

Fig. 8. Ice ring near the Nizhneye Izgolovye Cape, 3-4 April 2014. Left - needle ice crystals (10-12 cm long) from the ice lower surface. Right - current strength and direction.

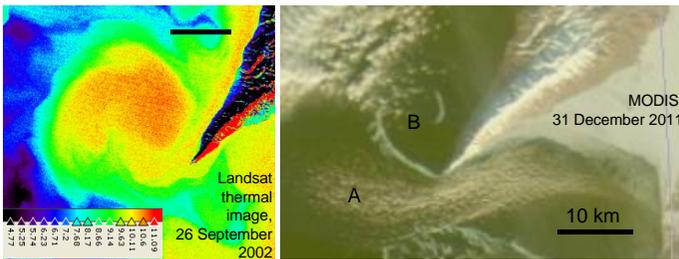


Fig. 9. Near the Nizhneye Izgolovye Cape anticyclonic eddies often form before ice formation. Left - warm eddy. Right - strong wind from Barguzin bay carries clouds (A) and forms an eddy, surrounded by young ice (B).



Fig. 10. A.Ya. Suknev and dog Buran perform measurements of water parameters under the ice. Every year since 2010 (for Lake Baikal) and 2014 (for Lake Hovsgol) we conduct field studies on the ice.

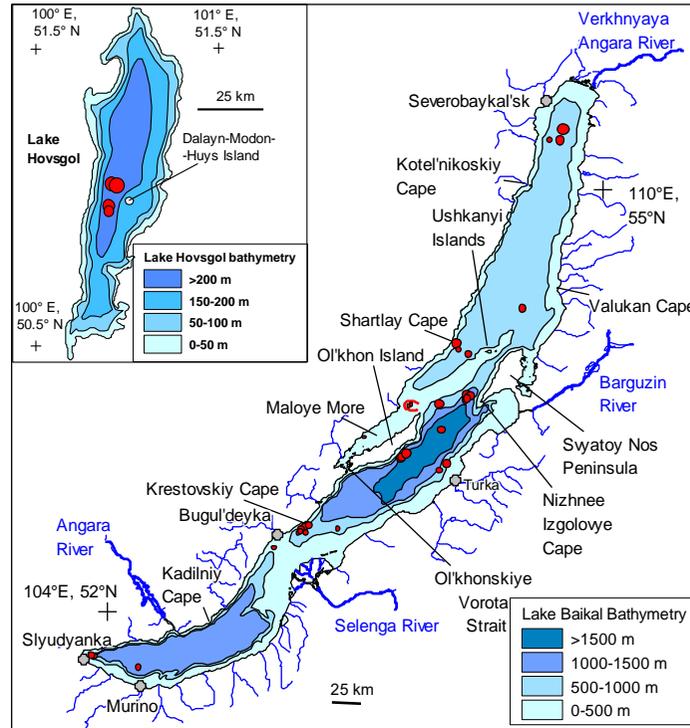


Fig. 11. Giant ice rings (red circles) on lakes Baikal and Hovsgol

How do you minimise the risk of getting into an ice ring?

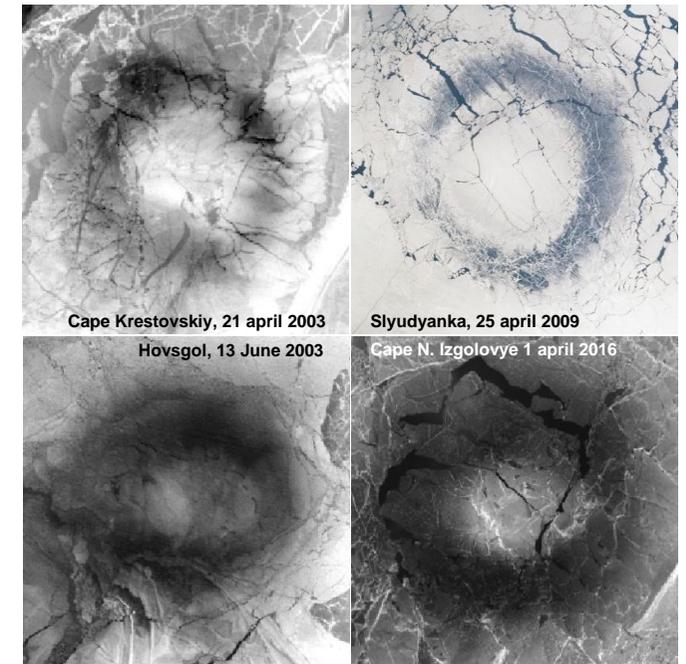
While cracks are relatively easy to spot, in the region of the ring, the ice has the same appearance as usual, but its thickness is much smaller (Fig. 1). **It is better to avoid regions where ice rings usually appear (Fig 11), even if the ice in other regions is solid.** It is important to issue timely warnings if ice rings have been detected on satellite images. It is possible to forecast ice ring formation if a warm eddy is detected in the beginning of winter, but this requires large-scale and detailed field work.

I want to know more.

Please visit our web site www.icerings.org. Also you may find more information in our papers: Kouraev et al., *Limnology and Oceanography*, 2016, 2019, *The Cryosphere* 2021 - freely available at www.icerings.org in Section "Resources".

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Fig. 1. Examples of ice rings for lakes Baikal and Hovsgol



GIANT ICE RINGS OF LAKES BAIKAL AND HOVSGOL IN QUESTIONS, ANSWERS AND PICTURES



Fig. 2. Even an experienced driver may get into a difficult situation. The UAZ vehicle stuck in ice in the region of the ice ring near Nizhneye Izgolovye Cape, 18 March 2016. © A. Beketov.

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What are ice rings?

They are dark rings on the ice with a diameter of 5-7 and a km width of about 1 km (Fig. 1). In the ring center and outside the ice is thick and white, in the ring itself it is dark and thinner. Rings appear in an unpredictable manner, in different places and in different years.

How can one observe ice rings?

Rings are too big to observe them from the ice or from the shore. But they can easily be seen from above - from an airplane or (even better) from a satellite

Where can one observe ice rings?

Ice rings were first observed in Lake Baikal. By analysing satellite imagery we have detected over 70 ice rings (Fig. 11) - for Lake Baikal and also lakes Hovsgol in Mongolia (1975, 2003, 2008 and 2015) and Teletskoye in Altay (2010). They probably exist in other lakes too, but have not yet been found.

Is it a recent phenomenon?

Since the advent of MODIS imagery (twice per day) at the end of 2002 it has become easier to observe ice rings. But ice rings are not a recent phenomenon - we have detected ice rings on satellite images as early as 1969.

Where and when do ice rings appear?

Usually they are observed in the second part of April (Table 1, Fig. 3), but they have appeared earlier (31 January) and later (26 May). They often appear near Capes Krestovskiy and Nizhneye Izgolovye in Lake Baikal and near Dalayn-Modon-Huys island in Lake Hovsgol. But in Baikal they have been observed in many other places (Fig. 11).

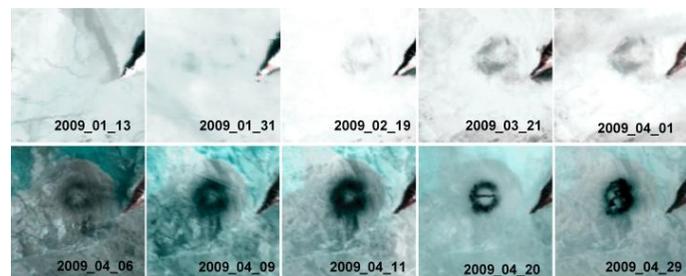


Fig 3. Appearance (31 January) and development of the ice ring near the Nizhneye Izgolovye Cape in 2009.

What creates ice rings?

Initially there were many hypotheses - from atmospheric influence, to biological activity in the upper water layer to UFO and hoaxes (crop circles etc.). Many hypotheses relate ice rings to methane escaping from the bottom sediments and gas hydrates. However, detection of ice rings in regions with small

depth or without known gas emission sources rule out gas release as a universal explanation of ice ring formation.

If it is not methane, then what is the reason?

Results of our field surveys show (Fig. 4) that before and during ice ring manifestation there are warm anticyclonic (clockwise) eddies under the ice cover. They have a lens-like (double-convex) form. Water from the eddy center (40-45 m depth) extends upwards and downwards.

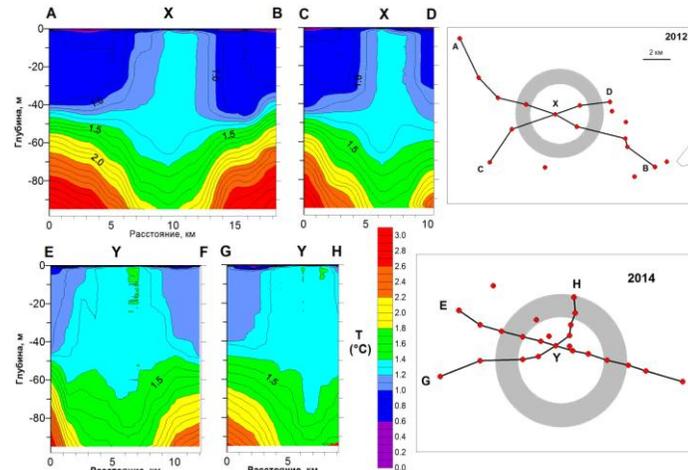


Fig. 4. Hydrographic measurements in April 2012 and 2014 in the ice ring near the Nizhneye Izgolovye Cape. Left - vertical transects of water temperature (°C), right - map of transects (location of ice rings is shown in grey)

How exactly do eddies lead to ice ring formation?

In the eddy center currents are weak, and although there is warmer water under the ice, the ice does not melt. But on the eddy boundary, currents are strong (Fig. 6) and warmer water leads to rapid ice melting. First ice needles are formed on the lower ice boundary, then ice breaks, and steamthroughs, leads and large areas with open water appear. Giant ice rings are surface manifestation of eddies activity under the ice. We documented this for Lake Baikal in 2016, 2018 and 2019, when the position of eddy - detected in situ first in mid-February and then in end of March - corresponded to the position of a giant ice ring.

What is generating the eddies?

By analysing satellite images we found that for Lake Baikal near Nizhneye Izgolovye Cape (Fig. 6) eddies are generated due to combination of river input, strong winds and coastline shape. Eddies that lead to formation of ice rings appear in late autumn, before ice is formed. For other regions there could be other mechanisms of eddy generation. We continue our research on these issues.

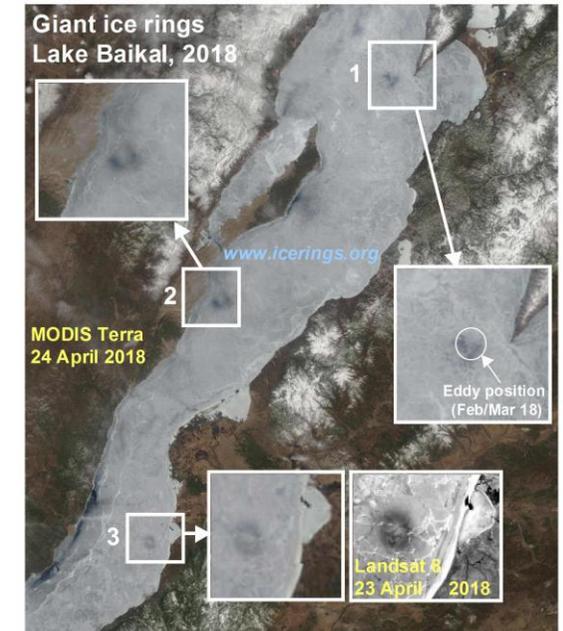


Fig. 5. Three ice rings appeared in 2018 on Lake Baikal. For Cape Nizhneye Izgolovye we also show position of eddies detected during our field work



Fig. 6. Field work on Lake Hovsgol, 2014



Fig 7. Hovsgol, 2016