Geometry of floating vegetation mats on the margins of a thermokarst lake, Northern Seward Peninsula, AK

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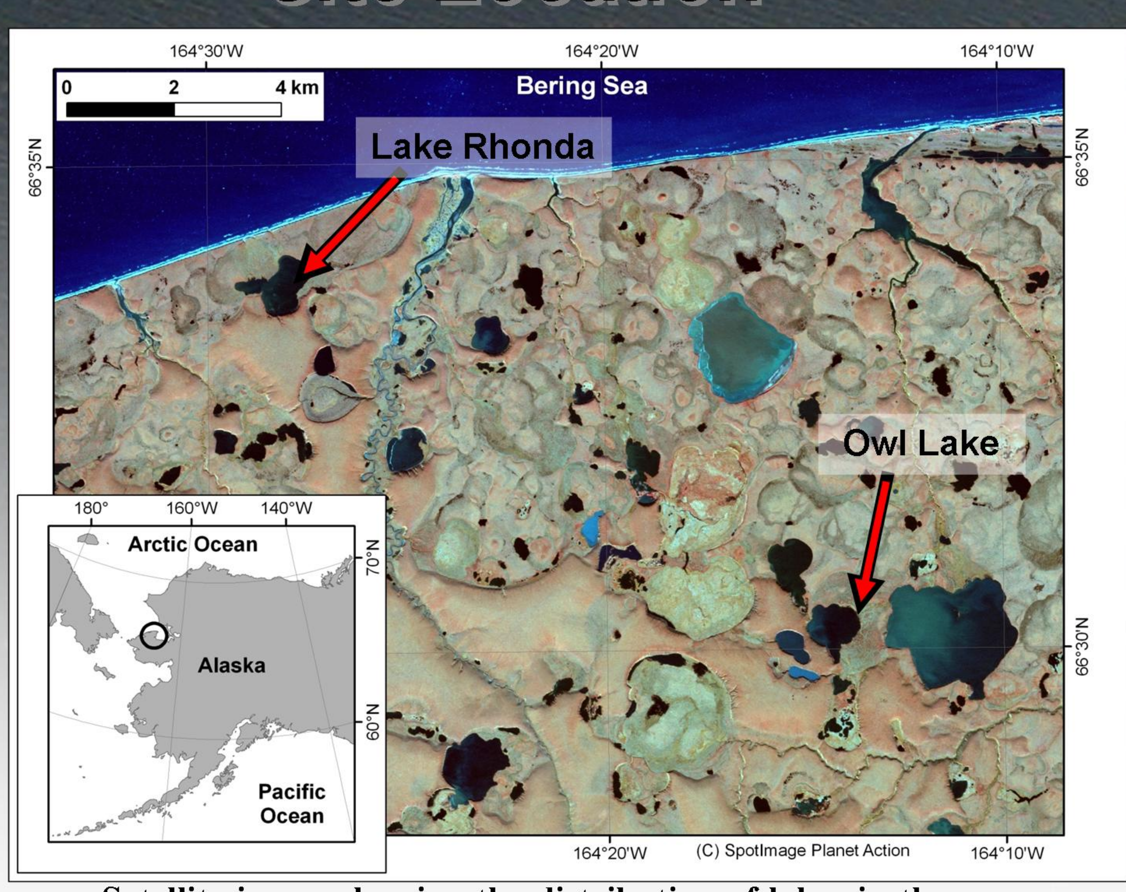
Introduction

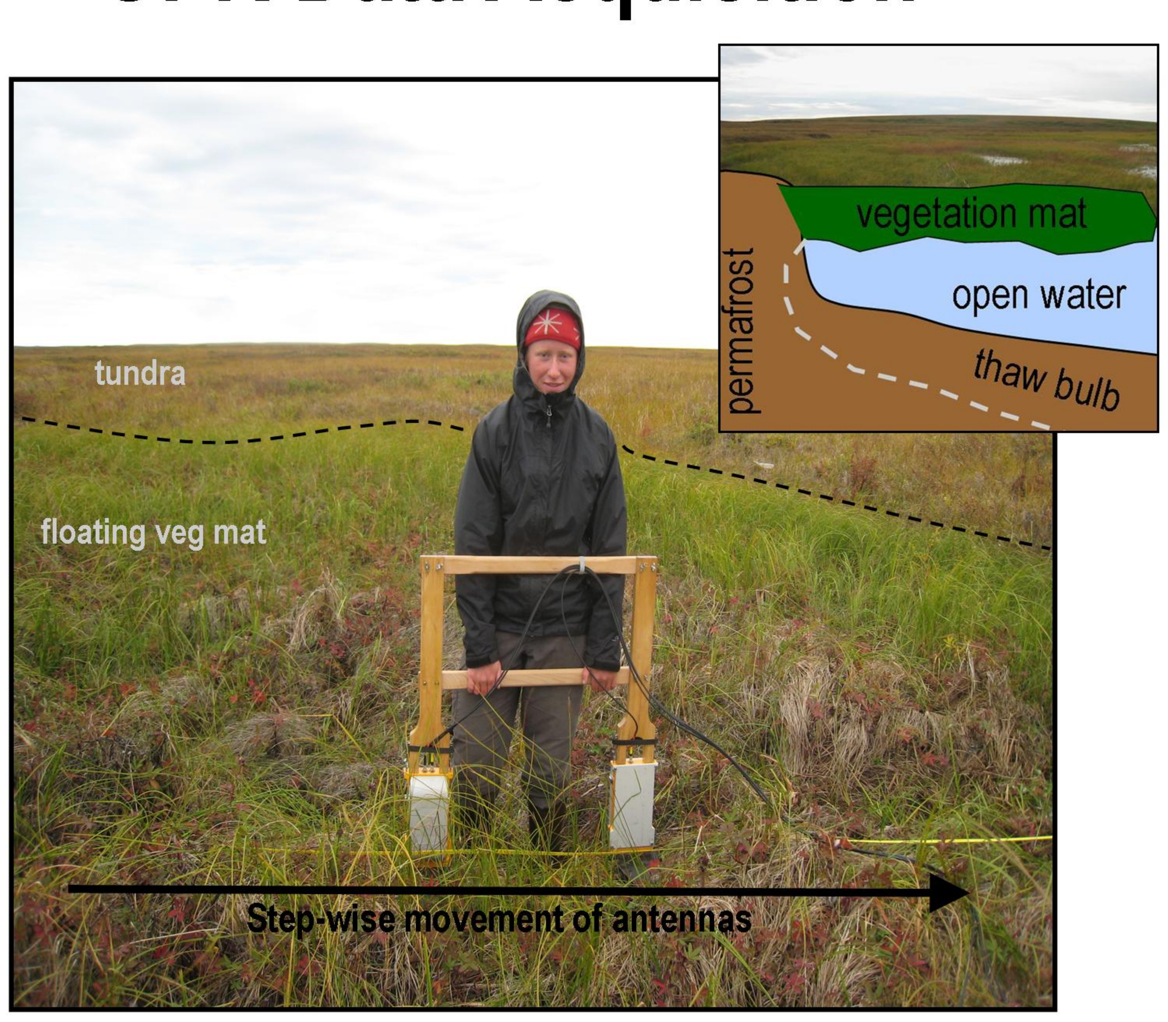
Thermokarst lakes are complex, dynamic systems that have the potential to be an important positive feedback to the global carbon cycle. Thermokarst lakes in yedoma are especially important due to the higher percentage of labile carbon present in newly formed thaw-bulbs. Permafrost thaw underneath expanding lakes and erosion of permafrost along lake margins result in tapping old Pleistocene and Holocene carbon stocks. This organic carbon is decomposed to methane in anaerobic environments in lake bottoms and thaw bulbs and released to the atmosphere. Understanding mechanisms of lake-margin expansion is essential to predictions of the growth of thermokarst lakes and their greenhouse gas emission potential in the future. Floating vegetation mat features around the margins of thermokarst lakes have recently been identified on the Seward Peninsula. These features are an indicator of rapid lake expansion (up to 2.5m/yr) and represent a recent, widespread mode of thermokarst lake expansion in the region. These vegetation mats have similar spectral properties as the surrounding tundra surface and are therefore not identified in automated remote-sensing-based lake mapping approaches. Since the floating vegetation mats are essentially part of the thermokarst lake, discounting their surface area underestimates permafrost degradation associated with thermokarst lake expansion as well as methane emission potentials. In this study, we have determined the geometry of the floating vegetation mats in a typical second generation thermokarst lake on the Northern Seward Peninsula. Ground penetrating radar determined the thickness of the floating mat and the water column. Aerial photography was used to calculate lateral spatial extent of the mats along the 3.4 km perimeter of the lake. Vegetation mats were 0.5 – 0.8 m thick floating on 0.5 – 0.9 m of water. The thickness of the mat varies little over distances up to 60 m. Initial temperature measurements indicate that the thick organic mats act as insulation, such that a thaw bulb can develop beneath the mats despite the shallow water depth (less than 1m). The insulating quality of the mats also warms adjacent permafrost further promoting lateral expansion. Understanding the geometry of these vegetation mats has implications for determining expansion rates of thermokarst lakes and correctly estimating carbon release potential from remote sensing and aerial photography studies.

Site Location



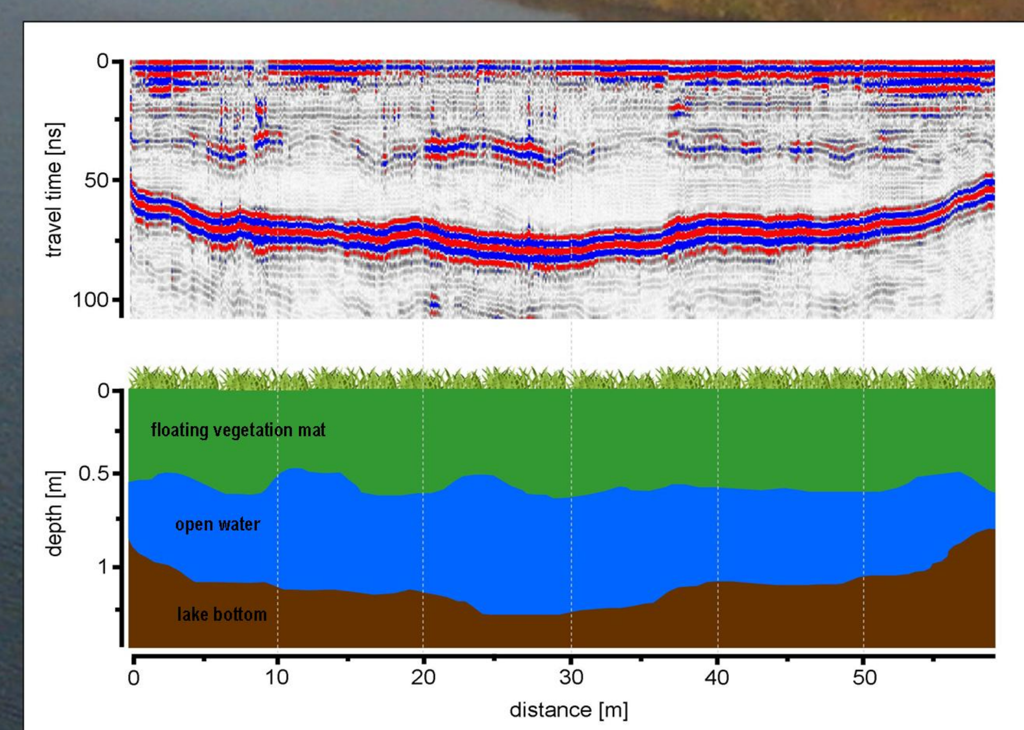
Satellite image showing the distribution of lakes in the region. The focus of the ground-penetrating radar portion of this study is at Owl Lake. Temperature measurements were made at nearby Lake Rhonda.

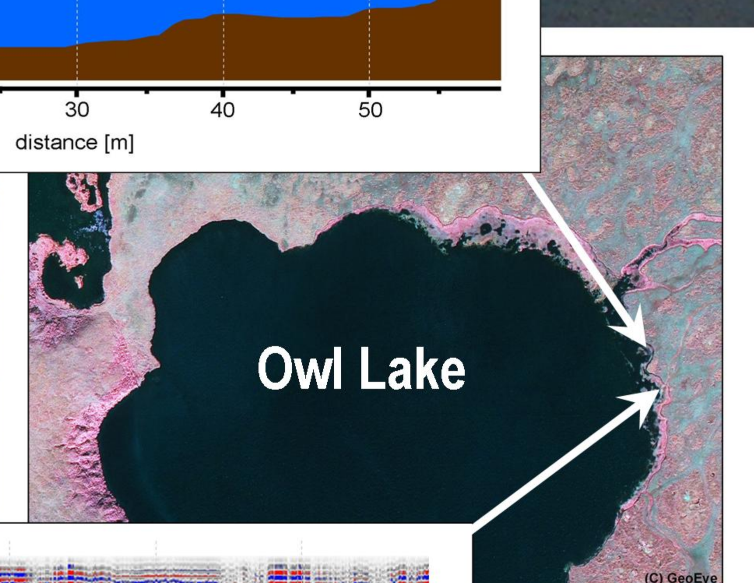
GPR Data Acquisition



An operator using the 200 MHz ground-penetrating radar system to collect data in 2-D profiling mode.

GPR Results



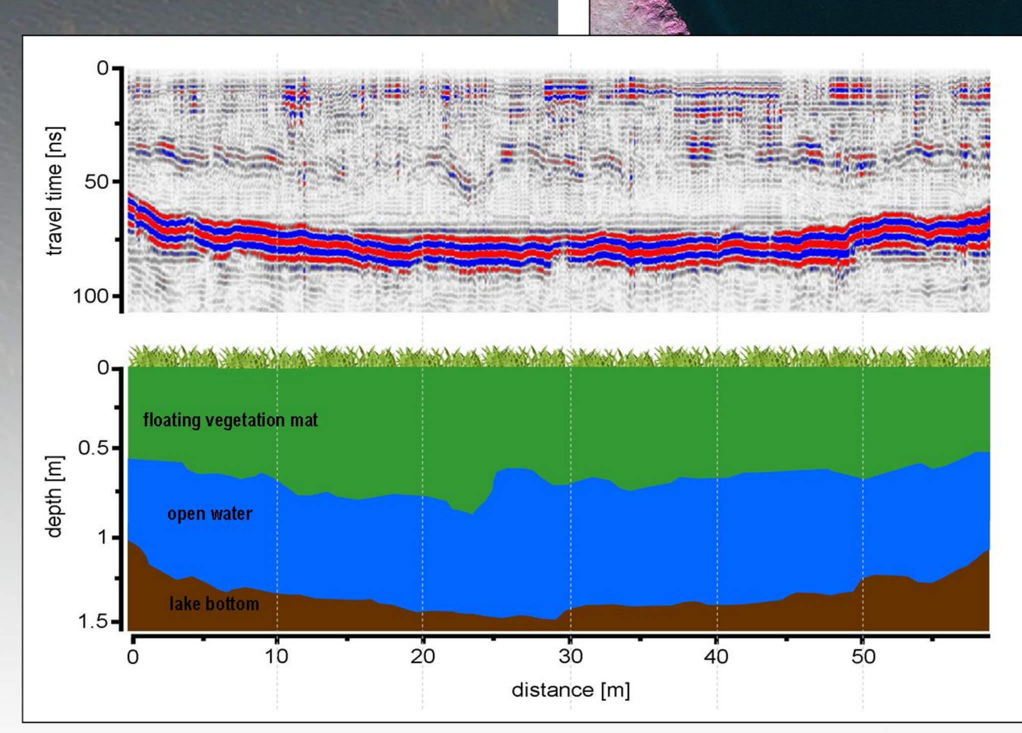


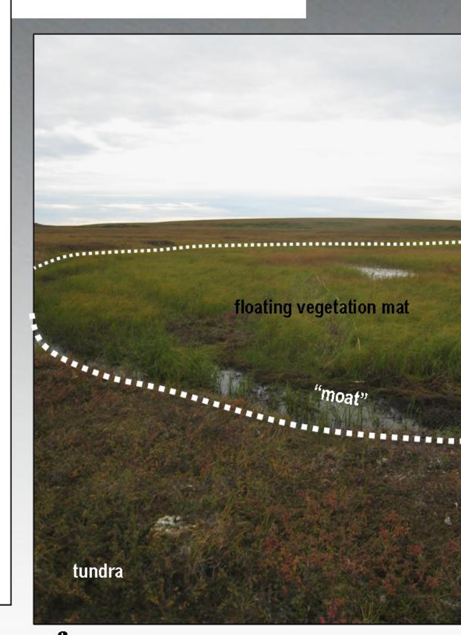
Vegetation mat thickness: 0.4 m – 0.6 m

Water depth below mat: 0.2 – 0.8 m

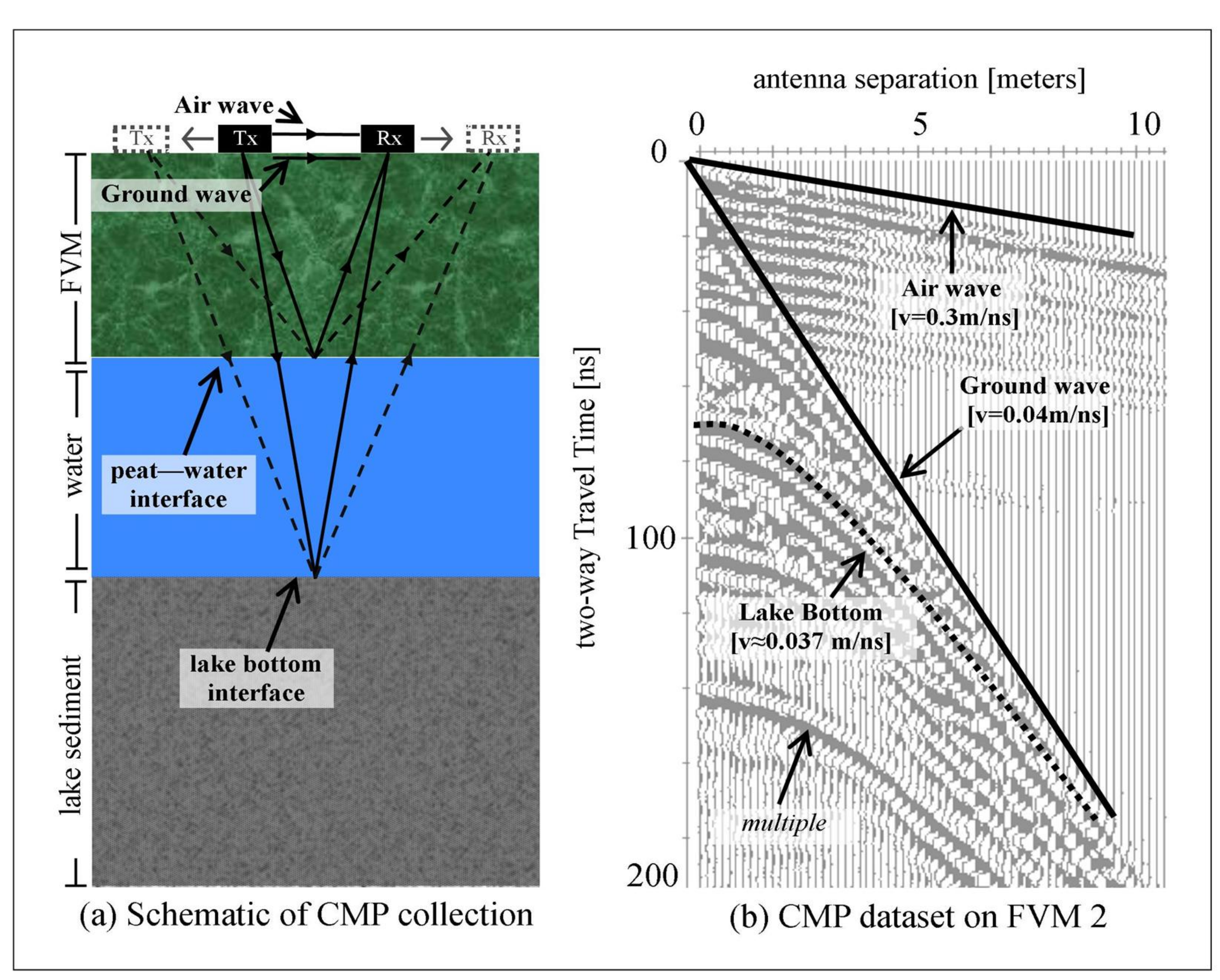
Max vertical GPR resolution: 0.05 m
(based on 1/4 λ assumption)

Max horizontal GPR resolution: ≈ 0.32 m
(based on Fresnel zone calculation)





Processed GPR datasets and interpreted cross sections from two floating vegetation mats on the margins of Owl Lake.



The orientation of the GPR antennas during common mid-point data collection is shown in part (a). This method was used to determine the site-specific radar wave velocity used in assigning the depth axis to the interpreted profiles. A sample common mid-point radargram from the southern floating vegetation mat is shown in (b)

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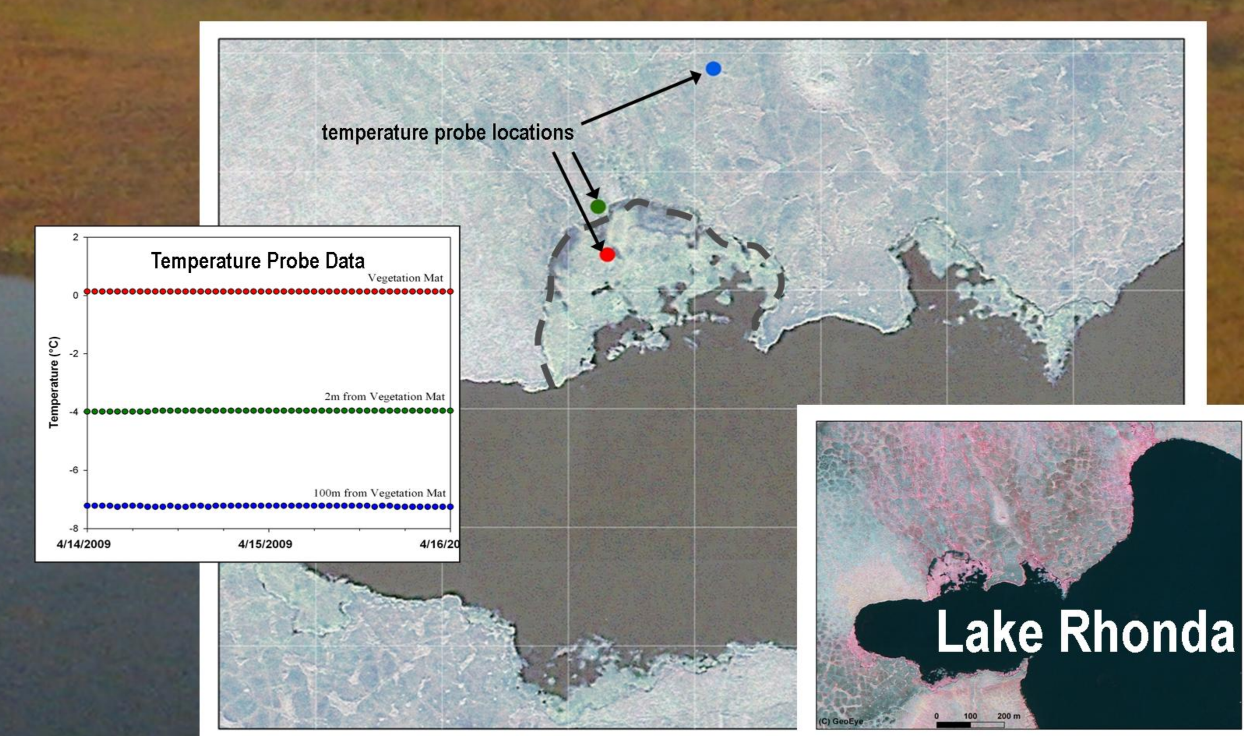
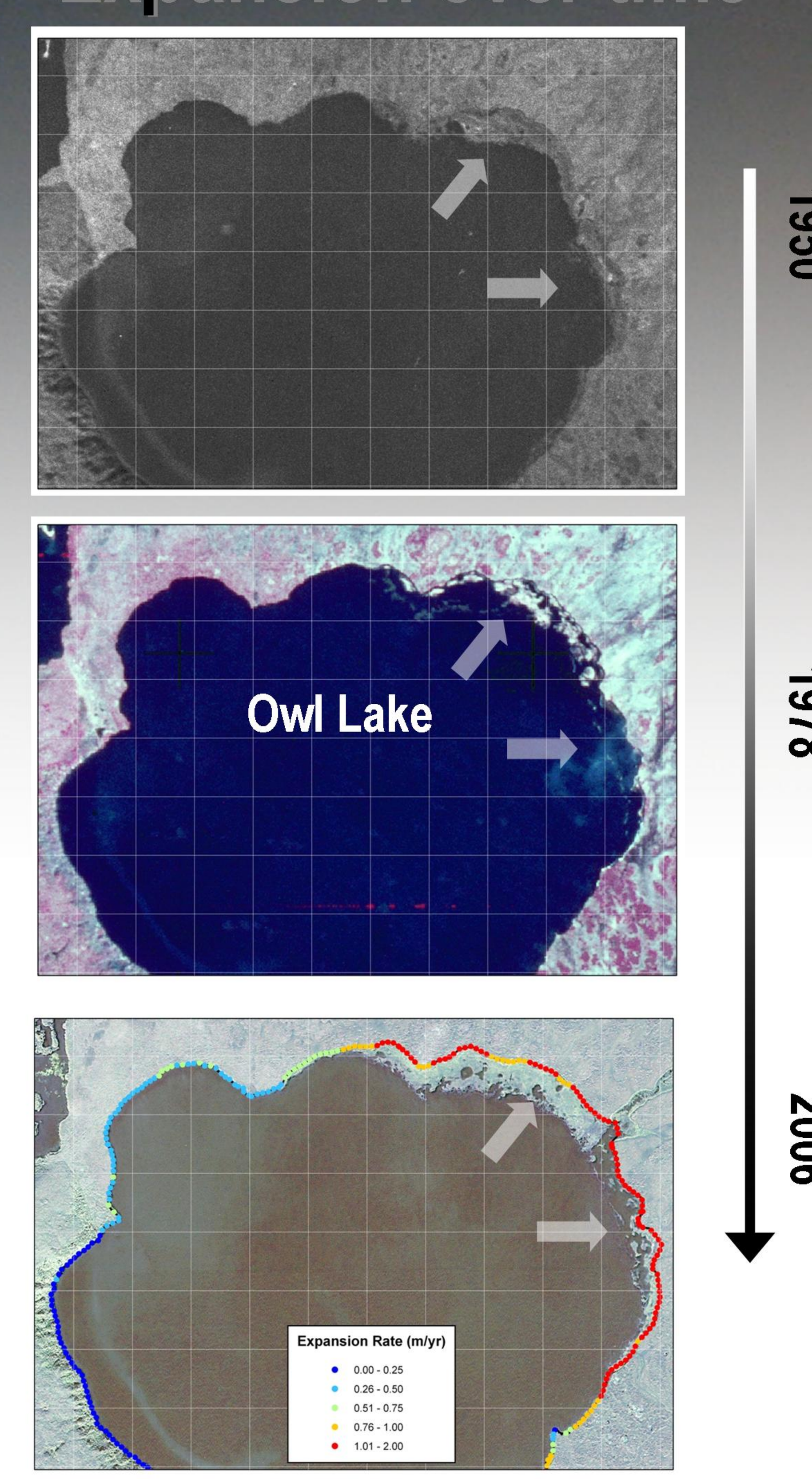
Insulating Effect



Initial temperature data readings indicate that a talik is present at a depth of 1.5m beneath the vegetation mat at Lake Rhonda and that the permafrost temperature adjacent to the mat is 3degreesC warmer than a control site located 100m from the mat edge. It is likely that the mat influences permafrost temperatures adjacent to it which likely leads to "easier" expansion due to the permafrost being warmer.

Expansion over time



Vegetation mats are expanding at rates up to 2 m per year. The eastern margins with the highest rates shown in the 2006 photo area have lower topographic relief than the western edge.

Conclusions

- Floating vegetation mats were observed to have a consistent thickness of 0.4-0.6 m and can be 10's - 100's of m long
- Mats can keep lake bottom above freezing during winter
- Lateral expansion rates are observed up to 2 m per year
- The presence of these mats may lead to underestimates of lake area from aerial surveys therefore effecting gas release estimates
- a talik can start forming under the vegetation mats despite the very shallow water depths because of the insulating effect