CO_2 Storage Monitoring, Verification and Accounting

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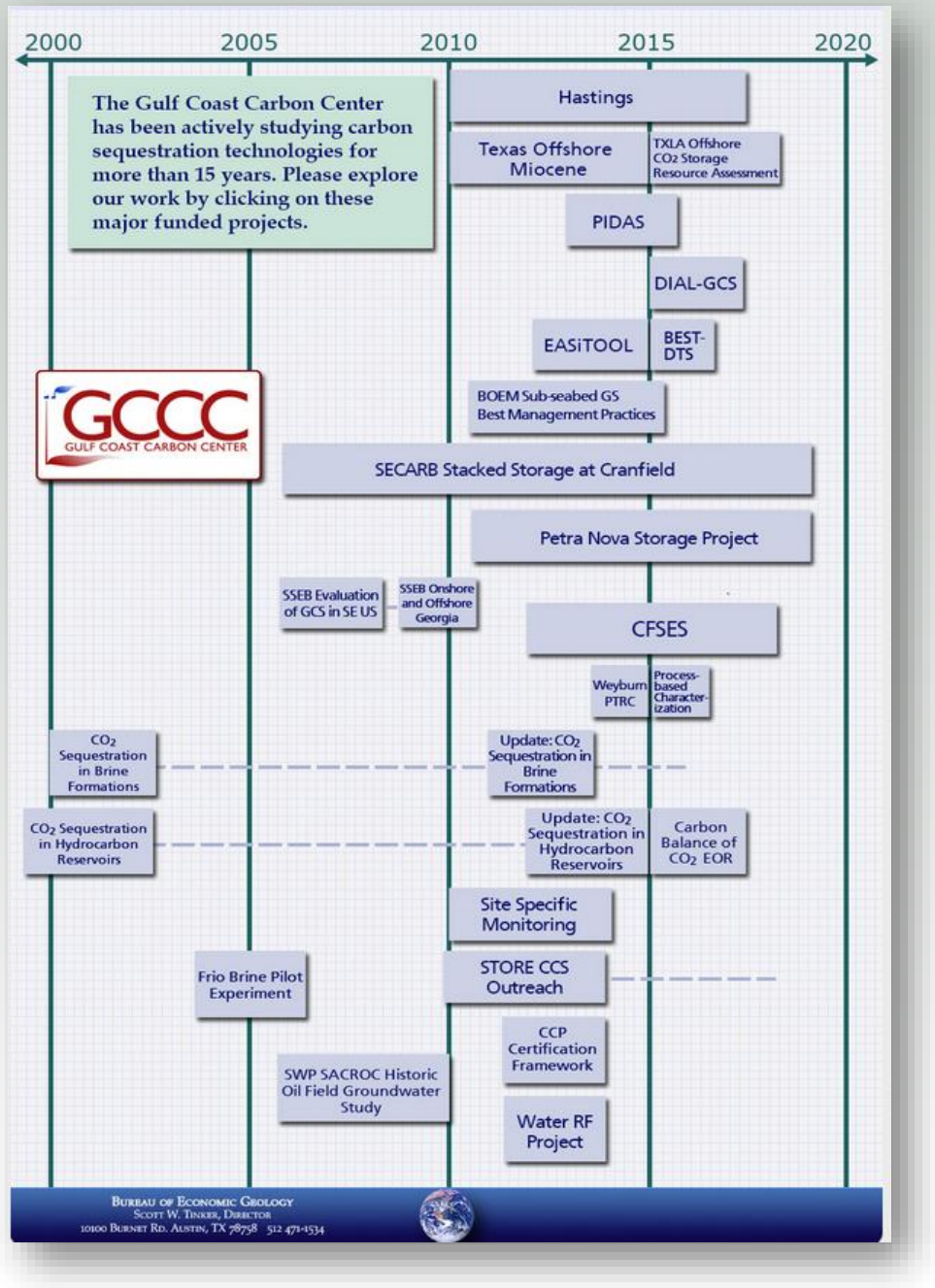
The University of Texas at Austin

- 20 years experience
- Develop and implement monitoring programs for geological CO_2 storage sites
- Monitored >9 demonstration CO_2 storage projects
- Actively monitored over 10 million tonnes of CO_2 in the ground
- Mostly from CO_2-EOR sites



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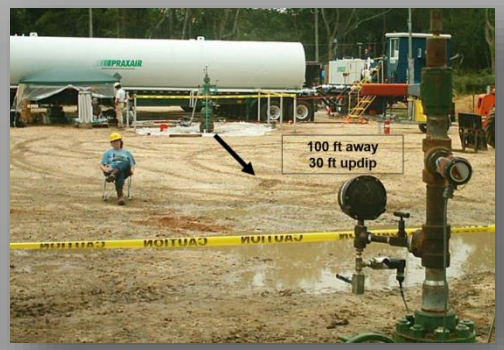
Evolution of Monitoring

Pilots → Demonstrations → Industrial

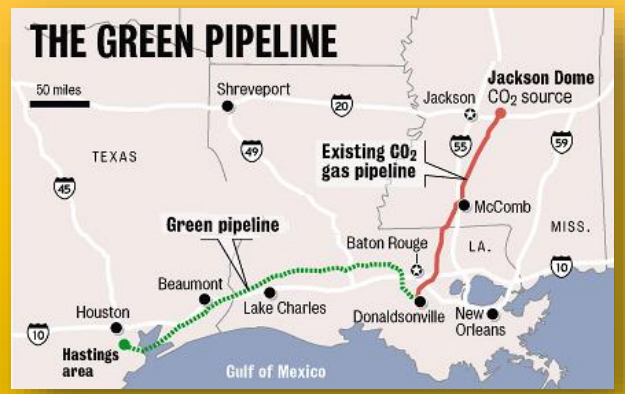
500 T



Frio Brine Storage Pilot 2004

SECARB Early Test- Cranfield Mississippi

Hastings Project



NRG Petranova Project

1.6 MMT/year

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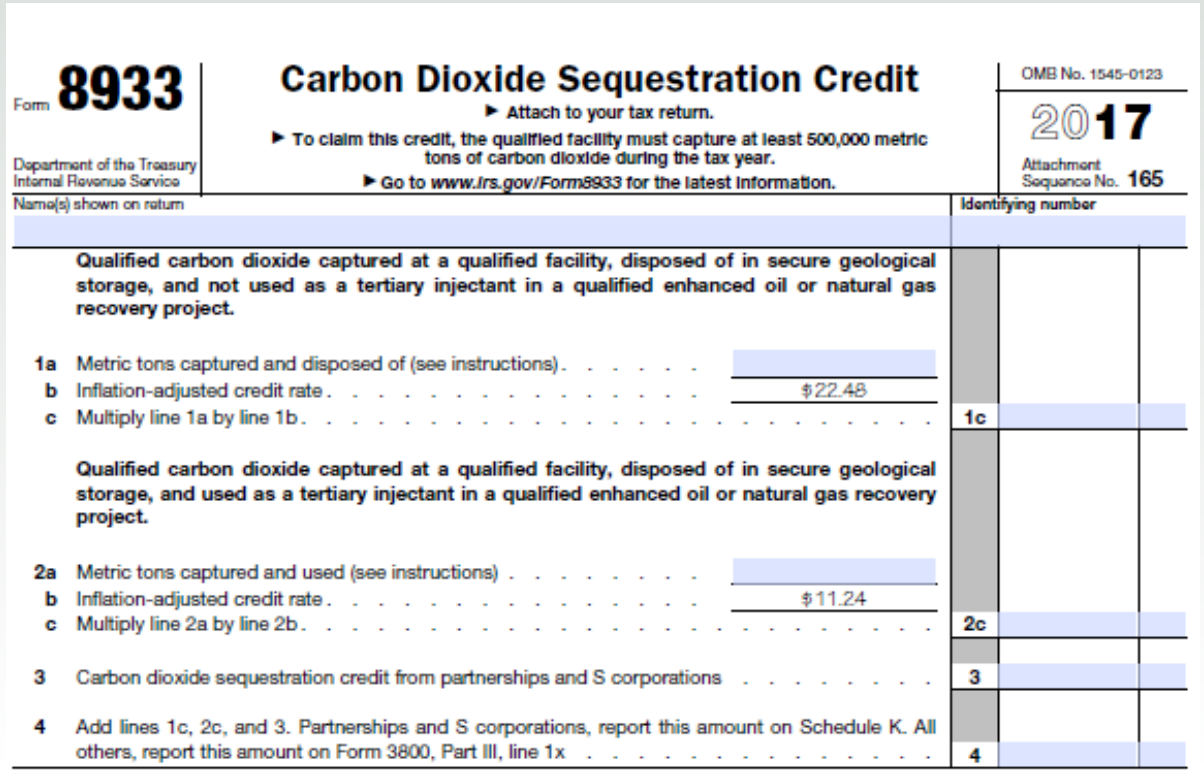
Monitoring For New Tax Incentives and Credits

Need to demonstrate secure storage

Post-injection Site Care -100 years!



Form **8933** — Department of the Treasury, Internal Revenue Service

Carbon Dioxide Sequestration Credit

- ▶ Attach to your tax return.
- ▶ To claim this credit, the qualified facility must capture at least 500,000 metric tons of carbon dioxide during the tax year.
- ▶ Go to *www.irs.gov/Form8933* for the latest information.

OMB No. 1545-0123

2017

Attachment Sequence No. 165

Name(s) shown on return | Identifying number

Qualified carbon dioxide captured at a qualified facility, disposed of in secure geological storage, and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project.

1a	Metric tons captured and disposed of (see instructions)		
b	Inflation-adjusted credit rate	$22.48	
c	Multiply line 1a by line 1b		1c

Qualified carbon dioxide captured at a qualified facility, disposed of in secure geological storage, and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project.

2a	Metric tons captured and used (see instructions)		
b	Inflation-adjusted credit rate	$11.24	
c	Multiply line 2a by line 2b		2c
3	Carbon dioxide sequestration credit from partnerships and S corporations		3
4	Add lines 1c, 2c, and 3. Partnerships and S corporations, report this amount on Schedule K. All others, report this amount on Form 3800, Part III, line 1x		4

Carbon Capture and Sequestration Protocol under the Low Carbon Fuel Standard

August 13, 2018

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Monitoring to Show Secure Storage

- MRV Plans Approved under EPA - Subpart RR
  - One saline (ADM)
  - Four CO_2-EOR
- Data collection from existing oil field practices

Project Name	Type	Date of Final Decision	Final Decision Documents
Core Energy Northern Niagaran Pinnacle Reef Trend	MRV plan	October 12, 2018	Decision
Shute Creek Facility	MRV plan	June 20, 2018	Decision
Archer Daniels Midland Company Illinois Industrial Carbon Capture and Sequestration Project	MRV plan	January 19, 2017	Decision
Hobbs Field	MRV plan	January 12, 2017	Decision
Denver Unit	MRV plan	December 22, 2015	Decision

Overall Plans for Subpart RR

- Mass balance approach
- Delineation of monitoring area (plume modelling)
- Leakage pathways assessment-
- Leakage detection monitoring:

Main Questions from Stakeholders

- Is it safe?
- Will it leak?
- What happens if it leaks?

CCS- Safe by Design

1. Site Characterization – Permitting requires high level of assurance
2. Risk Assessment- Modeling identifies potential unwanted outcomes
3. Project Design - to minimize potential risk
4. Monitoring Plan

<u>Deep Subsurface – Verification</u>
Behavior conforms to predictions

<u>Shallow Subsurface - Assurance</u>
No unwanted outcomes to environment

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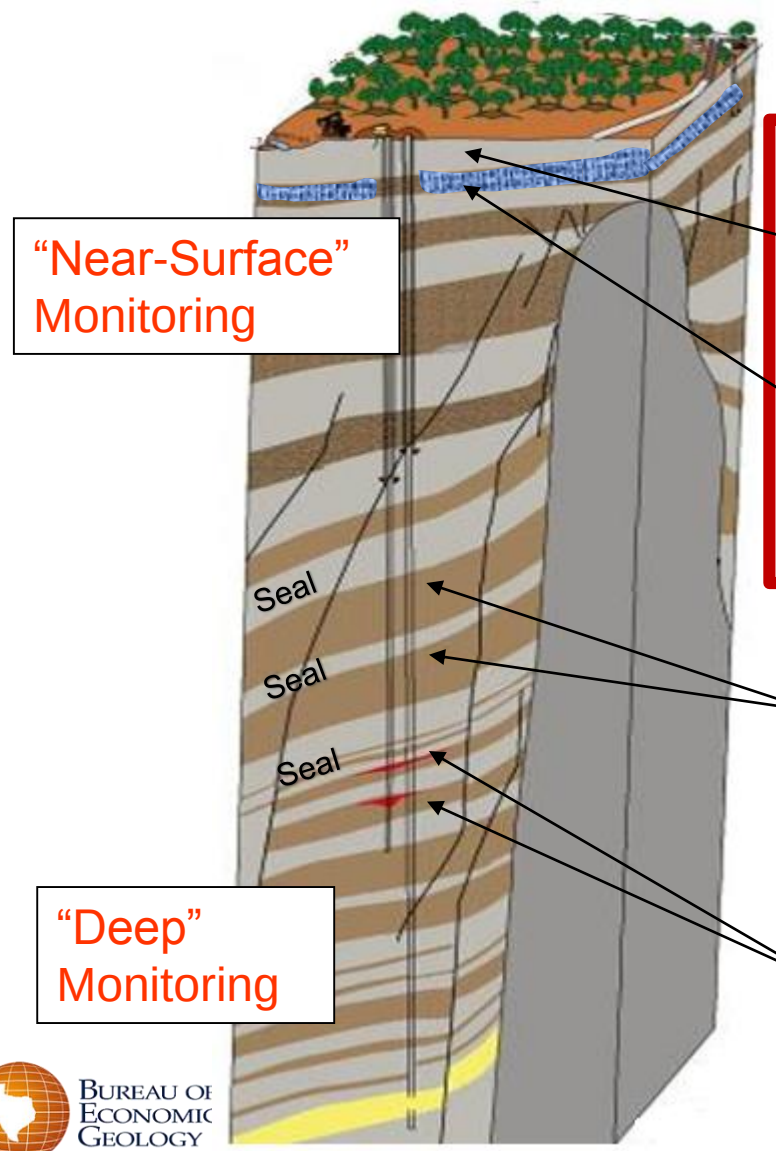
Overview of Monitoring Zones



"Near-Surface" Monitoring

"Deep" Monitoring

Vadose zone

Strong variability, dynamic, many challenges, release to atmosphere, biosphere impacts

Shallow groundwater

Moderate baseline variability, assurance of no damage to drinking water, easy access

Above Zone Intervals

Minimal variability, early detection, small signals

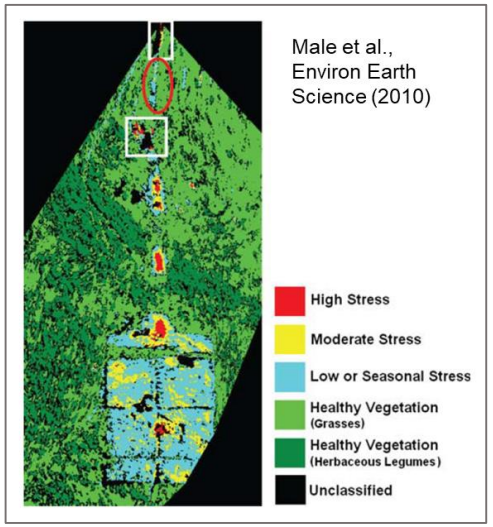
Reservoir

Static, quiet environment, variability is from CO_2 injection, CO_2/brine migration

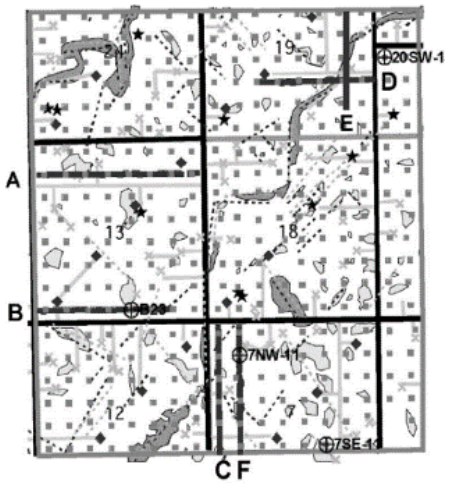
Figure courtesy of Sue Hovorka

The Lengths We Go To - Finding a Leak

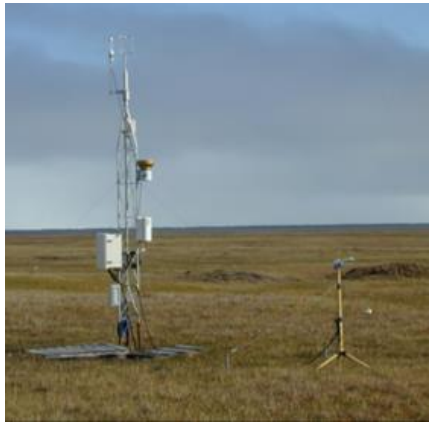
- Soil gas Grids
- Remote Sensing
- Drones/AUVs
- Sonar
- Open path lasers
- Eddy covariance
- Hyperspectral for Vegetation health



(Jones et al. 2009)



Weyburn soil-gas grid: 14 km^2, 200 m spacing (Riding and Rochelle, 2009).



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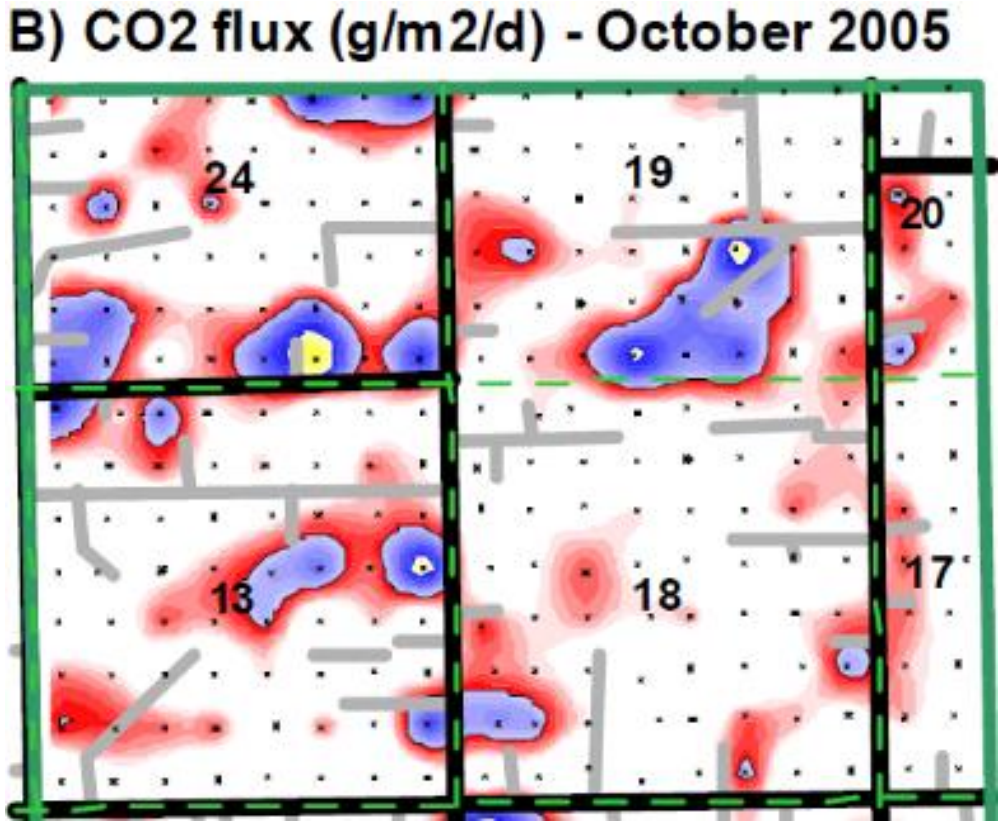
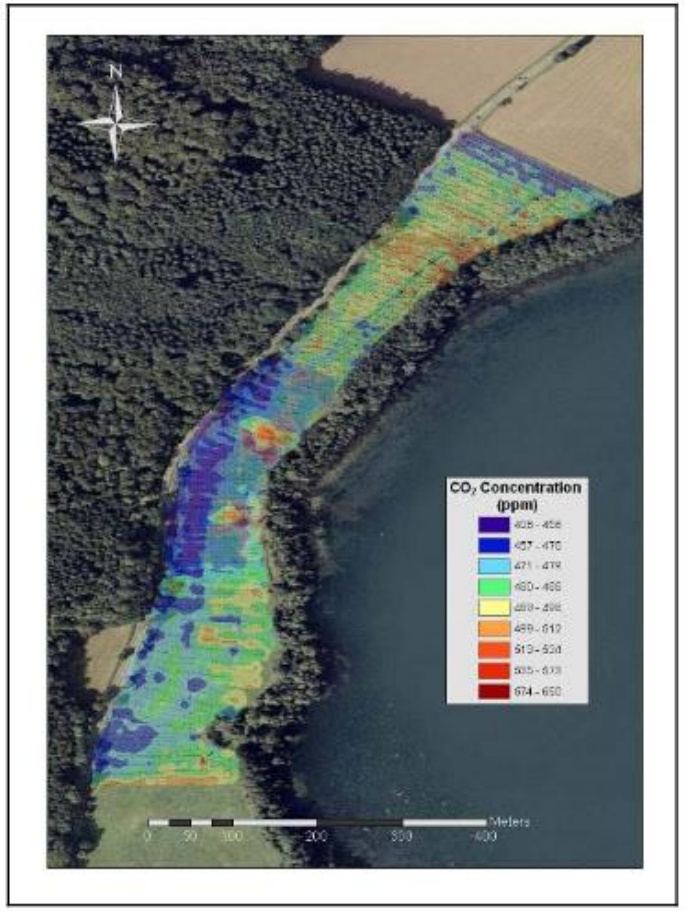
CO_2 Source Attribution



Weyburn soil-gas grid: 14 km^2, 200 m spacing. Jones et al., 2006, Soil Gas Monitoring at the Weyburn Unit in 2005



Walking traverses over gas vents at Latera with the ground surface measurement system (infrared analyzer) measuring CO2 concentrations (Jones et al. 2009)

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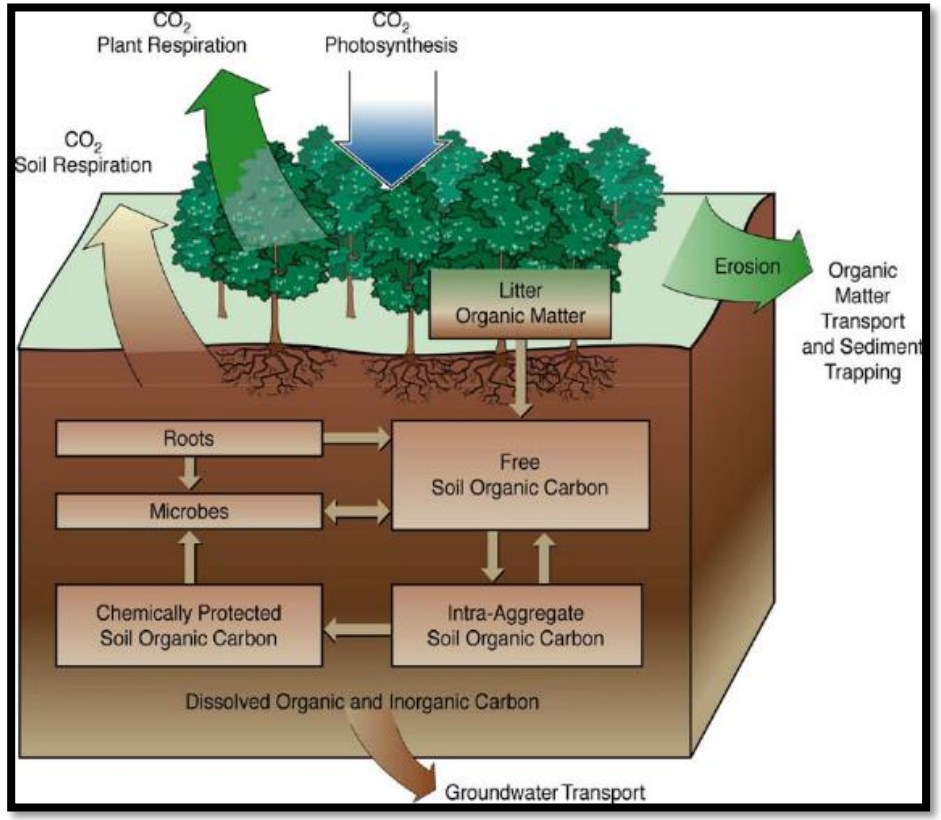
CO_2 Variability

- CO_2 is naturally everywhere
- Dominant source is biological respiration
- Dynamic over space and time (temperature, rainfall, pressure…)
- CO_2 is reactive
- Very difficult to discern leakage from natural variability.
- Difficult to determine what is anomalous



Source: DOE, 1999: *Carbon Sequestration Research and Development*

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Determining Anomalies Using Baselines

- Measure "baseline" CO_2 for 1 year before project starts to document seasonal variability.
- Monitor CO_2 during project and compare to baseline.
- Significant increase from baseline during a project signals a leak anomalous CO_2
- Did the storage project cause the anomaly?
- "Attribution" is a missing step

http://www.sustaenable.eu/?page_id=932

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Global Regulations

Regulatory Body / Monitoring Objectives:	IPCC GHG Guidelines	EU		London Convention and Protocol	OSPAR	UNFCCC Clean Development Mechanism	US EPA	
		CCS Directive	ETS Directive				UIC Class VI well regulation	GHG reporting Subpart RR
Overall Objectives	GHG accounting	Protection of the environment	GHG accounting	Protection of the marine environment	Protection of the marine environment	GHG accounting and protection of the environment	Protection of the environment (underground sources of drinking water)	GHG accounting
Baseline/ Background Measurements	✓	✓				✓	✓	✓
Storage Performance	✓	✓		Only in terms of retention	Only in terms of retention	✓	Only in terms of pressure and plume extent	
Detection of Leaks or Anomalies	✓	✓		✓	✓	✓	✓	✓
Attribution of Leaks and/or Anomalies	Mentions in the context of baseline isotopic ratios. Not included as a step					Not included as a step but accommodates a range of monitoring techniques		Mentions in the context of baseline CO_2 concentrations. Not included as a step
Environmental Impacts		✓		✓	✓	✓	✓	
Quantification of GHG	✓		✓			✓		✓

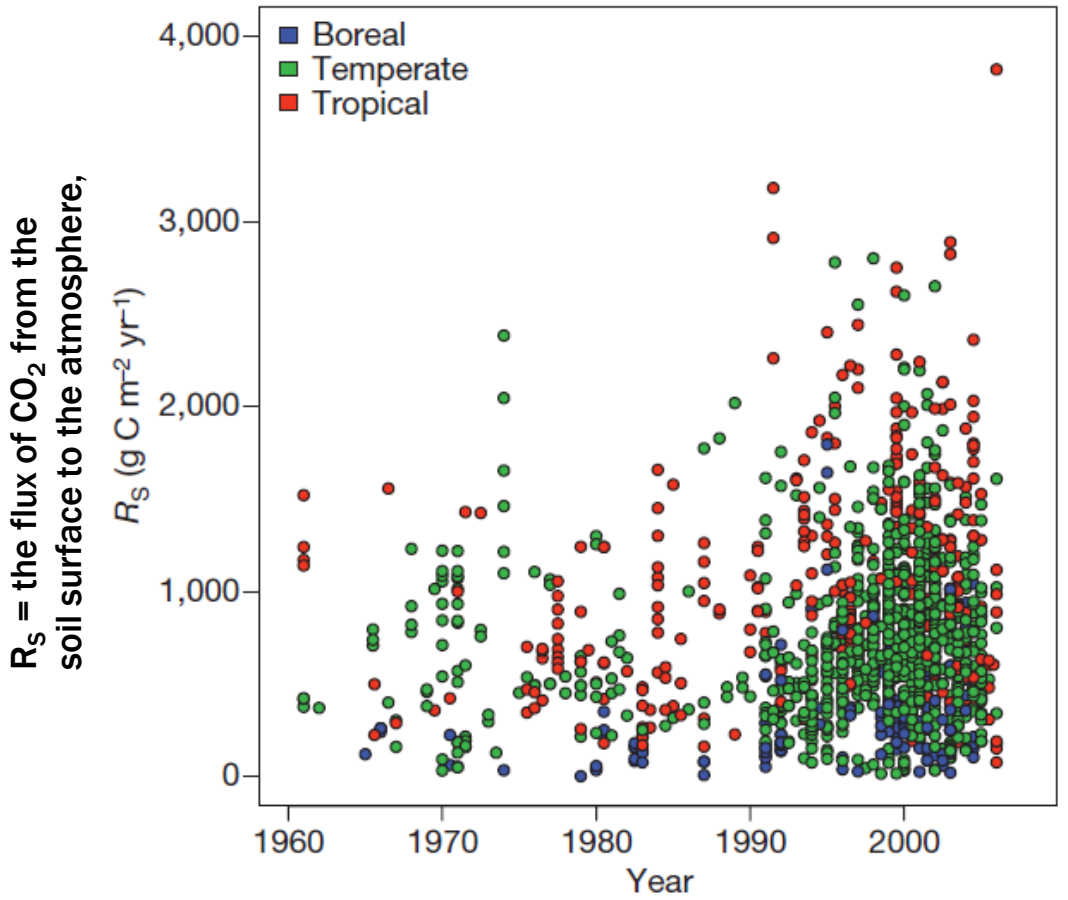
Dixon and Romanak, 2015, *International Journal of Greenhouse Gas Control*, *41*, 29-40.

“Baselines” in Soils are Shifting Upwards

Vol 464|25 March 2010|doi:10.1038/nature08930 nature

Temperature-associated increases in the global soil respiration record

Ben Bond-Lamberty[1] & Allison Thomson[1]



R_S = the flux of CO_2 from the soil surface to the atmosphere,

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“Baselines” in Groundwater are Shifting Upwards

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Geochimica et Cosmochimica Acta 72 (2008) 5581–5599

Geochimica et Cosmochimica Acta

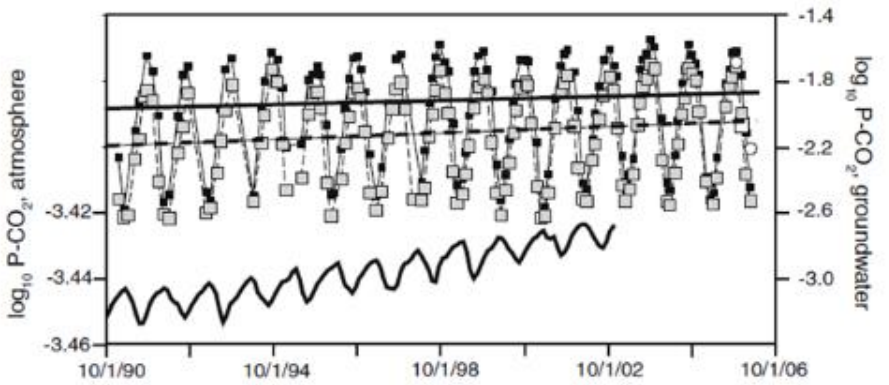
www.elsevier.com/locate/gca

Increasing shallow groundwater CO_2 and limestone weathering, Konza Prairie, USA

G.L. Macpherson [a,*], J.A. Roberts [a], J.M. Blair [b], M.A. Townsend [c], D.A. Fowle [a], K.R. Beisner [d]

[a] *Department of Geology, University of Kansas, 1475 Jayhawk Blvd., 120 Lindley Hall, Lawrence, KS 66045, USA*
[b] *Kansas State University, Manhattan, KS, USA*
[c] *Kansas Geological Survey, Lawrence, KS, USA*
[d] *University of Utah, Salt Lake City, UT, USA*

Received 28 January 2008; accepted in revised form 2 September 2008; available online 18 September 2008



Increased dissolution of CO_2 in groundwater and associated mineral dissolution

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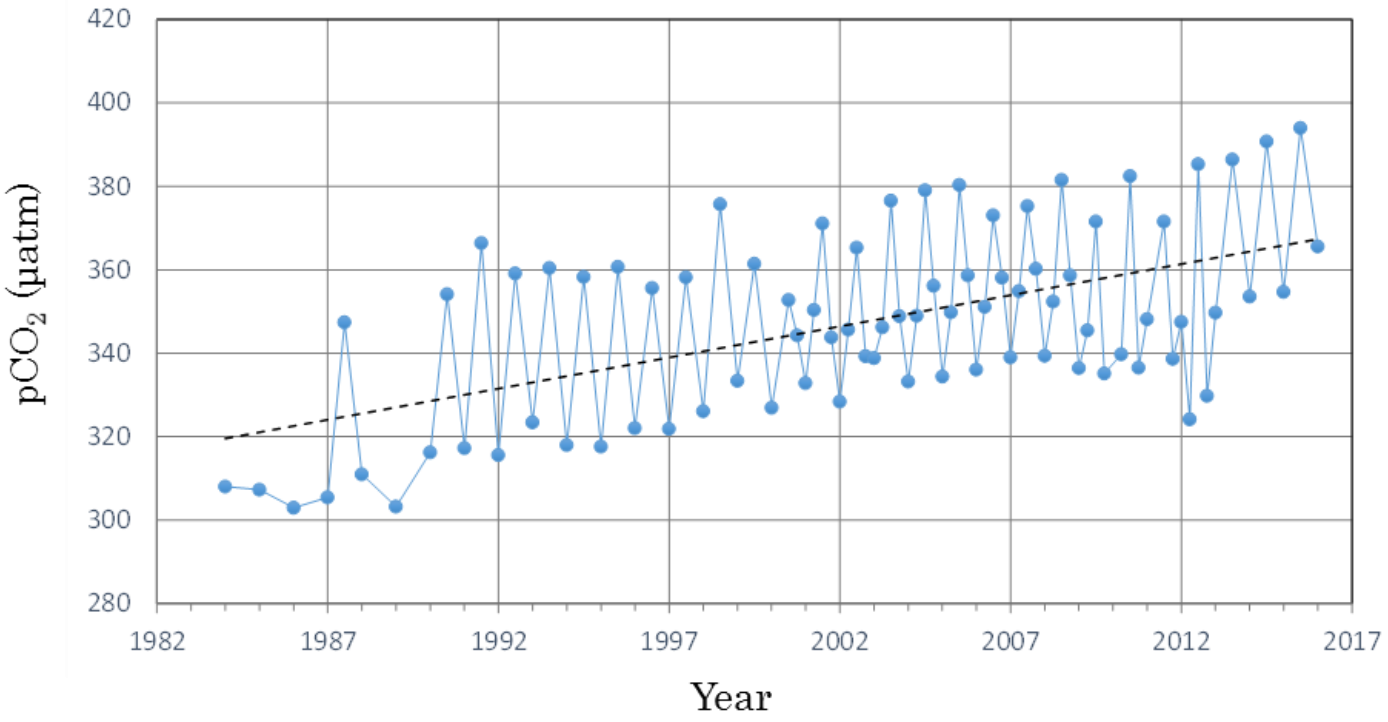
“Baselines” in Seawater are Shifting Upwards



Time series of surface seawater CO_2 level near Japan. Source data by Japan Meteorological Agency, Courtesy of Jun Kita, RITE

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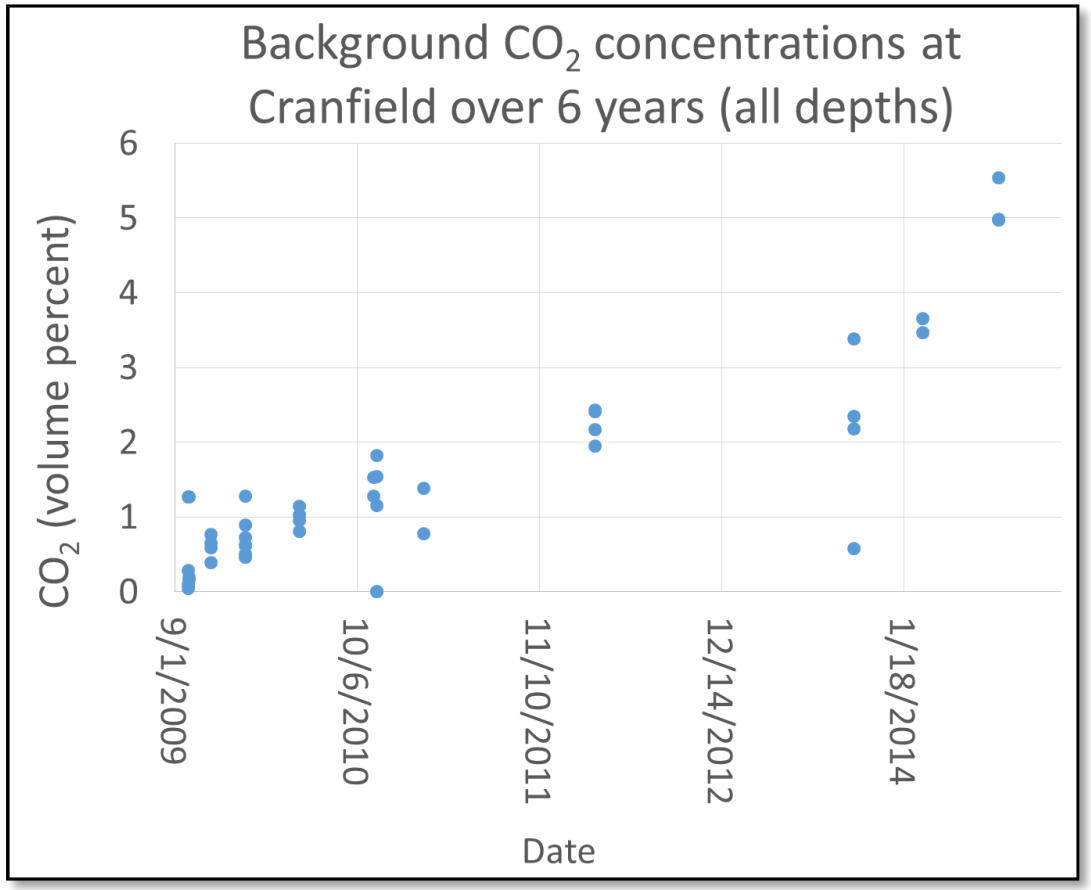
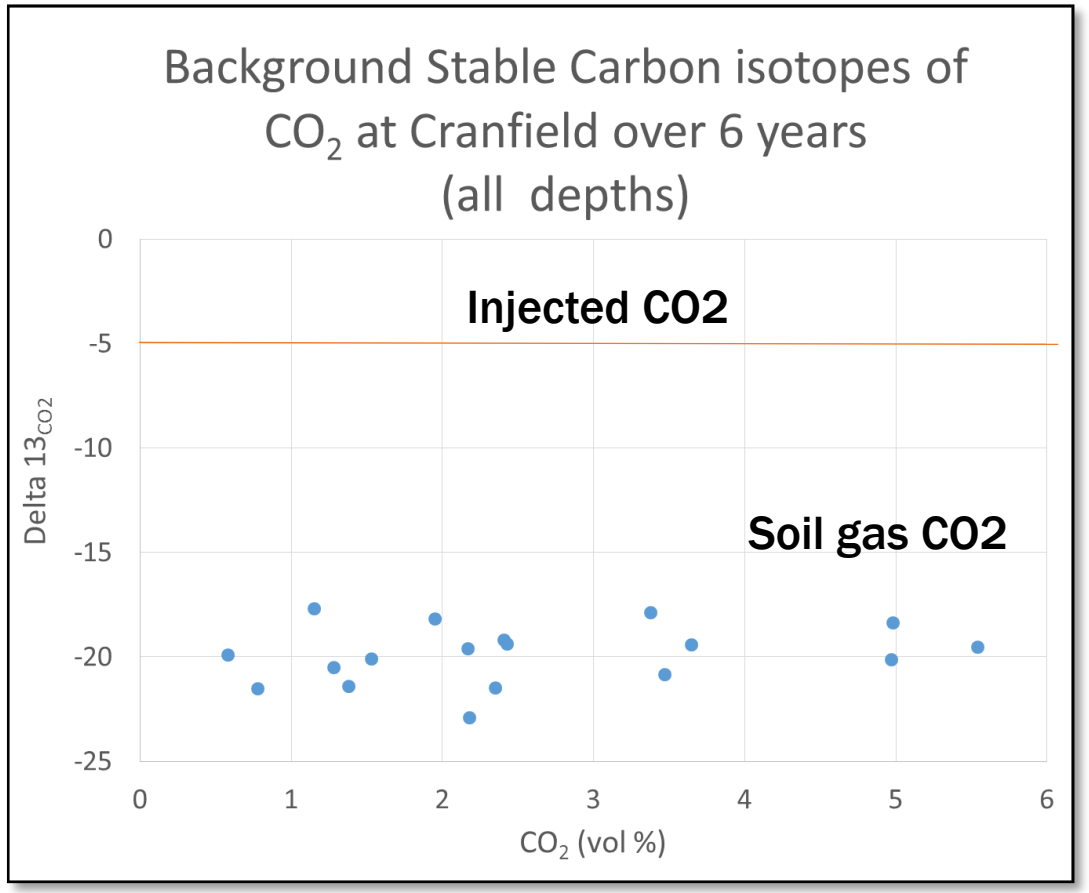
Example – Soil Gas at Cranfield Project (Mississippi, USA)





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Revelation #1

- Naturally produced CO_2 in the biosphere is increasing due to climate change
- Use of “concentration-based” or “baseline” methods will result in false positives for leakage
- **The risk of false positives is greater than the risk of actual leakage**
- False positives put projects at unnecessary risk

Tomakomai Project

- Tomakomai Offshore demonstration project Hokkaido Japan
- Derived leakage thresholds from 1 year of baseline data
- Injection began April 2016 with routine environmental monitoring plan
- May, 2016, operations were halted after 7,163 ton CO_2 was injected
- High CO_2 levels observed in the routine monitoring
- February 2017 operations resumed

Shifting baselines cause false positives and project shutdowns

Slide courtesy of Jun Kita, MERI

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Revelation #2

- If we actively look for “leakage” (e.g. via routine monitoring) we will find an abundance of natural anomalies
- We will need to attribute the source of these anomalies.
- Baseline methods are not effective or accurate.
- So how do we adequately assure environmental safety?

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2011 Kerr Leakage Allegation

- IEAGHG Weyburn CO_2 Monitoring and Storage project, Saskatchewan Canada
- Perceived environmental change was blamed on the CO_2 storage project
- Protocols for responding to stakeholder concerns were not in place
- Unexperienced consultant wrongly attributed leakage


THE GLOBE AND MAIL

IN PICTURES

Carbon capture leak forces Saskatchewan couple to leave farm

Published Tuesday, Jan. 11, 2011 6:12PM EST

Pair abandon Saskatchewan farm because of blowouts, dead animals and algae

1 of 10

(Troy Fleece/The Canadian Press)

Show caption

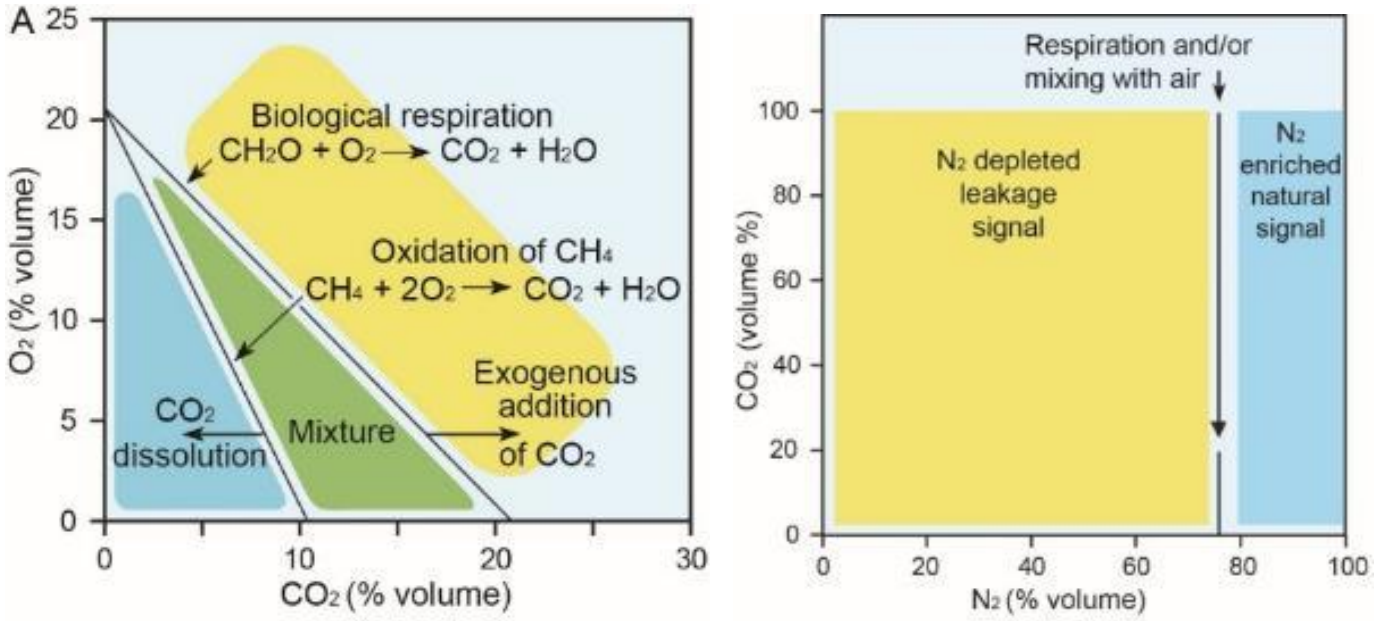
Negative Media Storm

Revelation #3

- Environmental change resulting from climate change will cause stakeholders to question the storage project
- When CCS is fully deployed, responding to stakeholders concerns may be our main activity.
- Develop fast accurate stakeholder-friendly methods with clear thresholds
- Methods that are easily communicated to stakeholders are needed

Process-Based Soil Gas Ratios

- Uses simple gas relationships to identify **processes.**
  - Biologic respiration
  - Methane oxidation
  - Dissolution
  - Leakage
- No need for years of background
- One time characterization
- Method can be applied in any environment regardless of variability



Romanak et al., 2014, International Journal of Greenhouse Gas Control, 30, 42-57
Romanak et al., 2012, Geophysical Research Letters, *39* (15).

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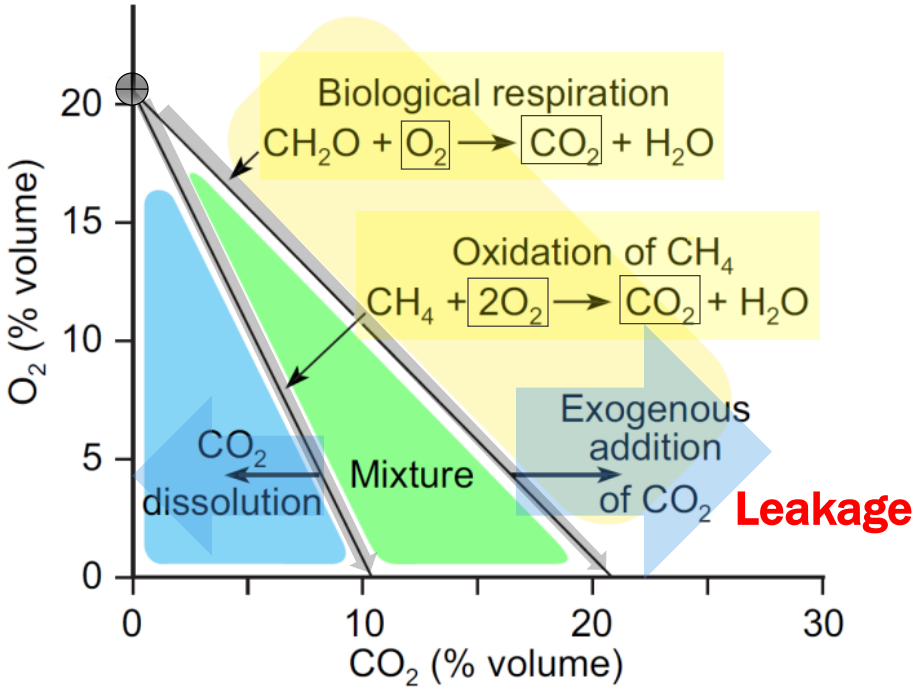
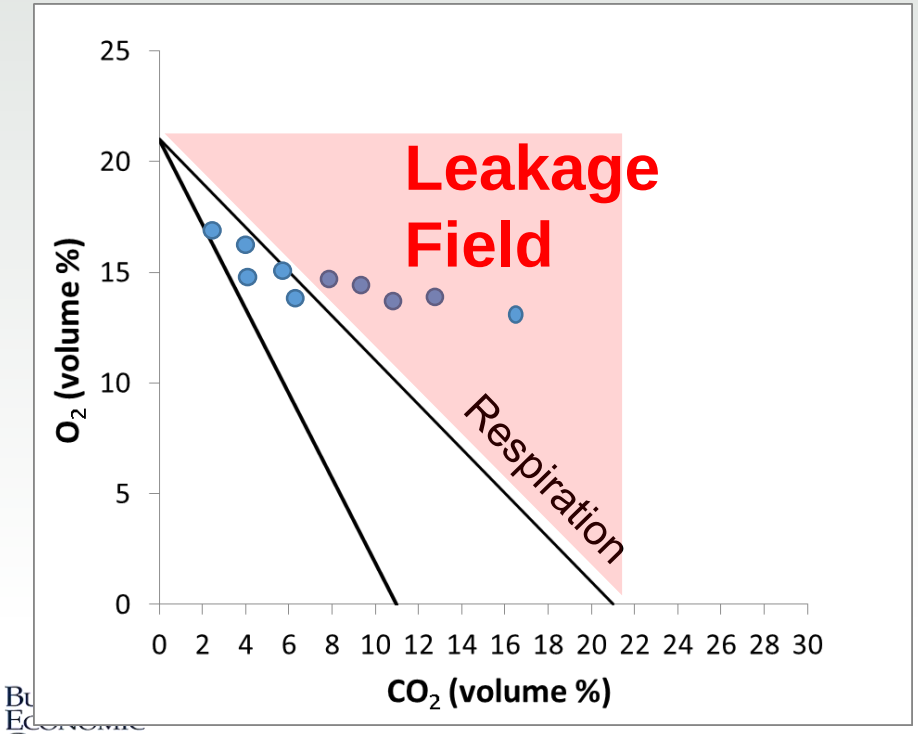
Process-Based Example

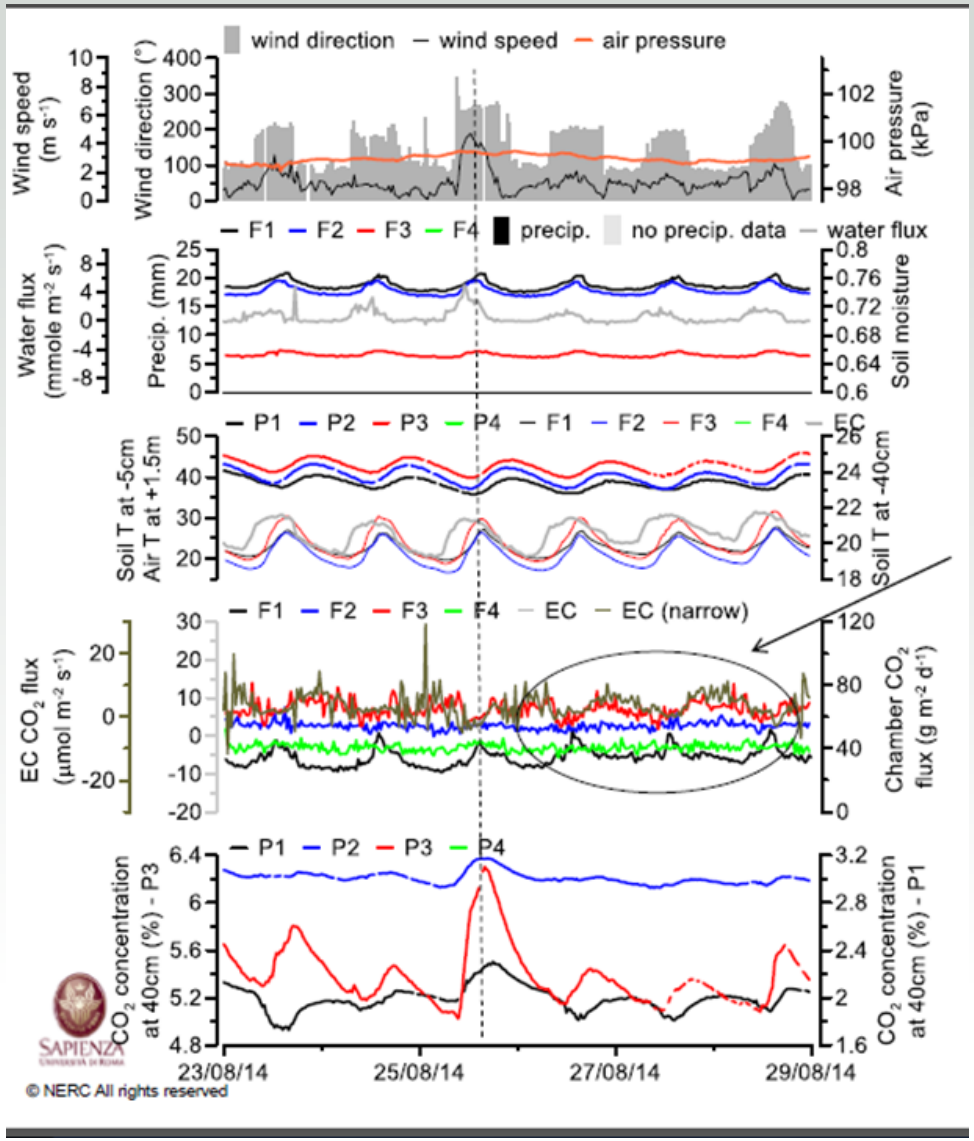
- Uses geochemical relationships to identify key processes rather than concentration comparisons



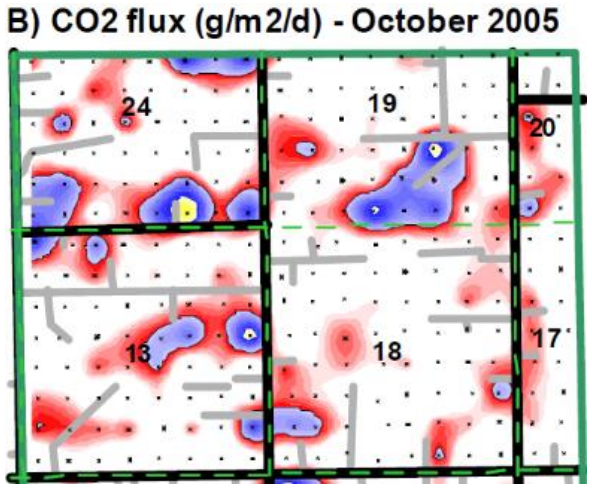
"User-Friendly" for Public Engagement

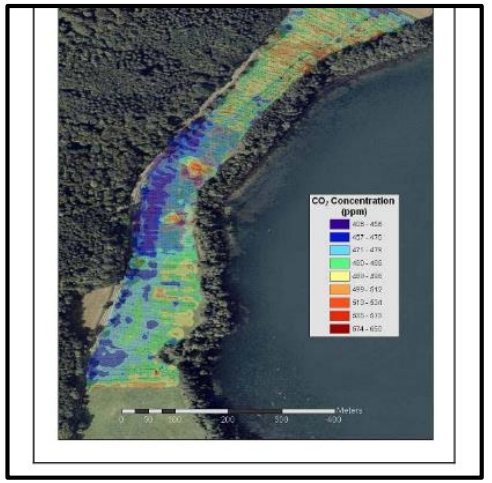
- Respiration line as a universal trigger point
- No need for years of baseline- only need a one-time characterization.
- Easy to explain and engage stakeholders
- Instant data reduction and graphical analysis

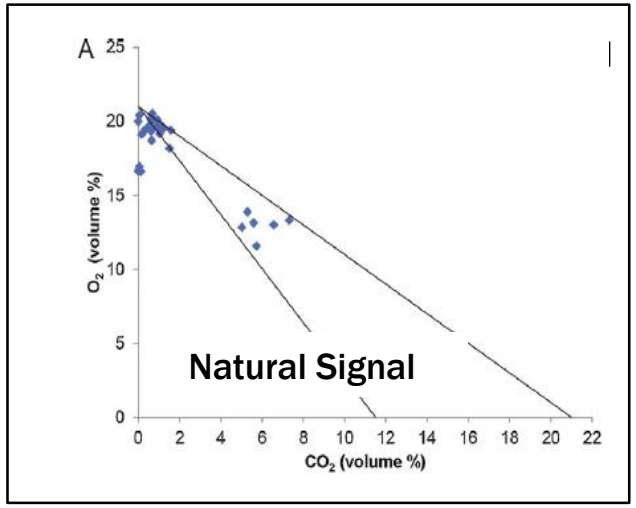


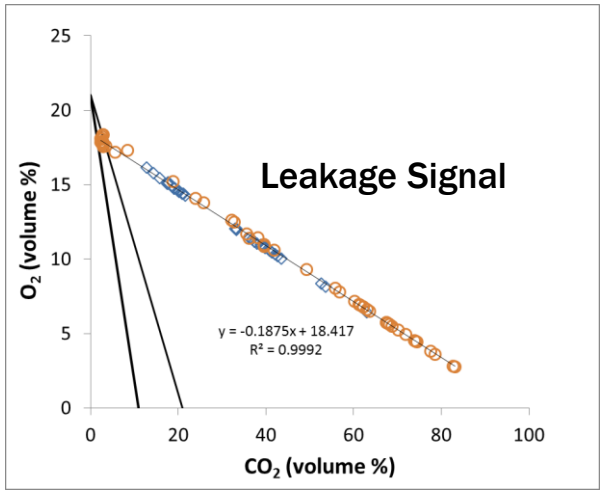


Process-based Attribution









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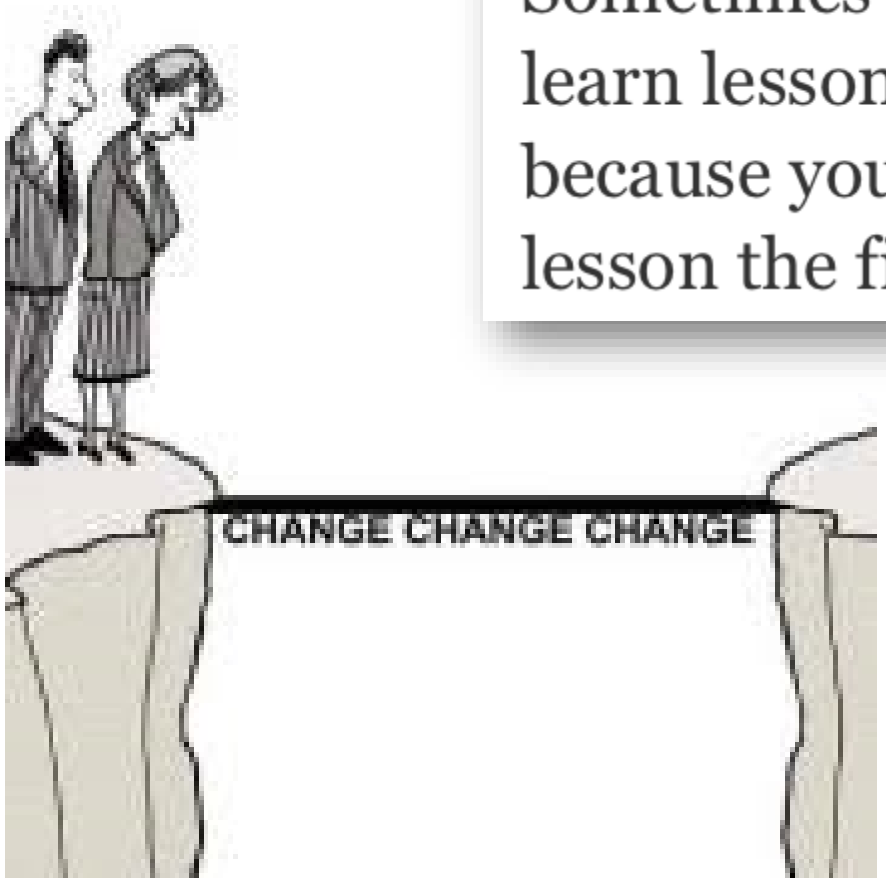
Learning from our Experience



Sometimes the reason you have to learn lessons the hard way is because you didn't learn your lesson the first time (the easy way).

Summary

- Monitoring plans are evolving with experience and new incentives
- CO_2 storage is safe by design
- Baselines should not be used for attribution! They are shifting due to climate change, will result in false positives for leakage, and will cause project shutdowns.
- Protocols and regulations need updating.
- The Kerr claim shows a great need for accurate methods and protocols for attribution for responding to stakeholders concerns.
- The risk of a false leakage claim is higher than the risk of actual leakage.
- A process-based type of approach will give more accurate, immediate, and stakeholder-friendly monitoring results and may be useful for quantification and remediation monitoring.

Thank You

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http://www.beg.utexas.edu/gccc/