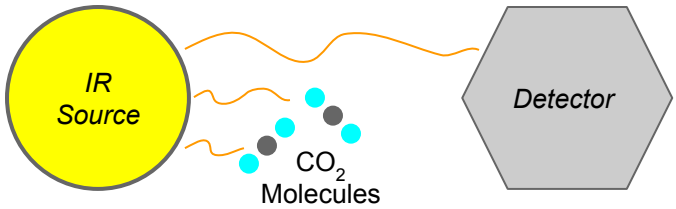
eosGP dual range calibrations for increased measurement range and higher accuracy

Introduction

Small Non-Dispersive Infrared (NDIR) sensors that can be deployed *in-situ* offer great opportunities for monitoring and understanding the biological, chemical and physical processes that drive gas production and consumption in natural environments. Often in these *in-situ* studies, researchers observe gas concentrations that span several orders of magnitude spatially and temporally. However, many sensors are calibrated to measure a single range of gas concentration (e.g. 0-50,000 ppm CO_2). In general, NDIR sensors that are calibrated to low concentration ranges tend to be quite accurate, but suffer from data loss once the observed concentration exceeds their maximum threshold. Conversely, sensors that have a high calibration range are well suited for measuring large changes in gas concentrations that occur seasonally, but suffer from reduced accuracy when concentrations are low. In this application note we will demonstrate the "dual-range" calibration method that allows the eosGP sensor to make accurate measurements at low concentration while maintaining the ability to measure CO_2 concentrations over several orders of magnitude.

NDIR Theory

In brief, NDIR sensors consist of an infrared light source and a detector. As infrared light travels from the source to the detector, some light is absorbed by gases present in the cavity. The detector compares the lamp “brightness” in the absence of the target gas to that observed when a gaseous sample is present in the cavity. This change in brightness when a sample is present is correlated to the sample concentration via Beer’s Law.



Dual Range Calibrations

The Beer’s Law best fit to a 7 point calibration over a large range of CO_2 concentrations (for example 0-50,000 ppm, shown below) is likely to offer good results in the high concentration range, but have the largest amount of error at low concentrations.

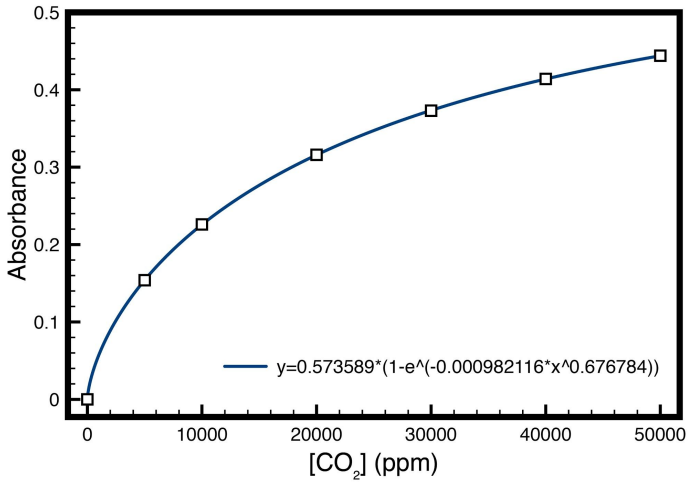


Figure 1. Best fit to a 7-point 0-50,000 ppm CO_2 calibration.

The error in concentration due to fitting for this 0-50,000 ppm range is displayed below (Figure 2) in the blue curve, showing clearly that the error is largest (~20-30% error) at lower CO_2 concentrations.

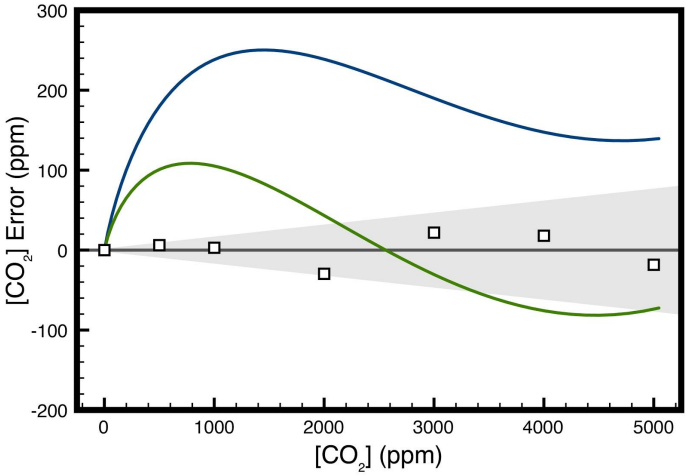


Figure 2. Error due to fitting 7 points spanning 0-50,000 ppm (blue), fitting 13 points spanning 0-50,000 ppm (green), and fitting 7 points spanning 0-5,000 ppm (open squares).

One might assume that increasing the number of calibration points in the low range would help to eliminate this high error rate. While adding a further 7 points in the low CO_2 range does change the fitting function parameters (Figure 3), it unfortunately does not improve the error to within the desired limit of 1% of measurement (Figure 2; Green line).

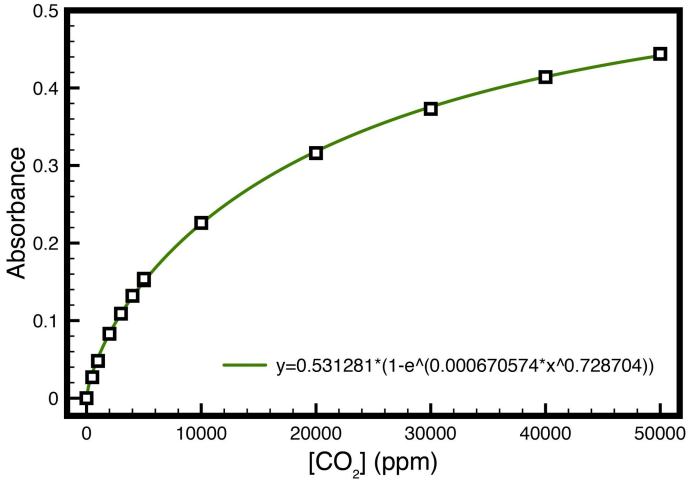


Figure 3. Best fit to a 13-point 0-50,000 ppm CO_2 calibration.

The Eosense Solution

Using a calibration curve that is fit over a large range will not allow for sufficient accuracy at low concentrations, even if many points are used in the fit. However, when a smaller portion of the total range is fit (e.g. 0-5,000 ppm CO_2) the error falls within the desired 1% error bounds (Figure 2; Open squares; 1% boundary shown in grey shading).

Eosense uses a piecewise set of calibration curves in the eosGP that are fit independently over the low and high-range sections of the calibration data. Both curves are factory-loaded onto the eosGP unit and during data analysis the user can choose which calibration is most appropriate for the environment in which the sensors are deployed.

This dual range calibration technique allows for the maintenance of high accuracy readings at low CO_2 concentrations, while still allowing the sensor to span a wide range of possible concentration values and thereby minimize data loss in *in-situ* installations.

Eosense Calibrations

In order to offer our customers the most versatile accuracy across a range of environmental conditions and gas concentrations, Eosense provides a variety of standard and custom calibrations.

CO_2 Concentrations - Standard

To ensure the highest accuracy, each eosGP sensor is independently calibrated at a minimum of 7 points over the desired CO_2 concentration range. These 7 concentrations are carefully chosen such that the parameters of the Beer's Law exponential fit can be obtained with minimal error.

Calibration Options	
Standard single range #1	0-20,000 ppm
Standard single range #2	0-50,000 ppm
Standard single range #3	0-125,000 ppm
Standard dual range	0-5,000 / 0-20,000 ppm

Temperature Corrections - Standard

Due to a combination of ideal gas behavior and electronics change (e.g. resistance) with temperature, apparent gas concentrations measured by NDIR sensors also change with temperature. Eosense performs its 7-point concentration calibration at 4 temperature steps ranging from 0 C to +40 C in order to correct the Beer's Law fits and ensure the highest accuracy over a wide range of field conditions.

Dual Range Calibrations - Optional

When you order the optional standard dual range calibration (0-5,000 ppm / 0-20,000 ppm), Eosense calibrates your eosGP using 9 different concentration points chosen carefully to ensure maximum accuracy, over 4 different temperature conditions. Similarly, when you choose a custom dual range calibration your sensor will be calibrated at a minimum of 9 points over your chosen range; however, for custom calibrations we select the concentration and temperature calibration points to ensure that your sensor is properly characterized for your specific application.