Authors reply

**Review of "Impacts of climate variability on wetland salinization in the North American Prairies" by Nachshon et al.**

**General comment:**

The paper by Nachshon et al. presents analysis of the field measurement data from the case study in the Saskatchewan, Canada to explore temporal salt dynamics in prairies, assuming that pond processes are an adequate equivalent for analyzing the system behavior under climate change. The main result of the work is the clear evidence of the different system response to wet conditions associated with snowmelt and rainfall. While the significant snowfall does not induce any significant changes in pond salinity, intensive summer rainfall triggers processes that contribute greatly to the changes in salinity values, with potentially significant implications for local community and ecosystems. The manuscript is very well written, and my only comment considers the clarity of presented results. While the data sources and analysis are presented in details, I was struggling to follow the story, with different ponds and years used in different analysis. Finally, although the results show clearly the unresponsiveness of the salt pattern to increased snowmelt, the clear justification for this conclusion is not given. As such, I find that the manuscript would be suitable for publication if the authors would address a few minor comments discussed in more detail below.

We highly appreciate this review and the detailed comments and suggestions provided by the reviewer. To address the overriding issue of clarity of the manuscript (which was also raised by the first reviewer) we will add another section before the conclusions which summarizes our hypothesized conceptual model of the system in a clear way, with a new diagram (please see response to reviewer 1). In addition we have considered all of the reviewer's comments and we will make revisions to the manuscript as described in the responses below.

**Specific comments:**

Page 13476, Line 14: In the rest of the manuscript, as well in the data analysis, you mention and use a period of 20 yr of observations, though one plot is shown for the period of 40 yr (Fig. 4). For the clarity of the paper, and since you mainly use the data from 1993 onwards, I would suggest that you change the sentence to "… taken over the last 20 yr", and present Fig. 4 using the same time range. That way the temporal changes of the pond depth that you are explaining in the text would be more perceptible as well.

We understand the reviewer's point, but we prefer to leave Figure 4 as is (with 40 years of data) as it shows the observed changes in the pond depth over a longer period, which highlights how exceptional the recent period has been. However, since all of the other data is from 1993

onward (20 years) we will change the text to indicate that the majority of the data is from the last 20 years and not 40 as written.

Page 13476, Line 20: Please indicate what is your explanation why the wet conditions associated with high snowmelt do not pose a threat to salinization. The statement that it is your conceptual understanding of the system is quite vague.
We agree and the sentence will be improved in the revised manuscript for clarity. Under snowy conditions snowmelt runs off mainly as surface runoff above the frozen soils, picking up only a small amount of salt. Under rainy conditions, subsurface runoff is dominant, with the water flowing through the soil to the depressions, picking up significantly higher amounts of salts. As mentioned previously, we will add another section toward the end of the paper to summarize and present the conceptual model in a concise and clear manner.

Page 13478, Line 1: I would like to see few sentences explaining briefly the conceptual representation of salt dynamics from Nachshon et al. (2013). This would give insight into salt dynamics you are trying to capture with experimental data analysed in this work. Finally, I think you should come back to some of the findings in 2013 paper when explaining the results presented in this manuscript (please see comments Page 13476, Line 20 and Page 13490, Line 3).
We will add a short overview of our paper from 2013 in the introduction and we will relate our experimental findings back to this conceptual model in the conclusions.

Page 13478, Line 12: I think the manuscript would be easier to follow if here you would give a brief description of the analysis you will undertake, emphasising that you will be starting with the field scale analysis, followed by looking at a specific transect and finally finishing with small scale (single pond) analysis.
We agree and we will add the following text before describing the field site: “In this work extreme rain and snow conditions will be examined with respect to their impact on salt transport, salt accumulation and wetland salinization. Salinization processes are studied at field scale by examining changes in ponds salinity throughout the entire site; at the pond scale by observing a specific pond with a high temporal resolution; and along a transect connecting two neighbouring ponds with high temporal and spatial resolution”.

Authors reply

Page 13479, Line 5: A table summarising available data, corresponding locations, period and frequency of acquisition would, I think, contribute greatly to following the results presented (e.g. Precipitation / 35km of St Denis site / 1993-2012 / daily?).

This is a good idea and we will provide this table as shown below:

| **Property** | **Location of measurement** | **Measurement period** | **Temporal resolution** |
|---|---|---|---|
| Precipitation (rain+snow) | Saskatoon | 1993-2012 | continuous hourly |
| Rain | St. Denis | 5-24/7/2012 | continuous hourly |
| Ground water levels | St. Denis | 1997-2012 | continuous daily / hourly |
| Pond 109 depth | St. Denis | 1968-2012 | continuous monthly |
| Ponds salinity | St. Denis | 2009-2012 | sporadic monthly |
| Pond 109 salinity | St. Denis | 1993-2012 | continuous monthly / weekly |
| Pond 109 chemical composition | St. Denis | 2007-2009, 2012 | sporadic monthly |
| Mini-observation wells | St. Denis | 7/2012 | continuous weekly / daily |
| EM-38 | St. Denis | 24/7/2012 | One time |

Page 13479, Line 8: Please add location of the climate station to Fig. 1A.
The station is in Saskatoon (Appear on the map in Figure 1A). We will rephrase the text to describe the location of the station in Saskatoon.

Page 13480, Line 4: Please add the information where you obtained the data for the pond depths presented in section 3.1.
We will rephrase the text to indicate that these measurements were taken by Environment Canada.

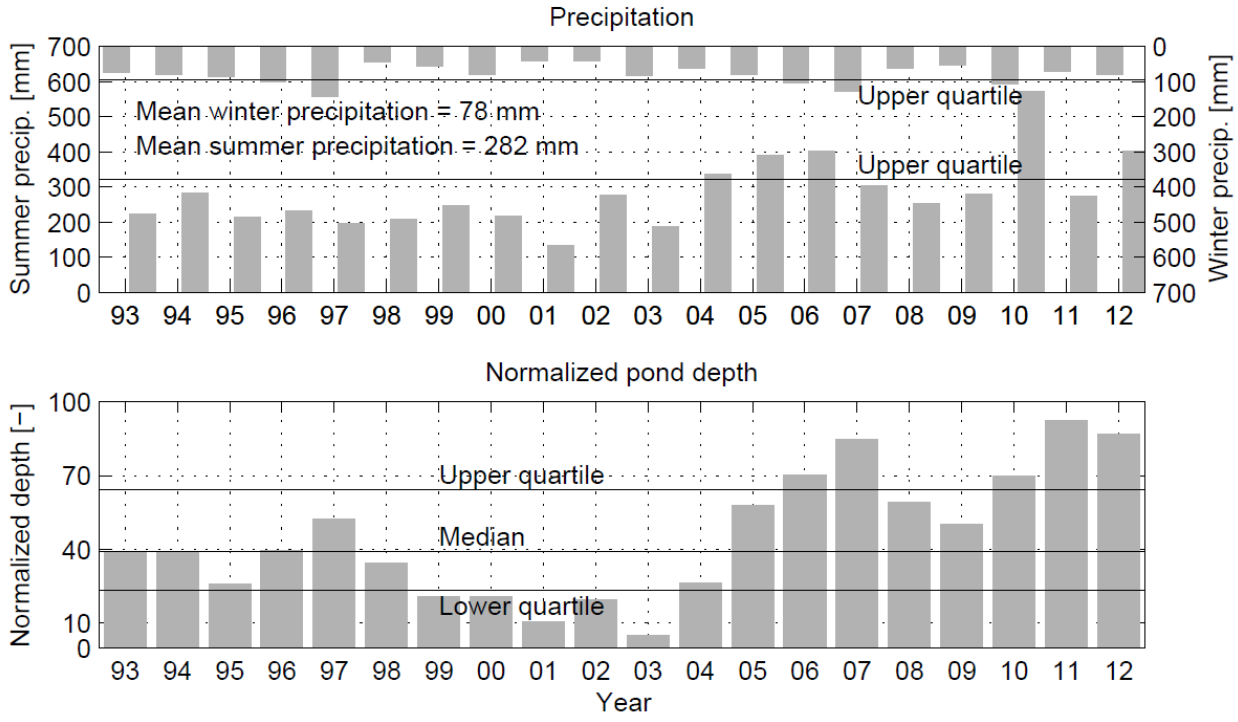
Authors reply

Page 13482, Line 22: Why some of the ponds used for water level analysis are different than ones used in section 3.2 for salinity analysis? It would make sense that you use the same ponds for field scale analysis, as you are trying to correlate the water levels with pond salinity.

The reviewer is correct, but unfortunately, we can only use the data that are available.

Page 13482, Line 26: Please explain why you have chosen the normalized water level of 70% as representative for wet conditions.

We did not intend this threshold to be over interpreted – we do not have enough data to do rigorous statistical analysis of extremes. Originally, we simply selected the years which appeared to be significantly wetter than the rest of the data using our best judgment. However, we have modified this analysis very subtly to focus instead on the upper quartile of pond levels and precipitation data. This is still an arbitrary selection, but is a bit more transparent. The upper quartiles are indicated as thresholds in a revised Figure 2 (attached below), which is now completely consistent with Table 1 (accounting for the correction pointed out by the reviewer, see response immediately below this one).




Page 13483, Line 2: Table 1 would make even more sense if the data would be sorted from the highest (2011) to lowest (2010) water table level. This could give indication of the dominant processes that influence high water levels in the ponds – it seems that high water levels in

previous year and highly saturated soil at the beginning of winter are the dominant factors that cause the increase in the pond depth. Furthermore, in Table 1 if you include year 2006 as High Winter Snowpack, then based on Fig. 2 year 2010 should be included as well.
We prefer to leave the table sorted chronically. The point is that all four of the factors in the table can contribute to high pond levels, but they have different impacts on salinity, as is brought out later in the paper. We do not discuss groundwater/water tables, in this section of the paper, as it is difficult to have a single, meaningful measure of groundwater for the entire site. We agree on the comment regarding 2010 and this year will be marked as a snowy year as well.

Page 13483, Line 19: I am assuming that the pond classification based on salinity presented in Fig. 3 was determined based on the measurements of EC from 2009 – please clarify.
Reviewer is correct and this point will be clarified.

Page 13483, Line 22: All brackish-saline ponds become diluted, except pond 70 during 2010. Please comment on that.
The reviewer is correct that there is a single datapoint that is not consistent with the overall pattern – in Pond 70 there is an anomalous drop in concentration in 2010. We do not know whether this is real or a measurement error. We had previously written that the pattern was "almost completely consistent" (Page 13483, Line 20) and the "almost" was referring to this datapoint. We will add the following sentence (bold): "There is an almost completely consistent pattern in the response, with fresh water ponds becoming salinized over the wet period from 2010 onwards, brackish-saline ponds becoming diluted, and moderately-brackish ponds having relatively stable EC values. **The only significant anomaly to this pattern is in Pond 70 in 2010, which we cannot explain.**"

Page 13483, Line 23: I am not sure what you mean by sentence: "The water flushed into ponds…. ". Please clarify.
We meant to say that the fact that the moderately-brackish ponds didn't change their salinity under rain associated wet conditions indicates that the salinity of the water entering the ponds is similar to the moderately-brackish ponds salinity. We will improve the sentence to improve clarity.

Authors reply

Page 13484, Line 2: The conclusion about increase in the salt mass would be clearer if the subplot showing Msalt for the selected pond vs. time would be added in Fig.3 (if Msalt can be calculated using Eq. 1 and 2 with data from section 3.1).
This would be good, but unfortunately Msalt for all of the ponds presented in Figure 3 cannot be calculated as we don't have observations of all of the pond depths and do not know all of the pond depth-volume relationships, both of which are required to estimate Msalt. This relationship has been established for a small number of ponds, notably pond 109, which we focus on in detail.

Page 13484, Line 14: As mentioned before, I would present water depths in pond 109 from 1993, to correspond to all the other data analysis.
As mentioned above, we prefer to leave this figure for the 40 years record to emphasize the unique conditions observed at 2010 onward.

Page 13485, Line 25: As mentioned before, please explain why you think snowmelt has a negligible effect on the salt cycle.
As mentioned in our reply earlier, we will rephrase the manuscript, mainly by adding another section at the end to explain the conceptual model we suggest and to explain why snowmelt impact on ponds salinization is minimal.

Page 13487, Line 15: I am assuming that the valid assumption could be that there is more than one inflow/outflow point to the pond, and hence though the piezometers analysed show the inflow at that locating, the overall system could be receiving water causing decrease in salinity.
This is true and this is the point we wanted to make. Apparently it is not clear enough and we will improve the sentence.

Page 13490, Line 3: In the Nachshon et al. (2013) the potential impacts of increased snowfall and precipitation are analyzed, concluding that more rainfall could cause the raise of groundwater levels beneath uplands compared to ponds, which could direct the groundwater flow from upland to pond and hence increase the pond salinity. On contrary, the increase in snowfall will increase spring snowmelt, hence increasing surface runoff and diluting the pond water. These conclusions entirely correspond to ones presented in this manuscript, and support the conceptual representation of the process given in Nachshon et al. (2013). Hence, I would

suggest the authors to use the 2013 paper to support the conclusions in this manuscript, and also add additional value to their previous work.

We highly appreciate the reviewer for raising this point and we will do so in the new section we will add at the end of the manuscript regarding the conceptual model and summary of the presented concepts from the paper.

**Technical corrections:**

All lines: The text is generally too dense in a sense that separating it into more paragraphs would make it much easier to read.

We will go again over the text and will try to improve it as much as possible.

All lines: Since you use capital letters in Figure labelling, please use the same notation in the text as well (e.g. Fig. 1A instead of Fig. 1a).

Will do that.

Page 13477, Line 14: Please add the full stop at the end of the sentence "…Montana and the Dakotas in USA."

Will do that.

Page 13477, Line 21: I would use full stop rather than semicolon (the same applies for Line 25). If, however, the semicolon is used, then please use the small letter in Line 21 for snowmelt.

We will put a full stop.

Page 13478, Line 24: You use willow ring term twice, once with and once without (Line 26) quotation marks. Please correct.

OK. We will omit the quotation marks.

Page 13481, Line 14: Please replace "For this period,…" with "During this period,…"

Will do that.

Page 13485, Line 4: When explaining Fig. 5, please put subplot notation before the text, i.e. "Fig. 5 presents (A) estimated pond…."

Will do that.

Authors reply

Page 13486, Line 20: Please add comma in the sentence: "…, and epsomite (MgSO4 7H2O), which…."

Will do that.

Page 13499: In Fig. 5 please indicate what you mean by NC and WC (NC=normal conditions, WC=wet conditions?).

Will do that.

Furthermore, the scale for the y-axis in subplot (B) for EC and Msalt could be decreased at least to 3000, which would make the trends in salinity change more visible.

This is true for all years excluding 2012, where Msalt reaches 4000. We did previously try the plots with a decreased scale on the y-axis, but we prefer to leave the scale as is to show the high values reached in 2012 and to enable easy comparison on the same scale between all the years.

Page 13503: In Fig. 9 please indicate dates of data sampling.

The dashed line in Column (A) indicates the day the measurements were taken, and this is pointed out in the figure caption