Analysis of the Influence of the Metropolitan Area of Belo Horizonte/Brazil on Local Meteorology Using WUDAPT – Urban WRF Model

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Overview

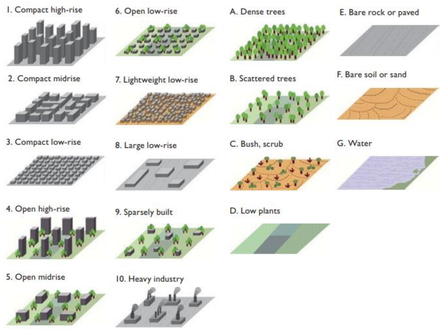
- Population growth has intensified land use change by the **expansion of urban areas**. Variations in surface features are capable to interfere in the energy balance causing **local meteorological changes.**
- The Metropolitan Area of Belo Horizonte (MABH), located in Brazil, is the seventh most populated metropolis in South America with 5.3 million inhabitants and for which an increase on temperature has been verified through the years, being, possibly, related to the changes on land cover.
- Objectives:

  ✓ Investigate the impact of **future scenario of urban growth** on local meteorology during a dry season, using the mesoscale model **Weather Research and Forecasting (WRF)** coupled with the urban module **Building Effect Parameterization (BEP)** (Martilli et al., 2002).

Methodology

- Land use Classification – WUDAPT Methodology

Processes that contribute to generation of urban climatic effects are closely related to cities form (land cover, construction materials and tridimensional morphology) and function (industrial and commercial activities). The Local Climate Zones (LCZ) represent a generic description of land use and occupation, free of cultural factors and easy to understand. There are seventeen LCZ types, including ten constructed types (LCZ 1-10) and seven land cover types (LCZ A-G).



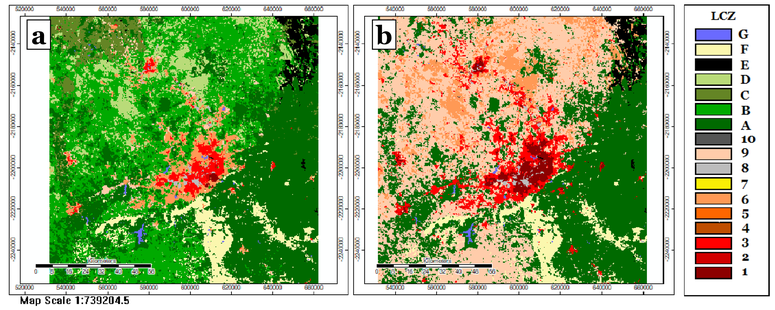
This classification were applied to the MABH in order to simplify the existent heterogenous land use and to enable an easier adoption of urban canyons parameters from literature, since observed data is hardly available. Methodology from WUDAPT (World Urban Database and Access Portal) was followed, in which selected training areas on the Google Earth along with Landsat 8 images were imported to SAGA software for supervised classification.

- Future urbanization scenario

Belo Horizonte is a relatively recent occupation (120 years) expecting to present a moderate growth in the next 50 years. In order to check the effect of urban expansion on the local meteorology, a scenario of future urbanization was proposed. Local climate zones from the current situation were converted into more urbanized areas, as the following criteria: LCZ 3 were converted into 1, LCZ 6 and 9 into LCZ 3, LCZ B and C into LCZ 9 and LCZ D into LCZ 6. To classes not mentioned, current land use was maintained.

- WRF setup
  - ✓ Three simulations: a) WRF default with no landuse update (MODIS); b) WRF coupled with BEP (urban WRF) with current landuse; c) urban WRF with future urbanization scenario;
  - ✓ Date: 10 days during a dry season of 2017;
  - ✓ Three nested domains and a vertical resolution of 44 eta levels (first 18 levels below 1.5 km height). Spatial resolutions: D01 – 25 km, D02 – 5 km and D03 – 1 km;
  - ✓ Initial and boundary conditions: NCEP GFS final analysis data 0,25 x 0,25°;
  - ✓ Warm-up: 24 h;
  - ✓ BEP's urban canopy parameters: adopted from LCZ papers and observed data (height distribution only).

LCZ Classification – Current (a) and Future Scenario (b)

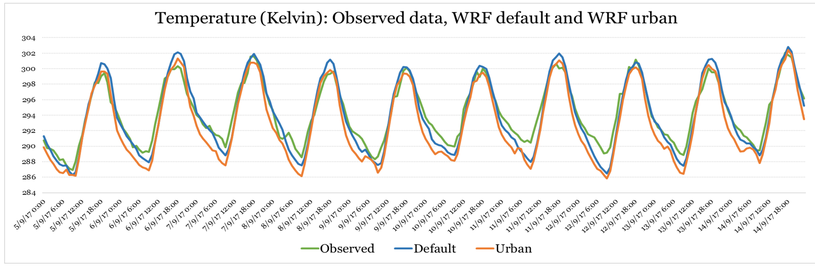


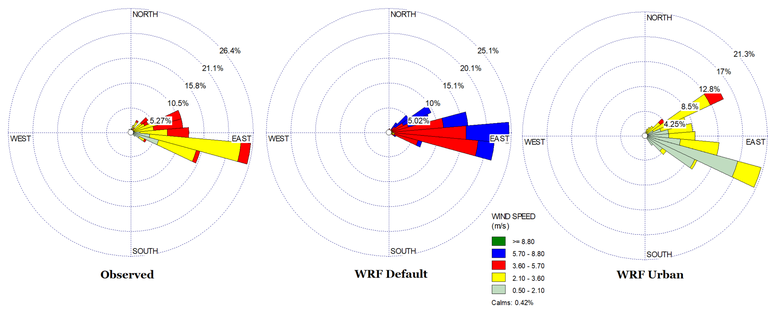
- On the current scenario of urbanization, MABH covers less than 10% of inner domain (a) . On future hypothetical scenario number rises up to ~ 55% (b) . Scenario considered that the capitol will be more verticalized, while the suburbs, with low and sparse vegetation, will be converted into more open urban areas. It was assumed that dense vegetation areas will be conserved.

WRF: Default and Urban

- Simulated results were analyzed as suggested by Emery *et al.* (2001). From observed and modelled data were calculated statistical indexes and verified model performance by benchmarks agreement. For the model validation were used data from the INMET meteorological station Pampulha, located at Belo Horizonte. Results of temperature (at 2m) and vector wind were also plotted. Time is on GMT (Local time -3h). Main findings are:
  - ✓ uWRF tends to follow better the maximum daily temperatures but presents limitations on predicting minimum values during the nighttime, what leads to a global underestimation of air temperature (negative mean bias).
  - ✓ Urbanized version was capable of reducing the common overestimation of wind speed on WRF simulations, also better predicting it (root mean square error minored).

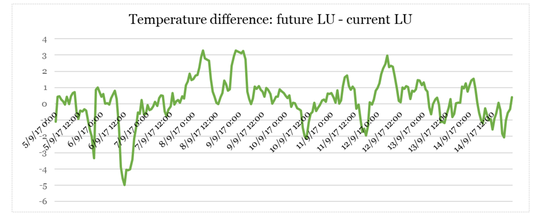
Meteorological parameter	Index	Benchmark	Default	Urban
Temperature (2 m)	MB (K)	≤± 0.50	-0.34	-1.37
	MAGE (K)	≤ 2.00	1.00	1.56
	IOA	≥ 0.80	0.98	0.95
Wind speed (10 m)	MB ($m.s^{-1}$)	≤± 0.50	2.40	-0.64
	RMSE ($m.s^{-1}$)	≤ 2.00	2.67	1.09
Wind direction (10 m)	MB (°)	≤± 10.00	-1.09	6.32
	MAGE (°)	≤ 30.00	18.61	20.49

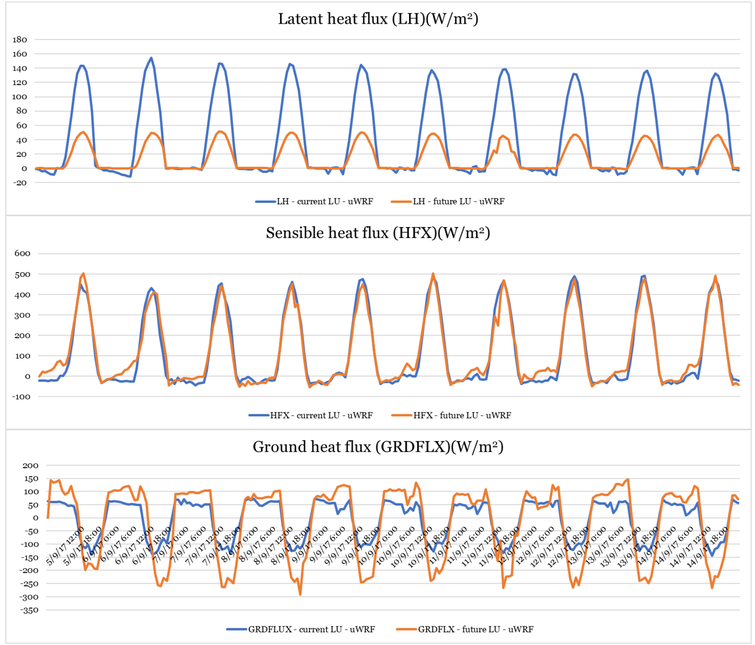




Urban Expansion and Local Meteorology

- Results for an urban cell located at the city center of Belo Horizonte. LCZ3 (current land use – LU) converted into LCZ 1 (future LU). Time expressed on GMT.
- BEP's urban canopy parameters altered: constructed fraction; height distribution; heat capacity, thermal conductivity and surface albedo of ground, wall and roof.
- In general, the future land use (LU) proposed will contribute to temperature (at 2m) elevation (up to 3°C).
- Fluxes sign convention
  - ✓ Positive: surface to the atmosphere; Negative: atmosphere to the surface;
- Increase in temperature can be attributed to:
  - ✓ Decrease of the parcel dissipated as latent heat (LH);
  - ✓ Increase of the parcel absorbed by the ground (GRDFLX) during day time and increase of the parcel dissipated during night time.
- Land cover changes were not drastic enough to cause upward sensible heat flux any alteration.





Conclusions

- Comparison between default and urbanized version: tendency to underestimate temperature but to improve wind speed prediction.
  - ✓ Urban canopy parameters must be replaced by observed data when available, in order to improve model performance.
- BEP was able to recognize two different land uses and to produce coherent results.
- Future urbanization scenario:
  - ✓ Conversion from a LCZ 3 to a LCZ 1 can produce an increase of 3°C on temperature;
  - ✓ Urban fraction increase can reduce the parcel dissipated as latent heat;
  - ✓ Densification and verticalization can be responsible for an increase of the heat parcel absorbed during the day time, consequently increasing the amount of heat that is dissipated during the night time. Such situation is a important contributor to the generation of the nocturnal urban heat islands.
  - ✓ Vertical profile and other variables will be analyzed to future studies.