

CRAICC-PEEX Workshop on Carbon exchange in the soil – cryosphere – vegetation – atmosphere continuum

Feb 9-10, 2015, Cultural Center Sofia, Helsinki, Finland

Organizers: Jaana Bäck, Liisa Kulmala (Department of Forest Sciences, University of Helsinki), Tuomas Laurila (Finnish Meteorological Institute)

Background

The 2nd CRAICC-PEEX workshop brought together 43 participants from Russia, Sweden, Germany and Finland for several topical sessions on the carbon exchange research and the ecosystem research infrastructures in the Arctic and subarctic regions of Eurasia.

The aims of the workshop were to explore and enhance the collaboration possibilities among participants, to design the PEEEX observation infrastructure in carbon exchange research, and to search links between Nordic and Russian research and education activities. The different research networks and exchange programs, existing and potential funding possibilities and new research initiatives were discussed, as well as the issues on measuring the key processes and feedbacks, key regions and interactions between measurements and models.

The workshop was organized in a form of six sessions: 1) Net Biome Exchange; 2) Role of disturbances in carbon cycle; 3) Permafrost; 4) Enhancing unexplored fields; 5) Changing Arctic; and 6) Methane. Below the outcomes of these sessions are summarized by the session chairs, with some key recommendations of future research activities

Session 1: Net Biome Exchange (chair: Timo Vesala)

Martin Heimann (MPI for Biogeochemistry - Jena) gave a keynote talk on the status and prospects on GHG budgets of northern Eurasia. Fundamental biogeochemical questions are how carbon and methane budgets change with time and space, how sensitive they are to climate and what are the impacts from anthropogenic perturbations like forestry and fire. To answer to these questions a long-term in situ observation strategy complemented by remote sensing is needed. One good example on the long-term observation is Zotino Tall Tower Observatory (ZOTTO) and Cherskii-Ambarchik (CHE-AMB) station, which have produced a lot of valuable field data. The methods include both bottom-up (eddy covariance) and top-down (tall towers) approaches. However, the question remains: what are the opportunities to expand GHG observation network.

Tiina Markkanen and Tuula Aalto (Finnish Meteorological Institute) gave a short talk on carbon cycle studies based on a land surface model on vegetation-climate interactions. The further model development and validation for northern regions would benefit on collaboration in PEEEX providing test data and forcings. Liisa Kulmala (University of Helsinki) gave a short talk on CO₂ exchange measurements for a very northern pine forest close to timberline in Finnish Lapland (SMEAR I station). The measurements include both eddy covariance and shoot and soil chamber methods. The partitioning of the forest floor exchange to components of tree roots, heterotrophic respiration, mosses/lichens and vascular plants is in progress.

Session 2: Role of disturbances in carbon cycle (chair: Liisa Kulmala)

Elena Lapshina (Yugra State University) gave a keynote by introducing their field station Mukhrino that is established in 2009 by on a mire in West Siberia, 26 km south from Khanty-Mansiysk, Russia, where that kind of mires cover about 50 % of the land surface. Current scientific research on the station mainly concentrates on climate change, biodiversity and carbon and water fluxes for example using in situ manipulations of the microclimate. The station is well facilitated and it opens great possibilities for future collaboration to increase understanding about the response of Siberian mires to the future warming and other disturbances.

The knowledge of human-induced disturbances to the ecosystems is still rather sparse as highlighted by Sergey Goryachkin (Institute of Geography, RAS). He showed several case study examples on the notable effects of land-cover changes in Arctic and Boreal areas on the CO₂ effluxes. However, the spatial variation is huge and thus, there is still a need to study these more carefully to comprehensively understand the accurate effect of land cover change on carbon exchange. By contrast, the human-induced changes are sometimes smaller than assumed as Kajar Köster (University of Helsinki) showed in his presentation: the grazing of Reindeer in northern Finland does not seem to significantly affect the differences in soil CO₂ flux and soil C content even it causes major differences in the appearance of the nature. The last presented human-induced disturbance was the forestry-drainage of peatlands that was a common practise in Finland and in Russia some decades ago. Annalea Lohila (Finnish Meteorological Institute) showed constricting effects of CO₂ balance on two drained peatlands: The net ecosystem exchange (NEE) is very negative indicating a high accumulation of carbon at a poor site whereas at a rich, drained site, the NEE is around zero. Pavel Alekseychik (University of Helsinki) stressed also the varied response of peatland ecosystems of a different kind by showing how individually the ecosystems react to natural disturbances such as drought and changing water level. These findings give pressure to diversify the study sites in the future.

Frank Berninger (University of Helsinki) illustrated how fires in Boreal forests decrease the potential of soil to decompose organic matter. Jukka Pumpanen (University of Helsinki) continued the subject and presented an ongoing project ARCTICFIRE that aims to reveal the long term effects of fire on carbon and nitrogen pools and fluxes in the arctic permafrost and subarctic forests. Fire is one of the major disturbances in boreal forests and according to the current knowledge, the effect of occasional fire on carbon exchange in the continuum of soil, vegetation and atmosphere still holds many unknown aspects and shared collaboration interests of the different countries.

Session 3: Permafrost (chair: Torben Christensen)

Trofim Maximov (Institute for Biological Problems of Cryolithozone, SB RAS) gave a keynote talk titled "Climatic and biogeochemical features of permafrost-dominated forest and tundra ecosystems, North-Eastern Russia". He showed that carbon stocks in the soils of forest and tundra ecosystems of Yakutia amount to 17 billion tons but the increase in air temperature in the zone of permafrost development is activating biogeochemical processes and speeding up the release of greenhouse gases that are conserved in permafrost. He presented diverse results on the biogeochemical cycles that they have monitored and studied on the SakhaFlux network that they have established in the north-eastern permafrost area in Russia.

Örjan Gustafson (Stockholm University) gave another keynote on the carbon (CH₄ and CO₂) release from thawing permafrost and collapsing hydrates in the East Siberian Arctic Ocean, area that is experiencing the fastest rate of climate warming. There have been substantial uncertainties in both carbon and methane stores in these systems as well as of their vulnerability toward remobilization

and release. The presentation focused on decade-long observation-based approaches to apportion the sources, better understand the transport, degradation and fluxes.

The session was closed by a short presentation by Martin Stendel from Danish Meteorological institute. In his presentation, he showed that Global climate models are unsuitable to adequately model soil thawing and freezing processes. Instead of the traditional approach via degree-day based frost indices, they used a very high resolution version of a regional climate model to create boundary conditions for an advanced permafrost model. He presented the results from integrations for different parts of the Arctic.

Session 4: Enhancing unexplored fields (chair: Örjan Gustafsson)

The session included two keynote and two shorter presentations, which had in common that they either employed a lesser-used sampling strategy or addressed a process that so far has been sparsely investigated. Arshinov presented an impressive decade-long observational program where research airplanes have been used to survey the horizontal and vertical distribution of greenhouse gases and aerosols over central Siberia. It is important to get information of the vertical distribution both to ground truth model predictions and as it may hold clues (especially for aerosols) of both sources and actual radiative effects. This program should be a high priority for further funding and expanded with international collaboration, including tight coupling with modeling. Prokushkin presented an impressive upstart field program centered around the Yenisey river, including sampling and observations of both soil, water and air. This broad approach is timely and has good prospects to contribute a better understanding of the sources of remobilized carbon and the multi-dimensional fate and transport as part of the Boundless Carbon Cycle. Appropriate collaboration with groups of Heimann and Amon are already in place, yet there are good opportunities for mutually beneficial collaboration with additional both Nordic and Russian partners. The ambition to establish a coastal observatory at Dickson, near the Yenisey mouth is strategically important as continuous observations near Kara Sea are presently missing.

The presentations by Vesala and Rasilo highlighted processes in need of further investigation (some is ongoing) that relates to lake-air exchange of gases. The standard equations for estimating the diffusive flux components may not be directly applicable to small fetch inland waters. Exchange through ice-covered and partly ice-covered systems require rethinking observational approaches; a challenge also addressed by the presentation of Makshtas in the following session.

Session 5: Changing Arctic (chair: Mikhail Arshinov)

At this session two keynote lectures and two short talks were listened to with great attention, because the Arctic is highly sensitive to the climate change and we should investigate possible feedbacks to be expected in the future in this key region of the globe.

Prof. Alexander Makshtas talked about the importance to take into account a release and absorption of carbon dioxide by the sea ice covering the Arctic Ocean. Based on the field measurement data obtained at the Russian drifting station NP35, he showed that summer melting of the first year sea ice can lead to the CO₂ uptake from the atmosphere. Also he exhibited increasing annual amplitude of CO₂ mixing ratio observed at stations located in Arctic, drawing a conclusion that it is important to keep in mind the above marine uptake when calculating CO₂ balance in the polar atmosphere.

Professor Heikki Seppä gave an impressive speech on long-term changes of the climate and ecosystems observed in the Eurasian arctic in the past. He put a very interesting question, is the recent expansion of the boreal vegetation to the Arctic unprecedented or not. Prof. Seppä proposed an approach of comparing the current rate of forest expansion with the ones observed during the earlier Holocene warm periods, allowing to forecast how quickly forests will expand northward to the tundra under rising temperatures in the future.

The short presentation given by Paul Mathijssen was focused on the reconstruction of the methane fluxes through the peatland development by analyzing composition of fossil plants in combination with modern eddy covariance and chamber flux measurements.

Tarmo Virtanen reported achievements in developing detailed maps of land cover, leaf area index, soil and permafrost properties, which enable the carbon fluxes and permafrost properties to be explained more accurately.

Session 6: Methane (chair: Annalea Lohila)

Torben Christensen demonstrated how our understanding of natural CH₄ emissions has evolved during the last 40 years. Already then, the variability of the emissions from pristine wetlands was high and has not been significantly decreased during the last decades despite a large amount of new research papers. According to current understanding, the impact of climate change on wetland methane emissions is small and no drastic changes are expectable. However, there are still open questions related to the dynamics of methane emissions from permafrost soils. For example, although the soil temperature is known to be the most important factor controlling the CH₄ flux, one is still not able to predict the emissions of following years using data from previous years. T.C. also demonstrated how small changes in e.g. snow layer thickness impact the soil active layer thickness and in that way GPP and potentially CH₄ emissions.

Tuomas Laurila showed ambient air CH₄ concentration data collected in Tiksi observatory in North-East Siberia. Amongst all arctic monitoring stations, the concentrations seem to be highest at Tiksi, and there is indication that the highest peaks are related to changes in hydrology in the large wetland areas east from Tiksi. Although the shallow coastal area of Laptev sea is responsible for part of these high emissions, the year-to-year variation is more likely connected to the wetland emissions.

In short presentations, Mari Pihlatie presented an ongoing project which aims to reveal the unknown sources of methane in boreal upland forest. Although the results were initial and measurements are still going on, they show that trees emit methane, either by acting as a conduit for the CH₄ produced in soil or by providing conditions suitable for CH₄ production within the tree structures. Aki Tsuruta and Maarit Raivonen both talked about modelling methane emissions, however in very different scales. While A.T. demonstrated the usability of inversion modelling on assigning the surface methane sources from atmospheric methane data by using Carbon Tracker Europe model, M.R. presented the details and current development status of the methane model which can be coupled to the larger scale Earth system model.

Conclusions and recommendations

1) Collaboration:

The Workshop provided many informal collaboration possibilities among participants, during the sessions and the breaks in between the sessions. One important topic in discussions was how to improve the joint work of the community in sharing data, and making better use of the existing measurements, instead of just getting new things measured. It was agreed that the data flow should be improved, but that there are great obstacles to obtain data from Russia. One way of collaborating is to harmonize measurements with common protocols.

Some presentations emphasized the land use history aspect – Russia has experienced a major transformation from agricultural landscapes to forested landscapes in last two decades, and this transformation clearly has an impact on e.g. the biogeochemistry and carbon and nitrogen fluxes.

Terrestrial fluxes of methane and atmosphere is well known but Arctic Ocean is still unknown although now new data is being obtained with permanent stations and cruises.

The question of what drives the annual amplitude of CO₂ concentration was raised, and Prof. Heimann indicated that climate effects are important. Forests are also currently growing more and better: increased photosynthesis, leading also to increased respiration and larger amplitude. Boreal ecosystems are relatively sensitive to SO₂ deposition, which has been decreasing in the last decades. China is a great source for SO₂, but planning to cut the emissions.

The question about forest fires as a methane source was brought up. They must be a major source and the climate change will change the fires. Interactions: dark layer getting warmer

2) RI networks:

The western side of Russian Arctic-Subarctic was considered to be less represented in the current measurement activities. For example the Seida station with a lot of background material and data is closed for now. At the shorelines of the Arctic Ocean on the other hand many interesting stations and campaigns are in operation, and a good network is actively exploring the area. The CRAICC network has ca. 30 permanent measurement stations, and the Interact network >200 listed stations all over the Arctic. The NEESPI approach should be explored further.

Since measuring everything everywhere is impossible, the coverage of data for models was also discussed. The GHG fluxes are rather small compared to anthropogenic emissions that rule, and thus it seems that the potential misrepresentation or lack of measurements does not affect the outcomes of GCMs. What really matters are the energy exchange, snow cover changes, albedo, and these measurements should be improved. It was also questioned if EC data is currently fully used or not.

Overall, the models include poor quality of wetland emissions. A novel wetland emission map where wetlands are in right places should be made. This seems to be a general problem with vegetation maps: for example maps of plant functional types are missing. Lakes and rivers are not as high methane sources as wetlands but they are still bigger sources than upland forests. Are the lakes and rivers seen as wetlands in the vegetation maps? Satellite estimates on wetness can be made with 50 km pixel size. You can observe the temporal variation in wetness using these. From Sodankylä data is provided on a daily basis. In tundra, there are a lot of shallow lakes in permafrost area. Their

emission dynamics are very different from bigger lakes, they have high emissions in early spring but not as much during the summer. How much the variability of wetness is reflected to fluxes? In general, the northern wetlands are there consistently every year compared to tropical wetlands that are differing strongly. The depth of the active layer is probably very important factor regulating the GHG emissions.

Isotopes: Some caution to use stable isotopes. Isotopic composition changes due to the breakdown of CH₄ in the atmosphere. MPI has methane isotope measurements from Zotto, 3 years or something (flask samples), it is possible to send bottles out of Russia but it is not trivial.

DOC: Do we know how dissolved organic carbon is changing, the interphase in the soil and river, hydrology? Some sampling is done from rivers (e.g. Lena) jointly with US researchers, but so far rather little.

3) Searching links between Nordic and Russian research and education activities

Potential Nordic - Russian future funding opportunities were discussed. Horizon 2020 is opening several calls this year, but finding Russian researchers is difficult, and the total budget is reduced. Solution would be bilateral agreements, combined with national funding. Finnish Academy has an arctic research project and planning bilateral Finnish-Russian project. Interact 2 is going to be resubmitted – no funding for Russian stations but they were listed there. In Sweden, the framework is there but only warm hands. Russian foundations are small, the grants are really small and the international big ones are not any better due to the rouble collapsing. Money is also lacking from running the stations, in most cases very dependent on soft money sources. One solution is mobility grants: PhD students moving.

It was also noted that community aspects, outreach etc are taken in the account in Canada but they seem to be missing in Europe.

The decision makers like simple projects and we should concentrate on planning a simple project. Objectives are very important and a good coordination is needed too. For funders it is not easy to understand the need of a global CO₂ network, although there are still many issues we don't understand on the processes of CO₂ variation in time and space.

Appendix 1: Carbon exchange-related Training activities for MSc and PhD students organized by PEEEX partners

- 1) Peatland ecology (10 days) Contact: Elena Lapshina
- 2) Diversity of peatland types and mapping (10 days), Contact: Elena Lapshina
- 3) Geobiosphere processes in the Arctic (25 Feb-20 Aug 2015), Contact: Margareta Johansson (margareta.johansson@nateko.lu.se)
- 4) InGOS/ICOS (May 20-29 2015), Contact: timo.vesala@helsinki.fi
- 5) Annual international course of biogeochemistry and climatology (2 weeks)
Place: NEFU, Yakutsk, Contact: Trofim Maximov. Dr.Sci., Prof.
- 6) Summer field course on permafrost –biogeochemistry – climatology –ecology (2 weeks)
Place: Spasskaya Pad forest scientific research station of Institute for Biological Problems of Cryolithozone, Siberian Branch of Russian Academy of Sciences (IBPC). Yakutsk, Contact: Trofim Maximov. Dr.Sci., Prof.
- 7) Winter laboratory course on stable isotope. Place: Hokkaido University. Sapporo, Japan,
Contact: Trofim Maximov. Dr.Sci., Prof.
- 8) Hyytiälä Winter school, March 2015, contact: jaana.back@helsinki.fi
- 9) Hyytiälä Autumn school, October 2015, contact: jaana.back@helsinki.fi

Appendix 2: Program

Monday 9 Feb 2015

9:00-09:10 **Aims of the workshop: Jaana Bäck and Tuomas Laurila**

9:10-9:20 **Introduction to PEEX: Hanna Lappalainen**

9:20–10:20 **Session 1: Net Biome Exchange**

Chair: Timo Vesala

Keynotes:

Martin Heimann: Quantifying regional greenhouse gas budgets of northern Eurasia: Status and prospects

Short presentations:

Tiina Markkanen/Tuula Aalto: Carbon cycle studies in northern region with a land surface model

Liisa Kulmala: CO₂ exchange measurements at SMEARI, Northern Finland

Vladimir Shishov: Process-based modeling of tree rings in Eurasia: from separate tree to forest landscape

10:20–10:40 Coffee break

10:40–12:00 **Session 2: Role of disturbances in carbon cycle**

Chair: Liisa Kulmala

Keynotes:

Elena Lapshina: Experimental multidisciplinary approach to study the response of boreal Siberian peatland ecosystems to climate change

Short presentations:

Sergey Goryachkin: Disturbances in carbon cycles in arctic and boreal areas: consequences of natural and anthropogenic landcover change

Frank Berninger: Linkages between below ground succession and biogeochemistry

Jukka Pumpanen: Long term effects of fire on carbon and nitrogen pools and fluxes in the arctic permafrost and subarctic forests (ARCTICFIRE)

Kajar Köster: Reindeer as a disturbance agent in subarctic boreal forest – influences on soil carbon dynamics

Pavel Alekseychik: Energy balances of eight fennoscandian peatlands: sensitivity to drought and changing water level

Annalea Lohila: Contrasting impact of forestry-drainage on CO₂ balance at two adjacent peatlands in southern Finland

12:00–13:00 Lunch

13:00–14:20 **Session 3: Permafrost**

Chair: Torben Christensen

Keynotes:

Trofim Maximov: Climatic and biogeochemical features of permafrost-dominated forest and tundra ecosystems, North-Eastern Russia

Örjan Gustafson: Studies on carbon release from thawing permafrost and collapsing hydrates in the East Siberian Arctic Ocean

Short presentations:

Martin Stendel: Permafrost modelling at the Danish Meteorological Institute

14:20–15:30 **Session 4: Enhancing unexplored fields**

Chair: Örjan Gustafson

Keynotes:

Mikhail Arshinov: Collaborative investigations of trace gases and aerosols carried out in Siberia: current status and future needs

Anatoly Prokushkin: Sensitivity of carbon fluxes in land-atmosphere-hydrosphere system of Yenisey river catchment to climate variability: development of Krasflux network for the long-term analysis

Short presentations:

Timo Vesala: Bottlenecks in the understanding of the freshwater-atmosphere interactions?

Terhi Rasilo: Methane under the ice in boreal lakes

15:30–15:50

Coffee break

15:50–17:20 **Session 5: Changing Arctic**

Chair: Mikhail Arshinov

Keynotes:

Alexander Makshtas: Carbon dioxide in the arctic

Heikki Seppä: Long-term change of climate and ecosystems in the Eurasian arctic

Short presentations:

Paul Mathjissen: Methane flux reconstructions through peatland development using plant macrofossils

Tarmo Virtanen: Use of extremely high resolution spatial data to study carbon and permafrost changes

17:20–18:00 **Future needs and education activities**

Chair: Jaana Bäck and Tuomas Laurila

18:00→

Dinner

Tuesday 10 Feb 2015

8:30–9:00 Coffee

9:00–10:30 **Session 6: Methane**

Chair: Annalea Lohila

Keynotes:

Torben Christensen: Reducing uncertainty in methane emission estimates from permafrost environments

Tuomas Laurila: Processes affecting methane concentrations in northern Eurasia -Implications for the observational network

Short presentations

Mari Pihlatie: Revealing sources of methane emissions in boreal upland forests

Aki Tsuruta and Tuula Aalto: Methane emission estimates for 2000-2012 using Cte-CH4 inverse model

Maarit Raivonen: Modelling methane emissions from peatlands

10:30–11:45 **Future needs and following steps**

Chair: Jaana Bäck and Tuomas Laurila

11:45 Lunch

13:00 → The 1st Pan-Eurasian Experiment (PEEX) Science Conference & The 5th PEEX Meeting

Appendix 3: List of participants

Name	Institute	Country	Type
Tuomas Aakala	University of Helsinki, Dept. Forest Sciences	Finland	Participant
Tuula Aalto	Finnish Meteorological Institute	Finland	Participant
Syed Ashraful Alam	University of Helsinki, Dept. Forest Sciences	Finland	Participant
Pavel Alekseychik	University of Helsinki, Dept. Physics	Finland	Presenter
Mikhail Arshinov	V.E. Zuev Institute of Atmospheric Optics, RAS	Russia	Keynote presenter
Jaana Bäck	University of Helsinki, Dept. Forest Sciences	Finland	Chair
Leif Backman	Finnish Meteorological Institute / Helsinki University	Finland	Participant
Frank Berninger	University of Helsinki, Dept. Forest Sciences	Finland	Presenter
Torben Christensen	Lund University	Sweden	Session Chair, keynote presenter
Yao Gao	Finnish Meteorological Institute	Finland	Participant
Leonid Golubyatnikov	Obukhov Institute of Atmospheric Physics, RAS	Russia	Participant
Sergey Goryachkin	Institute of Geography, RAS	Russia	Presenter
Örjan Gustafson	Stockholm University	Sweden	Session Chair, keynote presenter
Martin Heimann	Max Planck Institute for Biogeochemistry	Germany	Keynote presenter
Vladimir Kazantsev	Obukhov Institute of Atmospheric Physics, RAS	Russia	Participant
Atte Korhola	University of Helsinki	Finland	Participant
Kajar Köster	University of Helsinki, Dept. Forest Sciences	Finland	Presenter
Liisa Kulmala	University of Helsinki, Dept. Forest Sciences	Finland	Chair, Presenter
Timo Kuuluvainen	University of Helsinki, Dept. Forest Sciences	Finland	Participant
Hanna Lappalainen	University of Helsinki, Dept. Physics	Finland	Presenter
Elena Lapshina	Yugra State University	Russia	Keynote presenter
Tuomas Laurila	Finnish Meteorological Institute	Finland	Chair, Keynote presenter
Aleksi Lehtonen	Natural Resources Institute Finland	Finland	Participant
Annalea Lohila	Finnish Meteorological Institute	Finland	Session chair, presenter
Alexander Makshtas	Arctic and Antarctic Research Institute	Russia	Keynote presenter
Tiina Markkanen	Finnish Meteorological Institute	Finland	Presenter
Paul Mathijssen	University of Helsinki, Dept. Environmental Sciences	Finland	Presenter
Trofim Maximov	Institute for Biological Problems of Cryolithozone, SB RAS	Russia	Keynote presenter
Paavo Ojanen	University of Helsinki, Dept. Forest Sciences	Finland	Participant
Mikko Peltoniemi	Natural Resources Institute Finland	Finland	Participant
Mari Pihlatie	University of Helsinki, Dept. Physics	Finland	Participant

Anatoly Prokushkin	Sukachev Institute of Forest, RAS	Russia	Keynote presenter
Jukka Pumpanen	University of Helsinki, Dept. Forest Sciences	Finland	Presenter
Maarit Raivonen	University of Helsinki, Dept. Physics	Finland	Presenter
Terhi Rasilo	Université de Québec à Montréal	Canada	Presenter
Meri Ruppel	University of Helsinki, Dept. Environmental Sciences	Finland	Participant
Heikki Seppä	University of Helsinki, Dept of Geosciences	Finland	Keynote presenter
Vladimir Shishov	Siberian Federal University	Russia	Presenter
Martin Stendel	Danish Meteorological Institute	Denmark	Presenter
Aki Tsuruta	Finnish Meteorological Institute	Finland	Presenter
Minna Väiliranta	University of Helsinki, Dept. Environmental Sciences	Finland	Participant
Timo Vesala	University of Helsinki, Dept. Physics	Finland	Session chair, Presenter
Tarmo Virtanen	University of Helsinki, Dept. Environmental Sciences	Finland	Presenter
Evgeny Zarov	Ugra State University	Russia	Participant