CERES SCALES GROUND VALIDATION CAMPAIGNS FOR GERB. ASSESSMENT OF THE *VALENCIA ANCHOR STATION* CAPABILITIES
(In the framework of EUMETSAT/ESA MSG-RAO Project no. 138 *GIST Proposal for Calibration/Validation of SEVIRI and GERB* (PI: J.E. Harries)

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ABSTRACT/RESUME

The *Valencia Anchor Station* (VAS) was set up by the *University of Valencia* at the natural region of *Utiel-Requena Plateau* in 2001. The plateau is a large and reasonably homogeneous area suitable for validation of low spatial resolution satellite data and products such as GERB's. In the framework of the EUMETSAT/ESA MSG-RAO Project no. 138 *GIST Proposal for Calibration/Validation of SEVIRI and GERB*, and of the *Spanish Research Programme on Space* Project SCALES (*SEVIRI & GERB Cal/Val Area for Large-scale Field ExperimentS*), three GERB ground validation campaigns have so far been carried out at the VAS under different land surface conditions. CERES instruments onboard NASA EOS *Aqua* and *Terra* satellites, operating in PAPS (*Programmable Azimuth Plane Scanning*) mode, have generously provided additional SW and LW radiance measurements to support validation efforts. These have shown to be most valuable as intermediate validation step between ground measurements and the large GERB pixel size.

1. INTRODUCTION

Calibration/Validation, or simply "*Cal/Val*", is the activity that endeavours to ensure that remote sensing products are highly consistent and reproducible. This is an evolving discipline that is becoming increasingly important as more long-term studies on global change are undertaken, and new satellite missions are launched. *Calibration* is the process of quantitatively defining the system responses to known, controlled signal inputs. *Validation* is the process of assessing, by independent means, the quality of the data products derived from the system outputs [1]. Agencies usually undertake the calibration of their respective mission satellite systems, however to extend this beyond the *commissioning phase* is potentially very difficult. Thus, well-instrumented benchmark test sites and data sets for calibration should be supported, particularly for land applications, to provide calibration information to supplement or substitute for on-board calibration, in a coordinated way, and ensuring continuity, and reliability to access to their data with minimal delay.

The primary objective of validation is to assess the quality, and as far as possible quantify the accuracy of remote sensing products. Ideally, validation activities seek to compare data products to more accurate independent measurements of the same quantity over a statistically significant number of samples and wide variety of situations. The problem is that the space and time scales of *in-situ* and satellite data are rarely directly comparable. Typically, there are insufficient *in-situ* measurements to cover a satellite field of view,

Proceedings of the 3rd MSG RAO Workshop, 15 June 2006, Helsinki, Finland
(ESA SP-619, August 2006)

whether the field of view is some meters (high resolution imagers) or several km (broadband radiometers). Even a perfect remote sensing measurement will differ from *in-situ* verification measurements due to the inability to match the observations in time or space. *In-situ* measurements are invariably taken at small space and time scales, while a satellite overpass is a few second snapshot of a large area. The matching error can be reduced (but not eliminated) by increasing the number of surface observations within the field of view (level 2 data) or grid box (level 3 data). It can also be minimized by using very large ensembles of matched data.

The *Valencia Anchor Station* (VAS) was set up by the *University of Valencia* at the Spanish natural region *Utiel-Requena Plateau* (Valencia, Spain) in 2001. The *plateau* is a large and reasonably homogeneous area suitable for validation of low spatial resolution satellite data and products such as GERB's.

In the framework of the EUMETSAT/ESA MSG-RAO Project no.138 *GIST Proposal for Calibration/Validation of SEVIRI and GERB*, and of the Spanish Research Programme on Space Project SCALES (*SEVIRI & GERB Cal/Val Area for Large-scale field ExperimentS*), three GERB ground validation campaigns have so far been carried out at the VAS under different land and atmosphere surface conditions. During these campaigns, CERES instruments onboard the NASA EOS *Aqua* and *Terra* satellites have generously provided additional radiance measurements to support validation efforts, which have shown to be most valuable as an intermediate validation step between ground measurements and the large GERB pixel size.

2. THE *VALENCIA ANCHOR STATION*

The main objective of the SCALES Project has been to develop an adequate methodology to validate large scale remote sensing products, specifically addressed to the GERB instrument [2], and for that we counted on a suitable reasonable homogeneous site at GERB's scale, the *Valencia Anchor Station*, robustly equipped with standard meteorological instruments and with a large suite of mobile instruments to account for the site non-homogeneities. It is placed in a reasonably homogeneous and flat area of about 50x50 km^2, mainly dedicated to vineyard crops, at about 80 km West of the city of Valencia. The area includes other typical Mediterranean ecosystem species such as shrubs, olive and almond trees and alepo pine forests, being the latter only present in a small mountain formation in the area (Figs. 1 and 2) [3]. According to the land use classification of Fig. 2, and considering that in winter vineyards have the same behaviour as bare soil, we may assume that the area is composed of about 76.6 % bare soil and 23.4 % vegetation (mainly matorral, shrubs and pine trees) at CERES footprint scale, and of about 33% bare soil and 67% vegetation at GERB footprint scale.

The excellence of the CERES (*Clouds and the Earth's Radiant Energy System*) instrument, particularly its versatile special programmable scanning modes targeting the *Valencia Anchor Station*, has enable us not only to assess the suitability of the site for large scale observations, but also to validate our methodology which clearly has shown to be capable of independently reproducing top of the atmosphere (ToA) CERES SW and LW radiances in a highly extense now dataset of situations [4], including a large variety of surface and atmospheric conditions.

Figure 1. The Valencia Anchor Station

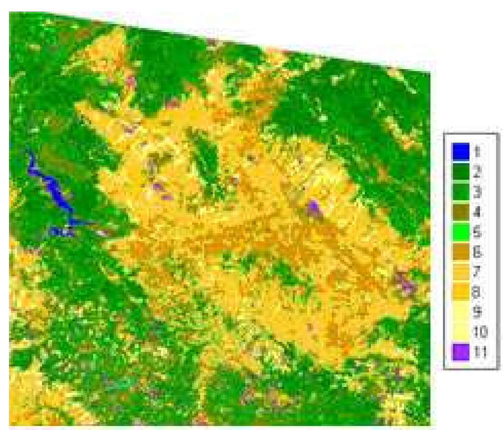

Figure 2. Land use classification of the Valencia Anchor Station area (LANDSAT-TM5 of 5th July 2003). Classes: 1.water, 2. pine trees, 3. low density pine trees and shrubs, 4. shrubs, 5. irrigated crops, 6. vineyards, 7. low density vineyards, 8. very low density vineyards, 9. herbal crops, 10. bare soil, 11. urban areas [6]

3. GERB GROUND VALIDATION CAMPAIGNS

During the three field campaigns, apart from the valuable CERES SW and LW observations, atmospheric and ground measurements were taken by sun photometer, GPS precipitable water content, on-purpose radiosounding ascents, *Anchor Station* operational meteorological measurements including the 4 radiation components at 2m. Mobile stations were used to characterize the rather large extense area, including a mobile air-quality station from the Regional Government of Valencia (*Directorate General for Environmental Quality*) in the February 2004 campaign. The first campaign took place between 18-24 June, 2003, and also included some lidar measurements carried out by the *Electromagmetic Engineering and Photonics Group*, *Polytechnic University of Catalonia*. The second one developed between 9-12 February, 2004, and the third one between 12-18 September, 2005, included full coverage of a sun-tracking photometer from the *Solar Radiation Group* of the *University of Valencia*. These activities were carried out within the GIST (*GERB International Science Team*) framework.

This paper describes the instrumental set up and deployment during the ground campaigns, the data obtained from the ground, the exclusive CERES PAPS observations over the VAS and the results of analyses and good comparisons between ToA measurements and radiative transfer simulations that confirm the good capabilities of the station to get reliable independent products to be used for the validation of GERB [5]. The work includes a realistic BRDF estimation for the large-scale study area and *Streamer* [6] radiative transfer simulations of ToA SW and LW radiances under clear and cloudy sky conditions. For cloudy sky simulations, MODIS data has been used to get the necessary input cloud parameters.

4. USE OF CERES PAPS OBSERVATIONS AS AN ASSESSMENT OF THE *VAS* CAPABILITIES FOR VALIDATION OF LOW SPATIAL RESOLUTION DATA AND PRODUCTS

To be able to reproduce CERES observations from independent ground and atmospheric measurements, it is necessary to properly characterize the surface and the atmosphere. The methodology has gradually been developed, first starting with CERES ES8 data [7-8] and is taking its final shape by using the more accurate CERES SSF (*Single Scanner Footprint*) data [9].

In summary, atmospheric profiles needed as input for the *Streamer* simulations are of three types:

- Radiosoundings ascents, generously provided by the *Spanish Meteorological Institute* (INM), launched on spot, during both *Terra* and *Aqua* CERES overpassing times. The water vapour profile is obtained by scaling total water vapour content to the integrated water vapour measured by the GPS system. The correlation between both set of measurements is really high [7-9]
- Aerosol profile, from *Streamer* Mid-Latitude Winter/Summer (MLW/MLS, depending on the season) standard atmosphere profile, assuming background tropospheric aerosols and background stratospheric aerosols, with the aerosol optical depth obtained from on-ground sun-photometer transmissivity measurements
- Ozone profile, also from *Streamer* MLW/MLS but scaled to the TOMS (*Total Ozone Mapping Spectrometer*) corresponding measurement (http://toms.gsfc.nasa.gov)

As far as surface parameters are concerned:

- Surface emissivity [10] is obtained from CERES/SARB (*Surface and Atmospheric Radiation Budget)* database (http://www-surf.larc.nasa.gov/surf/)
- Surface temperatures were measured at the VAS and at the mobile stations, weighting up the respective contribution of each one in the whole area by taking into account the land use classification of the study area (Fig. 2)
- Surface BRDF for the whole area is estimated from three contributions, namely broadband albedo weighted from those measured at the VAS and at the mobile station (a_0^{BB}), spectral albedo for the same type of soil from the *ASTER Spectral Library John Hopkins University* (a_λ^{JHU}), and from bidirectional reflectance measurements ($\rho_\lambda(\theta_0, \theta, \phi)$) over bare soil from Ahmad and Deering [11]. See [7-9] for the details

The satellite data used proceed from the specific CERES PAPS acquisitions generously programmed by the *CERES Science Team*. The CERES data finally used are CERES SSF data products which contain CERES PSF (*Point Spread Function*) weighted imager (MODIS) parameters that will be useful to simulate cloudy sky conditions. For Terra FM2, Edition 2B data were used and for Aqua FM3, Edition 1B.

We are here showing results corresponding to the February 2004 campaign with the period 10th to 12th under perfect clear sky conditions as we infer from SSF cloud parameters and from radiation measurements carried out at the VAS. The 9th of February is classified as cloudy with cloud percent cover between 99% and 100% for about 78% of the footprints and between 40% and 99% for the rest of the data. All footprints are classified as one level, liquid water, low cloud with effective pressure above 680 mb, and with optical thickness over 22.63. Some SSF parameters were selected as inputs for *Streamer* simulations such as cloud top pressure, cloud optical thickness, cloud effective radius, and cloud liquid water path (Fig. 5).

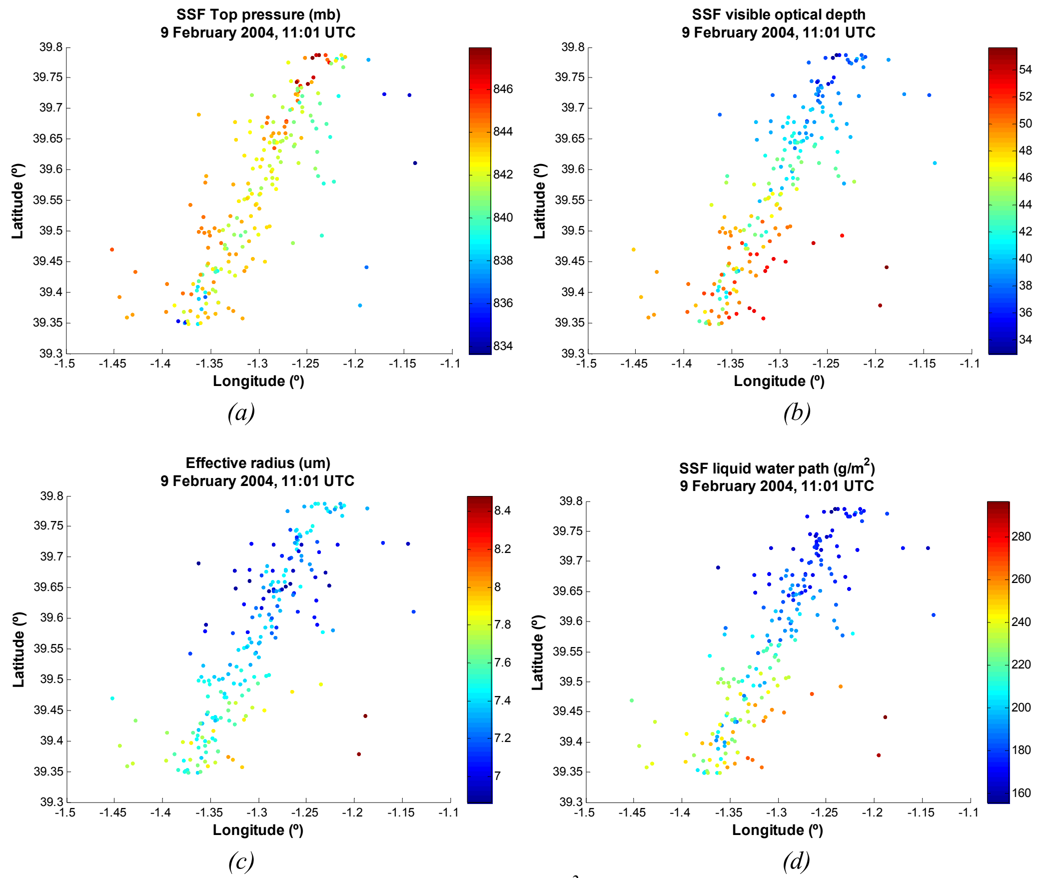

Figure 5. SSF cloud parameter products for the whole 50x50km^2 area: (a) SSF-93, mean cloud top pressure (mb), (b) SSF-83, mean visible optical depth (c), SSF-103, mean water particle radius, (d) SSF-89, mean liquid water path (g/m^2)

4.1. ToA Radiance Comparisons

A sample of the results of the radiance simulations performed is shown in Figs. 6-8. The left hand side image of each picture shows the observation geometry in a polar plot where we can also see the magnitude of the SW radiances for the full CERES PAPS acquisition pass. The right hand side image of each picture shows the comparison between *Streamer* simulations and CERES ToA radiances (SW and LW). In all cases it is easy to see the radiance anisotropy between the forward and backward scattering directions.

Under clear sky conditions (Figs. 6-7), the agreement is good between satellite data and simulations. In all the cases analysed, the backward radiances are always higher than the forward ones, both in the SW and, less pronounced, in the LW. This anisotropy varies with RAA, with a minimum in the orthogonal plane (plane where observation and illumination planes are orthogonal) and with a maximum in the principal plane (when those planes are colinear). Anisotropy on clear sky scenes depends on SZA, specially in the SW, being the LW dependence possibly due to changes in boundary layer temperatures during the day [12].

For the cloudy conditions of 9th of February (Fig. 8), we can see that the forward scattering radiances are much higher than the backward ones. The comparison between CERES ToA SW radiances and simulations shows an overestimation of the modeled radiances in the forward scattering direction, being these differences greater as VZA increases. However, there is a really good agreement between CERES ToA LW radiances and *Streamer* simulations. Differences between simulated and measured shortwave radiances may be due to small changes in droplet size that could induce large changes in cloud albedo. Accurate determination of microphysical properties of boundary layer stratus is essential for the correct treatment of these clouds in radiative transfer and global climate models [13]. It is definitely necessary to properly measure cloud parameters from the ground.

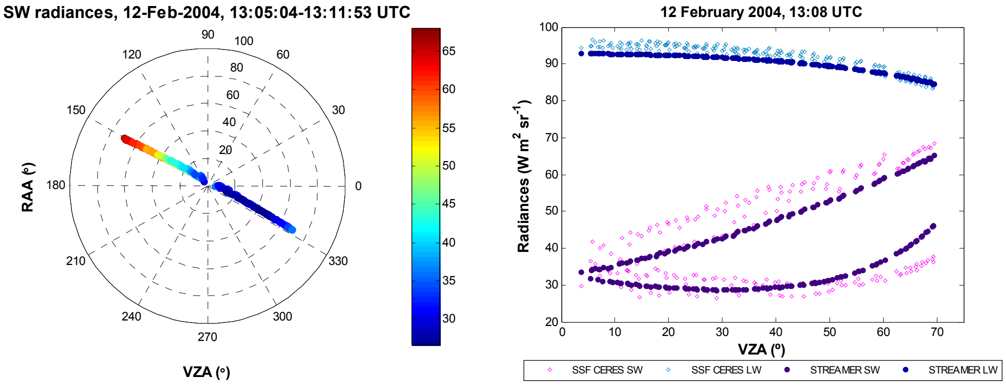

Figure 6. Results for Terra FM2 CERES PAPS observations on 12th February 2004. (Left): CERES ToA SW radiances and observation geometry (almost nadir acquisitions along the full PAPS). Radial axis corresponds to VZA and azimuthal direction to RAA. (Right): Comparison of Streamer simulated ToA radiances to CERES measurements

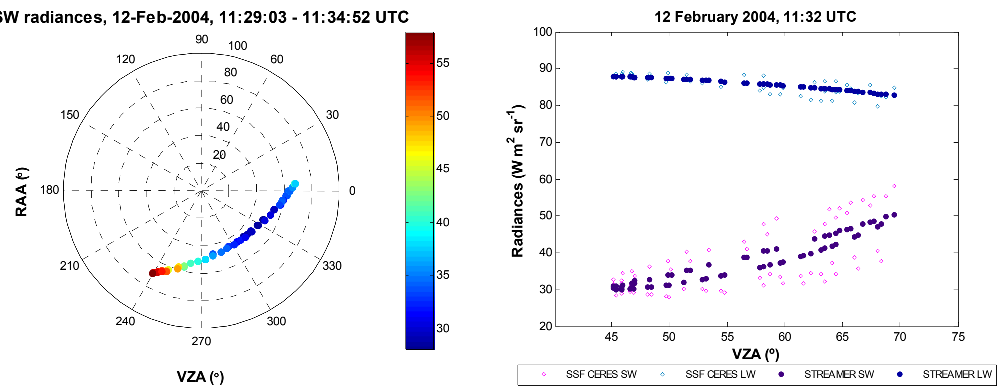

Figure 7. Results for Terra FM2 CERES PAPS observations on 10th February 2004. (Left): CERES ToA SW radiances and observation geometry (quite slant along the full PAPS). Radial axis corresponds to VZA and azimuthal direction to RAA. (Right): Comparison of Streamer simulated ToA radiances to CERES measurements

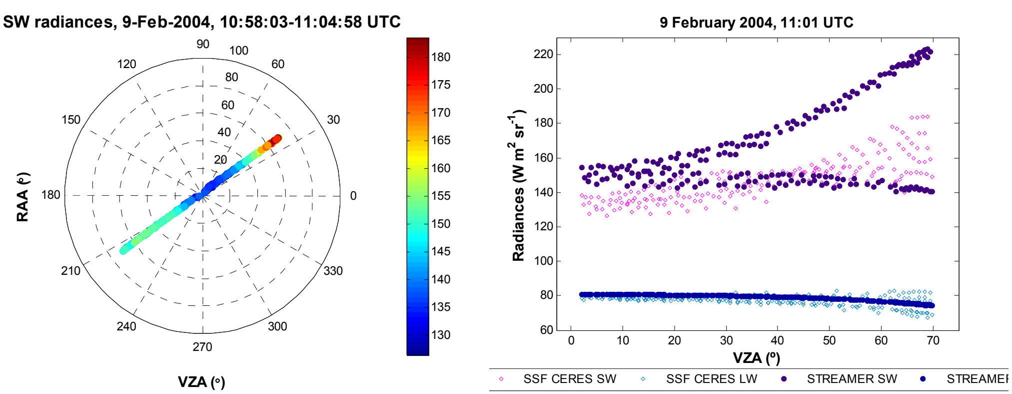

Figure 8. Results for Terra FM2 CERES PAPS observations on 9th February 2004. (Left): CERES ToA SW radiances and observation geometry. Radial axis corresponds to VZA and azimuthal direction to RAA. (Right): Comparison of Streamer simulated ToA radiances to CERES measurements

5. CONCLUSIONS

We have been able to carry out a number of field campaigns addressed to the validation of GERB products. Under clear sky conditions, the *Valencia Anchor Station* has proved to be a good instrument for the ground validation of low spatial resolution remote sensing data and products by being able to reproduce CERES ToA unfiltered radiances from simulations carried out using independent ground measurements of input parameters. In the shortwave, simulated radiances reproduce accurately the anosotropy of the radiance field with RMSEs below 8 W $m^{-2}sr^{-1}$. The agreement still improves between simulated and CERES ToA longwave radiances, with RMSEs below 4 W $m^{-2}sr^{-1}$. For cloudy conditions, for the shortwave, there is always a slight overestimation in the forward direction. In the longwave, the agreement remains good. Most likely, in the future, the way to improve the results for cloudy conditions in the shortwave, would be by having ground measurements of cloud parameters.

CERES dedicated PAPS observations over the Valencia Anchor Station are of great value to develop the methodology to validate low spatial resolution remote sensing data and products. In this way, the methodology is presently being extended and applied to GERB products, recently been public.

6. ACKNOWLEDGMENTS

The authors thank ESA and EUMETSAT for the selection of this project. They also acknowledge the *Spanish Programme on Space Research* (*SCALES Project* and its continuation now as *MIDAS-4/UVEG Project*) in which context some of the activities will be carried out. The help of the *Regional Government (Directorate General on Environmental Quality)* is appreciated as well for the installation and provision of the Alacant *Anchor Station* and for the use of data from their air quality network.

The authors thank A. Comeron, F. Rocadenbosh and M.Sicard (*Electromagnetic Engineering and Photonics Group, Universitat Politecnica de Catalunya*), J.V. Miró, R. Orts and M. Poquet (*Directorate General for Environmental Quality, Regional Government of Valencia*) and V. Estelles (*Solar Radiation Group, University of Valencia*) for their collaboration in the field campaigns.

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