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Study Of Atmospheric Absorption And PWV In The Suffa Plateau (Uzbekistan)

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ABSTRACT

Radio Astronomical Observatory of Suffa, and new proposals for radioastroclimatic (seeing) studies for atmospheric radio prediction are described. The paper presents the results of many-year (2015-2020) and seasonal observations of the astroclimate at the construction site of the RT-70 radio telescope on the Suffa plateau (an altitude of 2400 m above sea level). Observations were carried out automatically every 10 minutes throughout the year, starting from November 2014.

KEYWORDS

Radio astronomy in Uzbekistan, radio telescopes, devices: adaptive optics, radiometer, lines: general, millimeter, submillimeter, on-site tests, atmospheric effects

INTRODUCTION

Short-term and long-term regularities of changes in atmospheric transparency parameters are considered, statistical diagrams are constructed. The main result of the work is statistical data characterizing the astroclimate, which makes it possible to predict the possibility of radio astronomy observations in the transparency windows of the millimeter and submillimeter wave length ranges.

Recently, there has been renewed interest in the main instrument of the observatory - the RT-70 project radio telescope with a 70-meter main reflector, as one of the largest instruments for the short-wave part of the millimeter wavelength range with unique design characteristics. The operating frequency range of the radio telescope is from 5 to 300 GHz, the radiation pattern is up to three arc seconds. Modern technologies will allow this tool to be endowed with a number of unique properties: in particular, the adaptive surface of the mirror will increase the effective area, and the use of CFRP will significantly reduce the weight of the structure.

In addition to the characteristics of the instrument itself, the astroclimate of the area in which the radio telescope is installed plays an important role in the overall performance of the observatory. One of the most important problems in the development of the short-wavelength part of the millimeter and submillimeter ranges for the purposes of radio astronomy and telecommunications is the significant absorption of radiation of these wavelengths by atmospheric gases. It is subject to significant seasonal and diurnal variations and significantly depends on the local climate and altitude. The most reliable way to determine the astroclimate of a particular area is to carry out regular measurements of the integral atmospheric attenuation (i.e., optical thickness) in the atmospheric transparency windows that are closest to the operating frequencies of the radio telescope. Often the local climate of a specific area (valleys, gorges, plateaus etc.) is decisive, and therefore the use of meteorological data, satellite data and aerosounding (not from this site) is possible only for assessment.

The study by the authors of the astroclimate at the Suffa observatory began in 2013, but the measuring complex was fully launched only at the end of 2014. The results of continuous monitoring of the astroclimate in transparency windows near 2 and 3 mm, which began in November 2014, are presented in this article.

OBSERVATION STATISTICS

The radiometric complex is programmed to measure atmospheric optical thickness every 10 minutes, while one measurement takes about 50 s. Thus, the complex records the temporal dynamics of the atmospheric thickness in two windows of atmospheric transparency. As an example, Fig. 1 shows the records for the six-year period 2015-2020.

Both plots show daily variations in atmospheric absorption with a value of about 0.03 Np. Clear (without visible cloud formations) time is characterized by a small scatter of points; with the appearance of cloudiness, the conditions of applicability of the plane-layered model of the atmosphere, adopted in the method of "sections", are not satisfied, as a result of

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which a noticeable scatter of points appears. The atmospheric thickness values in summer are about 2 times higher than in winter, mainly due to frequent cloudiness and an increase in the integral moisture content (the so-called amount of precipitated water, PWV).

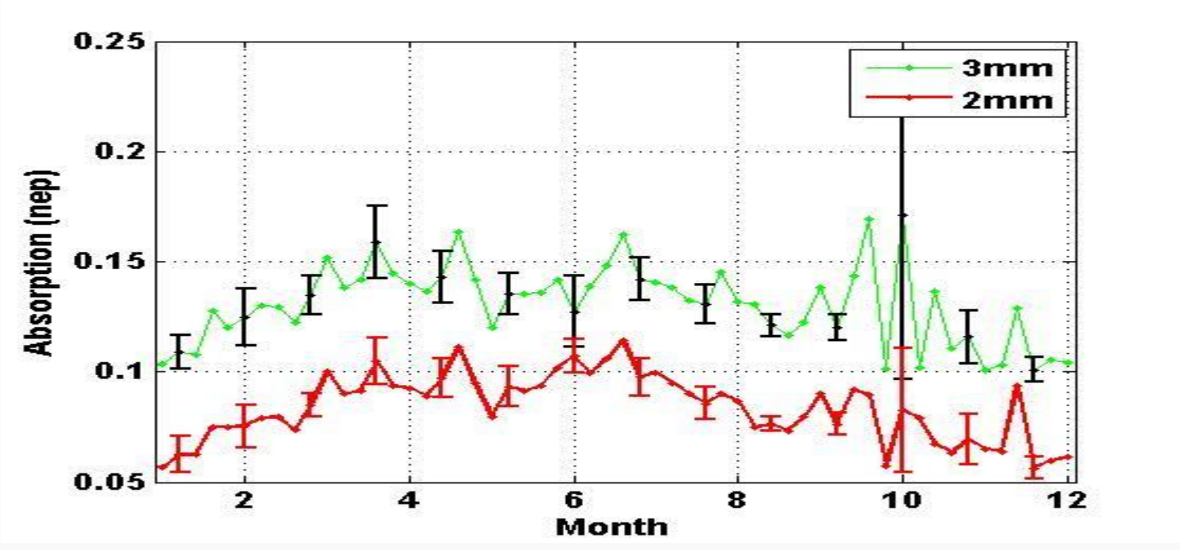

Fig. 1. Daily mean values of atmospheric absorption during the period from 2015-2020 on 2 mm and 3 mm wavelength ranges

QUANTITY OF DRAINED WATER AND SEASONAL TRENDS

Observations in two transparency windows make it possible to calculate the amount of precipitated water (integral moisture content or precipitable water vapor, PWV) according to the method presented in, using the methods for calculating the specific absorption coefficients (β) for a given radiometer given in our work (see formula (1)). The results of PWV calculations are shown in Fig.2. The PWV values are found separately for each channel, but in a clear time they coincide to within the measurement error, and during cloudy periods an accurate analysis of the data obtained by the "sections" method is extremely difficult.

The resultant is the arithmetic mean between the values for the two channels at each point in time.

Among other parameters, an absolute surface humidity H is measured every 3 hours at an automatic weather station and according to the obtained value

PWVPsyhr [mm] = 2.054H [g / m3] + 0.279(1)

PWV is calculated. The coefficients in this formula were obtained experimentally from aerosound data in 1991.

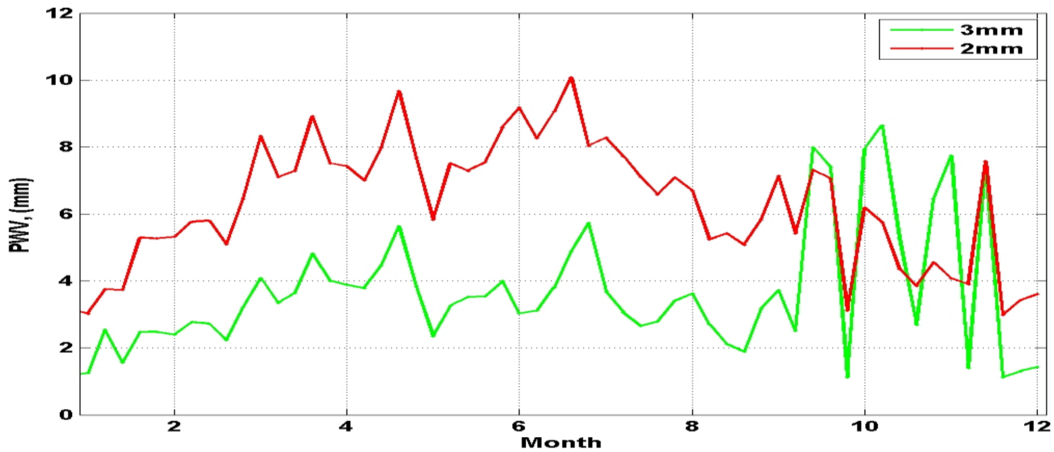

Fig. 2. Daily mean values of the integral amount of precipitated water from January 2015 to December 2020 for 2 mm and 3 mm ranges

The dependences shown in Fig. 2, reflect the temporal dynamics of precipitated water in January and July 2015-2020 and are characteristic of two extreme states of the climate. The average value of precipitated water in January is about 6.2 mm, and in June it is twice as much - about 13.3 mm.

The diurnal variations in PWV in summer are much more significant than in winter. In summer, cloudy weather is more common, accompanied by a scatter of points, and in winter, the state of the atmosphere is more stable, and on some nights in December and January the PWV drops to minimum values of about 2 mm.

When comparing data from different sources in winter and summer, the following trend is observed: the nature of variations and the average PWV level according to the data of the meteorological station and the AIRS satellite practically coincide with the data of radiometers in winter, but increase by some constant in summer. This is primarily due to the nature of the local climate of the Suffa Plateau.

Table 1.presents monthly averaged valuesatmospheric absorption and the integral amount of precipitated water in the 2 and 3 mm ranges from January 2015 to December 2020.

Obtained results of observations of atmospheric parametersare used in the development of methods for predicting the main parameters of the atmosphere on the Suffa plateau in the millimeter range.

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Table 1

Monthly averaged values of atmospheric absorption and integral amount of precipitated water for the period from January 2015 to December 2020

Months	Abcorption 3mm	Abcorption 2mm	PWV 3mm	PWV 2mm
January	0,0822	0,0746	6,15	2,41
February	0,0848	0,0767	6,47	2,51
March	0,1156	0,1323	10,22	4,92
April	0,1156	0,1628	10,22	6,25
May	0,1397	0,1833	13,16	7,14
June	0,1102	0,1281	9,56	4,74
July	0,1284	0,1734	11,78	6,71
August	0,1181	0,1521	10,53	5,78
September	0,1195	0,1542	10,71	5,87
October	0,0768	0,0923	5,49	3,19
November	0,0979	0,1029	8,06	3,64
December	0,0959	0,0859	7,51	2,91

CONCLUSION

The choice of the site for the construction of RT-70 was due to the peculiarities of the astroclimate on the Suffa plateau. However, realizing a high surface utilization factor on a 70-meter mirror for waves with wavelengths of the order of 1 mm seems to be a very difficult task. There is no doubt about the possibility of achieving the declared parameters of the RT-70 [1], the question is only about the preservation of these parameters over time, their effectiveness in terms of astroclimate and, as a consequence, the expediency of working out the main reflector to the declared accuracy.

Based on the measurements made and taking into account the known model of the atmosphere, it can be reasonably assumed that observations in the submillimeter range (namely, at wavelengths 1.3; 0.87 and, possibly, 0.75 and 0.65 mm) will be more effective. from the nearest peak with an altitude of 3400 m. In this context, it seems appropriate to supplement the existing RT-70 project with a cheaper instrument of small dimensions, placing it on the nearest peak and transferring to it some of the observation functions in the submillimeter range.

At present, regular observations of the astroclimate on the Suffa plateau continue.

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