The comparative analysis of latitudinal changes in seasonal dynamics of the brightness temperature of the underlying surface in different natural zones of West Siberia

Romanov A N, Khvostov I V
Institute for Water and Environmental Problems SB RAS, 1, Molodezhnaya St., Barnaul 656038, Russia
e-mail: romanov_alt@mail.ru

Abstract. The paper presents the results of studies of the brightness temperature of the underlying surface in different natural zones of West Siberia based on the daily data from SMOS (ESA). The effect of change in phenological phases of soil cover and vegetation in the Arctic desert, tundra, forest tundra and taiga on emissivity of the underlying surface is studied by the example of test sites adjacent to research stations of the Siberian Environmental Change Network (SecNet). We investigate the regularities and peculiarities of microwave radiation of the underlying surface in different natural zones of West Siberia depending on seasonal freezing and thawing of the underlying surface as well as on different physical characteristics of permafrost and seasonally frozen soils and vegetation.

1. Introduction
Climate change has a significant impact on many natural processes that gives rise in frequency occurrence of dangerous natural events. The aggregate exposure of climate change and increased technogenic load on the natural environment transforms physical properties of the latter greatly [1]. In the last decade, hydrological and climatic changes occur with different frequency in natural zones all over the world. The warming of the Arctic occurring twice as fast as anywhere else entails climatic changes in temperate latitudes and contributes to emergence of hazardous meteorological and hydrological events (abnormal droughts, winter thaws, heavy snowfalls, soil icing, flash floods and inundations). Such natural phenomena are related with changes in mechanisms of interaction of the Arctic, forest and steppe areas located in different climatic zones as well as with shifted dates of tundra thawing, earlier warming, increased evaporation rate, and defrosting effect of the northern rivers Ob, Yenisei, Lena, Northern Dvina, and Pechora. Changes in hydrological cycles of the Arctic rivers, a decrease in number and total area of thermokarst lakes and ice cover, an increase in air temperature in the near-surface layers of the Arctic territories during autumn-winter periods are responsible for dangerous hydrological events onset in the future [2-4].

Other paragraphs are indented (BodytextIndented style). Reliable prediction of dangerous hydrological and meteorological events requires the proper study of regularities and peculiarities of these changes. Operation data on hydrological response to climate change, which can be obtained due to remote sensing techniques, is crucial in planning the environmental protection activities and social adaptation to varying living conditions [5].

An important task is to study the regularities of seasonal/annual dynamics of the brightness temperature of the underlying surface in different regions of Northern Eurasia and the occurrence of
dangerous hydrological events in a particular region. This paper presents the analysis of annual/seasonal dynamics of the brightness temperature of the underlying surface measured by SMOS (L1C product) at test sites located in different natural zones of West Siberia.

2. Data and methods

Test sites for space monitoring of the underlying surface adjacent to research stations of the Siberian Environmental Change Network (SecNet) served as the study object. L1C SMOS product [6] was used to measure the brightness temperature ($T_{BH}$) of the underlying surface. The product contains values of the brightness temperature obtained at incidence angle of 42.5° on horizontal polarization. Here, we used only $T_{BH}$ [K] (in Kelvin) on horizontal polarization. L1C (L1S) data are represented as a discrete geodetic grid DGG ISEA 4H9 [7], a fragment of which is given in Fig. 1. The linear cell size is ~16 km, the area ~195 km$^2$. The L1C product is based on the data from passive microwave (1.41 GHz) 2D radiometer; its longitudinal and transverse resolution for incidence angle of 42.5° is ~64 and ~35 km, respectively. Thus, the value for any cell in the L1C product is generated by the terrain underlying surface area of ~1760 km$^2$. SMOS sensors receive radiation from some objects with different emissivity if the underlying surface is spatially inhomogeneous.

The studied cells of the geodetic grid (Fig. 1) corresponded to different natural zones of West Siberia: 1 – the Arctic desert (island Bely, DGG ISEA 4H9 № 4067470); 2 – tundra, forest tundra (Labytnangi, 4041318); 3 – forest tundra, taiga (Numto, 4036168); 4 – taiga, paludal forest (Mukhri, 4023863); 5 – forest tundra, taiga (Khanymei 4040765); 6 – taiga (Kaibasovo, 4027392). The share of open water bodies in selected cells of this grid was small (less than 5%).

3. Results and discussion

Figure 2 presents the graphs of annual/seasonal dynamics of the brightness temperature of the underlying surface for different natural zones of West Siberia in 2012 - 2014. Typical for all natural areas of West Siberia, annual fluctuations of $T_{BH}$ due to seasonal freezing and thawing of the underlying surface vary from 120 to 260 K. Natural and climatic features of the territory as well as seasonal changes in physical characteristics of soil and vegetation greatly influence on seasonal variations of $T_{BH}$.

For the Arctic desert, $T_{BH}$ depends on temperature and humidity of permafrost soil, including temperature, biomass and moisture content of vegetation. According to the SMOS daily data, the duration of the cold period makes up 6-7 months, the warm period lasts 2-3 months (Fig. 2 (1)). Variations of $T_{BH} = 220-250$K in the cold period are induced by different temperature of the underlying surface, the influence of thickness and density of snow cover. In the warm period, $T_{BH} = 120-150$K is associated with temperature and humidity of the seasonally thawing layer of permafrost soil.

Figure 2(2) shows seasonal dynamics of $T_{BH}(JD)$ for the test area at the junction of tundra and forest tundra. This site is situated between the Polar Urals spurs and the Ob river, in the vicinity of settlements (towns Labytnangi and Kharp, station Obskaya) and major mining enterprises. Significant variations of $T_{BH} = 220-300$K in the warm and 260-300K in the cold periods may be due to natural factors (change in temperature, humidity) as well as the impact of industrial facilities and settlements in case if they hit the radiometer`s pixel.

Figure 2(3-5) demonstrates seasonal dynamics of $T_{BH}(JD)$ for test sites at the junction of forest-tundra and taiga situated in the extremely swampy area. Variations of $T_{BH} = 190-230$K in the warm period depend on how the area is waterlogged as well as on temperature and moisture of the underlying surface, emissivity of wetland soil and marsh vegetation at different stages of vegetation. In the cold period, variations of $T_{BH} = 230-260$K depend on surface temperature and peculiarities of freezing wetlands. Increase in $T_{BH}$ during the whole cold period due to gradual freezing of wetlands merits notice.

Figure 2(6) shows seasonal dynamics of $T_{BH}(JD)$ for the test site in the taiga zone. From the graphs, $T_{BH}(JD)$ maximum (probably associated with phenological characteristics of wood and grass
vegetation) is recorded in the warm period. Seasonal and interannual variations of $T_{BH}$ reach 230-270K. In the cold period, $T_{BH}$ varies as 220-240K depending on water reserve in snow cover, temperature and soil moisture.
Figure 2. Seasonal dynamics of the brightness temperature of the underlying surface in test areas of West Siberia (according to L1C SMOS product).
4. Conclusion
The analysis of SMOS data has proved that along with similar regularities of annual dynamics of brightness temperature of the underlying surface caused by seasonal freezing and thawing, seasonal dynamics of $T_{BH}(JD)$, specific for each natural zone, does exist. Specificity of $T_{BH}(JD)$ for each natural zone depend on different emissivity of permafrost and seasonally frozen soils as well as tundra, marsh and woody vegetation.

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