

An impact of ARMEX data on limited area model analysis and forecast system of India Meteorological Department - A preliminary study

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सार – भारत मौसम विज्ञान विभाग के अन्य उत्पादों के साथ-साथ पूर्वानुमान उत्पादों का उपयोग अरब सागर मानसून प्रयोग (आरमेक्स) की अवधि के दौरान मौसम विज्ञान से संबंधित और महासागरीय आँकड़ों के संग्रहण के कार्य से जुड़े हुए फील्ड वैज्ञानिकों को दिन प्रति दिन का मानीटरन और मार्गदर्शन प्रदान करने के लिए किया गया है। इस अध्ययन में आरमेक्स की अवधि के दौरान घटित हुए कुछ महत्वपूर्ण सिनॉप्टिक तंत्रों के लिए सीमित क्षेत्र पूर्वानुमान तंत्र के सक्रियात्मक विश्लेषण और पूर्वानुमान उत्पादों की जाँच की गई है। इसके अलावा, आरमेक्स चरण-II नामतः एस. वाई. एन. ओ. पी. से उपरितन वायु और उपग्रह के आँकड़ों से उपलब्ध अतिरिक्त आँकड़ों का उपयोग करते हुए मानसून 2003 के आरंभ की अवस्था के समय भारत मौसम विज्ञान विभाग के प्रचालनात्मक सीमित क्षेत्र पूर्वानुमान तंत्र के इन आँकड़ों के प्रभाव की जाँच की गई। इन अतिरिक्त आँकड़ों के साथ प्रमाणन विश्लेषण और पूर्वानुमान क्षेत्रों से मॉडल पूर्वानुमानित वर्षा और इसके विश्लेषण में महत्वपूर्ण सुधार दिखाई दिया है।

ABSTRACT. During the Arabian Sea Monsoon Experiment (ARMEX) period India Meteorological Department (IMD) forecast products along with other products are utilised for day-to-day monitoring and providing the guidance to the field scientists engaged in the collection of meteorological and oceanographic data. In the present study, the operational analysis and forecast products of limited area forecast system for some of the major synoptic systems that occurred during the ARMEX period was investigated. Further, using the additional data available from ARMEX Phase-II namely SYNOP, upper air and also satellite data, the impact of these data in the IMD's operational limited area forecast system during the onset phase of monsoon 2003 has been investigated. Verification of analysis and forecast fields with this additional data has shown substantial improvement in the analysis and model predicted rainfall.

Key words – ARMEX, Data, Impact, Analysis and forecast system.

1. Introduction

Difficulties and inaccuracies in numerical weather prediction over low latitudes are mainly attributed to data problems and thus to the overall treatment of diabatic processes. Tropical general circulation is mainly governed by convective heating. Thus Numerical Weather Prediction (NWP) over low latitudes is sensitive to the four dimensional structure of parameterized convective heating. In the initial fields, there is a greater degree of uncertainty in the quality of the divergence and moisture fields on which this convective heating depends. In spite of the use of vast amount of a synoptic and non-conventional data sets from satellites, large data gaps are evident over both land and ocean areas of tropics. The present ARMEX program has generated additional data sets during

monsoon-2002 and pre onset phase of monsoon-2003. Utilization of these data on the analysis and prediction of various monsoon systems is one of the objectives of the program.

IMD is running the limited area analysis and forecast system in real-time for the last 10 years. The numerical products such as wind, temperature and rainfall were used for day-to-day operational use. Also these products are utilised for diagnostic and research by various users. During the ARMEX period, IMD forecast products along with other products were utilised for day-to-day monitoring and providing the guidance to the field scientists engaged in the collection of meteorological and oceanographic data. In the present study, some of the major synoptic system that occurred during the ARMEX

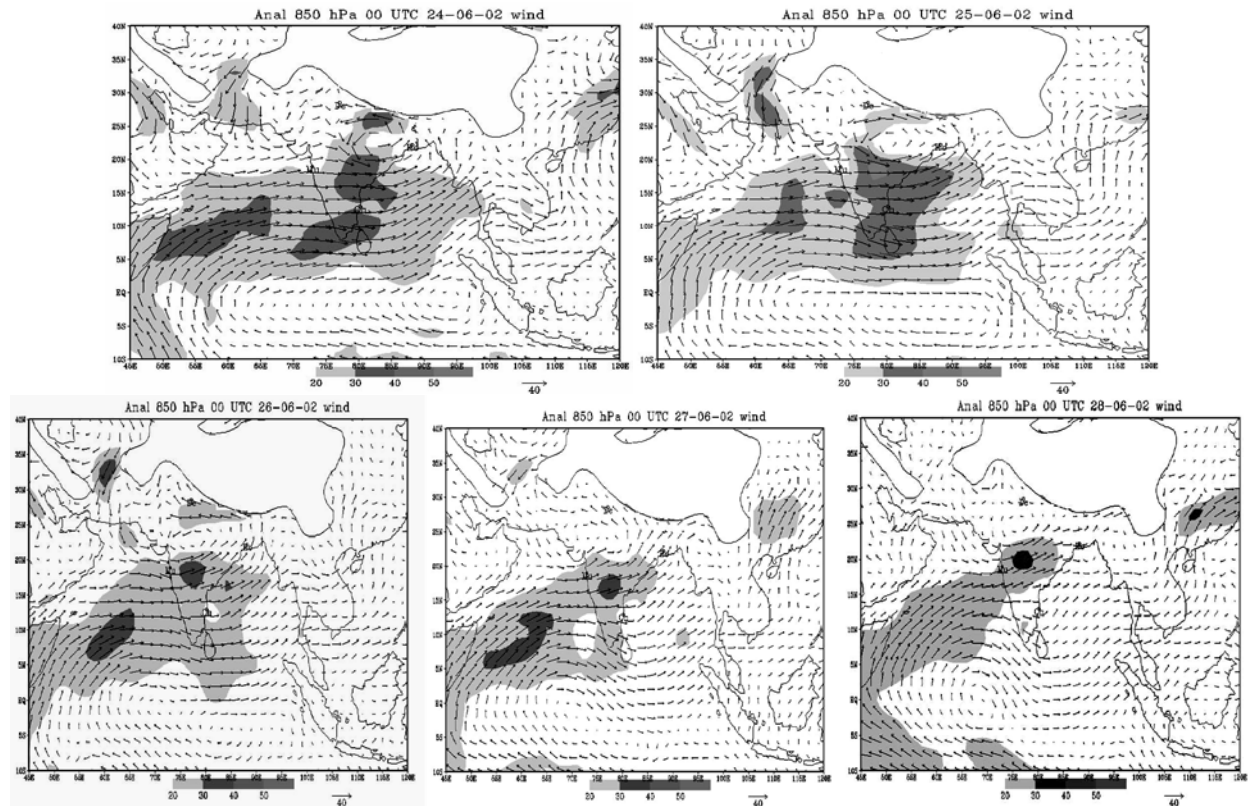


Fig. 1. Wind (kt) at 850 hPa based on analysis valid at 0000 UTC of 24, 25, 26, 27 and 28 June 2002. Shaded region indicate higher magnitude of wind

period was investigated. Also using additional data available from ARMEX Phase-II namely SYNOP, upper air and satellite data, the impact of these data in the IMD's operational limited area forecast system during the onset phase of monsoon 2003 has been investigated.

2. IMD's operational NWP system

IMD's operational NWP is based on a limited area analysis and forecasting system (LAFS) that consists of real time processing of data received on Global Telecommunication System (GTS), objective analysis by 3-D multivariate optimum interpolation (OI) scheme and limited area forecast model.

2.1. Input data

The grid point fields for running the model are prepared from the conventional and non-conventional data received through GTS. The data consists of the surface SYNOP/SHIP, upper air TEMP/PILOT, SATEM, SATOB, AIREP, DRIBU and AMDAR, which are extracted and decoded from the raw GTS data sets. The synthetic observations such as cyclone bogusing data are

included as per requirement. In the present study, additional data available from ARMEX Phase-II *viz.*, SYNOP observations from AWS, special SYNOP/SHIP, upper air and satellite data are included as synthetic observations. Method for assimilation of this additional data as pseudo observations in the analysis scheme has been developed and implemented in the regional analysis scheme. All the data are quality controlled and packed into a special format for objective analysis.

2.2. Analysis procedure

The objective analysis is carried out by three dimensional multivariate optimum interpolation (OI) procedures. The variables analysed are the geopotential, u and v components of wind and specific humidity. Temperature fields are derived from the geopotential fields hydrostatically. Analysis is carried out on 12 sigma surfaces from 1.0 to 0.05 in the vertical and $1^\circ \times 1^\circ$ horizontal Lat./Long. grid for limited area horizontal domain of 30° S to 70° N ; 0° to 150° E. The first guess fields for analysis are used from the global forecasts produced at the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi.

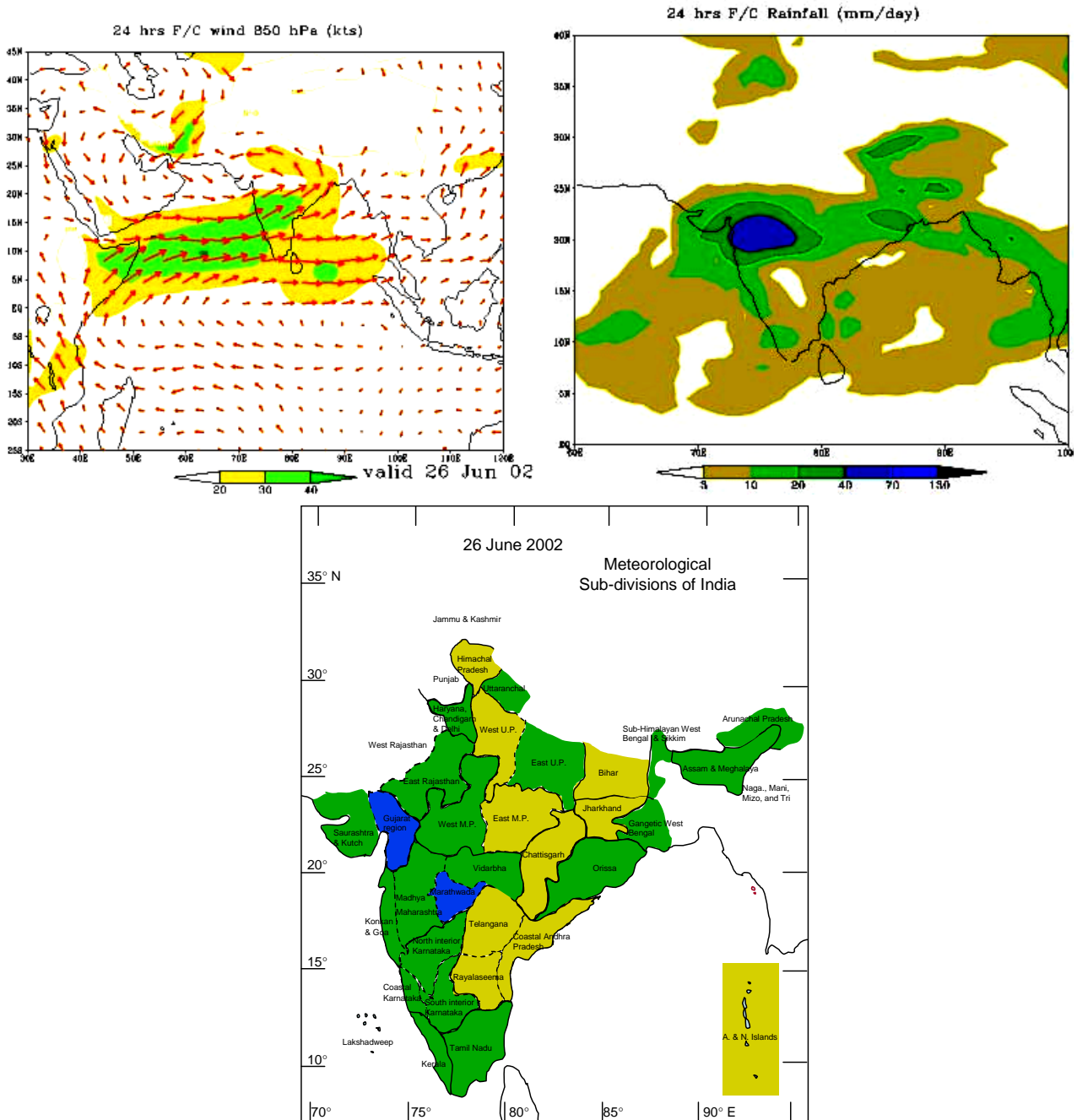


Fig. 2. 24 hrs Forecast wind field (kt) 0000 UTC of 850 hPa, rainfall (mm) valid at 0300 UTC of 26 June 2002 and corresponding 24 hours observed rainfall

2.3. Forecast model

The IMD limited area forecast model is a semi-implicit semi-Lagrangian multilayer primitive equation model based on sigma co-ordinate system and Arakawa C-grid in the horizontal. The present version of the model has a horizontal resolution of $0.75^\circ \times 0.75^\circ$ Lat./Long. (domain 30° S to 50° N and

25° E to 130° E) and 16 sigma levels (1.0 to 0.05) in the vertical. The detailed description of model formulation, horizontal and vertical discretization and time integration scheme used in the experiment is given in Prasad *et al.* (1997) and Krishnamurti *et al.* (1990). The lateral boundary conditions are obtained from the global forecasts produced at the NCMRWF, New Delhi.

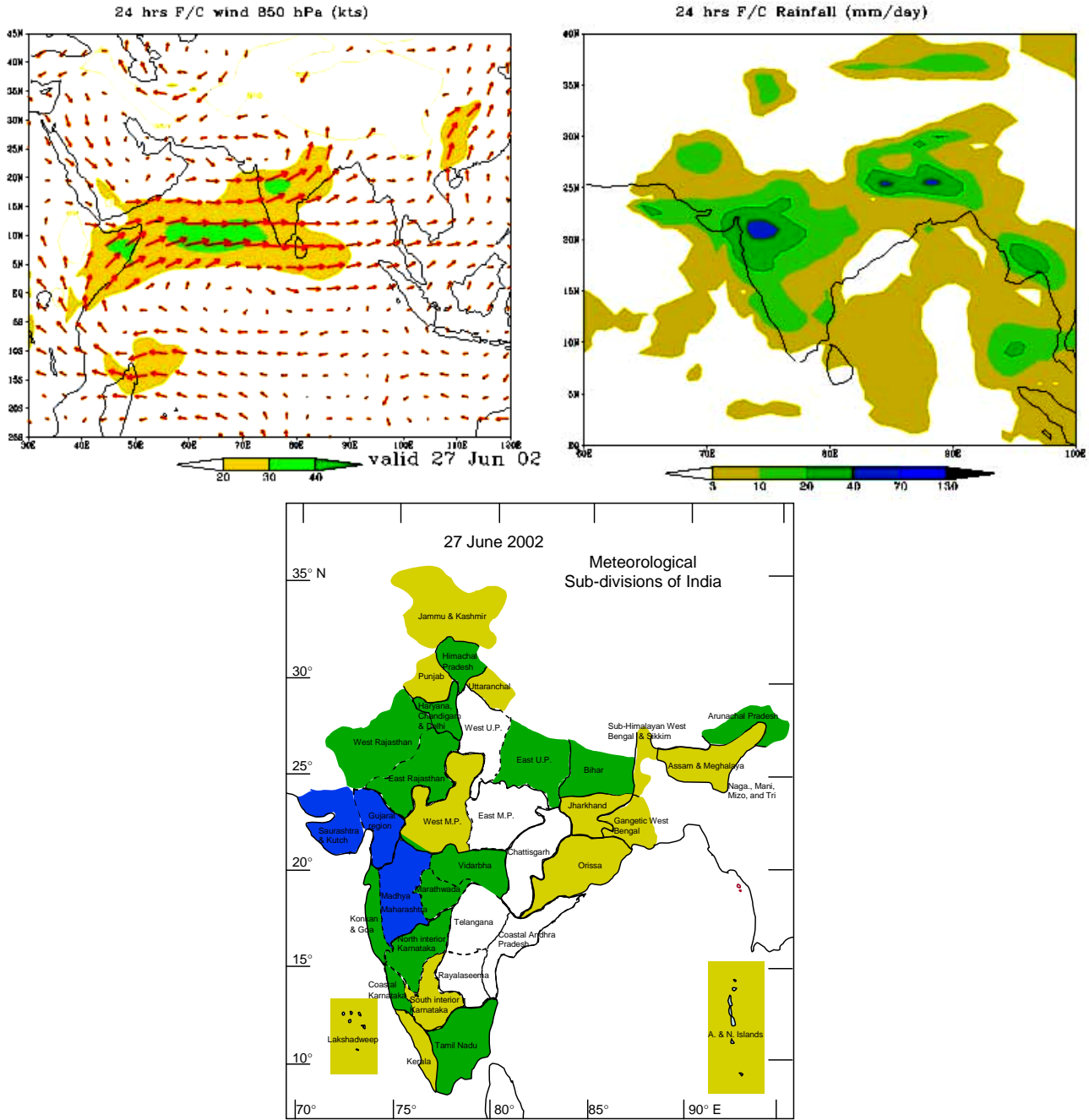


Fig. 3. 24 hrs Forecast wind field (kt) 0000 UTC of 850 hPa, rainfall (mm) valid at 0300 UTC of 27 June 2002 and corresponding 24 hours observed rainfall

3. Results and discussion

In this study some of the major synoptic systems that occurred during the ARMEX Intense Observation Period (IOP) 26-28 June 2002 Phase-I and 07 - 12 June, 2003 Phase-II which coincided with the onset of monsoon over Kerala were considered. Numerical experiments were conducted with additional ARMEX data (experiment) and

the results are compared with the operational products without these additional data (control) in the later case.

3.1. Case 1: 26-28 June 2002

A low pressure area formed over northwest Bay of Bengal on 20th and it became a well marked low pressure area by the same evening. It moved initially in a northerly

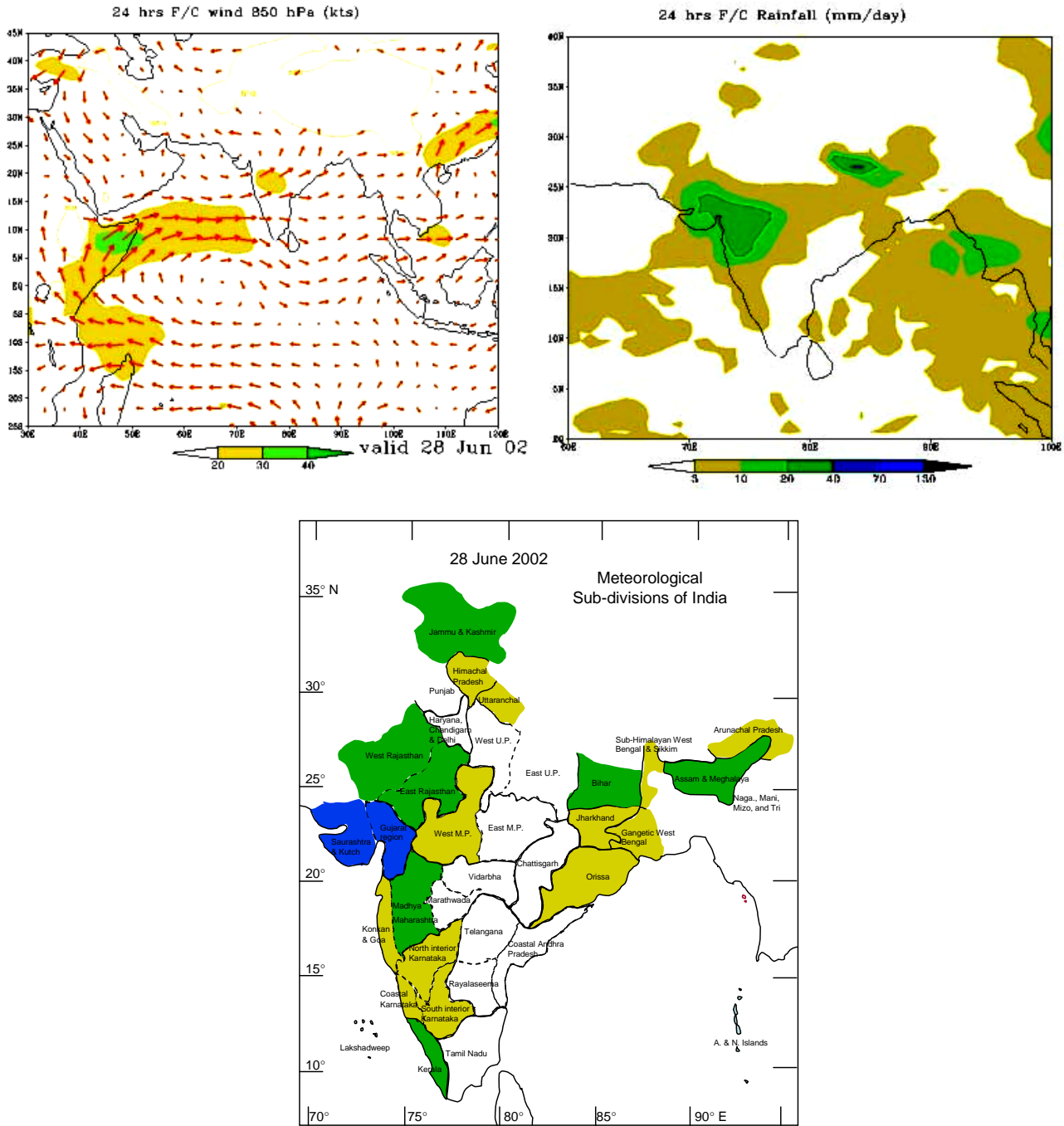


Fig. 4. 24 hrs Forecast wind field (kt) 0000 UTC of 850 hPa, rainfall (mm) valid at 0300 UTC of 28 June 2002 and corresponding 24 hours observed rainfall

direction and later took a westward course across central parts of the country up to Madhya Pradesh and then west-northwesterly direction up to southeast Rajasthan where it weakened into a low pressure system on 28th. Under the influence of this system monsoon advanced into central India and parts of north India and heavy to very heavy rainfall occurred in central and western parts of the

country. During the period the monsoon was active to vigorous over Maharashtra & Goa and Gujarat state where heavy rainfall of more than 20 cm reported in Konkan-Goa coast and Gujarat. The 850 hPa analysis of wind for 24, 25, 26, 27 and 28th June are given in Fig. 1. It shows, on 24th the well marked low pressure system was over Orissa and monsoon westerlies with wind speed

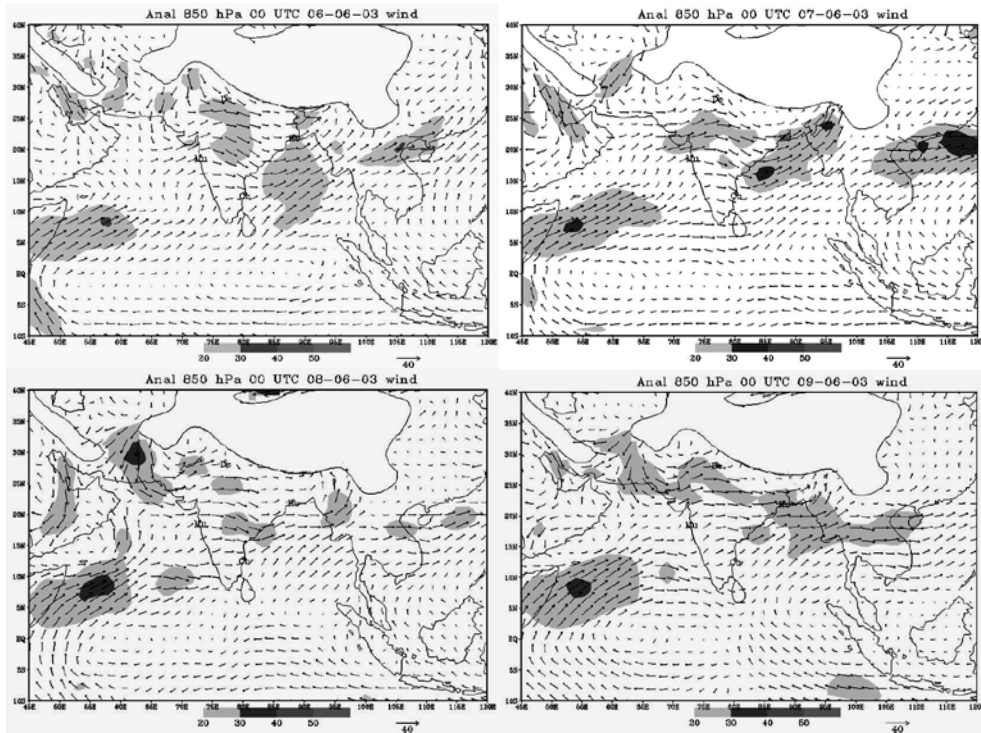


Fig. 5. Same as Fig. 1 except for 0000 UTC of 06, 07, 08 and 09 June 2003

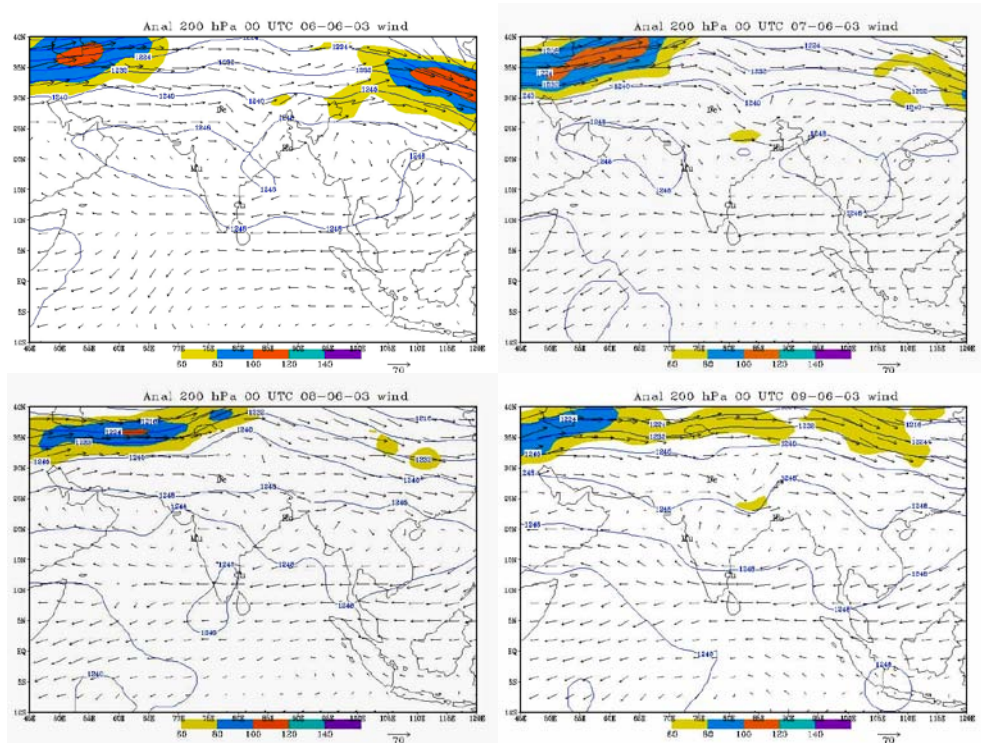
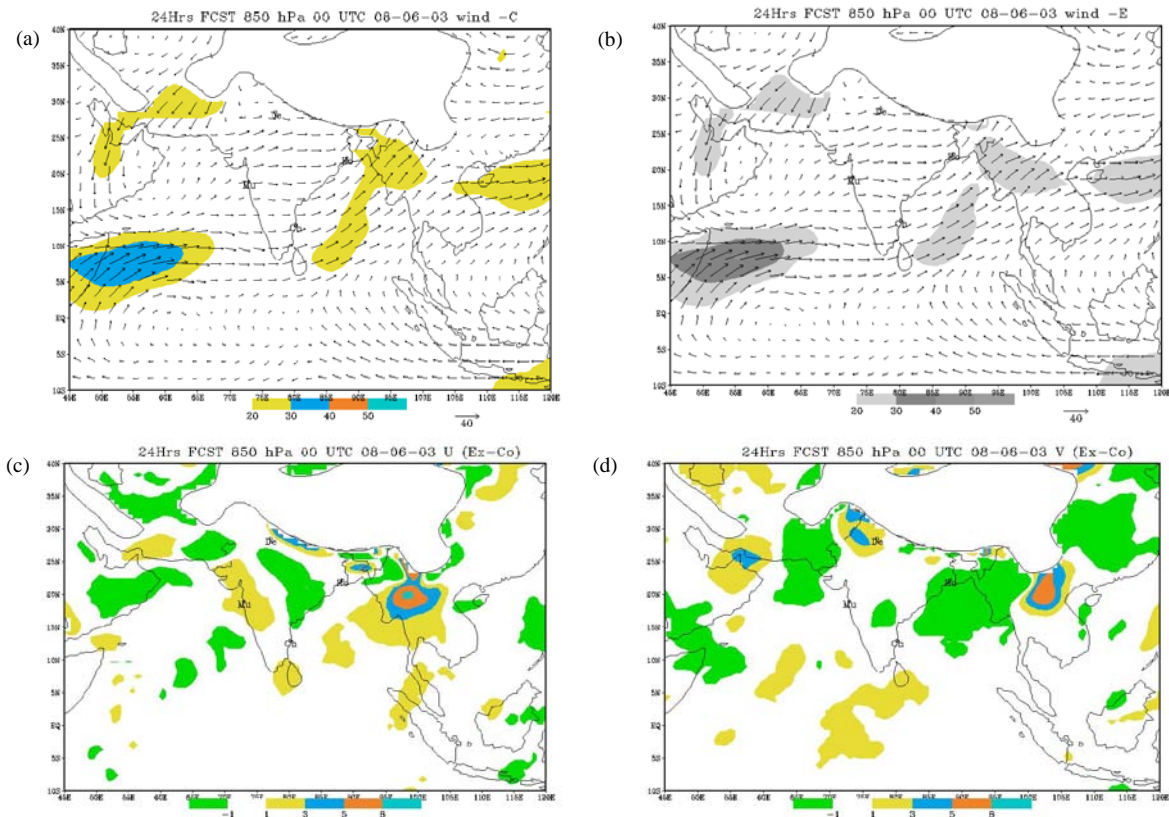


Fig. 6. Wind (kt) and contour height (gpm) at 200 hPa based on analysis valid for 0000 UTC of 06, 07, 08 and 09 June 2003. Shaded regions indicates higher magnitude of wind

30-40 knots located over southwest sector of the system. On 25th the area of strong winds extended eastwards,

which shows the strengthening of the system. In the subsequent two days, with the movement of the system



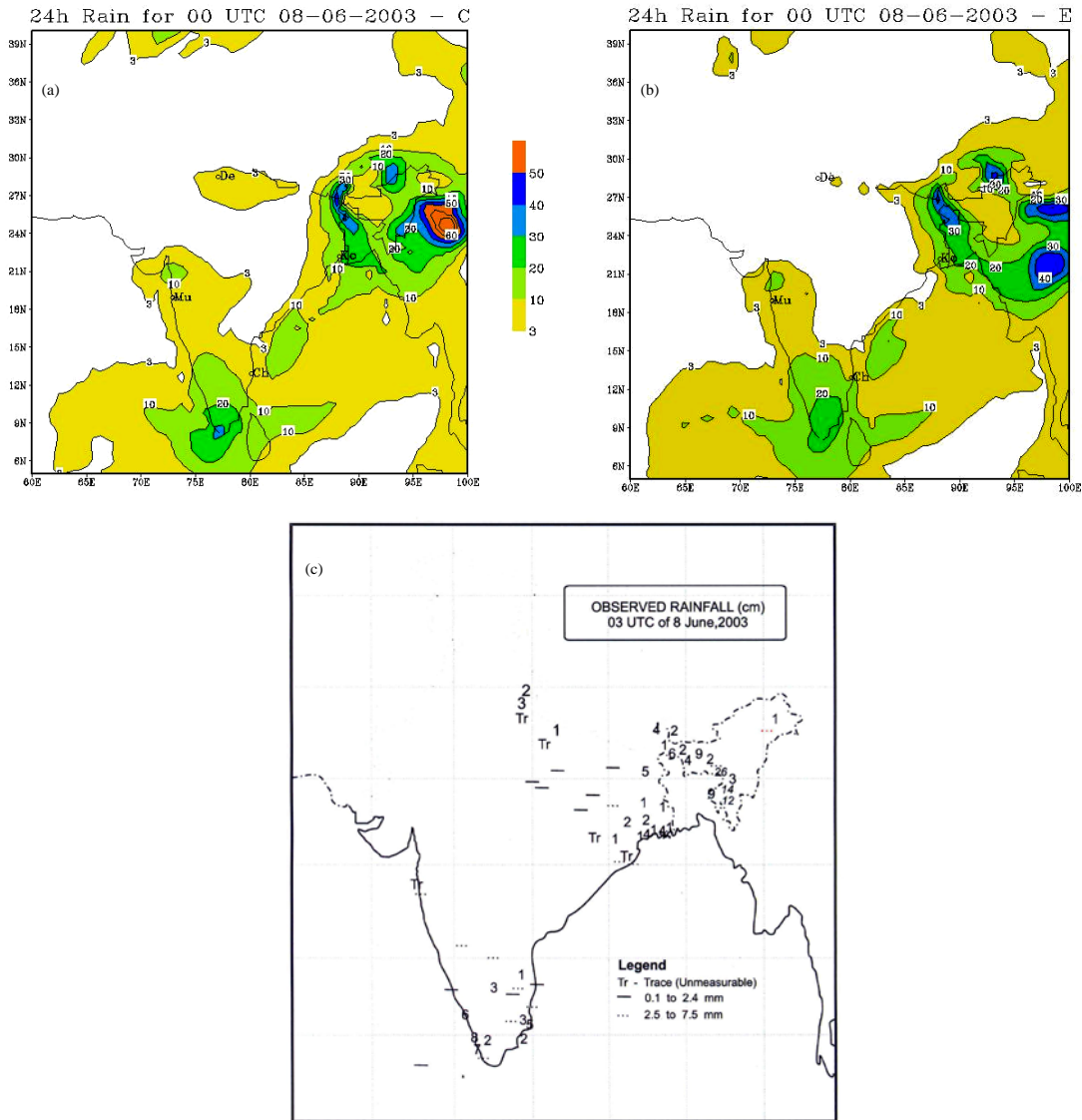
Figs. 7(a-d). Wind at 850 hPa based on 24 hrs forecast valid at 0000 UTC of 8 June 2003 (a) without additional ARMEX data (b) with additional data, (c) Difference of u between (a) and (b), (d) Same as (c) except for v component

westwards the area of strong winds decreased over southern sector. The 24 hours forecast 850 hPa wind and rainfall (mm) along with observed rainfall (mm) of 26, 27 and 28th June are given in Figs. 2, 3 and 4. The forecast wind of 26 and 27 shows the strengthening of low level westerly flow over Arabian Sea, which was stronger than the analysis. The rainfall prediction by the model is comparable with the observed rainfall pattern. Model was able to capture the heavy rainfall event over Gujarat. However, the predicted rainfall is lower than the amounts actually observed.

3.2. Case 2 : 05-09 June 2003

Southwest monsoon advanced into Kerala and adjoining parts of Tamil Nadu on 8th June with a delay of about a week. It advanced into parts of coastal and south interior Karnataka and some more parts of Tamil Nadu on 10th. In the present study the performance of the limited area model during the onset phase of the monsoon was investigated. The model forecasts are produced with the additional ARMEX data and compared with the operational real-time forecasts produced without these additional data. The 850 hPa analysis for 6, 7, 8 and

9th June are given in Fig. 5. It shows wind speed of 20-30 knots over Somali coast and north Bay of Bengal on 6th and further strengthening on 7th with northward extension into Arabian Sea. On 8th the southwesterly flow over Arabian Sea increased to 30-40 kts. On 9th these westerlies extended to more eastwards and a weak trough off Kerala-Karnataka-Goa coast was observed. The 200 hPa analysis for 6, 7, 8 and 9th June are given in Fig. 6. It shows on 6th and 7th the strength of westerly jet stream is of the order of 100-120 kts, which weakened to 60-80 kts by 8th, whereas the upper tropospheric easterlies over peninsular parts of India showed strengthening by about 10 knots from 6 to 9th. Based on the 7th analysis the 24 hours forecast 850 hPa wind in respect of experiment and control run and the change in zonal and meridional wind component with the additional data are given in Figs. 7(a-d) and rainfall in Figs. 8(a-c). It shows, with additional data positive impact was observed over Arabian Sea where the wind speed increased by 2-3 kts. The 24 hours forecast rainfall based on the experiment for 8th June showed slight northward propagation in the rainfall belt compared to the control run (Fig. 8) that agrees better with the observations. Verification analysis and forecast fields with this additional data have shown substantial improvement in the analysis and model predicted rainfall.



Figs. 8(a-c). 24 hours rainfall (mm) based on forecast valid at 0000 UTC of 8 Jun 2003 : (a) without ARMEX data (b) with ARMEX data and (c) 24 hours observed rainfall (cm) reported at 0300 UTC of 8 June 2003

4. Conclusions

The operational limited area analysis and forecast system has fairly well simulated the major synoptic systems during the ARMEX phase-I & II. In the case of well marked low pressure system, the model has captured observed westward movement of the system. The rainfall prediction by the model is comparable with the observed rainfall pattern. Model was able to capture the heavy rainfall event over Gujarat. However, the predicted rainfall is lower than the amounts actually observed. In the second case during onset of monsoon-2003, positive impact was observed with the additional ARMEX data.

Verification of analysis and forecast fields with this additional data has shown substantial improvement in the analysis and model predicted rainfall.

References

Krishnamurti, T. N., Kumar, Arun, Yap, K. S., Dastoor, Ashu, P., Davidson, Noel and Sheng, J., 1990, "Performance of a high resolution mesoscale tropical prediction model", *Advances in Geophysics*, **32**, Academic Press, INC, 133-286.

Prasad, K., Rama Rao, Y. V. and Sanjib Sen, 1997, "Tropical cyclone track prediction by a high resolution limited area model using synthetic observations", *Mausam*, **48**, 3, 351-366.