AGROFLUX

Improving the agrosystem GHG budget through data- assimilation of surface fluxes

DURATION
1/02/2023 – 1/05/2027

BUDGET
956 196 €

PROJECT DESCRIPTION

Agriculture is responsible for more than 10% of the greenhouse gas (GHG) emissions in the EU. The quantification of the GHG surface-atmosphere exchanges is crucial to decide which agrosystems and which practices should be privileged in the context of reducing our environmental footprint. To date, these exchanges are monitored using flux towers, which are organized in continental networks (ICOS for Europe), and the global FLUXNET database. The cornerstone of these infrastructures is the single-point micrometeorological eddy-covariance (EC) equipment.

However, a longstanding issue of FLUXNET is the systematic underestimation of gas fluxes for specific atmospheric conditions, as information on the sub-mesoscale transport processes generated by surface heterogeneity is not directly available. The eddy-covariance method relies on the idea that in high turbulence conditions, and for sufficiently homogeneous terrain and flow conditions, the transport of CO2 (or likewise heat) is dominated by the vertical turbulent transport. The method thus fails when turbulence is low and advective fluxes are not negligible; this leads to the systematic underestimations of (i) the trace gas flux (e.g. CO2), in particular in atmospheric stable conditions, typical of cloud-free nights and of (ii) the available energy, in particular in atmospheric free convective conditions, typical of sunny windless days.

In the current research project, in order to solve those issues, we believe that we can realize a significant breakthrough in EC flux tower source reconstruction by leveraging and combining recent scientific and technological progresses in (I) measurements, (II) simulations and (III) inference and assimilation techniques. The objective is to provide correction procedures to improve the assessment of the GHG budgets performed over the different types of agrosystems.

First of all, AGROFLUX aims at improving the estimation of flow properties in the lower atmospheric boundary layer (ABL) through innovative atmospheric measurements and their combination. Specifically, we will complement EC-tower measurements with tower-based, Wind Doppler LIDAR (WDL) and Unmanned Aerial Vehicle (UAV)-based wind and scalar measurements with a particular attention to the observability of the targeted quantities in the specific micro-meteorological scenarios discussed above. This involves the optimization of WDL scanning patterns, of the UAV design itself and of the UAV flight strategies.

Second, this project will use Large Eddy Simulations for the atmospheric boundary layer that covers the scales going from ABL to the very instruments that will be combined. In particular, this entails the simulation of the ABL down to fine scales in the near-wall region in order to reproduce EC-tower measurements. This virtual environment will enable the reproduction of realistic emission scenarios, shedding light on sub-mesoscale events, and replicate their measurements performed by the AGROFLUX equipment.

Finally, AGROFLUX aims to leverage the maturing of inference methods and machine-learning (ML) techniques to generate more accurate flux estimates even in advection-affected scenarios. This implies the use of a computationally affordable model that will be fed with the measurements to be assimilated. The development of such a model, and in particular its turbulence closure terms, will require the offline calibration (or training in a machine learning perspective) of large amounts of data that do provide the expected insights into the quantities of interest.

AGROFLUX will exploit two Belgian ICOS sites: Lonzée and Vielsalm which offer already existing extensive EC data. The project will however focus on the FLUXNET/ICOS-ESFRI Lonzée crop site where extensive measurement campaigns combining the different measurement techniques (I) will be carried out to serve simulation (II) and to allow model calibration (III).

The Lonzée crop site can be considered as a rather simple site in terms of micrometeorology (flat and horizontal terrain, short and even canopy). We expect that it should enable the transfer of model and methods to similar sites in the flux tower network (e.g. half of the Belgian ICOS ecosystem stations have a similar orography and vegetation structure, namely the Lochristi and Maasmechelen sites).

By proposing a way of improving surface fluxes (short-term horizon), potentially transferable to the network of flux towers, AGROFLUX therefore also opens the way to an improvement in the quality of all associated downstream applications and derived products (mid-term horizon). This is for example the case for global carbon fluxes that are estimated from satellite data feeding machine-learning methods, and that need to be calibrated/validated using the global ground EC flux tower network. Another example are those paired flux tower experiments comparing ecosystem management strategies (e.g no-till vs conventional ploughing, low-fertilizer cropping vs conventional cropping, etc). Those applications could serve a variety of environmental and policy needs, including carbon markets, climate policy choices, improvement of national greenhouse gas emissions reporting, prediction of climate change through better calibration of upscaling and prognostic models.

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