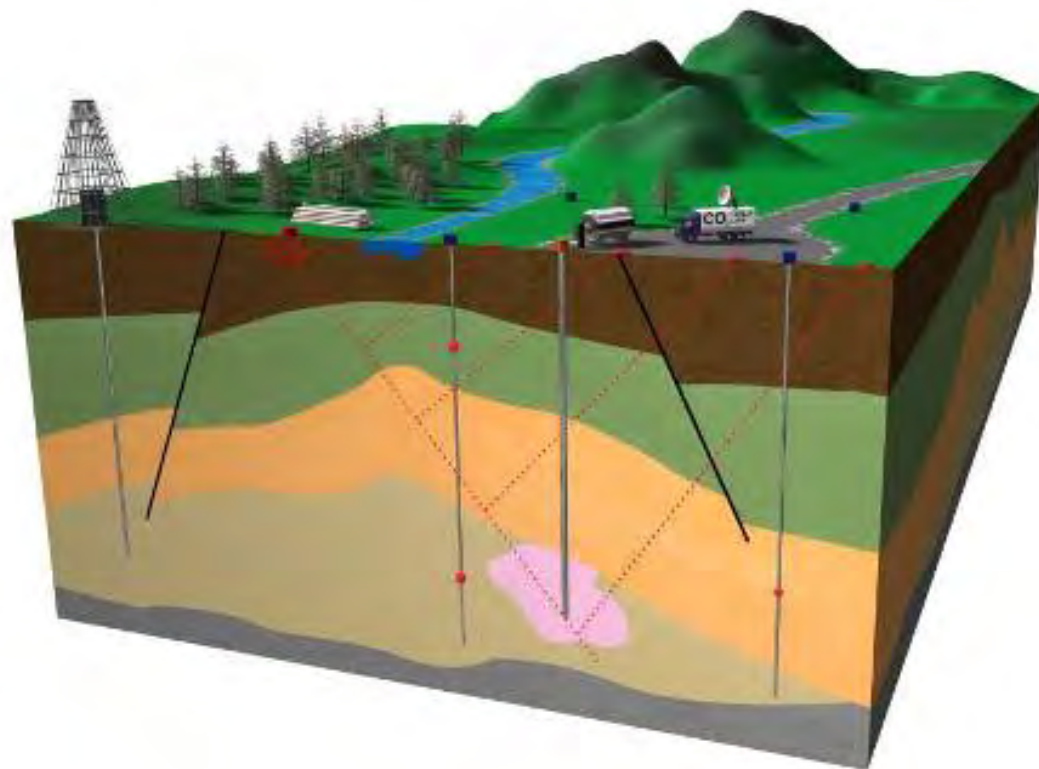


” Knowing the sensitivity of the monitoring equipment.”



CO₂FieldLab

CSLF Technical Group, 12th June 2012

Background



- Regulatory framework
- Leakage must be well addressed
 - Safety
 - Mitigation and early remediation
 - Public acceptance
 - Accounting
- Validated monitoring system for leakage
- Technology assessment

**Crucially
needed!!!**

CO₂FieldLab near Oslo



Objectives

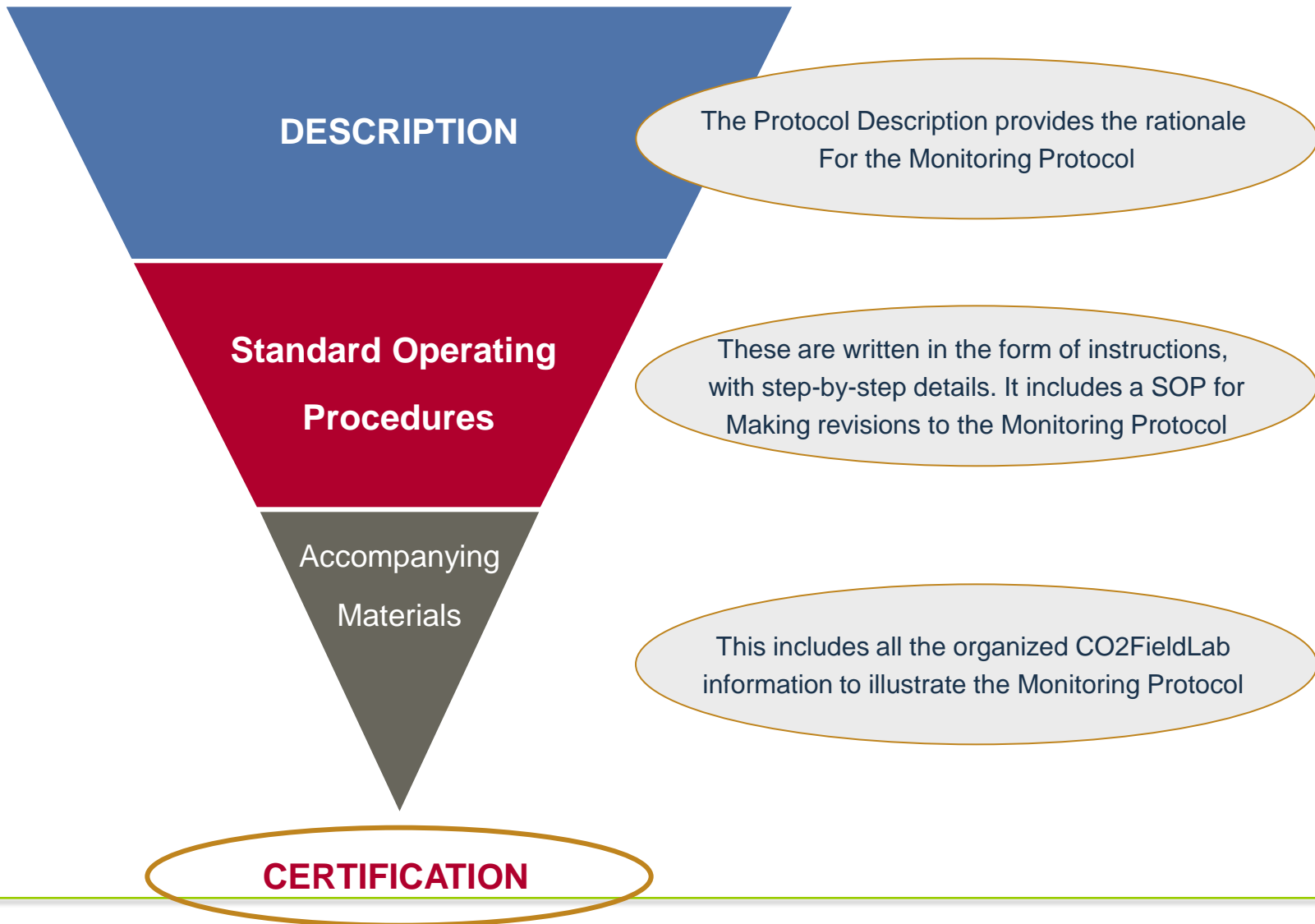
- Sensitivity of monitoring systems
- Monitoring systems and requirements
- Migration models
- Inform the public
- Input to monitoring protocol & certification scheme



Monitoring of CO₂

| Geophysical surface measurements | Monitoring well measurements | Soil / surface / atmospheric m. |
|---|---|---|
| <ul style="list-style-type: none"> • 4D ERT, SPT • EM, NMR • Passive seismics • Active seismics • Time-lapse ERT | <ul style="list-style-type: none"> • CO₂, isotopes, induction logging, pressure, temp. • Permanent electrode array, logging • Water sampling • Analysis of bacteria activity | <ul style="list-style-type: none"> • Soil gas • Surface gas: Laser gas analyser, accumulation chambers, atmospheric tower • Shallow wells: water sampling • Analysis of bacteria activity |
| <p>Modeling: History matching</p> | | |

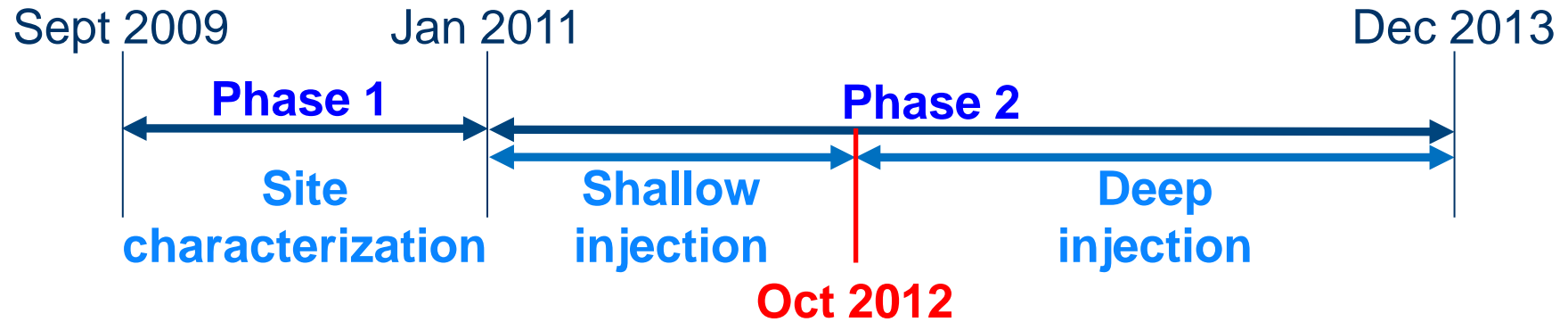
Protocol & Certification



Status

- Project approved by
 - EUROGIA+ board (June 2009)
 - French Ministry (July 2009)
 - Gassnova (CLIMIT Program) (September 2009)
 - CSLF recognition (October 2010)
- Phase 1 concluded (Sep. '09 – Jan.'11)
 - Site characterisation: Geological surveys successfully performed
 - June '10: Drilling and logging 300 m deep exploration well
 - Update models based on logged data
- Phase 2a (start May '11)
 - 2011: Shallow injection performed
 - VSP survey at 200 m & continuous sampling performed
 - Deep permeability test (planned Sept. 2012)

Phases - overview



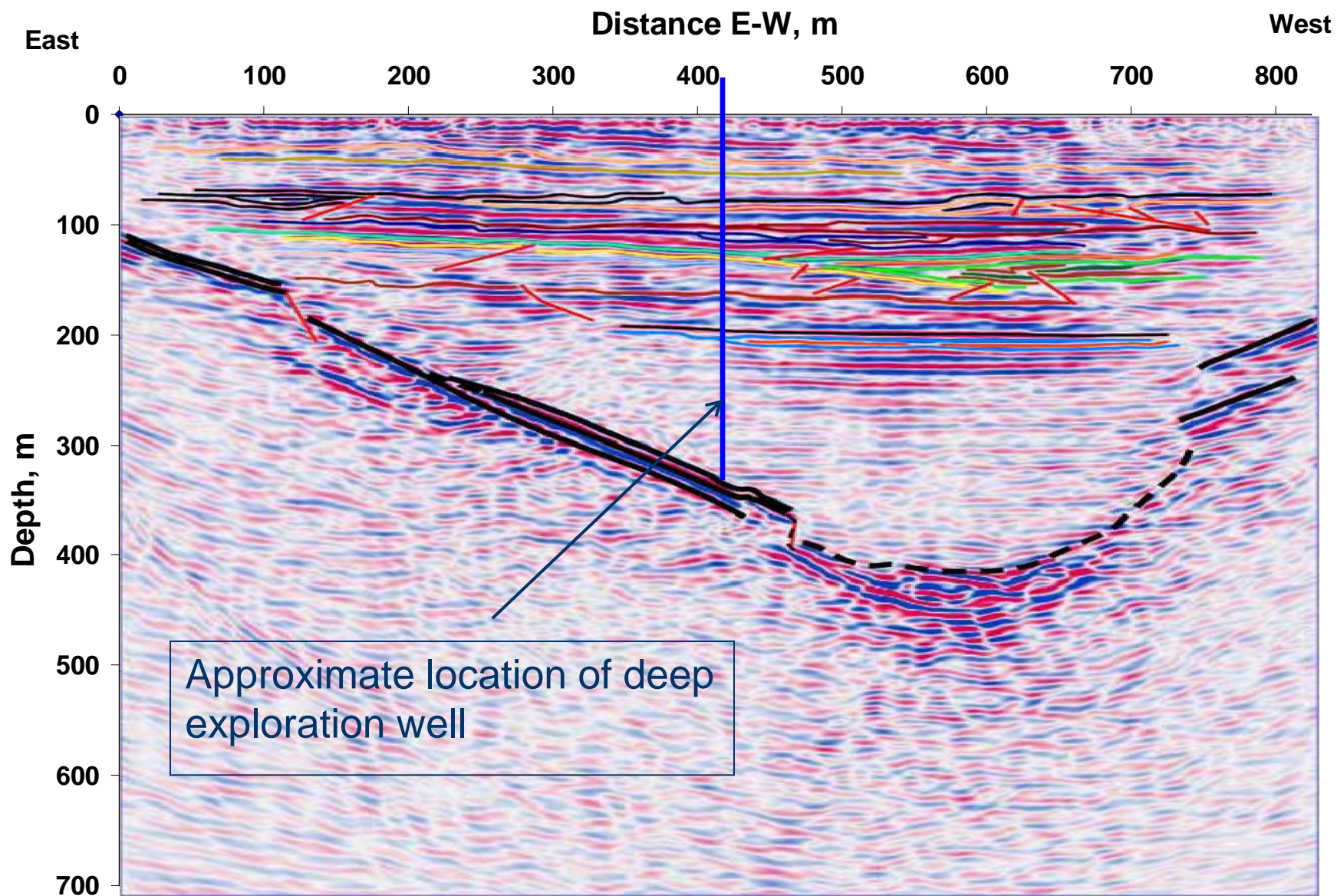
Seismic survey at -20°C November 2009



Drilling – June 2010



Seismic E-W profile of the Svelvik sand



Approximate location of deep exploration well

Injection of 1.7 tonne CO₂ at 20 m depth

September 7. -13. 2011



Injection well



Downhole instrumentation (0- 20 m)

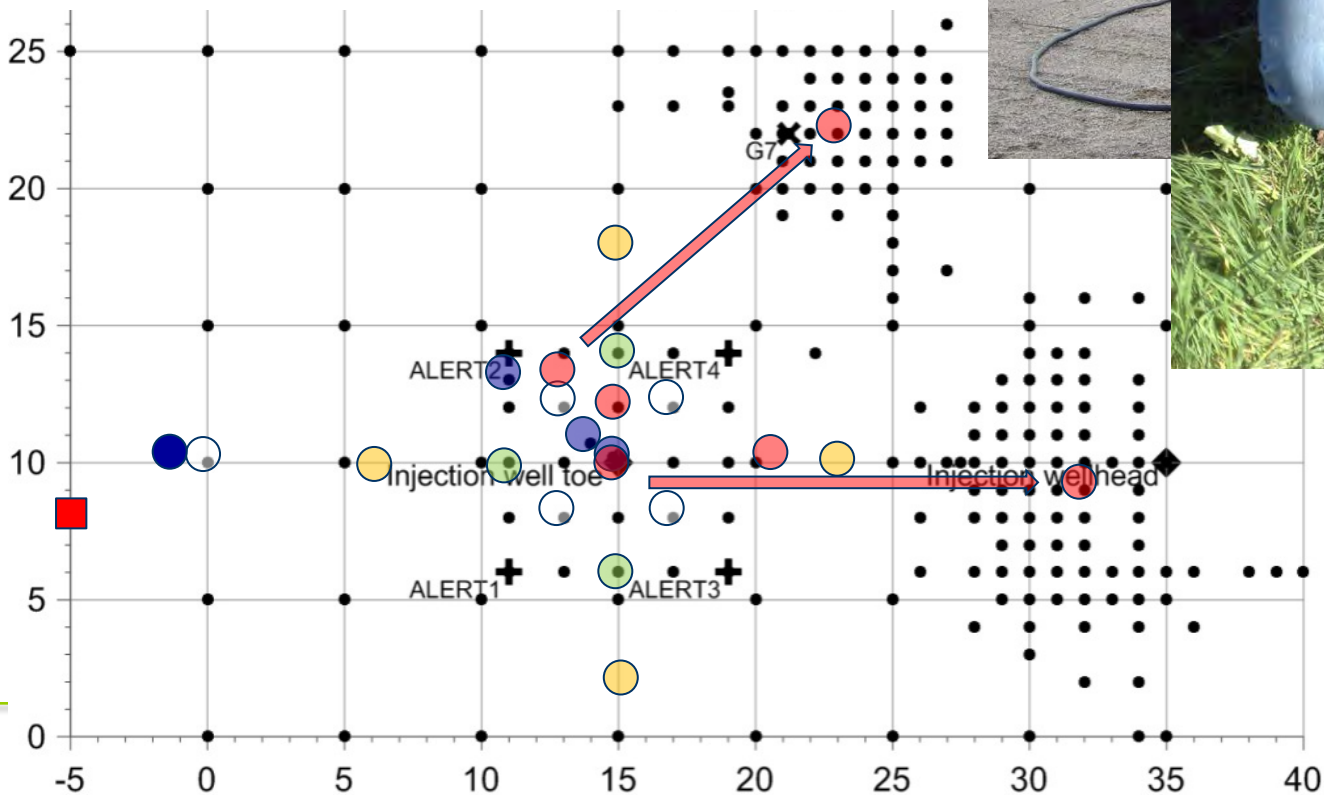
- ALERT (BGS) – Continuous
- Raman Spectrometer (Continuous)*
- Water/gas extractor (Intermittent)*
- GPR (BRGM) - Intermittent
- Schlumberger WestBay multipacker completion
- Downhole geophysical observatory (Imageau)
- PVC casing for repeat logging during injection (induction & sonic logging)
 - Continuous pressure monitoring
 - Continuous pore space saturation during and after injection

Instrumentation at (near) surface

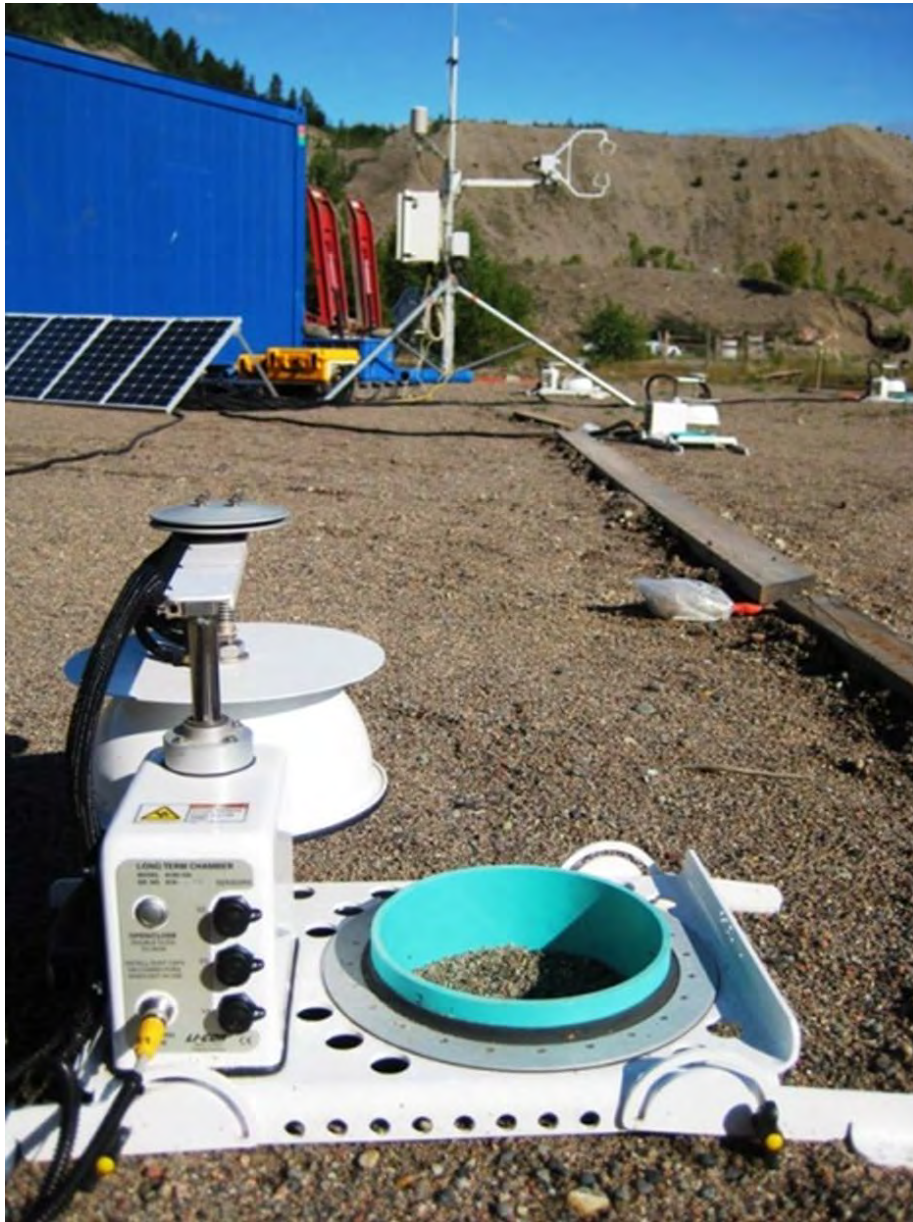
| Tool | Depth | Deployment | Mode |
|---|---------|-------------------|--------------|
| GAS | | | |
| Gas monitor station | c. 1 m | Fixed | Continuous |
| Flux station | Surface | Fixed | Continuous |
| Eddy covariance | Surface | Fixed | Continuous |
| Fixed probes | c. 1 m | Fixed | Intermittent |
| Mobile laser | Surface | Mobile | Intermittent |
| Soil gas | 0-1 m | Point (not fixed) | Intermittent |
| Flux | Surface | Point (not fixed) | Intermittent |
| *Licor or FTIR | 1m | Fixed | Continuous |
| Radon/ CO ₂ monitoring probes | 0.8m | Fixed | Continuous |
| CO ₂ , O ₂ and CH ₄ monitoring | 1m | Fixed/ mobile | Intermittent |
| Portable GC | Surface | Fixed | Intermittent |
| *Aerodyne isotopic analyser | 1m | Fixed | Continuous |
| WATER | | | |
| *Perisaltic pumps | Surface | Fixed | Intermittent |
| *Idronaut probe | Surface | Fixed | Intermittent |
| *Precision balance | Surface | Fixed | intermittent |

* Tubing connected to ALERT boreholes

Positioning of monitoring equipment



Some surface measurement equipment



Crosswell GPR time-lapse monitoring



Injection control manifold



KARBONDIOKSID



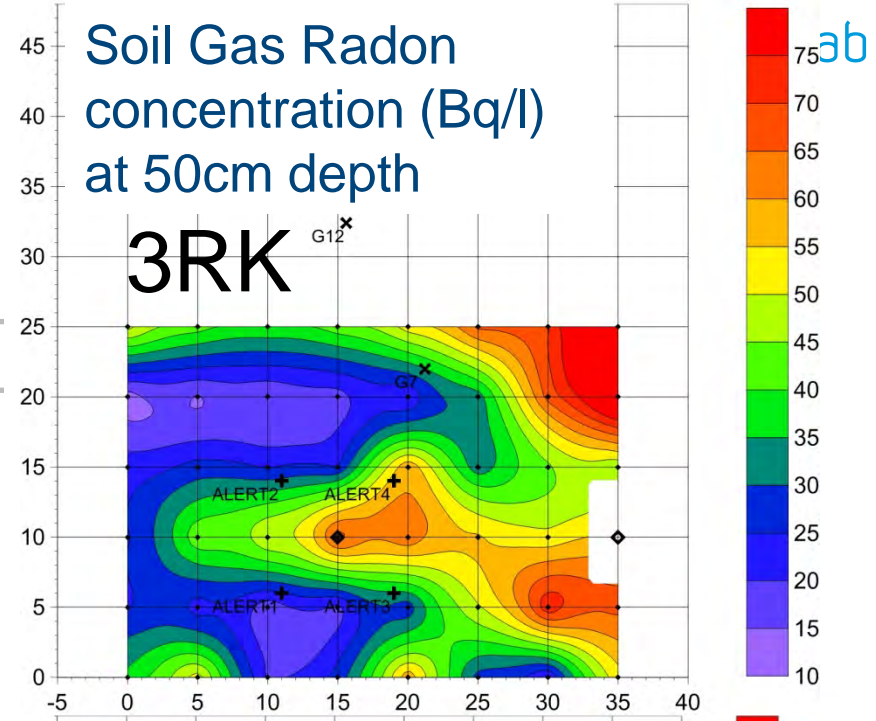
7/9/11 (Survey 3)

Baseline survey



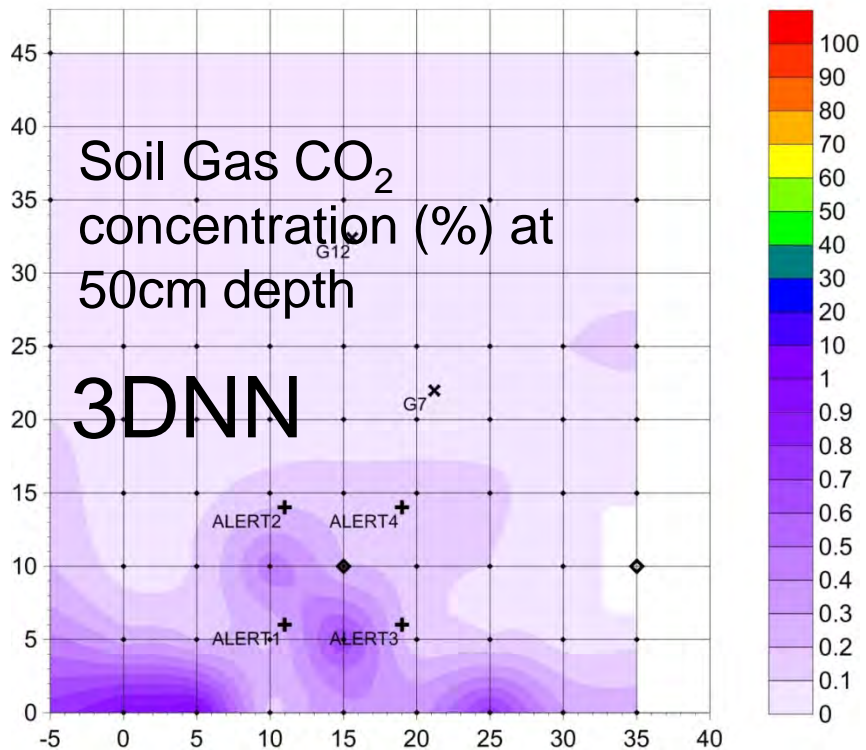
Soil Gas Radon concentration (Bq/l) at 50cm depth

3RK



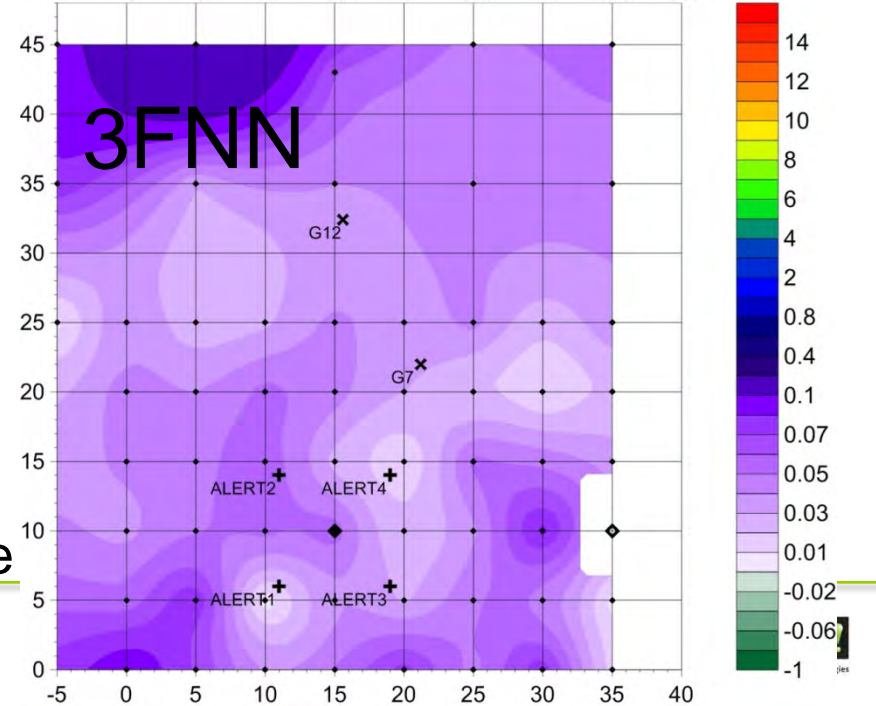
Soil Gas CO₂ concentration (%) at 50cm depth

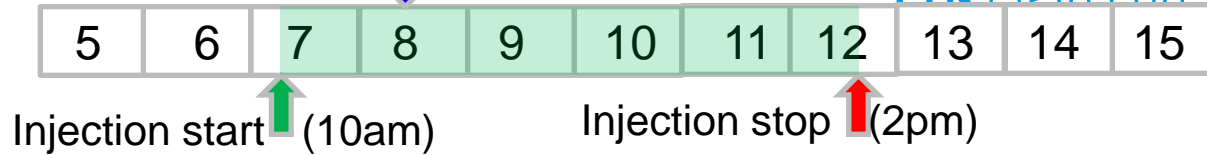
3DNN



Soil Gas CO₂ flux (mol/mq/day) at surface

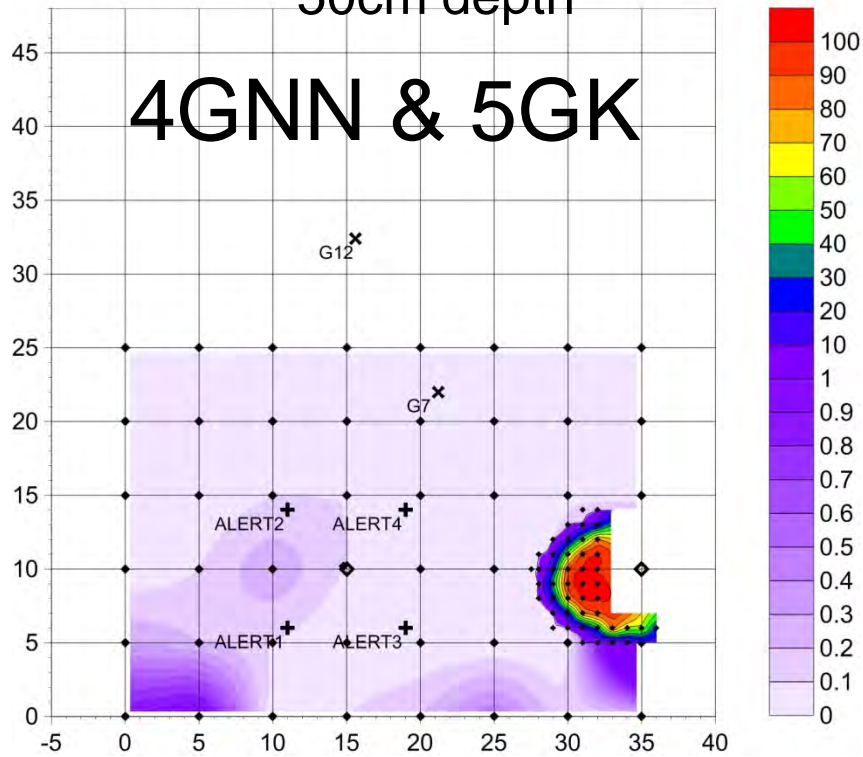
3FNN



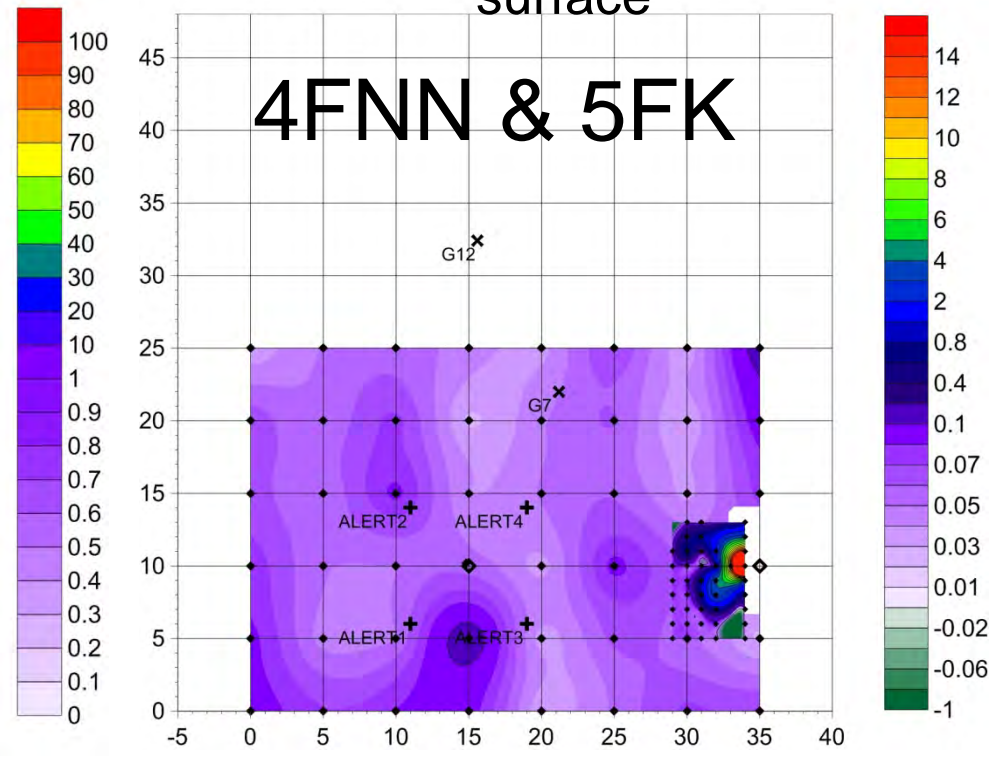


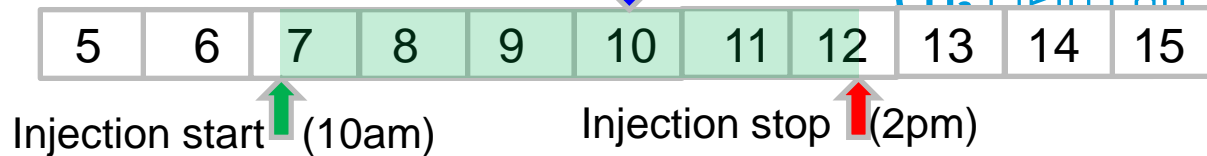
8/9/11 (Surveys 4 & 5)

Soil Gas CO₂ concentration (%) at
50cm depth



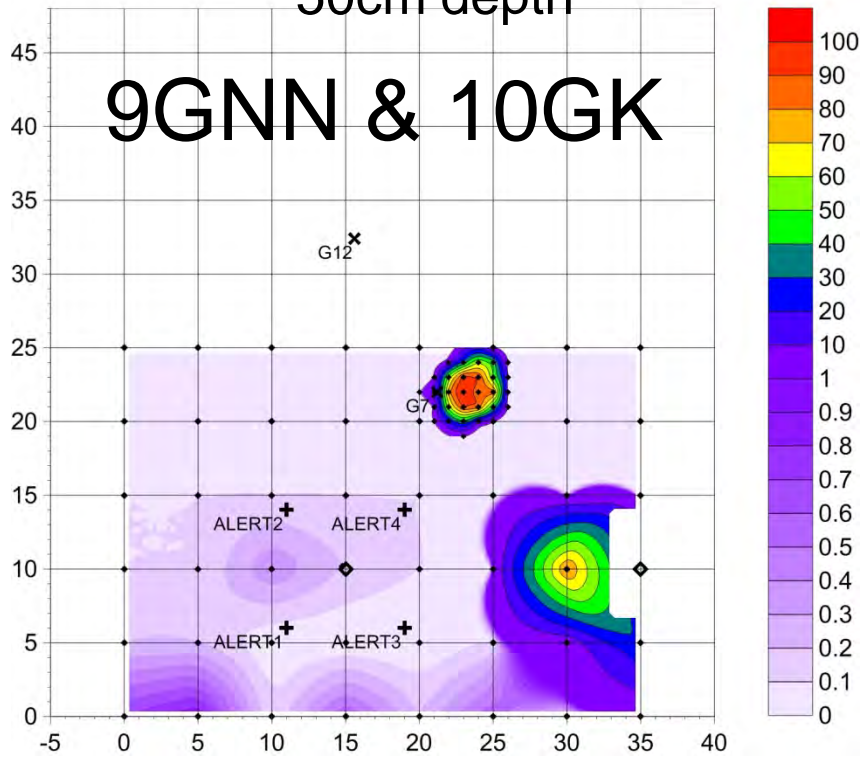
Soil Gas CO₂ flux (mol/mq/day) at
surface



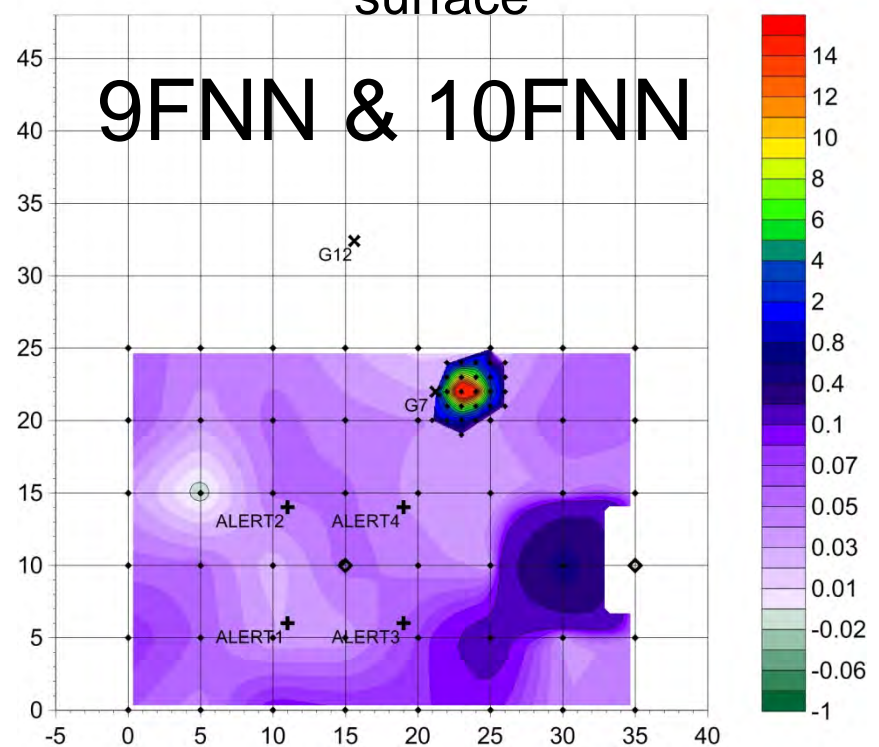


10/9/11 (Surveys 9 & 10)

Soil Gas CO₂ concentration (%) at
50cm depth



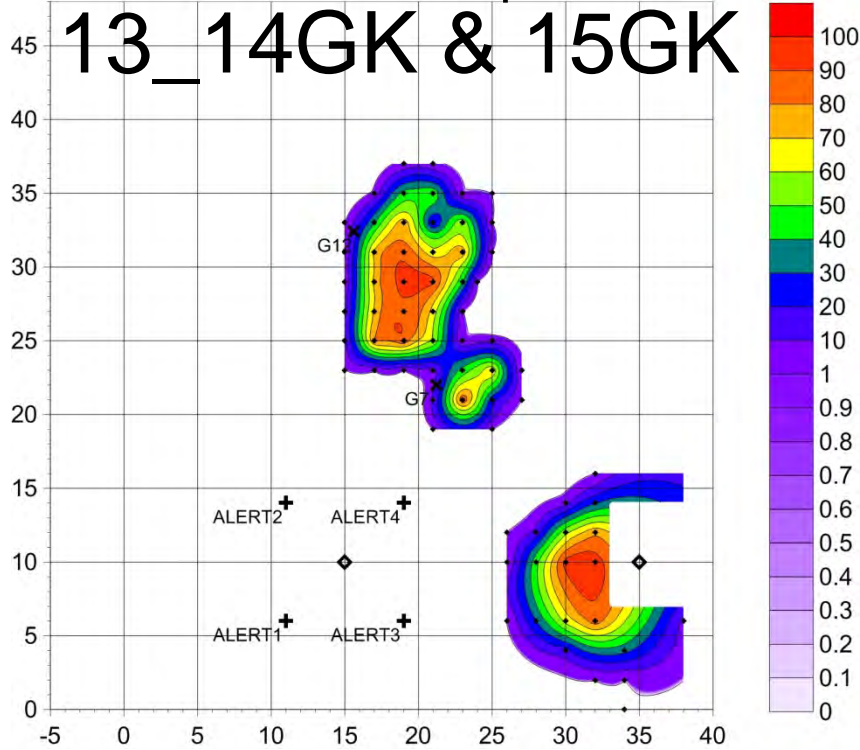
Soil Gas CO₂ flux (mol/mq/day) at
surface



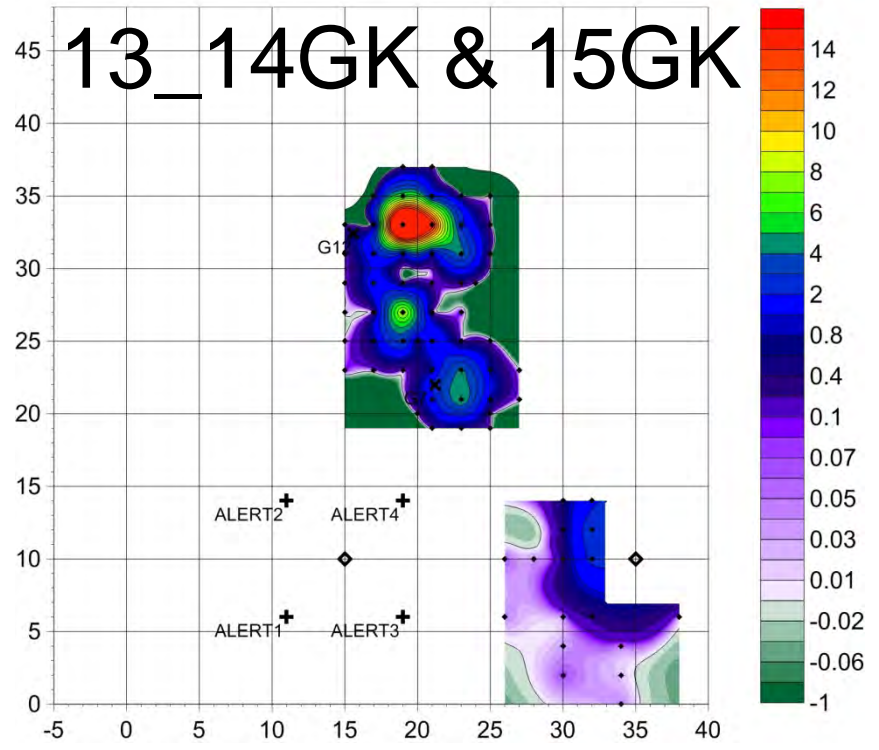


12/9/11 (Surveys 13,14,15)

Soil Gas CO₂ concentration (%) at 50cm depth



Soil Gas CO₂ flux (mol/mq/day) at surface





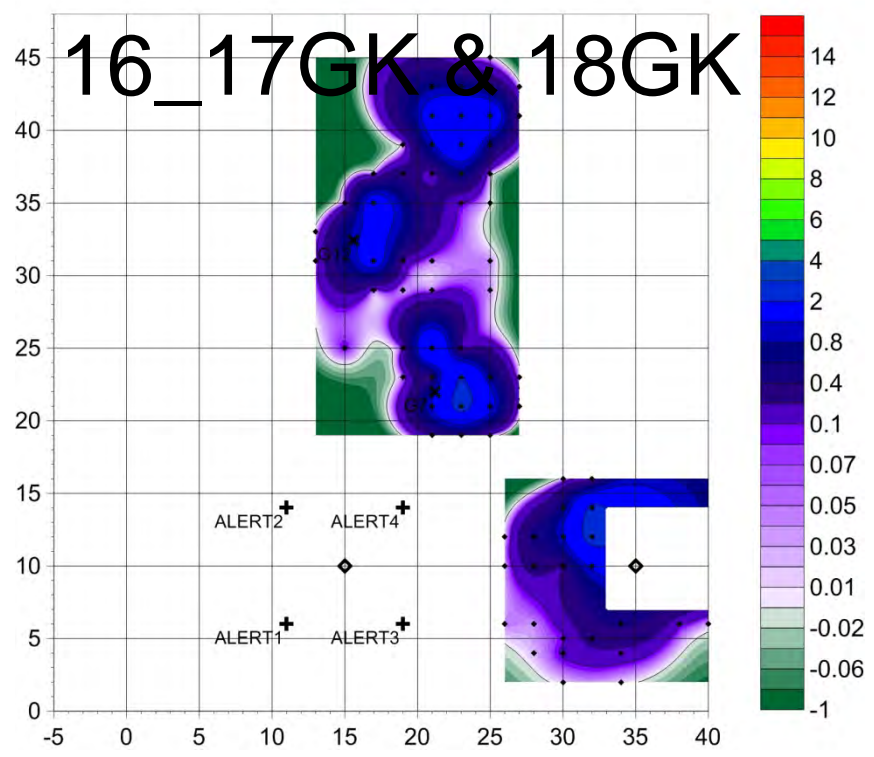
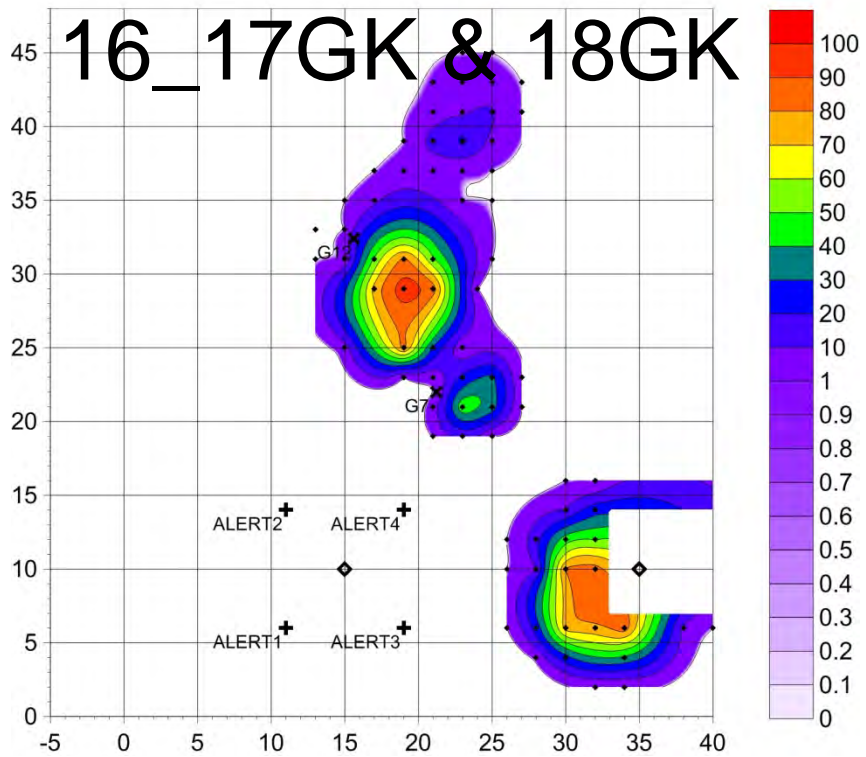
Injection start (10am)

Injection stop (2pm)

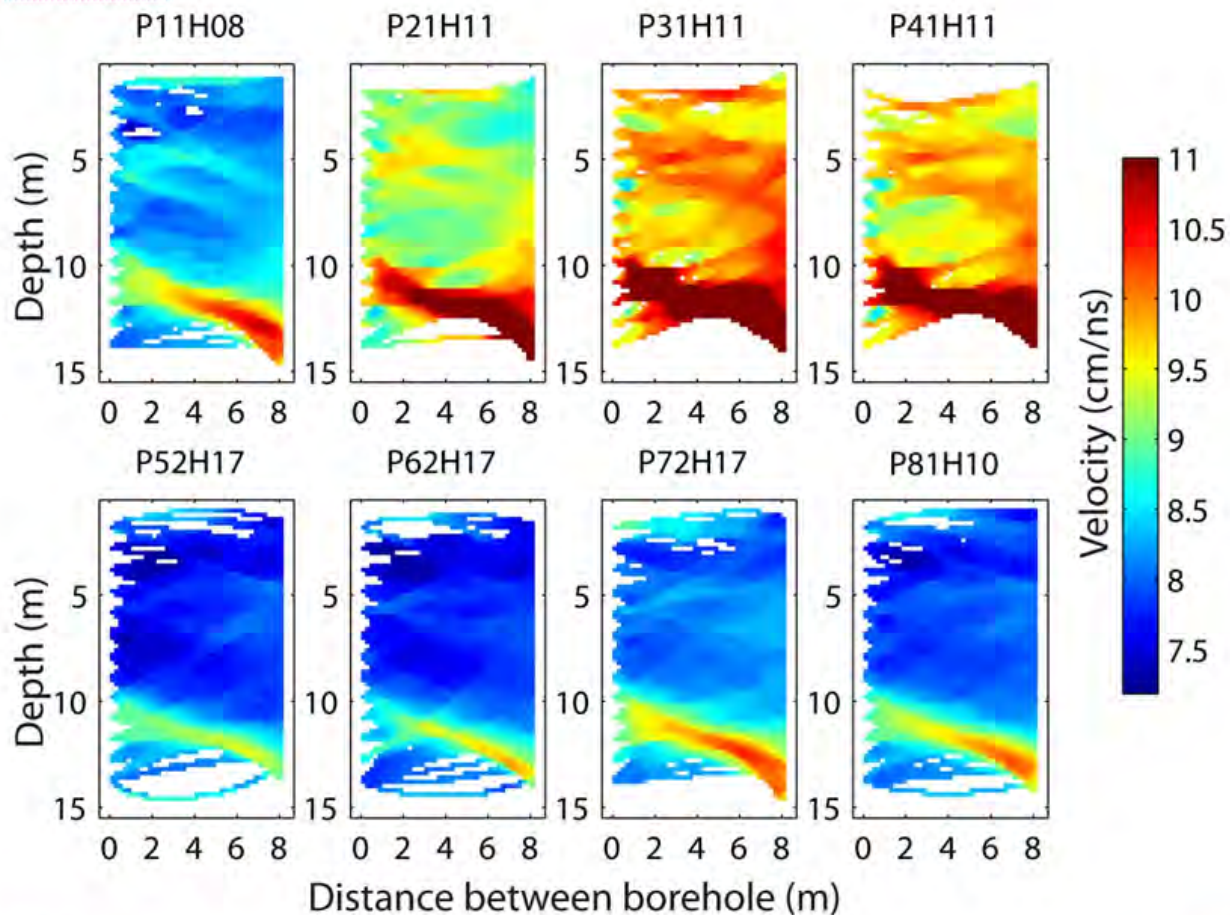
13/9/11 (Surveys 16,17,18)

Soil Gas CO₂ concentration (%) at 50cm depth

Soil Gas CO₂ flux (mol/mq/day) at surface



Crosswell GPR Time-lapse monitoring Field Results



Main result

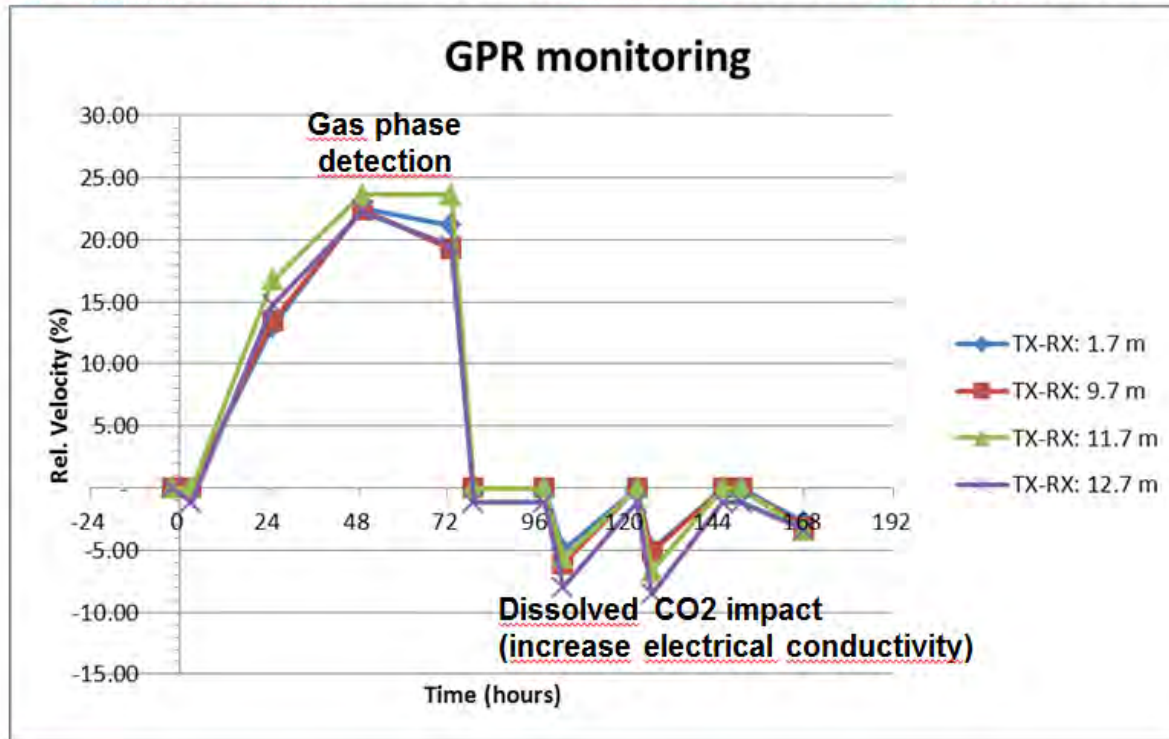
- first a 20% increase of velocity: detection of gas phase
- After 3 days of injection, abrupt return to a constant value, ~ -5% than initial conditions: detection of electrical conductivity increase.



Crosswell GPR - ZOP results

Velocity variation vs time

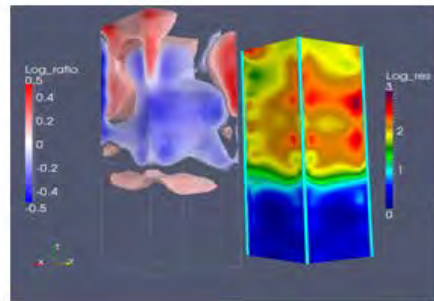
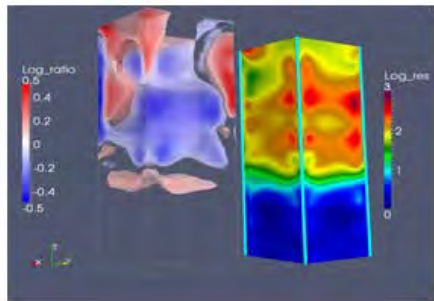
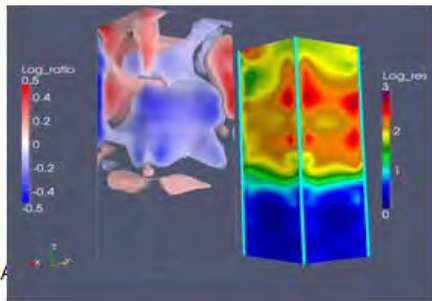
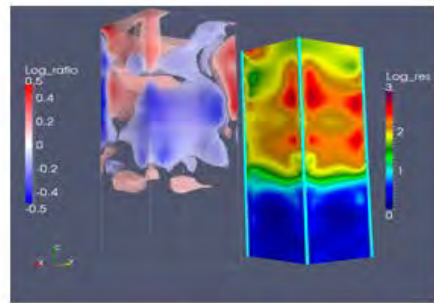
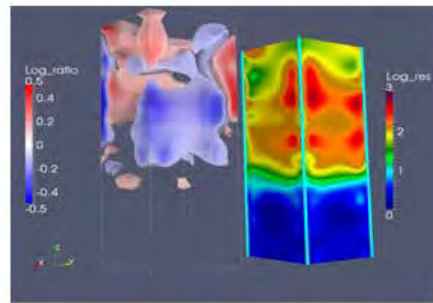
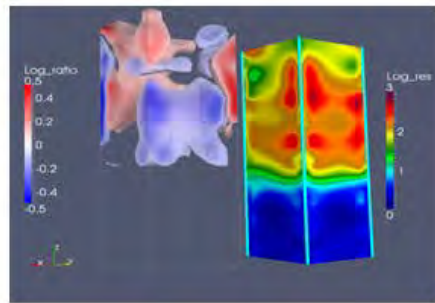
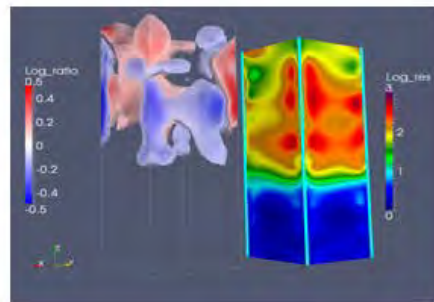
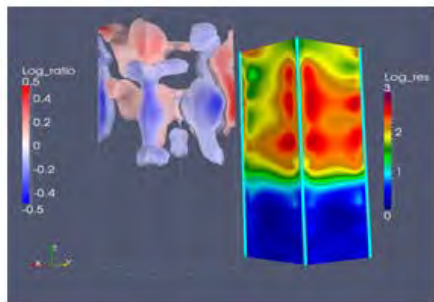
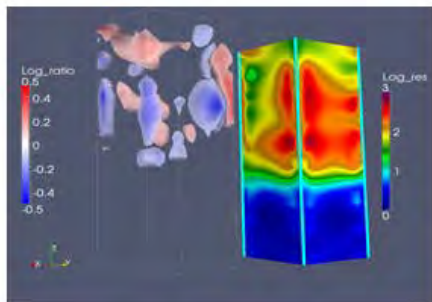
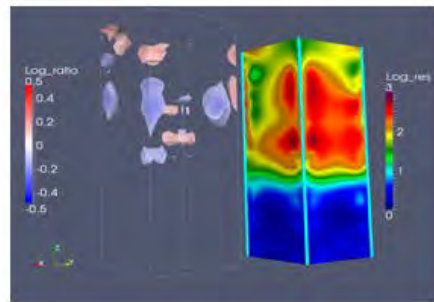
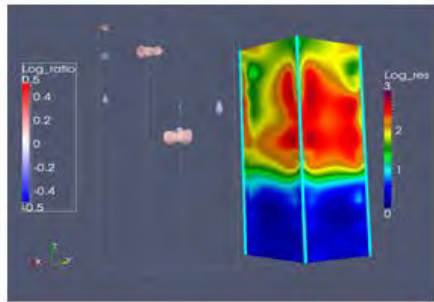
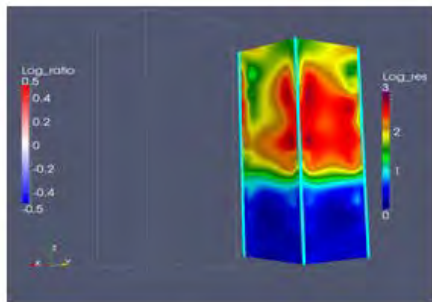
At 4 depths, the travel time has been converted to relative velocity variations



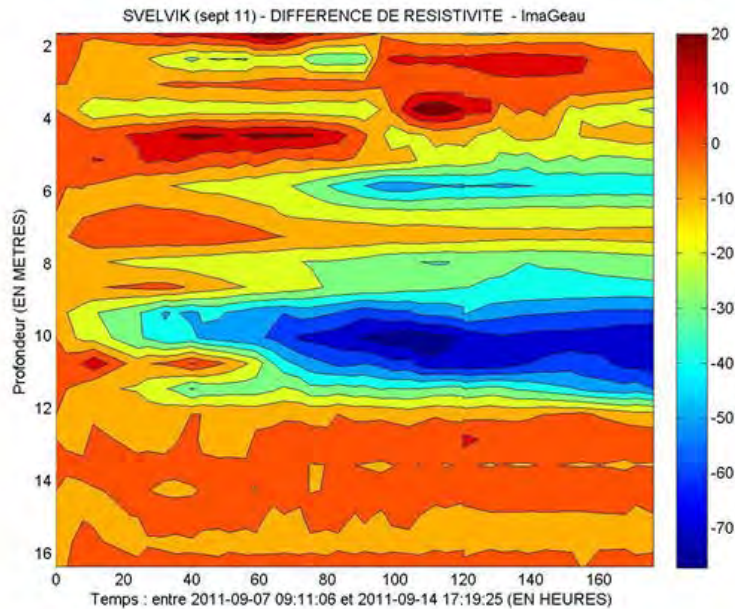
Main result

- first a 20% increase of velocity: detection of gas phase
- After 3 days of injection, abrupt return to a constant value, ~ -5% than initial conditions: detection of electrical conductivity increase.

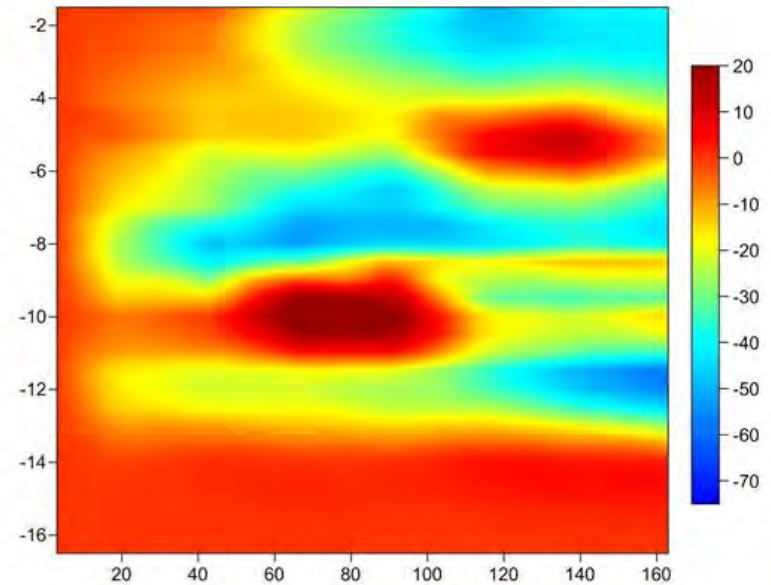




Comparison between ALERT and imaGeau data (Evolution of resistivity with depth over time)



imaGeau
Time [hrs]



ALERT
Time [hrs]

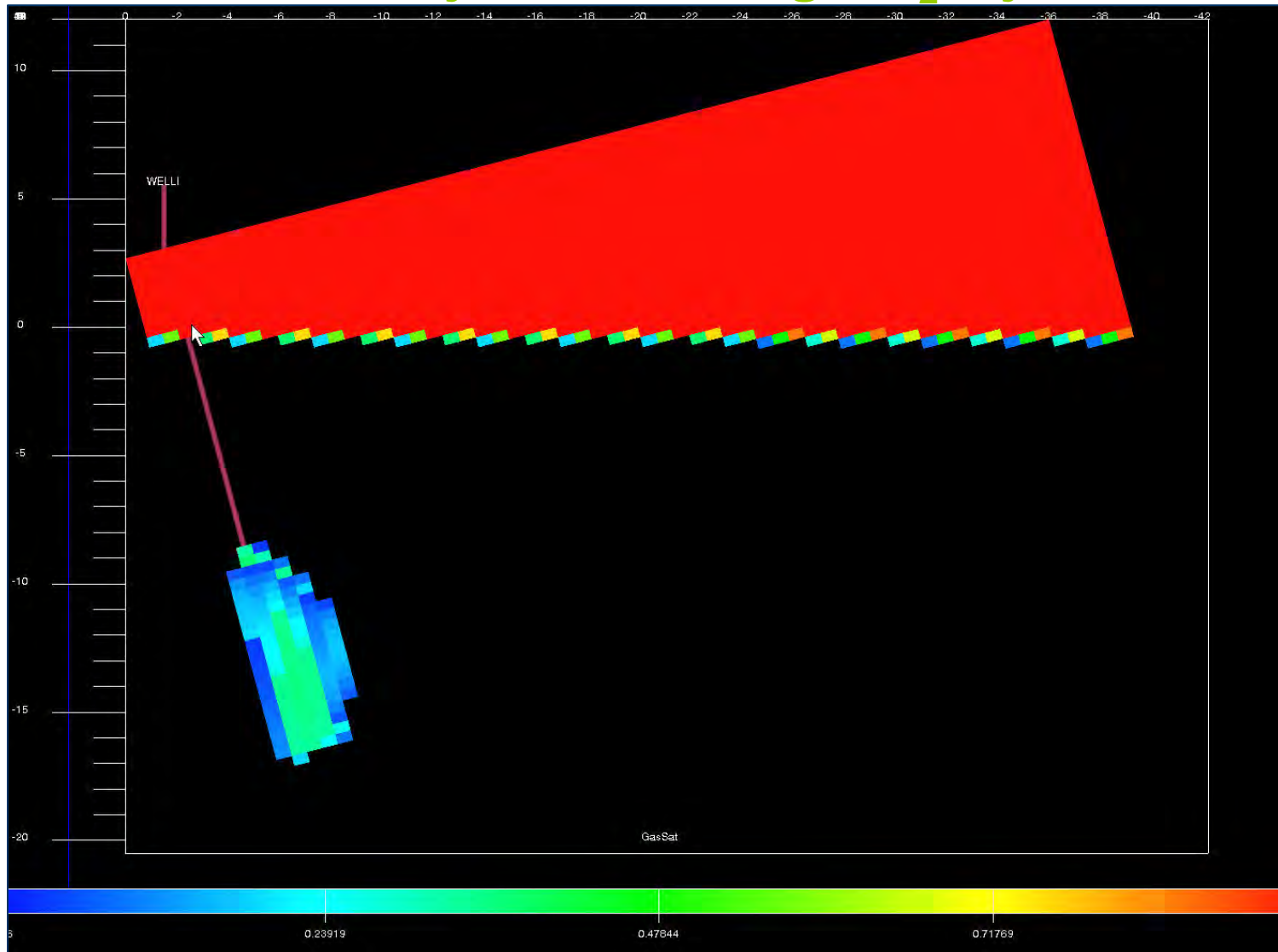
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High permeability model

28 hours of injection, 190 kg CO₂ injected

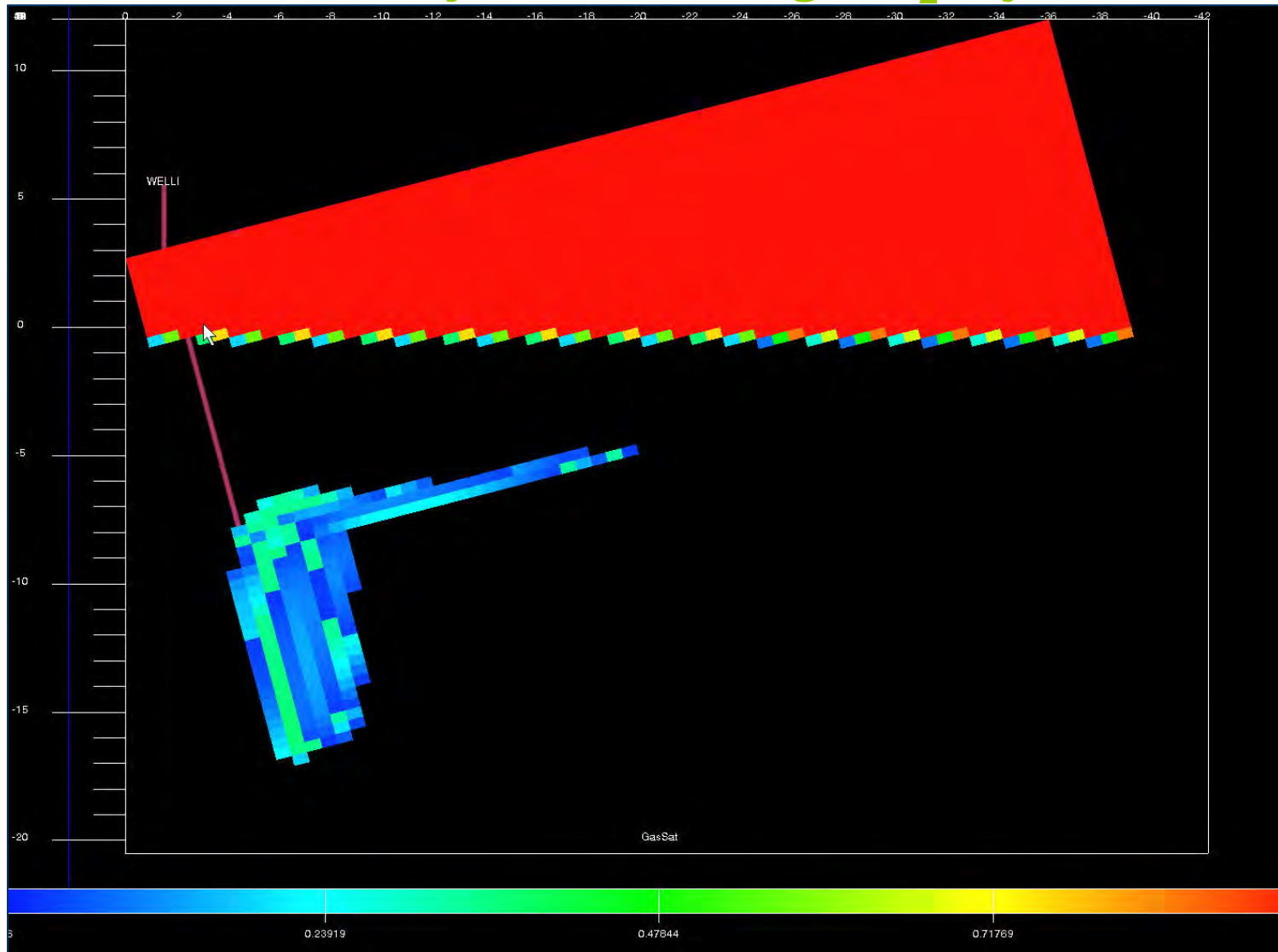
CO₂ Field Lab



High permeability model

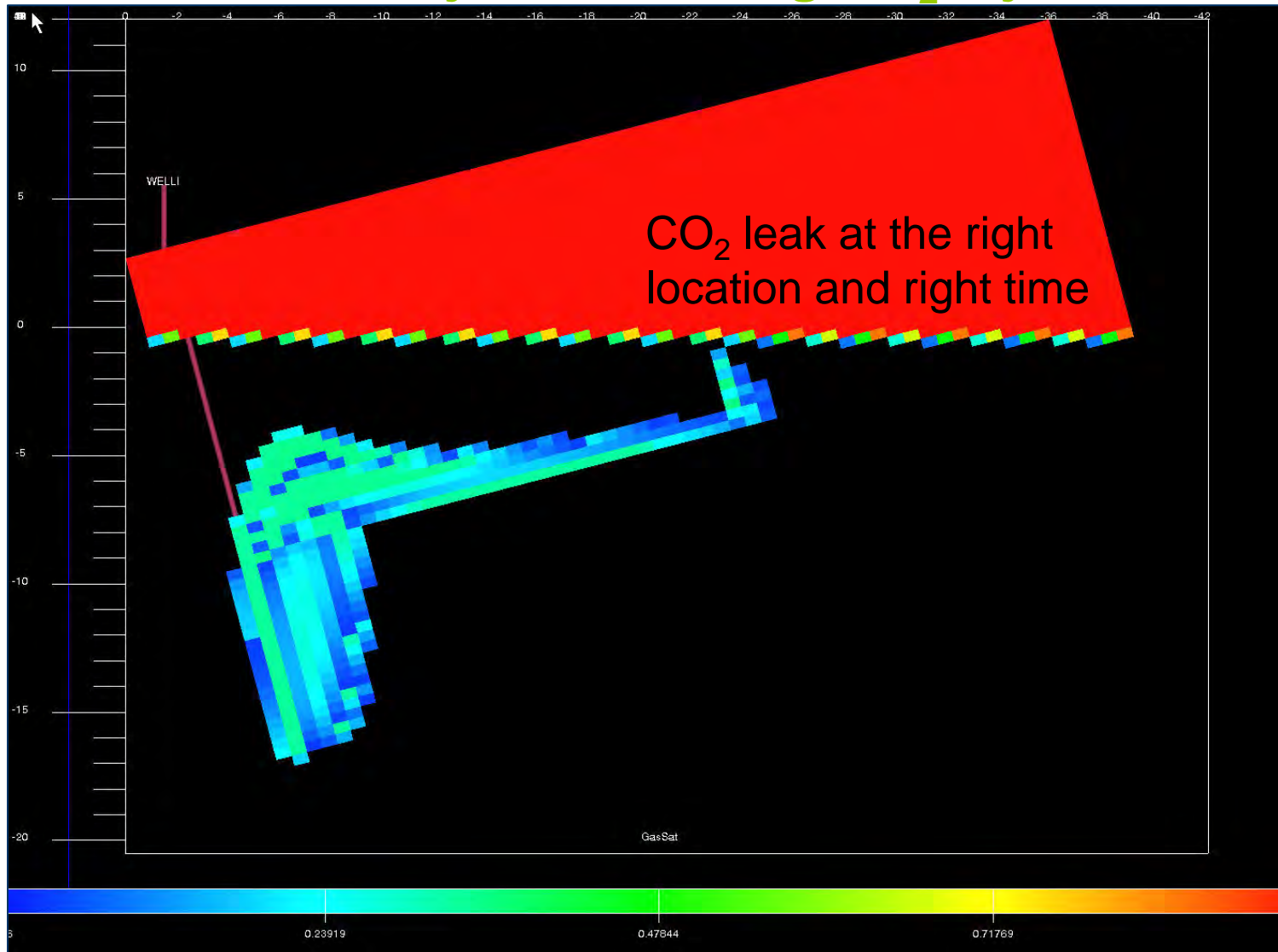
54 hours of injection, 464 kg CO₂ injected

CO₂ Field Lab



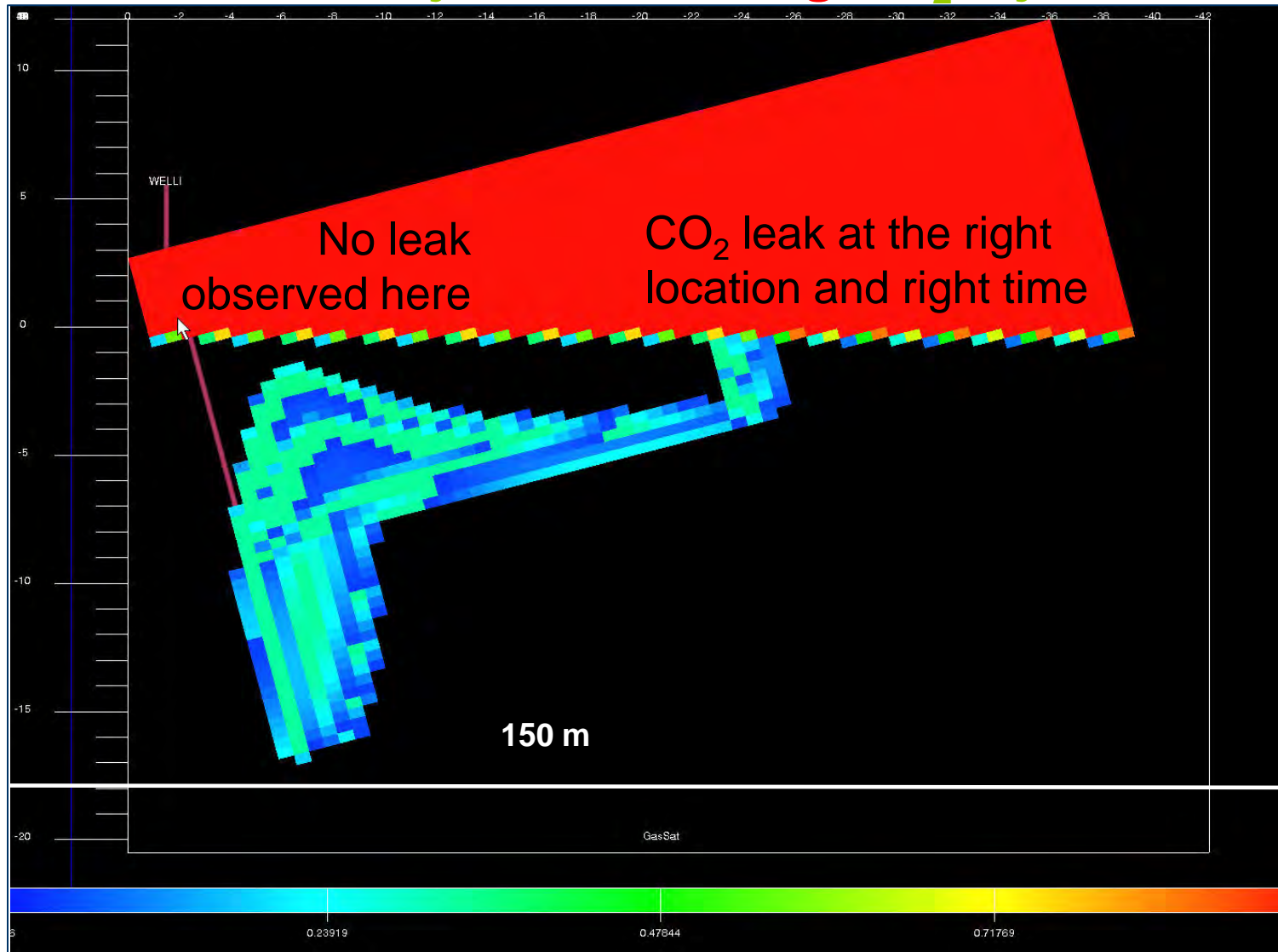
High permeability model

74 hours of injection, 840 kg CO₂ injected



High permeability model

96 hours of injection, 1166 kg CO₂ injected



SP7: Dissemination

External Communications

➤ Exposure in media

- Newspaper articles
- Norwegian national TV:
- Oil & energy minister's site visit



➤ Personal contact

- Public hearings (SINTEF, UiO)



- Direct mail about first survey

➤ Future exposure

- Press book (BV)
- Scientific publications
- Press releases

Conclusion

- Part of the monitoring system missed the plume
 - Site characterization is very important
 - Sufficient areal coverage is needed
- A diverse monitoring system gives complementary information
- The CO₂ Field Lab test site is an excellent environment to test and compare technologies under controlled conditions
- More R&D and field testing is needed to determine the optimum instrumentation and sensitivity of a monitoring system

Acknowledgments

CO2FieldLab open for cooperation and industrial support

Project manager: Maria.Barrio@sintef.no

www.sintef.no/CO2FieldLab

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- CLIMIT via Gassnova SF (NO)
- DGCIS, Direction générale de la compétitivité, de l'industrie et des services (FR)