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

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

\[ P(Z_x, Z_y) = \frac{1}{\pi \sigma^2} \exp\left(-\frac{Z_x^2 + Z_y^2}{\sigma^2}\right) \quad \tan \beta = \sqrt{Z_x^2 + Z_y^2} \]

\[ Z_x = \frac{\sin \theta_v \cos \varphi - \sin \theta_s}{\cos \theta_v + \cos \theta_s} \quad Z_y = \frac{\sin \theta_v \sin \varphi}{\cos \theta_v + \cos \theta_s} \]

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

$\sigma = 0.164$

$f = 95\%$ Lambert non-polarizer
**Refractive index of quartz**

**Interspecimen Comparison of the Refractive Index of Fused Silica**

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(Received 14 May 1965)

The index of refraction of optical quality fused silica (SiO₂) was determined for 60 wavelengths from 0.21 to 3.71 μm at 20°C. The dispersion equation

\[
\frac{n^2 - 1}{\lambda} = \frac{0.6961663\lambda^2}{(0.0084048\lambda + 0.1162414\lambda^2 + 0.8974794\lambda^3} - \frac{0.4079426\lambda^3}{(0.0084048\lambda + 0.1162414\lambda^2 + 0.8974794\lambda^3} + \frac{0.8974794\lambda^4}{(0.0084048\lambda + 0.1162414\lambda^2 + 0.8974794\lambda^3}.
\]

where \( \lambda \) is expressed in microns was found to yield an absolute residual of 10.5 × 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.
Desert dust AOD

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.
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
WL = 670 nm  
RAZ = 90°

ADRTM
SZA = 28.77°

PARASOL
SZA = 27°-30°

RAZ = 270°

VZA (°)

Reflectance

VZA (°)

Reflectance
WL = 670 nm
ADRTM
SZA = 28.77°

PARASOL
SZA = 27-30°
Comparing model results with satellite data at a wavelength of 670 nm and a SZA of 56.94 deg
WL = 670 nm
ADRTM
SZA = 54-57°
SZA = 56.94°
VZA (°)
RAZ = 90°
Reflectance
VZA (°)
RAZ = 270°
WL = 670 nm
ADRTM
SZA = 56.94°

PARASOL
SZA = 54-57°
Comparing model results with satellite data at a wavelength of 865 nm and a SZA of 28.77 deg.
WL = 865 nm  \( \text{RAZ} = 90^\circ \)

ADRTM

PARASOL

SZA = 28.77°  \( \text{SZA} = 27-30^\circ \)

RAZ = 90°

\( \text{DOP} \)

\( VZA (^\circ) \)

Reflectance

\( VZA (^\circ) \)

RAZ = 270°

\( \text{DOP} \)

\( VZA (^\circ) \)

RAZ = 90°

\( \text{DOP} \)

\( VZA (^\circ) \)

RAZ = 270°

\( \text{DOP} \)

\( VZA (^\circ) \)
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°.
ADRTM
SZA = 56.94°
VZA (°)
DOP

RAZ = 90°
VZA (°)
Reflectance

RAZ = 270°
VZA (°)
Reflectance

WL = 865 nm
PARASOL
SZA = 54-57°
VZA (°)
DOP

RAZ = 90°
VZA (°)
Reflectance

RAZ = 270°
VZA (°)
Reflectance
WL = 865 nm
ADRTM
SZA = 56.94°

PARASOL
SZA = 54-57°

VZA (°)
AOLP (°)

RAZ (°)

0 30 60 90 120 150 180
0
15
30
45
60
75
90
105
120
135
150
165
180
Model results at a wavelength of 320 nm

WL = 320 nm

RAZ = 0°

ADRTM

DOP

VZA (°)

Reflectance

RAZ = 0°

RAZ = 180°

SZA = 28.77°
SZA = 56.94°
Reflectance

WL = 320 nm

ADRTM

RAZ = 90° / 270°

VZA (°)

DOP

0 15 30 45 60 75
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

SZA = 28.77°

SZA = 56.94°
Model results at a wavelength of 2300 nm

WL = 2300 nm  
RAZ = 0°

ADRTM
SZA = 28.77°
SZA = 56.94°

RAZ = 0°
WL = 2300 nm

Reflectance
VZA (°)

RAZ = 180°

Reflectance
VZA (°)
WL = 2300 nm  
ADRTM  
SZA = 28.77°  
SZA = 56.94°  
RAZ = 90° / 270°
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: