

# **Deriving Polarization Properties of Desert-Reflected Solar Spectra with PARASOL Data**

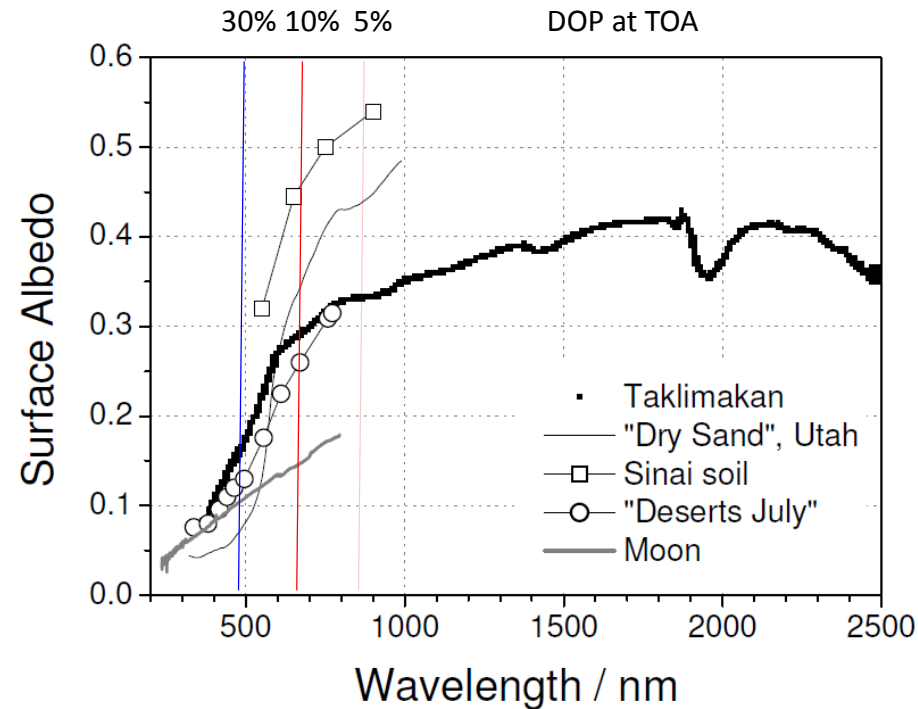
Wenbo Sun, Rosemary R. Baize, and Constantine Lukashin

## **Introduction**

1. Reflected solar radiation from desert is strongly polarized by sand particles.
2. To date, there is no reliable desert surface reflection model to calculate desert reflection matrix.
3. In this study, the PARASOL data are used to retrieve physical properties of desert. These physical properties are then used in the ADRTM to calculate polarization of desert-reflected light for the whole solar spectra.

# Why modeling polarized RS from desert?

- Sunlight is strongly polarized by desert surface
- Desert polarization to solar radiation is a strong function of wavelength
- Empirical PDMs from PARASOL data can be obtained only at 3 wavelengths, cannot be applied to whole solar spectrum



## Theory for modeling polarized RS from land surface

$$R(\theta_s, \theta_v, \varphi) = fR_L + (1 - f) \frac{\pi \rho_{\text{specular}}(n)}{4 \cos^4 \beta \cos \theta_s \cos \theta_v} P(Z_x, Z_y)$$

$$P(Z_x, Z_y) = \frac{1}{\pi \sigma^2} \exp\left(-\frac{Z_x^2 + Z_y^2}{\sigma^2}\right)$$

$$\tan \beta = \sqrt{Z_x^2 + Z_y^2}$$

$$Z_x = \frac{\sin \theta_v \cos \varphi - \sin \theta_s}{\cos \theta_v + \cos \theta_s}$$

$$Z_y = \frac{\sin \theta_v \sin \varphi}{\cos \theta_v + \cos \theta_s}$$

Once we know  $f$   $n$   $R_L$   $\sigma$ , we can calculate land surface reflection matrix elements.

## Physical surface model of desert

$1-f = 5\%$  quartz-rich polarizer with facets



$f = 95\%$  Lambert non-polarizer



+

$$\sigma = 0.164$$

# Refractive index of quartz

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VOLUME 55, NUMBER 10

OCTOBER 1965

## Interspecimen Comparison of the Refractive Index of Fused Silica\*†

I. H. MALITSON

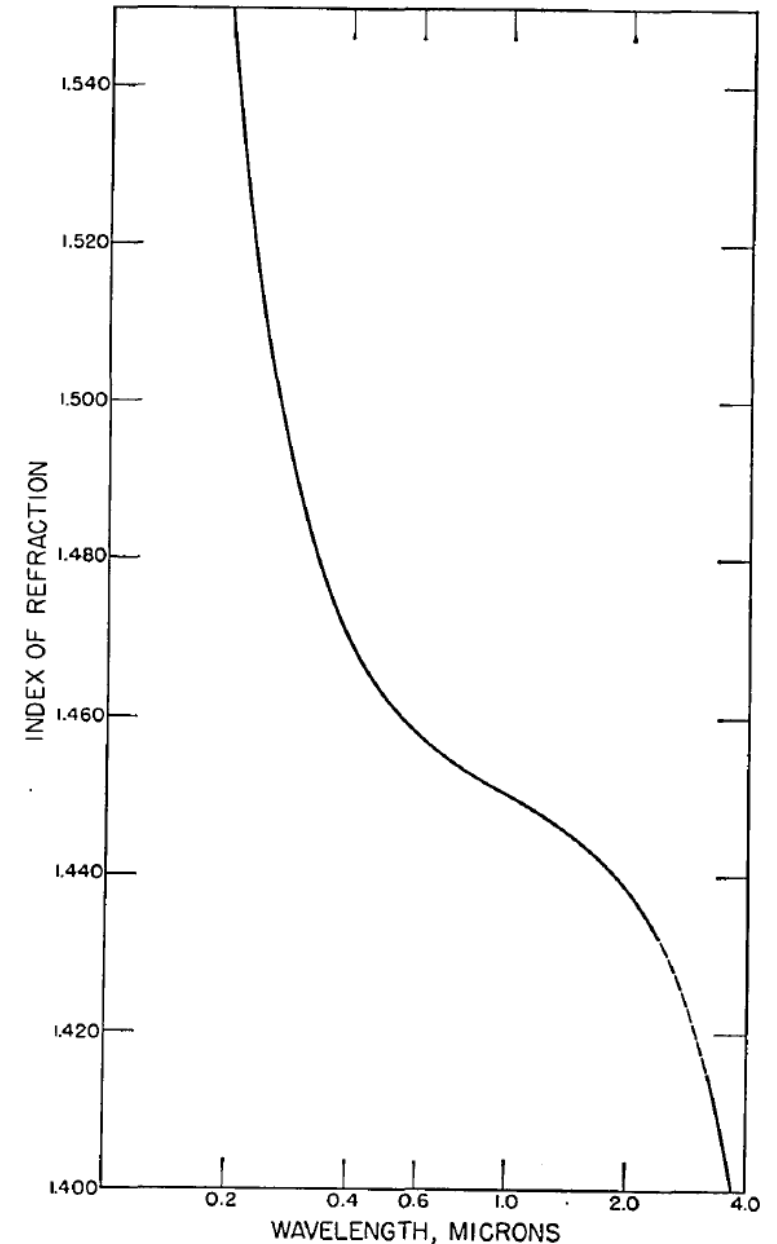
*National Bureau of Standards, Washington, D. C. 20234*

(Received 14 May 1965)

The index of refraction of optical quality fused silica ( $\text{SiO}_2$ ) was determined for 60 wavelengths from 0.21 to  $3.71\ \mu$  at  $20^\circ\text{C}$ . The dispersion equation

$$n^2 - 1 = \frac{0.6961663\lambda^2}{\lambda^2 - (0.0684043)^2} + \frac{0.4079426\lambda^2}{\lambda^2 - (0.1162414)^2} + \frac{0.8974794\lambda^2}{\lambda^2 - (9.896161)^2},$$

where  $\lambda$  is expressed in microns was found to yield an absolute residual of  $10.5 \times 10^{-6}$ . The variation in index between 12 specimens was determined. Dispersive properties of the material and thermal coefficient of index are graphically presented. A comparison with previous NBS index data is discussed.

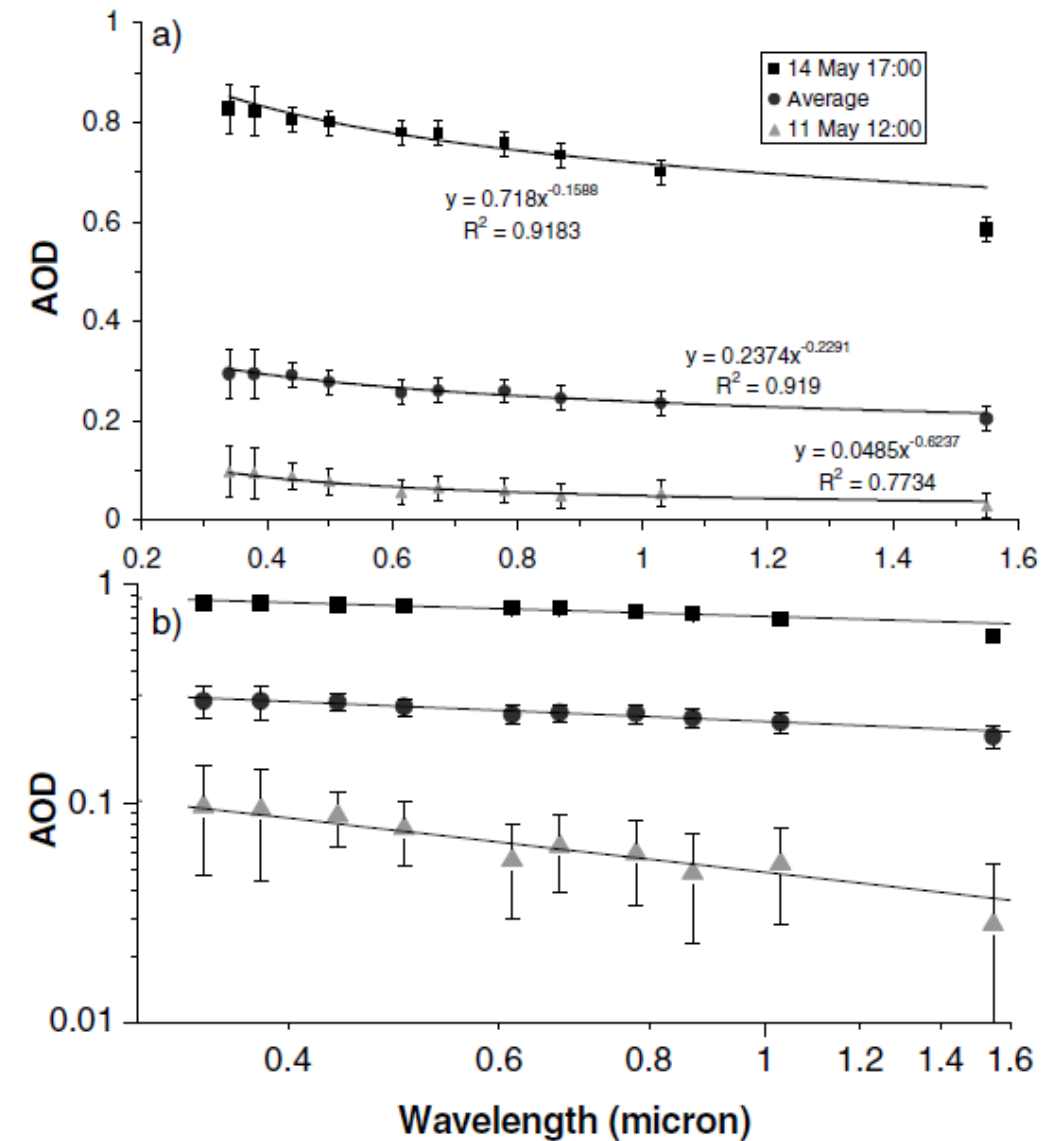
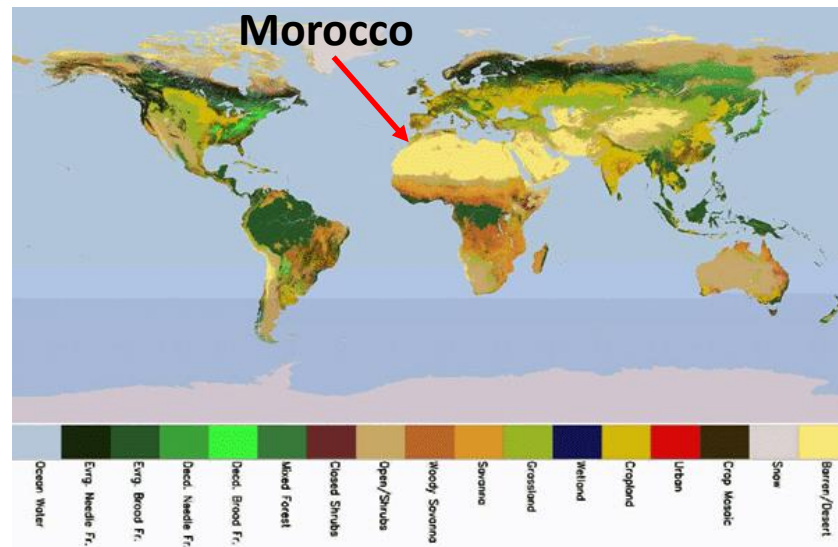


# Desert dust AOD

## Spectral aerosol optical depth characterization of desert dust during SAMUM 2006

By C. TOLEDANO<sup>1\*</sup>, M. WIEGNER<sup>1</sup>, M. GARHAMMER<sup>1</sup>, M. SEEFELDNER<sup>1</sup>,  
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(Manuscript received 28 December 2007; in final form 1 August 2008)



*Fig. 4.* (a) Wavelength dependence of the aerosol optical depth for average conditions (circles), severe dust (squares) and background conditions (triangles); (b) Same in log–log scale.

# Desert spectral reflectance

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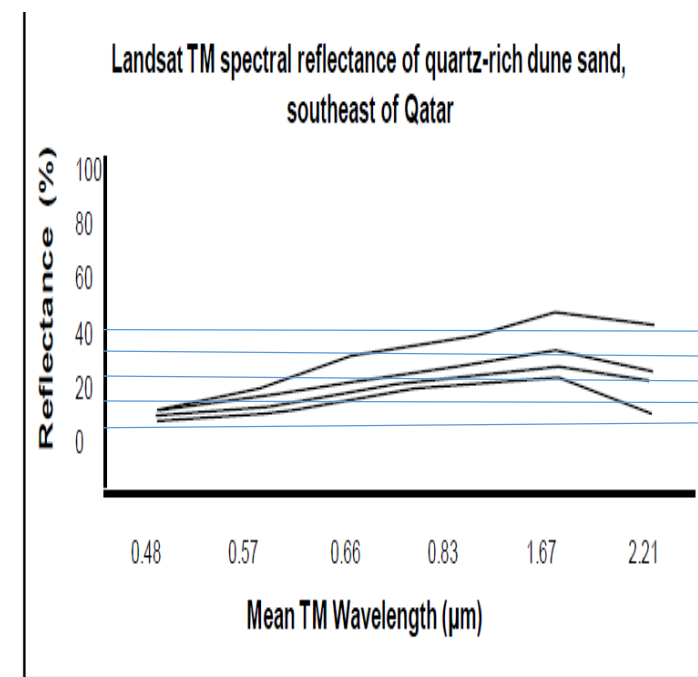
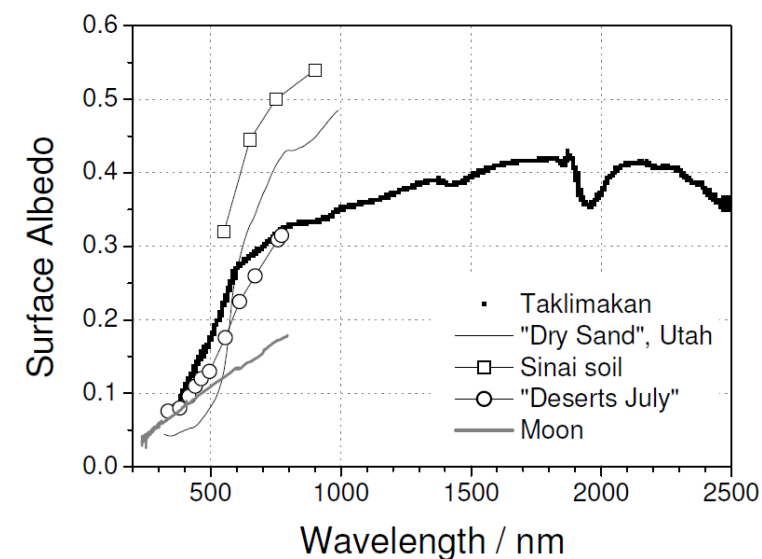
Article

## Remote Sensing and Spectral Characteristics of Desert Sand from Qatar Peninsula, Arabian/Persian Gulf

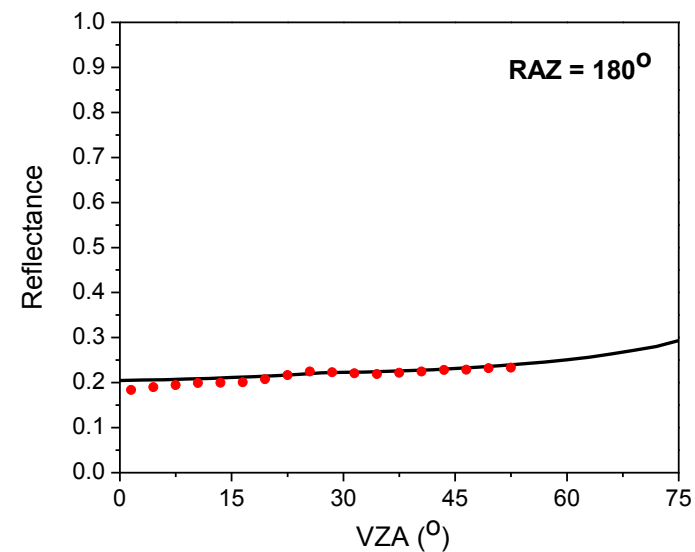
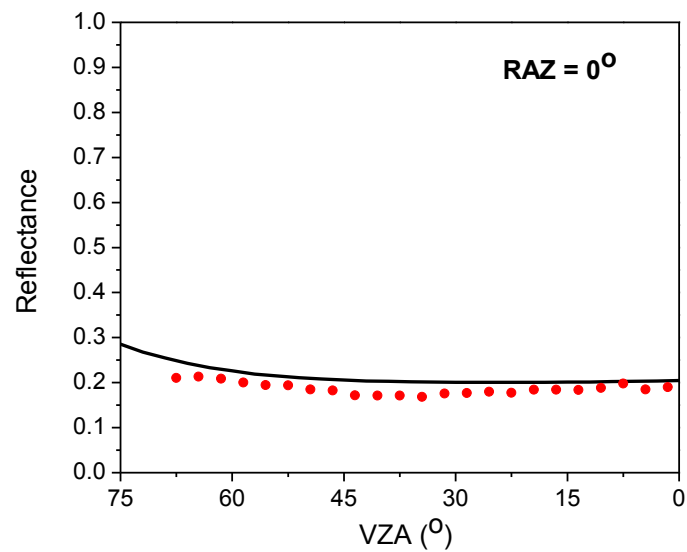
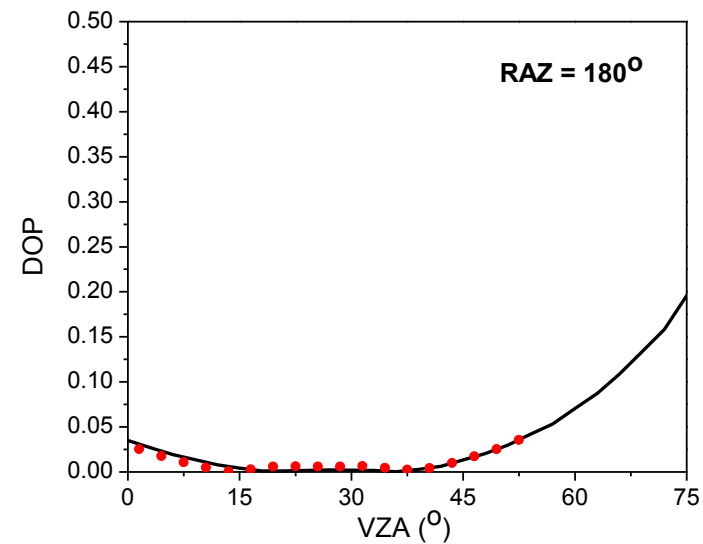
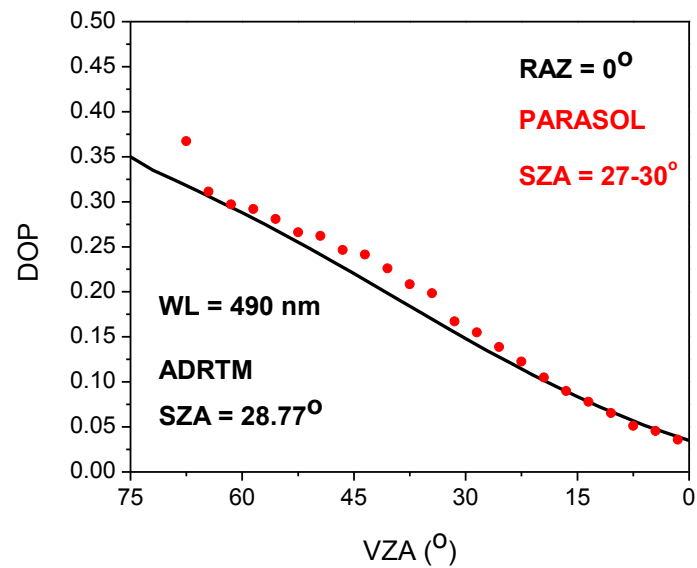
Abdulali Sadiq <sup>1</sup> and Fares Howari <sup>2,\*</sup>

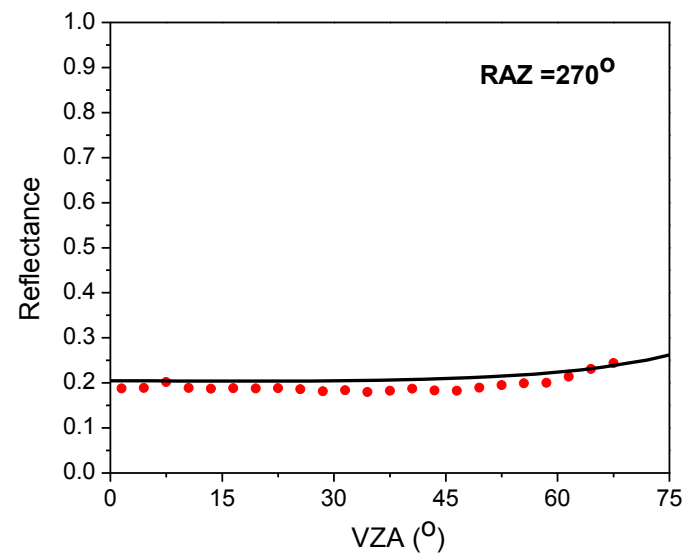
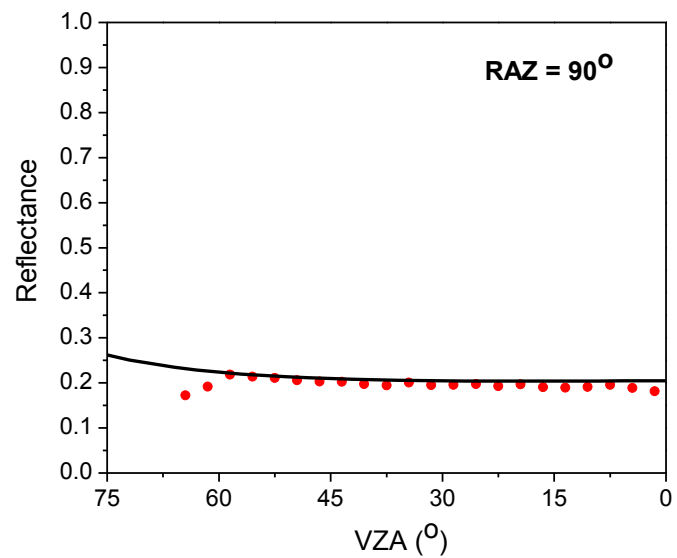
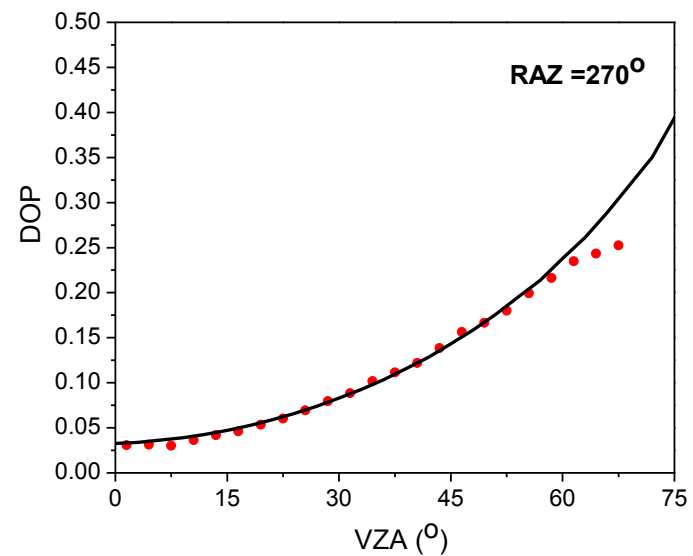
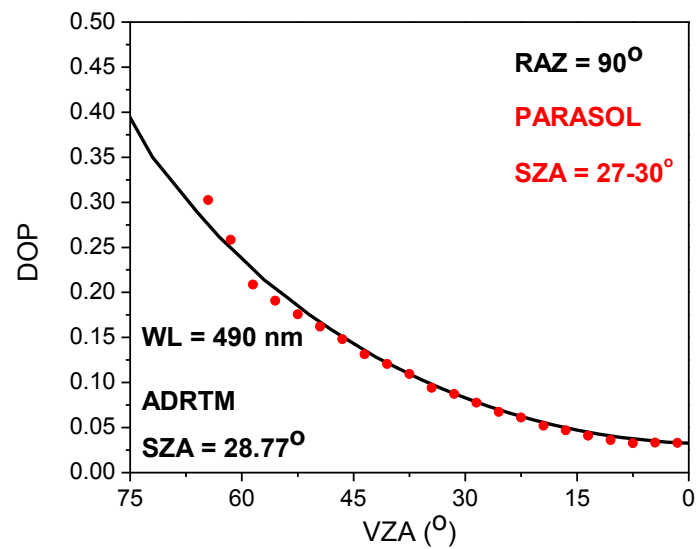
<sup>1</sup> Department of Chemistry & Earth Sciences, Qatar University, P O Box 2713, Doha, Qatar;  
Tel: +974-485-2755; E-Mail: [a.sadiq@qu.edu.qa](mailto:a.sadiq@qu.edu.qa)

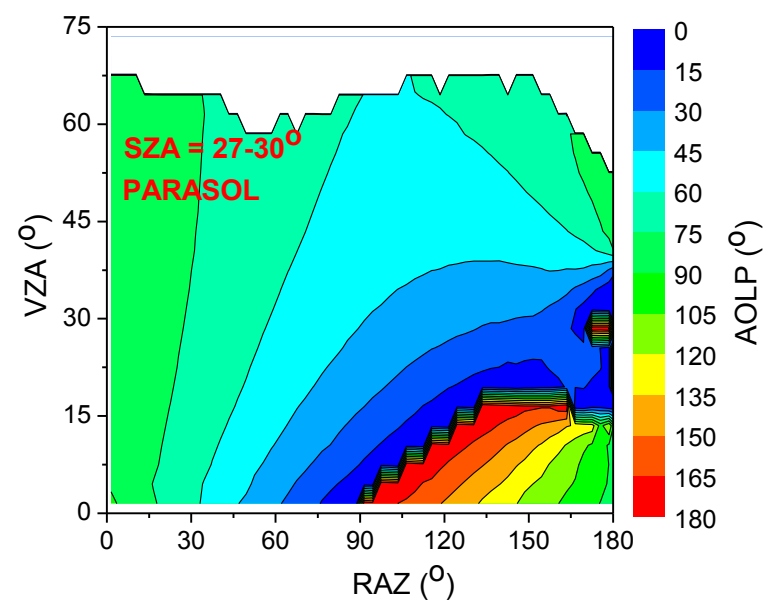
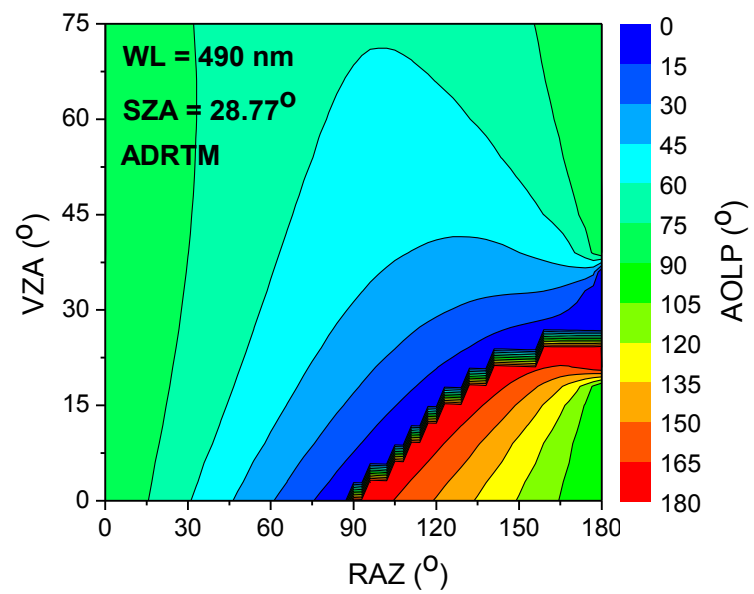
<sup>2</sup> Environmental Science Program, College of Arts and Science, The University of Texas of the Permian Basin, 4901 East University, Odessa, TX 79762, USA



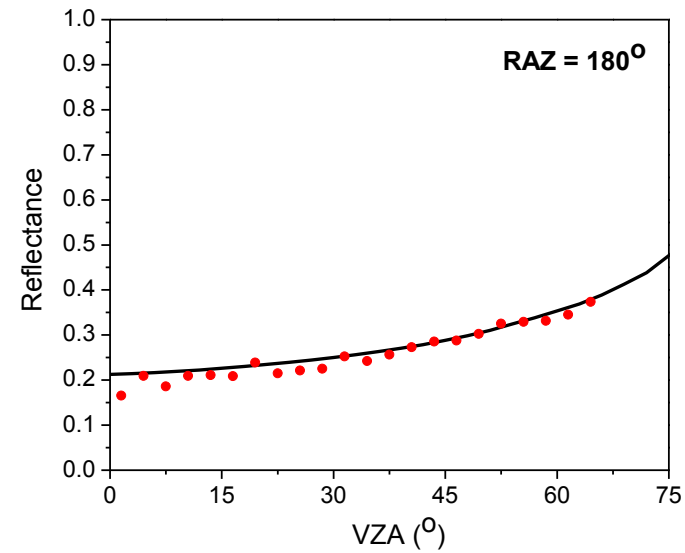
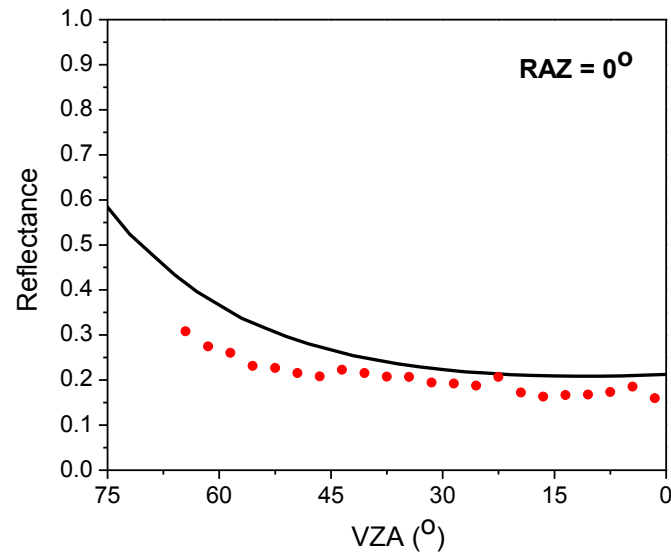
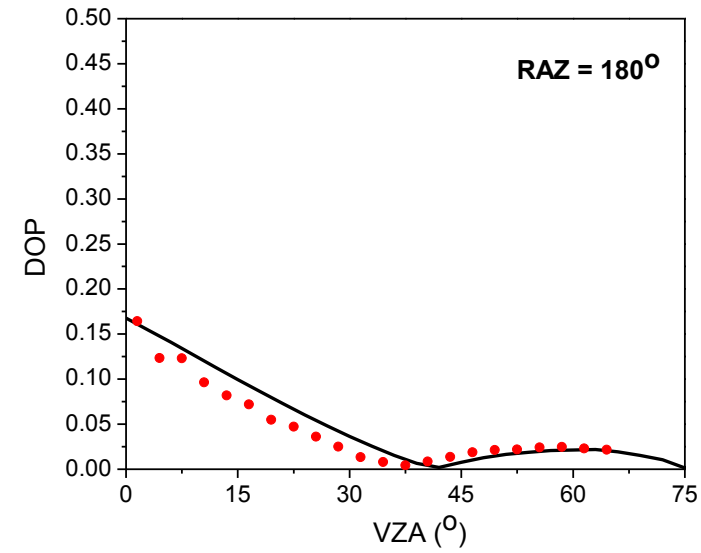
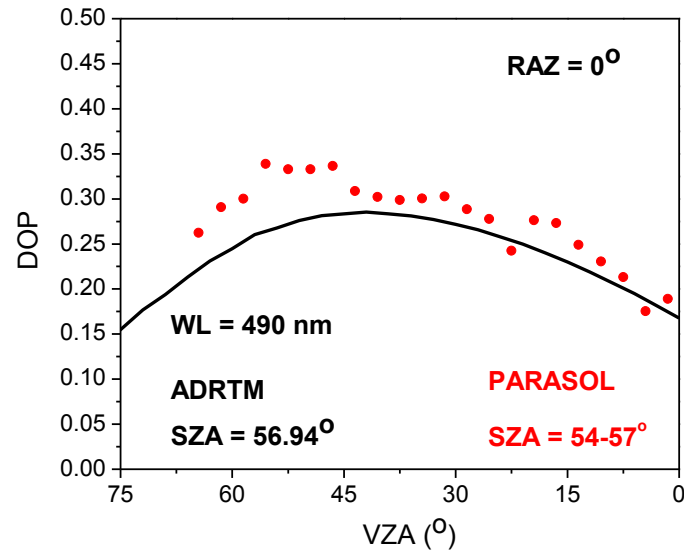
# Comparing model results with satellite data at a wavelength of 490 nm and a SZA of 28.77 deg

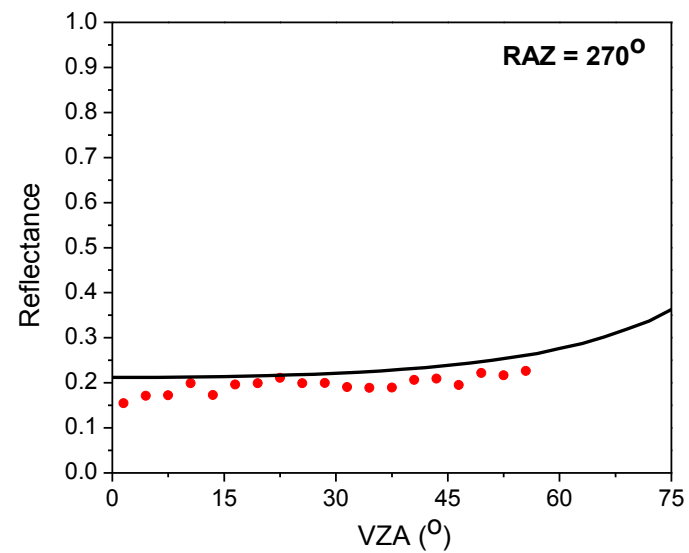
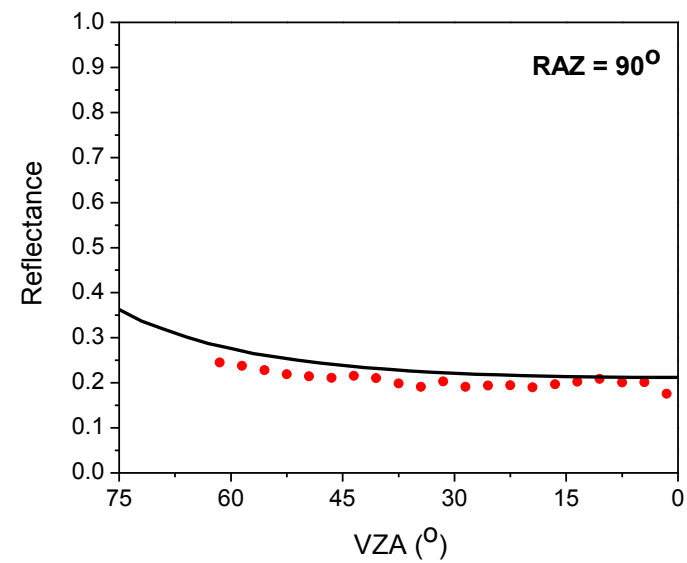
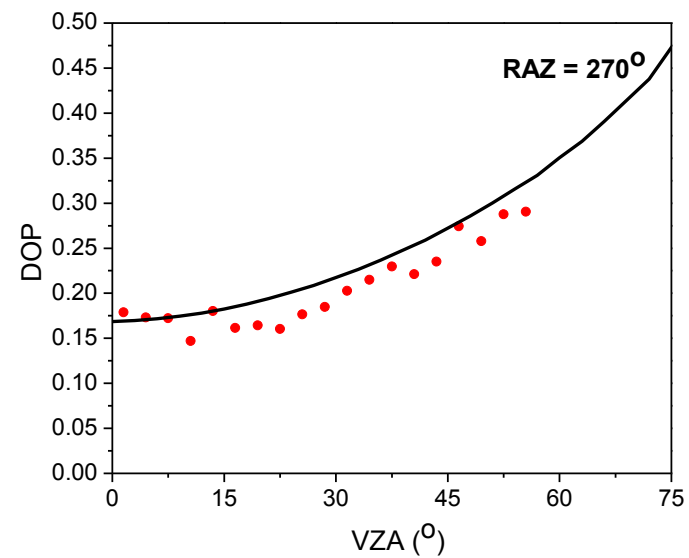
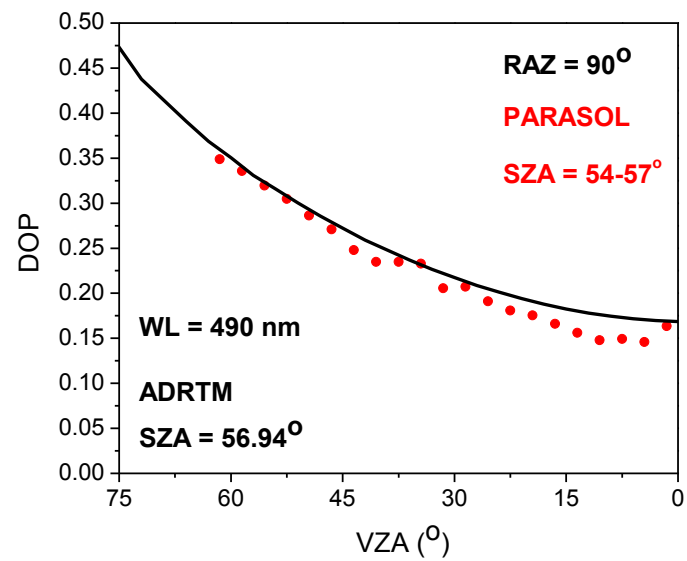


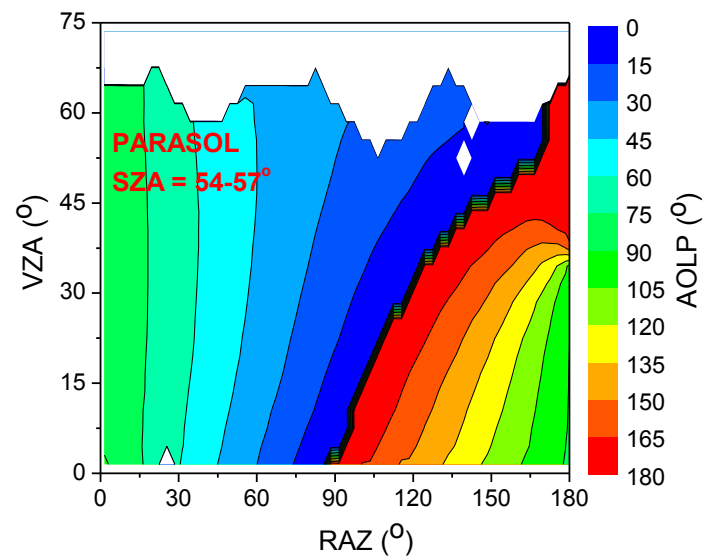
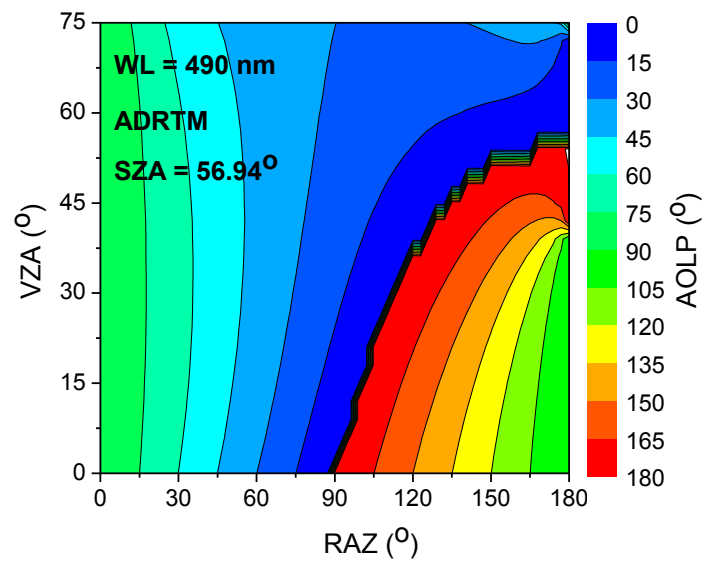




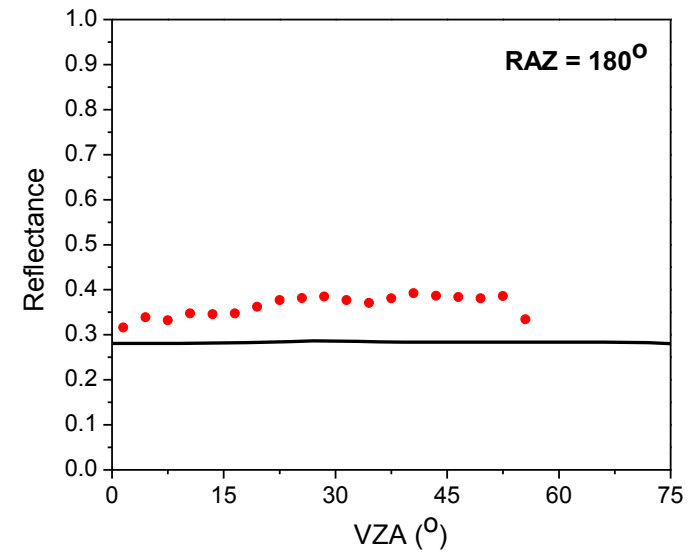
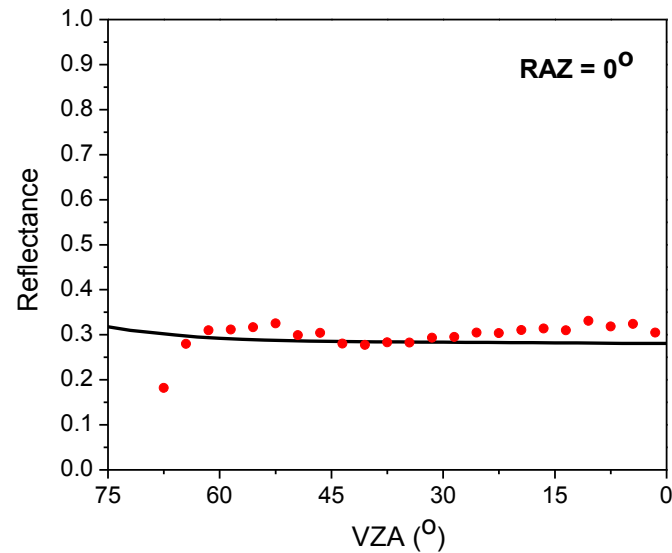
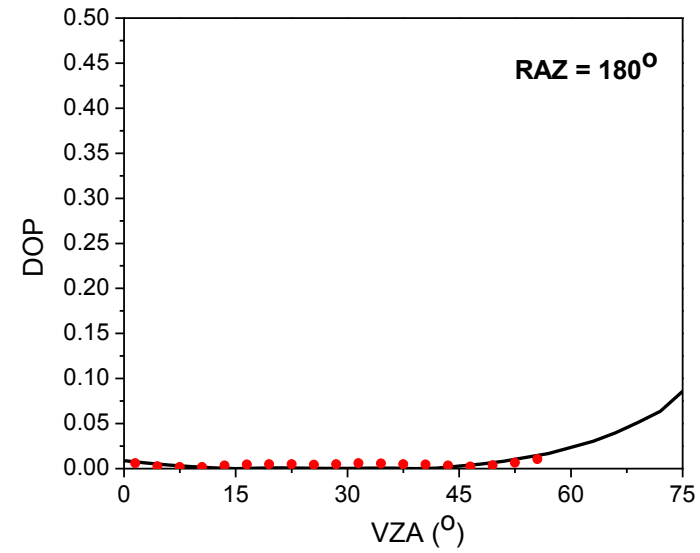
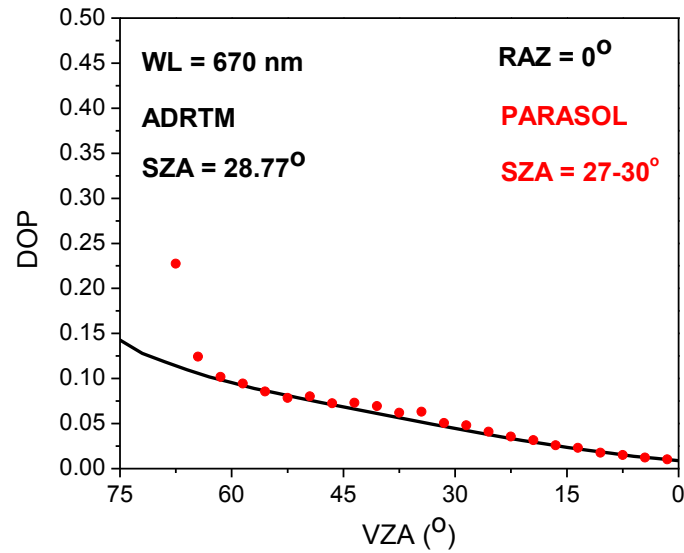
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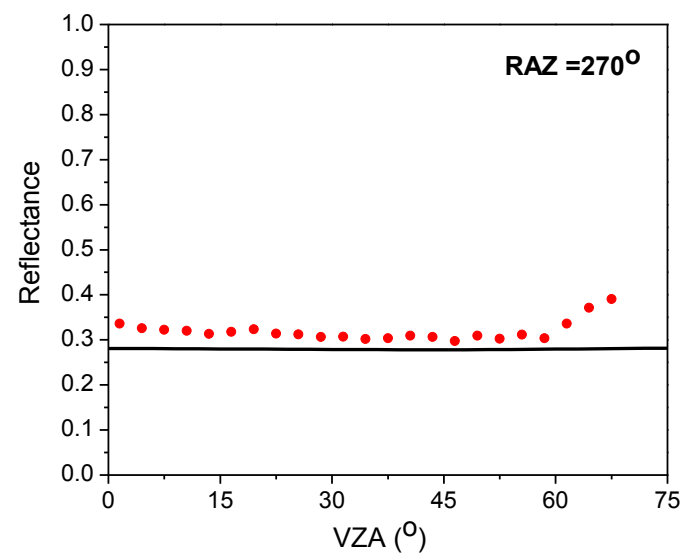
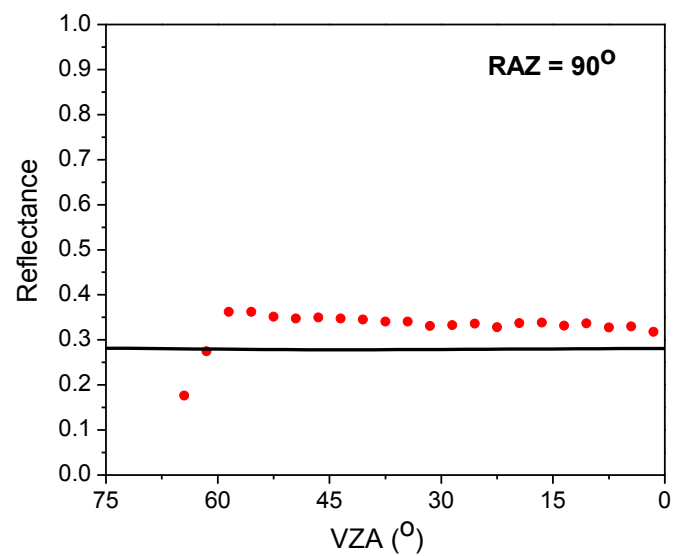
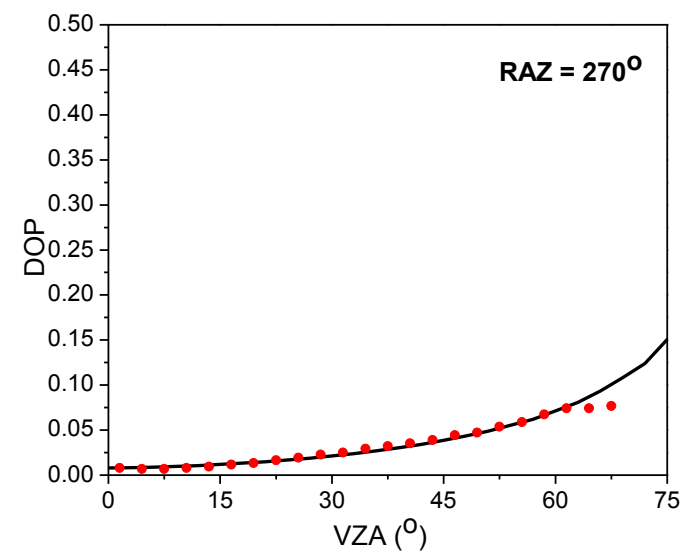
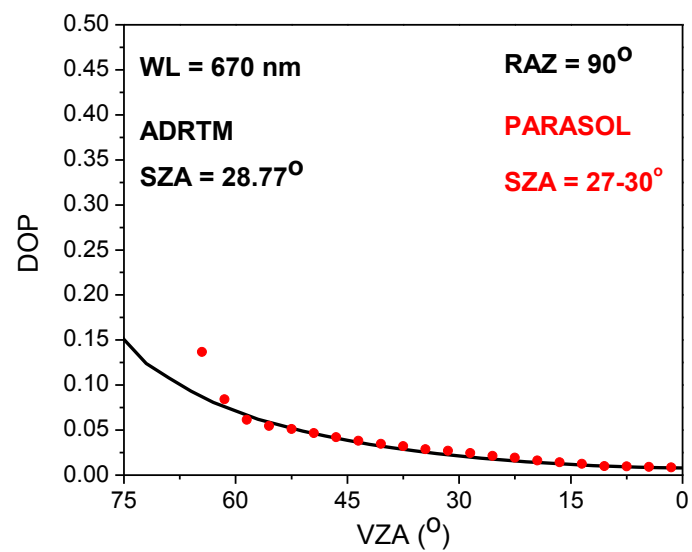


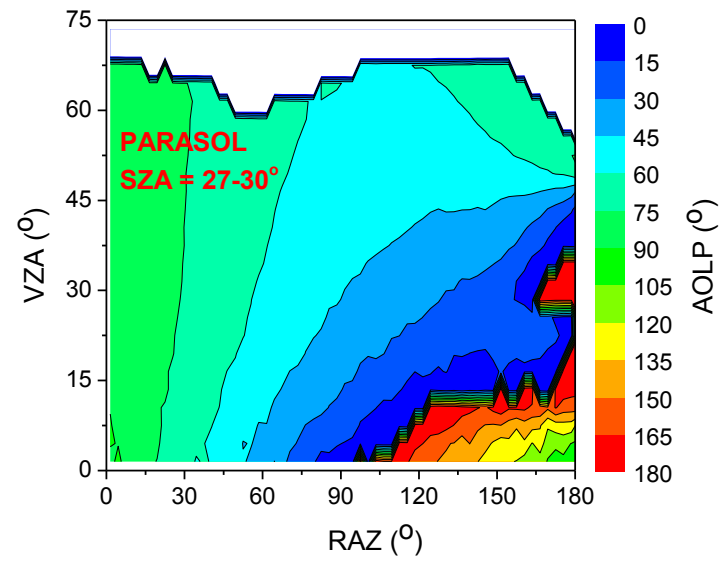
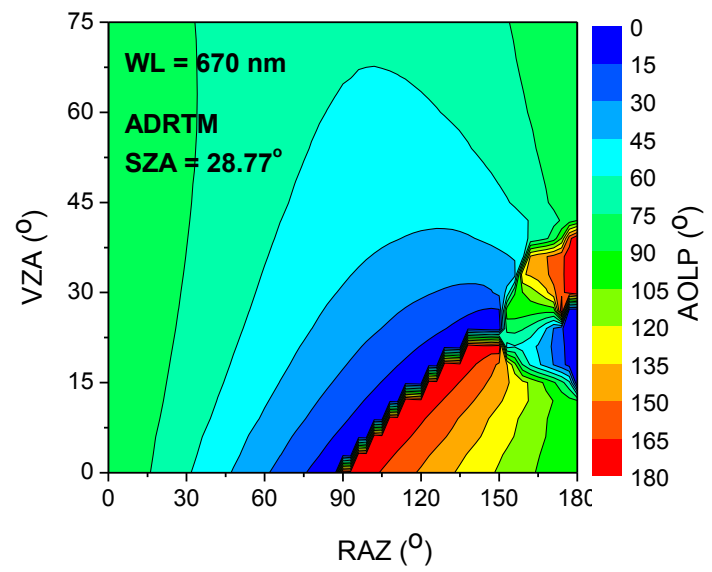




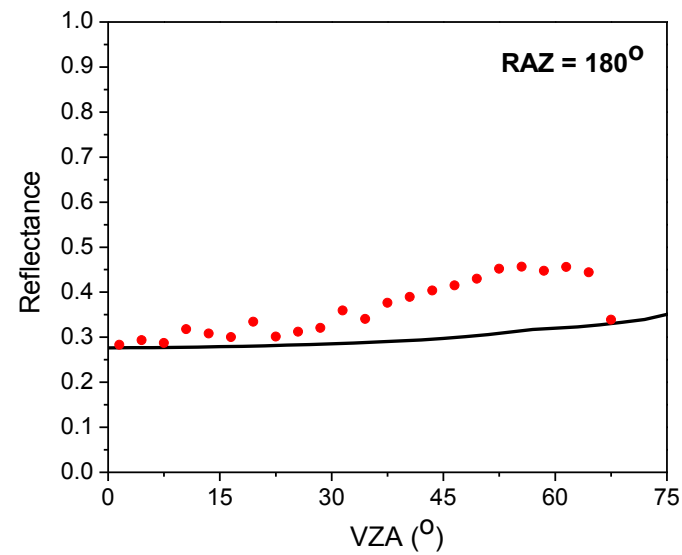
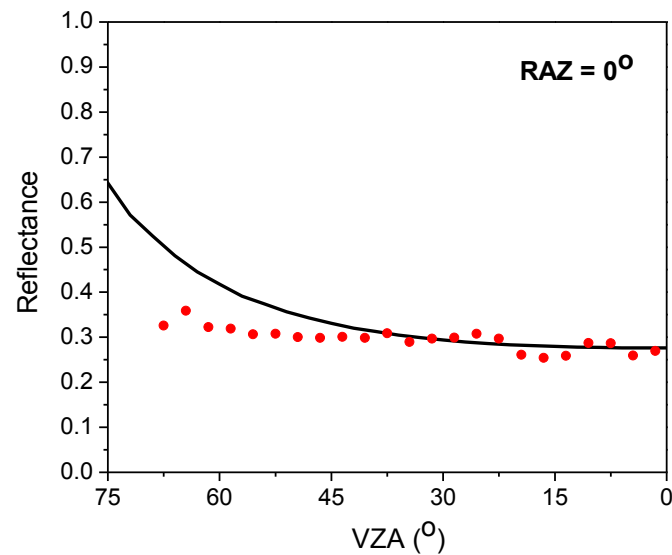
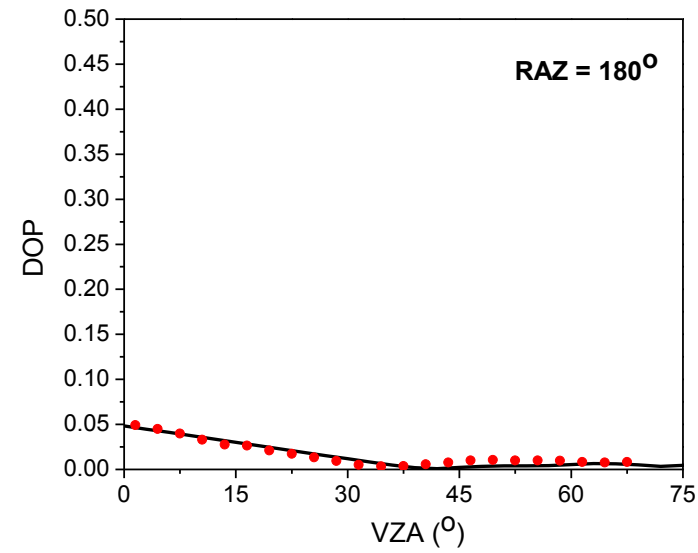
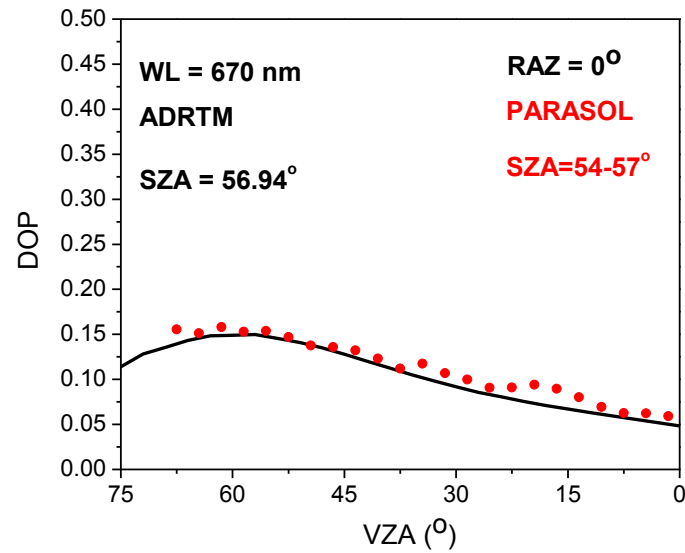
# Comparing model results with satellite data at a wavelength of 670 nm and a SZA of 28.77 deg

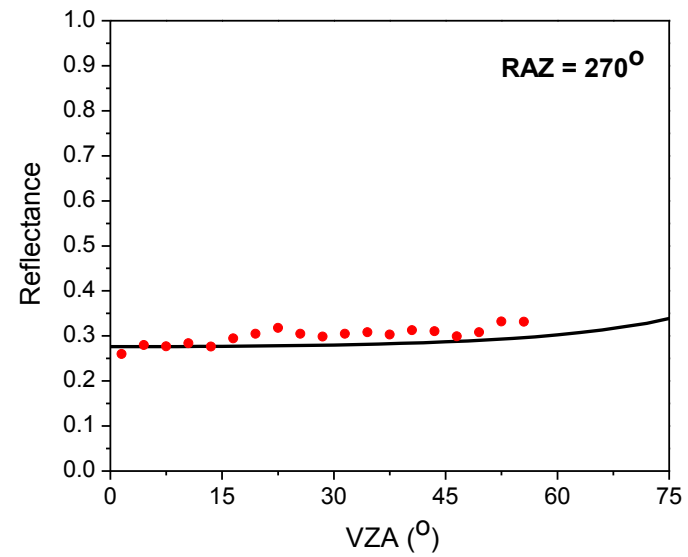
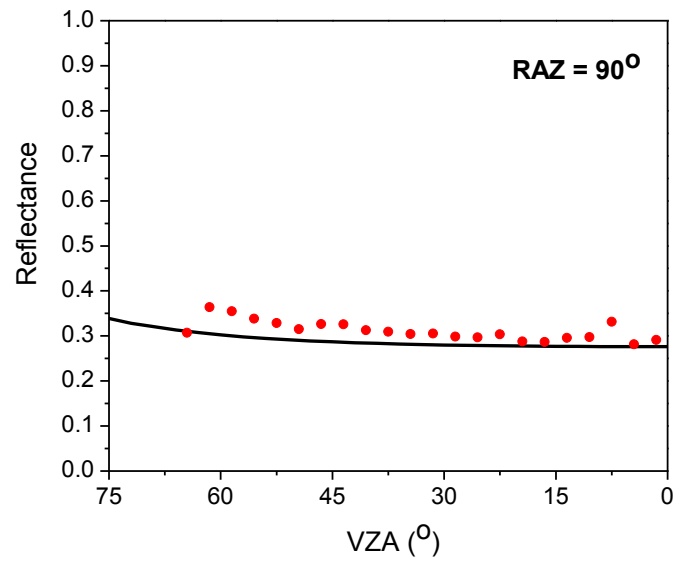
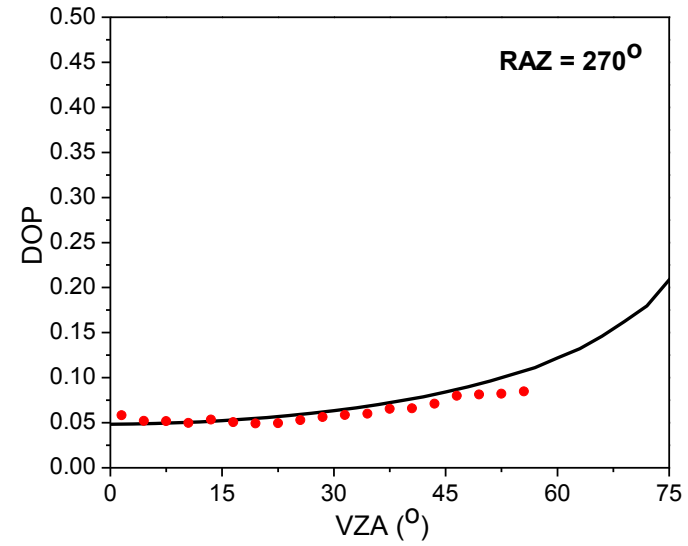
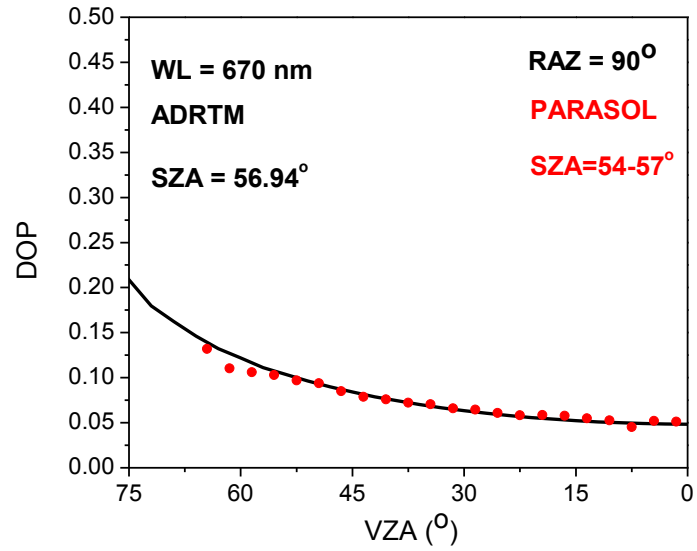


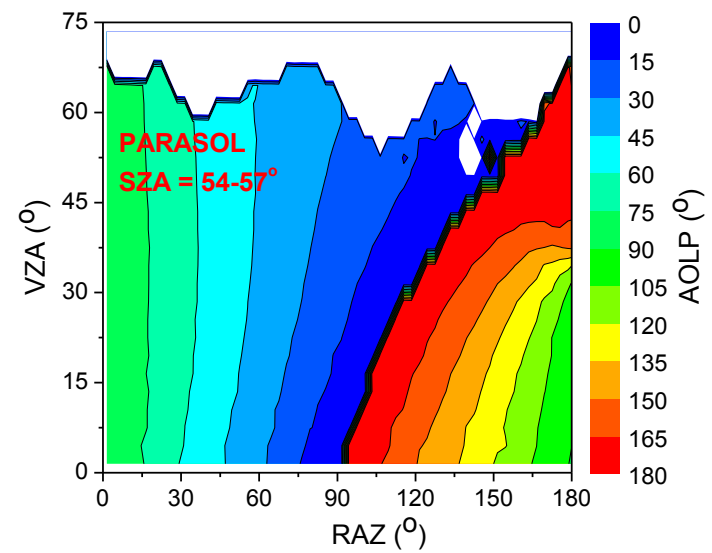
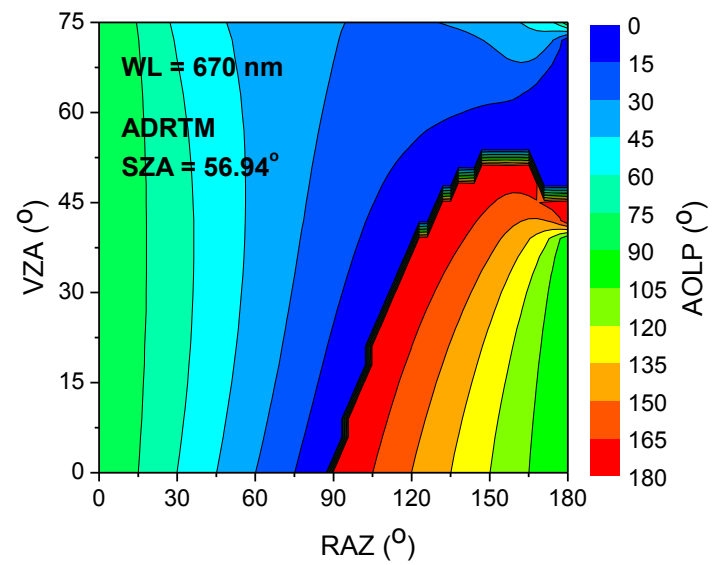




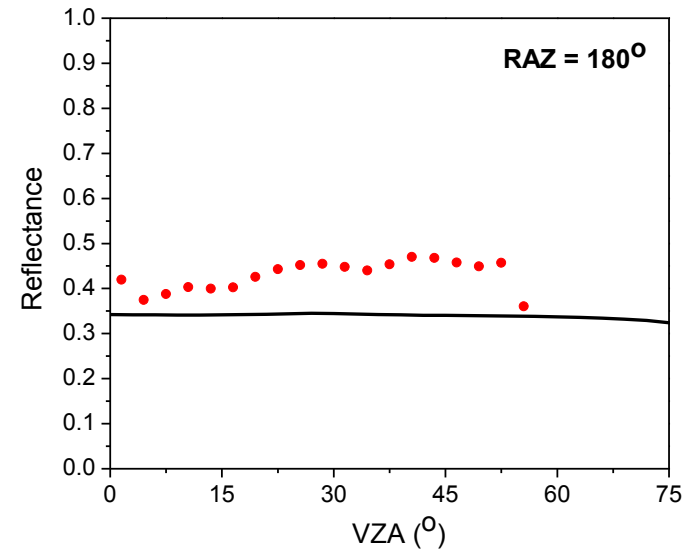
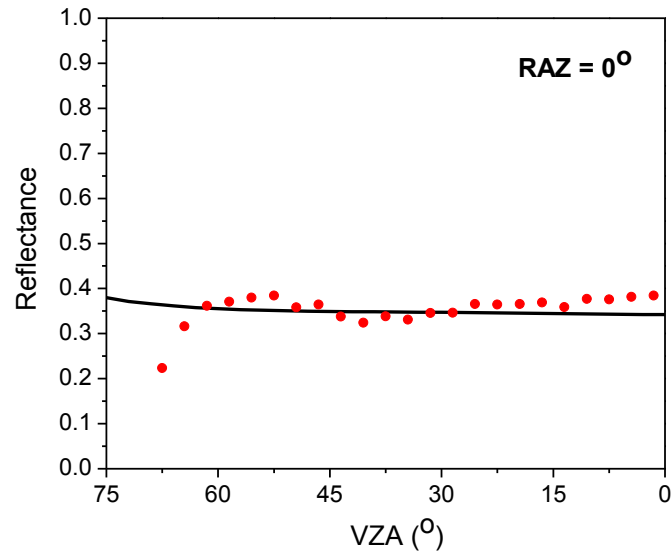
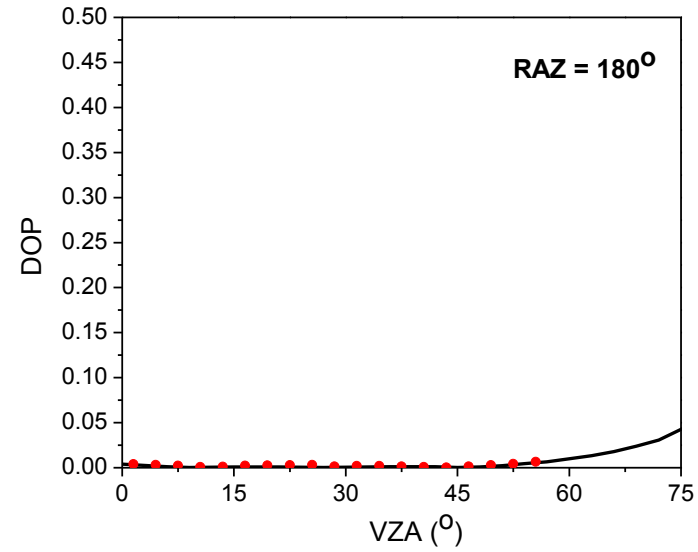
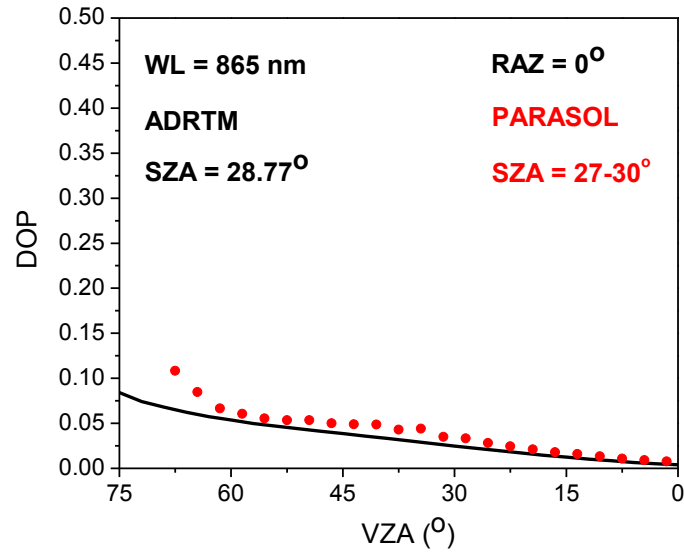
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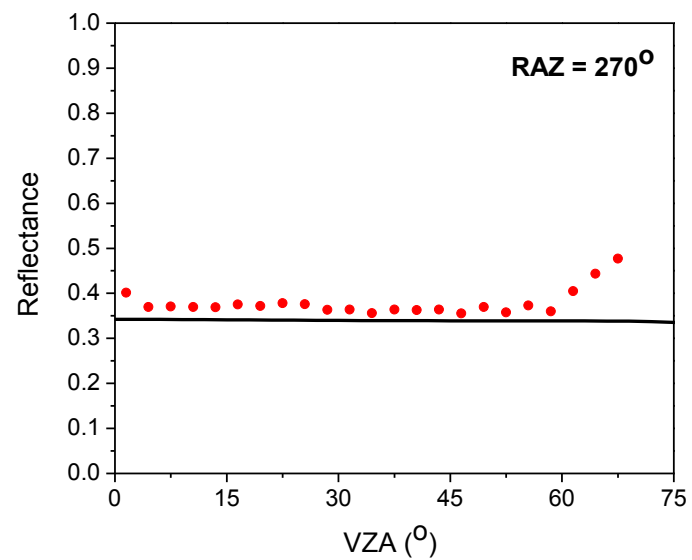
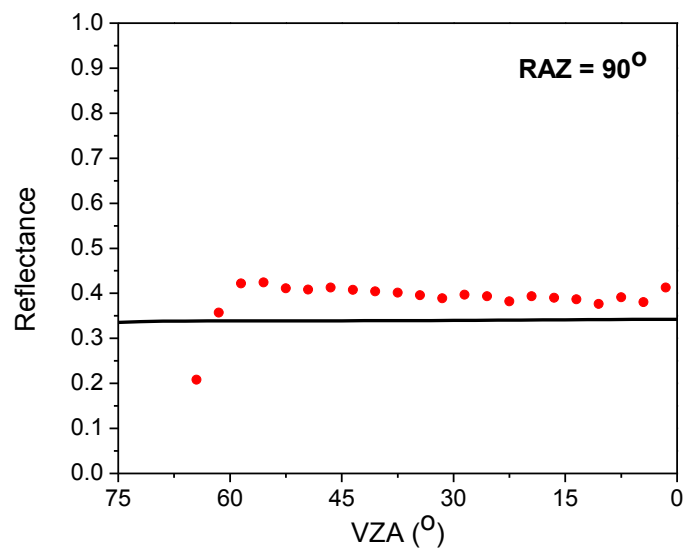
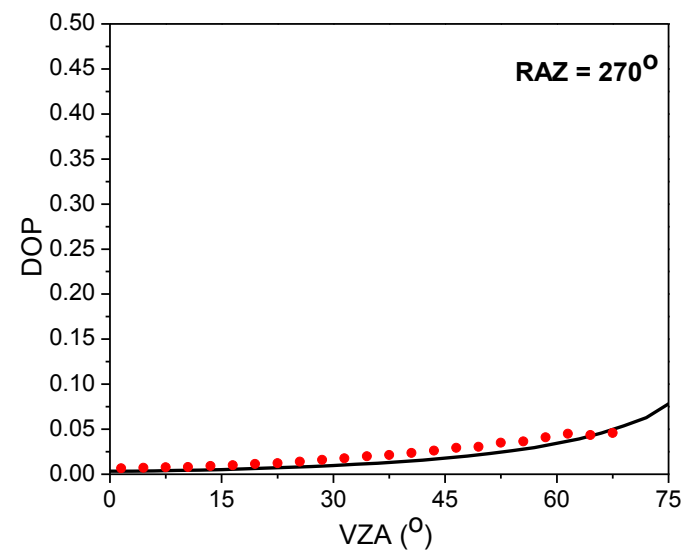
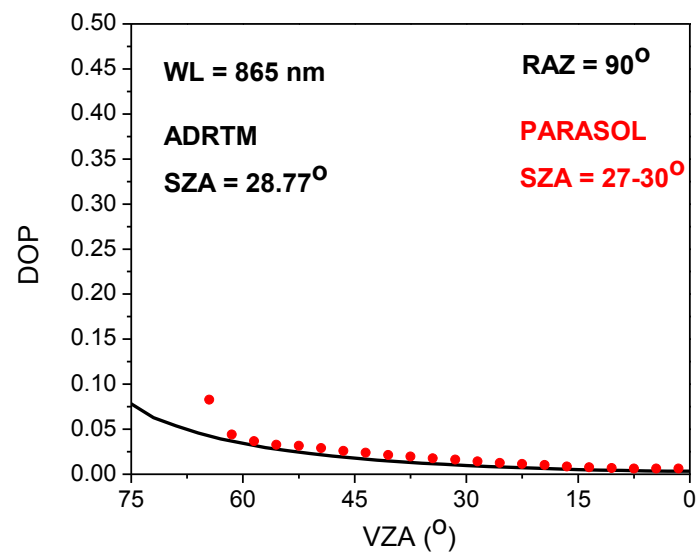


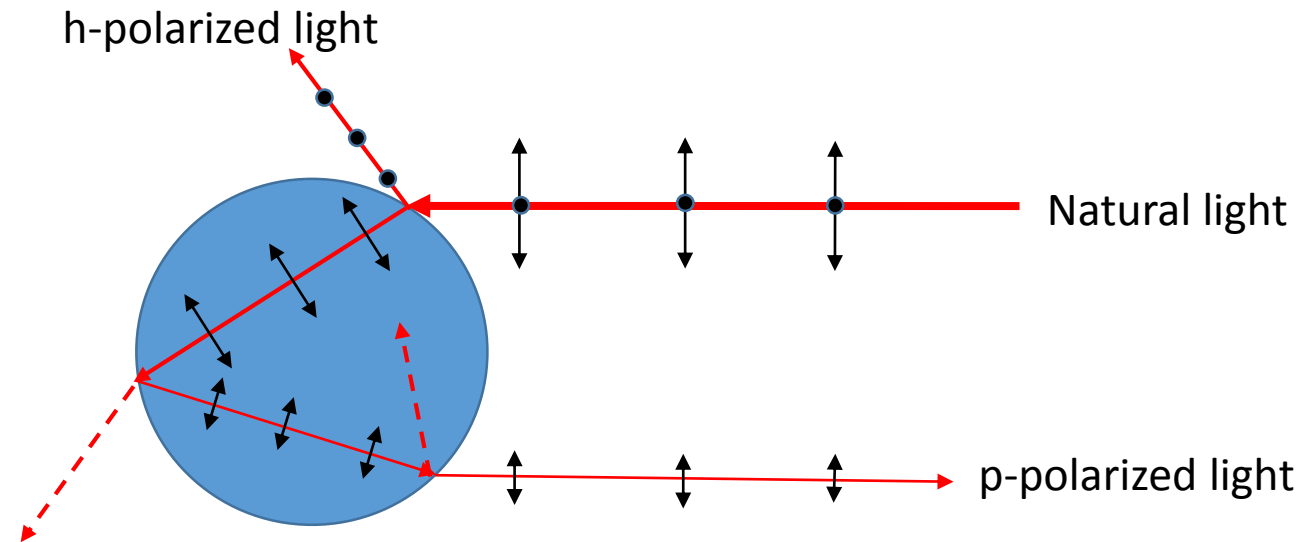
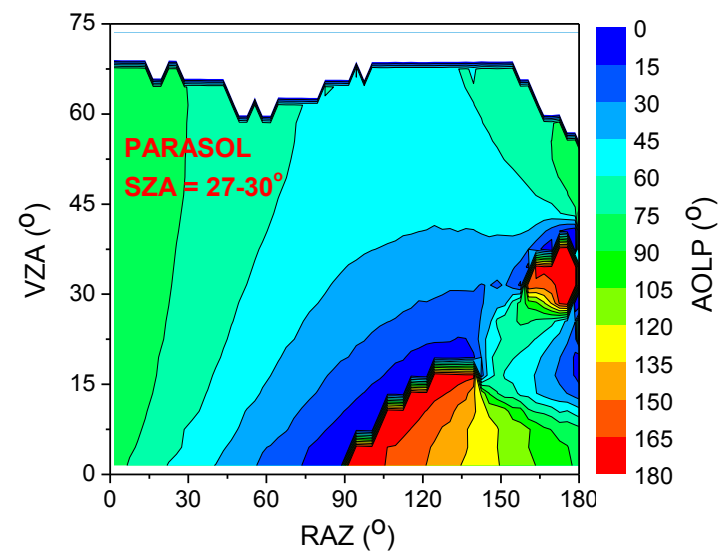
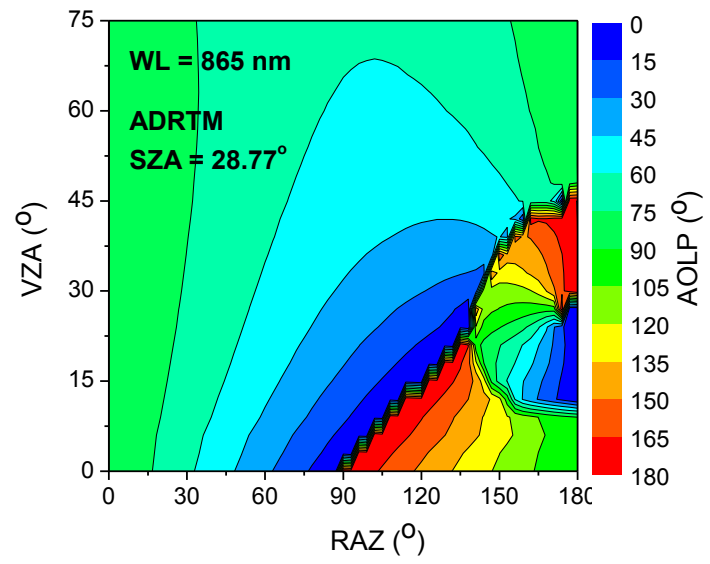




# Comparing model results with satellite data at a wavelength of 865 nm and a SZA of 28.77 deg

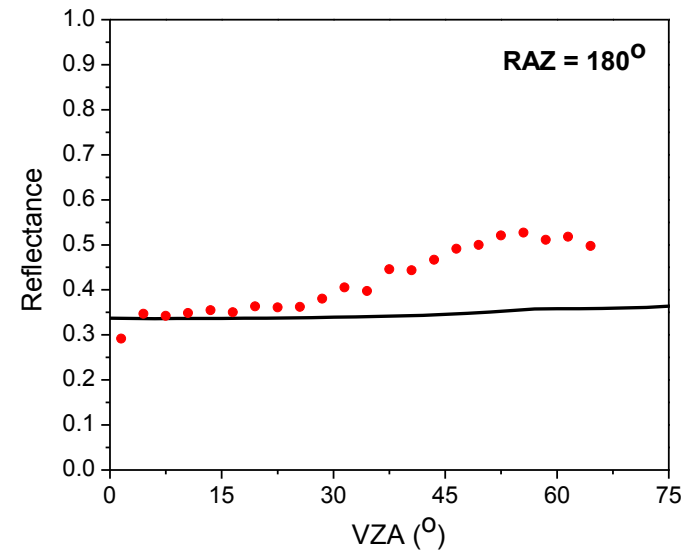
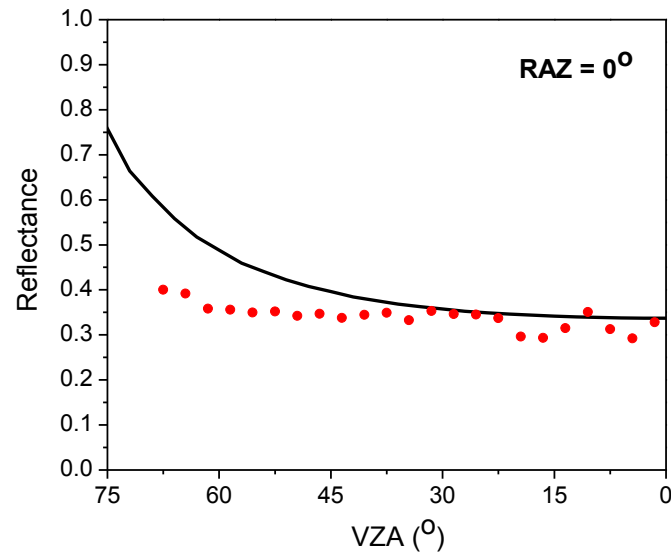
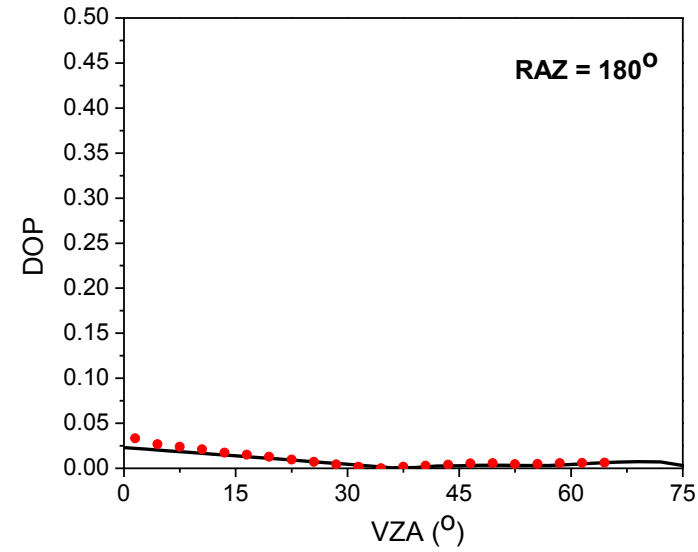
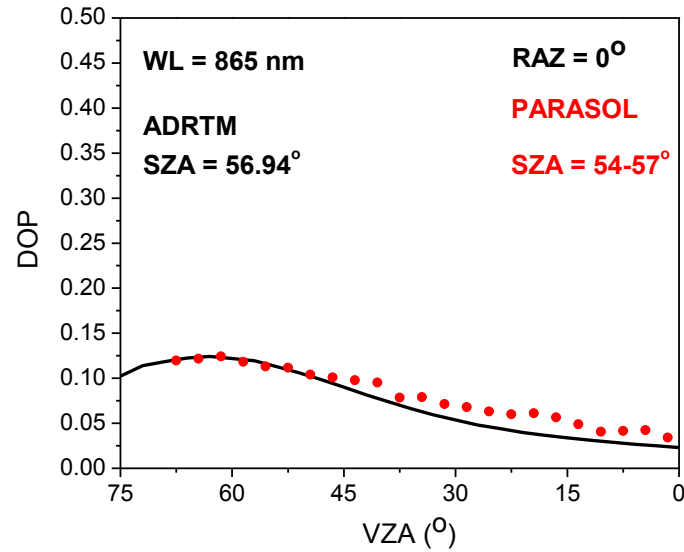


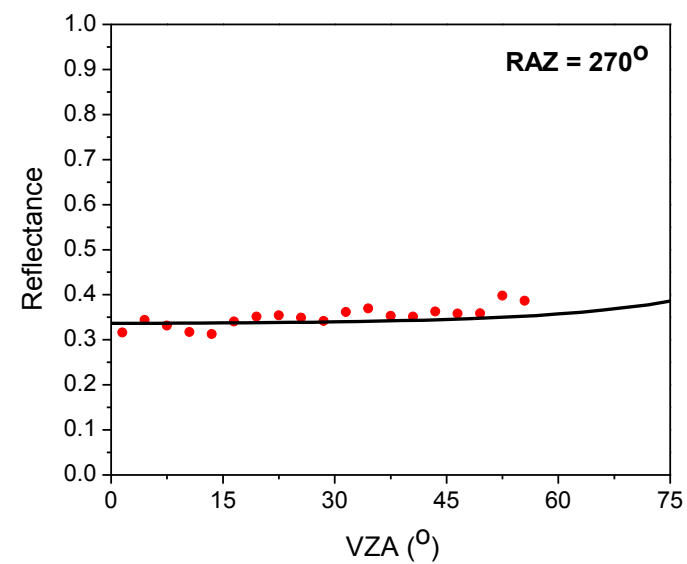
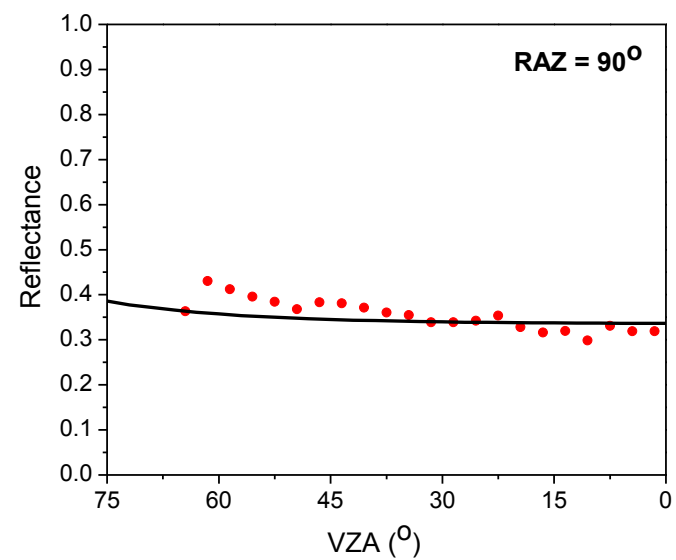
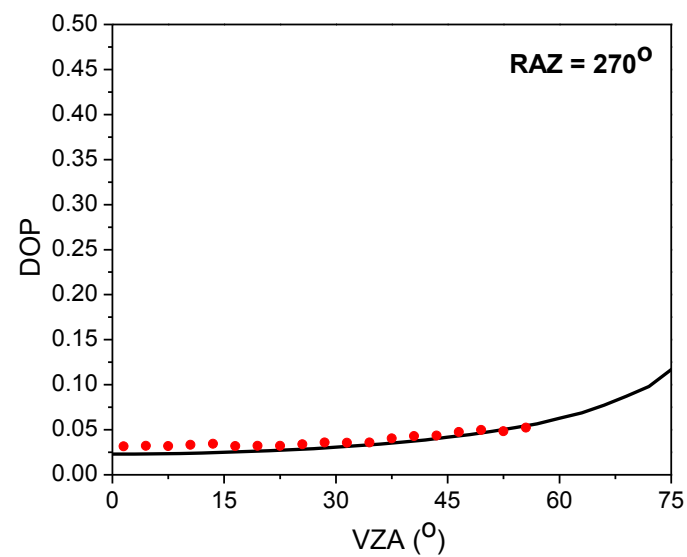
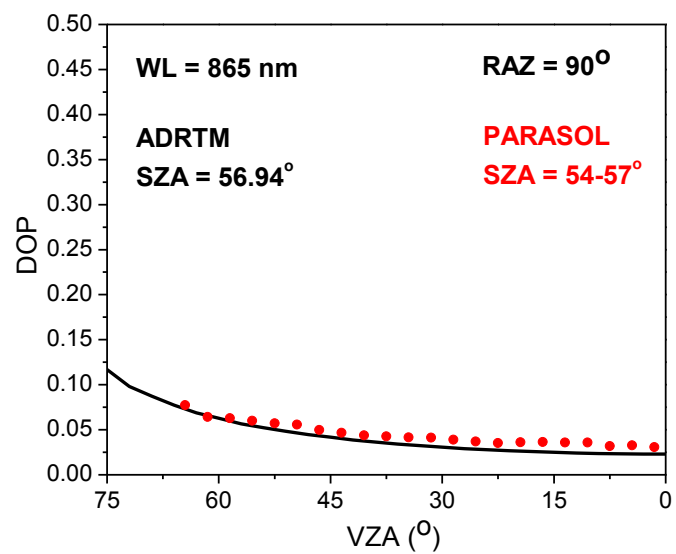


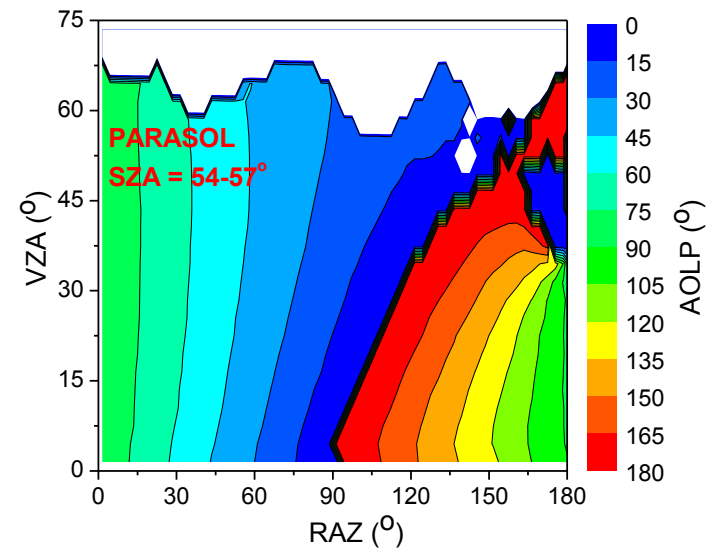
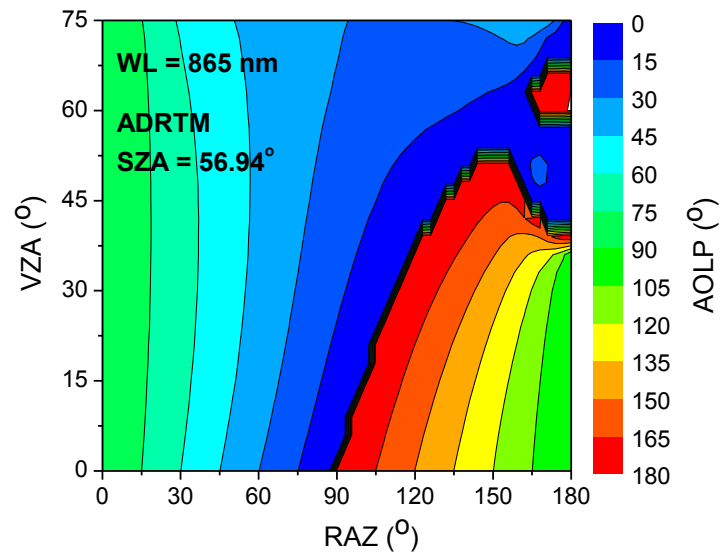


A plausible explanation of this cloud optical phenomenon

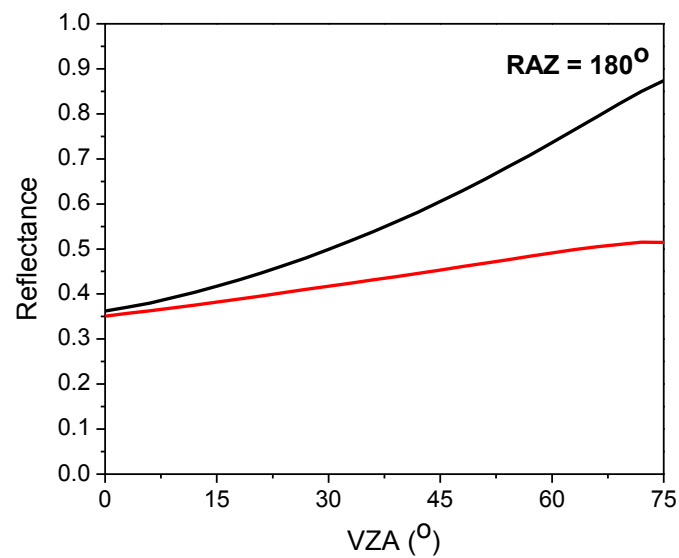
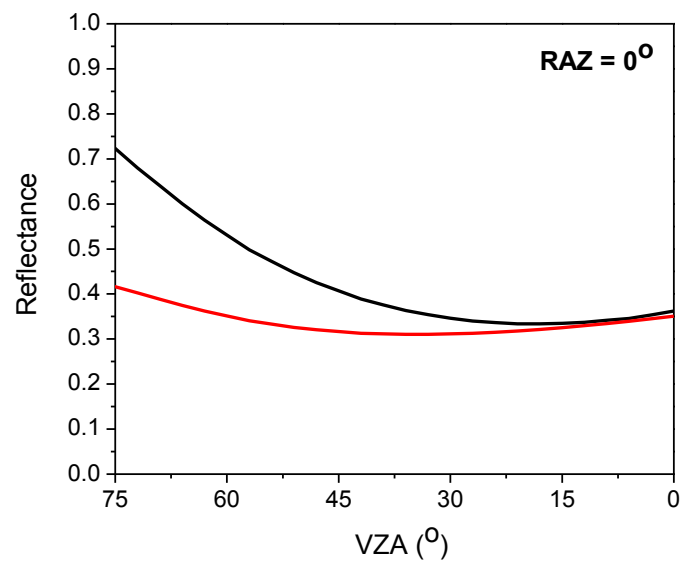
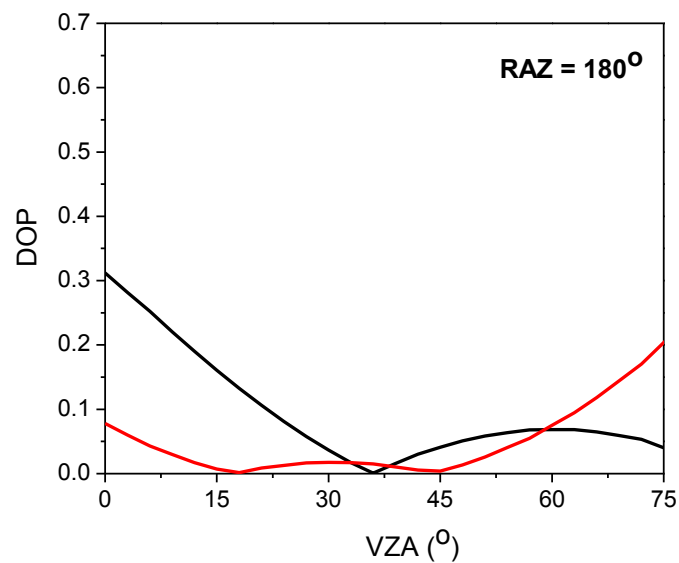
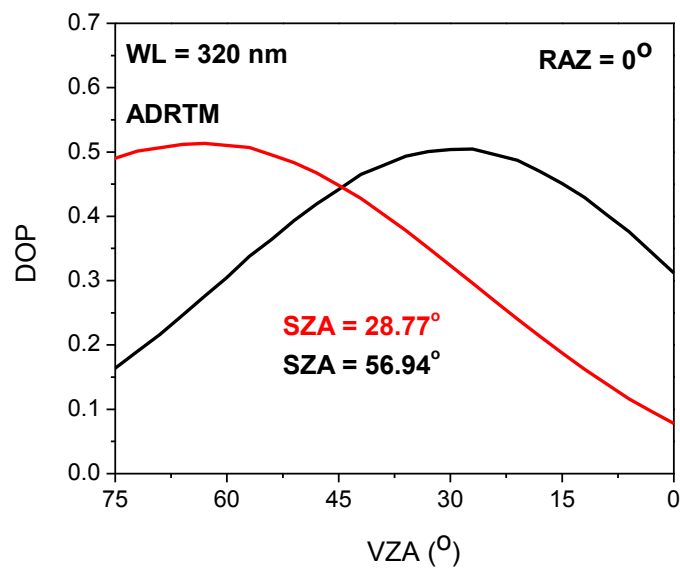
# Comparing model results with satellite data at a wavelength of 865 nm and a SZA of 56.94 deg

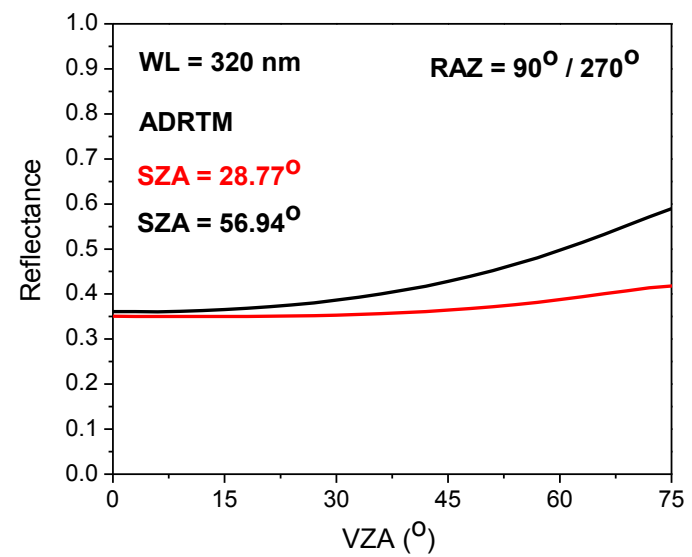
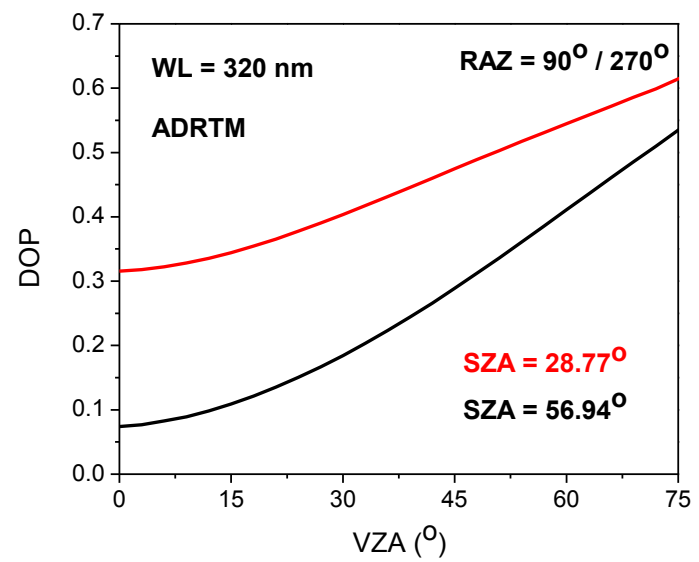


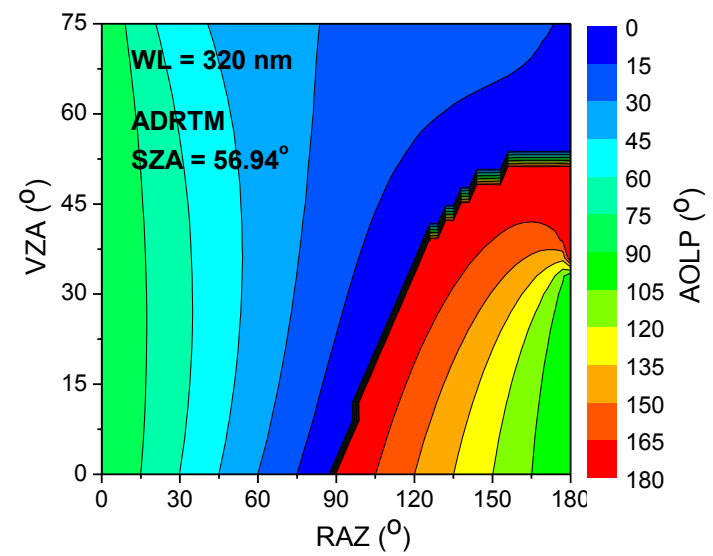
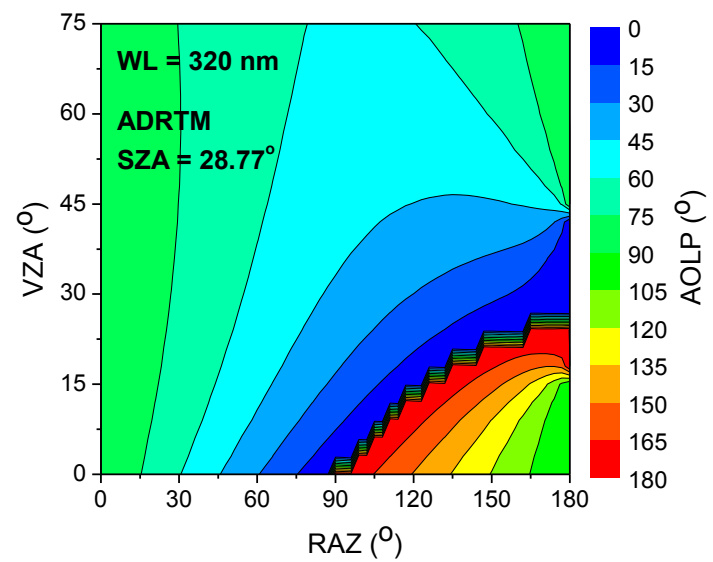




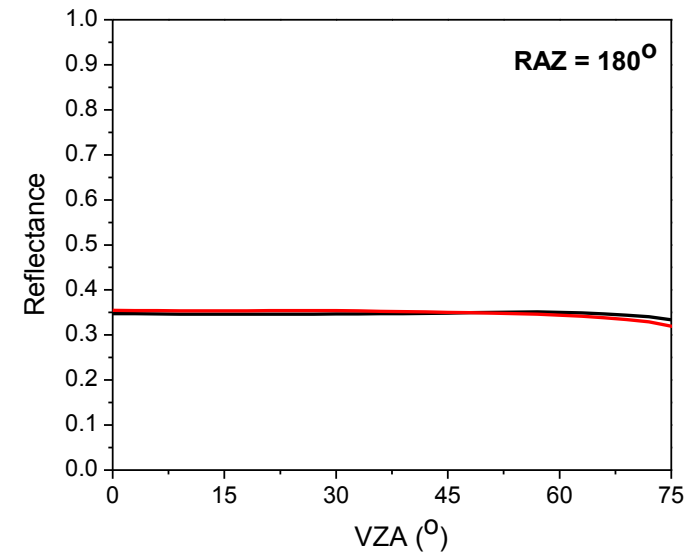
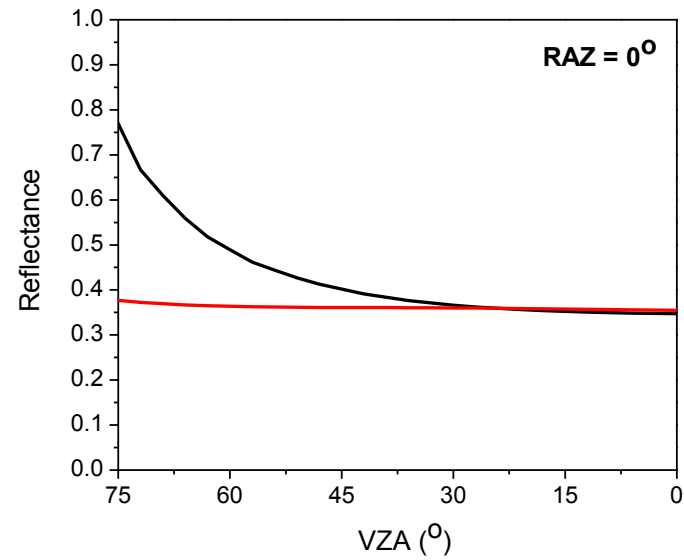
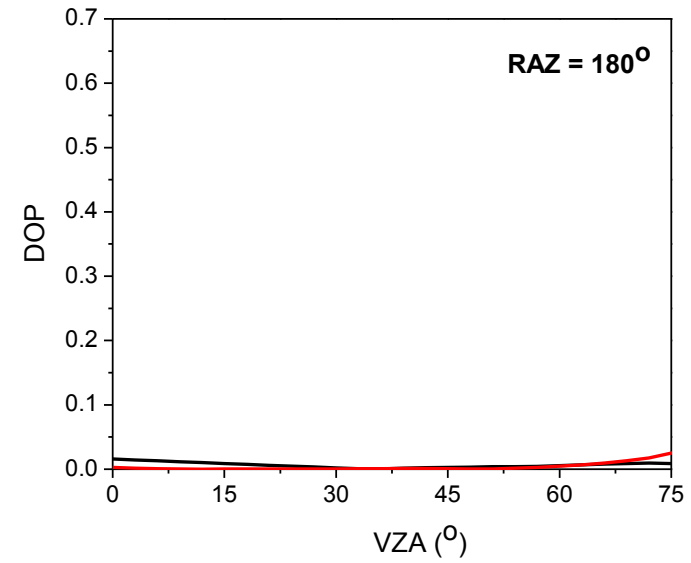
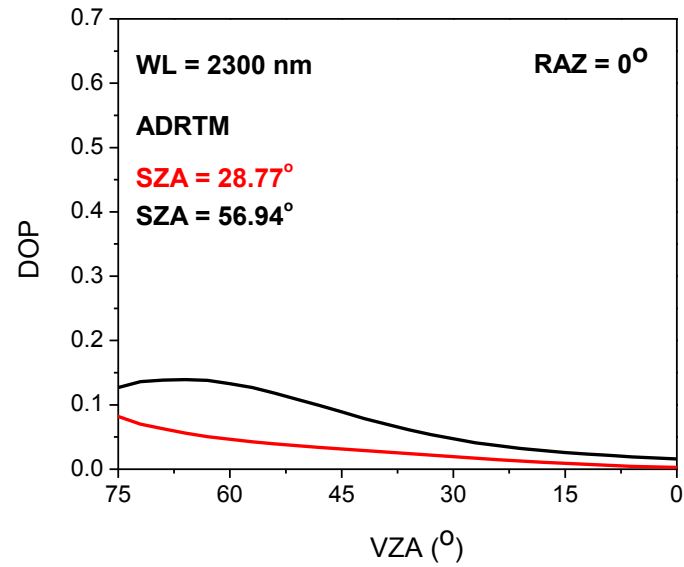
# Model results at a wavelength of 320 nm

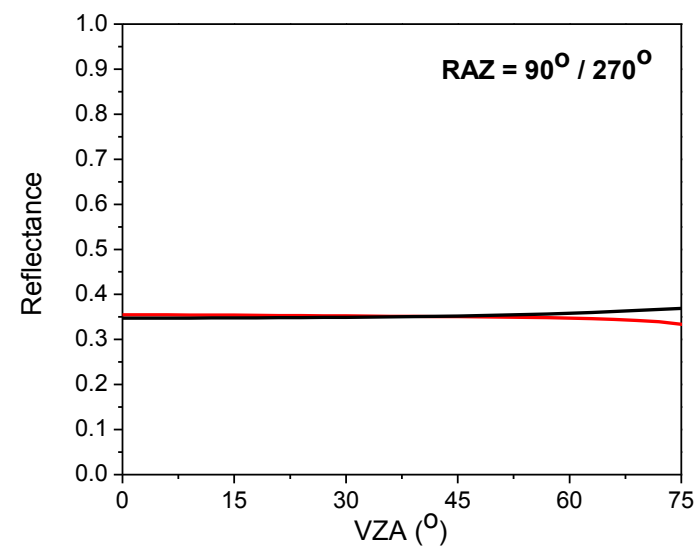
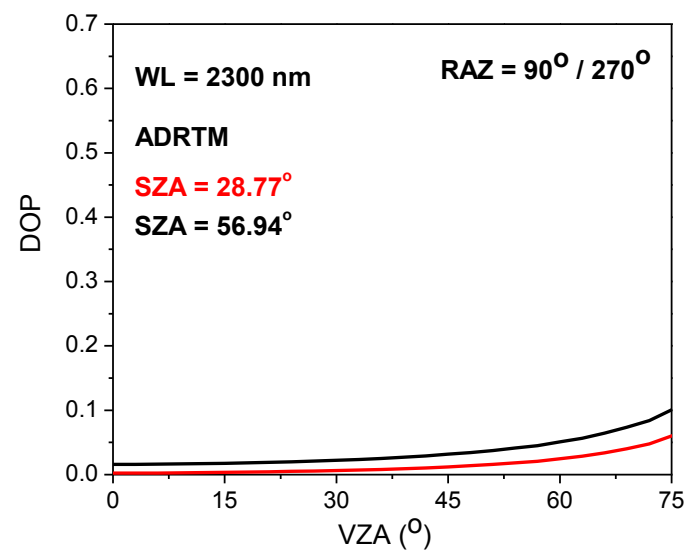


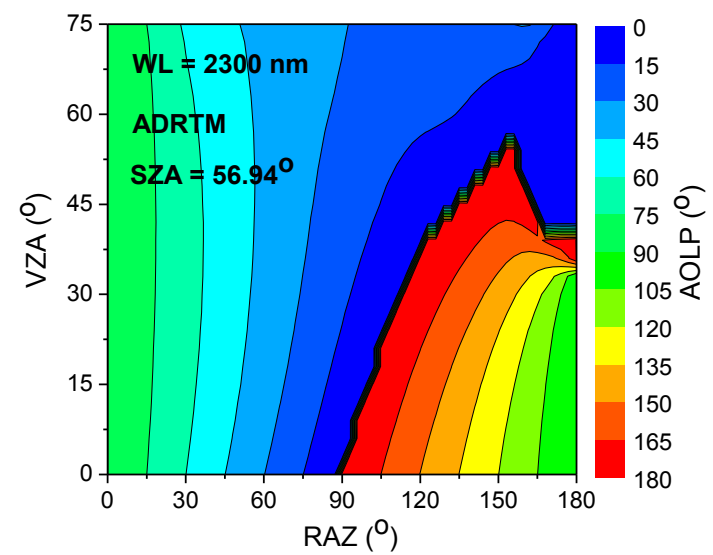
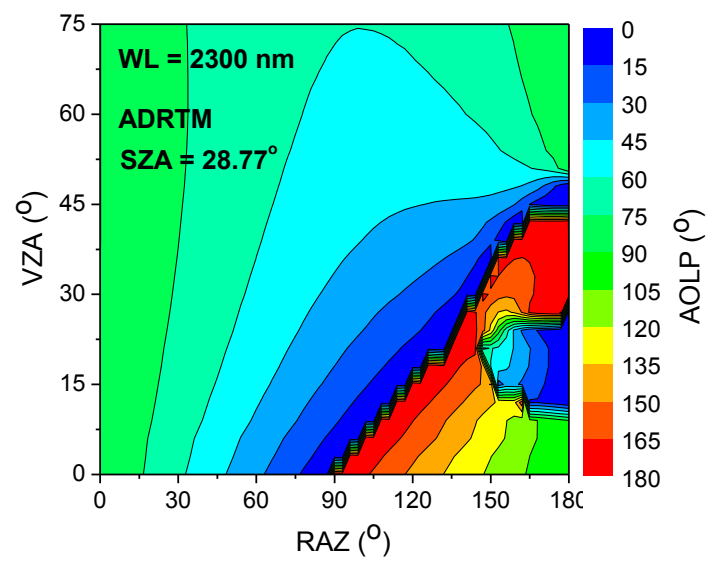




# Model results at a wavelength of 2300 nm









## Next: Snow/Ice Land

Using the same algorithm as for desert, we may derive the polarization properties of light reflected by snow/ice land with PARASOL measurements and solar spectral reflectance from other sources ...

**Solar spectral reflectance in this process can be updated by the CLARREO data in the future.**

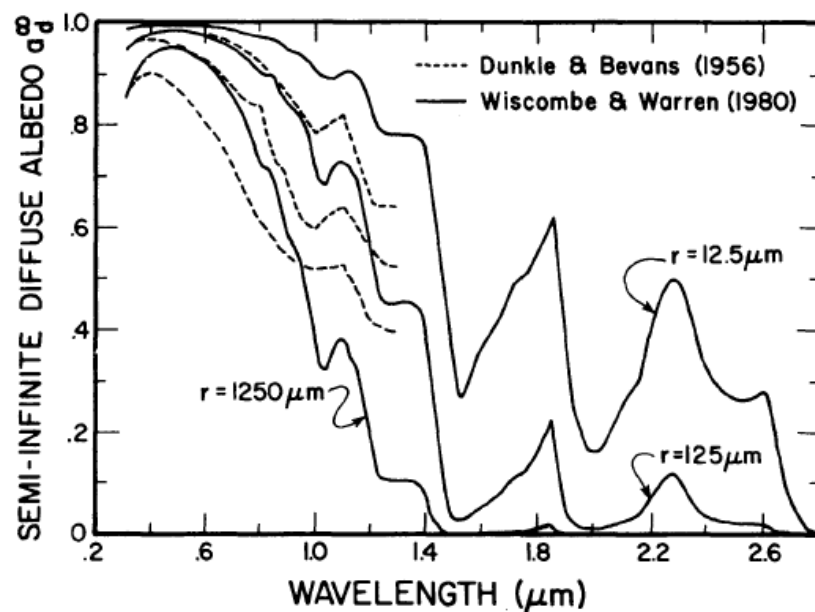
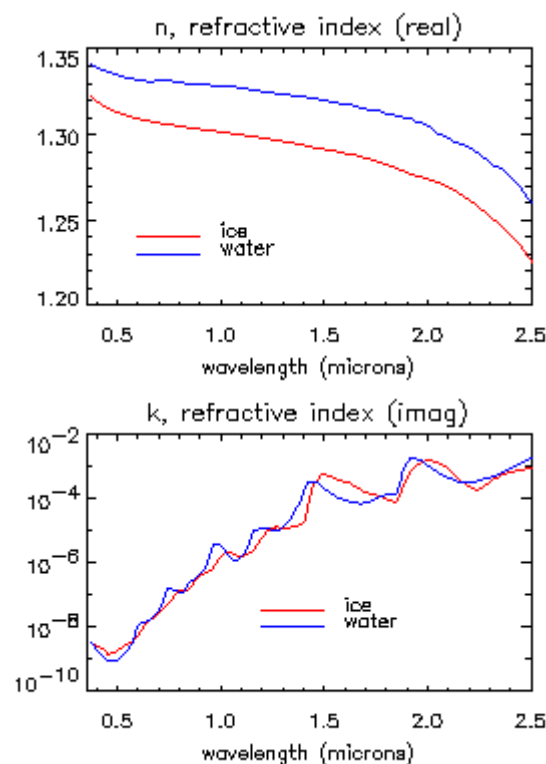


Fig. 1. Model calculations of semi-infinite diffuse albedo as a function of wavelength for various snow grain radii. Dashed lines are calculations by *Dunkle and Bevens* [1956, Figure 3]. Solid lines are calculations using the model of WWI, with the new  $m_{im}(\lambda)$  measured by *Grenfell and Perovich* [1981].



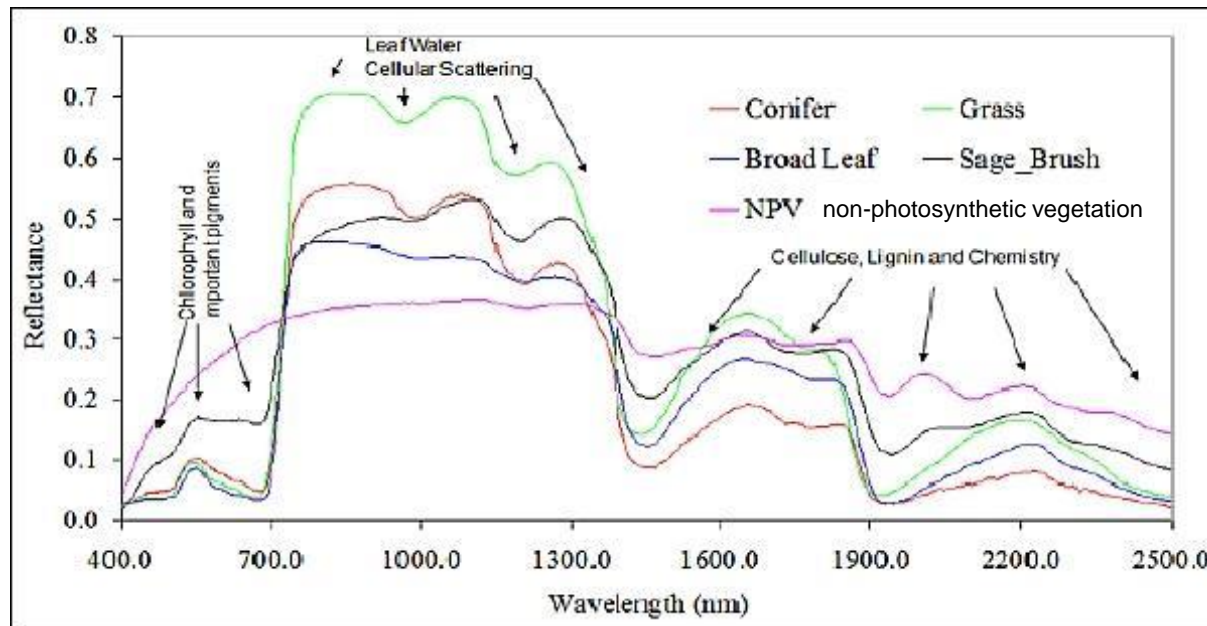
Refractive index of ice

## Next after Next: Vegetation Land

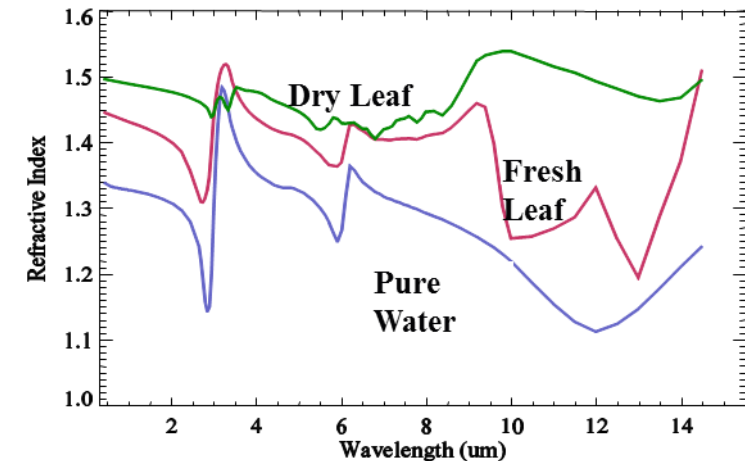


Using the same algorithm as for desert, we may derive the polarization properties of light reflected by vegetation land with PARASOL measurements and solar spectral reflectance from other sources ...

**Solar spectral reflectance in this process can be updated by the CLARREO data in the future.**



Broad leaf DOP can be ~70% for Wavelength < 865 nm



**A set of rock forming minerals and vegetation reflectance spectral measured from 400 to 2500 nm in the solar reflected light spectrum (NASA/JPL AVIRIS)**

Leaf refractive index by Variational Kramers-kronig Analysis (Chen and Weng, 2012)

## Summary

1. An algorithm for deriving spectral polarization state of sunlight from desert is developed.
2. PARASOL data at 3 polarized channels are used in estimating desert surface physical properties.
3. Using the physical properties of desert surface, polarization state of radiation from desert at any solar wavelength and incident and viewing geometries can be obtained with the ADRTM.
4. ~80% of the Earth surface (Ocean and Desert) polarization spectra can be modeled now.
5. Modeling for the polarization state of solar radiation from snow/ice and vegetation surface is under study.

## Reference:

Wenbo Sun, Rosemary R. Baize, Constantine Lukashin, and Yongxiang Hu, “Deriving Polarization Properties of Desert-Reflected Solar Spectra with PARASOL Data”, Atmos. Chem. Phys. (Submitted)