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A review of astroclimate conditions at possible locations for the Eurasian Submillimeter Telescopes (ESMT)

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Abstract. The paper presents the results of studying the astroclimate at possible locations for the Eurasian Submillimeter Telescopes (ESMT), including the sites of Kurapdag in the Agul district of Dagestan, Khunzundallbak (3676 m) in the Rutul district of Dagestan, Khulugaisha peak (Eastern Sayan), Tashanta checkpoint in the intermountain basin of the Altai Republic, Boguty (3350 m) in the foothills of the Altai Mountains near the border with Mongolia, the Suffa plateau (Aktashtau, 3282 m), and the Ali region in Tibet. The expected radio brightness temperatures of the clear and cloudy atmosphere at wavelengths of 2 and 3 mm and the characteristics of the 3-mm range radiometer for measuring the optical thickness of the atmosphere are presented.

Keywords: site testing; telescopes; atmospheric effects

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1 Introduction

Due to the high interest in the construction of large single submillimeter telescopes in Eurasia, it is relevant to study the astroclimate at possible sites for their placement (Khaikin et al. 2020, 2022; Balega et al. 2022). Several new sites are considered for the next-generation Event Horizon Telescopes (ngEHT, Raymond et al. 2021). Li et al. (2024) provide plans for the placement and equipping of a 15-m submillimeter telescope with a range of 80–690 GHz on the Quinghai-Tibet Plateau (4820 m). To study the astroclimate at possible locations for the Eurasian Submillimeter Telescopes (ESMT) (Khaikin et al. 2020) in the Russian Federation, the data from the European Center for Medium-Range Weather Forecast Reanalysis v5 (ERA5) and geodetic stations of the Global Navigation Satellite Systems (GNSS) were used.

2 Results

Figure 1 shows the measurements of precipitated water vapor (PWV) at the Ali Observatory using two methods. The analysis of astroclimate at 25 potential sites (Khaikin et al. 2020) shows that in the Russian Federation there are 3–4 places that may be suitable for placing a 20-m class submillimeter telescope: Kurapdag (3778 m) in the Agul region of Dagestan, the slope of Mt. Khunzundalilbak (3676 m) in the Rutul region of Dagestan, the Khulugaisha peak (3016 m) (Eastern Sayan), the Tashanta checkpoint (2100 m) in the intermountain basin of the Altai Republic, Boguty (3350 m) in the foothills of the Altai Mountains near the border with Mongolia. At these places, astronomical stations have been organized with various equipment installed: the automatic weather stations, GNSS stations for monitoring the PWV and geodynamics, solar photometers (pyranometers) for measuring the duration of sunny weather and the presence of clouds, ultrasonic anemometers for measuring wind pulsations and structural characteristics of the fluctuations in the refractive index of the near-surface atmosphere C_n^2. The PWV measurements obtained at one of the new astronomical stations are shown in Table 1 and Fig. 2.

Figure 3 shows the calculated radio brightness temperatures of the clear and cloudy atmosphere at the zenith at wavelengths of 3 and 2 mm in summer and winter. To measure the radio brightness temperature and the optical thickness of the clear and cloudy atmosphere at new astronomical stations using the absolute method, a radiometric complex has been developed, consisting of a broadband radiometric module of the 3-mm range, an input waveguide filter (80–100 GHz), a conical horn, and a thermostated blackbody "field" load. The measured fluctuation sensitivity of the 3-mm radiometer in the "total power" mode is 12 mK/Hz$^{1/2}$ (sustained for

Table 1. Monthly PWV statistics calculated from the GNSS measurements at the Khulugaisha astronomical station in the period from November 16, 2023 to June 24, 2024 at night and during the daytime.

Month	Min	Max	Average, mm			Median, mm			RMS, mm			δ PWV, mm		
	mm	mm	A	N	D	A	N	D	A	N	D	A	N	D
1	0.06	7.03	2.61	2.43	2.74	2.11	1.75	2.25	1.79	1.78	1.81	1.02	1.06	0.86
2	0.01	6.00	2.79	2.77	2.83	2.75	2.73	2.80	1.43	1.41	1.43	0.80	0.74	0.77
3	0.00	6.13	2.53	2.55	2.55	2.62	2.71	2.65	1.30	1.33	1.27	0.84	0.75	0.78
4	0.02	6.87	2.35	2.24	2.66	1.94	1.91	2.35	1.89	1.87	2.09	1.77	1.23	1.26
5	0.02	15.10	7.39	7.22	7.99	7.11	7.03	7.55	3.10	3.49	2.74	1.29	1.09	1.43
6	2.29	18.01	8.79	8.18	9.56	9.08	8.68	10.02	3.06	3.05	2.95	3.33	3.36	3.39

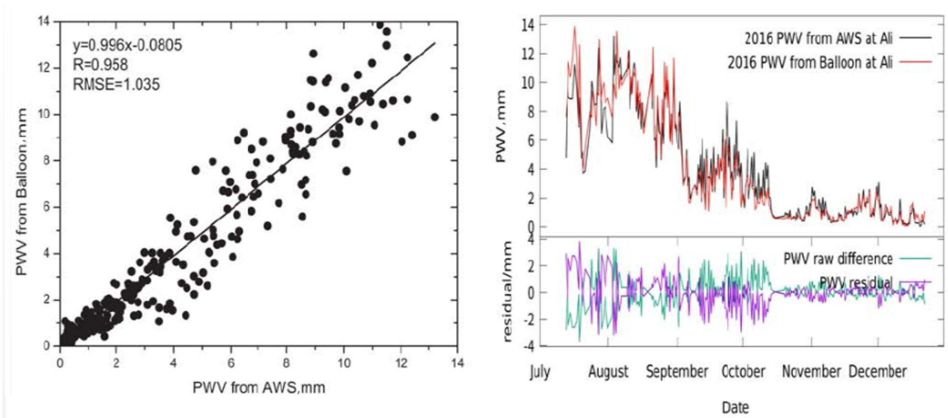

Fig. 1. PWV measurements at the Ali Observatory (5100 m) by two methods: an all-weather station (AWS) and an air balloon.

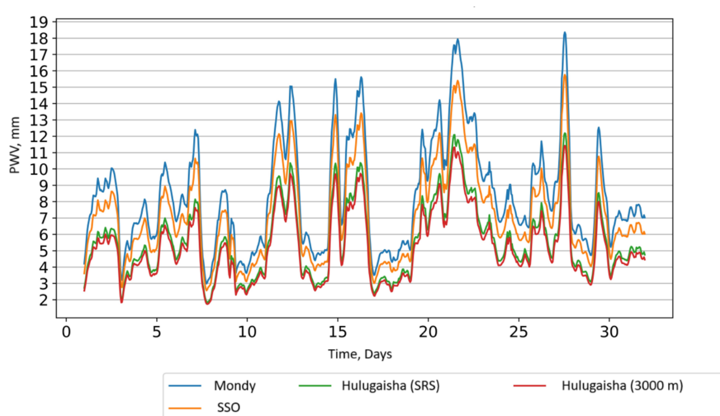

Fig. 2. Variation of hourly PWV values at different locations in May 2024, calculated from the ERA5 data.

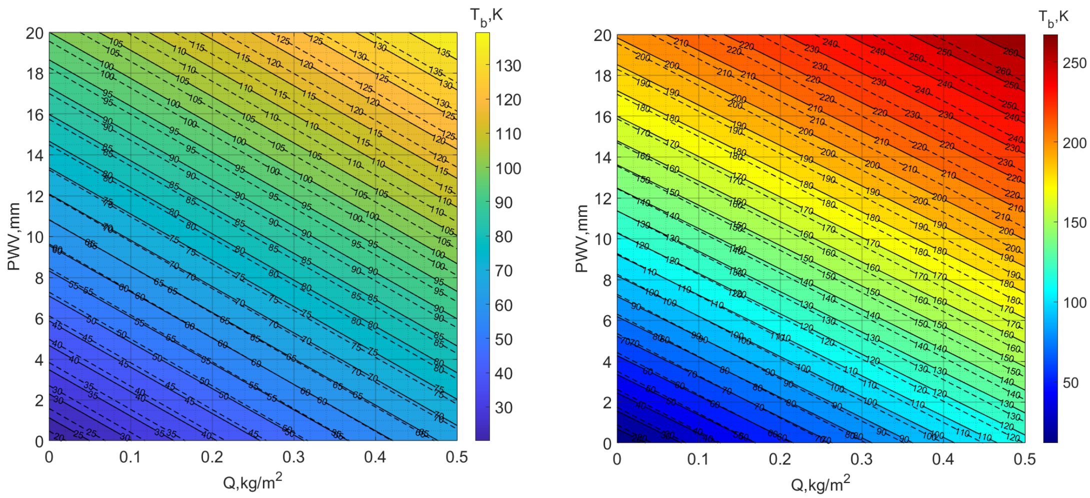

Fig. 3. The calculated radio brightness temperatures of the clear and cloudy atmosphere at the zenith at a wavelength of 3 mm (left) and 2 mm (right) for winter (−20°C, solid line) and summer (+20°C, dashed line); Q is the amount of water in the clouds.

20–30 seconds) with the noise temperature of the black body equal to 299 K at its physical temperature of 300 K.

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