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WEATHER RESEARCH FORECAST LOCAL AREA MODEL APPLICATION FOR GEORGIA'S CONDITIONS

Kutaladze N., Mikuchadze G., Davitashvili

Abstract. We have elaborated and configured Whether Research Forecast - Advanced Researcher Weather (WRF-ARW) model for Caucasus region considering geographical-landscape character, topography height, land use, soil type and temperature in deep layers, vegetation monthly distribution, albedo and others. Porting of WRF-ARW application to the SEE-Grid was a good opportunity for running model on larger number of CPUs and storing large amount of data on the grid storage elements. On the grid WRF was compiled for both Open MP and MPI (Shared + Distributed memory) environment and on the platform Linux-x86. In searching of optimal execution time for time saving different model directory structures and storage schema was used. Simulations were performed using a set of 2 domains with horizontal grid-point resolutions of 15 and 5 km, both defined as those currently being used for operational forecasts. Interaction of airflow with complex orography of Caucasus with horizontal grid-point resolutions of 15 and 5 km were studded.

Keywords and phrases: Advanced researcher weather model, SEE-Grid, numerical calculations.

AMS subject classification (2000): 65M12; 35Q80

The improvement in forecast skills makes atmospheric models prevalent in operative weather numerical prediction and grants them great social demand. It have been achieved by better numerical schemes, more realistic parameterizations of physical processes, new observational data from satellites and crucially, more sophisticated methods of determining the initial conditions, variational assimilation and effective integration numerical methods for solution of prognostic equations. Mathematical models of atmosphere manipulate with the huge datasets and perform the complex calculations using the most powerful supercomputers in the world. Such a power of computing is required for running high-resolution global models. The elaboration of optimal technology for calculation of numerical weather prediction is to be based on parallel (computing) processing. Nowadays in developed counters massive parallel structures (such as supercomputers CRAY) are used for weather prediction with numerous (million and milliard) parallel working processors. From this point of view the adaptation of abovementioned direction for weather prediction task can be considered as a taking advantage of parallel computing. Since 90-s the revolutionary development of information technologies (IT) stimulated parallel computing evolution. New directions, based on the modern microprocessors achievements were established. The special software technologies were designed for the solution of above-mentioned problem. The parallel programming of data processing and appropriate software for macro scale parallel computing took up the challenge. The last one is resulting from increasing capacity of computers (among them personal computers) and significantly reduced economical expenses (several hundred USD).

Global atmosphere models, which describe the weather processes on the macro scale (1000 km and more), can predict the weather conditions one week ahead. It gives the general character of the weather, but can not catch the smaller scale processes, especially local weather. Small-scale processes such as convection often dominate the local weather, which cannot be explicitly represented in models with grid boxes of size more then 10 km. A much finer grid is required to properly simulate frontal structures and represent cumulus convection. A grid of few kilometers is needed. Even w ith the powerful computers available today, such resolution cannot be achieved over the entire globe, so for local weather prediction a limited area models are elaborated. The spectrum of such models has great diversity, they also known as regional models or meso-scale models. They have artificial boundaries where the values of the model variables are provided by a global model run on a coarser grid. Regional models describe real weather conditions, which are dominated by meso and micro-scale atmosphere processes, lying beyond the capability of global models. Limited area models WRF-EMS (Weather Research Forecast -Environmental Modeling System) and WRF-ARW (Advanced Researcher Weather) were elaborated and configured for Caucasus region. The WRF project is an ongoing collaboration to develop a next-generation regional forecast model and data assimilation system for operational numerical weather prediction and atmospheric research (www.wrf-model.org). The methodology of the model have been developed in The Meso scale and Micro scale Meteorology (MMM) Division of NCAR and the National Center for Environmental Predictions (NCEP). The methodology gives possibility to use the real time outputs of global model - GFS (Global Forecast System), as lateral boundary and initial conditions for regional domain and recalculating its results adjusted for local physical-geographical parameters and some meso and micro atmosphere, biological and chemical processes. Structure of the model can be formally divided into "physical package" and dynamical part. Configuration of the model for Caucasus region considers fitting of "physical package" for geographical-landscape character, topography height, land use, soil type and temperature in deep layers, vegetation monthly distribution, albedo and others. The dynamical part provides transformation of global circulation processes influenced by regional factors, such as complex orography and the proximity to Black and Caspian Seas, which determine the local weather character. Furthermore, ARW provides more precise resolution by adding horizontal grid (nesting), with finer space-time scale (about 4 km), focusing on the sub-region of interest and moving nesting infrastructure. Before describing of model settings and configuration it's worth to mention the complexity and novelty of WRF model's elaboration from view point of Informational technology. Programming of systems, with taking advantage of multi processor capacity, has different technological peculiarities. WRF consists of about 360,000 lines of Fortran 90 and C source code, and is parallelized using the MPI programming model. WRF has been ported to a wide variety of platforms including Linux Clusters. In our case, model was installed on two different work stations with shared memory (SMP). a) PC with Intel core 2 duo 2X2.4Ghz CPUs 2Mb Cache, Shared memory (2Gb) configuration, RHEL5.1-x86, IFC, ICC 9.1.043. b) PC with AMD quad core 4X2.2Ghz CPUs 2Mb+2Mb (L2+L3) Cache, Shared memory (4Gb) configuration, RHEL5.2-x86, PGI v7.1.6 Programming technology for them is simpler. There is a high quality software for them. Each component of these systems has high quality and therefore, is significantly more expensive. Systems with distributed memory are unity of several autonomy calculation nodes (PC or Workstation), they are connected by high-speed data transfer net. In case of equal number of central processors those systems are much cheaper than SMP systems, but there are some big problems to control and programming those systems. Software for the systems are more sophisticated than that for SMP systems and requires more specific knowledge. Nowadays there are two basic parallel computing technologies. 1. OpenMP (Open Multi-Processing), used in symmetric MPS 2. MPI Message Passing Interface, for distributed memory MPS These technologies determine optimal calculation models, which in turn define programming algorithms. In our case grid technology was used with Shared + Distributed memory configuration with openMP and MPI v 1.2.7 32bit application. After complete technological elaboration of the model the main attention was paid to adequate simulation of local circulation process during the different direction and character air masses penetration. The model gives possibility to determine trajectory of the air flows by moving nesting frames along the Black and Caspian seas surface and the over the whole territory of Georgia to catch influence of Likhi range and small and great Caucasus. Consideration of different atmosphere meso and micro processes in the model is controlled by several physical schemes: a) sophisticated mixed-phase physics suitable for cloud-resolving modeling; b) cumulus parameterization. The schemes are intended to represent vertical fluxes due to unresolved updrafts and downdrafts and compensating motion outside the clouds; c) surface physics: Multi-layer Land Surface Models ranging from a simple thermal model to full vegetation and soil moisture models, including snow cover and sea ice. The 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 to provide heat and moisture fluxes over land points and sea-ice points; d) the Land Surface Models have various degrees of sophistication in dealing with thermal and moisture fluxes in multiple layers of the soil and also may handle vegetation, root, and canopy effects and surface snow-cover prediction; e) planetary boundary layer physics: turbulent kinetic energy prediction or non-local K schemes. The planetary boundary layer (PBL) is responsible for vertical sub-grid-scale fluxes due to eddy transports in the whole atmospheric column, not just the boundary layer; f) atmospheric radiation physics: long-wave and short-wave schemes with multiple spectral bands and a simple short-wave scheme. Cloud effects and surface fluxes are included. The radiation schemes provide atmospheric heating due to radiation flux divergence and surface downward long-wave and short wave radiation for the ground heat budget. Within the atmosphere, radiation responds to the model-predicted distributions of clouds and water vapors, as well as to the concentrations of specified carbon dioxide, ozone and (optionally) trace gases. The range of application of meso-scale models is quite wide including first of all the early warning of extreme events. Gales, floods and other anomalous weather events can cause huge financial losses. Medium-range guidance generally signals large-scale events well in advance. But meso-scale models can give better timing and localization of extreme events. The higher spatial resolution and use of more recent observation data enables meso-scale models to catch the development of small-scale, localized events that is hidden in the net of medium-range models. The early warnings enable to save both - life and property. There are some investigations of WRF usage for extreme precipitation prediction for South Caucasus (N.Kutaladze, L.Megrelidze, G.Mikuchadze, I.Chogovadze, T.Davitashvili, 2008). The performance of the WRF-ARW v2.2 model was evaluated over South Caucasus in order to study the feasibility of being implemented operationally in the Meteorological Service. Due to the importance of precipitation forecasts in this area, the first goal in this task was to assess the model sensitivity to several configurations of convective and microphysical parameterizations. Simulations were performed using a set of 2 domains with horizontal grid-point resolutions of 15 and 5 km, both defined as those currently being used for operational forecasts The coarser domain is a grid of 94x102 points which covers the South Caucasus region, while the nested inner domain has a grid size of 70x70 points mainly territory of Georgia. Both use the default 31 vertical levels. Model verification, calibration and tuning processes are having been in progress. The fixed options have been kept without change through all the simulations, while the options defined as tested schemes, which include cumulus and microphysics parameterizations, have been combined leading to 6 possible combinations of different physical schemes for the coarser domain and 8 available configurations for the inner one. These configurations can be defined as: 1. KF.WSM5: Kain-Fritsch (KF) cumulus scheme with the WSM5 microphysics, KF.Thom: KF scheme with the Thompson microphysics; 2. BMJ.WSM5: Betts-Miller-Jnjic (BMJ) cumulus parameterization with the WSM5 microphysics; 3. BMJ.Thom: BMJ cumulus scheme with the Thompson microphysics; 4.GD.WSM5: Grell-Devenyi (GD) cumulus parameterization with the WSM5 microphysics; 5. GD.Thom: GD cumulus scheme with the Thompson microphysics; 6. EXP.WSM5: Explicitly resolved convection with the WSM5 microphysical scheme; 7.EXP.Thom: Explicitly resolved convection with the Thompson microphysics. Each simulation has been repeated for each possible configuration in order to evaluate the sensitivity of all these forecasts to each of these possible combinations of cumulus and microphysics schemes. The best results for the coarser domain have been done by the KF.WSM5 configuration, while for the inner domain only it has been concluded that the EXP.Thom configuration shows the worst skill. Results of the study have been published in several articles. The main purpose was to find a stable configuration for the model for operational forecasts Model output products include all products that use model fields. The model forecast variables can be looked at directly, post processed into grids, plots, station predictions, etc., and used in combination with climatology and other data sources in statistical forecasts. Collectively, they are an important part of the forecast process.

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Authors' addresses:

N. Kutaladze and G. Mikuchadze
Georgian Hydro-Meteorological Department
150, Agmashenebeli Av., Tbilisi 0112
Georgia
E-mail: cwlom08@gmail.com

T. Davitashvili
I. Vekua Institute of Applied Mathematics of
Iv. Javakhishvili Tbilisi State University
2, University St., Tbilisi 0186
Georgia
E-mail: tedavitashvili@gmail.com