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

Численное моделирование интенсивных осадков в Московском регионе на примере случая 30 июня 2017 года

Yarinich Yulia [1,2] (julia.yarinich@yandex.ru), Varentsov Mikhail[2,3,4], Platonov Vladimir [1], Stepanenko Victor [3,1]

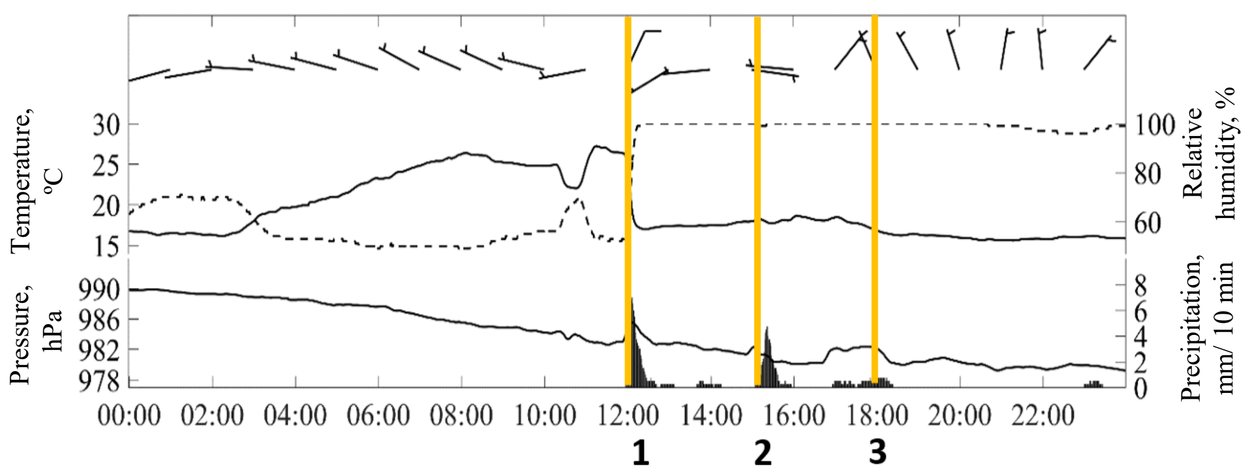
[1]Lomonosov Moscow State University, Faculty of Geography, [2]Obukhov Institute of Atmospheric Physics, [3]Lomonosov Moscow State University, Research Computing Center, [4]Hydrometeorological Research Center of Russian Federation

Abstract: The paper considers the physical and synoptic causes of extreme rainfall on June 30, 2017 in the central part of the European territory of Russia, which determined the record precipitation amount per day in Moscow (65 mm) since 1970. Based on meteorological observations, radar data and reanalysis ERA5 we showed that rainfall was associated with three mesoscale convective systems (MCS's) that arose in the warm sector of the cyclone in a strip of anomalously high moisture content for the considered region (which arose due to advection and evaporation). The simulation result using COSMO model confirmed an idea of the significant role of evaporation from the earth's surface in precipitation intensity and denied the idea of urban effect's role in it.

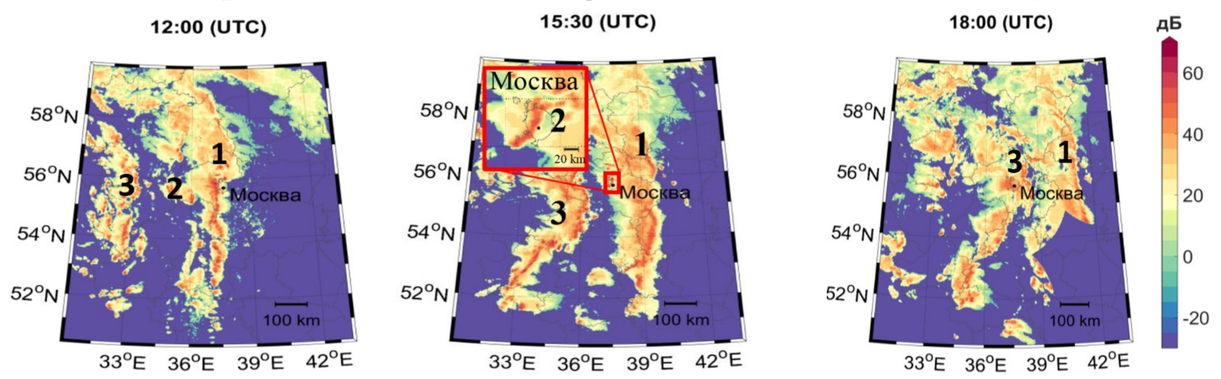
Аннотация: В работе рассмотрены физико-синоптические причины экстремального ливня 30 июня 2017 года в центральной части Европейской территории России, определившего рекордное для Москвы количество осадков за сутки с 1970 года (65 мм). На основе данных наблюдений и реанализа ERA5 показано, что осадки были связаны с тремя мезомасштабными конвективными системами, возникшими в тёплом секторе циклона в полосе аномально высокого для рассматриваемого региона влагосодержания атмосферы. Результат моделирования с помощью мезомасштабной негидростатической модели COSMO дал представление о значимой роли величины испарения с поверхности земли в интенсивности осадков. Подключение параметризации города в модели не обусловило заметного увеличения суммы осадков в пределах мегаполиса.

A case study June 30, 2017: 65 mm/day

Moscow State University meteorological observations



53% * **(1) First squall line** | **31%** * **(2) Meso-β scale MCS** | **16%** * **(3) Second squall line**



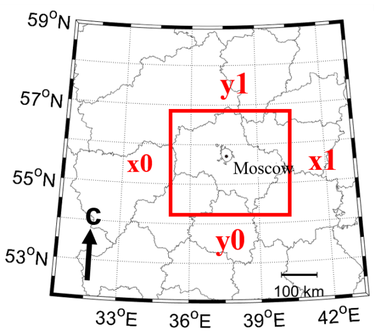
Radar reflectivity (maximum value in column)

* percent of daily precipitation (using MSU's station data)

Water vapor balance

Methodology

Data source: **ERA5 reanalysis**



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

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

Total column WV | Vertical integral of WV flux during Δt | Evaporation during Δt | Source function

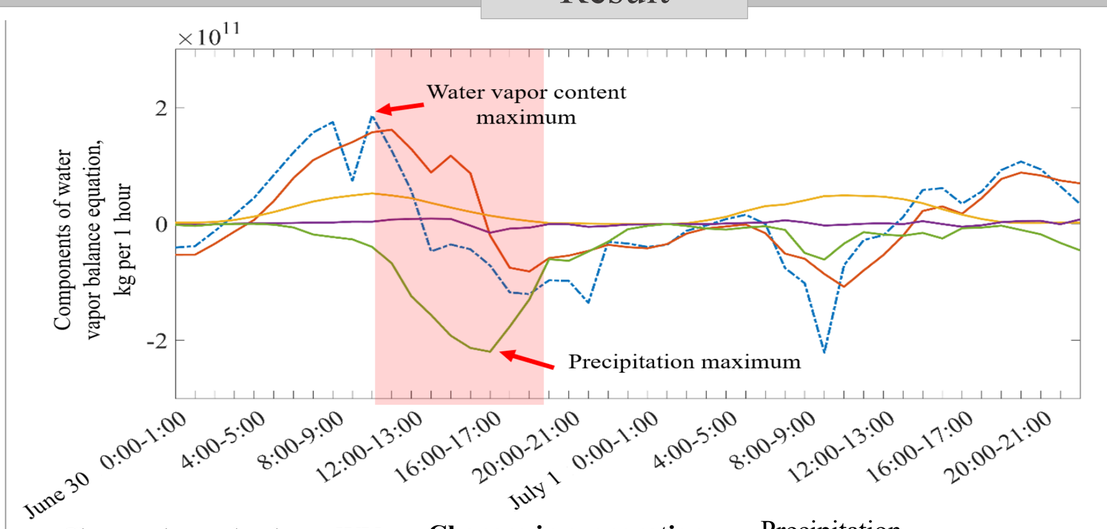
$$F_i = \frac{1}{2}\left(F_i^{t+\Delta t} + F_i^{t}\right), \quad i = x0, x1, y0, y1$$

Fi – fluxes – the average value during [t; t+Δt])

$$R = \iiint_{H\,x\,y} \left(-r - \frac{\partial (W_i + W_e)}{\partial t}\right) dx\, dy\, dz$$

r – precipitation intensity
Wi – total column cloud ice water
We – total column cloud liquid water

Result



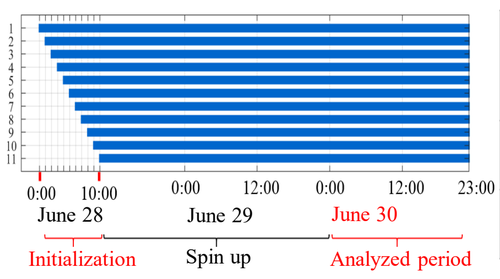
Changes in total column WV — **Changes in evaporation** — Precipitation
Changes in WV flux — Total column cloud water — MCS's over the Moscow region

Numerical experiments: COSMO 5.05-urb

Methodology

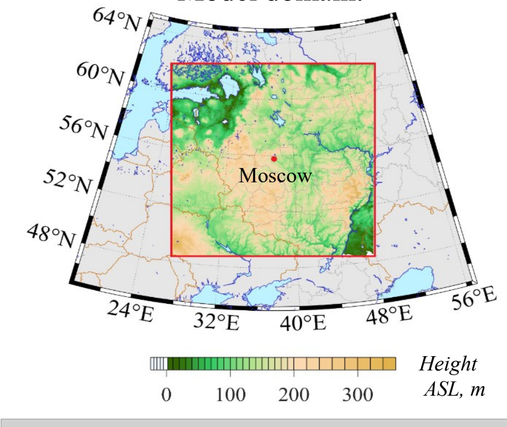
Configuration of experiments

Changes in forecast time	Changes in soil moisture content	Urban effects
Start time: 0:00 – 10:00 (UTC) 28.06.17	**10-times decrease in 0 – 1.65 m layer**	**Urban parametrization TERRA_URB**
(11 experiments) x	*(2 experiments)* x	*(2 experiments)*



	Initial soil moisture from ERA5	10-times decreased soil moisture
No TERRA_URB	REF_NOURB	DRY_NOURB
Using TERRA_URB	REF_URB	DRY_URB

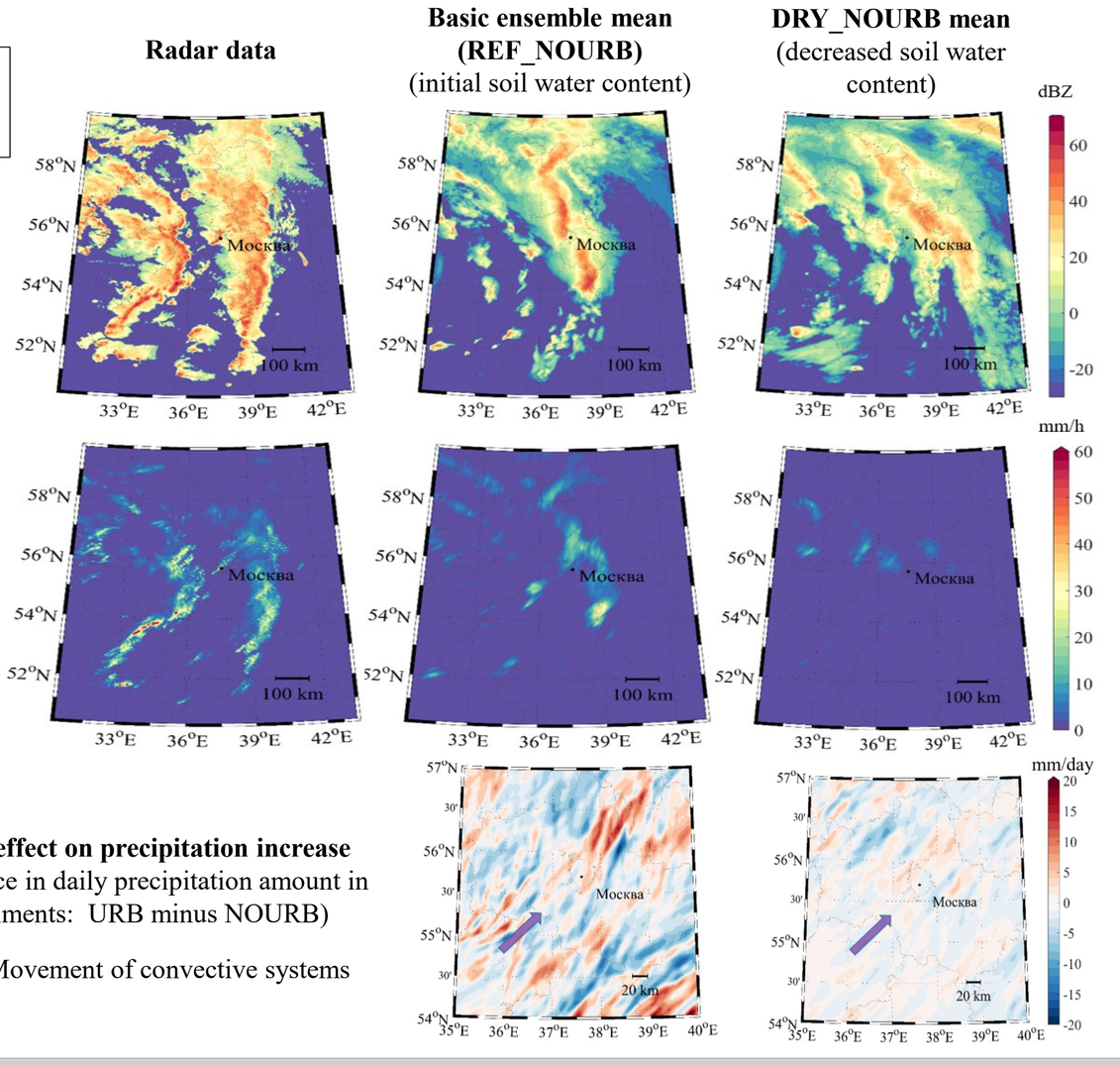
Model domain:



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

Result

15:00 (UTC) 30.06.17



Urban effect on precipitation increase
(Difference in daily precipitation amount in experiments: URB minus NOURB)

➡ Movement of convective systems

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).