
# Impacts of climate and environmental change on tourism in Svalbard

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| WNRI Report | 9-2023 |
| Issued by<br>Address | Western Norway Research Institute / Vestlandsforsking<br>PO Box 163, NO-6851 Sogndal, Norway |
| Project title | Sustainable Tourism in Svalbard – A Balancing Act. Funded by the Norwegian Research Council (Grant number 302914), Visit Svalbard and Arctic Expedition Cruise Organizers (AECO). |
| Employer | Halvor Dannevig: Western Norway Research Institute<br>Janne Søreide: University Centre on Svalbard (UNIS)<br>Anna Sveinsdottir: Nordland Research Institute<br>Pernille B. Eidesen: University Centre on Svalbard (UNIS) |
| Front cover | Hikers in Svalbard. Photo: Visit Svalbard |
| ISBN | 978-82-428-0462-4 |

Parts of the report is also published in a journal article:

Dannevig, H., Søreide, J., Sveinsdottir, A., Olsen, J., Hovelsrud, G. K., Dale, R. F., & Rusdal, T. (n.d.). Coping with rapid and cascading changes in Svalbard: the case of nature based tourism in Svalbard. *Frontiers in Human Dynamics*, *5*, 21. https://doi.org/10.3389/FHUMD.2023.1178264



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# Content

# List of figures

# Norsk sammendrag

## Dramatiske endringer i natur og klima

Svalbard er et av de stedene på klodene med størst klimaendring, med tilhørende endringer i øvrige naturlige prosesser og økosystem. Svalbard opplever en kraftig økning i temperatur og nedbør. Snøsesongen er allerede tre uker kortere enn for 30 år siden.  Legger vi et høyt utslippsscenario til grunn, slik Miljødirektoratet anbefaler at man gjør i langtidsplanlegging som skal ta høyde for klimaendringer, vil Svalbard få samme klima som Danmark ved slutten av dette århundre. Se også en oppsummering av de viktigste endringene i Figure 1

Det vil være kun få dager med snødekke langs kysten. I høyereliggende områder vil snømengdene øke, takket være økning i nedbør, men antall dager med snødekke reduseres kraftig også i indre og høyereliggende strøk.

Som følge av reduksjon i snøsesongen blir det også en kortere sesong for ski og scooterturer. Samtidig utvides sesongen for sommerprodukter i reiselivet i takt med at snøen- og fjordisen kommer seinere på høsten. De mildere og kortere vintrene har flere negative effekter for landbasert turisme:

- Når snøen forsvinner fra lavlandet, tvinges scootertrafikken opp på breene. Også mangel på fjordis bidrar til dette. På breene er man utsatt for bresprekker og mer utsatt for dårlig vær og «whiteout».
- Regnvær på vinteren kan føre til oversvømmelse og flom som ødelegger og stenger viktige ferdselsårer for snøscootere, hundespann og skiløpere i dalene.
- Økt nedbør gir flere dager med betydelig og høy snøskredfare.

## Plante og dyreliv på land

Av de tre mest sårbare naturtypene på Svalbard for klimaendringene- varme kilder, arktisk steppe og arktisk ørken, er det bare førstnevnte som på grunn av sin beliggenhet er i fare for å bli negativt påvirket av ferdsel.

Tundravegetasjonen holder fremdeles stand mot klimaendringene, men det observeres endringer i dyrelivet, blant annet en stor økning i gjess og en reduksjon i vadere. Det forventes at tundravegetasjonen vil endres i takt med at snøsesongen kortes ned.

Det er ventet at sannsynligheten for at uønskede arter sprer seg i Svalbardnaturen vil øke som følge av klimaendringer, men til nå er uønskede arter på land kun registrert i de bebodde områdene av Svalbard.

Enkelte lokasjoner som er mye brukt til ilandstigning fra cruiseskip og mindre turistbåter har fått skader på vegetasjon. Påvirkning og forstyrrelser som følge av lokal menneskelig aktivitet per i dag er svært liten sammenlignet med påvirkningen fra klimaendringer, men klimaendringene kan på sikt gjøre naturen mer sårbar for lokal aktivitet.

## Raske og store endringer i dyre- og planteliv i fjordene og langs kysten

Fjord- og kystsonen på Svalbard er hjem til et rikt plante- og dyreliv, men disse er også blant de økosystem i verden som opplever raskest endring som følge av klimaendringer. Tinende permafrost, sjøis som forsvinner fra fjordene og breer som ikke lenger kalver i fjordene bidrar til disse endringene. En av mekanismene her er økt avrenning av sedimenter som igjen gjør sjøvannet mer grumsete, slik at mindre lys blir tilgjengelig for plantelivet i sjøen – slik at dette får dårligere vekstvilkår. Samtidig bidrar temperaturøkningen til økt vekst.

Polare fuglearter er i nedgang som følge av endringene, samtidig som arter som også finnes lenger sør opplever en oppgang. Ringselen får dårligere vilkår i fjordene etter hvert som sjøisen forsvinner. Klima- og miljøendringene gjør også dyrelivet mer sårbart for påvirkning fra menneskelig aktivitet.

## Varmere hav og mindre sjøis

I forhold til breddegraden er det vestlige Svalbard ganske varmt takket være Golfstrømmen, og dermed er det generelt lite sjøis vest for Svalbard. Likefullt var det frem til omlag 2005 vanlig med is i fjordene. Siden 2005 har endringer i værmønster ført til mer omfattende inntrenging av relativt varmt atlanterhavsvann inn i fjordene. Dette bidrar igjen til mildere og fuktigere vintre, og fraværet av is bidrar igjen til en positiv tilbakekoblingseffekt ved at vind og vær blander det kalde overflatevannet med varmt atlanterhavsvann også gjennom vinteren, noe som igjen bidrar til å hindre dannelsen av sjøis.

Fraværet av landfast is på vestsiden av Svalbard og tilhørende fjordstrøk har muliggjort en ny sesong for skipsbasert turisme (det vil si både ekspedisjonscruise og ordinær cruisetrafikk) i vårmånedene. Det har vært en stor vekst i skipstrafikk i vårmånedene (mars-mai) de siste 10 årene, drevet av økt etterspørsel i markedet. Etter at et forbud mot tungolje trådte i kraft i verneområdene, er det nå ekspedisjonscruiseskip, med maksimalt 500 passasjerer, som dominerer blant skipene som trafikkerer vestkysten.

Lyd fra skip og båter virker forstyrrende på marine pattedyr, som bruker lyd til å kommunisere under vann. En økning i skip- og båttrafikken vil derfor øke forstyrrelsene. Økt småbåttrafikk, spesielt i stor fart øker også risikoen for påkjørsler på sjøfugl. Økningen i skipstrafikken bringer også med seg større risiko for utslipp av olje og kjemikalier.

## Naturfarer

Det forventes at klimaendringer vil føre til økt risiko for naturfarer på Svalbard. Det øvre laget med permafrostlag er allerede i ferd med å tine i kyst- og lavhøydeområder, som igjen fører til jordskred og økt erosjon. Som følge av nedbørsøkningen blir det også hyppigere snøskredfare og andre typer skred vil øke og bli mer utbredt. Økt nedbør fører også til hyppigere flommer. Økt risiko for naturskader vil få betydelige konsekvenser for menneskelig aktivitet på Svalbard. Noen spesifikke samfunnsmessige konsekvenser av klimaendringer på Svalbard vil inkludere implikasjoner for næringsvirksomhet, logistikk i Stor-Svalbard-området, reiselivsvirksomhet og lokalsamfunnet i Longyearbyen.

Økt vinternedbør bidrar til at det oftere blir dager med høy skredfare, som gjør at turoperatørene må avlyse turer som går i skredutsatte traseer, som f. eks turen fra Longyearbyen til Barentsburg.

### Klimaendringer og fremtidig reiselivsutvikling i og rundt Longyearbyen

Føringer som er gitt for fremtidig reiselivsutvikling på Svalbard er tydelige på at videreutvikling av reiselivet bør konsentreres i Longyerbyen, Longyerdalen og Adventdalen. Dette betyr at klimaendringer og virkninger av disse i dette området er av særlig betydning. Utvikling av reiselivsinfrastruktur, som stier, leskur etc. må også konsentreres innenfor arealplanområdet til Longyerbyen lokalstyre. En slik utvikling må derfor ta hensyn til:

- Økt fare for flom og sørpeskred
- Økt jordskredfare
- Økt snøskredfare

NVE har både installert flom- og skredforebyggende tiltak i Longyerdalen som reduserer disse naturefarene, men med den forventede endringshastigheten i temperaturer og nedbør er det betydelig usikkerhet disse forebyggende tiltak er tilstrekkelige.

Adventsdalen er hovedutfartsporten fra Longyearbyen til Isfjorden-området samt Nord-Spitsbergen. Varmere og våtere vintre og vårsesonger vil skape utfordringer for snøscooterkjøring, hundekjøring og skigåing gjennom denne dalen på grunn av hyppigere forekomst av åpne bekker og oversvømmelse av løypene.

Den økte forekomst av isbjørn rundt Isfjorden som er observert i senere år kan være midlertidig, men det kan også signalisere en mer varig trend. Det legger uansett et større ansvar for reiselivsaktørene ved planlegging og gjennomføring av reiselivsaktiviteter i Isfjorden-området, som også omfatter områdene rundt Longyearbyen.

## Om rapporten

Rapporten er basert på gjennomgang av nyere forskningslitteratur om klimaendringer og konsekvenser av klimaendringer på natur og miljø i Svalbard. Det er gjort få studier av hvordan klimaendringene på Svalbard vil påvirke menneskelig aktivitet, inkludert reiseliv. Forfatterne har derfor i noen tilfeller supplert med egne vurderinger av mulige konsekvenser av klimaendringer for reiselivet. Visit Svalbard og Arctic Expedition Cruise Organizers (AECO) har bidratt med kommentarer og innspill til rapporten. Rapporten er et resultat av arbeid i forskningsprosjektet «Sustainable tourism in Svalbard – a balancing act» med finansiering fra Forskningsrådet. Deler av rapporten er også publisert i en tidsskriftartikkel:

> Dannevig, H., Søreide, J., Sveinsdottir, A., Olsen, J., Hovelsrud, G. K., Dale, R. F., & Rusdal, T. (n.d.). Coping with rapid and cascading changes in Svalbard: the case of nature based tourism in Svalbard. *Frontiers in Human Dynamics*, *5*, 21. https://doi.org/10.3389/FHUMD.2023.1178264

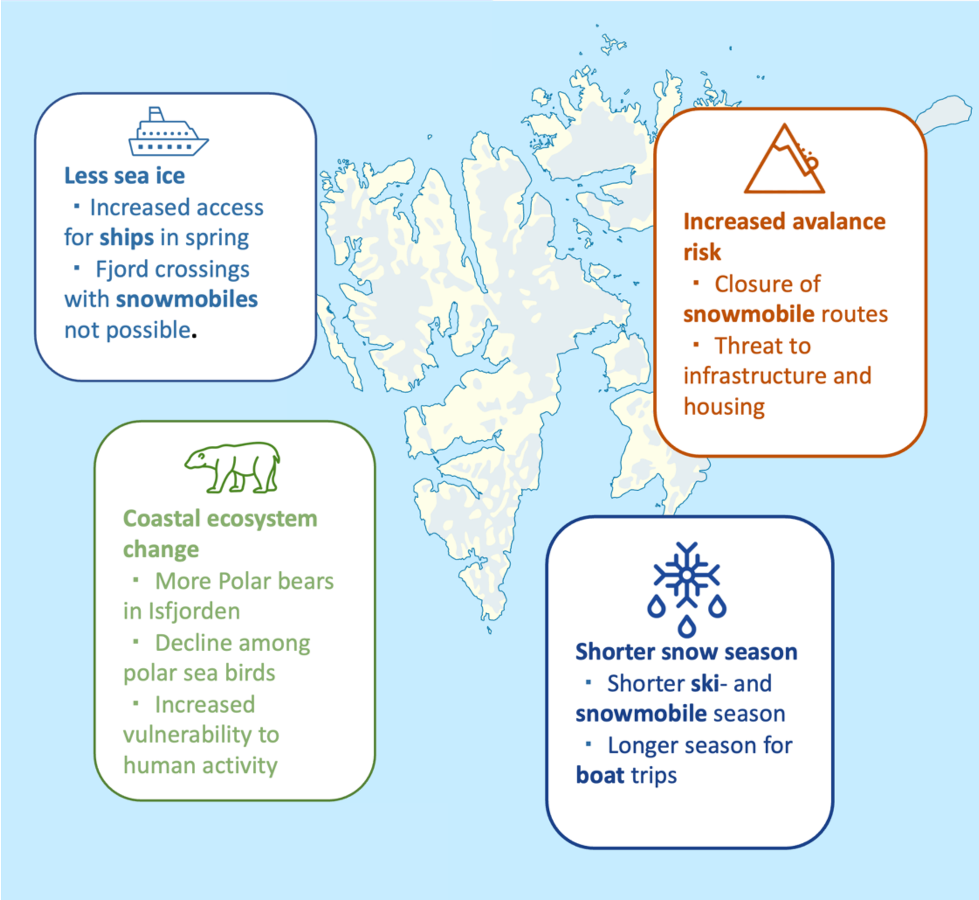


*Figure 1. Highlighted climate change impacts for tourism in Svalbard.*

# 1. Introduction

**This report reviews and summarizes the existing literature on climate change and ecosystem change on Svalbard, with particular focus on the consequences of rapidly changing climate and environmental conditions for tourism in the archipelago.**

Svalbard, much like the rest of the Arctic, is experiencing rapidly changing climate and environmental conditions at a rate that far surpasses other regions of the world (Prost et al. 2019). Climate projections indicate that the Arctic will continue to warm faster than the rest of the world in the twenty-first century (Koenigk et al., 2020). Expected consequences of increased Arctic warming include ongoing loss of land and sea ice, threats to wildlife and traditional human livelihoods, increased methane emissions, and extreme weather at lower latitudes (Post et al., 2019). As the tourism sector relies on natural elements such as sea ice, permafrost, flora, and fauna, as well as physical infrastructure that are directly or indirectly affected by climate change, climate change will have far-reaching consequences for the future of tourism in the Arctic (and elsewhere) (AMAP 2017, Hovelsrud et al. 2011, Scott et al. 2019).

One of the major impacts of climate change observed in Svalbard, thus far, is the ongoing loss of land and sea ice. Spatial and temporal reduction in sea ice cover has expanded the navigation season and area of operation, which has enabled a demand-driven growth in cruise traffic (Stocker et al. 2020). The sea ice season in the Barents Sea–Svalbard region is getting shorter, and recent studies project that the Barents Sea will be totally ice free by 2040 (Bennett et al. 2020). The changing climate is thus widely believed to enable continued expansion of Arctic marine-based tourism and to lead to opportunity-based adaptation to climate change (Dawson et al. 2016; Olsen et al. 2020). A recent estimate on shipping development around Svalbard indicates that the level of activities will continue to increase toward 2040 (Olsen et al. 2020). In July 2022, a French cruise ship company reached 90 degrees north with tourists for the first time.

Until then, only Russian icebreakers had brought tourists to the North Pole. Cruise ship tourism to the North Pole is thus already a reality (Humpert 2022; Kubny 2022).

At the same time, climate change is causing what can best be described as an emergency response crisis in Longyearbyen (Hovelsrud et al. 2021). An avalanche destroyed 11 houses and killed two persons in 2015 (Sokolickova et al. 2022). Subsequent avalanche risk assessment led to the relocation of several residential buildings. Major investments have also been made in landslide protection and flood protection, as well as in reinforcing roads and buildings to withstand thawing permafrost (Meyer 2022). There is also a concern that climate change is making ecosystems and wildlife more vulnerable to negative impacts from human activities (Hovelsrud et al. 2021; NEA 2022). Increased human traffic in the far North may introduce new species and potentially harmful microorganisms to the ecosystem (e.g., through ballast water; Goldsmit et al. 2018). Further, the ongoing Atlantification of the marine ecosystem changes the trophic interactions, with increased predation pressure on many Arctic key species, such as polar cod and large-sized Arctic copepods (Misund et al. 2016).

Ongoing changes in Svalbard tourism create numerous opportunities for the tourism industry and for the community of Longyearbyen. These include a shift from seasonal to year-round tourism, the emergence of new markets and tourism segments, and a shift from land-based to marine-based tourism. Additionally, Longyearbyen is increasingly promoted as a tourism destination in and of itself and not only as a transit hub (e.g., Olsen et al. 2020). However, these opportunities are increasingly balanced against climate change impacts, and shifting sustainability requirements and governance procedures.

Tourism regulation on Svalbard addresses the protection of nature in the context of tourism growth (Ministry of Justice and Public Security 2018) by limiting the area for access and passage, setting requirements for organized outdoor activities, and developing regulation instruments, such as environmental taxes (Hovelsrud et al. 2023). The Svalbard Environmental

Protection Act (SEPA) stipulates that environmental concerns shall trump economic interests in case of conflict and that large areas will remain unchanged for the purposes of research and monitoring (MoJPS 2016). Meanwhile, Svalbard's flora, fauna, and cultural remains shall be sustained without influence from human activities, preserving opportunities to experience nature undisturbed by motorized activities, even in the vicinity of settlements (MoJPS 2016). In September 2021, the Norwegian government began a public consultation process[1] on suggested amendments to the SEPA and associated regulations.[2] The proposed changes signal increased state control (Sokolickova et al. 2022), and the process resulted in significant reactions from Longyearbyen business operators, the local population, and other actors (Haugli 2022). In January 2023, the Norwegian Environment Agency published their suggested amendments, which maintained the major points in the hearing document, including suggestions to limit the number of passengers on tourism vessels ships to 200 and reduce the number of sites allowed for visitors. The decision by the Norwegian government is awaited with both eagerness and apprehension, depending on one's point of view.

The rapid changing climate and environmental conditions in the Arctic warrant a greater effort in understanding socio-ecological systems on Svalbard (Øian and Kaltenborn, 2020). However, as of today, there is limited knowledge available about the interplay between human activities, ecosystems, and climate- and environmental change on Svalbard. Moreover, the current scientific knowledge that exists is predominantly characterized by fundamental research that is not necessarily relevant for policy making and management system design. As a result, the precautionary principle and stronger environmental protection prevail in management practices in the archipelago. There is therefore a need for more research that actively contributes to building

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[1] In Norwegian public administration, a consultation process (*høringsprosess*) is used by a ministry to consult affected parties on suggested laws and regulations, suggested changes in public administration, jurisdiction changes, etc.

[2] Norwegian Environment Agency. *Amendments to the Svalbard Environmental Protection Act and Associated Regulations on Nature Conservation Areas, Motor Traffic, Camping Activities and Area Protection and Access to Virgohamna*, 2021.

a scientific knowledge for knowledge-based, rather than precautionary principle-based, management system (Nyseth & Viken 2016: 70).

# 2. Methods

As there already exists a notable amount of research that includes projections for future climate change and biophysical impacts, the Balancing Act project aimed to assess and synthesize this existing knowledge and deliver it to the tourism industry. During an input meeting with key actors from the tourism industry (representatives from tourism industry organizations and the destination marketing organization (DMO)), salient categories of climate change and impacts were identified. This then informed the selection of literature for review.

Based on the above-mentioned input meeting, the authors defined five categories of climate change impacts relevant for tourism and divided responsibility for literature review within these categories. The categories were: 1) ecosystem change, including marine and terrestrial ecosystems 2) sea temperature and sea ice change; 3) natural hazards; and 4) other changes, including temperature, precipitation and glacier changes. The point of departure for the review was existing climate change and climate change impact assessment reports, such as the "Climate in Svalbard 2100" report by the Norwegian Climate Service Centre (Hanssen-Bauer et al. 2019) and the "Snow, Water, Ice and Permafrost in the Arctic" report from the Arctic Monitoring and Assessment Programme (AMAP 2017). We reviewed both scientific reports and peer reviewed journal articles and book chapters.

# 3. Observed and projected ecosystem change with relevance for tourism

## 3.1 Environmental change on land

Despite large ongoing changes in climatic conditions (Bilt et al. 2019), the latest report assessing the ecological condition of Norwegian Arctic tundra ecosystems conclude that sub-ecosystems in the Norwegian Arctic tundra are still resilient to ongoing changes. The assessment is based on evaluation of seven ecosystem characteristics (Pedersen et al. 2021). Overall, the Arctic ecosystem shows minor changes compared to the reference condition (Pedersen et al. 2021). However, observed changes are substantial for certain characteristics and within certain geographical regions, sub-ecosystems and for single species.

For High Arctic tundra in Svalbard, two ecosystem characteristics (non-biological factors and landscape-ecological patterns) show substantial deviation from the reference condition (Pedersen et al., 2021). Non-biologic factors, such as July mean temperature, which has increased with 0.3–1.1 C per decade since 1990, permafrost temperatures have increased by close to 1.0°C/decade since the monitoring was initiated, and the duration of snow cover has decreased with three weeks. Reduced snow cover has, for instance, been shown to alter functionality of Arctic tundra (Niittynen et al. 2020). These changes are likely to continue, and, in a few decades, it is expected that eco-systems included in this assessment will be far outside the climate envelopes of their reference (Pedersen et al. 2021).

The observed changes in landscape-ecological patterns in Svalbard are tightly linked to climatic changes. The changes are regarded to be substantial due to an extensive loss of areas that climatically belong to the coldest bioclimatic subzone A (Arctic polar desert zone) (Pedersen et al. 2021). Polar deserts are also one of the nature types that are listed as near threatened in the Norwegian red-list of nature types (Arnesen et al. 2018). Hot springs, Arctic steppe and calcareous formations of permafrost bog edges are nature types considered critically endangered in Svalbard, mainly due to the combination of currently restricted range extension and vulnerability to changing climate conditions.

The ecosystem characteristics «Biodiversity» and "Functional groups within trophic levels» are reported to show no deviation from the reference condition in Svalbard (Pedersen et al., 2021). However, both are listed with an "inadequate" indicator coverage», meaning that the set of indicators used have several shortcomings (Pedersen et al. 2021). Thus, changes might be present but not detected. Some species and species groups have changed distribution and abundance dramatically the last decades. Geese have, for instance, shown a strong positive response to climate changes (Tombre et al. 2019, Smith et al. 2020), whereas numbers of waders have declined (Smith et al., 2020). The grazing impact of geese are currently believed to have limited ecosystem significance; however, this may change soon and should be monitored closely (Pedersen et al. 2021). Whether the positive climate-change response in geese will continue is also questioned (Layton-Matthews et al., 2020).

A resent status report on freshwater systems in Svalbard revealed lack of sufficient reference data (Brittain et al, 2020). However, based on available information, the largest foreseen changes are related to climate change, where increased water temperatures and changes in ice-cover are postulated to have large impact on freshwater ecosystems. Increased nutrient-input through increased number of geese might also be substantial.

Thus, observed changes are overall strongly associated with phenomena driven by climate change. Climate change is clearly the most influential anthropogenic driver compared to other drivers, such as technical infrastructure, harvesting, or natural resource management (Pedersen et al. 2021).

## 3.2 Consequences for tourism

Hot springs are directly affected by tourism and other recreation activities, and direct damage due to human visits are reported (Arnesen et al. 2018). Since

2020, the hot springs that are least accessible (Trollkjeldene, Bockfjorden) are prohibited to visit, whereas it is still possible to visit Jotunkjeldene. The Arctic steppe areas are in the inner parts of Wijdefjorden and are rarely visited due to their remote location. Calcareous formations of permafrost bog edges are found in some very restricted areas in Sassendalen, Gipsdalen, Kapp Thordsen, Ossian Sars, and in a few locations in Wijdefjorden. None of the locations are regarded threatened by direct human disturbance or activities, but the spots in Ossian Sars are at risk due to increased reindeer grazing (Arnesen et al. 2018).

Other types of changes due to human activities are registered, such as erosion due to trampling at common landing sites (Hagen et al 2012), as well as the risk of introducing alien species. However, these drivers are minor in comparison - or their impacts are mainly noticed through the amplification driven by climate change. Today, alien plant species are only found in settlements, and have not spread to high-risk natural habitats like bird-cliffs. However, the risk of alien species becoming invasive is expected to increase along with warmer climate (Bartlett et al. 2021).

## 3.3 Coastal change

Estuarine, coastal and fjordic waters are among the most productive regions in the high Arctic, but also among the most rapidly changing ecosystems in the world. Melting of permafrost, reduction of land fast sea ice and retreat of glaciers impact the nearshore ecosystems in Svalbard and elsewhere in the Arctic (McGovern et al. 2019, 2020). The melting glaciers, increased precipitation and river run-off add massive amounts of sediments to the coastal waters resulting in increased turbidity (suspended particulate matter, SPM), thereby decreasing light penetration and potentially the primary productivity counteracting the effects of reduced sea ice cover (Singh et al. 2022). Further, glaciers, snow caps, and permafrost contain stores of contaminants that have been atmospherically transported from lower latitudes (AMAP 2017, 2021). Thus, runoff from these systems potentially represent a secondary source of legacy contaminants. Global warming and increased human activity impact

Arctic coastal biodiversity and ecosystem processes, which, in turn, will impact food security and daily life in these coastal communities.

Currently 77% of the coastline in Svalbard is categorized into coastscapes (Figure 2). The roughly 23% unmapped coastline is primarily located in Nordaustlandet, but also includes some newly exposed coastline that is the result of glacial retreat since the aerial pictures were taken in the late 1980s.

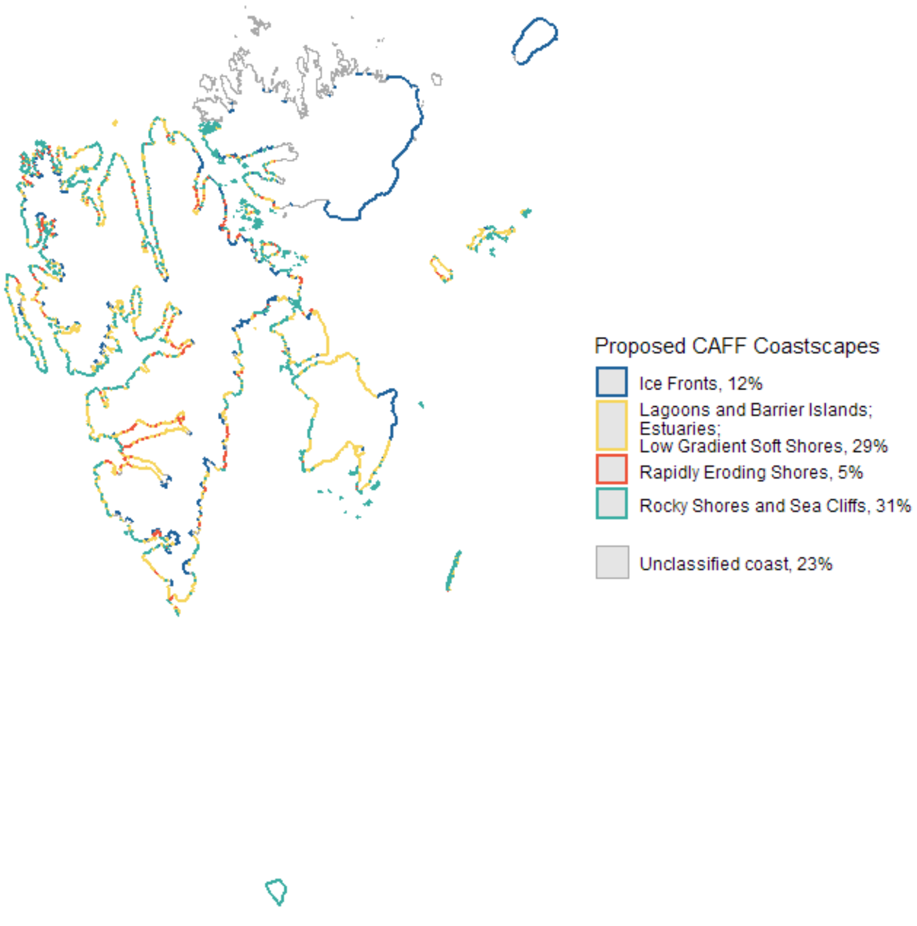



*Figure 2. Coastscapes categories. Source: Søreide et al. 2021*

The dominant coastscapes are: 1) rocky shore and sea cliffs (31%), followed by 2) low gradient soft shores, intermixed with 3) estuaries and lagoons, and 4) barrier islands (29%). Svalbard is covered by glaciers (57%) and approximately

12% of the coastline comprises of 5) ice fronts. Steep soft shoreline, often containing ice, is termed 6) rapidly eroding shore. In Svalbard this costscape is poorly represented (5%). New calculations show that 303 km (7.2 %) of new coastline has appeared on Spitsbergen after glaciers have retreated onto land (Urbanski et al. in prep). In total, for the entire Svalbard archipelago, 350 km new coastline was found, with only minor changes for the other islands (<3.7%), except for Storøya with 12% more coastline (1.8 km) (Urbanski et al. in prep.).

Svalbard stretches over a steep climate gradient (see chapter 3 below) and, so far, most studies have taken place in western Svalbard for which biological time series of 20 years and more exist. In the cold region of Svalbard, no regular biological monitoring takes place, except for annual to biannual sampling of plankton and benthos in Rijpfjorden. In the coming years and decades, it is proposed that especially the northeastern Svalbard will experience the largest changes due to the predicted disappearance of sea ice. In western Svalbard, big changes have already taken place (after 2005), changes, that when combined, can be understood as a regime shift.

In Svalbard, the fjord ecosystem is the coastscape that has been best studied. Regular studies on hydrography, phytoplankton and zooplankton have existed since 1996 in Kongsfjorden (NPI and IOPAS), since 2000 in Hornsund (IOPAS), since 2007 in Rijpfjorden (UNIS and NPI), since 2011 in Isfjorden (UNIS) and in Van Mijenfjorden since 2014.

## 3.4 Marine and coastal ecosystems

The last two decades, boreal species have become more prominent in Svalbard waters and this "Atlantification" of the Svalbard marine ecosystem is particularly prevalent along West Spitsbergen (e.g., Berge et al. 2015, Gluchowska et al. 2016, Hop et al. 2019a, Vithakari et al. 2018) due to regular intrusions of warm Atlantic water since 2005 (Muckenhuber et al. 2016, Cottier et al. 2019, Tverberg et al. 2019, Skogseth et al. 2020). The big year classes of

Atlantic cod (*Gadus morhua*) in 2011-2013 led to high numbers of Atlantic cod in the deeper, open fjords in western Svalbard (Misund et al. 2016). This relatively new, big predator in the fjord system may have large top-down effects on the smaller key fish species, such as polar cod (*Boregadus saida*), shrimps and others. For the benthos, a similar 'Atlantification' of the community composition has been observed, but in threshold fjords with glacial basins the Arctic benthic communities have largely survived, demonstrating the importance of these cold isolated refugees in the otherwise warm Atlantic influenced fjords for securing the overall biodiversity (Renaud et al. 2007, Drewnik et al. 2017).

These glacial fjord bays are also important habitats for sea ice dependent seals, since calving glacier produce ice bergs on which the seals can rest. These chunks of glacier ice accumulate drifting snow and make it possible for ring seals to make protective snow caves for their pups. In eastern Svalbard, sea ice starts to form in autumn and snow piles up over the season, while late sea ice formation in western Svalbard result in often very little snow on top of the sea ice. As such, ring seals have very limited possibilities for hiding their pups from polar bears and other predators such as glaucous gulls (Hanssen et al. 2022).

Polar bears have increased in numbers in West Spitzbergen after hunting was banned in 1973 (Prop et al. 2015). Here, they have adapted to changed hunting grounds. In summer, they predate heavily on bird colonies (Prop et al. 2015) and reindeer, which they can hunt year-round (Stempniewicz et al. 2021).

The increase in ship and boat traffic comes with underwater noise, which can disturb marine mammals (Olsen et al. 2019). Increase in boat traffic (smaller, open vessels) also leads to an increased risk of hitting seabirds and marine mammals while driving. Open boat tourism traffic is first and foremost prevalent in the Isfjorden area.

# 4. Sea temperatures and sea ice

Western Svalbard is relatively warm due to the strong influence of the West Spitsbergen Current (the continuation of the Gulf Stream) along the western and northern Spitsbergen shelf break, resulting in little or no sea ice in this region (Figure 3). Prior to 2005, sea ice formed in many of the fjords in western Spitsbergen, but after 2005 changes in weather patterns combined with slight changes in sea water densities have resulted in more frequent and larger intrusions of warm Atlantic or modified Atlantic water into fjords (Nilsen et al 2008, Skogseth et al 2020).

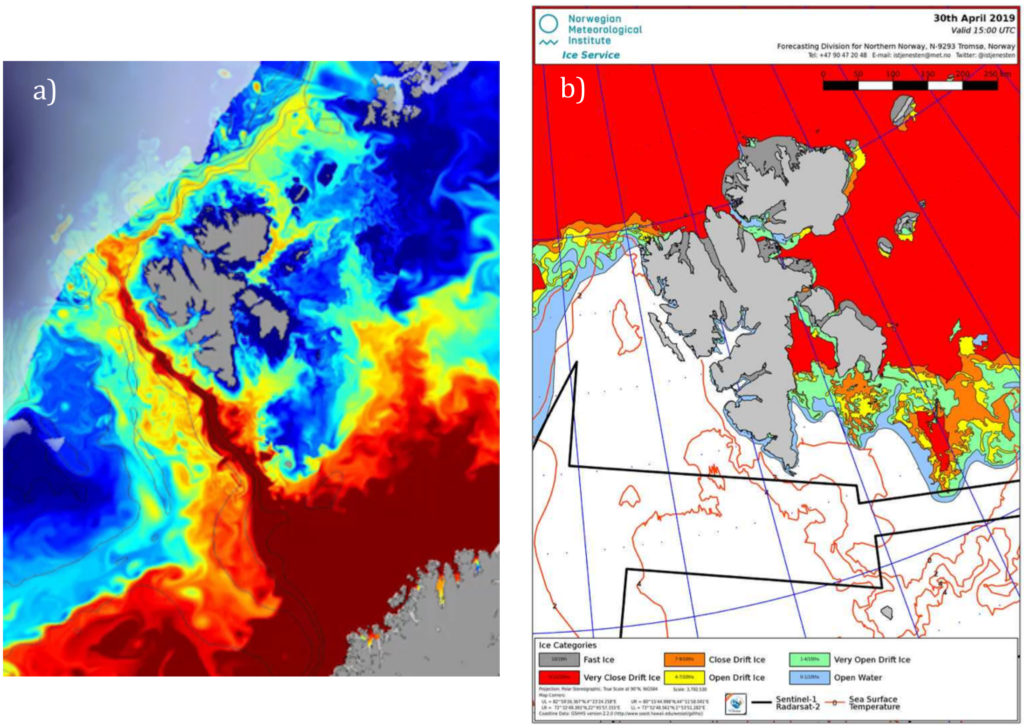



*Figure 3. Svalbard archipelago showing a) surface water temperatures with warm Atlantic water in colored red and the colder Arctic water in blue with mixing regions with a scale from primarily cold (light blue) to primarily warm (orange) (from Hattermann et al. 2016) The sea ice cover b) mirror the sea surface temperatures with little or no sea ice formation in the west and northwest Svalbard.*

This large amount of heat that enter the fjords has positive feedback on the local and larger scale weather, leading to warmer and more humid winter temperatures in Svalbard (Binder et al. 2017, Hanssen-Bauer et al. 2019). As a consequence, less intense cooling of surface waters occurs in winter, which prevents sea water from freezing, with the exception of shallow inlets and fjords, as well as fjords with physical barriers, or sill fjords, which prevent warmer water from the outside to enter the fjords in first place (see figure 4). Open water allows for more wind mixing and warmer heavier Atlantic water from below is continuously mixed up to the surface (Ivanov et al., 2016).

In the north-eastern parts of Svalbard, cold Arctic waters and seasonal sea ice still prevail. Continuous sea temperature measurements from sea observatories (moorings) placed in Kongsfjorden (West Svalbard) and Rijpfjorden (North Svalbard) since 2001 and 2006, respectively, show that Kongsfjorden has become much warmer while in Rijpfjorden the temperatures are very variable with no significant increase in sea temperature the last decade (see Figure 4; Cottier et al. 2021).

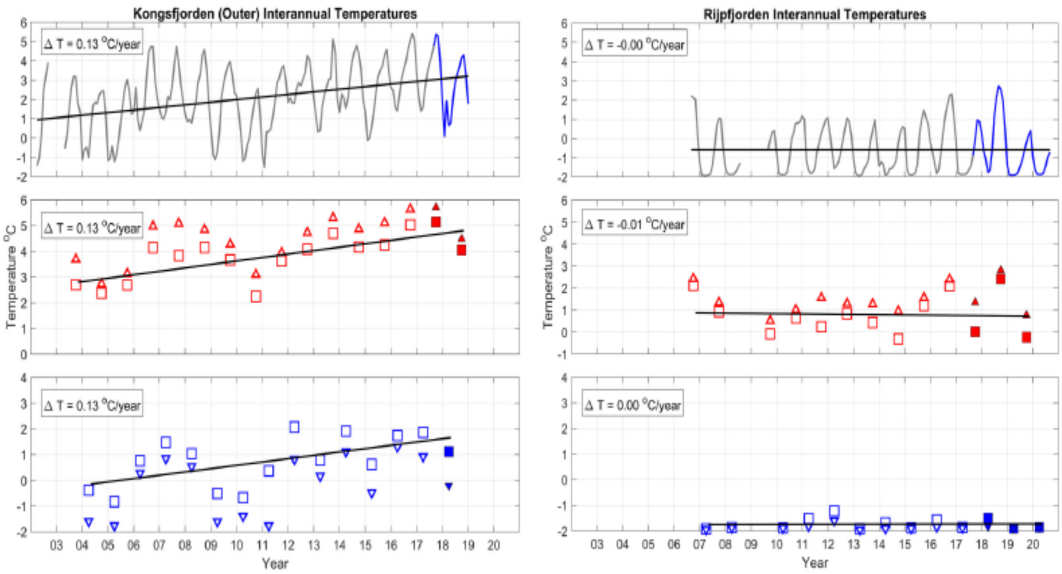



*Figure 4 from Cottier et al. 2021. Model simulations show that in 50-year time the surface waters around Svalbard will likely be 1°C warmer, and in some regions even warmer. Landfast fjord ice will largely disappear with a +4°C increase in winter air temperatures which may happen already 2050 (Søreide et al, 2021).*

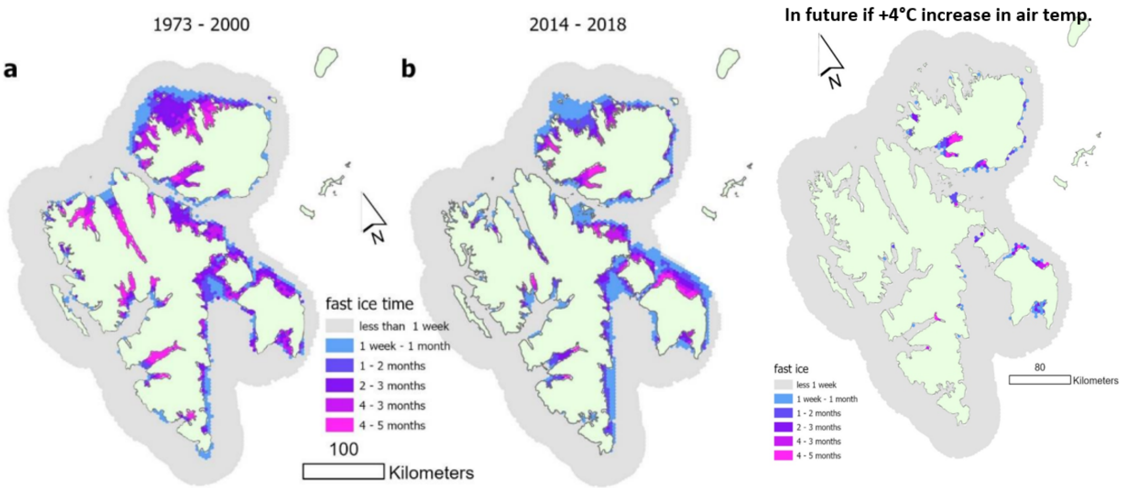



*Figure 5 Since the 1973-2000 average, fjord ice with duration 2 months or longer has decreased drastically (from Urbański and Litwicka 2021). Sea ice is also much thinner today than previously making it more dangerous to travel on sea ice.*

## 4.1 Impacts on tourism

For ships, less sea ice makes it easier to operate in Svalbard and since 2006, a strong increase in ship traffic, both fishing vessels and passenger ships, is registered in Svalbard. In addition, the season now starts much earlier and ends later than before (see Figure 6, Stocker et al. 2020). Less sea ice in Western Svalbard has turned the spring months (March to May) into a significant tourism season for ship-based tourism, particularly the expedition cruise segment, after a ban on heavy fuels was introduced in protected areas. It is likely that a continued reduction in sea ice in northern and easter part of the archipelago will allow the spring cruise tourism season to also expand to these regions, barred any regulatory hindrances. On the other hand, reduced fast ice in the western fjords bars snowmobile tourism traffic, particularly the route between Longyearbyen and Pyramiden (see figure 6). While the part of the fjord where the snowmobile route crosses used to have fast ice for four to five months, it now only has ice for one to two months. In a future with a high emission scenario, there will barely be any fast ice in any of the fjords of Spitsbergen.

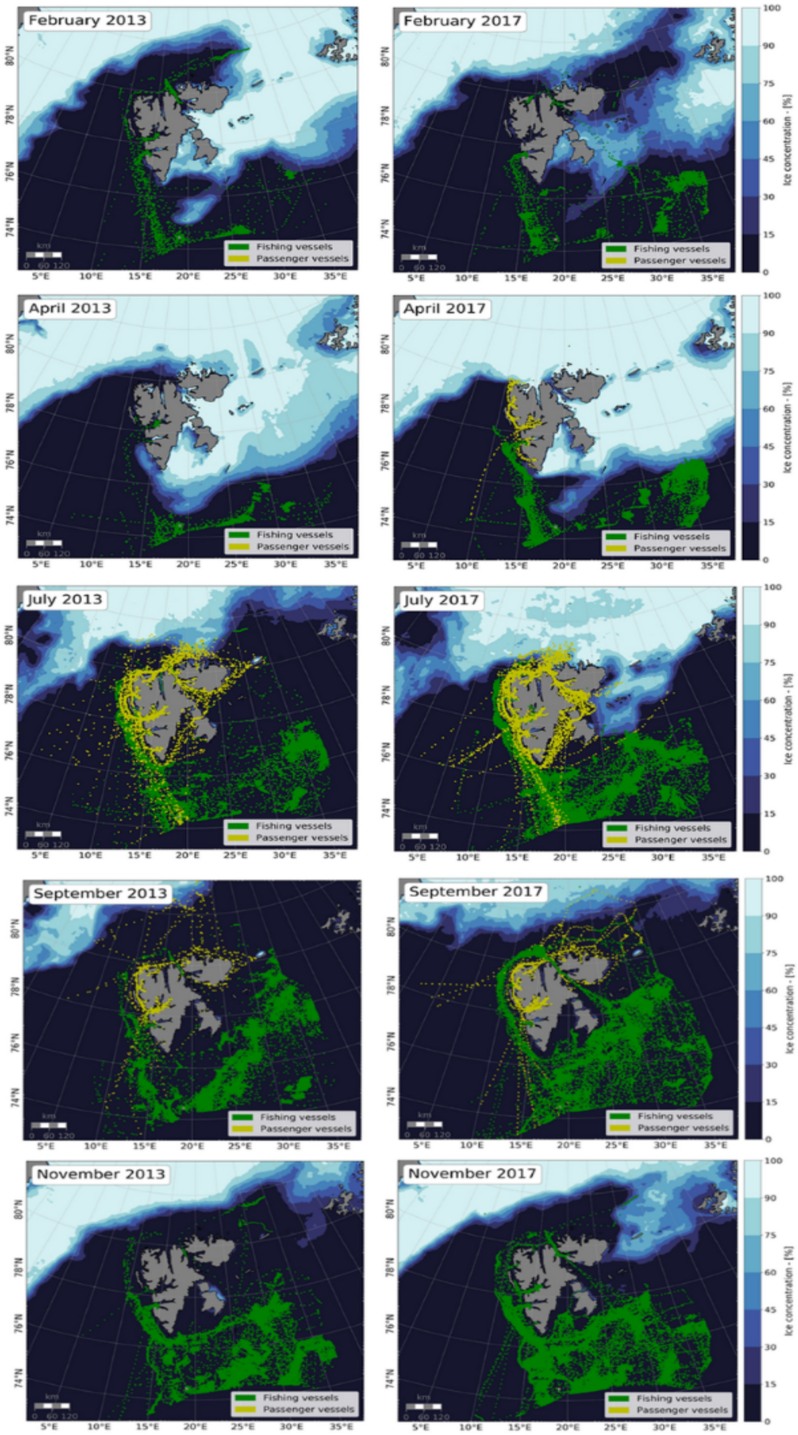



*Figure 6. Maritime traffic around Svalbard for selected months in 2013 and 2017. Yellow is tourism vessels, and the green are fishing vessels. Source: Stocker et al. 2020, CC.BY.4.0*

# 5. Natural hazards

This section reviews the existing literature on natural hazards and climate change in Svalbard, focusing particularly on the effects of climate change on **permafrost**, **avalanches**, **landslides**, **rockfalls**, and **floods**. The section concludes by discussing the relevance of climate change and natural hazards for tourism in Svalbard.

The key findings regarding natural hazards and climate change in Svalbard are that: 1) upper layer permafrost is projected to thaw in coastal and low altitude areas; 2) many types of avalanches and landslides will become more prevalent; and 3) increased precipitation will lead to increased rain-floods and increased combined snowmelt-, glacier melt- and rain floods. Combined, these changes have significant consequences for human activity on Svalbard.

## 5.1 Permafrost

Svalbard is facing significant changes related to permafrost thaw. Monitoring of permafrost thermal states provides clear evidence of warming permafrost in Svalbard, and near-surface permafrost in coastal and low altitude areas is projected to thaw before the end of the century (Hansen-Bauer et al. 2019, Isaksen et al. 2022).

Warming and thawing permafrost increases risk of natural hazards. A thicker active permafrost layer in combination with increased precipitation will result in unstable slopes, increasing the risk for landslides and avalanches (Christiansen et al. 2019a, Haeberli et al. 2010, Hanssen-Bauer et al. 2019, Meyer 2022). Deteriorating permafrost conditions will also affect coastal erosion processes, especially where the coastline consists only of sediments (Hanssen-Bauer et al. 2019:11).

Permafrost degradation also poses an increased risk of infrastructure damage (Isaksen et al. 2022). For example, buildings and structures may experience strength deterioration and deformation, and possible foundation failure due to increases in permafrost temperature and degradation (Instanes 2003).

## 5.2 Avalanches

Projected climatic changes with increasing temperature and precipitation (as both snow and rain), coupled with increasing permafrost temperatures, will likely increase the frequency of all types of avalanches and landslides in Svalbard in the coming decades (Hanssen-Bauer et al. 2019). Towards the end of the century, gradually increasing temperatures may lead to a substantially shorter snow season and reduction in the maximum annual snow amounts in coastal low altitude areas, and the snow line will gradually shift to higher altitudes. Over time, these factors are expected to decrease the probability of dry snow avalanches. However, the probability of wet snow avalanches and slush flows is expected to increase (like the wet snow avalanches and slush flows in 2012). While glide avalanches are not common in Svalbard in the present-day climate, they may become a problem at some locations in a future warmer and wetter climate (Hanssen-Bauer et al. 2019:124).

On Svalbard, increased avalanche activity threatens infrastructure and utilities, such as buildings, roads, bridges, pipes, and masts (Hestnes et al. 2016). Increased avalanche activity also poses a risk to human life and residential areas. Longyearbyen experienced two major avalanche events in December 2015 and February 2017. In 2015, two people lost their lives when a large slab avalanche from the ridge of Sukkertoppen destroyed ten houses in Longyearbyen. The 2017 avalanche damaged several buildings, but there were no fatalities (Hestnes et al. 2016, Hanssen-Bauer et al. 2019, Meyer 2022).

Increased human activity on Svalbard, particularly in the Longyearbyen area, affects people's exposure to natural hazards such as avalanches. Population and tourism have grown considerably since the 1960s and, consequently, the number of people involved in backcountry activities has strongly increased. Human triggered slab avalanches seem to cause most fatalities among recreational backcountry skiers and snowmobilers (Figure 7), while naturally triggered avalanches are the main threat to infrastructure, transport routes and residential areas (Hanssen-Bauer et al. 2019:122).

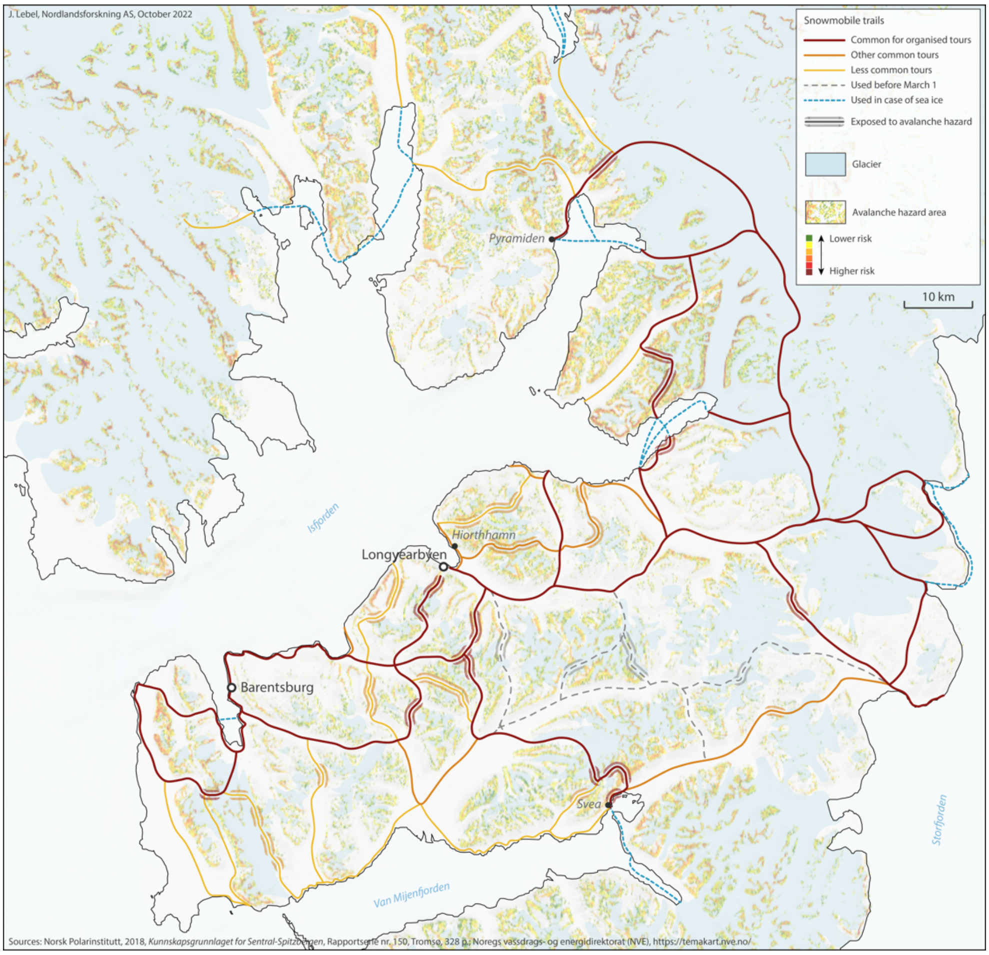



*Figure 7 Map of snowmobile routes around Longyearbyen and avalanche risk areas. Section of routes that crosses avalanche risk zones are indicated by grey. Map produced by Julien Lebel, with map layers from Norwegian Polar Institute and NVE.*

## 5.3 Floods

While flood estimates for Svalbard are highly uncertain, changes in the frequency and magnitude of floods are strongly linked to changes in precipitation, snow storage and glacier regimes. On Svalbard, increased precipitation will thus likely lead to increased rain-floods and increased combined snowmelt-, glacier melt- and rain floods. In turn, increases in rain, glacier melt, and river flows will increase erosion and sediment transport (Hanssen-Bauer et al. 2019).

In regions where the annual maximum snow storage is expected to decrease, snowmelt floods will become smaller. Increased precipitation and a larger fraction as rain will increase the magnitude and frequency of rain floods and combined snowmelt, glacier melt and rain floods. For the high emission scenario towards the end of the century, the glacier area and volume in several catchments will be reduced to the extent that the contribution from glacier meltwater to floods will be negligible (Hanssen-Bauer et al. 2019:10).

## 5.4 Landslides and rockfalls

Increased air temperature and permafrost thawing, combined with increasing frequency of strong precipitation events will lead to more active slope processes and significantly greater instability in mountain slopes, leading to an overall rise in landslide activity in Svalbard (Hanssen-Bauer et al. 2019:125). While there are currently no studies published on the effect of permafrost on rockslides in Svalbard itself, studies from Northern Norway show that increasing temperatures leading to degradation of permafrost may play an important role in the detachment of larger rockslides. (Blikra et al. 2015; Frauenfelder et al., 2018, Hanssen-Bauer et al. 2019:124). Degradation of permafrost is thus likely to play an important role in the detachment of larger rockslides on Svalbard as well.

## 5.5 Relevance of natural hazards and climate change for tourism.

Svalbard is experiencing the impacts of climate change at a rate that far surpasses mainland Norway and the concomitant risk of natural hazards will likely have significant consequences for human activity in the archipelago. While more research on the relevance of natural hazards and climate change for tourism is needed, several recent studies shed light on some of the societal impacts of climate change on Svalbard and in Longyearbyen (see Kaltenborn et al 2020, Hovelsrud et al. 2021, Jaskólski et al. 2018, Meyer 2022, Tvinnereim, Angell, Kolstad, Brekke & Mortensen 2016, Timlin et al. 2022). These studies find that environmental changes due to climate change will have implications for industrial activities, logistics in the greater Svalbard area, tourism operations, and the town of Longyearbyen.

The future development of natural hazards is particular salient for Longyebyen area, which is exposed to all categories of natural hazards mentioned above. Norwegian Svalbard policy state that future tourism growth and development should be concentrated in the Longearbyen area (Hovelsrud et al. 2023). Natural hazards is a thus a major shaping factor in how tourism development in Longyerbyen can take place. Already, hotels in the upper part of the town needs to be evacuated when avalanche risk is high.

Some authors conclude that large parts of Longyearbyen will need to be either upgraded or relocated due to the increased risk of natural hazards such as landslides and avalanches, thawing permafrost and flooding (Meyer 2022). Hovelsrud et al. (2020) moreover discuss how heightened avalanche risk affects people's psychosocial health and quality of life. Increased risk of flooding, avalanches and landslides will also limit the area available for new construction and continued development on Svalbard. Additionally, erosion may put coastal cultural heritage at increased risk and may also expose old graves and burial sites (Hovelsrud et al. 2020, Nicu et al. 2021). All these can have further impacts on residents' lives and scope for tourism development in the Longyearbyen valley (Hovelsrud et al. 2020, Jaskólski et al. 2018, Timlin et al. 2022).

*"Longyearbyen with poppy fields" -image created with the image generator Dall E 2.*

# 6. Observed and projected climate change and impacts on other areas

Svalbard is one of the places on Earth with the fastest rate of warming. Since 1961, the mean temperature has increased by 5,6 C (Hanssen-Bauer et al. 2019). The archipelago used to be semi-arid, but that is no longer the case. During recent decades there have been several episodes of heavy rainfall during winter. These changes are bringing about unprecedented changes for the environment in Svalbard, which both directly and indirectly impacts tourism activities on the islands.

## 6.1 Temperature and precipitation

Over the last 100 years, temperatures have increased by an average rate of 0,3 degrees per decade, with the largest increase observed in winter temperatures. Downscaled CMIP 5 models for various emissions scenarios (RCPs) show a mean annual temperature increase from 3 degrees Celsius (RCP 2.6), 6 degrees Celsius (RCP 4.5) and over 10 degrees Celsius (RCP 8.5) by 2100. It's worth noting that even the "middle of the road" emission scenario (RCP 4.5) has a high-end projection increase in winter temperatures of 16 degrees Celsius, by the end of the century, and a median annual temperature increase by 5 degrees Celsius by 2050 (see figure 8). If the temperature continues to rise at its current rate of increase, in 100 years, the climate in Svalbard will be like the current climate in Demark (Hanssen-Bauer et al. 2019).

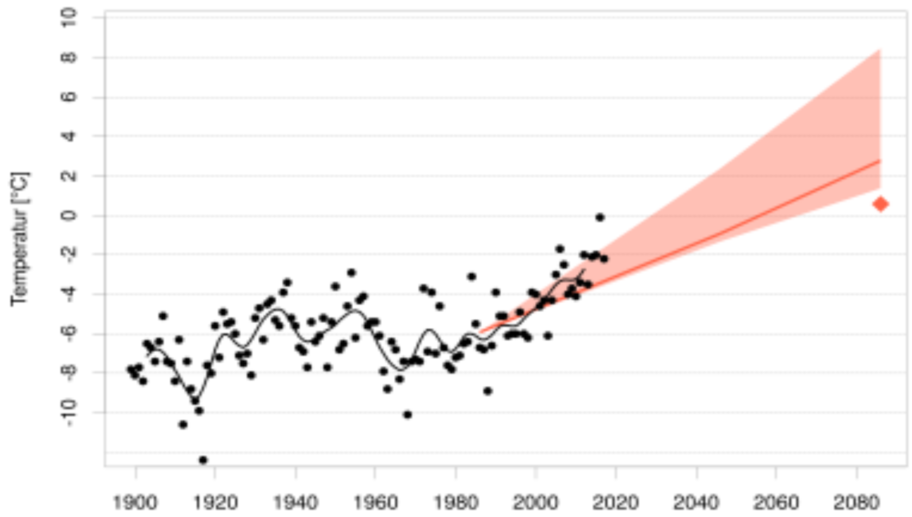



*Figure 8. Projections for future temperature development with a high emission scenario (red line) and historical temperature records (black dots). The light red shading shows the interval between low and high model estimates. (Norsk Klimaservicesenter 2021)*

The projected temperature increase will have massive effects on ecosystems. The growing season (successive days per year with temperatures above 5 degrees Celsius) in the Isfjorden area increases from between 2 and 55 days to 128 days by 2100 (see figure 9). The non-glaciated part of Svalbard is projected to increase by three to four months – three to four times the reference period level (1970-2000).

Precipitation is also increasing, and in Longyearbyen, precipitation has increased by over 20% since 1971. By 2100, annual precipitation is projected to increase by 40% compared to the 1971-2000 baseline (see figure 8). Projections show that episodes with rain during winter in the Longyearbyen area will triple (Norsk Klimaservicesenter 2021). An increase of 35% in extreme precipitation events is also projected. These tend to happen in the autumn and winter months.

The snow season has decreased by 20 days from 1958 to 2017, but the amount of snow that has fallen has increased in line with the increased precipitation. Climate projections estimate a further increase in snow, but a rapid shortening of the snow season. The most widespread climate model used for downscaling, the CORDEX, gives a huge difference between the RCP 4,5 and RCP 8,5 scenarios (see see figure 10). With the RCP 8,5 scenario, there will be no snow during winter in the coastal areas around much of the islands. This correspond to Svalbard getting the climate in Denmark.

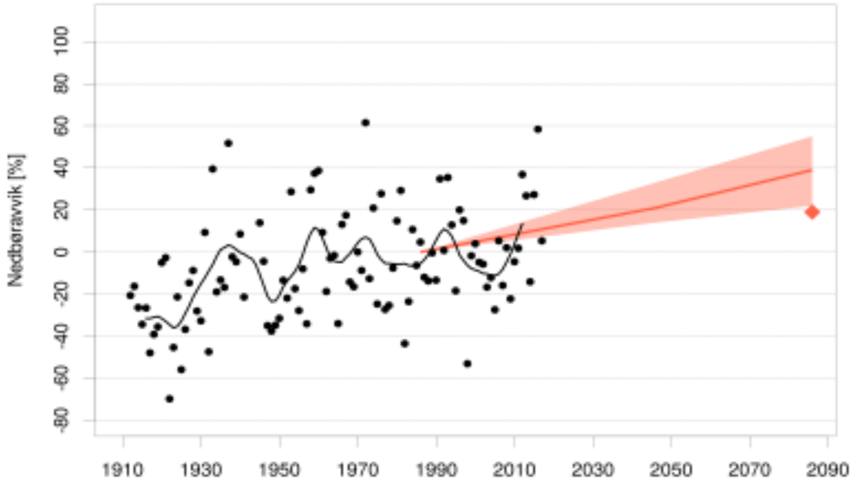
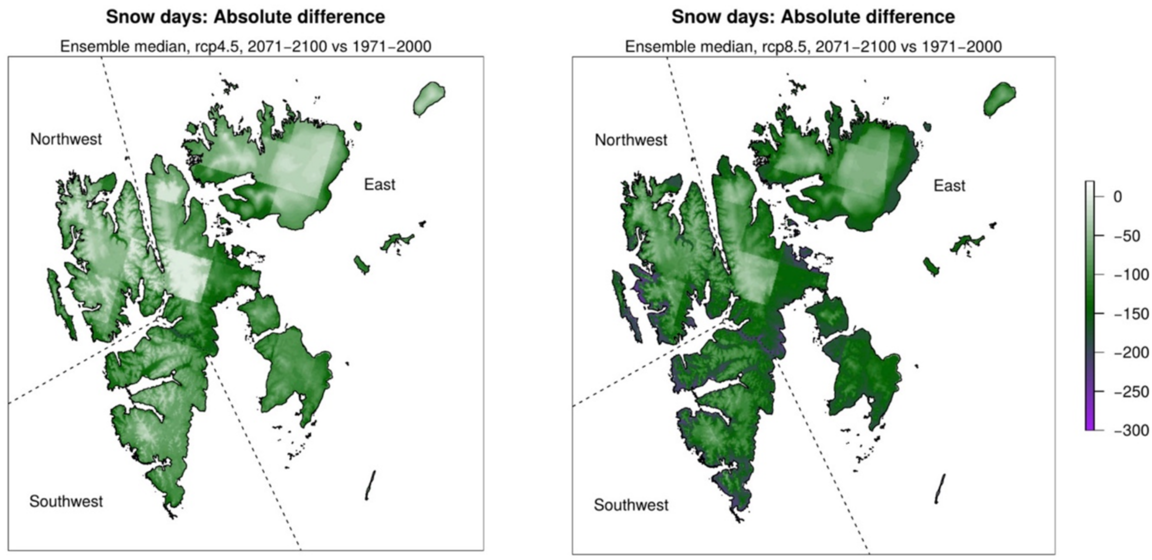
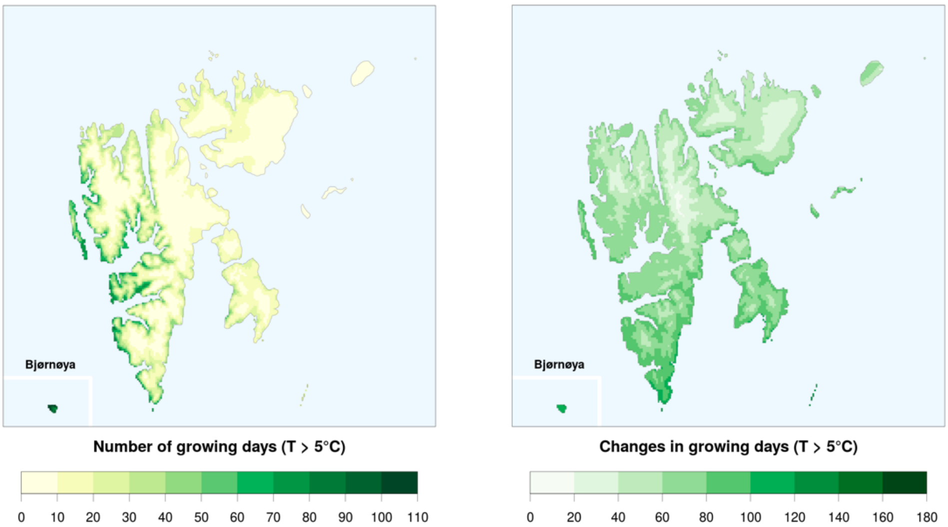



*Figure 9. Projected and recorded precipitation in Svalbard (high emission scenario). (Norsk Klimaservicesenter 2021)*




*Figur 10. Projected changes in length of season with snow cover in number of days from 1971-200 to 2071-2100. Coastal areas will lose 300 days with snow cover, (purple) meaning that the coast also will be mainly without snow during winter. (Hanssen-Bauer 2019)*




*Figur 11. Current number of growing days (Temperatures above 5 degrees C) and changes in growing days by 2100. (Hanssen-Bauer et al. 2019)*

## 6.2 Relevance for tourism

The increased temperature is already noticed among tourism operators and has already consequences: the summer season products – day trips with boats, are extending much longer into the autumn than just 10 years ago according to local informants. While autumn on Svalbard used to be short, higher temperatures and less sea ice allows for boat trips and hiking trips during September. The reduced daylight is more of limiting factor during the winter months. With the projected changes, it's likely that this development will continue if there is demand.

The increase in precipitation is projected to be greatest in autumn and winter. It might therefore have a minimal impact on summer and boat tourism. Increased snowfall in winter creates more days with avalanche risk, as outlined above. Furthermore, a shortening of the snow season (days with snow cover) is likely to shorten the spring season for snowmobile trips, which as of now extends into mid-May. One consequence is that snowmobilers and skiers must traverse glaciers instead of travelling along the coast or in the valleys where there is a lack snow. This comes with its own set of risks that we will outline below. Warmer winters also include more frequently occurring episodes of rainfall, which can cause flooding that block transportation routes.

## 6.3 Glaciology

The glaciers of Svalbard are rapidly losing mass (Figure 12). A recent survey found a 1,5-meter decline of the Longyear glacier measured during the summer of 2022. Where glaciers that terminate in the fjords are receding, they are altering entire coastal ecosystems. Glacier fronts are hot spots for marine life, particularly for marine mammals in periods where there is no sea ice. Seals are attracted to floating pieces of glacier ice that they can rest on. (NP 2018)

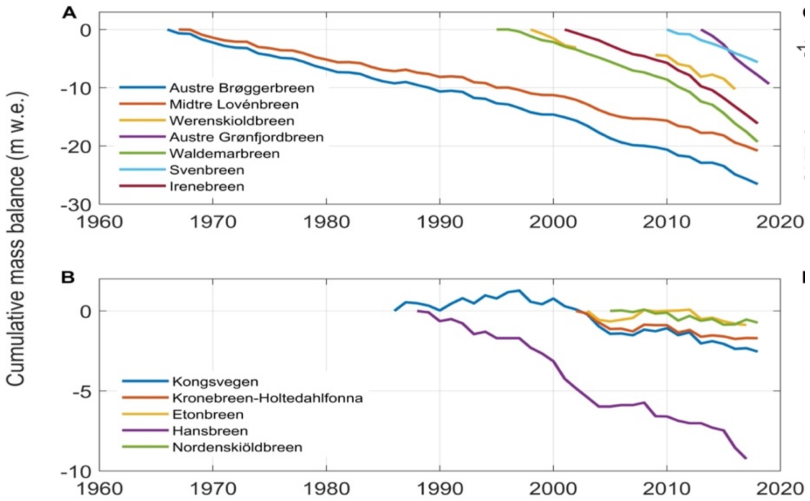



*Figure 12. Cumulative mass balance development for larger (A) and smaller (B) glaciers. Y axis is Giga ton. Schuler et al. 2020*

## 6.4 Relevance for tourism (impacts on and from tourism)

The retreat of glaciers does damage and disrupt major tourism transportation routes in central Spitsbergen, used for snowmobiles, skiers, dog sledders (mushers) and to some extent hikers. The shortening of the snow season and loss of sea ice is forcing a relocation of snowmobile routes towards the inner parts of Spitsbergen, which includes long stretches of glacier and ice cap crossings and higher altitude terrain. This exposes snowmobilers to crevasses and more challenging weather conditions.

# 7. Summary of most important likely impacts for tourism

Svalbard is experiencing rapid changes in environment and climate at a rate that far surpasses mainland Norway, which in turn presents both opportunities and challenges for the tourism industry. One of the major impacts experienced so far is the disappearance of land fast ice in the fjords of Western Svalbard in the late winter and spring months. This has opened a new season for cruise- and expedition cruise tourism in late winter and spring and has also extended the summer season. However, the extended season increases risk of accidents, for example, ship damage due to sea ice collision and stormy weather when approaching the winter (and darkness).

The increased ship and boat traffic also increases the risk of hitting seabirds and marine mammals while driving (especially at speed >25 knots). Underwater noise from ships and boat traffic is also thought to disturb marine wildlife. Increased risk of pollution from marine traffic, such as oil spills, is also a growing concern. Fishing boats are by far the largest contributors to plastic pollution (fishing gears etc.).

Climate change is also heightening the risk of natural hazards, which will likely have significant consequences for all human activity on Svalbard. Climate change is projected to accelerate permafrost thaw, exacerbate risk of avalanches and landslides, increased precipitation will lead to increased flood risk. Increased avalanche risk, for example, is likely to cause more frequent closure of major inland snowmobile routes, such as the one between Barentsburg and Longyearbyen (see figure 11). More frequent rain episodes in winter also pose a challenge for land-based tourism activities (ski tours, dog mushing or snowmobiles), for example, by causing flooding of transportation routes in valleys. The season for guided snowmobile trips has already been cut short because of the shortening snow season and due to loss of sea ice. This has forced tour groups to more frequently travel into higher altitudes and onto glaciers, which involves increased safety risks due to longer travel routes, crevasse danger and more challenging weather conditions ("whiteouts" etc.).

## 7.1 Climate change implications for further tourism development around Longyerbyen

Recent strategies for tourism development on Svalbard state that further development of tourism should be concentrated in Longyerbyen and Longyerdalen and Adventdalen valleys (Hovelsrud et al. 2023). This means that climate change impacts in this area is of particular significance. Further tourism infrastructure development, such as trails, shelters etc. also need to be concentrated within the planning area of Longyerbyen local council. Such development thus need to take into account:

- Increased risk of flash floods and slush avalanches
- Increased land slide risk
- Increased avalanche risk

The Norwegian agency responsible for avalanche and flood protection, NVE has both installed flood and avalanche prevention measures in the Longyerdalen valley that mitigate these risks, but with the rate of change in temperatures and precipitation that is projected it is likely significant uncertainties wether the prevention measures is sufficient.

Adventsdalen valley is the main gateway from Longyearbyen to the wider Isfjorden Area as well as Northern Spitzbergen. Warmer and wetter winters and spring seasons might complicate snowmobiling, dogsledding and skiing through this valley, due to open streams and inundation of the trails.

Increased presence of polar bears around Isfjorden might be temporary, but it might also signal a more lasting trend. In any case it places a larger responsibility for tourism operators when planning and executing tourism activities in the Isfjorden area, which also includes the areas around Longyearbyen.

## 7.2 Climate change increases ecosystem vulnerability to human activities

Economic opportunities for the tourism industry are increasingly constrained by the need to take climate change impacts and environmental requirements into account. In fact, from a climate change perspective, the tourism industry faces a greater diversity of risk than other economic sectors (Scott, Hall, & Gössling, 2019). Hovelsrud et al. (2021) conclude by specifying that ecosystem services such as sea ice, permafrost, flora, and fauna are directly or indirectly affected by climate change (Hanssen-Bauer et al., 2019; Hovelsrud, Poppel, Oort, & Reist, 2011), thereby affecting the infrastructure and products at the heart of Svalbard tourism. The new regulations for environmental protection and tourism management is partly motivated by the increased climate change induced vulnerability of ecosystems to human activities. In the short term, this regulations, which will have sweeping impacts on tourism, might turn out to be the most significant indirect impact of climate change.

To sum up – until now, impacts of climate change have been a greater benefit than challenge to tourism in Svalbard, in the way it has allowed for a new tourism season with ship and boat traffic in the spring. However, the rapid and cascading changes projected in the coming decades is likely to be disruptive, particularly in terms of increased risk of natural hazards.

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