Relative and multitemporal calibration of AVHRR, SeaWiFS, and VEGETATION using POLDER characterization of desert sites.

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Abstract

This paper presents the last results of a continuing study aiming at a better characterization of desertic sites for satellite borne optical sensors calibration. The study relies on the gathering of long term archive of satellite data and coincident atmospheric variables, and use of physical properties of the surface as extracted from POLDER measurements, over a set of carefully selected desertic sites in North Africa and Saudi Arabia. All these data sets are included in a repository specifically designed which is also presented.

Results are included for AVHRR/NOAA14, SeaWiFS and VEGETATION from 1996 up to present and extension to MODIS and MISR are presented.

1. INTRODUCTION

The ever increasing amount of data acquired by Earth observing satellites has reached paramount importance with the launch of TERRA. Still, the use of these newly acquired data sets will rely heavily on the use of existing archives. Availability of long term series (more than 10 years) allows analysis of major trends regarding terrestrial environment or climate change. Inter calibration of past, present and future sensors is therefore a major issue for the use of these archives as well as forthcoming measurements.

One way to address this issue is to rely on the stability and the monitoring of satellite-borne instruments by means of onboard calibrating devices. But, even when available, onboard calibrating devices are not sufficient to ensure consistent intercalibration due to the wide diversity of crossing times, spectral responses, sampling techniques and period of life. To account for all these differences, one has to apply techniques known as vicarious calibrations to the intercalibration problem.

Making this techniques easy to apply on a routine basis, it has been found necessary to build a repository able to include large time series of measurements from various sensors, over selected targets, along with ancillary information. A more complete description of this repository and all the data types it has to contain can be found in Cabot, 1997.

1. DATA SETS

The selected data sets included in this repository span almost three years, starting from the beginning of life of POLDER onboard ADEOS in early November 1996. Since then, we have been gathering measurements from AVHRR over the whole period, SeaWiFS and VEGETATION as Orbview-2 and SPOT4 were launched. Beside these data sets, ancillary data such as water vapor content from ECMWF or NCEP and ozone content from TOMS (onboard ADEOS then onboard Earth Probe) are also acquired routinely. Figure 1 shows period of time covered by the various data sets.

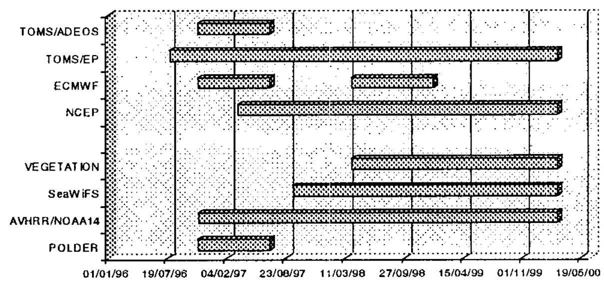

Figure 1. Periods covered by the different data sets

All the data sets acquired by the various instruments go through the same processing including calibration using preflight coefficients (except for AVHRR, for which the coefficient of the beginning of the period is used), cloud and high aerosol contamination screening, and averaging over the 100x100km² area. Results of these processing, along with geometry and atmospheric information are stored in a database which contains (as of 04/01/00) more than 56000 multispectral measurements of TOA reflectances over the 20 desertic sites.

2. METHODS

Despite the relatively short period of operation of POLDER onboard ADEOS - and thanks to unique POLDER capabilities - we have been able to gather enough data to characterize the surface bidirectional reflectance of desertic sites for solar zenith between 10° and 50° and for view zenith angles up to 60°, in a spectral domain ranging from 443 nm to 865 nm. This data set is used as a reference and made comparable to measurements from other instruments through spectral interpolation and atmospheric effects correction.

In order to minimize needed assumptions, we choose not to introduce any model for surface bidirectional effects. The comparison are conducted only when we can find a match between geometries in the reference and in the measured data sets.

The intercalibration process can be summarized according to figure 2.

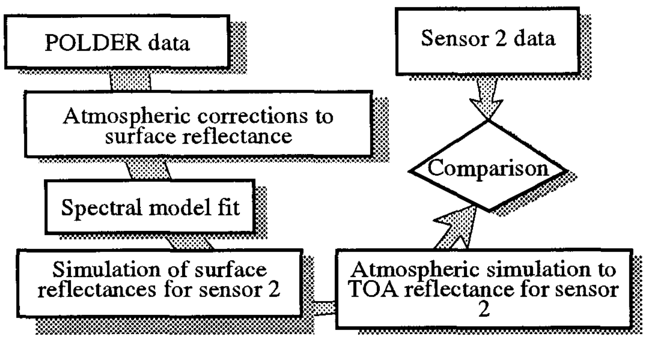

Figure 2. Basic principle for the method, for estimating reference reflectance from POLDER data

When a match is found in acquisition geometry between POLDER and any other sensor, the POLDER measurements is corrected for atmospheric effects to surface reflectance, considering the state of the atmosphere at time of POLDER acquisition, for all the useful POLDER bands. This spectral surface reflectance is used to fit a continuous spectral model, which is integrated according to the spectral response of the other sensor to produce surface reflectance in sensor 2 spectral bands. These reflectances are used to compute TOA reflectance considering the state of the atmosphere at time sensor 2 acquisitions. Intercalibration is then achieved by comparing this reference value to the sensor 2 measurement.

This process is detailed in Cabot et al., 1999.

3. RESULTS

The results presented here consist in monthly means of calibration coefficients for each sensor. Figures 3 through 5 show the temporal evolution of the retrieved calibration coefficients for the 3 sensors in blue, red and near infrared domains.

Table 1 - Results of calibration with reference to POLDER

	412	443	490	510	555	670	765	865
SeaWiFS	0.977	1.091	1.062	1.038	1.009	0.999	1.014	0.988
	-0.03	*-0.08*	*-0.02*	*-0.02*	*-0.01*	*-0.02*	*-0.08*	*-0.29*
VGT	B0			B2			B3	
	1.012	*-0.28*		0.927	*-0.14*		0.977	*-0.07*
AVHRR		C1			C2			
		1.018	*-0.06*		1.045	*0.05*		

Each graph show the results of our comparisons (circles), the linear trend derived from these (solid line) and the temporal evolution of the calibration coefficient as provided by each instrument team (dashed line).

Table 1 shows all the results for the three sensors. The given coefficients are relative to preflight calibration. Italic figures represent the linear temporal trend estimated from our results, expressed in terms of %/month.

3.1. AVHRR

Trends estimated from our comparisons appear slight when compared to what is estimated by Rao and Chen and made available on NOAASIS web site. The absolute level is also a concern and will be discuss below. Still, little evidence of a seasonal behavior seems favor the good accounting for directional effects, especially concerning illumination geometry. Unfortunately, due to the orbital shift of NOAA-14, the range of solar zenith angles available during winter is now above 60° and comparison is not possible for longer periods. As of end of February, no occurrence have yet been found for year 2000.

3.2. SeaWiFS

The agreement, in terms of temporal evolution, with results from Barnes *et al* 1999, is good. The temporal trends of all the bands, including bands 1 through 6, as stated by SeaWiFS project for reprocessing 3 are in close agreement with what is estimated from lunar and solar observations. The absolute level, especially for 443nm band is a major concern. The disagreement of nearly 10% is well beyond the accuracy of the method and of the claimed accuracy for both sensors.

The case of band 443nm can be explained by recently discovered - through analysis of these comparisons - problems in the POLDER data sets, leading to inconsistencies between long and short integration time that have been used for this band throughout POLDER life. This behavior can have impacts in other bands as far as the spectral interpolation is concerned and, at a lesser extend, if the detector itself (which is common to all bands) is involved. This has to be kept in mind when examining results for all sensors since all present problems in absolute levels. For instance, the continuous decrease of the retrieved calibration coefficients for SeaWiFS bands 2 through 6 (443 nm to 670 nm) is probably an effect of an incorrect behavior at 443nm, yielding incorrect spectral model.

At last, the seasonal evolution that can be observed in all bands has to be investigated. The fact that its amplitude decreases with increasing wavelength lets suspect atmospheric perturbation as seasonal evolution of the aerosol optical thickness. To try to evaluate if this can be the source of this evolution, we simulated the temporal evolution of a desert target, using 6S with a surface reflectance as given by Rahman *et al.*, 1993 model and aerosol optical thicknesses taken from Tegen and Fung, 1994. The simulations show seasonal variations around 5%, with a maximum in winter for 443 nm and around 2% with a summer maximum for 670 nm. This is in good agreement with what is observed on figures 3 and 4. This effect will be investigated more finely as global measurements of aerosol optical thickness become available.

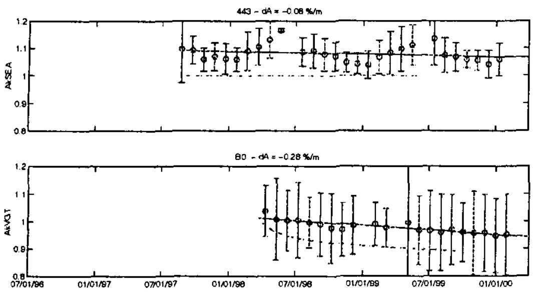

Figure 3. Calibration coefficients for SeaWiFS at 443nm (top) and VEGETATION B0 band (bottom). Dashed lines represent the calibration as provided by project teams.

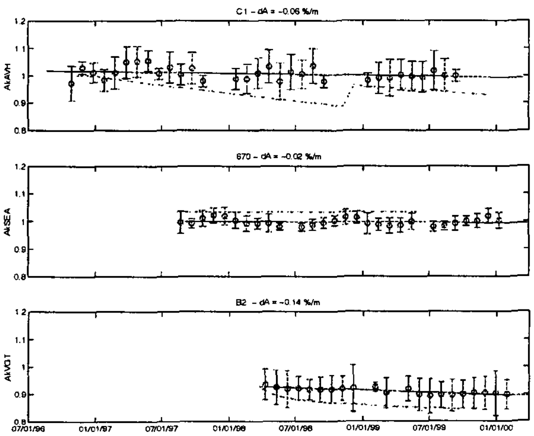

Figure 4. Calibration coefficients for AVHRR channel 1 (top), SeaWiFS at 670 nm (center) and VEGETATION B2 band (bottom)

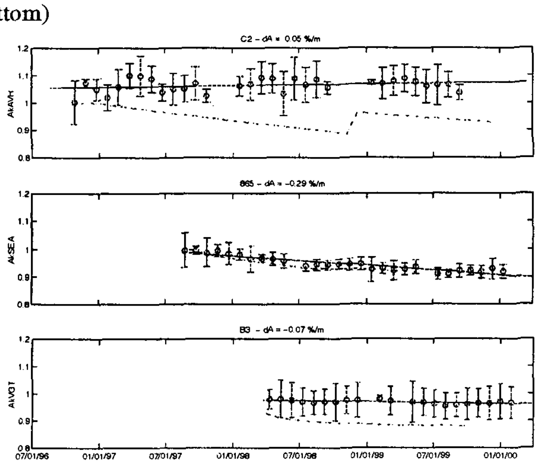

Figure 5. Calibration coefficients for AVHRR channel 2 (top), SeaWiFS at 865 nm (center) and VEGETATION B3 band (bottom)

3.3. VEGETATION

In the case of the VEGETATION instrument, we have to underline that, despite a global disagreement in terms of absolute level, the temporal trend is in very good agreement with what is estimated from measurements conducted with the onboard lamp.

4. CONCLUSION

In this paper are presented results and potentialities offered by the continuous monitoring of desertic sites over extensive periods of time. From this close monitoring, we are able to describe accurately the temporal evolution of various sensors sensitivity. Beside, our knowledge of the sites and overlying atmosphere is also increasing, giving positive feed back to the accuracy we can expect for the intercalibration.

The comparison of various sensors is also proven to be beneficial to all sensors, whether they are used as reference or for comparison.

The repository that was used in this study is now ready to store data from other sensors, as will be done in the next months, including MODIS and MISR onboard Terra. Preliminary comparisons with ATSR-2 onboard ERS-2 have also been conducted with promising results and will be completed in the near future.

References

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