Numerical modelling of flow and dispersion in Rome area

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Aims of the study

- Simulation of the regional circulation during breeze episodes.
- Characterisation of the urban heat island (UHI) of Rome.
- Validation of a meteorological mesoscale model in the neighborhood of Rome.
- Evaluation of pollutant dispersion in Rome area, during the interaction between breeze and UHI.

Meteorological Model

CSUMM (Colorado State University Mesoscale Model)

- Governing equations
  - mass
  - momentum (hydrostatic approximation)
  - thermodynamic energy
  - moisture
  - turbulent kinetic energy (TKE)

- Boundary conditions
  - Zero-gradient lateral b.c. on all prognostic variables
  - No-slip condition at the ground surface
  - Temperature and moisture are predicted from soil balance equations

- Initial conditions
  - Vertical profiles of velocity, temperature and moisture in atmosphere
  - Vertical profile of soil temperature

Dispersion Model

Statistical Lagrangian model developed by the authors

- Based on the "Well-Mixed Condition"

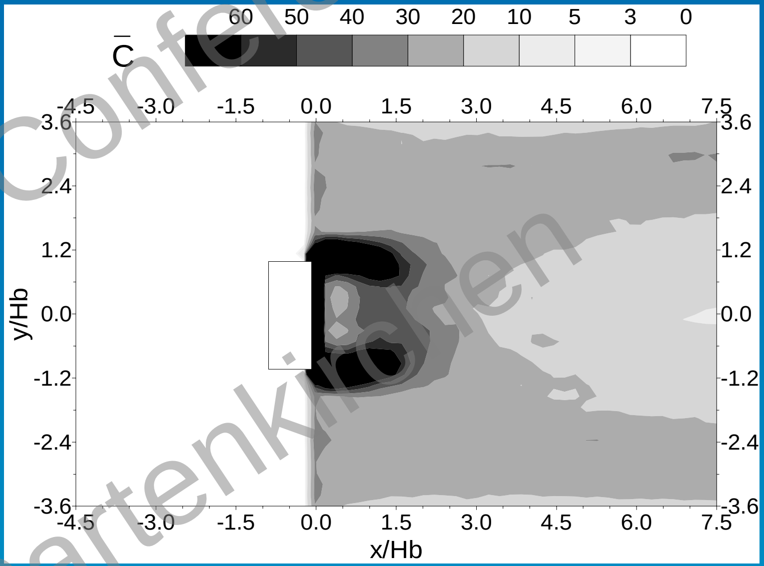
  (Thomson D.J.; *J. Fluid. Mech.* 1987, 180: 529-556)

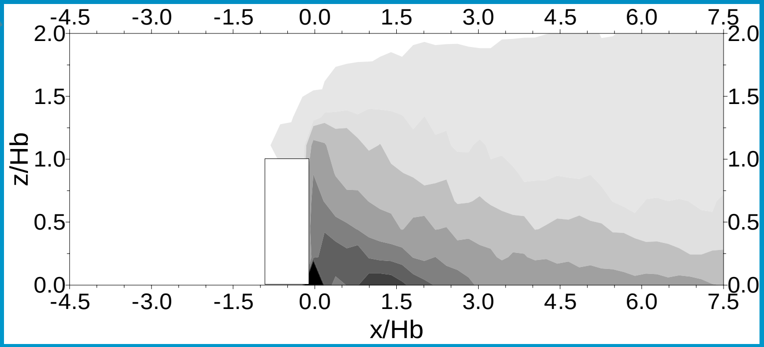
- Extended to three-dimensional flows with non-Gaussian turbulence

  (Monti P. and Leuzzi G.; *Bound.-Layer Met.* 1996, 80: 311-331)

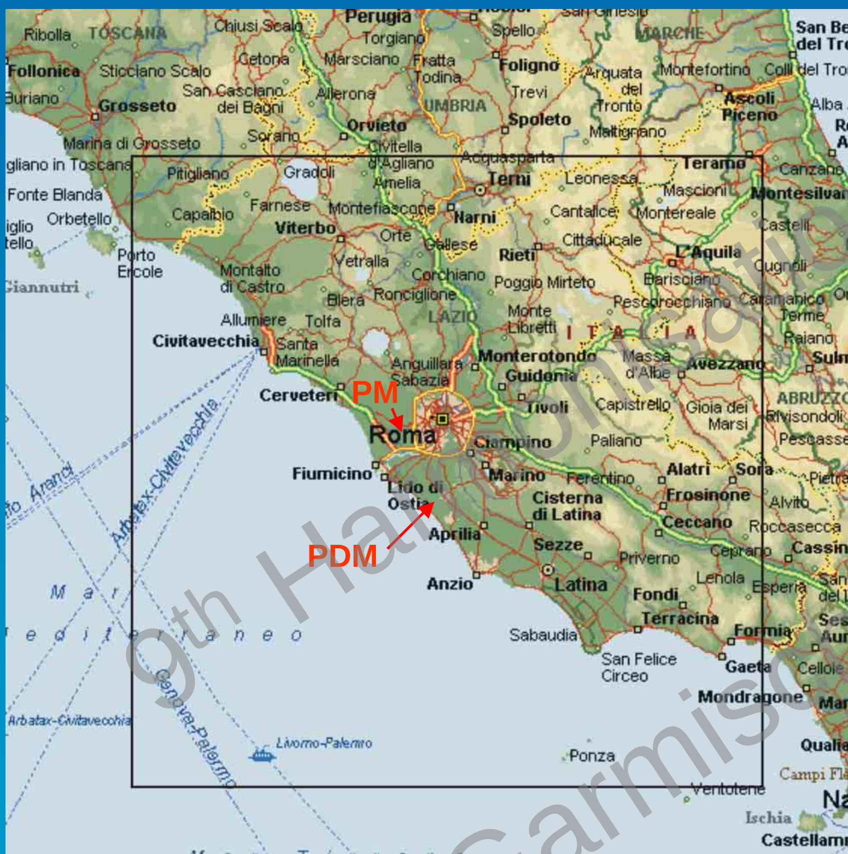
- Validated for dispersion around buildings

  (Leuzzi G. and Monti P.; *Atm. Envir.* 1998, 32: 203-214)





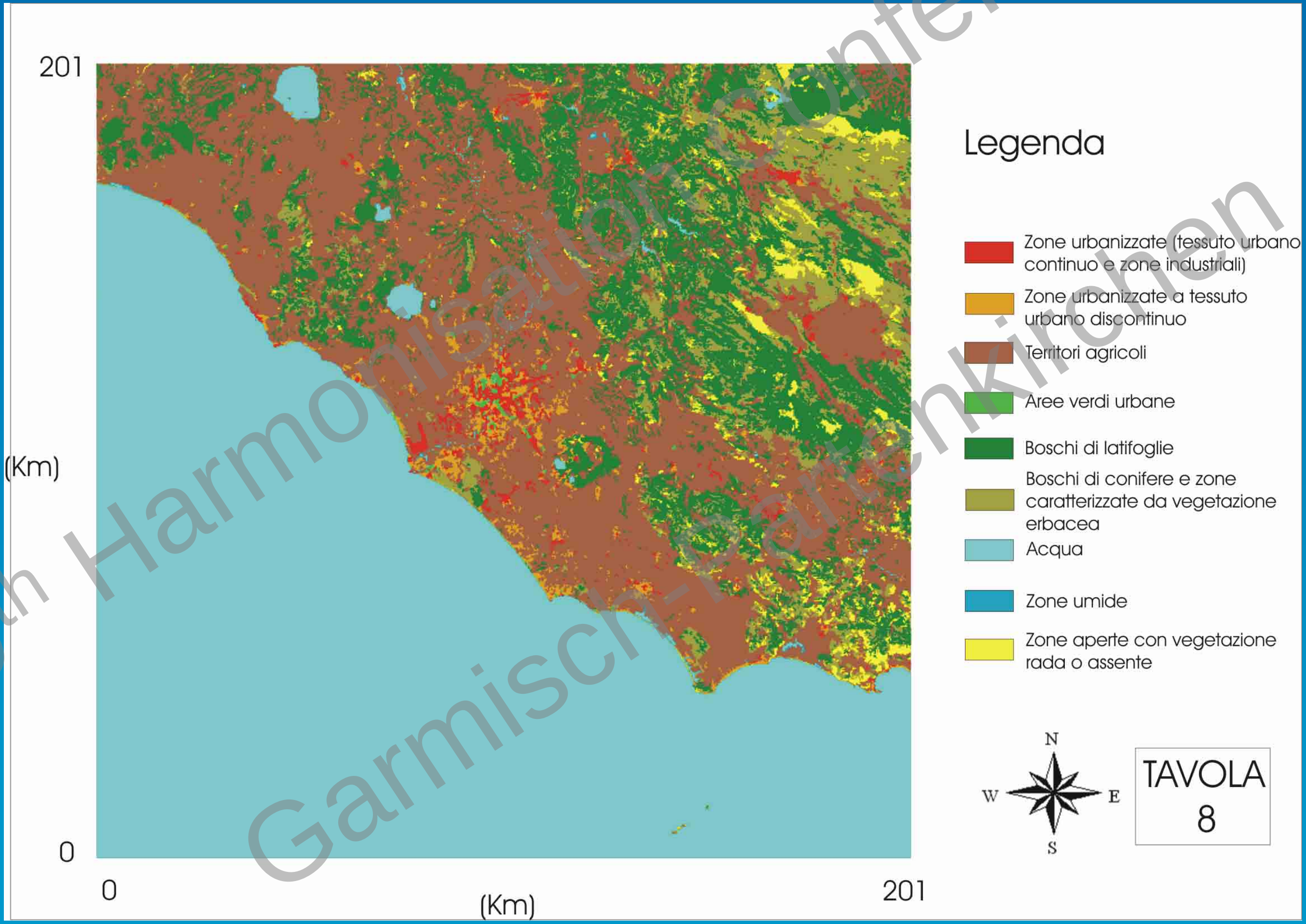
Modeling Domain



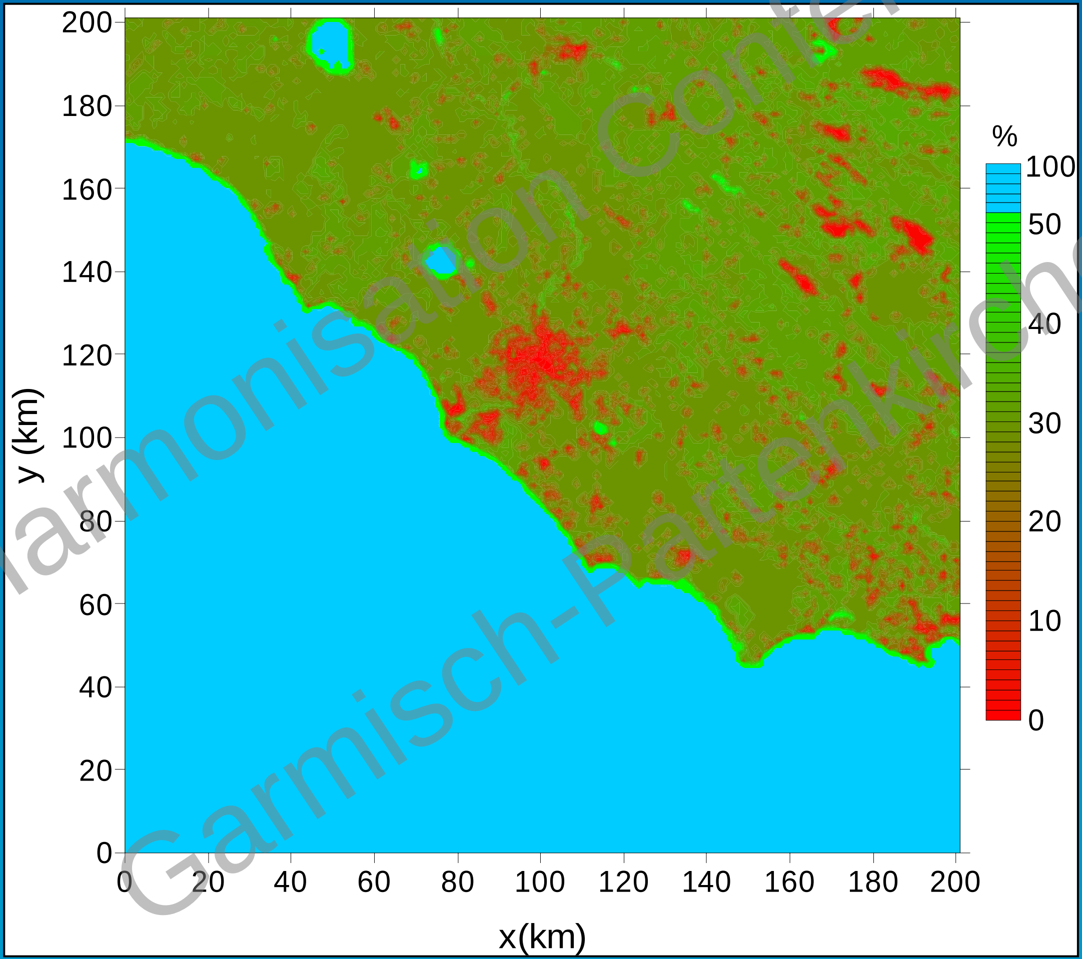
- Dimensions
  - 200x200 Km^2 in the horizontal plane
  - 9 Km along the vertical
- Discretisation
  - 201x201x19 nodes
  - $\Delta x=\Delta y=1$ Km
  - Δz variable from 2 m to 1 Km
  - $\Delta t=5$ sec
- Observational sites
  - PM (Ponte Malnome): Mast and Doppler-Sodar station
  - PDM (Pratica di Mare): Radiosounding station

Topography

Corine Land Cover



Soil Moisture Availability



Case specification

- Period of simulation:

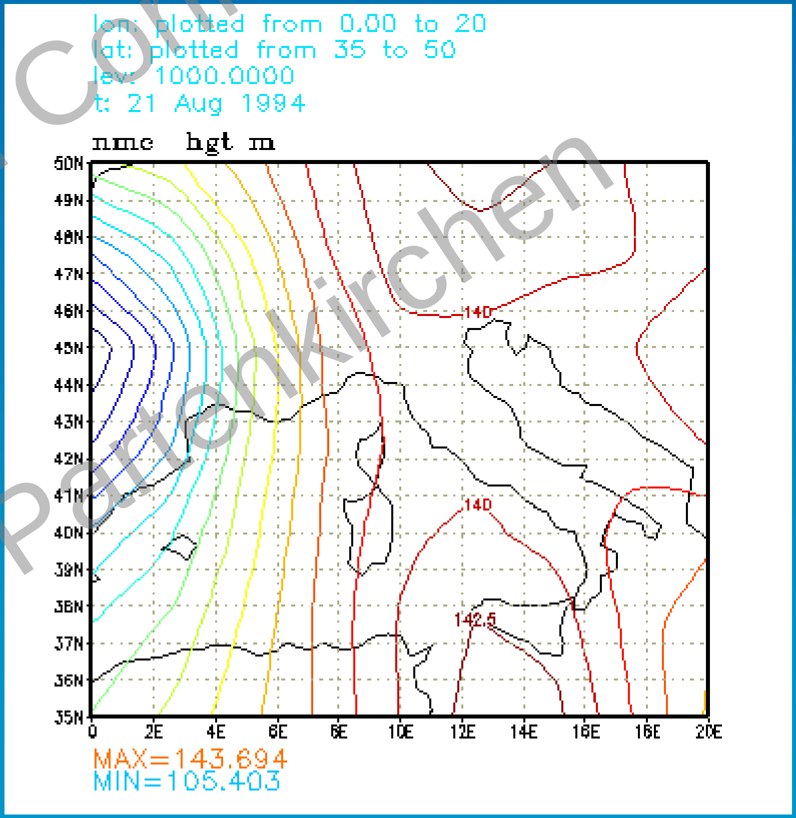
  48 hours (21-22 August)

- Synoptic conditions:

  high leveled pressure

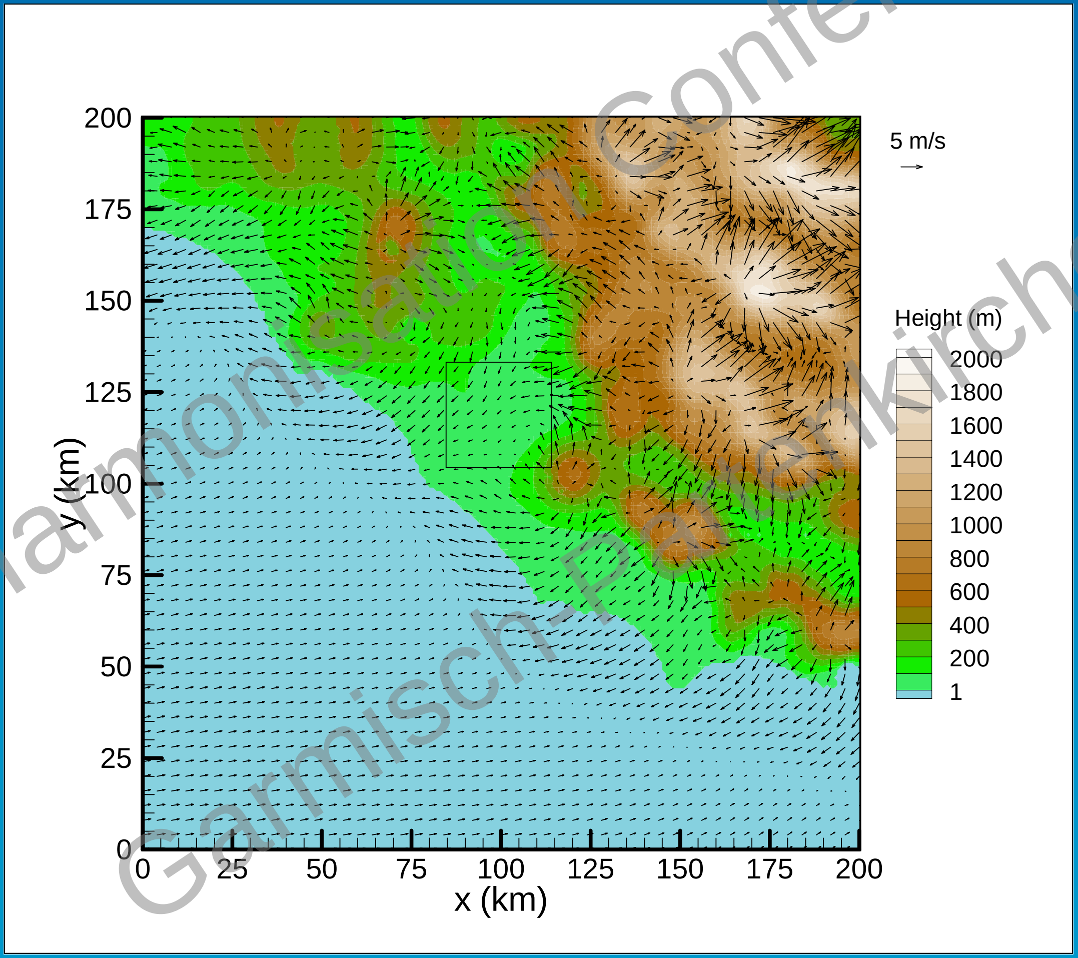
- Initial conditions:

  radiosounding taken at
  Pratica di Mare station



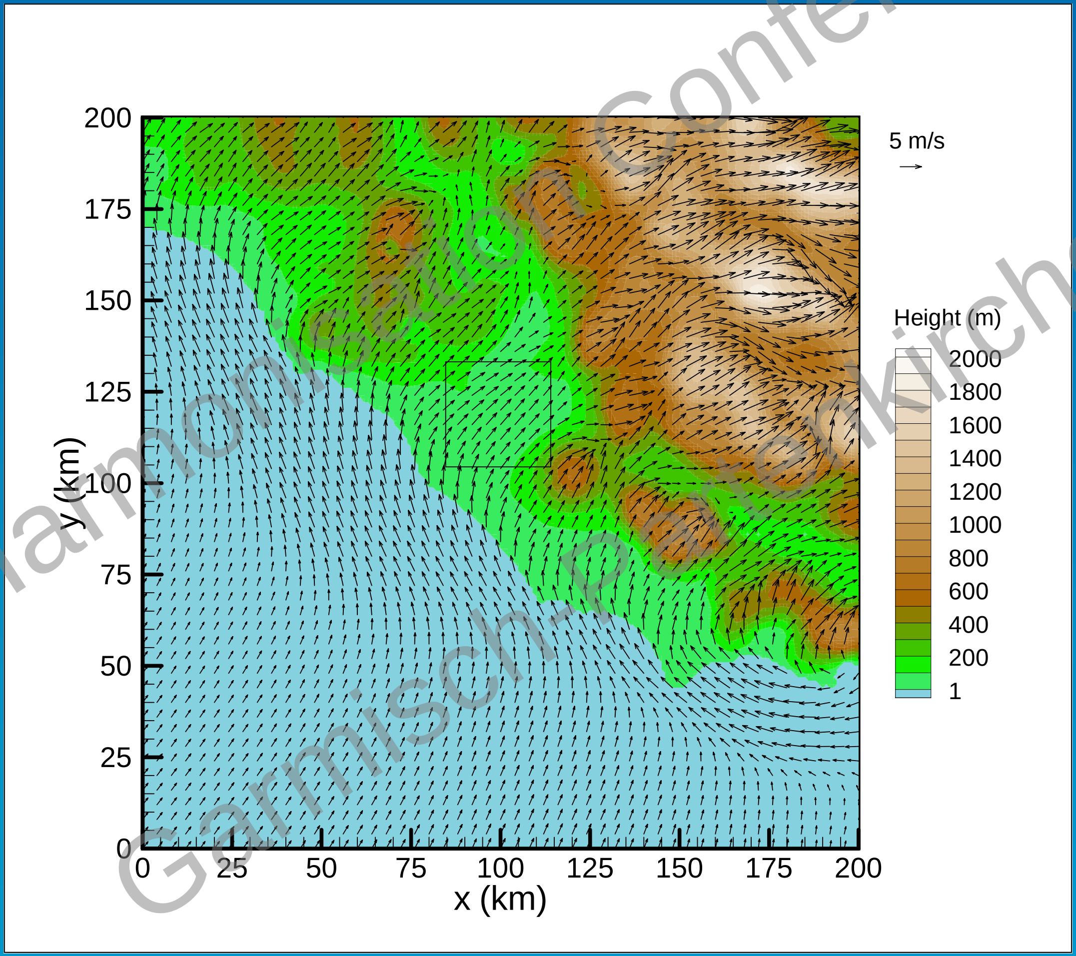
Nocturnal breezes

simulated wind field at 02:00 LST at 10 m AGL

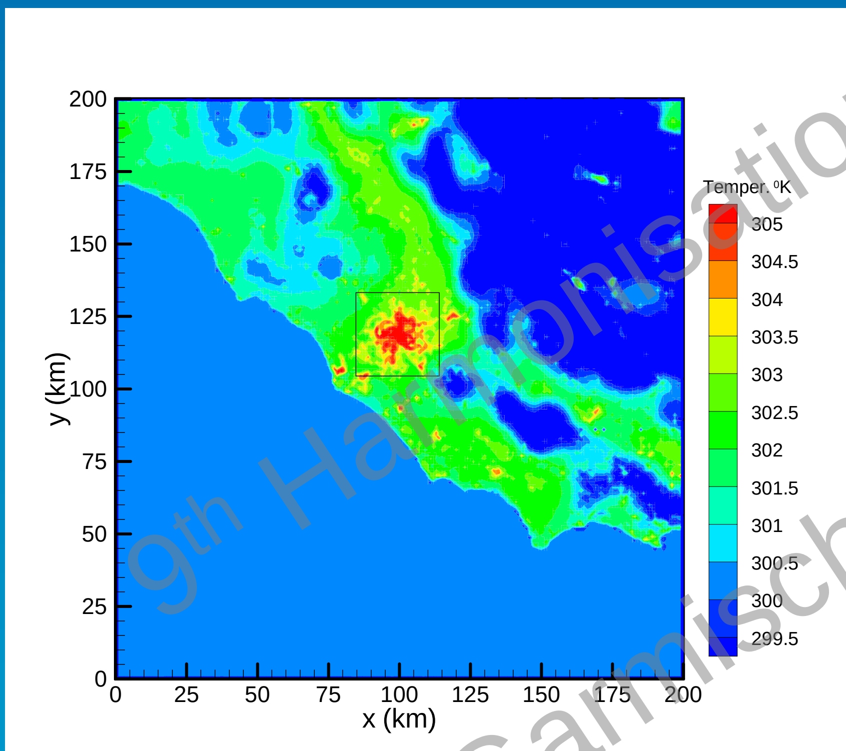


Diurnal breezes

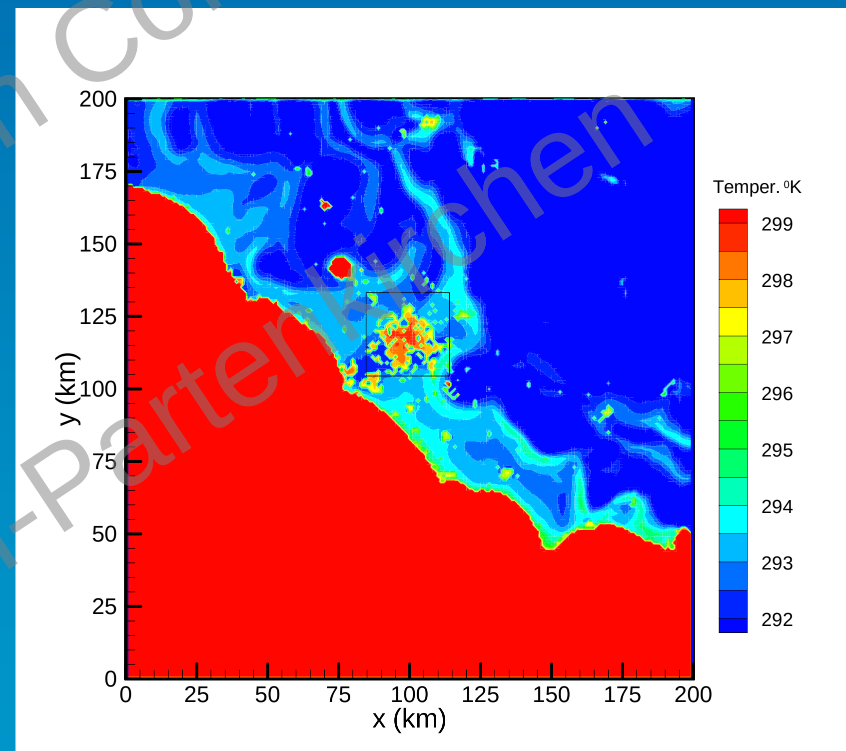
simulated wind field at 13:00 LST at 10 m AGL



Maps of surface temperature

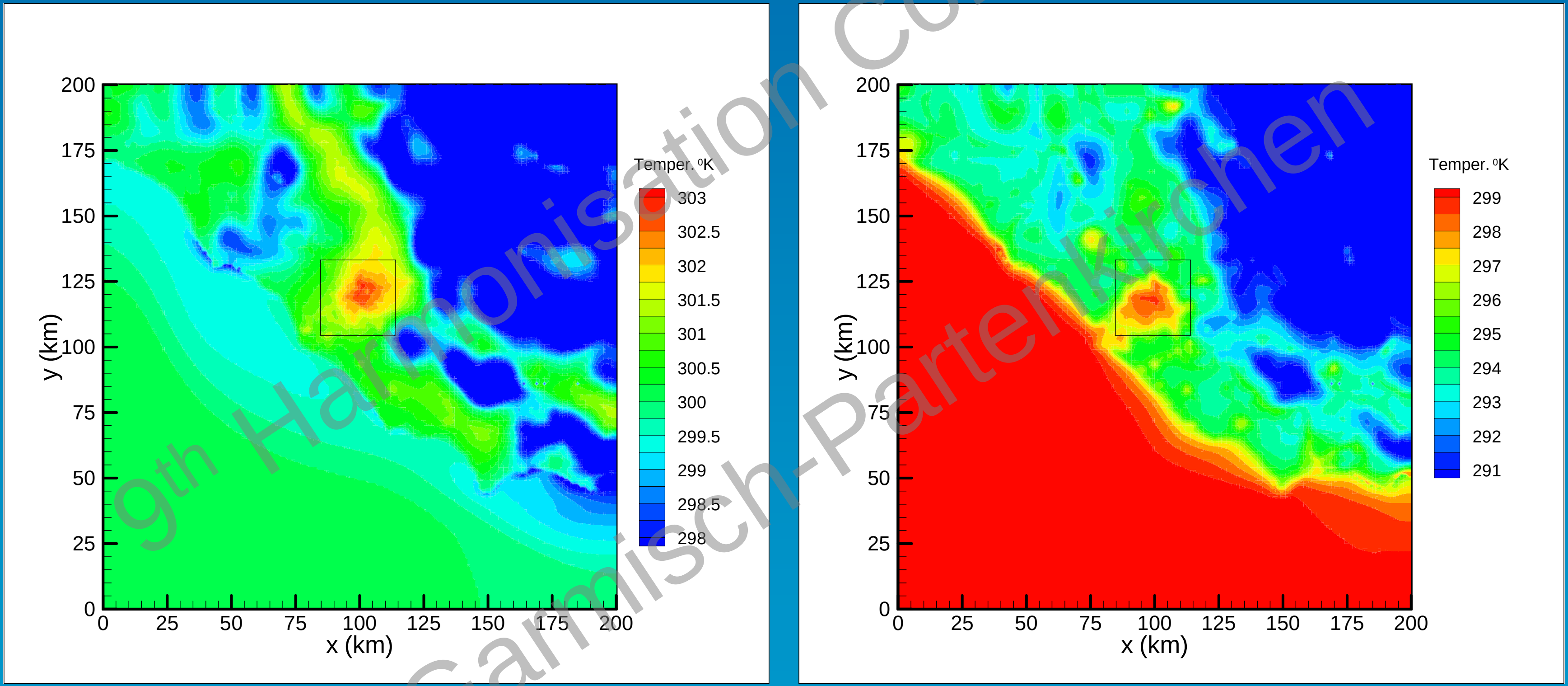


13:00 LST



24:00 LST

Maps of temperature at 6 m AGL

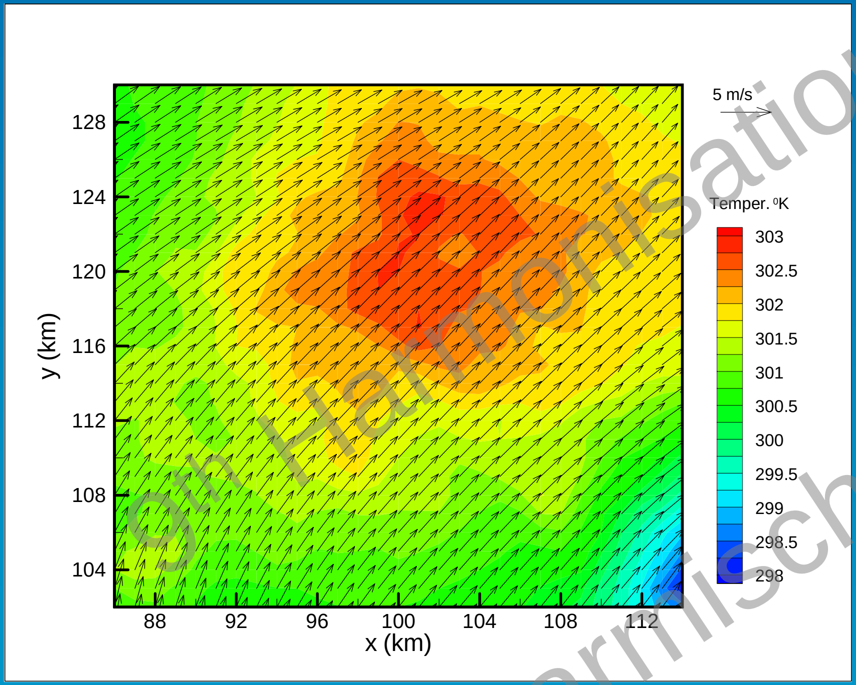


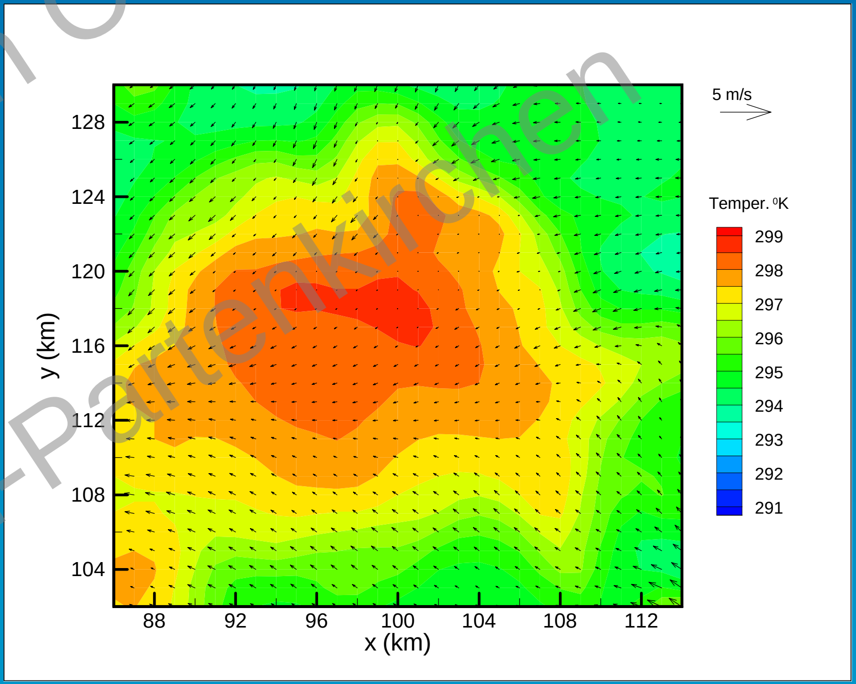
13:00 LST

24:00 LST

Urban Heat Island

maps of temperature at 6 m AGL



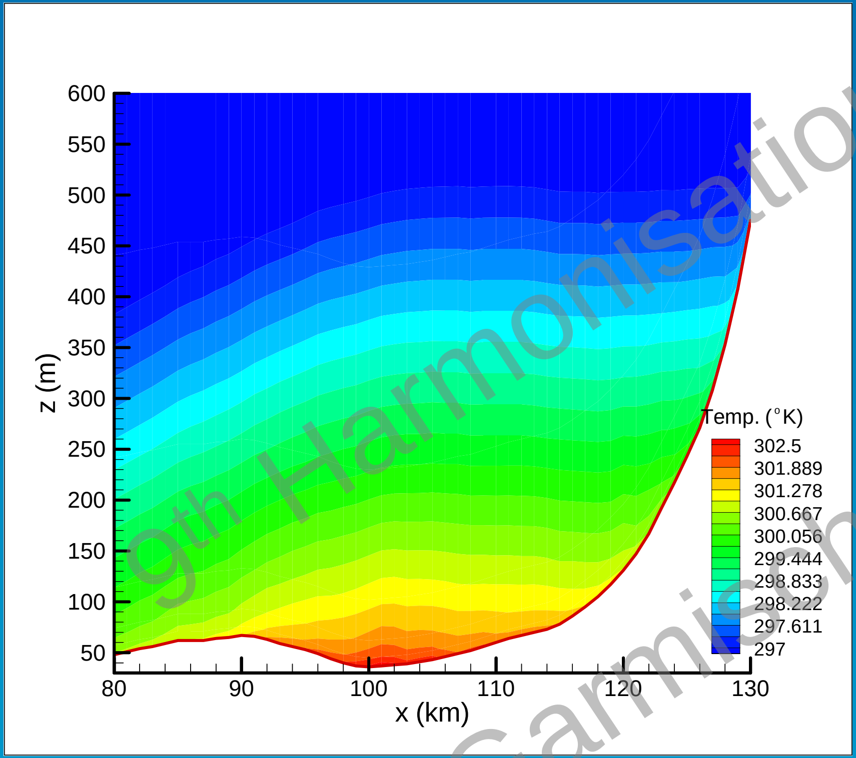


13:00 LST

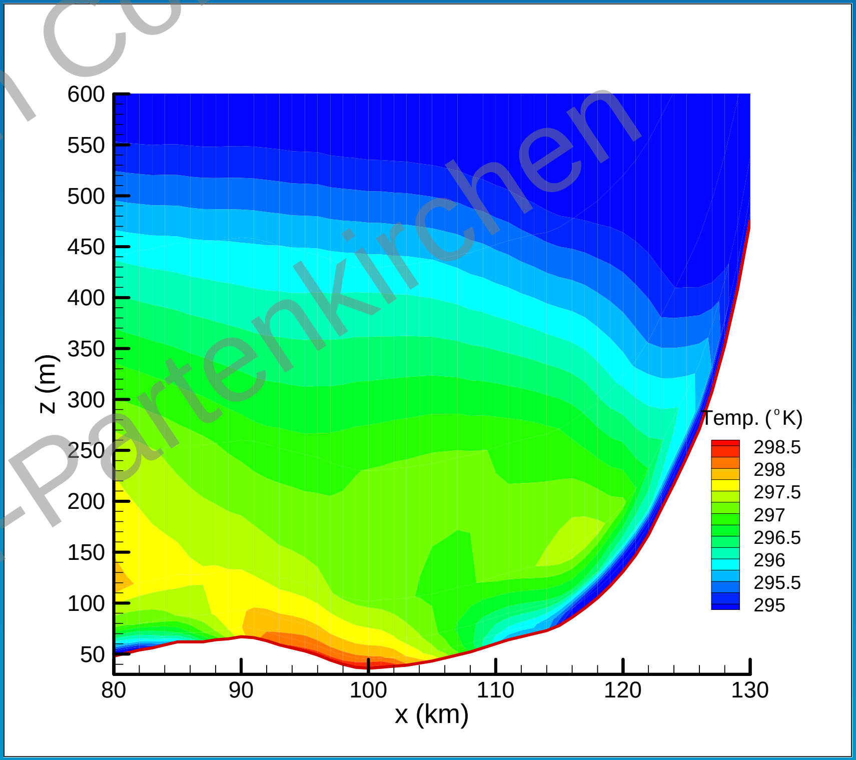
24:00 LST

Urban Heat Island

vertical fields of temperature (y=117 km)



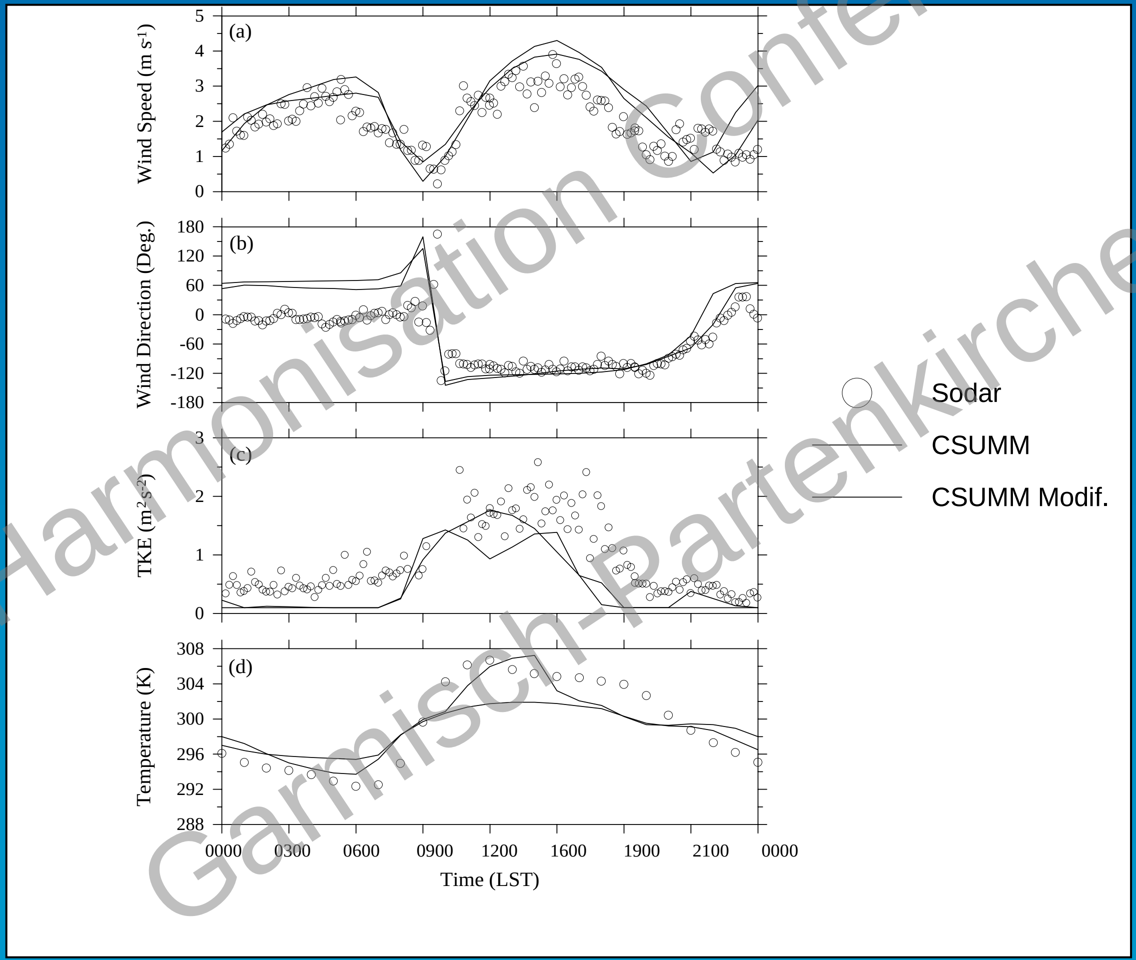
13:00 LST



24:00 LST

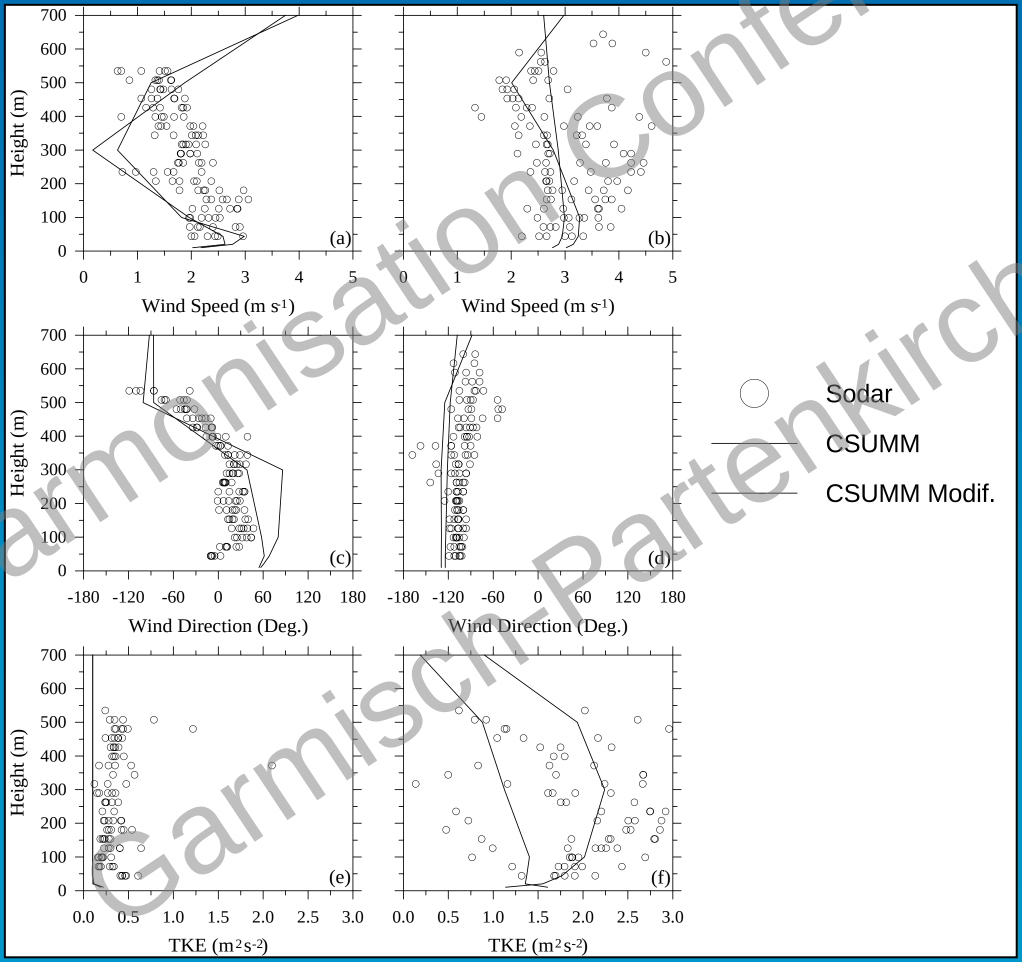
Comparison with Sodar and Mast measurements

diurnal cycle at 44 m AGL



Comparison with Sodar measurements

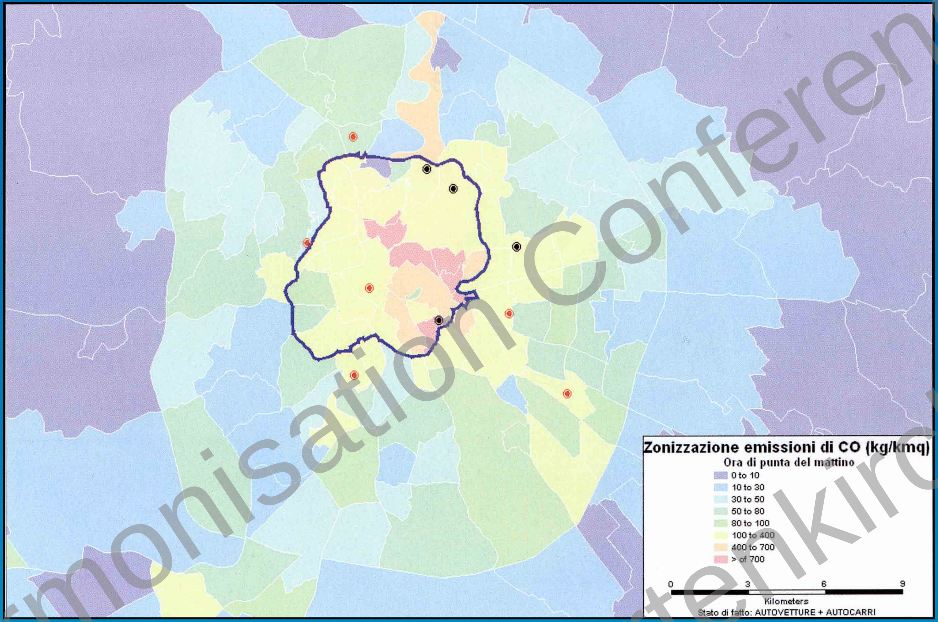
nocturnal and diurnal vertical profiles



03:00 LST

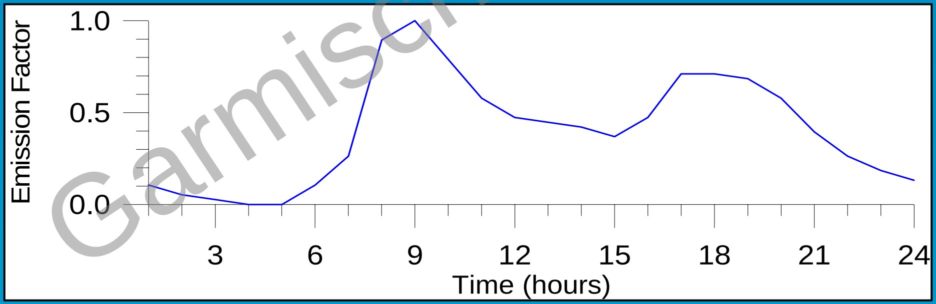
12:00 LST

Vehicular emissions of CO



Zoning of CO emissions during the morning peak hour

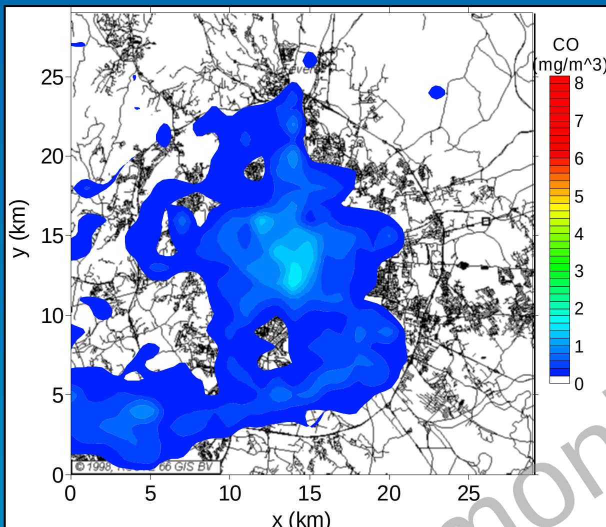
(STA-Mobility Agency for the City of Rome, 2001)



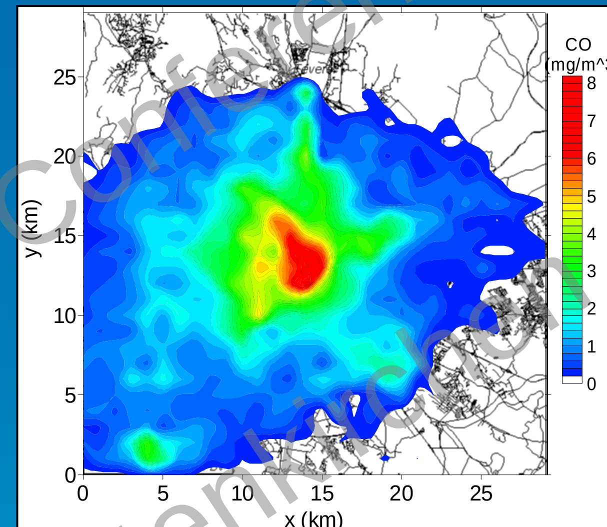
Emission cycle for a typical ferial day

Dispersion of pollutants

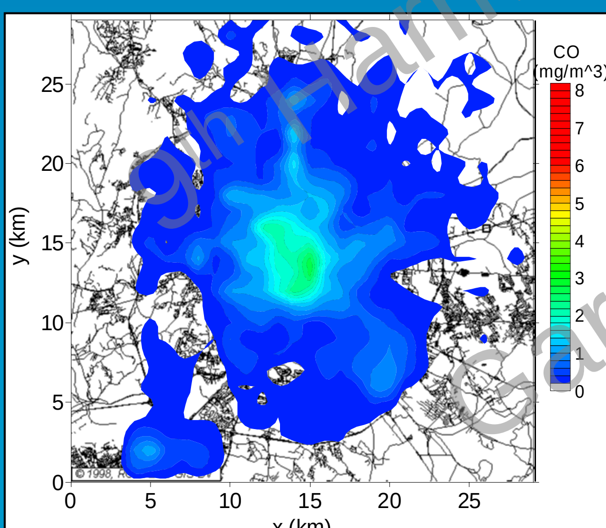
CO concentrations near the ground (0 ÷ 6 m AGL)



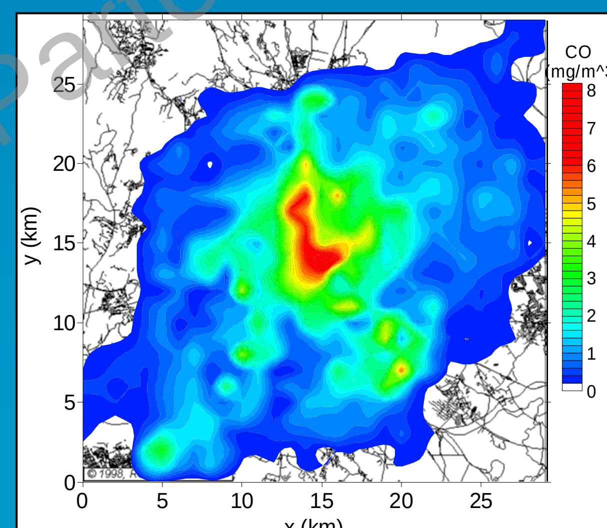
06:00 LST



09:00 LST



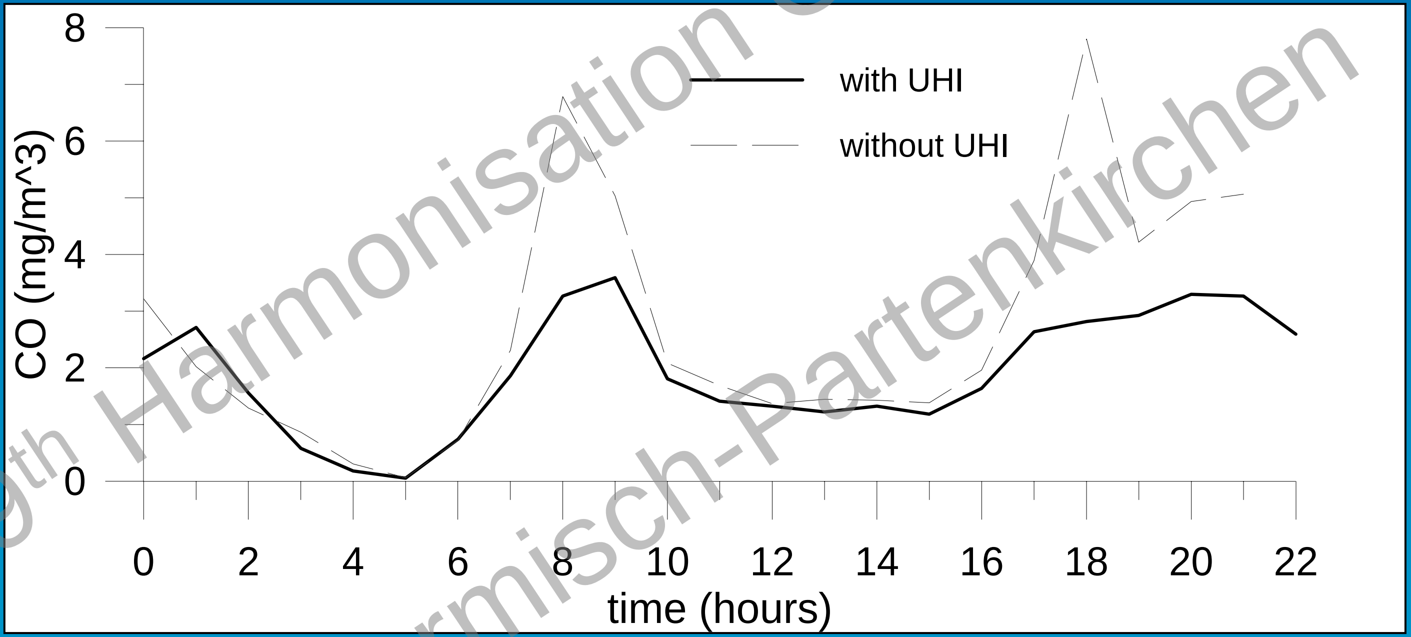
12:00 LST



20:00 LST

Influence of the UHI on the pollutant dispersion

CO concentration averaged in the center of Rome



Conclusions

- The urban boundary layer of the Rome area is strongly influenced by the land and sea breeze regimes, both these winds are reinforced by interaction with slope winds.
- Because of the low soil moisture availability and the high thermal diffusivity, a strong urban heat island (UHI) forms.
- During the morning and the night the thermal plume of UHI is advected in reversal direction by sea and land breezes.
- The comparison between simulations and observations shows a good agreement with the exceptions of wind direction and turbulence during the night.
- Early morning and late afternoon emission peaks correspond to wind drops due to the alternate switching between land and sea breeze. This fact increases the concentration peaks.
- Because of the mixing increasing, the UHI lowers both the concentration peaks.