NEW APPROACHES FOR THERMAL EXCHANGE PROCESSES SIMULATION IN MOSCOW'S ATHMOSPHERIC BOUNDARY LAYER

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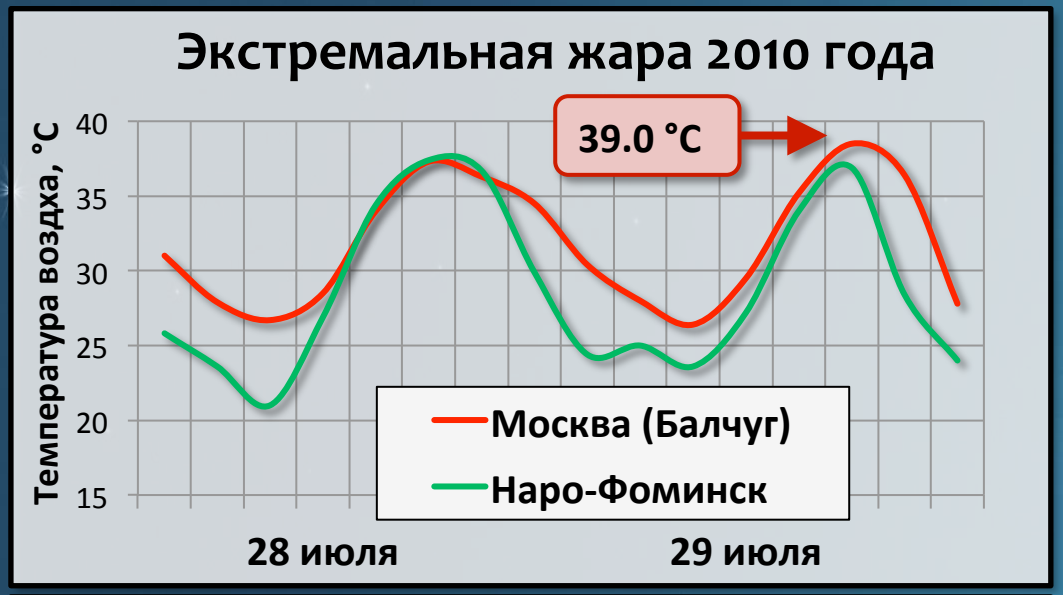
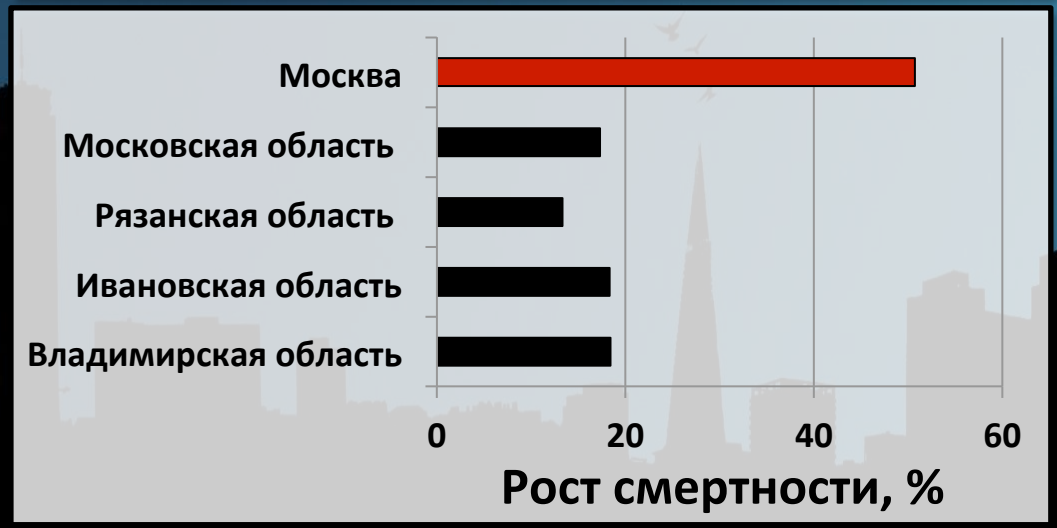
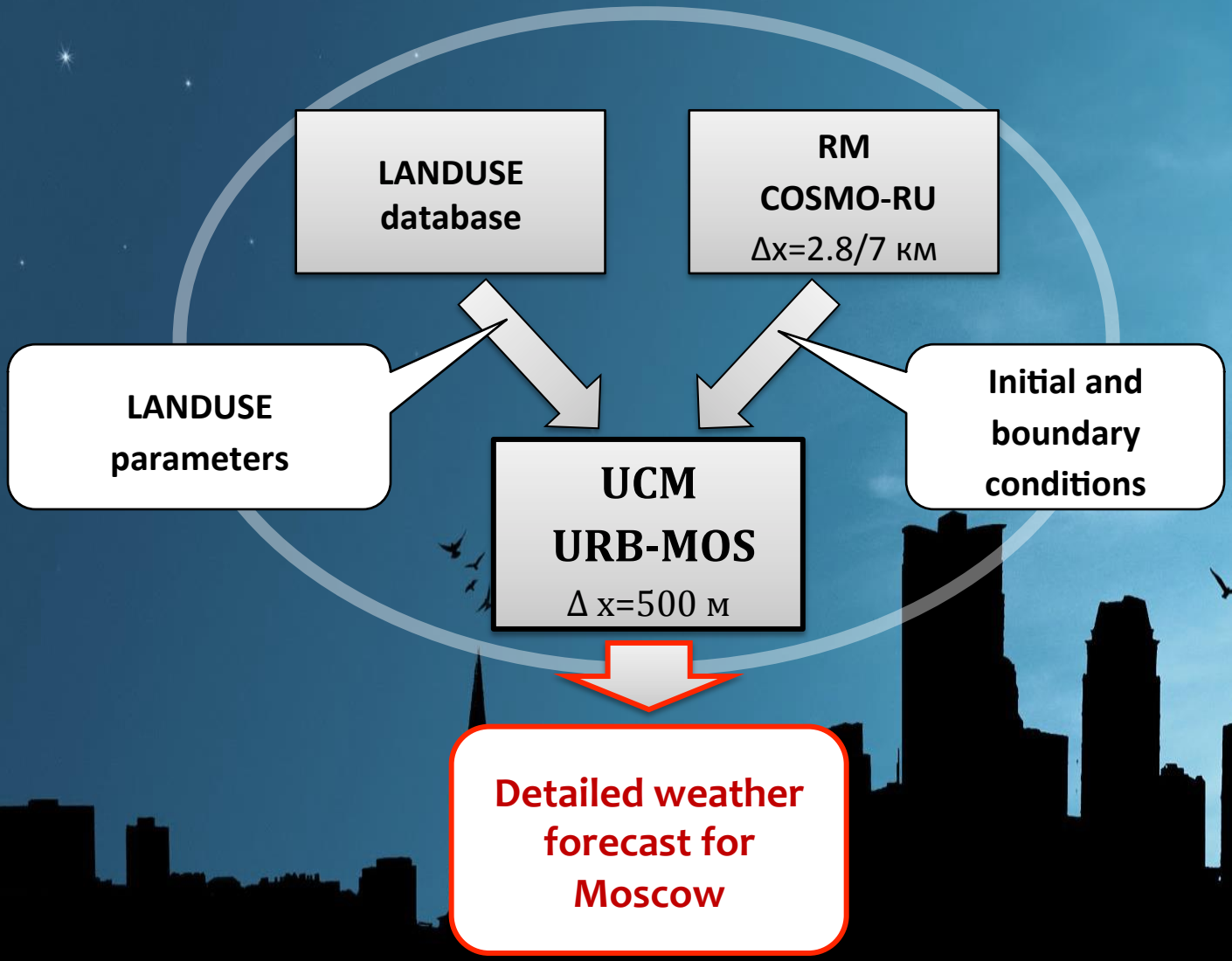
MOTIVATION

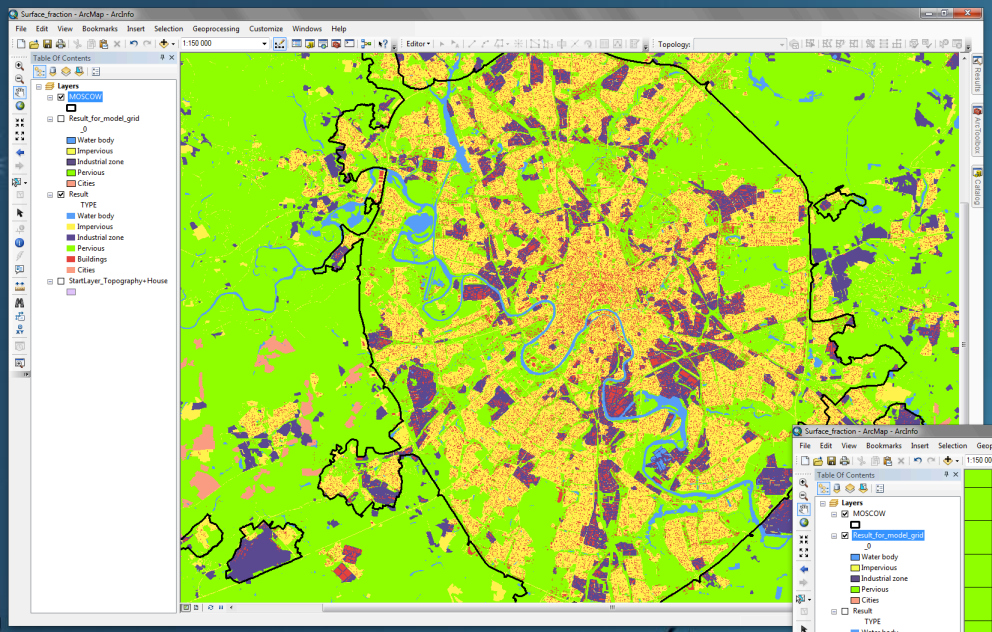

Экстремальная жара 2010 года
Температура воздха, °C
40
35
30
25
20
15
39.0 °C
Москва (Балчуг)
Наро-Фоминск
28 июля
29 июля


Москва
Московская область
Рязанская область
Ивановская область
Владимирская область
0
20
40
60
Рост смертности, %

MODEL COMPLEX

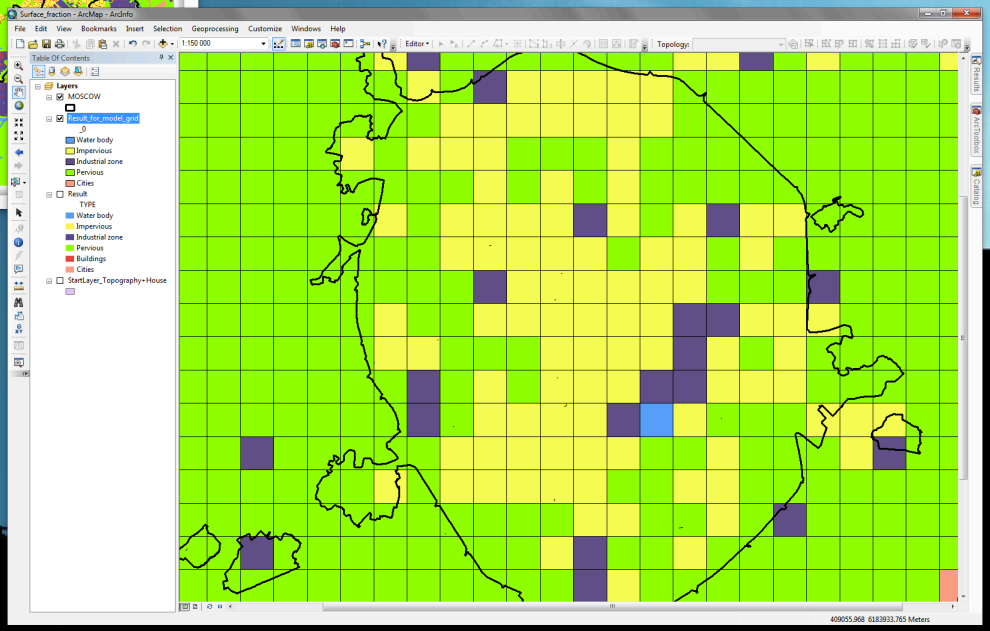


Calculation result of geoprocessing model ‘Surface fraction’



Categories:

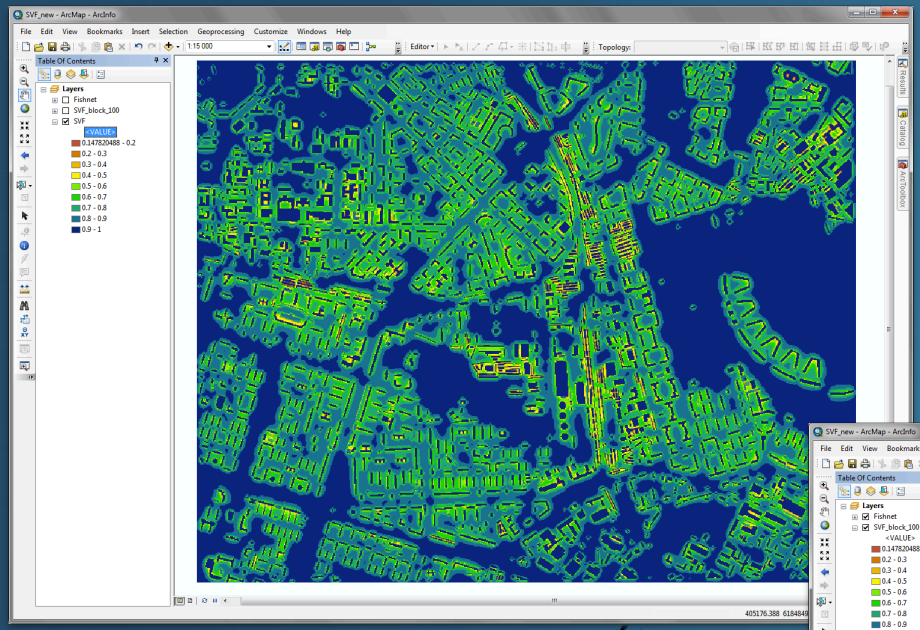
- impervious surface
- pervious surface
- water body
- industrial territory

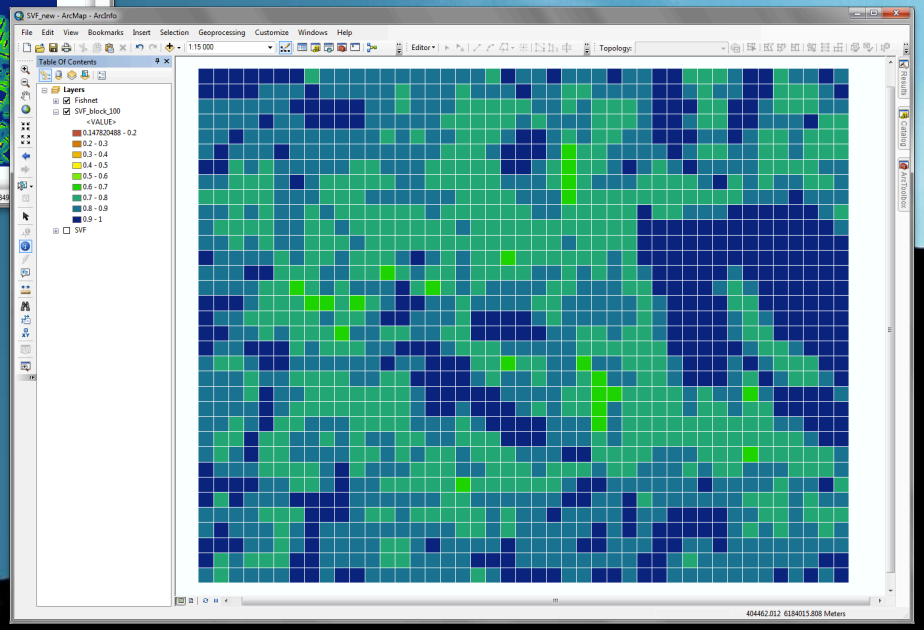


Average surface fraction for model regular grid WRF-ARW.

Resolution 2.2 km.

Calculation result of ‘sky view factor’ geoprocessing model.

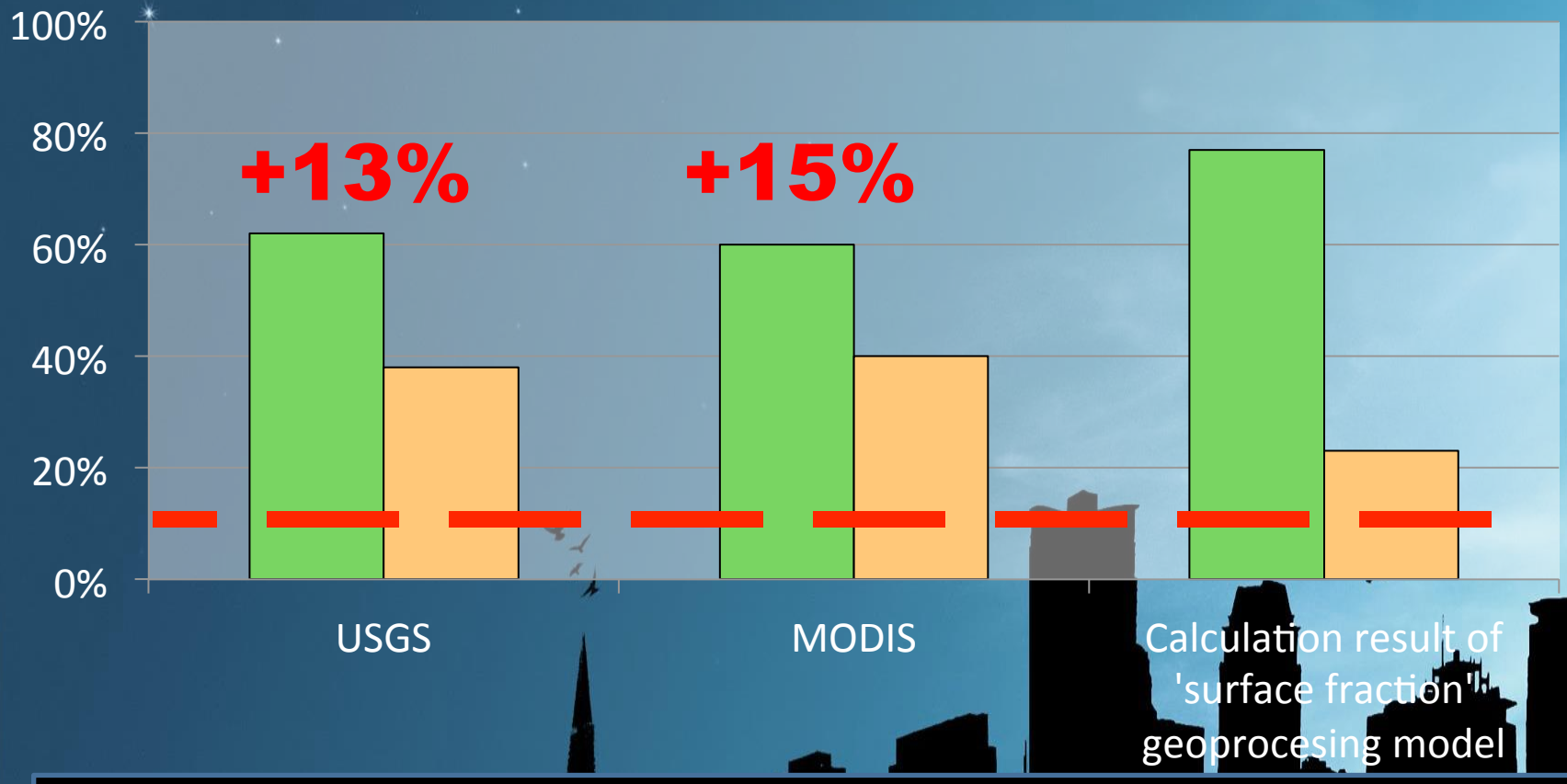




Average sky view factor for model regular grid.

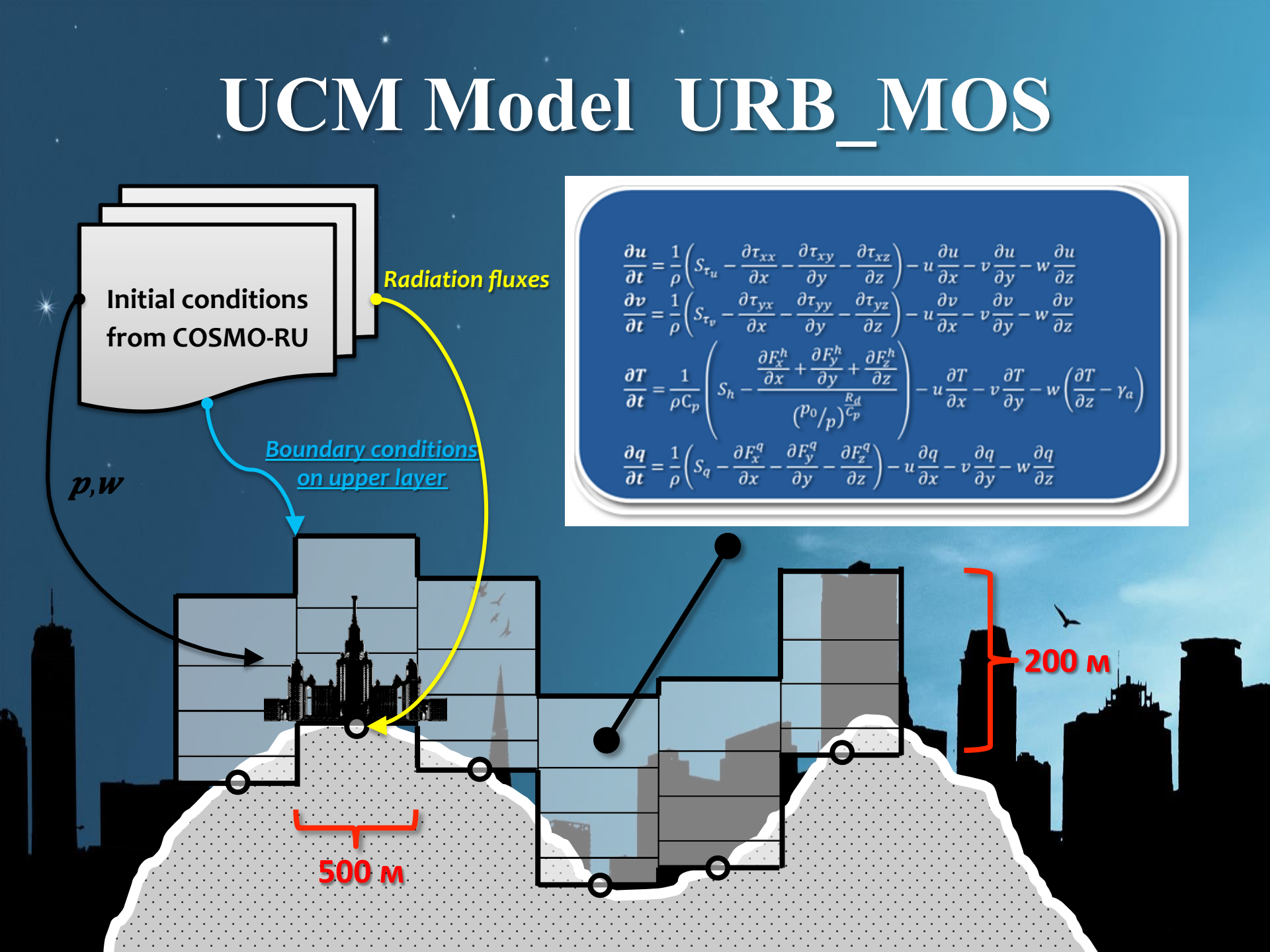
Resolution 100 m.

DATABASE MODIS AND USGS OVERESTIMATES URBAN AND BUILD-UP SURFACE



Conclusion 1: For cities with not well-known surface parameters RM can't produce good wind speed & temperature results

UCM Model URB_MOS



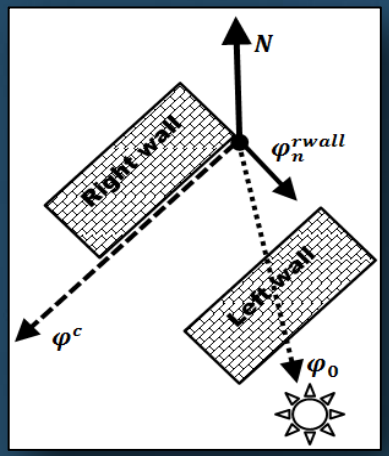
$$\frac{\partial u}{\partial t} = \frac{1}{\rho}\left(S_{\tau_u} - \frac{\partial \tau_{xx}}{\partial x} - \frac{\partial \tau_{xy}}{\partial y} - \frac{\partial \tau_{xz}}{\partial z}\right) - u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} - w\frac{\partial u}{\partial z}$$

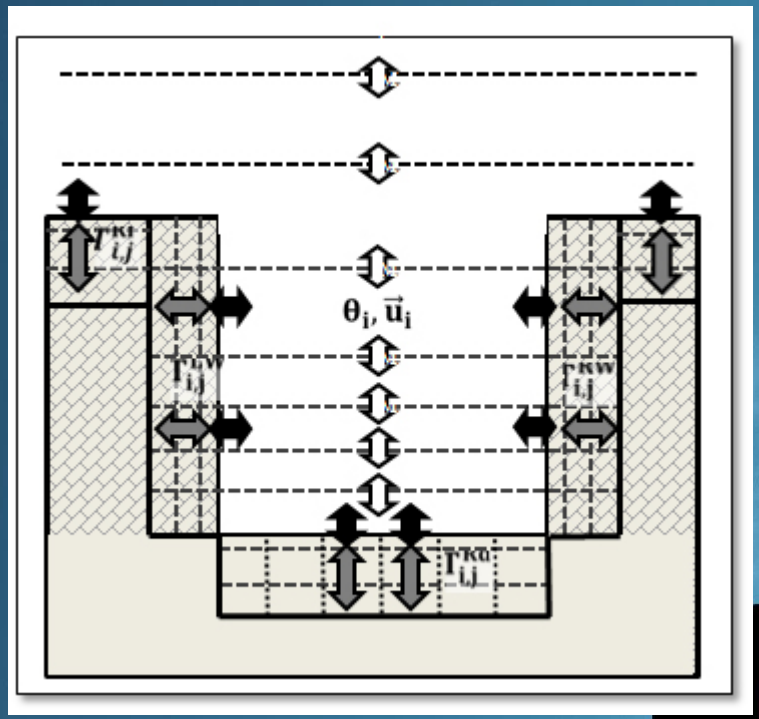
$$\frac{\partial v}{\partial t} = \frac{1}{\rho}\left(S_{\tau_v} - \frac{\partial \tau_{yx}}{\partial x} - \frac{\partial \tau_{yy}}{\partial y} - \frac{\partial \tau_{yz}}{\partial z}\right) - u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - w\frac{\partial v}{\partial z}$$

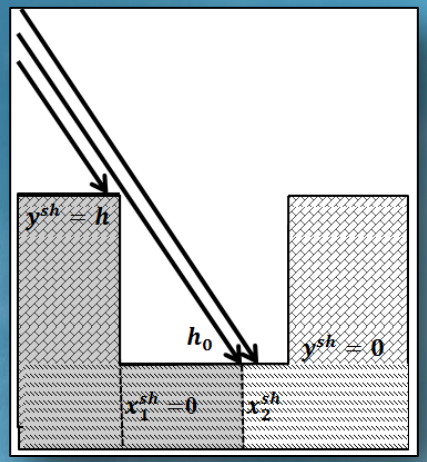
$$\frac{\partial T}{\partial t} = \frac{1}{\rho C_p}\left(S_h - \frac{\frac{\partial F_x^h}{\partial x} + \frac{\partial F_y^h}{\partial y} + \frac{\partial F_z^h}{\partial z}}{\left(P_0/p\right)^{\frac{R_d}{C_p}}}\right) - u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} - w\left(\frac{\partial T}{\partial z} - \gamma_a\right)$$

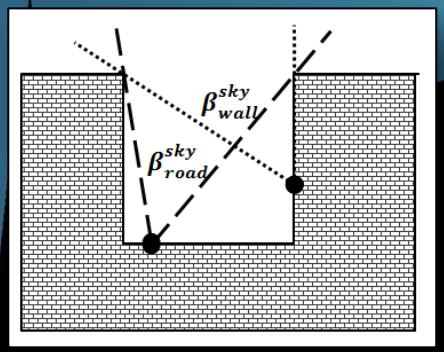
$$\frac{\partial q}{\partial t} = \frac{1}{\rho}\left(S_q - \frac{\partial F_x^q}{\partial x} - \frac{\partial F_y^q}{\partial y} - \frac{\partial F_z^q}{\partial z}\right) - u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial y} - w\frac{\partial q}{\partial z}$$

Canyon submodel :



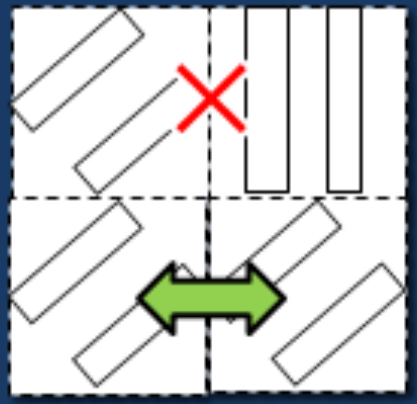






Diffusion and advection

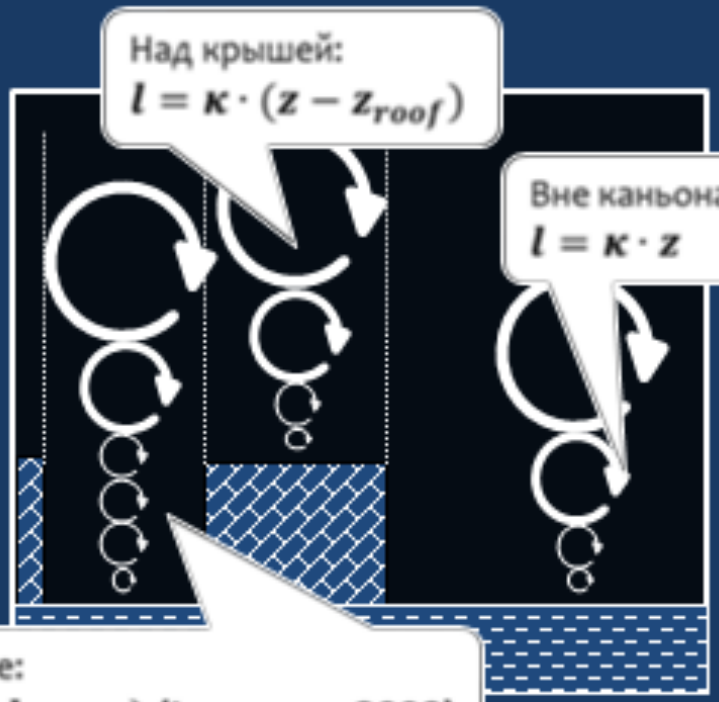
Diffusion filter



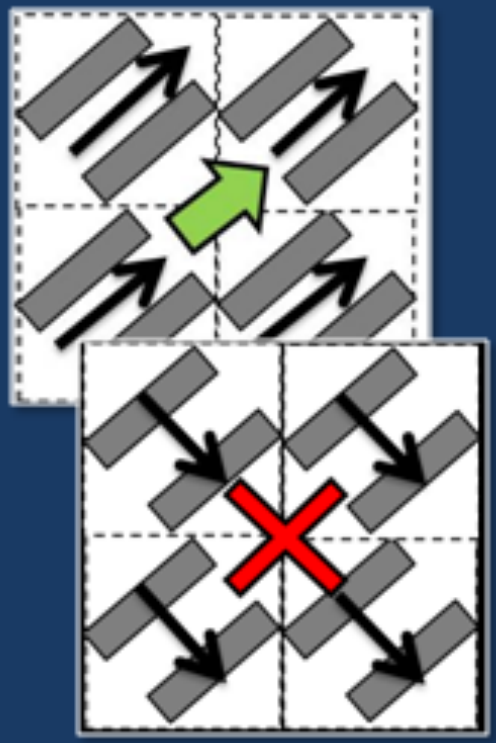
Turbulence closure

$$K = l \cdot F(Ri) \cdot \frac{\partial |u|}{\partial z})$$

Turbulent eddy scale



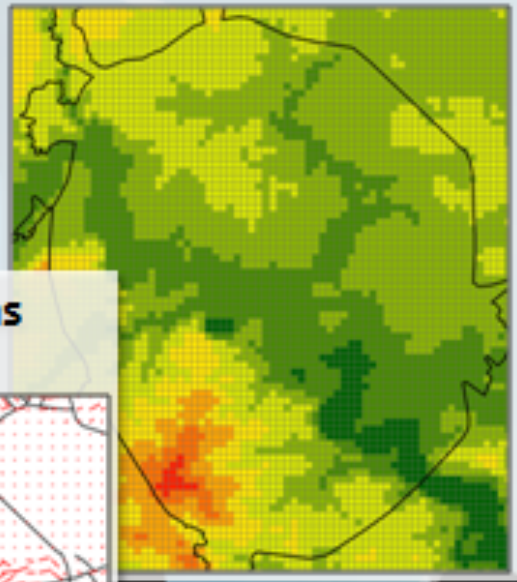
Advection filter



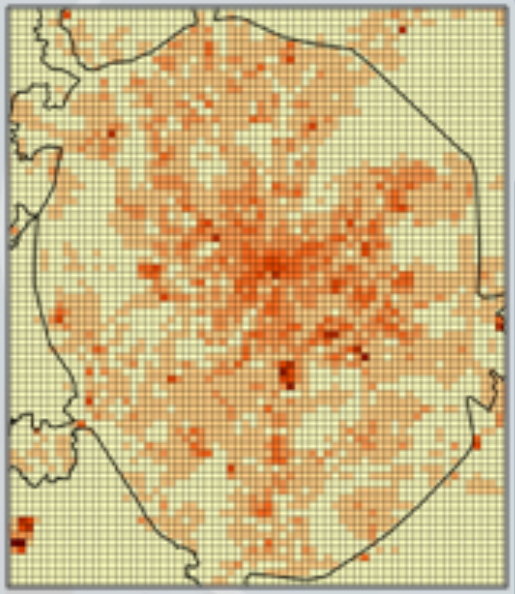
Surface parameters database

42 parameters:

Height ASK



Building density



Canyon directions

Turbulence

Для горизонтальных поверхностей:

Bulk-формулы:

$$\tau_z = \rho u_z^2 \cdot C_m(z, z_0, \xi, \Psi_m)$$

$$H_z = \rho c_p u_z \Delta T \cdot C_h(z, z_0, z_{0h}, \xi, \Psi_m$$

Параметры шероховатости:

z_0 - экспериментальная оценка

$$z_{0h} = z_0 / \exp(2.46 (Re^*)^{0.25} - 2.0)$$

Универсальные функции Ψ_m, Ψ_h :

Bussinger (1971), Grachev (1998), Grachev (2007, данные SHEBA)

Параметр устойчивости ξ :

Численное решение уравнения:

$$F(\xi) = z\kappa\beta H(\xi) / \rho c_p u_*(z)^3 - \xi = 0$$

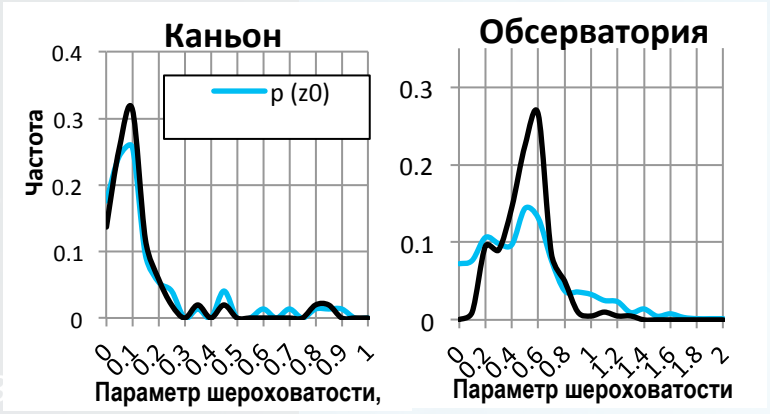
Для вертикальных поверхностей (стен):

Эмпирические формулы (Martilli, 2002):

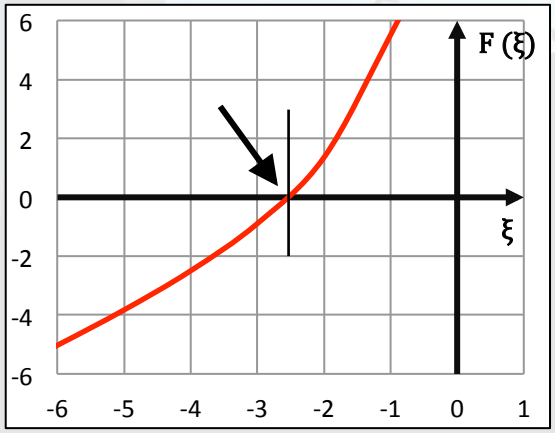
$$H_{z}^{wall} = c_c (a_c + b_c + |u_z| / d_c / C_p (\theta_{z}^{wall} - \theta_z)$$

$$\tau_{z}^{wall} = -\rho C_{drag} |u_{z}^{ort}| \cdot u_{z}^{ort}$$

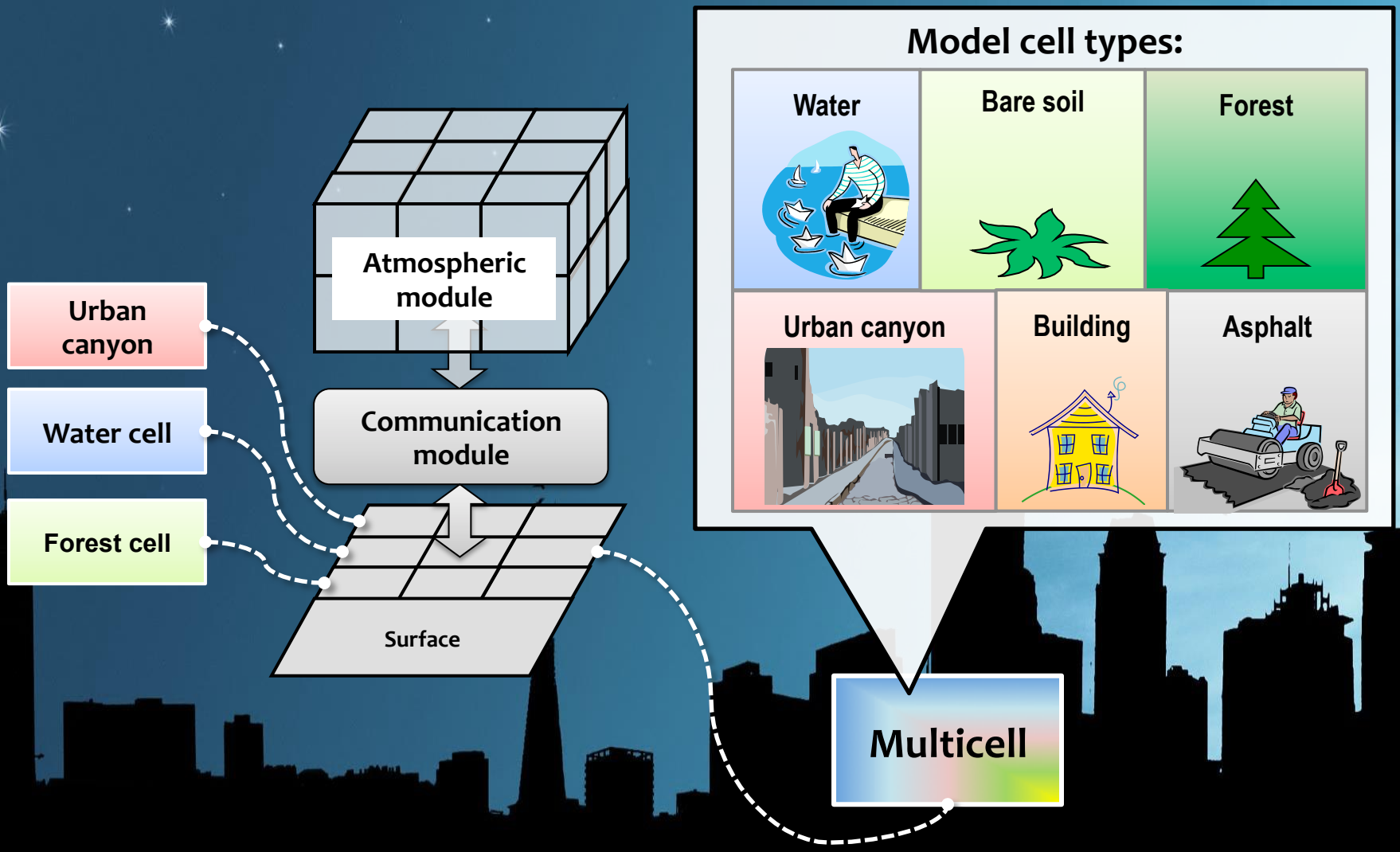
Экспериментальная оценка параметров шероховатости



Численное решение уравнений М-О:

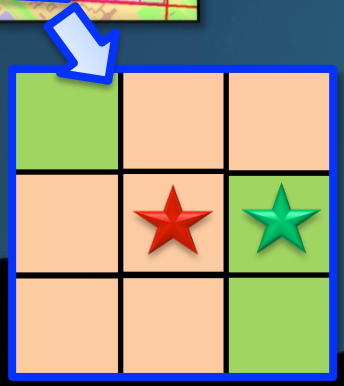


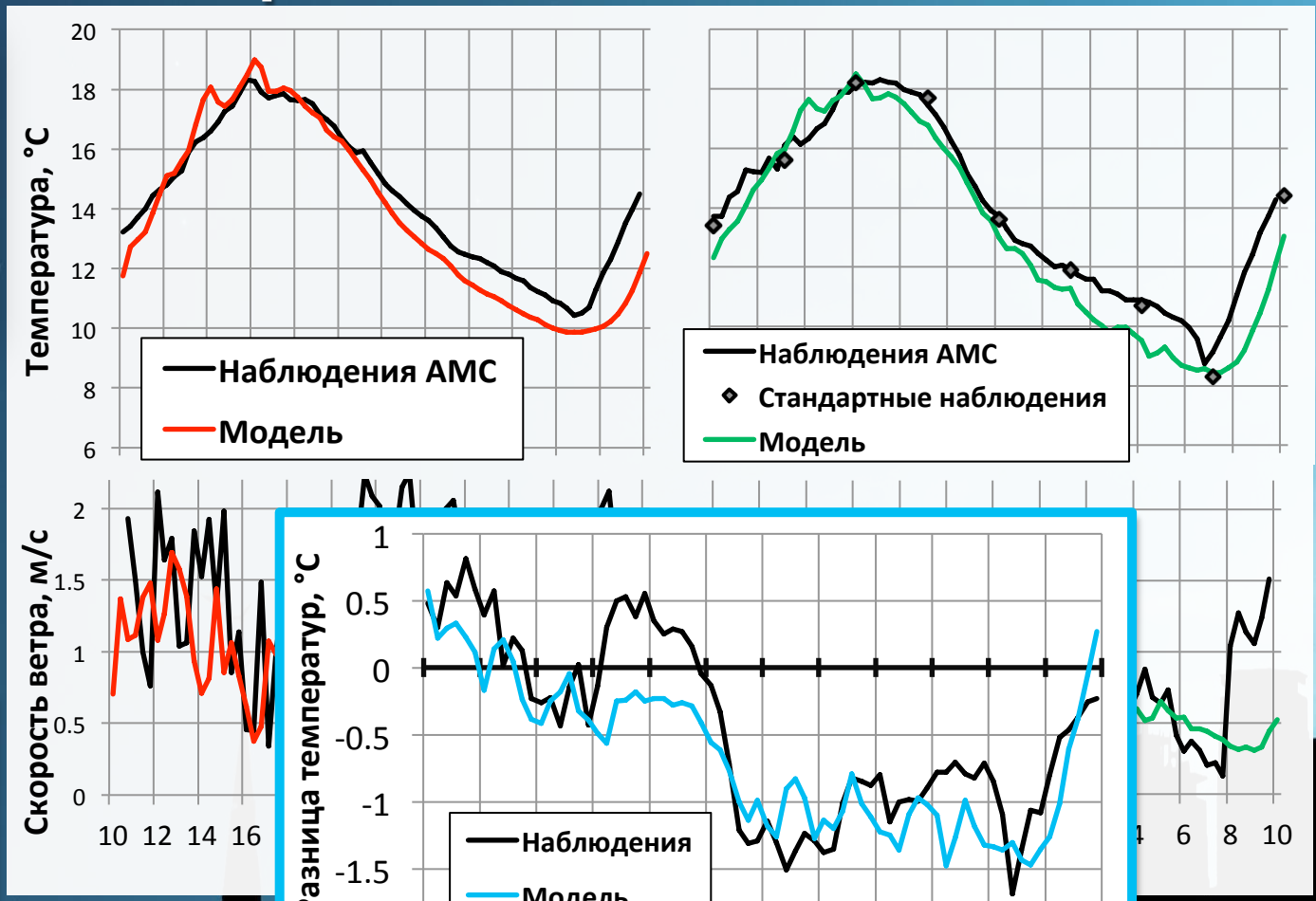
Heterogeneity of surface



Urb_Mos validation

Urban Experiment UrbEx-2011



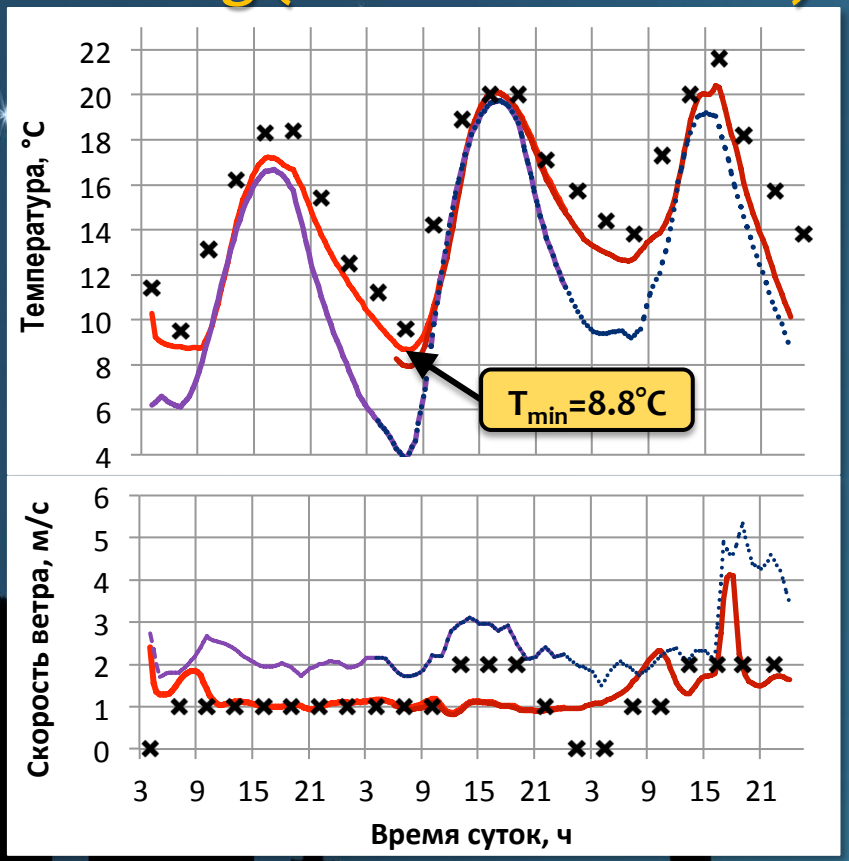


- метеор
- «экспер

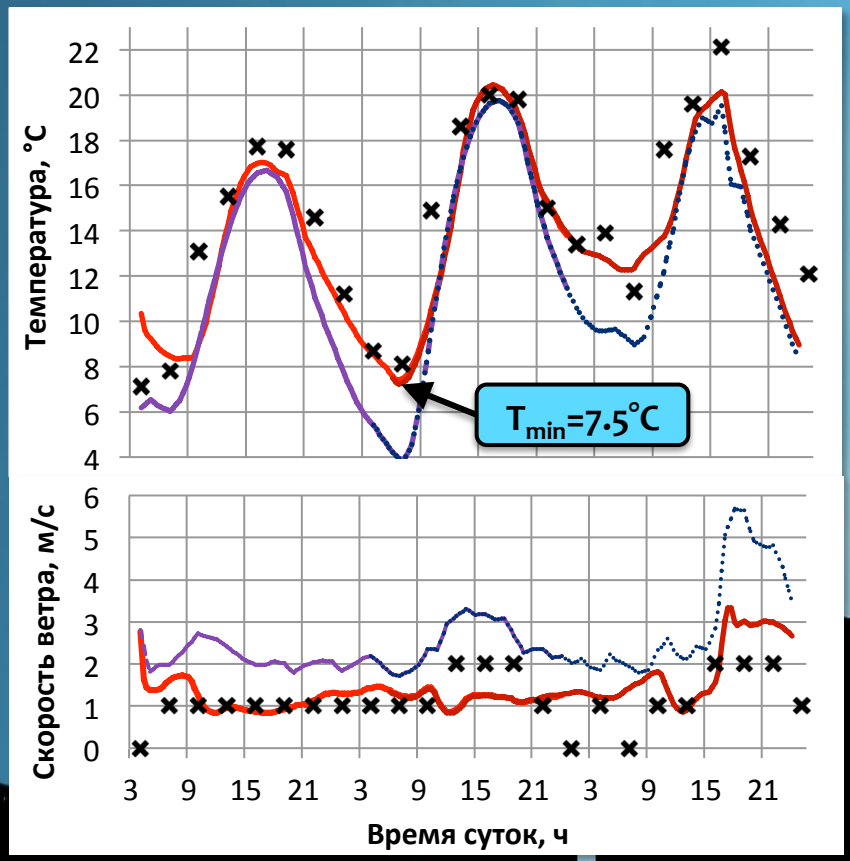
Urb_Mos validation

Weather stations data

Balchug (center of Moscow)

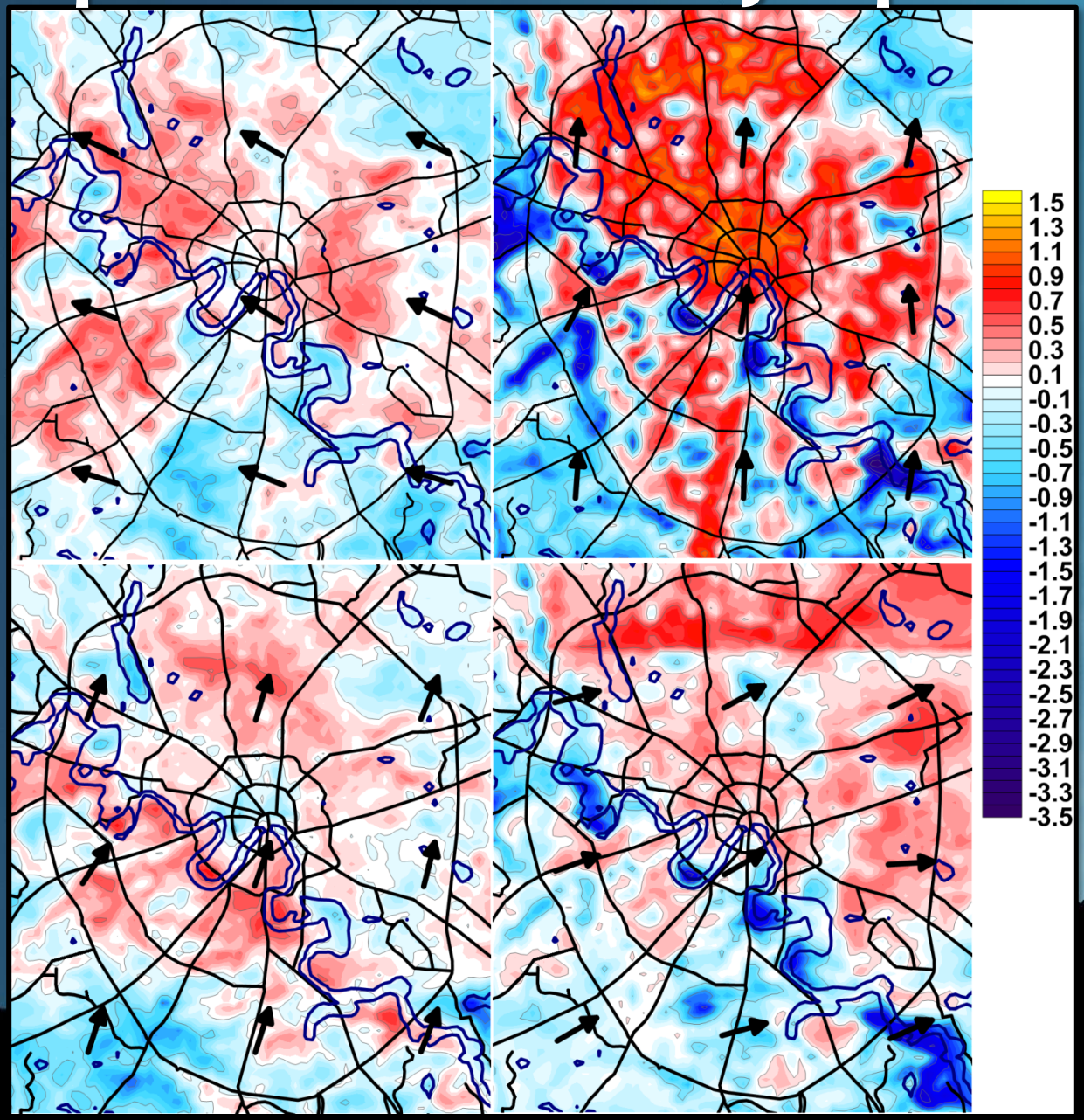


WTC

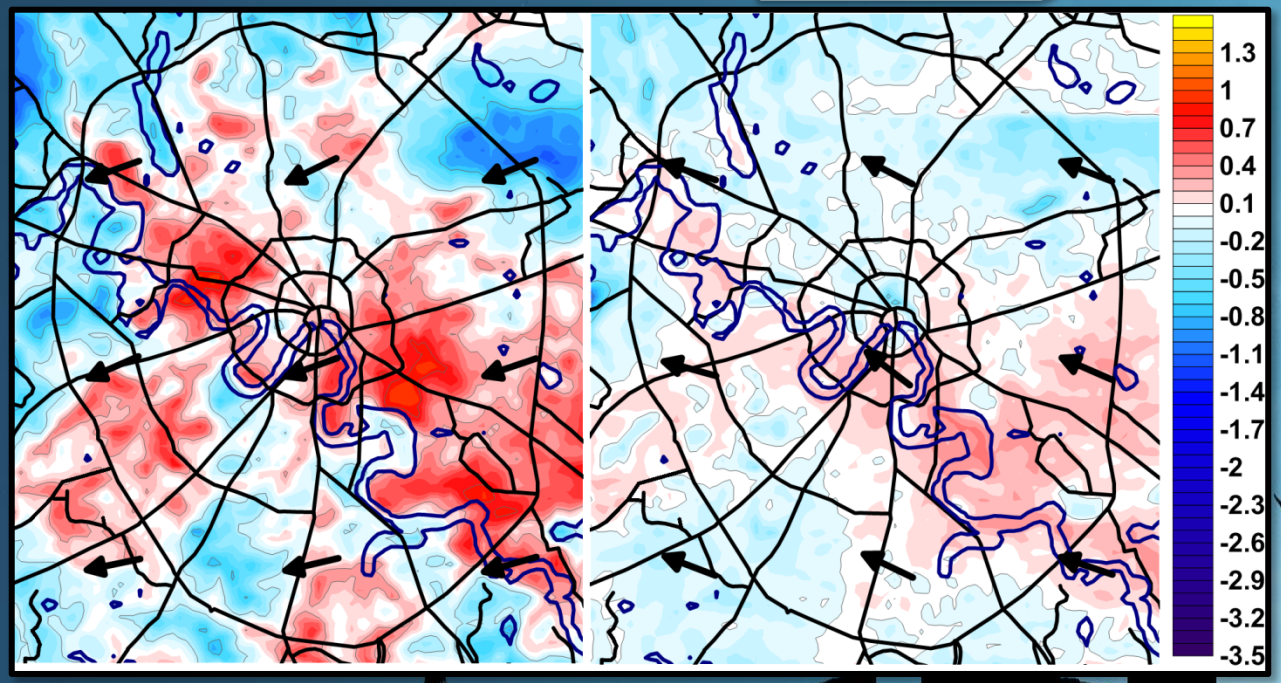


URB-MOS (от 26 апреля)
URB-MOS (от 27 апреля)
Наблюдения
COSMO-RU (от 26 апреля)
COSMO-RU (от 27 апреля)

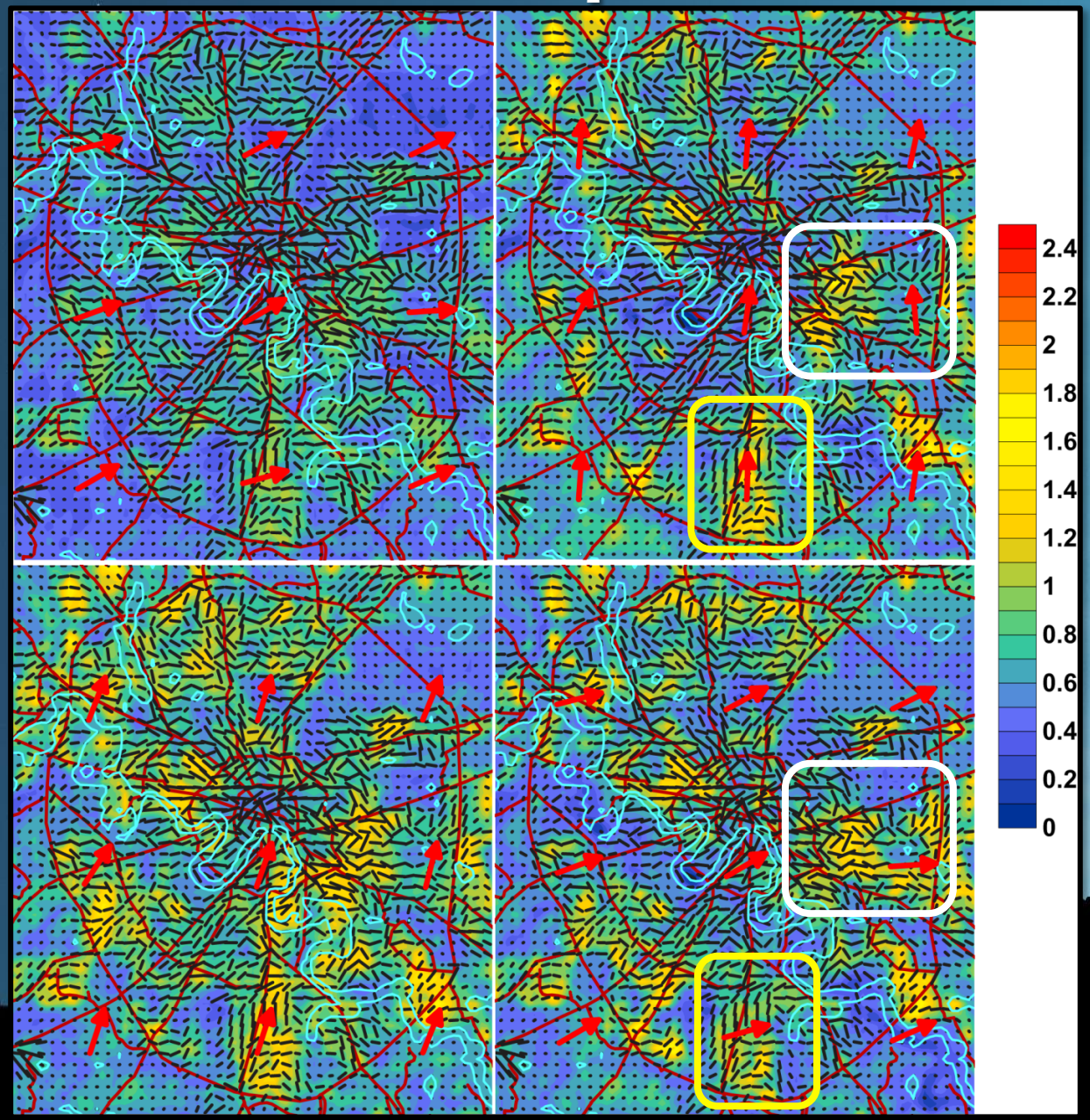
Temperature anomaly: april 2011



Temperature anomaly: April 2011



Wind speed


26 апреля, день
27 апреля, ночь
27 апреля, день
28 апреля, ночь
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

Urban heat island dynamics

SUMMARY

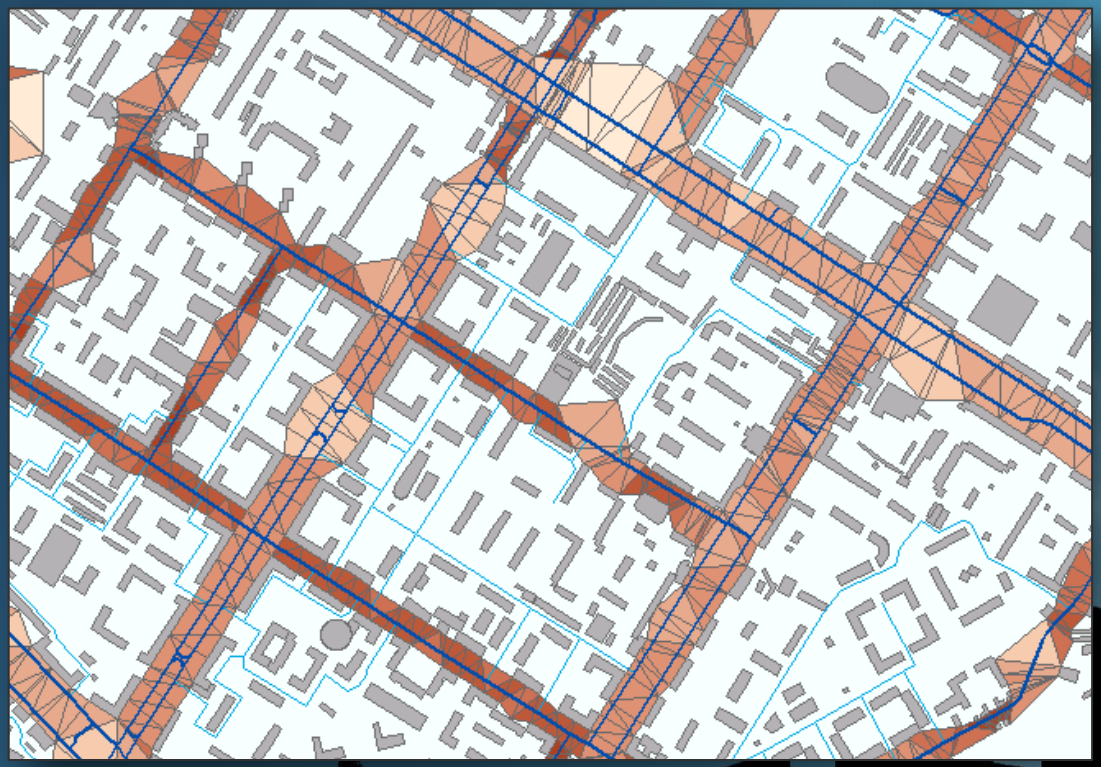
- ✓ Microscale Urban Canopy Model **URB-MOS was elaborated;**
- ✓ We develop new physical downcalling technology based on large urban surface parameters database **URB-MOS + COSMO-RU;**
- ✓ Modelling complex was successfully validated;

PERSPECTIVES: Experimental studies in 4 Russian Polar cities

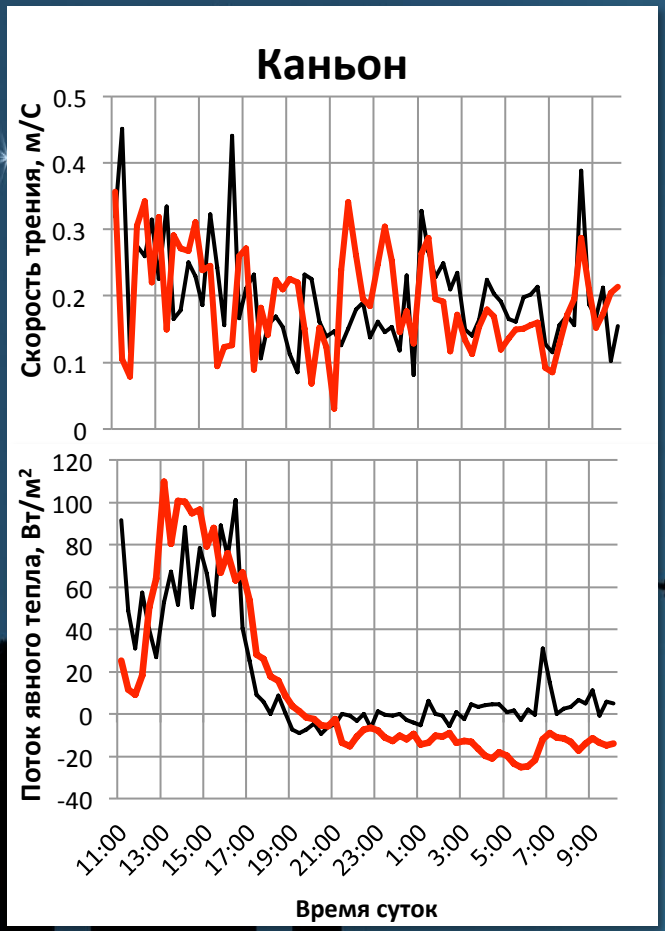
ИТОГИ РАБОТЫ

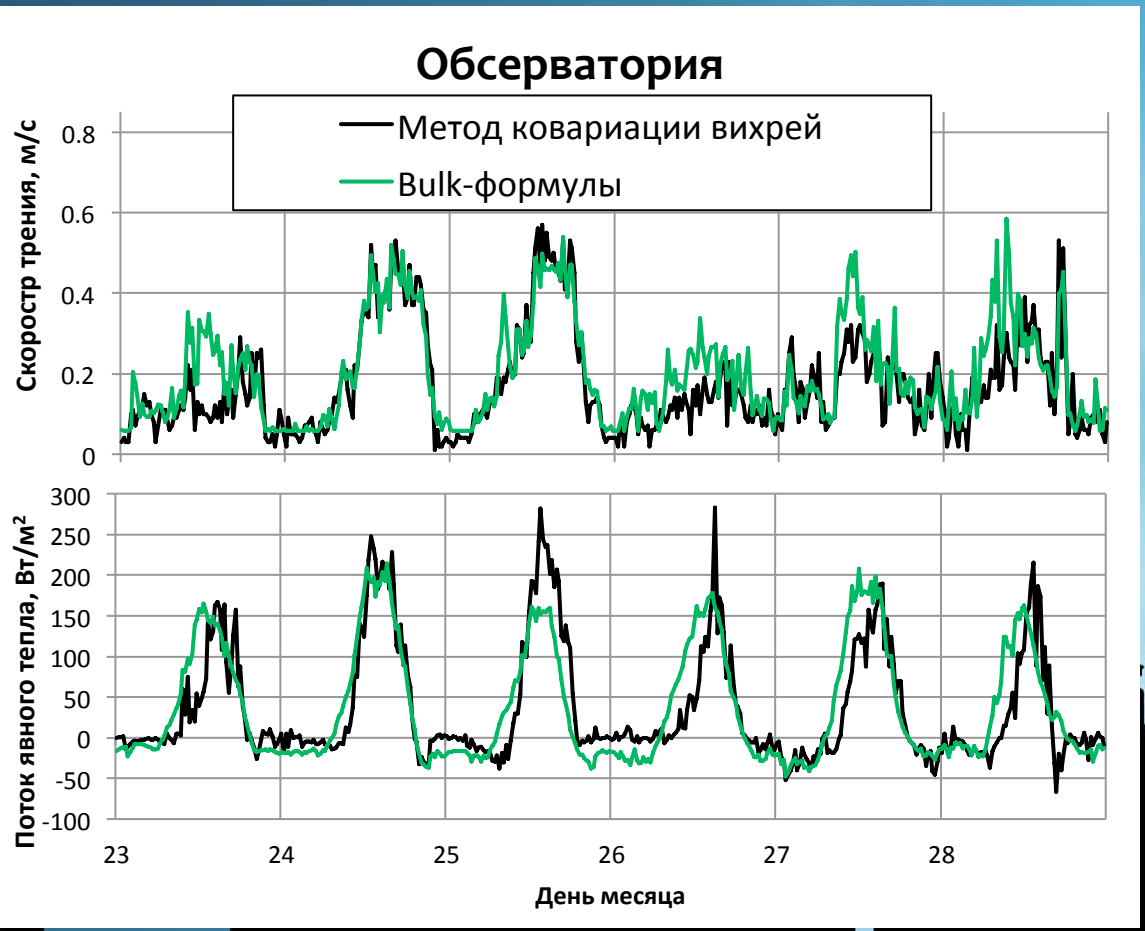
- ✓ Разработана **микромасштабная модель городского пограничного слоя UBR-MOS;**
- ✓ Разработан **метод уточнения и детализации прогнозов погоды для Москвы** на с помощью модельного комплекса URB-MOS + COSMO-RU;
- ✓ Проведена **успешная валидация** модельного комплекса;
- ✓ Изучены **особенности распределения метеовеличин** в Москве в апреле и августе;

ВЫДЕЛЕНИЕ ГОРОДСКИХ КАНЬОНОВ

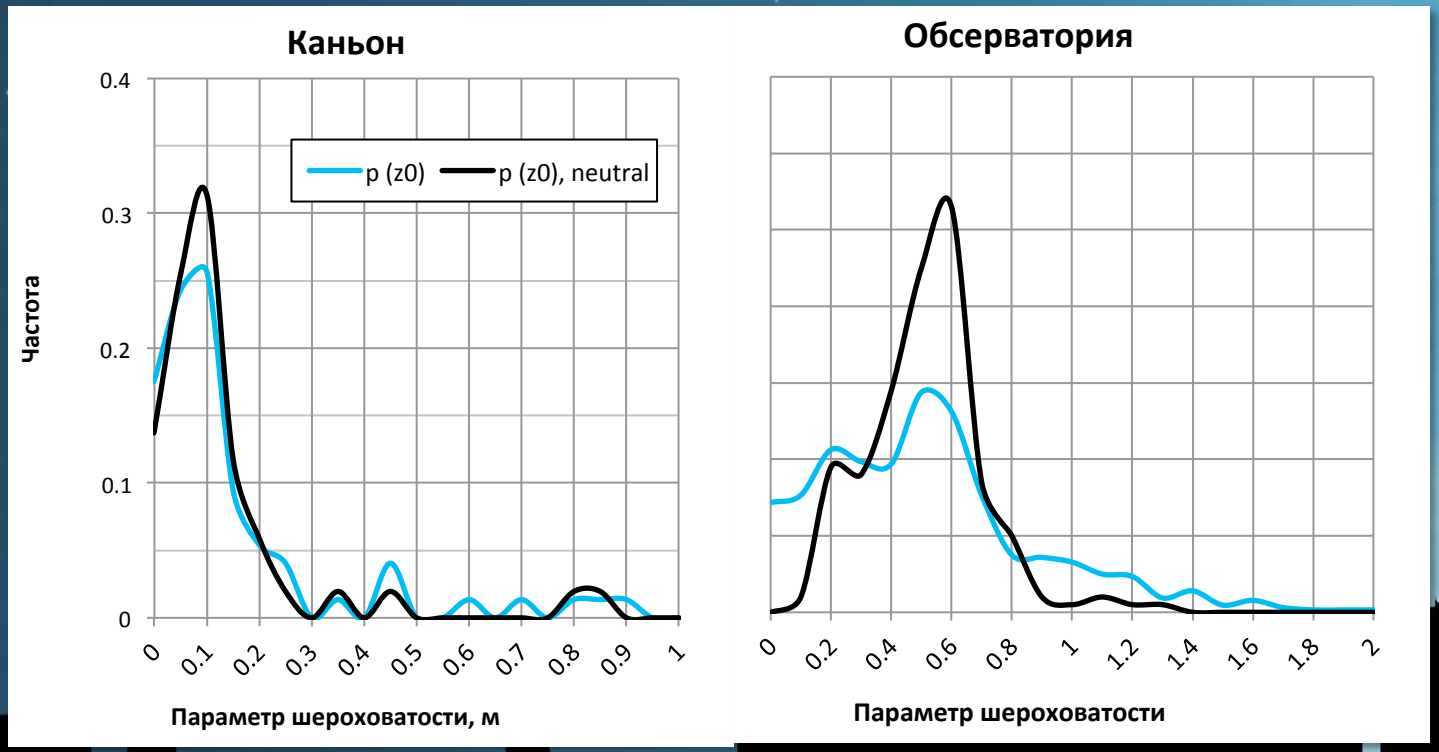


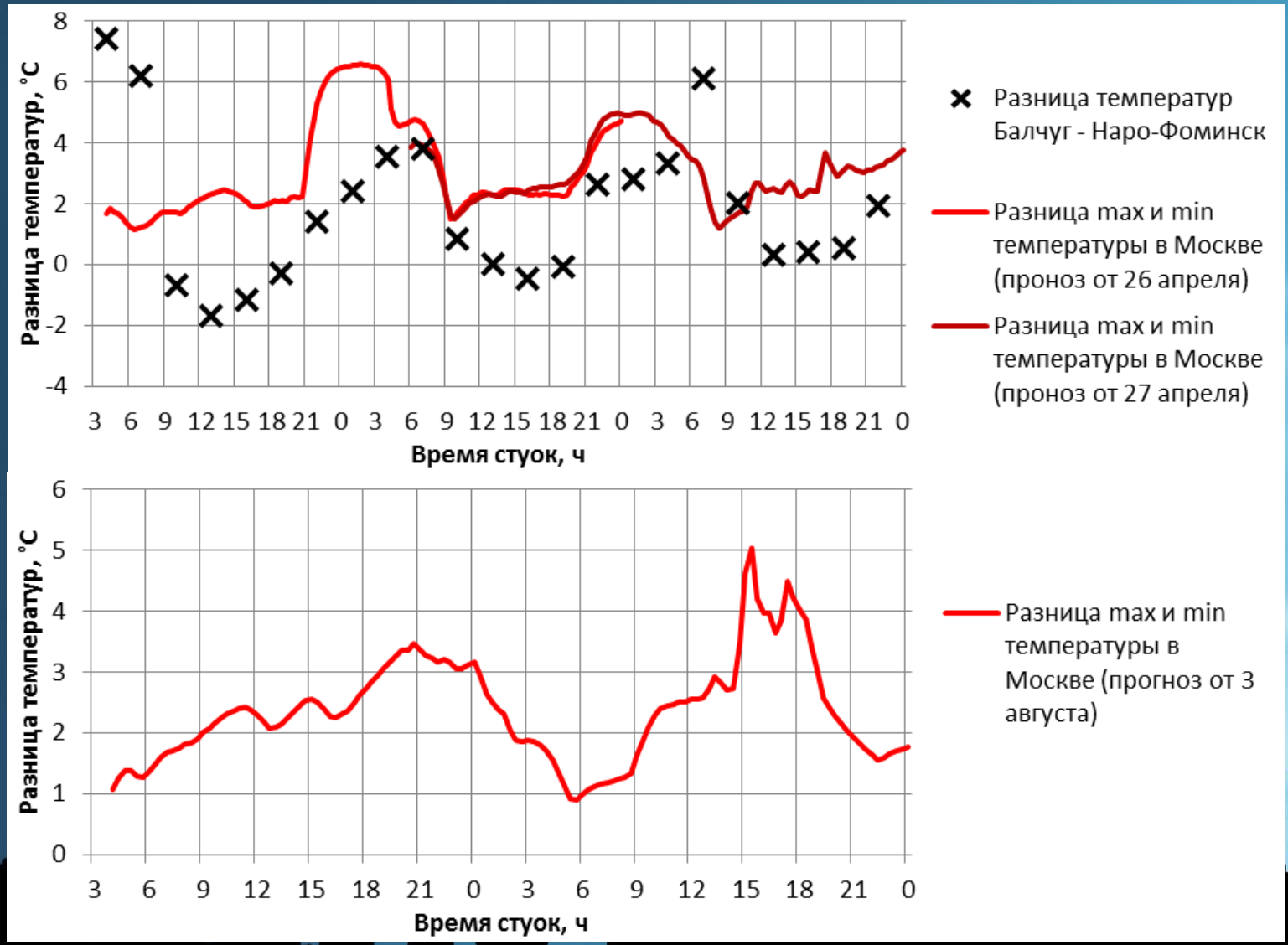
ТУРБУЛЕНТНЫЙ ОБМЕН





ЭКСПЕРИМЕНТАЛЬНОЕ ОПРЕДЕЛНЕИ ПАРАМЕТРА ШЕРОХОВАТОСТИ




Разница температур, °С
8
6
4
2
0
-2
-4
3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0
Время стуок, ч
Разница температур Балчуг - Наро-Фоминск
Разница max и min температуры в Москве (проноз от 26 апреля)
Разница max и min температуры в Москве (проноз от 27 апреля)
Разница температур, °С
6
5
4
3
2
1
0
3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0
Время стуок, ч
Разница max и min температуры в Москве (прогноз от 3 августа)