Surface-Atmosphere Exchange Processes

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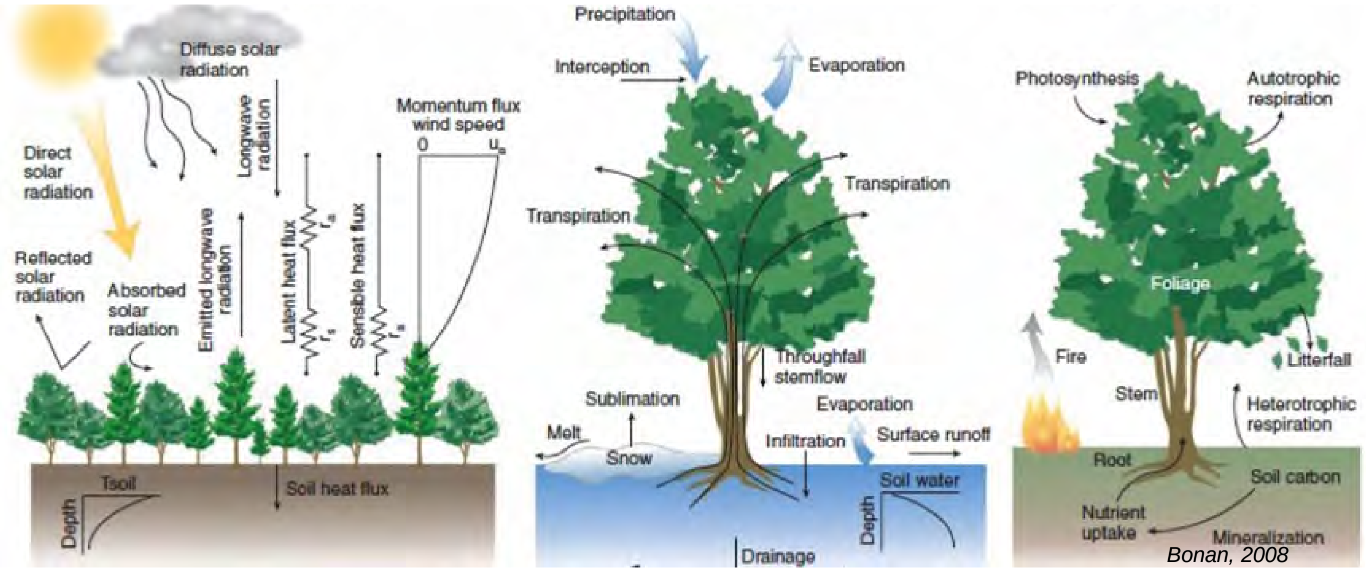
Theme: Surface – Atmosphere Exchange

- 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)

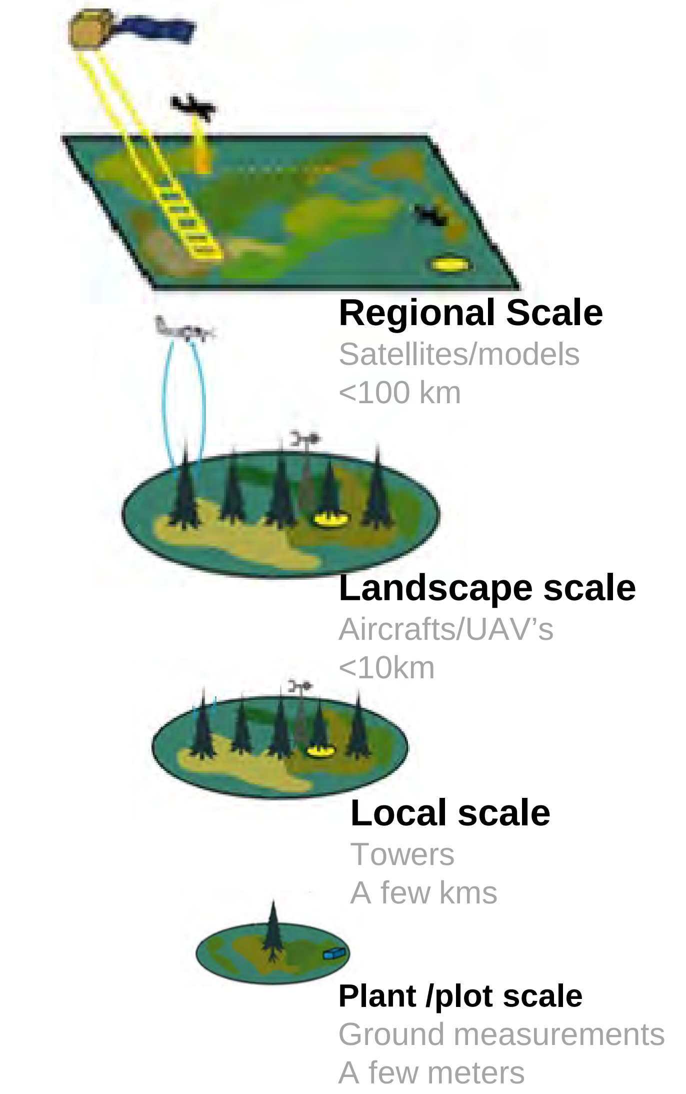
Surface energy fluxes **Water cycle** **Carbon cycle**



Bonan, 2008

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]

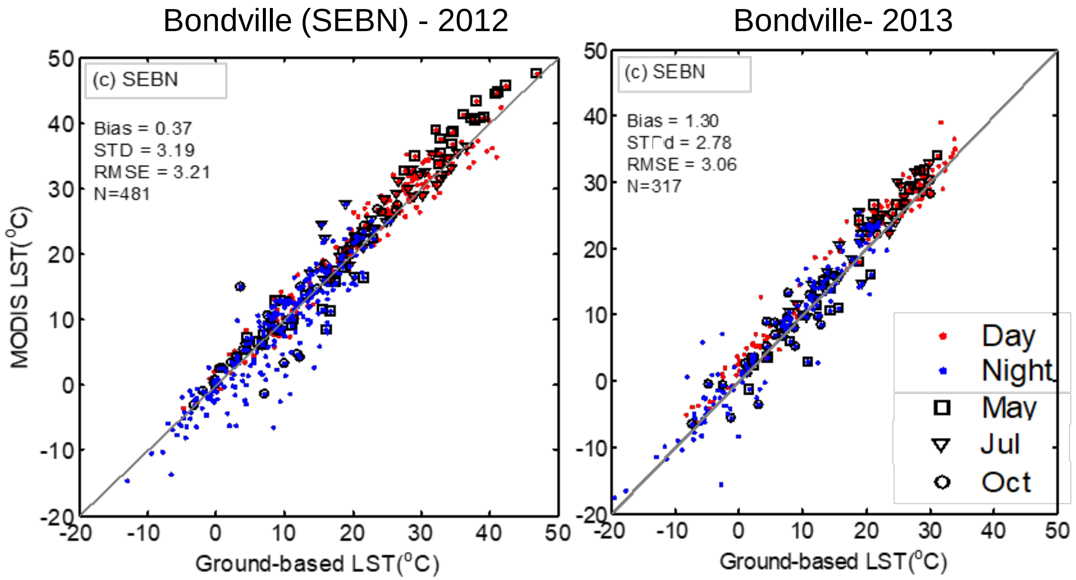
Supports NOAA's Mission to understand and predict changes in climate, weather, oceans, and coasts.

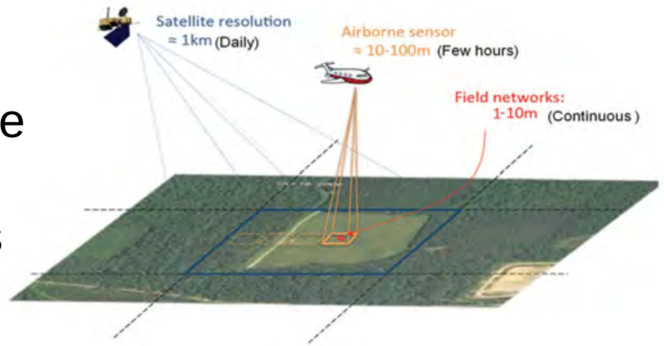
Land Surface Temperature (LST) measurements

- 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

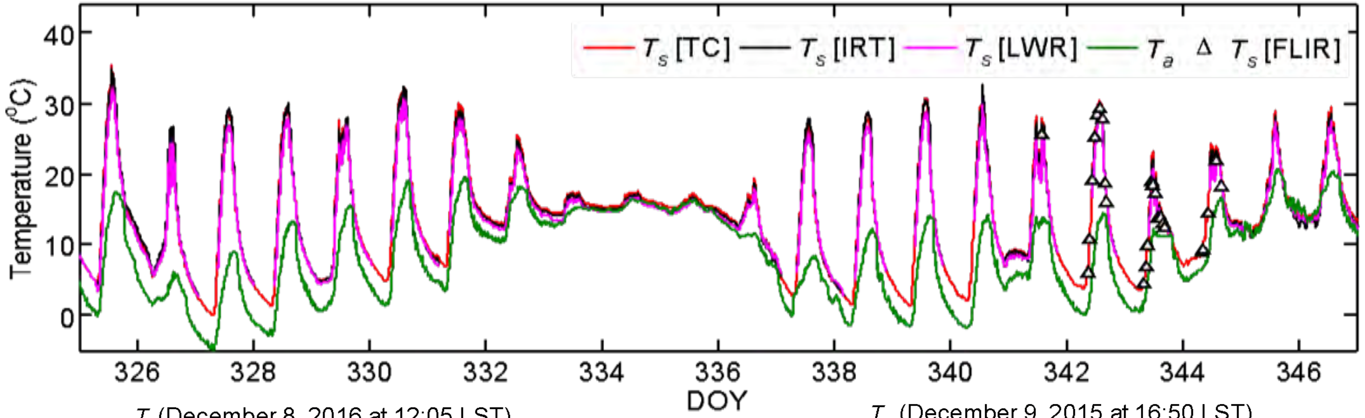


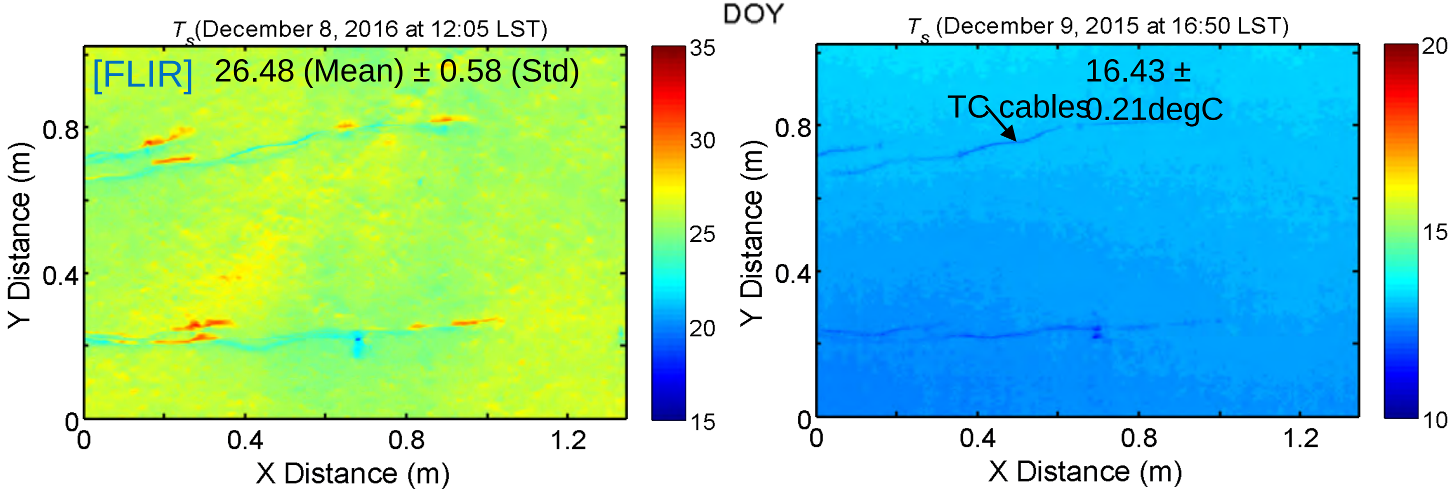


- ❑ Campaign mode observations using tower, aircraft and satellite LSTs
- ❑ Other participating sites USCRN, SURFRAD, SEBN, ENERGY FARM, SOYFACE

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.)

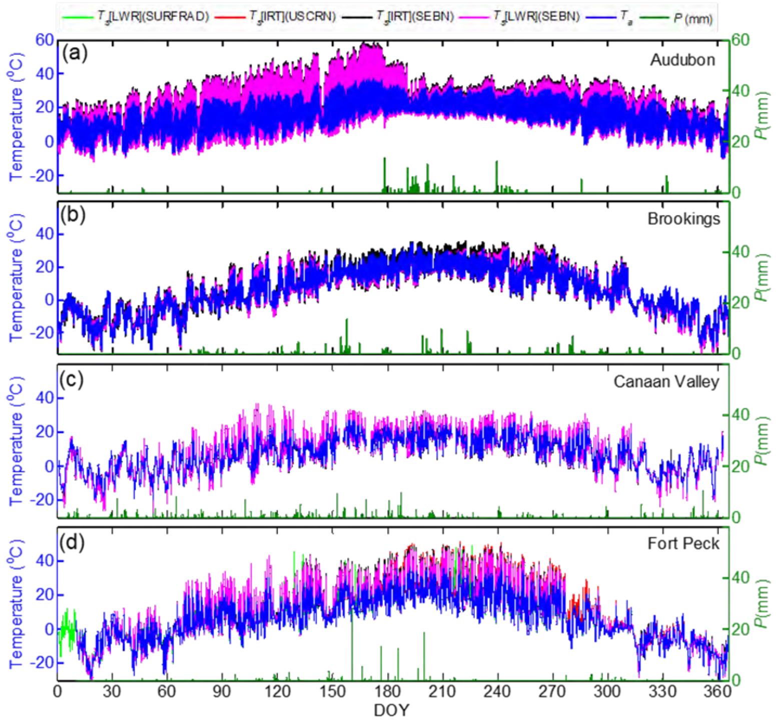
Location –ATDD parking lot
(10 Oct. 2015 to 8 Jan. 2016)

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

Krishnan et al., 2020, Sensors

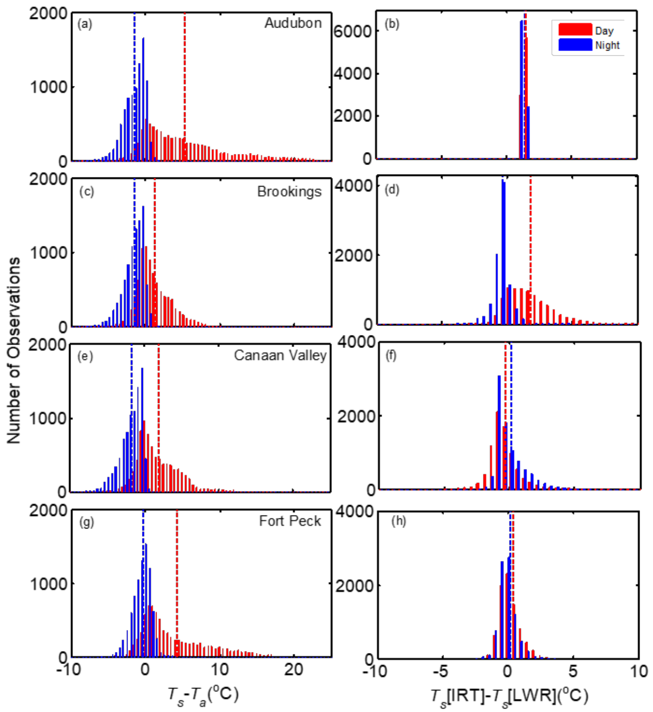
Collaboration with Jet Propulsion Laboratory

Accuracy of ground-based LST measurements



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

- ✓ 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*)



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 CO_2 & CH_4 flux measurements

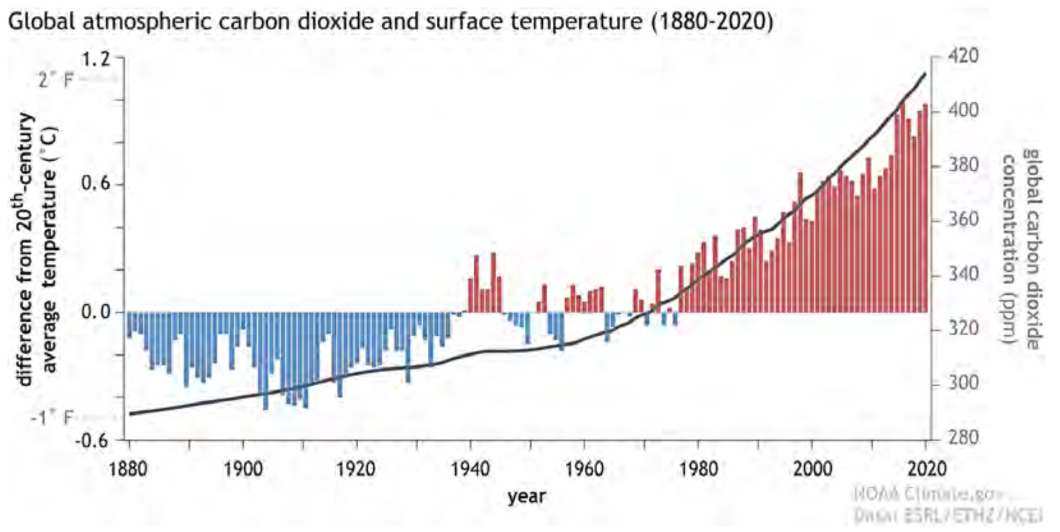
Motivation

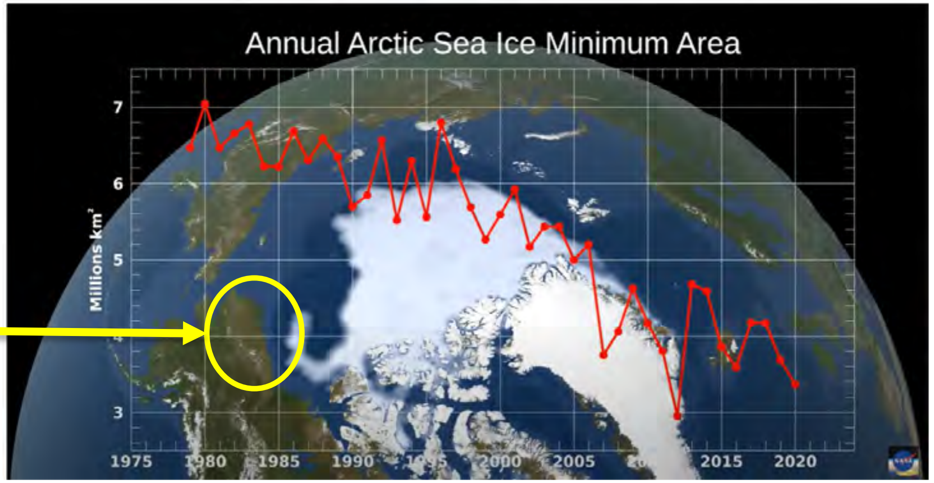
- The Arctic is warming at twice the global average and it can lead to thawing of permafrost and unquantified carbon emissions into the atmosphere in the form of CO_2 and CH_4

- A better understanding of the drivers of CO_2 and CH_4 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





Tower and Aircraft –based CO_2 & CH_4 fluxes during FOCAL

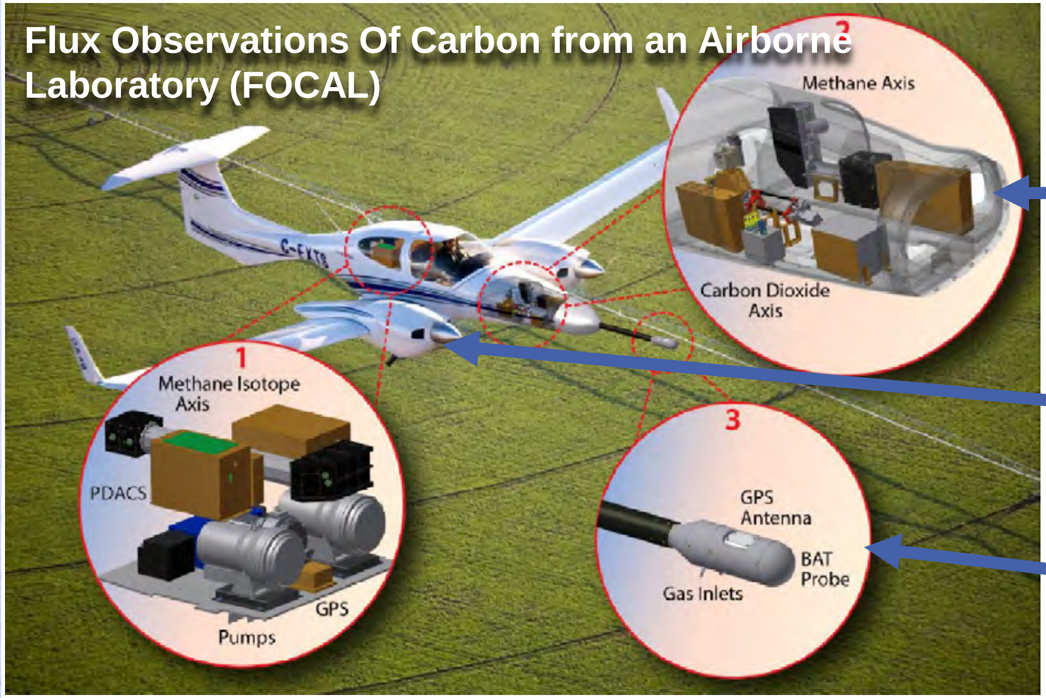
OBJECTIVE

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

Collaborators

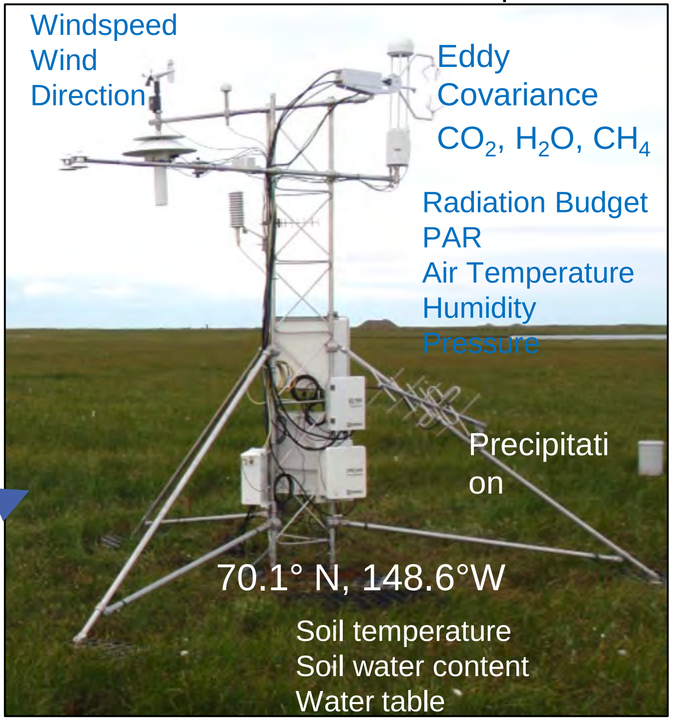
Funding by **NSF**



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

NOAA/ATDD tower at Northern Slope of Alaska

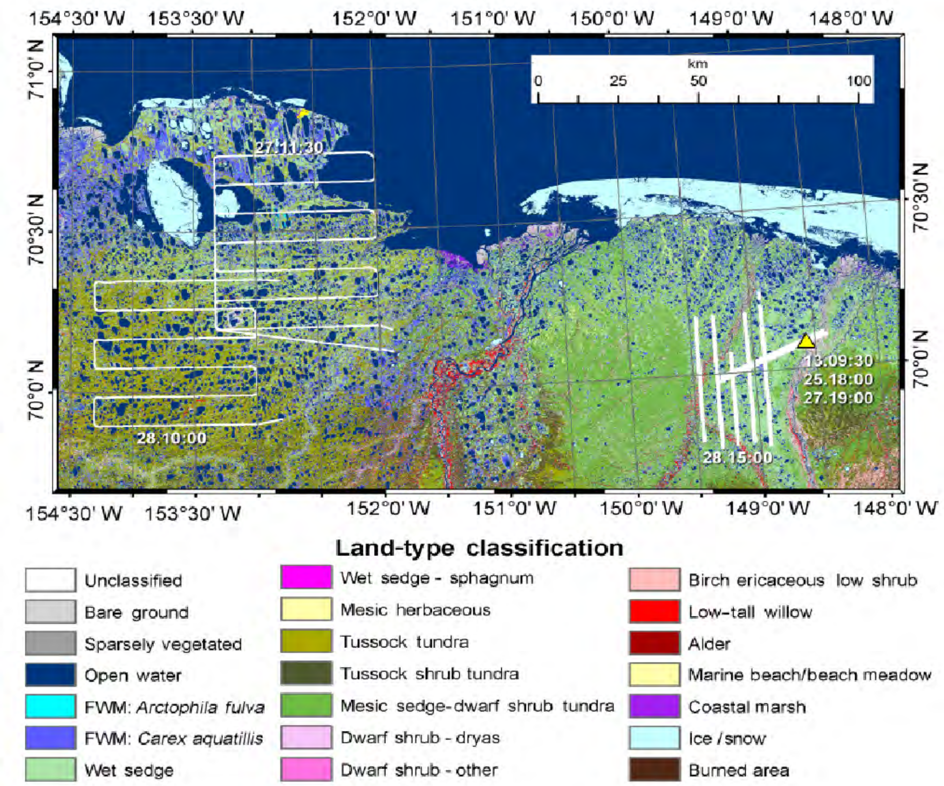


Aircraft–based flux measurements in the Arctic

FOCAL system flying near the
NOAA/ATDD flux tower in North Slope, AK.

- The FOCAL campaign during the summer of 2013 demonstrated how CH_4 fluxes could be successfully measured over large regions using airborne eddy covariance measurements from a small, low-flying aircraft (*Sayres et al*., 2017, ACP)

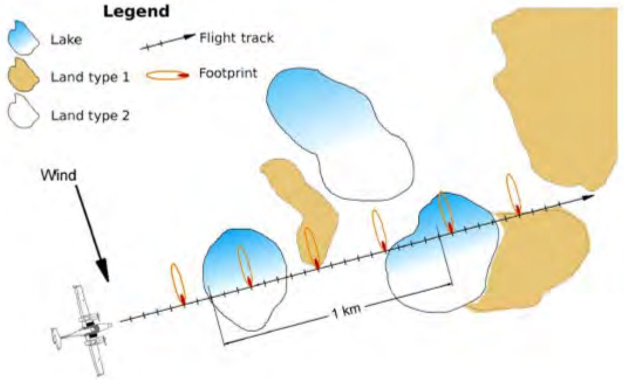
- The **first** airborne eddy-correlation flux measurement of isotopologues of CO_2 and CH_4 in the Arctic

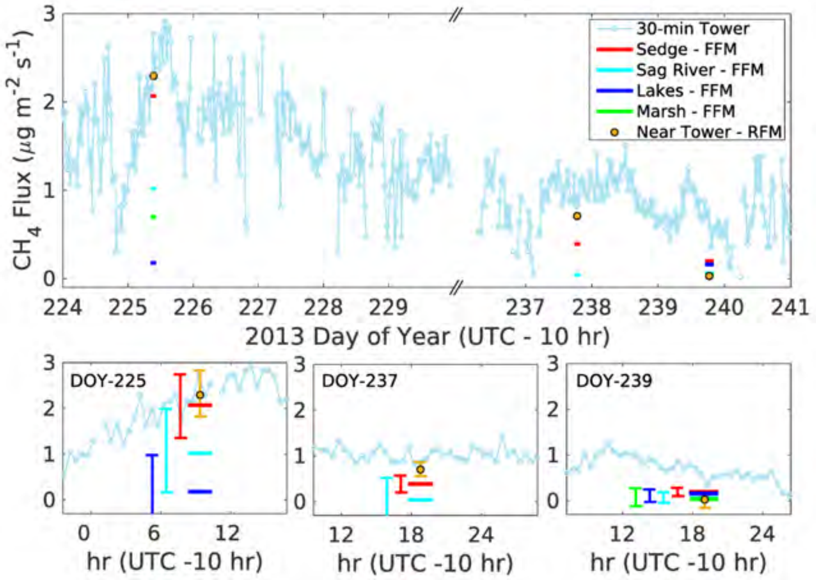


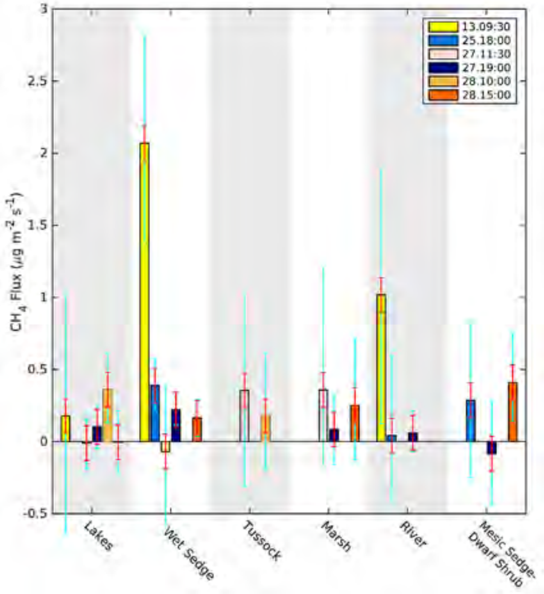
- Distinguish fluxes from different surface types over a heterogeneous landscape is very challenging

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*)



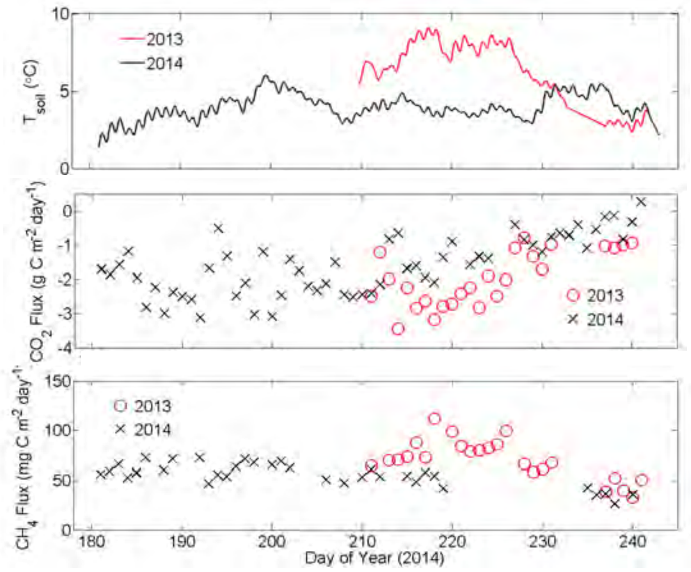


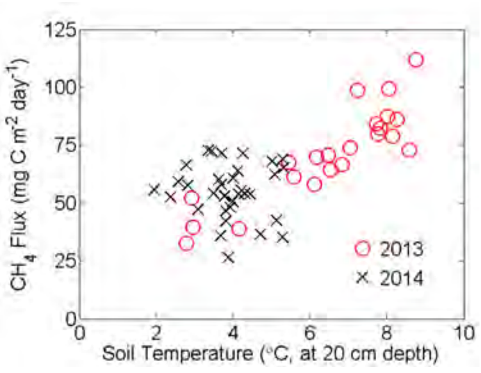


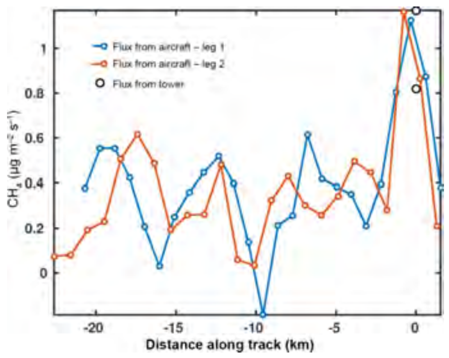
- Good agreement between airborne and tower based flux measurements when there was good overlap between the tower footprint and aircraft footprint

- The contribution to the total methane flux from individual land classes(*Sayres et al., 2017*)

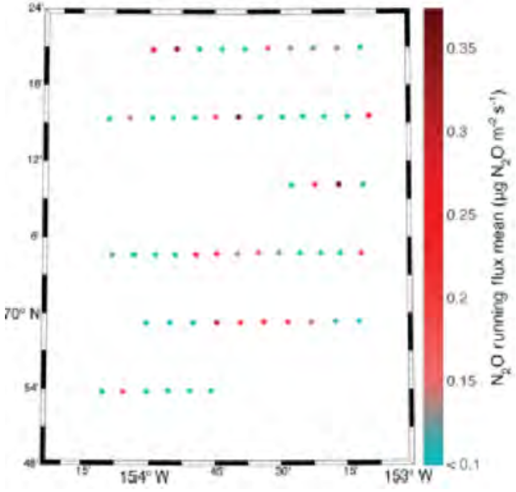
Tower and aircraft-based flux measurements







- ❑ Airborne eddy-covariance technique is also used to make in situ N_2O flux measurements

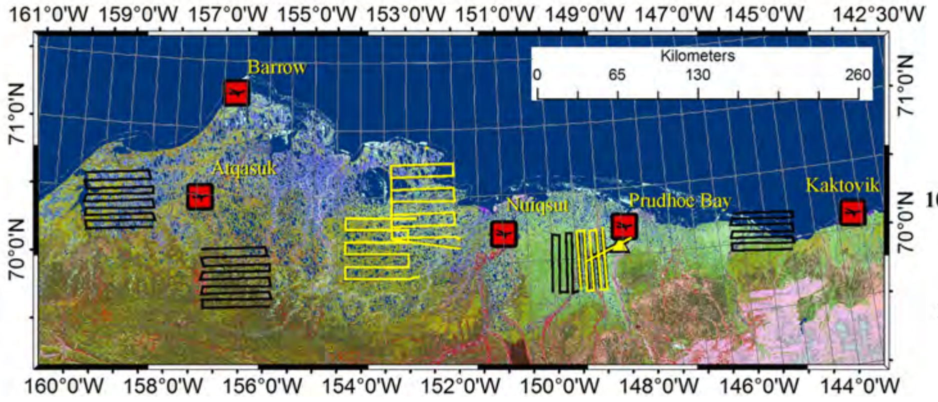


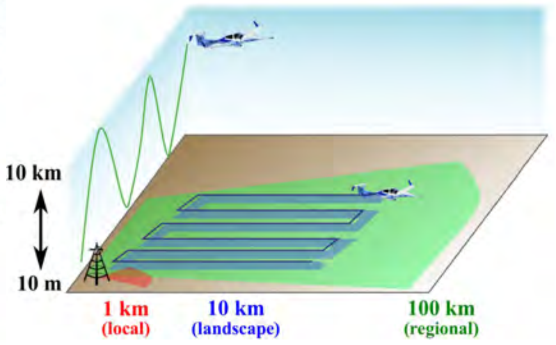
- ❑ Increased CH_4 emissions and CO_2 uptake were observed during warmer soil temperatures and increased photosynthetically active radiation

- ❑ The warm soil produced strong methane emissions
- ❑ Spatial heterogeneity even over relatively short distances

- ❑ Large variability of N_2O fluxes with many areas exhibiting negligible emissions (2.2–4.7) mg N_2O m^{-2} d^{-1} (*Wilkerson et al. 2018)*

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 CH_4 and CO_2 from the North Slope and adjoining Arctic waters
- ➢ Assess how the net CH_4 and CO_2 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

- Krishnan, P., T.P Meyers, S. J. Hook, M. Heuer, D. Senn, E. J. Dumas (2020), Intercomparison of in-situ sensors for ground-based land surface temperature measurements, **Sensors** , 2020, 20(18), 5268; https://doi.org/10.3390/s20185268
- Wilkerson, J., R. Dobosy, D. S. Sayres, C. Healy, E. Dumas, B. Baker, and J. G. Anderson (2019), Permafrost nitrous oxide emissions observed on a landscape scale using the airborne eddy-covariance method, **Atmospheric Chemistry and Physics**, 19 (7), 4257-4268, doi:10.5194/acp-19-4257-2019.
- Dobosy, R., D. Sayres, C. Healy, E. Dumas, M. Heuer, J. Kochendorfer, B. Baker, and J. Anderson (2017), Estimating random uncertainty in airborne flux measurements over Alaskan tundra: Update on the Flux Fragment Method, **Journal of Atmospheric and Oceanic Technology**, doi: 10.1175/JTECH-D-16-0187.1.
- Sayres, D. S., R. Dobosy, C. Healy, E. Dumas, J. Kochendorfer, J. Munster, J. Wilkerson, B. Baker, and J. G. Anderson (2017), Arctic regional methane fluxes by ecotope as derived using eddy covariance from a low-flying aircraft, **Atmospheric Chemistry and Physics,**17(13): 8619-8633; doi: 10.5194/acp-17-8619-2017.
- Huang, M., P. Lee , R. McNider , J. Crawford , E. Buzay , J. Barrick , Y. Liu , P. Krishnan. Temporal and spatial variability of daytime land surface temperature in Houston: Comparing DISCOVER-AQ aircraft observations with the WRF model and satellites, **Journal of Geophysical Research - Atmospheres**(2016)-doi:10.1002/2015JD023996.

Impact Factor
ACP= 6.1
JGR=4.261
Sensors=3.576

Quality and Performance

Presentations(7)

- Krishnan, P., Meyers,T.P., Hook, S.J., Heuer, M., Senn,D., E.J. Dumas , An intercomparison of ground-based land surface temperature measurements, **AGU Fall Meeting**, 7-11 Dec, 2020
- Wilkerson, J. P. , Dobosy, R. , Sayres, D. S. , Anderson, J. G., Significant Permafrost Nitrous Oxide Emissions Observed on a Regional Scale, **AGU Fall Meeting**, Washington, D.C., 2018
- Ronald J. Dobosy, P. Krishnan, E. J. Dumas Jr., D. S. Sayres, and C. E. Healy, Sources and Estimates of Uncertainty in Fluxes from Aircraft, 96th **AMS Annual Meeting**, 10–14 January, 2016 New Orleans, LA
- Wilkerson, J. P. , Sayres, D. S. , Dobosy, R. , Anderson, J. G., High Arctic Nitrous Oxide Emissions Found on Large Spatial Scales, **AGU Fall Meeting**, New Orleans, LA, 2017.
- Sayres, D. S., R. Dobosy, J. Kochendorfer, J. Wilkerson, and J. G. Anderson, Methane eddy covariance flux measurements from a low flying aircraft: Bridging the scale gap between local and regional emissions estimates, **AGU Fall Meeting**, New Orleans, LA, 2017
- Sayres, D.S., Dobosy, R., Healy, C., Munster, J., Dumas, E., Kochendorfer, J., Baker, B., Langford, J., Anderson, J.G., Using In Situ Eddy Covariance Flux Measurements from a Low Flying Aircraft in the Arctic to Measure Methane Fluxes Regionally**, AGU Fall meeting,** San Francisco, CA, 2016.
- Wilkerson, J. P. , Sayres, D. S. , Dobosy, R. , Healy, C. E. , Anderson, J. G., Aircraft-Based Eddy Covariance Fluxes of Nitrous Oxide over the Alaskan North Slope, **AGU Fall Meeting**, San Francisco, CA, 2016

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

LST measurements over Chestnut Ridge Site