Northumbria Research Link

Citation: Brock, Benjamin (2016) Shrinking sea ice, increasing snowfall and thinning lake ice: a complex Arctic linkage explained. Environmental Research Letters, 11 (9). 091004. ISSN 1748-9326

Published by: IOP


This version was downloaded from Northumbria Research Link: http://nrl.northumbria.ac.uk/27799/

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: http://nrl.northumbria.ac.uk/policies.html

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher’s website (a subscription may be required.)

www.northumbria.ac.uk/nrl
Shrinking sea ice, increasing snowfall and thinning lake ice: a complex Arctic linkage explained

This content has been downloaded from IOPscience. Please scroll down to see the full text.

View the table of contents for this issue, or go to the journal homepage for more.

Download details:

IP Address: 212.219.32.254
This content was downloaded on 22/09/2016 at 11:52

Please note that terms and conditions apply.

You may also be interested in:

Introduction to the Physics of the Cryosphere: Sea ice
M Sandells and D Flocco

Arctic sea ice decline contributes to thinning lake ice trend in northern Alaska
Vladimir A Alexeev, Christopher D Arp, Benjamin M Jones et al.

Estimation of the residence time of permafrost groundwater in the middle of the Lena River basin, eastern Siberia
Tetsuya Hiyama, Kazuyoshi Asai, Alexander B Kolesnikov et al.

Arctic lakes are continuous methane sources to the atmosphere under warming conditions
Zeli Tan and Qianlai Zhuang

Quantifying landscape change in an arctic coastal lowland using repeat airborne LiDAR
Benjamin M Jones, Jason M Stoker, Ann E Gibbs et al.

Less winter cloud aids summer 2013 Arctic sea ice return from 2012 minimum
Yinghui Liu and Jeffrey R Key

Modeling sub-sea permafrost in the East Siberian Arctic Shelf: the Dmitry Laptev Strait
D Nicolsky and N Shakhova
Shrinking sea ice, increasing snowfall and thinning lake ice: a complex Arctic linkage explained

Ben W Brock
Department of Geography, Northumbria University, Newcastle upon Tyne, UK
E-mail: Benjamin.brock@northumbria.ac.uk

Keywords: Arctic, sea ice decline, winter climate, freshwater ice, thermokarst lakes

Abstract
The dramatic shrinkage of Arctic sea ice is one of the starkest symptoms of global warming, with potentially severe and far-reaching impacts on arctic marine and terrestrial ecology (Post et al 2013 Science 341 519–24) and northern hemisphere climate (Screen et al 2015 Environ. Res. Lett. 10 084006). In their recent article, Alexeev et al (2016 Environ. Res. Lett. 11 074022) highlight another, and unexpected, consequence of Arctic sea ice retreat: the thinning of lake ice in northern Alaska. This is attributed to early winter ‘ocean effect’ snowfall which insulates lake surfaces and inhibits the formation of deep lake ice. Lake ice thinning has important consequences for Arctic lake hydrology, biology and permafrost degradation.

Lakes and ponds are very significant components of the landscape of the Arctic coastal lowlands of Alaska, western Canada and Siberia, and play an important role in the region’s ecology [1] and hydrology [2]. Lakes have a reciprocal relationship with permafrost: their formation is largely governed by patchy near-surface permafrost degradation, while winter freezing to full lake depth, known as a bedfast ice, promotes the preservation of sub-lake permafrost. Observations of a widespread shift from bedfast to floating ice regimes in Arctic lakes over the past two decades [3, 4] are of concern since surface lake ice overlying liquid water in contact with the lake bed leads to localised patches of thawed permafrost, known as taliks [5]. The thinning trend in northern Alaskan lake ice has been linked to warmer, snowier winters [3]. The question addressed by Alexeev et al [6] is: what role might reduced Arctic sea ice cover play in early winter climate and winter lake ice growth in the region?

North Alaska, like much of the Arctic, has seen temperature and precipitation increases over the last four decades far in excess of global averages, with these trends heightened in the autumn. The decline in Arctic sea ice cover over the same period is well established [7], and has been strongly implicated in regional warming through albedo feedback and evaporation from open water which increases atmospheric moisture [8]. Furthermore, observed increases in Arctic snowfall extremes have been attributed to the increased flux of water vapour to the atmosphere from open sea [9, 10]. Linking these observations, Alexeev et al propose that higher temperatures and increased snowfall in early winter, associated with reduced sea ice cover, combine to reduce ice formation on freshwater lakes and ponds. While enough temporal data are apparently available to test this hypothesis, establishing linkages in complex ocean-atmosphere-terrestrial systems based on correlation of time-series is highly problematic.

To overcome this problem, Alexeev et al devise a clever modelling experiment, based on the proposition that greater Arctic sea ice cover in autumn should lead to thicker lake ice in early winter, and vice versa. They identify two winters in the available record with contrasting maximum lake ice thickness: 1991/92, which had relatively high sea ice extent; and 2007/08, which had the second lowest sea ice cover on record. In order to link ocean sea ice conditions with atmospheric processes and snowfall over land they use the well-known Weather Research and Forecasting (WRF) regional climate model. After running the model to analyse lake ice growth under the known ocean surface and atmosphere conditions in the 1991/92 and 2007/08 winters, they then rerun the model with the same atmospheric conditions, but with the sea ice cover from the contrasting year: namely 2007/
08 sea ice conditions imposed on the 1991/92 winter and 1991/92 sea ice conditions imposed on the 2007/08 winter. This enables the effect of sea ice cover on land temperature and snowfall conditions to be established independently of variation in atmospheric conditions.

The regular 2007/08 model run, compared with the 2007/08 model run using Arctic sea ice cover from 1991/92, shows a twofold ‘open ocean’ effect. First, with low sea ice cover in 2007/08, there was a significant warming on the Arctic Coastal Plain of up to 5 °C. Second, the amount of snowfall was increased by 10–20 mm water equivalent depth, which amounts to 15%–20% of the snowfall in the regular 2007/08 model run. These results show that open ocean water in proximity to the Alaskan coast led to higher air temperatures and more intense early winter snowfall. Next, the WRF temperature and precipitation outputs from the model runs were applied in a model of lake ice formation, which was validated against lake ice thickness measurements from northern Alaskan lakes. Applying 1991/92 sea ice cover in the 2007/08 model run, which resulted in colder temperatures and less precipitation, increased lake ice thickness by 9% and the area of bedfast ice by an estimated 13%. When 2007/08 sea ice cover was applied in the 1991/92 model run, resulting in higher temperatures and increased snowfall, lake ice thickness decreased by 7% and the area of bedfast ice was estimated to decrease by approximately 9%.

These results clearly demonstrate a causal link between Arctic sea ice extent, atmospheric processes and their impacts on terrestrial freshwater systems. Furthermore, they show that impacts from an open Arctic Ocean in autumn are both direct, through increased air temperature and precipitation, and indirect, though inhibiting bedfast ice formation in lakes leading to localised permafrost degradation and talik formation [5]. Variation in the duration of lake ice cover also affects local energy balance and moisture availability with many uncertain consequences. Not all these changes are negative, as a shift from bedfast to floating ice regimes would provide overwintering fish habitats and could provide winter water supply for domestic and industrial use [11]. Key concerns remain, however, about the magnitude and frequency of ‘ocean effect’ snow and temperature increases in the future as sea ice cover continues to shrink leading to a potential acceleration of permafrost degradation in Arctic coastal lowlands.

References

[10] Bintanja R and Selten F M 2014 Future increases in Arctic precipitation linked to local evaporation and sea-ice retreat Nature 509 479–82