Cloud parameters and storm severity based on lightning activity over Ukraine

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This paper presents results of the analysis of cloud parameters (CP) determined from images of Rapid Scan Service of MSG (5 min update) and storm severity based on lightning activity (scaled from level 1 (weakest) to Dangerous Thunderstorm Alert).

1.Lightning data

Ukrainian Total Lightning Network (**UTLN**), as a part of **Earth Networks**, installed in Ukraine is capable to detects the components of both intra-cloud (IC) and cloud-to-ground (CG) flashes with a high efficiency and very precise spatial detection (200 m). Many studies have shown that the use of **total lightning** (IC and CG) provides significantly better identification of storm severity. The components of total lightning detection consist from lightning flashes and pulses, lightning cell (cluster of flashes), trajectory of lightning cell tracking, lightning flash rate (flashes/min) and a warning area ahead of the storm cell, based on combination of information from the cells, such as the moving speed and direction and size of the cell (fig.1). Depend on severity of storms there are three levels:

- level 1 (flashes/min in lightning cell < 10);
- level 2 (<10 flashes/min in lightning cell < 25);\
- DTA (flashes/min in lightning cell >25).

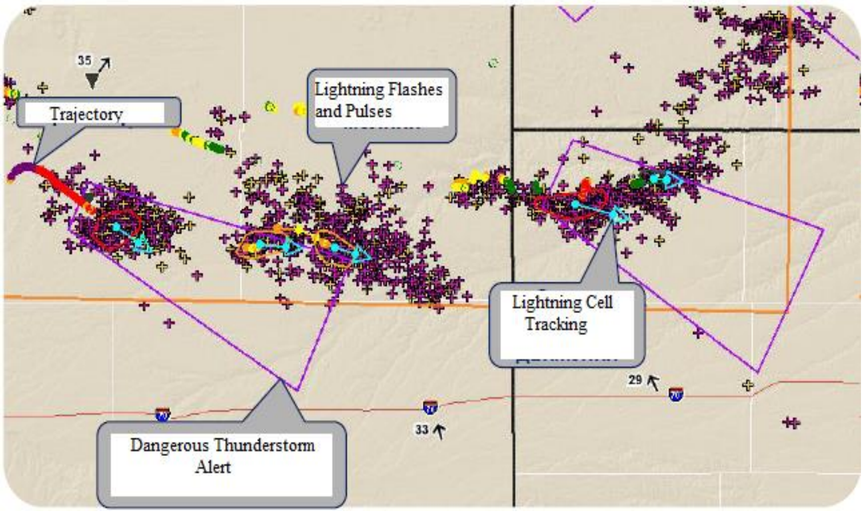

Fig.1.Components of total lightning detection and Dangerous Thunderstorm Alert [1].

2. Estimation of cloud cover parameters from satellite data

Satellite images are extremely important for estimation of cloud parameters, such as brightness temperature (BT), cloud optical thickness (COT), cloud effective radius (CER) of ice particles, cloud liquid water path (CLWP), cloud phase (CPH) and cloud top height (CTH). The MSG satellite, which has significant advantages compare to other one in spectral bands, spatial resolution and time sampling that provides a reliable tool to monitor these parameters of severe clouds life-cycle [2].

a) Estimation of CTH and BT.

The method is based on the brightness temperatures in infrared (IR) spectral region estimated from satellite and complementary temperature vertical profiles. These profiles provided by simulations performed by the mesoscale Weather Research Forecast (WRF) model. The algorithm of CTH retrieval from MSG data (10×10 km) has been developed in UHMI and its flowchart is shown with output on Fig.2.

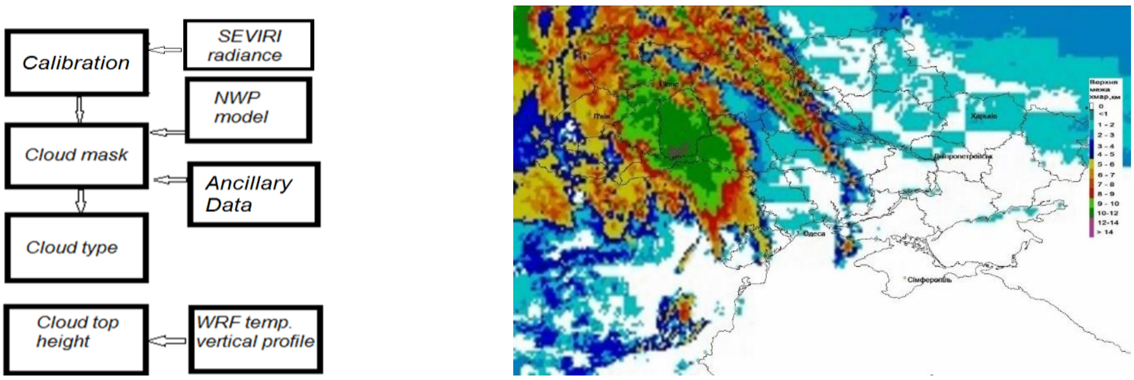

Fig.2.The flowchart of CTH retrieval algorithm and its output.

b) Estimation of COT, CER, CIWC and CPH.

The principle of methods to retrieve cloud physical properties (COT, CER, CIWC and CPH) is that the reflectance of clouds at a non-absorbing wavelength in the visible region (0.6 or 0.8 mm) is strongly related to the optical thickness and has very little dependence on particle size, whereas the reflectance of clouds at an absorbing wavelength in the near-infrared region (1.6 or 3.8 mm) is primarily related to particle size. The flowchart of the algorithm of cloud physical properties retrieval with spatial resolution (10×10 km) is shown on Fig.3 and examples of its output on Fig.4 . The CLWP is computed from the retrieved cloud optical thickness at wavelength at 0.6 mm and droplet effective radius (re) :$CLWP=2/3*\tau_{vis} r_e \rho_l$, where ρ_l is the density of liquid water. For ice clouds the CLWP is retrieved with an assumed effective radius from 20 mm to 40 mm for ice crystals. CPH is estimated depend on near-infrared and visible band ratio. We assumed that the ratio 0.75 ÷ 1.00 - liquid cloud, 0.25 ÷ 0.75 - mixed cloud and <0.25 – ice cloud.

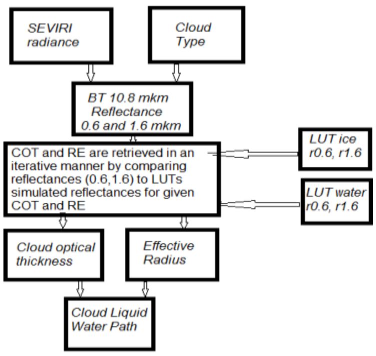

Fig.3. The flowchart of COT, CER, CIWC and CPH retrieval algorithm

3. Analysis of Cloud Parameters Depend on Lightning Severity

Collocated and coincidence satellite and lightning data for July – August 2016, May – August 2017 and April – September 2018 over Ukraine have been collected. Parallax correction to satellite derived cloud parameters has been applied. Because satellite data are available every 5 minutes we assume that coincidence lightning data are those that observed in less than 2.5 minutes to the nearest time-slot of satellite data. In the analysis we use only lightning cells more than15000 cases. The histograms of COT, CER, CIWC and CPH for different lightning severity are shown on fig.4

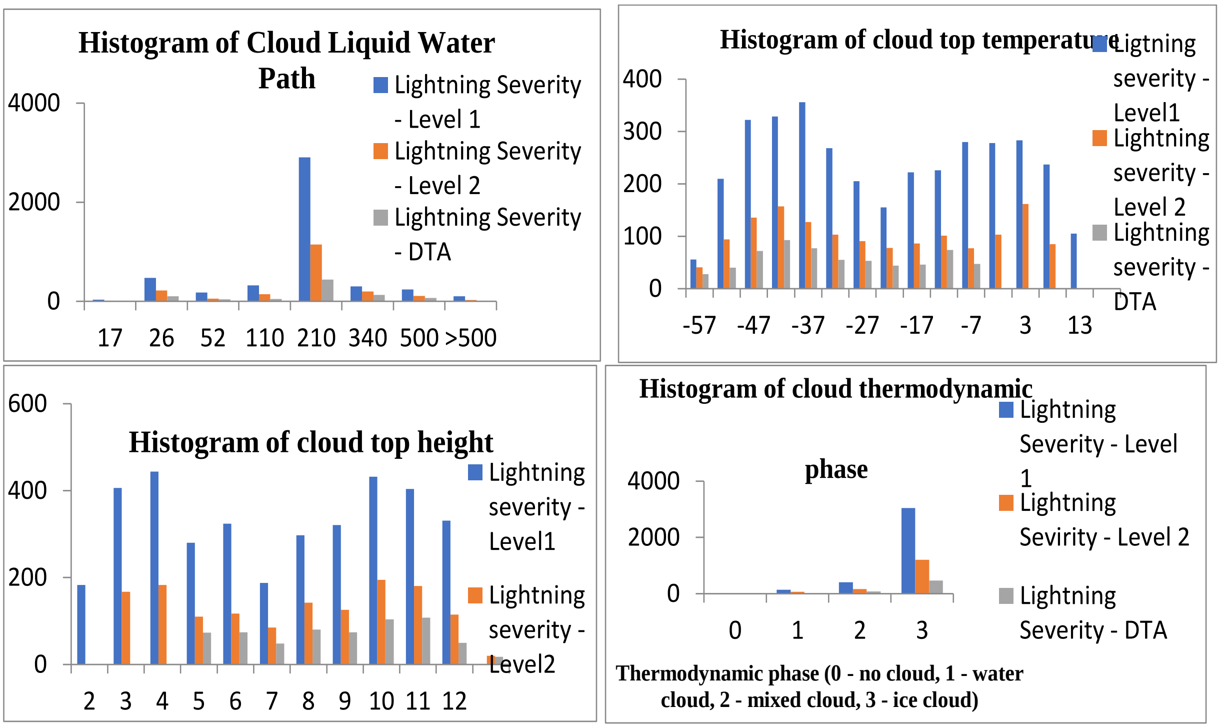

Fig.4. The histograms of COT, CER, CIWC and CPH depend on different lightning severity

Conclusion:

1. Analysis shows that an increase of CTH and a decrease of cloud BT lead to a changing of lightning severity, but most of other cloud parameters are not changed.
2. Two peaks on histograms show that severe lightning activity can be produced by small clouds or small active part of clouds, which size is less than satellite spatial resolution. In order to detect these clouds satellite data with higher spatial resolution is needed.
3. Analysis of time span between different levels of lightning severity shows that time span between level 1 and level 2 is much bigger that between level 2 and DTA, to detect the beginning of dangerous thunderstorms by satellite a temporal update of satellite data should be < 2 minutes.

References:

1. Charlie Liu, Chris Sloop, Stan Heckman. Application of lightning in predicting high impact weather. *Preprints, WMO Technical conference on meteorological and environmental instruments and methods of observation, July 7-9,* Saint Petersburg, Russian Federation, 2014.
2. Kryvobok O., Kulbida M., Savchenko L. Monitoring of Severe Weather in Ukraine With the Use of Satellite Data. *Use of satellite and in-situ Data to Improve Sustainability/ Part of the series NATO Science and Security/ Series C/Environmental Security*, Springer Netherlands, 2011, pp. 41-48