Lomonosov Moscow State University
Faculty of Geography
Department of Meteorology and Climatology

Numerical simulation of intense precipitation in the Moscow region: a case study of heavy rainfall event on 30th June 2017

Yarinich Yu.I. [1,2] (julia.yarinich@yandex.ru)
Varentsov M.I. [2,3,4], Platonov V.S. [1], Stepanenko V.M. [3,1]

1. Lomonosov Moscow State University, Faculty of Geography, Russia
2. A.M. Obukhov Institute of Atmospheric Physics, Moscow, Russia
3. Lomonosov Moscow State University, Research Computing Center, Russia
4. Hydrometeorological Research Center of Russian Federation, Moscow, Russia

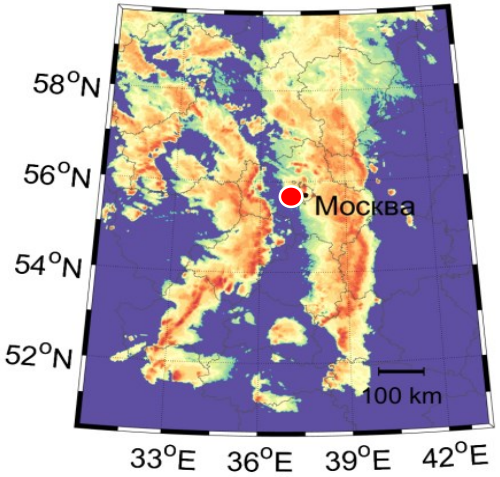
Motivation

Identification of causes of the extremum → Better understanding of the physical mechanisms of the phenomenon → The ability to predict better the next such extremum

Case:

June 30th, 2017

Three MCS's (2 meso-α and 1 meso-β) caused **65 mm** per day (A record for Moscow since June 1970)



Objective

Analysis of meteorological conditions in the central part of the European territory of Russia on June 30, 2017 and determination of physical and synoptic mechanisms of extreme rainfall, that caused almost a month norm of precipitation in Moscow during a day.

Tasks

1. Analysis of synoptic conditions and identification of the type of mesoscale convective systems;
2. Determination of water vapor balance components' role in the precipitation amount;
3. Determination the degree of influence of soil moisture and urban effects as factors of precipitation intensification using numerical modeling (mesoscale non-hydrostatic COSMO model).

Data and methods

Observations

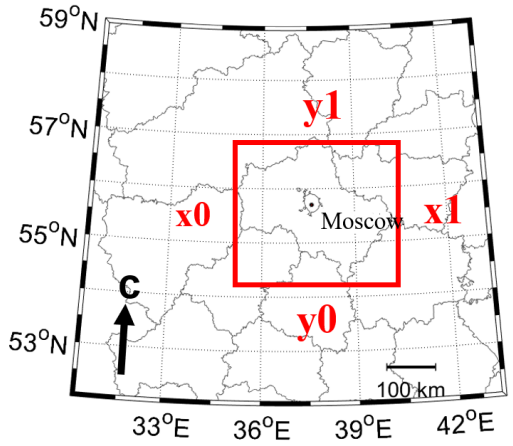
- Meteorological observations on MSU meteorological station;

- Radar data (composite map for central part of Russia);

- Sounding data

Water vapor balance

Data source:
ERA5 reanalysis



Water vapor (WV) balance equation in discrete form: a general concept

$$M^{t+\Delta t} - M^{t} = \left[F_{x0} - F_{x1} + F_{y0} - F_{y1}\right]\Delta t + E^{t}\Delta t + R^{t}\Delta t$$

$M^{t+\Delta t} - M^{t}$	$\left[F_{x0} - F_{x1} + F_{y0} - F_{y1}\right]\Delta t$	$E^{t}\Delta t$	$R^{t}\Delta t$
Total column WV	Vertical integral of WV flux during Δt	Evaporation during Δt	Source function

Data and methods: numerical experiments

Non-hydrostatic mesoscale model

COSMO 5.05-urb

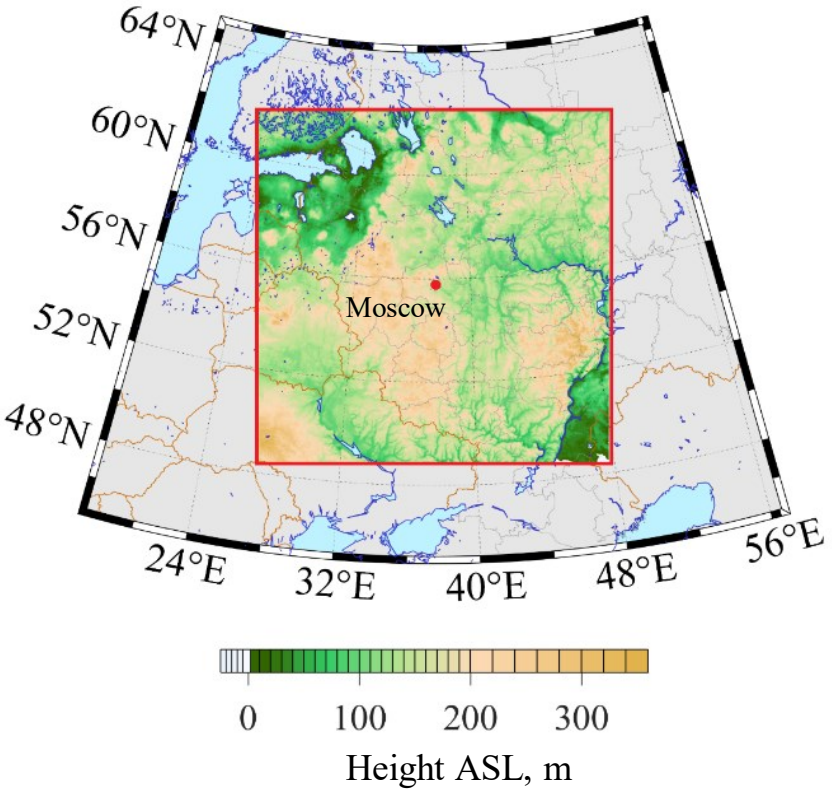
Lateral boundary conditions

Data source		**ERA5 reanalysis**
Base model resolution	area	**30 km (0.28 °)**
	time	**1 h**
Updating of lateral boundary conditions		**1 h**

Model domain characteristics and basic model settings

Grid	**3 km (0.027 °)**
Nodes	**500 x 500**
Urban Parametrization	**TERRA_URB** (on/off)

Model domain:



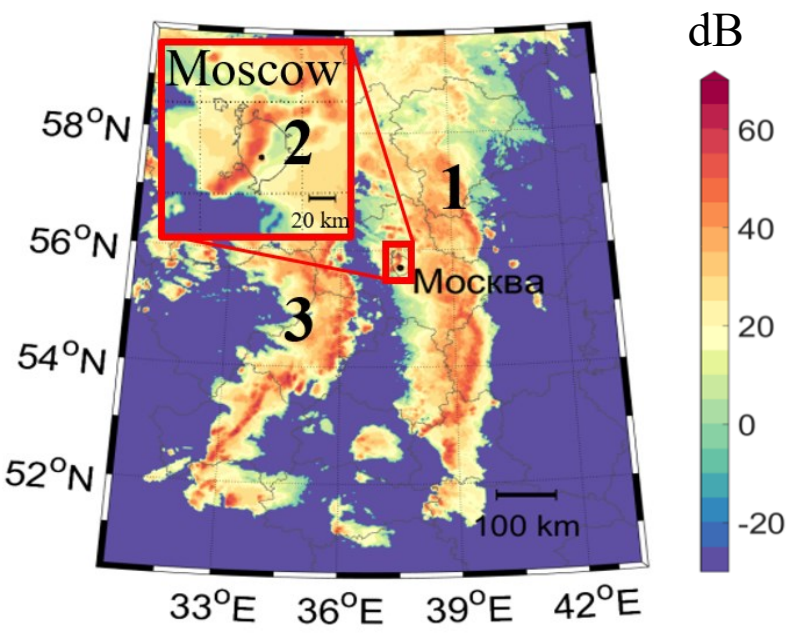
Configuration of experiments:

		Initial soil moisture from ERA5	10-times decreased soil moisture
Urban parametrization TERRA_URB	-	REF_NOURB	DRY_NOURB
	+	REF_URB	DRY_URB

Results: synoptic conditions and water vapor balance

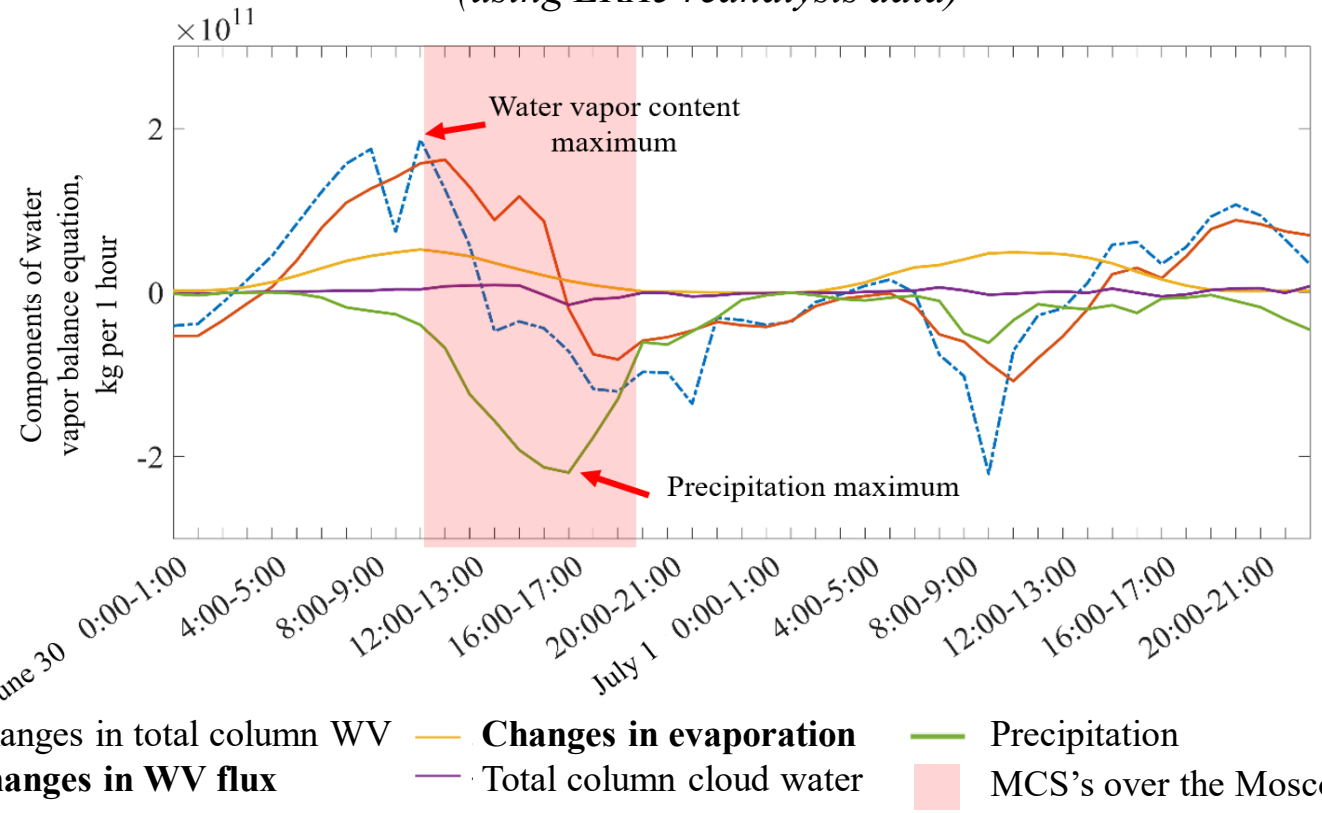
Synoptic conditions: **warm sector of cyclone**
Total column water vapor **41.5 kg/m²**
Deep layer wind shear (0 – 6 km AGL) **20 m/s**
Convective available potential energy (MLCAPE) **1200 – 1400 J/kg**

Radar reflectivity
15:30 (UTC)



(1) First squall line
(2) Meso-β scale convective system
(3) Second squall line

Graphical representation of the solution of the water vapor balance equation (using ERA5 reanalysis data)



Results: numerical experiments with COSMO 5.05-urb

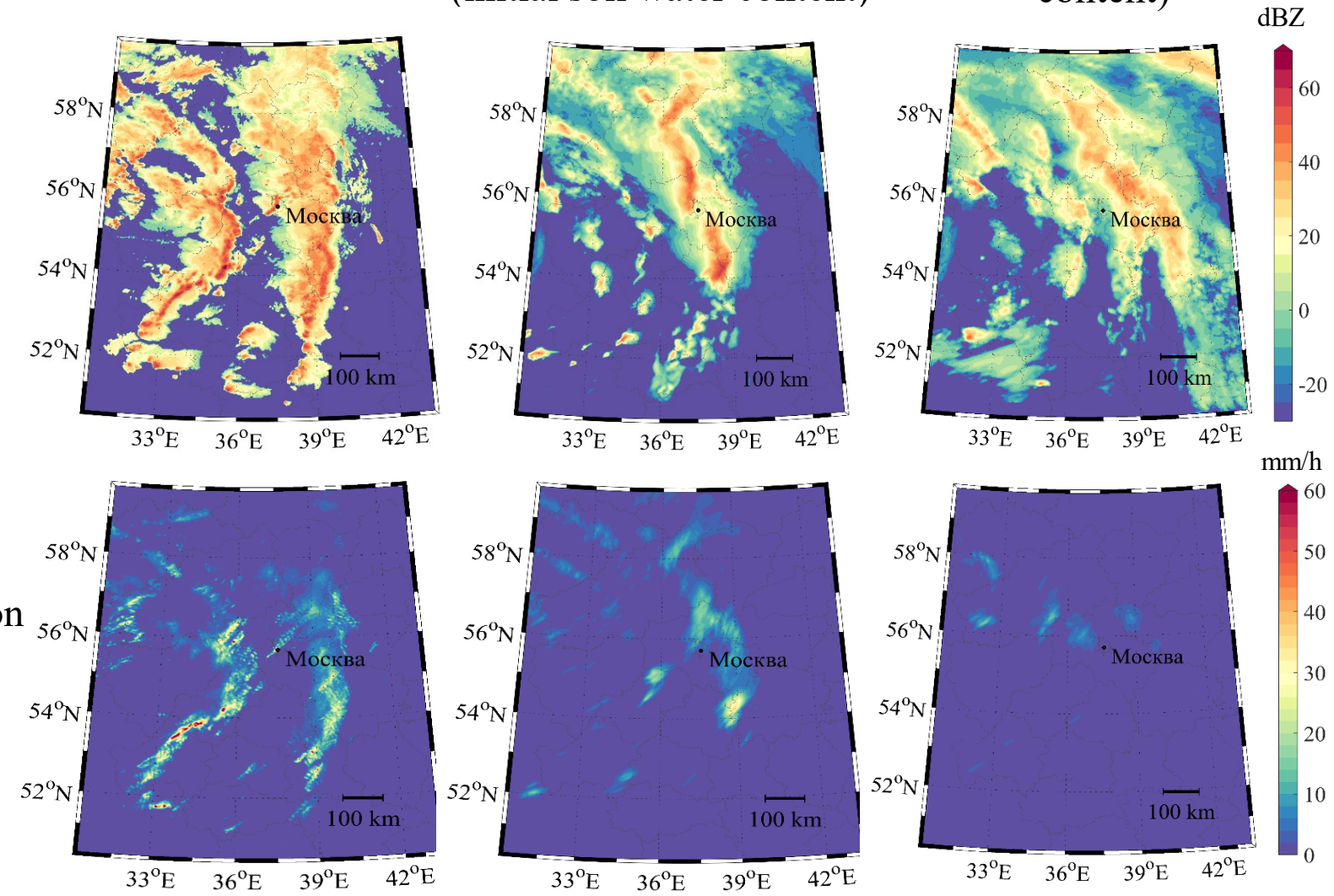
Radar data

Basic ensemble mean (REF_NOURB) (initial soil water content)

DRY_NOURB mean (decreased soil water content)

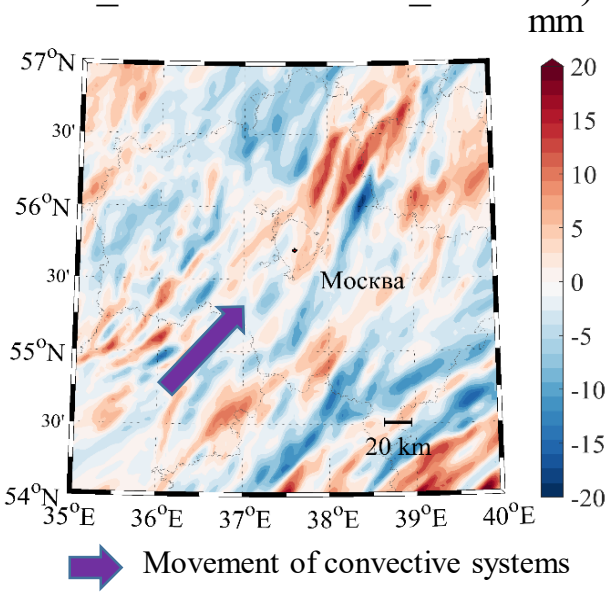
Radar reflectivity, dBZ

Precipitation intensity, mm/h



Urban effect on precipitation increase

Difference in daily precipitation amount in experiments: REF_URB minus REF_NOURB)



Movement of convective systems

		Initial soil moisture from ERA5	10-times decreased soil moisture
Urban parametrization TERRA_URB	-	REF_NOURB	DRY_NOURB
	+	REF_URB	DRY_URB

Conclusions

- The extreme amount of precipitation on June 30, 2017 was caused by three mesoscale convective systems in area of abnormally high atmospheric moisture content for Moscow (41.5 kg / m^2 − the 0.995 percentile in sounding data in Moscow for the period 1957 – 2017), which appeared due to advection of water vapor and evaporation from the earth's surface;
- The significant role of evaporation from the surface was also confirmed by series of numerical experiments with the COSMO 5.05-urb model: a 10-times decrease in soil moisture in the initial conditions led to a 3-times decrease in the amount of precipitation and its intensity;
- COSMO also reproduced the dynamics and structure of squall lines, as well as the extreme precipitation;
- Urban parametrization TERRA_URB does not affect the average amount of precipitation in the Moscow region, however, it causes redistribution of precipitation within it (an increase from the leeward side of the city).

Thank you for your attention!