

The parallax correction of MSG images on the basis of the SAFNWC cloud top height product

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Abstract

The so-called parallax effect is a considerable geometrical effect associated with satellite measurements. It is more important even when we are observing high clouds, far from the nadir. In the case of MSG, the parallax effect results in mapping deficiencies over Hungary. This means that the location of clouds above Europe's territory moves away from their real position.

The SAFNWC software calculates among other parameters the height of the cloud tops on which the extent of the parallax displacement depends. Therefore, the cloud top height (CTH) product is suitable for the assessment of the parallax effect which we calculate pixel by pixel. Thus, the CTH is an efficient tool for the parallax correction of MSG images. The correction is indispensable while comparing satellite images with radar images as radar measurements are not subjected to the parallax effect, and also in the case of quantitative verifications of satellite products.

The parallax correction requires different calculations in the case of the different MSG channels as the information of each channel has different physical meaning. The parallax correction of SAFNWC products such as cloud type also needs to be addressed differently because gaps appear on the image after the first shift which need to be filled by the most appropriate information possible. As the most widely used MSG image is the infra image of the 10.8 m channel, and it is important in the observation of heavy rainfalls, we started the development of the parallax correction method by these images.

Our results are demonstrated through case studies for the 20th August 2006 by comparing the original and corrected MSG images with radar information.

THE PARALLAX EFFECT CAUSES MISLOCATIONS IN HUNGARY

The parallax effect is a typical geometric effect related to satellite measurements. The more the satellite is close to the globe, the more the parallax effect can be high. Also, it is considerable when we are observing high clouds or when the clouds are far from the satellite nadir.

Figure 1 demonstrates the difference of the cloud positions in the case of two different geometry: the lower satellite sees the cloud from aside, thus identifies its location to the north of the real position.

In the case of the MSG satellite, the parallax effect results in mapping deficiencies which are due to the fact that the satellite is located above the Equator and thus sees Europe from relatively low angles. The extent of this shift can reach even four or five pixels over the territory of Hungary, the direction is always south-western direction, sometimes southern.

The parallax effect causes cloud mislocations in Hungary, which phenomenon was observed and reported several times by our forecasters. In Figure 2 and 3, we can notice the shift between the radar measurements and the satellite observations. These images show the case of an instable atmosphere on the spring day of 6th May 2007, with a lot of storm cells appearing.

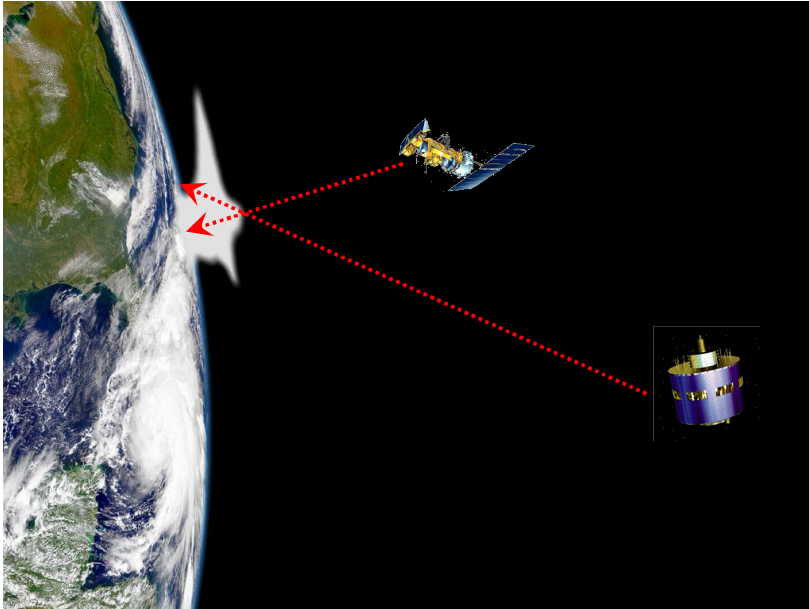


Figure 1: The demonstration of the parallax effect. The location of clouds seen from a certain angle from aside is affected

The parallax effect in Hungarian remote sensing observations of storm cells

Each storm cell has a representation on the radar and on the satellite images, only radar intensity bigger than 30dBz are marked. The south-western shift of the radar images compared to the satellite images are evident. On the storm composite image, where the orangish, yellowish colours mark the highest regions with the smallest ice particles, thus with the most intense upward flow, we can notice that the shape of the areas with the highest precipitation intensity is the same, but radar maximums fall on the south-western edge of these clouds. The second image, from the 10.8 m infra channel shows the temperature of each cloud top. The coldest ones . which are most possibly those assigned to storm activity - are in red, dark blue. Especially in the center of the image, where small storm cells appeared in the vicinity of the lower part of the eastern border of Hungary, we can notice the difference between the location of storm activities in radar and in satellite images.

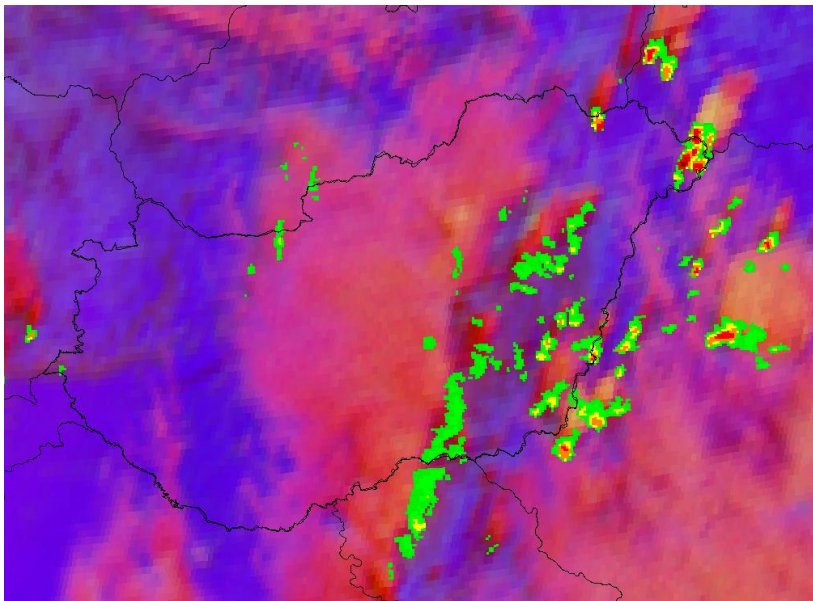


Figure 2: The storm composite image (WV6.2-WV7.3, IR3.9-IR10.8, NIR1.6-VIS0.6) overlaid by radar field

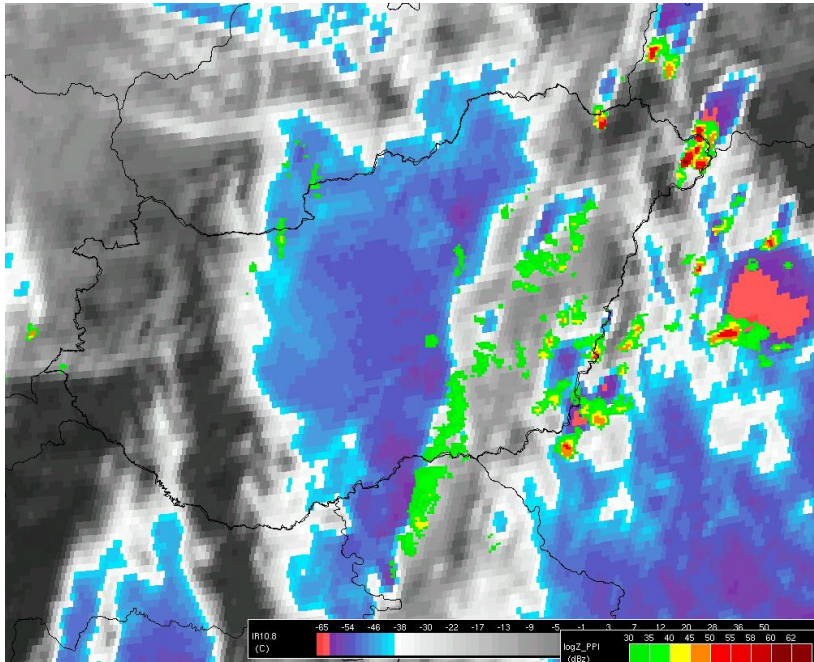


Figure 3: The IR10.8 channel overlaid by radar field

Highest precipitation intensity differently located on the satellite HRV and in the radar images

The highest precipitation intensity is related to the overshooting tops in storm clouds. Overshooting tops are useful as they can be observed from above by satellites as well. A case study has been carried out in the Hungarian Meteorological Service for the 29th June 2006 11:40 UTC time. The overshooting top identification was based on the HRV image of the MSG satellite. In Figure 4, these identified locations are marked, and the image is overlaid by the radar measurement field which clearly shows the shift between the radar and satellite images.

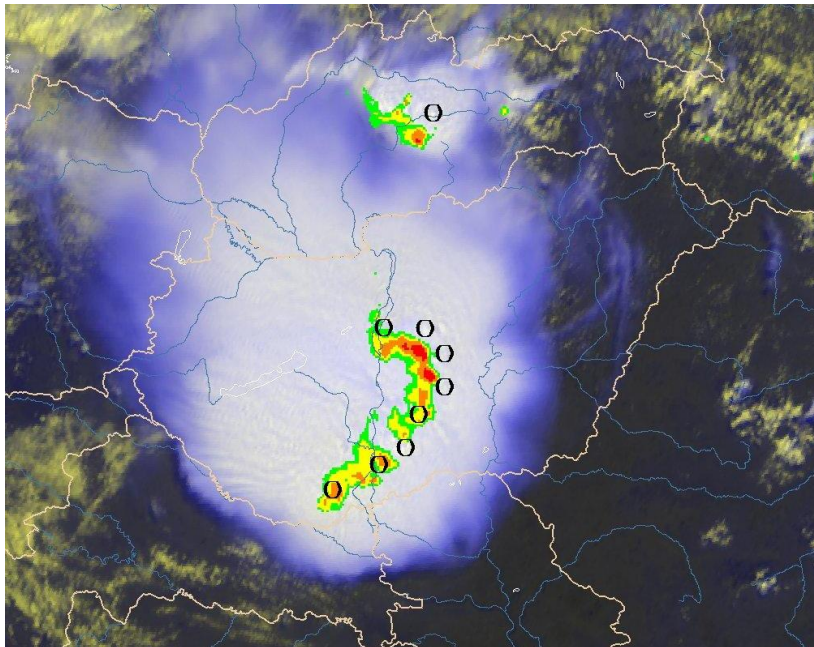


Figure 4: HRV high resolution composite image with the identified overshooting tops overlaid by the radar measurements

THE SAFNWC CLOUD TOP HEIGHT PRODUCT – BASED APPROACH TO CORRECT THE PARALLAX EFFECT

The SAFNWC (Satellite Application Facility for Nowcasting) software is an efficient tool in satellite image interpretation. One of its results is the calculation of the height of the cloud tops, which is performed in the Hungarian Meteorological Service on every satellite image every 15 minutes. As we already know, the extent of the parallax displacement depends on the height of the cloud observed. Therefore, the cloud top height (CTH) product is suitable for the assessment of the parallax effect and the correction of the cloud location.

The method developed in the Hungarian Meteorological Service consists of calculating the parallax effect pixel by pixel, considering the exact location of the MSG satellite and the height of each cloudy pixel. From this geometry, the shift can be determined for each pixel center point, which will determine the new location of the measured satellite pixel. The original pixel grid is preserved, the method determines the pixel with the nearest center point location to the shifted location. So, practically it is a tracking method of each pixel center point.

Due to the different height of the clouds, the extent of their shift after the correction also varies. Thus, some new pixels can fall on the same satellite image pixel, whereas the opposite case can also occur: there remain several pixels with no value. These problems necessitate a **posterior correction** (Figure 5) in the method.

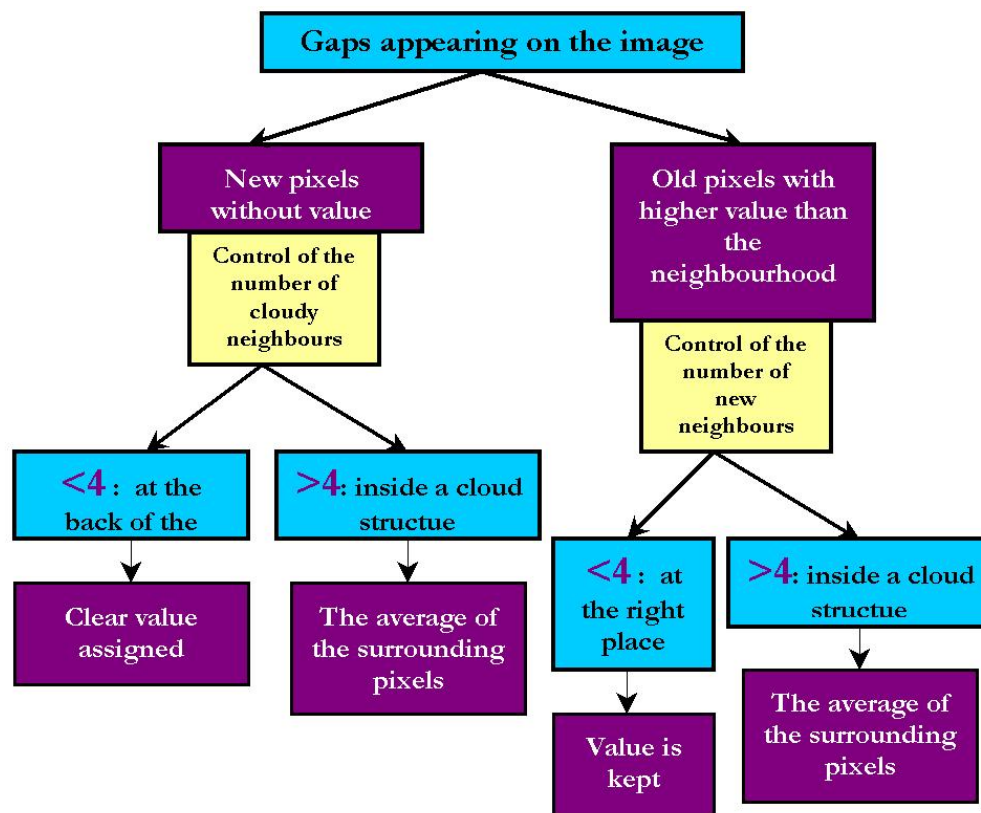


Figure 5: Flow chart of the posterior correction method, complementary to the pixel-by-pixel method

For the first problem, the solution is very simple: we take the lower value as this is assigned to the higher cloud that is more possible that the satellite sees.

Pixels with no value appear in two different situations: at the back of the clouds (meaning the the opposite side of the direction of the satellite), or inside a cloud, because the method that destroys+in some way the cloud structure. As no information is available for that region, we assume that they are

clear pixels. For the second case, the average of the surrounding values is used. It is determined whether it is inside the cloud depending on the number of cloudy pixels around it in the new image.

However, gaps in the image can also result from the fact that the cloud structure is broken, and that clear or low-level clouds remain on an area of a broken+cloud. This is also taken into account, using the same approach: if at least 4 of their neighbouring pixels are new ones, the value is changed for the average of the surrounding ones. This is illustrated on Figure 6, which is a punched+image produced without any posterior correction method. However, on Figure 7, the same MSG satellite image can be found, where the posterior correction methods were applied.

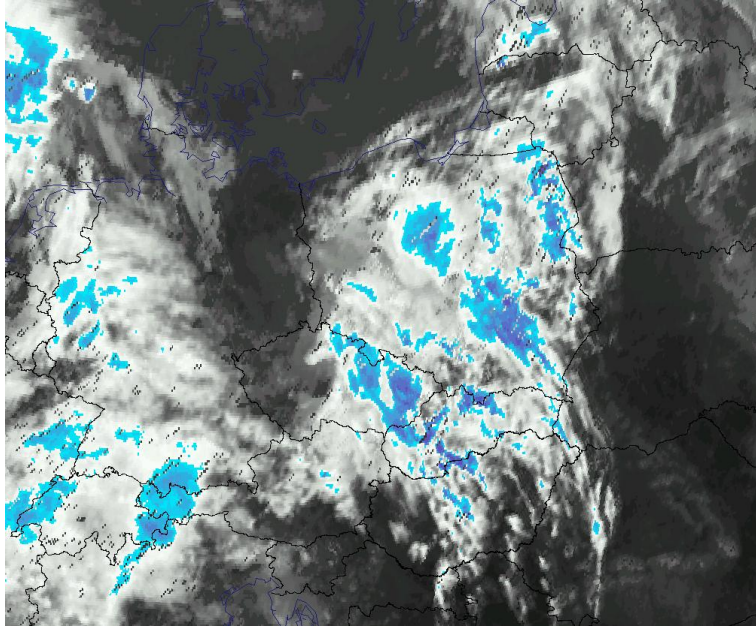


Figure 6: Simply shifted image by the pixel-by-pixel parallax correction method without posterior corrections

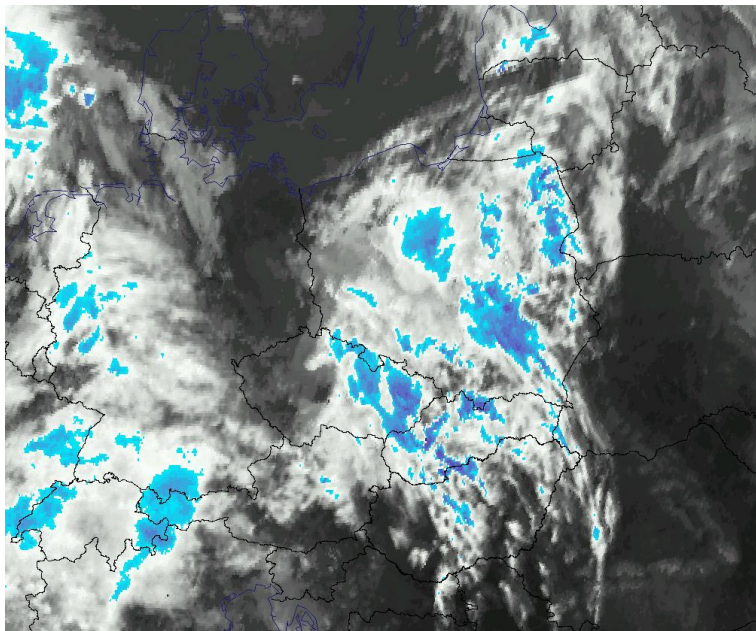


Figure 7: Shifted image by the pixel-by-pixel parallax correction method, completed by posterior corrections

THE PARALLAX CORRECTION METHOD USED IN DIFFERENT CASES

The following examples show the results of the application of the above described parallax correction method on MSG IR10.8 m images. These examples are prepared in a way that the differences between the original images and the new ones can be well observed, and thus the effects of the parallax shift can be evaluated. The original images can be always seen on the left on the top, and the corrected one on the right on the top.

Two other SAFNWC products are used in the demonstration of the actual weather situation, with regard to the cloud properties. One product, which can be seen in the left lower corner of the images in Figure 8 and 9, is the SAFNWC cloud height product, which shows the height of the clouds using 100m scaling. The other product is the SAFNWC cloud type product, which classifies the clouds observed by the satellite according to their height, but also to their transparency and thickness. Different colours refer to different classes in the cloud type images, the green colour is assigned to clear pixels, very high and opaque clouds are white and brownish.

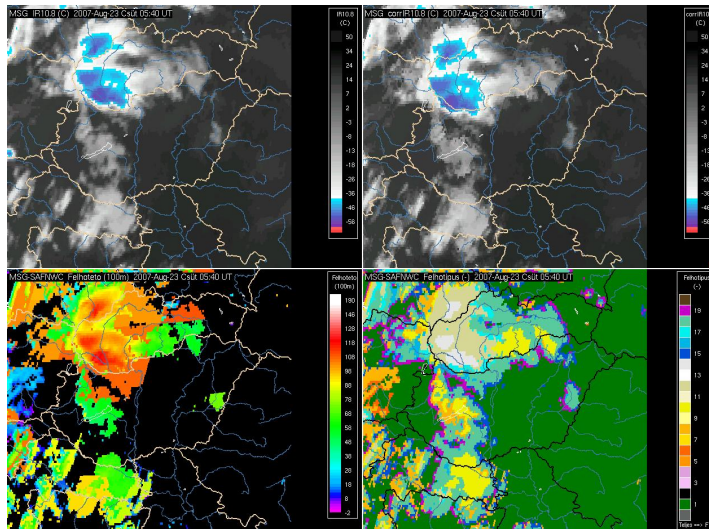


Figure 8: Comparison of the original and the corrected IR10.8 m, supplemented by the SAFNWC cloud height and the cloud type product for 23th August 2007 05:40 UTC

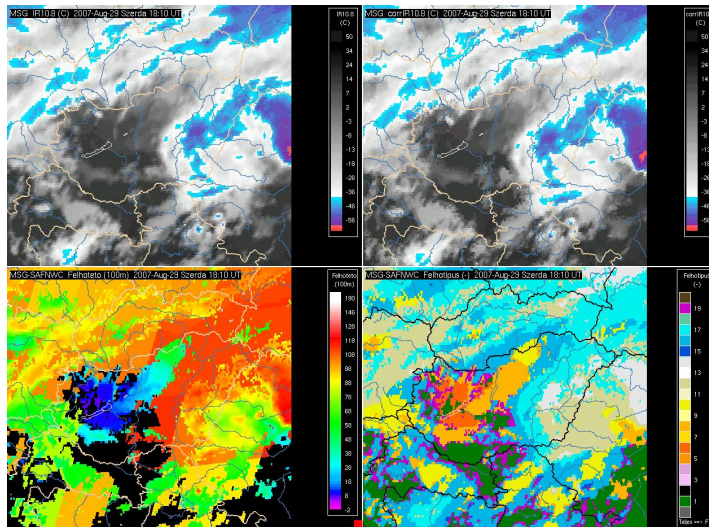


Figure 9: Comparison of the original and the corrected IR10.8 m, supplemented by the SAFNWC cloud height and the cloud type product for 29th August 2007 18:10 UTC

In the case study prepared for the 23th August 2007 at 05:40 UTC time (Figure 8), we can see one high cold cloud on the upper border of Hungary, and several lower clouds mainly over the Lake Balaton. These clouds in yellow are medium level clouds, the greenish colours represent high semitransparent clouds. It can be well seen that the structure of the cloudiness is well preserved during the parallax correction, however, the edges of the lower level clouds becomes more uncertain, and more disconnected. The location of the highest clouds is evidently shifted to the south.

In Figure 9, made for 29th August 2007 18:10 UTC, we can observe the effect of the presence of clouds with different height. In the center of the image, we have very low clouds, whereas around they are much higher reaching 10kms in some places. Although the correction assigns to the original pixels very differing values in this cases, the structure of the cloudiness is almost entirely preserved.

A CASE STUDY WITH ORIGINAL AND PARALLAX-CORRECTED INFRA IMAGES AND RADAR IMAGES FOR SEVERE STORMS

On the 20th of August 2006 Hungary was affected by severe storms which formed a line shape passing through the country very quickly. It entered across the western border early afternoon, and left Hungary through the eastern border around midnight. There were very heavy rainfalls all over the country, and there were extremely strong wind and high precipitation in some specific places. These most extreme cells can be well identified on the radar images as well as on the infra images by the most coldest parts. Moreover, as they are supposed to be very high, the effect of the parallax correction can be well demonstrated on them.

In Figure 10 and 11, we can see four different images: those on the top are the original infra satellite images, and those on the bottom are the corrected ones. The radar image is overlaid on each infra image, only marking the intensities bigger than 35dBz.

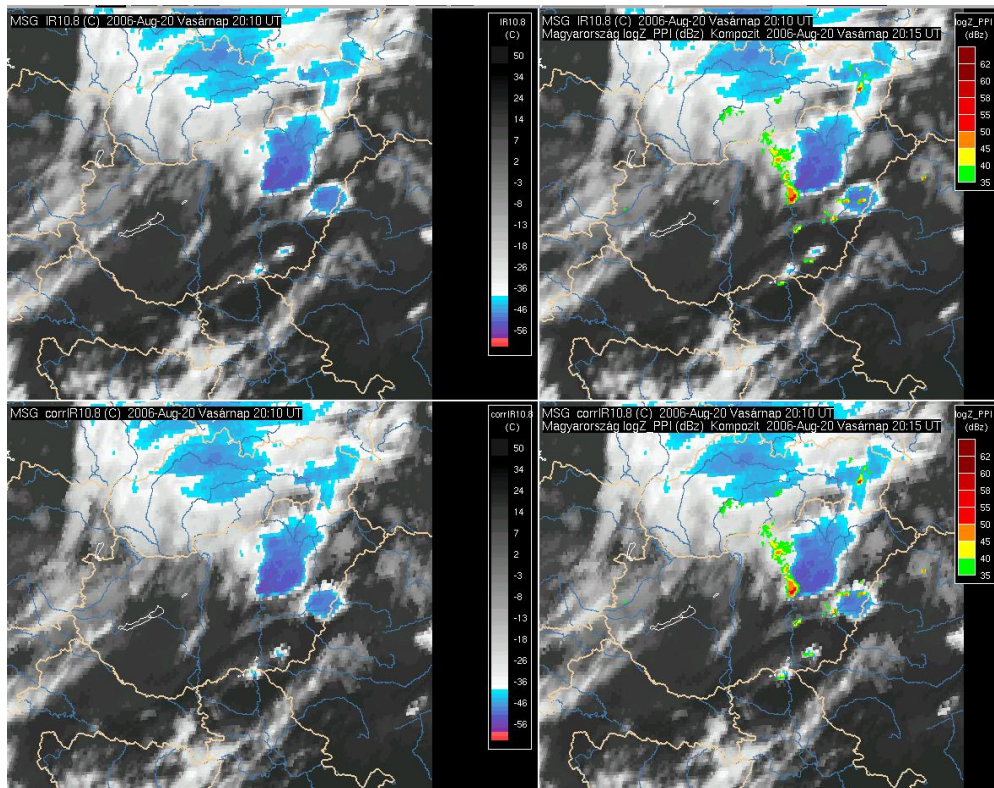


Figure 10: Evaluation of the effectiveness of the parallax correction method through a case study on the 20th August 2006 20:10 UTC. The infra images are overlaid by radar reflectivities more than 35dBz, the images without radar measurements can be seen on the left.

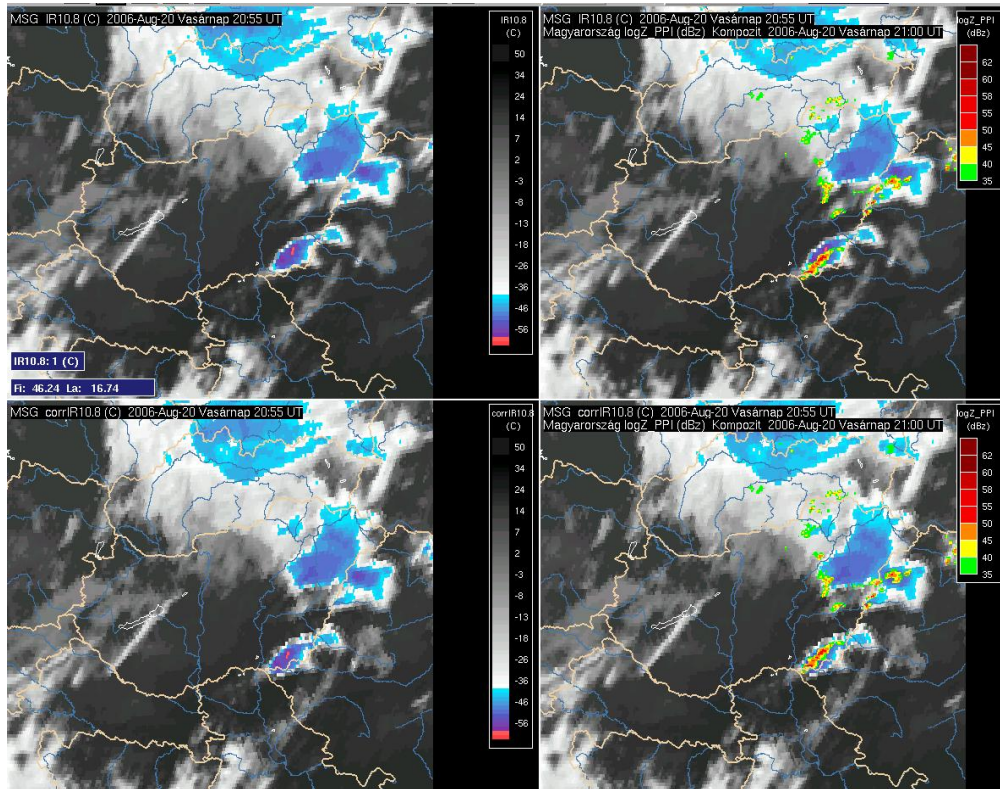


Figure 11: Evaluation of the effectiveness of the parallax correction method through a case study on the 20th August 2006 20:55 UTC. The infra images are overlaid by radar reflectivities more than 35dBz, the images without radar measurements can be seen on the left.

Both figures demonstrate the effectiveness of the parallax correction method in relocating the high clouds. On the original infra satellite images, we can see the differences of the location of radar maximums and coldest parts, even the radar cells do not fall on clouds on the satellite images. This is the case for both the upper storm cloud and the small ones at the southern border of Hungary. The parallax correction corrects these mislocations and matches well the location of the storm clouds.

CONCLUSIONS

It is well known that the parallax effect results in errors of cloud locations, especially in case of severe storm clouds, in countries at mid- and high latitudes. During our investigations, we have shown that the parallax effect can be efficiently corrected on the MSG 10.8 μ m images on the basis of the SAFNWC Cloud Top Height product. In the Hungarian Meteorological Service, we have developed an efficient methodology to correct the parallax effect on these MSG infrared images.

We have shown through case studies that the structure of the cloudiness is well preserved when the satellite images are corrected by our methodology. Finally, through a detailed case study prepared for the 20th August 2006, we have demonstrated that the correspondance with radar images improves considerably in case of severe storms.