A Changing Arctic Sea Ice Cover and the Partitioning of Solar Radiation

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INTRODUCTION

The changes in the Arctic sea ice cover are well established. There has been a reduction in sea ice extent, an overall thinning of the ice cover, a shift from perennial ice to seasonal ice, and a lengthening of the summer melt season. The physical changes in the ice cover result in less light reflected and more light absorbed in the ice and ocean impacting the heat and mass balance of the ice as well as biological activity in and under the ice cover. For example, a seasonal ice cover tends to have a smaller albedo than perennial ice throughout the melt season allowing more light to be absorbed in the ice and ocean. This poster first explores how the shift from first year to multiyear ice impacts surface conditons and albedo, then examines the impact of sea ice changes on solar heat input to the ice – ocean system.

One of the largest changes in the ice cover has been the shift from multiyear ice to first year ice. This shift has many consequences, including a change in the evolution of albedo. The photographs below show seasonal differences in surface conditions between first year and multiyear ice.

SEASONAL EVOLUTION OF FIRST YEAR AND MULTIYEAR ICE

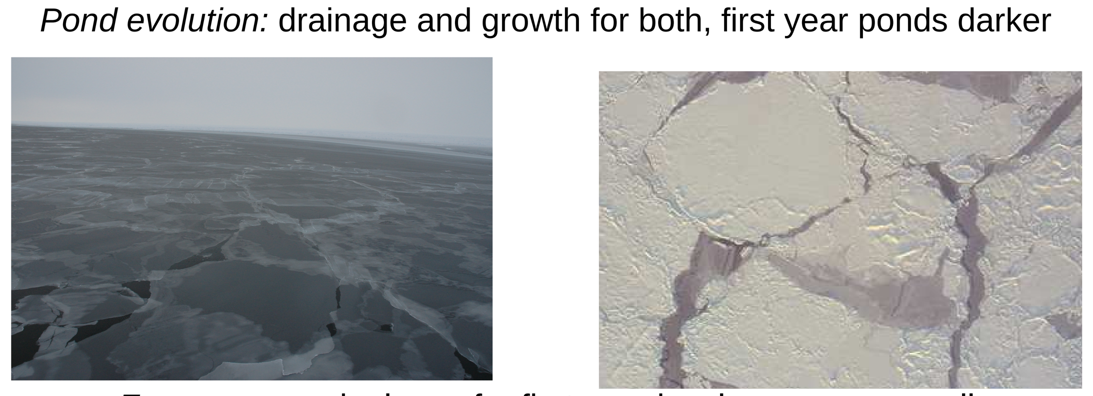
First year | Multi year

Cold snow: no differences when snow covered

Melting snow: thinner snowpack on first year ice, earlier meltout

Pond formation: huge difference, much larger pond fraction on first year

Pond evolution: drainage and growth for both, first year ponds darker



Freezeup: much slower for first year ice, less snow as well

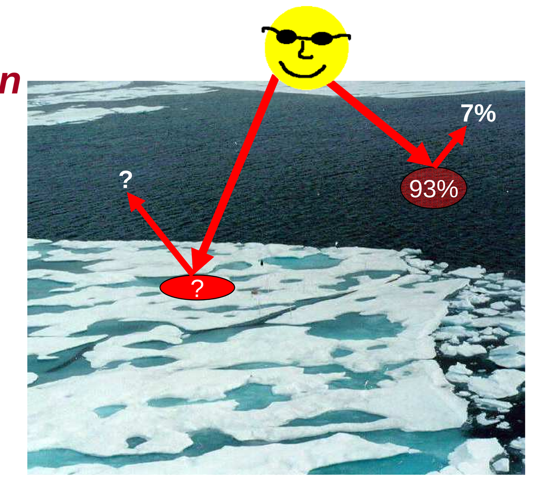
SOLAR HEATING OF THE ICE – OCEAN SYSTEM

Surface heating of the ice ocean system is simply:

Total solar heat = heat ice + heat ocean

$$Q_{in} = (Q_r)(A_i)(1-\alpha_{ice}) + (Q_r)(A_w)(1-\alpha_{ocn}) \quad \text{EQN. 1}$$

Ice albedo is big unknown

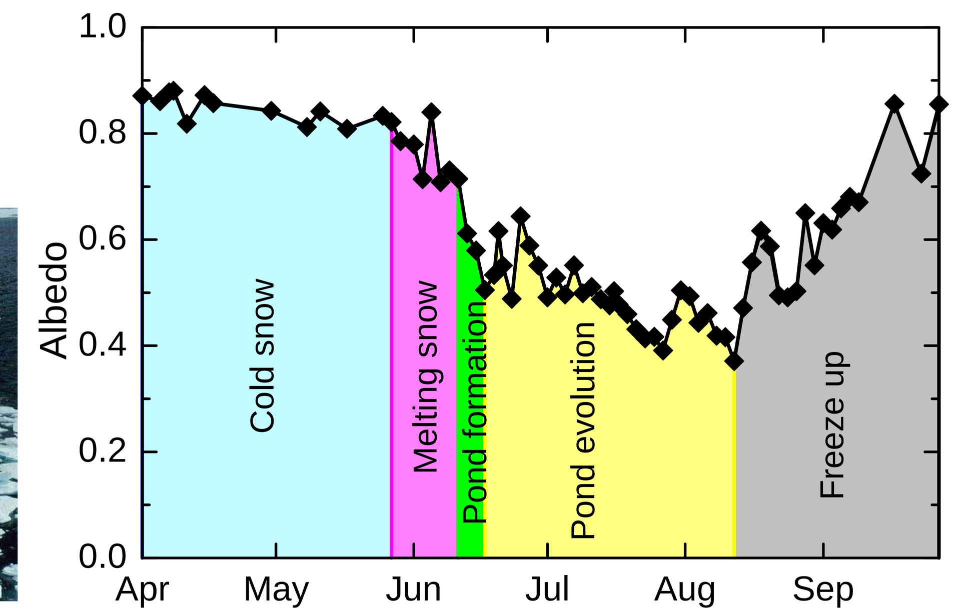


Input:
- Incident sunlight (Q_r)
- Area fractions of ice and water
- Water albedo (α_{ocn}) = 0.07
- Ice albedo (α_{ice}) –complicated

Output:
Solar heat input to ice and ocean

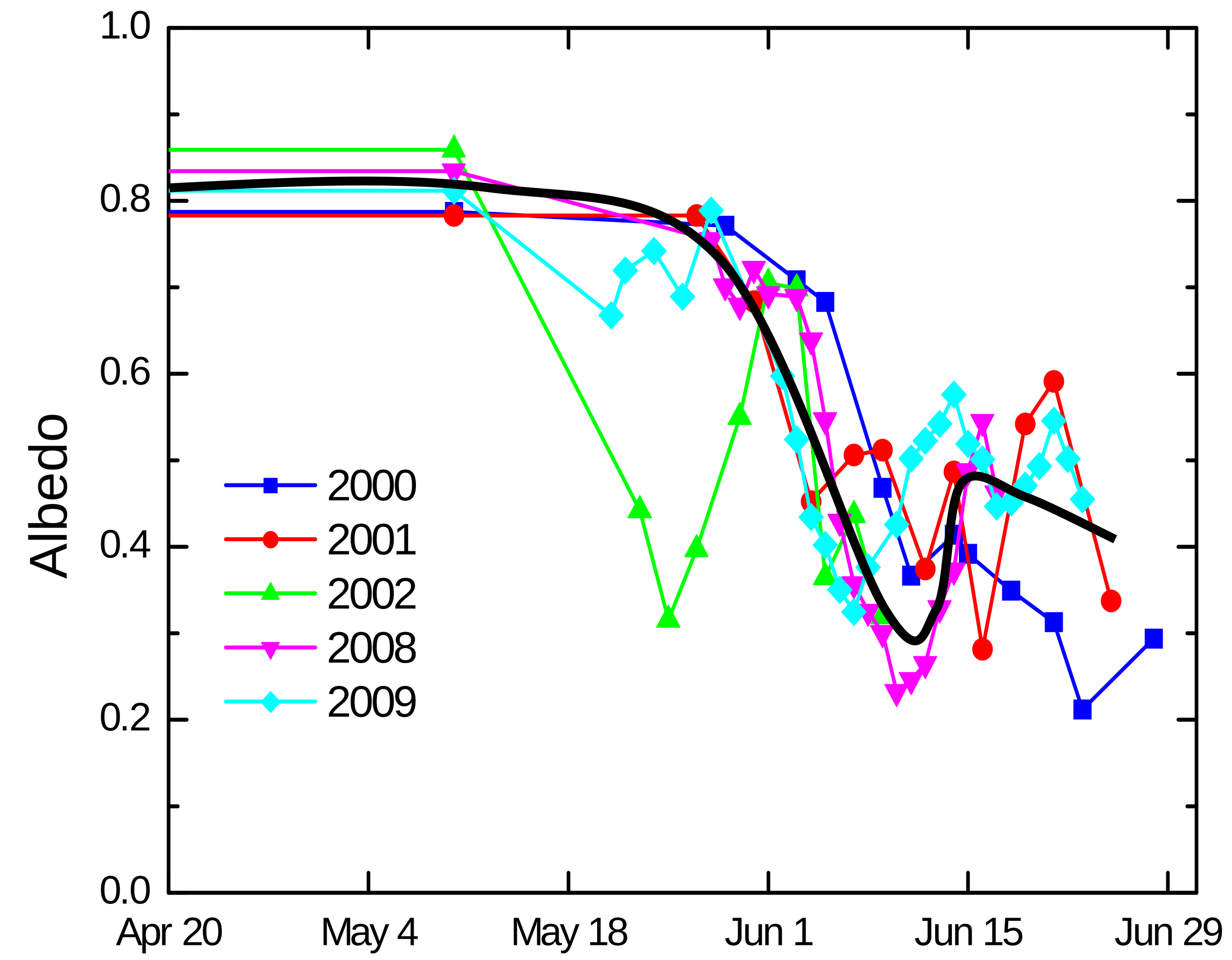
How does the albedo evolve over the melt season?

MULTIYEAR ICE ALBEDO

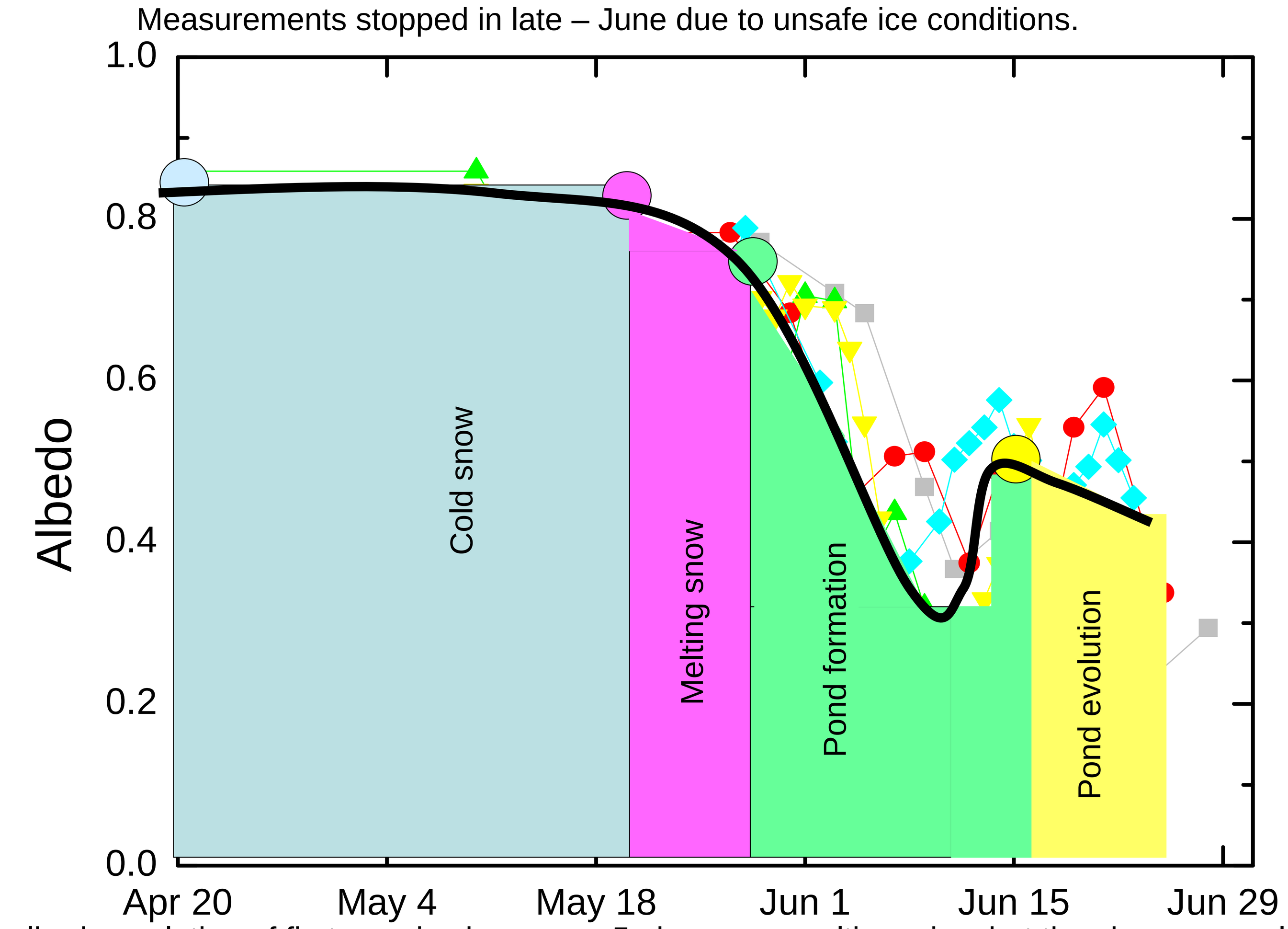


Multiyear ice albedo determined from field observations made during SHEBA. The albedo evolution has 5 phases.

FIRST YEAR ICE ALBEDO



Five years of field observations of first year ice albedo made at Barrow, AK.There is considerable interannual variability, but a general trend (black line) is evident. Measurements stopped in late – June due to unsafe ice conditions.

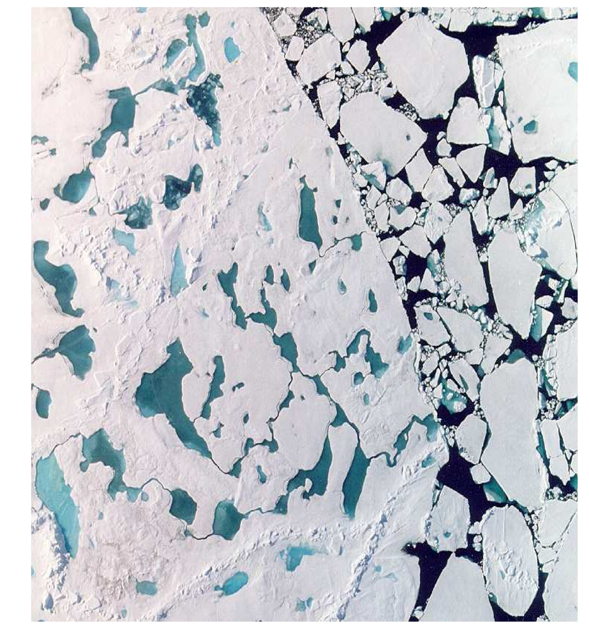


The albedo evolution of first year ice has same 5 phases as multiyear ice, but the changes are larger and happen faster. First year ice has pond coverage of 70 to 90% during pond formation compared to 20 to 40% for multiyear ice. There can be a period of open water. Fall freezeup takes much longer for first year ice than for multiyear ice.

WHAT IMPACTS THE SOLAR HEAT INPUT?

Many factors that impact the solar heat input into the ice – ocean system including ice concentration, pond fraction, ice type, and the timing of melt onset and freezeup. We will explore the impact of these factors by evaluating equation 1 from April through September for different ice concentrations and albedo evolutions. The following case studies are presented:

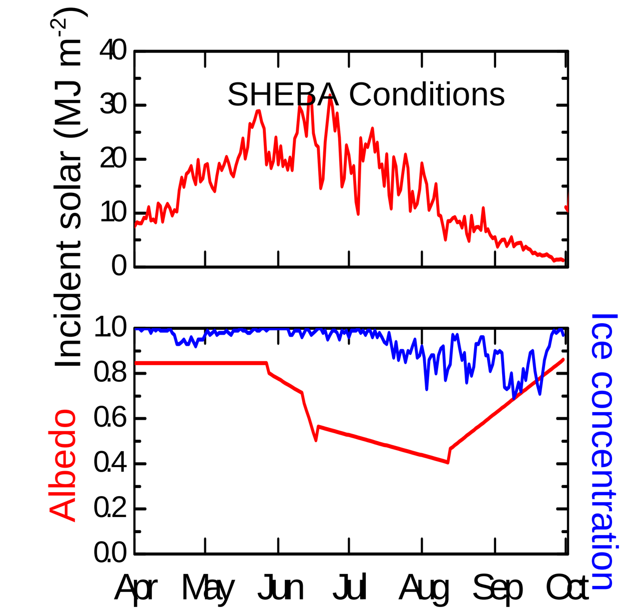
- Ice concentration
  - No leads
  - 0.05 more leads
- Melt ponds
  - No ponds
  - All ponds
- Ice type
  - First year some melt
  - First year all melt
- Melt onset
  - 2 weeks earlier
  - 1 week earlier
  - 1 week later
- Start of freezeup
  - 1 week earlier
  - 1 week later



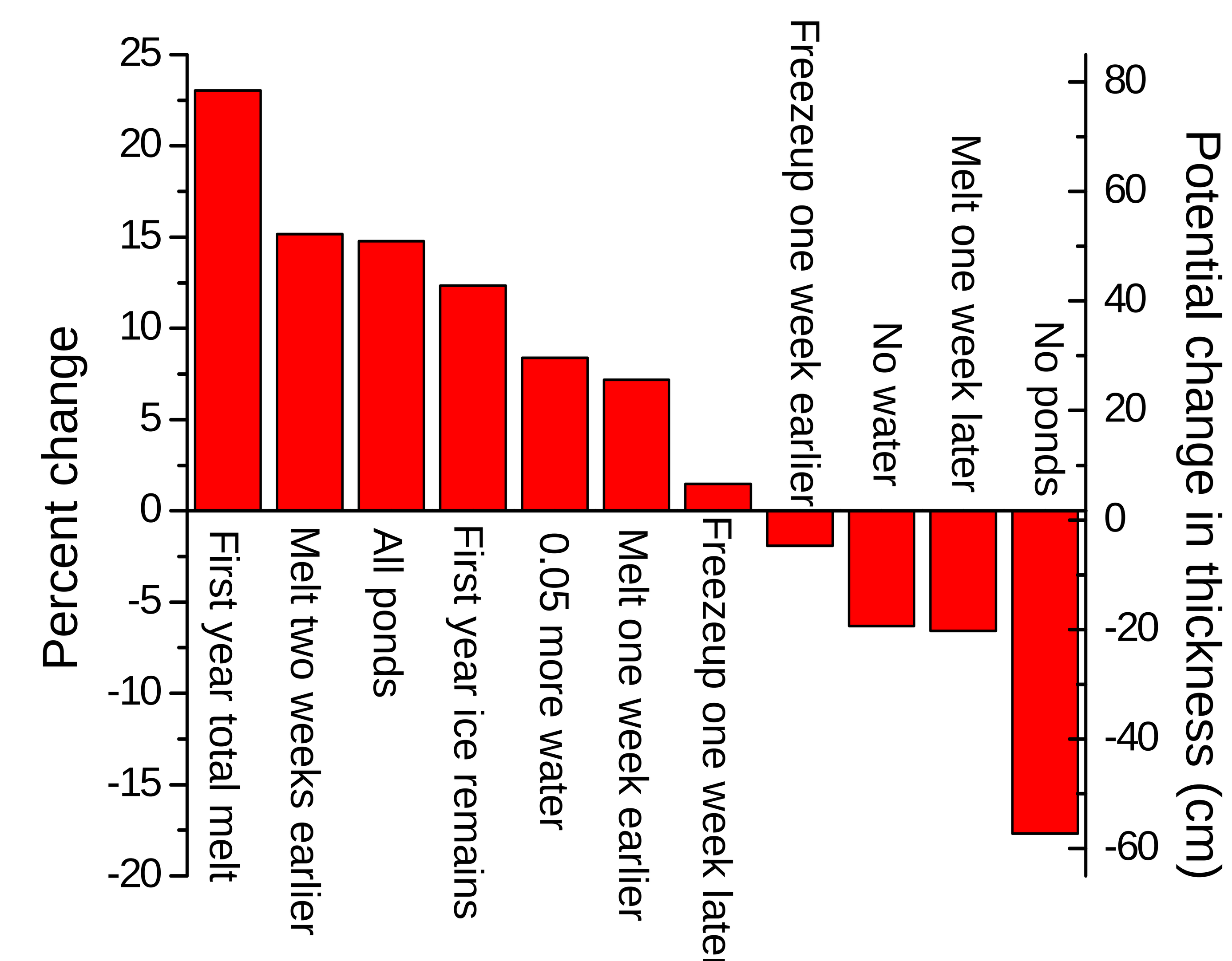
SOLAR HEAT INPUT - SHEBA

Results are compared to the solar heat input computed using data from SHEBA. The plots on the right show the time series of incident solar irradiance, areally – averaged albedo, and ice concentration observed at SHEBA. For this case the total solar heat input to the ice – ocean system was 940 MJ m^{-2}. This is roughly enough heat to melt 3 m of ice.

The incident solar incident radiation observed at SHEBA was used for the 11 cases listed above. A water albedo of 0.07 was used. The time series of ice albedo and ice concentration were determined by the characteristics of the particular case.



CHANGE IN SOLAR HEAT INPUT



SUMMARY / FUTURE WORK

The physical changes occuring in the Arctic sea ice cover will lead to significant increases in solar heat input to the ice – ocean system and an ice albedo feedback. While there are physical changes that reduce solar heat input, such as a shorter melt season, no open water, no melt ponds, they are unlikely to occur. Additional heat deposited in summer will likely contribute to additional melting. The greatest increase is solar heat input results from changing from a perennial to a seasonal ice cover. The solar heat input is much more sensitive to the timing of the onset of melt than the onset of freezeup.

Future work needs to determine the evolution of melt ponds on both first year and multiyear ice, the albedo of thin melting ice, and the transmission of solar heat through ice and melt ponds.

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