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Advancements in Micrometeorological Technique for Monitoring CH_4 Release from Remote Permafrost Regions: Principles, Emerging Research, and Latest Updates

George Burba (1), Artem Budishchev (2), Beniamino Gioli (3), Sami Haapanala (4), Manuel Helbig (5), Salvatore Losacco (6), Ivan Mammarella (4), Virginie Moreaux (6), Patrick Murphy (6), Walter Oechel (6), Olli Peltola (4), Janne Rinne (4), Oliver Sonnentag (5), Cove Sturtevant (7), Timo Vesala (4), Donatella Zona (6,8), and Rommel Zulueta (9)

(1) LI-COR Biosciences, Lincoln, United States, (2) VU University Amsterdam, The Netherlands, (3) CNR-Institute of Biometeorology, Florence, Italy, (4) University of Helsinki, Finland, (5) University of Montreal, Canada, (6) San Diego State University, USA, (7) University of California-Berkeley, USA, (8) University of Sheffield, UK, (9) NEON Inc., Boulder, USA

Flux stations have been widely used to monitor release and uptake rates of CO_2, CH_4, H_2O and other gases from various ecosystems for climate research for over 30 years. The stations provide accurate and continuous measurements of gas exchange at time scales ranging from 15 or 30 minutes to multiple years, and at spatial scales ranging from thousands m^2 to multiple km^2, depending on the measurement height.

The stations can nearly instantaneously detect rapid changes in gas release due to weather or man-triggered events (pressure changes, ice breakage and melts, ebullition events, etc.). They can also detect slow changes related to seasonal dynamics and man-triggered processes (seasonal freeze and thaw, long-term permafrost degradation, etc.).

From 1980s to mid-2000s, station configuration, data collection and processing were highly-customized, site-specific and greatly dependent on "school-of-thought" practiced by a particular researcher. In the past 3-5 years, due to significant efforts of global and regional flux networks and technological developments, the methodology became fairly standardized.

Majority of current stations compute gas emission and uptake rates using eddy covariance method, as one of the most direct micrometeorological techniques. Over 600 such flux stations operate in over 120 countries, using permanent and mobile towers or moving platforms (e.g., automobiles, helicopters, airplanes, ships, etc.).

With increasing atmospheric temperatures in the Arctic likely resulting in a higher rate of permafrost degradation, measurements of gas exchange dynamics become particularly important. The permafrost regions store a significant amount of organic materials under anaerobic conditions, leading to large CH_4 production and accumulation in the upper layers of bedrock, soil and ice. These regions may become a significant potential source of global CH_4 release under a warming climate over the following decades and centuries.

Present measurements of CH_4 release in permafrost regions have mostly been made with static chamber techniques, and 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 soil layer. Closed-path gas analyzers for measuring CH_4 eddy fluxes require climate control, employ high-power pumps, and generally require grid power and infrastructure.

As a result, spatial coverage of eddy covariance CH_4 flux measurements in cold regions remains limited. Existing stations 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 manpower and infrastructure.

In this presentation, basic principles of eddy covariance flux measurements are explained, along with details on the CH_4, CO_2 and H_2O exchange measurements using low-power flux stations.

Also included are latest updates on the emerging research utilizing such stations in remote permafrost regions, and on the 2013-2014 development of fully automated remote unattended flux station capable of processing data on-the-go to continuously output final CH_4 release rates.