Analysis of the Millimeter-Band Astroclimate at the Caucasus Mountain Observatory

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Abstract. In this article, we consider the results of studying the astroclimate in the millimeter wavelength range in the region of the Caucasian Mountain Observatory(CMO SAI MSU). opacity measurements were carried out at an altitude of 2112 meters, in a transparency windows of 2 and 3mm, by the atmospheric dip method. Two expeditions were organized: the long-term expedition from January to March 2016 and the short-term expedition in 2020. Using the obtained data on the measurement of atmospheric opacity, the amount of precipitated water and comparison with other studied sites, it is possible to evaluate the suitability for the construction of a millimeter-wave observatory.

Keywords: atmospheric effects

DOI:10.26119/978-5-6045062-0-2_2020_184

1 Introduction

The development of millimeter-wave radio astronomy requires the search for new sites with a good astroclimate for construction of telescopes (Bubnov et al. 2020a). We have carried out two short cycles of studies of the millimeter-wave astroclimate at the Caucasian Mountain Observatory SAI MSU. This study is a base for evaluating the radio astronomy capabilities of the site. The place was chosen taking into account engineering communications and astroclimatic

conditions for observations (Panchuk & Afanas'ev 2011; Voziakova 2011). The research was carried out in two blocks, long and short, in different years. This approach of direct measurements and forecast calculations allows one to compare different sites when long-term measurements are difficult for various reasons. Comparison of the received data with the data of meteorological satellites allows us to interpret the received data with greater reliability. It was compared with the extinction measurements by the the CMO. Also we compared this site with other potential sites for the future construction of the radiotelescope.

2 Metod and Tools

The measurements were carried out using a MIAP-2 device in a two-channel mode, 2 and 3 mm. It allows us to estimate the contribution of various atmospheric components such as dry absorption and atmospheric moisture content, and to calculate the value of total absorption in different transparency windows of mm and submm range. In more detail, the device and measurement technique are described in Nosov et al. (2016). MIAP-2 measures the opacity by the atmospheric dip method. The device is fully automated. The use of remote access via the Internet allows us to perform long-term measurements without the presence of the researcher. The equipment and measurement technique are constantly being improved and adapted to specific tasks (Bubnov et al. 2018, 2020b).

3 Results Processing

The site near the CMO is characterized by well-developed infrastructure. Fig. 1 shows the opacity and extinction obtained in February 2016 and it's median values.

On this example record we can consider that no correlation between opacity and optical extinction was found. The study period includes the coldest time of the year, as the most favorable to estimate the smallest opacity at a given site, and the off-perion. In the comparison of the records of the opacity and integral humidity by MODIS satellite the following tendency is observed, Fig. 2: an increase of the integral humidity is accompanied by an increase of the scatter of the opacity data as a result of the arrival of humidity and cloudiness. On these graphs, one can clearly distinguish the periods of the good weather, when the opacity value changes insignificantly. This slow change in opacity is directly associated with the change in air masses and, accordingly, with the total amount of precipitated water in the atmosphere. Under cloudy conditions,

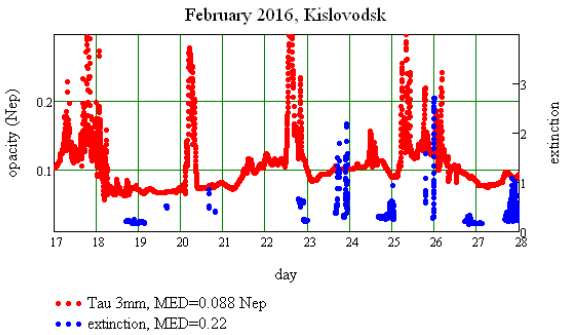

Fig. 1. PWV and extintions 02.2016 CMO

sharp "jumps" of opacity are observed. This behavior is not connected with the change of air masses, but it is due to inconsistency of the flat-layered model incorporated in the atmospheric dip method with the cloudy atmosphere. A similar nature of errors is observed on clear days and it has a random nature. For the clear periods of time, the random errors can be unambiguously filtered out by the noise filtering algorithm (Nosov et al. 2016). Thus, the developed method reduces the error of the opacity measurements, and, at the same time, it does not artificially change the statistical values of opacity.

On the one hand, cloudy time intervals are of little interest for astronomical observations, since the opacity is very large. In this case, it does not matter much what causes the opacity: the hydrometeors scattering or the water vapor absorption. On the other hand, all, including large opacity values, are taken

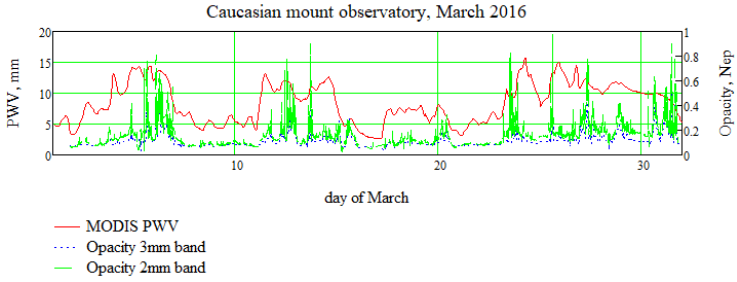

Fig. 2. MODIS satellite PWV vs 3mm and 2mm band opacity

into account in the statistical processing, which allows one to reasonably argue about the statistical suitability or unsuitability of the site for millimeter radio astronomy. The histograms in Fig. 3 shows the opacity statistics for three months. We compare the statistical characteristics for the same period of time

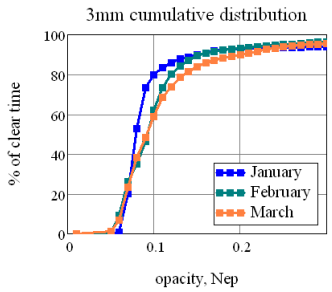

Fig.3 Cumulative histograms for 3mm waveband in CMO

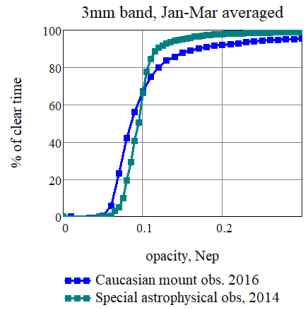

Fig.4 Cumulative histograms for 3mm waveband in CMO vs BTA

of the astroclimate at CMO with the astroclimate observations in the similar site of the North Caucasus, nearly the BTA telescope (SAO RAS, 2070 a.s.l.). The Fig. 4 shows the cumulative distributions of opacity at the site of the SAO RAS and CMO SAI MSU, averaged over the period from January to March. The results obtained at the site of CMO do not show statistically significant differences, which is expected for sites located in the same climatic zone at the same altitude.

One-day short-term measurements in February 2020 confirmed the previously obtained results for the long-term cycles. And the comparison of data obtained practically at the same time from different sites (RATAN-600, Terskol peak). For comparison, we chose stable cloudless weather. A comparative analysis of measurements for 2 and 3 mm is shown in Fig. 5 and Fig. 6

4 Conclusion

Two cycles of studies of the astroclimate in the millimeter wavelength range were carried out in the area of the Caucasus Mountain Observatory (SAI MSU) and opacity calculations were made in the transparency window of 2 and 3 mm. A comparative analysis of this site with similar sites in the North Caucasus is made. From the data obtained, we can conclude that there is no significant difference between these sites.

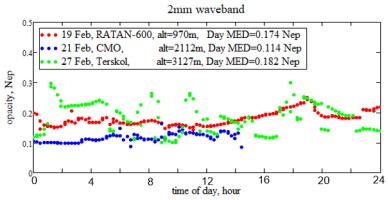

Fig.5 Day record of opacity in 2mm waveband

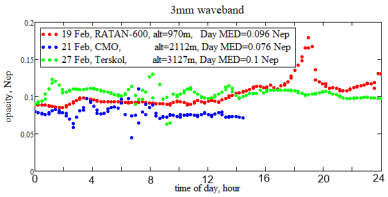

Fig.6 Day record of opacity in 3mm waveband

Acknowledgements. The expedition to study the astroclimate was carried out under the scientific program of the RSF grant (project No. 19-19-00499), astroclimate data is processed under the scientific program of the Russian President's scholarship SP-5103.2018.3, and the data processing methodology was developed within the framework of the IAP RAS (Project 0035-2019-0005).

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