

# Warming Climate Shortens Ice Durations and Alters Freeze and Breakup Patterns in Swedish Water Bodies

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**Journal:** *The Cryosphere*

1. **Summery:** In this paper Hallerbäck et al investigated icing pattern in different lakes and rivers in Sweden. By application of MK-trend test, they analyzed 1)ice duration, shifts in 2)freezing and 3)breakup time. They concluded that the mean observed ice durations is decreased considerably in northern (11 days) and southern Sweden (28 days). Additionally they showed while freezing is occurring later in the year, break up time happens sooner.

## 2. General Comment

I find this very paper interesting. The presented data is indeed unique. Given the spatial coverage of Sweden, this paper cast light on a very important process (icing) for climate change impact assessment. The data is well presented. To make the paper even stronger and provide with a rigid scientific backbone I have following remarks: 1- there are a few points where I think providing with more discussion, clarification and information is necessary. This specifically is the case for part 3-2 and 3-3. 2- Some sentence needs to be brushed up. Specifically, in introduction part, the references should undergo cosmetic adjustments 3- The time period for different analysis are varying through study. It is worth justification (or reminding) the readers why specific periods are chosen for each analysis.

Considering the extent of my comments and the capacity of this work, I suggest **minor revision**.

## 3. Specific Comment

**Abstract:** The abstract is generally clear and is in line with the content of the paper.

L16: please change the order of ice duration, later freeze and earlier break up to 'earlier break up, shorter icing duration and later freeze' to match the order of your result section.

L17: What do you mean by dates from 1913-2014? Please clarify. Also, please specify to what periods are these changes relative to.

L19: Maybe it is not necessary to have this sentence: the rate of the change is ... . From the previous sentence, one can easily deduce the ratio of change.

L21: please specify by exact dates when was 'previously observed' period.

L23: What do you mean by 1 degree increase? Do you mean from now (2021) onwards if we have 1 degree of more increase in temperature (in what time span would this increase happened?), then we would see decrease in ice duration by the end of 2100? Please clarify.

**Introduction:** Please check all references to be inline with one of the referencing styles. In line 27 (and some others) for example, the references are mentioned separately.

L 76- 87: These two paragraphs would fit better in method and data part in my opinion. Either merge this part to the existing content in the method part or consider removing it.

Then in the last paragraph maybe it is of use again to specify why your study is different from Weyhenmeyer et al 2004. Remind of all the key things that you additionally looked at (and maybe they did not).

### **Methodology:**

L90-91: Is Thorne river, the only data provided by SYKE? Then consider rephrasing the first two lines to: 'the refreeze/ice data records are provided from two sources: Most data consisting of river and lake ice record is provided by SMHI while Thorne river data is obtained from SYKE'. If more data is provided by SYKE, consider adding number/percentages.

L92: consisting of [number of] lakes and [number of] river.

L94: Given the data spans 1700-2004 please specify why the data from 1860-2014 is presented in figure 3.

L95: Consider rephrasing please. Suggestion: 'systematic observation of lake icing started in 1870 by and observer responsible for manual monitoring a specific lake ...'

L99: not necessary to start a new paragraph.

L103: This sentence is unclear to me. Please consider simplifying it. Suggestion: 'The ice year is defined from 1<sup>st</sup> of September to 31<sup>st</sup> of August.' If this is what you intended to say in the first sentence.

L107-L111: In my opinion this part needs some shuffling of text. Uncertainty and the issue with numerous observation has already been mentioned previously in this part of the text. Please consider either moving them to where you already talked about these points or removing them.

### **Statistical tests, trends and spatial analysis**

For the sake of part 3.3 (changes in the timing of ice cover), it might be of use to add some test to check if data are coming from the same distribution with tests such as chi test or Mann Whitney u test. Please consider adding such tests for reasons I will explain in the relevant part.

### **Results:**

**3.1** – I personally find figure 1 very interesting. I also think that a bit explanation of the results would be beneficial. For example it seems like there were fewer observation sites in the first 4 decades. This might affect blue, purple and red contour lines vicinity and the area covered by contours (please note that in figure representing 1881-1890 period, the blue line does not intersect with Sweden boundaries). It is beneficial to remind readers of the changed number of observational points and its potential effect and uncertainty on this presentation.

L134:L 145: since quite a big portion of result in this section is allocated to extracted data from Torne river and Väserås Fjäld, I think it is beneficial to add a map with the location of these two waterways for readers who are not familiar with exact Geography of Sweden. Please consider adding such map.

L:138: Either try to add more references other than Sharma 2016 here to back up such findings or consider moving this part to discussion where you would thoroughly put your finding into context.

**3.2:** L157. Please consider rephrasing the first sentence of the paragraph to a more formal language.

L158: What is ice phenology? Please consider bringing this technical term either earlier in the manuscript (in the introduction where you already have it) or remove it because 'breakup dates' has already been used numerous times.

Please also specify why this particular period is used (1913-2014).

Figure3: **This is one of my main comments.** I personally have some difficulties understanding why these particular points are selected. First I thought in total, each map contains 40 water bodies that represent some significant behavior in either of the three characteristics.

But I the data does not add up to 40 in all three (for example please check figure 3 which seems to have 55 water bodies according to notation under the map). Additionally, there are some points that do not add show up in all maps. For example, note the data point with insignificant trend in the west coast of Sweden (Maybe around Trollhätten) in figure B. I could not find this point in any of the other maps.

Can you either revisit the maps or make a more clear explanation of what these maps show?

L170: The sentence is unclear. Please rephrase.

L174: It is very difficult to find blue mark in figure 3.B. Consider reshaping or using another marker.

L175: Can you add reference to SMHI's temperature data? Also please make a connection between this statement and previous sentence to explain how this is relevant for this study.

L180: What is the main finding of these studies? And how does it help to put current paper into context for a broad audience?

**3.3: This is one of my main comments.** Although the change in mean (first moment), most probably is significant, it is also important to back up such finding by analyzing if the changes in ice duration is significantly different in two samples. For example you can use Z test, Mann-Whitney U test or Wilcoxon rank-sum test. Without such analysis, it is not easy to know if this changes are happening randomly or there is more to it.

L186: please mention that these two periods are specifically selected to cover 30 years climatic normal periods otherwise it is not quite clear why these periods are selected.

L198: I am not sure what does this part means: 'resulting from an increase (of what?) in extremely short duration'

L203-204: I am not entirely sure why do we have this sentence here : 'Nonetheless, other lake characteristics such as mean depth, volume, and area also influence the duration of ice cover and its freeze and breakup dates'. Please clarify or make connection to other parts of the study.

3.4 L 212: I am not entirely sure why do you have 30,000 observations. is it derived from number from timeseries of 464 lakes? If it is the case isn't it more straight forward if the start and end point of observed temperature was reported?

L215: I am not sure what part of appendix you refer to.

Figure 5:**This is also another major comment I have:** I personally find it easier to understand these plots if different colormaps were used for each plot. From these 4 plots I cannot really see the effect from Depth and volume. In fact it still seems like the pattern is highly moderated by latitude compared to Depth or Volume. I think the connection/disconnection between area,

volume and depth to ice duration needs a little bit more discussion or better clarification/justification (if there is any).

In fact it is also quite important for the readers to know if Swedish lakes are being moderated by their characteristics or are only controlled by climatic patterns or location.

L222: same as what I already commented in abstract part, in what period would 1 degree increase in temperature happen? Please clarify. Generally I am not sure how these ratio is being captured and what has happened here? Did you extrapolate data to future? Please add more detail to the content here.

According to Figure 6, does it mean that e.g., in ice duration some catchments encounter -30 day ice duration in case of 1 degree (per what period?) temperature rise. If this is the case please add more information about what this plot actually represents.

L251. 252: how does the relationship between breakup date and mean temperature representation via arc cosine function relate to your study? Please clarify.

L260: please clarify what do you mean by smaller temperature amplitude.

Sincerely

**Faranak Tootoonchi**