PARAMETRIZATION OF WEATHER RESEARCH FORECAST MODEL OVER WESTERN HIMALAYAN REGION – INDIA

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KEY WORD: Geospatial, forecast, WRF, Weather, Western Himalaya

ABSTRACT:

In this study geospatial forecast model WRF (Weather Research & Forecast) has been used to simulate weather variables over Western Himalaya, India. WRF produces simulation which is based on idealized condition or actual atmospheric conditions includes both observation and analyses. WRF Pre-Processing System setup is a collection of Fortran and C programs which requires static and meteorological input data having specific resolution and can be used for nested domain i.e., for more than one grid. For the simulation purpose of the model real time atmospheric data has been used and the result has been compared with existing products. The output generated was for a single time-period with 30 km and 10 km of spatial resolution for outer and inner nest respectively which cover the study area. Mid of May month has been preferred for this study and analysis of the result carried out. Accumulated precipitation and surface soil moisture is very less in lower region whereas as we move up, there is inflation of these two parameters. Similarly, the temperature is very high in lower region in both cases of surface temperature as well as temperature at 2m above the earth surface.

INTRODUCTION

To understand the natural science deep learning is considered as important approach as it helps in simulation and prediction using various data-driven and numerical equation (Rasp et al., 2020). Weather variables forecast considered as important issue as it severely impacts the community of users. A good and user friendly predictive model can be used as priority tool that can help in decision making during various activities such as farming (Jaseena & Kovoor, 2022), tourist activities, travelling, construction etc., including risk and mitigation plan at the time of disaster occurrences due to unexpected weather condition (Fente & Singh, 2018). Wide range of computer based physical models are in use helps in predicting the current weather as well to project the future climate (Bauer et al., 2015). The Weather Research Forecast (WRF) models is a well-established numerical model come into existence in the year 2000 (Skamarock et al., 2005) designed to accomplish research purpose and weather prediction (Skamarock et al., 2012). It becomes a community model due to its long-term development and improvement in each series of latest version (Powers et al., 2017), and was supported by world – wide user community.

The aim of this work is an attempt to simplify the complexity of parametrization of WRF system by involving generalised equation in simpler domain with data-driven approach. The objectives involve how to do simulation of major weather variables (precipitation, temperature at 2meter, surface soil moisture content, surface temperature & wind velocity) and comparison of weather variables at 30km and 10km nested domain over the study area.

STUDY AREA

Northern part of India as shown in Figure (1) has been selected as study area for this research work. It includes state of Uttarakhand (UK), Himachal Pradesh (HP) & Jammu Kashmir (JK). The total geographical area it covers is nearby 4,71,230 Km^2 and longitudinal extent is between 73° 20' E and 80° 30' E whereas latitudinal extent is between 27° 48' N and 36° 13' N. The area is dominantly covered by hills, mountain and even with glacier in higher altitudinal region. The low lying area comes under plain category falls under 174msl and it goes on increasing reaches to 8387msl. The climate can be defined as tropical or subtropical (average temperature 20°C and reaches to negative in winters) in low lying plain area whereas it is temperate in mountainous region (Sabin et al., 2020).
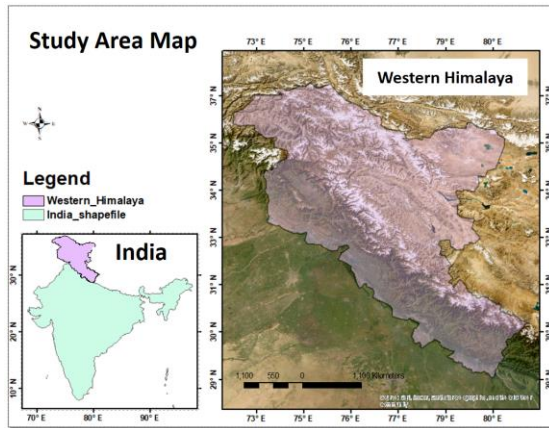
Figure 1: Study Area Map
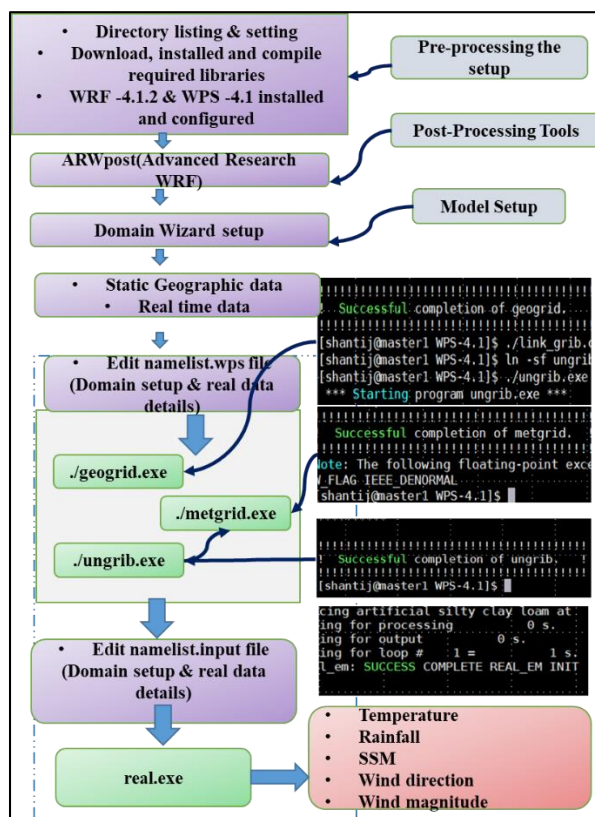
MATERIALS & METHOD

Figure 2: Overall set up requirement and successful run of each final output has been illustrated in above figure.

WRF Model Setup

Weather research and forecasting (WRF) is a weather predicting model (Chow et al., 2013; Michalakes et al., 2005) which has a high accuracy in predictions and this model runs on Linux machine. Before installing the WRF, firstly few libraries have to be installed and for pre-installing these libraries system compatibility test of Fortran and C++ which are needed to execute the code within the model. The five libraries required for model are netcdf, mpich, zlib, libpng and Jasper has to be downloaded and have to set the environment file for making these installations permanent in machine.

Now the next step is to build WPS V3.8.1 (In our case), tar file has to be downloaded and after un-taring, configuration have to be done of the model. After this, WPS has to be compiled and after compilation of WPS, similar steps have to be taken for WRF V3.8.1, downloaded, configuration and compile, it will take some time for completion. In WRF em_real has to be installed. After this static data has to be downloaded from the source of WRF public domain users page link: http://www2.mmm.ucar.edu/wrf/users/download/get_sources_wps_geog.html (Skamarock et al., 2019) and path of this data has to be given in 'geog_data_path' in namelist.wps file.

WRF Domain Wizard (Figure 3) is next step before actually running the WPS. Domain wizard is a and enables users to easily define domains (Janjic et al., 2014) and it also creates the namelist file for WPS and WRF. To run the WPS for nested-domain simulations is same as running for single domain case, the difference between single and nested domain is that in nested the geogrid and metgrid programs process more than one grid. The domain wizard dependent variables in namelist variables are 'parent_id' which is main domain id, 'parent_grid_ratio' which is recommended to be in 1:3.

The size of nested domain to parent domain should be in 1 is to 3 ratio, next is the our left corner of nest is specified as (i,j) location in the parent domain, this is done through the 'i_parent_start' and 'j_parent_start' variables, and then dimensions of each nest is given by 's_sn' and 'e_sn' variables. In our case dx and dy determines the resolution of individual grid. Next step is setting up static data in namelist file which we need to use, the unit for selecting 'geog_data_res' is in degree and minutes for example 1-degree, 30-minute etc. All the variables of namelist need to be matched properly with the namelist.wps for WPS and namelist.input for WRF. Then we need to download the real time atmospheric data for the WRF simulation from NCAR UCAR https://rda.ucar.edu/datasets/ds083.2/index.html#sfol-wl-/data/ds083.2?g=2 (contributor, 2000), it is the GRIB2 data available from July 1999 till current period, it is the NCEP final analysis data at 1 degree spatial and 6 hourly temporal resolution also known as GFS-FNL. The start date and end date with hour minute and seconds have to be mentioned in both namelist files according to the GFS-FNL data or the period for which model has to be simulated.
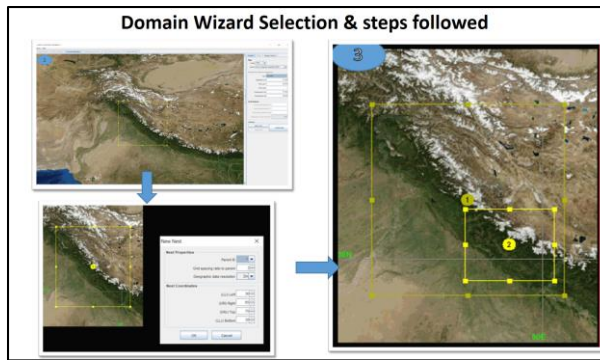
Figure 3: Illustration of nested domain of the study area

Then in WPS there are three.exe files, these have to be done in a proper sequence:

1. Running geogrid.exe (make sure geo_data_path has been given)
2. Linking GFS data after successfully running first step to WPS folder and also linking to correct Vtable
3. Running ungrib.exe and the successful run will make files with prefix "FILE"
4. Running metgrid.exe and output files will have named with prefix "met_em" for each time period.

After running the WPS, now final step is to run WRF which has two files to run until final outcome:

1. Link the "met_em" files which are output of metgrid.exe to the em_real folder or copy that files to this folder

2. Running the real.exe and we can check for errors and if there is none we can proceed

3. Running the wrf.exe which is the final step of WRF model and it can take some time to run according to specification of machine and mainly according to the duration for which model is running.

RESULTS & DISCUSSION

The results of this work demonstrate the potentialities of WRF model parameterization at regional level. The variables taken into consideration are Accumulated Total Precipitation in Mm (PPT), Temperature at 2meter in kelvin (T2), Surface Soil Moisture in M3 M-3 (SSM), Soil Temperature in Kelvin (ST), Wind Magnitude in km/hr3 (WM) & Wind Direction (D) and spatial comparison of these variables at 30km and 10km nested domain over the study area. This chapter deals with the results obtained while simulating the weather variables and its analysis with the help of above specified methodology. The maps obtained has been illustrated in Figure 4. The output generated were .nc files and hence to handle such files QGIS platform has been used further. The output generated was for a single time-period and simulated to give output at 6-hour of interval of temporal resolution for the year (2018-05-14) with 30 km and 10 km spatial resolution for outer and inner nest respectively which cover the study area.
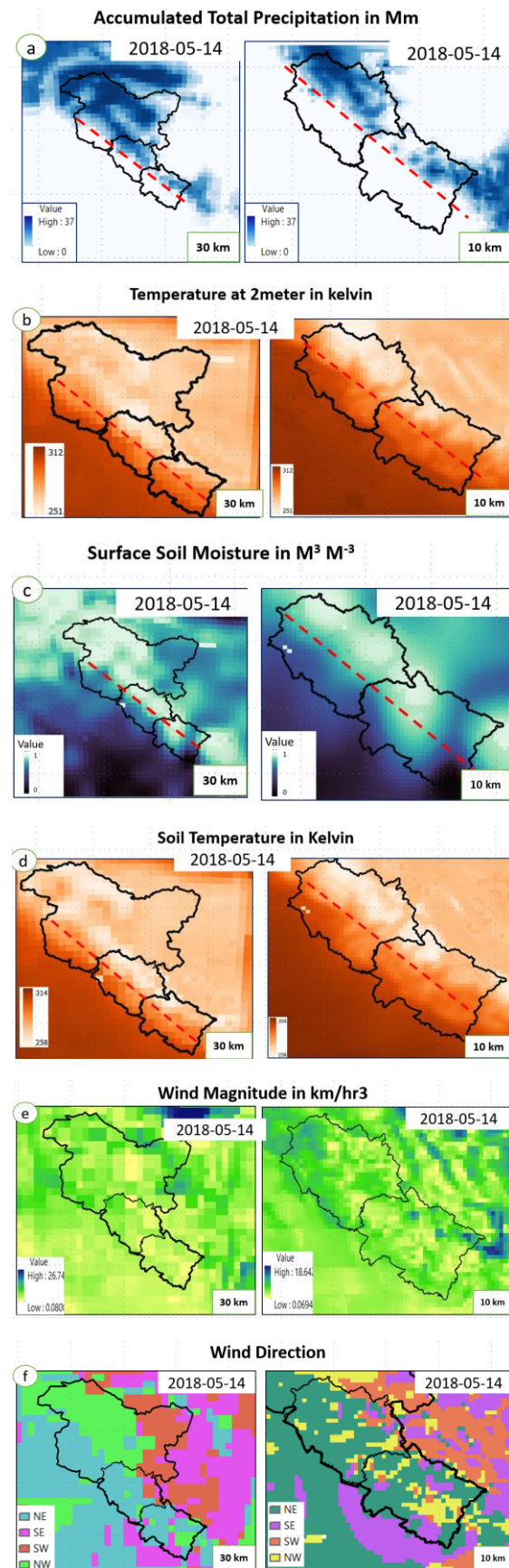

Figure 4: Illustration of output maps obtained using WRF model at 30km and 10km (a) PPT, (b) T2, (c) SSM, (d) ST, (e) WM & (f) D

Figure 4 shows spatial variability of the selected variables at two grid level i.e., 30km and 10km. No rainfall or very less amount of PPT was observed in the low lying plain. The higher altitudinal region also having very less amount of PPT with value ranging from 0-37mm. T2 variable reaching to 312 kelvins in plain whereas it is quit lower in values over the hilly terrain i.e., 251 kelvins, SSM values obtained ranging from 0-1 in mm/mm^3 which is negligible in amount. Also the time period chosen was mid-May which is considered as dry month over the study area (). The soil temperature obtained was higher below the red line whereas it reaches to 258 kelvins above the red lines.

Figure 4 also shows wind direction and wind magnitude which was extracted using the following equation under raster calculator:

$$(WM) = \sqrt{V^2 + U^2} \qquad (1)$$

Where

WM = Wind Magnitude
V= Output generated as v10 during WRF simulation
U= Output generated as u10 during WRF simulation

$$D = \left(\frac{ATan2(v,u)}{2*3.14159265} + 0.5\right) * 360 \qquad (2)$$

Where

D = Wind Direction
V= Output generated as v10 during WRF simulation
U= Output generated as u10 during WRF simulation

Wind magnitude ranges from 0-26km/hr at 30km grid whereas it ranges from 0-18km/hr in 10km grid which can be considered as great factor that can support hazards such as fire spread. Wind direction obtained ranges from 0 °-360 °, So it was re-index into four directions as North-East (0°-90°, NE), South-East (90°-180°, SE), South-West (180°-270°, SW) & North-West (270°-360°, NW). Most of the area occupied by N-E direction of wind in both nested domains and also at higher spatial resolution the central part was dominated by N-W direction of wind.

CONCLUSION

- Conceptual studies of forecast model have been done and complete setup has been carried out in context of parameterization of weather research forecast model.
- In this study geospatial forecast model WRF (Weather Research & Forecast) has been used to simulate weather variables over Western Himalaya, India. WRF produces simulation which is based on idealized condition or actual atmospheric conditions includes both observation and analyses.
- WRF Pre-Processing System setup is a collection of Fortran and C programs which requires static and meteorological input data having specific resolution and can be used for nested domain i.e., for more than one grid.
- For the simulation purpose of the model real time atmospheric data has been used and the result has been compared with existing products. The output generated was for a single time-period with 30 km

and 10 km of spatial resolution for outer and inner nest respectively which cover the study area.
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BIBLIOGRAPHY

Bauer, P., Thorpe, A., & Brunet, G. (2015). The quiet revolution of numerical weather prediction. *Nature*, *525*(7567), 47–55.

Chow, F. K., De Wekker, S. F. J., & Snyder, B. J. (2013). *Mountain weather research and forecasting: recent progress and current challenges* (Vol. 750). Springer.

contributor. (2000). *NCEP FNL Operational Model Global Tropospheric Analyses, continuing from July 1999*. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory. https://doi.org/10.5065/D6M043C6

Fente, D. N., & Singh, D. K. (2018). Weather forecasting using artificial neural network. *2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT)*, 1757–1761.

Janjic, Z., Black, T., Pyle, M., Ferrier, B., Chuang, H. Y., Jovic, D., McKee, N., Rozumalski, R., Michalakes, J., & Gill, D. (2014). User's guide for the NMM core of the Weather Research and Forecast (WRF) modeling system version 3. *Developmental Testbed Center/National Centers for Environmental Prediction*.

Jaseena, K. U., & Kovoor, B. C. (2022). Deterministic weather forecasting models based on intelligent predictors: A survey. *Journal of King Saud University-Computer and Information Sciences*, *34*(6), 3393–3412.

Michalakes, J., Dudhia, J., Gill, D., Henderson, T., Klemp, J., Skamarock, W., & Wang, W. (2005). The weather research and forecast model: software architecture and performance. In *Use of high performance computing in meteorology* (pp. 156–168). World Scientific.

Powers, J. G., Klemp, J. B., Skamarock, W. C., Davis, C. A., Dudhia, J., Gill, D. O., Coen, J. L., Gochis, D. J., Ahmadov, R., & Peckham, S. E. (2017). The weather research and forecasting model: Overview, system efforts, and future directions. *Bulletin of the American Meteorological Society*, *98*(8), 1717–1737.

Rasp, S., Dueben, P. D., Scher, S., Weyn, J. A., Mouatadid, S., & Thuerey, N. (2020). WeatherBench: a benchmark data set for data-driven weather forecasting. *Journal of Advances in Modeling Earth Systems*, *12*(11),

e2020MS002203.

Sabin, T. P., Krishnan, R., Vellore, R., Priya, P., Borgaonkar, H. P., Singh, B. B., & Sagar, A. (2020). Climate change over the Himalayas. *Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India*, 207–222.

Skamarock, W. C., Klemp, J. B., Duda, M. G., Fowler, L. D., Park, S.-H., & Ringler, T. D. (2012). A multiscale nonhydrostatic atmospheric model using centroidal Voronoi tesselations and C-grid staggering. *Monthly Weather Review*, *140*(9), 3090–3105.

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Barker, D. M., Wang, W., & Powers, J. G. (2005). *A description of the advanced research WRF version 2*. National Center For Atmospheric Research Boulder Co Mesoscale and Microscale ….

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Liu, Z., Berner, J., Wang, W., Powers, J. G., Duda, M. G., & Barker, D. M. (2019). A description of the advanced research WRF model version 4. *National Center for Atmospheric Research: Boulder, CO, USA*, *145*(145), 550.