Potential seasonal biases in retrievals of XCO_2 related to the use of a static digital surface map

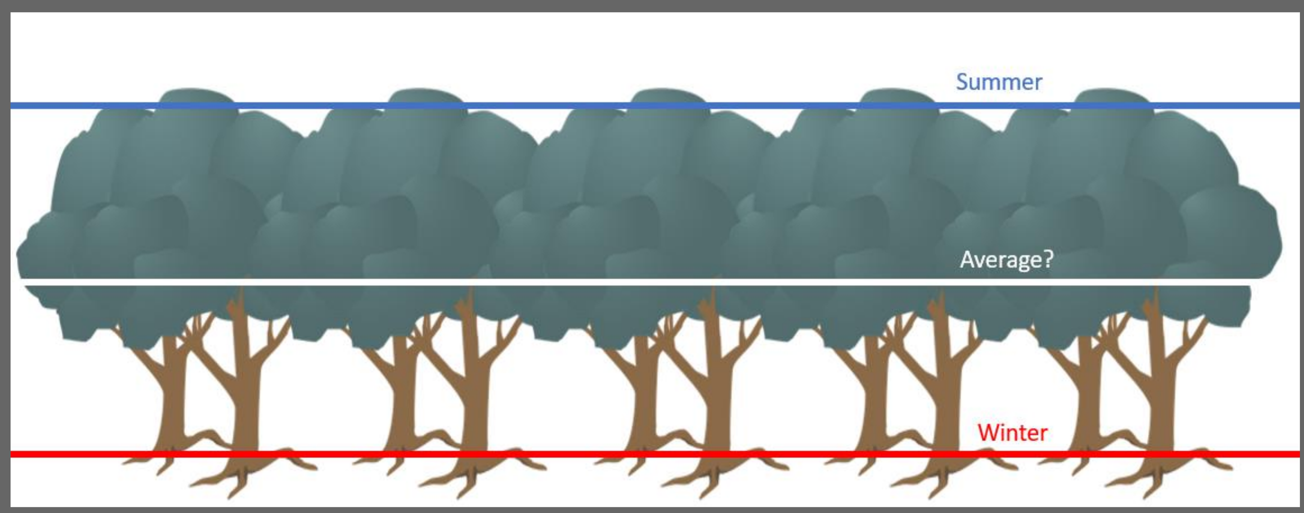
Julia Marshall*[1], Marie Lachaise[2]

[1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen
2Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Methodik der Fernerkundung, Oberpfaffenhofen
*Julia.Marshall@dlr.de

Hypothesis: by using a static digital elevation map (DEM), we are imposing a seasonal bias on XCO_2 retrievals that is regionally correlated with the carbon uptake period

DEMs (or Digital Surface Maps, DSMs) are used by most retrieval algorithms to convert the measured CO_2 column to XCO_2:
XCO_2 = column of CO_2 / amount of dry air,
locally adjusting surface pressure from meteorological models.

However: the effective surface height can vary seasonally, especially for deciduous forests.



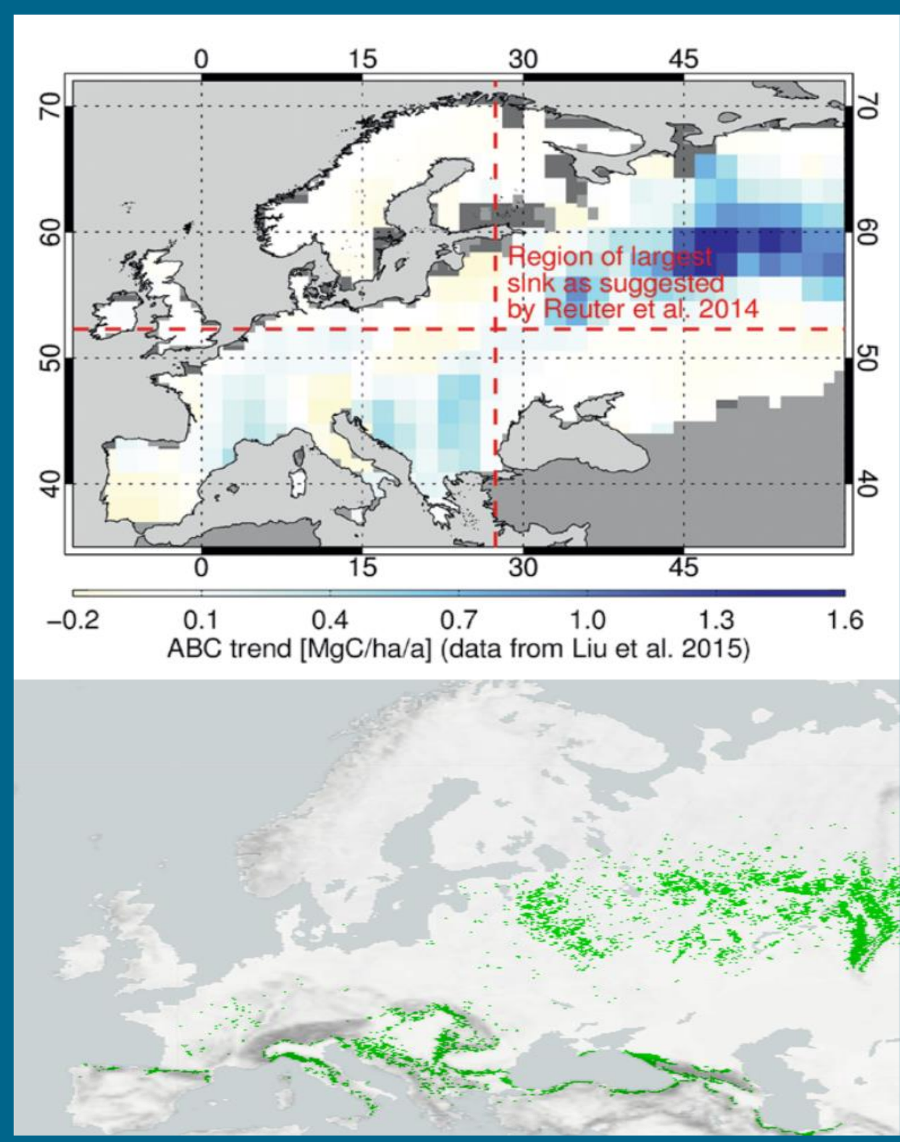
In summer:
The dry air column may be overestimated by the mean value, leading to an **underestimation of XCO_2.**

In winter:
The dry air column may be underestimated by the mean value, leading to an **overestimation of XCO_2.**

This systematic error will overestimate the seasonal cycle (and perhaps the sink?) in these regions.

Take-away messages

- New time-stamped data product from TanDEM-X shows seasonal differences in retrieved height
- These systematic errors will be mapped onto the retrieved XCO_2, where a 10-m height difference results in around 0.4 ppm difference in XCO_2
- This is a systemic error, correlated with the carbon uptake period
- The height differences seen in x-band radar may underestimate the effective height differences in reflected/scattered sunlight
- This may help bring together surface-based and satellite-based inversion results (see box below)



Could this help explain the large European carbon sink?
The top panel shows trends in Above-ground Biomass Carbon, proposed by Reuter et al. (2017) to explain the anomalously large carbon sink deduced from satellite data. These regions correspond to the location of deciduous broadleaf forests in the Copernicus 100-m land cover product (bottom panel, Buchhorn et al. 2020).

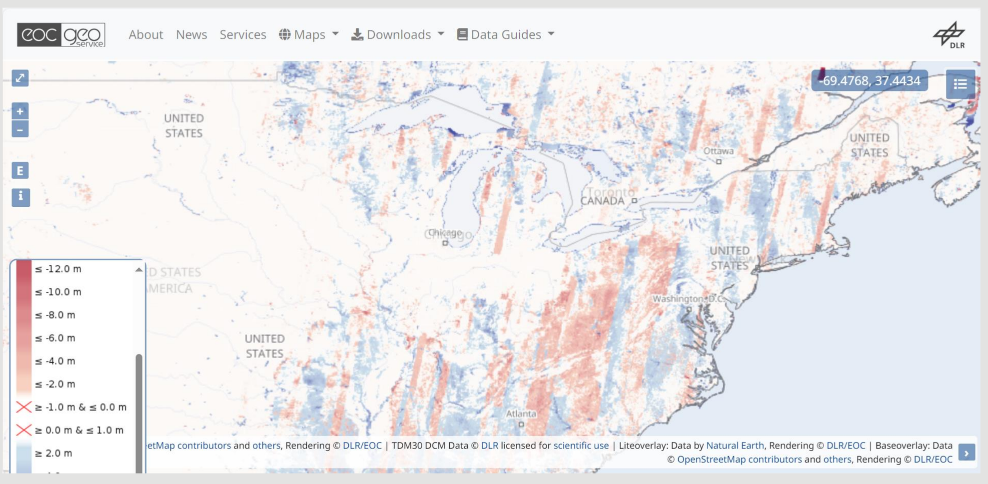
Baseline DEM

- Jacobs et al. (2024) pointed out the importance of an accurate DEM, switching to the Copernicus GLO90 DEM starting from ACOS v11.1 for OCO-2 retrievals
- The Copernicus GLO90 DEM is based on TanDEM-X data collected between 2010-2015, with a weighted average over several acquisitions and some gap-filling/smoothing

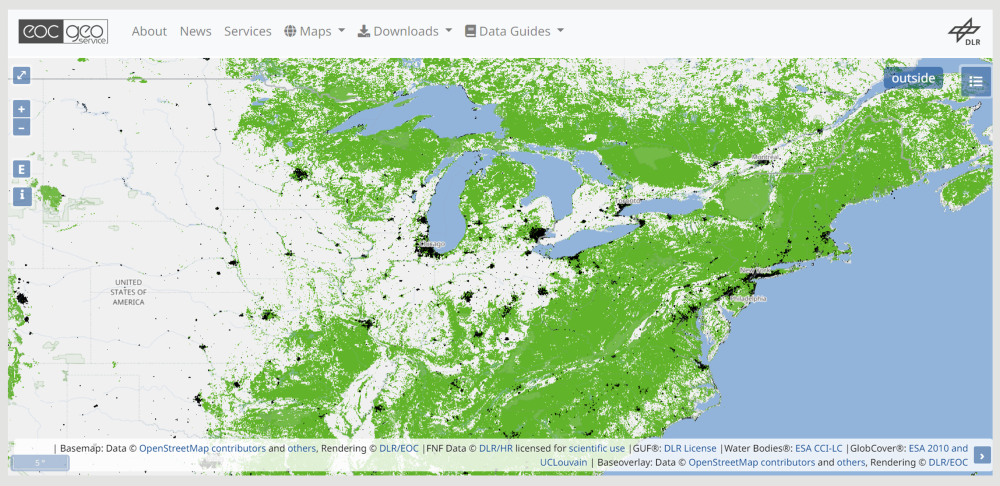
TanDEM-X DEM Change Maps (DCM)

- In October 2023 a new product with additional acquisitions taken between 2016 and 2021 was released (Lachaise et al., 2022)
- Provides up to two additional time slices, with height differences relative to the reference DEM
- Available to browse and download at https://geoservice.dlr.de

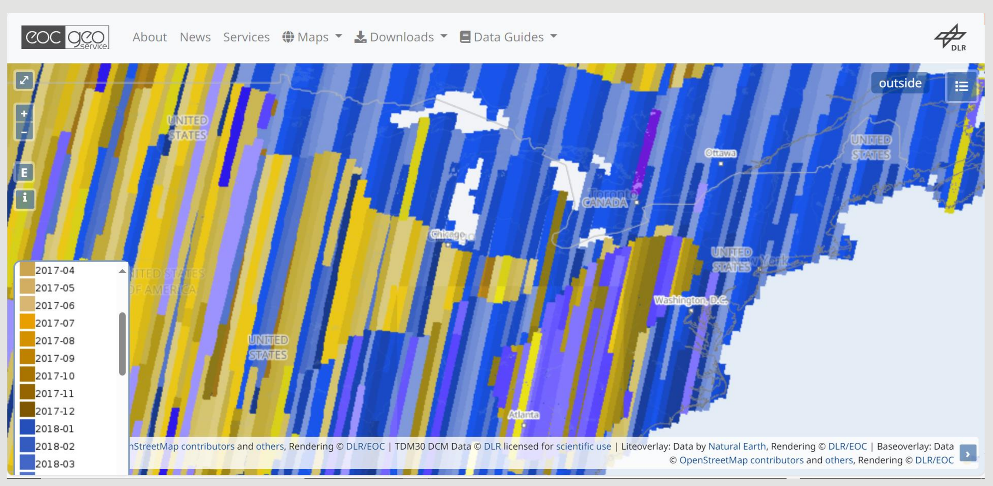
What this looks like:



With larger values for forested areas:

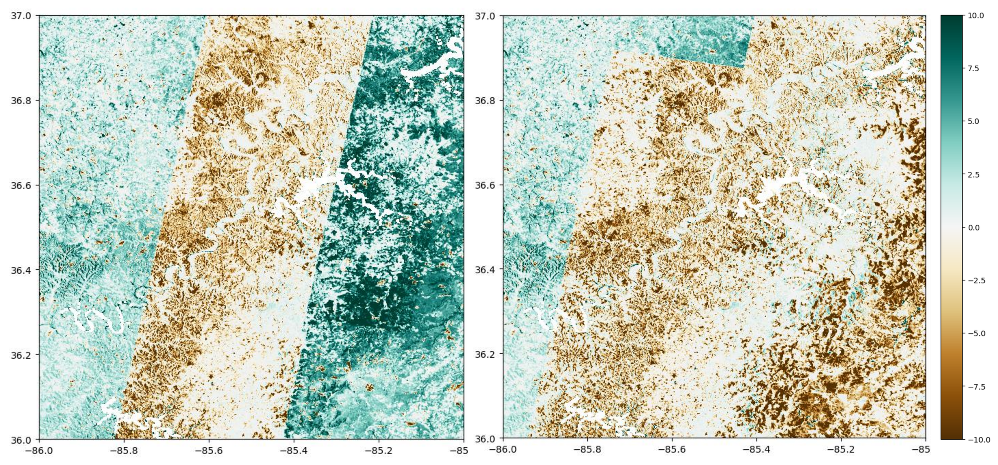


And striping linked to acquisition date:



Processing steps for one 1° x 1° tile

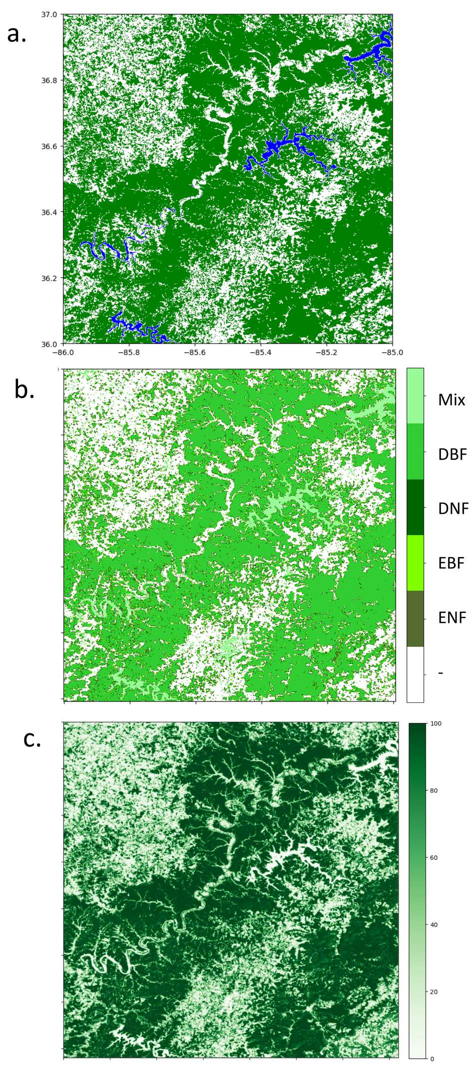
Height differences from DEM Change Map (m)
"FIRST" "LAST"



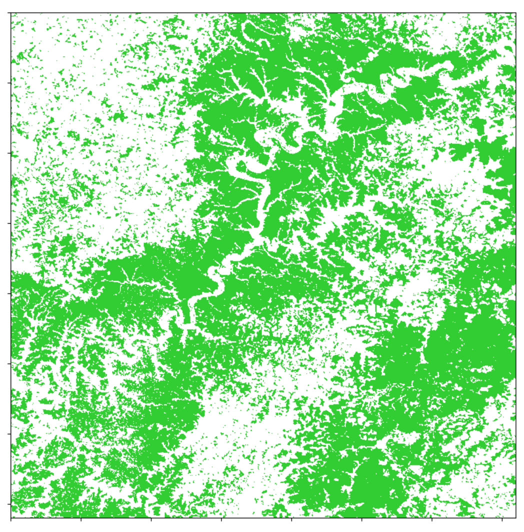
Mask based on three layers:

a. Forest / Water / Other mask from reference DEM
b. Forest type from Copernicus 100-m Land Cover (Buchhorn et al., 2020)
c. Percentage tree cover from Copernicus 100-m Land Cover product

Combined to give e.g. a mask for pixels classified as Deciduous Broadleaf Forest (DBF) with more than 70% tree cover:



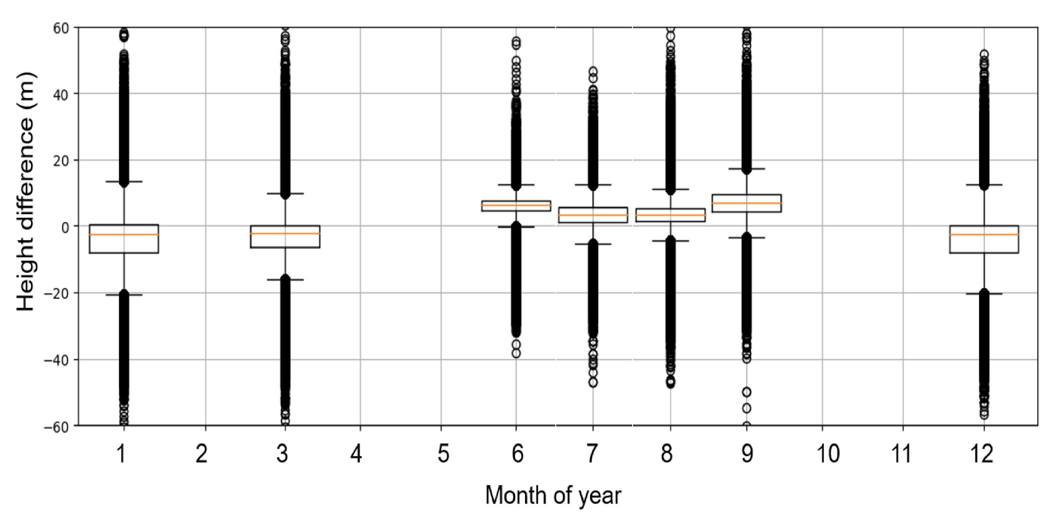
DBF70 mask



Then:

- Mask both the FIRST and LAST change maps
- Remove duplicates (when there was only one new acquisition)
- Sort by month, combining acquisitions from different years

Results in a noisy, but significant, seasonal signal:



Next steps

- Look at seasonal height differences in lidar height product GEDI02_A.002, measuring at 1064 nm, closer to the SWIR wavelengths
  - Determine if the heights seen by the lidar are comparable to those measured by the x-band radar or TanDEM-X
  - Back out the effective zero height, as the mean value in the reference DEM has no temporal information
- Look for signals in TCCON colocations, screened by land cover type
- Develop monthly delta-XCO_2 perturbation based on aggregated delta-height results
- Calculate impact on retrieved fluxes by looking at the difference of inversions performed with and without the perturbation on XCO_2
- Work to be carried out in the project DiSMISS (**Di**gital **S**urface **M**aps **I**nfluencing **S**easonal **S**ignals) at the University of Leipzig – now hiring!

DKRZ
DEUTSCHES KLIMARECHENZENTRUM

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1. Buchhorn et al., Copernicus Global Land Service: Land Cover 100m: collection 3: epoch 2019: Globe, https://doi.org/10.5281/zenodo.3939050, 2020.
2. Jacobs, N. et al., "The importance of digital elevation model accuracy in XCO_2 retrievals: improving the Orbiting Carbon Observatory 2 Atmospheric Carbon Observations from Space version 11 retrieval product, Atmos. Meas. Tech., 17, 1375–1401, https://doi.org/10.5194/amt-17-1375-2024, 2024.
3. Lachaise, M. et al., "The New Tandem-X DEM Change Maps Product," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022, pp. 5432-5435, https://doi.org/10.1109/IGARSS46834.2022.9883612, 2022
4. Reuter, M. et al., How Much CO_2 Is Taken Up by the European Terrestrial Biosphere?. Bull. Amer. Meteor. Soc., 98, 665–671, https://doi.org/10.1175/BAMS-D-15-00310.1, 2017

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