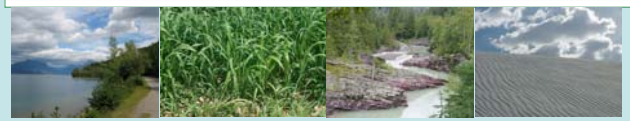
Vector 6S for Atmospheric Correction of MODIS Data



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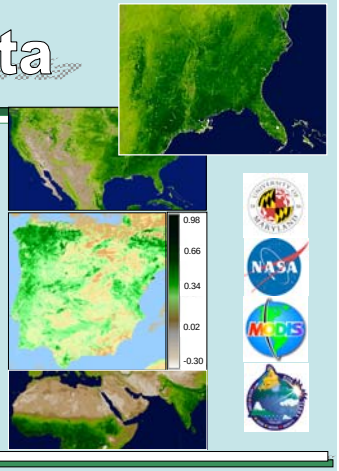

Validation of the Vector 6S

1. The first part of the validation study has been completed and summarized in the paper "Validation of a vector version of the 6S radiative transfer code for atmospheric correction of satellite data. Part I: Path radiance", S.Y. Kotchenova, E.F. Vermote, R. Matarrese, & F.J. Klemm, Jr., *Applied Optics*, 45(26), 6762-6774, 2006.

Paper abstract: A vector version of the 6S radiative transfer code (6SV1), which enables accounting for radiation polarization, has been developed and validated against a Monte Carlo code, Coulson's tabulated values and MOBY (Marine Optical Buoy System) water-leaving reflectance measurements. The developed code was also tested against the scalar codes SHARM, DISORT, and MODTRAN to evaluate its performance in scalar mode and the influence of polarization. The obtained results have shown a good agreement of 0.7% in comparison with the Monte Carlo code, 0.2% for Coulson's tabulated values, and 0.001-0.002 for the 400-550 nm region for the MOBY reflectances. Ignoring the effects of polarization led to large errors in calculated top-of-atmosphere reflectances: more than 10% for a molecular atmosphere and up to 5% for an aerosol atmosphere. This new version of 6S is intended to replace the previous scalar version used for calculation of look-up tables in the MODIS atmospheric correction algorithm.

2. The second part will include the influence of different homogeneous Lambertian and anisotropic surfaces.

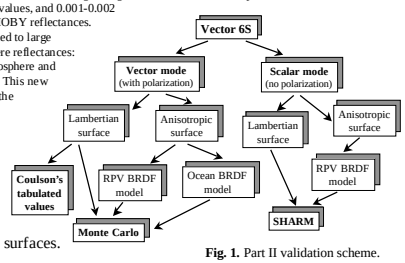

Fig. 1. Part II validation scheme.

Description of the Vector 6S

6S (**S**econd **S**imulation of a **S**atellite **S**ignal in the **S**olar **S**pectrum) is a basic radiative transfer (RT) code used for the calculation of look-up tables in the MODIS atmospheric correction algorithm. It enables accurate simulations of satellite and plane observations, accounting for elevated targets, use of anisotropic and Lambertian surfaces, and calculation of gaseous absorption.

Its first vector version (**6SV1.0B**), which accounts for the polarization of light in the atmosphere, was publicly released in May, 2005, and can be downloaded from http://6s.ltdri.org. This Web site also contains a link to the 6S interface for building input files. Information on most recent 6S updates is posted at http://rtcodes.ltdri.org.

Recent Updates

Several new subroutines, simulating measurements of the ALI, ASTER, ETM, HYPBLUE, VGT, and VIIRS instruments, have been integrated into the vector 6S.

Currently, the 6S list of satellite instruments include:

AATSR	ETM	MAS	POLDER
ALI	GLI	MERIS	SeaWiFS
ASTER	GOES	METEO	TM
AVHRR	HRV	MODIS	VIIRS
	HYPBLUE	MSS	VGT

The spectral response curves for all these instruments can be found in the 6S manual, version 3.

The new subroutines were developed by Dr. T. Miura, University of Hawaii at Manoa, Honolulu, USA.

Joint Code Comparison Project

In addition to its own elaborate validation process, 6S is participating in a joint RT scalar/vector code comparison project performed by the MODIS atmospheric correction group in collaboration with the NASA Goddard Space Flight Center. Within this project, the performance of the vector 6S is compared to the performance of several other commonly-used RT codes (Fig. 3). All information on this project, including the descriptions of the codes, conditions and results of the comparison, can be found at http://rtcodes.ltdri.org. The scalar codes have been included in the project to perform a standard evaluation of the effects of polarization under given comparison conditions.

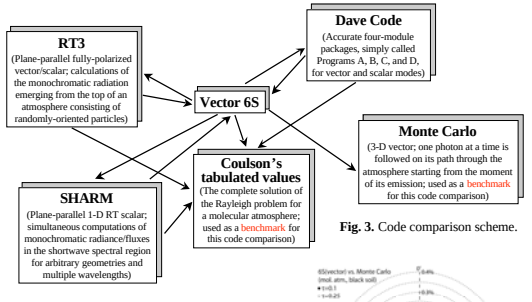

Fig. 3. Code comparison scheme.

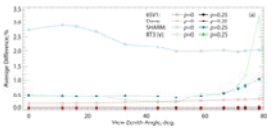

Fig. 4a. Results of the comparison for a pure molecular atmosphere with _ = 0.1.

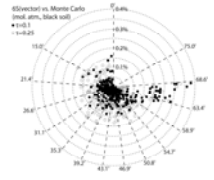

Fig. 5. Results of the comparison of the vector 6S and Monte Carlo.

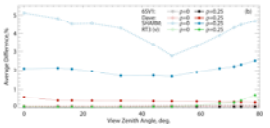

Fig. 4b. Results of the comparison for a pure molecular atmosphere with _ = 0.25.

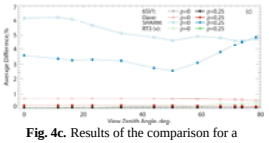

Fig. 4c. Results of the comparison for a pure molecular atmosphere with _ = 0.5.

Effects of Polarization

The effects of polarization are demonstrated here through the comparison between 6S vector and scalar simulations of top-of-atmosphere (TOA) reflectances. The comparison has been performed under the following conditions:

1. Molecular atmosphere:
Accepted as modeled in 6S on the basis of the standard US62 pattern.

2. Aerosol atmosphere:
Modeled based on the AERONET data collected over Midway Islands on January 31st, 2002.

Midway Islands is a coral atoll in the Pacific Ocean located 2,334 km northwest of Honolulu near the end of the Hawaiian Archipelago (28.12°N, 177.22°W). It is characterized by a subtropical climate with cool, moist winters (December to February) and warm, dry summers (May to October), moderated by prevailing easterly winds.

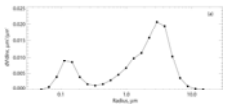

Fig. 2a. Average volume size distribution of aerosol particles, measured by AERONET over Midway Islands.

3. Geometrical conditions:
A wide range of possible geometrical configurations.
SZA = {0.0°, 10.0°, 23.07°, 45.0°, 58.67°, 75.0°};
VZA = {0°-79°}; AZ = {0°, 90°, 180°}.

4. Spectral conditions:
MODIS band 3 (0.45 – 0.4825 nm)
MODIS band 4 (0.54 – 0.57 nm)

5. Ground boundary:
- Lambertian surface with _ = 0.3
- Ocean surface simulated by the Ocean Model embedded in 6S on the basis of the following parameters:
  wind speed = 11 m/s
  wind direction = 30° (measured clockwise from the North)
  salt concentration = 35 ppt
  pigment concentration = 0.3 mg/m^3 (Chlorophyll a + Pheo a)

Results of the Comparison:

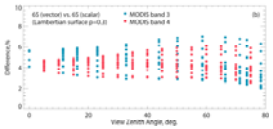

Fig. 2b. Effects of polarization for the mixed (aerosol + molecular) atmosphere bounded by the Lambertian surface.

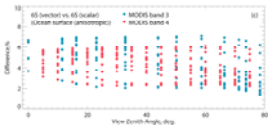

Fig. 2c. Effects of polarization for the mixed (aerosol + molecular) atmosphere bounded by the ocean surface.

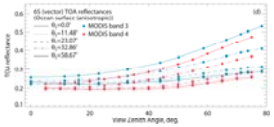

Fig. 2d. TOA reflectances for the mixed atmosphere as calculated by the vector 6S (for AZ = 90°).

Conclusions:

Ignoring the effects of polarization has led to large errors in the calculated TOA reflectances. The maximum relative error is more than 7% for both Lambertian and ocean surfaces (error = ((vector – scalar)/vector)*100%). Therefore, the accounting for radiation polarization is extremely important for atmospheric correction of remotely sensed data, especially those measured over dark targets, such as ocean surfaces or dark dense vegetation canopies.