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A Subgrid Surface Scheme for the Analysis of the Urban Heat Island of Rome

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Summary

- Analysis of the atmospheric circulation in correspondence of the Roman urban area and the surrounding region of the Italian Peninsula (Lazio Region) by using the standard Regional Atmospheric Modeling System (RAMS Ver. 6.0).
- As expected, RAMS underestimates turbulent fluxes and air temperature within the urban and suburban areas.
- This motivated the replacement of the standard surface scheme LEAF-2 used by RAMS by the Town Energy Balance scheme (TEB, V. Masson, 2000, *BLM* **94**), able to parameterize town-atmosphere dynamic and thermodynamic interactions.
- First comparison of the two schemes with field observations.

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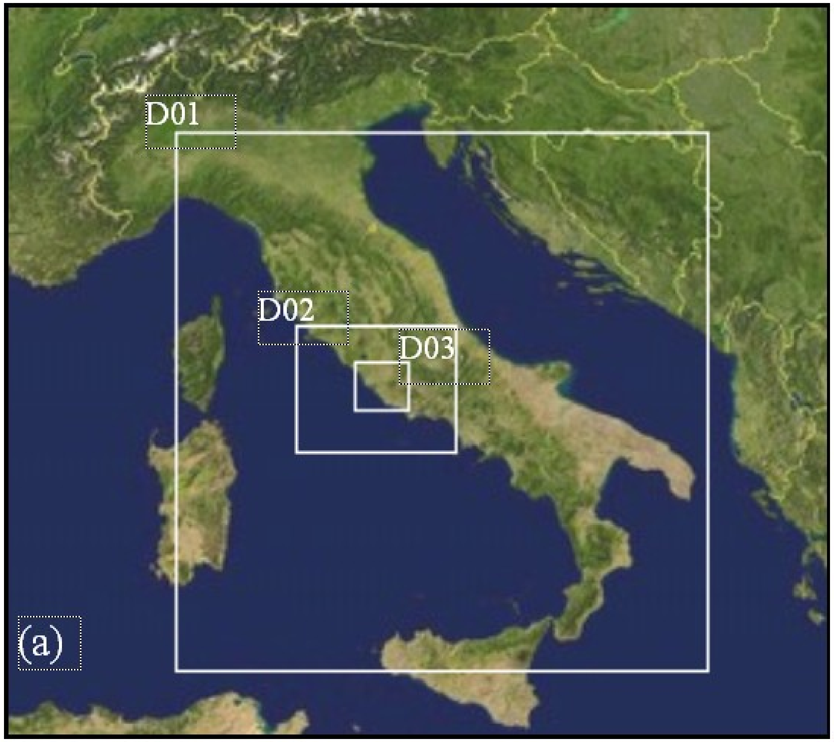
Study Domain

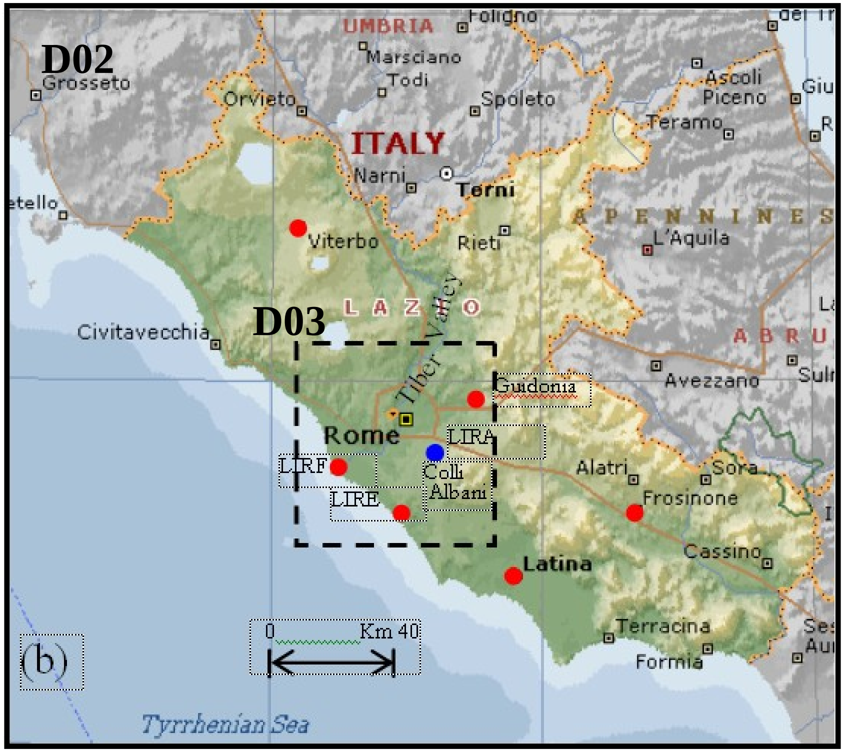
Rome and its surrounding area (Lazio Region)

- Rome is located nearly 25 Km inland from the shoreline in a relatively flat area in central Italy.
- The inland area is mountainous (up to 2000 m a.s.l.).
- The Lazio Region is strongly influenced by land and sea breezes for large part of the year.

Study Domain

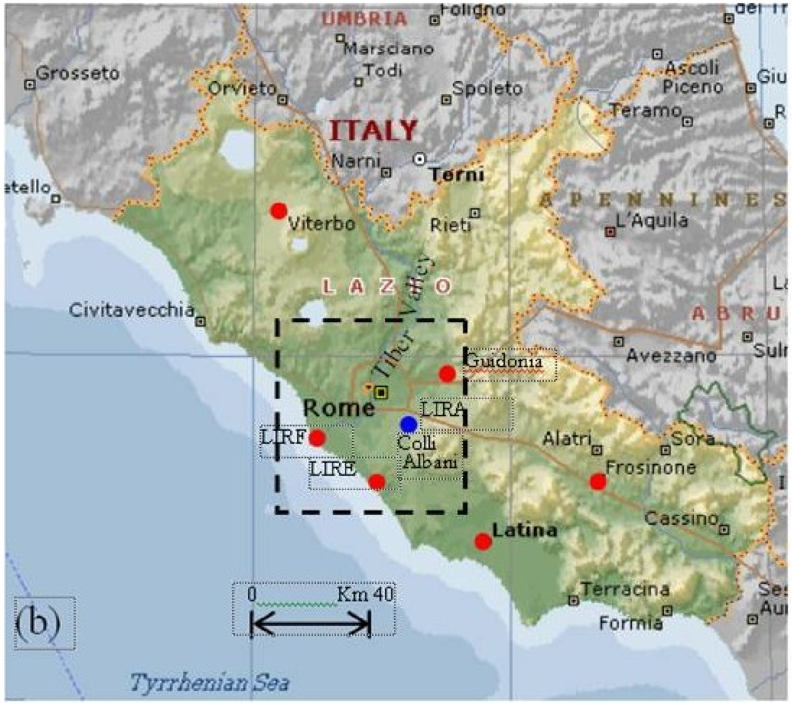
- Domain DO1 (1000x1000 Km^2): horizontal resolution 16 Km.
- Domain DO2 (250x250 Km^2): horizontal resolution 4 Km.
- Domain DO3 (60x60 Km^2): horizontal resolution 1 Km.
- 52 stretched sigma levels along the vertical (first level at 12 m a.g.l. in D03).
- Domain top 19 Km.





Input Data

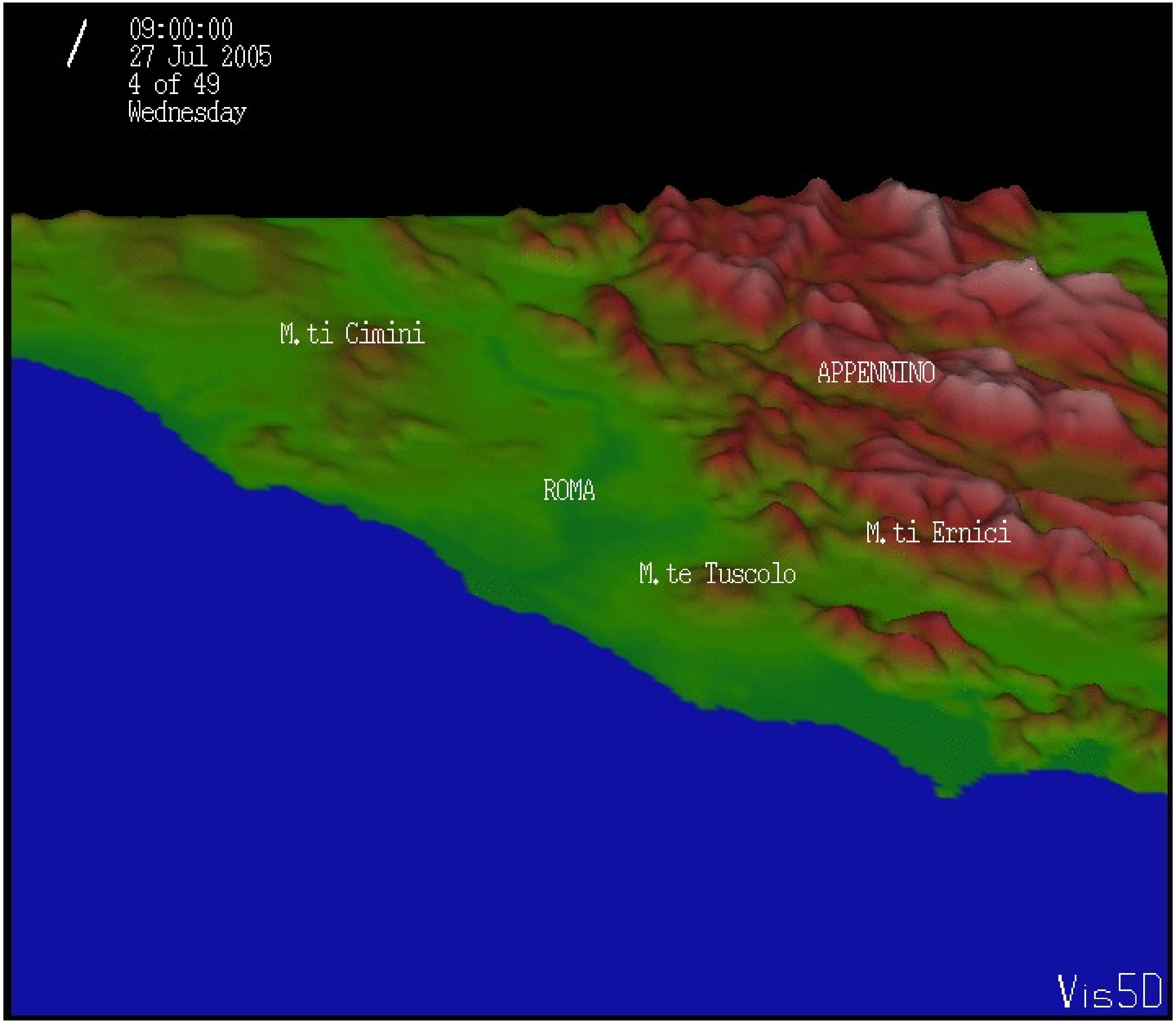
- Topography and Land Use are taken from the 30’’ USGS data set.
- Soil temperature and humidity are taken from NOAA.
- Reanalysis taken from the UCAR (University Corporation for Atmospheric Research) used both as initial condition and for data assimilation at the synoptic hours. Radio soundings from LIRE, Zagreb, Trapani and Milano have been also used.
- Surface observations taken at six airports located within the Lazio Region (Red circles).



Case Studies

- 23-25 June 2005 & 26-28 July 2005. In both the cases a high pressure system was present over Italy.
- For each of the two cases, two runs were performed:
- RUN I: simulation with the non-modified RAMS using the standard LEAF-2 scheme (Land Ecosystem Atmospheric Feedback; R.L. Walko et al., *JAM*, 2000) for the calculation of the net surface radiation in each grid node at the surface.
- RUN II: RAMS simulation using:
  - TEB scheme in the urban grid nodes;
  - LEAF-2 scheme elsewhere.

Model results



RUN I

Wind velocity vectors
at 50 m a.g.l.
on 27-28 July 2005

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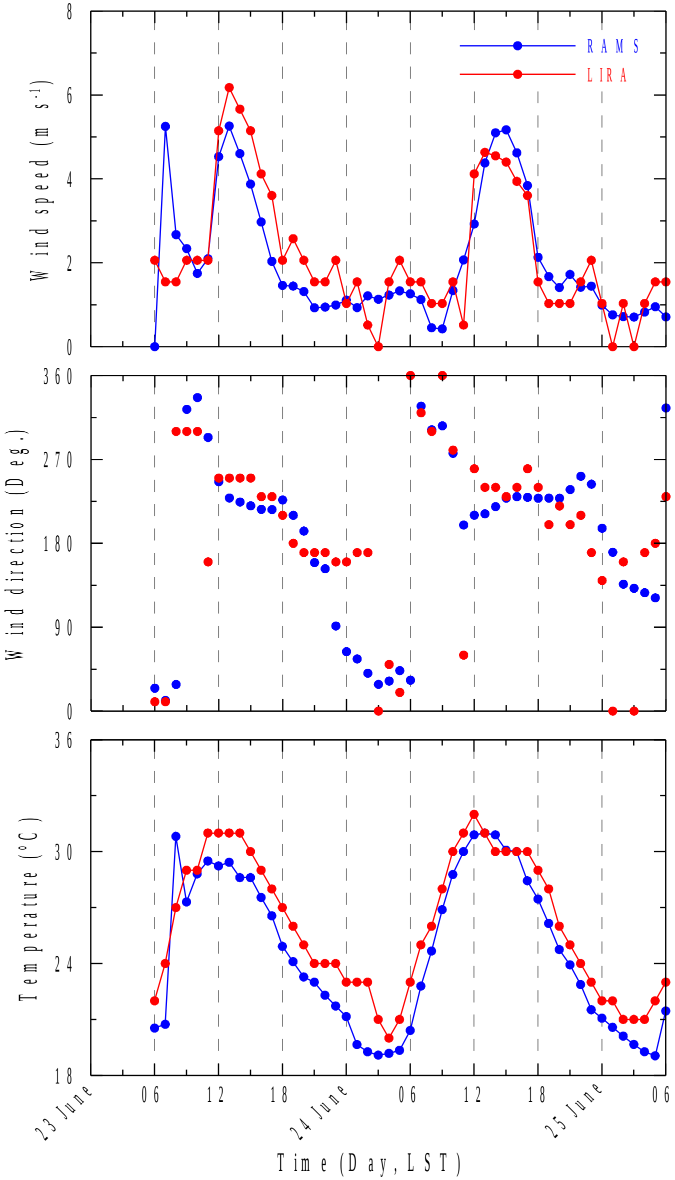
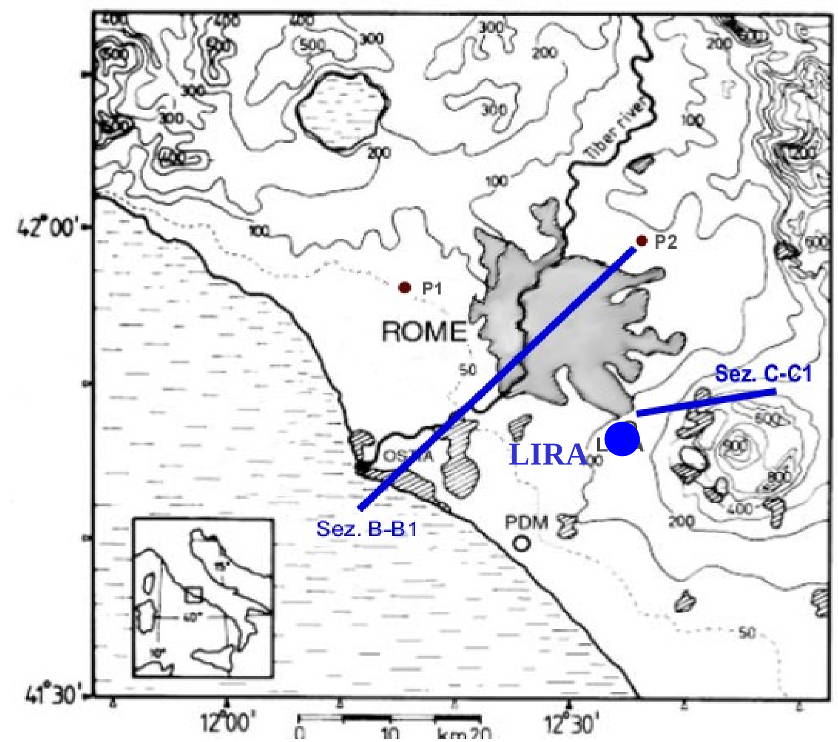
Model results



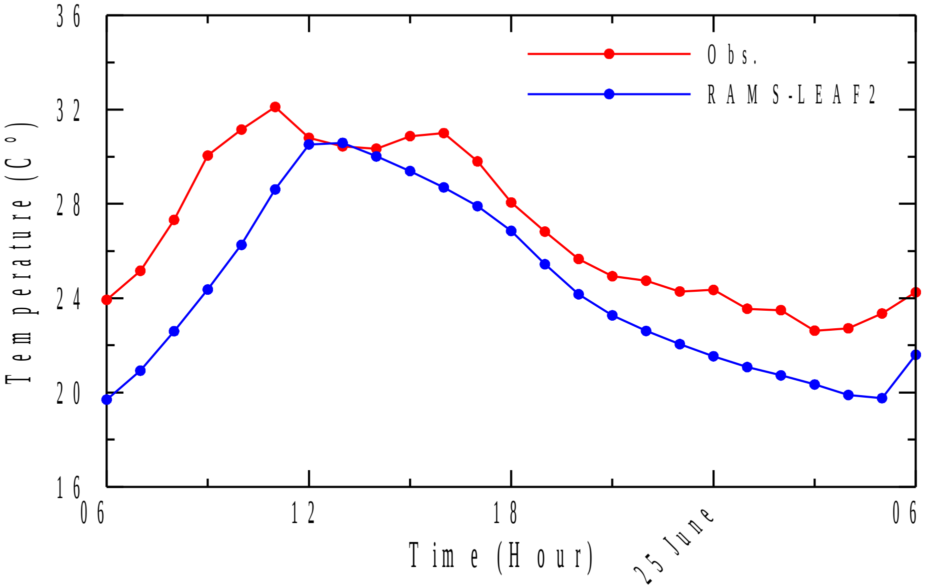
RUN I

Comparison with observations at LIRA (CIAMPINO AIRPORT, suburban site) at ~12 m a.g.l on 23-25 June 2005

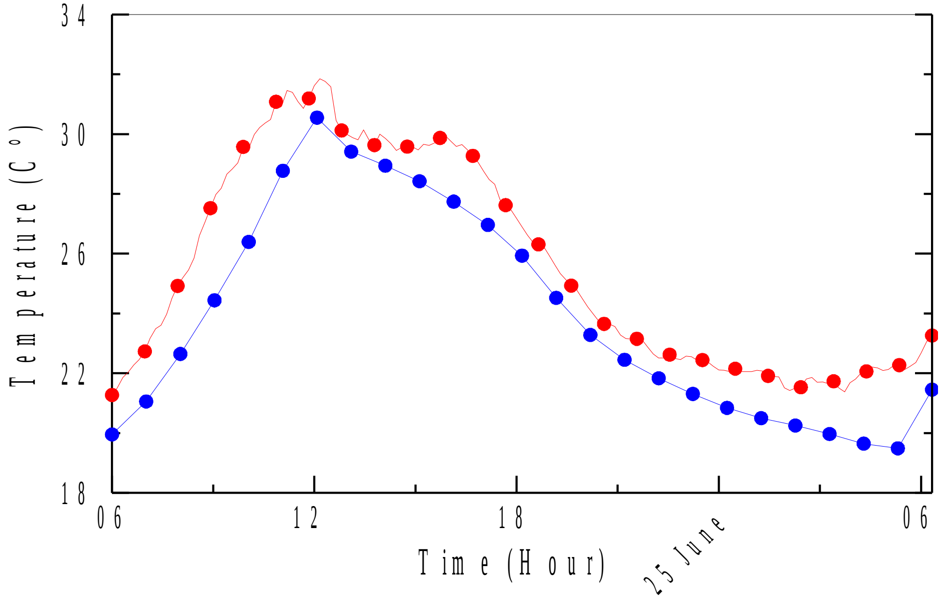


Model results

RUN I

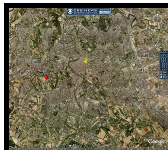


Comparison with observations at
ROMA CENTER
(Urban site)

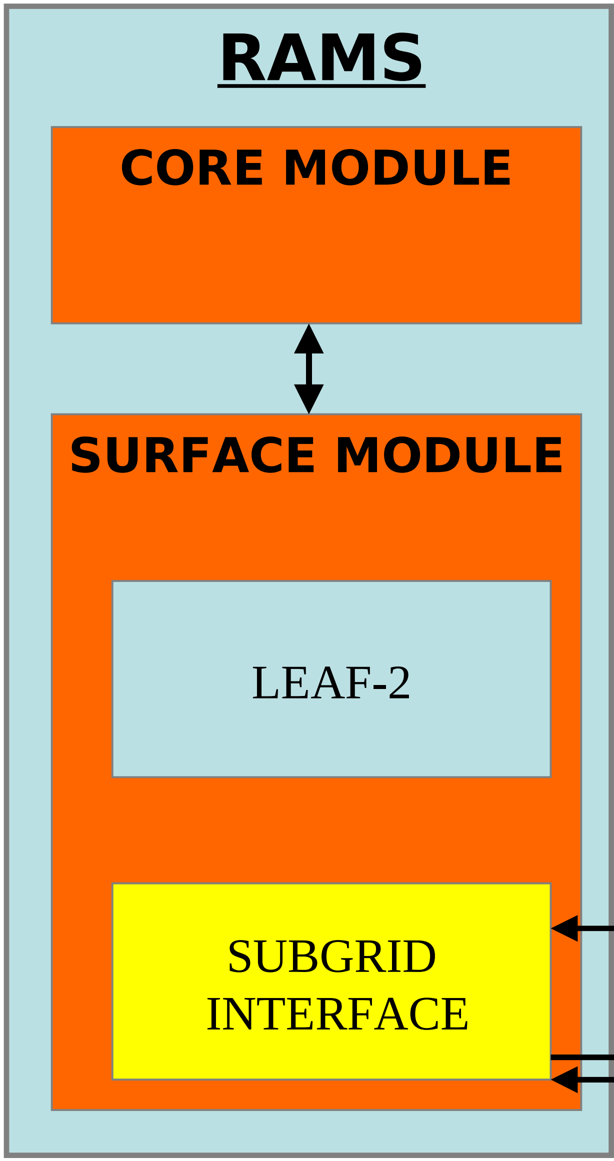


Comparison with observations at
ROMA "Villa"
(Suburban site)

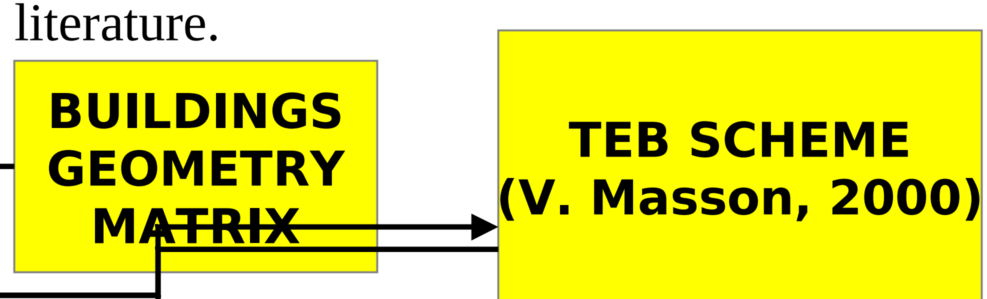
LEAF-2 scheme underestimates air temperature both in urban and suburban environments !!



TEB scheme



- For each grid node (i-j) belonging to the city, it identifies the urban canyons falling within the cell corresponding to (i-j).
- The TEB scheme gives to RAMS the calculated turbulent fluxes referred to all the "urban" nodes.
- It contains coordinates and main characteristics (geometry, thermal properties, ….) of each canyon of the Roman urban area (~8600 main roads).
- Thermal and radiative properties of materials have been assumed as constants within the urban domain. Their characteristics were found in the literature.



TEB module

From shapefile to urban canyon geometry

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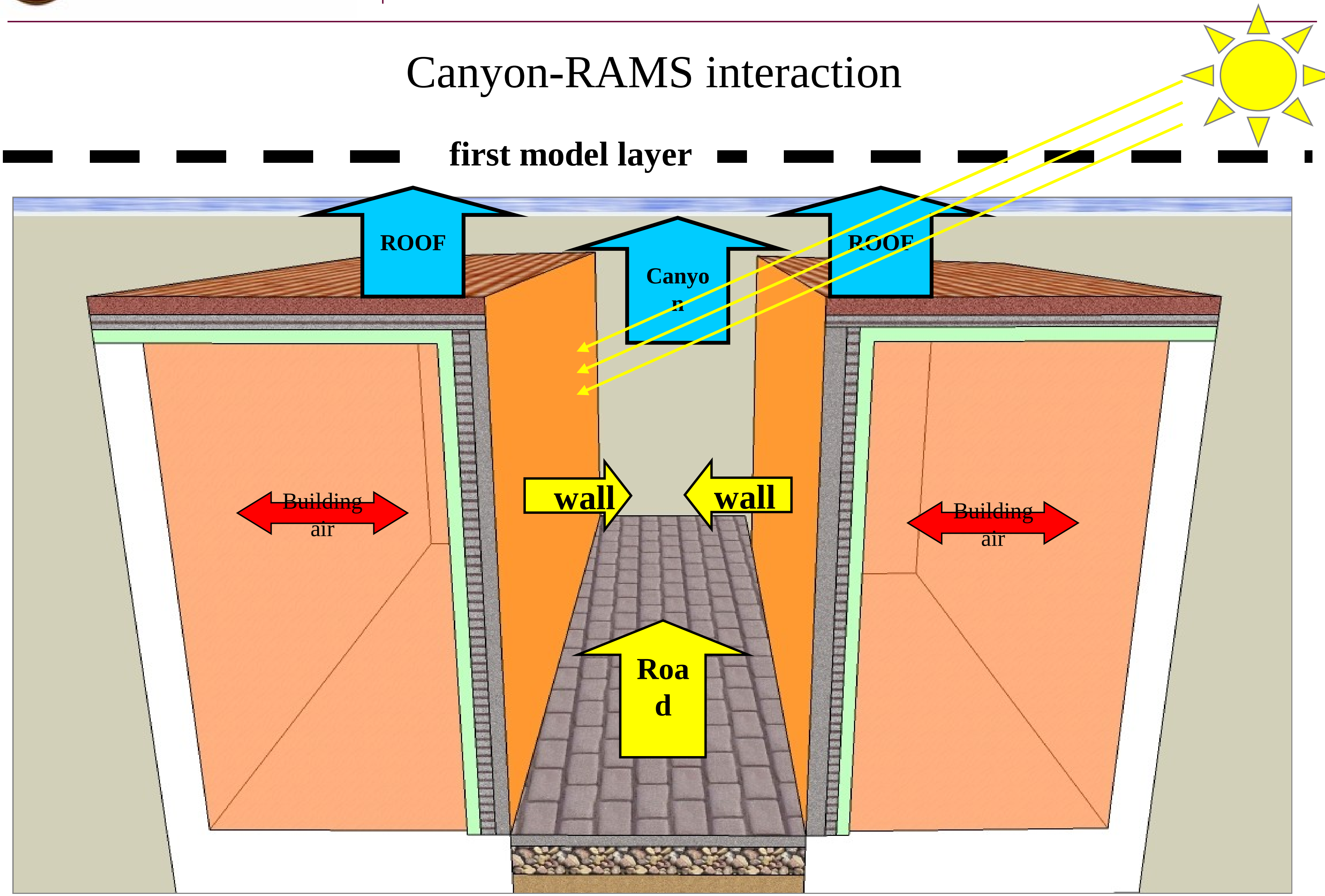
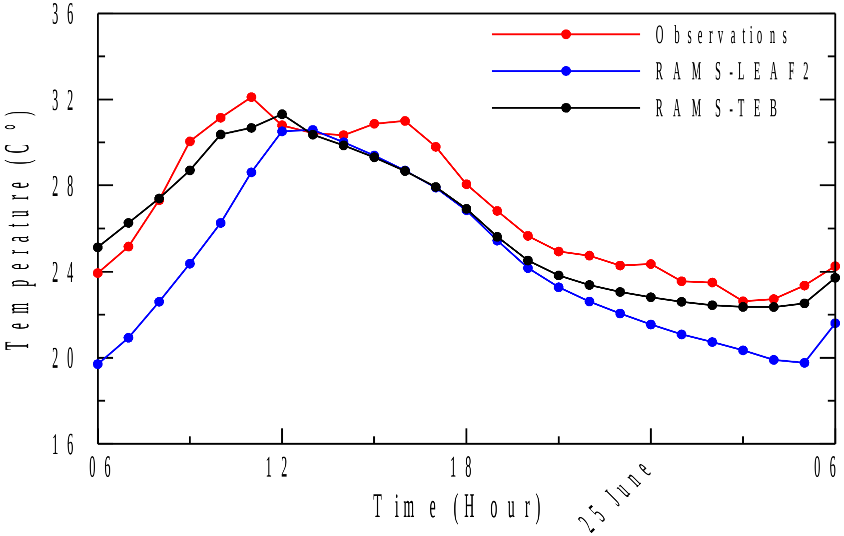
TEB module

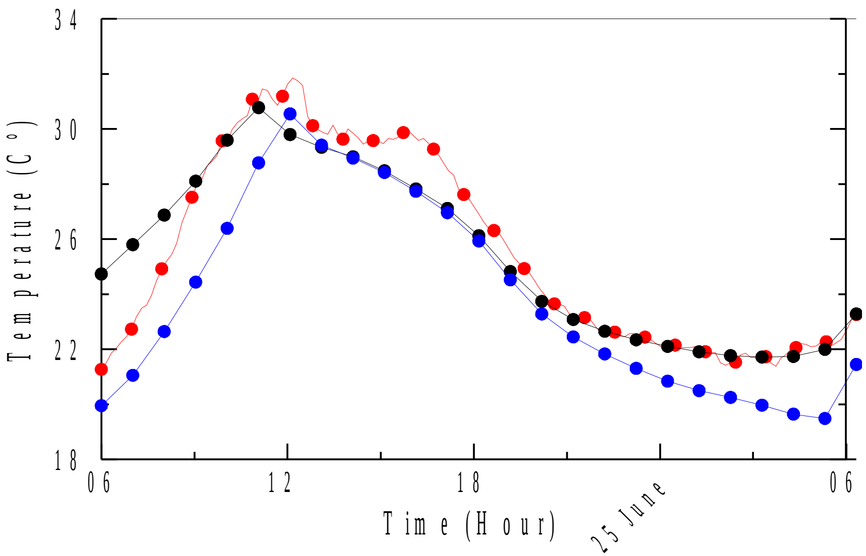
Canyon-RAMS interaction

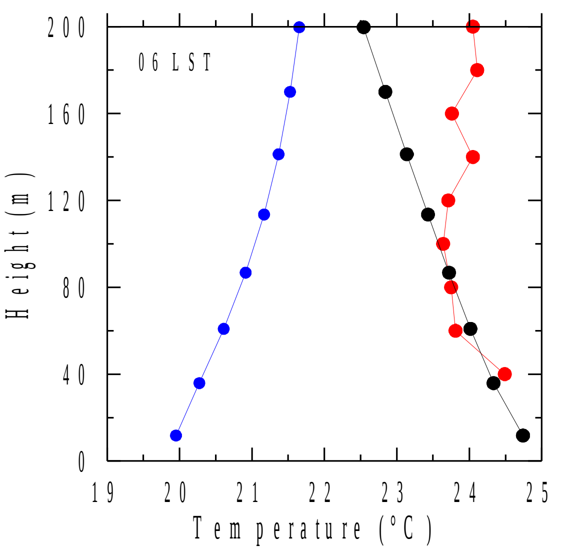


TEB Vs. LEAF-2



Comparison with observations at
ROMA CENTER
(Urban site)





Comparison with observations at ROMA “Villa” (Suburban site)

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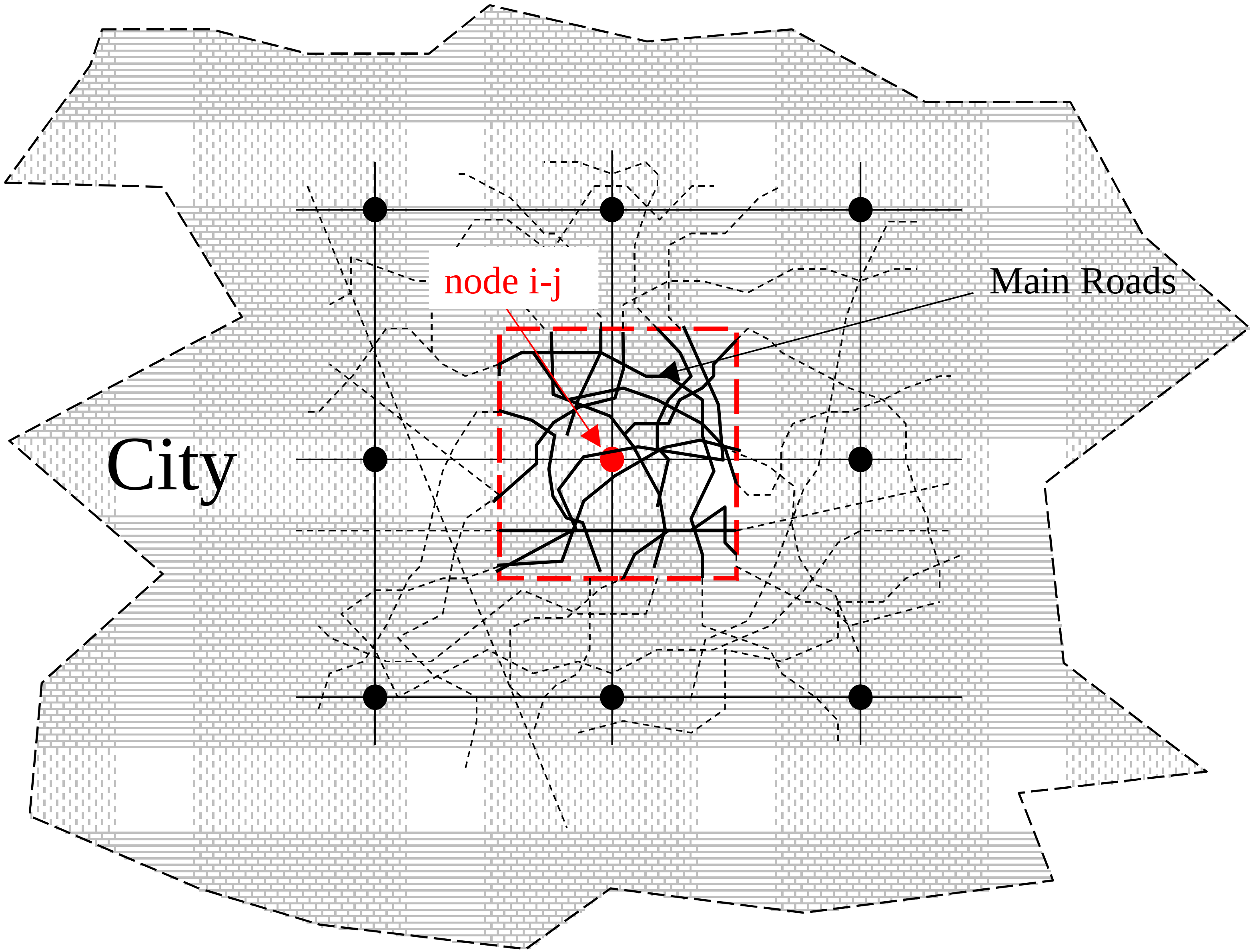
Conclusions

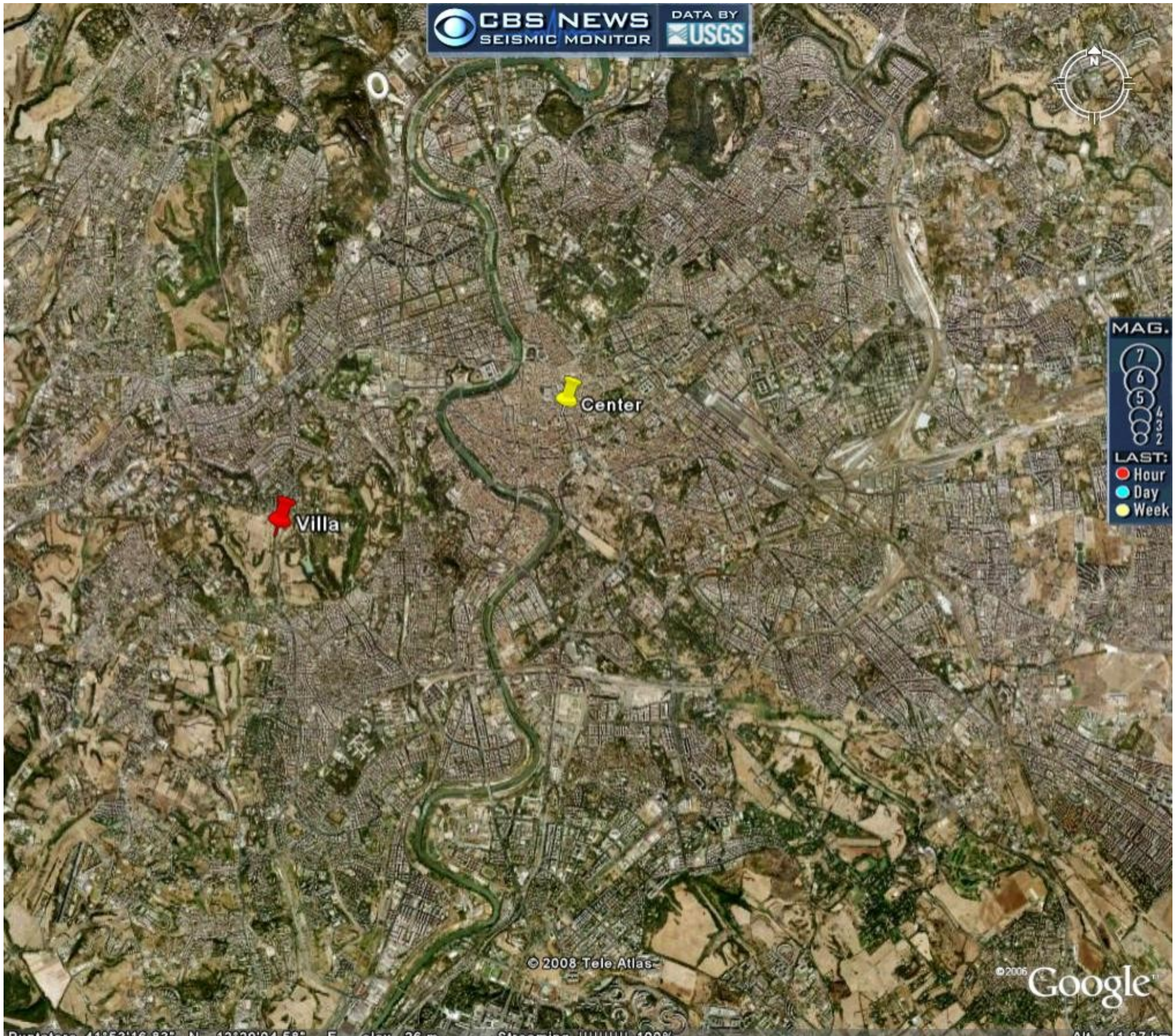
- The coupled system RAMS-TEB provides a reasonable agreement with the observations in particular during the night.
- The TEB scheme requires detailed information regarding construction material characteristics which are not always easy to estimate for a large number of roads. Thermal and radiative parameters assumed as constant in the present work is certainly an approximation of the reality.
- Further investigation is needed to confirm the improvement of the results and the general applicability of the method.

Thanks for Your attention!!

TEB module



TEB module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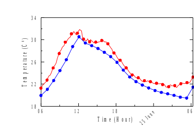
Google
Puntatore 41°53'16.83" N 12°29'04.58" E elev 26 m
Streaming |||||||||| 100%
Alt 11.87 km



TEB (Town Energy Budget)

- It is based on the "canyon" assumption. From the energy balance (net solar radiation, sensible and latent heat fluxes, conduction heat fluxes) performed in each canyon, TEB calculates the three surface temperatures representative for:
  - ✓ Roads
  - ✓ Vertical walls
  - ✓ Roofs
- It takes into account:
  - ✓ Canyons orientation
  - ✓ Sky viewing
  - ✓ Direct and reflected solar radiation
  - ✓ Trapping of longwave radiation by the canyon surfaces
  - ✓ Water reservoir evolution
  - ✓ Wind inside the canyon
  - ✓ …..
- Main parameters:
  - ✓ Geometric $\Rightarrow$ fractional area occupied by artificial materials, building height, building aspect ratio, Canyon aspect ratio, roughness length.
  - ✓ Radiative $\Rightarrow$ roofs, roads and walls albedos and emissivity.
  - ✓ Thermal $\Rightarrow$ thickness, thermal conductivity and heat capacity of roofs, roads and walls.
- TEB evaluates turbulent fluxes emitted from roofs and canyons towards the first grid level of the atmospheric model.