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Impact of ATOVS geopotential heights retrievals on analyses generated by RPSAS

Jairo Geraldo Gomes Junior, Dirceu Luis Herdies, Luciano Ponzi Pezzi, Luiz Fernando Sapucci

*Centro de Previsão de Tempo e Estudos Climáticos – CPTEC.
Cachoeira Paulista, São Paulo – SP, Brazil.*

Abstract: South America and the adjoining oceans are known for having a very irregular and sparse meteorological data acquiring net. The sparsity of data causes the Numerical Weather Prediction models operated by most weather predictions centers to perform worse than they should on computational capability. However, this lack of *in situ* observations has been addressed by the usage of satellite-processed radiances. In this work, conventional data (e.g. from surface and oceanic stations, airplane and radiosondes) and ATOVS retrievals, in the form of geopotential heights, were assimilated by RPSAS (Regional Physical-Space Statistical Analyses System) at CPTEC (Center of Weather Prediction and Climate Studies – Centro de Previsão de Tempo e Estudos Climáticos) and verifications were done with RPSAS outputs to quantify the impact of the assimilated data on its analyses. Also a case study was carried out about a frontal system that appeared in Brazil in 09 of July of 2007. Comparisons to a control experiment without ATOVS profiles, as Mean Absolute Error, were made to observe the impact of these retrievals on the analysis generated by RPSAS. Furthermore, an Analysis Impact Index (AI) was calculated by taking the NCEP analyses as a “perfect” representation of the atmosphere state at some synoptic times during the period of 01st to 31 of July of 2007. The results show that the profiles assimilation of the profiles provided improvements in analysis quality, although these improvements were not observed over the entire RPSAS domain.

Introduction:

In a data assimilation system, satellite data are combined with conventional data (e. g. surface data, TEMP) and short range forecasts (first guess) to yield a best estimate of the atmospheric state. This representation is the “analysis” and will be used as an initial condition to a new run of the atmospheric model. The satellite data can be used in one of two ways: the most traditional, using geophysical variables derived from vertical profiles, or by direct assimilation of the radiance (Joiner and Da Silva, 1998).

The main purpose of this study is to evaluate the impact of the assimilation of geopotential ATOVS (Advanced TIROS N Operational Vertical Sounder) retrievals on the analyses generated by RPSAS, and on the precipitation forecast generated by a frontal system that took place in the South region of Brazil in July of 2007.

The chosen frontal system started on the 9th of July and originated from a low pressure system in the state of Rio Grande do Sul. It then intensified due to a low level jet and a trough in medium and high levels, which gave support to the system at surface. By the coastline, this system went fast since Florianópolis-SC till Campos-RJ, where arrived on 12th of July. Due to its strength, anomalous precipitation totals were observed in its convective area and intense cold was also observed in the South of Brazil.

Data and Methodology:

Two experiments were conducted with RPSAS, coupled with Eta model, using a horizontal resolution of 20km. In the first, hereafter called ATOVS, conventional and geopotential ATOVS profiles were assimilated, from the 01st through the 31st of July of 2007. In the second experiment, hereafter called CONTROL, only conventional data were assimilated over the same period. The ATOVS profiles used in both experiments were obtained from the GTS (Global Telecommunication System) after using the Hydrostatic relationship.

NCEP analyses were interpolated for the Eta grid, after being processed by the global model CPTEC/COLA T213L42 to trigger its Physical packages.

With the RPSAS outputs some verification was performed:

A) The Mean Absolute Error (MAE) between the ATOVS and CONTROL analyses was calculated for the synoptic times of 00, 06, 12 and 18Z on the pressure surface layers of 850, 500 and 300hPa. In addition, the MAE was calculated for the mean of 00 and 12Z between NCEP's analysis over the same period, for the temperature, specific humidity, geopotential height and zonal wind fields. In the first case, the spatial distribution of MAE indicates the regions where the profiles' inclusion had the larger impact, although it does not indicate if there is improvement in the analysis quality.

B) The Analysis Impact Index (IP) was calculated for the ATOVS and CONTROL experiment analyses, taking NCEP analysis as the standard. IP was calculated using the formulation proposed by Zapotocny et al (2005) for forecasts and by Andreoli et al (2007) for analysis. The period used in the integrations was the 01st through the 31st of July, 2007, and the synoptic times were 00 and 12Z.

$$IP = 100 * \left\{ \left[\sqrt{\frac{\sum_{i=1}^N (CONTROL_i - NCEP_i)^2}{N}} - \sqrt{\frac{\sum_{i=1}^N (ATOVS_i - NCEP_i)^2}{N}} \right] / \sqrt{\frac{\sum_{i=1}^N (ATOVS_i - NCEP_i)^2}{N}} \right\} \quad (1.1)$$

This index indicates, as a normalized percentage, the positive/negative impact produced by the inclusion of ATOVS data on the same fields and levels of the latter analysis. Positive values show a closer relationship between the analysis generated by RPSAS (ATOVS experiment) and that of NCEP, while negative values indicate the contrary.

C) Analyses of precipitation forecast for 1 to 3 days, and subjective compares between ATOVS and CONTROL experiments data with observed data obtained from the INMET (National Meteorological Institute - Instituto Nacional de Meteorologia) observation net, for the period of 09 to 11 of July.

Results and discussions:

The verification based on MAE proves that the impact of assimilation of geopotential ATOVS heights is greatest at 06 and 18Z, except in the specific humidity fields (figures not shown). This fact is due to the larger number of profiles assimilated at those times (see Figure 1), which is a function of the satellite orbit (figure not shown). Thus, only the field states for 06 and 18Z will be presented for MAE.

Figure 2 shows the MAE values for temperature, zonal wind, geopotential height and specific humidity for the pressure levels of 850, 500 and 300hPa. It is possible to observe the regions where the assimilation of ATOVS profiles generates stronger impacts, in a monthly mean approach, in comparison with the CONTROL. Also it is observed that, except for the specific humidity, the impact was greater in high and medium levels.

Figure 3 presents the absolute difference between analyses from ATOVS and analyses from NCEP. This indicates the “mean accuracy” of the RPSAS, when it is assumed that the NCEP analyses represent the real, or perfect, state of atmosphere. The fields of geopotential and specific humidity are not shown.

When looking at the results for Analysis Impact Index (IP), it must be considered that they provide relative information. Figure 4 shows that, for the temperature field, there are negative impacts on North and South regions of Brazil, and on the adjoining Atlantic at 500hPa, and positive impacts in western Colombia and Peru. At 300hPa, positive impacts are seen over Northeast and North of Brazil, southeast of Argentina, and negative impacts over Southeast and South of Brazil, and on the adjoining ocean. For the zonal wind field, it is observed a negative impact over South and Southeast regions of Brazil and on the adjoining Atlantic, at 500 and 300hPa. Positive impact is observed northward of North

region of Brazil, also at 500 and 300hPa. In the geopotential height field, negative impacts are observed over Atlantic Ocean close to South and Southeast regions of Brazil, at 500 and 300hPa, and positive on Northeast region of Brazil and adjoining ocean, at 500hPa. For the specific humidity field, it is observed at 850hPa, negative impacts over Center-West of Brazil, Southeast of Brazil and adjoining Atlantic. Positive impacts are seen, at that pressure level, on the Northeast of Brazil.

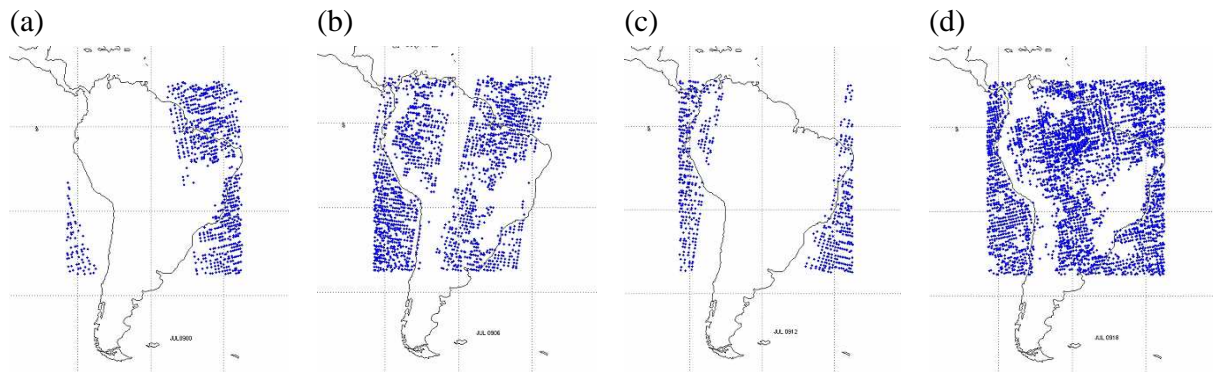


Figure 1: Typical distribution of ATOVS profiles along synoptic times for experiment ATOVS. (a) 09th, at 00Z. (b) 09th, at 06Z. (c) 09th, at 12Z. (d) 09th, at 18Z.

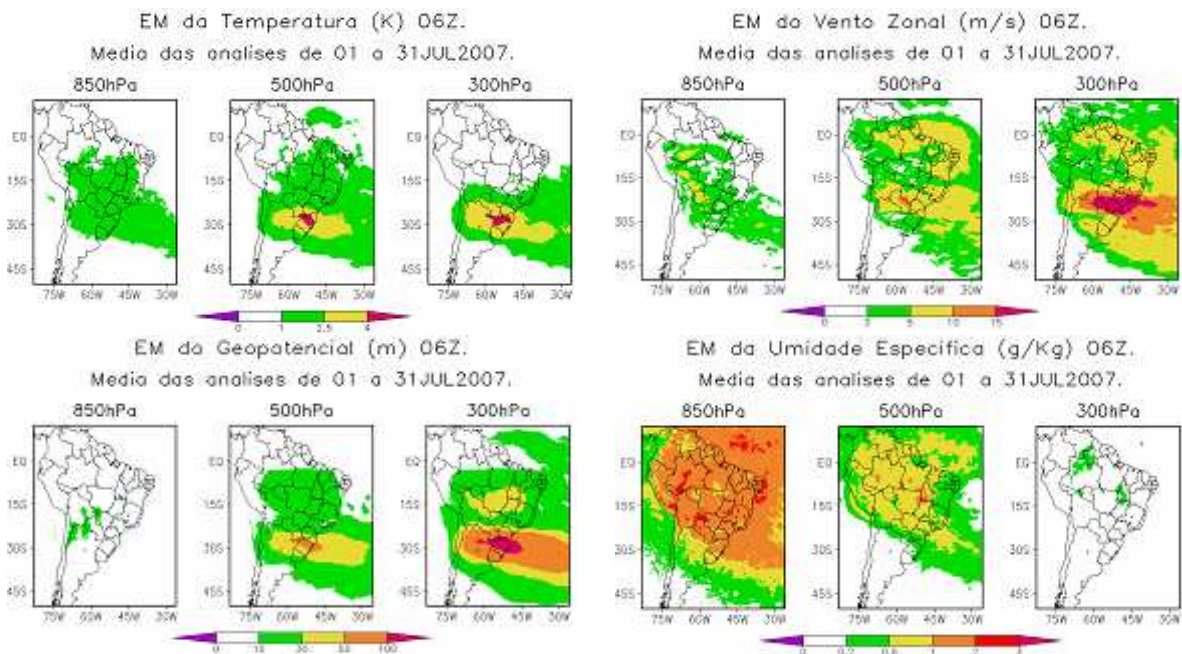


Figure 2: Mean Absolute Error for temperature, zonal wind, geopotential height and specific humidity fields for the synoptic time of 06Z (monthly mean for RPSAS analyses for the period of the 01st through 31st of July of 2007).

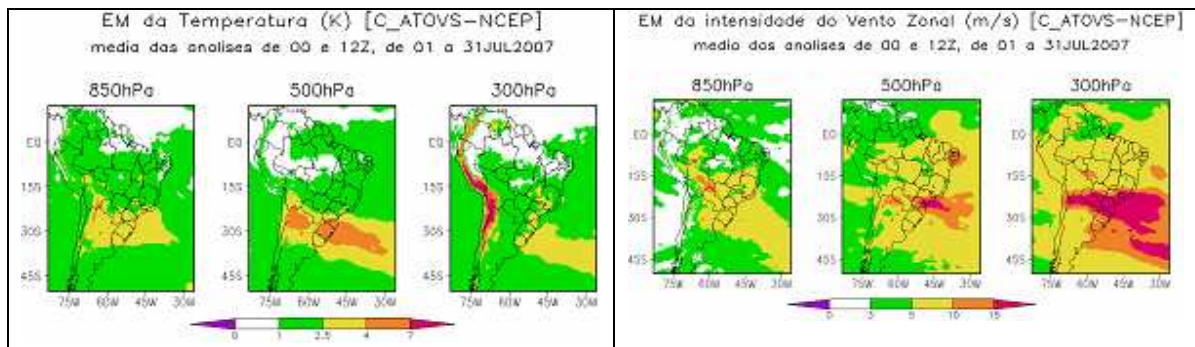


Figure 3: Mean Absolute Error for temperature and zonal wind fields. Mean for 00 and 12Z synoptic times averaged monthly for the period of the 01st through 31st of July of 2007).

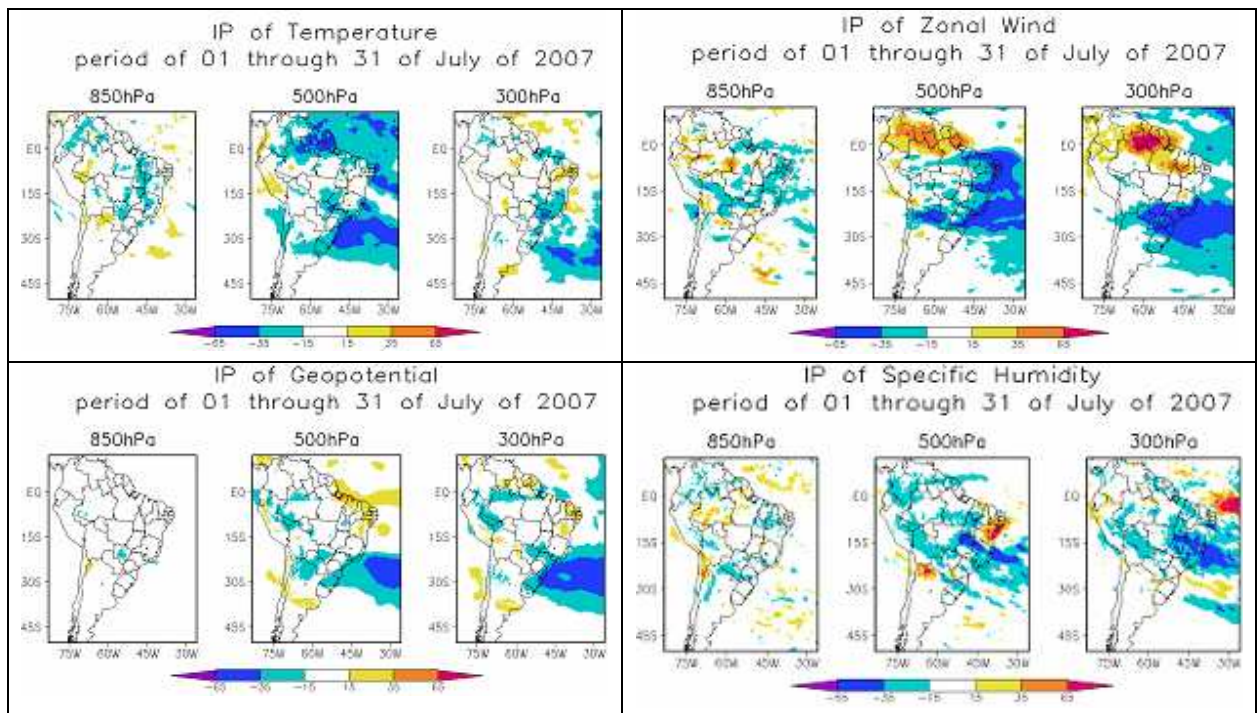


Figure 4: Analyses Impact Index for Temperature, Zonal wind, Geopotential and Specific Humidity fields. Improvements to analysis are showed in yellow, orange and red. Aqua and dark blue shows the opposite.

Figure 5 shows the precipitation forecasts for 24, 48 and 72h for the ATOVS and CONTROL experiments and the observed precipitation data for 10th of July for the South region of Brazil. Like the comparisons conducted for the 09th and the 11th (figures not

shown), the precipitation fields from ATOVS and CONTROL with observed precipitation (derived from SYNOP net) indicate that the inclusion of ATOVS geopotential profiles does not yield better precipitation forecasts. This can be attributed to the Eta model deficiencies in forecasting precipitation. For the period studied, 48h and 72h forecasts produced better results than 24h forecasts, which is an already operationally known response of the Eta model (Espinoza et al, 2002, 2004).

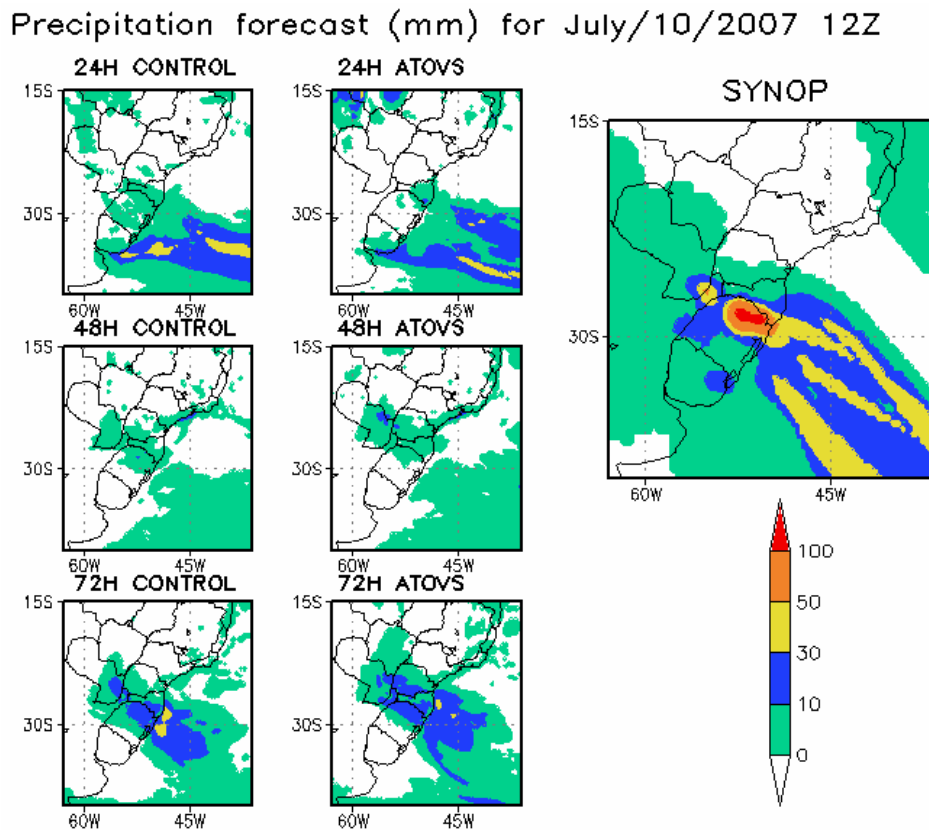


Figure 5: Precipitation Forecasts for 1-3 days generated by CONTROL and ATOVS experiments, and the observed precipitation field for the 10th of July of 2007 (data from INMET).

Final Comments and grateful:

This preliminary study suggests that, for the period of July 1st to 31st, 2007, the ATOVS data assimilation yields a significant improvement in a quality of analysis fields over much, but not all, of the domain of RPSAS. More diagnostic studies are needed to determine, with more confidence and accuracy, the impacts of ATOVS geopotential height data assimilated by RPSAS over South America. Further studies will also evaluate whether there exists a temporal dependence (monthly or seasonal) in the experiment's performance.

Further studies made by the Data Assimilation Group of CPTEC, in a form of Operational Research, suggested that the newer parameterizations of surface changes implemented to RPSAS implied a “spin-up” (time demanded for the system to be stabilized) of about two and a half months, because the boundaries conditions have been taken from Eta model instead of from global model CPTEC/COLA T213L42. This work was carried out using data processed within this spin-up period, and some care must be taken with analyses considered specially with humidity near the surface and other surface chances.

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