LAND SURFACE TEMPERATURES ESTIMATED ON GROUND-OBSERVED DATA AND SATELLITE IMAGES, DURING THE VEGETATION PERIOD IN THE OLTENIA PLAIN

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Abstract. - Land surface temperatures estimated on ground-observed data and satellite images, during the vegetation period in the Oltenia Plain. The purpose of this study is to analyze the land surface temperatures by using climatological and remote sensing data during the vegetation period in the Oltenia Plain. The data used in this study refer both to climatological data (namely monthly and seasonal air and soil temperatures), and to remote sensing data delivered by MODIS Land Surface Temperature (LST), with a spatial resolution of 1 km. The analyzed period spans from 2000 to 2013 and the vegetation period considered is April-September. As main results, there were observed four years with high temperatures, namely 2000 (20.4^{o}C-air T, 24.6^{o}C soil T, and 26^{o}C LST), 2003 (20.2^{o}C air T, 23.9^{o}C soil T and 24.5^{o}C LST), 2007 (20.5^{o}C air T, 24.3^{o}C soil T and 25^{o}C LST) and 2012 (21.3^{o}C air T, 25.7^{o}C soil T and 26.5^{o}C LST). The correlations between air temperature, soil temperature and LST were statisticaly significant. The diference between air temperature and soil temperature values ranked within 3-4^{o}C, while the difference between soil temperature and land surface temperature obtained from MODIS images was about 0.8^{o}C. Spatially, the highest temperatures were recorded on the Leu-Rotunda Field, the Caracal Plain and the Nedeia Field, and pretty high variations of observed temperatures seemed to depend on vegetation cover. The MODIS images represent one of the most important types of satellite data available for free, which can be successfully used in determining the climatic parameters and can help to predict the changes in plant activity, due to weather phenomena.

Keywords: air and land temperatures, satellite images, the Oltenia Plain

1. INTRODUCTION

Temperature is one of the most important elements in climatology and meteorology, also being frequently used in the assessment of climate change. LST is a good indicator of the energy budget on the Earth's surface and the so-called greenhouse effect because it is one of the key parameters in the physics of land-surface processes both at regional and global scales (Wan, 1996). It combines the results of surface-atmosphere interractions and heat-flows between the atmosphere and the ground cover. It is useful in a wide variety of climatological, hydrological, ecological, and biogeochemical studies (Mannstein, 1987, Wan, 1996, Wan, 1999).

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In Romania, the temperature increase was a favourite subject in many studies (Bojariu, Paliu 2001, Busuioc et al, 2007, Vladut, 2013, etc) and the results are similar with the results of other studies made in Europe. According to Vladut, Ontel, 2013 referring to the summer season, all the trends are statistically significant at α = 0.001 level of significance within the entire Oltenia Plain, excepting Băilești and Bechet weather station where the trends are statistically significant at α = 0.01 level of significance (Mann-Kendall test).

The high temperature causes an increased evaporation and evapotranspiration which lead to manifestation of drought. For agriculture, the canopy temperature might be used to evaluate the water requirements of vegetation. When water becomes restrictive for plants, the heat load increases with the leaf surface and its temperature is similar to that of the surrounding air (Jackson et al, 1977, Sandu et al, 2010). Besides classical methods of analysis of temperature, in Romania was made a study which uses remote sensing data to estimate the land surface temperature (Cheval et al, 2009, Diamandi et al, 2010).

2. DATA AND METODS

The data used in this study refer both to climatological and remote sensing data provided by the *ROCADA: Romanian daily gridded climatic dataset V1.0. National Meteorological Administration* and by the *Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC*). The climatological data are represented by soil temperature and air-temperature at five weather stations (Craiova, Caracal, Calafat, Bailesti and Bechet), while the remote sensing data consist of a MODIS product, namely the Land Surface Temperature (LST). The data used for the regression analysis and Bravais-Pearson correlation test were the values of the raster cell where each weather station is located (Table 1). The period analyzed in this study was 2000 to 2013 (for the warmer half of the year: April-September).

Table 1. ***Location of the weather stations***

Weather stations	*Latitude*	*Longitude*	*Altitude (m)*
Calafat	43°59`	22°57`	61
Bechet	43°47`	23°57`	36
Băilești	44°01`	23°20`	57
Caracal	44°06`	24°22`	106
Craiova	44°19`	23°52`	192

The LST products, retrieved with the generalized split-window algorithm (Wan and Dozier, 1996) in most cases, have been validated within ±1 K in clear-sky conditions, with in-situ measurement data collected in field campaigns over lakes, silt playa, grasslands and agricultural fields (Coll et al, 2005; Wan et al, 2002b; Wan et al, 2004). The quantity and quality of MODIS LST products depend on clear-sky conditions because of the inherent limitation of the thermal infrared remote sensing (Wan, 2008).

$$Ts = C + \left(A_1 + A_2\frac{1-\varepsilon}{\varepsilon} + A_3\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T31+T32}{2} + \left(B_1 + B_2\frac{1-\varepsilon}{\varepsilon} + B_3\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T31+T32}{2}$$

where $\varepsilon = 05(\varepsilon_{31} + \varepsilon_{32})$, and $\Delta = \varepsilon_{31} - \varepsilon_{32}$ are the mean and the difference of surface emissivities in MODIS bands 31 and 32 and T_{31} and T_{32} are the brightness temperatures in these two split-window bands. The coefficients C, Ai and Bi, i=1, 2, 3, are given by interpolation on a set of multi-dimensional look-up tables (LUT). The LUTs were obtained by linear regression of the MODIS simulation data from radiative transfer calculations over wide ranges of land surface and atmospheric conditions (Wan et al, 2002b, 2004).

Our study area refers to the Oltenia Plain, which is located in the southern part of Romania, namely on the western rim of the Romanian Plain. This sector is limited by the Danube River to the West and South and by the Olt River to the East, while the northern limit is represented by the Getic Piedmont. In this area, agriculture roughly occupies the largest share of the total land surface, followed by forests and semi-natural areas (Fig.1). Therefore, any increase in ground-cover temperatures may have negative effects on crops.

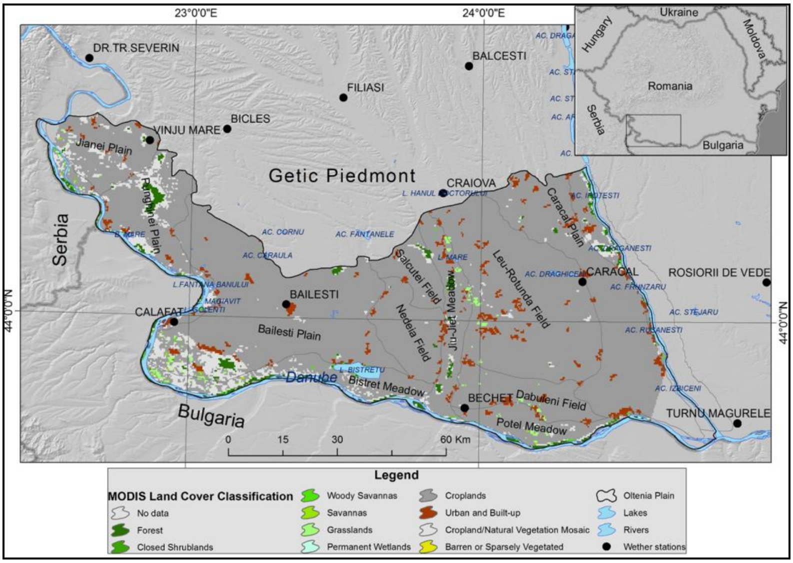


Fig. 1. ***MODIS Land Cover Classification in the study area***

3. RESULTS

According to MODIS data recorded at the weather stations in the Oltenia Plain, the mean ground-cover temperature (2000-2013) was about 22.6°C. The highest values were recorded in the Dăbuleni Field and on the western part of the Leu-Rotunda Field, while the lowest values were recorded in the Danube floodplain (Bistret Meadow), (Fig. 2). It is well known that in the Dăbuleni Field and Eastern part of the Jiu River (Leu-Rotunda Field) are sandy soils, therefore it was observed that the LST (between 2000 and 2013) recorded high values in this areas, although the sand dunes have been reinforced and covered by vegetation.

The soil mean temperature (2000-2013) on ground-observed data was 23.4°C, while the mean air temperature was 19.7°C. The difference between the MODIS LST and the soil temperature was about 0.8°C and the difference between LST and air temperature, 2.9°C. For the warmer semester of the year (April-September), the LST registered mean values above 23°C in 4 years (2000, 2003, 2007 and 2012), the warmest year being 2012, and at the same years it was recorded the highest air and soil temperatures (Fig. 3).

From the spatial distribution viewpoint, the remote sensing observations allowed us to identify the areas with a higher frequency of the values which exceeded the temperature average between 2000 and 2013, thus, a few areas can be mentioned: the Dabuleni Field, the western part of the Leu-Rotunda Field, and also the South of Caracal Plain (Fig. 4 and Fig.5).

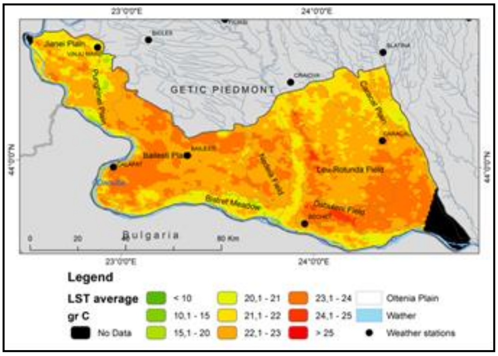


Fig. 2. ***The mean LST in the Oltenia Plain (for the warmer half of the year: April-September, 2000-2013)***

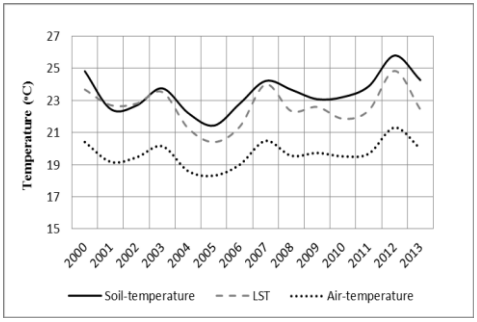


Fig. 3. ***Variability of the mean temperatures recorded at the weather stations (2000-2013)***

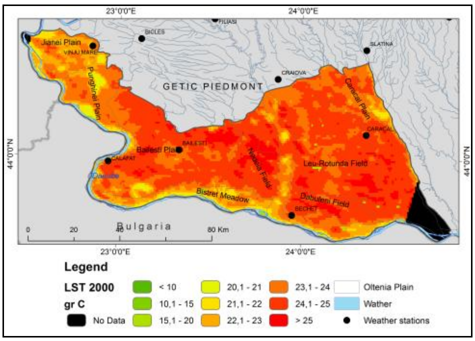


Fig. 4. ***The LST (Apr.-Sept.) in the Oltenia Plain (2000)***

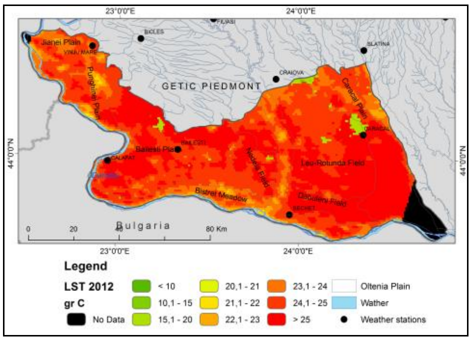
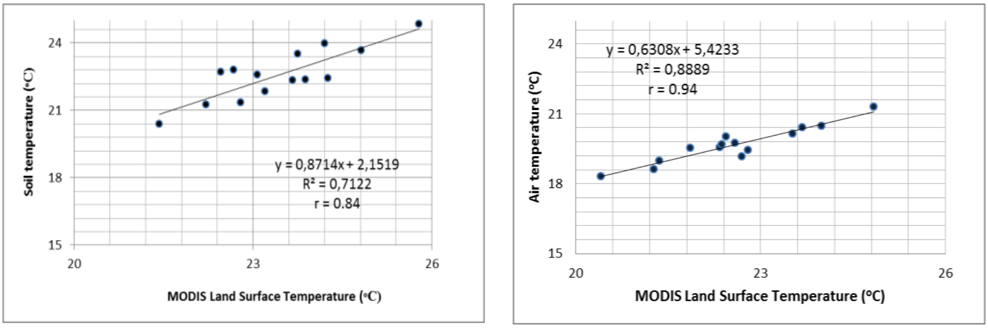


Fig. 5. ***The LST (Apr.-Sept) in the Oltenia Plain (2012)***

The correlation coefficient between the analyzed parameters was 0.84 (LST - Soil temperature) and 0.94 (LST – Air temperature), (Fig. 6). Therefore, according to Bravais-Pearson correlation test, the relationship between remote sensing data and climatological data is statistically significant at the 0.01 level (Table 2).

The relationship between LST,–soil and air temperature on ground-observed data was statistically significant at the 0.01 level for all wather stations on the Oltenia Plain, except Calafat station where the correlation coefficient was 0.65 which means that correlation was significant at the 0.05 level, according Pearson test (Table 2).



a) b)

Fig. 6. ***Correlation between MODIS Land Surface Temperature and soil temperature (a) and MODIS Land Surface Temperature and air temperature (b) recorded at the weather stations, in the Oltenia Plain (2000-2013)***

Table 2. ***Correlation between Land Surface Temperature, Soil-temperature and Air-temperature registered at the weather stations, according to Pearson test (2000-2013)***

Correlation coefficient (r)	MODIS Land Surface Temperature					
	Calafat	Băilești	Bechet	Caracal	Craiova	Mean
Soil Temperature	0.65*	0.76**	0.87**	0.88**	0.75**	0.84**
Air Temperature	0.90**	0.87**	0.96**	0.94**	0.88**	0.94**

*** Correlation is significant at the 0.001 level; ** Correlation is significant at the 0.01 level;
* Correlation is significant at the 0.05 level; + Correlation is significant at the 0.10 level

Monthly, the correlations between LST and soil-temperature or air-temperature, were statistically significant at the 0.01 level for most of the months analyzed except for April and June (Table 3). The highest thermal values were registered in July 2007 and 2012, when they exceeded 30°C (Table 4). Also, the soil temperatures recorded, were 32.7°C and 34°C respectively.

Table 3. ***Monthly, correlation between LST and Soil-temperature or Air-temperature recorded at the weather stations, according to Pearson test (2000-2013)***

Correlation coefficient (r)	MODIS Land Surface Temperature					
	IV	V	VI	VII	VIII	IX
Soil Temperature	0.32	0.89**	0.56*	0.89**	0.96**	0.88**
Air Temperature	0.27	0.85**	0.63*	0.91**	0.92**	0.89**

*** Correlation is significant at the 0.001 level; ** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level; + Correlation is significant at the 0.10 level

Table 4. ***Monthly LST recorded at the weather stations in the Oltenia Plain***

LST	IV	V	VI	VII	VIII	IX
2000	16.7	24.5	28.0	26.7	27.3	19.0
2001	14.9	20.2	27.4	26.8	27.1	19.9
2002	17.7	23.4	29.4	26.3	22.6	17.7
2003	17.9	24.3	26.3	26.2	27.3	19.1
2004	15.6	19.1	23.5	25.1	24.7	19.7
2005	15.6	19.0	22.9	25.1	21.5	18.3
2006	15.5	21.2	24.3	25.5	22.2	19.5
2007	18.2	23.5	28.1	31.6	25.2	17.3
2008	16.2	21.2	24.7	25.6	26.2	20.1
2009	15.6	21.9	25.1	25.6	26.1	21.1
2010	15.7	19.3	23.8	26.1	25.2	21.0
2011	14.1	21.4	23.9	24.9	26.4	23.5
2012	17.8	20.9	27.4	30.1	28.6	24.2
2013	17.9	-	26.1	27.7	-	18.0

	Low				High	values
Legend						

4. CONCLUSIONS

In the last fourteen years, the temperature values were higher than the mean between 2000 and 2013, such as in 2000, 2007 and 2012. Also, in some areas like the Dabuleni Field, the highest values of the entire surface analyzed were recorded. The correlations between air temperature, soil temperature and LST were statistically significant, r = 0.84 (LST - Soil temperature) and r = 0.94 (LST – Air temperature). The difference between air temperature and soil temperature values ranked to 3-4^{o}C, while the difference between soil temperature and land surface temperature obtained from MODIS images was about 0.8^{o}C.

The MODIS Land Surface Temperature is a useful parameter in any spatial and temporal analysis. The little difference between the ground-observed data and the satellite images lead to an increase in degree of confidence for the use of these alternative data sources. Also, the remote sensing data provide continuous information in space, allowing continuous monitoring of thermal variations.

REFERENCES

1. Birsan M.V., Dumitrescu A (2014): ROCADA: *Romanian daily gridded climatic dataset (1961-2013)* V1.0. Administratia Nationala de Meteorologie, Bucuresti, Romania, doi:10.1594/PANGAEA.833627
2. Bojariu, R, Paliu D (2001), *North Atlantic Oscillation projection on Romanian climate fluctuations in the cold season*, Climate Change and Associated Impacts, 345-356
3. Busuioc, A, Dumitrescu, Al, Soare, E, Orzan, A (2007), *Summer anomalies in 2007 in the context of extremely hot and dry summers in Romania*, Romanian Journal of Meteorology, 9(1-2), 1-17
4. Cheval, S, Dumitrescu Al, Bell, A, (2009) *The urban heat island of Bucharest during the extreme high temperatures of July 2007*, Theor Appl Climatol (2009) 97, 391–401
5. Coll, C, Caselles, V, Galve, J M, Valor, E, Niclòs, R, Sánchez, J M, (2005), *Ground measurements for the validation of land surface temperatures derived from AATSR and MODIS data* Remote Sensing of Environment, 97, 288-300
6. Diamandi, A, Oancea, S, Alecu C, (2010) *Analysis of the land surface temperature estimated from different satellite sensors over Romania*, Romanian Reports in Physics, Vol. 62, No. 1, P. 185–192
7. Jackson, R D, Reginato R., Idso, S., (1977), *Wheat canopy temperature: a practical tool for evaluating water requirements*, Water Resou Res, vol 13, p. 651-656
8. Mannstein, H, (1987), *Surface energy budget, surface temperature and thermal inertia*, Remote Sensing Applications in Meteorology and Climatology, ed R A Vaughan and D Reidel, NATO ASI Ser C: Math Phys Sci Vol 201, pp 391-410
9. Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) 2014 MODIS subsetted land products, Collection 5 Available on-line [http://daacornlgov/MODIS/modishtml] from ORNL DAAC, Oak Ridge, Tennessee, USA Accessed November 29, 2014
10. Sandu I, Mateescu Elena, Vătămanu V, (2010), *Schimbări climatice în România și efectele asupra agriculturii*, Edit. Sitech, Craiova;
11. Vlăduț, A, (2013), *Evaluarea riscurilor climatice în Câmpia Olteniei în contextul schimbărilor climatice globale*, Edit. Universitaria, Craiova, pp 163
12. Vladut A, Ontel I, (2013), *Summer air temperature variability and trends within Oltenia Plain*, Spatial and Temporal Distribution of Natural Disasters - Empirical Evidence, Serbia;
13. Wan, Z, Dozier, J. (1996), *A generalized split-window algorithm for retrieving land-surface temperature from space* IEEE Transactions on Geoscience and Remote Sensing, 34, 892-905
14. Wan, Z, (1999), *MODIS Land-Surface Temperature Algorithm Theoretical Basis Document (LST ATBD)*, Institute for Computational Earth System Science, University of California, Santa Barbara. modis.gsfc.nasa.gov/data/atbd/atbd_mod11.pdf

15. Wan, Z, Zhang, Y, Zhang, Y Q, Li, Z, (2002b) *Validation of the landsurface temperature products retrieved from Moderate Resolution Imaging Spectroradiometer data* Remote Sensing of Environment, 83, 163-180
16. Wan, Z, Zhang, Y, Zhang, Y Q, Li, Z (2004), *Quality assessment and validation of the global land surface temperature* Inter. Journal of Remote Sensing, 25, 261-274
17. Wan, Z (2008), *New refinements and validation of the MODIS Land-Surface Temperature/Emissivity products*, Remote Sensing of Environment, 112, 59–74.