Protocols for GHG Measurements from Tall Towers as Part of the GHG Quantification Project

25 November 2024

Overview

The Greenhouse Gas (GHG) Research Network is measuring the impact of management practices on nitrous oxide and methane emissions, and soil carbon sequestration. Data will be used by researchers to improve outcome estimates, including through the advancement of models and tools. The GHG Research Network is organized into four sub-teams that target GHG measurements in different agricultural sectors, including Land Emissions, Enteric Methane, Animal Housing and Manure Storage, and Tall Towers.

Each of these four sub-teams has developed GHG measurement protocols to provide technical information on the methods used to measure GHGs and applicable data processing procedures. Protocols outline the method used by the Agricultural Research Service (ARS) for this specific project. Other efforts may use different protocols. The protocols are published to promote dialogue and feedback, and to serve as a reference for other research, when applicable. Protocols will be updated as needed. This document is the protocol for the Tall Tower subteam.

The objectives of the Tall Tower subteam are to:

1. With the highest possible accuracy, collect continuous regional boundary layer concentration measurements of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2)at six broadcast towers across the central US,
2. Use those data in conjunction with meteorological data and atmospheric transport models to test and improve ground-based models of greenhouse gas emissions from agricultural landscapes.
3. Provide the data to the National Greenhouse Gas Inventory to track progress in reducing agricultural GHG contributions.

GHG measurement and data processing protocol for Tall Towers

***Sites*:** All sites will have radio or TV towers of at least 100 m height above the local terrain, with a climate-controlled structure at the base that can house gas analyzers and will have upwind fetch that is primarily in agricultural land use.

Equipment - (analyzers, sampling systems) - All sites will be identically instrumented, with state-of-the-art cavity ringdown spectrometer (CRDS) analyzers, using identical systems. The sampling manifold systems (sample lines, filters, pumps, valves) will also be identical across all sites, following a design developed by engineers at the NOAA Global Monitoring Laboratory. All sites will also have ceilometers (lidar systems) for continuous estimation of boundary layer height, a key parameter in transport modeling.

***Standard Gases*:** Continuous, highest-accuracy concentration measurements require routine, frequent switching of standard gases of known concentration through the analyzers. These must be directly traceable to standards prepared by the NOAA Global Monitoring Laboratory- Earth System Research Laboratories (ESRL). The network will purchase four ESRL standards for each gas (CH_4, N_2O, and CO_2) with concentrations ranging from 0 to twice the global mean average. These will be maintained in the laboratory in St. Paul, Minnesota and will be used to propagate secondary standard gases for all locations in the network.

***Target ambient air standard*:** A standard cylinder representing ambient air will be used to check the air handling and calibration routine that is employed at each site. These target standards will be calibrated in St. Paul, Minnesota against the ESRL standards. The target tank will be sampled once per day at each site.

***Plumbing*:** Two sample inlets (1 Teflon and 1 Synflex) will be installed on each tower at a height of 100 m above the surrounding terrain. Each line will have a Whatman 2700T PTFE Pore size 0.1-micron Inlet filter 3/8-inch Outlet. One inlet will be connected *via* Teflon sample lines (TPH0308-063 PFA 3/8 “ID × 1/2” OD, Jensen Inert Products, Coral Springs, FL, USA) to a manifold system in the building at the tower base. A second line (Synflex, Type 1300, Aurora, OH, USA using same ID/OD) will also be used for sampling at the same level. All sites will have identical manifold systems, built to design specifications provided by the NOAA Global Monitoring Laboratory for use in their Trace Gas Observing program. Base sample flow rates will be maintained between 10 and 20 L/min. The base flow rate will be subsampled for trace gas analysis.

***Switching Strategy and Signal Sampling Frequency*:** All analyzers will be calibrated at least once per day using secondary standards. The duration and frequency of calibration will be optimized according to onsite testing of new analyzers in relation to the air handling manifold system. The same strategy will be applied across all sites. Routine air sampling will include equal amounts of sample time per 100 m inlet. The calibrated concentration measurements will be estimated *via* post processing by applying drift, gain, and offset

corrections. The calibrations will also be applied to the target tank for detecting long-term drift and consistency among network sites.

***Data Acquisition*:** All raw data will be acquired at 1 Hz. This will allow analysis of equilibration times following valve switching. Hourly values of raw and calibrated data will be archived, with the intent to make publicly available according to USDA procedures. All raw 1 Hz data will be archived in case there is a need for reprocessing of data following updates to calibration tank values or in case of long-term drift in primary standards.

***Initial Data QA/QC*:** The hourly gas measurement values will be filtered using a basic low pass/high pass filter. Extreme outliers will be identified using moving window and appropriate probability density functions to determine mean and standard deviations. Further, data from any hourly periods with known analyzer or sampling problems (i.e. analyzer offline, low flow, poor pressure control) will be flagged and removed.

***Troubleshooting*:** A lead research technician at St. Paul, Minnesota will generate a daily check report for each tower site. Any problems identified will be flagged and sent to the that location's technician for attention.