\[ \lambda = 0.06217 \text{мкм}. \] Из сравнения результатов для обоих кристаллов показалось, что максимальная энергия холостой волны \( I_l \) в BaGa\(_4\)S\(_7\) кристалле почти в 4 раза превышает аналогичный результат в LiGaS\(_2\). Данный факт ранее был экспериментально получен авторами [3-4].

Анализ нелинейных оптических свойств двуосных кристаллов LiGaS\(_2\) и BaGaS\(_4\) в приближении заданной интенсивности и сравнение с существующими экспериментальными результатами, позволяет обнаружить оптимальные параметры задачи для повышения эффективности частотного преобразования в среднем ИК диапазоне спектра.

REFERENCES


THE ROLE OF THE WRF MODEL PARAMETERIZATION SCHEMES ON THE QUALITY OF METEOROLOGICAL VARIABLES FORECAST OVER TANZANIA

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Abstract. The combinations of cloud microphysics, cumulus, planetary boundary layer, radiation and land-surface schemes in the model play significant role in the formation of complex meteorological variable. Therefore, the purpose of this study is to assess the performance of different WRF model physical parameterization schemes on the quality of the forecast of meteorological variables, compare the results to the observed data and select the best model configuration. The model was integrated for 72 hours from 08th - 22nd April 2014, the main focus being the period from 11th - 13th April 2014 because it was associated with strong downpour over the coastal areas of the Indian Ocean. The model configured with Purdue Lin - Grell 3d - Asymmetric Convective Model (ACM2) scheme was selected for April rainfall forecast over the coastal areas of the Indian Ocean.

Keywords: Tanzania, Indian-Ocean, WRF model, Meteorology, Parameterization schemes.
1. Introduction.

The WRF model is a numerical weather prediction (NWP) and atmospheric simulation system designed for atmospheric research, operational forecasting and dynamical downscaling of General Circulation Models (GCMs). The development of WRF-ARW has been a multi-agency effort to build a next-generation mesoscale forecasting model and data assimilation system to advance the understanding and prediction of weather and accelerate the transfer of research advances into operations.

One of the most important tasks in adapting a numerical model to use in a particular area is to find its appropriate physical model configuration because each region has its own features which have direct impact on the whole mechanisms of weather formation. So, default and best model setting for one region might not work perfectly for another region.

Two rainfall seasons and patterns are experienced over the country. The long rains of March – May (MAM) and short rains of October – December (OND), and bimodal rainfall regime (MAM and OND) mainly; the northern part and the northern coast including Dar es Salaam, Tanga, Zanzibar and Pemba islands and, unimodal rainfall regime (November to April) mainly; the central, Southern and Western part of the country respectively. These rains are normally associated with the northwards and southwards seasonal movement of Inter-tropical convergence zone (ITCZ).

Numerical and climate models have not been extensively studied for research and operational weather forecasting in developing countries including Tanzania. Therefore, this kind of work must be done in order to improve the quality of meteorological parameters forecasts and fully utilize the capabilities of the model as a helping tool for a forecaster. The post processing was done using the Climate Data Operator (CDO) and Python scripting language.

2. The principal components of the WRF system and the WRF model system of equations.

The principal components of the WRF system includes the WRF Software Framework (WSF) which provides the infrastructure that accommodates the dynamics solvers, physics packages that interface with the solvers, programs for initialization, WRF-Var, and WRF-Chem. There are two dynamics solvers in the WSF: the Advanced Research (ARW) WRF solver (originally referred to as the Eulerian mass or “em” solver) developed primarily at NCAR, and the Non-hydrostatic Mesoscale Model (NMM) solver developed at NCEP. The WRF model consists of WRF preprocessing System (WPS) and model initialization, WRF model (dynamic model ARW or NMM and parameterization), WRF-Var and WRF Post processing System.

The ARW dynamics solver is fully compressible, nonhydrostatic model. The equations are cast in flux form using variables that have conservation properties, written in Cartesian coordinates by using horizontal and orographic η coordinate, which resembles a sigma-coordinate, but differs from it in the sense, that it is not determined by the total pressure p, but through its hydrostatic component Ph. The grid staggering is Arakawa C grid. Higher order numeric are Runge Kutta 2nd and 3rd order time integration schemes, and 2nd to 6th order advection schemes in both vertical and horizontal directions.

3. Data and methodology.

WRF-ARW two nested domains were configured to set up a 14 day numerical simulations from 08th April 2014. These dates were selected because they were associated with periods of strong downpour over the coastal areas of Indian Ocean, in Tanzania especially from 11th to 13th April 2014. The courser and finer domains were at 15 and 5 km with 101x244 points from South to North and 147x322 points from west to east respectively. Map projection used is Mercator system coordinate. The package setting for treating clouds microphysics, cumulus and boundary layer physics that probably will gives the good results for this study are presented in Table 1. It should be noted that only simple ensemble combinations of clouds microphysics schemes (Kessler (KS), Thompson (TH), Purde Lin (PL) and Weather Sophisticated Model six class (WSM6), cumulus schemes (Kain-Fritsch (KS)-New Eta, Betts-Miller-Janjic (BMJ), Modified ensemble Grell-Devenyi (GD) and ensemble Grell 3d (G3d and boundary layer schemes (Yonsei State University (YSU), Miller-Yamada-Janjic TKE (MYJ) and Asymmetrical Convective Model (ACM2)) are changed. Of the fixed physics Unified Noah land-surface was used to represent land-surface atmosphere interaction, surface-layer by Monin-Obukhov (Janjic) scheme, Rapid Radiative Transfer Model (RTMM) for long wave radiation, and shortwave radiation by Goddard scheme.

Initial conditions are 6h dataset (083.2) derived from global final analysis (FNL) at 1.0°×1.0°, generated by the National Center for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS).
Fig. 1. WRF modeling inner domain, terrain height (m) and location of stations

Table 1 - Total number of cases analyzed in this paper

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4. Results:
Model outputs for variables such as terrain height, temperature, pressure, winds and rainfall were first interpolated to station location and verified against reanalysis data and station observations. The Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Mean Bias (MB), and the Correlation Skill Score (CSS) were computed over the entire 2 day period.

If X and Y represent the simulated by the model and observed data respectively,

\[
\text{MAE} = \frac{1}{N} \sum_{i=1}^{N} |X_i - Y_i|; \quad (1)
\]

\[
\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - Y_i)^2}; \quad (2)
\]

\[
\text{MB} = \frac{1}{N} \sum_{i=1}^{N} X_i - Y_i; \quad (3)
\]

\[
\text{CSS} = \frac{\sum_{i=1}^{N} (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{N} (X_i - \bar{X})^2 \sum_{i=1}^{N} (Y_i - \bar{Y})^2}}; \quad (4)
\]

Where
\[ \overline{X} = \frac{1}{N} \sum_{i=1}^{N} X_i , \]  
\[ \overline{Y} = \frac{1}{N} \sum_{i=1}^{N} Y_i , \]  

\( N \) – Total number of days.

RMSE is a measure of the differences of the values forecasted by the model and actually observed or predicted by another model. The RMSE tends to aggregate these differences into a single power of predictive power, the least the value the better. MB is a measure of how much off the predicted values are from the observed ones. A positive bias for a particular variable means the model over predicts the quantity while the negative value of the bias implies the model under predict the quantity. A large bias means the errors are systematic caused by the instruments, models or misinterpretation of the results. The closer the bias to zero is the better.

CSS indicates degree of linear dependence between parameters. It varies from -1 to 1. A positive value implies that statistical relationship is increasing linearly while a negative value of CSS indicates decreasing of linearity.

Figure 2 shows the stations actual height compared with the height used in the model. The maximum difference of 303.4 m is found at Mahenge and the minimum of 0.6 m at Arusha. On average over all stations the difference is 62.7 m. Therefore, terrain is fairly well modeled.

![Model Height vs Actual Height](image)

**Fig. 2. Model terrain height compared with actual terrain height at each station**

From figure 3, chronological plot depicts that in the first case (left panel) of numerical experiment, diurnal temperature change was well reproduced by the model up to 18 hour time step, but the model struggled during the second case (right panel), the period associated with strong downpour independently of the combination of parameterization schemes.

Result in figure 4 shows the best performance was obtained when the model was configured with an experiment 237 with CSS and RMSE of 3.80 and 0.85 respectively. Spatial maps for rainfall tendency (In Fig 5a), outgoing long wave radiation (In Fig. 5b) and geopotential height and winds at 850 (In Fig. 6b) as well as skew-t diagram at JNIA (In Fig. 6a) as predicted by the best selected scheme. It can be seen that, the Indian Ocean, north eastern highlands and almost entire country were under the influence of strong easterly and south easterly winds. Skew-t diagram shows significant moisture and strong winds at low levels.
Fig. 3. Chronological graphs for 2m Temperature at JNIA Met. Station as per 6 different parameterization schemes

Fig. 4. The CSS against RMSE for rainfall at JNIA Met. Station per different experiments

Animated surface dew point temperature and 10 m winds fig.5 (a,b,c) shows that the coastal area of Indian ocean was dominated by strong south easterly and strong humid easterlies along the southern and eastern coast respectively. The moist air then became south easterlies over the land in the northern part over the country while south easterlies to easterlies were persisted over the land throughout the country.

Thermodynamic diagrams, fig.5 (d,e,f) shows dry conditions and significant humidity at mid and low levels respectively, and strong south easterlies at low and high levels between 300 and 200 hPa. These conditions probably led to strong thunderstorms over these areas.

Spatial maps for 1 hour rainfall tendency displayed in fig.5 (g,h,i) indicates how the model configured with schemes 237 performed.

Conclusion.
The objectives of this study have been addressed and the following initial conclusions were made:

According to the results in figures 2, 3, 4 and 5 and, together with the results for other parameters, the WRF model configured with Purdue Lin — Grell 3d — Asymmetric Convective Model (ACM2) scheme was selected for April rainfall forecast over the coastal areas of the Indian Ocean. It is possible that the best setting has not yet configured, therefore as future perspectives, efforts are in progress to simulate and evaluate large data set with the aim to obtain best model setting for the entire country.
Fig. 5. Spatial plots as per configuration 237, left to right animated dew point temperature and 10 m winds, skew-t diagram and 1 hour rainfall distribution at three time steps

REFERENCES