RETRIEVAL OF TEMPERATURE AND MOISTURE PROFILES OVER BRAZIL USING THE ICI INVERSION SYSTEM

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INTRODUCTION

The vertical structure of temperature and water vapor plays an important role in the meteorological processes of the atmosphere. For years the radiosonde network has been the primary observing system for monitoring tropospheric temperature and water vapor. However due to logistics and economic problems, there is a lack of observation in several regions of the Earth. For example, in Brazil only a dozen radiosonde launching are done in a daily basis. As a consequence there is almost no data covering the Amazon basin. In this sense, became important the retrievals of temperature and humidity profiles from satellites, for applications such as weather analyzes and data assimilation in numerical weather predictions models.

This work shows the ability of ATOVS for retrieving temperature and moisture profiles for different atmospheric conditions over Brazil. The analysis was done using the Inversion Coupled with Image (ICI) model (Lavanant et al. 1999a). To accomplish this work we used 35 days of NOAA-15 satellite data pre-processed with the ATOVS and AVHRR Processing Package (AAPP) model (Klaes 1997; Klaes et al. 1999). The obtained temperature and moistures retrieved profiles are compared with radiosonde profiles for different locations in Brazil. Also the retrieved horizontal fields of temperature and moisture are analyzed for different pressure levels.

MODELS AND DATA SETS

In this study 35 days of NOAA-15 satellite data over southeastern Brazil were used for reconstructing temperature profiles for the period of 02/23/2000 - 03/08/2000. The meteorological data used in the initialization and validation process (radiosonde and numerical weather forecasting data) were supplied by the Brazilian Centre for Weather and Climate Forecast (CPTEC). Since the satellite raw data is received in the HRPT (High Resolution Picture Transmission) format, it is necessary to process it before the retrieval process. The AAPP model was used to perform the ingestion and pre-processing of the HRPT data. This procedure supplies calibrated data of brightness temperature for all ATOVS channels located in the terrestrial coordinates (latitude and longitude) and mapped in a common grid resolution.

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 (Lavanant et al. 1997; Lavanant et al. 1999a). The ICI version used in the current study uses the RTTOV-6 model, a fast radiative transference code (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

precipitable water content (TPWC)). In the AMSU microwave spectral channels, especially for AMSU-B, the presence of rain and ice hydrometeors particles becomes important due to scattering and absorption processes. Thus, a technique based on the 21, 23 and 89 GHz AMSU-A channels brightness temperature differences (Grody et al. 1998) was used for precipitation and scattering identification over sea and land locations.

In the ICI current version the infrared emissivity over sea is given following Masuda et al. (1998). Over land the emissivity is considered as a constant and set to 1. In the microwave spectral range, the emissivity over sea is calculated using the algorithm FASTEM (English et al. 1998). The microwave emissivity over land is provided by an emissivity atlas estimated from SSM/I scanner (Pringent et al. 1997). The originals frequencies and scanning angle (56°) provided by that atlas were interpolate/extrapolates for the AMSU frequencies and scanning angles using Pringent et al. (1999) methodology.

RESULTS

Fig. 1 shows the error statistics concerning the mean (bias) and the standard deviation (stdev) of the difference between the simulated and measured brightness temperature. These errors are caused by factors such as forward models approximations and measurement errors, among others (McMillin et al. 1993). As expected, the error levels change considerably from channel to channel, and the model accuracy depends on the surface type (sea and land). Standard deviation values are higher over land, especially in the AMSU channels. This occurs because the surface parameters have lower variability and are easily estimated over sea.
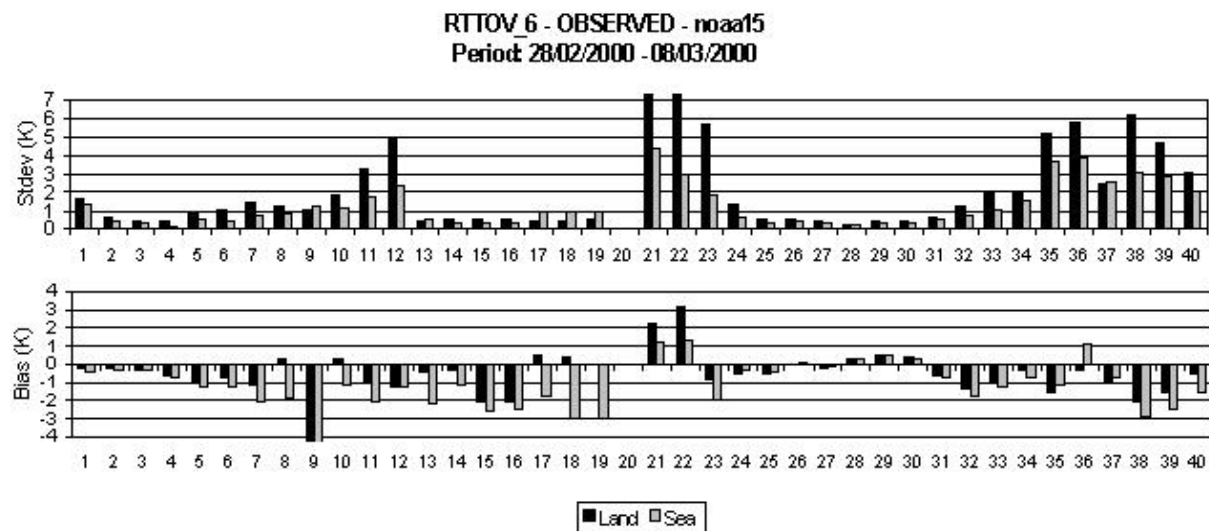

Fig. 1: Error statistics concerning the bias and the standard deviation (stdev) of the difference between the simulated and measured brightness temperature. The statistics were performed for the 02/28/2000 to 03/08/2000 period, using NOAA-15 data.

In this study we have used channels 2-8, 10-16, 25-32, 37-40 for clear conditions (less than 10% of cloud cover in the HIRS field of view); channels 2-3, 25-32, 37-40 for cloudy conditions (more than 10% of clouds in HIRS field of view), and for pixels contaminated by scattering effects (cloudy to the infrared and microwave channels) only the 2- 3, 26-32 channels were considered. Besides the ATOVS channels an additional information were used in the guess selection process as a "pseudo channel"

which constrain the 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.

Fig. 2-a presents the temperature error statistics concerning the mean and stdev of ICI inversion compared to the CPTEC analysis. Statistics have been performed for a 15 days period and for two cloud sky conditions (clear and cloud). In the first case the average RMSE computed for 1000 hPa and 0.1 hPa levels are 0,89 K and 0,75 K respectively, over land and sea. For cloudy situations the average RMSE is 0,88 K over land and 0,81 K over sea. The higher error levels are found over land near the surface and around 100 hPa (tropopause region), but in general the error levels are similar for all situations. Fig. 2-b presents the same as Fig. 2-a, but for moisture profiles (g/kg). On the contrary of the temperature retrievals, the moisture retrievals show a significant difference in the statistics results over sea and land. Over land, the stdev is about 2g/Kg and over sea it is lower than 1.5 g/kg. For clear sky conditions the average RMSE computed to 1000 hPa to 500 hPa levels is 1,25 g/kg over land and 0,82 g/kg over sea. On the other hand for cloudy conditions the average RMSE is 1,22 g/kg over land and 0,81 g/kg over sea. It should be pointed out that there is a significant difference between the time of the observation (analysis and radiosonde) and the NOAA-15 over pass in the study region (around 1:30 h). Also, moisture fields usually have large spatial and temporal variability, especially in tropical regions, which makes difficult the comparison with observed data.

(a)   (b)
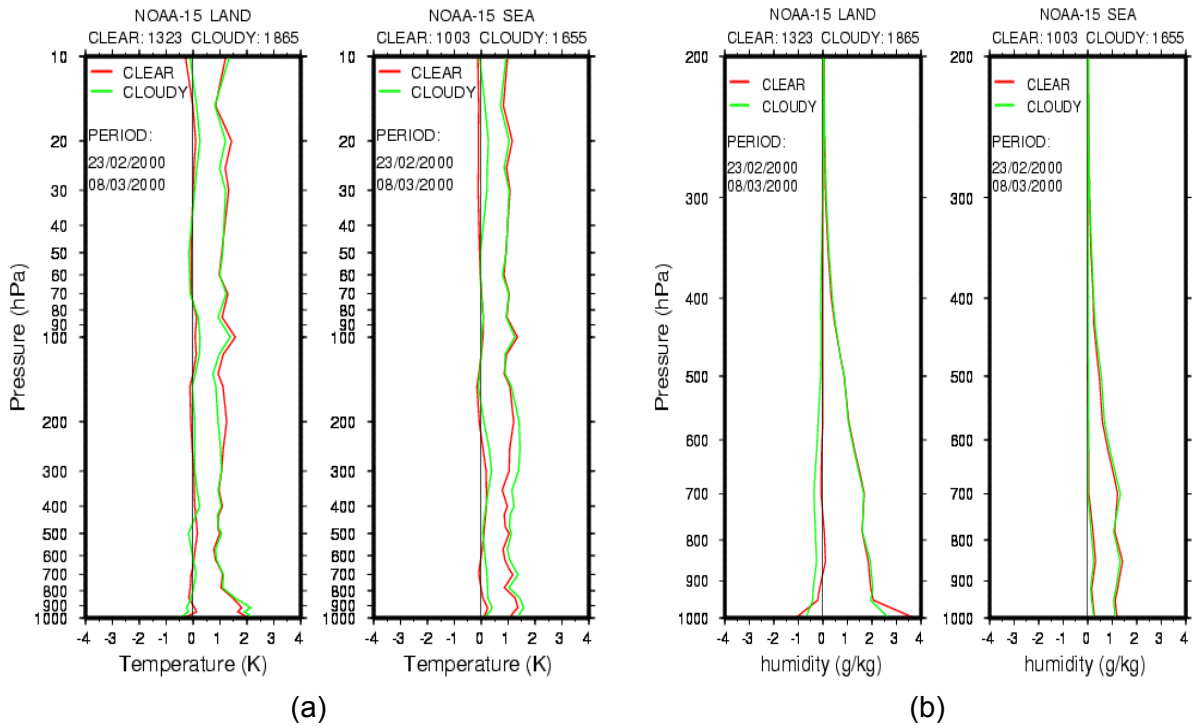
Fig. 2: Statistics error for NOAA-15 concerning the mean and standard deviation for land (left) and sea (right) situations of the inversions compared to a) temperature and b) humidity.

Fig. 3 shows the horizontal structure of temperature retrievals fields at 500 hPa and 850 hPa. The retrieved fields are coherent with the statistics presented before, and the images are dominated by error less than 2 K. One can notice also an homogeneity in the horizontal distribution of the error and that the retrieval method has identified correctly the different air mass structures between the cold and warm air.
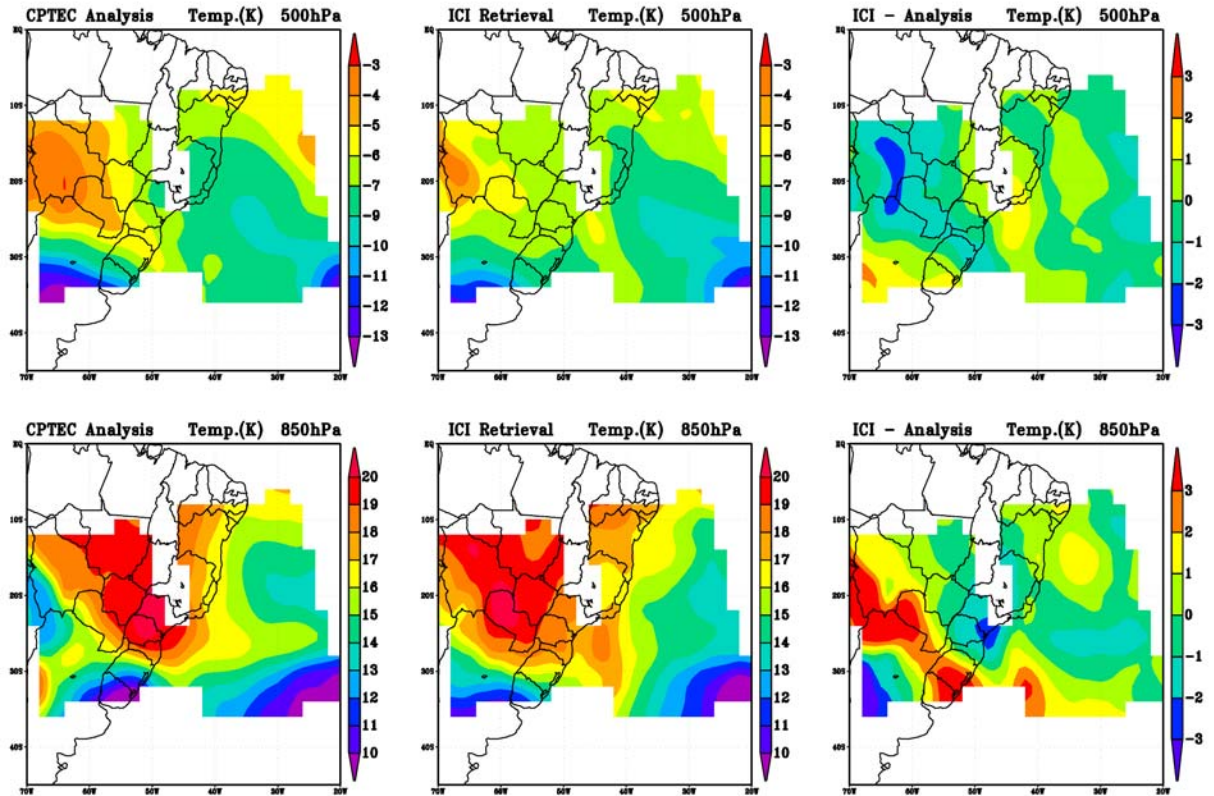
Fig. 3: 500 hPa and 850 hPa temperature field derived from ATOVS for 02/29/2000: (left) CPTEC analysis; (center) ICI model; (right) ICI-CPTEC analysis.
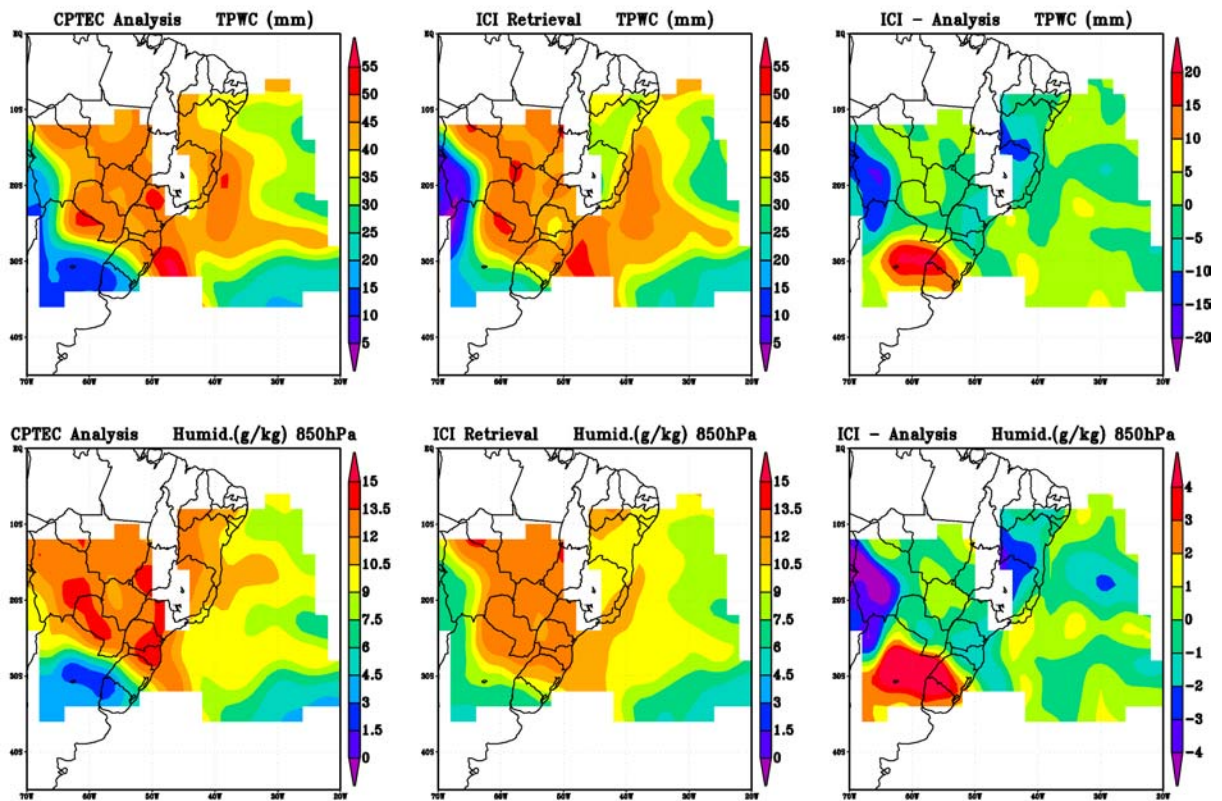

Fig. 4: 850 hPa specific humidity field and TPWC (mm) derived from ATOVS for 02/29/2000: (left) CPTEC analysis; (center) ICI model; (right) ICI-CPTEC analysis.

Fig. 4 shows the same as Fig. 3, but for TPWC and moisture retrievals at 850 hPa. It is observed that areas with higher and lower water vapor content are correctly represented by the ICI inversion system specially over sea. On the other hand, quantitatively one can notice areas (specially over land) where the discrepancy between the fields is significant. In general, the ICI-analysis moisture fields show larger differences in areas with high elevation (e.g. Andes Mountain), and also in the boundary of different air masses. The best agreement is found over sea and in areas with large water vapor content.
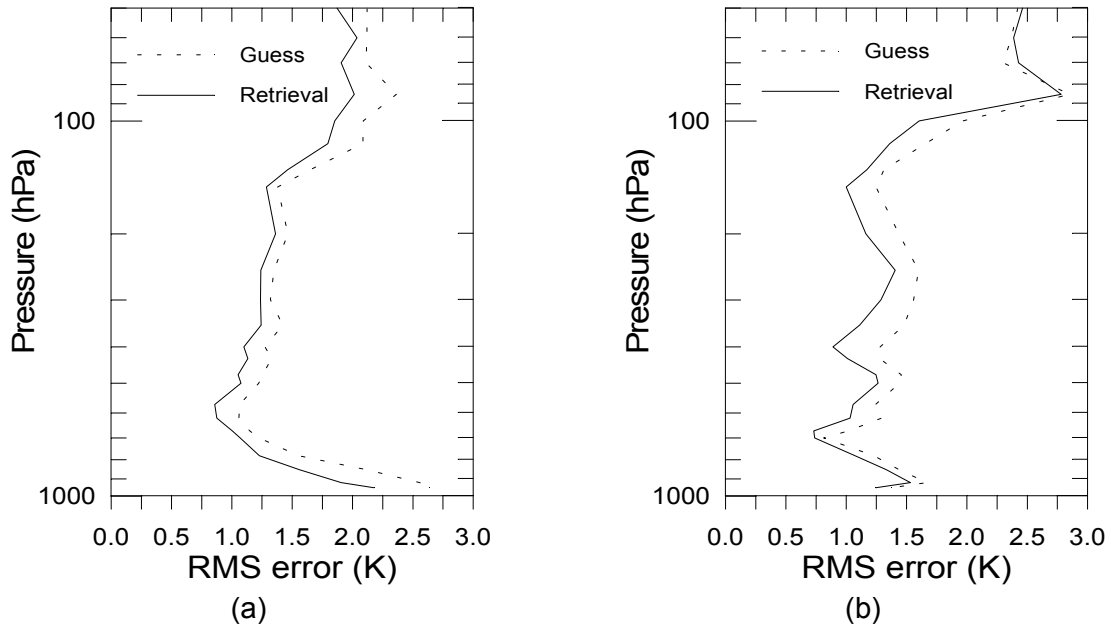
Fig. 5: RMSE of the ICI–radiosonde temperature profiles: a) over land (140 profiles) and b) over sea (22 profiles).
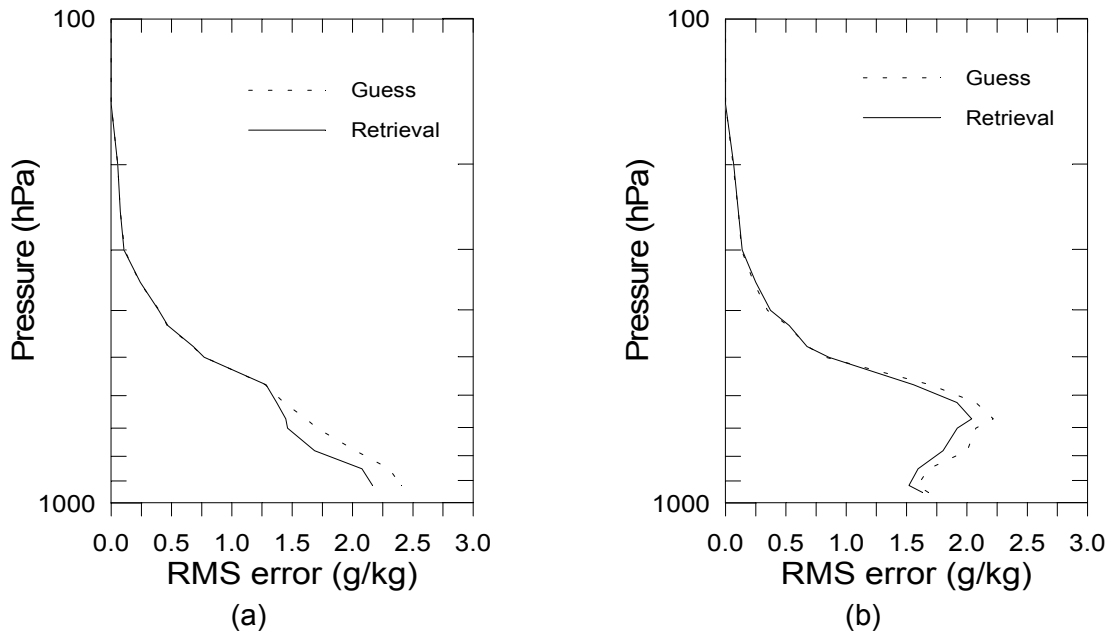
Fig. 6: RMSE of the ICI–radiosonde specific humidity profiles: a) over land (140 profiles) and b) over sea (22 profiles).

To evaluate the satellite retrievals representativeness, the satellite/radiosonde temperature profiles are intercompared (Fig. 5). Both profiles, except near the tropopause and surface, show RMSE smaller than 1,5 K. As expected, the ICI RMSE first guess is larger than the ICI RMSE retrieval in all levels. Over southern Atlantic Ocean, in general the RMSE are smaller near the surface. The RMSE of the ICI retrieval and ICI guess specific humidity profiles are presented in Fig. 6. In general the RMSE are smaller than 2,5 g/kg and they decrease with height. Over sea, apparently as the first guess moisture profile seems anormal, the ICI RMSE follows this trend. Obviously these intercomparisons are constrained by the relatively small number of radiosonde observations used, especially over sea, where the frequency of observations is small. The RMSE mean for the guess and retrieval temperature profiles and specific humidity profiles are presented in Table 1.

Table 1: RMS error of first guess temperature profiles derived from ICI and ICI inversion profiles (over land and sea) for temperature (surface to 10 hPa) and moisture (surface to 500 hPa) profiles over Brazil.

VARIABLE	GUESS (land)	ICI (land)	GUESS (sea)	ICI (sea)
Data points	140	140	22	22
Temperature (K)	1.70	1.51	1.61	1.44
Specific Humidity (g/kg)	1.92	1.75	1.85	1.75

CONCLUDING REMARKS

This work has evaluated the performance of temperature and moisture retrieval over Brazil using the ICI system and NOAA-15 local acquisition data. Regarding moisture retrieval, the areas with high and low water vapor content associated with different air masses, are correctly represented by the ICI inversion system, especially in oceanic areas. On the other hand, over land there are regions where the errors are significant. In general, the ICI shows large discrepancy (from CPTEC analysis) over high elevations areas such as the Andes Mountains, and also in the boundary of the air masses (high moisture gradient). The best agreement is found over sea and in areas with large water vapor content. Based on these results one can conclude that in general, the ICI temperature retrievals has achieved a good quality levels, with mean errors around 1.5 K. However, despite of that it is noted that there are regions where the retrieval still presents problems. As example we can cite the retrievals near surface (over land), where there is a strong influence of surface parameters, such as the surface temperature and microwave emissivity, which represent a significant source of error in the retrieval process. Another source of error is related to the tropopause height estimative, which is responsible for significant RMSE. Currently, the ICI system is in stage of being operational at CPTEC to provide satellite data for an assimilation data scheme.

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