Real-time modeling of dangerous wind speed gusts and thermal comfort conditions in campus of Moscow State University (Moscow, Russian Federation)

Pavel Konstantinov[1,2], Anastasia Perkhurova[1] , Elizaveta Nikolaeva[1] , Sergey Bukin [2] , and Mikhail Varentsov[2,3,4]

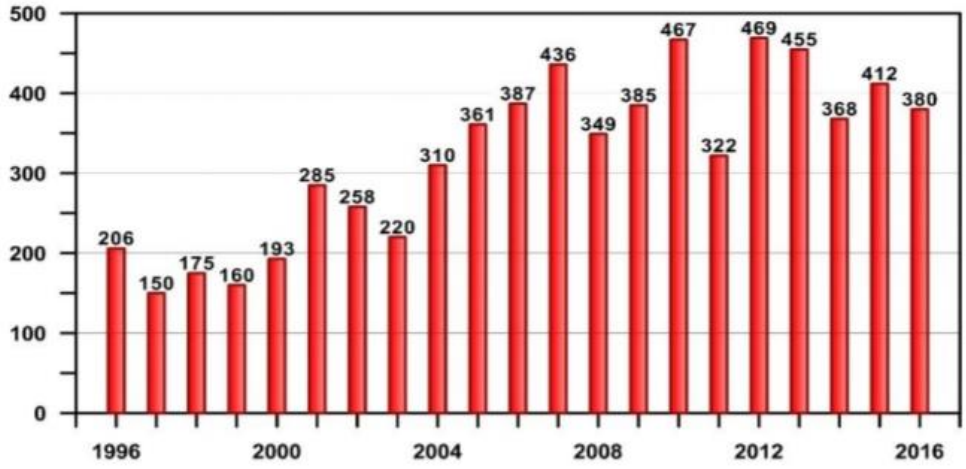
[1] Lomonosov Moscow State University, Faculty of Geography, Meteorology and climatology, Moscow, Russian Federation (kostadini@mail.ru)

[2] RUDN University, Laboratory of smart technologies for sustainable development of urban environment under global changes , Moscow, Russian Federation

[3] Lomonosov Moscow State University, Research Computing Center Moscow, Russian Federation

[4] A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, Russian Federation

Motivation of study



Dangerous weather events in Russian Federation since 1996 (annual)

(National report of Climate Risks..., 2017)

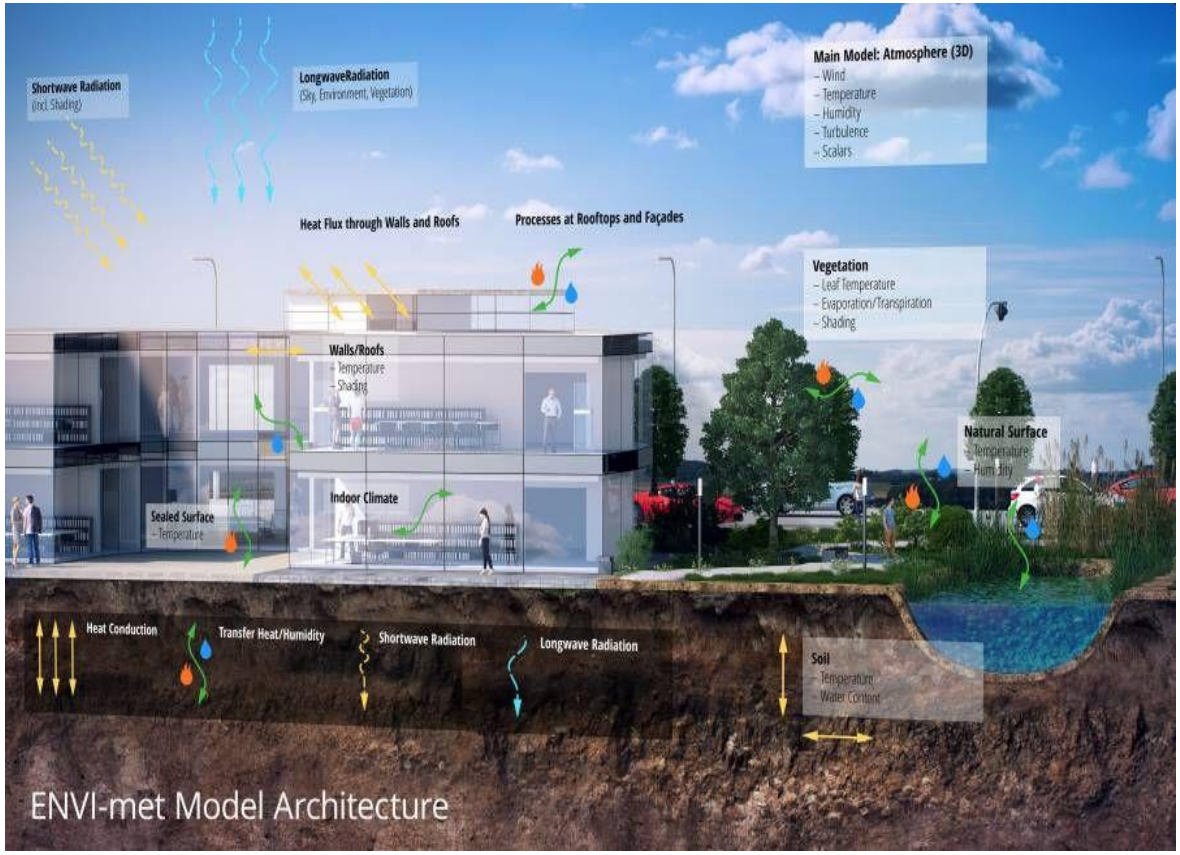
Main goal of study

Development of Real-time algorithm for wind-gusts and thermal comfort prediction in small city district

Tasks:

- Adaptation of **ENVI-met** model to MSU campus area
- Test of stability results for wind gusts modeling (according to initial wind direction)
- Realization of real-time algorithm for thermal comfort evaluation in prediction MSU campus area
- Выявление «**опасных зон»** на исследуемой территории

ENVI-met microscale model



ENVI-met is a three-dimensional non-hydrostatic microclimate model and is able to calculate and simulate climate in urban areas with a typical grid resolution of 0.5 to 10 meters in space and 10 seconds in time. It calculates the dynamics of microclimate during a diurnal cycle using fundamental laws of fluid dynamics and thermo dynamics. Main prognostic variables of the program are wind speed and direction, air temperature and humidity, turbulence, radiative fluxes, bioclimatology and gas and particle dispersion.

Basic equations (3D- Navier–Stokes)

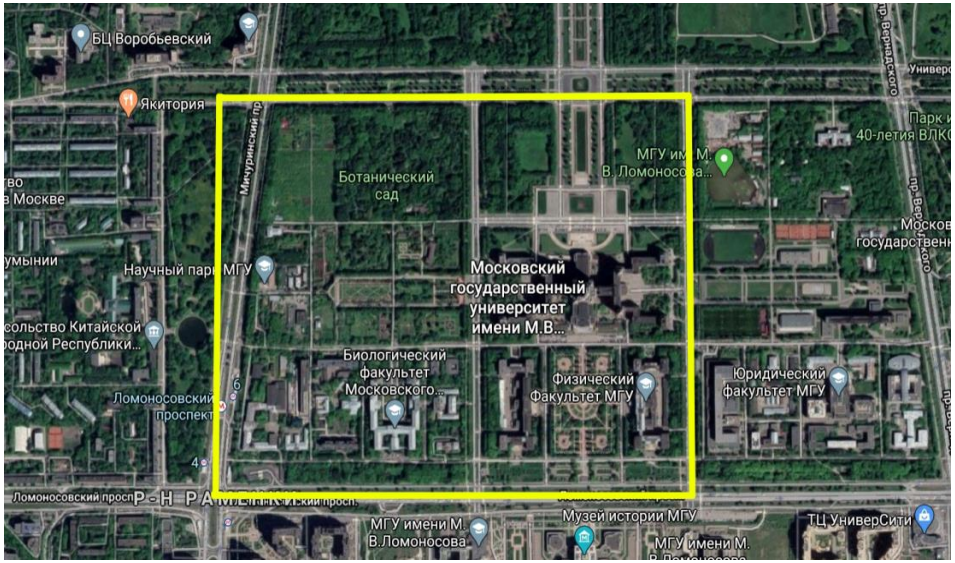
$$\frac{\partial u}{\partial t} + u_i \frac{\partial u}{\partial x_i} = -\frac{\partial p'}{\partial x} + K_m \left(\frac{\partial^2 u}{\partial x_i^2}\right) + f(v - v_g) - S_u$$

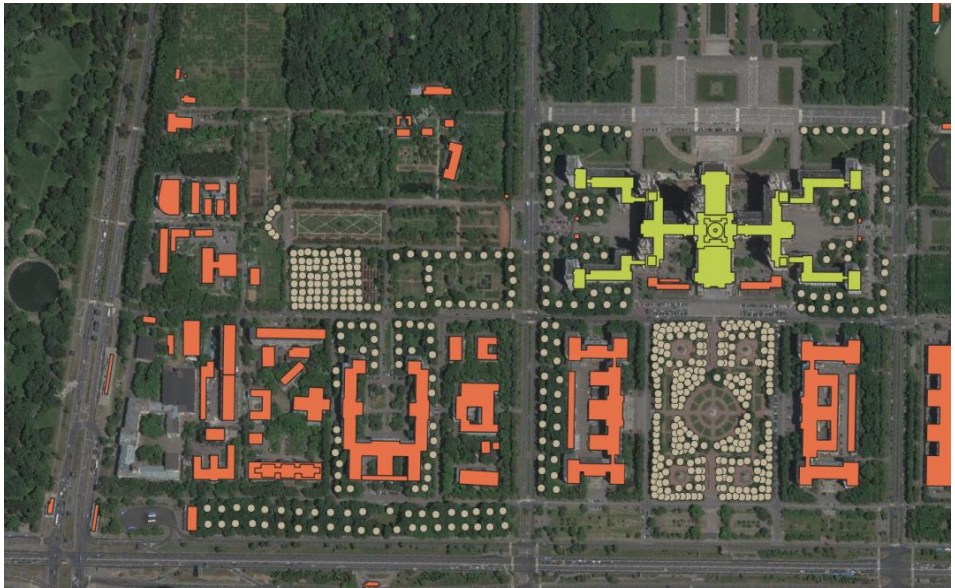
$$\frac{\partial v}{\partial t} + u_i \frac{\partial v}{\partial x_i} = -\frac{\partial p'}{\partial y} + K_m \left(\frac{\partial^2 v}{\partial x_i^2}\right) + f(u - u_g) - S_v$$

$$\frac{\partial w}{\partial t} + u_i \frac{\partial w}{\partial x_i} = -\frac{\partial p'}{\partial z} + K_m \left(\frac{\partial^2 w}{\partial x_i^2}\right) + g\frac{\theta(z)}{\theta_r e f(z)} - S_w$$

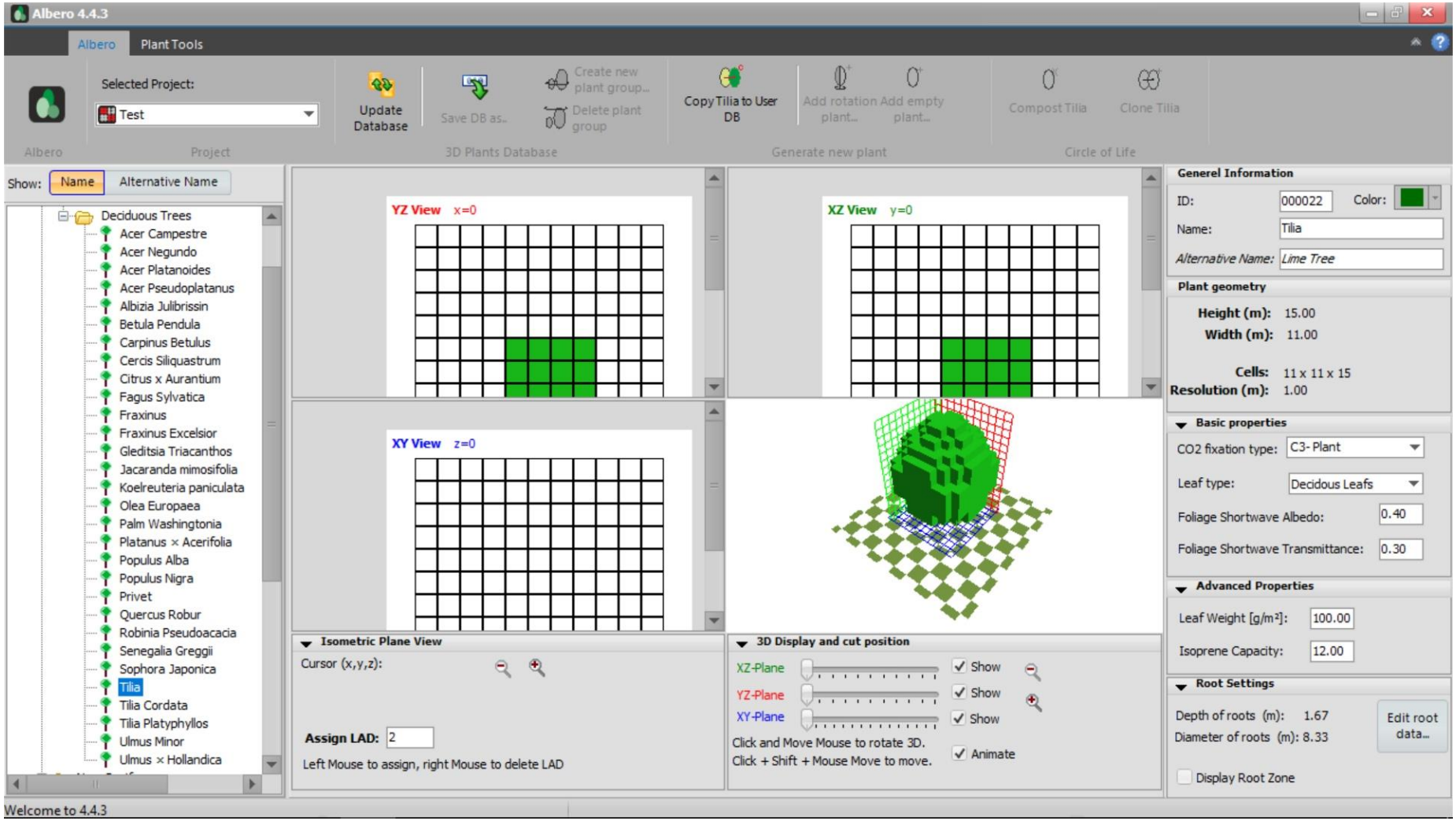
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

MSU-campus district

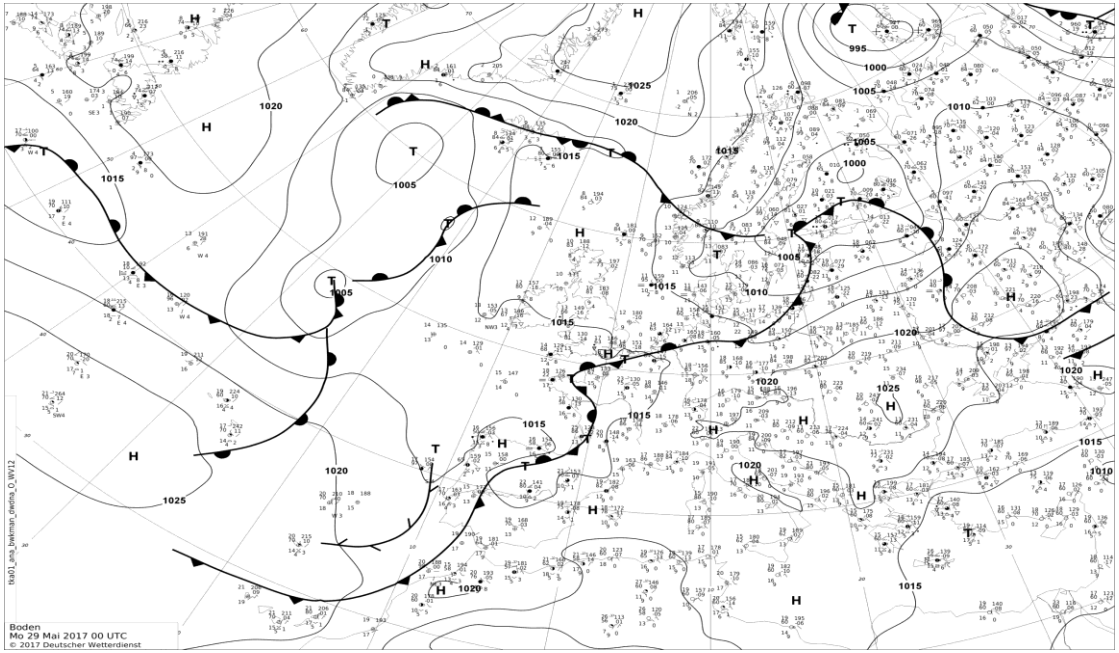




Adding trees

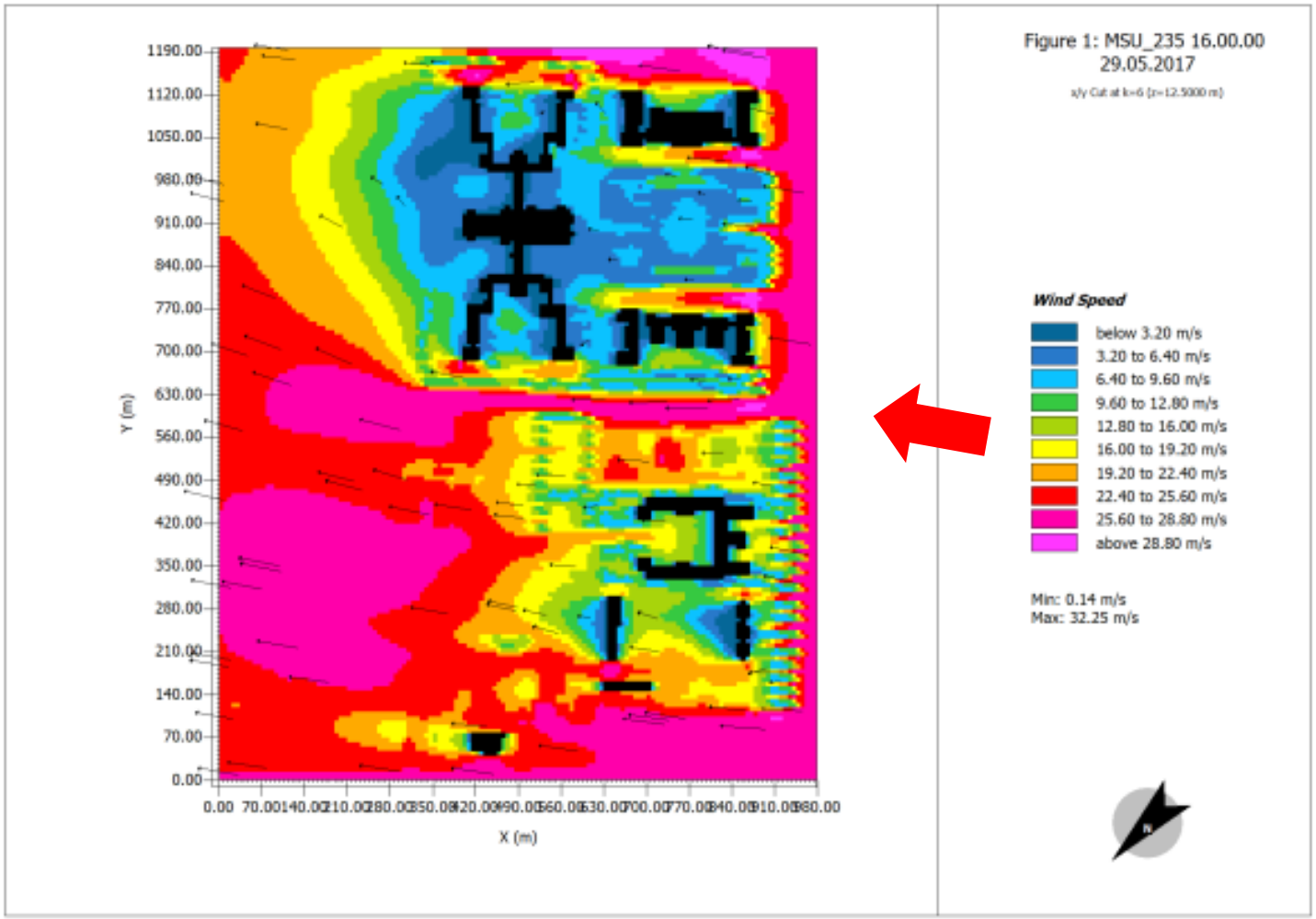


Squall in Moscow May 29 in 2017

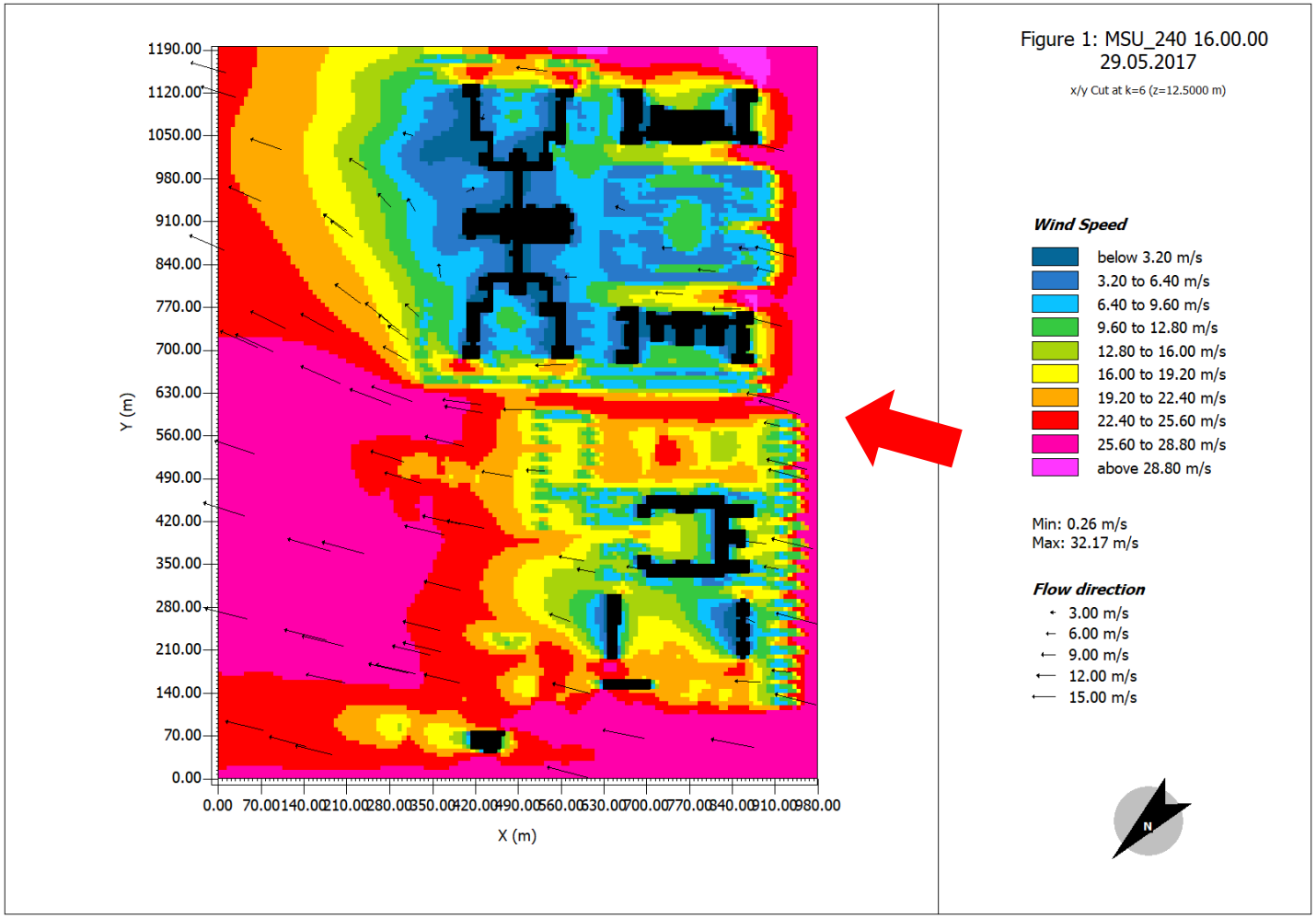


Wind gusts:
15.38 - 19,4 м/с
15.39 - 27,9 м/с
15.40 - 28,3 м/с

Initial wind direction: 235



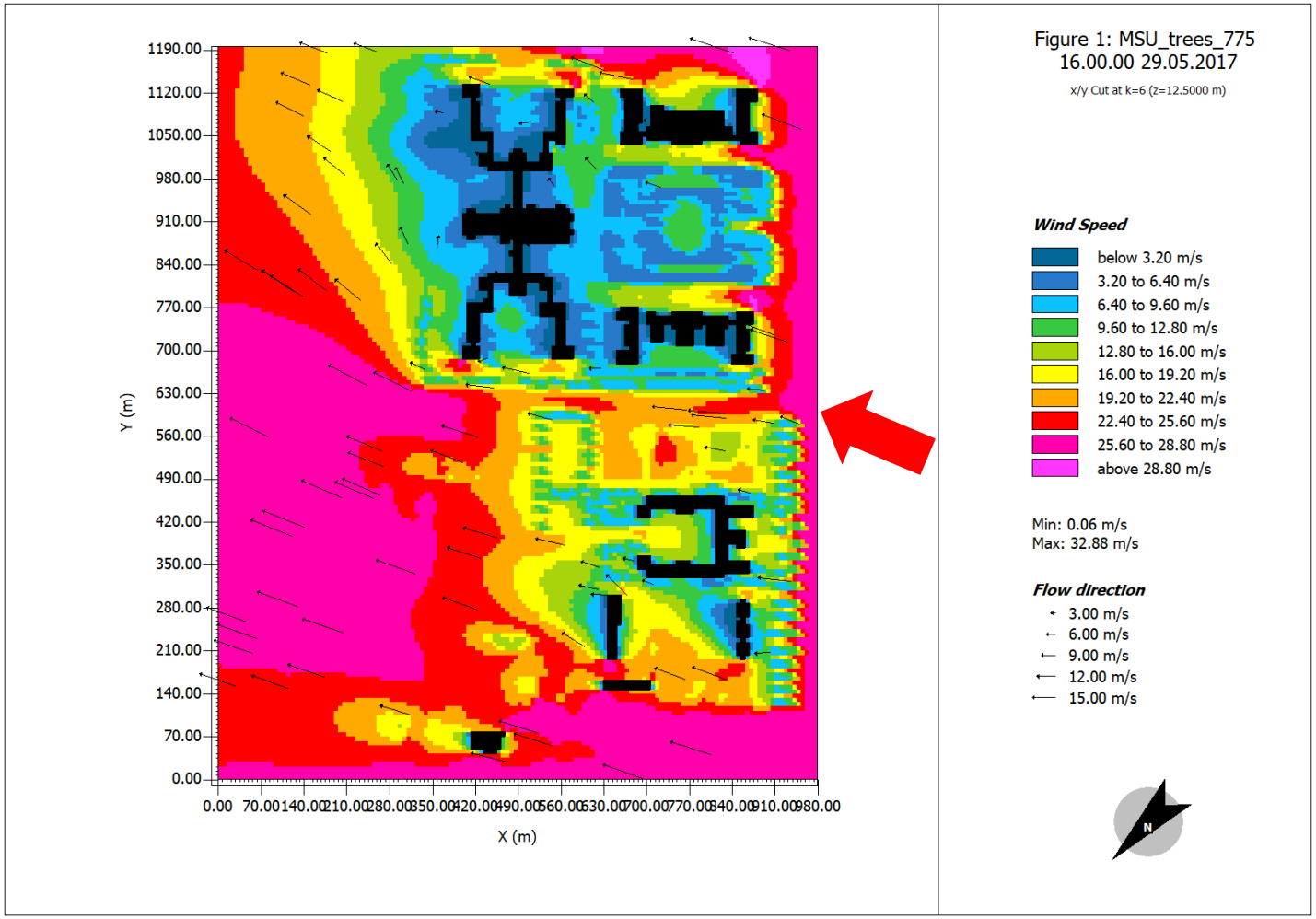
Initial wind direction: 240



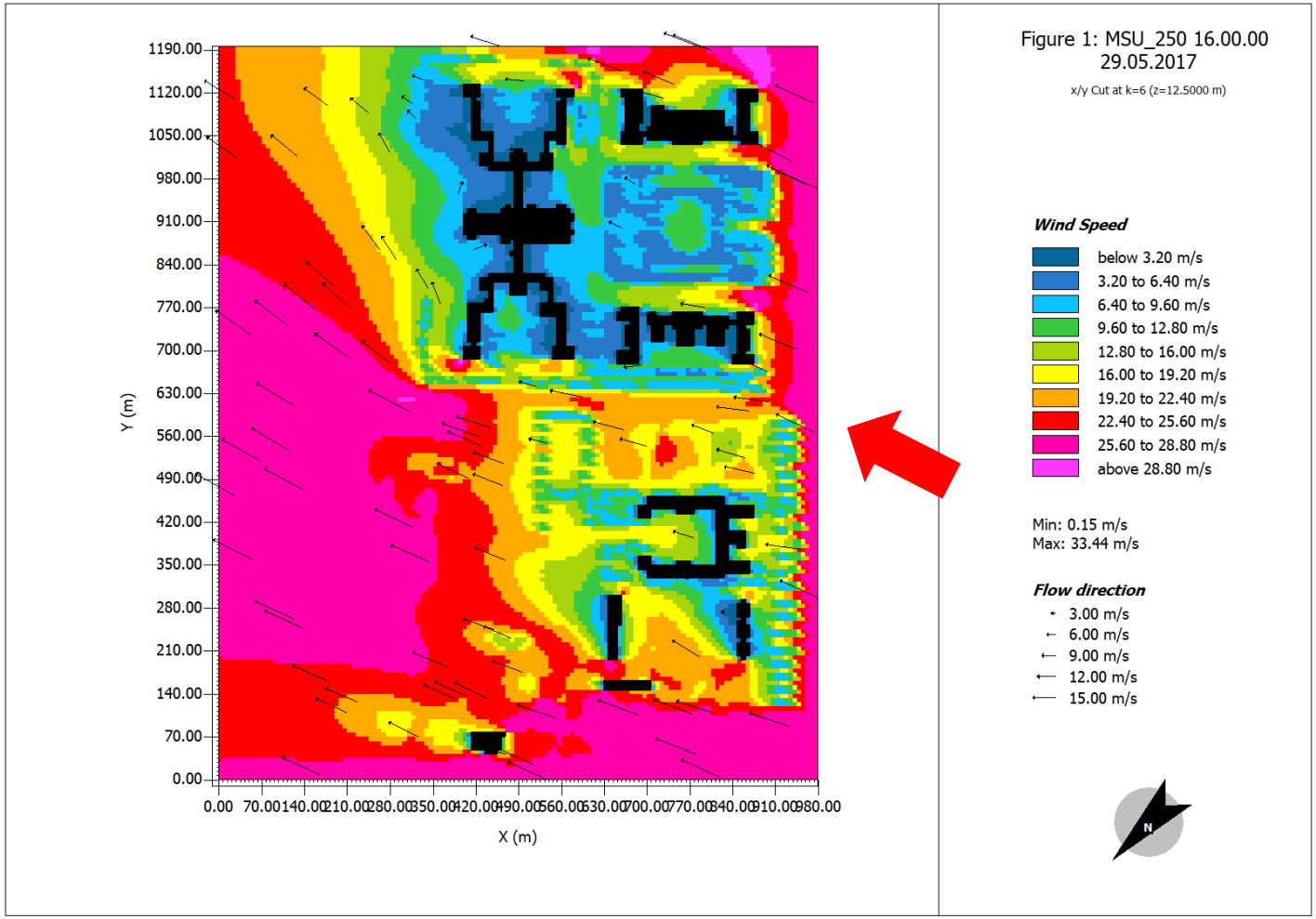
ENVI_met

<Right foot>

Initial wind direction: 245 (real wind)



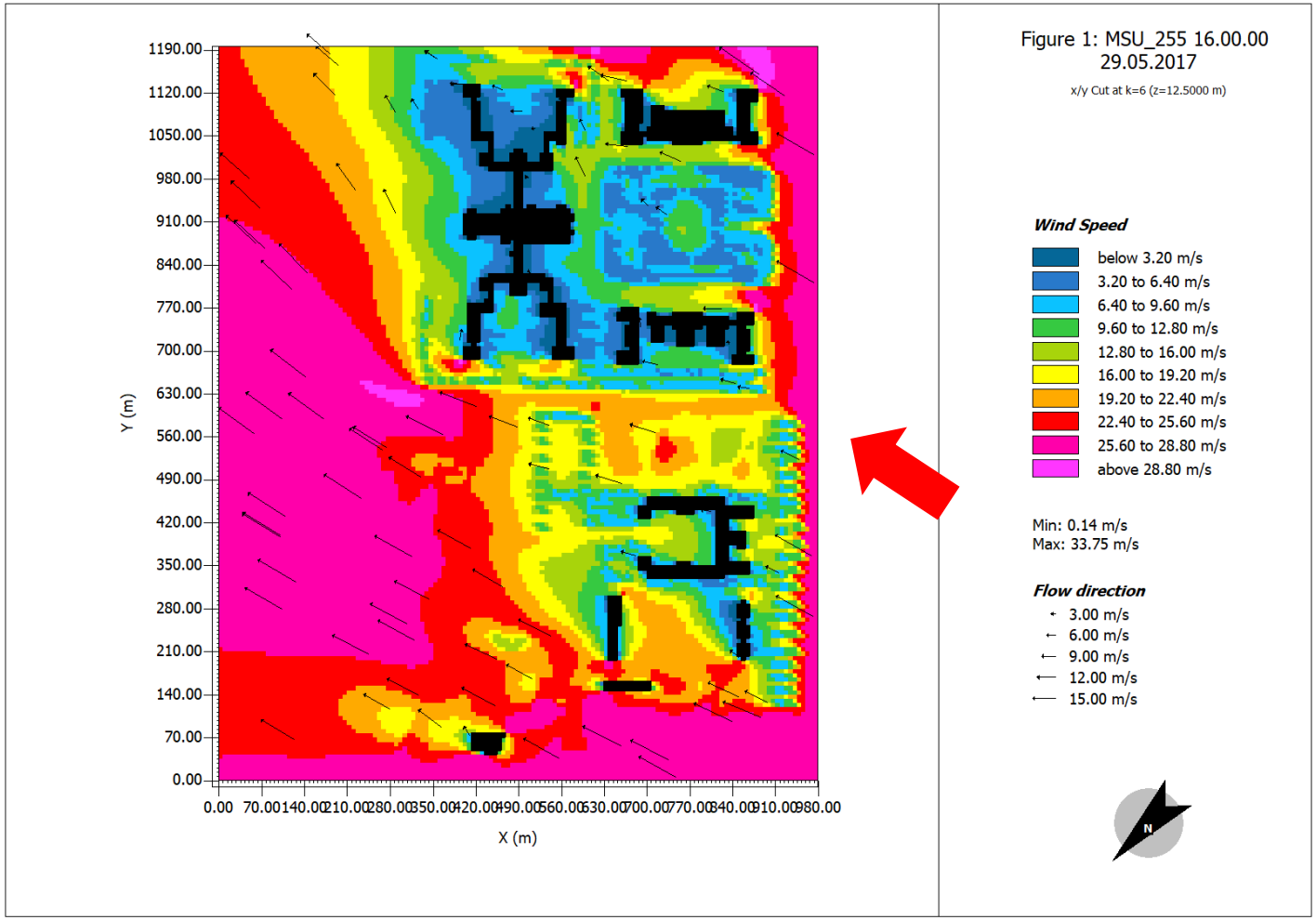
Initial wind direction: 250



ENVI_met

<Right foot>

Initial wind direction: 255



Modeling of wind speed with different initial wind direction:

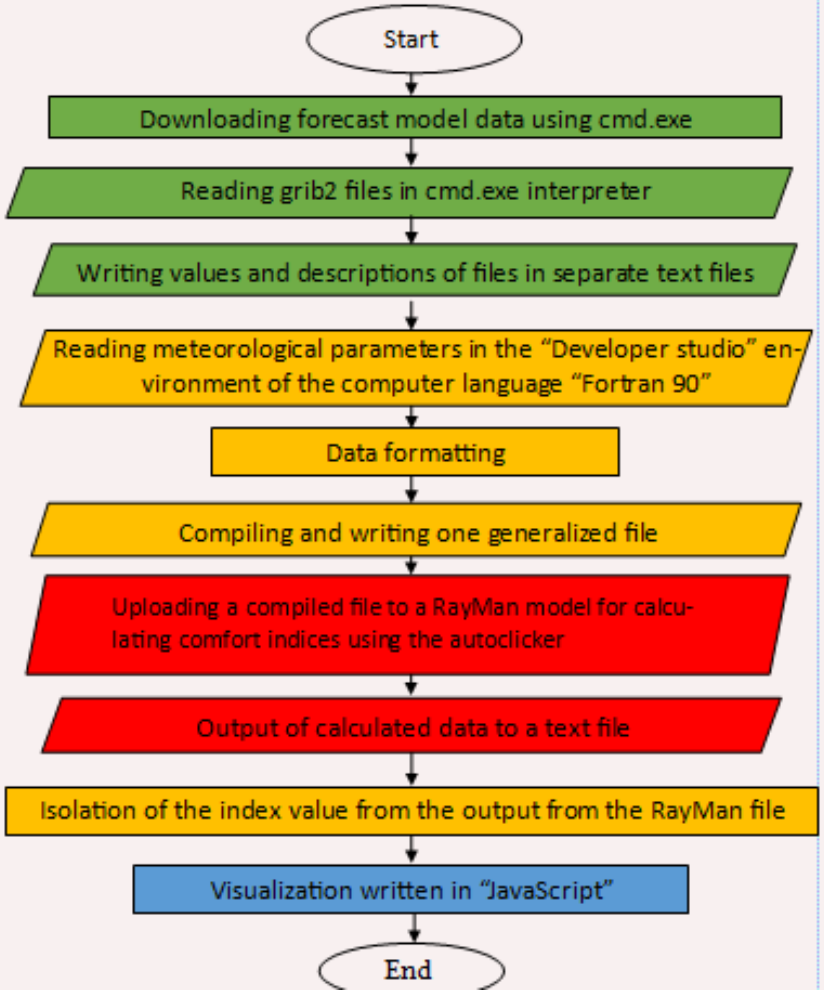
WIND DIRECTION	**245**	235	240	250	255
MAX WIND SPEED	**32,88**	32,25	32,18	33,44	33,75
MIN WIND SPEED	**0,06**	0,14	0,26	0,15	0,14
Mean	**19,13**	18,90	19,03	19,32	19,53
Dispersion	**57,62**	58,87	58,30	57,25	56,68
Mode	**27,05**	27,00	27,03	27,07	27,09
Number of cells where V> 30 м/с	**20/0,08%**	56/0,23%	26/0,11%	14/0,06%	11/0,05%
Number of cells where V>25 м/с	**6873/28,7%**	6564/27,4%	6743/28,2%	7160/29,9%	7482/31,3%
Number of cells where V<10 м/с	**4010/16,8%**	4372/18,3%	4110/17,2%	3839/16%	3642/15,2%
Spatial difference					
Coordinates of cell with max wind speed	126,161	87,169	126,161	126,161	126,161
Coordinates of cell with min wind speed	113,105	105,105	53,147	113,105	98,151

Real-time thermal comfort modeling

THE BLOCK DIAGRAM OF THE TECHNOLOGY OF FORECAST OF THERMAL INDICES

Diagnostic models for calculating comfort indices have already been invented in the biometeorology industry. However, to minimize the harm caused to health, a person must be informed about the conditions of conditional comfort, so there is a need to create a prognostic model. Nevertheless, the calculation program is hidden from the user. In this paper, an attempt was made to solve this problem.

When developing the technology, it was necessary to create several sequentially executed blocks. Blocks operating in the same environment are indicated in one color.



Input data :

CMC global (Canada)

Index of /model_gem_global/high_resolution/grib2/lat_lon/00

Name	Last modified	Size	Description
Parent Directory		-	
000/	2019-04-15 03:38	-	
003/	2019-04-15 03:38	-	
006/	2019-04-15 03:39	-	
009/	2019-04-15 03:39	-	
012/	2019-04-15 03:39	-	
015/	2019-04-15 03:41	-	
018/	2019-04-15 03:41	-	
021/	2019-04-15 03:44	-	
024/	2019-04-15 03:44	-	
027/	2019-04-15 03:45	-	
030/	2019-04-15 03:45	-	
033/	2019-04-15 03:46	-	
036/	2019-04-15 03:46	-	
039/	2019-04-15 03:47	-	
042/	2019-04-15 03:47	-	

Bash-convert with wgrib utility

Grib2

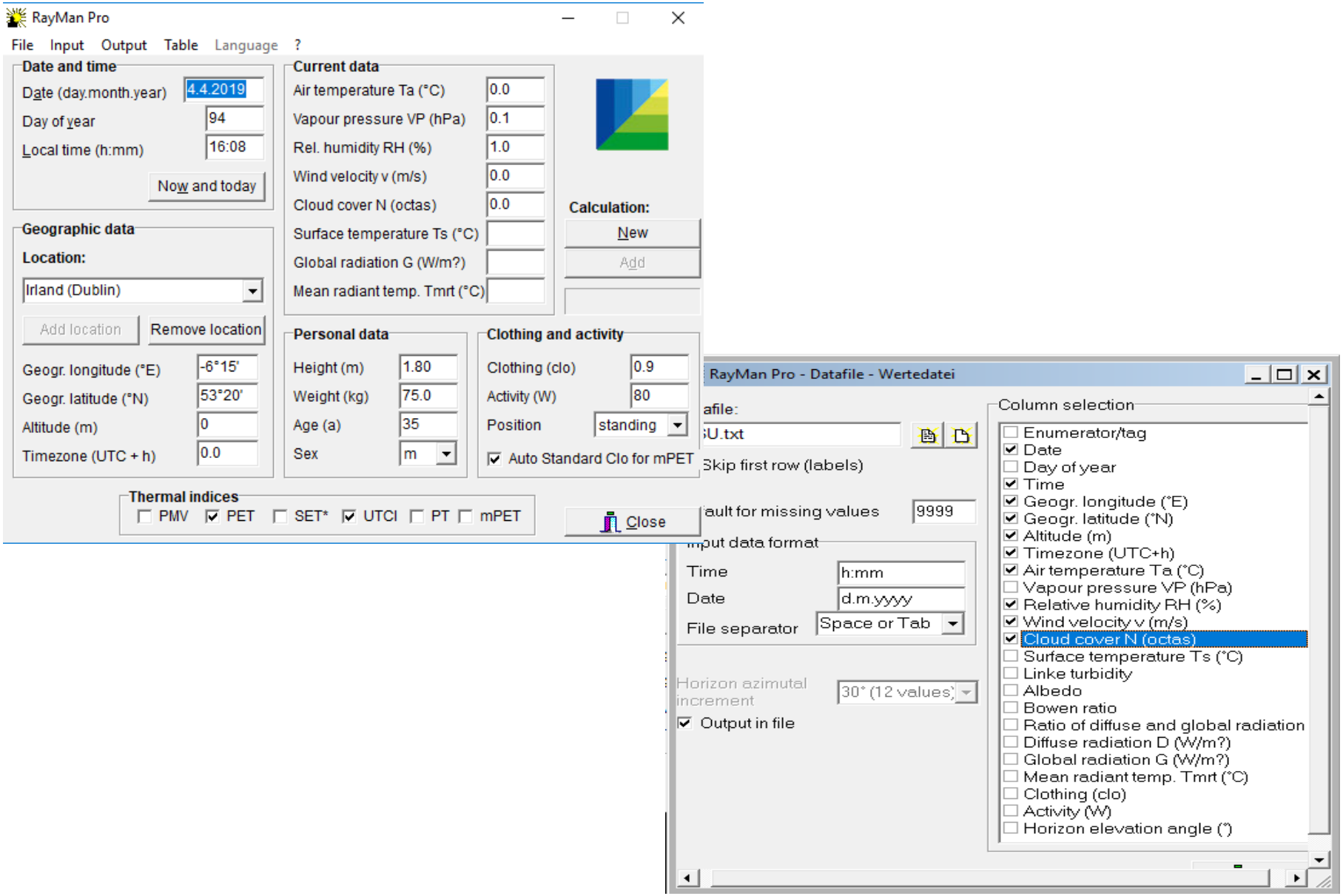
```
-no_nc_pack      init        no packing in netcdf for NEW variables
-no_nc_table     init        disable previously defined conversion_to_netcdf_table
-no_nc_time      init        netcdf, disable previously defined initial or relative date and time step
-not             init X      process data that does not match X (POSIX regular expression)
-not_fs          init X      process data that does not match X (fixed string)
-one_line        init        puts all on one line (makes into inventory format)
-order           init X      decoded data in X (raw|we:sn|we:ns) order, we:sn is default
-persistent      init X      makes file X persistent if already opened (default on open), CW2
-rewind_init     init X      rewinds file X on initialization if already opened, CW2
-set_ext_name    init X      X=0/1 extended name on/off
-set_regex       init X      set regex mode X = 0:extended regex (default) 1:pattern 2:extended regex & quote metachara
cters
-tigge           init        use modified-TIGGE grib table
-transient       init X      make file X transient, CW2


C:\Users\Admin\Desktop\bat>wgrib2 -ij 364 244 temp.grib2  1>t.txt

C:\Users\Admin\Desktop\bat>wgrib2 -ij 364 244 pres.grib2  1>p.txt

C:\Users\Admin\Desktop\bat>wgrib2 -ij 364 244 hum.grib2  1>h.txt

C:\Users\Admin\Desktop\bat>wgrib2 -ij 364 244 cloud.grib2  1>cl.txt

C:\Users\Admin\Desktop\bat>wgrib2 -ij 364 244 wind10.grib2  1>w10.txt

C:\Users\Admin\Desktop\bat>wgrib2 temp.grib2 -V  1>inv.txt

C:\Users\Admin\Desktop\bat>pause
Для продолжения нажмите любую клавишу . . .
```

Конвертация файла при помощи “cmd.exe”.

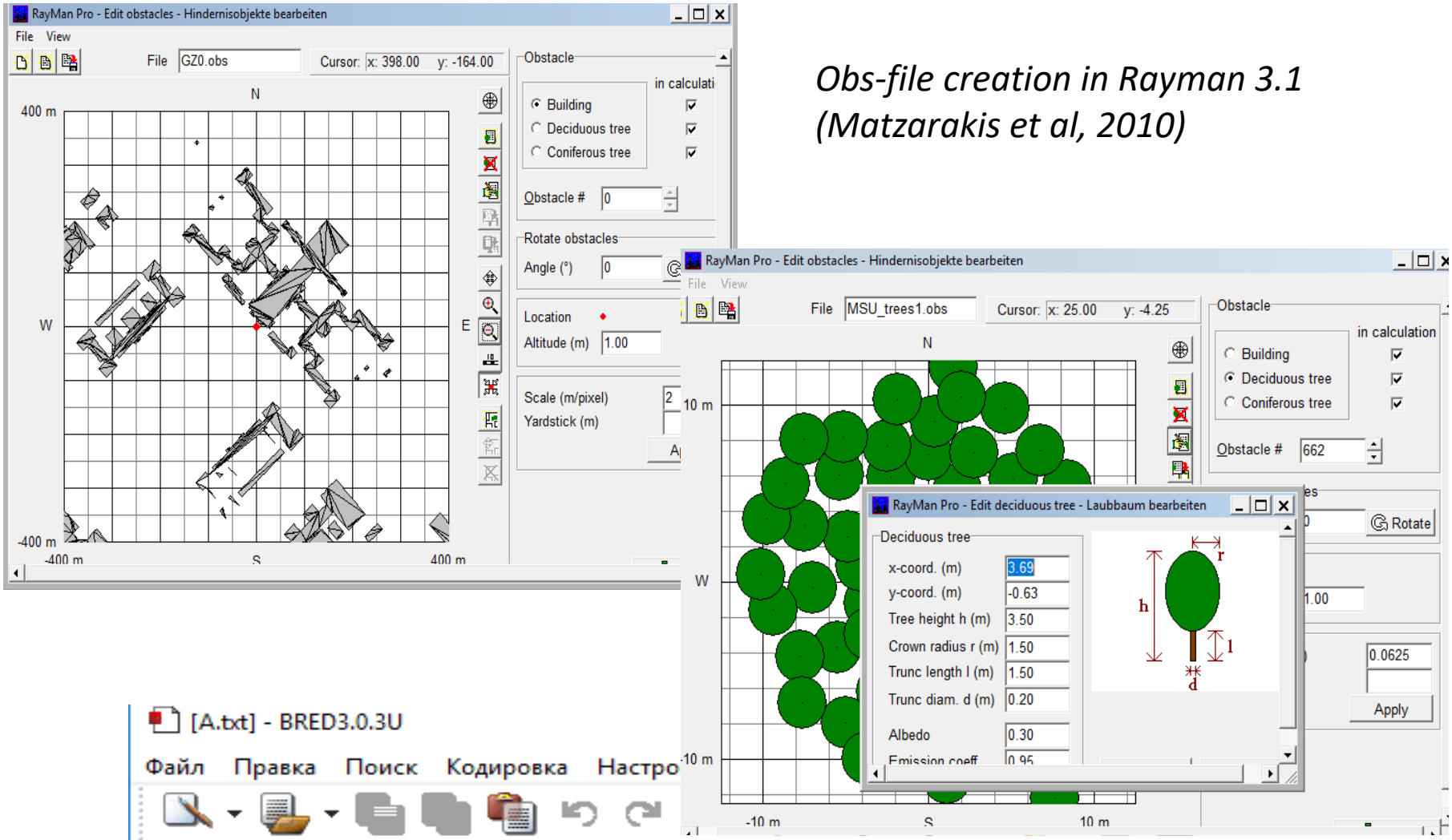
Automatisation of Rayman 3.1: with autoclicker

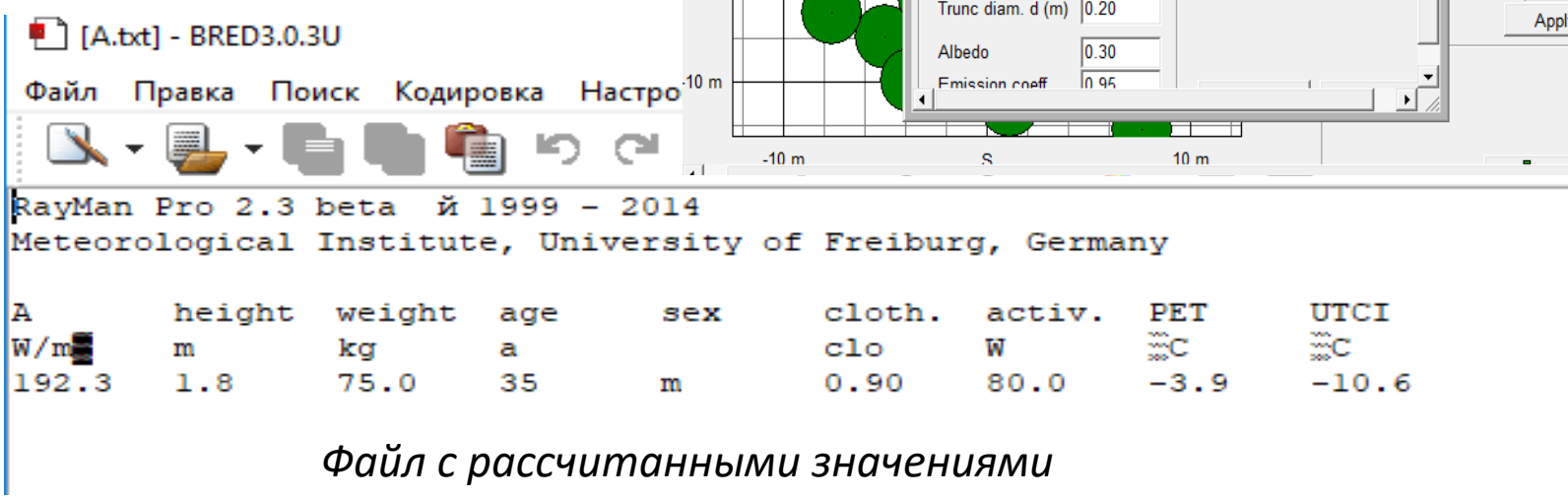
Autoclicker AutoClickExtreme

Rayman 3.1 interface



Obs-file creation in Rayman 3.1 (Matzarakis et al, 2010)

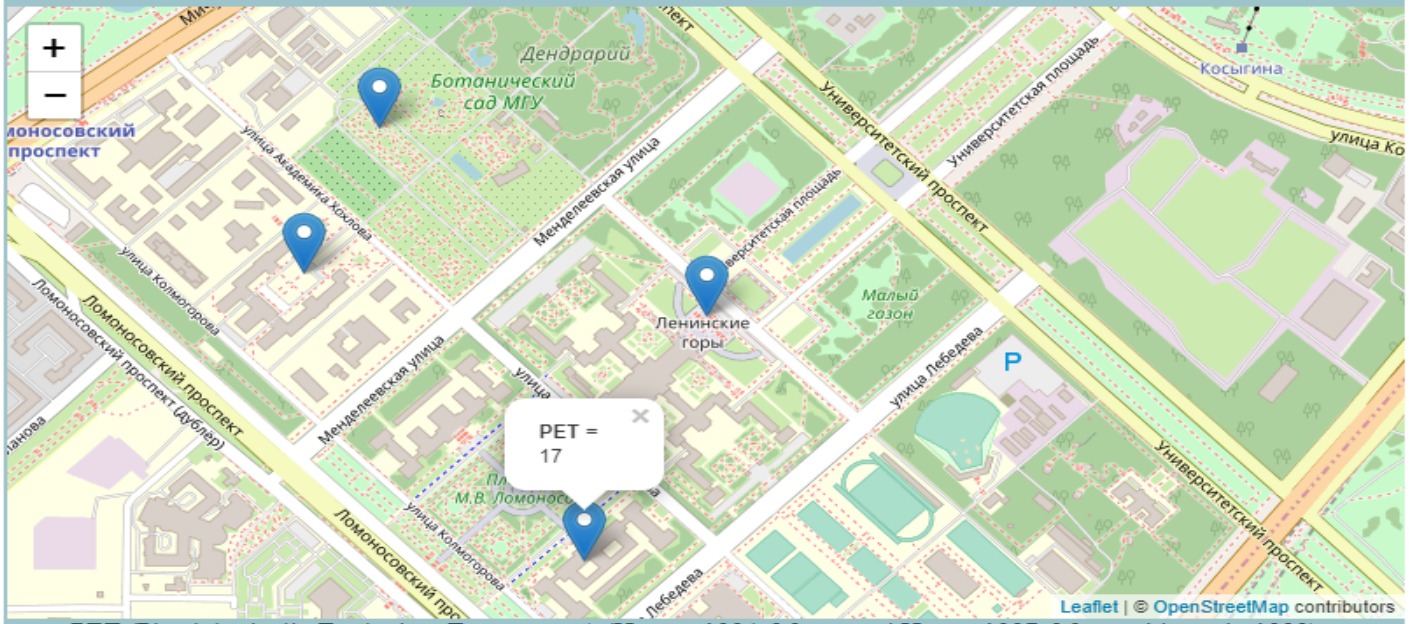




Файл с рассчитанными значениями

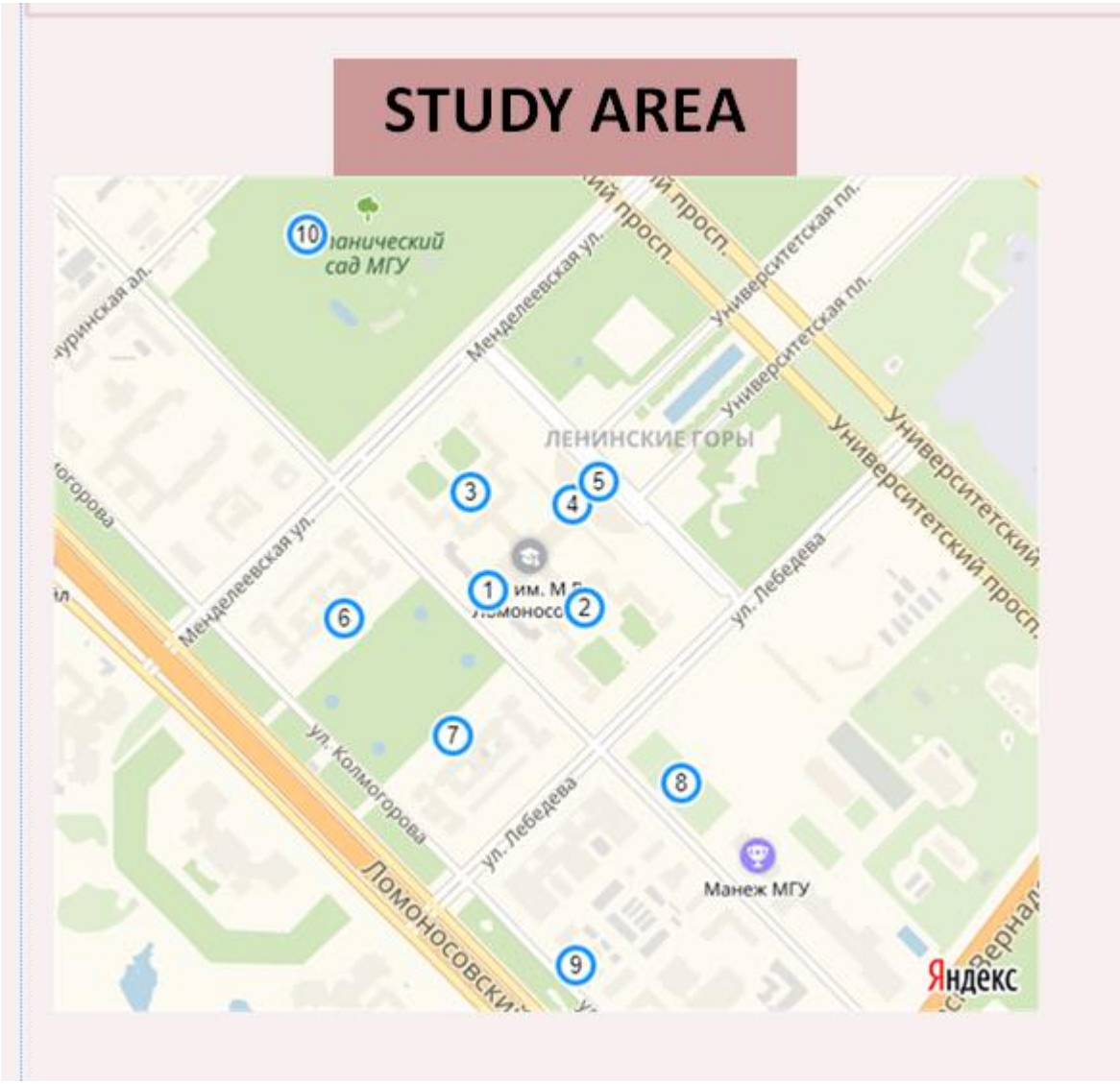
Vizualisation

Онлайн-прогноз комфортности в районе кампуса МГУ



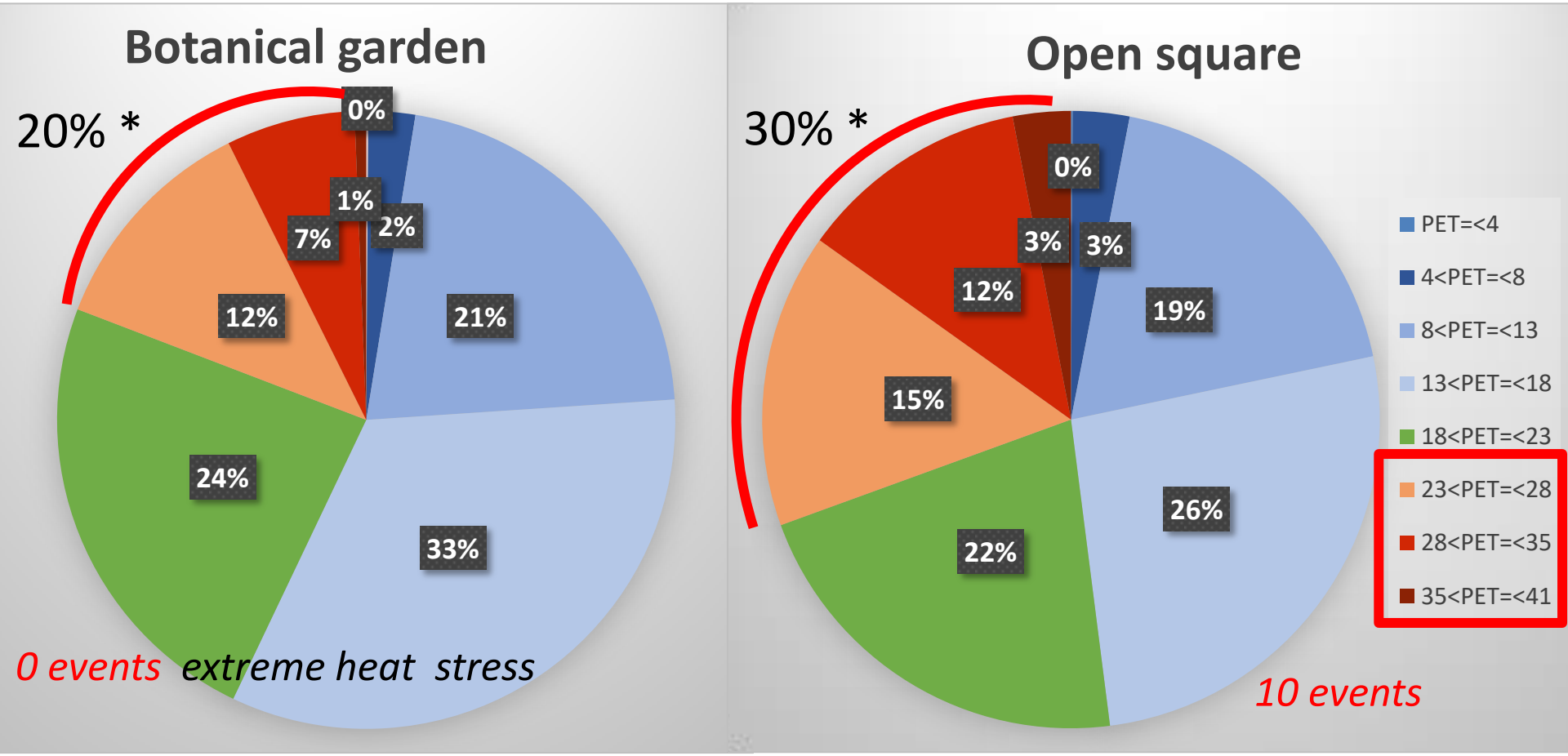
PET (Physiologically Equivalent Temperature) (Hoppe, 1984; Mayer and Hoppe 1987; Matzarakis et al., 1999) – физиологически эквивалентная температура – параметр, рассчитываемый при помощи модели энергетического баланса тепла человека (Munich Energy-balance Models for Individuals – MEMI) и определяемый, как температура воздуха, при которой для обычных комнатных условий тепловой баланс человеческого тела остается неизменным со значениями температуры внутренних органов и температуры кожи для данной ситуации. Помимо стандартных метеорологических параметров таких, как температура воздуха, скорость ветра и относительная влажность при расчёте PET учитываются процессы метаболизма человека, активность и теплоизоляционные свойства одежды. В настоящее время PET является одним из наиболее часто используемых показателей комфорта человека.

MSU-campus territory



Points

Different thermal stress (PET, July 1980-1999)



* moderate, intense and extreme heat stress

Perspectives:

The development of such work can be continued for other cities (primarily for the Arctic), as well as millionaire cities. In the framework of the technology, it is possible to use in the future as input data output products of regional models, which ultimately should lead to an improvement in the quality of climate services for the population of Moscow and the Moscow region

Acknowledgements

Research was supported by the grant program of Russian Foundation of Basic Research (project no. 19-35-70009 mol_a_mos).

The work of Pavel Konstantinov, Elizaveta Nikolaeva and Sergey Bukin was supported by Russian Science Foundation (project no. 19-77-30012)