ANALYSIS OF SYNOPTIC CONDITIONS OF HAIL CLOUDS DEVELOPMENT AND SOME POSSIBILITIES OF NOWCASTING OF STORM'S TRACKS.

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I. INTRODUCTION

Typical synoptic conditions that affect the formation of hail clouds are considered in light of more accurate prediction of storm's severity and meso-regions of their formation and development. Special attention is paid to regions where hail suppression projects or radar observations have been conducted for many years.

Our data-base consists of many-year radar observations of hail thunderstorms and corresponding meteorological data collected during scientific and operational projects conducted in Northern Caucasus (Russia).

As it's known, one of the most reliable methods of the prediction of hailstorm's severity and meso-region of their formation is the method presented in Barekova,1990.

On the other hand, radar observations of the hailstorms in the regions where scientific or operational hail suppression projects have been conducted for many years show us that some typical groups of hailstreaks can repeat every season (Makitov, 1999, 2003, 2004). In this case we have an interesting possibility to predict one or the other group of these trajectories. The successful solution of this problem helps significantly increase efficiency of the hail suppression projects independently of the seeding technology.

In this connection the goals of the given study are the following:

- determination of the most frequent trajectories of supercell and long-lived multicell hail clouds;
- analysis of synoptic and thermodynamic conditions of the formation and development of the hail clouds for the each group of their trajectories;
- more accurate prediction of hailstorm's severity and meso-regions of their formation on the base of the forecast delineation of the main groups of hail cell trajectories for given region.

II. ANALYSIS OF HAIL CELLS TRAJECTORIES.

The radar observations have been conducted using two-wavelength (S and X bands) weather radars of the MRL-5 type with a computerized systems for hailstorm detection and data processing. The system allows us to obtain in real time any type of horizontal and vertical sections of the radar echo, images of the upper and lower limits of the radar echo at any level of reflectivity, and maps of the total amount of precipitation and hail precipitation, which are expressed as projections of the levels of radar reflectivity and as isolines of total amount of the precipitated rain and kinetic energy of the precipitated hail.

At processing the radar data, the trajectory of every hail cell was restored (presented) as consecutive horizontal sections from the moment of registration of the first radar echo until the complete dissipation of a cloud.

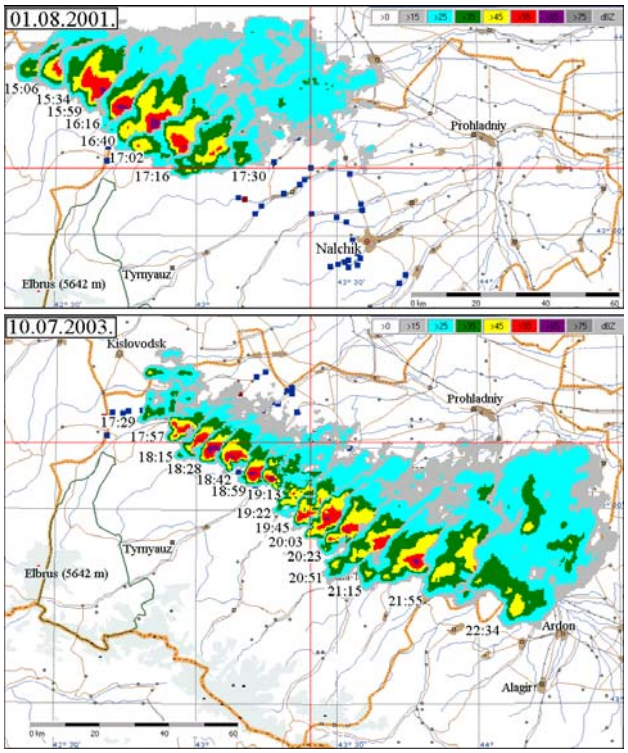

FIG.1: Hail cells movement on 01.08.2001 and 10.07.2003. The consecutive radar patterns are shown on a background of the map of central part of Northern Caucasus (Russia).

The typical trajectories of the supercell and long-lived multicell hail clouds in the Northern Caucasus have been analyzed by Makitov et al, 1991, and Barekova et al, 1999.The results of the analysis of 142 hail cells trajectories are presented in Fig. 2 as four main groups of a hailstreaks.

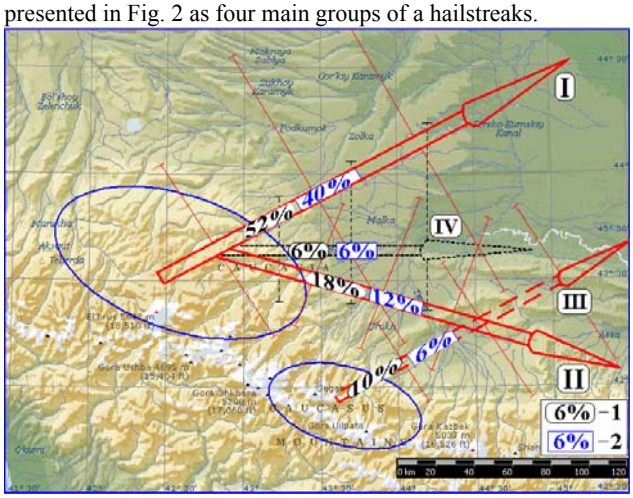

FIG.2. The distributions of the main trajectories of supercells (1) and long lived multicells (2) in the central part of Northern Caucasus.

III. SYNOPTIC AND THERMODYNAMIC CONDITIONS OF THE HAIL CLOUDS DEVELOPMENT.

The analysis of synoptic situations leading to the development of hail clouds has been conducted according the following conception:

- the severity of the hail clouds is determined not only by instability and parameters of meso-circulation of the atmosphere but also by factors of macro-scale circulation (Barekova,1990).

Date	Traject. type	Type of macro-circulation	Arctic minimum		Main cyclone		Local advection on AT_{500}, F и F' 10^5°C·m/s
			Number of closed isohypses	Temperat. in the middle °C	Number of closed isohypses	Temperat. in the middle °C	
25.06.85.	**I**	W_C	3	-28	1	-17	-1.28 / -12.85
26.06.85.	**I**	W_C	5	-27	2	-19	-2.00 / -13.00
20.06.83.	**I**	C	7	-36	2	-19	-1.20 / -8.90
21.06.85.	**II**	W_C	-	-25	3	-21	-1.86 / -12.21
21.07.90.	**II**	W	-	-22	2	-18	-0.29 / -7.49
21.08.85.	**III**	C	3	-30	3	-25	-1.52 / -10.3
22.08.85.	**III**	C	2	-31	2	-17	-1.23 / -13.3
14.06.88.	**III**	C	7	-30	1	-23	-0.82 / -7.14

Table I: The factors of macro- and meso-circulation of the middle troposphere, which determine the development of supercell hail clouds in Northern Caucasus.

In Northern Caucasus most favorable conditions for the development of supercell and long-lived cells of multicell hail clouds are formed in the meridian type of the macro-scale circulation, C, with a well developed deep trough the front part of which intersects the studied region. Most frequently this trough is formed with 3-7 closed isohypses and a cold arctic minima ($-25 \geq t \geq -40$ °C). To categorize hail clouds on intensity, the values of local advection of cold air in the "hail danger zone" in the middle troposphere are used. Catastrophic hail clouds are developed at $|F|\cdot 10^5$ that equals or larger than unity and $|F'|\cdot 10^5$ larger than or equal to 10. Intense hail clouds develop at low parameters: $F = -0.285\cdot 10^{-5}$ °C·m/s and $F' = -7.494\cdot 10^{-5}$ °C·m/s (21 July,1990).

If macro scale synoptic parameters of the troposphere are responsible for the structure and intensity of the hail clouds then such meso scale surface parameter like a gradient of wet bulb temperature using in the direction of mean wind $\Delta t_{wb}/\Delta x$ is responsible for the region of the hail clouds development.

The direction of propagation of the zone of gradient $\Delta t_{wb}/\Delta x$ is depend of the mean wind's direction but orientation of low-altitude instability zones with $\Delta t_{wb}/\Delta x \geq 2$°C/100 km can predict the group of the trajectories of hail cells on the quasi stationary stage. The zones of low-altitude instability are oriented along with the major ravine of the main Caucasus Ridge and coincide with hailstreaks on the ground for trajectories of group **I** and **III**. For hail cells of group **II**, we have obtained either altitude orientations of the zones of low-altitude potential instability or the localizations of these zones are biased toward the high-maintain regions (FIG.3). The forecast delineation of the trajectory groups **I** and **II** allows for more accurate definition of the "meso-region of development" and for obtaining the most likely trajectory on a particular day. Taking into consideration the average repetition of a particular group (FIG. 2), the forecast for **I** and **II** trajectory groups contains 70% of supercells and 52% of long-lived cells of multicell hail clouds.

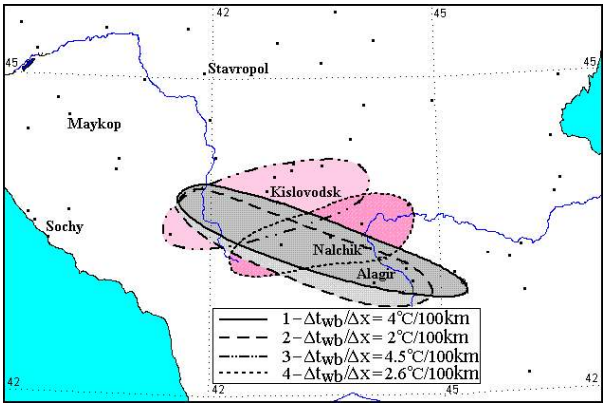

FIG. 3. The examples of low-altitude potential instability zones for hailstorms of the **I** and **II** trajectory groups.
1- 21.07.1990. 2 – 21.07.1990. 3 – 25-26.06.1985. 4 – 20.06.1983.

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