



Supplement of

Glacier surge activity over Svalbard from 1992 to 2025 interpreted using heritage satellite radar missions and Sentinel-1

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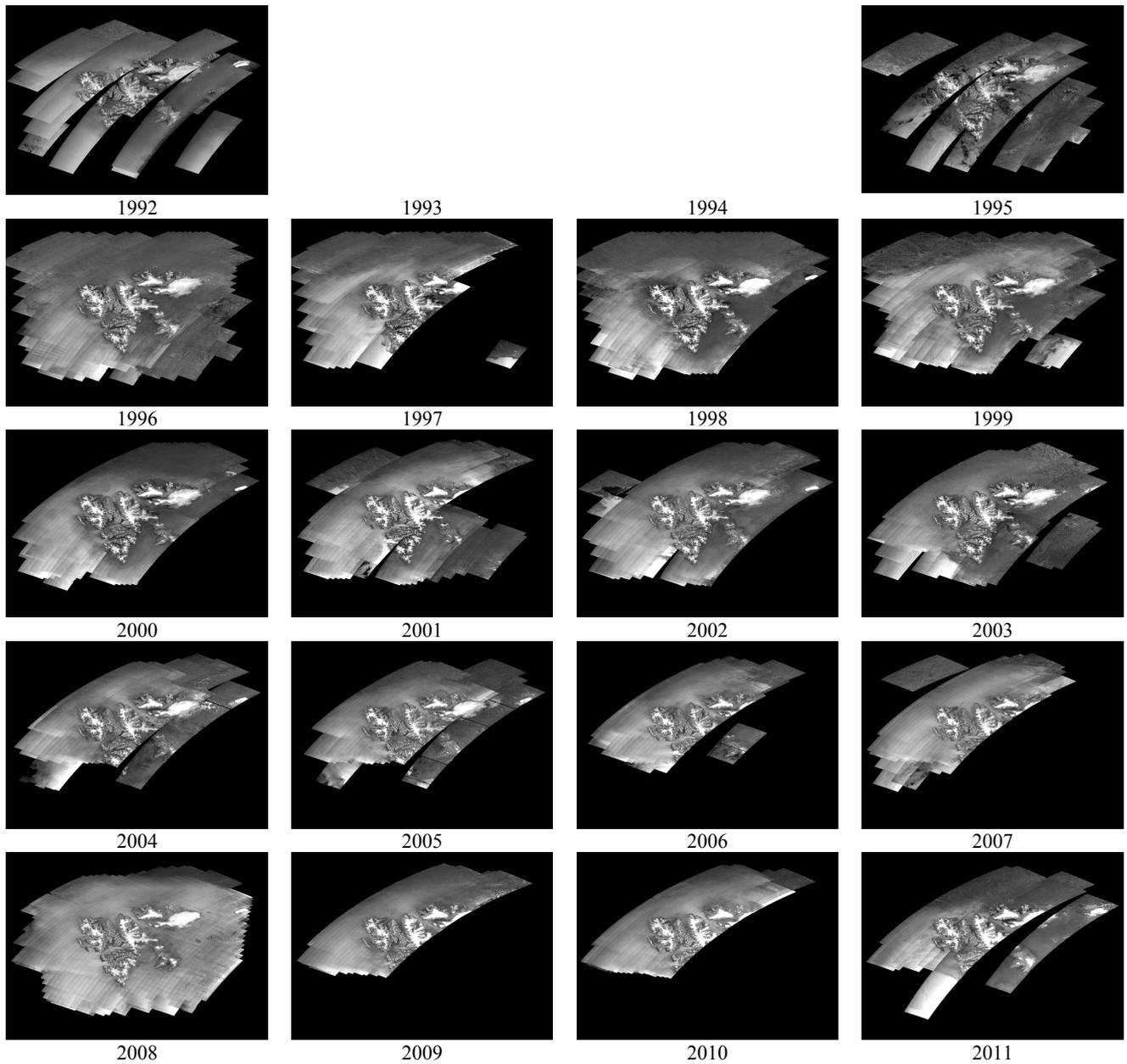


Figure S1. Mosaics of the ERS-1/2 average backscatter intensity from November to April of every year between 1992 and 2011 for the descending orbits. Note that years in the legend refer to the start of the winter, i.e., 1996 means e.g. November 1995 to April 1996. ERS-1/2 data © ESA.

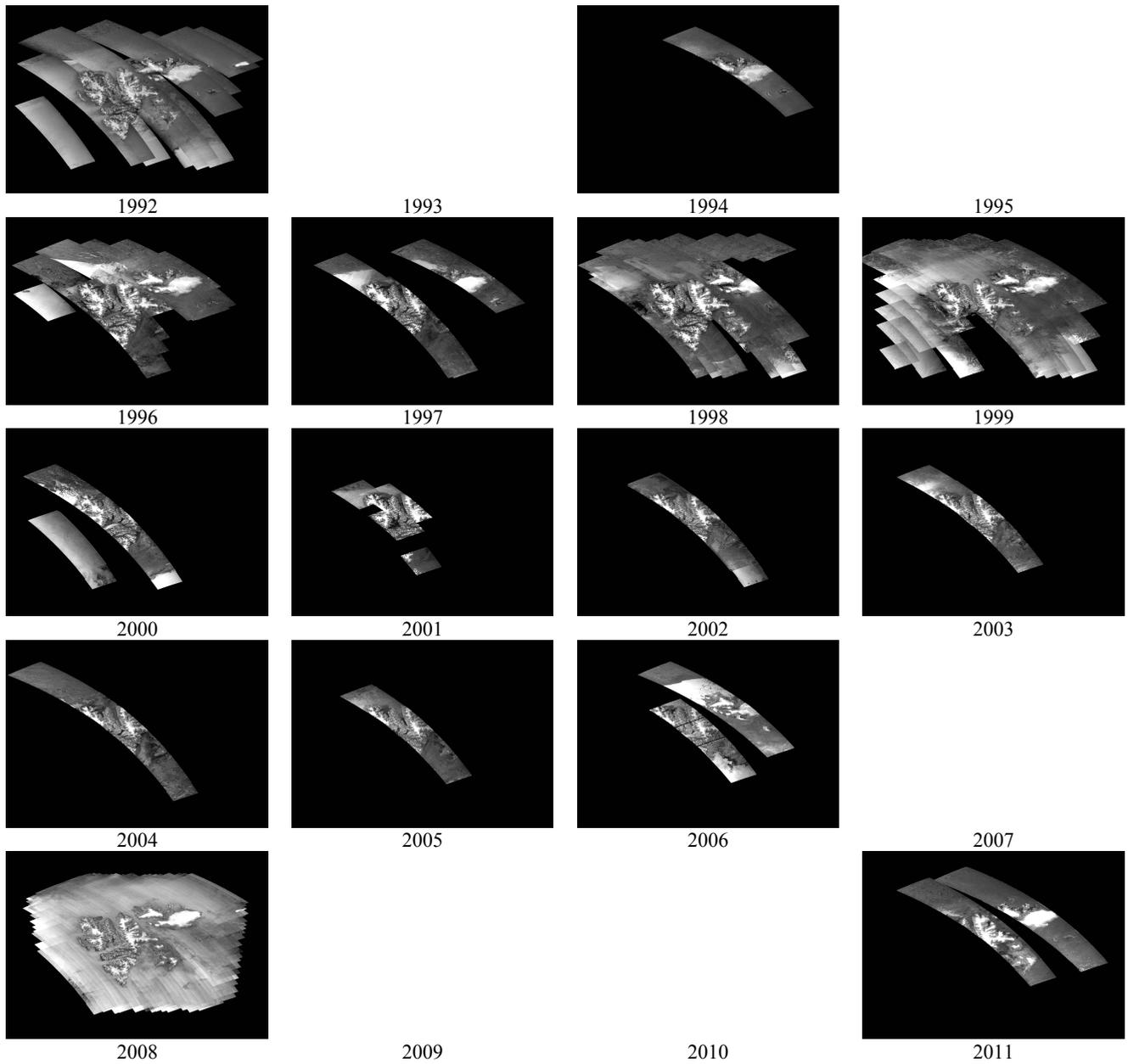
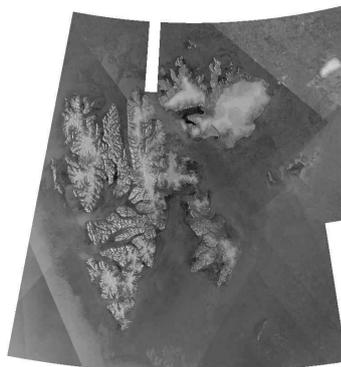


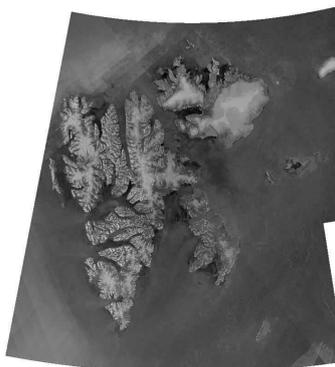
Figure S2. Mosaics of the ERS-1/2 average backscatter intensity from November to April of every year between 1992 and 2011 for the ascending orbits. Note that years in the legend refer to the start of the winter, i.e., 1996 means e.g. November 1995 to April 1996. ERS-1/2 data © ESA.



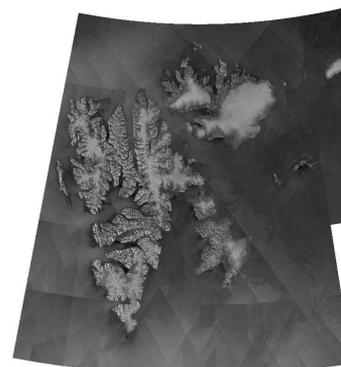
Figure S3. Mosaics of the JERS-1 SAR backscatter intensity for the months November to April of every year between 1992 and 1998. Note that the year refer to the end of the winter, i.e., 1993 means e.g. the winter season November 1992 to April 1993. Outlines from the Randolph Glacier Inventory 7.0 (RGI 7.0 Consortium, 2023) are shown in black. JERS-1 data © JAXA.



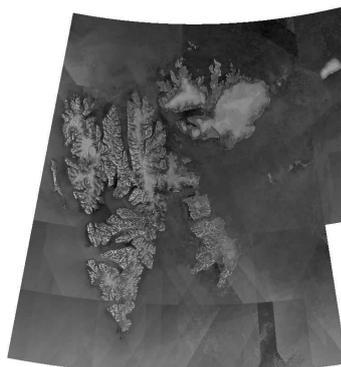
2003



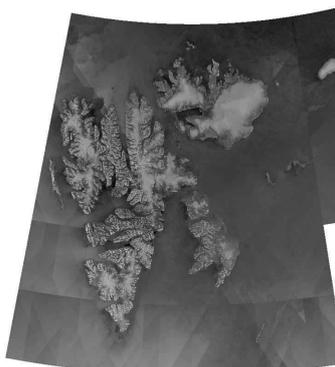
2004



2005



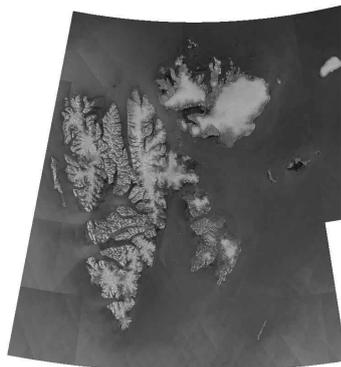
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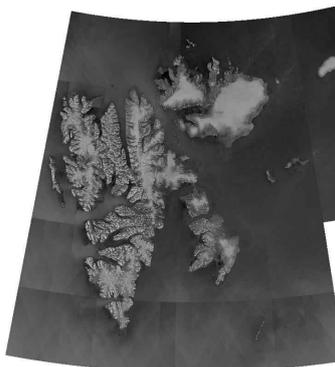
2007



2008



2009



2010

Figure S4. Mosaics of the ENVISAT ASAR backscatter intensity from January to March of every year between 2003 and 2010. Note that there are no acquisitions in the period from January to March 2005. ENVISAT ASAR data © ESA.

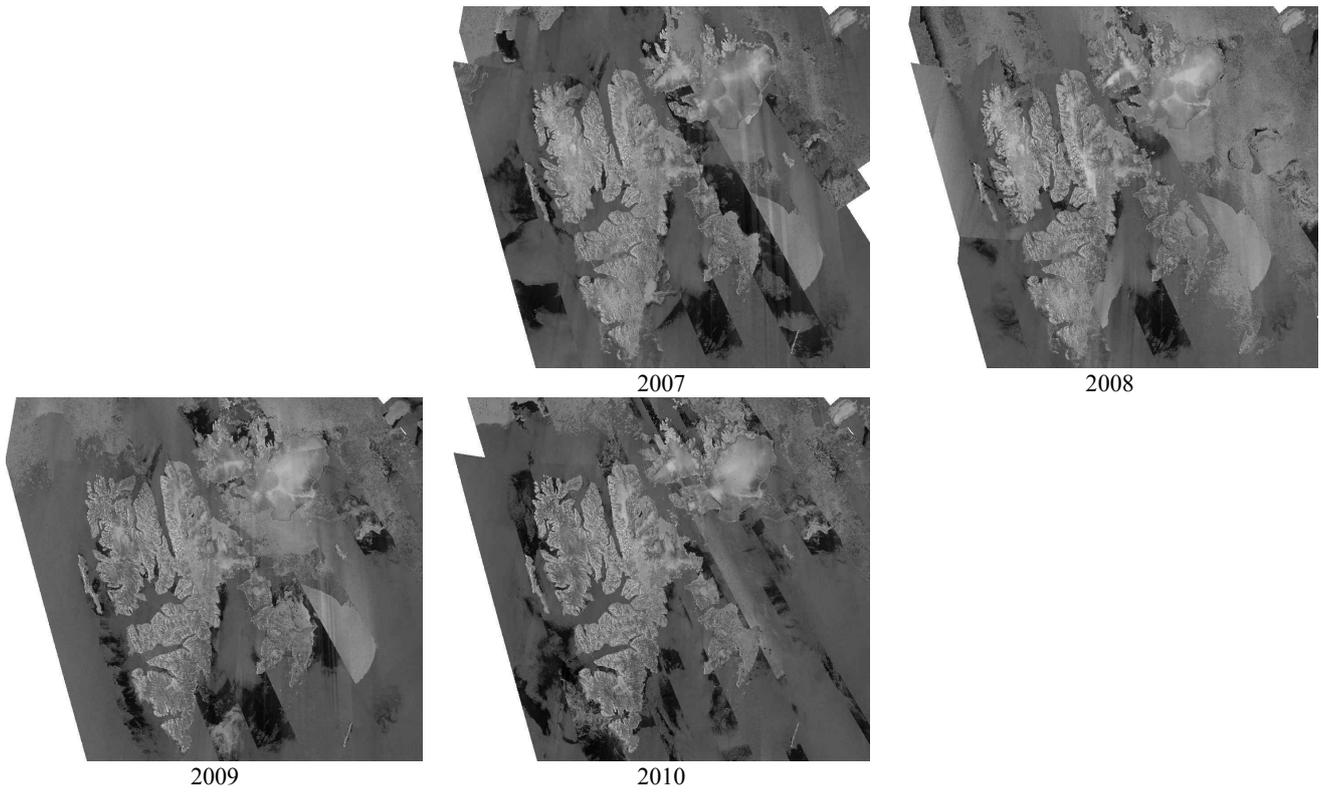


Figure S5. Mosaics of the yearly ALOS PALSAR backscatter intensity between 2007 and 2010. ALOS PALSAR © JAXA.

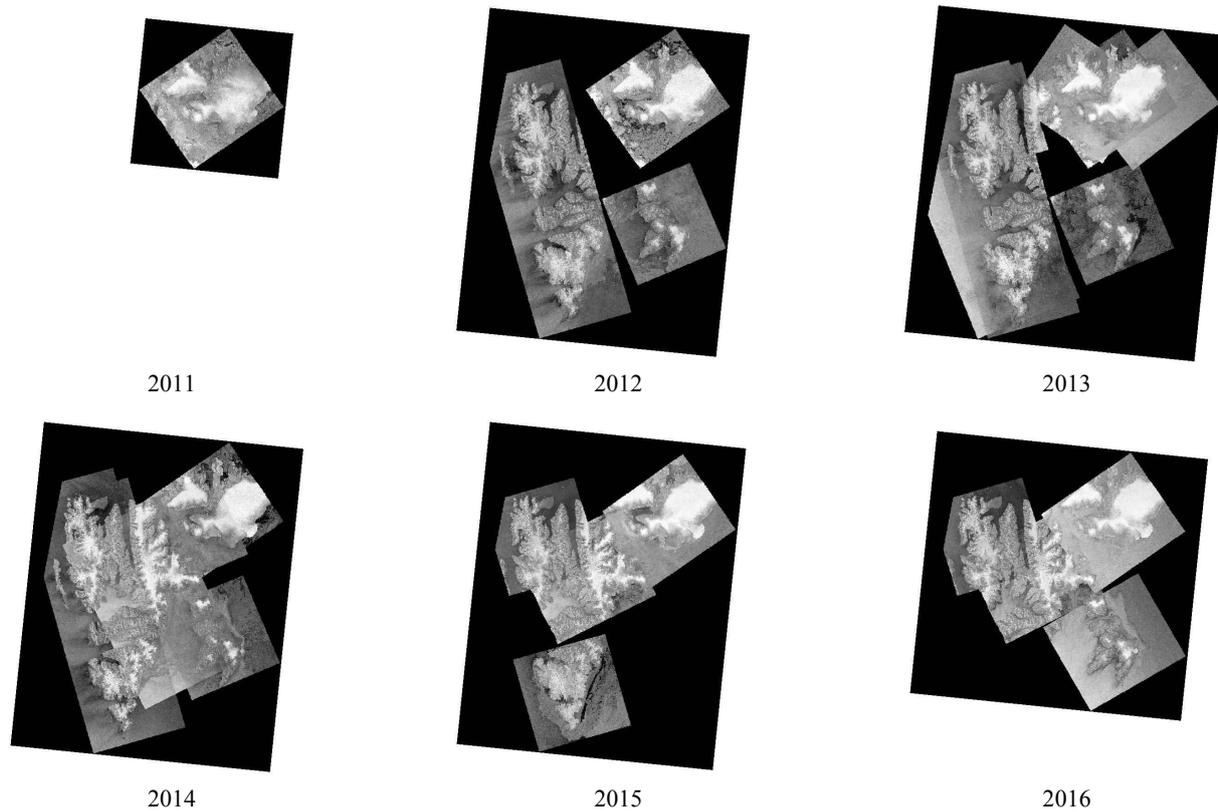
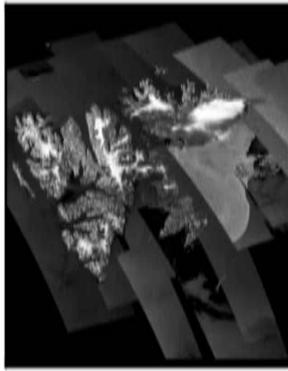
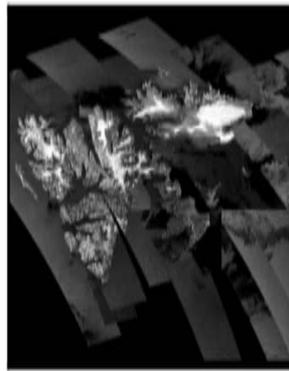


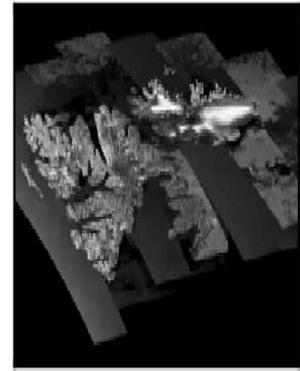
Figure S6. Mosaics of the RADARSAT-2 average backscatter intensity from October to April of every year between 2011 and 2016. Note that years in the legend refer to the end of the winter, i.e., 2016 means e.g. October 2015 to April 2016. RADARSAT-2 data © MDA.



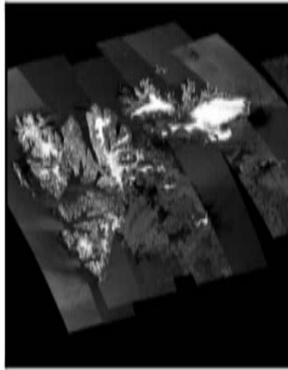
2015



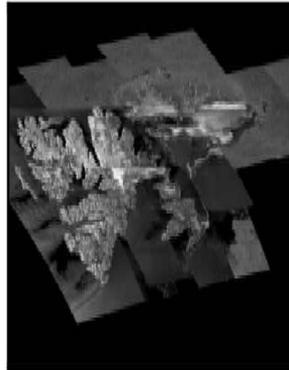
2016



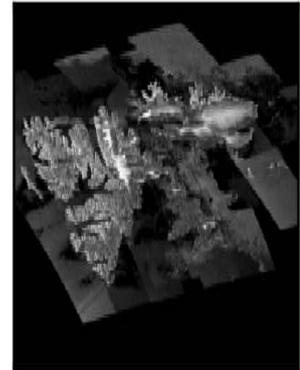
2017



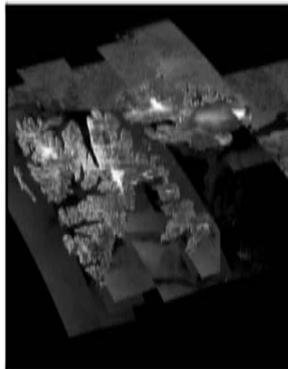
2018



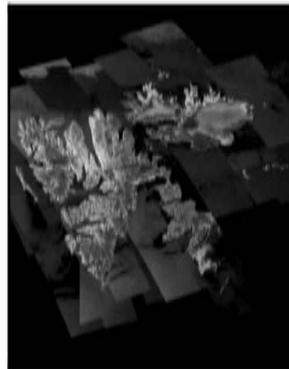
2019



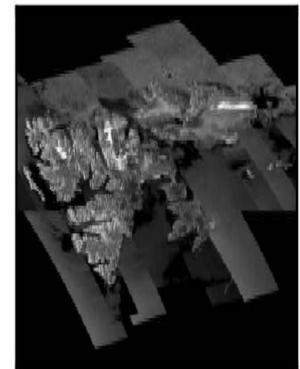
2020



2021

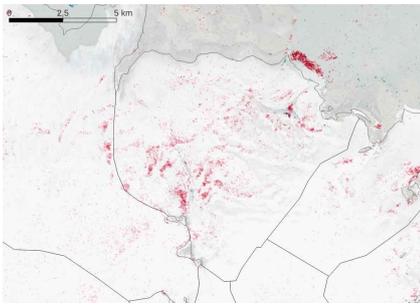


2022

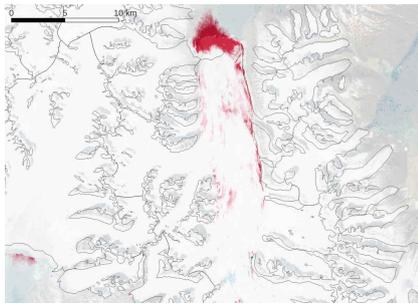


2023

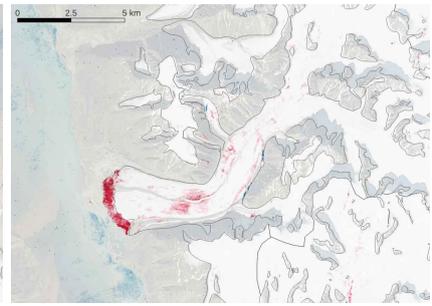
Figure S7. Mosaics of the yearly ALOS-2 PALSAR-2 backscatter intensity between 2015 and 2023. ALOS-2 PALSAR-2 data © JAXA.



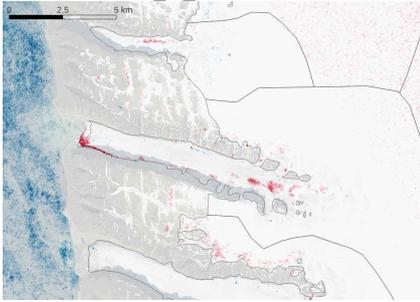
NULL_D 1996-1992



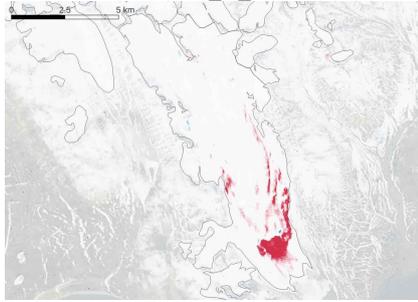
Monacobreen_D 1996-1992



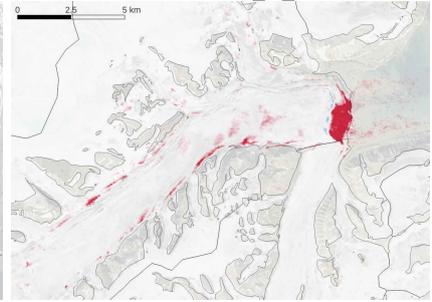
Stubendorffbreen_D 1996-1992



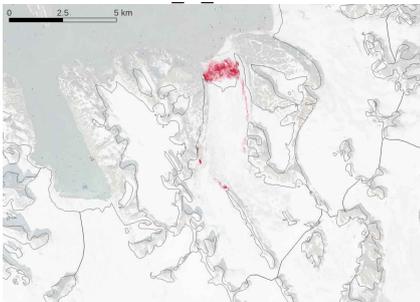
Midtbreen_A 1996-1992



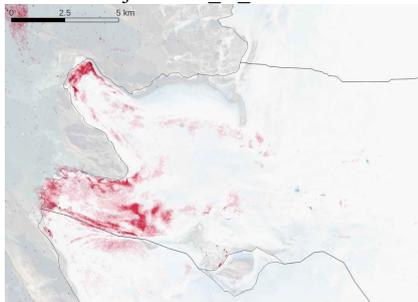
Fridtjovbreen_D 1996-1992



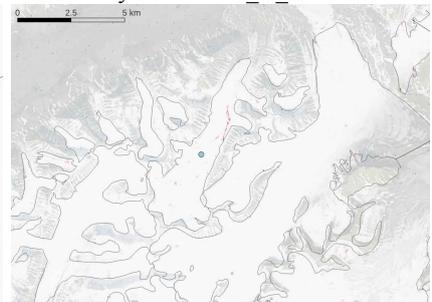
Chydeniusbreen_D 2002-1999



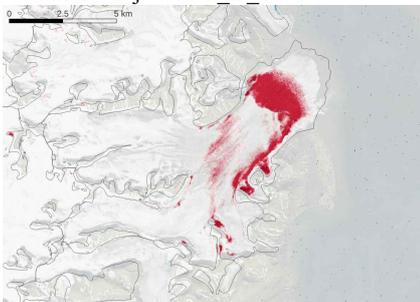
Mendelejevbre D 1999-1998



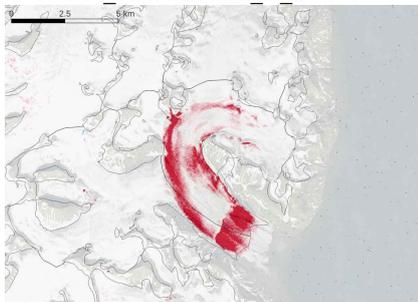
Nordre Franklinbreen_D 2002-1999



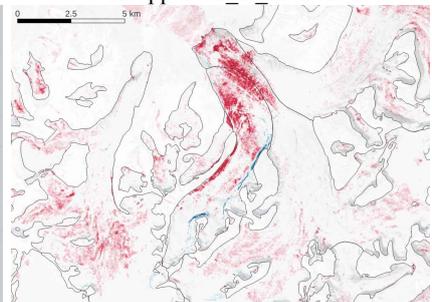
Kroppbreen_D 2002-1999



Perseibreen_D 2002-1999



Ingerbreen_D 2002-1999



Skobreen_D 2008-2003

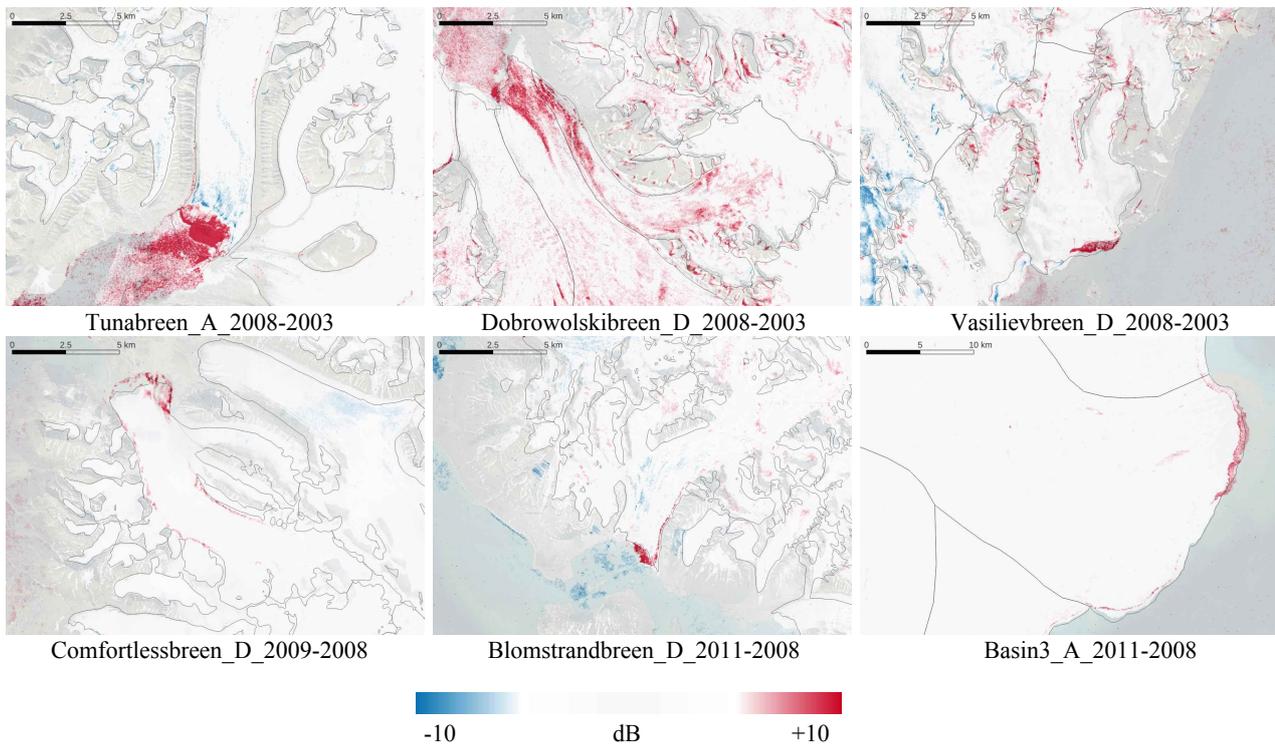


Figure S8. ERS-1/2 backscattering intensity change images for the surge-type events mapped over Svalbard over the period 1992-2011. The name of the glacier, the orbit direction (A: ascending, D: descending) and the dates of the winter mosaics are indicated below each image. Note that years in the legend refer to the end of the winter, i.e., 1996 means e.g. November 1995 to April 1996.

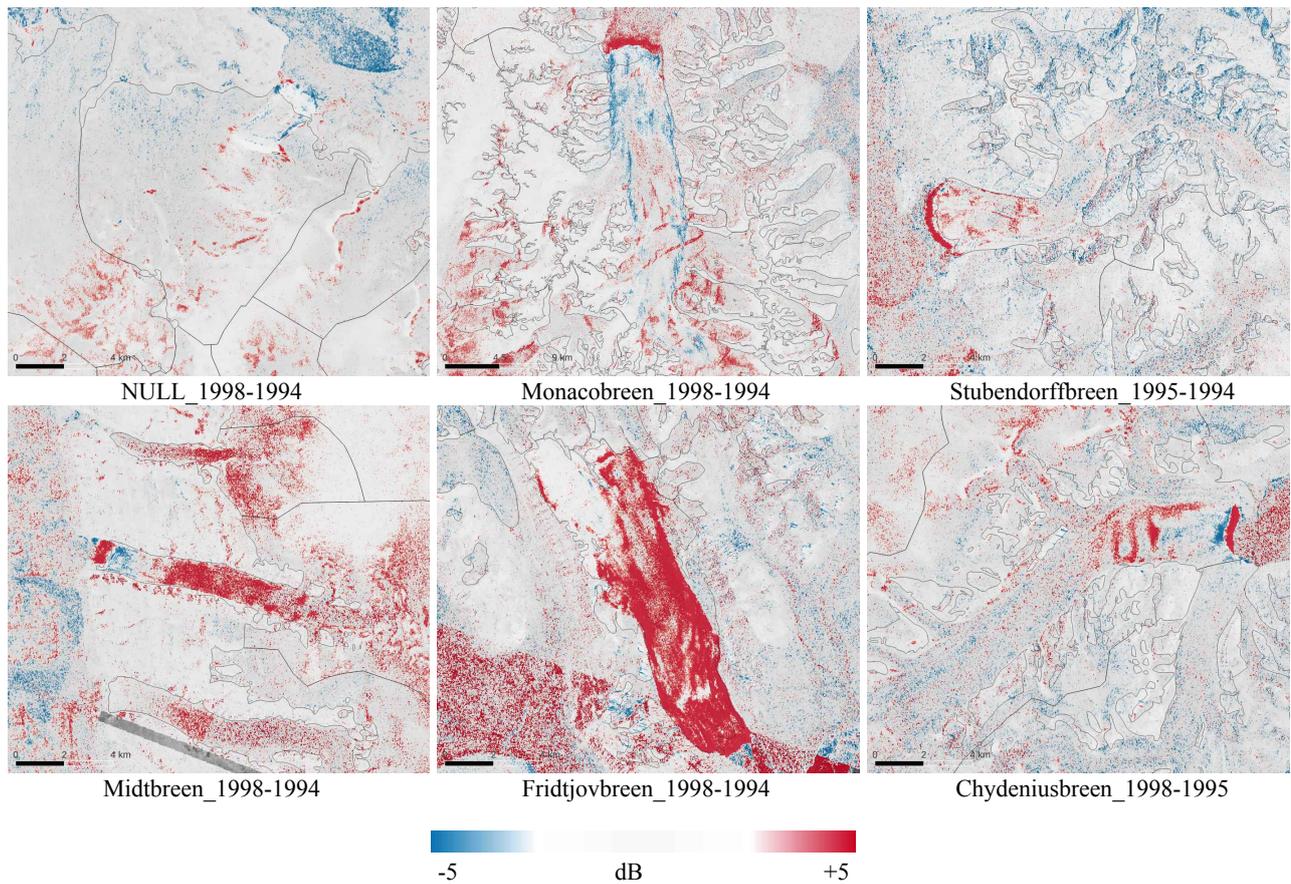
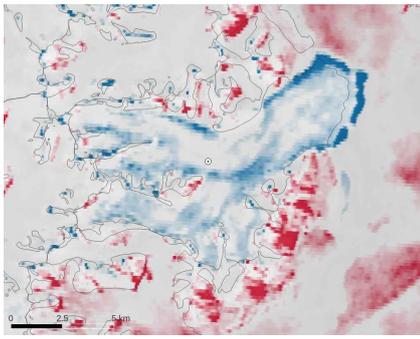
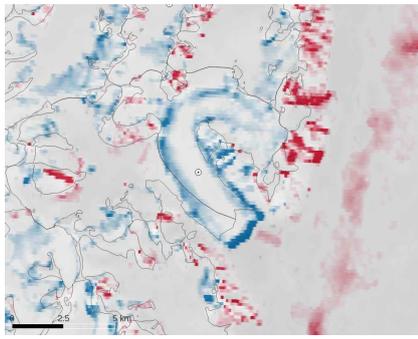


Figure S9. JERS-1 backscattering intensity change images for the surge-type events mapped over Svalbard over the period 1993-1998. The name of the glacier and the dates of the winter mosaics are indicated below each image. Note that years in the legend refer to the end of the winter, i.e., 1995 means e.g. the winter season 1994 to 1995.

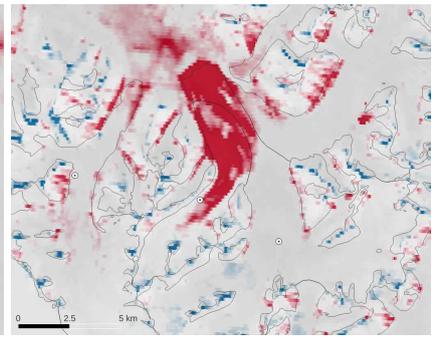
Figure S10. ENVISAT ASAR backscattering intensity change images for the surge-type events mapped over Svalbard over the period 2003-2010. The name of the glacier and the dates of the winter mosaics are indicated below each image.



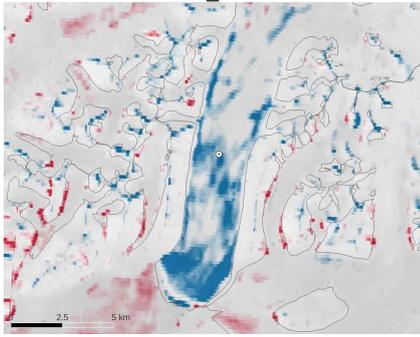
Perseibreen_2006-2004



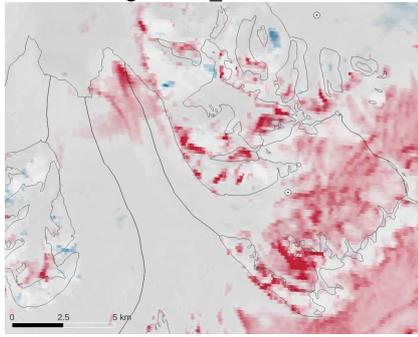
Ingerbreen_2004-2003



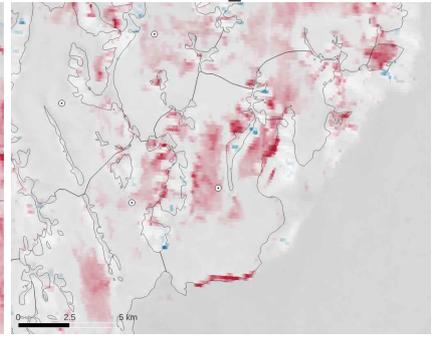
Skobreen_2006-2004



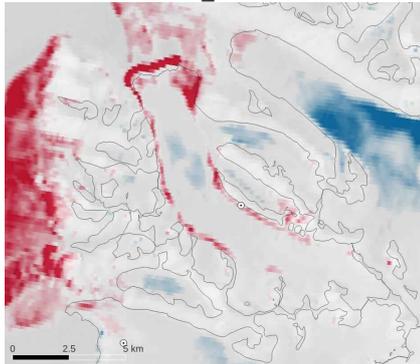
Tunabreen_2006-2004



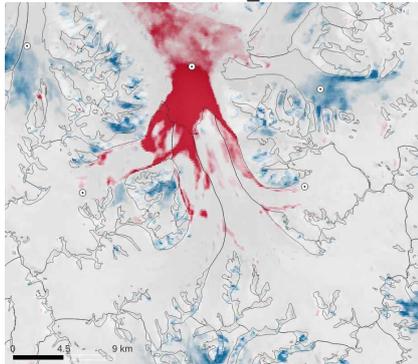
Dobrowolskibreen_2007-2006



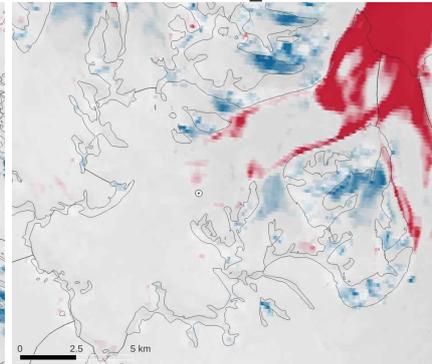
Vasilievbreen_2007-2008



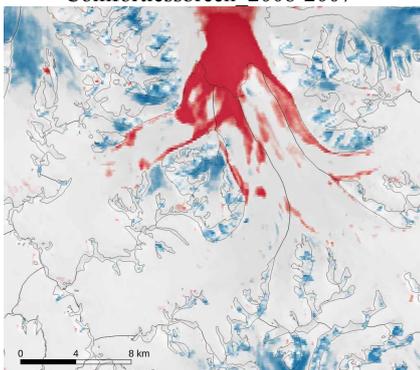
Comfortlessbreen_2008-2007



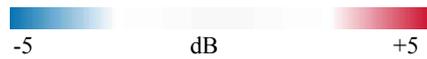
Nathorstbreen_2009-2008



Zawadzki breen_2009-2008



Polakkbreen_2009-2008



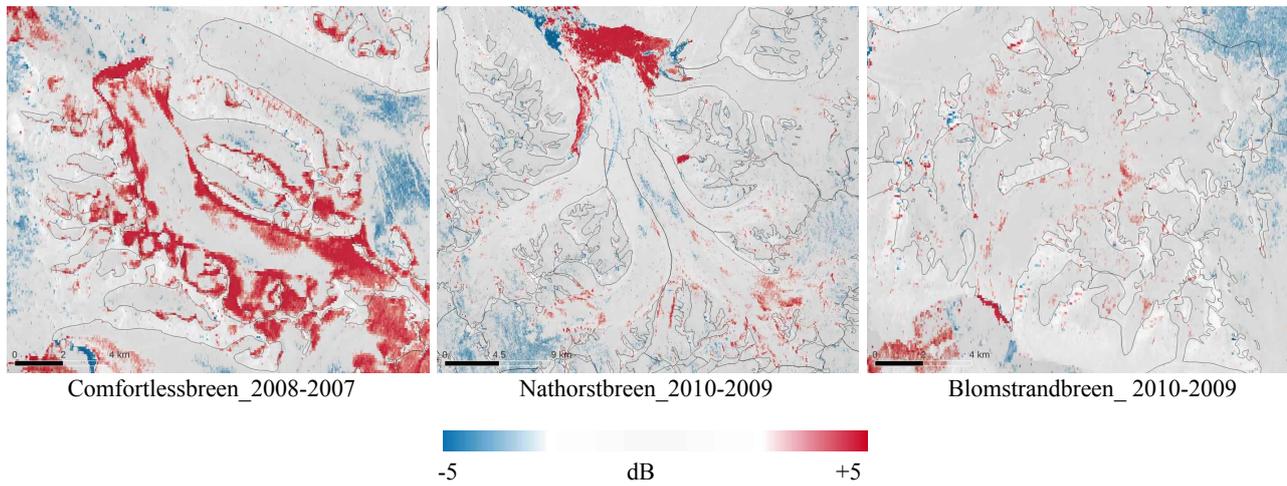


Figure S11. ALOS PALSAR backscattering intensity change images for the surge-type events mapped over Svalbard over the period 2007-2010. The name of the glacier and the dates of the yearly mosaics are indicated below each image. The Nathorstbreen glacier system also includes Zawadzki breen and Polakkbreen.

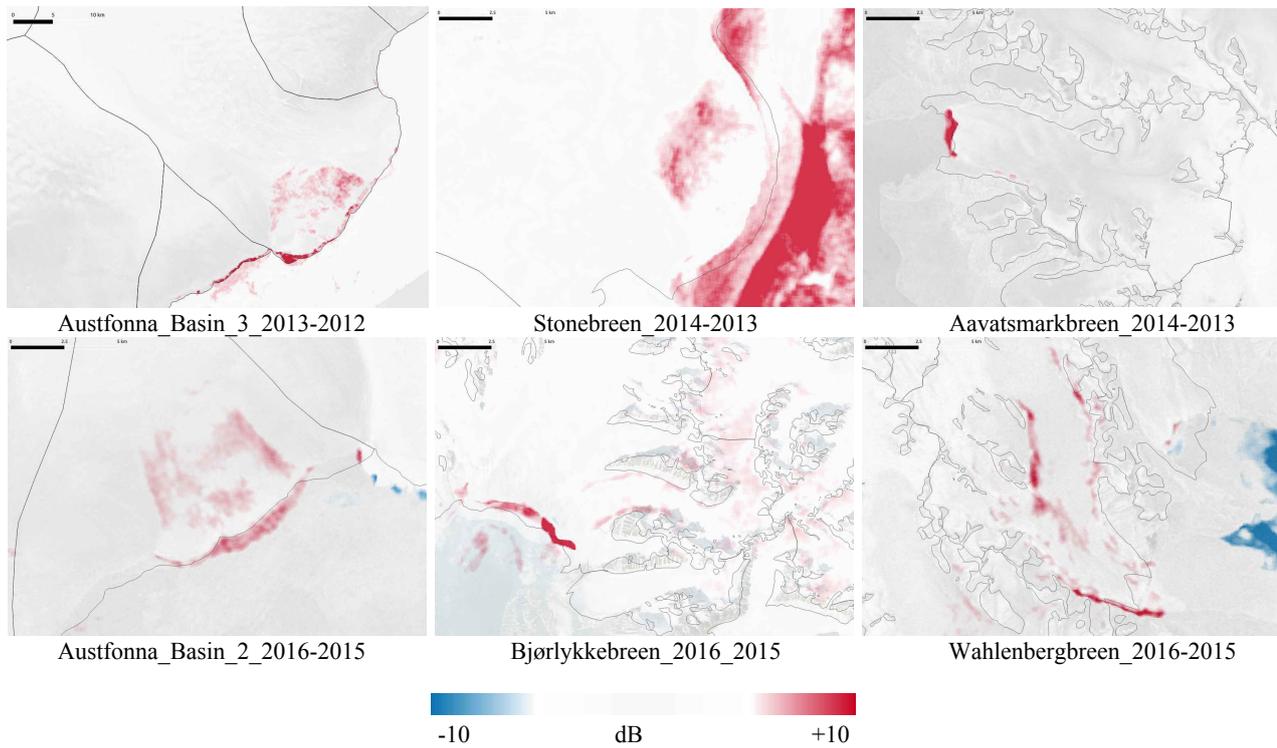


Figure S12. Radarsat-2 backscattering intensity change images for the surge-type events mapped over Svalbard over the period 2012-2015. The name of the glacier and the dates of the winter mosaics are indicated below each image. Note that years in the legend refer to the end of the winter, i.e., 2016 means e.g. October 2015 to April 2016.

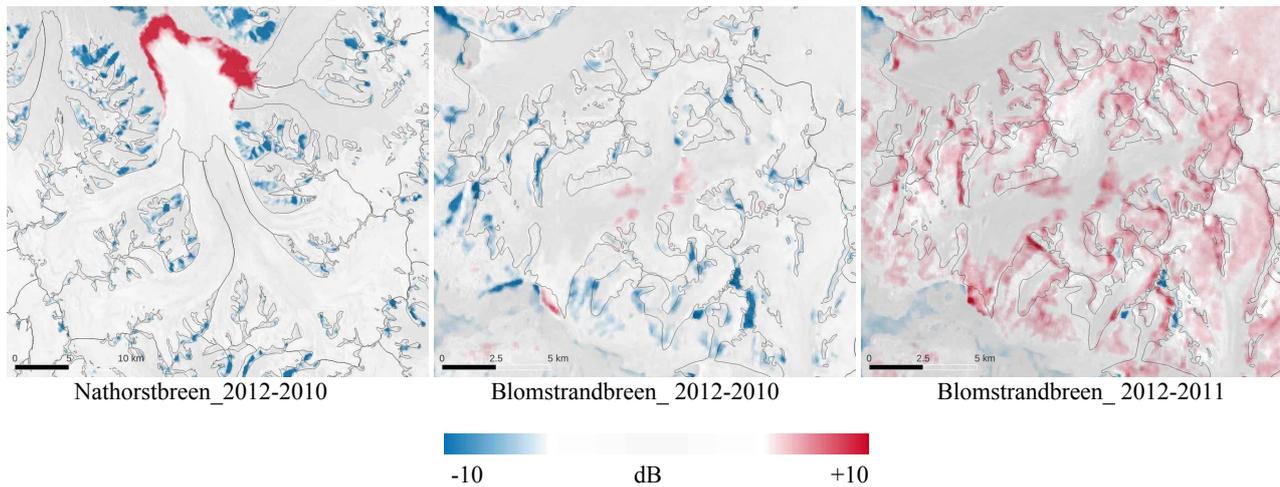


Figure S13. Backscattering intensity change images between ENVISAT in 2010 and Radarsat-2 in 2012 for (left) the Nathorstbreen glacier system, also including Zawadzki breen and Polakkbreen, and (middle) Blomstrandbreen. Backscattering intensity change image between ERS-2 in 2011 and Radarsat-2 in 2012 for Blomstrandbreen (right). The name of the glacier and the dates of the winter mosaics are indicated below each image. Note that for ERS-2 and Radarsat-2 years in the legend refer to the end of the winter, i.e., 2012 means e.g. October 2011 to April 2012.

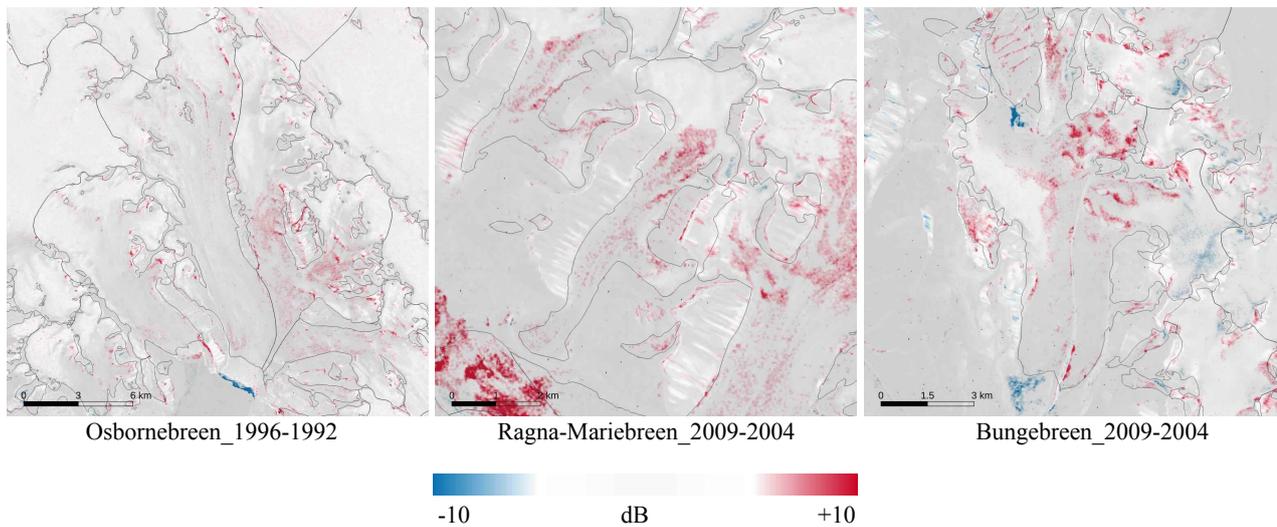


Figure S14. ERS-1/2 backscattering intensity change images for glaciers over Svalbard indicated as surge type or with strong evidence for surging in the earlier catalogues of the 1990s and 2000s, but with no clear indication of an increase or decrease in backscattering. The name of the glacier and the dates of the winter mosaics are indicated below each image. Note that years in the legend refer to the end of the winter, i.e., 1995 means e.g. the winter season 1994 to 1995.

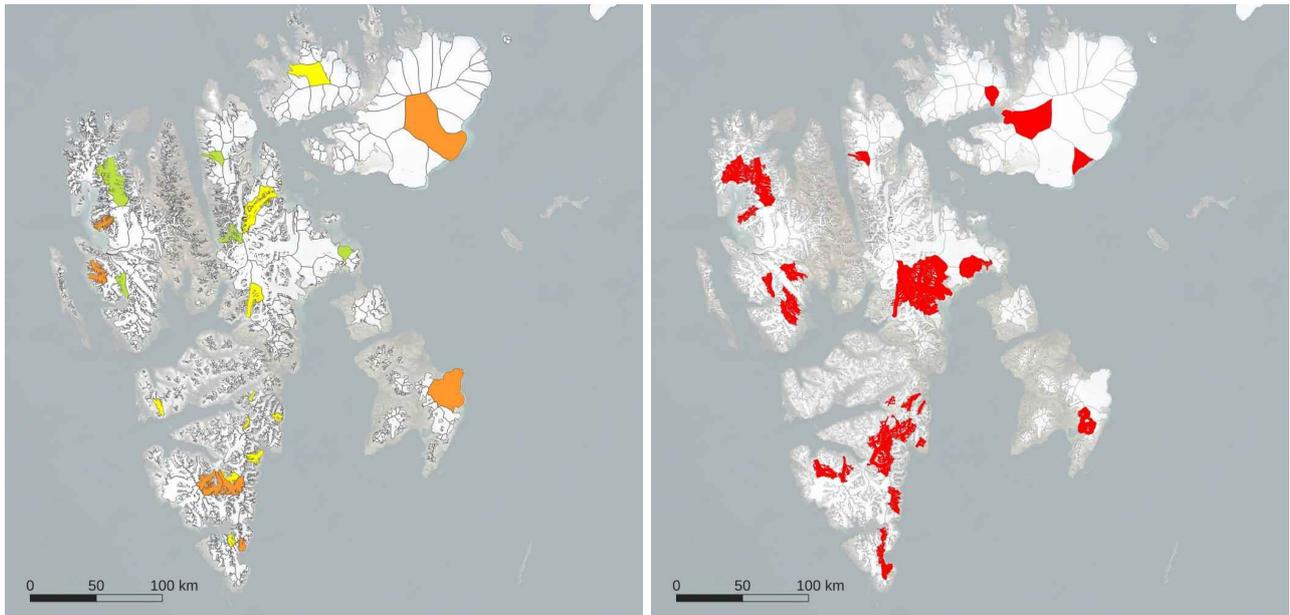


Figure S15. Surge events interpreted over Svalbard in the period 1992-2025 using ERS-1/2 SAR, JERS-1 SAR, ENVISAT ASAR, ALOS PALSAR, Radarsat-2 and Sentinel-1 data listed by start date. Left: green is before 1994, yellow is 1995-2005 and orange is 2005-2014. Right: red is 2015-2025. Outlines from the Randolph Glacier Inventory 7.0 (RGI 7.0 Consortium, 2023) are shown in black. Image background is Bing Satellite, © Microsoft.