Review of the manuscript egusphere-2023-1069

WRF-Comfort: Simulating micro-scale variability of outdoor heat stress at the city scale with a mesoscale model

By Martilli et al.

Summary: In this study the authors use WRF model simulations using the BEP-BEM scheme at 1 km grid spacing for the city of Madrid to estimate human thermal comfort indices. This is done through estimating ranges for the mean radiant temperature, wind speed and temperature within a grid cell. This spans up 54 possible thermal comfort options for every grid cell and every time step. From this distribution the 10th, 50th and 90th percentile are presented to indicate mean human thermal comfort as well as for cool spots and for hot spots. I find this an interesting and new way to quantify the variability in human thermal comfort indices in a computationally cheap way, so in principle support publication of this manuscript. However, some aspects could be improved or advanced without much effort.

Recommendation: Minor revision required

Major remarks:

1. Obviously the modelling effort is a nice extension of what has been done before, but it lacks a verification against observations. It would be good to add some general model validation for the WRF simulation for the specific days, like performance for the airport + sounding at Barajas, as well as for the surface weather stations within Madrid.

   *Answer: WRF validation is not the objective of the paper. WRF with this set-up has been used and validated extensively for summer (Salamanca et al. 2012, Brousse et al. 2016), and winter periods (Martilli et al. 2021). The simulations used in this paper, have been validated in Rodriguez-Sanchez (2020), with 5 meteorological stations located in the urban area of Madrid. Below are the RMSE and BIAS for these stations:*

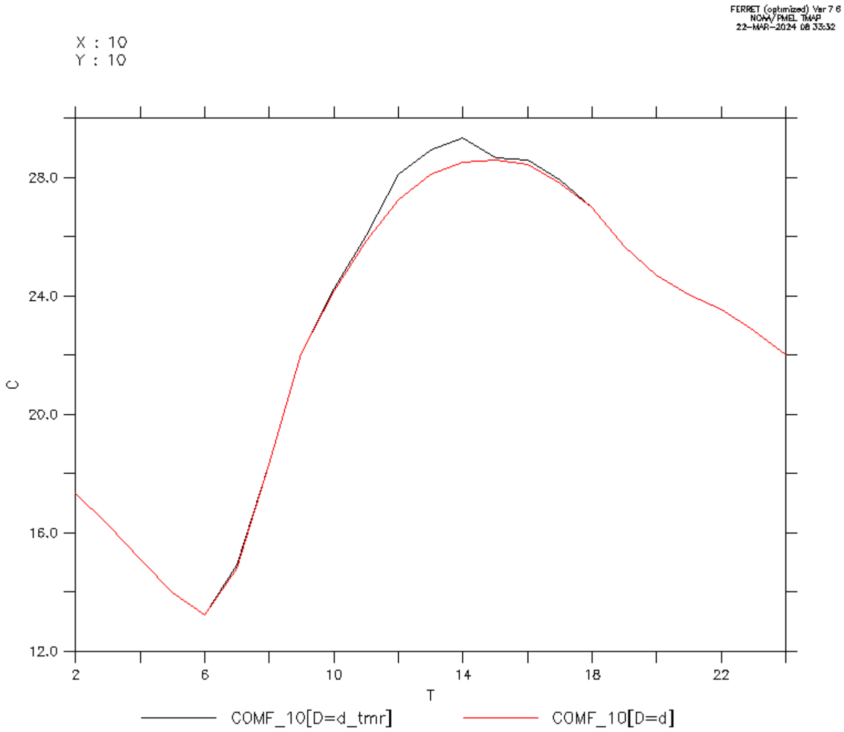
| *station* | *BIAS (Celsius)* | *RMSE (Celsius)* |
|---|---|---|
| Centro Municipal Acústica | *4.02* | *4.24* |
| Junta Municipal de Distrito Hortaleza | *0.58* | *1.06* |
| Estación Depuradora de Aguas Residuales La China | *-0.90* | *1.12* |
| Junta Municipal de Distrito Moratalaz | *1.44* | *1.84* |
| Junta Municipal de Distrito Villaverde | *0.98* | *1.74* |

*With the exception of station 1, located close to the Manzanarre's river not resolved by the model, the statistical error for the other stations is in the range of what is commonly found for mesoscale models.*

*Ref:*
*Brousse, O., Martilli, A., Foley, M., Mills, G., & Bechtel, B. (2016). WUDAPT, an efficient land use producing data tool for mesoscale models? Integration of urban LCZ in WRF over Madrid. Urban Climate, 17, 116-134.*
*Martilli, A., Sanchez, B., Rasilla, D., Pappaccogli, G., Allende, F., Martin, F., ... & Fernandez, F. (2021). Simulating the meteorology during persistent Wintertime Thermal Inversions over urban areas. The case of Madrid. Atmospheric Research, 263, 105789.*
*Salamanca, F., Martilli, A., & Yagüe, C. (2012). A numerical study of the Urban Heat Island over Madrid during the DESIREX (2008) campaign with WRF and an evaluation of simple mitigation strategies. International Journal of Climatology, 32(15), 2372-2386.*

2. I find the discussion section can be strengthened by discussing whether less than 54 combinations of meteo input for the UTCI calculations would also do the job, or would let's say 108 do a better job? Or would 27 work as well? In other words: one need to discuss how robust are the estimated subgrid-scale distributions of UTCI.

*Answer: 54 is coming from the combination of 3 wind speeds, 3 air temperatures and 6 mean radiant temperatures. The calculation is done only at the time when the output is printed, and so is not a big penalty in terms of CPU. We consider this as the minimum amount of values to account for the variability in the grid cell. In particular, for the mean radiant temperature, the magnitude with greater spatial variability, we consider, for each street direction, the two locations close to the walls (the most likely to be either on full shade or full sun, and therefore representing the extreme values, and also a location where people usually are), plus the value in the middle of the street. In order to check this, an idealized simulation has been done where the mean radiant temperature is computed in 5 points, instead of 3, for each street direction. The new points added are half way between the one in the center of the street and those close to the walls (for a 14m wide street, as the one used in the test, this means that the points are at 1.5m, 4.25m and 7m from each wall). The statistics is therefore computed over 90 values (3X3X10) instead of 54. The results obtained are shown in the graphs below. They represent the time evolution over 24hrs of the 10$^{th}$ percentile (first plot), the 50$^{th}$ percentile (second plot), and 90 percentile (third plot) of the simulation with 5 mean radiant temperatures per street direction (e.g. 90 values of UTCI) in black, and the original version with 3 mean radiant temperatures (54 values of UTCI) in red.*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22-MAR-2024 08 33:32
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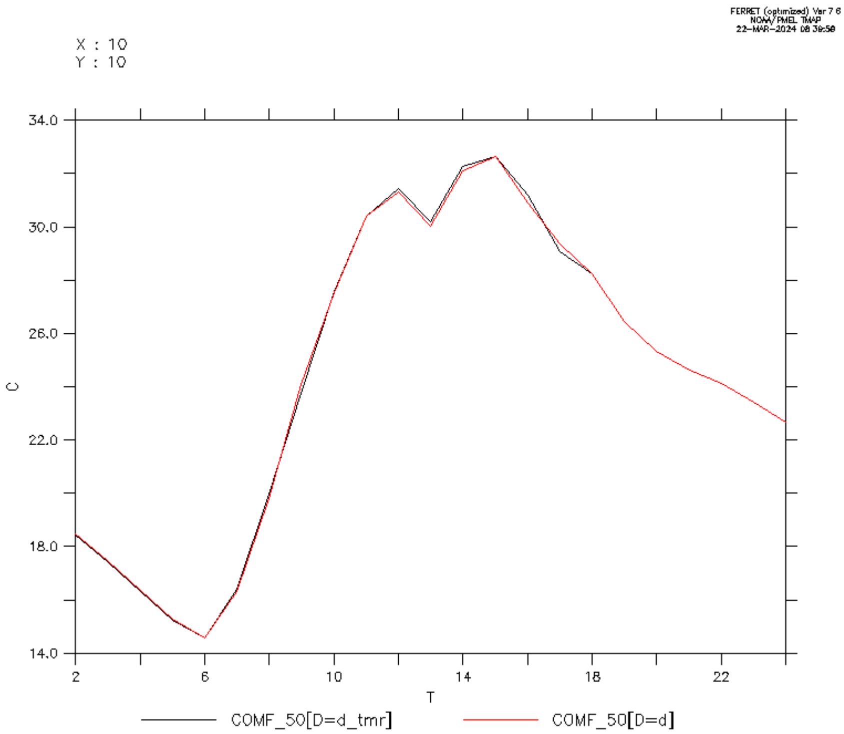
FERRET (optimized) Ver 7 6
NOAA/PMEL TMAP
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Y : 10
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22.0
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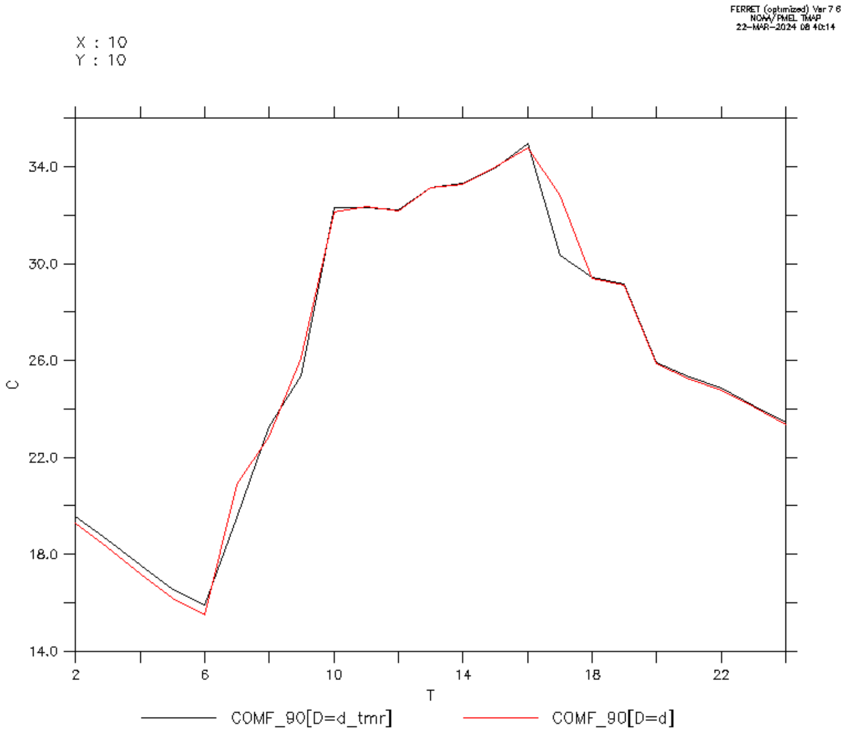


*As it can be seen, the differences are small, indicating that adding more values to compute the statistics is not worth.*

Minor Remarks:

General remark: the authors call the method a “parameterization”. One could discuss this is indeed a parameterization. Classically one uses the term parameterization to estimate a higher order moment from the lower order moment available on the grid. Would the term “downscaling” not fit better here?

*Answer: Here we consider “parametrization” an approach that allows to estimate processes that are too small scale to be resolved explicitly in the model. But the reviewer makes a good point, since, to a certain extent, our procedure “downscales” wind and mean radiant temperatures, so we re-phrased it at line 22 to reflect this.*

Ln 119: short -> short- (or shortwave)

*Answer: modified*

Figure 2: TUF-Pedestrian: perhaps add in the caption TUF-Pedestrian acts here as a reference.

*Answer: modified*

Figure 3: I have doubt about the extrapolation of sigma_u/U to be zero at vanishing lambda’s. Classical boundary layer scaling for neutral flows says this ratio goes to a constant value, so for lambda_p =0.

*Answer: This is a very important point, and we thank the reviewer for asking this. The variability we refer here is for the* ***mean*** *value of the wind speed, where* ***mean*** *should be* *intended as ensemble average (average over many realizations), or time average over time scales much longer than the turbulent time scales (but shorter than the time scale at which mesoscale features vary). Note that since there is spatial hetereogenity in the urban canopy, the classical Taylor hypothesis that space, time and ensemble averages are equal does not hold anymore. Space average is not equal to time or ensemble averages. However, lambda going to zero, means that there are no buildings, and so the space becomes horizontally homogeneous, and the* ***mean*** *wind must be the same in all the points of the space, implying that the sigma_u (standard deviation of the spatial variability of the mean wind speed) must be zero. The sigma mentioned by the reviewer is connected to the variability of the instantenous wind speed, and is induced by the turbulence, and indeed, is not zero for homogenous surfaces. We decided to neglect the impact of the turbulence since we make the assumption that the mean wind speed is the relevant quantity for thermal comfort – extending this method to the impact of the turbulence is left for future studies. This has been explained in the text (lines 161-168).*

Ln 178: please add a justification for limit/clipping introduced in speed1

*Answer: this is to avoid negative values for the wind speed.*

Ln 182: a simple log law… Please add a justification to use this. One cannot extrapolate the wind speed from within the canyon to the 10-m level using a simple log law.

*Answer. Clearly, the relevant wind for thermal comfort must be at the pedestrian level (e. g. around 2m), and not at 10m above ground. The reason why 10m is used in UTCI must be because this is the reference height in WMO standard measurements, which are the type of measurements usually available. The assumption we make is that the location where the UTCI formulation have been derived and tested is close to a WMO station, on open ground, where the log law is valid. Therefore, the relation between the relevant wind for thermal comfort (U2m), and the wind speed at 10m (U10m) at the location where UTCI has been derived and tested is* ***U2m=U10m log(2m/z0)/log(10m/z0)*** *(neglecting the atmospheric stability). What we do in our approach is to inverse the formula and extrapolate U2m_mod (the wind computed by the model at 2m), to 10m above ground using the log formula, or* ***U10m_ext=U2m_mod log(10m/z0)/log(2m/z0).*** *In other words, U10m_ext is the wind that – interpolated logarithmically – gives at 2m the wind speed produced by the model at that height (U2m_mod).*

Equation 1: in fact there is not justification for using 1 K temp variability. In classical boundary-layer theory sigma_T scales with theta_star, which depends on the sensible heat flux from the grid cell and the friction velocity in the grid cell, which are both available. So I think a physically more consistent temperature variance can be taken than was done here.

*Answer: Similarl, to what mentioned for the wind, we must keep in mind here that the sigma_T is not the variability of the instantaneous temperature induced by turbulence fluctuations, but the spatial variability of the* ***mean*** *value of temperature. Unfortunately, we do not have a complete set of non-neutral CFD simulations to assess this variability as we did for the wind speed. This should span not only different types of urban morphology, but also different atmospheric stabilities and solar angles (see for example Santiago et al.* https://doi.org/10.1016/j.uclim.2014.07.008, Nazarian et al. https://doi.org/10.1007/s10546-017-0311-9) *. We start to have also simulations over urban morphologies that resemble real ones (that were not available when the paper has been submitted almost one year ago), like the one performed by Esther Rivas (CIEMAT, personal communication) over a regular neighborhood of Madrid (barrio Salamanca) during a heat wave. These results indicate that for* *this morphology the spatial variability of air temperature ranges between 0 C during the night, and 1.2 C during the day, which are in the same range of the 1C that we used as estimate. Indeed, here there is a huge possibility of improvement in the future, when these type of non-neutral simulations will become increasingly available. This has been mentioned in lines 194-197.*

Figures 4, 9, 10: please add scale bar and north arrow

*Answer: The map is oriented so that left is West, and up is North, and its size is 50x50km. This has been added in the caption.*

Ln 331: Gaussian distribution -> wind never follows a Gaussian distribution. So it is better to discuss here whether you could have better drawn the wind values from a Weibull distribution (the standard one for wind speed).

*Answer: Instantaneous wind speed follows a Weibull distribution, but here we are talking about a distribution of the mean wind speed. In fact, we do not know what kind of shape the distribution of the mean wind speed would follow in an urban canopy – probably it would be strongly sensitive to details of the urban morphology that are not captured by the urban canopy parameterization. This is why we decided to give the same probability to the three values.*