Comments from first reviewer and responses from the authors

The paper as submitted represents a significant effort to measure and analyse long-term trends in Boreal Lake ice behaviours and the results are very relevant to ongoing monitoring of climate changes. The paper also details useful developments in the instrumentation used and the methods of analysis of the data the instruments produce.

This reviewer is an Engineer involved in the initial development of the instrumentation used and cannot comment on the metrological and climatological issues raise and analysed. Comments are limited to instrumentation matters only.

The work details a considerable programme of over a decade duration over which the SIMBA instrument has developed. The authors present advances made in the instrument itself and improved methods of deployment but more significantly is the presentation of results from a newly developed algorithm to process the SIMBA data. This is a major advancement in the use of the SIMBA device as to date the interpretation of results has been largely subjective human activity. The use of this algorithm now allows for a repeatable and consistent analysis of the considerable data set collected.

Specific comments on the text are as follows.

The SIMBA sensors are calibrated at a single point to remove large offsets in a very accurately controlled bath. The sensors have been shown to be very linear and so the largest source of error becomes the resolution of the sensors. The absolute accuracy is therefore in the region of the resolution plus the error in the water bath accuracy which is very small. The quoted +-0.01C is not possible and the accuracy more like +-0.0625C. The sensor drift over time is small and can largely be ignored.

Reply: Thank you to point out this error. We made correction accordingly. The new text read: The accuracy of the SIMBA thermistor sensor is ± 0.1 ºC, which is comparable with other type of thermistor string based IMBs (Richter-Menge et al. 2006).

Diffusivity is a transient measure of how heat is conducted away when a temperature change occurs (i.e. how cold to the touch something is). The SIMBA heating cycle is usually long enough for the temperature rise at the sensor to reach a steady state so is it not the thermal conductivity which dominates?

Reply: We modified the text to: The SIMBA heating cycle is usually long enough, often 60 or 90 s, for the temperature rise at the sensor to reach a steady state. Thermal conductivity determined how the heat is conducted away of the heated sensors placed in air, snow, ice and lake water. As a result, the SIMBA-HT profiles can greatly enhance the detection of the interfaces between air, snow, ice and water.

Really impressive plots!

Reply: Thanks

Overall this is a paper worthy of publication and represents an impressive and well executed effort at studying important phenomena.

Thank you for your positive comment on this work, we appreciate your great effort making this novel，compact and cost cutting instrument, which allow us to carry out sustainable field campaigns.

Comments from second reviewer and responses from the authors

This paper used a thermistor string-based snow and ice mass balance apparatus (SIMBA), which is a novel monitoring method for snow and ice thickness, to monitor the temperatures of air, snow, ice and water, and to get the snow and ice products applying a algorithm, finally to reveal the relationship between climate change and snow/ice thickness. Based on the decadal date sets, authors described the snow and ice temperature regimes, snow depth, ice thickness, and ice compositions as well as meteorological variables at the Finnish Space Centre. These decadal data sets provided firstly can also be used for numerical and satellite validation and can be comparable to the results obtained from other cold regions. So, it is important and interesting issue and is worthy of publication after some revisions. Some comments are raised as follows.

The paper is wrote well entirely. However, there are still some problems in English writing. Such as, "thermal heat conductivity" is suggested to be "thermal conductivity"; Please check "Figure 8" in Line 195 and "Figure 9" in Line 211. It is suggested to revise the English description entirely.

Reply: Thanks for your suggestions. We made corresponding corrections and the language of the entire manuscript has been checked carefully.

"Figure 8" in Line 195 should be "Figure3"
corrected

"Figure 9" in Line 211 should be "Figure4"
corrected

"thermal heat conductivity" in Line 194 modified to "thermal conductivity"
Done

In Lines 328-329, author described "….a decrease of FDD is expected to result in less formation of columnar ice". Please explain why.

To be more precise, in the revised manuscript, we change FDD and TDD to AFDD and ATDD, respectively. So AFDD is the accumulated freezing degree day, and ATDD is the accumulated thawing degree day. So FDD is a measure of how cold the day is and AFDD is a quantitative estimation on how cold a winter is. Based on classical Stefan's law (1891), i.e., ice growth is proportional to the accumulated freezing degree day (AFDD). A decrease of AFDD means the winter is less cold, so the columnar ice (ice frozen due to freezing of lake water) is reduced. To avoid confusion, we updated the figure caption: Figure 11. The seasonal accumulated negative freezing degree day (AFDD) and positive thaw degree day (ATDD) during the observation period (2009/2010 – 2019/2020).

In Lines 381-383, the increase of air temperature in winter season is highly correlated with seasonal total accumulated precipitation. Please address its reasons.

In Scandinavia, warm winter weather is typically associated with higher precipitation rates. This is because they are due the same reason. Transient cyclones transport warm, moist air masses to Scandinavia. Without transient cyclones, colder and drier winter weather would prevail in the region. We added two sentences in the conclusion to emphasis this important issue.

In Lines 388-390, the seasonal accumulated FDD is reducing, suggesting reduced formation of columnar ice and, hence, a smaller role of air temperature in controlling the ice thickness. It is a little partial. In cold regions, air temperature is still the dominant factor controlling the ice thickness. Maybe other factor, such as precipitation in winter, play an important role in ice thickening. Please offer the accurate description.

The original description was not very accurate. We were meant to say that the role of air temperature on lake ice formation is getting smaller (because the general warming trend of air temperature in the polar region) rather than the role of air temperature is small. The air temperature is still the number one factor affect ice formation. So, the new sentence is:

Because of the air temperature increase, the seasonal AFDD reduces. This results in a decreasing impact of below-zero air temperatures on lake ice growth during the freezing season, as the growth of columnar ice is reduced. Simultaneously, the role of precipitation on total ice formation is enhanced because snow-ice and superimposed ice contribute to an increasing fraction of the total ice thickness.