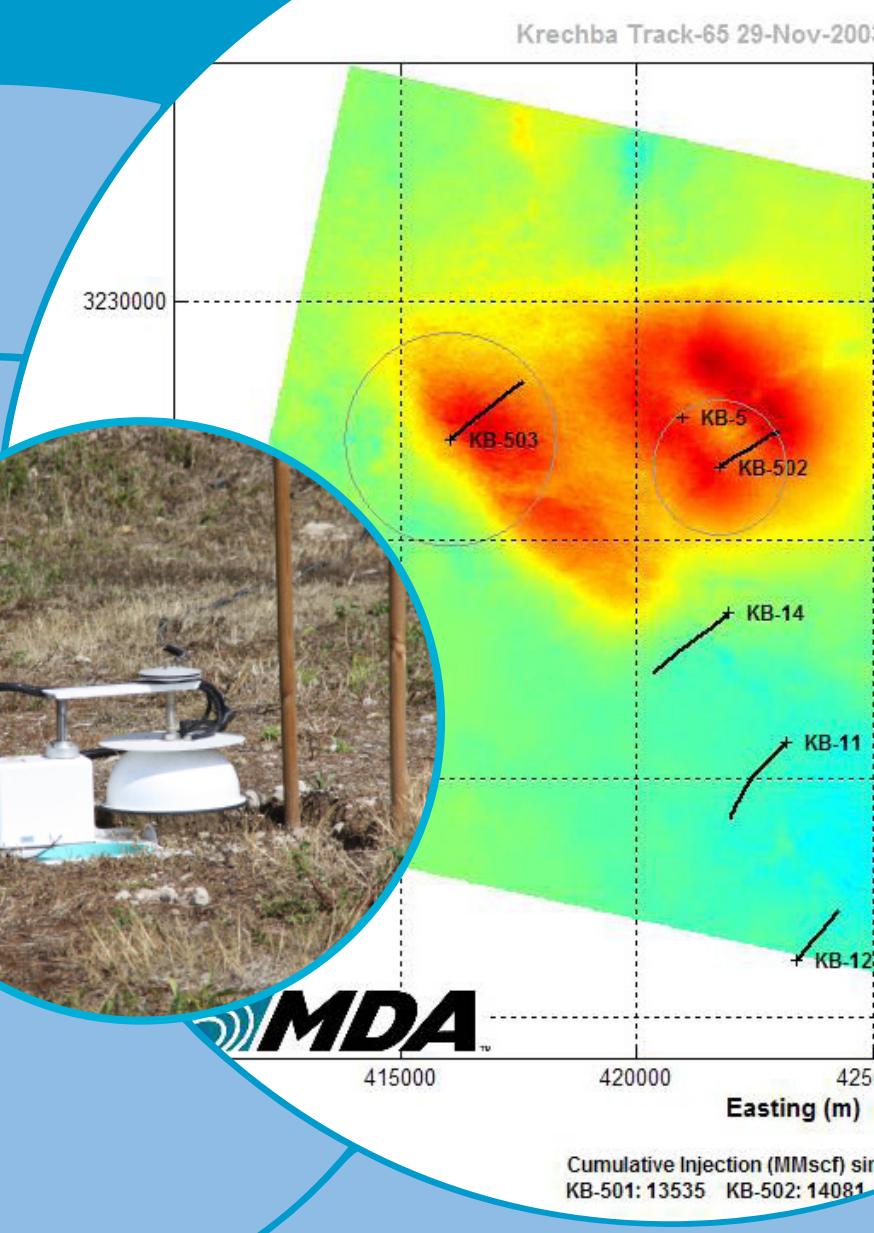

7th monitoring network meeting

7th - 9th June 2011

IEA GREENHOUSE GAS R&D PROGRAMME

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IEAGHG supports and operates a number of international research networks. This report presents the results of a workshop held by one of these international research networks. The report was prepared by IEAGHG as a record of the events of that workshop.

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Attendees of the Monitoring Meeting/Ketzin Site Image

Introduction

The 7th IEAGHG monitoring network meeting was held in Potsdam, Germany and hosted by the GFZ (German Centre for Geosciences). Sponsors were GASSNOVA and Vattenfall.

The session started with introductions from Michael Kühn, GFZ and Tim Dixon, IEAGHG. Kevin Dodds, BP gave an update from the previous year's monitoring meeting, highlighting the main learnings. This was followed by an introduction to this meeting and its aims, which was given by Andy Chadwick of BGS.

The theme for this year's meeting centred on the 3 criteria for transfer of responsibility in the EU directive:

- Actual behaviour of the injected CO_2 conforms with the modelled behaviour
- No detectable leakage
- Storage site is evolving towards a situation of long-term stability

While the directive is European, the aims are applicable and necessary to all worldwide storage projects. There is no information yet from experience for the 3rd point, which also derives from the first two, so the focus was on the first 2 aims.

The agenda was structured in accordance with the 3 criteria with sessions on review of performance monitoring tools, data integration and demonstrating monitoring data conforms with predictive modelling, developing protocols and strategies to form a monitoring plan and monitoring of the outer envelope – demonstrating no leakage. There was also a discussion session on CCS in the CDM – what modelling is required for monitoring and a session on updates and permanent Installations; current and future activities. The meeting ended with a review of the main learnings taken from the meeting.

Attendees of Meeting. Image Courtesy of GFZ

Review of Performance Monitoring Tools

The aim of this session was to look at the capabilities of each technology reviewed and compare this across different sites.

The session was split in three parts with the first part dealing with seismic and electrical monitoring, with talks on Otway, Nagaoka and Ketzin. Roman Pevzner, Curtin University compared 4D VSP and 4D seismic results at the Otway project, Akihisa Takahashi, JGI, talked about 4D seismics at Nagaoka, Stefan Lüth talked about using seismic monitoring at Ketzin to give a quantitative description of the CO_2 plume and Conny Schmidt-Hattenberger, GFZ talked about lessons learnt from geoelectric measurements at Ketzin.

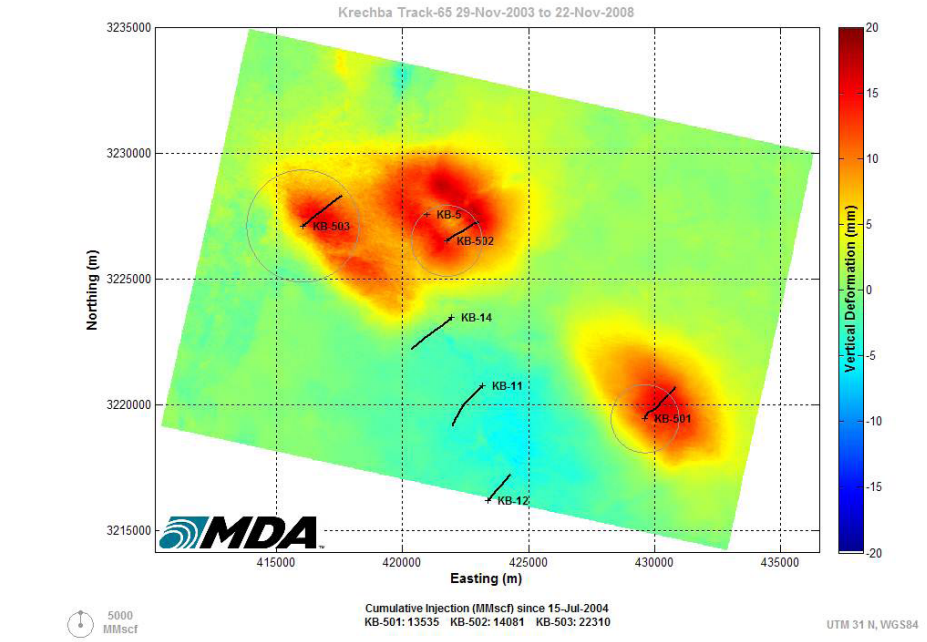
Much of the discussion focussed on the difficultly around 4D seismic surveys, getting a good timelapse signal and the signal to noise ratio. It was noted that firstly a good baseline survey was essential. There are also more difficulties with getting a good timelapse signal onshore than offshore and therefore more issues with repeatability.

The second part looked at pressure monitoring, with talks on Cranfield and Ketzin. Tip Meckel presented pressure monitoring at Cranfield and Axel Liebscher, GFZ talked on Phase relations of pure and impure CO_2 - their impact on fluid-rock interactions and storage capacity. At the Cranfield site, pressure measurements are taken above the injection zone above a thick confining system. Full interpretation is yet to take place, but there appear to be some measurements that are not consistent with other monitoring data. One idea is that this may be due to a gas effect.

The third part of the session dealt with InSar and included two talks on In Salah, one from Eric Davis, Pinnacle looking at interpretation of induced surface deformation over KB-502 and one from Kevin Dodds, BP, looking at the current status of geomechanical inversion, which showed the different interpretations that can come from the same set of data. All interpretations show the presence of a fault beneath the surface, but the location and size of this varies depending on the interpretation.

Some of the main issues and conclusions of the session were that the applicability of monitoring tools is case-dependent; for example there is variability in results from seismic monitoring results at Nagaoka, Ketzin and Otway. There needs to be better assessment of results and uncertainties of the results prior to communication to regulators. Good seismic baseline surveys are important if time-lapse is to be applied, as seen in Nagaoka and In Salah. At In Salah there is a scarcity of data on the first survey, so if used as a baseline then much data collected in consequent surveys cannot be used in the 4-D interpretation. There is the need for complementary monitoring/ modelling datasets to reduce the non-uniqueness in interpretations, such as that seen with pressure measurements at Cranfield and differing geomechanical models in In Salah. There is also the issue of being able to interpret what there is, so it is important to know what is being monitored and not just to accumulate data. This is necessary to keep regulations simple and non-prescriptive and to keep monitoring costs at a reasonable level. It is necessary to be selective in what is monitored as monitoring results will have to be explained; therefore it is necessary to know why you are monitoring. Also noted was that models are required to translate monitoring data (InSar, seismic, pressure, electrical) into subsurface CO_2 distributions.

InSAR Measured Deformation at In Salah - Slide from Pinnacle presentation given by Eric Davis.



Data Integration and Demonstrating Monitoring Data Conforms with Predictive Modelling

The aim of this session was to consider monitoring tools that can be used in conjunction with each other and to compare models to monitoring data.

Jean François Girard, BRGM presented the first talk on geophysics and geochemistry, which looked at electrical resistivity changes caused by movement of saline formation waters, which has been confirmed in-situ and from lab samples. Ola Eiken, Statoil presented how gravimetric and seismic monitoring have been used in conjunction at Sleipner. The seismic data shows the location of the plume, whereas the gravity data can be used to estimate CO_2 dissolution in formation waters. At Ketzin electric and seismic monitoring can be used to validate each other and show conformance with modelling data. Jan Henninges, GFZ, presented near-wellbore characterisation using PNG and DTS measurements and Peter Bergmann, GFZ, presented geophysical modelling as a tool for CO_2 storage monitoring: results from the geoelectric and seismic monitoring at the Ketzin site.

Two talks on history matching were given, one on Ketzin by Thomas Kempka, GFZ and one on Otway, by Charles Jenkins, CSIRO. This allows the initial model to be improved upon once real data is available. Therefore previously unknown parameters, such as heterogeneity can be taken into account.

Ketzin Site Image, Image Coutesy of Sarah Hannis, BGS

Discussion focussed on which technologies are best used in conjunction with each other, but that it is important not to stipulate what should be used to avoid prescriptive regulations for commercial projects. Flexibility is needed to decide on the monitoring methodologies best for each site and through the characterisation process it should become clear what is best for each site.

Modelling with respect to history matching was discussed. There are only so many modelling runs that can be carried out as they take a long time, so it is important to decide what to model and how sophisticated a model needs to be. It is necessary to know limits and the significance of them, for example at Ketzin the predictive model showed the plume over a much larger area than the monitoring data later showed. It is important to know the limits of the model and how to manage risks. Using breakthrough is too simplistic a parameter for modelling performance, parameters such as area would be better. There is also a need for leak tests to test models.

Developing Protocols and Strategies to Form a Monitoring Plan

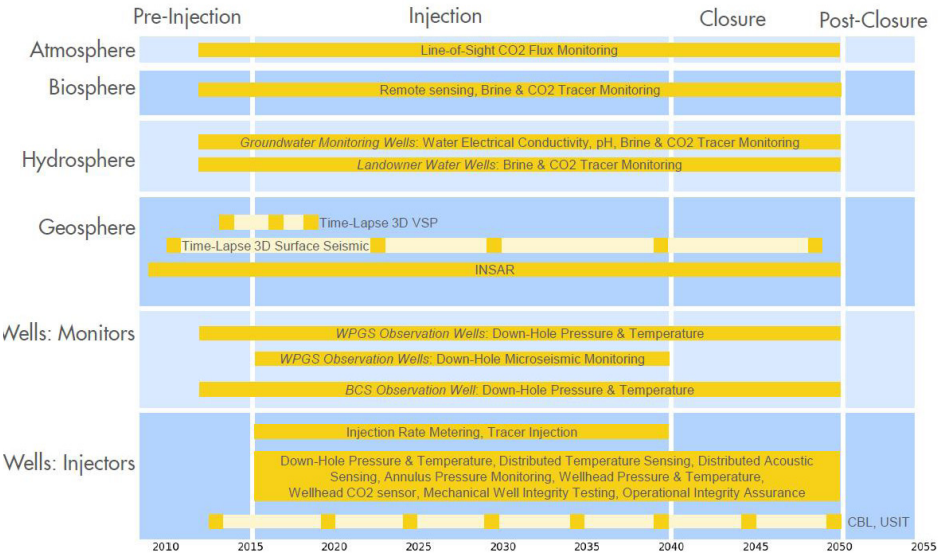
This session included a presentation on the measuring monitoring and verification in Shell CCS projects, given by Wilfred Berlang, Shell, which outlined the approach used. The designed MMV plans aim to demonstrate permanent, secure storage of CO_2. The approach taken is risk based, storage site specific and adaptive. This is necessary due to inherent heterogeneity of the subsurface and will give different monitoring strategies for each site. The MMV approach was illustrated with some examples from the Longannet-Goldeneye and Quest projects.

This was followed by a more general overview talk on developing protocols and strategies to form a monitoring plan, by Andy Chadwick, BGS. This included regulations that need to be adhered to, core monitoring plans and an additional monitoring programme. The additional programme covers irregularities that have become significant (decided by conversation with the regulator) and measurements of leakage under the ETS (Emissions Trading Scheme).

The following discussion covered the importance of communication between technical and commercial teams in order to communicate with the regulators. The monitoring plan will be a negotiation between the developer and regulator and should be site specific and adaptive. It is important to focus on the core MMV plan with an additional plan provided in case of significant irregularity. The regulations cannot be too stringent as each plan needs to be site specific, it was noted that for both the Quest and Goldeneye projects there has been a series of meetings with the regulators to agree on monitoring plan. As these are some of the first industrial scale projects to be going ahead, future projects are likely to depend on the outcome of these negotiations.

Detection of leakage was also discussed and it was noted that leakage of formation fluid also needs to be monitored for as well as CO_2. The notion of "detectable" leakage remains vague but will likely be settled in negotiation

Diversified Monitoring Program Eliminates Dependence on any Single Technology



Slide from Shell presentation given by Wilfred Berlang

Monitoring of the Outer Envelope – Demonstrating No Leakage

This session was split into three parts with the first section looking at recent and ongoing IEAGHG studies. The first talk from Anna Korre, Imperial College, was on the quantification of leakage, which has attempted to rank technologies according to capabilities, though this will need to be carried out on a site specific basis. This was followed by Linda Stalker's presentation on monitoring of substances mobilised by CO_2, which showed the availability of many new tools, though currently only a few are capable on being used on a commercial site.

Soil-Gas Monitoring, Ketzin. Image Courtesy of Sarah Hannis, BGS

The second part dealt with monitoring saline and fresh water. A talk was given by Jeff Paine, University of Texas, on conductivity measuring to detect brine displacement; a method that was shown to have been successfully used to detect leaky wells across old oilfields. There was another talk given by Katherine Romanak, University of Texas on behalf of Elizabeth Keating, LANL, looking at sites of natural release of CO_2 to help create better predictive models; an important issue noted is the differing spatial and temporal scales that need to be used for various processes. The last presentation in this session from Dirk Schäfer, Univeristy of Kiel described monitoring methods that have been analysed to detect CO_2 intrusion in shallow aquifers. The talk concluded that there are many methods available to detecting CO_2, but fewer for large scale detection needed to detect the location of the leak, though not necessarily to quantify leakage; research is ongoing in this area.

The third part of the session was on soil-gas and atmospheric monitoring. Katherine Romanak, University of Texas, covered a new process based approach for testing CO_2 leakage and distinguishing from natural and exogeneous CO_2 in soil by looking at ratios of CO_2 with N_2, O_2 and CH_4. This approach has been tested at multiple locations with promising results and research is ongoing. Ulrike Schacht, CSIRO, then presented soil-gas monitoring at Otway, including the two baseline surveys taken in 2007 and 2008. The final talk in this section from Sarah, Hannis, BGS was on mobile laser and eddy covariance techniques at natural and man-made leakage sites at In Salah.

Much of the discussion focussed on the difficulty achieving the EU directive's instruction to quantify leakage. There are proposals to use one toolkit to detect leaks, with the possibility to enlarge the toolkit in a second step, qualifying leakage. Once leaks are located then they can be quantified using a second toolkit. Speakers all gave reasons that near surface detection and quantification should be undertaken, even if it is difficult. The very large footprint of industrial scale storage is a major issue. Some feasible techniques are available for wide areal coverage, although the sensitivity of these techniques to leakage types and volumes is in general not known. There is however, current research ongoing in this area.

Discussion Session: CCS in the CDM – What Modelling is Required for Monitoring?

Tim Dixon, IEAGHG gave an talk outlining decisions made at COP16 in Cancun December 2010, where it was decided to keep the possibility of CCS being part of the clean development mechanism for developing countries

The decision text states that work is required this year to address a list of issues, including:

- Stringent monitoring plans shall be in place and be applied during and beyond the crediting period in order to reduce the risk to the environmental integrity of carbon dioxide capture and storage in geological formations
- Further consideration is required as regards the suitability of the use of modelling, taking into account the scientific uncertainties surrounding existing models, in meeting the stringency requirements of such monitoring plans, in particular taking into account the 2006 IPCC Guidelines for National Greenhouse Gas Inventories'

The aim of this session is to discuss the following points:

- Can we provide 'stringent monitoring plans'?
- Is this meaningful?
- Can criteria be set for monitoring plans?

The discussion focussed on answering these questions. Whether stringent monitoring plans can be provided depends on how this is defined. Overall it was considered that the IPCC GHG guidelines should be used applied appropriately to provide 'stringency', also that experience from other projects should be used. Criteria for monitoring plans should be site specific and risk based, so there could be a criteria for the process used to develop monitoring plans. The IPCC guidelines contain a 3rd party audit, which would give an independent view of the monitoring plans for each project, consistent with the role of CDM's verifiers (Designated Operational Entitities).

Updates and Permanent Installations; Current and Future Activities

This session covered a talk given by Martin Zimmer, GFZ on the planned gas membrane sensors at Ketzin, which are in-situ geochemical sensors to detect distribution of CO_2 in the observation wells. The CO2Field Lab project in Norway, presented by Hubert Fabriol, BRGM, will test monitoring methods (leakage detection and quantification) in the shallow subsurface by controlled injection into permeable rocks. The CO_2Care project, presented by Michael Kühn, GFZ, will review and test site abandonment and closure across a range of projects.

There was also an update on wireline measurements at Nagaoka, from Ziqiu Xue which showed that CO_2 saturation during the imbibition stage shows little change and that CO_2 dissolution into low salinity brine is an important trapping mechanism. A presentation on atmospheric monitoring at the 'Arcturus' monitoring station in Queensland Australia by Zoe Loh, CSIRO was given. The station uses two wavelength scanned cavity ringdown instruments to measure concentrations of carbon dioxide (CO_2), methane (CH_4), water vapour and the isotopic signature (d13C) of CO_2.

The discussion focused on the difficulty of baseline measurements as other activities may be associated with CO_2 and CH_4 fluxes, which is why long term baselines over several years may be needed in order to understand natural variability of CO_2 in the atmosphere and associated trace gases.

It is also important to focus on what monitoring is needed as some sites have many methods, whereas other sites may need less. Sonja Martens, GFZ gave a talk on Ketzin - Current monitoring and Future Activities, as an introduction to the fieldtrip to Ketzin the next day.

Conclusions

Throughout the meeting the 3 criteria from the EU directive were considered and discussed, and the conclusions and summary for the first two criteria are presented here:

Actual behaviour of the injected CO_2 conforms with modelled behaviour

Seismic detection limits have been discussed for Otway, Ketzin and Nagaoka and it is clear that repeatability is key to be able to compare results over time and with modelling data. At Ketzin, monitoring results show that the plume migrated to a lesser extent than expected from the initial modelling due to the heterogeneity in the subsurface. This is within expected limits; however, history matching has been carried out since to improve the model. It will always be the case that the models improve with more information, but a range of models may show the expected plume limits. Breakthrough was also later than detected, which was unexpected, but not negative. This all shows how important it is to define monitoring and performance indicators.

The talks from In Salah on In Sar show how even excellent datasets can have non-unique explanations. It can also be seen that combinations of tools can reduce overall uncertainty. Results from pilot sites are necessary for understanding and demonstrating processes as well as testing monitoring tool capabilities.

No detectable leakage

This was mostly considered in the session on monitoring of the outer envelope. Traditional techniques include soil-gas and atmospheric monitoring as well as monitoring of shallow water sources. It is very important to capture the full natural variation of CO_2 and associated compounds in the baseline. There are issues with sampling and what points to measure. There are also areal methods to detect possible leakage, but these may not be able to quantify the CO_2, necessitating a 2 step approach to first locate the leak, and then quantify it. A new process based approach to soil monitoring was also presented, for which a baseline is not needed as the amount of exogenous CO_2 is derived from the ratios of CO_2 to other gases.

The excellent work and results from monitoring at the Ketzin project were highlighted throughout the meeting, and delegates visited the Ketzin project site.

Overall, there was much progress being made, with the increasing amount of monitoring results becoming available and providing good learnings and experiences from real projects. The use of risk assessments to define monitoring programmes was also demonstrated for real projects.

Presentations given can be found on the monitoring pages of the IEAGHG website: **http://www.ieaghg.org/index.php?/20110217242/7th-monitoring-network-meeting.html**

Evaluating technology options to mitigate greenhouse gas emissions

IEA Greenhouse Gas R&D Programme

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