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Seasonal and Inter-annual Controls on CO_2 Flux in Arctic Alaska

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In order to advance the understanding of the patterns and controls on the carbon budget in the Arctic region, San Diego State University has maintained eddy covariance flux towers at three sites in Arctic Alaska, starting in 1997.

Project Objectives

1) Determine the seasonal and inter-annual patterns of CO_2 and CH_4 flux, and their relationships to changes in vegetation, thaw depth, soil moisture, and water table depth.
2) Compare the CO_2 and methane dynamics of three different Arctic landscapes.

Final Progress

We have measured eddy covariance fluxes at Barrow, Atqasuk, and Ivotuk within the capabilities of the resources and support available. Over the course of four years, we have made repairs and upgrades these towers to maximize the collection of reliable, high quality data. All data from the grant period is being processed and reported Ameriflux.

The tower at the Climate Monitoring and Diagnostics Laboratory (CMDL), operated by the National Weather Service and National Oceanographic and Atmospheric Administration, is the closest to the sea and is in well-drained coastal tundra. There are also four more towers (BEO, BES, BEC, BEN) in Barrow at the Barrow Environmental Observatory, an outdoor laboratory managed by the Ukpeagvik Inuit Corporation. The tower in Atqasuk, Alaska, about 100 km south of Barrow, is an example of moist tussock tundra, and is quite different from Barrow tundra in growth form, moisture, and land surface type. The tower in Ivotuk, near a small camp and airstrip at the foot of the Brooks Range, is the most inland and most southerly of our towers. In the foothills of the Brooks Range, this site is expected to show the earliest and initially most extreme impacts of warming along this transect.

Running these towers in the Arctic can be challenging for a number of reasons. Access to the sites can be impossible during some periods of the year, and extreme conditions constantly affect the instruments' ability to collect good data. We made a concerted effort to improve and upgrade the towers to ensure that we measured quality fluxes, even during the winter months when no other groups were doing so.

An important requirement for reporting data from remote sites is to have remote access. This is critical to ensure continuity of data collection, as it allows us constant monitoring, access, and provides a back-up copy should the on-site computer fail. Therefore, a full-time internet connection is required at each site to report data in near real time to the server at SDSU, to check system function via VNC, and troubleshoot. Though at the beginning of the grant period very few towers were accessible and controllable remotely, we now have the ability to access and manipulate many of our instruments from our labs in Barrow or San Diego. This was a difficult upgrade, but it allows us the ability to check on the data quality daily. In addition, the data collection computers automatically upload data to a secure server on our campus once a day. This is critical in case severe weather or another event cripples the hardware and destroys the on-site data. One financial benefit of this is that we can avoid unnecessary trips to the Atqasuk and Ivotuk sites, scheduling visits only when necessary.

In our efforts to continue data collection year-round, and in collaboration with funding from NASA CARVE and NSF OPP, major upgrades were performed. Our first major upgrade came in 2011, when we replaced open-path LI-7500 CO_2/H_2O analyzers with closed-path LI-7200 CO_2/H_2O analyzers. The closed-path sensors installed at the site have performed well in collection of the carbon dioxide and water vapor flux measurements. These data do not require a sensor heating correction, meaning that our data is more reliable with fewer processing steps and fewer corrections. We also have fewer interruptions in data collection due to the sensor path being blocked by condensation or rain accumulation (a common problem with the open-path sensors). In 2012, the Barrow CMDL tower was upgraded with an LI-7700 to measure methane fluxes in addition to the CO_2/H_2O data. We were also able to begin measurements in IVO in August, 2012 using a portable tower.

Beginning May 2013, we had a much larger field crew available during the summer, as well as continuous support during the fall, winter, and spring months. This allowed us to expand our measurement capability. We followed the earlier upgrades with the addition of four high precision, fast response, LGR CO_2, H_2O, CH_4 cavity ring-down laser spectrometers at Barrow CMDL, BEO, BES, and ATQ. These allow for constant measurement of all three greenhouse gasses, giving us data when the other open-path sensors (LI-7500, LI-7700) might be affected by inclement weather. The portable tower in IVO was replaced with a much more secure GHG system that provided CO_2, H_2O, CH_4 data with very low energy demands. We also installed heated ultrasonic anemometers (Metek GmbH) at CMDL, ATQ, and IVO.

Although we largely met and exceeded our project objectives, we did encounter some problems. In the spring of 2012, the organization (BASC) that had previously provided logistics services at Atqasuk for our research was almost entirely disbanded. As a result, we lost data collection and communication at Atqasuk in winter and spring seasons of 2012. Equipment was reinstalled in a new, secure location in June, 2012 allowing us to continue the collection of fluxes and meteorological data using the current system. Issues with our LI-7700 at CMDL resulted in the instrument being sent back to the manufacturer for repairs. We were unable to reestablish data collection until October, 2012, much later than we anticipated. Do to its remote location, and the lack of any local support, the tower in Ivotuk has been the most difficult to access and maintain. This was in part due to our initial inability to come to a satisfactory agreement with CPS and NSF for logistical support at the site. However, this agreement was established such that we have had continuous power and communications support since June, 2013.

Another challenge we faced was support during the off-season months of September-April. In 2011 and 2012, this resulted in data loss because of equipment malfunction and lack of access to clean and maintain instruments. We now have much more control over these problems, and have significantly improved the amount of data collected during this time of year.

Data analysis will continue, data and meta-data on AmeriFlux will be updated, and manuscripts on recent fluxes as well as long-term controls on and patterns in fluxes are being prepared.

Daily CO_2 fluxes over the year, average daily net radiation, average daily PAR, average daily air temperature and average daily soil respiration from Atqasuk 2006 is presented in Figure 1. The high variability of CO_2 and CH_4 fluxes in different sites in 2013 is also shown in Figure 2 and 3.

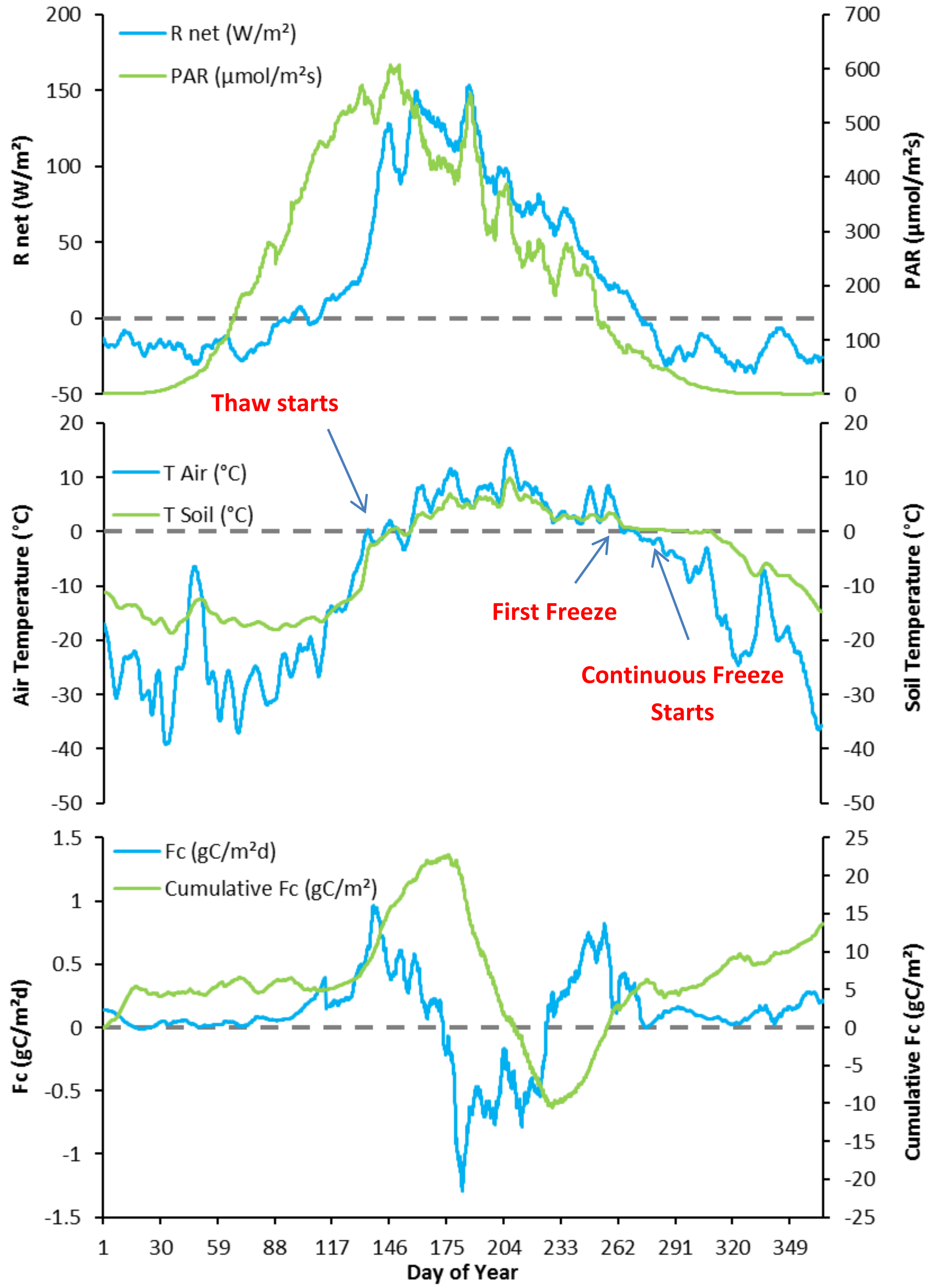

Figure 1. Daily CO_2 fluxes over the year, average daily net radiation, average daily PAR, average daily air temperature and average daily soil respiration (at -5 cm). (Oechel et al., 2014).

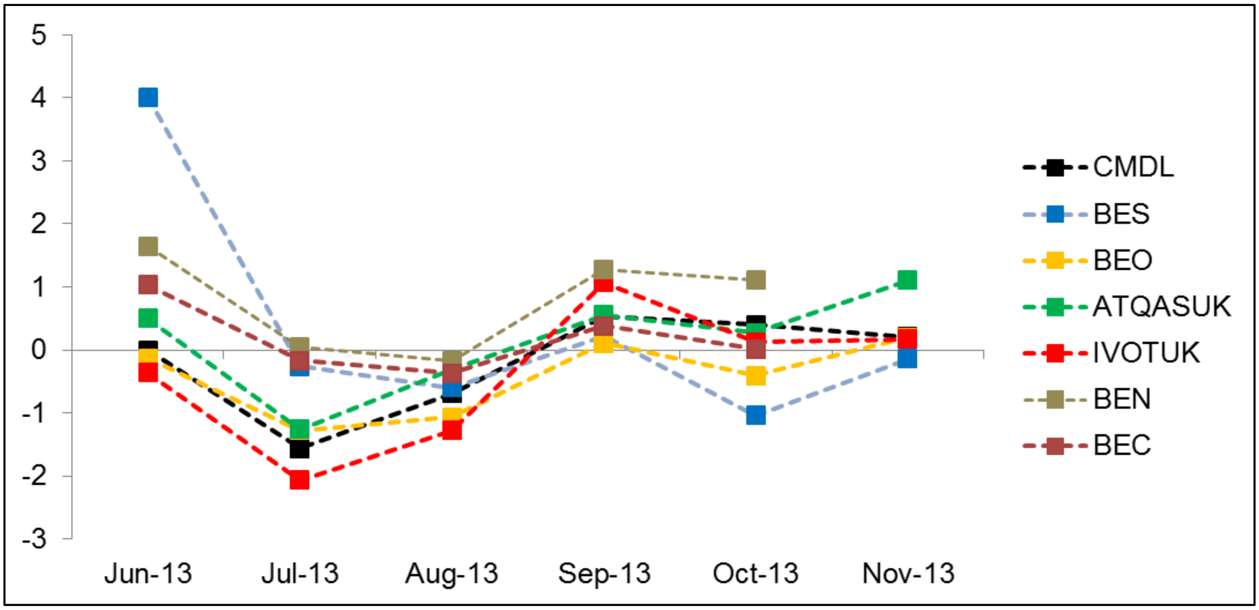

Figure 2. Daily mean CO_2 flux g C-CO_2 m^{-2} d^{-1}

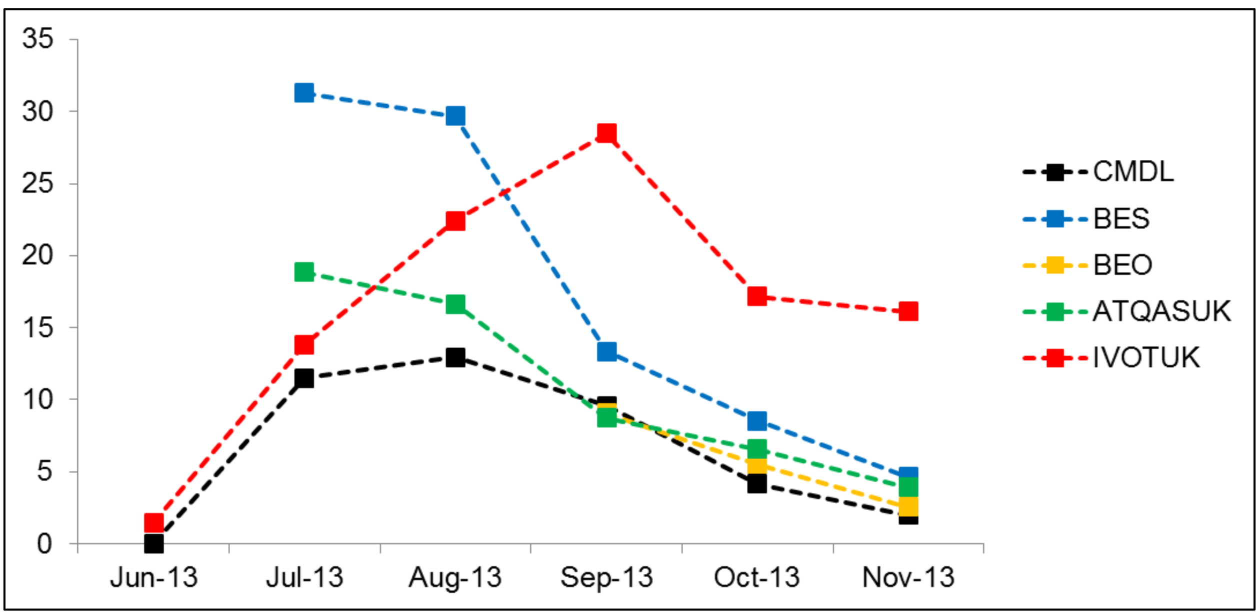

Figure 3. Daily mean CH_4 flux mg C-CH_4 m^{-2} d^{-1}

The CO_2 and CH_4 fluxes, Rnet and Tair for the period of snow melt in CMDL (05/29/2013 to 06/13/2013) are shown in Figure 4.

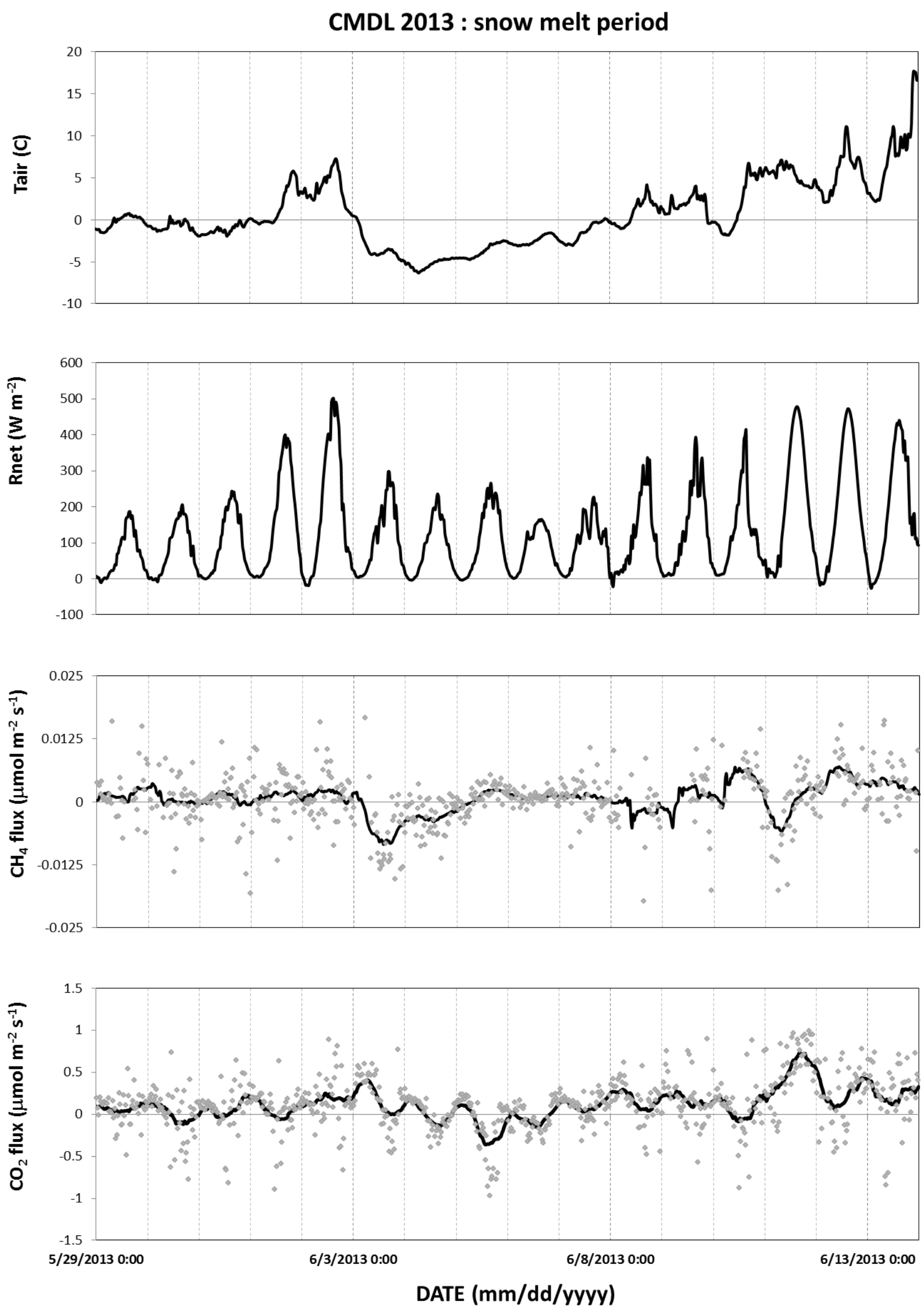

Figure 4. CO_2 flux, CH_4 flux, Rnet and Tair for the period of 05/29/2013 to 06/13/2013 in CMDL.

The mean daily CO_2 and CH_4 fluxes, mean daily Rnet and Tair for CMDL 2013 are also presented in Figure 5. If the daily pattern is stronger for the CO_2, it is not the case for CH_4 which is highly variable from one day to another.

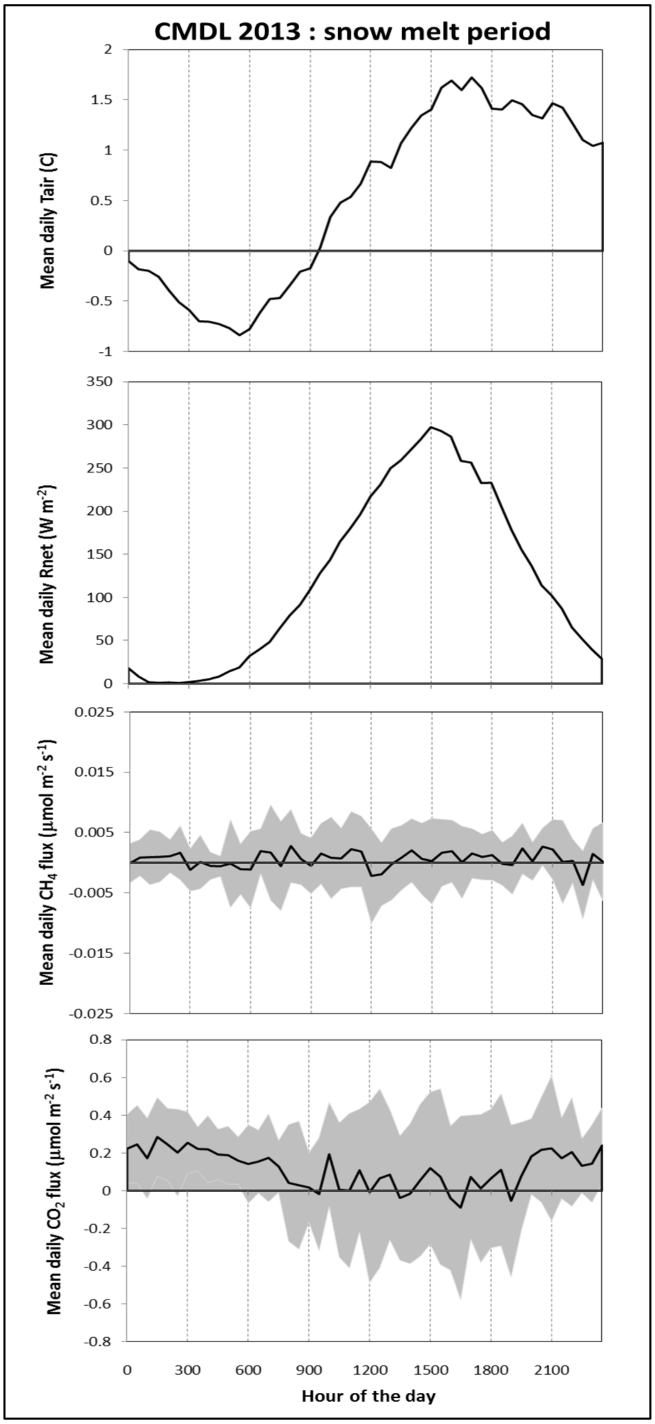

Figure 5. Mean Daily CO_2 and CH_4 fluxes And Mean Daily Rnet and Tair in CMDL 2013.

We are now working on a manuscript of the long term pattern of CO2 flux at CMDL, Barrow, Alaska. This is intended to be submitted to Nature or Nature Climate Change.

Recent Publications and Presentations:

- Oechel W. C., Moreaux, V., A. M. Kalhori, A., Murphy, P., Wilkman, E., Zona, D. 2015. Spatial and Temporal Variation of Arctic CH_4 and net CO_2 Fluxes Using Nested Chamber, Tower, Aircraft, Remote Sensing, and Modeling Approaches for Regional Flux Identification and Estimation. EGU General Assembly 2015. Abstract # EGU2015-8168.

- Oechel W. C., Laskowski, C. A., Burba, G., Gioli B., A. M. Kalhori, A. 2014. Annual patterns and budget of CO_2 flux in an Arctic tussock tundra ecosystem. Journal of Geophysical Research: Biogeosciences, 119 (3), 323-339. DOI: 10.1002/2013JG002431.

- Oechel W. C., Moreaux, V., A. M. Kalhori, A., Losacco, S., Murphy, P., Wilkman, E., Zona, D. 2014. Annual and Spatial Patterns of CO_2 and CH_4 Fluxes in Arctic Alaska. US-IALE, Annual Symposium. Anchorage.

- Zona, D., Hufkens, K., Gioli, B., A. M. Kalhori, A., Oechel, W. C. 2014. Changing snow cover in tundra ecosystems tips the Arctic carbon balance. EOS Trans. AGU Fall Meeting. Suppl., Abstract, Oral presentation # B32B-03, San Francisco, USA.

- Oechel, W. C., Moreaux, V., A. M. Kalhori, A., Murphy, P., Wilkman, E., Zhuang, Q., Miller, C., Dinardo, S., Fischer, J., CARVE Science Team., Zona, D. 2014. Heterogeneity of CH_4 and net CO_2 fluxes using nested chamber, tower, aircraft, remote sensing, and modeling approaches in Arctic Alaska. EOS Trans. AGU Fall Meeting. Suppl., Abstract, Oral presentation # B24C-02, San Francisco, USA.

- Oechel W. C., Moreaux, V., A. M. Kalhori, A., Losacco, S., Murphy, P., Wilkman, E., Zona, D. 2014. Large scale, regional, CH_4 and net CO_2 fluxes using nested chamber, tower, aircraft flux, remote sensing and modeling approaches in Arctic Alaska. EGU General Assembly. Abstract # EGU2014-5320.

- Sturtevant, C. S. and W.C. Oechel. 2013. Spatial variation in landscape-level CO_2 and CH_4 fluxes from Arctic costal tundra: Influence from vegetation, wetness and the thaw lake cycle. *Global Change Biology*, 19 (9).

- A. M. Kalhori, A., Burba, G., Gioli, B., Oechel, W. C. 2013. Annual pattern and budget of CO_2 flux in Arctic tussock tundra ecosystem at Atqasuk, Alaska. EOS Trans. AGU Fall Meeting. Suppl., Abstract # GC23B-0927, San Francisco, USA.

- Moreaux, V., Oechel, W. C., Losacco, S., Mcewing, R., Murphy, P and Zona, D. 2013. CH4 fluxes

along a latitudinal transect in Northern Alaska using eddy covariance technique in challenging conditions. EOS Trans. AGU Fall Meeting. Suppl., Abstract # B11H-06, San Francisco, USA.

- Murphy, P., Oechel, W.C., Moreaux, V., Losacco, S., Zona, D. 2013. Expanding Spatial and Temporal Coverage of Arctic CH_4 and CO_2 fluxes, EOS Trans. AGU, Fall Meeting. Suppl., Abstract # B51E-0337.
- Wilkman, E., Oechel, W.C., Zona, D. 2013. Chamber and diffusive based carbon flux measurements and design protocols in an Alaskan Arctic ecosystem. EOS Tans. AGU Fall Meeting. Suppl., Abstract # B33K-0619, San Francisco, USA.