Comparison of CO_2 fluxes from mixing ratio and mass density with a closed-path gas analyzer

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ABSTRACT

The new type closed-path CO_2/H_2O infrared gas analyzer (LI-7200, LI-COR) measures both temperature and pressure in the cell simultaneously with concentration of CO_2, and thus it enables us to calculate CO_2 fluxes from both mixing ratio and mass density of CO_2. After WPL correction was applied, both fluxes were almost in accord with each other. However, CO_2 flux from mass density with the WPL correction tended to be slightly larger than that from mixing ratio, which resulted in a significant difference in cumulative CO_2 fluxes. This difference was explained by the pressure covariance term, which is omitted in the WPL correction. To reduce uncertainties in calculations, we recommend using the mixing ratio for calculation of CO_2 fluxes when using the new type closed-path infrared gas analyzer.

EXPERIMENTAL DESIGN

LI-7200 (LI-COR) and WindMaster Pro (Gill) were installed in an ongoing study site in a burned black spruce forest on a hilltop of the Poker Flat Research Range, UAF. Measurement height was about 2.5 m above the ground. The data of 8/6 – 9/14, 2010, were used in this study.

CALCULATION OF CO_2 FLUX

Since the mixing ratio of CO_2 χ_c (μmol mol^{-1}) is measured by LI-7200, CO_2 flux can be derived by:

$$F_c^{MR} = \overline{\rho_d}\,\overline{w'\chi_c'}, \qquad \overline{\rho_d} = \left(1-\overline{f_v}\right)\frac{\overline{p_{cell}}}{R\overline{T_{cell}}}$$

Pressure in the cell (Pa)
Temperature in the cell (K)
Molar density of dry air (mol m^{-3})
H_2O mole fraction (mol mol^{-1})

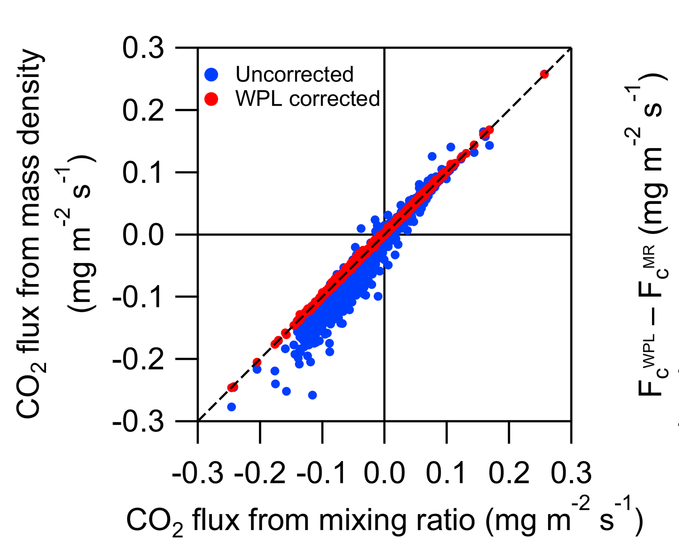
CO_2 flux of LI-7200 from mass density with WPL correction is also available for temperature variation in the cell as follows:

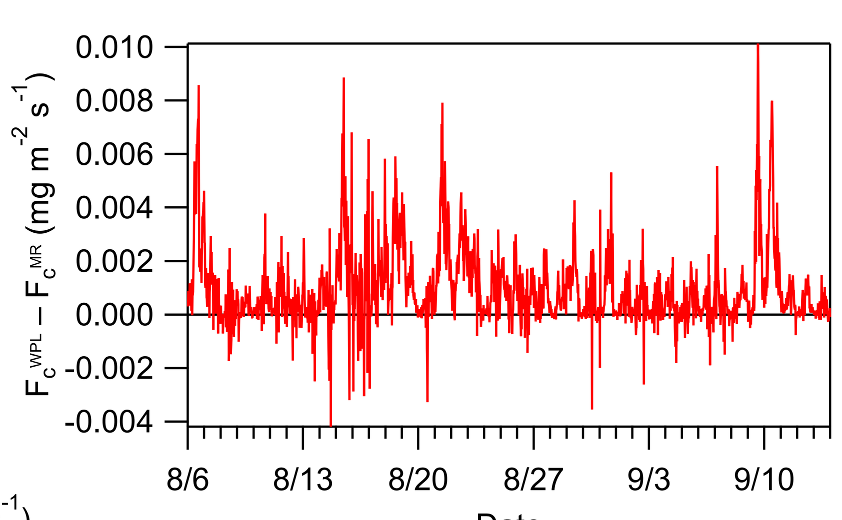
$$F_c^{WPL} = \overline{w'\rho_c'} + \frac{m_d}{m_v}\frac{\overline{\rho_c}}{\overline{\rho_d}}\overline{w'\rho_v'} + \overline{\rho_c}\left(1+\frac{m_d}{m_v}\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'T_{cell}'}}{\overline{T_{cell}}}$$

WPL correction term

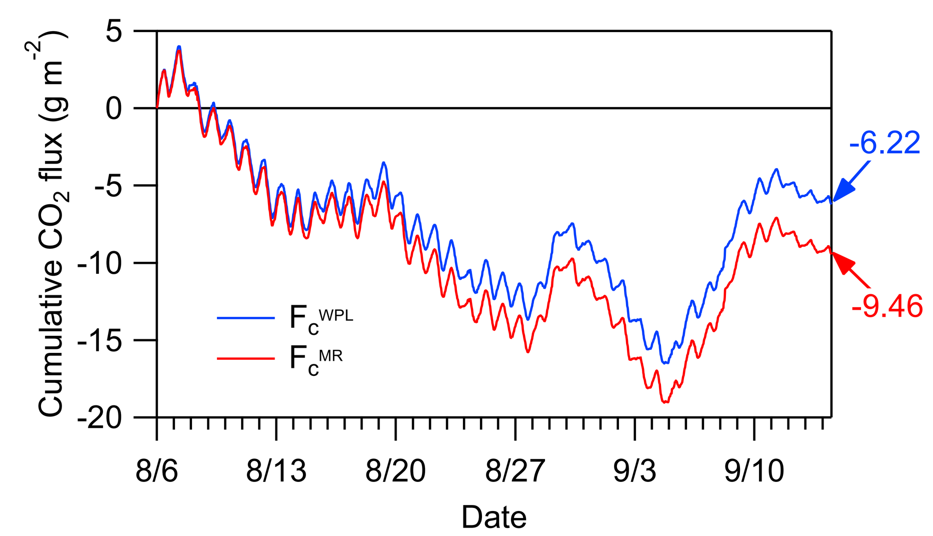
COMPARISON OF THESE CO_2 FLUXES

Both calculations were in accord with each other, indicating that these methods are consistent. However, F_c^{WPL} tended to be slightly larger than F_c^{MR}, irrespective of day and night.





Though the difference between F_c^{WPL} and F_c^{MR} was small, it turned out to be a significant difference in cumulative CO_2 fluxes in the whole period.

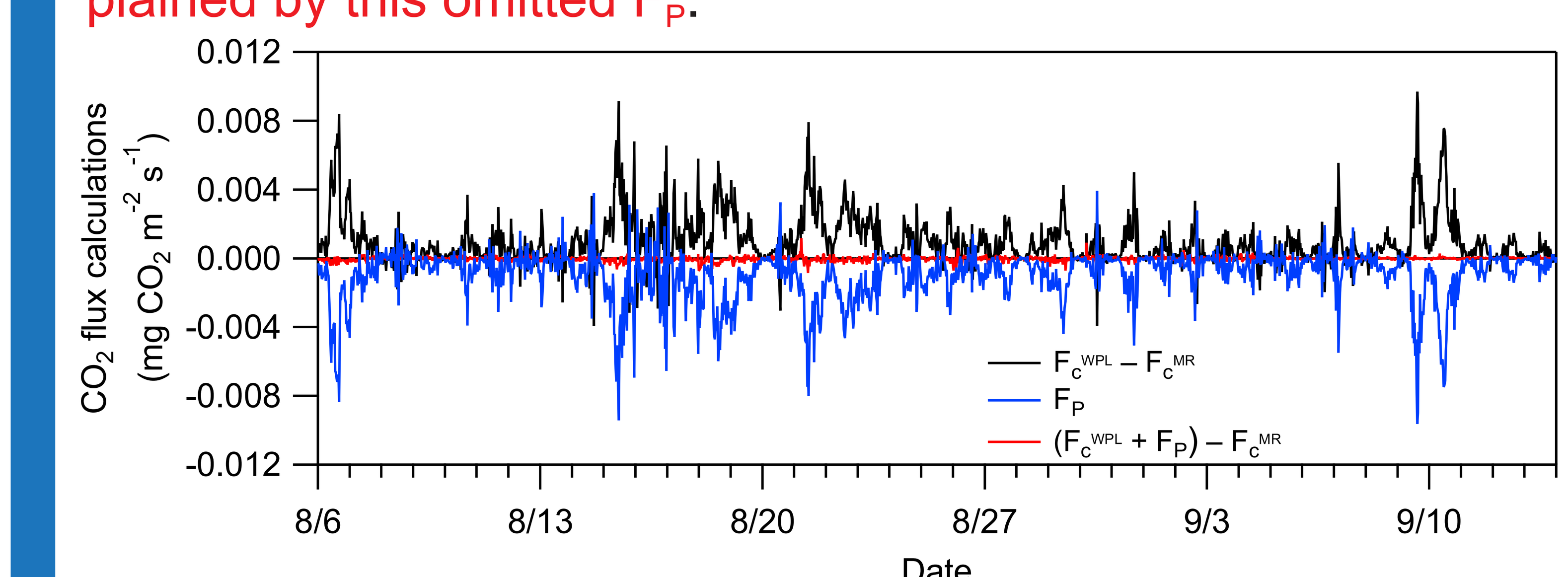


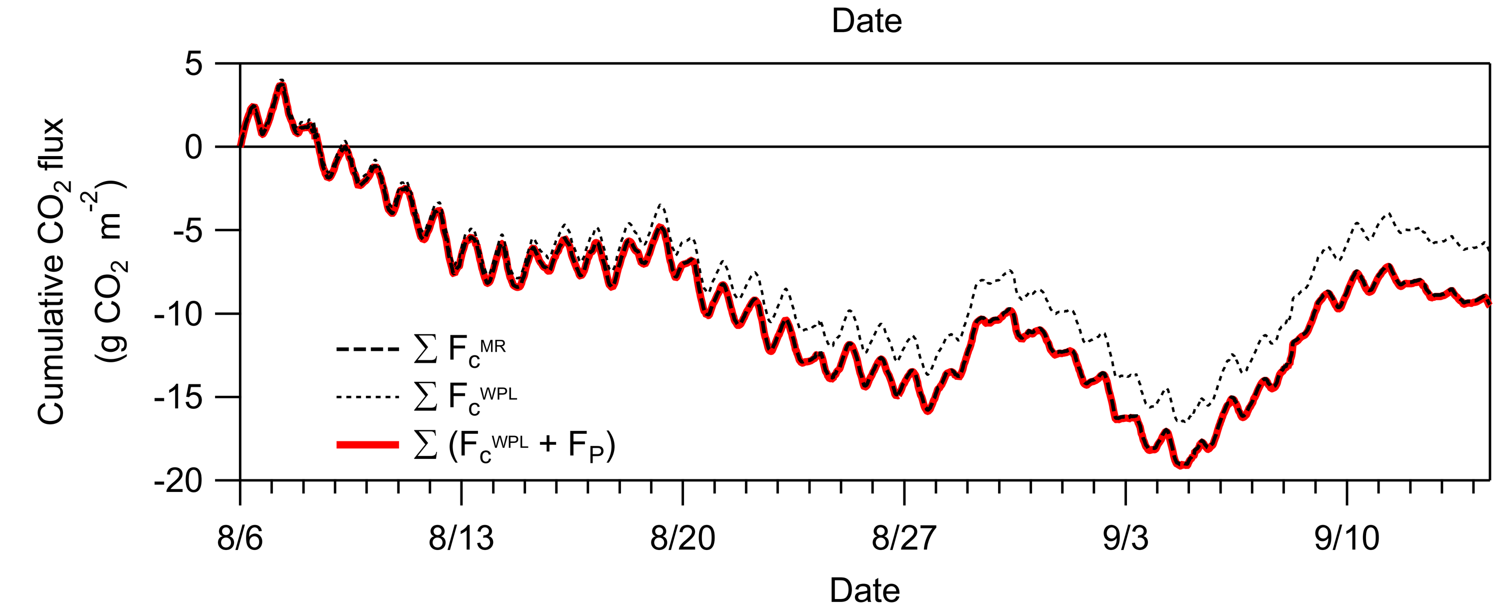
WHAT MADE SUCH A DIFFERENCE?

In the original WPL correction, pressure covariance term F_P is omitted.

$$F_P = -\overline{\rho_c}\left(1+\frac{m_d\overline{\rho_v}}{m_v\overline{\rho_d}}\right)\frac{\overline{w'p_{cell}'}}{\overline{p_{cell}}}$$

We found that the difference between F_c^{MR} and F_c^{WPL} is explained by this omitted F_P.

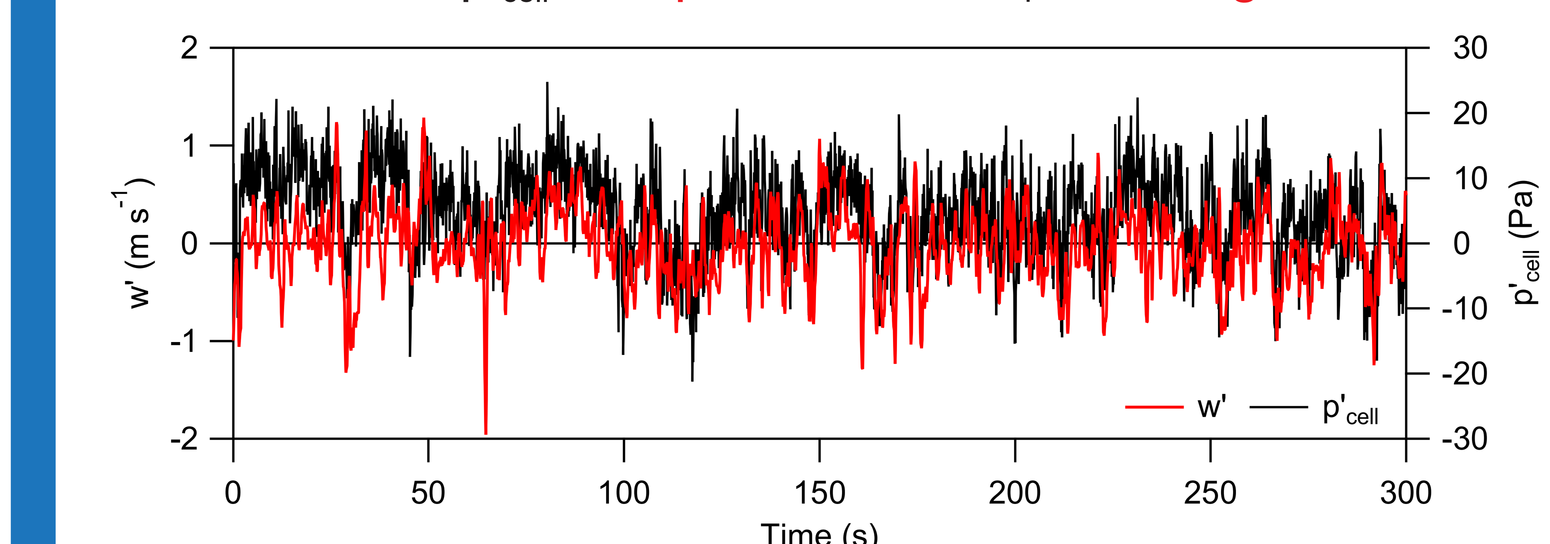




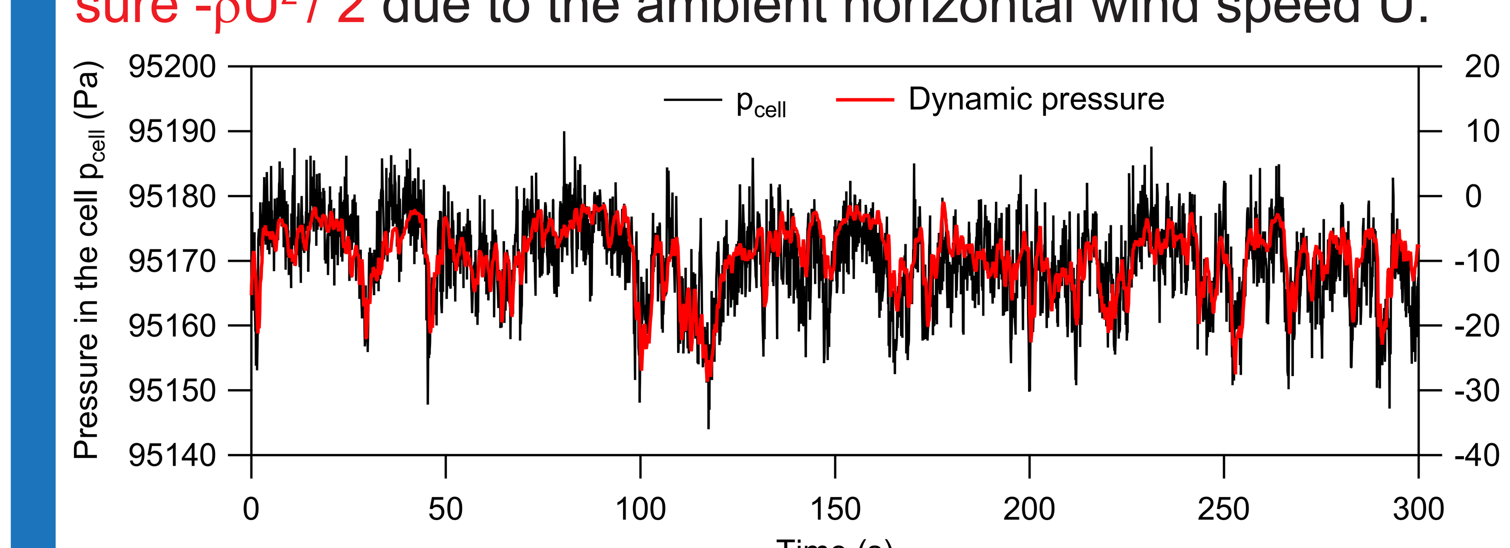
This study is the first to actually confirm by experiment that F_c^{MR} and $F_c^{WPL} + F_P$ are identical. To reduce uncertainties in calculations, we recommend using the mixing ratio for calculation of CO_2 fluxes when using the new type closed-path infrared gas analyzer.

ON THE PRESSURE COVARIANCE TERM

Zhang et al. (2011) pointed out that the correlation between w' and p' (static pressure) is negative in the open air (i.e., open-path system), which resulted in a positive F_P. However, in our closed-path system, the result was the opposite: the correlation between w' and p'_{cell} was positive, and F_P was negative.



Note that the physical mechanisms that underlie the pressure fluctuations are different between the open- and closed-path systems. One possible explanation of the pressure fluctuation in the closed-path system (LI-7200) is as follows. Since the inlet of the intake tube faced downward in this study, horizontal wind was orthogonal to the inlet, and thus the increase of horizontal wind speed resulted in a decrease of pressure inside the intake tube and the sampling cell. Actually, fluctuations in the p_{cell} were mostly explained by the variation in the negative dynamic pressure $-\rho U^2/2$ due to the ambient horizontal wind speed U.



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Nakai, T., Iwata, H., Harazono, Y. Importance of mixing ratio for a long-term CO_2 flux measurement with a closed-path system.

REFERENCES

Zhang, J., Lee, X., Song, G., Han, S. Pressure correction to the long-term measurement of carbon dioxide flux. *Agric. For. Meteorol.*, **151**, 70–77, 2011.