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Melting temperature of ice and total gas content of water at the ice-water interface above subglacial Lake Vostok

Content

It is generally assumed that the gas composition and the total gas content of Lake Vostok's water are, to a large extent, governed by the budget of atmospheric gases entering the lake together with glacier ice melt, mostly in its northern part. Since the ice accretion that prevails in the south of the lake leads to the exclusion of gases during the freezing process, these gases can build up in the lake water. Earlier theoretical works [Lipenkov & Istomin, 2001, McKay et al., 2007] have demonstrated that about 30 water residence times are required to attain equilibrium between gases in solution and those in a hydrate phase, which sets the upper bounds of concentrations of nitrogen and oxygen dissolved in sub-ice water (approx. 2.7 g N2/L and 0.8 g O2/L).

Here we attempt to estimate the real gas content of the lake water based on the link between the pressure melting temperature of ice and the concentration of gases dissolved in the liquid phase. We use the stacked borehole temperature profile extended to 3753 m depth and the measurements of temperature of sub-ice water that entered the borehole after the second unsealing of Lake Vostok to estimate the melting temperature of ice (−2.72±0.1℃) at the ice sheet-lake interface (depth 3758.6±3 m, pressure 33.78±0.05 MPa). The gas content of the near-surface layer of lake that corresponds to this melting temperature is calculated to be 2.23 g/L, meaning that the concentration of dissolved oxygen must be as high as 0.53 g/L, i.e. one-two orders of magnitude higher than in any other known water bodies on our planet.

The inferred gas content of sub-ice water is, by a factor of 1.6, lower than the maximal solubility of air in water in equilibrium with air hydrate, though it is still higher, by a factor of 19, than the total air content of melting glacier ice. The relatively low concentration of dissolved air in the near-surface layer of the lake revealed in this study provides a new experimental constraint for understanding the gas distribution in Lake Vostok as affected by the circulation and mixing of water beneath the ice sheet.

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