A Stochastic Approach for Representing Ice Cloud Microphysical Processes in Models

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1. Motivation

- Model parameterizations use different hydrometeor categories characterized by varying mass (m) – dimension (D) relations
  - Empirical a and b parameters defining $m=aD^b$ for each category are based on observations and are held fixed in models
- Previous studies have derived a and b for different environments (Fig. 1)
- Unknown how dependence on environmental conditions and variability & uncertainty within same conditions affect a and b
- Here a and b characterized as surface of equally plausible solutions for given conditions following approach of McFarquhar et al. (2015)

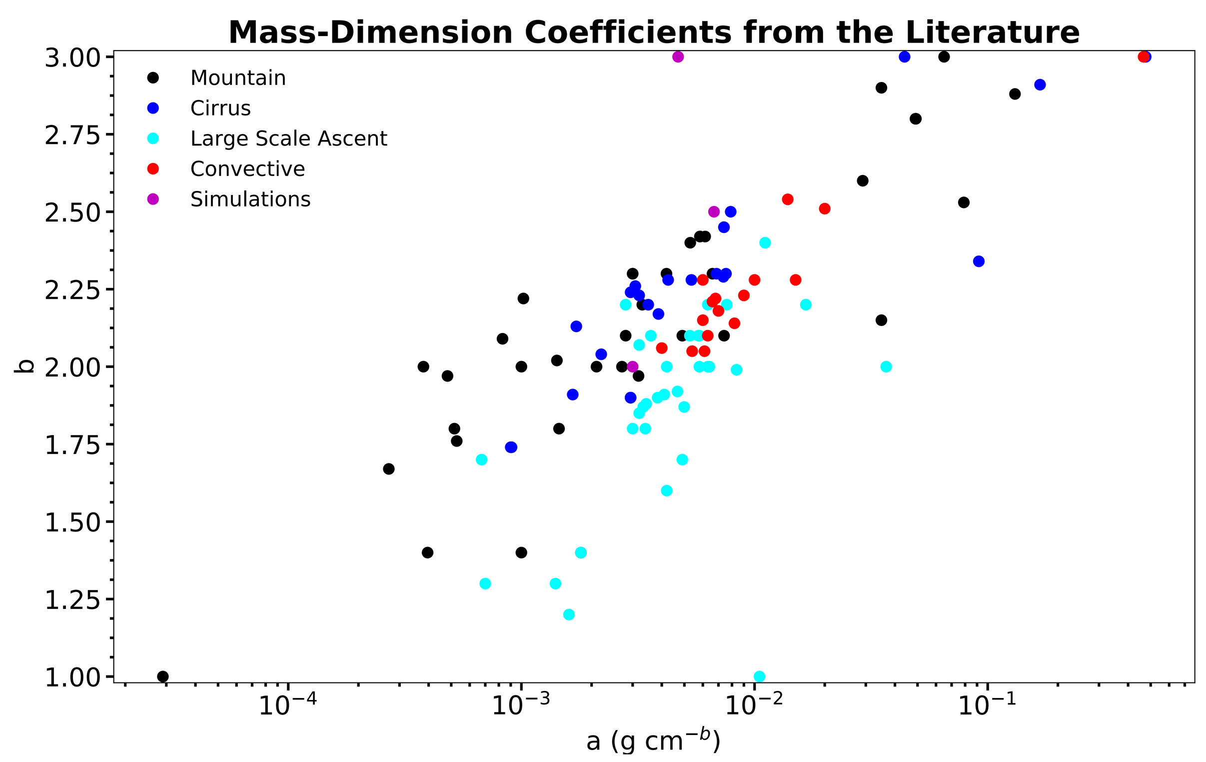
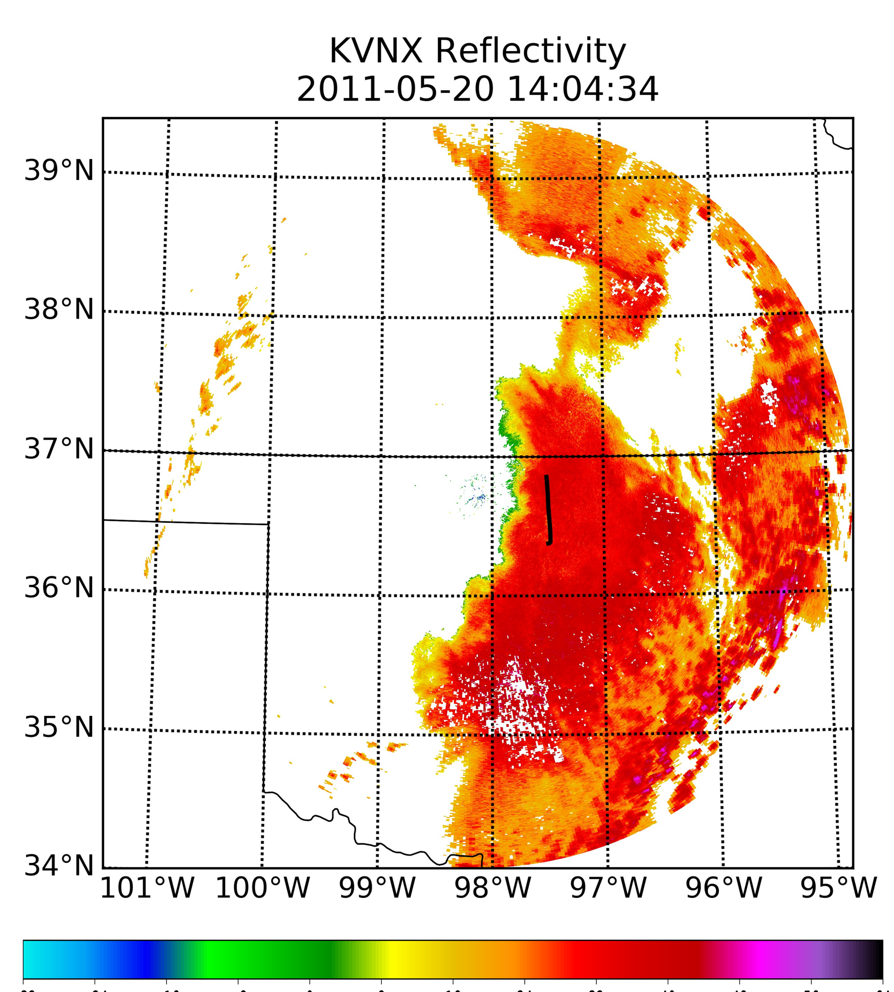


Fig. 1: Dependence of a & b parameters derived in previous studies as function of environment in which data used to derive parameters obtained.

2. Data

Instrument	2DC	HVPS	Nevzorov
Measurement	Size-shape distributions from shadowed images		Total Water Content (TWC)
Resolution	30 µm	150 µm	N/A
Range	30 ≤ D ≤ 960 µm	150 ≤ D ≤ 19200 µm	0.03 ≤ TWC ≤ 3 g m^{-3}

***Table 1:** Microphysical instruments used to derive cloud/precipitation particle size-distributions (SDs) and to measure total bulk mass during MC3E.*



- Analysis from 20 May 2011 event during Mid-Latitude Continental Convective Cloud Experiment (MC3E)
- Convective clouds in vicinity of ARM SGP site sampled in-situ with UND Citation
- Radar reflectivity (Z) obtained by Vance Air Force Base, OK S-band (λ = 10 cm) radar (KVNX) matched to location of aircraft using Airborne Weather Observation Toolkit radar matching algorithm

***Fig. 2:** Radar reflectivity from the KVNX radar. Black line denotes UND Citation track for a 10-minute in-cloud, near-constant temperature flight leg.*

3. Methodology

- Most likely (a,b) for single size distribution (SD) determined by minimizing χ^2 difference between observed TWC/Z and TWC/Z obtained from measured SD & a/b parameters
- Tolerance ($\Delta\chi^2$) allowed determined by statistical uncertainty in individual 10-sec averaged SD
  - All χ^2 within $\Delta\chi^2$ of minimum χ^2 are equally plausible solutions
  - a/b solutions highly co-variable
- 100 a-b solutions from equally plausible surface chosen at random for each observed SD (Fig. 3i)
  - Process repeated for each observation of similar TWC and temperature (T) environment to obtain larger sample of stochastic parameters (Fig. 3ii)

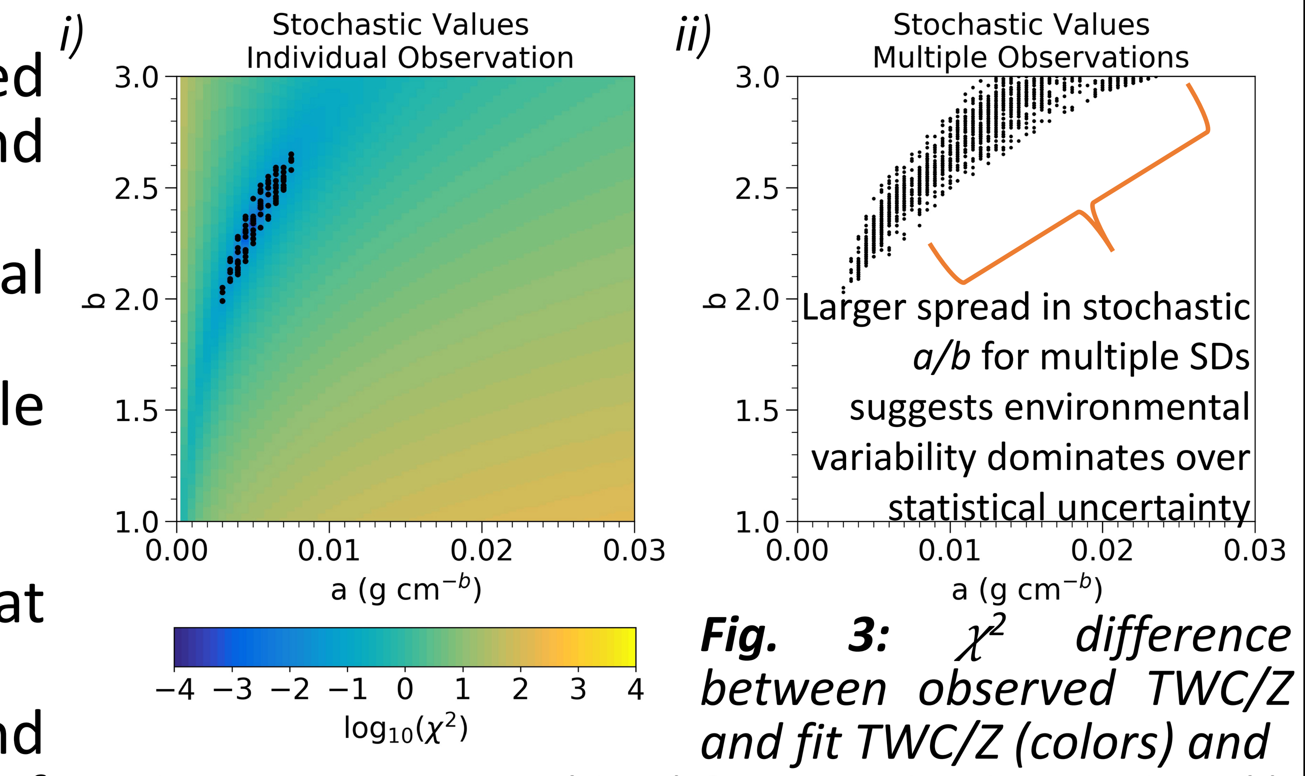
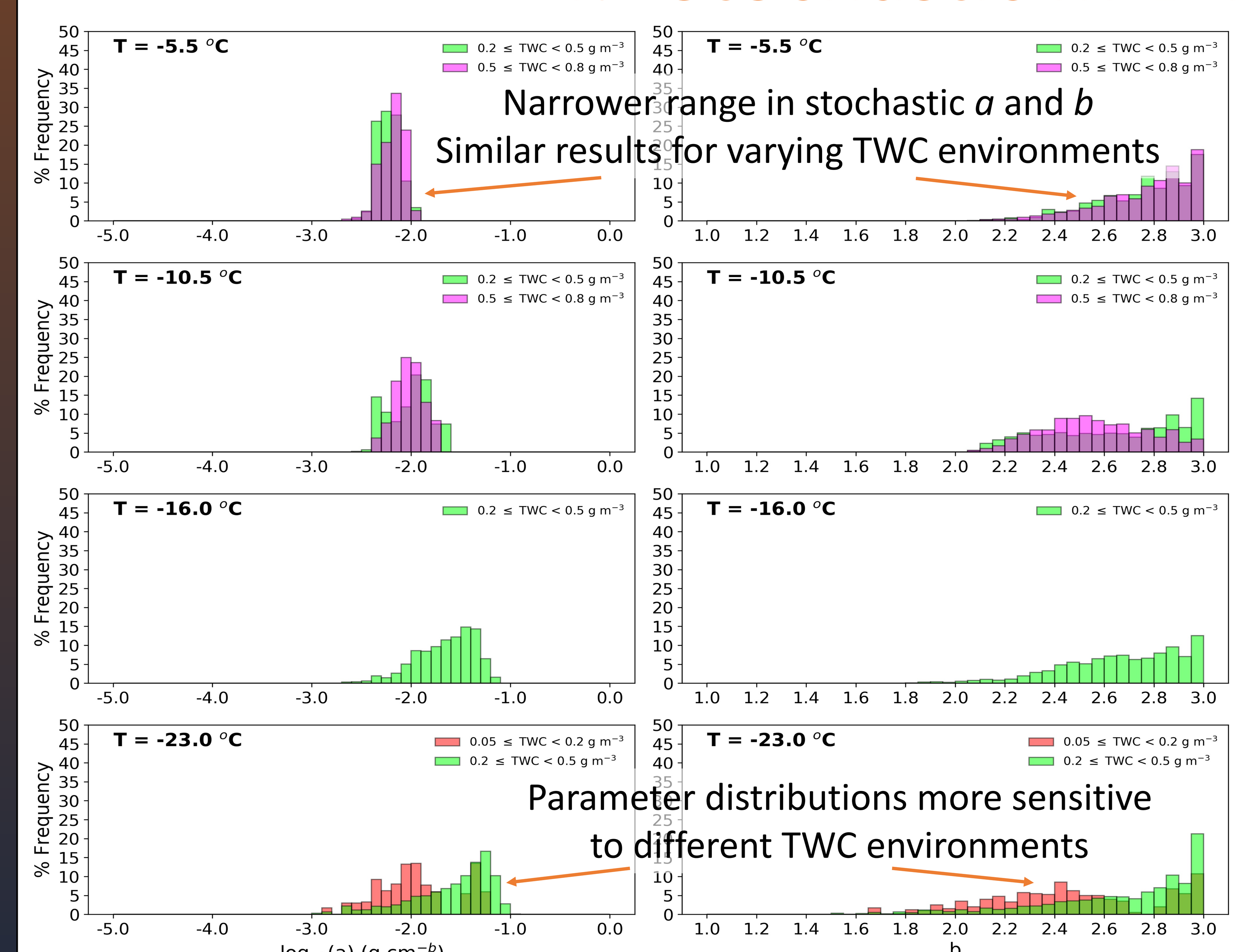


***Fig. 3:** χ^2 difference between observed TWC/Z and fit TWC/Z (colors) and stochastic parameters (dots) for a single observed SD (i), and stochastic parameters for multiple SDs observed at similar TWC and T (ii).*

4. Stochastic m-D Parameters



- Stochastic parameters from observations with similar environmental conditions (Fig. 3ii) represented as distributions of a and b
  - Solutions can be implemented in stochastic model (see poster of Stanford et al.)
- Distribution of a correlates well to distribution of b (Fig. 3)
  - Larger values of b can exist provided a also larger
- Greater range in parameters for lower T
  - Less variability in SDs allows more a/b (due to co-variability) to represent similar environment

***Fig. 4:** Distribution of stochastic a (left) and b (right) parameters for each temperature (row) and TWC.*

5. Future Work

1. Apply technique to more events/environments and analyze sensitivity of stochastic parameters for different temperatures and bulk mass regimes
2. Quantify impact of statistical uncertainty vs. environmental variability on stochastic parameters for use in models

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