Analysis of severe storms in summer time in the Northwest region of Russian Federation using satellite data

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Cloud analysis which used summer time (June-August, 2001, 2002) data gathered over the Northwest region of Russian Federation by radiometer AVHRR/ NOAA has been performed. For this purpose the situations with cumulonimbus cloud form connected with severe weather phenomena (squall lines, downpours, thunderstorms) were chosen. The analysis was compared with the precipitation means and severe weather phenomena occurrences obtained from the ground weather observations. The results of the cumulunimbus cloud classification by the types of the weather pattern and results of the statistical analysis of the cloud top height and of the precipitation amounts are presented.

Keywords: cloud, severe storms, satellite, precipitation

1. INTRODUCTION

The Northwest region of Russia occupies a territory of about 58^0 N to 67^0 N bounded by the western shore of the White Sea and eastern shores of the Gulf of Finland and Lake Chudskoye including the water areas and adjacent regions of Lakes Ladoga, Onega, Ilmen and Beloye and the northern part of the Rybinsk water basin. Due to geographical position of the territory in the Northwest region of the Russian Federation cloud monitoring can most adequately be realized from polar-orbital satellites NOAA. The main dangerous phenomena in the Northwest region are connected with summer convective processes, namely squall lines, storms and thunderstorms.

Satellite analysis of the cumulonimbus clouds, which cause severe weather phenomena during summer time (June – August), is holding for the first time for the NW region of Russia. The main aim of the current researches is exposure thunder cumulonimbus cloud characteristics using AVHRR/NOAA radiometer data and ground network observations.

Experimental convective cloud characteristics are given by Sinkevich (2001). However there are gathered only results of aircraft probing of the flights through Cb clouds, reaching a height of 5-6 km. Methodically important researches for the cloud types identification are operationally used AVHRR-based cloud classification schemes (Karlsson, 1996, Phulphin et al., 1983, Saunders and Kriebel, 1988). The accuracy of retrieval cloud top height (CTH) is still under investigation, mainly because of a great lack of ground-based measurements to compare with (SAF-CM Facility User Manual-Products, 2004, Arking and Childs, 1985).

2. DATA AND METHOD

Situations with the congestus cumulonimbus formations were selected and identified by the satellite data processing system 'Varjag" in order to conduct cloud analysis. "Varjag" is a Windows© software application intended for the operative use in the synoptic practice at the St.Petersburg Regional Center for Hydrometeorology and Environmental Monitoring. It perfumes calibration, geographical referencing, processed data visualization, identification of cloud and ground surface types and cloud top meteorological characteristics retrieval. The satellite data acquired by the 5-channel radiometer AVHRR operating onboard weather satellites of the NOAA series is used as the input data. The process of detection and analysis of severe convective phenomena by system Varjag is divided into two main stages and is based on identification of the mass of severe convective clouds. At the first stage, identification of cloudiness and earth's surface is realized. For this purpose, provision is made for a method of cluster analysis of a multidimensional brightness histogram of AVHRR spectral ranges in combination with threshold method. At the second stage, are identified cloud clusters in the following eight types: Sc/St – stratocumulus/stratus; Cu – cumulus (vertical development clouds); Cb – cumulonimbus; Ns – nimbostratus; As – altostratus; Ac – altocumulus; Ci – cirrus, cirrus-cumulus and cirrus-stratus; Mist .

106 AVHRR/NOAA data sets with severe cumulonimbus clouds from summer period 2001 and 2002 (81 and 25 relatively) were processed. The severe meteorological phenomena such as thunderstorms, squalls and storm rainfalls have been verified by with ground-based observations in 85% of cases.

3. THE SYNOPTIC ANALYSIS

The most cases with the severe weather phenomena occurred during summer period of 2001. All satellite data for the year 2001 describe only 39 cumulonimbus cloud formations. 4 weather patterns with cumulunimbus clouds have been specified: cold front, warm front, occlusion and weak-gradient pressure field.

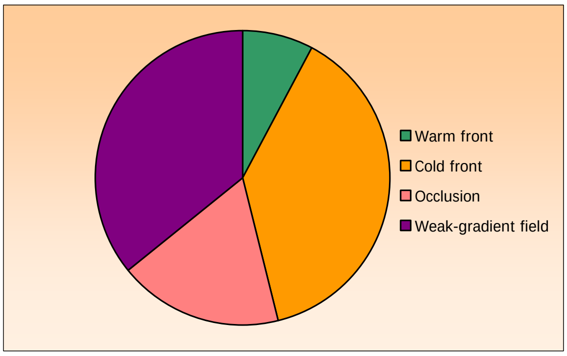

Figure 1. Diagram: severe storms situations distribution by the weather patterns.

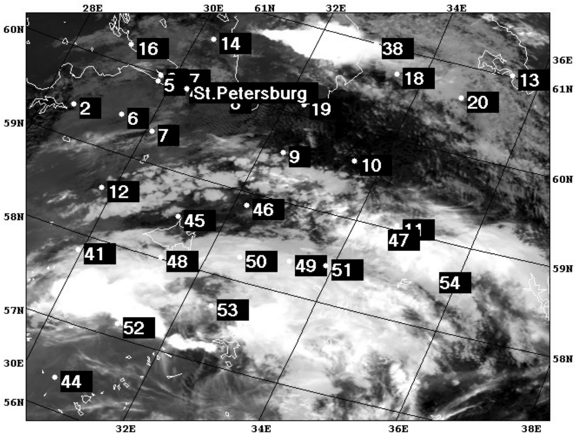

Figure 2. Cumulonimbus clouds, warm front.
4th channel, AVHRR 10:38 GMT, 07.26.2001

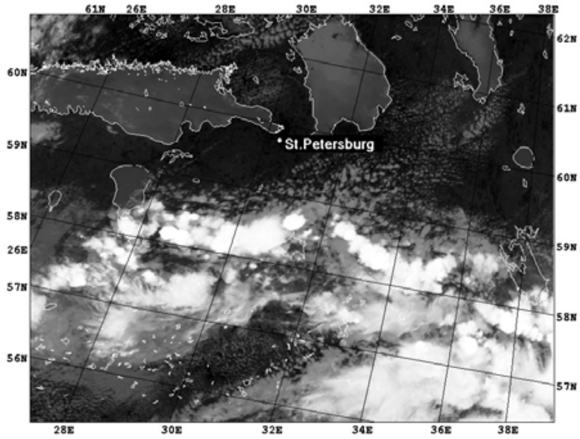

Figure 3. Cumulonimbus clouds, occlusion.
4th channel, AVHRR 11:11 GMT, 06.24.2001

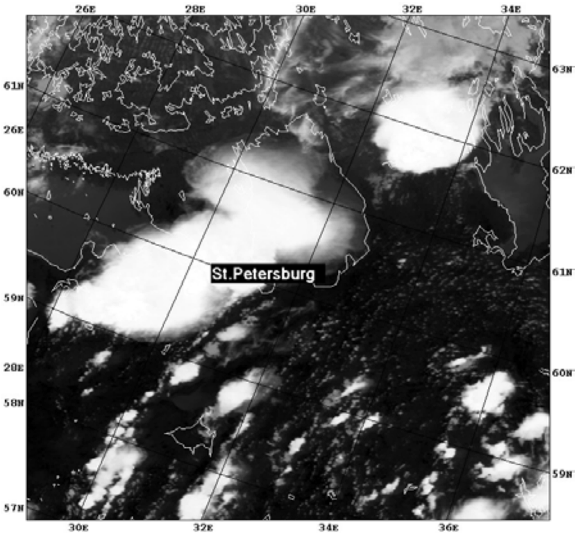

Figure 4. Cumulonimbus clouds, cold front.
4th channel, AVHRR 13:55 GMT, 07.17.2001

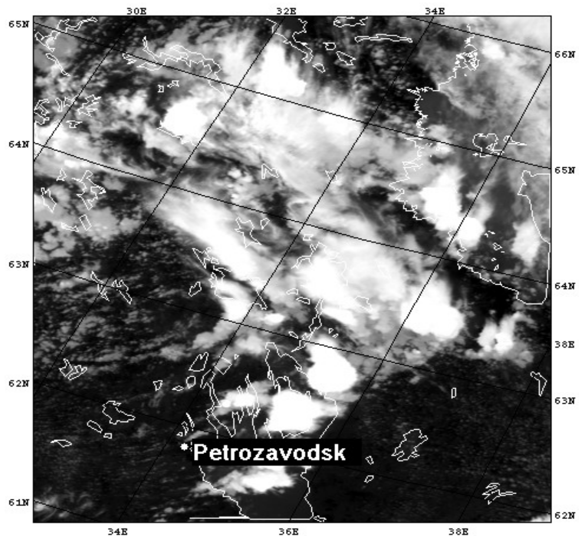

Figure 5. Cumulonimbus clouds, weak-gradient field.
4th channel, AVHRR 13:26 GMT, 08.10.2001

The most frequent cases are connected with cold fronts passing through the different parts of cyclones and weak-gradient pressure field (Fig. 1). Typical examples of cumulonimbus clouds, related to the specified weather patterns are presented on the images (Fig. 2-5).

4. CLOUD TOP HEIGHT

Cloud top height is retrieved by the "Varjag" system in the automatic regime using brightness temperature (4th AVHRR channel) and assuming that high-dense cloudiness radiates as a blackbody. Both statistical zonal temperature pattern (Zuev, Komarov, 1986) and radiosonde observations were used for the CTH retrieval. Radiosonde data were used with the closest time to satellite data receiving time.

CTH averaged throughout the whole massive of the cumulonimbus clouds is calculated for every processed image using radiosonde data and statistical model. Correlation coefficient between two obtained rows comes

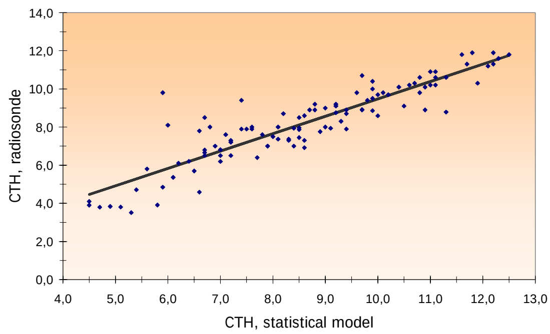

Figure 6. Correlation between Cb-Cloud Top Height retrieved by means of radiosonde and statistical model data (Zuev, Komarov, 1986), June – August 2001

to mean 0,9 while the mean-square error is 0,8 km. Correlation dependence between these data sequences is shown in Fig. (6).The retrieved result confirms a possibility of using given zonal statistical model for the

CTH calculation in the cumulonimbus cloudiness analysis of the satellite data when the aerological sounding data is missing. Average height of the cumulonimbus which cause severe weather events varies from 4,5 up to 12,5 km, when the maximum reiteration is in the range of 8-11 km and presents 37% from the general cases number (Fig. (7)).

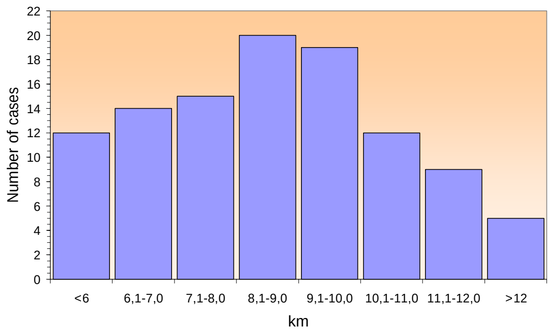

Figure 7. Histogram of the Cb-Cloud Top Height, June-August, 2001

Minimum and maximum values of the CTH were also calculated. Minimum value (3,2 km) was registered for clouds within the weak-gradient pressure field. CTH value exceeds tropopause height of 11-12 km in the 78% of cases. Spatial distribution is shown in the Fig (8).

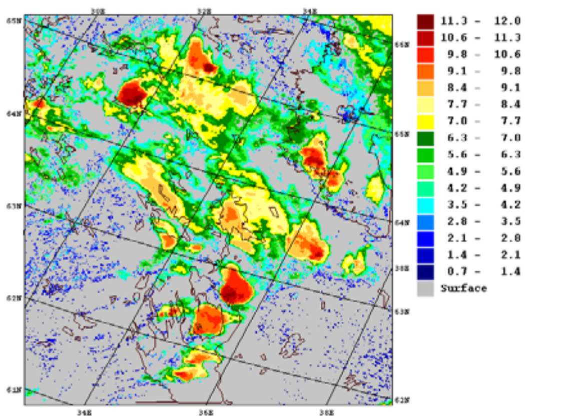

Figure 8. Cloud Top Height. 13:26 GMT, 08.10.2001

In the synoptic plan this example (08.10.2001) corresponds weak-gradient pressure field. Cloudiness is expressed strongly by congestion of cumulonimbus forms.

The results of the process of the operative work with "Varjag" system are usually presented in the form of color raster images. The retrieved raster images of CTH give a concept of the zones of maximum magnitudes within a cumulonimbus massive.

Unfortunately the attempt to compare the CTH values obtained with meteorological radar observations and satellite sounding (retrieved by means of statistical model and radiosonde data) wasn't successful enough due to the lack of statistical data. Radar data were available only in summer period 2002. A comparison of the obtained values is shown in the Fig. (9). The major trend of setting the satellite sounding CTH values higher than radar observations is registered.

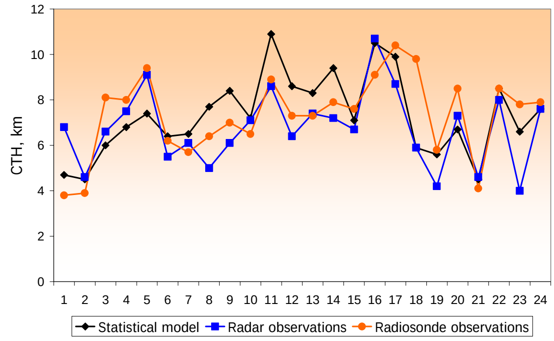

Figure 9. Cloud top height values obtained by means of radar data, radiosonde observations and statistical model, June-August 2002

5. PRECIPITATIONS

On the current stage of the project, information AVHRR/NOAA has been used only for the qualitative assessment. Analyzing the precipitation amount, connected with severe weather events of cumulonimbus clouds origin, the software system "Varjag" is used for cloud types identification and their further geographical referencing to the ground-based observation stations network (Fig. 2).

Thus interactively the ground-based observation stations which get to the zones cumulonimbus massives passing were chosen. Next step the situations with severe weather events registered by ground meteorological stations during the moments of satellite data receiving were chosen. Precipitation means retrieved on these stations have been recorded in the closest time following the satellite data receiving (daily, 06.00 and 12.00, GMT). Thus data sequence with precipitation means was formed.

In the Fig. 10 precipitation values are distributed by the value ranges, corresponding to the different weather patterns. Intensive precipitations (>11 mm) are connected with occlusion and cold fronts and they have not been recorded at warm fronts. The warning precipitations mean (> 50 mm) weren't fixed during summer period 2001 as well. The maximum precipitation value recorded during that term is 32 mm with the downpours as the main type.

6. RESULTS AND DISCUSSION

According to the results of conducted analysis it's necessary to stress that all of the severe weather events in the NW region of Russia during the summer period 2001 were connected with cumulonimbus clouds at occlusions and cold fronts, as well as warm and secondary fronts within the weak-gradient pressure fields.

The CTH values retrieved from AVHRR/NOAA are exceeding tropopause height in 78% of cases. Important conclusion about zonal model (Zuev , Komarov, 1986) use possibility has been obtained by the comparison of the

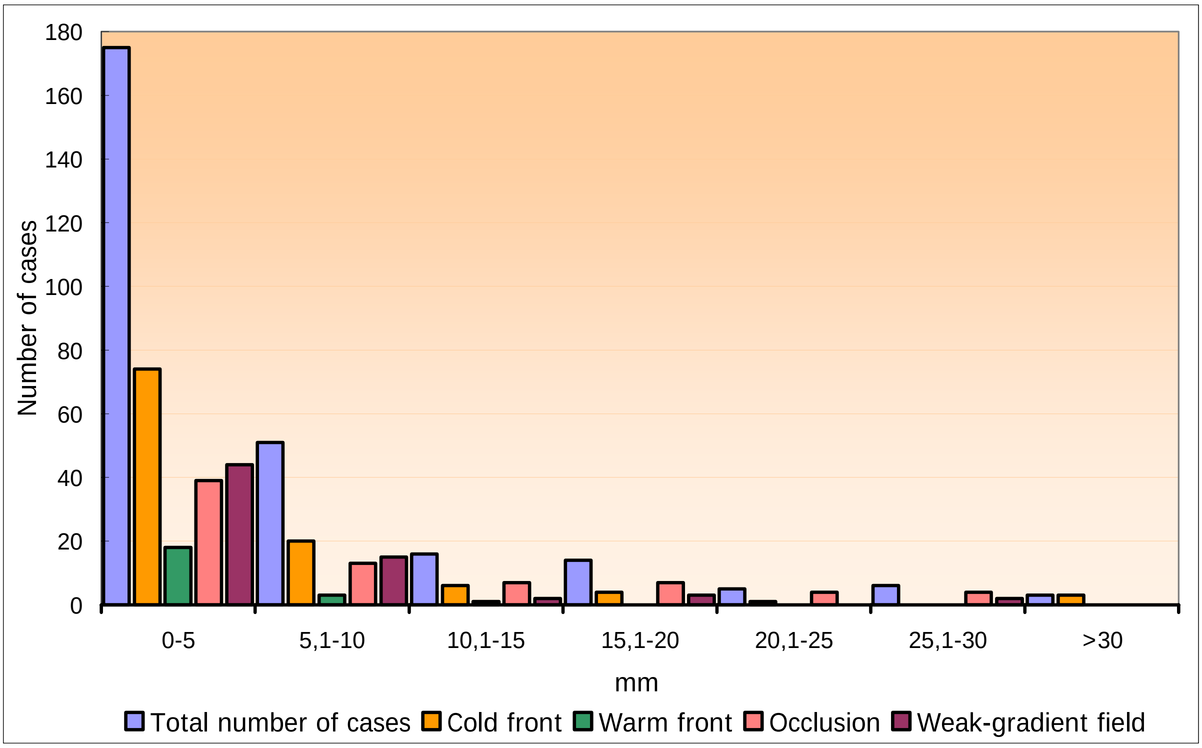

Figure 8. Histogram of the Cb-precipitation distribution concerned different weather patterns.
June-August, 2001

CTH values, calculated via radiosonde cross-section and model data.

Satellite data was used in indirect for the precipitation analyzing in thunderclouds. It's important to notice that nowadays satellite data is already in use for precipitation analysis but all of the suggested for this aim methods need additional researches and algorithm development (Adler et al., 2001, Lensky, Rosenfeld, 1997, Simson, et al, 2000). Unfortunately, because of inadequate data in the 1,6 micron channel (AVHRR) it's not possible to use the vertical probing capacity in deep clouds for the comparison with precipitation.

7. SUMMARY

The capability of satellite technologies increase it's role in the weather nowcasting and analysis of the weather phenomena every year. This research is intended to show another perspective application for satellite data in the field of cloud analysis in a concrete region. Conducted CTH cumulonimbus clouds estimations will enrich corresponding parts of cloud climatology in the area of the NW region of Russian Federation.

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