# The relation between cloud parameters and storm severity based on lightning and satellite data

O.Kryvobok (kryvobok@uhmi.org.ua)

Ukrainian Hydrometeorological Institute, Kyiv, Ukraine

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City Hotel Ljubljana Slovenia

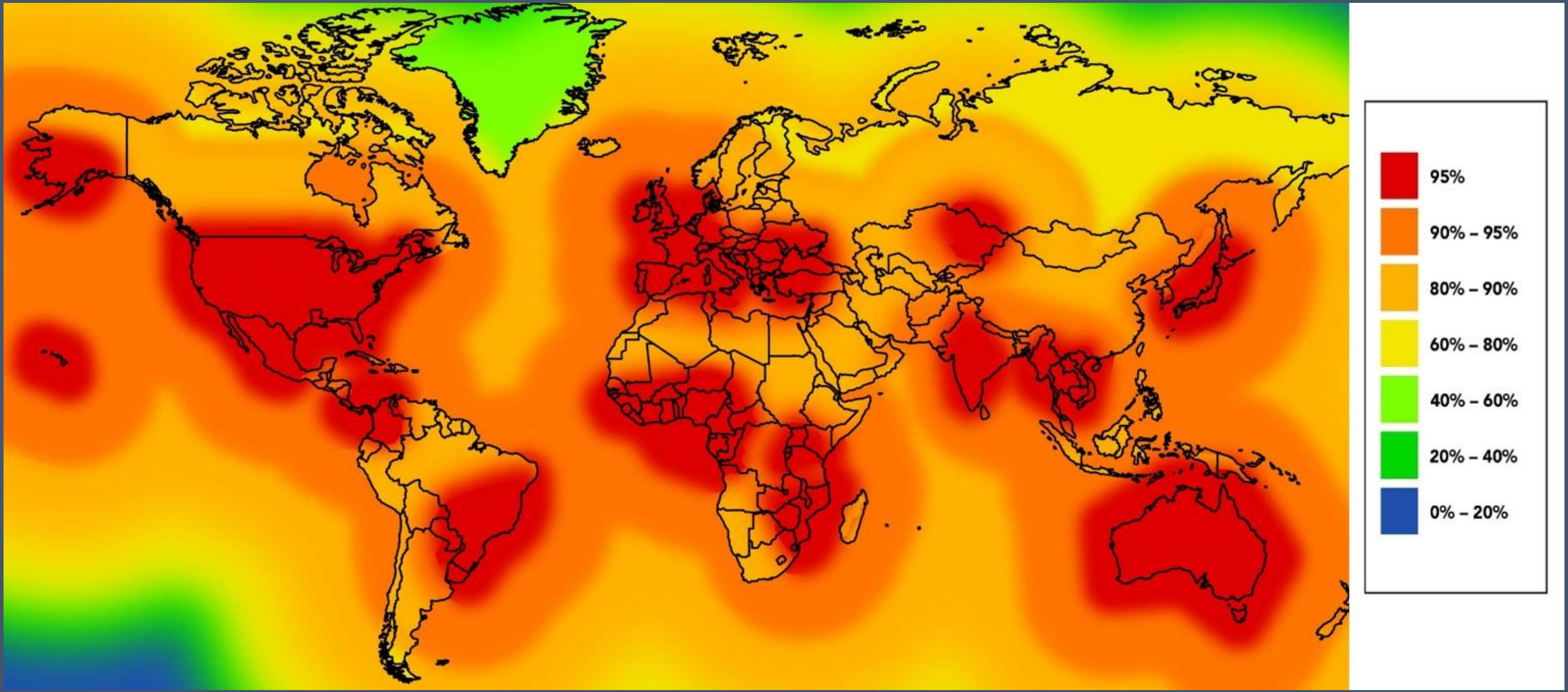
# OVERVIEW

a. Motivation ;
b. Lightning data (“lightning cells” of different kind of severity);
c. Satellite data and products used;
d. Results.
e. Summary and future work.

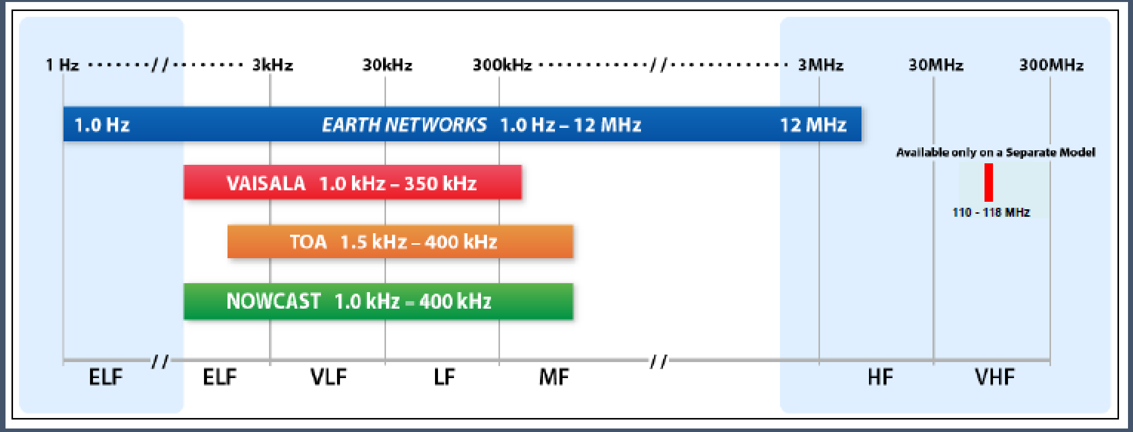
# MOTIVATION

- Clouds need to be 3-4km thick before we notice significant electrification. The deeper the clouds the more electrification (lightning)
- Only cold clouds show significant electrification (ice is important)
- Electrification observed in clouds with strong updraft velocities;
- Recent research has indicated a strong correlation between total lighting data (both in-cloud and cloud-to-ground) and severe weather such as hail and high wind storms.

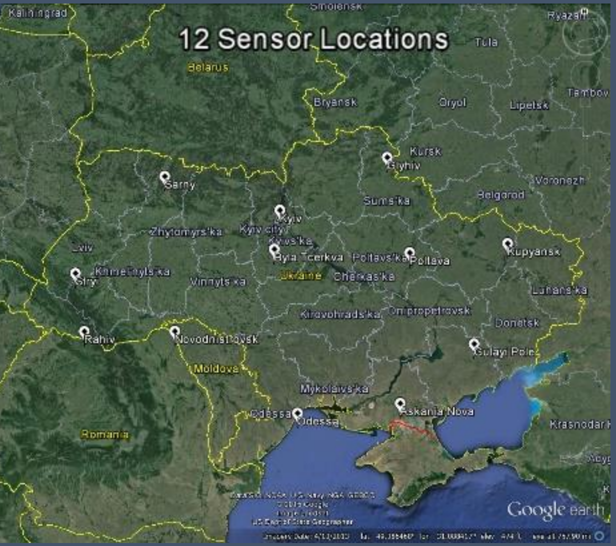
# LIGHTNING DATA
# EARTH NETWORKS TOTAL LIGHTNING NETWORK

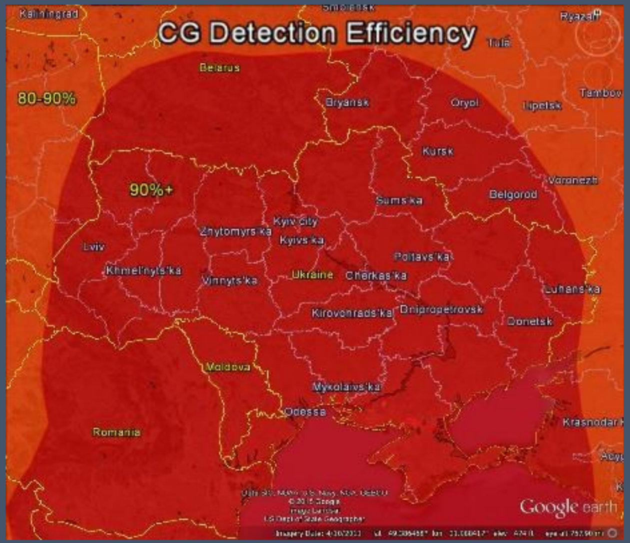


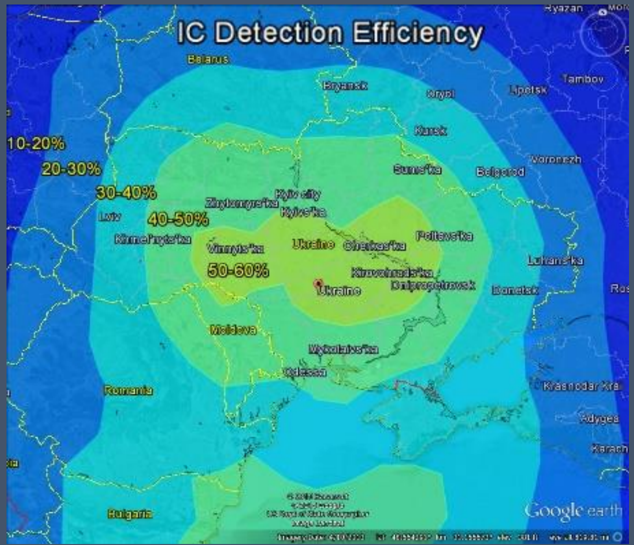
# LIGHTNING DATA




- Ukrainian Total Lightning Network (**UTLN**), as a part of **ENTLN**, installed in Ukraine is capable to detects the components of both intra-cloud (IC) and cloud-to-ground (CG) flashes, and algorithms use waveform shapes to differentiate between the IC and CG pulses (i.e., components) with a high efficiency and very precise spatial detection (200 m).





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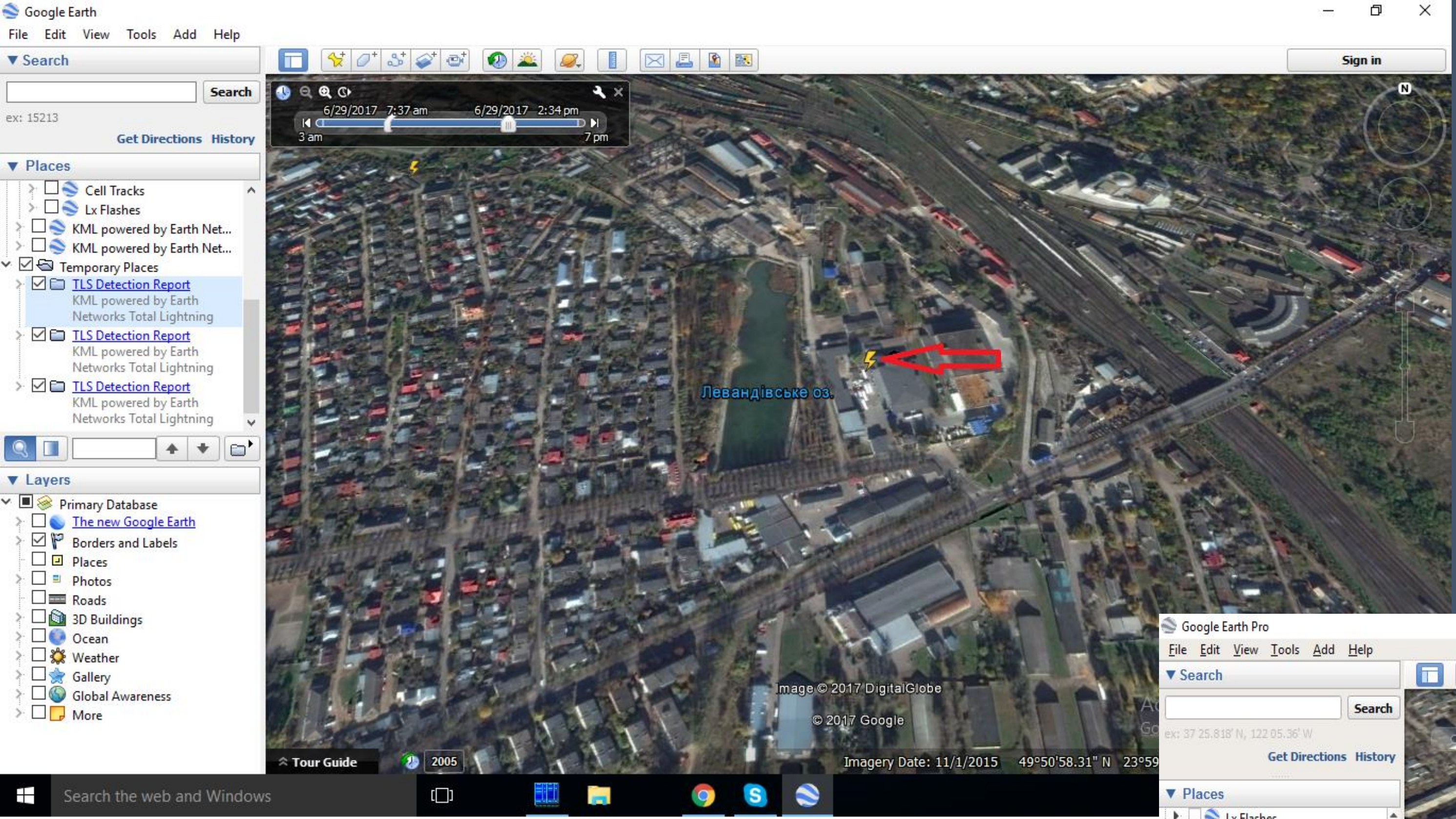
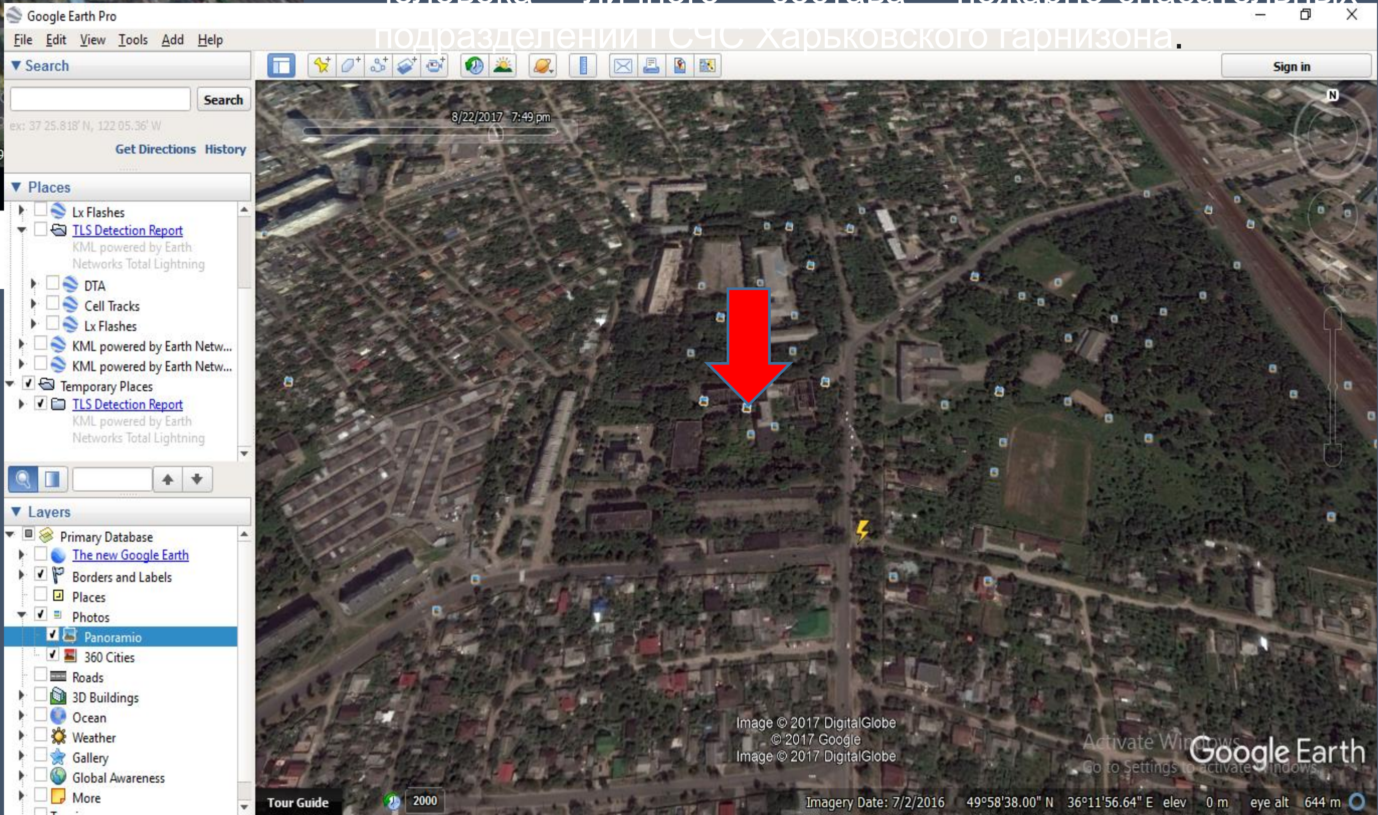



**Огонь гасили до 7 утра.**

В Харькове ликвидировали пожар в трехэтажном здании апелляционного административного суда. Об этом сообщает пресс-служба Госслужбы по чрезвычайным ситуациям (ГСЧС).

"В 19:40 22 августа 2017 года поступило сообщение о пожаре по улице Семинарская, 46 в трехэтажном здании Харьковского апелляционного административного суда. В 6:50 23 августа 2017 пожар ликвидирован на площади 1,8 тыс. квадратных метров", - говорится в сообщении.

Согласно информации пресс-службы, к ликвидации пожара привлекалось 39 единиц техники и 133 человека личного состава пожарно-спасательных подразделений ГСЧС Харьковского гарнизона.



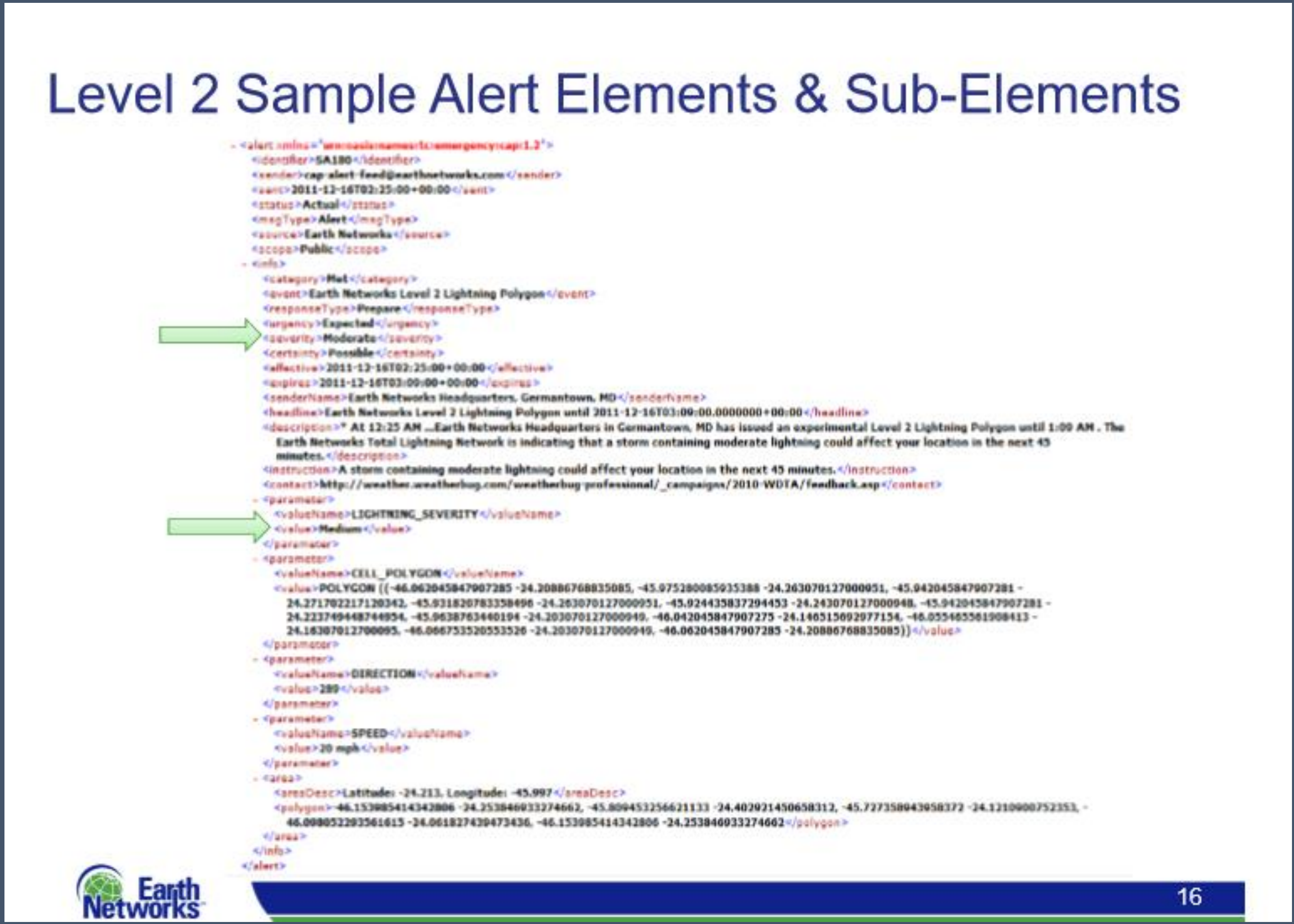

У Львові внаслідок удару блискавки загинули дев'ятирічна дівчинка та чоловік, а семирічний хлопчик та його батько отримали важкі опіки.

Про це повідомляє відділ комунікації поліції Львівської області. «Сьогодні, 29 червня, близько 15.00 до правоохоронців надійшло повідомлення про те, що у Залізничному районі Львова на Левандівському озері внаслідок удару блискавки загинуло двоє осіб, ще двоє - травмовані», - йдеться у повідомленні.

# Format of lightning data

ASCII Flash Feed Format

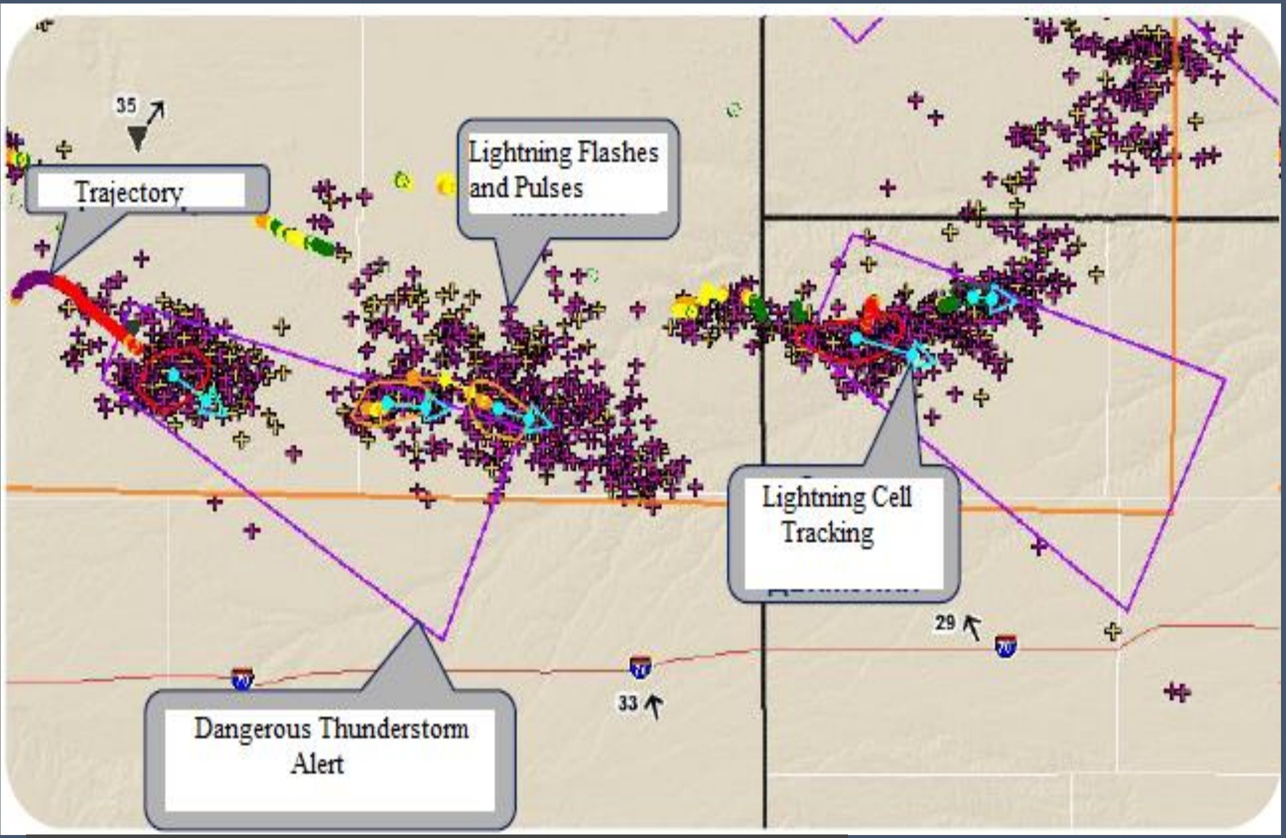

```
0x00,0x00,0x01,0x4D{
  "time": "2014-09-05T16:47:42.705711103Z",
  "type": 0,
  "latitude": 52.5970937,
  "longitude": -78.4994495,
   "peakCurrent": -14796,
  "icHeight": 0,
 "numSensors": 19,
 "icMultiplicity": 3,
 "cgMultiplicity": 1,
 " }
```

## Level 2 Sample Alert Elements & Sub-Elements


```
- <alert xmlns="urn:oasis:names:tc:emergency:cap:1.2">
    <identifier>SA180</identifier>
    <sender>cap-alert-feed@earthnetworks.com</sender>
    <sent>2011-12-16T02:25:00+00:00</sent>
    <status>Actual</status>
    <msgType>Alert</msgType>
    <source>Earth Networks</source>
    <scope>Public</scope>
  - <info>
      <category>Met</category>
      <event>Earth Networks Level 2 Lightning Polygon</event>
      <responseType>Prepare</responseType>
      <urgency>Expected</urgency>
      <severity>Moderate</severity>
      <certainty>Possible</certainty>
      <effective>2011-12-16T02:25:00+00:00</effective>
      <expires>2011-12-16T03:00:00+00:00</expires>
      <senderName>Earth Networks Headquarters, Germantown, MD</senderName>
      <headline>Earth Networks Level 2 Lightning Polygon until 2011-12-16T03:00:00.0000000+00:00</headline>
      <description>* At 12:25 AM ...Earth Networks Headquarters in Germantown, MD has issued an experimental Level 2 Lightning Polygon until 1:00 AM . The Earth Networks Total Lightning Network is indicating that a storm containing moderate lightning could affect your location in the next 45 minutes.</description>
      <instruction>A storm containing moderate lightning could affect your location in the next 45 minutes.</instruction>
      <contact>http://weather.weatherbug.com/weatherbug-professional/_campaigns/2010-WDTA/feedback.asp</contact>
    - <parameter>
        <valueName>LIGHTNING_SEVERITY</valueName>
        <value>Medium</value>
      </parameter>
    - <parameter>
        <valueName>CELL_POLYGON</valueName>
        <value>POLYGON ((-46.062045847907285 -24.20886768835085, -45.975280085935388 -24.263070127000051, -45.942045847907281 -24.271702217120342, -45.931820783358496 -24.263070127000051, -45.924435837294453 -24.243070127000048, -45.942045847907281 -24.223749448744954, -45.9638763440194 -24.203070127000049, -46.042045847907275 -24.146515692977154, -46.055465561908413 -24.163070127000095, -46.066753520553526 -24.203070127000049, -46.062045847907285 -24.20886768835085))</value>
      </parameter>
    - <parameter>
        <valueName>DIRECTION</valueName>
        <value>289</value>
      </parameter>
    - <parameter>
        <valueName>SPEED</valueName>
        <value>20 mph</value>
      </parameter>
    - <area>
        <areaDesc>Latitude: -24.213, Longitude: -45.997</areaDesc>
        <polygon>-46.153985414342806 -24.253846033274662, -45.809453256621133 -24.402921450658312, -45.727358943958372 -24.1210900752353, -46.008052293561615 -24.061827439473436, -46.153985414342806 -24.253846033274662</polygon>
      </area>
    </info>
  </alert>
```

# LIGHTNING DATA




Cell Tracks

Cell: SAS201804151136002
04/15/2018 06:50 PM ICT

| | |
|---|---|
| Alert Level | 0 |
| IC Rate | 3.3 flash/min |
| CG Rate | 1 flash/min |
| Direction | 83 |
| Speed | 9.5 kph |
| Expire Time | |
| Details | |

| Time | Alert Level | IC Rate flash/min | CG Rate flash/min | Total Rate flash/min |
|---|---|---|---|---|
| 02:50 PM | | 3.3 | 1 | 4.3 |
| 02:49 PM | | 5.7 | 1 | 6.7 |
| 02:51 PM | | 2.3 | 0.3 | 2.7 |
| 02:48 PM | | 6.3 | 1 | 7.3 |
| 02:47 PM | 1 | 4.7 | 1.7 | 6.3 |

## Components of total lightning detection and Dangerous Thunderstorm Alert

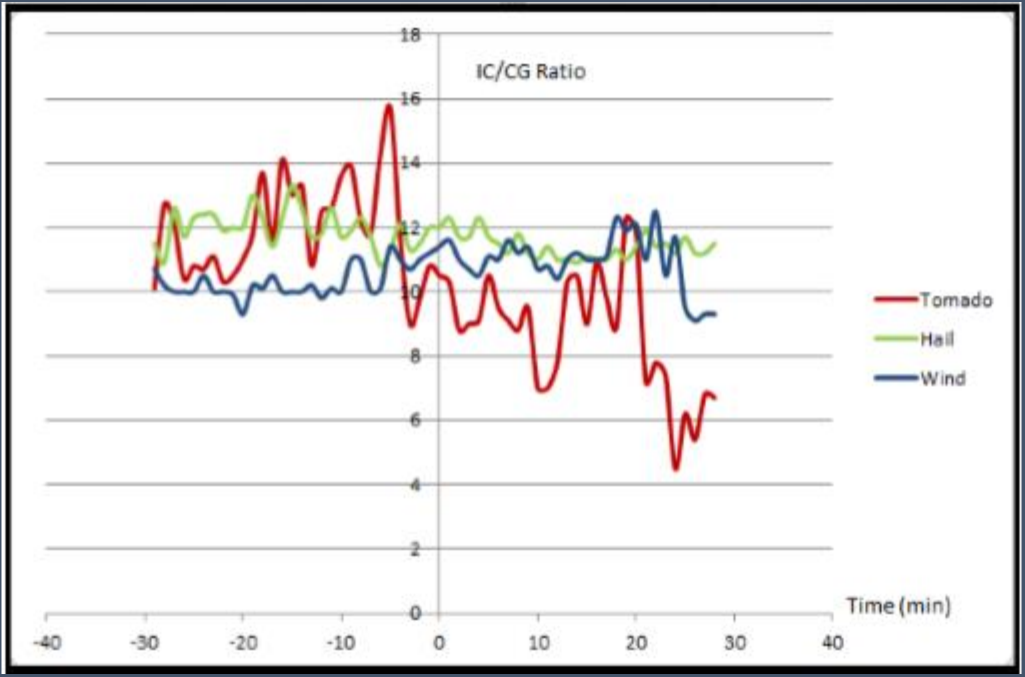
**(Charlie Liu, Chris Sloop and Stan Heckman,.APPLICATION OF LIGHTNING IN PREDICTING HIGH IMPACT WEATHER, OBS/IMO/TECO-2014 )**

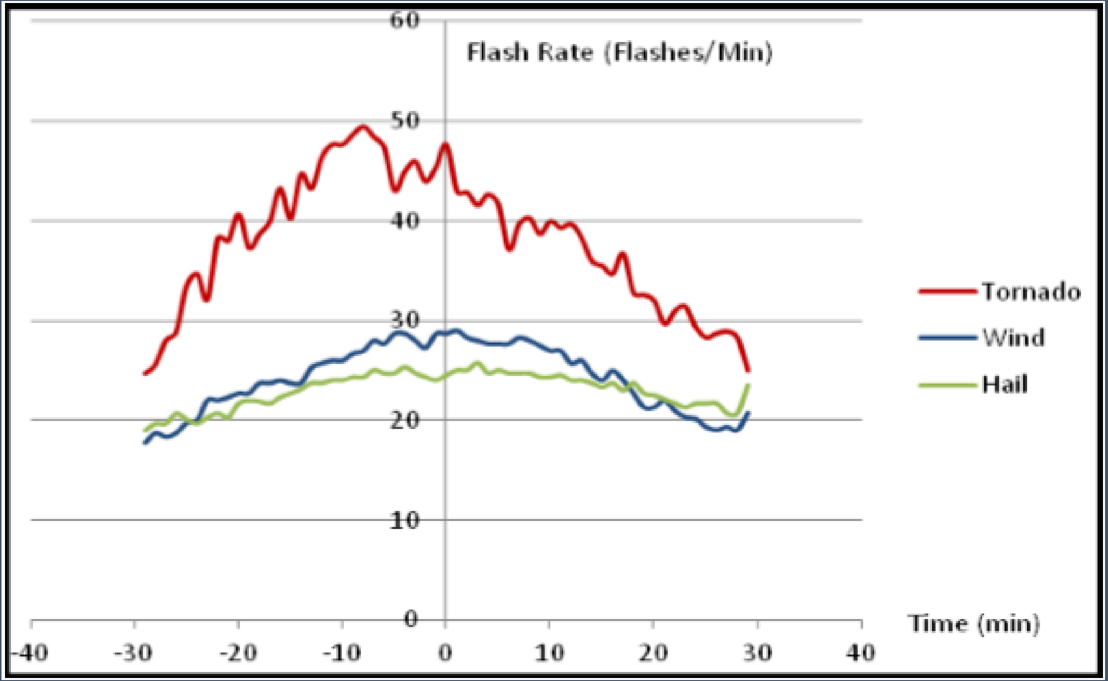
- A **lightning cell** is a cluster of flashes with a boundary as a polygon determined by the flash density value for a given period. The polygon is calculated every minute with a six-minute data window. The cell tracks and directions can be determined by correlating the **cell polygons** over a period of time. By counting the flashes in the cell, it is possible to estimate the **lightning flash rate** (flashes/min). The cell speed and area are also calculated. The flash data is streamed from a lightning manager service to the cell tracker as soon as a flash is located. The cell tracker keeps flashes in a moving time window of six minutes. Two gridding processes are executed every minute, using a snapshot of the flash data in that time window. The first gridding is on a coarse grid to quickly locate areas of interest and the second gridding is operated on a much finer grid using density functions to find the closed contours. Once a lightning cell is located and tracked, the total flash rates, including **IC** and **CG**, are calculated. By monitoring the flash rates and the rate changes, the severe storm cells or the ones to potentially become severe, can be identified. When a cell is identified and the total lightning rate jumps passing the threshold, a **dangerous thunderstorm alert (DTA)** can be issued. The threshold of total lightning rate may vary in different regions or different type of storms. To simplify the study, a threshold of 25 flashes/min was chosen. Combining the information from the cells, such as the moving speed and direction and size of the cell, **a warning area ahead of the storm cell** can be determined. The cell may reenergize and repeat the process again and trigger more alerts. 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 ).

# LIGHTNING DATA

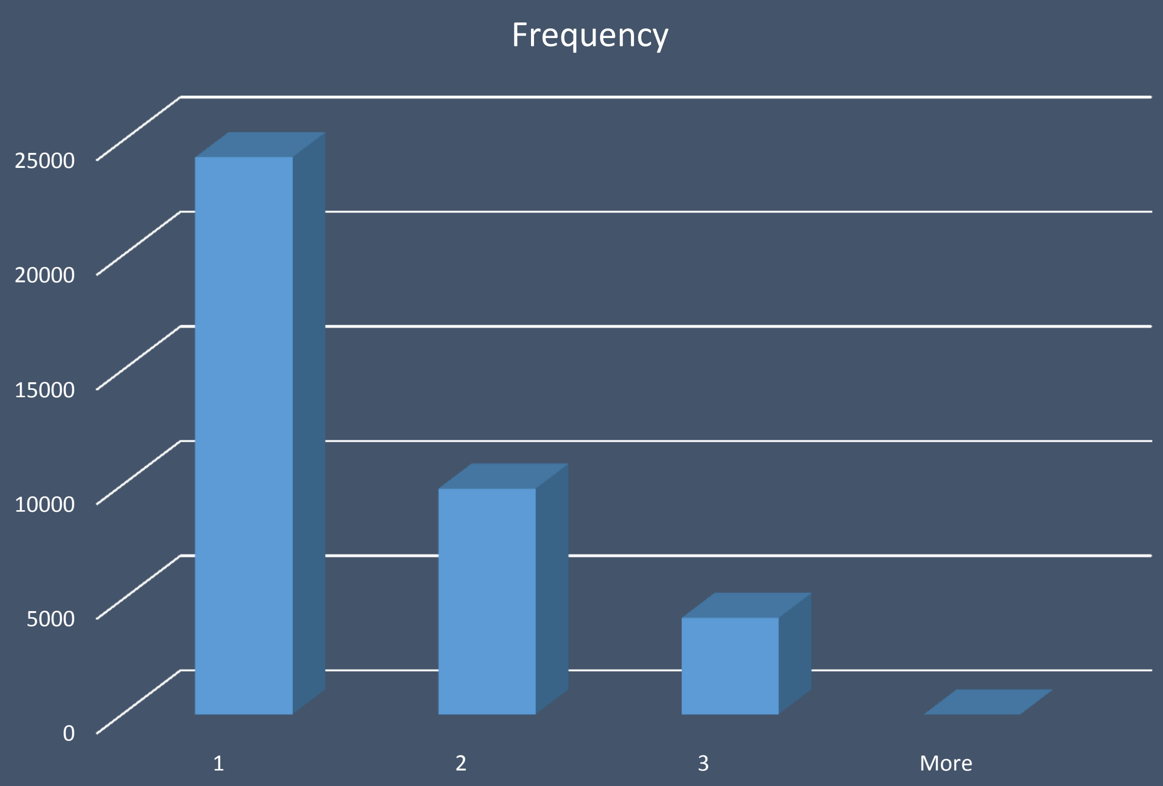
- Recent research has indicated a strong correlation between total lighting data (both in-cloud and cloud-to-ground) and severe weather such as hail and high wind storms. The lightning activities preceding severe storms have certain characteristics in lightning flashes, such as high in-cloud (IC) flash rates in the storm formation stage. The greater volume of strong updrafts during a severe thunderstorm results in more charging overall, leading to greater numbers of ICs and positive cloud-to-ground (CG) flash rates. The detection of total lightning data, especially IC lightning, enables improvements in the lead time of severe weather prediction and alerting. (APPLICATION OF LIGHTNING IN PREDICTING HIGH IMPACT WEATHER . Charlie Liu, Chris Sloop and Stan Heckman )

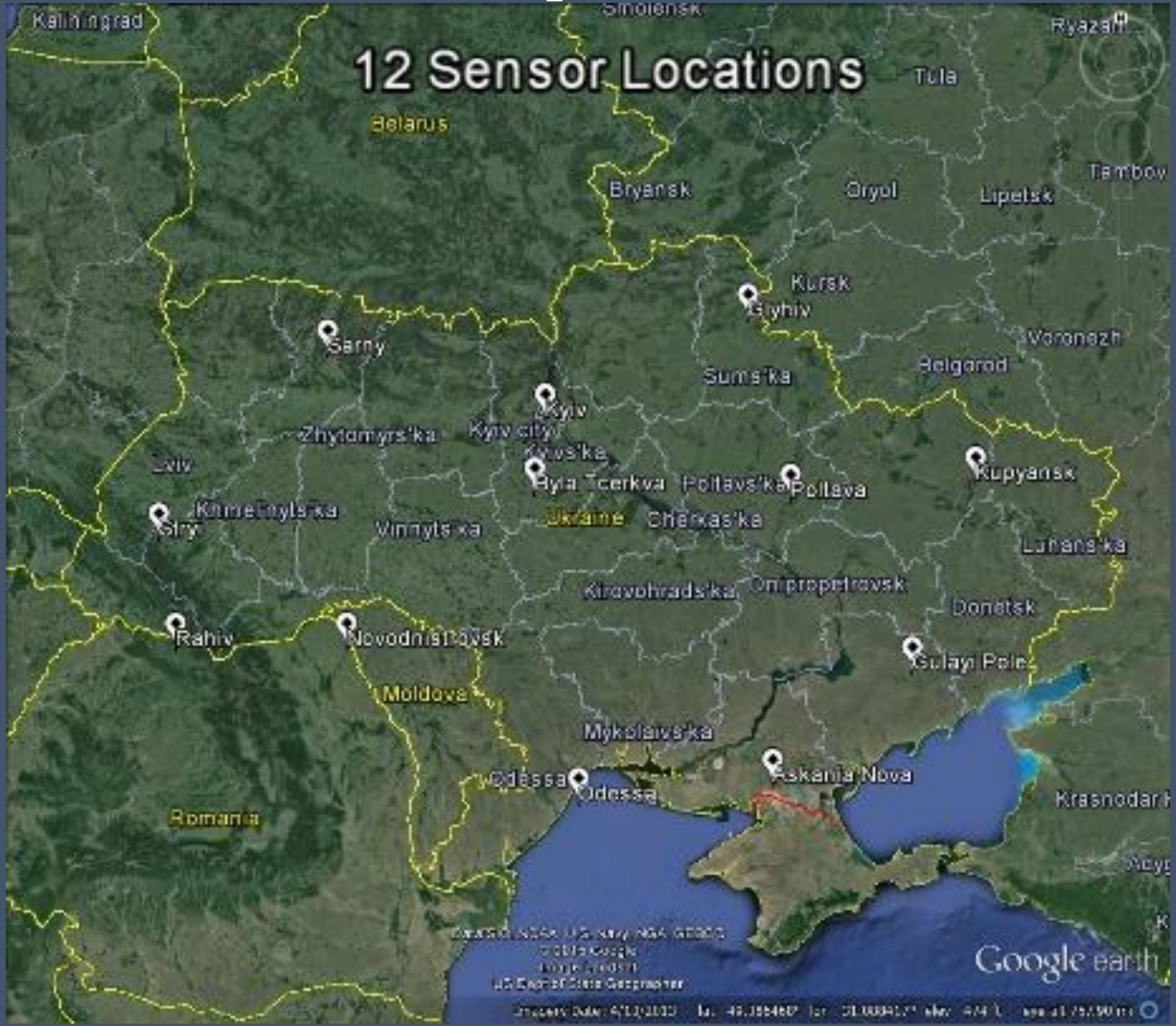


# LIGHTNING DATA

- We have collected lightning cells data from June to September 2017 over Ukraine > 30000 cases.



# SATELLITE DATA

- Meteosat/SEVIRI RSS 5 min.
- Satellite products* (to monitor the severe clouds life-cycle) such as:

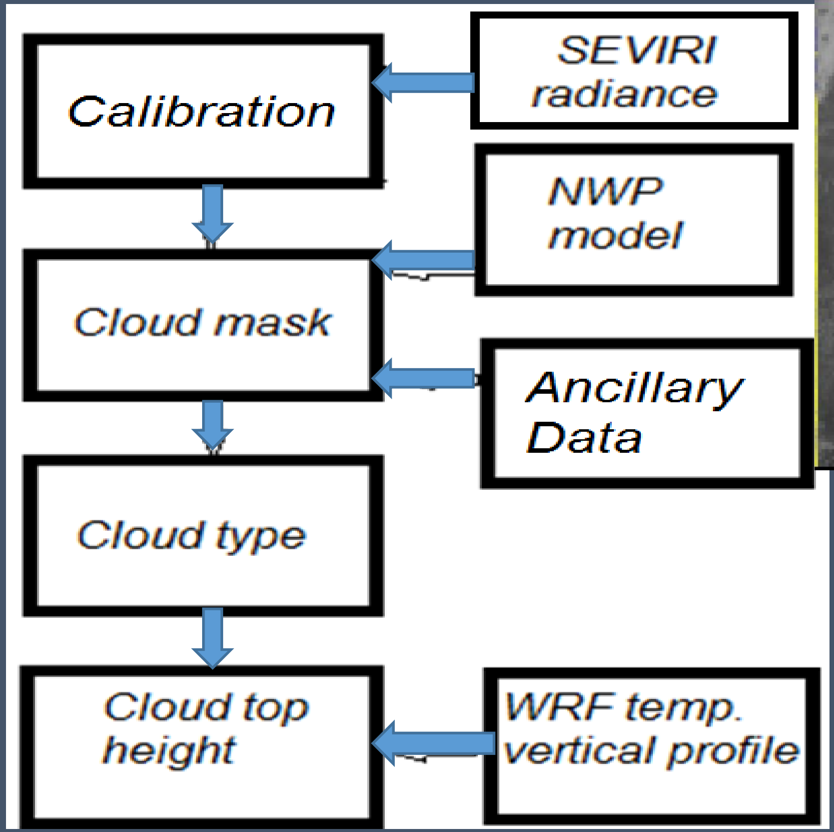
- brightness temperature (BT);      Day night
- cloud top height;  Day night
- cloud effective radius (CER) of water, ice particles;  Day
- cloud liquid/ice water path (CLWP, CIWP); Day
- cloud phase (CPH) and cloud optical thickness (COT). Day

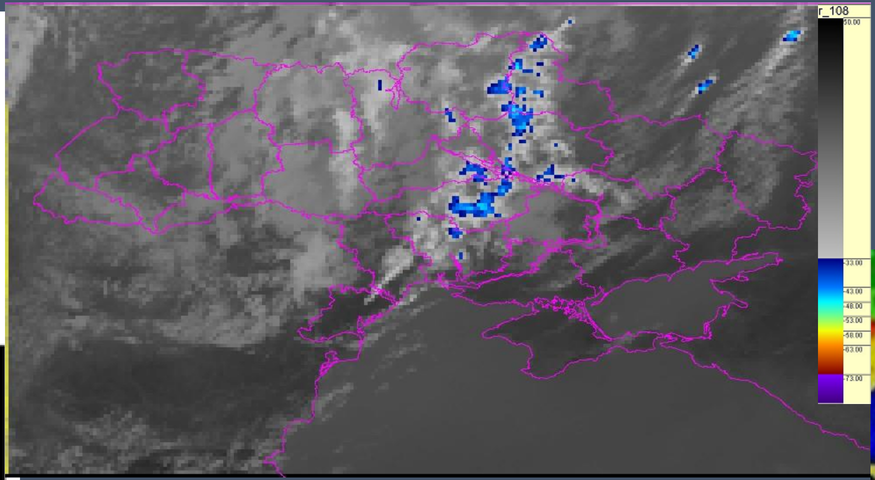
* all products are parallax corrected.

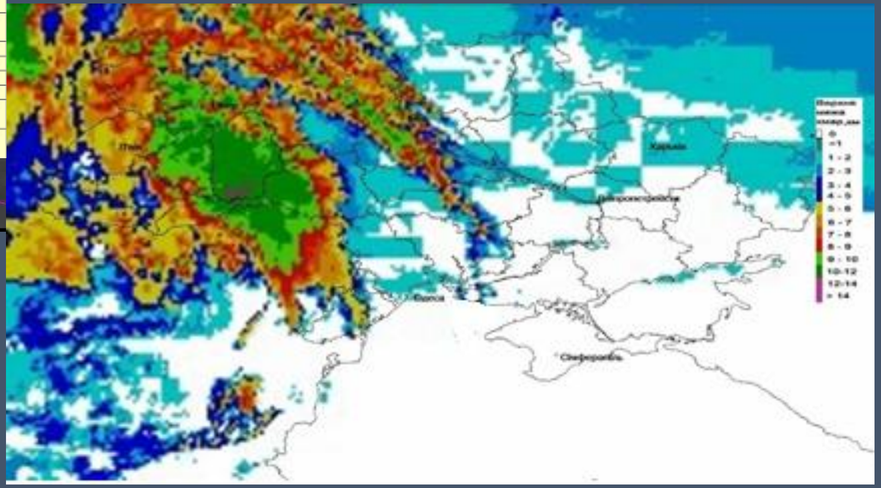
# SATELLITE DATA

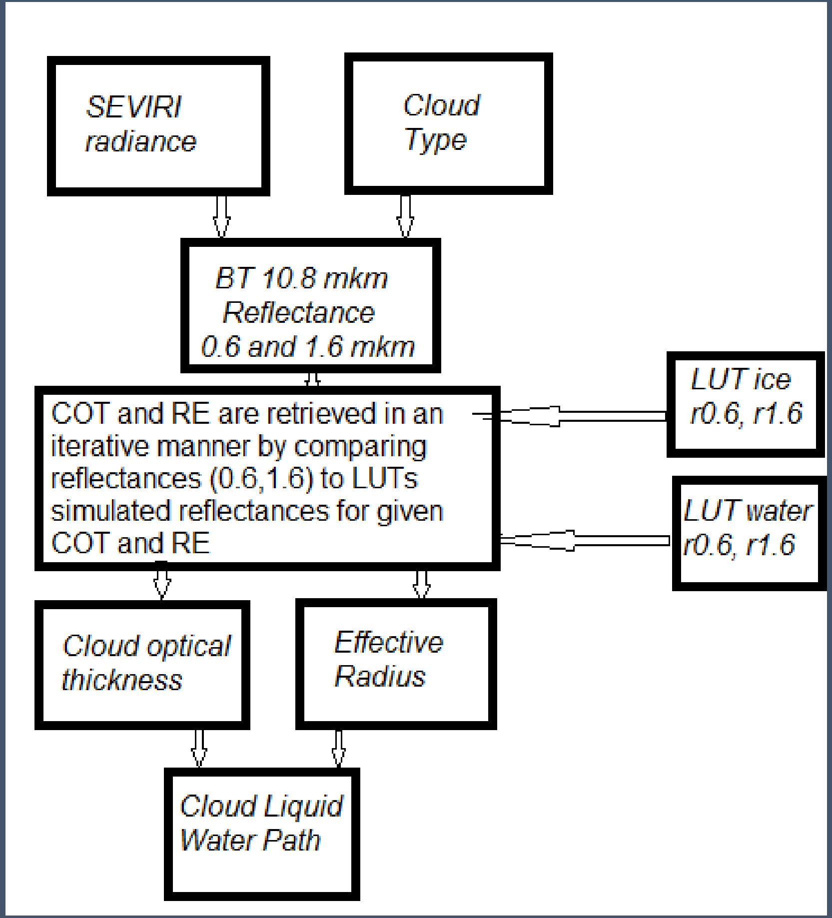
- **Estimation of CTH and BT**

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 (7×7 km) has been developed in UHMI and its flowchart is shown.








# SATELLITE DATA

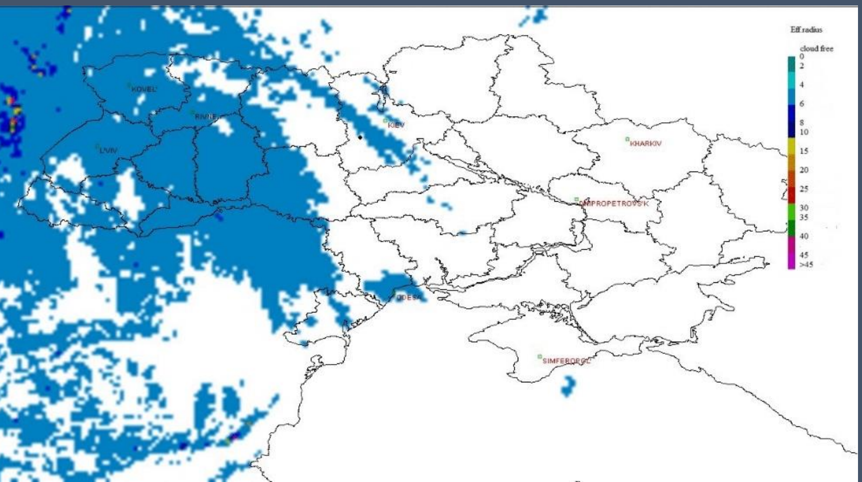
**Retrieval of Cloud Properties**

The principle of methods to retrieve cloud physical properties (**COT, CER, CIWP**) 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 cloud liquid water path may be derived with the cloud optical thickness and the droplet effective radius estimates using the following equation [Stephens, 1978] , [Bennartz, 2007] LWP = 5/9*τ*r*ρ (4) where ρ is the density of liquid water. where $\rho_l$ is the density of liquid water.

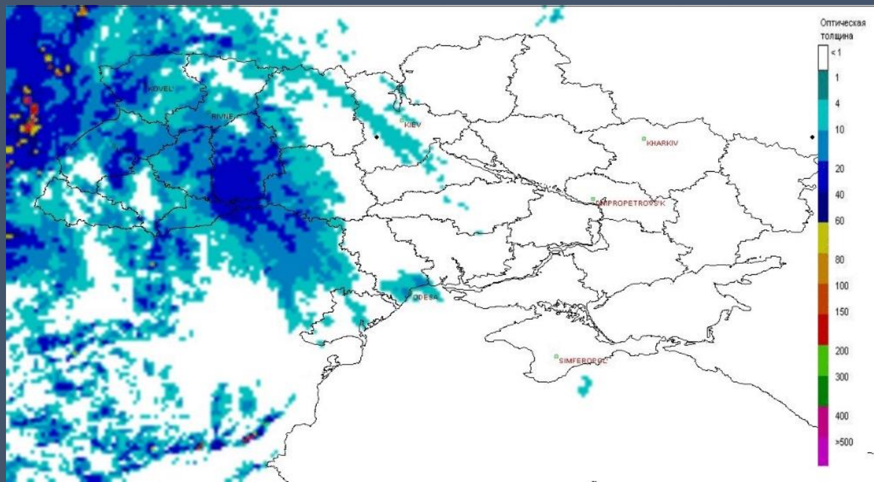
The ice water path (IWP) can be derived by (Heymsfield, 2003)

$$IWP = (\tau^{\frac{1}{0.84}})/\mathbf{0.065}$$



CER

COT

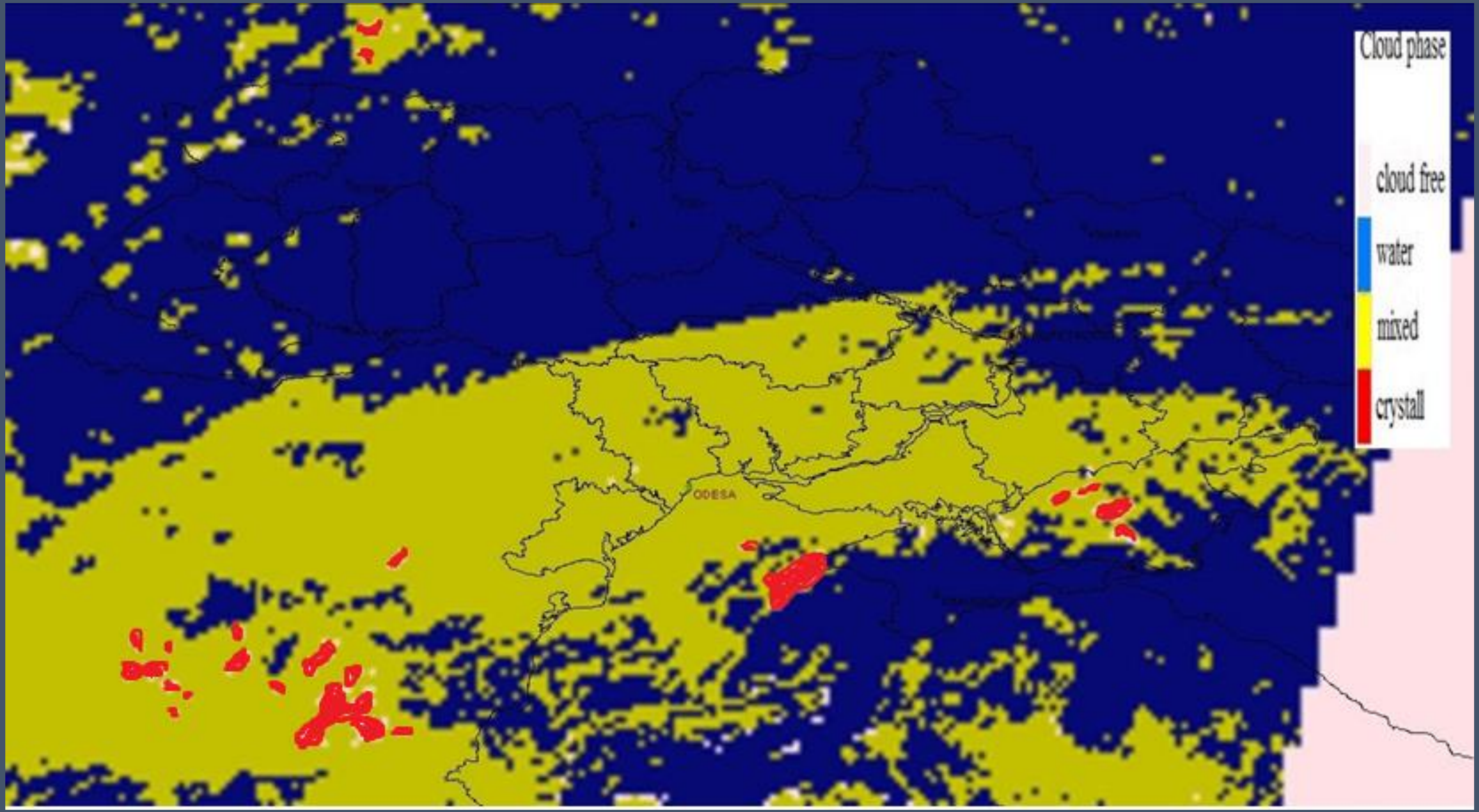


# Cloud PHAZE

Adopted algorithm developed by *W. Paul Menzel , Bryan A. Baum     Richard A. Frey     Kathy I. Strabala*

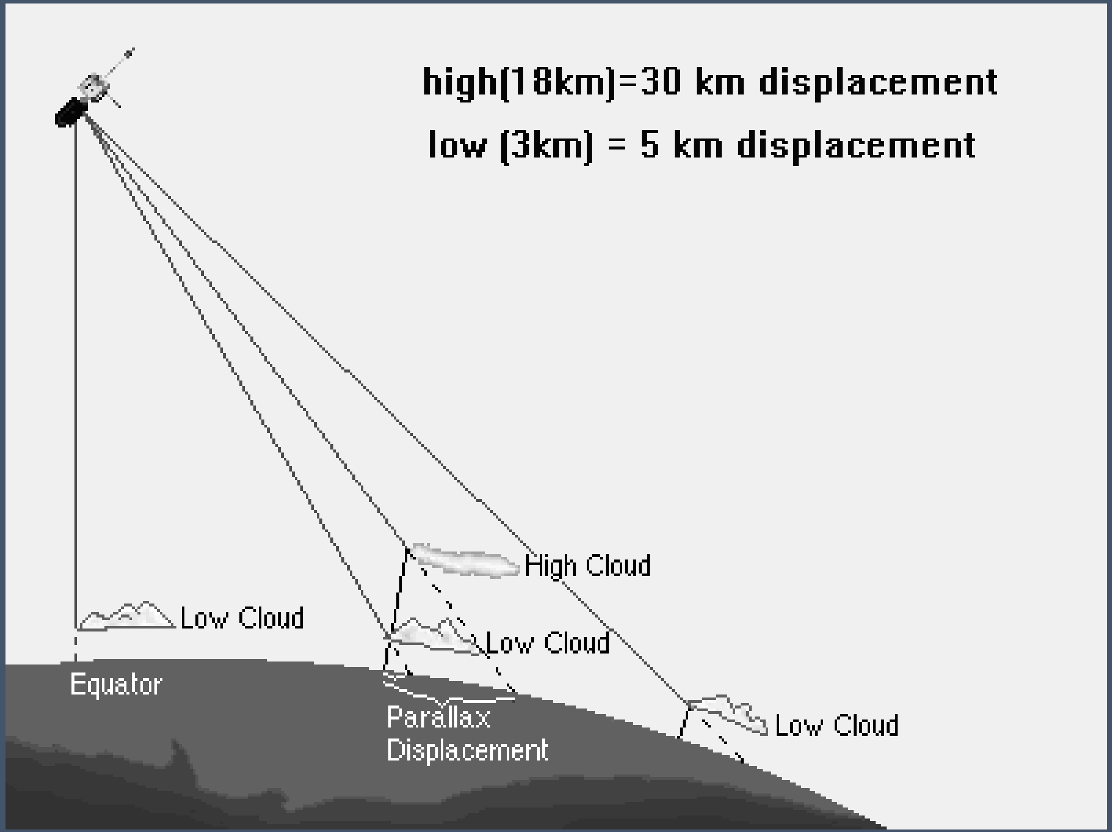
( **Cloud Thermodynamic Phase Retrievals Using MODIS Multispectral Data)**

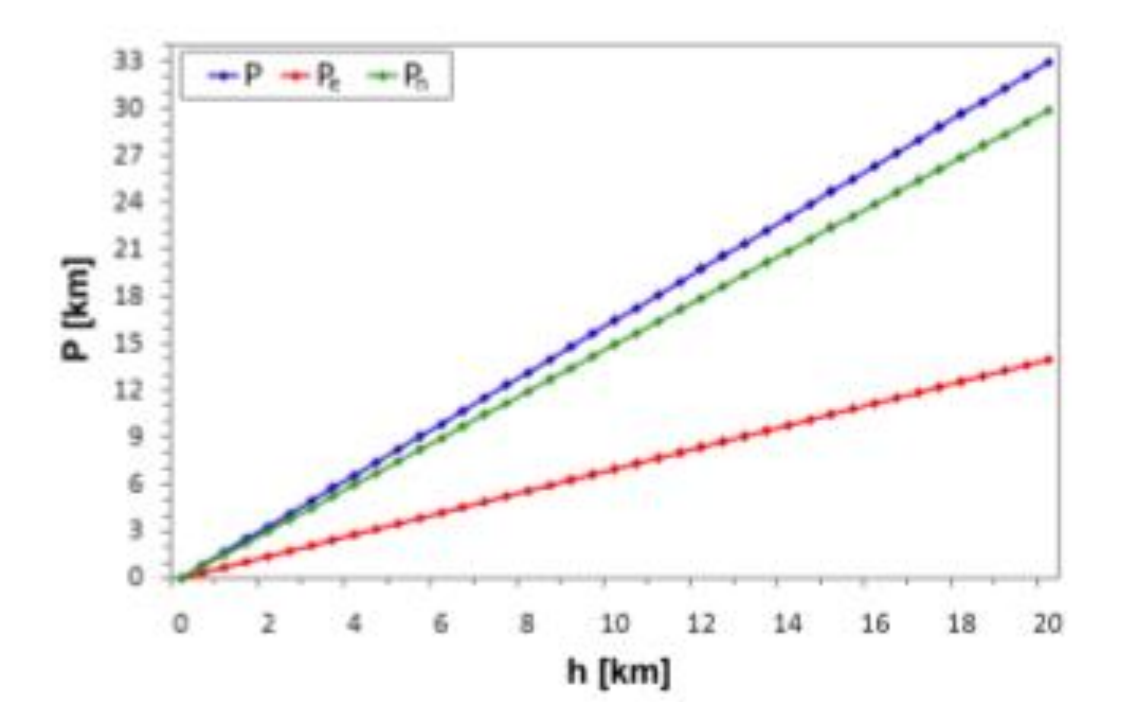
- Cloud phase is inferred from measurements at 8.7 and 10.8 microns of MSG/SEVIRI.
- ice phase
- water phase
- mixed phase



# Parallax correction of satellite data

Parallax is an apparent displacement of cloud location with regard to the Earth's surface in satellite imagery which results from a non-zero viewing angle of the satellite. Parallax depends on the height of the cloud top, its geographic location as well as the position of the satellite.

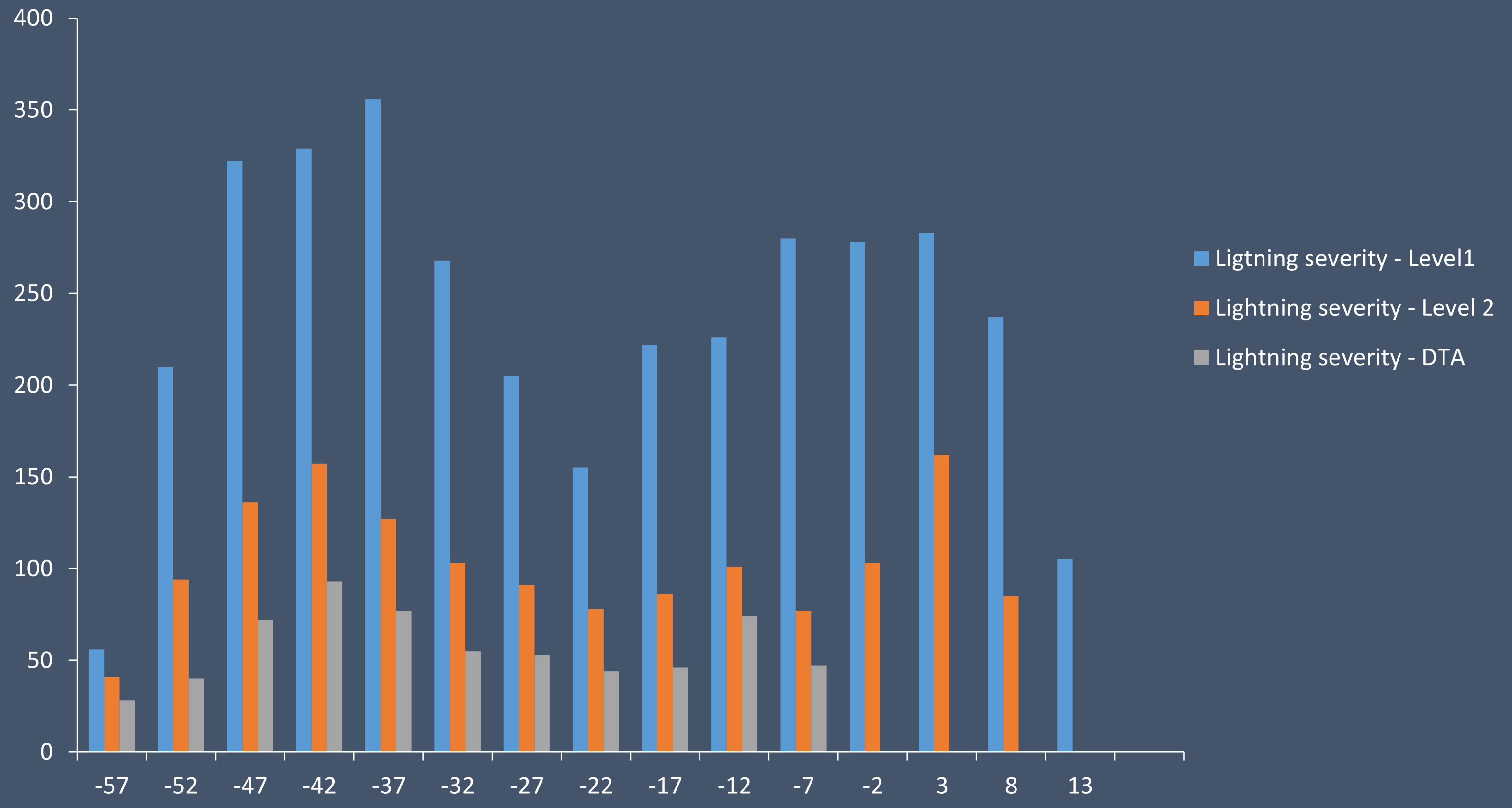



Parallax (P) and its eastward and northward components (Pe and Pn) related to geodetic height (h) of the spot in cloud top located at 48.507°N and 31.453°E for the MSG-9 (location 9.5°) satellite.

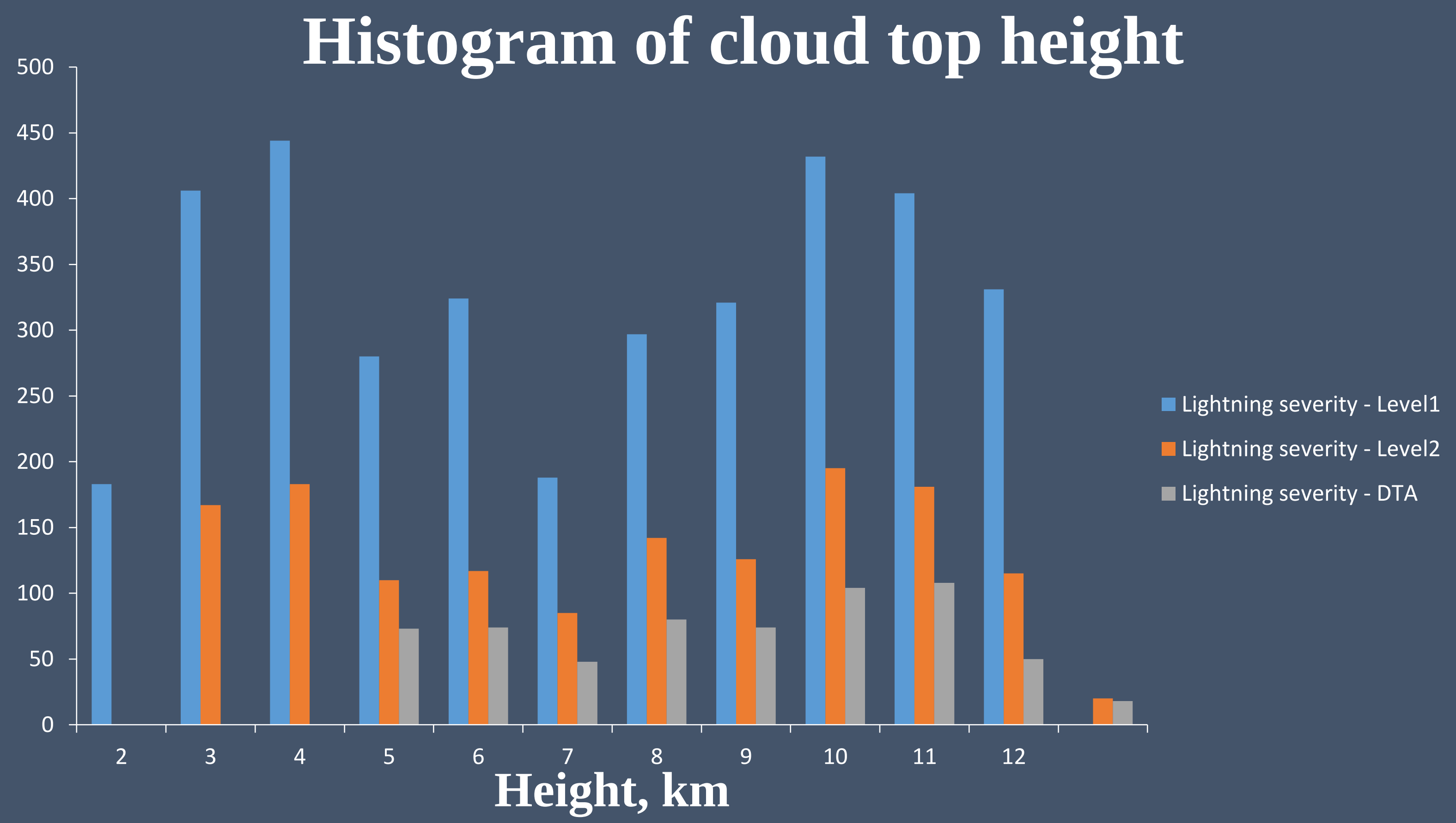
# RESULTS

## Histogram of cloud top temperature



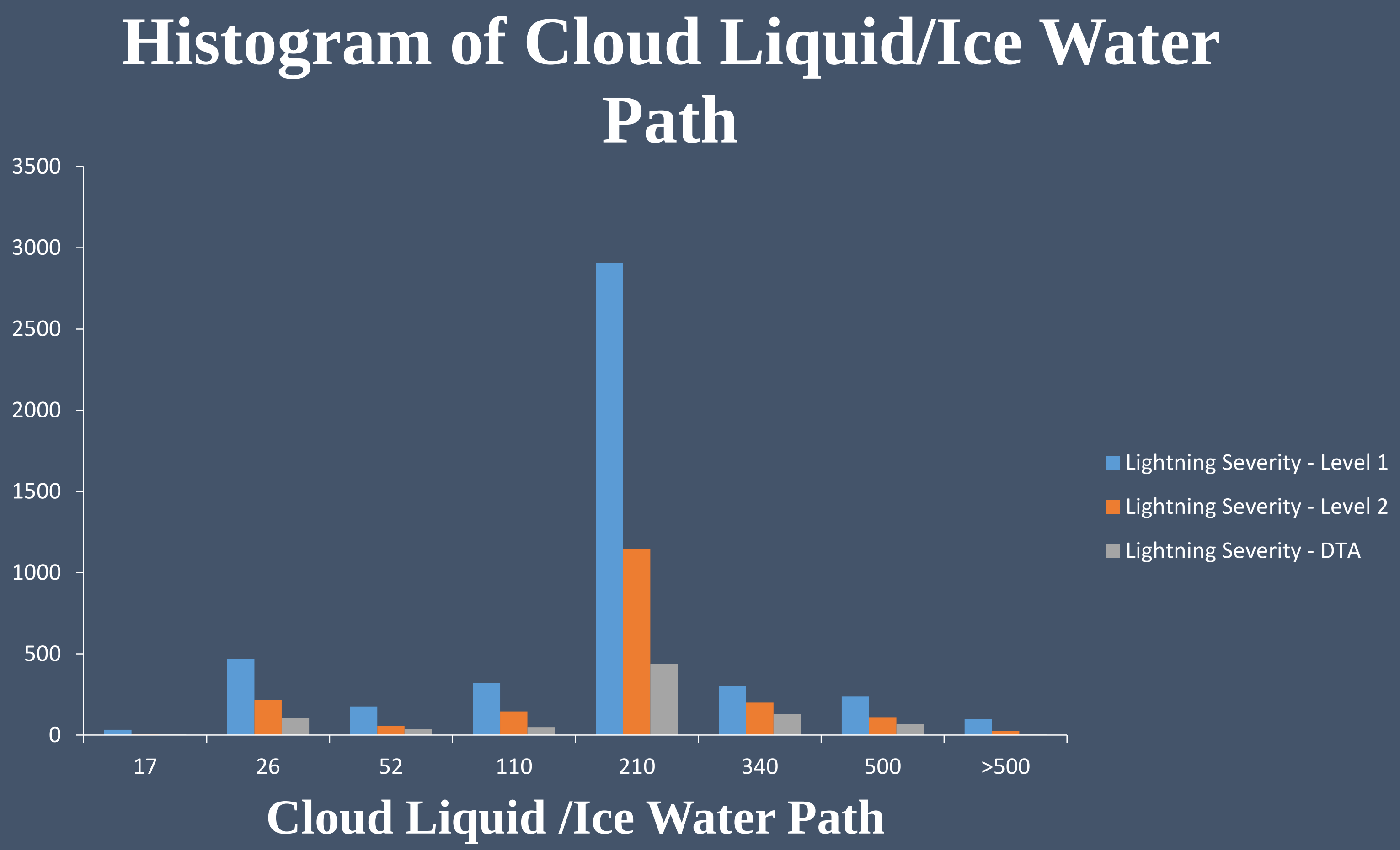

**Temperature, C°**

# RESULTS

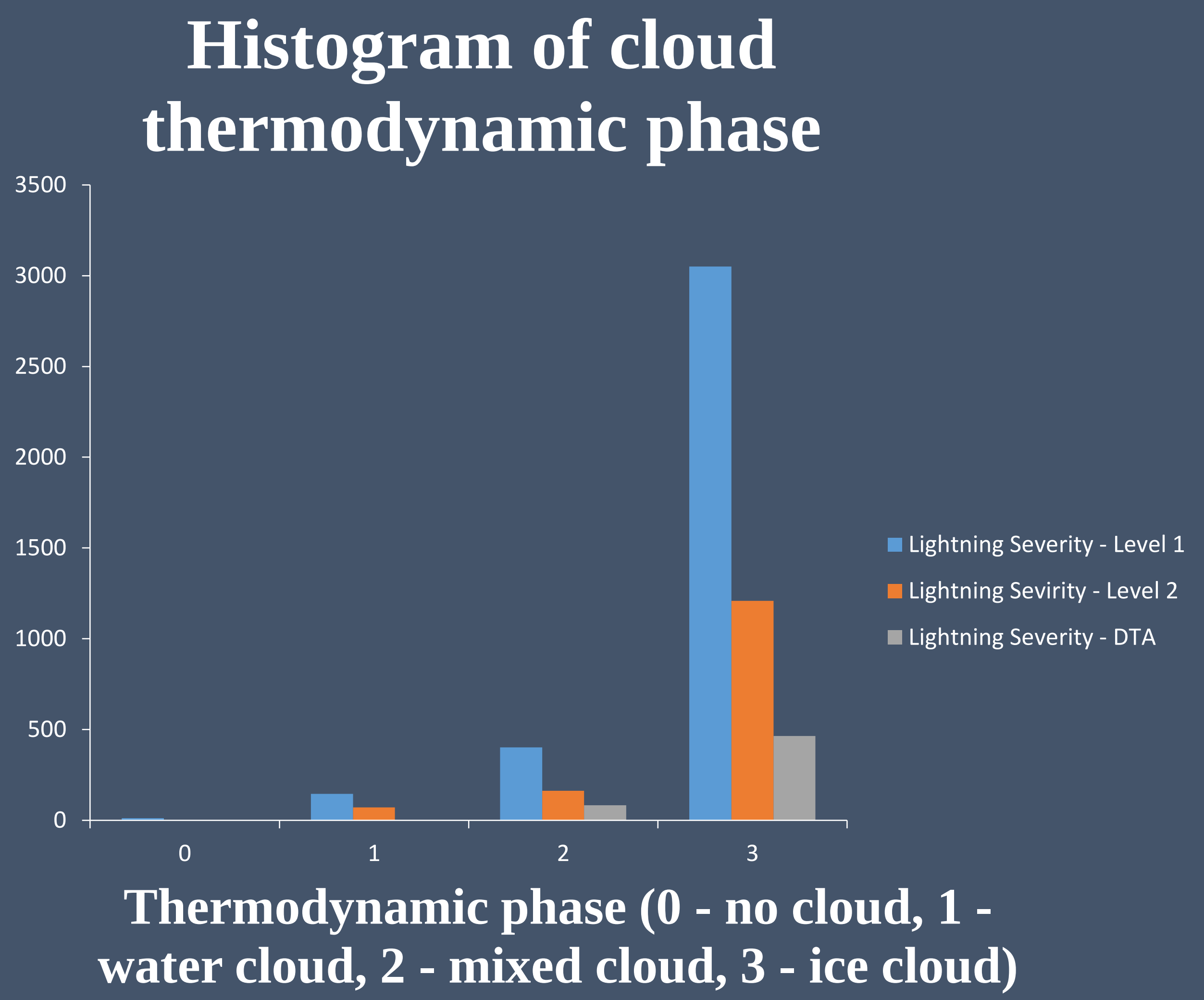


Histogram of cloud top height
500
450
400
350
300
250
200
150
100
50
0
2
3
4
5
6
7
8
9
10
11
12
Height, km
Lightning severity - Level1
Lightning severity - Level2
Lightning severity - DTA

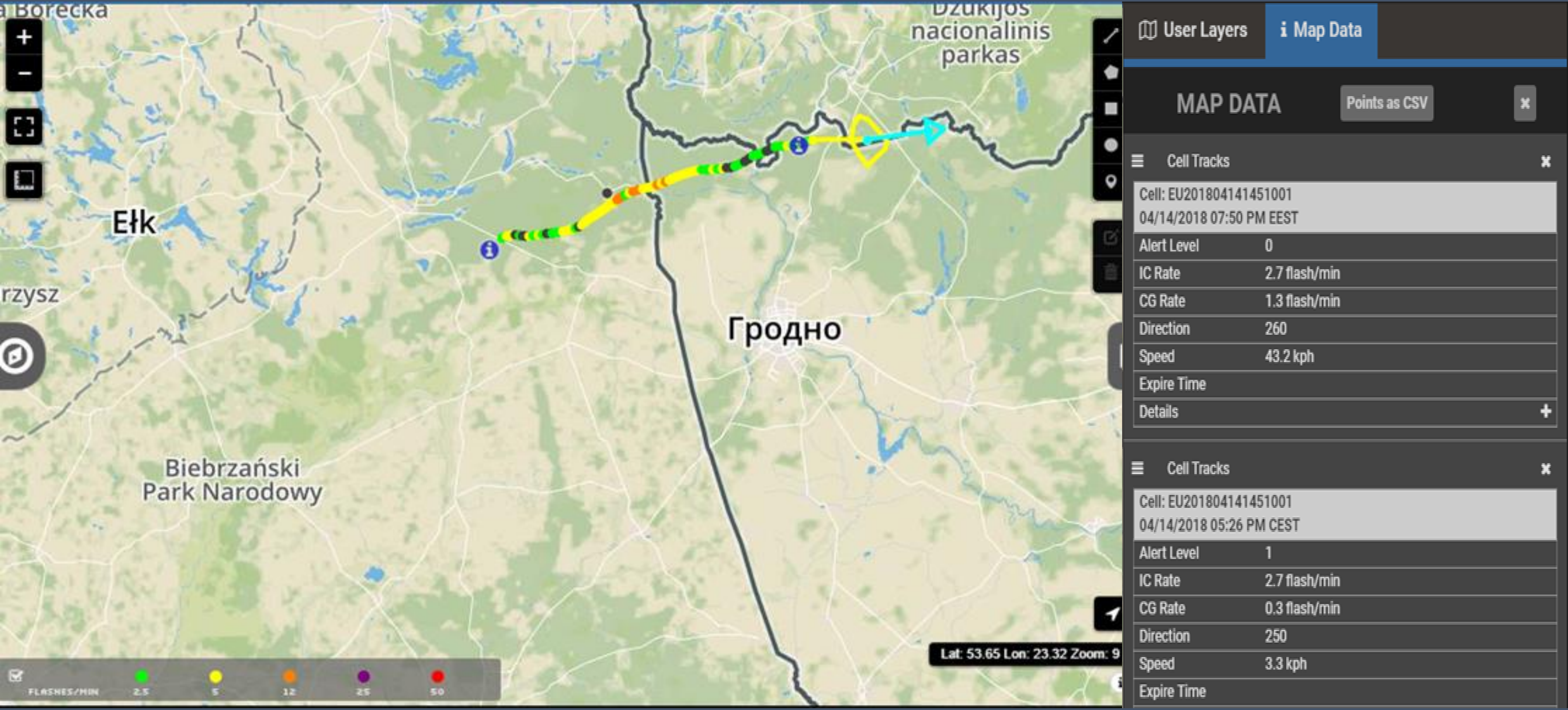
# RESULTS


Histogram of Cloud Liquid/Ice Water Path
3500
3000
2500
2000
1500
1000
500
0
17
26
52
110
210
340
500
>500
Cloud Liquid /Ice Water Path
Lightning Severity - Level 1
Lightning Severity - Level 2
Lightning Severity - DTA

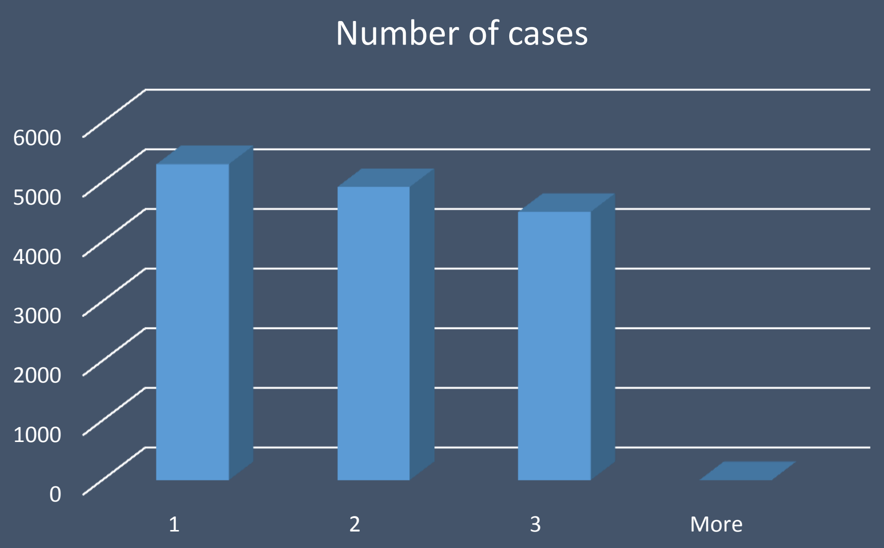
# RESULTS

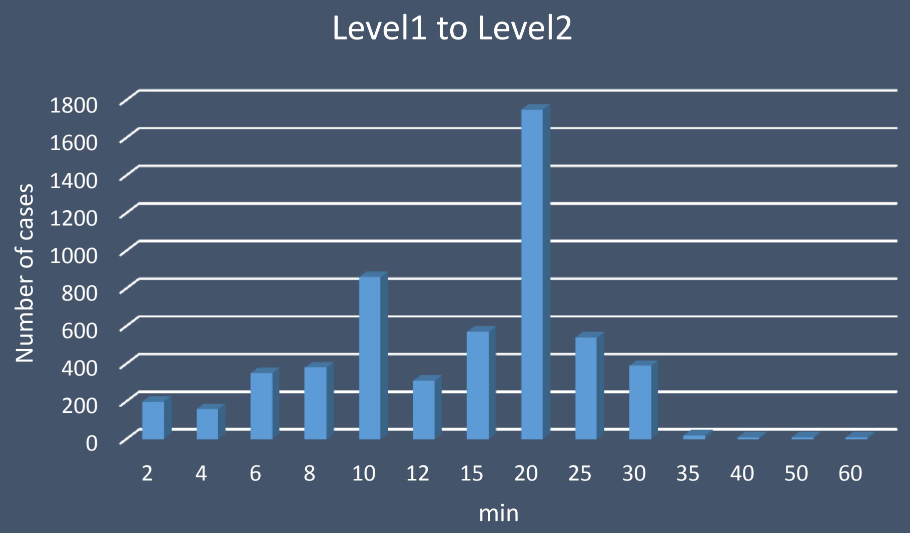

Histogram of cloud thermodynamic phase
3500
3000
2500
2000
1500
1000
500
0
0
1
2
3
Lightning Severity - Level 1
Lightning Sevirity - Level 2
Lightning Severity - DTA
Thermodynamic phase (0 - no cloud, 1 - water cloud, 2 - mixed cloud, 3 - ice cloud)

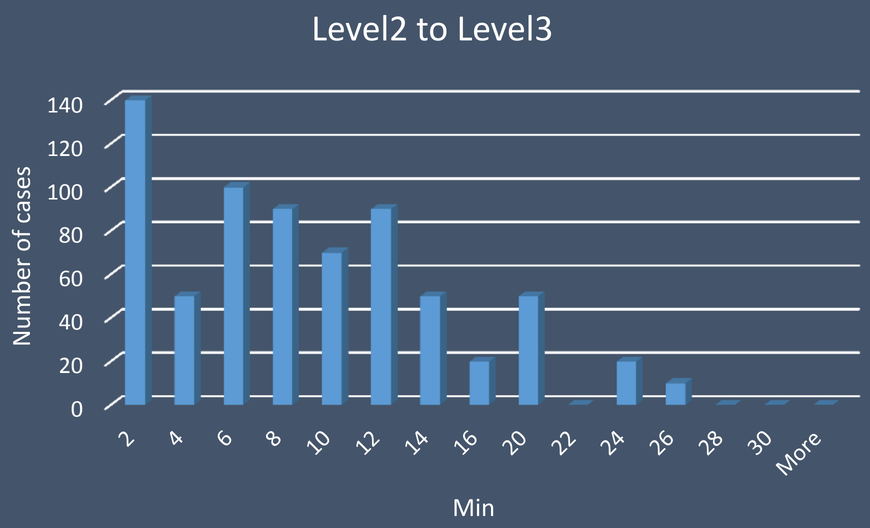
# LIGHTNING DATA



# LIGHTNING DATA



| Lightning Severity | BT(C°) | CTH(km) | COT | CIWP, (kg/m2) | RE, (µm) | CPH |
|---|---|---|---|---|---|---|
| 1 | - 24.6 | 6.763 | 35 | 210 | 30 | 2.798 |
| 2 | -26.2 | 7.113 | 34.5 | 208 | 30 | 2.787 |
| DTA | -34.3 | 8.350 | 45 | 235 | 28 | 2.817 |

| Lightning Severity | BT(C°) | CTH(km) | COT | CIWP, (kg/m2) | RE, (µm) | CPH |
|---|---|---|---|---|---|---|
| 1 | - 30.5 | 7.163 | 38 | 220 | 30 | 2.898 |
| 2 | -31.7 | 7.313 | 38.5 | 228 | 31 | 2.887 |
| DTA | -34.5 | 8.390 | 46 | 235 | 27 | 2.917 |

# Summary

1. Our analysis shows that the changing of lightning severity leads to an increase of CTH and to decrease of cloud BT, but not to significant changing in other cloud parameters (for the cases when we consider successive changes in lightning activity an increase of CTH and a decrease of cloud BT is less).

2. Two peaks that is observed on histograms shows that severe lightning activity can produce small clouds, which size is less than satellite spatial resolution. |In order to have a reliable information of cloud parameters satellite data with higher spatial resolution are needed.
3. Analysis of time between different levels of a flash rate(severity level) shows that time between level1 and level 2 is much more that between level2 and level3. Temporal resolution of satellite should be higher.

# Future work

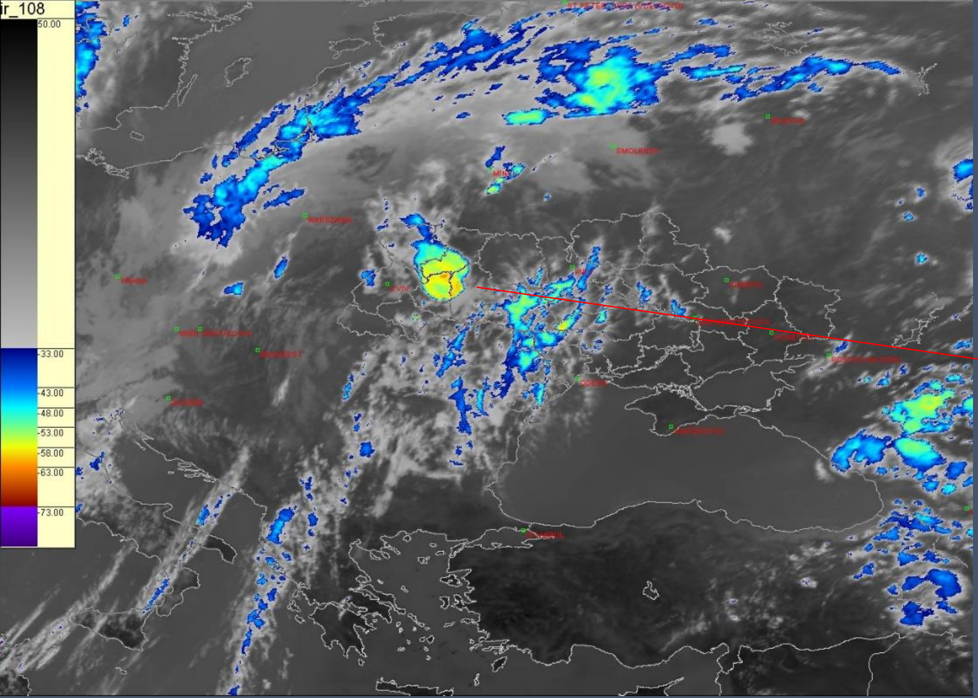
- To use NWC SAF software to retrieve cloud parameters (microphysical);

- Analysis of different RGB images;

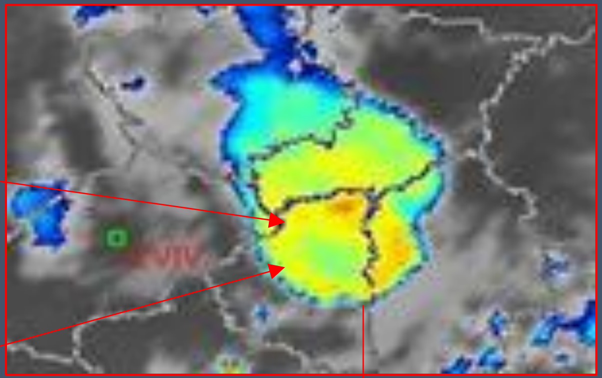
- To collect cases with severe weather over Ukraine;
- To collect lightning cells (area comparable with sratial resolution of satellite data)

- Regression analysis, NN based on different parameters:

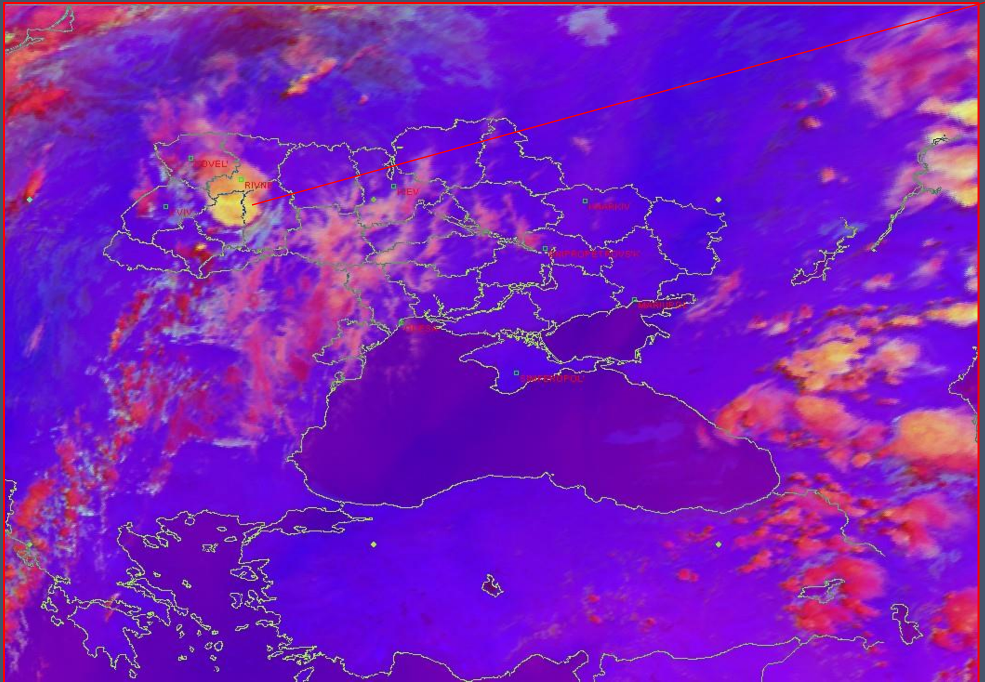
IC jump, max CG+ amplitude, stroke current, CAPE, satellite cloud parameters and other.

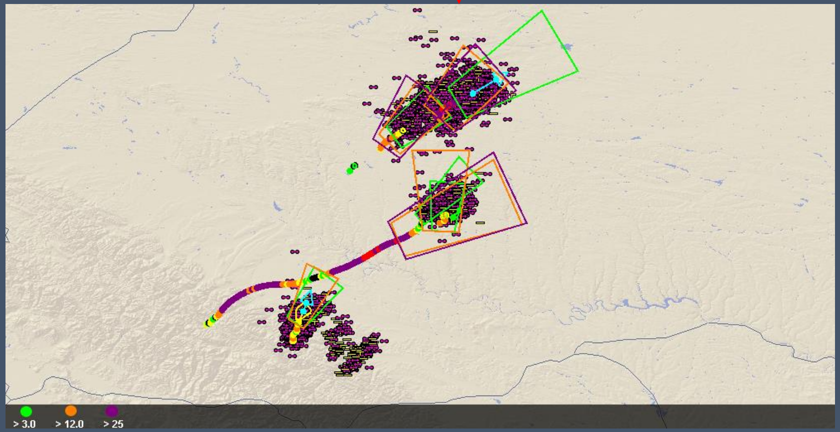



# Detection of severe storm by SEVIRI MSG (enhanced IR108, RGB)



# THANK YOU






Lightning detection by ENTLN (Earth Networks Total Lightning Network)