Astroclimatic Conditions of the Altai Republic According to Satellite Observations

Egor Yu. Mordvin[1], Anatoly A. Lagutin[1,2]; Nikolay V. Volkov[1,2], Artemy I. Revyakin[1], Mikhail A. Klyepov[1]

[1] Altai State University, Barnaul, Russia
[2] Institute of Computational Technologies of SB RAS, Novosibirsk, Russia

Abstract. The results of the studies of astroclimatic conditions for the territory of the Altai Republic for ground-based observations of extensive air showers initiated by very high energy cosmic rays using an array of atmospheric Cherenkov telescopes are presented. Information about the fraction and spatial distribution of cloudless events for considered areas was obtained from the night data of the VIIRS sensor on board the Suomi NPP weather satellite for the period of October 2017 – March 2018. The most suitable zone for construction of an array of optical Cherenkov telescopes was identified.

Keywords: Astroclimate, cosmic rays, gamma-rays, extensive air showers, Cherenkov telescopes, Altai Republic, Chuya Steppe, VIIRS/SNPP sensor.

1 Introduction

The results of long-term astrophysical observations carried out by the TAIGA (Tunka Advanced Instrument for cosmic rays and Gamma Astronomy) gamma-ray observatory [1] allowed to formulate a new approach for the investigation of gamma-rays with energies above 30 TeV. Retrieval of energy, direction and position of the axis of extensive air showers (EAS) is performed according to atmospheric Cherenkov detectors TAIGA-HiSCORE. To retrieve the type of primary particle, that initiated the EAS, the information on the shape of the Cherenkov image of the EAS obtained by the imaging atmospheric Cherenkov telescopes TAIGA-IACT is used. This hybrid approach allows to increase the distance between the IACT telescopes up to ~1 km. On the other hand, there are strong requirements for the area of the whole array. The first stage of the TAIGA project, which implements a hybrid approach in Cherenkov light measurements, will reach the sensitivity limit for gamma-ray detection with energy above 100 TeV by 2020. To increase the sensitivity, the area of the observatory should reach 10 km^2 or more. The project of the second stage of the Observatory is currently under development.

To perform night optical astrophysical observations there are also a number of serious requirements to the location of the Observatory, concerning the content of water vapor and aerosols in the atmosphere, the frequency of cloudy nights, the level of light pollution. Transport and telecommunications infrastructure are also important.

In the design of the second stage of the TAIGA Observatory, taking into account the requirements mentioned above, the remote sensing data from satellites can play a key role. Such an instrument as VIIRS (Visible Infrared Imaging Radiometer Suite) [2], located on the Suomi NPP (Suomi National Polar-orbiting Partnership) satellite platform [3], provides sufficient information about the main meteorological characteristics of the region, and methods of modern geographic information systems (GIS) allow to use data from heterogeneous sources and significantly reduce the time spent on processing and analysis of the result.

The aim of the present paper is to study the astroclimatic conditions for the territory of the Altai Republic using satellite observations and to identify zones suitable for gamma-astronomy observations.

2 Technical and informational base

The information basis of the research is the data from VIIRS radiometer aboard Suomi NPP satellite, received by the UniScan-24 station of the Space Monitoring Center of Altai State University in near real-time mode. The data acquisition and processing scheme implemented in the Center consists of the following main steps:

- unpacking of raw data stream received from the satellite;
- geolocation and calibration of data;
- cloud mask determination;
- determination of measuring values (geophysical parameters of the atmosphere and underlying surface) according to the algorithms implemented in the Center and their integration to GIS.

The main source of information used to solve this problem is the VIIRS Cloud Mask product of algorithm for processing VIIRS/Suomi NPP data, version 1.5.08.04 [4].

Data from digital terrain model SRTM (Shuttle Radar Topographic Mission) with a spatial resolution of 90x90 m was used to determine the parameters of the underlying surface relief [5].

Statistical data processing and post-processing were performed using GRASS (Geographic Resources Analysis Support System) GIS, version 7.2 [6].

The areas of the Altai Republic best suited for gamma ray observations were selected on the basis of the following requirements:

- maximum fraction of cloudless nights during the active phase of observations from October to March;
- area altitude (above 1500 m);
- angle of the terrain slope within the area(<5º);
- extensive transport and telecommunications infrastructure availability.

3 Results

At the first step, the fraction of cloudless events for the Altai Republic territory was established using the night data from the VIIRS/SNPP sensor for the period October 2017–March 2018. Figure 1 shows the fraction of cloudless atmosphere nights obtained from VIIRS/SNPP data for the study period. It can be seen that the areas with the largest fraction of cloudless nights are mainly in the highland part of the Altai Republic, that mostly consists of hard-to-reach mountain ranges.

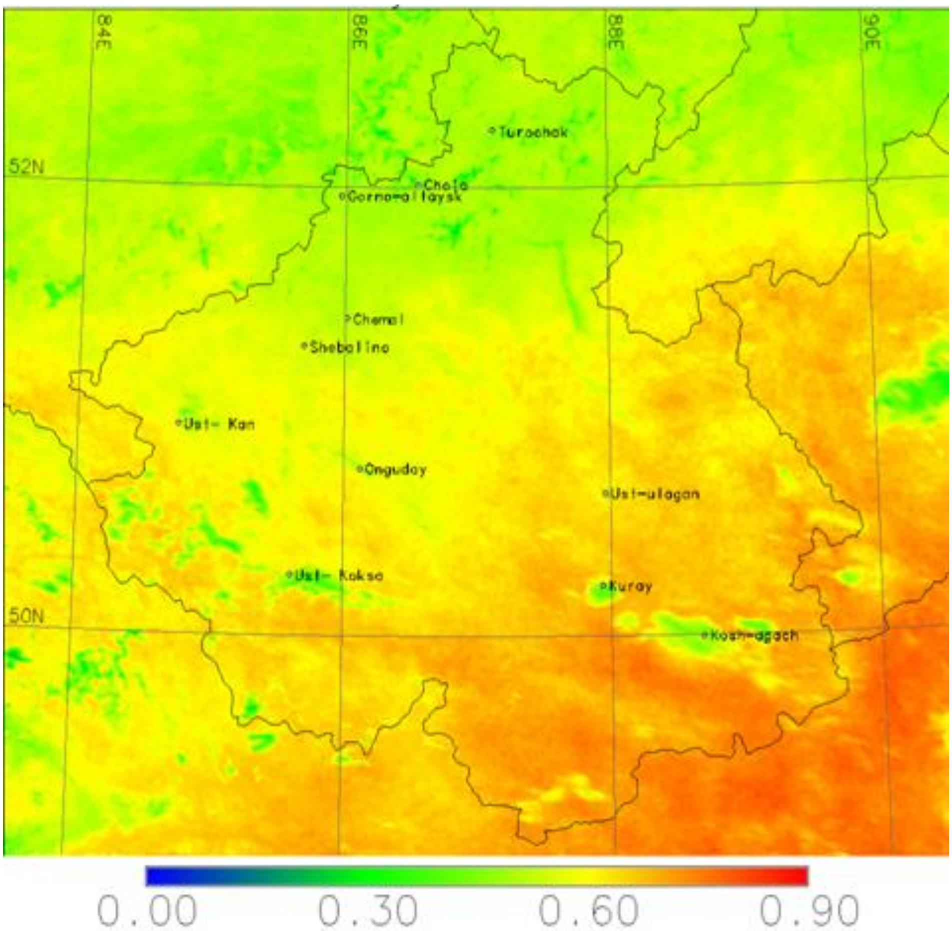

Figure 1. Fraction of events with cloudless atmosphere according to VIIRS/SNPP data for the territory of the Altai Republic for the period October 2017-March 2018.

Figure 2 shows the results of the SRTM digital terrain model data processing. Angles of the terrain slope of the Altai Republic territory are displayed. The joint analysis of the data shown in figures 1 and 2 allowed to identify the regions of the Altai Republic, for which the altitude range is 1000-2000 m above sea level and the slope angle does not exceed 3-5º.

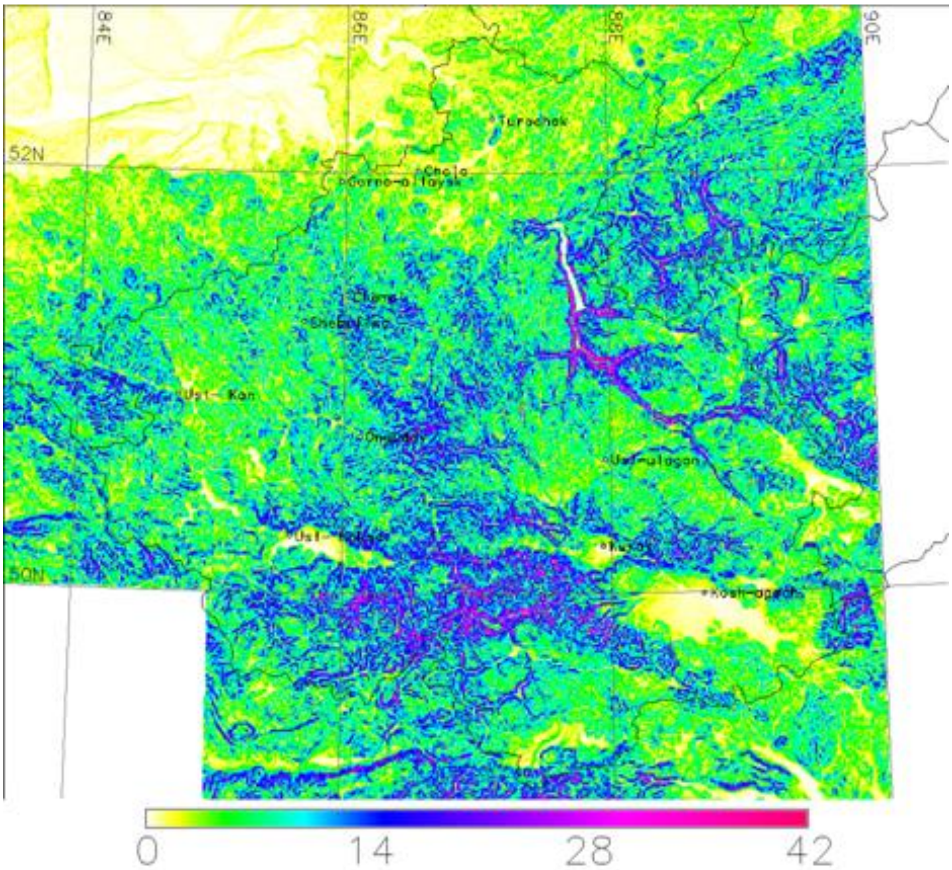

Figure 2. The slopes of the underlying surface for the territory of the Altai Republic obtained according to the digital terrain model SRTM.

Figure 3 shows the fractions of cloudless nights in areas that meet these conditions. It is seen from the figure that the most suitable area for gamma-astronomy experiment construction is the western part of the Chuya Steppe with a fraction of cloudless nights reaching 0.75.

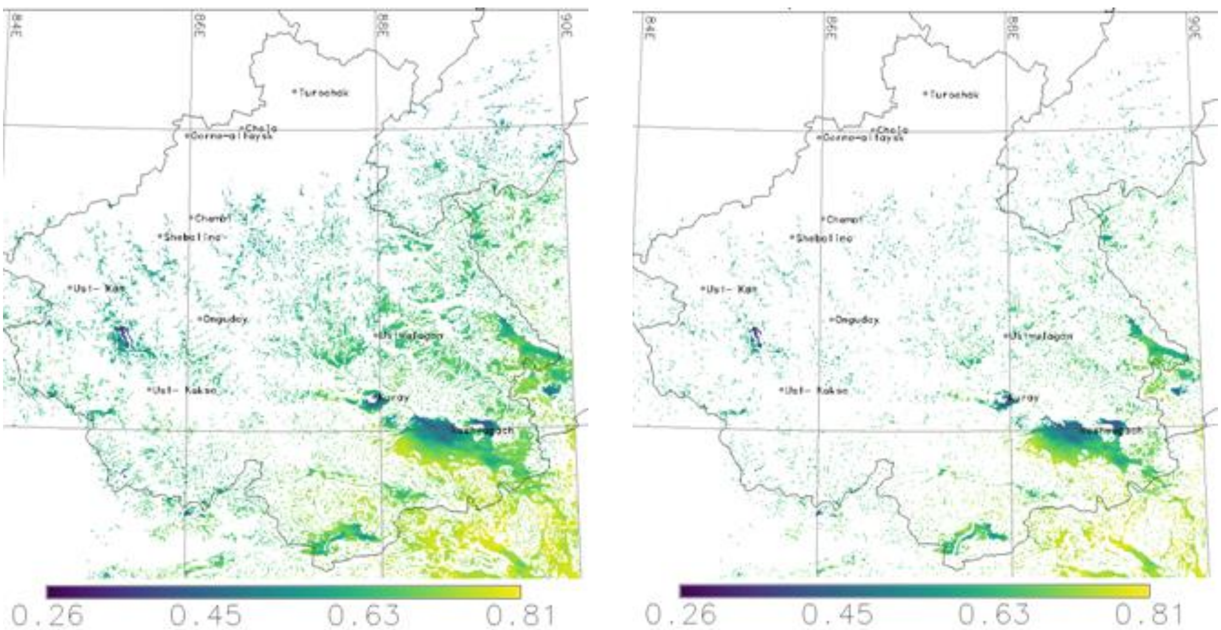

Figure 3. Fraction of the cloudless events according to VIIRS/SNPP for the territory of the Altai Republic for the period October 2017 — March 2018 at altitudes >1500 m above sea level and a slope less than 3º (left) and 5º (right).

4 Conclusion

The study of astroclimatic conditions for performing night astrophysical observations on the territory of the Altai Republic is carried out. The spatial distribution of cloudless events is obtained according to the nighttime data of the VIIRS radiometer aboard the Suomi NPP satellite platform for the period October 2017 – March 2018.

As potential regions for the second stage of TAIGA observatory construction, in terms of topography and infrastructure criteria, the most suitable areas are the Kurai and Chuya Steppes. A significant part of these zones is located at altitudes of ~1000-2000 m above sea level, that meets the requirements for terrestrial gamma-ray observations. The location of these regions is distant enough from large agglomerations and industrial centers that leads to low aerosol content in the atmosphere and low light pollution.

At the same time, it was found that the fraction of cloudless nights in the Kurai steppe (average height ~1000 m) does not exceeds 35% during the study period at night. For the western part of the Chuya steppe (average height ~2000 m) it reaches ~75%, which makes this area the most suitable place for gamma-ray astronomical observations using optical Cherenkov telescopes.

References

[1] Budnev N., Astapov I., Bezyazeekov P. et al. TAIGA experiment: present status and perspectives // JINST. 2017. Vol. 12. C08018.

[2] Hillger D., Kopp T., Lee T. First-light imagery from SUOMI NPP VIIRS // BAMS. 2013. Vol. 94. Pp. 1019-1029.

[3] Powell A.M., Jr., Weng F. Introduction to special section on Suomi National Polar-Orbiting Partnership satellite calibration, validation, and applications // J. Geophys. Res. Atmos. 2013. Vol. 118. Pp. 12216–12217.

[4] NASA Goddard Space Flight Center’s (GSFC) Direct Readout Laboratory (DRL). VIIRS Cloud Mask Science Processing Algorithm. User's Guide. Greenbelt. Maryland, 2018.

[5] Reuter H.I, Nelson A., Jarvis A. An evaluation of void filling interpolation methods for SRTM data // International Journal of Geographic Information Science. 2007. Vol.21. No.9. Pp. 983-1008.

[6] Geographic Resources Analysis Support System. https://grass.osgeo.org/