Changes in Sea Ice Extent Will Outweigh Changes in Snow Cover in Future Arctic Climate Change

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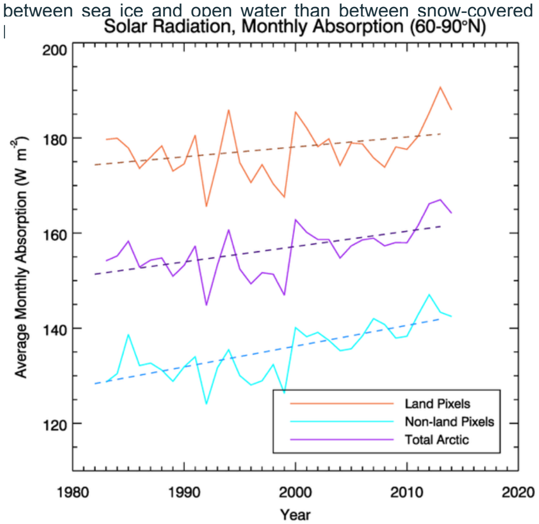
Introduction

Recent declines in Arctic sea ice and snow extent have led to an increase in solar energy absorption at the surface, resulting in additional heating and a further decline in snow and ice. Here we examine how changes in surface albedo over the ocean and land areas of the Arctic have separately affected shortwave absorption, and how the interplay between albedo and shortwave absorption may change in the future. **How do the trends in absorbed (net) solar radiation at the surface over land and ocean compare?** Based on these trends from the AVHRR Polar Pathfinder Extended (APP-x) dataset, we ask: what is the relative importance of the ice-albedo and snow-albedo feedbacks?

Trends in Absorbed Solar Radiation

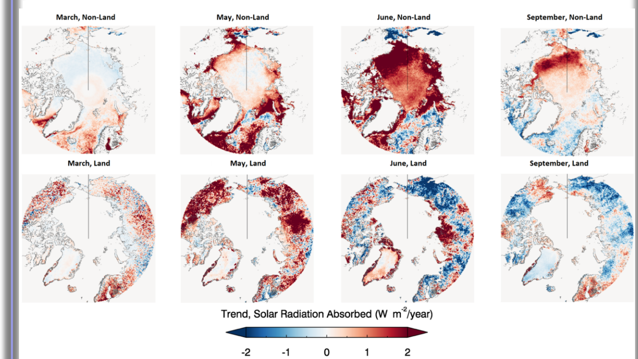
The annual mean absorbed solar radiation at the Arctic surface has increased over the period 1982-2015, though the magnitude and rate were different over land and ocean. **Absorption over land increased 0.21 W m^{-2} yr^{-1}. Over ocean it increased 0.43 W m^{-2} yr^{-1}.**

This equates to an increase of 0.3% of the annual mean per year, resulting in a 10% increase over 34 years. Over land, the increase was 0.09% per year, increasing only 2.7% over the study period. The larger trend over ocean results from the larger albedo difference between sea ice and open water than between snow-covered and



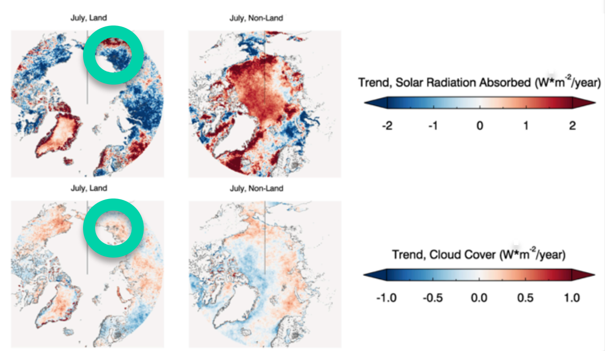
Average monthly shortwave absorption per year (W m^{-2}), 60-90°N for combined land and ocean (purple), land only (orange), and ocean only (cyan). Dotted lines are linear trends.

Absorbed Surface Radiation Trends, 1982-2015



Trends in absorbed radiation for selected months over ocean (top) and land (bottom) in March, May, June, and September..

Surface Radiation vs. Cloud Trends, 1982-2015

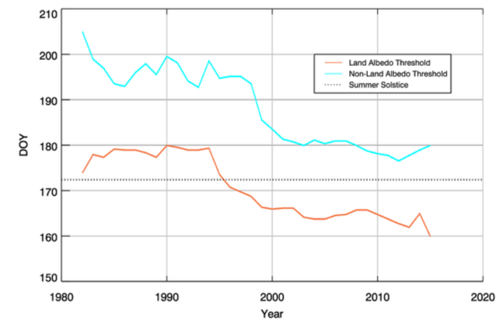


Trends in absorbed radiation (top) and cloud cover (bottom) for July 1982-2015.

Absorption Spatial Patterns

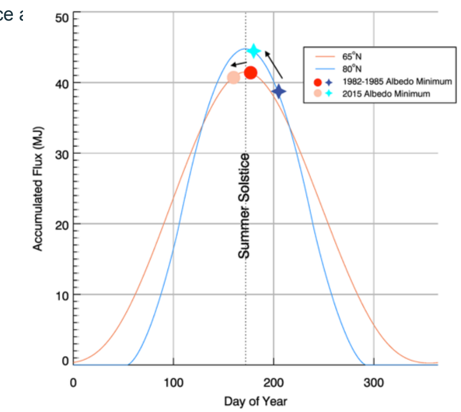
A strong increase in absorption due to decreasing springtime snow cover over land is seen in May. In June through October, the ocean area absorption rate increased faster than absorption over land. Changes in cloud cover also effect surface absorption. Over land, increasing (decreasing) cloud cover is associated with a decrease (increase) in surface absorption. The effects of cloud cover changes over ocean are muted due to the similar reflectivities of ice and cloud. Trends in absorbed radiation showed from APP-x agreed with trends in MERRA2 over the same time period.

Timing of Low-Albedo Threshold



Day of year when low-albedo threshold was reached land (orange) and ocean (cyan).

In the first few years of the APP-x dataset (1982-1985), the minimum average albedo over the Arctic ocean was reached during the first two weeks of September. This value of 0.265 is used as the "ocean low-albedo threshold." A similar land "low-albedo threshold" was found to occur between June and July. The day-of year that these low-albedo thresholds were reached over land and ocean was determined for each year. **The low-albedo threshold was reached ~20 days earlier in 2015 than in 1982-1985 over ocean, and ~13 days earlier over land.** The regression of the low-albedo period towards earlier in the year results in lowered ocean albedo during the summer solstice a ... olstice.



Average TOA insolation at 14:00 Local Solar Time over 65°N and 80°N showing the regression of the low-albedo threshold between 2015 and 1982-1985.

Reference: *Letterly, A., J. Key, and Y. Liu, 2018, Arctic Climate: Changes in Sea Ice Extent Outweigh Changes in Snow Cover, The Cryosphere, 12, 3373–3382, https://doi.org/10.5194/tc-12-3373-2018.*