A study of the Athens Urban Heat Island effect during the 2009 THERMOPOLIS campaign

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Introduction

Measurements of air temperature in the urban canopy layer were performed during July 2009 in 29 sites in Athens (Fig. 1). These allowed for the mapping of the daily spatiotemporal evolution of the Urban Heat Island in Athens. City districts to the east were the hottest during the afternoon, while being among the coolest during the early morning hours. While during the early morning some coastal sites were the hottest, the "heat plume" slowly moved to the center of the city until 14:00 – 15:00 moving then further east during the afternoon. Satellite-derived Land Surface Temperature (LST) data from AATSR, ASTER, AVHRR and MODIS for the pixels corresponding to the Tair ground stations showed that LST can be up to 5 K lower than the respective Tair (during late afternoon/nighttime), while it can be up to 15 K higher (during the rest of the day).

For each station, timeseries of Tair and the corresponding LST timeseries (i.e. the LST for the satellite pixel where each station lies within) show that generally late afternoon AATSR LST acquisitions agree very well with Tair for all stations and all days, i.e. for Athens the AATSR LST afternoon retrieval is a very good approximation of Tair. The same holds for the AVHRR LST late afternoon acquisitions. The MODIS late afternoon/early morning LST data agree also fairly well (although not as good as AATSR and AVHRR) with Tair for most stations and most days, in all cases the difference being < 4 K.

Results

Foolowing the classification of all sites (see example in the Appendix), to obtain T_{air} UHI maps, a spatial interpolation of the 29 station data was performed using the Delaunay triangulation (Delaunay, 1934). To test the triangulation results, the mean spatial T_{air} was computed using the Delauney triangulation for each hour of the day for three cases (Fig. 2): 1. using measurements at all 29 available stations. 2. Using only 10 stations in the center, and finally 3. using only 16 stations. Cases 1 and 3 gave almost identical results. Case 2 gives results only for the central part, since this is where these stations were located, and despite the fact that in this Case much more stations are located in the center, the results for this part of Athens are almost identical with Case 3 where very few stations are located in the center. This gives further credibility to the assumption of a very good interpolation. In fig. 2, results of this interpolation exercise for 00, 06, 12, and 18 hrs are presented. Fig. 3 shows the spatiotemporal evolution of T_{air} UHI.

Figure 1. Map of measuring sites used for urban canopy air temperature (Tair) analyses in the Greater Athens Area.

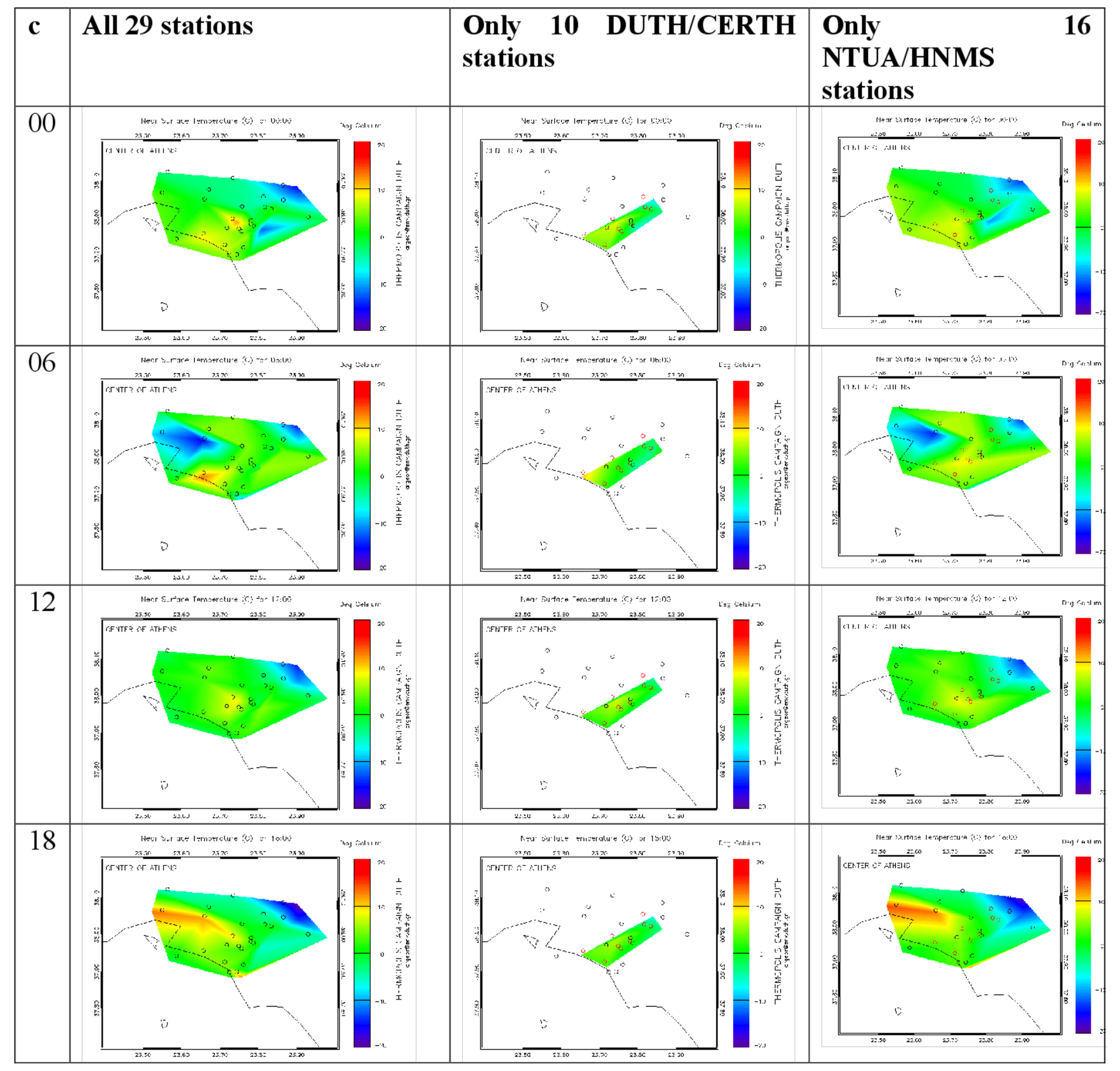
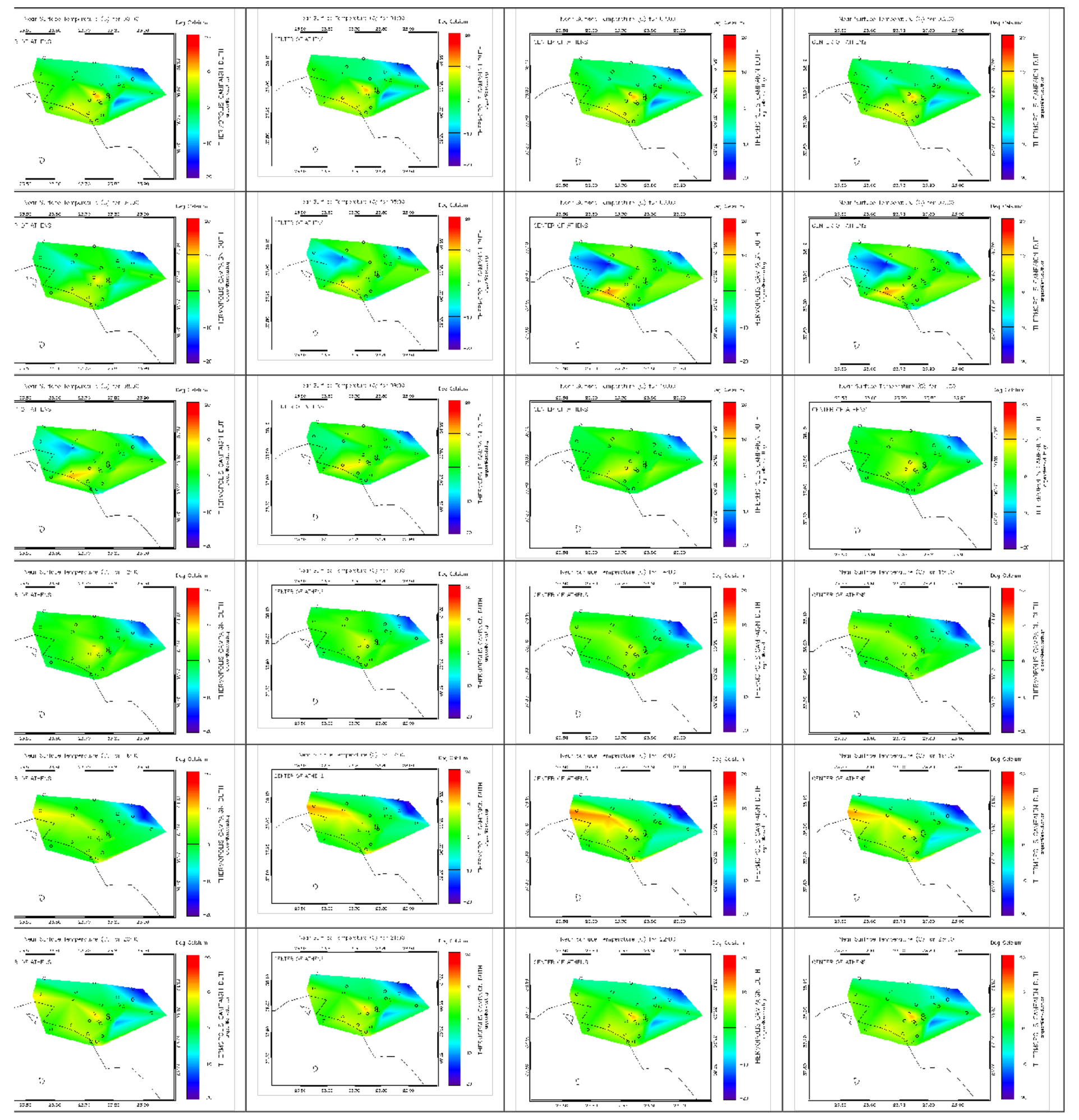


Figure 2. Results of the interpolation for 00, 06, 12 and 18 hrs using different station data as input.

Mean diurnal variation of Tair



Mean diurnal variation of spatial Tair features for the Athens area during the THERMOPOLIS 2009 campaign. All stations (29) with available data were used. Time is at 00 hrs at the upper left panel. Time proceeds with 1-hr step from left to right and from top to bottom.

T_{air} (in situ data)-LST (satellite data) differences

Satellite acquisition data for the pixels corresponding to the T_{air} ground stations were retrieved from four sensors. For each station, timeseries of T_{air} and the corresponding LST timeseries (i.e. the LST for the satellite pixel where each station lies within) were plotted (Fig. 4). Generally, it can be said that

1. Late afternoon AATSR LST acquisitions agree very well with Tair for all stations and all days, i.e. for Athens the AATSR LST afternoon retrieval is a very good approximation of T_{air}.

2. The same holds for the AVHRR LST late afternoon acquisitions.

3. The MODIS late afternoon/early morning data agree also fairly well (although not as good as AATSR ande AVHRR) with T_{air} for most stations and most days, in all cases the discrepancy being < 4 K.

It follows from the above that it might be possible to reconstruct the spatial evolution of the daily course of the T_{air} in Athens from afternoon AVHRR observations (or AATSR, although at this case there is no daily coverage) IN THE CASE that a robust statistical relationship exists between afternoon Tair and Tair in other times of the day.

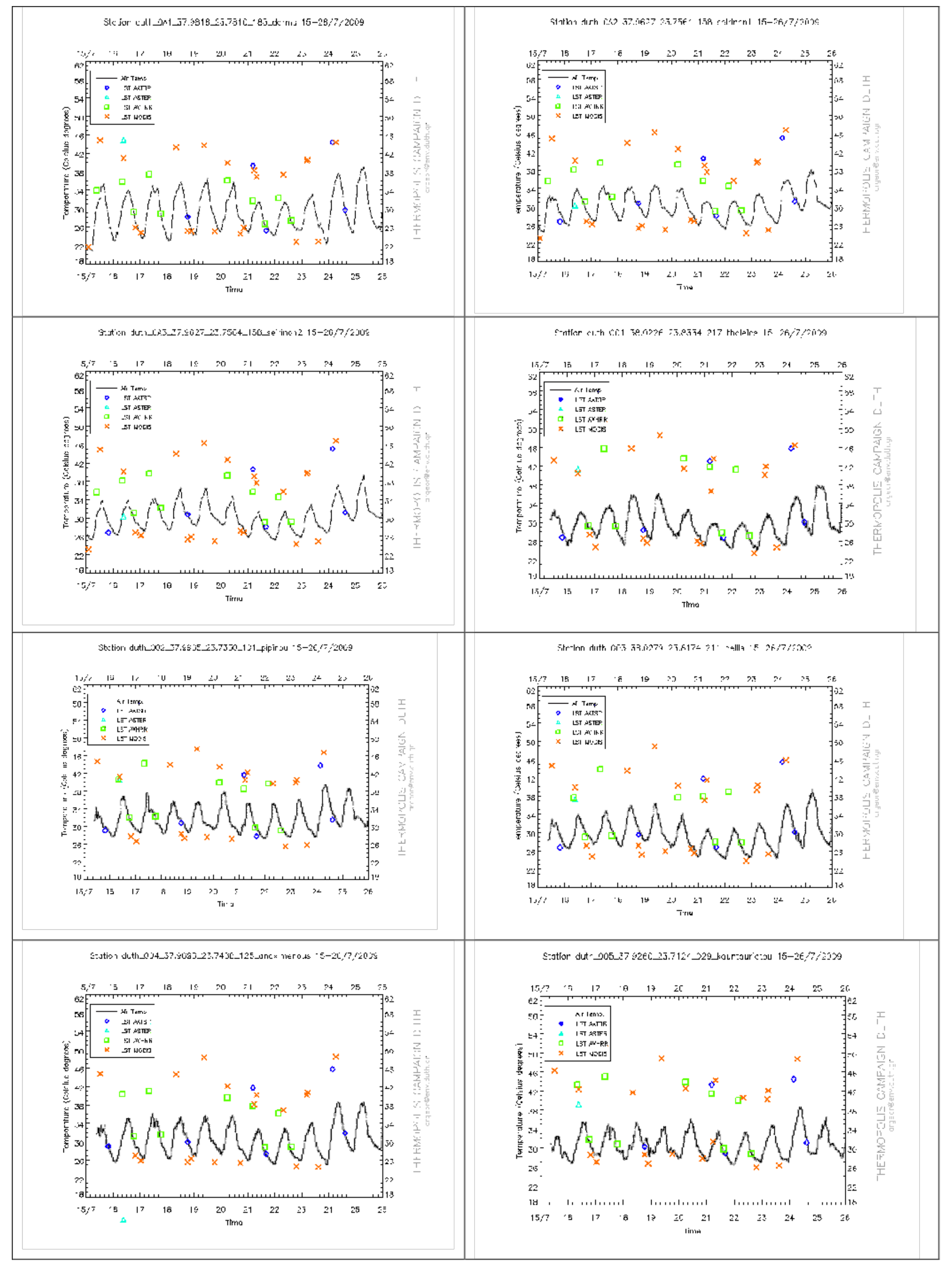


Figure 3. Timeseries of Tair and concurrent satellite acquisition data for the pixels corresponding to the Tair ground stations.Figure 3. Timeseries of Tair and concurrent satellite acquisition data for the pixels corresponding to the Tair ground stations.

References

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Delaunay B. (1934), Sur la sphère vide, Izvestia Akademii Nauk SSSR, Otdelenie Matematicheskikh i Estestvennykh Nauk, 7:793–800.

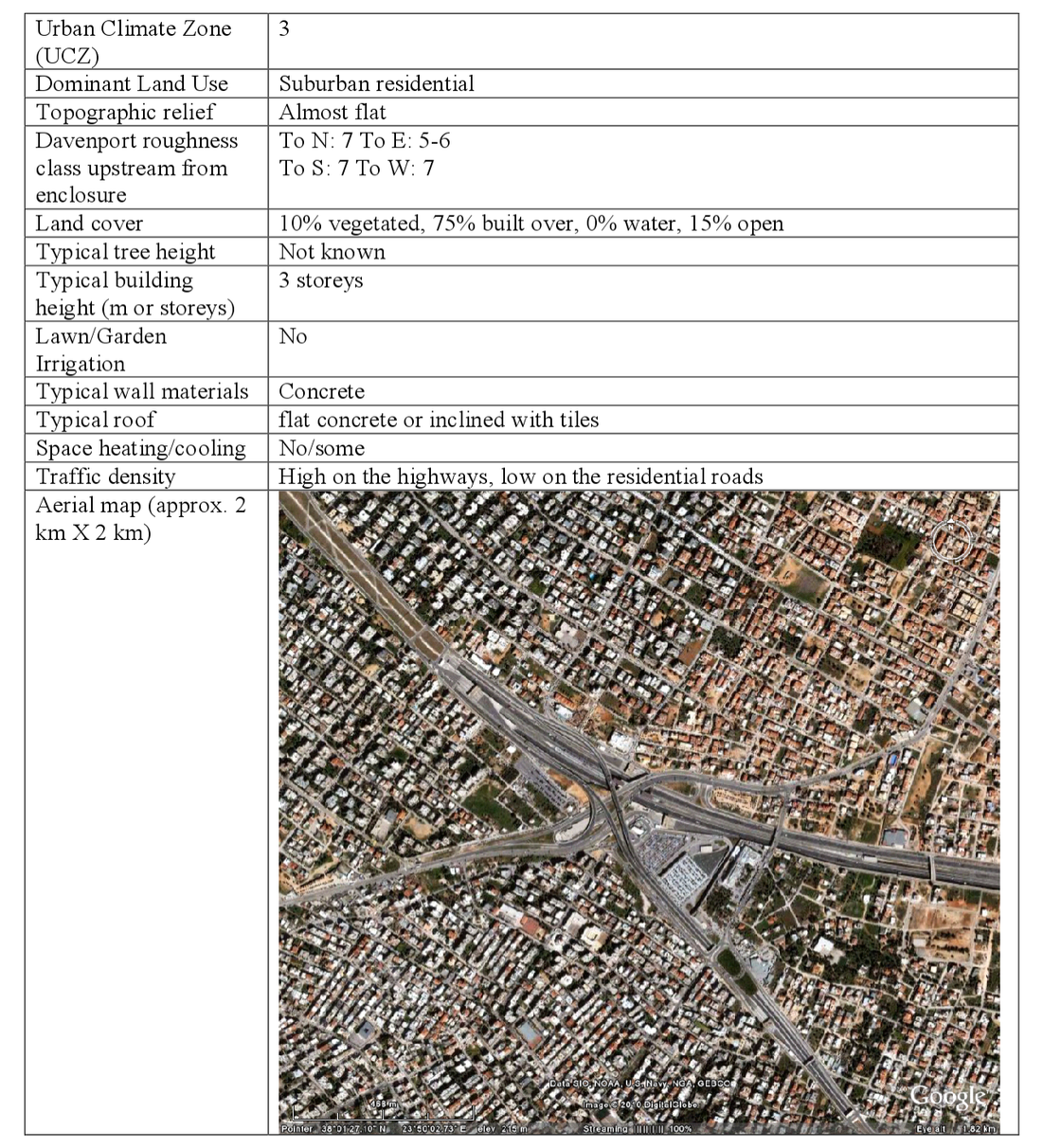
Oke T.R. (2006), Initial Guidance to obtain representative meteorological observations at urban sites, Instruments and observing methods Report No. 81, WMO/TD-No. 1250, World Meteorological Organisation, Geneva.

Wieringa J. (1992), Updating the Davenport roughness classification, Journal of Wind Engineering and Industrial Aerodynamics, 41-44, pp. 357-368.

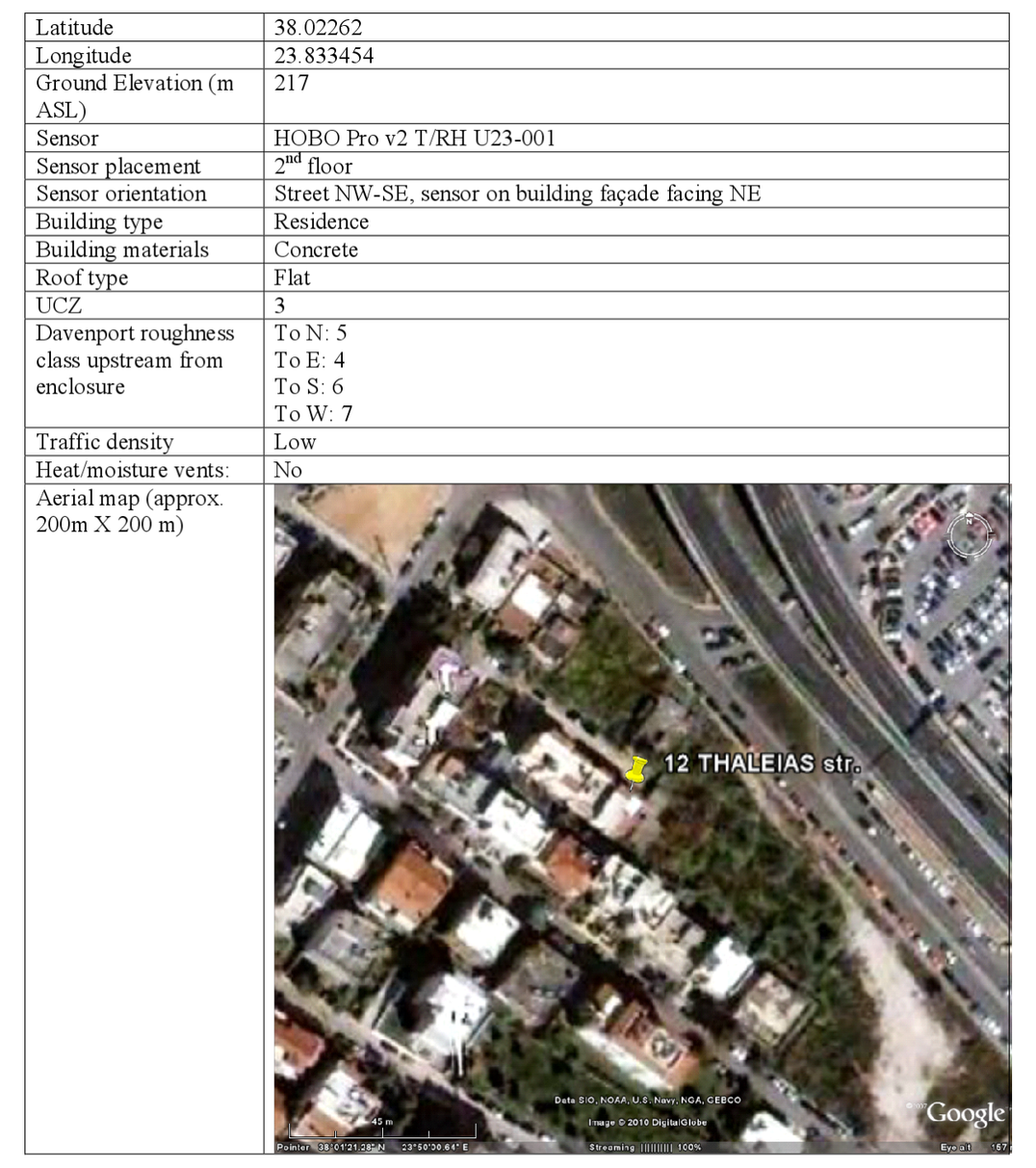
APPENDIX

Station id: DUTH_001, Address: 12 Thaleias str., Date of update: 30.7.2009

Local Scale



Microscale



Example of station classification files.