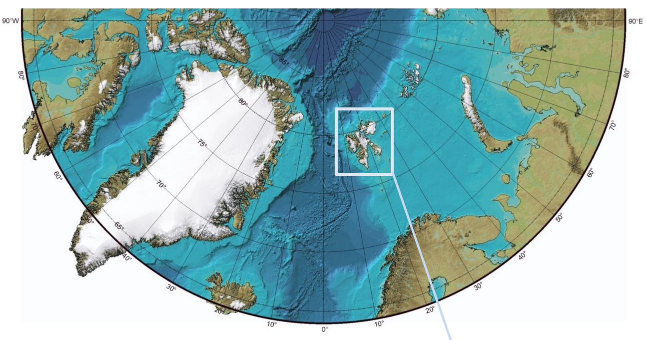
Svalbard glacier-mass balance: Freshwater discharge and implications for the marine ecosystem

Thorben Dunse[1], Kjetil Schanke Aas[1], Jon Ove Hagen[1], Thomas V. Schuler[1], Thomas Schellenberger[1], Leif Christian Stige[2]

Department of Geosciences, University of Oslo, Oslo, Norway; e-mail: thorben.dunse@geo.uio.no

Centre for Ecological and Evolutionary Synthesis, University of Oslo, Oslo, Norway

GreenMAR — GREEN GROWTH BASED ON MARINE RESOURCES: ECOLOGICAL AND SOCIO-ECONOMIC CONSTRAINTS



Outline

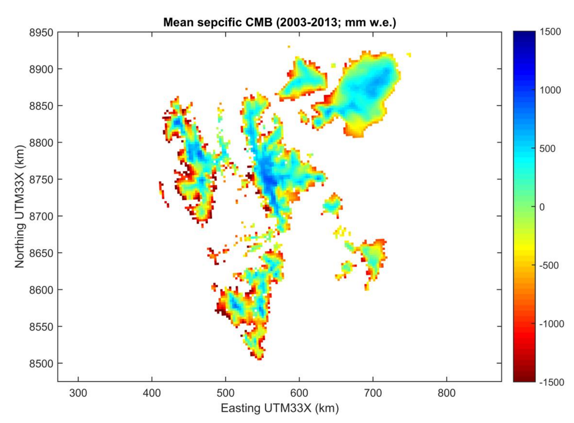
Glacier wastage accounts for two-thirds of the observed global sea-level rise. Accelerated mass loss since the 1990s coincides with atmospheric warming in the Polar regions, both of which are expected to further increase in the future.

Here we focus on the Svalbard archipelago in the Eurasian Arctic, bordered by the Barents and Greenland Sea, to the East and West, and the Arctic Ocean to the North. 34000 km^2 or 57% of the total land area on Svalbard is covered by glaciers and ice caps. 68% of the glacierized area drains through tidewater glaciers with a total calving-front length of ~740 km (Nuth et al., 2013).

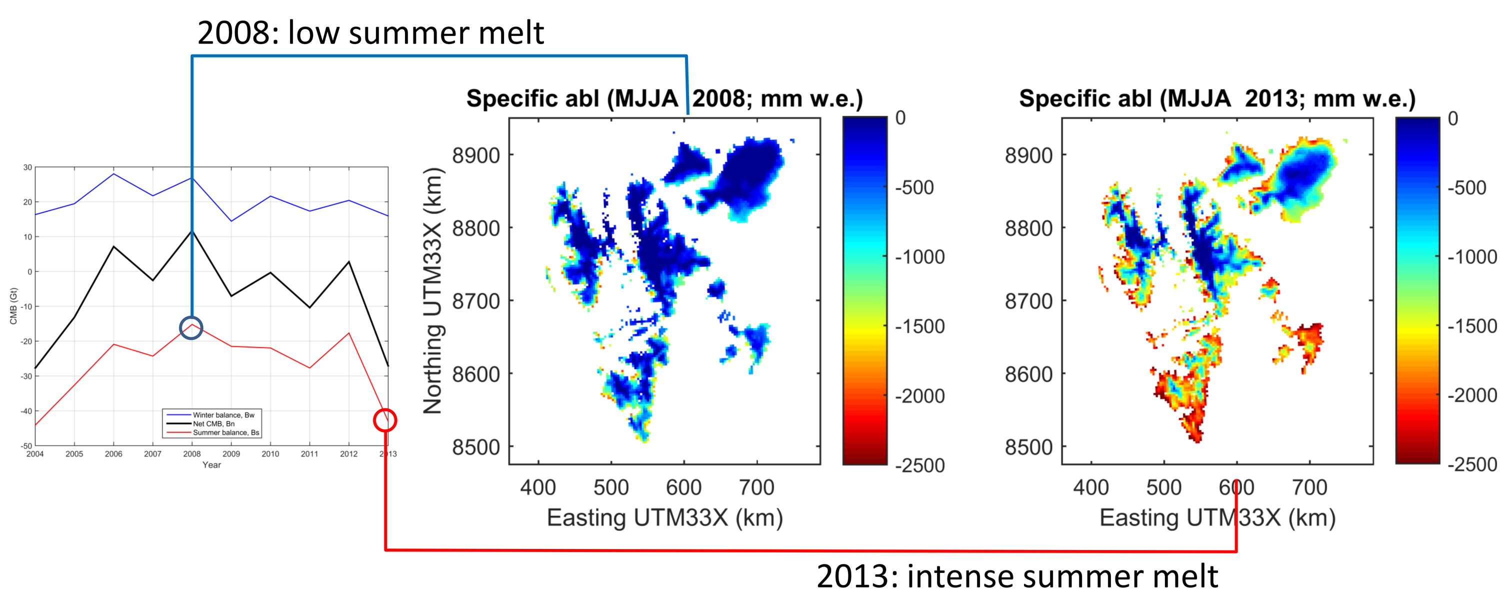
Tidewater glacier environments are important habitat and foraging ground for seabirds and marine mammals (Lydersen et al., 2014; Figs. Box 4). In addition, freshwater discharge from glaciers into the ocean affects the physical and chemical properties of the fjord systems and adjacent shelves (Meire et al., 2015). Increased freshwater input enhances estuarine circulation and nutrient input, with positive effects on biological productivity (Rysgaard et al., 2003). Glaciers discharge freshwater either in the form of meltwater runoff or iceberg calving.

1: Climatic mass balance: Snow accumulation & meltwater runoff

The climatic mass balance (CMB) addresses glacier-mass changes driven by climate processes at or near the glacier surface. The CMB comprises a winter balance where the glacier gains mass, mainly by snow accumulation, and a summer balance, where it looses mass, mainly by surface melt and run-off.



A 10-year simulation of Svalbard-wide CMB using the Weather Research and Forecasting model (WRF) coupled to a climatic mass balance model (Schanke et al., in prep.) shows large interannual variation, especially in terms of the summer balance. Summer ablation in 2008 was low, whereas in 2013 it was very high, resulting in a small and large freshwater contribution into the surrounding seas, respectively.

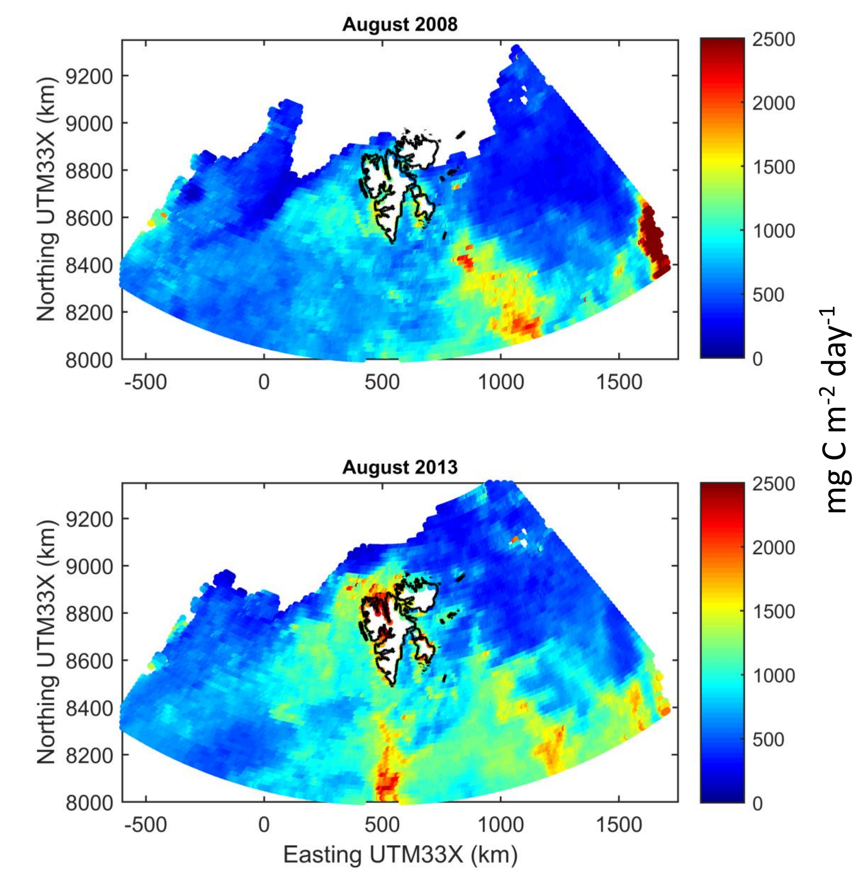


2: Does the primary production in the ocean reflect the pattern of glacier meltwater runoff?

At high latitudes, ocean-primary production can be co-limited by light and iron (Sigman & Hain, 2012). Studies from Greenland revealed that high glacial meltwater runoff stimulated primary production through supply of nutrient-rich glacier meltwater (Juul-Pedersen et al., 2015), which may balance iron deficiency in the euphotic zone (Bathia et al., 2013).

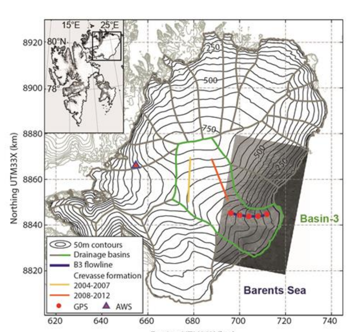
Primary production in Svalbard fjord systems and adjacent shelves was higher and more widespread in August 2013 then in 2008, coincident with high and low summer melt / freshwater run-off, respectively (Box 1).

Monthly net primary production around Svalbard provided by the Ocean Productivity webpage (www.science.oregonstate.edu/ocean.productivity/); based on MODIS chlorophyll a and sea-surface temperature (SST), SeaWiFS Photosynthetically Available Radiation (PAR) and depth of the euphotic layer as inputs to the Vertically Generalized Production Model (VGPM; Behrenfeld and Falkowski, 1997)



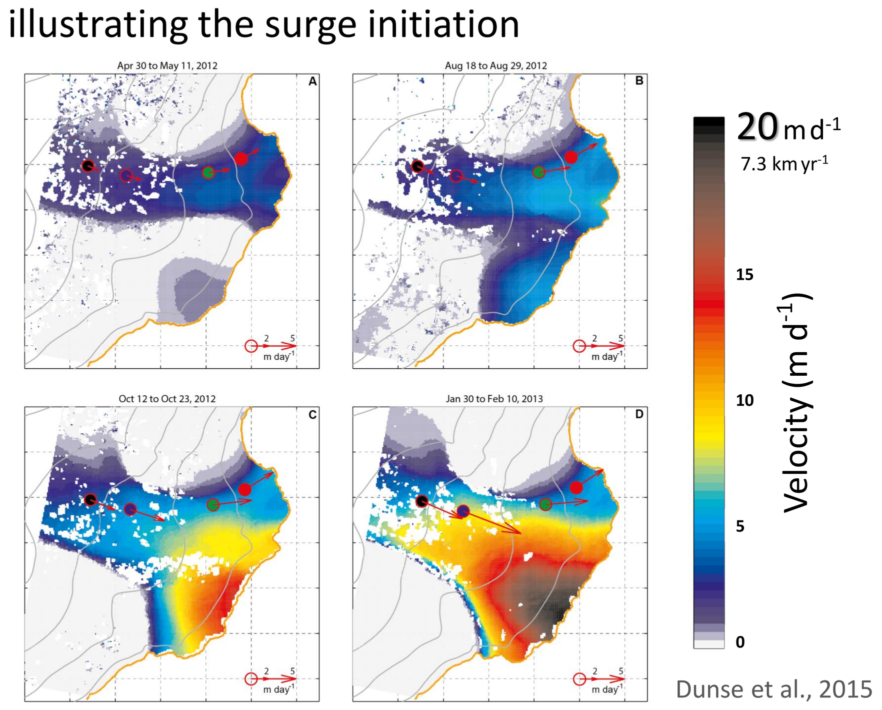
3: Dynamic mass balance: Iceberg calving

Dynamic mass loss refers to transport of ice towards tidewater margins and release of iceberg ("calving") at the calving front.



Iceberg calving allows for rapid mass loss, such as evident during dynamic instability ("surge") of Basin-3, an outlet glacier of the Austfonna ice cap. The surge started in autumn 2012, reaching peak velocities of >20m day^{-1} in early 2013 (Dunse et al., 2015). The associated iceberg discharge during April 2012 and May 2013, amounted to 4.4 ±1.6 Gt, increasing the long-term calving flux from the entire Svalbard archipelago by >50%.

Satellite-derived ice-surface velocity maps (TerraSAR-X) illustrating the surge initiation



Dunse et al., 2015

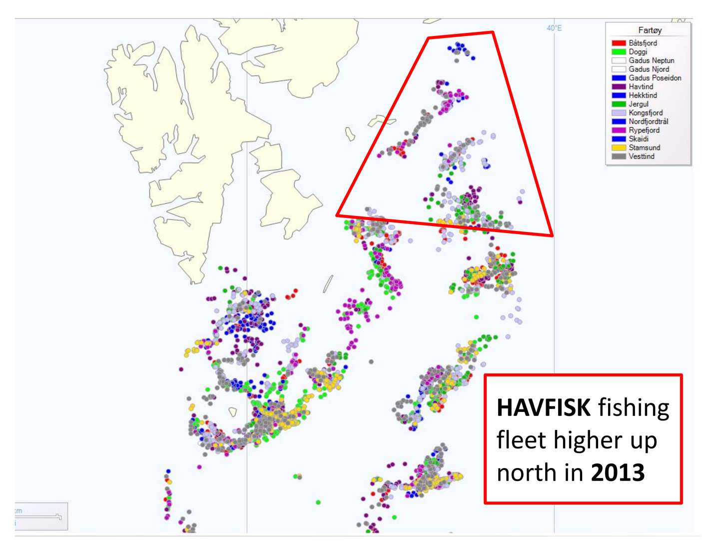
Turbid meltwater plumes indicate release of large amounts of sediment-rich subglacial meltwater during surge initiation

MODIS true color image, Sep 2013

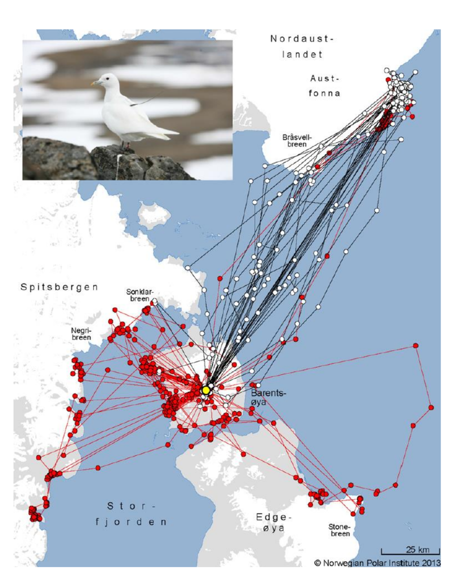
4: Is there a glacial footprint on the interannual variability of fish-stock around Svalbard?

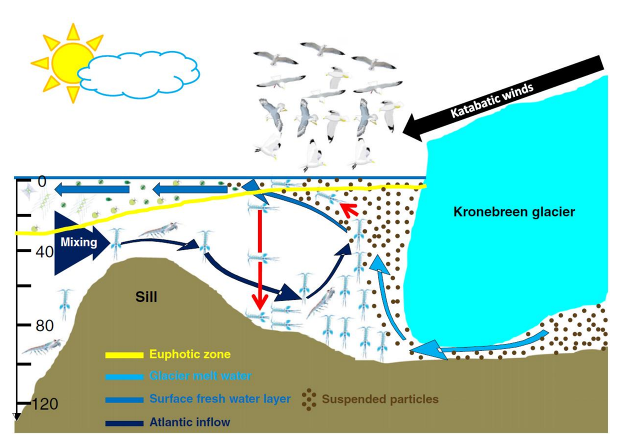
Annual track logs from HAVFISK fishing fleet reveals activities in 2013, higher up north than in other years. Abundance and distribution of fish may be related to temperature through several mechanisms. Is there also a glacial footprint?

- Extreme summer melt 2013 and Svalbard-glacier runoff, in general
- Surge of Basin-3 and associated iceberg discharge and upwelling of nutrient rich subglacial waters , in particular



Figure, courtesy of HAVFISK ASA





Lydersen et al., 2014

- Basin-3, Austfonna: ivory gulls feed on zooplankton suffering from osmotic shock upon entrainment into glacier meltwater (Lydersen et al., 2014)

References

Aas, K.S., T. Dunse, et al., manuscript in prep.: *The climatic mass balance of Svalbard glaciers from 2003-2013 simulated with an interactive glacier-atmosphere model.*

Bhatia, M. P.; Kujawinski, E. B.; Das, S. B.; Breier, C. F.; Henderson, P. B. & Charette, M. A., 2013: *Greenland meltwater as a significant and potentially bioavailable source of iron to the ocean*, Nature Geoscience, 6, 274-278

Behrenfeld, M. J., and P. G. Falkowski, 1997: *A consumer's guide to phytoplankton primary productivity models*, Limnology and Oceanography, 42, 1479-1491

Dunse, T., Schellenberger, T., Hagen, J. O., Kääb, A., Schuler, T. V., and Reijmer, C. H. , 2015: *Glacier-surge mechanisms promoted by a hydro-thermodynamic feedback to summer melt*, The Cryosphere, 9, 197-215, doi:10.5194/tc-9-197-2015

Juul-Pedersen, T., Arendt, K. E., Mortensen, J., Blicher, M. E., Sogaard, D. H. & Rysgaard, S., 2015: *Seasonal and interannual phytoplankton production in a sub-Arctic tidewater outlet glacier fjord, SW Greenland,* Marine Ecology Progress Series, 524, 27-38

Lydersen, C., Assmy, P., Falk-Petersen, S., Kohler, J., Kovacs, et al. , 2014: *The importance of tidewater glaciers for marine mammals and seabirds in Svalbard, Norway*, Journal of Marine Systems, 129, 452-471

Meire, L., Sogaard, D. H., Mortensen, J., Meysman, F. J. R., Soetaert, and 4 others, 2015: *Glacial meltwater and primary production are drivers of strong CO2 uptake in fjord and coastal waters adjacent to the Greenland Ice Sheet,* Biogeosciences, *12*, 2347-2363

Nuth, C., Kohler, J., Konig, M., von Deschwanden, A., Hagen, J. O., Kaab, A., Moholdt, G. & Pettersson, R. , 2013: *Decadal changes from a multi-temporal glacier inventory of Svalbard.* The Cryosphere, 7, 1603-1621, doi:10.5194/tc-7-1603-2013

Rysgaard, S., Vang, T., Stjernholm, M., Rasmussen, B.,Windelin, A. & Kiilsholm, S., 2003: *Physical conditions, carbon transport, and climate change impacts in a northeast Greenland fjord*, Arctic Antarctic and Alpine Research, 35, 301-312

Sigman, D. M. & Hain, M. P. , 2012: *The Biological Productivity of the Ocean,* Nature Education Knowledge 3(10):21

For questions or suggestions, please contact

Thorben Dunse
Post-doc in Glaciology
Department of Geosciences,
University of Oslo
Tel: +47 2285 5836
E-mail: thorben.dunse@geo.uio.no

CRYOMET