heat island in the urban environment and the synergy of the influence of heat waves and air pollution on population mortality

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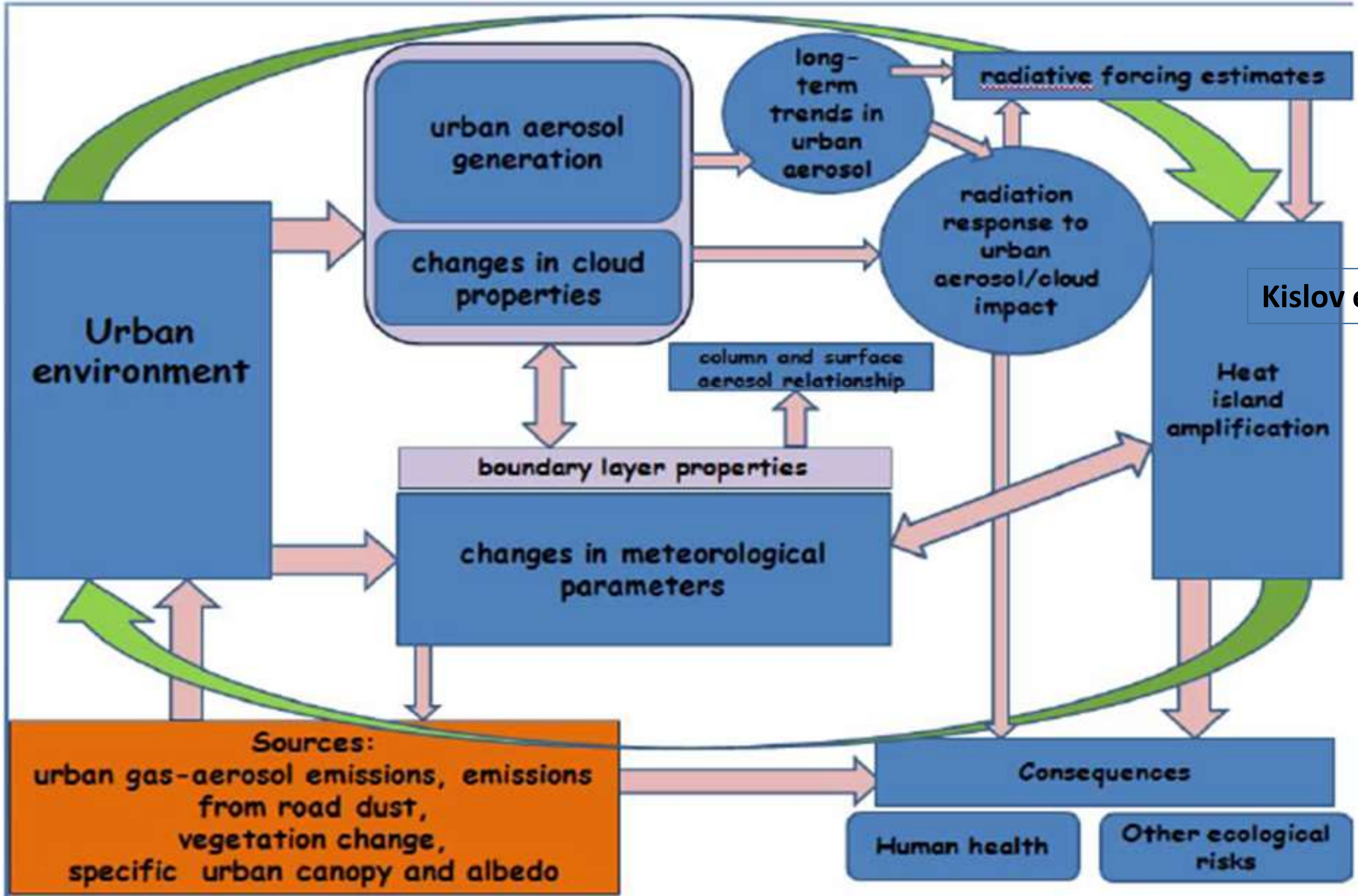
Outline:

- The description of the physical interaction between the processes in urban environment - WP3- tasks,
- Instruments: descriptions of available measurements and models,
- Analysis of long-term variability of atmospheric aerosol and radiation,
- Urban aerosols assessment,
- Moscow spring 2020 lockdown due to COVID-19 pandemic: specific features of gas-aerosol dynamics during the;
- Microscale modelling of the city environment
- Synergistic effects of heat waves and air pollution on urban mortality.

Structure of interactions of different processes within the WP3



Kislov et al; 2020

Instrumentations:

- ***Aerosol-Radiative interactions in urban conditions:***

- COSMO-ART / ICON-ART chemical transport models and COSMO/ICON forecast hydrodynamic models with a new experimental scheme for accounting cloud-aerosol interaction with a grid step of 1 km;
- The urban aerosol trends evaluation will be based on long-term aerosol measurements using AERONET site at Meteorological Observatory (MO) of Moscow State University (MSU) and, in parallel, AERONET measurements in the suburbs of Moscow;
- Long--term satellite measurements (MODIS/MAIAC, MISR), and a joint satellite aerosol product (Sogacheva et al., 2020).
- The datasets of air pollutants concentrations from Mosecomonitoring Agency.
- The aerosol measurements provided from WP2. The planning measurements of black carbon concentration (WP2 results) will be used to assess its impact on the absorbing properties of urban aerosol as well as detailed 3D spatial model simulations (WP2 results).
- The radiation effects of aerosol pollution will be evaluated based on long-term radiation measurements at the MO MSU and using radiative transfer models and COSMO-ART model.

- ***Micro-climatic modelling:***
- The ENVI-met microclimatic model complex with a bunch of necessary meteorological, and radiative input parameters from the dataset of MO MSU.

- ***The influence of heat waves and air pollution on population mortality***
- Different statistical models, well as the datasets of air pollutants concentrations from Mosecomonitoring Agency and meteorological data from MO MSU and Rosstat Agency.

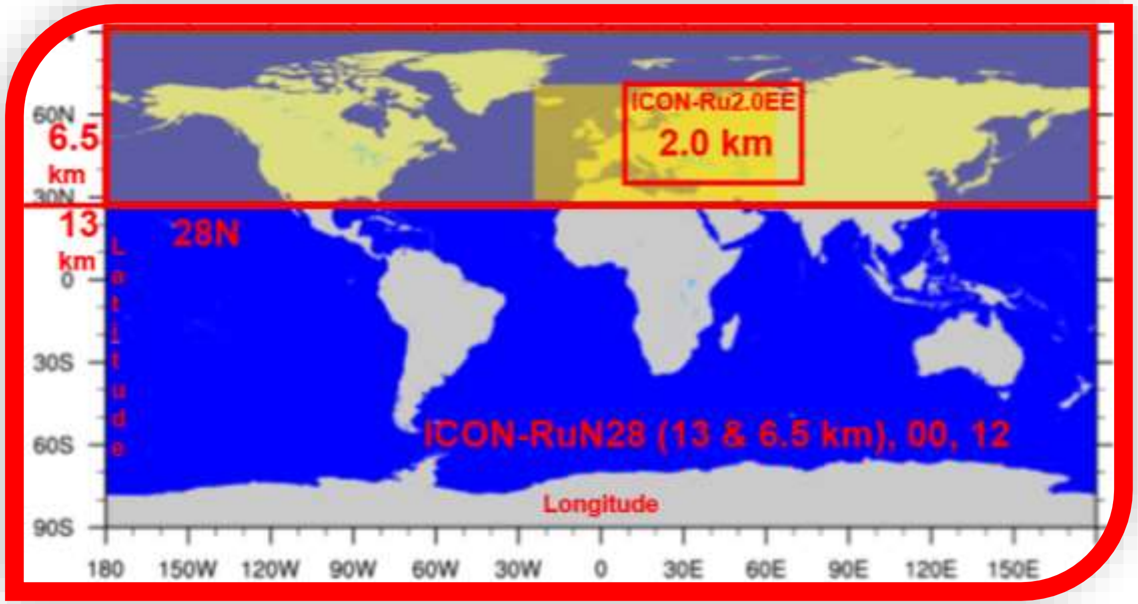
COSMO Consortium:

8 National Meteorological Services

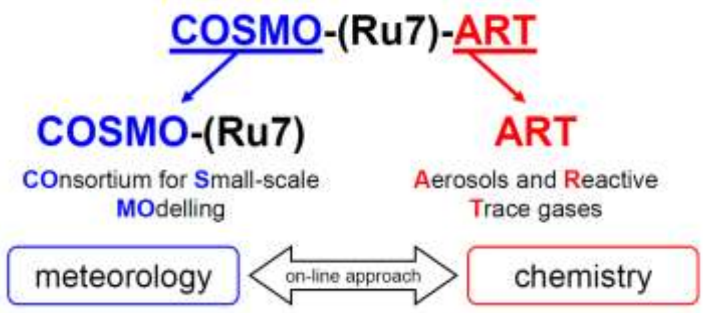
New:
Global ICON-RuN28

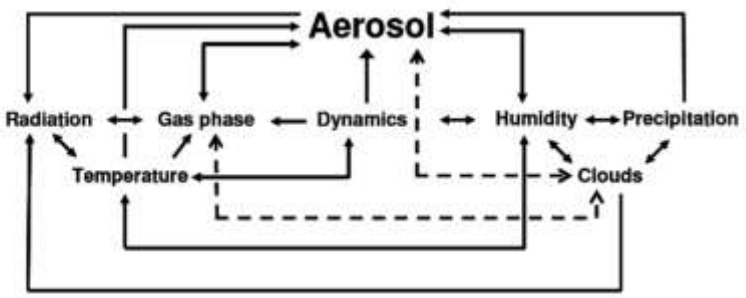
With **ICON-Ru2EE – LAM**

(Eastern Europe, шаг 2.0 км)



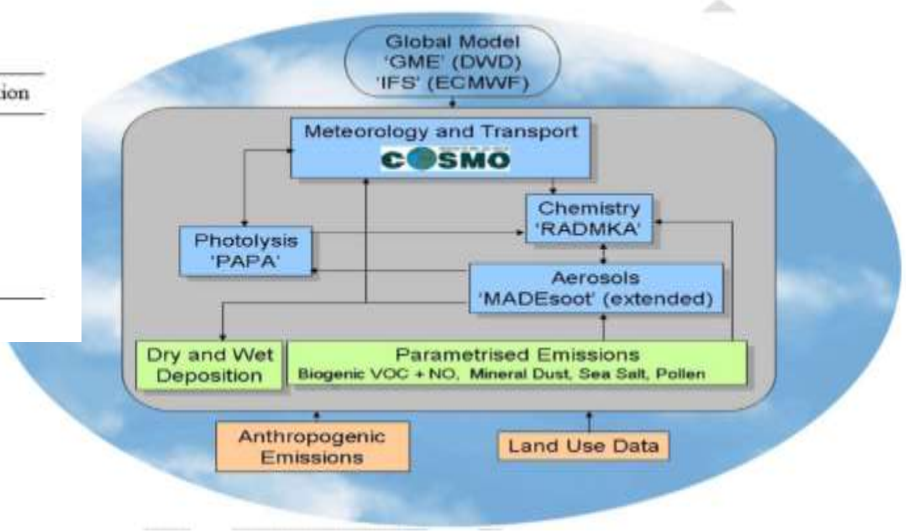
COSMO-ART model and experimental data



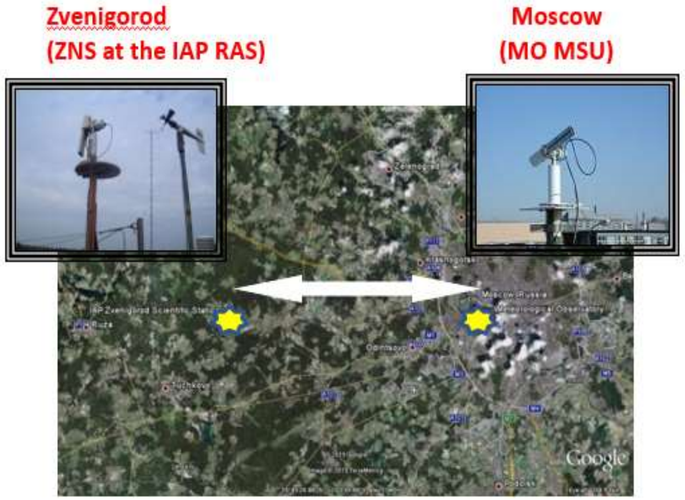


Mode	Chemical composition and mixing state	Standard deviation
if	SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA (internally mixed)	1.7
ic	SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, soot (internally mixed)	1.7
jf	SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA (internally mixed)	2.0
jc	SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, soot (internally mixed)	2.0
s	soot	1.4
c	direct PM_{10} emissions	2.5

Satellite Modis/MAIAC and MISR dataset with 1 km retrievals



AOD (total) =AOD (regional) +AOD(urban) from the two AERONET sites



B. Vogel, et al. ACP, 2009
Vil'fand et al., 2017

Monitoring program

Meteorology

Standard meteorology;

Automated meteorological station (Vaisala);

Sodar program

Radiation

net radiation components (direct, diffuse, global irradiance, longwave components)

UV-B, UV 300-380nm radiation since 1968

BSRN station will be purchased in 2021

Precipitation quality

concentration of SO_4^{2-}, HCO_3^-, Cl^-, NO_3^- Ca^{2+}, Mg^{2+}, Na^+, K^+ NH_4^+ and pH in each rain and snowfall

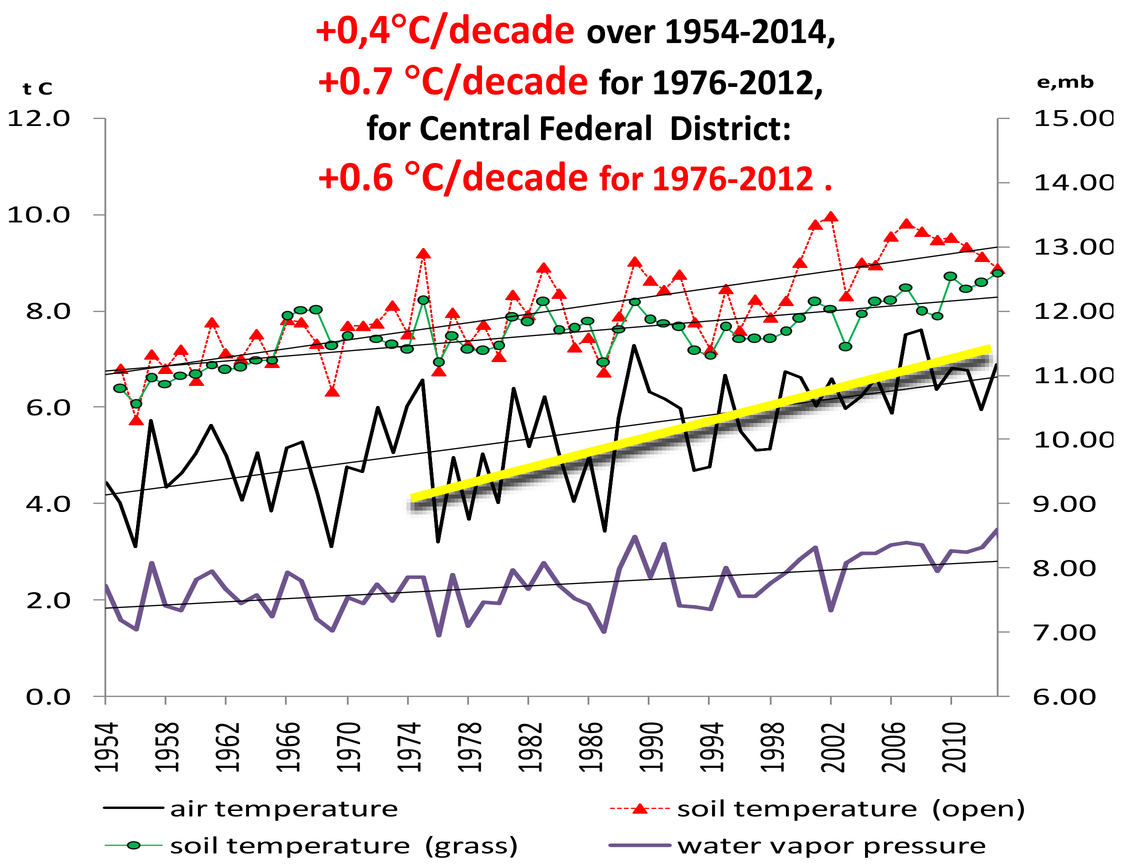
Urban aerosol and air quality

Aerosol properties in the column (AERONET) and the gas-aerosol surface measurements monitoring (part of the Mosecomonitoring measurement program)

New aerosol station

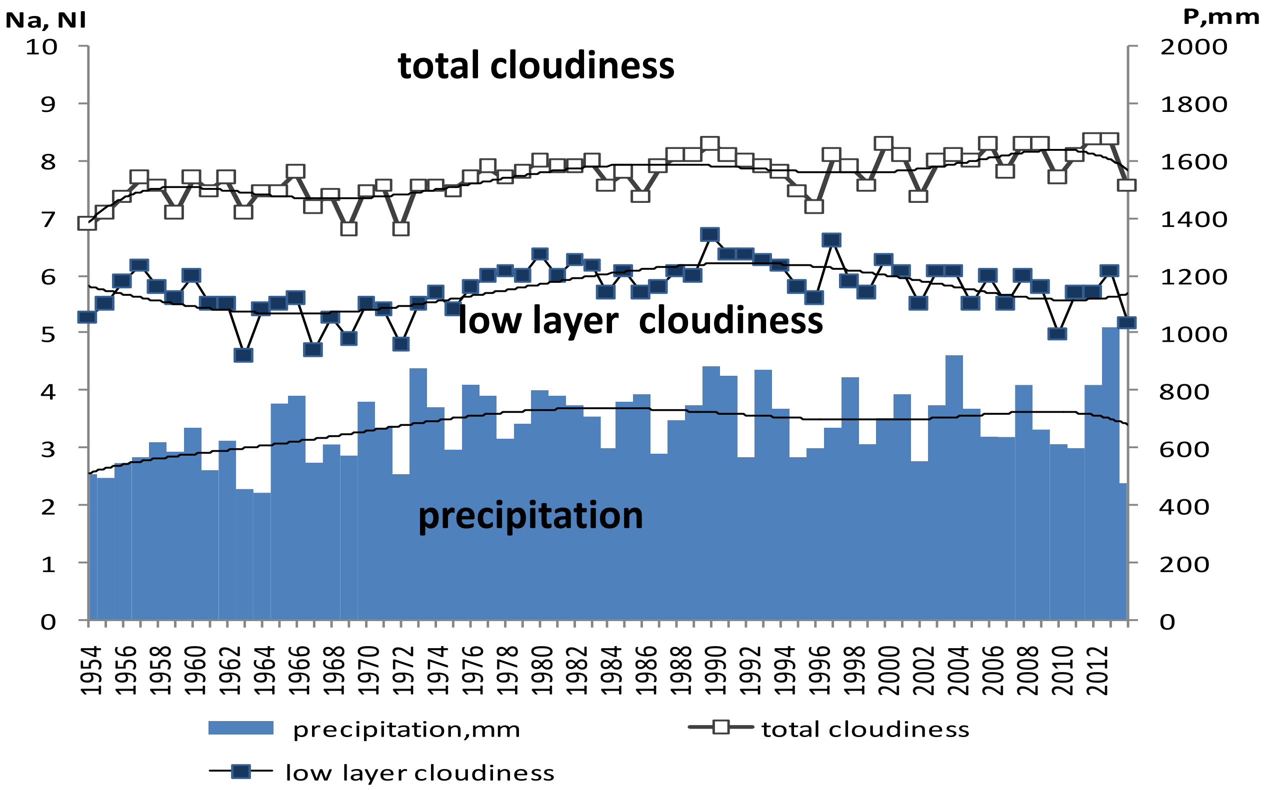
Interannual variations in meteorological characteristics: air temperature, soil temperature, water vapor pressure, total, low cloud amount, and precipitation.

Moscow air temperature:



Trend in water vapor pressure is +0.12 hPa per decade

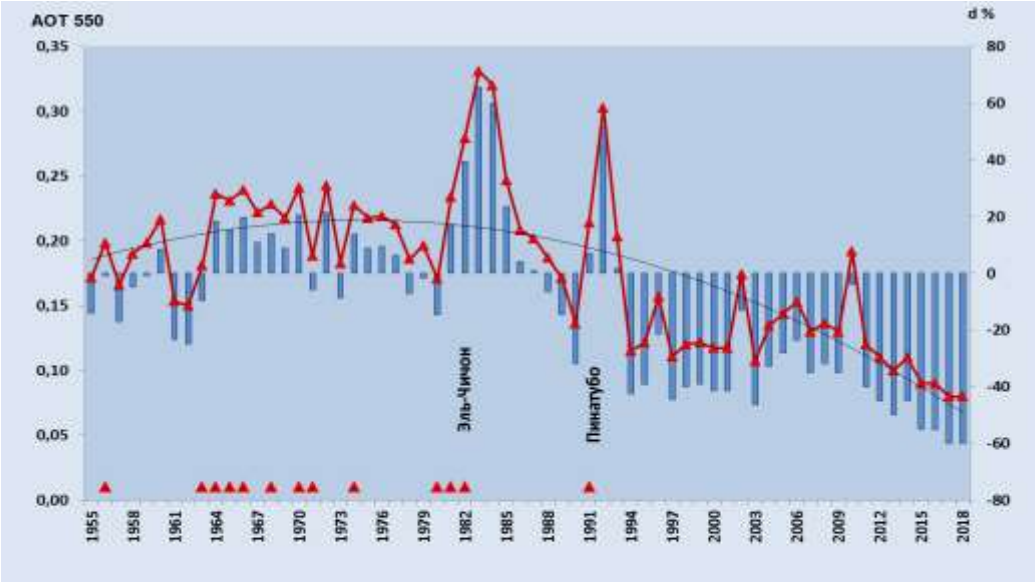
Moscow, MSU MO dataset

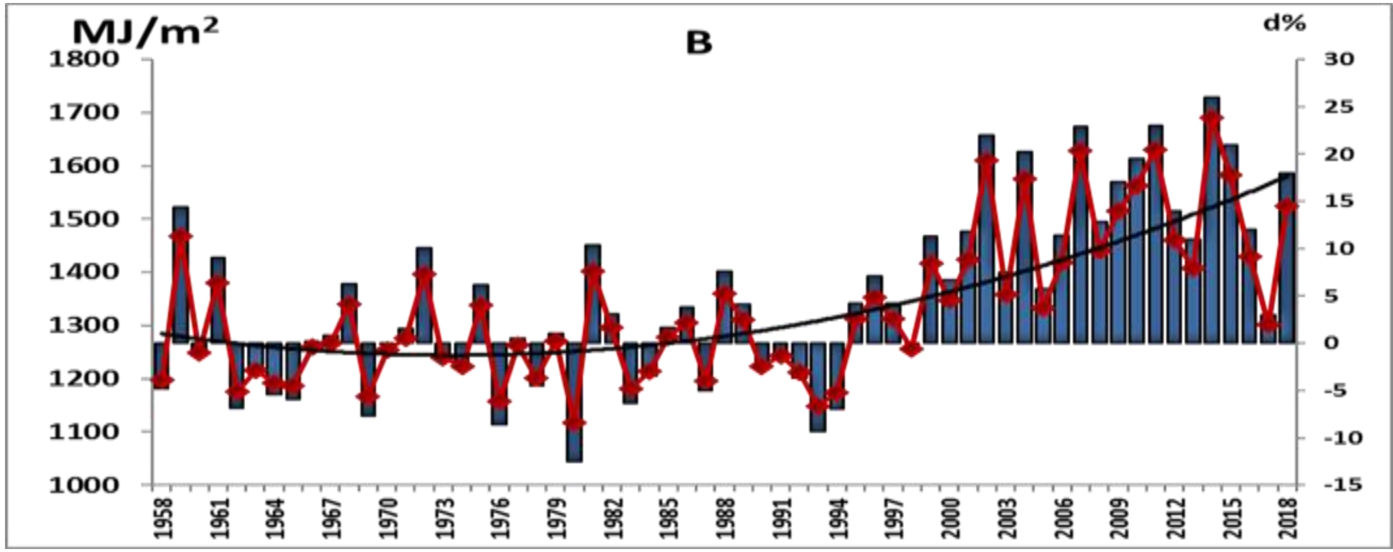


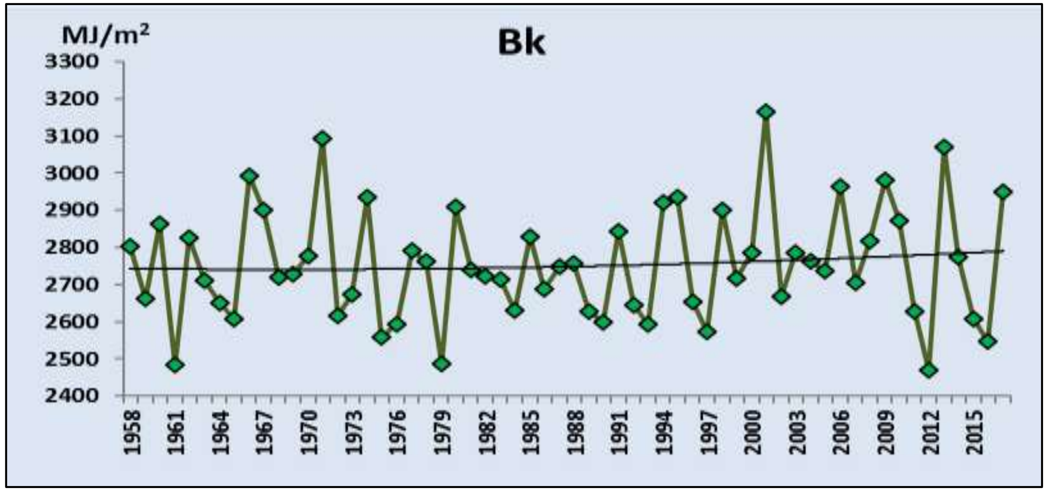
Trend in total cloudiness +0.1 per decade

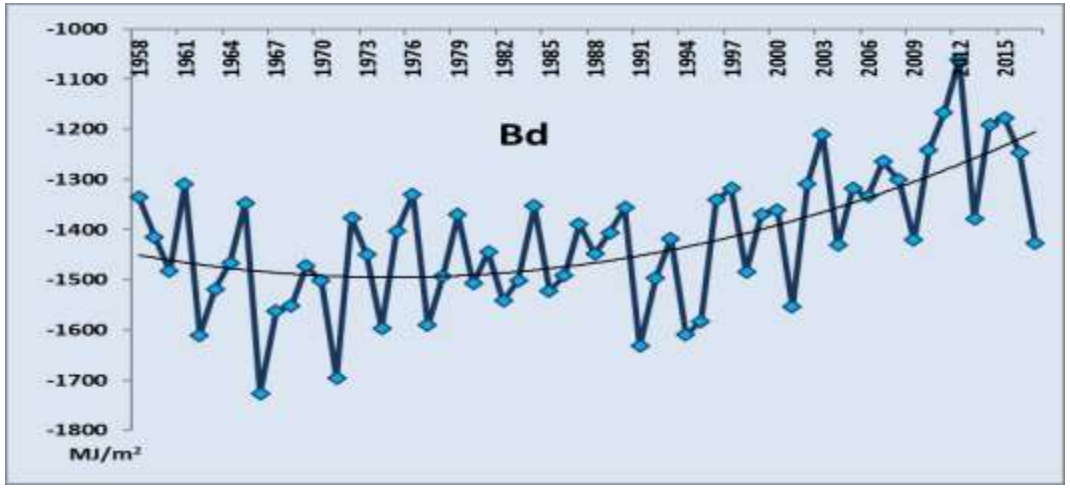
From Chubarova et al., 2014, Russian Meteorology and Hydrology

Long-term aerosol optical depth AOD550 changes retrieved from direct solar irradiance and water vapor content (Tarasova, Yarkho, 1991) and changes in total net radiation (B) and its shortwave (Bk) and longwave (Bd) components.





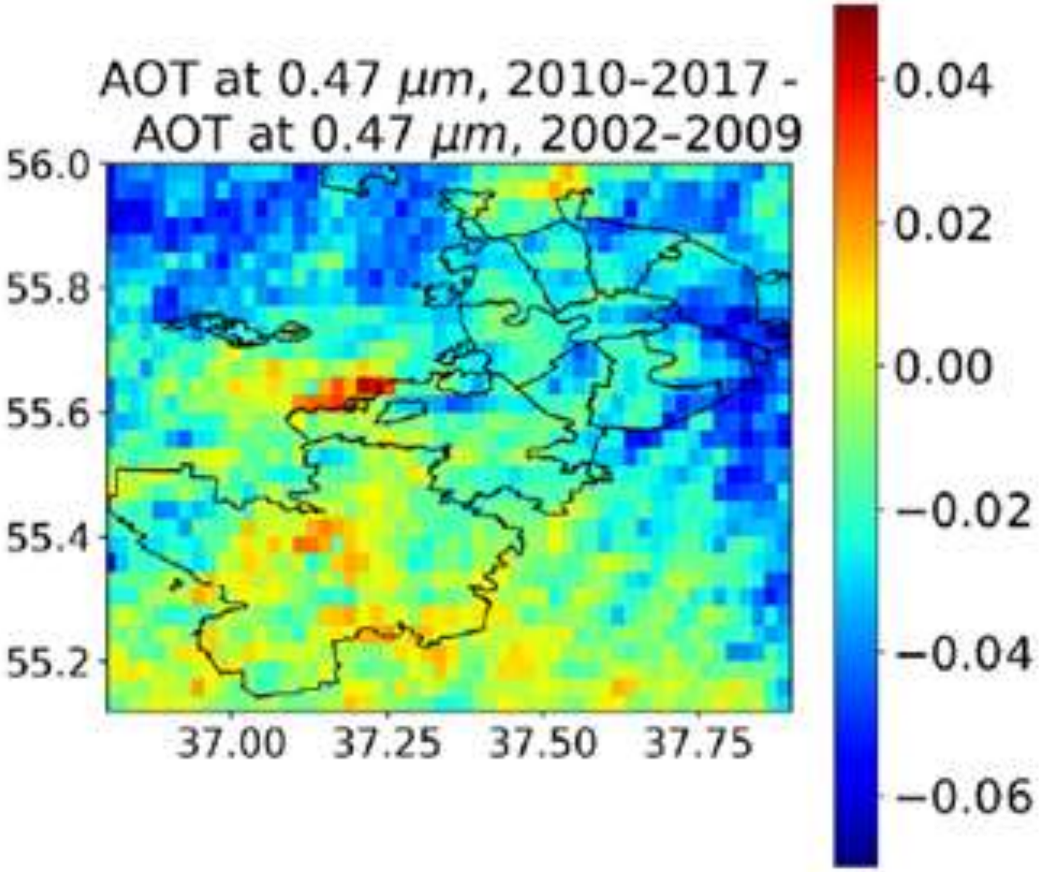




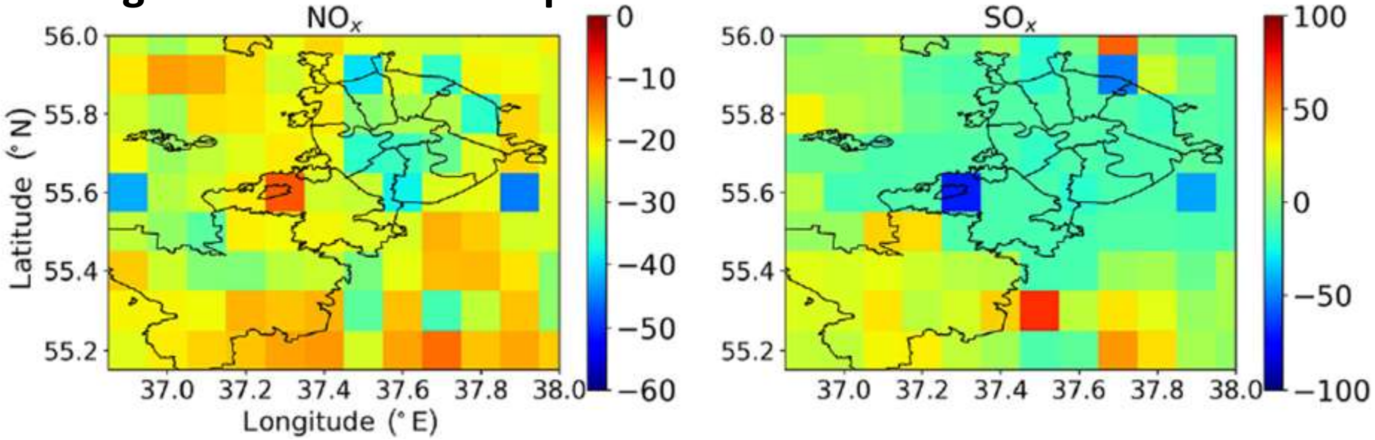
Updated from Gorbarenko, 2020

Satellite AOD urban retrievals:

The AOD MAIAC/MODIS median difference between the 2010-2017 and 2002–2009 periods



Changes in urban aerosol precursors:



From Zhdanova, Chubarova, Lyapustin, AMT 2020

Columnar AOD500 and AOD500 fine and coarse modes versus PM10 for different classes of intensity of pollutant dispersion (IPD). 2018-2019

IPD1 – very stable atmosphere

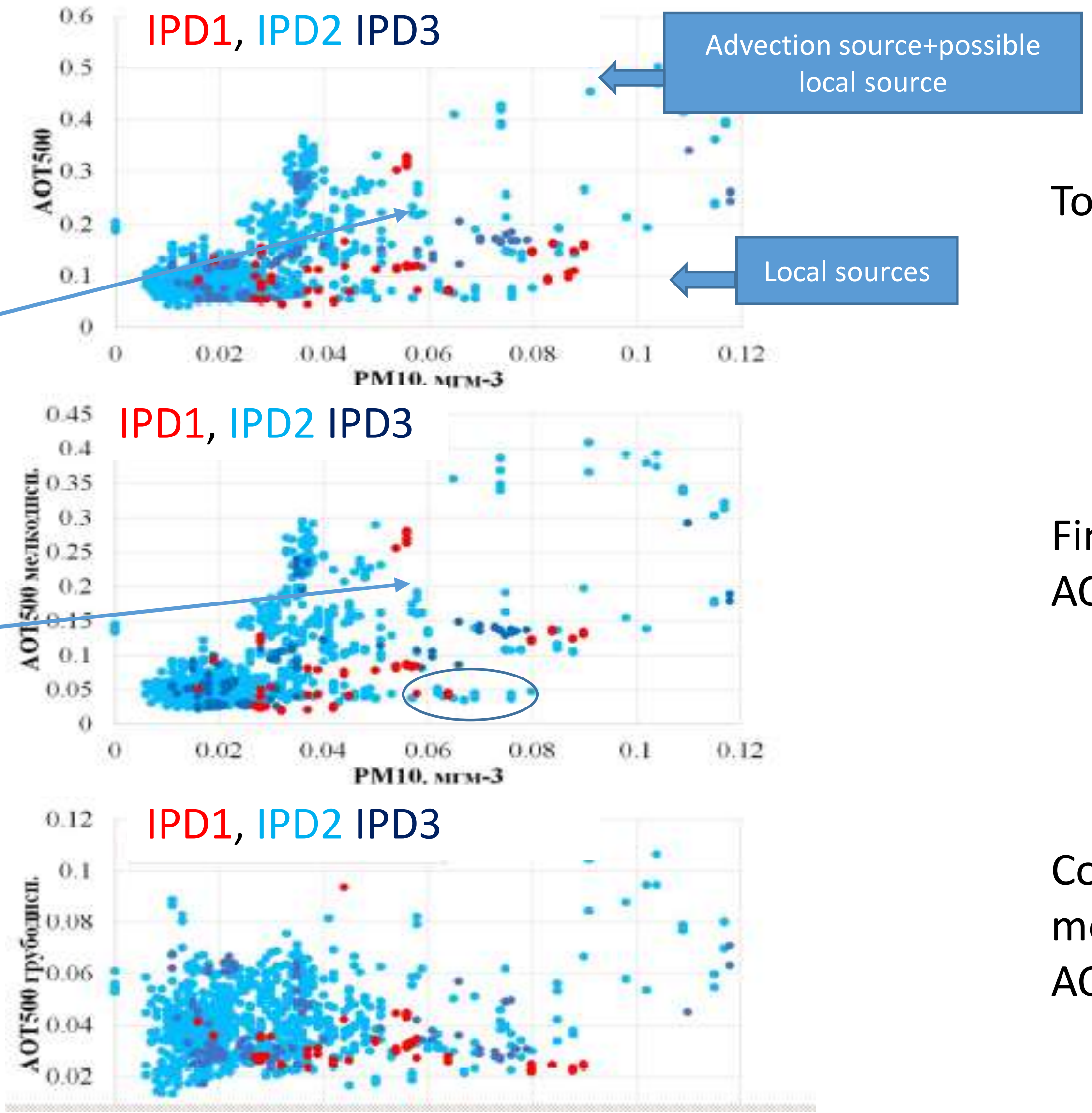
IPD2 - intermediate

IPD3 – unstable atmosphere

Bifurcation point

Bifurcation point

No bifurcation point for coarse fraction

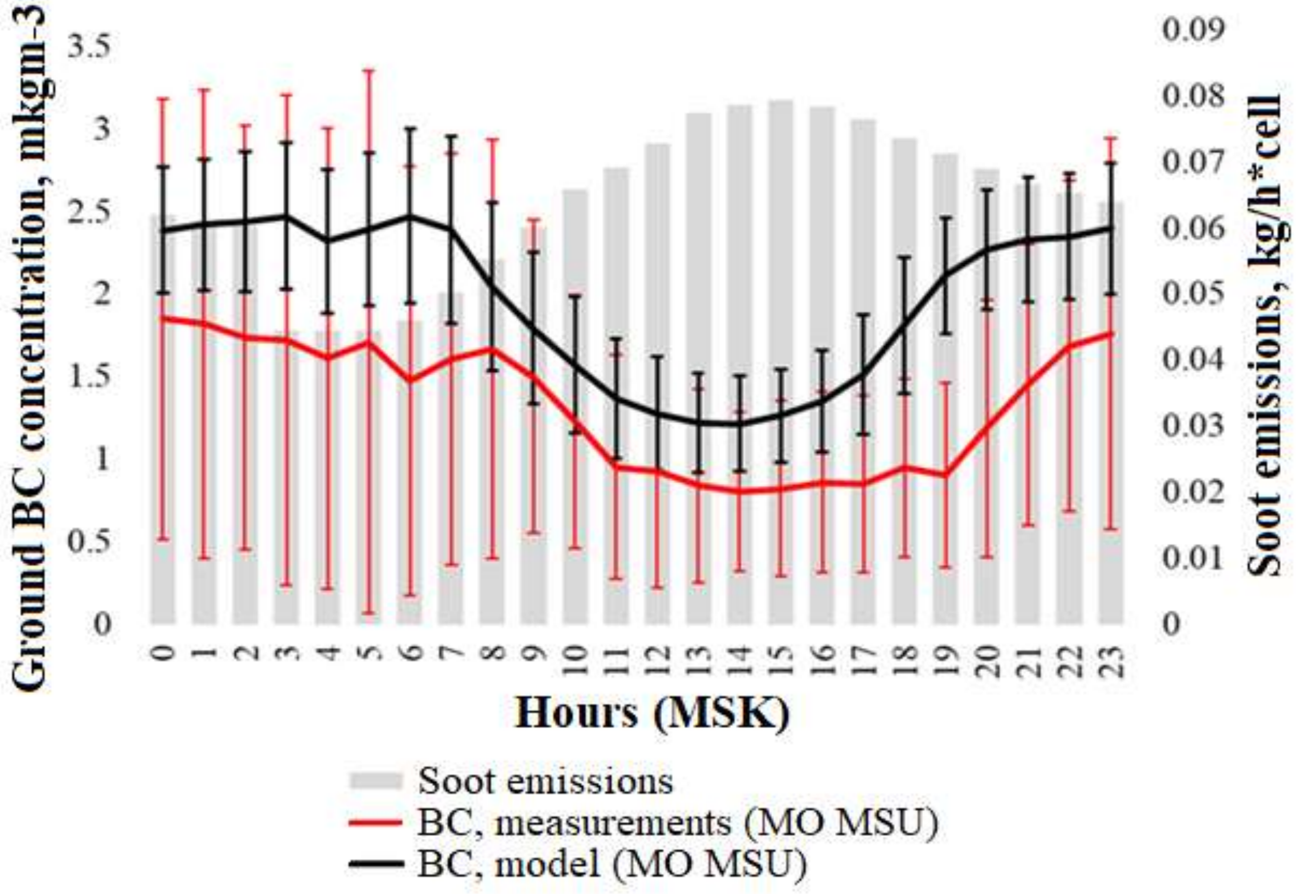


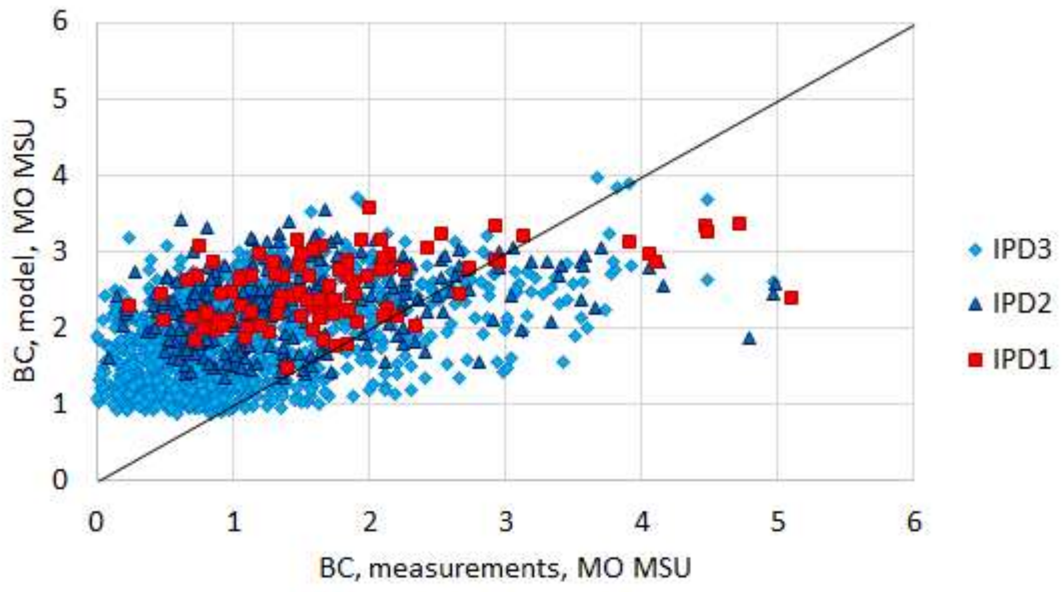
Total AOD

Fine mode AOD

Coarse mode AOD

Black carbon aerosol: comparisons between model (COSMO-ART) and measurements. *2018-2019 AeroRadCity experiment.*





IPD1 – very stable atmosphere
IPD2 - intermediate
IPD3 – unstable atmosphere

BC measurements at the MSU MO were carried out by Dr. O.B. Popovicheva (2020)

Chubarova et al. Regional aerosol pollution….Monograph, 2020

Measured and modelled (COSMO-ART) mass concentrations of Black Carbon (BC) versus PM, NO_2 and SO_2 at different Intensity of Particle Dispersion (IPD) levels

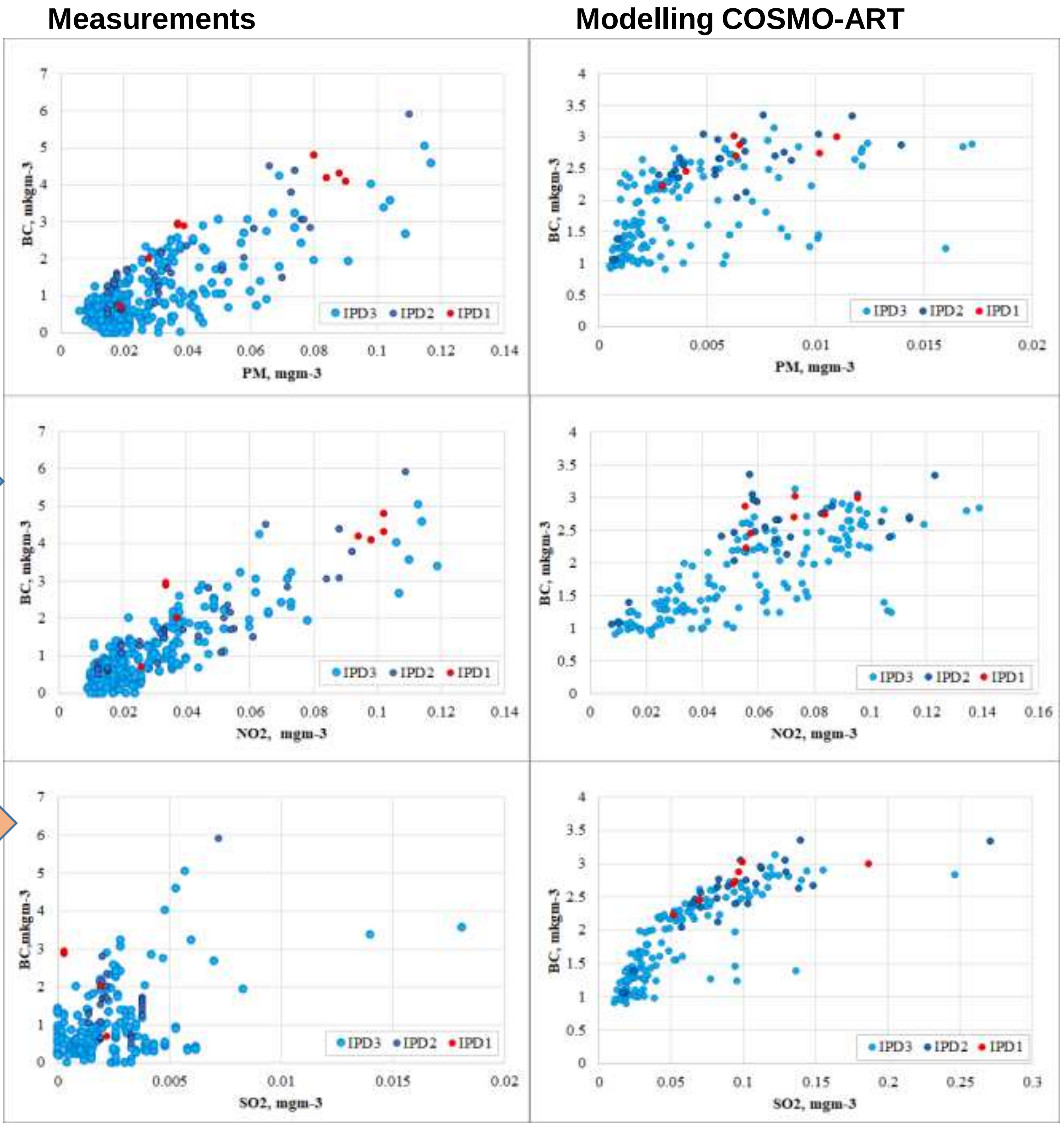
An existing correlation between BC and NO_2 concentrations due to same source of traffic emissions.

No correlation between measured BC and SO_2 due to extremely low SO_2 concentrations in Moscow in contrast with modelled data.

IPD1 – very stable atmosphere

IPD2 - intermediate

IPD3 – unstable atmosphere

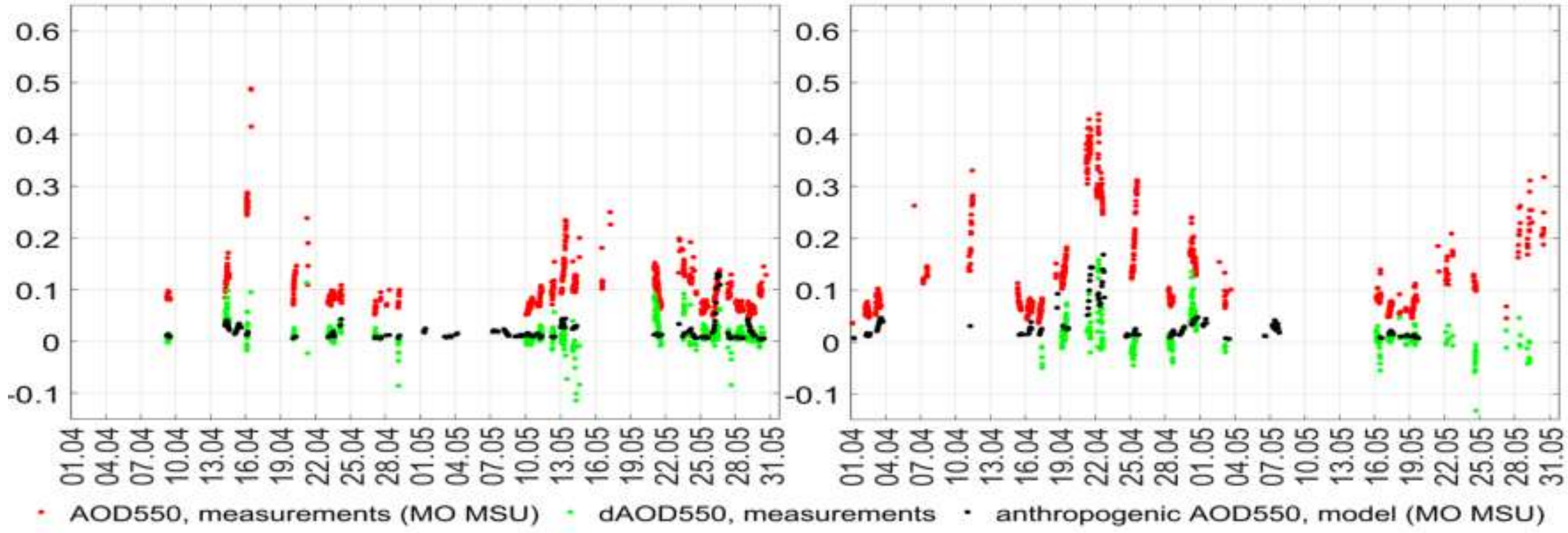


From Chubarova et al. Regional aerosol pollution….Monograph, 2020

Time series of the observed and modelled (COSMO-ART) AOD difference between Moscow and background conditions (measured urban AOD550 shown in Green and model urban AOD550 - in Grey or black dots) and observed total AOD in Moscow (in Red). 2018-2019.

AOD urb =AOD (Moscow) -AOD(Zvenigorod)

quasi-clear sky



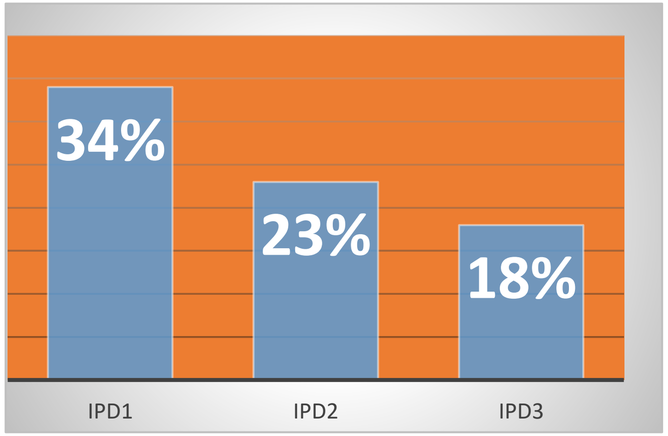
Compare black dots with Green dots

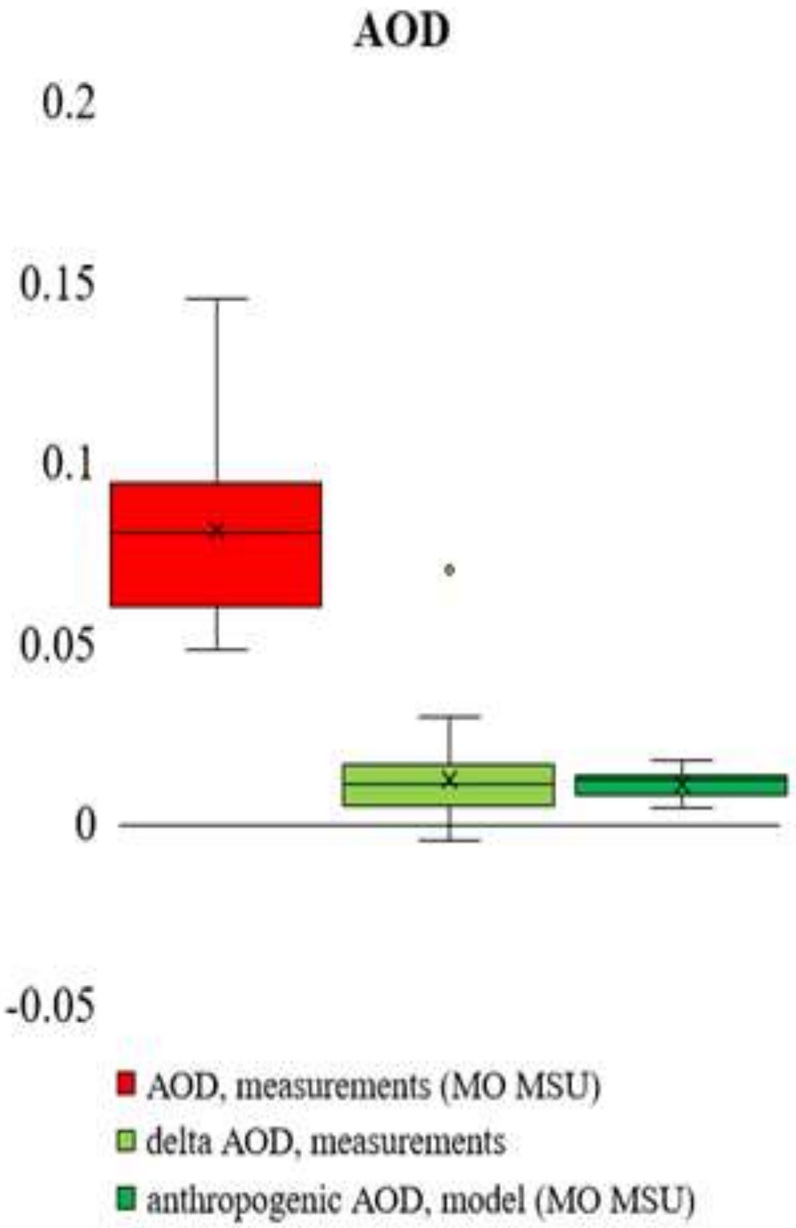
From Chubarova et al., Monograph Regional aerosol pollution…. 2020

Measured and modelled urban AOD

Main statistics on AOD550 and their urban components in conditions with no advection from Moscow at background Zvenigorod site. Quasi-clear conditions.

Ratio of AOD urban /AOD tot is about 18-34% depending on atmospheric stability conditions



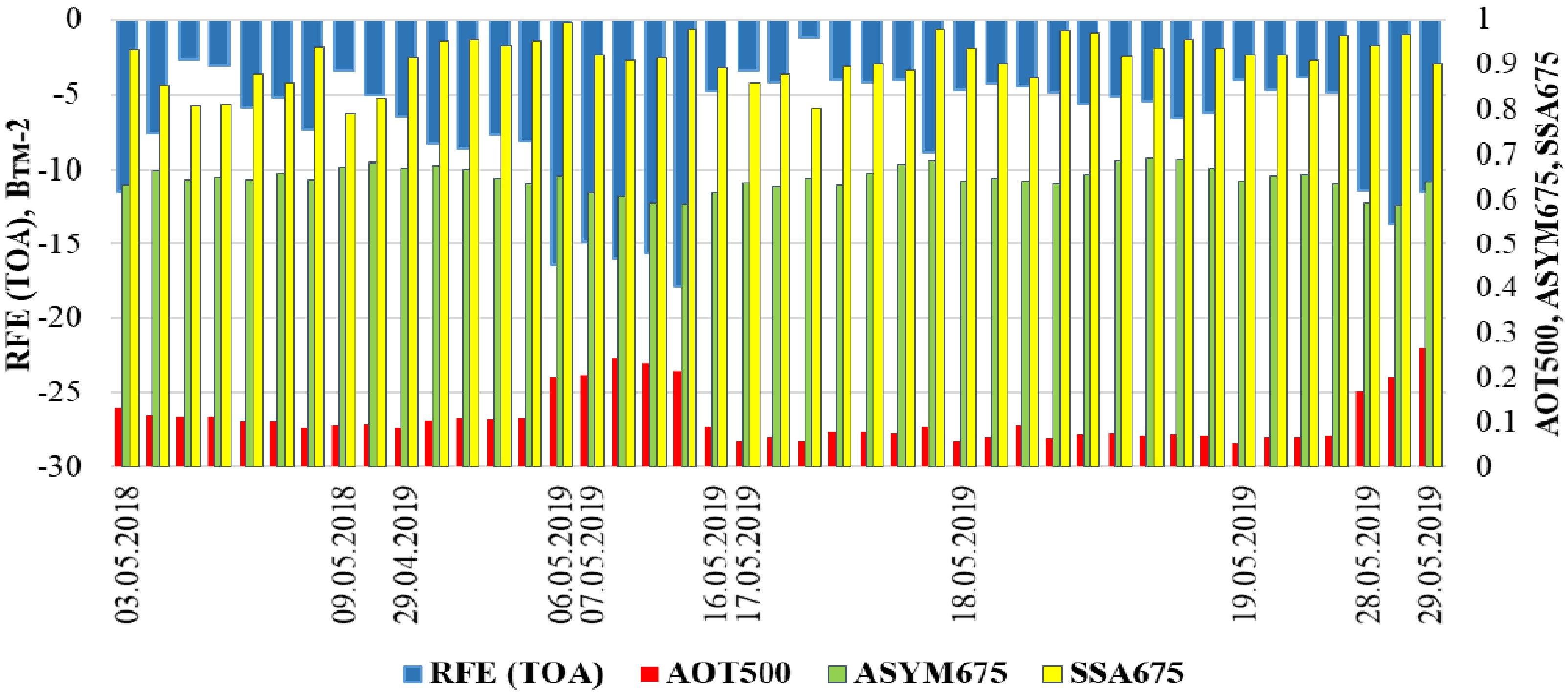


PARAMETER	Median values:
AOD, measurements (MO MSU)	0.080
urban AOD, measurements	0.010
Urban AOD, model	0.012
PM, measurements (MO MSU), mgm-3	0.026
Urban PM, model, mgm-3	0.003
BC, measurements (MO MSU), mkgm-3	1.06
Urban BC, model (MO MSU) mkgm-3	1.94

From Chubarova et al. Regional aerosol pollution….Monograph, 2020

Radiative effects:

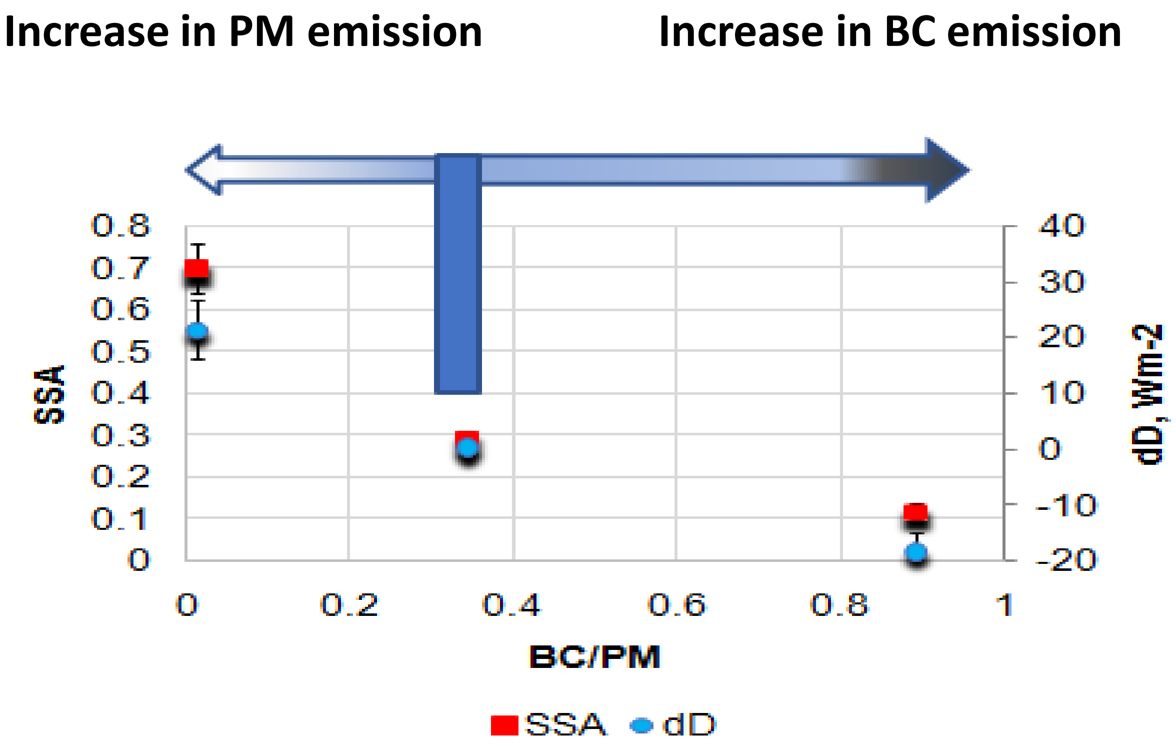
Aerosol radiative forcing effect (RFE) at the top of the atmosphere and aerosol characteristics in clear sky conditions during the experiment.



The changing RFE from -18 Wm^2 to -1 Wm^2 are due to both smaller AOD and SSA.

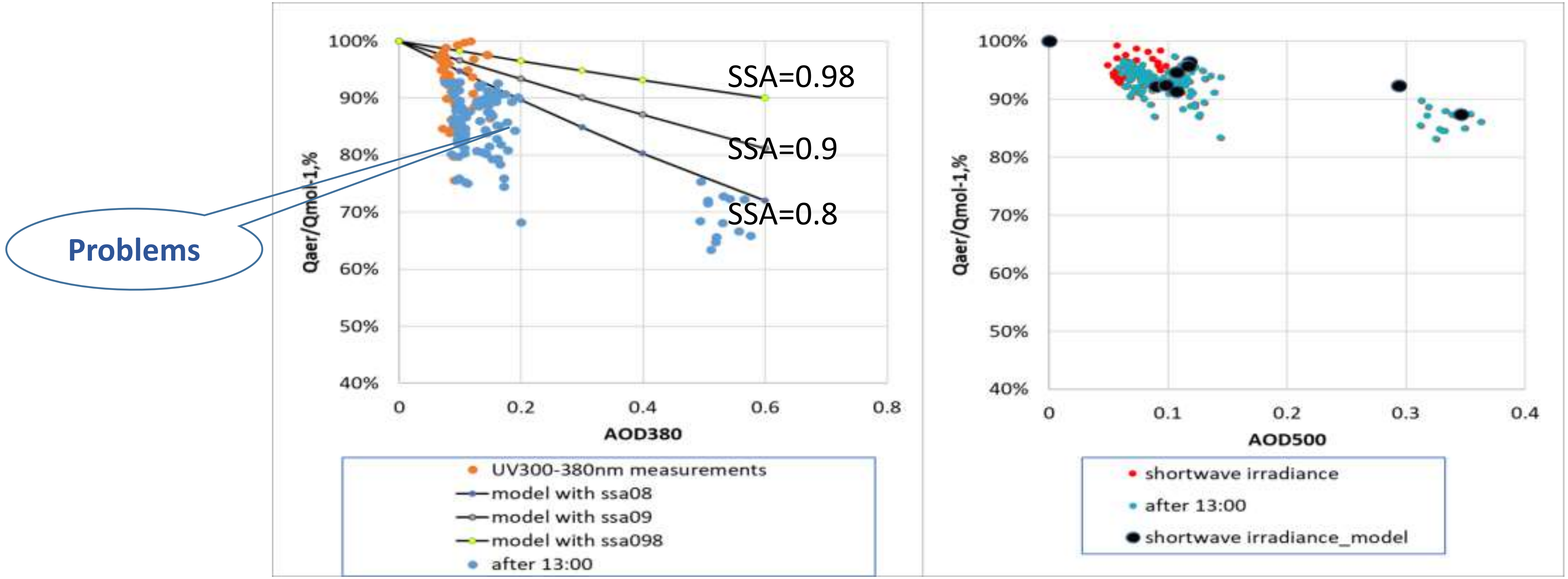
From Chubarova et al., 2020

Single scattering albedo and the difference in diffuse solar radiation due to the changes of BC/PM10 at surface layer according to COSMO-ART



Radiative effects:

The dependence of normalized on molecular atmosphere UV (left) and shortwave (right) irradiance on aerosol optical depth according to observations and radiative transfer DISORT model. Clear sky conditions.



Chubarova et al., 2019

Diurnal dynamic of aerosol optical depth, single scattering albedo diffuse and net radiation at ground. Clear sky conditions. May 18 2019. COSMO-ART. TNO 2009 emissions.

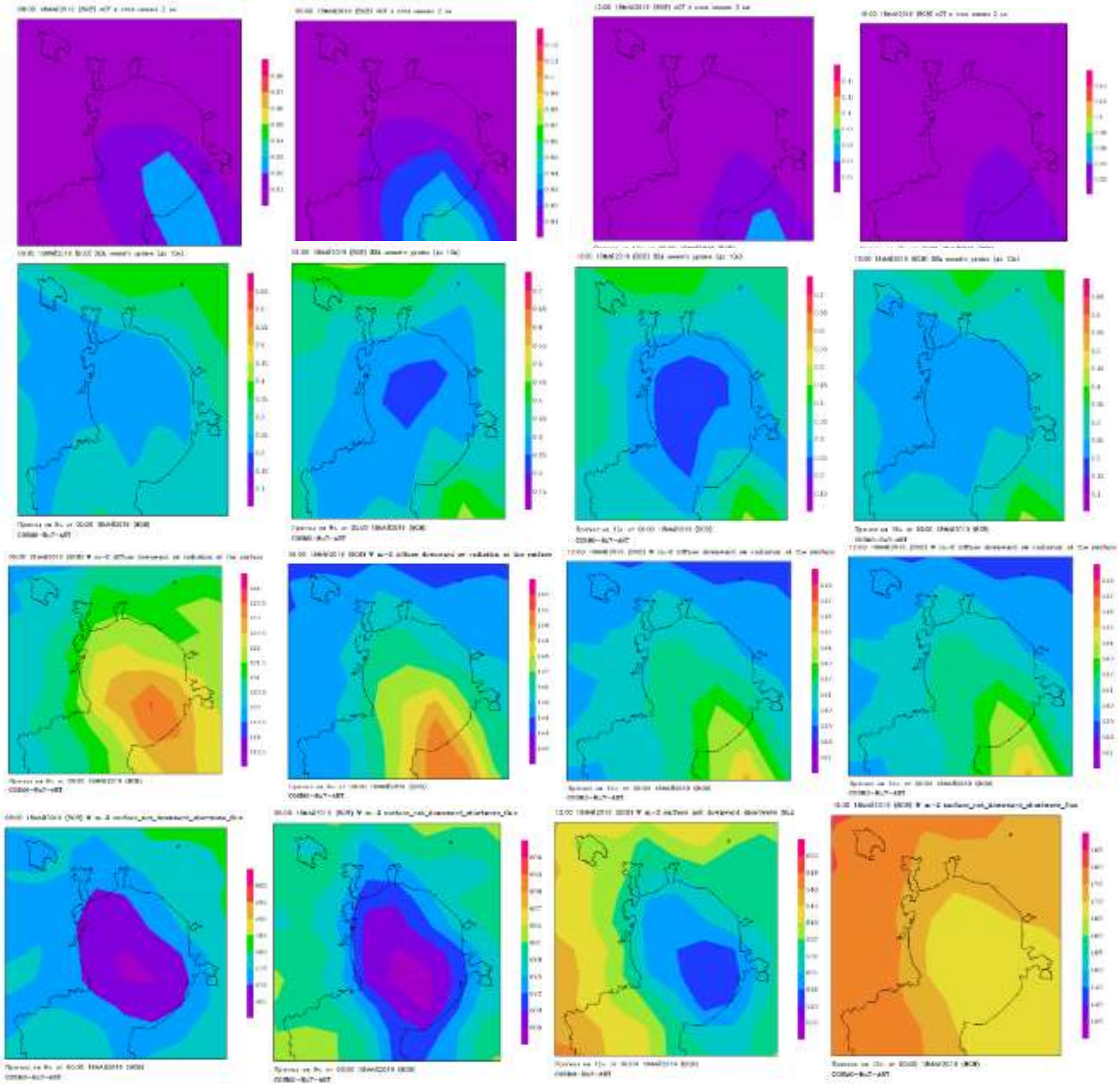
	6 h	9 h	12 h	15 h

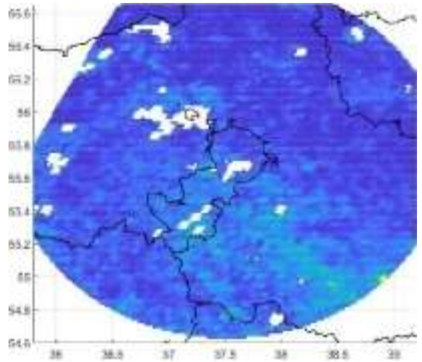
AOT

SSA

Diffuse radiation

Net radiation

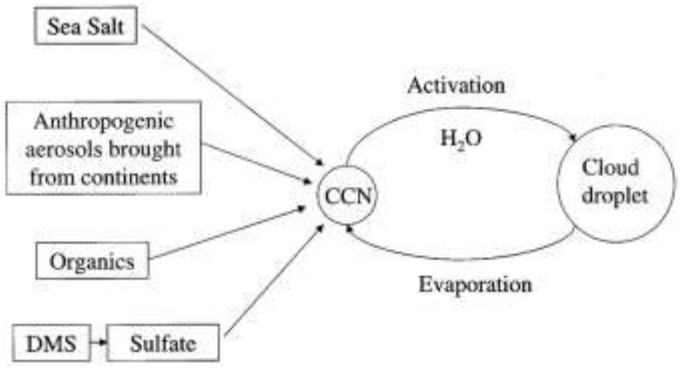




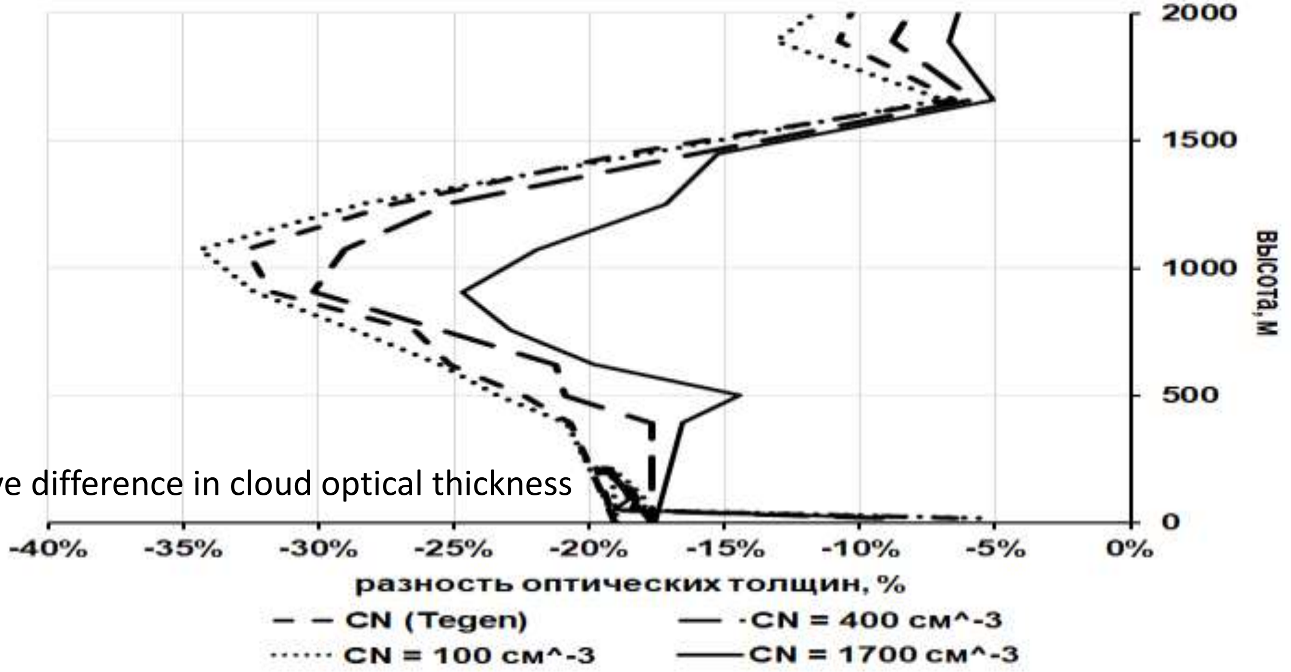
AOD MODIS /MAIAC
May 18 2019.

Non-direct aerosol effects:

Relative difference in cloud optical thickness according to COSMO-Ru simulations with a cloud-aerosol interaction computational scheme using different numbers of Cloud Condensation Nuclei (CCN) against simulations with the standard approach, Moscow.



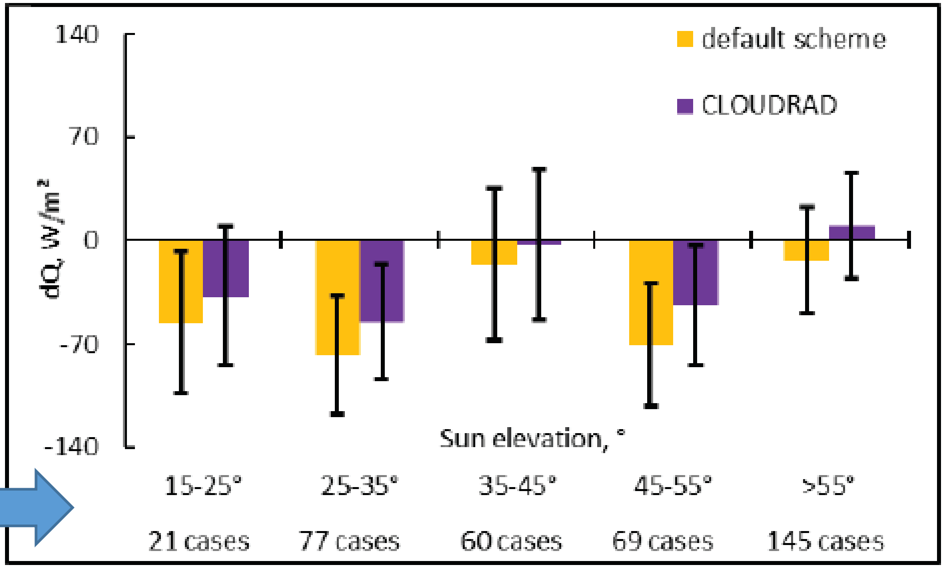
Height, meters



Relative difference in cloud optical thickness

The difference between simulated and measured global irradiance (dQ, W/m2) for the default cloud-radiation interaction scheme (yellow columns) and for the CLOUDRAD scheme (violet columns) at Lindenberg and Munich.

IMPROVEMENT OF THE AGREEMENT WITH SOLAR RADIATION MEASUREMENTS



Khlestova et al., 2020

Daily mean changes in gas-aerosol concentrations

before Moscow spring <u>COVID-19</u> lockdown (01.01-29.03) (blue),

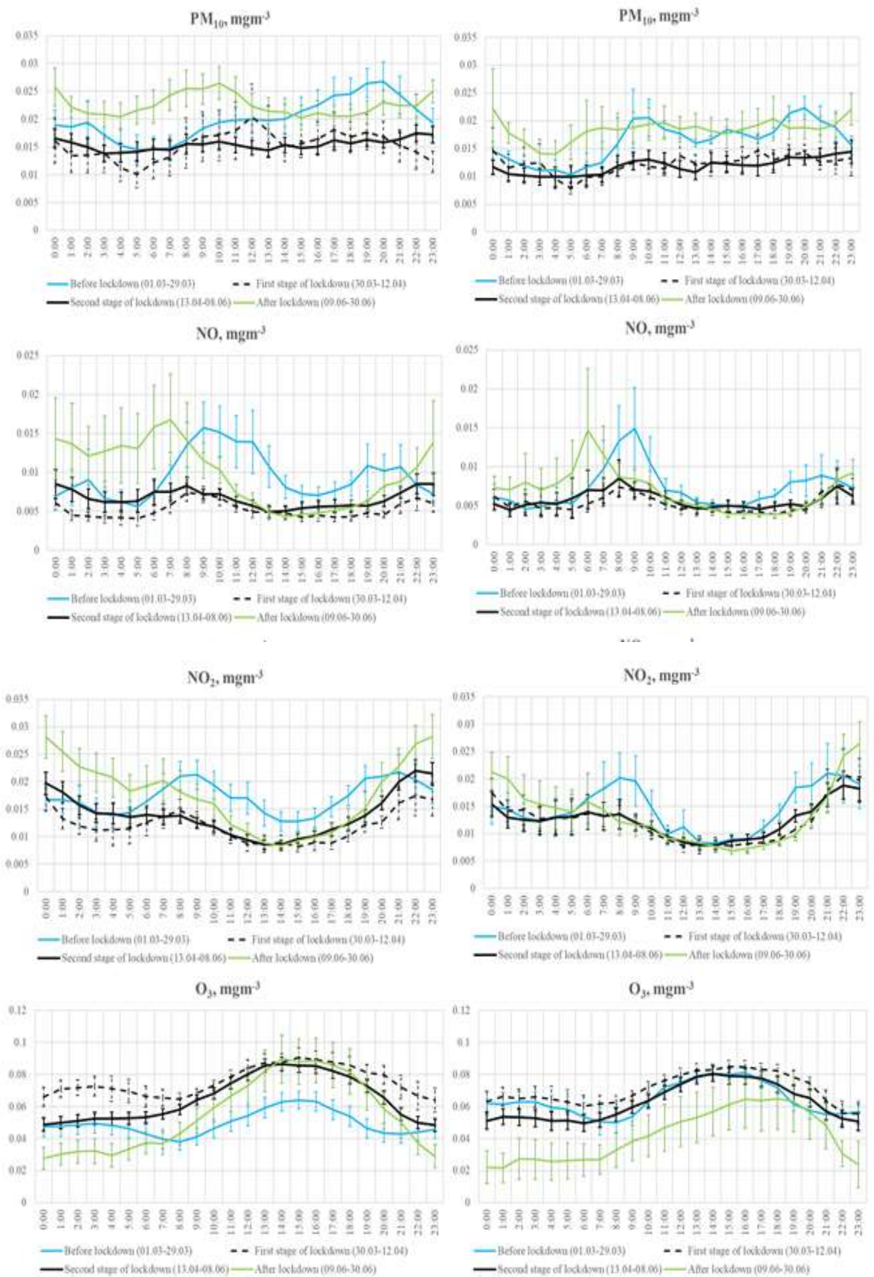
first period of lockdown (30.03-12.04) (black dot),

second period of lockdown (13.04-08.06) (black line),

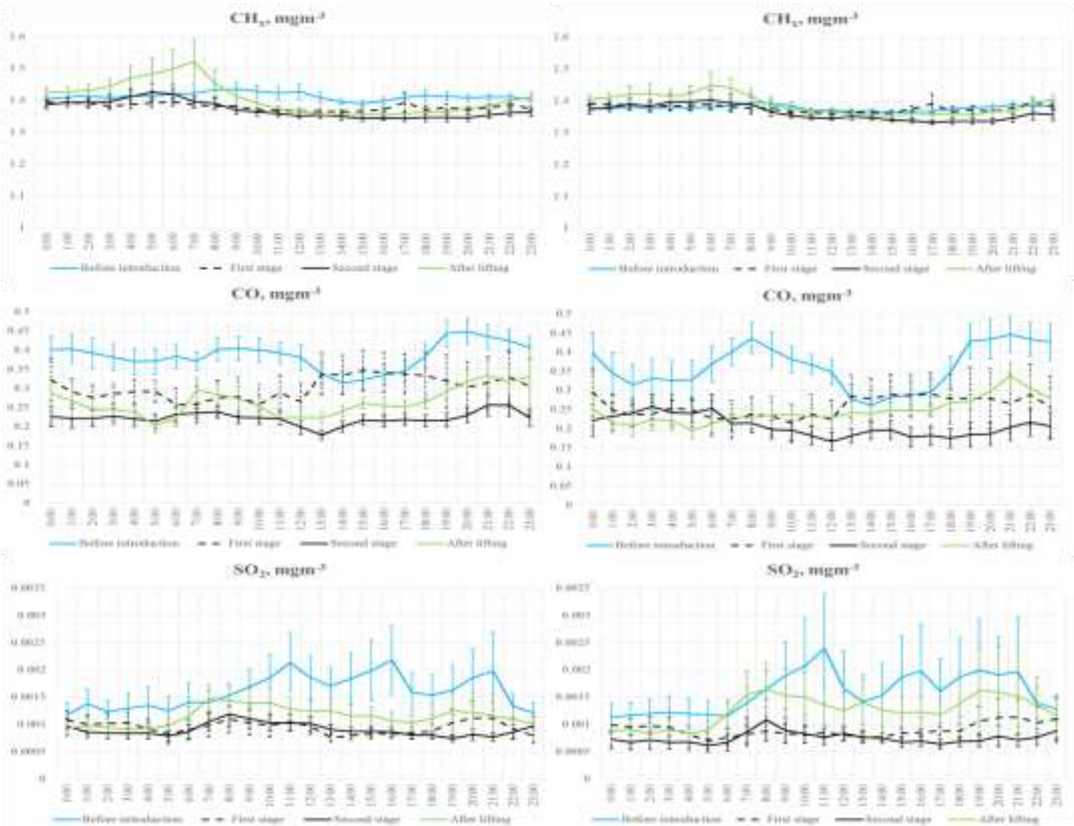
after lockdown (09-30.06) (green).

a –all cases, b – cases with arctic flow. No smoke advection cases.

a b



a b



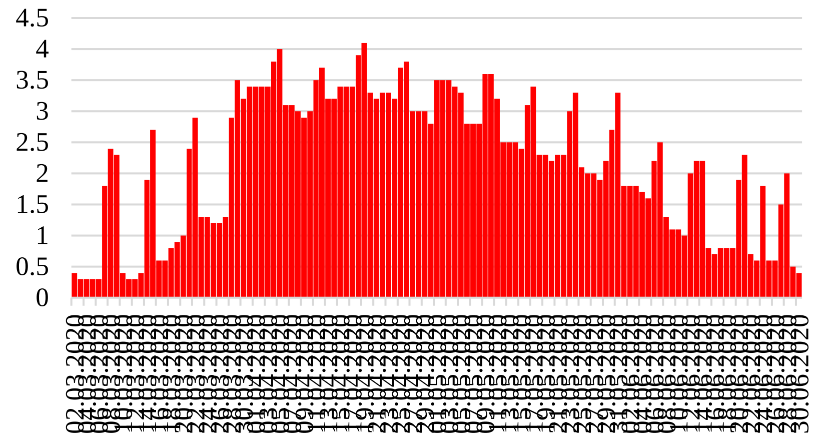
Moscow COVID-19 lockdown conditions.

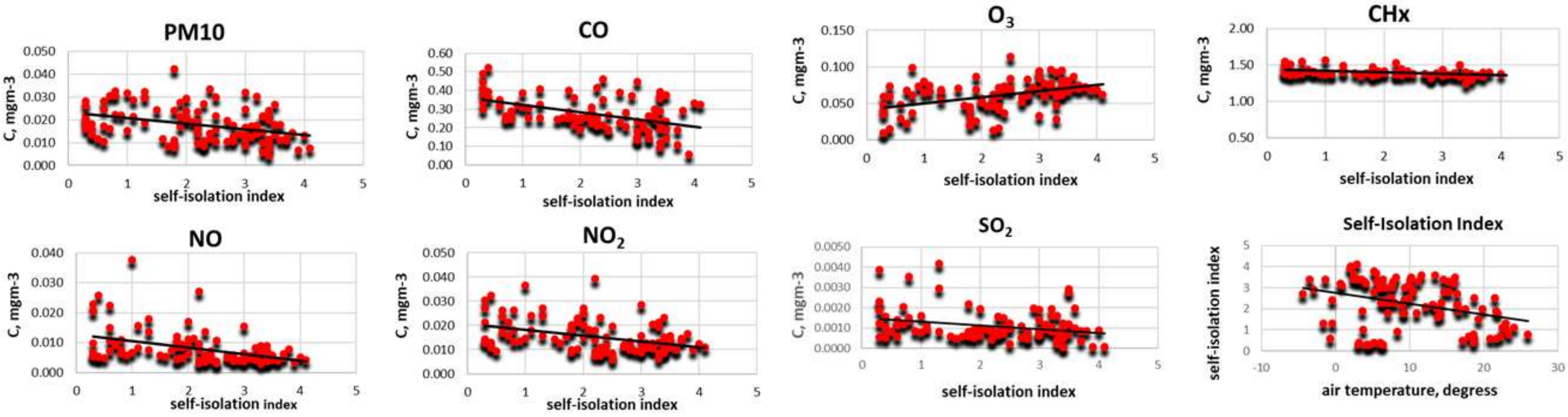
The correlation between daily-mean mass concentrations

C (mgm-3) and self-isolation index

(https://yandex.ru/company/researches/2020/podomam).

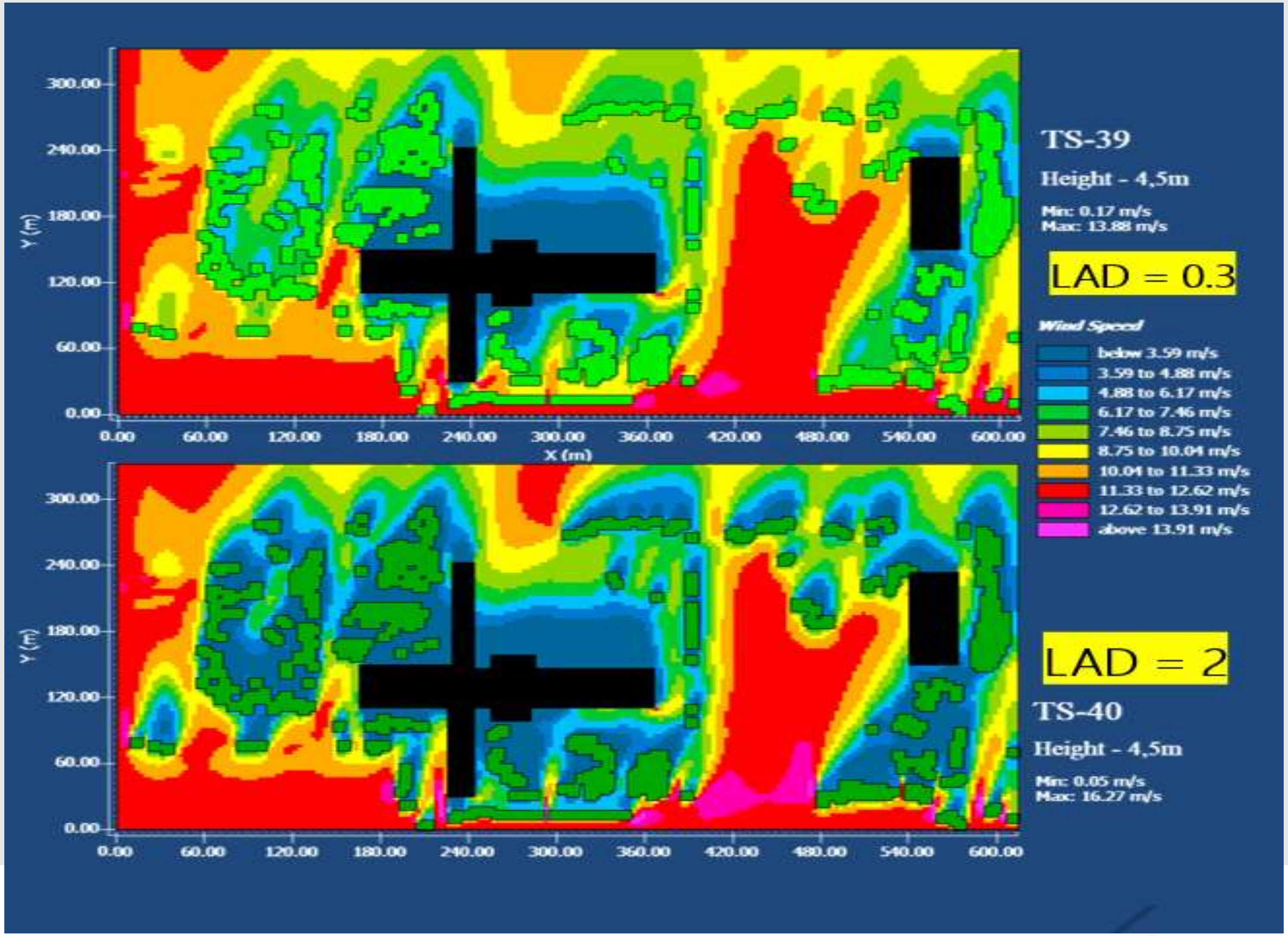
No smoke advection cases.





Micro-scale dynamics of the microclimate

Leaf area density(LAD) and wind speed modeling



Leaf area density impact (LAD index) on the behaviour of wind flows

RUDN University site based experiment

Low LAD

- Lower maximum wind speed
- The aeration level is higher
- Higher mean speed

High LAD

- Increasing of the maximum wind speed
- Large area of low-aeration zones
- Lower mean speed

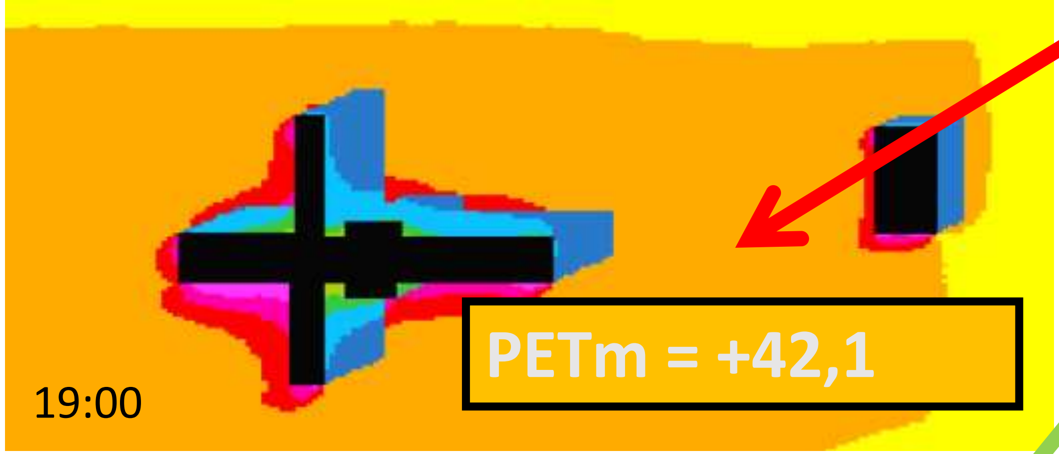
Bukin et al., 2020

Konstantinov et al., 2020

Microscale human thermal comfort modeling in urban landscape according to different greening and building planning structure

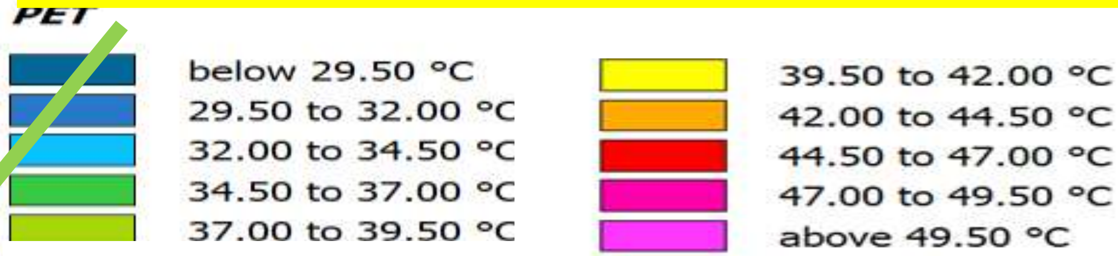
Influence of trees on thermal comfort July 13 2010 (GR Heat-wave 2010)

RUDN area with no trees

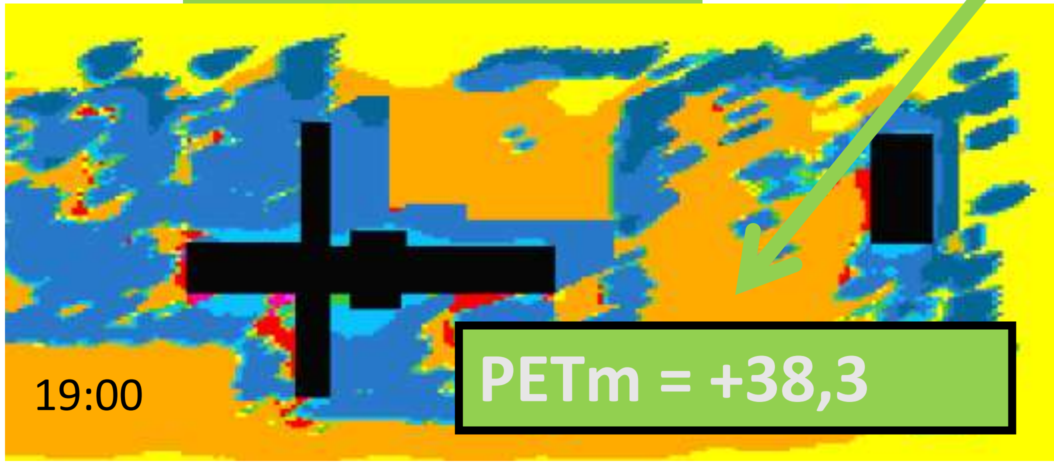


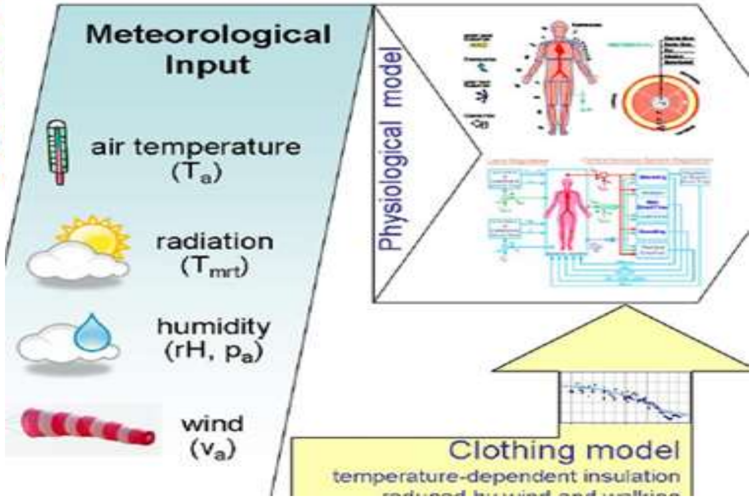
Extreme heat stress

Severe heat stress



RUDN area with trees





PET:
Physiological Equivalent Temperature

modeling approach (Matzarakis et al, 2007; 2010)

The influence of heat waves and air pollution on population mortality

Step 1 - Statistical models

Variables:

Air Pollution

Daily PM 10, PM 2.5, Black carbon

Urban Heat Island and Thermal Stress

Daily temperature and bioclimatic indices

Aggregation:

Generalized linear models,
Generalized additive models etc.

R packages

Health Outcomes

Daily mortality data (gender, age, cause of death)

Results:

- Best predictors of mortality (including bioclimatic indices in comparison with air temperature)
- Temperature and pollution thresholds;
- Relative mortality risk and additional mortality assessment (including seasons patterns)

Weather and pollution data – "Mosecomonitoring Agency", MSU Meteorological Observatory
Mortality data – "Rosstat" 10-15 years

Step 2 – Spatial assessment

The influence of heat waves and air pollution on population mortality

Step 2 – Spatial assessment

The concept of vulnerability and capacity

WP2; WP3

Exposure

Mitigation

Increasing

Population sensitivity

Urban Adaptive capacity

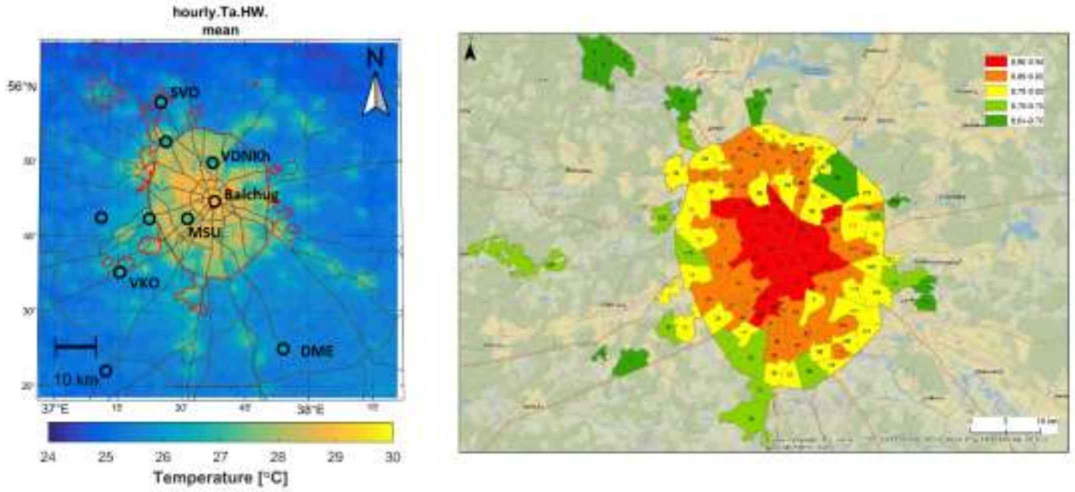
Spatial heterogeneity of urban thermal stress and air pollution

Age, poverty, etc

Health care, green places, etc

Vulnerability

Health risk



An example of spatial heterogeneity of thermal stress (air temperature and PET index) during heat wave 2010

Brooke Anderson and Bell, 2010; Birkman, 2013; Garschagen et al., 2016

- Thank you for your attention!

- Questions?