Top-of-atmosphere radiance simulations over snow-covered surfaces for satellite-based carbon dioxide remote sensing

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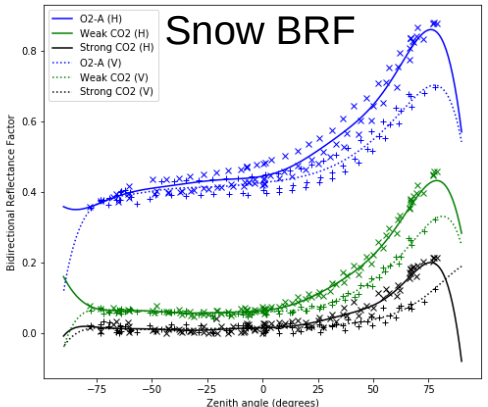
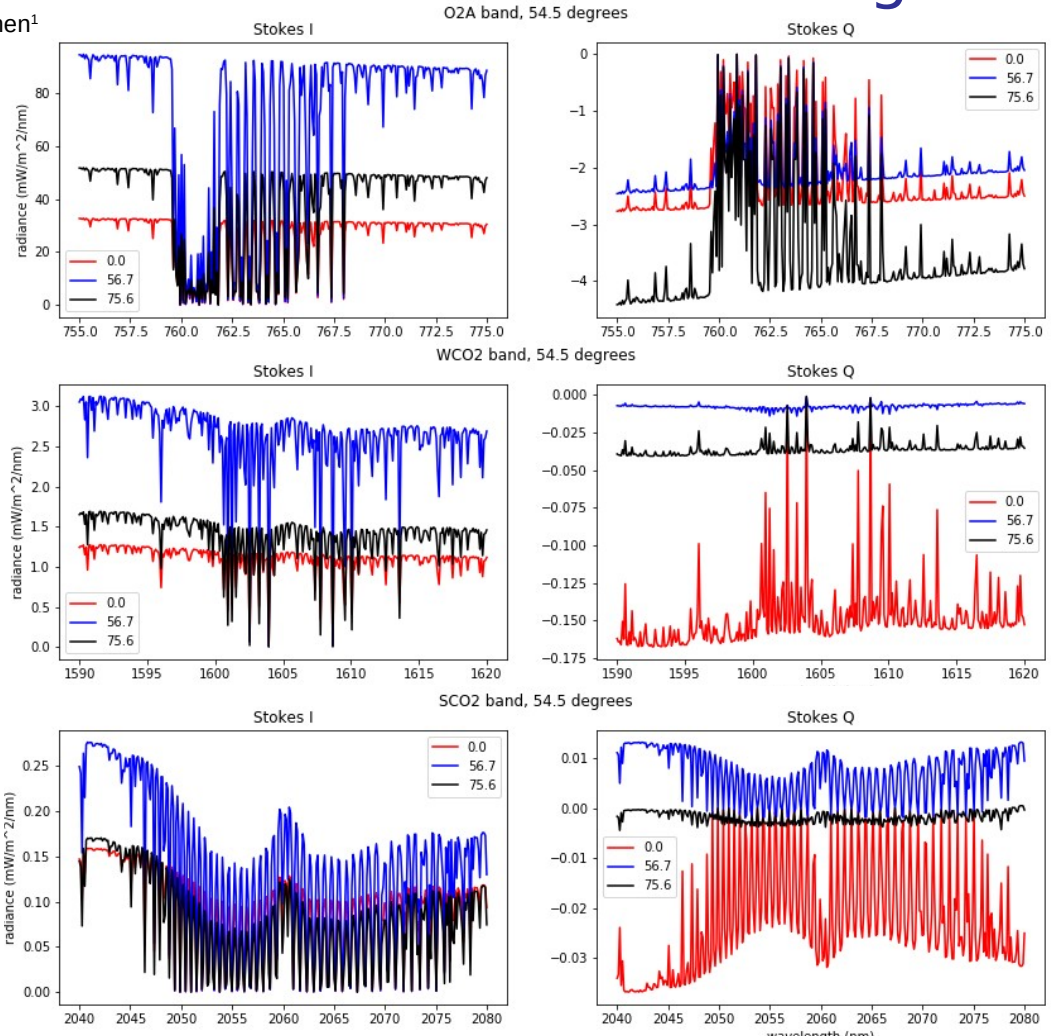
Detailed modeling of snow surface reflectivity could improve the satellite-based remote sensing of CO2 in the high-latitude regions especially during the shoulder seasons.

We created a measurement-based BRDF for a snow surface and simulated atmospheric radiative transfer.

Findings so far

- The reflectivity of snow surfaces in weak CO2 band is about 2 to 4 times stronger than in strong CO2 band.
- The strongest spectral signal is visible in the near-glint geometry.
- Polarization effects of the surface reflection are pronounced in the CO2 bands.





Motivation

- To better constrain the carbon fluxes in the Arctic and boreal regions, an increased seasonal coverage of satellite observations is necessary.
- One of the challenges in high latitudes is the snow cover in Spring as snow is extremely dark in SWIR wavelengths.

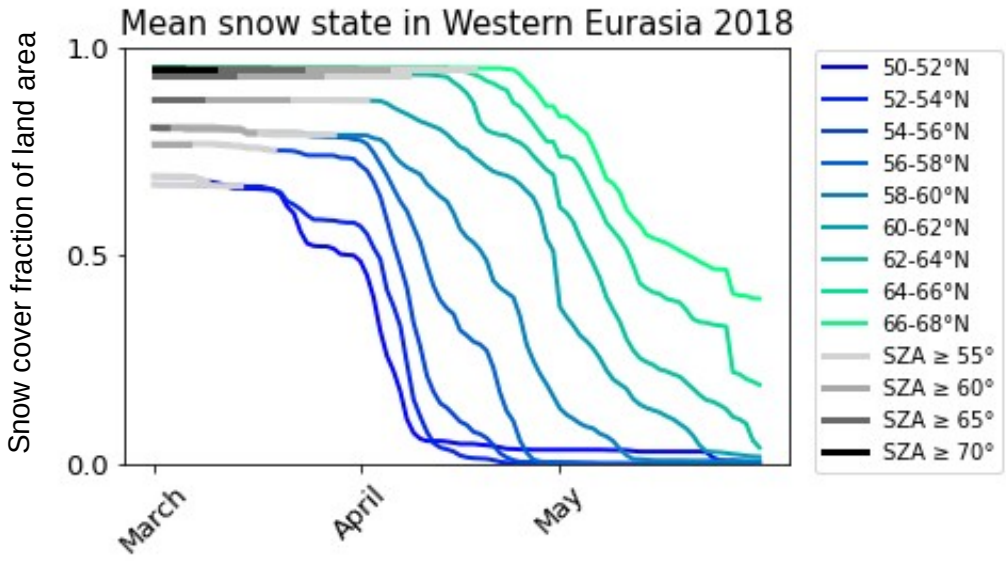
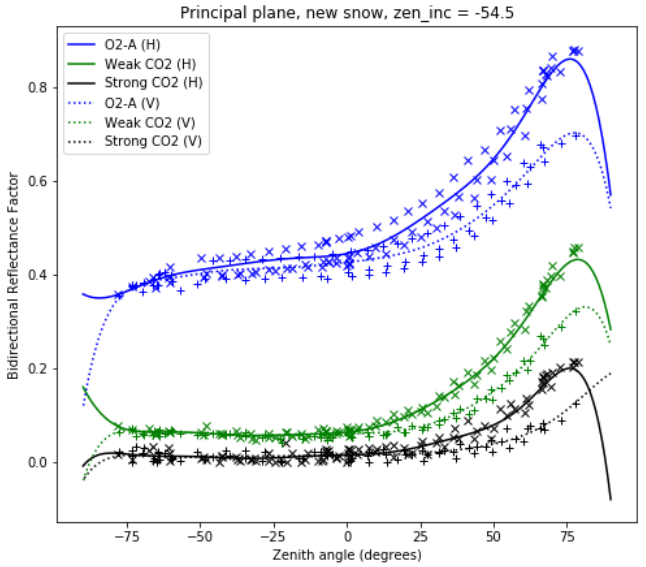
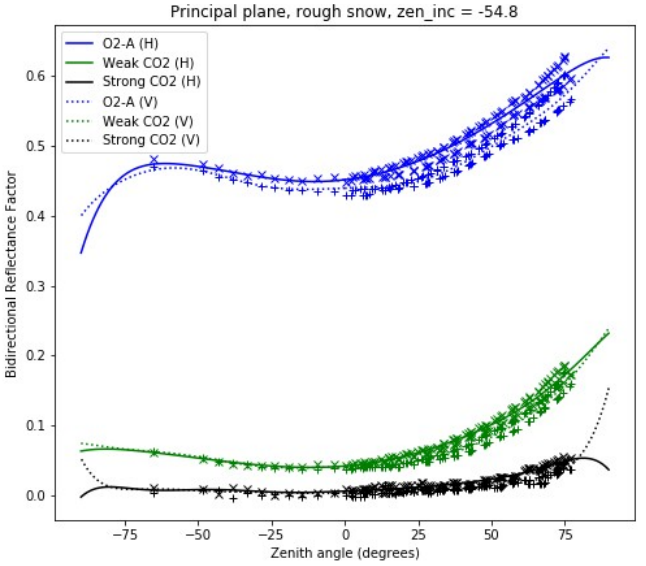


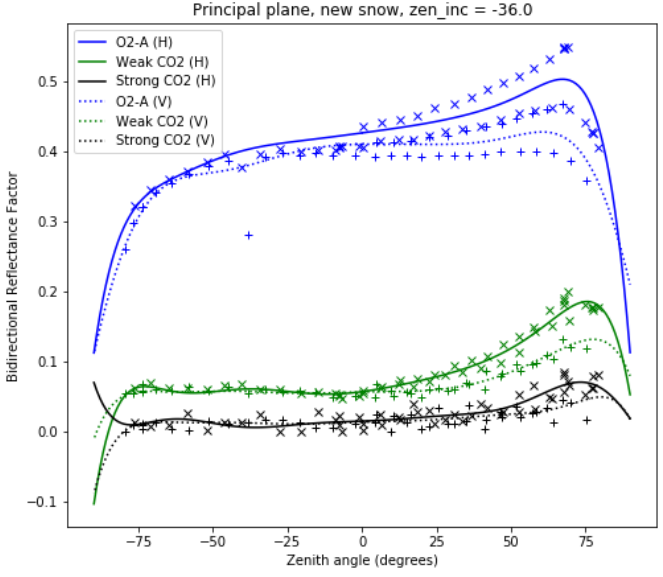
Image: E. Kivimäki, FMI
Data: Combination of Globsnow v3 SWE (Snow Water Equivalent) and snow clearance day products

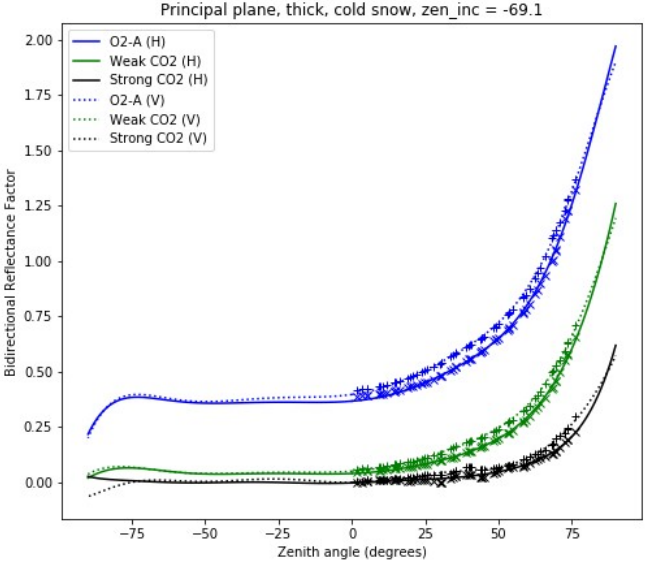
Snow surface BRF models

- Spherical harmonic functions were fitted onto reflectivity data measured by J. Peltoniemi et al., FGI.
- The reflectivity depends on the snow's grain size, temperature and age, but in general snow surfaces are highly forward scattering.

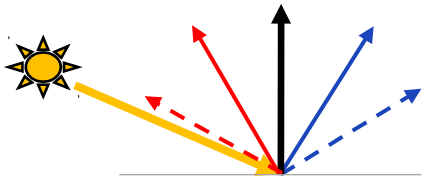








Example snow reflectance spectra, measured



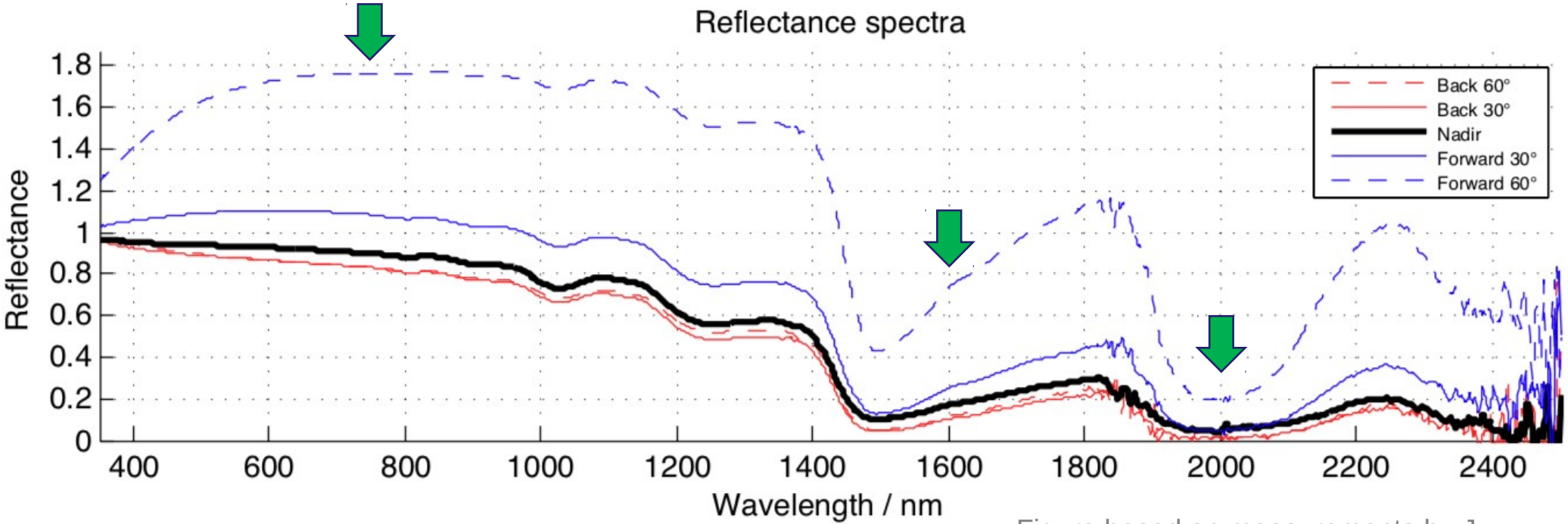
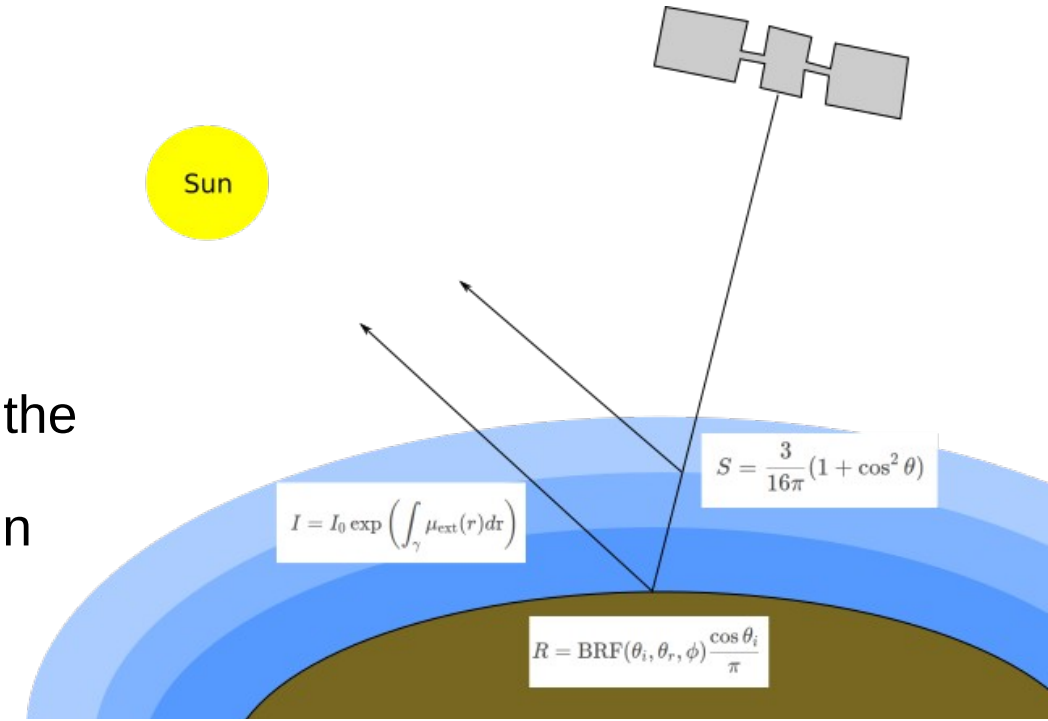


Figure based on measurements by J. Peltoniemi, FGI

Novel atmospheric radiative transfer model RaySca

- Deterministic ray-tracing model
- Only first-order scattering considered
- Fully 3D atmosphere
- HITRAN API used for gas absorption spectra computation
- Full Stokes vector of radiation (i.e. polarization) considered
- Arbitrary (polarizing) BRDF model on the planetary surface
- First mention: Mikkonen et al. (2021, in preparation)



ESA SNOWITE

- This research is being conducted as part of ESA funded project *Study on Improved Glint Retrieval for CO2M* (SNOWITE: SNOw, Water and Ice Treatments Explored for CO2M).
- First study of the feasibility of retrievals over snow with the aim of improving CO2M observations at high latitudes.
- The 18-month project includes simulated radiances and retrievals, assessment of existing missions at high latitudes, and new AirCore measurements.
- Collaboration between FMI, FGI and University of Leicester