Comparative analysis of the parameters of two radars MRL-5 and DMRL-C

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Abstract. The scope of application of radar technology is currently very wide, and with the use of the achievements of modern circuitry, electronic technology and computer technology, it is expanding more and more. Therefore, consideration of the basic principles used in the construction of radar devices and systems is highly relevant. Radio technical equipment and means intended for performing radar tasks are called radar systems, or devices. In this article, we will consider two meteorological radars MRL-5 with the installed software and hardware complex ASU-MRL and DMRL-C with different wavelengths \( \lambda = 10 \) cm and \( \lambda = 5.2 \) cm. And also consider the assessment of the possibility of using information from the Unified radar field of the Roshydromet DMRL-C network to ensure work on protection against hail, including technical requirements for radar information of the DMRL-C for its use in work on AB on the territory of the South and North Caucasian Federal Districts. The first section in your paper.

1. Introduction
Currently, there is a rapid development of radar methods in meteorological research and observations, as they have a number of advantages – the ability to observe meteorological targets at any time of the day and any weather; large radius of action; high efficiency of the survey of vast spaces without disturbing the natural structure of the fields of meteorological elements; the ability to obtain a spatial picture of the structure of clouds, three-dimensional fields of microstructure and air flows in them, the ability to measure the intensity and amount of precipitation, size and kinetic energy of hail over a vast territory; recognition of various weather phenomena (hail, thunderstorm, downpour, rain, snow, tornado, squall, etc.) [1].

Therefore, the rational use of existing radar stations for solving certain specific problems is very important.

For many years, High Mountain Geophysical Institute has been conducting research on powerful convective clouds on the automated meteorological radar MRL-5. The purpose of such studies is: to identify the mechanisms of hail formation, the development of hail suppression technology, the development of methods for short-term forecasting of dangerous meteorological phenomena in the Central Caucasus. As a result, a technology for certification of hail processes was created [2], a radar data base was developed and is annually updated [3-5], and physical and statistical models of hail clouds of various types were developed [6-7].

This work was carried out to assess the possibility of using information from the Unified radar field of the Roshydromet DMRL-C network to ensure work on protection against hail damage, to develop technical requirements for the radar information of the DMRL-C when it is used in work on hail protection on the territory of North Caucasus.
2. Research methodology

This article discusses two meteorological radars: MRL-5 with wavelengths $\lambda=10$ and 3.2 cm and Doppler meteorological radar DMRL-C with wavelength $\lambda=5.3$ cm, which were used to study convective clouds in the Southern Federal District. Each radar has its own system for collecting, processing and displaying information for the MRL-5 it is a software and hardware complex ASU-MRL [8], and for the DMRL-C it is the software for secondary information processing GIMET-2010. [9].

MRL-5 was created for radar support of hail protection work and storm warning [10]. It includes two unified transceiver devices operating at wavelengths $\lambda=3.2$ and $\lambda=10$ cm, but only the wavelength $\lambda=10$ cm was used in the work.

Meteorological radar DMRL-C is a modern Doppler radar created in 2008-2010. Concern Almaz-Antey radar is designed to create a radar network for geophysical monitoring, storm warning and meteorological support of aviation.

The performance characteristics of two radars MRL-5 and DMRL-C are presented in table 1.

| Parameter values in SI units | MRL-5          | DMRL-C          |
|------------------------------|----------------|-----------------|
|                              | 1 channel      | 2 channel       |                 |
| Wavelength $\lambda$, cm     | 3.13           | 10.15           | 5.33            |
| Transmitter power $P_\tau$, kW | 180           | 600             | 15              |
| Receiver sensitivity $P_{0s}$, W | $2.5*10^{-14}$ | $1.6*10^{-14}$ | $8.0*10^{-15}$  |
| Pulse duration $\tau$, s     | $(1 \text{ and } 2)10^6$ | 60              |                 |
| Pulse repetition rate $F$, Hz | 250 and 500    | 300 and 1500    |                 |
| Antenna diameter $D$, m       | 4.5            | 4.2             |                 |
| Antenna gain $G$, dB         | $1.29*10^3$    | $1.44*10^4$     | $3.16*10^4$     |
| Beam width $\theta/\phi$, degrees | 0.5/0.5       | 1.5/1.5         | 1.0/1.0         |
| $C_\lambda$, cm$^3$          | $6.5*10^{27}$  | $7.9*10^{26}$   | $4.1*10^{27}$   |

Parameter values in dB

| Parameter values in dB | MRL-5 | DMRL-C |
|------------------------|-------|--------|
| $20\lg \lambda$       | 9.91  | 20.13  | 14.53  |
| $10\lg P_\tau$         | 51.80 | 57.00  | 41.76  |
| $10\lg P_{0s}$         | -136.00 | -138.00 | -141.0 |
| $10\lg \tau$           | -57.00 | -57.00 | -42.21 |
| $20\lg G$              | 102.25 | 83.16  | 90.0   |
| $20\lg \phi$           | -41.13 | -31.6  | -35.2  |
| Loss of reception and transmission $\zeta$, dB | 6 | 5 | 6 |
| $10\lg C_\lambda$      | 258.1 | 269.0  | 276.1  |

The potential of both channels of MRL-5 is given for the case of operation with a probe pulse duration $\tau=2 \mu$s, without a small antenna mirror and with installed low-noise microwave amplifiers.

To compare the measurement results, the data of two radars located in close proximity to each other were used: the MRL-5 of the Stavropol paramilitary service and the DMRL-C located at the airport in Stavropol (figure 1). The distance between the radars is 170 meters.
For comparison, days with hail were selected, and since we do not have the opportunity to synchronize two radars to scan the same space, the survey files that were as close in time as possible were selected. However, it should be borne in mind that the duration of the review cycle, adopted on the DMRL-C network (10 minutes), and the review cycle of the MRL-5 is 3.5 minutes. For anti-hail operations, the survey cycle of the DMRL-C is too long, since it is comparable to the time of hail formation.

The particles of clouds and precipitation in the atmosphere interact with the sounding electromagnetic pulses of the radar. In this case, radar reflectivity is a specific characteristic of a meteorological target in accordance with its reflective properties. In the general case, the radar reflectivity of a cloud consists of four terms (groups of physically homogeneous particles): the sum of the cross sections of cloud drops, ice crystals, precipitation drops and hailstones per unit of cloud volume.

\[ \eta = \sum_{j} \sum_{i} n_{i,j} \sigma_{i,j}, \]  

(1)

where \( n_{i,j} \) — the concentration of scattering particles in the group \( j \) with a diameter \( \sigma_{i,j} \), \( n \) — the number of all particles of the \( j \)-th group in a unit of cloud volume. In the general case, the backscattering diameter has a well-known and rather complicated form for calculation:

\[ \sigma = \frac{\lambda^2}{4\pi} \left( \sum_{n=1}^{\infty} (-1)^n (2n + 1)(a_n - b_n) \right)^2. \]  

(2)

In the region of particles small in comparison with the wavelength (Rayleigh region for the case \( \pi \cdot d/\lambda \leq 0.13 \)), the backscattering cross section has a simpler form:

\[ \sigma = \frac{\pi^5}{\lambda^2} \left( \frac{m^2 - 1}{m^2 + 2} \right)^2 d^6. \]  

(3)

For the centimeter wavelength range, relation (3) is fulfilled in clouds without precipitation or in light (drizzling) precipitation. In the case of small particles for reflectivity, you can write:
\[ \eta = \frac{\pi^5}{\lambda^2} \left( \frac{m^2 - 1}{m^2 + 2} \right) \sum_{i=1}^{n} N_i d_i^6 \]  

(4)

The sum in expression (4) is called the reflectivity factor. In the practice of radar measurements, the reflectance multiplier Z is usually used, measured in dBZ. For \( \lambda = 5.3 \) and \( \lambda = 10 \) cm:

\[ z_{5.3} = 124.5 + 10 \log \eta_{5.3} \]
\[ z_{10} = 135.7 + 10 \log \eta_{10} \]  

(5)

Since in weak clouds the reflectivity factor is independent of the wavelength, the radio echo of clouds for \( \lambda = 5.3 \) and \( \lambda = 10 \) cm (provided that the calibration is correct and there is no attenuation) will coincide.

3. Results and discussion

In hail clouds, the differences in the radio echo of clouds for \( \lambda = 5.3 \) and \( \lambda = 10 \) cm will be the greater the more powerful clouds. This article compares the readings of two radars located in close proximity to each other in terms of maximum reflectance \( Z_{\text{max}} \) in dBZ, maximum reflectance height \( H_{Z_{\text{max}}} \), cloud top height \( H \) and precipitation intensity \( I \).

For comparison, the data archive of 2019 was used. DMRL-C of Roshydromet and MRL-5 of the Stavropol paramilitary hail-fighting service. For example, figure 2 (a) and (b) shows the maximum reflectivity of a hail cloud located in the immediate vicinity of two radars, measured using MRL-5 and DMRL-C. Figure 2 (c) and (d) shows the maximum reflectivity of a hail cloud located at a distance of about 60 km, measured using MRL-5 and DMRL-C. Table 2 shows data comparing the readings of the two radars. As can be seen from the figures, both horizontal and vertical sections differ.

**Figure 2.** a) Maximum reflectivity on May 08, 2019 at 18:20 (MRL-5), b) Maximum reflectivity on May 08, 2019 at 18:20 (DMRL-C), c) Maximum reflectivity on May 20, 2019 at 11:40 (MRL-5), d) Maximum reflectivity on May 20, 2019 at 11:40 (DMRL-C).
4. Conclusions
As a conclusion, it can be noted that both horizontal and vertical sections are different. For a powerful hail cloud, and for weaker clouds, both in the table and in the maps of maximum reflectivity, the data are more similar than for a powerful hail cloud. This can be explained by the difference in wavelengths and, as a consequence, by attenuation in a hail cloud of a smaller wavelength. The table also shows a striking difference in the radar readings in terms of precipitation intensity, which will still need to be checked against the reference value; it is planned to use a meteorological weather station as a reference. For a correct comparison of two radars, it is necessary to synchronize the radars and scan the same area space in time. Unfortunately, it is not possible to synchronize the two radars, since they are not in the same property.

It can also be noted that it is recommended to use the information from the Unified radar field of the Roshydromet DMRL-C network to ensure work on protection against hail damage, in «Duty» mode, to save resources of anti-hail service radars, since the resources of the MRL-5 are exhausted and have doubled their resource.

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