Polarization characteristics of the atmosphere

: Sensitivity study and variable information

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Background

- The polarization of the measured light depends on the optical system (mirror, grating, ...) and the actual incoming light (Schutgens and Stammes, 2003).

- Incorporating the polarization enables a more accurate retrieval of atmospheric properties and constituents (Mishchenko and Travis, 1997)

- Satellite groups measure the state of polarization to improve radiometric calibration.
  1. *GOME (Burrows et al., 1999)*
  2. *SCIAMACHY (Bovensmann et al., 1999)*
  3. *GOME-2 (Callies et al., 2000)*

- GEMS will develop a polarization correction algorithm using the RTM simulation results.

- List of variables affecting the polarization
  - **Solar & Observation Geometry**
  - **Surface reflectance**
  - **Trace gases**
  - **Aerosols**
  - **Clouds**
  - **…… etc.**

- We plan to apply a real-time polarization correction using Look-Up-Table

- The table will be prepared based on the RTM simulation results

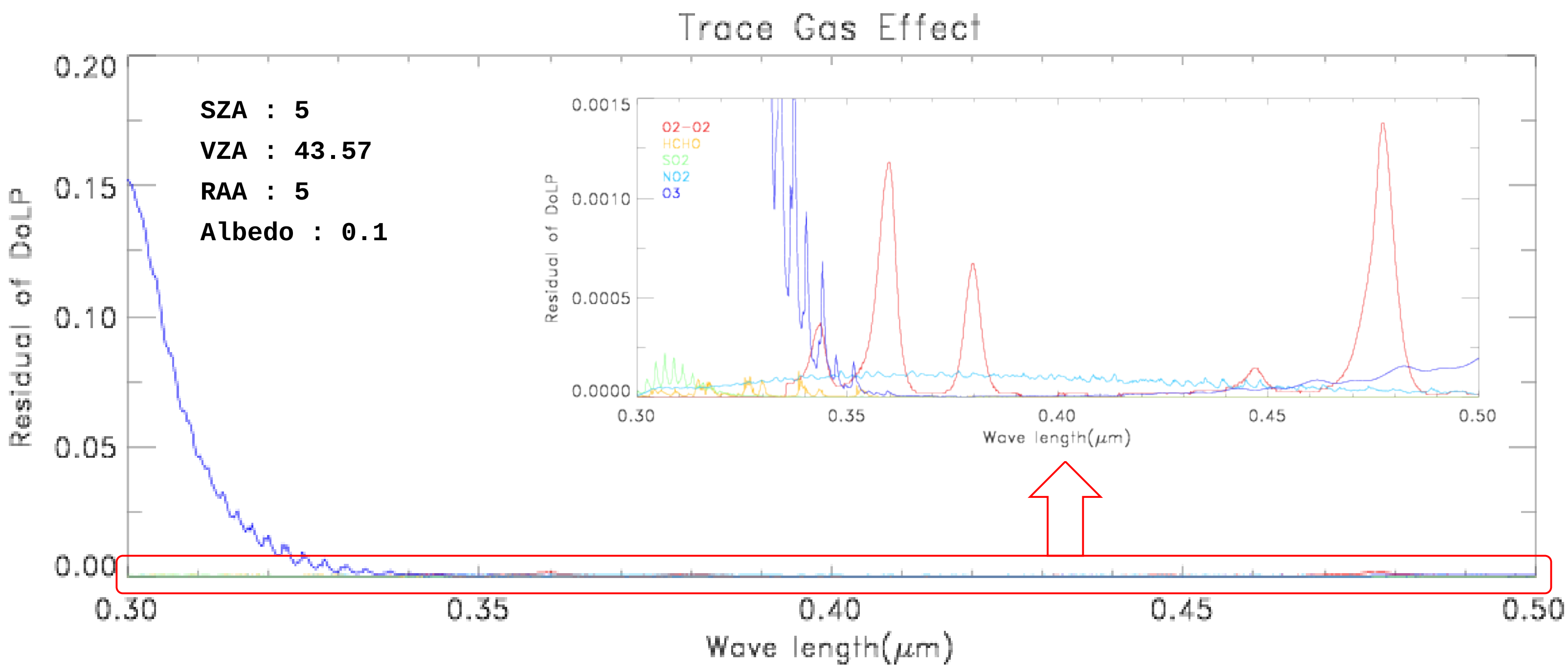
Method

- Polarization Correction Algorithm(Sun and Xiong, 2007)

$$I' = hI\underbrace{\{1 + fa\cos[2(\phi - \chi)]\}}_{\text{Polarization Term}}$$

I': *Intensity reaching the CCD*
h: *Transmittance of the optical system*
I: *Intensity reaching the diffuser*
a: *Degree of polarization*
ϕ: *Angle of maximum transmission*
χ: *Phase angle of polarization w.r.t. instrument reference plane*
f: *Linear polarization sensitivity*

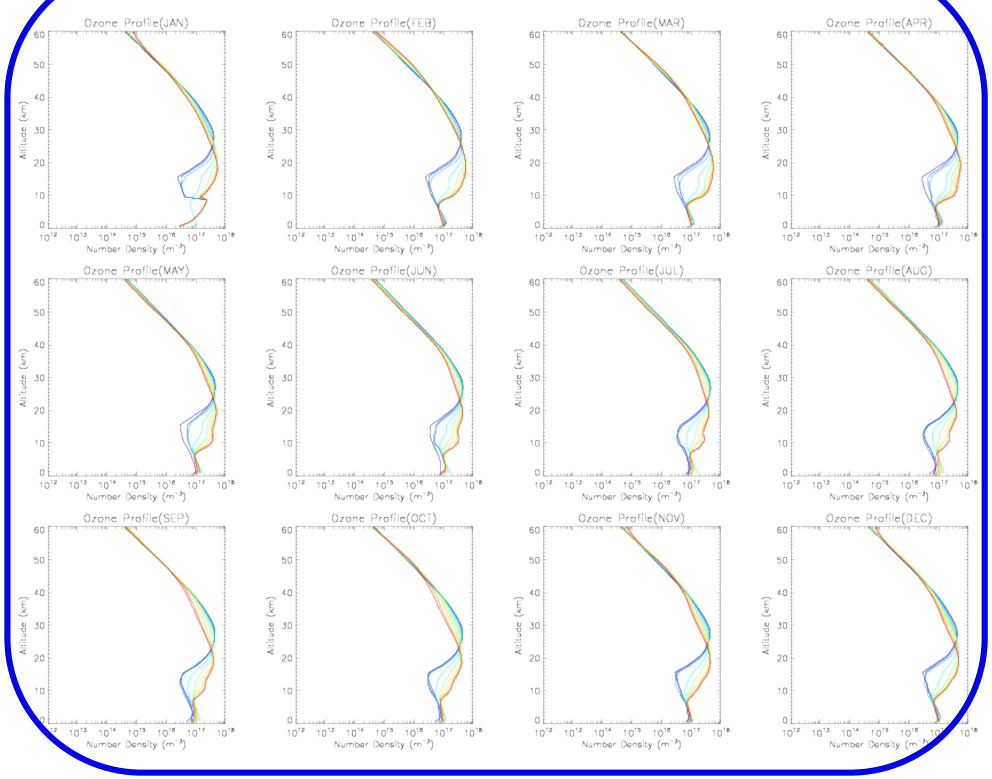
Polarization : Trace Gases



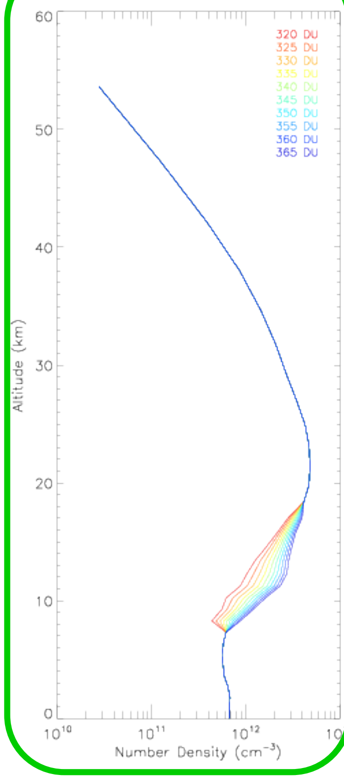
- Simulation is done for a molecular atmosphere using VLIDORT
  - **Residual of DoLP = DoLP (molec atm) – DoLP(molec atm w/o X species)**
  - $\mathbf{DoLP} = \frac{\sqrt{Q^2+U^2}}{I}$
- Trace gas influence
  - $O_3 >> O_2\text{-}O_2 > NO_2, SO_2$, HCHO
- Changes in the amount of ozone should be considered

Sensitivity : Ozone profile

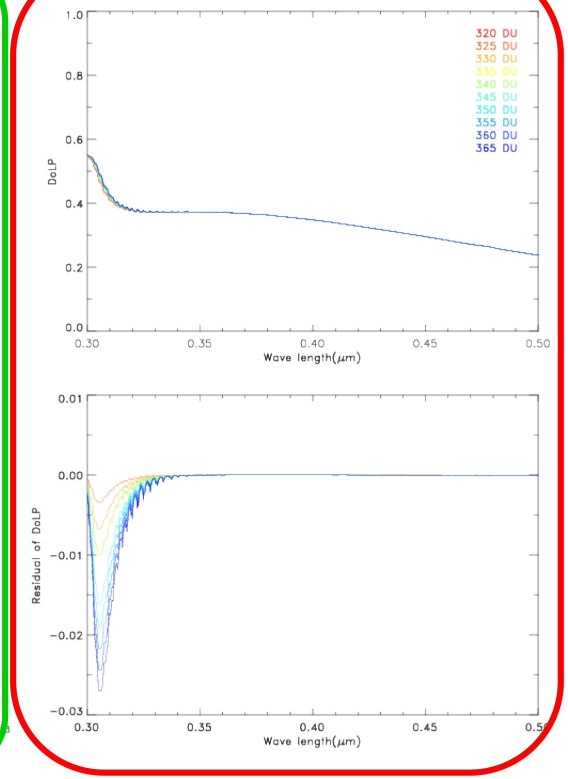
ML ozone climatology



Test Profile



DoLP result



$DoLP(320\ DU) - DoLP(X\ DU)$

- Ozone profile changes with latitude (especially, 10~20 km) and with season.
- DoLP depends on the ozone amount (and peak height).
- DoLP change is the largest around 308 nm.

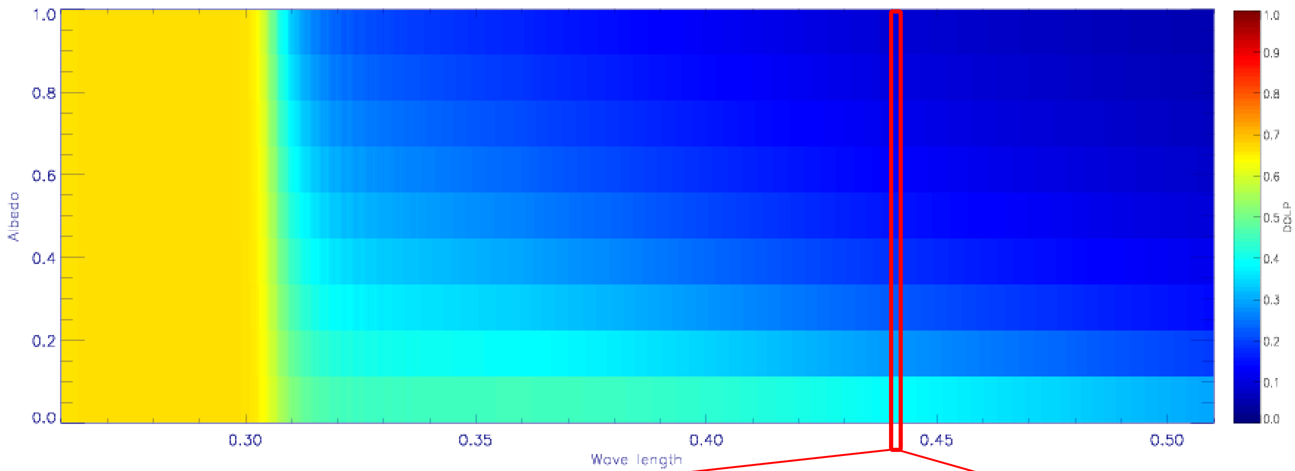
Sensitivity : Surface Reflectance

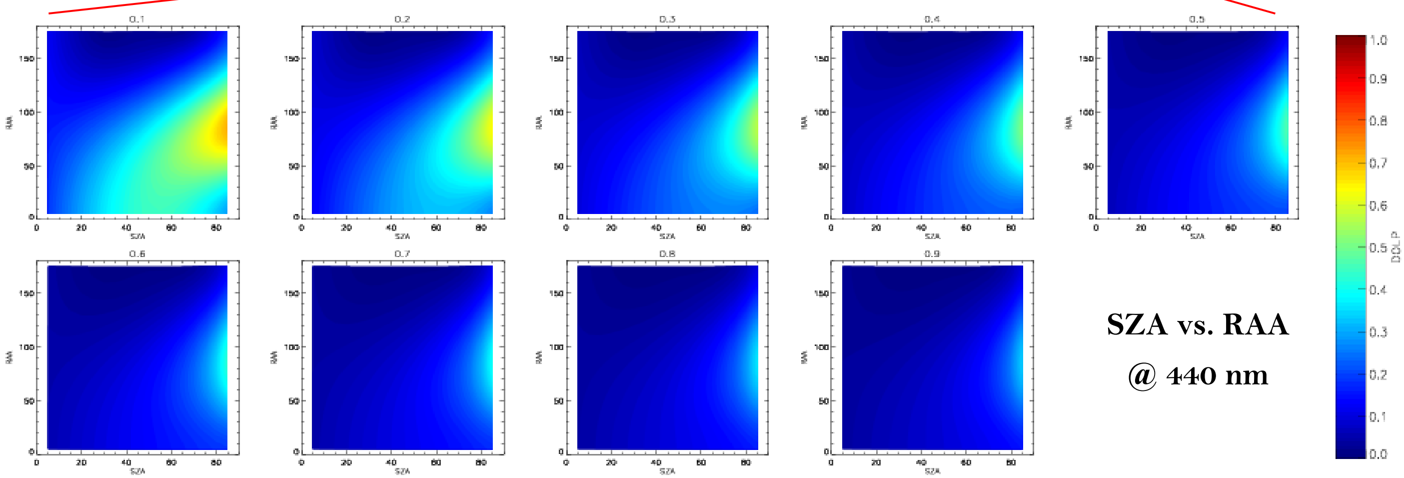
SZA : 55

VZA : 43.57

RAA : 90

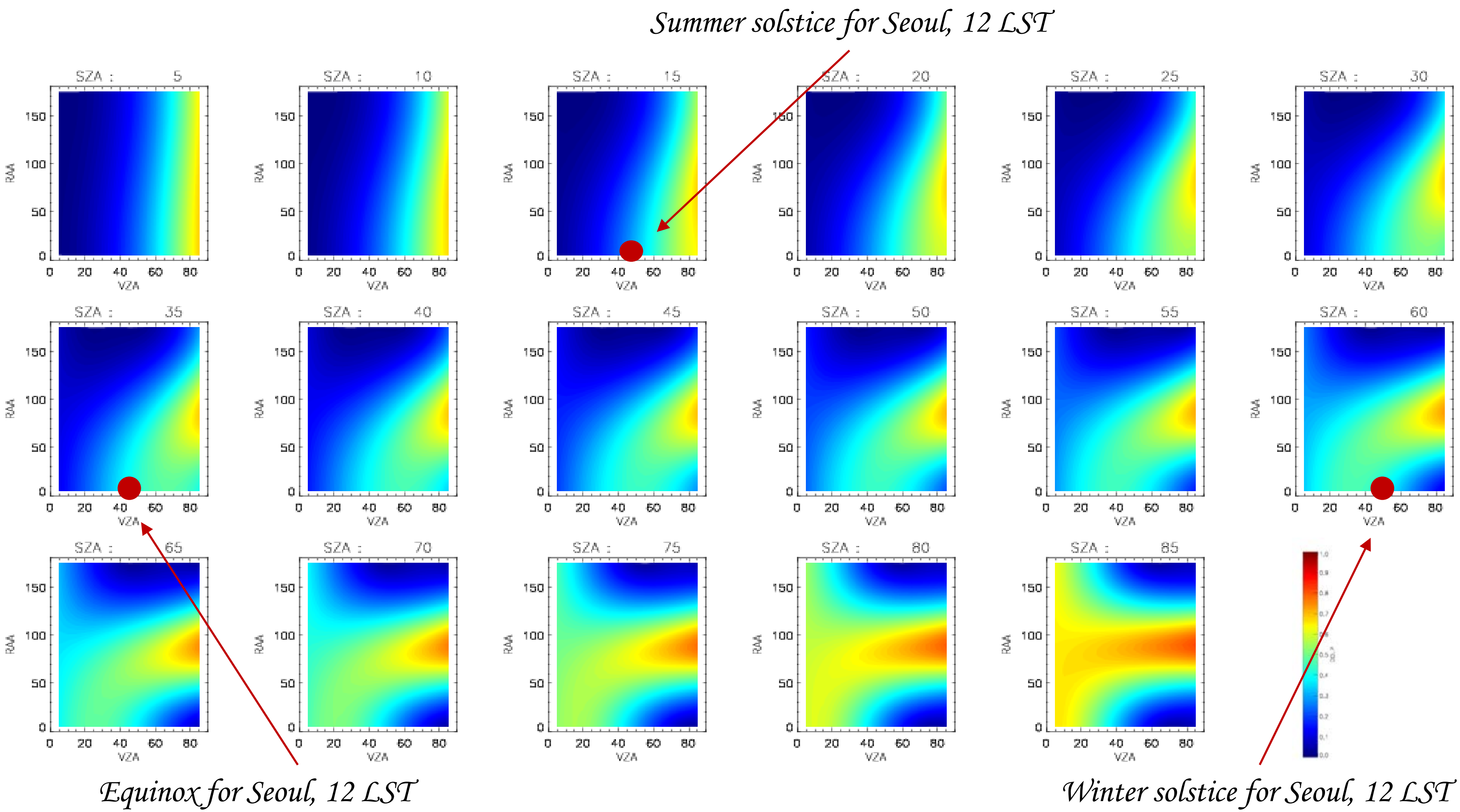
Molecular Atmosphere



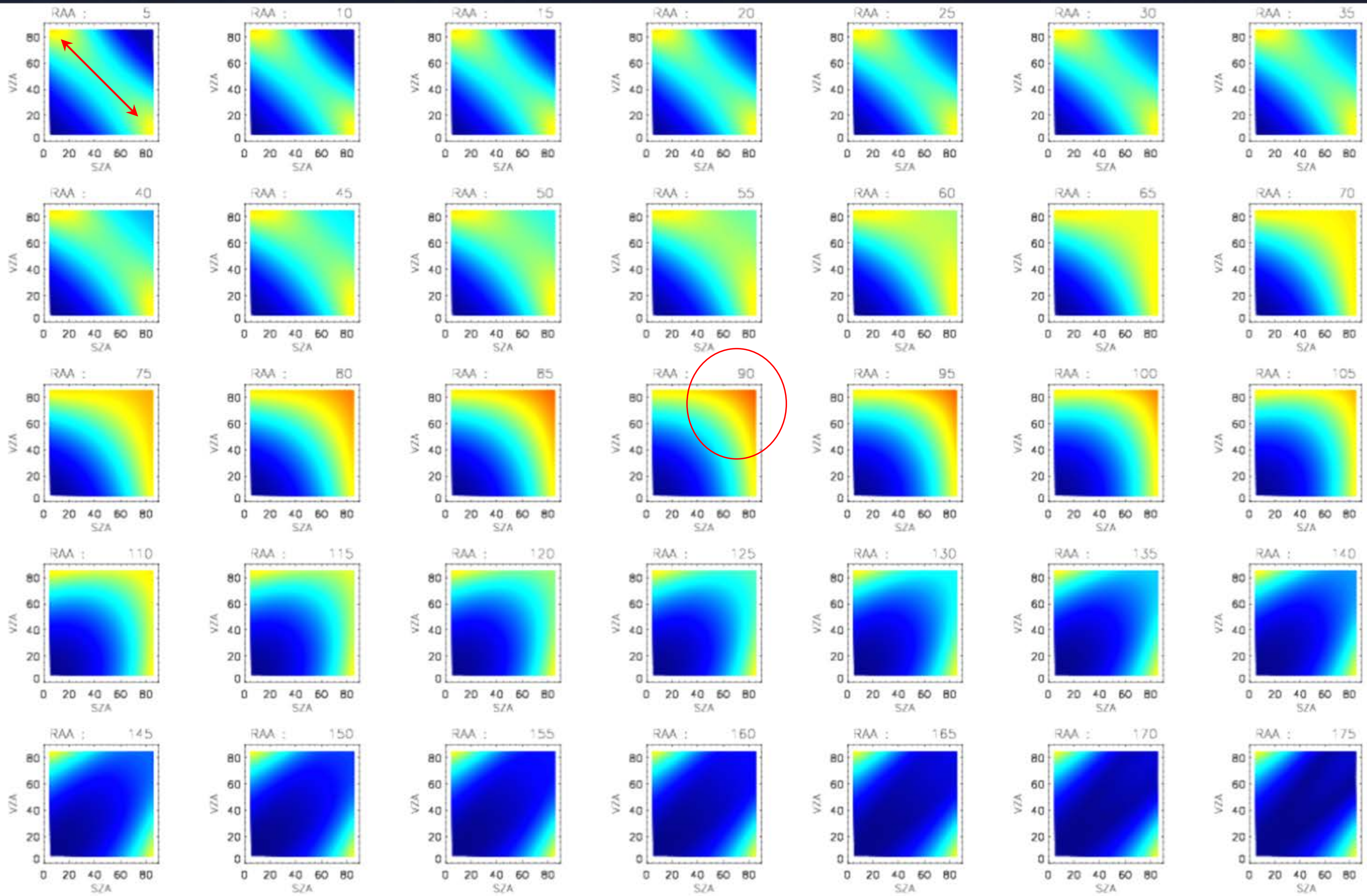


- DoLP at 440 nm for various albedo (plot on SZA vs RAA)
  - Relatively large DoLP occurs for SZA=90, RAA=90 when albedo is small

Sensitivity : Observation Geometry



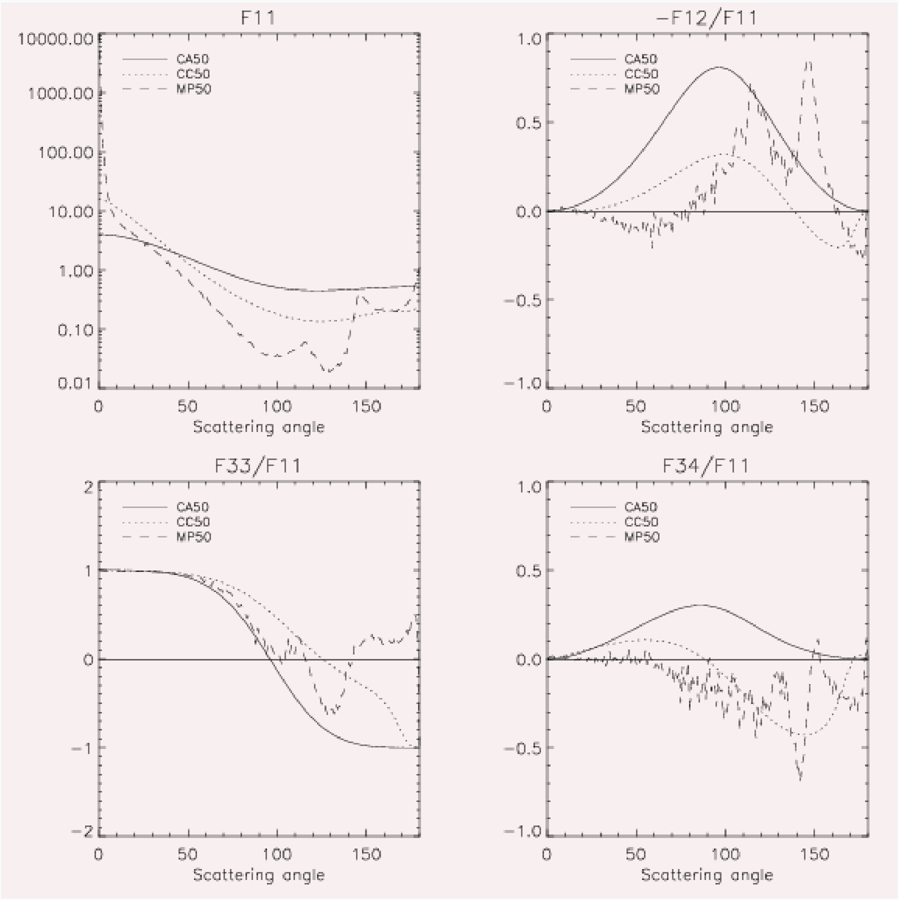
- DoLP at 440 nm as a function of SZA (plot on VZA vs RAA), with albedo=0.1
  - DoLP tends to increase with VZA at small SZA, and large DoLP occurs for VZA=90 at large SZA.

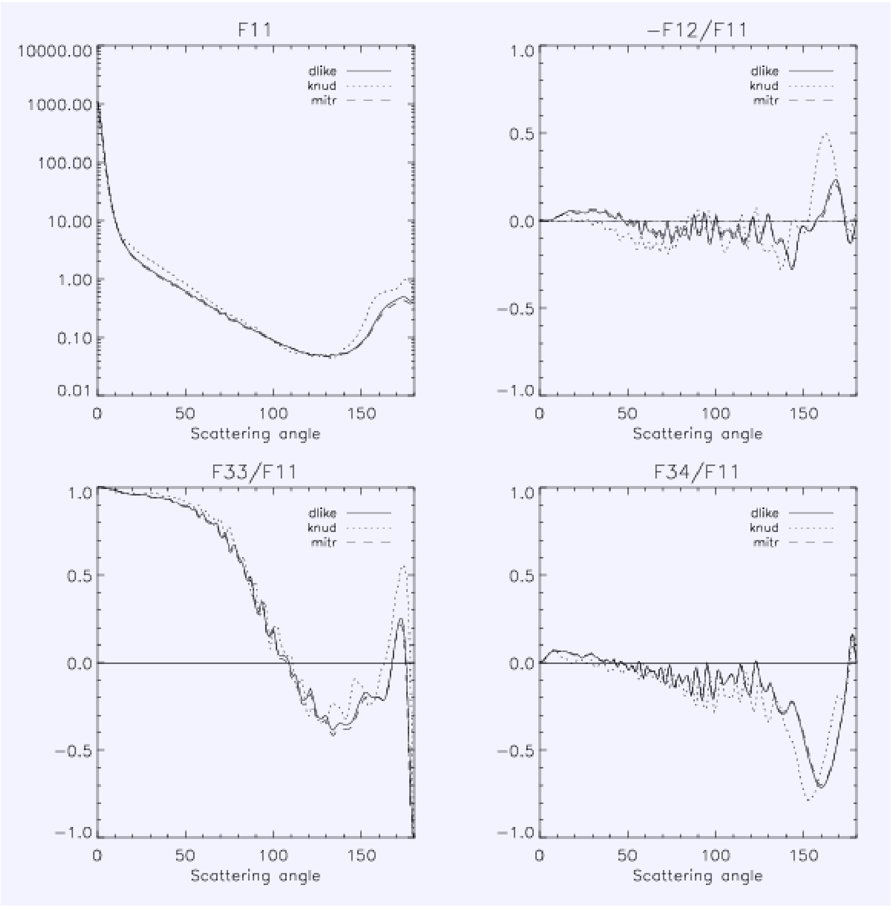


- DoLP at 440 nm for various RAA (plot on SZA vs VZA), with albedo=0.1
  - When RAA is small, large DoLP occurs ……

Phase Function of Aerosols

▣ Mixed aerosols (OPAC) and Dust aerosols

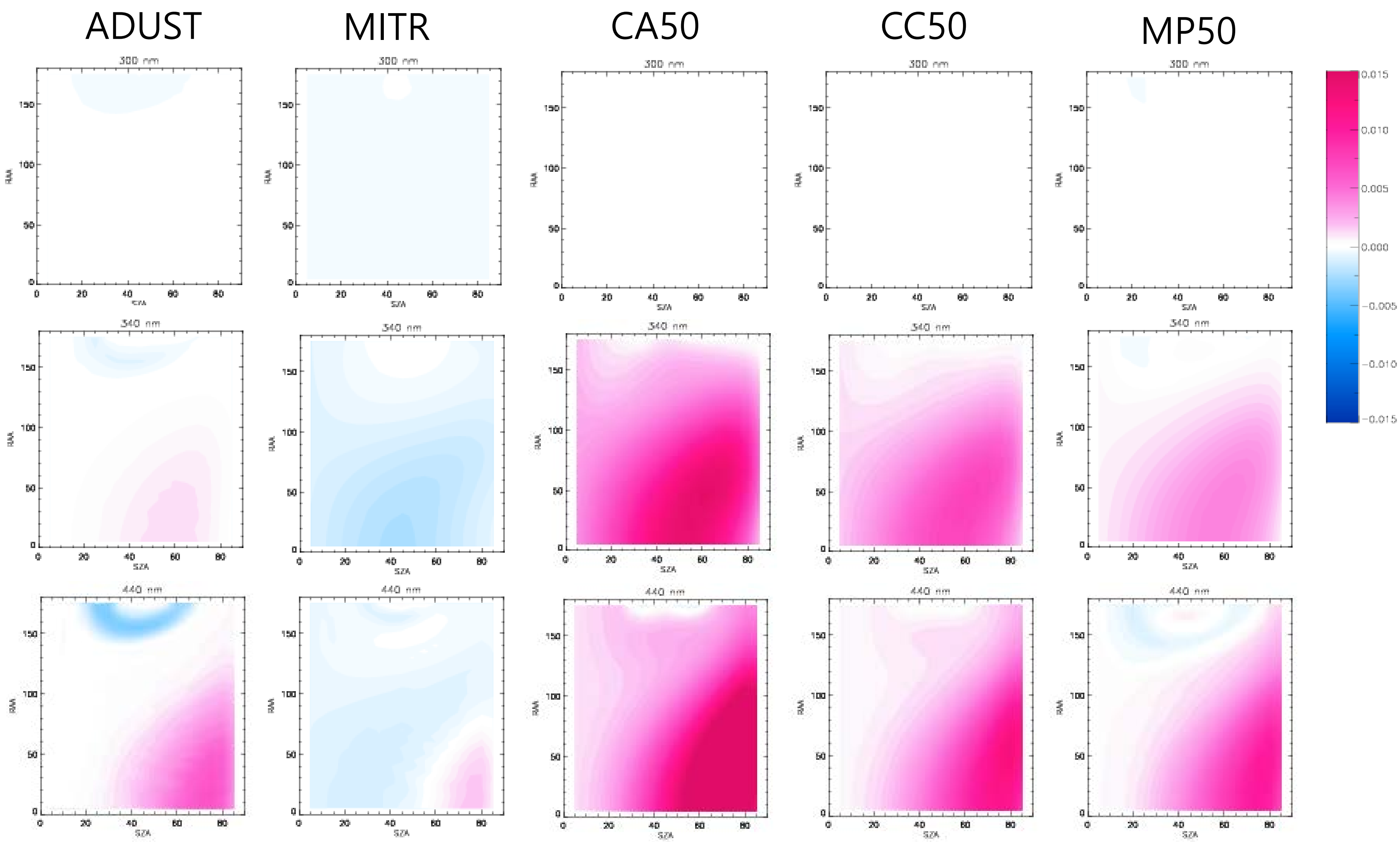




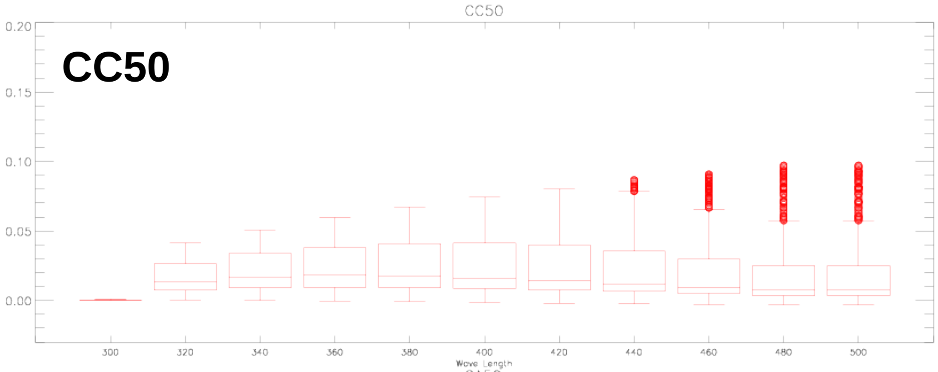
- **OPAC: CA(Continental Average), CC(Continental Clean), MP(Maritime Polluted) for RH=50%**
- **Dust: Asian Dust – knud, Saharan Dust – mitr(OPAC), dlike(dust-like)**

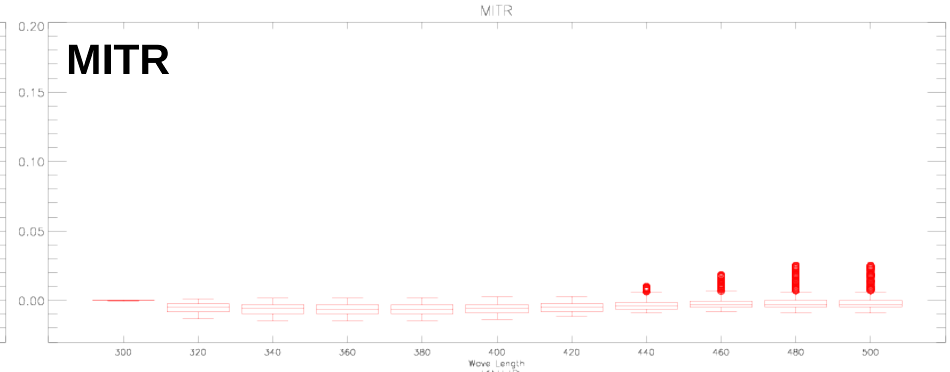
Polarization : Aerosol Type

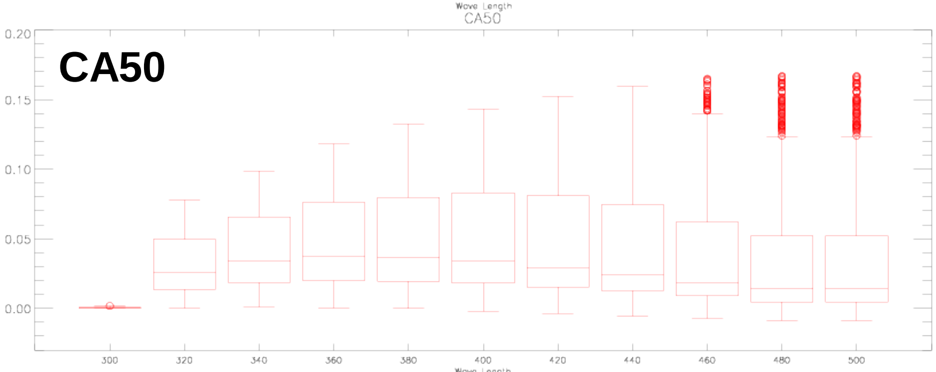
AOD : 1.0
Albedo : 0.1

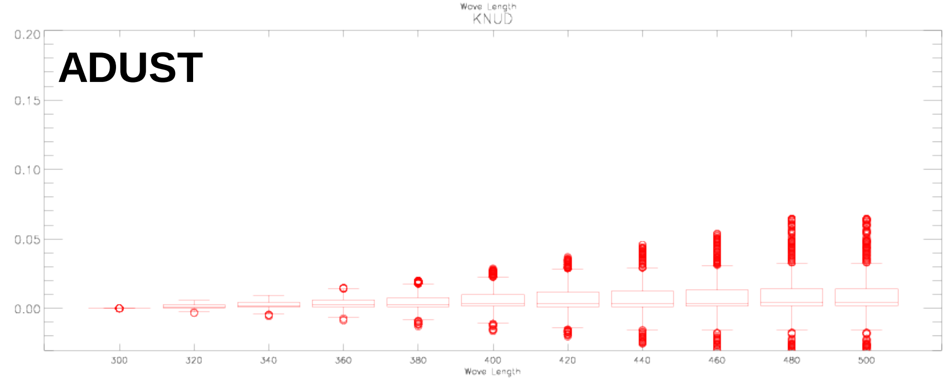


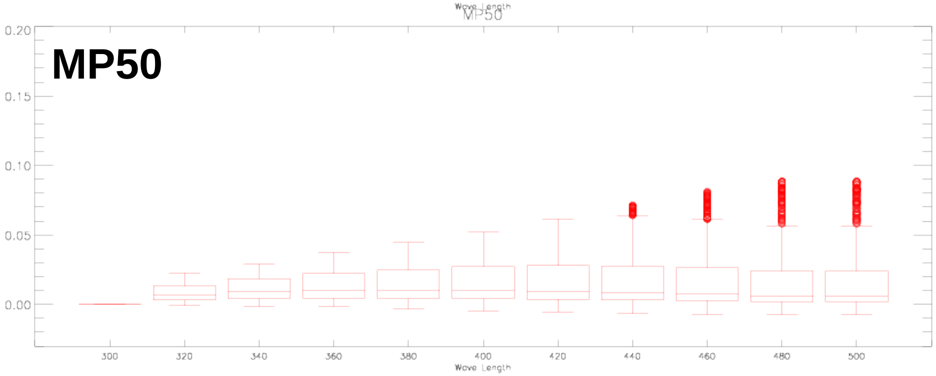
- Residual=DoLP(Molec Atmo) – DoLP(with Aerosol) for 300, 340, and 440 nm.
  - Aerosols (CA, CC, MP) tend to decrease DoLP







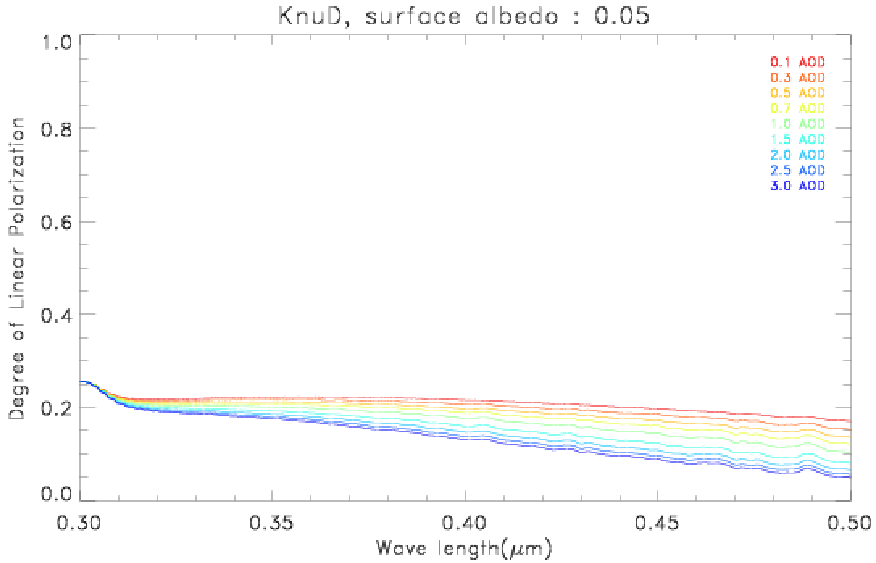




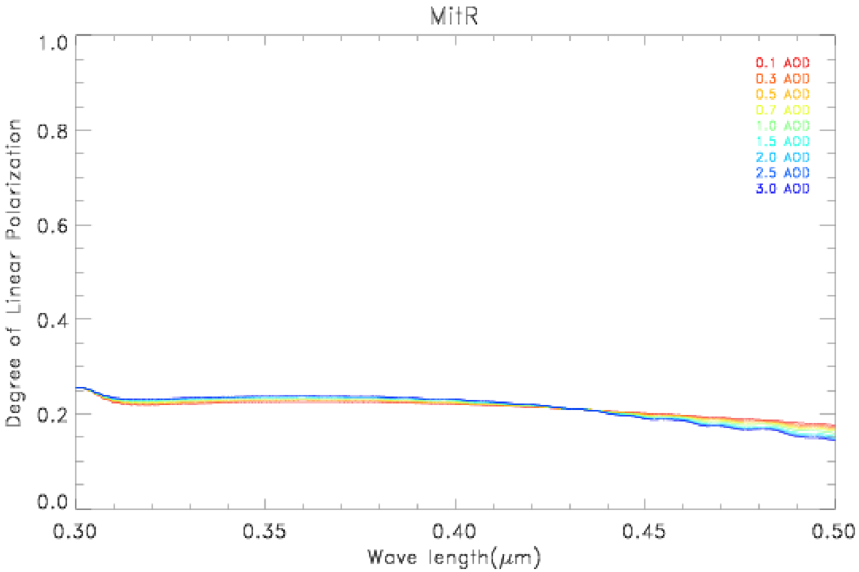
320~500	mean±std	min	max
CC50	0.022±0.021	-0.003	0.097
CA50	0.043±0.040	-0.008	0.166
MP50	0.015±0.018	-0.007	0.088
ADUST	0.006±0.012	-0.029	0.064
MITR	-0.004±0.005	-0.014	0.025

Polarization : AOD(Mineral Dust)

Asian Dust



Saharan Dust



- DoLP changes with AOD
- DoLP changes for Adust and Saharan (MitR) dusts are different

Conclusion and Future Plan

- Polarization effects were simulated using RTM for GEMS polarization correction.
- Polarization is affected by observation geometry, trace gases, surface reflectivity and ...... etc.
- The polarization due to the aerosol is different depending on the optical characteristics. On the other hands, it is less affected at shorter wavelengths.
- Additional analysis of aerosol and cloud polarization effects will be done.
- A polarization correction will be applied to improve accuracy of GEMS raw data.

Thank you ~

GEMS 측정 에너지 모의

Time(hour)	Spring Equinox		Summer Solstice		Autumn Equinox		Winter Solstice	
	μ_o†	φ_o‡	μ_o	φ_o	μ_o	φ_o	μ_o	φ_o
06	91.18	88.83	76.20	70.82	88.16	91.06	103.68	109.21
07	79.46	98.05	64.76	78.89	76.60	100.40	92.68	117.69
08	67.92	108.00	52.99	87.20	65.19	110.70	82.65	127.12
09	57.05	119.68	41.12	96.76	54.61	123.01	73.95	137.95
10	47.53	134.39	29.57	109.80	45.62	138.73	67.01	150.54
11	40.49	153.55	19.33	132.57	39.45	159.06	62.50	164.91
12	37.43	177.02	14.13	178.45	37.60	183.07	60.98	180.43
13	39.30	201.11	18.85	225.62	40.67	206.44	62.67	195.92
14	45.50	221.47	28.95	249.30	47.71	225.54	67.33	210.20
15	54.52	237.18	40.48	262.64	57.21	240.23	74.39	222.70
16	65.12	249.48	52.34	272.32	68.07	251.90	83.17	233.44
17	76.54	259.77	64.12	280.66	79.61	261.85	93.29	242.79
18	88.10	269.11	75.58	288.73	91.35	271.07	104.30	251.25

† *Solar Zenith Angle*

‡ *Solar Azimuth Angle*

Aerosol types	Components	N_i (cm^{-3})	M_i ($\mu g\ m^{-3}$)	Number mixing ratios (n_j)	Mass mixing ratios (m_j)
Continental clean	total	2600	8.8		
	water soluble	2600	5.2	1.0	0.591
	insoluble	0.15	3.6	0.577E–4	0.409
Continental average	total	15 300	24.0		
	water soluble	7000	14.0	0.458	0.583
	insoluble	0.4	9.5	0.261E–4	0.396
	soot	8300	0.5	0.542	0.021
Continental polluted	total	50 000	47.7		
	water soluble	15 700	31.4	0.314	0.658
	insoluble	0.6	14.2	0.12E–4	0.298
	soot	34 300	2.1	0.686	0.044
Urban	total	158 000	99.4		
	water soluble	28 000	56.0	0.177	0.563
	insoluble	1.5	35.6	0.949e–05	0.358
	soot	130 000	7.8	0.823	0.079
Desert	total	2300	225.8		
	water soluble	2000	4.0	0.87	0.018
	mineral (nuc.)	269.5	7.5	0.117	0.033
	mineral (acc.)	30.5	168.7	0.133E–1	0.747
	mineral (coa.)	0.142	45.6	0.617–4	0.202
Maritime clean	total	1520	42.5		
	water soluble	1500	3.0	0.987	0.071
	sea salt (acc.)	20	38.6	0.132E–1	0.908
	sea salt (coa.)	3.2E–3	0.9	0.211E–5	0.021
Maritime polluted	total	9000	47.4		
	water soluble	3800	7.6	0.422	0.160
	sea salt (acc.)	20	38.6	0.222E–2	0.814
	sea salt (coa.)	3.2E–3	0.9	0.356E–6	0.019
	soot	5180	0.3	0.576	0.006