Standards and Open Access are the ICOS Pillars

Reply to "Comments on 'The Integrated Carbon Observation System in Europe'"

Dario Papale, Jouni Heiskanen, Christian Brümmer, Nina Buchmann, Carlo Calfapietra, Arnaud Carrara, Huilin Chen, Bert Gielen, Thanos Gkritzalis, Samuel Hammer, Susan Hartman, Mathias Herbst, Ivan A. Janssens, Armin Jordan, Eija Juurola, Ute Karstens, Ville Kasurinen, Bart Kruijt, Harry Lankreijer, Ingeborg Levin, Maj-Lena Linderson, Denis Loustau, Lutz Merbold, Cathrine Lund Myhre, Marian Pavelka, Kim Pilegaard, Michel Ramonet, Corinna Rebmann, Janne Rinne, Léonard Rivier, Elena Saltikoff, Richard Sanders, Martin Steinbacher, Tobias Steinhoff, Andrew Watson, Alex T. Vermeulen, Timo Vesala, Gabriela Vítková, and Werner Kutsch

AFFILIATIONS: **Papale**—Department for Innovation in Biological Agro-Food and Forest Systems, University of Tuscia, Viterbo, Italy, and IAFES, Euro-Mediterranean Center on Climate Change, Viterbo, Italy; **Heiskanen**—Faculty of Biological and Environmental Sciences, University of Helsinki, Helsinki, Finland; **Brümmer**—Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany; **Buchmann**—Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland; **Calfapietra**—Institute of Research on Terrestrial Ecosystems, National Research Council, Porano, Italy; **Carrara**—Fundación Centro de Estudios Ambientales del Mediterráneo, Paterna, Valencia, Spain; **Chen**—Centre for Isotope Research, University of Groningen, Groningen, Netherlands; **Gielen and Janssens**—Department of Biology, University of Antwerp, Wilrijk, Belgium; **Gkritzalis**—Flanders Marine Institute, Ostend, Belgium; **Hammer and Levin**—Institut für Umweltphysik, Heidelberg University, Heidelberg, Germany; **Hartman**—National Oceanography Centre, Southampton, United Kingdom; **Herbst**—Centre for Agrometeorological Research, German Meteorological Service, Braunschweig, Germany; **Jordan**—Max-Planck-Institute for Biogeochemistry, Jena, Germany; **Juurola**—Institute for Atmospheric and Earth System Research, University of Helsinki, Helsinki, Finland; **Karstens, Lankreijer, and Vermeulen**—ICOS ERIC, Carbon Portal, Lund, Sweden; **Kasurinen, Saltikoff, and Kutsch**—Head Office, Integrated Carbon

In his comment (Kowalski 2023) on our recent publication (Heiskanen et al. 2022) where we present the Integrated Carbon Observation System (ICOS) research infrastructure, Andrew Kowalski introduces three important and, in our opinion, different potential issues in the definition, collection, and availability of field measurements made by the ICOS network, and he proposes possible solutions to these issues.

It is a density

The first comment by Kowalski is about the definition of the "flux density" that we, in ICOS and in general in the FLUXNET community, simplify and shorten as "flux." There is no doubt that what Andrew Kowalski nicely explained with a clear example using radiation to illustrate the difference between flux and flux density is absolutely correct.

If on one side the measurement units (W m^{-2} or $\mu molCO^2$ m^{-2} s^{-1}) clearly define that nature of the variable reported (a flux density), it is also correct to point out that the right definition should be used, at least in the description of the variables. This will probably not avoid that the commonly used short name "flux" will continue to be used to designate the flux density measured at the eddy covariance stations. However, the use of a correct naming in the official documents and portal will at least help to clarify the correct definition.

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Observation System European Research Infrastructure Consortium, Helsinki, Finland; **Kruijt**—Department of Environmental Sciences, Wageningen University and Research, Wageningen, Netherlands; **Linderson**—Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden; **Loustau**—INRAE, ISPA, Villenave d'Ornon, France; **Merbold**—Agroscope, Research Division Agroecology and Environment, Zurich, Switzerland; **Myhre**—Atmosphere and Climate Department, Norwegian Institute for Air Research, Kjeller, Norway; **Pavelka and Vítková**—Department of Matter and Energy Fluxes, Global Change Research Institute, CAS, Brno, Czech Republic; **Pilegaard**—Department of Environmental Engineering, Technical University of Denmark, Lyngby, Denmark; **Ramonet and Rivier**—Université Paris-Saclay, CEA, CNRS, UVSQ, Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), Gif-sur-Yvette, France; **Rebmann**—Institut of Meteorology and Climate Research, Karlsruhe Institut of Technology, Karlsruhe, Germany; **Rinne**—Bioeconomy and Environment, Natural Resources Institute Finland, Helsinki, Finland; **Sanders**—Climate Department, Norwegian Research Centre, Bergen, Norway; **Steinbacher**—Laboratory for Air Pollution/Environmental Technology, Duebendorf, Switzerland; **Steinhoff**—Chemical Oceanography, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, and NORCE Norwegian Research Centre AS, Bergen, Norway; **Watson**—College of Life and Environmental Sciences, University of Exeter, Exeter, United Kingdom; **Vesala**—Institute for Atmospheric and Earth System Research, and Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland

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Corresponding author: Dario Papale, darpap@unitus.it

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For this reason we support the proposal made by Andrew Kowalski to update the flux density entry in the Glossary of Meteorology (American Meteorological Society 2022), while for the flux definition, where we agree on the proposed text, we also suggest to keep the second point in the glossary, namely, "In the field of atmospheric turbulence and boundary layers, often used as a contraction for flux density, namely, the flow of a quantity per unit area per unit time." The abbreviated term was and will be largely used, and it is important that the AMS Glossary reports this information.

At the same time, we also agree that in the ICOS Carbon Portal the term "flux density" should be used at least in the official variables' definitions, and the ICOS Ecosystem Thematic Centre (ETC) will ensure that the correct terminology is used.

Where are the data?

The second comment and the corresponding suggestion are about the recording and availability of the turbulent flux densities along the x and y directions (horizontal with respect to the rotated sonic anemometer wind vectors), arguing that these can be still relevant in the fluxes' computation and interesting for scientists, given the fact that the eddy covariance technique is still not definitive and can still evolve. It is first important to clarify that the eddy covariance stations record high-frequency data of the three wind vector components, sonic temperature, and scalar concentrations. For this reason, the turbulent flux densities in the three directions can be always calculated from the original measurements, and so stating that these data are not recorded is not fully correct.

On the data availability, it is important to remark that ICOS is a fully open access Research Infrastructure, where all data (from raw data to final products) and all codes used to generate the products are available to all users, under a CC BY data policy, and that this is a pillar of the ICOS philosophy. We calculate and derive, solely for the eddy covariance measurements, more than 130 output variables and products that are distributed by the ICOS Carbon Portal.

There will always be variables that could be potentially interesting and that are missing from this list, but this is the unavoidable compromise between providing useful information and keeping the whole system manageable, ensuring the maximum quality. A variable, when provided by ICOS, must be quality controlled, with full traceability and respecting the Findable, Accessible, Interoperable, Reusable (FAIR) principles. The selection of variables to be routinely provided has been defined on the basis of what the user community generally requests and searches. The ICOS ETC is, however, always offering to provide on request the hundreds of "secondary variables" that are produced during the standard data processing.

Parallel to what?

The third aspect covered by Andrew S. Kowalski in his comment is related to the orientation of the radiation sensor in the eddy covariance sites. He states that "if the PAR sensor and ecosystem are not parallel, then the measured flux systematically misrepresents the ecosystem flux," and for this reason he suggests that for "fluxes measured by single-surface radiation sensors [...] such sensors should be oriented with care to ensure that the measured flux corresponds to the flux of interest."

In this case, however, the question would be to define and measure which is the right orientation. Landscape, when not perfectly horizontal, like in the case of some agricultural fields or lakes, is rarely with a homogeneous and constant slope and aspect. In addition, one could argue that the radiation flux density relevant for the ecological processes is the one happening toward the leaves, that could have a predominant orientation, not always (or better, rarely) parallel to the orographic slope.

In addition, even hypothesizing that a representative nonhorizontal orientation could be unequivocally and standardly defined, the precise installation of the radiometers with the orientation parallel to this surface would be practically impossible or prone to rather important errors. The sensors are often a few centimeters in diameter

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and are mounted over high towers, where already ensuring the horizontal position using the bubble spirit level is hard and requires periodic fine adjustments.

For this reason, we think that the correct way to measure these fluxes is to follow a common standard and then consider the specific elements structure (orography, vegetation, leaves, etc.) when the measurements are analyzed and interpreted. In fact, this is also the standard followed by the WMO that, in its Guide to Instruments and Methods of Observation (WMO 2021), suggests installing the pyranometers "levelled [...] so that, when properly exposed, the receiving surface is horizontal, as indicated by the spirit-level." In ICOS, from the first definition of the protocols and procedures, it was decided to follow, whenever available, internationally recognized standards in order to maximize the level of interoperability. This is why the WMO and ISO standards on meteorological variables are the basis of the ICOS protocols.

For this reason, although we agree that the geometry of the flux–surface interaction and, in particular, the incidence angle should be always considered, we think that this should be done after the measurements collection, which instead should follow a clear, unequivocal, and practically feasible-to-apply standard setup protocol.

Data availability statement. No datasets were generated or analyzed during the current study.

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