Prediction of hydrometeorological hazardous events in Armenia by implementing WRF-ARW physics sensitivity experiments: a case study for heavy rainfall

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ABSTRACT

Armenia due to its complex mountainous terrain and geographical location is exposed to various types of hydrometeorological hazardous events, among those it is worth noting heavy rainfall, strong winds, hailstorm, snowfall, frosts, etc. These hazards often lead to disasters, causing big economic and human loss. In order to be prepared to the mentioned hazards and prevent population from disasters it is vitally important to produce accurate forecasts and issue warning with sufficient lead time. With this purpose WRF sensitivity experiments have been conducted for the territory of Armenia which will allow to identify the most optimal combination of the parameterization options for the territory of Armenia. The model was run for a single case on 12 May, 2013 when a heavy rainfall was reported throughout the country in some regions accompanied with hail.

The results showed that the combination of physics parameterization schemes with WRF Single-Moment 6-class (WSM6) scheme of microphysics showed better results, capturing heavy precipitation over the northern regions of the country. However, this is one of the first attempts for this kind of experiments with quite promising results. Therefore it is planned to continue the experiments changing also other physics parameterization options.

Keywords

Hydrometerological hazards, heavy rainfall, numerical weather prediction, WRF-ARW, sensitivity experiments, physics parameterization

1. BACKGROUND

Within the framework of the state program a joint team of leading specialists from ASHMMS/MES and the Institute for Informatics and Automation problems (IIAP) of the National Academy of Sciences of Armenia started the deployment of the Weather Research and Forecasting (WRF) numerical weather prediction model for the territory of Armenia, which is a next-generation mesoscale (from a few to several hundred kilometers) forecast model and assimilation system that advances both the understanding and the prediction of mesoscale precipitation systems and promotes closer ties between the research and operational forecasting communities.

Since this system requires a huge number of parallel computations, it uses the available computational resources of Armenian National GRID Infrastructure (ArmNGI), which consists primarily of computational (about 500 cores) and storage resources, located in the leading scientific research and educational organizations of Armenia. On daily base this system automatically downloads the required input data from National Centers for Environmental Prediction and using ArmNGI resources does the calculations required for weather prediction. This system takes under consideration the local meteorological data (the values of local measurements, e.g. temperature, wind, etc.). This system produces weather prediction based on WRF model and supports the user interaction with the system allowing to handle a huge number of settings.

In the current system ARW core is used. The spatial resolution is 2 km, the model is run twice per day producing forecast for the next 72 hours. The simulation outputs are in NetCDF format, which are being visualized using GrADS package producing high quality readable maps. These products are provided to the operative forecasting division at Armstatehydromet to be utilized as an addition to currently used other products from GCMs and RCM.

The preliminary results show that with implementing WRF the accuracy of forecasts in general has increased, from 86-87% to 90-91%. These results are quite promising, however, there is still scope of further improving the forecasts through implementing physics sensitivity experiments.

2. DATA AND METHODOLOGY

Model data

WRF-ARW model simulations for the days with heavy rainfall occurred over Armenia on May 11-12, 2013 have been used in the study. The model configuration is set up for the parent domain (6x6km) covering a wide region of the South Caucasus, and the nested domain with resolution 2x2 covering mostly Armenia and the adjacent region. The vertical resolution of the model is 27 levels. WRF model is initialized using NCEP Global Forecast System (GFS) analysis for 00:00 am as initial/boundary conditions.

Observed data sets

Observed values of total daily precipitation observed at 48 meteorological stations on May 12, 2013 have been used for qualitative validation of the forecast.

Physics sensitivity experiments

Armenia due to its complex mountainous terrain and geographical location is exposed to various types of hydrometeorological hazardous events, among those it is worth noting heavy rainfall, strong winds, hailstorm, snowfall, frosts, etc. These hazards often lead to disasters, causing big economic and human loss. In order to be prepared to the mentioned hazards and prevent population from disasters it is vitally important to produce accurate forecasts and issue warning with sufficient lead time.

Since the number of days with heavy rainfall and hail have been reported very often during the spring and summer 2013, it was decided to start experiments with the WRF model different physics parameterization schemes in order to explore the ability of the model to predict hazardous events and to identify the combination of schemes which provides better forecast.

WRF offers multiple options for the physics and dynamics, which can be combined in many ways, as well as enabling the user to optimize the model for specific scales, geographical locations and applications. It is difficult to define what combination better describes a meteorological phenomenon, application or interest region. For the global forecasts, only regular physics options without any modification are used. The options typically range from simple and efficient to sophisticated and more computationally costly, and from newly developed schemes to well tried schemes such as those in current operational models. This is one of the first attempts to study and analyze the WRF sensitivity for the territory of Armenia depending on the parameterization options. These works sought the best model configuration to short and medium range forecasts focusing on the territory of Armenia. The model runs for a single case on 12 May, 2013 when a heavy rainfall was reported throughout the country in some regions accompanied with hail.

In the experimental run two combinations of physics parameterization schemes have been used, i.e. the first with Milbrandt-Yau Double-Moment 7-class scheme microphysics, and the second one with WRF Single-Moment 6-class scheme (table 1), other physics components remained the same in both cases.

Micro-physics	1) Milbrandt-Yau Double-Moment 7-class cheme, It includes separate categories for hail and graupel with louble-moment cloud, rain, ice, snow, graupel and hail. 2) WRF Single-Moment 6-class scheme: A cheme with ice, snow and graupel processes suitable for igh-resolution simulations.
Long wave radiation	RRTM scheme: Rapid Radiative Transfer Model. An ccurate scheme using look-up tables for efficiency. Accounts or multiple bands, trace gases, and microphysics species
Short wave radiation	Dudhia scheme: Simple downward integration allowing fficiently for clouds and clear-sky absorption and scattering.
Surface Layer	MM5 similarity: Based on Monin-Obukhov with Carslon-Boland viscous sub-layer and standard similarity functions rom look-up tables
Land Surface	Noah Land Surface Model: Unified NCEP/NCAR/AFWA cheme with soil temperature and moisture in four layers, ractional snow cover and frozen soil physics.
Planetary Boundary layer	Yonsei University scheme: Non-local-K scheme with explicit ntrainment layer and parabolic K profile in unstable mixed layer.
Cumulus Parameterization	Kain-Fritsch scheme: Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale

The model was run starting from May 12 to 24 every 3 hours with 24 hours lead time. However, in the current study the heavy rainfall reported on May 12 across the country accompanied with hail in central region (Armavir marz) is being investigated. Based on the model output data spatial distribution maps have been constructed for accumulated daily total precipitation, relative humidity at 850 hPa, and wind pattern at 850 hPa. A qualitative comparison of these plots with observed precipitation patterns was carried out so to have a rough estimate of the ability of model to forecast heavy rainfall and hail over the complex terrain of Armenia.

3. ANALYSIS

The figure 1 shows the amount of rain reported over Armenia on May 12, 2013. It is seen, that the central and northern regions received maximum amount of precipitation (Sevan – 41mm, Hrazdan – 28mm, Armavir – 23mm, Vanadzor - 21mm). On the same day a hailstorm was reported in Armavir region, with the diameter of hailstones 0.5 – 2.5 cm. It occurred in the result of the intensive convection process (upstream movement of cold air mass), which was formed on the front line of the cyclone approaching Armenia from the south-west.

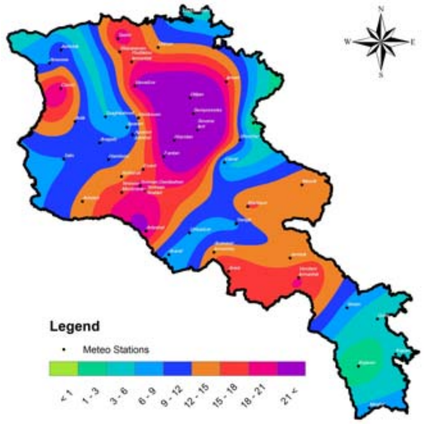
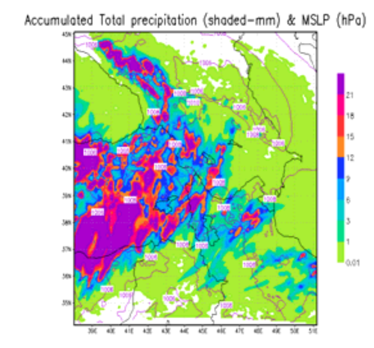
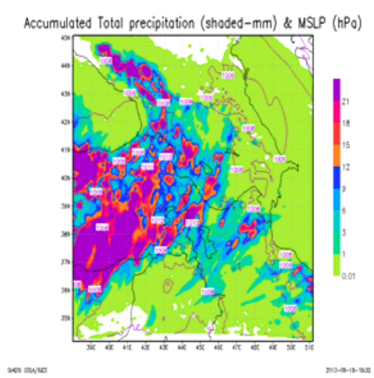


Figure 1. Spatial distribution of daily total precipitation (mm) observed on May 12 over Armenia

Comparison of the observed plot with the WFR forecast values of precipitation presented on the Figures 2,3 showed that the model captured well the maximum precipitation over the northern regions, (Lori, Tavush, Kotayk). Furthermore, the combination of physics parameterization schemes with WRF Single-Moment 6-class (WSM6) scheme of microphysics showed better results, than that with Milbrandt-Yau Double-Moment 7-class scheme. However, the model didn't reproduce well precipitation pattern over the southern regions, which also received relatively high precipitation amount. Moreover, the intensive hailstorm observed in Armavir region is not captured by the model, it predicted rather moderate amount of rain for this location.



a



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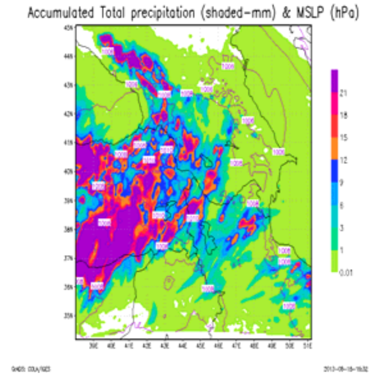

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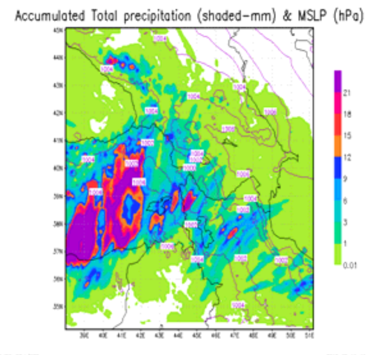
Figure 2. Accumulated daily total precipitation forecast (mm) for May 12 (a) 12pm, (b) 15pm and (c) 18pm with WRF Single-Moment 6-class (WSM6) scheme microphysics.



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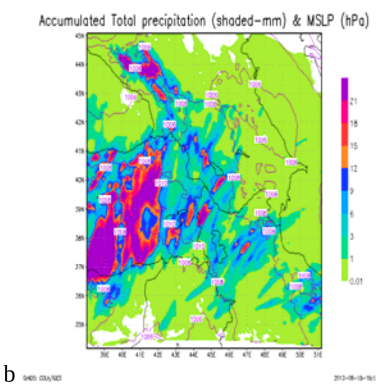

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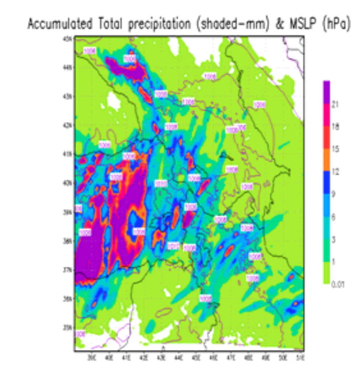

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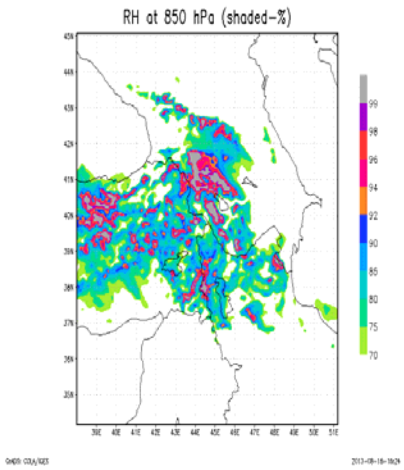
Figure 3. Accumulated daily total precipitation forecast for May 12 (a) 12pm, (b) 15pm and (c) 18pm with Milbrandt-Yau Double-Moment 7-class scheme microphysics

Relative humidity and wind components at 850 hPa are predicted rather well in case with WSM6 scheme (Fig. 4 a,b). The patterns of relative humidity coincide with those of precipitation, i.e. the highest values are predicted over the northern regions, where maximum precipitation is expected. Winds at 850 hPa reproduced the air masses (cyclone) approaching from the eastern Black Sea region.



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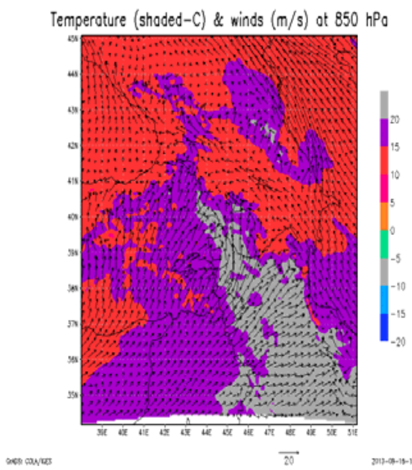

b

Figure 4. Relative Humidity (a) and Wind patterns (b) at 850 hPa predicted by the model with WRF Single-Moment 6-class (WSM6) scheme microphysics

4. CONCLUSIONS

Prediction of hazardous hydrometeorological phenomena for Armenia is a challenging task. Weather Research and Forecasting (WRF) numerical weather prediction model, which is a next-generation mesoscale (from a few to several hundred kilometers) forecast model and assimilation system, advances both the understanding and the prediction of mesoscale precipitation systems and promotes closer ties between the research and operational forecasting communities. Therefore, this model is being implemented in order to improve the accuracy and lead time of short range forecasts for Armenia.

A case study was carried out on the example of a heavy precipitation observed on May 12, 2013 over Armenia, conducting WRF sensitivity experiments for the territory of Armenia depending on the parameterization options. For this purpose WRF-ARW model was run with two combinations of physics parameterization schemes, i.e. the first with Milbrandt-Yau Double-Moment 7-class scheme microphysics, and the second one with WRF Single-Moment 6-class scheme, other physics components remained the same in both cases. The results showed that the combination of physics parameterization schemes with WRF Single-Moment 6-class (WSM6) scheme of microphysics showed better results, capturing heavy precipitation over the northern regions of the country. However, this is one of the first attempts for this kind of experiments with quite promising results. Therefore, it is planned to continue the experiments changing also other physics parameterization options.

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