# Carbon Dynamics Working Group

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<th>Member Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Sue Natali (Chair)</td>
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<td>Bill Munger</td>
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<td>Walt Oechel</td>
<td>San Diego State University</td>
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<td>Neal Pastick</td>
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<td>Dave Risk</td>
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<td>Brendan Rogers</td>
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<td>Steve Wofsy</td>
<td>Harvard University</td>
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<tr>
<td>Debra Wunch</td>
<td>University of Toronto</td>
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## Carbon Dynamics Projects

- Gamon-01
- Kimball-04
- Meyer-01
- Miller-C-01, 02, 03
- Moghaddam-03
- Munger-03
- Natali-01
- Striegl-01 *(Hydrology)*
- Wilson-01
- Keeling-08
- Miller-05
- Munger-04
- Neigh-01
- Oechel-01
- Rocha-01
- Rogers-02
- Sweeney-01
- Wunch-01
Institutional Collaborations

**Federal & State Agencies**
- Environment Canada
- National Park Service
- USDA
- USGS
- US Fish & Wildlife Service
- DOE/NGEE-Arctic
- DOE/ARM NSA & ARM Airborne Facility
- NOAA
- Natural Resources Canada
- NWT Geoscience
- Alaska DNR Division of Geological and Geophysical Surveys
- NSF Arctic Observing Network
- NASA Atom airborne campaign

**Other Stakeholder Organizations**
- Alberta Biodiversity Monitoring Institute
- Alaska Ecoscience
- Atmospheric and Environmental Research
- Flux Tower sites
Science Objectives

- *Elucidate how climate change and disturbances interact with above- and belowground communities and processes to alter carbon biogeochemistry, including release to surface waters and the atmosphere (Objective 2)*
  - impacts of snow distribution on carbon biogeochemistry (Objective 4)
  - greening and browning trends and their impacts on ecosystem form and function (Objective 5)
Field Measurements, overview

1. Carbon fluxes from terrestrial and aquatic sites
2. Soil & water carbon pools and OM composition
3. Water environ. parameters (e.g., temp, pH)
4. Optical phenology
5. Soil moisture and temperature, thaw depth
6. Streamflow & hydrological measurements
## Field Measurements
### Pre-existing Networks

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Location</th>
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<tbody>
<tr>
<td>CO₂ and CH₄ fluxes, Eddy covariance towers</td>
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<tr>
<td>Atmospheric trace gases: CO₂, CH₄, CO from tall towers</td>
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<tr>
<td>Optical phenology, Eddy tower sites</td>
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<td>Active Layer Depth, CALM Network and tower sites</td>
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<tr>
<td>Active layer and permafrost temperatures, Borehole network</td>
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<tr>
<td>Meteorology and environmental parameters, tower and other sites</td>
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Current Field Locations

- Rocha-01
- Meyer-01
- Striegl-01
- Moghaddam-03
- Natali-01
- Kimball-04/Oechel-01
Field Research Highlights

Striegl-01

• Lake water quality & dissolved CO$_2$ sensors at 2 lakes
• Lake chemistry & fluxes at 20 lakes in Yukon Flats, AK
• Stream and permafrost seep carbon chemistry, flux & flow network established at ~8 catchments in AK

Meyer-01

• Bubble surveys completed for SAR validation
• Historical optical images rectified; historical & current lake mapping completed
• Quantified CH$_4$ emissions from thaw lakes (Walter Anthony et al., Nature Geo 2016)
Field Research Highlights

Kimball-04

- **Eddy covariance flux retrievals** at Barrow, Atqasuk and Ivotuk
- Installing **soil temperature & moisture network** in and adjacent to the flux tower footprints at **Ivotuk and Atqasuk** in summer 2017

Gamon-01

- **Eddy covariance CO₂ flux data collected** from across ABoVE domain
- **Partitioning 16 years of flux tower NEE data** to develop consistent data record

Natali-01

- **Automated soil CO₂ flux systems, temperature & moisture probes** installed at 10 AK sites
- **Vegetation/soil surveys** at these sites

Moghaddam-03

- **Soil moisture sensors** installed at two locations w/ satellite communication
Field: lessons learned & synergies

• **Lessons learned** & impacts on 2017 field
  – Natali: instrumentation issues highlight the need for remote communication; 2 sites may be relocated; increase power supply
  – Moghaddam: based on field observations of soil structure, update radar models for organic soils.
  – Moghaddam: more extensive sampling of organic soils within the radar flight tracks

• **Identified synergies** with other WG projects
  – Moghaddam: soil moisture sensor installation near Natali sites; collaboration Tabatabaeenejad
Airborne RS: Plans & measurement needs

- **Gamon**: Compare **SiF data** from airborne measurements to GPP estimates from reflectance indices
- **Moghaddam**: Conducting 3 sets of flights of **L-band and P-band radars** (UAVSAR and AirMOSS) in Alaska and additional lines that extend to Canada.
- **Moghaddam**: Produced **maps of active layer thickness** and preliminary maps of **soil moisture content** for most of the existing AirMOSS+UAVSAR flight lines acquired in 2015
- **Meyer**: Continue to collect **aerial photos of frozen lakes** for remote sensing analysis of methane seeps associated with lake ice
Airborne results: CARVE

- More than 50% of the North Slope CH$_4$ flux occurs during the cold season (Zona et al., PNAS, 2016)
- No significant increase in long-term CH$_4$ emissions from North Slope Alaska (Sweeney et al., GRL, 2016)
- Alaska CH$_4$ fluxes (2012-2014) estimated from CARVE (S. Miller et al., GBC, 2016)
Satellite Remote Sensing, overview

- Land cover
- Vegetation indices (NDVI, EVI)
- Plant productivity
- Snow cover
- Surface temperature
- Ground freeze-thaw state
- Soil moisture
- Albedo
- Surface reflectance
- Atmospheric CO$_2$ and CH$_4$
Remote sensing updates

• **Gamon-01:**
  – Analysis of **MODIS**, meteorological & CO$_2$ flux data from tower sites within the ABoVE domain
  – Application of MODIS-derived **Chlorophyll:Carotenoid Index (CCI)** as indicator of photosynthetic phenology ([Gamon et al., PNAS 2016](#))
  – Examining sun angle and viewing angle effects on reflectance values and vegetation indices (MODIS MAIAC C6); **products to correct for angular effects**

• **Striegl-01:** Remote sensing analyses of lake distribution & color; vegetation & ground surface conditions
Remote sensing updates

- **Kimball-04**: Data from > 14 eddy covariance sites used to calibrate/validate **remote sensing based terrestrial carbon flux model**, output daily at a 1-km resolution

- **Moghaddam-03**: Plan to incorporate PALSAR-2 & Sentinel-1/2 into analyses. Upscale from airborne tracks to regional/statewide scale

- **Natali-01**: EVI (MOD13Q1) as driver of pan-Arctic non-growing season respiration
Modeling goal: Quantify patterns and variations in carbon exchange across ABoVE region

- Assess processes within local-scale models
- Use models to scale up field measurements to the larger region
- Integrate field data & remote sensing w/ global terrestrial biosphere models (Fisher)
# Models & applications

<table>
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<tr>
<th>Type of Model</th>
<th>Applications</th>
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<tbody>
<tr>
<td>Light-use efficiency model</td>
<td>Changes in <strong>plant phenology &amp; productivity</strong> (Gamon)</td>
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<tr>
<td>Satellite-driven carbon model</td>
<td><strong>CO₂ &amp; CH₄ fluxes and environmental controls</strong> on the net ecosystem carbon budget (Kimball)</td>
</tr>
<tr>
<td>Talik, regression &amp; GIS models</td>
<td><strong>permafrost thaw effects on CH₄</strong> release from lakes (Meyer)</td>
</tr>
<tr>
<td>Community Land Model, w/ meteorology &amp; sea ice:</td>
<td><strong>Impacts of a seasonally sea ice-free Arctic</strong> on permafrost, snow cover, biogeochemical cycling (Miller)</td>
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<tr>
<td>Geostatistical inverse modeling</td>
<td><strong>Net ecosystem exchange</strong> and parameters that explain <strong>variability</strong> in carbon fluxes (Miller)</td>
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<tr>
<td>Lagrangian particle dispersion modeling</td>
<td><strong>CO₂ &amp; CH₄ flux</strong> for the Mackenzie basin (Miller)</td>
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<tr>
<td>CO2 flux models w/ map of active layer properties</td>
<td>Impact of <strong>permafrost soil dynamics and surface hydrology on carbon flux</strong> (Moghaddam)</td>
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<tr>
<td>Ecosystem model of greenhouse gases</td>
<td>assess whether <strong>changes in climate and vegetation are leading to detectable large scale changes in carbon exchange</strong> (Munger)</td>
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<tr>
<td>Statistical model</td>
<td><strong>Drivers of winter CO₂ emissions</strong>, response functions (Natali)</td>
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Modeling updates

- **Kimball**: Data from > 14 eddy covariance sites being used to calibrate/validate a remote sensing based Terrestrial Carbon Flux model, output daily at a 1-km resolution.

- **Moghaddam**: Collaborative w/ Kimball’s group—modeling permafrost active layer dynamics & sensitivity to landscape spatial heterogeneity.

- **Gamon**: Statistical & machine learning methods to understand how new MODIS dataset relates to fluxes, as foundation for GPP modeling.
Education, Outreach & Stakeholder Engagement

- Several new **postdocs & graduate students** on a number of CDWG projects
- **Collaboration with USFWS and the Western Boreal LCC;** field support from Yukon Flats National Wildlife Refuge (*Striegl-01*)
- **Collaboration with ARCUS to establish STEM outreach with remote Alaska Native communities,** focused on validation of NASA/ABoVE remote sensing data products and collection of thaw depth, snow cover, soil moisture, soil temperature, and land disturbance data (*Kimball-04*)
- **Coordination of data sharing with the NPS Inventory & Monitoring Networks** in preparation for upcoming airborne activities (*Kimball-04*)
- Working to **engage Canadian colleagues** in ABoVE activities (*Kimball-04*).
- Vegetation and thaw depth **data sharing with Yukon Delta National Wildlife Refuge** (*Schaefer-05, Natali-01*)
- Field work with high school teacher and students; **integrating ABoVE CO₂ flux data into high school curriculum** (*Natali-01*)
- Presentation about lake **CH4 emissions for middle school students** in UAF’s AK Summer Research Academy (*Meyer-01*)
- Methane lake emissions research featured in social media and many **print, radio and television interviews** (*Meyer-01*)
Gaps/needs

- Soil moisture, soil organic content, and ALT data from Canada for airborne cal/val
- Data from Canadian sites, esp winter CO₂ flux
- CH₄ oxidation: drivers, magnitude & variation across ABoVE domain
- Integration of terrestrial and aquatic fluxes, using airborne, field sampling and satellite data
- High resolution 3-km Polar WRF reanalysis fields for the ABoVE domain through 2018 (currently 2012-2016)
- Integration among groups through joint working group meetings—especially with hydrology/permafrost
- CDWG co-leads w/ expertise in modeling/remote sensing