LIVE MONITORING OF DEVELOPMENT OF ICE AND SNOW FEATURES AS PLANETARY ANALOGS ON LAKE BALATON.
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Introduction: The development of features in ice and of snow bedforms on ice was monitored during the winter of 2011/12 on Lake Balaton, Hungary. We could successfully observe the formation of a finger rafting feature; snow whaleback dunes, snow barchans and transverse snow dunes, allowing us to give exact data on the timescales of the formation and development of these features.

Snow dune studies were initiated by [5] in Canada and by [6] in Transylvania. Recent snow features studies are based Antarctic [7, 8, 9, 10] and Arctic [11] observations, and very rarely they are reporting observations of blowing snow features on lake ice [12] or land [13]. Similarities of terrestrial ice rafts (pack ice) and features on Europa were noted by [14, 15], and on Mars, Athabasca Valley [3], however its interpretation as ice features is debated.

Methods: For monitoring, we used the web cameras of the Időkép community weather website whose imagery is publicly available for viewing and download. Data on temperature, wind velocity and snow depth was taken from automated community weather stations. Web camera images also display temperature, humidity, wind speed and direction data burnt into its images that are updated every minute. Acquisition of ground truth data of the field of view of the web camera took place during a field work during which we have measured true sizes of dunes, and took high resolution photographs.

Prerequisites of snow bedform formation and observation: Formation of such features requires special "alignment" and timing of different weather phenomena: snow, freezing conditions and wind. Formation of snow dunes takes place only if lake ice freezes in snow free conditions and snow comes only afterwards, during high wind (e.g., the passage of a front) (Fig 5). Snow bedform formation can only be observed if this event takes place during daylight hours (6AM to 5PM). In such an event, the solid, transparent ice provides a dark background for the white snow, giving high contrast for its observation.

Description of weather events during the winter of 2012: In 27 Jan, 2012 very thin, discontinuous floating ice patches started to form, when temperature lows dropped below 0 C°. It became a continuous layer of new ice during the next night. During the next days, temperature highs remained at the freezing point. On 1 February, a finger rafting [4] event took place. At 15-25 km/h easterly winds, a crack formed about a km from the shoreline on the new ice, along which a large block of ice was pushed towards the shoreline. The other end of the block immediately finger rafted under the ice block at the shoreline, forming about 4 "fingers". The event took place in about 20 minutes (Figs 1, 2). The fingers then froze and the structure remained visible until 27 Feb, when the ice broke and melted. During this disintegration, a major crack formed at another location, in northerly winds of 40-60 km/h. On 4 Feb a heavy snowstorm occurred that brought 40-50 km/h N winds. This was the first time that snow fell onto the ice. The storm started at 8 AM and wind speed remained constantly 40-50 km/h during the day. The first snow deposits started to accumulate only at 2 PM, still in freezing temperatures. The first, small patches of snow began to grow and concentrate as now the largest obstacles let more snow to accumulate on their slopes. The formation of few larger dunes from many small patches took place in a few minutes. Around 3 PM whaleback shaped snow dunes formed that moved at constant speed from N to S. They moved the distance of their longer axis (about 5-6 m) in 30 minutes. At 4 PM the whaleback forms got a clear teardrop shape and some of them produced the characteristic horns of barchans. The entire field of view of the webcam was filled with these forms at variable density (Fig 4.). At 6 PM the Sun went down when the individual bedforms were still moving together at a constant pace of c. 6-10 m/hour. The next day saw much less forms remained, their horns truncated. Atop some of them small crescentic forms of opposite horn direction were seen (Fig 3). That day was quiet. On 6 Feb, the wind was rising, and snowfall started at 9AM. In 20-30 km/h northerly winds, the ice remained snow-free until 11AM, when suddenly – again, still in freezing temperatures – snow became attached onto the ice (probably due to increased intensity of snowfall), first as decameter sized densely packed patches, that began moving at 12PM, probably initiated by 50 to 60 km/h gusts of winds. At 2 PM, the moving structures began to shrank and the newly formed small patches completely disappeared in minutes, in similar, 30-40 km/h winds. The large forms that formed earlier did not move or changed considerably during this day. On 7 Feb, 60+ km/h winds moved the older, larger whaleback forms about a distance of 2-3 of their longer axis (20-30 meters), in 6 hours. On 11 Feb the ice was completely covered with new snow, but the next day it began to melt in 10-20 km/h winds, and it formed transverse forms (snow-free and snow-covered corridors). These forms remained unchanged for a few days, when snow covered the whole landscape and when temperature rose even above 10C°, the snow melted into the ice, making it pale white.

Fig. 1a, b. Webcam observation of the formation of finger rafting. There is about a 20 minutes of difference between the two images. Courtesy idokep.hu.

Fig. 2. Finger rafting close-up: two layers of broken ice.

Analog features: (1) Finger rafting was observed on Mars, and were interpreted as evidence of equatorial sea ice [2, 3] although a volcanic interpretation is also possible. (2) Although snow deposits have special thermodynamics, snow features can also be used as analogs to other aeolian and niveo-aeolian features, cemented or active, on Mars.

Formation rate: Individual barchans were displaced by around 6-10 m/h in 40-50 km/h N wind. This is similar to their length, making turnover time about one hour, compared to few months to years for sand barchans on Earth and 10 to 100 thousand years on Mars [1].

Conclusion: Snow bedforms formed at times simultaneously when the whole snowfield became moving in 40-60 km/h winds. Some of them formed characteristic horns, that were later truncated. Most were whaleback-shaped. Finger rafting feature formed in 20 minutes in lake ice. Such observations make a unique opportunity of monitoring geological processes in action.

Fig. 3. Secondary barchans with opposite horn direction or, alternatively, parabolic dunes, formed on the top of the large barchan. Longer axis is about 6 m. Earlier horns are still visible. Layering of the barchan is visible. Photo by author.

Fig 4 a, b, c. Webcam observations of barchans. The field of view is similar, the upper image shows the initial state that lasted for minutes. There is about 2 hours of difference between the two lower images. Courtesy idokep.hu.

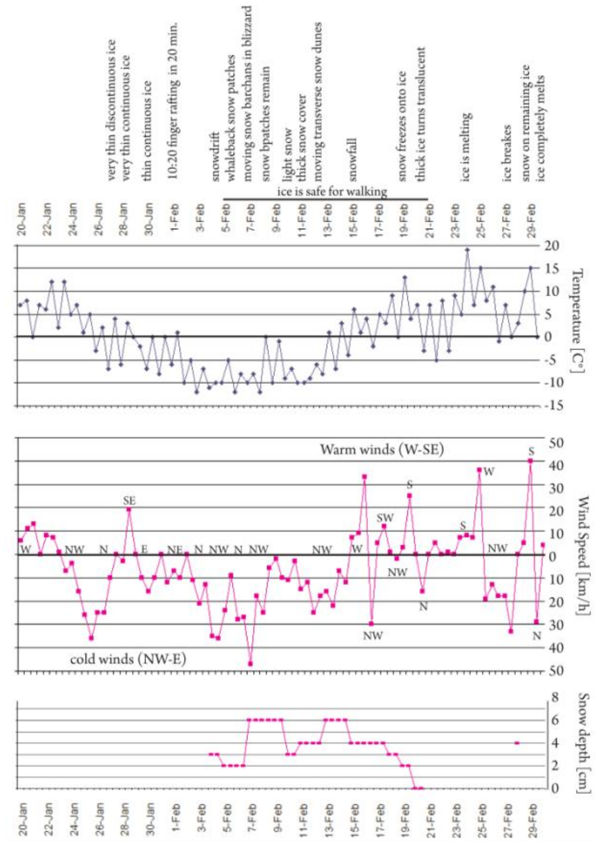

Fig. 5. Weather data and events of the described winter season in Keszthely, Hungary. Data from idokep.hu community members.

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