Expanding Spatial and Temporal Coverage of Arctic CH_4 and CO_2 Fluxes

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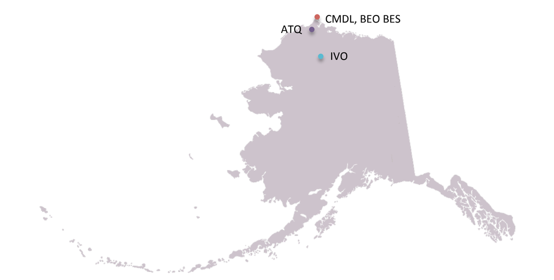
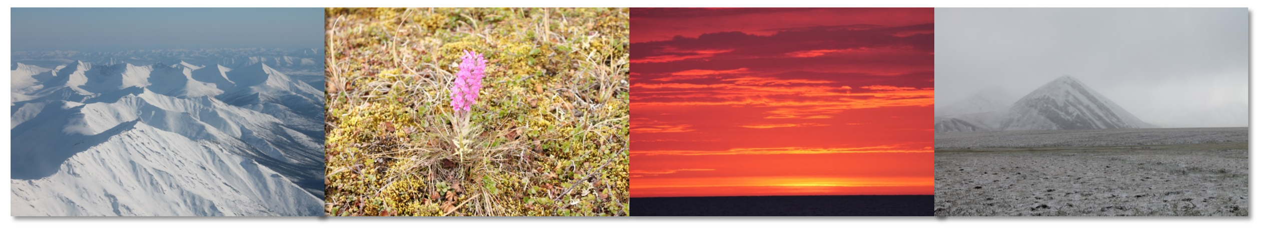




Introduction

Measuring carbon fluxes in the Arctic is no easy task, but it is a crucial part of understanding how significant this biome is to contributing to global climatic processes. The purpose of this study is to augment current CO_2 and CH_4 flux measurements by utilizing new technology and new techniques. Over the course of three years, we expect to have reliable data that will point us towards an annual budget for both CH_4 and CO_2. In addition to contributing to historical datasets of carbon exchange in the Arctic, this data – especially the CH_4 fluxes – will be helpful to modifying and strengthening models of future carbon exchange.

In order to implement year-round measurements of CH_4 and CO_2 fluxes, as well as concurrent meteorological measurements, it was necessary to fabricate a new tower system. This system had to be designed to withstand the exceptional winter conditions in Northern Alaska, account for redundant equipment, provide reliable data acquisition, and still be cost-effective enough to allow for five installations in sites with a varying availability of resources.

Equipment

Clockwise from top left:

- Gill R3, Metek uSonic-3, Li-Cor LI-7200, and intake for LGR FGGA in Atqasuk. July, 2013.
- Metek uSonic-3, Li-Cor LI-7200, and LI-7700 in Ivotuk. August, 2013.
- Gill WindMaster Pro and Li-Cor LI-7500 on the BES tower in Barrow. July, 2012.
- Inside the Los Gatos Research FGGA in our lab in Barrow. June, 2013.

The equipment we procured and installed in Alaska had to meet specific requirements. The principal pieces for this year were the Los Gatos Research Fast Greenhouse Gas Analyzer (FGGA), the Li-Cor LI-7200 and LI-7700, and the Metek uSonic-3. Together, these new instruments provide better coverage of fluxes during poor weather conditions. It was agreed that closed-path systems would likely provide much more reliable data than the legacy open-path instruments we have used prior.

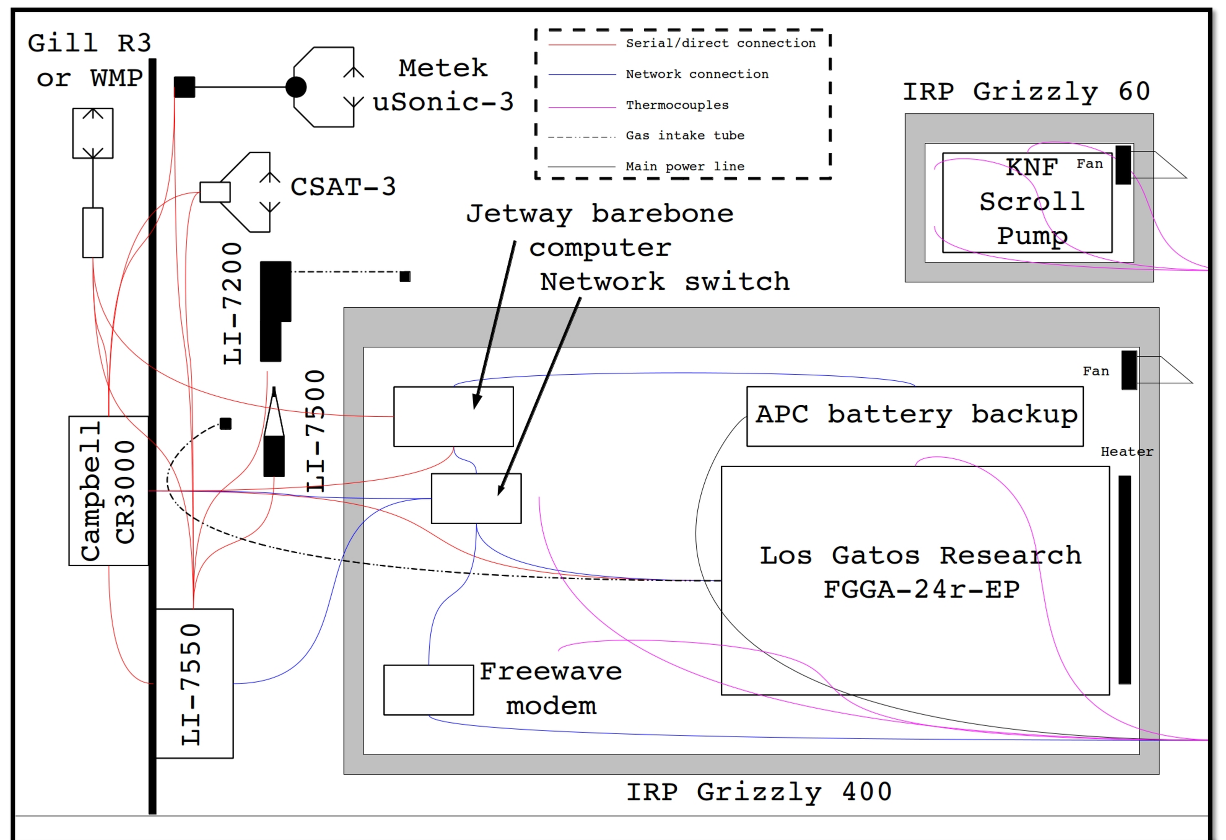
It is important to note that we chose how to distribute instruments based on need and resource availability. Despite the LI-7700 resulting in more gaps, we decided to use it exclusively to measure methane concentration in Ivotuk due to its low power requirements. However, at one site in Barrow we were able to place it alongside an FGGA due to plentiful power, bandwidth, and on-site help for maintenance and troubleshooting.

From top left to right:

- Salvatore wipes methanol on the LI-7700 mirror to clear sea-spray and other fine particles. October, 2013.
- Patrick cleans the internal mirrors of the LGR FGGA after a mosquito was sucked into the measurement cell. July 2013.
- Salvatore tightens the filter between the intake line and the LGR FGGA's measurement chamber. August, 2013.

Maintenance of these delicate and precise instruments is very important for reliable data collection. The Li-Cor and LGR gas analyzers require regular cleaning and calibration to perform optimally. Because of this, the members of our research group are in Alaska nearly year- round. Maintenance, repairs, and cleaning are done constantly with the help of local logistics support in Barrow and Atqasuk.

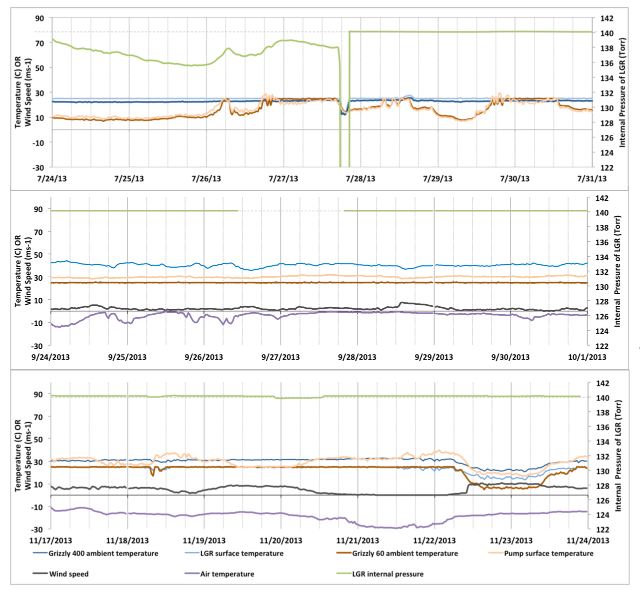
Box Design



As we set about planning to install the new equipment, one thing became obvious to us: The LGR, along with other ancillary instruments and accessories, were not designed to be weather-proof. Temperatures on the North Slope of Alaska vary widely between -50°C and 20°C, snowfall can reach 100cm in a year, and wind speeds are regularly as high as $20ms^{-1}$. Because we expected to continue measurements even during extreme conditions, the instruments needed to be housed in a steady environment that could be regulated regardless of external conditions.

The Iowa Rotocast Plastics Grizzly Coolers were chosen for their ability to withstand damage from bears and other wildlife, as well as their exceptional insulation. We decided to separate the LGR FGGA's external pump from the instruments to prevent vibrations from contributing noise to the 10Hz data. It was necessary to modify the coolers to control the internal temperature. The following was done to each box:

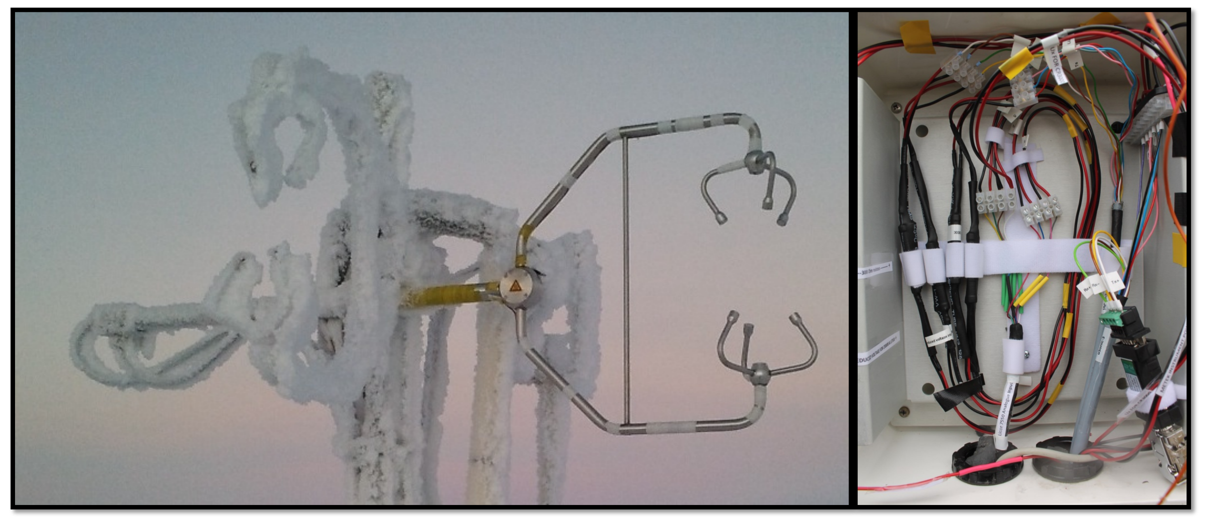
- One hole was drilled to provide access for cables and gas lines.
- Two holes were drilled to allow ventilation when needed. The air intake hole featured a vent facing down to prevent snow from entering, while the exhaust featured a flap that remains closed when no air is flowing. Both holes were secured with nets to prevent mosquitoes from entering.
- Redundant fans were controlled by both a temperature sensing program in the data logger and a common household thermostat.
- Two 90W heaters were installed in each large box. Most of the year, the LGR and external pump both provide enough heat to maintain their respective boxes within the operating temperature range.
- The boxes were raised at least 1m above the tundra to prevent snow drifts from forming around the tower.



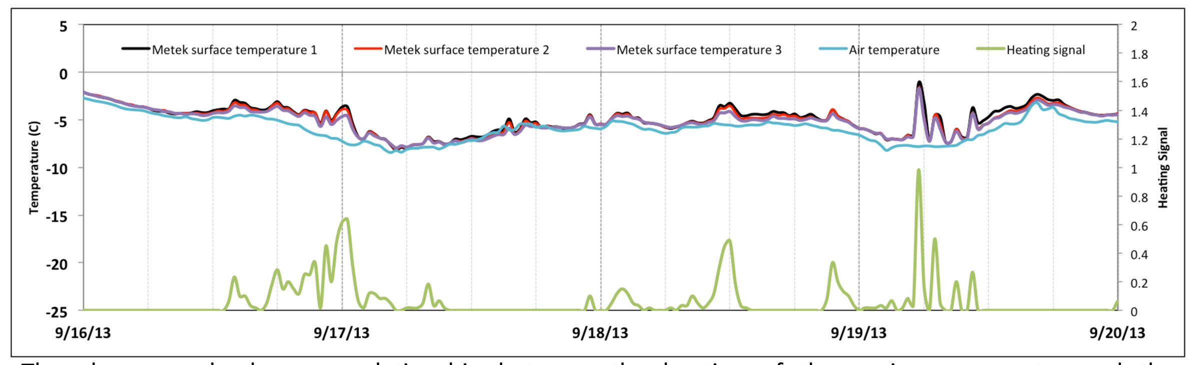
Until now, the temperatures within the Grizzly boxes have been maintained very consistently. We have noticed an occasional drop in pressure in the LGR. We are not yet sure what causes this, although it may be a result of the direction the wind and/or a restriction in the intake pipe. The data become noisy as the pressure moves away from 140 torr, something the manufacturer has specifically emphasized. We are still troubleshooting these and similar problems as they arise.

Anemometer Heating

A critical component of the eddy covariance technique is the measurement of three-dimensional wind speed and direction (u, v, w), as well as the sonic temperature (Ts). Eddy covariance data are susceptible to noise and gaps when the sonic anemometer's transducers are blocked by ice and snow. Our solution to combat this is to use a heated sonic anemometer. This prevents ice and rime from forming over the instrument. This ensures that data collection can continue during the harsh Arctic winter.

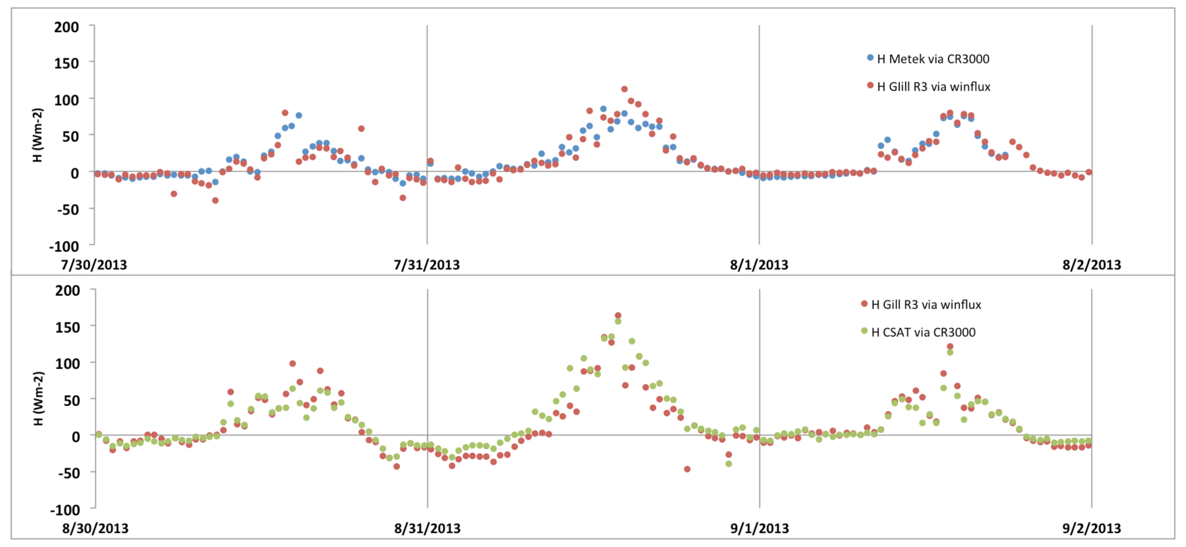


Left: The Metek uSonic-3 remains clear of ice during riming conditions, while the CSAT-3 and R3 remain covered.
Right: This wiring helps control when the heating is on or off, which saves energy in remote sites.

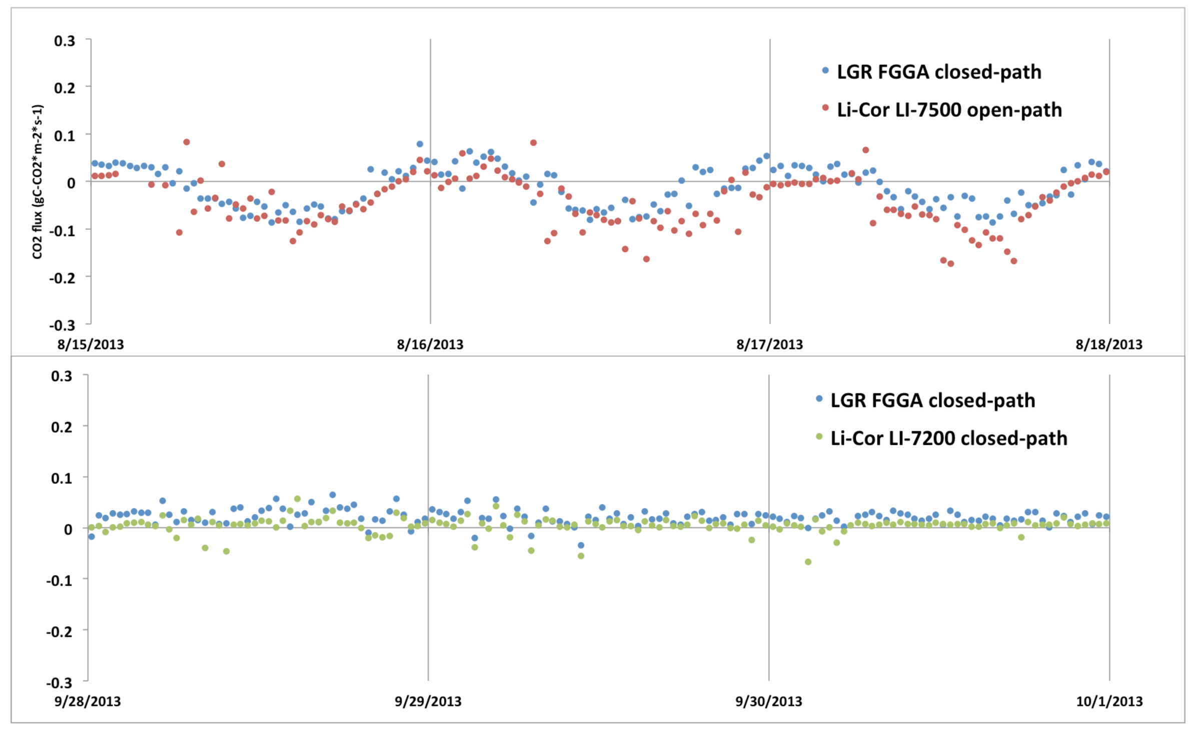


The above graph shows a relationship between the heating of the sonic anemometer and the temperature of the instrument's surface.

Equipment Cross-Comparison

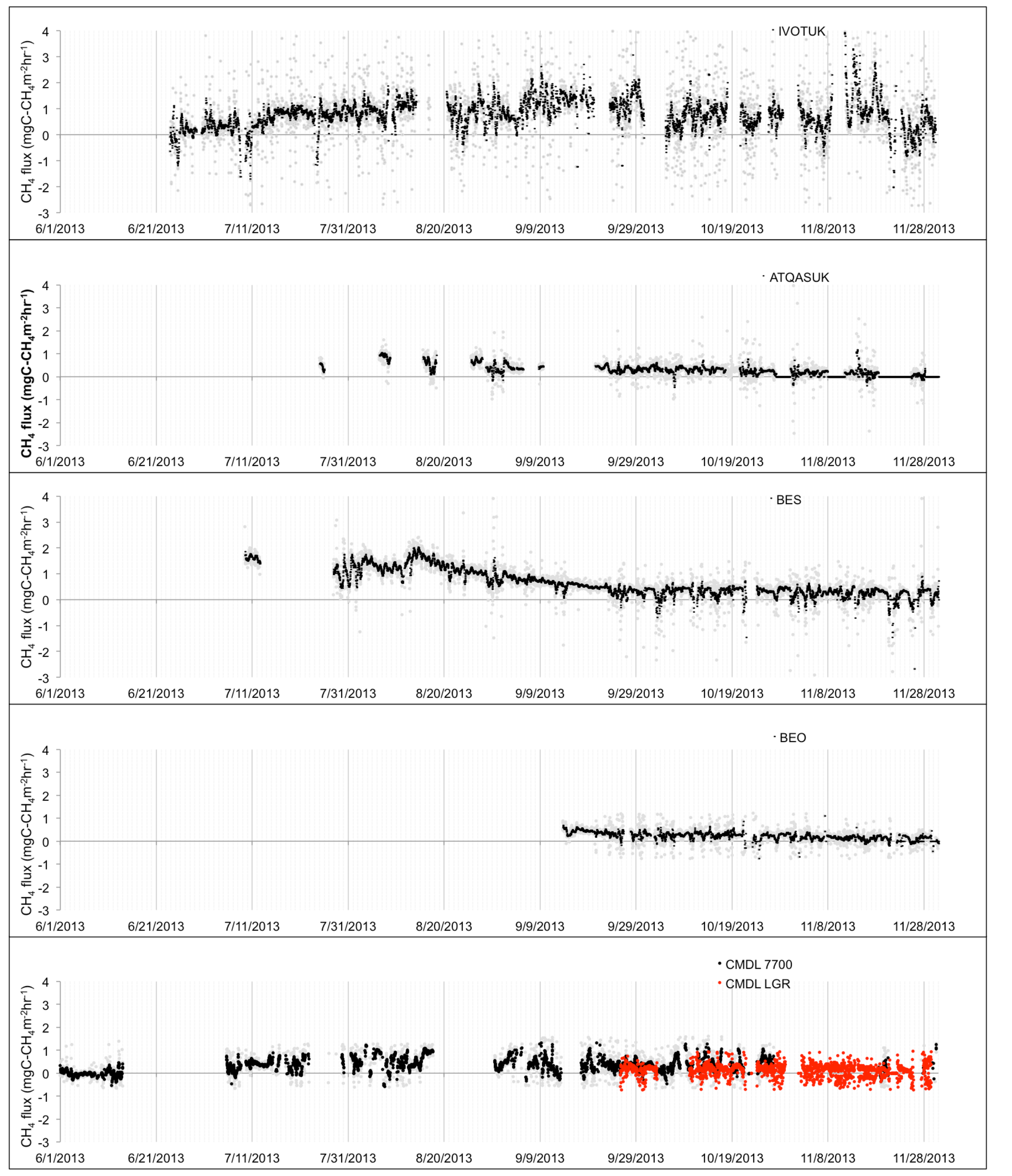


These graphs highlight the differences between three sonic-anemometers used on various eddy covariance towers in Alaska. Sensible heat is shown between the Gill R3 (on both graphs), the Metek uSonic-3 (top), and the CSAT-3 (bottom). The trends and spikes match nicely after corrections, showing that data obtained from each should be comparable. All measurements taken in Atqasuk.



Samples of CO_2 flux are shown here. The top graph displays the FGGA along with the LI-7500 measured at one site in Barrow. The bottom graph shows the FGGA compared to the LI-7200 in Atqasuk.

Methane Flux Spatial Distribution



Methane fluxes are shown here from all our Arctic towers that have the necessary equipment. Gray data points are half-hourly averages calculated during processing, while the black data are a 6 hour running average. The bottom graph shows data from both the FGGA (red) and LI-7700 (black) at the CMDL site. Despite gaps, data coverage until the end of November, 2013, has been between 50% and 93%. We expect to continue to refine the systems as they collect data throughout the winter, and reduce the frequency of gaps in the future.

Conclusion

The first several months of this multi-year study have presented our group with many challenges and successes. As a result of very hard work from everyone, all seven of our eddy covariance towers in Alaska are working. Five of seven have new equipment, the remaining two are not presented here. As winter progresses and 2014 begins, we expect to continue collecting reliable fluxes for both CO_2 and CH_4. Some notes and accomplishments:

- To continue reliable methane flux measurements through winter, we used new closed-path instruments installed within a dedicated, temperature-controlled environment.
- To avoid large data gaps, our group developed a system to heat a sonic anemometer and melt ice.
- While difficult, it is possible to continue measurements of methane and carbon dioxide fluxes through winter in northern Alaska using these methods
- For both methane and carbon dioxide, we have seen fewer and shorter gaps in data due to poor weather conditions.

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