The role of WPL correction in determining the latent heat flux through the eddy-covariance method at the rainfed site of Els Plans

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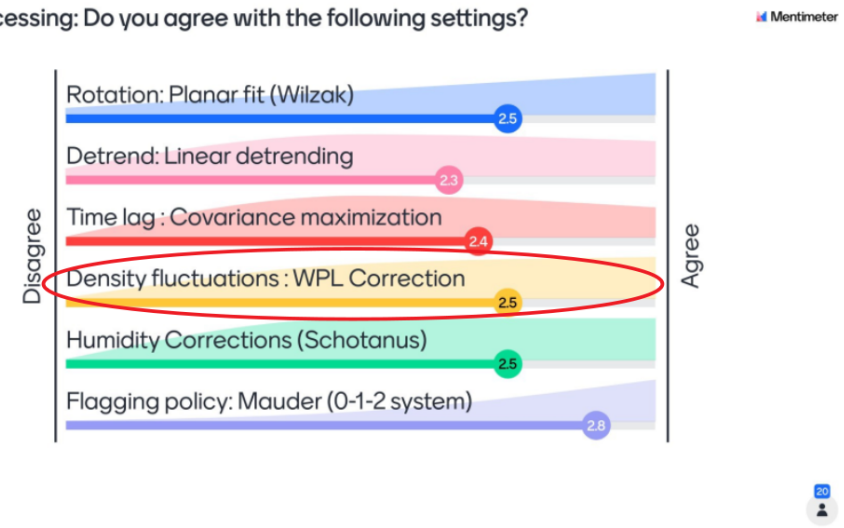
LIAISE

Motivation

- The **WPL density correction** is broadly applied to eddy-covariance fluxes, available in most of the software applications for data post-processing (EddyPro, TK3,...).
- It was included in the **LIAISE unified eddy-covariance processing** protocol (WG1, Jan 2022).

- The delivered turbulent data for the 50-m tower at Els Plans is **not corrected** for WPL.



Mentimeter questionnaire

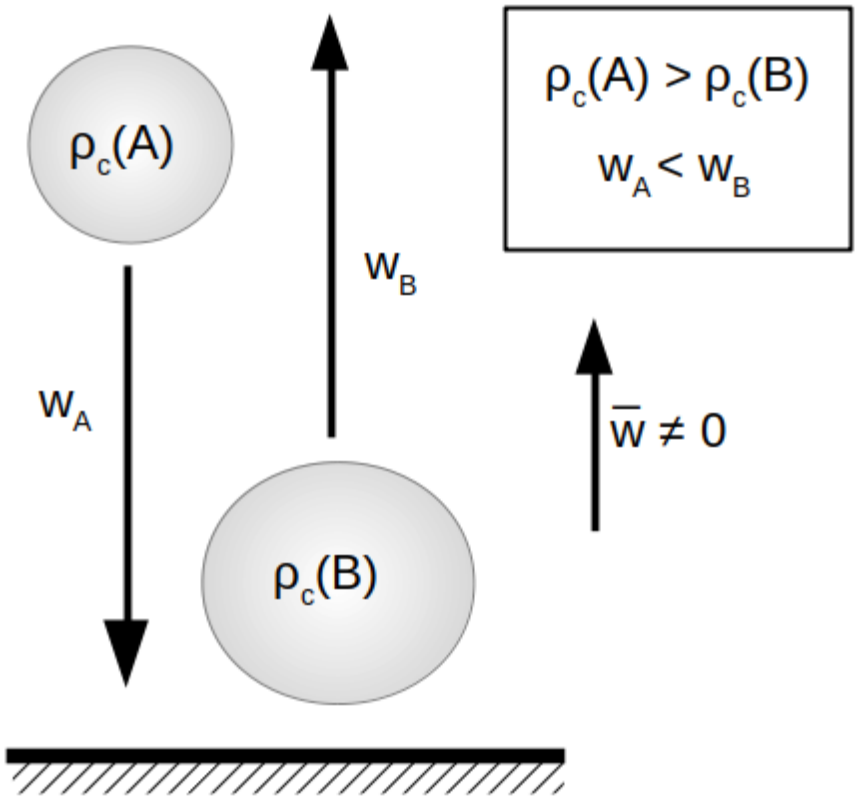
- **Objective**:
  - What is the **importance of WPL density correction** in the calculation of the latent heat flux in a semi-arid, rainfed site such as Els Plans?

The WPL density correction

The total vertical flux of any trace gas constituent depends on two terms (after Reynolds avg):

$$F_c = \overline{w'\rho_c'} + \bar{w} \cdot \bar{\rho}_c$$

The second term can not be neglected when the **trace gas density** ρ_c is measured instead of **mass mixing ratio** according to Webb, Pearman and Leuning (WPL, 1980).



- Vertical velocities of ascending air parcels (less dense) must be larger than descending ones (more dense) to keep the mass balance.
- Averaged vertical velocity depends on heat and moisture fluxes:

$$\bar{w} = \mu \frac{\overline{w'\rho_v'}}{\bar{\rho}_d} + (1 + \mu\sigma)\frac{\overline{w'T'}}{\bar{T}}$$

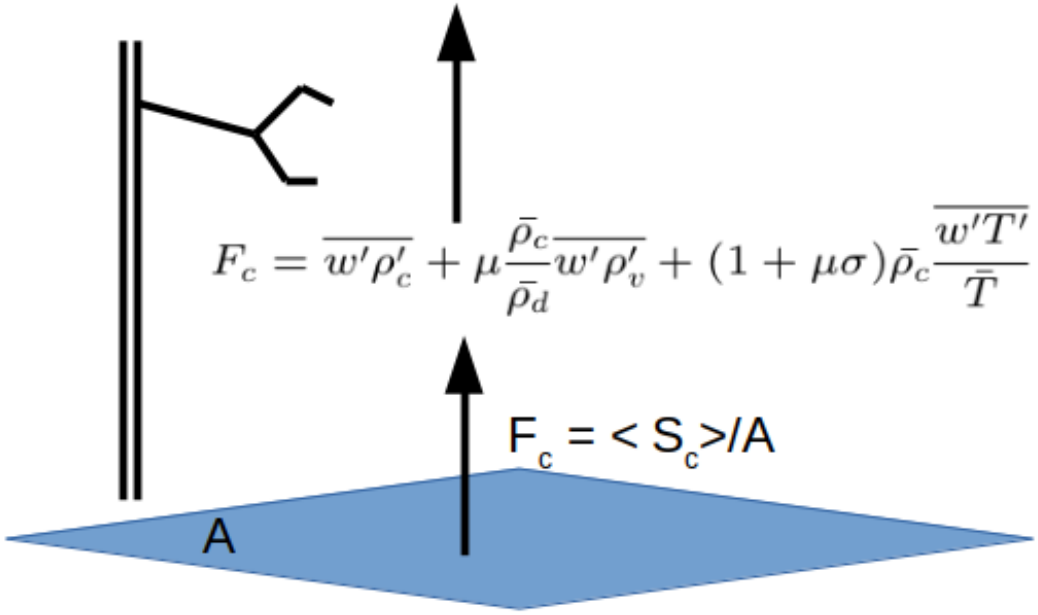
  where $\mu = m_d/m_v$ and $\sigma = \bar{\rho}_v/\bar{\rho}_d$.
- Total vertical flux is:

$$F_c = \overline{w'\rho_c'} + \mu \frac{\bar{\rho}_c}{\bar{\rho}_d}\overline{w'\rho_v'} + (1 + \mu\sigma)\bar{\rho}_c\frac{\overline{w'T'}}{\bar{T}}$$

The WPL density correction (II)

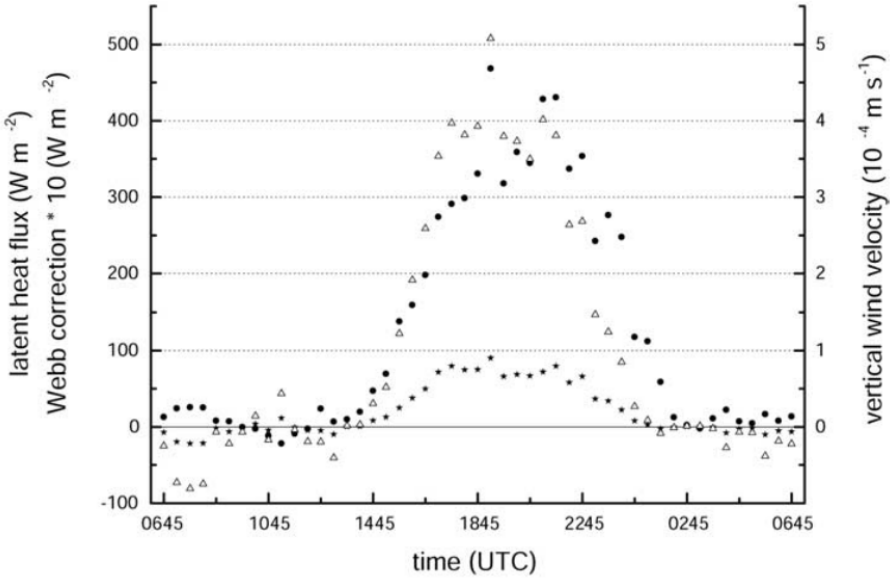
1. The density correction has been **refined by adding terms** of smaller influence to include other effects such as **air pressure fluctuations** although the original WPL terms are the most relevant.

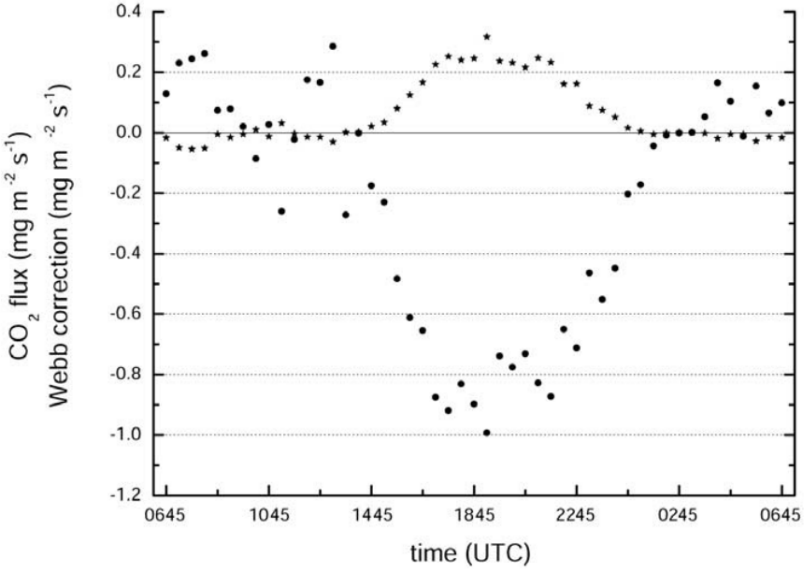
2. For **steady and horizontally homogenous** flows, the eddy flux measured at a certain distance from the surface is related to the source or sink through the WPL terms.



Significance of WPL terms

The impact of WPL terms on water vapour fluxes is usually considered small compared to other error sources and to CO_2 fluxes.



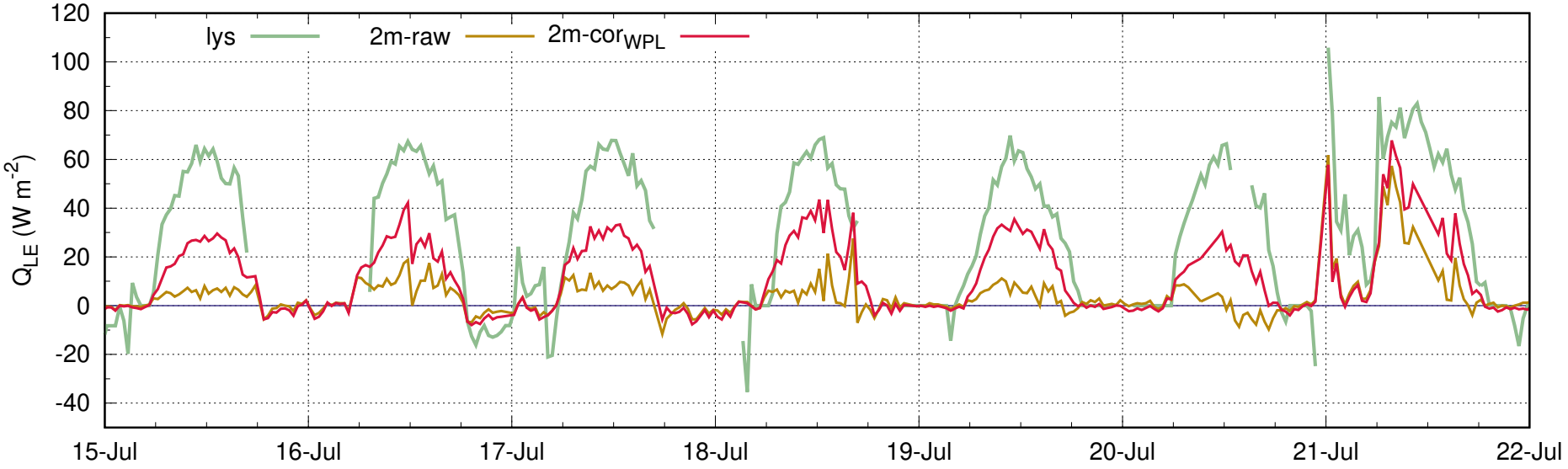


Daily evolution of H_2O [Left] and CO_2 [right] for measured eddy fluxes (•) and total WPL-corrected fluxes (stars) for the EBEX-2000 experiment (Liebethal and Foken, 2003).

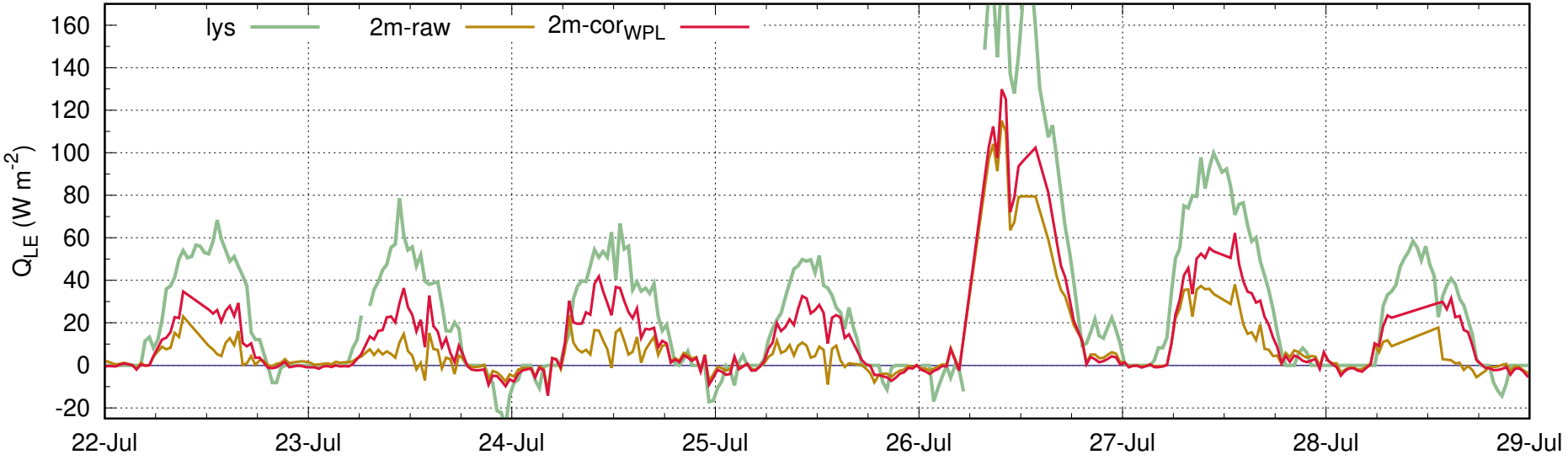
WPL term represents 3% of latent heat and 30% for CO_2 fluxes. Cases analysed typically contain small Bowen ratios $Bo = H/\lambda E < 1$

$$F_v = (1 + \mu\sigma)\left\{1 + \frac{\lambda}{C_p}\frac{\bar{\rho}_v}{\bar{\rho}\bar{T}}Bo\right\}\overline{w'\rho'_v}$$

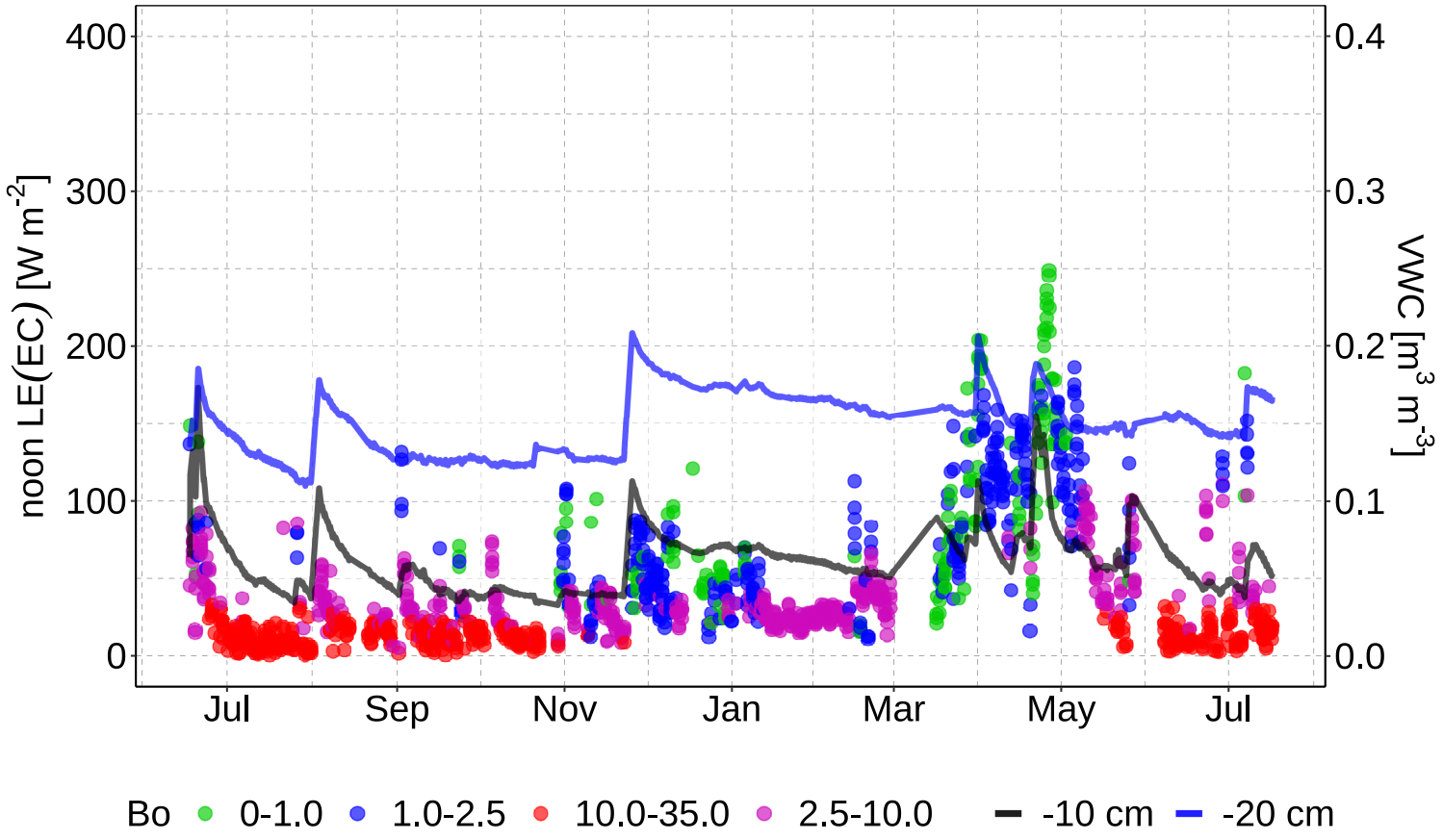
LE at Els Plans during SOP (15–28 Jul'21)



LE at Els Plans during SOP (15–28 Jul'21)

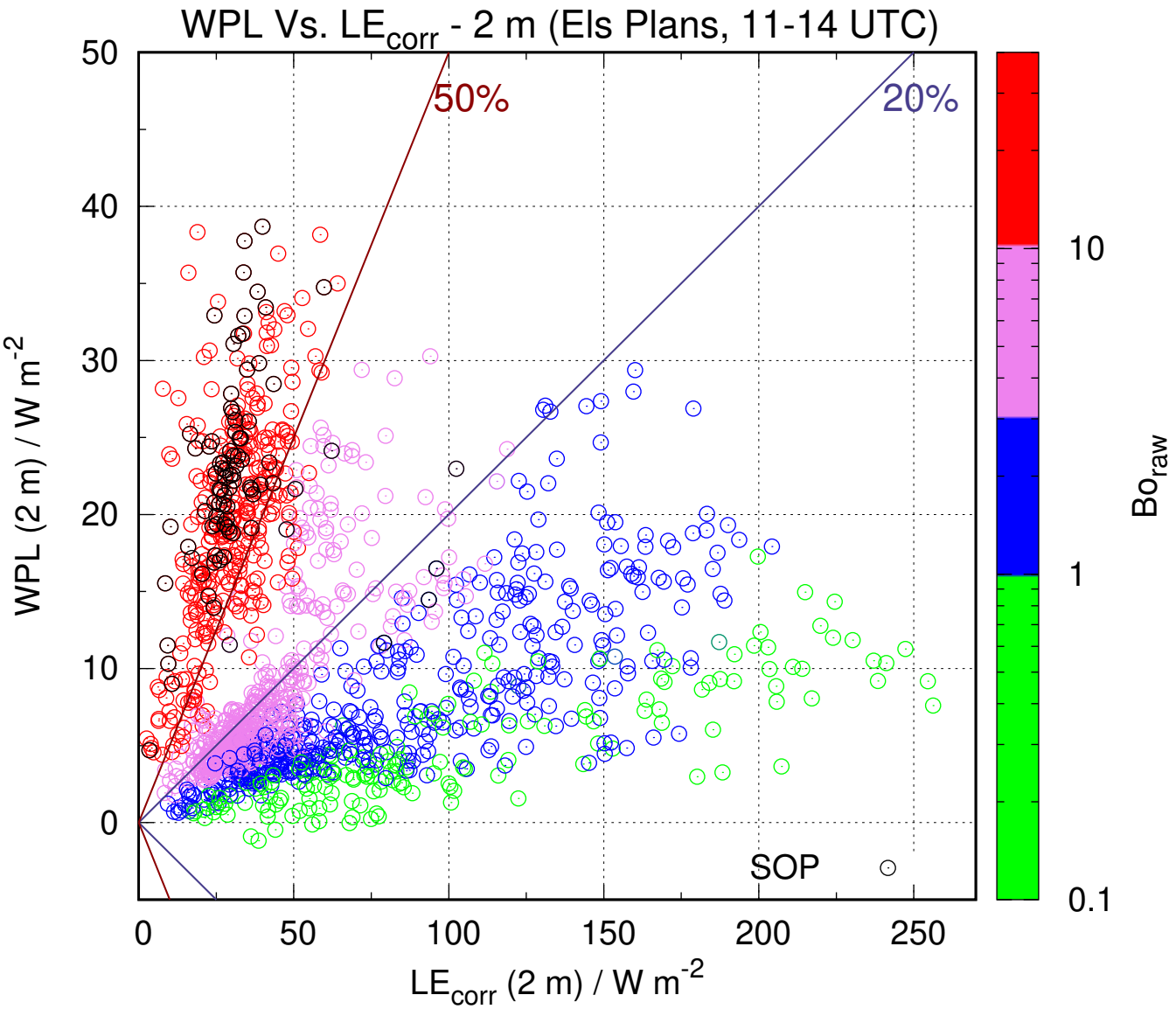


Els Plans 13-month period (Jun'21–Jul'22)

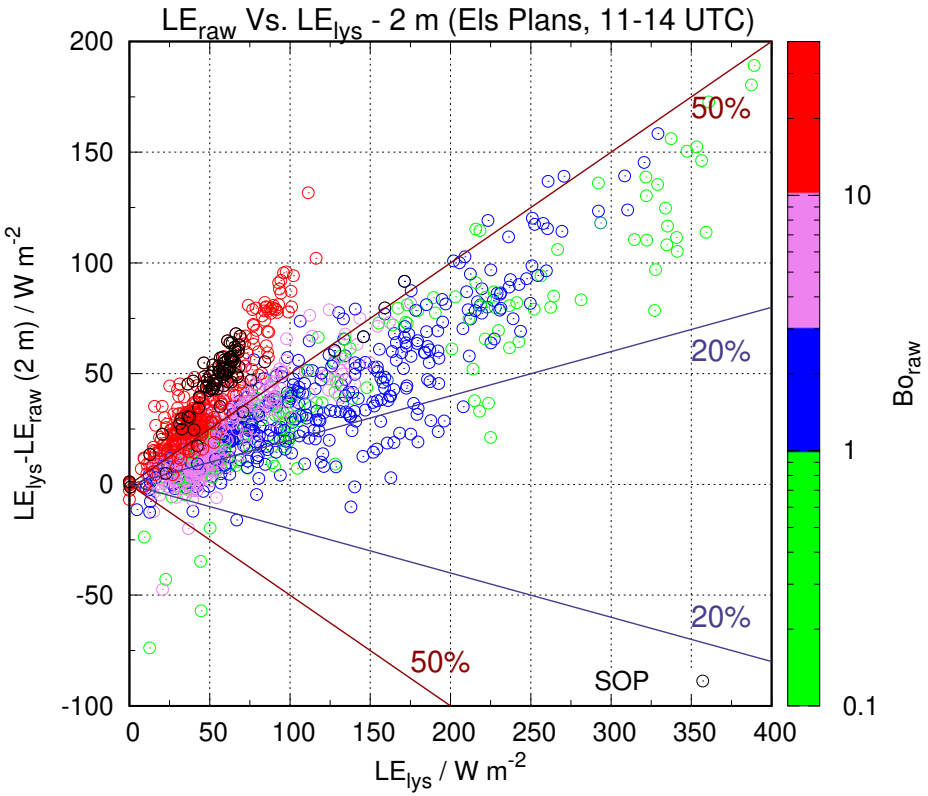


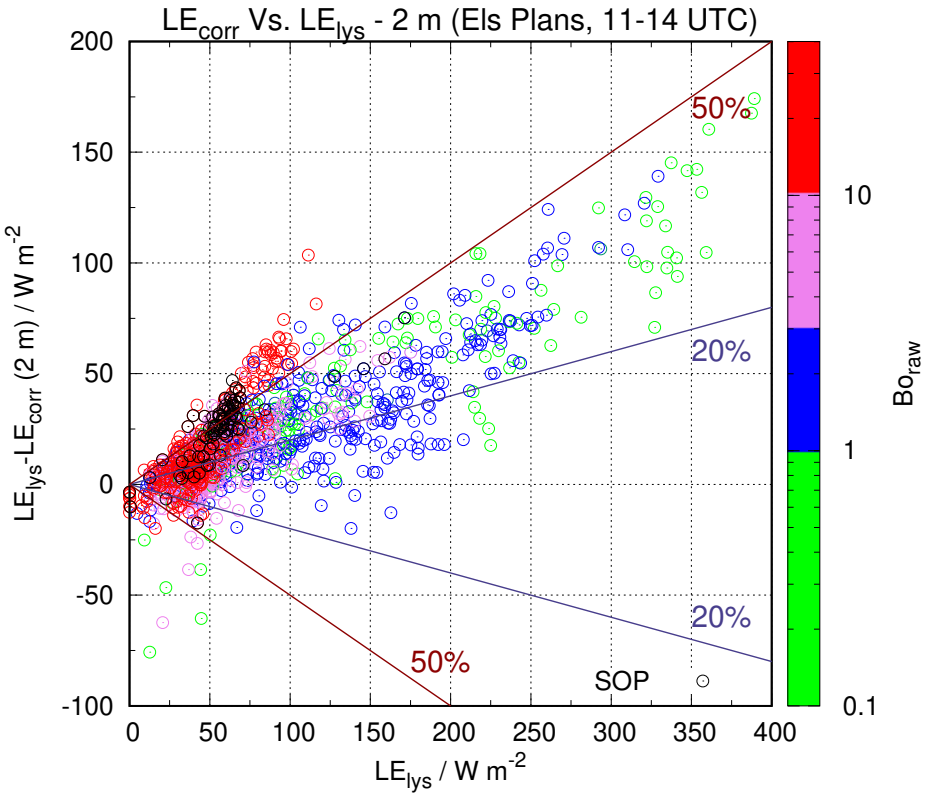
Latent heat flux (LE, dots) and soil volumetric water content (VWC, solid line) between 11 and 14 UTC (Jun'21–Jul'22). Dot colours refer to Bowen ratio (Martí et al, 2023).

WPL vs LE_{corr} (Jun'21–Jul'22)



eddy-covariance vs lysimeter (Jun'21–Jul'22)





Conclusions

- The WPL term for the latent heat flux at the rainfed site of Els Plans during SOP explains more than 50% of the corrected flux for density fluctuations (except for those days with precipitation: 21 and 26 July).
- The analysis for daytime cases around noon along a complete yearly cycle reveals that the significance of WPL term increases with Bowen ratio:
  - $Bo < 3$ (WPL/LE <20%)
  - $3 < Bo < 10$ (20<WPL/LE <50%)
  - $Bo > 10$ (WPL/LE >50%)
- When eddy fluxes are compared against lysimeter observations, the WPL terms must be considered.
  - The difference between lysimeter and EC observations (after WPL correction) are large (between 20 and 50% of relative error).
  - Other factors must be explored:
    - Three dimensionality of the flow.
    - A study addressing the environmental factors that control the observed differences between lys and EC is currently undertaken (Han et al., 2023: in preparation).