MERIS / ENVISAT
Vicarious Calibration Over Land

Mathias Kneubühler (a), Michael E. Schaepman (b), Kurtis J. Thome (c)
(a) Remote Sensing Laboratories (RSL), Dept. of Geography, University of Zurich, Switzerland,
(b) Centre for Geo-Information, Wageningen UR, The Netherlands, (c) Optical Sciences Center, Univ. of Arizona, Tucson, AZ 85721 USA

Abstract

The launch of ESA's ENVISAT in March 2002 was followed by a commissioning phase for all ENVISAT instruments to verify the performance of ENVISAT instruments and recommend possible adjustments of the calibration or the product algorithms before the data was widely distributed. The focus of this work is on the vicarious calibration of the Medium Resolution Imaging Spectrometer (MERIS) radiance product (Level 1b) over land. From August to October 2002, several vicarious calibration (VC) experiments for MERIS were performed by the Optical Sciences Center, University of Arizona, and the Remote Sensing Laboratories, University of Zürich. The purpose of these activities was the acquisition of in-situ measurements of surface and atmospheric conditions over a bright, uniform land target, preferably during the time of MERIS data acquisition.

The experiment was performed on a dedicated desert site (Railroad Valley Playa, Nevada, USA), which has previously been used to calibrate most relevant satellite instruments (e.g., MODIS, ETM+, etc.). In-situ data were then used to compute top-of-atmosphere (TOA) radiances which were compared to the MERIS TOA radiances (Level 1b full resolution product) to determine the in-flight radiometric response of the on-orbit sensor. The absolute uncertainties of the vicarious calibration experiment are found between 3.36-7.15%, depending on the accuracies of the available ground truth data. Based on the uncertainties of the vicarious calibration method and the calibration accuracies of MERIS, no recommendation to update the MERIS calibration is given.

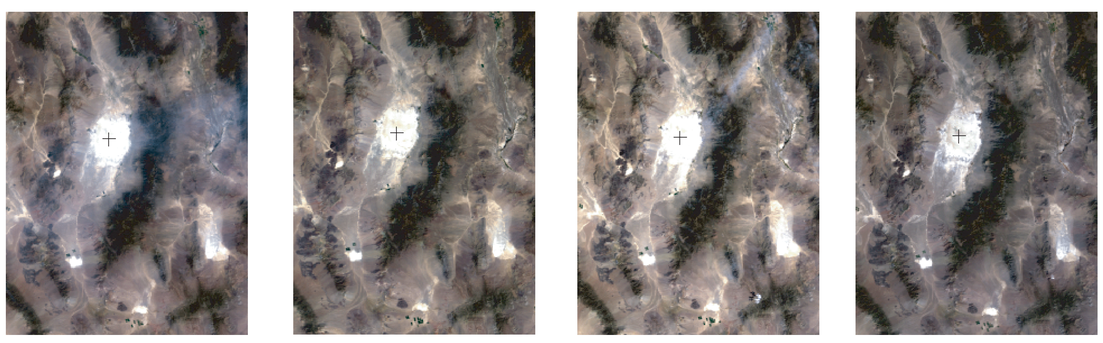
MERIS

The Medium Resolution Imaging Spectrometer (MERIS) is one of ten instruments on board ESA's ENVISAT platform. MERIS is a 68.5° field-of-view pushbroom imaging spectrometer that measures the solar radiation reflected by the Earth, at a ground spatial resolution of 300 m (full resolution) and 1200 m (reduced resolution), in 15 spectral bands in the visible and near infra-red. MERIS allows global coverage of the Earth in 3 days. MERIS data products provided by ESA include georeferenced TOA radiance data (Level 1b) as well as various water, land and cloud products (Level 2).

Full resolution data sets of the Railroad Valley Playa test site (TOA radiances, Level 1b) from four different days between August and October 2002 are investigated. Multitemporal vicarious calibration allows both for monitoring sensor stability and for investigation of the robustness of the vicarious calibration method.

Vicarious Calibration

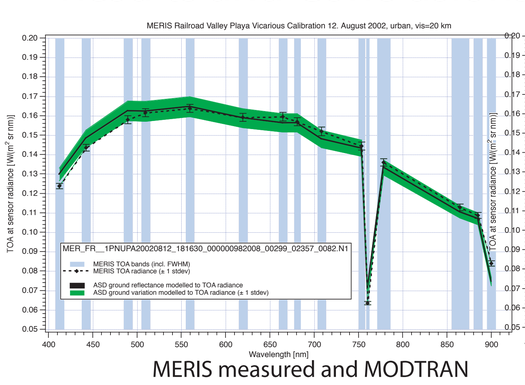
Vicarious calibration is an independent pathway for monitoring instrument radiometric performance, including error assessment with reflectance standards, field instruments and atmospheric radiation measurements. In general, the experiment follows a reflectance-based approach with ground measurements of the atmospheric optical depth and surface reflectance over a bright natural target.
In this experiment, spectral ground truth data was measured using an ASD FieldSpec Pro FR spectroradiometer. In-situ sunphotometer data from all four dates of MERIS data takes were available. However, extensive wildfires in California and Oregon led to spatially very varying atmospheric conditions. As a consequence, large variations in the atmospheric optical depth must be assumed within small regional extent, depending on whether clouds of smoke were in the line of sight of both the sun photometer and MERIS.
Only the sun photometer data of August 22, 2002 could be used to determine aerosol model and horizontal visibility, subsequently applied for radiative transfer calculation. For the other three dates, large offsets between measured and modelled TOA radiances indicate an inadequate atmospheric characterization. In these cases, a best fitting atmosphere was applied for vicarious calibration, without the use of any sun photometer data.
MODTRAN-4, a radiative transfer code (RTC) is used, constrained by field data, to calculate the top-of-atmosphere radiance at the sensor. Input parameters include ground measurements of the surface reflectance, sun-target-sensor geometries and atmospheric properties (aerosol model, horizontal visibility).



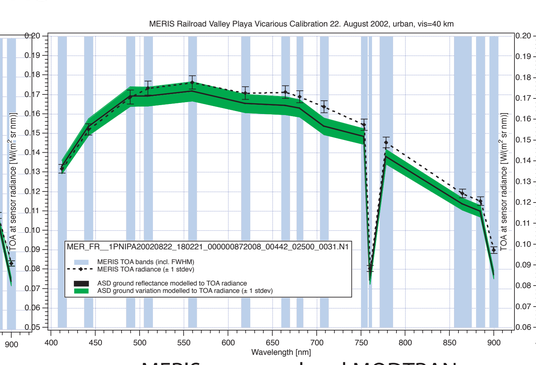
MERIS Full Resolution subsets of the Railroad Valley Playa test site.
Left: August 12, 2002, left middle: August 22, 2002, right middle: August 31, 2002, right: October 21, 2002

Railroad Valley Playa test site

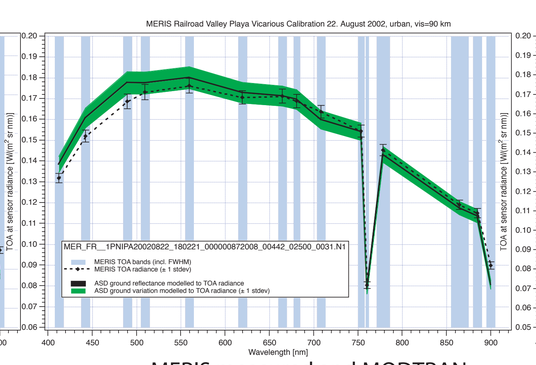
Results and Conclusions



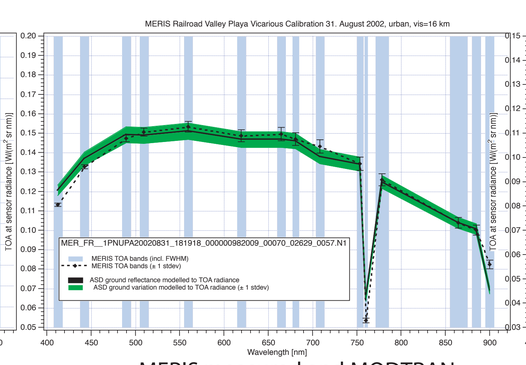
MERIS measured and MODTRAN modelled TOA radiance for August 12, 2002 (best fit approach)



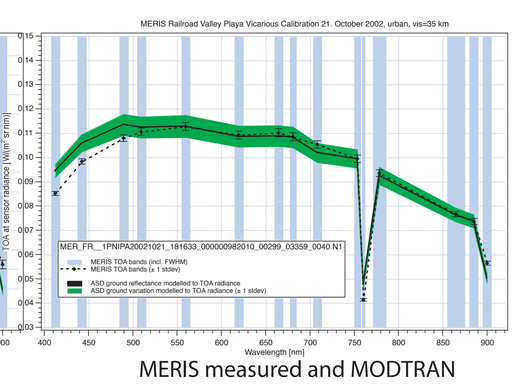
MERIS measured and MODTRAN modelled TOA radiance for August 22, 2002 (sun photometer data inversion approach)



MERIS measured and MODTRAN modelled TOA radiance for August 22, 2002 (best fit approach)



MERIS measured and MODTRAN modelled TOA radiance for August 31, 2002 (best fit approach)



MERIS measured and MODTRAN modelled TOA radiance for October 21, 2002 (best fit approach)

- The first band at 412.5 nm (aerosol type sensitive), band 11 (oxygen at 760 nm), and band 15 (water vapour absorption region at 900 nm) are critical in the modelling (see Table A). These bands need more precise atmospheric reference data (e.g., meteorological data) for vicarious calibration.
- Apart from these bands, the relative differences between MERIS measured and radiative-transfer modelled TOA radiances do not exceed 6% (except for band 2 on October 21, 2002).
- The mean relative differences between MERIS- and VC- mean TOA radiances do not exceed 4.1% for any of the dates under investigation. Exclusion of band 11 and band 15 results in mean differences between 1.8-2.5% for all data sets.
- The absolute uncertainty of this study's VC activities is estimated around 3.36%, given reliable sun photometer data is available. Under the absence of such data, the absolute uncertainty of the method exceeds 7% (see Table B).
- An incorrect assumption about aerosol absorption can strongly affect the VC accuracies of the shorter wavelengths bands (influence of North American wildfires in summer 2002).
- Based on the uncertainties of the vicarious calibration method and the calibration accuracies of MERIS, no recommendation to update the MERIS calibration is given.

MERIS channel	Center Wavelength (nm)	Differences between MERIS and TOA radiances from VC (%)				
		12. 8. 2002 urban vis=20 km	22. 8. 2002 urban vis=40 km	22. 8. 2002 urban vis=90 km	31. 8. 2002 urban vis=16 km	21. 10. 2002 urban vis=35 km
1	412.545	-4.879	-0.604	-4.994	-6.614	-10.879
2	442.401	-3.360	-0.844	-5.745	-3.141	-7.658
3	489.744	-2.890	-0.335	-5.314	-1.267	-5.069
4	509.700	-0.394	2.356	-2.498	1.147	-1.624
5	559.634	-0.469	2.543	-2.167	1.530	0.054
6	616.620	0.212	3.035	-1.278	1.325	0.634
7	664.640	1.994	4.028	0.040	1.805	1.317
8	680.902	0.359	3.442	-0.482	0.674	0.298
9	708.426	2.637	5.884	2.318	3.657	3.282
10	753.472	0.857	3.856	0.238	0.218	0.097
11	**760.354**	**-11.750**	**6.999**	**2.524**	**-21.662**	**-15.637**
12	778.498	1.949	5.011	1.520	0.941	1.195
13	864.833	2.098	4.512	1.336	-0.026	0.550
14	899.849	1.562	4.465	1.374	-0.436	-0-083
15	**899.860**	**11.086**	**13.230**	**10.370**	**16.217**	**11.107**
Mean difference (%)		3.100	2.685	2.813	4.044	3.966
Excl. channel 11 and 15		**1.820**	**2.140**	**2.254**	**1.752**	**2.518**
Mean relative rms error (%)		4.690	5.943	4.019	7.146	5.953
Excl. channel 11 and 15		**2.911**	**3.783**	**2.910**	**3.684**	**5.311**

Table A: MERIS and VC TOA radiances differences for the observed data takes

Error Source	Absolute Uncertainty (%)
Solar Irradiance Knowledge	2
Spectralon Reflectance Knowledge	1.5
Relative Surface BRF Knowledge	1
Atmospheric Characterization	< 2[1] < 7.15[2] < 4.58[3]
Cosine of Solar Zenith	< 0.1
Root-mean-square	**< 3.36[1]** **< 7.15[2]** **< 5.31[3]**

Table B: Vicarious calibration error budget

1 Using representative sun photometer data
2 Based on maximum relative rms error of atmosphere fit including all channels (August 31, 2002)
3 Based on maximum relative rms error of atmosphere fit without channels 11 and 15 (October 21, 2002)

Acknowledgements

This project is supported by the Swiss Federal Office for Education and Science in the framework of CH-Intex (Nationaler Unterstützungskredit an internationale Experimente) and the University of Zürich. The on-site support of the Remote Sensing Group of the University of Arizona is greatly acknowledged

University of Zurich

REMOTE SENSING LABORATORIES RSL