Expert Workshop on Coupled Terrestrial Monitoring

Boulder | March 24 2025

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Summary

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Coupled Terrestrial Monitoring

Boulder, March 24, 2025

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Introduction

A scientific/technical expert workshop jointly organized by Permafrost Pathways and the Arctic Monitoring and Assessment Programme (AMAP) Secretariat took place at the Arctic Science Summit Week (ASSW) in Boulder, CO USA on March 24th, 2025.

22 experts with experience on greenhouse gas fluxes and monitoring systems attended the workshop online or in-person for plenary and break-out group discussions to advance the thinking around what a future Arctic coupled climate monitoring network might look like and what specific guidelines would best enable its operationalization.

Rationale

This workshop was part of a larger exploratory discussion on the pathway to designating AMAP as a coordinating entity for a pan-Arctic carbon monitoring strategy with the objective of enabling more accurate estimates of Arctic terrestrial-based greenhouse gas fluxes. AMAP has a long tradition of developing integrated systems for monitoring contaminants to provide data that supports its assessment work, and a similar approach for monitoring climate variables would be beneficial.

Background information

The first Arctic monitoring network preliminary workshop organized by Permafrost Pathways and AMAP was held in Reykjavik in October 2024. The report from that workshop can be found here. To move forward the discussion, topics raised at the expert workshop at ASSW were:

- Pathways for coupling existing monitoring systems collecting data on soil processes, ecosystem processes, and abiotic/atmospheric processes for robust monitoring
- Potential solutions to resource and funding limitations, including the use of shared research infrastructure (such as the Integrated Carbon Observing System (ICOS))
- Research priorities, existing methodologies, and critical expertise that should inform future governance solutions, including updated monitoring guidelines from AMAP

Expected Outcomes

The workshop intended to generate concrete output to advance the research of participants and respective research communities, including inputs and directions for updating the AMAP monitoring guidelines that will allow for more streamlined data sharing and use among researchers and policymakers tasked with responding to the climate crisis. The goal was also to increase engagement from monitoring and modeling experts to the AMAP assessment processes.

Findings from the Workshop

The appendix includes notes from the workshop that will serve as a starting point (together with the report from the Workshop in Reykjavik in 2024) for developing a white paper and/or a peer-reviewed paper in a scientific journal to make recommendations for consideration to AMAP or other stakeholders for harmonizing systems for monitoring greenhouse gas fluxes in the Arctic.

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ANNEX 1: ASSW Workshop Notes

Key Takeaways

- There is high interest in preparation of a **peer-reviewed paper, white paper, and/or EOS or similar story**
- Annual coverage, super-sites, representation/heterogeneity, timely reporting/data, and more collaboration between networks and groups were consistently highlighted

Expert Panel: (Panelists; Lori Bruhwiler, Aleksandr Makarov, Craig Tweedie, Vladimir Romanovsky, Colleen Iversen):

1. What has worked regarding keeping networks going

- Consistent funding is required to keep networks going long term
  - E.g., GTNP is now getting funding from AWI
- Early career scientists are more willing to share data
- People are the best resources for long term monitoring, dedicated people need to be a priority when it comes to funding
- If data sharing is mandated and supported by funding agencies, it is much more likely that datasets will be available and in a curated good format

2. What is needed to build a better coupled monitoring network:

- Participants agreed that there is enough interest in the community
- Sharing of infrastructure/resources is crucial
- Good people are needed, consistency in measurements and knowledge
- Co-location of coupled measurements would be helpful, especially if we want to use data for modeling purposes
- Models need the 'boring' data too (e.g., soil characteristics), Meta-data are absolutely crucial and a more consistent format of what meta-data are would be helpful too -> we need to do a better job with ancillary data
  - *This is where coupled networks are necessary, where certain factors may not be pertinent to the site PI but are of use to the broader community*
- Collect information for a site and location of what has been measured before and what the history of a site is i.e., better metadatabase
- Long-term measurements are necessary to account for interannual variability

-> if you are doing a short-term experiment at a given location putting that in context to long-term trends would be really helpful

Panel Discussion:

- Paleo measurements need to be better included to close the Arctic carbon budget in order to understand the source of carbon emissions
- Better integration of disturbances into coupled monitoring, ideally short- and long-term
- High-resolution where possible, RECCAP3 is now starting and hoping to improve some of the gaps in carbon accounting (bottom-up vs top-down)
- There was some discussion around 'we are not in a data-deficit' necessarily for every variable or region, some data is under-utilized, models need to be challenged with the data that is out there, make use of what is available, collecting more data is not always the only important thing
- Protocols for everything measured are very important, sometimes things exist and have been collected but they aren't stored or published in the same place it might require a bit of work to go through datasets -> graduate assistants?
- PCN has done a great job of bringing together different datasets and requesting datasets (published and unpublished)

Breakout Groups

1. Ambition (What does an ideal monitoring system look like), lead: Merritt Turetsky

- a. Co-location and transdisciplinary measurements at sites
    - i. Detailed soil map, active layer temperatures, at least one permafrost core from each ecotype, biomass and vegetation maps
- b. Harmonized and searchable metadata
- c. Embrace heterogeneity and cover spatial variability
    - i. Could be in the structure of a core long-term site with smaller surrounding sites to fully capture heterogeneity
    - ii. Tower and chambers to parse apart landscape types
- d. Year-round automated stations
- e. Remote sensing products that operate during polar night
- **f. Next Steps**
    - ***i. Near-term***
        1. Review paper assessing best upscaling design and ideal tower network placements or super sites
        2. Metadata protocol

- ii. ***Mid-term***
    1. Resurrect metadata for existing datasets
    2. Better methods for $14CH_4$ (emphasis on understanding old carbon vs new carbon respiration)
- iii. ***Long-term***
    1. Instrument commercial aircraft and cell towers
    2. Establish long-term coupled sites

g. Many easy access, low hanging fruit sites are already covered, a network extension may need to include harder to reach places

h. Increased monitoring should be steered towards areas where some, but not all, measurements already exist
- i. Co-location of measurements is key, fully coupled, land, atmosphere, and aquatic

i. Near real-time could be great, at least an approximately 1-year lag at most
- i. Issue with how to operationalize and incentivize near real-time data processing and publication

j. Should also utilize satellite data and consider machine learning-based upscaling and develop data assimilation frameworks for this

k. Long-term trends are key, will not be able to analyze trends and change without long-term data

2. Logistics and Infrastructure; Lead: Kyle Arndt

a. Utilize existing infrastructure
- i. Cell towers for tall tower measurements
    1. Greenhouse gas concentrations along with carbon monoxide (CO) to remove anthropogenic signal
    2. Cell towers are in Arctic communities and along existing infrastructure (e.g., roads, pipeline etc.), could help in regional scale inversions

b. Coastal issue
- i. Many sites are coastal (i.e., within a few km) which are outside of remote sensing products due to water masks and buffers

c. Utilize super sites

d. What is “good enough”. If we can decide on a minimum resolution/accuracy/precision for different factors we could utilize cheap sensors

e. A statistical approach on which sites are needed should be used, both in current network and ideal network

f. Missing factors
- i. Disturbance features

   ii. Aquatic ebullition measurements
   iii. Lake edge and coastline measurements
   iv. Ice-out timing/fluxes
   v. Ice cores of lakes for gas concentrations to understand winter/spring flux
   vi. Lake temperature profiles

g. Airborne platforms should be used to link scale
h. Year-round tall towers necessary for polar winter and cloudy days, satellites are getting better but will not get over these obstacles for inversions
i. Need to decide what scale is appropriate and the definition of regional
j. Utilize the INTERACT network for super-sites
k. Install temperature profiles in boreholes when taking cores (i.e., infrastructure and resource sharing)
l. Start with cross-network collaboration, where do we have some but not all measurements?
m. Local partners needed for maintenance should involve local communities throughout
n. A network could look like an ITEX network but for Arctic fluxes
o. Utilize local programs depending on what exists
   i. Land guardians in Canada
   ii. Maniilaq in NW Alaska
   iii. Alaskan Native Health Consortium
   iv. Dept of environmental health
   v. IGAP
p. Be sure to include whole ecosystem in representation
   i. Aquatic, whole land surface, interfaces
q. C14, old carbon vs new carbon, correlate to thaw rates
r. Energy sources for equipment are an important consideration, need year-round data
s. It would be useful to know what infrastructure (transport, housing etc.) is available at existing towers, boreholes, etc.
t. Adequate computing resources are required by modelers
u. Could use more vertical profiles and satellite remote sensing, e.g., TCCON sites
v. Personnel are important and scarce, even in places with year-round residents. Support for meaningful full-time work is necessary
w. Could “portable” short-term tower deployments be utilized
   i. Advances in energy technology and lithium batteries
      1. Issue: lithium batteries are hazardous and more difficult to transport via air
x. CIRES in Boulder has an autonomous monitoring setup that works in the winter
y. Knowledge exchanges are crucial and can be very helpful

z. shorter-term projects are not as appealing to communities, could AMAP help provide support for community training and engagement?

3. Data; Lead: Kate Petersen

a. Different funders have different obligations towards making data available
b. A pan-arctic data hub could be useful
    i. Example of NSF Arctic data center
c. Need to ensure data standards
    i. Units
    ii. Positive and negative delineations
        1. E.g., water table, are positive values above or below surface?
        2. Is positive a sink or source for a carbon flux?
d. Data sovereignty is an important factor
e. Time lags
    i. Waiting for publication and data processing can delay data availability
    ii. Could preprints or preliminary data standards aid in faster publishing?
f. What benefits are there for data holders to publish faster and more regularly?
    i. Citations
    ii. collaboration/co-authorship
        1. Real co-author participation (i.e., not just data sharing) could lead to higher quality results
g. AON has 33 data centers
    i. Shared catalogs through data ONE (https://www.dataone.org/)
h. NOAA OBS-PAC for atmospheric
    i. Some data are not standardized here
i. Many repositories exist with different limitations and restrictions
    i. ESS-DIVE, some DOE data is private
    ii. NSF Arctic data center, mostly only NSF funded
j. A central Arctic data hub or portal would be ideal
    i. This would need a synthesis coordinator
        1. Similar to Ameriflux management project
        2. NEON good model but limited in scope like ICOS
k. Do data-sharing incentives have to be top-down? Like a mandate? Or can a scientist-to-scientist norm/network work better?
    i. Example CMIP
        1. Easy access
        2. High awareness
        3. International
        4. Began at the grass roots level
    ii. Start with certain data streams

l. Need good metadata
m. AMAP could be coordinator of networks
n. ecoflux-lab.github.io
    i. Resources to help data standardization and processing for sites not already a part of standardized networks
o. WMO could be helpful in data sharing and funding for atmospheric data. Drawback may be motivation as weather is immediately important to lives and property
p. Getting timely processing and sharing of EC data will be key but may be a challenge
q. Could shared students/postdocs help motivation since many groups have more data than they have opportunity to work up and publish

4. Problem Solving & Opportunities, Lead: Chip Miller

a. One-stop shop solutions
    i. Coordination and not just collection of new data
b. Monitoring systems working towards an **operational data assimilation**
    i. Pan-arctic flux estimates
    ii. Large ensemble runs
    iii. Machine learning emulations in near-real time (maybe a part of AWARE, from Ted Schuur)
    iv. Observing System Simulation Experiments (OSSEs)
c. Better connection between modeling and observation teams
d. Consider heterogeneity of ecosystems
    i. E.g., Footprint models, wind direction from fluxes included
    ii. Heterogeneity of change, be sure to measure hot spots AND areas where no change is occurring. Both are important to understand
    iii. Consider representativeness in network design and data analysis
e. How can AMAP help?
    i. Data submission and availability
    ii. Data & metadata formats and protocols
    iii. Coordinate who is doing what and where to help connect different networks (**Craig Tweedie** has some similar maps)
    iv. Coordinate with all Arctic nations
f. Challenges
    i. Empirical complexity and variability are under-represented
    ii. Sites are decoupled across disciplines
    iii. Space-based observations may be misread or misleading
        1. E.g., greening signal
g. Can AMAP help with data sharing and push for long-term monitoring?

ANNEX 2: Attendees List

Experts:

In person participants: *Roisin Commane, Marie Frost, Alexander Kholodov, McKenzie Kuhn, Dave Lawrence, Colleen Iversen, Chip Miller, Vladimir Romanovsky, Merritt Turetsky, Craig Tweedie*

Virtual participants: *Lori Bruhwiler, Mathias Goeckede, Gustaf Hugelius, Sara Knox, Aleksandr Makarov, Ivan Marmarella, Isla Myers-Smith, Johanna Maard, Youmi Oh, Martijn Pallandt, Frans-Jan Parmentier, Virve Ravolainen*

Organizers:

Woodwell Climate Research Center: *Susan Natali (not present), Kyle Arndt, Kate Petersen, Brendan Rogers, Christina Schaedel, Melissa Shapiro (not present)*

AMAP Secretariat: *Sarah Kalhok Bourque (AMAP chair), Maria Malene Kvalevåg, Janet Pawlak, Rolf Rødven*

Arctic Initiative at Harvard Kennedy School: *Jennifer Spence*

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ANNEX 3: Program

Towards an integrated Arctic greenhouse gas monitoring program
24 March 2025 | 8:00-12:00 (MDT)
Onsite at ASSW2025 – Boulder, CO.
Room UMC Fourth Floor – 417 & Virtual (zoom link will be made available for remote participants)

8-10:00 AM | Session 1: Dialogue on existing approaches to coupled monitoring and pathways for improvement

8:00-8:30 Welcome and introduction of session purpose and goals

An overview of the workshop, which will focus on the coordination of an integrated pan-Arctic carbon monitoring network to enable more accurate and timely estimates of Arctic terrestrial-based greenhouse gas fluxes. Workshop attendees may consider:

- *Findings from the Arctic monitoring network preliminary workshop organized by Permafrost Pathways and Arctic Monitoring and Assessment Programme (AMAP) in October 2024 (see summary report);*
- *Examples of existing approaches and barriers to integrating monitoring systems and collecting data on soil processes, ecosystem processes, and abiotic/atmospheric processes for robust monitoring; and*
- *Actionable steps towards a fully realized coupled GHG monitoring system.*

8:30-9:15 Moderated Expert Panel

Panelists will briefly present and advise on approaches to better coordinate among monitoring systems collecting data on greenhouse gas fluxes and soil/permafrost, vegetation, aquatic, disturbance, abiotic/atmospheric, and other relevant ecosystem properties and processes.

9:15-9:50 Plenary Discussion

Participants will be invited to react to the expert panel, ask questions of panelists and other participants, and propose alternative solutions and challenges not previously identified.

9:50-10:00 Preview of Session 2

10-10:15 Coffee Break

10:15-11:45 AM | Session 2: Identifying actionable steps towards a coordinated monitoring program

10:15-11:30 Breakout

Breakout groups will be presented with a set of guiding questions that will support the identification of concrete and tangible short-term and long-term actions for improved coupled GHG monitoring systems.

11:30-11:45 Plenary Share Out

Participants will share highlights from breakout group discussions.

11:45-12 | Next Steps and Close

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For more information,
contact AMAP at www.amap.no

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