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Application of Netatmo personal weather stations data for urban climate research, monitoring and mapping of meteorological conditions and thermal comfort in the Moscow megacity

Mikhail Varentsov[1-4]*,

Timofey Samsonov[1,3], Pavel Kargashin[1],
Korosteleva Polina[1], Varentsov Alexander[1], Perkhurova Anastasia[1]
and Pavel Konstantinov[1,4]

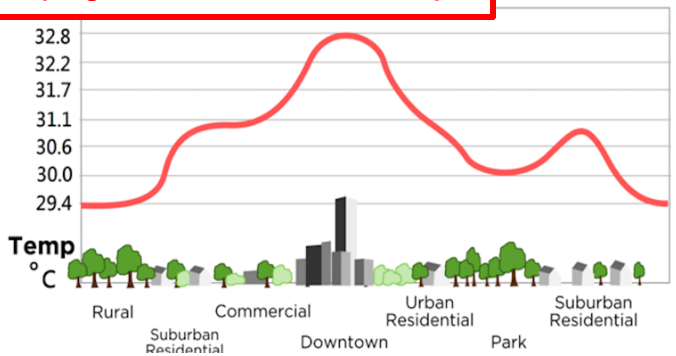
1) Lomonosov Moscow State University, Russia
2) A.M. Obukhov Institute of Atmospheric Physics, Moscow, Russia
3) Hydrometeorological Research Center of Russian Federation
4) RUDN University, Smart Urban Nature Laboratory, Moscow, Russia

*mvar91@gmail.com

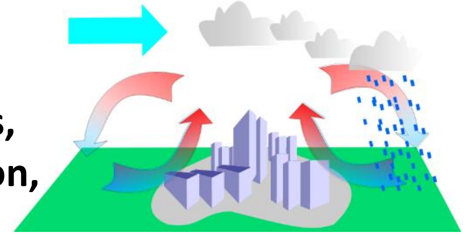
Lomonosov Moscow State University
RUDN university

Motivation: needs for urban weather observations

Urban climate features (e.g. urban heat island)



- **Mesoscale circulations, precipitation, air quality**



- **Outdoor thermal comfort**
- **Plants and ecosystem**

- **Energy demands for cooling/heating**

Urban meteorological observations

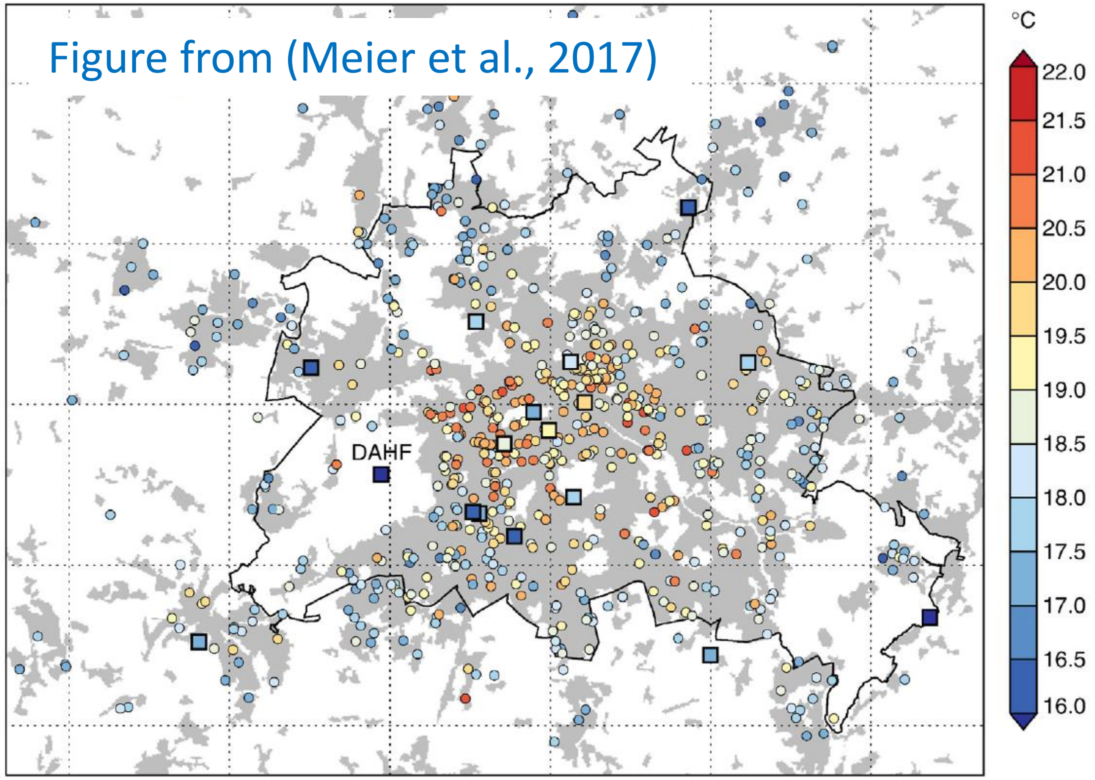
- **Fundamental and applied urban climate research**
  (Climate change trends, UHI climatology, etc.)
- **Monitoring applications, including heath stress warning**
- **Verification of models and remote sensing products**
- **Assimilations to numerical weather forecast models**

Urban meteorological networks exist only in a few cities

Among the big Russian cities, only 15% are covered by representative <u>urban</u> meteorological observations

Motivation: citizen weather stations (CWSs)

- ❑ **Crowdsourced CWS networks as part of "Internet of things" concept**
- ❑ **The world's biggest CWS network Netatmo (www.netatmo.com)**
- ❑ **Already used for urban climate studies** (e.g. Chapman et al., 2017; Fenner et al., 2017; Meier et al., 2017) **and in NWP** (Nippen et al., 2020)

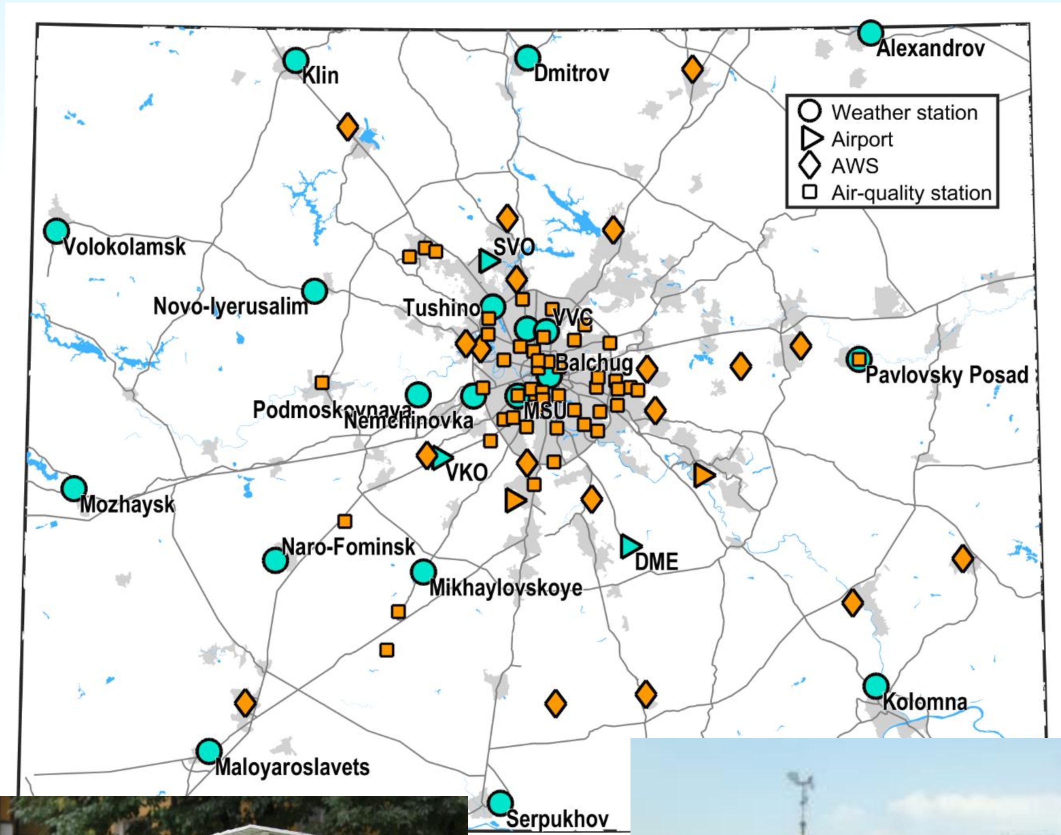


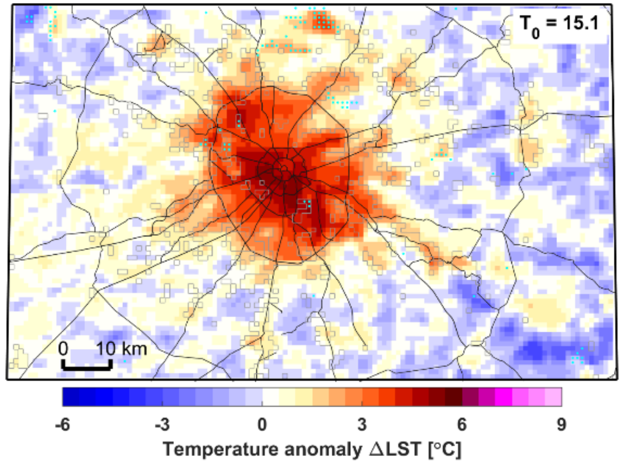
City	# CWS June 2018
Basel	940
Berlin	2100
Bern	650
Gothenburg	410
Hamburg	1190
Lisbon	150
London	830
Moscow	730
Paris	6380
Toulouse	720
Stuttgart	840
Atlanta	90
New York City	210
Phoenix	160
Santiago de Chile	130
Vancouver	150
Seoul	20

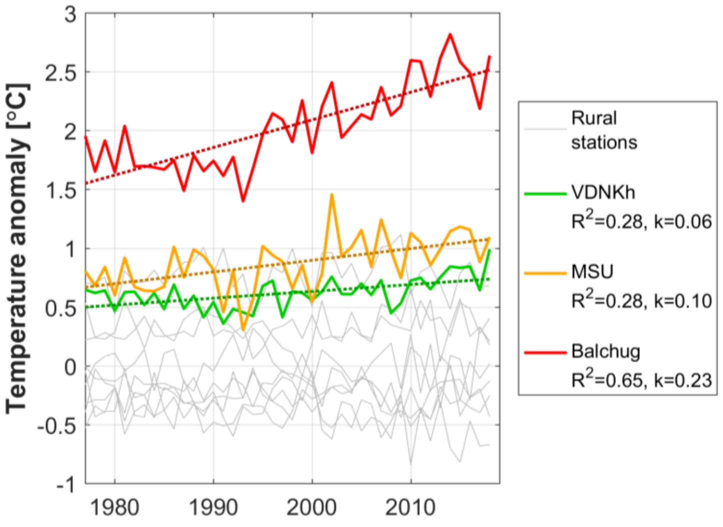
Data from (Meier et al., 2018)

Moscow as a test-bed for urban climate studies

- ✓ The biggest agglomeration in Europe (≈$17 \cdot 10^6$ people)
- ✓ Flat and homogenous surrounding landscape
- ✓ Dense official meteorological networks
- ✓ Intense UHI, already analyzed in many studies based on observations, remote sensing and modelling







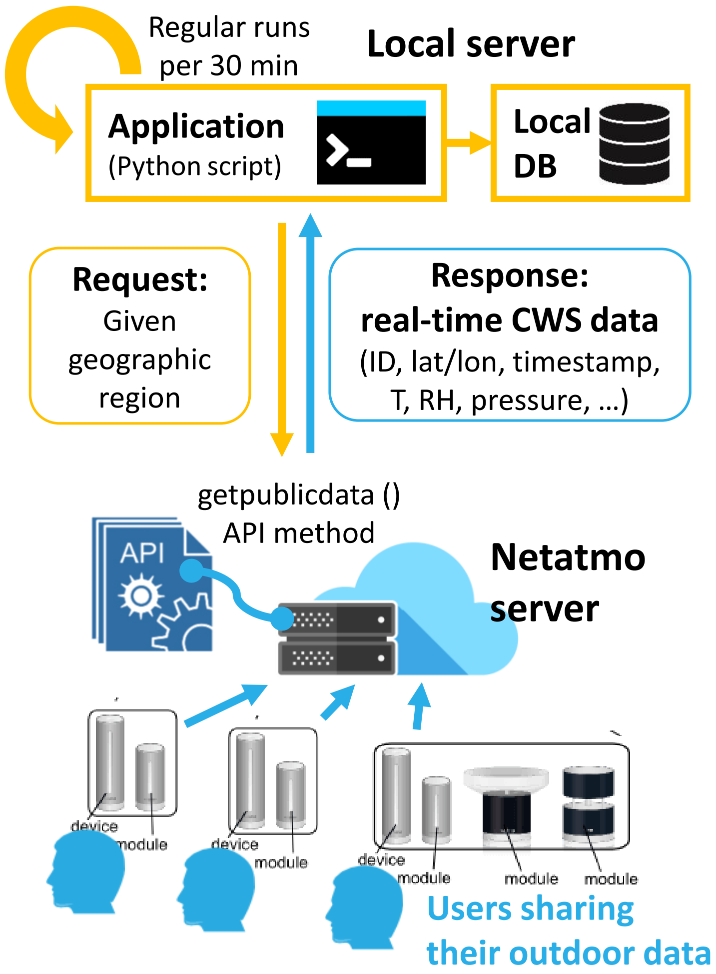
(Varentsov et al., 2019; 2020)

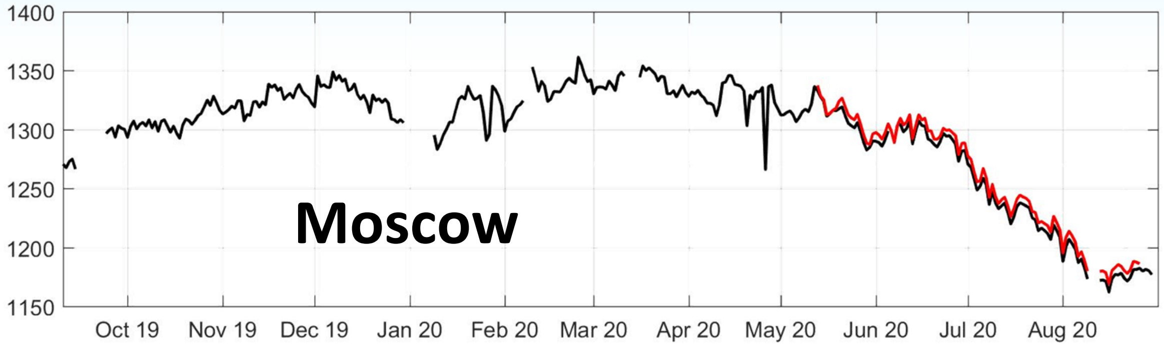
Balchug weather station
(city center, 500 m from Kremlin)

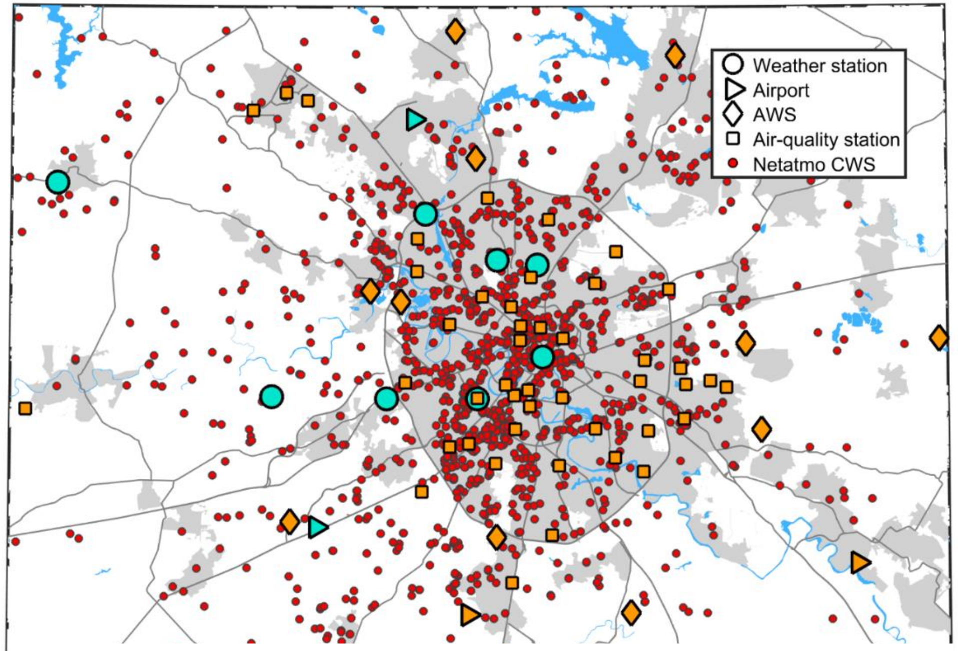
Mosecomonitoring air-quality stations

CWS data collection

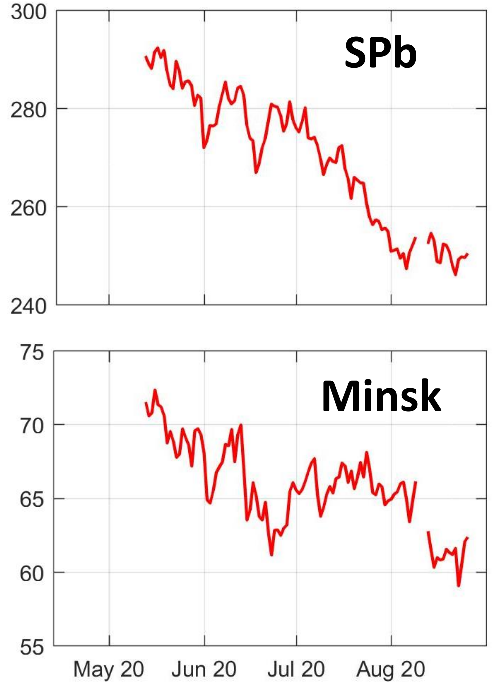
- Original software for automated data collection using Netatmo API is developed
- Running for Moscow region since September 2019 and for other selected cities since May 2020





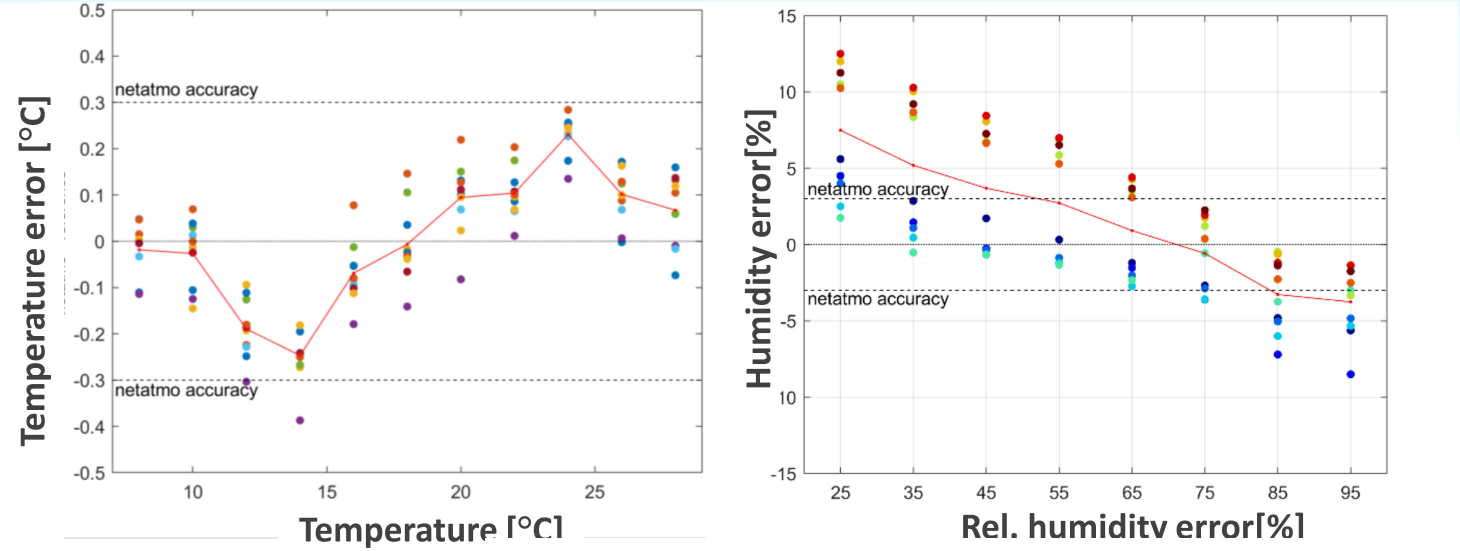


Almost 2000 unique CWS in Moscow region!

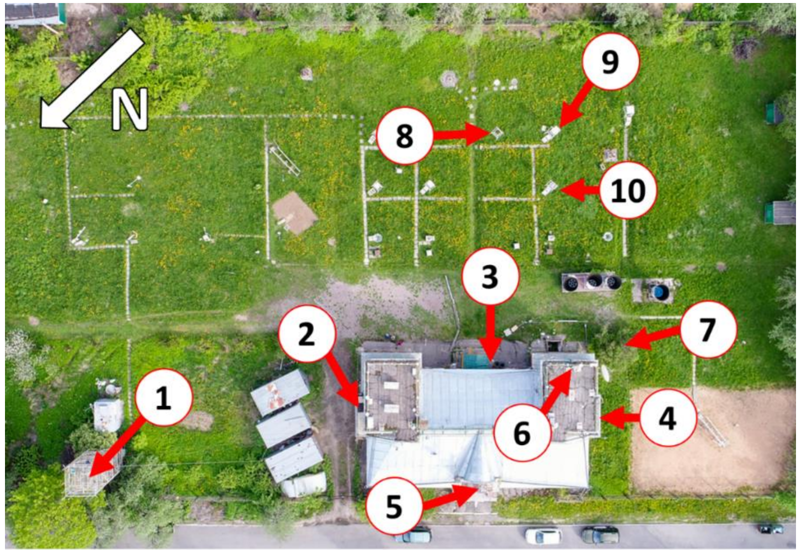


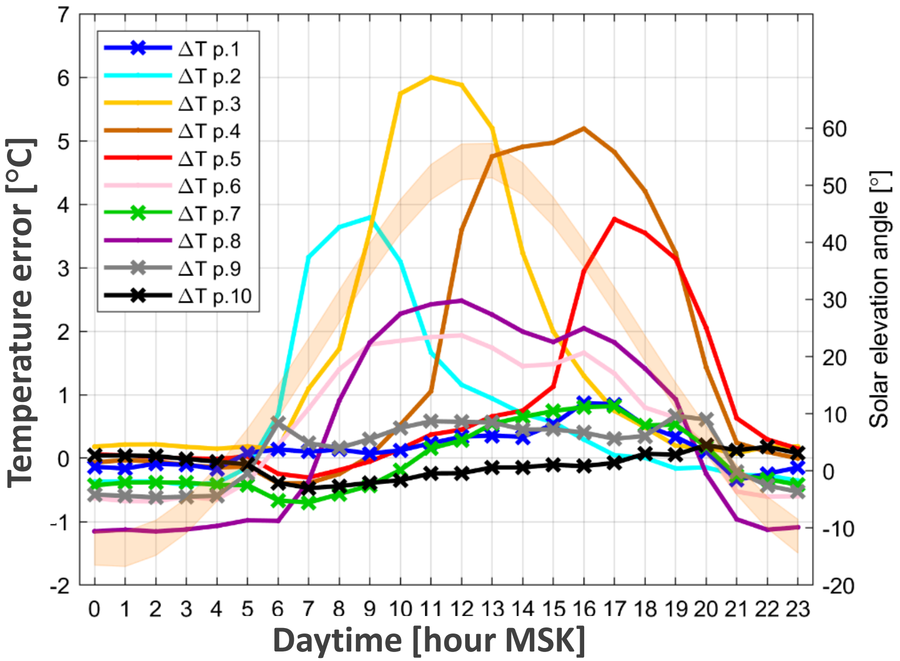
How good are Netatmo observations?

Stage 1: instrumental uncertainties



Stage 2: uncertainties, induced by the different typical ways of the CWS installation by the users





(Varentsov et al., 2020)

Quality control of CWS data

- Quality control (QC) is essential part of the work with CWS data
- QC algorithm for Moscow is based on the ideas from previous studies (Meier et al., 2017; Napoly et al., 2018), but involve more intensively the reference (official) data

L0: CWSs with same locations are removed

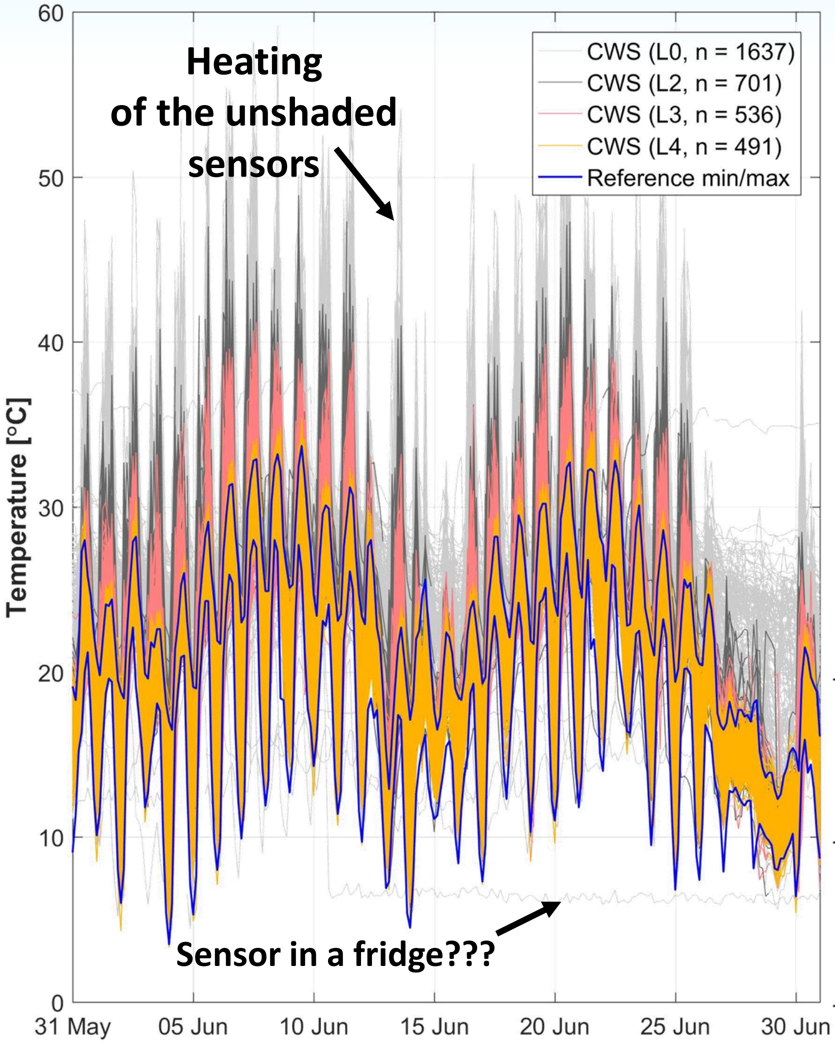
L1: CWSs with high ration of missing data are removed

L2: filtering based on temperature means and STDs for given intervals (14 days). Acceptable ranges are determined by the reference data set.

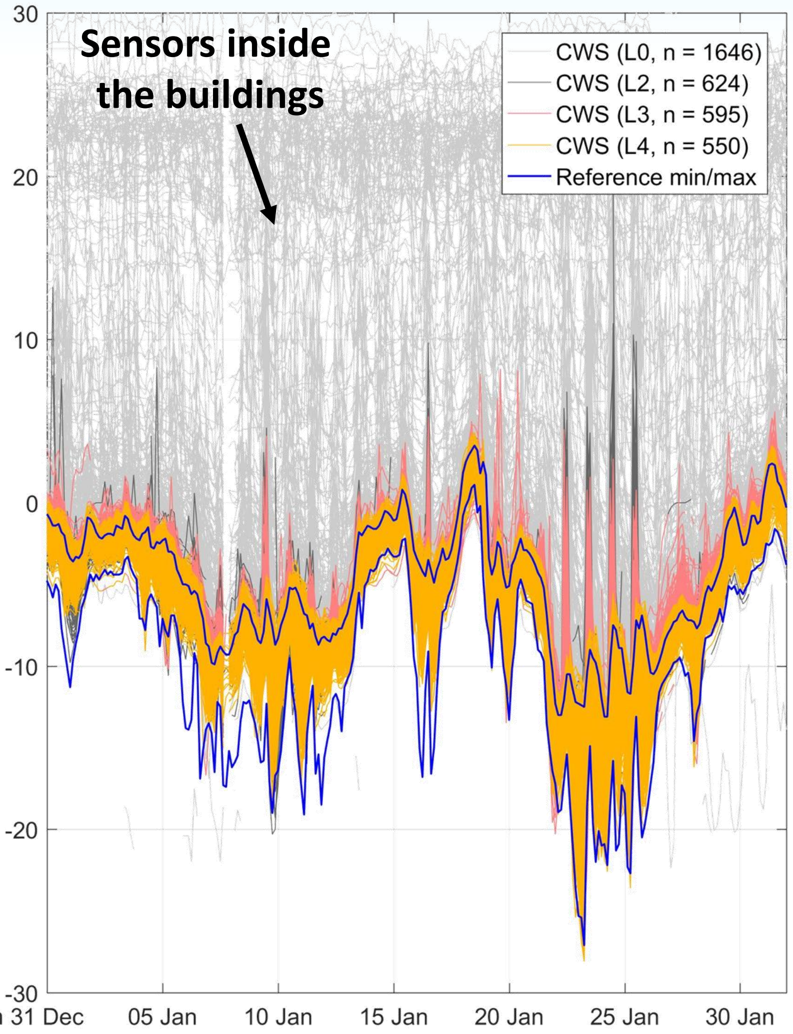
L3: filtering based on correlation between CWS and reference temperature time series STDs for given intervals (14 days).

L4: filtering of the data for specific moments based on the ranges of the reference data in Moscow city and surrounding (100 km)

May-June 2019

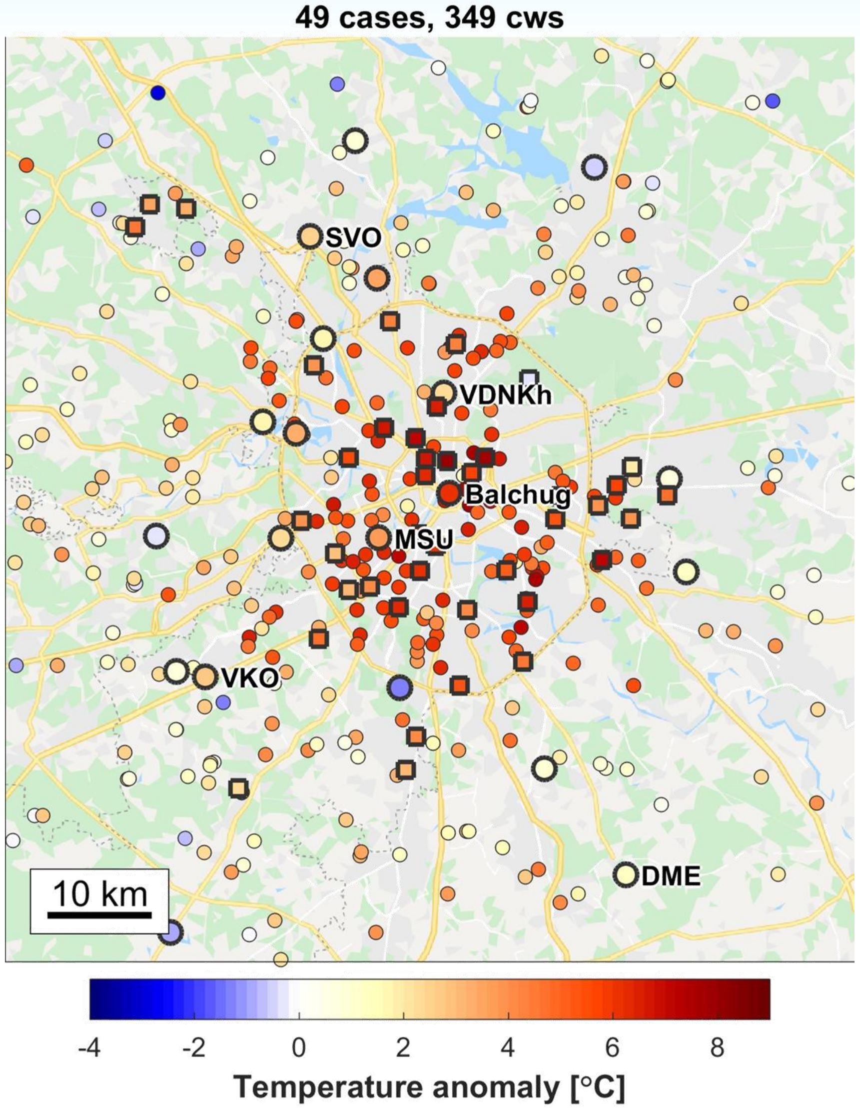


Dec 2018 – Jan 2019

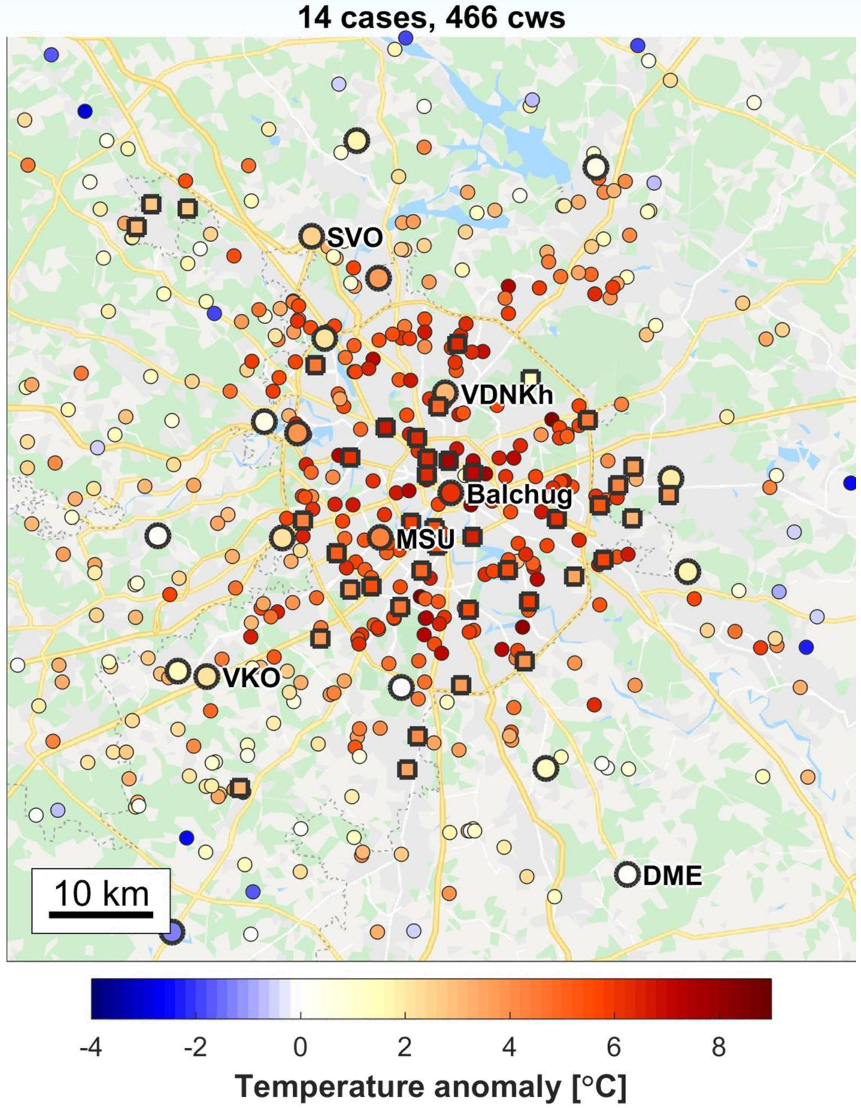


CWS data for urban climate research

Summer (May-June 2019)



Winter (Dec-Jan 2018/19)



Reference weather station

Reference air-quality station

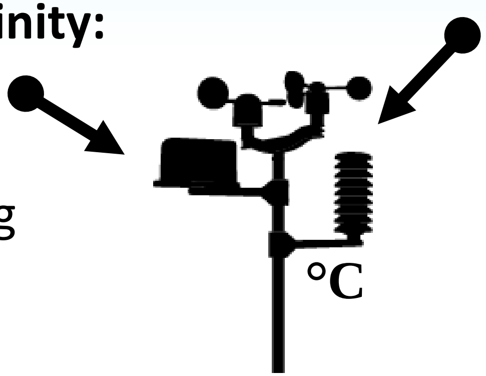
Netatmo CWS

UHI intensity: temperature anomaly with respect to the mean rural value, averaged over 9 stations around Moscow

These and all further results are shown for the selection of nocturnal cases when $UHI_{center} > 4°C$

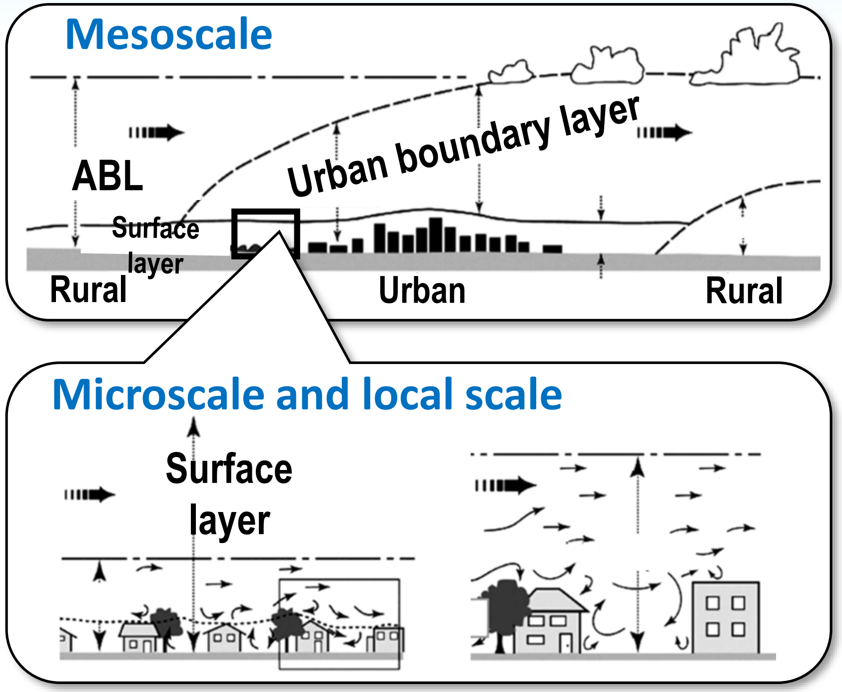
CWS data for urban climate research

Local-scale factors of the station's vicinity:
LCZ type,
Impervious area fraction, building density, etc.



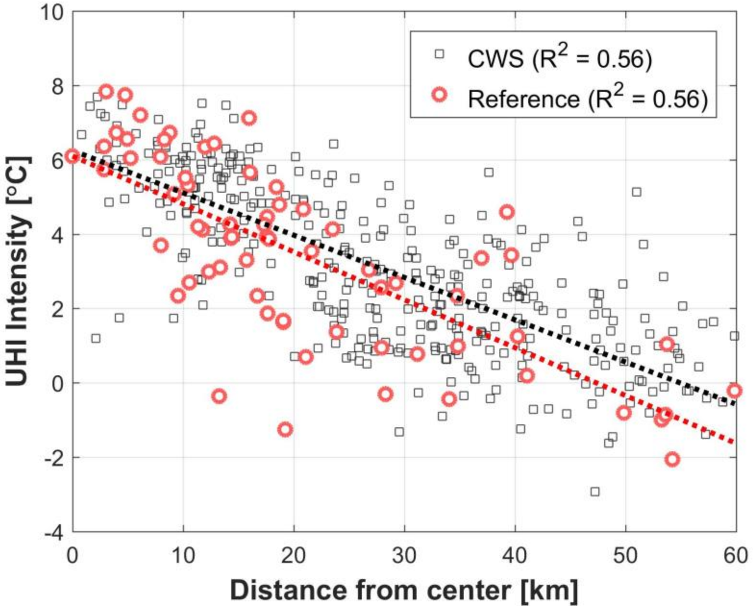
Non-local (mesoscale) factors:
Influence from the rest of the city.

Extreme simplification:
dependence from the distance from the city center (reasonable for Moscow)



Scales of urban-atmosphere interaction (Oke, 1987)

Summer (May-June 2019)



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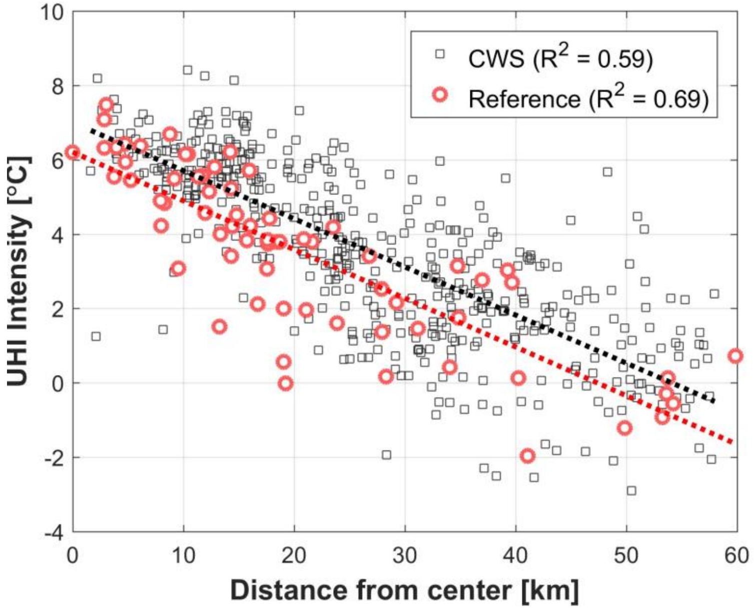
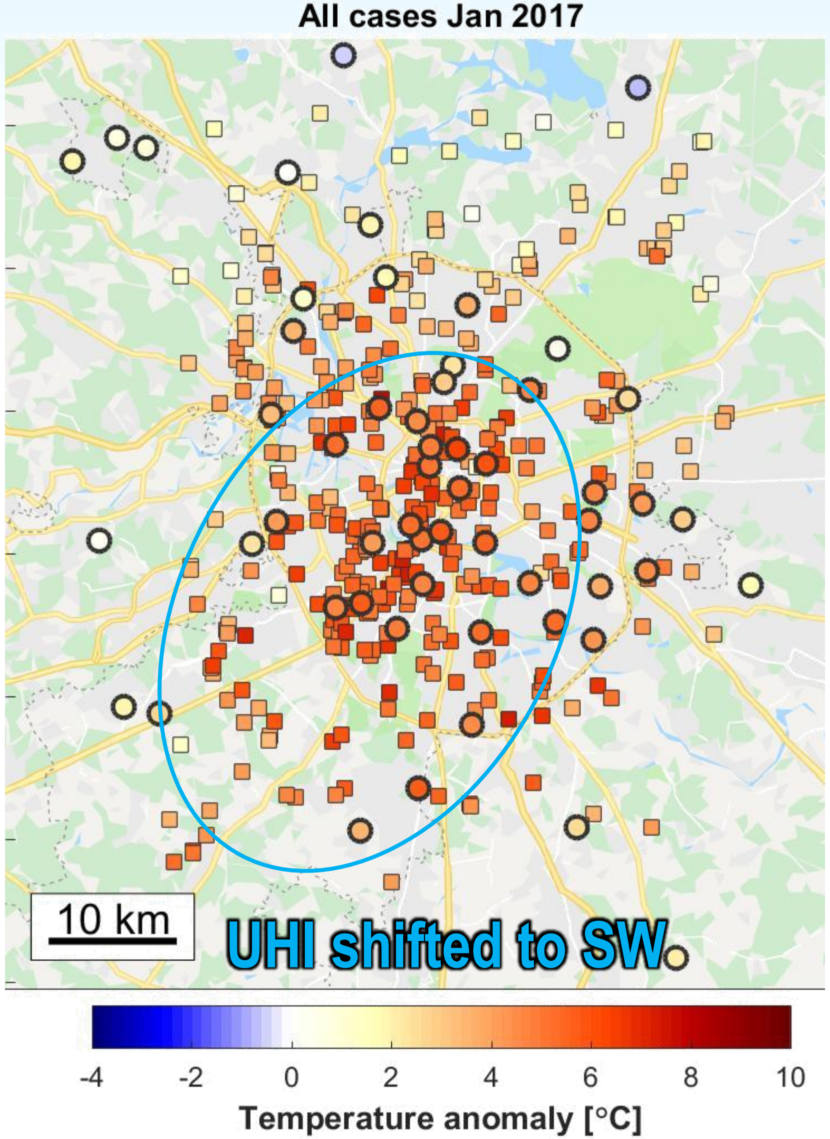
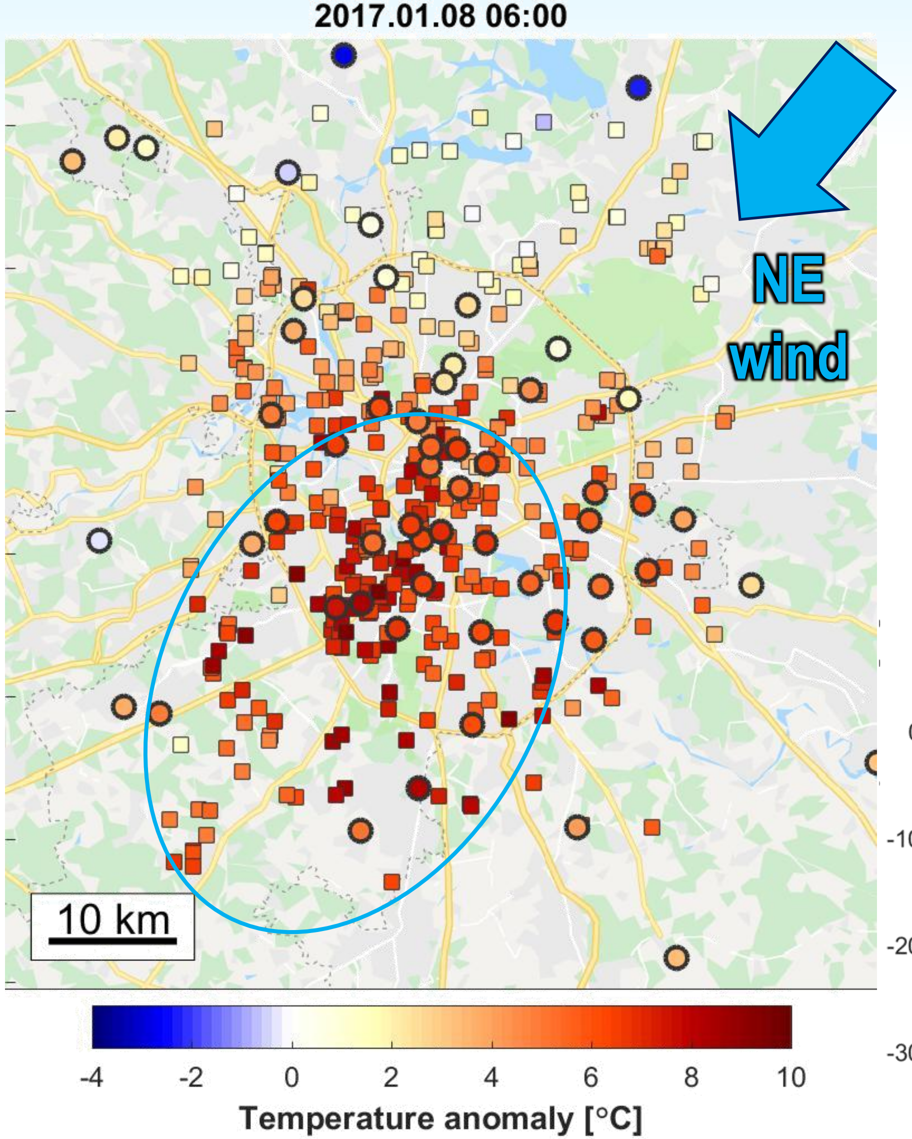


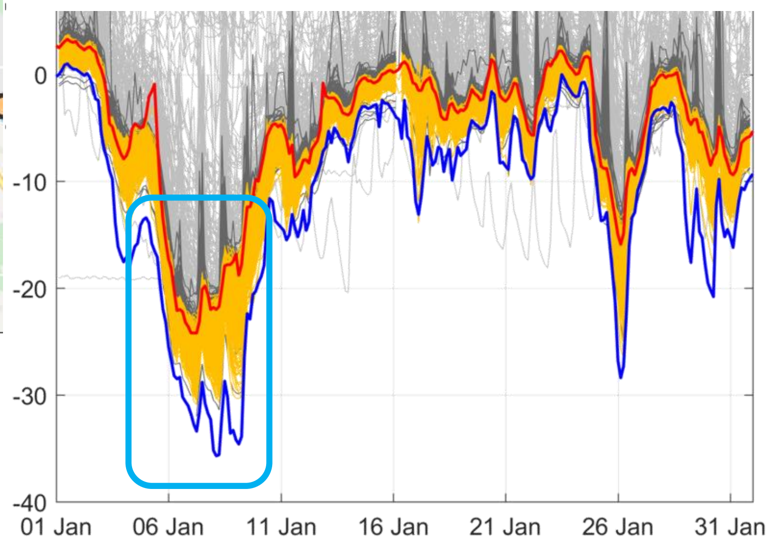
More detailed analysis is under development…

Spatial patterns of the winter UHI





7-9 Jan 2017 – one of the coldest periods in Moscow in XXI century (Yushkov et al., 2019)



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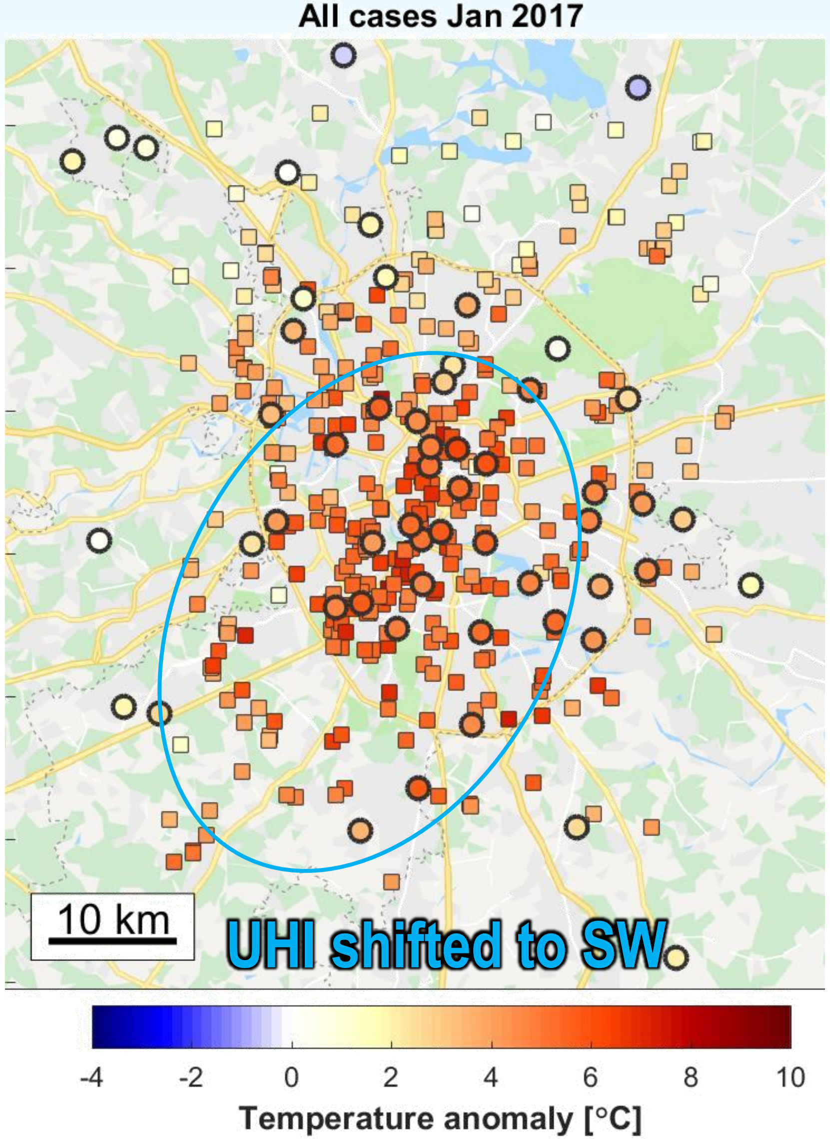

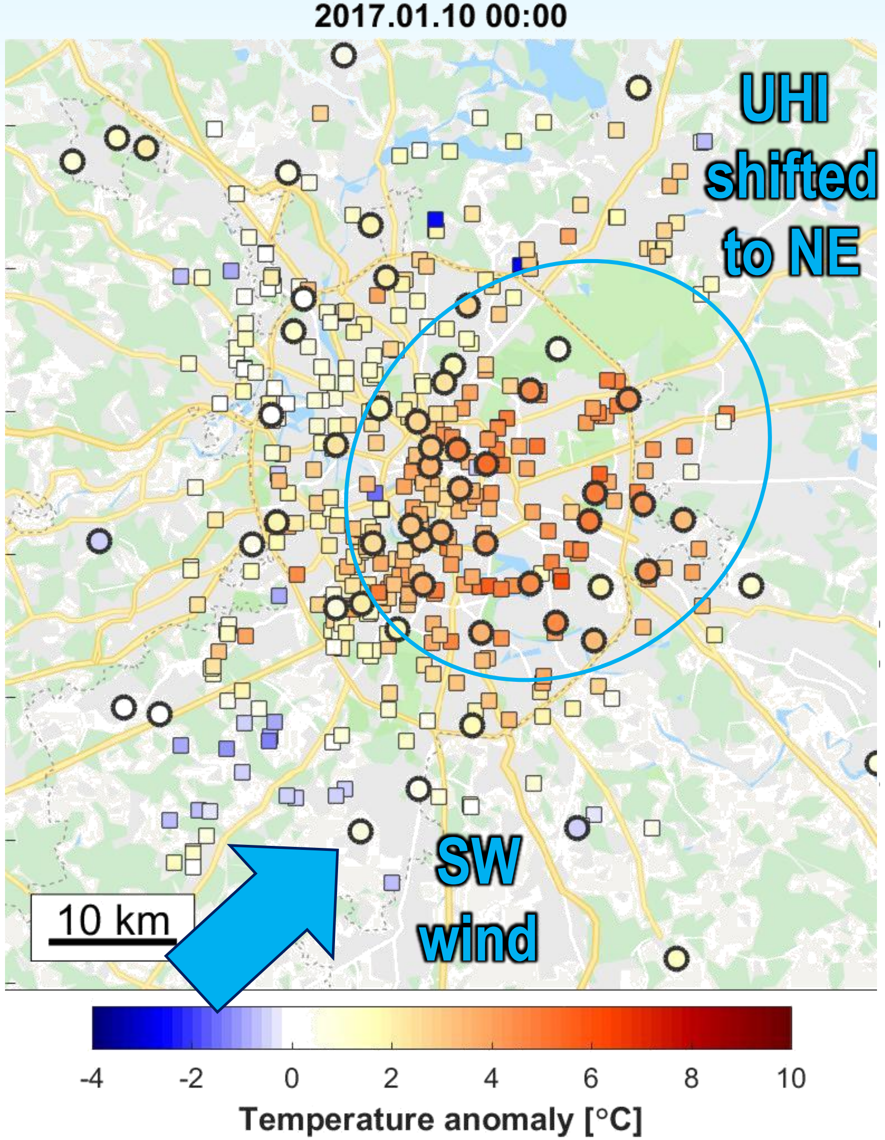

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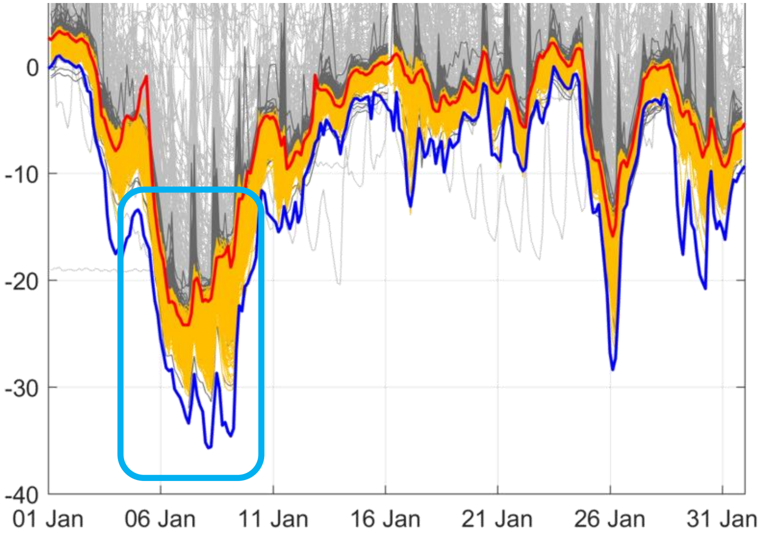


CWS data for real-time monitoring applications

The prototype of the near-real-time mapping web-application

CWS data download by Netatmo API requests

Parsing of the official Roshydromet data from **open-access source** (**www.pogodaiklimat.ru**)

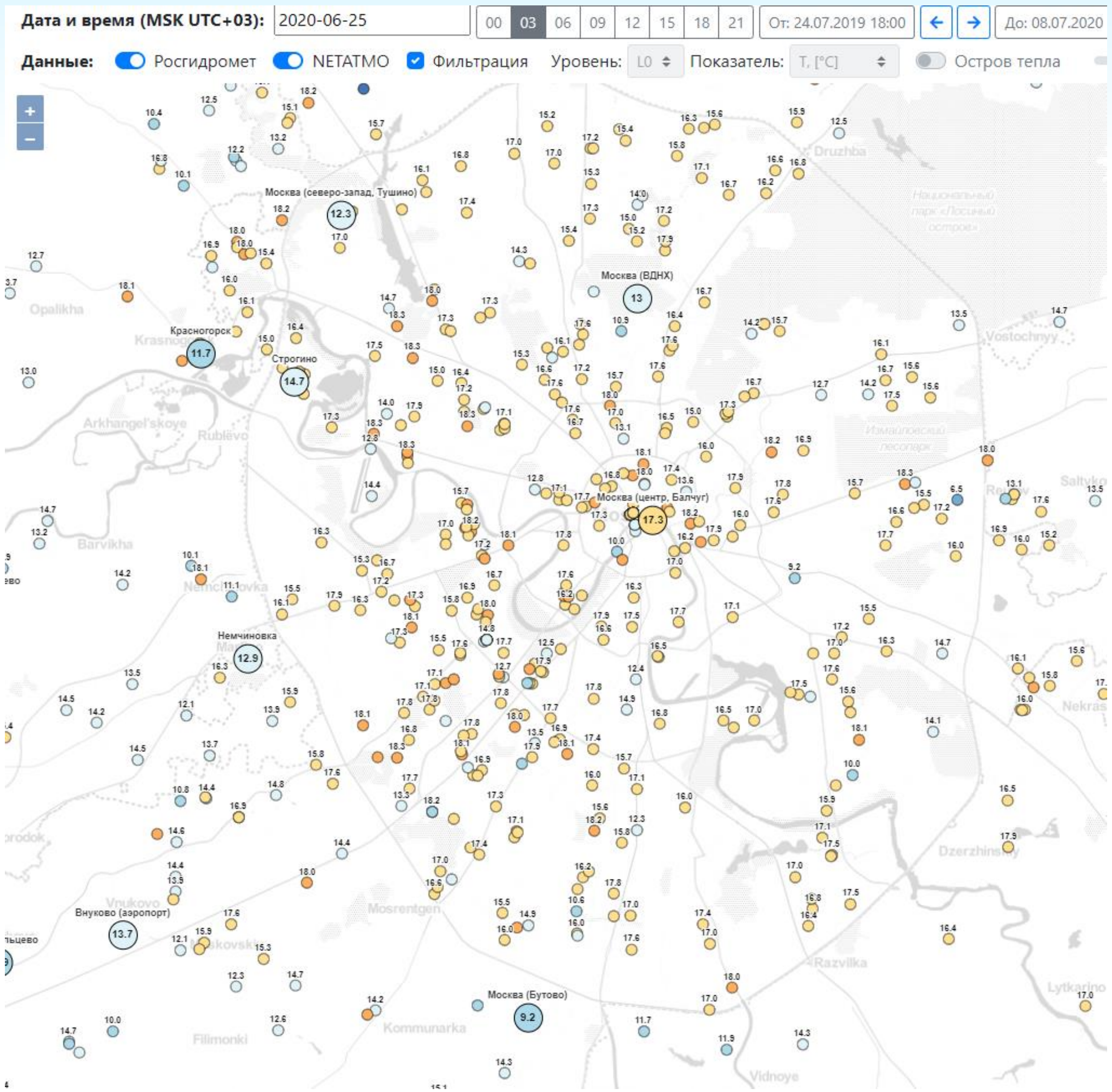
Database in PostgreSQL

Pre-processing, quality control (under development)

Spatial interpolation (planned)

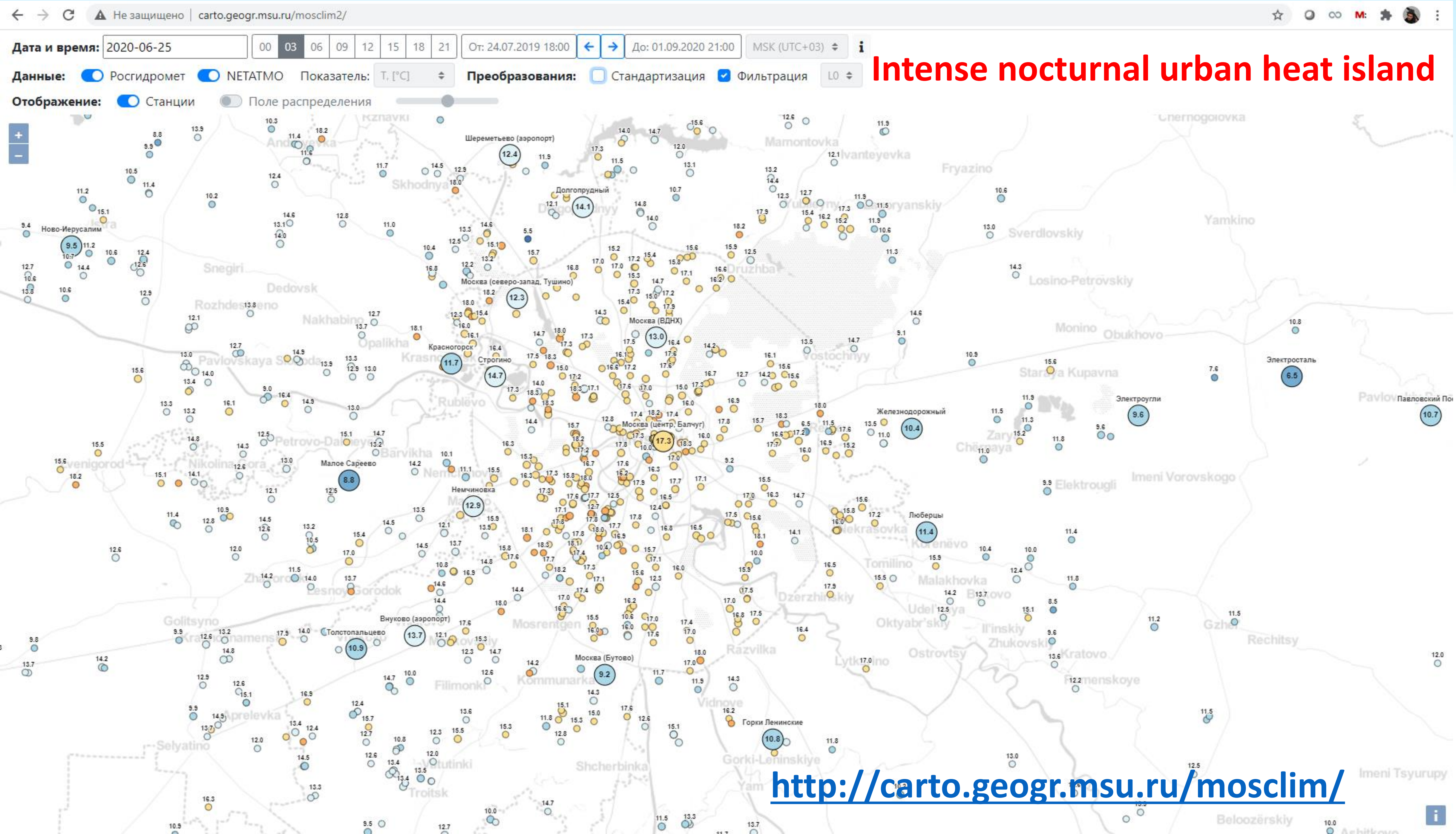
Real-time calculation of the thermal comfort indices (planned)

Visualization using Node.js & OpenLayers



http://carto.geogr.msu.ru/mosclim/

Intense nocturnal urban heat island



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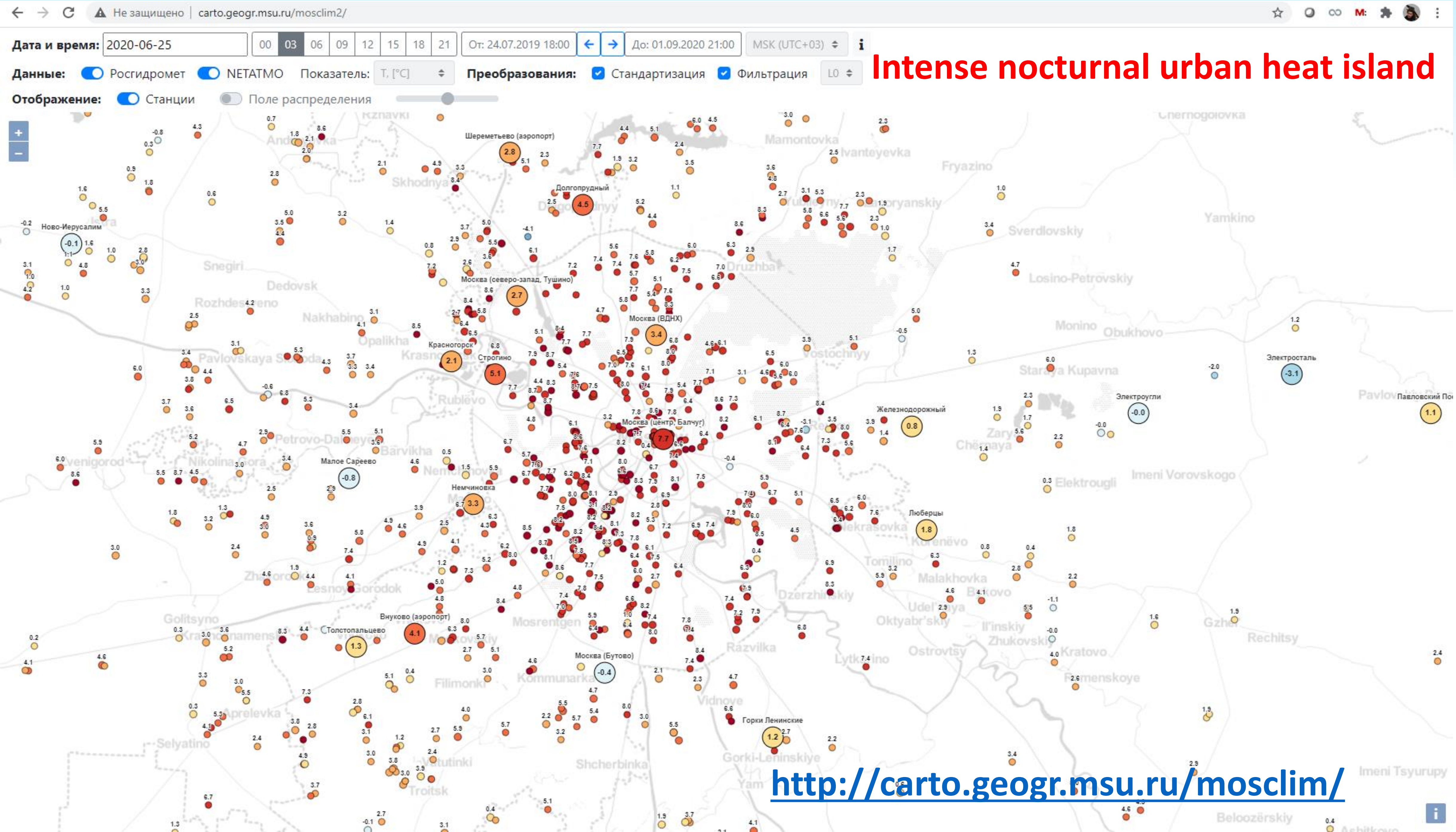

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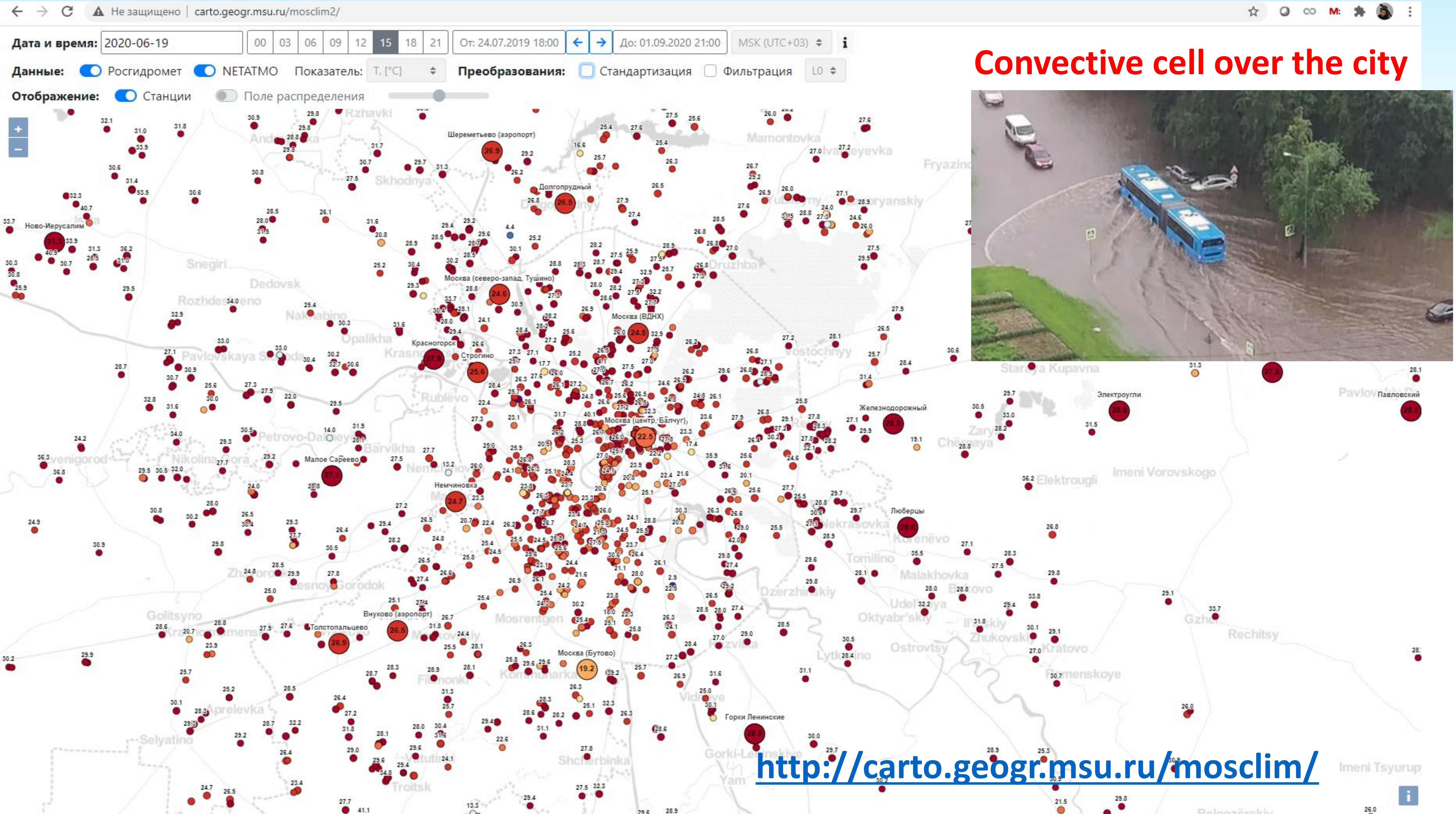
Convective cell over the city



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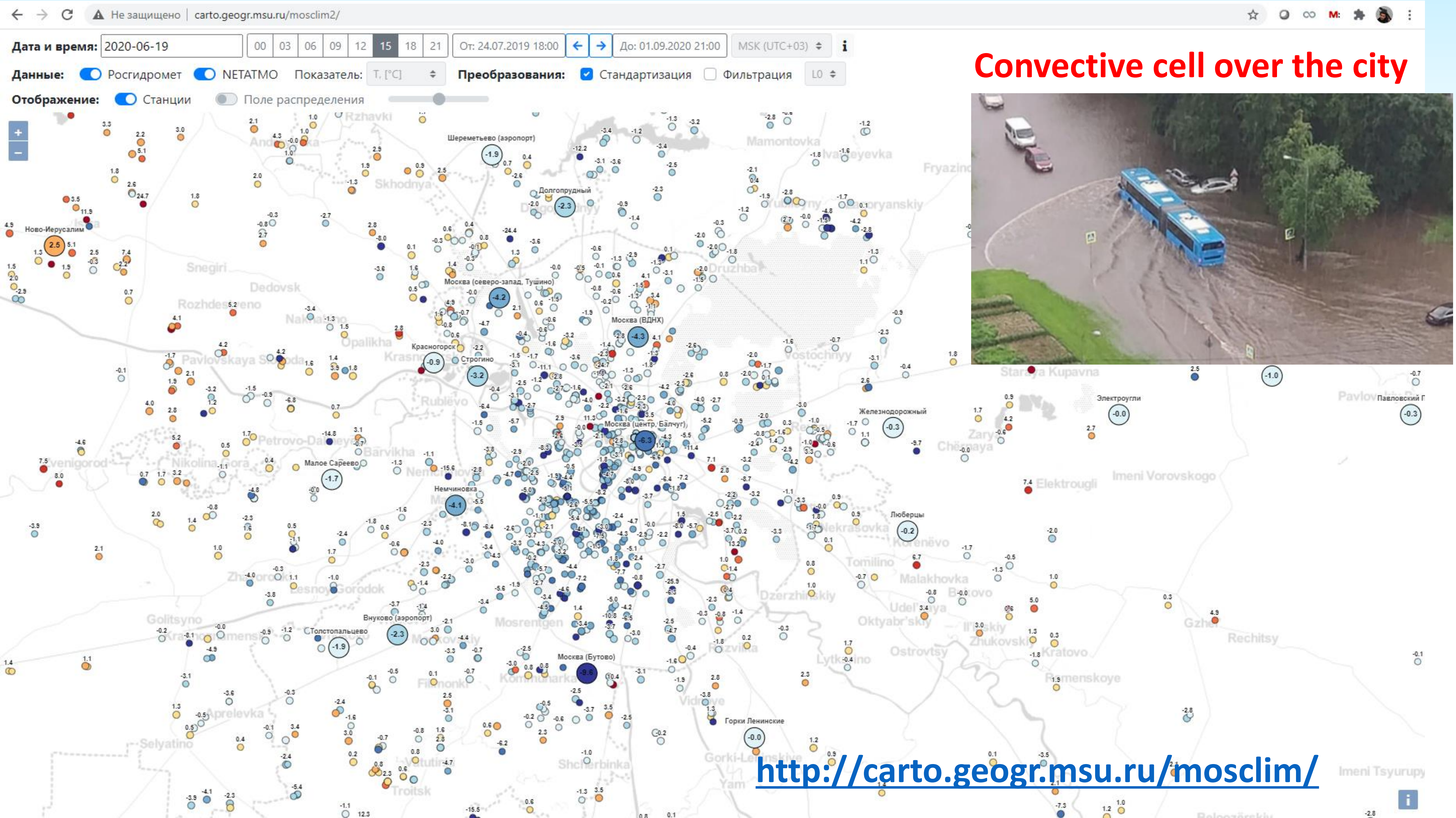
Convective cell over the city



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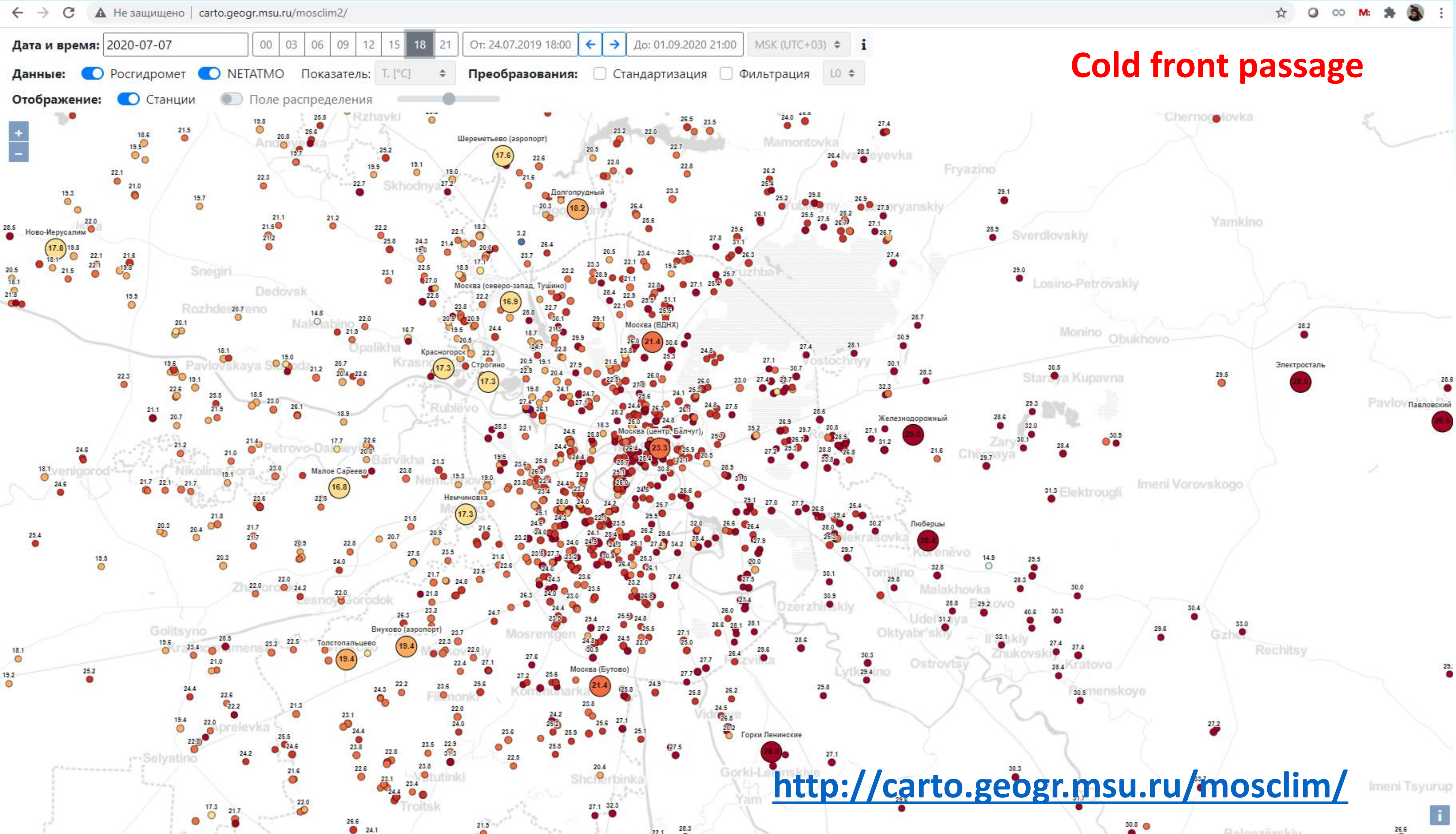
Cold front passage



http://carto.geogr.msu.ru/mosclim/

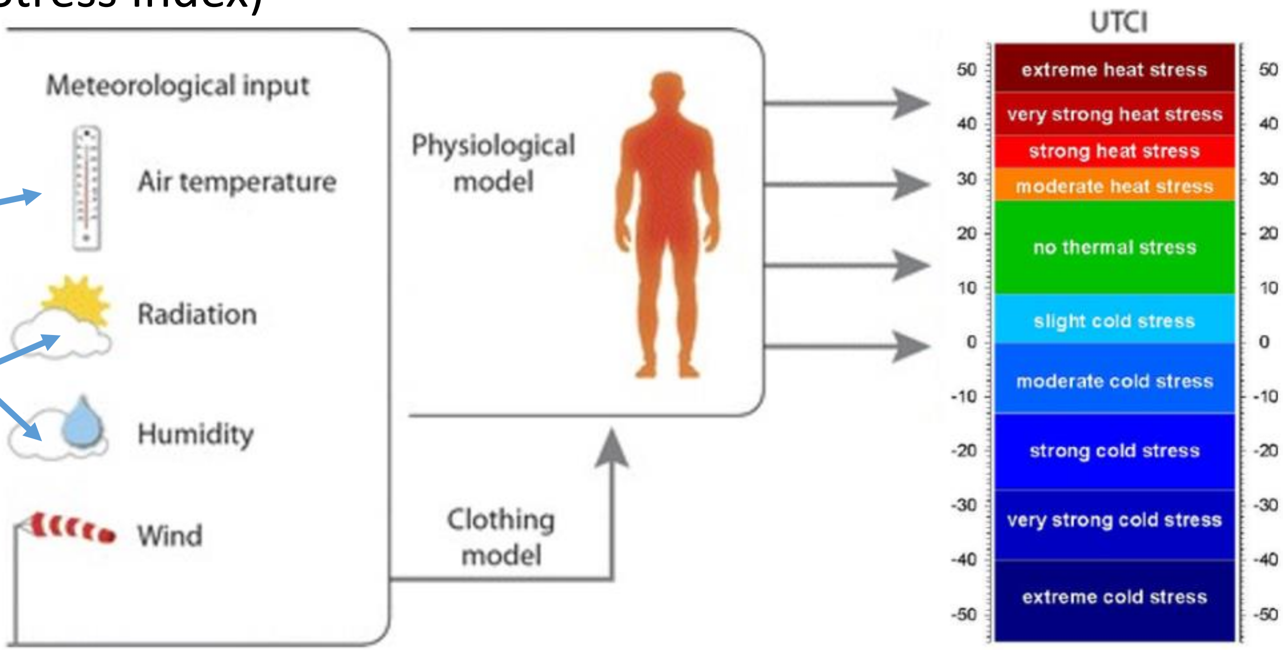
Towards real-time thermal comfort assessment

Modern biometeorological indices, based on environmental data and physiological models:

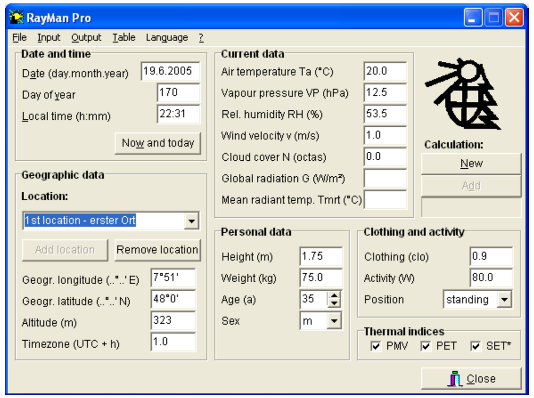
- PET (Physiologically-Equivalent temperature)
- UTCI (Universal Thermal Stress Index)

Interpolated fields based on CWS and official observations

Data from official weather stations



Near-real-time thermal comfort mapping at the intra-urban scale



The problem: convenient tool for calculating PET and UTCI is RayMan software (Matzarakis et al., 2010), which is not adopted for automated work.
Possible solutions: to use external software for automatization (Perkurova et al., 2019), to re-write the model or to use open-source tools (only possible for UTCI).

Conclusion

- ✓ The data of Netatmo CWSs could open a new era in the spatially-resolved urban climate studies.
- ✓ CWS data could be strongly biased, but QC algorithms allows to filter out the representative data
- ✓ Importance of the non-local effects for UHI spatial patterns is already shown with a use of CWS and reference data
- ✓ CWS data is prospective for real-time monitoring applications, with a focus on human thermal comfort as well as on dangerous atmospheric processes such as a deep convection

Preliminary results will be published soon: Varentsov M.I., Konstantinov P.I., Shartova N.V., Samsonov T. E., Kargashin P. E., Varentsov A.I., Fenner D., Meier F. ***Urban heat island of the Moscow megacity: the long-term trends and new approaches for monitoring and research based on crowdsourcing data*** // IOP Conference Series: Earth and Environmental Science. 2020. (accepted)

Thank you for attention?
Any questions, ideas or suggestions?

mvar91@gmail.com

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References

- **Chapman, L. et al (2017):** Can the crowdsourcing data paradigm take atmospheric science to a new level? A case study of the urban heat island of London quantified using Netatmo weather stations. Int. J. Climatol. 37 (9): 3597-3605.
- **Fenner, D. et al. (2017):** Intra and inter 'local climate zone' variability of air temperature as observed by crowdsourced citizen weather stations in Berlin, Germany. Meteorol. Z. 26 (5): 525-547.
- **Meier, F. et al (2017):** Crowdsourcing air temperature from citizen weather stations for urban climate research. Urban Clim. 19: 170-191.
- **Matzarakis A. et al. (2010).** Modelling radiation fluxes in simple and complex environments: Basics of the RayMan model. International Journal of Biometeorology, 54(2), 131–139.
- **Nipen T. N. et al. (2019):** Adopting Citizen Observations in Operational Weather Prediction. BAMS, 101(1), E43–E57.
- **Napoly, A. et al. (2019):** Development and application of a statistically-based quality control for crowdsourced air temperature data. Front. Earth Sci. 6:118.
- **Oke T. R. (1987).** Boundary layer climates (2nd ed.). Routledge.
- **Perkhurova A. A. et al. (2019). Real-time microscale modeling of thermal comfort conditions in Moscow region. IOP Conference Series: Earth and Environmental Science, 386, 12046.**
- **Varentsov M. et al. (2019):** Simultaneous assessment of the summer urban heat island in Moscow megacity based on in situ observations, thermal satellite images and mesoscale modeling // Geogr. Environ. Sustain, 12 (4), 74–95.
- **Yushkov V. et al. (2019):** Modeling an Urban Heat Island during Extreme Frost in Moscow in January 2017. Izvestiya, Atmospheric and Oceanic Physics, 55 (5), 389–406.