Project information

Keywords

Arctic, climate change, winter disturbance, pollutants, multistress, Svalbard, Poland, vegetation

Project title

Ecosystem stress from the combined effects of winter climate change and air pollution - how do the impacts differ between biomes? (WICLAP)

Year

2017

Project leader

Jarle W. Bjerke, NINA

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

Five localities provided as indicated in the guidelines. 1: Ny-Ålesund area, 78.9115 °N 12.0593 °E (example from Gluudneset). 2: Longyearbyen area, 78.2494 °N 15.4353 °E (example from Hotellneset-Vestpynten). 3: Hornsund, 76.9373 °N 15.8892 °E. 4: Tromsø, 69.6544 °N 18.9099 °E (Example from Holt Climate Laboratory). 5: Beskid Zywiecki (alpine parts of Poland) 49.4489 °N 19.0782 °E.

Participants

Current project participants from Fram Centre institutions: Dr. Hans Tømmervik, NINA; Dr. Dagrun Vikhamar Schuler and coworkers, Meteorologisk institutt. Associated partner: Stein Rune Karlsen and coworkers, NORUT. In addition, partners from the Polish Institute of Geodesy and Cartography (IGiK), Warsaw University, Opole University and University of Sheffield. Administrative responsibility: Research Director Cathrine Henaug, NINA.

Flagship

Terrestrial

Funding Source

The Polish-Norwegian Programme of the EEA Norway Grants (project ID 198571)

Summary of Results

For the academic communication of results, we have published many of our findings in peer-reviewed journals; see list under “Published/Planned publications”. This list now includes 17 publications, of which 11 are in international peer-reviewed journals. We have also shared our findings in conference presentations, reports and proceedings, including the Arctic Report Card. Tømmervik recently organized a science workshop funded by Svalbard Science Forum/RCN, which attracted many Norwegian and international scientists interested in the state of Arctic vegetation. We are also currently preparing additional articles based on results gathered during this project. These are also listed under “Published/Planned publications”.

Here follow a summary of our recent findings and their implications. These adds to the summary of results provided in our 2015 and 2016 reports to the flagship.

We have documented that the winter climate of Svalbard is under rapid change (Vikhamar-Schuler et al. 2016, Journal of Climate). We have provided evidence that recent winter warming events have caused major dieback of key tundra plants in Svalbard. The two perennial dwarf shrubs *Cassiope*

tetragona and *Dryas octopetala* were suffering from frost drought and anoxic ice conditions after warming events had reduced the snow cover, either exposing the tundra in midwinter or turning the snow cover into ground-ice. Both situations are potentially deadly for tundra plants, especially plants with overwintering buds above the soil surface. See Bjerke et al. 2017, Science of the Total Environment. A news article based on these results are under preparation.

The study by Bjerke et al. (2017) was based on vegetation surveys undertaken in 2014 and 2015. Our data from 2016 and 2017 show that the damage to tundra plants is still prevailing, and that many other species, including mosses and lichens, show signs of decline in cover in areas that have been snow-free or covered in ice in midwinter (Bjerke et al. in prep.).

A more detailed study on the applicability of using spectral leaf properties using a handheld spectrometer in evaluation of health status was undertaken on tundra plants of contrasting health. This study shows that the reflectance in red edge region of the electromagnetic spectrum is strongly linked to plant health. The Red Edge Normalized Difference Vegetation Index (RENDVI) measured in situ showed strong relationship with remotely sensed RENDVI, suggesting that remotely sensed damage to tundra vegetation is best detected and monitored using this index (Zagajewski et al. in review).

Our estimates of recent trends in Arctic tundra green biomass will soon be reported in the Arctic Report Card (Epstein et al. in press). Since this flagship report goes online immediately, we cannot provide any highlights from the Arctic Report Card here before it is published.

Two studies initiated during WICLAP's "sister project" EWWA (flagship funding 2012-14) was adopted by WICLAP and completed as part of the WICLAP project. We have shown that mosses damaged by frost drought during winter are not able to regain previous growth rates during subsequent no-stress years. This implies that sublethal stress impacts on moss growth can have long effects after the stress event. Given the key importance of mosses for soil insulation, shelter and carbon sequestration in high-latitude regions, such persistent impacts may ultimately affect important ecosystem functions (Bjerke et al. 2017, Functional Ecology).

An extreme icing event hitting the world's northernmost botanical garden in Tromsø, in subarctic Norway, rendered an opportunity to study the impacts of ice encasement on alpine garden plants from six continents. We found that mortality was negatively correlated with terrain slope, that cryptophytes were most vulnerable, and that good soil drainage improved all plants' survival. The study revealed that botanical garden studies may be a valuable supplement to field studies, as plants of different origins could be studied under similar climatic conditions (Bjerke et al. 2017, Norwegian Journal of

Geography).

We have also shown that plant and fungal samples collected in the Longyearbyen area contain relatively high concentration of nickel, and this is assumed to originate from coal dust from the mining. Moderate concentration of lead, mercury and caesium (Cs-137) in soil and biological samples probably originate from sea aerosols. These elements may constitute a baseline stress element for the tundra vegetation causing higher sensitivity to other types of stress, for example frost drought (Kłos et al. 2017, Ecological Chemistry and Engineering S).

Overall, we have in this project thus far provided extensive evidence that Svalbard vegetation is under change due to stressful impacts from changing winter climate, and additional results supporting this view is to be published in 2018. The rapid and massive changes in winter climate may result in major changes to the vegetation composition of Svalbard's tundra that will far exceed the changes imposed by a slightly warmer, relatively speaking, summer climate. Through our contribution to the Arctic Report Card, we place the unique studies undertaken in Svalbard and mainland Scandinavia in a pan-Arctic perspective.

We are also providing new knowledge on winter climate change and changes in air pollution, and biological responses, on a temperate-alpine area (Poland). These results are in review and in preparation.

Master and PhD-students involved in the project

Bjerke and Tømmervik are co-supervisors for a PhD student, Rachael Treharne, at the University of Sheffield through the ACCE doctoral training partnership funded by the British Natural Environment Research Council, to which NINA is a so-called CASE partner (https://acce.shef.ac.uk/people/case-partners/). The student is associated with WICLAP and did fieldwork for her thesis at Svalbard in 2015.

Elmar Ritz, a student at the Institut für Geographie und Geoökologie at Karlsruhe Institute of Technology wrote in 2017 a diploma thesis on WICLAP-related topics, with Bjerke and Tømmervik as supervisors. Title of thesis: The contribution of mosses and dwarf shrubs to the greenness of subarctic ecosystems.

For the Management

This project addresses several priorities of international climate and pollution agendas. The studies contribute to our knowledge on an understudied, but highly important, element of climate change, namely the frequency, magnitude and spatial extent of winter warming events and their impacts on ecosystem health at different latitudes. Parallel studies of ecosystem pollution by heavy metals and other types of pollutants, and temporal variability in ecosystem pollution, enhance our knowledge of the combined stressors of climate change and air pollution on different biomes. Knowledge of biological and societal consequences of these phenomena is enhanced, and the most vulnerable and stressed areas and ecosystems are being detected and identified.

As the project relates to climate and pollution at several levels – from extremes histories, via impacts on natural ecosystems and agroecosystems, to impact projections for the future – the results are of high relevance to the population at large in both countries involved and the entire EU, the nature management and agricultural sectors, and to the development of industry and livelihood.

Published Results/Planned Publications

Epstein H.E., Bhatt U.S., Raynolds M.K., Walker D.A., Forbes B.C., Horstkotte T., Macias-Fauria M., Martin A., Phoenix G.K., Bjerke J.W., Tømmervik H., Fauchald P., Vickers H., Myneni R. & Dickerson C. 2017. Tundra greenness. In: *Arctic Report Card 2017*. National Oceanic and Atmospheric Administration, Silver Spring, MD, USA. In press.

Bjerke J.W., Treharne R., Vikhamar-Schuler D., Karlsen S.R., Ravolainen V., Bokhorst S., Phoenix G.K., Bochenek Z. & Tømmervik H. 2017. Understanding the drivers of extensive plant damage in boreal and Arctic ecosystems: Insights from field surveys in the aftermath of damage. *Science of the Total Environment* 599-600: 1965–1976, doi: 10.1016/j.scitotenv.2017.05.050.

Bjerke J.W., Elvebakk A. & Tømmervik H. 2017. Alpine garden plants from six continents show high vulnerability to ice encasement. *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography* 71, early view, doi: 10.1080/00291951.2017.1391876.'

Bjerke J.W., Bokhorst S., Callaghan T.V. & Phoenix G.K. 2017: Persistent reduction of segment growth and photosynthesis in a widespread and important sub-Arctic moss species after cessation of three years of experimental winter warming. *Functional Ecology* 31 (1): 127–134, doi: 10.1111/1365-2435.12703.

Epstein H.E., Bhatt U.S., Raynolds M.K., Walker D.A., Forbes B.C., Macias-Fauria M., Loranty M., Phoenix G.K. & Bjerke J.W. 2017. Tundra greenness. *Bulletin of the American Meteorological Society* 98 (8): S145–S147. doi: 10.1175/2017BAMSStateoftheClimate.1.

Kłos A., Ziembik Z., Rajfur M., Dołhańczuk-Śródka A., Bochenek Z., Bjerke J.W., Tømmervik H., Zagajewski B., Ziołkowski D., Jerz D., Krems P., Zielińska M. & Godyń P. 2017: The origin of heavy metals and radionuclides accumulated in the soil and biota samples collected in Svalbard, near Longyearbyen. *Ecological Chemistry and Engineering S* 24 (2): 223–228. doi: 10.1515/eces-

2017-0015.

Vikhamar-Schuler D., Isaksen K., Haugen J.E., Tømmervik H., Luks B., Schuler T.V. & Bjerke J.W. 2016: Changes in winter warming events in the Nordic Arctic Region. *Journal of Climate* 29: 6223–6244. doi: 10.1175/JCLI-D-15-0763.1.

Anderson H.B., Nilsen L., Tømmervik H., Karlsen S.R., Nagai, S. & Cooper, E.J. 2016: Using ordinary digital cameras in place of near-infrared sensors to derive vegetation indices for phenology studies of High Arctic vegetation. *Remote Sensing* 8: 847 (17 pp.). doi: 10.3390/rs8100847.

Phoenix G.K. & Bjerke J.W. 2016: Arctic browning: events and trends as drivers. *Global Change Biology* 22: 2960-2962. doi: 10.1111/gcb.13261.

Vickers H., Høgda K.A., Solbø S., Karlsen S.R., Tømmervik H., Aanes R. & Hansen B.B. 2016: Changes in greening in the high Arctic: insights from a 30 year AVHRR max NDVI dataset for Svalbard. *Environmental Research Letters* 11: 105004. doi: 10.1088/1748-9326/11/10/105004.

Bokhorst S., Pedersen S.H., Brucker L., Anisimov O., Bjerke J.W., Brown R.D., Ehrich D., Essery R.L.H., Heilig A., Ingvander S., Johansson C., Johansson M., Jónsdóttir I.S., Niila I., Luojus K., Macelloni G., Mariash H., McLennan D., Rosqvist G.N., Sato A., Savela H., Schneebeli M., Sokolov A., Sokratov S.A., Terzago S., Vikhamar-Schuler D., Williamson S.N., Qiu Y. & Callaghan T.V. 2016: Changing Arctic snow cover: A review of recent developments and assessment of future needs for observations, modelling and impacts. *Ambio* 45: 516–537. doi: 10.1007/s13280-016-0770-0.

Treharne R., Bjerke J.W., Emberson L., Tømmervik H. & Phoenix G.K. 2016: Arctic browning: vegetation damage and implications for carbon balance. *Geophysical Research Abstracts* 18: EGU2016-8838.

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Tømmervik H., Bjerke J.W., Karlsen S.R., Storvold R., Thuestad A., Johansen B. & Høgda K.A. 2015: Monitoring human and climate change-induced plant stress in the Nordic Arctic Region and Svalbard using remote sensing and field surveys. *Brief Report Series* (Norwegian Polar Institute) 32: 50–53.

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aircraft systems (UAS) in a multi-scale vegetation index study of Arctic plant communities in Adventdalen on Svalbard. *EARSeL eProceedings* 13, S1: 47–52. doi: 10.12760/02-2014-1-09.

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Bjerke J.W. 2014: Winter warmer. *International Innovation* 151: 116–118.

In review / in preparation:

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Parmentier F.-J., Rasse D.P., Lund M., Bjerke J.W., Drake B.G., Weldon S., Tømmervik H. & Hansen G.H.: Ecosystem-wide impacts on the carbon exchange of a subarctic peatland following an extreme winter event. In review.

Kłos A., …, Tømmervik H., Bjerke J.W. ….: Using mosses and lichens in biomonitoring of heavy-metal contamination of forest areas in southern and north-eastern Poland. In review.

Bjerke J.W., Bochenek Z., Zagajewski B., Kłos A., Ziembik Z., Elverland E., Jaakola L., Lund L. & Tømmervik H.: The high-Arctic plants *Salix polaris* and *Luzula confusa* are tolerant to winter icing, but less tolerant to late frost. In prep.

Mezghani A., Vikhamar-Schuler D., Dobler A. & Bjerke J.W. Projected changes in warming events over Poland. In prep.

Tømmervik H., Bjerke; J.W et al.: Winter warming effects on growing season productivity of northern vegetation (Poland to Svalbard) inferred from long-term remote sensing data. In prep.

Tømmervik H, Bjerke, J.W. et al. Applicability of different sensors for in-situ measurements of plant

health in high Arctic tundra. In prep.

Bjerke J.W., Tømmervik H. et al.: Spatiotemporal variation in physiological performance of Arctic plants. In prep.

Phoenix G.K., Bjerke J.W., Tømmervik H. et al.: Review: Event drivers of Arctic browning. In prep.

Communicated Results

Bjerke J.W. 2017: Understanding the drivers of extensive plant damage in High Arctic Ecosystems. Talk at: SvalbardBiomass Workshop, Longyearbyen 9-12 October 2017.

Tømmervik H. 2017: Changes in winter warming events in Svalbard. Talk at: SvalbardBiomass Workshop, Longyearbyen 9-12 October 2017.

Phoenix G.K. & Treharne R. 2017: Extreme events as drivers of Arctic browning: vegetation damage and implications for carbon balance. Talk at: SvalbardBiomass Workshop, Longyearbyen 9-12 October 2017.

Bjerke J.W. 2017: Extent of recent browning events in boreal and arctic Norway. Talk at: Event Drivers of Arctic Browning. Workshop. University of Sheffield, Sheffield, 10-11 May 2017.

Tømmervik H. 2017: Detection of browning events using Sentinel-2, World-View 2/3 and UAV-imagery: Examples from Lofoten and Svalbard. Talk at: Event Drivers of Arctic Browning. Workshop. University of Sheffield, Sheffield, 10-11 May 2017.

Treharne R. 2017: Arctic browning: vegetation damage and implications for carbon balance. Talk at: Event Drivers of Arctic Browning. Workshop. University of Sheffield, Sheffield, 10-11 May 2017.

Bjerke J.W. & Tømmervik H. 2016: Understanding the drivers of extensive plant damage: insights from field surveys in the aftermath of damage in boreal and Arctic regions. Lecture at: Impact of climate change and pollution on vegetation distribution and condition in the temperate, boreal, alpine and polar zones. Poland-Norway projects & Warsaw University, Warsaw, 26-27 October 2016.

Vikhamar-Schuler D., Isaksen K., Haugen J.E., Tømmervik H., Luks B., Mezghani A. & Bjerke J.W. 2016: Changes in winter warming events in the Nordic Arctic Region and in Poland. Lecture at: Impact of climate change and pollution on vegetation distribution and condition in the temperate, boreal, alpine and polar zones. Poland-Norway projects & Warsaw University, Warsaw, 26-27 October 2016.

Tømmervik H., Karlsen S.R., Vickers H., Høgda K.A. & Zagajewski B.: Changes in growing season productivity of northern vegetation inferred from long-term remote sensing data. Lecture at: Impact of climate change and pollution on vegetation distribution and condition in the temperate, boreal, alpine and polar zones. Poland-Norway projects & Warsaw University, Warsaw, 26-27 October 2016.

Isaksen K. 2016. Arktis smelter, og jeg er hverken betenkt eller bekymret. Jeg er skremt. Feature article published in Aftenposten, p. 13, 15 November 2016. (Includes a description of main results from our article in Journal of Climate).

Treharne R., Bjerke J.W., Emberson L., Tømmervik H. & Phoenix GK.: Arctic Browning: vegetation damage and implications for carbon balance. Poster at: European Geosciences Union General Assembly 2016, Vienna, 17-22 April 2016.

Markusson H.M. & Bjerke J.W.: Hvorfor blir Arktis brunere? News report published at Forskning.no, 29 April 2016.

Tømmervik, H.: Klimautfordringer og konsekvenser for reindrifta - Hva skjer med reinbeitene i Nordland når vintrene blir mildere og vekstsesongen lengre? Reindriftsseminar for Nordland, Fauske, 10-11 February 2016.

Bjerke J.W.: Increasing climatic and biotic disturbance severity – can we influence the direction of Arctic vegetation change, and if so, which direction should we promote? Lecture at: ‘ArcticBiomass’ Final Workshop, open programme, 21 October 2015, Longyearbyen.

Bjerke J.W.: Impacts of contrasting snow, ice and soil frost conditions on northern primary productivity – insight from manipulative and observational studies. Lecture at: Fram Centre, the terrestrial flagship's thematic day on snow: Measuring, remote sensing and modelling snow properties important for northern ecosystems, 28 November 2014, Tromsø.

Karlsen S.R.: Growing season and primary production mapped by MODIS and Landsat 8 data on Svalbard. Lecture at: ‘ArcticBiomass’ Final Workshop, open programme, 22 October 2015, Longyearbyen.

Treharne R., Bjerke J.W., Tømmervik H., Emberson L. & Phoenix GK.: Arctic browning: vegetation

damage and implications for carbon balance. Poster at: UK Arctic Science Conference 2015, 16 September 2015, Sheffield.

Tømmervik H., Bjerke J.W., Karlsen S.R., Thuestad AE., Storvold R., Johansen B. & Høgda K.A.: Monitoring man- and climate change-induced plant stress in the Nordic Arctic Region and Svalbard using remote sensing and field surveys. Lecture at: Assessing vulnerability of flora and fauna in polar areas. Norwegian Polar Institute, 3 November 2014, Tromsø.

Tømmervik H., Johansen B., Strand O., Park T., Fauchald P., Myneni R.B. & Bjerke J.W. Arctic biomass: Greening and browning in the Arctic – implications for reindeer and caribou. Lecture at: 14th International Arctic Ungulate Conference, 16 August 2015, Røros.

Vikhamar-Schuler D., Isaksen K., Haugen J.E., Tømmervik H., Luks B. & Bjerke J.W.: Changes in winter warming events in the Nordic Arctic Region. Lecture at: EGU General Assembly Conference, 14 April 2015, Vienna.

Vikhamar-Schuler D., Isaksen K., Haugen J.E., Tømmervik H., Luks B. & Bjerke J.W.: Changes in winter warming events in the Nordic Arctic Region. Lecture at: 3rd Conference on Modelling Hydrology, Climate and Land Surface Processes, 7 September 2015, Lillehammer.

Bjerke J.W.: Highlights from the Fram Centre flagship projects WINNIT and WICLAP. Lecture at: Årsmøte for Framsenterets terrerstre flaggskipprogram, Uit –Arctic University of Norway, Tromsø, 16 December 2015.

WICLAP consortium: WICLAP website: www.wiclap.eu (frequently updated project website with news)

NINA: Vinterforstyrrelser og luftforurensning: http://www.nina.no/Forskning/Prosjekter/Vinterklima/WICLAP (frequently updated website in Norwegian).

The project consortium includes researchers from several disciplines: meteorology-climatology, physical geography – especially related to earth observation, chemistry, ecology, and physiology. This interdisciplinary cooperation resulted in several research articles on various disciplines.

Budget in accordance to results

The entire funding from the Fram Centre for 2017 was consumed within this calendar year, and funding was allocated between the three Norwegian institutes according to the budget provided in the proposal. The entire funding this year was allocated to coverage of time consume. The funding obtained allowed us to work on and complete more manuscripts, some still being in review or in preparation. With the additional support from the Svalbard miljøvernfond, we were also able to do another season of field work, with strengthened our datasets. The Fram Centre funding is a very welcome addition, especially in light of the slightly reduced funding from EEA without allowing to reduce ambitions of the project plan, and the steadily increasing costs of undertaking fieldwork at Svalbard. The funding has also provided opportunities to participate in two highly relevant workshops, one on Arctic browning and one on Arctic plant biomass; see list of communicated results. These participations have resulted in new research and collaboration opportunities.

Could results from the project be subject for any commercial utilization

Yes

If Yes

The enhanced competence on drivers of environmental change and nature vulnerability gained by the Norwegian institute researchers make the personnel more attractive for consultancy assignments in environmental sciences. Know-how consulting is in such a context a commercial product. For example, Bjerke was elected as member of a national expert committee for testing the international IPBES framework for assessment of a Norwegian habitat system. Norut and Meteorologisk Institutt also apply their acquired research results and increased competence in development of services of potential commercial utilization. Our Polish partners at the Institute for Geodesy and Cartography (IGiK) have, as one of their main roles, development of commercial products relevant for environmental and agricultural sectors. This project helps them to improve their earth observation-based products, and this is in line with the EEA call, namely to enhance the competence of Polish institutions in their fields of expertise.

Conclusions

The added funding from the Fram Centre has been invaluable for the project. It has strengthened our data collection scheme and provided better opportunities for dissemination of scientific results highly relevant for the scientific community and for national and international management policies for the Arctic and other seasonally snow-covered regions.