IMPACT OF KALPANA-1 CLOUD MOTION VECTORS IN THE NUMERICAL WEATHER PREDICTION OF INDIAN SUMMER MONSOON

S.K.Roy Bhowmik, D. Joardar, Rajeshwar Rao, Y.V. Rama Rao, S. Sen Roy, H.R. Hatwar and Sant Prasad
India Meteorological Department, Lodi Road, New Delhi-110003, India

ABSTRACT

The coverage of satellite derived winds over the data gap Indian Ocean region has improved with the operation of India's first dedicated satellite for meteorology KALPANA-1 since 12 September 2002. Availability of these data has opened up a new possibility to examine the impact of these data on the NWP system for simulation of Indian summer monsoon. In this paper, we examine the impact of these data in the operational NWP system of India Meteorological Department (IMD) for the monsoon season 2003.

This study demonstrates the impact of these data in the model to capture monsoon circulations, cross equatorial flow and tropical easterly jet. The impact of additional wind data in the model is found to be positive and beneficial.

1. INTRODUCTION

The Indian summer monsoon is an important event, which has great influence in the agriculture sector of the region. A major problem in the use of Numerical Weather Prediction (NWP) model for simulation of monsoon features is the near absence of data over the large Indian Ocean where the monsoon processes originate (Rama Rao et al. 2001; Rizvi et al., 2002; Roy Bhowmik and Sud, 2002). The coverage of satellite-derived winds over the data gap Indian Ocean region has improved with the operation of India's first dedicated satellite for meteorology KALPANA-1 which was launched to its orbital slot of longitude 74°E. on 12 September 2002. Cloud Motion Vectors (CMV) are derived for three layers, namely lower, middle and upper troposphere using three half hourly images through a detailed pattern matching processes. Day to day comparison of these data with respect to Meteosat-5 and RS/RW observations suggest that the quality of data is fairly accurate and acceptable for use in application. In this paper, the impact of these data in the operational NWP system of India Meteorological Department (IMD) for the monsoon season 2003 is examined.

2. DESIGN OF EXPERIMENT

To evaluate the impact of additional CMV data, two data sets of experiments performed are: (a) Control run: In this experiment no CMV data (Kalpana-1) is used and the analysis procedure is run only with the operationally available GTS data and (b) Experiment run: In this the analysis procedure is run with the additional CMV data together with all data used in operational run. With each of these two sets of analysis fields based on 00 UTC observations, model is run every day upto 24 hours forecast for the months of June to August of monsoon 2003.

2.1 Analysis procedure

The operational NWP system of India Meteorological Department (IMD) consists of real time processing of data received on Global Telecommunication System (GTS), decoding and quality control procedure handled by AMIGAS software and a multivariate optimum interpolation scheme. The first guess field for running the analysis is obtained online from the global forecast (T-80/18L) run at National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi. The input data used for the analysis consist of :Surface – SYNOP/SHIP; Upper air – TEMP/PILOT, SATEM, SATOB; Aircraft reports – AIREP, AMDAR, CODAR. These are extracted and decoded from the raw GTS data sets. All the data are quality controlled and packed into a special format for objective analysis. The methodology applied for objective analysis scheme is the statistical 3-dimensional multivariate Optimum Interpolation (OI) scheme (Dey and Morone, 1985). The scheme is based on applying correction to a first guess, the corrections being the weighted average of (observation-first guess) residuals at the observation locations. The variable analyzed in this scheme is geopotential (z), u and v components of wind and specific humidity. Temperature (T) field is derived from geopotential field hydrostatistically. Analysis is carried out on 12 sigma (pressure divided by surface pressure) surfaces 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.07, 0.05 in the vertical and on 1°x1° horizontal lat./long. grid for a regional or limited horizontal domain covering lat. 30°S to 60°N and long. 0° to 150°E.

2.2 Description of the model

The forecast model is a semi-implicit, semi-Lagrangian, multi level primitive equation model cast in sigma co-ordinate and staggered Arakawa C-grid in the horizontal. The model consists of the usual equations of motion, thermodynamic energy equation, mass continuity equation, moisture continuity equation, hydrostatic equation and equation of state. The model includes number of physical processes such as cumulus convection (modified Kuo; Krishnamurti et al., 1983), shallow convection (Tiedke, 1984), large scale condensation, atmospheric boundary layer (Monin-Obukhov formulation of surface layers with stability dependent vertical diffusion in mixed layer), radiation (Harshvardan and Corsetti, 1984; Lacis and Hansen, 1974), envelope orography (Wallace, 1983) and dynamic normal mode initialization (Sugi, 1986). Further details of the model formulation can be found in Krishnamurti et al. (1989). Horizontal resolution of the coarser grid (operational) model is 0.75^o X 0.75^o latitude/longitude. and 16 sigma levels in the vertical. The orography prescribed in the model is smoothened by a nine point smoother to prevent instability due to steep gradients of terrain over the Himalayan region. The other features of the model include time dependent lateral boundary conditions and dynamic normal mode initialization (Sugi, 1986). Model is run up to 48 hours, twice daily initialized with 00 UTC and 12 UTC observations. Lateral boundary conditions of the model are from the global spectral model (T-80/18L) run of the National Center for Medium Range Weather Forecasting (NCMRWF), New Delhi and are updated every 12 hours. The time step of the model is 900 seconds.

3. THE IMPACT STUDY

During 23-24 July 2003, a low pressure area lay over the northwest Bay of Bengal. On 25 July evening, the system intensified into a monsoon depression and lay over the northwest Bay of Bengal and adjoining coastal areas of Orissa with the associated upper air cyclonic circulation extending up to midtroposperic levels. Another low pressure area lay over north Gujarat region and adjoining areas of northeast Arabian Sea during 24 and 25 July. On 26 July mornings, the depression crossed north Orissa coast and the other low pressure area lay over Saurastra Kutch and adjoining areas. Figure 1 represents wind analysis of 700 hPa and 200 hPa at 00 UTC of 25 July based on CMV and without CMV. The third column indicates difference of respective fields with and without CMV. Though both the analysis (CMV and without CMV) could capture circulation features associated with the system, the strengthening of wind at 700 hPa over the Bay of Bengal (higher by about 10 ms^{-1}) is captured better in the analysis with CMV. The tropical easterly jet at 200 hPa over the East Central Arabian sea is considerably stronger in the analysis with CMV. Figure 2 shows corresponding 24 hours forecast valid at 00 UTC of 26 July 2003. Strengthening of lower tropospheric westerlies over the Bay of Bengal and parts of the Arabian Sea are comparatively simulated better in the forecast with CMV.

Impact of CMV data in the monthly mean field is also examined. Figure 3 shows the mean wind field of 700 hPa and 200 hPa for the month of July based on daily analysis field. The corresponding mean wind field based on 24 hours forecast is shown in Figure 4. The comparison reveals that in the analysis with CMV the strength of lower tropospheric cross equatorial flow along Somali coast, Arabian Sea and Bay of Bengal is captured better. At 200 hPa, strength of easterlies over the Indian monsoon region is relatively stronger in the analysis with CMV. It is interesting to note that these features are considerably well captured in the forecast with CMV.

The vertical cross section of mean zonal and meridional component of wind based on analysis and forecast are shown in Figures 5 and 6 respectively. The longitudinal mean is taken between longitude 60^oE to 100^oE.

Positive impact of CMV data is noticed both in the analysis and forecast. Strengthen of the sub-tropical westerly jets in both the hemispheres, tropical easterly jet over the southern latitudes of India is found to be higher with the use of CMV data. Some increase in the lower troposheric westerlies over the southern latitudes of India is also noticed when CMV data is used. The corresponding mean rainfall field for the month of July is presented in Figure 7. Both the forecast (CMV and without CMV) could capture large scale rainfall features over the domain of monsoon circulations and western Ghats of India, but the comparison reveals that the intensity of rainfall is slightly higher in the forecast with CMV.

4. CONCLUSION

The study has brought out a distinct positive contribution of CMV data in the analysis and forecast of the limited area model of IMD, which suffers in the oceanic region due to sparsity of data. Though both operational as well as experimental run is able to capture the circulation features of Indian summer monsoon, strength of lower tropospheric cross equatorial flow, subtropical westerly jet in both hemispheres and tropical easterly jet over the southern latitude of Indian region are better captured both in the analysis and forecast with the additional CMV data. The impact of these data is found to be positive and useful.

5. ACKNOWLEDGEMENTS

The authors of this paper are grateful to the Director General of Meteorology, India Meteorological Department, New Delhi for his encouragements and providing all facilities to complete this research work. The first author likes to express his gratitude to the Director General of Meteorology for permitting the author to attend and present this paper in this Workshop.

6. REFERENCES

Dey,C.H. and Morone, L.L., 1985, Evolution of the National Meteorological Center Global data Assimilation System, January 1982-December 1983, *Mon. Wea. Rev*., 113, 304-318

Harshvardan and Corsetti T.G., 1984, Long wave radiation parameterization for ULCA/GLAS GCM, NASA Tech. Memo No. 86072, 51pp

Krishnamurti, T.N. and Low-Nan and Pasch, R., 1983, Cumulus parameterization and rainfall rates, *Mon. Wea. Rev*., 111, 815-828

Krishnamurti, T.N., Kumar, A., Yap, K.S., Davidson, D. and Sheng, J, 1989, A documentation of FSU Limited Area model, FSU Rep No. 89/4 Florida State University, USA.

Lacis, A. A. and Hansen, J. E.,1974, A parameterization for the absorption of solar radiation in the earth's atmosphere, *J. Atmos. Sc.*, 31, 118-133

Rama Rao, Y. V., Prasad K. and Prasad S., 2001, A case study of the impact of INSAT derived humidity profiles on precipitation forecast by limited area model, *Mausam*, 52, 647-654

Rizvi, S.R.H., Kamineni Rupa and Mohanty U.C., 2002, Impact of MSMR data on NCMRWF Global Data Assimilation System, *Meteorl. Atmos. Phys*.,81, 257 -272

Roy Bhowmik, S.K. and Sud A.M., 2002, Impact of MSMR surface wind on the analysis and forecast of a limited area model over Indian region, presented in the 6^{th} International Wind Workshop held in Wisconsin, USA during 7-10 May, 2002, pp. 207-213

Sugi M., 1986, Dynamic Normal mode initialization, *J. Meteor. Soc*, Japan, 64, 623-636

Tiedke, M., 1984, The sensitivity of the time mean large scale flow to cumulus convection in the ECMWF model. Workshop on convection in large scale numerical model, ECMWF, 297-317

Wallace, J.M., Tihaldi, S. and Simon, J., 1983, Reduction of systematic forecast errors in the ECMWF model through introduction of envelope orography, *Quart. J. Roy Meteor. Soc*., 109, 683-718

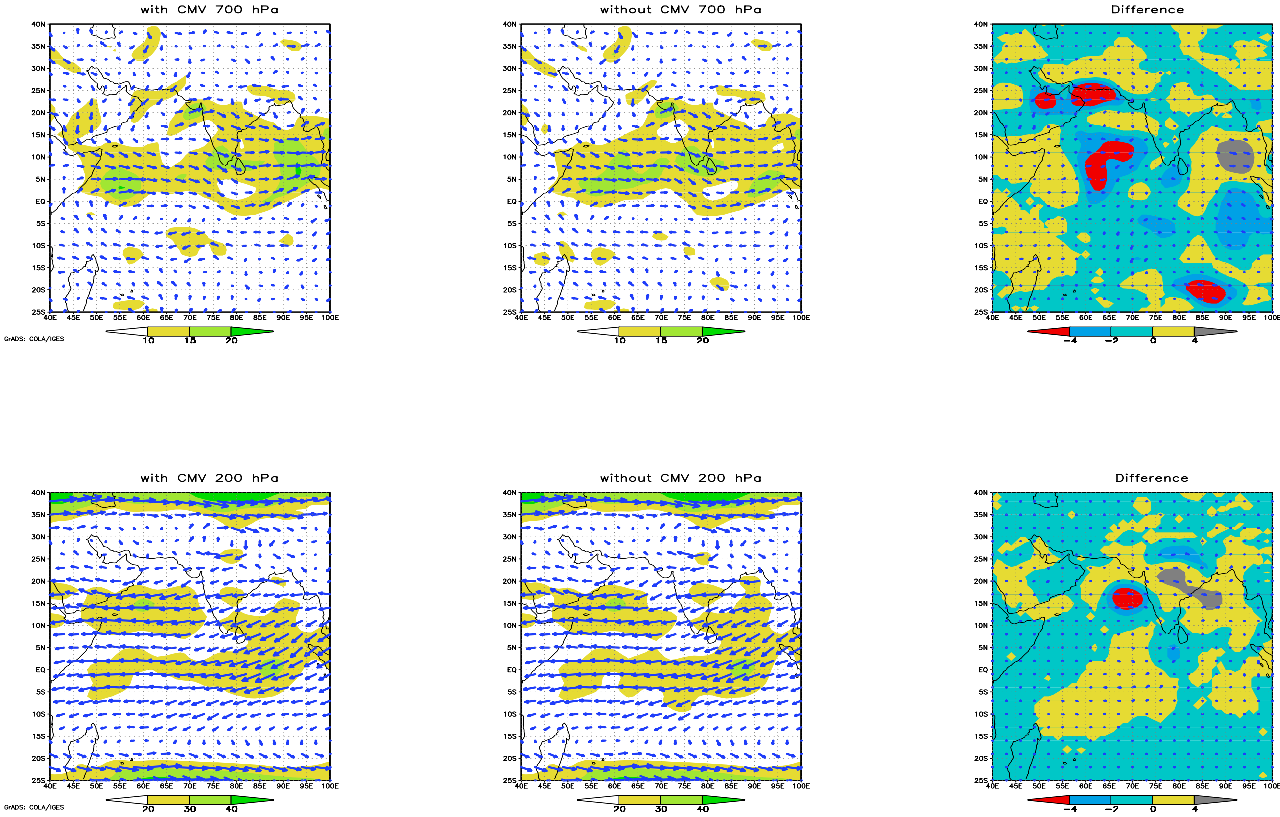

Figure 1. Analysis (ms^{-1}) at 0000 UTC of 25 July 2003.

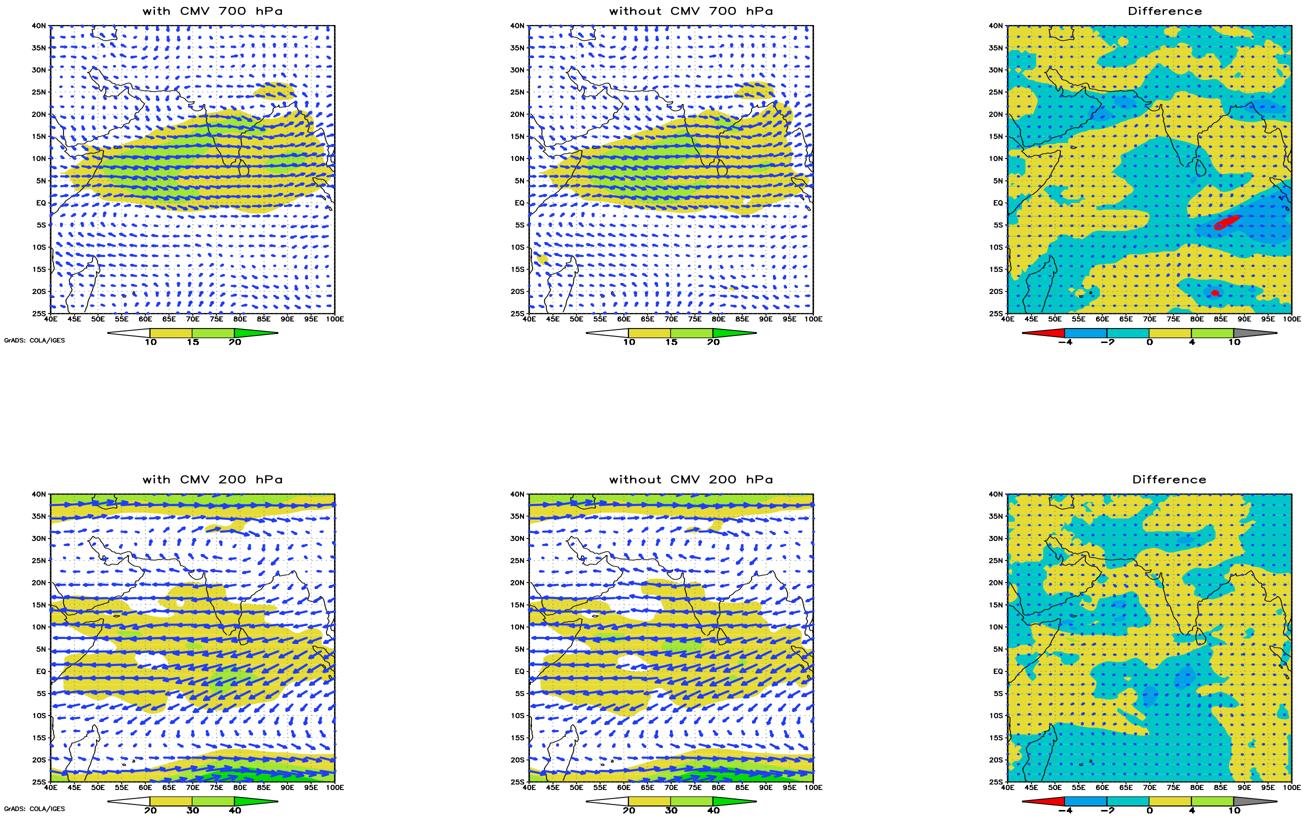

Figure 2. 24 hours forecast (ms-1) valid at 0000 UTC of 26 July 2003

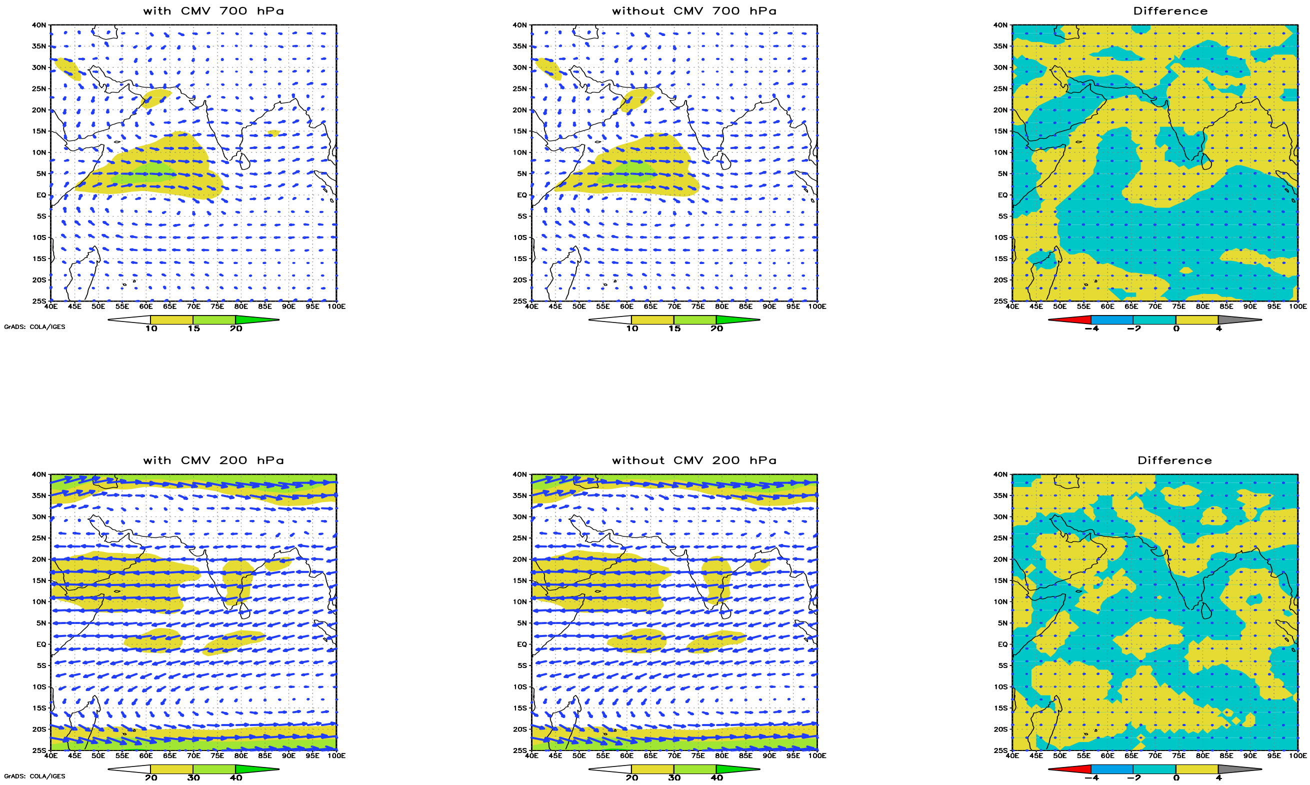

Figure 3. Mean analysis (ms-1) of July 2003

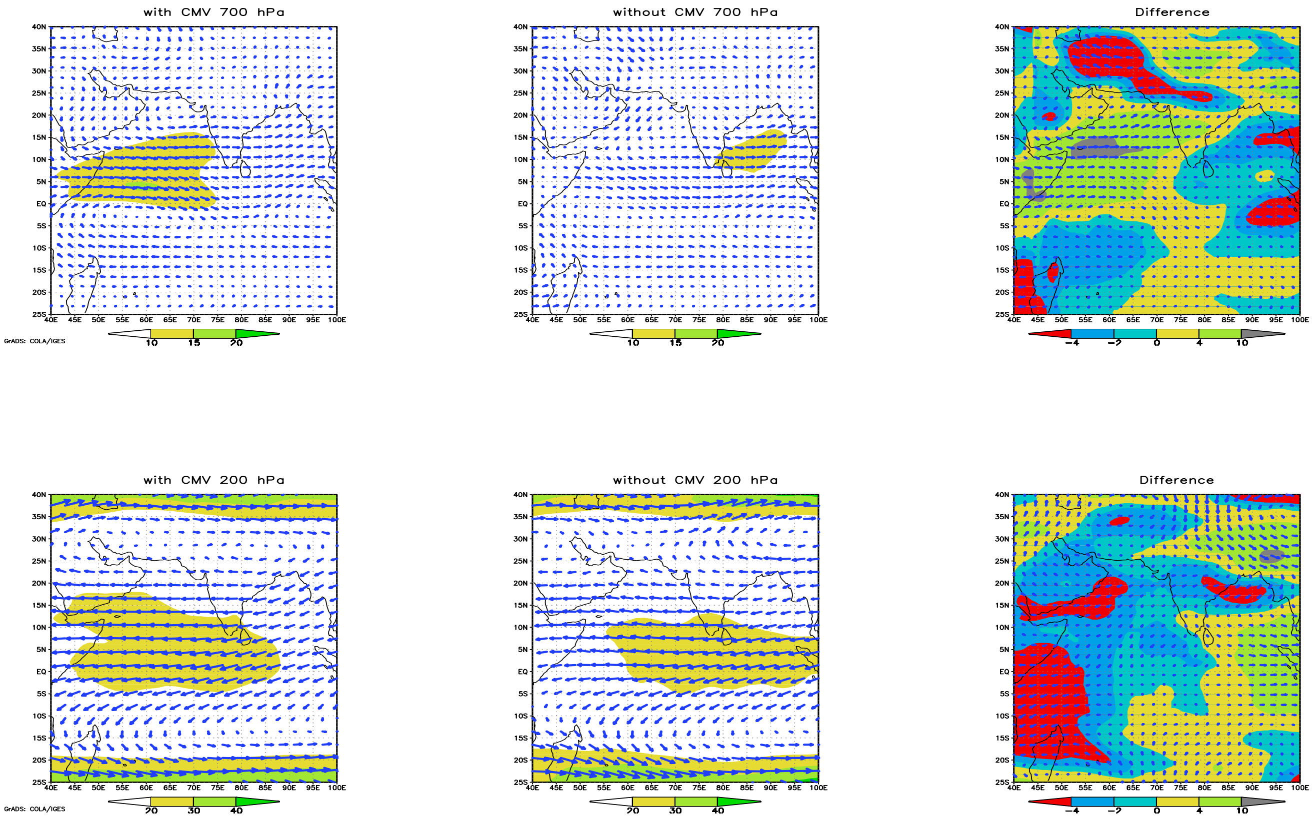

Figure 4. Mean 24 hours forecast (ms-1) of July 2003

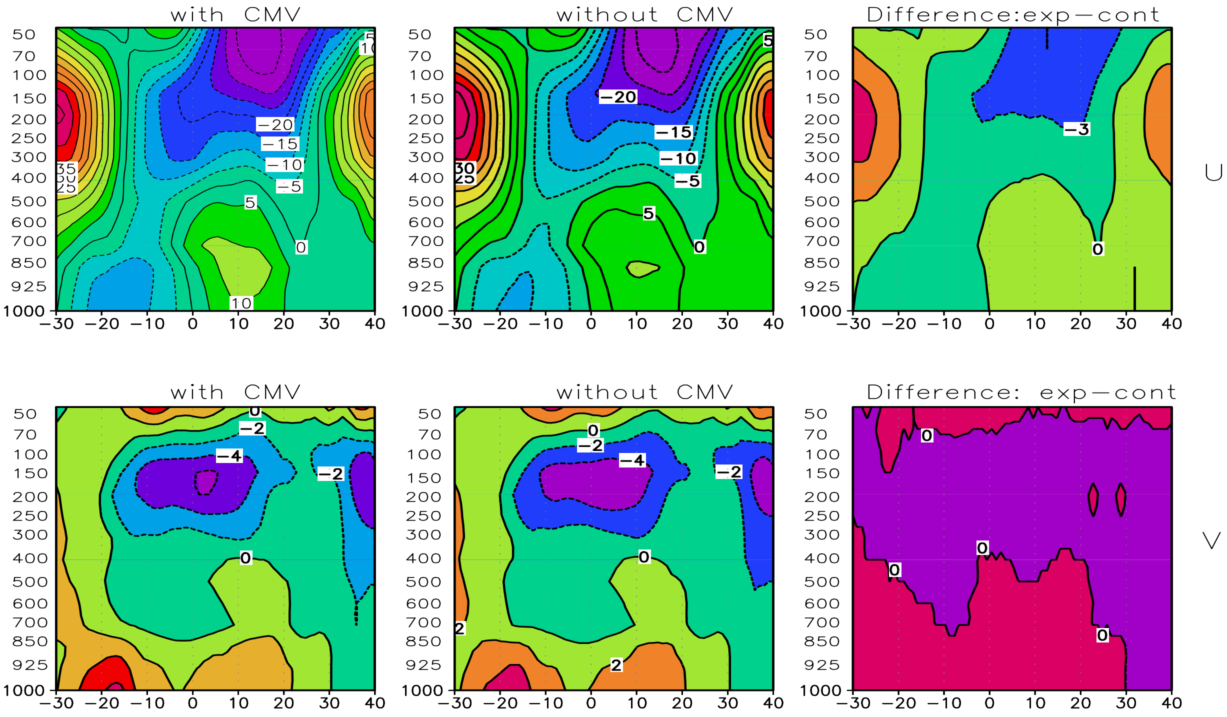

Figure 5. Vertical cross section of wind components (ms-1) based on analyses of July 2003.

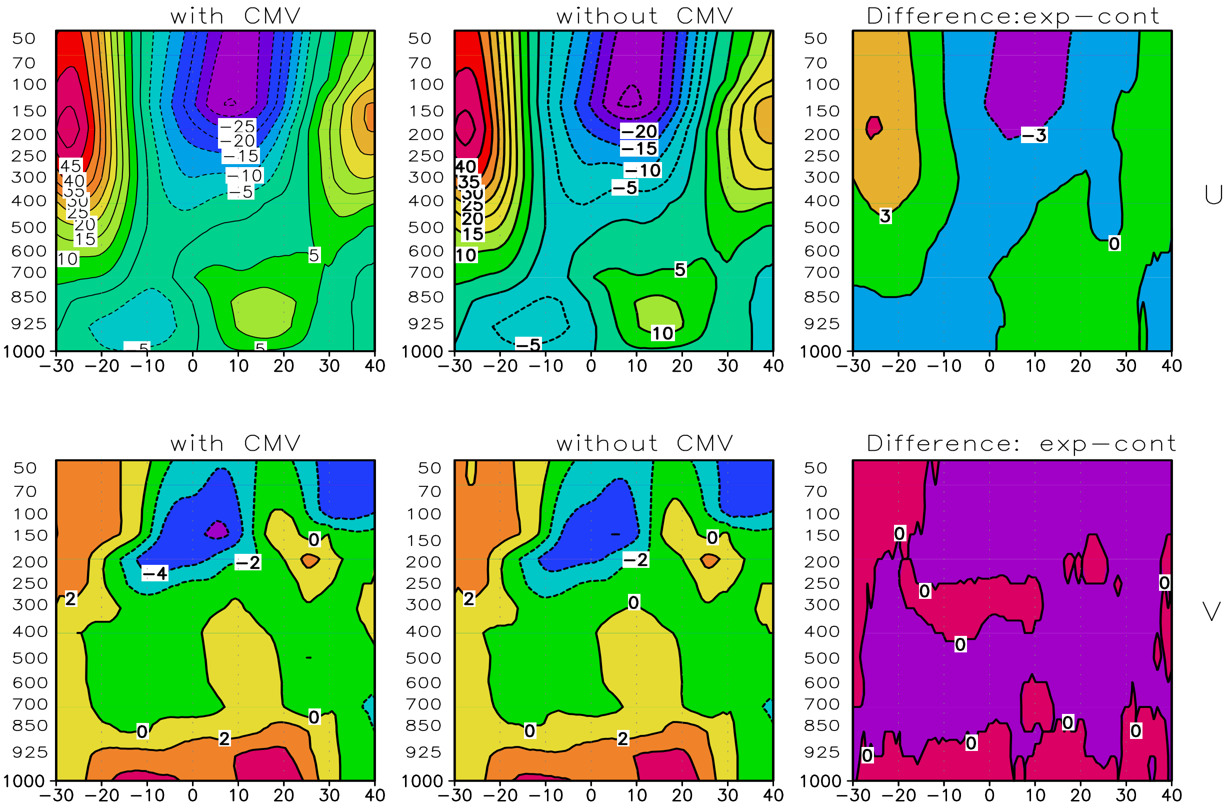

Figure 6. Vertical cross section of wind components (ms-1) based on 24 hours forecasts of July 2003.

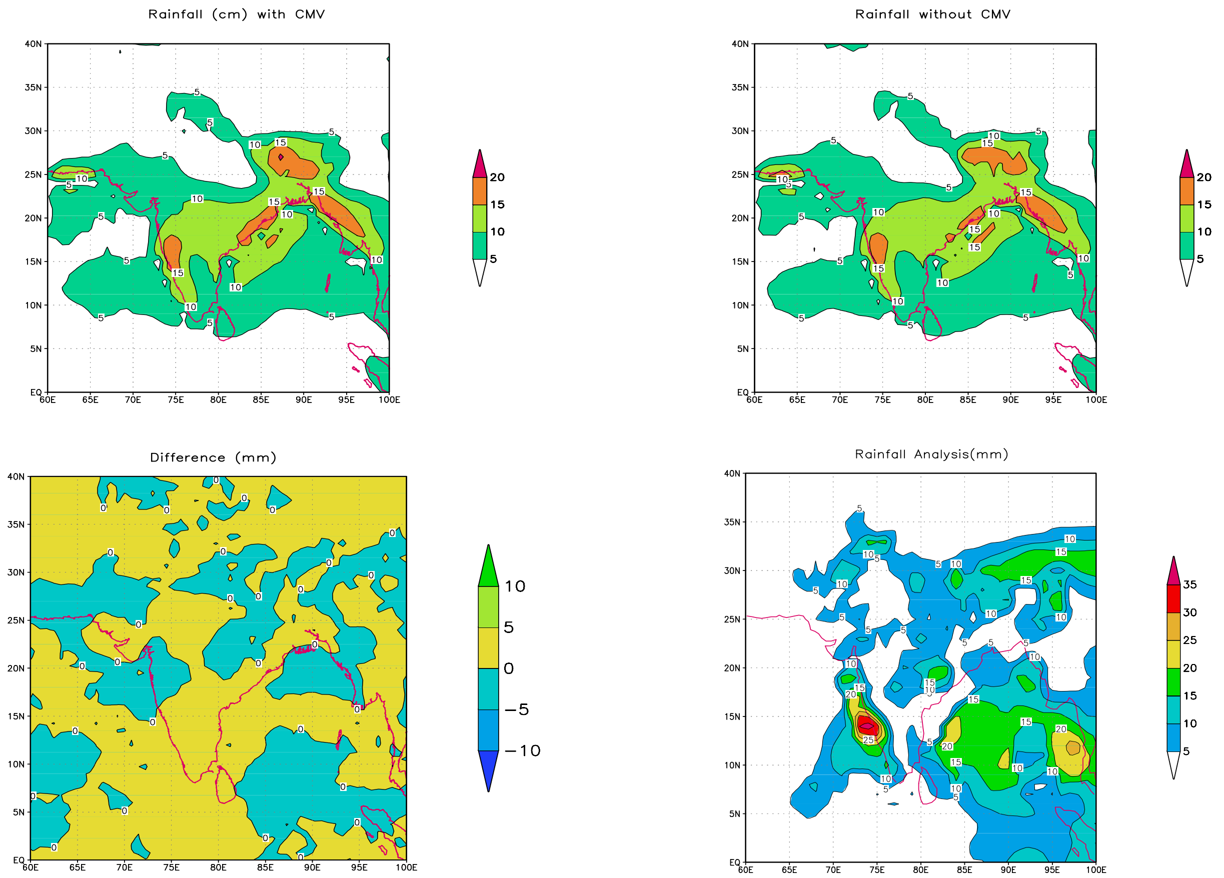

Figure 7. Mean Rainfall (mm/day)of July 2003