Real-time soil flux measurements and calculations with CRDS + SFP: comparison among flux algorithms and derivation of whole system error

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Introduction

Soil flux chamber measurements are a key tool for determining production and sequestration of direct and indirect greenhouse gases. The Picarro G2508 Cavity Ring-down Spectrometer radically simplifies soil flux analyses by providing simultaneous measurements of five gases: CO_2, CH_4, N_2O, NH_3, and H_2O, and by ready field deployment. The Picarro Soil Flux Software (SFP) provides a flexible user interface for Chamber Flux Error Evaluation. This poster highlights two types of errors in chamber flux measurements and demonstrates the SFP tools to evaluate these errors.

Objectives

Demonstrate the SFP Tools to Evaluate:

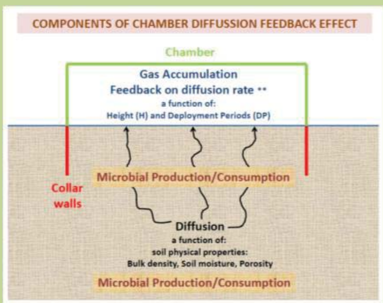
I. Error in F_o due to incorrect flux model selection.

II. Whole System Measurement Error.

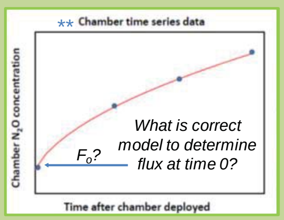
G2508 Analyzer

Figure 2. Picarro G2508 concentration analyzer. Simultaneous, continuous measurement of five species: N_2O, CH_4, CO_2, NH_3, H_2O.

Background: Non-linear chamber accumulation rate



Closed-System Physics: Non-linear rate with time.



I. Tools to Evaluate Error due to Model Selection

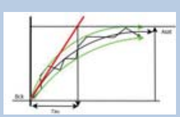
A. Select from three standard flux algorithms available in SFP:

Linear:

$C(t) = m * t + b$,
$Flux_o = V_e/A * m$

Exponential:

$C(t) = B_{ck} + A_{sat} [1 - e^{-t/\tau}]$,
$Flux_o = V_e/A * (slope = A_{sat} / \tau)$
"Hutchinson and Mosier (1991)"



Quadratic Polynomial:

$C(t) = at^2 + m * t + b$,
$Flux_o = V_e/A * m$

Where V_e = effective chamber volume corrected for actual temperature and pressure; A = area of chamber footprint; m = slope; b = intercept; t = time elapsed; B_{ck} = background concentration; A_{sat} = saturation concentration; τ = concentration saturation rate (s^{-1})

I. Tools to Evaluate Error due to Model Selection

B. Customize specific flux algorithm in User-defined interface:

For Example: Livingston et al. (2006)

Non-steady-state Diffusive Flux Estimator (NDFE) Model

$$C(t) = Co + Flux * \frac{\tau}{H}\left(\frac{2}{\sqrt{\pi}}\sqrt{\frac{t}{\pi}} + \exp\left(\frac{t}{\tau}\right) erfc\sqrt{\frac{t}{\tau}} - 1\right)$$

..where τ is an estimate of rate that the concentration gradient of the gas in the soil responds to build-up in the chamber.

User-defined interface: Parameters given: background, slope, tau and time, t

```
def livingston_fit(t, background, slope, tau):return
    background + slope * tau*
    (2.0*np.sqrt(t/tau)/np.sqrt(np.pi) +
    np.real(wofz(1j*np.sqrt(t/tau))) - 1.0)
```

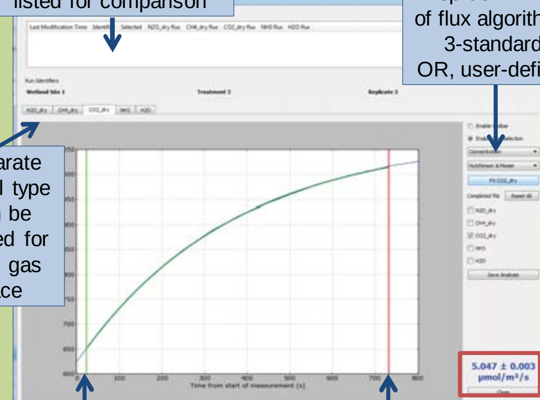
Sze Tan's program/solution.

Flux Software: Sophisticated Chamber Flux Analysis

Multiple fit attempts listed for comparison

Drop-down menu of flux algorithms; 3-standard, OR, user-defined

Separate model type can be applied for each gas trace



Easy left click to set start

Easy right click to set end

Convenience of Serial Interface to Collect Associated Parameters:

- Serial interface with user-provided external data logger allows real-time monitoring of chamber environment, and collection from other sensors (soil moisture, soil temperature).
- Dashboard interface also provides generic input variables for site specific contents: bulk density/porosity, soil pH.

I. Tools to Evaluate Error due to Model Selection

C. Use Auxiliary Senor and Dashboard Inputs to assimilate and export initial flux estimates and modification parameters:

For Example: Venterea et al. (2006)

Chamber Bias Correction (CBC) Model

Models Diffusion Effect by Examining the Physical Meaning of Tau (from NDFE):

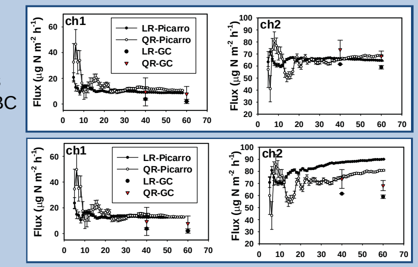
H = chamber height (volume to area ratio)
S = Soil-gas storage term
D_s = Soil diffusion coefficient

S and D_s can be further defined as functions of: *bulk density, porosity, water content, Henry's law constant, and temperature*

All of which can be measured and assembled in the SFP Dashboard

Chamber flux values without CBC

Chamber flux values with CBC

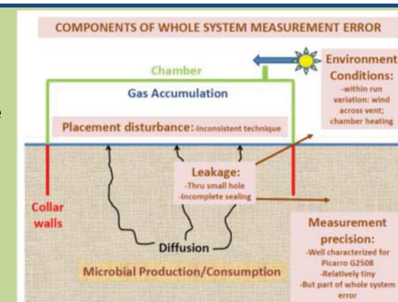


Note: Some conditions do not have diffusion effect (ch1)

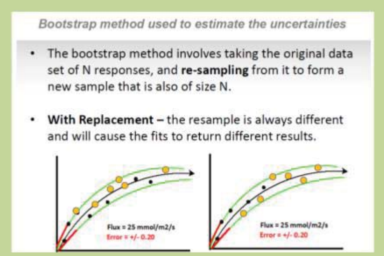
Others are under-estimated by diffusion effect (ch2)

II. Evaluation of Whole System Flux Measurement Error

G2508 High Frequency Measurements Provide New Opportunities in Error Analysis



Calculated Whole System Error



- *Error attributes misfit to instrument and procedural variability.*
- *Provides powerful tool for separating flux measurement error from site to site heterogeneity.*