Measuring Very Small Soil Fluxes of N_2O & CH_4 Using a New OF-CEAS Technology

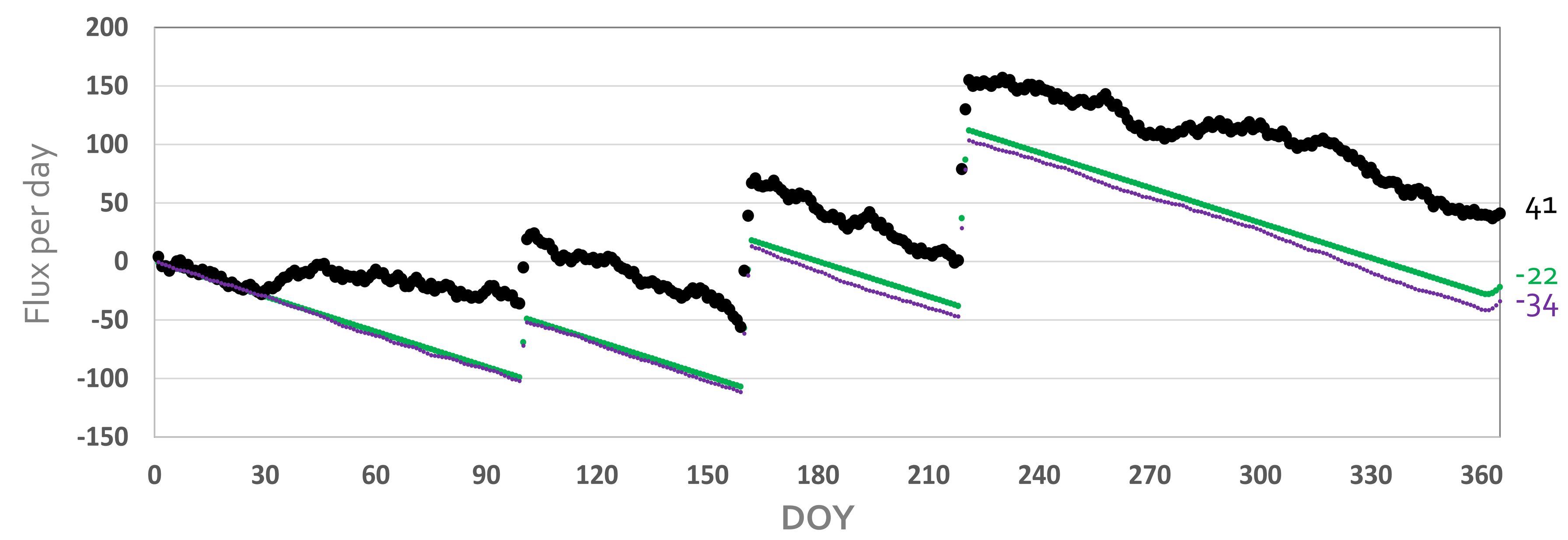
G. Burba[1,2], I. Begashaw[1], G. Leggett[1], K. Minish[1]*, and L. Xu[1]

[1]*LI-COR Biosciences, Lincoln, Nebraska USA*; [2]*Daugherty Water for Food Institute & School of Natural Resources, University of Nebraska, Lincoln, Nebraska, USA*

Introduction

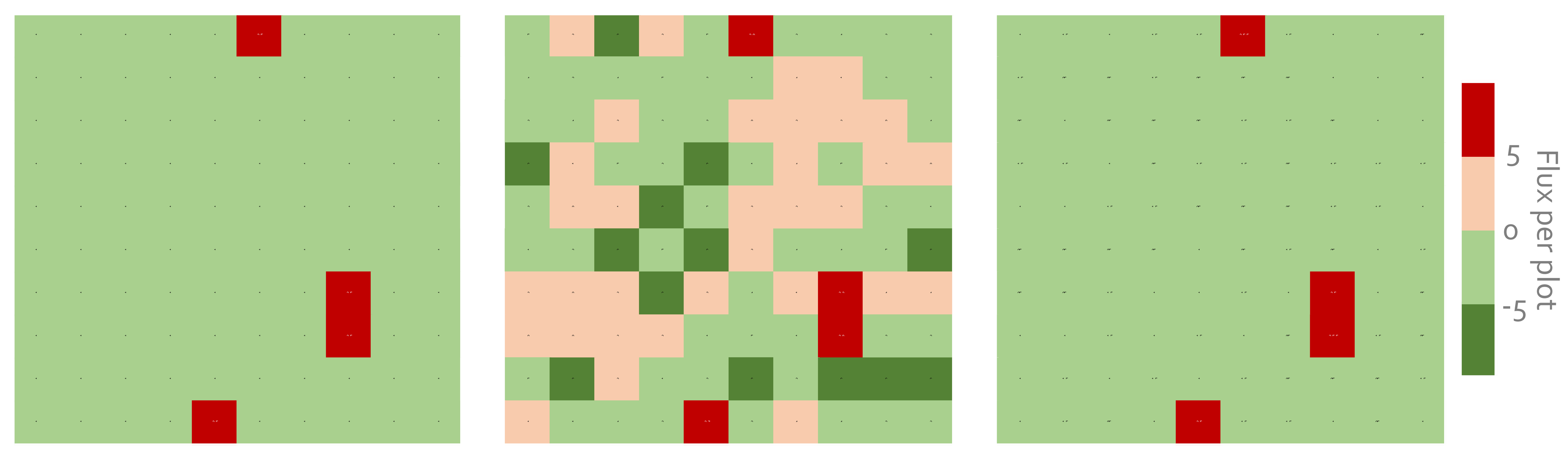
- N_2O and CH_4 soil flux studies traditionally consider certain time periods and certain ecosystems to be of low importance due to very small or negligible expected flux rates.
- Periods of such "negligible" fluxes are rarely reported because small fluxes are hard to resolve, measurements are costly, time-consuming, and often take a lot of power.
- Sites with expected "negligible" fluxes are also rarely studied because small fluxes are hard to resolve, measurements are time-consuming and costly, and it is hard to get funding to measure something when the error bars cross zero.
- However, such fluxes may not be negligible in time when multiplied by long time duration, for example, 340 out of 365 days per year. Similarly, these may not be negligible in space when multiplied by a large area.
- When GHG budgets are of interest, very small fluxes multiplied by hundreds of days or square kilometers, or both, could easily exceed large fluxes multiplied by few days or square kilometers.
- The new application of Optical Feedback-Cavity Enhanced Absorption Spectroscopy (OF-CAES) to measuring soil flux [1-10] results in a very low minimum detectable flux limits which may help make more of such measurements valuable and valid in both time and space.
- Field tests below demonstrate the actual data on the N_2O and CH_4 soil flux performance of this new technology. Conceptual simulations on the right demonstrate the significant advantages of using the technology when measuring *very small* N_2O and CH_4 fluxes over time and space.

Concept of Resolving Very Small Fluxes over Time



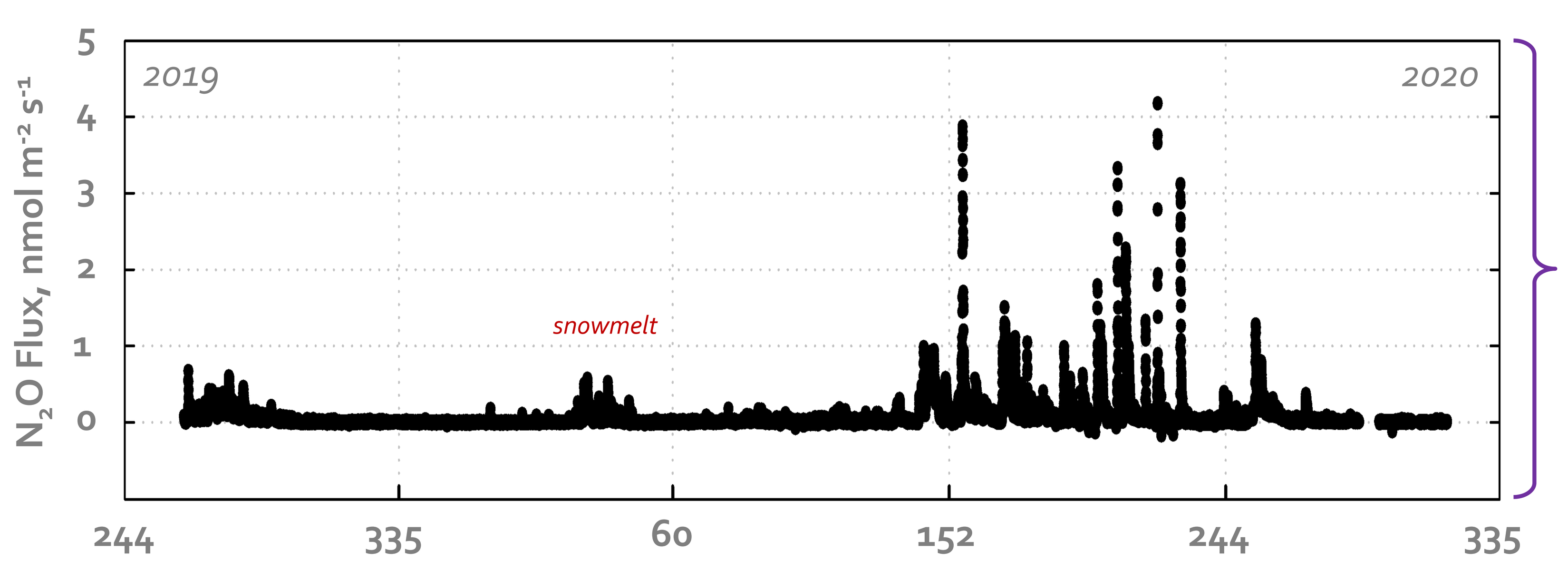
- Here we show a conceptual yearly dataset simulating cumulative fluxes with a *very small* gas consumption of -1 units of gas per area per day most of the time, and with large episodic releases of 25-75 units of gas per area per day on a few occasions.
- This would be a proxy for a typical situation for an agricultural field with periodic fertilizer applications (for N_2O) or manure applications (for CH_4).
- The true expected flux is shown in green, the flux with a random error of +/-5 units is shown in black, and the flux with a much smaller random error of +/-0.5 units is shown in purple.
- The errors were applied to true flux data in this simulation using a random number generator: results from the generator vary widely each run, so aggregated examples are shown.
- The proxy of typical soil flux measurements (black) with errors exceeding the base flux have led to -300% error in the yearly budget, and indeed could not be used when measuring in such situations.
- The proxy for a new OF-CEAS technology application (purple) is much closer to the true flux (green) and may be used for such measurements in many more situations.

Concept of Resolving Very Small Fluxes over Space



- Here we show a simulated dataset over an area consisting of 100 small plots with a *very small* gas consumption of -1 units of gas per plot per time in most plots, and with large gas releases of 25 units per plots in a few plots.
- This would be a proxy for a typical situation for a desert or a forest environment with a few wetlands (for CH_4), or for a mixed-use area with fertilized agricultural fields, unfertilized pastures and other areas (for N_2O).
- The true expected flux is shown on the left map, the flux measured with a random error of +/-5 is shown in the middle, and the flux with a much smaller random error of +/-0.5 is shown in the right map above.
- The sum of fluxes over each area in these examples was 4 for true flux, -56 for the flux measured with a larger random error, and 4.5 for a flux measured with a smaller random error.
- The proxy for typical soil flux measurements (center) with errors exceeding very small fluxes from most of the area have led to over -1000% error, and indeed could not be used when measuring over such territories.
- The proxy for a new OF-CEAS technology application (right) is much closer to the true flux (left) and may be used for such measurements over many more territories.

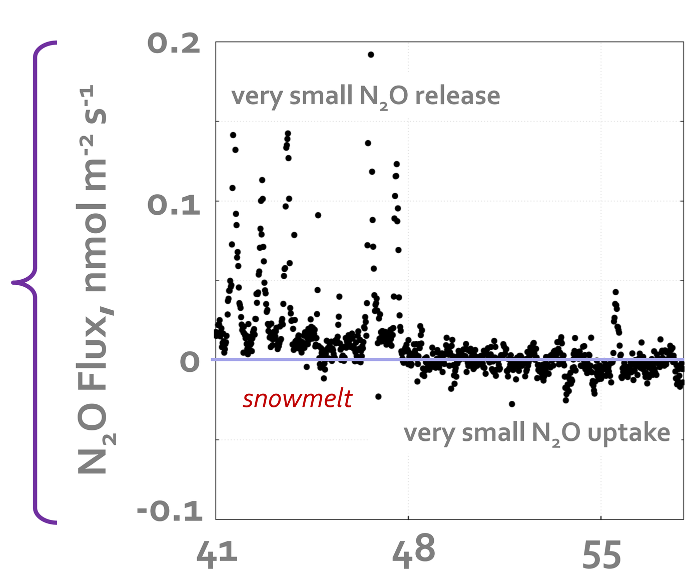
Minimum Detectable N2O and CH4 Fluxes and Speed of OF-CEAS Soil Flux Measurements

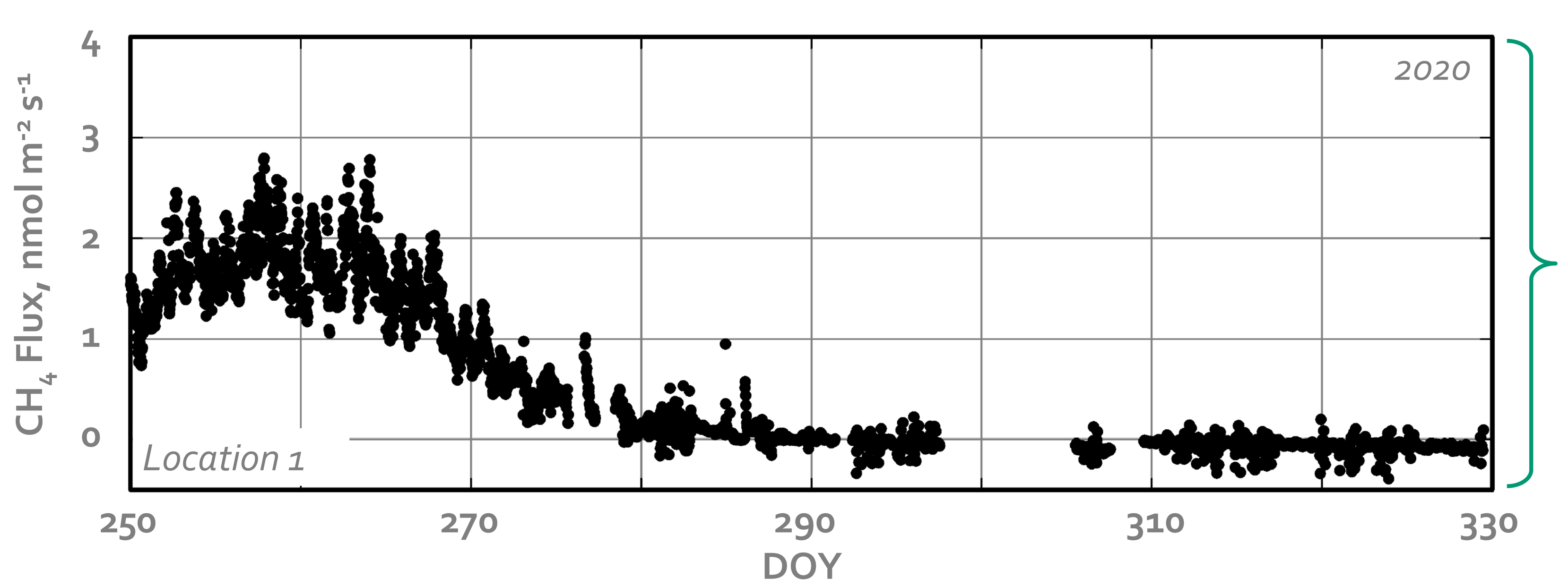


Minimum Detectable N2O Flux:

~0.05 nmol m-2 s-1 after 2 minutes

Ryegrass, hourly flux, details in [9]

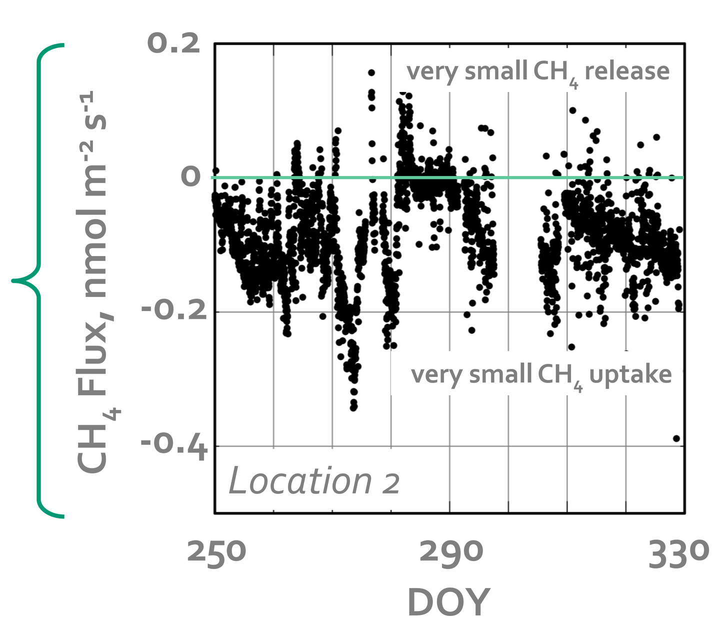




Minimum Detectable CH4 Flux:

~0.05 nmol m-2 s-1 after 2 minutes

Ryegrass, hourly flux, details in [10]



Conclusions

While the concepts presented above may be obvious in a theoretical sense, the new application of OF-CAES technology [1-10] opens up a real practical possibility to measure *very small* N_2O and CH_4 fluxes over the time periods and over the areas traditionally neglected or excluded due to costs, power and time demands.

Particularly, new scientific knowledge and important long-term budgeting can be generated over vast areas of deserts, forests, prairies and other ecosystems, and agricultural areas with a very small N_2O and CH_4 gas uptakes.

Likewise, new knowledge and significantly improved budgeting estimates can be done over long time periods with a very small N_2O and CH_4 gas fluxes in nearly all ecosystems.

The very low minimal detectable flux achievable with OF-CAES can also help better resolve soil heterogeneity: example is not shown due to lack of space, but it can be easily visualized as a reverse example of the above map.

Expanding N_2O and CH_4 flux measurements in time and space, as well as over heterogeneous areas, can also help secure additional funding as a part of GHG, climate or agricultural research and modeling.

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