IMPLEMENTATION OF THE WRF-URBAN CANOPY MODEL OVER THE GREATER ATHENS AREA (GREECE)

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INTRODUCTION

In order to study the characteristics of the urban canopy layer (UCL) and the urban boundary layer (UBL) over the greater Athens area (Greece), the WRF model is implemented, using high spatial resolution (0.5km). Moreover, utilizing high resolution land-use data and specifying fine-scale urban parameters, the option of a coupled land-surface model with an urban canopy model is considered. Therefore, by analyzing the diurnal evolution of basic meteorological parameters, the aspects of the urban climate, are satisfactorily represented. Preliminary results show a significant heat stress in the urban center due to local-scale atmospheric flow defined by the surrounding topography and the lack of sufficient vegetation cover because of the dense built-up. Simulations of different land cover scenarios, by replacing urban areas with vegetation cover (construction of urban parks, etc.), are conducted, in order to determine the magnitude of the 'park cool island' (PCI) effect and thus to assess and provide future urban planning solutions for the improvement of the observed excess warming of the urban atmosphere and surfaces.

1. Model Configuration

Weather Research and Forecasting **(WRF-ARW)** model, **version 3.1.1** (*Skamarock et al.*, 2008) coupled with the **Unified Noah3.1 LSM** (Tewari et al.2009) and the single-layer **UCM** (Kusaka et al. 2001; Kusaka et al. 2004; Tewari et al. 2007).

WRF Parameterizations :

Microphysics: WSM 3 - class simple ice scheme.
Long/short radiation schemes: RRTM/Dudhia.
Surface-layer physics option: Monin–Obukhov scheme.
Boundary Layer option: YSU scheme *(Hong et al., 2006).*
Initial and boundary conditions: **(NCEP)** operational Global Final (FNL) Analyses on a 1.0x1.0-degree grid (every 6hrs).
Land-use data:
- USGS 30''
- High resolution satellite data for the greater Athens area (30m).

Period of simulations:
24h: 0000LST 19 Sept 2007 – 0000LST 20 Sept 2007.

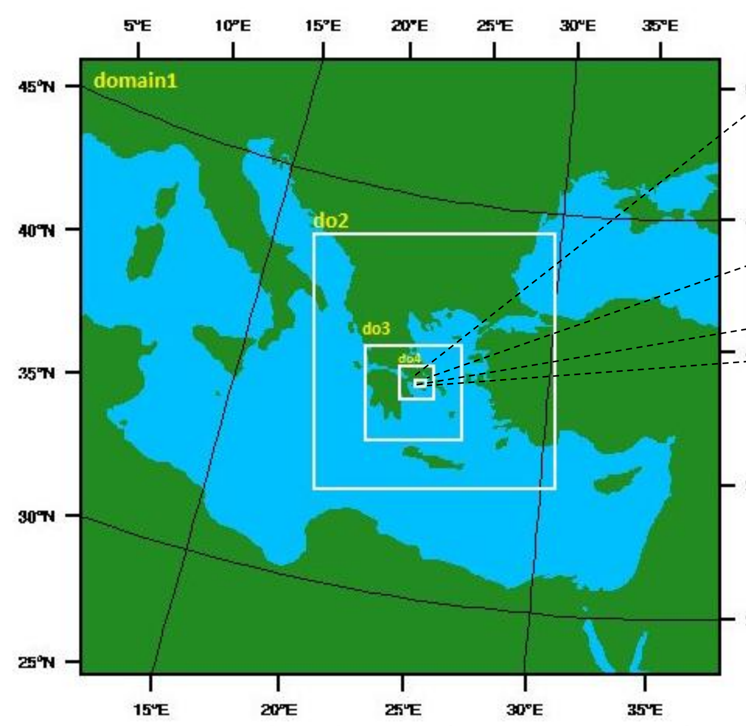


Figure 1. Area of application (two-way nesting):

Domain1	40.5km	grid spacing,	*(67X64) cells.*
Domain2	13.5km	grid spacing,	*(76X79) cells.*
Domain3	4.5km	grid spacing,	*(91X88) cells.*
Domain4	1.5km	grid spacing,	*(97X91) cells.*
Domain5	0.5km	grid spacing,	*(91X58) cells.*

The city of Athens, is located near an irregular coastline surrounded by moderately high mountains (up to 2 km). Athens, although considered an inland urban area (about 8 km from the shore), is actually in proximity to the urbanized harbour of Peiraias and channeling effects of the sea breeze in the basin are favoured because of the influence of the complex topography. These specific topographic characteristics make Athens an example of a coastal city located in very complex terrain, where sea-breeze and heat-island circulations interact. **(Dandou et al. 2009)**

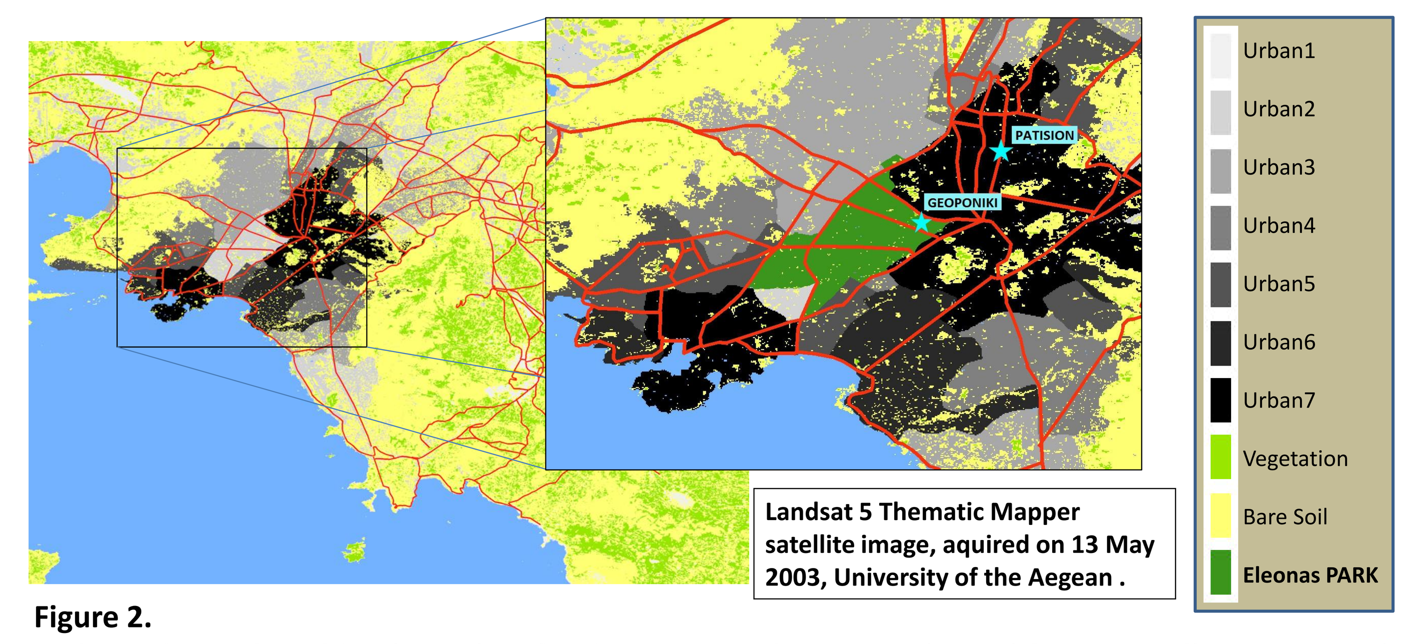


Figure 2.
High resolution **(30m)** land-use data for the greater Athens area derived from a **satellite image** and the position of two measurement sites (**GEOPONIKI** and **PATISION**).

The **Noah/UCM modules and tables are configured** in order to account for **2 vegetation** and **7 urban categories**, for a more 'realistic' representation of the Athens city area.
A test-case run is conducted in order to simulate the micro-scale and macro-scale climate effects of an **urban park scenario** in the Athens centre (**Eleonas**). A 9 km² area in the centre of Athens, of mainly industrial, commercial and storage related activities and with a significant percentage of open space surfaces, **is replaced with vegetation (Eleonas PARK).**

2. Model Evaluation against Observations

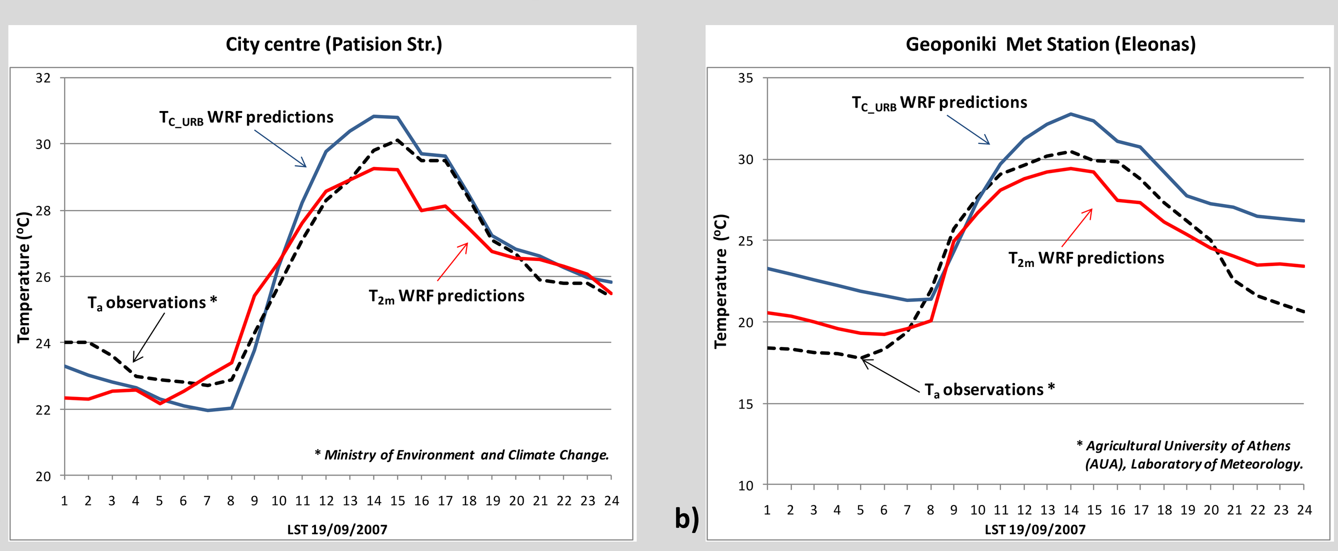
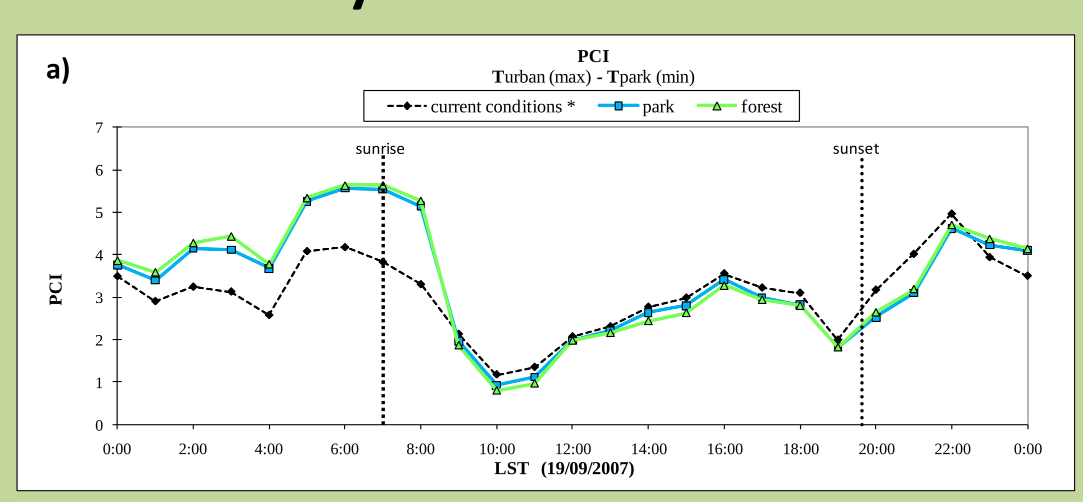
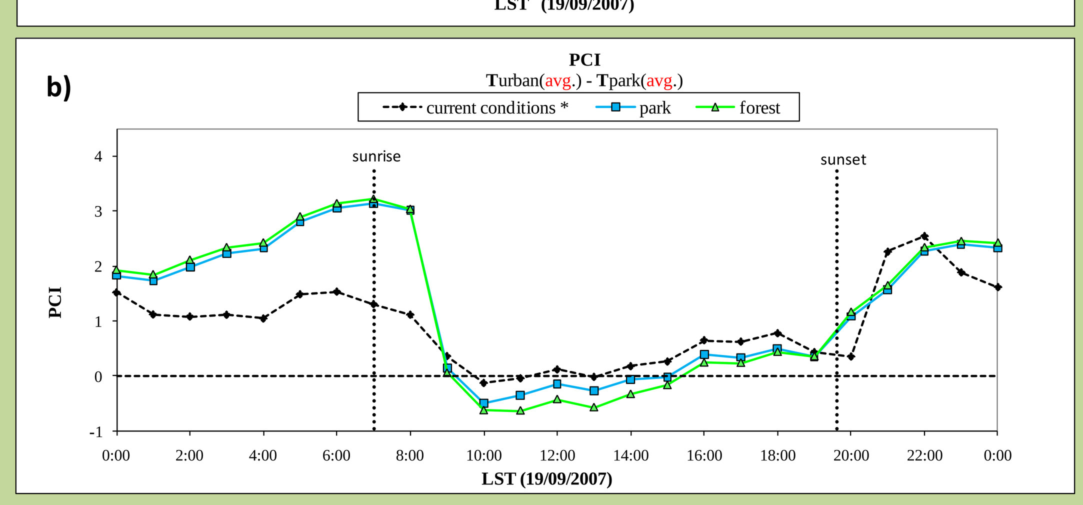


Figure 3. Air temperature time series as calculated by WRF model at 2m (T_{2m}, red line) and inside the urban canopy (T_{C_URB}, blue line) and as measured (dotted line) for :
a) City center (Patision) and **b)** Geoponiki, stations.

- **Fig 3a.** WRF predictions (T_{2m} **&** T_{C_URB}) are in good accordance with measurements .
- **Fig 3b.** Geoponiki station, is located in a small park of the Eleonas area (AUA), thus it is considered representative of a park's micro-climatic conditions and is used for the evaluation of the T_{2m} WRF predictions of the 'Eleonas PARK' run, (red line).

3. Preliminary Results and Discussion





3a. Calculation of the PCI index

- **High pressures prevailed over Greece resulting in low wind speeds (<4m/sec) and high air-temperature values during the day**, which favour the evolution of the **sea breeze** circulation. **Calm and clear night conditions** favour the development of large microclimate temperature differences **('park cool island' effect)** when simulating the urban-park test case.
- **Sensitivity tests** are performed with various vegetation cover for the selected area (Eleonas). In this presentation, **2 USGS vegetation categories** are presented :

1. 'Mixed Dryland/Irrigated Cropland and Pasture' (**park**)(see **3b.**) and
2. 'Evergreen Needleleaf Forest' (**forest**).

***To simulate the **current conditions** of the 'Eleonas' area, high resolution (30m) land-use data is used (see Figure 2).

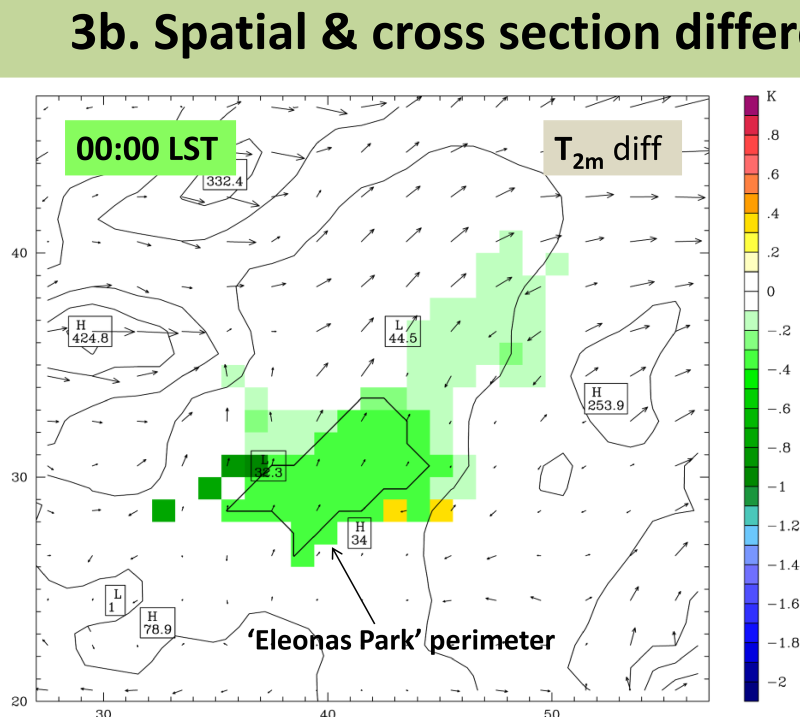
Figure 4a. The maximum '**park cool island**' (**PCI**) is calculated by subtracting the **minimum park** air temperature (T_p) from the **maximum urban** air temperature (T_u) (Spronken-Smith and Oke, 1998) :

$$PCI = Tu - Tp$$

Figure 4b. The average '**park cool island**' (**PCI**) is calculated by subtracting the average park air temperature (T_p) from the average urban air temperature (T_u) (This study) :

$$PCI = Tu - Tp$$

3b. Spatial & cross section differences ('park' — 'current conditions')



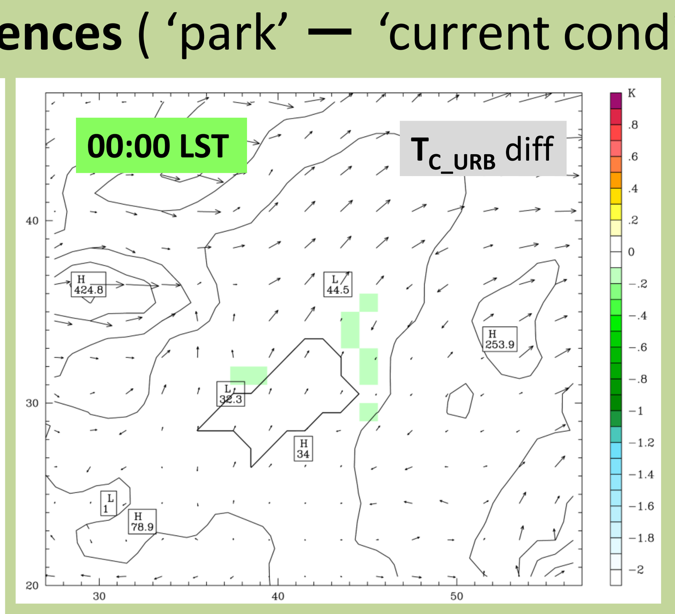
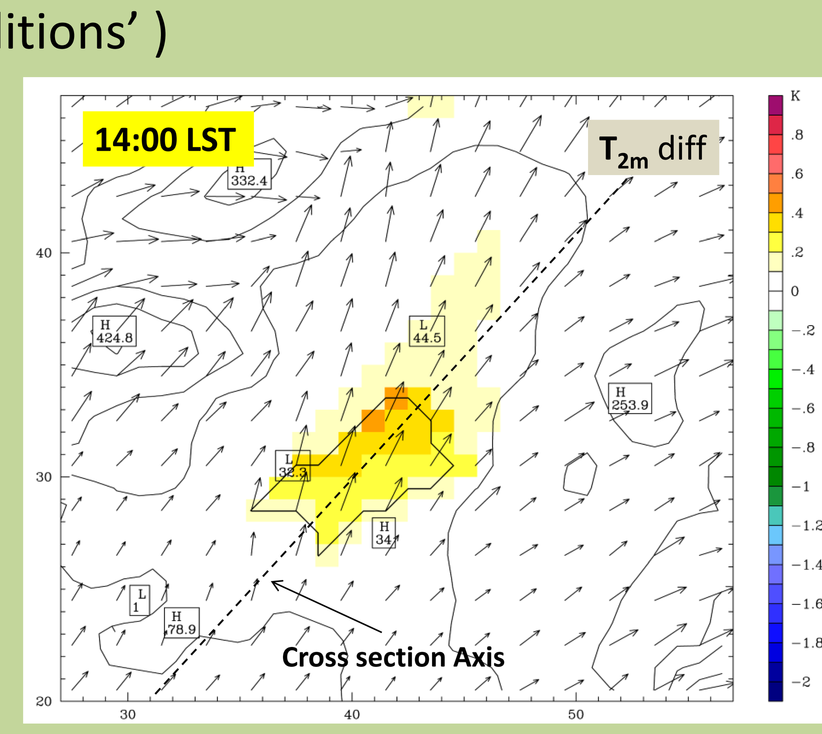
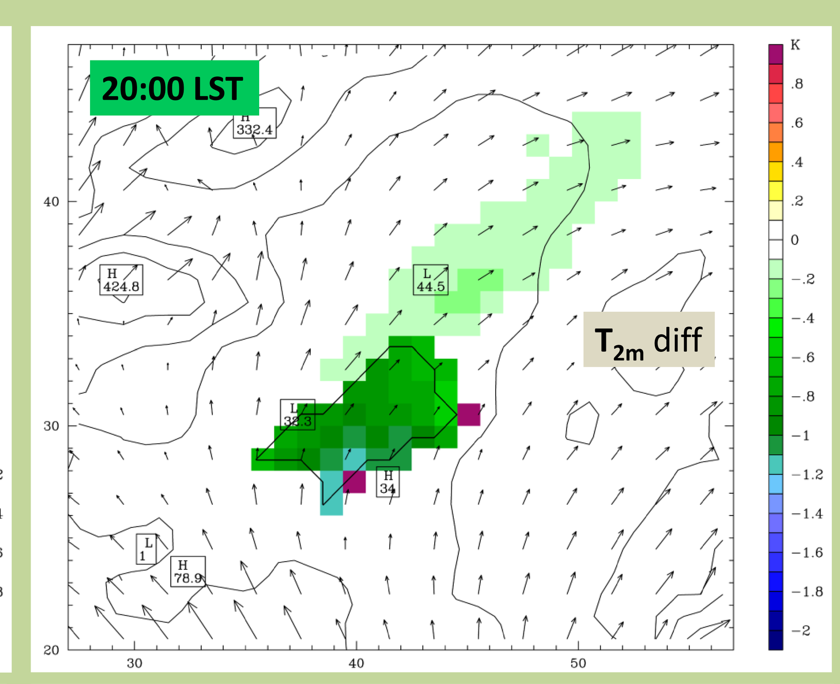


Figure 5. The 'park' cools the air (T_{2m}) above it and beyond its borders due to advection. Inside the urban canopy (T_{C_URB}), this has a minor effect.





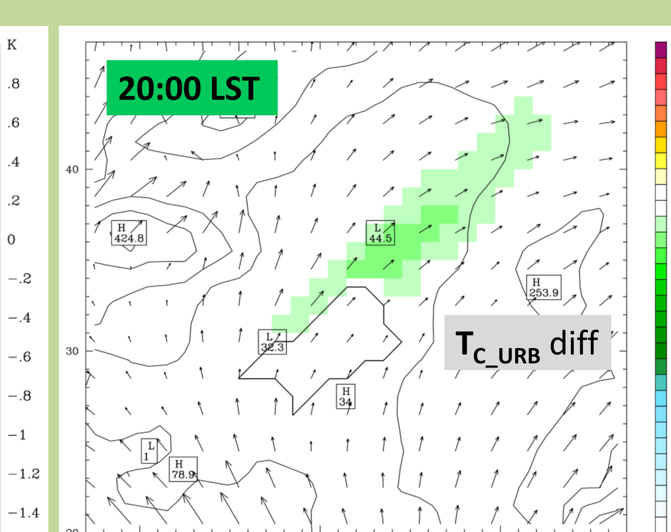
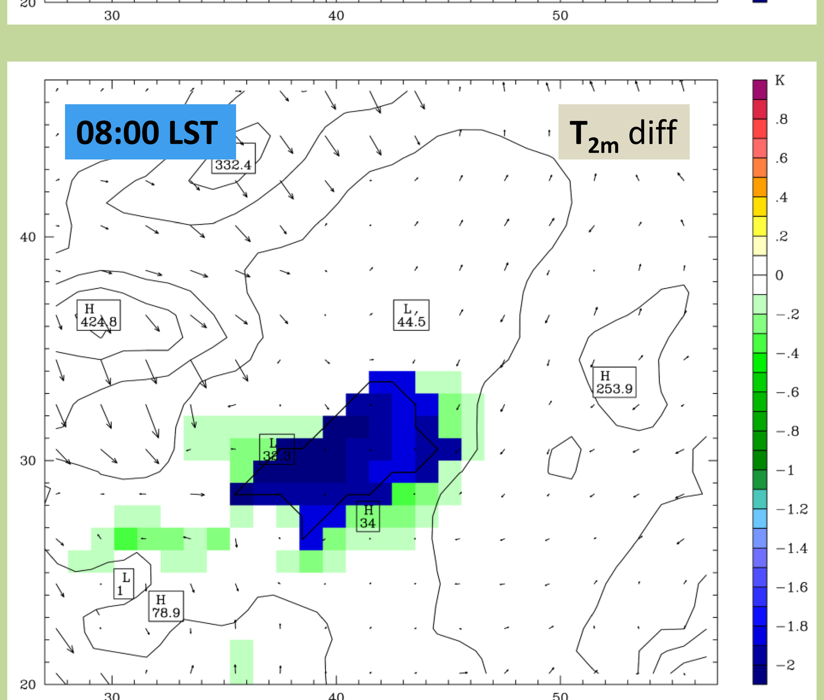


Figure 8. After sunset, the cooling effect of the 'Park' is triggered and cooler temperatures are simulated over the Eleonas area and over a part of the city (T_{2m}). The urban canopy model (**UCM**) simulates lower temperatures (T_{C_URB}) inside the urban canopy, compared to the current conditions.



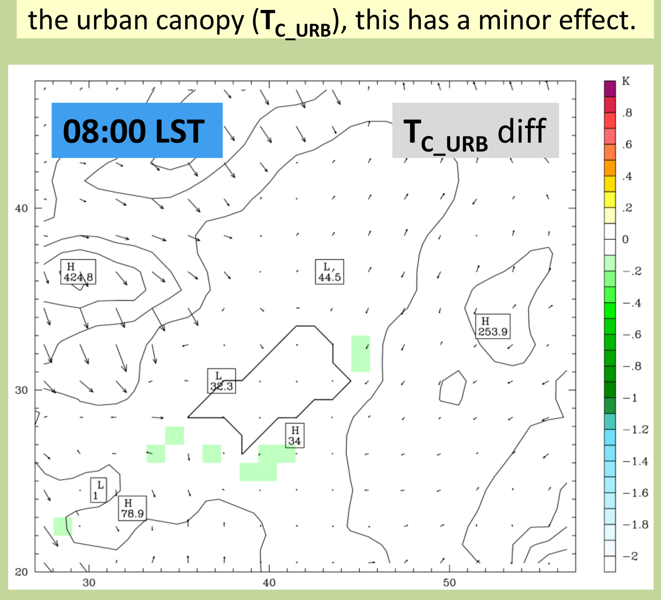
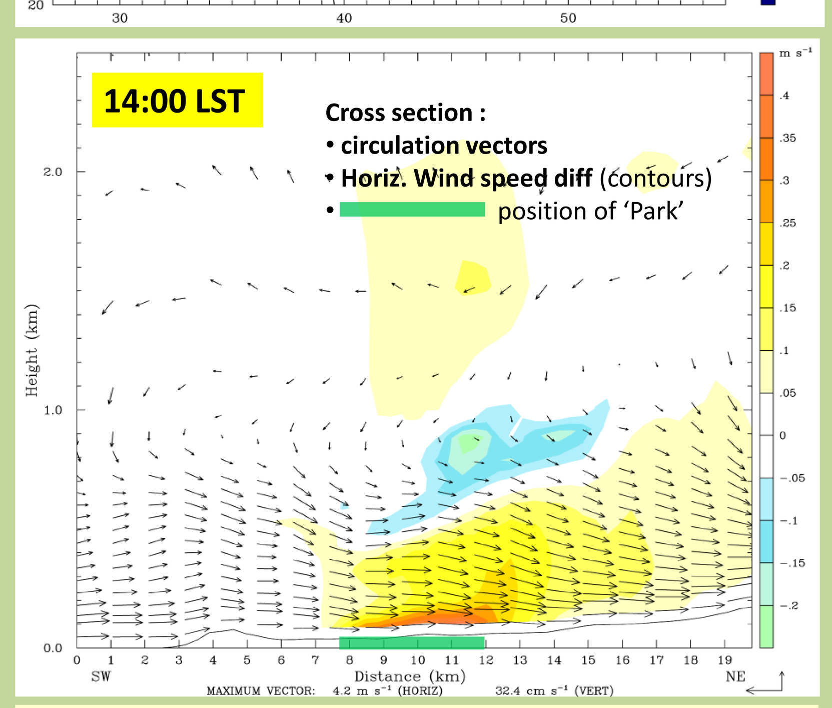


Figure 6. The **PCI** effect reaches its **maximum** value near sunrise (T_{2m}).



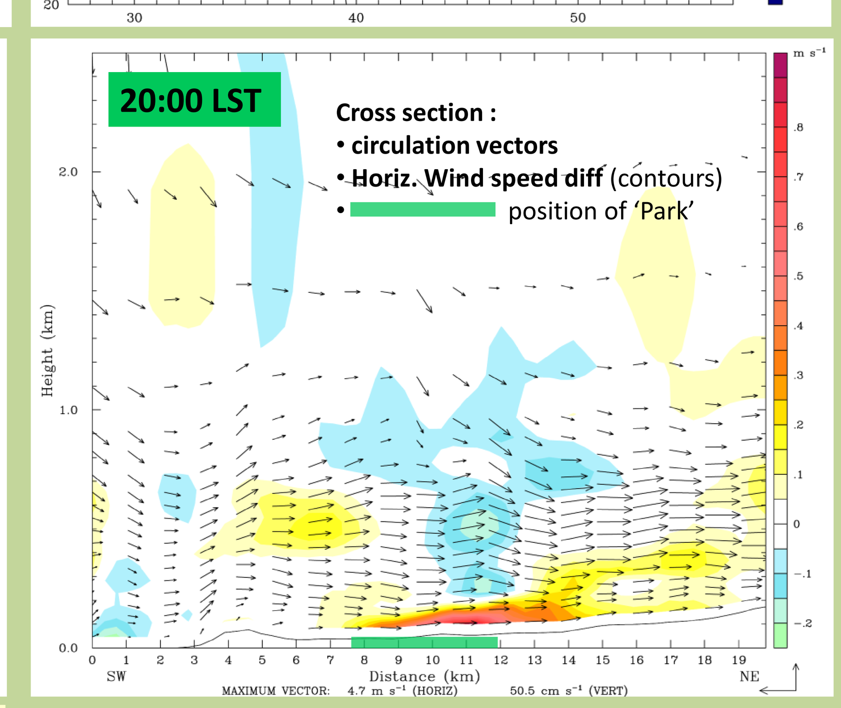


Figure 7. During midday the air temperature above the 'park' is slightly warmer (T_{2m}), as an effect of direct solar radiation, higher surface albedo and lower thermal admittance than the surrounding urban areas. As a result, the **sea-breeze** flow is locally enhanced (**cross section**).

Discussion :
- **After sunset,** the 'Park's' surface cools at a faster rate than that of its urban surroundings. The large microclimate temperature differences, between the 'park' and the city, in combination with the existing weak wind flow, produce an **advection of cool air** masses north-easterly of the 'park's' borders.

Discussion :
- Park cooling establishes **a zone of large advective influence (during night-time)** beyond its borders to a distance of about **one park width** (diameter).
- **PCI** thermal effects depend on the **urban surroundings** and **macroclimate** of the city.

- The formation of this local circulation is also evident by the **increase of the horizontal wind speed** near the surface (cross section).

4. Conclusions

- **The WRF/Noah/UCM simulations satisfactorily depict the 'park cool island' effect and its diurnal evolution.**
- **During day-time higher air temperatures (up to 0.7 K) are calculated over the park than the existing built up area.**
- **During night-time lower air temperatures (up to 2 K) are calculated over the park than the existing built up area resulting in a zone of a large advective influence beyond its borders at a distance of about one park width.**
- **Overall, the urban-park scenario simulation gives promising insight on the benefits of urban green planning.**

5. References

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