Study on the evolution process of lake ice and related influencing factors in northeast China

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Introduction

Lake ice is an important part of the cryosphere and often provides an indicator for regional climate change. The formation, growth and decay of lake ice are not only driven by the heat exchange between the atmosphere and the lake, but also influenced by the morphology of the lake, which has significant regional characteristics. The prototype observation data of lake ice is the key to calculating the energy balance of the ice cover, and it is also the cornerstone of lake ice research using numerical simulation and physical model tests. Northeast China is located in the middle and high latitudes and has abundant lake resources. Lake ice is very important for the construction of regional water conservancy projects and water ecological environment protection. This study conducted prototype observation experiments on mid-latitude lakes in Northeast China in the winter of 2019, trying to record the complete lake ice evolution process and explore key influencing factors, in order to provide reference and help for future ice engineering research and ice ecology.

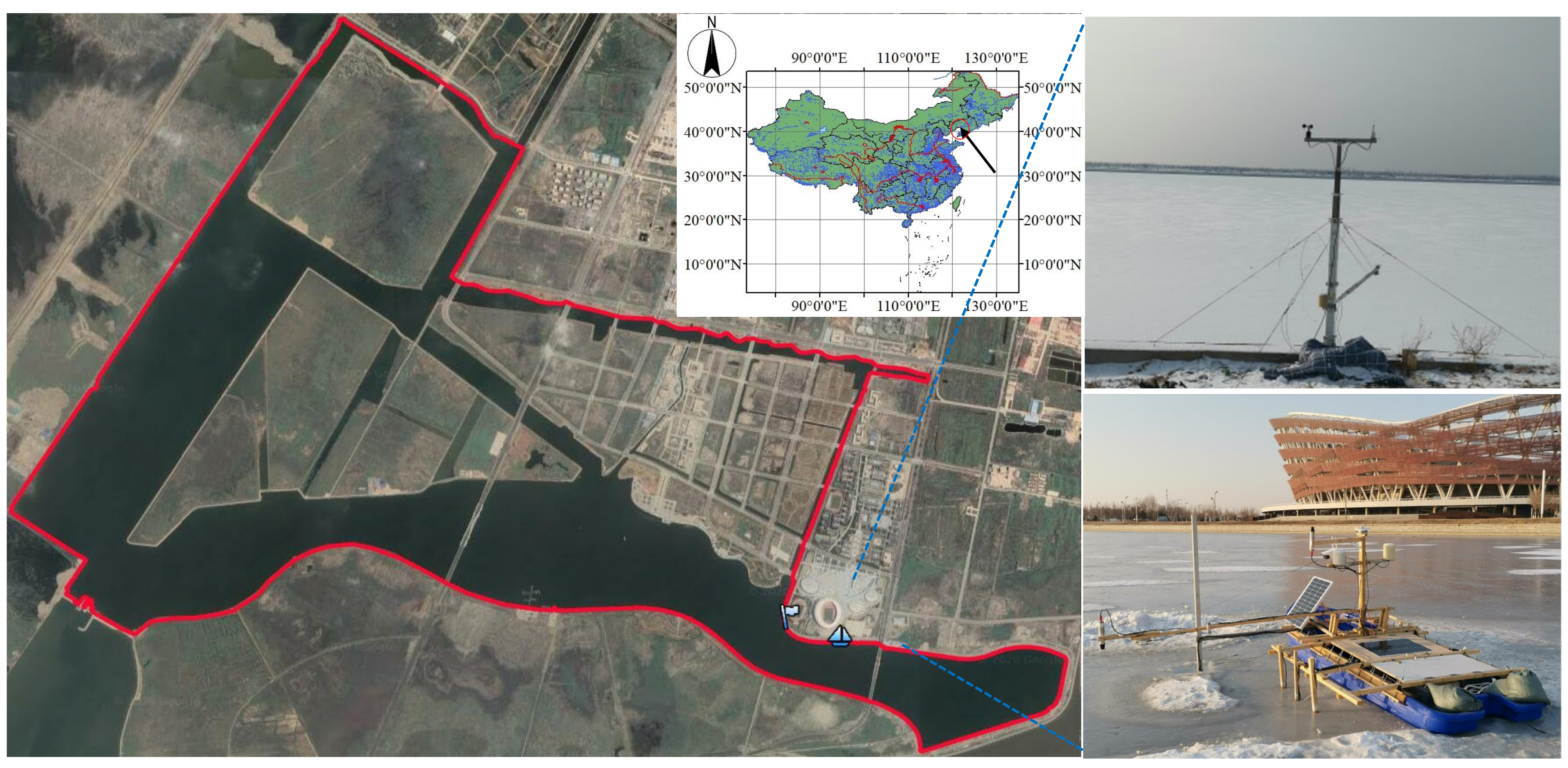

Figure 1 Research area (40° 40'N~40° 43'N, 122° 02'E~122° 08'E) and observation equipment (Mooring system and weather tower)

The evolution of weather and ice thickness

Throughout the observation period, the temperature first decreased and then increased. In particular, the temperature dropped sharply from December 4 to December 6, with the lowest temperature as low as -13℃, which was also the time when the lake was frozen. The average ice thickness growth rate was 0.46 cm/d. It stabilized for seven days after reached the maximum ice thickness(30.7 cm), and then melted rapidly at a rate of 1.3 cm/d.

Because the lake water contains 5-8ppt salt, the freezing point of the water is below 0° C, which is about -0.4° C. It could be found that in the stable period when the ice thickness was unchanged, there was obvious water temperature stratification at a depth of 50 cm; as the stratification depth approached the water surface, the ice thickness gradually decreased.

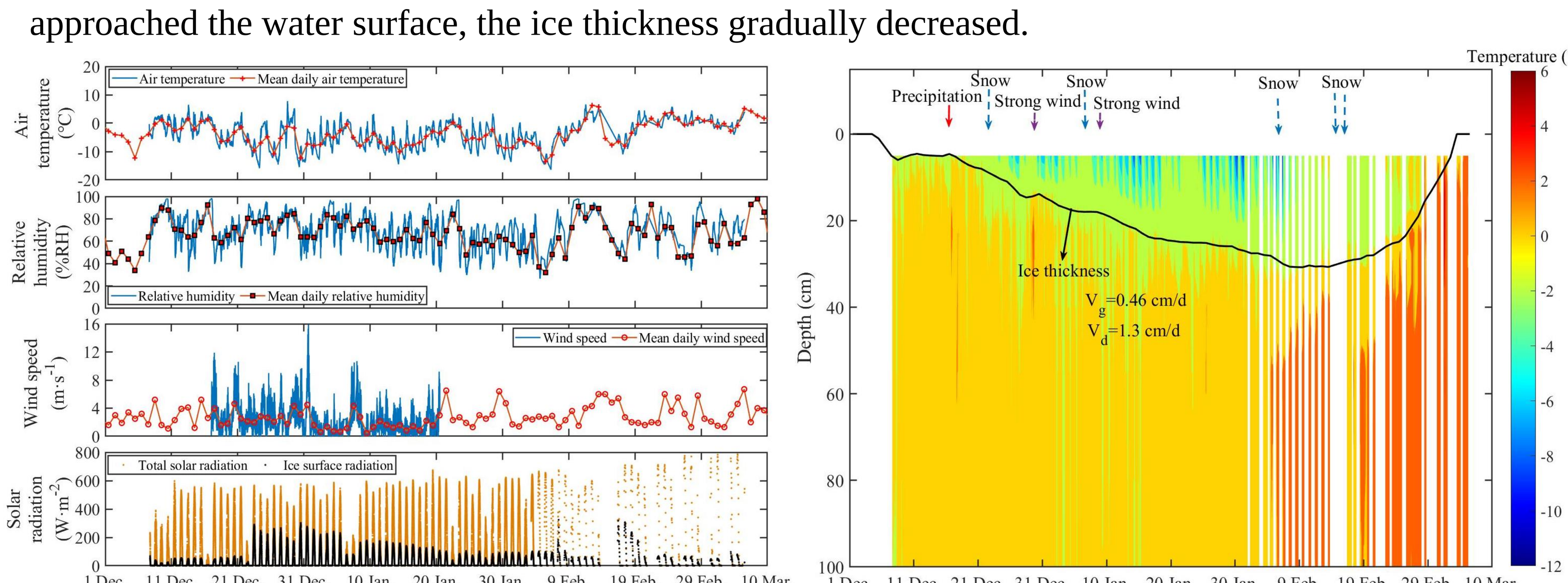

Figure 2 The evolution of weather and ice thickness

Result

Air temperature

According to the relationship between ice thickness and freezing-day, it was found that the increase of ice thickness and the accumulation of negative accumulated temperature had a high correlation, indicated that temperature was the main factor affecting the increase of ice thickness. At the same time, ice temperature (ice thickness: 5-17 cm) had a significant hysteresis effect on air temperature changes. The lag time was 70-158 mins, and the correlation coefficient was 0.89-0.52. Based on this, it could be seen that the ice thickness growth stage of the lake was mainly controlled by air temperature.

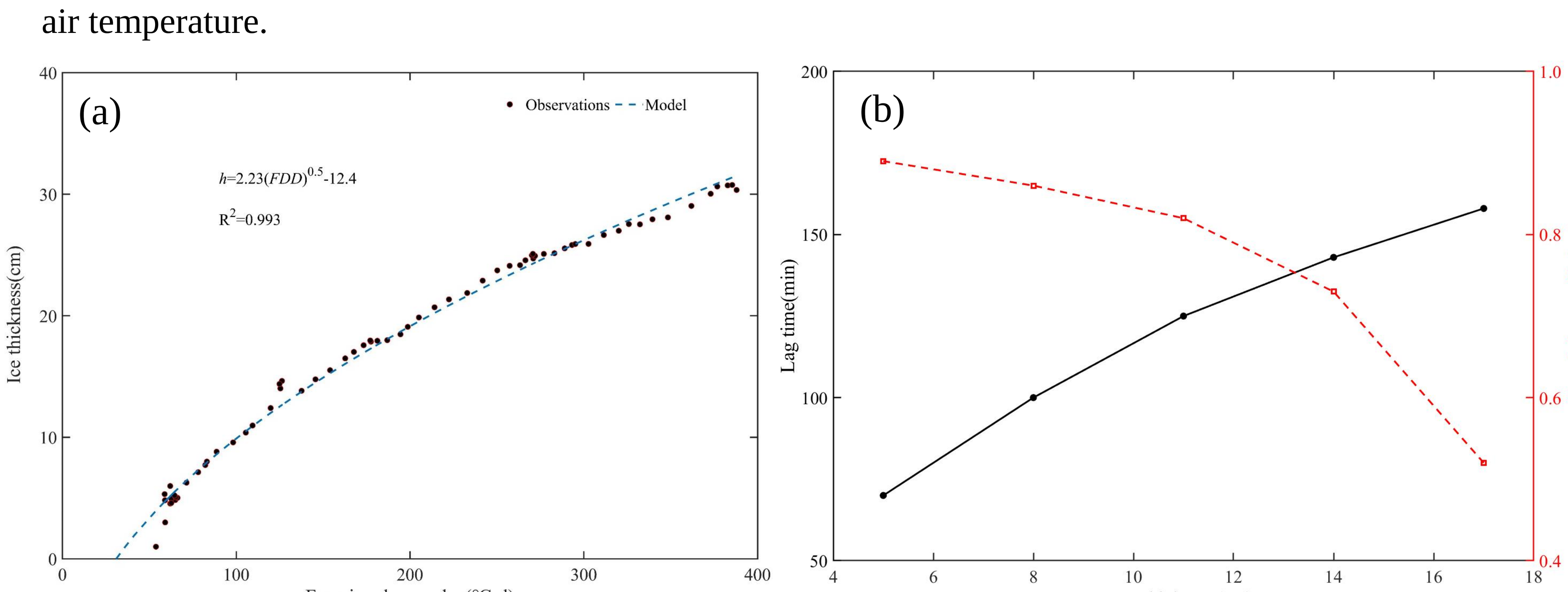

Figure 3 (a) The relationship between ice thickness and freezing degree-day (b) Lag time of ice temperature response to air temperature changes

Precipitation

The rainfall was about 14 mm. The precipitation caused the ice surface albedo to decreased (0.4~0.1), the environmental humidity increased, the ice surface at the bottom of the lake melted about 0.5 cm, and the water temperature gradient of 5-40 cm immediately droped from 4 ℃/m to 1.4 ℃/m. However, as the water on the ice surface freezed, the environmental humidity droped again, and the ice surface albedo increased rapidly.

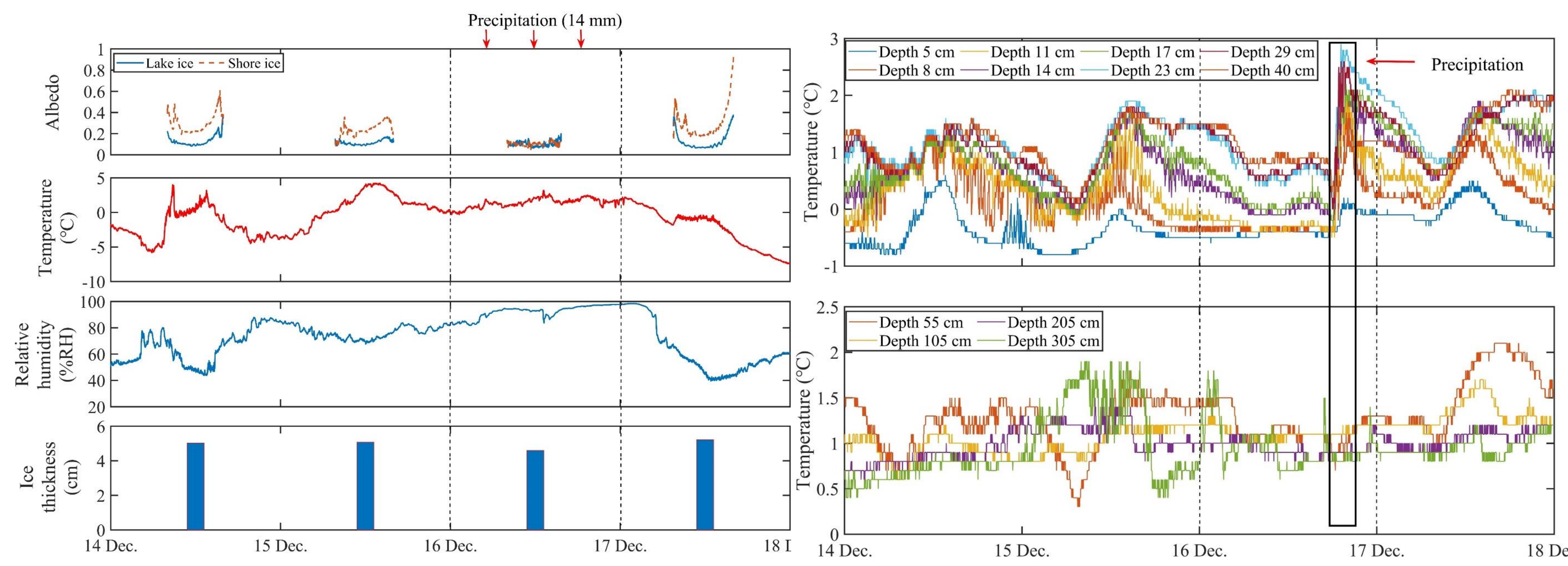

Figure 4 The impact of precipitation on lake ice

Snow

Snowfall increased the albedo of the ice surface to 0.8, and the ice temperature no longer had a significant hysteresis effect on the temperature change; as the strong wind blowed away the snow, the ice surface was gradually exposed and the albedo decreases again. The albedo of shore ice was slightly higher than that of lake ice because more fresh snow blowed to the lake shore. Unlike lake ice, which was almost always columnar, the component of shore ice contained more grain ice. Compared with precipitation events, lake ice experienced more frequent snowfall events

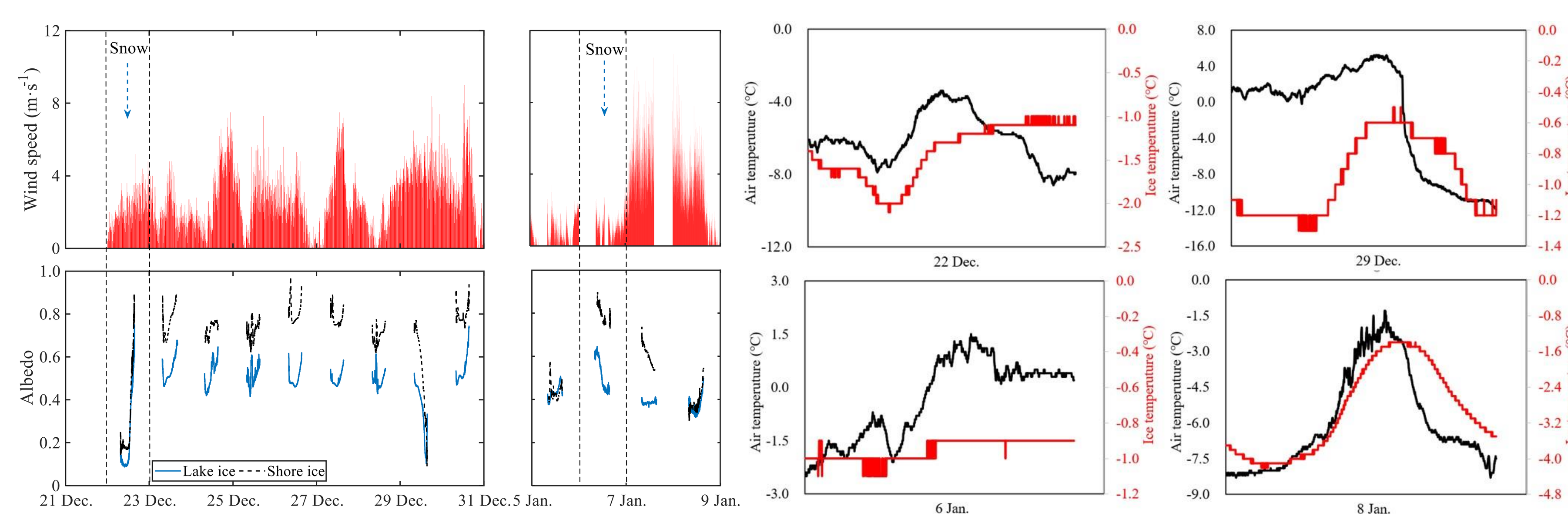

Figure 5 The impact of snow on lake ice

Solar radiation and lake morphology

Since late February, the ice surface albedo had been maintained at a relatively low level, and the temperature had only fluctuated at 0℃, while the ice thickness had decreased significantly. Combining the pictures taken on the east side bridge on February 25, it could be seen that a large area of open water was advancing westward. During the melting of lake ice (lake shape), the increase in solar radiation intensity and the increase in open water area were the main factors that caused the rapid melting of lake ice.

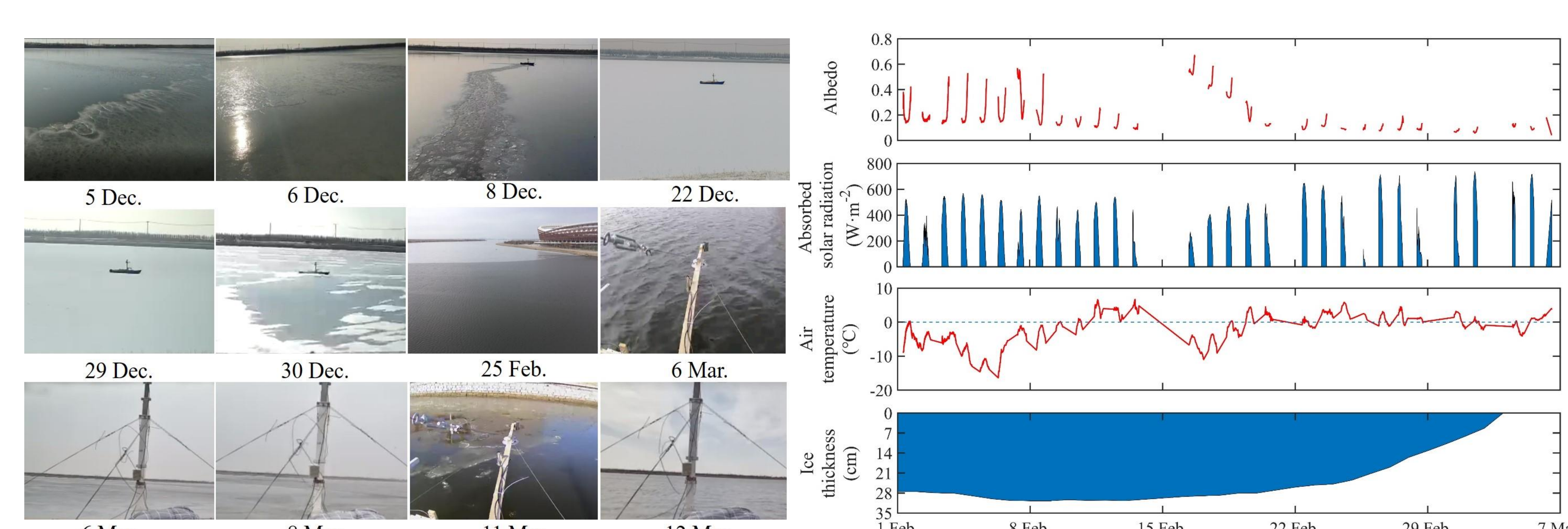

Figure 6 The evolution of lake ice and the melting of ice thickness

Conclusions and Discussions

Central latitude lakes in Northeast China have similar evolution characteristics with other lakes at the same latitude. The ice thickness growth rate is 0.5 cm/d; and the negative gas temperature for 3 consecutive days makes the lake complete the freezing process. However, the effect of precipitation events on the overall development of lake ice is short-lived. snowfall events have a greater impact on the development of lake ice because snow on ice interferes with the gas-ice heat exchange level; in spring, temperatures close to 0 ℃ do not attenuate much heat to lake ice. melting of lake ice mainly depends on solar radiation and lake morphology.

The factors affecting the evolution of lake ice in Northeast China include temperature, precipitation, snowfall, wind, solar radiation, and lake morphology. The effects of different factors on the entire lake ice are not single, but coupled. This study is only preliminary to the exploration of mid-latitude lake ice, and there are still many problems.

What is the impact of salinity migration in the heat exchange process of the entire lake ice?
What is the energy balance in the evolution of lake ice?
How to carry out ice ecology and ice engineering research around this lake in the future?

We have already carried out some work on the above issues, but we have not had time to analyze it. In the next few years, we will continue to carry out lake ice prototype observations for further exploration.

Acknowledgement

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