Supplementary online material for "Disappearing Arctic Lakes," by Laurence C. Smith, Yongwei Sheng, Glen M. MacDonald, and Larry D. Hinzman (Methods, SOM text, References and Notes)

Methods

In July 1972, the U.S. National Aeronautics and Space Administration (NASA) launched the Earth Resources Technology Satellite (later renamed Landsat-1), the first in a continuing series of NASA Earth observing satellites. Its payload included the Multispectral Scanner (MSS), which acquired digital-format imagery with ~80 m spatial resolution in four spectral channels (0.5-0.6 µm, 0.6-0.7 µm, 0.7-0.8 µm, and 0.8-1.1 µm). We used digital image processing to precisely co-register and compare thirty-eight of these earliest MSS images acquired over Siberia in 1973 with recent data (1997-1998) from the Russian RESURS-1 satellite, which carries a multi-spectral optical-mechanical radiometer (MSU-SK) acquiring images with ~150 m spatial resolution in five spectral channels (0.5-0.6 µm, 0.6-0.7 µm, 0.7-0.8 µm, 0.8-1.0 µm, and 10.4-12.6 µm). All images were acquired during summer. Lakes and other surface water bodies are readily identified in the satellite data owing to their very low reflectance in infrared channels of both sensors (0.8-1.1 µm MSS, 0.8-1.0 µm MSU-SK). To enable precise comparison between the two datasets, MSS images were resampled to a uniform 150 m grid spacing and lake locations, perimeters and areas inventoried in a geographic information system (GIS). From a starting coverage of 624,496 km^2, we manually delineated and removed areas of cloud cover (19,487 km^2) and seasonally inundated river floodplains (89,991 km^2), the remaining 515,018 km^2 were subjected to analysis. Spatial overlaps between images acquired on different dates in the same year were used to quantify seasonal variability in lake abundance and size. This sensitivity analysis found (i) absolutely no ephemeral water bodies exceeded 40 ha in size (i.e. lakes 40 ha or larger are “stable” landscape features that do not appear or disappear in response to short-term seasonal variability, Fig. S1); and (ii) seasonal variations in the total inundation area of such lakes did not exceed 3%. The former led to the 40 ha lake size criterion used in this study; the latter confirms that the observed changes are ~4X greater than the maximum observed seasonal variability. Finally, the currently known distribution of permafrost (continuous, discontinuous, sporadic, and isolated, S1) was mapped across the region (Fig. 1a). Total lake counts, areas, and changes between 1973 and 1997-98 were then tallied for the four permafrost zones and the region as a whole. One hundred and twenty-five drained lakes identified in the 1997-98 MSU-SK data were subjected to further monitoring (3 – 6 visits) in subsequent years (2000 – 2004) using time series of Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data (250 m spatial resolution, 0.841 - 0.876 μm). The MODIS data were used for the purpose of identifying the presence or absence of water in drained lakes only. None refilled over this period, the lakes are therefore regarded as permanently drained.

SOM text

In continuous permafrost, our findings do agree with previous reports of lake expansion and growth (S2, S3, S4, S5). However, the opposite trend is found in discontinuous, isolated and sporadic permafrost. Even in continuous permafrost, lake drainages have occurred, perhaps owing to spatial heterogeneities in permafrost thickness or distribution.

Changes incurred by individual lakes must be interpreted with caution, as they are subject to complex, locally varying processes of thermal erosion, energy absorption and infilling and a single occurrence of lake change should not be used as proof of climatic change (S6). Similarly, many thermokarst lakes follow a well-known life cycle of formation, expansion and drainage quite independent of climate (S7, S8). For these reasons, it is important to examine broad-scale patterns in lake abundance, area, and drainage, as done here for western Siberia. Through study of thousands of lakes, net changes in their overall abundance and area may be identified and attributed to regional driving mechanisms such as climate and permafrost degradation.

Changes in the extent of Arctic lakes and wetlands would have significant ramifications for the region's ecology, carbon cycle, land-atmosphere exchange, hydrology, and human use. Arctic lakes and wetlands currently support a variety of endemic ecosystems and are vital feeding and nesting sites for a great number of bird species that migrate annually over long distances (S9). They also release large quantities of carbon dioxide (S10) and methane (S11) to the atmosphere, absorb five to seven times more solar energy than surrounding terrain (S6), and are prime sources of evaporation to the atmosphere. A shift from above-ground storage of surface water (in lakes and wetlands) to the subsurface would likely decrease surface runoff, erosion and water availability to vascular plants, while increasing aerobic soil decomposition, groundwater supply, river baseflows, and perhaps dissolved organic carbon export to streams (S12). Arctic lakes and wetlands also provide important habitats for fish, birds and certain mammals vital to human subsistence and indigenous economies (S13, S14).

References and Notes

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