Paper

Brief communication: Accelerated glacier mass loss in the Russian Arctic (2010-2017)

The Cryosphere Discuss. https://tc.copernicus.org/preprints/tc-2020-358/

Comments to the authors

1. Summary and general comments

The presented work estimates the mass balance of three glaciated archipelagos of the Arctic Ocean in Northern Russia, namely Novaya Zemlya (NZ), Severnaya Zemlya (SZ) and Franz Josef Land (FJL). The three groups of islands are largely glaciated and were subject of several investigations related to their ice mass loss in the recent years using gravimetry and altimetry data. This study is based on elevation data from bistatic SAR satellite mission TanDEM-X and applies the meanwhile well-established method of calculating the ice surface elevation difference between DEMs acquired during the mission at different dates (here the winters 2010/2011 and 2016/2017). The methodology is one of the most precise for estimating spatially distributed, high resolution surface elevation change rates.

However, since NZ's mass loss is the largest of the three archipelagos (50% of the total) and because 70% of the TanDEM-X data in the winter 2016/2017 mosaic were acquired earlier, namely in September/October 2016, while the other two smaller archipelagos have each about a quarter contribution to the mass loss and the TanDEM-X data processed here were acquired in the same season a particular attention has to be given to the processing and analysis of NZ. Two problems arise here regarding the measured elevation changes:

1. the glaciological cycle is not fully covered missing parts of the accumulation period in the elevation change rate dh/dt.
2. the different reference surfaces of the InSAR DEMs from late summer/early autumn vs. winter introduce apparent changes in surface elevation due to differences in radar signal penetration.

Although these issues are addressed along the paper they are not clearly separated and the effects on the results are confusing. The uncertainty assessment of the mass change rate presented in this paper consists of three terms, the vertical coregistration being explained in detail. This term includes also the effect of SAR signal penetration as the factor S_{pen} (eq 2) resulted from the winter-autumn (WA) and winter-winter (WW) elevation changes of NZ. The authors apply a bulk correction which is a questionable approach because the surfaces of NZ glaciers extend over an elevation range of 1500 m and thus include ice/snow volumes of very different penetration properties, from close to zero for glaciers ice to several meters in the upper sections of the accumulation area (if dry). The elevation range implies a typical temperature difference of about 10 °C, so that – in particular in late summer and autumn – surface melt all over is rather unlikely. This indicates the need for localised penetration corrections, e.g. using backscatter coefficients in SAR amplitude images for assessing the melting state. The SAR backscattering coefficient on each archipelago is a more precise indicator than one mean monthly value of skin temperature (see specific comments).

2. Specific comments, minor comments & typos

Line 55: …$\times\ \sigma^2_{\Delta h/\Delta t\ AW}$… (in case this equation comes from the spherical variogram model)

Line 57: correct subscripts (S_{cor}, S_G)

Line 73: delete **/17** after autumn 2016. The explanations of the polynomial correction are insufficient and the results over NZ aren't traceable. See comments below.

Line 75 ff. melting/ penetration: the presence of melt should be assessed by checking the backscatter coefficients. In case differences in sigma0 between the data used for retrieving the elevation change are indicating differences in signal penetration, these should be corrected.

Lines 77 and 78: replace "images" with "TanDEM-X data" or "SAR data"

Line 94 to 98 and Fig. 2a: According to this analysis the period December-April 2010/11 to November-January 2016/17 (WW) shows higher average rates of elevation loss (dh/dt) than the period December-April 2010/11 to September-October 2016 (WA). This is contrary to the expected behaviour if the annual mass balance cycle is taken into account (as I mentioned at point 1. the winter accumulation is partly missing). A possible explanation could be a bias in the penetration correction. Fig. 2b: Novaya Zemlya extends from 71 N to 77 N and 0 m to 1500 m a.s.l. A single mean monthly mean skin temperature is not a useful indicator for estimating the melting state as major spatial and temporal differences have to be expected.

Line 100 ff.: Which "differences in the SAR derived elevation change rates" exactly? Cross reference Fig 2a if you are referring to the dh/dt of NZ for WW and WA periods. Or is a general statement?

Line 104: If accumulation is only partly included in the 2016/17 elevation this would lead (without applying a correction) to an overestimation of the surface elevation loss.

Lines 105: … elevation change of the WA period is less negative than of the WW period at all altitudes, …

Line 107 replace "decreases during melting conditions" with "is close to zero for melting snow surfaces and for bare glacier ice in general".

Line 117: I see in Fig S3a reddish areas (warmer temperatures) on the ocean and on the northern islands (FJL, SZ) not on the southern islands (NZ). The skin temperature does not show any temporal trend for the glaciers on NZ, supporting the comment above that the temperatures shown in Fig. 2b are not representative for the main glacier areas. The skin temperature increase is most pronounced on the ocean, due to the decrease in sea ice coverage.

Line 133: "indicate"

Line 254: Caption of Table 1: Overview of glacier elevation and mass change in the Russian Arctic between 2016 and 2017. This is probably a typo and should mean "2010/2011 to 2016/2017".

Line 275: The **a)** and **b)** notations on Fig 2 are missing.

Supplement

Fig. S1: Total precipitation units cannot be meter/day, but mm/day. Please add reference/data source for the ERA5 temperatures and precipitation and give the locations of the measurements.

Fig S3 the **a)** and **b)** notations are missing. But references to climate data related studies of the same period are more convincing in demonstrating the long term trends than the trends shown in these figures.

Please add a table with the specifications for the TanDEM-X database used in the study.