Spatial and Temporal Influences of Thermokarst Failures on Surface Processes in Arctic Landscapes

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Permafrost has been warming

- WD: West Dock
- DH: Deadhorse
- FB: Franklin Bluff
- HV: Happy Valley
- GL: Galbraith Lake

Osterkamp 2002
Permafrost will eventually thaw

U.S. Arctic Research Commission (Hinkle et al., 2004)
When permafrost finally thaws, various *thermokarst* features may form.

- **Glacial Thermokarst**
- **Thermokarst Gully**
- **Retrogressive Thaw Slump**
- **Active layer detachment slide**
There are more of these features now than used to be the case.

Feniak Lake (Noatak) 1985 vs 2006

Gooseff et al. (2009)
Potential environmental impacts of permafrost degradation

- Subsidence and thermokarst
- Mass movement and soil loss
- Redistribution of nutrients across landscape
- New niches for plant growth (shrubs?)
- Increased sediment and nutrient loading to aquatic ecosystems
- Altered microbial processing
- Accelerated CO$_2$ and CH$_4$ emissions
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A systems approach to address hypotheses about how thermokarst failures influence the structure and function of the arctic landscape.
Overview: Structure and Focus of the ARCSS Thermokarst Project

• The local scale
  – Hillslope processes (Gooseff, Godsey, Lewkowicz)
  – Soil/emission processes (Jones, Schimel, Abbot)
  – Vegetation processes (Mack, Schuur, Baron)
  – Aquatic processes (Bowden, Kling, Larouche, Flinn, Kampman)

• The regional scale
  – Permafrost dynamics (Jorgenson)
  – Landscape dynamics (Crosby, Krieger)

• Synthesis
  – Extrapolation over space (Balser, Gens)
  – Prediction over space & time (Rastetter, Bowden)

• The Human Dimension
  – Social ecology of change (Kofinas, Butler)
  – Outreach and education (Sparrow, Baeseman)
Thaw depth is more variable in space and time with thermokarst features

M. Gooseff, S. Godsey, and T. Lewkowicz, unpublished data
Thawed permafrost alters nutrient dynamics with feedbacks to the atmosphere

Schuur et al. (2008)
Soil nutrients differ by thermokarst age

NE14 (D) Retrogressive thaw slump

A. Baron, M. Mack, T. Schuur, unpublished data
Respiration Differs by Site Type

Exposed < Control < Vegetated

Respiration (µmol m⁻² sec⁻¹)

J. Jones and B. Abbott, Objective A.2
Thermokarst export sediment and nutrients to streams and lakes

Thermokarst export

Toolik River flow direction

Lake NE-14 and thaw slump
Thermokarst feature increase stream benthic primary producers and particulate nutrients

J. Larouche and W. Bowden, Objective B.1
Thermokarst features increase nutrient and sediment loading to lakes but decrease benthic primary producers.

G. Kling, Objective B.2
How do thermokarst features age?

Toolik River Gully Thermokarst
Over time thermokarst features help sculpt the arctic landscape.

*Watertracks north of “Horn” Lake, Anaktuvuk Burn area*

B. Crosby, Objective C.3
The Multi-Element Limitation (MEL) Model

E. Rastetter et al. (1997)
Application of MEL

...locally across habitats in a feature  ...regionally across the landscape

E. Rastetter and W. Bowden, Objective C.4
Summary

- Thermokarst features are common and their rate of formation has probably increased in recent years.
- Thermokarst features, especially hillslope mass failures, have the capacity to rearrange massive quantities of soil and the C/N/P it contains, on the landscape.
- These thermokarst failures open new niches for plant colonization, create sites of intense microbial activity and trace gas emission, are sources of nutrients and sediment to receiving waters, and alter the local topography with impacts on snow accumulation.
- The “risk” of thermokarst formation may be predictable (at least in an aggregate sense).
- Thermokarst failures after permafrost thaws have the capacity to substantially alter the form and function of the arctic landscape.
Connecting Science to People

Students measuring depth of freezing of active layer using a frost tube

Scientists meeting with journalists to share perceptions and misperceptions

Contributions to development of young polar scientists
Collaborators and Facilitators

- The University of Vermont
- Penn State
- Boise State University
- NSF
- MBL Marine Biological Laboratory
- UCSB
- University of Michigan
- UF University of Florida
- UAF University of Alaska Fairbanks
- uOttawa
- Idaho State University
- Murray State University
- ABR Environmental Research & Services
- CH2M Hill Polar Services
- NPS National Park Service
- Arctic Program
Thank you!

For additional information please see:

http://thermokarst.psu.edu/

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