GEMS-AMI hybrid aerosol absorption retrieval algorithm development: preliminary results

Minseok Kim[1] (minskim@yonsei.ac.kr), Jhoon Kim[1], Yeseul Cho[2], Yujin Chai[1], Hyeji Cha[1]

[1]Department of Atmospheric Sciences, Yonsei University, Seoul, South Korea

[2]Earth System Sciences Interdisciplinary Center (ESSIC), University of Maryland, MD, United States.

1. Introduction

- Aerosol absorption and scattering are critical parameters for assessing radiative forcing and identifying aerosol types. Accurate retrieval of these properties is essential for climate and air quality studies.
- However, current aerosol algorithms for GEO satellites, such as GEMS, struggle to retrieve aerosol absorption. The difficulty lies in **simultaneously constraining aerosol loading and absorption from UV-visible spectra**.
- **AMI provides stable AOD retrievals** at longer wavelengths, which are less sensitive to uncertainties in aerosol optical properties. Combining GEMS and AMI observations offers a more robust framework for constraining aerosol absorption.
- This study introduces a synergistic retrieval algorithm **incorporating a deep learning radiative transfer (RT) model**. By replacing traditional RT calculations, it enables real-time, flexible, and accurate retrieval of aerosol absorption.

2. GK-2A/AMI & GK-2B/GEMS

Table 1. Instrument specifications of AMI and GEMS.

	AMI	GEMS
Satellite	Geo-Kompsat-2A (GK-2A)	Geo-Kompsat-2B (GK-2B)
Channels	16	1,033
Spatial resolution (km)	0.5/1 (VIS), 2 (IR)	3.5 x 7.7
Spatial coverage	Full-disk	Asia
Temporal resolution	10 min.	1 h.
Wavelength range	0.4–13 μm	300 – 500 nm
FWHM	10–20 nm	0.6 nm
Launch	December 2018	February 2020
Lifetime	10 years	
Location	128.2 ˚E	

3. Aerosol retrieval from GK-2 synergy

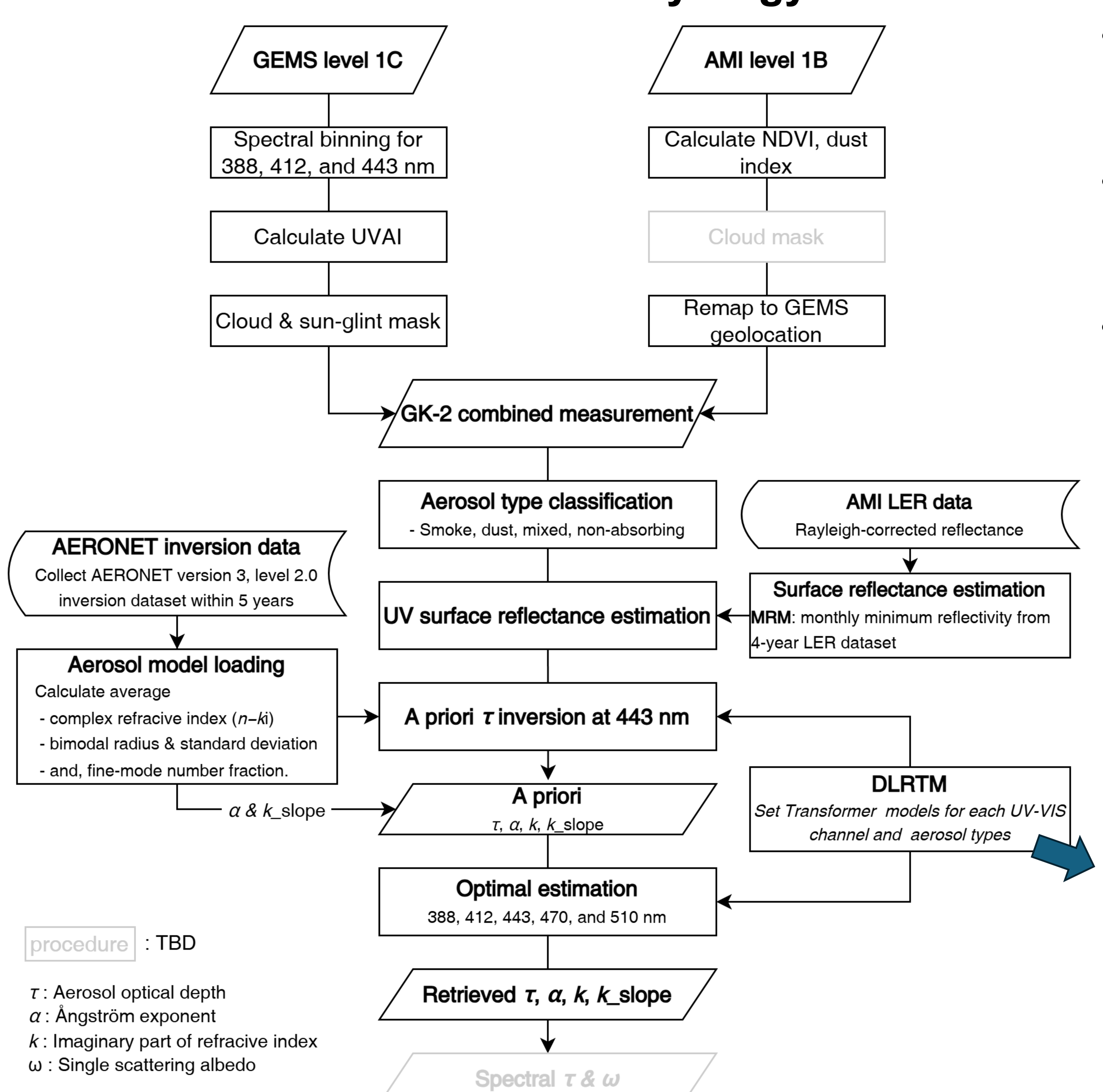

Figure 1. Flowchart for aerosol retrieval using AMI–GEMS synergy.

- A priori aerosol optical depth at 443 nm is first retrieved with assumed refractive index ($n - ki$).
- Spectral aerosol loading and spectral aerosol absorption are then retrieved via optimal estimation method.
- A priori of k is fixed with 0.07 for all aerosol types.

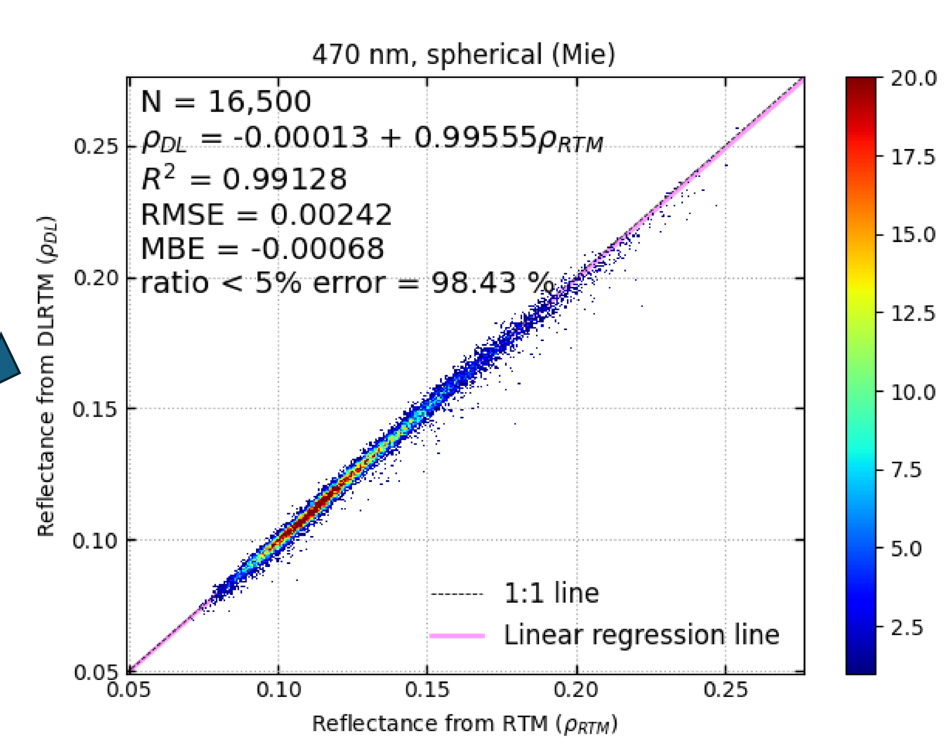

Figure 2. Comparison of reflectance from radiative transfer model (RTM) and deep learning-based radiative transfer model for 470 nm assuming Mie scattering.

- Radiative transfer model simulation is replaced with deep learning models.
- RMSE is ~1.6 % of reflectance.

4. Optimal estimation

- Optimal estimation minimizes below cost function, $\boldsymbol{J}(\mathbf{x})$ (Rodgers, 2000)

$$\boldsymbol{J}(\mathbf{x}) = \left(\mathbf{y} - \mathbf{F}(\mathbf{x})\right)^T \boldsymbol{S}_{\varepsilon}{}^{-1}\left(\mathbf{y} - \mathbf{F}(\mathbf{x})\right) + (\mathbf{x}_a - \mathbf{x})^T \boldsymbol{S}_a{}^{-1}(\mathbf{x}_a - \mathbf{x}).$$

Table 2. Definition of the measurement vector and state vector and their covariances.

Name	Setting
Measurement vector ($\mathbf{y}$)	$(I_{388}, I_{412}, I_{443}, I_{470}, I_{510})^T$
Observation uncertainties ($\boldsymbol{S}_\varepsilon$)	$\epsilon_I^2 I^2(\lambda)$, ϵ_I = 1.5% for UV, ϵ_I = 5% for VIS
State vector ($\mathbf{x}$)	$(\tau_{443}, \alpha_{388-510}, k_{443}, k\_\text{slope}_{388-510})^T$
A priori estimates uncertainties ($\boldsymbol{S}_a$)	$\begin{pmatrix} 0.2 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 \\ 0 & 0 & 0.01 & 0 \\ 0 & 0 & 0 & 0.1 \end{pmatrix}$

5. Aerosol detection

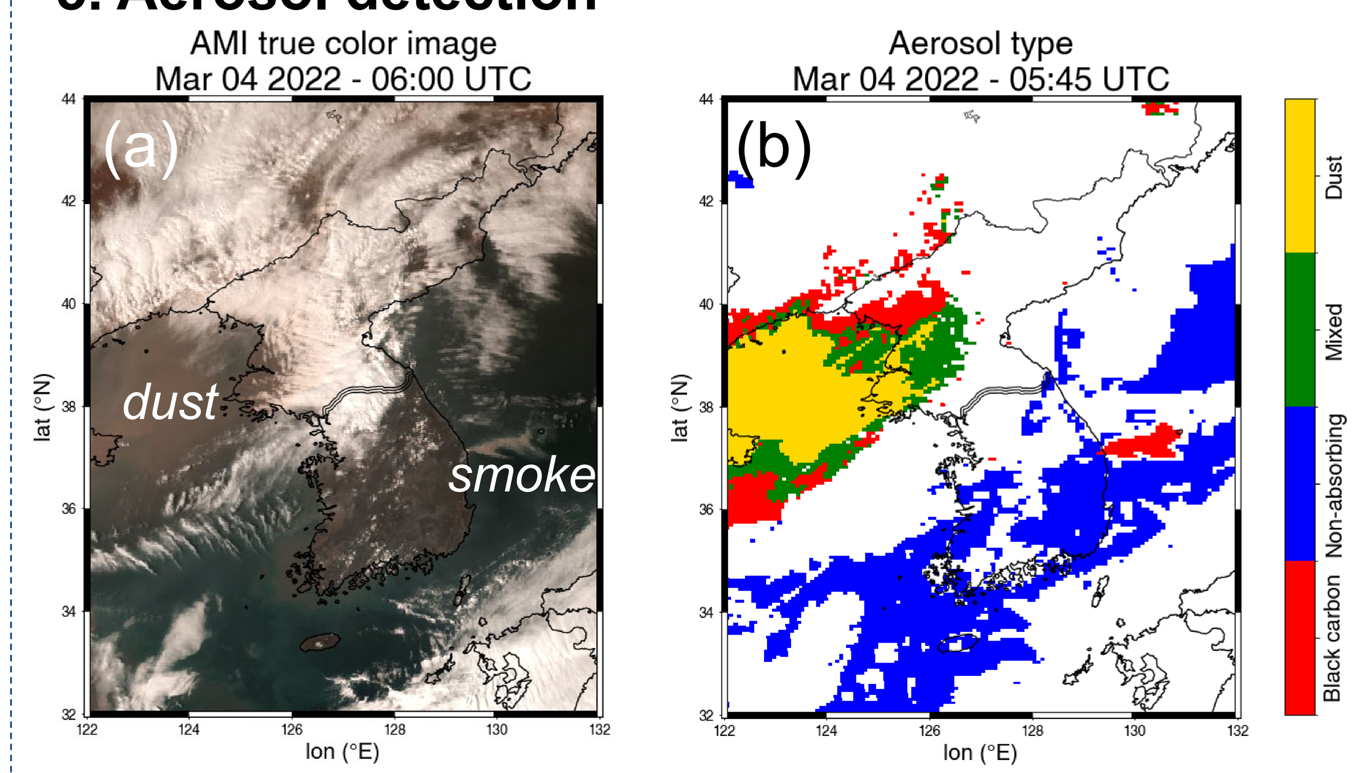

Figure 3. (a) AMI true color image at 06:00 UTC and (b) aerosol type classification result at 05:45 UTC from AMI–GEMS synergy for a case with both dust transport and wildfire on March 4th, 2022.

- Aerosol types are classified using UV aerosol index and dust index.
- Dust above cloud are detected and it may cause error in aerosol optical depth retrieval.
- Types are classified when a priori aerosol optical depth at 443 nm >0.4.

6. Preliminary results

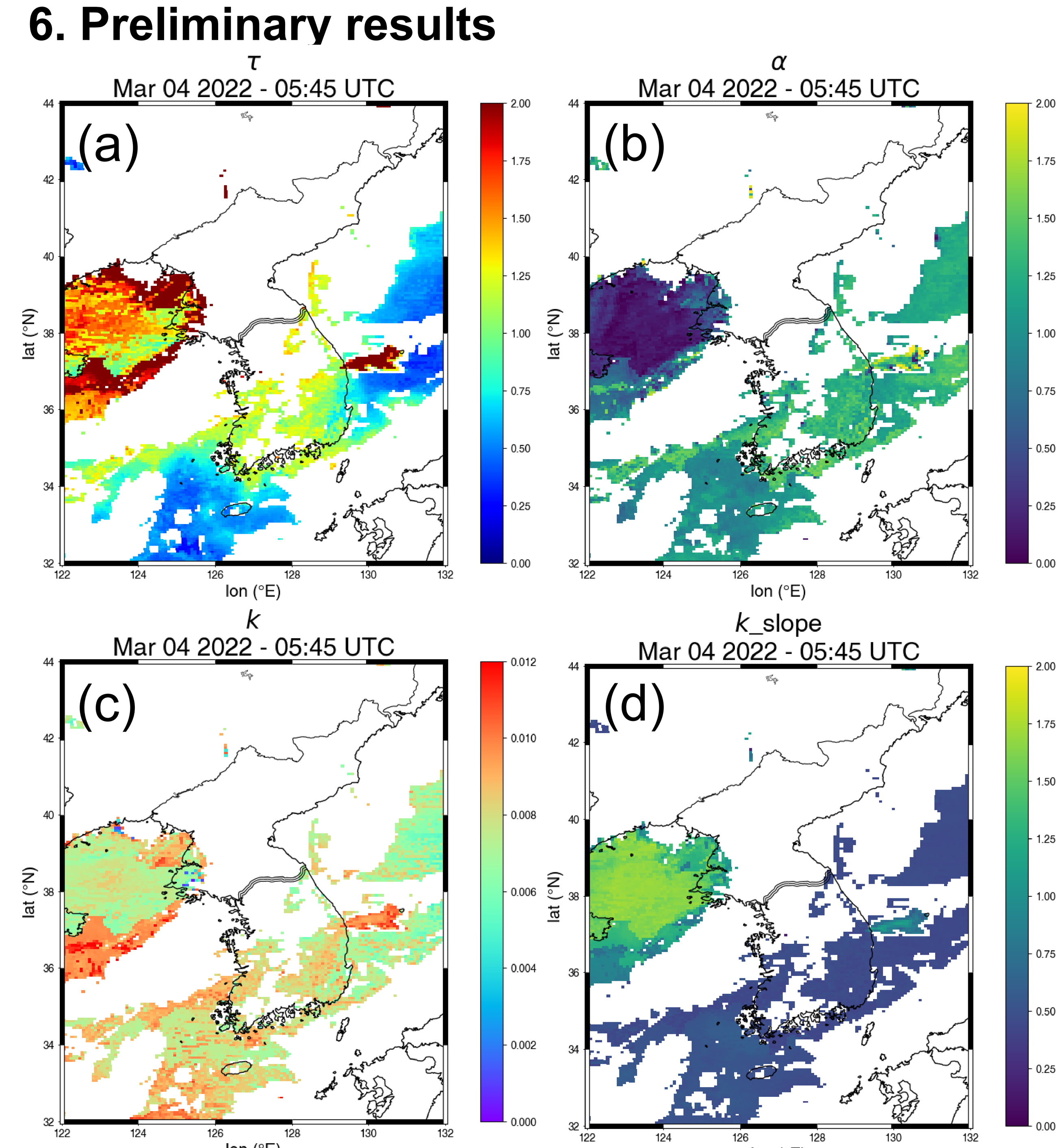

Figure 4. (a) Aerosol optical depth (τ) at 443 nm, (b) Ångström exponent (α) at 388–510 nm, (c) imaginary part of refractive index (k) at 443 nm, and (d) spectral slope of imaginary part of refractive index (k_slope) 388–510 nm result at 05:45 UTC from AMI–GEMS synergy for a case with both dust transport and wildfire on March 4th, 2022.

- Optimal estimation has not converged well at the dust pixels.
- For smoke aerosol, high α, k (~1.3 and ~0.01, respectively), and moderate k_slope (~1.1) are well retrieved.
- Further validation with ground-based aerosol measurements is needed.

Acknowledgement

This research was supported by a grant from the National Institute of Environmental Research (NIER), funded by the Ministry of Environment (ME) of the Republic of Korea(NIER-2025-04-02-063).