2009 EUMETSAT Meteorological Satellite Conference – Bath, UK, 21 - 25 September 2009

Preliminary results on the retrieval of Land Surface Temperature from MSG-SEVIRI data in Eastern Spain

Raquel Niclòs[1], Jose A. Valiente[1], Maria J. Barberà[1], Maria J. Estrela[2], Joan M. Galve[3], & Vicente Caselles[3]

[1] Unidad Mixta CEAM-UVEG. Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM). Charles Darwin, 14, 46980 Paterna, Spain. niclos@ceam.es
[2] Unidad Mixta CEAM-UVEG. Departamento de Geografía. Universidad de Valencia (UVEG). Blasco Ibáñez, 28. 46010 Valencia , Spain.
[3] Depart. Física de la Tierra y Termodinámica. Universidad de Valencia (UVEG). Dr. Moliner, 50. 46100 Burjassot, Spain.

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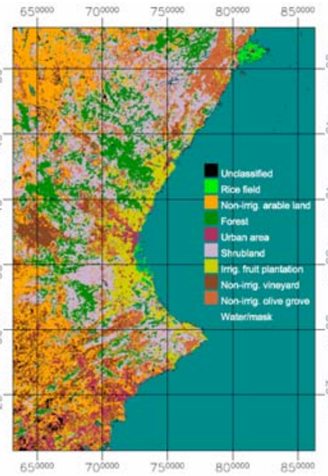
INTRODUCTION

A preliminary comparison between Land Surface Temperature (LST) images generated by the LSA SAF (Land Surface Analysis of the Satellite Application Facility) and ground measurements carried out in a large, flat, homogeneous rice crop area of Eastern Spain showed a bias and a standard deviation of 3K and ±1.4K, respectively. These results pointed out the need for a study on potential error sources. One source of error could be the land cover classification adopted by the LSA SAF to estimate the surface emissivity required by the LST algorithm. The angular behaviour of surface emission for different land covers should also be investigated due to the large range of observation angles used by the MSG-SEVIRI. Moreover, the soundness of the LST algorithm itself should be evaluated and compared with the results of other atmospheric and emissivity correction techniques. Two ground-truth validation sites have been set up in eastern Spain to validate LST algorithms. This work shows the first results of our research on the above issues, which is aimed at improving the determination of LST from MSG-SEVIRI HRIT imagery in eastern Spain.

LAND COVER CLASSIFICATION

Classification errors have been observed in the land cover maps used by the LSA SAF to estimate surface emissivity. E.g., the rice crop area used for testing the LSA SAF LST product was incorrectly classified as evergreen needleaf forest (IGBP 1).

We suggest a periodic generation of regional land cover maps by means of a supervised classification method (maximum likelihood) based on the use of representative and tested CORINE polygons as ground-truth areas and of spectral images (bands 1-7) of the isotropic BRDF parameter given by the MODIS MCD43A1 product. The analysis of the confusion matrix between the classification images and the ground-truth data gives overall training and validation accuracies of 80% and 70%.



Land cover map generated for Eastern Spain in August, 2007 (UTM, European 1950, 30N).

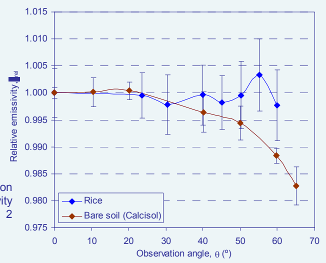
ANGULAR BEHAVIOUR OF SURFACE EMISSION

We have designed a mobile goniometric system to measure the angular behaviour of the surface emission.

Goniometric system: Observation of the same target area with different viewing angles by simultaneously modifying the angle, height and horizontal distance to the measurement point.

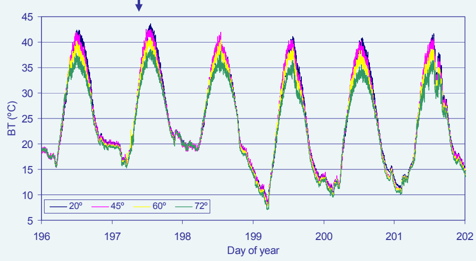
$$\varepsilon_{rel}(\theta) = \frac{\varepsilon(\theta)}{\varepsilon(0^o)} = \frac{\exp(-\alpha / T_{rad}(\theta)) - \gamma \exp(-\alpha / T_{atm}(0^o))}{\exp(-\alpha / T_{rad}(0^o)) - \gamma \exp(-\alpha / T_{atm}(0^o))}$$

α=14388/λ , λ=11.05μm and γ=1.3 for the radiometer Apogee SI-111 (IRR-PN)

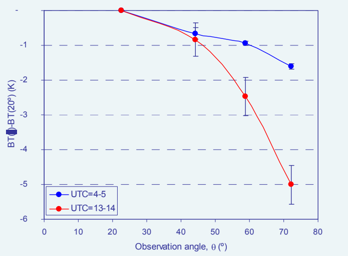


Angular variation of the emissivity measured for 2 samples.

Additionally, 4 Apogee SI-111 (IRR-PN) radiometers set up in a tower are measuring brightness temperature continuously at different zenith angles (20, 45, 60, 72º) but for a fixed direction in a large, high-plain, homogeneous area of scrubland.



Example of the brightness temperatures, BT, measured at different observation angles (6 days, 2009).



Relative angular variation of BT measured on a cloud-free day (199) at times of minimum (UTC 4-5) and maximum (UTC 13-14) temperature

LST ALGORITHMS

LSA SAF LST algorithm: Madeira (2002), adapted from Wan and Dozier (1996)

$$LST = \left(A_1 + A_2\frac{1-\varepsilon}{\varepsilon} + A_3\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T_9 + T_{10}}{2} + \left(B_1 + B_2\frac{1-\varepsilon}{\varepsilon} + B_3\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T_9 - T_{10}}{2} + C$$

↓ MODTRAN 4.0 + 90 atmospheric profiles

$$\varepsilon = \frac{\varepsilon_9 + \varepsilon_{10}}{2} \qquad \Delta\varepsilon = \varepsilon_9 - \varepsilon_{10} \qquad A_1, A_2, A_3, B_1, B_2, B_3, C = LUT(W, \theta)$$

$$\varepsilon_i = \varepsilon_{i,v} FVC + \varepsilon_{i,bg}(1 - FVC)$$ where FVC=LSA SAF FVC product; W from ECMWF

Proposed LST algorithm: adapted from Coll and Caselles (1997)

$$LST = T_9 + a(S)(T_9 - T_{10}) + b(S)(T_9 - T_{10})^2 + c + \alpha(W)(1 - \varepsilon) - \beta(W)\Delta\varepsilon$$

$$a(S)=(a_0+a_1S),\ b(S)=(b_0+b_1S),\ \alpha(W)=(\alpha_0+\alpha_1W+\alpha_2W^2),\ \beta(W)=(\beta_0+\beta_1W)$$

$S=\sec(\theta)-1$, $W=W_0/\cos(\theta)$ (in cm^{-1}), T_9 y T_{10} in K.

↓ MODTRAN 4.0 + 382 atmospheric profiles (CLAR, Galve et al. 2008) T_0-6K, T_0-2K, T_0+1K, T_0+3K, T_0+5K, T_0+8K, T_0+12K

a_0	1.04±0.03
a_1	0.13±0.04
b_0 (K^{-1})	0.249±0.006
b_1 (K^{-1})	0.135±0.008
c (K)	0.32±0.04
α_0 (K)	51.07±0.18
α_1 (K cm^{-1})	0.47±0.13
α_2 (K cm^{-2})	-1.049±0.019
β_0 (K)	95.2±0.2
β_1 (K cm^{-1})	-14.26±0.06

Coefficients for the SEVIRI (MSG-2).

GROUND-TRUTH DATA AND VALIDATION

We have set up **two fixed ground-truth stations**:

Zone A: Mediterranean calcic thermophile scrubland: Extensive high-plain area of scrubland dominated by rosemary (*Rosmarinus officinalis* L.) and gorse (*Ulex parviflorus* L.). FVC_{nadir}=0.49. 39,224ºN, -0,903ºE (WGS-84).

Zone B: Extensive and homogeneous area of rice fields with a FVC~1 in summer. 39,224ºN, -0,903ºE (WGS-84).

Sensors: Thermal radiometers, Apogee SI-111/SI-121 (IRR-PN/P) (calibrated against an NIST blackbody, BT accuracy: ±0.2K at 293K) + complete meteorological stations (solar irradiance, air temperature, wind speed,…) + measurement of biophysical variables.

$$R = \varepsilon\, B(LST) + (1-\varepsilon)\, L^{\downarrow}_{atm\ hem}$$

ε (8-14μm): Vegetation Cover Method (Valor & Caselles 1996) + Box Method (Rubio et al. 1997).

Zone	θ	FVC	Vegetation	Bareground	ε_v	ε_s	ε
A	20º	0.6	*Rosmarinus officinalis* L. & *Ulex parviflorus* L.	70% Chromic Luvisol + 30% Lithic Leptosol	0.984±0.007	0.956±0.009	0.986±0.007
	55º	0.95					0.989±0.008
B	0º	1	Rice	-	0.985±0.005	-	0.985±0.005

Validation results:

	(1) Zone A , W_0 (MODIS)		(2) Zone A , W_0 (NCEP)		(3) Zone B , W_0 (NCEP)	
LST algorithm	Proposed algorithm	LSA SAF	Proposed algorithm	LSA SAF	Proposed algorithm	LSA SAF
Bias (K)	0.7	1.5	0.6	1.6	-0.14	-0.08
σ (K)	1.2	1.3	1.0	1.1	0.9	1.0
RMSE (K)	1.4	2.0	1.2	1.9	0.9	1.0
N. events	59	59	527	527	89	89

(1) A first validation by using concurrent MSG-SEVIRI and MODIS W_0 (MOD05) for Zone A showed an RMSE of ±1.4K for the proposed algorithm and ±2K for the LSA SAF LST product.

(2) The use of W_0 estimated from NCEP data (RMSE of ±0.3cm^{-1} in comparison with MODIS W_0) enabled us to use a larger number of ground-truth and algorithm-retrieved LST matchups (527). RMSEs of ±1.2K and ±1.9K were obtained for both the proposed and the LSA SAF algorithms in this case.

(3) Similar results (±0.9K and ±1K) were obtained for both algorithms in an "ideal" site like Zone B. However, this was not the case for Zone A, where the bareground-vegetation structure is more complex and there is a wide thermal diurnal variability (~25º).

CONCLUSIONS

Several topics have been investigated with the aim of improving LST retrievals from MSG-SEVIRI data in Eastern Spain. Our first conclusion is to suggest that periodic and regional land cover maps be generated by using a selection of representative and tested CORINE polygons and MODIS MCD43A1 images. In addition, our preliminary results from carrying out angular measurements of surface emission show that there is an emissive angular dependence for some surfaces that should be taken into account in LST retrievals from satellite data. Furthermore, the validation of satellite-retrieved LSTs by comparison with ground-truth data measured by the two fixed stations set up in the East of Spain shows accuracies higher than ±1.5K for the quadratic split-window equation proposed for the MSG-SEVIRI and near to ±2K for the LSA SAF MSG LST product, which seem to have improved since the radiance definition change in the MSG Level 1.5 product.

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Acknowledgements

This work has been supported by the Spanish Ministerio de Ciencia e Innovación (projects CGL2007-65774/CLI, CGL2008-04550, CGL2005-03386, and CONSOLIDER-INGENIO 2010 CSD2007-00067), and by Dr. R. Niclòs' Juan de la Cierva Research Contract, which is co-funded by the European Social Fund and the European Union (Project CIRCE No. 036961). Fundación CEAM is supported by the Generalitat Valenciana and BANCAIXA.