

## Operational use of improved profiles by using neural network technique derived from NOAA satellites microwave data in NWP model over Indian region

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*(Received 4 February 2004, Modified 20 May 2004)*

**सार** – भारत मौसम विज्ञान विभाग, नई दिल्ली एन. ओ. ए. ए., टी. ओ. वी. एस. और ए. टी. ओ. वी. एस. आँकड़ों को वास्तविक समय के आधार पर प्राप्त करता है तथा उन्हें संसाधित करता है। भारतीय क्षेत्र के एन. ओ. ए. ए. – 16 एवं 17 उपग्रहों से ए. एम. एस. यू. आँकड़ों के आधार पर तापमान और नमी प्रोफाइलों को पुनः प्राप्त करने के लिए प्राकृतिक और तंत्रिका संजाल पद्धतियों का उपयोग किया गया है। तंत्रिका संजाल तकनीक में उपयोग किए गए भूमंडलीय आँकड़ों पर आधारित केवल दो ऋतुओं के पहले के प्रशिक्षण आँकड़ों के स्थान पर इस निदर्श में सभी ऋतुओं के स्थल और समुद्र के क्षेत्रीय आँकड़ों पर आधारित नये प्रशिक्षण आँकड़ों का उपयोग किया गया है। प्राकृतिक पद्धति की तुलना में इन नये प्रशिक्षण आँकड़ों के योगदान से तंत्रिका संजाल पद्धति से पुनः प्राप्त किए गए तापमान और नमी प्रोफाइलों की परिशुद्धता में सुधार हुआ है। वर्ष 2002 से 2003 तक की विभिन्न ऋतुओं के संबंध में समुद्र और स्थल पर अलग अलग किए गए ई. सी. एम. डब्ल्यू. एफ. विश्लेषणों के माध्यम से तापमान और नमी प्रोफाइलों की विस्तार से पुष्टि और उनकी परस्पर तुलना भी की गई है। प्राकृतिक पद्धति की तुलना में तंत्रिका संजाल तकनीक का कार्यनिष्पादन अधिक बेहतर पाया गया है।

एन. ओ. ए. ए.–16 ए. टी. ओ. वी. एस. आँकड़ों से हाल ही में पुनः प्राप्त किए गए भारतीय क्षेत्र के तापमान और नमी प्रोफाइलों का उपयोग क्षेत्रीय एन. डब्ल्यू. पी. मॉडल में तत्काल प्रभाव के अध्ययन हेतु किया गया है। भारत मौसम विज्ञान विभाग की व्यावहारिक एन. डब्ल्यू. पी. प्रणाली सीमित क्षेत्र विश्लेषण और पूर्वानुमान प्रणाली (एल. ए. एफ. एस.) पर आधारित है जिसमें भूमंडलीय दूरसंचार प्रणाली (जी. टी. एस.) पर प्राप्त आँकड़ों का वास्तविक समय के आधार पर संसाधन त्रिविमीय बहुचर अनुकूलतम अंतर्वेशन (ओ. आई.) पद्धति से वस्तुपरक विश्लेषण और बहुस्तरीय आरंभिक समीकरण निदर्श शामिल है। एन. ओ. ए. ए. – 16 ए. टी. ओ. वी. एस. आँकड़ों से पुनः प्राप्त किए गए तापमान और नमी प्रोफाइलों का उपयोग करके कई प्रयोग किए गए हैं। इन आँकड़ों का उपयोग करके मानसून अवदाब और मानसून 2003 के दौरान सक्रिय मानसून जैसी कुछ महत्वपूर्ण मौसम प्रणालियों पर इन आँकड़ों के प्रभाव की जाँच करने के लिए कई प्रयोग किए गए हैं। आरंभिक अध्ययन से यह पता चला है कि इन अतिरिक्त आँकड़ों का सीमित क्षेत्र निदर्श के वर्षा के पूर्वानुमान पर सकारात्मक प्रभाव रहा है। इस शोध-पत्र में प्रभावों का पता लगाने से संबंधित अध्ययनों के विशिष्ट मामलों के परिणामों पर विचार किया गया है।

**ABSTRACT.** India Meteorological Department, New Delhi receives and process NOAA TOVS and ATOVS data in real time. The physical and neural network approaches have been used to retrieve atmospheric temperature and moisture profiles from NOAA-16 & 17 satellites AMSU data over Indian region. The earlier training data set based on global data only for two seasons used in neural network technique has been replaced by new training data set based on regional data over land and ocean for all the seasons. The new training data set has improved the temperature and moisture profiles accuracy retrieved using neural network approach compared to physical method. The detail validation and inter comparisons of temperature and moisture profiles have also been carried out with ECMWF analysis over sea and land separately for different seasons for the year 2002-2003. The performance of neural network technique is found to be superior compared to physical method.

Recently, temperature and moisture profiles retrieved from NOAA-16 ATOVS data over Indian region have been used in regional NWP model for the impact study. The operational NWP system of India Meteorological Department is based on a Limited Area Analysis and Forecasting System (LAFS), which consists of real time processing of data received on Global Telecommunication System (GTS), objective analysis by 3-D multivariate optimum interpolation (OI) scheme and a multi-layer primitive equation model. Several experiments were performed using temperature and moisture profiles retrieved from NOAA-16 ATOVS data. Using this data several experiments were undertaken to examine the impact of these data sets on some of the important weather systems such as monsoon depression, active monsoon conditions during monsoon 2003. The preliminary studies reveal that these additional data have a positive impact on rainfall prediction of the limited area model. Results of specific cases of impact studies are presented in the paper.

**Key words** – Neural network, AMSU, Model Impact, NOAA, GTS.

## 1. Introduction

Neural network technique has been used for temperature and moisture profiles using AMSU observations over Indian land region only and validated against the radiosonde observations. [Singh, *et al.*, 2002; Singh & Singh 2003 (a&b). However, NWP model requires the profiles over land and sea simultaneously. Due to non availability of radiosonde observations over sea, ECMWF analysis over land and sea has been taken for the validation of temperature and moisture profiles in this study. An evaluation of this method versus a physical inversion approach for retrieval of atmospheric temperature and moisture profiles from Advanced Microwave Sounding Unit (AMSU) measured brightness temperatures is presented in this paper. The evaluation is based on four different seasons of the year 2002-2003 using ECMWF analysis data. The results presented here are only for summer (July, 2002) and winter (January, 2003). Further, comparisons have also been carried out for the temperature and moisture profiles using NOAA-16 and NOAA-17 satellite data over sea and land separately.

India Meteorological Department (IMD) (Prasad *et al.*, 1997) which has shown the positive impact of this data in a limited area model. Impact study was also carried out using high resolution (80 km) TOVS temperature-humidity profile data locally derived at IMD, New Delhi (Bhatia *et al.*, 1999). This high-resolution data was able to bring out the impact in the synoptic scale prediction associated with tropical easterly wave activity over the north Indian Ocean. In view of the importance of accurate initial humidity fields in tropical NWP, it is necessary to maximize use of these data from non-conventional sources. With this end in view, the present study was taken up to study the impact of ATOVS temperature and moisture profile data on limited area analysis and forecast fields.

## 2. Data and analysis procedure

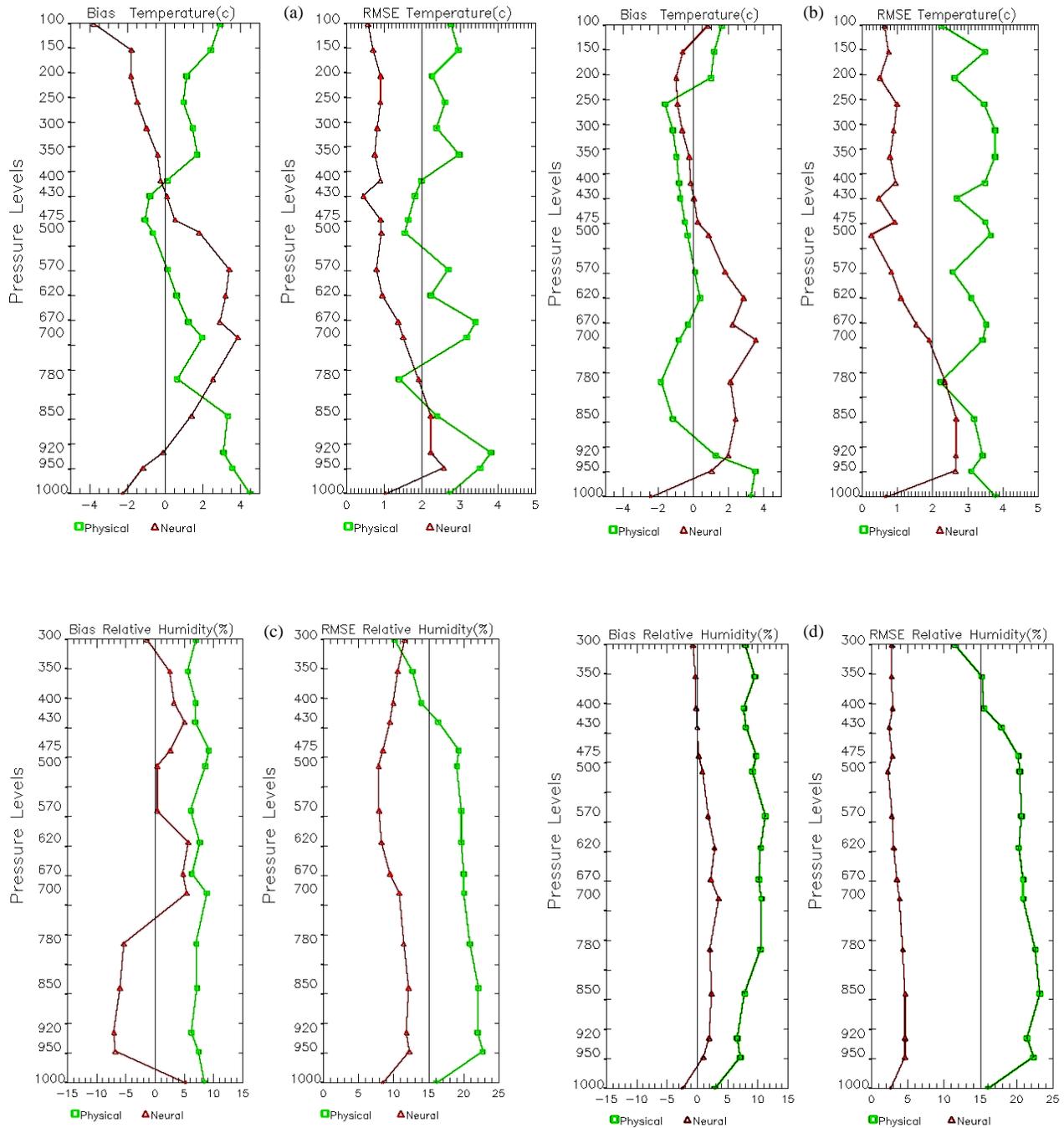
Using the limited area analysis and forecast fields as inputs to ATOVS and AVHRR processing package (AAPP), processed temperature and moisture profiles are being retrieved from AMSU data using ICI (inversion coupled imager) software package developed by CMS, Lannian, Meteo France and IAPP software package developed by University of Wisconsin, USA. The package is interfaced with the ATOVS and AVHRR Preprocessing Package (AAPP) level 1d files and makes use of AVHRR cloud and surface parameters. The main AVHRR cloud mask outputs retrieved inside the HIRS fov are : cloud cover, cloud temperature when black-body cloud layers are retrieved, skin surface temperature when AVHRR clear pixels are detected.

These profiles have also been derived using Neural Network Technique. In the present study the temperature and moisture profiles retrieved using ICI package have been used using LAM model guess and IAPP without using LAM model guess. However, work is in progress to feed LAM model guess into IAPP package also. The NOAA-16 & 17 locally processed ATOVS data have an advantage of more data within short cut-of-time. Daily 2 to 3 passes data approx. 1100 observations in a single pass covering the land and ocean area are generally available over the Indian region.

## 3. Accuracy of temperature and moisture profiles

Neural network techniques are applied to the retrieval of atmospheric temperature and humidity profiles from NOAA-16 Advanced Microwave Sounding Unit-A (AMSU-A) and Unit-B (AMSU-B) measurements. The neural network training sets are built based on the AMSU-A and AMSU-B measurements and the corresponding ECMWF analysis over the region 5° N - 50° N and 50° E - 120° E. For the temperature retrieval, the AMSU-A data consist of channels with weighting functions peaking below 10 hPa, *i.e.*, channels 1-12 and channel 15. For the humidity profile retrieval, the scheme is based on channels 1-8 of AMSU-A measurement and all five channels of AMSU-B measurement. Once the neural network is trained and the parameters are optimized, the neural network model is ready for retrieval of new profiles. The neural network scheme can be applied to either direct readout of local passes or recorded global data. During actual operations of temperature and humidity retrieval, the scheme uses only the satellite measurements and satellite geometry data, without requiring additional first-guess from modeled profiles. This gives advantage to many operational sites including those with limited internet connections.

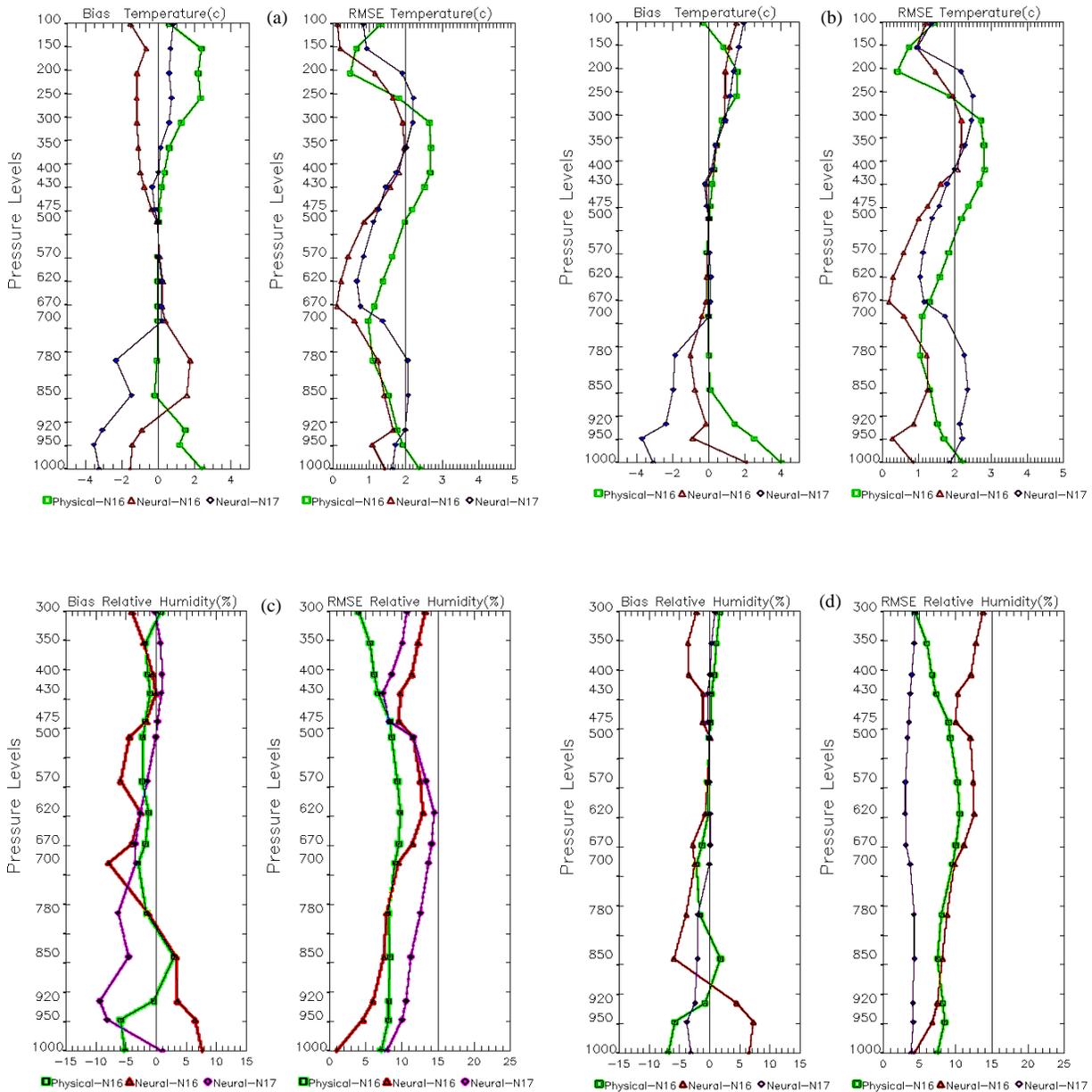
The temperature and moisture profiles have been retrieved using two different retrieval techniques namely Neural Network and Physical inversion using NOAA-16 & 17 AMSU measurements. The bias and rms error of temperature and moisture profiles were computed for the month of July 2002 and January 2003 separately on land and sea over India and it surrounding regions. These errors have been computed against ECMWF analysis. It has been observed that these errors are smaller for Neural Network compared to the physical inversion approach in both seasons over land and sea Figs. 1(a-d). This may be probably due to lack of proper NWP guess in case of physical inversion method. Further, a comparison has been carried out for temperature and moisture profiles using Neural Network technique for NOAA-16 and NOAA-17 satellite data for the month of January



**Figs. 1(a-d).** Comparison of errors of (a) Temperature profiles over land, (b) Temperature profiles over sea, (c) Relative humidity profiles over land and (d) Relative humidity profiles over sea during July 2002 using Neural Network and physical inversion approaches for NOAA – 16 satellites AMSU data

2003. The bias and rms error against ECMWF analysis data indicate that these are comparable for both the

satellites Figs. 2(a-d). The temperature profiles retrieved using Neural Network Technique from NOAA satellites



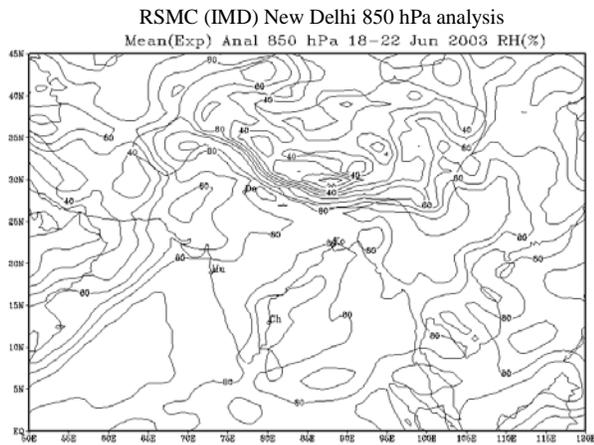
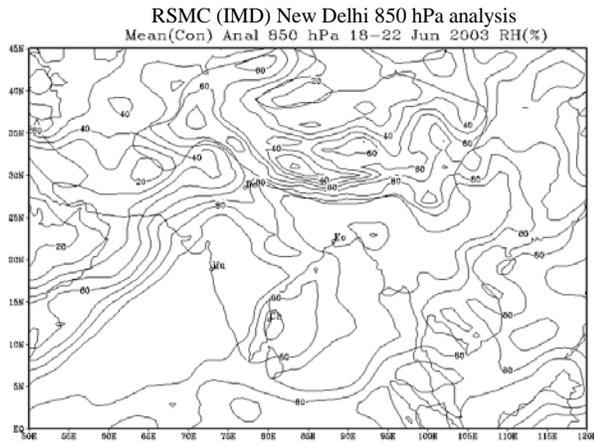
**Figs. 2(a-d).** Comparison of errors of (a) Temperature profiles over land (b) Temperature profiles over sea, (c) Relative humidity profiles over land and (d) Relative humidity profiles over sea during January 2003 using Neural Network and physical inversion approaches for NOAA – 16 satellites AMSU data

microwave data have been found useful for the intensity measurements of tropical cyclones over Indian region (Singh *et al.*, 2004).

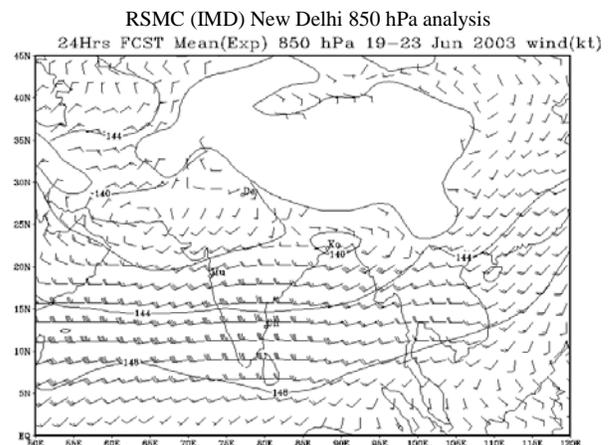
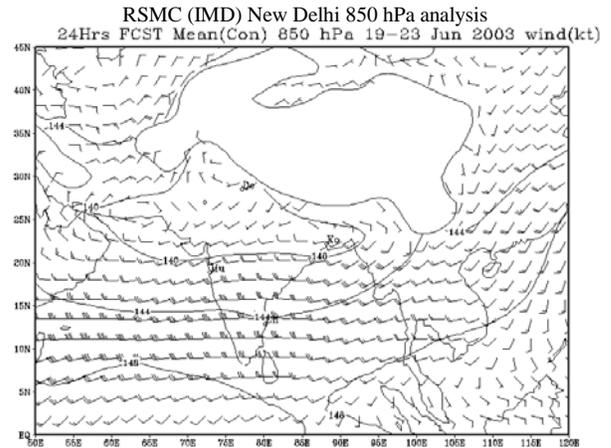
#### 4. IMD's operational NWP system

IMD 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. 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



**Fig. 3.** Mean Relative Humidity (%) analysis for 18-22 June 2003 at 850 hPa level. Up ; Control, Down : Experiment



**Fig. 4.** Mean Day-1 forecast wind (kt) for 19-23 June 2003 at 850 hPa level. Up : Control, Down : Experiment

AMDAR, which are extracted and decoded from the raw GTS data sets. The synthetic observations such as cyclone bogusing data and ATOVS temperature and humidity profile data also included as per requirement. All the data are quality controlled and packed into a special format for objective analysis.

#### 4.1. Analysis procedure and forecast model

The objective analysis is carried out by three dimensional multivariate optimum interpolation 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 Latitude/Longitude grid for limited area horizontal domain of  $30^\circ$  S to  $70^\circ$  N ;  $0^\circ$  to  $150^\circ$  E. The generated ATOVS temperature and relative humidity data

are included into the regional OI scheme as bogus observations. The observations are generally horizontally consistent over synoptic scales and very few are rejected by the analysis system. 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  $0.75^\circ \times 0.75^\circ$  Latitude/Longitude in horizontal and 16 sigma levels (1.0 to 0.05) in vertical [Prasad *et al.* (1997), Krishnamurti *et al.* (1990)]. The lateral boundary conditions are obtained from the global forecasts of the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi.

## 5. The impact studies

The impact study was carried out for the active monsoon conditions of 18-22 June 2003, heavy rainfall events of 9 July 2003 and 24-28 July 2003 corresponding

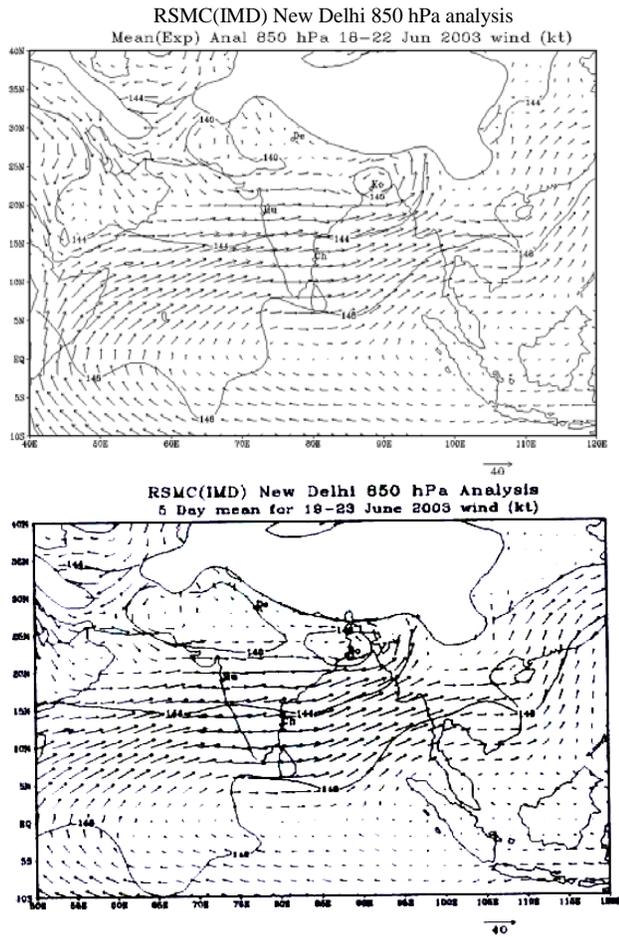


Fig. 5. Mean wind (kt) analysis at 850 hPa level. Up : for 18-22 June 2003. Down: for 19-23 June

to the movement of a monsoon depression across central parts of the country. The specific humidity fields were found to be 12-13 gm/kg over the monsoon trough region over central parts of India with a decrease of moisture towards north. The temperature fields also showed similar features. These features are consistent with the normal meteorological conditions prevailing over this area, which conforms that qualitatively NOAA sounding products are good.

5.1. Active monsoon conditions – 18-22 June 2003

During the period a low pressure area was formed on 19<sup>th</sup> June over Gangetic West Bengal & adjoining areas with associated cyclonic circulation extending upto mid-tropospheric levels and it persisted over the same area up to 23<sup>rd</sup>. Another upper air circulation lies over southwest Rajasthan & neighborhood on 19<sup>th</sup> and persisted on 20<sup>th</sup>. It moved to northwest Madhya Pradesh and adjoining east Rajasthan on 21<sup>st</sup> and over west Uttar Pradesh &

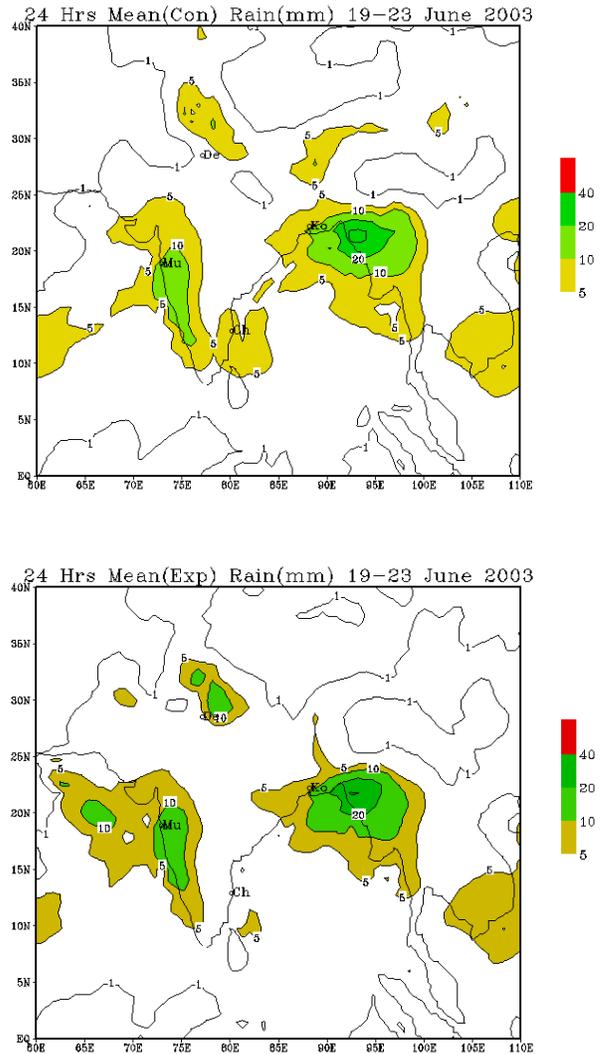
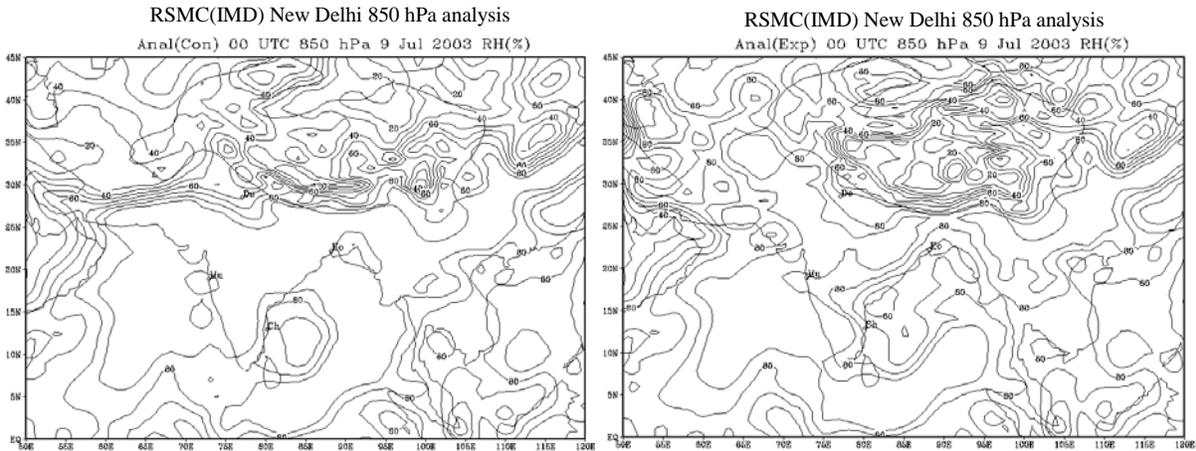
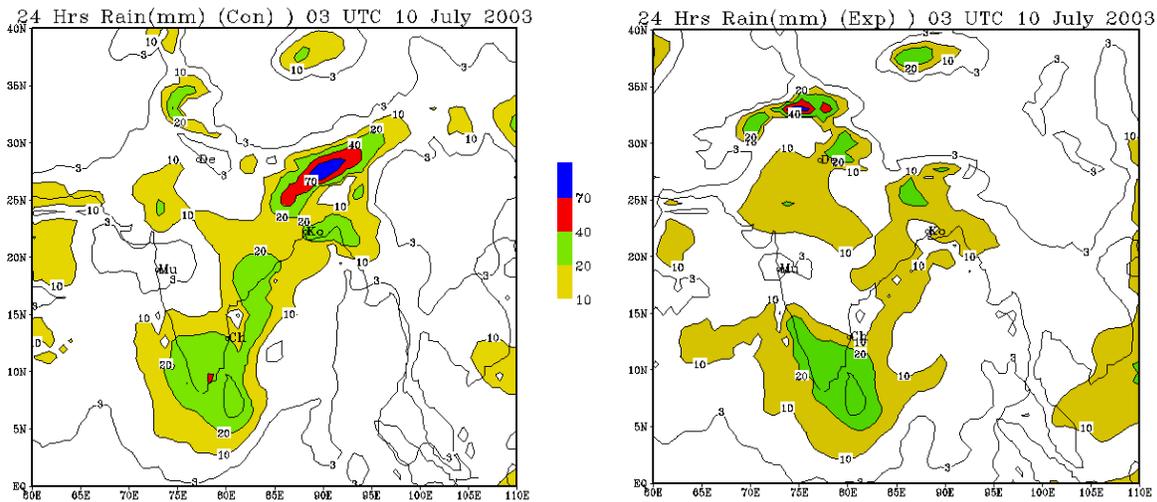


Fig. 6. Mean day-1 forecast rainfall (mm) for 19-23. Up : Control, Down : Experiment

neighborhood on 22<sup>nd</sup>. Under the influence of these systems heavy rainfall occurred over western and northeast parts and moderate rainfall over central parts of the country. Using the ATOVS data the experiment was conducted for the above period. The mean humidity analysis at 850 hPa for 18 to 22 June 2003 in the Control run (without using pseudo humidity profiles left panel) and Experiment (with humidity data included right panel) is presented in Fig. 3. The difference in the control run and experiment are clearly visible and inclusion of pseudo humidity observations has substantially modified the analysis over north and northwest parts of India where high resolution humidity data was available. The mean



**Fig. 7.** Relative Humidity (%) Analysis for 09 July 2003 at 850 hPa level. Left : Control Right : Experiment



**Fig. 8.** Day-1 forecast rainfall (mm) for 10 July 2003. Left : Control, Right : Experiment

wind forecast valid for the above days and verification analysis are given in Figs. 4 & 5. The forecast experiment wind fields after including the moisture had shown a circulation over west Bengal and adjoining Bay of Bengal that was observed in the verifying analysis. However, the same was not observed in control run. The 5 day accumulated rainfall based on 24 hour forecast by limited area model valid for 19 to 23 June 2003 are presented in Fig. 6, control in the left panel and experiment in the right panel. The rainfall prediction after including the profile data has shown 20-30 cm over northern parts of India where as in the control run it was 10-20 cm. The predicted

rainfall of 20-30 cm is more close to the observed rainfall over northern parts of India.

### 5.2. Heavy rainfall event of 9 July 2003

A low pressure area formed on 10<sup>th</sup> over Haryana and adjoining areas of east Rajasthan & west Uttar Pradesh (northern parts of India) on 9<sup>th</sup> evening with associated cyclonic circulation extending up to mid-tropospheric levels. Under its influence heavy to heavy rainfall occurred at most places over north and northwest parts of India and moderate rainfall over peninsula and

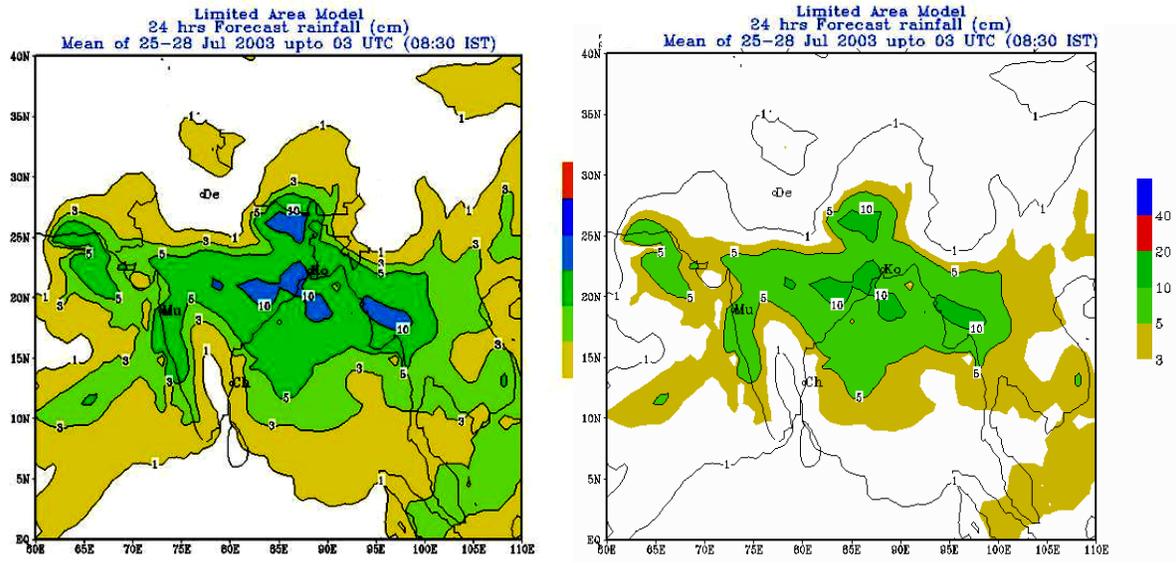


Fig. 9. Mean Day-1 forecast rainfall (mm) for 25-28 July 2003. Left : Control, Right : Experiment

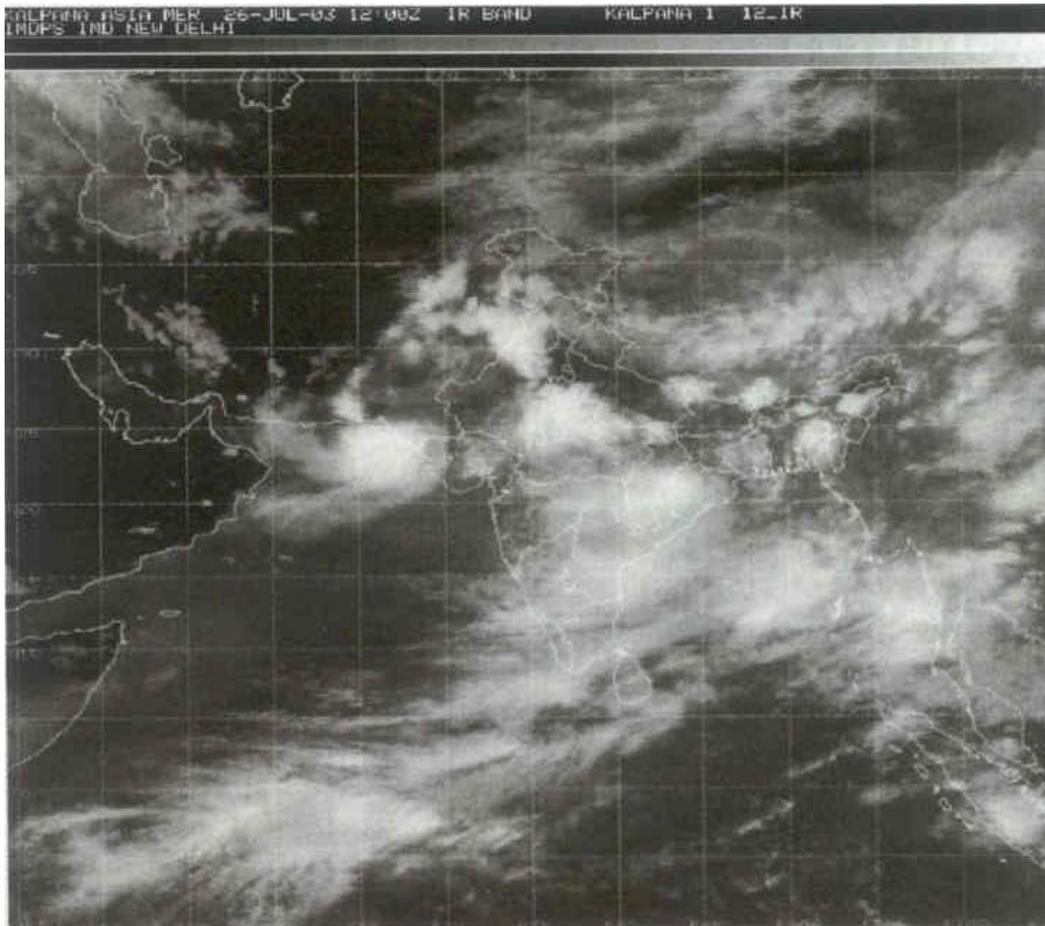


Fig. 10. KALPANA-1 IR image on 1200 UTC of 26 July 2003

northeast parts of India. In this case the humidity analysis at 850 hPa for 09 July 2003 in the Control run and experiment is presented in Fig. 7. In this case the control run shows humidity of less than 60% over most of the northern parts of India. However, the experiment fields shows 60-80% appears over the area as against a poorly defined pattern in the control run. The day-1 rainfall forecast by limited area model valid for 10 July 2003 presented in Fig. 8. A marked improvement is seen in the predicted rainfall pattern over northwest parts of India where the control run was unable to predict the heavy to very heavy rainfall that occurred at most places over northern and northwest India. In the control run most of this area showed 3 to 10 mm rainfall and in experiment it shown from 10 to 40 mm, where as the realized rainfall was 30 to 80 mm with isolated heavy rain fall of 130 mm over Delhi.

### 5.3. Monsoon Depression over the Bay of Bengal (25-28 July 2003)

A low pressure area formed over northwest Bay of Bengal on 24 July near the southern end of monsoon trough. It intensified into a depression on 25<sup>th</sup> and further into deep depression by evening and moved in a northwesterly direction and crossed the Orissa coast on 25<sup>th</sup> morning. After crossing the coast the system retained its intensity for the next two days and moved west northwesterly direction. The system weakened into a depression on 27<sup>th</sup> and further moved westwards and weakened into low pressure area over northwest India. Under the influence of this system widespread rainfall occurred over Orissa, Jharkhand and Chattisgarh, central and western parts of India (Fig. 10). In this case a marked improvement is seen in the predicted rainfall pattern over central and northern parts of India. In the control run the accumulated rainfall for 25-28 July 2003 predicted heavy to very heavy rainfall belt of 20-30 cm as shown (Fig. 9) more north of the actual position in the first few days and more westwards in the subsequent 3 days. However, in the experimental runs the rainfall belt of 5-10 cm lay along the movement of depression with heavy to very heavy rainfall belt of 20-30 cm more concentrated along the coastal areas of Bay of Bengal and north Arabian Sea and adjoining Pakistan. In this case the heavy rainfall over northwest India was not captured in both control and experiment where the humidity profile data over the area was not available during the above period.

## 6. Conclusions

The training data set based on the regional input for all the seasons has improved the accuracies of temperature and moisture profiles retrieved from AMSU

measurements of NOAA satellite series. During actual operations of temperature and humidity retrieval, the scheme uses only the satellite measurements and satellite geometry data, without requiring additional first-guess from modeled profiles. This gives advantage to many operational sites including those with limited Internet connections.

The study has brought out a distinct positive contribution of the ATOVS derived humidity profile data, used as pseudo observations in the limited area analysis scheme. The forecast model runs to study the impact of the additional humidity data on the rainfall predictions have shown a considerable improvement over northwestern parts of India, as seen from the corresponding observed rainfall. Maximizations of use of such satellite based observations are expected to considerably improve the initial humidity analysis and subsequent forecasts produced by NWP models.

### Acknowledgements

The authors are grateful to the Director General of Meteorology for constant encouragement during the course of this study. The authors are also thankful to Dr. Lydie Lavanant, Météo-France for providing the ECMWF analysis data.

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