EVALUATION OF THE LAND SURFACE REFLECTANCE FUNDAMENTAL CLIMATE DATA RECORD

Roger, Jean-Claude[1,2], *Vermote, Eric*[2], *Skakun, Sergii*[1,2], *Emilie Murphy*[1,2], *Holben Brent*[3], *Justice, Christopher*[1]

[1] Department of Geographical Sciences, University of Maryland, College Park, MD, USA
[2] Terrestrial Information System Branch-Code 619, NASA/GSFC, Greenbelt, MD, USA
[3] Biospheric Science Branch-Code 618, NASA/GSFC, Greenbelt, MD, USA
Corresponding email: roger63@umd.edu

ABSTRACT

The land surface reflectance is a fundamental climate data record at the basis of the derivation of other climate data records (Albedo, LAI/Fpar, Vegetation indices) and has been recognized as a key parameter in the understanding of the land-surface-climate processes. In this presentation, we present the validation of the Land surface reflectance used for MODIS, VIIRS, Landsat 8 and Sentinel 2 data. This methodology uses the 6SV Code and data from the AERONET network. The overall accuracy clearly reaches the satellite specifications. To understand how to improve the validation, we developed an exhaustive error budget. Results show an impact of the absorption of aerosol and of the fine mode volume concentration.

Index Terms – Atmospheric correction, validation, AERONET, MODIS, VIIRS, L8, S2.

1. INTRODUCTION

The land surface reflectance is a fundamental climate data record at the basis of the derivation of other climate data records (Albedo, LAI/Fpar, Vegetation indices) and a key parameter in the understanding of the land-surface-climate processes.

It is essential that a careful validation of its uncertainties is performed on a global and continuous basis. One approach is the direct comparison of this product with ground measurements but that approach presents several issues related to scale, the episodic nature of ground measurements and the global representativeness. An alternative is to compare the surface reflectance product to reference reflectance determined from Top of atmosphere reflectance corrected using accurate radiative transfer code and very detailed measurements of the atmosphere obtained over the AERONET sites which allows to test for a large range of aerosol characteristics; formers being important inputs for atmospheric corrections [1] [2] [3] [4].

However, the application of this method necessitates the definition of a very detailed protocol for the use of AERONET data especially as far as size distribution and absorption are concerned, so that alternative validation methods or protocols could be compared [5]. In a previous work, we presented the rough protocol of the method applied for MODIS and VIIRS. This paper describes the new protocol in detail with an exhaustive error budget.

2. PROTOCOL FOR GENERATING THE AEROSOL MODELS FROM AERONET DATA.

The first part was to define a protocol to use the AERONET data. To correctly take into account the aerosol model, we used the aerosol microphysical properties provided by the AERONET network including size-distribution ($\%C_f$, $\%C_c$, r_f, r_c, σ_r, σ_c), complex refractive indices and sphericity. Over the 670 available AERONET sites, we selected 230 sites with sufficient data.

To be useful for validation, the aerosol model should be readily available anytime, which is rarely the case due to satellite overpassing time (no almucantar protocol measurement + partial cloud cover…).

$\%C_f$	r_f	σ_f	$\%C_c$	r_c	σ_c	n_r	n_i	%sp
23%	14%	11%	21%	15%	8%	3%	55%	21%

Table 1: Global relative percentage of the Uncertainties for the retrieval of each microphysical parameters over the 230 AERONET Sites

Following *Dubovik et al.*, 2002 [6] approach, we used regressions for each microphysical parameters using as parameter τ_{440} and α (*Angström* coefficient). Comparisons with the AERONET dataset indicate APU (Accuracy-Precision-Uncertainties) up to 30% less than while using directly Dubovik's 2002 approach for each parameter (with τ_{550} only).

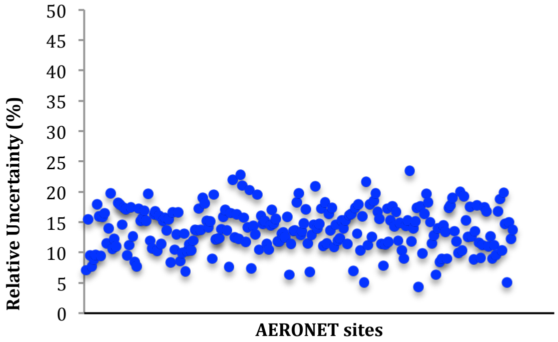


Figure 1: Relative percentage of the Uncertainties of the retrieved fine mode radius.

Table 1 gives details of the global relative percentage of the uncertainties for the retrieval of each parameters and Figures 1 and 2 highlighted an example of those APU for the fine mode radius of aerosols, respectively in relative percentage for all sites and in absolute versus the aerosol optical thickness τ_{550} .

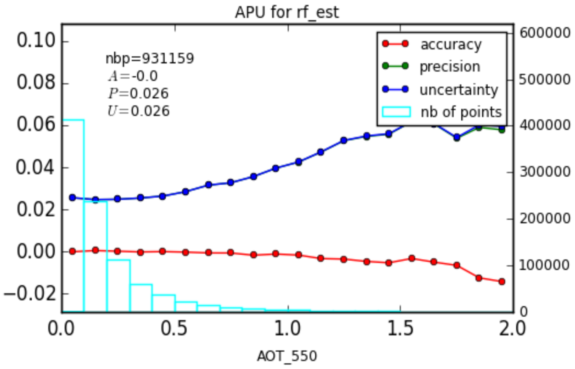


Figure 2: Same than Figure 1 but for the absolute uncertainties versus the aerosol optical thickness.

3. REFERENCE FOR THE VALIDATION OF THE SURFACE REFLECTANCES

The second part of the study relies on the theoretical land surface retrieval. We generated TOA synthetic data using aerosol models from AERONET (20 different models for each site and 80 geometrical conditions) and determined APU on the surface reflectance retrieval while applying the MODIS, VIIRS, Landsat 8 and Sentinel 2 Atmospheric correction software. Over more than a hundred AERONET sites, the global uncertainties are reported Figure 3 for MODIS band 1 (red channel) versus the atmospheric reflectance in the MODIS band 3 (blue channel).

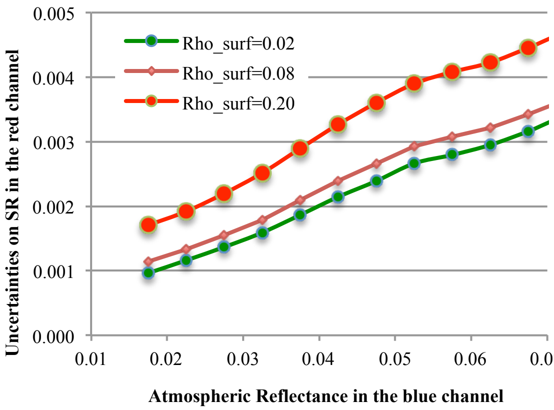


Figure 3: Uncertainties in the MODIS Red channel versus the atmospheric reflectance in the MODIS Blue channel for the 230 AERONET Sites.

The new protocol allows us to define a reference (for surface reflectance validation) with an uncertainty in the MODIS red channel (as an example) always lower than 0.004 in term of surface reflectance for the 230 AERONET Sites (which is much lower than required specifications), Figure 4.

For a mean loaded atmosphere, τ_{550} less than 0.25, the maximum uncertainty is 0.0025 corresponding to a relative uncertainty (in the MODIS RED channel) :

$$U < 1\% \quad \text{for } \rho_{surf} > 0.10$$
$$1\% < U < 2\% \quad \text{for } 0.10 > \rho_{surf} > 0.04)$$

The result can be easily generalized to other satellites (VIIRS, Landsat 8 and Sentinel 2 – not shown here).

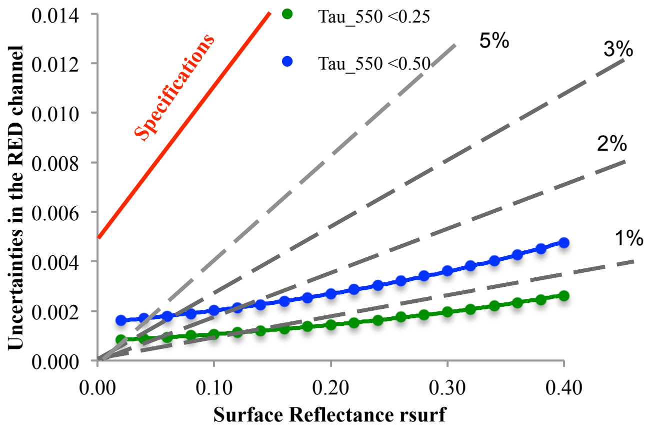


Figure 4: Same than Figure 3 but versus the surface reflectance.

To go further in detail, a study was performed to estimate the impact of the uncertainties of our aerosol models (represented by the 9 components given Table 1) on the surface reflectance to be used for validation. Table 2 shows results for the MODIS Red Channel and, as expected, the imaginary part of the refractive index (i.e. absorption) generated the highest part of the uncertainties followed by the radius of the fine mode.

4. APPLICATION TO SATELLITE DATA

Last step, we then applied this approach to real MODIS, VIIRS, Landsat 8 and Sentinel 2 data. As an example, Figures 5 and 6 shows respectively the APU for the whole 2003 year data set for the MODIS band 1 (red channel) and whole 2015 year data set for the Landsat 8 band 4 (red channel). In both cases, uncertainties are lower than the required specifications (magenta line).

Finally, Figures 7 show of APU for Landsat-8 according a pixel classification (here we only provide examples of croplands, urban and forest pixels).

The conclusion of this second part is that the new protocol, using τ_{440} and α, gives uncertainties lower than 30% in MODIS band 1 (red) and 15% in MODIS band 3 (blue) than the previous one.

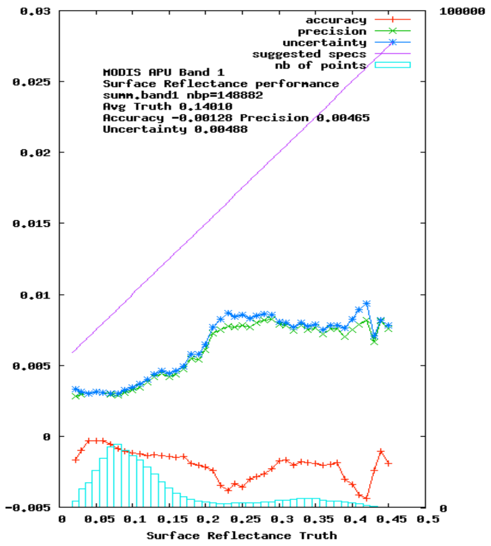


Figure 5: APU for MODIS band 1 (red) for the whole 2003 year data set applying the new method.

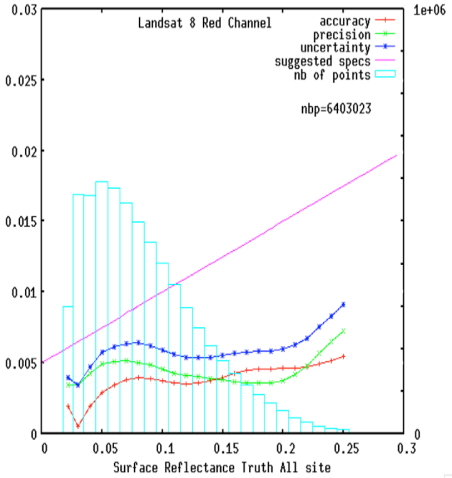
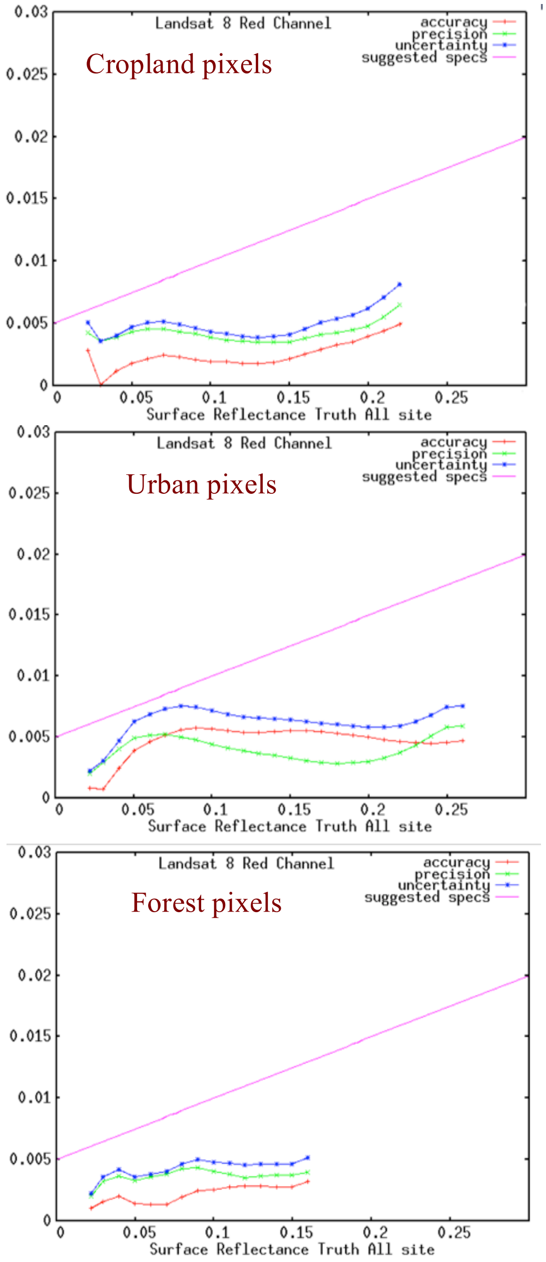


Figure 6: APU for Landsat-8 band4 (red) for the whole 2015 year data set applying the new method.

	$\%C_f$	r_f	σ_f	$\%C_c$	r_c	σ_c	n_r	n_i	%sp
Input	23%	14%	11%	21%	15%	8%	3%	55%	21%
U on surf. Refl.	1.5E-04	**4.5E-04**	4.6E-05	1.5E-04	5.7E-05	3.1E-05	**3.7E-04**	**1.1E-03**	5.5E-05

Table 2: Surface reflectance uncertainties (in the MODIS RED channel) due to the aerosol model uncertainties (all surface reflectances)



Figures 7: Examples of APU for Landsat-8 band4 (red) for the whole 2015 year data set according a pixel classification.

5. REFERENCES

[1] Vermote E.F., Claverie, M., Franch, B., Justice C, 2015, Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product, Remote Sensing of Environment, 185, 46-56.

[2] Vermote E.F., El Saleous N, Justice C, 2002, Atmospheric correction of the MODIS data in the visible to middle infrared: First results, Remote Sensing of Environment, 83, 1-2, 97-111.

[3] Kotchenova, S. Y., & Vermote, E. F., 2007, Validation of a vector version of the 6S radiative transfer code for atmospheric correction of satellite data. Part II. Homogeneous Lambertian and anisotropic surfaces. Applied Optics, 46(20), 4455-4464.

[4] Vermote, E.; Justice, C.; Csiszar, I., 2014, Early evaluation of the VIIRS calibration, cloud mask and surface reflectance Earth data records, *Remote Sensing of Environment*, 148, 134-145.

[5] Holben B.N., Eck T.F., Slutsker I., Tanré D., Buis J.P., Setzer A., Vermote E.F., Reagan J.A., Kaufman Y.J., Nakajima T., Lavenue F., Jankowiak I., Smirnov A., 1998, AERONET - A federated instrument network and data archive for aerosol characterization, Remote sensing of Environment, 66:(1) 1-1

[6] Dubovik, O., B.N.Holben, T.F.Eck, A.Smirnov, Y.J.Kaufman, M.D.King, D.Tanre, and I.Slutsker, 2002: Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J.Atm.Sci.*, **59**, 590-608