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The Cryosphere Discussions

Interactive comment on "Spatial analyses of thermokarst lakes and basins in Yedoma landscapes of the Lena Delta" *by* A. Morgenstern et al.

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This informative, careful, and well-written paper provides a valuable contribution to a growing literature that is using satellite remote sensing, geoinformatics and, when possible, field work to understand how long-term environmental changes influence the size, distribution and morphology of Arctic lakes. While attributions to past and current climate changes have dominated this field as of late, the authors also incorporate the widely appreciated yet understudied importance of stratigraphy, geomorphology and relict landscapes as controls on lake characteristics and their evolution over time.

Perhaps the most significant idea advanced in the paper is that on Russia's carbon-

rich Yedoma uplands, many modern lakes reside within larger, abandoned lake basins, that are relicts from ∼12 ka when conditions for large thermokarst lake expansion were more favorable than today. At that time, the Arctic Ocean lay several hundred kilometers further north, the region was a broad plain rather than the dissected, geomorphologically complex river delta of today, and – as becomes important in this paper – the landscape was generally less disturbed by prior lake activity. In such an environment, thermokarst lakes had greater capacity to expand to very large sizes (several km) before intersecting a channel or other low-lying surface feature, at which point the shoreline breaches thus triggering lateral drainage. Another important argument of the paper is the role of underlying ice-poor fluvial sands as a limiting factor on thermokarsting. While some nice work partitioning relict from contemporary lake basins has previously been done for Alaska's North Slope, it's new for Russia where few previous studies have distinguished between thermokarst lakes on Yedoma uplands and those residing within older relict basins.

The paper provides a good literature review, tracing back to early Soviet-era work by Soloviev, Katasonov, Romanovskii and others. Another strength is its close attention to geology and permafrost ice properties in the uppermost stratigraphic units (two Pleistocene, one Holocene) of its Lena River delta study area. The paper incorporates new and prior field work to supply relevant details like the influence of terrain slope on presence of ice-wedge polygons (apparently, slopes of ∼0 to 2 degrees support polygons whereas steeper slopes do not) and lake bathymetry. The importance of coalesced (vs. single) lakes is recognized, as the former are less likely to regrow after drainage owing to better integration with local surface drainage networks.

Other findings include discovery of statistically significant differences between lakes located on the Yedoma uplands (smaller, smoother shorelines) and basins, and identifying differences in prevailing lake orientation. The latter will add to a small ongoing literature, again rooted mainly in North America, debating the roles of wind direction, limnology and other processes on thaw lake orientation.

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The study area focuses on only ∼1700 km2 but the benefit of this is a process- and landscape-level understanding of controls on lake formation, stability, and drainage. The authors display good appreciation of the influence of RS pixel size on derived lake metrics, a power-law lake size distribution (heavily skewed towards tiny ponds), and other problems that plague efforts to map Arctic lakes from satellite imagery. To help mitigate them 2,327 "water bodies" (1 pixel) initially mapped in the Landsat ETM+ classification are culled to 514 lakes of size > 14,400 m for further morphometric analysis.

As mentioned earlier, the authors specifically consider stratigraphy in their analysis. A shrewd attempt to estimate the stratigraphic penetration of lake beds is based on its elevation, i.e. all lakes and basins located at or below 17 m a.s.l. are assumed to have beds in fluvial sands of the lower stratigraphic unit. The importance of this arises in later discussions in the paper (pp. 1511-1512) and has to do with low thermokarst potential in this material. I wonder if some independent validation of this approach might be enabled by examining the visible bands of the ETM+ mosaic. I know from previous experience that sand bars are clearly visible along Siberian rivers, at least, using ETM+, and the photograph in Figure 2 suggests sizable sand outcrops are visible in the study area. The authors might get lucky if any lakeshores and/or bottom reflectance (if water is clear enough) lend some independent, if qualitative support for their stratigraphic estimates.

Section 5.3 is one long paragraph and quite indigestible in its present form, especially the latter part (discussion of taberites). I recommend separating this section into distinct paragraphs with an eye towards improving the reading flow.

If possible, the conclusion and abstract could be strengthened by better addressing the "so-what" question. The key, take-home message of this paper is that undisturbed, upland permafrost landscapes that have not already experienced widespread thermokarsting in the past have more potential to experience lake expansion in the future under a warming climate; whereas landscapes that previously experienced lake expansion in the past are limited as to how much lake expansion can occur, mainly

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confined to small 2nd- and 3rd- generation lakes trapped within larger relict basins. This important finding would have even broader impact if the authors could posit how much of the Russian north (i.e. in continuous permafrost) falls into this "restricted" category of landscape. Do previously disturbed Yedoma areas represent only a small fraction of the overall landscape, or are the prospects of widespread thermokarst lake expansion – together with all of its carbon cycle ramifications - dimmed by the findings of this study? Because changing surface hydrology is highly relevant to soil carbon and trace gas exchange, placement of this paper's central conclusion into an even broader context would expand its appeal to researchers in other fields.

Figure 10 label font is a bit small/hard to read.

Figure 13 right-hand legend is outsized. Rather than shrink it, perhaps fix by horizontally stretching the 5 schematic diagrams in the right-hand column to match the dimension of the legend.

Interactive comment on The Cryosphere Discuss., 5, 1495, 2011.