Characteristics of Cold-Ring Pattern on Meteosat/SEVIRI IR Satellite Images over Slovenia and their relation to hail reports

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ABSTRACT

In this paper a study on the characteristics of cold rings and cold U/V shapes as seen atop convective clouds in infrared imagery from SEVIRI/Meteosat was done. The characteristics of such features over Slovenia were studied. The database of such features is presented with typical values. The case of 11 July 2011 is presented where severe weather in Slovenia with strong wind, strong precipitation and a deep layer of hail on the ground (up to 20 cm) was reported which caused a lot of damage. On that day a long lasting cold ring was detected in IR SEVIRI/Meteosat imagery and is presented. Additionally for the summer 2011 the cold rings and cold U/V shapes were detected using automatic detection algorithm SATSEVERE. An analyse is presented for the days when hail on the ground was reported.

1. Introduction

Satellite data gives very important information about the state of the atmosphere. In this paper we focus on the special patterns that can be detected atop a deep convective cloud in the infrared spectrum of satellite imagery. Studies performed several decades ago documented that the characteristics of convective cloud tops in weather satellite imagery can be used to infer information about storm intensity, possible severity (Purdom, 1976; Adler and Fenn, 1979). A special category of storms, exhibiting a feature called a cold U/V shape, as seen on infrared (IR) satellite images was documented. In recent years, this topic again became important with the use of the Meteosat Spinning Enhanced Visible and Infrared Imager (SEVIRI) data. An extensive overview of the research during previous years on the cold U/V shape and the cold ring is given by Setvak et al. (2010).

2. Database of cold rings and cold U/V shapes

For this study we used Meteosat Spinning Enhanced Visible and Infrared Imager (SEVIRI) data. The database consists of 139 cases of cold rings or cold U/V shapes as seen on Meteosat/SEVIRI IR imagery in the summer time in the period 2006-2010 in the region of Slovenia and its surroundings (see Fig. 1) and it is called a SATCR-SI database.

Fig. 1. Area over which the cold rings or cold U/V shapes were collected in the database.
The SATCR-SI database was established for studying the characteristics of cold rings and for the development and validation of the automatic cold-ring detection algorithm, (Iršič Žibert et al. 2012). The cold rings were subjectively detected, diagnosed and marked as cold rings with the tool, which makes it possible to visualize all the SEVIRI channels and it provides a basic functionality for labeling cold rings as interactive polygons on a selected area of the image. The polygons are saved in the database and can be exported to a file. The SATCR-SI database will be extended also with future cases.

The characteristics of SATCR-SI database are presented in Table 1, where Tmin represents the minimum cloud-top brightness temperature observed from the satellite. Tmin is usually near the apex of the cold U/V or, in the case of cold ring, it represents the minimum temperature of the cold ring. It is associated with adiabatic expansion owing to air parcels in the thunderstorm updraft region overshooting the tropopause, (Brunner et al., 2007). The latitude and longitude of the Tmin were recorded and used for the reference position of each cold ring. Tmax is the maximum cloud-top brightness temperature detected within the central warm spot (CWS), also known as the embedded warm area. Tdiff is the difference in the cloud-top brightness temperatures between Tmin and Tmax. Dist represents the distance between the Tmin and Tmax locations.

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tmax</td>
<td>-62.9 °C</td>
<td>-48.8 °C</td>
<td>-53.6 °C</td>
</tr>
<tr>
<td>Tmin</td>
<td>-70.4 °C</td>
<td>-55.6 °C</td>
<td>-61.3 °C</td>
</tr>
<tr>
<td>Dist</td>
<td>11 km</td>
<td>65 km</td>
<td>27 km</td>
</tr>
<tr>
<td>Tdiff</td>
<td>3 °C</td>
<td>13.4 °C</td>
<td>7.1°C</td>
</tr>
</tbody>
</table>

*Table 1. Characteristics on SATCR-SI database.*

### 3. Case 11 July 2011

On 11 July 2011 there was a huge damage in SE Slovenia due to severe convection.

*Fig. 2. Hail on the ground for the location Bizeljsko on 11 July 2012, (c) RTVSLO.*

*Fig. 3. Daily radar VIL and hail reports (red triangles) on 11 July 2011.*
The damage in SE Slovenia, especially in the area of Kozjansko was on buildings, cars and on extensive agriculture area due to strong wind, strong precipitation and especially large hail. In the area near Bizeljsko there were very deep layers of hail on the ground (up to 20 cm), see Fig. 2. The agriculture area of size >6,200 hectare near Bizeljsko was completely destroyed, the damage was estimated to be at least 10 million EUR for that day.

On Fig. 3 there is a daily radar Vertically Integrated Liquid (VIL) with three thresholds for hail indication: yellow – possible, orange - likely, pink – very likely. Red triangles are location with hail reports on ground network stations and black dots the locations of ground stations with no report on hail on 11 July 2011.

On the HRV satellite image the overshooting tops were clearly visible near the border Slovenia-Croatia, see an example at 16:30 UTC on Fig. 4. At the same time on IR image cold ring was clearly visible on IR image, see Fig. 5.

![Fig. 4. Meteosat SEVIRI HRV image at 16:30 UTC on 11 July 2011.](image)

![Fig. 5. Meteosat SEVIRI IR image at 16:30 UTC on 11 July 2011.](image)

Cold rings at different times were detected in Meteosat/SEVIRI IR imagery. The characteristic of the coldest part 30 minutes before cold ring was observed are plotted in Fig. 6 in pink. Cold ring was observed at 16 UTC, lasting 1 h. On Fig. 6 the time changes of minimum brightness temperature on the cold ring (Tmin) and the value of maximum brightness temperature in the central warm spot (Tmax) are shown on Fig.6, where it can be seen that the difference between these two values were more than 10 K.
Such long lasting cold rings or cold U/V shapes are typical for severe weather with strong wind, strong precipitation and many times also large hail (>2 cm).

4. Summer 2011: Hail reports and CR

The SATSEVERE algorithm for automatic detection of cold-ring (CR) patterns or cold U/V shapes enables large-scale analyses of such patterns over large regions or over long periods of time, (Iršič Žibert et al., 2012). The main design objectives of SATSEVERE were the computational speed and the robustness of the detection.

The algorithm was developed to operate in real time, which enabled the rapid processing of large amounts of data and possible utilization in the operational process of a weather-warning system. The second design objective was achieved by reducing the input constraints of the algorithm and by processing only IR images, which enabled the detection of CR patterns also during the night. For the summer period from April to September 2011 the SATSEVERE algorithm was used to detect the cold rings or cold U/V shapes as seen on IR images. These data were combined with the ground observation data on hail from the Slovenian ground network. On the Fig. 7 there is display of days with cold ring detected by SATSEVERE algorithm (red bars) and days when hail was reported by the ground stations (blue bar), where also the number of stations

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[Fig 6. Brightness temperature of the cloud tops near Bizeljsko before cold ring was observed (pink) and minimum brightness temperature on the cold ring (red) and maximum brightness temperature in the central warm spot (blue).]

[Fig 7. Days with hail in Slovenia from end of April to September 2011 (blue) and cold ring or cold U/V shape as seen on Meteosat IR images (red).]
reporting the hail is indicated. In the summer 2011 there were 35 days with hail in Slovenia reported by ground stations.

We have found out that there were many days in 2011 when cold ring or cold U/V shapes were detected, but not in all cases, see Fig. 7. More detailed study taking into account also the size of hail (>3 cm) and severe wind will be further performed.

5. Conclusions and future plans

Nowcasting and monitoring of convective storms is important especially in the event of severe weather. Cold rings or cold U/V shapes as seen atop convective clouds (Setvak et al., 2010) are together with other sources of information very important for recognizing and alerting in case of severe convection. Characteristics of cold rings and cold U/V shapes were studied and automatic algorithm SATSEVERE for detection of such features was used. In the show case 11 July 2011 where large hail in deep layer was reported in SE Slovenia, cold rings and cold U/V shapes were clearly seen in IR imagery and the characteristics are presented. Overview of the summer 2011 showed that cold rings or cold U/V shapes are not always present when hail is reported. In the future studies the analyse of large hail (>3 cm), strong wind and strong precipitation over many years in combination to cold ring or cold U/V shapes detection based on SATSEVERE will be performed and discussed.

REFERENCES


