APPLICATION OF METEOSAT SEVIRI CHANNEL DIFFERENCES 0.6-1.6 AND 0.6-3.9 µM IN CONVECTIVE CELLS DETECTION

Nataša Strelec Mahović

Meteorological and Hydrological Service, Grič 3, Zagreb, Croatia

Abstract

One of the most challenging tasks in the operational nowcasting is the early detection of potentially dangerous convective clouds. Convective cells detecting algorithms, used in the operational weather services, are frequently based on single infra-red channel data. The main advantage of such methods is their applicability during both day and night. However, due to the fact that the criteria in these methods are only cloud-top temperatures and the shape of the clouds, they have proven to be unsuccessful in many cases. Taking into account the properties of solar channels, giving insight into the optical depth of clouds and enabling the differentiation of cloud phase and particle size, an attempt has been made to introduce the data from Meteosat SEVIRI channels 0.6 ,1.6 and 3.9 µm in the automatic convective cell detection. In order to utilize properties of two channels at the same time, and to rule out the clouds which are not of the interest, difference of reflectance in 0.6 and 1.6 µm as well as 0.6 and 3.9 µm channel is used. The differences of reflectance values were calculated for numerous cases and the results were compared to radar reflectivity data. The comparison shows that the differences show small developing cells almost at the same time they are seen by the radar, provided that a proper threshold is set for the difference values. It has also been shown that all potentially dangerous cells are detected which means operationally applicable result and enables the early detection of convective cells in the areas not covered by the radar measurements.

INTRODUCTION

Automatic convective cloud detection method, used traditionally in Croatian weather service, is based on single infra-red channel data. Convective cells are detected based on the cloud top temperature as well as on the difference between that temperature and the temperature of the surrounding, providing that the shape of the cloud is circular or oval. Detected cells are then classified into three types, according to the temperature, and in the visualisation marked by signs in three different colours. An example of the operational cell detection product is seen in Figure1. It can be noticed that most of the detected clouds (marked by a cross in the cell centre) are in deed convective cells, but some of the cells remain overseen by the IR algorithm. Besides that, some of the large systems, consisting of more cells, are not detected properly and are marked by just one sign. In other words, due to the fact that the criteria in this method are only cloud-top temperatures and the shape of the clouds, misdetections occur mostly due to detecting cirrus clouds as convective or missing small cells with warm cloud tops. The problems also occur with very large cells, since the maximum radius of the cell to be detected is fixed. This method of convective cell detection has been inherited from the time when the first generation of METEOSAT satellites was active. Now, with a far bigger range of channels available, trying to improve that method was a logical step forward. Taking into account the properties of solar channels, which enable the differentiation of cloud phase and particle size and give the insight into the optical depth of clouds, an attempt has been made to reinforce the automatic convection detection method by introducing data from Meteosat SEVIRI channels 0.6, 1.6 and 3.9 µm.

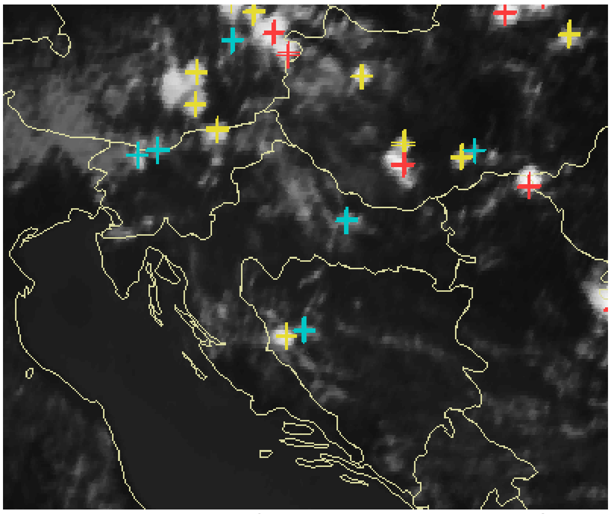

Figure 1: **IR 10.8 image for 09 June 2007, 11:00 UTC combined with the IR based cell detection product used at the Croatian meteorological service. Crosses of different colours mark the positions of convective cells and stand for the cloud top temperature; blue: -33 >T>-42, yellow:-42>T>-55, red: T<-55°C.**

THE METHOD

The solar channels give the information about the depth of the cloud, its water or ice content and also cloud particle size and phase. Visible reflectance at 0.6 µm is a measure of the optical depth of clouds or the albedo. The highest reflectance values in 0.6 µm channel come from optically thick water clouds and snow. Reflectance values for very thick clouds (large Cb clouds) can sometimes be above 90%. On the other hand, transparent clouds (such as cirrus clouds) produce much lower reflectance values. In the 1.6 µm channel the radiation is slightly absorbed by cloud water and the ratio between scattering and absorption makes it sensitive to the particle size (Nakajima and King, 1990) and especially to cloud particle phase (Rosenfeld et al., 2004). In other words, solar reflectance component of 1.6 µm channel gives the information about cloud particle size and enables the distinction between ice and water clouds. Due to much higher absorption of the ice, the 3.9 µm channel is even more sensitive to cloud phase then 1.6 µm channel.

In order to utilize properties of two solar channels at the same time, and to rule out the clouds which are of no interest, difference of reflectance values in 0.6 µm and either 1.6 or 3.9 µm channel is used (Strelec Mahovic and Zeiner, 2008). For the purpose of calculating the difference of reflected components, radiance values in channel 0.6, 1.6 and 3.9 µm were transferred to reflectance values. The relations for calculating the reflectance values can be found in the MSG Interpretation Guide.

High positive value of the difference means that reflectance in 0.6 µm channel is very high, signalising the clouds are dense and thick, whereas the reflectance in 1.6 (or 3.9) µm channel is very low because of the ice particles on top of the clouds. Therefore, very high positive values of the difference are found only at thick clouds with ice on the top, i. e. convective clouds. On the other hand, the areas which show low reflectance values in 1.6 µm channel due to small vertical depth have also low reflectance values in 0.6 µm channel and can therefore be easily discriminated in the difference image, because the resulting difference value is small. If the threshold is set properly this difference of reflectance values can be used to detect convective cells.

COMPARISON TO RADAR DATA

The differences of reflectance values of 0.6-1.6 and 0.6-3.9 µm channel have been calculated pixel by pixel for many cases of convective development during summer season 2007 and 2008 and the detected systems were compared to radar reflectivity data. The main reason for insisting on comparison with radar data is the problem of poor radar coverage of the Croatian territory. Namely, only the northern part of the territory is covered by radar measurements, whereas the southern part, which includes a large part of the Adriatic Sea and the coast, has no coverage at all. Therefore, besides improving the infra-red channel based convection detection method, it was desired to make this difference method a substitute for missing radar data. Radar data used for the comparison come from two radars, located in the northern, continental part of Croatia.

The difference threshold in the visualisation is set to be 20% for 0.6-1.6 μm difference and 40% for 0.6-3.9 μm difference. These thresholds are empirically set to make the detected areas most similar to the maximum reflectivity observed by radar. If the thresholds are set to lower values, much larger areas appear as “convective”, whereas if the threshold would be set higher, some small cells would not be detected. However, this threshold is still a matter of investigation.

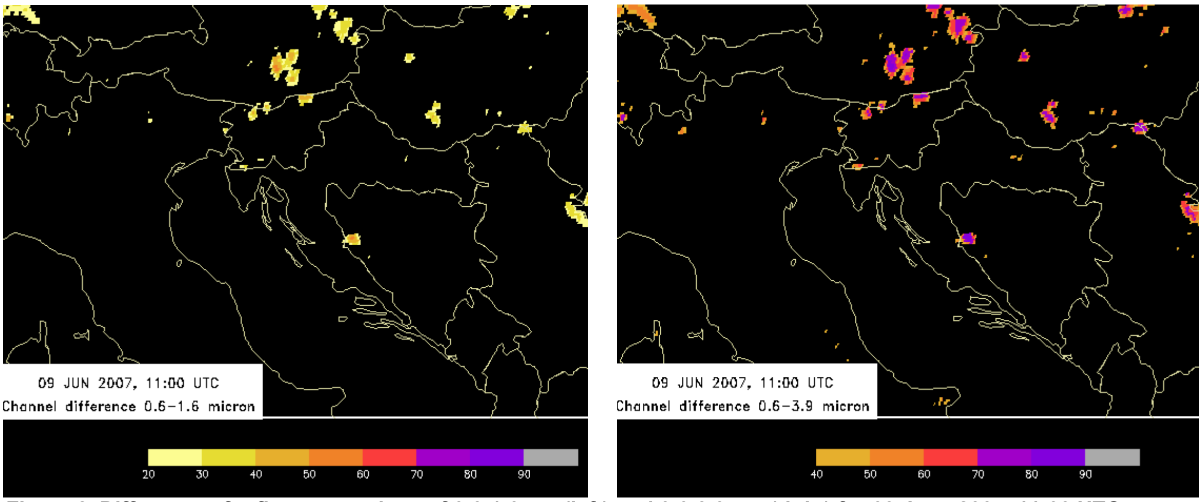

Figure 2: **Difference of reflectance values of 0.6-1.6 μm (left) and 0.6-3.9 μm (right) for 09 June 2007, 11:00 UTC**

Figure 2 shows the difference between 0.6 μm and 1.6 μm channel reflectances in the left image and 0.6 μm and 3.9 μm channel reflectances on the right for the same case of 09 June 2007 at 11:00 UTC. Several regions of high positive difference are clearly seen in both images. Compared to the image in Figure 1 the obvious benefit of the difference method is more precise definition of the single cells within the larger systems and detecting small cells overseen by the IR based method.

Comparison to radar reflectivity data (Figure 3), shows that the systems detected by the difference method look very similar to the features in the radar image. The systems with the largest difference values are comparable to the regions with the highest radar reflectivity between 40 and 50 dBz and the highest tops reaching 12 to 15 km height.

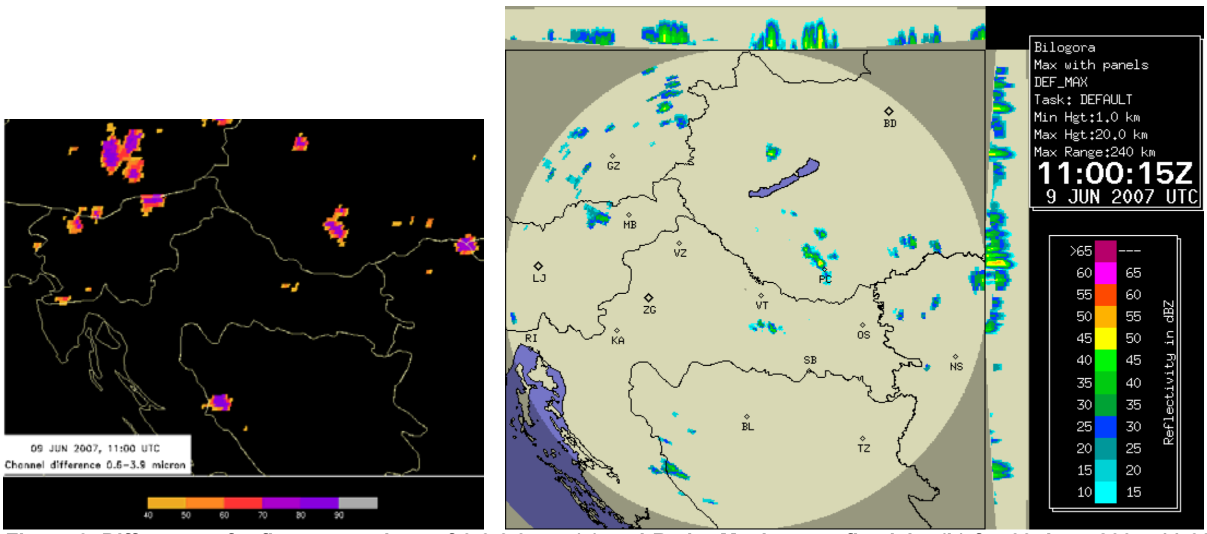

Figure 3: **Difference of reflectance values of 0.6-3.9 μm (a) and Radar Maximum reflectivity (b) for 09 June 2007, 11:00 UTC**

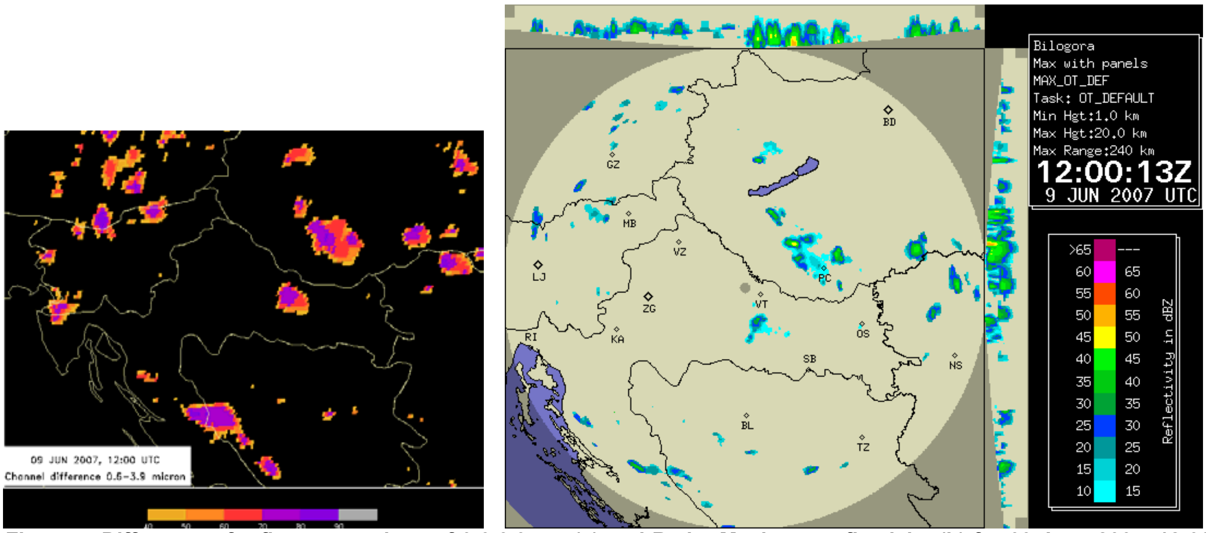

Figure 4: **Difference of reflectance values of 0.6-3.9 μm (a) and Radar Maximum reflectivity (b) for 09 June 2007, 12:00 UTC.**

The problem seems to arise when the cells develop towards a mature stage in which they have large cirrus anvils on the top. This large ice makes the reflectance in 3.9 μm channel very low and the difference between 0.6 and 3.9 μm very high, a seen in Figure 4 in the left-hand image. At the same time, the radar reflectivity of the system is getting lower, since the system is not precipitating that much any longer. This means that the difference values are not proportional to radar reflectivity values and only the positions of the systems are comparable. However, since the difference value changes according to the quantity of the ice present on the top of the cloud, it seems that the difference between 0.6 and 3.9 μm reflectances could be used to determine the stage in the life-cycle of the cell.

It has also been noticed that the difference method enables the detection of small cells in the early development phase, which is certainly an advantage compared to the methods based on the infra-red channel data. An example of this can be found in the case of 03 July 2007. Meteosat 9 IR image for 14:00 UTC is overlaid by signs indicating positions and the cloud-top temperatures of the convective cells, as detected by the IR-data based algorithm (Figure 5).

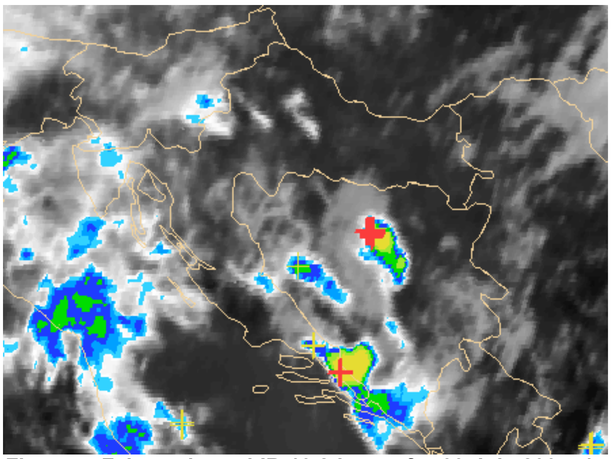

Figure 5: **False coloured IR 10.8 image for 03 July 2007, 14:00 UTC combined with the IR based cell detection product used at the Croatian meteorological service. Crosses of different colours mark the positions of convective cells and stand for the cloud top temperature; blue: -33 >T>-42, yellow:-42>T>-55, red: T<-55°C.**

In Figure 6a, in addition to the cells detected by the IR method, there is a small cell in the central Croatia that was not detected by the IR algorithm. Comparison to radar reflectivity (Figure 6b) shows that convective cell is present at that position, with maximum reflectivity above 50 dBz and top height of about 10 km. Radar image 30 minutes prior to that time didn't show any signal at the same position, indicating that the detection in the satellite image was almost simultaneous with the occurrence in the radar image.

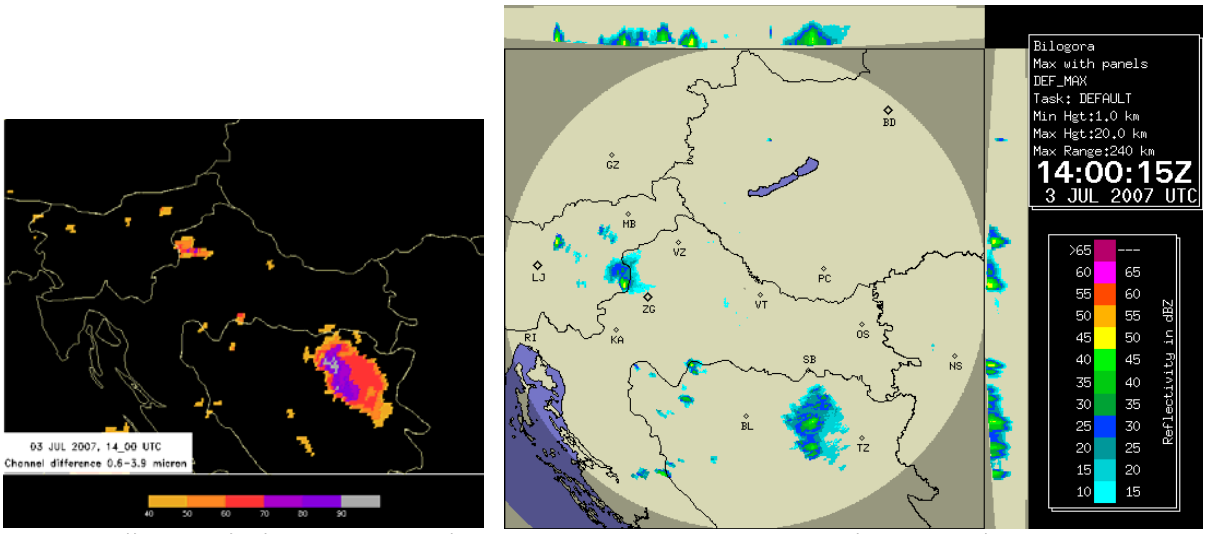

Figure 6: **Difference of reflectance values of 0.6-3.9 µm (a) and Radar Maximum reflectivity (b) for 03 July 2007, 14:00 UTC.**

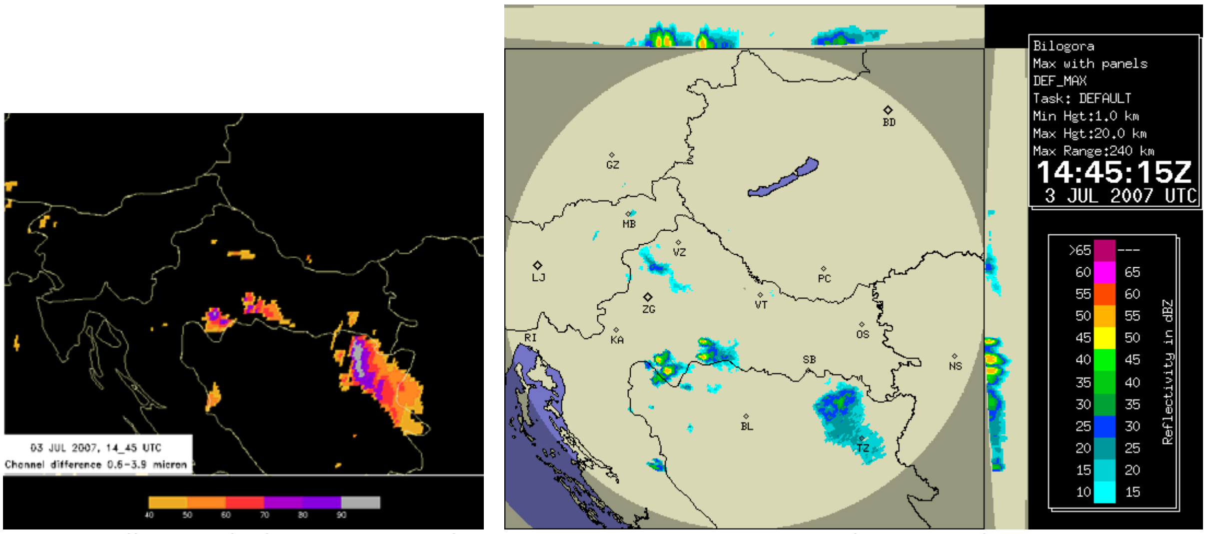

Figure 7: **Difference of reflectance values of 0.6-3.9 µm (a) and Radar Maximum reflectivity (b) for 03 July 2007, 14:45 UTC.**

Following the same development further in time shows that the system developing in Central Croatia, detected in the early stage by the difference method, was an important system since all further development at that day was triggered at the same spot and moved north-westwards. The situation on 03 July at 14:45 UTC is shown in Figure 7. The difference values are now higher then in the previous images suggesting either that larger ice particles have formed on top of the storms, making the reflectance in 3.9 µm very low, or that reflectance in 0.6 µm is very high. Two systems with large positive differences of 0.6 µm and 3.9 µm reflectance values are detected in the region of northern Croatia (Figure 7a). They consist of two cells each, which is confirmed by the corresponding radar data (Figure 7b). The system at the south-eastern Croatian border is the remnant of the previously active system, now showing only relatively weak radar reflectivity, but still having large difference values, due probably to large ice anvil on top.

CONCLUSION

The possibility of using reflectance information from the satellite data in detecting the first signs of convection and thereby improving the operational convection detection scheme is presented. Investigation of numerous convective cases and comparison to radar reflectivity data showed that the difference of reflectivity 0.6 μm-1.6 μm and 0.6 μm-3.9 μm channels gives a good indication of convective cells and can be used in convective clouds detection schemes, provided that the thresholds are set properly. For the operational use in Croatia, a direct benefit is the ability to detect convective cells coming from the sea to the Croatian Adriatic coast, where no radar coverage is present. Besides coastal areas, this method seems also promising for mountainous areas where the radar cannot observe clouds developing in deep, narrow valleys.

The difference values are much higher for 3.9 μm reflectance, due to much larger absorption at 3.9 μm than at 1.6 μm. However, in both 0.6-1.6 and 0.6-3.9 μm differences even very small cells in the early development phase are seen. Additionally, it seems that the difference of reflectances 0.6 μm-3.9 μm channel could be used for identifying the phase in the life-cycle of the convective storm. This has to be further investigated. The efforts in the future will also include testing the method for winter convection cases and the thresholds will be further examined. The results of the difference method will be combined with the IR detection method into one operational product.

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