Validation of the background simulation model MATISSE: comparing results with MODIS satellite images.

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ABSTRACT

Generally available satellite images, e. g. from the MODIS sensor, provide data in spectral bands, which are suitable for remote sensing applications and earth surface observations. However, for some applications different bands as well as specific cloud formations for a certain region may be of interest, thus making the simulation of background data essential. Therefore, the software MATISSE ("Advanced Modeling of the Earth for Environment and Scenes Simulation") proved to be the appropriate tool. MATISSE is an infrared background scene generator developed by ONERA for computing natural background spectral radiance images including atmosphere, sea, land and high and low altitude clouds. In order to validate the model, comparisons with MODIS satellite data have been carried out using images in available spectral bands. The investigations comprised selected surface structures like sea, desert, lowland (dry) and highlands (humid). In general, the results on radiance images show a good correlation between MODIS image and the MATISSE-simulation.

This paper focuses on comparing results between simulated MATISSE radiance images and the MODIS observations. Based on this, possible sources of error and the limits of the model are discussed.

1. INTRODUCTION

In some fields of science, e. g. satellite based detection of forest fires or missiles, the need for satellite images in certain spectral bands is given. However, existing space based sensors do usually observe in channels only suitable for remote sensing or meteorological applications. Thus, the calculation of images simulating the background as observed from a satellite's point of view became indispensable. A software capable of performing that task is MATISSE (Advanced Modelling of the Earth for Environment and Scenes Simulation). This model is suitable for radiative transfer line of sight computations and natural background scene image generation [1][2][3]. Validations have been conducted concerning sea radiances and give promising results. In order to go further in the validation process of MATISSE-v2.0, the comparisons with MODIS satellite images presented during SPIE Security, Defense and Sensing in Orlando [17] have been continued and further refined. The paper is organized as follows: MATISSE-v2.0 main functionalities in both line of sight (LOS) mode and imaging mode are described in section 2. Then, the different comparisons realized are detailed with results given and discussed in section 3. This section closes with an outline of the future work. Finally, section 4 gives concluding remarks.

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2. DESCRIPTION OF MATISSE-V2.0

A new version of the software (MATISSE-v2.0) has been released last year. The code can be used to compute atmospheric radiatives parameters such as spectral radiances and transmissions along lines of sight and it can produce local illumination around a target point, direct solar irradiance as well as background radiance images. The spectral bandwidth ranges from 0.4 to 14 µm. Natural backgrounds include atmosphere, low and high altitude clouds, sea and land. In order to be able to generate images with satellite viewing configuration as well as grazing viewing, a multiresolution scheme was developed. It enables MATISSE to get the necessary levels of details to treat kilometric size footprints and/or metric size footprints. An analytical sea surface optical properties model was developed taking into account sub-pixel variability as well as larger scales fitting the need of multi resolution in the simulated field of view [1]. Moreover, a java-based graphical user interface (GUI) enhances the usability of MATISSE helping the user in defining scenarios or managing atmospheric profiles databases. As far as code distribution is concerned, the code is available in two versions. The first is distributed under French MoD Preliminary validations using radiometric measurements have been conducted concerning sea radiances and give promising results. In order to go further in the validation process of MATISSE-v2.0, first comparisons with MODIS satellite images have been carried out.

This new version 2.0 of MATISSE has been extensively described in [1]. MATISSE provides different modes in order to compute radiative quantities. The first one is line of sight mode (LOS). It can predict atmospheric properties including path radiances, path transmission, sky radiances and solar irradiance for a wide range of wavelengths and spectral resolutions. The second mode is an imaging mode which can compute spectral irradiance images and transmission images of natural backgrounds at moderate spectral resolution. The third and last mode is an application programming interface (API) which provides direct access to core computation functions such as spectral radiance and transmission computation along a LOS at moderate spectral resolution as well as other useful radiative, geometrical or atmospheric computed quantities. MATISSE has been designed to produce a consistent scenario anywhere on the globe. This statement implies global coverage databases. In this section, we will recall the main functionalities of this version and focus on the database and models used by the imaging mode. MATISSE includes atmospheric data (section 2.1.1), global digital elevation model (section 2.3) linked to models as thermal model for ground temperature estimation (section 2.3).

2.1 Atmospheric Modelling

2.1.1 Atmospheric data

Atmospheric data include thermodynamic profiles and aerosol optical properties. The thermodynamic profile database is divided in two categories according its spatial extension:

1D profiles database: the same profile is used on the path. 1767 atmospheric profiles are available. These include 1761 radio-soundings measured over the whole Earth (TIGR database[6]) and the 6 standard AFRL profiles (US Standard, Midlatitude summer/winter, Subarctic summer/winter and Tropical). Moreover user atmospheric profiles are also available. Radio soundings are easily included, with the help of the atmospheric management tool and its dedicated GUI, which extrapolate radio sounding data up to the top of the atmosphere (100 km in MATISSE).

2D profiles database: the profiles come from a climatology[7] providing the average thermodynamic profile on each latitude band with a 10° latitude sampling and for 2 seasons (winter and summer).

Aerosol data are divided in two categories:

Horizontally uniform aerosol data on the whole scene. This includes part of the Shettles's aerosol data (rural, urban, maritime and tropospheric)[8] and profiles generated by the AP (Atmospheric Profiles) model. This last, developed by the DRDC (Defense Research and Development for Canada) gives the aerosols optical parameters from the sea surface up to an altitude of 3 km allowing computation in the maritime boundary layer (MBL). For above altitudes, MATISSE extrapolates data with the Shettles's aerosol models.

A specific desert aerosol model is also implemented.

3D data from GADS climatology [9] providing all the optical parameters on a grid of global coverage with a 5°x5° (in longitude – latitude) spatial resolution over two seasons.

Some of the data mentioned above are not available, depending on the version of MATISSE-v2.0 used (see code distribution section).

2.1.2 Molecular absorption model

Two models are available: the first one is based on a Correlated K (CK) model for which the thermodynamic values are transformed into a set of CK parameters for each altitude, thus allowing moderate spectral resolution; the second one is using a line by line model at high spectral resolution. The CK model used by MATISSE has been developed by ONERA and covers spectral bandwidth ranging from 700 to 25000 cm^{-1} (0.4 to 14 µm) with an adaptable spectral resolution. MATISSE can create several CK datasets from one thermodynamic profile from the database. In order to create one dataset, the user can select different molecules from the 31 which are available in this model and the spectral resolution ranging from 1 cm^{-1} to 25cm^{-1} or more. The strategy chosen here is to limit the radiance computation time in preventing the datasets from being computed online. Moreover, they can be reused for different radiance computations.

MATISSE can contribute to the target / background contrast evaluation by computing the thermal radiance (assuming no scattering and no aerosols) and transmission using a line by line model[10] along a single LOS. Radiance and transmission are computed from 700 to 25000 cm^{-1} with a resolution ranging from 0.1 to 0.005 cm^{-1} (automatic resolution computation according to thermodynamic conditions) along the LOS. The line by line model is not available in imaging mode to limit computation time.

2.1.3 Atmospheric background modelling

MATISSE is designed to model its atmosphere by a 3D grid, in which thermodynamic parameters (pressure and temperature) along with all computed radiative parameters (atmospheric source functions, local illumination, extinction coefficients, aerosol phase function) are stored on each volume element. Thanks to this modeling and the availability of 2D and 3D atmospheric databases (cf. section 2.1.1), MATISSE can take into account atmospheric spatial heterogeneity along each LOS in both LOS and imaging mode. Atmospheric multiple scattering is computed using a two stream model or a discrete ordinates method RTN21[11]. The choice of the model is up to the user depending on its required computation time versus accuracy compromise. Radiation is then propagated using Beer's law.

2.1.4 Clouds radiation

Clouds are modelled assuming a total coverage over the whole scene with horizontally homogeneous but vertically heterogeneous cloud parameters. Thus it does not produce any cloud radiance horizontal spatial variability. Radiation is computed by mixing cloud's optical parameters (phase function, extinction and scattering coefficients…) with atmospheric quantities. This computation approach is similar to the one applied to aerosols. Modelled clouds are Cumulus, Cumulus Congestus, Stratus (2 kinds), Stratocumulus (3 kinds), Nimbostratus (2 kinds), Altostratus and Cirrus (4 kinds). All these clouds are modelled under the assumption that all liquid water or ice particles are spherical. In addition, six Cirrus clouds with more realistic hexagonal column ice particles are available in the database. Their radiative properties come from a database developed specifically for MATISSE by the "Laboratoire d'Optique Atmosphérique" (LOA) in France and assures a good representativity of the Cirrus clouds radiation.

Computation with two superimposed cloud layers (low and high altitude clouds) is also possible.

2.2 Line of sight (LOS) mode

The different functionalities of this mode has been detailed in [1]. This mode not only compute path radiances and transmission on a single LOS but is able to compute direct spectral local illumination computation around a target point, i.e. collecting radiance coming from every direction around a target position. Moreover, MATISSE-v2.0 includes an API consisting in a library of 13 functions, which allows direct access to internal computed data or codes outputs. This API was developed in order to use MATISSE in other codes. These functions are developed in C language and give access to radiative quantities along a LOS, local illumination creation, solar irradiance computation, local atmospheric profiles, horizon angles computation or 3D scene definition.

2.3 Imaging mode: new developments

In order to be able to produce one-meter scale spatial variability (grazing viewing configurations) as well as kilometric scale spatial variability (satellite viewing configurations) in background images computed by MATISSE, a new multi-scale model has been developed and included in the code as the core of its architecture. This new multi resolution scheme is based on the geometry clipmap method [12]. The way this method has been applied to MATISSE background images generation is explained in [1]. This method produces terrain geometry data (facets) whose size is proportional to the distance from the sensor. As a result, an object far from the sensor is not described with the same level of details as a closer one. This approach prevents images from spatial aliasing and provides a uniform size of facets in the sensor’s field of view. The geometry levels of details are constructed from DTED (Digital Terrain Elevation Model) available in MATISSE databases. Two spatial resolutions are currently available: 30 arc-second (900m at equator) with a global coverage, and 3 arc-second (90m at equator) limited to Europe and parts of North Africa. Geometrical details added to reach sub-DTED resolutions are synthesised. This multiresolution scheme can be interfaced with all kind of background optical properties models. Moreover, a new image rendering system has been implemented in this version. It is based on a raytracing algorithm which was optimised by the use of an octree to render clipmaps. A 3D-DDA[13] method is used for octree traversal. As far as land thermo-optical properties are concerned, MATISSE uses a spectral reflectivity database linked to a selection of 17 IGBP (International Geosphere-Biosphere Program) categories [14] as in MATISSE-v1.5[15]. The code also includes a thermal model to compute the temperature of each ground facet. The model assumes absence of heat transfer between facets and periodical temporal evolution of radiative energy deposit on the ground. Under these assumptions, surface temperature temporal variation can be obtained with a Fourier transform model. Deposited radiative flux comprises direct and scattered components. Scattered energy is computed with a 2-streams model using local atmospheric profile. When a total cover of low or high altitude clouds is set by the user, the thermal model assumes they do not undergo temporal evolution. Sea temperature comes from the ASST climatology (Average Sea Surface Temperature[16], spatial resolution of 0.5°x0.5°) derived from ATSR (Along Track Scanning Radiometer) satellite measurements.

A model of multiresolution sea surface optical properties in the infrared (2-14 µm) has been developed [4][1], based on the statistical average of local unpolarized emissivity and reflectivity given by Fresnel's formula and Kirchhoff's law (first-order geometrical-optics approach and opaque sea surface). It takes into account spatial variability ranging from 1-meter scale to large scale variability. Breaking waves may not be modelled, multiple reflections are neglected but inner shadowing and hiding effects are taken into account.

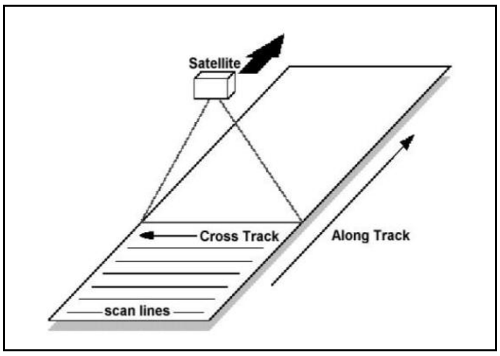
3. COMPARISON OF MODIS SATELLITE IMAGES AND MATISSE SIMULATION

Preliminary validations using radiometric measurements have been conducted concerning sea radiances and give promising results [16]. In order to go further in the validation process of MATISSE-v2.0, the comparisons with MODIS satellite images presented during SPIE Security, Defense and Sensing in Orlando have been continued and further refined [17].

3.1 MODIS

MODIS is a scientific instrument for measuring electromagnetic radiation. NASA launched it into earth orbit in 1999. MODIS is a payload on the Terra and Aqua satellites and has a high responsivity in 36 spectral bands ranging from 0.4 µm to 14.4 µm and at varying spatial resolutions. The satellites revolve the earth in a sun-synchronous orbit with a height of 705 km. The earth’s surface is entirely imaged every 1 till 2 days. For more technical details see Table 1. An overview of the spectral bands covered by the MODIS sensor is given in Figure 1.

Table 1: MODIS – technical details [18].

MODIS		
orbit height	705 km	 204 Scans each 1354 x 10 Pixel
scan-rate	20.3 rpm	
swath width	2330 km (cross track) x 10 km (along track, nadir)	
spatial resolution	250 m (Band 1-2) 500 m (Band 3-7) 1000 m (Band 8-36)	
integration time	73 µs (Band 1-2) 157 µs (Band 3-7) 323 µs (Band 8-36)	
FOV	110° x 163.2°	
IFOV	0.08°	

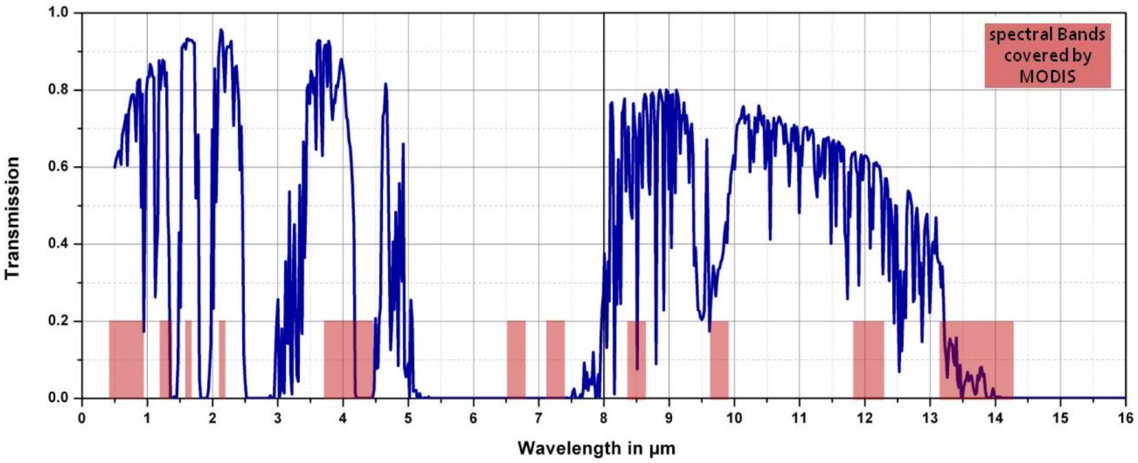


Figure 1: Overview of the spectral Bands covered by MODIS.

For further analyzing, the MODIS image of the same geographic region as presented in [17] have been chosen to allow a better comparability of the former and latest results of comparison. Figure 2 displays this image in the visual spectrum (RGB composite).

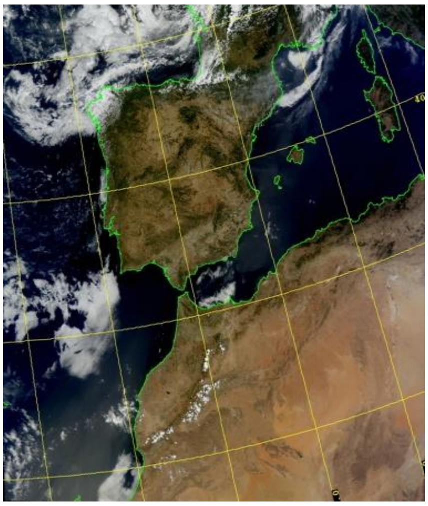


Figure 2: RGB- composite of the selected region (Iberian Peninsula and Northwestern Africa)

3.2 Simulation with MATISSE

For the calculation of a synthetic image with MATISSE-v2.0, the corresponding MODIS image parameters like date, time, sensor position, viewing direction etc. have been used as input. In the first calculations [17], neither the spectral responsivity of the MODIS sensor nor a specific atmospheric profile were included, so that an ideal spectral responsivity and a 1D standard climate profile (AFRL: Midlatitude Summer) were assumed for the atmosphere. For the present paper, the calculation options were chanced to incorporate the spectral response of MODIS and a 2D radiosounding profile. The MODIS image consists of 204 stripes, each measuring 1354 x 10 pixels. Within its standard calculation mode, MATISSE-v2.0 generates scenes where the observed position is the center point of the scene (Nadir). For simulating MODIS images, the calculation mode had to be adjusted to fit the format of the satellite image: every single MODIS-stripe (height: 10 pixels) was computed and afterwards assembled as a whole scene (see Figure 3).

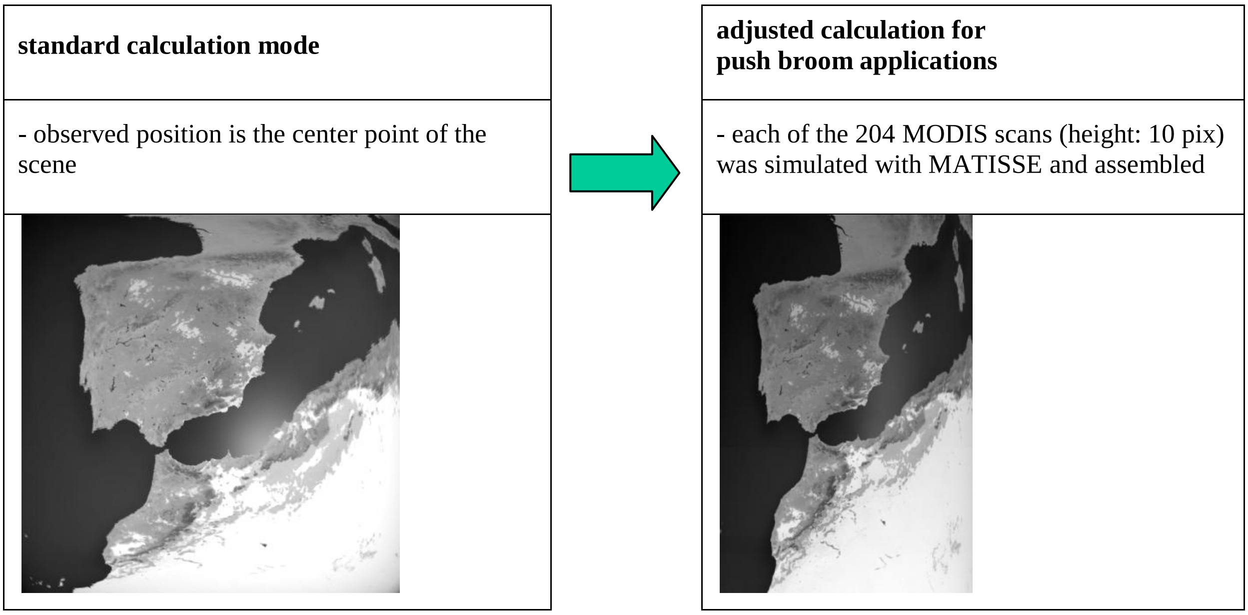


Figure 3 : Adjusted MATISSE calculations for push broom applications (right) in comparison to center point image (left).

During the comparison process, three spectral bands have been analyzed so far:

Band 7:   2.105 – 2.155 µm
Band 21: 3.929 – 3.989 µm
Band 23: 4.020 – 4.080 µm

For the calculations, the spectral response of the MODIS sensor in the selected bands has been taking into account. Those “Relative Spectral Response (RSR)” tables are available on the MODIS Characterization Support Team (MCST) website [19]. The figures below show the spectral response of the sensor in the bands 7, 21 and 23.

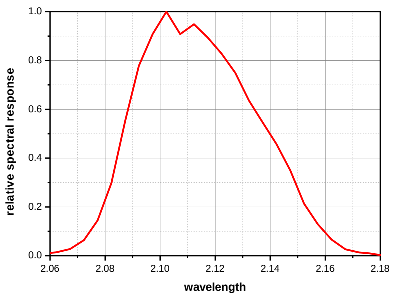
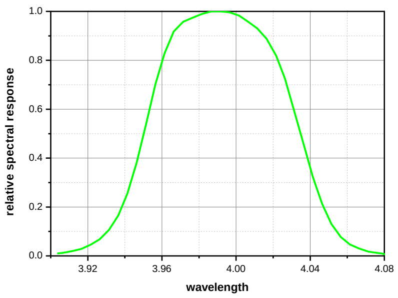
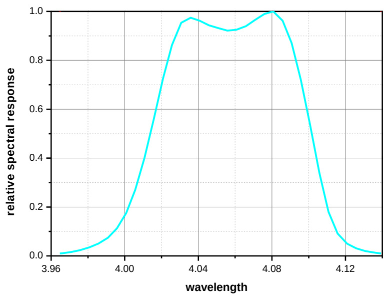
Band 7 (2.105 – 2.155 µm)	**Band 21 (3.929 – 3.989 µm)**	**Band 23 (4.020-4.080 µm)**
		

Figure 4: Relative spectral response of the MODIS sensor in selected bands.

Figure 5 compares the measured MODIS image with the corresponding MATISSE simulation for each of the selected bands. The simulations have been calculated for clear sky, although the original MODIS image is slightly cloudy (mainly the Bay of Biscay and Bay of Cádiz).

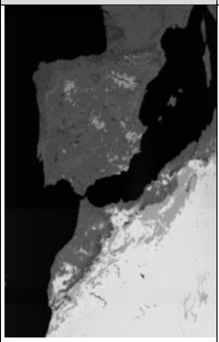
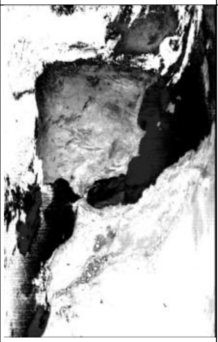
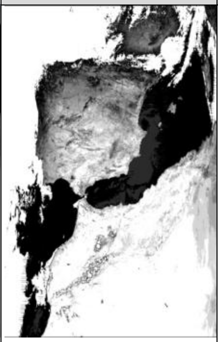
Band 7 (2.105 – 2.155 µm)		**Band 21 (3.929-3.989 µm)**		**Band 23 (4.020-4.080 µm)**	
MODIS	MATISSE-v2.0	MODIS	MATISSE-v2.0	MODIS	MATISSE-v2.0
					

Figure 5: Comparison of measured and simulated bands used for the analysis.

3.3 Analysis

For taking a closer look at the radiance values in each band, distinct (non-cloudy) regions have been chosen, see Figure 6. Each of them represents one major vegetation type occurring in the scene.

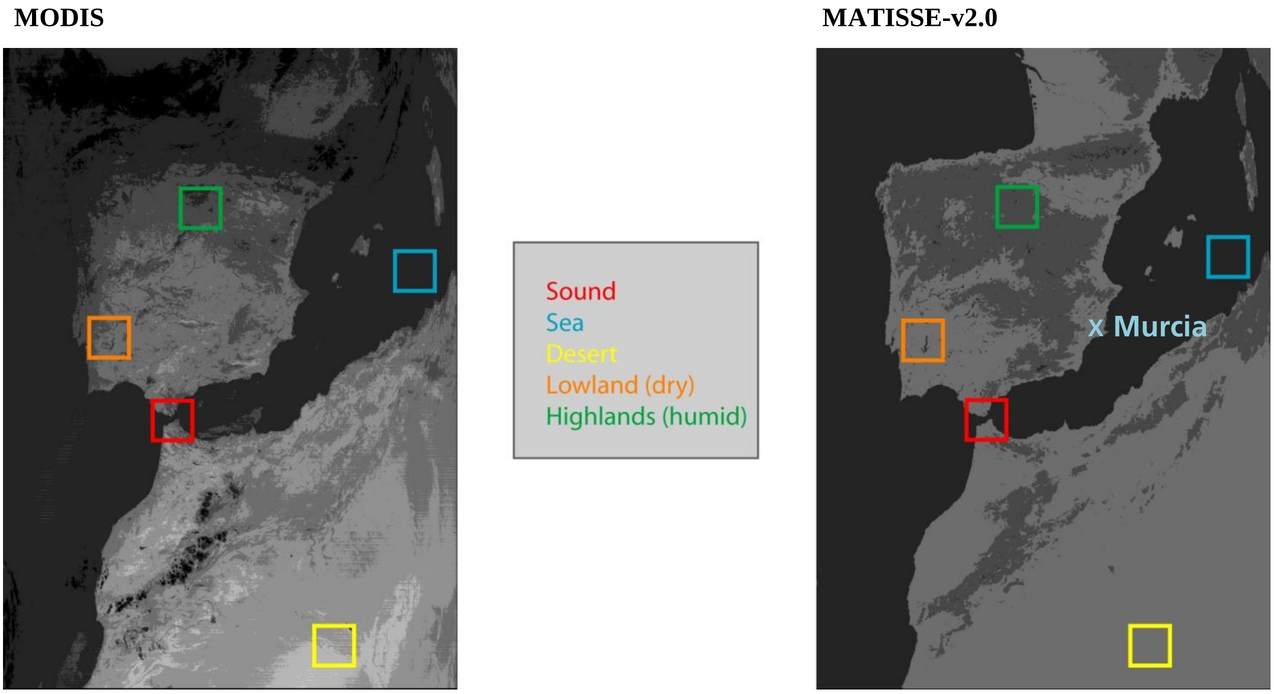


Figure 6 : Regions of Interest (ROIs) using the example of Band 21 (3.929-3.989 µm)

In contrast to the results published in [19], the present simulation outputs yield a much better concurrence to the MODIS radiances than the prior ones. This was accomplished by refining several calculation parameters:

1) Instead of using the thermodynamical data from 1D Mid-Latitude Summer profile, data of a local radiosonding profile was included. The profile was downloaded from the website of the University of Wyoming [20]. In the fields of this study, radiosonding data of the Spanish city Murcia (38° N, 1.16° W, Station Number 8430) were used. A profile matching the MODIS image creation date (27/08/2010) and the approximate MODIS image recording time (11h05 UTC) was chosen. The following table shows an excerpt from the radiosounding file:

Table 2: Radiosounding profile for Murcia, 27/08/2010, 10:00 UTC (Excerpt).

```
-----------------------------------------------------------------------------
   PRES   HGHT   TEMP   DWPT   RELH   MIXR   DRCT   SKNT   THTA   THTE   THTV
    hPa     m      C      C      %    g/kg    deg   knot     K      K      K
-----------------------------------------------------------------------------
 1006.0     62   37.2   21.2     40  16.03    180      2  309.8  359.0  312.8
 1000.0    115   35.6   12.6     25   9.24    230      3  308.8  337.3  310.5
  972.0    373   33.4   13.4     30  10.03    223      3  309.1  339.9  310.9
  967.0    419   34.4    7.4     19   6.72    221      3  310.5  331.6  311.8
  925.0    819   31.2    5.2     19   6.03    210      2  311.2  330.3  312.3
  921.0    858   31.0    5.0     19   5.97    215      3  311.4  330.3  312.5
```

As the profile only contains values up to the height of about 19 km, the remaining atmospheric data was added by extrapolating the measured values using the 1D Mid-Latitude Summer profile in MATISSE.

2) Information about the wind data was extracted from the radiosounding file and incorporated into the calculation process.

A combination of these two factors mentioned above has enhanced the calculation process and thus led to good results in the course of validation. This improvement is displayed in Figure 7. On the left, the results for a MATISSE calculation using Midlatitude Summer profile is depicted, whereas on the right, the results using a radiosounding input is displayed.

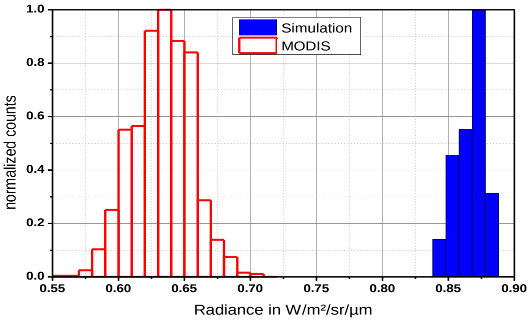
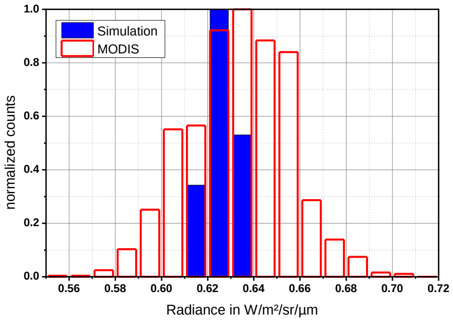
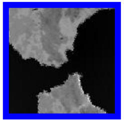
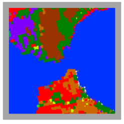
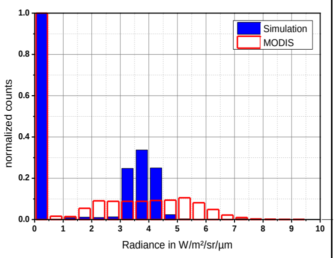
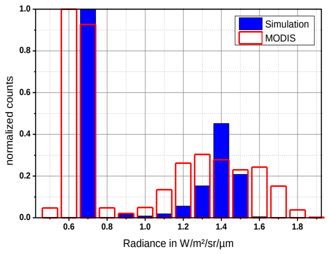
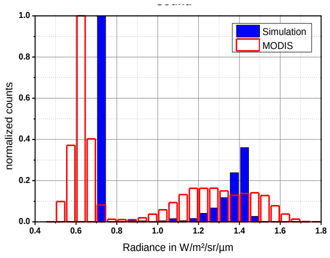
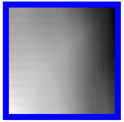
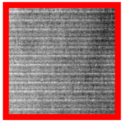
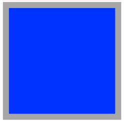
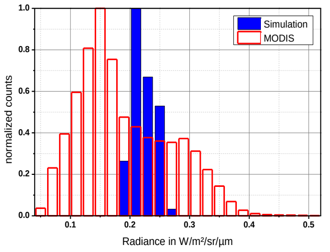
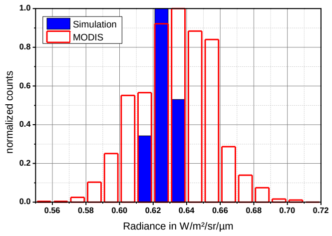
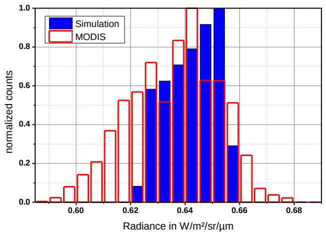
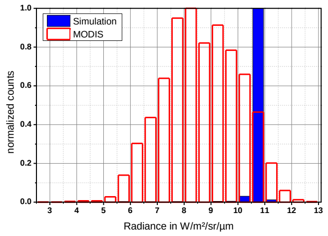
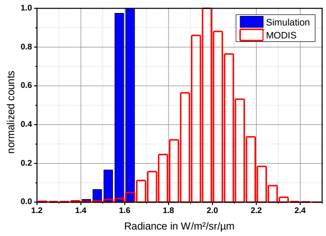
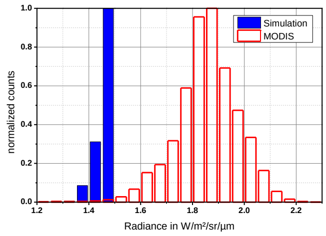
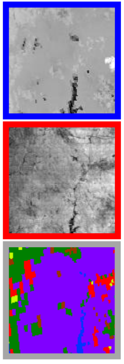
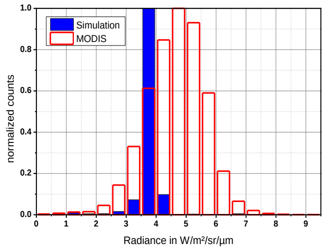
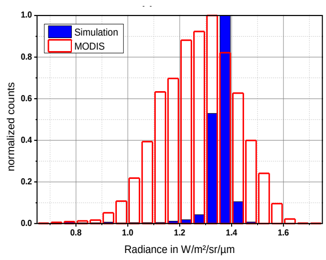
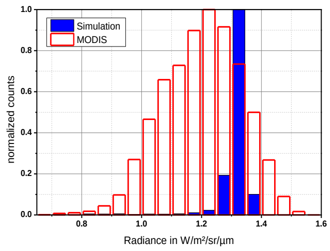
Sea – Band 21 (3.929 – 3.989 µm)	
previous calculations	latest calculations
	

Figure 7: Comparison of previous calculations (left) and improved calculations (right). Exemplarily depicted for Band 21 and ROI "Sea".

Figure 8 shows the entire results for the latest calculations. The left column depicts the ROIs in detail as well as the land use distribution of MATISSE, the adjacent columns display the comparison of simulated and measured image in each band. All of the ROIs have the same dimensions (120 x 120 pixels). For the analysis of both data sets, histograms were created. The radiance class width was adjusted to be equal and representative for the corresponding pair of ROIs. In addition - and for the purpose of better comparability - the data were normalized to the same maximum (amplitude).

	Band 7 (2.105 – 2.155 µm)	**Band 21 (3.929 – 3.989 µm)**	**Band 23 (4.020-4.080 µm)**
Sound			
  			
Sea			
  			 to be continued on the following page

	Band 7 (2.105 – 2.155 µm)	**Band 21 (3.929 – 3.989 µm)**	**Band 23 (4.020-4.080 µm)**
Desert			
			
Lowland			
			
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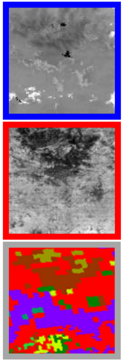	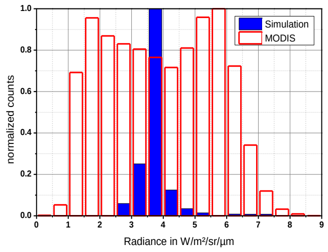	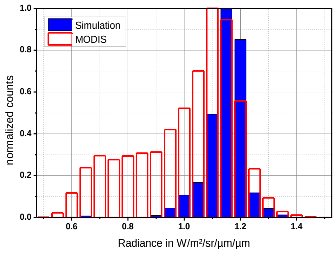	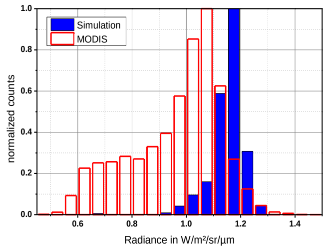

Figure 8 : Comparison of MODIS and MATISSE images for clear sky in band 7, 21 and 23.

The best concurrence of simulated and measured data is reached in the bands 21 and 23 for the ROI “sea”. In contrast, the most deviating results are obtained within the ROI “desert”. Band 7 yields the best results for “Highlands”, where as the reproduction of the remaining ROIs is of mediocre quality. Possible sources leading to occurring divergencies are discussed in section 3.4. For even better comparison, a statistical measure was chosen. These values are summarized in Table 3.

Table 3: Median of simulated and measured data by comparison. In addition, the *deviation of radiance values in % ((Median $_{\mathrm{MODIS}}$ –Median $_{\mathrm{MATISSE}}$) / Median $_{\mathrm{MODIS}}$ * 100) is displayed.

	Band 7			Band 21			Band 23		
	MODIS	Simulation	% *	MODIS	Simulation	% *	MODIS	Simulation	% *
Sea	0.17002	0.21963	29	0.63436	0.62654	1	0.63793	0.64329	1
Desert	8.61145	10.68768	24	1.98393	1.59716	19	1.85826	1.46281	21
Highlands	3.90715	3.71271	5	1.28001	1.15789	9	1.00845	1.16421	15
Lowland	4.70991	3.60285	23	1.28001	1.35944	6	1.20882	1.32251	9
Sound	0.29713	0.15912	46	0.66271	0.67003	1	0.68393	0.70574	3

Generally, the simulation yields better results in spectral regions, where emission is the dominant factor (bands 21 and 23). Here, the deviations within each ROI differ by 1-15 %, where as “Desert” has the highest difference with ~ 20 % and will be discussed here after. When taking a look at the results for band 7, the simulation generates values which are strongly varying from the measured data (except “Highlands”).

3.4 Discussion of Results

Table 3 showed some significant discrepancies in the concurrence of measured and simulated data. This case is best observable in band 7. Here, more detailed investigations concerning spectral reflection and emission are of need.

For the simulation of the sea, it is almost impossible to correctly estimate the temperature of the water surface over such a wide geographical range. MATISSE assumes the water to have a constant temperature, whereas under realistic conditions the temperature varies frequently even over a small area due to water surface currents. Figure 9 shows the effect on radiance values exemplarily for band 21, if the surface temperature is changed by 2°C. Even this relatively small modification leads to major differences. Nevertheless, the concurrence for maritime environment is very good for bands 21 and 23. In comparison with the measured data, the “sea” results can be improved by adjusting the temperature, whereas the error in band 7 stays close to 30 %, no matter what temperature is used. A possible illustration for this relatively high deviation compared to the ones for band 21 and 23 can be found in [22]: below 3 µm, light is scattered by foam bubbles occurring on the sea surface (applies to band 7). Beyond 3 µm this factor does not come into effect, thus explaining the better results for the remaining bands.

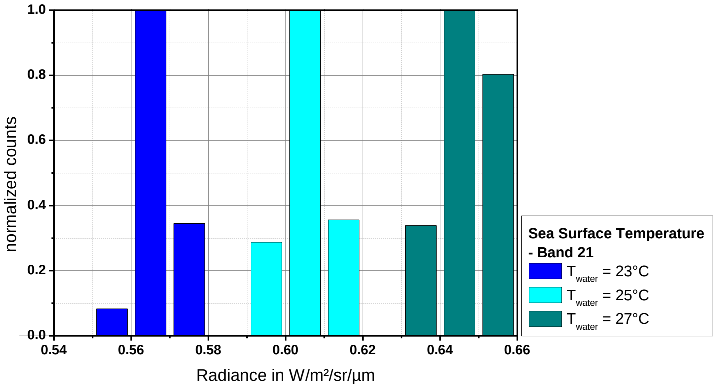

Figure 9: Effect of sea surface temperature change on radiance values using the example of band 21.

Another source of error adding up to the deviations for desert environment is the varying composition of sand. Depending on the geographical region, desert sands are formed of different native rocks and therefore deviate strongly in their reflectance. MATISSE simulations access only one entry in the database for sand reflectance, no matter which region on earth is observed. Figure 10 gives an overview on how much the reflectance for different dessert types [21] can diverge (left). For better comparison, the MATISSE assumption is shown on the right. Most eminent differences in reflectance are visible in the spectral region around 4 µm, where band 21 and 23 are located.

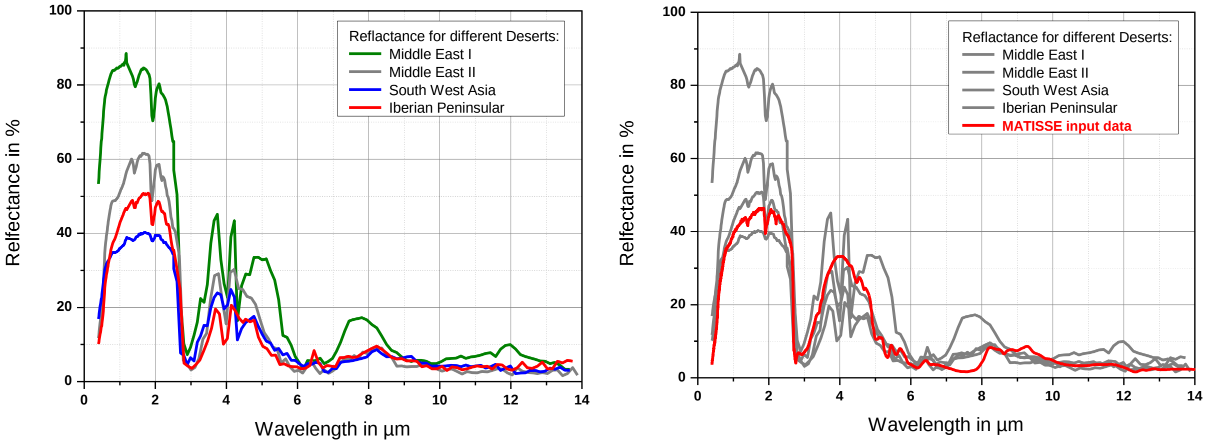

Figure 10: Reflectance of different desert types –measured data in comparison to MATISSE input data.

As far as sea ROI radiance levels are concerned, more uncertainties coming from lack of wind speed and wind direction data knowledge as well as sea mean altitude or temperature. Also, the distribution of the classes for MATISSE-v2.0 is smaller, which can be explained by the limited number of land use types (see section 2.3). This effect can be observed particularly in the ROI “desert” (3 – 5 radiance classes compared to 14 – 17 for the MODIS image). Another fact adding up to the remaining, (however small) deviations is the calibration bias of the MODIS sensor, which is declared as ~ 1 – 2 %.

In addition, it is very difficult to investigate, which parts of the MODIS image are entirely cloudless and which are not. Even after careful choosing of each ROI, it is not guaranteed that the selected areas are truly cloudless. This circumstance leads to another possible source of error. However, within the range of errors discussed before, the results show a good concurrence between measured and simulated histograms, in order of magnitude.

3.5 Future work

Future investigations will comprise the improvement of the simulation for spectral regions below 2.5 µm, where reflectance is the dominant factor (band 7). In connection with this, more details about the reflectance of e. g. sand are necessary. Also, 3D-Profiles will be incorporated into the computations giving a more accurate reproduction of the earth’s atmospheric environment. In the long term, investigations will comprise further bands (SWIR / LWIR) and a detailed analysis of the simulation of clouds to provide input for the improvement of the MATISSE code.

4. CONCLUSION

In the first part of this paper, the main functionalities of MATISSE-v2.0 have been recalled: from the LOS mode for direct computation of spectral radiance and transmission at moderate and high spectral resolution mode to the imaging mode for the computation of spectral irradiance and transmission images of natural backgrounds at moderate spectral resolution. In order to be able to treat spatial footprints from kilometric size down to metric size in different images or inside the same image, a multiresolution scheme was developed. This scheme enables MATISSE to produce images at any geometrical configurations. Comparisons with MODIS satellite images have been carried out and are detailed in the second part of this paper. For the analyzed scenario, the results of the MATISSE-v2.0 simulation show a good concurrence with the radiance values of the MODIS satellite images for spectral regions between 3.9 – 4.1 µm and a rather satisfying concurrence for spectral regions below 2.5 µm. Furthermore, sources of error have been pointed out and possible solutions have been presented. Taking this into account, MATISSE can be considered as a suitable model for generating synthetic background images. Nevertheless, more investigations on reflectances, e. g. desert sand types, are necessary, thus leading us to the assumption that the 17 land cover types derived from the IGBP (International

Geosphere-Biosphere Program) mentioned in section 2.3 represent an insufficient quantity. Also, the simulation of spectral regions below 2.5 µm, where reflectance is the dominant factor, needs to be analyzed in detail.

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