Optimized Aerosol Retrieval with Bayesian Model Selection Strategy for TROPOMI/S5P

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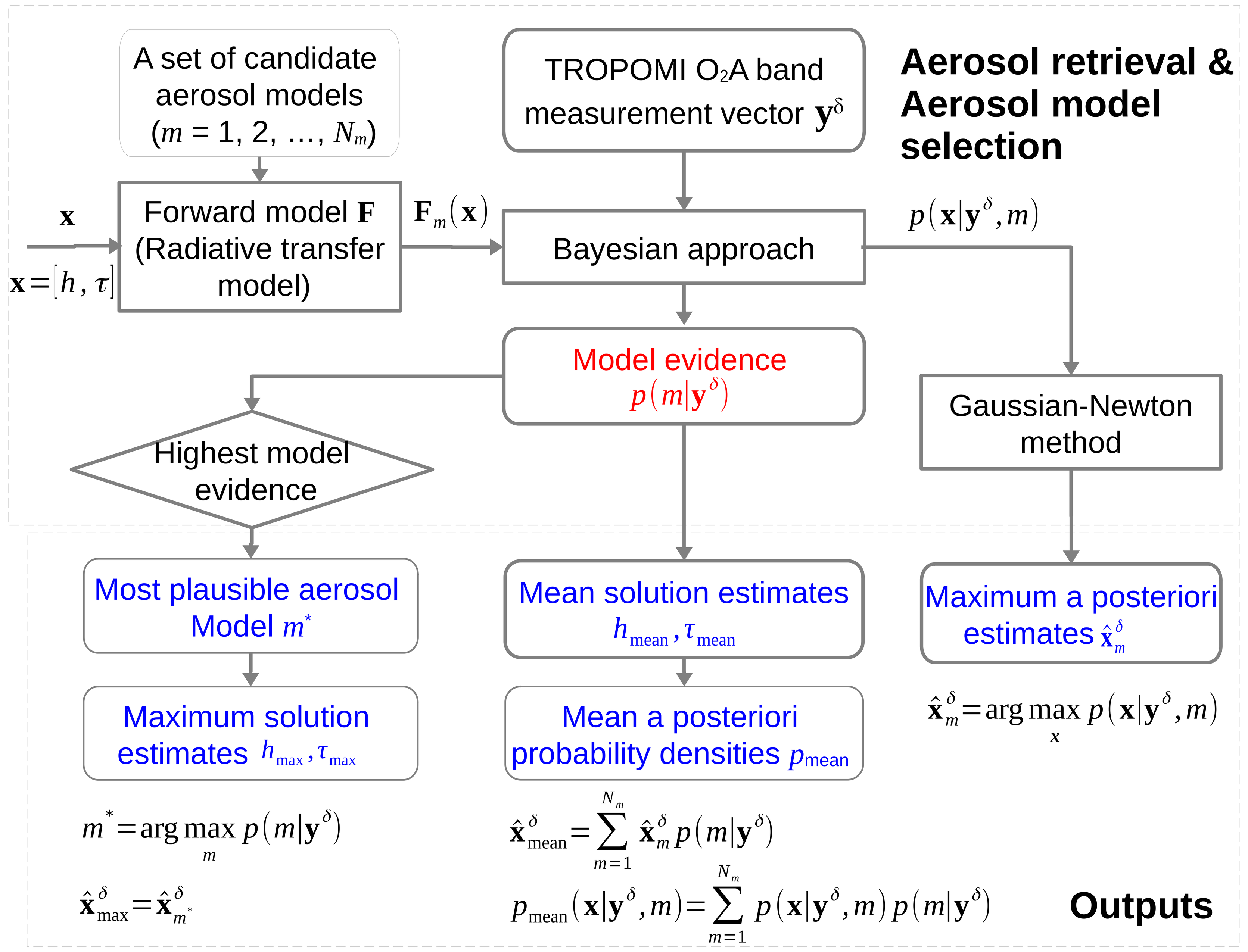
Introduction

Aerosol model plays an important role in retrieving aerosol properties from satellite measurements. We have developed a novel aerosol retrieval algorithm employing a radiative transfer model and the Tikhonov regularization method to estimate aerosol layer height (ALH) and aerosol optical depth (AOD) from the TROPOMI/S5P O_2A band (758-771 nm) measurements. In this research, we optimize the algorithm with a Bayesian-based aerosol model selection strategy and apply it to the TROPOMI measurements. The results show that in case of insufficient information for an appropriate micro-physical model selection, the optimized algorithm helps to find the most plausible aerosol model and to improve the accuracy of solutions.

Methodology



Aerosol Models

Aerosol models, Set 1

- from the MODIS Dark Target algorithm
- 4 aerosol models:
  - non-absorbing (NONABS) aerosols, generated from fossil fuel combustion in urban-industrial areas,
  - moderately absorbing (MODABS) aerosols,
  - absorbing (ABS) aerosols, generated from biomass burning,
  - desert dust (DUST), originated from desert and transported by wind.

Aerosol models, Set 2

- from the OMAERO algorithm
- 26 aerosol models representing 5 major aerosol types:
  - weakly absorbing (WA)
  - biomass burning (BB),
  - desert dust (DD),
  - marine (MA),
  - Volcanic (VO).

Test with Synthetic Data

Sythentic data

- generated with models from Set 1

Evaluation

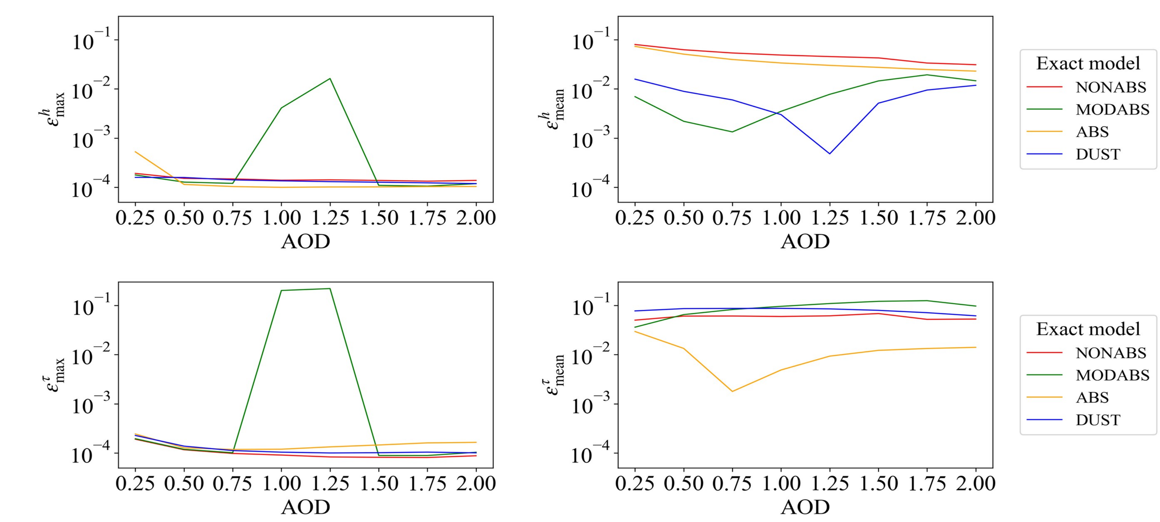
- The accuracy of solutions $h_{max}, h_{mean}, \tau_{max}, \tau_{mean}$ are qualified with relative errors:

$$\epsilon_{max}^h = \frac{|h_{max}-h_e|}{h_e}, \epsilon_{max}^\tau = \frac{|\tau_{max}-\tau_e|}{\tau_e}, \epsilon_{mean}^h = \frac{|h_{mean}-h_e|}{h_e}, \epsilon_{mean}^\tau = \frac{|\tau_{mean}-\tau_e|}{\tau_e}$$

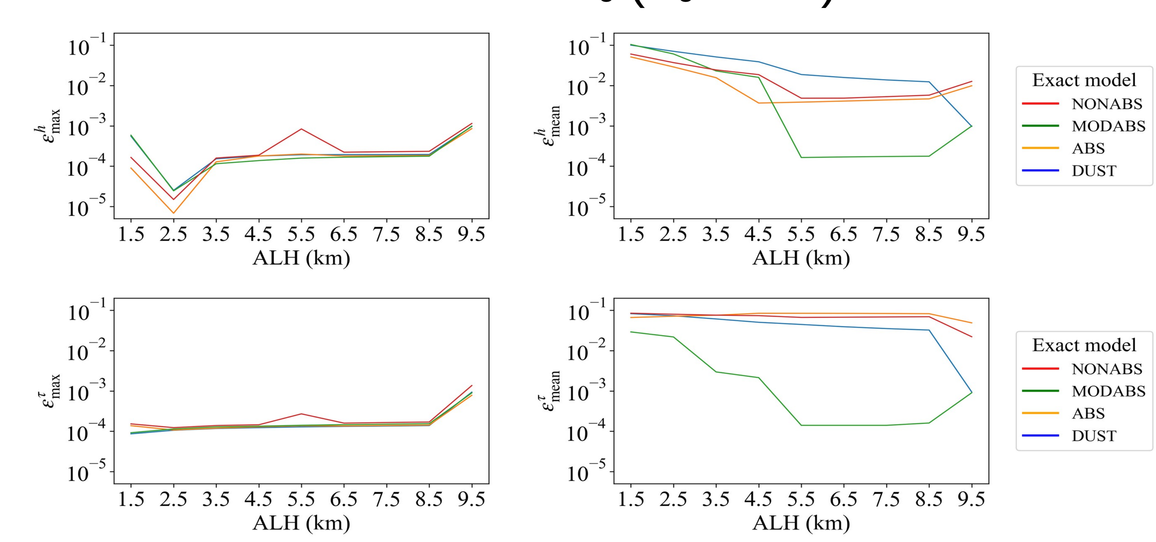
h_e, τ_e are the exact ALH and AOD to generate the synthetic data.

Test 1

- Retrieval with all the models from Set 1
  - Relative errors versus τ_e (h_e = 3.5 km)



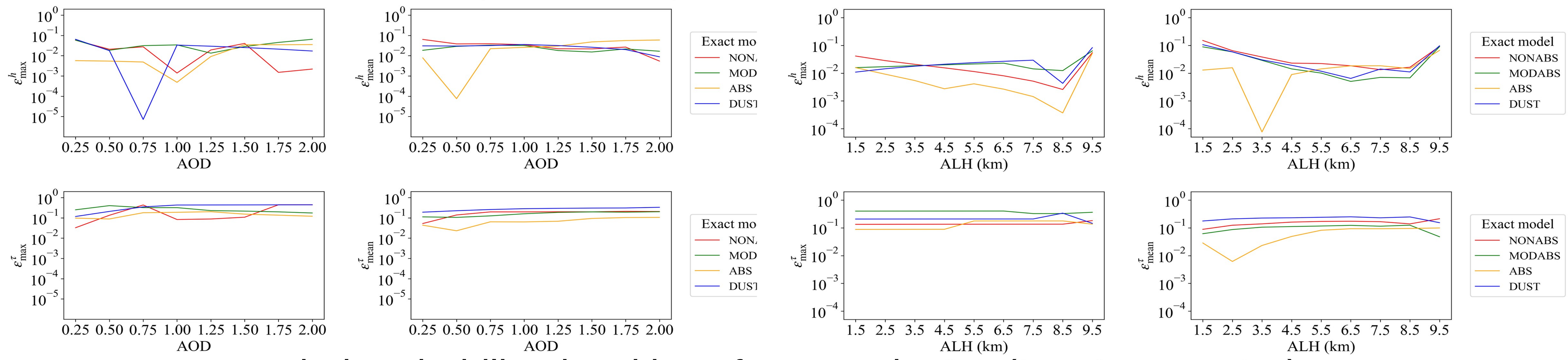
  - Relative errors versus h_e (τ_e = 0.5)



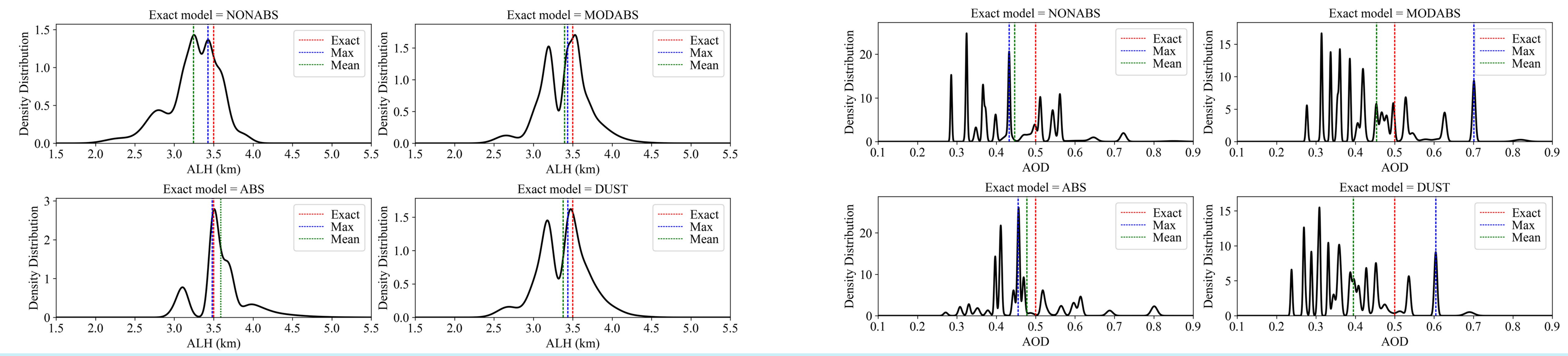
In most cases (except when $h_e = 3.5\,\text{km}$, $\tau_e = 1, 1.25$), the relative errors corresponding to the maximum solution estimate are acceptable and significantly smaller than those corresponding to the mean solution estimate, i.e., the retrieval algorithm recognizes correctly the exact aerosol model.

Test 2

- Retrieval with all the models from Set 2
  - Relative errors versus τ_e (h_e = 3.5 km)
  - Relative errors versus h_e(τ_e = 0.5)



  - Mean a posteriori probability densities of ALH and AOD (h_e = 3.5, τ_e = 0.5)

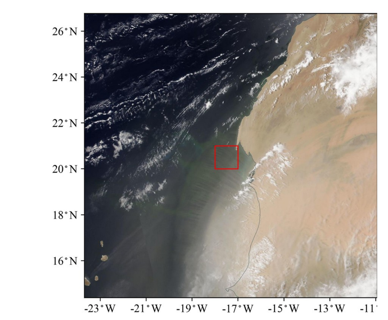


For ALH retrieval, the maximum solution estimate and the mean solution estimate have similar accuracy. For AOD retrieval, the mean solution estimate performs better than the maximum solution estimate. The ALH estimates obtain a higher accuracy than the AOD estimates.

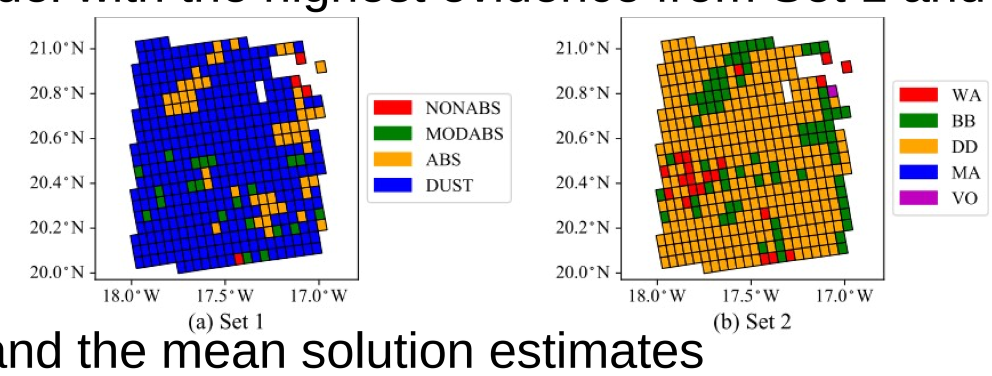
Test with Real Measurements

Desert dust case (on 6th June 2020 in Sahara)

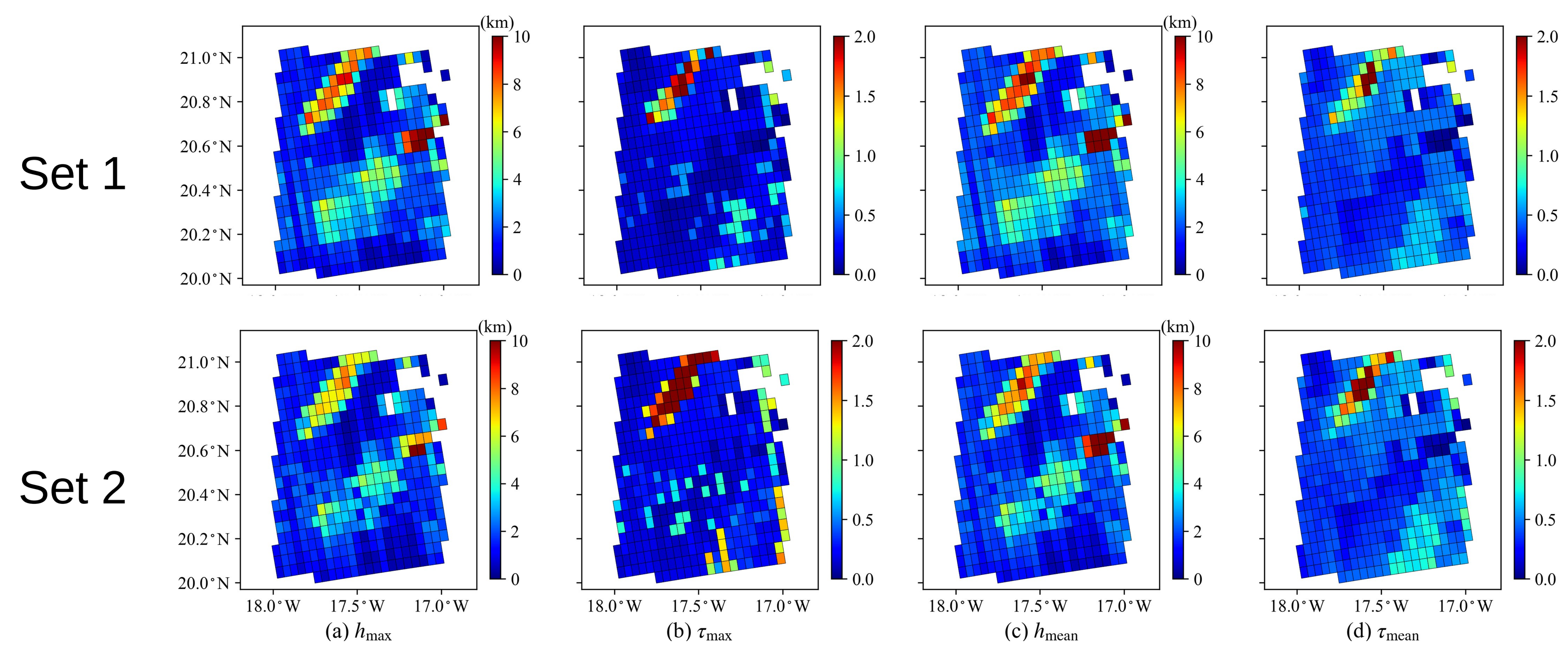
- True-color satellite image



- The aerosol model or aerosol type containing the aerosol model with the highest evidence from Set 1 and Set 2



- The maximum solution estimates and the mean solution estimates



The aerosol models with the highest model evidence are DUST model from Set 1 and DD type from Set 2 respectively. The mean solution estimates show a slightly smoother spatial pattern than the maximum solution estimates, and the spatial distributions of the mean retrieval results for Set 1 and Set 2 are comparable.