An intercomparison study of MM5 and RAMS simulations in a coastal desert area of Saudi Arabia

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1. Introduction

In a national project with the aim of creating a sustainable water cycle among sea, land, and atmosphere in a coastal desert, MM5 and RAMS are used as an effective tool to find out a cause of desertification and to estimate a greening effect on regional climate, especially on rainfall, when some kind of trees are planted in a part of desert area near the Red Sea. Ueda et al. (2005) showed preliminary results simulated by MM5 and RAMS for a few months.

This paper presents an intercomparison of MM5 and RAMS control runs in a coastal desert and mountainous area around Mecca for a year of 2000.

Fig.1 a map of Saudi Arabia

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2. MM5 Configuration

One part of numerical simulations using MM5 version 3.6 is performed for Saudi Arabia and surrounding area in the West Asia. Model domain includes the North West African continent and the Middle Asia, additional to Saudi Arabia and the West Asia, and also includes 1 nested domain, that includes additional nested domain in itself, and these 3 domains have the resolutions of 81km, 27km, and 9km, with the grid numbers of 134x93, 114x93, and 96x111, respectively. The common vertical coordinate consists of 34 layers as pressure based terrain following sigma coordinate with non equal depth from the surface as the lowest layer of 100m to the top boundary of 100hPa as the highest layer as 1000m. Initial and lateral boundary conditions for the global domain are set to 12hourly ECMWF reanalysis data with the resolution of 2.5 degree, and 4 dimensional assimilation is adopted with this ECMWF data, on the other hand for 2 nested domains, lateral boundaries are set to the values of its parent's fields, respectively.

As for physical schemes, the Medium Range Forecast (MRF) PBL scheme that is suitable for medium range simulations is applied to the boundary layer, the NCAR Community Climate Model (CCM2) that computes surface radiation fluxes is used to long and short wave radiations for each 30 minutes, the Grell parameterization that includes updraft and downdraft fluxes is for convective clouds, and the mixed phase scheme that gives effects of supercooled water and slow melting of snow is selected due to physics of clouds.

Data of elevation, landuse, vegetation type and vegetation fraction derived from USGS and satellite data are converted to the data of each grid and are used with physical parameters to solve the prognostic equations.

3. RAMS Configuration

In this study, RAMS version 4.4 is installed into the Earth Simulator. Focusing on around Mecca, we prepare 3 nested grids, with horizontal resolution of 80km, 16km, 4km. The numbers of grid cells in each grid are 60 x 62, 82 x 82, 74 x 50, respectively. The vertical structure consists of 37 levels with grid spacing ranging from 200m to 750m and a vertical grid stretch ratio of 1.1 is used. And we use topography and vegetation databases, which are originally prepared for RAMS and have 1km and 100km resolutions, respectively. We also use the monthly mean SST database with 1-degree resolution, which is obtained from Hadley Center of U.K., and the soil database with 10km resolution from IGBP-DIS. The ECMWF reanalysis field data with 0.5-degree horizontal resolution is employed as initial input and for nudging procedure, which is applied at the lateral boundaries of the each domain during the run. Between parent/child grids, 2-way nesting approach is applied.

We also use some schemes for some physical processes. Mellor-Yamada turbulent closure scheme is applied for parameterizing the vertical diffusion, and the Harrington scheme is applied for both shortwave and longwave radiation parameterizations every 20 minute simulation time. The modified Kuo cumulus parameterization scheme is activated for grid 1 and 2, and a microphysics parameterization is also activated, in which prognostic approaches are taken for cloud, rain, pristine ice, snow, aggregates, graupel, and hail processes. The soil/vegetation scheme, called LEAF2, is also used.

4. Results

The MM5 and RAMS simulations are verified against station observation, comparing time series of temperature, wind speed & direction, shown in Fig.2 as an example.

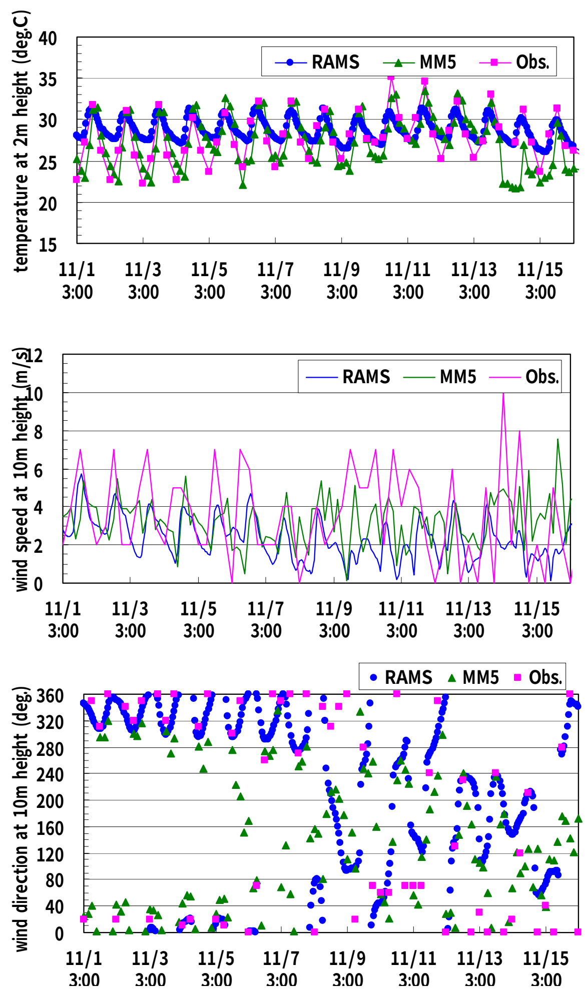


Fig. 2 Time series of temperature, wind speed, and wind direction at Jedda in November 2000

More statistical approaches are taken, calculating MBE(mean bias error), and RMSE(root mean square error) for 2m-height temperature, and 10m-height wind speed, in Fig.3 - 5.

As for temperature, the MBE results indicate that MM5 has slightly smaller errors than RAMS, while both RMSE results are almost the same. Among the 5 months, there is no prominent difference for the MBE and RMSE results.

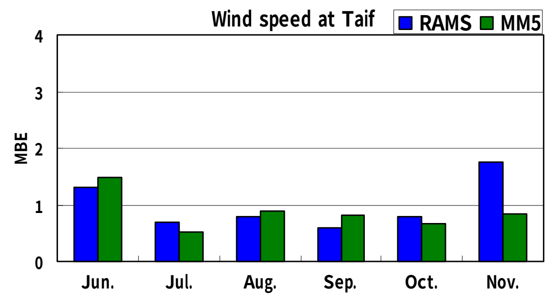


Fig. 4 MBE of wind speed at 10m-height at Taif

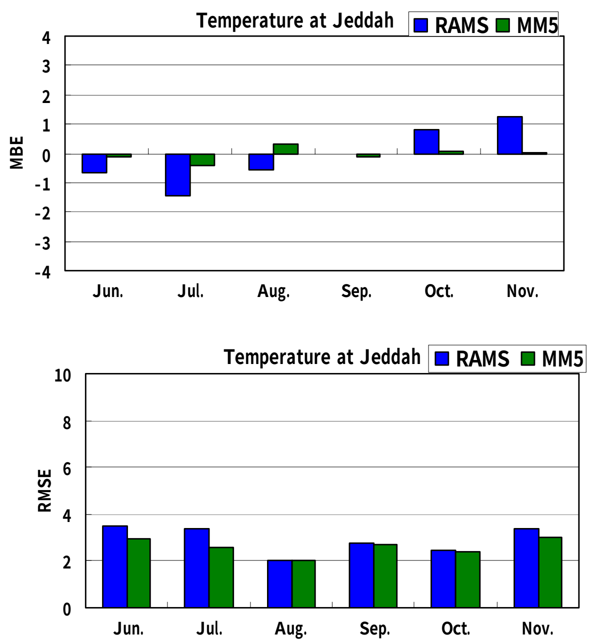


Fig. 3 Temperature at 2m-height at Jedda

(upper: MBE, lower: RMSE)

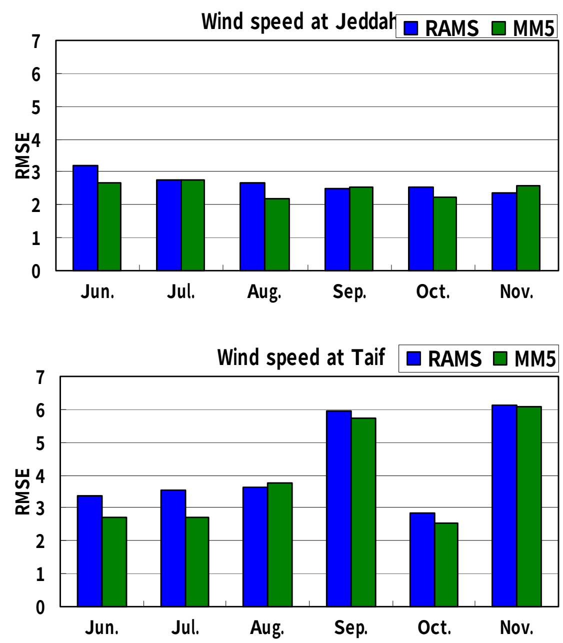


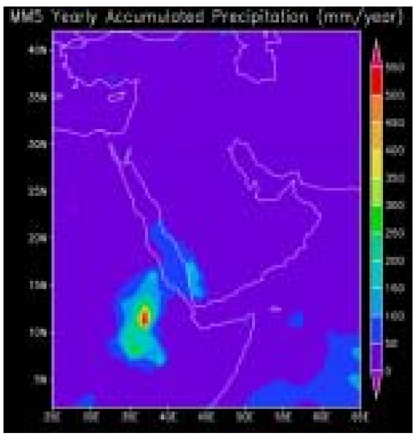
Fig. 5 RMSE of wind speed at 10m height

(upper: Jeddah, lower: Taif)

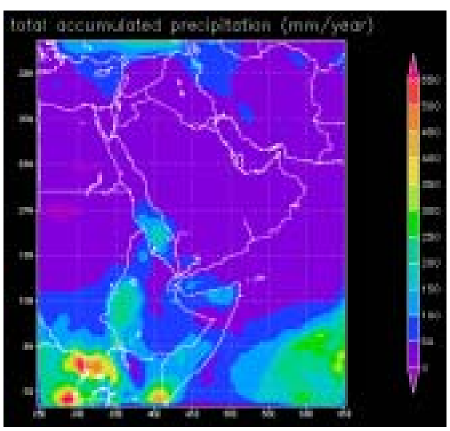
As for wind speed, MM5 and RAMS has almost the same errors for MBE and RMSE, as shown in Fig.4 and Fig.5. The most prominent thing, which is seen in both MM5 and RAMS, is that RMSE of wind speed has bigger errors in Taif, which is located in a mountainous area, than in Jedda, which is a coastal area, especially in September and November.

The annual accumulated precipitation is shown in Fig. 6. The maximum precipitation area is seen around 37E and 12N in MM5, while RAMS has precipitation in the same area, but it’ not the maximum area. The maximum precipitation area is seen at 31E and 3N.

Around Jeddah, no precipitation is found in RAMS, while MM5 has 100mm/year more or less. According to the observation data measured by the presidency of meteorology and environment of Saudi Arabia, Jeddah had, in fact, 65mm in 2000. Furthermore, from the TRMM precipitation database, as shown in Fig.7, we can see the distribution of precipitation in Mecca area. We thus need to reconsider a precipitation process through the cumulus and microphysics parameterizations for RAMS simulations.



MM5



RAMS

Fig. 6 Total accumulated precipitation

in 2000 [mm/year]

(upper: MM5, lower: RAMS)

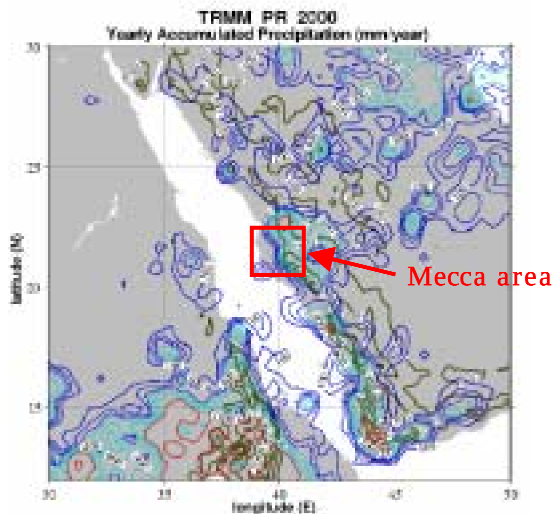


Fig. 7 Total accumulated precipitation

in 2000[mm/year] (TRMM)

5. Conclusions

We compared MM5 and RAMS simulations each other in a coastal desert area of Saudi Arabia through a year of 2000. Statistical approaches were taken for temperature and wind speed, and it was found that both results were very similar, but there were differences somewhat between coastal and mountainous areas. The most interest for us is the amount of precipitation, but RAMS had no precipitation in Mecca area, while MM5 had the accumulated precipitation of 100mm/year more or less, which seemed to be a reasonable value. We will reconsider a precipitation process through the cumulus and microphysics parameterizations.

6. References

Ueda, H., Ishikawa, H., Hozumi, Y. Yamagata, T., Ohba, R., 2005. Meteorological simulation for the improvement of environment by greening of desert. Second Oman-Japan Symposium: Preservation of Environmental and Water Resources amid Economic Development.