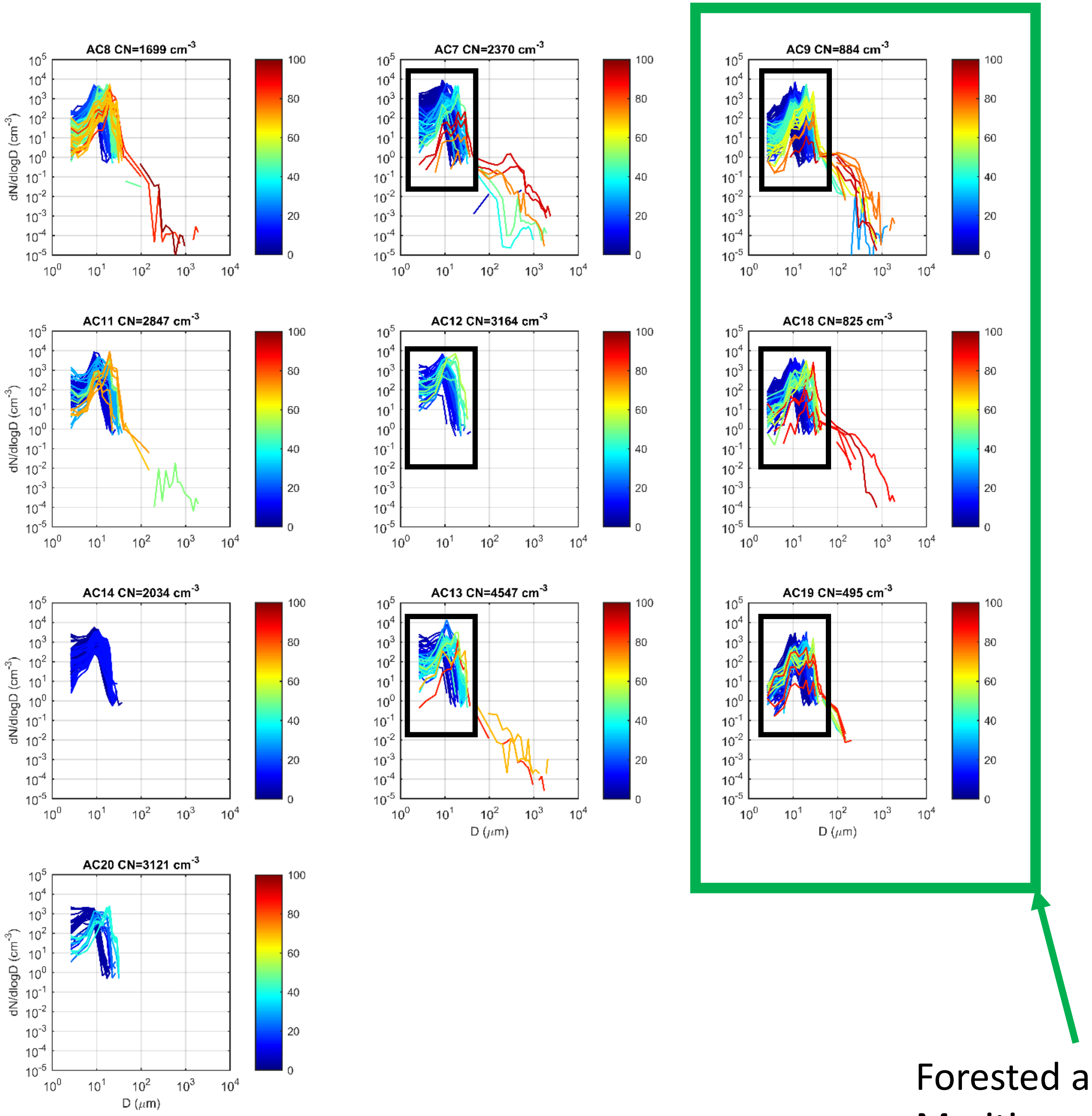

Forested and Maritime

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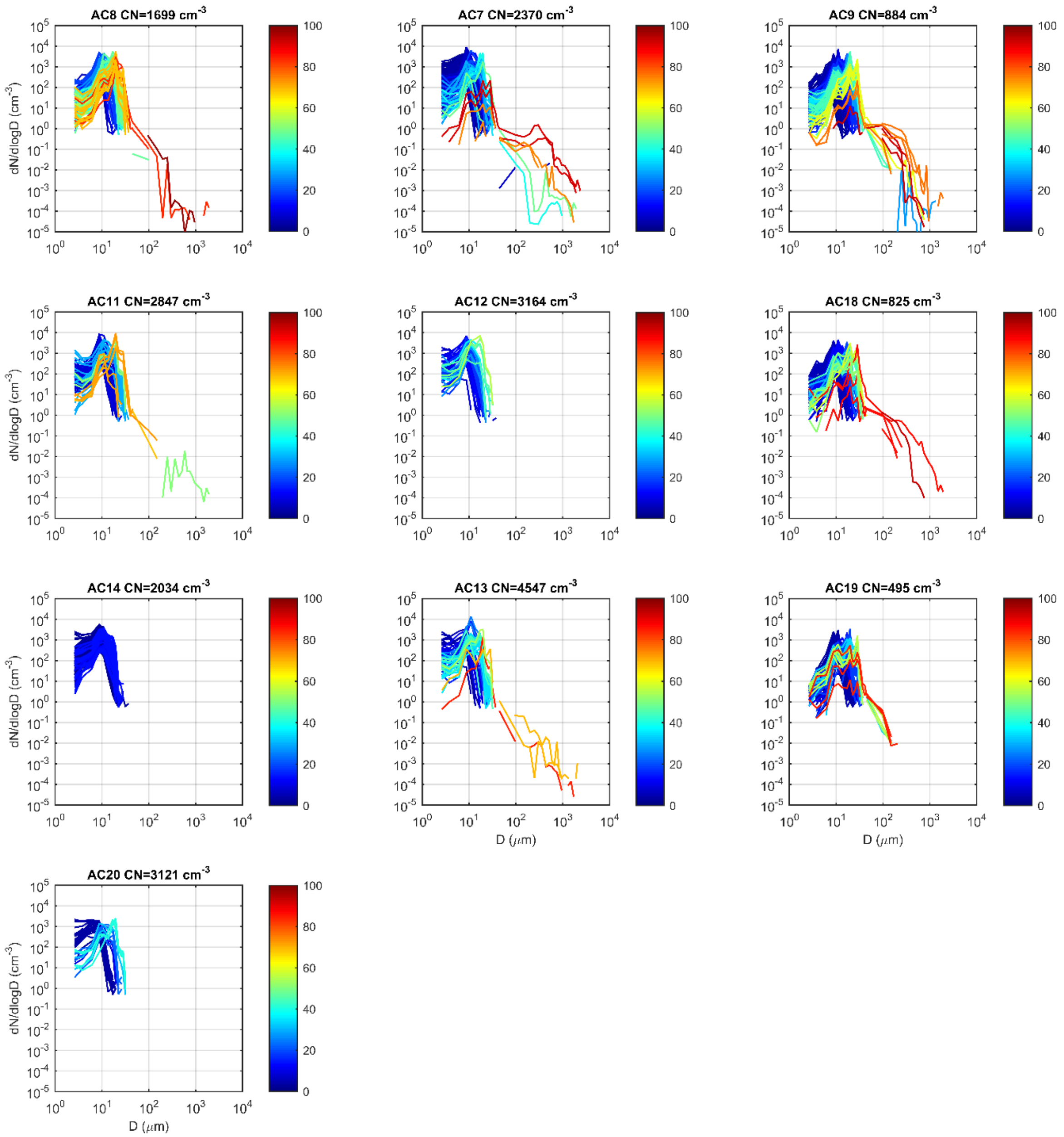

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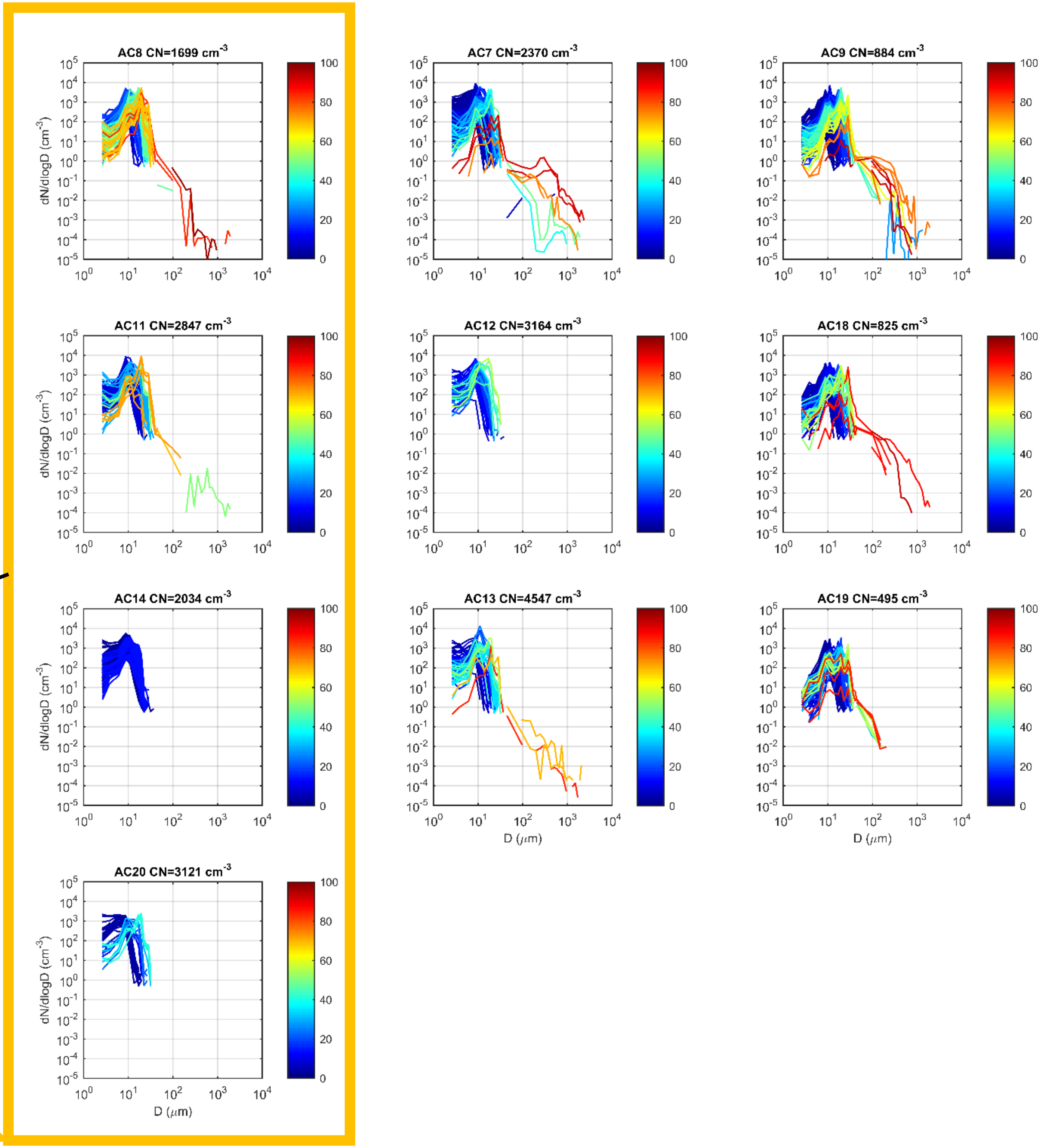
Similarities with deforested profiles due to pollution (BB, Manaus)

Closer to Manaus



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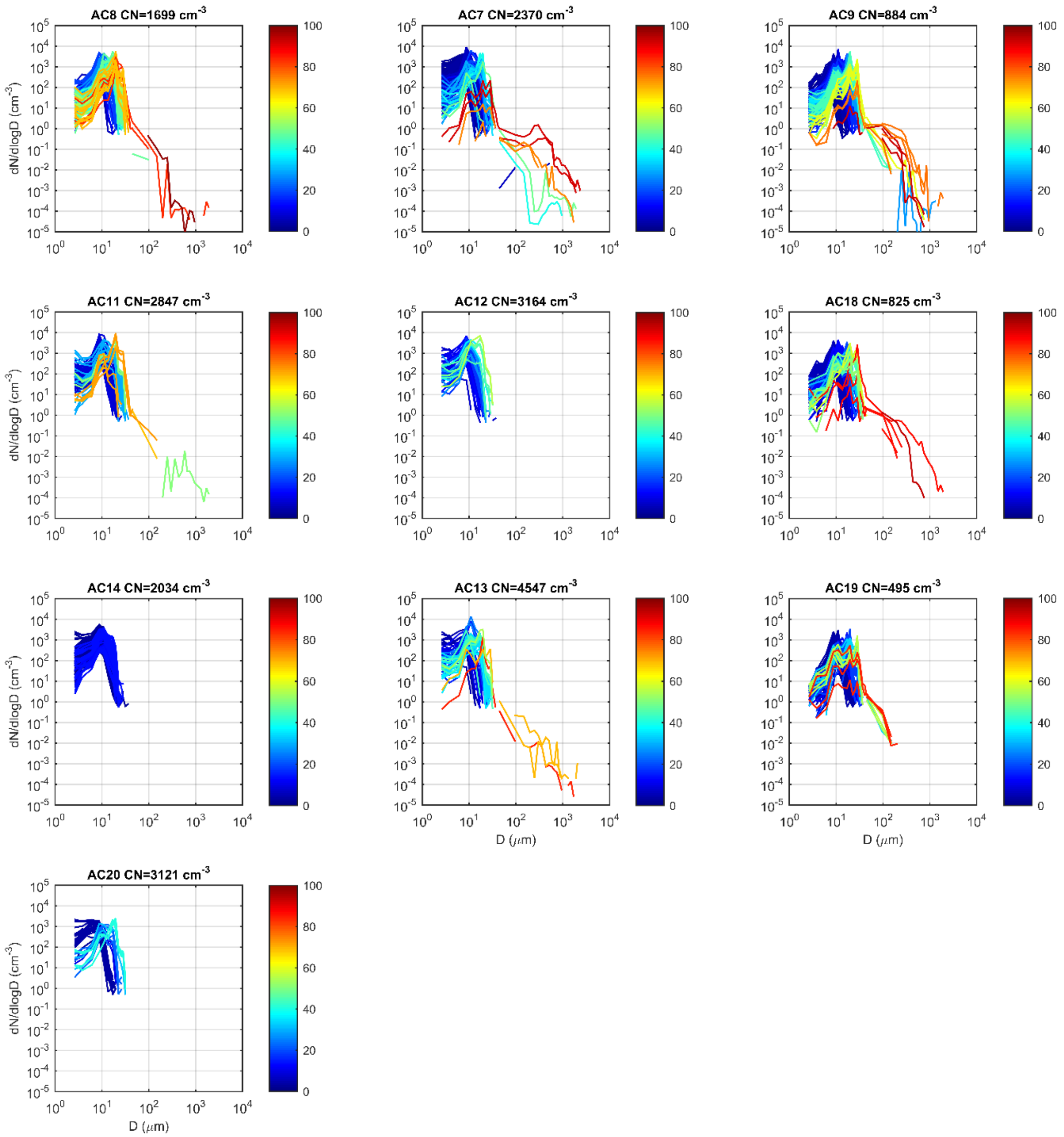
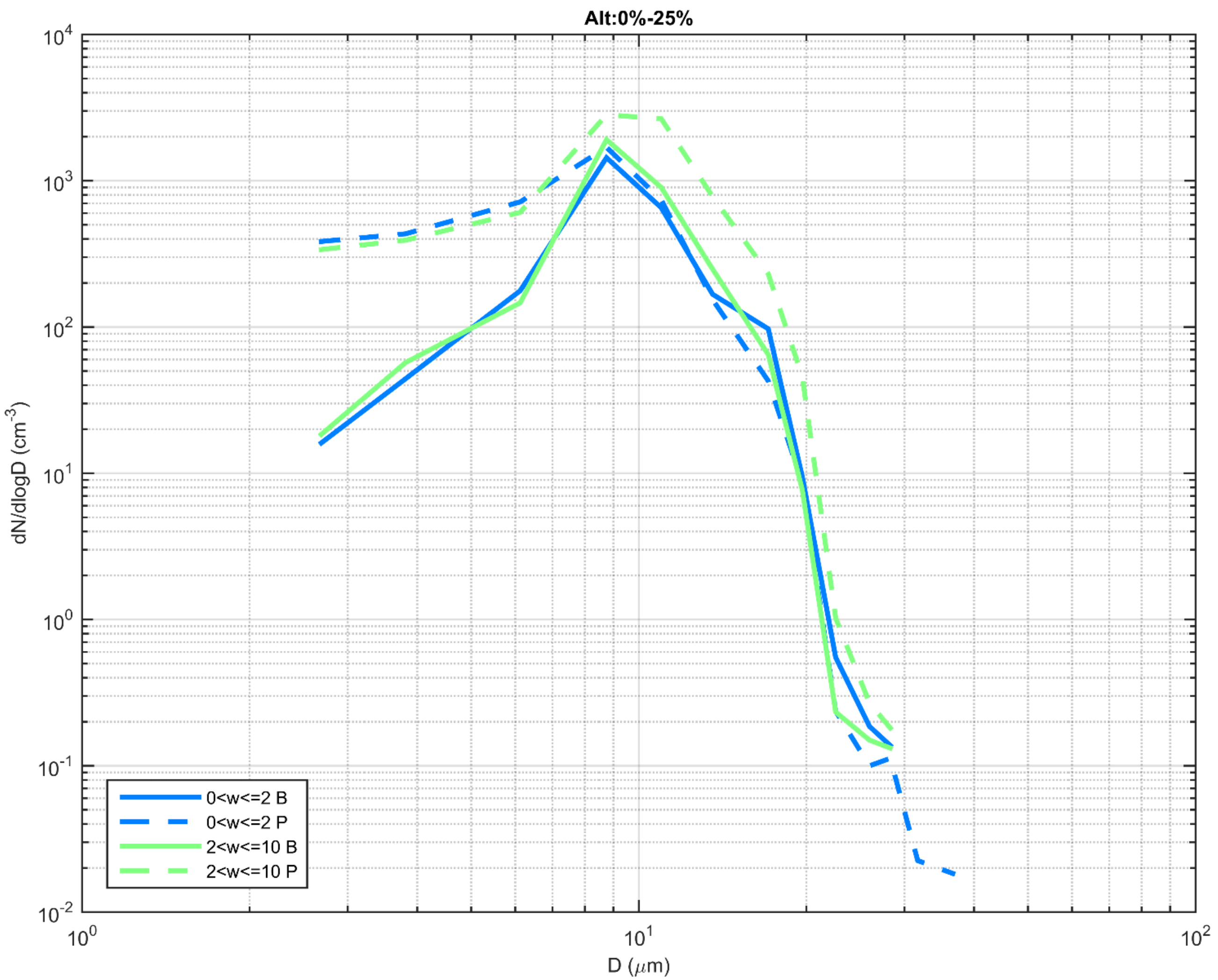


-> Differences due to aerosols > due to w close to cloud base
  - Lack of w data for Alt>25% (half of the w data is undefined for the chosen data points)



Gamma parameterization

- How to reproduce aerosol effects on the DSDs in models?
  - Need to understand how models treat the DSD -> Gamma
- Bulk microphysical models, widely adopted, usually treat DSDs as

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

- In 2-moments models, μ is either fixed or diagnosed
  - Statistics of Gamma parameters in tropical clouds can help
  - Observation of the evolution of the Gamma parameters also help – DSD variability throughout the lifecycle

-> Important to understand the role of each parameter before analyzing aerosol effects on them

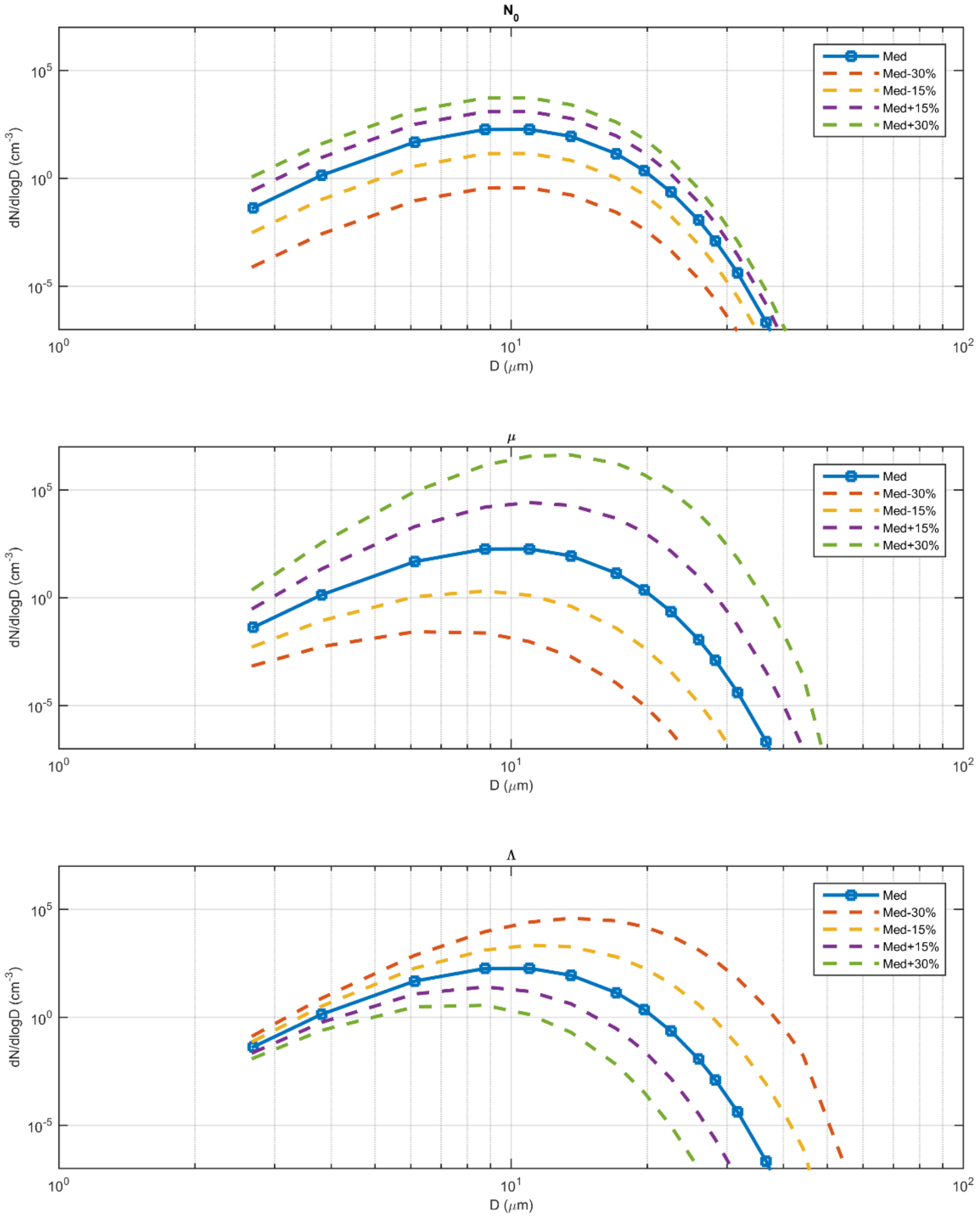
-> Main effects of the Gamma parameters on DSD properties

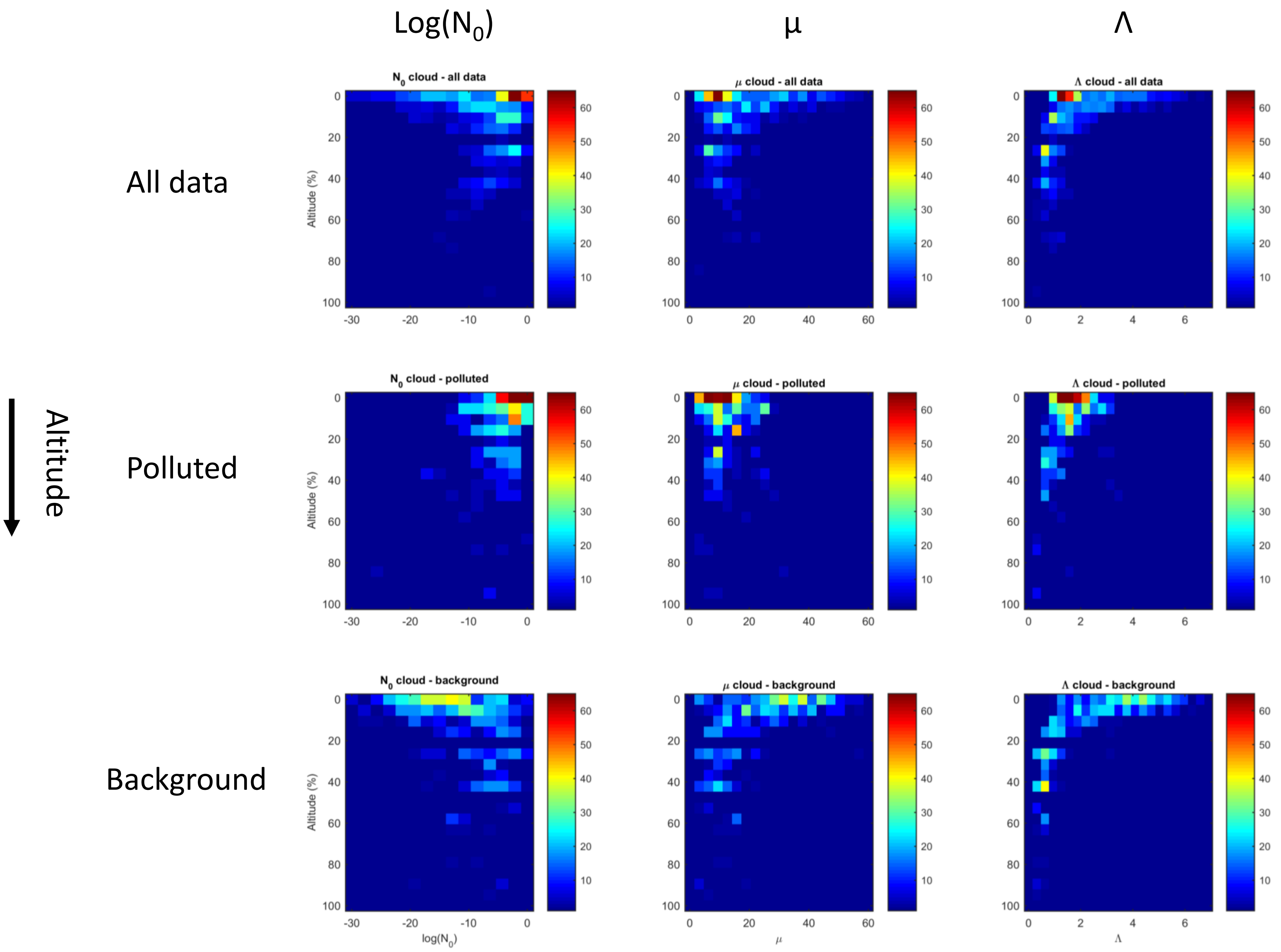
- N_0 – concentrations
- μ – concentrations and D
- Λ – D and width

-> Balance between parameters determine DSD bulk properties, not a single one

-> In figure: parameters varied by ±30% (N_0 in log scale, otherwise no observable effect)

-> For the measurements fitting, will use the parameters that conserve M0,1,3





-> Colors are in ‰

-> Data for cloud DSDs only (D<50µm) – not a lot of precipitation DSDs observed

-> May be interesting to compare this vertical structure to what models produce

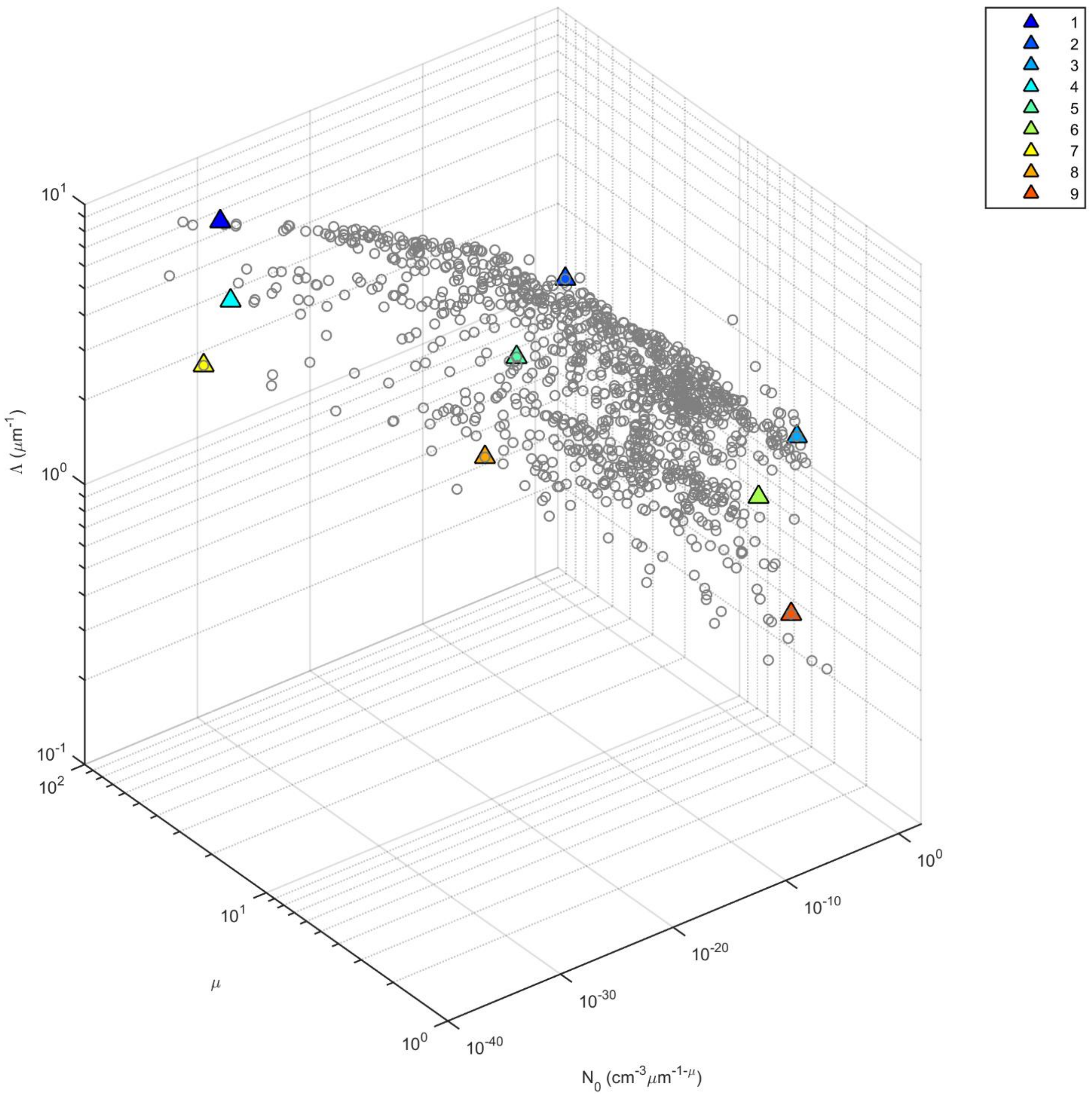
-> Clear tendencies with altitude

-> Distinct behaviours for polluted (AC7,12,13) and background (AC9,18) clouds
  - Parameters tendencies with cloud processing relatively similar

-> Would be interesting to analyze droplet growth processes impacts on the parameters

-> Gamma space – practical way to check DSD variability in models

-> It is also a phase-space



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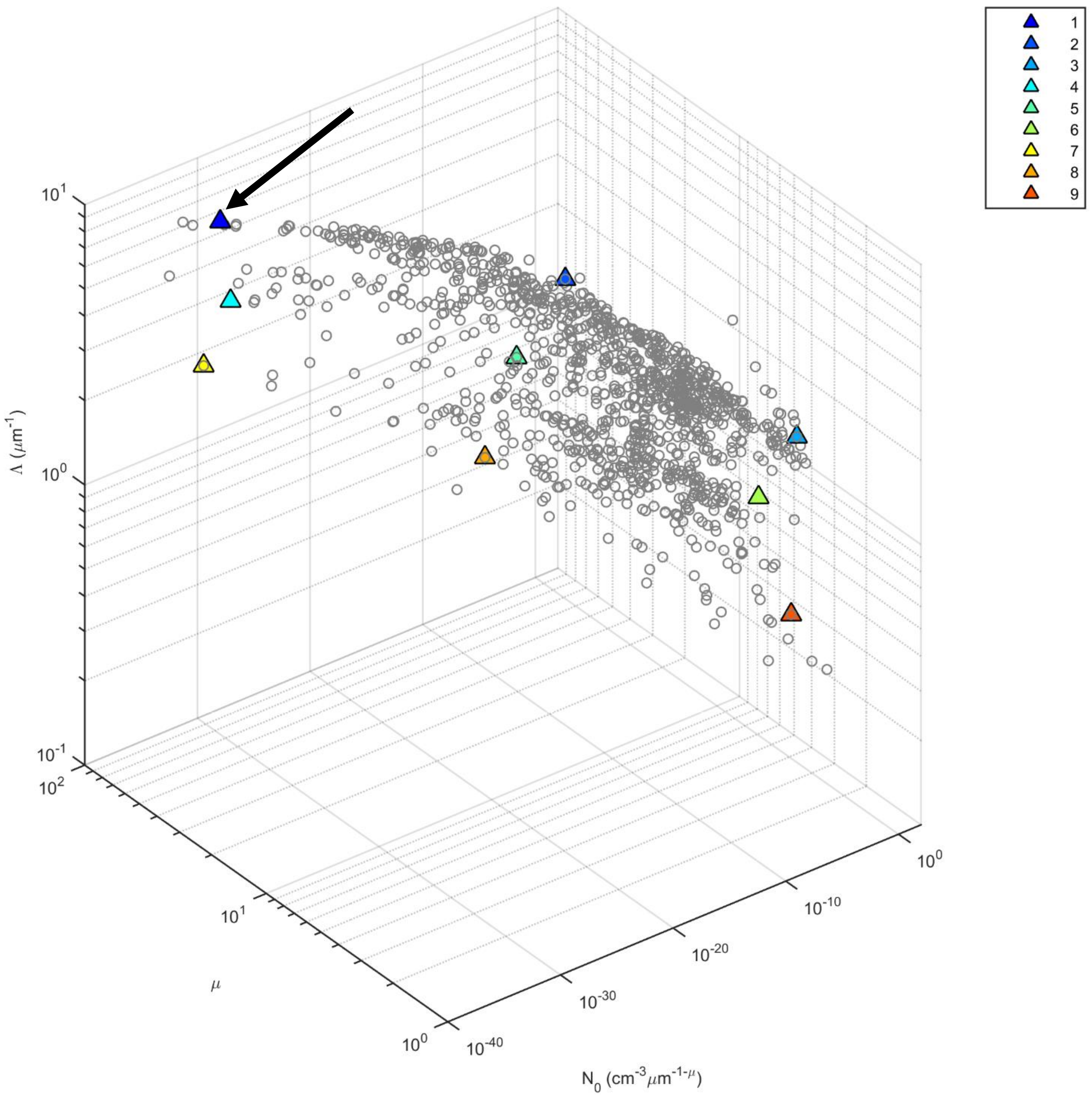

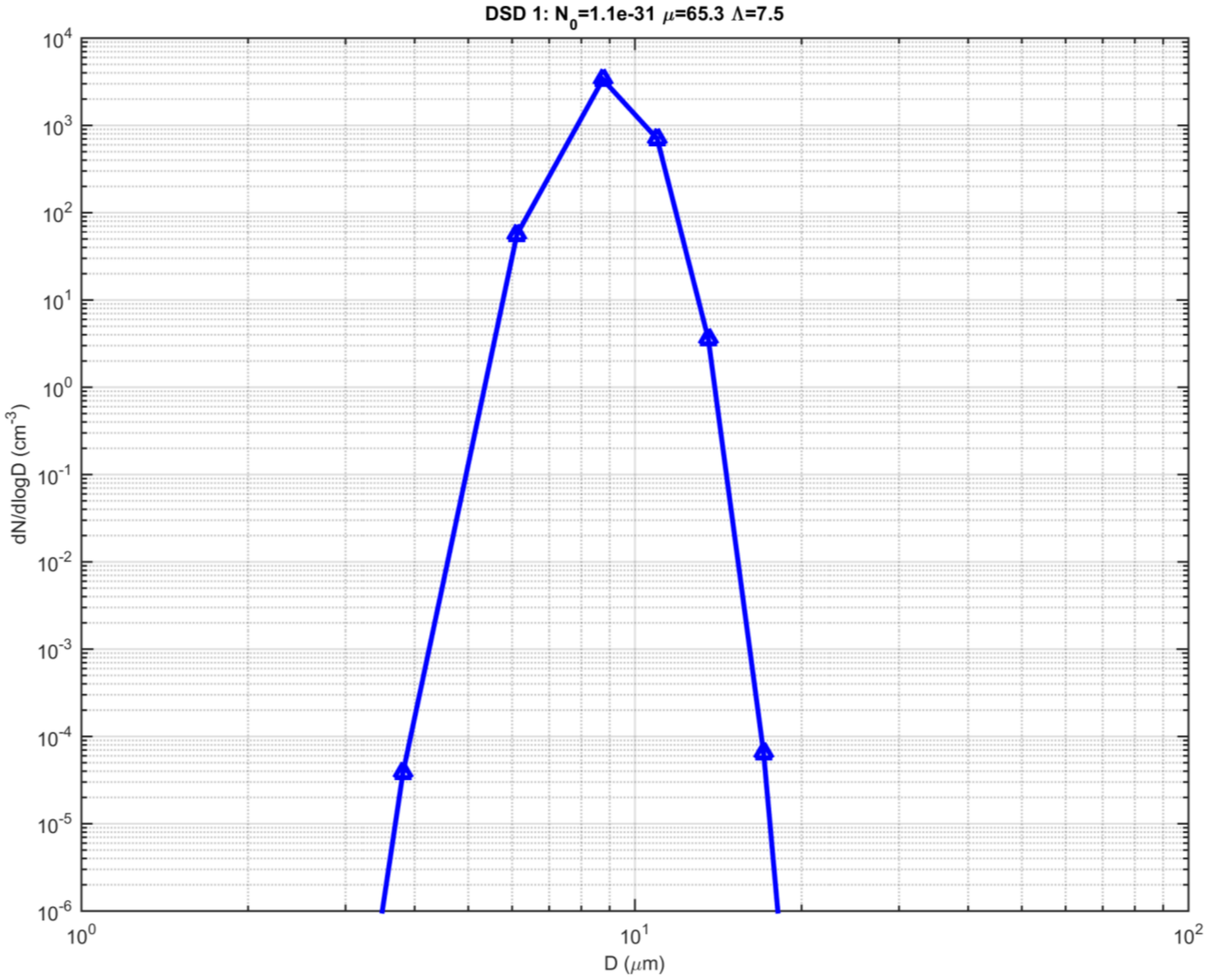

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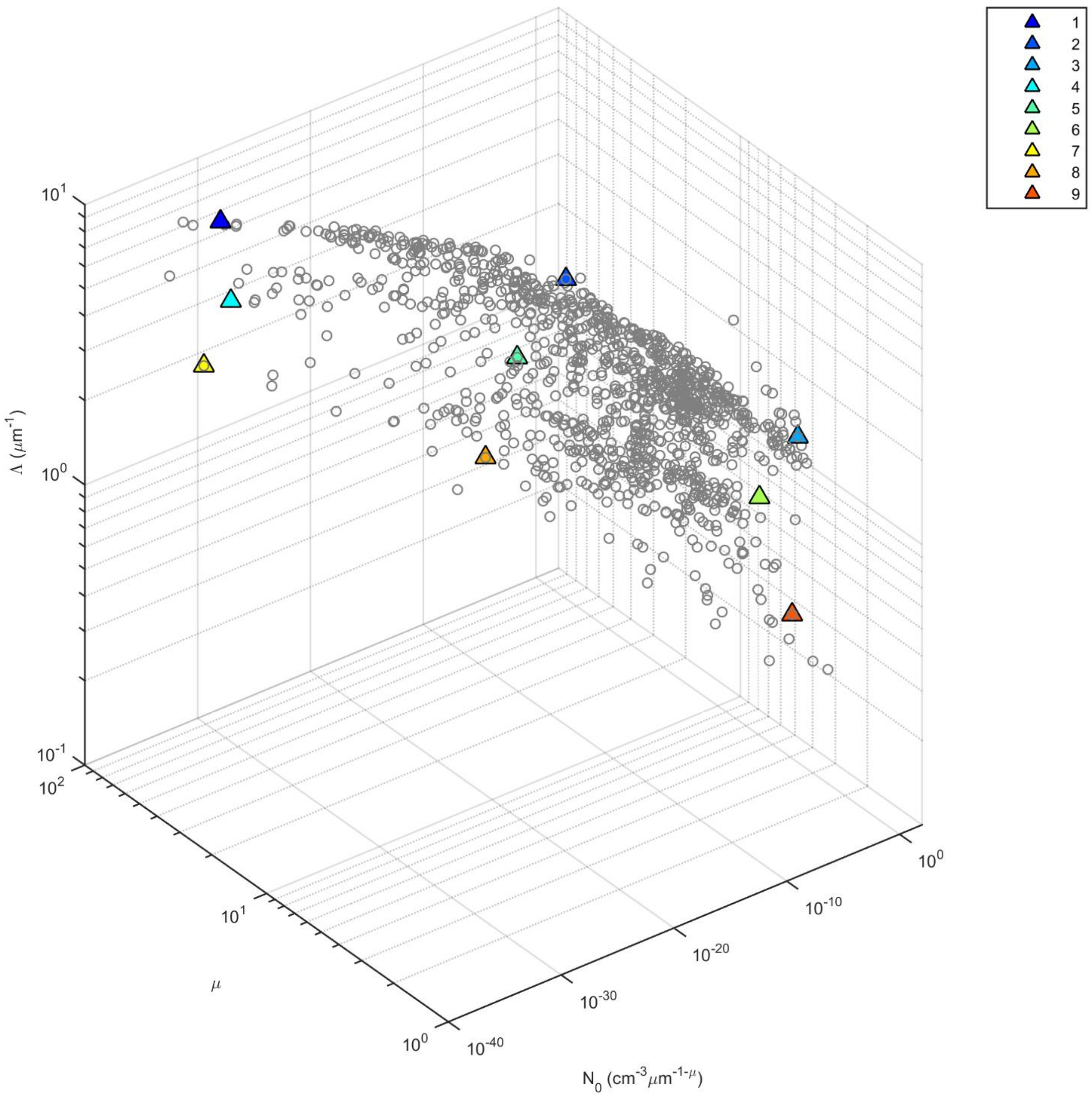

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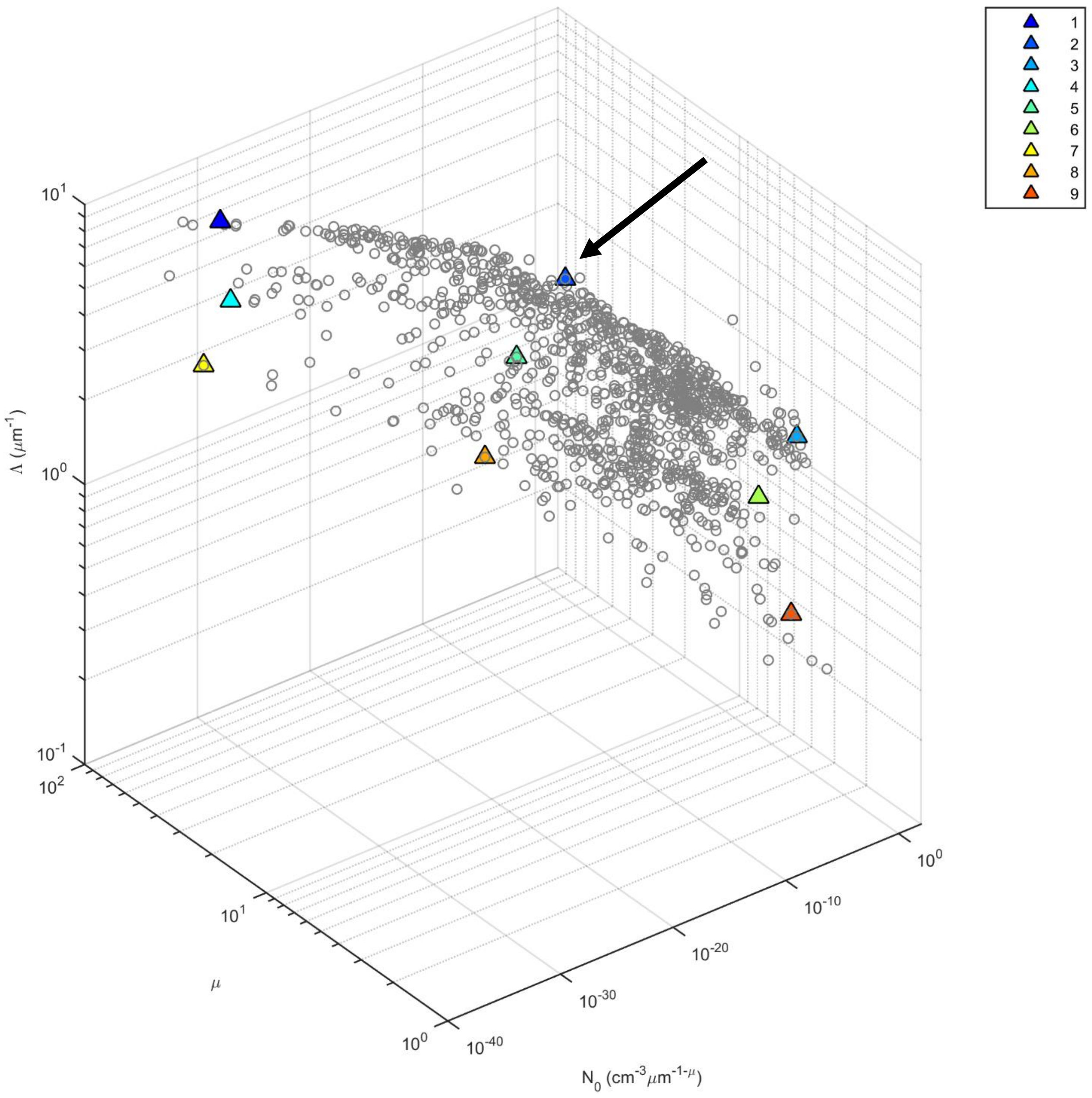

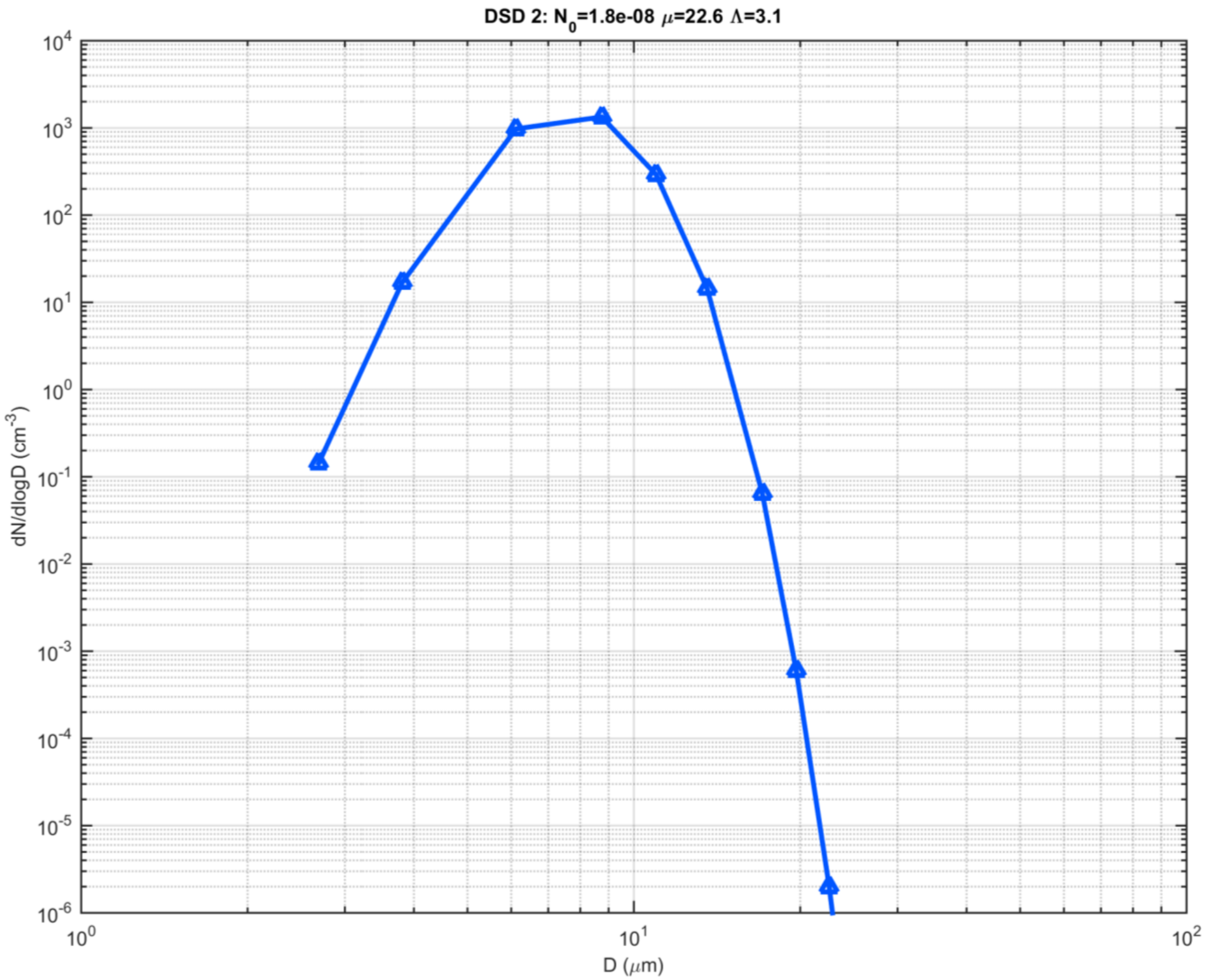

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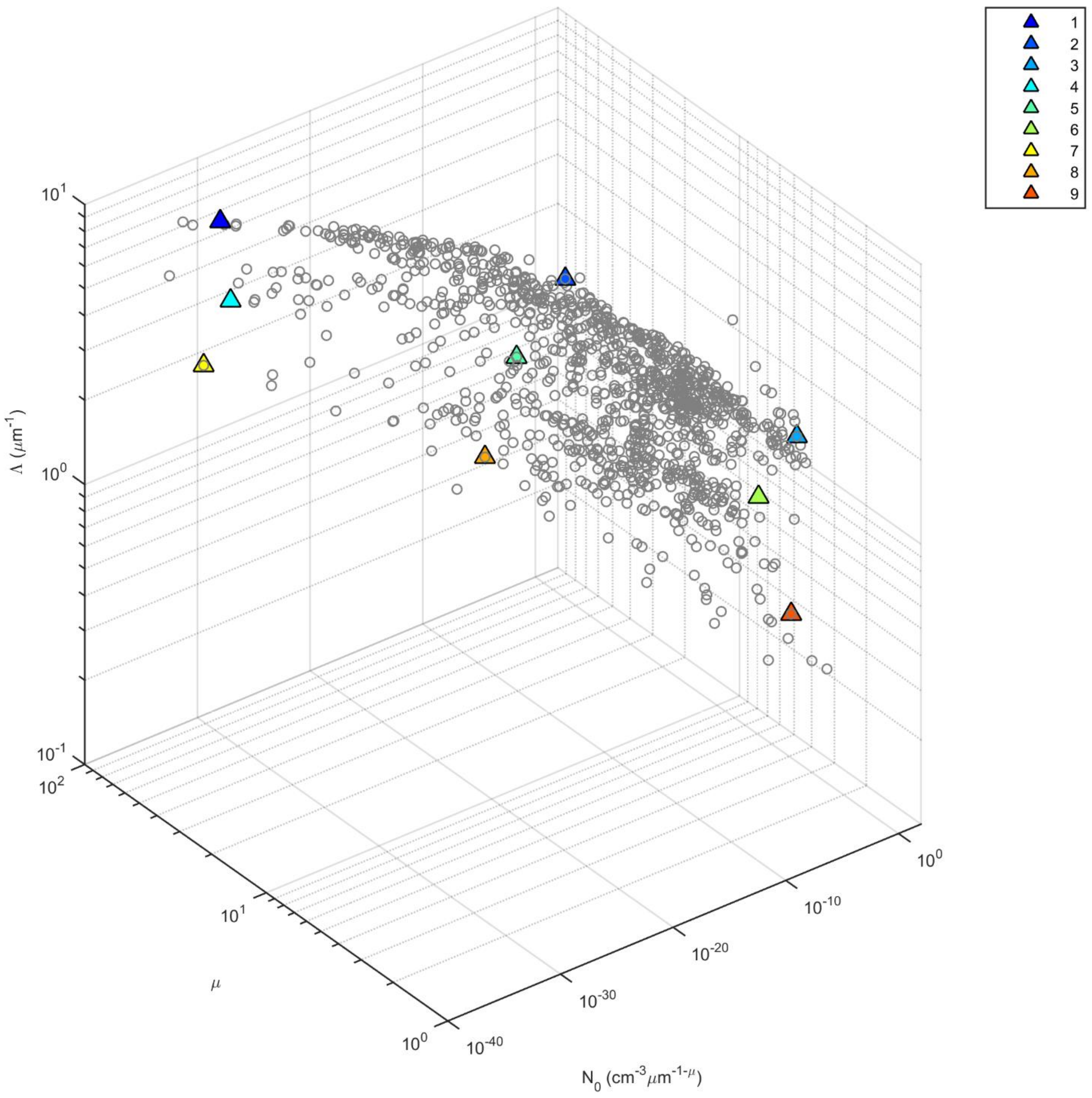

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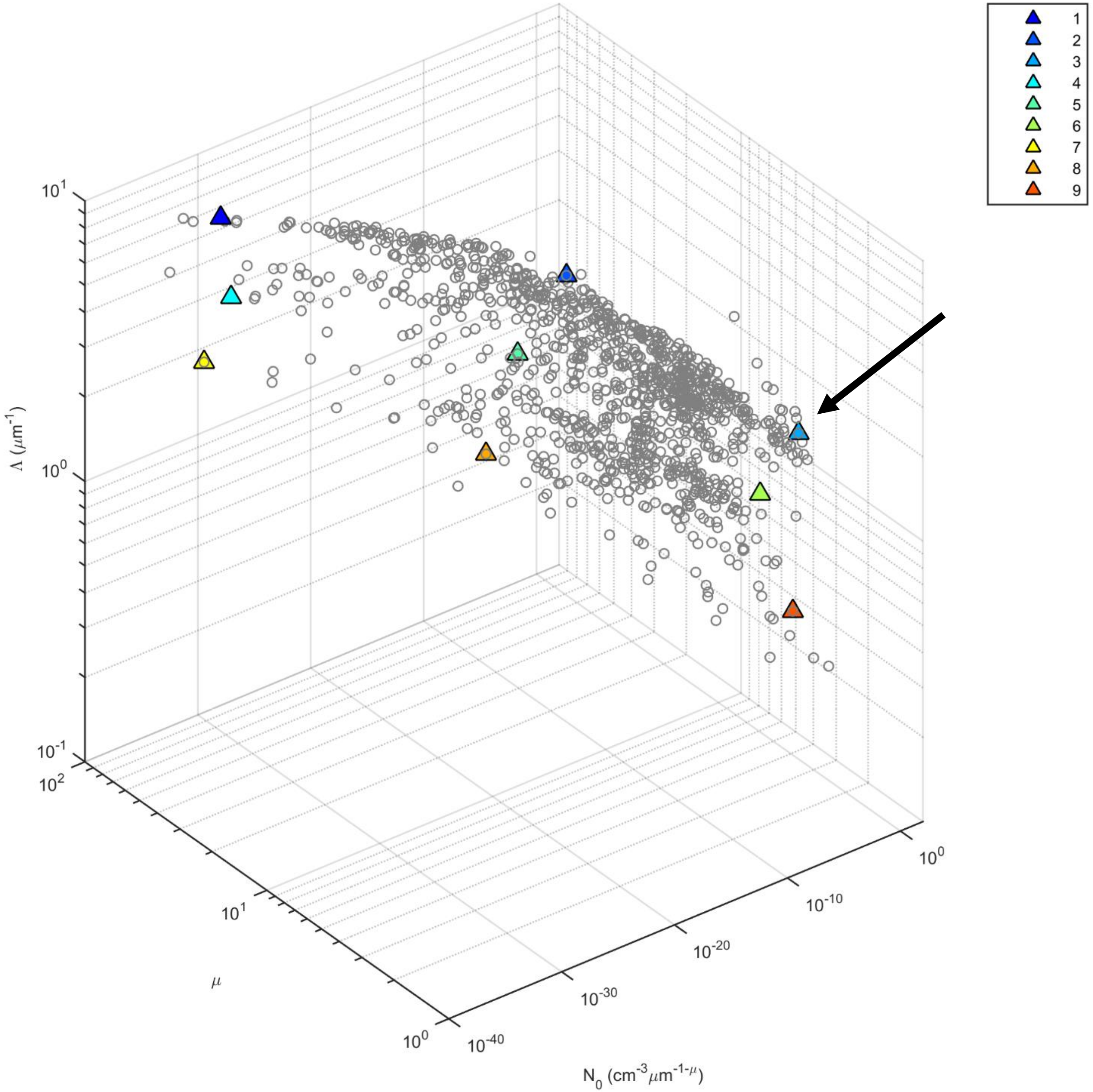

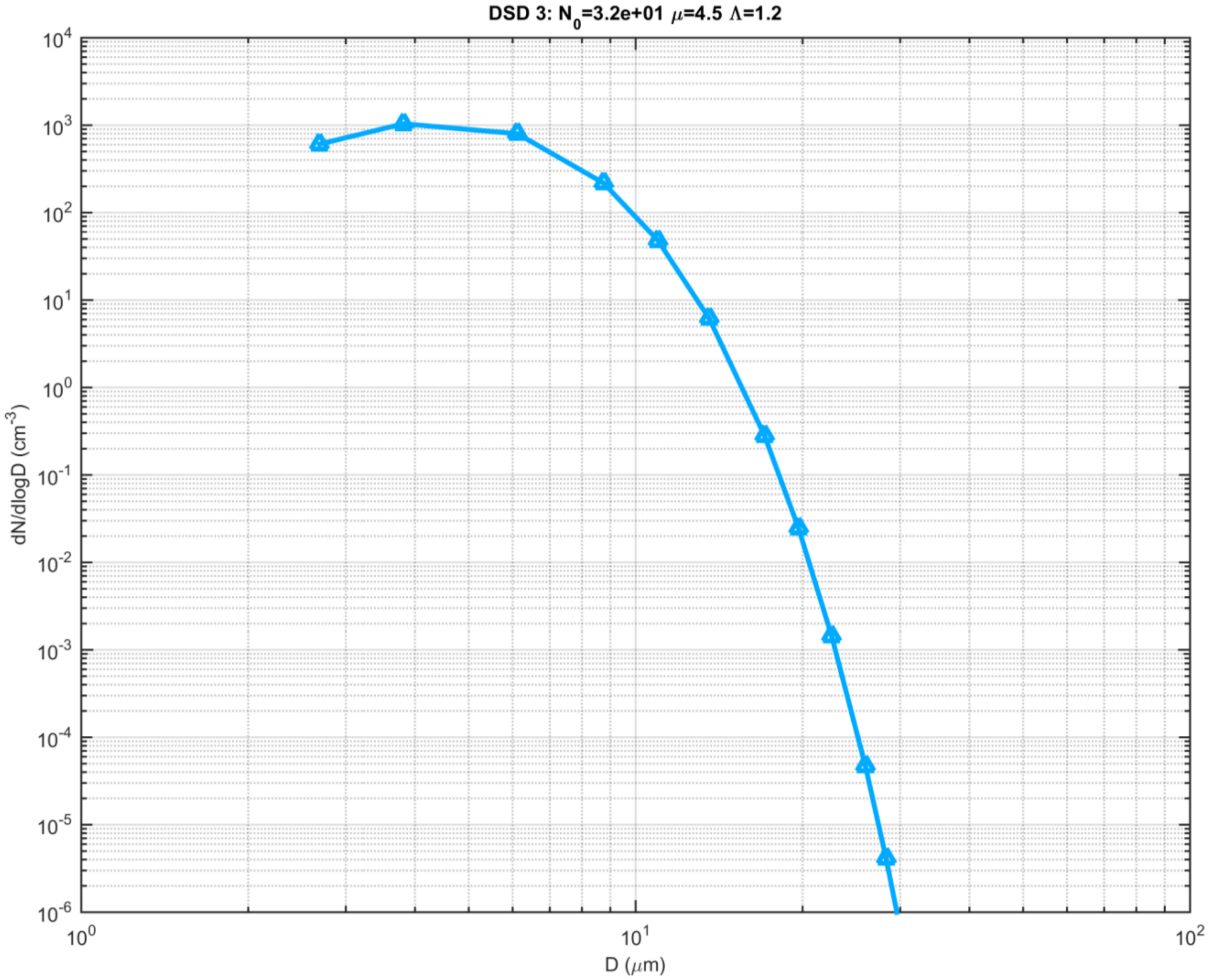

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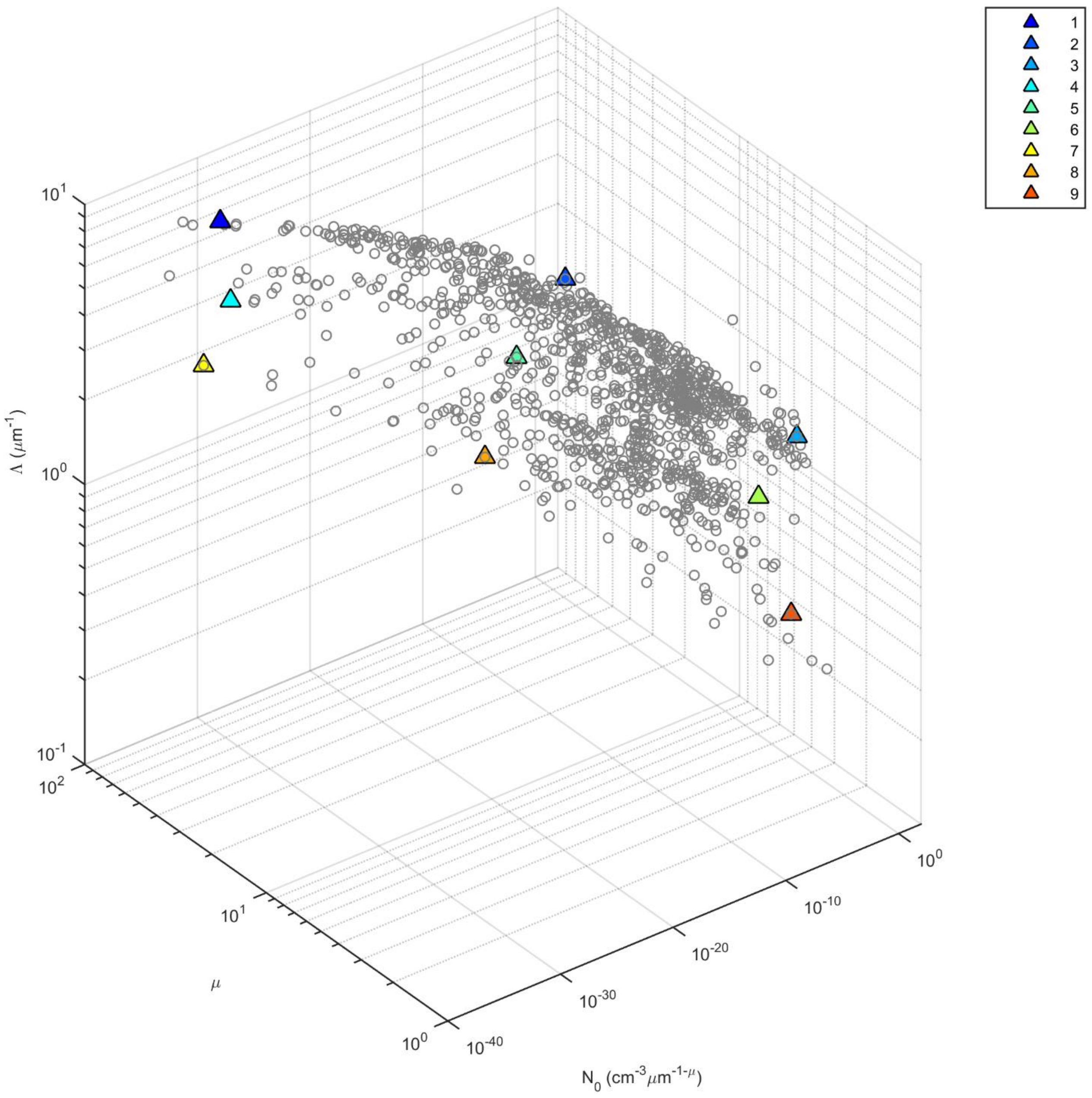

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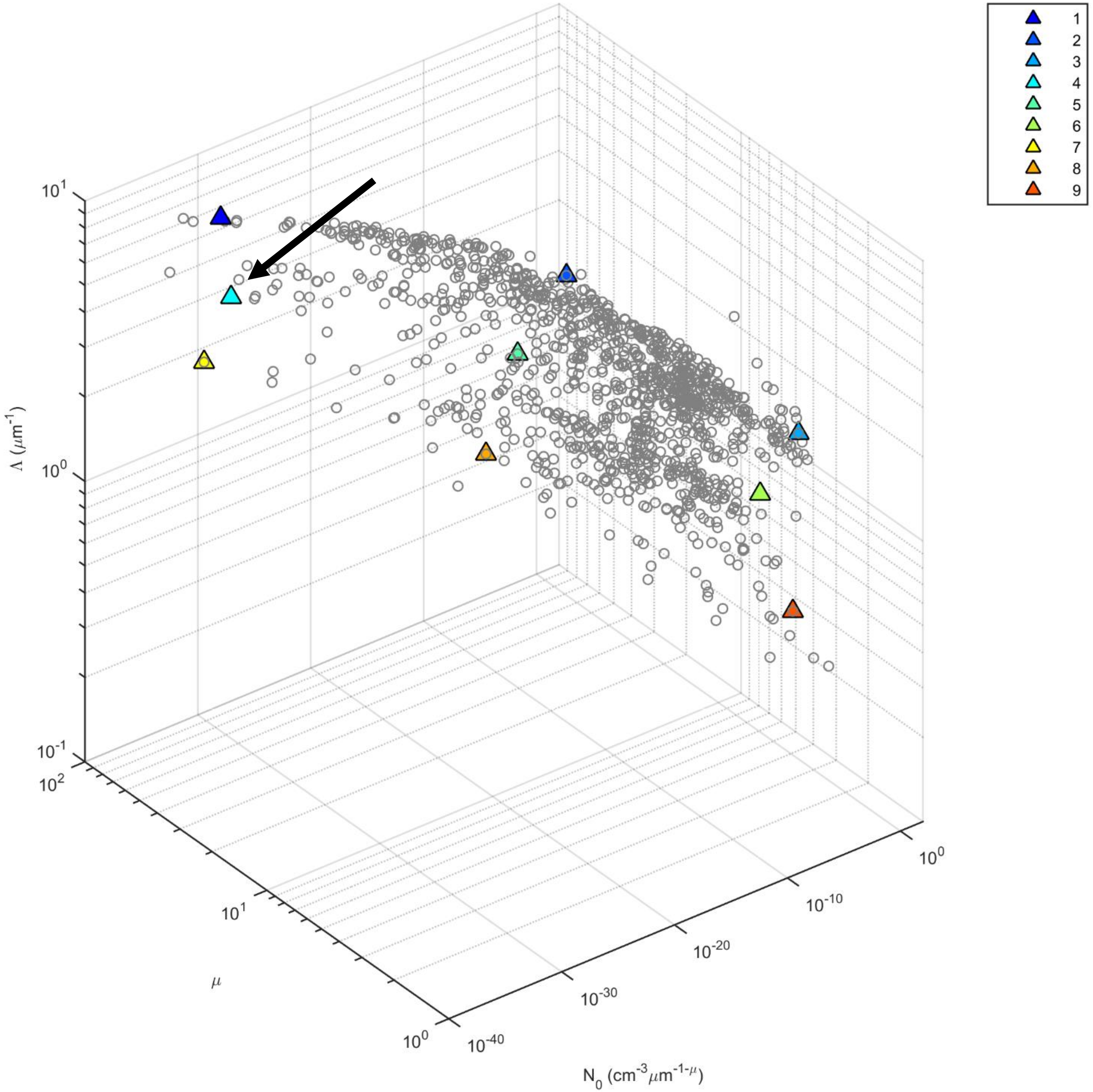

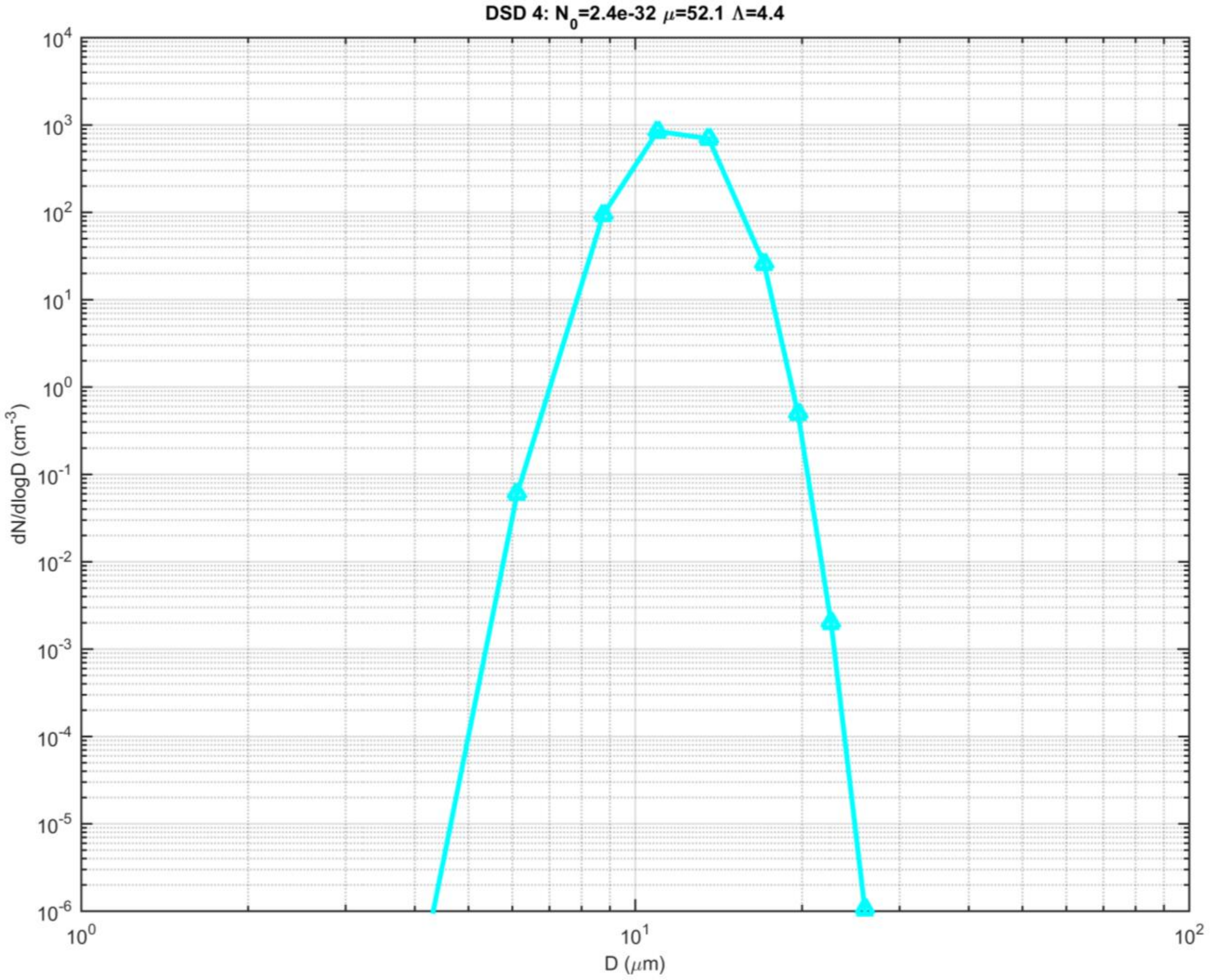

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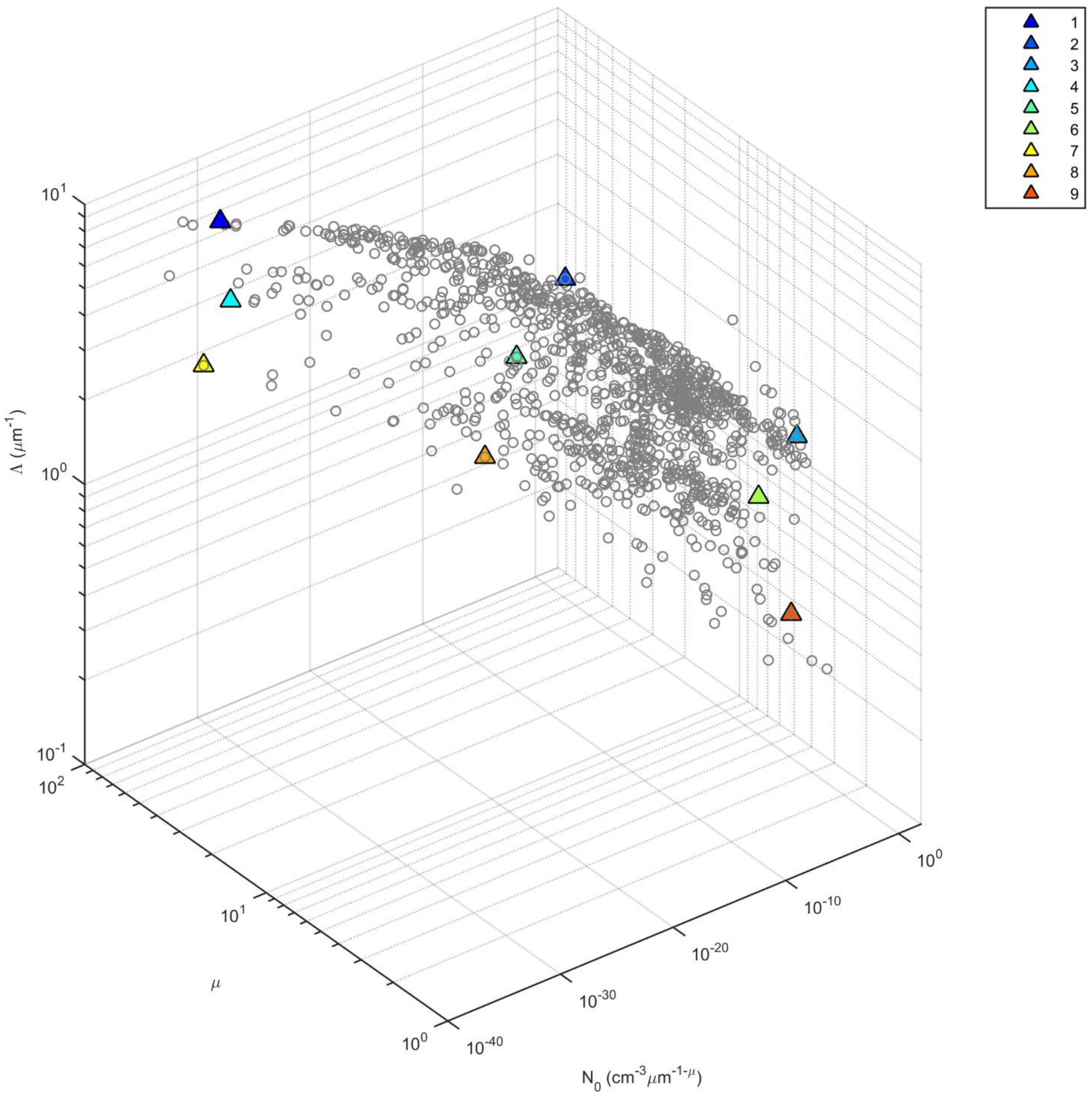

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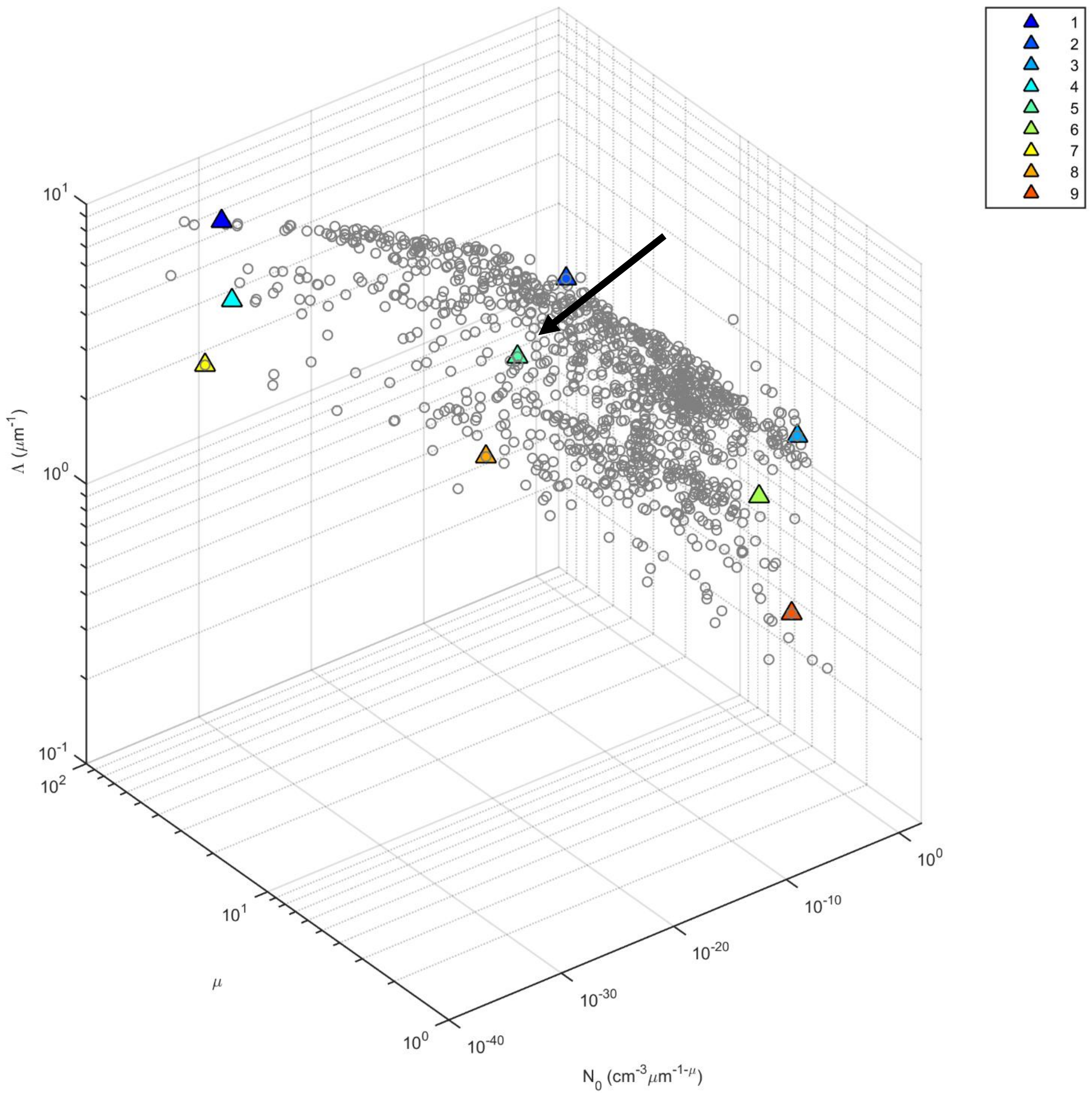

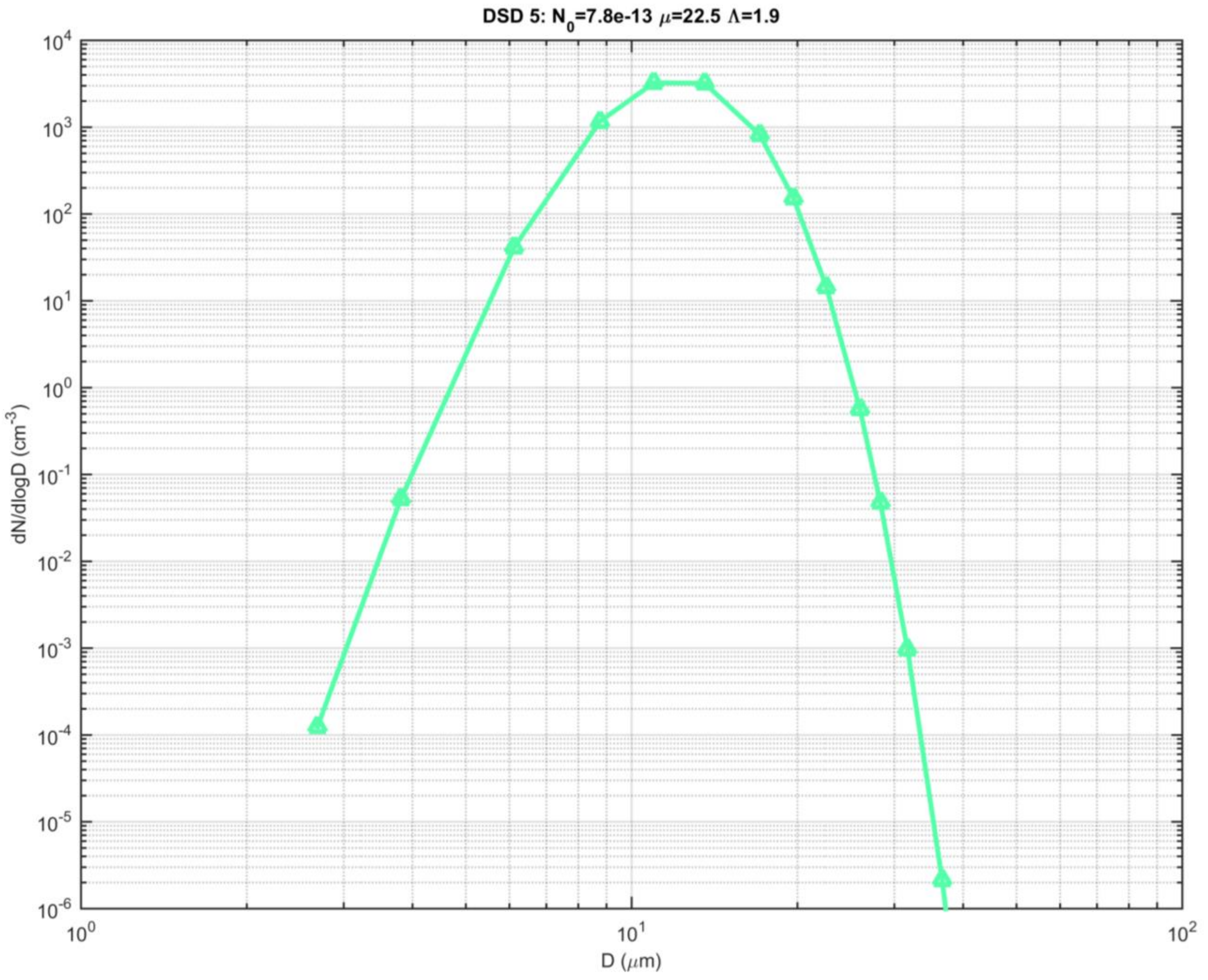

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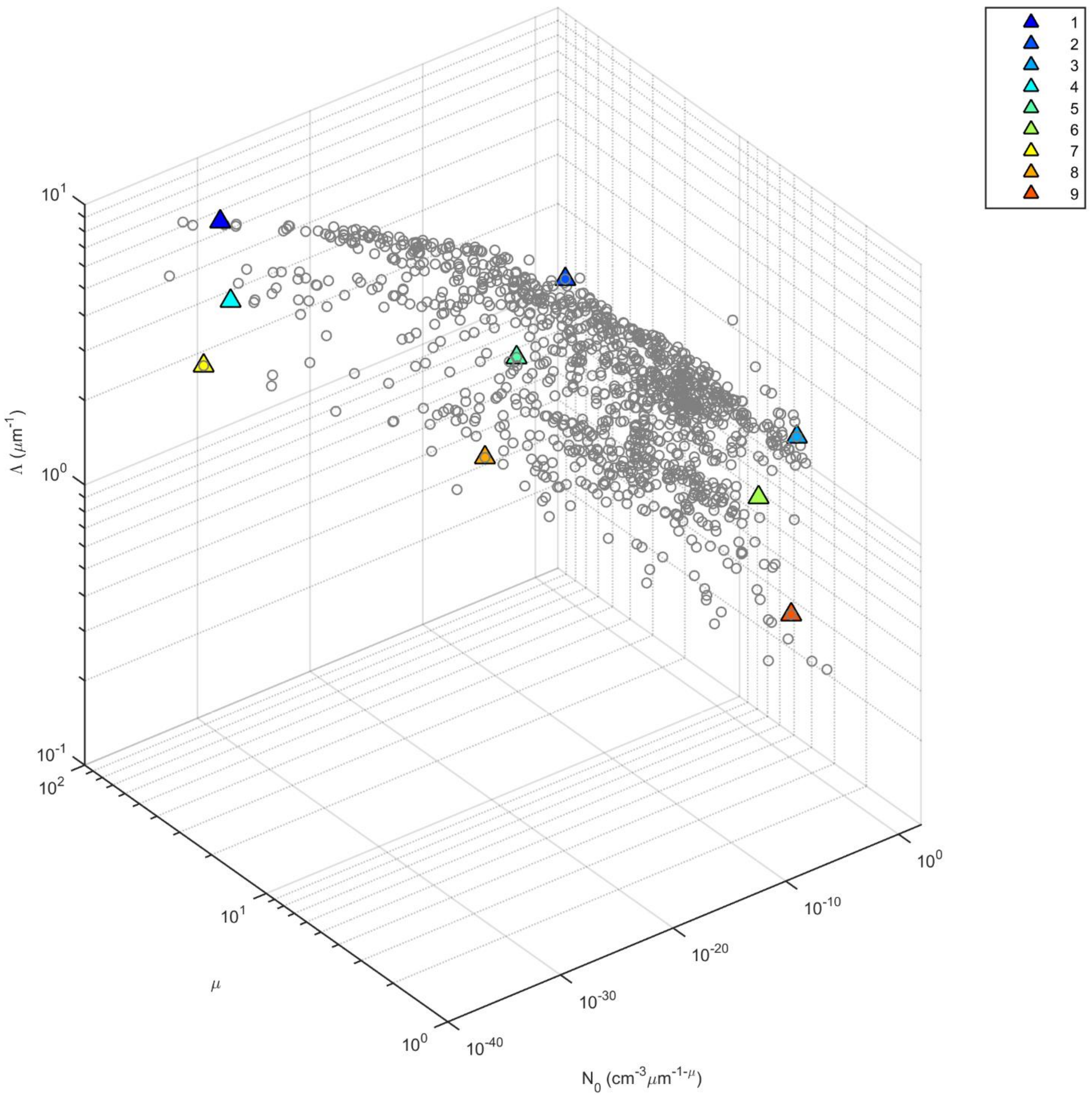

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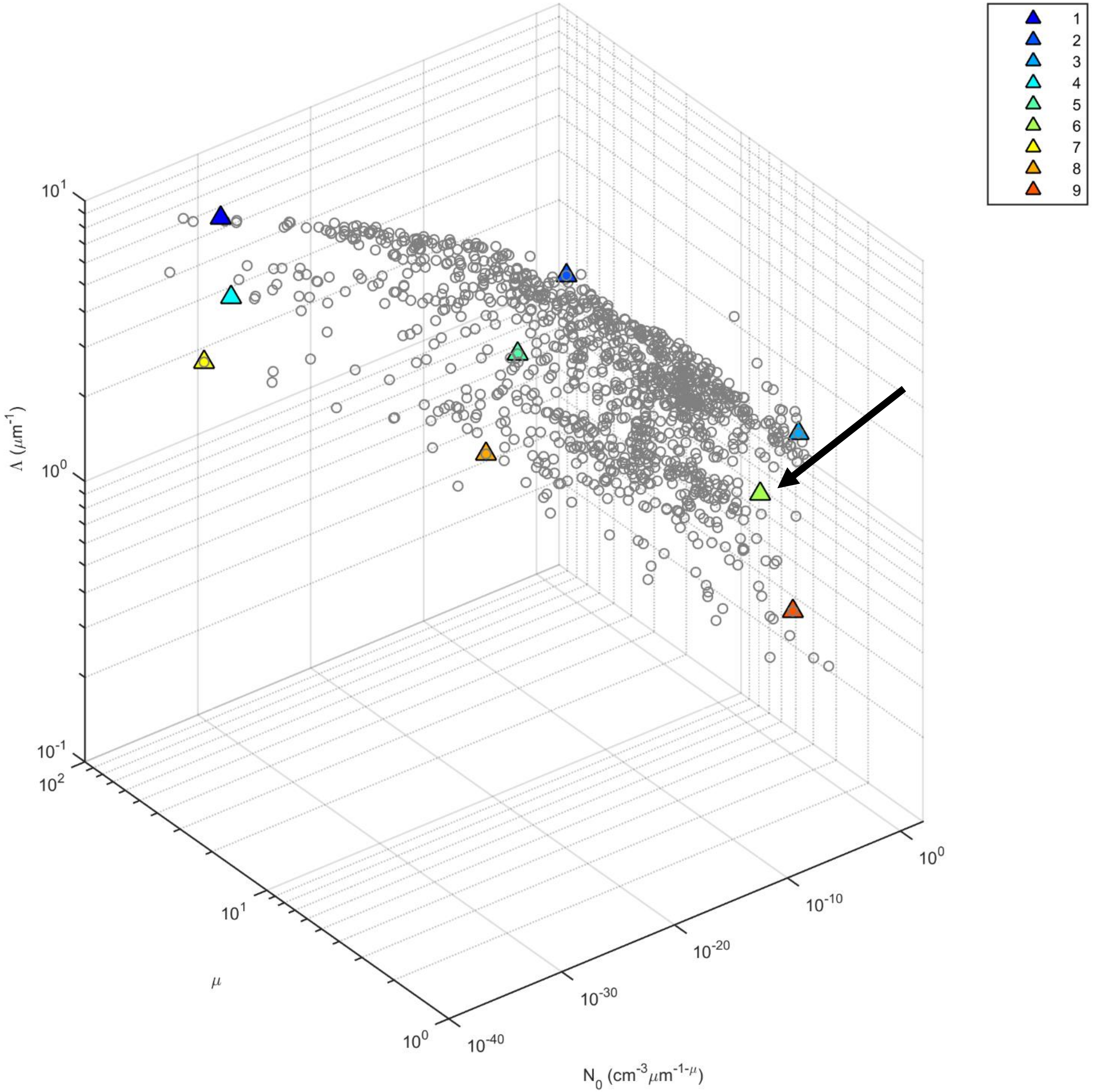

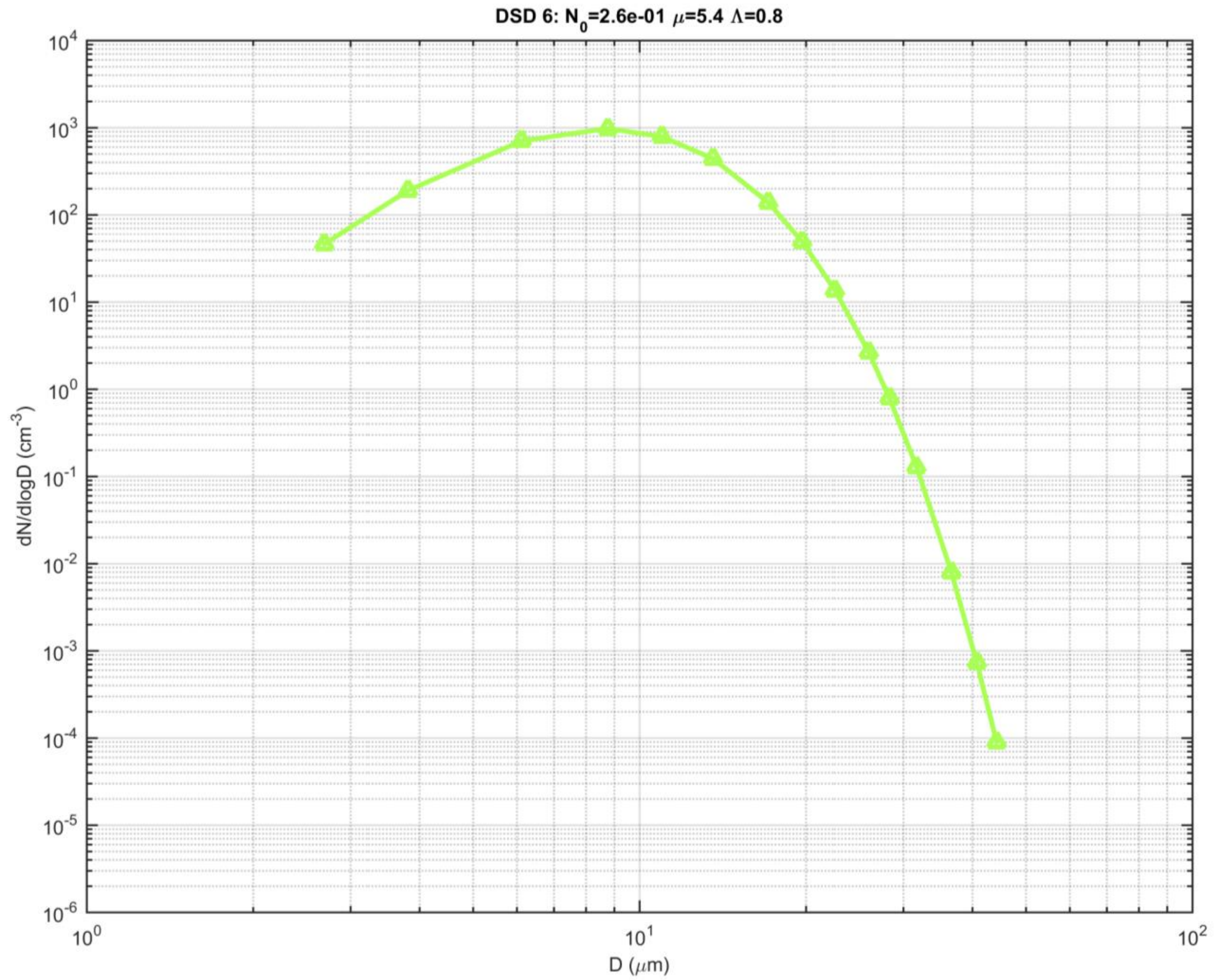

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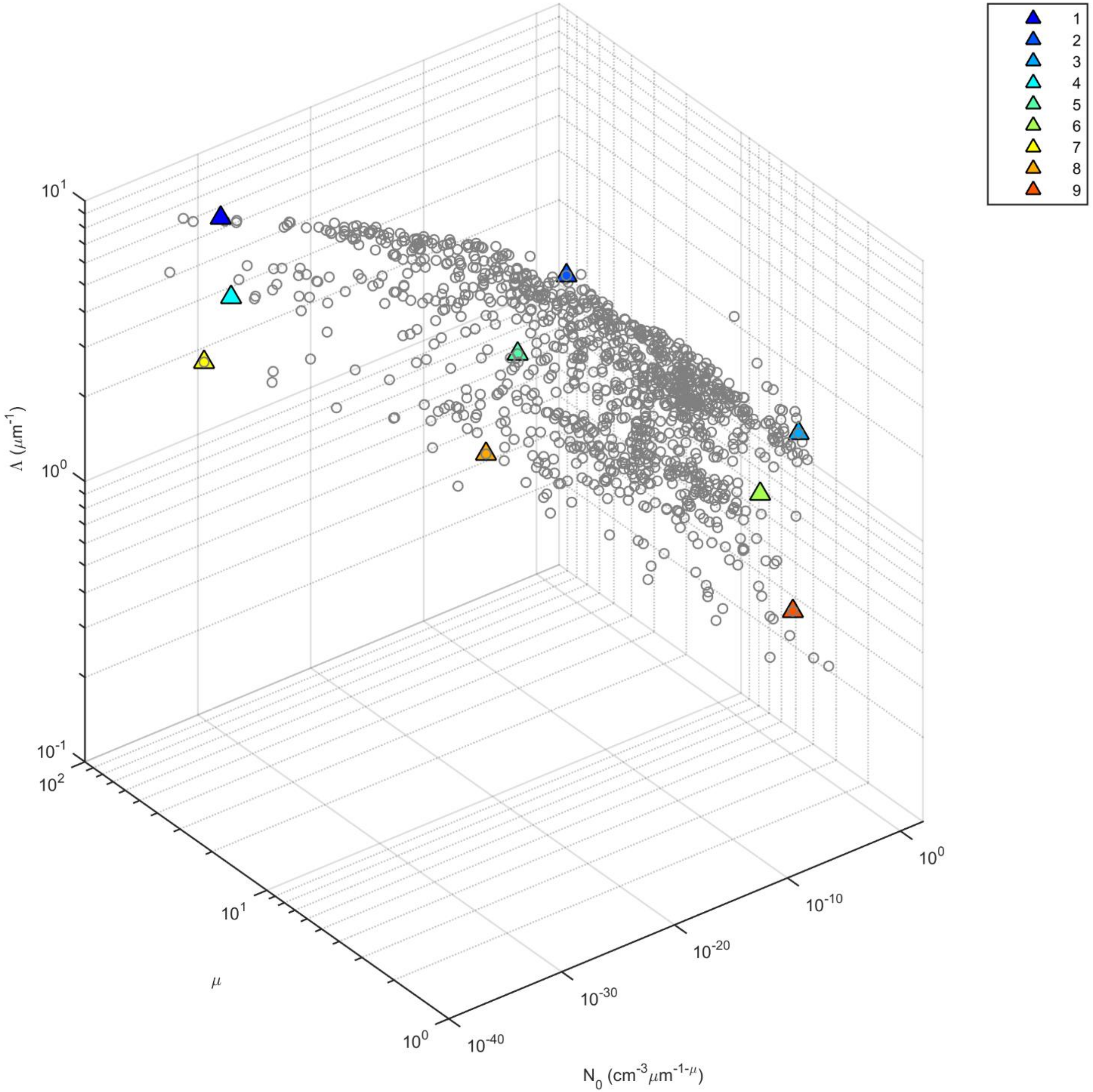

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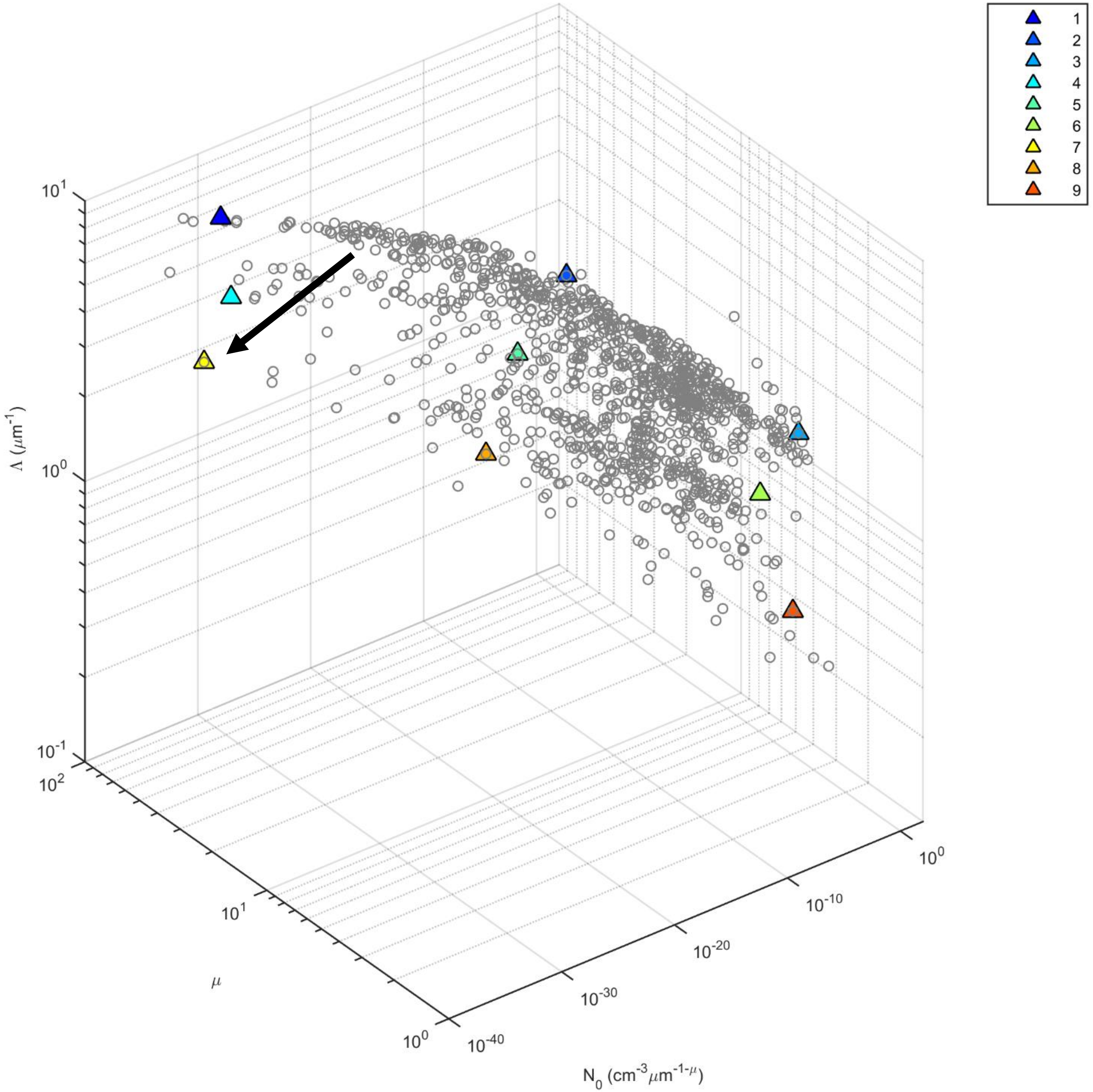

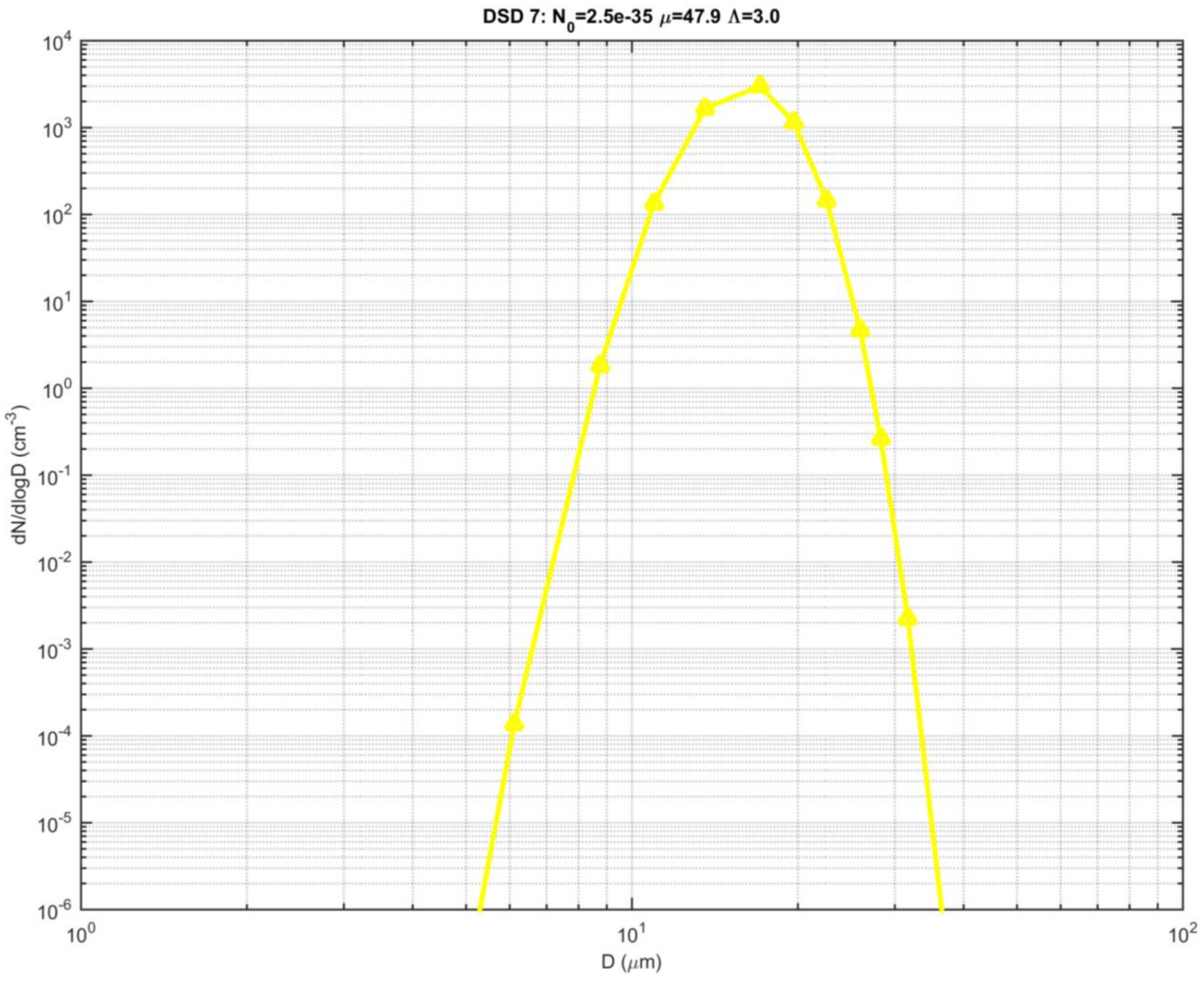

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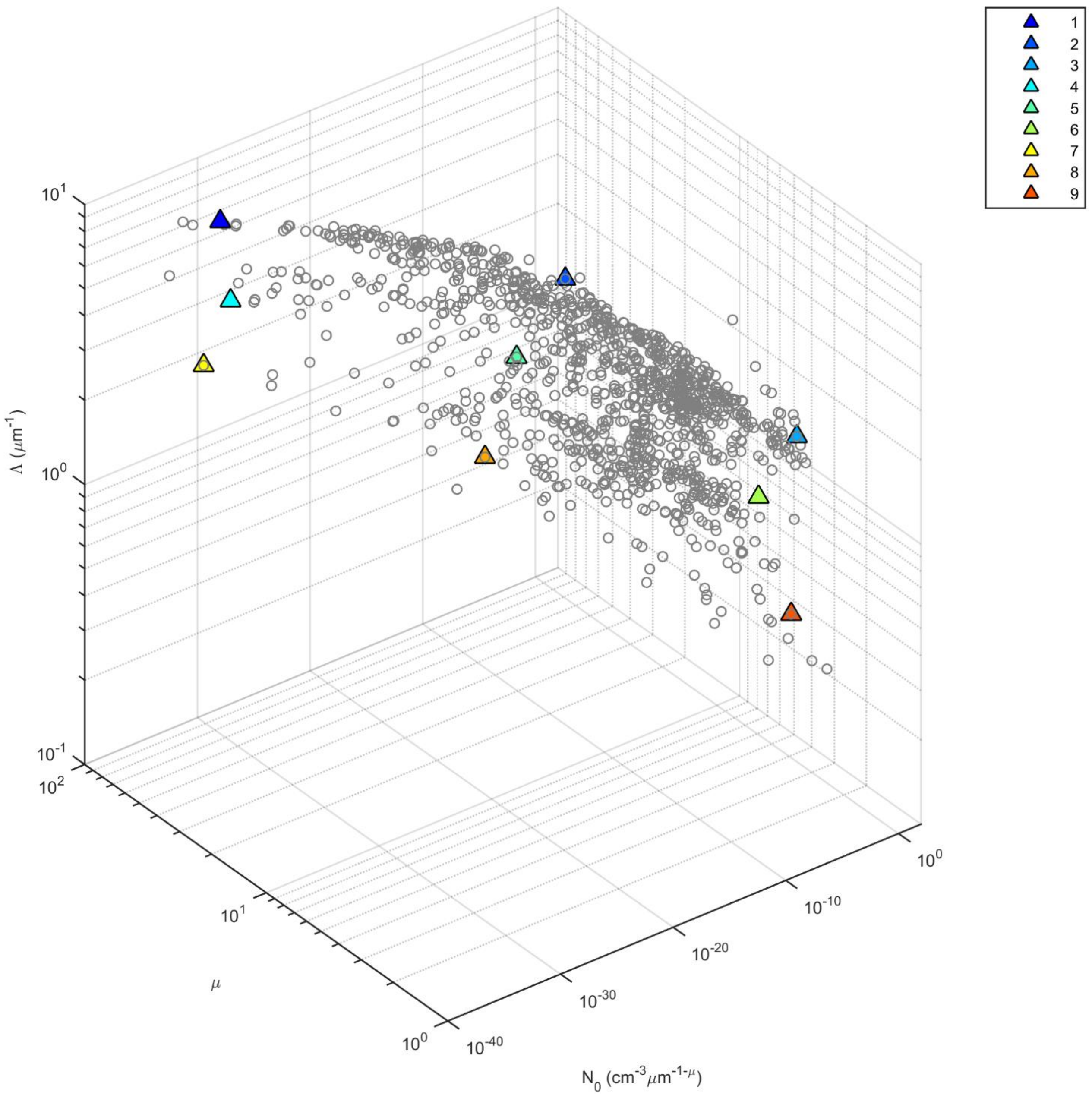

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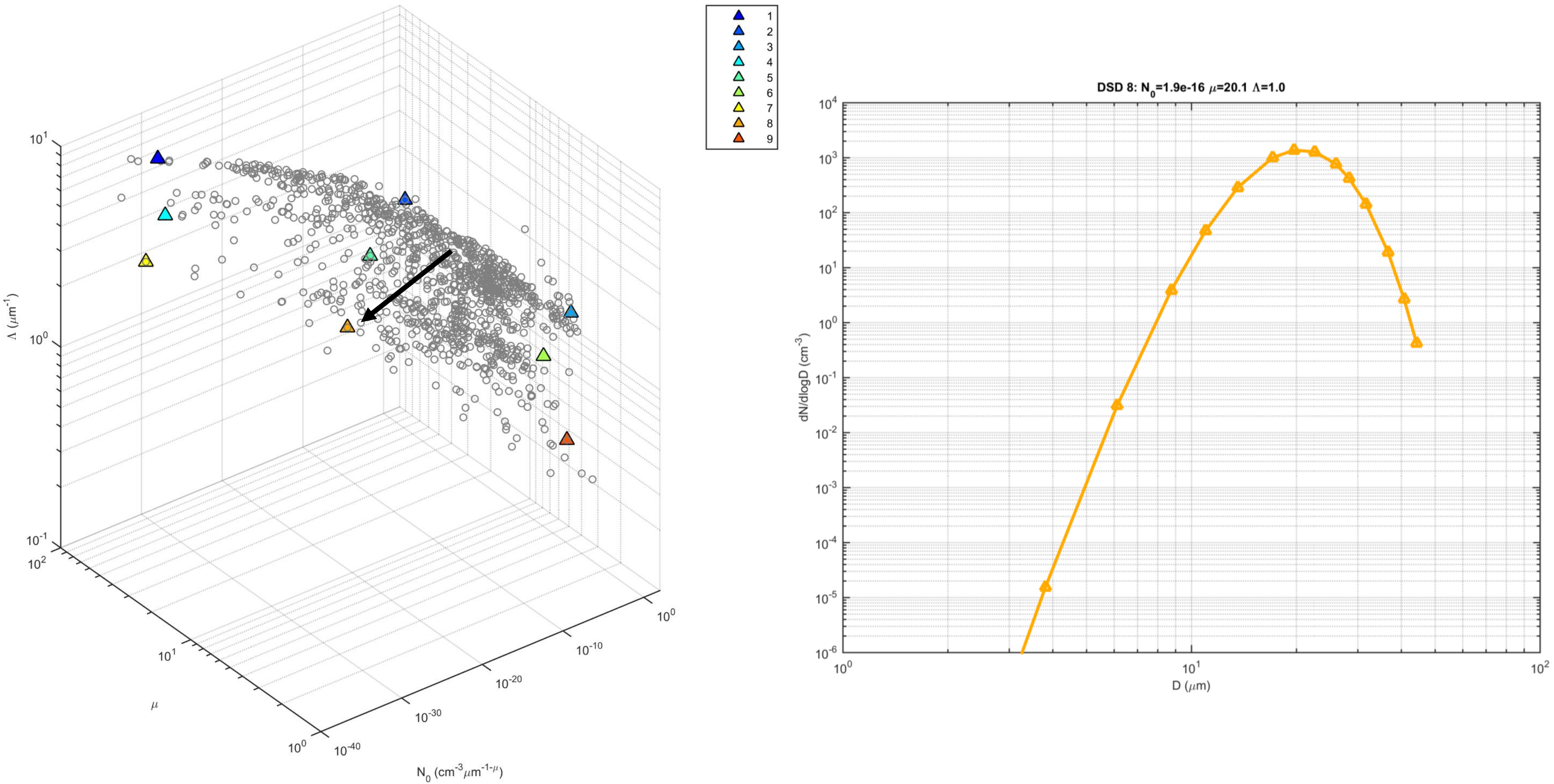

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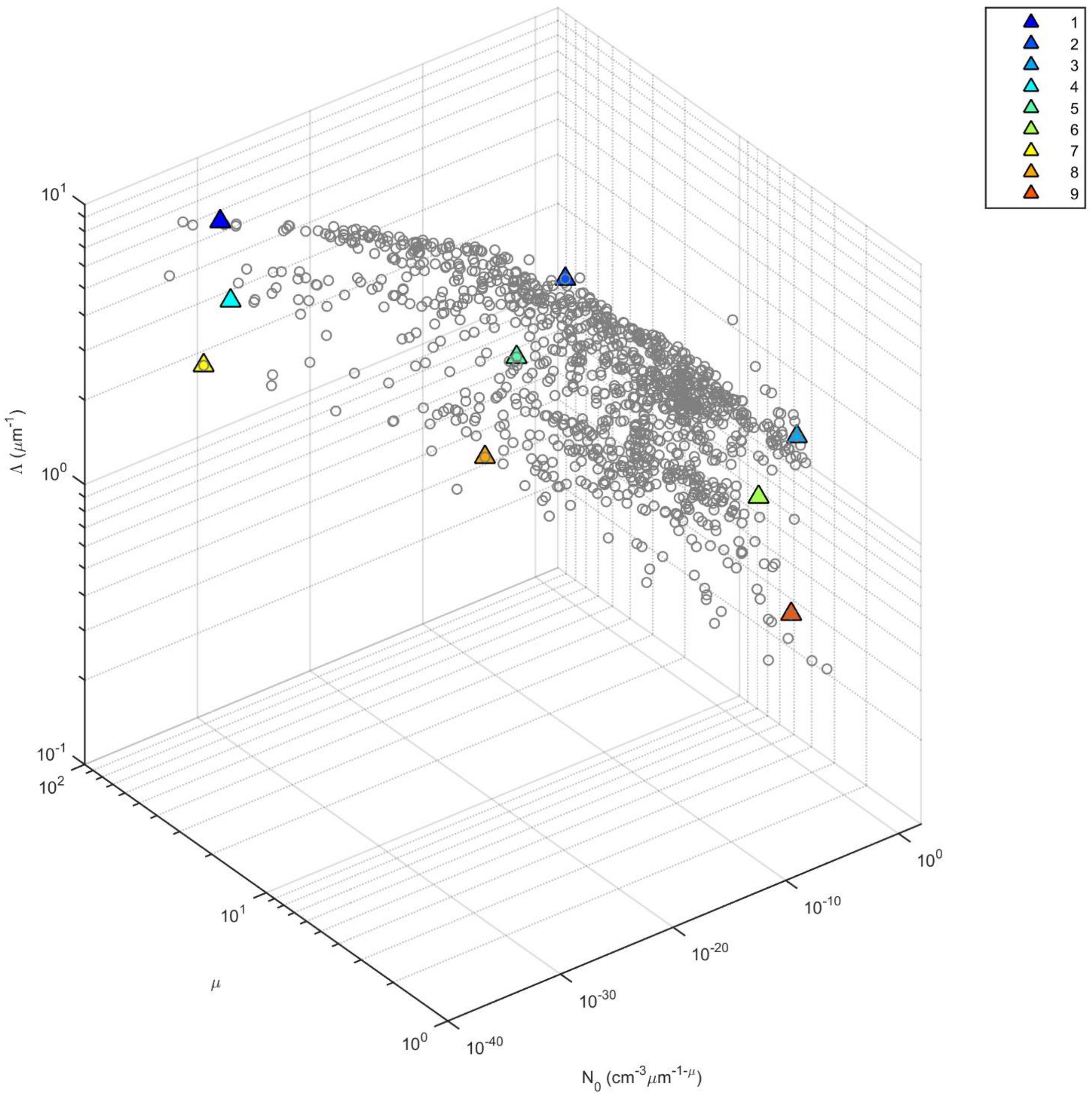

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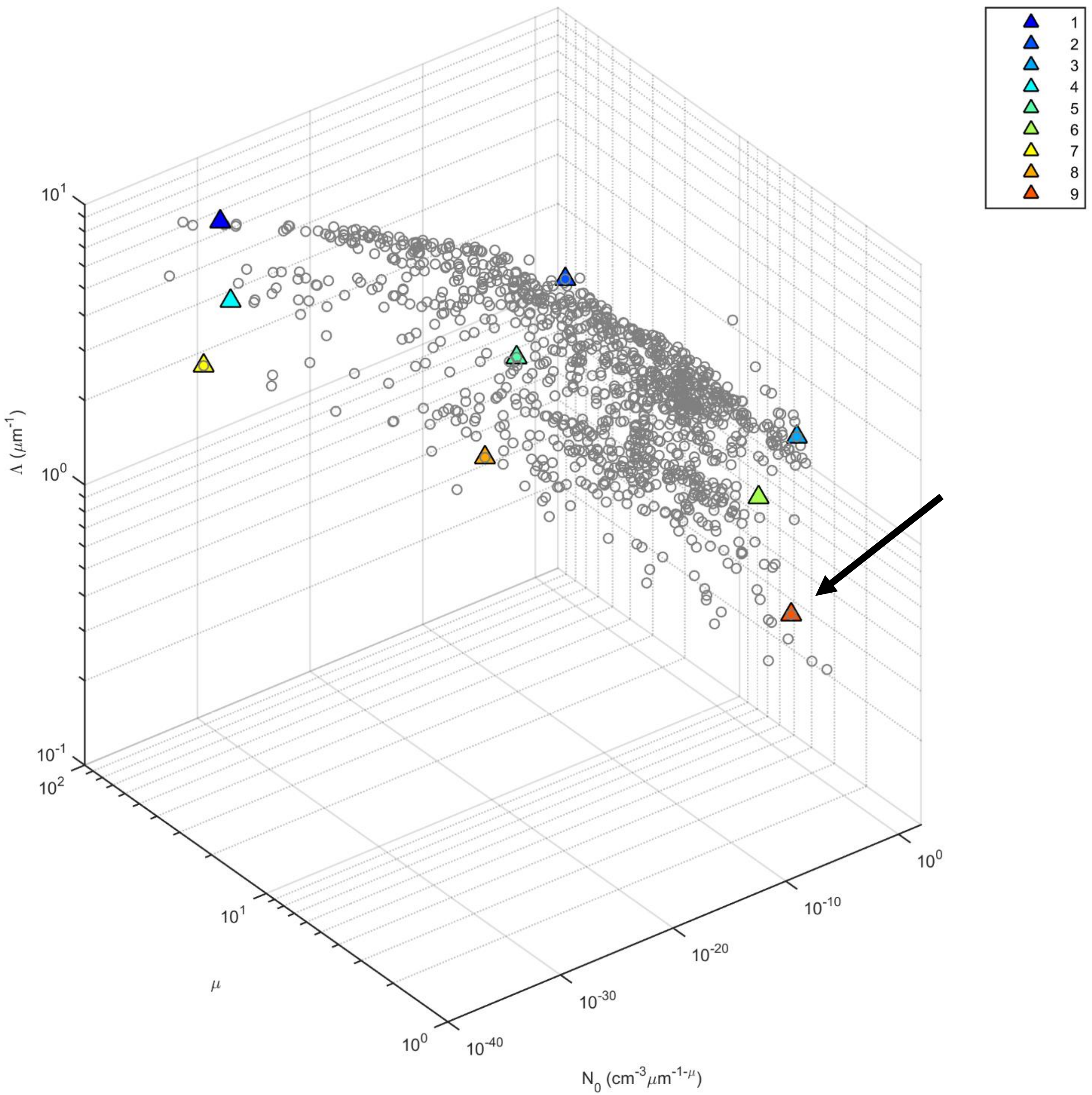

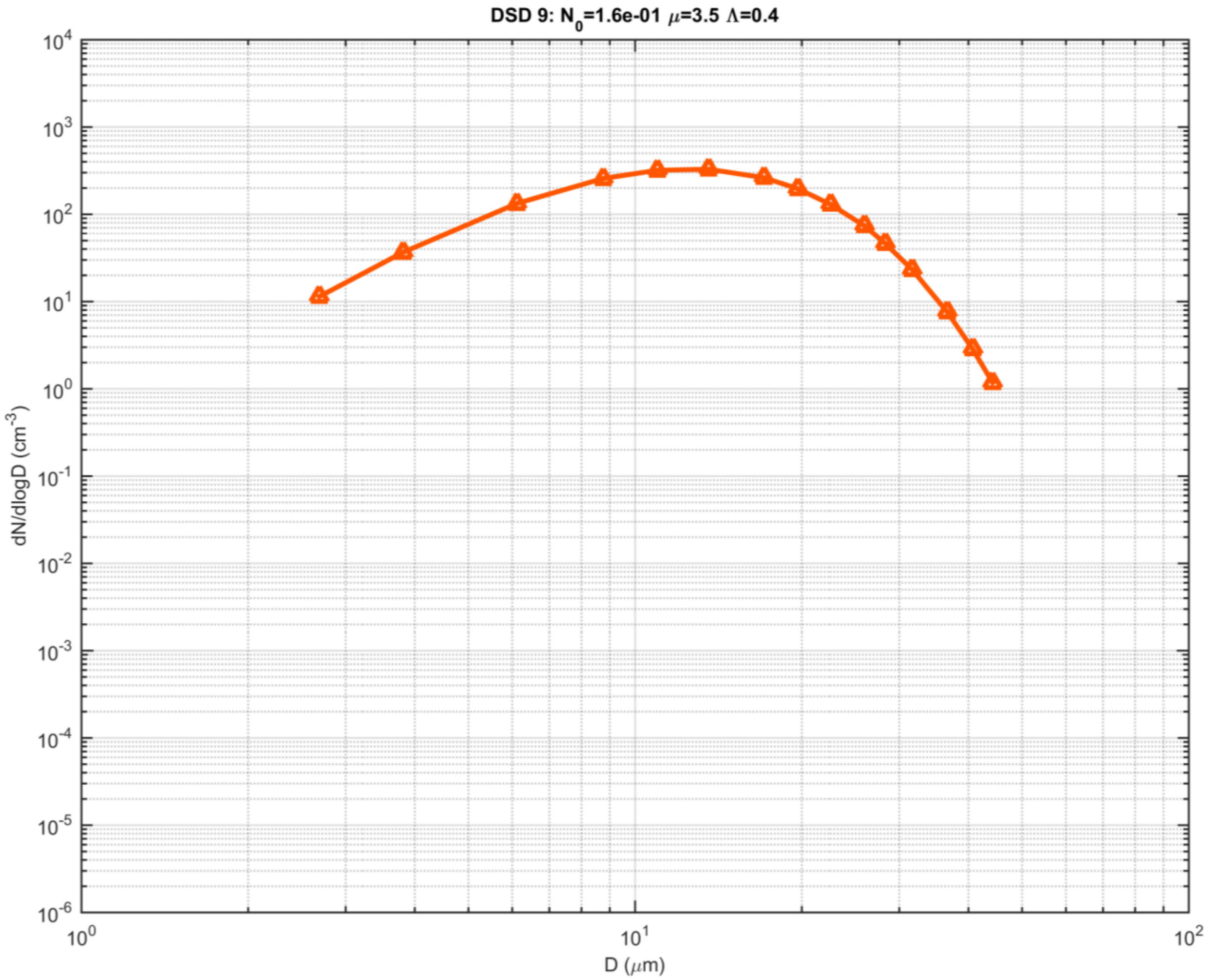

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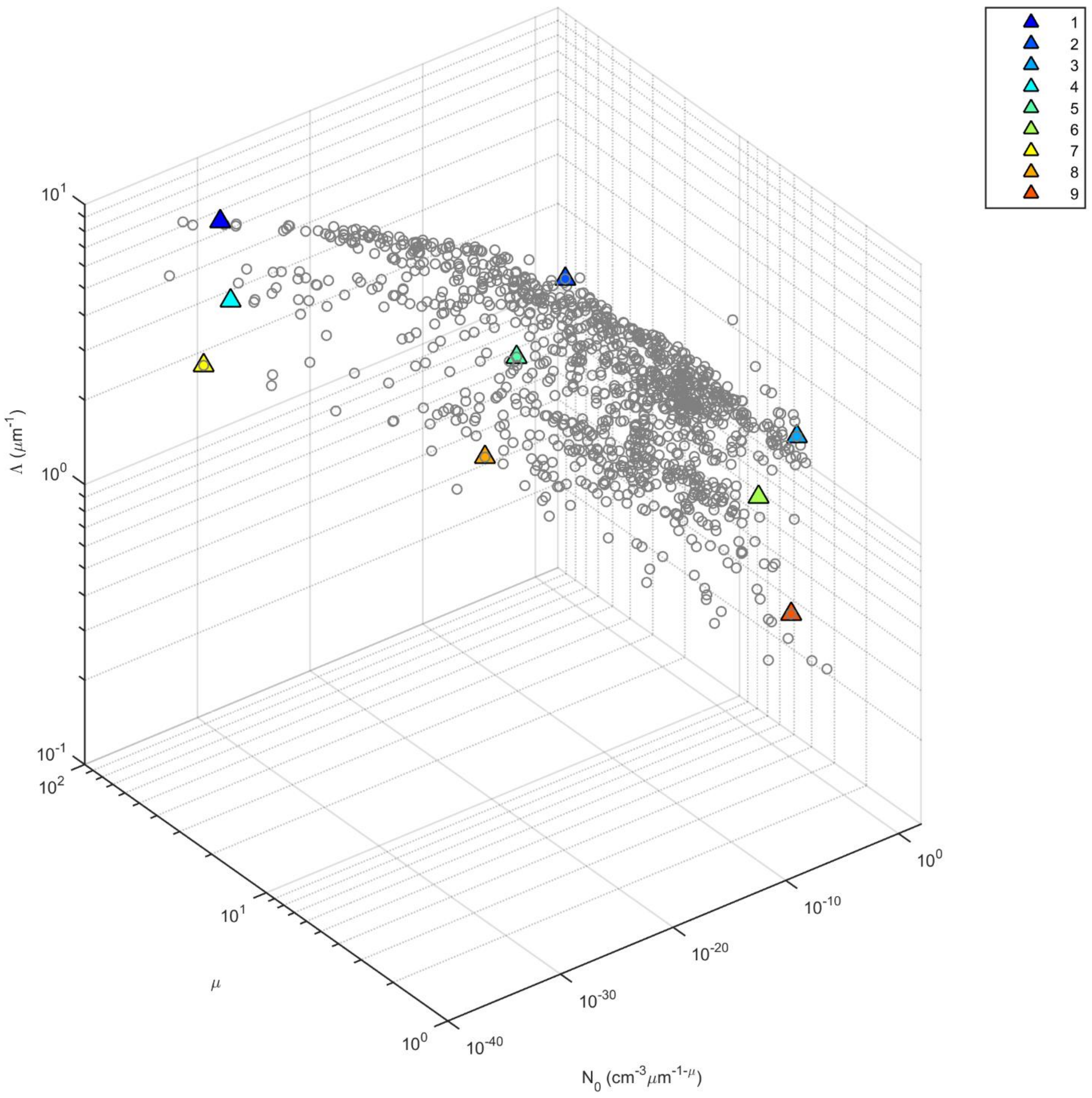
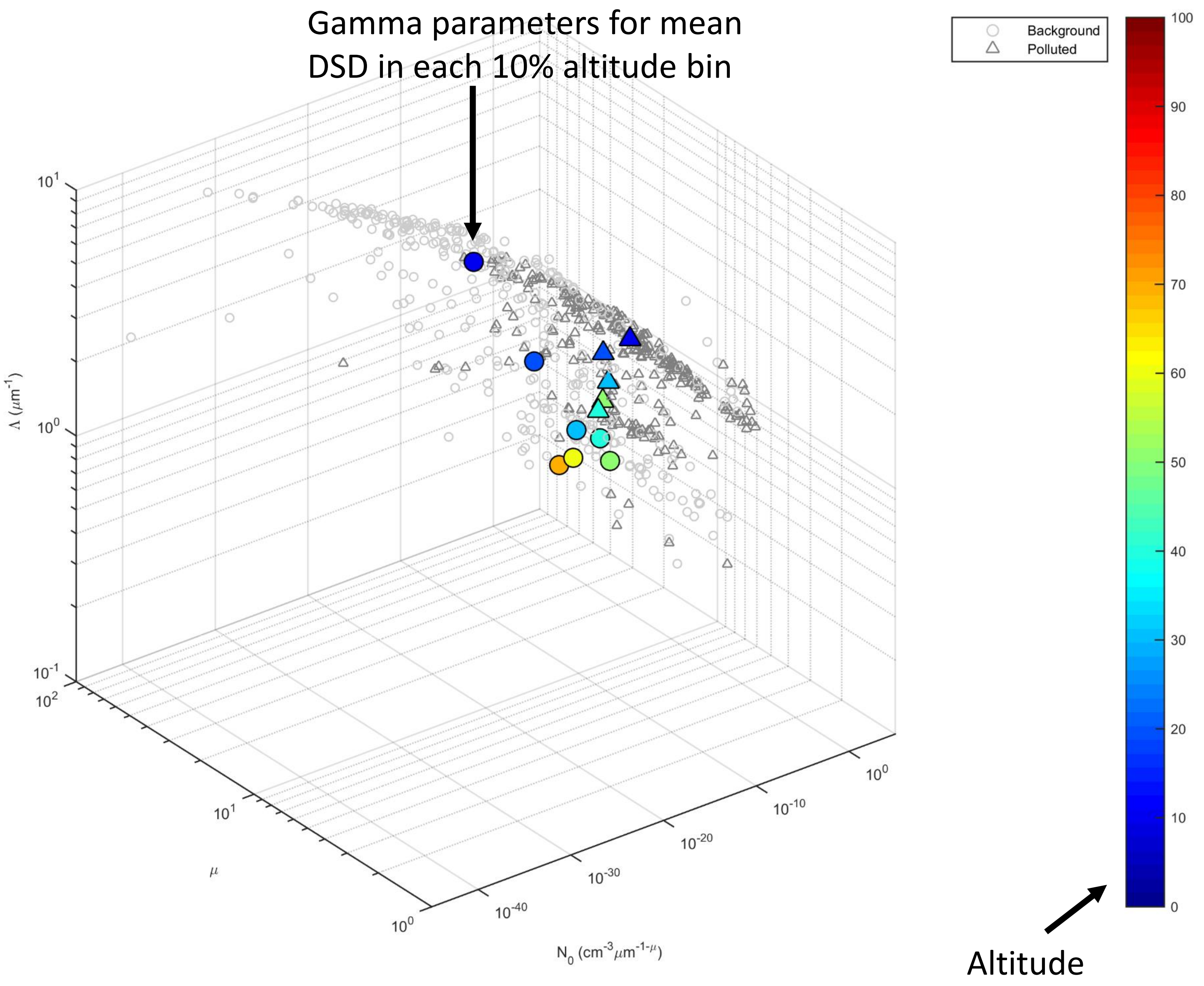


-> Cloud in initial stage + only spherical hydrometeors – DSD evolution with altitude as a proxy for droplet life cycle

-> Trajectories in the phase-space: solution curves
  - Might be an useful way to solve the cloud

-> Aerosol effect: very different starting points for the trajectories
  - Cloud processing brings trajectories closer
  - i.e., growth processes act as forces in this space, each process with a defined direction, sign and intensity

-> Trajectory in background clouds makes a turn at 50% - μ starts increasing and Λ decreasing – very effective growth

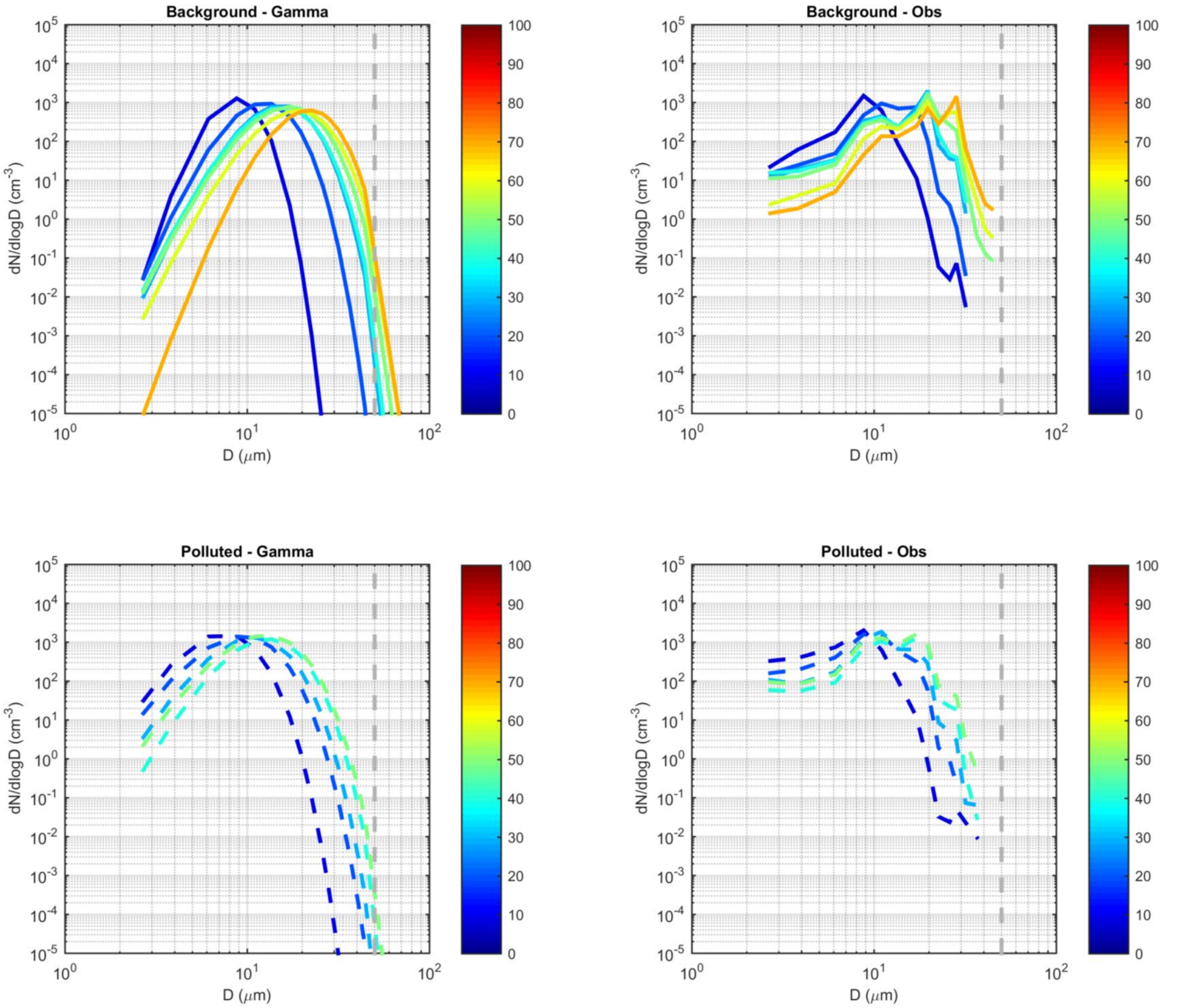


-> DSD evolution Gamma vs Obs

- Best case scenario because DSD_{obs} are known
- Can the current models reproduce this evolution? Unlikely given shape assumptions

-> Idea for solving the cloud:

- First guess for the DSD at cloud base based on aerosols/thermodynamics
- The rest of the DSD evolution may be obtained from the relation between growth processes and the Gamma parameters
- Possibly improve DSD variability modeling, does not require assumptions of shape (μ) or any other Gamma parameter
- Will benefit from closure study – only as good as first guess (Ramon and Daniel)



- Currently, this proposed methodology should work best for liquid droplets
  - Limited amount of growth processes
- The maximum altitude for this condition may change according to aerosol population

-> NIXECAPS classification:

- 1 -> **no** aspheric and T>0°C
- 1.1 -> aspheric and T>0°C (can be ice or ash particles)
- 2 -> **no** aspheric and -38°C<T<0°C
- 2.1 -> aspheric and -38°C<T<0°C
  - -- small liquid/frozen drops present ($NC_{3-50}>3cm^{-3}$)
- 2.2 -> aspheric and -38°C<T<0°C
  - -- **no** small liquid/frozen drops present ($NC_{3-50}<1cm^{-1}$ and $NC_{>50}>0cm^{-3}$
- 3 -> T<-38°C, no asphericity criteria
  - -- no observations of this one in the profiles analyzed

-> Aspherical hydrometeors appear in lower levels in background clouds

-> Thicker layer of coexistence between spherical and aspherical hydrometeors in polluted clouds above the 0°C level

- no guarantee that spherical is liquid (could be small frozen drops), but may be an indication of delayed freezing in polluted clouds
  - -- increased coverage for the parameterization