Technical Aspects of Greenhouse Gas Sampling and Analysis: Static and Automated Chamber Considerations

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OVERVIEW: The Kellogg Biological Station (KBS) Long-term Ecological Research (LTER) Program in SW Michigan studies the ecology of intensive field crop ecosystems as part of a national network of long-term ecological research sites. The Department of Energy (DOE) Great Lakes Bioenergy Research Center (GLBRC) has also established a number of field–scale research sites at KBS to investigate the environmental sustainability of potential bioenergy cropping systems.

KBS Static Chamber Types

Figure 1. The bucket type static chambers are often used by individual researchers. KBS studies show more flux variability as the number of users/technicians per bucket chamber rises. A proper soil seal is more difficult to maintain and soil compression around the chamber is more frequent because of the force needed for lid removal. These chambers are very inexpensive.

Figure 2. The square type chambers have a low vertical profile when installed with a base height of 5cms above the soil. These chambers are very expensive to produce and use a water trough around the base to create a seal. Technicians must use extra care to ensure that the water does not spill into the chamber prior to sampling. The square chamber has been seasonally deployed for over twenty years.

Figure 3. The cylindrical stainless steel chambers are designed for easy insertion, reflectivity, ease of sampling, and cost effectiveness. The vented chambers best resemble external environmental parameters and potential problems are minimized. The chambers are rugged and seal effectively.

RATIONALE: These research programs require intensive, year-round static and automated gas sampling to quantify the greenhouse gas (GHG) footprint of the numerous treatments and management practices under investigation. Here we present an overview of the different GHG chamber types and methodologies deployed at KBS. We highlight common concerns in relation to chamber methodology, and address the practical adaptations and testing carried out to ensure smooth day–to–day operations.

Figure 4 and 5. These images provide a side-by-side visual comparison of chambers during incubation (left) and open to the atmosphere (right). These chambers are similar in height, area/perimeter ratio, volume, and incubation duration. Technicians at KBS prefer the cylindrical stainless steel chambers because they are easy to deploy, the lid seal is more effective, and sampling is more efficient and practical. Currently, the LTER and GLBRC projects use hundreds of square and cylindrical stainless steel chambers.

Figure 6. A Gerstel Autosampler is fitted to an Agilent GC for the analysis of N_2O, CH_4 and CO_2 and is capable of sampling up to 440 vials per run. Currently, this system analyzes 40,000 samples annually. CV's for N_2O, CH_4 and CO_2 at ambient concentrations are typically 1.0%, 1.5%, and 4% respectively.

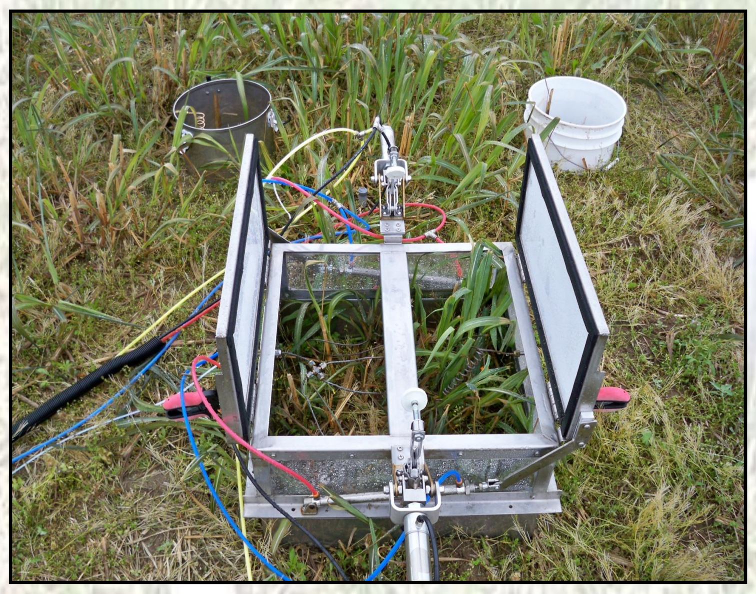


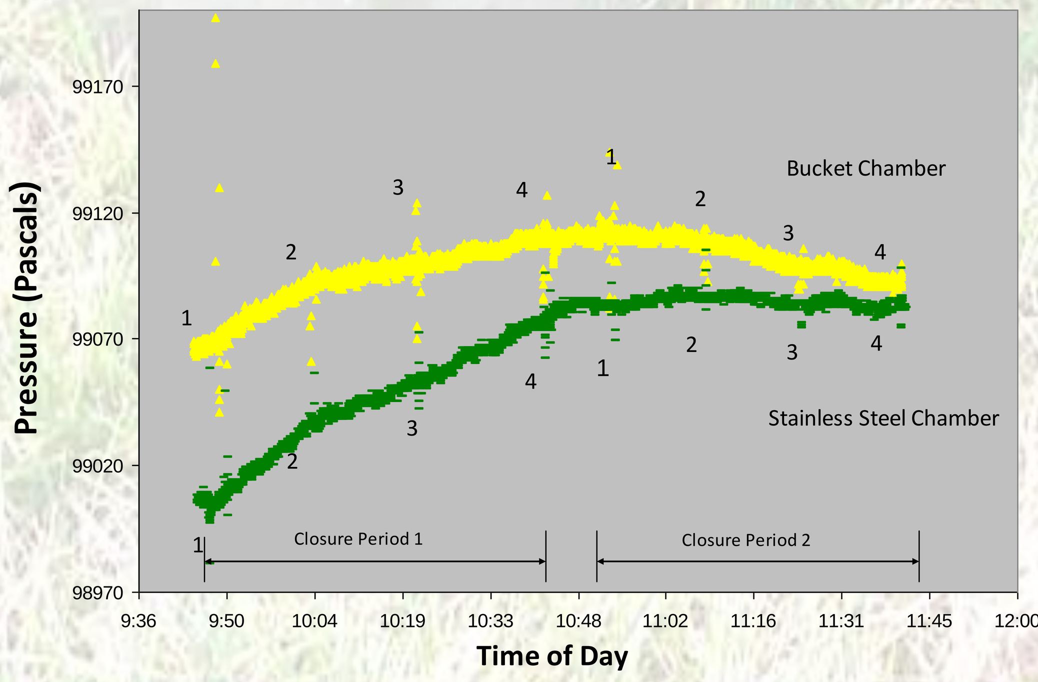
Figure 7 and 8. We also use automated chambers which provide a very good area/perimeter ratio. Coupled with an automated sampling system, these chambers provide the high flux resolution needed to capture short term events (rain, fertilization, tillage) that potentially drive GHG emissions in agricultural, grassland, and forest ecosystems. The automated chamber's expense and the technical expertise needed to operate limits its widespread deployment. Maximum temperature deviation from ambient during closure periods is 2C during warmer summer temperatures.

Important Chamber Design and Sampling Characteristics

Chamber Characteristics	Bucket Type	Square Chamber Type	Stainless Steel Chamber Type	Automated Chamber Type
Type of Chamber	Base/Lid	Base/Lid	Base/Lid	Base/Lid
Material/Cost	HDPE base/ lid Thin-wall ($10)	Aluminum base/Opaque Plastic lid ($200)	18 G Stainless Steel base w/ ½" HDPE lid ($70)	18G SS base w/ SS and acrylic panels white reflective tape ($400-500)
Insulation	No	Heavy gauge plastic lid	Metal	No – Lid w/ Reflective Tape
Vent	No	No	Yes	Yes
Chamber height	18 cm	20 cm	18 cm	Variable-Avg. 25cm
Base insertion depth	5-8 cm			5-8 cm
Area/perimeter ratio	6.44	6.75	7.06	12.5
Deployment duration	45-60 min			Variable – 40 min minutes avg.
Samples collected during incubation	4			4
Type of sampling vial	Glass Exetainer			Field Analysis Real Time
Time zero sample	Yes			Yes
Pressurized sample	Yes			No (field analysis real time)
Sample storage	< 15 days			Real Time
Quality control sampling	Yes (7 stds, air, duplicates)			Yes (air, std)
Nonlinear model considered	Yes	Yes	Yes	Yes
Chamber methodology	NFT-NSS	NFT-NSS	NFT-NSS	NFT-NSS or FT-NSS

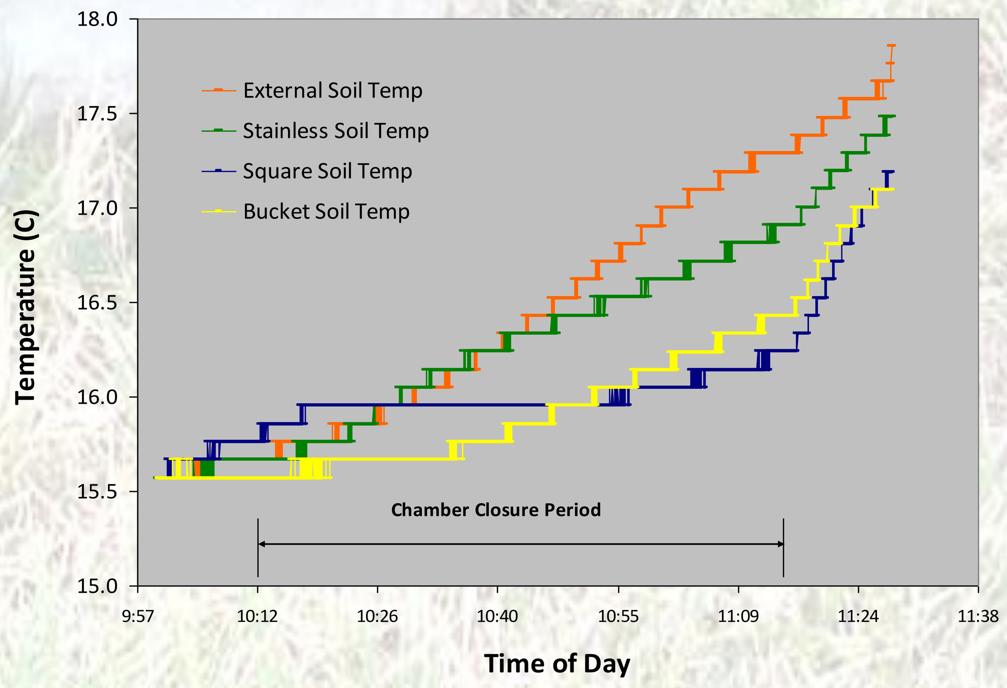
Table 1. Important design measurements and sampling parameters used to assess the quality of KBS greenhouse gas flux measurements using non-flow-through, non-steady-state (NFT-NSS) chambers. The table is constructed in sequence flowing from chamber construction to sampling parameters and finally to quantification parameters relating to fluxes.

Static Chamber Pressure



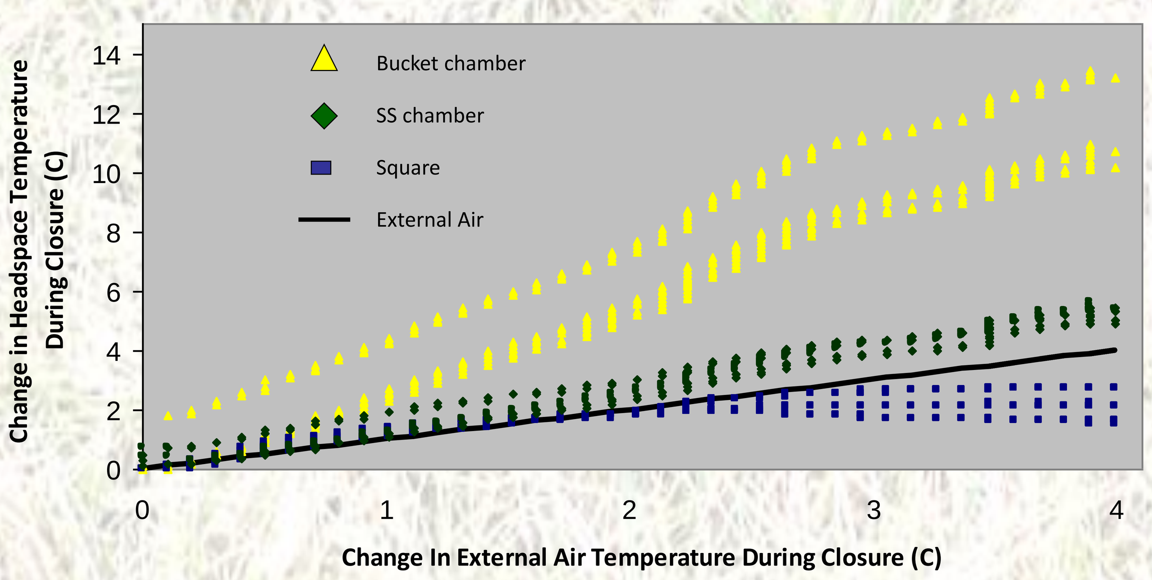
Graph 1. Barometric pressure altimetry cells were installed in the bucket and stainless steel static chambers to test for pressure anomalies during closure and syringe sampling. Closure pressure spikes are more prominent in the bucket type chambers. The pressure signature at each syringe sampling point (1-4) show more prominent pressure or vacuum spikes in the bucket chamber. Note that each pressure anomaly recovers quickly to baseline. Instrument design differences account for the pressure differences between each curve.

Static Chamber Soil Temperature



Graph 2. Static chamber soil temperatures were measured at 5cm depth. The stainless steel static chambers more closely mimic external soil temperature than either the bucket chamber or the lower base profiled square chambers in all weather conditions tested. Bucket chamber soil temperature deviate from ambient more commonly.

Air Temperature Differences - Chambers versus External Air



Graph 3. Static chamber headspace temperature was sampled at one second intervals during summer temperature maximums in a low growth/open field for a one hour incubation period. Data show that the white buckets chamber temperature increases most, the square chambers have a net cooling effect, while the stainless steel vented chambers closely mimic the external ambient temperature slope increase. These trends are consistent for most growing season temperatures.

Chamber System Advantages and Disadvantages

Characteristic	Bucket Chamber	Square Chamber	Cylindrical Stainless Steel Chamber	Automated Chamber
Cost	$	$$$	$$	$$$$$$$$
Ease of Construction	🔨	🔨🔨🔨	🔨🔨	🔨🔨🔨🔨🔨🔨🔨🔨
Ease of Deployment	★★★	★★★	★★	★★★★★★★★★
Headspace Temperature Effect	↑	↓	↔	↔
Soil Temperature Effect	↓	↓	↔	↓
Field Operations	☹	😐	☺	☺

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GREAT LAKES BIOENERGY RESEARCH CENTER

KBS LTER Kellogg Biological Station Long-term Ecological Research

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