CPTEC ATMOSPHERIC MOTION VECTORS: VALIDATION, ASSIMILATION AND CHARACTERISTICS

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ABSTRACT

This paper briefly describes the algorithm and improvements and validation of the cloud drift winds (CDW) method running operationally at CPTEC/INPE. A new quality control method and new CDW retrieval method, using visible and 3.9 μm channel, are described. The data from the infrared and water vapor wind derivation scheme is monthly compared against the radiossonde in South America. The results show a close similar performance, as those obtained by others operational Centers, for winds at high tropospheric levels. A CDW assimilation test was performed at CPTEC Global model. The preliminary result shows a positive impact in the CPTEC CDW assimilation.

1. INTRODUCTION

Wind fields obtained through clouds displacement observed in geostationary satellite images are important tools in the data production for assimilation in atmospheric general circulation models.

CDW is operational at CPTEC/INPE since 1998, this is a version based in the routines developed by ESOC (Schmetz et al., 1993 and Laurent, 1993) and adapted for GOES images (Machado and Ceballos, 2000). These routines were improved, in 2000, by two main modifications: a clouds semi-transparency height correction, using a new simplified radiative transfer model and a space consistency test. The radiative model performance was evaluated using calculations line by line (Laurent et al., 2002). At nearly the same time, the CDW using the water vapor channel were developed and implemented operationally (Sakamoto, et al., 2004). This year two new version were developed, based in the visible and 3,9 μm channels to describe low level winds (Galante and Machado, 2006). The CDW from this new methodology were compared against NCEP data showing very good agreement.

The CPTEC/INPE CDW is calculated using three successive images, for wind computation and symmetric test. For CDW using Infrared channel, one additional water vapor image, at the central time, is employed for semi-transparent clouds height correction (Schmetz et al., 1986, 1993). The height assignment uses the temperature and moisture profiles provided by the CPTEC-AGCM.

The satellite data assimilation as input for the CPTEC forecast model is a fundamental point, mostly for our region where conventional data coverage is sparse. The use of operational routines to retrieval wind, temperature and humidity profiles, precipitation and other atmospheric parameters, enable a more realistic representation of the initial conditions CPTEC must prepare the initial conditions, blending the result of its own model with other parameters, such as conventional data and data extracted from satellite images. The CDW computed by CPTEC has higher time and spatial resolution than the information available at the GTS. Figure 1 presents an example of the CDW output, from GOES-12 water vapor channel, operationally at CPTEC.

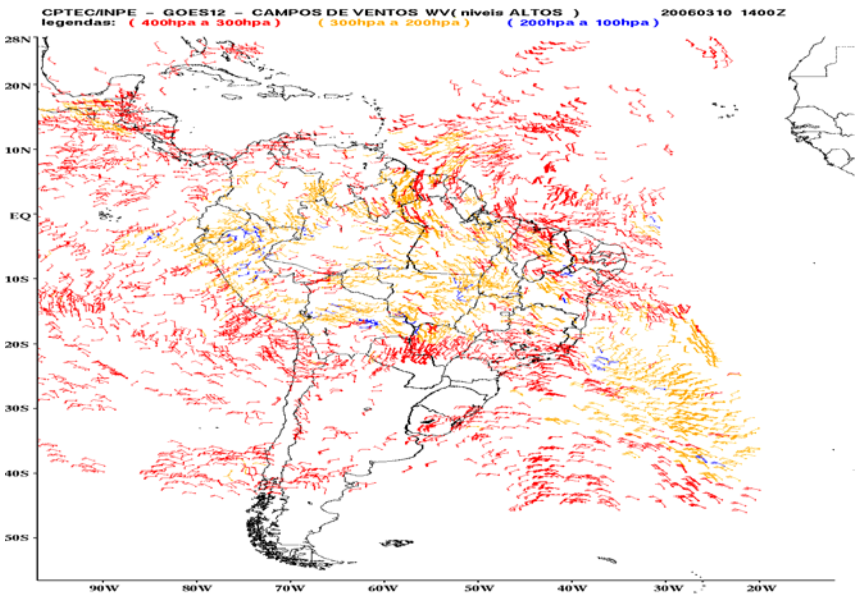

Figure 1- **Example of winds computed operationally at CPTEC. CDW computed for high levels using GOES-12 water vapor channel.**

2. THE CPTEC/INPE VISIBLE AND 3.9 μm CDW CHARACTERISTICS

Low level winds are important information to describe the dynamics of synoptic events. This information can be obtained by using the visible channel due to higher contrast, of clouds with the surface, than any other channel. Also, visible channel has high spatial resolution allowing the description of a detailed cloud field. However, during the night time, visible channel is not available and the more adapted channel to derive low level winds is the 3.9 μm, because it presents higher sensitivity to warmer temperatures and it is well adapted to discriminate Cirrus clouds.

A cloud classification (Bottino e Cebalos, 2003) is used to identify and eliminate middle and high clouds. These pixels are replaced by random values. Cloud Classification is based in cluster analysis and uses, during the daytime, infrared window and visible images and texture properties. During the nighttime, middle and high clouds are discriminated by using the infrared window threshold of 270K and Cirrus clouds are eliminated employing the difference between near infrared (3.9µm) and infrared window (10,7 µm) as suggested by Lee (2000). CDW were only computed when the target area to be tracked has less than 30% of random values.

The CDW were computed, for visible channel, using the same methodology employed in the infrared method. Many testes were achieved in order to define the best window size for wind computation. The 17 by 17 pixels area was considered the best window size to be employed due to the best ratio between numbers of winds computed and the number of winds rejected.

For the CDW calculation, using the near infrared channel, the target area has 32 by 32 pixels. The following qualities controls were applied: Symmetric test as described by Laurent et al. (2002) and Sakamoto e Laurent (2003). This test is based in the following equation:

$$\left|\overrightarrow{\mathrm{V}_2} - \overrightarrow{\mathrm{V}_1}\right| < \alpha_{sim} + \left|\overrightarrow{\mathrm{V}_2}\right| \gamma_{sim} \quad (1)$$

Where V_2 and V_1 are the CDW vectors computed 30 minutes before and 30 minutes after the central time, respectively. The α (2.0) and γ (0.15) values were adjusted considering the dynamic of low levels winds over tropical and subtropical regions, particularly over ocean regions where the majority of CDW are computed.

Another quality control routine applied to the data is the spatial consistency tests, which verify the spatial consistency of the vector field around its neighbors. It is applied after the vectors calculation because the wind field is necessary. For each vector the following relationships are verify:

$$\alpha_1 V(x) \leq \frac{1}{k}\sum_{n=1}^{k} V(n) \qquad (2)$$

$$\alpha_2 \leq \frac{1}{k}\sum_{n=1}^{k} Dif(n)\frac{1}{e^{qd_n}} \qquad (3)$$

Where:

V(x) is the wind speed of the computed vector.

V(n) are the n-th wind speed vector close to the computed vector V(x) (the search area is equal to 1,5 degrees).

Dif(n): is the absolute vector difference between the computed vector and the n-th vector.

d_n :is the distance of the n-th vector.

Obtained the best displacement, the corresponding correlation is calculated to analysis the quality in the target identification. If the correlation is lower than 0.60, the vector is rejected.

The wind vector height assignment is relatively complex, initially, because visible channel does not give any information about the cloud height, and also, because low level clouds moves preferentially by the winds in the cloud base and infrared channel gives information about the cloud top.

The methodology applied to assign infrared CDW height, considers that the pressure level of a given vector is the pressure level where the atmosphere temperature is equal to the cloud infrared brightness temperature. This information is obtained by using the temperature and pressure profiles from the CPTEC AGCM. However, as emissivity of the clouds is often lower than 1, a correction for semi-transparent clouds is needed. To use this well known “semi-transparency correction” (Bowen and Saunders, 1984, Schmetz et al., 1993) cloud radiances for clear sky are necessary for infrared (IR) and water vapor channels. Thus, it is calculated the average between the 20% colder pixels and the 10% hotter pixels in the calculation, using the radiative transfer model developed for this application (See Laurent et al., 2002).

However, for visible CDW, the height assignment is based in the methodology developed by Schmetz et al. (1996). This technique uses, for each vector, an infrared histogram computed over a region centered in the geographical position of the wind vector. This region had initially a size of 17 by 17 infrared pixels and a mathematical model (minimum square polynomial adjust) try to find two maximum representing the two pixels population corresponding to the signature of the surface and low clouds. If these the search of these two maximum is not achieved, the area is increased by 2 pixels and the histogram is again computed. This procedure is applied up to the time when the two maximum is found or the searched area reaches a size larger than 100 by 100 pixels, and in this case the wind vector is discarded. Figure 2 illustrated the histogram computed to set up the CDW height assigned.

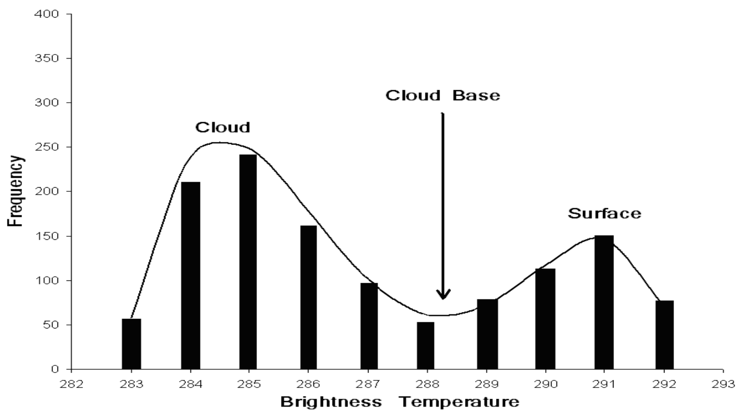

Figure 2: **Schematic view of the histogram computed for height assigned.**

The cloud base is defined automatically as the point of minimum in the histogram. The brightness temperature is transform in cloud base height by using the CPTEC model output to define the CDW height.

Figures 3 and 4 present an example of the Low level wind computed using GOES-12 images.

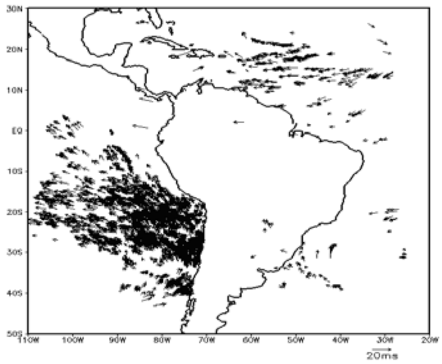

***Figure 3*: Low level winds computed using GOES-12 visible channel, for the day 24 March 2005 at 1522 Z**

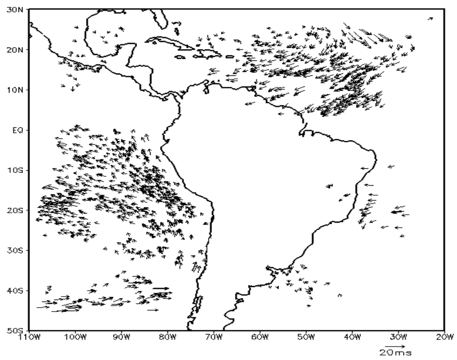

***Figure 4*: Low level winds computed using GOES-12 3.9 μm channel, for the day 24 March 2005 at 01:22Z**

3. CDW VALIDATION.

The low level winds computed using visible and 3.9 μm channel were validated against the NCEP data for the days 21 to 25 March 2005. This preliminary result shows reasonable quality of the winds extracted by the two channels.

	RMS Vector (m/s)	Bias Vector (m/s)	RMS speed (m/s)	Bias Speed (m/s)	Number
Only Visible	4.76	0.43	3.79	-0.11	6924
Only Near Infrared	5.13	0.89	3.71	-0.42	6580

***Table I* – RMS and Bias for the CDW calculation using GOES-12 visible and near infrared channels for the days 21 to 25 March 2005 compared with NCEP dataset.**

The Infrared and water vapor CDW are computed operationally at CPTEC since 2000 and an evaluation against the South America radiossonde network is performed since January 2004. Figure 5 presents the radiossonde stations available for the evaluation tests.

Figure 5 **– Shows the radiossonde station available for evaluation of CDW.**

Different statistics are computed for the evaluation but this study presents only the speed BIAS and the vector RMS. Both information are computed as:

$$BIAS = \overline{V_e} - \overline{V_r} \qquad (4)$$

Where $\overline{V_e}$ corresponds to the average estimated wind and $\overline{V_r}$ is the observed Wind.

$$RMS = \sqrt{\frac{\sum_{i=1}^{N}(u_e - u_r)^2 + \sum_{i=1}^{N}(v_e - v_r)^2}{N}} \quad \ldots(5)$$

Where u_e,v_e,u_r and v_r are the zonal and meridional components of the wind estimated and observed by radiossonde respectively. The observed wind vector is obtained by the closed radiossonde station in the 150 km neighborhood and a maximum time interval of one hour. The wind vector is interpolated to the CDW pressure level.

Figure 6 shows the statistics obtained for the infrared window and water vapor channel for high and levels.

One can note that infrared winds has a slight smaller RMS than those winds computed using water vapor channel, it is probably due to better height assignment, because CDW infrared window uses the semi transparent correction and the water vapor doesn't.

Besides the development of the CDW using visible channel, a new spatial consistence test was improved as described in section 2 (Equations 1 to 3). This new test was also implemented in the operational infrared and water vapor CDW method, using $f(x) = \frac{1}{e^{qx}}$, where x is the distance between the actual vector been tested and the others vectors inside a region of 1,5 degree and *q* is equal to 1,83. The q value was adjusted in the way that vectors far than 0,5 degrees will have a weighted function smaller than 40%. This new test was implemented in the operational version and a comparison was performed for January 2006 (See Fig. 7). The results show an improvement in the vector and speed RMS. Therefore, we expect that the operational CDW will increase its performance in despite of the smaller number of vectors retrieved at the end of the quality control process.

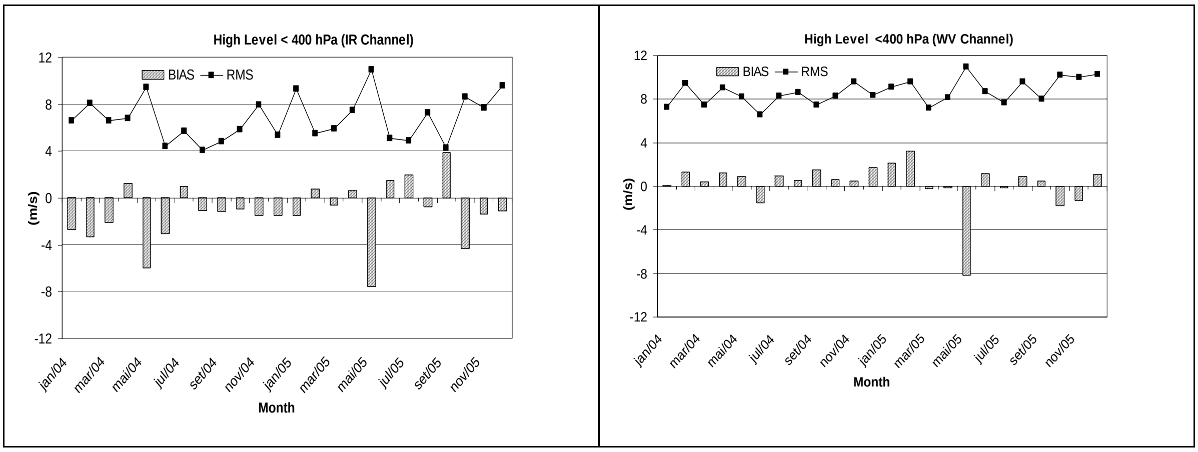

Figure 6 **– RMS and BIAS for High level winds computed for GOES-12 infrared and water vapor channel.**

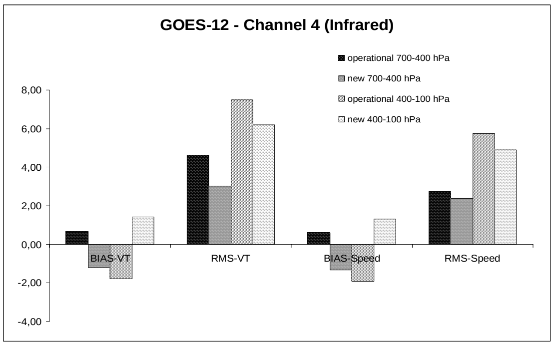

Figure 7 **– Evaluation of the infrared CDW using the new spatial consistency test for, January 2006.**

4. INCLUSION OF CDW IN DATA ASSIMILATION SYSTEM.

The CPTEC-GPSAS system (see Ferreira, 2004 for a detailed description) is an adaptation of the Physical-Space Statistical Analysis System (PSAS) (Guo et al., 1998) of the GMAO with the Spectral Atmospheric Global Circulation Model CPTEC/COLA (AGCM). In this system, analysis fields are produced by PSAS in a cyclical process that integrates a short time forecast field (first-guess) from AGCM and different kinds of observed data (Conventional data and ATOVS retrieval data). This analysis field is used in AGCM as an initial condition to produce weathers forecasts and first-guess for the next cycle. Most recently, cloud drift wind data (CDW) are being included in the GPSAS cycle to improve the quality of analysis and forecasts.

One part of this data is available through IDD (Internet Data Distribution) and is produced by JMA (Japan Meteorological Agency) and NOAA (National Oceanic & Atmospheric Administration). The other part of this data is produced locally at CPTEC Satellite Division. The figure 8 shows the coverage of each data source.

4.1 – IMPACT OF CDW IN DATA ASSIMILATION SYSTEM

The preliminary tests with CDW in GPSAS have shown that CDW improves the representation of eddies, troughs and ridges. Because of pressure-wind balance the CDW not just affected winds field but also the representation of geopotential height and sea level pressure fields. As an example, figure 9 shows an analysis of GPSAS and observed wind data over South America. This Figure shows that geopotential height isolines have good coherence with CDW and radiosonde winds. It well describes the troughs at 20S/40W, the height pressure center in the Pacific Ocean (at 35S/97W) and the Cyclone in the Atlantic (at 45S/45W). The figure 10 represents the analysis of GPSAS at same region and date, but without CDW data. In this case, the trough in the Atlantic was not represented. The aspect and position of the height pressure center at the Pacific and Cyclone in the Atlantic has been modified. It’s a good example of how important is the impact of high resolution CDW data can be in such a region. It’s important to note that these figures just represent the initial condition. Inside of AGCM the impact of CDW in weather forecasts can be greater. In means terms, the bias errors decreased 41% in analysis and 50% in first-guess at 850hPa. In 48 hours of weather forecast the position of precipitations was also better predicted.

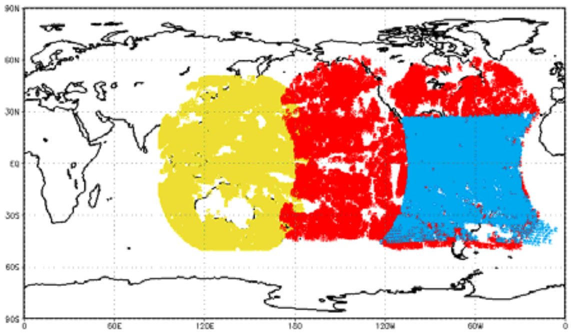

Figure 8 **– CDW data assimilated in GPSAS on October, 10th 2005: a) from JMA (Yellow), b) from NOAA (read), c) from CPTEC-DSA (blue) (overwriting part of NOAA data)**

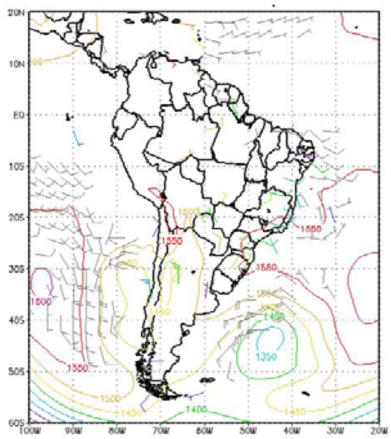

Figure 9 **– GPSAS Analysis of Geopotencial Height at 850 hPa (isolines) and observed winds assimilated by GPSAS from radiosondes station (barb if colors) and CDW (gray barb)**

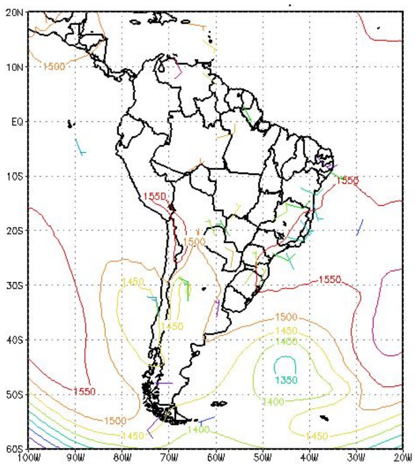

Figure 10 **– GPSAS analise of Geopotential Heght at 850 hPa (isolines) and radiossondes winds assimilated by GPSAS**

4.2 – QUALITY CONTROL ASPECTS

The PSAS performs a statistical quality control that compares each item of suspected observed data with neighboring data. The process excludes data that is probably incorrect or does not represent synoptic characteristic. During October of 2005, a total of 19.976 CDW data from CPTEC-DSA was introduced in GPSAS system and just 7% was rejected by the quality control. It's a good performance if we consider that data coverage includes an extensive irregular topography area in South America. The NOAA CDW data and JMA has better results (1% for rejection), but most part of this data was from ocean. On the other hands the winds data measure by radiosonde stations is undoubted very precise. Even though 5% was reject. Therefore, 7% of CDW data rejects can be considered a good result in terms of quality control.

5. - CONCLUSION

This paper presents the evaluation and news improvements in the operational CDW running at CPTEC/INPE.

The new visible and 3,9 μm channels CDW were developed to describe the low level winds field. The results show that the CDW evaluation has a considerable performance and will probably be very useful for data assimilation.

The evaluation of the infrared and water vapor channel CDW also shows a reasonable performance and this evaluation will have a better performance when the new spatial consistence test will be implemented operationally.

Related to the assimilation processes at the moments, more tests with CDW in GPSAS are been doing for operational use. The plans for the near future include the massively use of CDW data, at higher spatial and time resolution, in GPSAS and RPSAS (Regional PSAS) system, and the expansion of CDW coverage areas to Africa region, where other winds data are not available. These plans include the distribution of CDW data through GTS (Global Telecommunication System) and IDD system (Internet Data Distribution) in BUFR format (Binary Universal Form for the Representation of meteorological data).

6 – ACKNOWLEDGES

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