New Open-Path Low-Power Standardized Automated CO2/H2O Flux Measurement System: Concentrations, Co-spectra and Fluxes Comparison with Established Models

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Abstract

Spatial and temporal flux data coverage have improved significantly in recent years, due to standardization, automation and management of data collection, and better handling of the generated data. With more stations and networks, larger data streams from each station, and smaller operating budgets, modern tools are required to effectively and efficiently handle the entire process. These tools should produce standardized verifiable datasets, and provide a way to cross-share the standardized data with external collaborators to leverage available funding, and promote data analyses and publications. In 2015, new open-path and enclosed flux measurement systems1 were developed, based on established gas analyzer models2,3, with the goal of improving stability in the presence of contamination over older models4, refining temperature control and compensation5,6, providing more accurate gas concentration measurements1, and synchronizing analyzer and anemometer data streams in a very careful manner7. In late 2017, the new open-path system was further refined to simplify hardware configuration, to significantly reduce power consumption and cost, and to prevent or considerably minimize flow distortion8 in the anemometer to increase data coverage. Additionally, all new systems incorporate complete automated on-site flux calculations using EddyPro® Software9 run by a weatherized remotely-accessible microcomputer to provide standardized traceable data sets for fluxes and supporting variables. This presentation will describe details and results from the latest field tests of the new flux systems, in comparison to older models and control reference instruments. References: 1 Burba G., W. Miller, I. Begashaw, G. Fratini, F. Griessbaum, J. Kathilankal, L. Xu, D. Franz, E. Joseph, E. Larmanou, S. Miller, D. Papale, S. Sabbatini, T. Sachs, R. Sakai, D. McDermitt, 2017. Comparison of CO2 Concentrations, Co-spectra and Flux Measurements between Latest Standardized Automated CO2/H2O Flux Systems and Older Gas Analysers. 10th ICDC Conference, Switzerland: 21-25/08 2 Metzger, S., G. Burba, S. Burns, P. Blanken, J. Li, H. Luo, R. Zulueta, 2016. Optimization of an enclosed gas analyzer sampling system for measuring eddy covariance fluxes of H2O and CO2. AMT, 9: 1341-1359 3 Burba, G., 2013. Eddy Covariance Method for Scientific, Industrial, Agricultural and Regulatory Applications. LI-COR Biosciences: 331 pp. 4 Fratini, G., McDermitt, D.K. and Papale, D., 2014. Eddy-covariance flux errors due to biases in gas concentration measurements: origins, quantification and correction. Biogeosciences, 11(4), pp.1037-1051. 5 McDermitt, D., J. Welles, and R. Eckles, 1993. Effects of temperature, pressure, and water vapor on gas phase infrared absorption by CO2. LI-COR, Inc. Lincoln, NE. 6 Welles, J. and D. McDermitt, 2005. Measuring carbon dioxide in the atmosphere. In: Hatfield J. and J. Baker (Eds.) Micrometeorology in Agricultural Systems. ASA-CSSA-SSSA, Madison, W

NEW OPEN-PATH LOW-POWER STANDARDIZED AUTOMATED CO_2/H_2O FLUX MEASUREMENT SYSTEM

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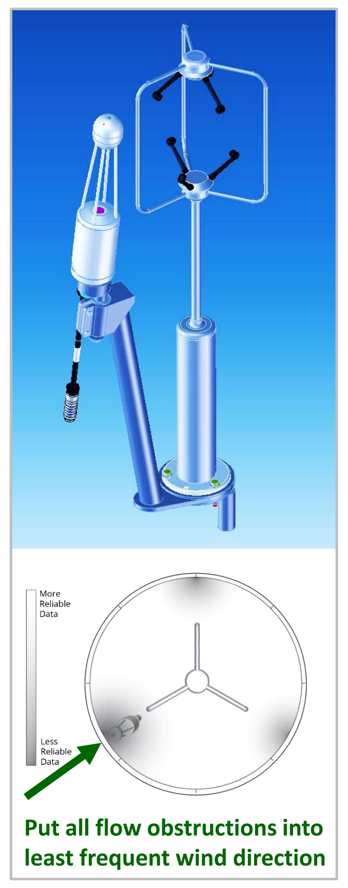
INTRODUCTION

- The latest 2017 model of CO_2/H_2O flux research system, LI-7500DS, is a streamlined, lower cost, lower power version of the 2015 model, LI-7500RS [1,2]
- Two 2015 flux research systems, open-path LI-7500RS and enclosed LI-7200RS, were in turn based on the original LI-7500/A and LI-7200 analyzers [3,4]
- Both RS and DS flux research systems include analyzers, but also have important additional functionality, significantly broader than just measuring gas concentrations:
  - increased stability under contamination and improved temperature controls
  - automation and standardization of final flux calculations in real-time
  - seamless integration with latest tools for flux tower networking, data sharing, and data analysis

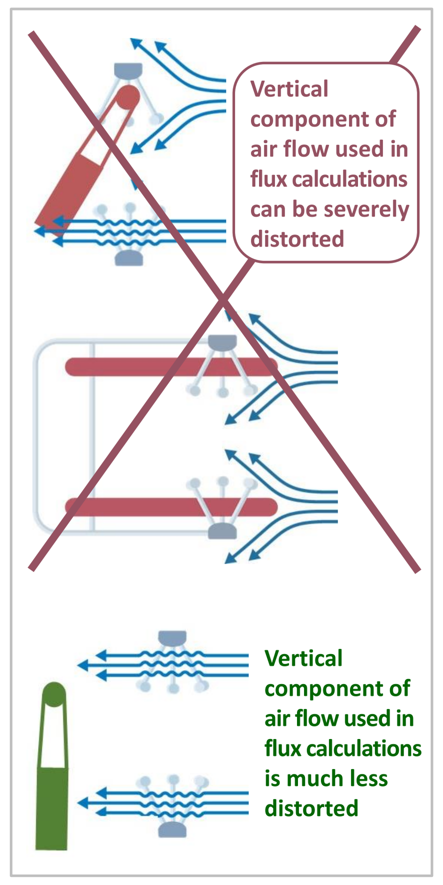
AUTOMATED SYSTEMS

- Automated flux systems output real-time fully processed fluxes of CO_2, H_2O, CH_4, H, τ, and auxiliary data [5]
- Low-power (1.5 W) weatherized field microcomputer, SmartFlux3, runs EddyPro same way as on desktop
- Fully configurable processing includes Fourier Transform, spectra, co-spectra, planar fit, progressive RH corrections, *etc.*
- Onsite clocks synchronized with PTP, clocks between stations are synchronized using GPS [6]
- Flux network tool, FluxSuite, shows status, fluxes, weather, flags etc., sends email alerts, and allows online data access and data sharing across the globe [see poster X1.59 on Thursday, April 12, for details]

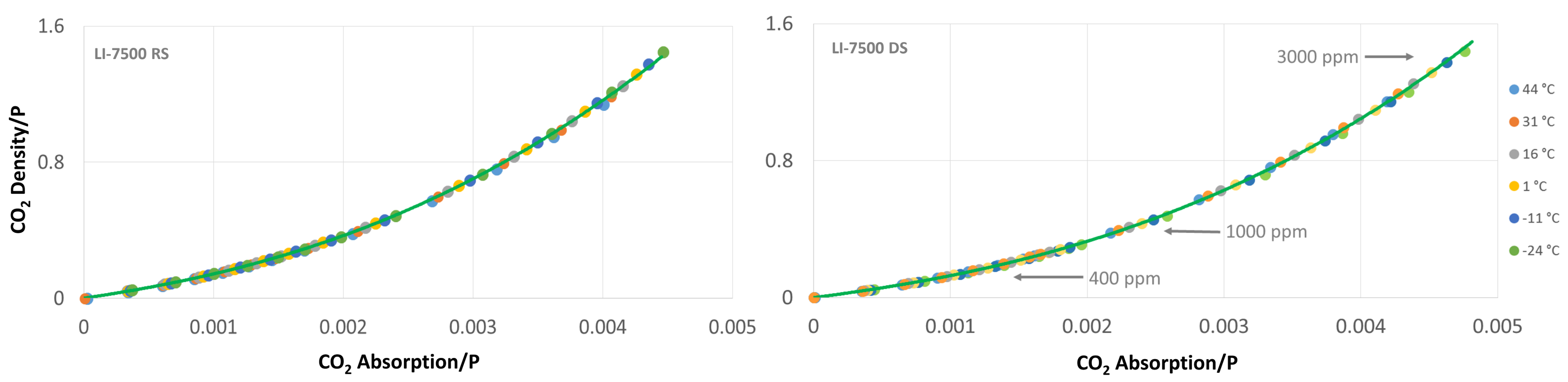
DS: POWER & SETUP



- Analyzer power consumption is reduced to 4W nominal to help cut overall site power
- LI-7550 box is eliminated to reduce cost, complexity and power demand
- The system includes SmartFlux3 microcomputer to fully compute fluxes, ogives, footprints *etc.*, and merge these with weather, soil and optical data
- Standard mount is provided to minimize the flow distortion in the anemometer and associated flux errors [7-15]



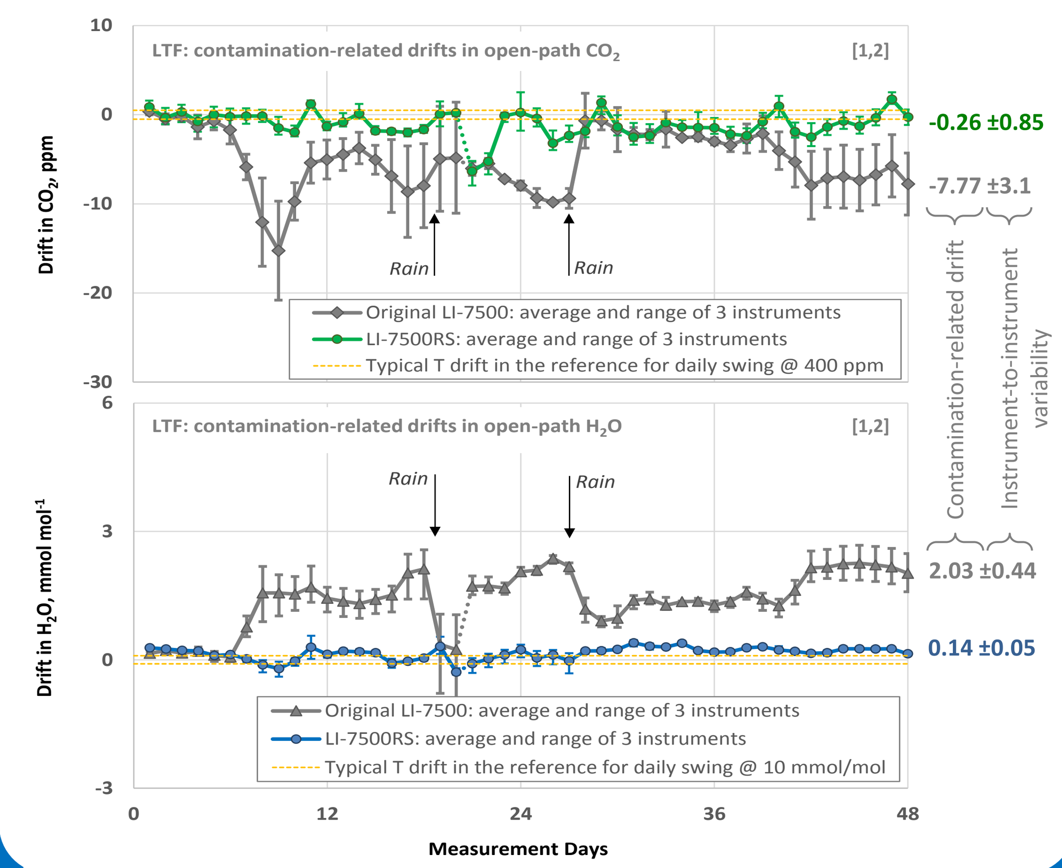
DS: TEMPERATURE CONTROL



- Temperature control of key electronics and optics is essential for reduction of temperature drifts in infrared gas analyzers [16, 17] and associated flux errors
- Examples above show typical calibration curves for 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 LI-COR IRGA as a part of routine factory calibration

RS: CONTAMINATION TESTS

Contamination-wise, DS has an identical design to RS



DS: COLD SEASON UPTAKES

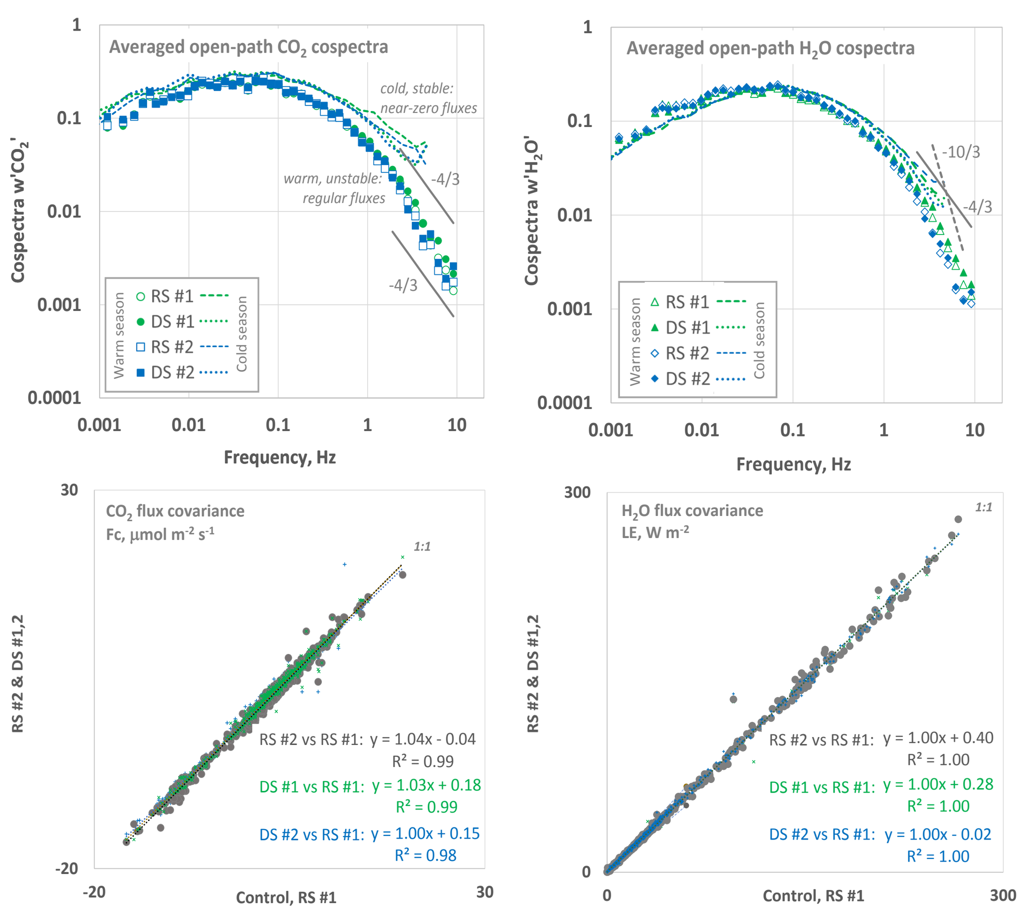
	Uptake events	Average uptake	Cumulative impact on winter CO_2 budget		Notes
			absolute	fraction	
	count	*μmol m^{-2} s^{-1}*	*mmol m^{-2}*	*%*	
Old LI-7500, *30 C*	174	1.62	507.4	**25.2%**	Typical, approx. from [18]
RS #1, *cold 5 C setting*	13	1.18	27.6	1.4%	Improvements in LI-7500RS vs. old LI-7500 are consistent with the switch from 5 C to 30 C settings for LI-7500A [19-21]
RS #2, *cold 5 C setting*	20	1.13	40.7	2.0%	
DS #1, *cold 5 C setting*	7	0.74	9.3	**0.5%**	Initial field results; experiments continue
DS #2, *cold 5 C setting*	8	0.59	8.5	**0.4%**	

- Cold season tests covered ambient temperatures range from -19 to 0 C; no uptakes were expected over a dormant and frozen ryegrass field
- Preliminary data suggest that LI-7500DS surface heating impact is 3-5 times smaller than that observed for LI-7500RS at cold settings, and 55-60 times smaller than that observed for the original LI-7500 model [4,18]

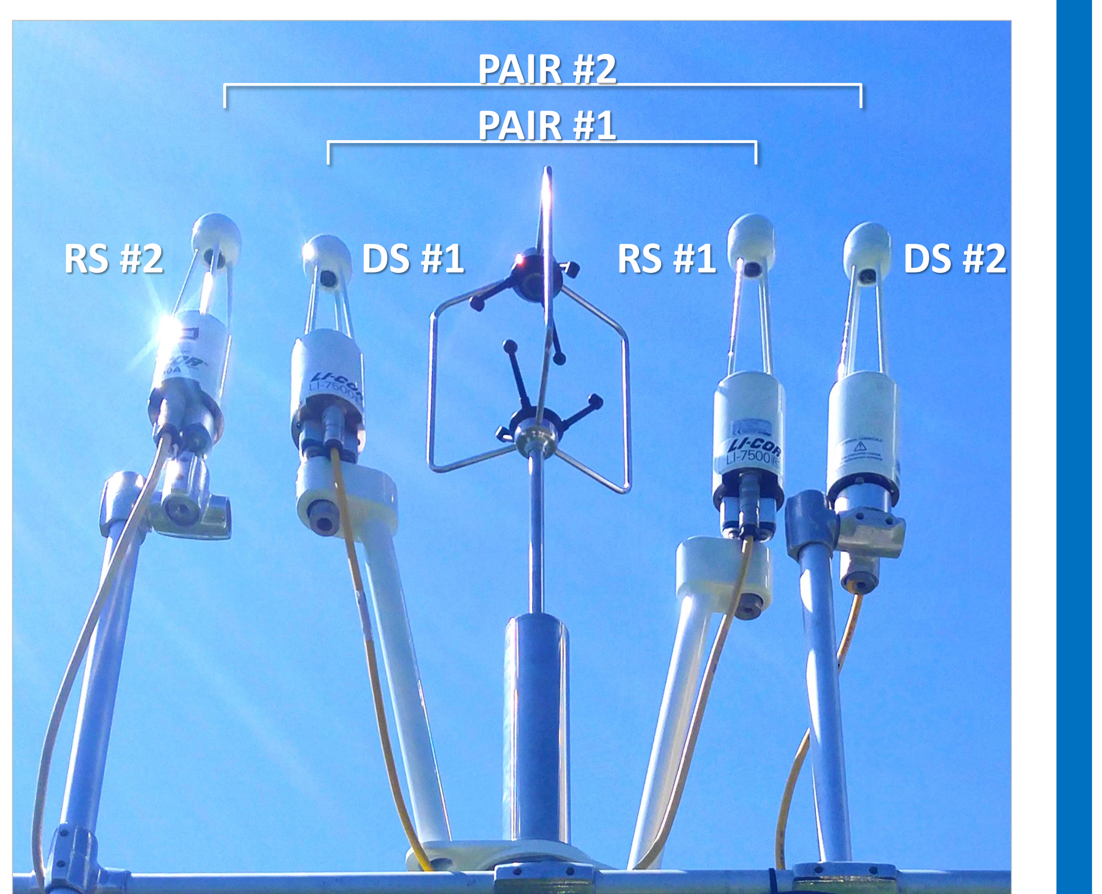
SUMMARY

- Field tests of RS systems were conducted over six periods 5-14 months long, at 6 diverse sites, using 26 gas analyzers [1,2]
- Instrument-to-instrument variability was reduced very significantly, 3-9 fold, in both open-path and enclosed RS models vs originals
- In terms of contamination-related drifts, the open-path LI-7500RS system performed significantly better than the original for both CO_2 and H_2O
- Improvements in CO_2 drifts in open-path RS were strong, with drifts few-to-tens of times less than the original
- Improvements in H_2O drifts were particularly significant, with RS drifts many tens of times less than the original
- Frequency response and hourly fluxes were substantially similar between the redesigned RS models and the original
- LI-7500DS system retained all the advantages of the RS models, but at much lower power consumption, and with reduced complexity and cost
- New models can significantly reduce site maintenance and improve flux data quality vs original models

DS: WARM AND COLD SEASON CO-SPECTRA & FLUXES



- Field tests at 3.5 m height covered ambient temperatures range from -19 to +36 C
- RS-DS Pair #1 was located 20 cm from the anemometer
- RS-DS Pair #2 was located 42 cm from the anemometer
- DS models performed similar or a bit better (nss) than RS models in terms of frequency response
- DS models performed similar (nss) to RS in terms of fluxes



REFERENCES

1. Begashaw I., G. Fratini, F. Griessbaum, J. Kathilankal, L. Xu, D. Franz, E. Joseph, E. Lamanou, S. D. Miller, D. Papale, S. Sabbatini, T. Sachs, R. Sakai, D. McDermitt, and G. Burba, 2016. Latest Results of Field Tests of the New Open-Path and Enclosed Systems for CO2 and H2O Flux Measurements. 32nd Conference on Agricultural and Forest Meteorology, Salt Lake City, Utah, June 20-2
2. Burba G., W. Miller, I. Begashaw, G. Fratini, F. Griessbaum, J. Kathilankal, L. Xu, D. Franz, E. Joseph, E. Larmanou, S. Miller, D. Papale, S. Sabbatini, T. Sachs, R. Sakai, D. McDermitt, 2017. Comparison of CO2 Concentrations, Co-spectra and Flux Measurements between Latest Standardized Automated CO2/H2O Flux Systems and Older Gas Analysers. 10th ICDC Conference, Switzerland: 21-25/08
3. Metzger, S., G. Burba, S. Burns, P. Blanken, J. Li, H. Luo, R. Zulueta, 2016. Optimization of an enclosed gas analyzer sampling system for measuring eddy covariance fluxes of H2O and CO2. AMT, 9: 1341-1359
4. Burba, G., 2013. Eddy Covariance Method for Scientific, Industrial, Agricultural and Regulatory Applications. LI-COR Biosciences: 331 pp.
5. Fratini, G., Mauder, M., 2014. Towards a consistent eddy-covariance processing: an intercomparison of EddyPro and TK3. AMT, 7: 2273-2281
6. Ediger, K. and Riensche, B.A., 2017. Systems and methods for measuring gas flux. U.S. Patent 9,759,703.
7. Wyngaard, J. C., 1981. The effects of probe-induced flow distortion on atmospheric turbulence measurements. Journal of Applied Meteorology, 20: 784-794.
8. Wyngaard, J. C., 1988. Flow-distortion effects on scalar flux measurements in the surface layer: Implications for sensor design. In Hicks, B. B. (Eds) Topics in Micrometeorology. A Festschrift for Arch Dyer. Springer, Dordrecht.
9. Frank, J. M., W. J. Massman, and B. E. Ewers, 2013. Underestimates of sensible heat flux due to vertical velocity measurement errors in non-orthogonal sonic anemometers. Agricultural and Forest Meteorology, 171-172: 72-81.
10. Horst, T. W., S. R. Semmer, and G. Maclean, 2015. Correction of a non-orthogonal, three-component sonic anemometer for flow distortion by transducer shadowing. Boundary-Layer Meteorology, 155 (3): 371-395.
11. Frank, J. M., W. J. Massman, E. Swiatek, H. A. Zimmerman, and B. E. Ewers, 2016. All sonic anemometers need to correct for transducer and structural shadowing in their velocity measurements. Journal of Atmospheric and Oceanic Technology, 33(1): 149-167.
12. Huq, S., F. De Roo, T. Foken, M. Mauder, 2017. Evaluation of probe-induced flow distortion of Campbell CSAT3 sonic anemometers by numerical simulation. Boundary-Layer Meteorology, 165(1): 9-28.
13. Horst, T. W., R. Vogt, and S. P. Oncley, 2016. Measurements of flow distortion within the IRGASON integrated sonic anemometer and CO2/H2O gas analyzer. Boundary-Layer Meteorology, 160(1): 1-15.
14. Dyer, A. J., 1981. Flow distortion by supporting structures. Boundary-Layer Meteorology, 20(2): 243-251.
15. Grare, L., L. Lenain, and W. K. Melville, 2016. The influence of wind direction on Campbell Scientific CSAT3 and Gill R3-50 sonic anemometer measurements. Journal of Atmospheric and Oceanic Technology, 33(11): 2477-2497.
16. McDermitt, D., J. Welles, and R. Eckles, 1993. Effects of temperature, pressure, and water vapor on gas phase infrared absorption by CO2. LI-COR, Inc. Lincoln, NE.
17. Welles, J. and D. McDermitt, 2005. Measuring carbon dioxide in the atmosphere. In: Hatfield J. and J. Baker (Eds.) Micrometeorology in Agricultural Systems. ASA-CSSA-SSSA, Madison, WI.
18. Burba, G., D. McDermitt, A. Grelle, D. Anderson, and L. Xu, 2008. Addressing the influence of instrument surface heat exchange on the measurements of CO2 flux from open-path gas analyzers. Global Change Biology, 14(8): 1854-1876
19. Burba, G., J. Hupp, D. McDermitt, and R. Eckles, 2011. Field examination of low temperature control setting for mediating surface heating effect in open-path flux measurements under cold conditions. European Geosciences Union General Assembly, Vienna, Austria, 03-08 April
20. Burba, G., D. McDermitt, D. Anderson, J. Hupp, and R. Eckles, 2011. Low Temperature Settings to Mediate Surface Heating Effect for Open-path Gas Analyzers in Cold Environments. Joint Meeting of AmeriFlux and North American Carbon Program, New Orleans, Louisiana, 1-4 February
21. Hupp., J., G. Burba, D. McDermitt, D. Anderson, and R. Eckles, 2010. Solution for Minimizing Surface Heating Effect for Fast Open-path CO2 Flux Measurements in Cold Environments. American Geophysical Union Fall Meeting, San Francisco, California, 13-17 December