Laboratory simulation of the pancake ice influence on the wind-wave interaction

Vienna | Austria
2–8 May 2020

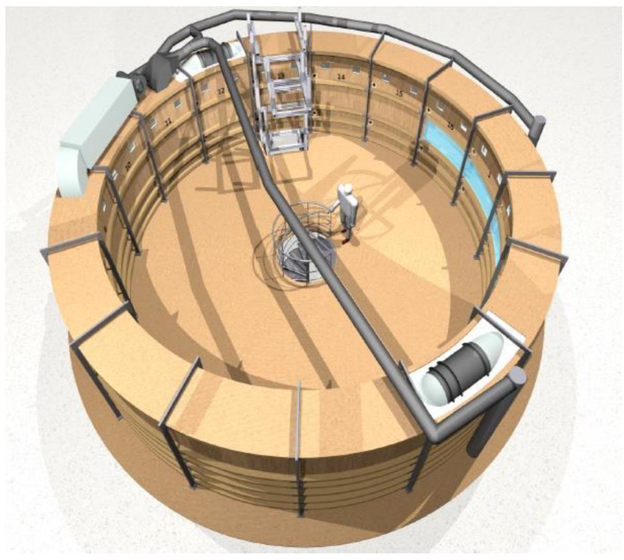
Daniil Sergeev, Yuliya Troitskaya and Alexander Kandaurov

Institute of Applied Physics of the RAS, Nizhny Novgorod, Russian Federation;

The AEOLOTRON facility

Experiments on modeling the interaction between the ocean and atmosphere in the presence of ice were carried out on a unique wind-wave facility AELOTRON (Circle Small-Scale Air- Sea Interaction Facility) :

- 60 cm width, 2.4 m height, circumference of 27.3m at the inner wall
- Water depth during experiments 1.0 m.
- Air cross-section 1.5 m height.
- Wind is generated by two axial fans mounted into the ceiling
- Annular wind-wave facility, wind speeds up to u_{ref} = 10.5 m/s (U_{10} = 16 m/s)

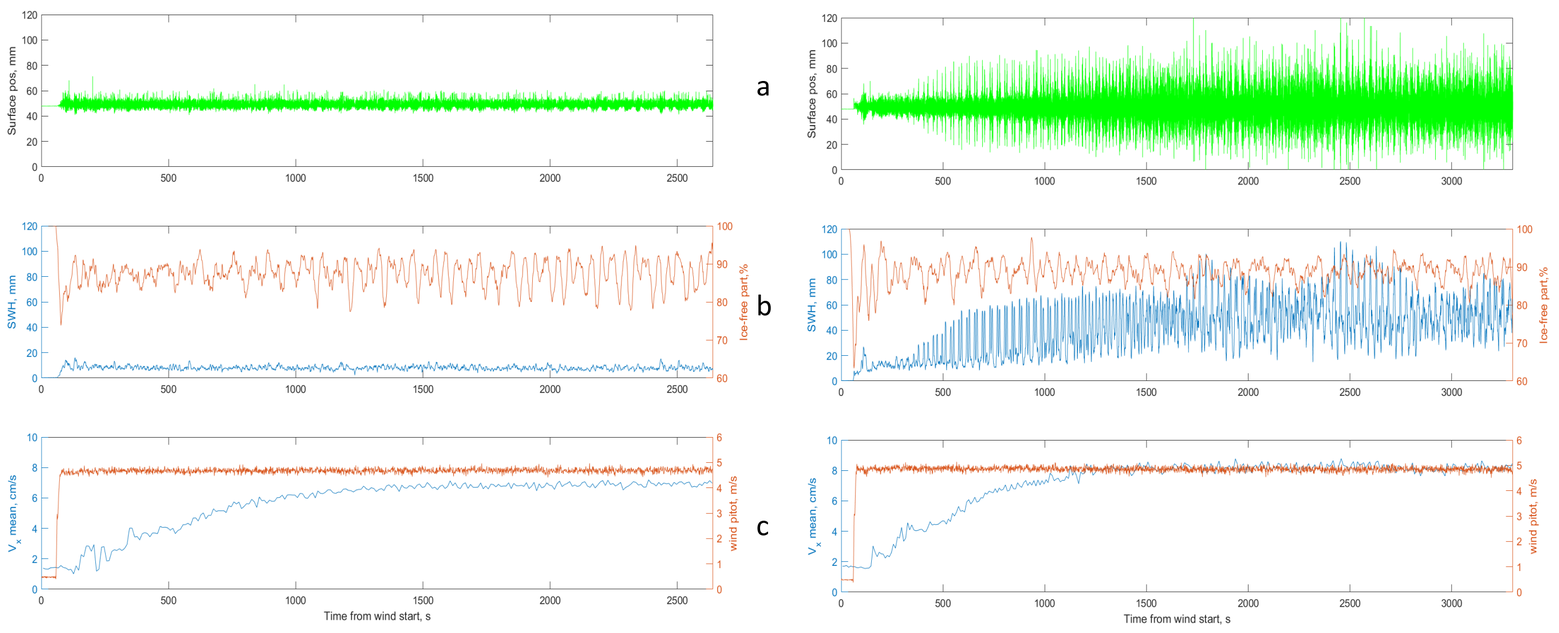


General view and principal diagram of the Aeolotron

Simulated ice on the water surface inside the flume
(maximum concentration of artificial ice, approximately)

Simulated ice

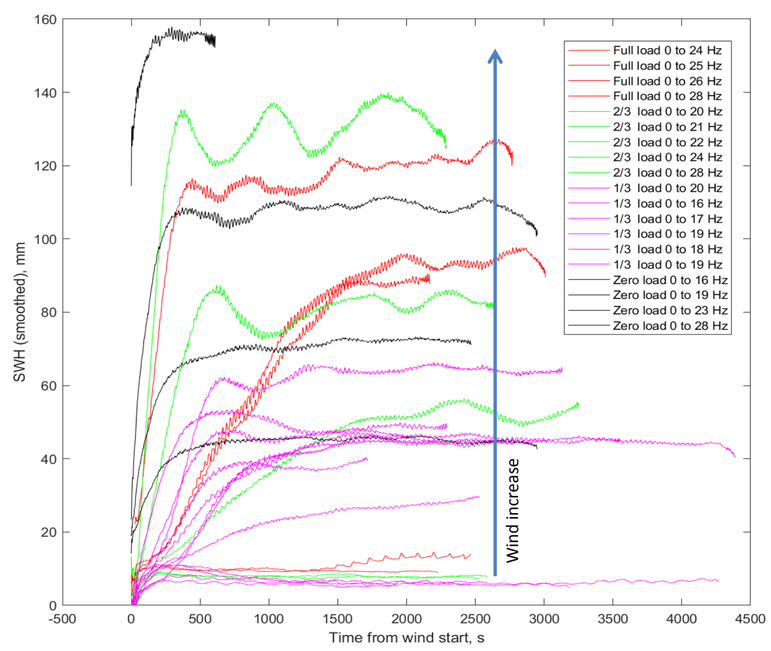
In the experiments pancake type of ice was modeled. Ice was simulated using disks (diameter 7 cm, thickness 1 cm) of porous rubber with density of 0.8 kg/m³. In total, about 1,700 pieces were used, which allowed covering about half of the water surface area in the flume. Studies of the establishment of wind waves at various concentrations of artificial ice were performed: the experiments were performed at three different concentrations of artificial ice (maximum, 2/3 and 1/3 of the maximum), as well as in pure water.



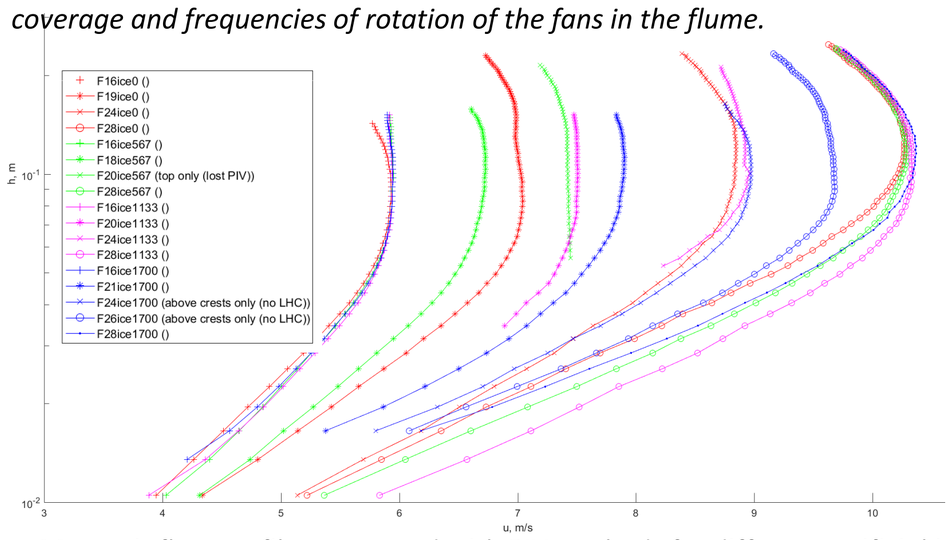
Time dependencies for the same ice coverage (2/3 of full load) for wind speeds below (left) and over (right) the threshold (frequency of rotation of the fans in the flume 21 vs 22 Hz): a) water surface elevation measured by contactless wave gauge; b) significant wave height (blue) and local percent of ice-free surface (orange); c) water (blue) and wind (orange) longitudinal velocities. Significant wave height was determined for 5 sec time interval.

Measurements

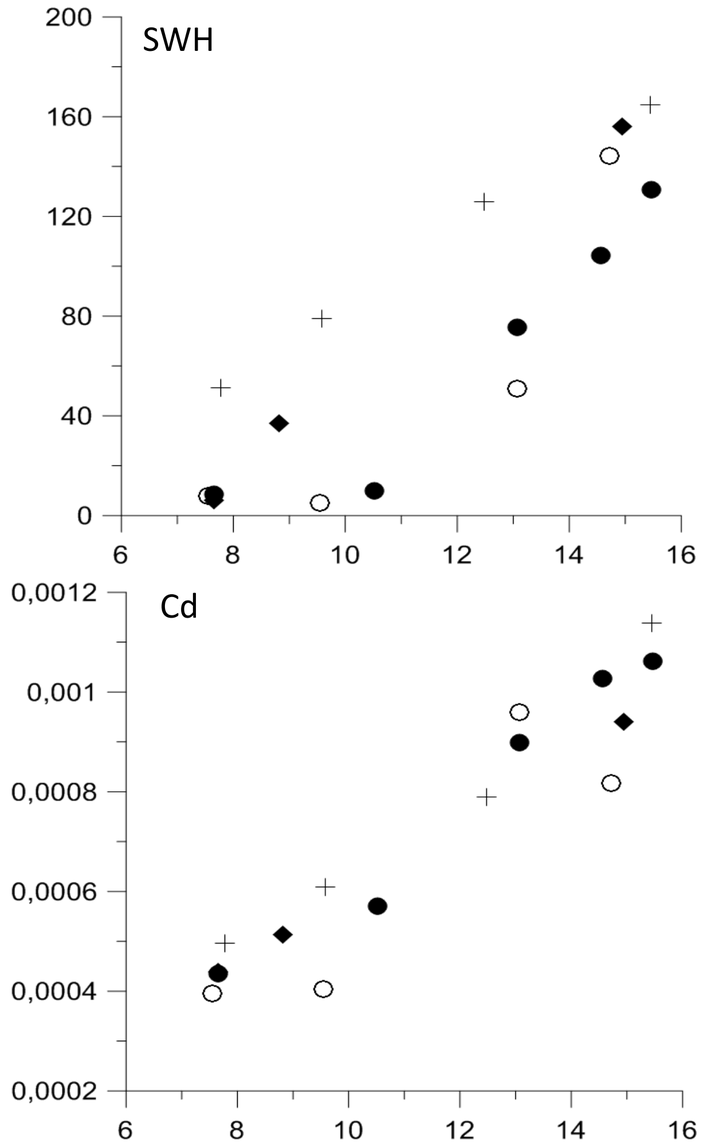
The main measurements were carried out using a contactless laser wave gauge at 400 Hz. The dependence of wind speed on time was controlled using L-shaped Pitot gauge attached centrally in the channel below the ceiling and connected to a differential pressure gauge. The water velocity was measured using acoustic doppler anemometer MAVS-3 mounted. An optical system for estimating ice concentration based on an top-down shadowgraph video shooting was developed for monitoring and studying the correlation of the parameters of the waves with local and instantaneous concentrations of artificial ice. Its measurements were synchronized with measurements of the parameters of the waves. PIV-measurements were carried out by using special visualization with chloride ammonium micro crystals aerosol, vertical continuous blue laser sheet illumination and filming with high speed camera DiMax.



The dependence of the significant wave height on time for different artificial ice coverage and frequencies of rotation of the fans in the flume.



Mean air flow profiles measured with PIV methods for different artificial ice coverage and frequencies of rotation of the fans in the flume.



(Top) significant wave height (bottom) aerodynamic drag coefficient dependence on the equivalent wind speed U10 (on 10-m height). Crosses – clean water, filed circles – maximum ice cover, open circles – 2|3 ice cover, diamond –1|3 ice cover

Results

In all three cases in presence of ice, the threshold mode of generation of long waves in the system was observed. There is a quite narrow range of wind speeds in the flume, at which the transition from the mode of drift movement of ice disks on the surface and small ripples with a length not exceeding the distance between the disks, to the mode of generation and development of long waves was possible, by analogy with clean water. The value of the threshold velocity increased with increasing concentration of ice.

According to the results of processing the velocity fields, the dependence of the aerodynamic drag coefficient on the equivalent wind speed was constructed. It is shown that the presence of ice weakly affects the momentum exchange for all concentrations and over the entire wind speed range.

The work was supported by RFBR grant 18-05-60299.