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Simulation and analysis of some non-ordinary atmosphere processes by WRF model based on the GRID Technologies

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WRF Model

The WRF model was constructed in 2000 and had been developed as a collaborative effort of the following institutes:

1. **National Oceanic and Atmospheric Administration's (NOAA) Division**
2. **National Centers for Environmental Prediction (NCEP) of the USA**
3. **Forecast System Laboratory (FSL) of the USA**
4. **Department of Defense's Air Force (DDAF) of the USA.**
5. **Weather Agency (AFWA)**
6. **Naval Research Laboratory (NRL)**
7. **Federal Aviation Administration (FAA)**
8. **Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma of the USA.**
9. **Nonhydrostatic Mesoscale Model (NMM) developed by the NCEP,**
10. **Advanced Research WRF (ARW) developed and maintained by the Mesoscale and Microscale Meteorology Division of NCAR,**
11. **A number of University Scientists of the World .**

Objectives of the WRF Model

- **WRF modeling system is intended:**

a) for understanding and prediction of mesoscale weather,

b) for providing a next-generation of mesoscale forecast models,

c) for improvement of the data assimilation system.

- **The WRF model was designed and configured:**

a) for research,

b) for operations.

- **The WRF model is suitable:**

a) for using in a broad spectrum of applications, across scales from Meters, to thousands of kilometers,

b) for climate modeling (WRF Climate),

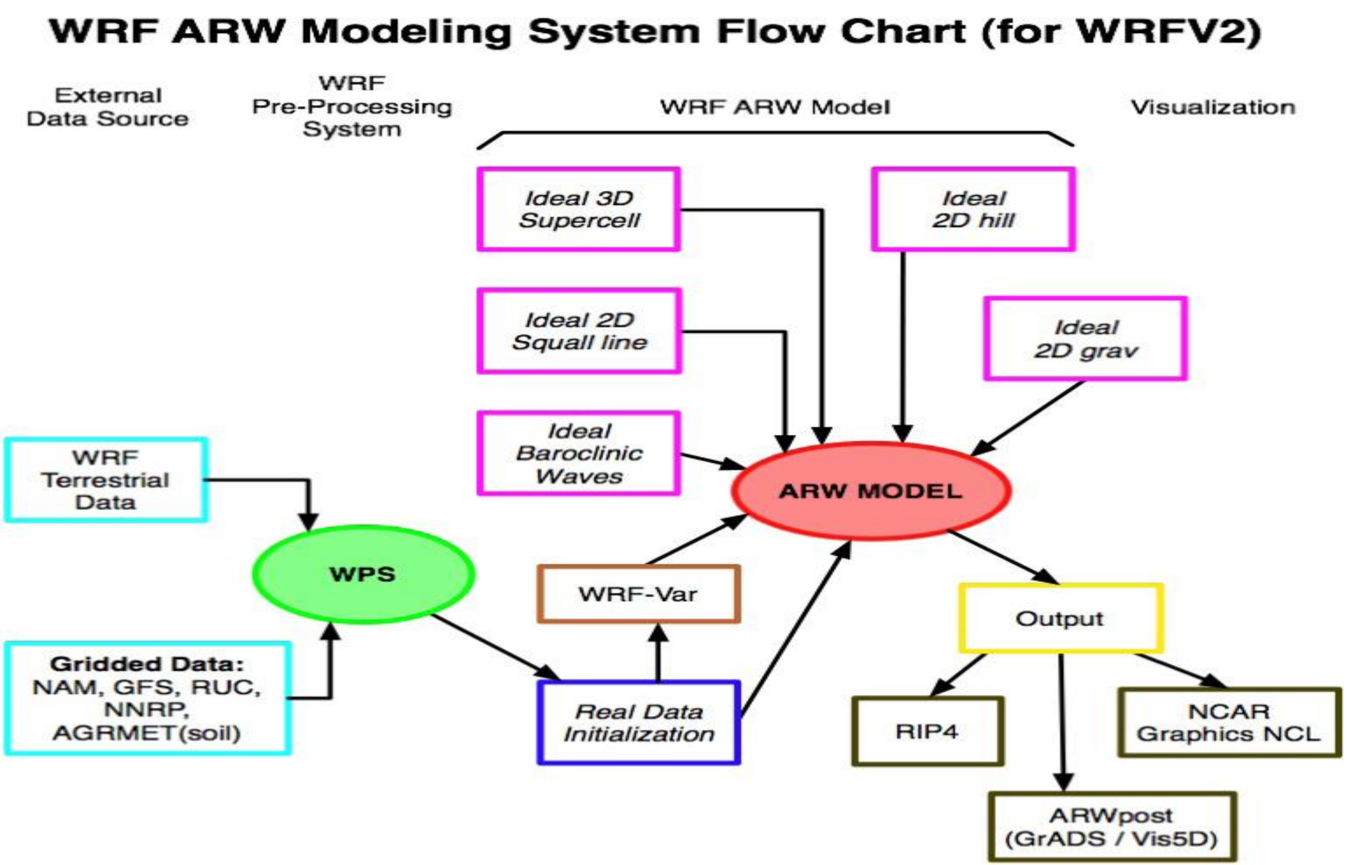
c) for pollutants modeling (WRF CHEM model).

- **There are currently over 20,000 users of WRF from 135 countries.**

WRF& ARW Modeling System Flow Chart

As shown in the diagram, the WRF Modeling System consists of these major programs:

- **External data source-(terrestrial data and gridded data)**
- **The WRF Preprocessing System (WPS)-**
- **WRF-Var*(variational data assimilation system)***
- **ARW model (solver)**
- **Output-Post-processing & Visualization tools**



What can WRF be used for?

Both ARW and NMM can be used for:

– Atmospheric physics (parameterization) research;
– Case-study research;
– Real-time NWP and forecast system research;
– Data assimilation research;
– Teaching dynamics and NWP.

ARW only can be used for:

– Global simulations;
– Idealized simulations at many scales (convection, baroclinic waves, large eddy-hurricane, simulations)
– Regional climate and seasonal time-scale research;
– Coupled-chemistry applications;

Parameterization of the WRF model

Parameterization of the WRF model is the representation of the physical processes in the parametrical form.

Parameterization becomes necessary because:

- ❖The physical processes can not be described directly (in equation format);
- ❖They are not yet sufficiently understood ;
- ❖They have not appropriate observation data;
- ❖Computers are not powerful enough to treat physical processes timely;
- ❖The processes are too small to represent on the special and temporally grids;
- ❖The processes are too complex to be resolved on the grids.

The main problem of parameterization is deficit of information on *sub grid-scale processes* while are using information only at the grid scale).

Problems derived also with interactions between parameterization schemes, where each scheme contains its own errors and assumptions.

Major parameterizations in models:

- **Microphysics (cloud processes)**
- **Convective parameterization**
  - **deep convection**
  - **shallow convection**
- **Planetary boundary layer**
- **Surface layer**
- **Land surface**
- **Radiation**
  - **shortwave**
  - **longwave**

WRF model simulation design

- **We have used the WRF v.3.6.1 model.**
- **One-way nesting** for the territory of Georgia was used.
- The **coarser domains** (resolutions of 19.8km and 6.6km) has a grid of 94x102 points which covers the Caucasus region.
- The **nested inner domain** (resolutions 2.2 km) has a grid size of 70x70 points mainly covers the territory of Georgia.
- Both use the **54 vertical levels** including 8 levels below 2 km.
- A time step of **10 seconds** was used for the nested domains.
- **The WRF model contains a number of different physics options such are:**
- **Micro physics**, **Cumulus parameterization physics,** Radiation physics, **Surface layer physics,** **Land surface physics,** and **Planetary boundary layer physics.**

WRF -Physics schemes options-
Microphysics

- **Microphysics processes controlling formation of cloud droplets and ice crystals, their growth and fallout as precipitation.**
- **Microphysics includes:** Explicitly resolved **Water vapor, Clouds and Precipitation processes**.

- **Microphysics**-contains a number of microphysics modules and in our study we have chosen:
- **Option 6 : WRF Single–moment 6–class Scheme (**WSM6**)** Hong, S.–Y., and J.–O. J. Lim, 2006: The WRF single–moment 6–class microphysics scheme (WSM6). *J. Korean Meteor. Soc.*, **42**, 129–151.
- **Option 8: Thompson Scheme,** Thompson, Gregory, Paul R. Field, Roy M. Rasmussen, William D. Hall, 2008: Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part II: Implementation of a New Snow Parameterization. *Mon. Wea. Rev.*, **136**, 5095–5115.
- **Option 2: Lin et al. Scheme** (Lin, Yuh–Lang, Richard D. Farley, and Harold D. Orville, 1983: Bulk Parameterization of the Snow Field in a Cloud Model. *J.Climate Appl. Met.*,**22**, 1065–1092.)
- **Option 10: Morrison 2–moment Scheme (**Morrison, H., G. Thompson, V. Tatarskii, 2009: Impact of Cloud Microphysics on the Development of Trailing Stratiform Precipitation in a Simulated Squall Line: Comparison of One– and Two–Moment Schemes.*Mon. Wea. Rev.*, **137**, 991–1007.**)**
- **Option 7: Goddard Scheme** (Tao, Wei–Kuo, Joanne Simpson, Michael McCumber, 1989: An Ice–Water Saturation Adjustment. *Mon. Wea. Rev.*, **117**, 231–235.)

Cumulus Parameterization Schemes

- **Cumulus Parameterization Schemes (CPSs) are responsible for the sub-grid-scale effects of convective or shallow clouds.**

- **CPSs** -contains a number of microphysics modules and in our study we have chosen:

❖ **Option 1 : Kain-Fritsch(Mass flux schem)** Kain, John S., 2004: The Kain–Fritsch convective parameterization: An update. *J. Appl. Meteor.*, **43**, 170–181

❖ **Option 2: Betts-Miller-Janjic (Adjustment)** Janjic, Zavisa I., 1994: The Step–Mountain Eta Coordinate Model: Further developments of the convection, viscous sublayer, and turbulence closure schemes. *Mon. Wea. Rev.*,**122**, 927–945.

❖ **Option 93: Grell-Devenyi(Mass flux scheme) Ensemble Scheme**Grell, G. A., and D. Devenyi, 2002: A generalized approach to parameterizing convection combining ensemble and data assimilation techniques. *Geophys. Res. Lett.*, **29**(14).

WRF model simulation design

Table 1. Five sets of the WRF model's parameterization used in this study

WRF Physics	**Set1**	**Set 2**	**Set 3**	**Set 4**	**Set 5**
Micro physics	WSM6	Thomp son	Purdue Lin	Morrison 2-Moment	Goddard
Cumulus Paramete rization	Kain-Fritsch	Betts-Miller-Janjic	Kain-Fritsch	Grell-Devenyi ensemble	Kain-Fritsch
Surface Layer	MM5 Simil.	MM5 Simil.	MM5 Simil	(PX) Similarity	MM5 Similarit
Planet. Boundary Layer	YSU PBL	YSU PBL	YSU PBL	ACM2 PBL	YSU PBL
Land-Surface	Noah LSM	Noah LSM	Noah LSM	Noah LSM	Noah LSM
Atmosphe ric Radiat.	RRTM/ Dudhia	RRTM/ Dudhia	RRTM/ Dudhia	RRTM/Dud hia	RRTM/Du dhia

Planet. Boundary Layer (PBL): directly influences on vertical wind shear, as well as precipitation evolution. We have chosen **Yonsei University** and **ACM2 PBL** schemes.

Atmospheric Radiation: provide atmospheric heating due to radiative flux divergence and surface downward longwave and shortwave radiation for the ground heat budget. Rapid Radiative Transfer Model (RRTM) Longwave.

Land-surface models (LSMs): use atmospheric inform ation from the surface layer scheme, radiative forcing from the radiation scheme, and precipitation forcing from the microphysics and convective schemes, together with internal information on the land's state variables and land-surface properties, to provide heat and moisture fluxes over land points and sea-ice points. Noah LSM.

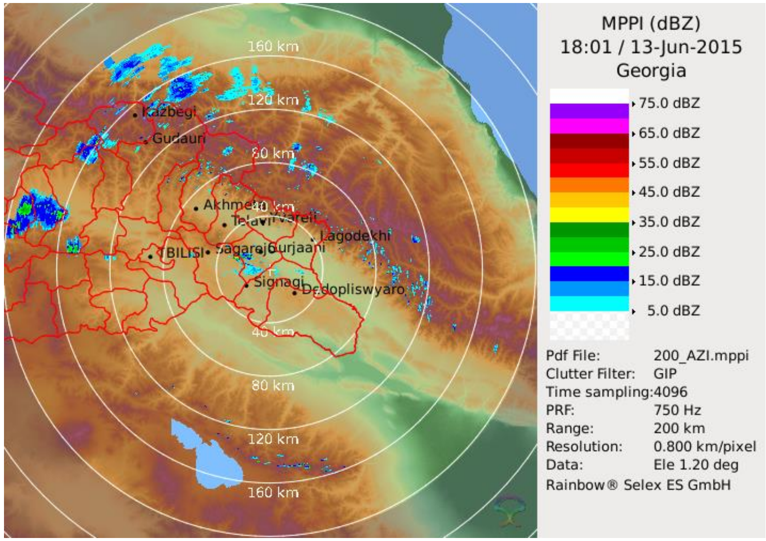
Surface layer schemes: calculate friction velocities and exchange coefficients that enable the calculation of surface heat and moisture fluxes by the land-surface models and surface stress in the planetary boundary layer scheme. MM5 Similarite and (PX) Similarity

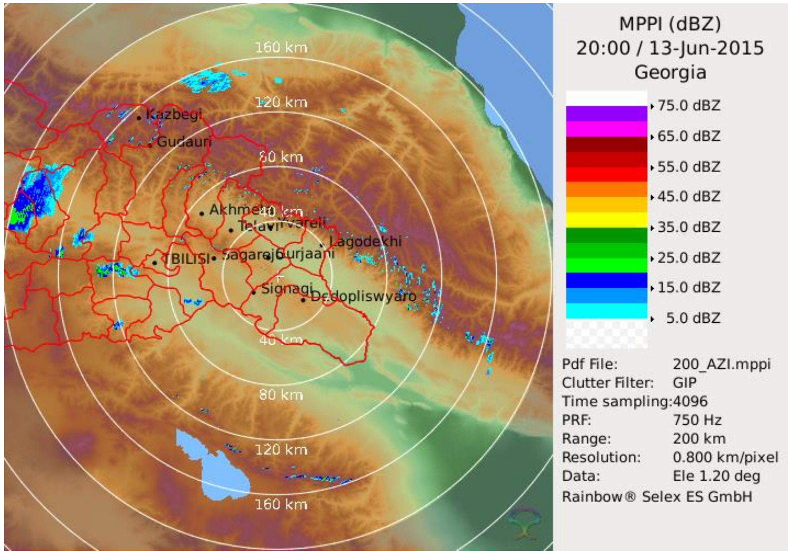
Observed convective event on the 13th of June 2015

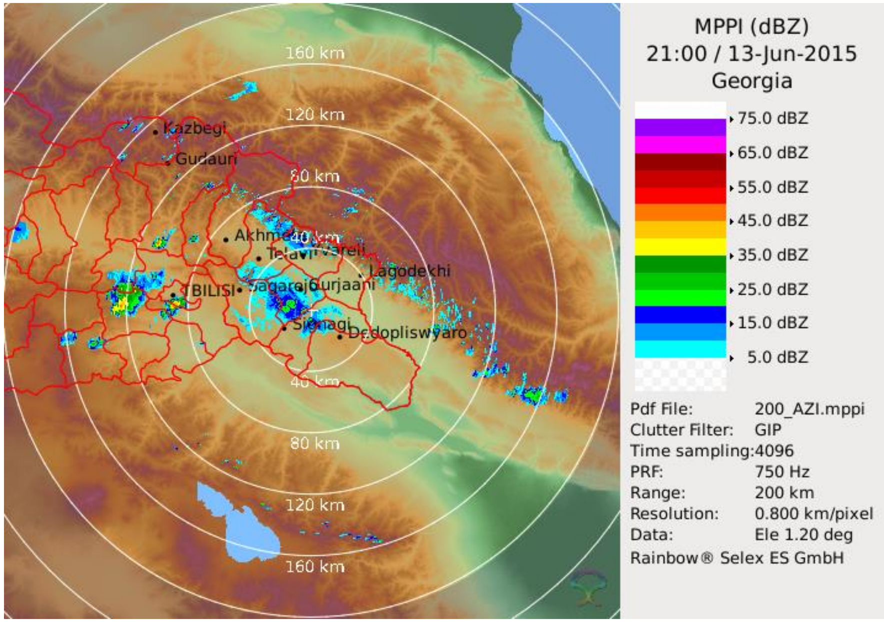
- Weather was terrible with showers, thunderstorms and lights on the night of 13 to 14 June 2015 in Tbilisi.
- According to the official data there was heat transfer by wave from the south which stipulated high temperature and showers on the territory of Tbilisi.
- The heavy rainfall (during 1.5-2 h) has stipulated a landslide in the village Akhaldaba which is located about 20 km southwest of Tbilisi.
- The collapsed 1 million m^3 of land, mud, rocks and trees moved down towards Tbilisi and dammed up the Vere river. Later a big wave (mixture of slush, rocks and trees) run across the Vere canyon and washed everything away until the square of Heroes in Tbilisi.
- The resulting flood inflicted severe damages in the different districts of Tbilisi (Zoo, Heroes' Square, nearby streets and houses).
- Unfortunately this process has resulted in at least 20 human deaths (including three attendants of the zoo) and half of the Tbilisi Zoo's animals.

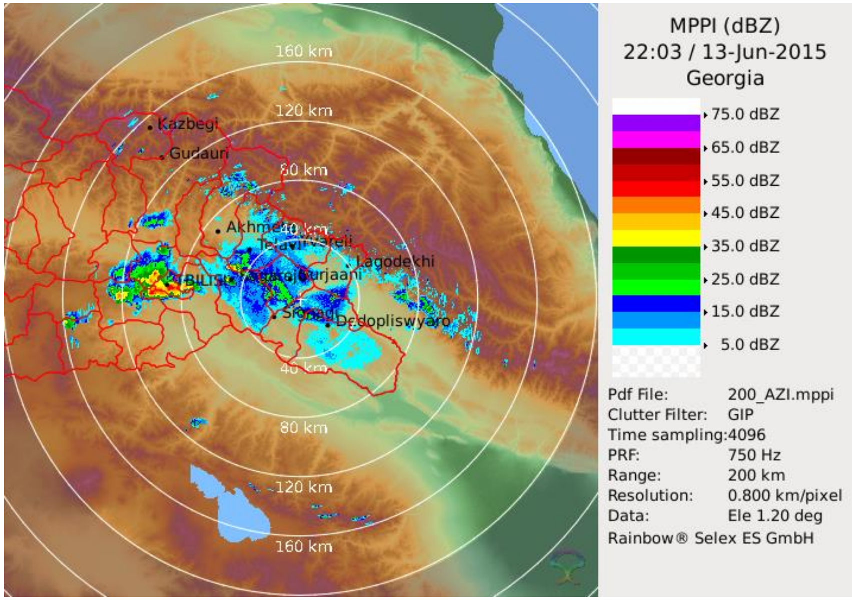
Fig.1. After flood in Tbilisi on 14 June 2015

Weather Radar Data (WRD) from 18:01 to 22:03 (13/06/2015)

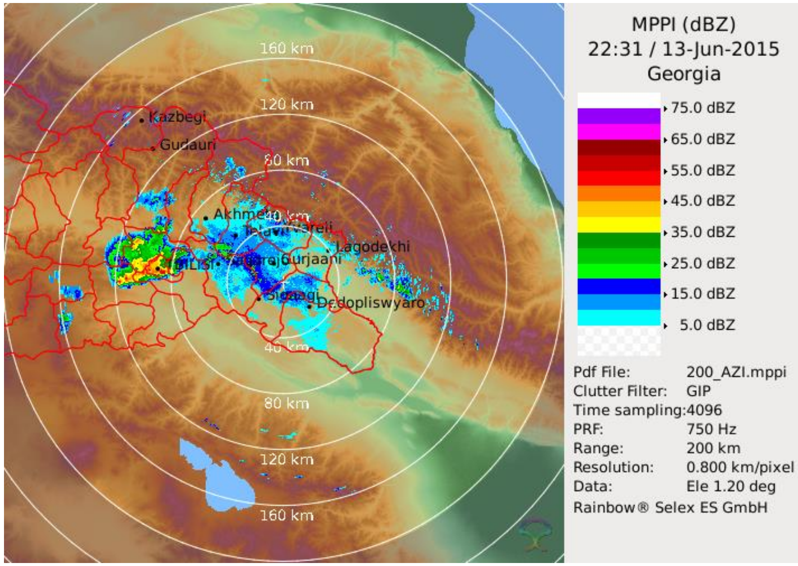


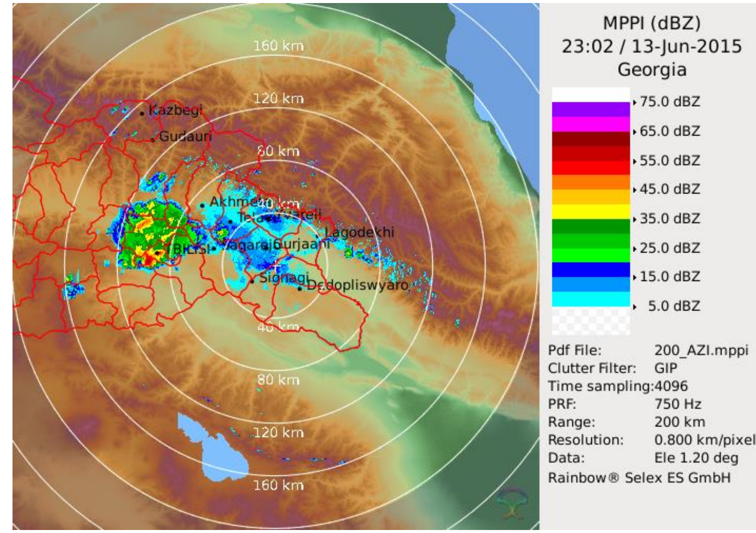


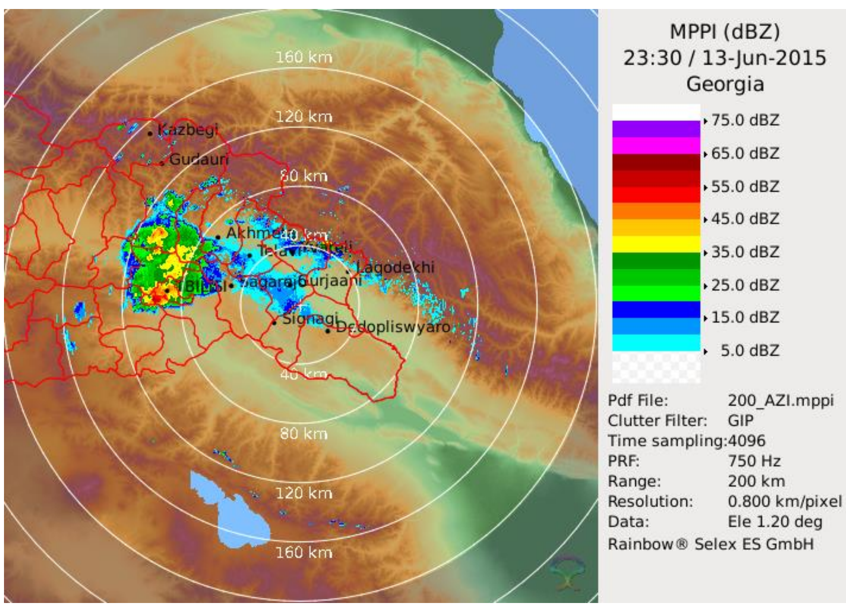


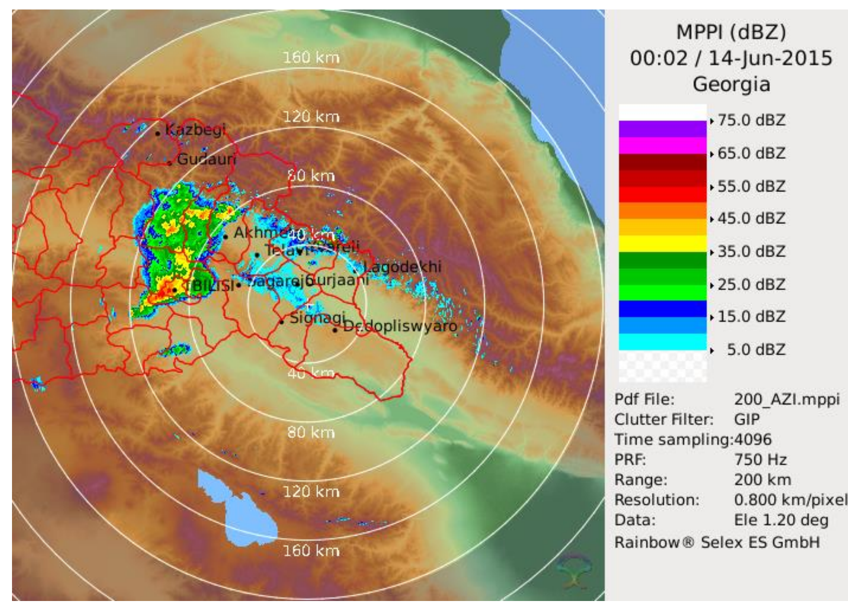


WRD from 22:31 to 00:02 (13-14/06/2015)









Results of Numerical Calculation for 13th of June 2015

Latitude and longitude coordinates of Tbilisi (**41.716667 ° N, 44.783333 ° E**)

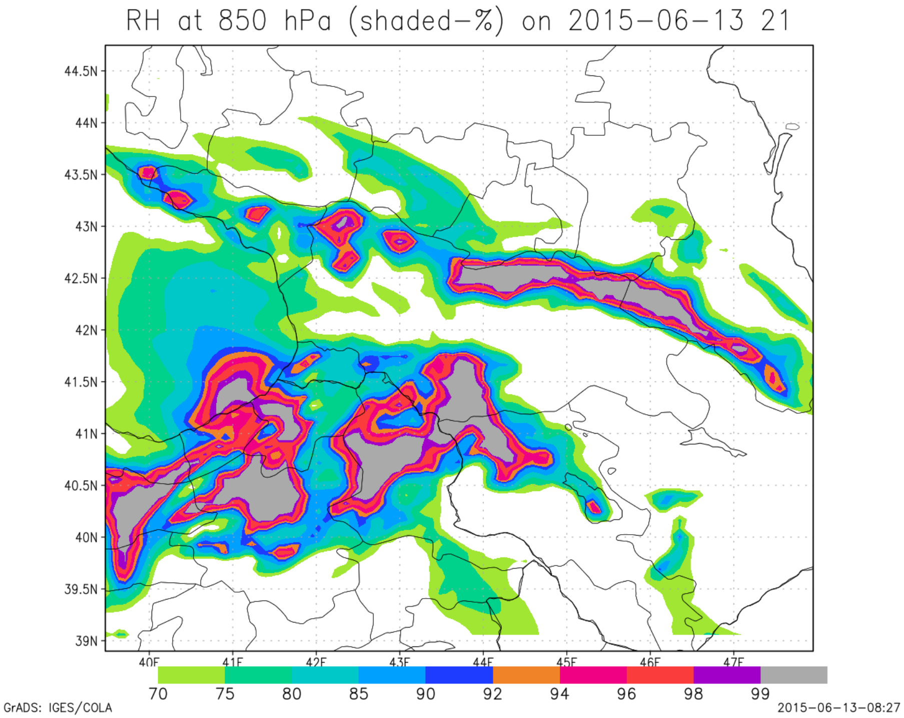


Fig.2 Map of the relative humidity at the 850 hPa for **13 June** 2015 (**21**UTC) simulated for the nested domain with 6.6 km resolution.

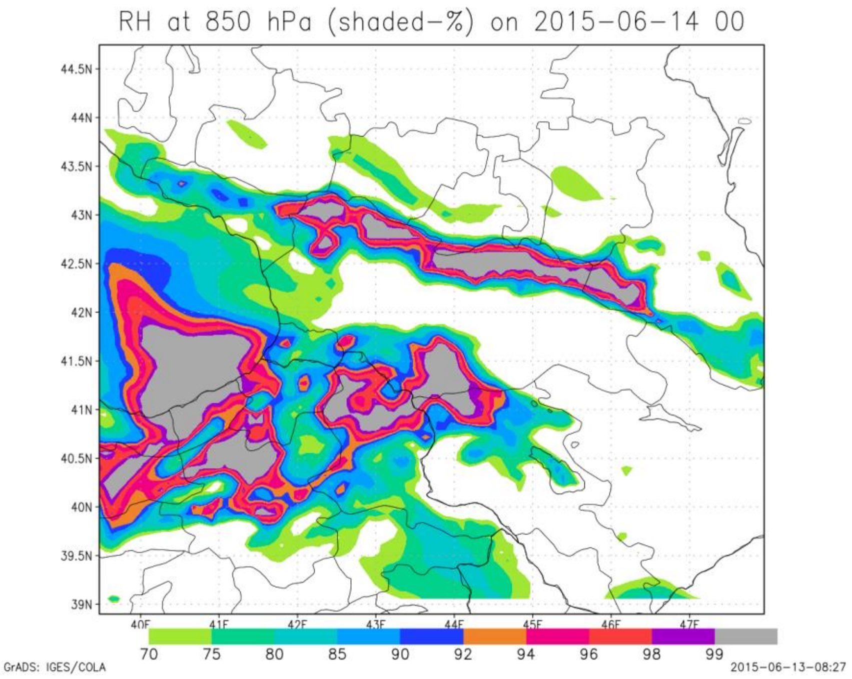


Fig.3 Map of the relative humidity at the 850 hPa for **14 June** 2015 (**00**UTC) simulated for the nested domain with 6.6 km resolution.

Results of numerical calculation have shown that not one of the combinations listed in the Table 1 were not able to model true atmospheric event which took place on the 13th of June 2015.

Results of Numerical Calculation for13th of June 2015 -(2)

Tbilisi (41.716667 ° N, 44.783333 ° E)

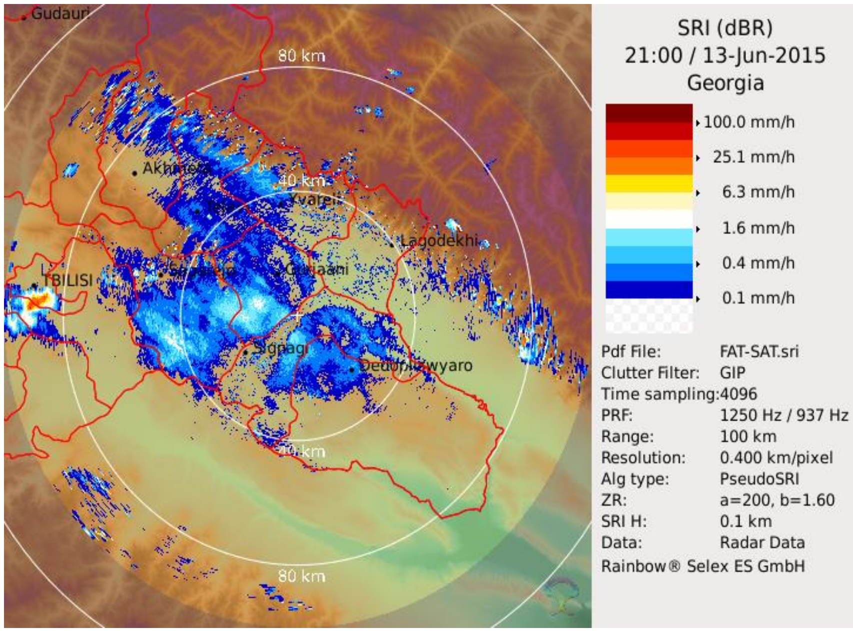


Fig.4.1 Map of Accumulated Total Precipitations (ATP) (12 h sum) in Tbilisi and Kakheti region obtained by WRD at 21:00

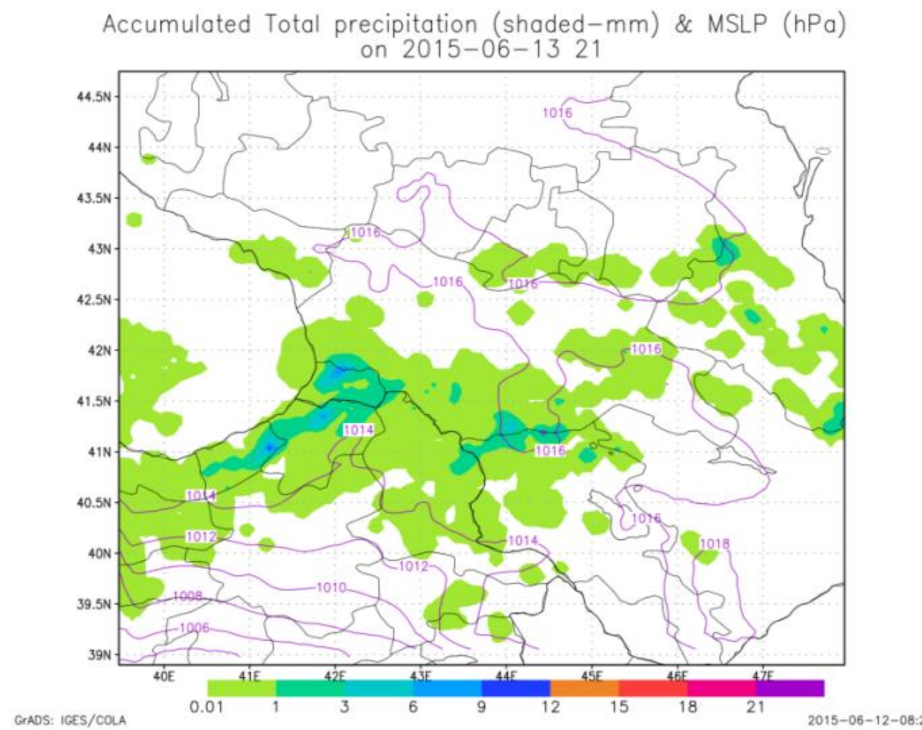
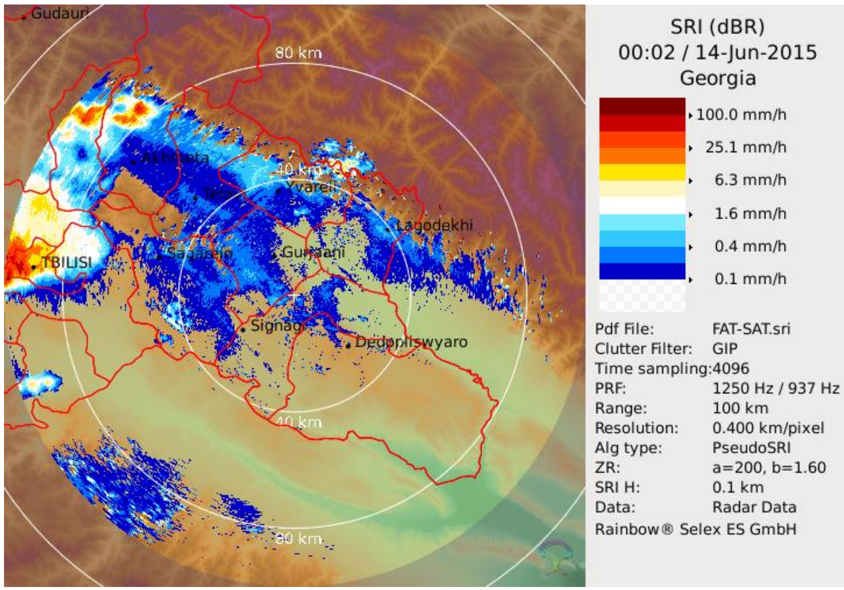


Fig.4.2 ATP (12 h sum) simulated by WSM6/KF on the fine mesh (6.6 km) resolution grid.

Results of numerical calculation have shown that not one of the combinations listed in the Table 1 were not able to model true atmospheric event which took place on the 13th of June 2015.

Results of Numerical Calculation for13th of June 2015 -(2)

Tbilisi (41.716667 ° N, 44.783333 ° E)



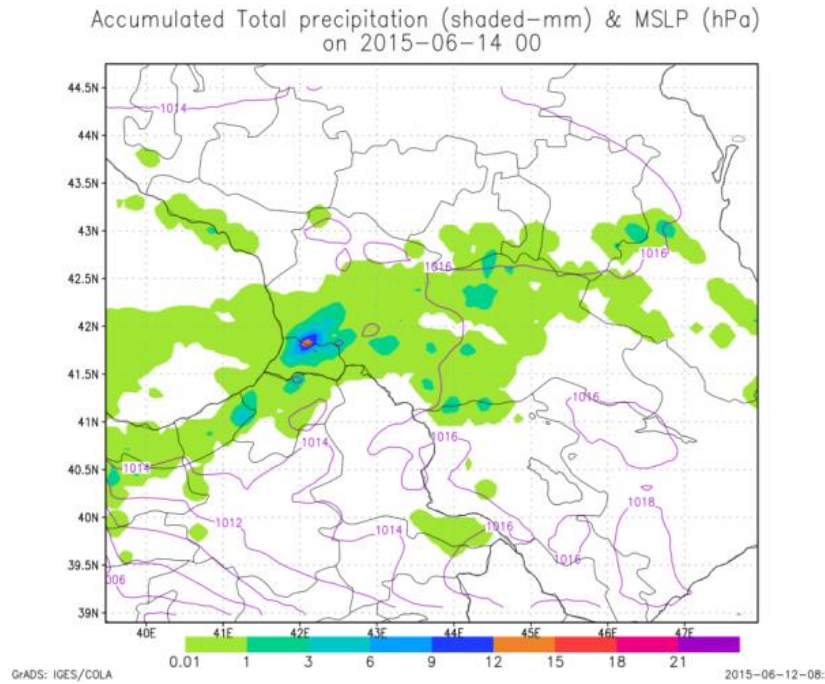


Fig.5.1 Map of ATP (12 h sum) in Tbilisi and Kakheti region obtained by WRD at 00:02 on 14/06/2015

Fig.5.2 Predicted fields of ATP (12 h sum) executed by WSM6/KF on the fine mesh (6.6 km) resolution grid.

Results of numerical calculation have shown that not one of the combinations listed in the Table 1 were able to model true atmospheric event which took place on the 13th of June 2015.

Observed convective events on the 21 June 2016

•Shower, thunderstorm and hails has a very local character and did not extend outside of Tbilisi in the afernoon (16:15-17:00) of the 21 June 2016.

•The fair weather suddenly changed with a strong wind (wind's velocity reached about 45m/s) at 16:00 in Tbilisi.

• The cloudy systems gradually grew above the different districts of Tbilisi from 16^{15} to16^{25} and after 5 minutes began heavy unexpected shower, which was accompanied with 2-3 mm diameter hail.

•Hailing stopped after 8 min but the shower was accompanied with thunder and electrical storm, (thunderstorm).

•At 16:50 the down pouring stopped and very soon (17: 00) stopped the raining too.

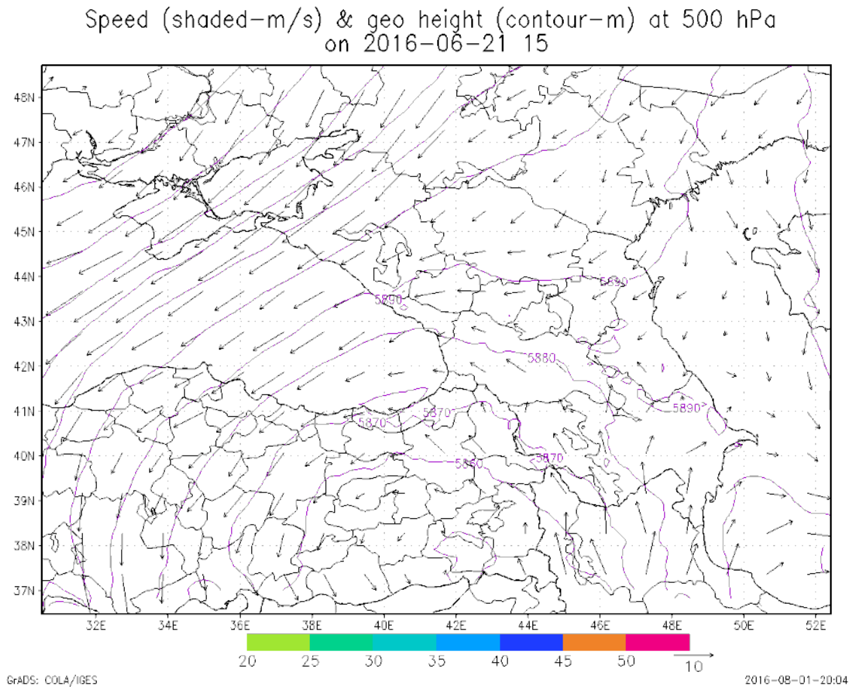


Fig.1. Wind velocities distribution over the Caucasus region obtained by the coarse grid calculations at 15:00 on the 21 June 2016

Results of Numerical Calculation executed by Set 1 (WSM6/KF) 21 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

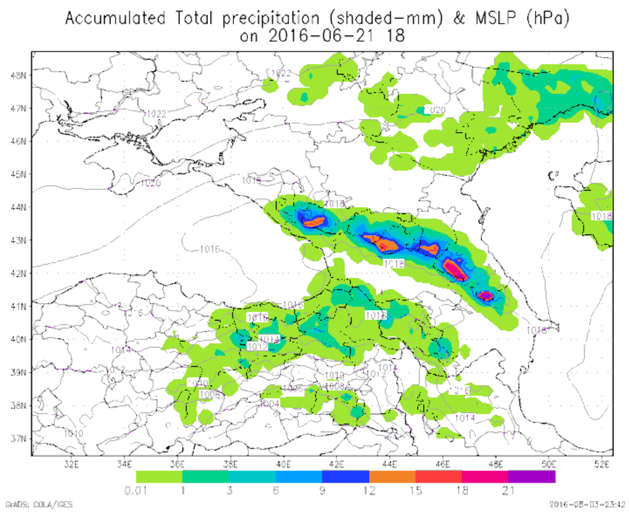


Fig.1.2 Coarse mesh (19.8km) calculations of ATP 18 h sum (21 June 2016)

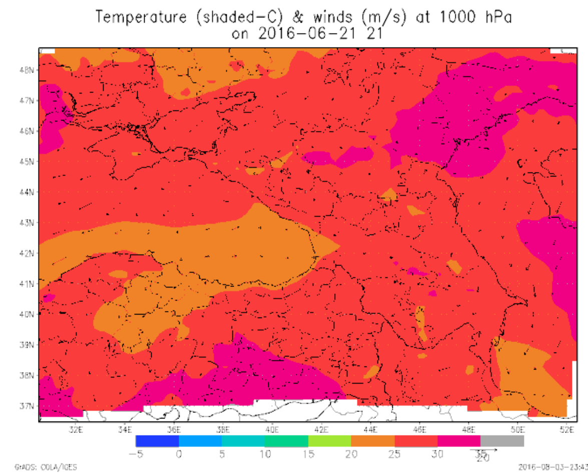


Fig.1.3 The coarse mesh calculations of Temperature and Wind velocity at 1000 hPa at 21:00 21 June 2016 (there is heat transfer from the southwest to the west)

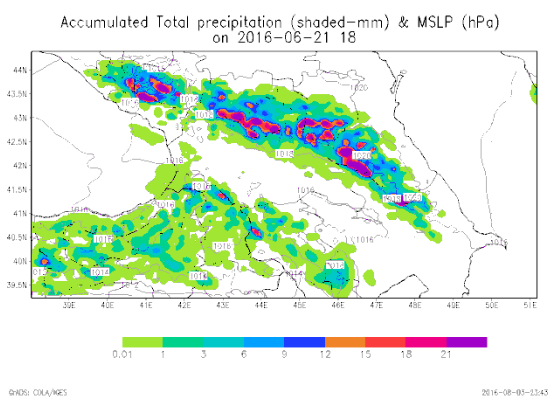


Fig.1.4 Fine mesh (6.6km) calculations of ATP 18 h sum (21 June 2016)

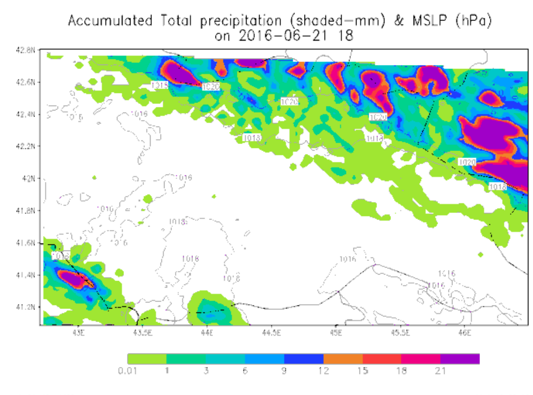


Fig.1.5 The finest mesh (2.2km) calculations of ATP 21 h sum (21 June 2016)

Results of Numerical Calculation executed by Set 2 (Thomson/BMJ) 21/06/ 16

Tbilisi (41.716667 ° N, 44.783333 ° E)

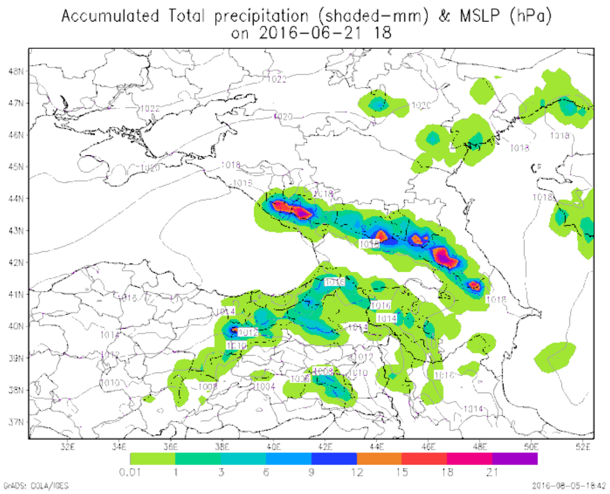


Fig.2.1 Coarse mesh (19.8km) calculations of ATP 18 h sum (21 June 2016)

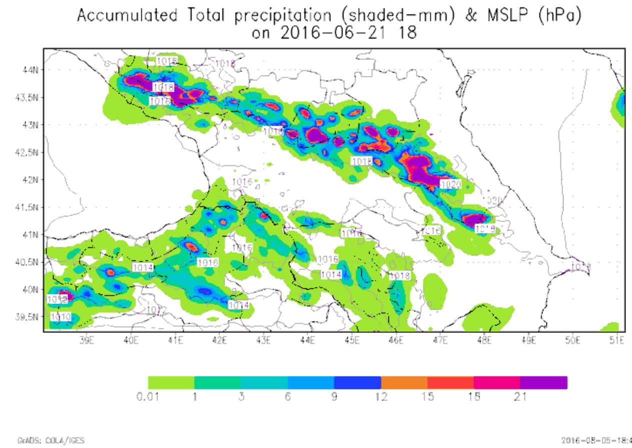


Fig. 2.2Fine mesh (6.6km) calculations of ATP 18 h sum (21 June 2016)

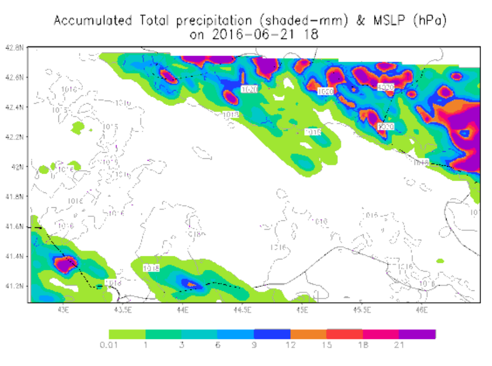


Fig.2.3 The finest mesh (2.2km) calculations of ATP 21 h sum (21 June 2016)

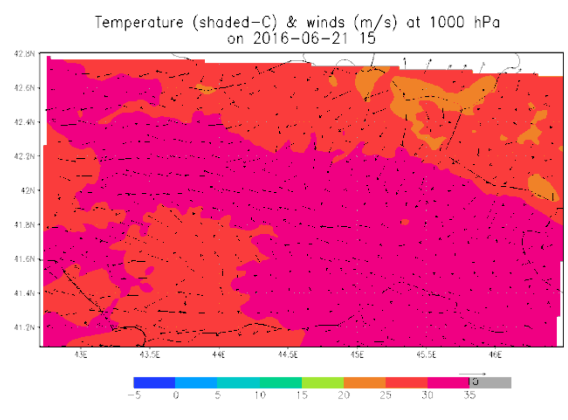


Fig.2.4 The finest mesh (2.2km) calculations of Temperature and Wind velocity at 1000 hPa

Results of Numerical Calculation executed by Set 3 (Lin/KF) 21 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

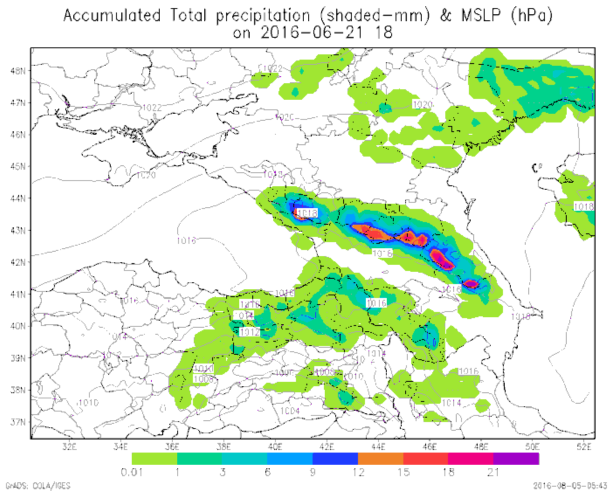


Fig.3.1 Coarse mesh (19.8km) calculations of ATP 18 h sum (21 June 2016)

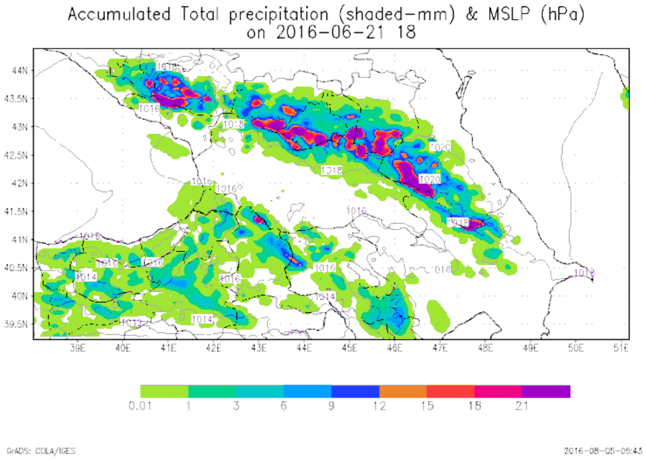


Fig.3.2Fine mesh (6.6km) calculations of ATP 18 h sum (21 June 2016)

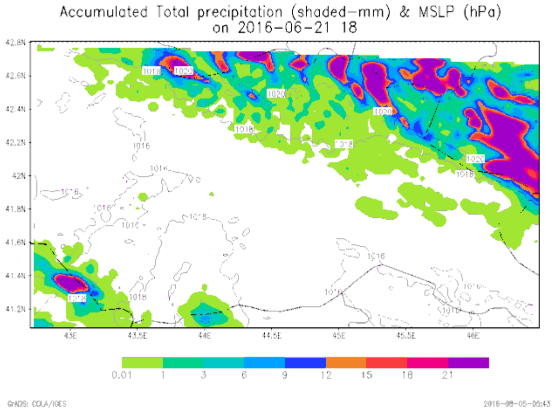


Fig.3.3 The finest mesh calculations of ATP 18 h sum (21 June 2016)

Results of Numerical Calculation executed by Set 4 (Morrison 2-M/GDE) 21/06/ 16

Tbilisi (41.716667 ° N, 44.783333 ° E)

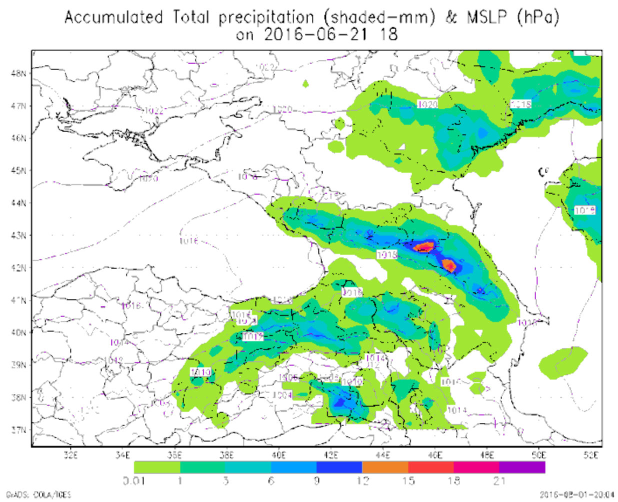


Fig.4.1 Coarse mesh (19.8km) calculations of ATP 18 h sum (21 June 2016)

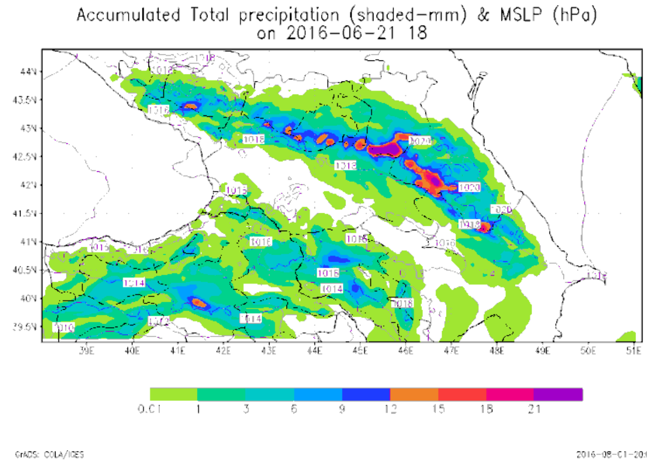


Fig.4.2 Fine mesh (6.6km) calculations of ATP 18 h sum (21 June 2016)

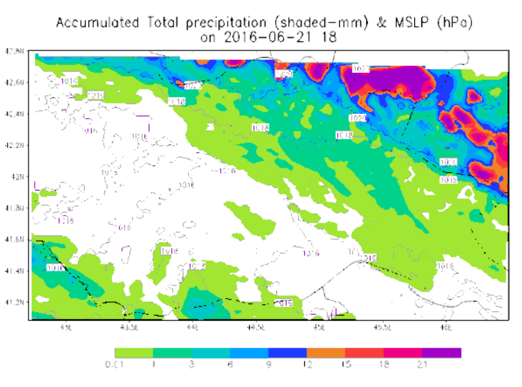


Fig.4.3 The finest mesh (2.2km) calculations of ATP 21 h sum (21 June 2016)

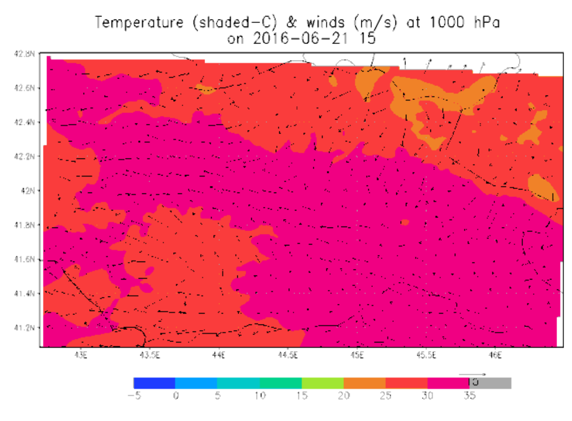


Fig.4.4 The finest mesh (2.2km) calculations of Temperature and Wind velocity at 1000 hPa at 15:00 21 June 2016 (there is heat transfer from the southwest to the west)

Results of Numerical Calculation executed by Set 5 (Goddard/KF) 21/06/ 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

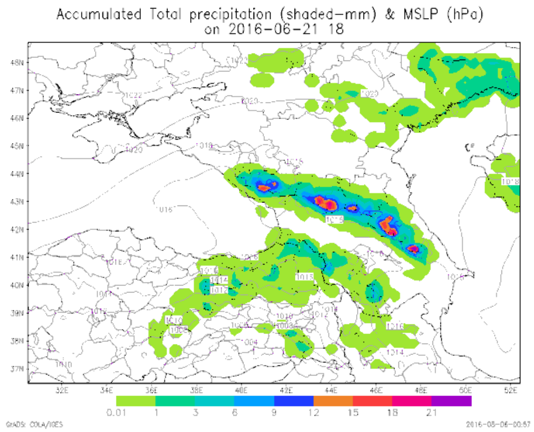


Fig.5.1 Coarse mesh (19.8km) calculations of ATP 18 h sum (21 June 2016)

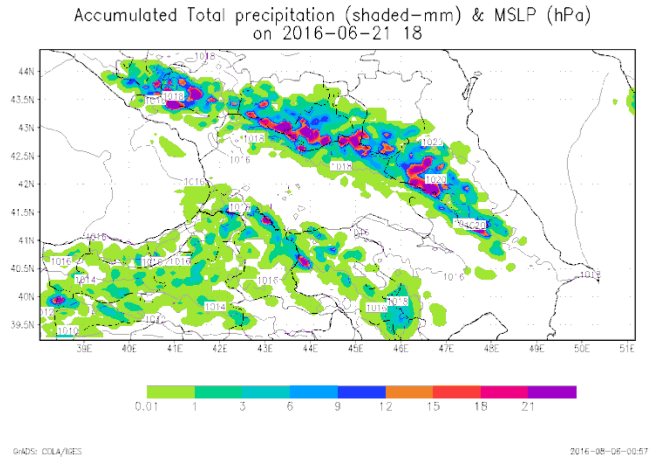


Fig.5.2Fine mesh (6.6km) calculations of ATP 18 h sum (21 June 2016)

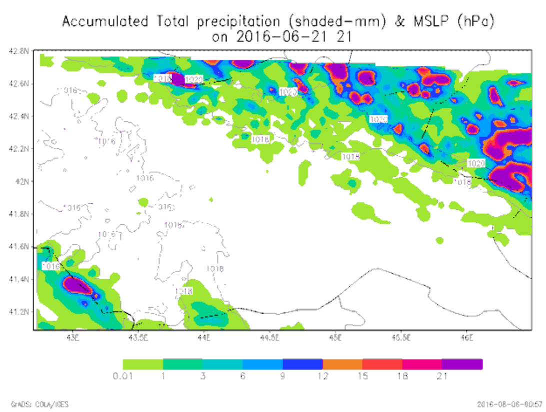


Fig.5.3 The finest mesh (2.2km) calculations of ATP 21 h sum (21 /06/ 2016)

Observed convective event on the 23 June 2016

- Weather was terrible with shower, thunderstorm, and hails during 2 hours in the evening of the 23 June 2016 in Tbilisi.
- Bit by bit has changed weather at 18:00 on 23/06/2016 in Tbilisi.
- Cloudy systems gradually collected above various districts of Tbilisi and after a sudden wind gust has begun to flow a rain which has stopped after 10 minutes.
- At 18:50 once again began to pour the rain and after 10 min the streets were full of rain water in Tbilisi.
- At 19:10 the downpouring stopped and very soon (19: 50)stopped the raining too.

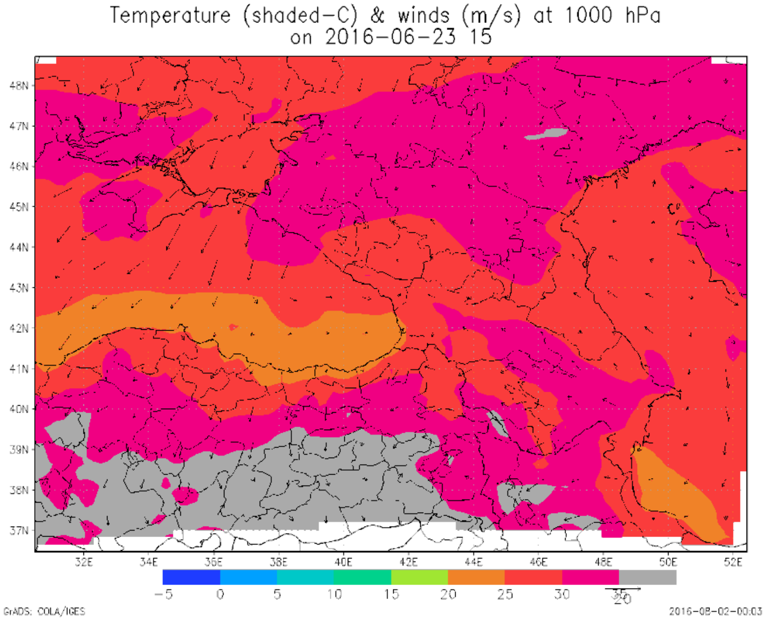


Fig.1. Temperature and Wind velocity distribution obtained by the coarse grid calculations at 15:00 on the 23 June 2016

Results of Numerical Calculation executed by Set 1 (WSM6/KF) 23 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

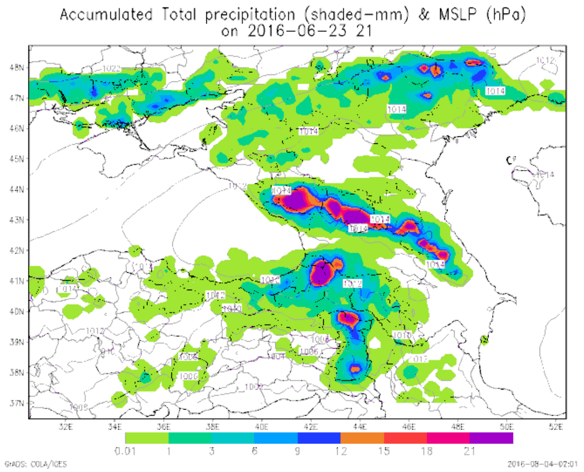


Fig.1.2 Coarse mesh (19.8km) calculations of ATP 21 h sum (23 June 2016)

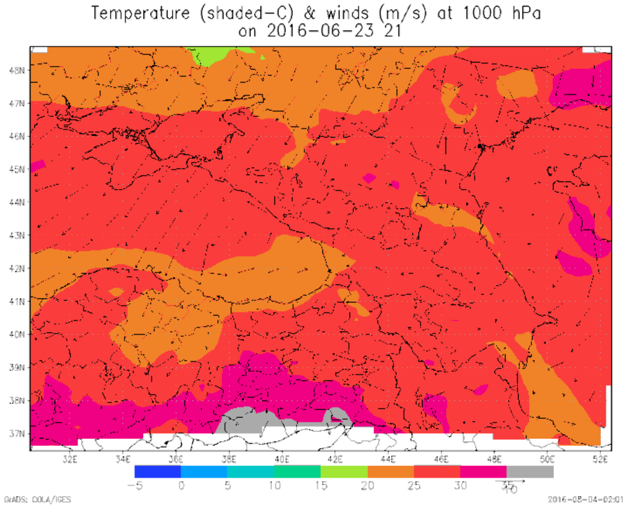


Fig.1.3 The coarse mesh calculations of Temperature and Wind velocity at 1000 hPa at 21:00 23 June 2016 (there is heat transfer from the southwest to the west)

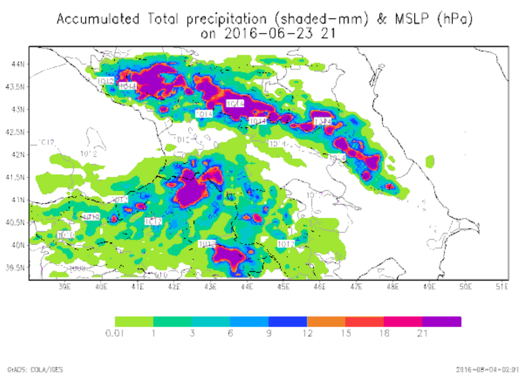


Fig.1.4 Fine mesh (6.6km) calculations of ATP 21 h sum (23 June 2016)

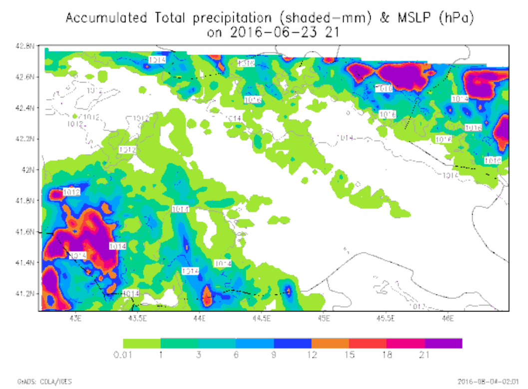


Fig.1.5 The finest mesh (2.2km) calculations of ATP 21 h sum (23 June 2016)

Results of Numerical Calculation executed by Set 4 (Morrison 2-M/GDE) 23 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

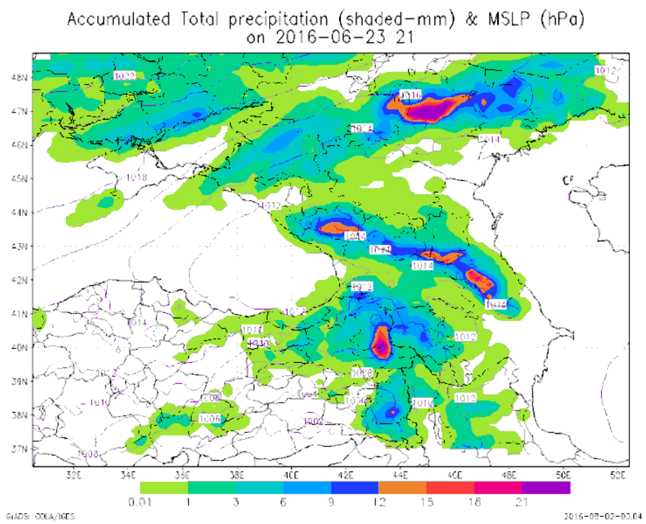


Fig.1.1 Coarse mesh (19.8km) calculations of ATP 21 h sum (23 June 2016)

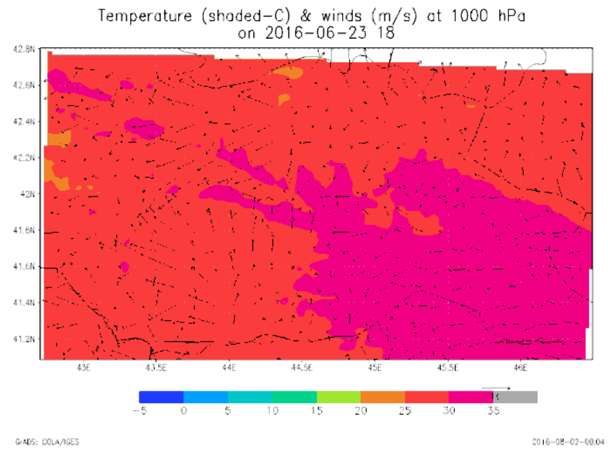


Fig.1.3 The finest mesh (2.2km) calculations of Temperature and Wind velocity at 1000 hPa at 18:00 23 June 2016 (there is complete chaos)

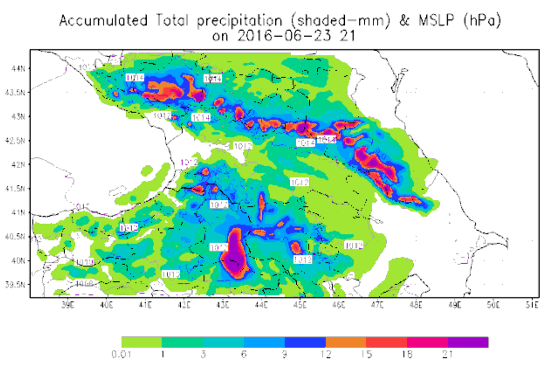


Fig.1.2 Fine mesh (6.6km) calculations of ATP 21 h sum (23 June 2016)

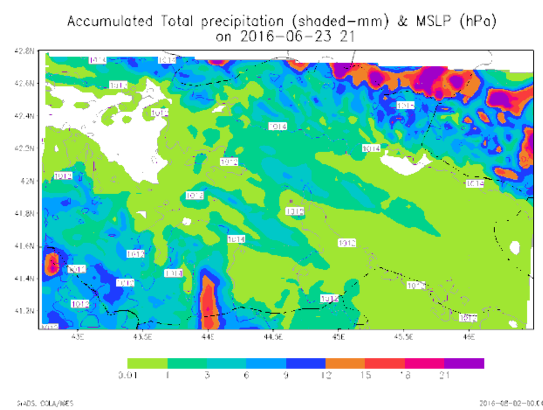


Fig.1.4 The finest mesh (2.2km) calculations of ATP 21 h sum (23 June 2016)

Results of Numerical Calculation executed by Set 2 (Thomson/BMJ) 21 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

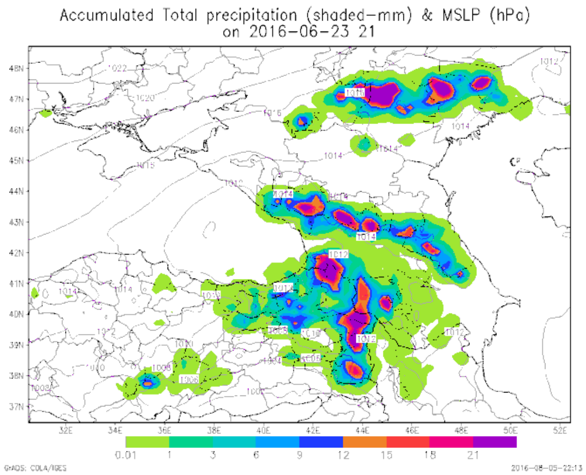


Fig.2.1 Coarse mesh (19.8km) calculations of ATP 21 h sum (21 June 2016)

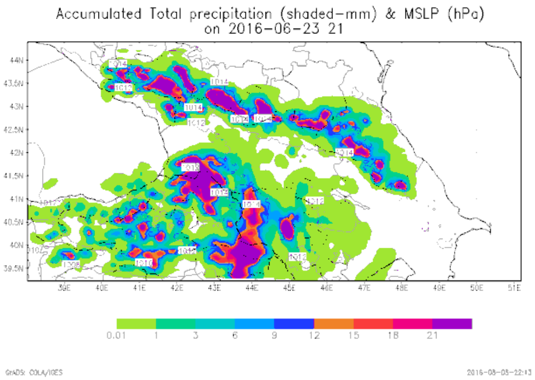


Fig.2.2Fine mesh (6.6km) calculations of ATP 21 h sum (21 June 2016)

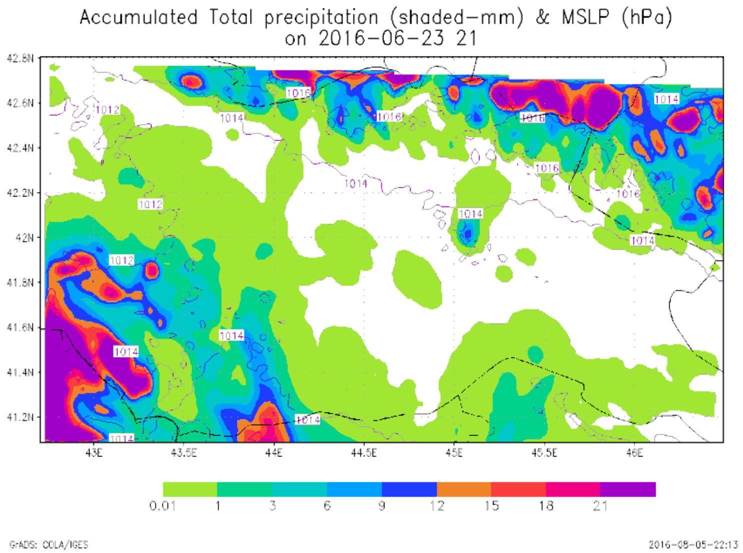


Fig.2.3 The finest mesh (2.2km) calculations of ATP 21 h sum (21 /06/ 2016) a bit **!!!**

Results of Numerical Calculation executed by Set 3 (Lin/KF) 23 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

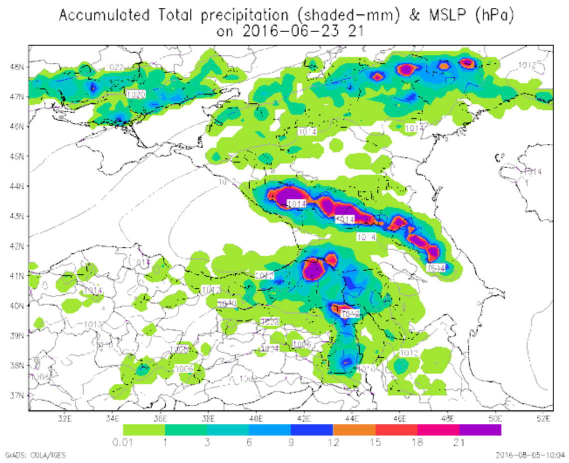


Fig.3.1 Coarse mesh (19.8km) calculations of ATP 21 h sum (23 June 2016)

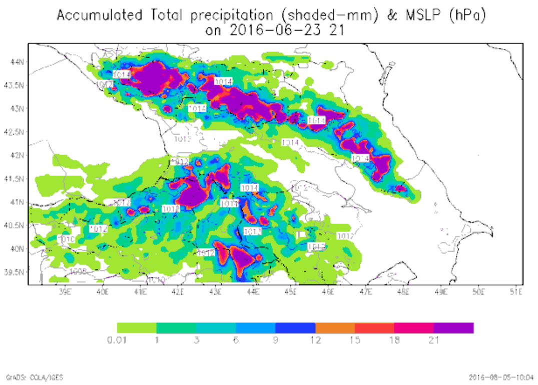


Fig.3.2Fine mesh (6.6km) calculations of ATP 21 h sum (23 June 2016)

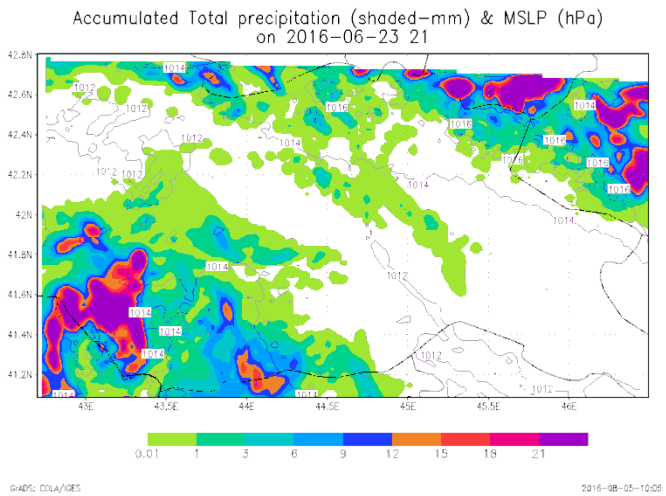


Fig.3.3 The finest mesh (2.2km) calculations of ATP 21 h sum (23 /06/ 2016)

Results of Numerical Calculation executed by Set 4 (Morrison 2-M/GDE) 23 June 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

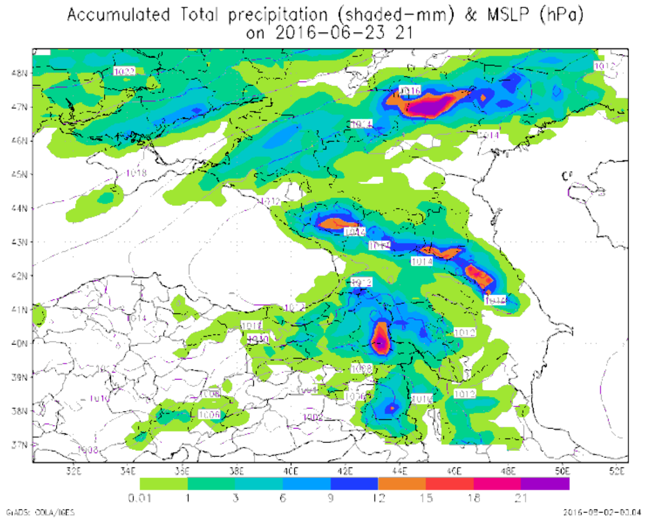


Fig.1.1 Coarse mesh (19.8km) calculations of ATP 21 h sum (23 June 2016)

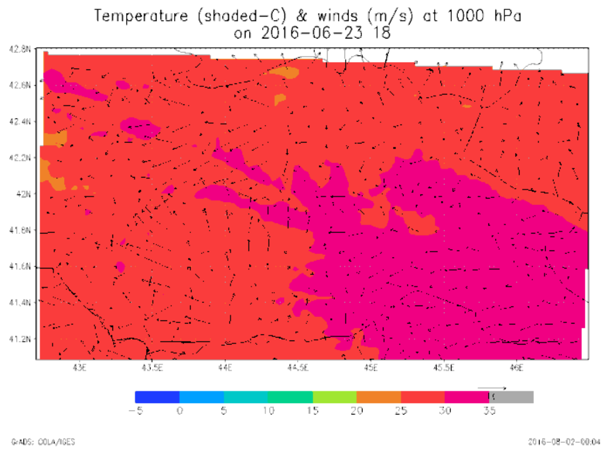


Fig.1.3 The finest mesh (2.2km) calculations of Temperature and Wind velocity at 1000 hPa at 18:00 23 June 2016 (there is complete chaos)

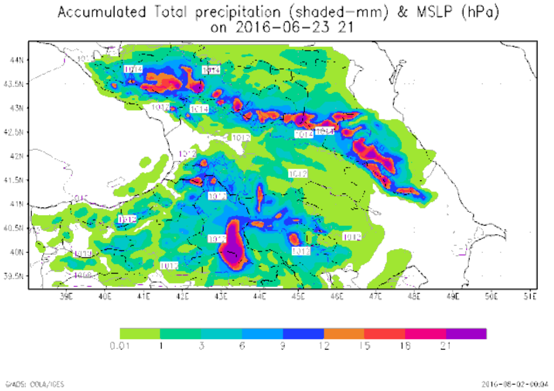


Fig.1.2 Fine mesh (6.6km) calculations of ATP 21 h sum (23 June 2016)

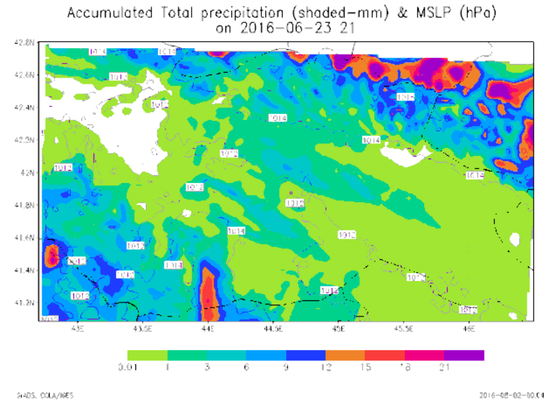


Fig.1.4 The finest mesh (2.2km) calculations of ATP 21 h sum (23 June 2016)

Results of Numerical Calculation executed by Set 5 (Goddard/KF) 23/06/ 2016

Tbilisi (41.716667 ° N, 44.783333 ° E)

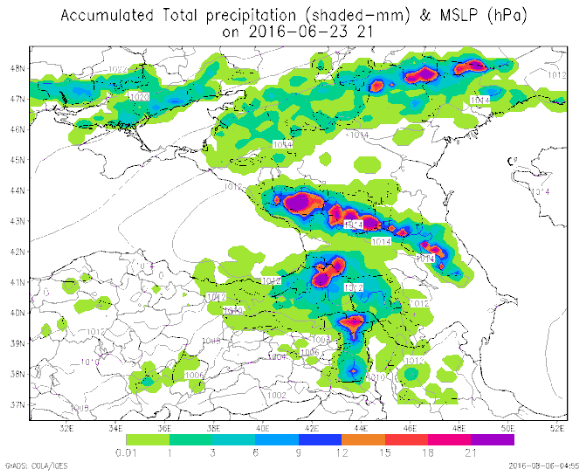


Fig.2 Coarse mesh (19.8km) calculations of ATP 18 h sum (23 June 2016)

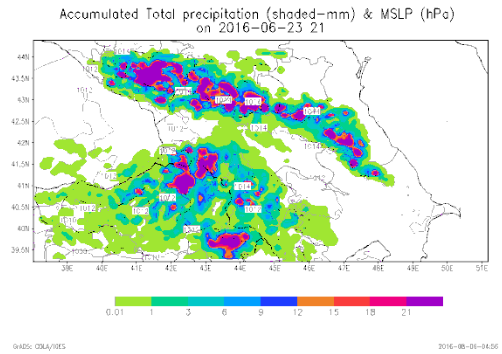


Fig.3Fine mesh (6.6km) calculations of ATP 18 h sum (23 June 2016)

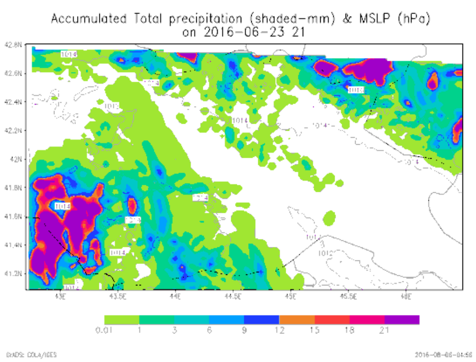


Fig.3 The finest mesh (2.2km) calculations of ATP 21 h sum (23 June 2016)

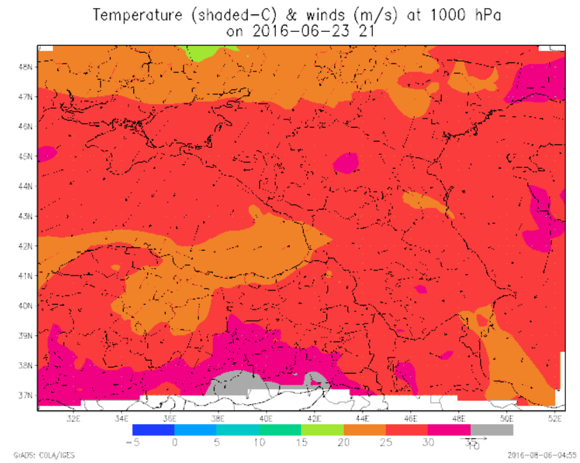


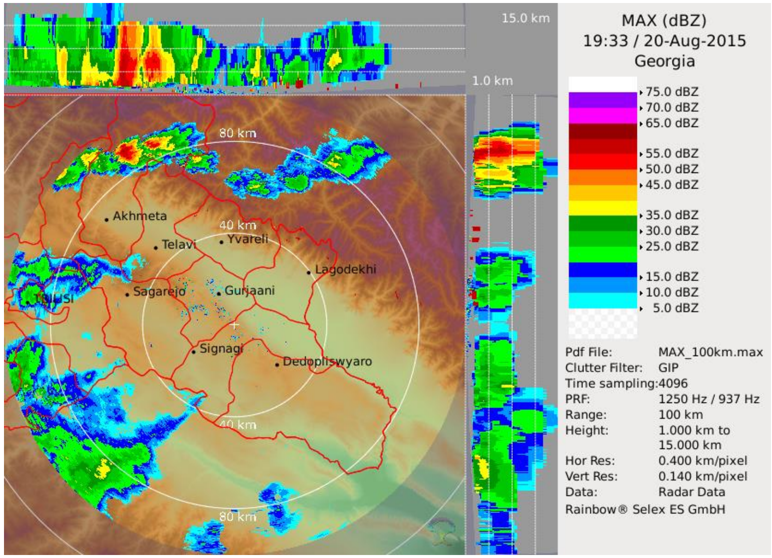
Fig.4 The coarse mesh calculations of Temperature and Wind velocity at 1000 hPa (23 June 2016)

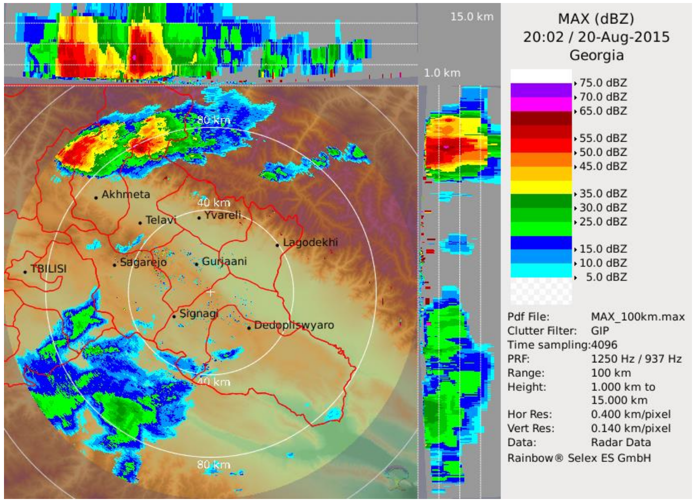
Observed convective event on 20-21 August 2015 in Kakheti

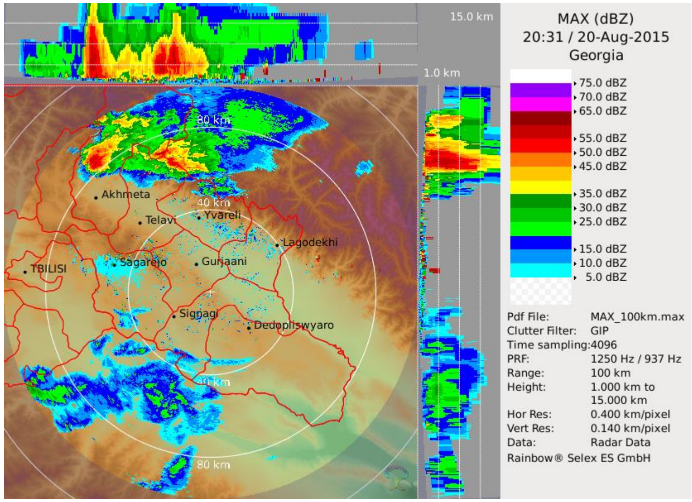
- The another case of heavy convective events was observed on 20-21 August 2015.
- It was dominated western atmospheric processes from 19 to 21 August 2015 above the territory of Georgia. 19th of August 2015 above the territory of Tbilisi developed inner massive processes and it was hailed in the evening of 19th August 2015 in Kakheti.
- On 20th of August 2015 again a heavy rainfall was observed above the Kakheti region (Kakheti is famous wine-making region in eastern Georgia) of Georgia.
- Downpours with hail cause destruction to some regions of Kakheti and resort suburbs of Tbilisi Kojori and Kiketi, where ground floors of many houses were flooded in the evening of 20th of August 2015.
- Namely, caused by the violent weather the rain with hail lasted for half an hour and in some settlements of the Gurjaani, Lagodekhi and Kvareli districts broke roofs and even walls of houses.
- 100% of **vine** grapes were destroyed by hail in Lagodekhi and Kvareli regions.

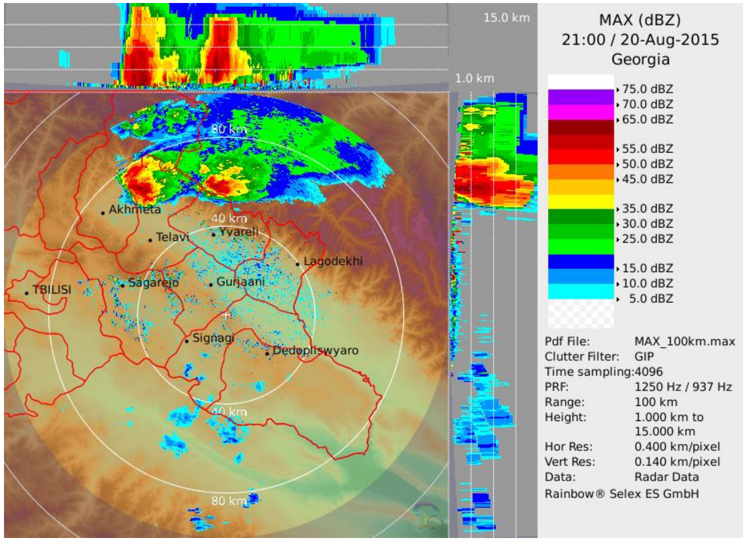
Fig.2. After hailing in Kvareli on 21 Aug. 2015

Radar's Data on Clouds Transformation from 19:33 to 21:00 (20/08/2015) R=100km

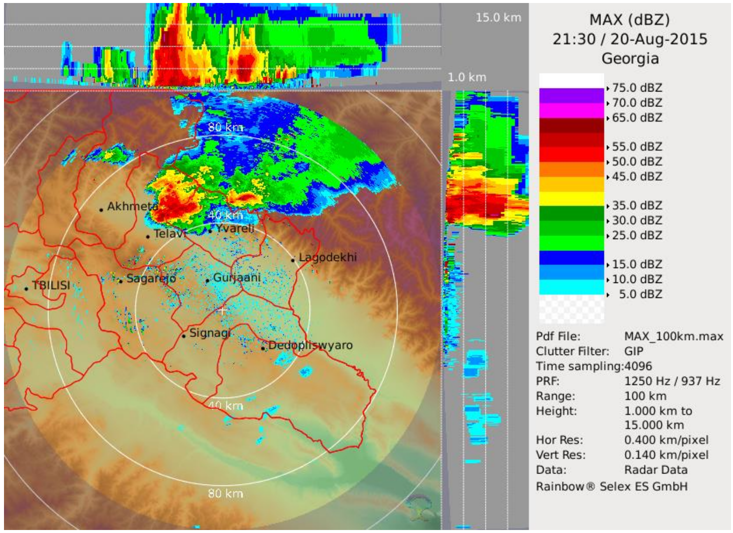


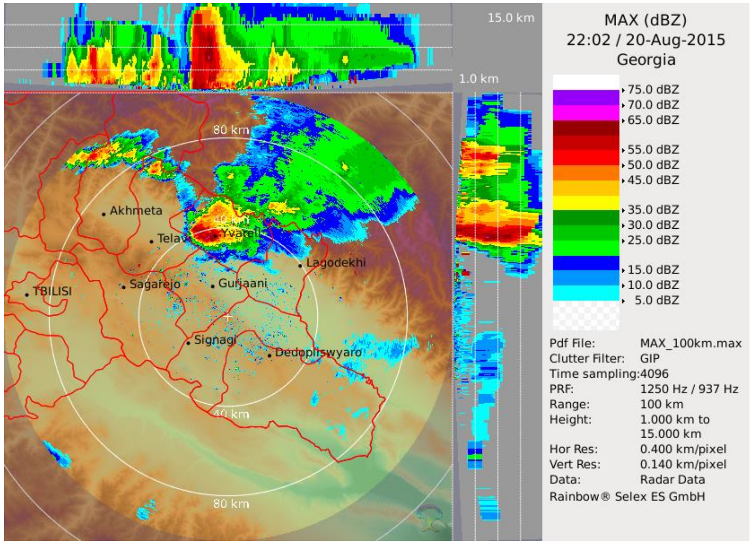


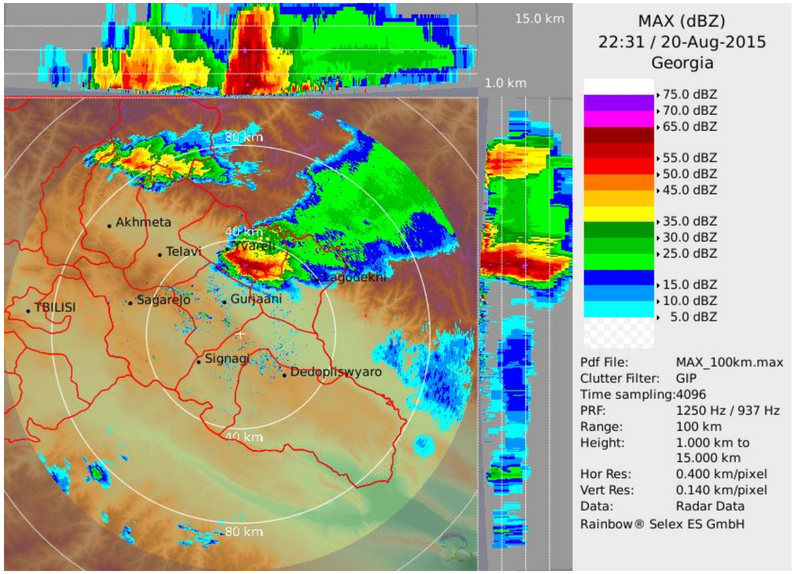


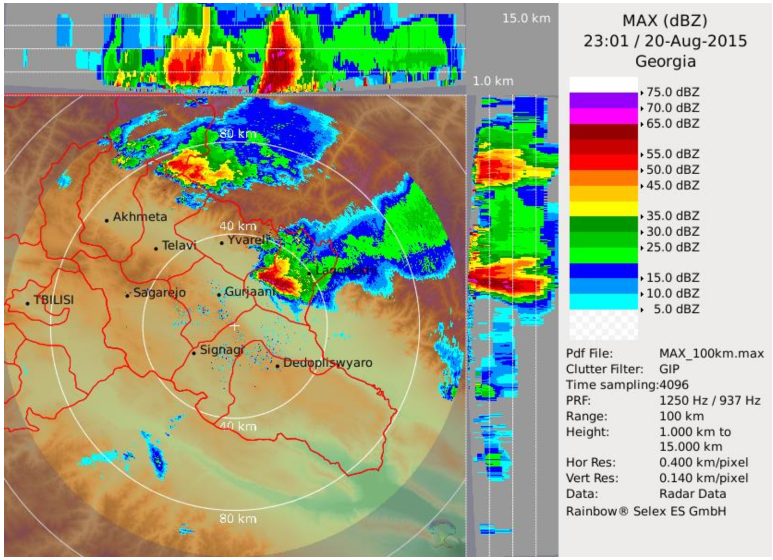


Radar's Data on Clouds Transformation from 21:30 to 23:01 (20/08/2015) R=100km.



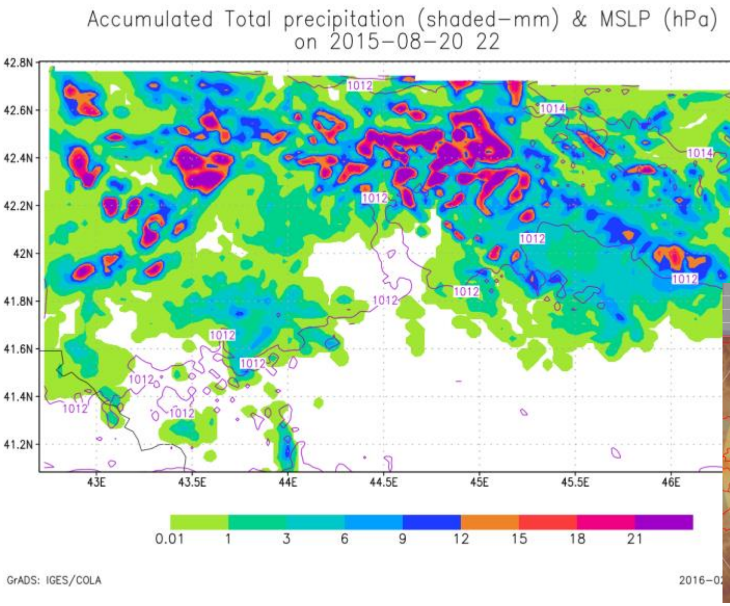


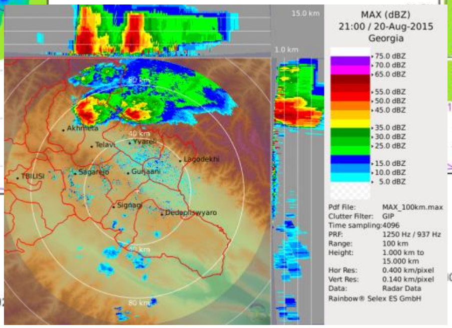




Results of Numerical Calculation on the 20th of August 2015

Coordinates of Telavi (41.91978 ° N ; 45.47315 ° E)





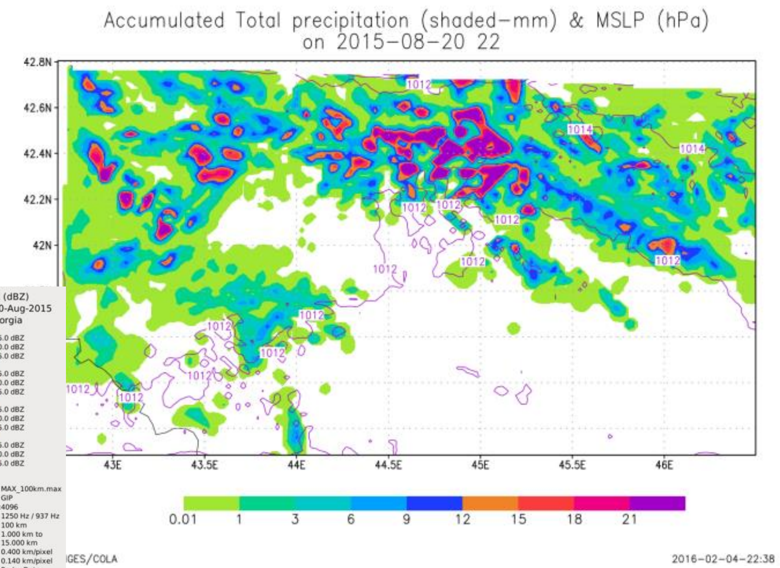


Fig.5 Forecasted (**Set-3,(Lin)** 20 August 21:00 UTC) ATP 12 h sum for nested domain 2.2 km resolution.

Fig.6 Forecasted (**Set-5,** (**Goddard**)20 August 21:00 UTC) ATP12 h sum for nested domain 2.2 km resolution.

Results of numerical calculation and comparison Fig.5 with Fig.6 had shown that the main features of accumulated precipitations were predicted almost similarly, but accurate study of the dynamics and its comparison against the data of observations had shown that **Set 3-(Lin et al.)** was able modelling that true atmospheric event which took place on the 20 -21 August 2015.

Results of Numerical Calculation for 20th of August 2015

Telavi (41.91978 ° N ; 45.47315 ° E)

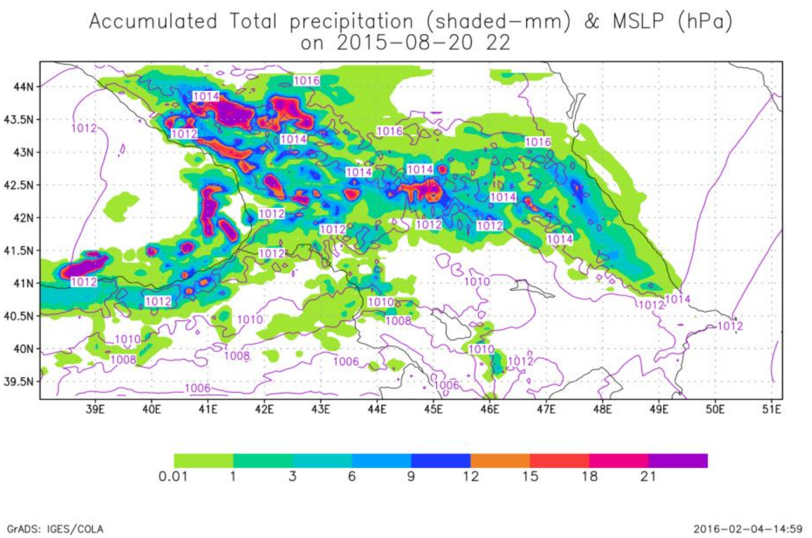


Fig.7 Forecasted (**Set-3,(Purdue Lin)** 20 August 22:00 UTC) accumulated precipitation 12 h sum for nested domain 2.2 km resolution.

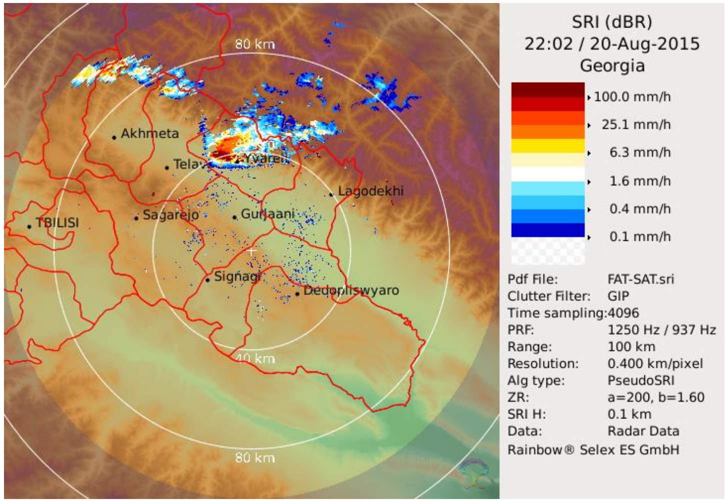


Fig.8 Map of ATP (20 August 22:00 UTC)

Results of numerical calculation and comparison Fig.7 against to Fig.8had shown that that 2.2 km resolution of **Set 3-(Lin)** was able modelling that true atmospheric event which took place on the 20 -21 August 2015.

Conclusion WRF-Nesting

- **In this study we have aimed to simulate and investigate small-scale inner massive atmospheric phenomena that leads to the development of deep thermal convection above the local territory having complex topography.**

- **Investigations have shown that a summer time extreme precipitations in the local territory with a complex orography remains a difficult forecast challenge for WRF model.**

- **Non one of the MP and CPSs schemes combinations listed in the Table 1 were not able to simulate properly atmospheric processes developed in Tbilisi and surroundings on the 13/06/2015 and on the 21, 23/06/ 2016.**

- **For these case studies, all of the precipitation predicted in Tbilisi and surroundings were not convective in nature.**

- **Nevertheless calculations executed on the fine mesh resolution (6.6 km) grids have shown hardly better ATP’s results in some regions in comparison with the coarse mesh calculations.**

Conclusion WRF-Nesting

- **Relatively better results (among all simulations) have been obtained for regional weather extreme prediction for western type synoptic processes (20th of August 2015).**

- **In this case study comparisons between WRF forecasts allowed verifying that in general the set of combinations of Set 3 (Lin et al. with Kain-Fritsch and MM5 Similarity Surface Layer schemes) and Set 5 (Goddard with Kain-Fritsch scheme and MM5 Similarity Surface Layer schemes) schemes gave better results than others.**

- **For this case, at a grid spacing of 2.2 km the simulation with no-CPS was able to represent precipitations properly.**

- **Though dynamics of the synoptic processes (atmospheric front transportation) have been modeled satisfactorily by the WS2M-6/KF schemes but observed and predicted values of ATP have actually been coherent only in some areas of the investigated regions.**

Conclusion

- **In summary it can be said, that above mentioned model can be successfully used for regional weather extremes prediction for western type synoptic processes.**

- **for evolution and improvement of model skill for different time and spatial scale the verification and assimilation methods should be used for further tuning and fitting of model to local conditions.**

- **statistical calibration should be done additionally.**

- **The results obtained by this study should be useful for future modernization parameterization schemes, for design the WRF v.3.6 model and for operational use at regional scales at the Georgian Environmental agency.**

Thanks for

your attention!