# NUMERICAL SIMULATION OF SUMMER MONSOON PRECIPITATION OF 1992 OVER PAKISTAN

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## Abstract:

*Regional climate model of the third generation (RegCM3) has been experimentally used in seasonal simulation of Rainfall in Pakistan using ERA-40 reanalysis of ECMWF as lateral boundary and initial conditions for driving the RegCM3. The performance of Regional Climate Model (RegCM3), version released in February' 2005, for Pakistan is examined through experiments to simulate the amount of total precipitation in monsoon of the year 1992, with model resolution of 60km and domain of about 50°E – 100°E, 05°N – 45°N. The model output is then compared with real time and Climatic Research Unit (CRU) observational grid Data. In this study, experiments have been done using Grell Convective Closure Scheme with 1-Arakawa & Schubert (AS), 2-Fritsch & Chappell (FC) closure assumptions. The effect of these convective closure assumptions has also been examined. It is found, in this study, that the simulation of summer monsoon rainfall over Pakistan is reasonable. The amount of simulated rainfall with Fritsch & Chappell closure is more than that with Arakawa & Schubert closure assumption in this experiment, over Pakistan. This study also revealed that the average amount of simulated rainfall, with both closure assumptions, is 51% approx. less than that calculated from Climatic Research Unit (CRU) data and almost 71% approx. less than the real time data.*

*Key Words: Regional Climate Model, Simulation, Precipitation, Convective Closure Scheme*

## Introduction:

RegCM3 is the latest version of The Abdus Salam International Centre for Theoratical Physics (ICTP) regional climate model, originated from NCAR-RegCM. It contains numerous options for different applications. The idea of Regional Climate Model (RCM) was based on the concept that large scale meteorological fields from General Circulation Model (GCM) runs can provide initial and time-dependent meteorological lateral boundary conditions for high resolution Regional Climate Model (RCM) simulations [Giorgi, F. 1990].

The first generation RegCM was built upon National Centre for Atmospheric Research (NCAR) - Pennsylvania State University, Mesoscale Model MM4 in the late 1980s. It included the Biosphere-Atmosphere Transfer Scheme, BATS, for surface process presentation, the radiative transfer scheme of NCAR Community Climate Model (CCM)

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version CCM1, a medium resolution local planetary boundary layer scheme, the Kuo-type cumulus convection scheme and the explicit moisture scheme. The dynamical core of RegCM is similar to that of hydrostatic version of MM5. The first major upgrade in model physics and numerical scheme was made in1993 and resulted in second generation of RegCM, hereafter referred to as RegCM2. The physics of RegCM2 was based on NCAR CCM version CCM2, and the mesoscale model MM5 [RegCM Version 3.0 User's Guide 2004].

There have been several improvements and additions to the newest version of the model, RegCM3. Changes in the model physics include a new large-scale cloud and precipitation scheme which accounts for the subgrid-scale variability of clouds [Pal et al. 2000], new parameterizations for ocean surface fluxes and cumulus convection schemes i.e.1-Anthese-Kuo, 2-Grell, 3-Betts-Miller. Also new in the model is a mosaic-type parameterization of subgrid-scale heterogeneity in topography and land use [Giorgi et al. 2003].

Other improvements in RegCM3 involve the input data. The USGS Global Land Cover Characterization and Global 30 Arc-Second Elevation datasets are now used to create the terrain files. In addition, NCEP, ECMWF global reanalysis datasets are used for the initial and boundary conditions [RegCM Version 3.0 User's Guide 2004]. The latest version of RegCM3 has been released on May 5, 2005 which is updated for FVGCM datasets.

A significant part of precipitation, especially during the warm season, is convective in nature. Models must try to predict convection and account for the collective influence of small-scale convective processes on large-scale model variables in each grid box. Procedures to do this in Numerical Weather Prediction (NWP) are called cumulus or convective parameterization schemes. In this study, precipitation in monsoon season of the year 1992 have been simulated with the help of RegCM3, version which was released in February 2005, using two different closure assumptions of Grell convective scheme. 1992 is the year in which Pakistan received 196.6 mm (area weighted rainfall) which is about 43% above normal which is 137.5 mm. A similar study for precipitation, previously, has been done only for the month of July 1992, for the whole south Asian region. It was found that Arakawa & Schubert closure assumption of Grell scheme is better for precipitation simulation for the region [Saeed et al. 2004]. Purpose of this study is to compare AS closure and FC closure for the whole monsoon season of 1992 for Pakistan only.

## Methodology:

The whole released RegCM modeling system is composed by four components: Terrain, ICBC, RegCM, and Postprocessor. Terrain and ICBC are the two components of RegCM preprocessor. Terrestrial variables (include elevation, landuse and sea surface temperature) and three-dimensional isobaric meteorological data are horizontally interpolated from a latitude-longitude mesh to a high-resolution domain on either a Rotated (or Normal) Mercator, Lambert Conformal, or Polar Stereographic projection.

Region for the study has been selected by setting up the domain of 30km resolution on Rotated Mercator projection, shown in Fig.1. GTOPO30 Terrain, GLCC Landuse, OISST sea surface temperature and European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis ERA40 datasets were used as Terrain and ICBC input data.

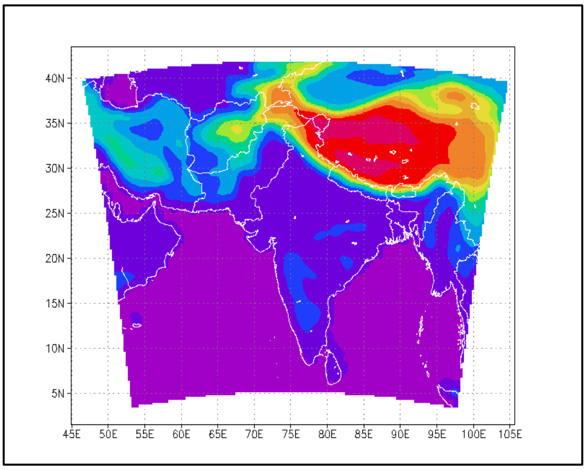


Figure 1: **Domain**

The model was run twice; firstly, with Fritsch & Chappell closure assumption and secondly with Arakawa & Schubert closure assumption for the months of July, August and September 1992.

In post processing step, the precipitation amount has been averaged for individual months July, August and September by running the postproc script and the precipitation for monsoon season was determined.

Simulated amount of rainfall for individual met stations in Pakistan were taken and area weighted rainfall for those stations was calculated and compared with Pakistan Metrological Department (PMD) observational rainfall data. Data plot has been obtained using MS Excel software.

Climatic Research Unit (CRU) observational data was made compatible to the domain used in this study for the purpose of comparison. The modal output data and the CRU data have been displayed graphically by using visualization software named GrADS.

Real Time precipitation data were collected from Computerized Data Processing Center, Pakistan Meteorological Department, Karachi. Map of monsoon seasonal rainfall was generated with the help of software Surfer version 8.

## Results and Discussion:

The amount of precipitation reproduced by the model is compared with CRU and real time data. The results are discussed region wise as below;

Fig. 2 represents the amount of precipitation of July, August, September (JAS)' 92 reproduced by the model integrated with Fritsch & Chappell (FC) closure assumption. The amount of precipitation in northern parts of Punjab and adjoining Kashmir is, unrealistically, in deficit. This deficit is obvious from Fig. 6, which represents the difference between simulated rainfall and CRU data. CRU data plots are shown in Fig. 4. The deficit in rainfall over northern parts of Punjab and adjoining Kashmir may be increased, remarkably, if compared with the real time data (Fig. 5). Simulated precipitation is also less than CRU data and real time data in southern Punjab. Replicated precipitation in Sindh is less than CRU data but it is in great deficit when compared to real time data. Model generated rainfall in northeastern Balochistan, adjoining Punjab, is more than the CRU data at an isolated place and it is close to real time data. The amount of simulated rainfall is less than the CRU data elsewhere in Balochistan. The simulation is in accordance with real time situation over Northwestern Balochistan. The model calculated the precipitation amount which is in accordance with real time observed data, reported by Pakistan Meteorological Department observatories, along the eastern coast of Balochistan and Karachi coast. The precipitation reproduced by the model is in excess over central parts of North Western Frontier Province (NWFP), adjoining Punjab, compared with the CRU data and is close to real time data. The results are better in other parts of NWFP, except, the area adjoining Kashmir where the simulated amount is in great deficit. Model generated precipitation in Northern Areas of Pakistan is less than real time data and in excess when compared with CRU data.

Fig. 3 represents precipitation generated by the model integrated with Arakawa & Schubert closure assumption. Simulation with this scheme suppressed the amount of precipitation. Fig. 7 shows the difference between models simulated rainfall and CRU data. The model yielded the rainfall which is in great deficit compared to the CRU data in northern parts of Punjab and adjoining Kashmir. It is also in deficit when compared to the real time data throughout Punjab. The simulated rainfall is in deficit compared to CRU and real time data over Sindh. This deficit increases from upper to lower Sindh. Model generated rainfall is in deficit over Balochistan as compared to CRU data but it is close to reality over Northwestern parts. The model calculated the precipitation amount which is in accordance with real time observed data along the eastern coast of Balochistan and Karachi coast. The simulated amount of rainfall is in great deficit over areas of NWFP which are adjacent to Punjab and Kashmir when compared to the CRU and real time data. It is more than the CRU data in other parts of NWFP but is less than the real time data. In Northern Areas of Pakistan, simulated rainfall is in excess compared to CRU data but is less than real time data.

Fig. 8 represents the difference of precipitation amount simulated by two different closure assumptions of Grell convective precipitation scheme. It shows that the total amount of rainfall with FC closure assumption is more than that of AS closure over the country especially along mountainous and sub mountainous areas. It can be seen that model with AS closure calculated more precipitation than FC closure over some parts Pakistan. For example, the area of central Punjab which remains the warmest during the season. Fig. 10 represents the temperature field simulated with FC closure and Fig. 11 shows the temperature field with AS closure, while Fig. 12 shows the difference of both. In Figs. 8, 10, 11 and 12, it can be seen that the warmest region is the same where the simulated rainfall with FC closure is less than that of AS closure. It can also be seen in Figs. 2 & 10 that in the areas of Pakistan, which receive monsoon rain, the precipitation is maximum at places where temperature ranges between 20°C – 25°C. It can also be seen that precipitation with FC closure is decreasing with the decrease of temperature below 10°C over extreme northeast Pakistan, where AS closure calculated more rainfall. This seems to be in connection with simulated amount of rainfall with both closure assumptions along with other forcing like topography.

Fig. 9 shows the comparison of real time total area weighted rainfall over Pakistan in the monsoon'92 with the total area weighted rainfall calculated with FC and AS closure. It can be seen that total area weighted rainfall simulated with FC closure is more than total area weighted rainfall simulated with AS closure and both are less than the total area weighted rainfall calculated from CRU and real time data. This figure also shows that the average of total area weighted rainfall with both FC and AS closure is 51% less than the total area weighted rainfall calculated from CRU data and 71% less than the real time area weighted rainfall over Pakistan in the year 1992.

## Conclusion:

The Regional Climate Model (RegCM3) at 60 km resolution is able to simulate the summer monsoon rainfall over Pakistan reasonably well. Inter-comparison of simulated rainfall yields that total rainfall over Pakistan simulated by RegCM3 using Fritsch & Chappell closure assumption is 39% more than that with Arakawa & Schubert closure assumption. On the average total amount of simulated rainfall is 51% less than the amount given by CRU data and 71% less than the amount of rainfall observed by Pakistan Meteorological Department. However, precipitation pattern, simulated by the model, over the region is well in accordance with actual pattern over the area. Some experiments should be done for the monsoon season of the years in which monsoonal rainfall over Pakistan remained below normal or normal and performance of the model should be evaluated by doing experiments with different resolutions.

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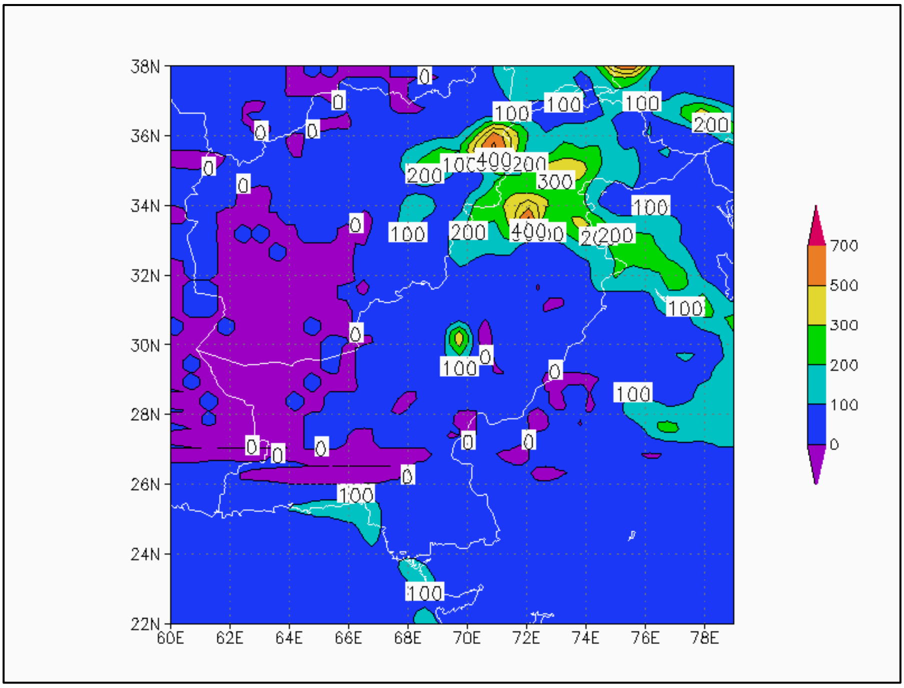


Figure 2: **Model Simulated JAS Rainfall with Fritsch & Chappell closure**

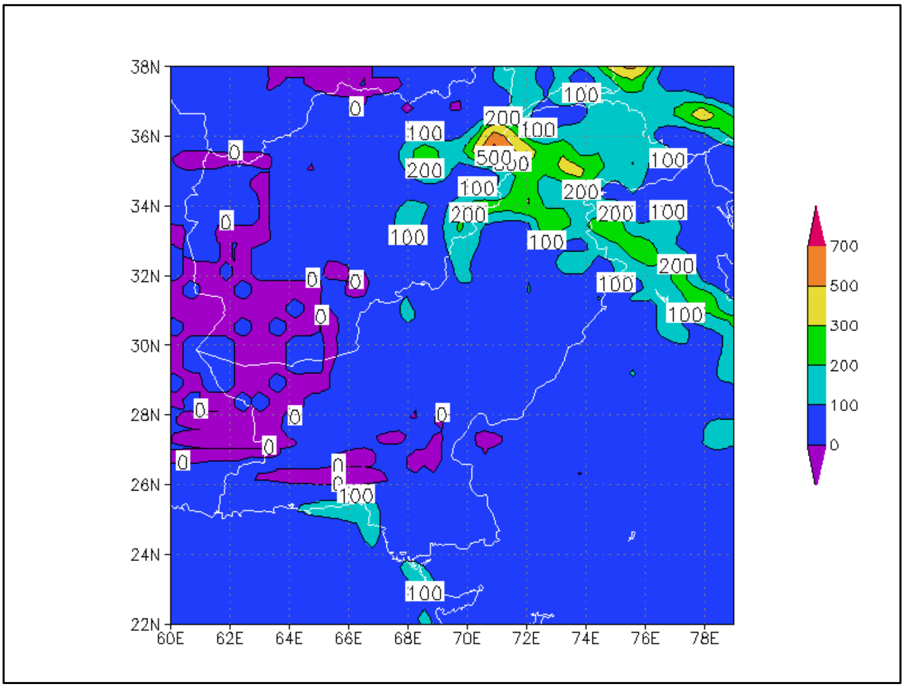


Figure 3: **Model Simulated JAS Rainfall with Arakawa & Schubert closure**

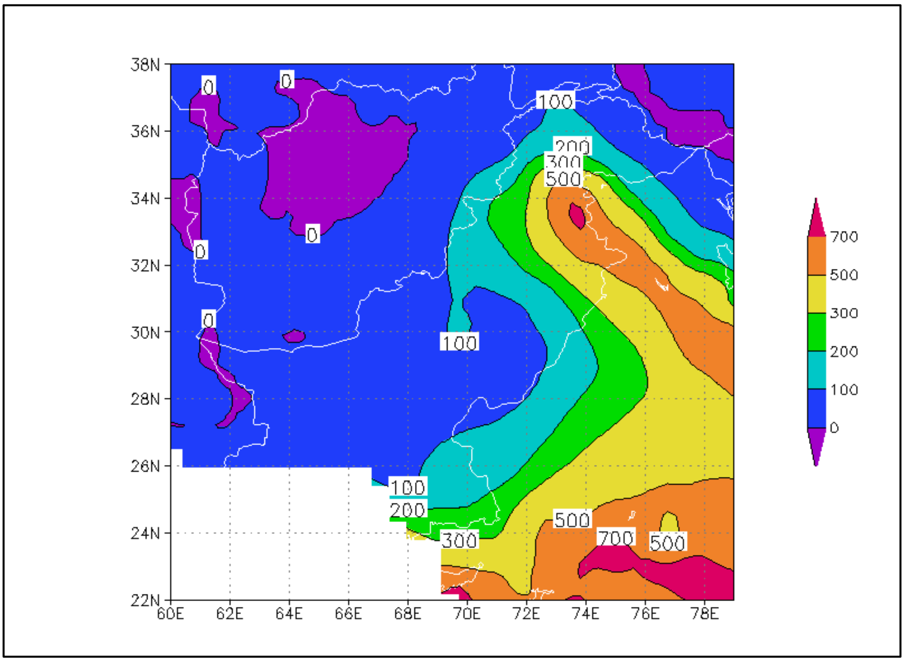


Figure 4: **Climatic Research Unit (CRU) data plot for JAS Rainfall for the year 1992**

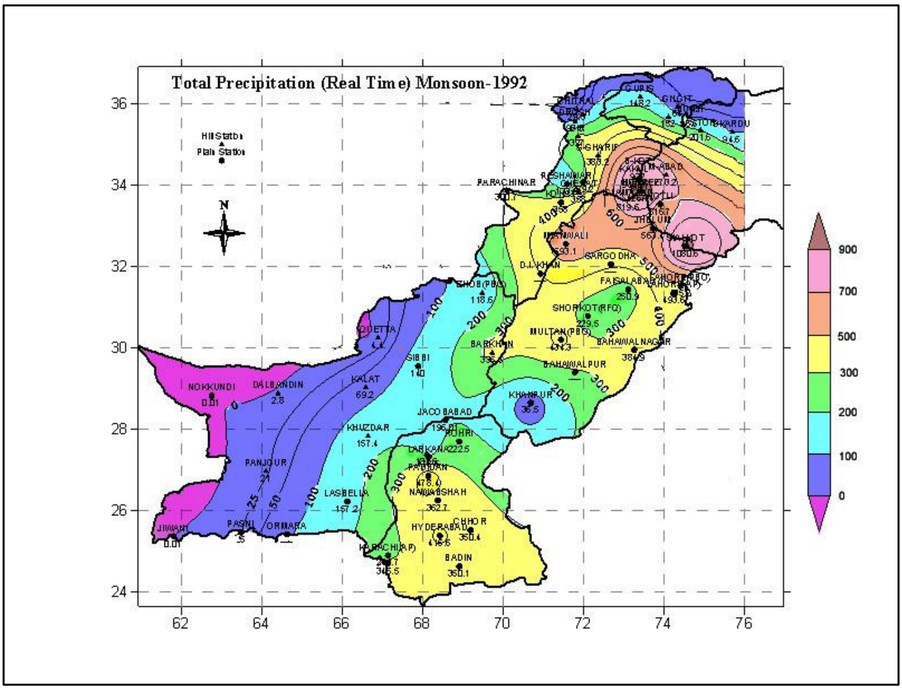


Figure 5: **Real Time data plot for JAS Rainfall for the year 1992**

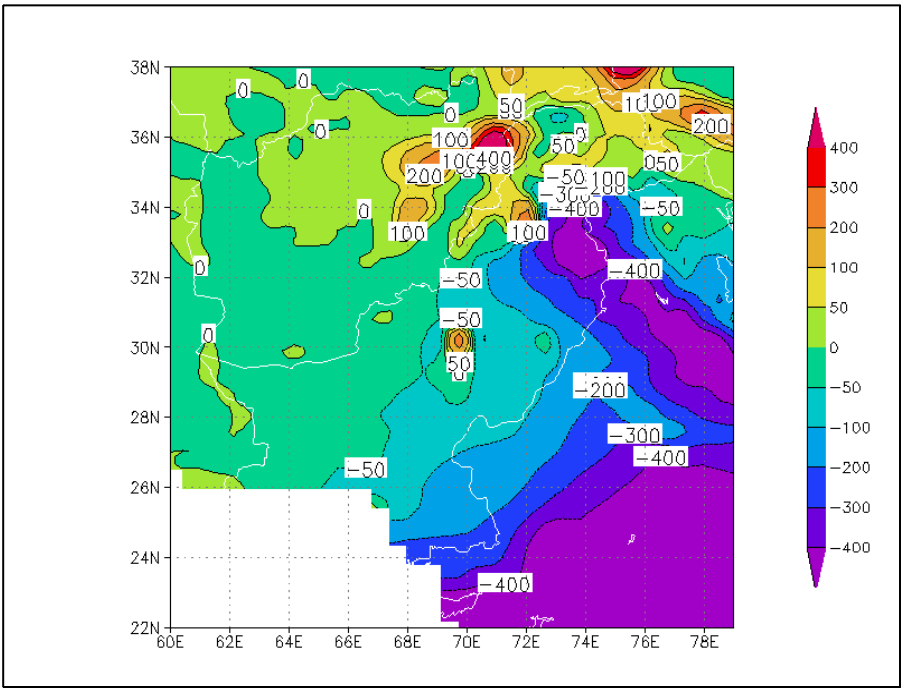


Figure 6: **Difference between Simulated JAS Rainfall with Fritsch & Chappell closure and CRU data (FC - CRU)**

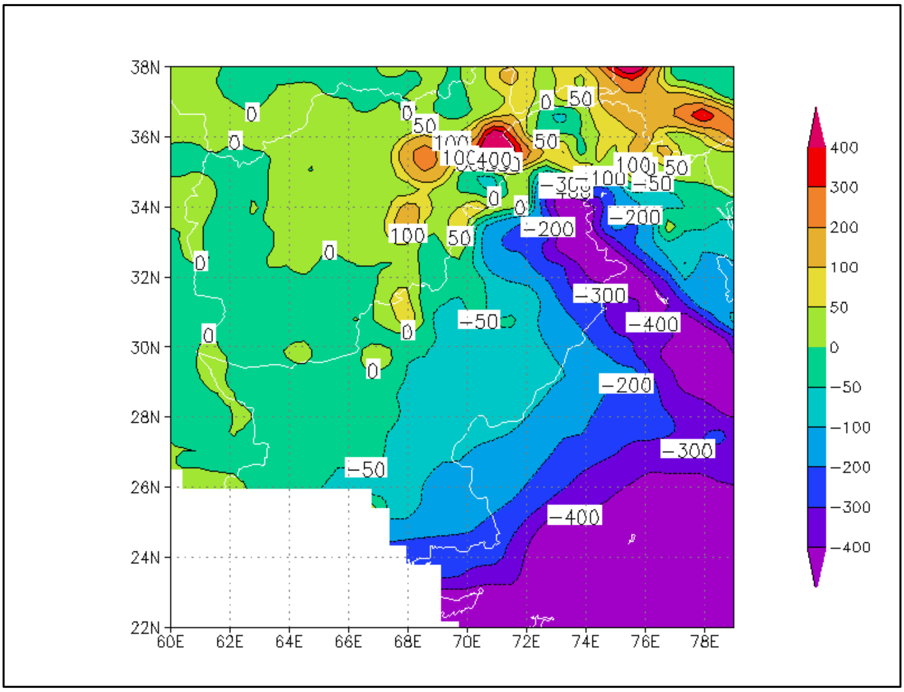


Figure 7: **Difference between Simulated JAS Rainfall with Arakawa & Schubert closure and CRU data (AS - CRU)**

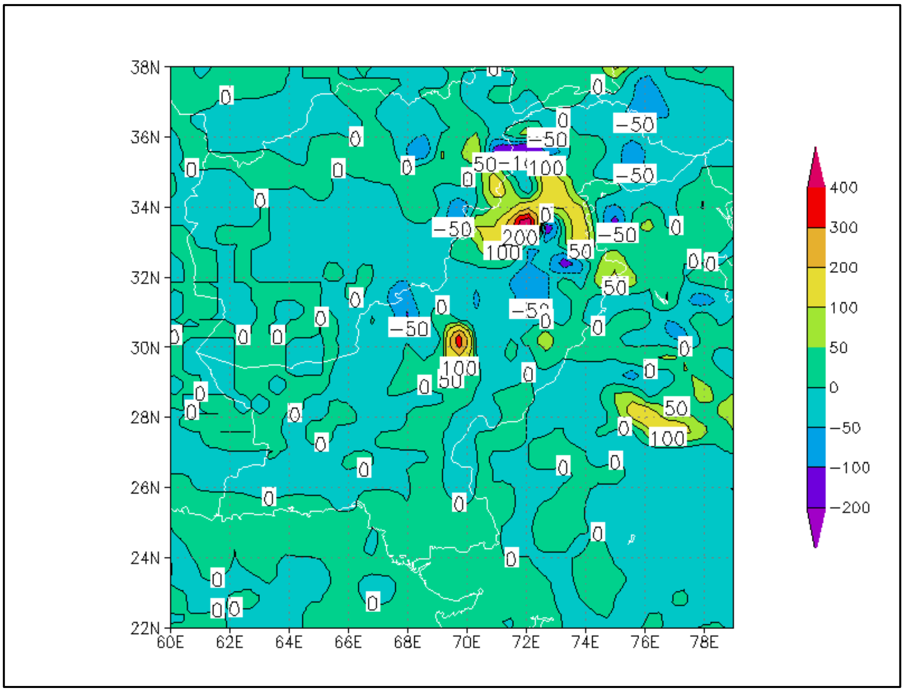


Figure 8: **Difference between Simulated JAS Rainfall with Fritsch & Chappell closure and with Arakawa & Schubert closure (FC - AS)**

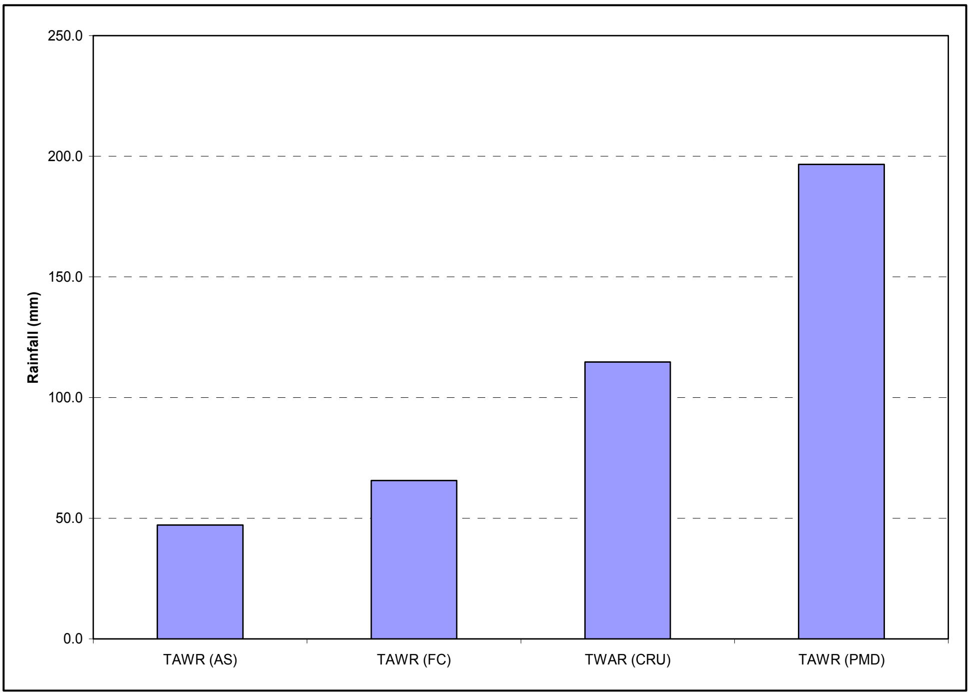


Figure 9: **Comparison of Simulated JAS Total Area Weighted Rainfall (TWAR) with Arakawa & Schubert (AS) closure, with Fritsch & Chappell (FC) closure, and Total Area Weighted Rainfall calculatd from CRU data and reported by PMD.**

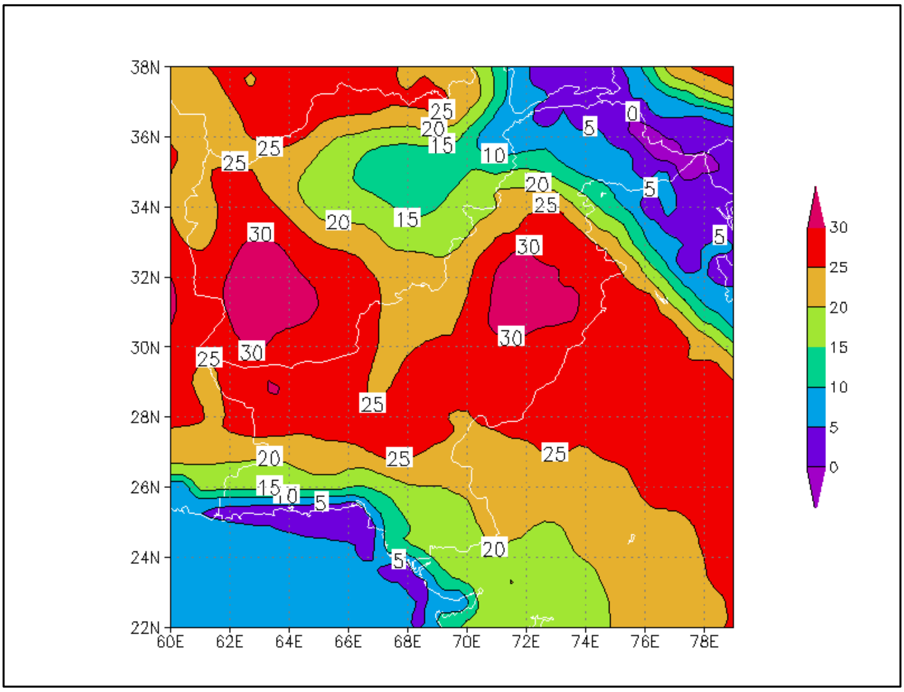


Figure 10: **Model Simulated JAS Average Temperature with Fritsch & Chappell closure**

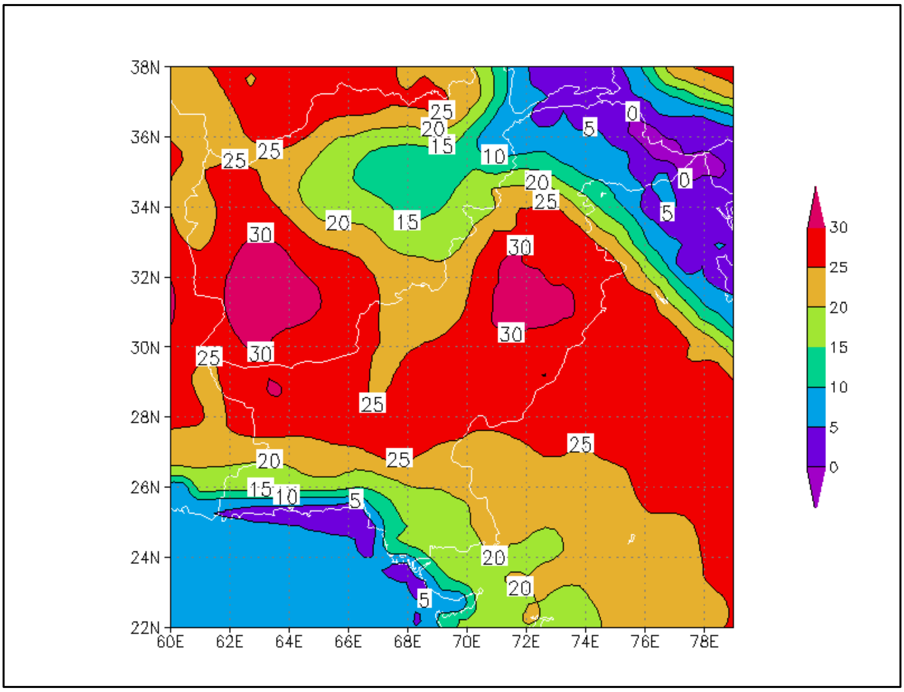


Figure 11: **Model Simulated JAS Average Temperature with Fritsch & Chappell Closure**

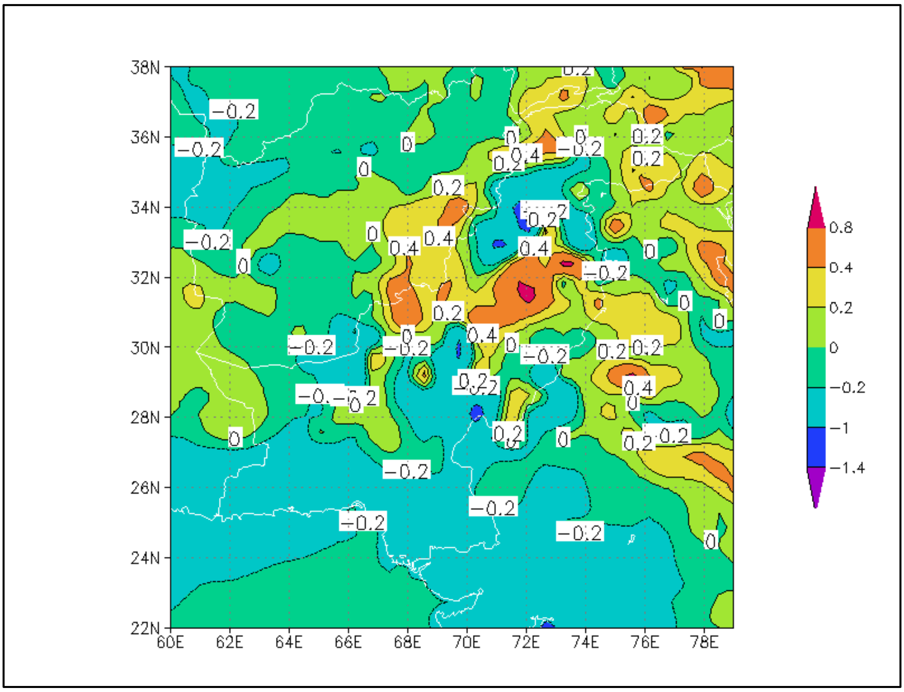


Figure 12: **Difference of JAS Average Temperatures simulated by model with FC closure and AS closure (FC – AS)**