Estimating CO_2 emissions from space

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Objective: Predict CO_2 fluxes using satellite data

- Understanding atmospheric CO_2 fluxes, i.e. **emissions and sinks** of CO_2, is a fundamental problem in climate science that can help monitoring CO_2 anthropogenic emissions.
- There exist several models to estimate global CO_2 fluxes. These are based on inverse modelling using ground-based CO_2 measurements, and more recently also satellite-based observations. These also use wind fields, which are computationally expensive.
- **We propose a machine learning (ML) approach to estimate global CO_2 fluxes using satellite data.** This will lean on the existing flux models, whose fluxes for previous years will be used as training data for the ML model.

EOxHub workspace and EDC Sentinel Hub

In this project we explored the EuroDataCube capabilities for future projects that involve using machine learning algorithms with satellite data. These face computational challenges that can be relieved by using cloud environments such as EOxHub workspace.

- Data from several years from different satellites need to be collected and uniformised in order to train the ML models.
- A JupyterLab environment with quick access to these data is a very convenient workspace.
- The possibility to upload and store data that is not directly available is very useful.
- Sentinel Hub data is easy to combine with the dedicated Python library *eolearn*, a library that acts as a bridge between Earth observation data and machine learning.

Predicting CO_2 fluxes from satellite observations

We consider 2 different machine learning models based on decision trees:

(1) **Random Forest algorithm**, parallel learning.

(2) **Extreme Gradient Boosting** algorithm (or XGBoost), iterative learning.

To train the ML models we use:

- **CarbonTracker** CT2019b CO_2 fluxes, developed at NOAA Global Monitoring Laboratory, available from 2000 to 2018.
- Copernicus Atmosphere Monitoring Service (**CAMS**) CO_2 fluxes, available from 1979 to 2020.

As features we use:

- Carbon dioxide (**CO_2**) measurements from OCO-2
- Carbon monoxide (**CO**) from MOPITT
- Nitrogen dioxide (**NO_2**) from OMI
- Solar induced fluorescence (**SIF**) from OCO-2

Preliminary results: Predictions of ML model XGBoost trained with CarbonTracker

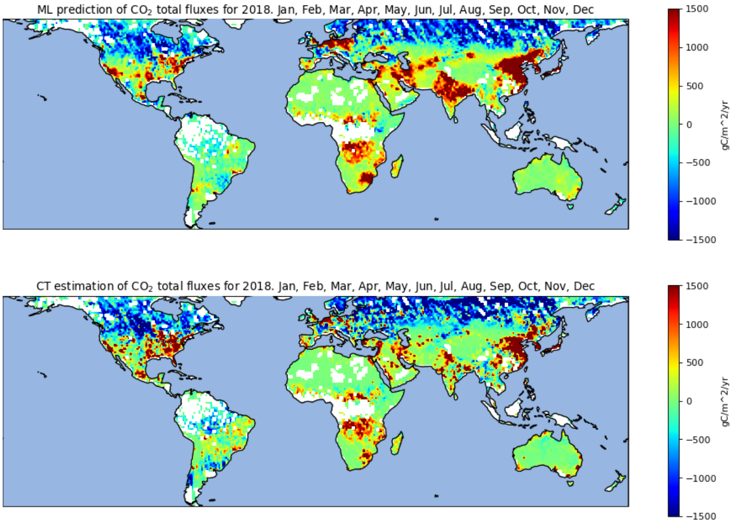

Figure: XGBoost vs CarbonTracker, 2018

Preliminary results: Predictions of ML model XGBoost trained with CAMS

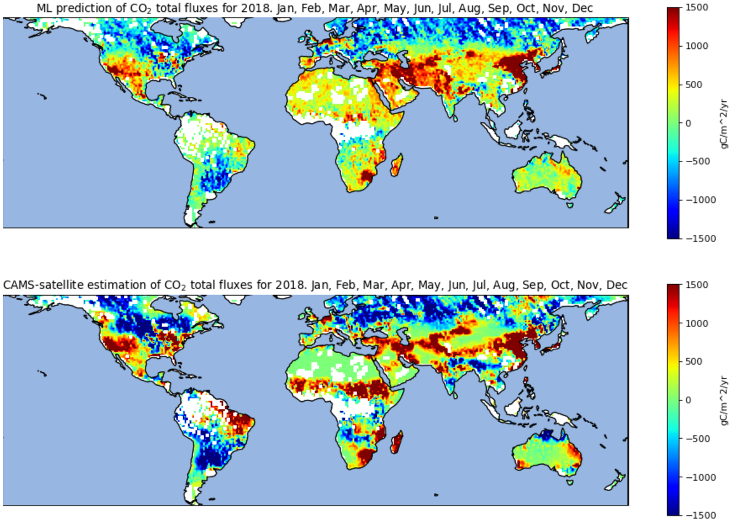

Figure: XGBoost vs CAMS, 2018

Societal impact

- This project has the potential to provide quick estimates for CO_2 fluxes predictions in contrast to more computationally costly inverse flux methods.
- The presented machine learning models, currently used at a large scale, could be improved to be used at a small scale, eg. at city or power-plant level. This could allow, for example, to test different mitigation policies to reduce greenhouse gas emissions and choose the most appropriate in each case.

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