

CC1: 'Comment on egusphere-2026-524, xiangmin sun, 24 Apr 20261

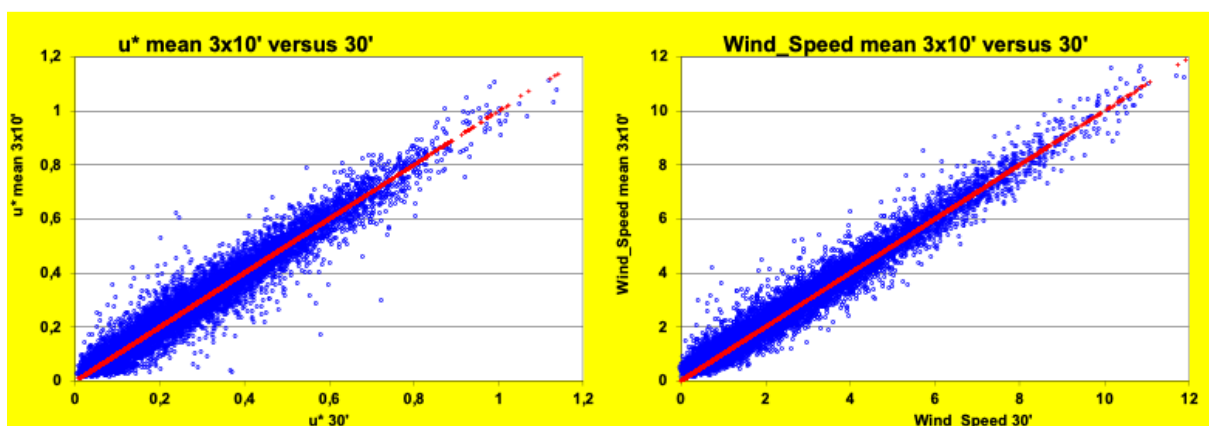
This study measured CO₂ fluxes from one eddy covariance tower over a heterogeneous agricultural landscape, and separated fluxes from each sector based on wind direction and the associated radians. These CO₂ fluxes, labeled by each land use, contained many gaps and were filled using a random forest algorithm for annual cumulative evaluation. A few of my questions related to eddy covariance data are:

Using a 10-minute averaging period for eddy covariance introduces random error, as it may fail to capture low-frequency turbulence. You may need to run an ogive analysis and a stationarity test for verification. In line 239, you mentioned that wind direction changes quickly. Can you validate based on your wind data?

We thank Professor Sun for his first comment also mentioned by Referees 2 and 3. We did not run ogive analysis but processed data were screened using tests for steady state and turbulent conditions through EddyPro following Foken and Wichura (1996), Foken et al. (2004) and Göckede et al. (2004) (see for instance Polsenare et al., 2012, bg-9-249-2012 and Mayen et al., 2024, bg-21-993-2024); we will add this information on the revised version of the manuscript.

We understand this comment with regard to the 10 min. average flux window we now use since several years, as adapted for more coastal and dynamic systems such as wetlands (present study), salt marshes (i.e., Mayen et al., 2024, bg-21-993-2024) and tidal flats (i.e. Polsenare et al., 2012, bg-9-249-2012), instead of the commonly used 30 min. averaged flux window for EC data processing over terrestrial ecosystems. The comment is fair since, our study site though being a wetland system, is surrounded by different crop and grassland fields and in any cases, we need, as for all atmospheric EC studies to be sure to measure and catch all eddy that contribute to the fluxes and be careful with the corresponding EC set-up in terms of measurement height and time averaging window for the chosen specific studied site.

To address this point and more strongly justify the 10 min. averaging time period chosen in the present study as rightly noticed, we did further computations comparing the friction velocity, wind speed and flux data between the mean of the three 10 min. values and the corresponding mean values obtained by reprocessing all data (February-September 2023 period) through EddyPro with an averaging time period of 30 min. (see attached graphs below). Although we can see some dispersion between both 10 min. and 30 min. mean values (u^* , wind speeds, mean fluxes), we also clearly notice that we did not have any low frequency losses on the 10 min. flux data.



Furthermore, we decided to choose a 10 min. averaging time period instead of 30 min. to lose less data due to non-stationary conditions and/or electrical noises leading to potential and more data suppression (with the 30 min. choice) according to our data quality check procedure adopted in the present study. The new computations and comparisons done between 10 min. and 30 min. data showed that, according to the land parcel, we would lose between 21% (wheat, sector 213°-283° with dominant wind directions) and 49% (wheat, sector 133°-173°) of data with a choice of 30 min. mean flux calculation instead of the 10 min. mean flux procedure used here.

All these considerations and new computations will be added to the revised version of the manuscript to specify and strengthen our choice.

Could you refer any study that used the u^*/u to delineate or separate the sectors? I would suggest to include a brief interpretation of " u^*/u " in the introduction section.

In the atmospheric surface layer, the presence of relief elements, whether they are plant-based as in our case or man-made as in Bolsée et al. (2026), causes an increase in surface roughness z_0 , which leads to an increase in the roughness coefficient u^*/u , as can be inferred from the following equation:

$$u(z) = (u^* / k) \ln((z - d)/z_0)$$

The spatial distribution of u^*/u , obtained from momentum flux measurements by Eddy Covariance, therefore allows us to differentiate the areas responsible for the CO₂ fluxes measured by the same setup.

Bolsée, S., Dupont, S., Lamaud, E., Lafont, S., Irvine, M., Chipeaux, C., Garrigou, C., Bonnefond, J.-M., Domec, J.-C., Loustau, D., 2026. Wind flow dynamics over a photovoltaic power plant: comparison with a vegetated canopy. *Agricultural and Forest Meteorology*, in press.

The ditch is very close to the tower and could be negligible. Have you investigated the along-wind distance providing the highest (peak) contribution x_{peak} and $x_{10\%}$ relative to turbulent fluxes? Footprint analysis along wind directions at different percentages can help you estimate whether the ditch's contribution is negligible.

We apologize for not mentioning any information on our footprint calculation in the submitted manuscript. The footprint was estimated with the Kljun et al. (2015) model and calculated using the constant measurement height ($Z_m=3\text{m}$), the constant displacement height ($d = 0.1 \text{ m}$), mean wind velocities (u_{mean} , m s^{-1}), standard deviations of the lateral velocity fluctuations after rotation (σ_v , m s^{-1}), the Obukhov length (L), friction velocities (u_{star} , m s^{-1}) and wind directions ($^\circ$), measured by the station from February, 1st 2023 to April, 3rd 2024. We also checked footprint model distance outputs parametrized under EddyPro using Kljun et al. (2004) and Kormann and Meixner (2001) footprint models to help estimate whether the ditch's contribution is negligible or not, as rightly suggested by Professor Sun.

EC measurements have limitations, including energy budget closure, equipment costs, and technical challenges in data processing. But I am inclined to argue that short gaps during maintenance and rainfall are the limitations, as these gaps are trivial. The assumption of EC measurements is homogeneous field across the fetch; thus EC is not applicable to sites with high footprint heterogeneity. This is not a limitation of EC measurement itself; the challenge is separating the footprints for this complicated mosaic.

We thank Professor Sun for his feedback and agree with him about EC measurement limitations/challenges due to i) sensor maintenance/issue period without any measured fluxes that need to be gapfilled and ii) heterogeneous site with different habitats seen differently in time and space according to wind directions/speeds. It is particularly true after having deployed several EC towers these last years since years of 2010's either over homogeneous (less heterogeneous) tidal flats, salt marsh systems (Polsenaere et al., 2012, bg-9-249-2012 and Mayen et al., 2024, bg-21-993-2024) or hereafter over clearly heterogeneous sites with different habitats around the EC mast as carried out in the present study for instance. This is the reason why, owing to RF modeling tool improvements, we propose our combined measured and modelled EC flux approach that, we believe, can overcome these limitations and proved EC measurements can be done over such heterogeneous crop field to have at the end consistent estimated flux (NEE) values for each parcel seen by EC sensors. In this way and as risen by all Referees, we significantly modified the manuscript in turn with further computations especially for better constrain and quantify NEE values coming from each parcel.

We also note that the interpretation of Eddy Covariance measurements in heterogeneous environments is fundamentally linked to the spatial structure of the flux footprint. In our study, this aspect is explicitly addressed through the sector-based framework introduced in Fig. 2a (submitted MS), which provides a directional decomposition of the contributing source areas. This representation is essential for our analysis, as it allows us to directly relate the reconstructed fluxes to the surrounding land-use mosaic. This is particularly important for sector 2 (70° – 103°), where multiple land-cover types are simultaneously present within the footprint, including

grassland, mixed grain fields, and riparian vegetation along the Brune canal. As already outlined in the introduction section of the submitted MS, this configuration does not correspond to a single dominant source area, which complicates the attribution of the observed CO₂ signal and justifies a sector-specific treatment. By contrast, the wheat-dominated sector (133°–283°) presents a much more homogeneous footprint, with a single crop type largely controlling the measured fluxes. In this case, the sectorisation confirms that the Eddy Covariance assumptions are much more closely met, and the interpretation of the reconstructed fluxes is correspondingly more direct. Nevertheless, even in this more homogeneous configuration, additional sources of uncertainty remain, as discussed in detail in response to Reviewer 2.

Since data availability is 39% (line 235) for your site. Thus, each land cover data will mostly be less than 20%. While the meteorological data is measured from the tower, not from each individual sector, the meteorological data carries the same gaps as the CO₂ flux. How do you deal with gaps in meteorological variables from each sector/land use type?

We thank Professor Sun for this important question. In our modelling framework, meteorological variables are not assigned independently to each land cover sector. Instead, for sector-specific predictions, we use only the data corresponding to valid wind directions associated with that sector. For time steps where the wind direction does not fall within a given sector, these data are not directly used for that sector's modelling.

To enable continuous predictions across time, we apply a simple sampling approach: for each sector, when a prediction is required outside its valid wind direction range, wind direction values are randomly sampled within the boundaries of that sector. This allows the meteorological input space to remain consistent while preserving sector-specific constraints. We will clarify this procedure in the Methods section of the coming revised MS.

Please see as well our Referee 3 response to similar comment (1-).

Some minor questions are listed below for the first half of this manuscript. A detailed proofreading is recommended before you resubmit.

We appreciate Professor Sun minor questions listed below that help, together with Referee 1, 2 and 3 comments help improving the submitted manuscript.

Line 43-44: I am not sure I understand the sentence. From my understanding, conventional agricultural practices, such as intensive tillage and heavy reliance on synthetic inputs, can lead to soil degradation and increased greenhouse gas emissions. On the other hand, sustainable farming practices, such as no-till farming and leaving crop residue (stalks, leaves) on the soil surface, can reduce soil erosion and boost organic matter/soil carbon. Residue retention can potentially reduce greenhouse gas emissions compared to traditional residue removal or burning.

We thank Professor Sun for this information we will add in our purpose rephrasing the corresponding sentence in the revised MS.

Line 51-54: seasonal uptake of "carbon"? Forgot to add "carbon" before the "uptake"? What are "no-harvest practices"? Cover crop? Can you add some specifics? Maybe add a "comma," before "and local environment"? Does "social-economic factors determining land-use intensity" refer to "farming common practices"?

The sentence will be rewritten in the revised MS for more clarity as suggested by Professor Sun.

Line 53: Maybe add "response" after "fast", or rephrase it to "high temporal frequency anemometer". It should be "gas", not "gaz".

These modifications will be done in the revised version of the MS.

Line 63: Could you be more specific about "dozens of"? There should be more representative articles besides "Baldocchi, 2020" to refer to for the developments in flux research.

The sentence will be modified in the revised MS as: “In Europe, the Integrated Carbon Observation System (ICOS) network similarly provides standardized CO₂ flux measurements through 180 stations deployed across 16 European countries.

Line 73: Any reason for the abbreviation of Q₁₀? Scenario when the temperature increases by 10 degrees.

The meaning of Q₁₀ will be specified in the revised MS.

Line 105: not sure of the meaning of “retro-littoral”.

Retro-littoral ecosystems correspond to freshwater, brackish and salt shallow systems separated from tidal immersion by dykes and locks, that are now numerous particularly along the French Atlantic coast (Bergeon et al. 2023; Mayen et al. 2023; Xaus et al. 2025). Indeed, over the past centuries, anthropogenic activities have strongly modified coastal marsh typology and hydrological connectivity this way. Originally, the aim was to gain artificial land surfaces on the sea to develop salt- and oyster-farming activities through strict tidal control; now, many coastal marsh ecosystems are managed to promote biodiversity and patrimonial uses (Tortajada et al. 2011).

Line 114-115: If the meteorological and soil variables are measured at the tower location, you need to make sure they are representative of all three fields. Are these variables homogeneous among the three fields? Since soil cannot be measured at the tower, you may add “spot” or “location” after “the tower”.

We will specify it in the revised version of the manuscript.

Line 115: Not sure how many percent of gaps were filled for each parcel? I assume each site might have more than 50% gaps.

We will specify it in the revised version of the manuscript.

Line 128: “with 62% of its surface spent to ...”, this expression seems not a common phrase.

We will rephrase this sentence as followed: “...agricultural landscape representing 62% of the total Charente-Maritime region surface, corresponding to 425,267 ha (Agreste, 2020).”

Line 145: Please check the grammar of this sentence.

The sentence will be rephrased as: “The Eddy Covariance (EC) tower was installed on the 1st of February 2023 within the 5 m wide narrow-grassed strip close to the Brune Ditch, corresponding to a safe and central location to run EC measurements coming from all multiple land covers around the mast. »

Figure 1: The left map can be smaller, showing the general location. Please mark the study site in a more visible and clear way in the left map. It might be helpful to add the wind rose map in this figure.

It will be done as suggested in the revised version of the manuscript.

Line 153: the eddies might not be “homogeneous”, with different frequencies and rotation sizes.

It is true, we will remove “homogeneous” in the sentence in the revised manuscript.

Line 154-161: the basic principle equation of eddy covariance measurement is common in textbook, and can be skipped for journal paper. In addition, the equation is not numbered and not correct technically. Air density should be dry air density. There should be separate parts, bar over rho, and bar over (w' and s').

It is right, as noticed by Referee 1 too. ρ given in the equation (l.155, p.6 in the submitted manuscript) was actually the dry air density air (ρ_d). We modified accordingly the equation associated text in this section as followed:

“The method relies on measuring the covariance between fluctuations in vertical wind velocity and scalar concentrations within these eddies. The CO₂ flux can be expressed as:

$$F = \overline{\rho_d w s} \approx \overline{\rho_d w' s'}$$

where the overbar indicates the time averaging and the prime represents fluctuations around this average (Burba, 2013; Reynolds, 1886). Here, (ρ_d) denotes the dry air density (kg m^{-3}), (w) the vertical wind velocity (m s^{-1}), and (s) the dry mole fraction of CO_2 (mol mol^{-1} , commonly expressed in $\mu\text{mol mol}^{-1}$ or ppm). The covariance between these variables yields a mass flux with units of $\text{kg m}^{-2} \text{s}^{-1}$. For CO_2 exchange studies, this mass flux is converted into a molar flux by dividing by the molar mass of CO_2 ($M_{\text{CO}_2} = 44.01 \text{ g mol}^{-1}$) and is therefore commonly reported in $\mu\text{mol m}^{-2} \text{s}^{-1}$. In this study, measured fluxes were averaged every 10 minutes to maximize the number of observations. Negative CO_2 fluxes indicate the ecosystem acts as a CO_2 sink, while positive fluxes indicate ecosystem source behaviour.”

Line 177: I am afraid that I can't see the rainfall sensor in Figure 2.

It is true, the rainfall sensor is not present in Figure 2. For information, here is the complete photo of our EC set-up taken on February 2023, 1st showing the sensor position:



Line 205: for more details of data processing protocol?

Indeed, please refer to the cited studies for more details on used data processing procedure, we add this precision in our revised version of the manuscript.

Figure 3: Note the meaning of the dashed red lines in the figure.

It will be noted in the revised version of the manuscript.

Line 224: usually the riparian corridor and the ditch is very close to the tower and should not be the major contributor. Did you check the flux footprint and the flux peak distance?

Please see our response above for this comment.