Geophysical Research Abstracts
Vol. 18, EGU2016-10451, 2016
EGU General Assembly 2016

Permafrost vulnerability and active layer thickness increases over the high northern latitudes inferred from satellite remote sensing and process model assessments

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Permafrost extent (PE) and active layer thickness (ALT) are important for assessing high northern latitude (HNL) ecological and hydrological processes, and potential land–atmosphere carbon and climate feedbacks. We developed a new approach to infer PE from satellite microwave remote sensing of daily landscape freeze–thaw (FT) status. Our results document, for the first time, the use of satellite microwave FT observations for monitoring permafrost extent and condition. The FT observations define near-surface thermal status used to determine permafrost extent and stability over a 30-year (1980–2009) satellite record. The PE results showed similar performance against independent inventory and process model (CHANGE) estimates, but with larger differences over heterogeneous permafrost subzones. A consistent decline in the ensemble mean of permafrost areas (-0.33 million km2 decade^{-1}; $p < 0.05$) coincides with regional warming (0.4 °C decade^{-1}; $p < 0.01$), while more than 40% (9.6 million km2) of permafrost areas are vulnerable to degradation based on the 30-year PE record. ALT estimates determined from satellite (MODIS) and ERA-Interim temperatures, and CHANGE simulations, compared favorably with independent field observations and indicate deepening ALT trends consistent with widespread permafrost degradation under recent climate change. The integration of remote sensing and modeling of permafrost and active layer conditions developed from this study may facilitate regular and effective regional monitoring of these parameters, and expand applications of remote sensing for examining permafrost-related feedbacks and consequences for biogeochemical and hydrological cycling in the Arctic.