CGMS-XXX WP-IND-05
Prepared by India
Agenda Item: II/3
Discussed in WG II

Recent improvements in temperature and moisture profile retrievals from NOAA polar orbiting Satellite Observations at IMD, New Delhi

With the establishment of a new High Resolution Picture Transmission (HRPT) reception system at IMD, New Delhi, the real time data from microwave sounding instruments onboard the NOAA-K, L, M and N series of satellites has also become available. The raw HRPT data is being interfaced with the recently acquired new 'Atovs and Avhrr Preprocessing Package (AAPP)' level1d files to perform temperature and moisture retrievals from AMSU data of NOAA-16 satellite using three separate schemes ICI (inversion coupled imager), Neural Network and statistical regression approach. In this study, NOAA-16 satellite data over Indian region were used for retrieving temperature and moisture profiles for the months of January and July 2002. The temperature and moisture retrieval results are evaluated by computing the bias and root mean square (RMS) difference using colocated ECMWF analysis. The results based on the analysis of data sets for the months of January, 2002 and July, 2002 representing winter and summer seasons respectively show that ICI approach yielded better results for all atmospheric levels for both the parameters.

Recent improvements in temperature and moisture profile retrievals from NOAA polar orbiting Satellite Observations at IMD, New Delhi

With the establishment of a new High Resolution Picture Transmission (HRPT) reception system at IMD, New Delhi, the real time data from microwave sounding instruments onboard the NOAA-K, L, M and N series of satellites has also become available. The raw HRPT data is being interfaced with the recently acquired new 'Atovs and Avhrr Preprocessing Package (AAPP)' level1d files to perform temperature and moisture retrievals from AMSU data of NOAA-16 satellite using three separate schemes ICI (inversion coupled imager), Neural Network and statistical regression approach. In this study, NOAA-16 satellite data over Indian region were used for retrieving temperature and moisture profiles for the months of January and July 2002. The temperature and moisture retrieval results are evaluated by computing the bias and root mean square (RMS) difference using colocated ECMWF analysis. The results based on the analysis of data sets for the months of January, 2002 and July, 2002 representing winter and summer seasons respectively show that ICI approach yielded better results for all atmospheric levels for both the parameters.

ATOVS Preprocessing and Data Sets

The ATOVS preprocessing and the physical retrieval method ICI have been briefly described in this para. The AAPP (ATOVS and AVHRR Preprocessing Package, (Ref. Klaes 1997) has been installed to process the sounding data being received from HRPT station at IMD, New Delhi. Since the satellite raw data is received in the HRPT (High Resolution Picture Transmission) format, it is necessary to preproces it before starting the retrieval process. The ATOVS and AVHRR Processing Package (AAPP) was used to perform the ingest and pre-processing of the HRPT data. This procedure produces calibrated data of brightness temperatures for all ATOVS channels, located in the terrestrial coordinates (latitude and longitude) and mapped for a common grid resolution. In order to use the infrared spectral channels in the retrieval process, it was also necessary to perform cloud cover detection in the study area. Clouds generally do not affect the microwave spectral channels, but in some frequencies (specially in the AMSU-B channels), the presence of rain and ice hydrometeors particles give rise to scattering and absorption processes. The meteorological data used in the initialization process was taken from numerical weather forecasting data of Local Area Model (LAM) operationally run by IMD at New Delhi. The analysis data of January and July 2002 from the European Centre for Medium Range Weather Forecasting (ECMWF) global model at 00, 06,12 and 18 UTC were used for the generating the colocated data sets. The ECMWF data consists of the temperature and moisture profiles at the pressure levels starting from 1000 hPa to 0.1 hPa. The collocated data sets were constructed based on the profiles data retrieved using ICI, Neural Network and statistical regression approaches that are within 1.5 hour of the 00 and 12 hrs UTC observations resolution and 1x1 degree latitude and longitude of the ECMWF analysis data.

Retrieval of Atmospheric temperature and moisture Profiles :

The ICI inversion system was developed at the Centre de Météorologie Spatiale (CMS), where it has been operational since 1996. Its structure is based on independent modules, which work separately and could be easily replaced. The key components are , initial profiles library, inversion module and the tuning module, which is responsible for the periodic ICI calibration (Ref. Lavanant et al. 1997 and Lavanant et al. 1999a). The ICI version used in the current study uses the RTTOV-6 model, a fast radiative transference code (Ref. Eyre 1991; Sanders et al. 1998) to simulate the brightness temperature during the retrieval process. A cloud cover classification is performed from the MAIA algorithm (Lavanant et al. 1999b)) and applied in the last step of the AAPP model. A mean clear percentage of cloud cover on HIRS field of view is calculated from AVHRR channels with the aid of ancillary data (surface temperature and total that constrain the (Total Precipitable Water Contents (TPWC). The TPWC is estimated over sea following Grody et al. (1998) methodology, while over land a multiple-regression algorithm using various channels was applied.

The radiance leaving the earth-atmosphere system, which can be sensed by a satellite-borne radiometer, is the sum of the radiation emissions from the earth's surface, from each of the atmospheric levels and those reflected by the surface. For a non-scattering stratified atmosphere in local thermodynamic equilibrium, the radiative transfer equation can be expressed as

$$E = e_s \cdot t\,(p_s,0) \cdot B(T_s) + \int_{ps\to 0} [B(T_p)(\partial t\,(p,0)/\partial(\ln\ p))d(\ln\ p)]$$

$$+ (1 - e_s) \cdot t\,(p_s,0) \cdot \int_{0\to ps} [B(T_p)(\partial t\,(p_s, p)/\partial(\ln\ p))d(\ln\ p)]$$

It is necessary to acquire realistic initial guess for use in the ICI scheme. Generally the analysis of NWP model is more representative of the real atmosphere than climatological data. In our processing, the analyses of the LAM NWP model are utilized to create a rolling library of vertical profiles over the last ten days. Once an initial guess profile has been obtained, inversion consists of perturbing this profile under certain limits in order to minimize the error between the measurement and the synthetic brightness temperature of the final profile. The most probable solution is the function minimizing the cost function (Eyre 1989)

$$J(T_a) = (T_a - T_{a_g})^t \bullet G^{-1} \bullet (T_a - T_{ag}) + (Tb_{mes} - Fw(T_a))^t \bullet (O + F)^{-1} \bullet (Tb_{mes} - Fw(T_a))$$

Retrieval Results and Their Validation

The ICI package can be run in many different configurations. In our application, ICI3 (Lavanant et al. 2000) has been run at a thinned resolution of 2 by 2 HIRS pixels which is about 50km*50km. The cloud classification is based on AVHRR cloud cover and AMSU precipitation flag. For monitoring the retrieval results and their statistics, a few specific examples are given below. To illustrate the capability of above mentioned algorithms, a case study of August, 27, 9:28 UTC NOAA 16 orbit ATOVS data was carried out for detailed comparison between rediosonde profiles and ATOVS sounding profiles. In order to compare the retrieval profile with radiosonde observations, the ATOVS data from NOAA-16 orbit within 3 hours difference of 12 UTC or 00 UTC were used. For inter-comparison ,the spatial separation between ATOVS and RAOB has been taken within 1.0-degree latitude. Two radiosonde stations Delhi and Mumbai were selected representing inland and coastal stations respectively.

Figure 1(a&b) and figure2 (a&b) show the comparison of temperature profiles retrieved using three different schemes with RAOB temperature profile over Delhi and Mumbai respectively on 27th August 2002 at 12UTC. The temperature profile from ICI agrees generally with RAOB temperature profile within 2^o C between 700 hpa and 200 hpa with isolated points showing differences up to 3^o C. Temperature differences above tropopause are generally high. However, the temperature profiles retrieved from NN and REG methods do not match so closely as from ICI with RAOB since the NOAA-16 over head pass is generally at 0746 UTC over Delhi and at 0928 UTC for Mumbai while RAOB temperature profile is at 12UTC. Therefore near the surface, satellite retrievals are colder by about 3^oC in case of Delhi while it is not so in case of Mumbai. It may therefore be stated that radiosonde and satellite-derived temperatures in general show good agreement between 700 –200 hPa with larger differences near about tropopause level and near the surface, which are generally the levels of discontinuity.

Figure 3(a &b) and figure 4(a & b) show the bias and rmse statistics using the three different retrieval techniques for the months of January and July 2002 respectively. The performance of ICI is found to be better in both seasons compared to other two retrieval techniques. It may also be noticed that the bias and rms errors have been reduced in the month of July as compared to January. This is because the analyses of the LAM NWP model are utilized to create a rolling library of vertical profiles consisting of various meteorological conditions over the Indian region since last five months. The inversion schedule consists of perturbing this profile within certain limits in order to minimize the error between the measurement and the synthetic brightness temperature derived from the final profile.

There are certain regions where the retrievals still pose some problems. For example, the retrievals near surface where there is a strong influence of surface parameters, such as the surface temperature and microwave emissivity, represent a significant source of error in the retrieval process. Further, it should be pointed out that there is significant difference between the time of observation (analysis) and the NOAA-16 overhead pass in the study region (1.5hr). Normally, we would like to use two data sets that are within half hour of each other since sometimes there are large diurnal temperature variations in the tropical region that could affect the temperature comparison significantly whenever two data sets are more than half hour apart. Also the moisture fields usually have large spatial and temporal variability, especially in tropical region, which makes difficult the comparison with observed data.

Summary

The ATOVS preprocessing scheme in general and the physical retrieval method ICI have been briefly described in this paper. The retrieval results from ATOVS observation are validated against ECMWF global NWP analyses. These results generally show good agreement between ICI retrievals and conventional observations, though at times there are large differences. Indian meteorologists are generally interested in using the retrieved atmospheric parameters for the weather analysis and forecasting etc. The ATOVS radiances are also needed to enable the assimilation of satellite data in a numerical weather prediction model. A joint study on the use of ATOVS data in the LAM NWP model is currently under progress to assess the impact of using ATOVS data in the analysis and forecasts.

References

Eyre, J.R. 1989. Inversion of cloudy satellite sounding radiance by non-linear optimal estimation: theory and simulation for TOVS, *J. Q .R. Meteor. Soc*, **115,** 1001-1037.
Klaes, K.D. 1997. ATOVS data processing in Europe, Technical proceedings of the 9th International TOVS Study Conference, 20-26 February, Igls, Austria, 267-274.
Lavanant, L. and P. Brunel et al. 2000. ICI Version 3 Retrieval Package, Technical Proceedings of the 11th International TOVS Study Conference, September 20-26, Budapest, Hungary, 203-205.

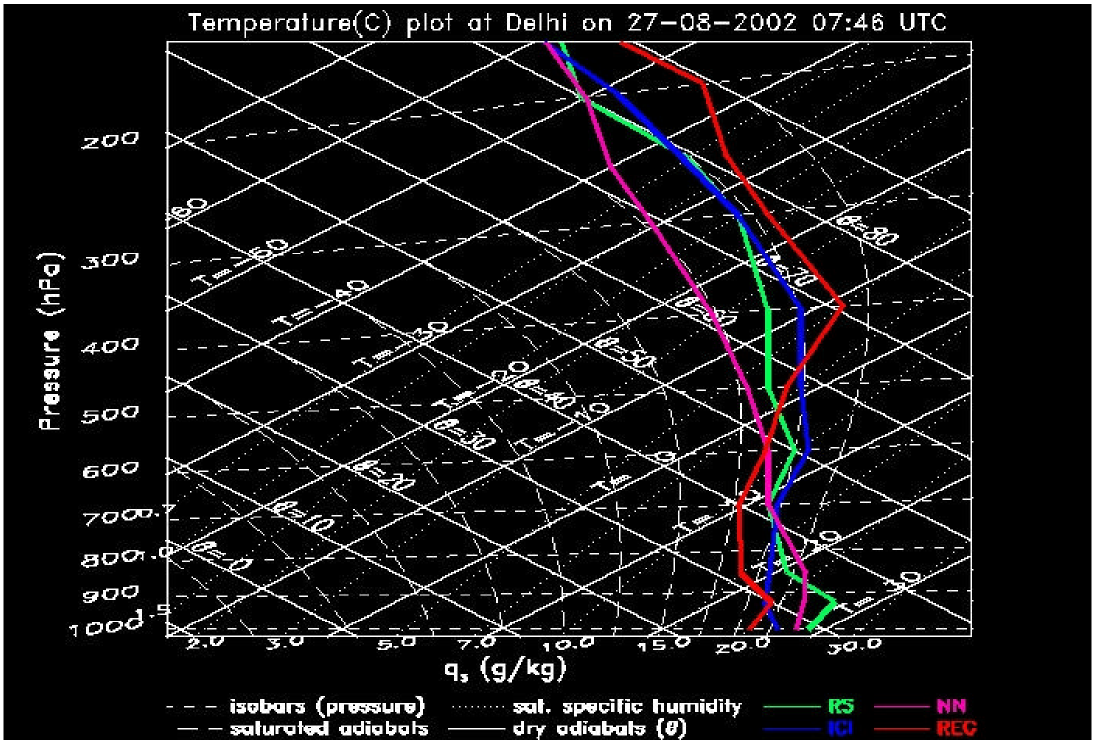

Temperature(C) plot at Delhi on 27-08-2002 07:46 UTC
Pressure (hPa)
200
300
400
500
600
700
800
900
1000
q_s (g/kg)
2.0
3.0
5.0
7.0
10.0
15.0
20.0
30.0
isobars (pressure)
saturated adiabats
sat. specific humidity
dry adiabats (θ)
RS
ICI
NN
REC

Fig.-1(a)

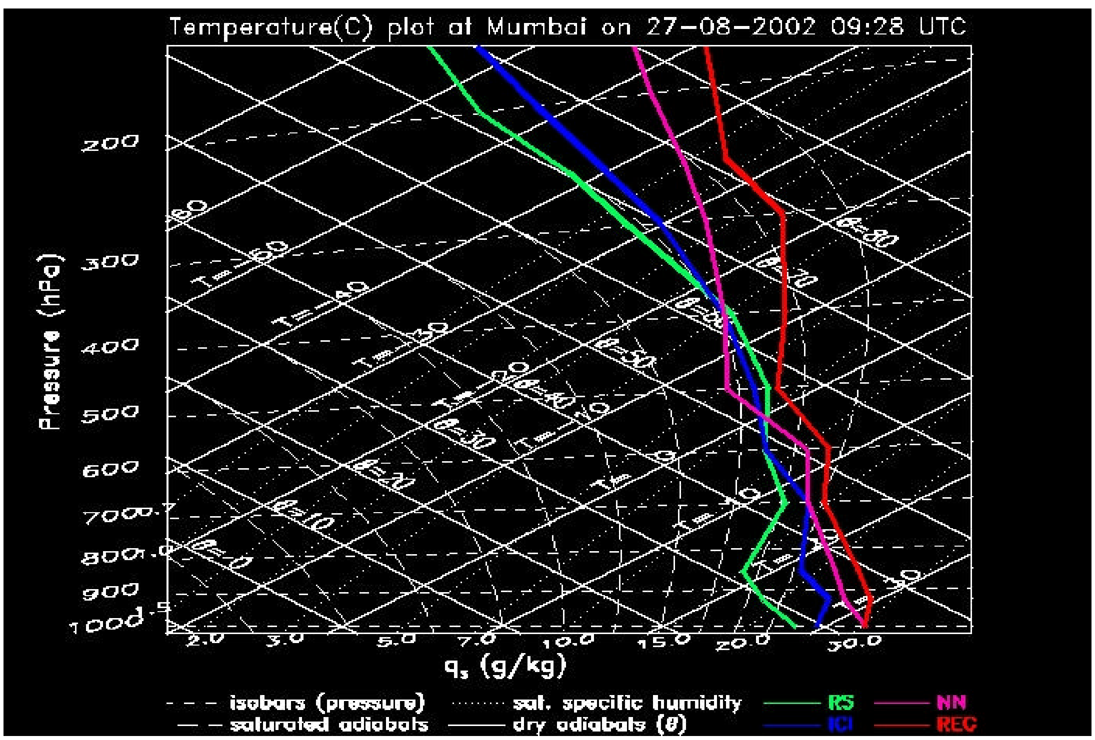

Temperature(C) plot at Mumbai on 27-08-2002 09:28 UTC
Pressure (hPa)
200
300
400
500
600
700
800
900
1000
q_s (g/kg)
2.0
3.0
5.0
7.0
10.0
15.0
20.0
30.0
isobars (pressure)
saturated adiabats
sat. specific humidity
dry adiabats (θ)
RS
ICI
NN
REC

Fig.-1(b)

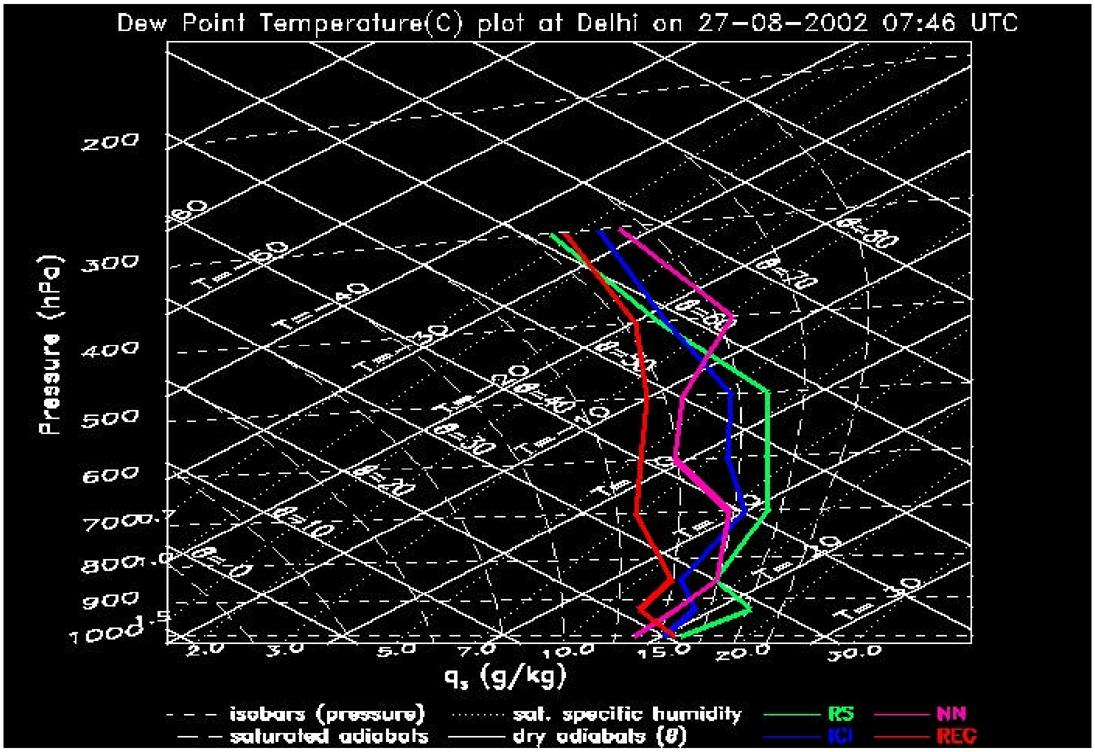

Dew Point Temperature(C) plot at Delhi on 27-08-2002 07:46 UTC
Pressure (hPa)
qs (g/kg)
isobars (pressure)
saturated adiabats
sat. specific humidity
dry adiabats (θ)
RS
NN
ICI
REC

Fig.-2(a)

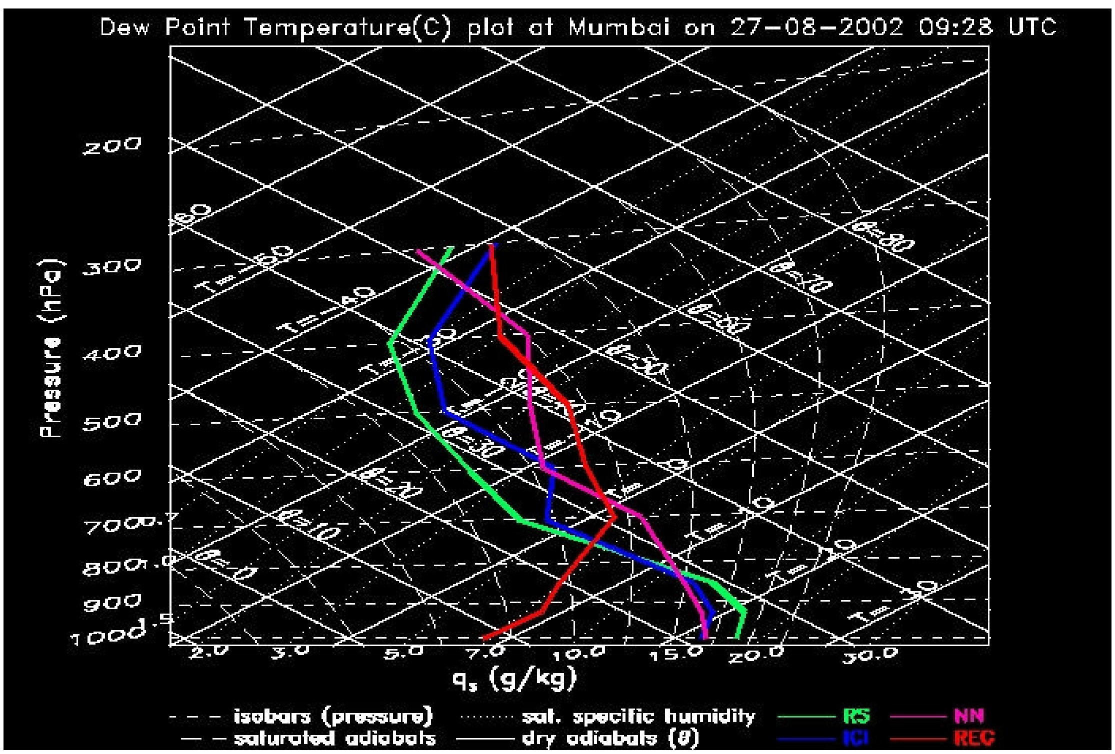
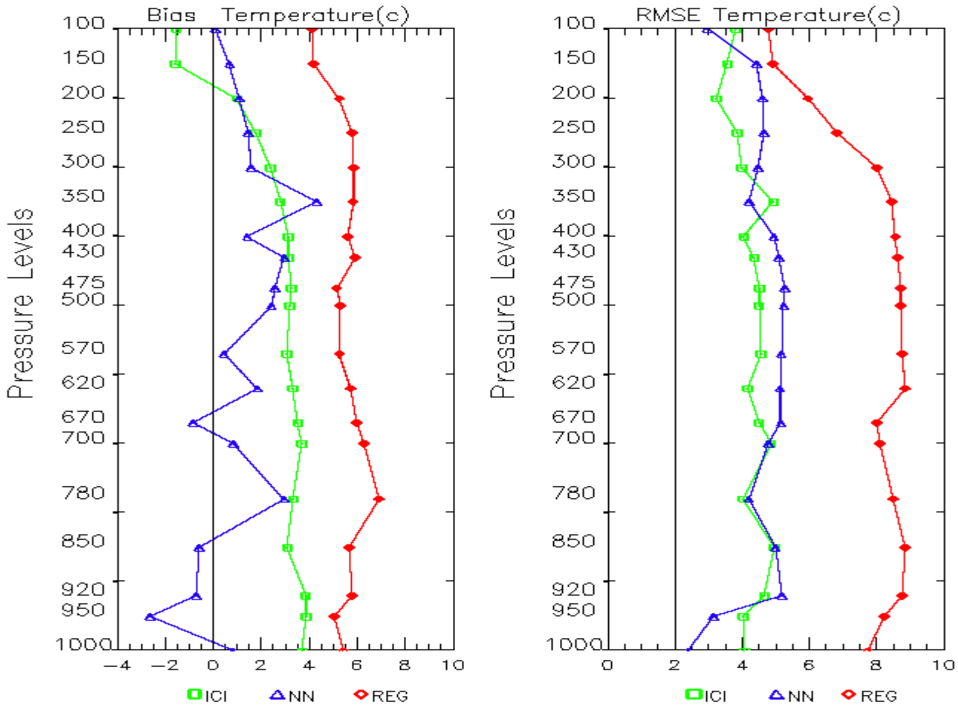
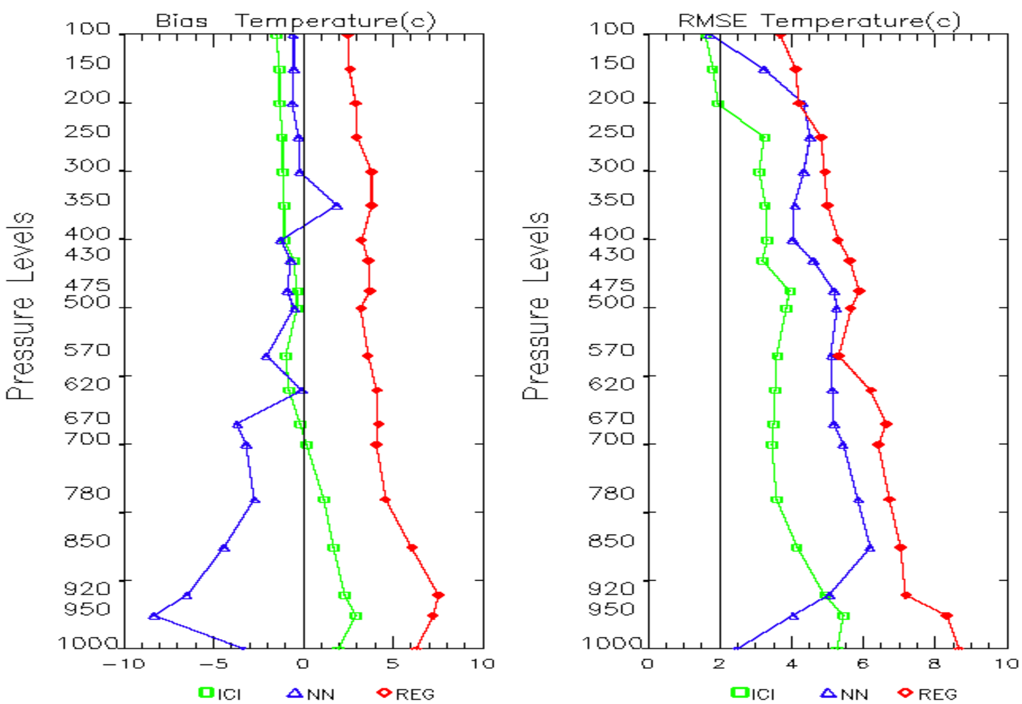

Dew Point Temperature(C) plot at Mumbai on 27-08-2002 09:28 UTC
Pressure (hPa)
qs (g/kg)
isobars (pressure)
saturated adiabats
sat. specific humidity
dry adiabats (θ)
RS
NN
ICI
REC

Fig.-2(b)



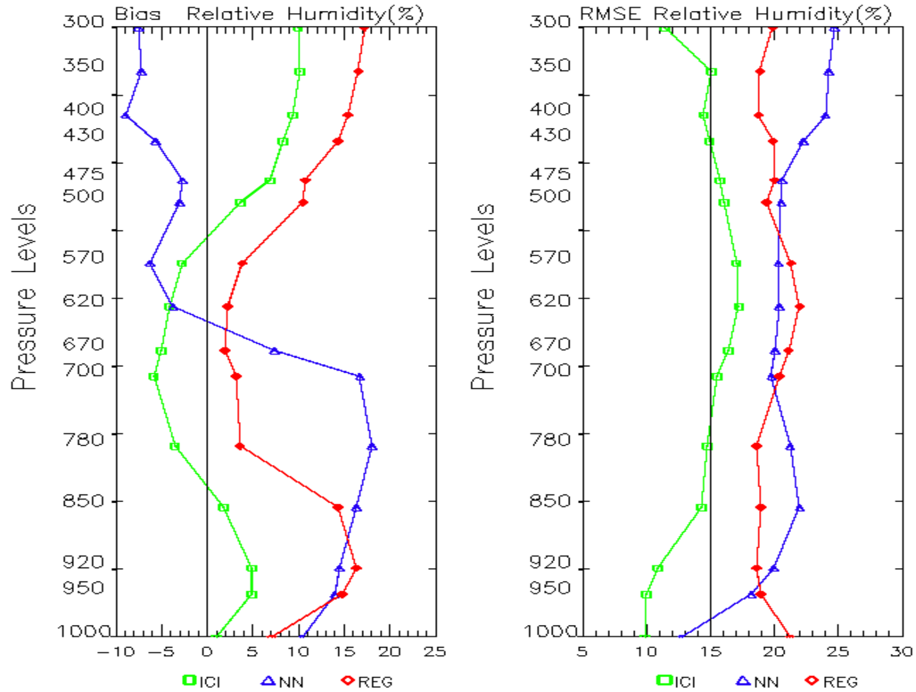
Bias and RMS error in Temperature profile January,2002

Fig.-3(a)



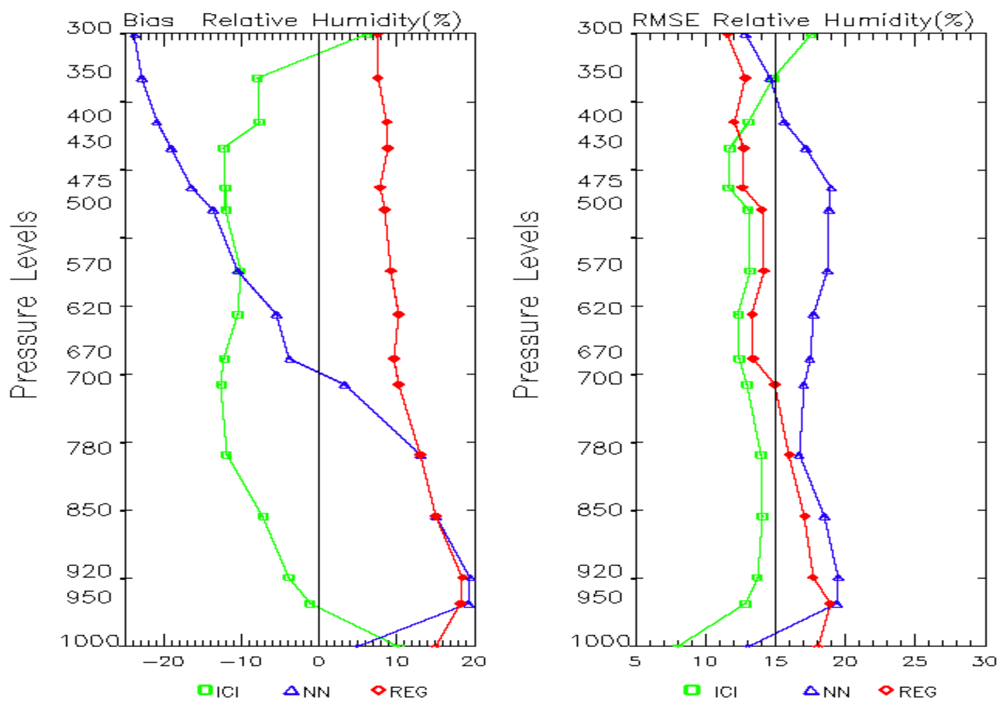
Bias and RMS error in Temperature profile July,2002

Fig.-3(b)



Bias and RMS error in Relative Humidity profile January,2002

Fig.-4(a)



Bias and RMS error in Relative Humidity profile July,2002

Fig.-4(b)