IMPORTANCE OF SPECTROSCOPIC EFFECTS IN LASER-BASED FLUX MEASUREMENTS

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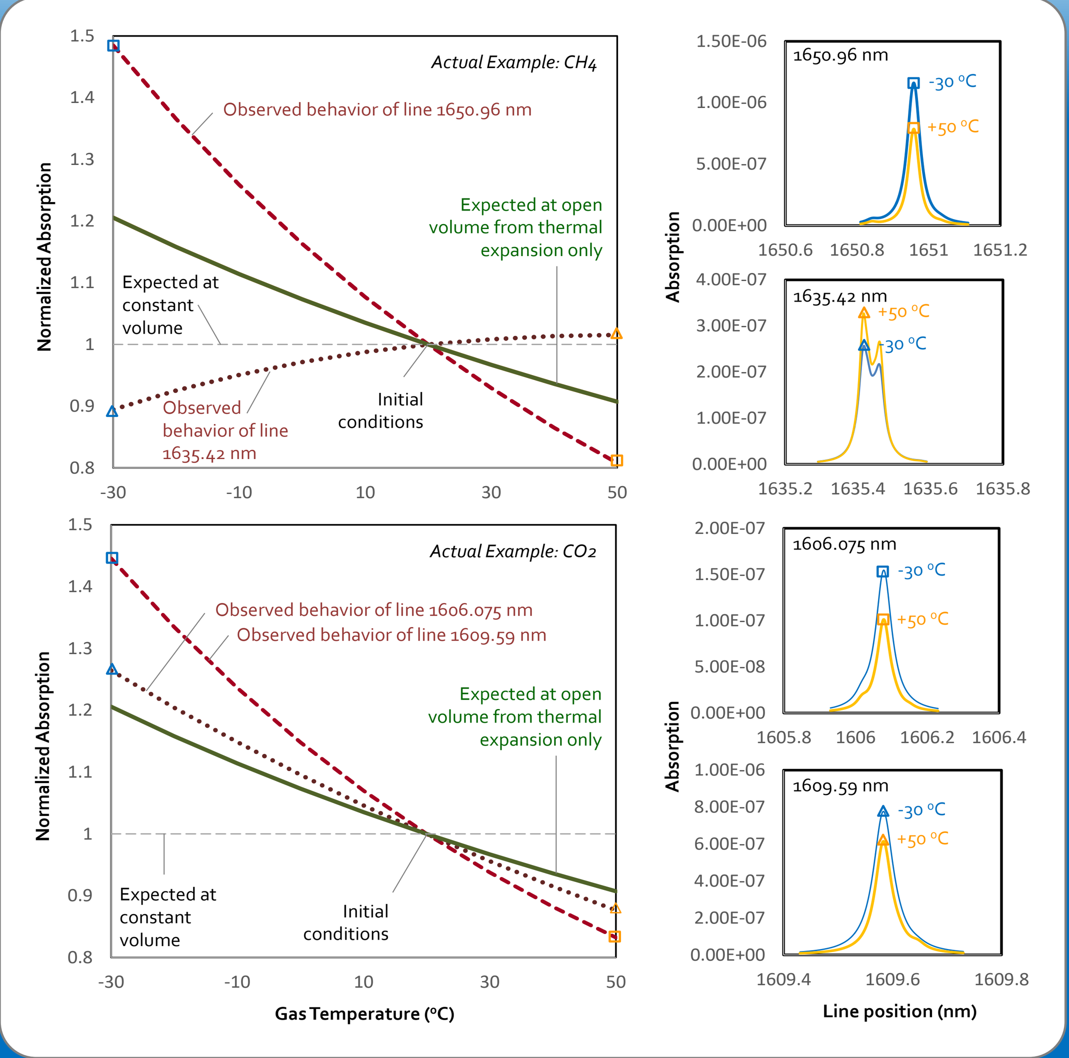
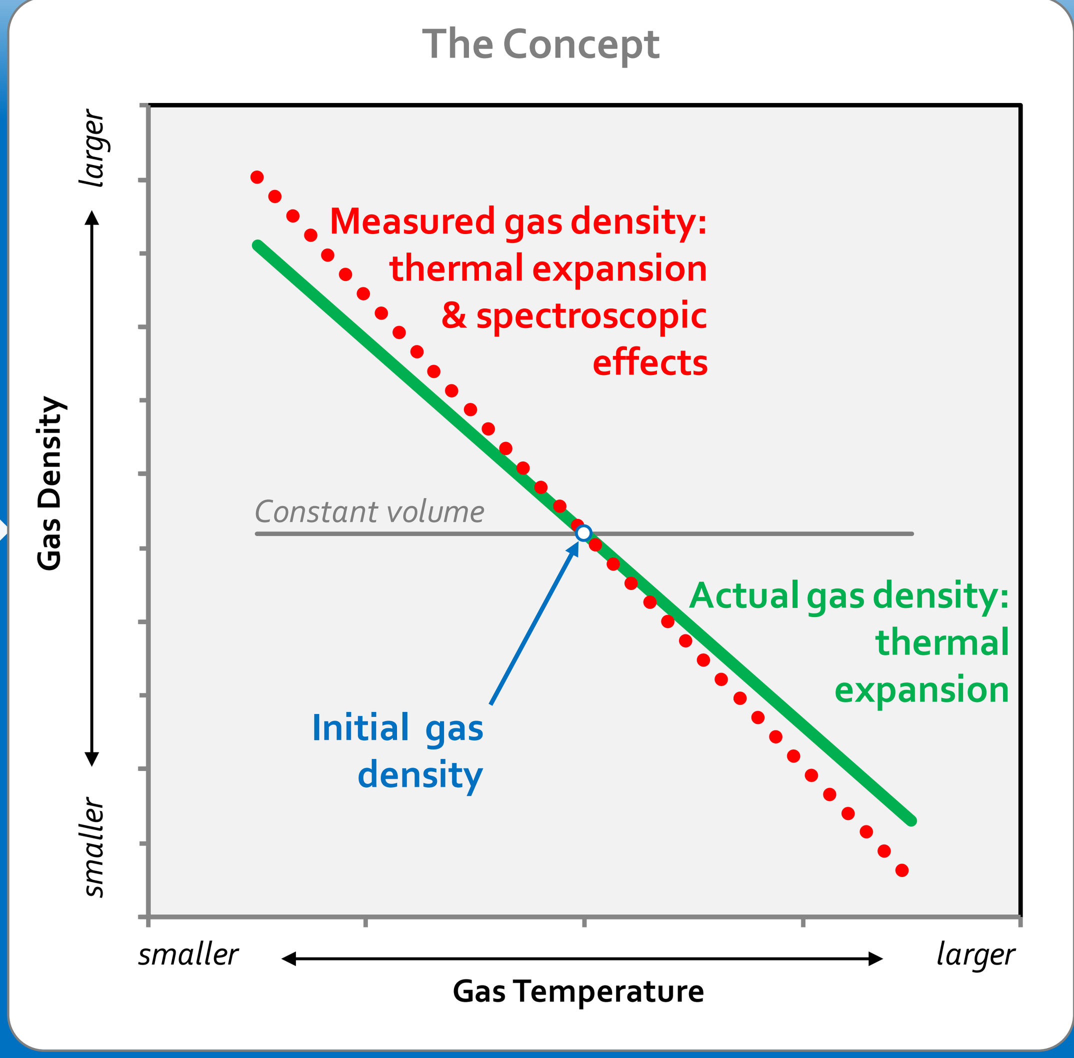
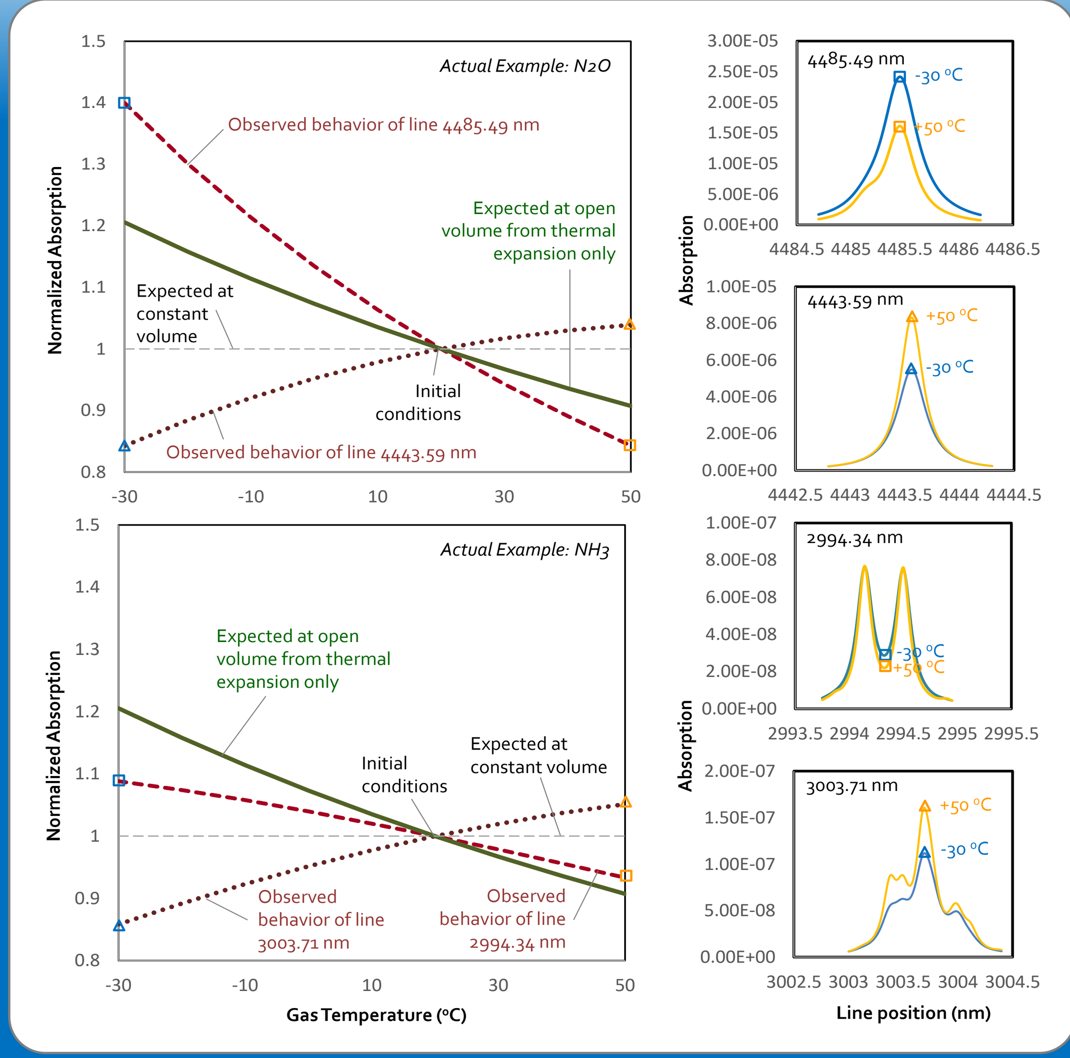
LASER MEASUREMENTS IN UNCONTROLLED VOLUME: LOW-POWER, OPEN-PATH, ENCLOSED PATH, UNCONTROLLED CLOSED-PATH, etc.







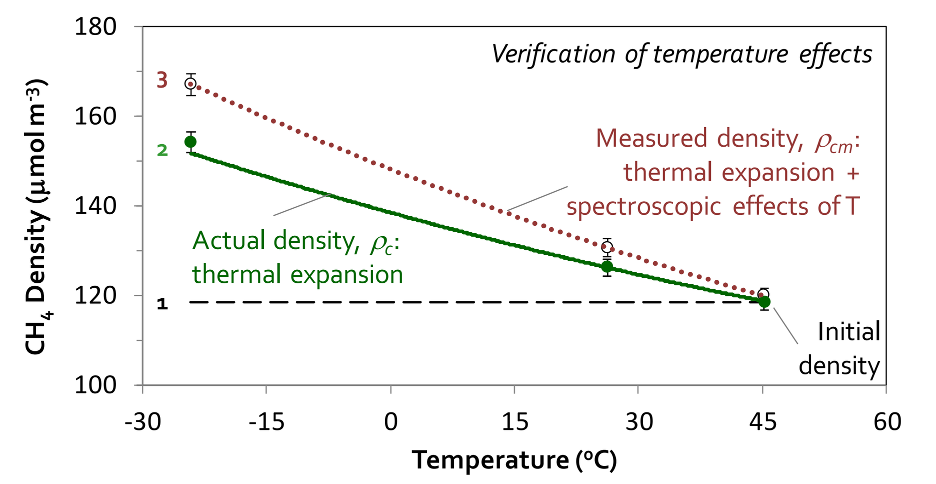
$$\rho_c = \rho_{cm} k$$

$$F_c = \overline{w'\rho_c'} + \mu \frac{\overline{\rho_c}}{\overline{\rho_d}}\overline{w'\rho_v'} + \left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_c}}{\overline{T}}\overline{w'T'} - \overline{\rho_c}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'p'}}{\overline{p}}$$

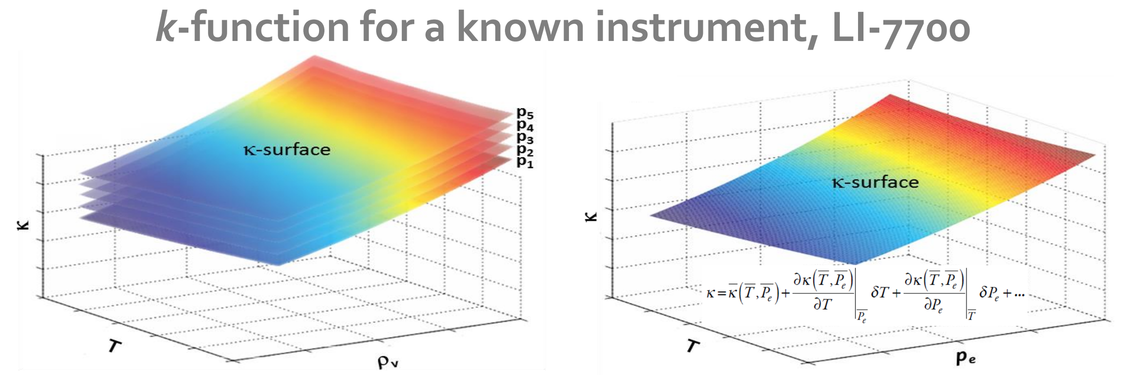
$$F_c = \bar{k}\,\overline{w'\rho_{cm}'} + \bar{k}\,\mu\frac{\overline{\rho_{cm}}}{\overline{\rho_d}}\overline{w'\rho_v'} + \bar{k}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_{cm}}}{\overline{T}}\overline{w'T'} - \bar{k}\overline{\rho_{cm}}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'p'}}{\overline{p}} + \overline{w'k'}\,\overline{\rho_{cm}} + \overline{w'k'\rho_{cm}'}$$

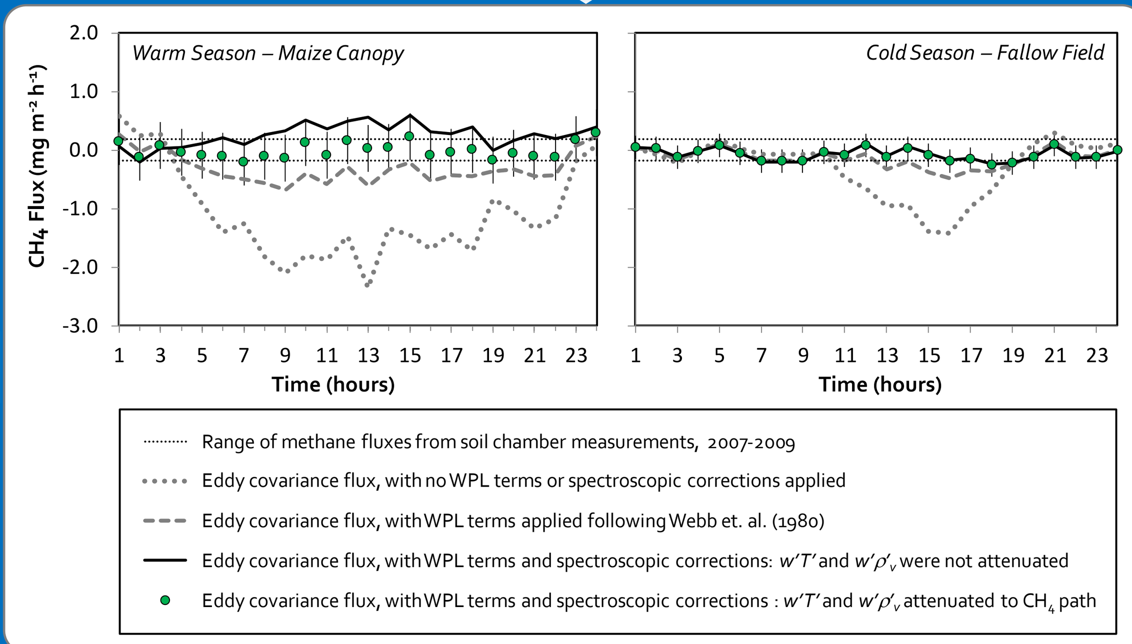
LABORATORY & FIELD EXPERIMENTAL VALIDATIONS FOR AN INSTRUMENT WITH A KNOWN *k*-FUNCTION

Developed from HITRAN & validated in the lab



k-function for a known instrument, LI-7700





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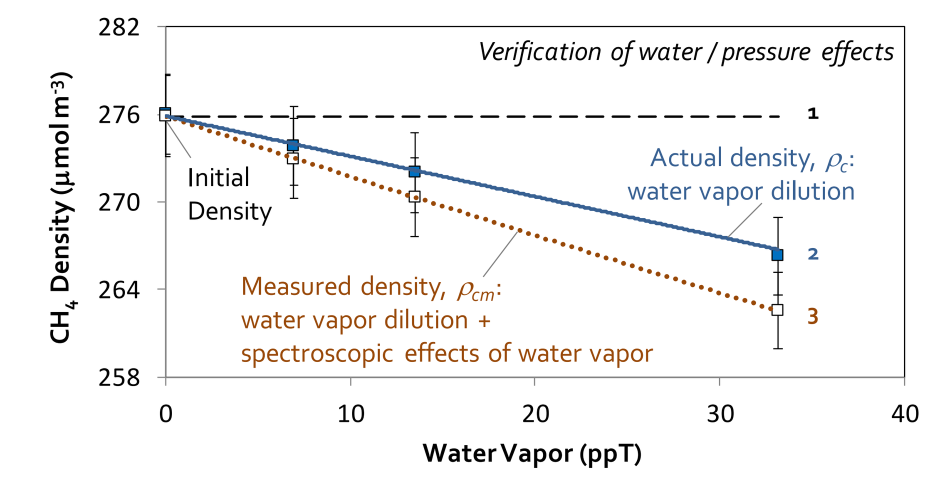


Implications for CH4

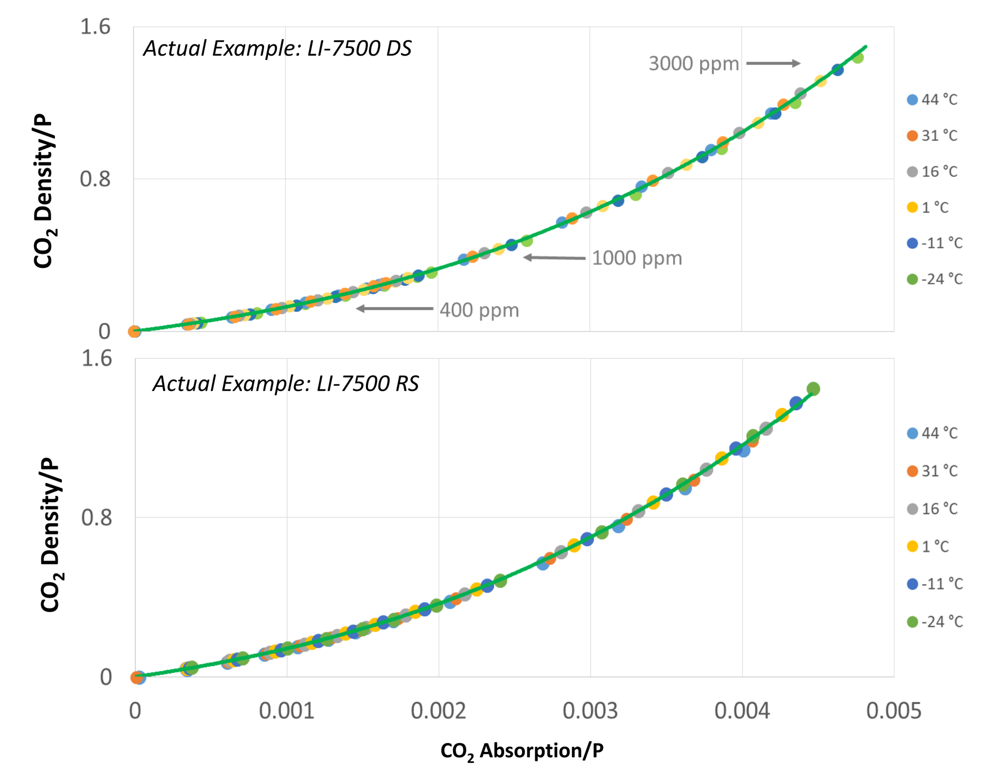
H	LE	WPL Terms		Spectroscopic Effects				
		WPLH	WPLLE	Temperature	Water Vapor	Contribution to final flux value		
$W\,m^{-2}$	$W\,m^{-2}$	$mg\,m^{-2}\,h^{-1}$	$mg\,m^{-2}\,h^{-1}$	$mg\,m^{-2}\,h^{-1}$	$mg\,m^{-2}\,h^{-1}$	$mg\,m^{-2}\,h^{-1}$	$umol\,m^{-2}\,s^{-1}$	% of flux
				(≈0.31xWPLH)	(≈0.41xWPLLE)			
0	0	0.00	0.00	0.00	0.00	0.00	0.000	0
50	50	0.61	0.13	0.19	0.05	0.24	0.004	8
50	200	0.61	0.51	0.19	0.21	0.40	0.007	13
50	400	0.61	1.03	0.19	0.42	0.61	0.011	20
200	50	2.46	0.13	0.76	0.05	0.81	0.014	27
200	200	2.46	0.51	0.76	0.21	0.97	0.017	32
200	400	2.46	1.03	0.76	0.42	1.18	0.021	39
400	50	4.92	0.13	1.52	0.05	1.58	0.027	53
400	200	4.92	0.51	1.52	0.21	1.73	0.030	58
400	400	4.92	1.03	1.52	0.42	1.94	0.034	65

Implications for other gas species

Specie	Line	Flux	Concentration	WPLH Term	Spectroscopic Effects of Temperature			
	nm	$mg\,m^{-2}\,h^{-1}$	ppm	$mg\,m^{-2}\,h^{-1}$	fraction of WPLH	$mg\,m^{-2}\,h^{-1}$	$umol\,m^{-2}\,s^{-1}$	% of final flux
CH_4	1650.96	3	1.81	2.46	0.44	1.08	0.019	36
	1635.42				-2.47	-6.06	-0.105	-202
CO_2	1606.08	720	391	1434	0.49	698	4.407	97
	1609.58				0.77	1105	6.978	154
N_2O	4485.45	0.02	0.31	1.13	0.54	0.60	0.004	3021
	4443.55				-1.54	-1.74	-0.011	-8684
NH_3	2994.35	0.00005	0.14	0.20	1.85	0.38	0.006	757915
	3003.70				-1.54	-0.32	-0.005	-631596

NOTE ON BROAD-BAND NDIR IRGAs

Properly designed IRGAs are different from laser



- The same fundamental spectroscopic effects have different impact on measurements by a properly designed broad-band instruments such as in NDIR IRGAs
- Examples above show typical calibration curves for two models, LI-7500RS and LI-7500DS, determined by using a full set of calibration gases at each specific temperature
- All the curves on each plot overlay each other well, showing that the calibration is consistent across the nearly 70 °C temperature range
- Such data are collected for each individual instrument as a part of routine factory calibration

SUMMARY OF EQUATIONS & CORRECTIONS FOR ANY INSTRUMENT OR GAS SPECIE

Application	Flux	Raw Covariance	Dilution by H_2O or any other dilutor	Thermal expansion & contraction	Pressure expansion & contraction	Spectr.	HOT
Any instrument No spectroscopic effects, WPL	$F_c =$	$\overline{w'\rho'_c} +$	$\mu\frac{\overline{\rho_c}}{\overline{\rho_d}}\overline{w'\rho_v'} +$	$\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_c}}{\overline{T}}\overline{w'T'} -$	$\overline{\rho_c}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'p'}}{\overline{p}}$	absent	absent
Any instrument Any spectroscopic effects	$F_c =$	$\bar{k}\,\overline{w'\rho'_{cm}} +$	$\bar{k}\,\mu\frac{\overline{\rho_{cm}}}{\overline{\rho_d}}\overline{w'\rho_v'} +$	$\bar{k}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_{cm}}}{\overline{T}}\overline{w'T'} -$	$\bar{k}\overline{\rho_{cm}}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'p'}}{\overline{p}}$	$+\overline{w'k'}\,\overline{\rho_{cm}}$	$+\overline{w'k'\rho'_{cm}}$
Any instrument Spectroscopic effects of T, ρ_v, p	$F_c =$	$\bar{k}\,\overline{w'\rho'_{cm}} +$	$\left(\bar{k}+\frac{\overline{\rho_d}}{\mu}k_{\rho_v}\right)\mu\frac{\overline{\rho_{cm}}}{\overline{\rho_d}}\overline{w'\rho_v'} +$	$\left(\bar{k}+\frac{\bar{T}}{1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}}k_T\right)\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_{cm}}}{\overline{T}}\overline{w'T'} -$	$\left(\bar{k}-\frac{\bar{p}}{1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}}k_p\right)\overline{\rho_{cm}}\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{w'p'}}{\overline{p}}$	unfolded into other terms	$+\overline{w'k'\rho'_{cm}}$
LI-7700 Spectroscopic effects of T, ρ_v, p	$F_c =$	$\overline{k_{7700}}\,\overline{w'\rho'_{cm}} +$	$(\bar{k}+(1-1.46\,\overline{x_v})\alpha_v\overline{p_e}k_{7700\,p_e})\mu\frac{\overline{\rho_{cm}}}{\overline{\rho_d}}\overline{w'\rho_v'} +$	$\left(\bar{k}+(1-x_v)\bar{T}k_{7700\,T}+\overline{x_v}(M_{v7700}-\bar{k})\right)\left(1+\mu\frac{\overline{\rho_v}}{\overline{\rho_d}}\right)\frac{\overline{\rho_{cm}}}{\overline{T}}\overline{w'T'} -$	neglected	unfolded into other terms	neglected

Details in the main text and in the supplements to: Burba, G., Anderson, T. and Komissarov, A., 2019. Accounting for Spectroscopic Effects in Laser-based Open-path Eddy Covariance Flux Measurements. *Global Change Biology*, 25(6), pp. 2189-2202. DOI: 10.1111/gcb.14614