COMPARISON OF CO2 AND H2O EDDY FLUXES DERIVED FROM DENSITY AND FROM MIXING RATIO MEASURED BY AN ENCLOSED GAS ANALYZER

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INTRODUCTION

- New fast CO_2/H_2O analyzer, the LI-7200, is made for low power operation when used with short intake tube of 1.5 m or less [1]
- Two fast air temperatures and one air pressure are measured in the cell synchronously with CO_2/H_2O
- This provides the ability to compute fast mixing ratio (MR), or dry mole fraction, on-the-fly
- MR can be used for Eddy Covariance flux calculations without the need for Webb-Pearman-Leuning density terms [2, 3, 4]
- This approach may offer substantial advantages in terms of reduced flux uncertainties and minimum detectable flux
- In order to use mixing ratio from LI-7200 to compute fluxes, field data should be examined to verify the following:

  (i) Density-based fluxes from LI-7200 match the standards

  (ii) Mixing ratio-based fluxes match density-based fluxes

FIELD EXPERIMENTS

Comparison of MR-based to density-based flux calculations was made in 8 field experiments covering broad range of conditions:

6 experiments from AmeriFlux Roving Station using LI-7200

1 experiment from USDA site in Arizona (AZ-2)

1 experiment from LI-COR field test facility in Nebraska (NE)

Site	Location	Coordinates	Elevation m	Ecosystem	Canopy ht m	Inst. ht m	Average T C	Measurement start	end
AZ-1	Arizona	31 54 30 N; 110 10 22 W	991	shrubland	0.7	3.6	28.3	5-Jul	14-Jul
AZ-2	Arizona	31 82 14 N; 110 86 61 W	1116	savanna	2.5	6.4	24.7	14-Apr	29-Jul
CA-1	California	33 22 38 N; 116 37 22 W	1429	shrubland	0.7	3.0	17.8	26-May	3-Jun
CA-2	California	37 4 4 N; 119 11 40 W	2020	forest	30	48	21.1	14-Jul	21-Jul
NE	Nebraska	40 51 22 N; 96 39 17 W	350	ryegrass	0.1	2.6	17.6	15-Sep	12-Nov*
NM-1	New Mexico	34 21 27 N; 106 41 0 W	1590	grassland	0.3	2.9	23.7	27-Jun	5-Jul
NM-2	New Mexico	34 20 6 N; 104 44 39 W	1593	shrubland	0.6	2.8	28.0	18-Jun	25-Jun
OR	Oregon	44 38 5 N; 123 12 5 W	70	ag. grassland	0.05	3.0	7.9	5-Mar	22-Mar

** data from 2009; the rest in the table are from 2010*

CONCEPT OF MR & WPL

Fundamentally, fluxes can be computed from a covariance between vertical wind speed and mixing ratio following [2, 3, 4]:

$$Fc = \overline{w\rho S} \approx \bar{\rho}_d \overline{w's'} \qquad (1)$$

However, traditional flux calculations usually use density measurements which are native to the gas analyzers:

$$Fc_o \approx \overline{w'q_c'} \qquad (2)$$

and then apply density corrections after Webb et al. [2]:

$$Fc = Fc_o + \mu \frac{E}{\rho_d} \frac{q_c}{1+\mu \frac{\rho_v}{\rho_d}} + \frac{H}{\rho C_p} \frac{q_c}{T_a} + 0 \qquad (3)$$

Dilution Term: E is computed from water vapor density measured in the cell simultaneously with CO2

Thermal Expansion Term: H in the LI-7200 cell is below 10% of ambient due to 1 m intake; remainder can be computed from in-cell fast temperatures

Pressure Expansion Term: It is usually neglected, but can be computed from fast measurements inside the LI-7200 cell

Fc – final corrected flux; w - vertical wind speed; ρ – total air density; S – wet mole fraction; ρ_d – dry air density; s – mixing ratio (dry mole fraction); Fc_o– uncorrected flux; q_c – gas density; E – evapotranspiration; H – sensible heat flux; ρ_v – H_2O vapor density; C_p – specific heat; T_a– air temperature in K; μ– ratio of mol. masses of air to water

MR can be computed in LI-7200 on-the-fly from density, using instantaneous water mole fraction (X_w), two temperatures (T) and a pressure (P) measured in the cell, and a gas constant (R):

$$S = q_c \frac{RT}{P} \quad => \quad s = \frac{S}{(1-X_w)} = q_c \frac{RT}{P(1-X_w)} \qquad (4)$$

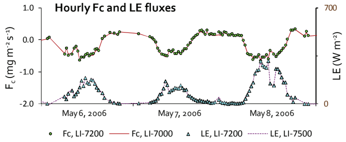
So, fluxes from LI-7200 could be computed both in traditional manner from density (Eq. 3), and from mixing ratio (Eq. 1)

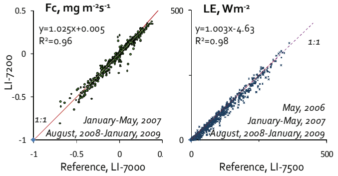
Fast MR has been used before with conventional closed-path analyzers, without fast T and P, because Ta was attenuated in the long intake tube, P' was small, and water vapor was measured

However, in the enclosed LI-7200, when used with short tube, most but not all of the fast fluctuations in Ta are attenuated, so calculating flux via MR from such instrument requires validation

DENSITY-BASED FLUXES

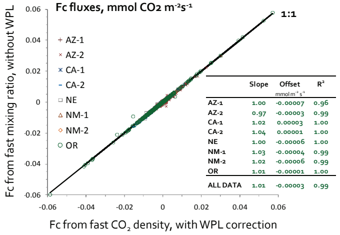
- Traditional density-based fluxes from LI-7200 were compared to the standards in field experiments over ryegrass in Nebraska and over a wetland in Florida [1]
- The open-path LI-7500 was chosen as a standard for water vapor flux (LE) because it does not attenuate water vapor in the intake tube
- The closed-path LI-7000 was chosen as a standard for CO2 flux (Fc) because it is not subject to surface heating effect in extremely cold conditions
- Hourly CO_2 and H_2O fluxes were within 2.5% of the standards (LI-7000 and LI-7500, respectively) in all experiments
- Observed 2.5% difference was not statistically significant, for P<0.05
- The field data confirmed good performance of LI-7200 in terms of the traditional density-based flux calculations and WPL correction



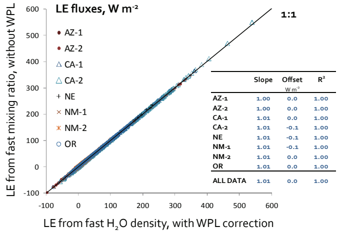


MIXING RATIO-BASED FLUXES

- Mixing ratio-based fluxes without WPL are plotted below vs. traditional density-based fluxes of Fc and LE for all 8 field deployments
- Mixing ratio-based CO2 flux was within 0%-4% of the density based flux at all sites
- The site with largest difference of 4%, CA-2, had measurement height 7-18 times taller than the any other site, highest LE flux affecting WPL terms, and least number of available data hours
- Water vapor fluxes were within 1% at all 8 sites, with 1% of LE leading to 2-5% of improvement in the energy budget closure



	Slope	Offset (mmol m⁻² s⁻¹)	R^2
AZ-1	1.00	-0.00007	0.96
AZ-2	0.97	-0.00003	0.99
CA-1	1.02	0.00003	1.00
CA-2	1.04	0.00001	1.00
NE	1.00	-0.00006	1.00
NM-1	1.03	-0.00004	0.99
NM-2	1.02	-0.00006	0.99
OR	1.01	-0.00001	1.00
ALL DATA	1.01	-0.00003	0.99



	Slope	Offset (W m⁻²)	R^2
AZ-1	1.00	0.0	1.00
AZ-2	1.00	0.0	1.00
CA-1	1.01	0.0	1.00
CA-2	1.01	-0.1	1.00
NE	1.01	-0.1	1.00
NM-1	1.01	-0.1	1.00
NM-2	1.01	0.0	1.00
OR	1.01	0.0	1.00
ALL DATA	1.01	0.0	1.00

SUMMARY

- New enclosed gas analyzer LI-7200 can use short intake tube, since fast T and P are measured in the cell with CO_2 and H_2O
- LI-7200 outputs fast gas density and MR at the same time
- This provides opportunity to compare MR-based fluxes without WPL correction with traditional density-based fluxes with WPL
- Traditional density-based fluxes from LI-7200, on-the-fly MR calculations, and resulting MR-based fluxes were examined:

  (i) The density-based fluxes from LI-7200 compared well with open-path and closed-path standards

  (iii) MR-based fluxes and density-based fluxes matched well in all 8 experiments over wide range of conditions

- The ability to compute MR-based fluxes is important for gas flux measurements, because elimination of density corrections can increase flux data quality and temporal resolution, and may help to reduce the magnitude of minimum detectable flux

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