SATELLITE-BASED PRODUCTS FOR MONITORING WEATHER IN SOUTH AMERICA: WINDS AND TRAJECTORIES.

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Abstract

The Brazilian Center for Weather Forecasting and Climate Studies (CPTEC) performs operational numerical weather prediction, running a GCM (CPTEC/COLA) and a regional model (ETA). Meteorological data are excessively sparse over the Southern Hemisphere so additional data sets are recommended, in order to enhance the quality of results over South America.

Full resolution satellite imagery from Goes-8 is currently detected and processed by the Brazilian Institute of Space Research. A series of products are in development and tests, aiming to provide operational meteorological information both for general users and for ingestion in circulation models. The products that will be described are:

a) Cloud drift winds over South American sector between 90W and 30W, 20N and 45S, assessed from low, middle and high level cloud detection. A procedure originally applied to METEOSAT images and developed by ESOC, was adapted for Goes 8. All procedures will be described, from the image reception up to the last manual quality control. Preliminary results show the quality of the winds obtained by this method

b) The trajectories of convective systems over the South American sector between 90W and 30W, 20N and 45S, to provide information for nowcasting. The convective system is followed in successive images through the similarity of the radiative and morphological properties The information available from the cloud tracking routines are: direction and velocity of propagation, size of the convective system, life cycle stage and tendency (decay, unchanged, developing)

1 – INTRODUCTION

This paper briefly describes the Brazilian state of art in the cloud drift wind (CDW) and convective system trajectories obtained from satellite imagery.

The CDW operational in CPTEC is a simplified version of the routines developed by ESOC (Schmetz et al. , 1993 and Laurent, 1993). These routines were initially prepared to extract CDW from successive METEOSAT-3 images (Atlantic subsatellite position) and METEOSAT-5 images. CDW was calculated using three Infrared images (IR), for wind computation and symmetric test, and one Water Vapor (WV) image for semi-transparent clouds height correction (Schmetz, 1986, 1993). A dry and a wet tropical atmosphere were defined to be used to assign cloud height The CDWs obtained from METEOSAT were compared with NCEP analysis (Laurent and Machado, 1994) and with radiossonde data from a Brazilian Experiment in Northeast Brazil (Sakamoto et al, 1996). The deactivation of METEOSAT-3 and the encryption of METEOSAT data interrupted the studies of CDW using METEOSAT. In 1997 CPTEC acquired a GOES full resolution reception station. The algorithms were adapted to GOES image channel four to produce CDW (Machado et al. 1998). GOES-CDW height assignment uses the temperature and moisture profiles provided by the CPTEC-GCM. The routines for semi-transparent cloud height correction are still being adapted to the new characteristic of the GOES radiometers. The final CDW quality control is a subjective analysis done by the operator. Then, CDWs are coded in a SATOB message ready to be assimilated by CPTEC models. The impact of this new data set in the analysis cycle is being studied.

An automated method for tracking mesoscale convective systems (MCS) from successive satellite images is an important tool for characterizing the behavior of this phenomenon and for nowcasting. Machado et al. (1998) present a tracking methods based on the similarity of morphological and radiative properties. The method can be used automatically setting up the criterions of similarity between MCS in different images. Machado et al. (1998) show that the small differences in most MCS statistics obtained with different tracking method (different criterious of similarities) indicate that most features of MCS life cycle are well determined, even with a simple tracking procedure based on the areal overlap. Several studies analyzed the life cycle of MCS using “manually” tracking procedures (Martin and Schreiner, 1981) or automated procedures (Williams and Houze, 1987). An operational version adapted from the “climatology” tracking procedure developed by Machado et al. (1998) to run using full resolution GOES images is being tested in CPTEC. This operational version will be used for nowcasting supplying MCS speed and direction of propagation, life cycle stage and an estimation of the total life cycle duration.

2 – EXTRACTION OF CLOUD DRIFT WIND FROM SATELLITE IMAGERY

2.1) Wind Vector Derivation

The CPTEC reception station (Seaspace running the Terascan software) pre-processes the image before the ingestion in CDW routines. This step is based on scripts programmed in Terascan language. The pre-processing system automatically does the follow tasks: 1) imagery navigation (pixel localization) and calibration (count to physical units) and 2) preparation of two subsets of image each 30 minutes (if available): a) the north sector covering the region 20°N to 20°S and from 30°W to 90°W, based in the extended north hemisphere and full disk image and b) the south sector covering the region 20° S to 47°S and from 30°W to 90°W, based in the South South Hemisphere and full disk image. North sector has 2564 columns and 1074 rows and South sector has 2390 columns and 550 rows.

The operational system uses three sequential infrared (channel 4) images to compute the CDW for t_0 e $t_0 +\Delta t$ (for CDW) and for t_0 e $t_0 - \Delta t$ (for quality control), Δt is at least 30 minutes. CDW is estimated by the smallest Euclidean distance between the brightness temperature value of images segments of 32x32-pixel area in both time steps. The segment in time t_0 searches the smallest Euclidean distance in a window of 96x96 pixels in $t_0 +\Delta t$.

2.2) Quality Control

Several quality control procedures are applied to the data. The main vector rejection procedure uses a temporal consistency check (symmetry test, Schmetz et al. 1993). Two wind vectors are computed using the images at time t, $t +\Delta t$ and $t–\Delta t$. The difference between these two vectors can not exceed a threshold. This threshold increases as the velocity increases (Schmetz and Nuret 1987) and is defined as smaller than 5+Vel*0.20 (m/s). Further quality control procedures are as follows: a) wind vector is rejected if correlation is low (<0.5). b) Weak winds (speed less than 3.0 m/s) are rejected, mainly to avoid lee cloud or surface tracking. c) Wind vectors in the boundary of the analyzed window are also rejected. The last quality control is an interactive visual check that allows to reject wind vectors by the analysis of the wind field consistence.

2.3) Height Assignment

The pressure level assigned to CDW is defined as the level in which the atmospheric temperature reaches the average brightness temperature of the lowest 20% colder pixels of the 32x32 pixels segment. The atmospheric temperature profiles are obtained from the CPTEC-GCM forecast for 6, 12 and 18 hours. The majority of the errors in height assignment occur for semi-transparent clouds. Corrections of the cloud height assignment, for this case, are possible using multichannel observation and a radiative model (Schmetz et. al, 1993). These routines were designed for METEOSAT; they are still being adapted for the spectral characteristics of the GOES radiometers.

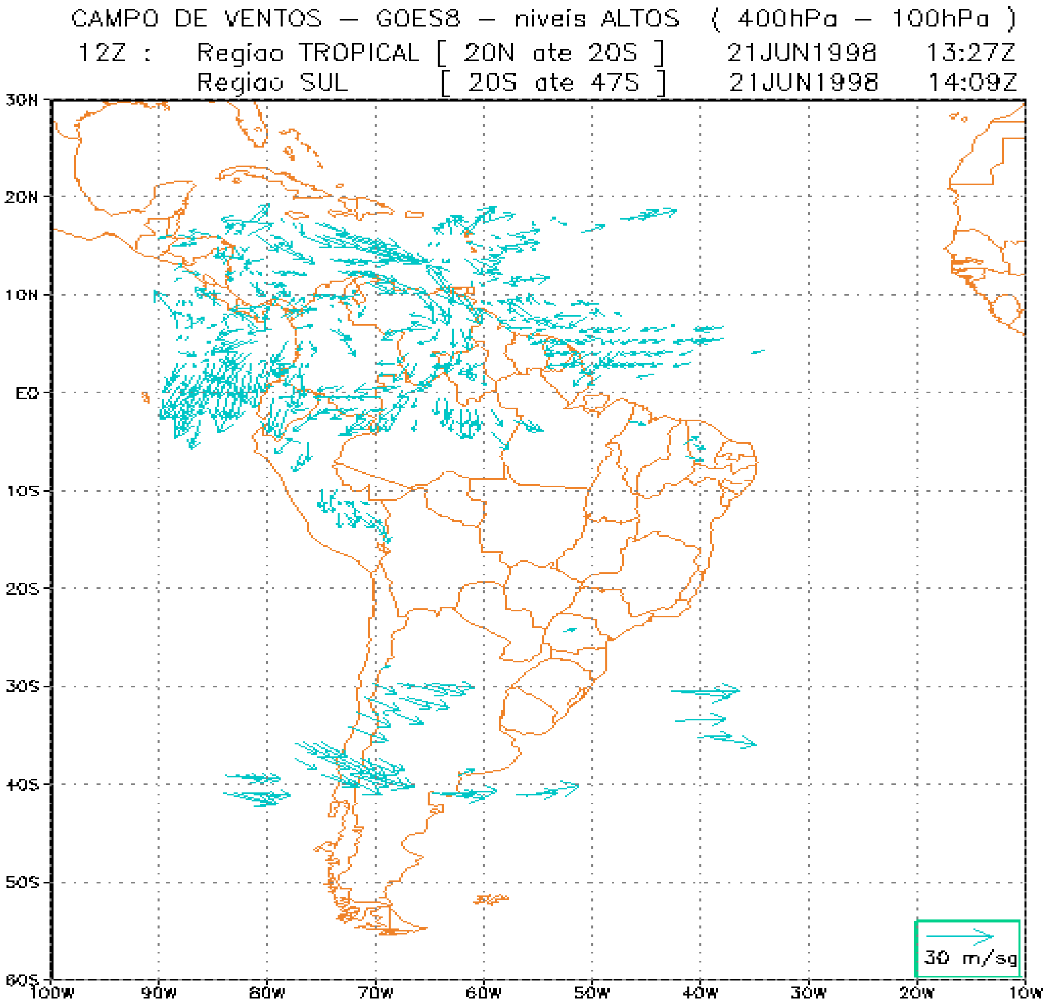

Figura1: An example of the high level CDW obtained in CPTEC in 21 June 1998 at 12Z.

2.4) Final product

The wind vectors obtained with this methodology are coded in SATOB message to be ingested in the ETA and GCM. This process is being tested for evaluating the impact of the CDW in the analysis cycle. Figure 1 presents an example of the high level CDW operational in CPTEC .

3) COMPARISON BETWEEN CDW AND RADIOSSONDE WINDS

The most important verification of the quality of CDW was performed with the data from the EMAS-1 (Mesoscale Experiment of the Atmosphere of Drought area – rain season). EMAS-1 was realized from 24 March to 05 April 1995 in Northeast Brazil. During 13 days 171 radiossondes were released from three points (Fortaleza, Barbalha and Campina Grande). Winds derived from the cloud motion observed by METEOSAT-5 images were compared with radiossonde-measured winds. The results indicated that wind fields derived by satellite match very well the tendency of radiossonde data, in direction and velocity (Sakamoto et al. 1996). Bias (BIAS) and root mean square error (RMS) were calculated following the same methodology employed by Kitchen (1989), i.e. considering the RMS associated with the difference in time (4 m/s) and location (7 m/s) between CDW and radiossondes. The BIAS and RMS were computed for two sets of calculations, one using the standard tropical atmosphere and another using the measured radiossonde to assign cloud height. The BIAS and RMS from these two sets of calculations are show in Table I.

Table I – Bias and RMS for two sets of calculations: a) using standard tropical atmosphere and b) using the profiles measured by the radiossondes. Values obtained for EMAS-1

BIAS Tropical atmosphere	**BIAS Radiossonde profile**	**RMS Tropical atmosphere**	**RMS Radiossonde profile**
1,83	**1,58**	**7,7**	**6,23**

The calculated BIAS and RMS are comparable to those ones obtained by other studies (cf. Schmetz et. al. 1993) and the results show that part of the errors are associated with poor description of the temperature and humidity profiles. The procedure to assign wind level is very sensitive to the type of vertical profile used. The comparative results are better when using local soundings instead of the standard tropical atmosphere. Sakamoto et al. (1996) also showed that the CDW describes very well the radiossonde wind field and the errors are mostly a consequence of wrong assignment of wind levels. In addition to the poor description of the atmospheric profiles (for the actual CDW using GOES the profiles are obtained from the GCM forecast), the definition of cloud top by the coldest 20% pixels is not very precise. Figure 1 presents the zonal wind component (the most important component) obtained from radiossonde and by satellite for the Barbalha station. We can see that the CDW obtained by satellite matches very well the tendency of the radiossonde data. However, mainly in the second part of the Experiment errors clearly increase. Comparisons were also performed in a different way, searching the radiossonde wind vector most similar to the CDW within a 200 hPa layer around the assessed cloud top height. Figure 2 presents the measured zonal components and those computed as described above Very good agreement is observed between radiossonde and satellite winds. This figure also shows the differences, in pressure, between the levels of the radiossonde data chosen and those assessed by the satellite.

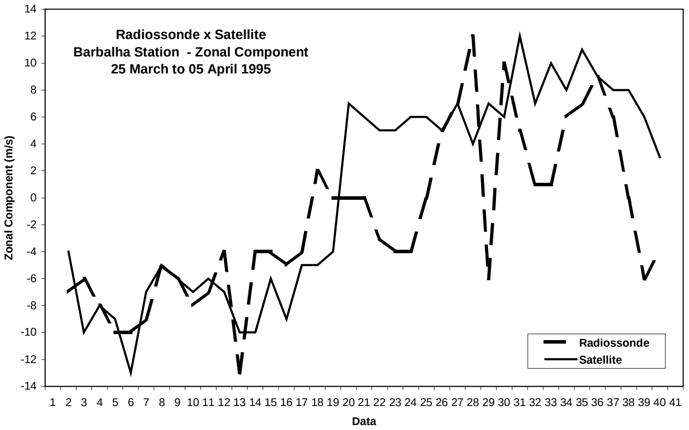

Figure 2: Comparison between zonal component measured by radiossonde and estimated by satellite, for Barbalha station during EMAS-1

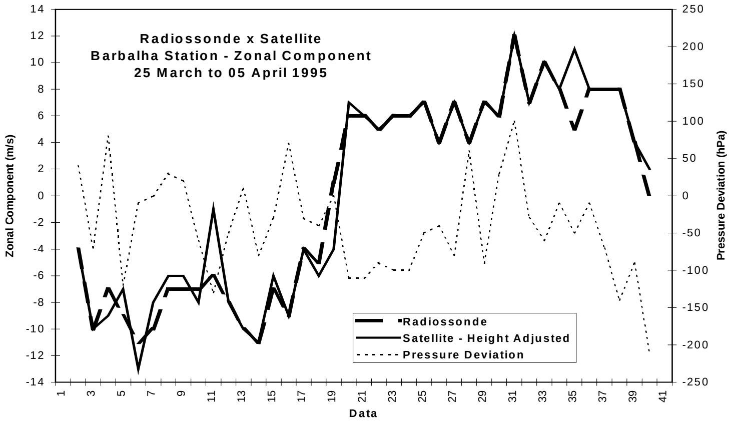

Figure 3: Comparison between zonal component estimated by satellite and the more similar zonal component measured by radiossonde closer to the level assessed by satellite (Barbalha station, during EMAS-1). The difference in pressure between the level assessed by satellite and the level of radiossonde zonal component chosen is also shown.

4) TRAJECTORIES OF MESOSCALE CONVECTIVE SYSTEMS

MCS are identified as all the pixels whose infrared brightness temperature are colder than 245K, and convective cells (CC) merged inside the MCS are those with brightness infrared temperature colder than 218K (Machado and Rossow 1993). With this information, two boolean matrixes are built and a methodology developed by Machado et al. (1992) is applied to isolate individual clusters of pixels, MCS and CC. Every CC locations are compared with the MCS locations to identify and count the number of CC embedded within each MCS. The size and center of mass of each MCS and CC together with the pixel values of brightness temperature are used to calculate a series of morphological (for instance eccentricity and fragmentation, see Machado et al. 1998) and radiative parameters (for instance variance, average and minimum brightness temperature).

The characteristics of each MCS in subsequent images are used in order to identify and track individual MCS through their life cycles. Different procedures ("manual" or automatic) can be used to determine a match of the same system in a pair of images. A tracking method allows to make two decisions: 1) if at least one candidate (one MCS in the subsequent image around the position of the MCS in the previous image) is available in the subsequent image, the procedure must decide whether the match is good enough to continue the time sequence or whether the sequence should be terminated (minimum match criterion); 2) if more than one candidate is available meeting the minimum criterion, the procedure must detect a single candidate which follows the sequence (best match criterion). For the operational version, we are using a single parameter to determine both the minimum and the best match criteria. The parameter used is the areal overlap; the best criterion is simply the maximum areal overlap and the minimum criterion is based on the time interval between successive image and the maximum velocity of propagation of MCS (in this case defined as 20 m/s).

5) RELATIONSHIP BETWEEN MEAN TRAJECTORIES AND AVERAGE WIND FIELD

The tracking method was applied to GOES-East ISCCP-B3 images (International Satellite Cloud Climatology Project) during July 1987 to June 1988 to study the distributions and life cycle behavior of the larger MCS (radii larger than 100 km) over the Americas. Based on these resulting statistics, seasonal charts were drawn to describe the mean direction of MCS propagation (arrow direction) and the mean MCS lifetime (arrow length). Figure 3 shows the result of this analysis for each 5^{0}x5^{0} region during the boreal summer and winter. The mean MCS propagation directions resemble the upper level large-scale circulation pattern. During the winter, the mean MCS trajectories indicate a prominent anticyclone circulation pattern (the Bolivia High) that is present mainly during the warm season.

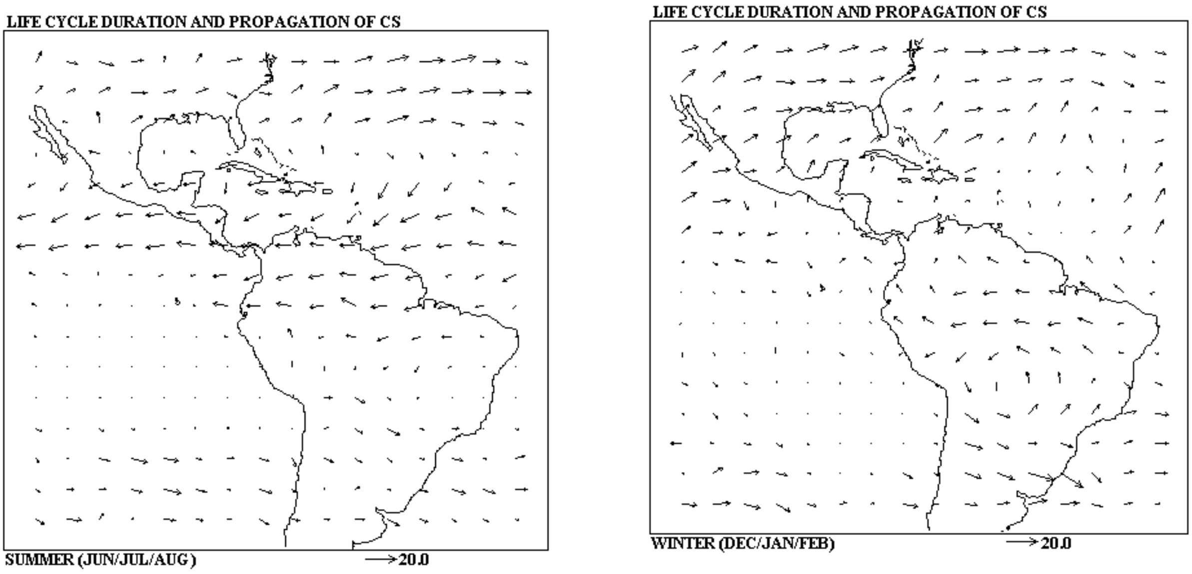

Figure 4: Average lifetime in hours (arrow length) and average direction of propagation (arrow direction) of MCS during boreal summer and winter.

6) OPERATIONAL PRODUCT

Machado et al. (1998) showed that: a) the areal time rate of expansion (AE) can be used to diagnostic the stage of development of the MCS and b) the initial value of AE might be used as a predictor of the peak size and duration of the MCS. The development of a tracking version to be used in Operational Centers can be a very important tool for nowcasting. The information about the AE (actually it corresponds to the high-level wind divergence) and the velocity and direction of propagation of the MCS assembled in a chart (see Figure 4) can be very useful for weather forecast.

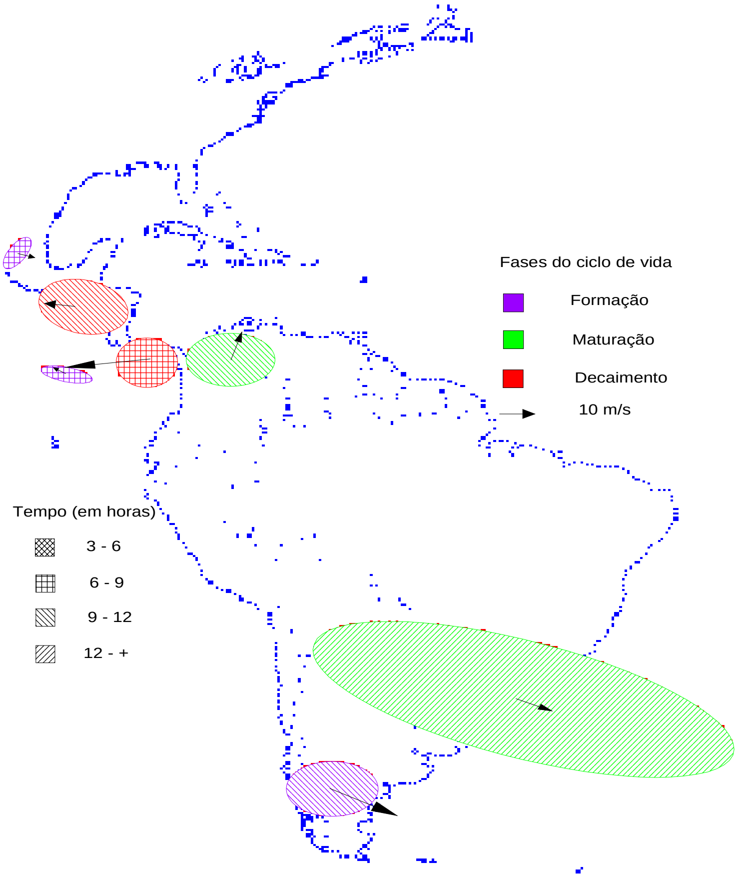

Figure 5: Prototype of the operational MCS tracking .

7) SUMMARY

The cloud drift winds are very important for weather prediction mainly in South America. This technique has been employed since 1994, aiming to provide operational meteorological information both for general users and for ingestion in circulation models. This work describes the method used in CPTEC to compute CDW. The verification of the quality of CPTEC-CDW shows a good agreement between radiossonde and winds extracted by satellite. Using data from a meteorological Experiment we have concluded that the main problem is the height assignment of the winds vectors extracted.

A methodology of cloud tracking is proposed to be used for nowcasting. The mean MCS propagation directions resemble the upper level large-scale circulation pattern. The use of the areal time rate of expansion provides an indicator of the stage of development and the initial rate can be used as a predictor for the lifetime duration of the MCS.

Current and future studies are being directed towards understanding the relationship between CDW and MCS trajectories. Preliminary results show, for the Amazon region, that small systems follow the large-scale circulation and larger ones moves against the circulation. Another subject of study is the comparison between upper level wind divergence obtained by CDW and the areal time rate of expansion.

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