



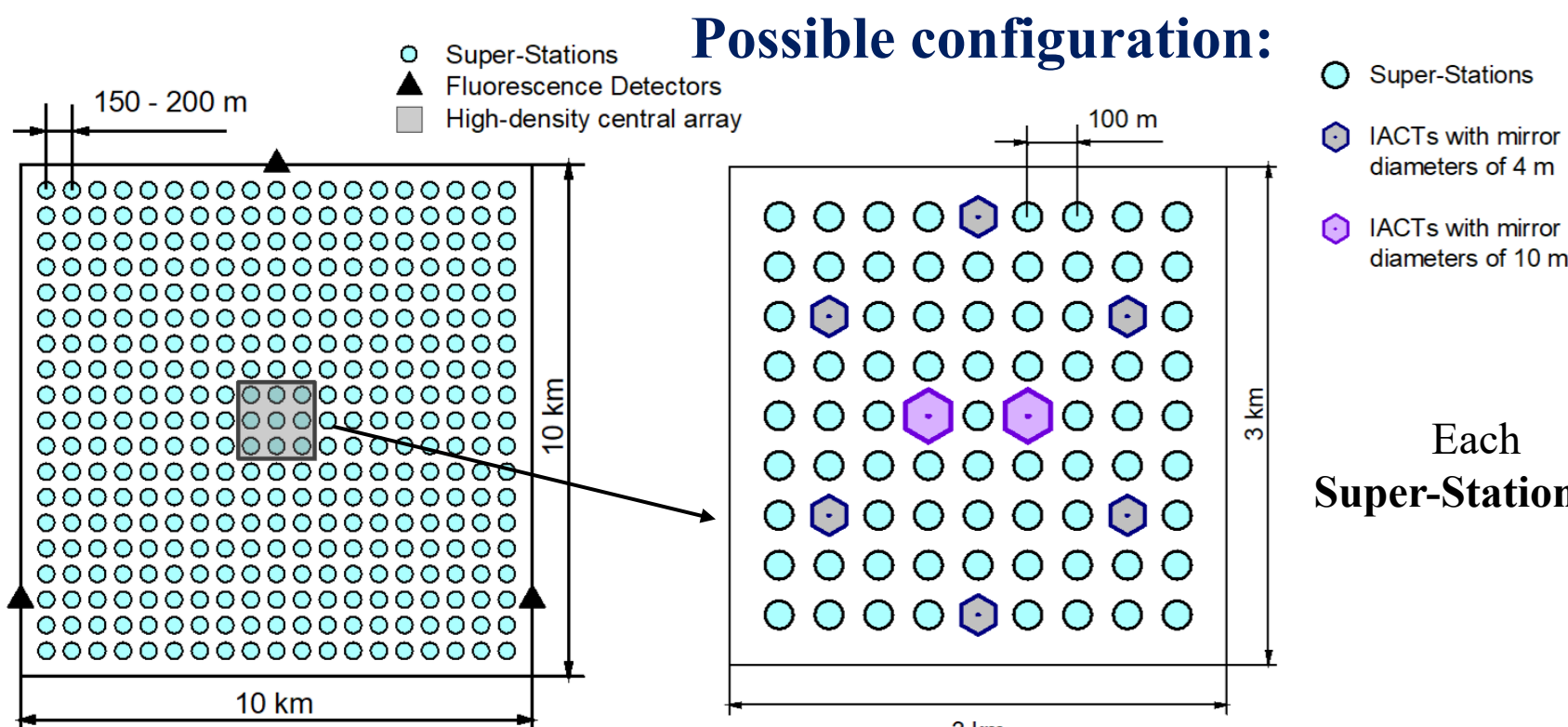
Abstract

The TAIGA-100 astrophysical complex is a project of a large-scale facility designed to solve a wide range of fundamental problems in gamma ray astronomy, cosmic ray physics and particle astrophysics. It will include several types of detectors to record various components of extensive atmospheric showers over an area of 100 square kilometers. A key aspect of the successful implementation of the TAIGA-100 project is choosing an optimal site for its location. The report examines potential sites and analyzes their astroclimate by satellite data. The importance of in-situ measurements is emphasized. A prototype of the astroclimate station deployed on the area of the Tunka Astrophysical Center for Collective Use, where the operating TAIGA-1 complex is located, is described. The results of the comparison of the predictions of the Era5 model based on satellite data with the measured soil temperature profile at a depth of up to 3 m are presented, which allows assessing the accuracy of climate models and their applicability for planning future studies.

Project of TAIGA-100 astrophysical complex [1]

Scientific program:

- detailed research in the field of sub-PeV gamma-ray astronomy and beyond;
- search for diffuse gamma rays in the 100 - 1000 PeV energy range;
- investigation of the nature of Galactic sources of cosmic rays with energies $E \geq 1$ PeV ;
- detailed studies of the energy spectrum and mass composition of CRs in the 1 PeV - 10 EeV energy range;
- search for extragalactic (active galactic nuclei, quasars) objects;
- detection of radio signals from near-horizontal EAS and the association of these showers with astrophysical neutrinos
- research at the intersection of astrophysics and Earth sciences.



Each Super-Station =
Wide-angle Cherenkov Detector
+
Water Cherenkov Detector
+
Scintillation Detector
+
Radio Antenna

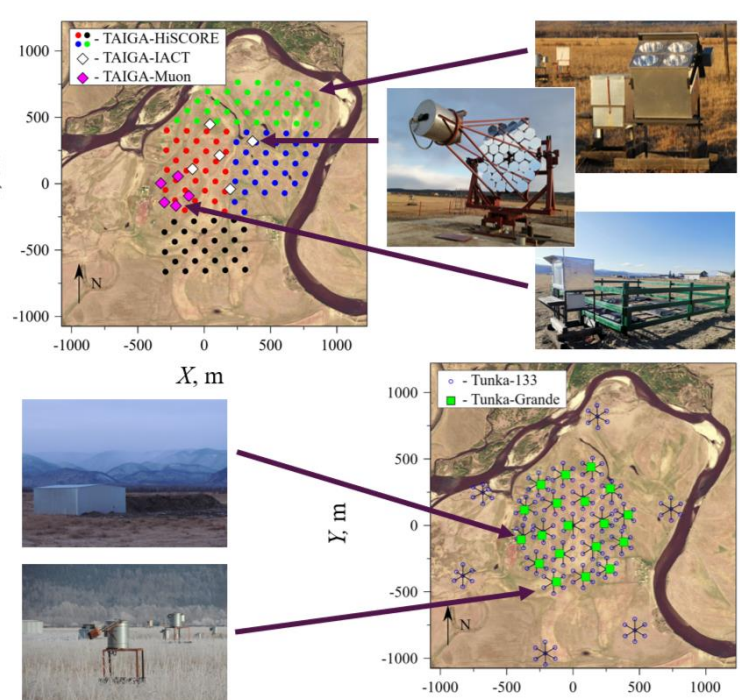
The proposed structure:

- ~ 3000 Wide-angle Cherenkov detectors (CD);
- ~ 3000 Water Muon detectors (MD), with an area of 40 m² each;
- 5-7 IACTs with a mirror diameter of 4 m;
- 1-2 IACTs with a mirror diameter of 10 m;
- ~ 3000 Scintillation Detectors (SD);
- ~ 3000 Radio Antennas;
- 1-3 Fluorescence Detectors (FD).

Selection criteria for the TAIGA-100 deployment site:

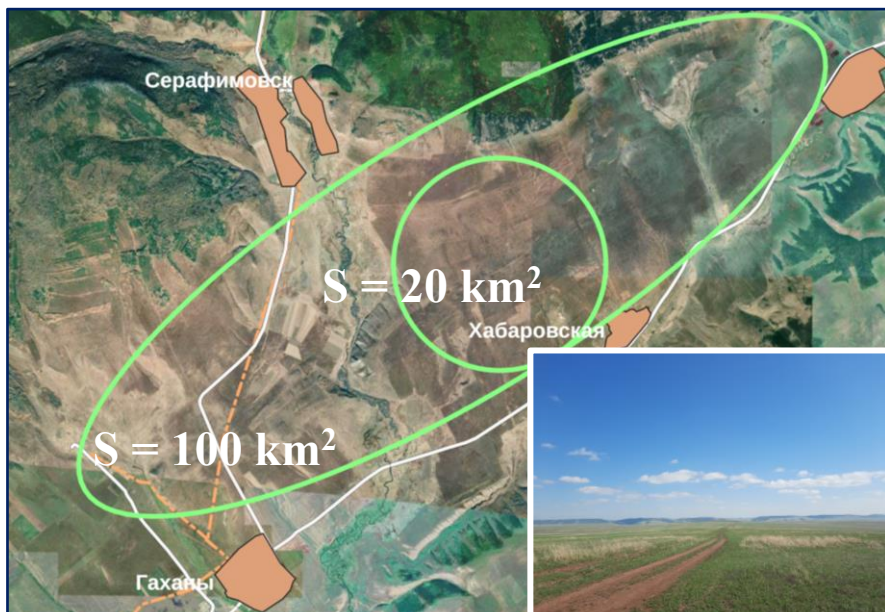
- 1) Astro climate:
 - minimum number of cloudless nights;
 - high transparency of the atmosphere
 - minimum humidity;
 - the minimum level of anthropogenic illumination.
- 2) Terrain features:
 - available for Astrophysical Complex area is ~ 100 km²;
 - the steepness of the slopes is up to 5°;
 - the soils are suitable for excavation at a depth of at least 3 m;
 - availability of water for Water Muon Detectors.
 - positive ground temperature at a depth of ~ 2 m > 0
- 3) Infrastructure:
 - distance to site;
 - transport accessibility;
 - land category, actual use;
 - availability of affordable energy and telecommunication infrastructure.

Site of the TAIGA-1 complex: Tunka Valley (Buryatia Republic)

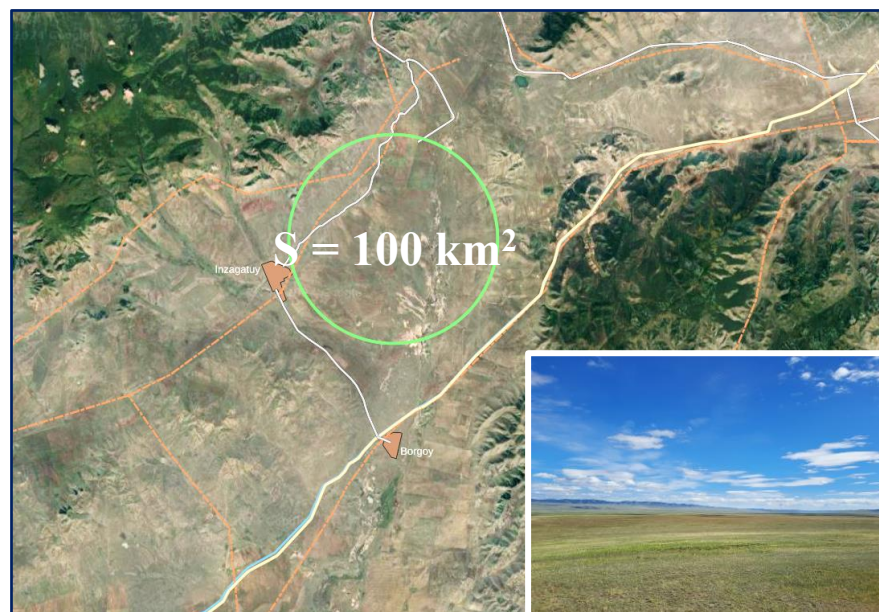


Pre-selected potential Sites of TAIGA-100:

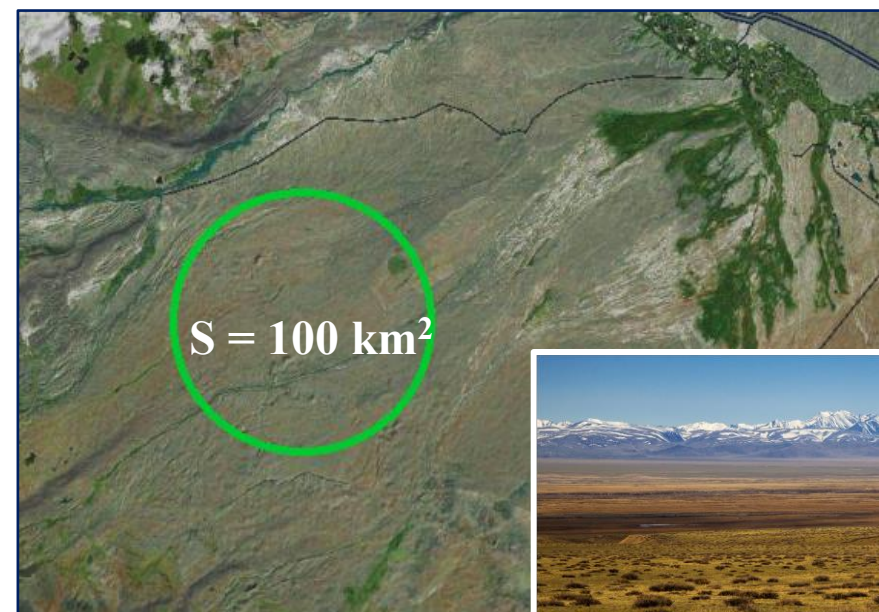
Vicinity of Gakhany village (Irkutsk region)



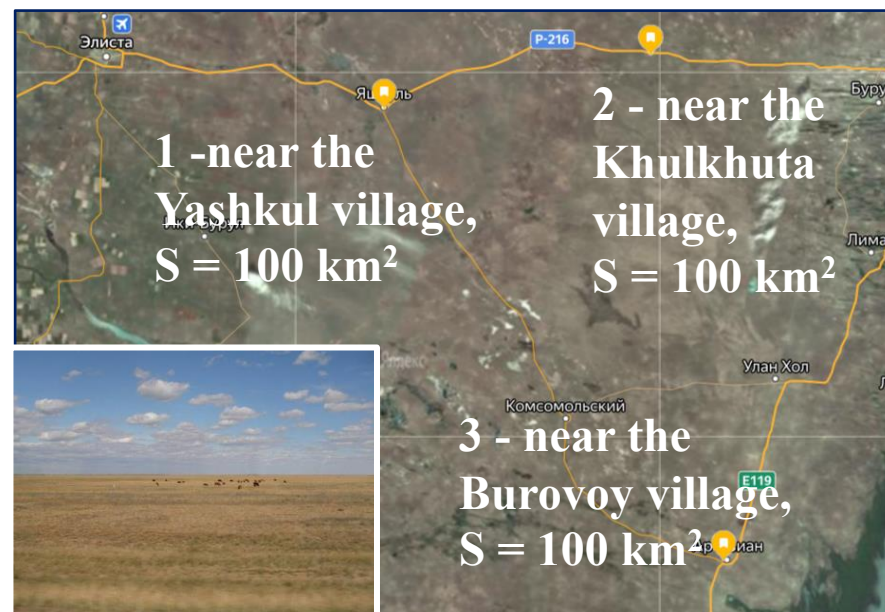
Borgoy Steppe (Buryatia Republic)



Chuya Steppe (Altai Republic)



Kalmykia Republic (3 potential sites)



Analysis of the some astroclimate and terrain features of the current and potential sites*

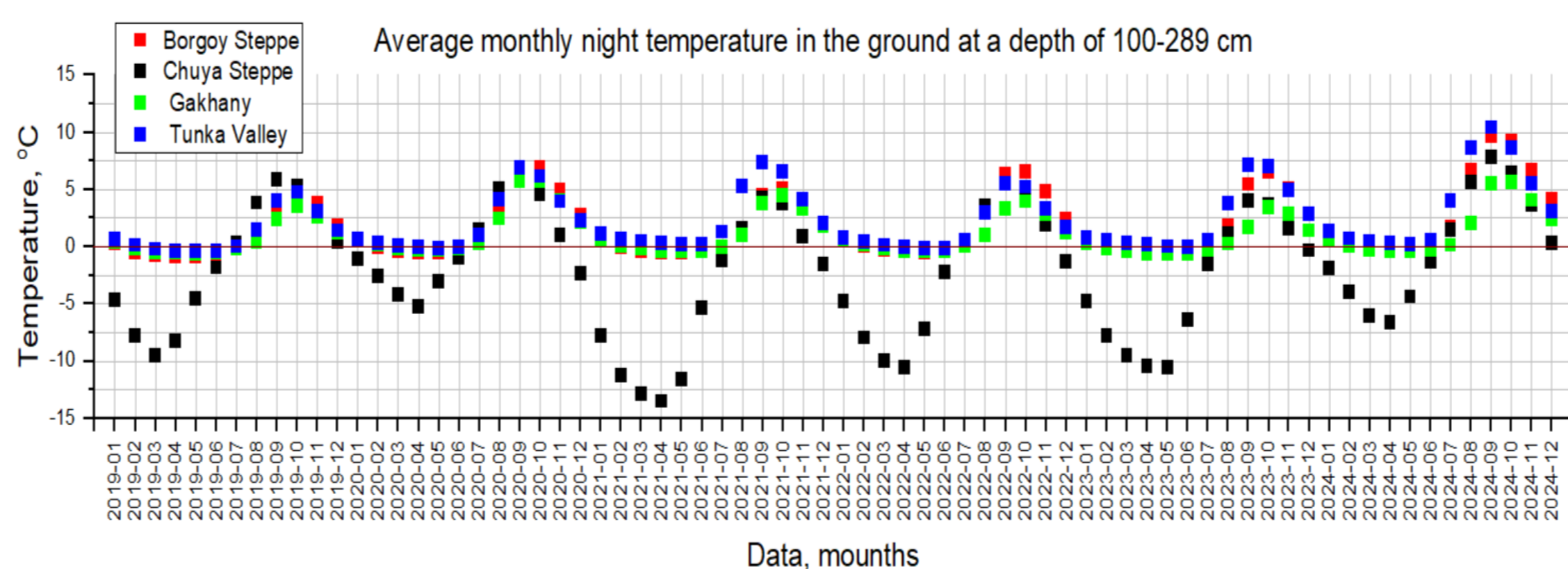
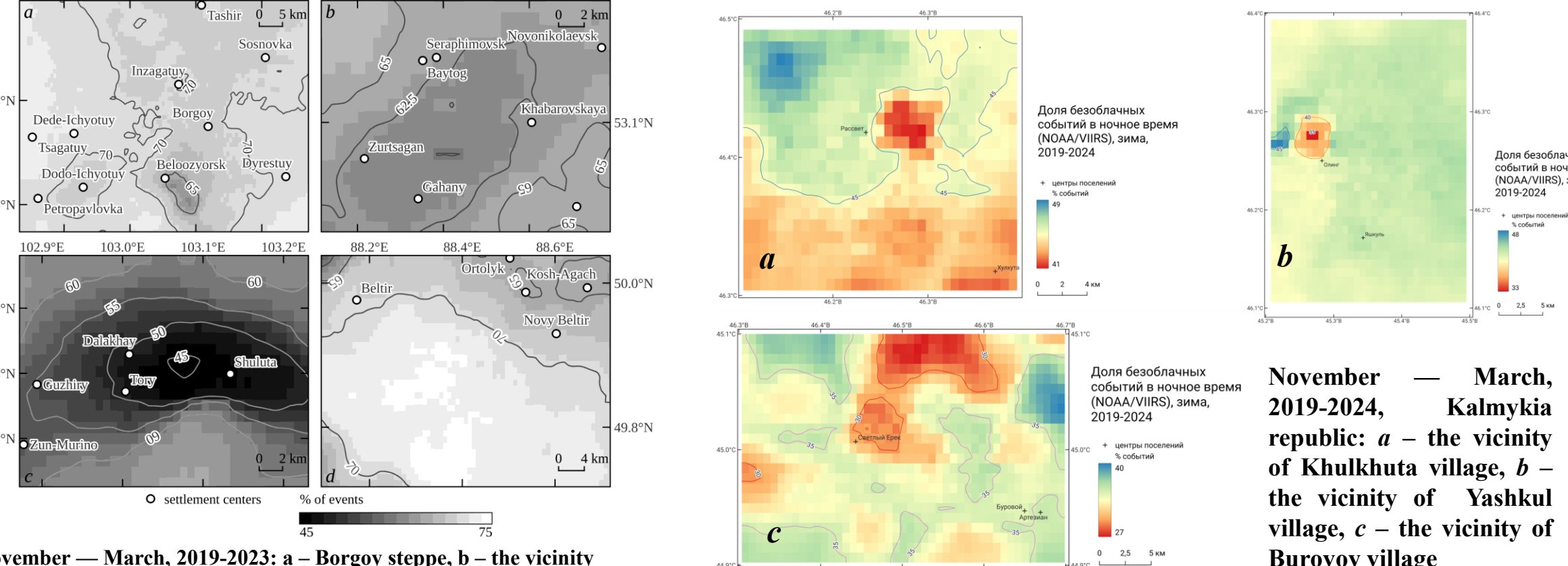
Parameter	Tunka Valley	Vicinity of Gakhany village	Borgoy Steppe	Chuya Steppe	Kalmykia Republic
Coordinates, degrees	51.81° N., 103.07° E.	53.11° N., 104.91° E.	50.84° N., 105.81° E.	49.89° N., 88.22° E.	46.17° N., 45.34° E. (1) 46.32° N., 46.37° E. (2) 44.95° N., 46.65° E. (3)
Altitude of a.s.l., m.	600 – 700	600 – 700	700 – 800	1700 – 1800	~ 0 (1); ~ 0 (2); ~ 28 (3)
Area, km ²	3	≤ 100 (~20 – central part) **	> 100	> 100	> 100 (1, 2, 3)
Landscapes	meadow steppe	meadow steppe	Dry steppe	Dry steppe / semi-desert	Dry steppe / semi-desert
Slopes steepness	subhorizontal surfaces are flat, < 5°	flat subhorizontal surfaces, < 5°	flat subhorizontal surfaces, < 5°	flat subhorizontal surfaces, < 5°	flat subhorizontal surfaces, < 5°
Soil suitability for excavation without the use of machinery at a depth of at least 3 meters	+	+	+	+	+
Availability of water for Water Muon Detectors	+	+	+	+	? (increased mineralization of the Kalmykia groundwater)
Number of cloudless night events, %	45 – 50 %	60 – 64 %	68 – 71 %	70 – 75 %	40 – 45% (1)** 45 – 47% (2)** 30 – 35% (3)**
Humidity, kg/m ²	3.0-3.2	3.4-3.5	3.1-3.3	2.2-2.5	
Average annual precipitation, mm per year	300 – 350	250-300	< 250	< 200	200-340
Atmospheric optical thickness (AOT)	0.18	0.12	0.11	0.19	0.07 (1), 0.09 (2), 0.1 (3)
Winter average night temperature, °C	-28.7	-28.8	-28.2	-28.9	~ -5
Average annual / minimum night ground temperature at a depth of 100 - 289 sm, °C ***	2. / -0.45	1.1 / -0.65	1.9 / -0.8	-2.4 / -13.5 **	> 0 / > 0
Snow depth, cm / duration, mounts	10-15 / 3.5 - 4	9-12 / 3.5 - 4	2-3 / ~ 3	0.01 – 2 / 2.5 – 3	0.01 – 2 / there is no permanent snow cover
Anthropogenic illumination, $\mu W \times m^{-2} \times sr^{-1}$	~ 5	~ 5 **	< 5	< 5	< 5 (1, 2, 3)

* The results were obtained from satellite data from MODIS (Terra, Aqua), VIIRS (NOAA), the MAIAC algorithm (Aqua, Terra) and the global climate analysis model Era5 for 2019-2024. The satellite data was analyzed and visualized using the geographic information system QGIS (+GDAL & GRASS), Google Satellite, ESRI Satellite, Open Street Maps, Copernicus Global DSM 30m, a digital terrain model with a pitch of 30x30 m obtained during the TanDEM-X satellite mission from 2011 to 2015.
** The parameter value does not meet the selection criteria.
*** The results were obtained from data of global climate analysis model Era5 (<https://confluence.ecmwf.int/display/CKB/ERA5%3A+data+documentation>) for 2019-2024. Field observations are needed to confirm the results.

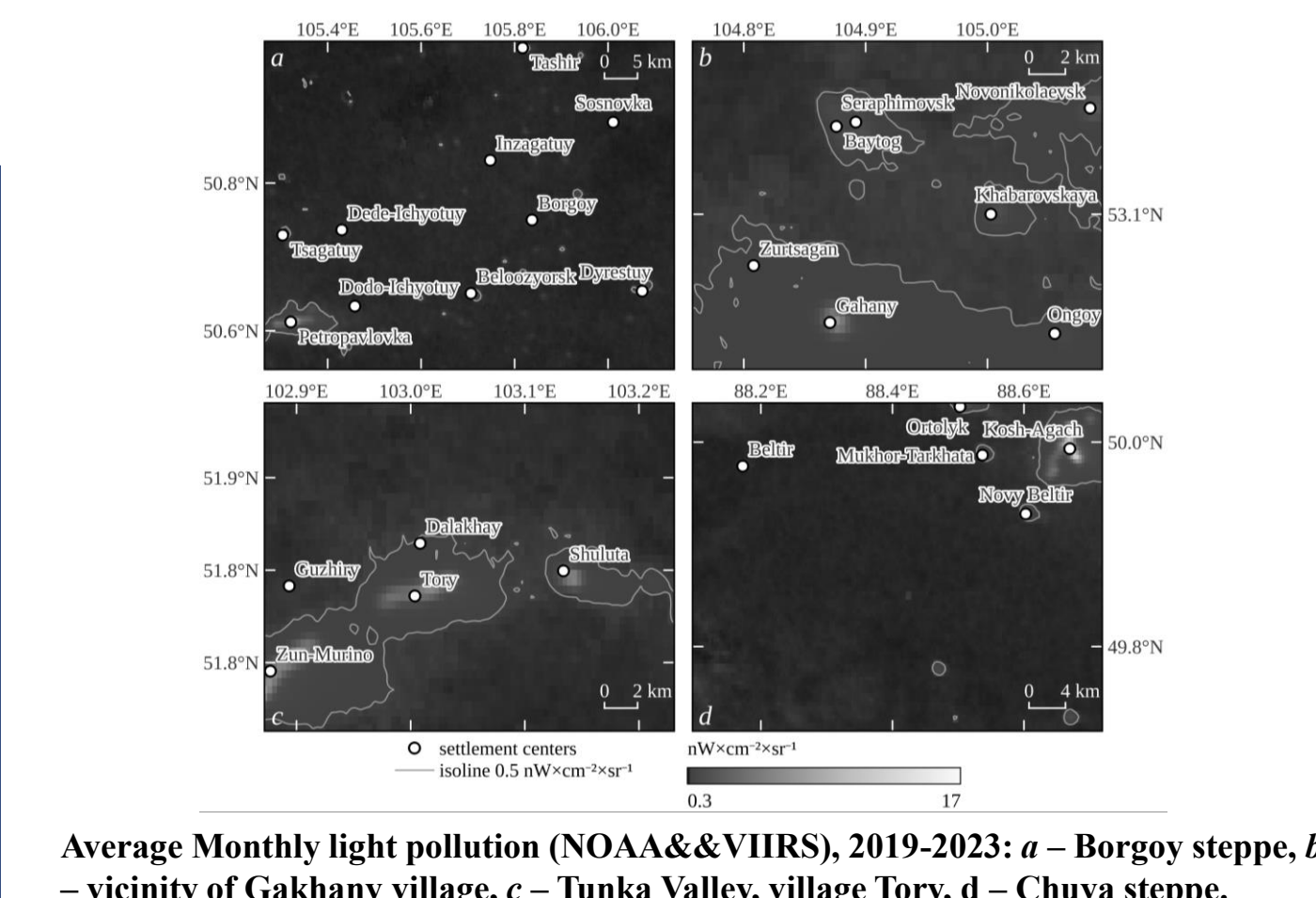
Comparison of infrastructure of the Borgoy and Chuya Steppes with Tunka Valley infrastructure

Parameter	Tunka Valley	Borgoy Steppe	Chuya Steppe
Distance to the nearest organization, an active member of the TAIGA collaboration, km / Distance to the nearest regional center, km	150 (ISU, Irkutsk) / 150 (Irkutsk)	630 (ISU, Irkutsk) / 200 (Ulan-Ude)	700 (ASU, Barnaul) / 450 (Gorno-Altaysk)
Transport accessibility (the presence of a highway, railway, the nearest operating airport with regular flights)	Federal highway (P-258, A-333), Irkutsk International Airport (150 km)	Federal highway (P-258, A-340, 81A-007), Railway (distance from the nearest railway station Jida is 39 km), Ulan-Ude International Airport (200 km)	Federal highway (P-256), Federal airport Gorno-Altaysk (450 km)
Availability of electricity. Power lines, substations (distance to the site, km)	Power line, 10 kV. 10 kV/400 V substation on the area of the TAIGA-1 astrophysical complex	Power lines, 110 kV, 35 kV, 10 kV. Substations 35/10 kV (first - 1-2 km, second - 7-10 km), 110/35/10 kV (5-7 km)	Solar power plant, power line 110 kV. 110/10kV substation (~30 km)
Availability of the telecommunication system	Cellular connection: H – 4G+ depending on the operator. Fiber-optic backbone.	Cellular connection: H – 4G+ depending on the operator. Fiber-optic backbone (1-2 km).	Cellular connection: H – 4G+ depending on the operator. Fiber-optic backbone (~30 km)

The fraction of cloudless night events (NOAA/VIIRS):



Soil temperature at a depth of 1 – 2.89 m according to the Era 5 climate model.

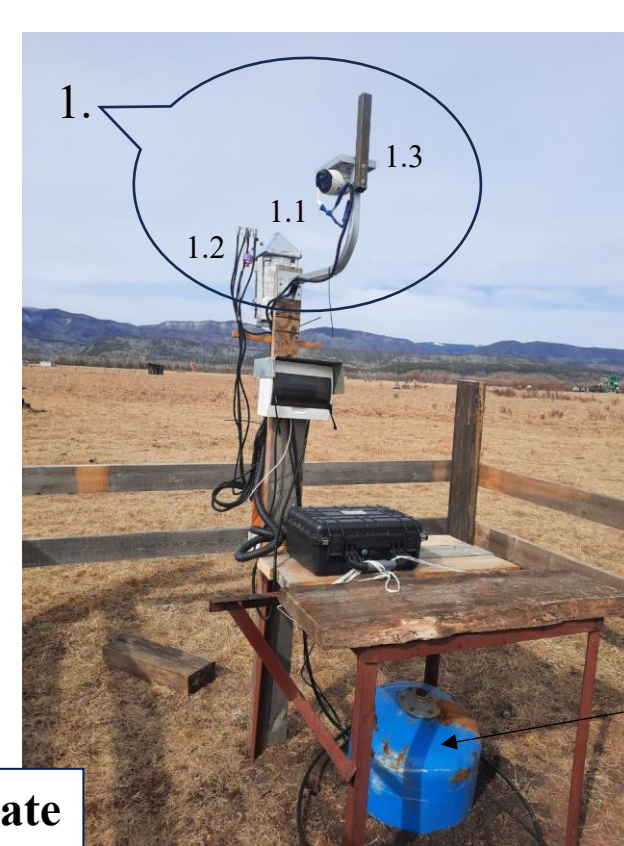


Some disadvantages of astroclimate analyzing from satellite data

- long time of the statistics accumulation;
- limited data (satellite overflight over the same territory occurs in a strictly defined time);
- the need to take into account:
 - data distortion due to clouds,
 - data distortion due to surface features (water, snow and ice cover),
 - data distortion related to the curvature of the Earth et al;
- problems of analyzing small details.

Field studies are needed.

Astroclimat station



The purpose of creating: comparison analysis of the astroclimate of the Tunka Valley and potential sites for the deployment of the TAIGA-100 project
Estimated parameters to study:
1. In Atmosphere:

- Temperature
- Pressure
- Humidity
- Cloud cover
- Transparency of the atmosphere
- Wind

2. In Soil:

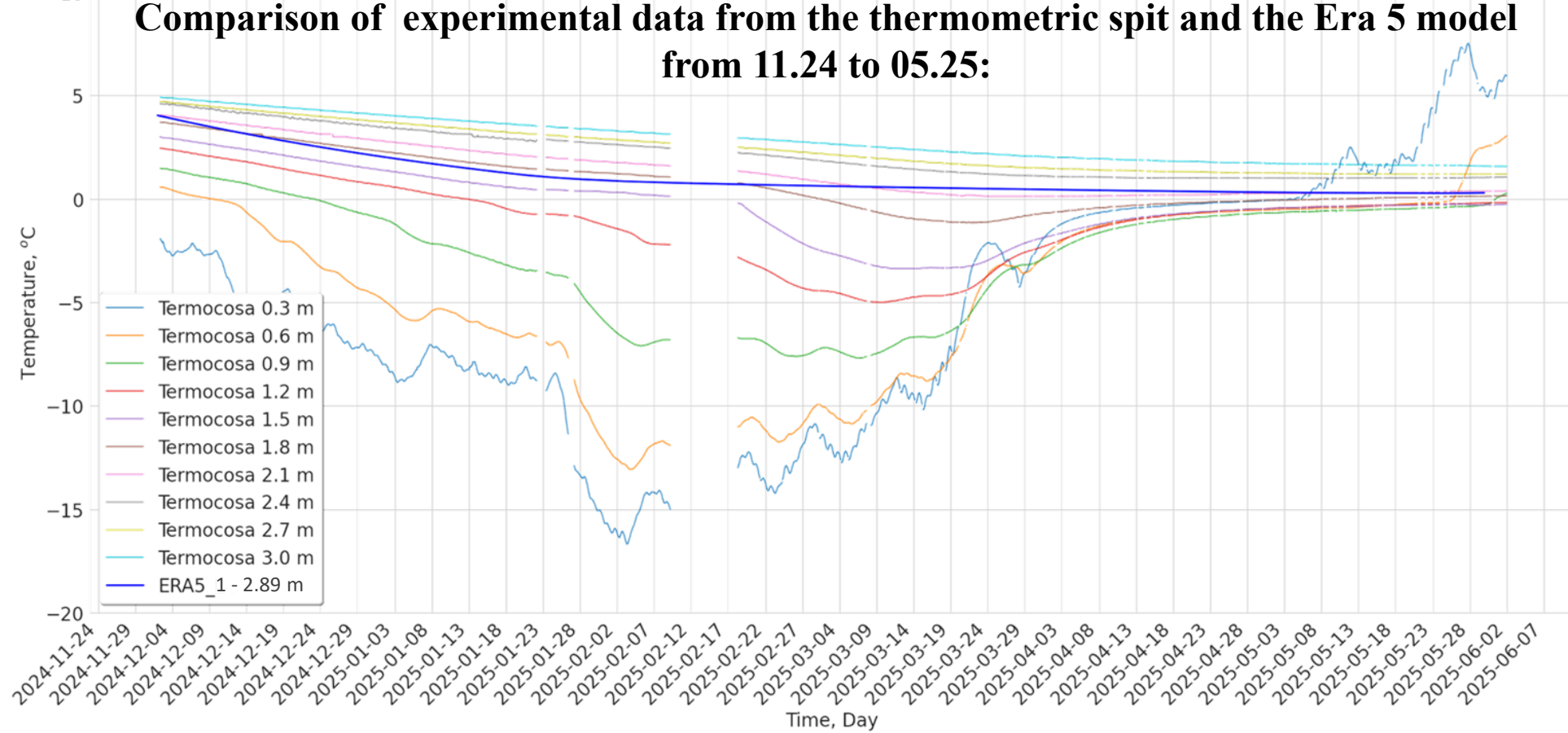
- Temperature (up to a depth of 3 m)

Astroclimat station components:
1. Module for measuring the optical properties of the atmosphere:

- 1.1. vertical camera + lens for high-resolution surveillance;
- 1.2 side view camera;
- 1.3 pyrometer.

2. Weather station.
3. Thermometric spit (for measuring ground temperature at a depth of up to 3 m).

The prototype of the astroclimat station in the Tunka Valley



Conclusion:

According to the combined assessment of astroclimatic, topographical and infrastructure criteria, the Borgoy Steppe appears to be the most promising location for the deployment of a full-scale TAIGA-100 astrophysical complex.