Large-scale quantifying of sources and sinks of atmospheric carbon in Siberia

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Northern hemisphere has slightly higher CO\textsubscript{2} concentration…

Data: Keeling et all http://cdiac.ornl.gov/trends/co2/
Boreal forests: biospheric role

The world's largest land biome, and makes up 29% of the world's forest cover with the largest areas located in Russia and Canada.

Siberian forests comprise ~ 10% of the global C stored in vegetation and soils, and contribute up to 10% of the global terrestrial NPP.
Observational strategies of the global carbon cycle

‘top-down’

...uses observations of the atmospheric composition at remote locations and only insignificantly influenced by local processes

Bridging the gap in scale is an important scientific challenge, for which direct observations are indispensable

‘bottom-up’

...is based on local in-situ observations of fluxes or changes in ecosystems, to be extrapolated and scaled up in order to make inferences at continental scale
Yenisei River basin

... over 2580 thousand km²

... is one of the most unique regions of Siberia to analyze biogeochemical processes due to high climatic, geomorphologic and ecological diversity
Observational network: major biomes of Yenisei River basin

2 Atmospheric observatories:
- ZOTTO – continental observatory (since 2006)
- DIAMIS – arctic/oceanic observatory (since 09.2018)

5 Eddy Covariance stations (“KrasFLUX”)

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ZOTTO – continental observatory

ZOTTO has been established as a Eurasian mid-continental observatory with a long-term perspective (>30 years). Details of the project, contact points and access to data can be found on the project website (http://www.zottoproject.org).

Living and infrastructure facilities

Metal 300-m tall mast

Underground measurement laboratory

Part of the global tall tower network

ZOTTO

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ZOTTO site

... is located in a boreal zone, in the center of Siberian taiga, 20km west of the Yenisei River and ≈600km north of Krasnoyarsk
ZOTTO footprint area: cumulative STILT

Average monthly footprint:
\[ 2.4 \times 10^6 - 4.2 \times 10^6 \text{ km}^2 \]

Coniferous forests: 39±2%
Tundra: 11±3%
Bogs: 11±1%
Mixed forests: 10±1%
Larch forests: 9±1%
Deciduous: 6±2%

The near-field of the tower produces the main influence on the measured mixing ratios up to 10 ppm/(μmol/(m²·s))

The driving meteorological fields are prescribed into STILT by forecast values of the European Centre for Medium-Range Weather Forecasts (ECMWF http://www.ecmwf.int/)
ZOTTO: daily daytime mean CO\(_2\) and CH\(_4\) mixing ratios

... year-to-year growth

Over 10 yrs of continuous measurements

Heimann et al., 2017
ZOTTO: Isotopic composition of GHG

Flasks:
- CO$_2$, O$_2$/N$_2$, CH$_4$, CO, N$_2$O,
- H$_2$, Ar/N$_2$, $^{13}$C/$^{12}$C, $^{18}$O

iSAAC – Isotope System for Analysis of Air Constituents (Wendeberg et al., 2011)
“KrasFLUX” EC network – 5 major vegetation types

Instrumentation:
• CO₂/CH₄/H₂O - LI-7700, LI-7500a, LI-7200, LI-7210,
• Heated anemometers: METEK, Gill-R3
• Meteorological packages

Lichen Pine
60°48'N; 89°22'E
% in the basin: 4.5%
MAAT: -3.3 °C
MAP: 558 mm
Since 2012

Peat Bog
60°48'N; 89°22'E
% in the basin: 6%
MAAT: -3.3 °C
MAP: 558 mm
Since 2012

Dark coniferous forest
61°01'N; 89°49'E
% in the basin: 6%
MAAT: -3.3 °C
MAP: 558 mm
Since 2015

Northern larch forest
64°12'N; 100°27'E
% in the basin: 48%
MAAT: -8.5 °C
MAP: 347 mm
Since 2004

“Palsa” site
67°28'N; 86°29'E
% in the basin: 13%
MAAT: -7.8 °C
MAP: 481 mm
Since 2016
“KrasFLUX”– measuring CO₂ fluxes

- Seasonal variability of NEE and climatic parameters
- Inter- and intra-annual variability of NEE (sink/source) in major biomes
- Scaling up to the region estimates using vegetation maps, forest biomass inventories and remote sensing information

<table>
<thead>
<tr>
<th>Site</th>
<th>Loc.</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lichen pine</td>
<td>60°48'N 89°22'E</td>
<td>-11.0</td>
<td>-21.1</td>
<td>-12.1</td>
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<tr>
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<td>61°01'N 89°49'E</td>
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<td>Peat bog</td>
<td>60°48'N 89°22'E</td>
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<tr>
<td>Larch forest</td>
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<td>-9.0</td>
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<tr>
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<td>n/a</td>
<td>-0.2</td>
<td>-6.8</td>
</tr>
</tbody>
</table>
Winter CO₂ fluxes – a case study

Cold season CO₂ flux is increasingly recognized as an important component of the terrestrial carbon cycle.

Three methods of measuring sub-snow CO₂ flux were compared:
(1) dynamic chamber measurements at the soil surface via snowpack (F soil),
(2) dynamic chamber measurements at the upper snowpack surface (F snow),
(3) static estimates based on measured concentrations of CO₂ and conductance properties of the snowpack (F diffusional).

Wintertime respiration constitutes on average 0.82 µmol m⁻² s⁻¹ in forest ecosystems and up to 1.05 µmol m⁻² s⁻¹ in peat bog – contributes ca. 15-40% of summer soil respiration rates.

Panov et al., 2019 (in prep.)
DIAMIS – arctic/oceanic observatory

A key Arctic location (set. Dikson) given the recent Arctic warming and the expansion of gas/oil production in the Yamal area. In the estuary of Yenisei River basin.

73°33’ N; 80°34’ E

Tasks:
• Better constrain the budgets of GHG in Siberia
• Trace the ocean-continent transport of GHG
• Extend the circum-Arctic observational network
Focus

Fate of carbon pools in a warming climate. Siberian forests contain large amounts of carbon stored in the forests and soils, in wetlands and the underlying permafrost. Knowledge of their response to climate change is vital.

Key challenges:

A year-to-year growth of atmospheric carbon dioxide concentration in the pristine conditions of Siberia.

Suggestions:

Longer periods of measurements should improve statistical significance of the observations and permit to distinguish between short-term variations and multi-decade climate variability. Multidisciplinarity and coordination of efforts in studying environment are of a great importance in addressing global challenges.
Thank you for your time!