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Large rotating ice discs on ice-covered rivers

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A rare natural phenomenon, a large circular rotating ice disc in a slightly larger hole in the ice cover, occurs infrequently in some rivers in cold regions. An illustration of a revolving ice cake on the Mianus River, USA, was published in 1995 (*Scientific American* 1995). Photographs of such discs, on the Nidelva River in Norway and Rancho Nuevo Creek in the USA, were published in *La Houille Blanche* (1971) and EOS (1983) respectively. The commentary text to the latter says that "disks with similar geometry, but inferred to consist of frazil ice, have been infrequently observed on freezing streams in North America and Europe".

The Mianus River ice disc had a diameter of about 8 m with a peripheral rotation speed of $0.1\,m\,s^{-1}$ while those on the Rancho Nuevo Creek and the Nidelva River measured 2 m and 50–60 m, with peripheral rotation speeds of $0.06\,m\,s^{-1}$ and $0.65\,m\,s^{-1}$ respectively. There

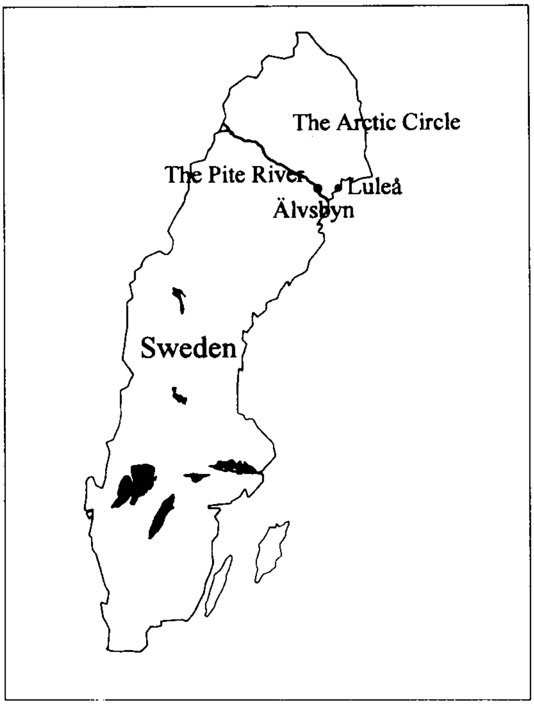

Fig. 1 Map of Sweden showing the location of the Pite River and the town Älvsbyn. The distance from north to south is 1600 km.

have also been more recent observations on the Nidelva River (Carstens, personal communication 1995). Large ice discs with a lifetime of months were reported in 1941, 1987 and 1994 in the environs of Älvsbyn on the Pite River, Sweden. The 1941 ice disc was estimated to have a diameter of 100 m. Usually one cannot go on to the ice disc, because neither it nor the border ice can carry the weight of a person. However, on the Pite River in 1987 and 1994 it was possible to perform measurements and observations from the ice disc.

Measurements and observations

Pite River, 1987

In January 1987 a large circular rotating ice disc occurred on the Pite River, 8 km south of Älvsbyn (Fig. 1). The ice disc was rotating in a circular hole in the border ice, which completely covered other visible parts of the river (Fig. 2). Observations and measurements of the rotating ice disc were reported by Nordell (1987).

The rotating ice disc had a diameter of 49 m while the hole in the ice was 54 m in diameter. The time of one full rotation was measured at 545 s and 575 s on 20 and 24 January respectively. Unverified measurements suggest that the time of rotation had been about 8 min a few weeks earlier. The rotation of the ice disc was anticlockwise and for most of the time the disc was in contact with the border ice. This contact point moved clockwise, *i.e.* the ice disc was not 'rolling' on the walls of the hole. This erosion by contact, which caused a low-frequency sound, explains why the hole in the ice was kept open for months.

The thickness of the border ice was 0.43 m and that of the ice disc, measured in seven boreholes, was between 0.46 and 0.60 m with a mean value of 0.50 m. Assuming that the density of the crystal-clear ice was 917 kg m^{-3}, the weight of the 1885 m^2 ice disc was 864 tonnes.

Frazil ice was observed in the water, aggregating in jellyfish-like bodies with a size of 0.2–0.3 m which were slowly moving towards the edge of the rotating ice disc under which it was accumulated. The thickness of the frazil ice was greater than 2 m under most of the rotating ice disc. The rotation of the ice disc ceased after about two months, at the end of February 1987.

Pite River, 1994

In mid-November 1994, a rotating ice disc formed on the Pite River, 5 km north of Älvsbyn. The first observations started two weeks later (3 December). The diameter of the ice disc was paced out to 81 m and the gap between the ice disc and the border was 1.6 m. The time of one (clockwise) revolution was 783 s.

The following week began with temperatures between −10 and −20 °C, but by the end of the week the snow was melting after two days of rain. On 11 December, measurements showed that the diameter of the ice disc was 79.8 m. The maximum gap between the ice and the surrounding ice cover was now reduced to 1 m and the time of one full rotation was 665 s (peripheral speed 0.38 m s^{-1}). The increased speed of rotation was assumed to be a result of weight reduction, due to snow melting. Ball-

Fig. 2 The rotating ice disc (diameter 49 m) on the Pite River, 1987. Tracks from snowmobiles are seen in the centre of the ice disc. (Courtesy of Per Pettersson, Robot Test Base North.)

shaped aggregates of frazil ice, about 1 m in diameter, were observed under the border ice. The ice thickness, measured in 20 boreholes in a diametrical line across the ice disc, varied between 0.27 and 0.4 m with a mean value of 0.32 m. The weight of the 5093 m^2 ice disc was about 1494 tonnes.

The central part of the ice disc (≈1000 m^2) was flooded with water which had a maximum depth of 0.2 m, *i.e.* a water volume of about 100–150 m^3. Apparently, the ice disc was slightly bowl-shaped. The ice-thickness measurements showed that the bowl-shape also existed under the ice cover. Calculations imply that the observed amount of water on the ice surface would have resulted in the observed bowl-shape, but there must have been an initial bowl-shape to collect the rain-water on the ice surface. The water was drained within 15 min through the holes drilled through the flooded part of the ice disc.

Figure 3 shows the river, which flows from the railway bridge through the little lake around the ice disc and downstream to the right. Figure 4 indicates the growth pattern of the ice disc. It seems that it started with an irregular floe of ice that gradually became circular. Larger blocks of ice are seen as whiter spots on the ice disc. On 16 December the rotation of the ice disc stopped, after about one month of rotation.

Levelling of the ice disc (18 December) showed a slightly bowl-shaped surface. The centre of the ice disc was 0.04 m lower than its edges. Since the water depth was originally about 0.2 m the surface of the ice disc had apparently become more horizontal, probably because of the load reduction of the drained water.

Discussion

The formation of the rotating ice disc on the Pite River in 1987 was observed by local people. Ice floes, formed upstream, were captured by a big whirlpool where the first ice of the season was forming. The eccentric rotation of the floes kept a 'circular' water area free from ice. Ice formed between the rotating floes, which built up into one big floe of ice; the

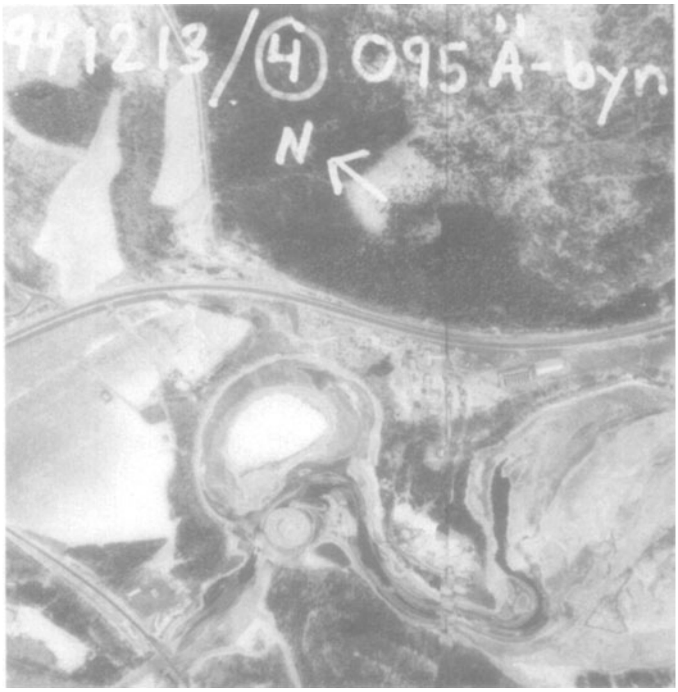

Fig. 3 Overview of the rotating ice disc (diameter 79.8 m) on the Pite River, 1994. The slightly oval shape of the ice disc indicates that the camera that took this high-altitude photograph was not exactly above the centre of the disc. (Courtesy of Akktu Stakki, Swedish Air Force.)

Fig. 4 Rotating ice disc on the Pite River, 1994. The structure of the ice disc is seen since there was no snow on the ice after two days of rain. The line of footprints indicates the rotation of the disc. A small area of open water is seen at the upper edge of the disc. (Courtesy of Akktu Stakki, Swedish Air Force.)

thickness of the rotating floe and border ice increased. The ice-breaking capability of the floe was a result of its size and weight. The edges of the ice floe and the surrounding ice cover were rounded off by erosion by contact and by this time the ice floe and the hole had become circular.

The 1994 ice disc was probably formed in the same way (see Fig. 4). The ice disc started with a rather large irregular floe that in the course of time became more circular. The long lifetime of the ice discs must be explained by the erosion due to contact between the ice disc and border ice.

The observations in 1987 and 1994 imply that the direction of rotation is that of the whirlpool that is necessary for the phenomenon to occur. In both cases rapid waters were located upstream of the ice disc. Frazil ice may be important for the formation and rotation of the ice disc. The mechanisms that form and drive the rotating ice discs are not yet known. Occurring ice discs should be studied and future measurements and observations made. More detailed data of the ice discs on the Pite River are available (Nordell and Westerström 1996).

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Air quality data summary, summer 1996

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This summary covers the months June, July and August 1996, and presents summary air quality data from six sites in five cities around the United Kingdom. Data are given for regional centre locations: Belfast, Birmingham, Cardiff, London (Bloomsbury and roadside data from Cromwell Road) and Edinburgh.

The pollutants reported here are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), fine particulate matter (PM_{10}) and sulphur dioxide (SO_2). The measurements are all made routinely and hourly data are stored in the National Air Quality Archive. These pollutants are all of concern due to their effects both on human health and on other parts of the environment. During the summer months O_3 is likely to reach its highest levels, usually once the concentrations of precursor pollutants (hydrocarbons and nitrogen oxides) have built up, and are transported towards the British Isles from the Continent on easterly winds. It is now also believed that secondary particulate matter, formed by atmospheric reactions involving sulphur and nitrogen, enhances PM_{10} levels during the summer months. In this summary, hourly data are given to show the extreme values which may be reached during such episodes, whilst daily means help to identify extended periods of poor air quality, and monthly means give an idea of the overall pollution climate of the British Isles.

Table 1 shows that monthly mean CO levels were highest at the Cromwell Road site in London. This contrasts greatly with the situation in Edinburgh, and also Belfast, where traffic pollution often represents less of a problem. However, highest hourly CO levels were recorded at the London/Bloomsbury site (an urban background site, designed to be representative of exposure to the general population), although these levels are still lower than the World Health