SATELLITES OBSERVATION OVER THE MARSEILLE-BERRE AREA, DURING THE UBL/CLU-ESCOMPTÉ EXPERIMENT

B. Dousset 1 and S. Kermadi 2
1. Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, USA
2. ESO, CNRS - Université du Maine, Le Mans, France

ABSTRACT

Remote sensing observations over the Marseille-Berre area were analyzed as part of the UBL/CLU ESCOMPTE experiment conducted in Marseille (France) in 2001. One hundred and fifty nine NOAA-AVHRR images, with a 1 km spatial resolution, were extracted over the period of June 4 to July 13 2001. Land Surface Temperatures (LST) and a fractional vegetation index were derived from the images. The temporal resolution of up to six images a day allows the study of LST diurnal variations and the construction of statistical averages. LST variations of up to 8 C were observed between the rural and the urban-industrial areas of Marseille and Marignane. Highest LST closely follows the contours of densely built or industrial districts. Urban parks generates cool islands of 1.5 to 3.5 C. This cooling effect is confirmed by the significant negative correlation between the afternoon LST and the fractional vegetation index. An EOS-ASTER image, with a high spatial resolution of 15 to 90 m, is being analyzed in an attempt to document the emissivities of urban surfaces, which are critical in deriving accurate LST and in studying the surface energy exchange. Results of remote sensed land surface temperatures are interpreted as a function: of a land cover classification from a multi spectral SPOT image; and of surface and atmospheric measurements from the ESCOMPTE experiment.

INTRODUCTION

Investigation of the dynamics and thermodynamics of the Urban Boundary Layer (UBL) of the Marseille-Berre area, has been conducted as a side project of the regional photochemistry ESCOMPTE experiment (http://medias.obs-mip.fr/escompte). The UBL experiment comprises both in-situ and remote sensed measurements (1). The main objectives of the UBL experiment are: to validate existing urban energy schemes; to test high resolution atmospheric models of the UBL, and to construct an important dataset of the dynamic fields and diurnal cycles to study the urban atmospheric physics and chemistry. Concerning, more specifically the satellite observations, the objectives are: to implement methods and algorithms to derive the surface albedo, emissivity and temperature that govern the surface heat fluxes, allowing their input into urban atmospheric models; and to analyze the temporal and spatial variations of land surface temperature and their relationship to surfaces and atmospheric properties recorded simultaneously during the ESCOMPTE experiment.

METHODS

The analysis is based on a continuous series of thermal infrared images, their combination with high resolution near infrared and visible images and with other remote sensed and in-situ surface and atmospheric measurements. The satellite observations come NOAA-AVHR 12, 14 and 16, EOS-ASTER-1 and SPOT-HRV4, which data processing and merging are shown in Fig.1.

From a dataset of more than 300 NOAA-AVHRR images, acquired from June 4 to July 13 2001, 159 were selected according to the image quality and satellite-zenith angle. The NOAA satellites, launched into near polar sun synchronous orbits, pass in view of any point on earth twice daily. Since 3 satellites were active simultaneously, they allow the study of the diurnal cycle of surface temperature. The Advanced Very High Resolution Radiometer (AVHRR), on board these satellites, scans in five channels (NOAA 12 and 14) or six channels (NOAA-16), from the visible and near-infrared to the thermal infrared. The image ground resolution is 1.1 km at the sub-satellite point. The size of the images selected for the experiment covers a domain of 120 x 120 km centered at 43° 30. N and 5° 20. E. The images were calibrated, navigated and remapped to a common
grid, on a four step processing described in the ESCOMPTE database. A profile and a zoom of a channel 4 image are shown in Fig. 2 and 4, respectively. The Vegetation Index (NDVI) is obtained from the Normalized Difference of the visible and near infrared channels 1 and 2, (not shown here).

Temperatures are Brightness Temperatures as seen by the AVHRR viewing through the earth's atmosphere. Brightness temperatures are typically colder than actual surface temperature for multiple reasons. Most of these, namely clouds, water vapor, aerosols, and departure of the surface from being a true blackbody, tend to lower the brightness temperature by an amount ranging from one to several C, depending upon atmospheric conditions. To derive Land Surface Temperatures (LST) from Brightness Temperatures it is necessary to use a radiative transfer model, and near-simultaneous radio sounding recorded during the ESCOMPTE experiment. Over the ocean (a near-perfect blackbody), an empirical multi-spectral correction for water vapor is generally computed based on the differential attenuation of infrared channels 4 and 5. This correction does not apply to land surfaces given the spatial and spectral variation of their emissivity.

The EOS-ASTER image was acquired on May 27 2001. The Advance Space borne Thermal Emission and Reflection Radiometer (ASTER) scans in 14 channels spanning the visible, near infrared and thermal infrared with a spatial resolution of 15, 30 and 90 m, respectively (Fig.3). Most important is the possibility to derive the surface emissivity, through a temperature-emissivity separation algorithm (2).

The SPOT HRV-4 multispectral image was acquired on June 17 2000. The High Resolution Visible imager has four spectral channels from the visible to the near-infrared. The image was re-sampled across-track to remove the off nadir imaging effect and to obtain a 10 m pixel size. The image was classified into 9 land cover classes, and further validated using the NDVI (not shown ). Fig. 5 presents a version of the unsupervised classification, re-sampled at 200-m resolution.
Fig. 2. (a) N.W – S.E, and (b) S.W – N.E profiles of brightness surface temperature, on a composite NOAA-AVHRR image, based on 2 images sensed at 13:05 and 12:54 UTC, on June 22 and 23 2001.

Fig. 3: zoom on the 15 m resolution EOS-ASTER VNIR image of May 27 2001, corresponding to the 0 -8 km area of Fig. 2, (northern Marseille).

Fig. 4: 1-km resolution NOAA-AVHRR surface brightness temperature image (ch. 4), sensed on 22 June 2002, at 13.05 UTC. The temperature scale ranges from 17 to 42ºC.

Fig. 5: 200-m resolution land use classification, from the SPOT HRV-4 image, sensed on 17 June 2000.
FIRST RESULTS AND DISCUSSION

During the Intensive Period Observation 2a, June 21 to 23, urban heat islands of up to 8 °C were observed between the rural and the urban and industrial areas of Berre, Marignane, and Marseille. Highest temperatures closely follow the contours of built surfaces, and lowest temperatures that of salt marshes, vegetated and mountain areas. The North-West to South-East profile temperature (Fig. 2), from a composite image of the NOAA-16 satellite passes at 13:05 (Fig.4) and at 12:54, on June 22 and 23 2001, displays large surface temperature variations which respond to surface properties and to building density seen in the land use classification image (Fig.5). Highest LST of 39.5-40 °C occurred in the industrial zones, piers and densely built areas. Small parks such as Park Billoux, generated cool islands of 1.5 to 3.5 °C. The scatter plot of afternoon LST versus the NDVI indicates a negative correlation of 8 °C for a 0.2 NDVI variation. This confirms the significance of urban park and vegetation in the partition of surface heat fluxes, as previously noticed in other cities such as Los Angeles or Paris (3). Low temperatures were observed on deep and coastal waters, 18 to 20 °C respectively, and 22 °C on the Etang de Berre.

The linear spectral profile of the sea surface, through the 5 TIR ASTER channels (not shown here), represents the homogeneity and near constant emissivity of the sea surface. The non linear spectral profiles of urban surfaces (terra-cotta roofs, asphalt or concrete paving, etc...) indicate lower emissivities, resulting in brightness temperature lower than actual LST, therefore calling for a few °C correction.

Ongoing work is attempting to derive accurate LST and construct emissivities maps, taking into account both the surface heterogeneity (4), and the directional effects (5) owing to the satellite field of view and to the sun angle, at the time of the sensing.

ACKNOWLEDGEMENTS

The NOAA-AVHRR images were provided by F. Parmigiani, and the EOS-ASTER image by NASA. Support was granted by the PATOM and the PNTS.

REFERENCES


* Corresponding author address: Bénédicte Doussset, Hawaii Institute of Geophysics and Planetology, University of Hawaii, 1680 East-West Road, Honolulu, HI 96822, USA; e-mail: bdoussset@soest.hawaii.edu