INTRODUCTION

The Chamber Error Analysis Tool (CEAT) Version 2.0 is a spreadsheet-based calculation scheme for estimating errors due to the "chamber effect" and the degree of imprecision resulting from random measurement error. Feedback or suggestions for improvement are welcome and should be communicated to rod.venterea@ars.usda.gov. For details regarding calculation methods, assumptions, terminology, and definitions, see the references.

CEAT requires that the Excel Analysis ToolPak is available and checked under Tools, Add-ins. This is needed to enable the complementary error function (erfc()). In addition, for the Precision analysis, the RiskAMP Monte Carlo add-in is required to generate randomly selected values from defined distributions. RiskAMP is available from Structured Data, LLC for approximately $130 (http://www.riskamp.com/).

SPREADSHEET OVERVIEW

The spreadsheet contains several sheets indicated by tabs at the bottom. The "Input" sheet is the only area within the spreadsheet that requires user input (as described below). Cells in all other sheets, which are used for viewing results or for calculation purposes, should not be altered in any way, as this will invalidate the calculations.

INPUT INSTRUCTIONS

User needs to enter the following information in the Input sheet:

Soil Property Data: including bulk density, gravimetric or volumetric water content, soil (and air) temperature, particle density, and clay percentage in units indicated. If the Campbell *b* parameter is known, this can be entered directly, otherwise *b* will be estimated from the clay content.

Since many if not all of the above properties may vary substantially over the depth of the soil profile, it is recommended that the near-surface (e.g., 0-5 cm) properties be used. In most cases, i.e., where bulk density and/or water content are lower near the surface compared to at depth in the profile, using the near-surface data will result in a conservative (worst-case) estimate of relative error (Venterea and Baker, 2008).

For accuracy analysis, the following information is needed:

Chamber Method Details: including total chamber deployment time (DT) and chamber volume to area ratio (*h*, equivalent to chamber height for a uniform geometry). The sheet accommodates a single deployment time and up to 6 *h* values for each set of calculations. If using output sheets A3 and/or A5 (see below), the *h* value entered into cell C16 will be used for the analysis.

Flux magnitude: A non-zero value for the predeployment flux (f_o) must be entered in the "Maximum flux to simulate" field. This value will be used for the accuracy analysis The entered Maximum f_o value will not affect the relative error values, but will affect the magnitude of chamber concentrations in the Theoretical Chamber Data graphs.

For precision analysis, additional information is needed:

Flux magnitude*:* If performing a precision analysis using the CV sheet or Analysis of Variance using sheets A3 or A5, a range of f_o values can be examined. In these cases, non-zero flux value must also be entered in the "Minimum flux to simulate" field.

Measurement Error*:* First, the user must select an Error type by entering 1 or 2, corresponding to a constant CV or exponential rise to maximum model describing standard deviation of the measurement system as a function of concentration. If "1" is selected, the CV value (%) needs to be entered where indicated. If "2" is selected, then alpha and beta values need to be entered where indicated. The relationship between standard deviation and concentration will be plotted as the solid line in the graph. If data are available, they can optionally be entered and will also be plotted. For option "1", the CV value can be taken from the slope calculation. For option "2", alpha and beta values need to be obtained separately using non-linear regression (Sigma Plot or SAS are recommended).

OUTPUT SHEETS

Accuracy Analysis:

Pars: (locked to user) This sheet contains parameters calculated from the Input Data that are required in the accuracy and precision analyses. This information may be of interest, but no user input is needed and cells are locked to prevent accidental alteration.

3, 4, and 5: (locked to user) These sheets contain graphs and tabulated values of theoretical chamber time series data for the case of 3, 4, or 5 sampling events, respectively. These results can be used to estimate the range of chamber concentrations and degree of non-linearity expected for given values of chamber deployment time, chamber height, and predeployment flux.

RE: (locked to user) This sheet contains relative error values tabulated and plotted versus h for each flux-calculation scheme as well as r^2 values from linear regression of chamber concentration versus time. Note: for the case of 4 sampling events, the HM model is not applicable since the data do not consist of three events equally spaced in time, and that results using the HM model for 3 and 5 events utilize exactly the same data and are therefore identical.

Precision Analysis:

Precision analysis requires that RiskAMP add-in is checked. In order to generate values in the following sheets, a Monte Carlo Simulation must be performed by selecting "Monte Carlo" and "Run Monte Carlo Simulation". Recommended number of iterations is 1000 for determining CV, RMSE and skewness. 1000 iterations should take less than 1 min depending on your processer. For ANOVA (sheets A3 and A5), a smaller number of iterations (maximum 50) is recommended. The "Allow Screen Updates During Simulation Box" should be kept unchecked, or the simulations will take longer.

CVs: (locked to user) This sheet contains coefficients of variation (CV) and root mean square errors (RMSE) as a function of flux and *h* for each flux-calculation scheme.

A3 and A5: (not locked) These sheets contain columns of flux values resulting from individual Monte Carlo simulations at varying predeployment fluxes. These data can be used to perform analysis of variance (ANOVA) to examine the sensitivity of a given chamber protocol to detecting differences (the ANOVA itself must be performed separately). For additional details on how this can be done, see Venterea et al. (In press). Sheets A3 and A5 use 3 and 5 sampling events, respectively.

***Hidden sheets*:** There are 10 sheets titled with the prefix "MC" that are used for the Monte Carlo simulations. These sheets are hidden to make navigation of the main sheets easier, but can be unhidden if desired for viewing. These sheets as well as sheets A3 and A5 need to remain unlocked, so care should be taken not to alter any cells.

MAIN LIMITATIONS

Error estimates calculated by CEAT 2.0 are based on the 1-D diffusive transport equation and therefore assume that chamber insertion depth and radius are sufficient to minimize lateral diffusion effects, that the chamber is properly vented, and that any gas re-circulation system is designed to reduce pressure perturbations. It also assumes homogeneous (well-mixed) chamber conditions. Livingston et al. (2006) concluded that temperature and pressure gradients within chambers are likely to induce sufficient advection to overwhelm pure diffusive mixing. However, the validity of this assumption may fail as *h* increases above some limit in the absence of induced mixing.

Vertical gradients in soil physical properties will likely exist. CEAT 2.0 is designed to estimate the worst-case relative error by using near-surface properties which generally result in conservative estimates. A more exact analysis can be done if detailed soil data are available, i.e., physical properties at multiple depths, using numerical modeling as described by Venterea and Baker (2008). Contact R. Venterea if interested.

REFERENCES

Venterea, R.T. and J.M. Baker. 2008. Effects of soil physical nonuniformity on chamber-based gas flux estimates. Soil Sci. Soc. Am. J. 72:1410–1417.

Venterea, R.T., K.A. Spokas and J.M. Baker. 2009. Accuracy and precision analysis of chamber-based nitrous oxide gas flux estimates. Soil Sci. Soc. Am. J. In press.