A Regional Analysis of Changing Climate Conditions and Glacier Mass Balance in Svalbard

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Abstract

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The Arctic archipelago of Svalbard has experienced among the greatest increases in temperature on Earth in the last few decades. The changing climatic conditions have a large impact on the glacier mass balance. This study makes use of a high-resolution model dataset with data on climatic and glacier conditions on Svalbard from 1957 to 2018. The model dataset is used to analyse the spatiotemporal variability in glacier mass balance across Svalbard and linking those changes to long-term trends in meteorological conditions. The study is focused on the spatial gradients in trends between two regions in Svalbard, the coldest part of the archipelago, Nordaustlandet and the milder southern part of the main island Spitsbergen. The north eastern (NE) region is found to have a greater increase in annual air temperature over the simulation period with 5.5 °C compared to 3.5 °C for the south western (SW) region. The increase in annual summer temperatures is much smaller with a total increase of 1 °C for the NW and 1.5 °C for the SW. Both regions show a small, but significant, increase of precipitation. Relative humidity and cloud cover in the NE are increasing slightly over the time period, probably due to retreating sea ice cover. Glacier melt and runoff are increasing in both regions, which is contributing to significant negative trends in the mass balance. The increase in melt and run off is stronger in the SW than in the NE. There’s a strong correlation between summer air temperature and glacier mass balance, melt and runoff. Refreezing in the NE is decreasing much faster than in the SW. Refreezing is strongly correlated with annual air temperatures in the NE and not in the SW, probably due to lower temperatures in the NE region.

Key words: glacier mass balance, model data, climate change, Svalbard

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Sammanfattning

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Svalbards arktiska skärgård har upplevt bland de största höjningarna av temperaturen på jorden under de senaste decennierna. De förändrade klimatförhållanden har stor inverkan på glaciärmassbalansen. Denna studie använder sig av ett dataset med hög upplösningsmodell med data om klimat och glaciärförhållanden på Svalbard från 1957 till 2018. Modelldatasetet används för att analysera den spatiotemporalna variabiliteten i glaciärmassbalansen över Svalbard och länka dessa förändringar till långsiktiga trender under meteorologiska förhållanden. Studien är inriktad på de rumsliga gradienterna i trender mellan två regioner på Svalbard, den kallaste delen av skärgården, Norra Austlandet och den mildare södra delen av huvudön Spetsbergen. Den nordöstra (NÖ) regionen har en större ökning av den årliga lufttemperaturen över simuleringssperioden med 5,5 °C jämfört med 3,5 °C för sydvästra (SV)-regionen. Ökningen i årliga sommartemperaturer är mycket mindre med en total ökning av 1 °C för NW och 1,5 °C för SW. Båda regionerna visar en liten men betydande ökning av nederbörd. Relativ luftfuktighet och molntäckning i NÖ ökar något över tiden, troligen på grund av minskade utsträckning av havsis. Glaciärmältning och avrinning ökar i båda regionerna, vilket bidrar till betydande negativa trender i massbalansen. Ökningen av smältning och avrinning är starkare i SV än i NÖ. Det finns en stark korrelation mellan sommartemperaturen och glaciärmassbalansen, smältningen och avrinningen. Omfrysningen i NÖ minskar mycket snabbare än i SV. Omfrysning är starkt korrelerad med årliga lufttemperaturer i NÖ och inte i SV, troligen på grund av lägre temperaturer i NÖ-regionen.

Nyckelord: glaciär massbalans, klimatförändringar, modelldata, Svalbard

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1. Introduction
Land areas in the Arctic have during the last few decades experienced a greater increase in temperature than any other place on earth. This phenomenon is referred to as “Arctic Amplification” and is thought to be caused by feedback mechanisms from the loss of sea ice. A reduction of sea ice and the melting of ice covers lowers the surface reflectivity (albedo), which in turn leads to an increase of absorption of solar radiation and additional surface warming (Serreze et al. 2011).

Arctic sea ice exhibits an annual cycle with maximum extent in spring and minimum extent in late summer. The warming of the Arctic has led to less sea ice during all seasons, with the record minimum extent in September 2012 (Nordli 2014).

Melting of land-based ice and thermal expansion of the oceans due to the atmospheric warming are the two main contributors to global sea level rise. The present-day sea-level rise is 3.0 mm per year, where about 2.0 mm is due to melting of ice masses and glaciers and the remaining 1.0 mm is due to thermal expansion (IPCC 2014).

Compared to the massive ice sheets of Greenland and Antarctica the smaller glaciers and ice caps in places as Svalbard are still regarded to be a major contribution to the current sea level rise. At present, about two thirds of the present-day contribution to sea level rise comes from smaller ice caps and glaciers outside the Greenland and Antarctic ice sheets (IPCC 2014).

Svalbard is an archipelago of various sized islands situated north of Norway and to the east of Greenland. Svalbard is on average a more mild, wet and cloudier location than other places on the same latitude. This is mostly due to the warm West Spitsbergen Current which flows along the western coast of Svalbard. The warm Atlantic water keeps the western side of Svalbard mostly ice-free year-round (Østby 2017; Van Pelt 2014). The heat transport to the atmosphere that the warm Atlantic water provides contributes to the spatial temperature difference found in Svalbard. The south western part of the archipelago is the area with the highest air temperatures and the coldest air temperatures are found in the high-altitude glacier areas in the north (NCCS 2019). South-western Svalbard also experiences a higher precipitation rates at sea-level than the northeast as well as larger precipitation to elevation gradients (Van Pelt et al. 2016).

The Arctic responds at a faster rate to the changing global climate, this is also true for the climate of Svalbard. Observational data from a weather station located at Svalbard Airport show a local increase of mean surface temperature of 0.26°C per decade since 1892 (Nordli 2014). Additionally, precipitation is found to weakly increase at Svalbard Airport by 2% per decade during 1912-2005 (Førland et al. 2011). This precipitation increase is consistent with large-scale (Arctic-wide) assessments (Zhang et al. 2013).

Up to 60% of the land area of Svalbard is covered by glaciers or ice caps. The glaciers have an estimated volume of about 6200 km³ that would equal a 1.5 cm sea level rise when melted entirely (Fürst et al. 2018). Svalbard hosts many types of glaciers and ice caps, largest by area are ice fields that are divided by mountain ridges into ice individual ice streams. Additionally, many small cirque glaciers are found in the mountain regions of western Spitsbergen. Some of the ice caps in Svalbard calve directly into the sea and with an estimated calving front length of 1000 km (Hagen et al. 2003). Because of the cold temperatures and the moisture from the Barents Sea in the north and eastern part of Svalbard this is also the area with the largest fraction of total land area covered by glaciers (Hagen et al. 2003).
This study focuses on two different regions in Svalbard. One region situated in the coldest part of the archipelago, Nordaustlandet, a large island in the north east and the much milder southern part of the main island Spitsbergen (Fig. 1). Nordaustlandet hosts two major ice caps, Austfonna and Vestfonna, that together constitute half of the volume of ice on Svalbard (Fürst et al. 2018). The south-western region consists of the part of the main island Spitsbergen which is south of Olav V land and Oscar II land (Fig. 1). The northeast and southwest regions will throughout the report instead be referred to as the NE and SW regions respectively. These two places are of interest to study as they to respond differently to the changing climate, particularly due to the varying impact of sea-ice retreat on the regional climate.

The impact of changing climate conditions on the state of glacier mass balance in Svalbard has been the subject of several previous modelling studies (e.g. Claremar et al. 2012; Van Pelt et al. 2012, 2016; Ostby et al. 2017; Möller et al. 2018). Here, I analyse output from a new model output dataset (Van Pelt et al. in review; https://doi.org/10.5194/tc-2019-53). Modelling studies provide important spatially distributed and temporally homogeneous information about climate and glacier conditions across Svalbard, that cannot be extracted from the typically scarce observational data.

This long-term modelling dataset describes climatic mass balance, snow conditions and runoff in Svalbard during 1957-2018. The model generates a 3-hourly temporal and 1 x 1 km spatial resolution of meteorological and glacier variables for the years 1957 to 2018. Here, the focus is on meteorological parameters of temperature, precipitation, cloud cover and humidity, and also the glacier mass balance, melt, refreezing and runoff. More details and information about the model dataset is given in the Data section and in Van Pelt et al. (in review).

The aim of this work is to use the high-resolution model dataset to analyse spatiotemporal variability in glacier mass balance across Svalbard, and to link those changes to long-term trends in meteorological conditions. There will be a particular focus on spatial gradients in trends between SW and NE Svalbard.
2. Data
The data used in this project is from the already existing model long term dataset of climatic mass balance, snow conditions and runoff in Svalbard (1957-2018) by Van Pelt et al (submitted). In which the surface energy balance model is coupled with a multilayer snow model, this is then applied to land and glacier-covered areas of Svalbard. The surface energy model accounts for heat exchange at the surface which determines the surface temperature and melt. The multilayer snow model accounts for snow compaction, water transport, refreezing, heat conduction, irreducible water storage and runoff to simulate temperature, density and water content below the surface.

To optimize and validate the model output, observational data was used in Van Pelt et al. (in review), including stake measurements, data from weather stations and shallow cores. This helped to assure unbiased model performance at the observation sites.

Together, this model generates a 3-hourly temporal and 1 x 1 km spatial resolution for both meteorological and glacial parameters from the 1957 to 2018 over the whole of Svalbard.

Instead of 3-hourly values for the variables from the original dataset it was determined that annual values were sufficient for most of the analysis that was done.
here. Additionally, mean summer air temperature is important to include as well as glacier melt only occurs during the summer months in Svalbard.

The data used in this study is limited to only include data for land areas that are covered by glaciers or ice caps. This means all glacier-free regions are excluded from the analysis. This is done to allow for studying the connection between climate and glacier variables. Two separate masks were used to isolate the area for analysis of the SW and NE region (Fig. 1). The mask outline is used to select each region and thereby only include data for the variables in the separate regions when doing calculations with the functions in MATLAB.

The following variables were selected for analysis in this study:

**Climate variables:**
- *Air temperature:* annual mean of the air temperature at 2m above the surface (degrees Celsius).
- *Summer mean temperature:* mean air temperature, 2m above the surface, during the summer months June to August (degrees Celsius).
- *Precipitation:* sum of all precipitation over a year in meter water equivalent (m w.e.).
- *Snow- and rainfall:* sum of precipitation as snowfall or rainfall over a year in meter water equivalent.
- *Relative humidity:* the relative humidity of the air, 2m above the surface (%).
- *Cloud cover:* mean cloud cover during a year (%).

**Glacier variables:**
- *Mass balance:* the annual mean change of the mass of the glacier due to glacier – atmosphere interactions (m w.e.).
- *Melt:* water from melting snow or ice at the surface (m w.e.). Runoff of melt water is apart from glacier calving the main contributor to glacier mass loss.
- *Refreezing:* meltwater and rainfall that refreezes in the snowpack on the glacier (m w.e.). Contributes both mass and energy to the subsurface as refreezing of water creates ice layers in snow packs and releases latent heat.
- *Runoff:* amount of melt and rain water that enters the glacier at the base of the snow pack (if present) or at the surface if snow is absent (m w.e.).

When calculating annual mean values for the climate and glacier variables, a year is always defined as a mass balance year, typically running from September to August. This definition is convenient particularly for the glacier variables as the record starts and ends between the interval of between two successive minima in surface height, in the beginning of the accumulation season and ends at the end of the ablation season.
3. Methods
All figures, plots, calculation of trends and correlations in this study were produced in MATLAB. The curve fitting toolbox (cftool) was used to determine trend lines and correlations between the produced time-series of the climate and glacier variables. Also included in the information provided by cftool are confidence limits of regression functions, which are used to detect whether a trend is significant at a 95-% confidence level.

To produce distributed maps showing the mean for the studied variables the pseudocolor plot function (pcolor) function was used. Furthermore, time-series of the different variables were created plotting the temporal variation of the variable to the time period 1958-2018 using the standard plot function.

The first focus of this project was to do a climate trend analysis in the NE and SW region with the provided data on temperature, precipitation, cloud cover and humidity for the time period 1957-2018. The long-term mean for each climate variable over 1957-2018 was also determined for every 1x1-km grid cell to generate distributed maps for all of Svalbard. Next, the same was done for the glacier variables, i.e. mass balance, melt, refreezing and runoff. Significance of trends is determined by testing whether a zero-slope is contained within the confidence limits of a trend.

To analyse how the changing climate affects the glacier conditions correlation analysis is performed between all climate and glacier variables. The resulting Pearson R-correlation values between the climate and glacier variables indicates how well they correlate on a year-to-year basis. The R-value ranges from 0 to 1, where 0 indicates no correlation and 1 would indicate a perfect correlation between the two variables.
4. Results

4.1 Climate conditions

Table 1. Mean and trend for climate conditions for the SW and NW regions in Svalbard over the period 1958-2018. Significant trends, which do not contain a zero slope within the presented interval are highlighted in bold.

<table>
<thead>
<tr>
<th></th>
<th>South West</th>
<th>North East</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Trend (yr⁻¹)</td>
</tr>
<tr>
<td>Annual temperature (°C)</td>
<td>-8.23</td>
<td>0.06±0.018</td>
</tr>
<tr>
<td>Summer temperature (°C)</td>
<td>1.9</td>
<td>0.02±0.007</td>
</tr>
<tr>
<td>Precipitation (m w.e yr⁻¹)</td>
<td>1.2</td>
<td>0.001±0.000</td>
</tr>
<tr>
<td>Snow fall (m w.e yr⁻¹)</td>
<td>0.98</td>
<td>0.000±0.002</td>
</tr>
<tr>
<td>Rain fall (m w.e yr⁻¹)</td>
<td>0.24</td>
<td>0.001±0.001</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>86%</td>
<td>0.040±0.012</td>
</tr>
<tr>
<td>Cloud cover (%)</td>
<td>78%</td>
<td>-0.03±0.06</td>
</tr>
</tbody>
</table>

Figure 2. a) Distributed map of mean air temperature during 1958-2018. b) Time-series of annual air temperature in the southwest and northeast region of Svalbard.

Mean air temperature for the time period 1957-2018 is generally milder in SW compared to the NE (Fig. 2). There’s a significant trend of an increase in mean air temperature for both regions. The NE has an annual temperature increase of about 5.5°C over the whole the time period. The SW has a smaller overall increase in
temperature of about 3.5°C. These trends are significant as they don’t contain a zero-slope gradient with a 95%-confidence level, see Table 1.

![Figure 3](image)

**Figure 3.** a) Mean summer (JJA) temperature during 1958-2018. b) Annual summer air temperature over the same period.

Mean summer air temperature is generally warmer in the SW parts of Svalbard (Fig. 3). There’s a significant trend in increasing summer temperature for the time period, a zero slope is not contained at a 95% confidence level. Notably the increase in summer temperature during the simulation period is much smaller than the increase of annual mean temperature, which is in line with observations at coastal weather stations in Svalbard (Førland et al. 2011). The increase in temperature at the end of the time series seems to be about 1°C for the NE and almost 1.5°C for the SW.

![Figure 4](image)

**Figure 4.** a) Distributed map of mean precipitation in Svalbard from 1958-2018. b) Annual precipitation for two regions over the same time period.

The mean precipitation of Svalbard seems to be higher inland with generally greater precipitation in the SW compared to the NE (Fig. 4). Despite large inter-annual variability, both trends are significant with a 95% confidence level (Table 1).
Interannual variability of precipitation appears coherent between the NE and SW (Fig. 4b).

Svalbard seems to have a higher mean of snowfall further inland, the NE seems receive less snowfall than the SW (Fig. 5). The time series for annual snowfall in the two regions exhibit strong interannual variability and opposing trends. The trend line for both regions are not significant as a zero slope is contained within the interval at a 95% confidence level, see Table 1.

Rainfall rates in Svalbard are typically small, except for coastal (low-elevation) areas in the southwest (Fig. 6). The trend of increasing rainfall in the SW might be significant as it contains a non-zero slope in the confidence interval. The rainfall trend in the NE region is hard to confirm due to high interannual variability and is not significant within a 95% confidence interval (Table 1).
Figure 7. a) Distributed map of mean relative humidity during 1958-2018. b) Time-series for the same period of annual mean relative humidity in the SW and NE of Svalbard.

The mean for relative humidity for the whole of Svalbard is almost identical, with a somewhat higher humidity in the NE (Fig. 7). Trend lines for humidity in the two regions are significant, see Table 1. The north east shows the highest increase of relative humidity from 81% to ca. 85% during 1958-2018.

Figure 8. a) Mean cloud cover over glaciers in Svalbard over the years 1958-2018. b) Annual cloud cover for the southwest and northeast region of Svalbard over the same time period.

At the start of the time series cloud cover shows a steady increase up until the 1990’s to then diverge at the end of the time period (Fig. 8). The trend line for decreasing cloud cover is not significant in the SW. The NE indicates a slight increase in cloud cover that is significant at a 95% confidence interval, see table 1.
4.2 Glacier conditions

Table 2. Trend and mean of glacial variables for two different regions in Svalbard.

<table>
<thead>
<tr>
<th></th>
<th>South West</th>
<th></th>
<th>North East</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (m w.e yr$^{-1}$)</td>
<td>Trend (m w.e yr$^{-1}$)</td>
<td>Mean (m w.e yr$^{-1}$)</td>
<td>Trend (m w.e yr$^{-1}$)</td>
</tr>
<tr>
<td>Mass balance</td>
<td>-0.15</td>
<td>-0.008±0.005</td>
<td>0.21</td>
<td>-0.003±0.004</td>
</tr>
<tr>
<td>Melt</td>
<td>1.30</td>
<td>0.009±0.003</td>
<td>0.71</td>
<td>0.005±0.002</td>
</tr>
<tr>
<td>Refreezing</td>
<td>0.22</td>
<td>0.0004±0.0002</td>
<td>0.23</td>
<td>-0.0008±0.0002</td>
</tr>
<tr>
<td>Runoff</td>
<td>1.27</td>
<td>0.010±0.004</td>
<td>0.55</td>
<td>0.006±0.003</td>
</tr>
</tbody>
</table>

Figure 9. a) Mean mass balance of Svalbard’s glaciers over the years 1958-2018. b) Annual mass balance in two regions over the same time period.

There is a positive mean mass balance in higher altitudes and a negative in lower altitudes closer to shore over the time period (Fig. 9). The trend line for mass balance is significant for both regions, see Table 2, with a greater decrease over time in the south west (Fig. 9).

Figure 10. a) Mean melt of Svalbard’s glaciers over the years 1958-2018. b) Annual melt in two regions over the same time period.
Mean melt in Svalbard is greater in the SW than in the NE. There’s increase of melt for the SW and NE over the time period and the trend line for significant for both regions, see Table 2.

![Mean melt in Svalbard](image1)

**Figure 11.** a) Mean refreezing in Svalbard 1958-2018. b) Annual refreezing in two regions over the same time period.

The trend line for annual refreezing is significant for both regions, see Table 2. There’s a higher decrease in refreezing for the NE region than the SW, the NE surpasses the SW in the early 2000’s in meter water equivalents per year (Fig. 7b).

![Refreezing](image2)

**Figure 12.** a) Distributed map of mean runoff in Svalbard over the years 1958-2018. b) Annual runoff in two regions over the same time period.

Mean annual runoff is lower in the NE and high elevations in Svalbard, higher in the SW (Fig. 12a). The trend lines for runoff is are significant over the time period for both regions and show an increase in runoff (Fig. 12b). The runoff trend is found to be substantially stronger in the SW than in the NE.
### 4.3 Correlation

**Table 3.** Correlation between climate and glacier variables described with corresponding R-value. Significant correlations are marked in **bold**.

<table>
<thead>
<tr>
<th></th>
<th>Massbalance</th>
<th>Melt</th>
<th>Refreezing</th>
<th>Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SW</td>
<td>NE</td>
<td>SW</td>
<td>NE</td>
</tr>
<tr>
<td>Annual air temperature</td>
<td>0.2</td>
<td>0.00</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>Summer temperature</td>
<td><strong>0.78</strong></td>
<td><strong>0.75</strong></td>
<td><strong>0.93</strong></td>
<td><strong>0.93</strong></td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.41</td>
<td>0.56</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Snowfall</td>
<td><strong>0.64</strong></td>
<td><strong>0.65</strong></td>
<td>0.23</td>
<td>0.03</td>
</tr>
<tr>
<td>Rainfall</td>
<td>0.28</td>
<td>0.12</td>
<td>0.48</td>
<td>0.39</td>
</tr>
<tr>
<td>Cloud cover</td>
<td>0.33</td>
<td>0.29</td>
<td>0.06</td>
<td>0.17</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>0.24</td>
<td>0.03</td>
<td>0.48</td>
<td>0.44</td>
</tr>
</tbody>
</table>
5. Discussion

Both the annual air temperature and the summer air temperature in the two regions are steadily increasing over the studied time period. The increase in summer temperature is smaller than annual temperature, this is coherent with the observed preferred winter/spring warming that is a known effect of Arctic warming (Førland et al. 2011).

Precipitation seems to be increasing slightly in both regions over the time period. With a modest increase in rainfall for the SW and a slight increase of snowfall in the NE.

Relative humidity is also increasing a few percent over the time period. This apparent trend might have some inaccuracies as the interannual variability is very large up until the 1990’s to then become more stable in the later years. The increase in relative humidity could be the result of increased exposure of open ocean around Svalbard, in connection with the retreat of sea ice around Svalbard. Sea ice retreat has a largest impact on ocean surface conditions around the NE of Svalbard, which may explain the largest relative humidity trend for NE Svalbard. On the other hand, it cannot be completely ruled out that trends in relative humidity may also result from time-dependent differences in the amount of observational data used to generate the reanalysis dataset that are at the basis of the downscaled regional climate model output analysed here. For example, the introduction of satellites may introduce biases in climate variables prior to the late 1970’s.

The above observational uncertainty also applies to cloud cover estimates. Nevertheless, as for relative humidity, the significantly increasing cloud cover in the NE may also be the result of decreased sea ice around Nordaustlandet in recent decades, which exposes ocean for a longer period of the year and enables more moisture exchange between the atmosphere and the surface.

All trends for mass balance, melt, refreezing and runoff are significant as they contain a non-zero slope within the 95% confidence interval. Mass balance is showing a decreasing trend for both regions, while at the same time melt and runoff is increasing. This is expected as a trend of decreasing glacier mass balance requires increased melting and subsequently, increasing runoff, since changes in precipitation (a source term for the mass balance) are comparatively small. Mass balance, melt and runoff trends are found to be more pronounced in the SW than in the NE of Svalbard. Conversely, the (negative) refreezing trend is found to be twice as strong in the NE of Svalbard.

There is a strong correlation between summer temperatures and mass balance, runoff and melting. This is expected as melting of the glaciers only occur during the summer months, this is reinforced by the even stronger correlation between summer air temperature and melt. There’s a very low correlation between annual temperatures and mass balance for both regions, which implies that temperatures outside the summer season are not important for the glacier mass balance. There is no significant correlation apparent between the mass balance and cloud cover and relative humidity. Which indicates that the mass balance is primarily controlled by precipitation and summer temperature.

Snowfall also has a correlation with the mass balance, which makes sense as it’s the main contribution to accumulation for the glaciers. Snowfall not only directly increases the amount of accumulation, it also reduces the amount of melt in ablation areas in the subsequent melt season, since a thicker snowpack takes more time to melt entirely, and therefore the surface reflectivity (albedo) may remain high for a longer period of time.
There’s a stronger correlation between refreezing and annual temperature for the NE compared to the SW region, this is most likely due to the overall lower temperatures for the NE. Also, in the SW higher temperatures lead to a pronounced increase in rainfall, which may increase refreezing and which partly outweighs the overall reduction in refreezing as winter warming generates warmer snow packs with less potential for refreezing at the start of the melt season. Refreezing is decreasing over time which could be explained by the increasing winter temperatures. Refreezing only occurs in snow that is below the melting point and warmer snow packs have less potential for refreezing melt and rainfall. Runoff and rainfall have a slightly higher correlation for the SW region, could be due to higher amounts of rainfall in the SW, again because of higher annual temperatures.

6. Conclusions
The aim of this work was to use a model dataset to link glacier mass balance to long-term trends of meteorological conditions on Svalbard. This was done by plotting temporal trends from 1957-2018 and by correlating climate and glacier variables using MATLAB.
Main findings:
- Significant warming across Svalbard, most pronounced in the NE and outside the summer season.
- A weak, but significant positive precipitation trend for both SW and NE Svalbard.
- Significant increasing relative humidity and cloud cover in NE Svalbard, possibly due to retreating sea ice conditions.
- Significant increases in melting and runoff, most pronounced in SW Svalbard, and contributing to significant negative trends in the mass balance.
- A significant reduction in the amount of refreezing over the simulation period, most pronounced in the NE.
- The mass balance is found to be most influenced by summer temperature and annual snowfall across Svalbard.

Acknowledgements
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References


Internet resources
