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

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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 \( f \quad n \quad R_L \quad \sigma \), we can calculate land surface reflection matrix elements.
Physical surface model of desert

$1-f = 5\%$ quartz-rich polarizer with facets $\quad f = 95\%$ Lambert non-polarizer

$\sigma = 0.164$
Interspecimen Comparison of the Refractive Index of Fused Silica

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

$$n^2 - 1 = \frac{0.6961663\lambda^2}{\lambda^2 - (0.0684046)^2} + \frac{0.4079426\lambda^2}{\lambda^2 - (0.1162414)^2} + \frac{0.8974794\lambda^2}{\lambda^2 - (9.896161)^2}$$

where $\lambda$ is expressed in microns was found to yield an absolute residual of $10.5 \times 10^{-4}$. 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.
Spectral aerosol optical depth characterization of desert dust during SAMUM 2006

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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

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Comparing model results with satellite data at a wavelength of 490 nm and a SZA of 28.77 deg
The image contains graphs showing the relationship between the Vertical Zenith Angle (VZA) and different metrics: DOP (Degree of Polarization) and Reflectance. The graphs are labeled with specific parameters:

- For RAZ = 90°:
  - PARASOL SZA = 27-30°
  - WL = 490 nm
  - ADRM SZA = 28.77°

- For RAZ = 270°:
  - DOP and Reflectance graphs are shown with data points and curves.
WL = 490 nm
SZA = 28.77°
ADRTM

SZA = 27-30°
PARASOL
Comparing model results with satellite data at a wavelength of 490 nm and a SZA of 56.94 deg
Comparing model results with satellite data at a wavelength of 670 nm and a SZA of 28.77 deg
**PARASOL**

$SZA = 27-30^\circ$

$WL = 670 \text{ nm}$

**ADRTM**

$SZA = 28.77^\circ$

$R \alpha = 90^\circ$

**DOP**

$VZA (\circ)$

$R \alpha = 270^\circ$

**Reflectance**

$VZA (\circ)$
WL = 670 nm
ADRTM
SZA = 28.77°
VZA (°)
RAZ (°)
AOLP (°)

PARASOL
SZA = 27-30°
VZA (°)
RAZ (°)
AOLP (°)
Comparing model results with satellite data at a wavelength of 670 nm and a SZA of 56.94°
Comparing model results with satellite data at a wavelength of 865 nm and a SZA of 28.77 deg.
WL = 865 nm
RAZ = 90°

ADRTM
PARASOL
SZA = 28.77°
SZA = 27-30°

RAZ = 90°

RAZ = 270°

Reflectance

RAZ = 270°
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°
WL = 865 nm

ADRTM
SZA = 56.94°

PARASOL
SZA = 54-57°

RAZ = 90°

VZA (°)

DOP

RAZ = 270°

VZA (°)

Reflectance

RAZ = 90°

VZA (°)

Reflectance

RAZ = 270°
Model results at a wavelength of 320 nm

**WL = 320 nm**

- **RAZ = 0°**
  - ADRTM
  - SZA = 28.77°
  - SZA = 56.94°

- **RAZ = 180°**

**VZA (°)**

- **Reflectance**
  - RAZ = 0°
  - RAZ = 180°

- **DOP**
  - RAZ = 0°
  - RAZ = 180°
Model results at a wavelength of 2300 nm

WL = 2300 nm

RAZ = 0°

ADRTM

SZA = 28.77°

SZA = 56.94°

RAZ = 180°

VZA (°)

DOP

Reflectance

VZA (°)
WL = 2300 nm
RAZ = 90° / 270°

ADRTM

SZA = 28.77°
SZA = 56.94°

VZA (°)

DOP

Reflectance

VZA (°)
WL = 2300 nm
ADRTM
SZA = 28.77°

WL = 2300 nm
ADRTM
SZA = 56.94°
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 Bevans [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.

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: