Use of Multitemporal Remote Sensing Thermal Data for the Creation of Temperature Profile of Alfios River Basin

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***Abstract*-In this paper, we present the creation of a temperature profile of the Alfios river basin using multitemporal thermal satellite images. With the appropriate algorithms we converted the radiation into Celsius Degrees in order to calculate the surface temperature of the area. We proceed to the control of the model accuracy using in situ temperature measurements. The results showed that the error is less than 0.3 ^{o}C and it is acceptable**.

I. INTRODUCTION

The electromagnetic radiation in the spectral region 8-14μm corresponds to the thermal area of the spectrum. All the materials (targets) on the surface emit thermal radiation that is collected by satellite sensors. The radiation emitted from the target at a given wavelength is a function of its temperature and its spectral emissivity. If we set the emissivity to one, assuming that the target is a blackbody, we can calculate the temperature of the target.

Many writers have used thermal images to study the behavior of minerals [1], [2], or soils [3]. Radiation collected by satellites has been used to measure the earth surface temperature taking into consideration the atmospheric attenuation [4] or to observe volcanic ash clouds [5] and detect ice leads in the Arctic [6] to name just a few examples.

Presently Landsat TM and ETM and ASTER are the only available high spatial resolution satellite sensors with a thermal spectral band.

II. AREA OF STUDY

Alfios is the biggest river of the Peloponnese and the ninth bigger river in Greece. It drains an area of almost 2575 km2 in Western Peloponnese (Fig.1) and discharges at Kiparissiakos Gulf. Due to its extent Alfios basin presents complex physiography and geomorphology. At the west, there are the coasts of the Ionian Sea and the relief is very low. At the east, there are many hills and mountains and so the elevation ranges from 0 to more than 2000 m. The climate of the area is typically Mediterranean with rainy winter and very hot summer.

In order to create the temperature profile of the Alfios river basin we used the following cloud free multitemporal satellite images:

A Landsat 5 TM, acquired on July 27 1984,

A Landsat 5 TM, acquired on September 18 1986,

Fig. 1 The Alfios River Basin

A Landsat 7 ETM, acquired on July 28 1999.

All the images covering the studied area have been geometrically corrected, taking into account about 200 ground control points distributed in whole image. For this correction the EGSA'87 grid of the 1:50.000 scale topographic maps of the area (Hellenic Army Geographical Service, 1987) has been taken into account. The resembling method for warping the data was nearest neighborhood interpolation and the new pixel size of 30 meters.

III. PROCESSING AND CALIBRATION OF THE LANDSAT-TM THERMAL BAND 6

The thermal bands have been used in order to calculate the surface temperature of the area. We have used the thermal band 6 of the Landsat-5 TM images and the thermal band 6.1 (low gain) of the Landsat-7 ETM (Fig. 2). The surface (ground), temperature (brightness) of the thermal bands data was calculated with the following steps:

First the digital number DN was converted into a radiance L with the following formula:

$$L = c_0 + c_1 * DN$$

where the coefficients [7],[8], for Landsat-5 TM band 6 are

c_0 =0.124, c_1 =0.00563 (mWcm-2sr-1,μm-1)

and for Landsat-7 ETM band 6.1 are

c_0 =0, c_1 =0.06708 (mWcm-2sr-1,μm-1).

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Then the radiance was converted into an equivalent blackbody temperature T (in Celsius degrees) at the satellite [9] with the following formula for Landsat-5 TM:

$$T_c = \frac{K_2}{K_1 - \ln L} - 273$$

For Landsat-7 ETM we used the formula [10]:

$$T_c = \frac{K_2}{\ln \frac{K_1}{L} + 1} - 273$$

The coefficients K1 and K2 depend on the range of blackbody temperatures. In the blackbody temperature range 260 -300 0K the default values [9] for Landsat-5 are K1 = 4.127, K2 = 1274.7 and for Landsat-7 [10] are K1 = 666.09 and K2 = 1282.71.

Fig. 2. The Landsat-7 ETM thermal band 6.1 (low gain)

After converting the brightness values of the image in Celsius degrees; and in order to better distinguish the thermal anomalies we have classified the temperatures in fourteen classes using the density slicing method.

In Fig. 3 we present the temperature profile of the Landsat 5 TM image, acquired on July 27 1984 and in Fig. 4 the temperature profile of the Landsat 7 ETM image, acquired on July 28 1999.

III. ACCURACY CONTROL

Then we proceed to the control of the model accuracy using in situ temperature measurements. For the days of the images acquisition, measurements from two different climatological

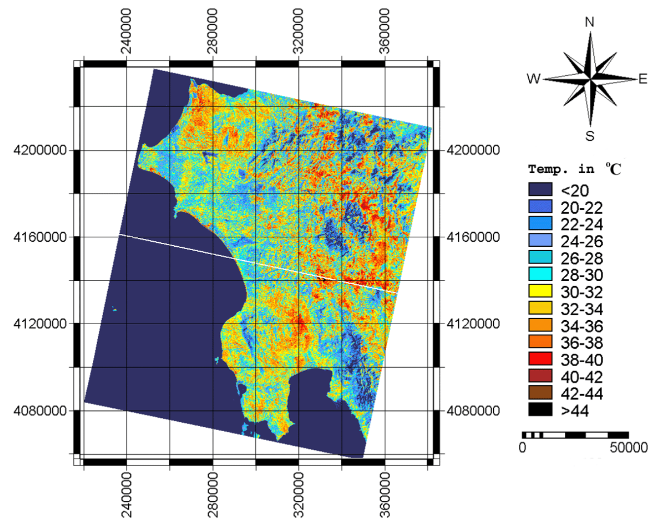

Fig. 3 Temperature profile of the Alfios River Basin from the 1984 image.

stations (they are mentioned with X in Fig. 4.) placed in the area of study were used. In Table 1 we present the temperatures at Pyrgos station and in Table 2 we present the temperatures at Andravida station.

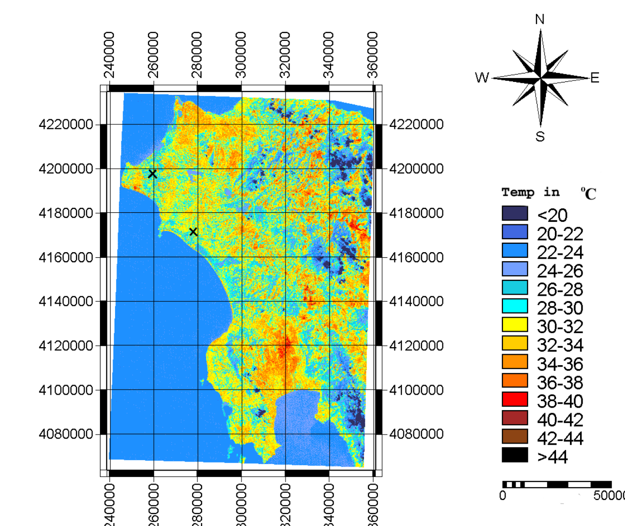

Fig. 4 Temperature profile of the Alfios River Basin from the 1999 image.

As we can see in Table 1 the temperatures at Pyrgos station at 26/7/1984 were 24 ^{0}C at 09:00 and 28,2^{0}C at 12:00. According to the thermal satellite image the temperature ranged between 26^{0}C and 28^{0}C. The equivalent temperatures at Andravida stations (Table 2) were 22,2^{0}C at 09:00 and 28,2^{0}C at 12:00. For the Andravida area the temperature according to the thermal satellite image was between 24^{0}C and 26^{0}C.

TABLE 1
PYRGOS STATION TEMPERATURES

Date	26/07/1984		28/07/1999		
Hour	09:00	12:00	09:00	10:00	11:00
Temp. in ^{0}C	24	28,6	26.4	28	29.4

As we can see in Table 1 the temperatures at Pyrgos station at 28/7/1999 were 26,4^{0}C at 09:00, 28^{0}C at 10:00 and 29,4^{0}C at 11:00. According to the thermal satellite image the temperature ranged between 28^{0}C and 30^{0}C. The equivalent temperatures at Andravida stations (Table 2) were 25,6^{0}C at 09:00, 26,8^{0}C at 10:00 and 28,2^{0}C at 11:00. For the same area the temperature according to the thermal satellite image was between 26^{0}C and 28^{0}C.

TABLE 2
ANDRAVIDA STATION TEMPERATURES

Date	26/07/1984		28/07/1999		
Hour	09:00	12:00	09:00	10:00	11:00
Temp. in ^{0}C	22,2	28,2	25.6	26.8	28.2

Taking into consideration that the satellite passes over the area at 10:40 local time we can understand that the model works successfully and the thermal maps are quite accurate.

IV. DISCUSSION

From the study of the Alfios Temperature profile we can understand that the hilly or mountainous areas present generally lower temperature than the flat areas. As it can be observed in Fig.3 and Fig. 4 the mountainous areas at the east and the south have a blue color. On the other hand areas with low relief at the west presents higher temperatures and they have a yellow color.

Concerning the Alfios river basin we have mapped areas along the river channel that present 6-8 ^{o}C lower temperature than the rest of area. As we can observe in Fig. 5 even the third or second order branches of Alfios River create long lanes of lower temperature.

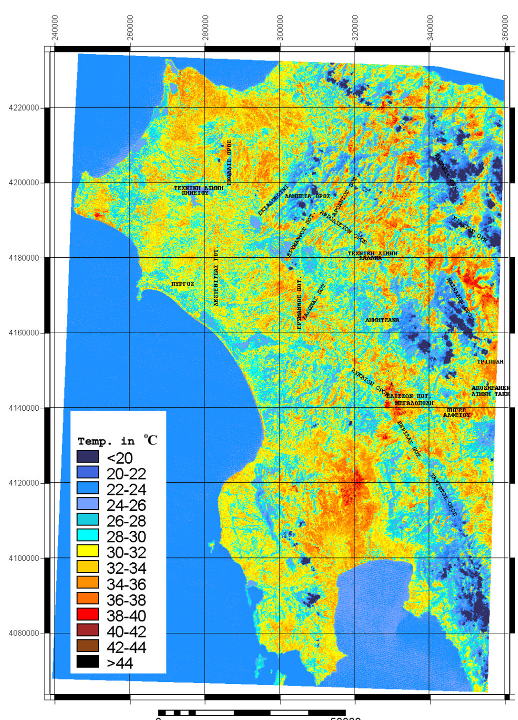

Fig. 5. Enlargement of the temperature profile of Alfios River Basin presented in Fig. 4

The sea temperature is 10 to 12 ^{o}C lower than the land temperature. Also the areas around the big artificial lakes of Pinios and Ladonas present significant lower temperature

V. CONCLUSIONS

According to the results obtained by the analysis that was carried out, the presence of water create lanes or lower temperature around the Alfios River branches.

The algorithms for the conversion of the radiation in Celsius Degrees give accurate results.

The general conclusion is that the TM & ETM thermal bands can be used for the creation of temperature profiles across large areas where the construction of climatological stations is difficult.

REFERENCES

[1] Lyon, R.J.P., 1972. *An Introduction to Atmospheric Radiation*. Academic Press, New York.

[2] Lyon, R.J.P., 1975. “Reflectance and emittance of terrain in the mid-infrared (6-25 μm) region”. *In Infrared and Raman Spectroscopy of Lunar and Terrestrial Minerals* (C. Karr, Jr., Ed.), pp.165-196. Academic Press, New York.

[3] Taylor, S.E., 1979. “Measured emissivity of soils in the southeast United States”. *Remote Sensing of Environment* 8:359-364.

[4] Price, J. C., 1983. “Estimating surface temperatures from satellite thermal infrared data-a simple formulation for the atmospheric effect”. *Remote Sensing of Environment*. Vol. 13 pp. 353-361.

[5] Prata, A. J., 1989. “Observations of volcanic ash clouds in the 10-12 μm window using AVHRR/2 data”. *International Journal of Remote Sensing*, vol. 10, nos. 4 and 5, pp. 751-761.

[6] Stone, R. S., 1993. “The Detectability of Arctic Leads using Thermal Imagery under varying Atmospheric Conditions”, *Journal of Geophysical Research - Oceans*, vol. 98, no. nc7, pp. 12469-12482.

[7] Metzler M.D. And Malila W.A.,1985.“Characterization of Landsat 4 and Landsat 5 Thematic Mapper Data”, *Photogrammetric Engineering and Remote Sensing*, 51:1315-1330.

[8] EOSAT, 1986. *Landsat Technical Notes*, Lanham, MD.

[9] Singh S.M., 1988. “Brightness Temperature Algorithms for Landsat Thematic Mapper Data”, *Remote Sensing of Environment* 24:509-512.

[10] NASA *Landsat 7 Science Data Users Handbook, 1998.*