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Validation of upper-air observations taken during the ARMEX-I and its impact on the global analysis-forecast system

M. DAS GUPTA, SOMESHWAR DAS, K. PRASANTHI*, P. K. PRADHAN*

and

U. C. MOHANTY*

National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi - 110 003, India

***Indian Institute Technology, New Delhi - 110 016, India*

e mail : mohanty@cas.iitd.ernet.in

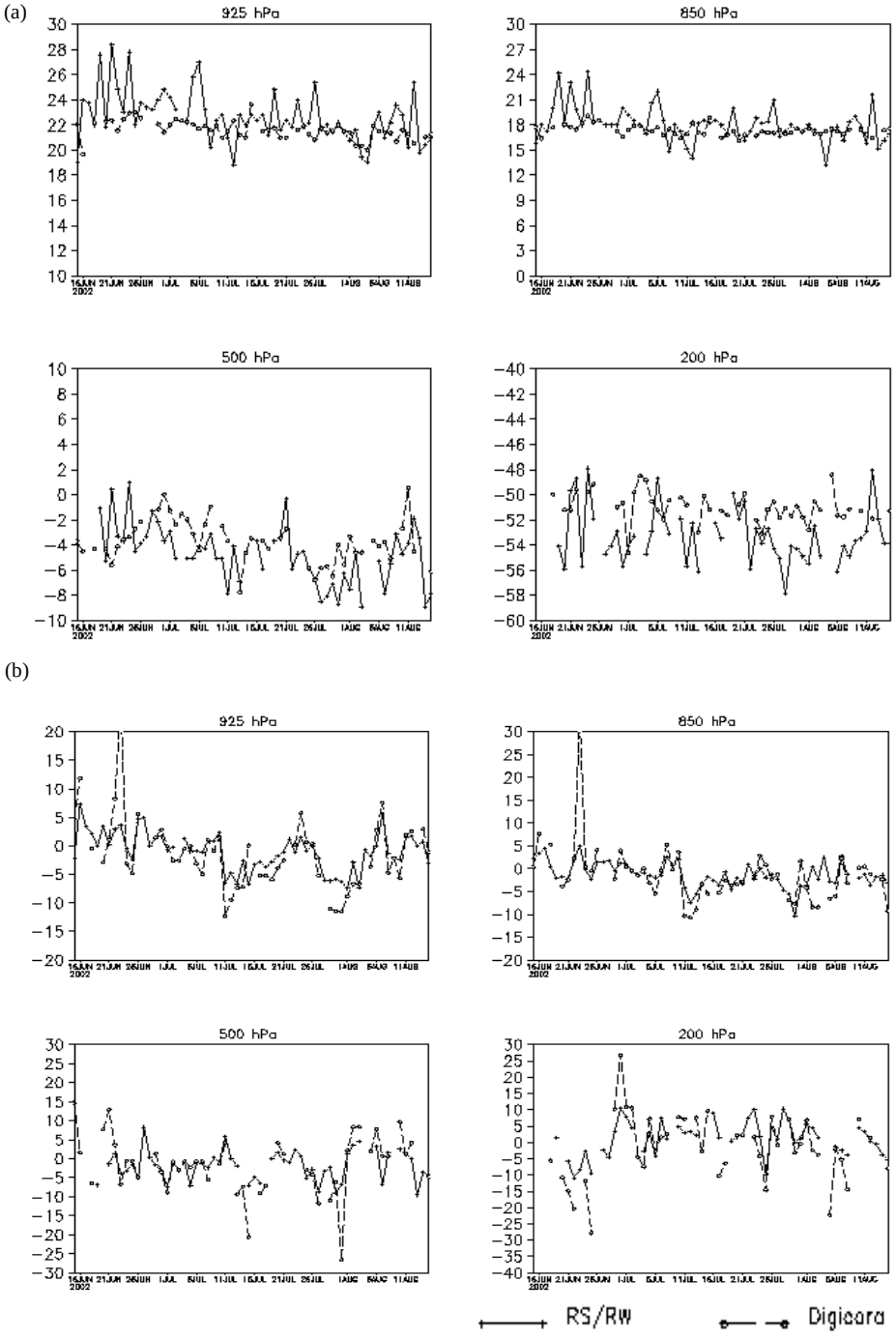
सार – इस शोध–पत्र में आरमेक्स – I के दौरान अरब सागर के क्षेत्र और उसके समीपवर्ती भारत के पश्चिमी तट पर विशेष प्रकार के अनेक प्रेक्षण लिए गए जिससे इस क्षेत्र के बारे में और अच्छी तरह से अध्ययन करने का सुअवसर प्राप्त हुआ। इतने बृहत आँकड़ा संग्रह के रखरखाव के लिए भारत मौसम विज्ञान विभाग (आई. एम. डी.) और भारतीय प्रौद्योगिकी संस्थान (आई. आई. टी.) दिल्ली के सहयोग से राष्ट्रीय मध्यम अवधि मौसम पूर्वानुमान केन्द्र (एन. सी. एम. आर. डब्ल्यू. एफ.) में आरमेक्स आँकड़ा केन्द्र स्थापित किया गया है । इस केन्द्र के अनेक कार्यों में से एक कार्य इन प्रेक्षणों का उपयोग करते हुए आरमेक्स की अवधि के पुनः किए गए विश्लेषण को प्रस्तुत करना है । सभी उपलब्ध स्रोतों से लिए प्रत्येक प्रेक्षण विशेष रूप से वायुमंडलीय परिसंचरण के त्रिविमीय संरचना का सही निर्धारण करने के लिए महासागरीय क्षेत्रों के अपर्याप्त आँकड़ों को सम्मिलित करना अनिवार्य है। राष्ट्रीय मध्यम अवधि मौसम पूर्वानुमान केन्द्र के भूमडलीय आँकड़ा सम्मिलन प्रणाली में इन आँकड़ों को शामिल करने से पहले अन्य स्रोतों से प्राप्त प्रेक्षणात्मक तथ्यों से इन आँकड़ों को प्रमाणित करने का प्रयास किया गया है। दबोलिम, गोवा में लिए गए उपरितन वायु प्रेक्षणों (दिगिकोरा) की तुलना भारत मौसम विज्ञान विभाग के आर. एस. /आर. डब्ल्यू. प्रेक्षणों के साथ पंजिम, गोवा में की गई । यद्यपि इन दोनों स्थानों के सभी मौसम वैज्ञानिक प्राचलों की परिवर्तनशीलताओं की प्रवृत्ति समान है किन्तु उनके निरपेक्ष मानों में बहुत अंतर है । विशेष रुप से एकत्रित किए गए उपरितन वायु प्रक्षणों का उपयोग करते हुए पुनः विश्लेषित प्रेक्षणों की तुलना राष्ट्रीय मध्यम अवधि मौसम पूर्वानुमान केन्द के प्रचालनात्मक विश्लेषण के साथ की गई है । निम्न क्षोभ मंडल में अरब सागर के क्षेत्र पर विश्लेषण और पूर्वानुमान प्रणाली में इन विशेष प्रेक्षणों के प्रभाव सीमित पाए गए हैं । यद्यपि ऊपरी क्षोभमंडल और समतापमंडल में प्रभाव भूमध्यरेखीय हिंद महासागर क्षेत्र में भी देखे गए हैं ।

ABSTRACT. During ARMEX-I several special observations were taken over Arabian Sea region and adjoining west coast of India, which gave an opportunity to study this region more thoroughly. To handle such voluminous data, ARMEX data center has been established at National Centre for Medium Range Weather Forecasting (NCMRWF), in collaboration with India Meteorological Department (IMD) and Indian Institute Technology (IIT), Delhi. One of the tasks of this center is to produce reanalysis for ARMEX period, utilizing these observations. It is essential to assimilate every observation from all available sources, especially over the data sparse oceanic regions for accurate determination of the three-dimensional structure of the atmospheric circulation. Before assimilating these data in global data assimilation system of NCMRWF, an attempt has been made to validate some of these data against observational facts from other sources. Upper-air observations (Digicora) from Dabolim, Goa have been compared with RS/RW observation of IMD, at Panjim, Goa. Though the trend in variations of all the meteorological parameters of these two stations is similar but there is a large difference in their absolute values. Reanalysis generated using the specially collected upper-air observations have been compared with the operational analysis of NCMRWF. The impact of these special observations on analysis and forecast system is found to be confined over the Arabian Sea region only in the lower troposphere. However, in the upper troposphere and stratosphere the impact is seen also over the equatorial Indian Ocean region.

Key words – ARMEX, Upper-air observations, Validation, Reanalysis, Impact.

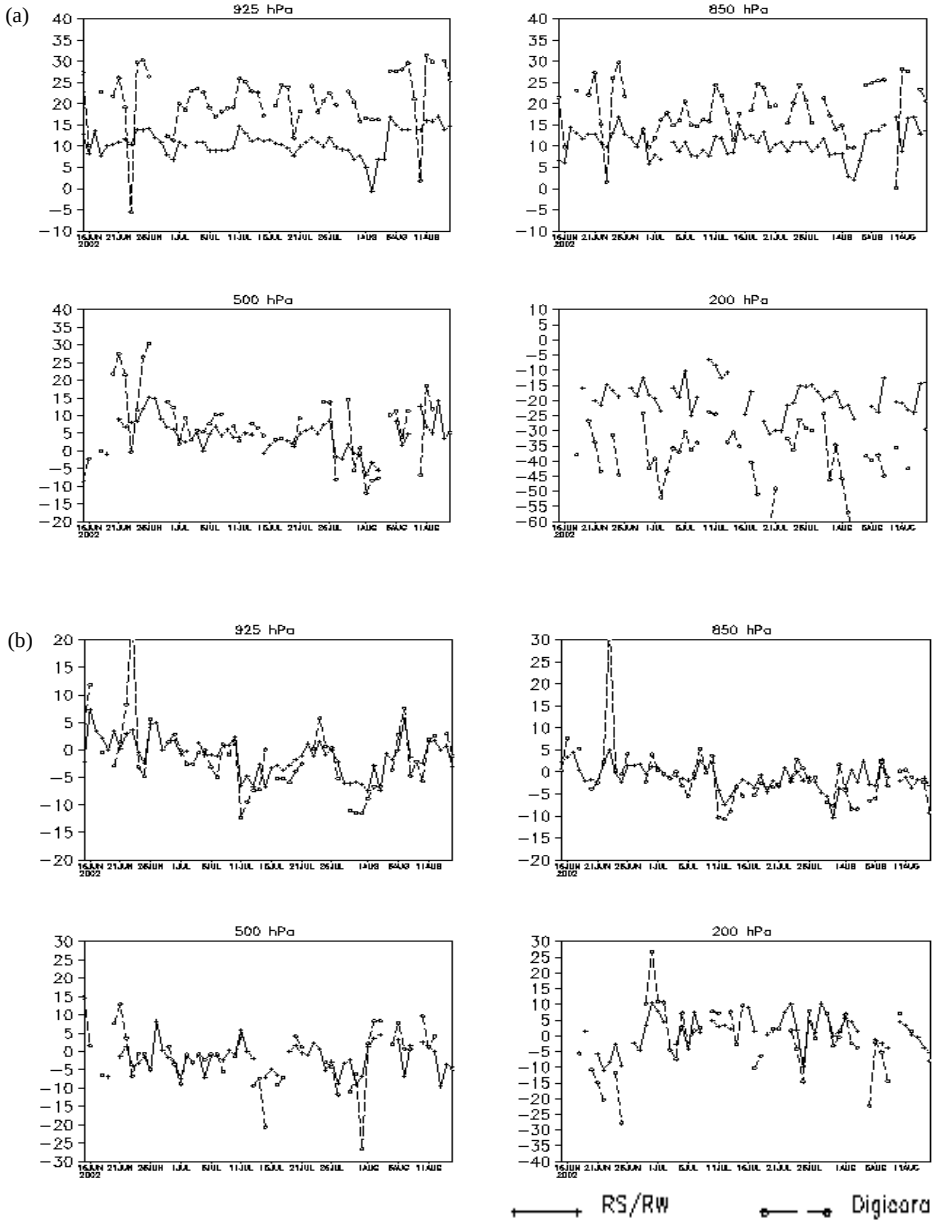
1. Introduction

Arabian Sea Monsoon experiment (ARMEX) was planned to study the convection associated with intense rainfall events on the west coast of India. One of the main objectives of the experiment was the modeling of the off-shore meso-scale convection. Satisfactory forecast of the evolution of the offshore trough and heavy rainfall events along the west coast of India require information about several aspects of the atmosphere including land-



Figs. 1(a&b). (a) Observed temperature and (b) Observed specific humidity at Panjim and Dabolim at 925, 850, 500 and 200 hPa level for 0000 UTC during 15th June – 15th August

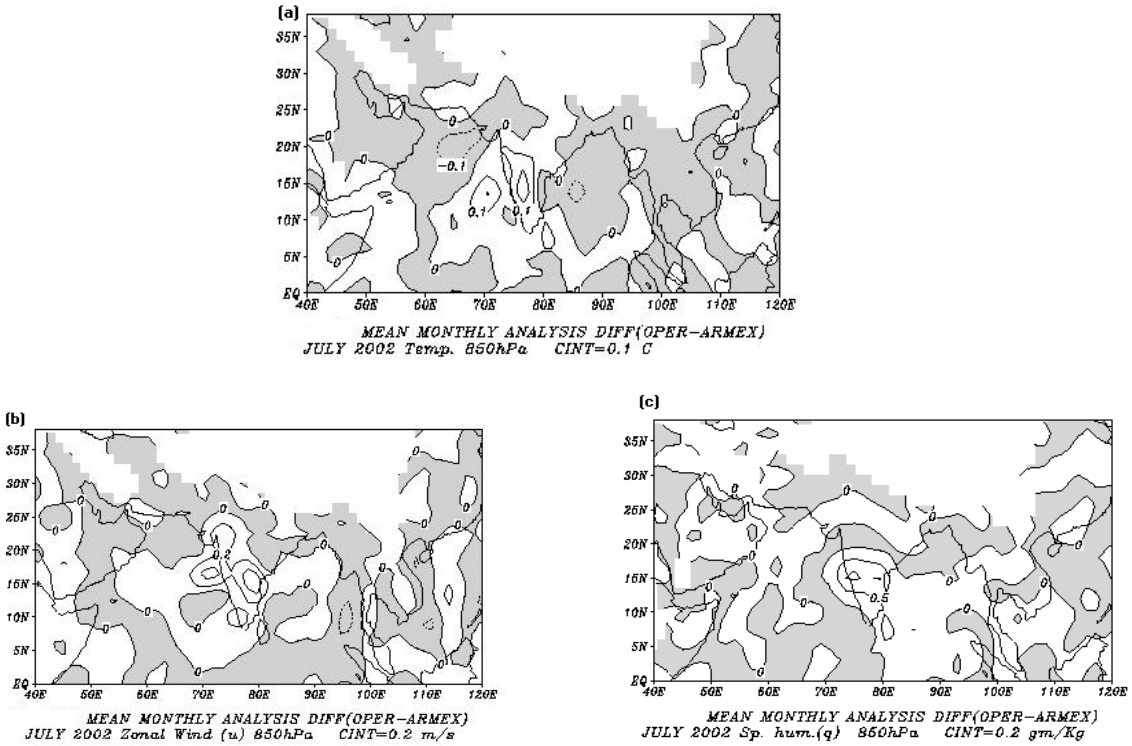
ocean-atmosphere interactions. Intensive meteorological observations have been taken during ARMEX- Phase I (15th June - 15th August 2002) with in 200 km of the coastline along the west coast of India. Observations were taken by setting up special meso-net observatories over the west coast and surrounding Arabian Sea along with routine observations from IMD stations. During intense observation period (IOP), the temporal frequency of



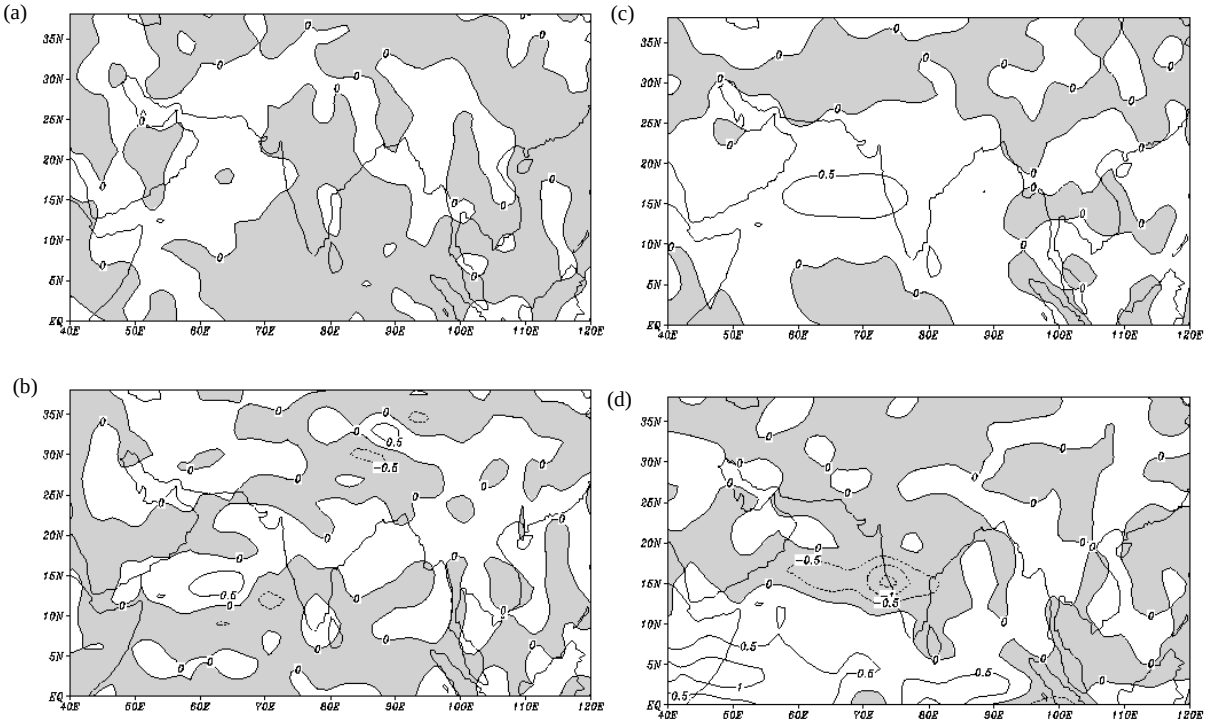
Figs. 2(a&b). (a) Observed zonal component of wind (*u*) and (b) Observed meridional wind (*v*) at Panjim and Dabolim at different vertical for 0000 UTC during 15th June – 15th August 2002

observations was also enhanced from the regular IMD stations. NCMRWF was designated as ARMEX data centre with responsibilities to process, quality check, archive and redistribute these specially collected observations. A major task of ARMEX data centre is to generate both global and meso-scale reanalysis ingesting these special observations and redistribute the same to other scientific organizations.

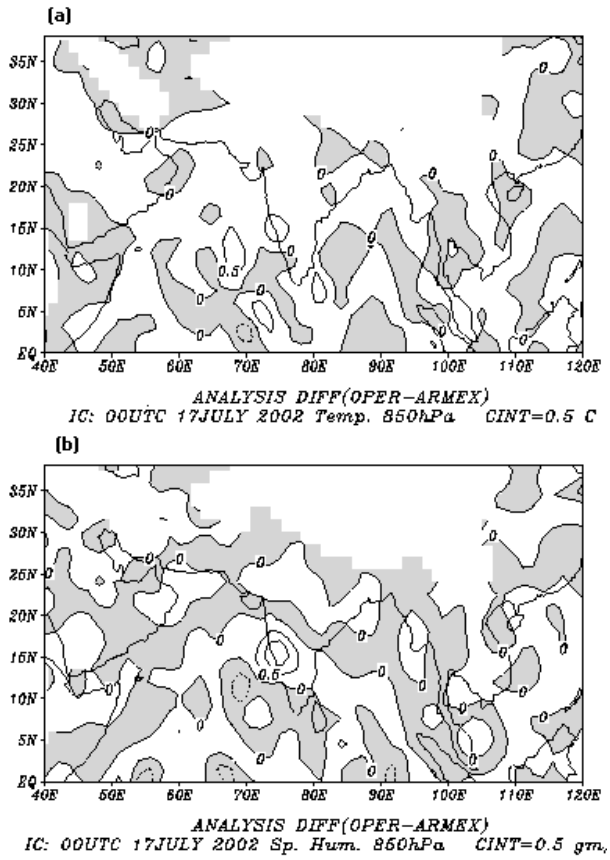
It is well known that the quality of any objective analysis of the atmospheric fields depends upon the density and the quality of the observations assimilated to produce the analysis. Data scarcity over the tropical oceanic region is one of the major problems associated with numerical weather prediction (NWP) over tropics. So the assimilation of any additional information over this region is likely to provide better initial condition (Basu &



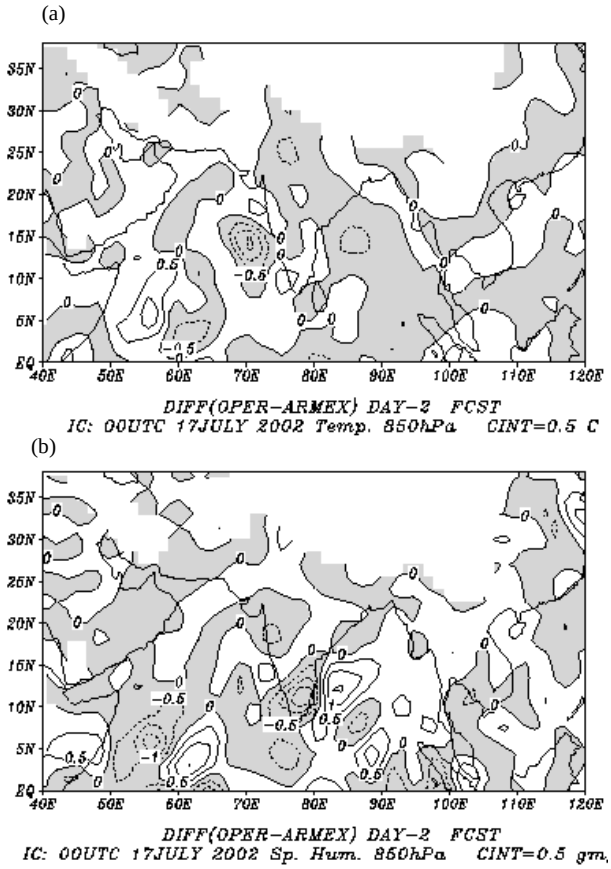
Figs. 3(a-c). Mean monthly analysis difference (OPER-ARMEX) for July 2002 at 850 hPa (a) Temperature, (b) Zonal wind component and (c) Specific humidity



Figs. 4(a-d). Mean monthly analysis difference (OPER-ARMEX) for July 2002 (a) Temperature at 500 hPa (ºC), (b) Temperature at 50 hPa (ºC), (c) Zonal wind at 500 hPa (m/s) and (d) Zonal wind at 50 hPa (m/s)



Figs. 5(a&b). Analysis difference (OPER-ARMEX) for 0000 UTC 17th July 2002 at 850 hPa (a) Temperature, (b) Specific humidity



Figs. 6(a&b). Day-2 Forecast difference (OPER-ARMEX) based on IC : 0000 UTC 17th July 2002 at 850 hPa (a) Temperature and (b) Specific humidity

Das Gupta, 2001, Das Gupta *et al*. 2003), which in turn would show positive impact on the subsequent forecasts. To start with, only the upper-air profile data, specially collected during ARMEX have been assimilated in Global Data Assimilation System (GDAS) of NCMRWF and the reanalyses and forecasts thus generated have been compared with NCMRWF's operational analysis. Prior to generating reanalysis an effort has been made to validate some of the upper air data. A Brief description data used for this study has been discussed in section 2. Global analysis-forecast system is described in section 3. The results are presented and discussed in section 4.

2. Data

Special observations of upper-air temperature, moisture and wind profiles from a coastal station at Dabolim (73.83° E, 15.38° N), Goa, taken by Directorate of Naval Oceanography & Meteorology (DNOM), Indian Navy have been used to generate the reanalysis. Generally there are two observations per day (0000 & 1200 UTC) from 15th June to 15th August 2002, with two additional observations (0600 & 1800 UTC) during IOPs. Temperature, moisture and wind profiles from ORV Sagar-Kanya (24th June - 15th August 2002) over Arabian Sea have been also assimilated. Pilot Balloon observations from three Indian Air Force (IAF) stations, Vadodara, Belgaum and Sulur with a frequency of 3 observations per day (0000, 0600 & 1200 UTC) have also been assimilated.

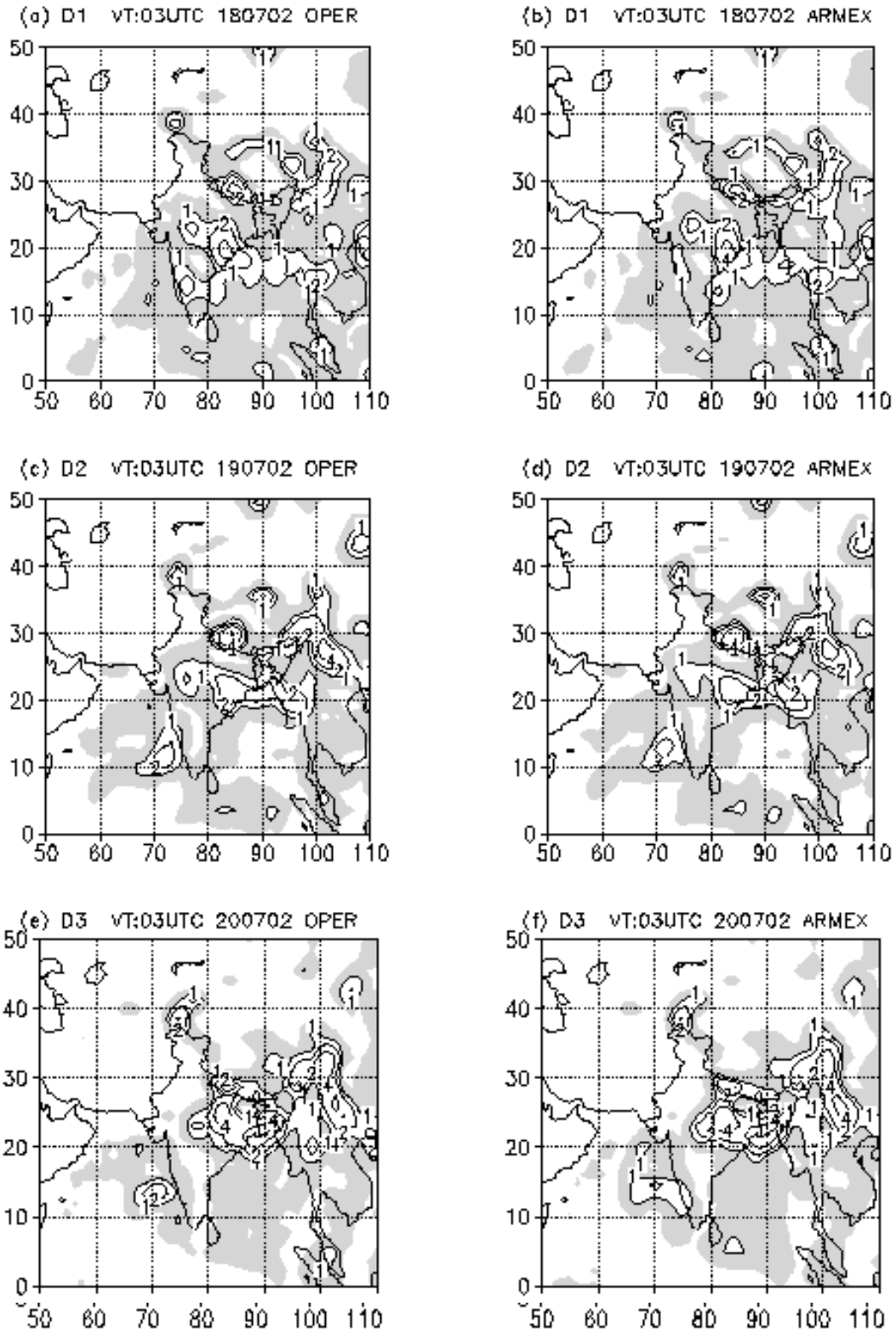
Data used in the operational assimilation system of NCMRWF are :

(*i*) Surface observations from land stations and voluntary observing fleet over sea (SYNOP/SHIP).

(*ii*) Drifting and moored buoy observations (BUOY).

(*iii*) Upper air profiles of temperature, moisture and wind (RS/RW & Pilot Balloon).

(*iv*) Satellite observed cloud motion vectors (CMV) from various geo-stationary satellites.



Figs. 7(a-f). Predicted rainfall for OPER & ARMEX based on IC : 0000 UTC 17th July 2002 (a&b) 24 hr. FCST , (c&d) 48 hr. FCST and (e&f) 72hr. FCST

TABLE 1

Comparison of observed value for different meteorological parameters at Dabolim & Panjim

Vertical levels	Meteorological parameters			
	Temperature (*t*)	Sp. humidity (*q*)	Zonal wind (*u*)	Meridional wind (*v*)
Lower level (1000-700 hPa)	Temp. of Dabolim is less by 4-5° C	Sp. Humidity of Dabolim is less (~ 5 gm/kg)	Zonal wind of Dabolim is stronger by 8m/s	Comparable at all levels except few days
Middle level (600-400 hPa)	Temp. of Dabolim is more by 2-3° C	Sp. Humidity of Dabolim is less (~ 2 gm/kg)	Zonal wind of Dabolim is stronger by 2m/s	
Upper level (300-100 hPa)	Temp. of Dabolim is more by 4-5° C	----------	Zonal wind of Dabolim is weaker by 2m/s	

(*v*) Satellite observed temperature and total precipitable water (ATOVS) from NOAA 15-16.

(*vi*) Upper level wind and temperature reported by aircrafts (AIREP/AMDAR).

(*vii*) Surface wind speed (SSM/I) form polar orbiting satellite DMSP.

3. Global analysis - forecast system

The Global Data Assimilation System (GDAS) operational at NCMRWF is a six-hourly intermittent three-dimensional scheme. At the NCMRWF, meteorological observations from all over the globe is assimilated four times a day *viz*. 0000, 0600, 1200 and 1800 UTC. The assimilation scheme utilizes all data collected within ±3 hours of the assimilation time and received within a specified cut-off period (~ 12 hours for 0000 UTC). A six-hour prediction from Numerical Weather Prediction (NWP) model (T80/L18), with a previous initial condition, valid for the current analysis time is used as the background field, or the first guess for the analysis.

The analysis scheme used in GDAS is based on the concept of Spectral Statistical Interpolation (SSI) technique developed originally at National Center for Environmental Prediction (NCEP), USA (Parrish and Derber, 1992). The analysis is done in spectral space at vertical sigma level, the analysis variables are the sigma level spectral coefficients of the empirical orthogonal functions (EOF's) of vorticity, mixing ratio, unbalanced part of divergence, temperature and log of surface pressure. The balanced parts of the various variables are computed using a quasi-geostrophic linear balance relationship (Haltiner and William, 1979). The forecast model (Kanamitsu 1989) operational at NCMRWF is a global model, which uses the spectral method for expansion of variables in a series of spherical harmonics. The forecast model variables are surface pressure, layer temperature, specific humidity, divergence and vorticity, all of which are at present expanded in a series of upto 80 waves. In the vertical, the atmosphere is sliced into 18 unequally spaced sigma layers, out of which about 12 are within the troposphere and the rest are placed in the stratosphere.

Reanalyses are generated by assimilating all the special upper-air observations discussed in section 2 along with other conventional and non-conventional data sets from the operational archive of NCMRWF for the period 20th June to 31st July 2002. Only the RS/RW data of Panjim has been dropped form the operational data set. A set of five-day forecasts was also made for every day, using 0000 UTC analysis of that day as initial condition. Analyses and forecast (ARMEX) thus generated using ARMEX data have been compared with operational analysis and forecast (OPER).

4. Result and discussion

Upper-air data of Dabolim, Goa (Navy station) is compared with RS/RW data of Panjim, Goa (IMD station). Fig. 1(a). depicts the daily variation (0000 UTC) of temperature at Panjim and Dabolim at 925, 850, 500 and 200 hPa level. In the lower levels (925 & 850 hPa), the temperatures at Panjim is seen to be on average 4 to 5 degree more than Dabolim and in middle & higher levels (500 & 200 hPa) it is just the opposite. Though in both the levels the temperature variation of these two stations follow the same trend, but the amplitude of variation at Panjim is much more than that at Dabolim. The variations of specific humidity are also similar in the lower level [Fig. 1(b)]. Variation in zonal wind (*u*) component at different vertical levels [Fig. 2(a)] shows strong wind at Panjim compared to Dabolim in the lower level and weak in the upper level, but the variation of meridional wind

component (*v*) of both the stations agrees well [Fig. 2(b)]. Comparison between the observations of different meteorological parameters at Dabolim & Panjim is summarized in the Table 1.

Figs. 3(a-c) depicts the difference between the monthly mean analysed lower level (850 hPa) temperature, zonal wind and specific humidity for July 2002. As seen from the plot, the cooling by 0.2° C was noticed over the west coast of India. Similarly the weakening of lower level westerly jet and moisture content are also noticed over the same region in reanalysis (ARMEX). The impact of data is more in the upper tropospheric and stratospheric levels Figs. 4(a-d) compared to lower and middle troposphere, as there are very few conventional data above 100 hPa level over Indian peninsular region and on the other hand Digicora and Sagar-Kanya have observations upto 50 hPa level. But the impact of data on monthly mean analyses is restricted over the Arabian Sea region, as expected.

An IOP was declared from 17th - 20th July associated with weak monsoon rainfall event over the west coast. Impact of data on forecast is examined by comparing the forecasted wind flow and rainfall during this IOP. Figs. 5(a&b) shows the difference of analysed temperature and moisture at 850 hPa of 0000 UTC, 17th July 2002 and Figs. 6(a&b) depicts the same for day-2 forecast. As seen from the plots, though on initial analysis the impact was only over the Arabian Sea region, but as the forecast day progresses the impact also felt over the larger domain. Figs. 7(a-f) shows the 24, 48 and 72 hour predicted rainfall patterns based on initial condition of 0000 UTC, 17th July 2002. It is clear from the plot that in all the three days the predicted rainfall of ARMEX is less than that of OPER and also closer to actual observations. This implies that the inclusion of ARMEX data in reanalysis has found to be beneficial and reanalysis should be carried over the entire period using data from all other sources.

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