

A multi-site comparison of spectral and co-spectral approaches for correction of turbulent gas fluxes with ICOS set-up

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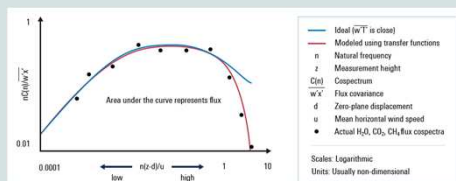
CONTEXT & OBJECTIVES

- Accurate estimation of turbulent gas fluxes using the eddy-covariance method requires correcting for high-frequency spectral attenuation.
- Both spectral (SP) and co-spectral (CS) approaches are widely used for this purpose, but their relative performance has not yet been assessed systematically across multiple sites.

We want to

- compare the two methods
- compare to ICOS release
- highlight the best practices

DATASET AND PROCESSING



Schematic co-spectra (after Burba 2022)

	Pros	Cons
Spectra (SP)	Pure signal (not polluted by w)	Needs theoretical description of sensor separation
Cospectra (CS)	No denoising needed	Noise removal needed in some cases
	No sensor separation description needed	TF determination could be difficult because of « pollution » of irga signal by w
		Time lag compensation

Pro/cons of the two approaches

Dataset

- Sites:** All 38 Class 1 and 2 ICOS ecosystem stations. Station codes in red for those with $z-d < 7$ m (low-measuring heights).
- Period:** a full year (2024)
- Gas:** CO₂ & H₂O

Processing

- Starting from ICOS Archive 2025 release, we applied our own spectral corrections scheme (spectra and co-spectra).
- Important points:
 - Findings from Aslan et al. 2021 included for SP approach (with adaptation)
 - Findings from Peltola et al. 2021 included for CS approach
 - Using Look-Up Tables for wind-speed and relative humidity dependencies on both cut-off frequencies and correction factors

RESULTS CO₂ correction factors

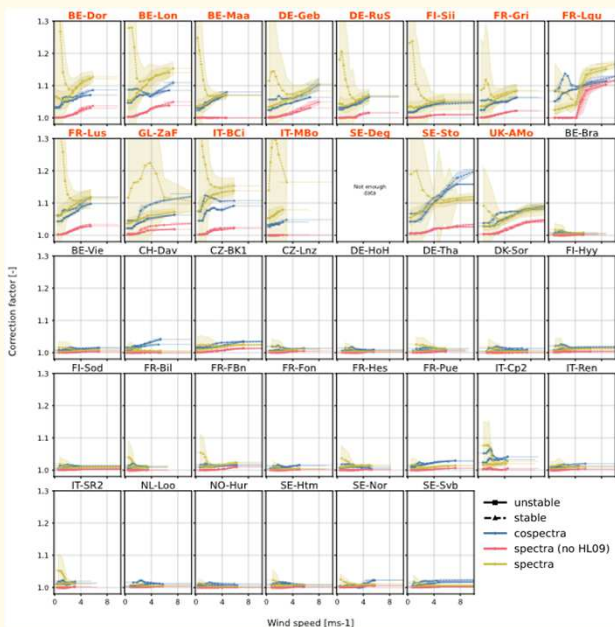


Fig1. CO₂ correction factors for SP and CS for unstable and stable conditions. "No HL09" stands for "no application of Horst & Lenschow 2009 correction factor for sensor separation".

Analysis

- Limited correction factors for CO₂, with SP > CS, especially for low-measuring sites (Fig. 1 yellow vs blue curves and Fig 2a)
- Sensor separation (HL09) dominates the SP correction for CO₂ (Fig. 1, red vs yellow curves)
- ICOS set-up standardisation proved effective (Fig. 1)
- ICOS 2025 release largely overestimates our SP approach, especially for H₂O (Fig. 2c and d, and Fig. 3).

Impact on half-hourly fluxes

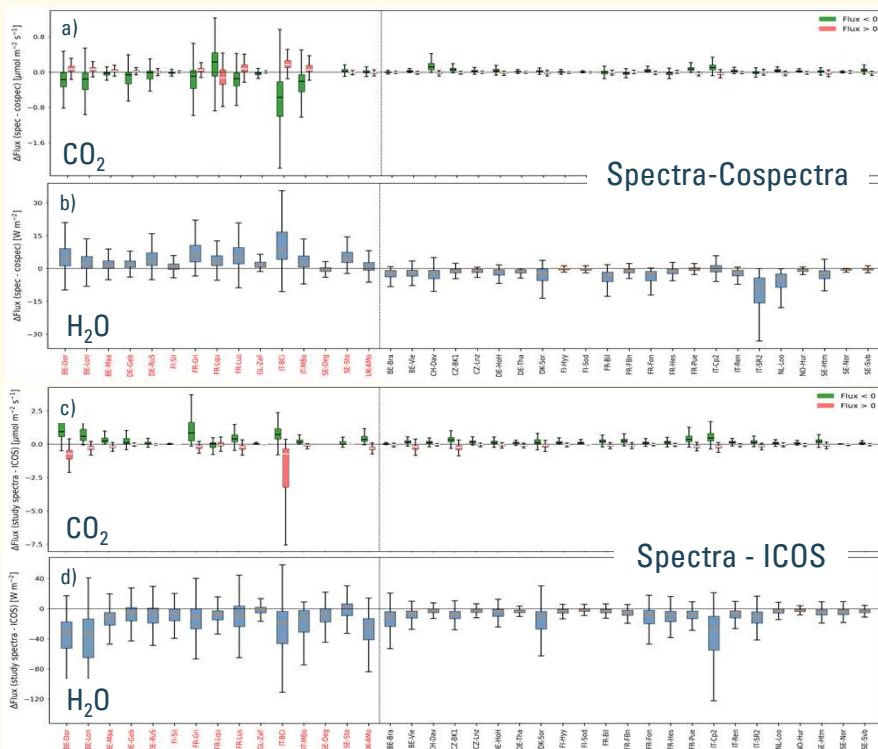


Fig2. Box-plots of half-hourly flux differences between SP and CS approaches for CO₂/H₂O (a and b). Idem for differences between SP and ICOS (c and d). Note the different y-scales. u* and QA/QC filtered data only.

Impact on yearly cumulative fluxes

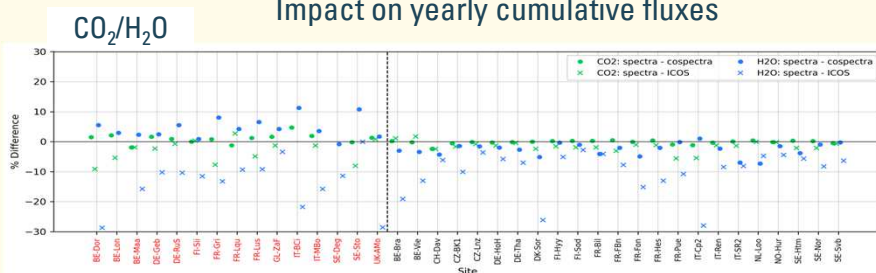


Fig3. Relative Cumulated flux differences between SP and CS and between SP and ICOS approaches for CO₂/H₂O. u* and QA/QC filtered data only, not gap-filled.

Take-home messages

- CO₂
 - Sensor separation is dominating the spectral losses
 - Co-spectral approach gives lower flux correction factors and has the advantage to be fully experimental
 - But impact of method overall limited
- H₂O
 - tube humidity effects are dominating (not shown)
 - Impact of method can be important
- ICOS set-up standardization proved effective, but ICOS corrections are higher and more erratic, suggestion for a revisit

Code availability

Our Python tool "FreqCor" is available on GitHub (QR code or <https://github.com/BernardHeinesch/FreqCor>). The tool is designed to plug directly into standard EddyPro outputs, enabling straightforward analysis even for non-expert users.



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