Advancing Arctic-Boreal carbon cycle science using OCO-2 retrievals

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Overview

One of the largest uncertainties in projected greenhouse gas concentrations and temperature trends is the impact from terrestrial and marine carbon-climate feedbacks in the Northern high-latitudes (NHL; Fig. 1). Lack of understanding of Arctic-Boreal carbon cycle dynamics can be directly attributed to the limited constraint provided by atmospheric CO_2 measurements, both in terms of quantity (only a limited number of in-situ observations are available) and quality (large biases in retrievals from space-based sensors such as OCO-2) - see Figs. 2 - 4.

As part of this OCO Science Team project, we are leveraging the current generation of retrievals from OCO-2 to -
(a) provide process-based insights into drivers and impacts of environmental change on the Arctic-Boreal C cycle (Figs. 5 - 6),
(b) innovate retrieval strategies for OCO-2 [and other passive CO_2 missions] over snow/ice surfaces (Figs. 7 - 8).

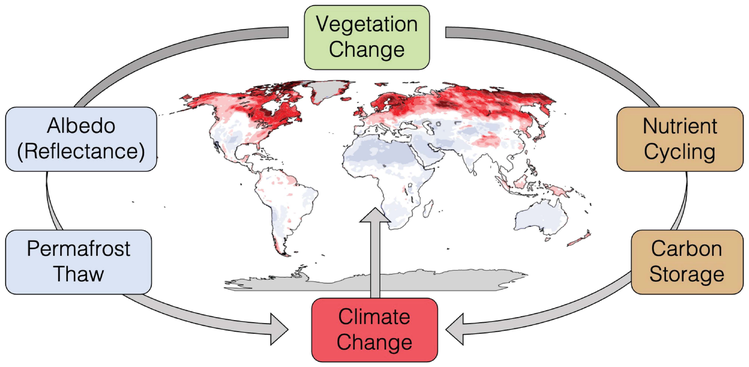


Figure 1: Schematic showing changes in Arctic-Boreal ecosystems and how changes at high latitudes can result in feedbacks to the climate system that can influence the planet as a whole.

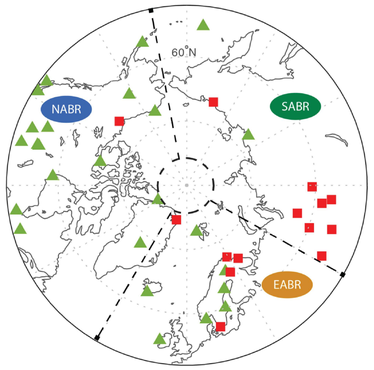


Figure 2: Northern high-latitude domain and distribution of in situ network - both green triangles and red squares.

Quantity and quality of v10 high-latitude retrievals

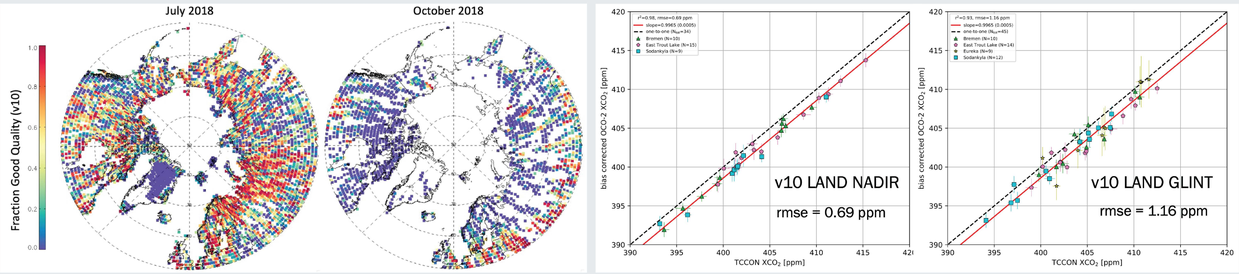


Figure 3: LHS Panel - Fraction of retrieved soundings passing the v10 quality flag for two representative summer months in 2018. Retrievals are primarily available between May - October with limited soundings between November - April. RHS Panel - Comparison of v10 land nadir and land glint retrievals against TCCON stations above 50°N.

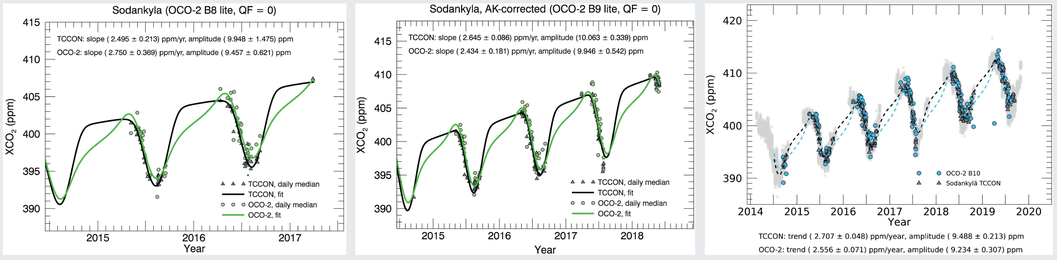
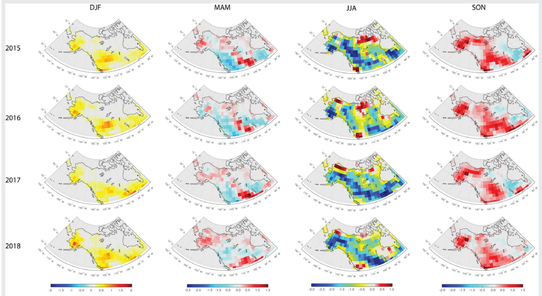
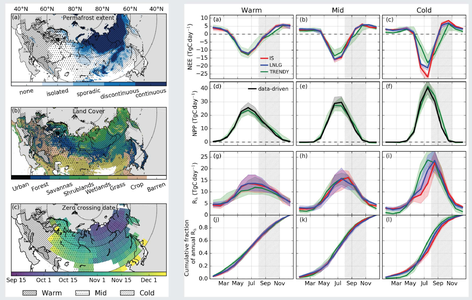


Figure 4: Improvements in OCO-2 high-latitude retrieval versions v8, v9 and v10, compared against TCCON measurements at Sodankylä station, Finland. With each retrieval version, both the quantity and the quality of retrievals over snow/ice surfaces have been improving.

Regional flux estimates based on current v10 retrievals



(LHS) **Figure 5**: OCO-2 provides strong constraints over the North American sector during the summer months (JJA), including reduced uptake and seasonality relative to in-situ inversions.
(RHS) **Figure 6**: OCO-2 recovers a large heterotrophic respiration signal across northeast Siberia - also see Byrne et al. 2022, Biogeosciences, in review

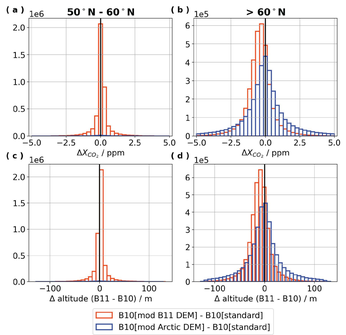


Improving retrievals throughput and quality

Currently, we have adopted a two-pronged strategy:

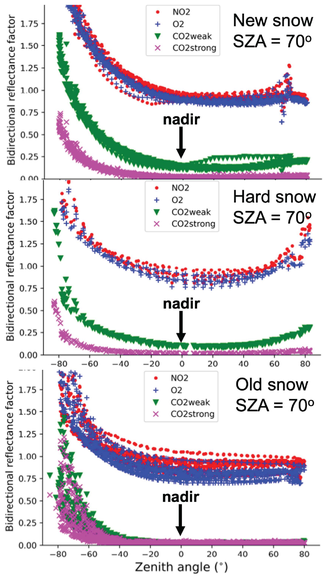
(1) Optimizing QA/QC flags, filtering and bias correction strategies for soundings above 50°N -
- head-to-head comparison between Jacobs (see Poster 3-P11) and Mendonca (see Poster 3-P07) approaches and the operational versions, adopt one or some combination of these approaches
- first step has been to improve the underlying DEM, including comparisons to an independent Arctic DEM (Fig. 7)

(2) Developing and implementing a high-latitude version of the retrieval algorithm (ACOS-NHL), tailored for snow and ice-covered surfaces -
- testing and implementing 2 BRDF models from Lindqvist ESA SNOWITE project (Fig. 8), Lyapustin MODIS MAIAC algorithm, testing other a priori choices related to clouds and aerosols



(TOP) **Figure 7**: Shows the change in X_{CO2} from substituting the B11 and Arctic DEMs into the B10 bias correction in the top row, and the change in altitude by sounding in the bottom row.

(RHS) **Figure 8**: Figure shows the measured BRF in principal plane for three snow types. X-axis shows the viewing zenith angle; forward scattering is on the left (minus-signed angles), Note how the reflectance brightens toward forward angles (including glint) in all channels and snow types, best with new snow. Figure courtesy: Jouni Peltoniemi, FGI



Ongoing and next steps

Arctic-Boreal systems are in transition:

- we are using OCO-2's unique vantage point to improve our understanding of the complex interactions between a changing climate, shifts in phenological cycles and effects on the state of the Arctic-Boreal carbon cycle

We are pioneering the use of X_{CO2} retrievals over snow- and ice-covered surfaces:

- developing and implementing a tailored ACOS-NHL algorithm to deliver X_{CO2} retrievals with greater coverage during the shoulder seasons (March - April and October - November) - this high quality high-latitude X_{CO2} data record will be invaluable for establishing critical baselines against which future changes can be measured and tracked

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