Simulation of Monsoon Precipitation over south-Asia using RegCM3

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Abstract

The objective of this study was to explore the capability of the regional climate model RegCM3, to predict extreme weather events in south-Asia region with particular reference to precipitation during monsoon season (July, August, September) over northern mountainous and southern plain regions of Pakistan. Different cumulus parameterization schemes in RegCM3 for prediction of convective precipitation were tested for monsoon period during the years 1998 and 2001. The model predicted results compared with the satellite pictures, CRU observational data and the surface synoptic observatories data of the Pakistan Meteorological Department (PMD). This may be mentioned here, that the year 1998 was a dry year and the starting year of a severe drought which lasted up to the year 2000. This may also be added here, that during the year 2001, the precipitation over some parts of the country exceeded the normal and some areas in the northern parts of the country observed exceptionally high rainfall rate.

The results indicated that some convective parameterization schemes of RegCM3, well captured the summer monsoon precipitation over south-Asia region. However, the schemes need to be selected carefully depending upon the region of any particular focus. Some interim findings were that the Grell scheme with both closures: Arakawa-Schubert (AS) and Fritsch-Chappell (FC) satisfactorily predicted the total monthly rainfall in the northern mountainous regions of Pakistan. However, both predicted high precipitations over southern and south-eastern plain regions. Both the modified-Kuo and Betts-Miller (BM) schemes substantially under-predicted the rainfall, although the patterns were captured adequately. The modified-Kuo scheme was more close to the observed data when compared with the performance of the BM scheme It is recommended to further test the model schemes, perhaps a further improvement in the modified-Kuo scheme

would yield a scheme even better than both of the Grell closures (which predicted exceptionally high precipitation over south-eastern plain regions of Pakistan and the adjoining Indian regions. In a future paper we shall be presenting more results and will try to suggest some modifications in the existing schemes to be able to better capture the summer monsoon precipitation over south-Asia.

Due to their coarse resolution General Circulation Models (GCMs) often perform poorly in simulating regional processes, especially in regions with local fine-scale forcing topography (Gates, 1992, Gao et al., 2002). On the other hand, modeling studies with regional climate models also indicated that some cumulus parameterization schemes do not perform well in some specific regions of the world e.g. Asian monsoon regions (Leung et al. 2003, Lee and Suh 2000). Scale interactions are extremely complex in the Asian monsoon regions (Holland 1995), which are further complicated due to the effects of Tibetan plateau, ocean-continent contrast and sea-air interactions. These specific features require special consideration in designing regional climate models to be used in this particular region.

The impacts of climate change on food and water resources of a country are linked with the regional climate rather than to the global scale. It is therefore imperative to understand and predict how global climate change is manifested at these regional scales. Using GCM output to drive limited-area atmospheric simulations on regional scales has been reported to be a promising approach for simulating regional climates (Giorgi and Mearns, 1991, 1999). The principle behind this approach is that, given a large-scale atmospheric circulation, a limited-area model with a suitably high-resolution, resolving complex topography, land-sea contrast, land use and detailed description of physical processes can generate realistic high-resolution (both spatial and temporal) information coherent with the driving large-scale circulation. The large-scale circulation can be supplied by either reanalysis data or a GCM output.

A critical weakness that needs improvement in both global and regional climate models is the treatment of clouds (Giorgi and Mearns 1999). Although the detailed explicit cloud microphysics parameterization for grid resolved moist processes, is considered in some of the regional climate models, the complex interaction between subgrid cumulus convection and grid scale moist processes is very crudely treated. Some studies have indicated the improvements in radiation budgets by using cloud microphysics information (Petch and Dudhia, 1998), but the cloud amount is treated in a quite simple way and is usually estimated by the relative humidity in most of the climate model applications (Giorgi et al. 1993, Dudek et al. 1996, Wang et al. 2000). Although some previous studies (Houghton et al., 1992) have shown the capability of regional climate models in reproducing intra-annual variability when driven by good quality driving fields, more analyses are needed to improve model performance in simulating climate variability at short timescales (days to weeks). The increased resolution of regional climate models can allow simulation of a broader spectrum of weather events to improve simulation of the daily to monthly precipitation intensity distributions.

We in this work, have studied the capabilities of a regional climate model, RegCM3 (available from http://www.ictp.trieste.it/~pubregcm/RegCM3) to simulate the precipitation intensity/patterns during summer monsoon season in the Indian sub-continent. The summer monsoon systems are originated from the Bay of Bengal, Indian Ocean and some times get accentuated by the juxtaposition of passing westerly disturbances and the Arabian Sea component. We have tried to identify some suitable cumulus parameterization schemes for predicting the summer monsoon precipitation (July to September) over the regions or to access the need of further modification in the model.

Different cumulus parameterization schemes in RegCM3 for prediction of convective precipitation were tested for monsoon period during the years 1998 and 2001. This would be interesting to mention here that 1998 was the starting year of a severe drought in Pakistan, which lasted up to the year 2000. Due to this drought the agricultural productivity in the country was badly affected. On the other hand, during the year 2001, the precipitation over some parts of the country exceeded the normal and some areas in the northern parts of the country observed exceptionally high rainfall rate. July 23, of the year 2001 witnessed heavy rainfall in a cloud burst fashion over some of the northern parts of Pakistan (Districts of Mansehra, Abottabad, Rawalpindi and Islamabad). This heavy precipitation exceeded the recorded maximum rainfall in Islamabad, during a single spell and caused severe economic and life loss. In this work, we have tried to explore the capabilities of RegCM3 and the effects of the use of different convective closure schemes on the intensity and spatial patterns of the precipitation during the summer monsoon months (July, August and September) of the selected years. The model was initialized using the NCEP reanalysis data having spatial resolution of 2.5^o x 2.5^o and temporal resolution of 6 h. The model domain was from 5N to 45N and 55E to 105E with a spatial resolution of 90 km and a 1:3 nesting was provided over a domain from 24N to 36N and 60E to 76E to focus on Pakistan. USGS Topographic data and US Department of Agriculture, land use data of 10 minutes resolution were used (see Figs. 1-2).