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GEOGRAPHY

Oxygen Isotope and Deuterium Composition of Snow Cover on the Profile of Western Siberia from Tomsk to the Gulf of Ob

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Abstract—The purpose of this work is to study the variability of the isotope composition ($\delta^{18}O$, δD, d_{exc}) of the snow cover on a long transect of Western Siberia from the southern taiga to the tundra. The study of the snow cover is of paleogeographic, paleogeocryological, and paleohydrological value. The snow cover of western Siberia was sampled on a broadly NS transzonal profile from the environs of Tomsk (southern taiga zone) to the eastern coast of the Gulf of Ob (tundra zone) from February 19 to March 4, 2014. Snow samples were collected at 31 sites. Most of the samples represented by fresh snow, i.e., snow that had fallen a day before the moment of sampling were collected in two areas. In the area of Yamburg, the snow specimens collected from the surface are most probably settled snow of different ages. The values of $\delta^{18}O$ in the snow from Tomsk to Yamburg varied from −21.89 to −32.82‰, and the values of δD, from −163.3 to −261.2‰. The value of deuterium excess was in the range of 4.06–19.53‰.

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Variations in the isotope composition of the snow cover are used as important climatic indicators for studying the cycles of atmospheric moisture and the hydrological and glaciological cycles [1–6]. The purpose of our work was to study the variability in the isotope composition ($\delta^{18}O$, δD, d_{exc}) of the snow cover along a transect of western Siberia from the southern taiga to the tundra and to identify isotope variations and features of formation of the isotope composition of the snow cover at the end of the winter season. The increase in snow reserves observed in recent years in the northern part of western Siberia [7, 8] could indicate a significant impact on the formation of the river runoff during the high-water period and a change in the isotope composition of freshwater supplied to the Arctic Ocean.

The snow cover was sampled at 31 sampling sites (Fig. 1) along a broadly NS transzonal profile from the environs of Tomsk (southern taiga zone) to the eastern coast of the Gulf of Ob (tundra zone) from February 19, 2014, to March 4, 2014 [9], 500 m or more away from the road (winter road). Most specimens are fresh snow. In two districts we collected young snow (near Tomsk and the town of Gubkinskii), and in the area of

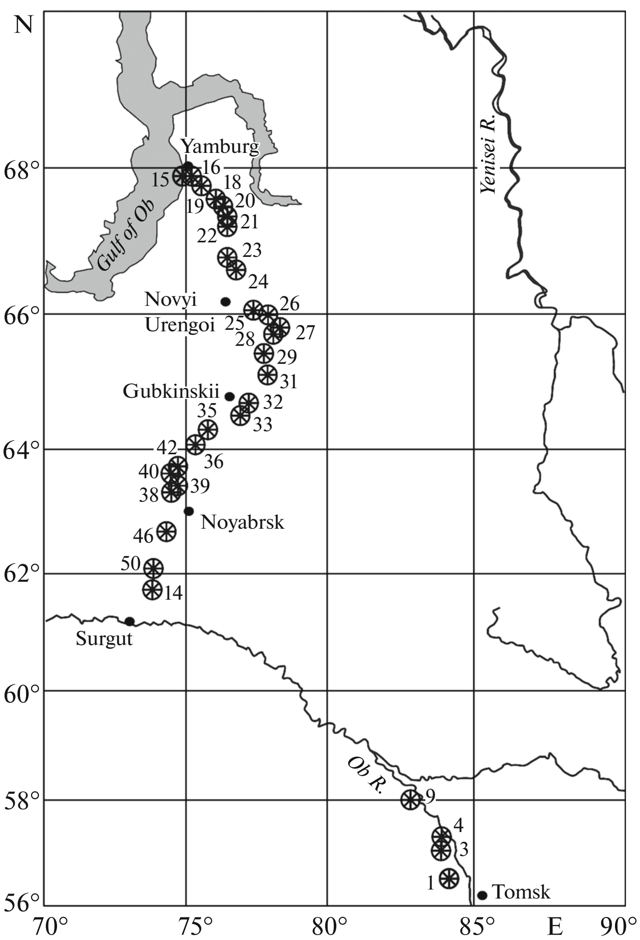

Fig. 1. Broadly NS transzonal transect across the central regions of Western Siberia, along which the snow cover was collected.

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Isotope composition of the surface snow along the broadly NS transzonal transect across the central regions of western Siberia

Sampling point	Date	Coordinates		$\delta^{18}O$, ‰	δD, ‰	d_{exc}, ‰
		N	E			
SF-1	Feb. 19, 2014	56°31'48"	84°09'44"	–25.17	–197.3	4.06
SF-3		57°06'26"	83°54'28"	–23.87	–176.23	14.73
SF-4		57°20'19"	83°56'32"	–24.40	–184.17	11.03
SF-9		58°04'26"	82°49'31"	–27.47	–205.59	14.17
SF-14	Feb. 22, 2014	61°58'24"	73°46'56"	–28.99	–219.75	12.17
SF-15	Feb. 25, 2014	67°54'13"	74°48'49"	–30.86	–233.21	13.67
SF-16		67°56'32"	75°05'10"	–31.55	–232.87	19.53
SF-18		67°46'39"	75°30'35"	–33.96	–260.15	11.53
SF-19		67°37'53"	75°54'49"	–28.79	–220.78	9.54
SF-20		67°32'10"	76°10'24"	–26.29	–195.92	14.4
SF-21		67°24'39"	76°21'12"	–26.12	–197.3	11.66
SF-22		67°15'48"	76°26'12"	–26.71	–201.79	11.89
SF-23		66°48'08"	76°24'15"	–27.63	–211.4	9.64
SF-24		66°38'34"	76°40'45"	–34.27	–261.2	12.96
SF-25		65°58'54"	77°34'05"	–30.67	–235.3	10.06
SF-26		65°59'03"	77°40'10"	–30.69	–236.0	9.52
SF-27		65°47'19"	78°10'07"	–32.82	–249.1	13.46
SF-28		65°42'04"	78°01'06"	–31.83	–248.04	6.6
SF-29	Feb. 26, 2014	65°23'25"	77°45'43"	–32.27	–247.69	10.47
SF-31		65°06'41"	77°47'59"	–32.60	–245.0	15.8
SF-32		64°40'10"	77°05'27"	–28.52	–212.1	16.06
SF-33		64°32'07"	76°54'20"	–27.99	–215.9	8.02
SF-35		64°17'32"	75°44'34"	–30.56	–230.5	13.98
SF-36		64°06'48"	75°14'07"	–23.40	–180.3	6.9
SF-38	Feb. 27, 2014	63°22'08"	74°31'50"	–29.88	–222.8	16.24
SF-39		63°36'52"	74°35'27"	–27.60	–212.5	8.3
SF-42		63°51'22"	75°08'17"	–29.26	–223.2	10.88
SF-43		63°49'15"	75°23'43"	–30.87	–232.2	14.76
SF-46	Marth 3, 2014	62°43'09"	74°13'46"	–21.89	–163.3	11.82
SF-50		62°07'13"	73°44'49"	–26.94	–203.8	11.72
LF 5 0–5	Marth 1, 2014	63°49'09"	75°34'44"	–27.28	–206.2	12.04

Yamburg, we sampled settled snow. The surface snow (upper 5 cm) was collected; it was thawed at 18–20°C and filtered through mylar nuclear filters with a pore size of 0.45 μm [9].

The specimens were analyzed using a Finnigan Delta-V mass spectrometer in the isotope laboratory of the Department of Geography, Moscow State University. International standards V-SMOW, GISP, and SLAP were used for measurements; the test error was ±0.6‰ for δD and ±0.1‰ for $\delta^{18}O$.

The values of $\delta^{18}O$ in the snow from Tomsk to Yamburg were –21.89 to –32.82‰, δD –163.3 to –261.2‰, 4.06 to 19.53‰ (table).

The temperatures corresponding to sampling dates were received from the websites www.meteo.ru and www.gismeteo.ru from the data of the nearest weather stations. Unification of specimens into groups on the basis of the sampling date and nearness to the main weather stations allowed for approximate estimation of the interrelation of the $\delta^{18}O$ values to the air temperature at the moment of snowfall (Fig. 2).

The two groups of specimens representing the young snow were collected within an interval of one week and at a distance of more than 900 km from each other. Specimens SF-1.1–SF-4 (table) near Tomsk, average value of $\delta^{18}O$ –24.4‰, were collected on Feb-

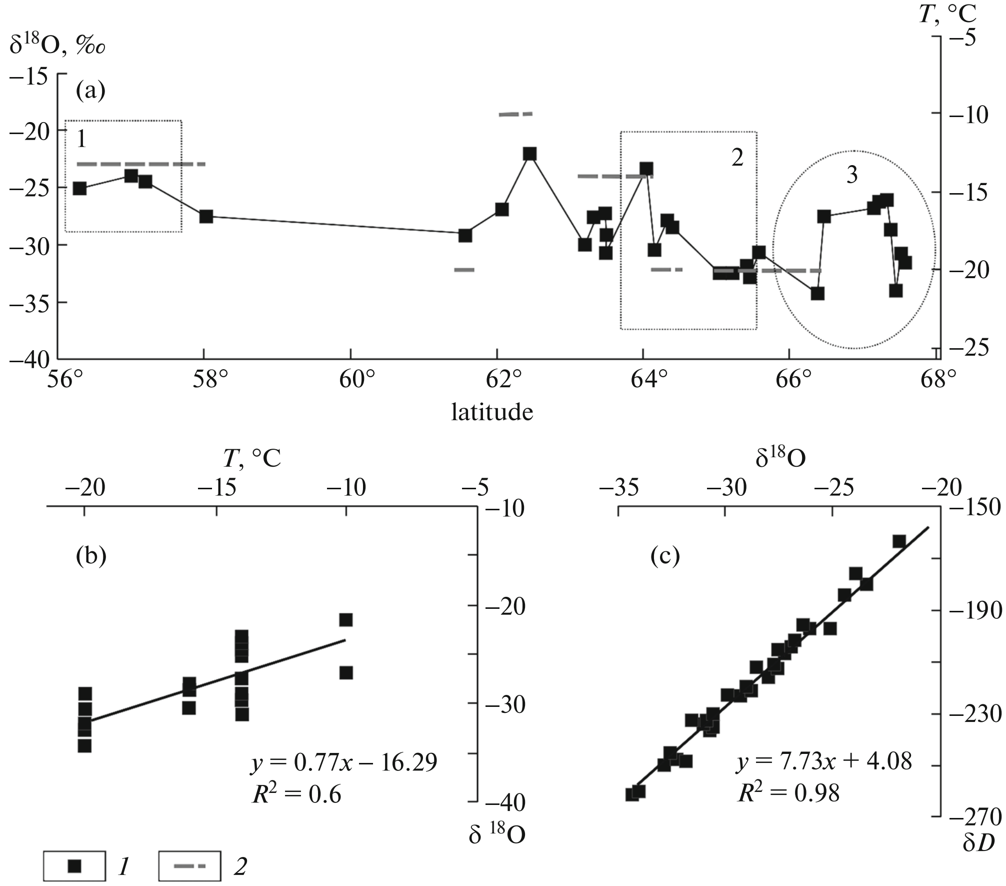

Fig. 2. Distribution of $\delta^{18}O$ values from the surface snow along the profile from Tomsk to Yamburg. (a) Depending on the area latitude: young snow near Tomsk (1) and in Gubkinskii (2), settled snow near Yamburg (3); (b) depending on the air temperature; (c) ratio of $\delta^{18}O$ and δD values: *1*, isotope values; *2,* air temperature from the data of the website meteo.ru.

ruary 19; snow fell for 3 days February 16–19 (most of the precipitation fell on February 18) at temperatures in the range of –9.7 to –18.0°C; the weighted average temperature of precipitation on February 17–19 was –13.6°C. Building of reverse trajectories (5 days) of air masses according to the HYSPLIY model [10, 11] as of February 18 showed that the air masses moved quite quickly from the central districts of Europe. On February 19 the air masses already had an in-continent origin and moved from the inner districts of Turkmenistan with slower speed.

Specimens SF-29–SF-36 (table) near Gubkinskii were collected on February 26; the snow fell at –16 to –21°C, and the average value of $\delta^{18}O$ in the snow was –30.4‰. The recovered reverse trajectories of air masses as of February 26 indicate the North Atlantic origin of the moisture.

In the young snow $\delta^{18}O$ becomes 6‰ lighter with an increase of the area latitude by 8°; i.e., the latitudinal isotope effect is approximately –0.75‰/1° of latitude. The gradient –0.6‰/1° of the latitude is considered average for marine and continental weather stations in Europe and the United States [12]. We found a pronounced isotope trend in a single snowfall in northeastern Russia from the village of Konoshi to the Polar Urals where $\delta^{18}O$ varied by –1.4‰/1° of the latitude [3]. In the area of Yamburg the isotope snow values indicate possible significant mixing of the snow; strong wind transfer determines the accidental distribution of values of the snow isotope composition [13].

The ratio $\delta^{18}O$–D is described by the equation $\delta D = 7.73\delta^{18}O + 4.08$, which agrees quite well with H. Craig's equation—for the Global Meteoric Water Line ($\delta D = 8\delta^{18}O + 10$). An insignificant reduction of the inclination in relation to the Craig's global line [14] was also noted by us in a single winter snowfall [3, 5].

The studies performed showed isotope variations in the snow cover along the broadly NS transzonal profile from Tomsk to the Gulf of Ob at the end of the winter period of 2014. The significant variability of the $\delta^{18}O$ values is mostly determined by sampling conditions (the snow in most points is probably of different ages, young and settled) and wind redistribution of the surface snow.

It is demonstrated for the first time that the study of stable isotopes of oxygen and hydrogen of the snow led to identification of latitudinal zoning of the snow cover in the central continental part of western Siberia associated with the temperature mode at the time of precipitation.

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