Performance of the NOAA-16 and AIRS temperature soundings over India

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Inversion Coupled with Imager (ICI version-3) is used to retrieve vertical temperature profiles from infrared and microwave brightness temperatures from a polar-orbiting satellite. This approach allows retrievals to be performed even in cloudy conditions – a limitation of infrared-only retrievals. Local Area Model analysis data were used for making the rolling guess library for the ICI retrieval package for the ten-day period (11–20 January 2004). Subsequently, temperature profiles were retrieved using ICI-retrieval package for January–September 2004. The vertical cross-section of rms differences was computed between ICI-retrieved temperature profiles and that of National Center for Environment Prediction reanalysis for the period January–March 2004. Further, validation of these temperature profiles was also carried out using radiosonde temperature profiles over land and sea, and also under clear sky and cloudy conditions for winter and summer. The rms differences in temperature profiles were found to be more over land (about 3°C) in lower atmosphere compared to that of middle and upper atmosphere, where the differences were less than 2°C respectively, compared to sea areas. Finally, comparison of temperature profiles retrieved from combined infrared and microwave and Atmospheric Infrared Sounder (AIRS + AMSU + HSB) profiles reveals that in general they are comparable. However, the best agreements have been observed over the oceanic region.

Kerywords: Radiosonde, retrievals, satellite, temperature profiles.

1. Introduction

Sensors mounted on satellite platforms provide global coverage that is relatively homogeneous in space and is of much higher resolution than the current radiosonde network. However, these instruments only provide a vertically integrated measure of the amount of outgoing radiation (radiance) at the top of the earth's atmosphere. Because these radiances are a function of the vertical distribution of water vapour and temperature in the atmosphere and not simply of their average values, the retrieval of these vertical profiles from the radiances is an ill-posed problem that cannot be solved directly1. As a result, numerous approaches have been undertaken for retrieving geophysical parameters from satellite radiances. The simplest approach is to develop semi-empirical relationships between satellite radiances and the parameters of interest[2–5]. Variables that are more readily estimated from satellite data (such as precipitation amount) can also be used in conjunction with a model initialization scheme to retrieve values that are less readily estimated, such as diabatic heating and vertical motion fields. This approach, referred to as physical initialization, has also been investigated by many researchers[6–12]. Retrievals can also be performed in conjunction with a numerical weather prediction (NWP) model using the model forecasts as a first-guess field for satellite retrievals and the satellite retrievals, in turn, to influence the NWP model solution[13–16]. A fourth approach is to use a data analysis technique such as linear regression[17] to determine the relationships between satellite radiances and geophysical parameters from a sample set of data.

The AMSU-A is a 16-channel microwave radiometer on-board the new generation of National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites. The second of this new series of satellites, NOAA-16, was launched on 21 September 2000. India Meteorological Department (IMD), New Delhi receives and processes the NOAA-16 satellite Advanced Tirosn Vertical Sounder (ATOVS) data in real time, covering the geographical area from the equator to 60°N and 50°E to 110°E at IMD. Since the satellite raw data are received in the High Resolution Picture Transmission (HRPT) format, it is necessary to process them before the retrieval process. The ATOVS and AVHRR (Advanced Very High Resolution Radiometer) Pre-processing Package (AAPP) was used to perform the ingestion and pre-processing of the HRPT data. NOAA-16 satellite data were pre-processed with the AAPP model[18-20]. The pre-processed data for brightness temperatures in the past have been used for several meteorological applications[21–24].

This paper presents an approach for retrieval of temperature profiles based on NWP model using the model forecasts as a first-guess field for satellite retrievals and the satellite retrievals, in turn, to initialize the NWP model. To accomplish this task, we chose the Inversion Coupled with Images (ICI) retrieval package developed the Centre de Météorologie Spatiale (CMS), where it has been operational since 1996. This package is based on independent modules which work separately and can be easily replaced. The key components are: initial profiles library, inversion module and tuning module, which is responsible for the periodic ICI calibration[25,26]. The ICI version used in the present study utilizes the RTTOV-7 model, a fast radiative transfer code to simulate the brightness temperature during the retrieval process[27,28]. Further, the retrieved temperature profiles are compared with a AIRS + AMSU + HSB data profiles. The objective of this work is to use these combined infrared and microwave temperature profiles to initialize a Local Area Model (LAM) for real-time application in all weather conditions.

2. Data and Methodology

Three island stations, namely Port Blair, Minicoy and Amini over the ocean and five stations, namely Delhi, Mumbai, Kolkata, Nagpur and Chennai over land, where radiosonde flights are taken daily two times at 00 and 12 UTC by the IMD were selected for the present study. The radiosonde profiles over stations were collected from January to December 2004 and were used as the main source of validation data for AMSU + HIRS (High Radiation Infrared Radiation Sounder) and AIRS + AMSU + HSB retrieved profiles. The collocated data (within ~1° of latitude–longitude in space and within +/– 2.0 h in time) have been accumulated for validation. To further enhance the quality control, only radiosonde data with five or more levels of good record and without three or more levels of lost or bad record under 300 hpa were kept for validation. The total number of quality-controlled radiosonde profiles was found to be 1487.

The meteorological data used in the initialization (numerical weather forecasting data) were taken from the LAM run operationally by IMD at New Delhi. The National Center for Environment Production (NCEP) reanalysis data were downloaded from the website http://www.cdc.noaa.gov/ncep_reanalysis/ and used for validation. Intercomparison was carried out using AIRS + AMSU + HSB downloaded from the website: http:// daac.gsfc.nasa.gov/AIRS/airsL2_Std.shtml.

3. Results and Discussions

The vertical accuracy statistics based on NOAA-16 AMSU + HIRS satellite data and NCEP reanalysis was computed for the period January–March 2004, using total collocations, which includes the type of land and sea, and clear and cloudy conditions. The results are illustrated in Figures 1 and 2, which show rms difference of temperature profiles over land and sea respectively for January– March 2004. All of them had similar rms differences in the lower troposphere (below 850 hPa) in clear and cloudy conditions with values about 3.2°C over land and about 2.0°C over sea. The rms errors were small over the sea compared to that over land in both situations. This is because of constant emissivity over the sea compared to highly variable emissivity over land.

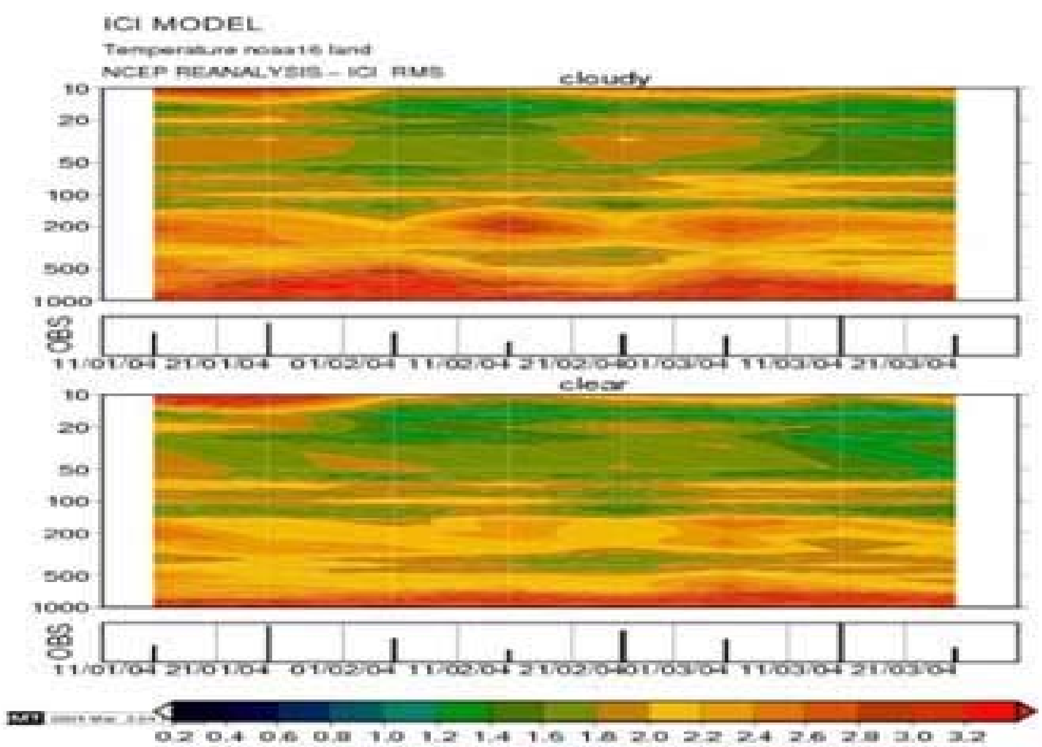

Figure 1. Vertical cross section of RMS error for cloudy and clear sky conditions over land.

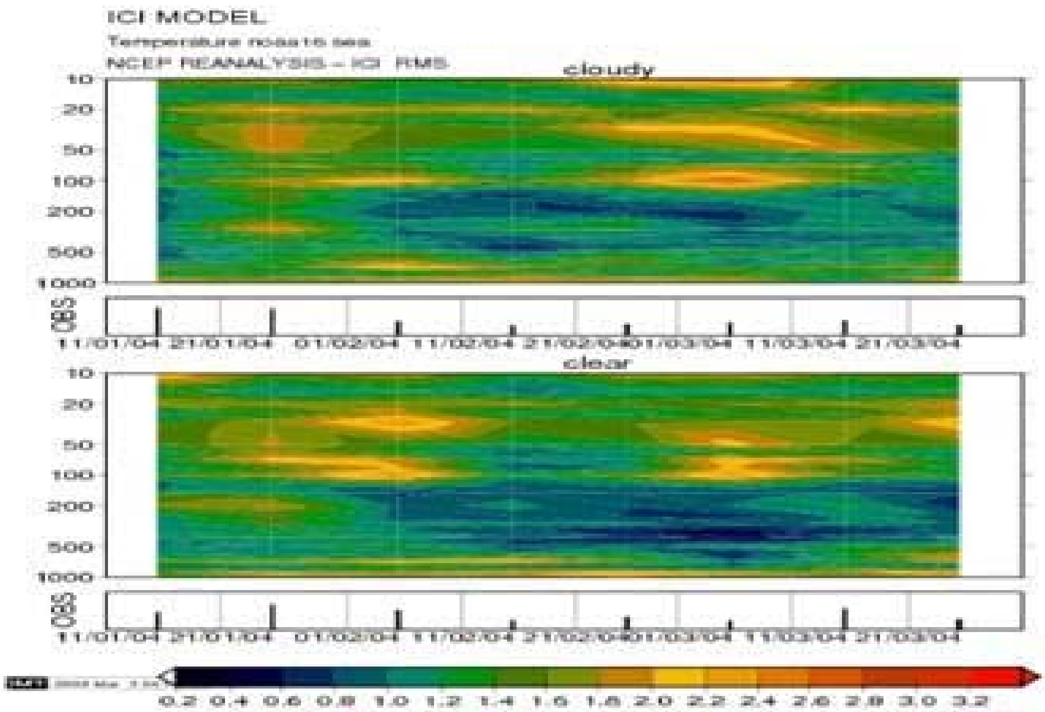

Figure 2. Vertical cross section of RMS error for cloudy and clear sky conditions over sea.

Figures 3 and 4 show the rms differences of temperature profiles retrieved from AMSU + HIRS using ICI scheme and AIRS + AMSU + HSB data against radiosonde profiles for the land and sea respectively, for January 2004. Similarly, Figures 5 and 6 show data for August 2004. The rms difference is smaller over sea compared to that of over land during both the months. This is because of constant emissivity over the sea compared to highly variable emissivity over land. The rms differences are smaller under clear sky conditions compared to cloudy conditions. This is because more channels (IR and MW) are used to retrieve temperature profiles under clear sky conditions than under cloudy conditions, where only MW channels are used. However, advantage of the MW data is that they are available under all weather conditions, unlike IR data.

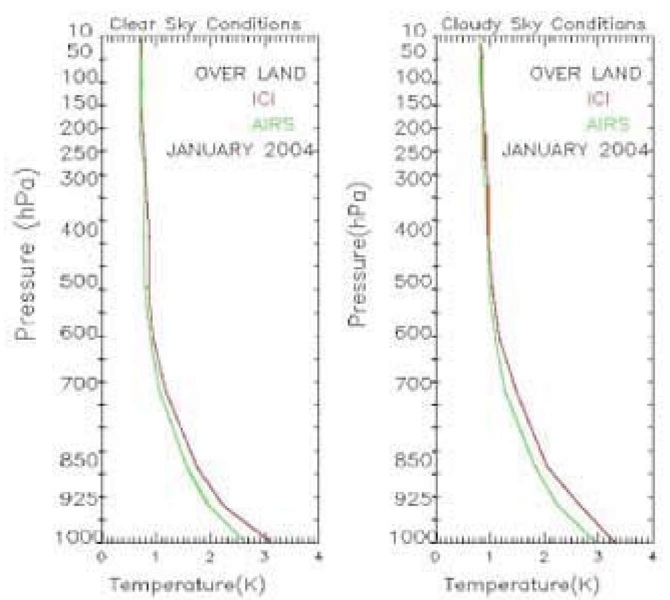

Figure 3 *a*, *b*. RMS error of temperature profiles for AIRS + AMSU + HSB and AMSU + HIRS against radiosonde profiles over land for January 2004.

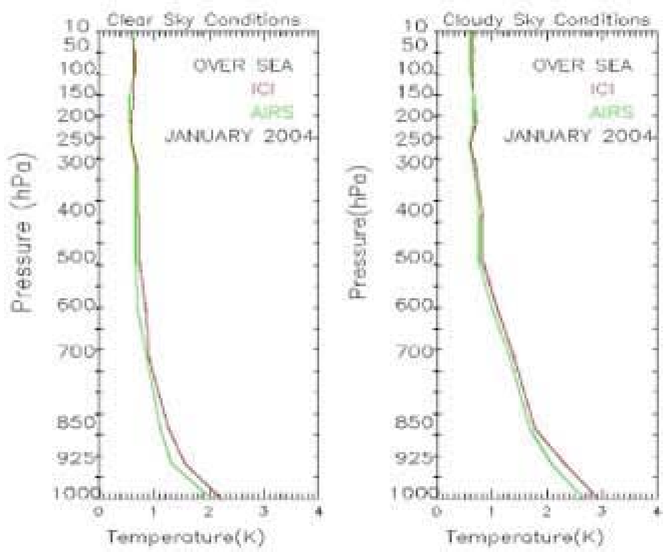

Figure 4 *a*, *b*. RMS error of temperature profiles for AIRS + AMSU + HSB and AMSU + HIRS against radiosonde profiles over sea for January 2004.

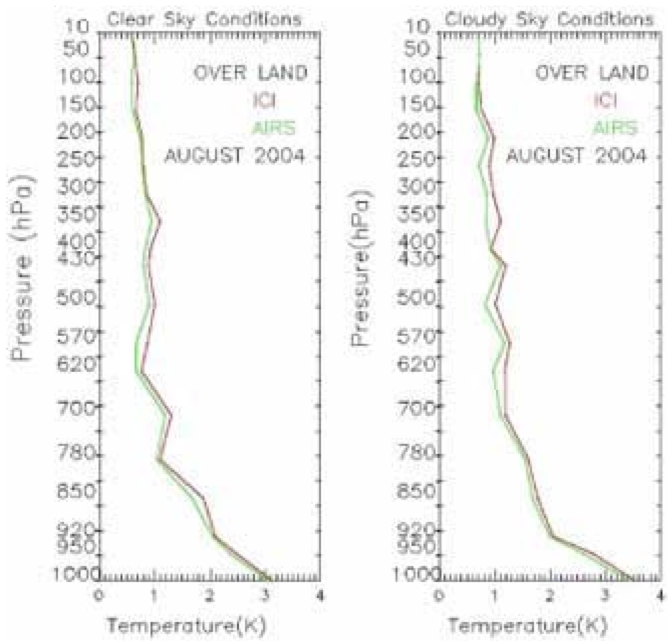

Figure 5 *a*, *b*. RMS error of temperature profiles for AIRS + AMSU + HSB and AMSU + HIRS against radiosonde profiles over land for August 2004.

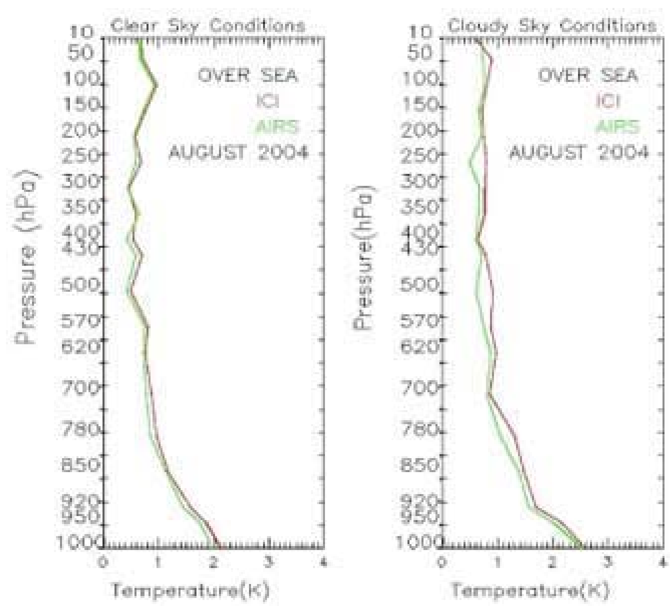

Figure 6 *a*, *b*. RMS error of temperature profiles for AIRS + AMSU + HSB and AMSU + HIRS against radiosonde profiles over sea for August 2004.

The nonlinear physical iteration approach using ICI to retrieve vertical profiles of temperature from NOAA-16 AMSU + HIRS combined measurements have been studied. Although the application of ICI to the satellite retrieval problem is not new, here infrared and microwave data were used together to combine their relative strengths: finer spatial resolution (in the horizontal and the vertical) of the infrared instrument and relative transparency to (water) clouds for the microwave. AMSU-A has four window channels at 23.8, 31.4, 50.3 and 89 GHz. Water vapour has a little effect on the measurement of the channel at 23.8 GHz, which is in the vicinity of the water vapour absorption line at 22.235 GHz. Because of the uncertainties of the surface and the cloud parameters, the accuracy of forward calculation in the window channels is low. As a result, the retrieval procedures based on theforward models are unable to yield all the low-level atmospheric information contained in the radiance measurements of these channels[29].

The higher rms error in the lower troposphere but comparable errors above and below could be due to depending of retrievals on real microwave, radiosonde observations and error caused by the imperfection of forward model calculations. There are three main sources of error for the comparisons. The first one is the instrument observation error. The second is caused by the differences in the observation time and location between the satellite and radiosonde. The third is sampling error due to atmospheric horizontal inhomogeneity of the field of view (FOV). This occurs because the satellite observation obtains information from a certain domain, but the radiosonde measures the parameters at a certain point. For example, if it is partly cloudly within the FOV, the radiosonde observation does not represent the average condition of the FOV. Furthermore, the capability of retrieving atmospheric temperature profiles is limited by the vertical resolution of microwave observation, which partly prevents the results from gaining further improvement.

The study has brought out the potential use of the ICI package based on nonlinear physical iteration for the retrieval of temperature profiles in cloudy sky conditions with reasonable good accuracy over both land and sea; this is not possible using infrared measurements only. The use of both microwave and infrared data together yields better accuracy and the results are comparable to that of hyper spectral infrared and microwave retrieved temperature profiles. The rms deviations of the temperature profiles achieved using ICI retrieval package are about 3.2°C at the surface, in the range 1.0–1.2°C in the middle troposphere, less than 1.0°C at the tropopause, and in the range 0.5–1.0°C throughout the stratosphere. Therefore, the ICI retrieval package showed great potential for retrieving the temperature profiles using both microwave and infrared data together under all weather conditions for real-time operational use.

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