Surface-Atmosphere Exchange Processes

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**Theme: Surface – Atmosphere Exchange**

- Land-surface processes, including the exchange of energy, water vapor and carbon fluxes between the land surface and atmosphere significantly influence weather and climate.

- A better understanding of surface energy, water and carbon cycles and the drivers of land–atmosphere feedbacks are essential for improving the performance of numerical models and to increase our confidence in predicting future water/carbon cycling–climate scenarios.

Continuous observations of fluxes of energy, water, and carbon dioxide have been made over different ecosystems by NOAA / ARL’s Surface Energy Budget Network (SEBN).
Land-surface processes and feedbacks: scales

- Accurate accounting of the biophysical processes that mediate surface-atmosphere exchanges occur at multiple spatial and temporal scales, necessitating cross-scale observational platforms in addition to long-term measurements.
- Land surface exhibits substantial surface heterogeneity so that the spatial and temporal scaling of surface variables/fluxes and its validation is important.
- These measurements are also needed to assessing the parameterizations used in atmospheric models to represent land–atmospheric interactions.

Short-term campaign-mode experiments
- Land surface temperature measurements in-situ, aircraft and satellite-based observations.
- Flux Observations of Carbon from an Airborne Laboratory (FOCAL) Campaign Phase 1 and 2 in the Arctic Region.
Relevance to OAR goals

- **OAR Strategy Goal 3: Make Forecasts Better**
  - 3.1 Develop interdisciplinary Earth system models
  - 3.3 Transition science that meets users' current and future needs

- **OAR Strategy Goal 2: Detect Changes in the Ocean and Atmosphere**
  - 2.2 Identify and address gaps in observation requirements needed to understand causes of variability and change
  - 2.3 Increase ability to access and use Earth system data

“Understanding the processes and environmental variables that control surface-atmosphere exchanges, and translating this understanding into more accurate model parameterizations, is a vital research activity that will lead to improved weather, climate, and air quality predictions” [Strategic Plan 2021-2016]

Also supports ARL Theme: Boundary Layer Characterization “ARL’s endeavor to develop and improve BL parameterizations for weather and climate predictions. Short and long-term measurements are part of a suite of carefully designed networks and planned observation campaigns”. [Strategic Plan 2021-2016]

Supports NOAA’s Mission to understand and predict changes in climate, weather, oceans, and coasts.
Land Surface Temperature (LST) measurements

- **LST is a key variable** in the study of land surface–atmosphere exchange processes from local to global scales and is widely used in many research fields

- LST measurements derived from infrared temperature sensors (IRT) or longwave radiation (LWR) measurements

- Validation of satellite LST for estimating the accuracy of LST data and to assess the uncertainty in retrieval methods/algorithms

- **Objective**: To assess the spatial variability and overall representativeness of the single point LST’s

- Campaign mode observations using tower, aircraft and satellite LSTs

- Other participating sites USCRN, SURFRAD, SEBN, ENERGY FARM, SOYFACE
Intercomparison of in-situ sensors for ground-based LST measurements

**Objective:** To evaluate and better quantify the uncertainties in ground-based LST measurements using an array of thermocouples, three narrow angle IR thermometers, one set of pyrgeometers with a nearly hemispheric field of view and a FLIR camera.

**Ts [IRT]**
Apogee infrared (IR) radiometers (SI-111 Model)
Heitronics IR Pyrometer (KT19.85 II model )
JPL Quasi Nulling IR Radiometer (500 series)

**Ts [FLIR]**
Forward-Looking Infrared Radiometer (FLIR) (Tau 2 model) camera (average of 100 images for each time)

**Ts [TC]**
Thermocouples(TC) type K (Nickel-Chromium / Nickel-Alumel)

**Ts [LWR]**
Pyrgeometer (Kipp & Zonen (CNR1-CG3)

**Ta**
PRT (Thermometrics corp.)

**Location – ATDD parking lot**
(10 Oct. 2015 to 8 Jan. 2016)

Surface emissivity (0.9) estimated using Ts [TC] and Ts [IRT]

*Krishnan et al., 2020, Sensors*

Collaboration with Jet Propulsion Laboratory
Accuracy of ground-based LST measurements

- Quantify the uncertainties in ground-based LST measurements
- Uncertainties in situ LST ( >1 to 2°C between IRT & LWR) measurements can be influenced by site surface heterogeneities, its characteristics and changes in vegetation phenology, if any.
- Accuracy of IRTs are within ± 0.5 °C (Krishnan et al., 2020)

Intercomparison of LST measurements using IRT and LWR data from four SEBN sites. Air temperature as a proxy for LST

Difference in LST estimates ($T_s$) using IRT and longwave radiation measurements (LWR) at four grassland sites and compare it with near surface air temperature ($T_a$)
Arctic CO₂ & CH₄ flux measurements

Motivation

- The Arctic is warming at twice the global average and it can lead to thawing of permafrost and unquantified carbon emissions into the atmosphere in the form of CO₂ and CH₄

- A better understanding of the drivers of CO₂ and CH₄ sources and sinks is crucial for predicting future emissions from the Arctic in response to a changing climate, and its impact on global carbon cycle and radiative forcing

Flux Observations of Carbon from Airborne Laboratory (FOCAL) campaign

Collaborative Research funded by NSF: Multi-Regional Scale Aircraft Observations of Methane and Carbon Dioxide Isotopic Fluxes in the Arctic
OBJECTIVE
To provide spatially resolved, high accuracy and high precision measurements of CH$_4$ and CO$_2$ isotopic fluxes from melt zones in the Arctic

CAMPAIGN - August 2013

Major components of the project
1. The carbon isotopologue instrument developed by Anderson group of Harvard University
2. DA 42 Aircraft from Aurora Flight Sciences
3. Best Airborne Turbulence (BAT) probe & tower-based measurements by NOAA/ARL/ATDD

Funding by NSF
Aircraft–based flux measurements in the Arctic

- The FOCAL campaign during the summer of 2013 demonstrated how CH₄ fluxes could be successfully measured over large regions using airborne eddy covariance measurements from a small, low-flying aircraft (Sayres et al., 2017, ACP).

- The first airborne eddy-correlation flux measurement of isotopologues of CO₂ and CH₄ in the Arctic.

- Distinguish fluxes from different surface types over a heterogeneous landscape is very challenging.
Airborne flux measurements over heterogeneous landscape

- Developed methods for airborne flux measurements - Running flux method (RFM) and Flux Fragment Method (FFM) for each land class (Dobosy et al., 2017)

- Good agreement between airborne and tower based flux measurements when there was good overlap between the tower footprint and aircraft footprint

- The contribution to the total methane flux from individual land classes (Sayres et al., 2017)
Increased CH$_4$ emissions and CO$_2$ uptake were observed during warmer soil temperatures and increased photosynthetically active radiation. The warm soil produced strong methane emissions. Spatial heterogeneity even over relatively short distances. Large variability of N$_2$O fluxes with many areas exhibiting negligible emissions (2.2–4.7) mg N$_2$O m$^{-2}$ d$^{-1}$ (Wilkerson et al. 2018). Airborne eddy-covariance technique is also used to make in situ N$_2$O flux measurements.
Flux Of Carbon from an Airborne Laboratory (FOCAL) Campaign 2

Objectives

- Bridge the scale gap between
  - process-level or local studies and landscape scale flux measurements.
  - landscape scale flux measurements in the boundary layer with regional scale estimates from inversion modeling.
- Define the current late summer and autumn net flux of CH₄ and CO₂ from the North Slope and adjoining Arctic waters
- Assess how the net CH₄ and CO₂ flux is expected to respond to a changing climate in the Arctic in the next decade and beyond.

**NSF funded project**: Collaborative Research: Bridging the scale gap between local and regional methane and carbon dioxide isotopic fluxes in the Arctic

**Aim**: To advance our understanding of the physical factors (mechanisms) controlling these fluxes in the Arctic and improving their representation in Earth System Models.

**Collaboration**: NOAA/ATDD & ORAU, Harvard U, Columbia U and Aurora Flight Sciences

**CAMPAIGN**: Main Phase in August 2023

~150 Flight hours & two towers
Quality and Performance

Publications


Quality and Performance

Presentations (7)


Future plans

Short-term

• Successful completion of FOCAL campaign in 2023 over the Arctic region
• Improve the methods for flux measurements from aerial platforms (aircraft and UAVs)
• Land surface temperature measurements to validate model (eg: HRRR) simulations

Long-term

• Long-term observations of energy, water and carbon fluxes over different ecosystems to examine the biophysical factors controlling their seasonal/inter-annual variability and to assess long-term trends, the impact of climate extremes (eg: drought, freeze) or natural/anthropogenic disturbances (eg: fire, harvest)
• Integrating surface flux and atmospheric boundary layer measurements to advance understanding of land-atmosphere interactions
• Bridging the scale gap between local, landscape and regional scale flux measurements in the boundary layer using field measurements, remote sensing, and modeling
Thank you

LST measurements over Chestnut Ridge Site