Contents

1. Summary
2. Introduction
3. Methodology
4. Application of the methodology to CERES data
5. Conclusions and future work
1. Summary

The purpose of this work is to develop a suitable methodology to compare measured TOA radiances and fluxes to independent radiative transfer (RT) simulations.

The RT simulations have been performed using surface and atmospheric measured parameters gathered during the GERB Surface Ground Validation Campaign at the Valencia Anchor Station (VAS) area in February 2004.
2. Introduction

The methodology developed is being tested for the NASA Clouds and the Earth’s Radiant Energy System (CERES) instrument in the framework of the SCALES project (SEVIRI and GERB Cal/val Area for Large scale field ExperimentS), and it will be eventually used to validate GERB much lower spatial resolution data over the VAS area.

The study includes the selection of atmospheric profiles from on-purpose radiosonde and GPS data, a BRDF (Bidirectional Reflectance Distribution Function) estimation for the large-scale study area and Streamer RT simulations of TOA SW and LW radiances and fluxes.
In winter (20x20 km² pixel):
- 76.6%: bare soil
- 23.4%: pine trees and shrubs

Study area

LandSat 5 image 5th July 2003

Land Use Classification
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
Study area (II)

Ground Validation Campaign
February 2004

June 2003
Footprint size

GERB and CERES pixel size vs VZA

\[ P \triangleq 2\cdot p = R \cdot (\gamma - \gamma_i) = 2 \cdot R \cdot (\theta - \theta_i - \delta) = 2 \cdot R \left( \theta - \sec^{-1} \left( \frac{R + h}{R} \cdot \sin (\alpha - \delta) \right) - \delta \right) \]
February 2004 Ground Validation Campaign outcome

Mobile station (shrubs)

VALENCIA ANCHOR STATION

Radiosounding and sun photometer

GPS

1 km
Surface radiation fluxes measured at the VAS
Radiosounding data

11 FEB 2004

12 FEB 2004
Integrated water vapour

Related to Zenith Tropospheric Delay of the signal received

Precipitable Water Content
6-13 February 2004

GPS Antenna
Soil temperature

Soil temperature (°C)

Day of Year

Soil Temperature (°C)

T1: 40 cm depth
T2: 30 cm depth
T3: 20 cm depth
T4: 10 cm depth
T5: surface

Valencia Anchor Station

Mobile station
T1: 30 cm depth
T2: 20 cm depth
T3: 15 cm depth
T4: 10 cm depth
T5: 5 cm depth
T6: surface
CERES TOA radiances over the study area (I)

LW anisotropy, 12-Feb-2004 13:05-13:12 UTC

SW anisotropy, 12-Feb-2004 13:05-13:12 UTC

Backward scattering
Forward scattering
W m² sr⁻¹

Backward scattering
Forward scattering
W m² sr⁻¹
CERES TOA radiances over the study area (II)

9 FEB 2004

10 FEB 2004
CERES TOA radiances over the study area (III)

11 FEB 2004

12 FEB 2004
3. Methodology

Parameter selection

Atmospheric profiles
a) Water vapour, pressure and temperature
   Radiosounding water vapour scaled to the GPS IWV.
b) Ozone profile
   Streamer MLW profile scaled to TOMS (Total Ozone Mapping Spectrometer) value
c) Aerosols profile
   Streamer MLW profile + sun photometer measurements + assume background tropospheric aerosols and background stratospheric aerosols.

Surface emissivity
   From CERES/SARB data

Surface temperature
   Measured temperatures at the VAS and the mobile station
BRDF (Bidirectional Reflectance Distribution Function)

TOA radiances are sensitive to the anisotropy of the surface reflectivity and its diurnal changes.

It is necessary to know the spectral albedo and the bidirectional reflectivity

From the land use classification: 76.6 % is bare soil

23.4 % vegetation

- Ahmad y Deering bare soil BRDF:

Bidirectional reflectances: every 10° in SZA and VZA and every 30° in RAA

2 spectral bands: red (0.662 µm) and near infrared (0.826 µm)

- Spectral albedo from Aster Spectral Library (JHU, John Hopkins University)

- Broadband albedo: weighted from the measured broadband albedo in the stations.
Study area BRDF

It is obtained from the broadband albedo measured at the VAS and the mobile station \(a_{0}^{BB}\), JHU spectral albedo \(a_{l}^{JHU}\) and the bidirectional reflectance from Ahmad y Deering for bare soil \(\rho_{\lambda}(\theta_{0},\theta,\phi)\)

1. scale the JHU spectral albedo

\[
a'_{\lambda} = \frac{a_{\lambda}^{JHU}}{\int_{\lambda_1}^{\lambda_2} a_{\lambda}^{JHU} d\lambda} a_{0}^{BB}
\]

2. scale the bidirectional reflectances from the model

\[
s_{\text{red}} = \frac{a'_{\lambda_{\text{red}}}}{\frac{1}{\pi} \int_{0}^{2\pi} \int_{0}^{1} \rho_{\lambda}(\theta_{0},\theta,\phi) \mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda_{\text{red}}}}{\rho_{\lambda}(\theta_{0})}
\]

\[
s_{\text{NIR}} = \frac{a'_{\lambda_{\text{NIR}}}}{\frac{1}{\pi} \int_{0}^{2\pi} \int_{0}^{1} \rho_{\lambda}(\theta_{0},\theta,\phi) \mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda_{\text{NIR}}}}{\rho_{\lambda_{\text{NIR}}}(\theta_{0})}
\]
Bidirectional reflectivity
4. Application of the methodology to CERES data

RMSE_SW = 2.5 W m\(^{-2}\) sr\(^{-1}\)
RMSE_LW = 2.6 W m\(^{-2}\) sr\(^{-1}\)

RMSE_SW = 2.5 W m\(^{-2}\) sr\(^{-1}\)
RMSE_LW = 2.0 W m\(^{-2}\) sr\(^{-1}\)
Results (II):

\begin{align*}
\text{RMSE}_{\text{SW}} &= 4.3 \text{ W m}^{-2} \text{ sr}^{-1} \\
\text{RMSE}_{\text{LW}} &= 1.5 \text{ W m}^{-2} \text{ sr}^{-1} \\
\text{RMSE}_{\text{SW}} &= 2.9 \text{ W m}^{-2} \text{ sr}^{-1} \\
\text{RMSE}_{\text{LW}} &= 3.2 \text{ W m}^{-2} \text{ sr}^{-1}
\end{align*}
Results (III):

RMSE_SW = 5.0 W m\(^{-2}\) sr\(^{-1}\)
RMSE_LW = 1.9 W m\(^{-2}\) sr\(^{-1}\)

RMSE_SW = 3.6 W m\(^{-2}\) sr\(^{-1}\)
RMSE_LW = 3.2 W m\(^{-2}\) sr\(^{-1}\)
Results (IV):

\[
\text{RMSE}_\text{SW} = 8.3 \text{ W m}^{-2} \text{ sr}^{-1}
\]

\[
\text{RMSE}_\text{LW} = 2.7 \text{ W m}^{-2} \text{ sr}^{-1}
\]

\[
\text{RMSE}_\text{SW} = 3.2 \text{ W m}^{-2} \text{ sr}^{-1}
\]

\[
\text{RMSE}_\text{LW} = 2.9 \text{ W m}^{-2} \text{ sr}^{-1}
\]
Fluxes comparisons


5. Conclusions and future work

• Conclusions:
  – Suitable methodology to simulate TOA CERES radiances
  – The analysis has been carried out under clear sky conditions
  – In winter we can assume that the study area is mainly composed of bare soil and vegetation
  – A representative BRDF for our study area has been developed

• Future plans:
  – Improve aerosol characterization
  – Include cloudy days in the simulations
  – Study limb darkening process in the LW
  – Use of MM5 as an interpolation tool
  – Use of BRDF measured from satellite or in situ BRDF
  – Extend the results to the last validation campaign carried out in September 2005
Study area BRDF

It is obtained from the broadband albedo measured at the VAS and the mobile station \(a_{0}^{BB}\), JHU spectral albedo \(a_{i}^{JHU}\) and the bidirectional reflectance from Ahmad y Deering for bare soil \(\rho_{\lambda}(\theta_{0}, \theta, \phi)\).

• 1. scale the JHU spectral albedo

\[ a'_{\lambda} = \frac{a_{\lambda}^{JHU}}{\int_{\lambda_{1}}^{\lambda_{2}} a_{\lambda}^{JHU} d\lambda} a_{0}^{BB} \]

• 2. scale the bidirectional reflectances from the model

\[ s_{\text{red}} = \frac{a'_{\lambda, \text{red}}}{\frac{1}{\pi} \int_{0}^{2\pi} \int_{0}^{1} \rho_{\lambda}(\theta_{0}, \theta, \phi) \mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda, \text{red}}}{\rho_{\lambda}(\theta_{0})} \]

\[ s_{\text{NIR}} = \frac{a'_{\lambda, \text{NIR}}}{\frac{1}{\pi} \int_{0}^{2\pi} \int_{0}^{1} \rho_{\lambda}(\theta_{0}, \theta, \phi) \mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda, \text{NIR}}}{\rho_{\lambda, \text{NIR}}(\theta_{0})} \]

Finite number of angles

\[ \rho_{i} = \sum_{k=1}^{i} (\phi_{k+1} - \phi_{k}) \sum_{j=1}^{i} \bar{\rho}_{i} \cdot (\sin^{2} \theta_{j+1} - \sin^{2} \theta_{j}) \]