GEMS
Polarization Correction

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Contents

Background

- Sunlight is polarized when reflected from the earth-atmosphere system.

- Radiometric response of an instrument depends on the polarization of the incoming light (Schutgens and Stammes, 2003).

- To reduce the instrument polarization sensitivity, two methods are used.

  - **Depolarization method**
    - destroys the polarization information by scrambling
    - used by TROPOMI, OMI, TOMS, SBUV

  - **Polarization characterization method**
    - characterizes instrument polarization sensitivity and atmospheric polarization
    - used by GOME, GOME-2, SCIAMACHY

Background

- Some instruments measure the state of polarization primarily for the purpose of improving their radiometric calibration.
  - GOME (Burrows et al., 1999)
  - SCIAMACHY (Bovensmann et al., 1999)
  - GOME-2 (Callies et al., 2000)

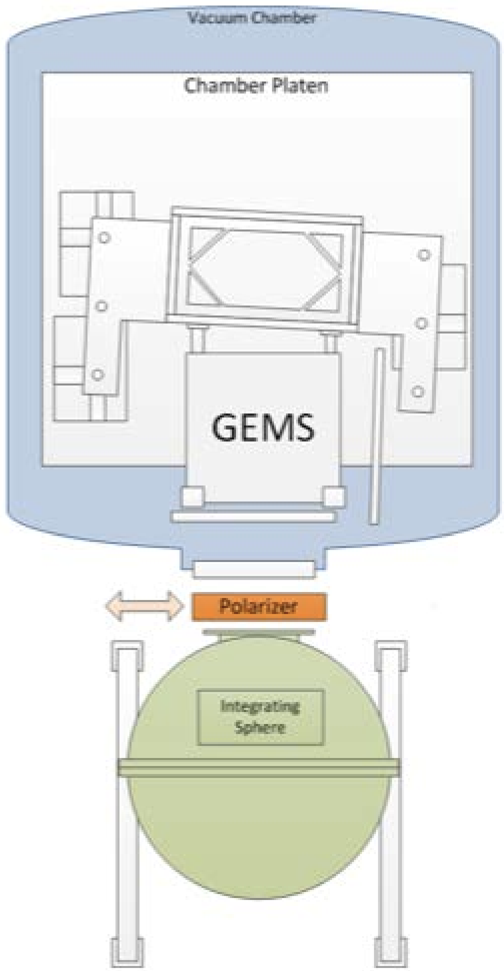
- GEMS does not have a sensor that observes polarization state.
  - GEMS will use a polarization correction algorithm based on RTM simulation results.
  - Enables a more accurate retrieval of atmospheric properties and constituents.

GEMS Polarization Ground Test

- A wire-grid polarizer is placed in the illumination path.
- The polarizer rotates from 0° to 725°. (5° interval)
- LPS (Linear Polarization Sensitivity) and PA (Polarization Axis) are derived.

$$LPS = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

- The model results (LPS ratio, from BATC) are applied to LPS and PA at the center of N/S and E/W scan mirror positions.



Calibration Test Station (CATS)

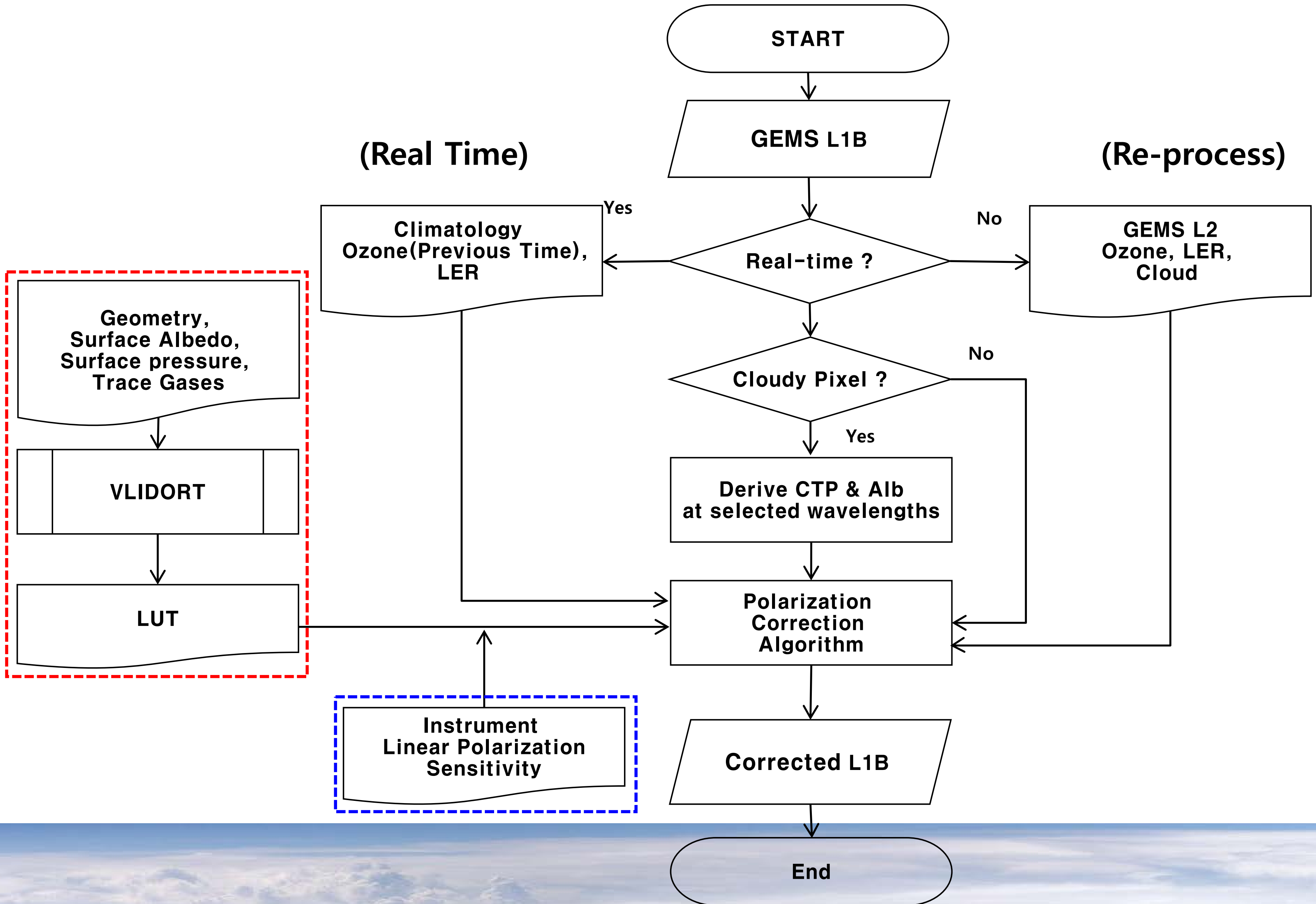
GEMS Linear Polarization Sensitivity

User Requirements

- ❖ Less than 2 %.
- ❖ No inflection point within 20 nm wavelength range.

- ❖ Considerable changes of LPS and PA were reported.
- ❖ Requirements are not satisfied in some regions.

Flow Chart



START
GEMS L1B
(Real Time)
(Re-process)
Yes
No
Climatology
Ozone(Previous Time),
LER
Real-time ?
GEMS L2
Ozone, LER,
Cloud
Geometry,
Surface Albedo,
Surface pressure,
Trace Gases
No
Cloudy Pixel ?
Yes
VLIDORT
Derive CTP & Alb
at selected wavelengths
LUT
Polarization
Correction
Algorithm
Instrument
Linear Polarization
Sensitivity
Corrected L1B
End

Polarization Correction Algorithm

▣ Polarization Correction Algorithm (Sun and Xiong, 2007)

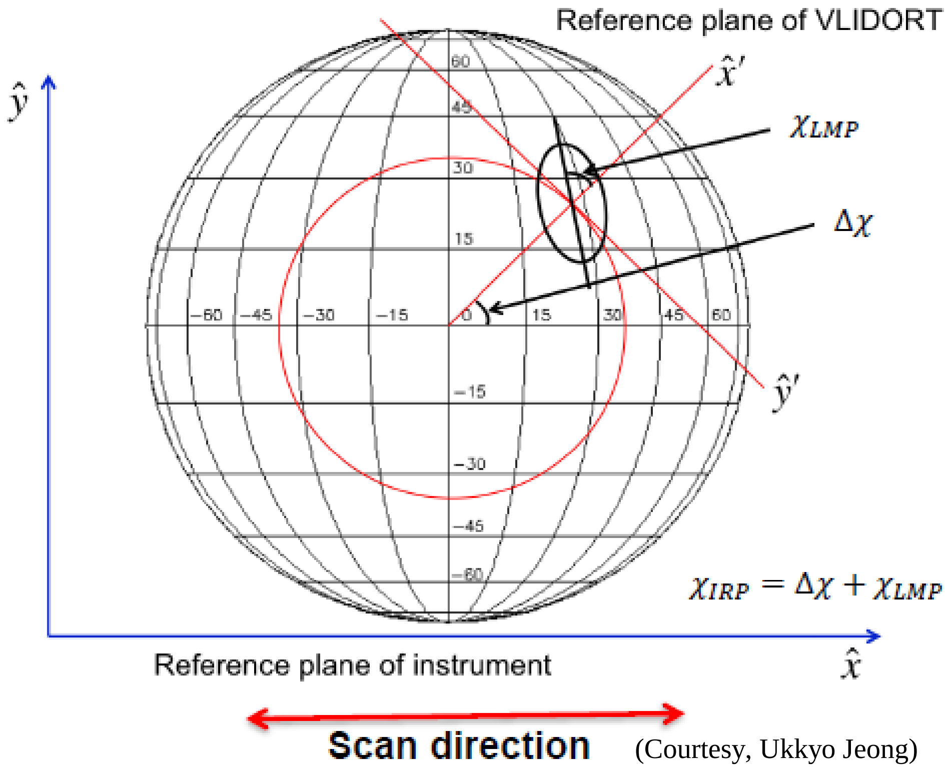
instrument　　Atmosphere

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

Polarization Correction Term

I': *GEMS L1B (Mesarused)*
h: *Transmittance (Radiometric calibration coefficient; assume to* 1)
I: *True Intensity (Corrected L1B)*
a: *Degree of (linear) polarization*
χ: *Polarization Axis*
ϕ: *Angle of polarization w.r.t. instrument reference plane*
f: *Linear Polarization Sensitivity (GEMS Polarization Factor)*

Polarization Angle



(Courtesy, Ukkyo Jeong)

$$\chi_{LMP} = \frac{1}{2} arctan\left(\frac{U}{Q}\right)$$

$$\Delta\chi = tan^{-1}\left[\frac{sin\theta}{cos\theta \sin(\Delta\phi)}\right]$$

$$\chi_{IRP} = \chi_{LMP} + \Delta\chi$$

χ_{LMP}: *Angle of polarization w.r.t. Local Meridian Plane (LMP); calculated by VLIDORT*
χ_{IRP}: *Angle of polarization w.r.t. Instrument Reference Plane (IRP)*
$\Delta\chi$: *Difference of polarization angles for IRP and LMP*
θ: *Latitude of ground location*
$\Delta\phi$: *Diffrence of Longitude between Satellite and ground location*

Look-Up Table

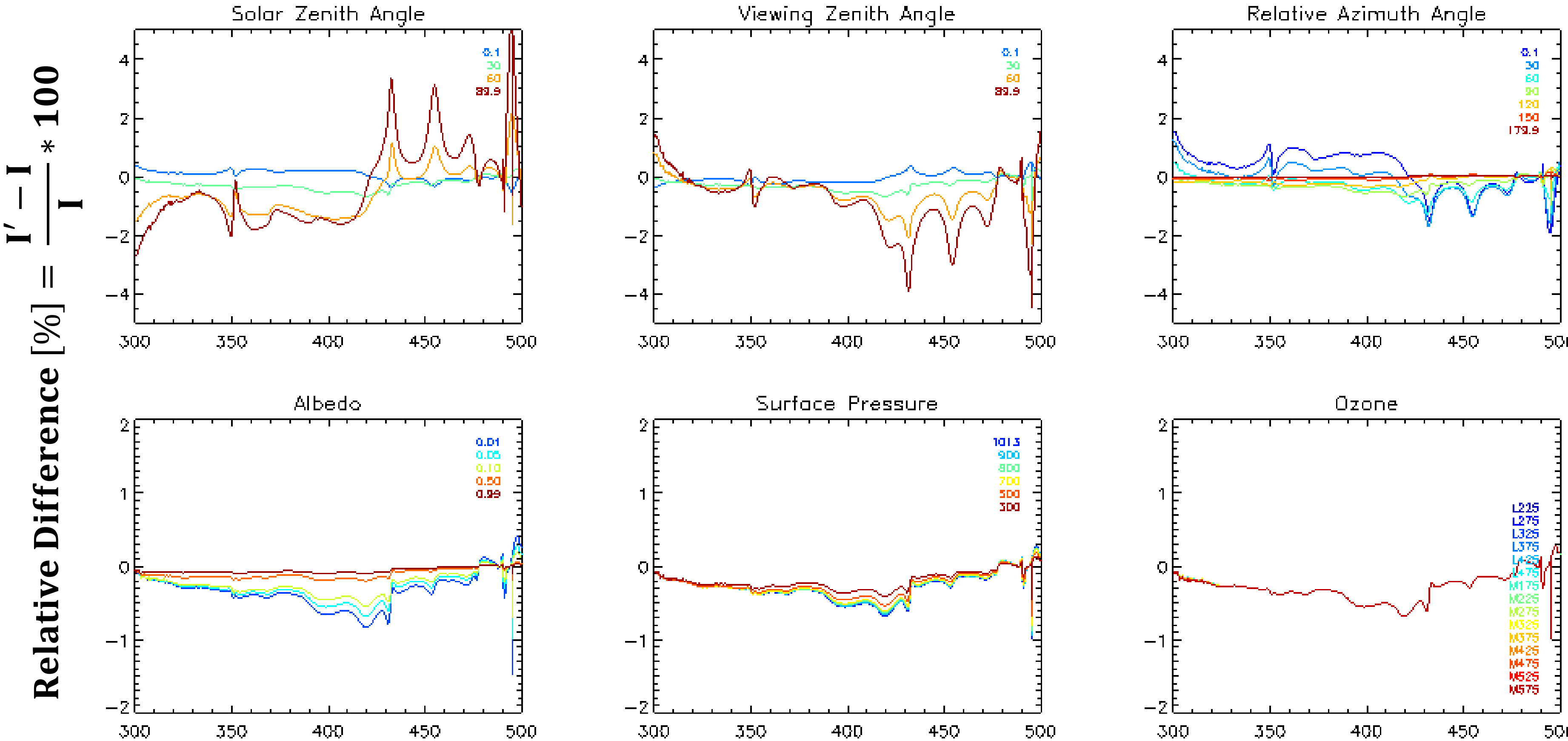
❖ Atmospheric Stokes Parameters(I, Q, U) are calculated using VLIDORT as a function of SZA, VZA, RAA, Albedo, Surface pressure, and ozone.

- US76 standard atmosphere with O_3, NO_2, SO_2, HCHO, O_2-O_2
- Ozone Profiles are based on TOMS V8 climatology
- Rayleigh scattering

Parameter	Nodes
Spectral Resolution [nm]	Δ0.2 (300 ~ 500)
SZA [degree] (10)	0.1, 10, 20, 30, 40, 50, 60, 70, 80, 89.9
VZA [degree] (10)	0.1, 10, 20, 30, 40, 50, 60, 70, 80, 89.9
RAA [degree] (11)	0.1, 5, 30, 45, 60, 90, 120, 135, 150, 175, 179.9
ALBEDO (5)	0.01, 0.05, 0.10, 0.50, 0.99
Surface pressure [hPa] (12)	1013, 900, 800, 700, 500, 300, 200
Ozone profiles [DU] (21) 0 ~ 30(L), 30 ~ 60(M)	M175,M225, M275, M325, M375, M425, M475,M525, M575 L225, L275, L325, L375, L425, L475

Red : Next Version (Updating Now !)

Polarization Error Sensitivity



Base Condition

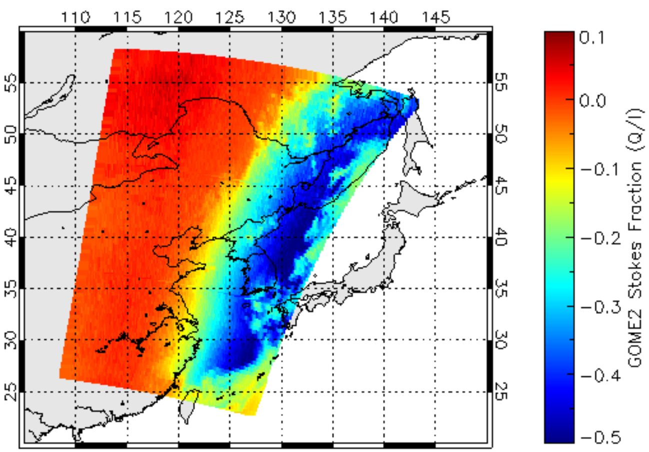
- Ozone : M325
- Alb : 0.05
- Surface Pressure : 1013 hPa
- SZA : 30
- VZA : 30
- RAA : 90

Geometry >> Alb > Surf_pres > O3

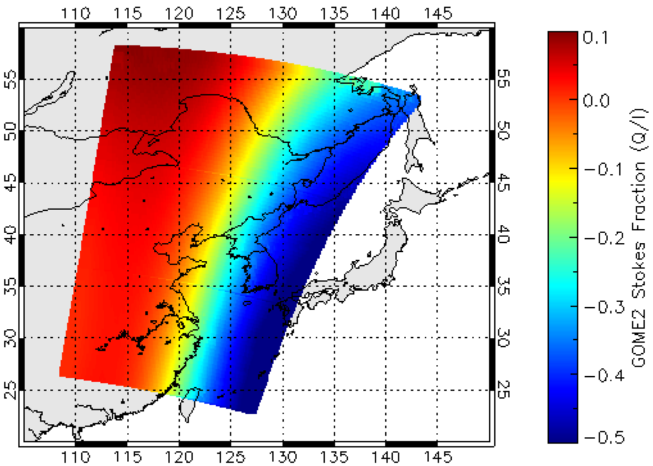
※ Without Polarization Correction, Radiance errors are up to 2 %

Verify RTM simulation (w/ GOME –2 PMD)

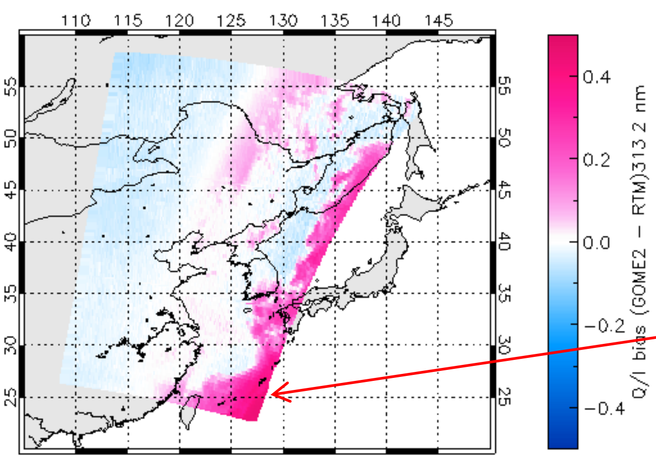
GOME-2 PMD @ 313.2 nm

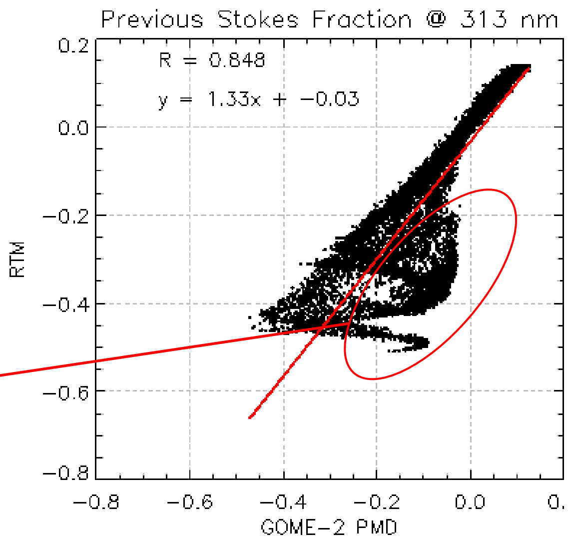


RTM results @ 313.2 nm



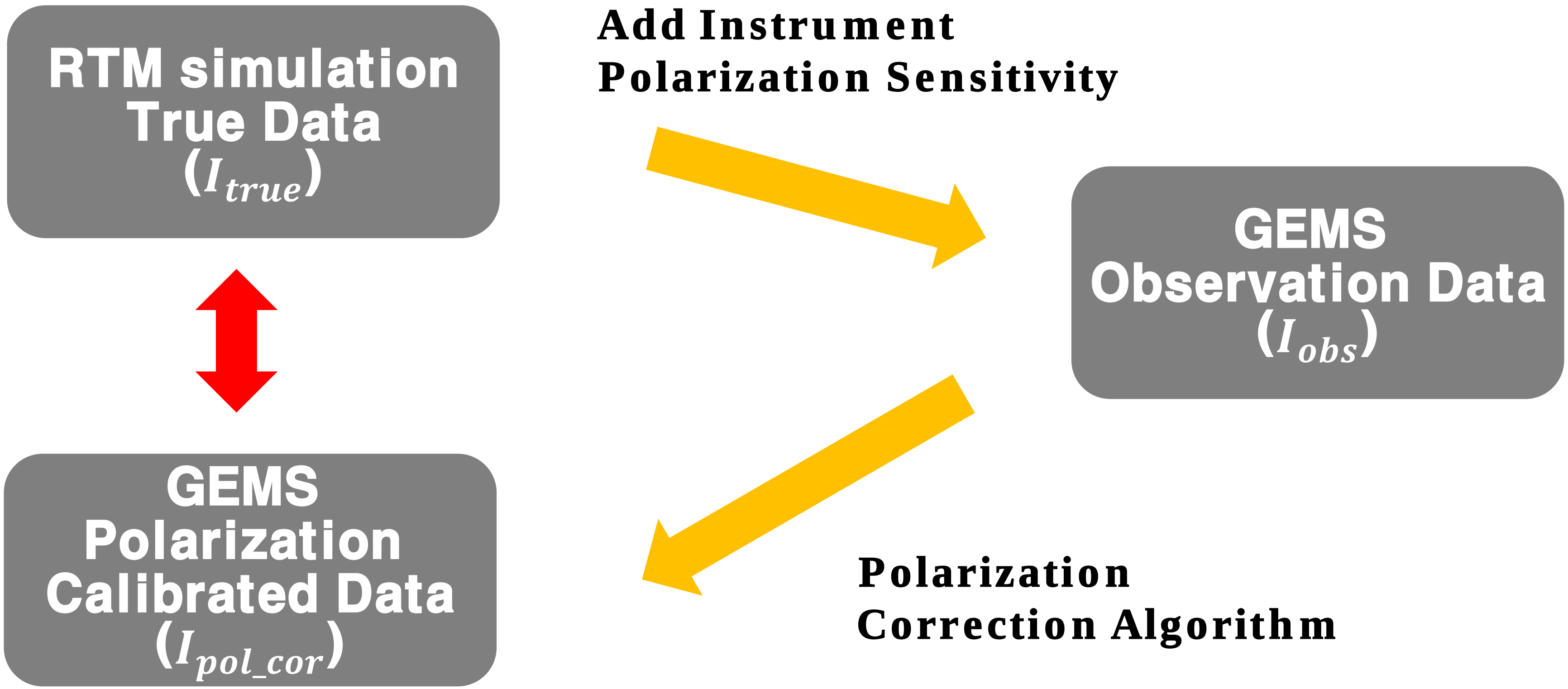
Q/I Bias (GOME2 – RTM)





- **Simulation of stokes fraction(Q/I) for Rayleigh atmosphere.**
- **Observation and RTM simulation are in good agreement.**
- **Large differences are observed in the cloud pixels.**
- **Polarization correction for clouds might reduce error.**

Test for Synthetic Data



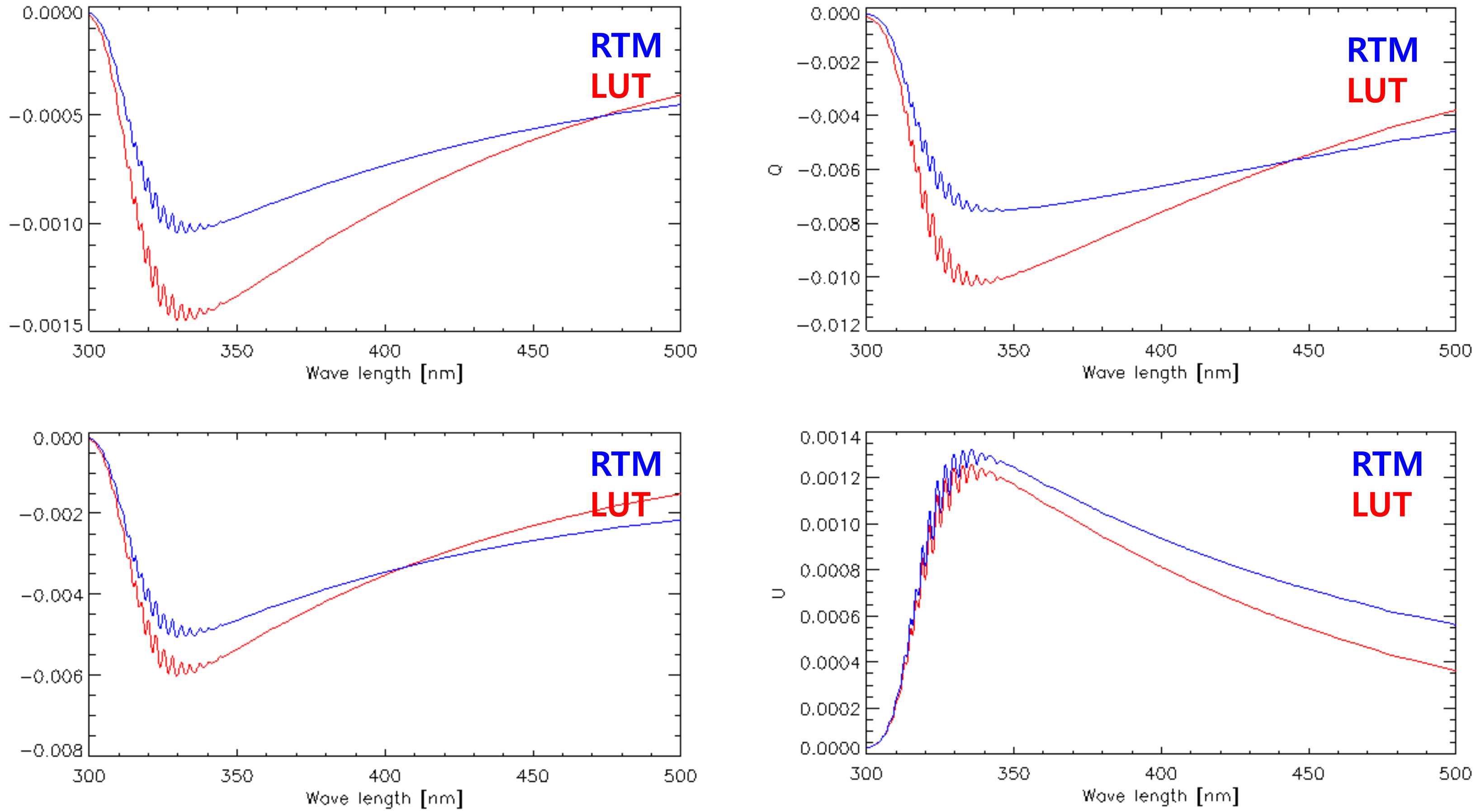
- Generated GEMS data (I_{obs}) from RTM simulation data (I_{true}) by adding the instrument polarization sensitivity.
- The GEMS polarization correction algorithm using LUT was applied to get corrected radiance (I_{pol_cor}).

Comparison of RTM and LUT

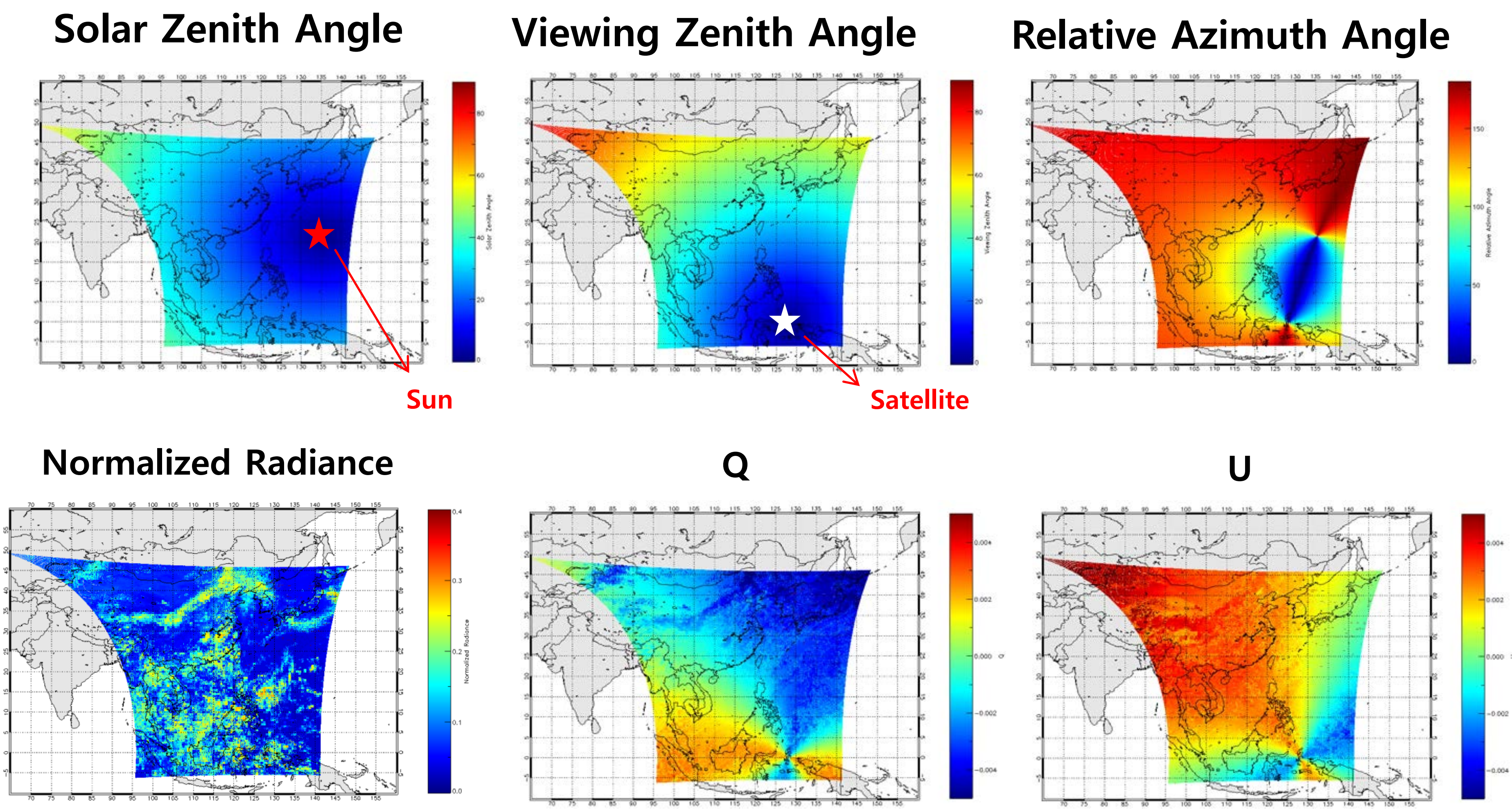
N/S pixel = 500 | N/S pixel = 2000

Q

U

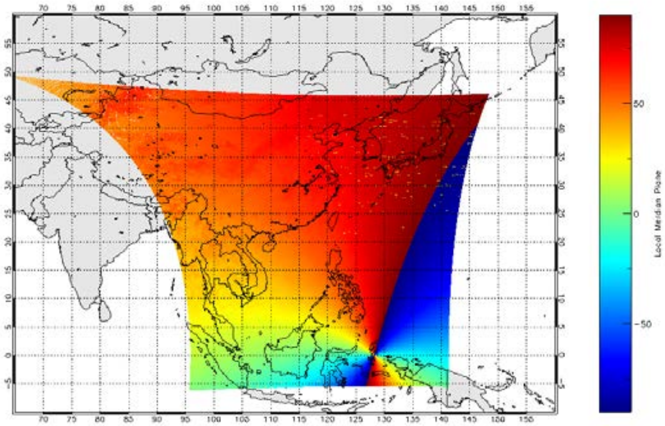


Synthetic Data Test (20130715 03UTC)

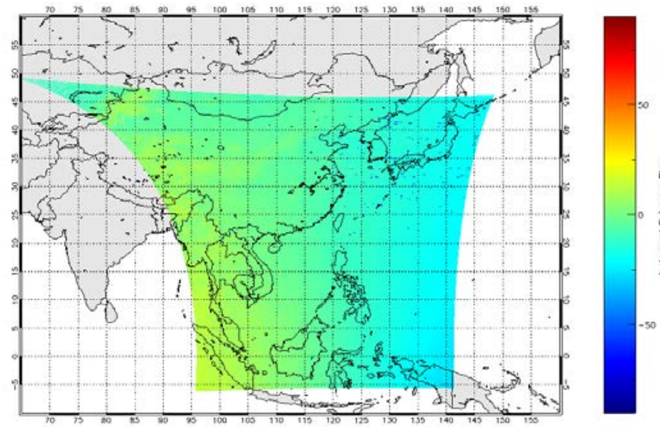


Synthetic Data Test (20130715 03UTC)

Polarization Angle (χ_{LMP})
Local Meridian Plane

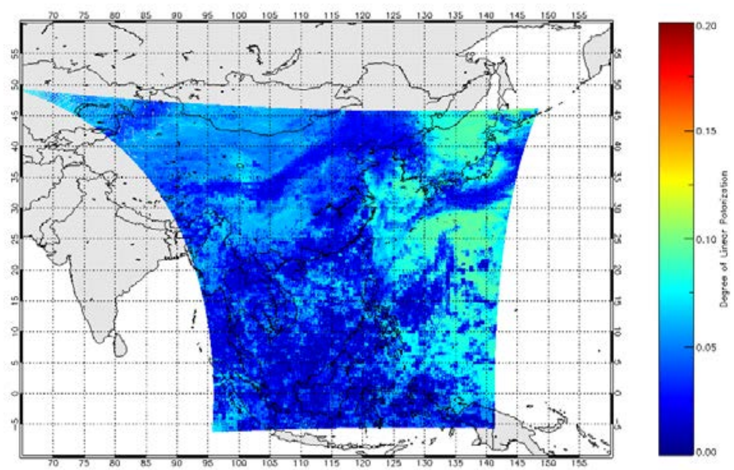


Polarization Angle (χ_{IRP})
Instrument Reference Plane



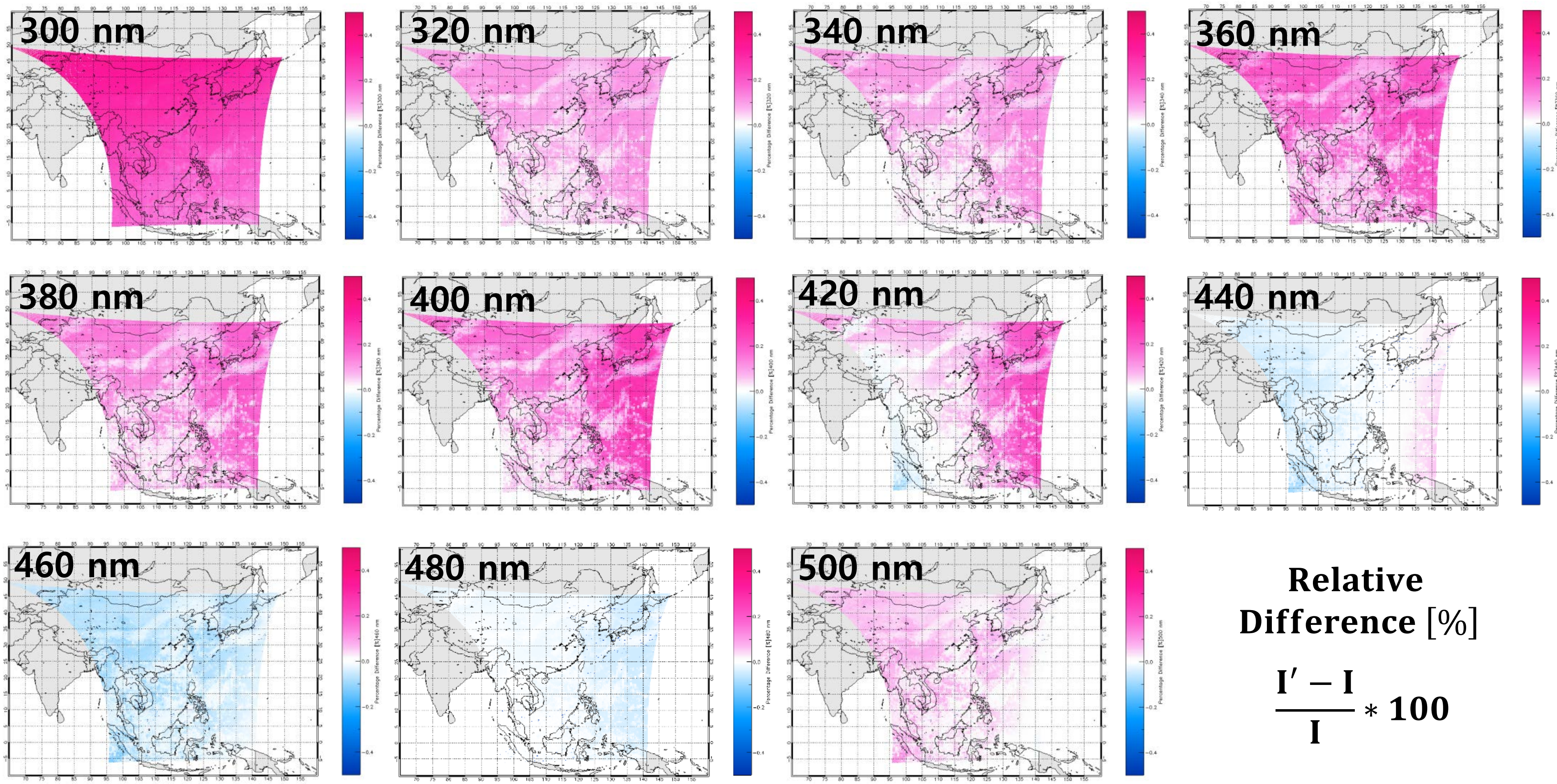
$$\chi_{LMP} = \frac{1}{2} arctan\left(\frac{U}{Q}\right)$$

Degree of Linear Polarization (a)



$$\chi_{IRP} = \chi_{LMP} + \Delta\chi$$

Synthetic Data Test (20130715 03UTC)



Relative Difference [%]

$$\frac{I' - I}{I} * 100$$

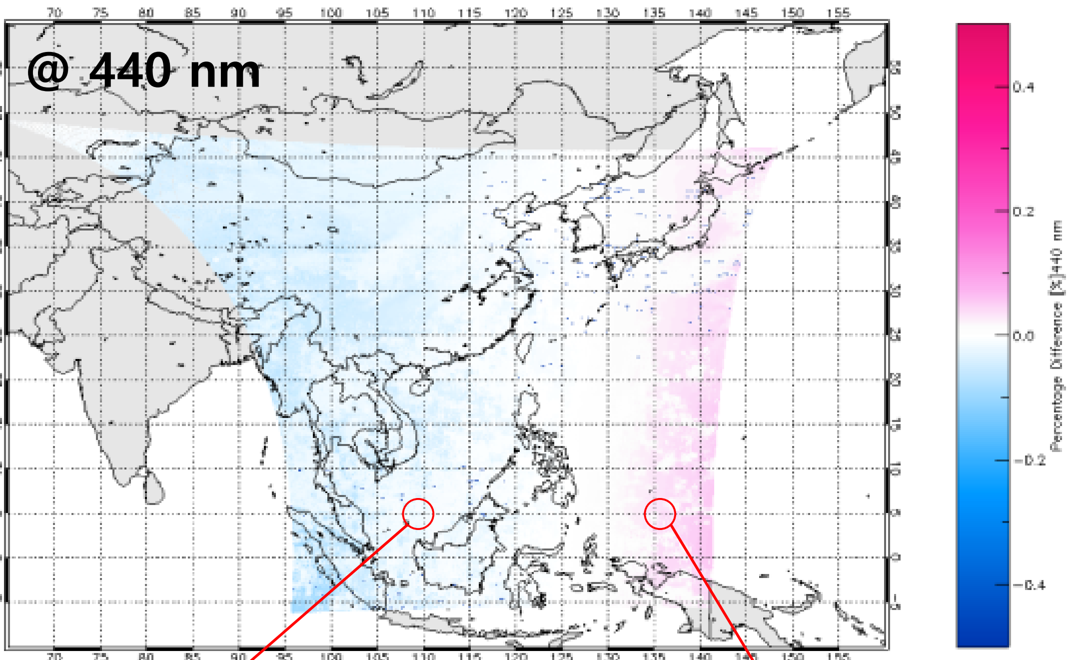
❖ The relative difference between I and I′ depends on the observation geometry (SZA, VZA, RAA) and wavelength.

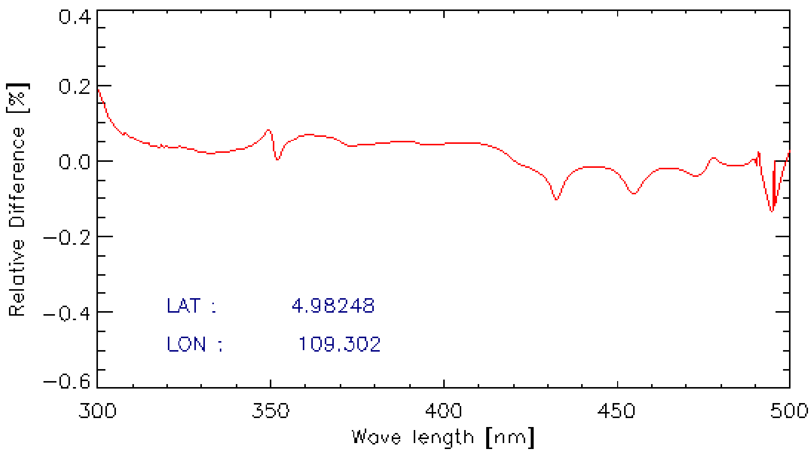
Synthetic Data Test (20130715 03UTC)

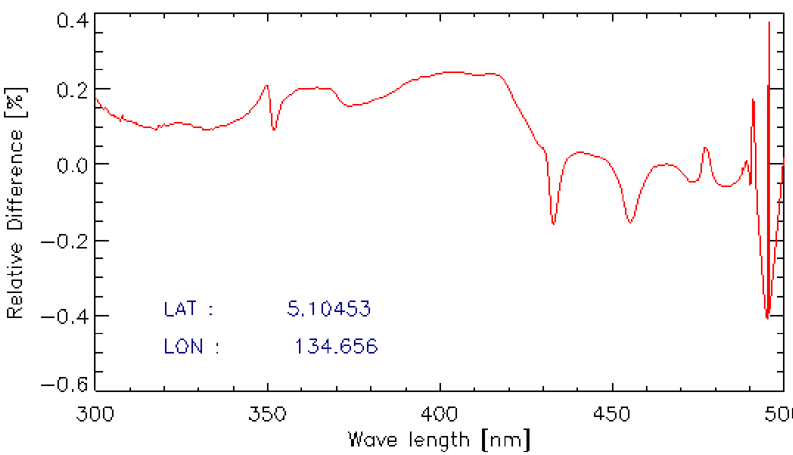
Relative Difference [%]

$$\frac{\mathbf{I'} - \mathbf{I}}{\mathbf{I}} * 100$$

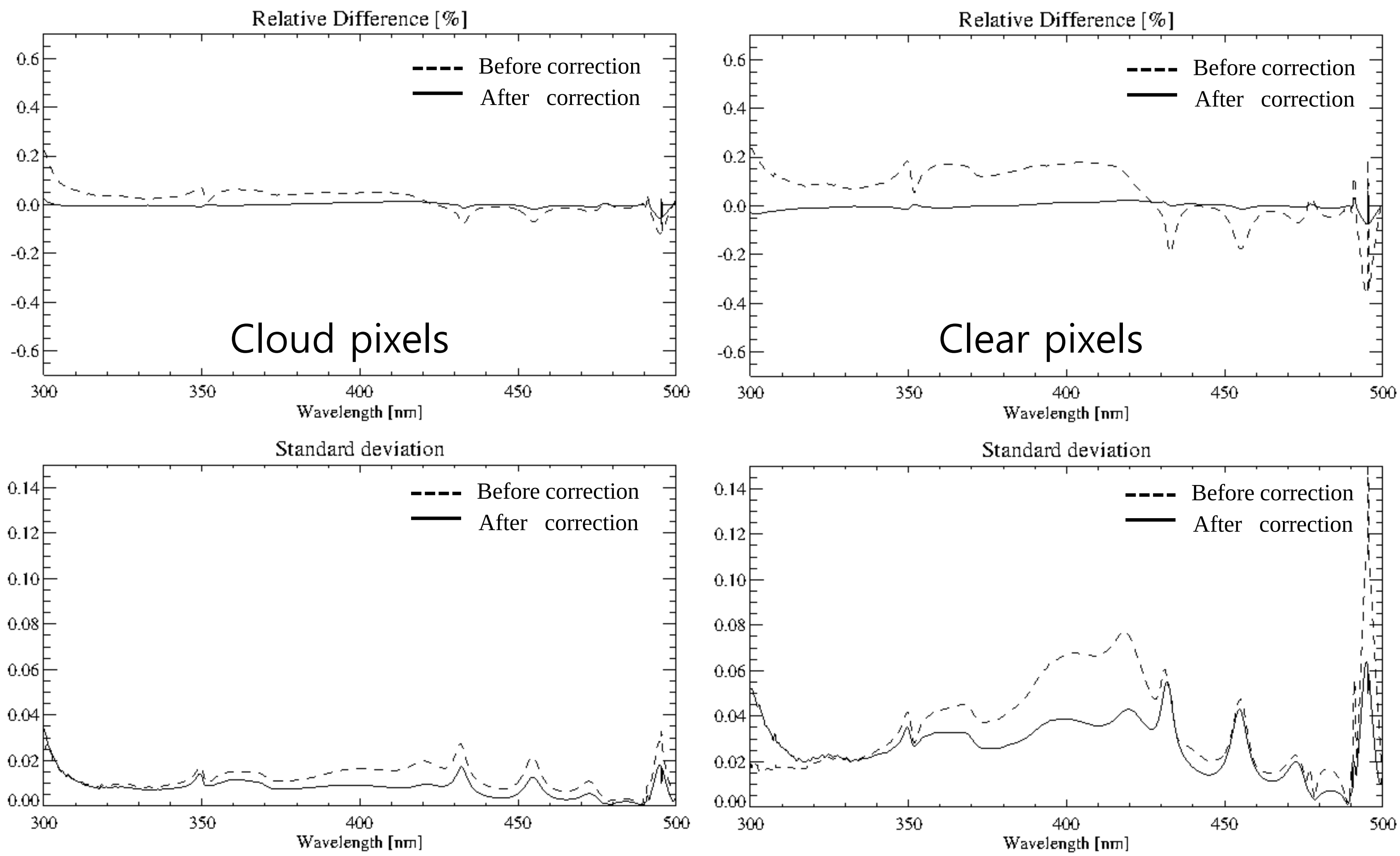
- **The shape of the relative difference depends on the LPS and PA as well as SZA, VZA, … etc.**
- **In these pixels, the relative difference is up to 0.4 %.**







Effects of Polarization Correction



Before : $(I_{obs} - I_{true}) / I_{true}$

After : $(I_{pol\_cor} - I_{true}) / I_{true}$

IOT and Future Plan

- **Verification of Polarization Correction during IOT**
  - Comparison of GEMS data with RTM simulation for target scenes with known meteorological and chemical field

    (e.g. clear, desert, ocean and opaque convection cloud)
  - Inter-comparison with other satellites

    (e.g. TROPOMI, Sentinel-5 and etc.)

- **Optimization of algorithm (Accuracy and Speed)**
  - Improve Look-Up Tables
  - Correction for cloud scenes

Conclusion

- Polarization characteristics of atmosphere were pre-simulated using RTM for GEMS polarization correction.

- Polarization error depends on the observation geometry, trace gases, surface information, and etc.

- Improve accuracy of GEMS L1B data through polarization correction, incorporating instrument polarization characteristics.

- During the IOT period, we will evaluate and optimize the polarization correction algorithm.

Thank you ~