Simulation of polarization effects in UV-VIS region by using the radiative transfer model for GEMS/GK-2B

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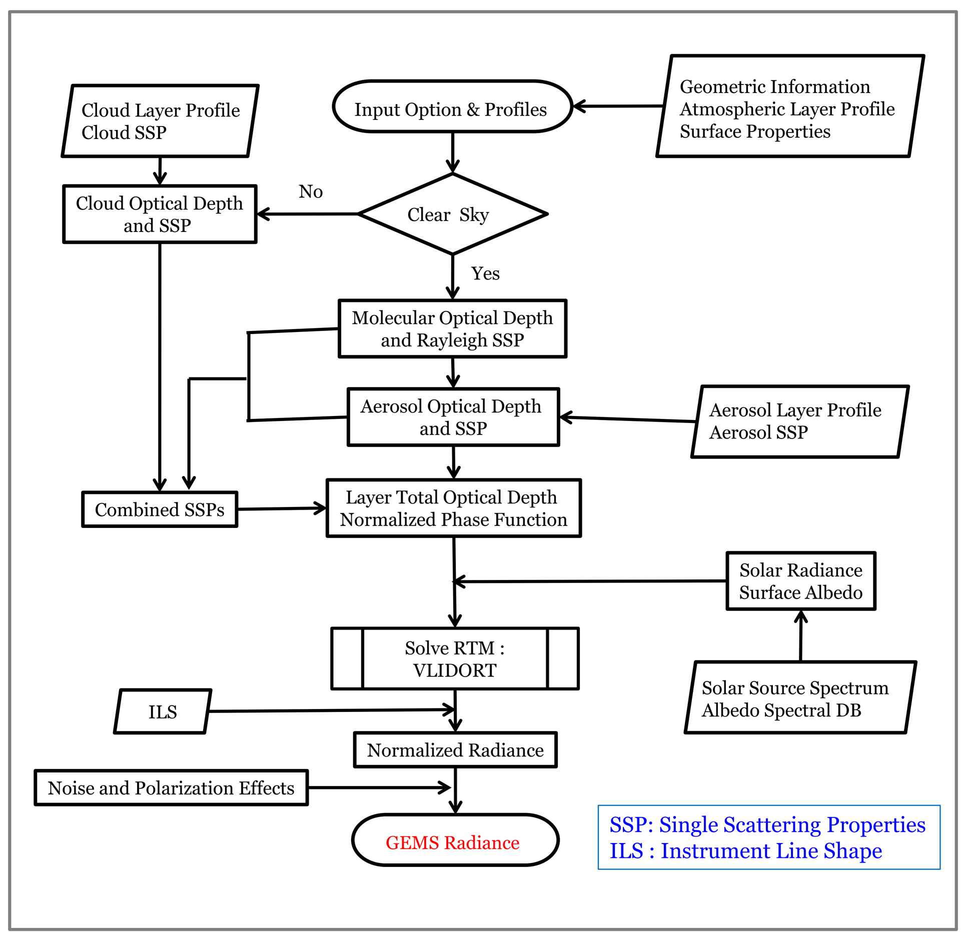
Abstract

- The radiative transfer model for GEMS/GK-2B (Geostationary Environment Monitoring Spectrometer) based on VLIDORT[Spurr et al., 2006] can be used as a simulation tool in the development of data processing algorithms. For example, it could be used in the production of synthetic data required for validation or correction of the data processing algorithms.
- GEMS RTM can be set to calculate normalized radiance for each component of Stokes parameter, using vector or scalar for a Rayleigh atmosphere with absorbing gases such as O_3, NO_2, SO_2, H_2CO, and O_4. Lorenz-Mie theory [Thomas et al., 2003] has been used to calculate the scattering properties of clouds and aerosols such as scattering, absorption, single scattering albedo and phase function.
- The scalar mode brings out the difference for the radiance in comparison with the vector mode. And these differences are greatly influenced by the polarization effects of the ozone.
- The effect of NO_2 and O_4 as compared to other absorbing gases is relatively large. In a given Rayleigh simulating condition, DOLP (Degree of Linear Polarization) is, on average, about 0.4 throughout the spectral region. From 0.3 to 0.5 μm, the DOLP tends to be somewhat weakened at longer wavelengths. Furthermore, when aerosols are loaded in the atmosphere, DOLP and DOCP (Degree of Circular Polarization) appear differently depending on the type of aerosols.

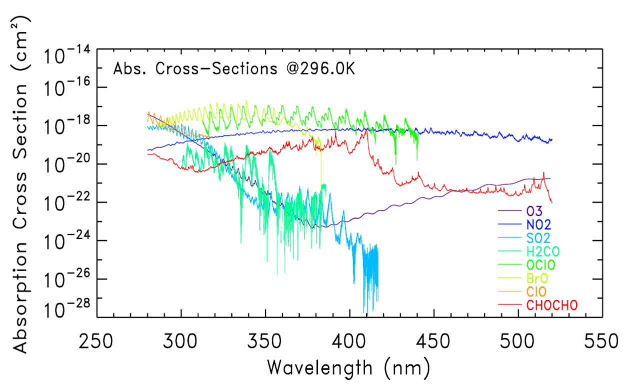
Radiative Transfer Model for GEMS/GK-2B

※ RTM description

- Linearized vector RTM(VLIDORT)
  - Compute stokes element(I,Q,U,V)
- Rayleigh Scattering(Bodhaine et al., 1999)
- Mie Scattering(Thomas et al., 2003)
- Optical properties of OPAC(Hess at al., 1998)
  - Gamma size distribution(Cloud)
  - Log-normal size distribution(Aerosol)
- Lambertian Surface Reflectance
- HITRAN database(Rothman et al., 2013)
- Solar spectrum(Kurucz et al., 1992)
- Instrument Line Shape
  - Gaussian ILS function
- Absorption Cross-Section



[Figure 1] The sequence flows of the radiative transfer model for GEMS/GK-2B.

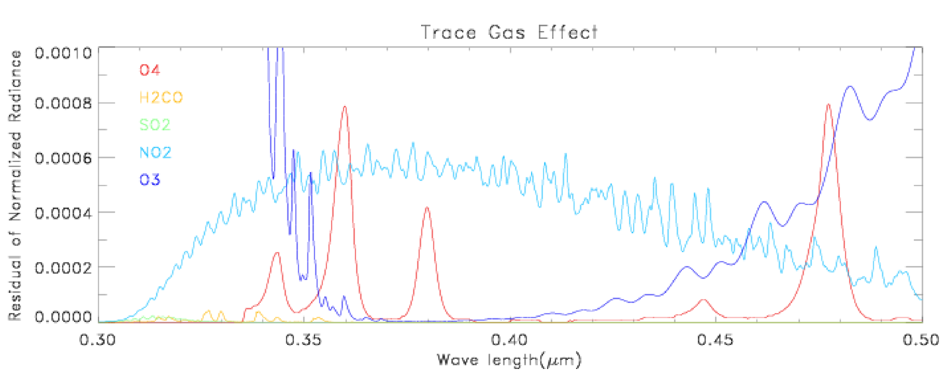


[Figure 2] Absorption cross-sections of ozone, nitrogen dioxide, sulfur dioxide, formaldehyde, bromine monoxide, and glyoxal from 250 to 550 nm.

Molecule	Common Name	Spectral Range (nm)	Source
NO2	Nitrogen Dioxide	238.08-666.62	HITRAN
SO2	Sulfur Dioxide	227.35-416.75	
H2CO	Formaldehyde	300.30-385.82	
O2-O2	Oxygen dimer	335.30-649.97	
BrO	Bromine Monoxide	286.38-383.04	
O3	Ozone	250.00-519.00	BDM
CHOCHO	Glyoxal	250.03-526.16	VOLK

[Table 1] Summary of molecular absorbing gases, included in the GEMS RTM. BDM and VOLK, respectively, stand for Brian-Daumont-Malicet, Volkamer mentioned in the text.

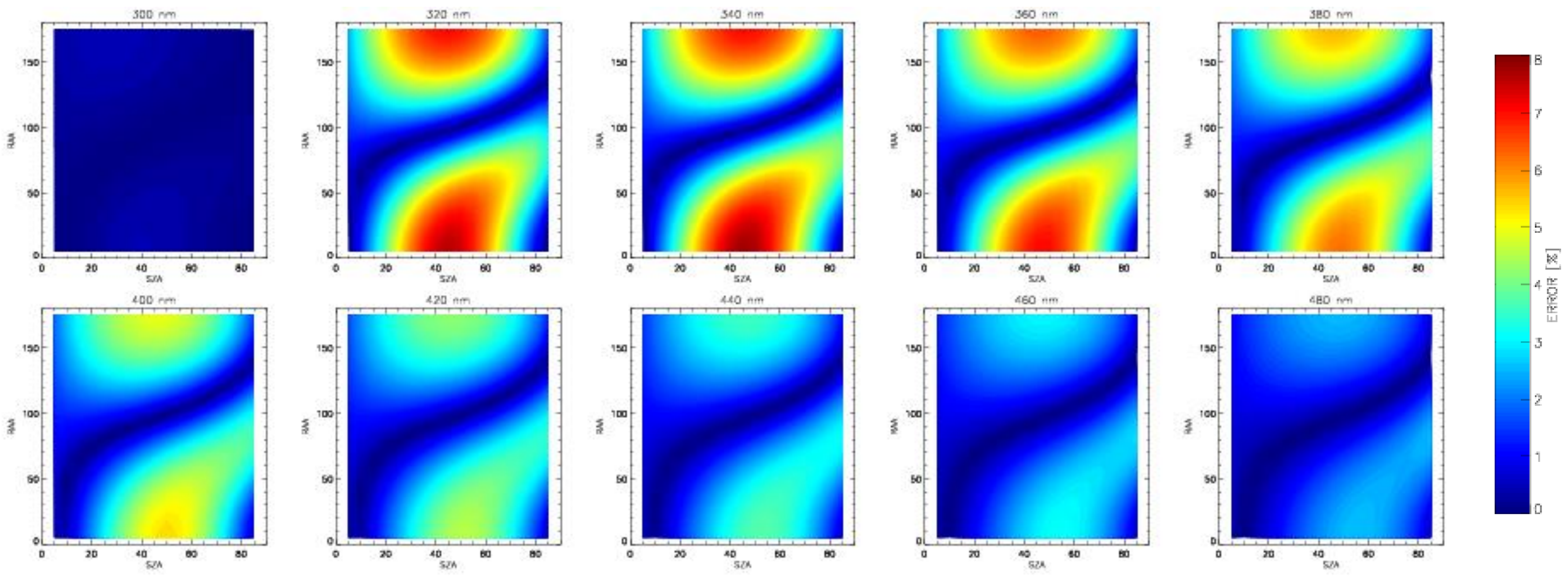
- Effects of each trace gases on simulation
  - Atmosphere profile (US76)
  - Only the particular absorption gas exist and calculate normalized radiance
  - Influence of O_3 is the strongest in the range of 300 to 350 nm
  - NO_2 and O_4, compared to other gases, are relatively large
  - BrO also has significant effect in the short wavelength range(Not shown here)



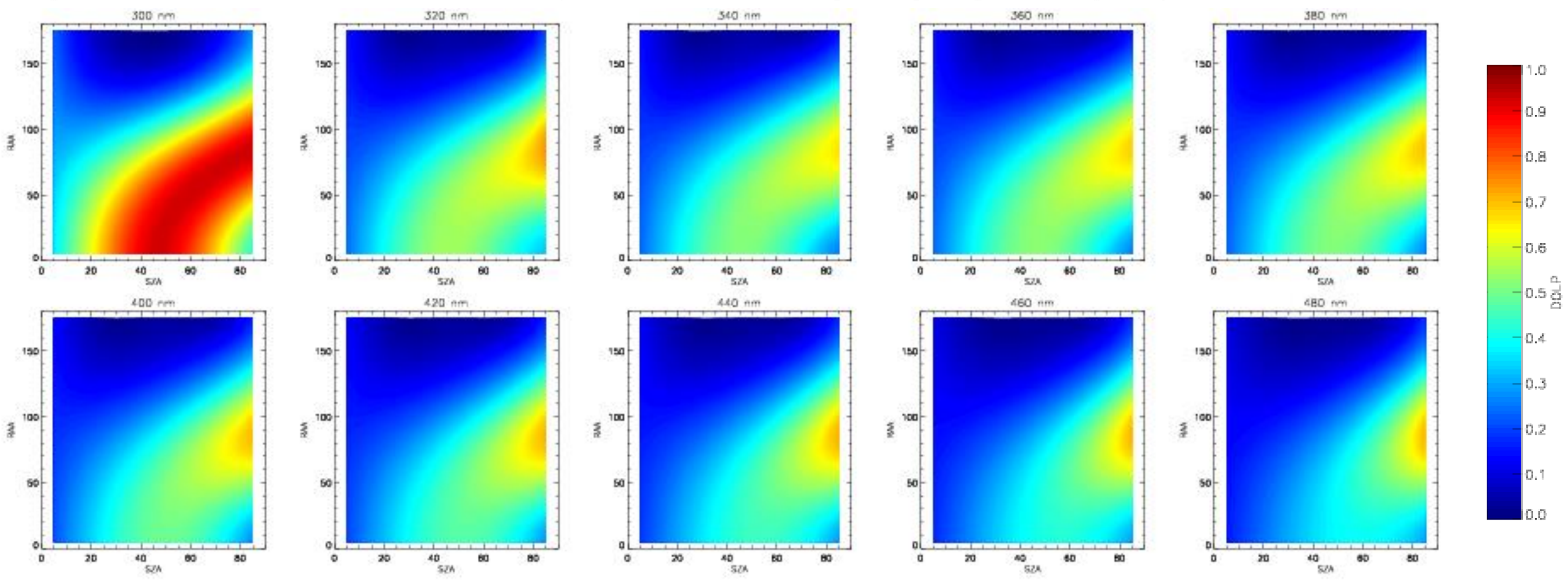
[Figure 3] Absorption cross-sections of ozone, nitrogen dioxide, sulfur dioxide, formaldehyde, bromine monoxide, and glyoxal from 250 to 550 nm.

Simulation Results

- Polarization effects for given observation geometry (Rayleigh Atmosphere)



[Figure 4] Relative simulation Error, i.e. (Vector – Scalar) * 100 / Vector, for a molecular atmosphere (depending on the solar geometry).



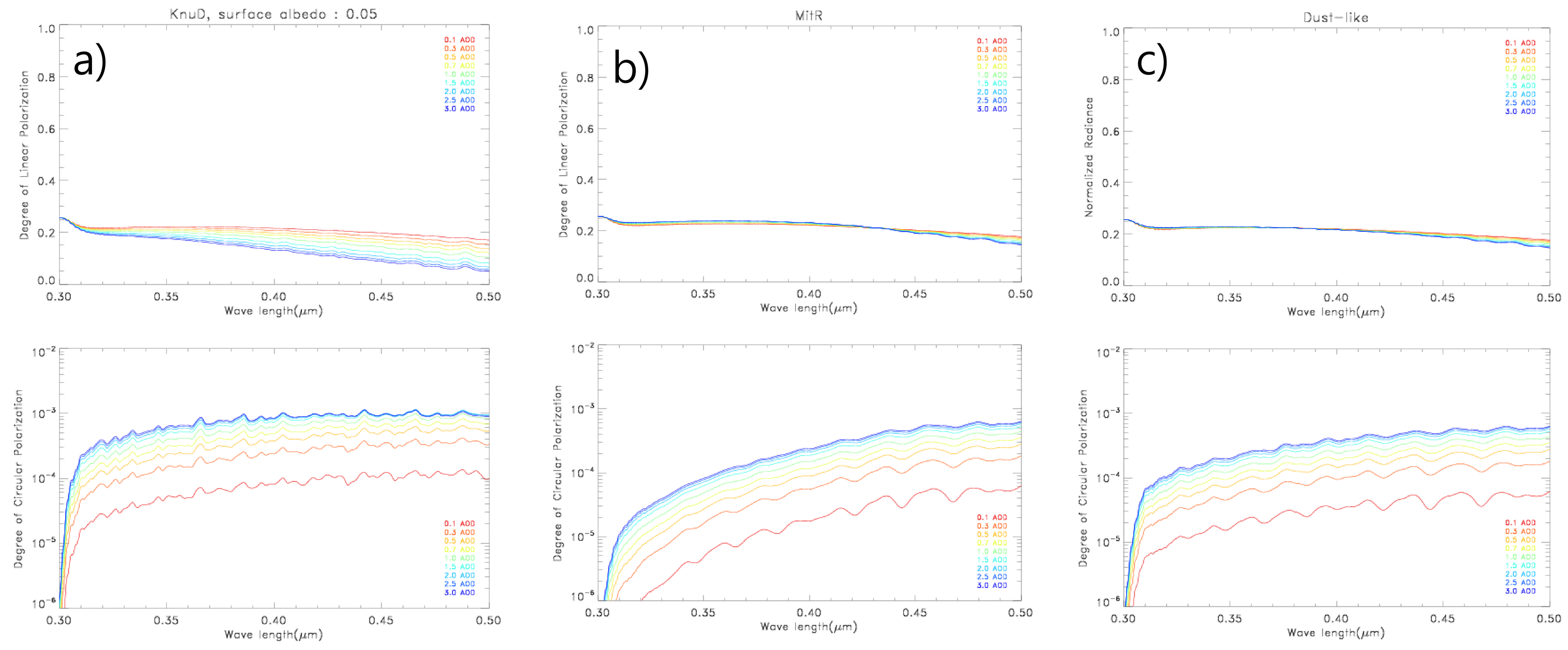
[Figure 5] Same as Figure 4, except for DOLP.

- Viewing geometry at Seoul(Viewing Zenith Angle:43.57, Viewing Azimuth Angle:178.0)
- Polarization Effect

$$Error\ [\%] = \frac{|VLIDORT - LIDORT|}{VLIDORT} \times 100$$

  - Up to 8% radiance difference for similar solar and satellite orbital geometry
- Degree Of Linear Polarization
  - DOLP is, on average, about 0.4 throughout the spectral region
  - DOLP tends to be somewhat weakened at longer wavelength and peaked at 300 nm
  - When solar elevation angle is low and the relative azimuth is perpendicular DOLP is relatively large at all wavelength

- DOLP & DOCP for various dust types (depending on AOD)



[Figure 4] Relative simulation Error, i.e. (Vector – Scalar) * 100 / Vector, for a molecular atmosphere (depending on the solar geometry).

- SZA : 42.61, VZA : 49.96, SAA: 54.54, VAA: 178.0
- Dust Aerosol Types(R_{eff} : 2.26 μm)
  - KnuD(Lee et al., 2014), Mitr(OPAC; Hess et al., 2008), Dust-like(Shettle et al., 1979)
- DOLP and DOCP occur variable pattern due to the dust aerosol types
- The shape of DOLP in KnuD due to changes in AOD is different from others
  - Imaginary part of refractive index (Dlike > Mitr > KnuD)
  - Strong absorption suppresses multiple scattering

Summary and Future Plan

- Optimized atmospheric radiative transfer model for GEMS has developed
- The major components of RTM are solar irradiance, optical thickness of absorption gas, air molecules, multiple scattering by the clouds and aerosols, and surface albedo.
- The gases(O_3, SO_2, NO_2, H_2CO, O_4) of interest of GEMS were all considered and simulated
- Simulation results
  - Effect of ozone is strongest, and signals of NO_2 and O_4 also appear well
  - Clear distinction between Scalar mode and Vector mode for the geometry was observed
  - DOLP appears strong at short wavelength and becomes constant as wavelength increases
  - Polarization occurred differently according to the aerosol types
- Future plan
  - Implement T-matrix scattering for non-sphere aerosol types
  - Bi-lognormal size distribution form for Asian dust(fine-mode and coarse-mode)
  - Consider Raman scattering and BRDF(Bidirectional Reflectance Distribution Function)

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Acknowledgement

- This research was supported by the GEMS program of the Ministry of Environment, Korea and the Eco Innovation Program of KEITI (2012000160002).