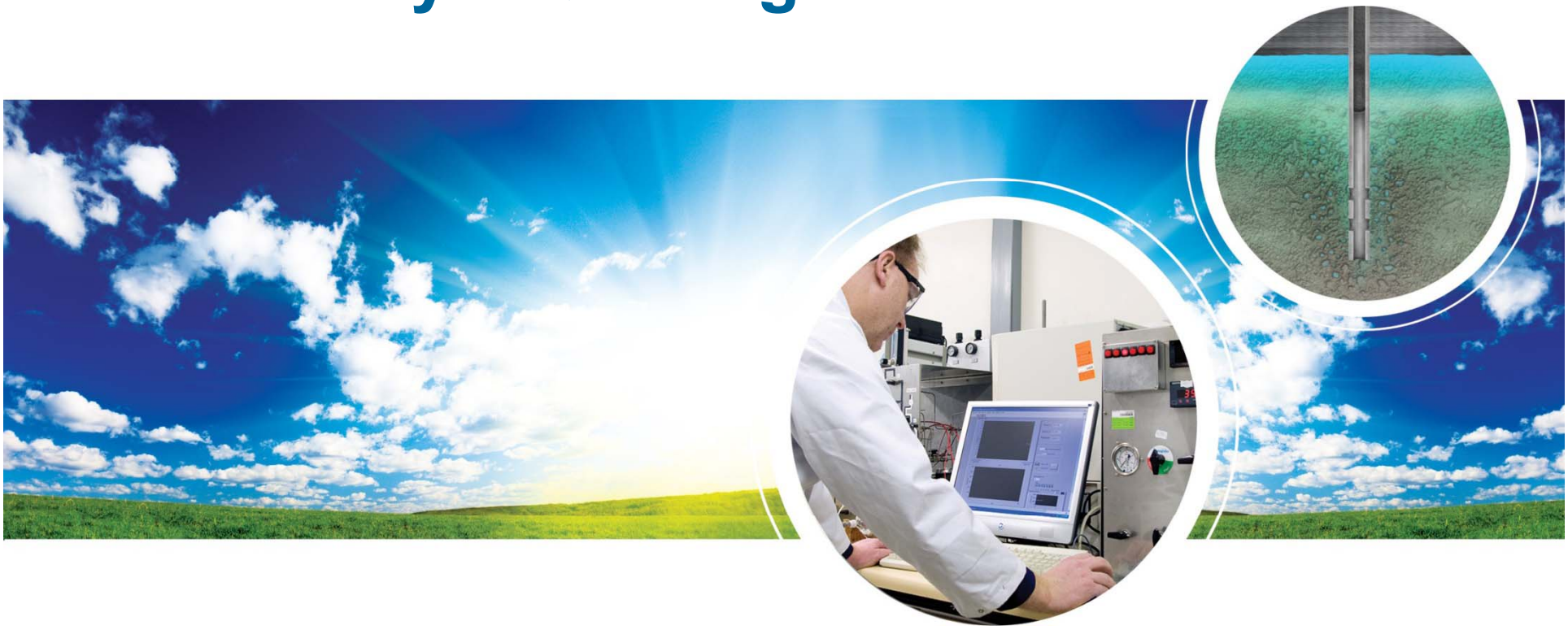
The Otway M&V Programme



Charles Jenkins
CSIRO and CO2CRC
and the Otway M&V team

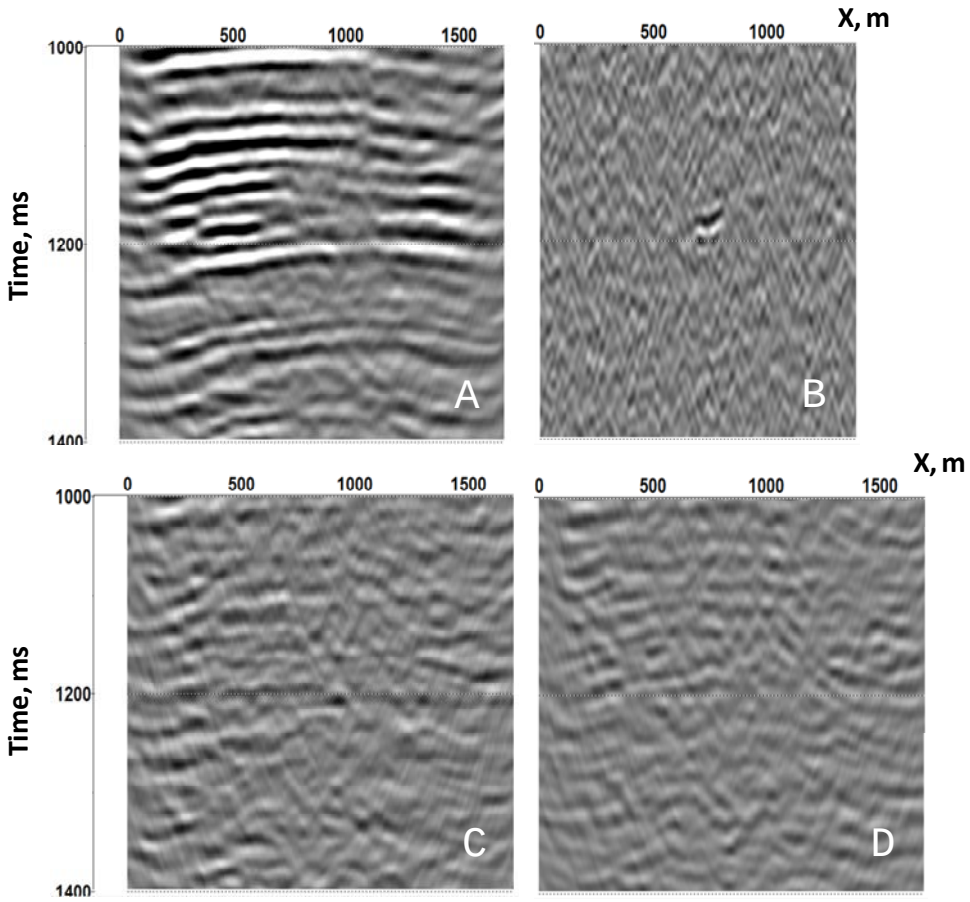
Elements

- Seismic
- Microseismic
- Fluid sampling
- Ground water
- Soil gas
- Atmospheric
- Pressure

Results - seismic

- **Nothing detectable above noise at reservoir level**
- **Consistent with all forward models**
- **Modelling of hypothetical leaks in overlying aquifer suggests point leak of ~5000 tonnes should be detectable**

Results - seismic



Results – fluid sampling

- **Sampling at three levels in reservoir – breakthrough of CO_2 and tracer at all three**
- **Consistent with the range of forward models dictated by reservoir and rock physics uncertainties**

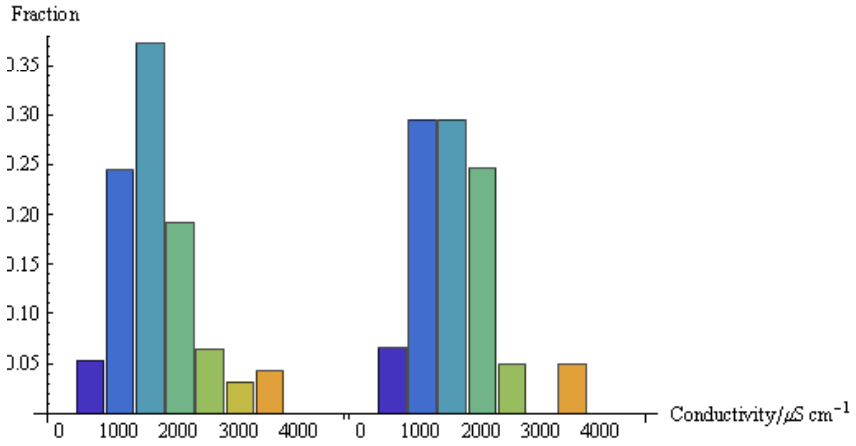
Results – fluid sampling

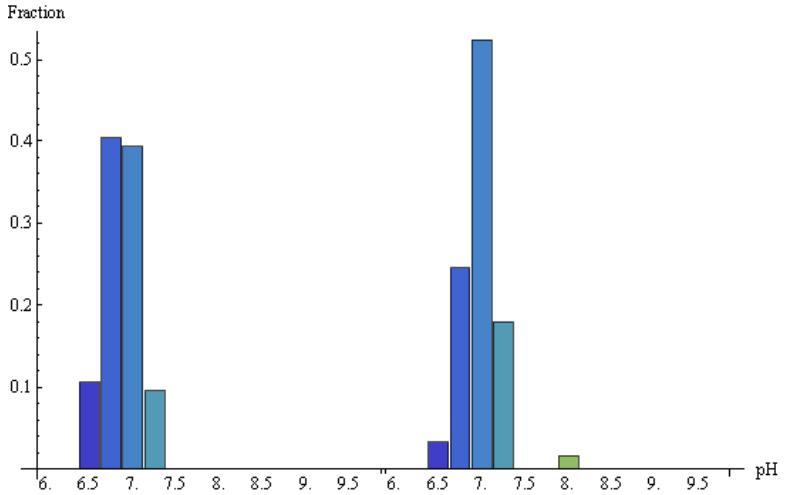
Days after injection

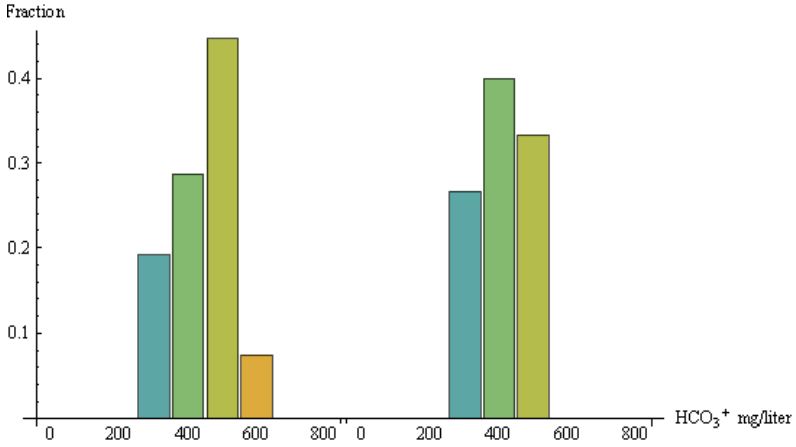
Results - groundwater

- **Comprehensive programme in shallow, heavily-used aquifer**
- **No changes above spatial and temporal variability in key indicators (pH, EC, HCO^{+})**
- **Tracers below detection limit**

Results - groundwater



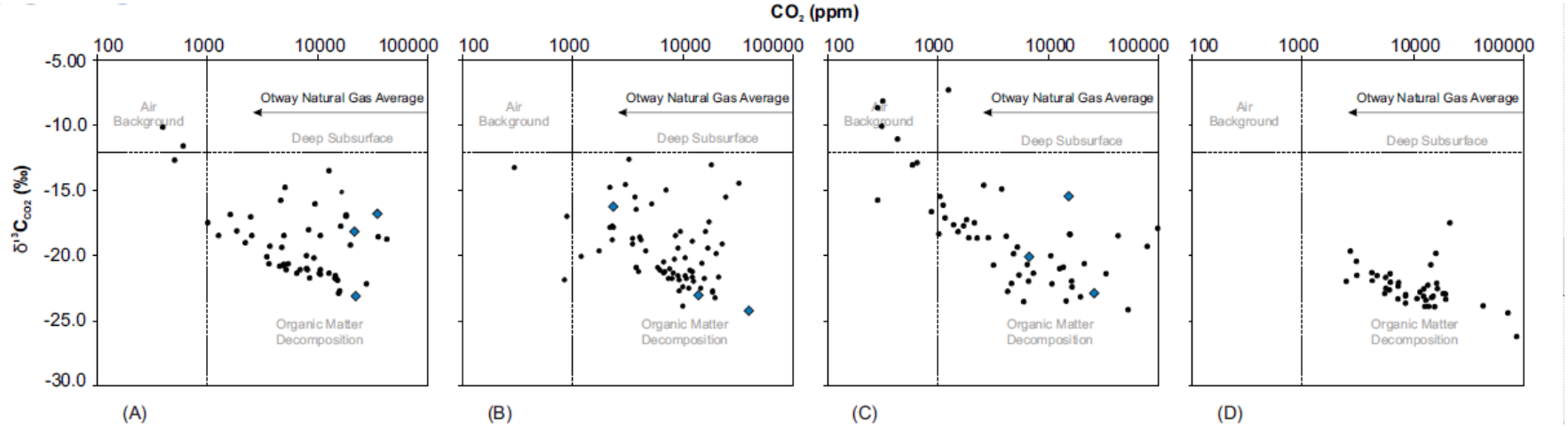




Results – soil gas

- **Matrix of locations now repeated yearly with good results since summer 2008**
- **Wide range in concentrations of CO_2 but repeatable correlation with $\delta^{13}CO_2$**
- **Tracers not yet examined**

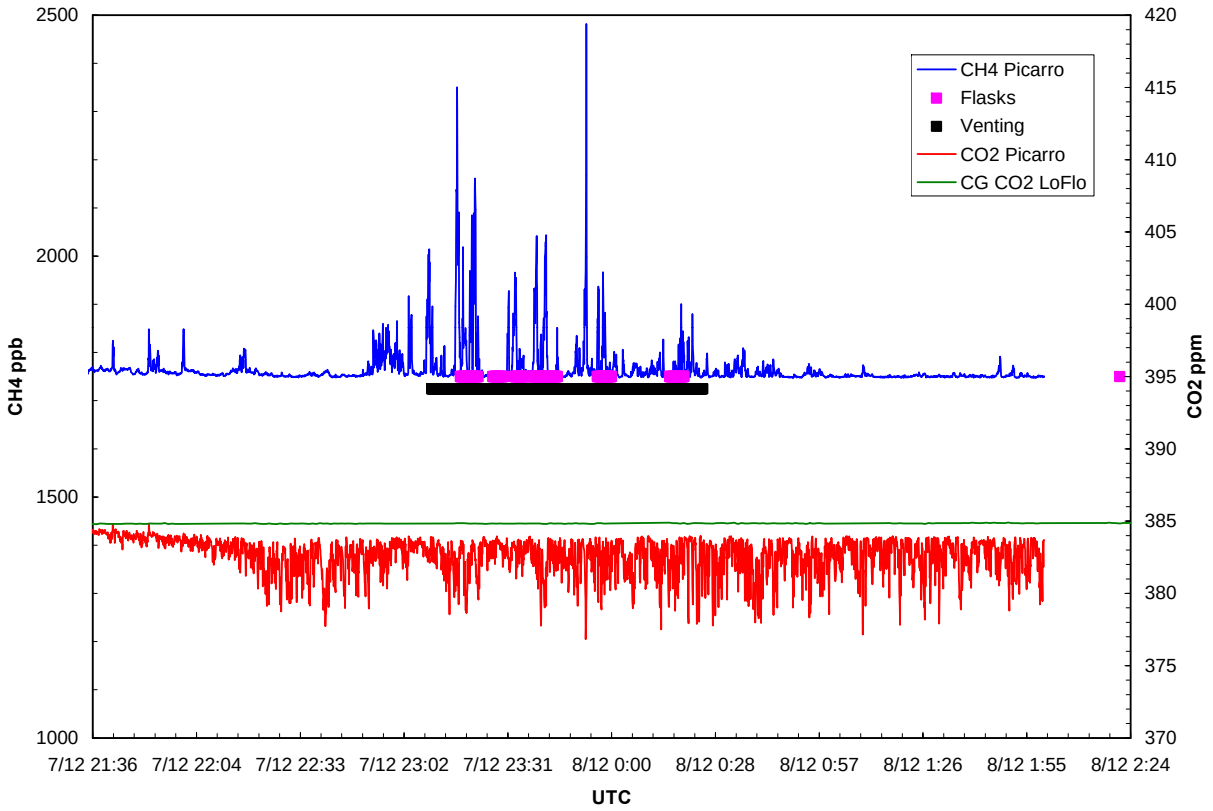
Results- soil gas



Results - atmospheric

- 3 ½ years of near-continuous CO_2 concentration and flux at one spot; latterly continuous CH_4 and $\delta^{13}CO_2$
- Two “releases” detected – drilling rig, and venting during fluid sampling – sensitive at ~1000 tonne p.a. level

Results - atmospheric



Results...

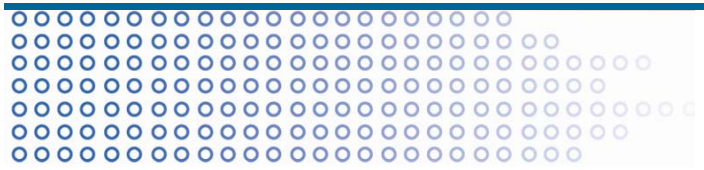
- **Deep microseismic array failed: single shallow seismometer (backup) shows steady but low levels of activity**
- **Monitoring well downhole pressure sensors failed; only downhole injection pressure available. Useful calibrator for bulk permeability.**

Interpretation/integration

- **What is the *question*, to which these results are the *answer*?**
- **Some common versions:**
  - "Is there a leak?"
  - "Is there a leak into the atmosphere that affects climate abatement?"
  - "Is there a leak that affects me, here, now?"

“Is there a leak?”

- **Too vague, because**
  - A site is chosen to be secure; this means no stand-out leak mechanisms; so many low-probability possibilities to evaluate. Impractical.
  - These possibilities are also poorly understood, except for being unlikely; so not a useful guide to *interpretation* (inversion)
  - ...or indeed to *design* of a M&V programme
- **Sensitivity to unqualified “leaks” is not a well defined notion.**



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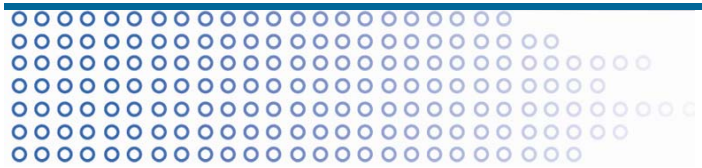
"Is there a leak?" continued...

- **Useful questions have to be tightly defined, e.g. is there a leakage up the wellbore/annulus?**
- **Typically the consequent investigation would be a cascade, e.g.**
  - Do we see excess CO_2 in soil gas near the well?
  - Are there pressure anomalies?
  - Obtain relevant ground water data, if possible.
  - Obtain well logs, if possible.
  - Etc.
- **The Paaratte seismic modelling is an example of an answer to a tightly defined question; but a tightly defined question does not answer all the possible questions!**



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“Is there a leak into the atmosphere...?”

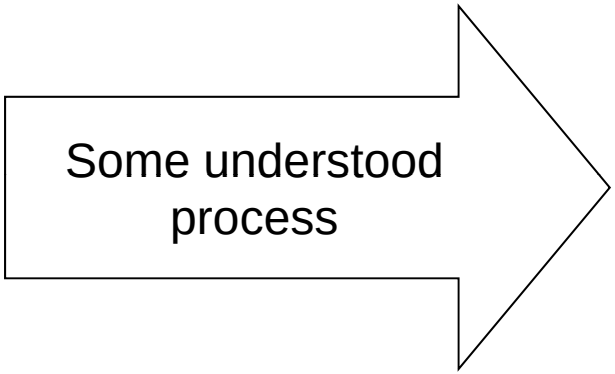
- ***If* CO_2 enters the atmosphere (mechanism undefined) we can quantify it if**
  - there is enough of it;
  - the leak site is near enough to a sensor;
  - it is upwind of a sensor ☺
  - it is not spatially too diffuse.
- **This is a well-posed, important, but quite restricted, question.**

“Is there a leak that affects me, here, now?”

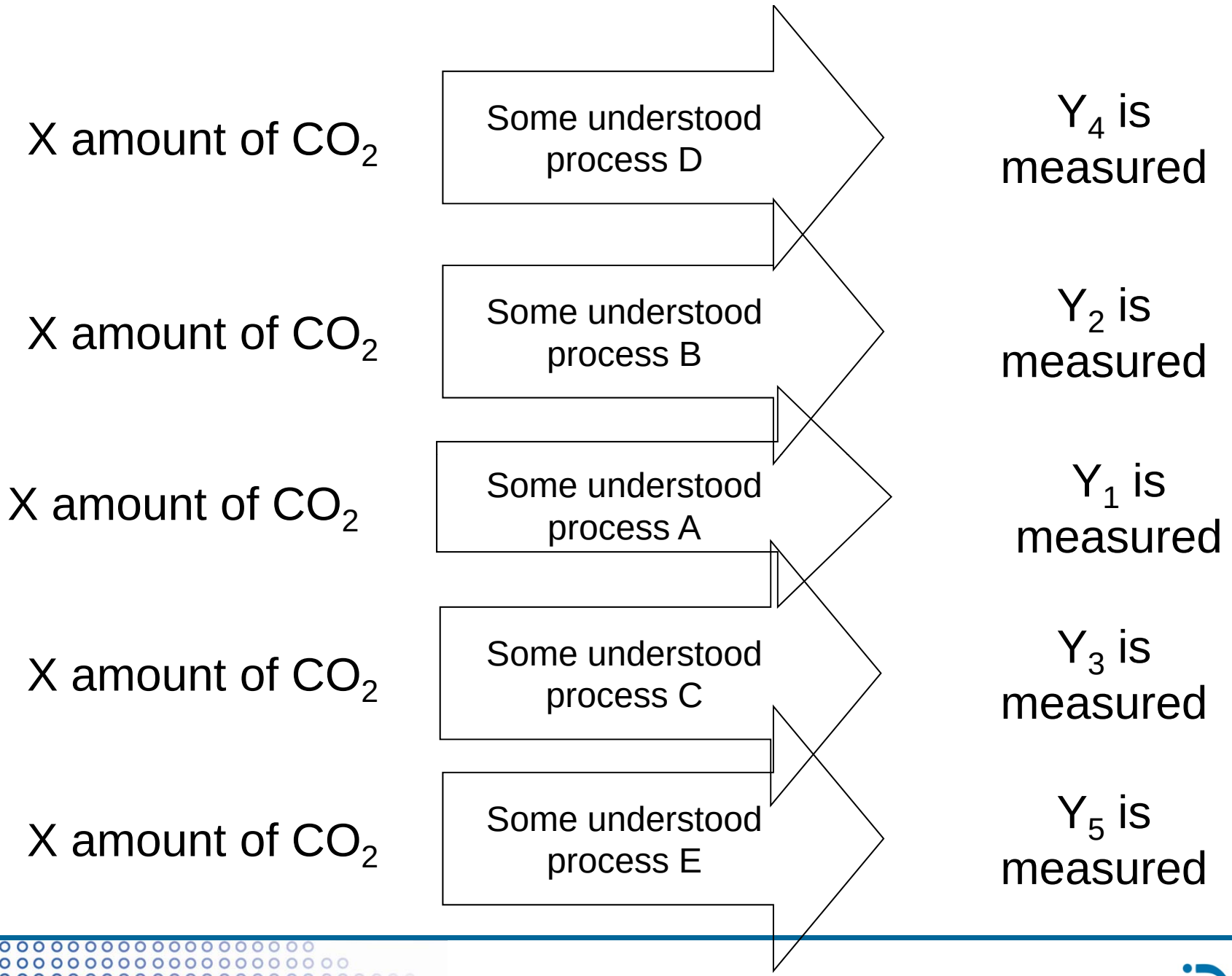
- **Soil gas and (shallow) groundwater monitoring answers this question**
- **The relevant metrics are**
  - differences pre- vs. post injection data; compared to
  - the *internal* (spatial, temporal) level of variability in the data.
- **These measurements are, in principle, “leak detectors” but their sensitivity is ill-defined; hence the emphasis on “no change within statistical variability”**

What about “sensitivity”?

X amount of CO_2



Y is measured


X amount of CO_2
Some understood process D
Y_4 is measured
X amount of CO_2
Some understood process B
Y_2 is measured
X amount of CO_2
Some understood process A
Y_1 is measured
X amount of CO_2
Some understood process C
Y_3 is measured
X amount of CO_2
Some understood process E
Y_5 is measured

Conclusions

- **Otway teaches us (or, at least, me ☺) that**
  - A M&V programme should be focussed on quite specific risks. A broad programme is difficult to interpret and may give rise to false alarms. Stand by your risk assessment!
  - Having a *plan* (ability to deploy an escalating set of investigatory techniques, as necessary) is as important as the *programme* (ability to pick up the clues that start this escalation).
  - Measurements to reassure stakeholders will be needed; but they should be for well-specified purposes, with a plan for interpretation laid out in advance.

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