A tool to detect inner cloud top dynamics of deep convective system

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Abstract

The knowledge of deep convective system formation process is a key feature in climate change and nowcasting. However the inner flows at the top of deep convection towers are not well understood due to several uncertainties linked to the dynamic itself. The new technique described in this study had been developed to extract concrete information about such features. This could help clarifying ring and U/V structures in deep convection and be potentially useful in nowcasting application. Indeed, the use of high resolution NWP models, which now include explicit microphysical processes, requires data assimilation at very high resolution as well. An usual atmospheric motion vector tracking algorithm has been applied to pair of images composed by combinations of Spinning Enhanced Visible and Infra-red Imager (SEVIRI) infra-red channels. Several ranges of channel differences were used in the tracking process, such intervals being expected to correspond to specific cloud top microphysics structures. Various consistent flows of motion vectors with different speeds and/or directions have been extracted at the same location depending on the channel difference intervals used. These differences in speeds/directions can illustrate local wind shear situations, or correspond to expansion or dissipation of cloud regions that contain specific kind of ice crystals or droplets. Comparisons of the results against European Centre for Medium-Range Weather Forecasts (ECMWF) forecast profiles allowed identifying situations for which the direction and speed differences describe wind shear situations. A comparison with radar measurements from Cloudsat project was done to correlate wind shear situations to vertical cloud structures.

1. Introduction

A cloud drift wind technique has been adapted to be used for the detection of microphysical properties of deep convection clouds. This new technique uses combinations of Meteosat 8 infra-red channels to select only some specifics components of the clouds (droplets or ice crystal of different size and shapes). Comparison between the Atmospheric Motion Vectors (AMV) obtained by this technique against forecasts of European Centre for Medium-Range Weather Forecasts (ECMWF) global model showed some situations for which the model wind is in good agreement with the AMV extracted from channel difference technique. A comparison with radar data from Cloudsat project was done, looking if the directions differences was associated with developing deep convection areas.

2. The technique

The new technique aims to detect the microphysical movements inner the deep convection cloud's top. It assumes that the combinations of infra-red channels pairs of Spinning Enhanced Visible and Infra-red Imager (SEVIRI) allow to isolate specifics cloud components (droplets of different sizes or ice crystals of different shapes) and then to track the displacement of these “structures”. The difference between two channels (for ex. 3.9 μm – 7.2 μm) gives a new image where each pixel represents a bright temperature difference (BTD). A sub range of the entire BTD range is used (for example from -12 K to -8 K) to select specific feature and the tracking algorithm is applied only on the selected pixels. Pixels having values out of range receive a random value. Only target windows having more than 25% valid pixels are used. Small target window sizes, 8, 10 and 12, have been tested, however, the results presented below consider only window size equal to 10. The Figure 1 show a example of a same area using target windows with dimensions 10x10 and 8x8 and 25% overlap in both cases. We have a little more detail when 8x8 is used but the field became more noisier too. The algorithm used for tracking was adapted from the *Centro de Previsão de Tempo e Estudos Climáticos do Instituto Nacional de Pesquisas Espaciais* (CPTEC/INPE) scheme (Negri and Machado, 2008).

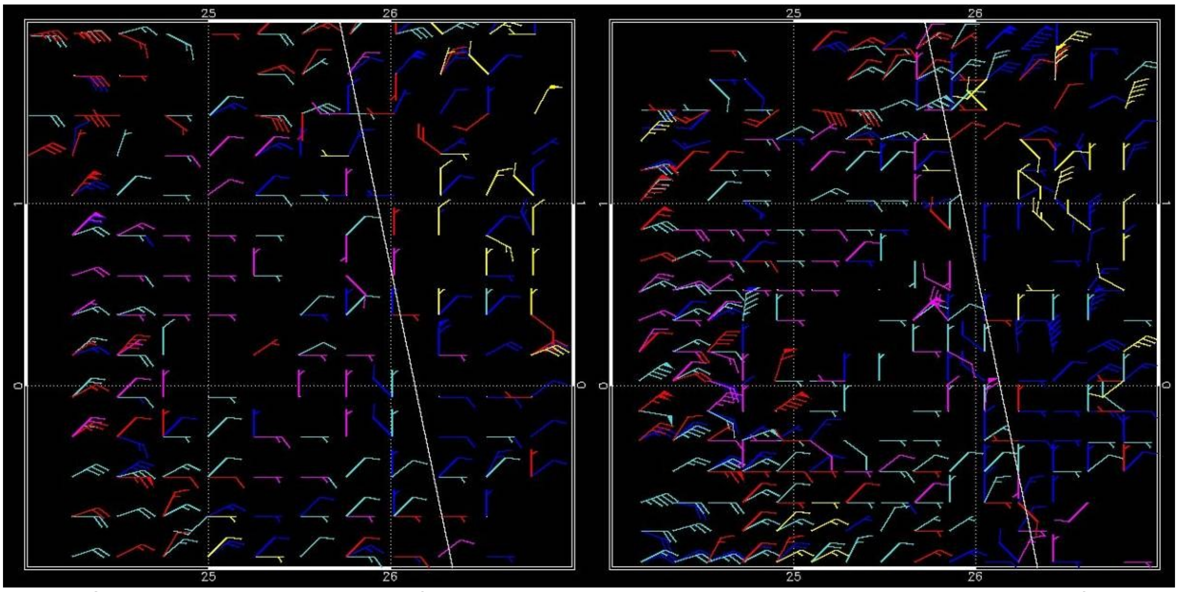

Figure 1: **Comparison between the wind field resulting when using target windows with sizes 10x10 (left) and 8x8 (right). Vectors blue and light blue are 6.3 µm and 10.8 µm respectively. Other colors as difference ranges, yellow is 5 to 12 K, pink is -5 to 2 K, red is 0 to 7 K.**

The tracking algorithm developed uses the assumptions below:

- No height assignment method is used, until now we not defined how this can be done.
- It uses only a pair of images. The time scale of these kinds of movement is very short, then it does not make sense to use a third image to have a time consistence of these motions.
- A small target window is used. Values between 8 and 14 pixels have been tested and a size of 10 pixels was chosen.
- The process authorises the considered target window to have an overlap with the neighbouring windows. Several overlaps were tested and a value around 25% has been chosen. In a target window of 10x10 pixels 20%, correspond to 2 rows of pixels.
- A range of values of the bright difference is chosen. Until now we don't defined which channel combinations we can use to search a specific cloud component. A study is currently being done in this issue at CPTEC/INPE. The current study only focuses on the possibility to track cloud structures in the meso-scale.
- All pixel out of the temperature difference range in the target window are set to a random value. These pixels do not participate to the correlation process.
- A minimum amount of valid pixel (the value is inside the chosen range of temperature difference) is required to allow the target window to be used. If this condition isn't satisfied, the vector is rejected. The minimum value of valid pixels is set to 35% of the pixels within the target window.

3. EUMETSAT analysis

A squall line observed in 03 August 2006 (Figure 2) has been studied. The speeds and directions of the vectors extracted using channel differences have been compared against corresponding atmospheric profiles. The ECMWF NWP forecast fields with 1°x1° horizontal grid resolution and 91 vertical levels has been used for comparisons (Mahfouf and Rabier, 2000).

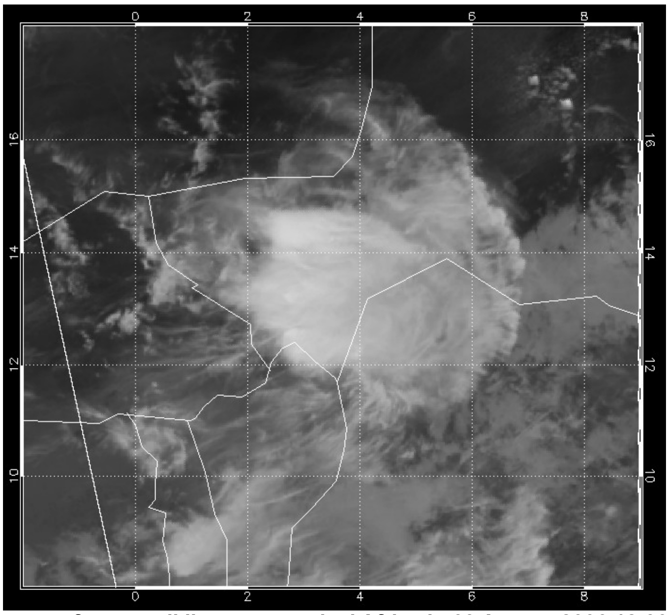

Figure 2: **10.8 µm SEVIRI image of an squall line over tropical Africa in 03 August 2006 12:30 UTC.**

A well representative situation where directions and speeds are different for a same location, when using new technique instead of the usual single channel method, is presented in Figure 3. The motion vectors extracted by the algorithm considering various intervals of 8.7 µm – 13.4 µm combination were compared to each other. The blue and light blue colors on Figure 2 represent AMVs extracted from 8.7 µm and 13.4 µm single channels respectively. The other colors represent various interval of the BTD, red: -10 to -3 K, orange: -5 K to 2 K and yellow: -15 to -8 K. Coloured numbers near the vectors correspond to the best fit pressure interpolated in forecast profile at the same place for the corresponding coloured vector.

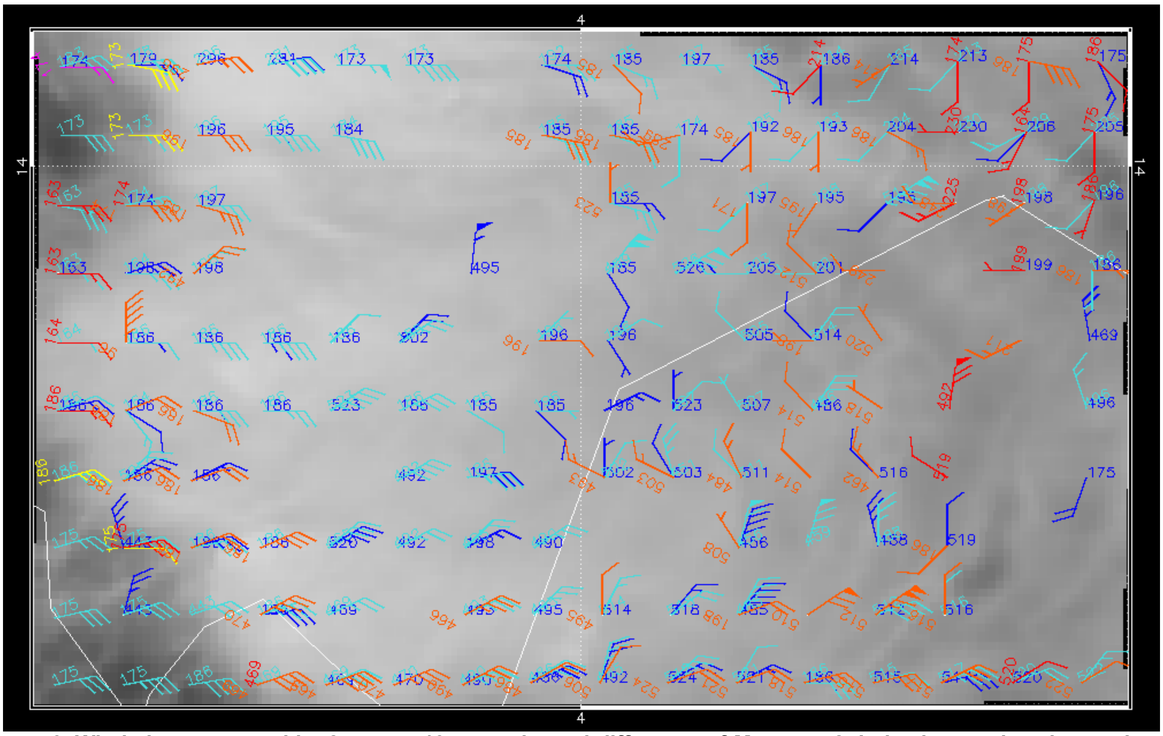

Figure 3: **Wind shear captured by 8.7 µm – 13.4 µm channel difference of Meteosat 8. In background we have a image from 10.8 µm. Blue and light blue are 8.7 µm and 13.4 µm SEVIRI channels, the other colors are the BTD range, red: -10 to -3 K, orange: -5 K to 2 K and yellow: -15 to -8 K.**

The red vectors in the top right corner were adjusted to a higher level, around 170 hPa while those from single channel were adjusted around 200 hPa. In the figure's center it is possible to see orange vectors showing a different flow than the one extracted from single channel but they were sometime adjusted at a lower level. In such cases, the extraction of AMVs from channel difference maybe describes a flow associated to a wind shear situation. Figure 3 also shows that AMVs extracted from the single channels and those extracted from channel differences are frequently similar or equals. This is expected when there is not any strong wind shear situation.

4. CLOUDSAT comparison

The wind vectors fields were compared to Cloudsat Cloud Profiling Radar (CPR) measurements to determine if the different speeds and directions captured by the technique correspond to vertical cloud structures. CPR works in the nominal frequency of 94 GHz making measurements in a nadir angle close to 0° with vertical resolution of 500 m and 1.4 km, 1.7 km in the cross-track and along-track resolutions respectively. Figure 4 shows a deep convection situation observed the 6th August 2006 over tropical Africa. MSG images taken at 12:30 UTC and 12:45 UTC were used. The corresponding Cloudsat measurement started at 12:48 UTC and the satellite was going from North to South. The Cloudsat data shows presence of deep clouds, going from near surface to the high troposphere. In Figure 4 the blue and light blue vectors correspond to the AMV estimated using channels 7.3 µm and 12 µm respectively. The others colors correspond to the following various BTD, yellow: -5 to 2 K, red: 5 to 12 K, green: 0 to 7 K. In the area delimited by a red square yellow vectors have different direction than those extracted from the 7.3 µm and 12 µm channels. The Cloudsat radar data show that those vectors are located in an area with strong vertical development, suggesting a relationship between the cloud vertical structure and the different movements detected. Otherwise, the channel difference vectors located out of the red square and corresponding to the cloud top, agree very well with the single channels vectors.

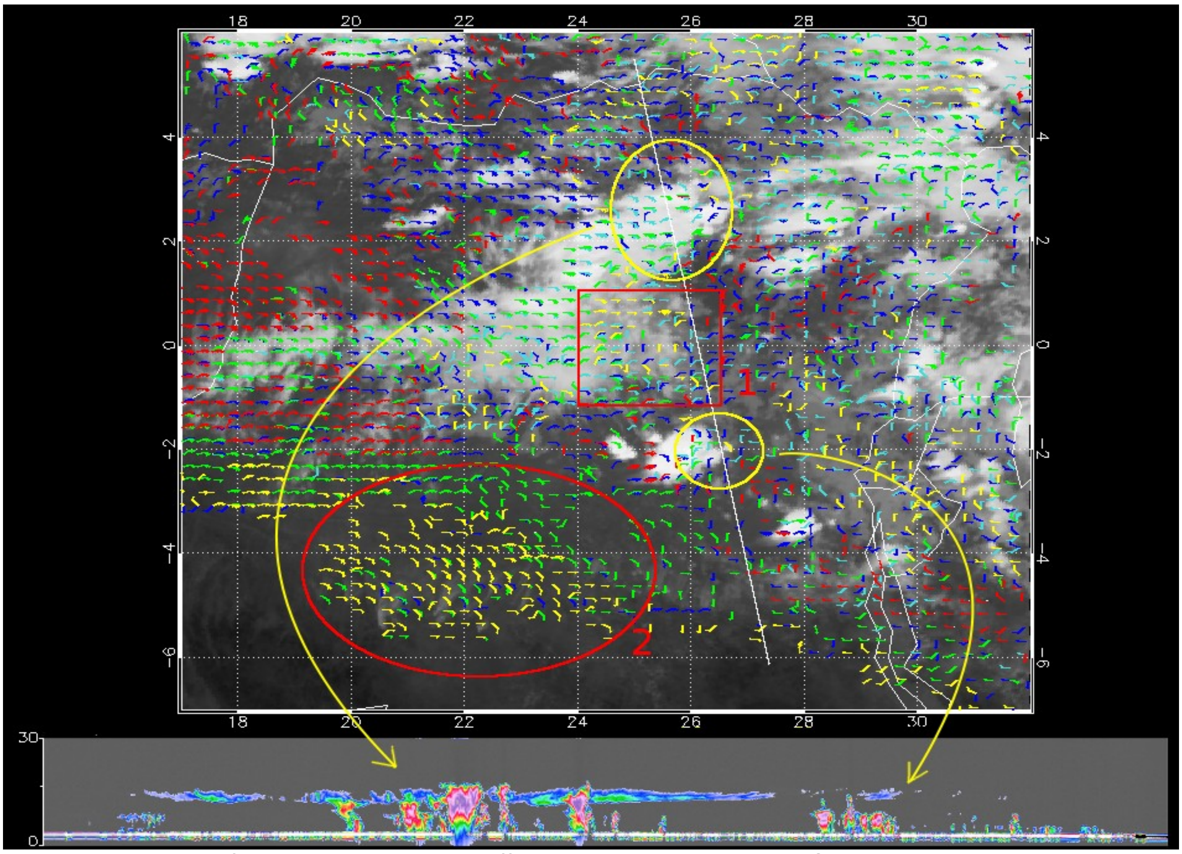

Figure 4: **Wind vectors from 7.3-12 µm channel difference plot above a 10.8 µm SEVIRI image. The straight white line represent the Cloudsat measurement for around 12:45 utc. In the bottom we can see the Cloudsat CPR radar measurements (raw echo power return), the left side represent the north west measurement and right the south east.**

Figures 5 show a zoom of the areas highlighted by the square and ellipse respectively in Figure 4. The yellow vector on Figure 5a are in a good agreement with the wind located at a higher level than the one found for the single channels 7.3 µm and 12 µm vectors.

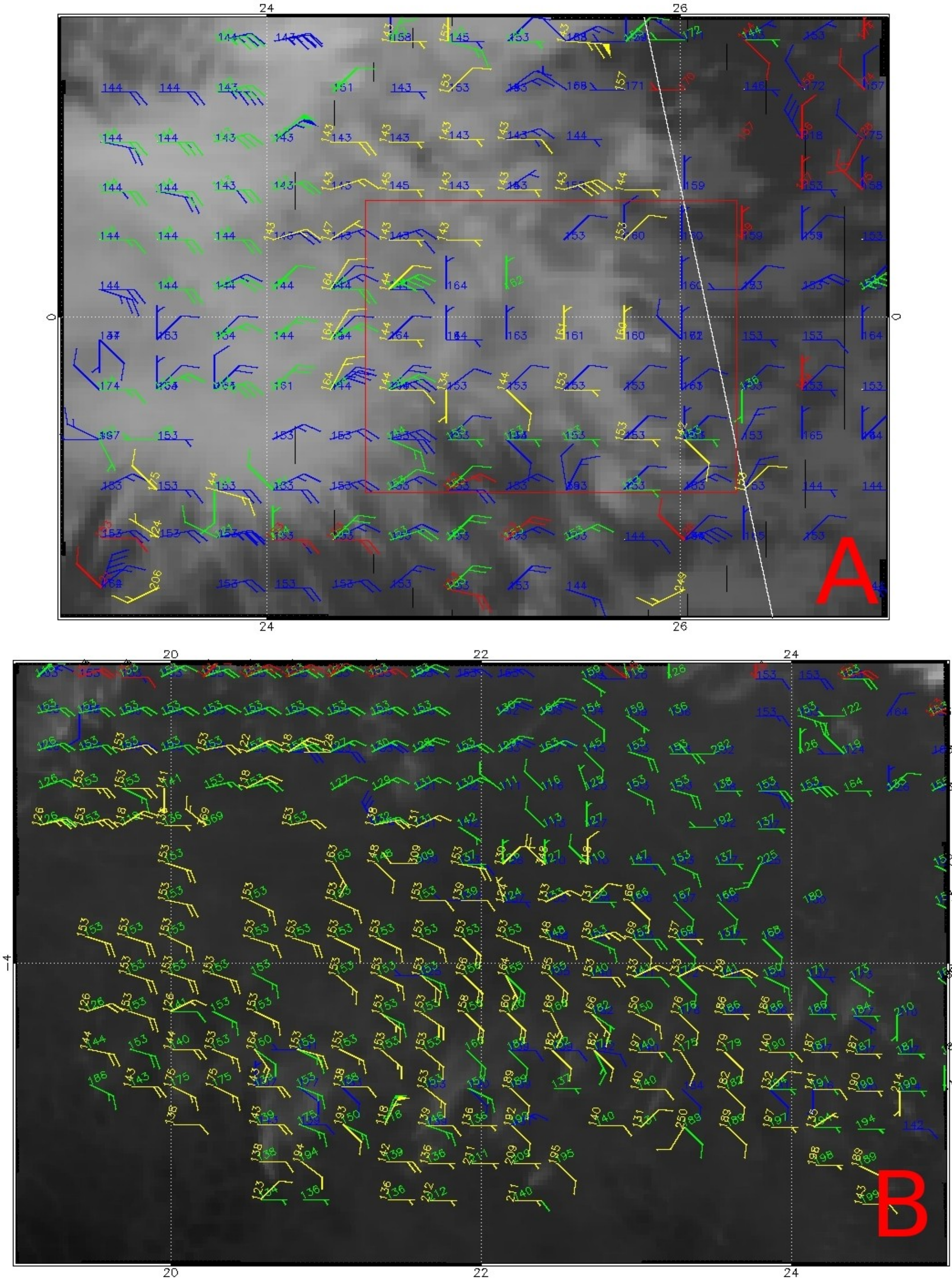

Figure 5: **Areas highlighted by the red square (A) and red ellipse (B) in Figure 3. The numbers close to the end of the barbs are the best fit pressure level reached in ECMWF profiles.**

Now, looking for the region highlighted by a red ellipse (Figure 5b), a different flow has been detected out of the deep convection regions. As the water vapour channel at 7.3 μm was used here, maybe the technique allowed isolating a specific layer of water vapor.

5. Results

This study tested the possibility to detect inner movements of deep convection applying AMV tracking algorithm to Meteosat-8 difference of channels. Retrieved motions have been compared against the corresponding NWP wind profiles and to Cloudsat radar measurements. The results show that the technique allows the detection of consistent movements that are sometimes different to the flow extracted by each single channel at the same place. These motions can correspond to local wind shear situations. Comparison against Cloudsat data showed a situation for which the difference in speed and direction of the AMVs extracted using difference of channels corresponded to the location of a strong vertical cloud development. The new technique is being developed aiming to the detection of inner movements of the deep convection, which are not reproduced by the ECMWF NWP model. So, another comparison against other kind of data (ground radar, model simulations, etc.) should be done in a near future, aiming to provide additional information on the features tracked using difference of Meteosat-8 channels. Using the radar measurements onboard of the Cloudsat satellite was possible identify an situation where the difference and a strong vertical development was correlated.

References

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