# Lower Stratospheric Water Vapor above Convective Storms
# MSG Rapid Scan Data Analysis

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## Introduction

The study addresses positive brightness temperature differences (BTD) between the water vapor and IR window bands above convective storms; these are generally attributed to presence of warmer water vapor and/or presence of very thin cirrus layers above the storm top. In some instances, the brightness temperature (BT) and BTD do not correlate (these cases are referred to as "BTD anomalies"), with some of higher BTD values located above warmer BT areas. Such cases are still not unambiguously explained. These can be caused by locally increased amount or temperature of the moisture. Setvák (2010) illustrates these effects in schemes similar to that in Fig. 1. Another possible explanation for the anomalies could be the storm-top microphysics, i.e. emissivity and transparency effects. The present work focuses namely on detection and analysis of the BTD anomalies.

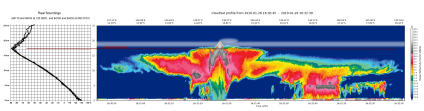

Fig. 1. Illustration of case with combination of a uniform layer of moisture above storm top and moisture injected into the lower stratosphere by the storm itself. Source: Setvák (2010).

## BTD anomaly detection algorithm

### Initial ideas

- anomaly – pixels with high BTD values not co-located with low BTs
- purpose – objective detection of BTD anomalous pixels

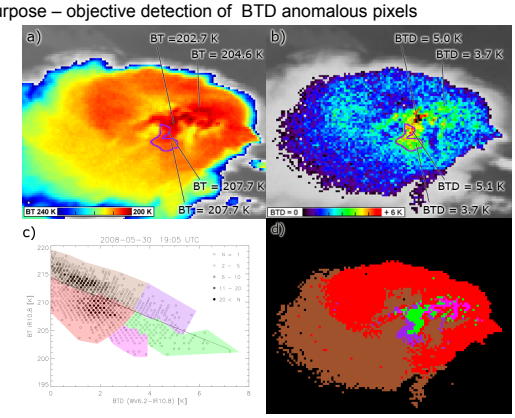


Fig. 2. Convective storm above Germany (30 May 2008, 19:05 UTC) in a) color enhanced IR 10.8 image, b) BTD image; c) scatterplot for pixels with BTD > 0K – the colored areas correspond to the areas of the same colors in part (d). The violet line in part (a) and (b) delimit pixels from the violet area in part (d).

- pixels corresponding to points from continuous areas in scatterplot form approximatly continuous areas in the satellite image (Figs. 2c and 2d)
- Figs. 2a and 2b show that different values of BT (IR 10.8) can correspond to equal values of BTD (WV 6.2 – IR 10.8)
- pixels from the violet area (Fig. 2d) – subjectively anomalous

### Methodology of the detection algorithm

- algorithm is proposed to select group of pixels containing the „violet" pixels
- pixels colder than 225 K are sorted by their BT into successive intervals at 1K steps
- anomalous pixels in each interval are detected as those with BTD higher than a defined BTD threshold based on the dispersion of data within the interval

### Example of the algorithm results

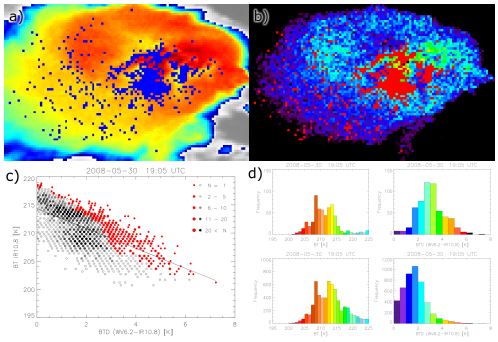


Fig. 3. Algorithm results for the same case and time as in Fig.2; a), b), c) - same as in Fig. 2 but with detected anomalous pixels marked in blue (a) and red ( b, c); d) - histograms for BT (left column) and BTD (right column) for anomalous pixels (upper row) and all pixels (bottom row).

## Results

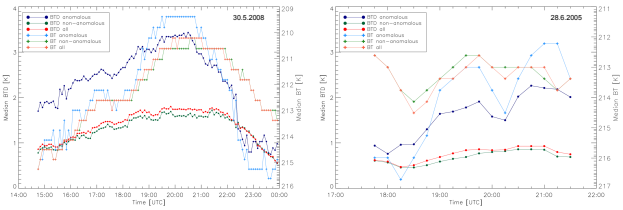


Fig. 4. Comparison of evolution of BTD and BT medians in time for three groups of pixels (anomalous, non-anomalous, all) for the storm of 30 May 2008 (left) and the (Setvák et al., 2008) storm above France on 28 June 2005 (right).

- The relationship between BT and BTD is very similar for all three groups of pixels – anomalous, non-anomalous and all of them – lower values of BT correspond to higher values of BTD. However, the BTDs reach higher values for anomalous pixels although their BT values can be almost the same as for non-anomalous pixels (Fig. 4).

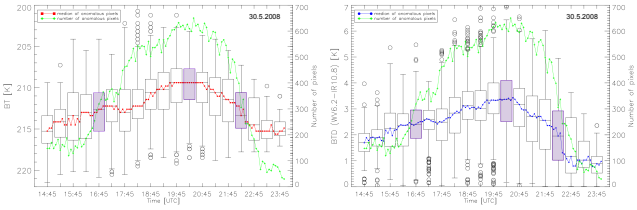


Fig. 5. Box plots showing the evolution of BT (left) and BTD (right) of anomalous pixels. Rectangles denote the 75% and 25% quartiles. The whiskers represent the non-outlier minimums and maximums and outliers are depicted by circles. Both graphs are for the same storm as in Fig. 4 left. Violet rectangles highlight times for which more detailed results are shown in Fig. 6.

- BTDs for anomalous pixels reach the highest values approximately in the same time of the storm evolution as when the number of these pixels culminates.

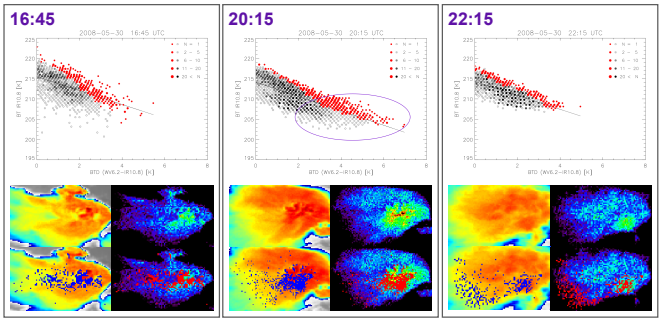


Fig. 6. Scatterplots and BT and BTD images without and with marked anomalous pixels (same as in Figs. 2 and 3) for three different evolution phases of the storm of 30.5.2008 (as in Fig. 5): 16:45 – early stage, 20:15 – maximal BTD anomaly, 22:15 – dissipating stage. Typical part of the scatterplot at time of maximal BTD anomaly is marked by the blue ellipse.

- Typical distribution of points in scatterplot at the time with maximal BTD anomaly (the highest BTDs + maximal number of anomalous pixels) as well as typical evolution of this distribution in time is shown in Fig. 6. The results confirm subjective observations that from certain stage of storm evolution the BTs are not decreasing anymore, however the BTDs are still increasing.

## Conclusions and future work

- It is not possible to see anomalous behaviour when investigating characteristics of all pixels with positive BTD. It is necessary to select anomalous pixels first.
- An algorithm for detection of anomalous pixels was proposed and first results are shown.
- It is necessery to process more cases for better understanding of the BTD anomalies and for making decision whether these features are caused by the warmer lower stratospheric water vapor, the storm-top microphysics, or some other mechanism.

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**References**

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Setvák, 2010: Satellite observations of storm tops, Part 1 and Part 2. In the EUMETSAT Data and Products, Online Training Library, http://www.eumetsat.int.