CLIMATE CHANGE TO THE NUCLEAR FUEL CYCLE: EXPANDING THE $^{14}CO_2$ DATABASE FOR NON-AMS FIELD MEASUREMENT SYSTEMS

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Abstract

Accelerator Mass Spectrometry is well known and universally employed for radiocarbon analysis but is not adaptable to field measurements limiting applications. $^{14}CO_2$ is a key tracer for fossil fuel CO_2 as well as for release of enriched $^{14}CO_2$ characteristic of the nuclear fuel cycle with $D^{14}CO_2$ values ranging from -1000 to ~ +500 per mil. However, to exploit the full value of in situ $^{14}CO_2$ data in diverse climate change and nuclear fuel cycle applications high data rate temporal and spatial field measurement systems are required. The development of non-AMS methods based on quantum cascade laser, cavity ring down and optogalvanic spectroscopy are emerging applications but not fully developed for field use or widely accepted. Spectral data for lasing transitions for $^{14}CO_2$ are lacking in contrast to HITRAN data available for $^{12}CO_2$ (626) and $^{13}CO_2$ (636) (among other isotopologues 628, 638, etc.) in the spectral databases limiting development and innovation in non-AMS $^{14}CO_2$ analytical systems. We review the corpus of $^{14}CO_2$ spectral data spectral data available in the literature and document grating tuned isotopic lasers (e.g., Freed 1990; Bradley et al., 1986) well suited for expanded spectral studies of $^{14}CO_2$ and inclusion in the HITRAN database. Available isotopic lasers for $^{14}CO_2$ collaborative studies are described.

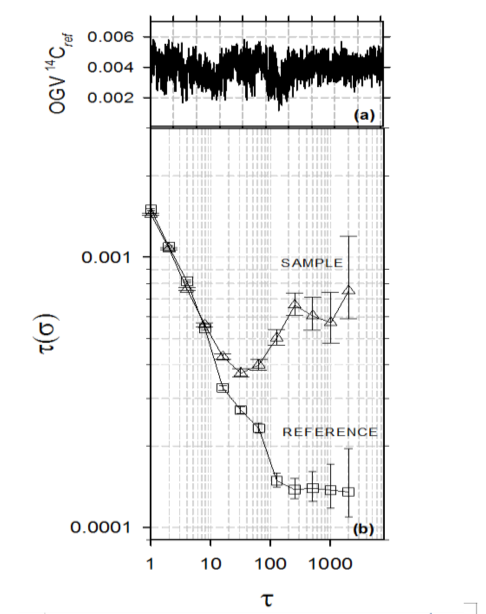
Objectives

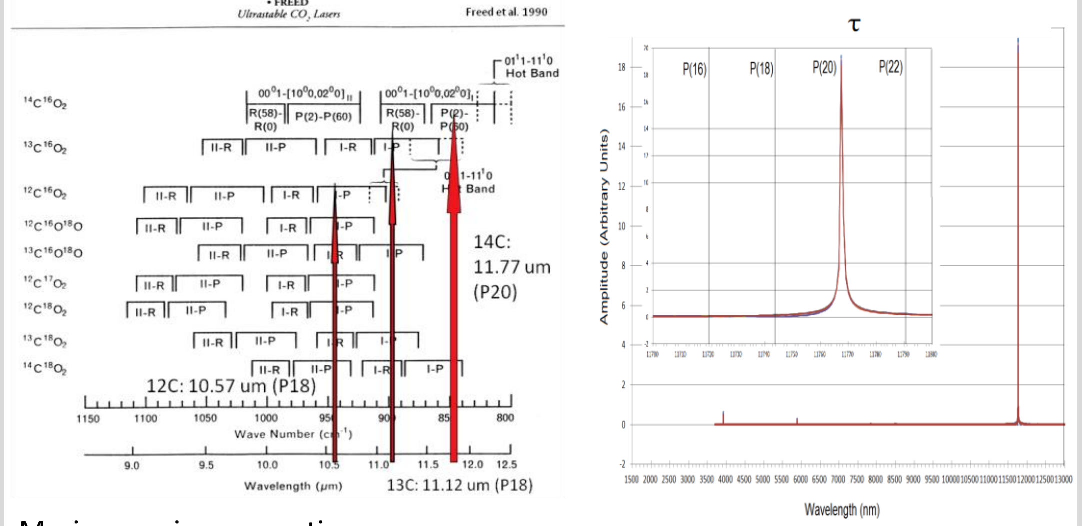
- ❑ Expand spectral database for $^{14}CO_2$
- ❑ Integrate spectral data with new non-AMS field analyzers
- ❑ Develop laboratory for $^{14}CO_2$ spectroscopy
- ❑ Collaborative instrument development
- ❑ Field testing of applications for fossil fuel & nuclear CO_2 emissions quantification

Status

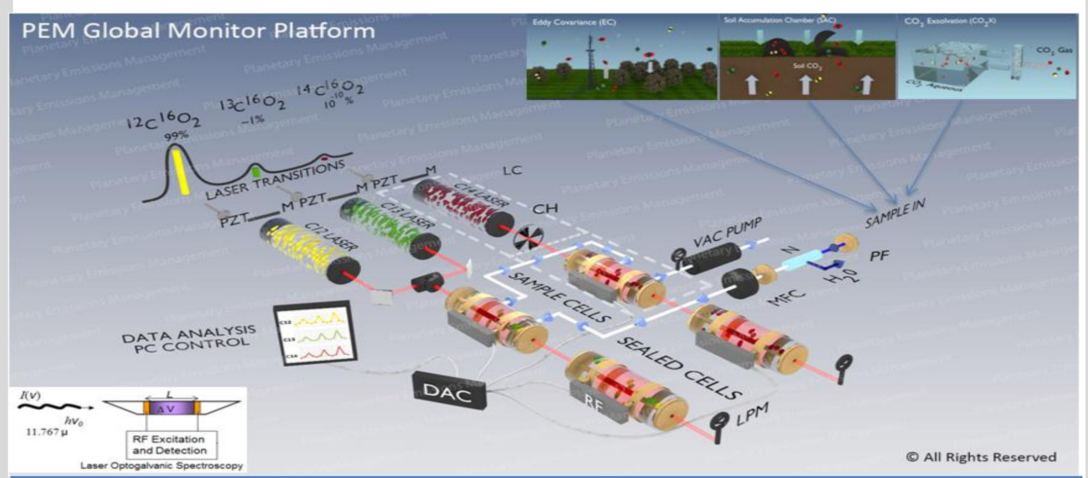
$^{14}CO_2$

- Ideal DIRECT FF-CO_2 Tracer
- Large Δ (~1050 ‰)
- Use natural radiocarbon
- Project lifetime MVA
- Avoids tracers
- External precision ~50 ‰
- Limited by technical noise
- Not an AMS replacement
- Leakage Rate Data Product

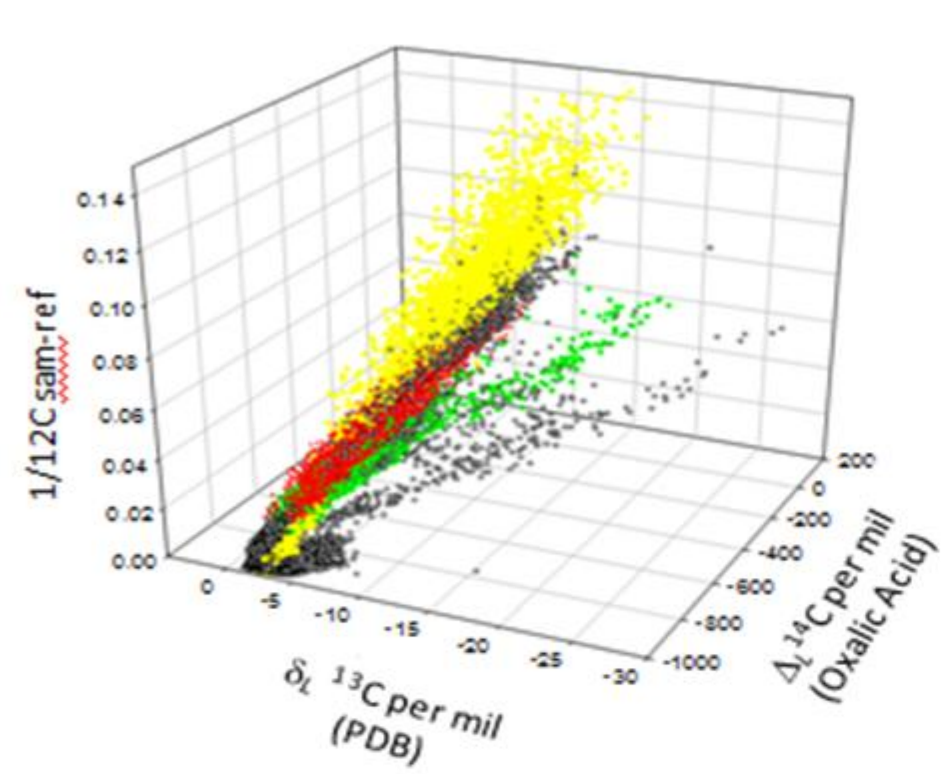




Marino, ms in preparation



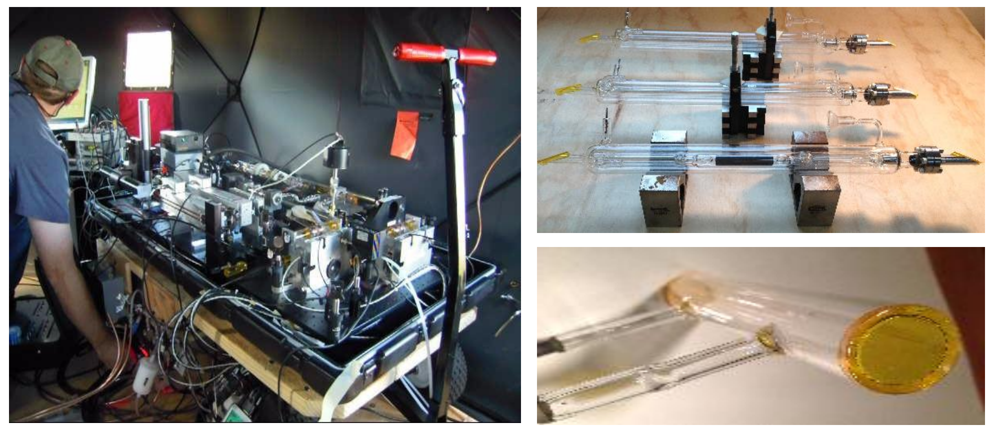
CCUS Leakage MVA



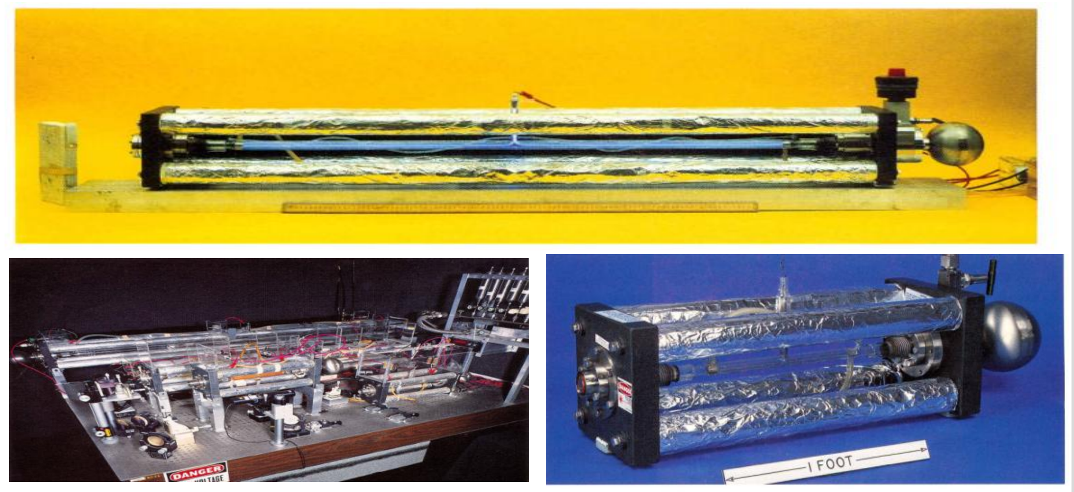
Eddy Covariance Results, Soda Springs, ID
Marino, ms in preparation

$^{14}CO_2$ Gas Lasers

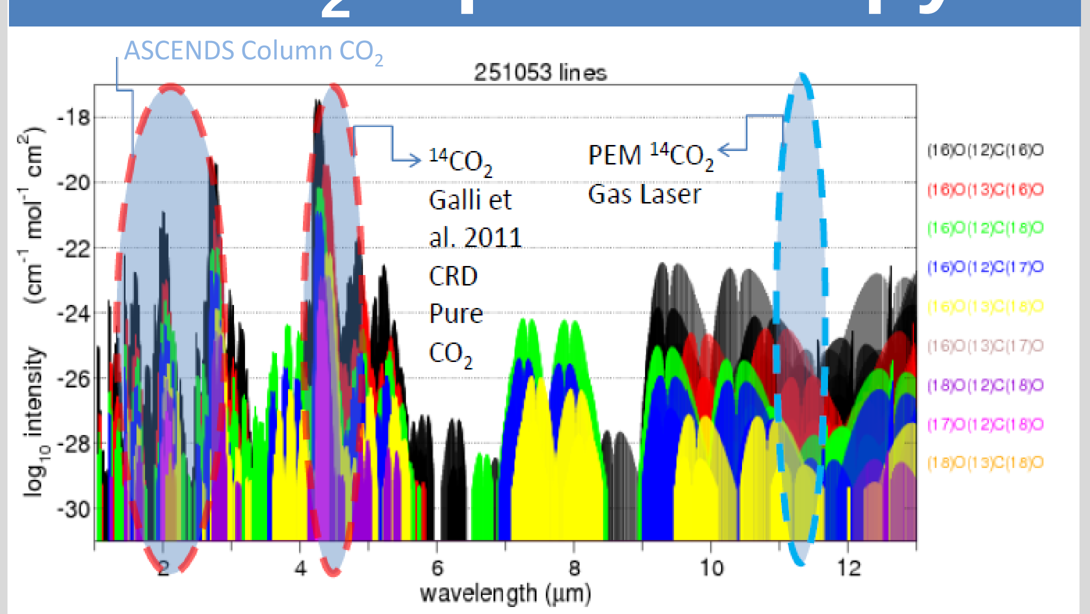
Free running and grating tuned $^{14}CO_2$ lasers available for development research



PEM is establishing a $^{14}CO_2$ spectroscopy laboratory using modular lasers developed by Charles Freed and colleagues of MIT LL



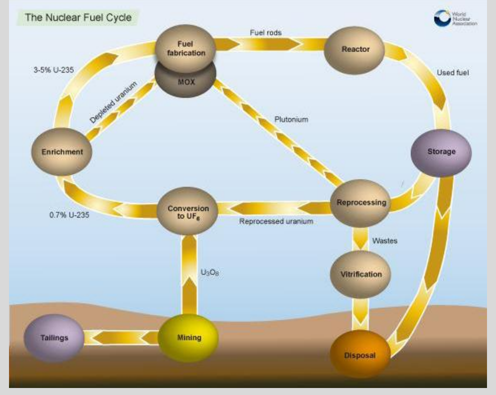
$^{14}CO_2$ Spectroscopy

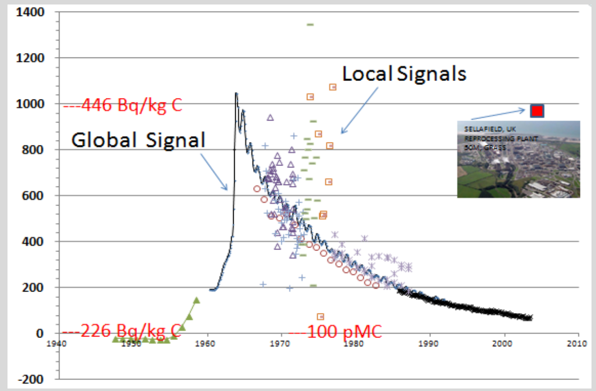


NON-AMS FIELD READY $^{14}CO_2$ ANALYZER

<u>Methods</u>
Laser Optogalvanic Spectroscopy (*LOGS* D_L), ICLAS
<u>Implementation</u>
Murnick et al. 2008
<u>Requirements</u>
Narrowband $^{14}CO_2$ Laser. Intracavity, High Sensitivity Detection Cell, Standard Reference Cells, Calibration Routines, Integration with Diverse Field Instruments
<u>Status</u>
Field Deployment Demonstrated (4 Sites), Integration with Soil, EC, Exsolvation Instrumentation, 14C Internal Precision (`2 per mil), 14C External Precision (~50 per mil)
<u>Problems</u>
Resetability & Exernal Precision , OGE Cell Noise, Component Upgrades, 14C Laser Fabrication, Persson et al. 2013
Kinetic OGE-C isotopologue model lacking

Nuclear Fuel Cycle





Twin Perils: Energy & Climate Change

- ❑ Proliferation Risk Increases (undeclared/denied)
- ❑ Challenge for IAEA Global Detection & Monitoring
- ❑ Expanded Safeguards Needed
- ❑ NFC MVA on Local-to-Global Scales
- ❑ Improved Field Analyzers (e.g., QCL) Needed

$^{14}CO_2$ Collaboration

- ❑ QCL, CRD laser fabrication
- ❑ Expansion of line positions, strengths
- ❑ Spectroscopy for field systems
- ❑ Testing evaluation of systems
- ❑ Satellite sensor systems
- ❑ Fossil-fuel emissions
- ❑ Nuclear fuel cycle emissions
- ❑ Integrated instrumentation platforms
- ❑ Landscape scale sensor networks
- ❑ Commercialization

References/Contacts

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