

NOCTURNAL MONITORING OF THE LAND SURFACE TEMPERATURE VARIATION IN THE RIO GRANDE DO SUL STATE USING AVHRR/NOAA SATELLITES

A. Gusso^{a,*}, D. C. Fontana^b

^aCEPSRM, Centro Estadual de Pesquisas em Sensoriamento Remoto e Meteorologia
Universidade Federal do Rio Grande do Sul, P.O. Box 15044, Porto Alegre, Brasil - anibal.gusso@ufrgs.br

^bFaculdade de Agronomia
Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil - dfontana@vortex.ufrgs.br

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ABSTRACT:

The surface temperature is the net result of the climatic energy balance to the environmental process at the Earth. Therefore, accurate estimation of land surface temperature (LST) can be regarded as an important information to global and regional monitoring as much as the understanding of the electromagnetic radiation and matter interactions over the surface of the Earth. A monitoring study of the nocturnal decreasing temperature of the land surface is developed. In the present study, the main problem is to verify the relationship of decreasing temperature due to the rate of loss of land surface energy that can occur in the region by means of the temporal satellite survey, compared with ground based stations. In order to quantify it, a linear regression to makes possible an operational understanding is developed. The thermal decreasing trends with the spectral reply of the soil coverage and the land surface emissivity has been analyzed. For the LST estimate it is used a published split-window algorithm, with strongly dependence from the surface emissivity. The algorithm has been evaluated over the Rio Grande do Sul State in the south of Brazil, with good accuracy and it takes data from two spectral bands in the thermal infrared radiation. The method to estimate LST measurements and emissivity parameter use both data collect from Advanced Very High Resolution Radiometer (AVHRR) instruments from National Oceanic and Atmospheric Administration (NOAA) satellites. Although the pioneering character in the estimate of the LST through the satellites of NOAA series in the Rio Grande do Sul State, this study intends also, to contribute for the improvement of the technologies of analysis in the orbital tracking for numerical forecasting and to prevent and esteem the prejudices in crop fields in Brazil. This paper also presents a discussion for the emissivity problem, with regards to the studied region.

1. INTRODUCTION

The land surface temperature (LST) is an important factor controlling most physical, chemical and biological processes in the Earth. Knowledge of the LST is necessary for many environmental studies and management activities of the Earth surface resources (Li & Becker 1993).

It is possible to obtain measures of the radiance data from space-borne devices by means records of the emitted energy directly from the earth surface. In order to obtain this parameter from space radiometry in the thermal infrared part of the electromagnetic spectrum, it is necessary to take into account emissivity and to correct the recorded signal for the perturbations created by the atmosphere along the path between the Earth's surface and the sensor (Becker & Li 1990). McMillin (1975) proposed a method called split-window based on the differential absorption in two adjacent spectral windows in the thermal infrared for correct the atmospheric effects.

The LST results from energy exchange at the surface and satellite-based monitoring can be regarded as an important prerequisite of regional or global observations of surface water, energy and radiation budgets (Andersen, 1997). This is because accurate estimation of LST implies understanding of the energy/matter interactions and physical parameters that change in space and time in the biosphere. In the last 10 years, very

complex models have been extensively applied to the accurate of LST estimation by means space-borne devices for monitoring some bio-geo-chemical processes over the Earth. However, a detailed knowledge of the processes that leads to errors in the LST estimations are still waiting to be addressed for.

The parameter temperature is classically referred as the kinetic movement of the particles inside the matter. On other hand, LST retrieved from satellite generally is defined as the skin temperature of the ground surface due to the longwave thermal infrared radiation that escapes from the surface. However, the ground surface is far from a skin or homogeneous surface with two dimensions (Vogt 1996 apud Qin & Karnieli 1999). Usually it is compared to various objects on the surface and some of them such as vegetation may be best described in three dimensions, even so, several times they are not conservative on time scales. The difference $T_{skin} - T_{air}$ varies particularly with the surface water status, the roughness length and the wind speed. Such physical conditions often makes the relation between T_{air} and LST into the biosphere thermodynamics understanding a lot obscure.

In this paper the authors compare a short-term monitoring of LST and T_{air} variations by means of two different night-time satellite overpasses. This informations can be very useful for agrometeorology in the growing crop fields. The objective is to

* Corresponding author.

observe the nocturnal LST decreasing and the variation in regard to the air temperature.

The data were acquire by visible, near infrared and thermal orbital scanning with “Advanced Very High Resolution Radiometer” (AVHRR) instruments of the “National Oceanic and Atmospheric Administration” (NOAA) of “Polar Operational Environmental Satellites” (POES) system. Currently, in orbit we have morning and afternoon satellites, which provide global coverage six times daily. Because of the polar orbiting nature of the POES system, these satellites are able to collect global data on a daily basis for a variety of land, ocean, and atmospheric fine structure applications.

Many researchers have studied the relationship between emissivity and some experimental data (van de Griend & Owe, 1993) or theoretical vegetation parameters (Valor & Caselles, 1996). In this study, the authors applied Valor & Caselles, (1996) algorithm for the surface emissivity estimation derived from measures of NDVI.

2. MATERIAL AND METHODS

This study area cover twelve (12) groud-based stations distributed over the Rio Grande do Sul State with 281.731.64 Km², at the South Brazil, delimitedated by following coordinates: Longitudes 49°42'22''W and 57°38'34''W. Latitudes 27°04'49''S and 33°44'42''S.

The study area presents particularly features of relief (canyon) and crop fields covering to the north and it is often covered by shrub and grassland vegetation in the other sites.

The satellite data used in this study with the highest elevation angle overpasses in the Winter season of the 2002, were received, analysed and selected from the permanent available files at the Centro Estadual de Pesquisas em Sensoriamento Remoto e Meteorologia (CEPSRM-UFRGS). The CEPSRM is located at coordinates: 51°11'35''W and 30°06'39''S.

The Table 1 present the geographical position of the 12 ground based-stations under shelter installed 1.5 meters above the surface in the Rio Grande do Sul State, Brazil.

Table 1. Geographical position of the stations

Ground-based stations location			
Station	Latitude	Longitude	Altitude (m)
1 Bajé	31° 20'S	54° 06'W	212
2 Bom Jesus	28° 40'S	50° 26'W	1046
3 Caxias	29° 10'S	51° 12'W	817
4 E. do Sul	30° 32'S	52° 31'W	432
5 Farroupilha	29° 14'S	51° 26'W	783
6 Iraí	27° 11'S	53° 14'W	776
7 Porto Alegre	30° 05'S	51° 10'W	3
8 Quaraí	30° 23'S	56° 26'W	112
9 Santa Rosa	27° 51'S	54° 25'W	277
10 S. Vitória	33° 31'S	53° 21'W	23
11 São Luiz	28° 23'S	54° 58'W	231
12 Taquari	29° 48'S	51° 49'W	54

It were selected 4 (four) night-time images from NOAA-15 and 16 with two overpasses in July 15 and September 04 dates, on High Resolution Picture Transmission (HRPT) format as shown in Table 2.

Table 2. Selected night-time images for LST data retrieval.

AVHRR data	Date	Overpass (GMT)
02196a16	July/15	04:59
02196a15	July/15	10:18
02247a16	September/04	05:41
02247a15	September/04	10:31

The determination of the LST variation analysis requires the use of data obtained from satellites together measurements taken on ground-based stations (*in situ*) measurements.

The main steps undertaken were: a) clear-sky satellite overpasses selection; b) georeferencing data; c) monthly maximum NDVI data genneration; d) emissivity data retrieval; e) computing of the 9 *pixels* mean LST over the ground-based stations position; f) generate of a *scatterplot* of LST variation against Tair variation data for each day.

Formerly, it was applied in the software ERDAS-Imagine version 8.5 the orbital algorithm for control points calculation based on the efemerids data provided by NOAA for the orbital route. This type of georeferencing with the *Spheroid* and *DATUM WGS84* for high elevation overpasses often present an mean accuracy of 2 *pixels* (2200m) for this region. Latter, it was undertaken a second georeferencing with a number of control points based on the well known location of water bodies in the dimension of few *pixels*. The obtained results in the georeferencing are quite good and necessary in the same way.

The ERDAS-Imagine 8.5 software was used to transform the 10 bits radiometric records, i. e. 1024 digital counter, in temperature data. This module permit to transform digital counters value in radiance and to get brightness temperature data through Planck's equation (Gusso & Fontana, 2003). However the calculation based on the black body's theory temperature by Planck's equation is complex numerically because it needs to consider the spectral response function of temperature to the radiance in differents wavelengths. Details of the physical fundamentals of thermal interpreting signals by the brightness temperature from the observed radiance in remote sensing theory, are very well discribed at Sullivan (1999).

2.1 Land surface temperature

At any time, the value taken by the surface temperature T_{skin} results from the balance between the various forms of energy exchanges at the surface: net radiation, convective sensible and latent heat fluxes and soil conduction heat flux. Because the long wave radiation losses of the surface T_{skin} (LST) and T_{air} both decrease during the night and reach their minimum values generally just before sunrise (Lagouarde and Brunet, 1993).

T_{skin} usually remains slightly lower than T_{air}.

The radiative cooling at night and the difference T_{air} – T_{skin} are greater the more important as the longwave downward atmospheric radiation is low. Low values of soil thermal conductivity, roughness and wind speed act in the same direction, by limiting the energy exchanges between the surface and the air above. However in most cases the night-time temperature differences T_{air} – T_{skin} does not usually exceed 3 degrees Celsius (Oliveira, 1997). Values greater than 4 or 5 Kelvin are rarely found and correspond to very stable atmospheric situations (Lagouarde and Brunet, 1993). Also, the maximum surface temperature reached shortly after solar noon strongly depends on surface conditions. For instance, on very dry bare soils the difference may reach 20 K (Seguin et al, 1982

apud Lagouarde and Brunet, 1993). In contrast, the surface temperature can rise rapidly (Goetz, 1997).

The daily amplitude of T_{skin} is strongly related to the intensity of soil cover and evapotranspiration. Under clear-sky conditions T_{skin} generally poses the same type of evolution (Lagouarde and Brunet, 1993). All over this behaviour the loss energy evolution of T_{skin} may be affected by fluctuations due to instantaneous variations of local weather conditions associated for instance with cloud passes or wind speed changes (Lagouarde and Brunet, 1993).

2.2 Emissivity

The potential of obtaining information about energy budget and water status of a surface through the relation between remotely sensed surface temperature and vegetation index (NDVI) has been investigated by several authors (Goetz, 1997; Sandholt *et al.* 2002; Ouaidrari *et al.* 2002). The LST and NDVI can provide informations of soil covering conditions because the amount of vegetation is important to LST estimations.

In keeping with Kerr *et al.* (1992) for no corrections on the emissivity factor the split window technic will give good results over water, slightly less over fully vegetated areas, and poor results on dry bare soil. In very low fractional vegetation covering situation, the energy interactions with the surface is controlled by soil type. The differences between LST and T_{air} are also highly related to temperature magnitude and predominant soil type (Ouaidrari *et al.*, 2002). Many researchers (Kerr *et al.* 1992; Van de Griend & Owe 1993; Andersen 1997 and Kerényi & Putsay 2000), have applied successfully the accurate calculation of NDVI for emissivity estimation associated to LST as a tracer of soil conditions.

For the LST estimation we applied the Sobrino *et al.* (1993) method that use a combination of the channels 4 and 5 of the AVHRR sensor. Gusso (2003) evaluated the LST results the method proposed by Sobrino *et al.* (1993) over this same region. This algorithm, called *Weak Split-window* (WSW), they consider four atmospheric models: *Tropical* (T), *Midlatitude summer* (MLW), *1976 standard USA* (US) e *Midlatitude winter* (MLW) as shown at equation 1:

$$T_s = T_4 + [0,53 + 0,62(T_4 - T_5)](T_4 - T_5) + 64(1 - \varepsilon) \quad (1)$$

where: T_s = land surface temperature;
 T_4 and T_5 = brightness temperature for channels 4 and 5 of AVHRR;
 ε = mean emissivity for channels 4 and 5, $(\varepsilon_4 + \varepsilon_5)/2$.

The Sobrino *et al.* (1993) method (eq. 1) use the retrieved emissivity computed by Valor & Caselles (1996) (eq. 2, 3 and 4) algorithm by means of the NDVI as representative of the emissive characteristics of the irradiating surface. The emissivity factor was retrieved as follows:

$$\varepsilon = 0,985P_v + 0,96(1 - P_v) + 0,06P_v(1 - P_v) \quad (2)$$

thus:

$$P_v = \frac{\left(1 - \frac{i}{ig}\right)}{\left(1 - \frac{i}{ig}\right) - k\left(1 - \frac{i}{iv}\right)} \quad (3)$$

and k is:

$$k = \frac{\rho_{2v} - \rho_{1v}}{\rho_{2g} - \rho_{1g}} \quad (4)$$

where: i , ig , iv = NDVI, NDVI bare soil, NDVI vegetated surface;

ρ_1 and ρ_2 = channels 1 and 2 reflectances of AVHRR
 v and g = indexes for vegetation and bare soil.

The monthly (July and September) mean values of reflectances of channels 1 and 2, NDVI for bare soil and vegetated areas of AVHRR are presented in the Table 3. The NDVI data computed (Rouse *et al.*, 1974) were extracted from monthly composites produced using the maximum NDVI procedure (Holben 1986). The later LST is subtracted from the early LST so that (final LST – initial LST = LST var). In the same way to the T_{air} .

Table 3. NDVI and channels 1 and 2 reflectances values applied corresponding for vegetation and bare soil.

Sample	ρ_1	ρ_2	NDVI
Bare soil	0.18	0.2	0.1
Vegetation	0.12	0.48	0.6

2.3 Analysis

Figure 1 shows the *scatterplot* graphic of the variation in the LST and T_{air} (*in situ*) measurements between two overpasses during night-time. A slightly direct trend is observed.

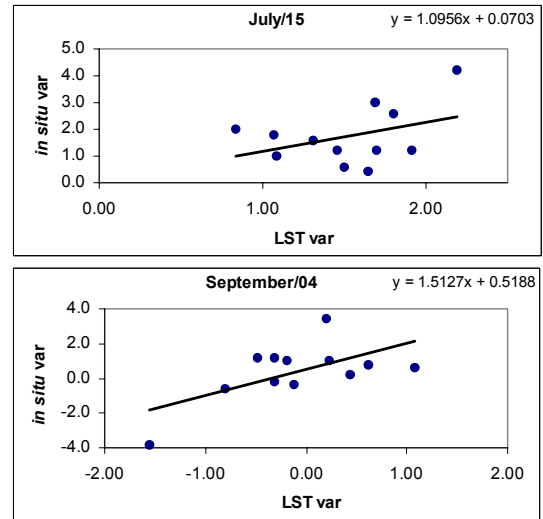


Figure 1. *Scatterplot* of LST and T_{air} (*in situ*) variation between two overpasses during night-time.

It is worthy to note the variation range of LST is closely to 2K and T_{air} variation is around 4K in the both dates. Small changes in the LST are followed by severely changes in the T_{air} .

3. CONCLUSIONS

The general patterns of decreasing night-time temperature conditions for which minimum air and surface temperatures appear correlated, can improve the understanding of the mechanisms between their day-time maximum values.

The modest differentiating to the levels of the reflectances for different types of bare soil and vegetation, the performance of the radiometric resolution available in the AVHRR (1024 digital counts), has the potential to improve data on the quality

of land surface coverage and the thermal dynamics. However, before any additional information of the atmospheric lower layers dynamics, the pronounced variations on the Tair during November 04 night remains unexplained. In doing so, taking into account only the obtained results, it lead us to conceive that the produced linearizations between Tair and LST are not theoretically reliable. It is due to the high uncertainty and variable state of the atmosphere (as wind speed regime) from one day to another, in the lower layers near the surface.

This type of verification is only contemplate very briefly here but will be the topic of future research on the analysis of these features.

Preliminary results within the same data base also suggested there is not relation for the both LST and Tair variations associated to the land surface altitude.

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