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Researching Soil Hydrogen Dynamics in Subarctic Sweden

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Research Articles

Researching Soil Hydrogen Dynamics in Subarctic Sweden

—Victoria Lynn Ward (Editor: Katy Sternberger)

During the summer of 2012, I had the incredible opportunity to study trace gas emissions near the Abisko Scientific Research Station in the tiny town of Abisko in subarctic Sweden. This was through the Northern Ecosystems Research for Undergraduates (NERU) program, a National Science Foundation-funded Research Experience for Undergraduates program at the University of New Hampshire. The director is Dr. Ruth Varner, research associate professor in the Institute for the Study of Earth, Ocean, and Space and in the Department of Earth Sciences at UNH. Since I was an environmental science major with a minor in French, this seemed like the perfect opportunity to gain an international perspective on scientific research.

NERU brought together nine undergraduate scientists from all over the United States. They came from places as diverse as California, Arizona, Michigan, and North Carolina. A second student from UNH, Sophia Burke, was also part of the program. Our participation was partially funded by Summer Undergraduate Research Fellowships (SURF), which we had applied for from UNH's Hamel Center for Undergraduate Research. The summer was divided into three sections: four weeks at UNH to finalize research questions and methods, four weeks in Sweden collecting data, and two final weeks analyzing data at UNH.


The nine NERU students by the Abisko River gorge in Sweden. Author is second from left (*Courtesy Kaitlyn Steele*).

The four weeks in Durham were spent preparing our projects and getting to know one another. Because Sophia and I had already worked with Dr. Varner to define individual research questions when applying for our SURFs, we spent this time preparing our supplies and ensuring we knew how to analyze our samples. The range of students' projects was astounding considering that everyone's research related to climate change in subarctic Sweden. Projects ranged from an analysis of vegetation diversity in Stordalen Mire to a study of reindeer diets over the past century.

My research would focus on soil hydrogen dynamics at Stordalen Mire, a large, boggy area near the research station. Relatively little is known about soil hydrogen, which accounts for approximately 75 percent of the global hydrogen budget (Ehhalt and Rohrer, 2009). Hydrogen is also a secondary greenhouse gas, which means it impacts the behavior of primary greenhouse gases such as methane and carbon dioxide; yet there remain gaps in the research, especially with respect to the impact of climate change on the hydrogen cycle. Subarctic Sweden was an ideal location in which to collect this data because the impacts of climate change are more evident at the extreme latitudes than in non-polar regions. The research station at Abisko, host to scientists from around the world, has been in existence since 1913, providing a century-long record of biological and meteorological trends.

The trip to Abisko from New Hampshire took an entire day due to its isolated location in far northern Sweden. Upon arrival, we were all impressed by the beauty of the site. Directly outside the research station was a beautiful lake surrounded by snow-capped mountains. Although it never snowed while we were there, the weather was still chilly, typically around 40 degrees Fahrenheit, and raining. Occasionally this made field work draining, but the gorgeous surroundings more than made up for the weather.

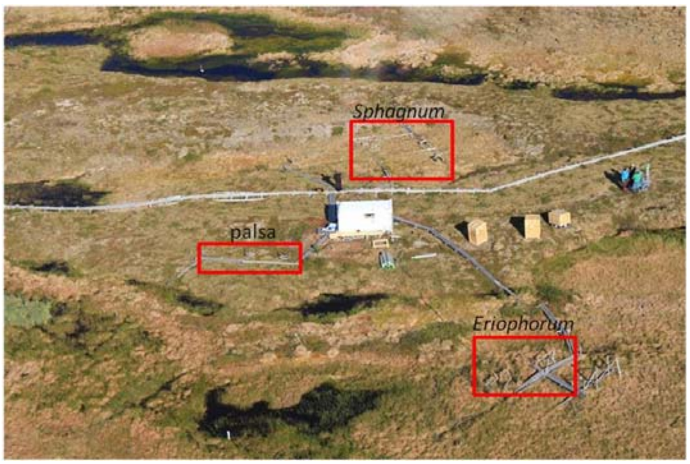
Working in the Mire

The amount of time spent in the field was highly dependent on each project. Some of the students spent almost all of their time in the field. My project was split roughly in half between field work and lab analysis. Each morning I would head out to the Mire and collect samples for about three hours before returning to the station. After a quick lunch, I would settle in the lab and analyze samples for about six or seven hours to determine the concentrations of hydrogen and methane.

The Abisko River Gorge, which was just a ten-minute walk from the station.

The goal of my project was to analyze the behavior of soil hydrogen in response to rain events. The thaw of permafrost will increase soil moisture and therefore the opportunity for anaerobic (without oxygen) conditions that increase the production and release of methane. Higher atmospheric concentrations of methane cause increasing atmospheric temperatures that, in turn, increase rates of permafrost thaw. This leads to higher concentrations of methane and more warming, suggesting that a positive feedback cycle could be in place. This means that, should hydrogen release from soils also increase, this cycle could be intensified because increased atmospheric hydrogen concentrations could lengthen the residence time of methane in the atmosphere (Novelli *et al*., 1999). By better understanding the response of soil hydrogen to increases in soil moisture, rain in this case, it is possible to better predict future climatic behavior. Samples were also taken from several different subhabitats, representing different thaw regimes, to better understand the impacts of climate change on soil hydrogen. These were a dry, frozen palsa site; a fully-thawed site dominated by the sedge species *Eriophorum*; a fully-thawed site dominated by the sedge species *Carex*; and a partially thawed site dominated by *Sphagnum* moss.

In order to gain insight into the cycling of hydrogen surrounding a rain event, I took samples of soil gas, soil porewater (water that fills the space between soil particles), and of the air in the autochambers. (An autochamber is a rectangular glass chamber installed in the peat whose lid automatically closes for a period of time, allowing researchers to determine the rate at which gas is emitted or consumed by the peat, known as the flux.) I then analyzed these samples for hydrogen and methane using a reduced gas (HgO) detector and flame ionization gas chromatograph, respectively. These samples were taken using syringes at the palsa, *Eriophorum*, and *Sphagnum* sites. Precipitation data was acquired from the Abisko Scientific Research Station's meteorological station.



Aerial photo of Stordalen Mire with three of the four subhabitats identified (*Courtesy Niklas Rakos*).

Acquiring Data and Facing a Challenge

While in Abisko, I was able to collect several days' worth of data for porewater, soil gas, and autochamber samples. A major precipitation event on July 14 and 15, a rainstorm, provided an excellent opportunity to observe the impact of soil moisture on soil hydrogen behavior. I took soil gas and porewater samples several times before, during, and after the storm. In acquiring these samples I encountered one major challenge.

This challenge was collecting soil gas samples from the palsa site. Our soil gas sampling arrays were an arrangement of tubes inserted to different depths in the soil; they were used to determine concentration profiles of dissolved soil gases. When an array had been inserted into the permafrost palsa site last summer, it caused a large rupture in the soil, meaning that samples would be a better reflection of hydrogen in the air than in the soil at this site. The palsa had not reformed around the array, and reinstalling it seemed likely to result in the same problem. As a result, I took samples from the palsa site using a sipper (a tube with small perforations on the bottom that could be inserted into the soil at varying depths). This presented a few new difficulties that I quickly resolved.

Author taking porewater samples using a plastic sipper on Stordalen Mire (*Courtesy Ryan Lawrence*).

The previous year, a metal sipper had been used to sample porewater at the semi-thawed and thawed sites. Due to the fact that the interaction of acids and metal can produce hydrogen, a plastic sipper was constructed for the samples I would take. This sipper was used for collecting soil gas at the palsa site in addition to porewater samples from the other sites. However, the plastic was much less effective at penetrating the soil, and the wooden dowel supporting it broke almost every time I inserted it. Additionally, the cable ties connecting the dowel to the plastic sipper snapped whenever the dowel broke, causing the sipper to bend and inaccurately reflect the depth at which samples were taken. I solved this problem by acquiring a stronger support and attaching far more cable ties. Fortunately, the remainder of the sampling equipment was in working order, meaning that upon arrival I could immediately begin sampling and that the only supplies I had to purchase were a few syringes.

During my last few days in Sweden I acquired data on the release of methane and hydrogen to the atmosphere over time by measuring fluxes in the autochambers. Because this data was not collected before the storm, it was used only to determine the impact of vegetation on the release of these gases.

Findings from the Samples

In order to determine the response of hydrogen and methane to the July rainstorm, I took samples during four time periods: before the storm, as the storm was starting, just after the storm, and about a week after the storm. By creating depth profiles featuring the average concentrations in each time period, I was able to determine the average impact of the storm event at each depth within each site and to better understand where, in the soil, hydrogen and methane are produced and consumed. (Fig. 1) Time series were created to gain further insight into the response to the rain event. (Fig. 2) All graphs were made when I was back at UNH so that I could analyze my data in its entirety.

Across all sites and depths, there was a general decrease in the concentrations of both hydrogen and methane in response to the storm. Samples taken using sippers and soil gas sampling arrays demonstrated the same decreasing trends. Eventually, the concentrations at most sites began to increase toward pre-storm levels; however, concentrations were restored much more quickly at some sites than others. The concentrations increased very quickly at the *Sphagnum* site after the storm and exceeded pre-storm levels by the end of sampling. At the *Carex* site, the concentrations were still declining by the time sampling ended. This difference in behavior is influenced by the differing hydrology and vegetation at each site. The *Eriophorum* and *Carex* sites are substantially wetter than the *Sphagnum* site, which may have resulted in a delayed return to pre-storm concentrations, but that does not explain the difference in response time between the *Eriophorum* and *Carex* sites. That is most likely a result of the differing vegetation.

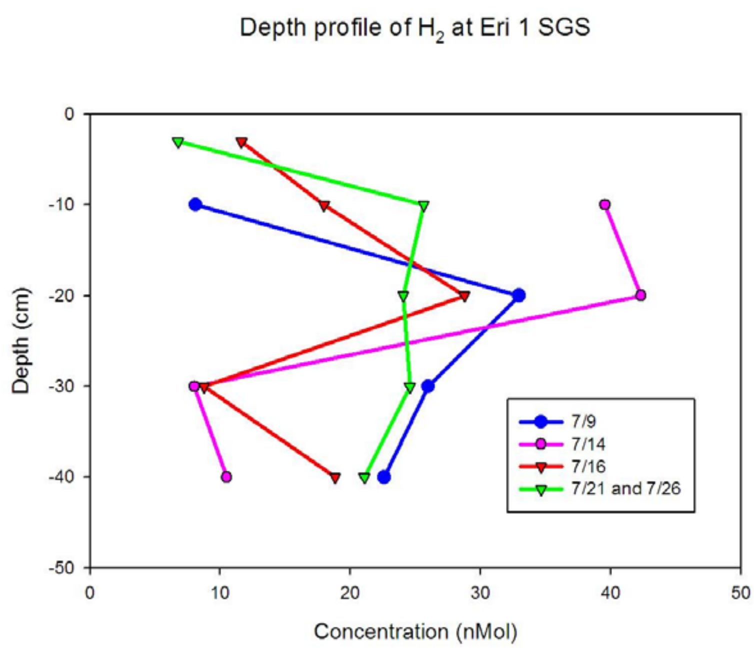


Figure 1: Depth profiles of hydrogen (H2) in soil gas at one of the *Eriophorum* soil gas sampling arrays surrounding the July 14 rain event.

Concentrations were highest toward the middle depths, around 20 to 30 centimeters below the surface of the soil. This observation is consistent with the fact that those regions exhibit high soil moisture and high carbon availability. Knowledge of carbon behavior helps us understand the cycling of hydrogen as it relates to other greenhouse gases. Although there may be more water deeper in the soil, the decline in organic material decreases the concentrations of methane and hydrogen.

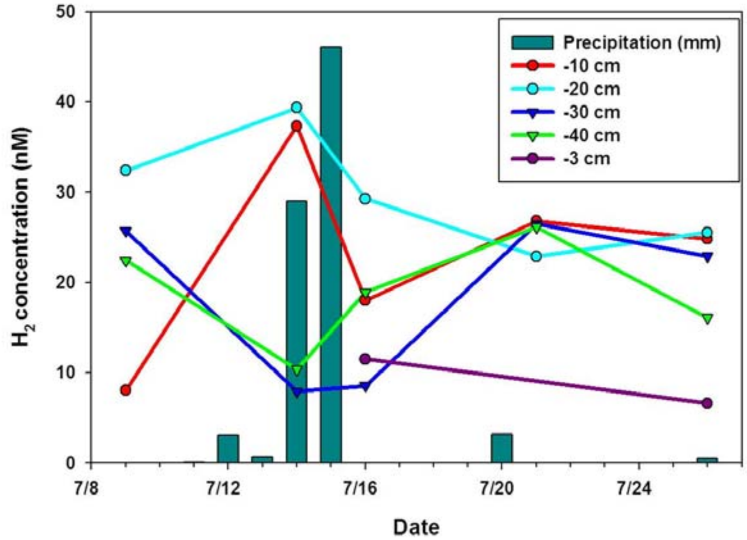


Figure 2: Time series of hydrogen at differing depths within the *Eriophorum* 1 soil gas sampling array showing that concentrations decreased at all depths around the precipitation event before beginning to increase again.

Autochamber flux measurements were averaged for each subhabitat. (Fig. 3) Unfortunately, there were not any autochambers located in the *Carex* subhabitat; but samples were available from the *Eriophorum*, *Sphagnum*, and palsa sites. With averages for methane, hydrogen, and carbon dioxide, it was possible to gain a larger picture on the behavior of hydrogen by better understanding the release of hydrogen to the atmosphere compared with soil concentrations, dominant vegetation, and the concentrations of two greenhouse gases. All three sites were net sinks of hydrogen and carbon dioxide during the period analyzed and net sources of methane. This means that they consumed more hydrogen and carbon dioxide than they released, and they released more methane than they consumed. The flux of methane was greatest from the *Eriophorum* site, which also demonstrated the most negative flux (largest uptake) of carbon dioxide and hydrogen. From this analysis, it seems possible that concentrations of hydrogen in the soil increased more quickly after the storm event at the *Sphagnum* site than at the *Eriophorum* site because not as much methane is released from the *Sphagnum* site.

Methane and hydrogen concentrations decreased during the storm due to a flushing of the system by the large influx of freshwater. After a certain amount of time, the system began to recover from this resetting of its biogeochemistry and the concentrations built back up toward pre-storm levels. The data I collected may be useful in models that depict the global cycling of hydrogen and primary greenhouse gases, allowing scientists to better understand the effects of large precipitation events on the Mire and similar regions. With this understanding, it will be possible to better anticipate future atmospheric concentrations of primary and secondary greenhouse gases.

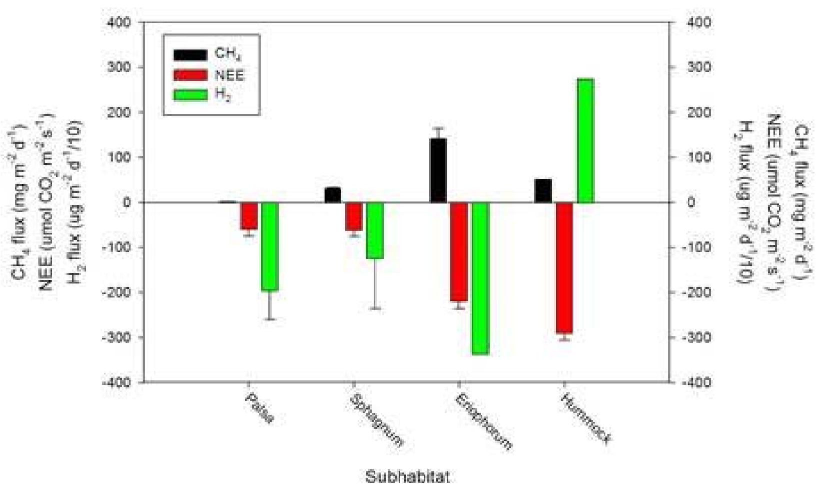


Figure 3: Fluxes of methane (CH4), carbon dioxide (NEE), and hydrogen at the *Eriophorum*, *Sphagnum*, and palsa sites. Samples were also taken from a hummock site.

I believe that the hydrology and vegetation coverage of each site also produced differences in the behavior of soil hydrogen. By considering the fluxes to the atmosphere, as shown in Figure 3, it was possible to gain an additional understanding of the relationship between all gases studied.

Participating in an International Scientific Community

Because Abisko is a remote town of only eighty-five permanent residents, we students were not fully immersed in the Swedish culture; however, the opportunity to experience fully an international scientific community was unparalleled. Researchers at the station hailed from a variety of nations, including Britain, Spain, Russia, Germany, and Bangladesh. All of the students in the NERU program lived in a small house with several researchers from these other nations, so we most frequently interacted with them while preparing and eating dinner. On our last night, the students from Bangladesh and members of our program prepared a traditional Bengali meal to celebrate the end of our successful trip.

Another wonderful cultural experience at the station was the daily Swedish tradition of *fica*, a coffee hour held at ten in the morning every day of the week. Unfortunately, NERU students were often too busy trying to collect samples and data to attend, but the occasions when we were free were delightful. These conversations were affirming for us young scientists who were treated as equals when discussing our research projects—the usual topic of conversation at the station.

Since returning from Sweden, I have continued to analyze the data I collected while writing my senior honors thesis and presenting at the American Geophysical Union Fall Meeting in San Francisco. As I look toward graduate school, I feel that my work in the Mire better prepared me for the rigorous research required to gain an advanced degree and to better understand and manage the earth's resources. Considering that the earth sciences are intrinsically global, I feel that maintaining an international perspective on research will be essential to my future work as a scientist.

This project would not have been possible without financial support from the Hamel Center for Undergraduate Research, particularly donors Mr. Dana Hamel and Mrs. Patricia Flowers, and the National Science Foundation, and the mentorship of Dr. Ruth Varner and Kaitlyn Steele '10 and '12G.

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Author & Mentor Bios

Senior **Victoria Ward** of Germantown, Maryland, is an environmental science major with a concentration in hydrology and a minor in French. A member of the University Honors program, Victoria never thought of writing for *Inquiry* until an editor suggested she describe her summer research experience with Dr. Ruth Varner's Northern Ecosystems Research for Undergraduates program (NERU). Having worked with Dr. Varner previously, Victoria saw her research on soil hydrogen as a perfect opportunity to continue working with Dr. Varner and to contribute data to a process that she says is "important yet poorly understood." Her research formed the basis for her honors thesis and was funded by NERU and a Summer Undergraduate Research Fellowship (SURF) Abroad from the Hamel Center. Participating in Dr. Varner's program reaffirmed how much she enjoys field work and helped her to become more confident in her research abilities. Upon graduating in May, Victoria plans to go on to graduate school where she hopes to focus on whole earth systems modeling.

Dr. **Ruth K. Varner** is a research associate professor in the Earth Systems Research Center at the University of New Hampshire. She is jointly appointed in the Department of Earth Sciences and in the Institute for the Study of Earth, Oceans, and Space. Dr. Varner completed her master's and doctoral degrees in earth sciences at UNH and has been a faculty member since 2003. She is a trace gas biogeochemist researcher and the director of the Northern Ecosystems Research for Undergraduates program (NERU). Among the many students Dr. Varner has mentored is Kaitlyn Steele, '10, '12G, who had a Summer Undergraduate Research Fellowship (SURF) in 2008 and participated as a research assistant and mentor to the undergraduates in the NERU project. Dr. Varner has been working with Victoria on various research projects for several years since they first met at a summer research field site in Barrington, New Hampshire. Throughout the NERU research, Dr. Varner was continually surprised by Victoria's independence and impressed by her work ethic and capacity to learn, noting that she became a vital part of the student group. Working with undergraduates on research, says Dr. Varner, "has enhanced both my ability to communicate and teach and my research skills and success." She believes that it is important for scientists to be able to communicate their work to a broader audience through publications such as *Inquiry*, particularly since society is ultimately impacted by the research findings of scientists.

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