Ice-wedge degradation: Why Arctic wetland are becoming wetter and drier


ABSTRACT

Ice-wedges are continuous permafrost features formed over hundreds to thousands of years by ice-wedge polygons, with implications for land-atmosphere and land-ocean fluxes of water, tundra water balance despite an identical snow water equivalent at the landscape-scale. These before and after melting. Our coupled hydrological and thermal model experiments applied over ice-wedge melting.

Unlike the multi-decadal warming observed in permafrost temperatures, the ice-wedge melt-drying due to a drying of both polygon centers and troughs. Near creeks, lake margins, and in hilly terrain, high-centered polygons form an overall landscape evident as increased surface water in the ice-wedge polygon troughs and somewhat ground subsidence has occurred at multiple sites in the North American and Russian Arctic. At

OBSERVED ICE-WEDGE DEGRADATION

Figure 1. Observations from the continuous permafrost region of the North American and Russian Arctic during 2005-2011 (Additional Information). A. Continuous permafrost region with large ice-wedge polygon complexes and associated features. B. Geophysical sensor locations with associated top melting and permafrost temperature changes. The color bar indicates the maximum temperature change in permafrost temperatures above 0 ºC in 2005 (a). A soil temperature sensor was installed at 68 cm (b), while a temperature sensor was only 44 cm (c). The early (top panel) and late images (middle panel) of the presented sites in the continuous permafrost region of the North American and Russian Arctic. Photo shows the landscape during the melt onset and duration of ice-wedge degradation. Also included are statistical significant trends (P-value < 0.01). Precipitation values were not corrected for undercatch.

Figure 2. Observations from the continuous permafrost region of the North American and Russian Arctic during 2005-2011. A. Location of the observed landscape-scale ice-wedge degradation. B. Locations of recent landscape-scale ice-wedge degradation. C. Locations of observed ice-wedge degradation and its hydrological impacts. The presented sites in the continuous permafrost region of the North American and Russian Arctic during 2005-2011 (Additional Information). A. Continuous permafrost region with large ice-wedge polygon complexes and associated features. B. Geophysical sensor locations with associated top melting and permafrost temperature changes. The color bar indicates the maximum temperature change in permafrost temperatures above 0 ºC in 2005 (a). A soil temperature sensor was installed at 68 cm (b), while a temperature sensor was only 44 cm (c). The early (top panel) and late images (middle panel) of the presented sites in the continuous permafrost region of the North American and Russian Arctic. Photo shows the landscape during the melt onset and duration of ice-wedge degradation. Also included are statistical significant trends (P-value < 0.01). Precipitation values were not corrected for undercatch.

Figure 3. Observed recent ice-wedge degradation and its hydrological impacts. The presented sites in the continuous permafrost region of the North American and Russian Arctic during 2005-2011 (Additional Information). A. Continuous permafrost region with large ice-wedge polygon complexes and associated features. B. Geophysical sensor locations with associated top melting and permafrost temperature changes. The color bar indicates the maximum temperature change in permafrost temperatures above 0 ºC in 2005 (a). A soil temperature sensor was installed at 68 cm (b), while a temperature sensor was only 44 cm (c). The early (top panel) and late images (middle panel) of the presented sites in the continuous permafrost region of the North American and Russian Arctic. Photo shows the landscape during the melt onset and duration of ice-wedge degradation. Also included are statistical significant trends (P-value < 0.01). Precipitation values were not corrected for undercatch.

Figure 4. The presented sites in the continuous permafrost region of the North American and Russian Arctic during 2005-2011 (Additional Information). A. Continuous permafrost region with large ice-wedge polygon complexes and associated features. B. Geophysical sensor locations with associated top melting and permafrost temperature changes. The color bar indicates the maximum temperature change in permafrost temperatures above 0 ºC in 2005 (a). A soil temperature sensor was installed at 68 cm (b), while a temperature sensor was only 44 cm (c). The early (top panel) and late images (middle panel) of the presented sites in the continuous permafrost region of the North American and Russian Arctic. Photo shows the landscape during the melt onset and duration of ice-wedge degradation. Also included are statistical significant trends (P-value < 0.01). Precipitation values were not corrected for undercatch.

Figure 5. Ice-wedge degradation: Why Arctic wetland are becoming wetter and drier

CONCLUSIONS

* Top melting of ice-wedges and subsequent ground subsidence is a widespread and recent phenomenon across the Arctic.
* Field and remote sensing observations document extensive ice-wedge degradation, which initially has resulted in increased wetness contrast across the landscape and an overall drying in later stages.
* Our coupled thermal and hydrological model experiments suggest that a connected thaw-front network reduces radiation and increases runoff and that changing patterns of moisture evolution due to the differential ground subsidence play a critical role in the development of wetlands and the subsequent increased spatial variability in increased wetness runoff and decreases WCA.