Retrieval of aerosol and surface properties with synthetic signals from a multi-angle, multi-spectral polarimeter in GRASP code

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The compact Multi-angle, Multi-spectral Polarimeter (cMAP) [1]

- ✓ Airborne demonstrator adapted from MAP/CO2M developed from TAS-UK
- ✓ Measures the polarization of sunlight reflected on the Earth's surface → S = [I, Q, U, ~~V~~]^T
- ✓ 7 bands in visible and near-infrared: 410, 443, 490, 555, 670, ~~753~~ and 865nm
- ✓ >40 different viewing angles
- ✓ **Target systematic errors: 0.003 for DoLP, 3% for I**

Why this study?

1. Quantify the uncertainties of the retrieved aerosol and surface properties using synthetic cMAP radiance and polarization measurements
2. Assess the effect of different parameters to the retrieval and product uncertainties
3. Is it possible to deliver the aerosol related parameters with the accuracies required for climate studies [6 and Table 2] using cMAP radiances?
4. Define optimum retrieval approach using GRASP algorithm [2]
5. Define strategy (e.g. time of the day, measurement geometry) for upcoming measurement campaigns

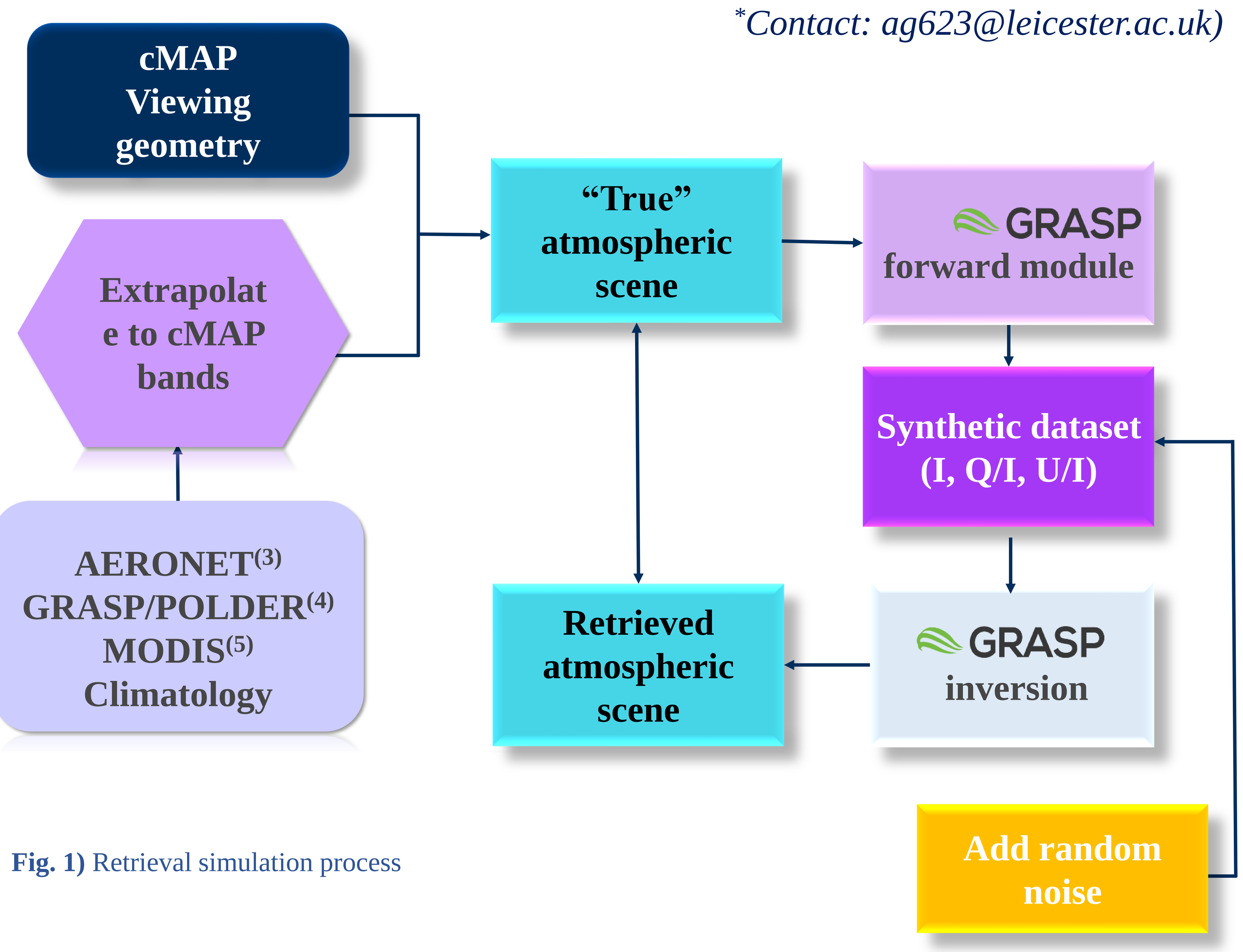


Fig. 1) Retrieval simulation process

RESULTS

Spectrally dependent parameters

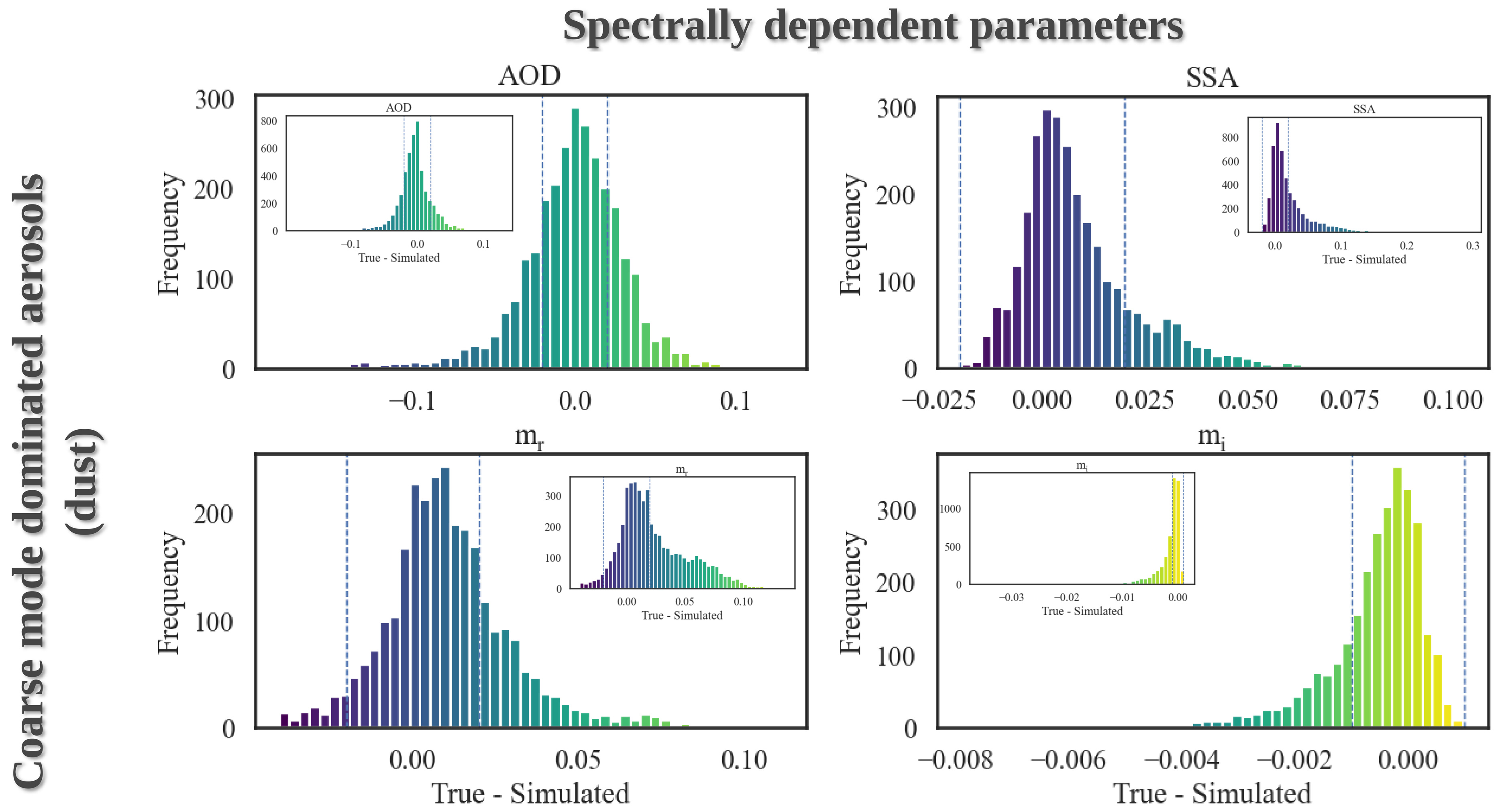
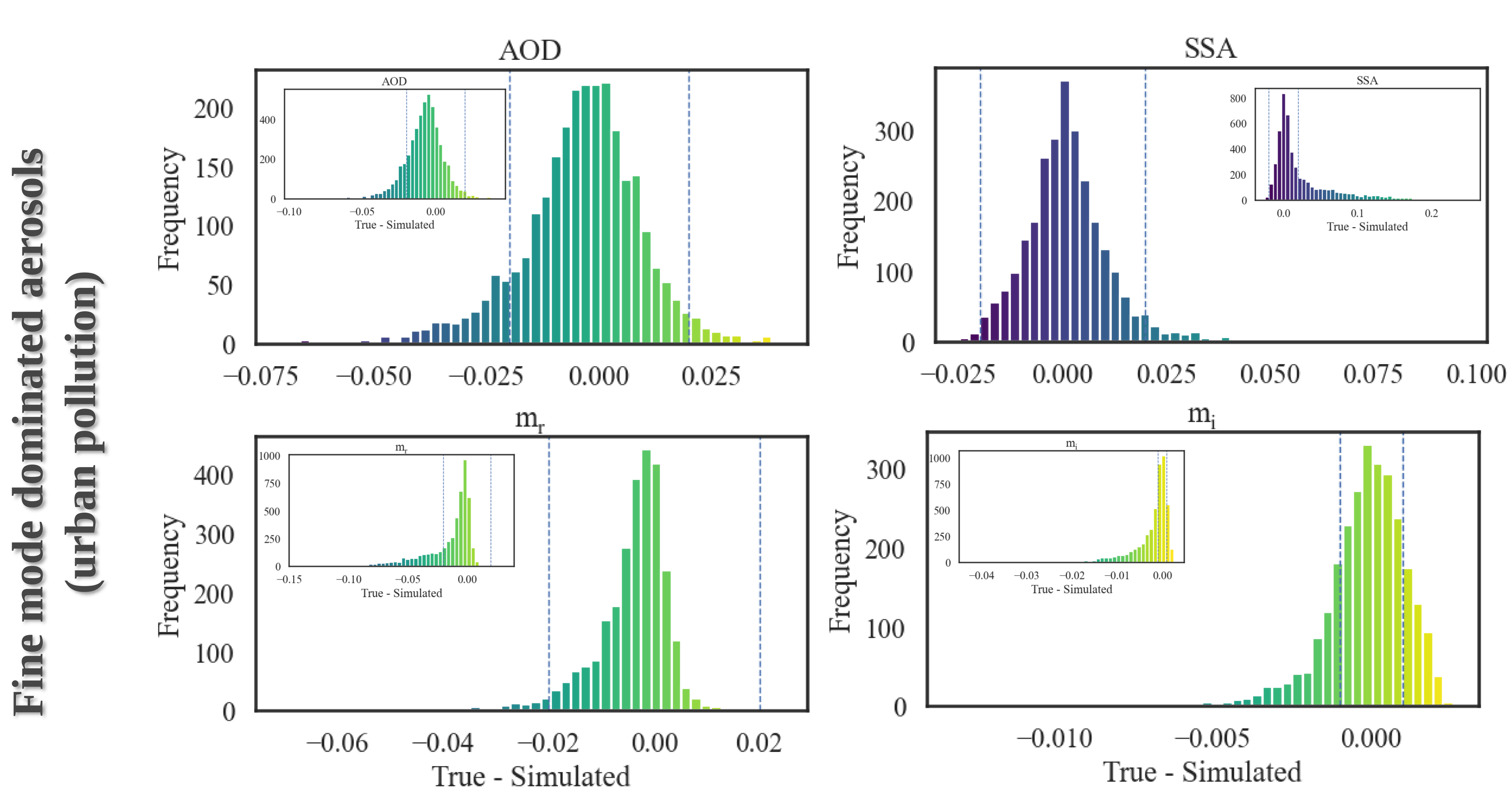


Fig. 2) (upper panel) Numerical test results for GRASP/cMAP retrievals for dust aerosols. Each test is performed 50 times for 5 AOD levels (0.05, 0.2, 0.4, 0.6 and 0.8) and 4 different realizations of random noise added to the cMAP synthetic signals (1000 runs in total). Simulations were performed assuming a SZA of 60°, flight path on the solar principal plane, 48 viewing angles in the range ±60° (scattering angle range ~58 - 180°), a grass underlying surface and 6 cMAP spectral bands. DoLP and radiometric accuracies of 0.003 and 3% were used. Each plot presents results only for AOD of 0.4, 0.6 and 0.8, while each subplot presents results for all AODs. Dashed lines represent the accuracy requirements for aerosol retrieval properties according to [6]. (lower panel) Same but for urban pollution aerosols.



Size distribution parameters

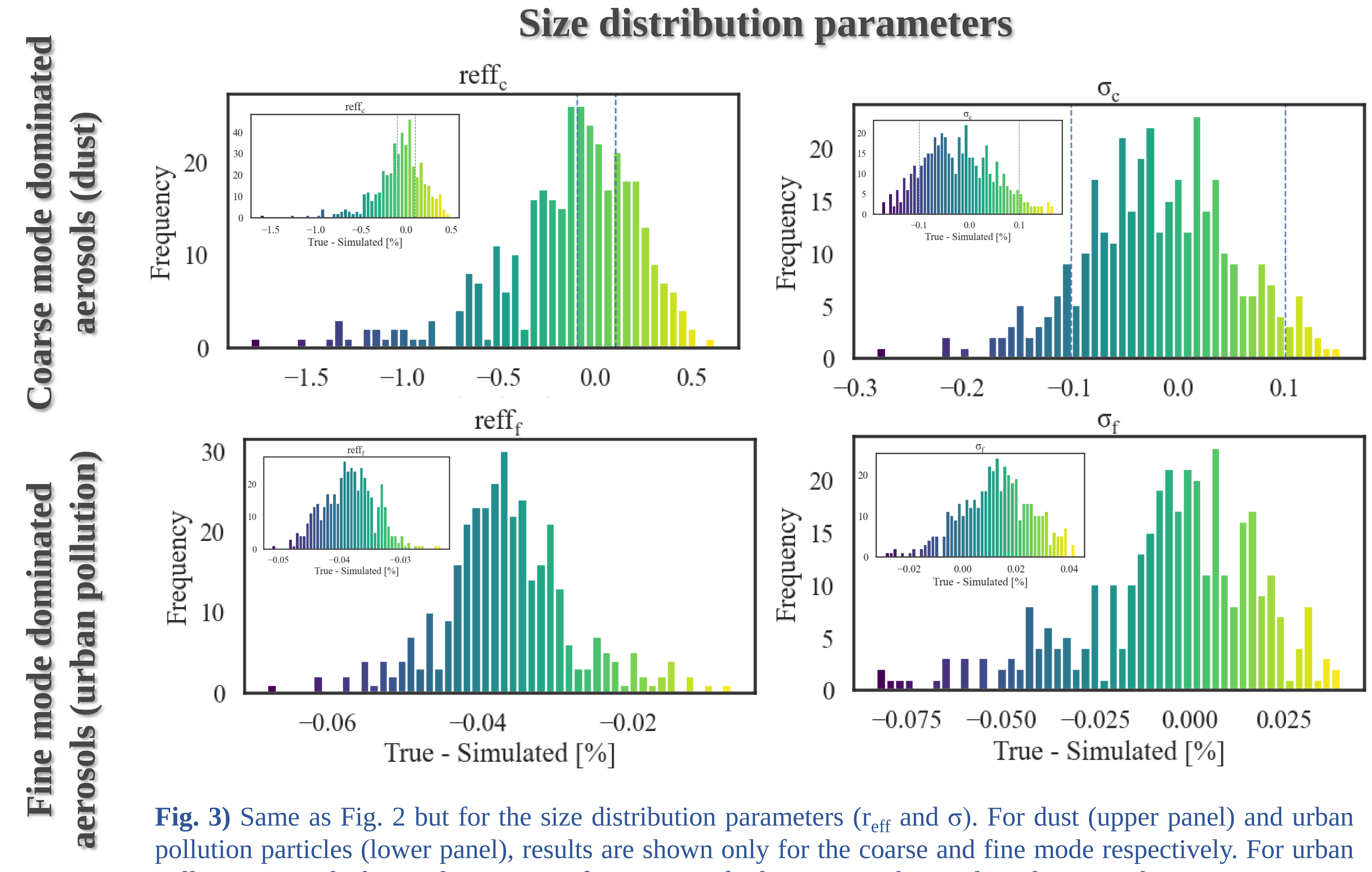


Fig. 3) Same as Fig. 2 but for the size distribution parameters (r_{eff} and σ). For dust (upper panel) and urban pollution particles (lower panel), results are shown only for the coarse and fine mode respectively. For urban pollution aerosols the results were satisfactory even for low AODs, thus no limit lines are shown.

Table 1: Retrieval setup

Retrieved aerosol parameters	Bi-modal log-normal size distribution, described by 16 triangular bins (r_{eff}, r_v, σ, volume concentration for fine and coarse mode)
	Complex refractive index (m_i, m_r)
	Sphericity fraction (f_{sph})
	Mean layer height (same for both modes)
	AOD, SSA, AAOD, Angstrom exponent
Retrieved surface parameters	Bidirectional Reflectance/Polarization Distribution Function parameters (BRDF/BPDF)
	Directional Hemispherical Reflectance

Table 2: Required accuracies for aerosol property retrievals according to [6]

AOD	SSA	m_i	m_r	r_{eff}	σ
0.02	0.02 (goal)-0.03 (threshold)	0.001 or 15%	0.02	0.1 μm or 10%	0.3 or 50%

*A sensitivity study with synthetic signals generated from GRASP algorithm for cMAP airborne polarimeter is performed for different aerosol types. The results shown here are only for coarse mode dominated dust and fine mode dominated urban pollution *Retrieval errors are reduced in all cases when filtering for very low AODs (0.05 – 0.2), as expected; apart from coarse mode AOD and r_{eff}, for which the results show that it cannot be retrieved within the requirements for most cases *The latter is mostly driven by the range of scattering angles sampled (~58 - 180° here), since sharp angular features present in smaller scattering angles for coarse aerosols are not resolved *For the other parameters and even for the current setup [Table 1], the results are quite satisfactory especially for fine mode aerosols, both for spectrally dependent parameters and PSD *Alternatively, we plan to use less detailed description of the PSD[2] to reduce the number of parameters in the inversions *Herein only the effect of random noise is examined (σ_I = 0.01 – 0.03, σ_{DoLP} = 0.001 – 0.003), but the effect of systematic errors (i.e. in viewing angles) will be also investigated *The underlying surface is assumed to be grassland, while we plan to expand this work for other land surface types

[1]Spilling, D., and Walker, A., 2021, [2]Dubovik, O. et al., 2011, [3]Dubovik, O. et al., 2002, [4] The authors would like to acknowledge the use of POLDER data "POLDER/PARASOL Level-1 data originally provided by CNES (http://www.icare.univ-lille1.fr/) processed at AERIS/ICARE Data and Services Center with GRASP software (https://www.grasp-open.com), [5]Schaaf, C., and Wang, Z., 2015, [6]Mishchenko et al, 2004; The cMAP system is being under development by Thales Alenia Space (https://www.thalesgroup.com/en/global/activities/space), under a UK Space Agency Centre for Earth Observation Instrumentation funded activity in collaboration with the University of Leicester. The authors would like to acknowledge funding from HARMONIA cost action (CA21119) to participate to the ELS conference.