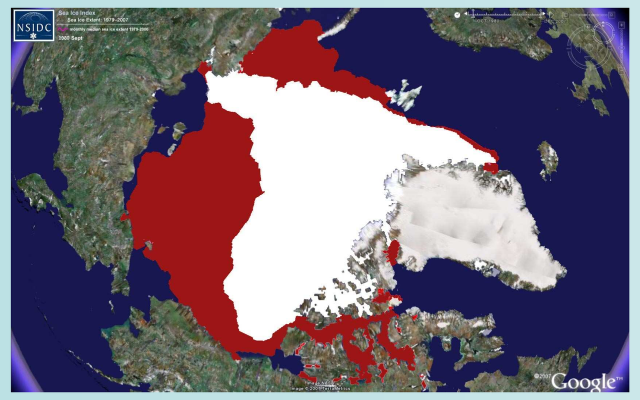
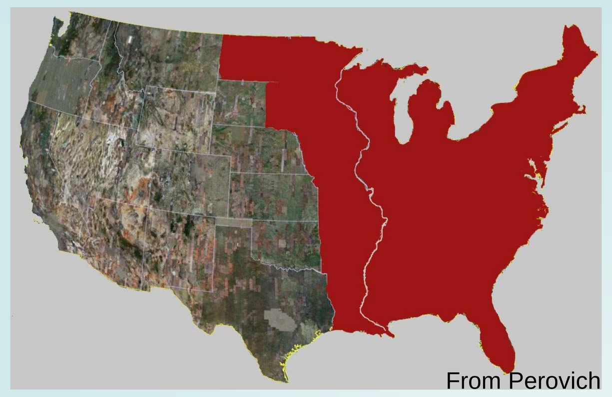
Sea Ice, Albedo, and Melt Ponds

Chris Polashenski – Thayer School of Engineering, Dartmouth College

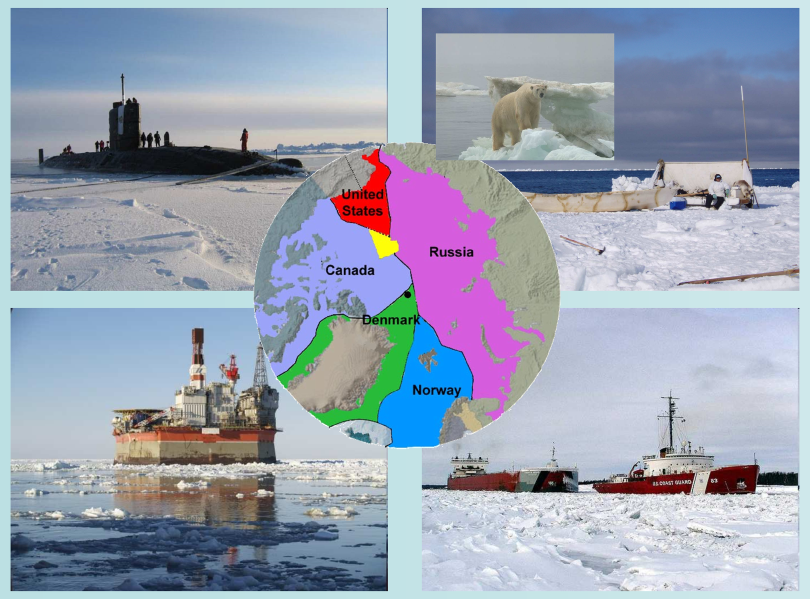
Sea Ice in the Climate System



=



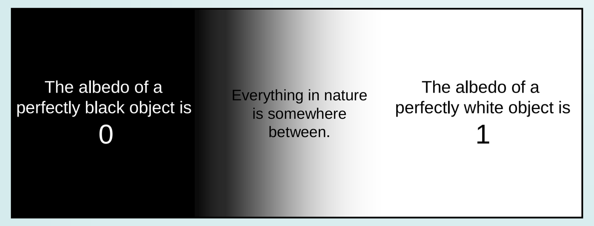
Sea ice, a thin veneer of floating ice averaging less than a few meters thick, forms on the world’s polar oceans when cold atmospheric temperatures cause the solidification of surface waters. The sea ice is an important component of the earth’s physical climate system, acting as a cap on the polar oceans which substantially retards oceanic heat loss, reflects shortwave radiation, stores substantial amounts of freshwater, inhibits transfer of light to photosynthetic organisms in the upper ocean, and limits transfer of many biogeochemically important compounds between the ocean and atmosphere. Sea ice is often seen as an indicator of climate change because it is much thinner and more responsive to perturbations in climate than the continental ice sheets. Arctic sea ice has already shown rapid responses to rising Arctic temperatures as sea ice spatial extent and volume have dropped significantly over the satellite observation record, most markedly during summer.

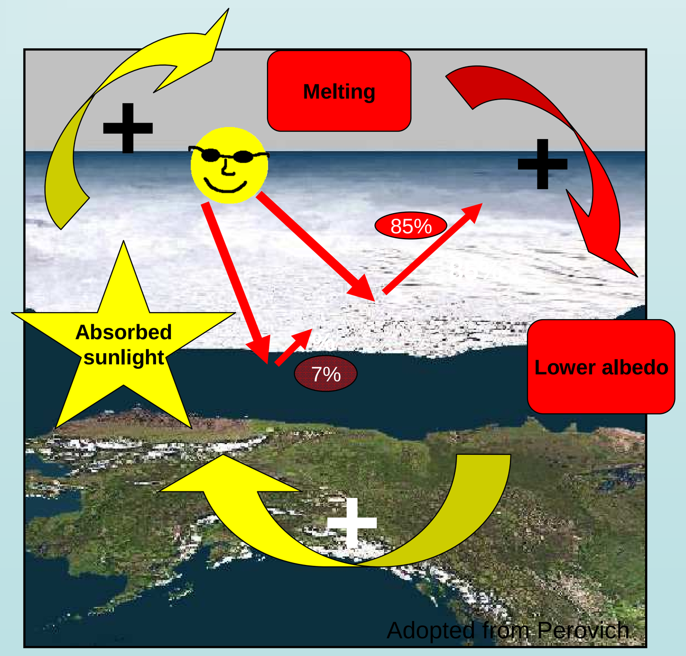


The importance of the changing ice cover reaches far beyond the Arctic due to strong coupling in the climate system, but ice cover changes also cause a wide range of environmental, social, national security, economic and transportation considerations within the ice covered regions of the Arctic itself.

Albedo Feedbacks

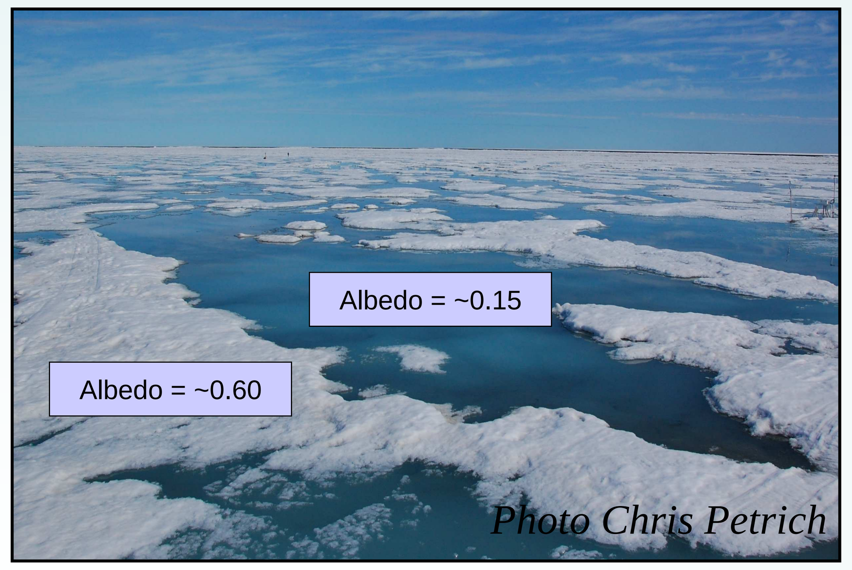
Albedo, the fraction of shortwave radiation reflected by a surface, plays a substantial role in concerns about the health of the Arctic sea ice. The drop in albedo that occurs when ice melts causes enhanced absorption of shortwave radiation, accelerating further losses of ice in a positive feedback cycle depicted at right. This ice-albedo feedback is partially responsible for the amplified warming seen in the Arctic, and raises concerns about whether the ice cover may pass through a tipping point beyond which a reversal of the temperature trend will not cause ice recovery.



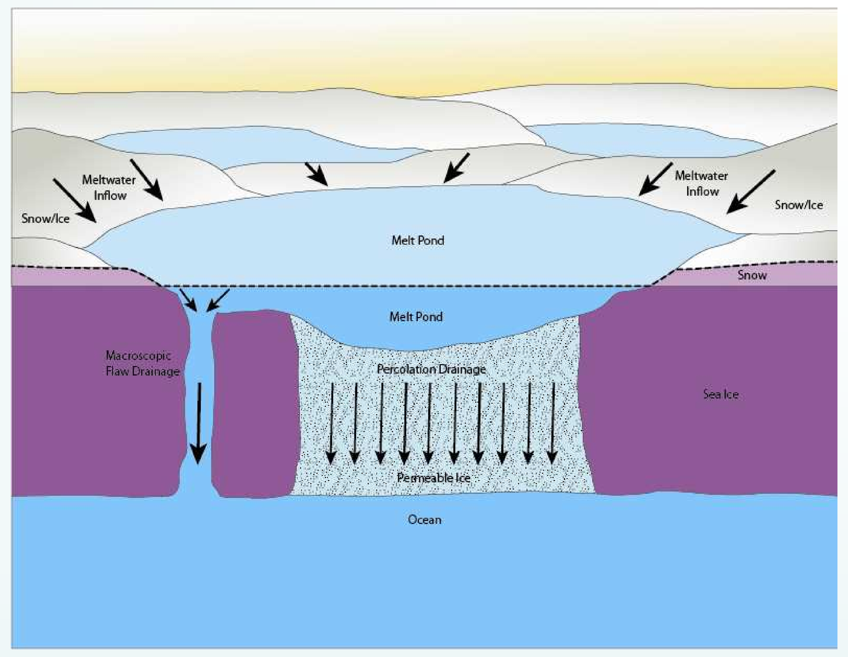


Melt Ponds and Albedo

The presence or lack of sea ice is not the only strong albedo control in the Arctic Ocean. Shortly after the onset of melt liquid water begins to collect on the surface of the sea ice in visible pools called melt ponds. The pooling water alters the light scattering properties of the ice surface and dramatically lowers albedo wherever melt ponds form. While exposing open ocean by melting the ice cover entirely takes weeks, the ponds form very rapidly, causing albedo changes in a matter of days. The timing of pond formation early in the melt season roughly coincides with maximum insolation, multiplying the energy effects of pond albedo still further. The area of these ponds is quite dynamic. A number of processes cause ponds to grow and shrink in spatial coverage throughout the season, suggesting other potential feedbacks.

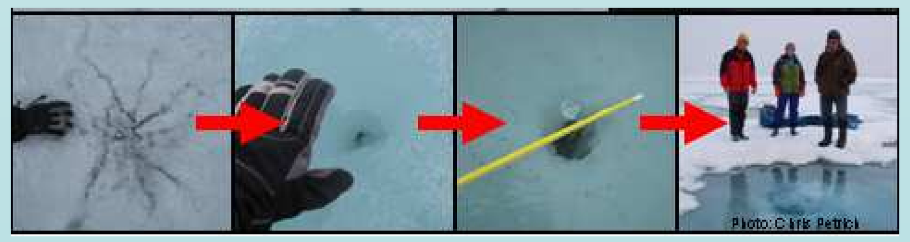


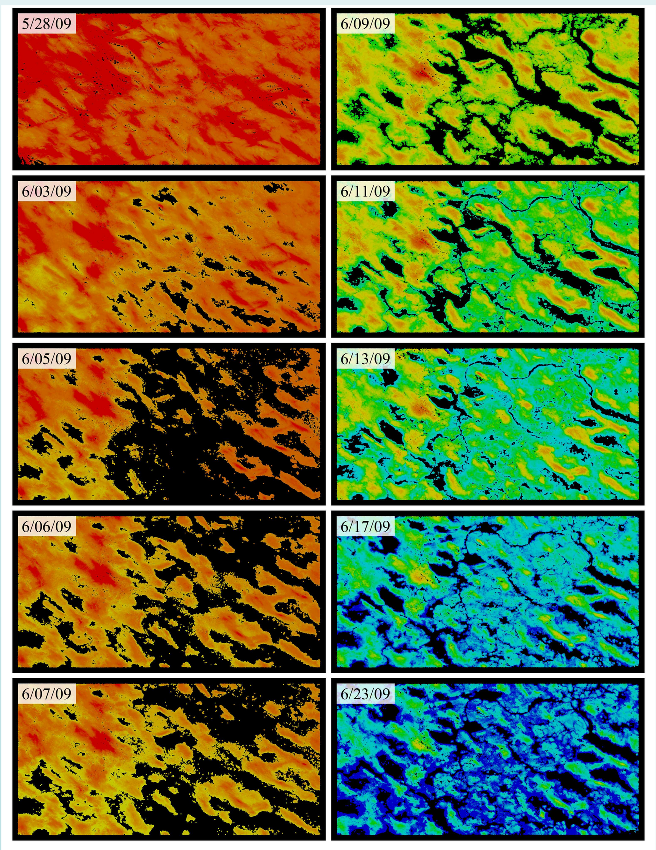
Melt Pond Dynamics



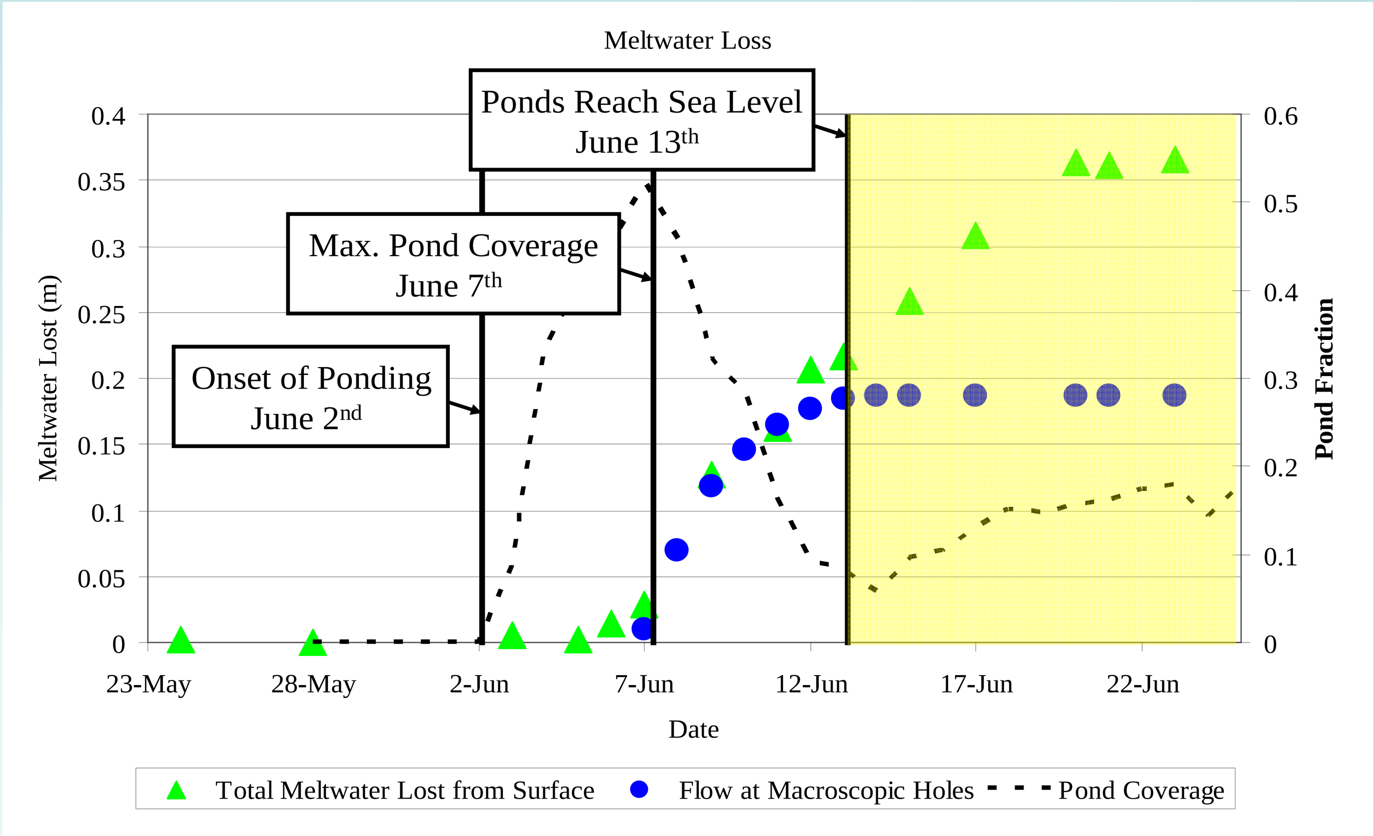
A melt pond can be thought of as simply a volume of meltwater retained at the surface of the ice. The volume is dictated by a balance of inflows and outflows, and the area covered depends on how the water is distributed in local surface topography.

Our observations were set up to learn more about how the processes changing retained volume and topography can be linked to pond coverage. Meltwater balance and flux was tracked throughout the melt season in a closed basin using a terrestrial LiDAR unit to create DEM’s of the surface, which are then subtracted day by day to calculate volumetric meltwater loss; plotted in green at the top right plot. Meanwhile water outflow at macroscopic flaws, which were observed to form as flowing water spontaneously enlarged brine drainage channels, (below) was monitored by measuring the cross section and flow rate in channels feeding the holes; plotted in blue.

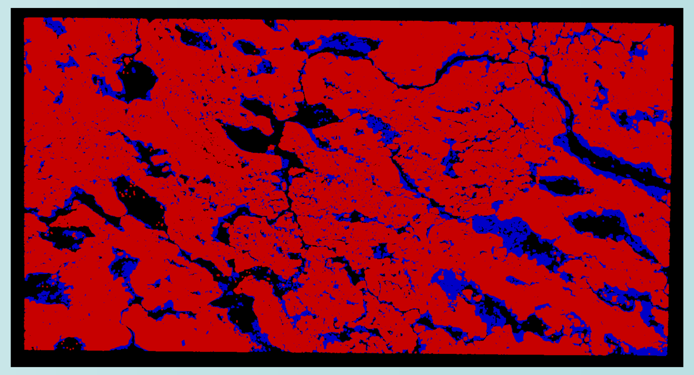




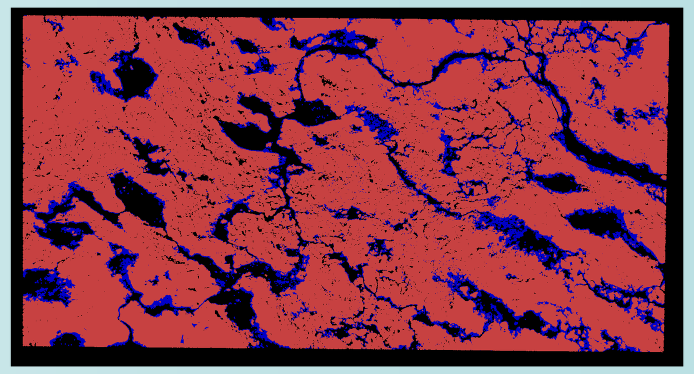
Surface Heights
2009 North Site
0m 0.6m



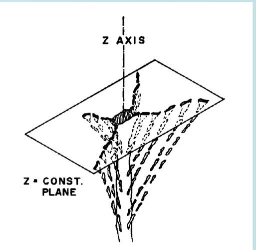
- Early pond coverage evolution controlled by outflow pathways
- Later evolution driven by freeboard loss
- Permeability transition later in melt season than expected from percolation theory
- FEM created of meltwater interactions with brine channel.
  - -Fresh meltwater can refreeze in pores.
  - -Pores below critical size become blocked
  - -Larger holes enlarge
  - -Heat delivery from meltwater vs. heat conduction into the ice.
- Stable isotope measurements show formation of interposed ice: meteoric water trapped in upper layers prior to percolation
- Single mechanism accounts for channel enlargement and interposed ice formation.
- Bimodal distribution of flaws in sea ice

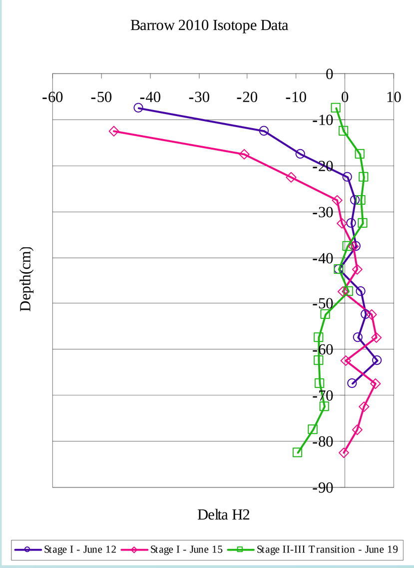


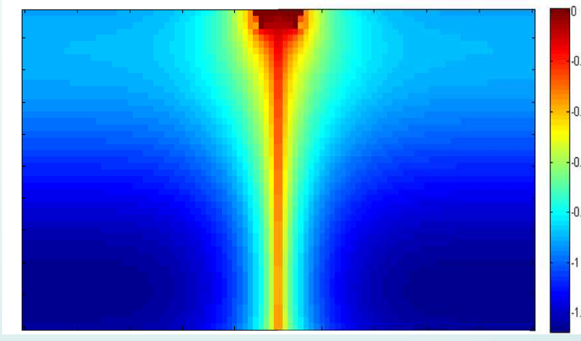
Area s within 4 cm of freeboard 6/13

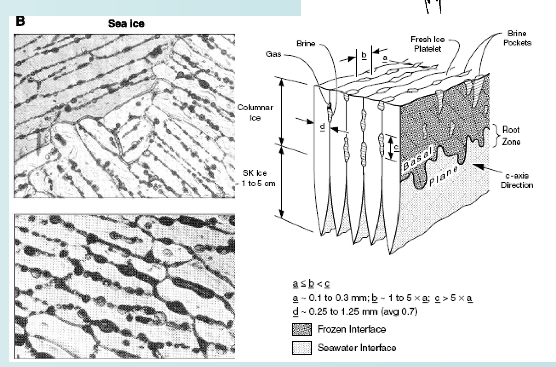


Area s which become pond covered 6/13-6/23



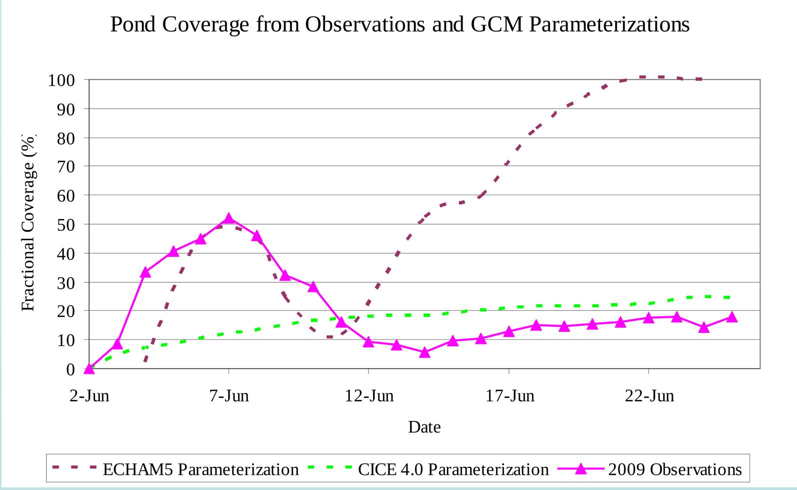






Improving Albedo in GCM’s

- Melt ponds just beginning to be included in GCM’s
- Early parameterizations not replicating observed pond coverage on FYI
- Pond depth not function of area.



Acknowledgements: I appreciate and acknowledge the contributions of the following individuals to this work:*Don Perovich, Kerry Claffey, Zoe Courville, Dave Finnegan, Matthew Druckenmiller, Hajo Eicken, Chris Petrich, and Matthew Sturm. Logistics were provided by the* Barrow Arctic Science Consortium and the USCGS Healy Crew and this work was conducted under funding from National Science Foundation Grant No. ARC-0454900 and the NASA ICESCAPE Program.