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The Importance of Vertical Symmetry in Open-path Gas Analyzer Design: Minimizing Flow-distortion effects

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The eddy covariance (EC) method is a micrometeorological technique used to measure turbulent exchange of energy and matter between the ecosystem and the atmosphere. It relies on synchronous and co-located measurements of vertical wind, temperature and gas concentration fluctuations provided by a sonic anemometer/thermometer (SAT) and by an infrared gas analyzer (IRGA), respectively. In open-path configurations, the distance between the IRGA and SAT sensing volume is critical. If the IRGA is too close to the ultrasonic transducer array, the bluff body distorts air flow, which affects the wind measurements. If the IRGA is too far from the SAT, the lack of synchronization significantly reduces the covariance between the gas concentration and vertical wind fluctuations. The reduced covariance causes an underestimation of the flux measurements, which needs to be corrected in post processing. Optimization of the sensor separation distance is required to balance these contradicting requirements. This study quantifies negative effects of flow distortion caused by open-path gas analyzers on ultrasonic turbulent wind field measurements. Insights to improve eddy covariance data quality for low measurement heights and criteria to filter out wind segments affected by the IRGA are discussed. The study consists of the following configurations:
A. Sonic-only installation mounted at 2 m height above the ground (used as a reference)
B. Sonic with an asymmetric IRGA (6.5 cm lower and 4 cm upper housing diameters) positioned 15 cm away from the measuring volume of the sonic and tilted at 15 degrees from the vertical axes
C. Sonic with a C-shaped, horizontally symmetrical IRGA (identical lower and upper housings with 3.2 cm diameters) that has a vertical measurement path positioned the same distance from the sonic as configuration B.
For the three configurations, the SAT was mounted over a flat gravel area, and the position and orientation of the SAT remained unchanged. Field measurements from the three configurations were analyzed for flow disturbance within the symmetrical and non-symmetrical IRGA structures, and for their influence on coordinate rotation angles. The study shows that horizontal flux cross-talk errors and stream line distortion effects can be minimized by using an open-path IRGA with small-diameter housings that are vertically symmetrical about the horizontal mid-plane.