GREENHOUSE GAS DYNAMICS IN STREAMS LOCATED WITHIN FORESTED LANDSCAPES OF THE US NORTHEAST

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McIntire-Stennis Formula Grant

Introduction

Research conducted in small streams draining agricultural and urban catchments shows that both the quantity and quality of terrestrially-derived solutes or nutrients in streams can influence production or consumption of greenhouse gases (GHG) during microbial metabolism. Relationships between site-specific attributes and GHG fluxes in streams can vary from season to season and year to year, and are influenced by hydrological events, antecedent moisture conditions, pH, sub-surface geomorphology, redox conditions, terrestrially-derived organic compounds, water table depth, etc. Heterogeneity in the distribution of controlling factors clearly presents a challenge to mapping and understanding biogeochemical hotspots that produce or consume GHG in streams. Challenges include: 1) the need to improve our understanding of how biogeochemical conditions vary in and around in-stream hydrogeomorphic (HGM) features; and 2) the need to better characterize flowpaths and water quality in and around in-stream HGM features.

Research Questions

- Where are the GHG hot spots? Looking at data within each reach, which hydrogeomorphic features (HGM) produce the most GHG?
- Does GHG production vary over time for different HGM features (e.g., pools, riffles, sediment bars, and natural impoundments)?
- How do GHG concentrations in each HGM feature relate to stream GHG concentrations? Do these relationships vary over time, over space? Do relationships between GHG concentration in the water column and stream water quality, air temperature, or antecedent moisture conditions exist? What is the nature of the relationships (linear or non-linear)?
- How confidently can we extrapolate and calculate whole stream GHG budget? How does it compare to the observed GHG fluxes in upland within a study site?

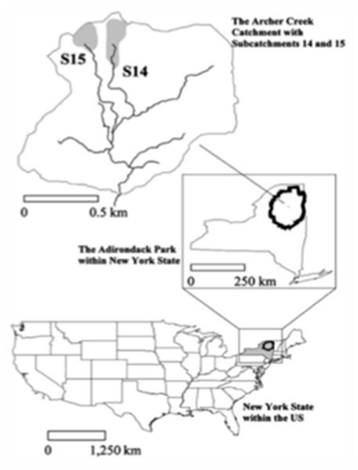
Research Approach

1. Quantify fluxes of naturally occurring GHG across distinct hydrogeomorphic (HGM) features within streams.
2. Examine the role of sediments in production of GHG.
3. Develop a GHG budget for streams that are found in a watershed typical of the US Northeastern Forest.

Corollary objectives include determining the role of streams and associated wetlands in regulating GHG emission 1) on a seasonal basis, 2) in relation to the surrounding landscape, and 3) as function of stream and groundwater quality and biogeochemistry

Site Description:

- This study site is located in the Adirondack Mountain Range in northern New York State within the Archer Creek watershed, a sub watershed of Arbutus Watershed.
- Archer Creek watershed is a long-term monitoring site managed by SUNY-ESF located in the Huntington Wilderness Forest in Newcomb, N.Y.
- S14 (3.5 ha) and S15 (2.5 ha) are two headwater catchment streams within the Archer Creek catchment (135 ha) that both begin as groundwater seeps.
- Typical northeastern forest with mix of hardwoods and conifers.



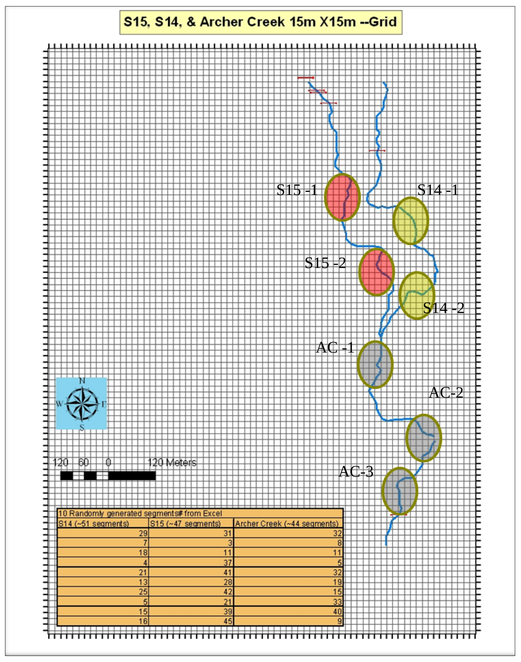
Site characteristics

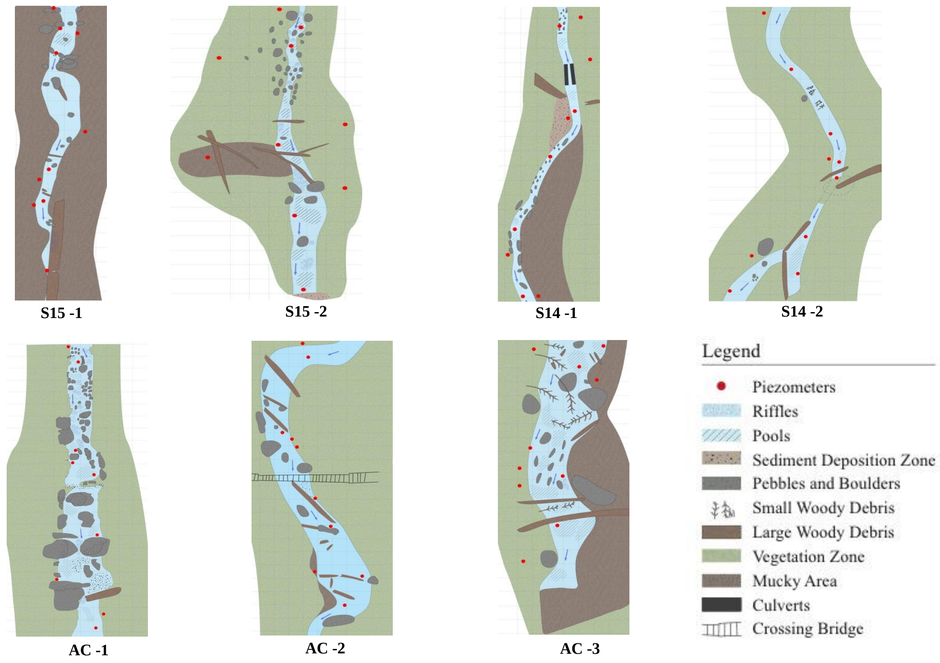
- **Area:** 135 ha
- **Average slope:** 11%
- **Total Relief:** 225 meters
- **Soil:** Glacial till and greenwood mucky peats
- **Climate:** cool, moist, & continental
- **Mean temperature:** 5ºC
- **Mean Annual Precipitation:** 1046 mm total; 303 cm snow.

Figure 1: Archer Creek Watershed encompassing catchment S14 and S15 (top) shown in context of New York State (middle) and the contiguous U.S. (bottom).

Methodology

Experimental Units: A total of **seven reaches**, each measuring 20 m in length, were selected in three streams. We selected two reaches in each headwater stream (**S14** and **S15)** and three reaches in a third-order stream (**Archer Creek).** A total of ten sampling points were established within a reach: five were within stream channel and five were in stream wetted perimeter.





GHG measurements:

- "Instrument Cluster" at each sampling location to capture GHG concentration. Upland vs Lowland, In-stream vs Wetted Perimeter.
- Use hypodermic needle to withdraw 15mL of head gas injected into an evacuated 10 mL glass vials also fitted with gray butyl rubber septa.
- All gas samples analyzed for CO_2, CH_4, and N_2O concentrations. Gas concentrations (i.e. CO_2, CH_4, and N_2O) analyzed utilizing a Shimadzu GC-2014 gas chromatograph.

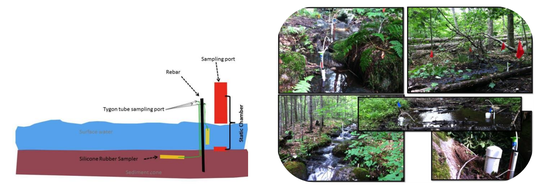
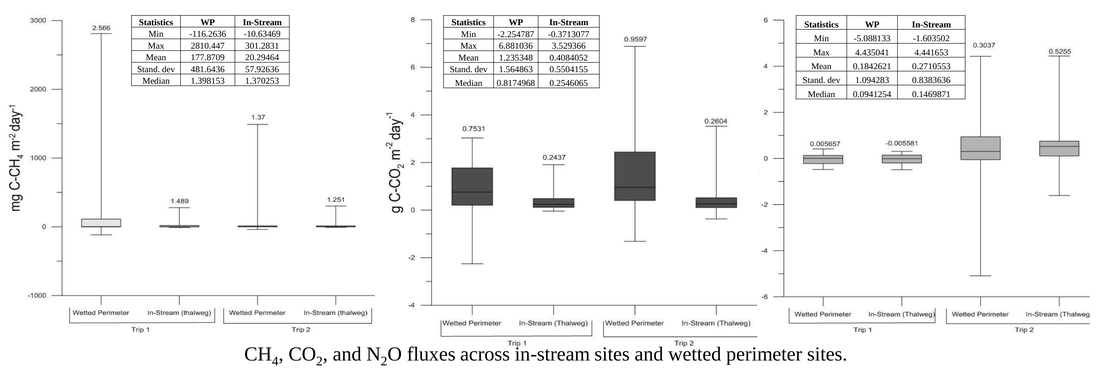


Figure 2: Schematic illustration of an instrument cluster. 1) A silicone-cell sampler in sediment profile; 2) A silicone-cell sampler suspended in water column; and 3) A static chamber to measure change in GHG concentrations over 30 minute period at 15-minute intervals during low/base stream flow conditions.

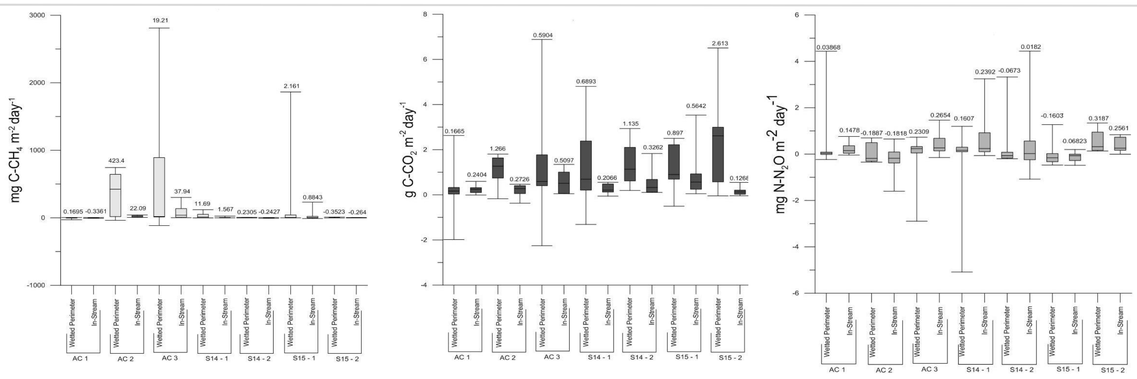
Preliminary Results

Box plots below depict descriptive statistics for the seven study sites across two sampling dates: Trip 1- July 14th-July 16th and Trip 2- July 22nd-July 24th for CH_4, CO_2, and N_2O fluxes. Median values are displayed above the upper whiskers.



CH_4, CO_2, and N_2O fluxes across in-stream sites and wetted perimeter sites.

- Patterns of CH_4, CO_2, and N_2O fluxes across two dates are similar between wetted perimeter sites and in-stream sites.
- CH_4 fluxes in the wetted perimeter are significantly higher than in-stream site (p-value = 0.007). The wetted perimeter had largest of median CH_4 flux of 1.39 mg C-CH_4 m^{-2} day^{-1}.
- CO_2 fluxes in the wetted perimeter are significantly higher than in-stream site (p-value = $5.34E^{-05}$). The wetted perimeter sites had largest of median CO_2 flux of 1.56 g C-CO_2 m^{-2} day^{-1}.
- N_2O fluxes in the wetted perimeter are not that different from in-stream sites (p-value = 0.6). The in-stream sites had the largest of median N_2O flux of 0.14 mg N-N_2O m^{-2} day^{-1}.



Site name	In-stream	WP
AC-1	-0.34	0.17
AC-2	22.09	423.45
AC-3	37.94	19.21
S14-1	1.57	11.69
S14-2	-0.24	0.23
S15-1	0.88	2.16
S15-2	-0.26	-0.35

Mean CH_4 fluxes in mg C-CH_4 m^{-2} day^{-1}

Site name	In-stream	WP
AC-1	0.24	0.17
AC-2	0.27	1.27
AC-3	0.51	0.59
S14-1	0.21	0.69
S14-2	0.33	1.14
S15-1	0.56	0.90
S15-2	0.13	2.61

Mean CO_2 fluxes in g C-CO_2 m^{-2} day^{-1}

Site name	In-stream	WP
AC-1	0.15	0.04
AC-2	-0.18	-0.19
AC-3	0.27	0.23
S14-1	0.24	0.16
S14-2	0.02	-0.07
S15-1	-0.07	-0.16
S15-2	0.26	0.32

Mean N_2O fluxes in g N-N_2O m^{-2} day^{-1}

Note: WP = Wetted Perimeter

CH_4, CO_2, and N_2O fluxes across topographic positions: Headwater Sites (S14 & S15) vs. Lowland Sites (AC)

Tukey's Studentized Range (HSD) Test

	In-stream Sites								Wetted-Perimeter Sites							
	AC-1	AC-2	AC-3	S14-1	S14-2	S15-1	S15-2	Overall p-value	AC-1	AC-2	AC-3	S14-1	S14-2	S15-1	S15-2	Overall p-value
CH_4	-1.3^{b}	22.75^{ab}	89.06^{a}	3.96^{b}	-0.3^{b}	27.8^{ab}	0.11^{b}	0.002	-3.3	366.1	525.6	34	1	320.3	1.5	0.04
CO_2	0.24^{ab}	0.21^{b}	0.58^{ab}	0.25^{ab}	0.51^{ab}	0.92^{a}	0.16^{b}	0.01	0.22^{b}	1.16^{ab}	1.13^{ab}	1.18^{ab}	1.37^{ab}	1.16^{ab}	2.42^{a}	0.11
N_2O	0.25	-0.29	0.41	0.75	0.49	-0.11	0.38	0.07	0.45	0.05	-0.06	-0.19	0.51	0.02	0.51	0.6

Means with the same letter are not significantly different.

	In-Stream Sites Lowland v. Upland	Wetted Perimeter Sites Lowland v. Upland
CH_4	0.03758	0.07504
CO_2	0.3884	0.06311
N_2O	0.206	0.06311

Conclusions/Significance

- Methane, carbon dioxide, nitrous oxides fluxes are variable in space.
- Sites located in lowland areas, Archer Creek sites, had the largest values of CH_4 fluxes.
- Headwater sites had the largest values of CO_2 fluxes.
- Spatial distribution of gas fluxes is apparent across three streams.

Outlook

- Examine the role of sediments and stream solutes to account for GHG fluxes in-stream and wetted perimeters in relation to upland areas. Quantify GHG production in HGM features.
- Explain heterogeneity factors controlling GHG fluxes at both temporal and spatial scales.
- Construct GHG budget model for all three streams.

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