# Technology of creating a long-term data archive of meteorological and radiation fields with high spatial and temporal resolution for the Moscow region

**Platonov V.S.[1], Konstantinov P.I.[1], Varentsov M.I.[1], Samsonov T.Ye.[2], Chubarova N.Ye.[1], Zhdanova E.Yu.[1]**

vplatonov86@gmail.com

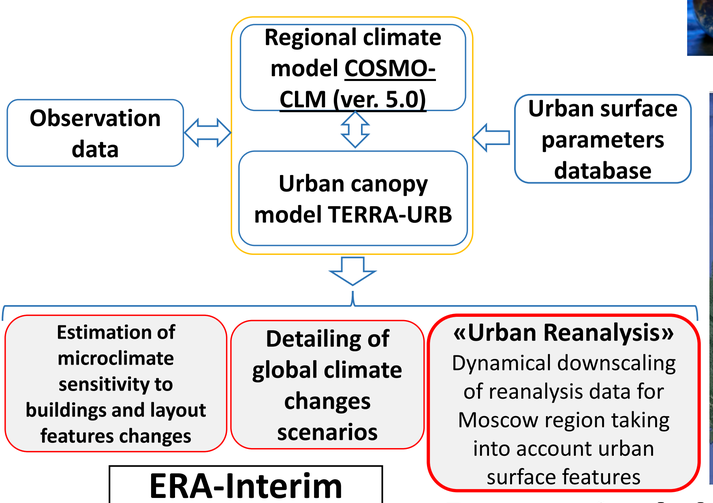
[1]Lomonosov Moscow State University, Faculty of Geography, Department of Meteorology and Climatology
[2]Lomonosov Moscow State University, Faculty of Geography, Department of Cartography and Geoinformatics

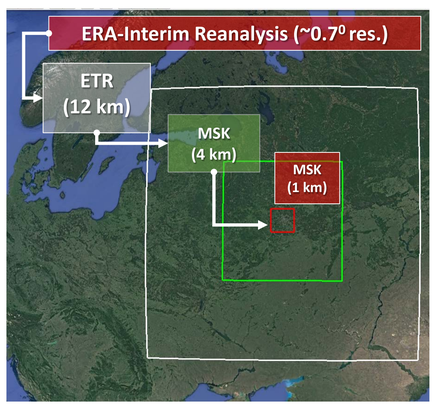
## Motivation/background

Large cities and **urban territories** has apparently strong influence on many aspects of meso- and microscale weather and climate patterns, biometeorological and human health conditions, radiation effects. An investigation of **urban climate and boundary layer features** is one of the most important modern challenges for microclimatology. Developing of the supercomputer technologies and non-hydrostatic physical weather and climate models is allowing now to simulate a wide range of microclimate features during a **long-term period**, such as decades, with **high spatial and temporal resolution**, up to few kilometers and hours, respectively. The reliable high-resolution modeling of atmospheric circulation and other boundary layer processes over the **complex urban terrain** including buildings, roads, parks, industrial facilities, etc. requires an appropriate detailed information about **spatial distribution and geometric properties** of these objects.

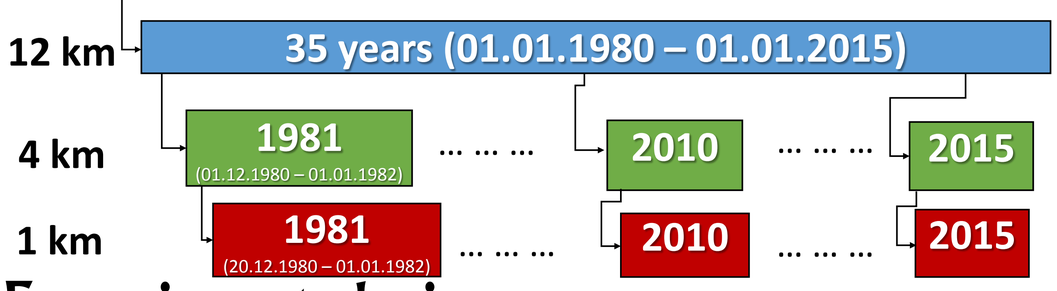
In this work, we have used the non-hydrostatic regional climate model **COSMO-CLM 5.0 version** as a tool for simulation of the climate conditions and radiation characteristics of Moscow city megalopolis and adjacent suburban areas during the period of **1981 – 2015** with the highest horizontal resolution of ~1 km and created the '**urban reanalysis**'.

## Technology description




### Dynamical downscaling scheme




## Urban canopy model and necessary parameters of urban surface

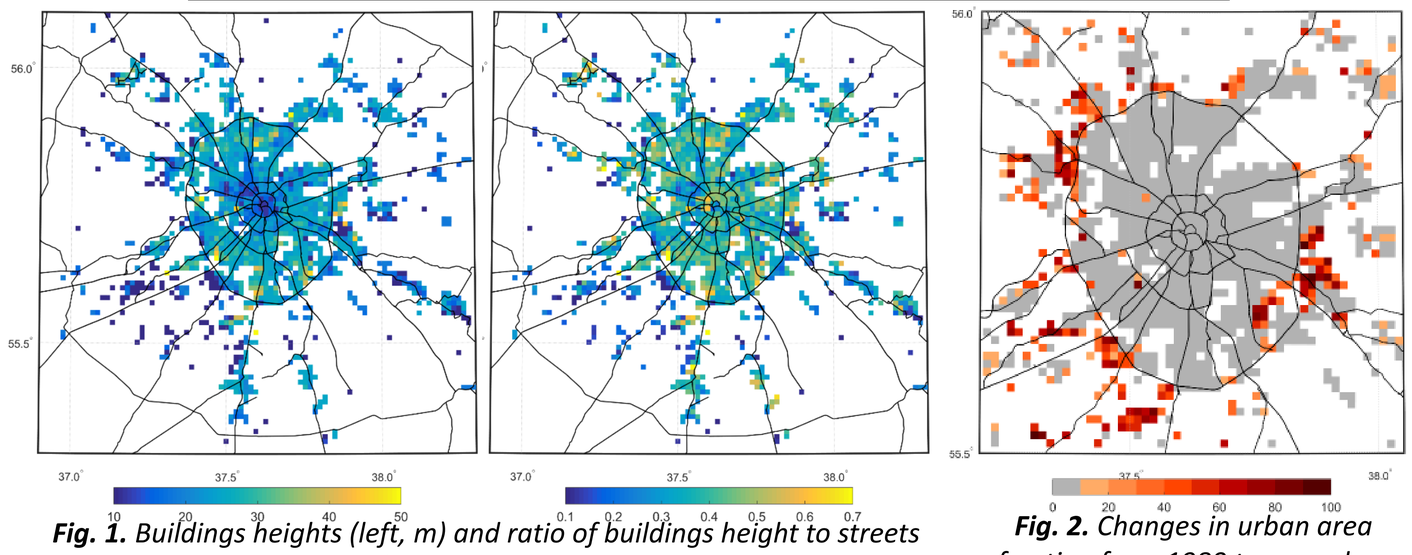



***Fig. 1.*** *Buildings heights (left, m) and ratio of buildings height to streets width (right, H/W) in cells area. Cell size 500 m.*

***Fig. 2.*** *Changes in urban area fraction from 1980 to nowadays*

Original technique (**Samsonov et al., 2015**) was applied to take into account morphometric parameters of city buildings based on the **OpenStreetMap** data (more than **40 parameters** total), including:

- ***urban area fraction;***
- ***buildings height (see Fig. 1) and density;***
- ***ratio of buildings height to street width (see Fig. 1),*** *etc.*

*Changes of these parameters was estimated for the* ***whole period (35 years)*** *according to given technique and used as input external parameters within the* ***MSK 1 km*** *domain simulations (see* ***Fig. 2****).*

### TERRA-URB scheme

- Correction of the surface thermophysical properties (albedo, emissivity etc.) taking into account buildings features;
- Anthropogenic heat flux is calculated for each cell based on the annual mean "climate" value taking into account typical annual, weekly and diurnal courses (**Flanner, 2009**);
- Semi-empirical urban canopy parameterization (SURY) (**Wouters et al., 2016**)

## Experiment design

**Downscaling technique.**

- Initial and boundary conditions for experiment over the **13,2 km domain** came from ERA-Interim reanalysis (every 6 hours) and from the global external parameters database (EXTPAR, provided by CLM-Community) for the **1980 – 2015 period**.
- Continuous runs has been executed for the whole period over the base domain to adapt properties of soil model TERRA to the long-term simulations.
- The **'spectral nudging'** technique was applied in order to get consistence between real and model atmospheric dynamics.
- Output fields **from 12 km** domain are initial and boundary conditions for 4 **km** domain during the whole 35-year period. Simulations started from 1. December of each year for 13 months.
- The same technique was applied for **1 km domain. TERRA-URB scheme** was implemented to take into account buildings and anthropogenic heat flux features and its influence on urban heat island and microclimatic regime.

| Characteristics of experiments | 12 km ETR domain | 4 km MSK domain | 1 km MSK domain |
|---|---|---|---|
| Total points over domain | 140*140 = **19600** | 180*180 = **32400** | 160*160 = **25600** |
| Horizontal resolution, degrees (~km) | 0.108⁰ (~12 km) | 0.036⁰ (~4 km) | 0.009⁰ (~1 km) |
| Time step (seconds) | 120 | 40 | 15 |
| Number of model levels in atmosphere | 40 | 40 | 50 |
| Number of model soil layers | 9 | 9 | 9 |
| Initial and boundary conditions | ERA-Interim (~0.75⁰) | COSMO-CLM 12 km | COSMO-CLM 4 km |

## Dataset summary

**Output files** created for **192 parameters** during the period **1981 – 2015**, including:

- 31 **3D grid parameters** (T, U, V, TKE, total radiation, UV radiation, …);
- Soil temperature and moisture at **11 soil levels** (up to 11 meters depth);
- **Separate values** of the main surface and soil variables for **urban and natural tiles** (***T_2M_1, T_2M_2***);
- Output area – **140x140 grid** (after relaxation zone cut-off), spatial resolution **1 km**, temporal resolution - **1 hour;**
- **50 vertical levels;**
- Total output volume: **38 Tb** for the whole domain, **26 Tb** after relaxation zone cut-off;
- Total CPU time spent: ≈ **760 000 CPU hours**

## Estimation of urban opacity and UV-resources

We have developed method for estimation urban opacity factor for **UV radiation** (see **Fig. 3**). The spatial distribution of noon UV indices with 1 km resolution was estimated for the central months of the seasons over the territory of Moscow for its different urban development in **1981** and **2012** years. UV transmittance was obtained using the empirical relationship between sky view factor (SVF) and UV irradiance measurements. The urban canopy can significantly influence on the UV level in the urban area of Moscow megalopolis. In average, urban canopy effect in **UV indices** over the Moscow area reach **70%**, **90%**, **90%** and **83%** in January, April, July and October, respectively.

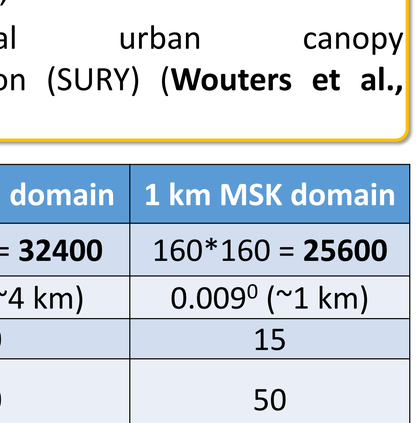



***Fig. 3.*** *Opacity factor distribution in Moscow, 2012, 5 m resolution*

## Conclusion and perspectives

The long-term **'urban reanalysis'** of meteorological and radiation fields was created for **Moscow region** using the high-resolution atmospheric modelling, **OpenStreetMap** dataset and modern urban canopy parameterization. The obtained dataset will continue to be used for a full and comprehensive analysis of the reproduction quality of hydrometeorological fields over urban areas, their statistical estimates, climatological trends and many other objectives. This dataset is a very important challenge for future investigations of detailed physical processes in the **urban boundary layer**, **biometeorological indices**, and could be used as driving conditions for LES and RANS modelling.

## References


- **Flanner M. G.** Integrating anthropogenic heat flux with global climate models //Geophysical Research Letters. – 2009. – Т. 36. – №. 2.
- **Konstantinov P. I. et al.** Developing of the database of meteorological and radiation fields for Moscow region (urban reanalysis) for 1981-2014 period with high spatial and temporal resolution. Strategy and first results. // Geophysical Research Abstracts. Vol. 19 EGU General Assembly 2017.
- **Konstantinov P.I., Samsonov T.E., Zhdanova E.Y., Chubarova N.Y.** Shading areas, sky-view factor and UV radiation in urban canopy of Moscow city. AIP Conference Proceedings. // Vol. 1810 of Radiation processes in the atmosphere and ocean (IRS2016): Proceedings of the International Radiation Symposium (IRC/IAMAS). American Institute of Physics New York, United States, 2017
- **Samsonov T. E., Konstantinov P. I., Varentsov M. I.** Object-oriented approach to urban canyon analysis and its applications in meteorological modeling. Urban Climate, 13, 122-139 (2015)
- **Wouters H., Demuzere M., Blahak U., Fortuniak K., Maiheu B., Camps J., Tielemans D. and van Lipzig N.P.M.** The efficient urban canopy dependency parametrization (SURY) v1.0 for atmospheric modelling: Description and application with the COSMO-CLM model for a Belgian summer. // Geosci. Model Dev., 9, 3027–3054, 2016