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ANALYSIS OF THE LAND SURFACE TEMPERATURE ESTIMATED FROM DIFFERENT SATELLITE SENSORS OVER ROMANIA

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Abstract. This paper deals with the analysis of the thermal field parameters using the space radiometry information for the infrared channels of MODIS-TERRA/AQUA/MSG satellite data and the infrared/microwave of the ATOVS system onboard NOAA/EPS satellites. Different methods and algorithms have been studied to derive land surface temperature (LST). Relatively homogenous surface emissivity areas from all over Romania were chosen based on the availability of appropriate satellite data and auxiliary data; the latter being used for validation. Each type of data has different ways of being acquired and processed and these are described in details. Two kinds of data (sensor and satellite characteristics and resolution) were taken into consideration in this study in order to estimate the land surface temperature. Modified split-window methods were mainly studied and there were chosen quasi-homogenous bodies were chosen as test areas for the emissivity values. A good correlation between existing LST products were obtained in the case of MSG data. The ATOVS temperature was then compared with the LST temperatures in order to find if there is a correlation between satellite derived air temperatures at 2m and LST temperatures, which, if true, could be usefull in estimating LST in cloudy conditions, since ATOVS derived profiles can be calculated with the same accuracy independently of the clod cover. A linear relationship was found.

Key words: SEVIRI, LANDSAF LST, ATOVS, surface temperature.

1. INTRODUCTION

The study of the Land Surface Temperature (herein referred to as LST) is a very interesting subject for applications in many fields of natural sciences, as stated in numerous papers. The surface temperature is a main indicator of the surface energy balance of the Earth and it is used as input data in climate change models, agro-meteorological or hydrological models to forecast the soil freezing, to analyse heat islands in urban areas, to decide the optimal timing of agricultural activities, to study volcanoes and geothermal activities, to detect fires, and the exploration of natural resources. A lot of these applications are of a great interest in Romania and this is why we need validated and complete LST data. Different algorithms for retrieving the surface temperature from satellite data have been developed since the first TIR (Thermal InfraRed) sensor was launched, first for the sea surface: SST (Sea Surface Temperature), then for the land surface: LST. A multitude of split-window algorithms, as presented in numerous papers e.g. '(Stancalie 2005)' has been developed and improved.

In this paper we analyse the results of the LST estimation from satellite data and discuss the associated constraints and challenges. Initially we tried to establish a validated split-window algorithm on MODIS (Moderate Resolution Imaging Spectroradiometer) data for test sites over Romania. As we were not able to obtain good split-window coefficients, using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) LST as ground-truth data, we turned to the MSG/SEVIRI (Meteosat Second Generation/Spinning Enhanced Visible and InfraRed Imager) data. For Romanian territory, the LST LANDSAF (Land Satellite Application Facilities) product does not cover the country entirely; therefore LST information is not complete over Romania. More algorithms were tested and finally a method of LST estimation with good accuracy was developed to fill the aforementioned gap in the temperature field obtained from satellite data. We adapted a split-widow algorithm and validated the LST data obtained, using LST LANDSAF data and LST measured in the meteorological stations network. Since optical sensors cannot "see" through clouds, for cloud covered areas we need some other method to calculate or at least to evaluate LST. In critical applications like fire detection for example, the possibility of getting any piece of usefull information can be crucial to rescue operations and fire controll actions. Satellite derived LST's and ATOVS temperatures profiles were compared and a linear relationship between the maxima of the air temperature and the LST was found.

2. METHODOLOGY

Concerning MODIS data, the methodology was to use a split-window linear equation for obtaining the coefficients *a* and *b* on samples datasets, then using them for independently estimating the LST from MODIS data:

$$T_{\mathrm{ASTER}} = T_{31} + \mathrm{a}\,(T_{31} - T_{32}) + b, \qquad (1)$$

where: T_{ASTER} – temperature values from ASTER LST product; T_{31}, T_{32} – brightness temperature in channels 31 and 32 respectively of MODIS; *a*, *b* – coefficients in the split-window equation, depend on atmosphere properties and ground emissivity.

Considering the ASTER LST data as ground truth, Eq.(1) become:

$$T_{\mathrm{ASTER}} - T_{31} = \mathrm{a}\,(T_{31} - T_{32}) + b, \qquad (2)$$

Thus, differences ($T_{\mathrm{ASTER}} - T_{31}$) and ($T_{31} - T_{32}$) can be represented by a linear relationship, depending on *a* and *b*. Figure 1 is an example of this relationship for a test site that shows a weak correlation between the two measures.

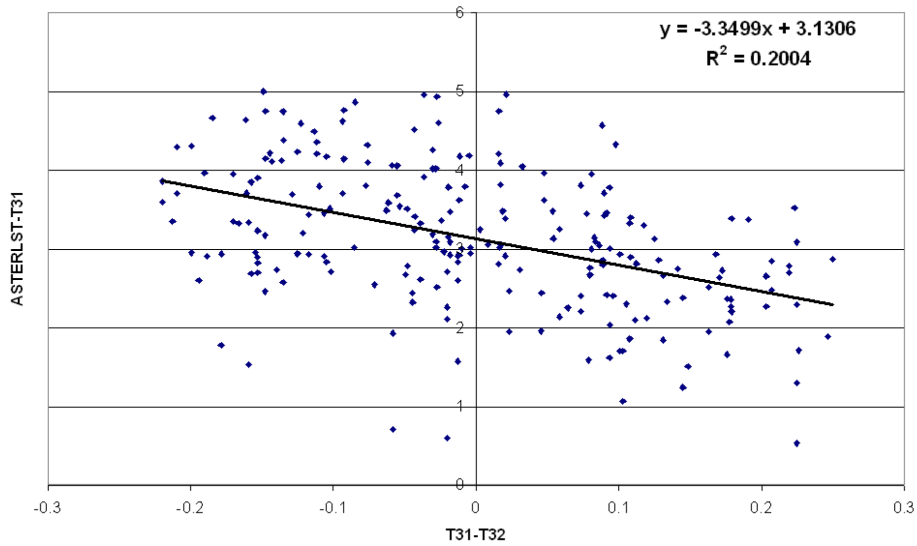

Fig. 1 – Graphic representation of ($T_{ASTER} - T_{31}$) and ($T_{31} - T_{32}$) differences.

ASTER LST was resampled to 1 km pixel resolution, as for MODIS TIR (Thermal Infrared) data.

The weak correlation of differences could be due to the misregistration of the two types of data, thus further research should be done to test this hypothesis.

We used a very similar method for MSG data, but instead setting up a split-window algorithm, we employed directly developed algorithms that take into consideration certain values of *a* and *b* coefficients or use NDVI (Normalized Difference Vegetation Index) for considering the ground emissivity influence. The objective was to obtain accurate LST values for the Eastern part of Romania, where there is no LST LANDSAF information. More generalized split-window algorithms were tested e.g. (Becker *et al.* 1995, Chrysoulakis *et al.* 2002, Liu *et al.* 2006, Mito *et al.* 2006) and LST LANDSAF values have been used to calibrate an algorithm that gives good results. A cloud mask was created based on NDVI threshold method. The algorithm chosen finally was adapted from those developed by Kerr et al. 1992:

$$T_s = C\,T_{vc} + (1 - C)\,T_{bs} - 12.25, \qquad (3)$$

where:

$$T_{vc} = -2.4 + 3.6\,T_{10} - 2.6\,T_{12} \text{ – for vegetation} \qquad (4)$$

$$T_{bs} = 3.1 + 3.1\,T_{10} - 2.1\,T_{12} \text{ – for bare soil} \qquad (5)$$

$$C = (\text{NDVI} - \text{NDVI}_{min}) / (\text{NDVI}_{max} - \text{NDVI}_{min}) \qquad (6)$$

where: $NDVI_{min}$ – minimum NDVI for bare soil; $NDVI_{max}$ – maximum NDVI for vegetation.

The LST was calculated for cloud-free pixels and the values obtained were validated against the LST LANDSAF values for the pixels where LST LANDSAF exists. LST pixel values, calculated using both methods, were compared against actual soil temperatures values registered by meteorological stations.

Other operations have been done in order to visualize the results.

The product generated as a result of this study, used operationally at the National Meteorological Administration (Romania) is LST obtained from MSG data covering Romania entirely. The product has a temporal resolution of 15 minutes. A daily synthesis is also produced that offers a less cloud covered image.

The ATOVS temperature profiles were generated with IAPP v3.0 (International ATOVS Processing Package), for all NOAA-16, NOAA-18 and MetOp passes over the territory of Romania. Radiosonde data was gathered for Bucharest and Cluj in order to calibrate the satellite profiles. A linear relationship was found between satellite calculated LST and the maxima of the afternoon satellite overpass calculated ATOVS air temperature at 1050 mb:

$$T_a = m_1 T_s + m_2 T_{1m},$$

where T_a is the temperature of air at 2m, T_s is satellite derived temperature at 1050 mb, m_1 and m_2 are the regression coefficients and T_{1m} is the long-term monthly maximum air temperature.

3. Data

The categories of data that have been used in this study are:

– satellite data: MODIS channels 31 and 32 radiance data and MSG channels 9 and 10 radiance data;
– satellite data : N16, N18, MetOp in hirs1d format;
– RAOB soundigs data: Bucharest 00 and 12, Cluj 12;
– satellite products: ASTER LST and LST LANDSAF;
– soil temperatures in meteorological stations in Romania, at local time 9:00 or 12:00;
– vector data: Romania boundary, meteorological stations network, land use / land cover.

MODIS, MSG and LST LANDSAF data cover Romania entirely or almost entirely (Fig.2), but the product ASTER LST covers only a fraction of Romania (Fig. 3).

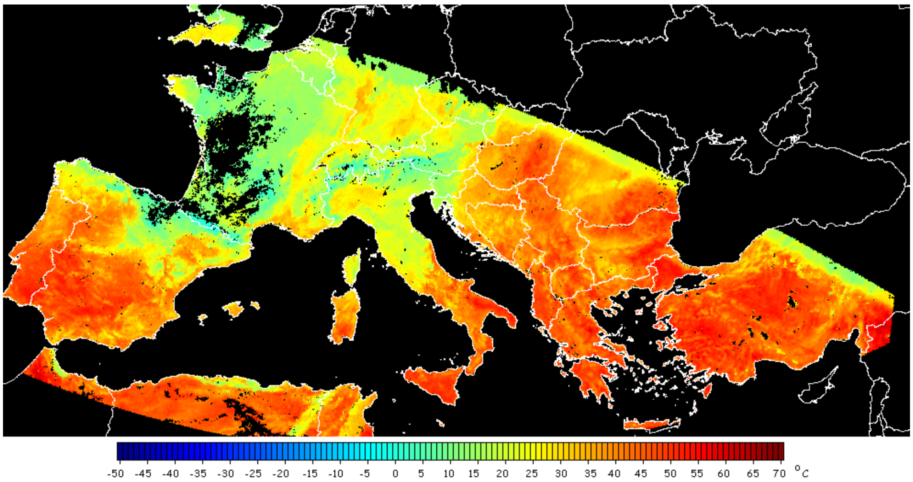

Fig. 2 – LST LANDSAF product covering Europe, from 23.08.2007.

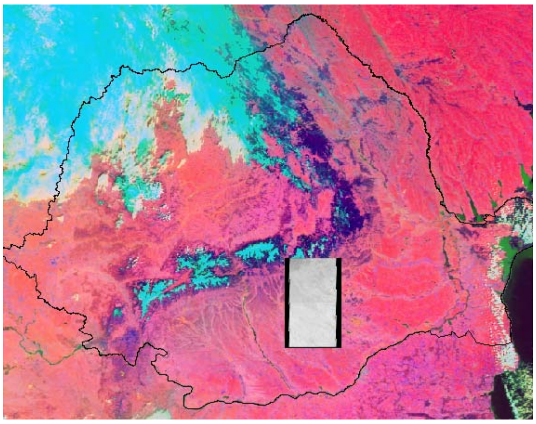

Fig. 3 – MODIS/TERRA image, colour composite ch3-ch2-ch1, from 04.04.2004
and the location of the two ASTER images.

4. RESULTS

The calibration of the MSG algorithm was achieved using both soil temperature data and LST LANDSAF at coincident locations. Fig. 4 shows an example of the correlation obtained between LST LANDSAF and observed values for those pixels were the soil temperature was measured.

A very good correlation was obtained for the validation of the adapted algorithm, where algorithm generated values compared with the LST LANDSAF values for the Romania territory (Fig. 5).

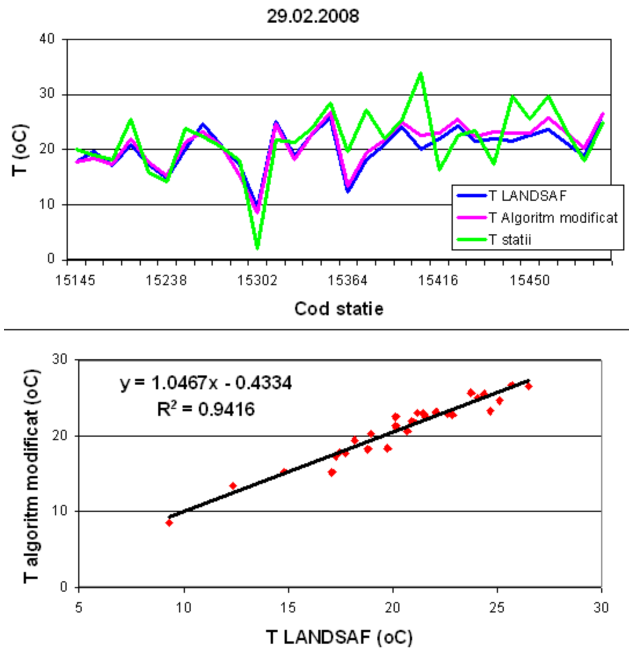

Fig. 4 – The graphic representation of the variation between T_{algoritm}, and T_{LANDSAF} on 29th of February 2008 (above) and the correlation relationship between them (below).

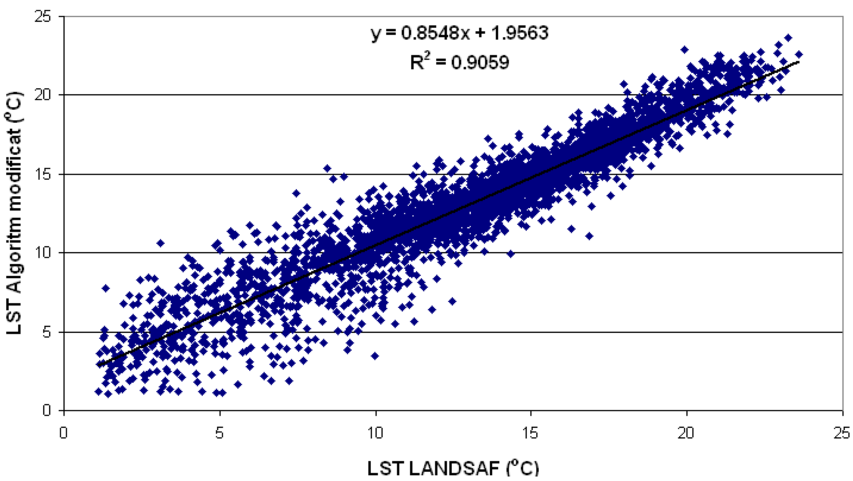

Fig. 5 – The graphic representation of the correlation between T_{algoritm}, and T_{LANDSAF} on 29th of February 2008.

The products obtained bring information in the areas not covered with LST LANDSAF (example in Fig. 6, for the 15 minutes frequency data).

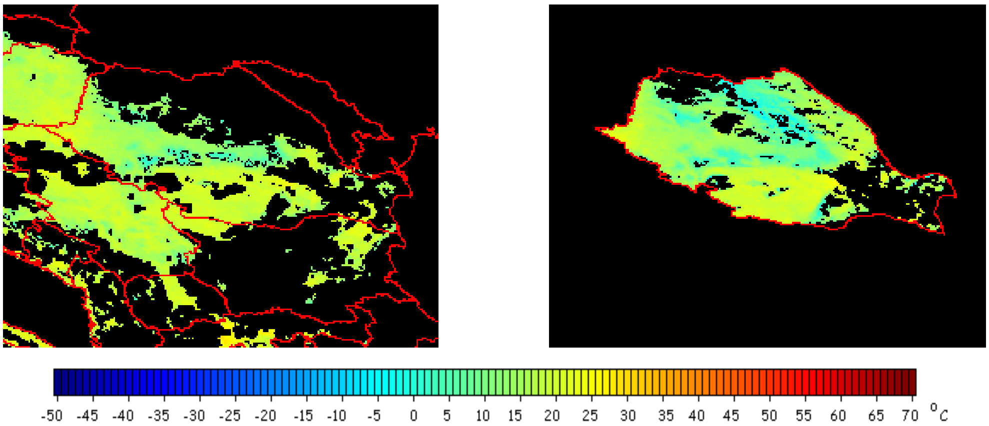

Fig. 6 – LST LANDSAF product (left) and LST adapted algorithm (right) for 28.02.2008, 13:30 GMT

5. DISCUSSION AND CONCLUSIONS

This paper presents an operational method to obtain LST accurate values over Romania from MSG data which can offer an estimation of the LST even in cloudy conditions through the use of validated temperature profiles derived from the NOAA's satellites sounder data ATOVS. The IAPP v3.0 was used to generate the satellite profiles and a space-time collocation with RAOB sounding data was run, using in-house written software. Suggestions for future work related to the air temperature – LST correlation include the extension of the study to the whole territory and a longer data set, in order to assess on the possible use in fire detection. The LST data obtained for the entire territory of Romania are of great interest for monitoring the surface in numerous applications. The main advantage of these data is, in spite of its broad spatial resolution, the high temporal resolution that allows for obtaining a daily LST synthesis less affected by cloud contamination. Ninety-six MSG images are received daily. This important data is processed for operational use using IDL (Interactive Data Language) scripts. The calculated LST values in this study were validated against the LST LANDSAF data. The correlation coefficient between the data sets (based on a linear regression technique) was 0.854.

More improvement could be made to the calculated LST from MSG data by refining the cloud mask used in this study.

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