Examples of detailed near-surface gas geochemistry baseline studies and the processes and conditions that can influence their results

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Introduction

Baseline monitoring of near-surface gas geochemistry

- **Baseline measurements are important to:**
  - **Define gas permeable structures in the site assessment phase**
  - **differentiate natural, near-surface biogenic CO_2 variability from a potential leakage signature for monitoring and carbon credit auditing. Proved critical in recent Weyburn controversy.**
- **Range of baseline values can depend on:**
  - **seasonal influence of changing temperature, rainfall, etc.**
  - **soil type, land-use, underlying geology, topography, etc.**
  - **sampling depth**
- **Here we present spatial and temporal monitoring data from SiteChar work in Denmark (as well as some data from the Weyburn CO_2-EOR site in Canada) to illustrate these differences**

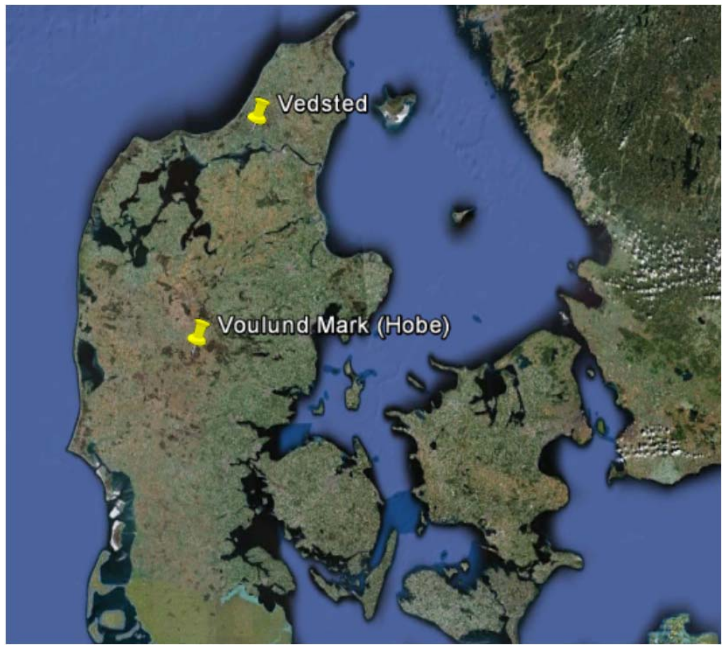
Near-surface gas geochemistry methods

Soil Gas: A sampling probe is pounded to 80cm depth and soil air is field analysed for CO_2 and in the lab for light hydrocarbons, O_2, N_2, CO_2, and He.

GasPro CO_2 monitoring sensors: UniRoma developed probes. Buried at 80cm depth and left for 3-6 months measuring every 1-6 hours.

CO_2 flux: A closed loop accumulation chamber is placed on the ground surface, with flux calculated based on CO_2 increase and chamber dimensions

Site description – Hobe, Denmark



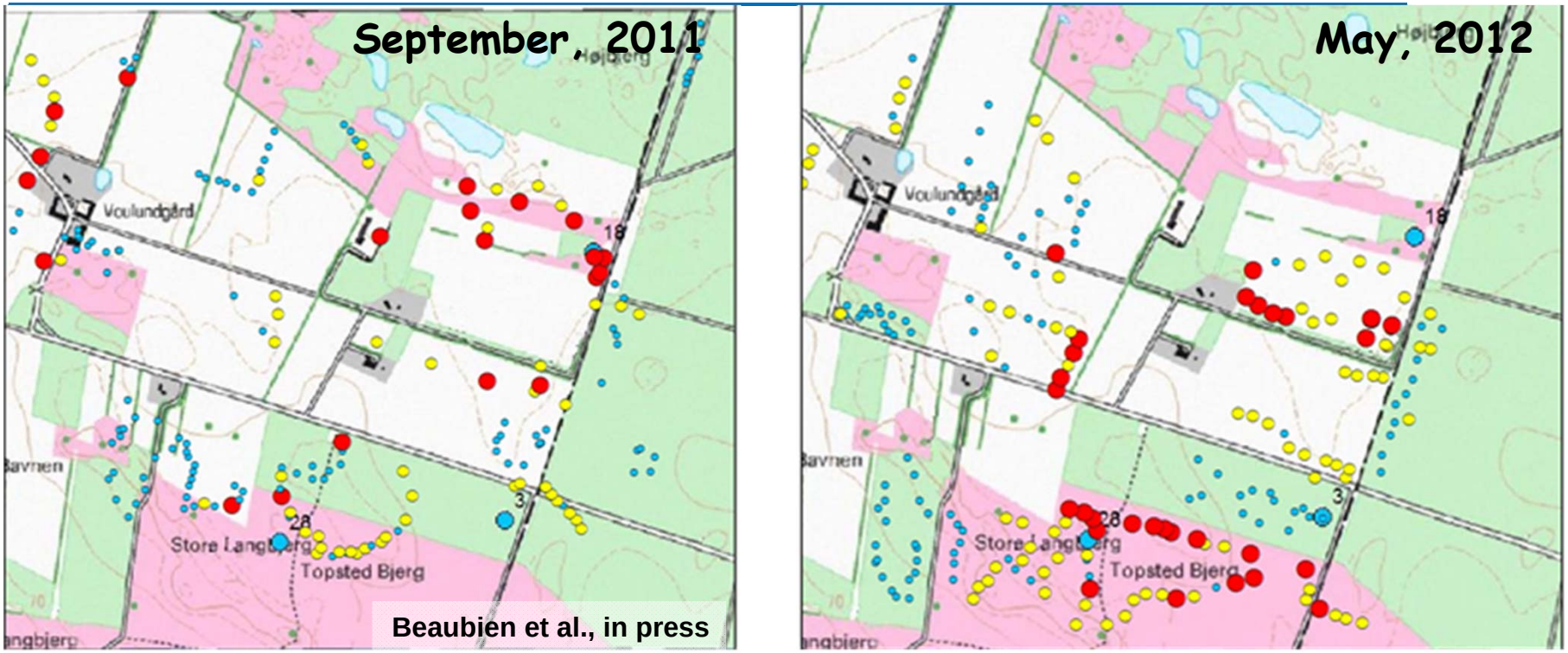
- **Study site - Hobe Agricultural Research centre at Voulund**
  - **Considered representative of northern European climate**
- **Three land-use types: Heath, Cultivated fields, and Forest**
- **30cm organic soil followed by a clean sand**

Heath

Cultivated

Forest

Work performed - Hobe

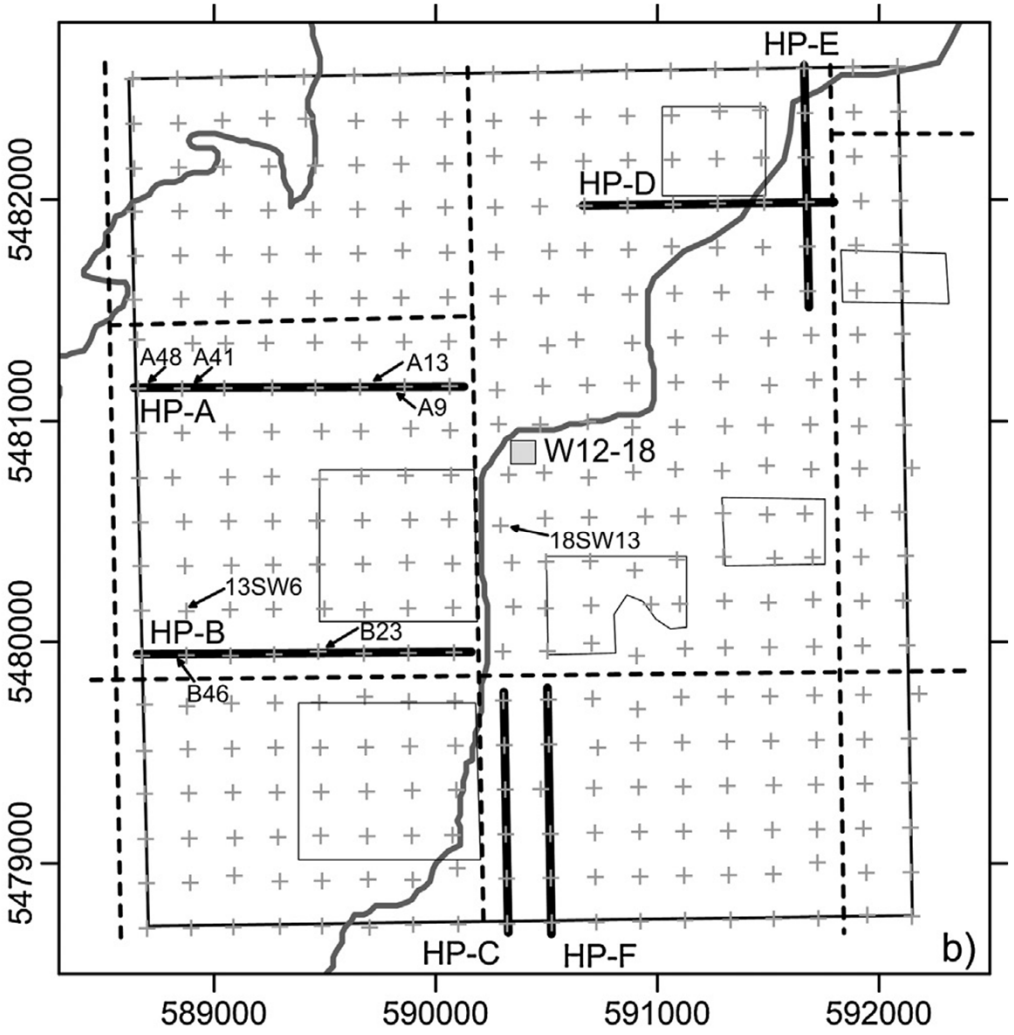


- Two campaigns, about 200 samples collected each, plus deployed 3 GasPro sensors
- Used random stratified sampling approach
- Heavy rains in first campaign limited flux measurements but sandy soil meant soil gas could be sampled

Site description – Weyburn, Canada

- **CO_2-EOR site, studied for CCS research using many techniques. No evidence of leakage, so near-surface gas geochemistry results considered biological baseline**
- **Agricultural prairie grassland, numerous areas with ephemeral standing water and swamps. Glacial till soil**

Work performed - Weyburn

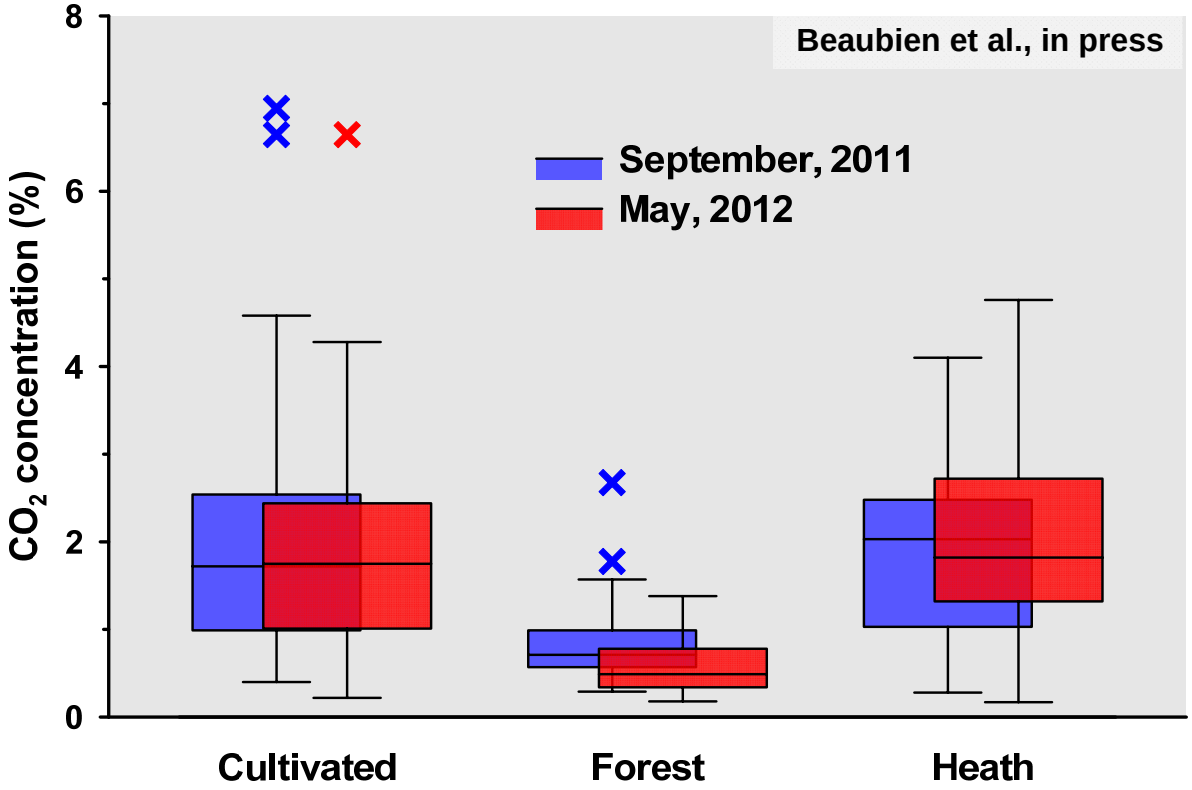


Beaubien et al., 2013

- Performed 6 campaigns between 2001 and 2011, collecting 400 to 600 samples each time
- Sampled along regular regional grid with 200m spacing and detailed 25m-spacing profiles
- One summer campaign, the rest progressively later in the fall with last ones at end of October
- During last campaign deployed 3 GasPro sensors for 6 months

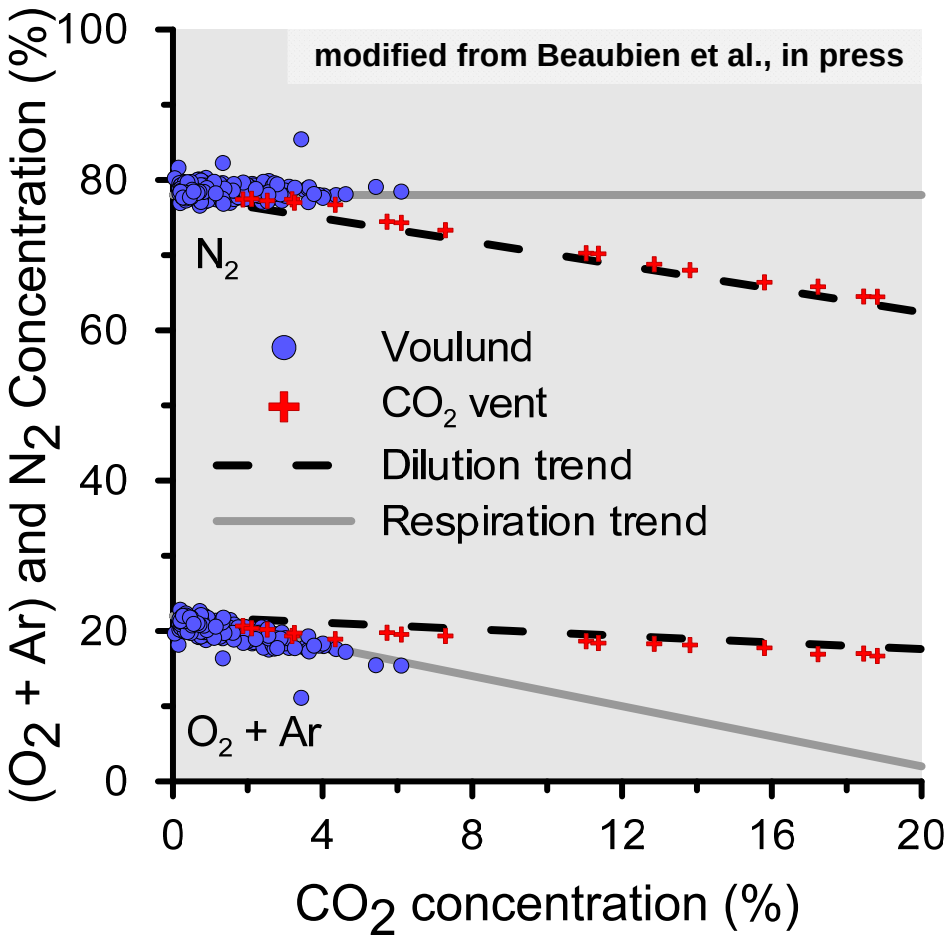
Influence of land-use

Hobe - soil gas CO_2 concentrations



- Statistical box-and-whisker plot – mean, quartiles, outliers, extremes
- Soil gas CO_2 concentrations are clearly lower in the forest areas in both campaigns, whereas heath and cultivated regions are similar
- Likely linked to lower soil temperatures in the shaded forest floor, resulting in lower microbial activity

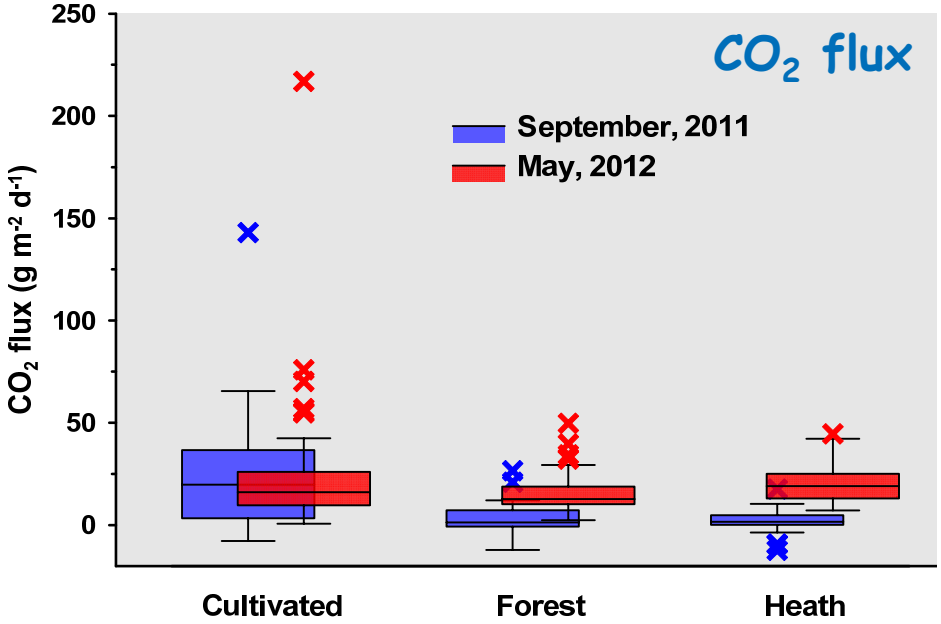
Hobe - soil gas CO_2 concentrations

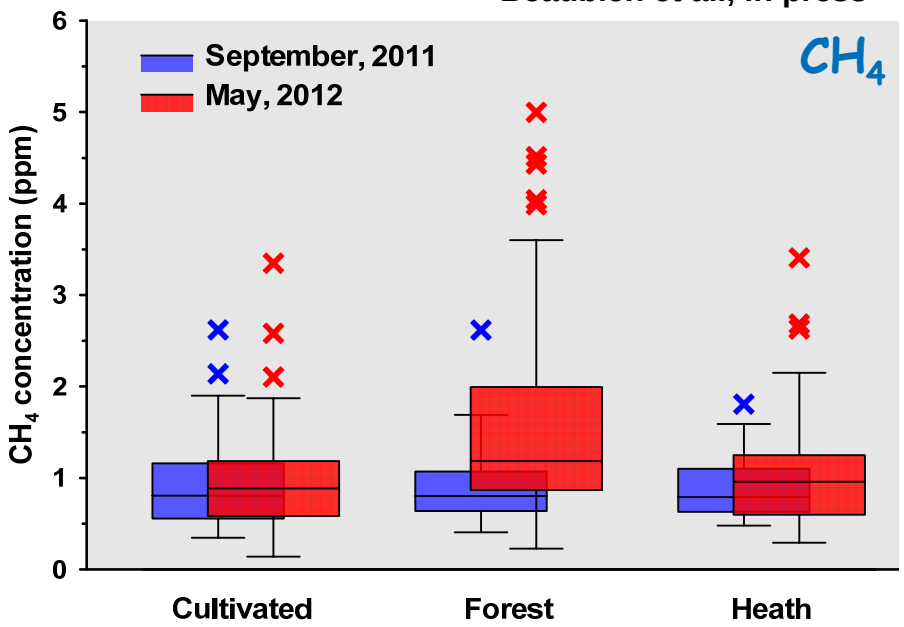


- Plot shows decrease in O_2 with increased CO_2 (towards a maximum of 20% CO_2), but relatively constant N_2 values
- Implies shallow biogenic CO_2 production, as soil respiration will consume approximately 1 mole of O_2 to produce 1 of CO_2, with no change in N_2
- The data does not following the "dilution" trend, which results when external CO_2 is added thus diluting both O_2 and N_2 towards zero at 100% CO_2.
- This plot can be very useful in distinguishing the two mechanisms

Hobe – CO_2 flux and soil gas CH_4

Beaubien et al., in press

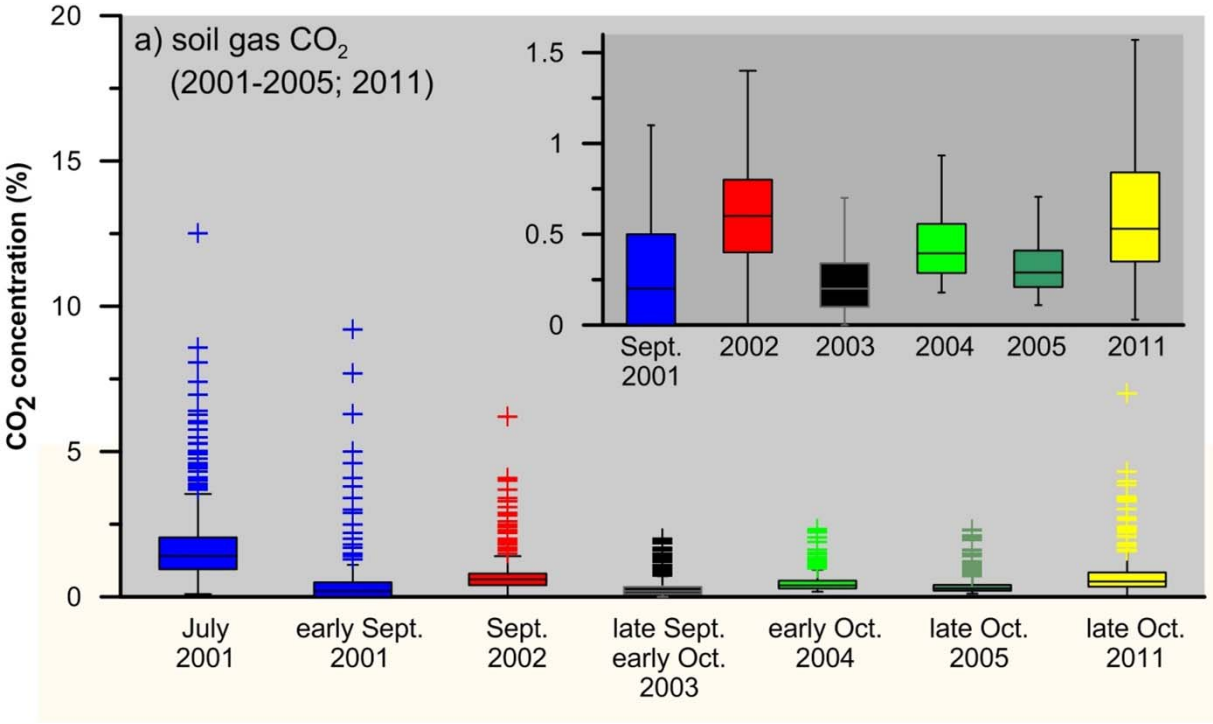




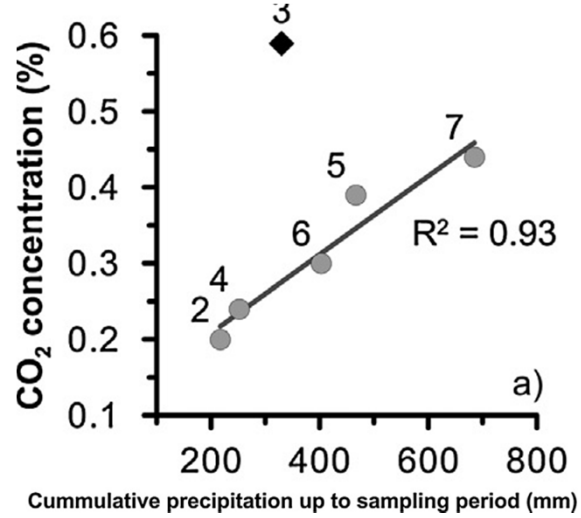
- CO_2 flux are highest on cultivated ground during the first campaign, but water on surface affected results. During second campaign there is an narrow distribution and little difference between land-use types
- CH_4 concentrations very similar in Sept. 2011 and most of May 2012, however distribution is higher and wider in forest soils. It has been documented that forest soils can alternate from CH_4 sink to source

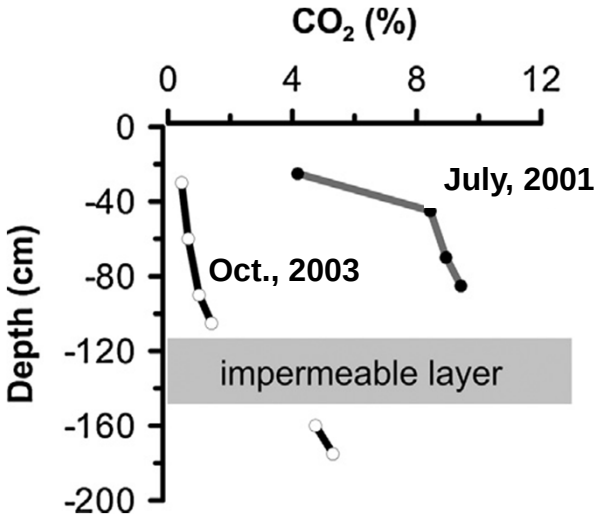
Influence of seasons

Weyburn – soil gas CO_2 concentrations



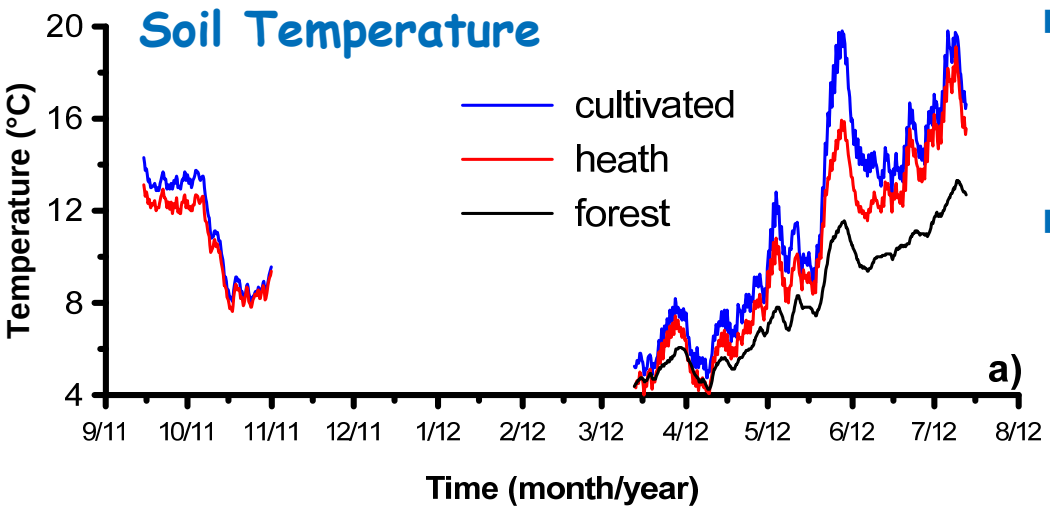
Beaubien et al., 2013

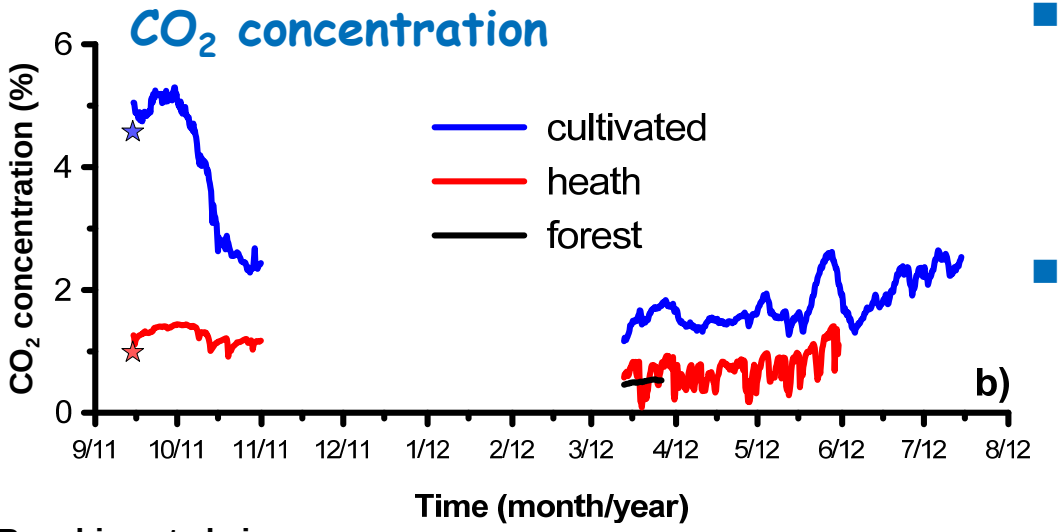




- **Much higher values in summer compared to fall due to higher temperature and more moisture. Even more pronounced in flux data**
- **Trend of fall campaigns correlates with cumulative precipitation**
- **Vertical profiles at one location at different times show very different results**

Hobe – GasPro monitoring results

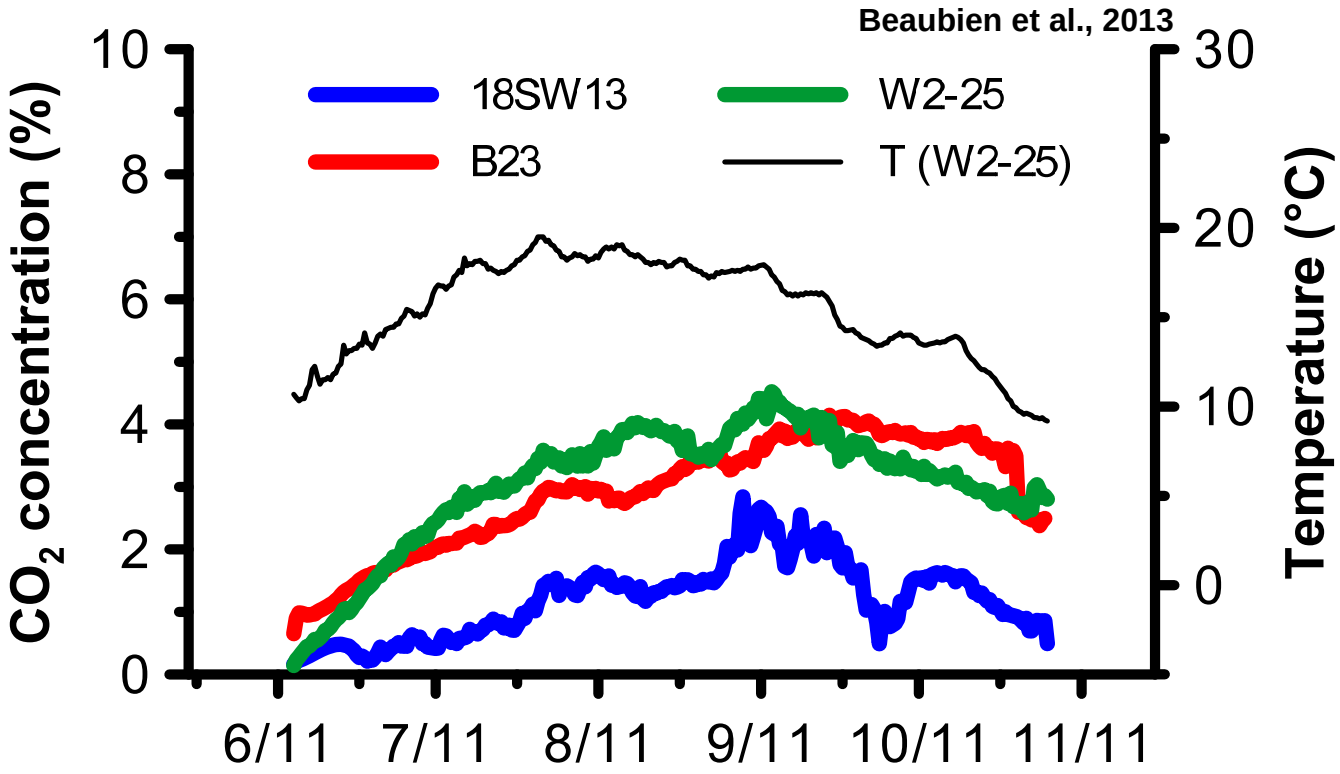




Beaubien et al., in press

- All probes show similar seasonal temperature trends and specific short term events
- Forest site clearly has lower temperatures during the summer, which may explain lower overall CO_2 values
- Probe in the cultivated field is correlated with temperature, both drop in fall and individual peaks in summer
- Values at the heath site are much lower. Site complicated by fact that it was plowed during the second deployment

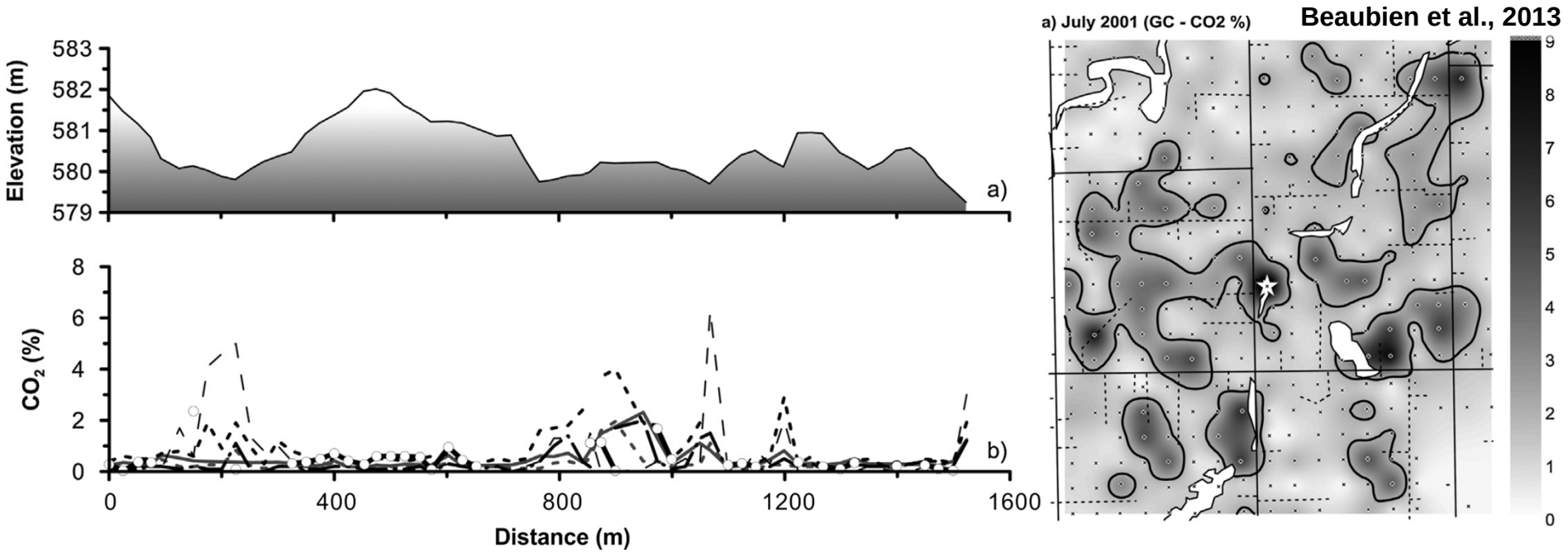
Weyburn – GasPro monitoring results



- **Trends at the Weyburn site were more regular, rising gently together with temperature**
- **Although temperature plateaus in mid-July, CO_2 concentrations continue to rise until early September, dropping when temperature starts to drop more rapidly**

Influence of Topography

Weyburn – soil gas CO_2 concentrations



Beaubien et al., 2013

- **Horizontal profile with samples every 25m, repeated during 5 campaigns, consistently shows higher values in depressed areas**
- **Grid results on the right show values over 10% in summer, with anomalies often associated with low-lying areas having ephemeral surface water**

Summary

- **Wide range of natural values observed at both sites. Up to 12% CO_2 at Weyburn, up to 6% CO_2 at Hobe.**
- **Clear differences for some parameters based on land use. Mapping of such surface features important for precise interpretation of spatial data**
- **Topography (combined with soil type and water content) can have a strong influence of baseline data**
- **Seasonal variations seen in monitoring data, most clearly in sampling at Weyburn and in probe results from both sites. Recommend 4 campaigns to better cover seasonal variability of spatial distribution, combined with a complete year of monitoring probe data for extrapolating temporal data**
- **Baseline study should extend beyond initial proposed injection area, to search for possible gas-permeable faults and because of eventual lateral migration of injected CO_2**

Thank you for your attention !!

- **References**

SiteChar research at Hobe compared to work at a southern European site in Sardinia (Italy):

Beaubien et al. (in press) The importance of baseline surveys of near-surface gas geochemistry for CCS monitoring, as shown from onshore case studies in northern and southern Europe. Oil & Gas Sciences and Technology (DOI: 10.2516/ogst/2014009)

Research at the Weyburn CO_2-EOR / CCS site in Canada

Beaubien et al. (2013) Monitoring of near-surface gas geochemistry at the Weyburn, Canada, CO_2-EOR site, 2001-2011. International Journal of Greenhouse Gas Control 16, Supplement 1, S236-S262 (DOI: 10.1016/j.ijggc.2013.01.013) .