Deep convection and intense precipitation detection using geostationary weather satellite data: a case study of air-mass and concealed frontal convection

Gorlach I.A., Shishov A.E.[1]

Remote sensing methods for deep convection and intense precipitation detection are becoming more accessible for operative analysis and comparison with other meteorological methods. New technologies, software tools, visualisation systems, and composite products are developed to identify patterns within cloud systems and severe weather phenomena.

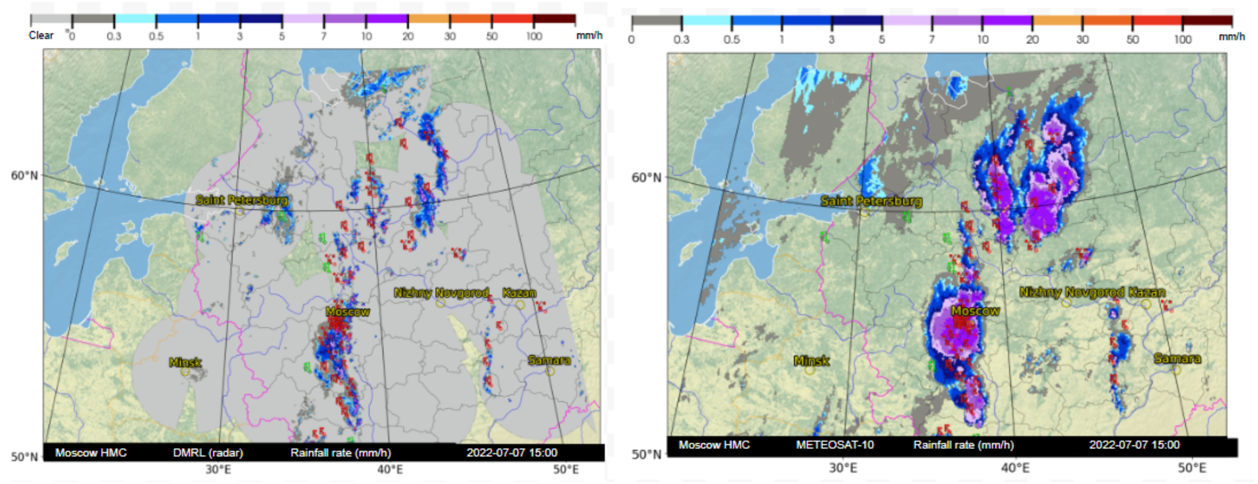
This paper is dedicated to the comparative analysis of satellite imagery and radar data based on the Deep Convection Cloud Monitoring System (DCCMS), developed by the authors [2]. The system provides a possibility to automatically detect deep convection and high rainfall rate (greater or less than 0.4 mm/h) zones based on brightness temperature and radar reflectivity measurements using a blend of thresholding and machine learning algorithms. It also provides interactive visualisation tools that are useful for further analysis. This paper describes the results of using DCCMS to study two cases of deep convection over European Russia (Figure 1): air-mass convection (7 July 2022) and concealed frontal convection (2 October 2022).

Rainfall rate (mm/h) was estimated based on 10-minute radar reflectivity (maximum value over 11 vertical levels) from radar network DMRL-S over European Russia to serve as the ground truth for both the air-mass deep convection case (7 July 2022) and the frontal clouds with concealed convection case (2 October 2022). Spatial resolution of these measurements was equal to 1x1 km.

Brightness temperature measurements in the infrared window (with the central wavelength equal to 10.8 micrometres) derived from meteorological geostationary satellite Meteosat-10 images were used to calculate rainfall rate according to a formula proposed in [1]. Temporal and spatial resolutions of these observations were equal to 5 min and 5x5 km, respectively.

The application of the DCCMS system designed for automated deep convection detection using machine learning algorithms allowed to identify deep convection regions (masks) in satellite images (Figure 1b) and evaluate high rainfall rate conditions in air-mass and concealed frontal deep convection (Figure 2).

The datasets were reprojected and resampled to match in space and time. Overall, 144 time periods of scene observations (images) were selected for each of the considered cases.



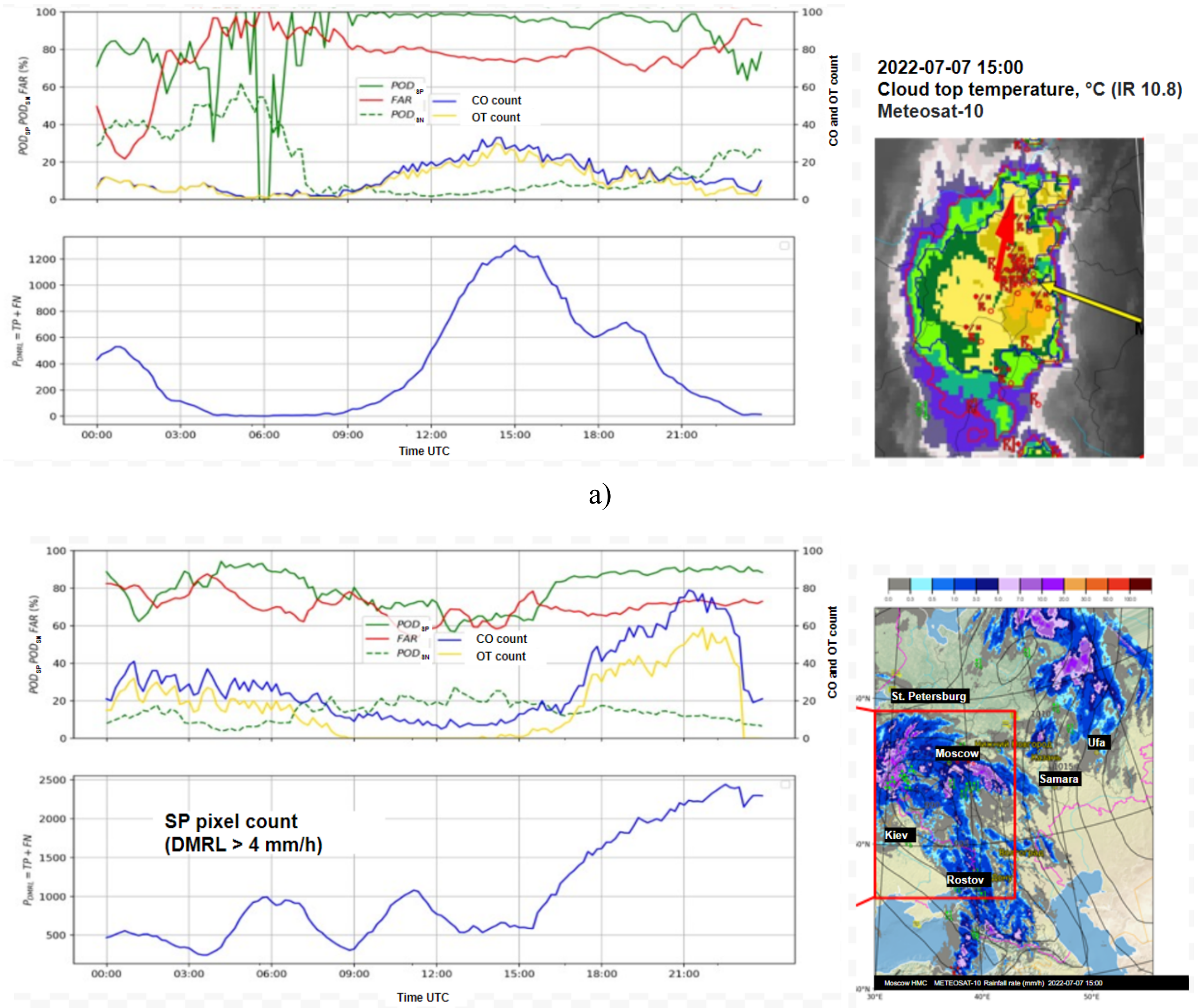
a) b)

Fig.1 Rainfall rate (mm/h) distribution estimated from radar (a) and satellite (b) data for 2022-07-07

---

[1] The Hydrometcentre of Russia, 123242 Moscow, Russia, B. Predtechenskiy per., shandruha@gmail.com

The comparison method consisted in pixel grouping according to the rainfall rate values derived from DMRL data: greater than 4 mm/h - showers present (SP), less than 4 mm/h - showers not present (SN). The following detection accuracy metrics have been computed: probability of detection (%) for phenomena from “SP” group - POD_{SP}; probability of detection (%) for phenomena from “SN” group - POD_{SN}; false alarm rate (%) - FAR. Hourly radar and satellite remote sensing data comparison results are depicted in Figure 2a) and 2b).


a)

b)

Fig. 2. Rainfall rate estimates (greater and less than 4 mm/h) comparison within and outside deep convection clouds for 2022-07-07 (a) and 2022-10-02 (b)

In conclusion, the detection of high rainfall rate regions proved to be accurate within deep convection zones (with POD varying from 90 to 100%), but the presence of false alarms, particularly in the case of small isolated cores, indicates the need for further improvement of the proposed algorithms.

References

1. Vicente G. A., Scofield R.A., Menzel W.P. The Operational GOES Infrared Rainfall Estimation Technique // Bulletin of the American Meteorological Society. – 1998. – T. 79. – № 9. – C. 1883-1898.

2. Shishov A.E., Gorlach I.A. Computer Software Copyright Registration Certificate No. 2022680485 from 01.11.2022. - Deep convection cloud monitoring system (DCCMS). «Hydrometcentre of Russia».2022.01.11.