Numerical simulations of boundary-layer processes and urban-induced alterations in an Alpine valley

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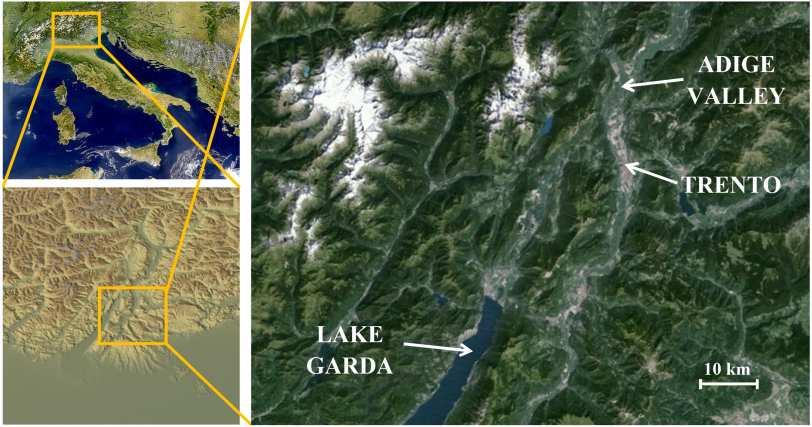
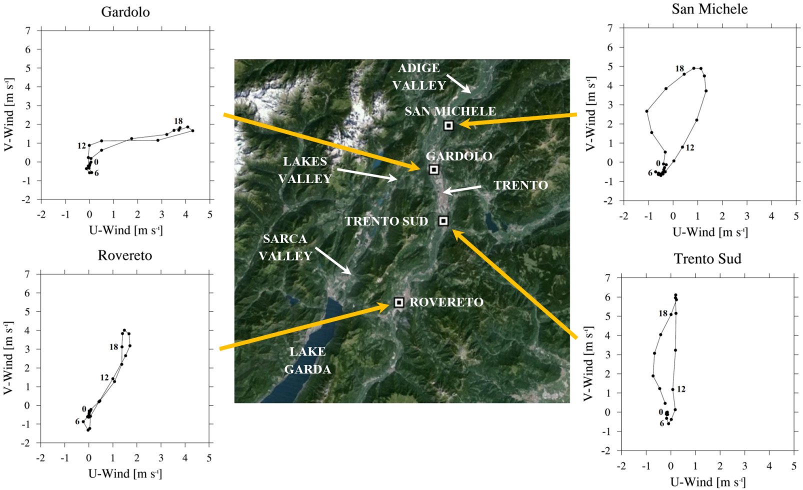
Leeds, 10 June 2014

21st Symposium on Boundary Layers and Turbulence

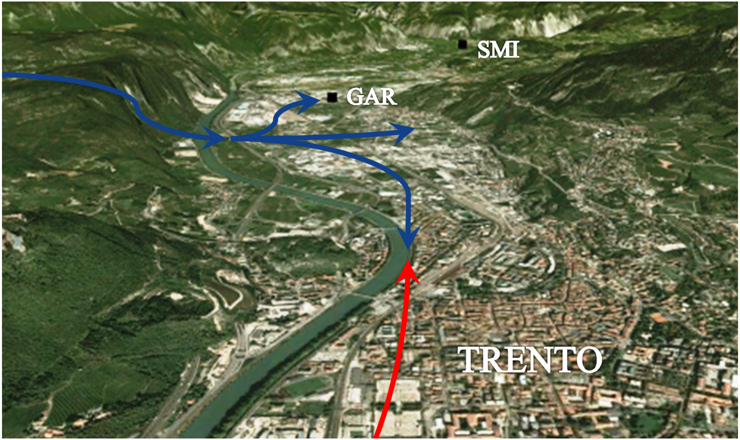
Study area



Local circulation systems



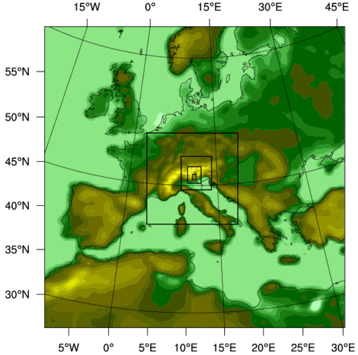
Local circulation systems



Main model settings

Simulations with the WRF model of a sunny summer day, 1 August 2010. Simulations start at 1800 UTC of the previous day.

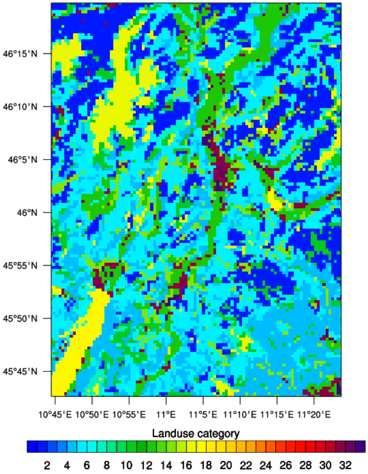
- Five two-way nested domains with a spatial resolution of 40.5 - 10.5 - 4.5 - 1.5 - 0.5 km
- 44 vertical levels, with first level at 10 m AGL and 11 levels in the first 1000 m
- BouLac boundary layer scheme
- Noah land surface model
- BEP multi-layer urban scheme



Input datasets: land use

Corine Land Cover (2006) dataset

- spatial resolution of 100 m
- 44 classes, reclassified to Modis classes in order to use the WRF look-up tables

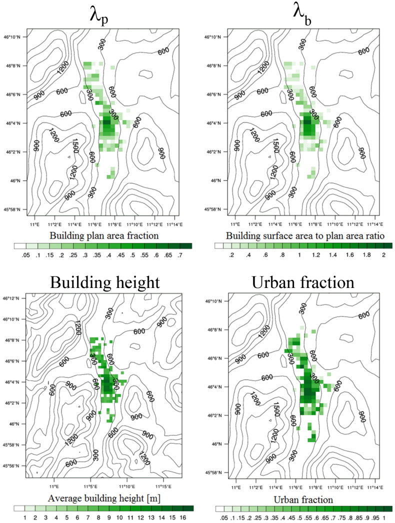


Input datasets: urban morphology

Urban morphology parameters for the BEP scheme:

- $\lambda_p = \frac{A_{roof}}{A_{tot}}$
- $\lambda_b = \frac{A_{roof} + A_{wall}}{A_{tot}}$
- Average building height
- Distribution of building heights (every 5 m)
- Urban fraction

Urban parameters for the city of Trento calculated with GIS techniques from high-resolution (1 m) lidar data



Input datasets: anthropogenic heat flux - vehicular traffic

Hourly vehicular fluxes obtained from the Municipality of Trento.

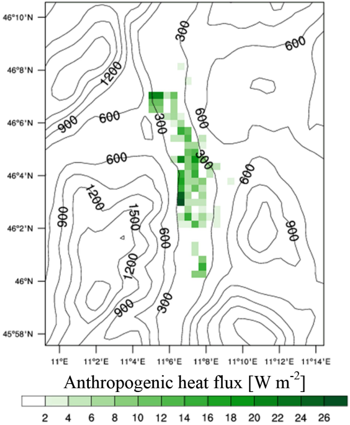
Formula proposed by Grimmond (1992):

$$Q_V = \frac{[(n_V(t) \cdot D_V) \cdot EV]}{A \cdot 3600} \quad [W\ m^{-2}]$$

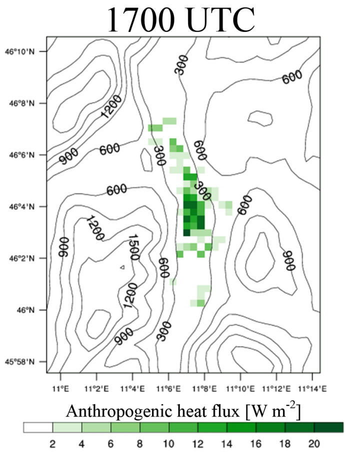
$$EV = \frac{(NHC \cdot \rho)}{FE} \quad [J\ m^{-1}]$$

n_V = number of vehicles
D_V = length of the road $[m]$
NHC = net heat combustion $[J\ kg^{-1}]$
ρ = density of fuel $[kg\ l^{-1}]$
FE = mean fuel economy $[m\ l^{-1}]$

1700 UTC

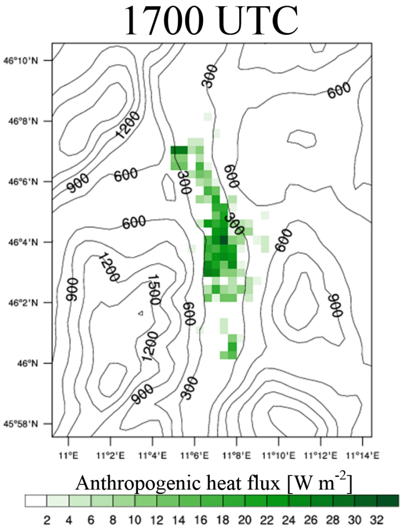


Input datasets: anthropogenic heat flux - buildings and industries



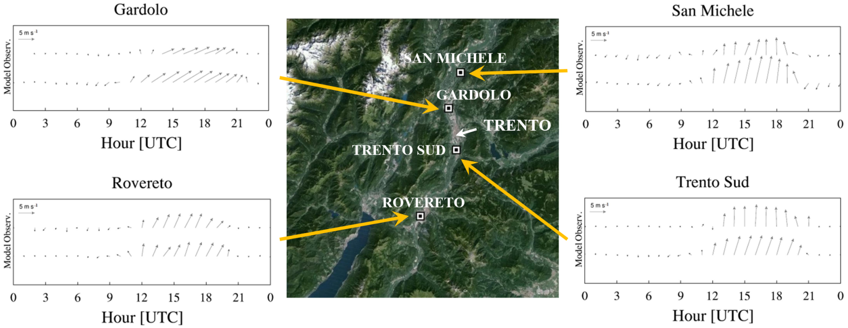
- Yearly gas consumption data with a high spatial resolution (more than 50000 users)
- Total yearly energy consumption in the city
- Typical Italian monthly and daily cycles of energy consumption

Input datasets: anthropogenic heat flux - total



Model results: local circulation systems

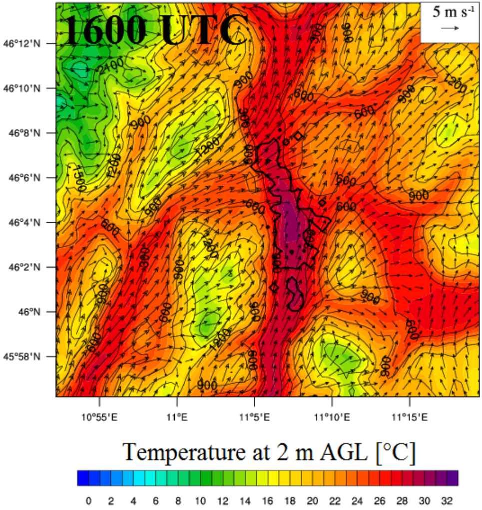
- The diurnal cycle of valley winds is generally well captured
- The Ora del Garda arrives too early in the Adige Valley



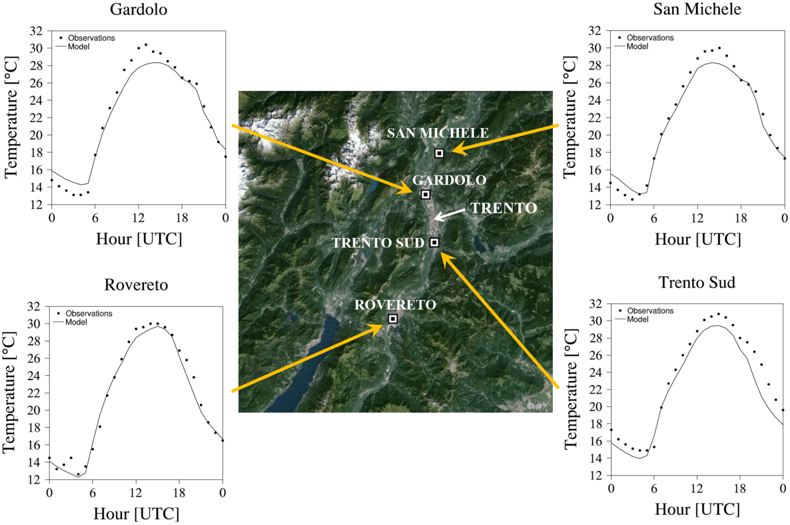
Model results: Ora del Garda

Outbreak of the Ora del Garda inside the Adige Valley:

- Strong south-westerly wind north of Trento, associated with lower temperatures

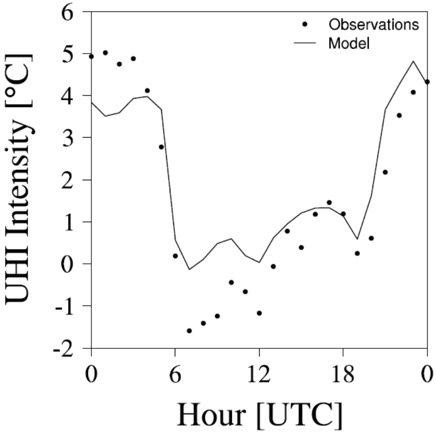


Model results: temperatures



Model results: diurnal cycle of the UHI

UHI intensity calculated from the temperature differences between Molino Vittoria (urban) and San Michele (rural) weather stations.



Sensitivity tests

Sensitivity simulations were run to investigate the role of different factors:

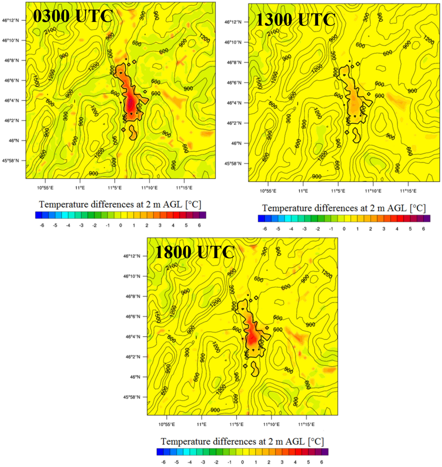
- Simulation without urban areas
- Simulation without the gridded datasets of urban morphology
- Simulation without anthropogenic heat flux
- Simulation with the bulk urban parameterization

More details in:

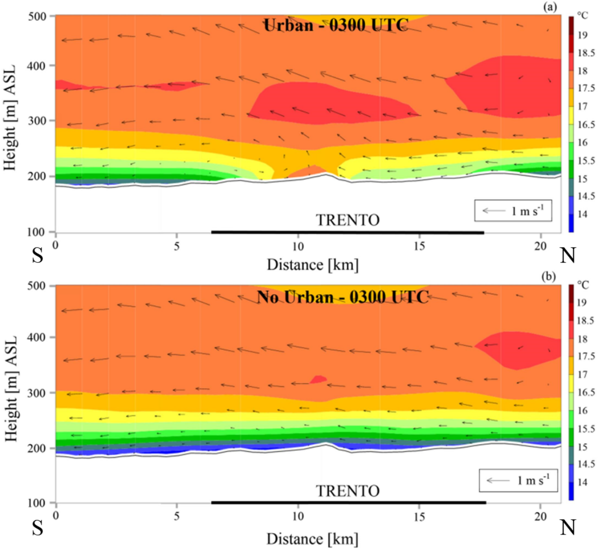
Giovannini L., Zardi D., de Franceschi M., Chen F., 2014: Numerical simulations of boundary-layer processes and urban-induced alterations in an Alpine valley. *International Journal of Climatology*, **34(4)**, 1111-1131.

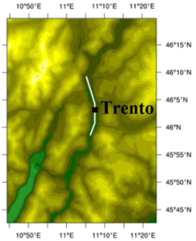
Sensitivity tests: simulation without urban areas

- Strong UHI at night, especially in the central part of the city
- Small urban effects in the morning and in the central hours of the day
- UHI starts in the evening from the central part of the city

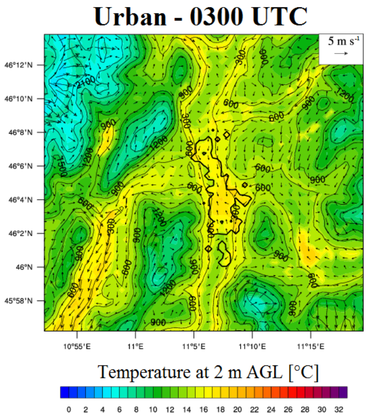


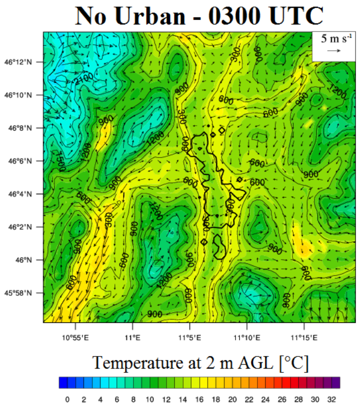
Sensitivity tests: simulation without urban areas



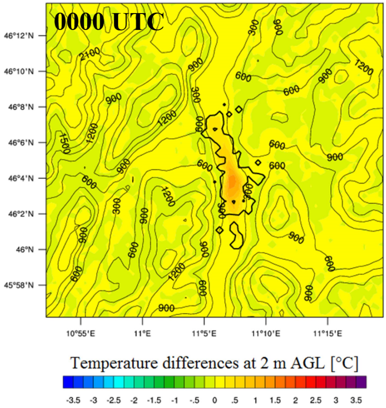


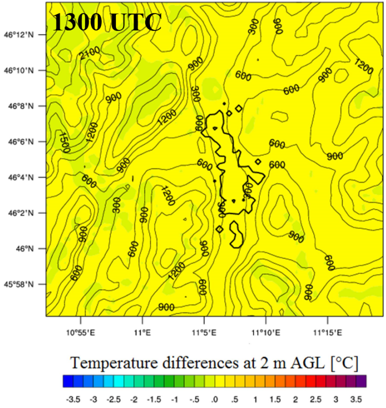
Sensitivity tests: simulation without urban areas





Sensitivity tests: simulation without anthropogenic heat





Conclusions

- The WRF model is able to reproduce reasonably well the diurnal cycle of local circulation systems in a narrow Alpine valley
- The diurnal cycle of the UHI is also well captured by the model
- The urban area of Trento has an impact on the ground-based thermal inversion and on the down-valley wind at night
- Significant impact of the anthropogenic heat flux at night

THANKS FOR YOUR KIND ATTENTION!