AN AUTONOMOUS, INEXPENSIVE, AND ROBUST CO_2 ANALYZER (AIRCOA)

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ABSTRACT

We will present our design of a new autonomous, inexpensive, and robust CO_2 analyzer (AIRCOA), a description of our quality control procedures, and data examples from ongoing deployments. Our current AIRCOA units require less than $10K (USD) in components, show intercomparability better than 0.1 ppm during laboratory tests, and are designed to run autonomously for months at a time.

DISCUSSION

There is a strong motivation to improve atmospheric carbon flux constraints from continental scales (~ 10,000 km) to regional scales (~ 1000 km) so that they can be better related to the underlying ecosystem processes, land-use histories, and climate forcing. This requires a considerable increase in the temporal and spatial density of accurate atmospheric CO_2 observations, which would be significantly

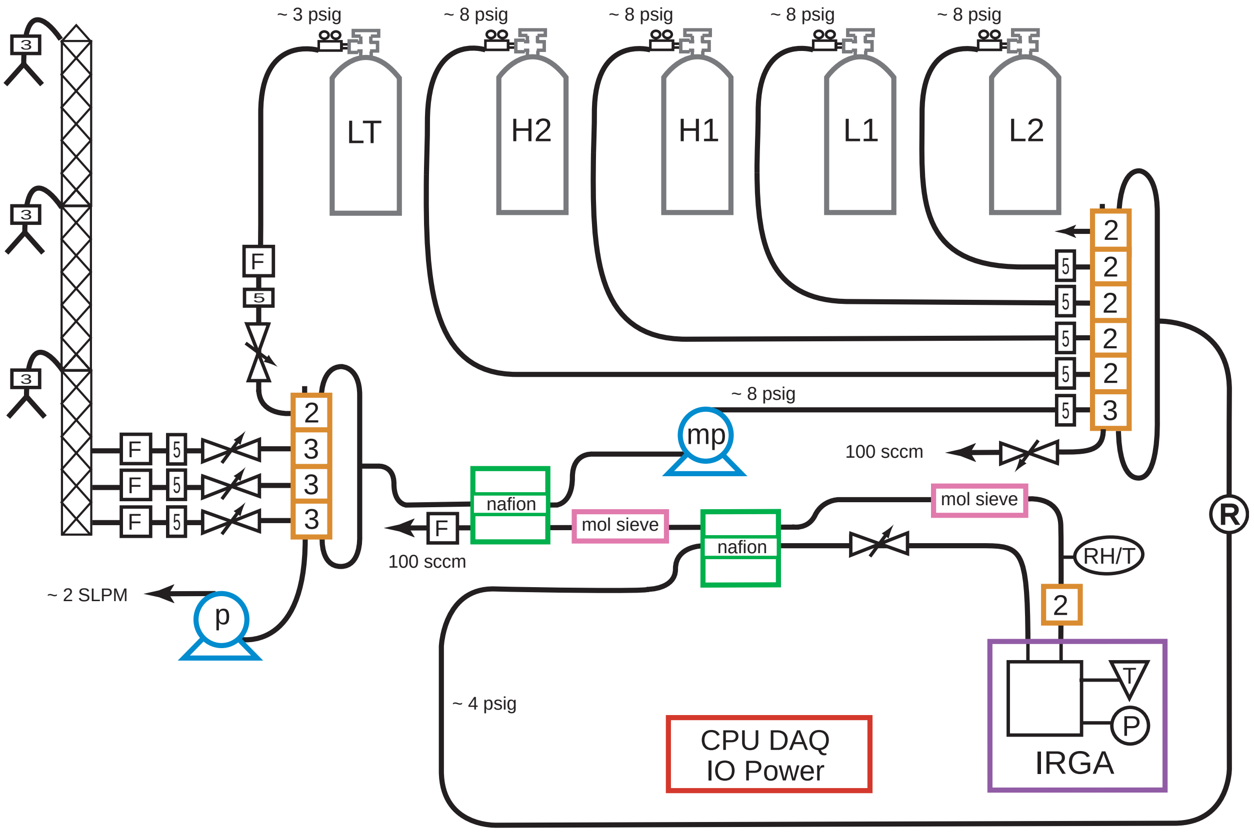

Fig. 1. Schematic showing the AIRCOA design. Components include rainshields and 3 μm inlet filters (3), mass-flow meters (F), 5 μm inline filters (5), manual needle valves, three-way (3) and two-way (2) solenoid valves and manifolds, Nafion driers, molecular sieve driers, a micropump (mp) and pump (p), high-pressure aluminum gas cylinders, two-stage pressure regulators, a single-stage pressure regulator (R), a humidity and temperature sensor (RH/T), a PC104 computer running Linux, PC104 relay and A/D boards, a power supply, and a LiCor 820 single-cell infrared gas analyzer.

aided by lowered costs and improved reliability of continuous CO_2 analysis systems. As part of the Carbon in the Mountains Experiment (CME), we developed AIRCOA for the purpose of observing local-scale CO_2 gradients across a network of towers at the Niwot Ridge carbon flux site, and are now deploying the same system in a regional CO_2 observing network [*Stephens et al.*, this volume].

Making accurate CO_2 measurements requires careful attention to gas handling, numerous automated quality control diagnostics, and a suite of reference cylinders closely linked to the WMO CO_2 calibration scale. Our approach builds on that of Zhao et al. [1997], but with considerable changes. AIRCOA is based on a single-cell IRGA, which dramatically lowers the cost but increases the short-term noise and instrument drift rate. We overcome the short-term noise with 2-minute signal averaging and instrument drift with 4-point calibrations every four hours and 1-point calibrations every 30 minutes. Additional potential sources of CO_2 measurement bias that we address with automated diagnostics include: incomplete flushing of the sample cell and dead volumes, incomplete drying of the sample air, IRGA sensitivity to pressure broadening, IRGA sensitivity to temperature, leaks to ambient air, leaks of calibration gas through solenoid valves, and modification of CO_2 concentrations by the drying system (see Table 1).

In a week-long laboratory intercomparison between 4 AIRCOA units all sampling outside air from a common mixing volume and using common reference cylinders, unit-to-unit differences on coincident 2 minute measurements showed 1-sigma variability of 0.1 ppm and systematic biases of 0.05 ppm or less. Field operation with different sets of calibration gases and larger temperature variations will lead to somewhat reduced performance. We are working closely with other investigators developing and deploying similar single-cell IRGA based systems, as well as investigators deploying longer-established but more expensive technologies, in an effort to improve the intercomparability between independent observing networks.

Table 1. Potential sources of CO_2 measurement bias and AIRCOA solutions

Measurement concern	Solution
Incomplete flushing of cell and dead volumes	Fast enough flow, alternate calibration sequence low-to-high / high-to-low to look for effects
Incomplete drying of air	Slow enough flow, two 96” Nafion driers, downstream humidity sensor to verify performance
Drift in IRGA sensitivity	4-hourly 4-point calibrations and 30-minute 1-point calibrations
Inadequate IRGA pressure calibration	Automated 4-hourly pressure sensitivity measurements
Leaks through fittings and solenoid valves	Automated 8-hourly positive pressure leak-down and 4-hourly ambient pressure leak-up checks
Temperature sensitivity of IRGA	30-minute 1-point calibrations, active temperature control in variable temperature deployment locations
Drying system changing CO_2	Maintain continuous flows and pressures through Nafions and run surveillance gas through entire system
Different pressure broadening with and without Ar	Use calibration gases made with real air
Different ^{13}C sensitivity between field and laboratory-calibration instruments, calibration gases with fossil CO_2	Laboratory tests limit effect in current design to 0.05 ppm, long-term plans to use cylinders with natural CO_2
Whole-system diagnostics and intercomparability verification	Long-term surveillance tank analyzed every 8 hours and occasional analysis of rotating cylinders

REFERENCES

Zhao, C.L., P.S. Bakwin, and P.P. Tans (1997), A design for unattended monitoring of carbon dioxide on a very tall tower, *J. Atm. Oc. Tech.*, *14*, 1139-1145.