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Use of a New Low-Power Laser-Based Instrumentation to Measure Methane Emissions from Remote Permafrost Regions

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The permafrost regions store significant amount of organic materials under anaerobic conditions, leading to large methane production and accumulation in the upper layers of bedrock, soil and ice. These regions are currently undergoing dramatic change in response to warming trends, and may become a significant potential source of global methane release under a warming climate over following decades and centuries.

Present measurements of methane fluxes in permafrost regions have mostly been made with static chamber techniques, and very few were done with the eddy covariance approach using closed-path analyzers. Although chambers and closed-path analyzers have advantages, both techniques have significant limitations, especially for remote or portable research in cold regions. Static chamber measurements are discrete in time and space, and particularly difficult to use over polygonal tundra with highly non-uniform micro-topography and active water layer. They also may not capture the dynamics of methane fluxes on varying time scales (hourly to annual). In addition, placement of the chamber may disturb the surface integrity causing a significant over-estimation of the measured flux.

Closed-path gas analyzers for measuring methane eddy fluxes employ advanced technologies such as TDLS (Tunable Diode Laser Spectroscopy), ICOS (Integrated Cavity Output Spectroscopy), WS-CRDS (wavelength scanned cavity ring-down spectroscopy), but require high flow rates at significantly reduced optical cell pressures to provide adequate response time and sharpen absorption features. Such methods, when used with the eddy covariance technique, require a vacuum pump and a total of 400-1500 Watts of grid power for the pump, climate control, and analyzer systems. The weight of such systems often exceeds 100-200 lbs, restricting practical applicability for remote or portable field studies.

As a result, spatial coverage of eddy covariance methane flux measurements in cold regions remains limited. Remote permafrost wetlands of Arctic tundra, northern boreal peatlands of Canada and Siberia, and other highly methanogenic ecosystems have few eddy covariance methane measurement stations. Those existing are often located near grid power sources and roads rather than in the middle of the methane-producing ecosystem, while those that are placed appropriately may require extraordinary efforts to build and maintain them, with large investments into man-power and infrastructure.

Alternatively, open-path instrumentation allows methane flux measurements at normal pressure without a need for a pump. As a result, the measurements can be done with very low-power (e.g., 7-10 Watts) light (5 .2 kg) instruments permitting solar- and wind- powered remote deployments in hard-to-reach sites from permanent, portable or mobile stations, and cost-effective additions of a methane measurement to the present array of CO_2 and H_2O measurements. The low-power operation and light weight of open-path eddy covariance station is important for number of ecosystems (rice fields, landfills, wetlands, cattle yards, etc.), but it is especially important for permafrost and other cold regions where grid power and access roads are generally not available, and logistics of running the experiment is particularly expensive.

Emerging research using low-power laser-based instrumentation to measure CH_4 emissions are presented from several permafrost ecosystems with contrasting setups, weather, and moisture conditions. Principles of open-path instrument operation, station characteristics and requirements are also discussed, as well as concurrent measurements of CO_2 and H_2O emissions using open-path and enclosed instrumentation.