Challenges associated with geochemical monitoring of active CO_2 injection for EOR

Space Geodesy and Geochemistry Applied to Monitoring and Verification of Carbon Capture and Storage – Training Grant
Award # DE-FE0002184

Combining Space Geodesy, Seismology, and Geochemistry for Monitoring Verification and Accounting of CO_2 in Sequestration Sites
Award #DE-FE0001580

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U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

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Accomplishments to Date for Training Grant

- Educating 3 graduate students
- Students are taking courses, engaging in research, presenting at meetings, and writing research proposals
- Instrumentation deployed to field site, with almost two years of geochemical data collected
- All students are within 2 years of graduating (Ph.D.)

Multi-technique approach

InSAR
Falk Amelung
Kenny Zhao

Geochemical
Peter Swart
Daniel Riemer
Ben Galfond

GPS
Tim Dixon

Modeling and Policy
Caitlin Augustin

Seismic
Guoqing Lin
Peng Li

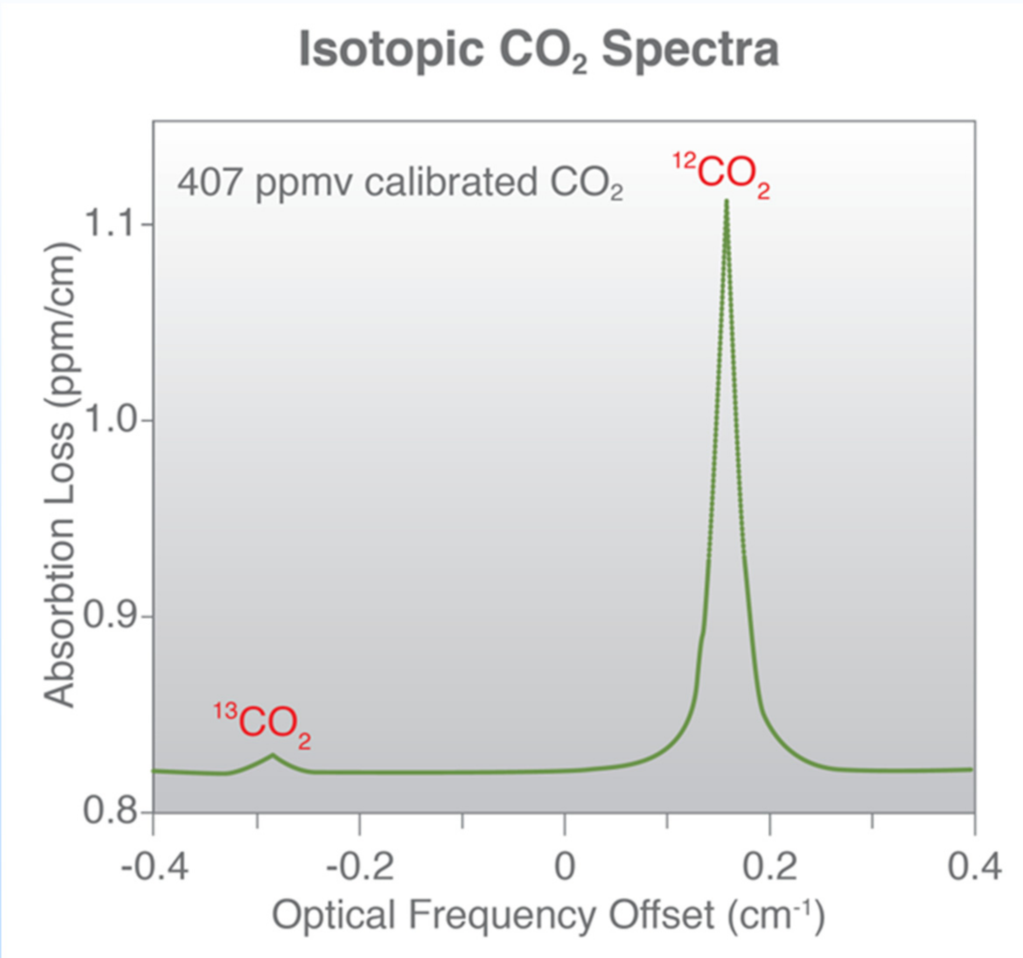
Our geochemical measurements are primarily made using commercially available CRDS instrumentation

- Operating Principles of CRDS
- Challenges with field deployment and application to CO_2 soil-gas surveillance

  H_2O and CO_2 concentration dependence
  Methane interference
  Response times
  Local biogenic variability
  Variability in soil organic carbon
  Operating temperature
  Data connectivity
  Large quantities of data

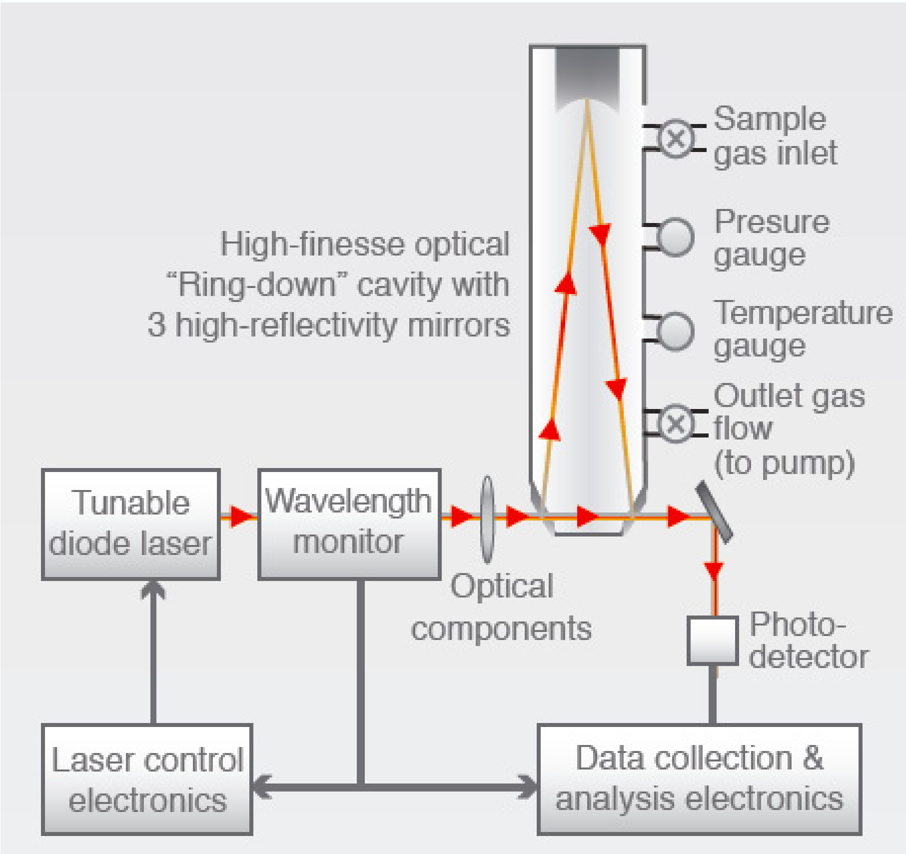
- Measured long-term background signals
- Additional geochemical monitoring

CRDS uses characteristic IR absorption to quantify concentrations of CO_2 and other gases

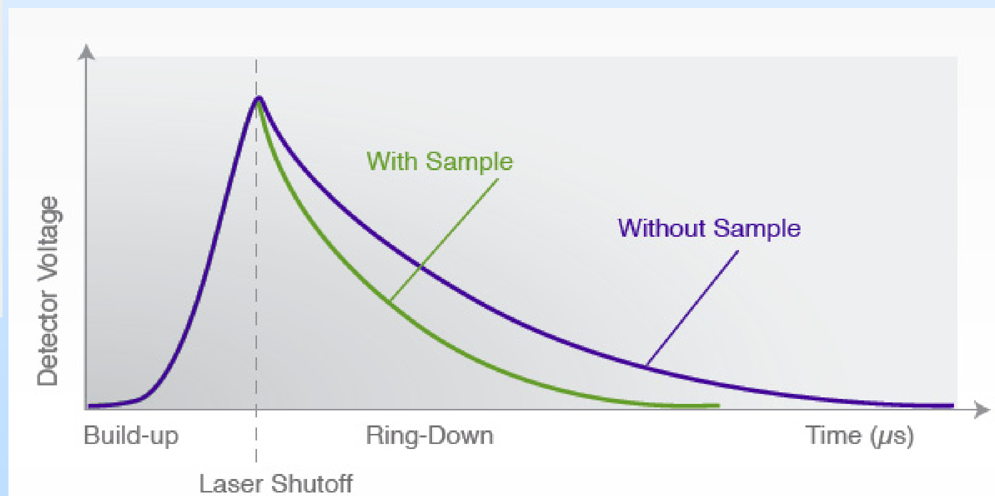


- Isotopic substitution slightly changes this wavelength, allowing isotopologue concentrations to be measured.
- A single laser can measure both CO_2 and H_2O at 1603 nm. A second laser at 1651 nm is required for CH_4.

Multi-pass optical cavity allows for an extended pathlength

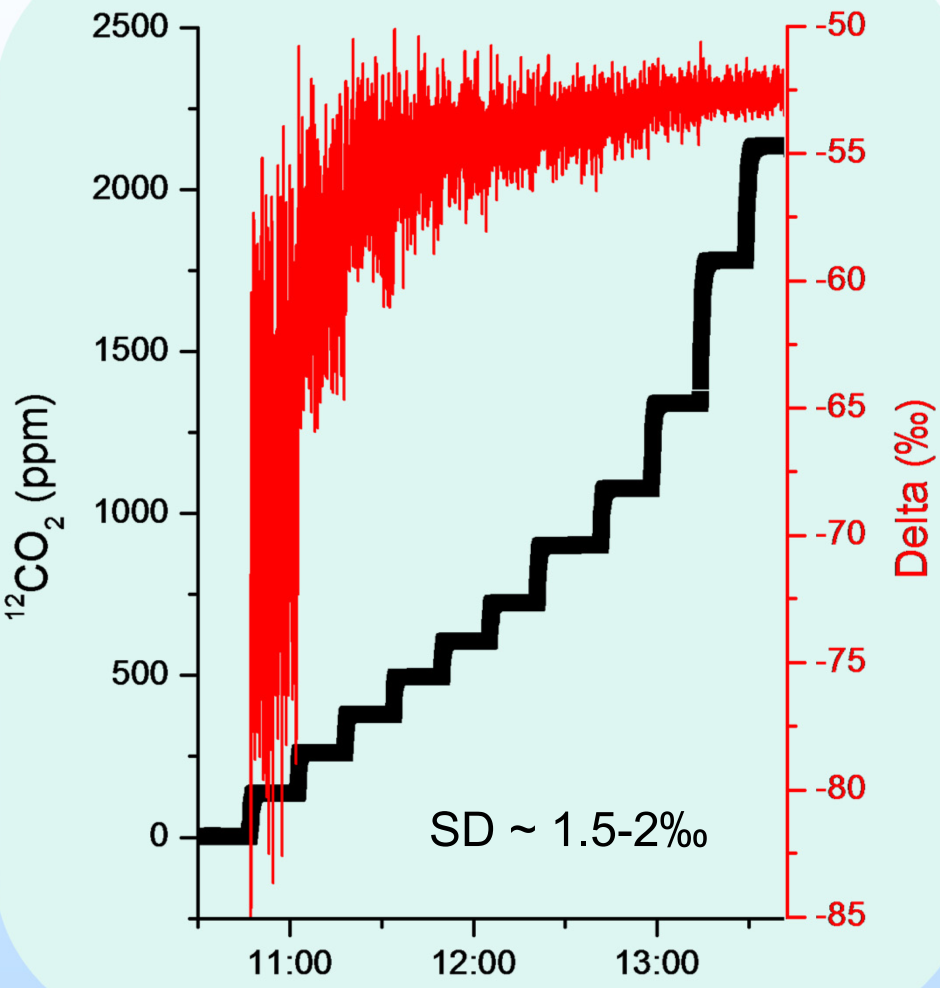


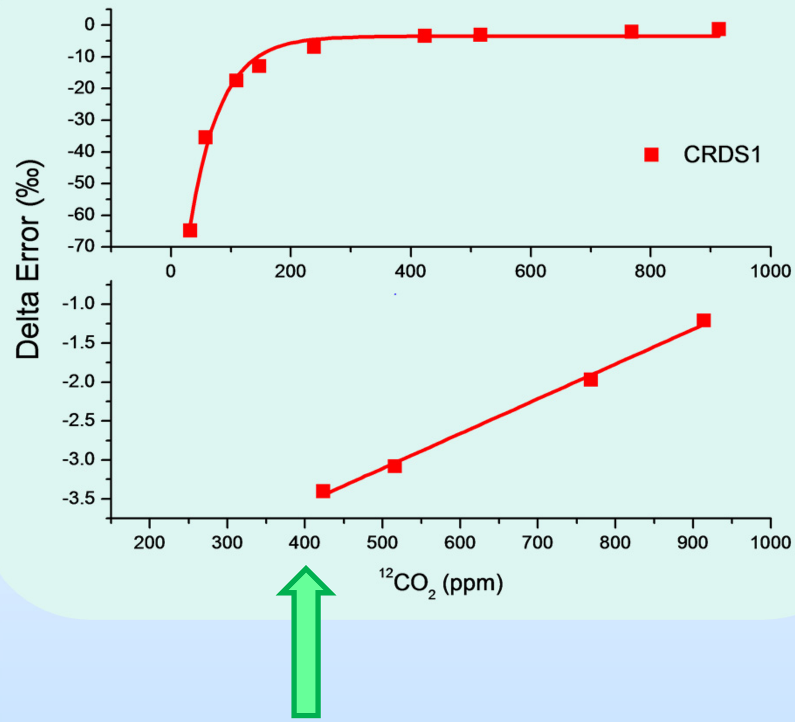
Length of the exponential decay time is related to the concentration of the absorbing gas



Picarro, Inc.

Measured $\delta^{13}C$-CO_2 is dependent on CO_2 concentration and H_2O concentration

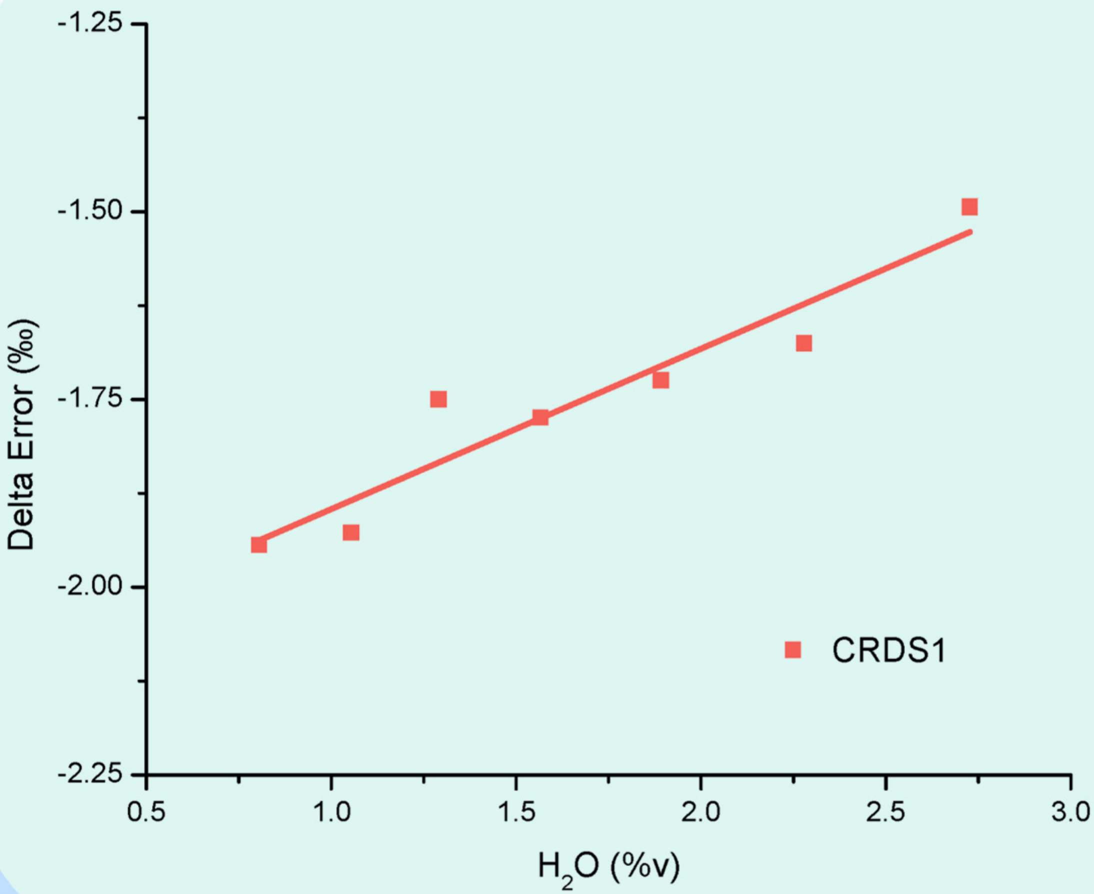




Atmospheric Background

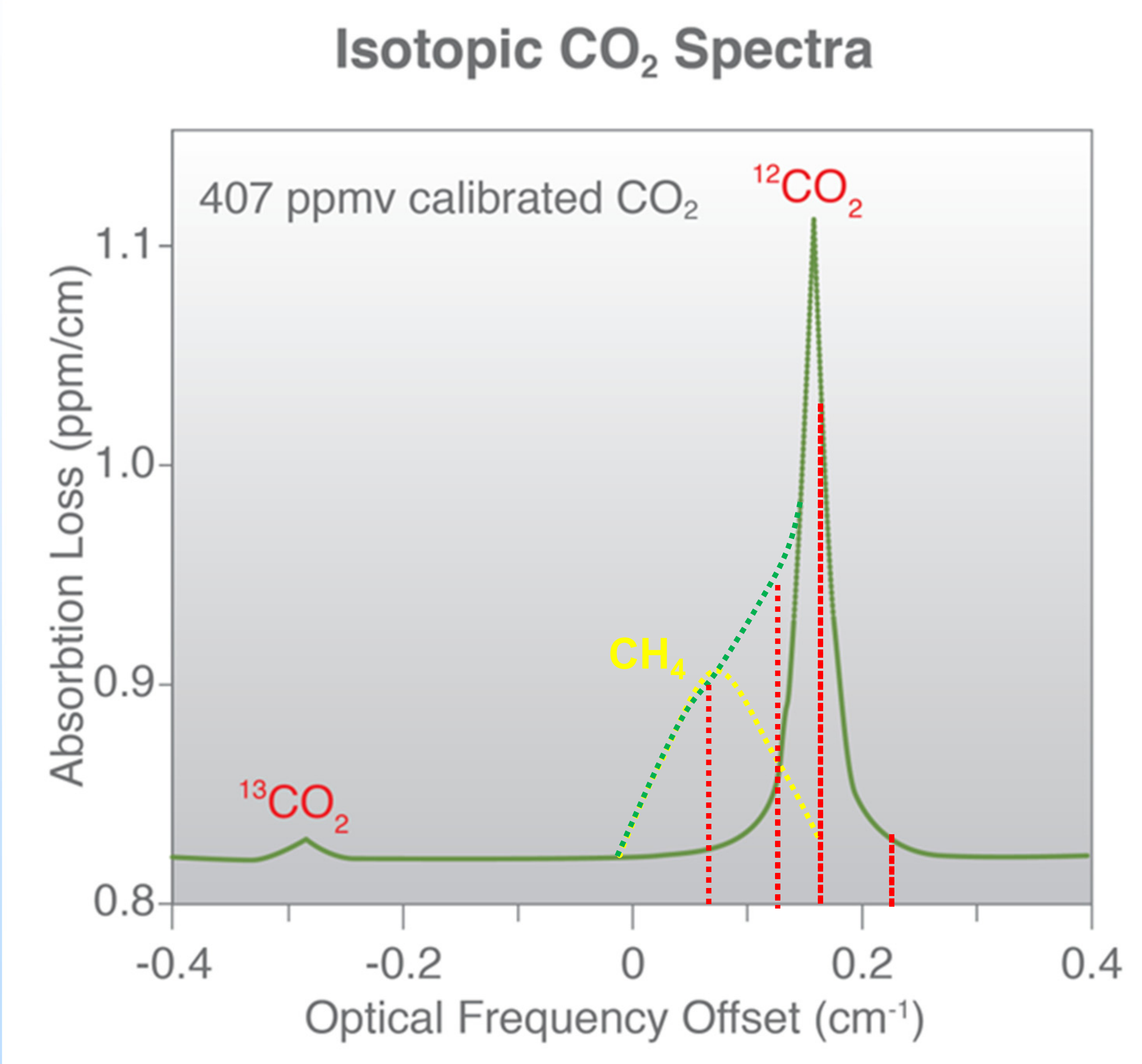
Also has limitations at higher concentrations (~ 5000 ppm)

Measured $\delta^{13}C$-CO_2 is dependent on CO_2 concentration and H_2O concentration

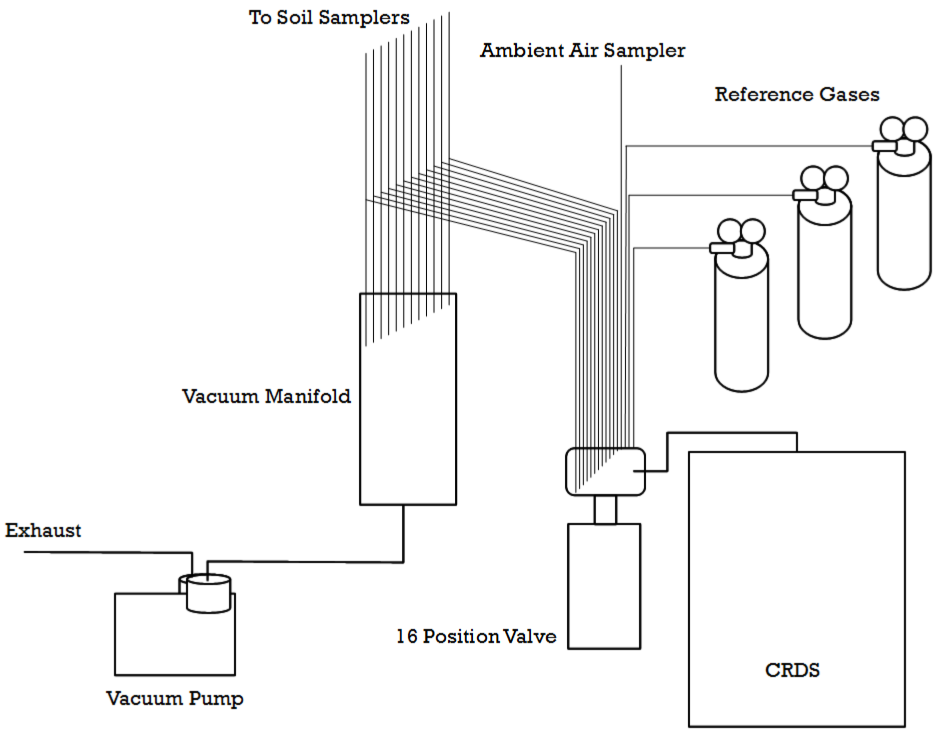


Linear dependency is corrected with software developed by Picarro, using already measured parameters.

Interference due to excessive and varying methane corrected with additional laser

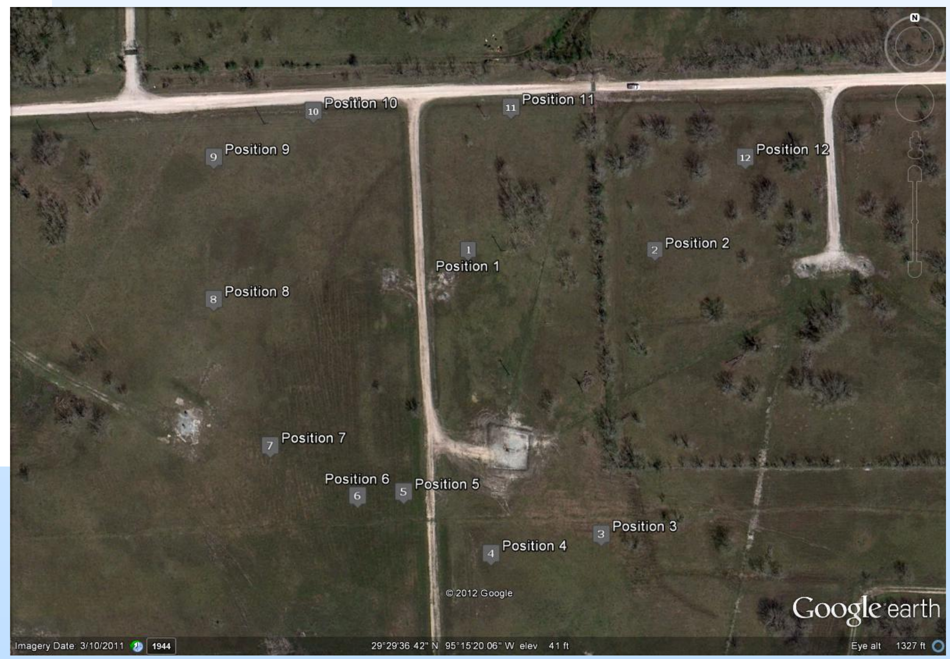


Field sampling manifold allows consecutive analysis of 12 soil-gas locations and the ambient atmosphere



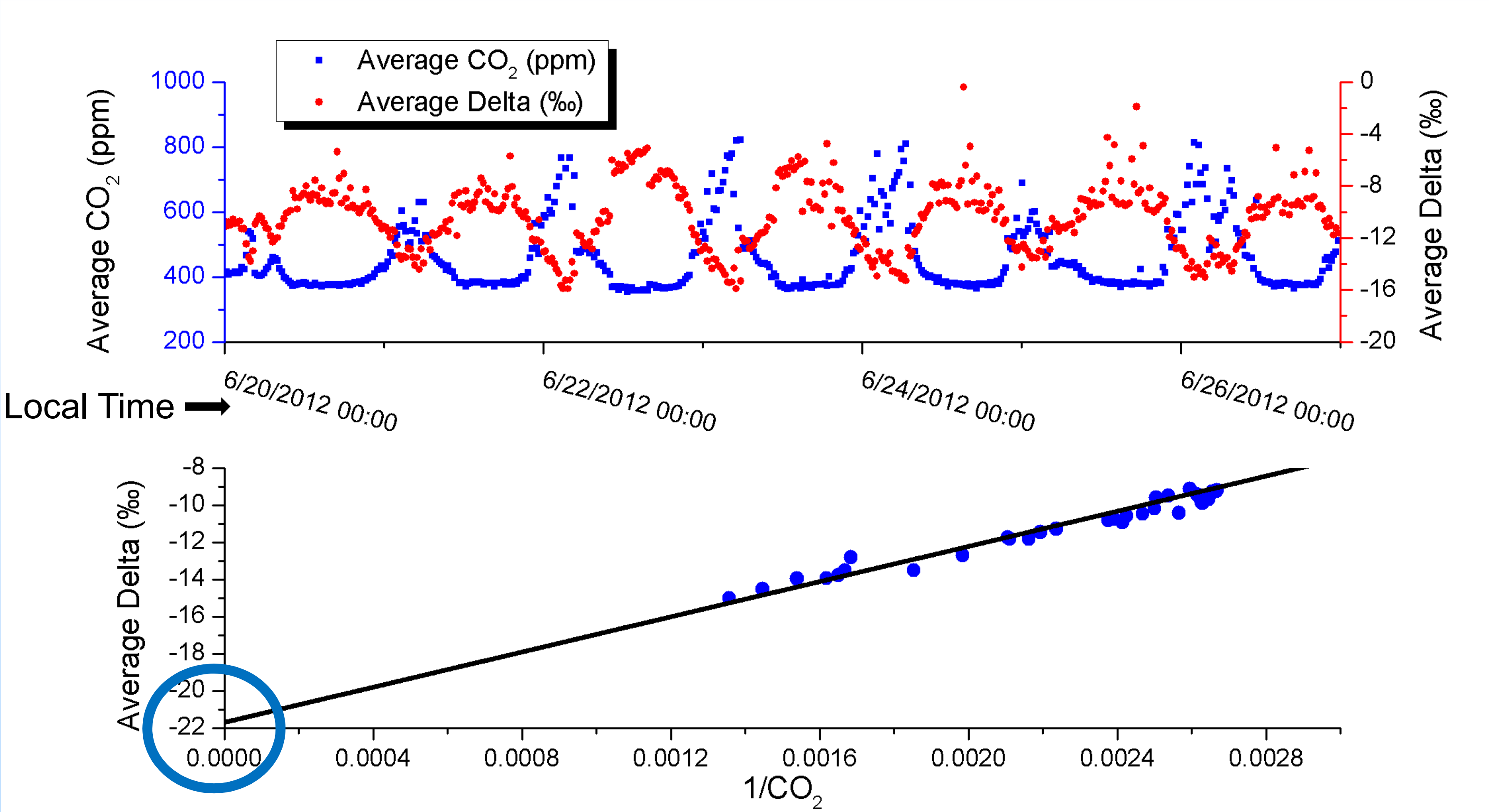
12 sites placed within ~ 0.1 km^2

Each site is sampled every 20 min.



Soil boreholes (45 cm depth)
Equal length sampling tubes
Constant flow (~5 mL min^{-1})
Reference gases (Concentration + isotopic value)

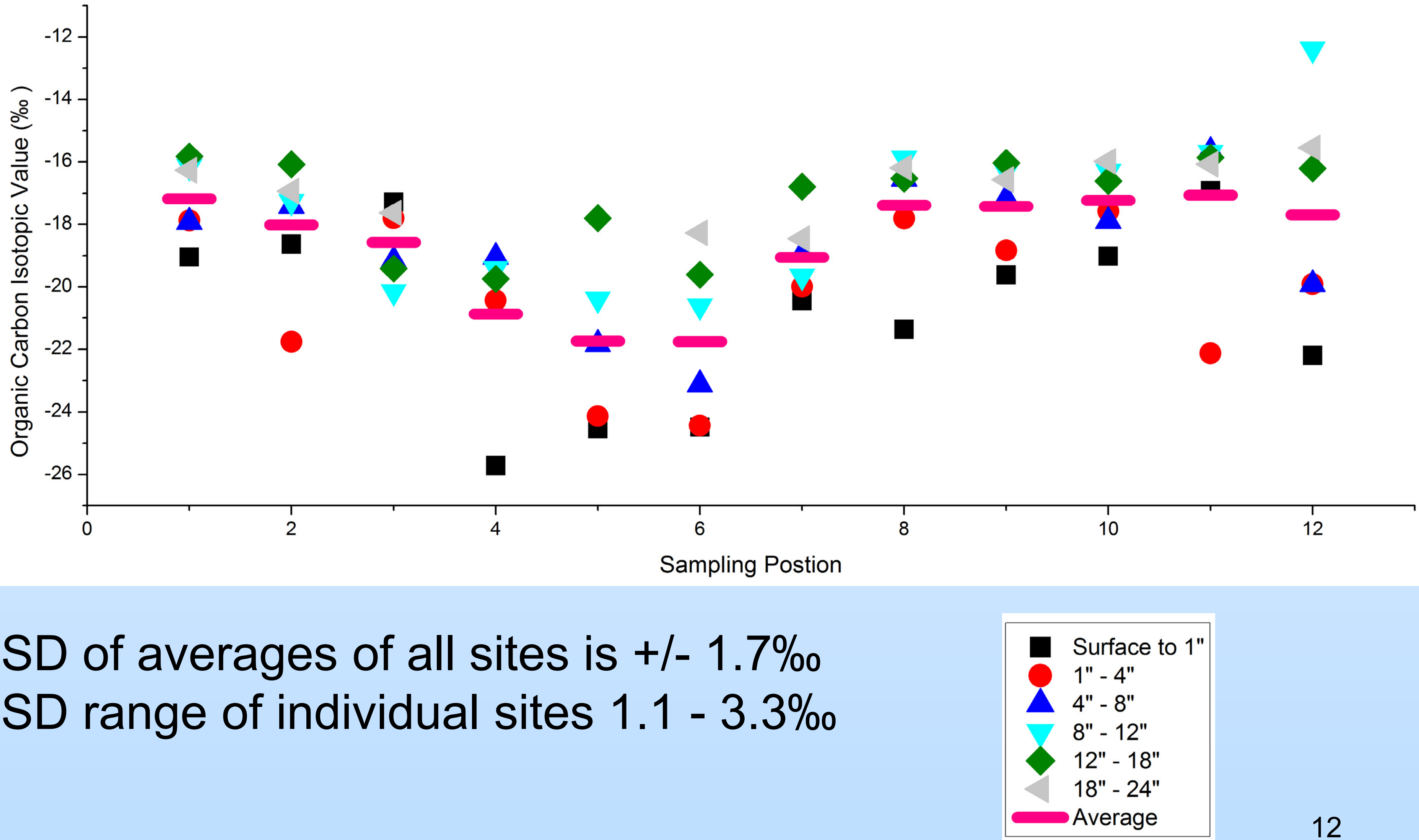
We observe a background biogenic signature and diurnal cycle



CO_2 concentration range above background ~400 ppm

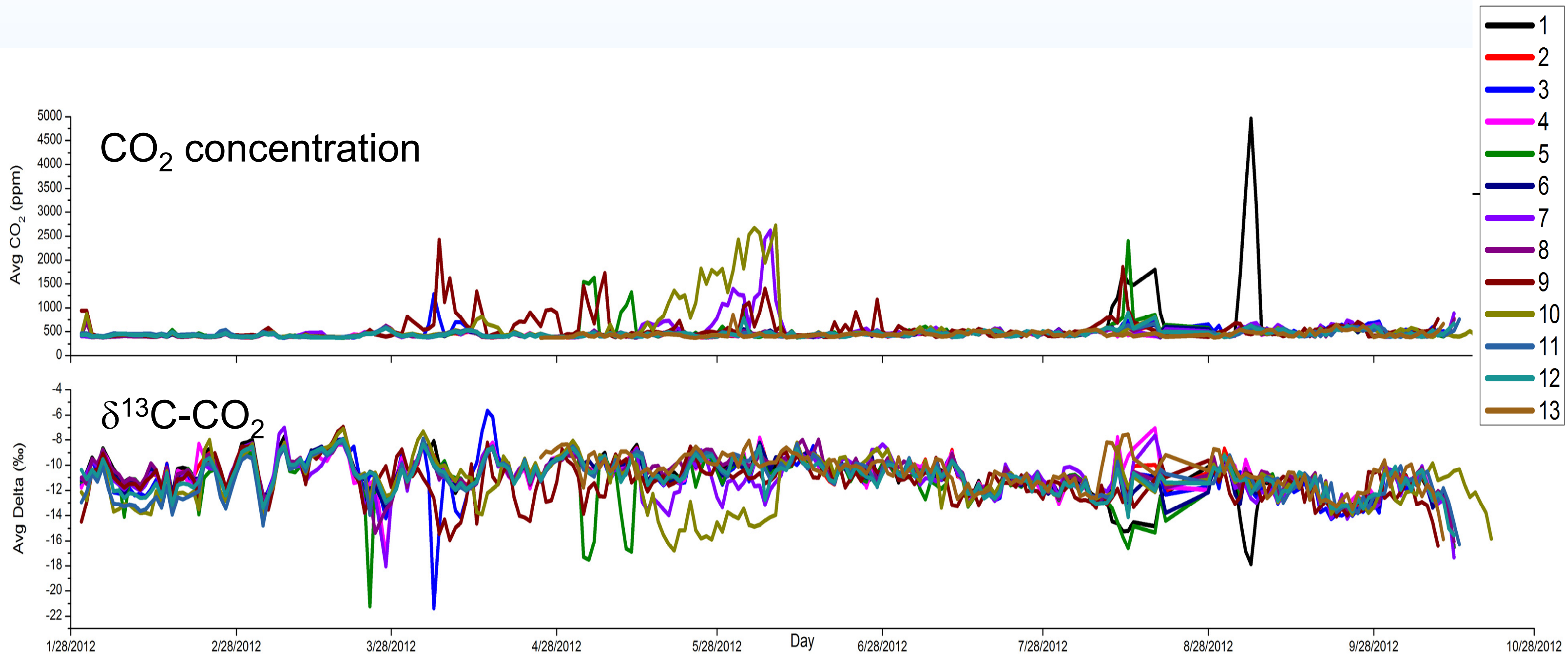
Daily $\delta^{13}C$-CO_2 range ~8‰

Soil organic carbon isotopic signature varies with site location and depth in the soil column

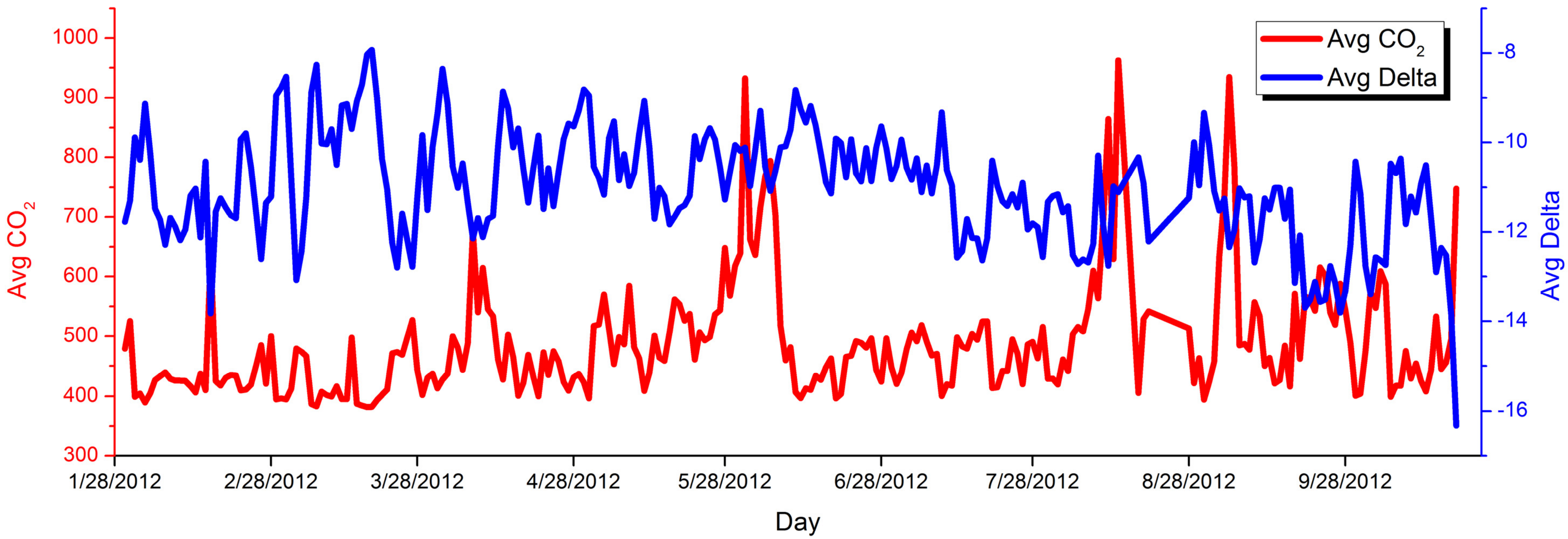


SD of averages of all sites is +/- 1.7‰
SD range of individual sites 1.1 - 3.3‰

Long-term soil-gas background signals show variability between sample sites and broad excursions occurring over periods longer than several days



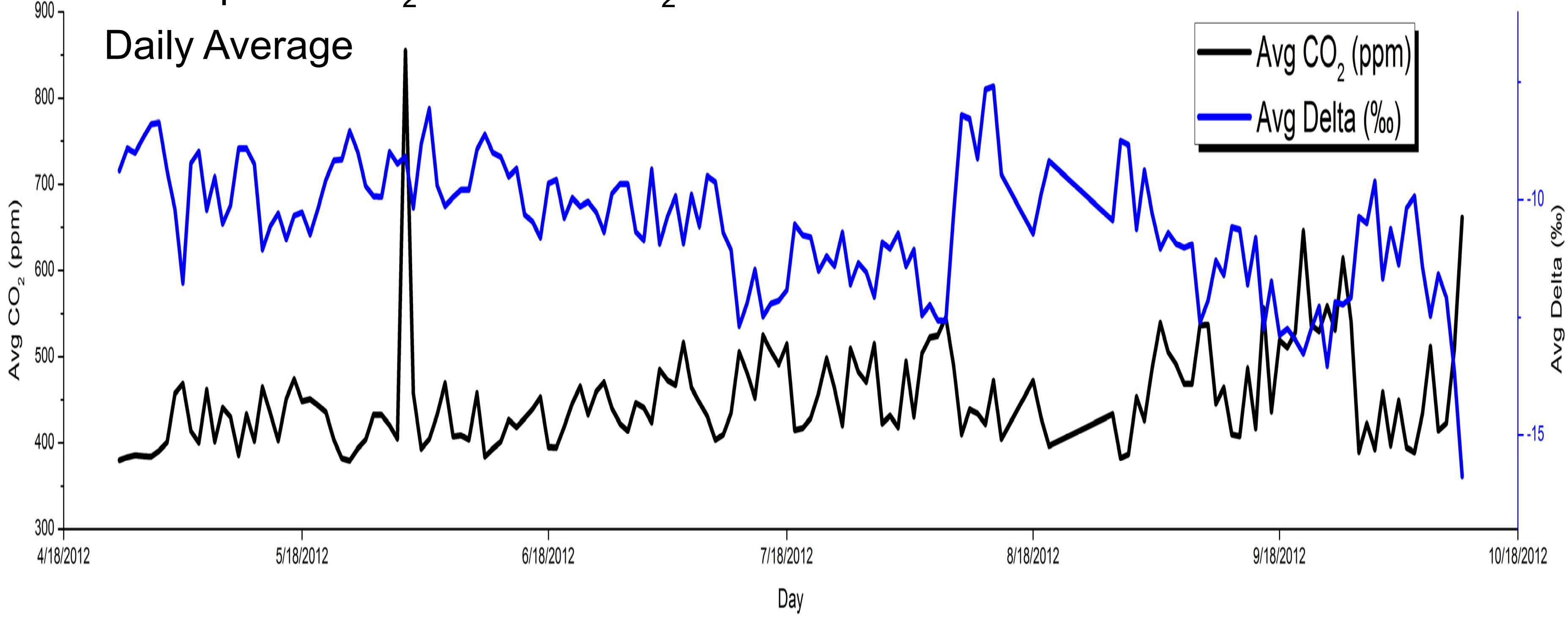
Averaging over all soil-gas sampling locations still shows high variability in both concentration and isotopic signature



Atmospheric measurements often show elevated CO_2 concentrations consistent with meteorological changes

Atmospheric CO_2 and $\delta^{13}C$-CO_2

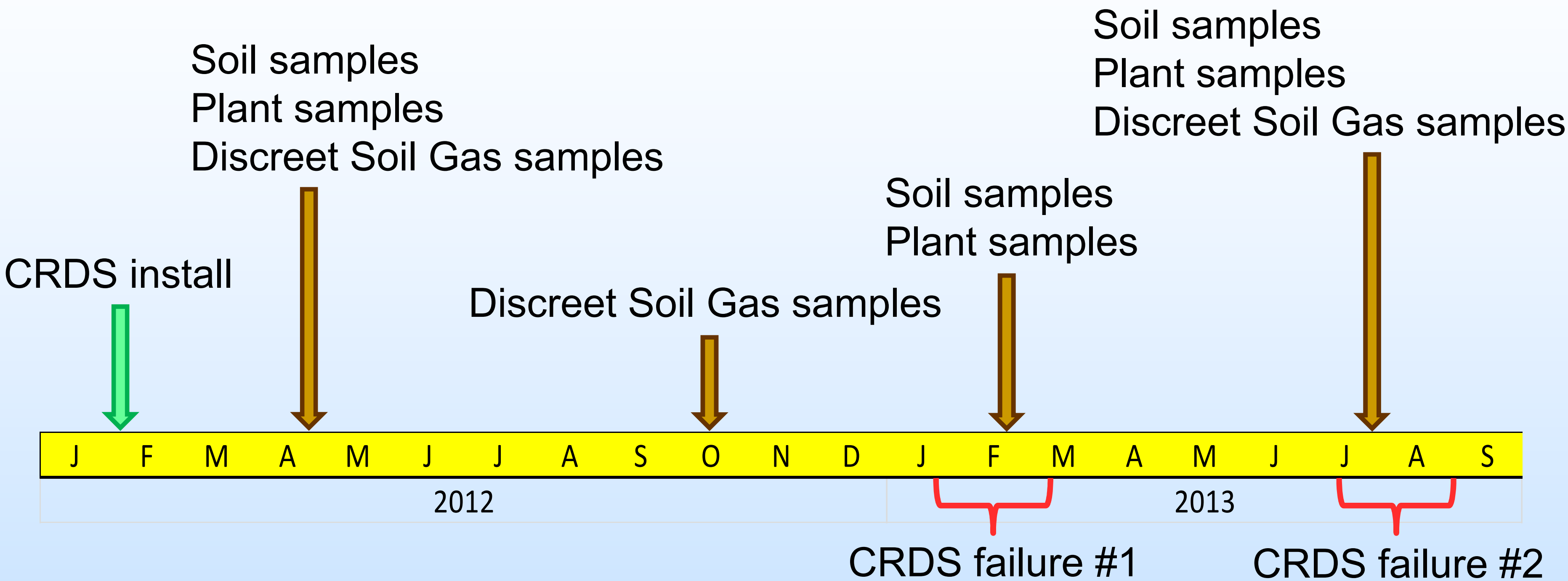
Daily Average



In support of the CRDS soil-gas and atmospheric measurements we collected additional geochemical and meteorological data

- Study of soil organic carbon across sampling area and at various depths
- Stable isotopic study of all plant life in area, both as biogenic input and potential long-term isotopic marker
- Collect and analyze discrete gas samples on GC-IRMS for carbon isotopic values, and GC-MS for trace gas composition
- Full meteorological analysis, including temperatures, wind direction, back-trajectories, precipitation, and soil temperature

Timeline of Geochemical Efforts



CRDS Failure #1 – Power issues, operating system corruption
CRDS Failure #2 – Pump and inlet valve failure

Summary

- CRDS is a robust technology allowing the measurement of CO_2 concentration and isotopic signature
- CO_2 concentration and isotopic signature variability is dominated by vegetation, microbial activity, and atmospheric connectivity with the soil
- To develop a capability of quantifying leakage from EOR or sequestration sites will require a good understanding of the “background” environment
- Our background measurements using multi-location soil-gas CRDS show limitations of conventional flask based sampling.