Proposed Working Group:

Ecosystem response to changing ice, snow, and permafrost in a warming climate

Convened by MCM and PAL**.**

Global patterns of the atmosphere are responding to anthropogenic sources of greenhouse gases (IPCC, 2007). Air temperatures are warming and the spatial distribution of precipitation, both in form (rain versus snow) and quantity are changing. One dramatic indicator of the changing climate is the altered state of the cryosphere, including thinner snow packs, retreating glaciers, shrinking sea ice, and melting permafrost (IPCC, 2007). We propose to examine the role of changing snow, ice, and permafrost on ecosystem structure and function and on ecosystem services (e.g. water quality, quantity, recreation) across diverse cryospheric habitats found in the LTER Network. Specifically, we will summarize the observed changes in cryospheric conditions and address the ecosystem response, either observed or predicted. We will also consider future ecosystem changes based on predicted changes in the cryosphere. Our effort will synthesize existing knowledge and mine available data through a workshop and follow up working groups. The conceptual framework is drawn from the strategic research initiative "Integrative Science for Society and the Environment" (ISSE) (Collins et al. 2007) whereby the long term press, climate warming and changing cryospheric conditions, will change community structure and function, and, in turn, alter ecosystem services and potentially invokes social responses. The proposed working groups will address all three thematic portfolios of the ISSE plan, including land/water use change; climate change; and nutrient mobilization. Our efforts will involve at least 14 LTER sites, ten of which have already agreed to participate. The product will be a journal article intended for BioScience or Frontiers in Ecology and the Environment and we will consider the potential for future proposals.

Snow, ice, and permafrost play an important role in ecosystem structure and function at high elevations and latitudes, and in the northern tier of temperate latitudes. Snow, the most ubiquitous cryospheric feature, insulates the soil from cold temperature extremes, provides runoff including a spring flush of nutrients, and may be an important contributor to groundwater recharge. Snow exerts strong controls on soil microbial activity, fish and wildlife habitats, and vegetation (Jones and Pomeroy, 2001). Glaciers are frozen reservoirs of water supplying much needed meltwater during the hottest and driest parts of the summer (Fountain and Tangborn, 1985), and alters water quality for significant distances downstream (Dougall and Fountain, submitted). Sea ice hosts its own microbial ecosystem and the ice itself plays a critical role in the life histories of species such as penguins, polar bears, seals and other marine mammals and seabirds (Horner, et al., 1992). Permafrost provides a structural foundation for Arctic forests, lakes, fens, and bogs.

In recent decades, snow, ice, and permafrost conditions have been changing across the globe (IPCC, 2007). In the western US, the April 1 snow pack, a key benchmark for predicting summer water supply, has been shrinking since 1950 (Mote, 2005). In response, peak spring flows have been shifting towards earlier dates. Earlier disappearance of snow may shift spring initiation of photosynthesis and plant transpiration, which decreases soil moisture and compounds the loss of late season snow melt, thus further increasing regional susceptibility to drought (Marshall et al., 2008). In the east, ski centers in New Hampshire have been migrating northward since the 1930s due to the loss of snow (Hamilton, et al., 2003), and we may witness a similar trend in the Cascades of Oregon and Washington (Nolin and Daly, 2006). The duration of lake and river ice has decreased as lakes freeze up later and melt out earlier (Magnuson et al.,

2000). For lakes, the change in duration of ice cover can change the timing of stratification of the waters with consequent effects on lake ecology. Analog processes with similar ecological effects have also been observed in polar oceans (Moline et al., 2008). Glaciers have shrunk and retreated since 1900 and their rate of retreat appears to be accelerating over the past decade (Jackson and Fountain, 2007; Basagic 2007), resulting in a release of water that is raising sea levels worldwide. Smaller glaciers also have a reduced capacity to buffer alpine stream flow against the effects of droughts, and the weathering of newly exposed landscapes changes stream water quality through increased heavy metals and nitrogen deposition (e.g. Baron et al., submitted; Williams, et al., 2007). Reduced sea ice along the western Antarctic Peninsula has dramatically reduced Adélie penguin foraging habitat (Ducklow et al., 2007), and in the Arctic the threat posed to polar bear populations by a similar reduction in sea ice forging platforms has made news worldwide. Thawing of permafrost can convert a terrestrial landscape and its associated ecosystem to an aquatic or wetland environment with an entirely new ecosystem (Jorgenson et al., 2001). Stream and lake chemistries change due to the release of solutes stored within the permafrost. In spite of these local and regional observations, we know of no study that synthesizes the overall impact of changing snow, ice, and permafrost on ecosystem structure and function and on ecosystem services.

The goal of the proposed working group is to write a journal article synthesizing published work and unpublished data on the effects of changing cryospheric conditions on ecosystems, including structure, function, and services, and to define how anticipated future changes in snow and ice may effect ecosystems and social response to those changes. We hope this work will be particularly useful to land management agencies as a component of their adaptive strategy in coping with climate change. During our investigations and deliberations we will also consider the potential of future proposals to investigate the details of ecosystem response to changing cryospheric conditions.

A 3-day workshop will be held to summarize current knowledge about the issues and their consequences. The workshop will break up into subgroups to tackle specific topics (e.g. snow, lake ice, permafrost). A preliminary synthesis report will be written at the end of the meeting with tasks assigned to the subgroups to further develop specific issues. A draft of the journal article will be written by a core group of authors and distributed to the entire working group for comment.

Invited Sites (14), all that have responded so far (bold) have agreed to participate (13)
Andrews, Arctic, Bonanza Creek, Cedar Creek, **Harvard Forest, Hubbard Brook**, **Kellogg, Konza Prairie, McMurdo Dry Valleys, Niwot Ridge, North Temperate Lakes, Palmer Station, Plum Island, Shortgrass Steppe.**

Budget:

Travel:	$16,000	(airfare/lodging $1,000/participant; food $45/day/person)
Hosting Institution:	$1,000	food/rooms
Publication cost:	$1,000	

	$18,000	

References

Baron, J.S., T.W. Schmidt, M.D. Hartman. Climate-Induced Changes in Nitrogen Dynamics in Loch Vale Watershed, Rocky Mountain National Park. In review for submission to Global Change Biology.

Basagic, H., 2007. Glacier change in the Sierra Nevada, California. M.S. Thesis, Department of Geography, Portland State University, 114pp.

Collins, S., Swinton, S., Anderson, C., Gragson, T., Grimm, N., Grove, M., Knapp, A., Kofinas, G., Magnuson, J., McDowell, B., Melack, J., Moore, J., Ogden, L., Reichman, O., Robertson, G., Smith, M., and Whitmer, A., 2007. The Decadal Plan for LTER: Integrative Science for Society and Environment: A Plan for Science, Education, and Cyberinfrastructure in the U.S. Long-Term Ecological Research Network. U.S. Long-Term Ecological Research Network. http://intranet.lternet.edu/documents/LTER_History/Planning_Documents/Integrative_Science_for_Society_and_Environment.pdf.

Dougall, J. and Fountain, A.G., submitted. The downstream extent of glacial water quality characteristics. Arctic, Antarctic, and Alpine Research.

Ducklow, H.W., Baker, K., Martinson, D.G., Quetin, L.B., Ross, R.M., Smith, R.C., Stammerjohn, S.E., Vernet, M. & Fraser, W.R. 2007. Marine pelagic ecosystems: the West Antarctic Peninsula. Philosophical Transactions of the Royal Society of London 362: 67-94 (special theme issue, Antarctic Ecology: From Genes to Ecosystems, A. Rogers, E. Murphy and A. C. Clarke, Eds.).

Fountain, A.G., and Tangborn, W.V., 1985. Effects of glaciers on stream flow variation: Water Resources Research, 21 (4), 579-586.

Hamilton, L., Rohall, D., Brown, B., Hayward, G., Keim, B. 2003. Warming winters and New Hampshire's lost ski areas. International Journal of Sociology and Social Policy. 23, 52-73.

Horner, R., Ackley, S., Dieckmann, G., Gulliksen, B., Hoshiai, T., Legendre, L., Melnikov, I., Reeburgh, W., Spindler, .M., and Sullivan, C. 1992. Ecology of sea ice biota. Polar Biology, 12, 417-427.

IPCC, 2007. Climate Change 2007: The physical science basis: Contribution of Working Group I to the Fouth Assessment, Report of the Intergovernmental Panel on Climate Change. Solomon,S., Quin, D., Manning, M. Chaen, Z. Marquis, M. Averyt, K., Tignor, M. and Miller, H. (eds). Cambridge University Press, New York, 966pp.

Jackson, K. and Fountain A., 2007. Spatial and morphological change on Eliot Glacier, Mount Hood, Oregon, USA. Annals of Glaciology, 46, 222-226.

Jones, H.G., and Pomeroy, J.W., 2001 The ecology of snow and snow-covered systems: Summary and relevance to Wolf Creek, Yukon. In Snow Ecology: An Interdisciplinary

Examination of Snow-covered Ecosystems H. G. Jones (Editor), J. W. Pomeroy (Editor), D. A. Walker (Editor), R. W. Hoham (Editor) Cambridge University Press. 378 pp.

Jorgenson, M., Racine, C., Walters, J. and Osterkamp, T. 2001. Permafrost degradation and ecological changes associated with a warming climate in central Alaska. Climatic Change, 48, 551-579.

Marshall, J., Blair, J., Peters, D., Okin, G., Rango, A., and Williams, M. 2008. Predicting and understanding ecosystem responses to climate change at continental scales. Frontiers of Ecology, 6, 273-280.

Magnuson, J., Robertson, D., Benson, B., et al. 2000. Historical trends in lake and river ice cover in the northern hemisphere. Science, 289, 1743-1746.

Moline, M.A., N.J. Karnovsky, Z. Brown, G.J. Divoky, T.R. Frazer, C.A. Jacoby, J.J. Torres, and W.R. Fraser. 2008. High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. In: The Year in Ecology and Conservation Biology (R.S. Ostfeld and W.H. Schlesinger, eds.) Volume 1. New York Academy of Sciences. Wiley-Blackwell Publishing, Hoboken, New Jersey (in press).

Mote, P.W., Hamlet, A.F., Clark, M.P. and Lettenmaier, D.P. 2005. Declining mountain snowpack in western North America. Bulletin American Meteorological Society, DOI 10.1175/BAMS-86-1-39.

Nolin, A., and Daly, C., 2006. Mapping “at risk” snow in the Pacific Northwest. Journal of Hydrometeorology, 7, 1164-1171.

Williams, M.W., M. Knauf, R. Cory, N. Caine, and F. Liu. 2007. Nitrate content and potential microbial signature of rock glacier outflow, Colorado Front Range. Earth Surf. Process. Landforms. DOI: 10.1002/esp.1455.