Analysis of the Land Surface Temperature changes around the Mediterranean during the period 2000-2012

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The Land Surface Temperature (LST) is important for the determination of earth surface changes, while it constitutes a crucial parameter in climate change studies. In the present study, satellite observations were processed for the creation and analysis of a 12-year time series of the LST spatial distribution around the Mediterranean. Both day and night LST data, at 1 km × 1 km spatial resolution, were extracted from corresponding MODIS (Moderate Resolution Imaging Spectroradiometer) sensor products. The time series were statistically analysed for the estimation of the LST seasonal variation and trends, on a monthly and pixel basis. In addition, all pixels were categorized according to land cover type data from the GlobCOVER product of the European Space Agency (ESA), and the LST trend analysis was repeated for each land cover type. The results revealed substantial spatiotemporal variability of the LST around the Mediterranean during the last twelve years, highlighting the great potential of satellite remote sensing in supporting studies related to LST and its role on climate, at both local and regional scales.

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1 Introduction

Land Surface Temperature (LST) has direct impact on the biotic diversity worldwide and contributes to climate change, both locally and globally. Hence, its study is important for the determination of these changes. Amongst climatically sensitive areas, the wider Mediterranean constitutes a region of high interest, due to changes already being observed, including decreasing precipitation and increasing high temperature extremes (e.g. Trenberth et al. 2007, Trenberth 2011, IPCC 2012) and imminent desertification, foreseen by climatic projections (e.g. Meehl et al. 2007), combined with high population density.

In the present study, high resolution satellite-derived day and night LST data were extracted from corresponding MODIS (Moderate Resolution Imaging Spectroradiometer) sensor products and analyzed for the investigation of LST spatial and temporal characteristics. The data set spans the period 2000 – 2012 and covers the wider Mediterranean region, including Northern Africa, the Middle East and Europe, except the Scandinavian Peninsula.

In the next section, the MODIS LST products and the corresponding processing methodology are described. The analysis includes calculation of monthly and seasonal averages, as well as changes (trends) during the period examined on a pixel basis. A land cover map for the study area was also used, for the investigation of possible differences in these changes among different land cover types. Representative results are presented in Section 3.

2 MODIS LST data and processing methodology

2.1 MODIS LST products

MODIS Level 3 LST products are available separately from NASA’s Terra and Aqua satellites, on a daily, 8–day and monthly mean basis. The Terra 8–day mean product, which is available at 1 km × 1 km spatial resolution, was used in this study. This data are available from March 2000, and for each 8–day they are separated in tiles, as shown in Figure 1a, with each tile corresponding to one file. Among other parameters, each file contains LST data obtained during day and night, depending on the satellite overpass times. The study area, shown in Figure 1b, corresponds to 23 tiles per 8–day, leading to a total of over 13000 files, which were retrieved and processed, for the entire time series analysis (03/2000–12/2012).

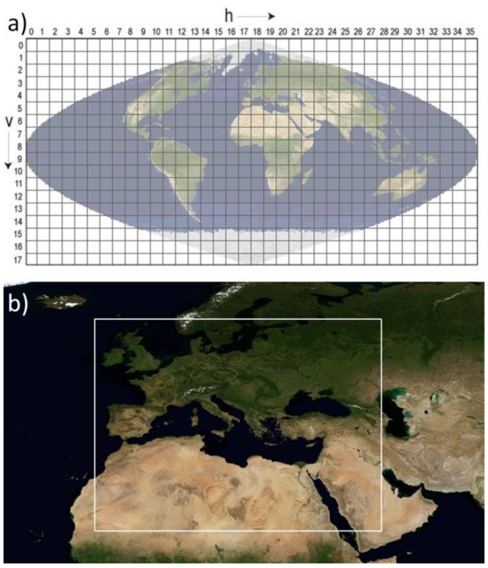

Fig. 1. a) MODIS tiles (black rectangles) and b) study area (white rectangle)

2.2 Statistical processing

Using MATLAB and HEGTool software, data of 8–day mean LST and daily cloud cover flags were extracted from the original HDF (Hierarchical Data Format) MODIS files and converted to GeoTIFF format, while LST data were also descaled (converted from digital numbers to Kelvin units, based on corresponding metadata).

Daily cloud flag data were used as weights for the computation of monthly mean LST values on a 1 km × 1 km pixel level, based on the corresponding 8–day averages. Specifically, daily cloud flag data, which acquire values of 0 or 1, contain information on the number of daily observations, which was used in the computation of monthly mean values. For the 8–day files that covered days in successive months, daily cloud flag data were also used for the identification of LST retrieval on a daily level, and the apportionment of the corresponding 8–day mean accordingly.

The seasonal (intra–annual) LST variation, for both day and night, was also estimated, based on the monthly mean results of the entire time series, and the corresponding numbers of daily observations.

For the investigation of possible trends in day and night LST during the 13–year period examined, a linear regression analysis was performed on a pixel level, using the least squares method. Trends were calculated separately for each month, as percent changes in LST, based on the equations derived from the linear regression. In order to ensure the representativeness of these changes, a threshold of at least 6 LST values per month was applied, while a second threshold of at least 8 monthly mean values out of 13 in the time series was also used.

2.3 Land cover based analysis

Land cover is among the primary factors controlling LST. A land cover based statistical analysis was performed in the present study, for the investigation of possible differences in LST changes, among different land cover types. For this purpose, the ESA's GlobCOVER product was used, which was created in 2009, based on observations of MERIS (Medium Resolution Imaging Spectrometer) sensor (Bicheron et al. 2008). GlobCOVER classifies land cover into 21 categories, using a spatial resolution of about 300 m × 300 m. These data were collocated with, and upscaled to the MODIS LST spatial resolution, based on the land cover type which occupied the majority of GlobCOVER pixels in each 1 km × 1 km LST pixel. Average values of LST trends were then calculated for each land cover type, separately for day and night, based on the entire study area.

3 Results

Figure 2 shows the spatial distribution of the seasonal mean LST values (in K), in January (left) and July (right), separately for day (upper) and night (lower). These two months were selected as representative of winter and summer, respectively. It should be noted that the color scale is different in each image. In all cases, highest temperatures are reported primarily in Northern Africa, and secondarily in the Mediterranean coastal areas, while the lowest are constantly observed over Russia. Local topography effects are also evident; mountainous regions, such as the Alps or the Pyrenees, are always colder than their lowland surroundings.

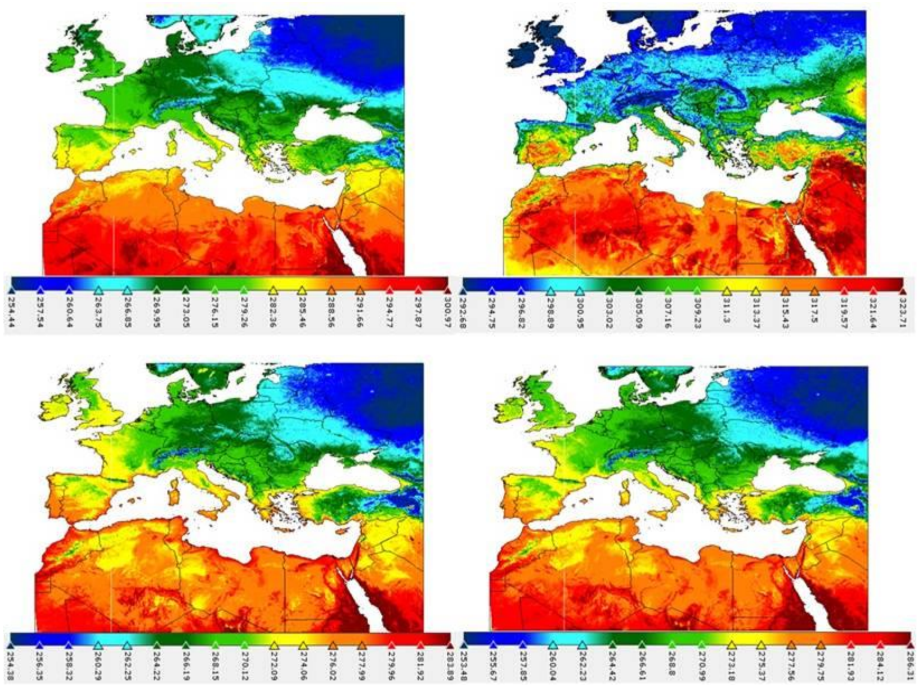

Fig. 2. Spatial distribution of the LST (in K) over the study area, in January (left panels) and July (right panels), separately for day (upper panels) and night (lower panels).

The spatial distribution of LST trends (in %), is shown in Figure 3. Blank regions correspond to cases where the linear regression threshold criteria were not met. In the majority of cases, LST change does not exceed 2% in absolute value, while signs of changes are usually intermixed on a local level. The most pronounced cases of apparently systematic LST change on a regional scale are an increase around the Adriatic Sea and decreases in the British Islands and the greater part of Turkey. Increasing trends are also observed in many parts of Northern Africa.

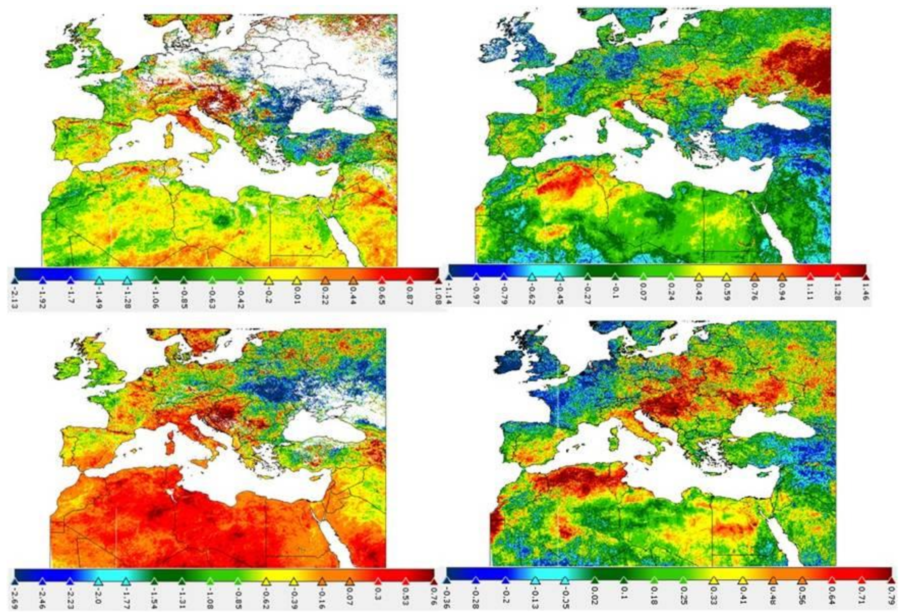

Fig. 3. Spatial distribution of the LST trends (in %) over the study area, in January (left panels) and July (right panels), separately for day (upper panels) and night (lower panels).

LST trends based on land cover revealed mixed signs in almost every land cover type. This result should be attributed to the extent of the study area, whereby pixels of the same land cover type may be thousands of kilometres apart, in areas with totally different climatic conditions and corresponding trends. The fact that bare areas, located mainly in Northern Africa, is the only land cover type exhibiting a systematic increasing trend almost throughout the year, confirms this conclusion.

4 Conclusions

MODIS LST data from Terra satellite, available on a 1 km × 1 km spatial resolution and 8–day averages, separately for day and night satellite overpasses, and for the period 2000–2012, were retrieved and analyzed. The study area comprised the Mediterranean Basin, including Northern Africa, the Middle East and the greater part of Europe.

Statistical analysis included seasonal and monthly mean LST computations on a pixel basis, investigation of LST trends during the period examined, and assessment of these changes based on land cover type classification.

Results showed that during the last 13 years, in the study area, where a significant percentage of the world population lives, the spatial distribution of LST and its corresponding changes, is very diverse and heterogeneous, highlighting the importance of each assessment at this high spatial resolution.

The data set created in this study can be used in a variety of cases, including local scale studies, such as urban heat island and heat waves effects, and validation of corresponding modeled distributions. Future work also includes the assessment of LST changes based on corresponding land cover type changes, which will give insight on the importance of land cover in local to regional climatic conditions. Finally, the Aqua/MODIS observations will be also exploited to study the diurnal LST variation patterns in the study area.

References

Bicheron P, Defourny P, Brockmann C, Schouten L, Vancutsem C, Huc M, Bontemps S, Leroy M, Achard F, Herold M, Ranera F, Arino O (2008) GlobCOVER: Product Description and Validation Report. MEDIAS-France, Toulouse, France

IPCC (2012) Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptations. Cambridge University Press, Cambridge, UK and New York, NY, USA

Meehl GA, Stocker TF, Collins WD, Friedlingstein P, Gaye AT, Gregory JM, Kitoh A, Knutti R, Murphy JM, Noda A, Raper SCB, Watterson IG, Weaver AJ, Zhao ZC (2007) Global Climate Projections, in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Trenberth KE, Jones PD, Ambenje P, Bojariu R, Easterling D, Tank AK, Parker D, Rahimzadeh F, Renwick JA, Rusticucci M, Soden B, Zhai P (2007) Observations: Surface and Atmospheric Climate Change, in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Trenberth KE (2011) Changes in precipitation with climate change. Clim Res 47:123–138