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CARB-ARC: Assessment of high latitude carbon processes

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ARKTIKO seminar
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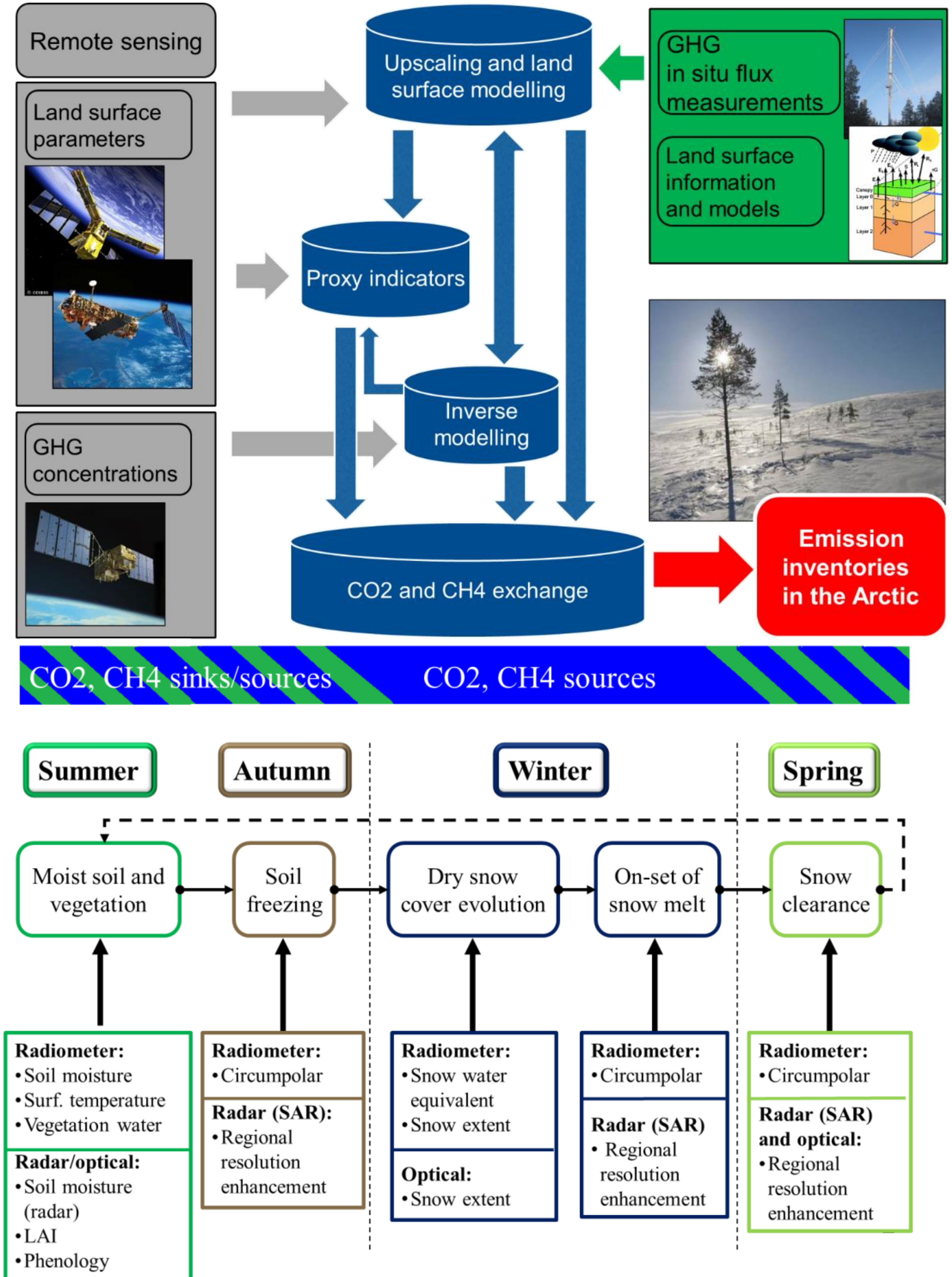
The CARB-ARC approach:

Integrated view on the terrestrial cryosphere's snow-soil-vegetation processes using satellite and *in situ* data together with modelling

Using diverse satellite data at high latitudes allows full seasonal view on soil/vegetation processes relevant to

- *carbon exchange*
- *annual carbon balance*

Microve instruments sensitive to amount and phase of water (liquid-frozen)



Highlight I:
Increase of carbon sink due to earlier snow melt (circumpolar boreal forest zone)

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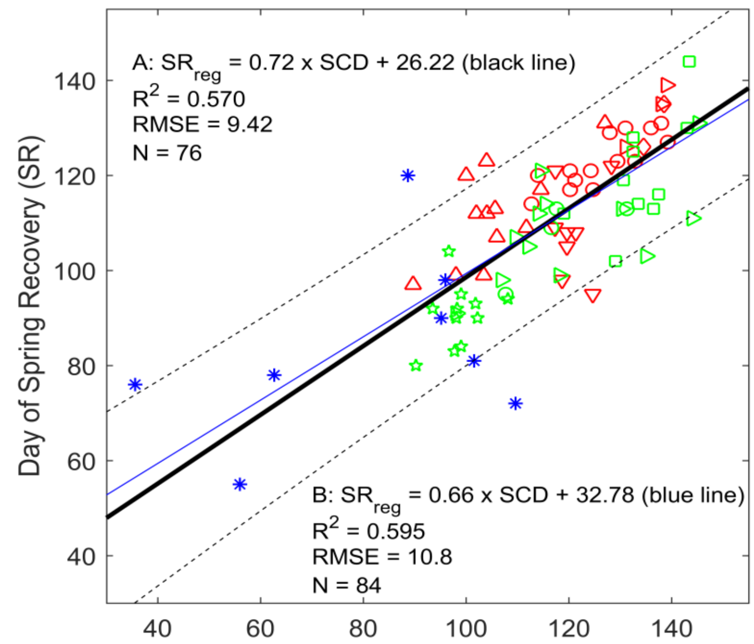
Combining satellite and ground based observations for carbon cycle research

Snow clearance as indicator for carbon exchange

- **Spring recovery** of plant photosynthesis is a major controller of the total carbon uptake in Northern latitudes

- In the northern hemisphere boreal forests, spring recovery can be linked to occurrence of **snow melt-off** (*snow clearance*) which is measured by Earth Observing satellites for almost 40 years.

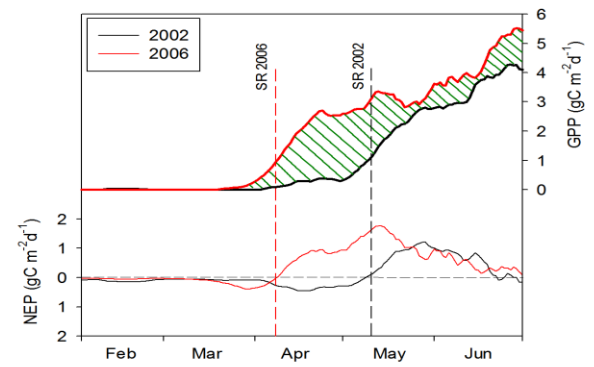


Pulliainen et al., PNAS, 2017

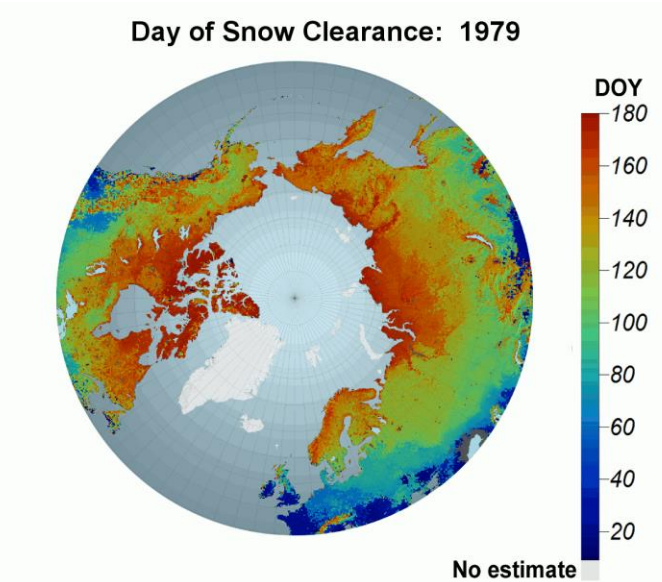
Snow Clearance Day using microwave radiometry is a good proxy for spring recovery when calibrated with *in situ* carbon flux measurements

Earlier spring has increased carbon uptake in boreal forests (4-7% per decade)

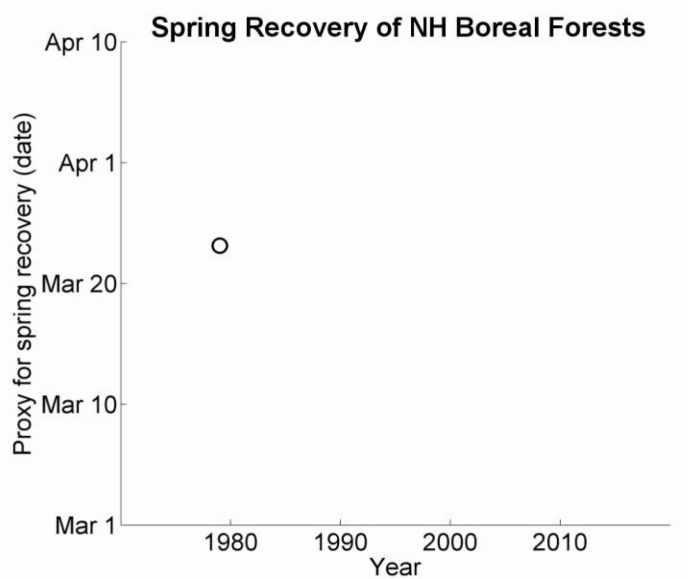
Pulliainen et al., PNAS, October 2017



Relation between spring recovery date (SR) and carbon uptake of boreal forests in terms of GPP (thick lines) and NEP (thin lines).



Snow clearance day from passive microwave observations (Takala et al., 2009)



Trend of boreal forest Spring recovery 1979-2015 estimated from snow clearance

- 36 years of satellite data shows that the spring recovery has occurred earlier by 2 days / decade.
- Increase in springtime cumulative GPP of carbon was 4-7% per decade

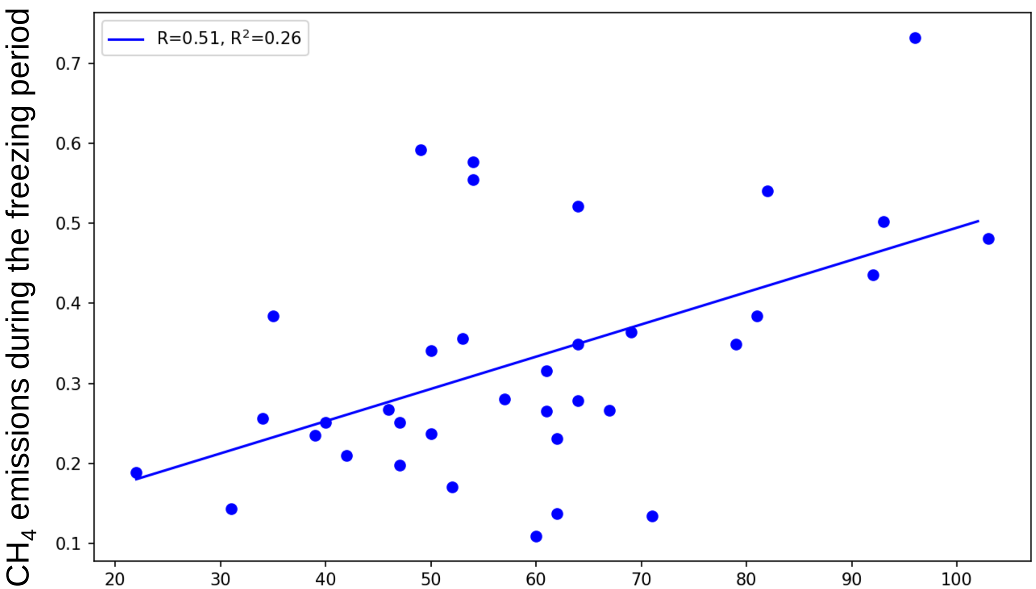
Highlight II:
Increase of methane emissions from Arctic and Sub-Arctic wetlands with delayed soil freeze

Changing soil freeze patterns and CH_4 emissions from northern wetlands

Delay in the freezing of soil (wetlands) increases methane emissions

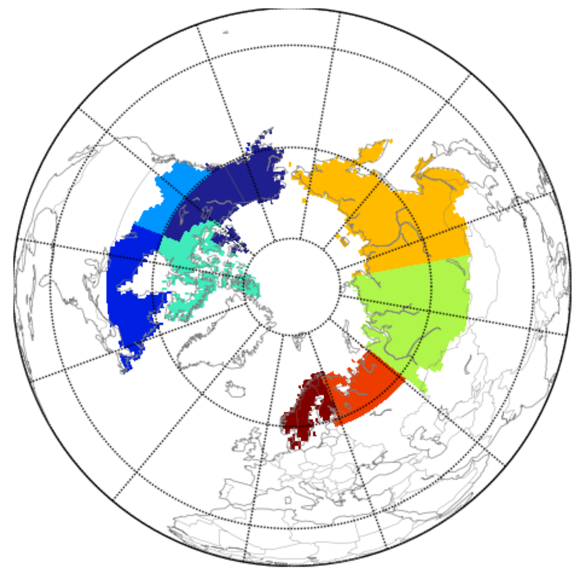
- New satellite missions (**ESA SMOS** and **NASA SMAP**) enable reliable mapping of global soil freeze/thaw

Modelled methane fluxes vs. soil freezing period



Length of regional soil freezing period by SMOS data (days)

Regions of interest in **inverse modelling** and **SMOS data** analysis



Highlight III: Novel satellite missions to map greenhouse gases in the atmosphere for assessing global carbon sinks and sources

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Seasonal atmospheric CO_2 concentration mapping and regional anthropogenic CO_2 emissions

Reliably observed by satellites for the first time

March-April 2015

June-July 2015

March-April 2016

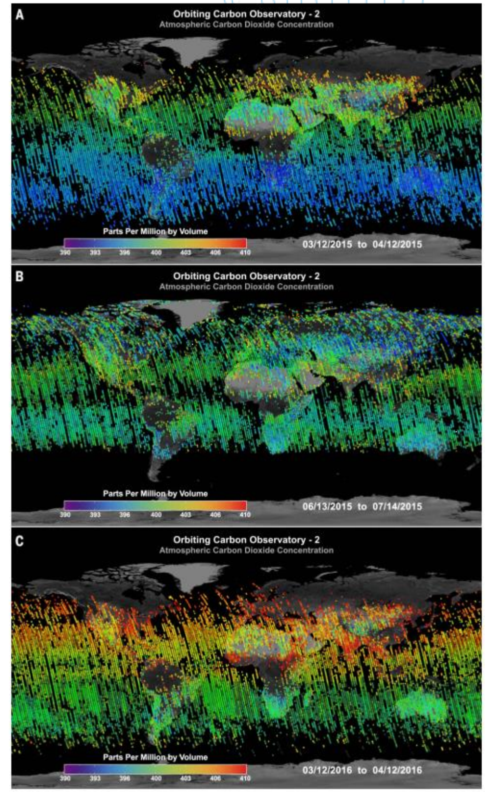
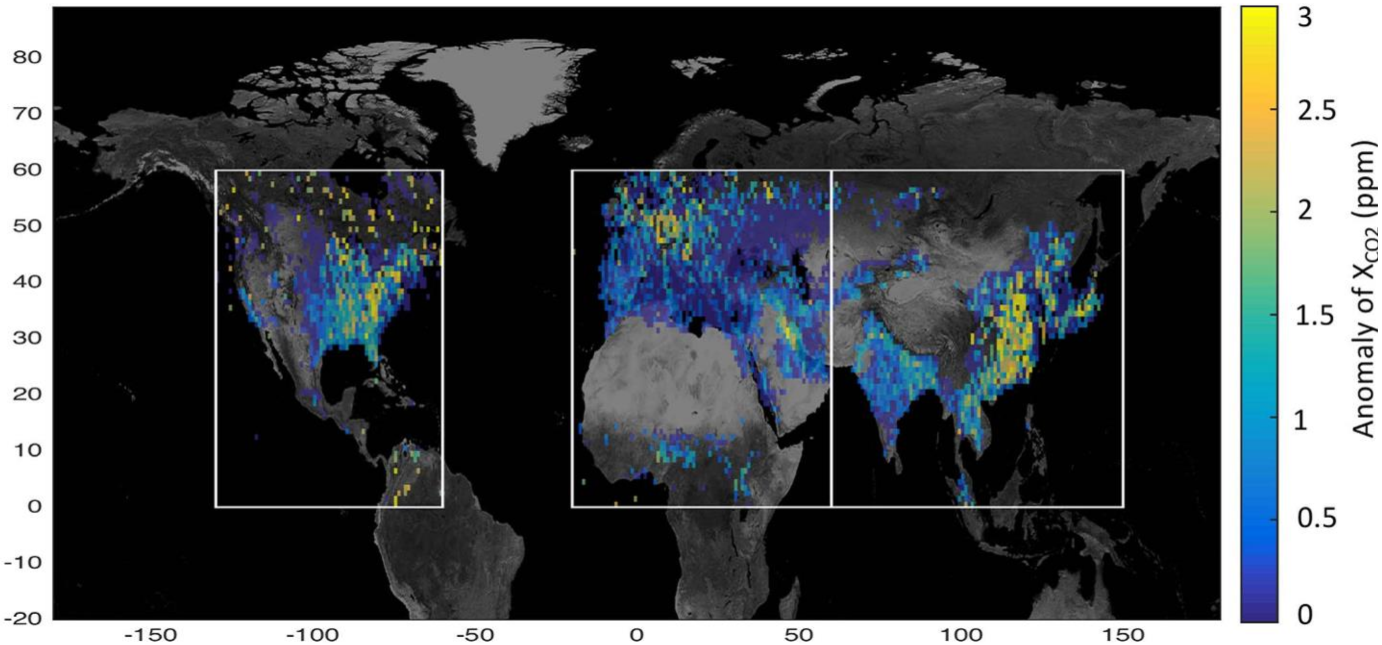


Fig. 2. Maps of OCO-2 X_{CO_2}. Maps of OCO-2 X_{CO_2} (bias corrected with quality flags applied) over 32-day periods in (A) March/April 2015, (B) June/July 2015, and (C) March/April 2016. The measurement area of each sounding has been exaggerated for visibility on a global scale.

Eldering et al, Science 2017, Hakkarainen et al, 2016 **.**

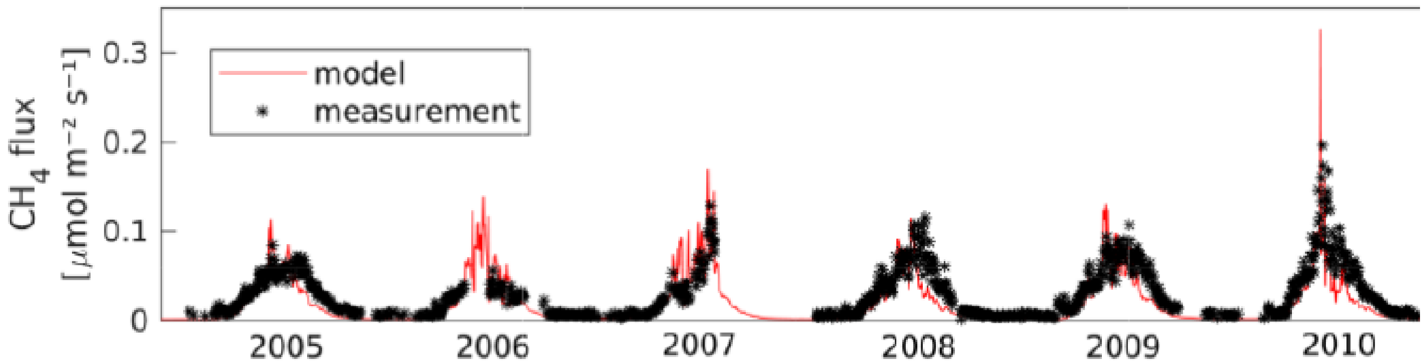


- Challenging to detect anthropogenic signal from CO_2 measurements due to strong seasonal variability and trend.
- ‘Anomaly’ method developed to detect enhanced regions.
- Indication of the origin of the emissions are obtained by cluster analysis with OMI NO_2 which indicate anthropogenic sources.

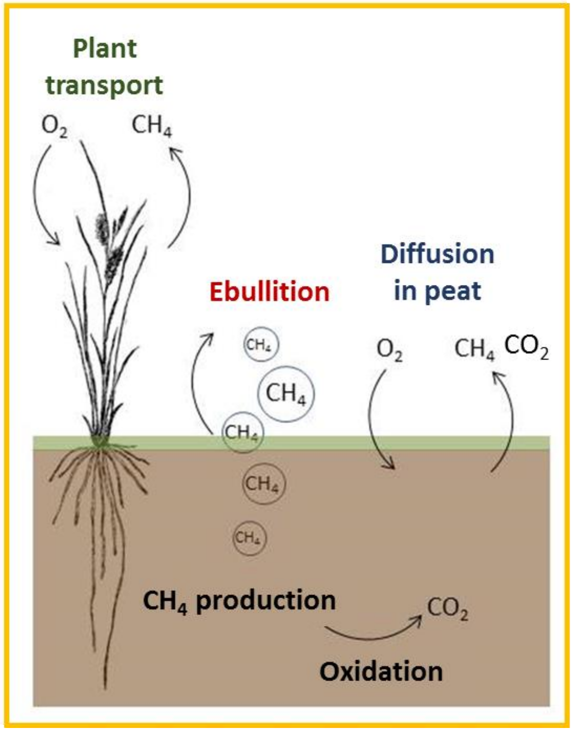
Conclusions

Reliable quantification of carbon cycle at the Arctic and Sub-Arctic regions requires the combination of models, *in situ* data and satellite observations

- High latitudes are problematic in obtaining *in situ* data, also gaps with current satellite systems



Raivonen et al. *Geoscientific Model Development* 2017
Susiluoto et al. *Geoscientific Model Development* 2018




Thank you for your attention!