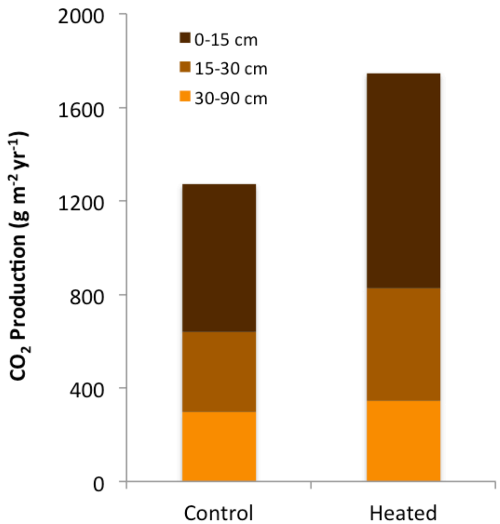
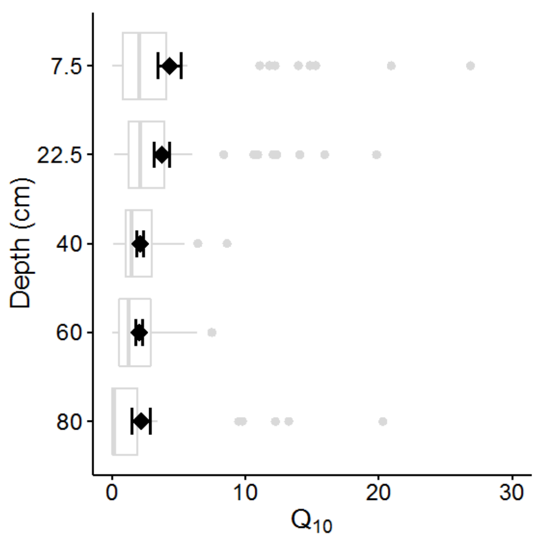
Whole-Soil Carbon Flux in Response to Warming

(A) Soil CO_2 production increased by about 35% in the heated plots with 40% of the response coming from >15 cm and 10% from >30 cm.



(B) Mean apparent Q_{10} over 20 months is similar at all depths (±SE, black diamonds).



- Berkeley Lab scientists created the first replicated field experiment to warm the whole profile of a mineral soil, in a conifer forest in California. Warming the whole profile by 4ºC increased annual soil respiration by 34-37%. More than 40% of this increase in respiration came from below 15 cm depth, which is below the depth considered by most studies.

- The impact of warming on soil CO_2 flux is a major uncertainty in climate feedbacks. This whole-soil warming experiment found a larger respiration response than (1) many other controlled experiments, which may have missed the response of deeper soils, and (2) most models. Thus, currently the strength of the soil carbon-climate feedback may be underestimated.

In this year-round experiment, plots were warmed by a ring of 22 vertical heating cables installed to 2.4m depth. Three plots (3 m diameter each) were warmed by 4°C and three served as controls. Soil respiration was measured three ways: continuous autochamber (1 per plot), monthly survey chambers (7 locations per plot), and gas tubes at 5 depths (1 set per plot). Radiocarbon content of CO_2 and soil fractions suggests that respiration—and its warming response—was dominated by decadal cycling carbon.

U.S. DEPARTMENT OF ENERGY | Office of Science

Hicks Pries, C.E., C. Castanha, R.C. Porras, and M. S. Torn. The whole-soil carbon flux in response to warming. Science. Science 2017; eaal1319 DOI: 10.1126/science.aal1319

EARTH & ENVIRONMENTAL SCIENCES | BERKELEY LAB

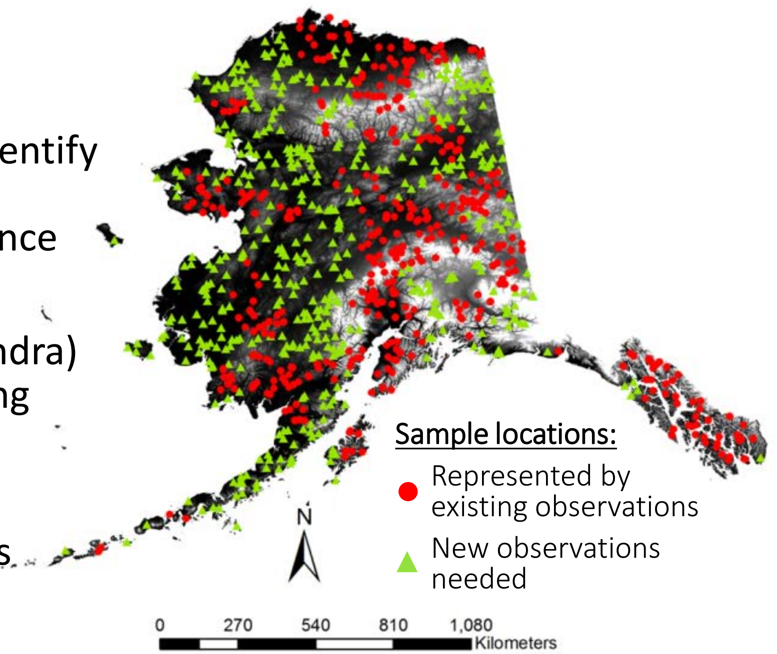
Observational Needs For Estimating Alaskan Soil Carbon Stocks Under Current and Future Climate

Challenge

- Existing estimates of Alaskan soil C stocks are based on an unbalanced spatial distribution of observations with vast areas of the region completely unrepresented

Approach and Results

- Geospatial relationships among climate data, land surface properties, and existing soil C observations were used to identify where new observations (green triangles) are needed to characterize soil C stocks across all of Alaska with a confidence interval of 5 kg m^{-2}
- Greatest needs for new samples are from scrub (mostly tundra) land cover types and from the Aleutian Meadows and Bering Taiga ecoregions (in southwestern Alaska)
- Future climate projections (to 2100) will not greatly alter number and locations of required observations



Significance and Impact

- Identified observation sites can inform studies seeking to reduce uncertainties in soil C estimates and create robust spatial benchmarks for Earth system model results

Reference: Vitharana U.W.A., U. Mishra, J.D. Jastrow, R. Matamala, and Z. Fan. 2017. “Observational needs for estimating Alaskan soil carbon stocks under current and future climate”. *Journal of Geophysical Research-Biogeosciences,* doi:10.1002/2016JG003421.

In Deep Active-Layer Boreal Soils, How Temperature and Moisture Affect Greenhouse Gas Emissions

Objective

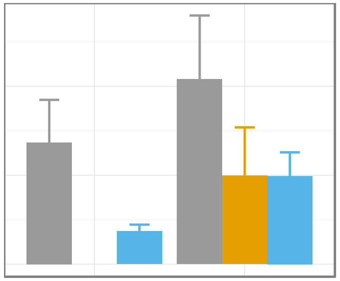
- Study deep active-layer soils to better understand how soils in high-latitude ecosystems—regions that hold large stocks of soil carbon—respond to changes in temperature and moisture and to changes in their overlying vegetation.

New Science

- Examined how temperature and moisture control CO_2 and CH_4 emissions in soils sampled from directly above permafrost in an Alaskan boreal region.
- After subjecting six groups of six samples each to a 100-day incubation at different temperatures (with some samples subjected to drying treatments to simulate drought), the researchers also characterized the soils according to chemical and structural properties.
- Three hypotheses were true: CO_2 would be the dominant pathway for carbon loss; soils kept moist and warm would lose more CO_2 than cold soils; and CH_4 fluxes would be small and sensitive to only temperature.

Significance

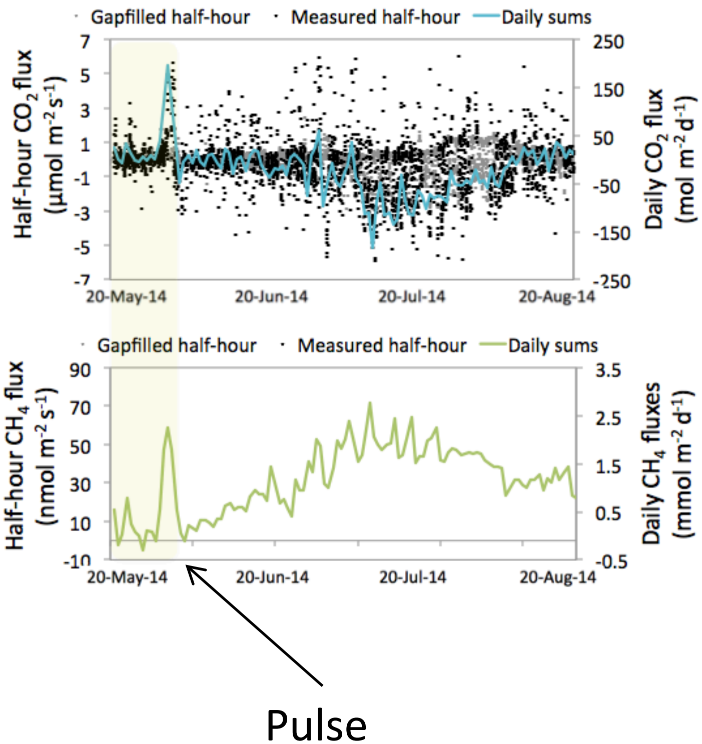
- The results underscore the particular importance of understanding the effects of moisture (more than temperature) on fluxes of carbon dioxide. It also identifies important areas for future research on northern soils, which sequester enormous and climate-critical quantities of soil organic carbon.



Cumulative carbon emissions from experimental soil cores, by gas: carbon dioxide (CO2) top, methane (CH4) bottom. Bars are colored by experimental treatment. Note difference in y-axis scale between panels

B. Bond-Lamberty, et al., "[Temperature and moisture effects on greenhouse gas emissions from deep active-layer boreal soils](http://www.biogeosciences.net/13/6669/2016/)." Biogeosciences, 13, 6669-6681, 2016. http://www.biogeosciences.net/13/6669/2016/. DOI: 10.5191/bg-13-6669-2016.

Large CO_2 and CH_4 Emissions from Polygonal Tundra During Spring Thaw in Northern Alaska



- Raz Yaseef, N., M. Torn, Y. Wu, D. Billesbach, A. Liljedahl, T. Kneafsey, V. Romanovsky, D. Cook, and S. Wullschleger (2016), Large CO_2 and CH_4 emissions from polygonal tundra during spring thaw in northern Alaska, Geophys. Res. Lett. , 43, doi:10.1002/2016GL071220.

- Berkeley Lab scientists measured a large pulse of carbon greenhouse gases released from the frozen Arctic tundra when soils started to thaw in early June 2014. Little has been known about such releases; the researchers show that the pulse was the result of a delayed mechanism, in which gases produced in fall were trapped in the frozen soils and released in spring.
-
- The research identified a large, underrepresented source of carbon emissions in the Arctic. The findings suggest that the Arctic may be even less of a carbon sink than previously thought. A multi-institution team linked hydrology, biogeochemistry, and geophysics to uncover the pivotal roles of warmer fall weather and of spring rain-on-snow events, implying these pulses may be more frequent in the future.

– Pre-thaw carbon flux pulse, measured by eddy covariance, offset 46% of CO_2 summer uptake and added 6% to CH_4 summer fluxes

– A similar pulse was measured 5 km away, indicating that this was a widespread phenomenon in 2014.

– Laboratory experiment linked pulse emissions to a delayed microbial production mechanism

– The type of rain-on-snow event that triggered the pulse is gradually becoming more frequent over the past 30 years

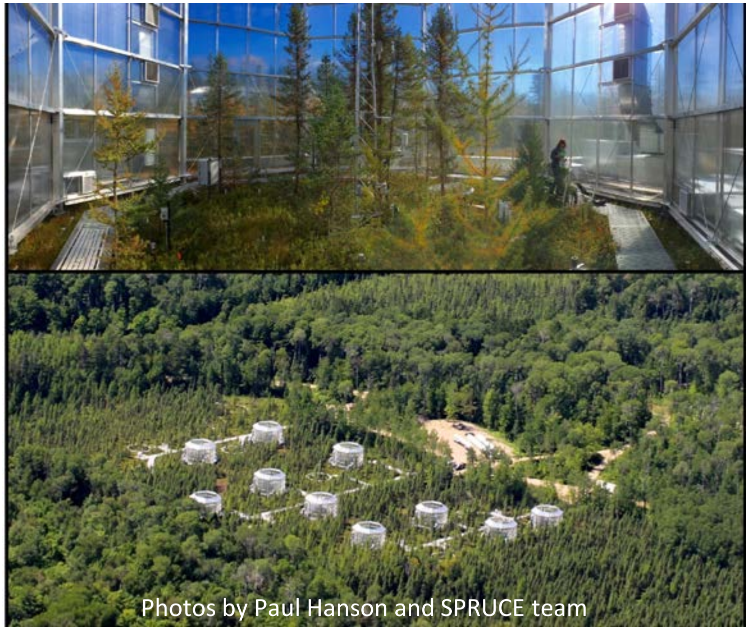
Stability of the Temperate Peatland Carbon Bank to Rising Temperatures

Objective

- Peatlands contain ~1/3 of Earth's soil carbon and are climatically sensitive. Our objective was to quantify the response of large belowground carbon stores, greenhouse gas emissions, and heterotrophic microbial communities in peatlands to warming.

New Science

- As part of the SPRUCE (http://mnspruce.ornl.gov) experiment led by ORNL, peat up to 2 m deep was experimentally warmed over 13 months in an ecosystem-scale climate manipulation that incorporates deep peat heating (DPH) up to 9°C above ambient. Although CH_4 emissions were found to increase exponentially with deep heating, the response was due solely to the warming effect on surface peat. No changes with warming were seen in microbial communities nor did geochemical analyses provide evidence of enhanced peat carbon degradation suggesting that deep peat is stable under increasing temperatures.



Photos by Paul Hanson and SPRUCE team

Significance

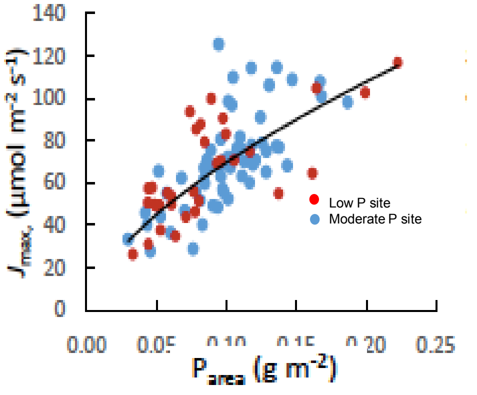
- This study demonstrates that most of the carbon residing under water-saturated anoxic conditions in the deep peat reservoir (catotelm) is stable under warmer temperatures providing important insights into the potential response of peatlands under future climate warming.

Citation - Wilson, R.M. and A.M. Hopple, M.M. Tfaily, S.D. Sebestyen, C.W. Schadt, L. Pfeifer-Meister, C. Medvedeff, K.J. McFarlane, J.E. Kostka, M. Kolton, R. Kolka, L.A. Kluber, J.K. Keller, T.P. Guilderson, N.A. Griffiths, J.P. Chanton, S.D. Bridgham, and P.J. Hanson. 2016. Stability of peatland carbon to rising temperatures. Nature Communications 7: 13723. http://doi.org/10.1038/ncomms13723 (Impact factor = 11.329).

Informing Models Through Empirical Relationships Between Foliar Phosphorus, Nitrogen and Photosynthesis Across Diverse Woody Species in Panama

Scientific Achievement

- Relationships between photosynthetic parameters of tropical trees and foliar nitrogen and phosphorus content were studied. These relationships important to predictive modeling were improved by including wood density, suggesting that a mechanistic approach incorporating trait covariation could be useful.



Research

- **Objective: assess relationships between photosynthetic parameters and foliar nutrient concentrations from tropical forests to inform model improvements.**
- **Gas exchange and nutrient content data were collected from upper canopy leaves of 144 trees at two forest sites in Panama, differing in species composition, rainfall, and soil fertility.**
- **Relationships between photosynthesis, foliar N and P, and wood density were evaluated against mechanistic and empirical models.**

Impact

Our study provides a basis for improving models of photosynthesis based on phosphorus nutrition and increases the capability of models to predict the future C uptake capacity of P-limited tropical forests.

Research support by ORNL Laboratory Directed Research and Development Program and Next Generation Ecosystem Experiments-Tropics (NGEE-Tropics), funded by U. S. Department of Energy, Office of Science.

Richard J. Norby, Lianhong Gu, Ivan C. Haworth, Anna M. Jensen, Benjamin L. Turner, **Anthony P. Walker, Jeffrey M. Warren, David J. Weston, Chonggang Xu,** and Klaus Winter. (2016), Informing models through empirical relationships between foliar phosphorus, nitrogen and photosynthesis across diverse woody species in Panama. *New Phytologist* doi: 10.1111/nph.14319

Global Analysis Reveals Accelerating Plant Growth

Objective

- Terrestrial photosynthesis is the fundamental coupling between global cycles of energy, carbon, and water. Yet, we lack a clear picture of global trends in photosynthesis over the last few centuries. Our objective was to infer a global history of photosynthesis from records.

New Science

- Gases trapped in different layers of Antarctic snow allow scientists to study global atmospheres of the past. The key to this study was finding a gas stored in the ice that provides a record of the Earth's plant growth. Previous studies have found that carbonyl sulfide (COS) has this property. It's a cousin of CO_2. Plants remove COS from the air through a process that is related to the plant uptake of CO_2. The researchers analyzed the Antarctic COS record and estimated that the sum of all plant photosynthesis on Earth grew by 30 percent during the industrial era.

Significance

- The rise in global photosynthesis has far reaching effects as virtually all life on our planet depends on photosynthesis. This important process creates food, shapes the water cycle, and influences climate.

nature

Citation - Campbell, J. E., Berry, J. A., Seibt, U., Smith, S. J., Montzka, S. A., Launois, T., Belviso, S., Bopp, L., and Laine, M. (2017). "Large historical growth in global terrestrial gross primary production." **Nature**, 544(7648), 84-87.

The New York Times

Outreach – New York Times, April 5, 2017, "Antarctic Ice Reveals Earth's Accelerating Plant Growth"