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TAKING THE PULSE OF OUR PLANET FROM SPACE

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Application of Very-High-Resolution Optical CubeSat Images at a Rewetted Peatland Site

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What is Peatland?

- Peat is usually defined as soil with a required minimum percentage of soil organic carbon (e.g., 20% - 50% per dry mass). (Joosten and Clarke, 2002; IUSS Working Group WRB, 2015)
- Peatland is peat-covered terrain, usually with a required minimum depth of peat (most common threshold is 30 cm). (Joosten and Clarke, 2002)


Kenya


Canada


Russia


Sweden


Malaysia


Argentina

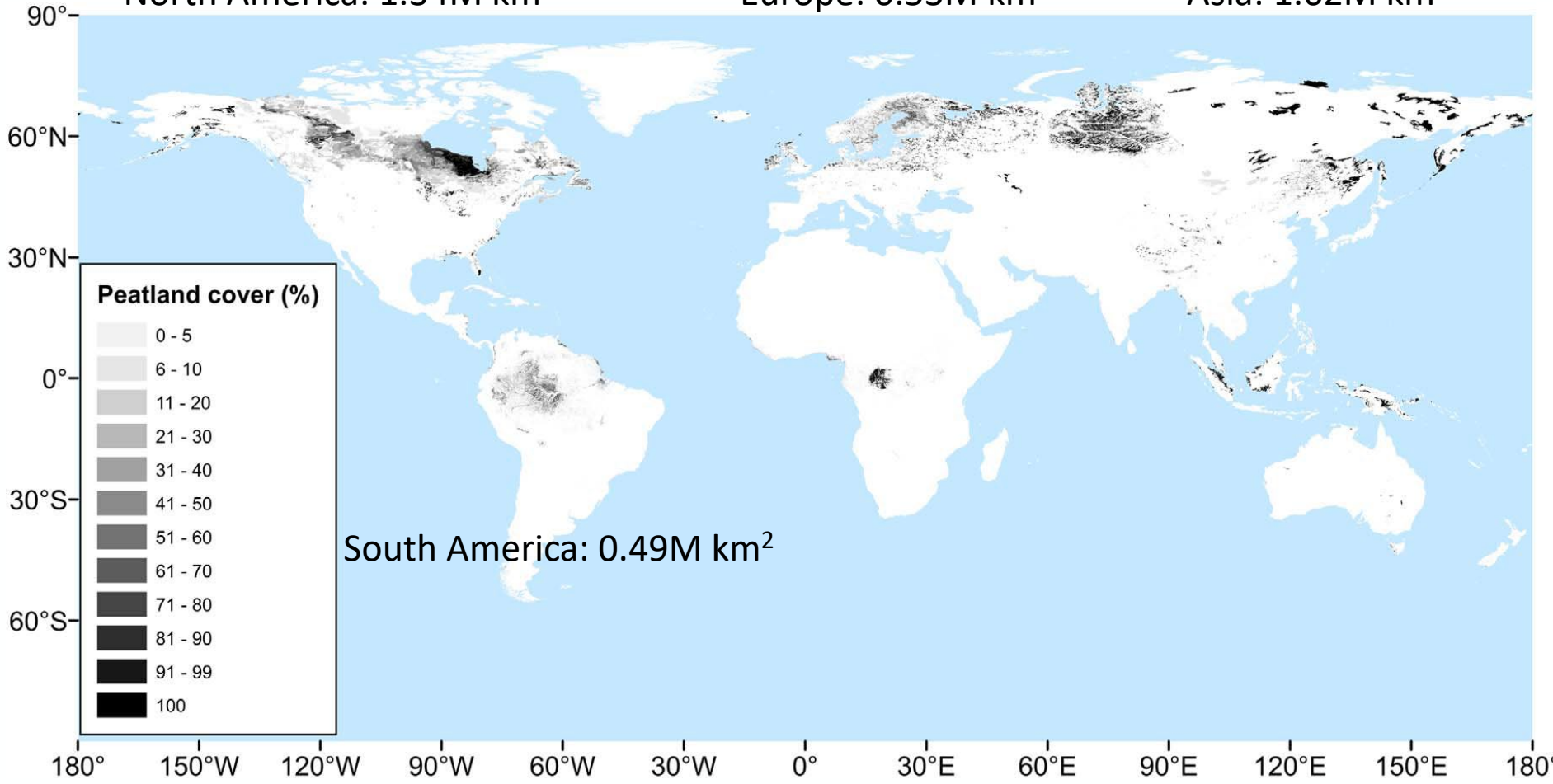
(Parish et al., 2008)

(Joosten and Clarke, 2002)

Why Peatlands?

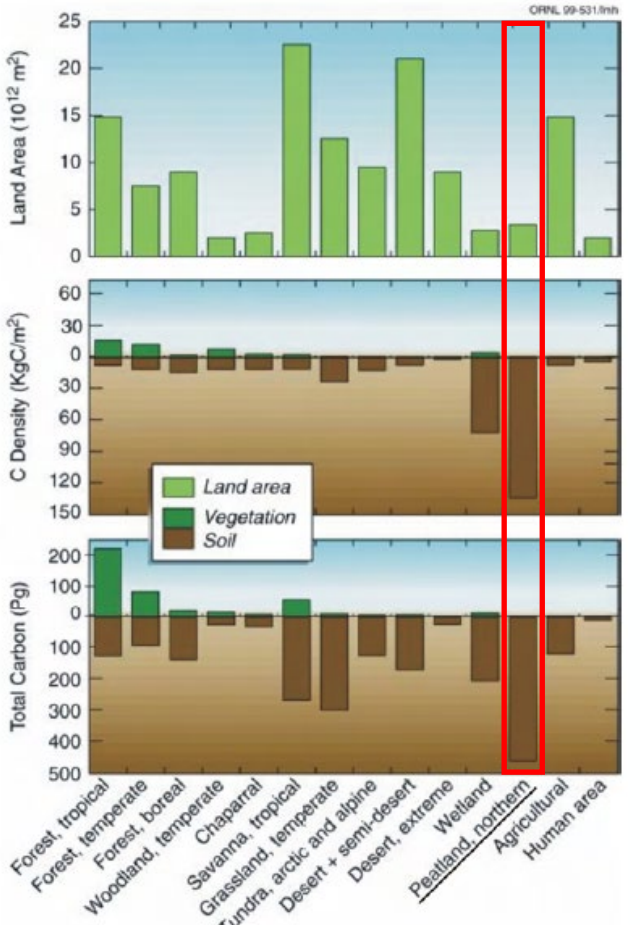
4.23M km² (Including drained peatlands), ~3% land area

North America: 1.34M km² Europe: 0.53M km² Asia: 1.62M km²



(Xu et al., 2018)

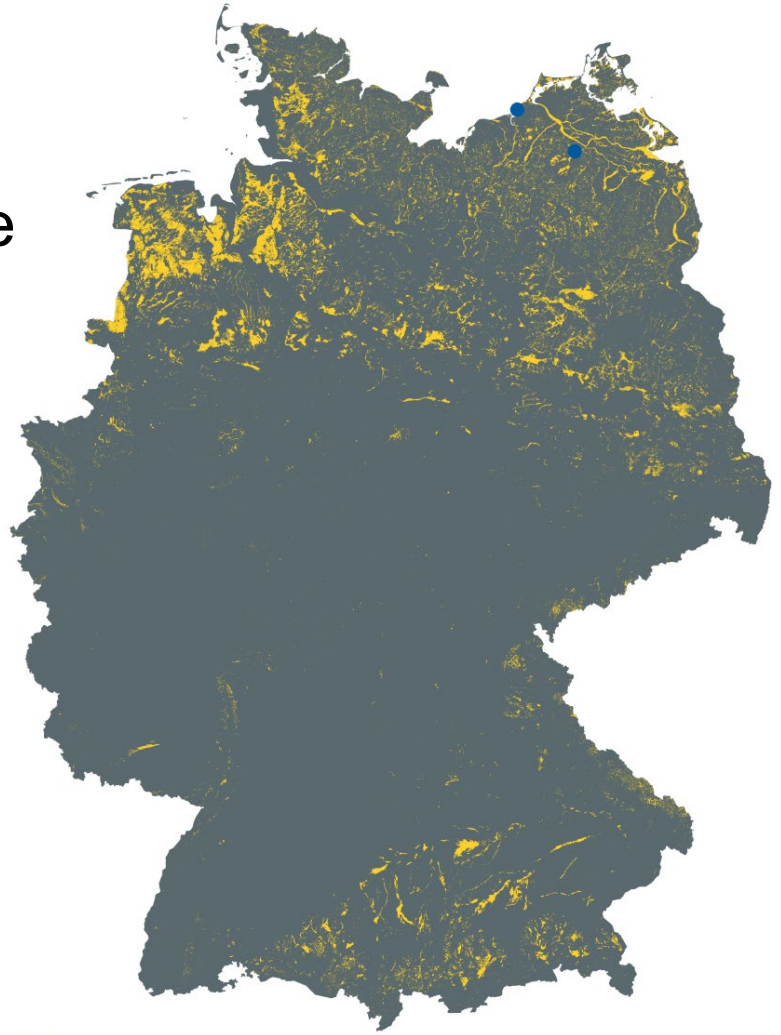
25-30% of soil carbon
50-75% of atmospheric CO_2



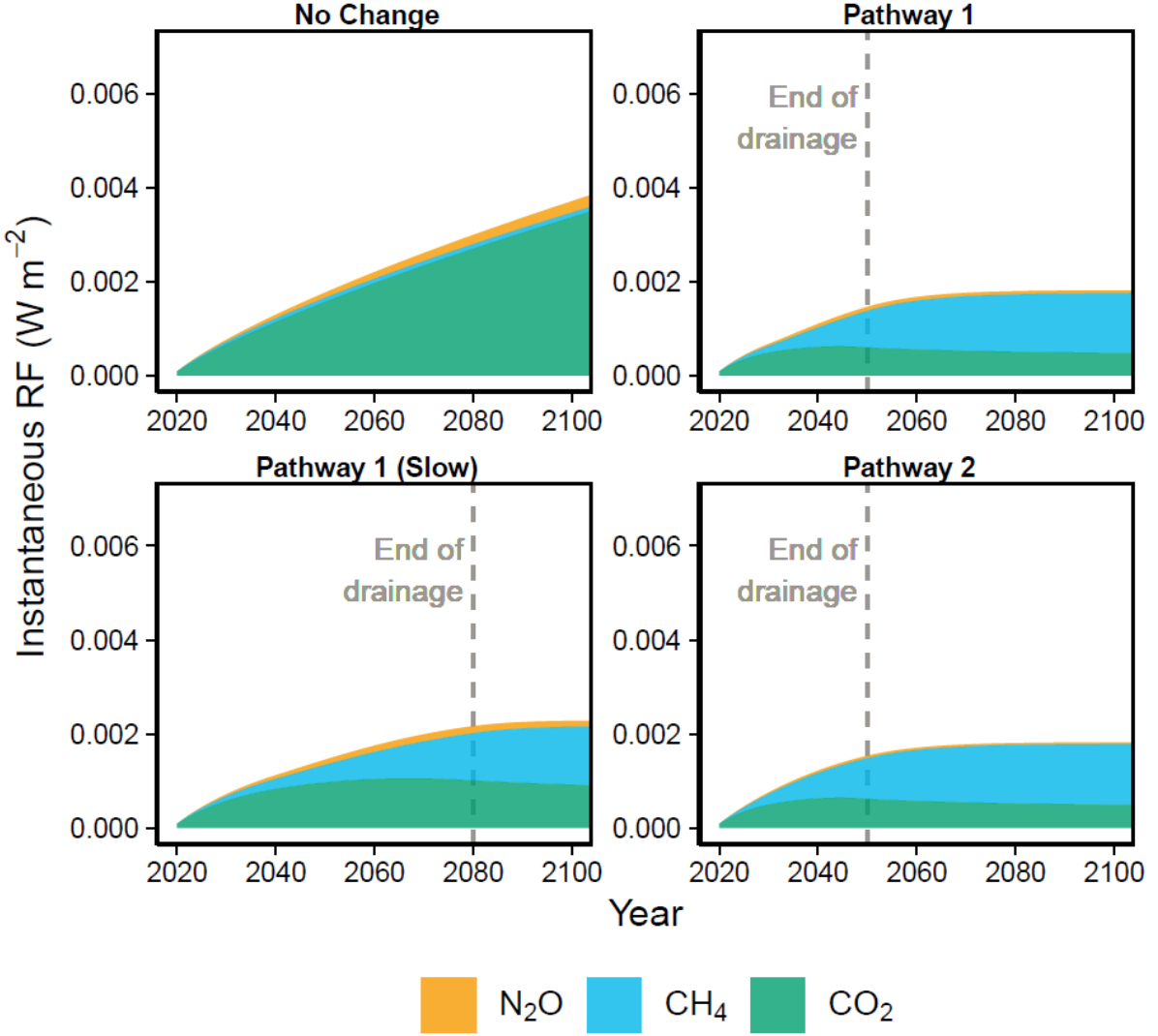
(Parish et al., 2008; Rydin and Jeglum, 2013; Adams and Faure, 1998)

Drained Peatland & Rewetting

1.41 Mha of organic soil in Germany, more than 98% is drained

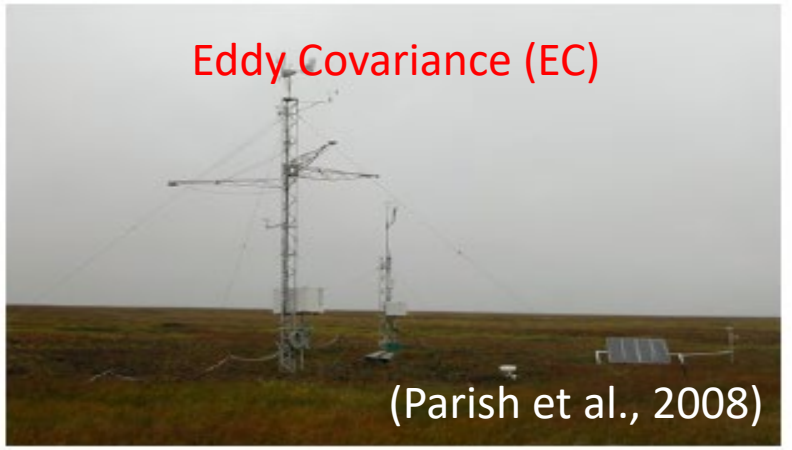


Greifswald Mire Centre (Trepel et al., 2017)



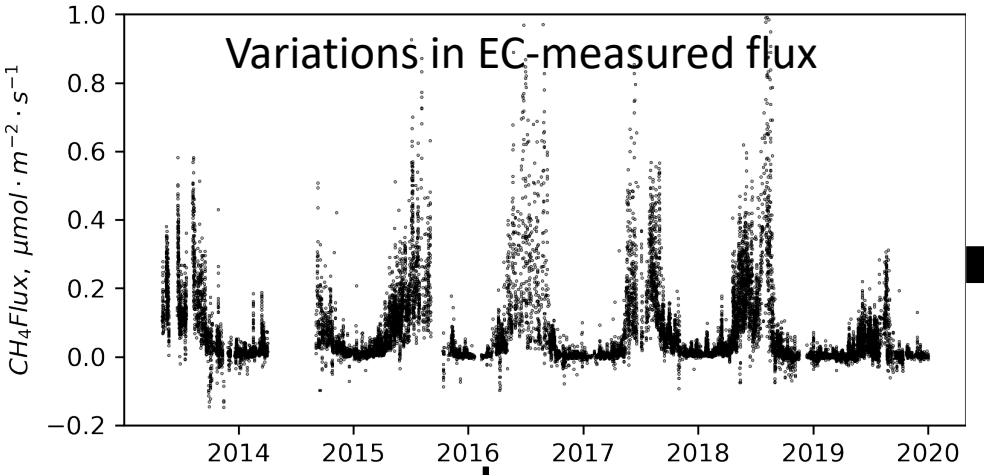
(Tanneberger et al., 2021)

Measure CO_2 and CH_4 fluxes

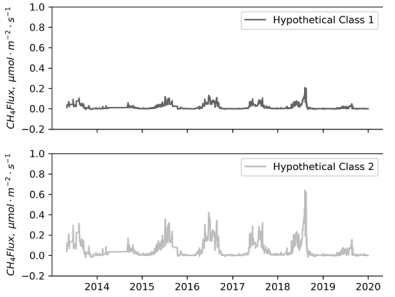


How can CubeSats VHR images help analyze EC measurements of carbon flux?

- Time series of carbon flux

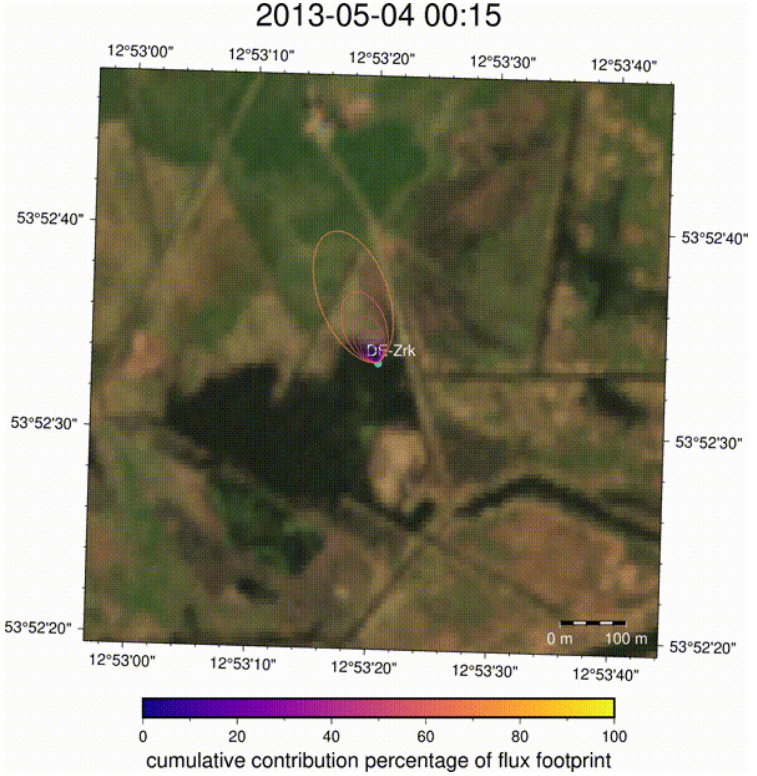


- Decomposed carbon fluxes per relative homogeneous surface cover

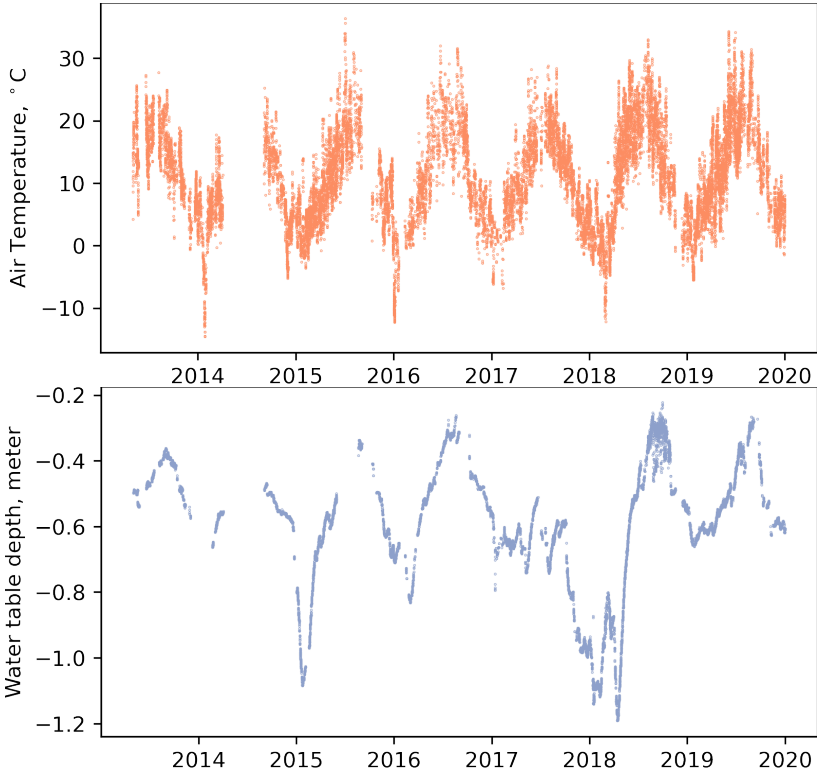


- Time series of Very-High-Resolution (VHR) images
- Time series of EC footprints

Spatial variations in surface cover and condition within EC footprints

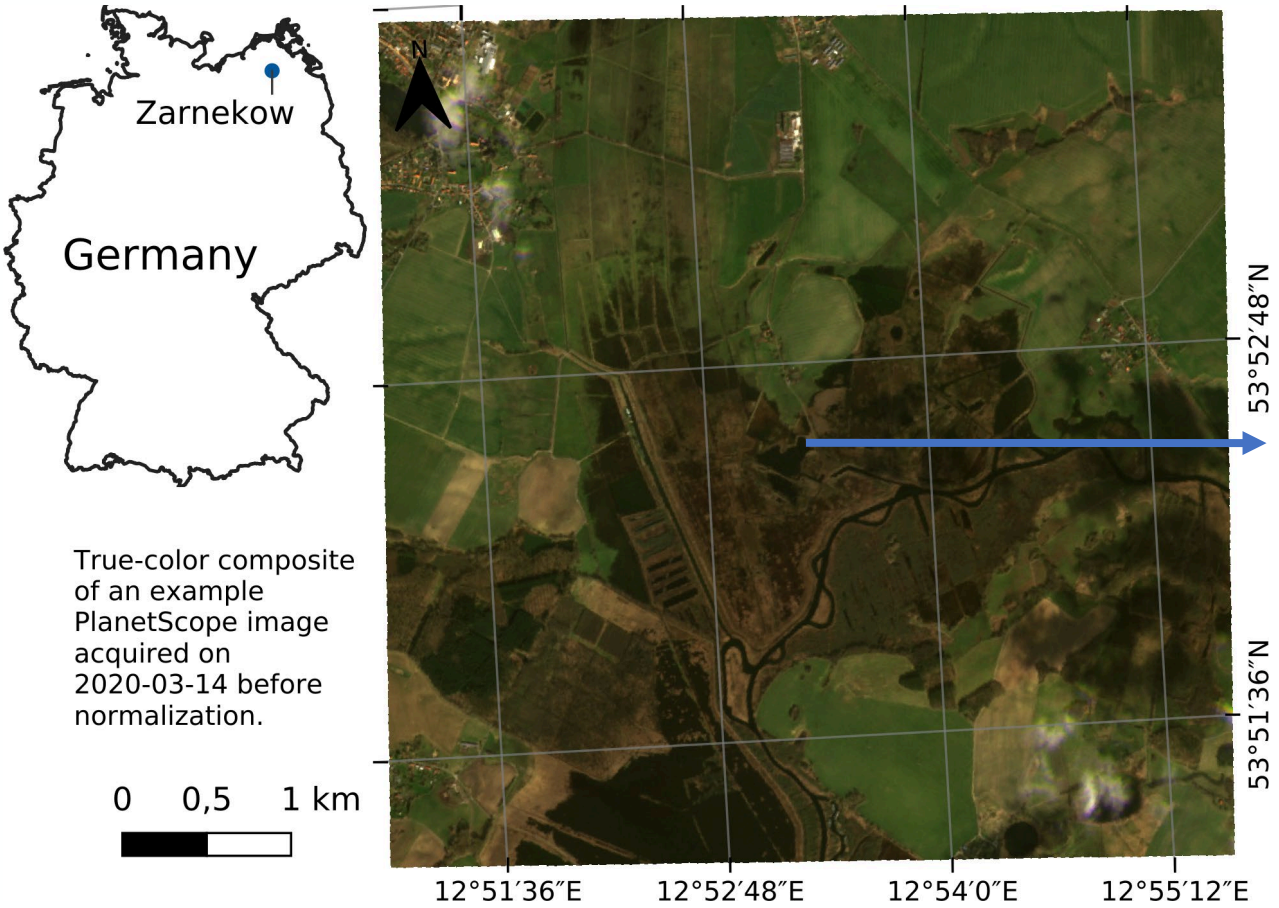


Temporal variations in environmental conditions



- Time series of environmental conditions

Test Site: Zarnekow



True-color composite of an example PlanetScope image acquired on 2020-03-14 before normalization.

- **Ground Observation[1]**
  - 2013 to present
  - CO_2 and CH_4 flux
  - Biomet data
  - Water table depth
  - Soil temperature and heat flux
- **Earth Observation[2]**
  - 2013 to 2020
  - ~120 VHR images from RapidEye (5-m) and PlanetScope (3-m) sensors
  - 5 km x 5 km Region

[1]:Site PI: Prof. Dr. Torsten Sachs, torsten.sachs@gfz-potsdam.de [2]:ESA TPM Programme

Workflow

Image Normalization

- Consistent time series of CubeSat VHR images

Surface Partition

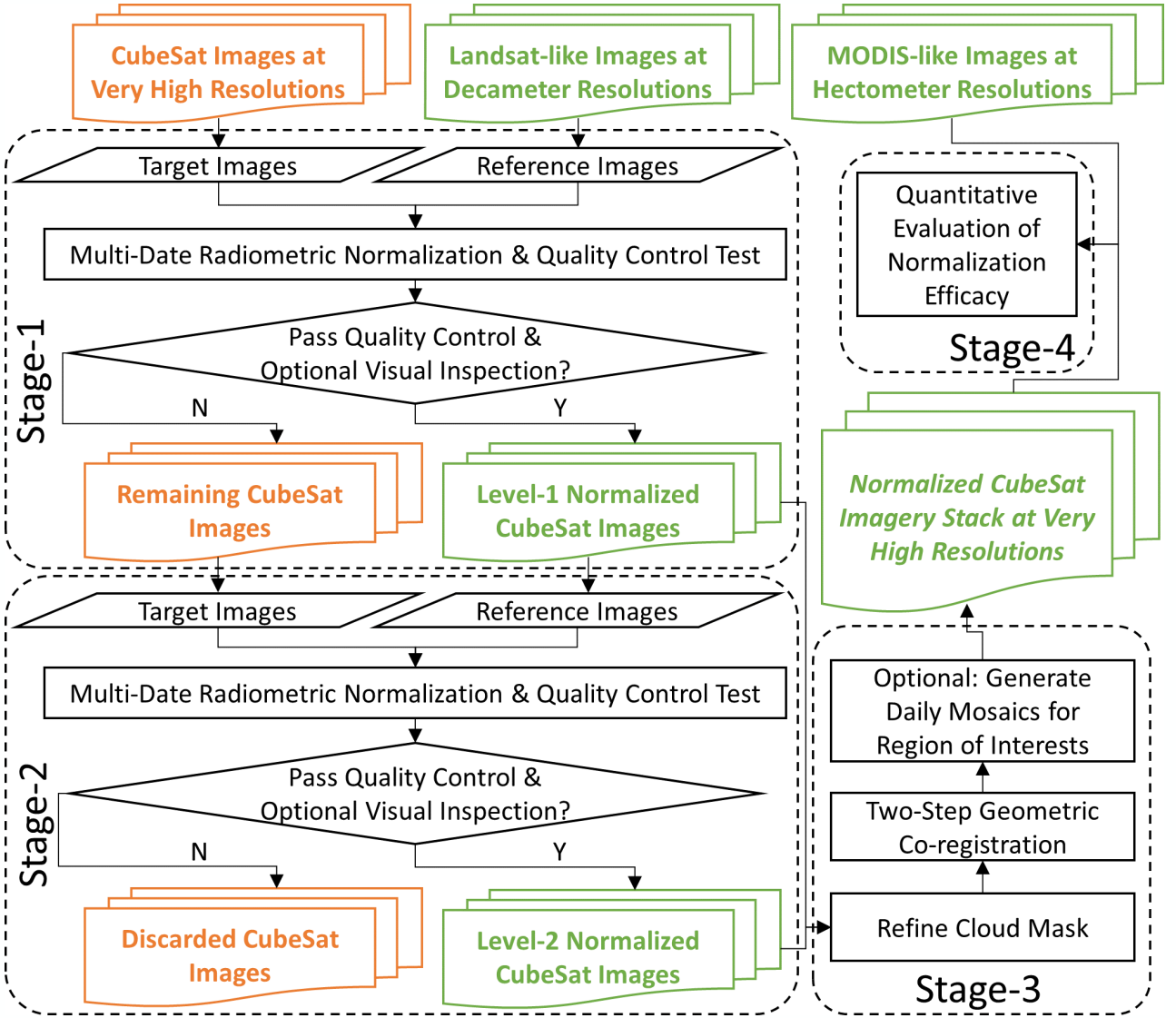
- Relatively homogeneous surface covers based on vegetation and water coverages

Flux Decomposition

- Time series of cover-specific gas flux

Image Normalization

A procedure customized to our small-area case to generate quasi-Analysis Ready Data (ARD)



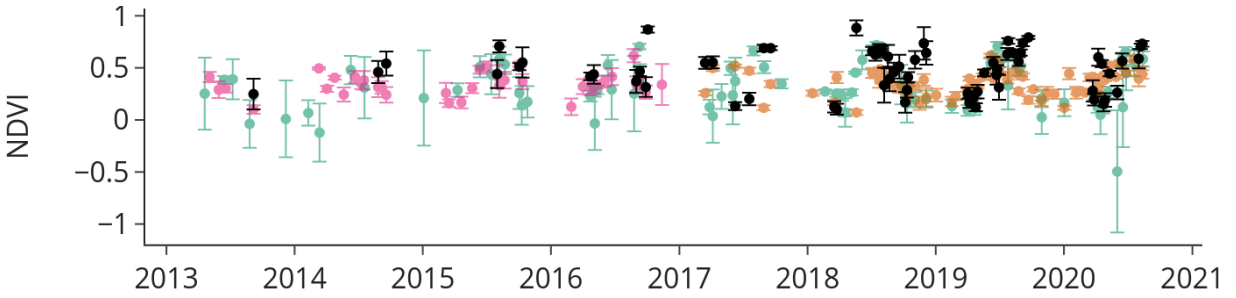
(Li et al., 2021)

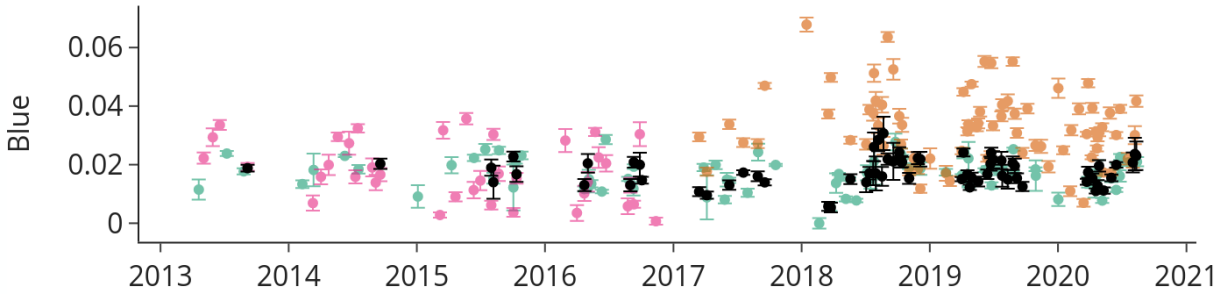
Image Normalization

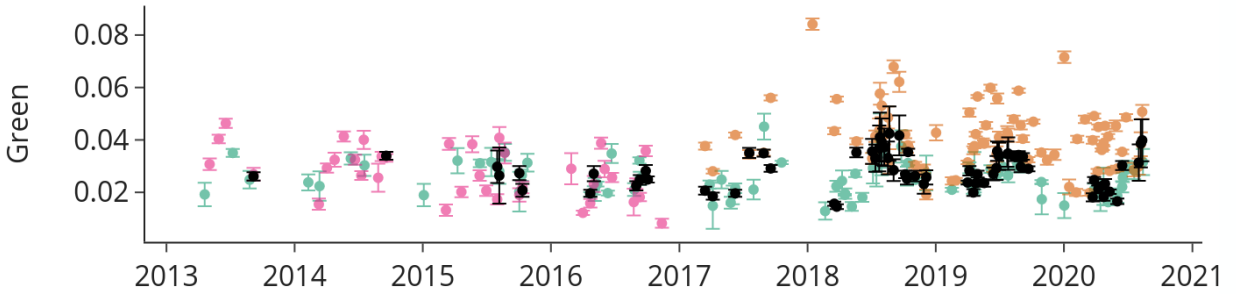
ROI 30x30 m^2 randomly selected vegetation area

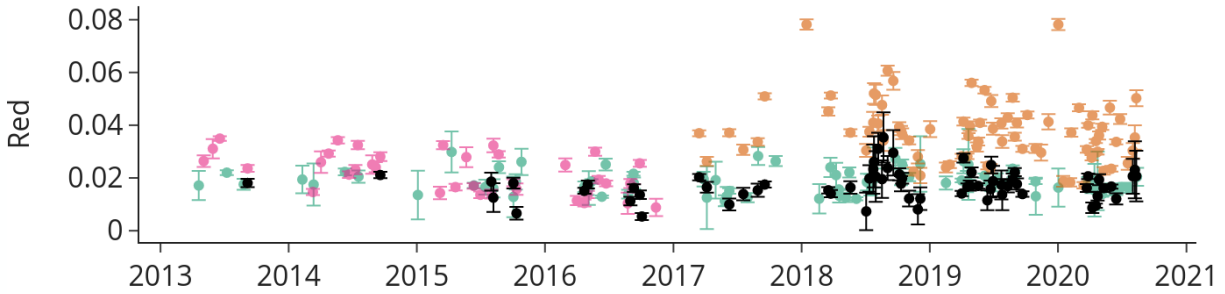
Image Normalization

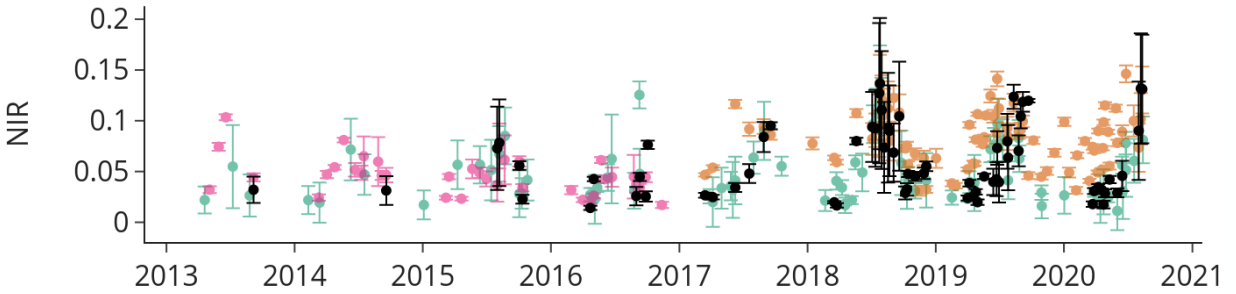
ROI 30x30 m^2 randomly selected water area





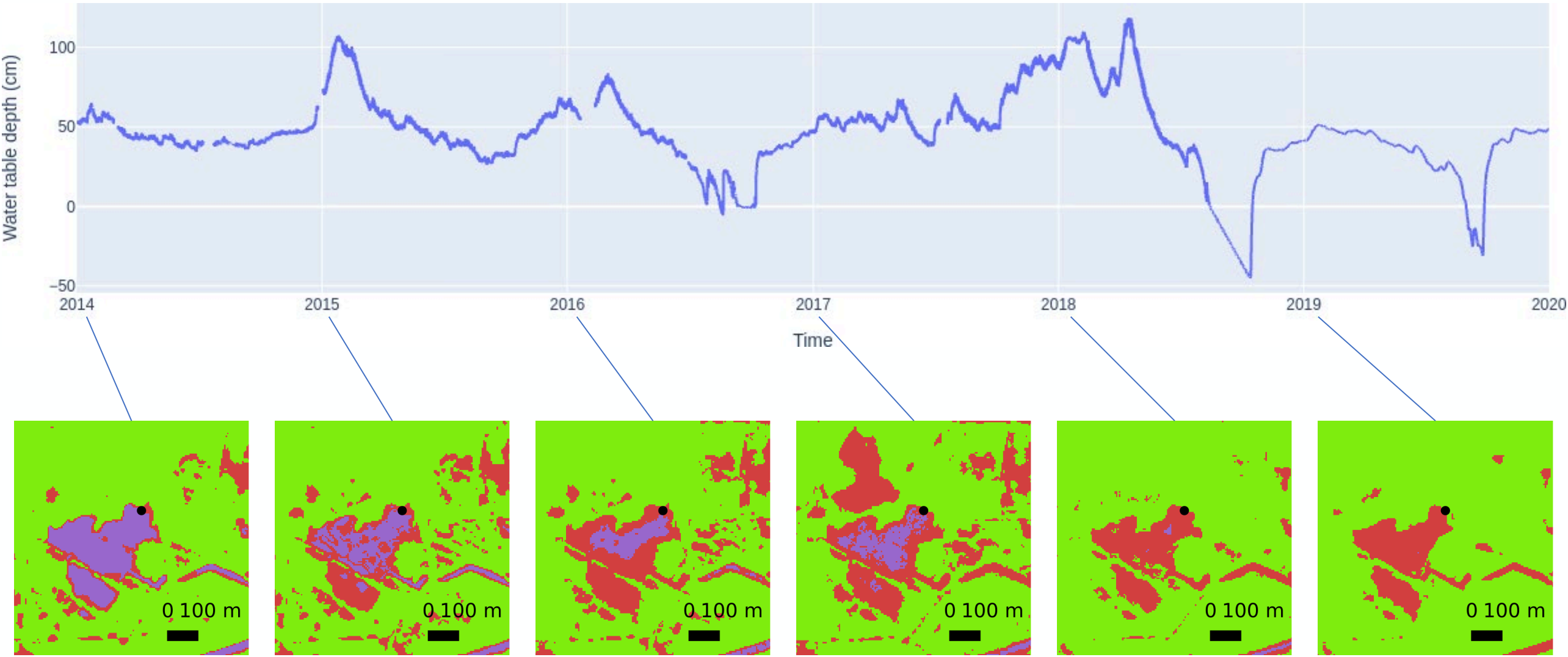






HLS · Prenorm. PlanetScope · Prenorm. RapidEye · Normalized CubeSat

Surface Partition



Flux Decomposition

Nonparametric Linear Unmixing

- In a short temporal window and in a cluster of measurements under similar values of environment variables:
  - Assume no temporal variation of cover-specific flux.
  - Assume only spatial variation of surface cover fractions within EC measurement footprints

m measurements
k cover types

Fractional contribution of surface cover types

$m \times k$

Cover-specific flux
- per environmental cluster
- per temporal window

$k \times 1$

EC-measured flux

$m \times 1$

Flux Decomposition

Generate half-hourly footprint-weighted fractions of surface cover types

- Roughness length and zero displacement height (Graf et al., 2014)
- Georeferenced half-hourly footprint rasters (Kormann and Meixner, 2001)

Cluster selected environment variables per temporal moving window

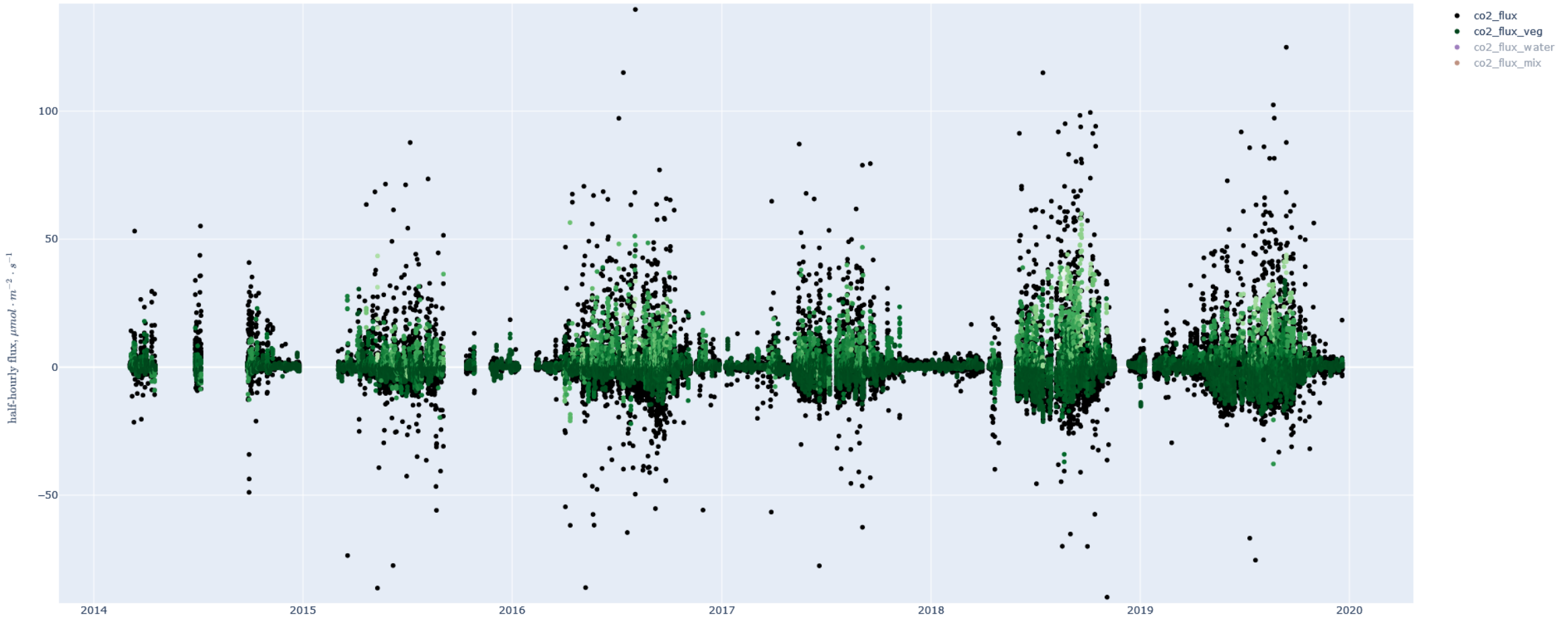
- Analysis of correlation and feature importance (16 variables selected)
- Agglomerative clustering

Linear unmix gas flux per environmental cluster in each short temporal window

- Constrained linear least square regression
- Similar to (Chen et al., 1999) for the decomposition of airborne flux measurements

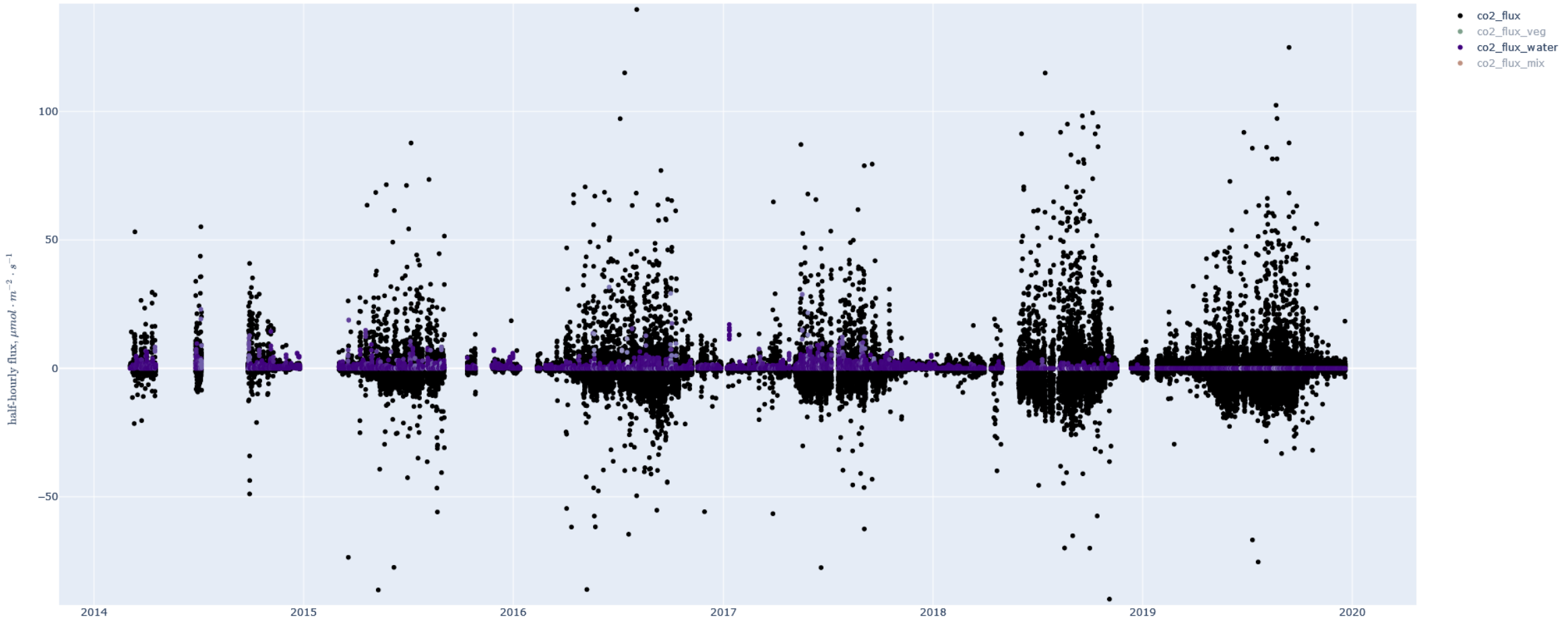
Flux Decomposition

CO_2 Flux, EC-measured & Vegetation-cover-specific



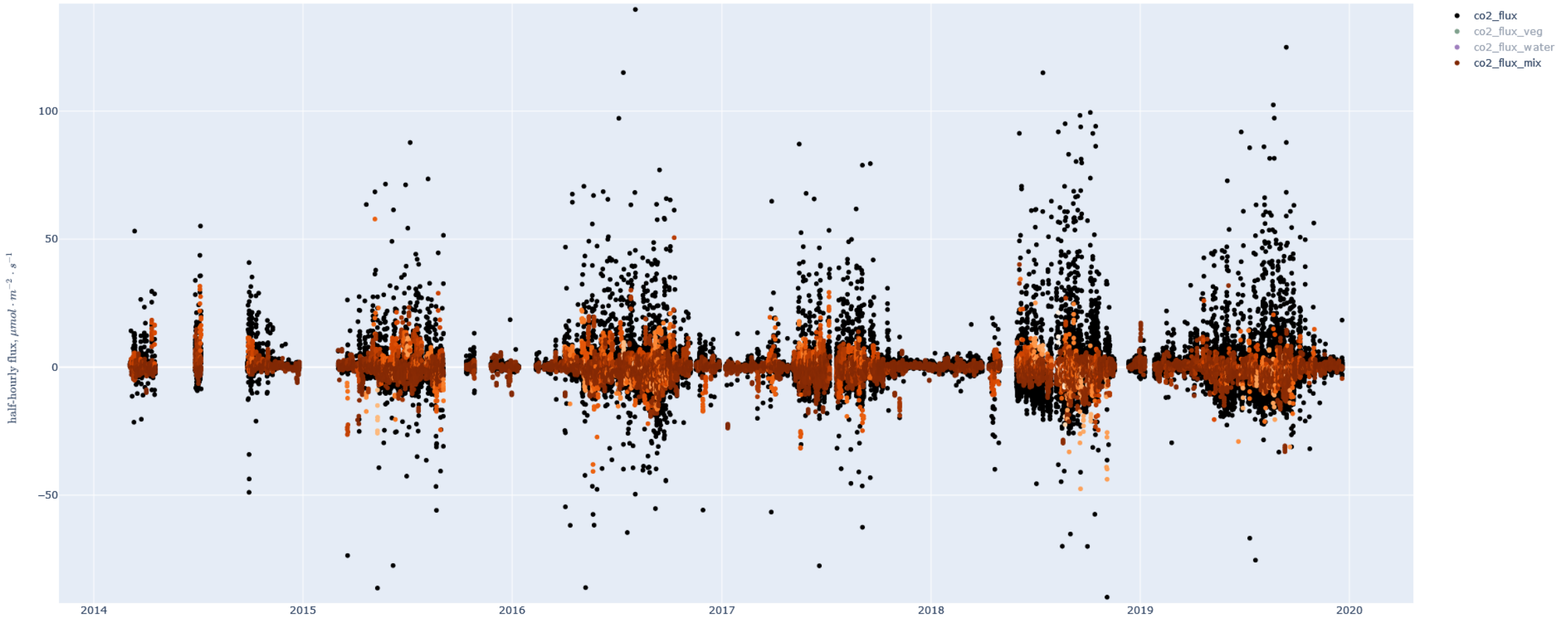
Flux Decomposition

CO_2 Flux, EC-measured & Water-cover-specific



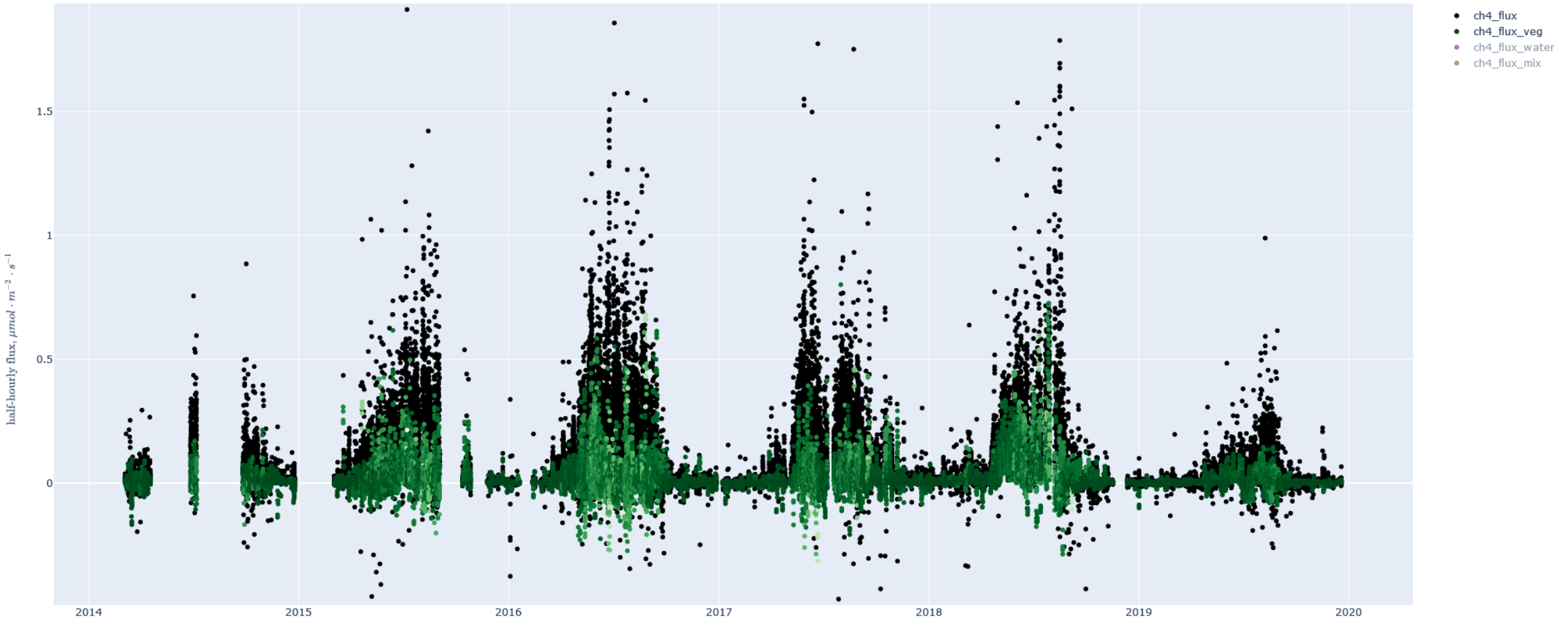
Flux Decomposition

CO_2 Flux, EC-measured & Mixed-cover-specific



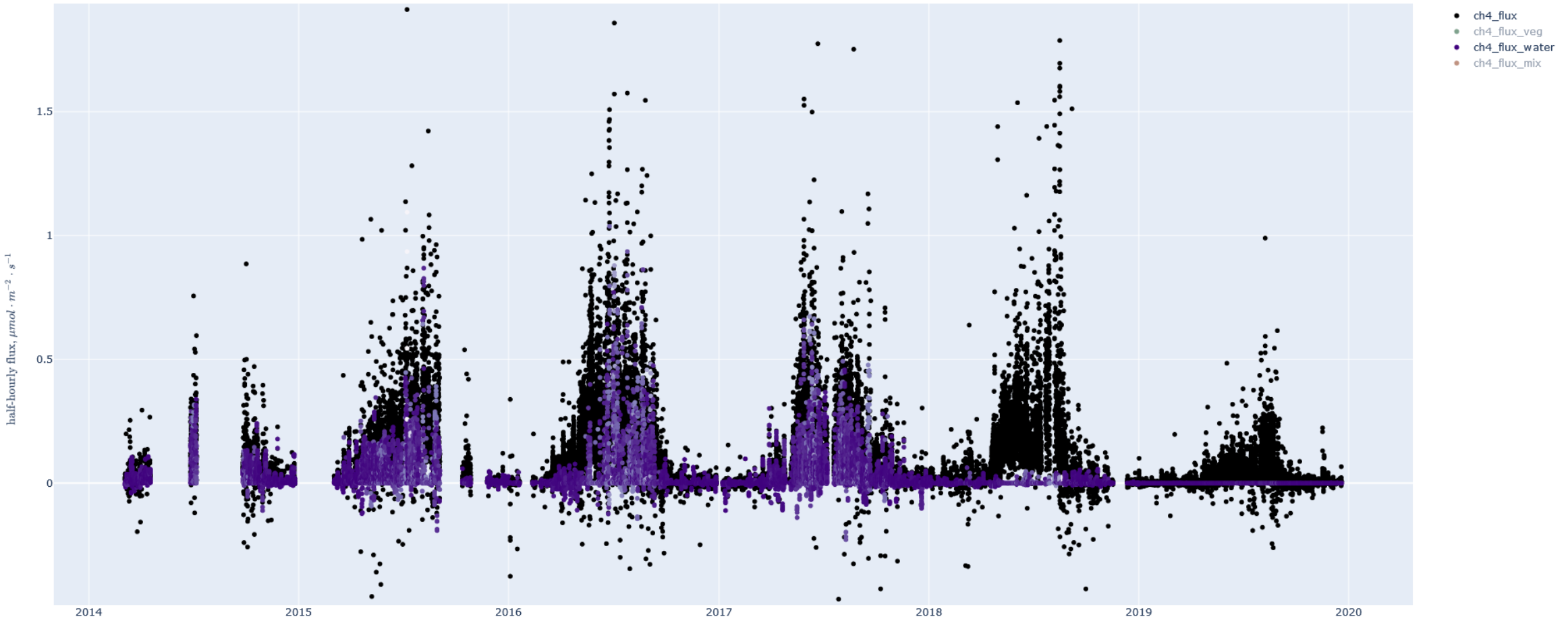
Flux Decomposition

CH_4 Flux, EC-measured & Vegetation-cover-specific



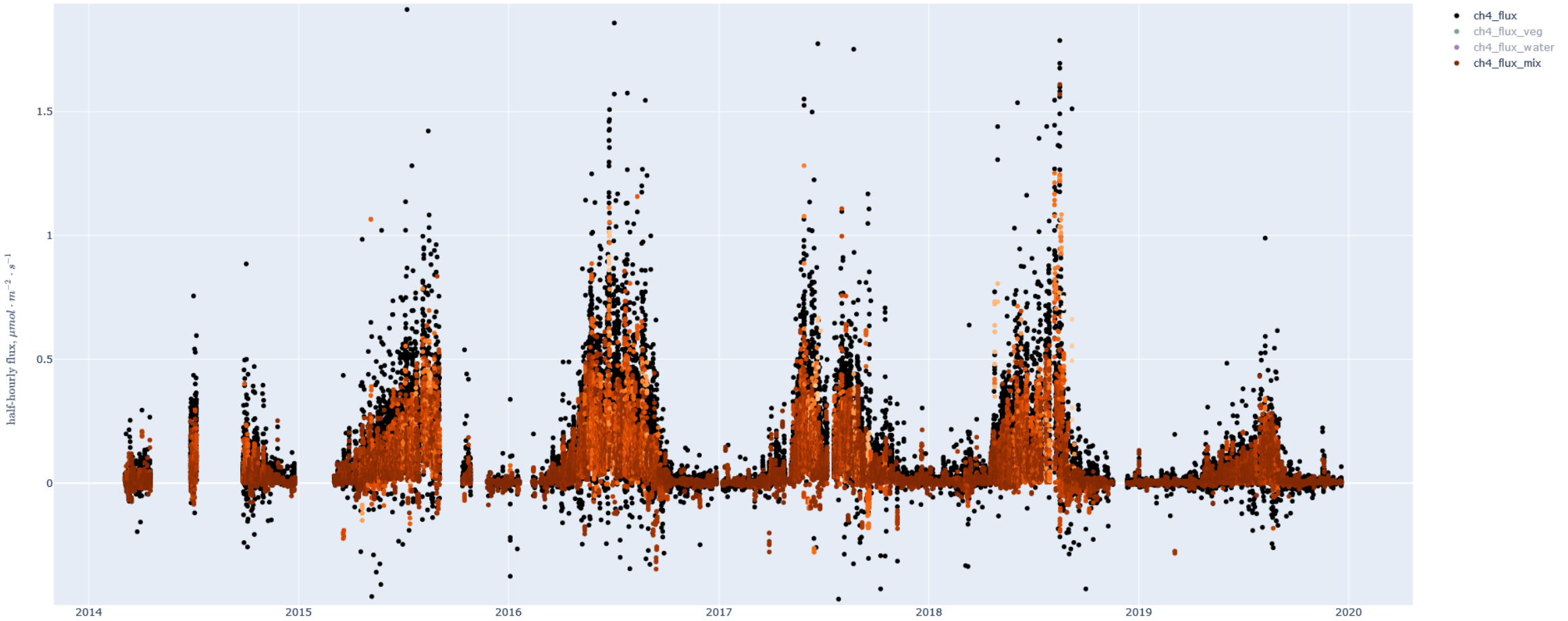
Flux Decomposition

CH_4 Flux, EC-measured & Water-cover-specific

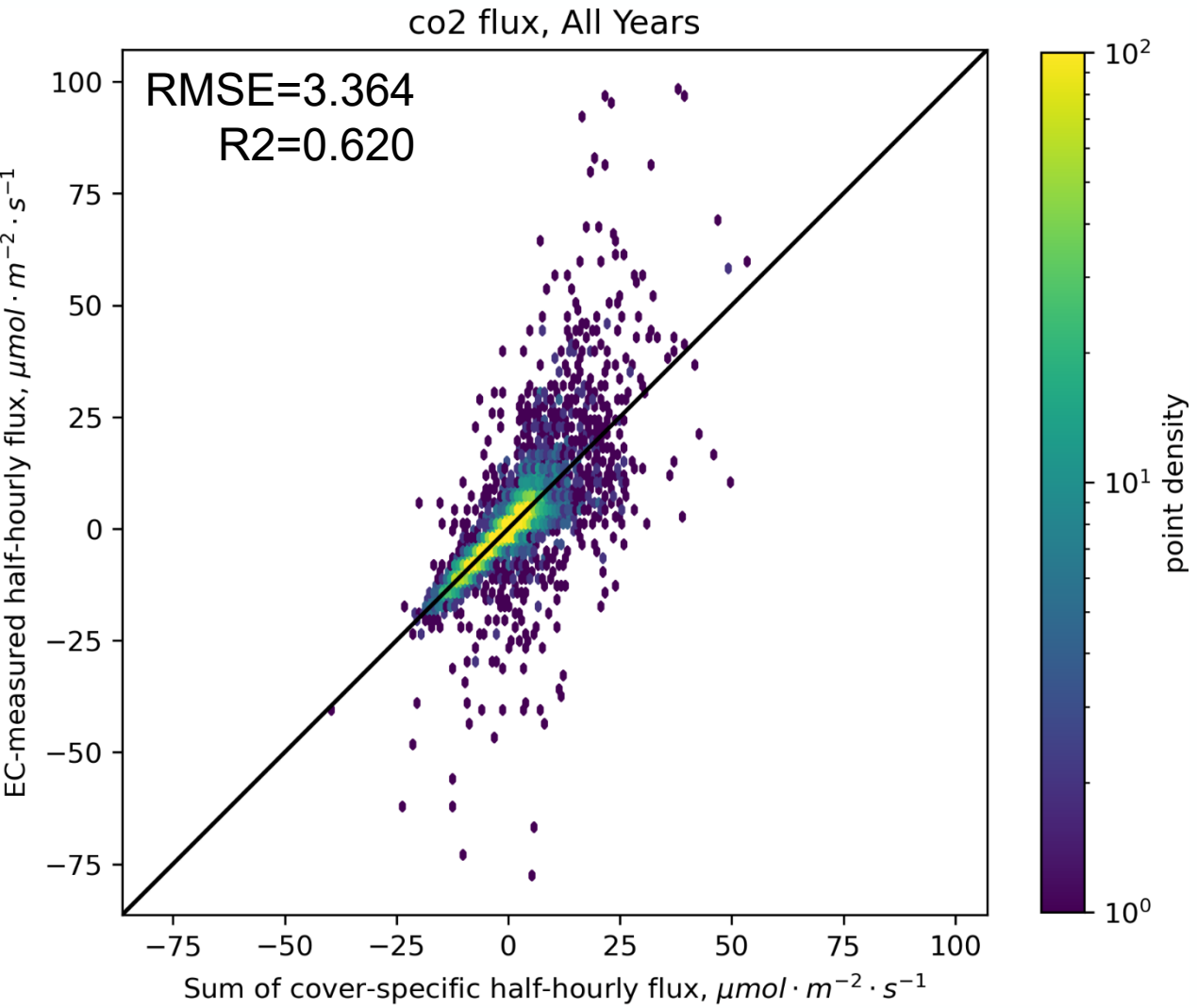


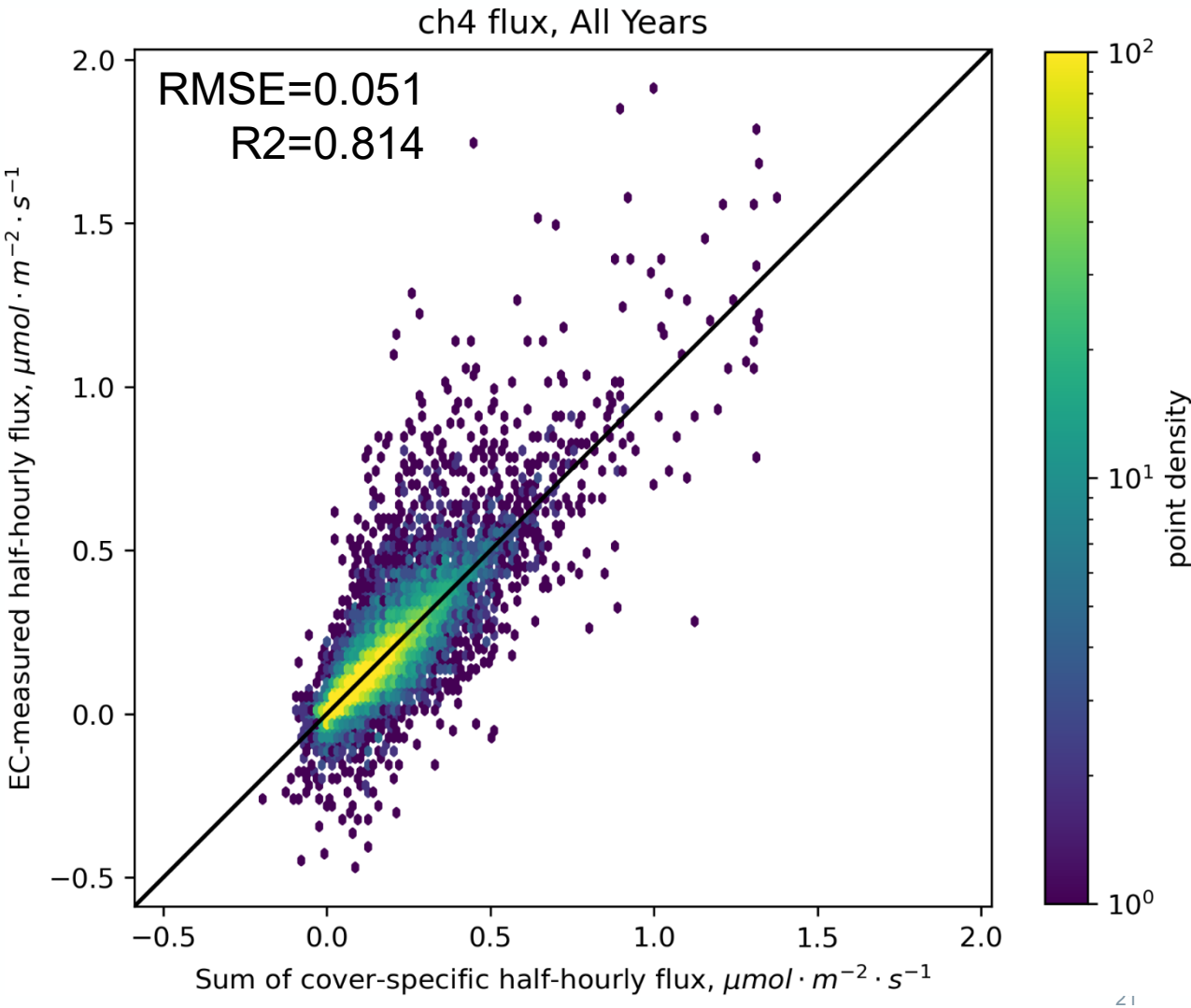
Flux Decomposition

CH_4 Flux, EC-measured & Mixed-cover-specific



Flux Decomposition





Concluding Remarks

- Know the areal coverage of your EC flux measurements!
  - EC measurements are areal like imagery data, not point-based.
  - Geo-referenced footprint raster data are needed for using VHR images with EC measurements[1].

- Vegetation as a proxy sensor of soil and belowground conditions.
  - Change in areas of vegetation and surface water is a reasonable indicator of changes in water table depth (at least at this fen peatland in Northeast Germany!).

- Reasonable estimates of cover-specific flux using linear unmixing.
  - Decomposition of CH_4 performs better than CO_2.

[1]:My scripts to generate geo-referenced footprint rasters in NetCDF, https://github.com/zhanlilz/scripts-ec-z0d-fp

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