Science Advances

AAAS

advances.sciencemag.org/cgi/content/full/3/3/e1601191/DC1

Supplementary Materials for

The frequency and extent of sub-ice phytoplankton blooms in the Arctic Ocean

Christopher Horvat, David Rees Jones, Sarah Iams, David Schroeder, Daniela Flocco, Daniel Feltham

Published 29 March 2017, *Sci. Adv.* **3**, e1601191 (2017)
DOI: 10.1126/sciadv.1601191

This PDF file includes:

text S1. Sensitivity to extinction coefficient in ice.

Figure S1 (a-c) shows curves of the area of the Arctic Ocean that may permit sub-ice blooms for three choices of the ice extinction coefficient κ_i. To bound the sensitivity of our results we show model results for extreme values of κ_i from the observational record: either $\kappa_i = 1$ m^{-1}, a low estimate from bare multi-year ice (19), $\kappa_i = 1.6$ m^{-1}, used in the paper, and $\kappa_i = 1.8$ m^{-1}, a high estimate from bare first-year ice (20). In each case a clear trend showing an increase in the potential for sub-ice blooms emerges in June and July.

text S2. Evolution of fields over time.

Figure S2(a-c) shows the evolution of the mean ice concentration over months May-July averaged in each decade from (a) 1986-1995, (b) 1996-2005, and (c) 2006-2015. Figure S2 (d) plots the total area covered by all points with at least 80% ice concentration as a function of year and month. Figure S2 (e-g) is the same as fig. S2 (a-c), but now for melt pond fraction. Figure S2 (h) plots the evolution of the mean melt pond fraction of all points in the ice-covered Arctic, defined as all ocean points $> 70°$N, excluding Baffin Bay that have an ice concentration greater than 80%, broken down by month. Figure S2 (i-l) is the same as (e-h), but for ice thickness. In all months there is a persistent downward trend in mean ice thickness and total ice coverage, and an upward trend in melt pond fraction. There is more year-to-year variability in melt pond fraction than there is in total ice area coverage and ice thickness.

text S3. Sensitivity analysis: Bounds on the area that permits sub-ice blooms.

Tables S1 and S2 show approximate bounds for the fraction of the Arctic ($> 70°$N, excluding Baffin Bay) that leads to blooms in each decade and month, based on the modeling of Sec. 3. In the case of ice thickness (table S1), we compute the standard deviation of ice thickness at a given location, for each month in each year. This field is then added or subtracted from the input ice thickness field, and the results based pn the analysis of Sec. 3 are displayed in table S1. For example, data at 70°N,0°E on day May 15, 1988 is offset by the standard deviation in ice thickness at 70°N,0°E using data from all days in May, 1988. Variation in ice thickness does not significantly influence results in May, but does in June and July. Variation in melt pond fraction

has a significant impact in May. In both cases, the trend of increasing bloom statistics over the previous three decades in June and July is upheld.

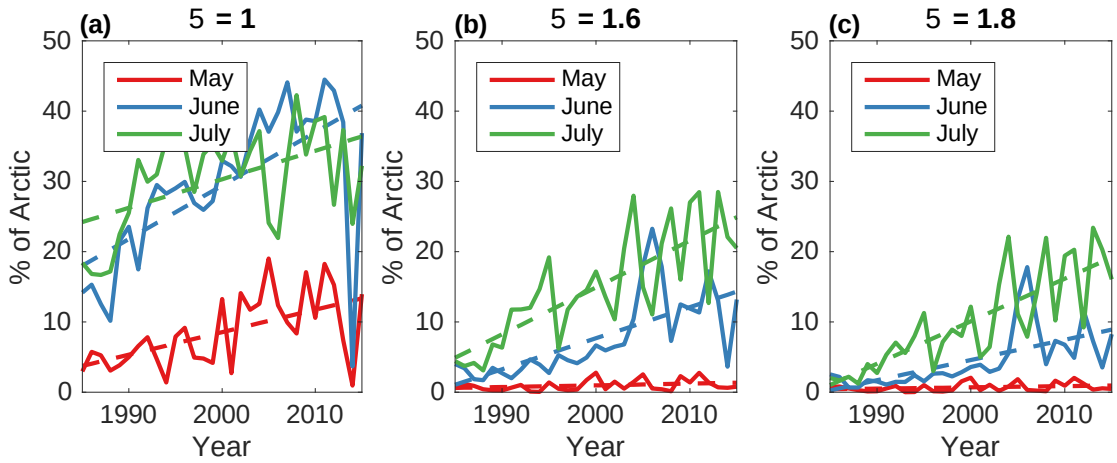

fig. S1. Sensitivity of bloom-permitting area to ice extinction coefficient. (**a**) Percentage by area of the Arctic ocean that has greater than 80% ice concentration and permits blooms over at least three consecutive days in May, June, and July, when the coefficient of PAR extinction in ice is $\kappa_i = 1$ m^{-1}. Dashed lines are linear fit to the data. (**b**) Same as (a), for $\kappa_i = 1.6$ m^{-1}. (**c**) Same as (b), for $\kappa_i = 1.8$ m^{-1}. See an explanation of parameter bounds in text S1.

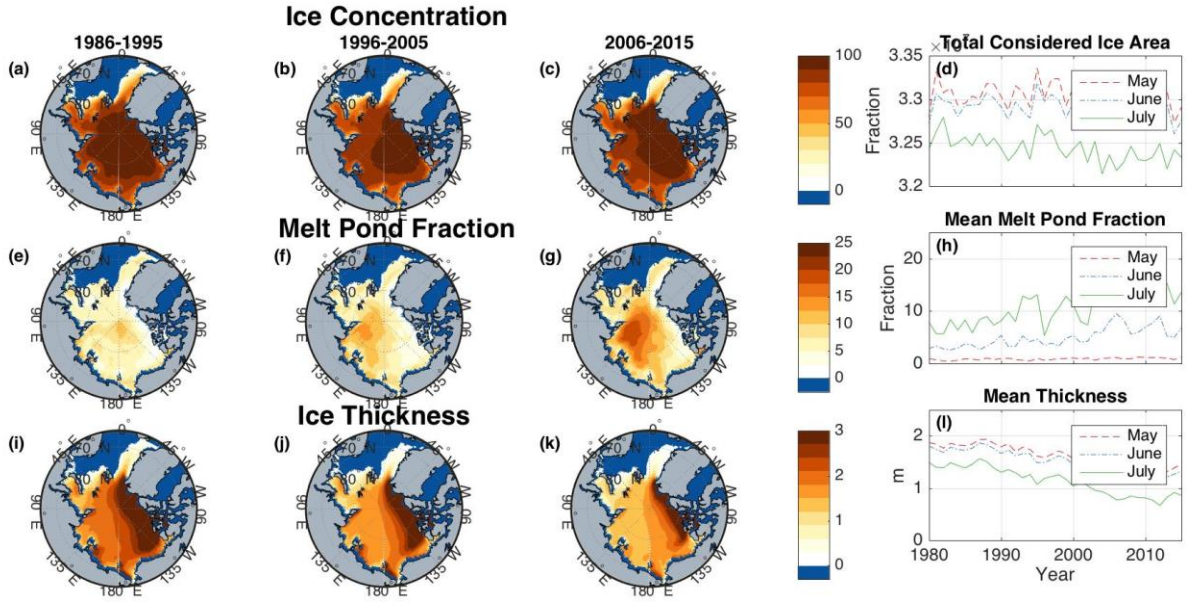

fig. S2. Evolution of ice concentration, melt pond fraction, and ice thickness over time. (**a-c**) The mean ice concentration over May 1-July 31 for (a) 1986-1995, (b) 1996-2005, and (c) 2006-2015. Baffin Bay, and regions which do not have an ice concentration greater than 80% at any point during each time period are colored blue. Continents are colored grey. (**d**) The total area of the ice-covered-Arctic with greater than 80% ice concentration on average for each month over the time period 1986-2015. (**e-g**) same as (a-c), but for melt pond fraction. (**h**) The mean melt pond fraction of the ice-covered Arctic. The ice-covered Arctic is defined as all ocean points > 70°N, excluding Baffin Bay that have an ice concentration greater than 80%. (i-l) Same as (e-h), but for ice thickness.

table S1. Ranges of the percentage of the Arctic Ocean (>70°N, excluding Baffin Bay) in which sub-ice blooms can occur, when sea ice thickness data are increased or decreased by 1 SD (for details on how this is computed, see text S2).

Years	Range of May	Range of June	Range of July
1986-1995	(0.5,0.8)	(2.1,4.1)	(6.7,12.2)
1996-2005	(0.9,1.6)	(5.9,9.2)	(12.7,17.8)
2006-2015	(0.9,1.4)	(11.0,15.4)	(19.0,23.9)

table S2. Ranges of the percentage of the Arctic Ocean (>70°N, excluding Baffin Bay) in which sub-ice blooms can occur, when the melt pond coverage data are increased or decreased by 1 SD (for details on how this is computed, see text S2).

Years	Range of May	Range of June	Range of July
1986-1995	(0.3,0.3)	(1.5,4.8)	(5.6,12.6)
1996-2005	(0.5,4.5)	(4.6,10.2)	(10.2,19.0)
2006-2015	(0.4,5.3)	(9.2,17.0)	(16.5,24.9)