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Characterisation of Regional Fluxes of Methane in the Surat Basin, Queensland

The continuous monitoring results – installation, commissioning and operation of two field stations and preliminary data

Milestone 3.1 GISERA Greenhouse Gas Research – Phase 3

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16 January 2016

ISBN (online) 978-1-4863-0830-9

ISBN (print) 978-1-4863-0830-9

Citation

D. M. Etheridge, S. Day, M. F. Hibberd, A. Luhar, D. A. Spencer, Z. M. Loh, S. Zegelin, P. B. Krummel, E. van Gorsel, D. P. Thornton, R. L. Gregory, C. Ong and D. Barrett (2016). Characterisation of Regional Fluxes of Methane in the Surat Basin, Queensland - Milestone 3.1 GISERA Greenhouse Gas Research – Phase 3. CSIRO, Australia.

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Acknowledgments

This project is supported by the Gas Industry Social and Environmental Research Alliance (GISERA). GISERA undertakes publicly-reported independent research that addresses the socioeconomic and environmental impacts of Australia's natural gas industries. For further information visit www.gisera.org.au.

Gordon and Sue McConnachie are thanked for providing access to their land for the Burncluith station and for support in installing and operating the facility.

The authors acknowledge the contributions from Bruker who provided the instrumentation and supported the acquisition of the Bruker HI90 data and processing of the datasets. Specifically, we thank Andrew Bales, Peter Maas and Armin Gembus for providing invaluable support and contributions.

Executive summary

This report describes progress against Milestone 3.1 of the GISERA project "Characterisation of Regional Fluxes of Methane in the Surat Basin, Queensland". It should be noted that the purpose of this report is to provide an update on progress to date; detailed analysis and interpretation of experimental datawill be presented in future reports.

Two fixed ground based stations for continuous monitoring of atmosphericgreenhouse gas concentrations and meteorology were installed in the Surat Basin to estimate fluxes (primarily methane) from the region. The locations were based on model results and results from previous stages of the GISERA greenhouse research to optimise their positions to intercept current and future emissions, and practical considerations.

The facilities, Ironbark and Burncluith, are located to the southwest and northeast respectively of the coal seam gas (CSG) region. Ironbark measures concentrations of methane, carbon dioxide, water vapour, fluxes of carbon dioxide, watervapour, heat and momentum, and meteorology. Burncluith measures concentrations of methane, carbon dioxide, carbon monoxide, and meteorology.

The instruments operate autonomously and have produced data since November 2014 (Ironbark) and July 2015 (Burncluith). The concentration measurements so far show mean levels and diurnal variations typical of continental sites. Peaks in methane concentrations at Ironbark are possibly caused by emissions from sources to the north such as gas facilities, powerstations, feedlots and sewerage treatment plants. Emissions from natural sources such as carbon dioxide from forest respiration and carbon monoxide from prescribed burns are seen on occasions at Burncluith.

The atmospheric monitoring stations will provide useful data over the next few years to help estimate methane emissions from the region using inverse modelling methods.

Further trials of a land based remote sensing system were conducted during this period. A Bruker HI90 Hyperspectral Imaging instrument was trialled at two locations as a proof of concept and to determine its application for spatially quantifying the distribution of methane. The trials were conducted in conjunction with the Geoscience Australia Ginninderracontrolled release trial and also at Chinchilla. Preliminary evaluation of the data from the trial found that the Bruker HI90 was able to identify methane plumes at the Ginninderratrial at near scale and also some known methane seepages near Chinchilla. Importantly, positive identification of the plumes could be ascertained as the spectral signature can be directly related to methane.

1 Introduction

This report describes atmosphericmonitoring activities at the start of Phase 3 of the GISERA methane seeps project. Reports from Phase 1 and Phase 2 present the background for monitoring methane emissions in the Surat Basin and identified continued ground based monitoring as a suitable methodology for Task 3, described in the Project Order (2013) as follows:

> *Ongoing ground based monitoring of pilot sites will provide a baseline of methane seepage fluxes and their seasonal variations as the basis of an ongoing monitoring program.*

Note that since the original project order it was agreed to run Phase 3 over three years (originally to be one year). This was to allow the baseline monitoring to extend overthe period of expected increase in gas production from the Surat gas fields and to reveal any seasonal variability in emissions that would be difficult to discern from a 12-month monitoring campaign.

This report presents an overview of progress against the GISERA Milestone 3.1:

- The continuous monitoring results – installation, commissioning and operation of the two field stations.
- Preliminary data available.

While some preliminary data are presented for the purposes of illustration, detailed analysis and interpretation of the results are ongoing and are not discussed here. The results of the modelling, including estimates of emission fluxes across the region, and longerterm monitoring will be presented in future reports throughout the project. Future work will address Milestone 3.2 (Model development and analysis of continuous data; Periodicmonitoring and field validation; Trial of remote sensing technologies) and Milestone 3.3 (Delivery of final report for Remote sensing baseline study and Ground detection baseline study). A further task (Milestone 4.1-4.4) will include new station monitoring data (greenhouse gases and tracers from ground based stations including new air quality stations) and an enhanced modelling effort to derive sources.

Also described in this report are the preliminary results of a trial of a hyperspectral remote sensing instrument. We had originally intended to conduct this trial as part of Task 3.2 (see the Project Order for GISERA Project: Gas 1315). However, an opportunity to access a suitable system was provided by the manufacturer during the middle of 2015 and consequently the remote sensing trial planned for the project was brought forward.

2 Monitoring Strategy

The monitoring strategy was based on a modelling study (Chapter 6 in the GISERA Phase 2 report; Day et al., 2015) that identified two locations where continuous ground based measurements of atmospheric greenhouse gas concentrations and meteorology would best detect methane emissions across the main coal seam gas region of the Surat Basin.

The criteria for site selection from the Phase 2 report are:

- To allow measurement of CH_4 concentrations of both the background (air arriving at the Surat Basin) and the signal resulting from CH_4 emissions in the Surat Basin (total CH_4 concentration minus background).
- To optimise the size and frequency of concentration signals from the broader CSG source area without being overly influenced by individual sources close to the measurement site.
- To differentiate as much as possible the emissions from non-CSG sources such as livestock, power stations, coal mines, vehicles, biomass burning and cities from CSG sources.
- To take into account characteristics such as land cover and topography.
- Practical considerations such as access, power and security.
- Potential assistance by land owner or operator.
- Future gas development possibilities which could affect the site.

Maps of coal seam gas projects (DNRM, 2014) and possible seepage (Gas Migration Area of Interest, June 2014, Brad Pinder, Arrow Energy) were used as a guide for potential methane source locations. Emissions strengths estimated from ground surveys in Day et al. (2015) were associated with the CSG project source areas. The emissions were used as input to atmospheric transport modelling (CSIRO's TAPM).

Figure 2.1 shows the resulting modelled methane signals across the region for cases based on emissions from current and projected future CSG projects given by DNRM (2014). Two locations were chosen for the monitoring sites to best fulfil the above criteria, particularly the need to estimate net emissions across the region with a pair of instruments providing up-down wind concentration differences. The locations are also shown in Figure 2.1.

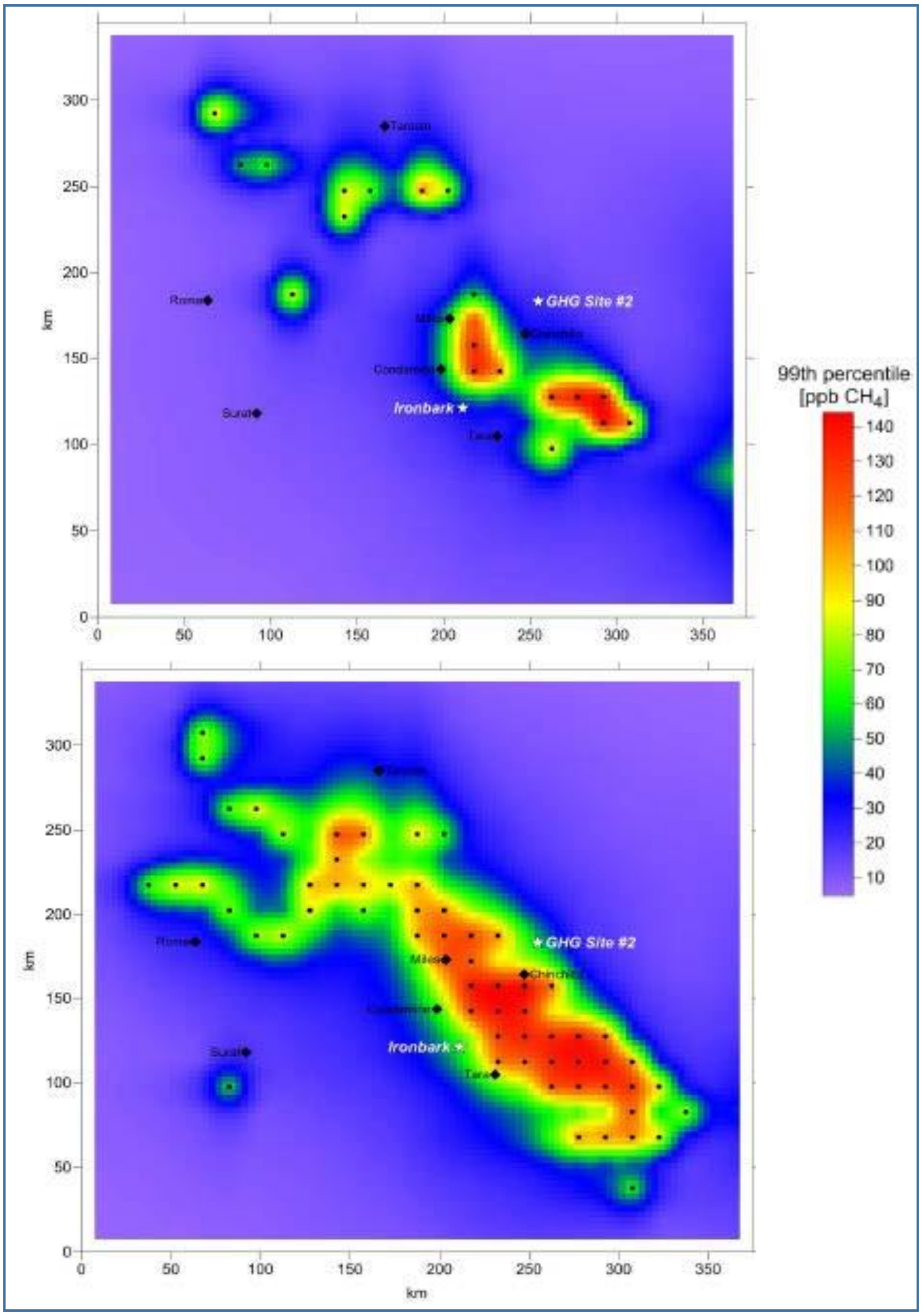

Figure 2.1. Methane concentration signals (99thpercentile, parts per billion or ppb) modelledover a 3 year period based on existing (top) and predicted(bottom) scenarios of emissions fromthe CSG regionof the Surat Basin (from Day et al., 2015). Nearby towns and the 2 CSIRO monitoring stations areshown.

3 Monitoring Stations

Once suitable local areas for each station were narrowed down by modelling, potential sites were surveyed for access, services and land use. Two sites, Ironbark and Burncluith, showed promise and discussions with landowners ensued and agreements were put in place. Prior to committing to the sites, they were first assessed by mobile ground based methane measurement surveys (Day et al., 2015) to confirm that no methane sources existed nearby which would dominate the detection of emissions from sources of interest further away. Figure 3.1 shows the locations of the stations.

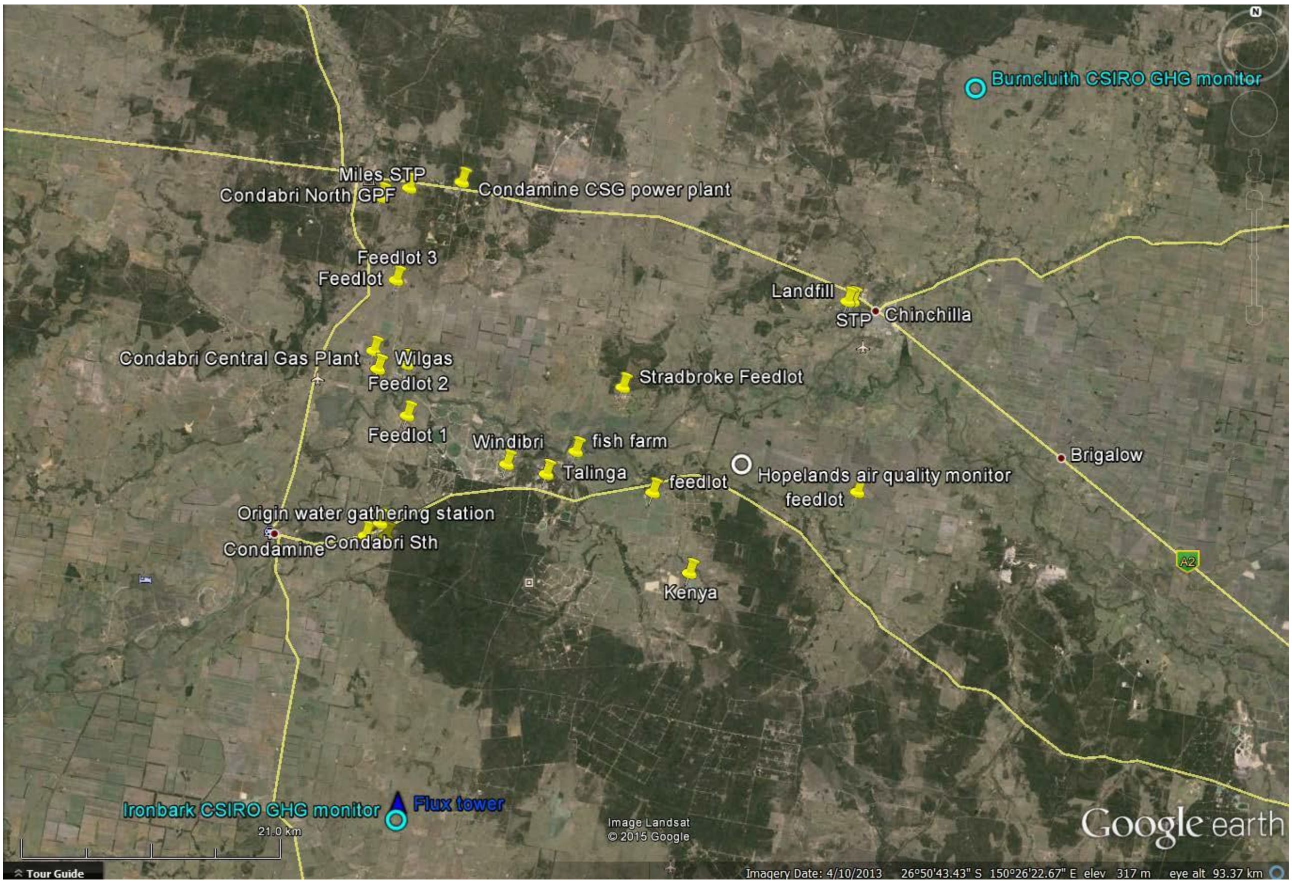

Figure 3.1. Atmospheric monitoring stations Ironbark and Burncluith (CSIRO), air quality station Hopelands (Origin Energy) and the locations of main roads, towns, some of the CSG infrastructure and some possible methane sources in the area (personal communication, M. Kernke).

3.1 Ironbark

The first station was installed to the southwest of the CSG region (26 km southeast of Condamine) on an Origin Energy property named Ironbark (formerly a homestead called Greenlea). The monitoring facility and instruments came from the CSIRO-Geoscience Australia site at Arcturus, Queensland which was decommissioned several months earlier. The installation occurred over about 4 days in November 2014.

The monitoring station consists of an insulated shipping container equipped with monitoring instruments, communication equipment and air conditioning. A 10 metre tower supports air inlets and meteorological equipment. Methane, CO_2 and water vapour concentrations are measured using a Picarro G2301 cavity ring down spectrometer and calibrated through regular reference gas and calibration gas measurements to international standards (World Meteorological Organisation Global Atmosphere Watch). Methane is calibrated to the NOAA04 scale and CO_2 to WMOX2007. Data are stored on an onsite PC and transferred regularly by modem to CSIRO servers where they are quality controlled, calibrated and averaged to 1, 5, 20 and 60 minute means. This analytical procedure is standard practice for CSIRO Oceans and Atmosphere atmospheric monitoring and ensures precise, accurate and stable measurements over long time periods so that trends and inter-station differences in concentration are reliably and accurately determined.

An eddy covariance flux station was installed about 150 metres to the northeast of the monitoring container. This consists of a 4 metre tower with instruments providing measurements of meteorology and the fluxes of CO_2, water, heat and momentum, which are transferred back to the PC and then to CSIRO servers. These data are used in the transport model that will derive emissions using inverse techniques. The Ironbark facility is shown in Figure 3.2.

A generator provided power in the first few months of operation. It was decided to switch off the facility to avoid potential damage to the instruments due to frequent power failures until mains power was connected in March 2015. Since then the facility has been successfully operating remotely, requiring only one visit for maintenance and gas cylinder renewal.

Figure 3.2. The Ironbark monitoring container (left) and concentration instruments (inset); the flux tower (right) and meteorological instruments (inset).

3.2 Burncluith

The second station was installed on a private farm owned by G. and S. McConnachie in the locality of Burncluith, 20 km northeast of Chinchilla, over a three-day period in July 2015. A specially built insulated and air conditioned walk in module was placed under cover in a farm shed. The module houses a Picarro series G2401 analyser for CO_2, CH_4, carbon monoxide (CO) and water vapour, inlet pump, reference and calibration gas cylinders, PC and communications gear. As for Ironbark, a 10 metre tower supports the air inlet. Calibration and data handling and processing protocols are the same as for Ironbark. The additional CO measurements will be useful in detecting combustion sources of CO_2 and CH_4.

Meteorological instruments are located on a pole 60 metres south of the module. These will provide wind and micrometeorological information (though not fluxes) for the transport modelling.

The Burncluith facility is shown in Figure 3.3. It has been successfully operating without intervention for 5 months.

Figure 3.3. The Burncluith monitoring facility showing instruments and calibration gases (left) and the installed module and meteorological instruments on a nearby pole (right).

4 Preliminary Data

Measurements of CO_2 and CH_4 concentrations at Ironbark are shown in Figure 4.1 for the full measurement period up to the end of October 2015. Also shown are measurements from two CSIRO baseline stations, Cape Ferguson (Queensland) and Cape Grim (Tasmania), which give the background concentrations for clean marine based air for each latitude. Although the necessary measurements and modelling are yet to be done to identify the causes of the variations, some general observations can be made about the preliminary data. Concentrations at Ironbark show the expected diurnal variations for a continental site as emissions are concentrated during stable night time atmospheric conditions and dispersed during the day. The diurnal variation of CO_2 is also caused by photosynthesis and respiration. Carbon dioxide is sometimes lower during the daytime than at the baseline stations due to photosynthetic uptake. A background seasonal cycle in methane can be seen in the lower Ironbark concentrations and in the baseline stations. Higher methane concentrations in September and October are possibly due to the higher frequency of northerly winds typical of that period directing emissions from sources from the north (see below).

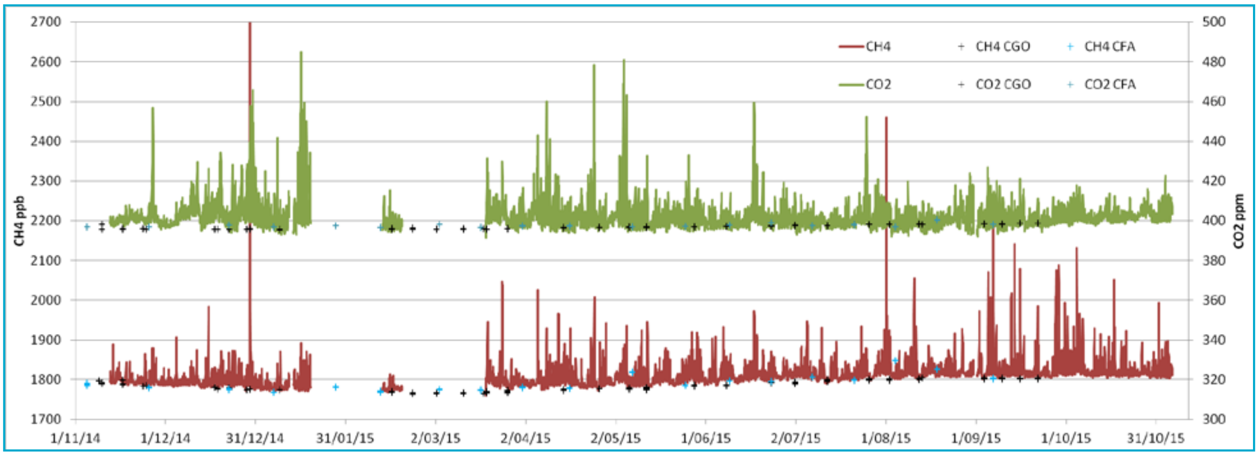

Figure 4.1. CO_2 and CH_4 concentrations (calibrated hourly means) at Ironbark compared to measurements at Cape Ferguson (CFA) and Cape Grim (CGO) for the baseline wind sector. Concentrations are calibrated hourly mean mole fractions in dry air. Measurement accuracy is better than 0.1 ppm CO_2 and 1 ppb CH_4.

Measurements of CO_2, CH_4 and CO for Burncluith are shown in Figure 4.2.

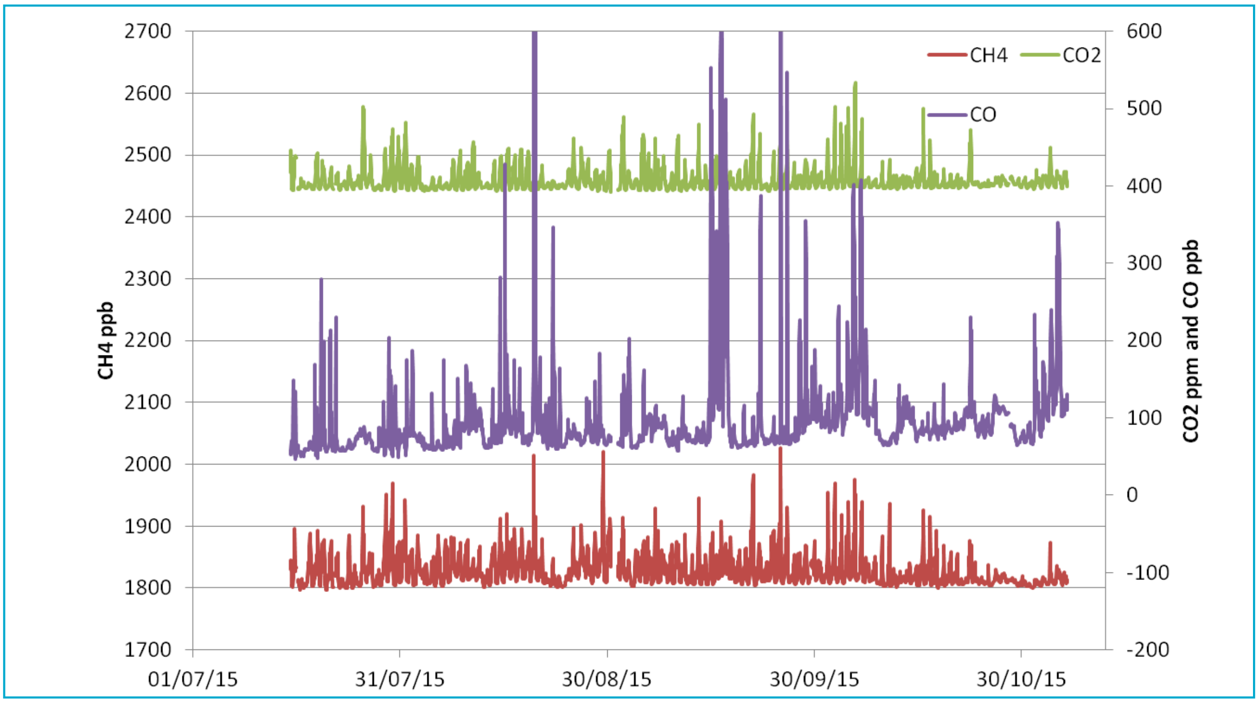

Figure 4.2. CO $_2$, CH_4 and CO concentrations (calibrated hourly means of calibrated hourly mean molefractions in dry air) at Burncluith since the beginning of monitoring in July 2015.

Comparisons of measurements from the two sites show some differences that likely relate to sources. For example, large peaks in CH_4 at Ironbark occur during northerly winds (Figure 4.3) and are possibly caused by point sources such as power stations, gas facilities, feedlots and sewerage treatment plants (see Figure 3.1).

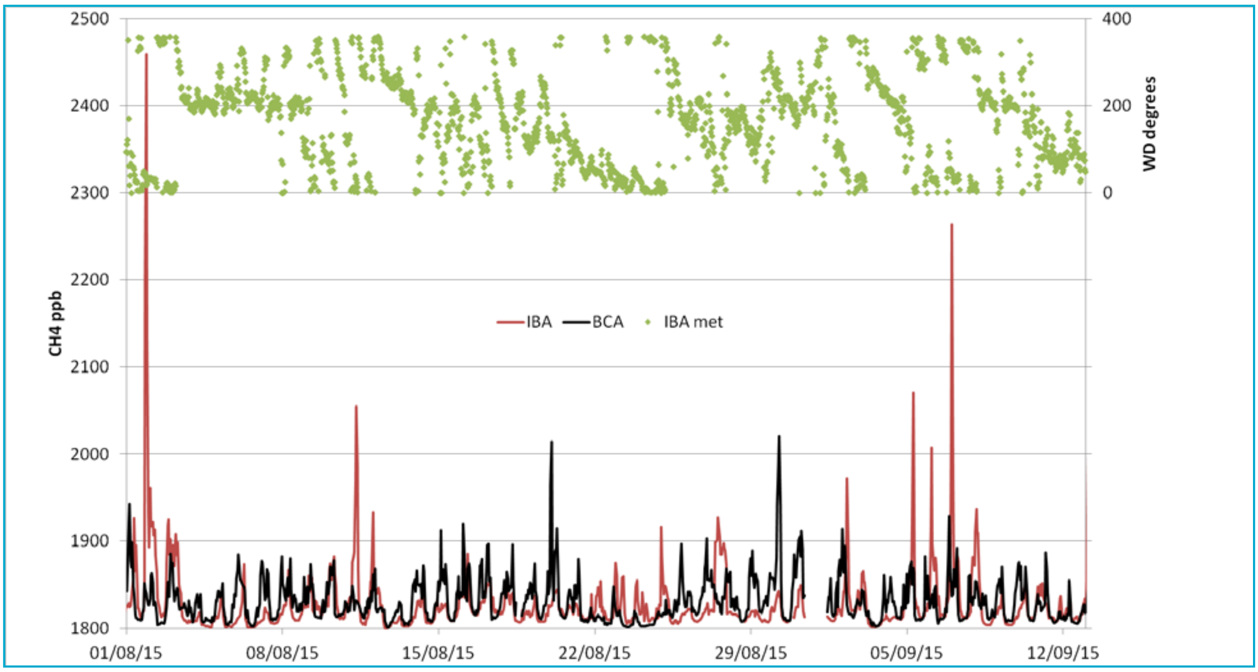

Figure 4.3. Methane concentrations (hourly means) over a 6 week period at Ironbark and Burncluith and wind directions at Ironbark.

Nocturnal CO_2 concentrations at Burncluith are typically 20-30 ppm higher than at Ironbark, particularly during light winds and north-westerly winds, while daytime concentrations are very similar (Figure 4.4). This may be due to respired CO_2 from the nearby Barakula forest.

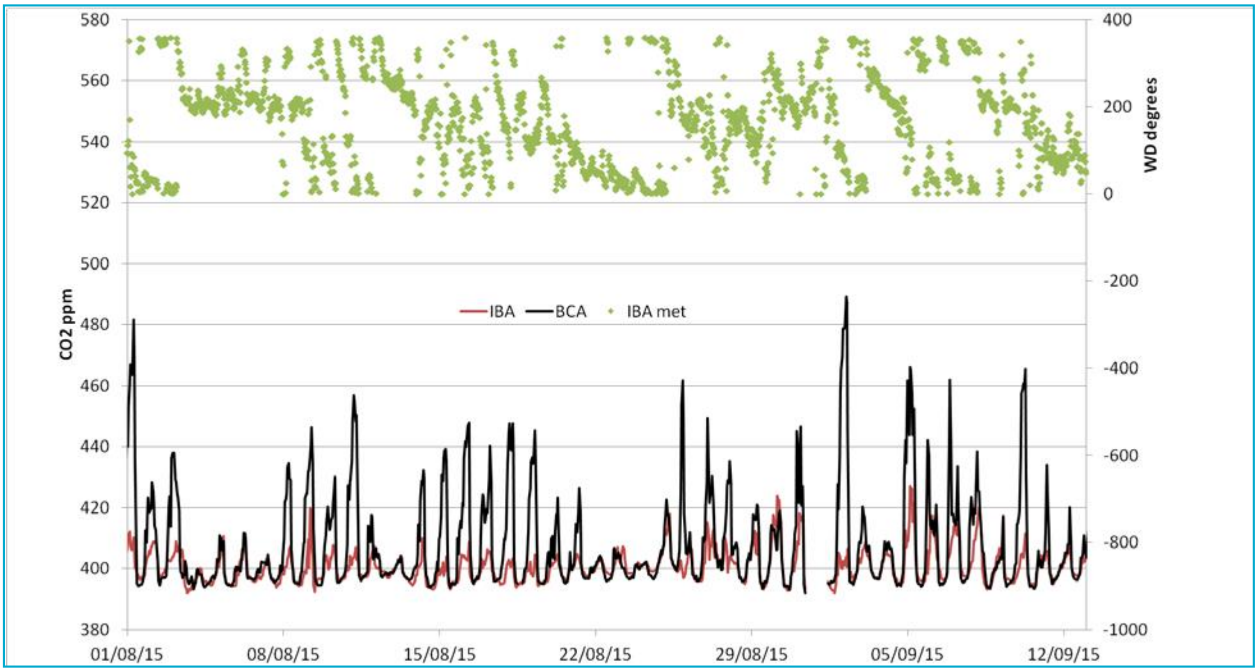

Figure 4.4. Carbon dioxide concentrations (hourly means) over a 6 week period at Burncluith and Ironbark and wind directions at Ironbark.

Carbon monoxide measurements at Burncluith show enhanced levels during several periods coincident with higher CO_2 and CH_4 concentrations (Figure 4.2). During one 4 day period, winds were from the west and the landowners reported episodes of smoke in the area. Minute mean data during this period showed the correlations more clearly. The relative CO_2:CO:CH_4 molar enhancements of 1: 0.07: 0.007 indicate woodland fire smoke as the origin (M. Meyer, CSIRO, personal communication). The occurrence of prescribed burns was confirmed by the local fire authorities. Carbon monoxide can thus provide information on methane emissions that originate from combustion (burning off, power stations) and not related to CSG.

5 Remote Sensing

5.1 Background

The Bruker hyperspectral imager (HI90) shown in Figure 5.1 is a passive Fourier transform infrared spectroscopy (FTIR) instrument developed by Bruker (https://www.bruker.com/). It is based on the combination of a Michelson interferometer and a 256×256 pixels focal plane array (FPA) infrared detector. The sensor package contains an internal calibration source, a video camera and a Global Positioning (GPS) receiver. In operation, the HI90 is mounted on a pan and tilt head which can then be controlled by software to provide a 360° field of view (FOV). The complete package also includes a ruggedized notebook computer used for data acquisition, storage and analysis and a Gigabit-Ethernet connection is used for control of the system and data transfer.

The instrument that was used for the trial operated in the 925 - 1440 cm^{-1} spectral range and spectral resolutions. The pixel resolution reduced and increased to optimise the detection limit but for the majority of the trial images of 64×64 pixels, 4 cm^{-1} full width half max (fwhm) was employed. Several experiments were also conducted at higher and lower spatial resolutions and spectral resolutions.

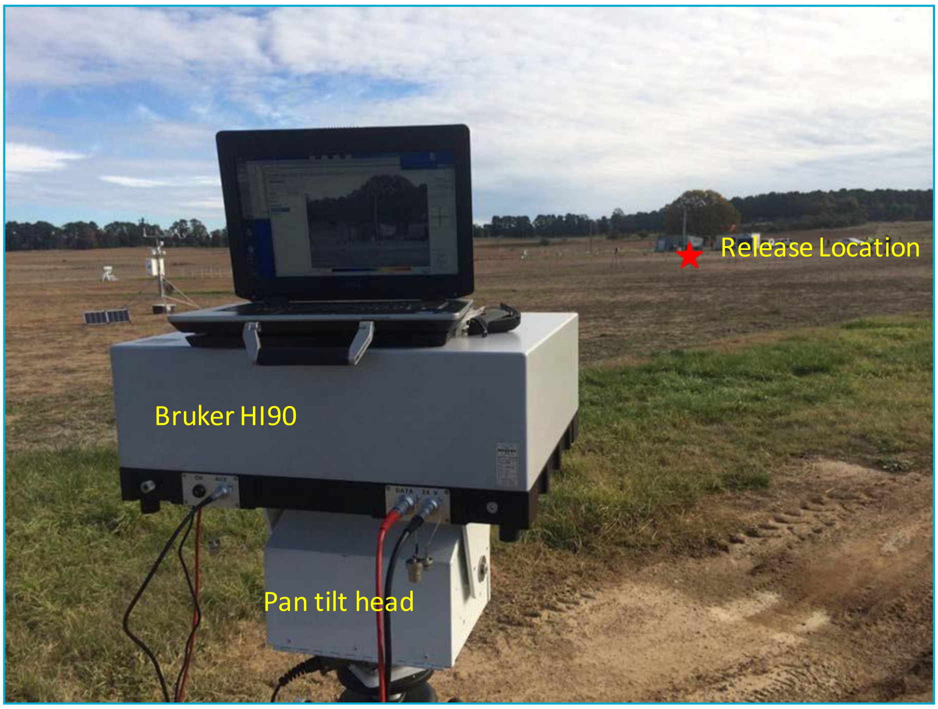

Figure 5.1. Bruker HI90 setup at 100m from the control release site at the Ginninderra experiment.

5.2 Experiment

5.2.1 Ginninderra

The Bruker was trialled at the Ginninderra Geoscience Australia controlled field experiment between 26th and 28th May 2015. Two experimental setups were employed to achieve this. The first consisted of setting up the HI90 approximately 100 m from the control release location (Figure 5.1). This experiment was to evaluate if the HI90 was able to detect the methane, the detection limits at various methane rates of release and the impacts of external environmental factors such as temperature and cloud.

The second experiment was designed to evaluate the possibility of detection at greater distances. The HI90 was setup at the top of a hill some 1.5 km awayfrom the source (see Figure 5.2). Note that the data were collected at non ideal conditions with high winds, cloudy skies and low temperatures (-2 to 13 °C on day one and 2 to 15 °C on day two).

Figure 5.2. Bruker HI90 capturing data from a hill 1.5km from the Ginninderra experiment.

5.2.2 Chinchilla

At Chinchilla, the trial of the Bruker was conducted between 2nd and 4th June 2015 along the Baking Board Road area. Locations of known seepages were used and the experiments were conducted at close as well as far range at distances of 50, 150, 200 (see Figure 5.3) and 500 m from the seepage source.

Figure 5.3. Bruker HI90 set up to measure approximately 200m from the seepage source.

5.3 Preliminary Results

At Ginninderra, the data acquired from the first experimental setup at 100 m from the controlled release indicated that the Bruker HI90 was able to identify the gas released as methane (Figure 5.4), capture the spatial distribution and provide quantification (relative abundances as shown on Figure 5.5) of the methane using methods developed by Bruker based on spectral matching with a reference library of methane and othergases (Harig et al., 2004).

Figure 5.4. Red indicates the area where methane was detected at Ginninderra.

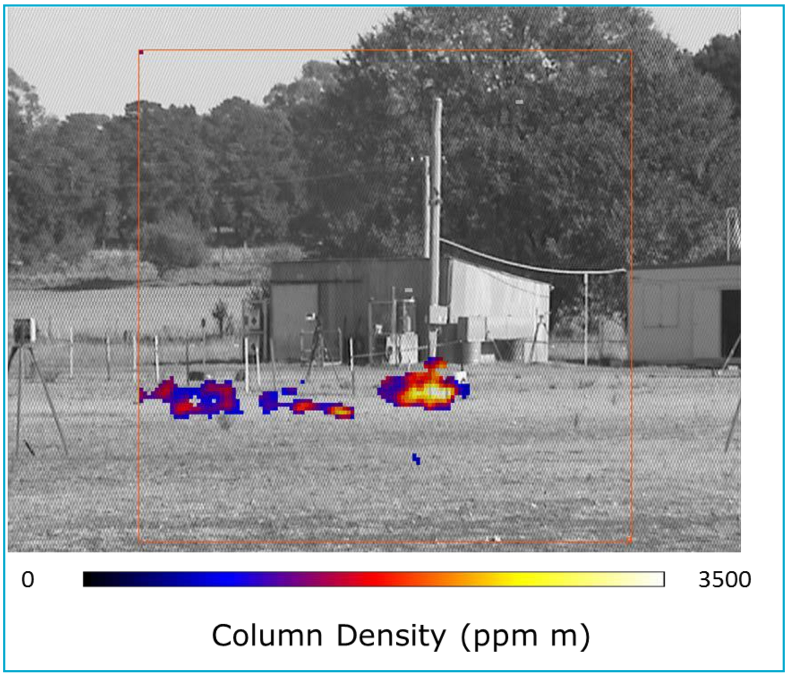

Figure 5.5. Column densities of methane derived from the spectral measurement at Ginninderra.

The experiment measuring at 1.5 km from the release point indicate that although methane absorption features were detected in the spectra collected it was constrained by dilution due to the wind and the measurement distance. Therefore, it was difficult to identify the release areaas an anomaly separate from ambient methane.

The Chinchillaexperiment was conducted with more favourable environmental conditions with relatively low wind. Methane was detected from an abandoned exploration borehole from the near to far field. Examples of the spatial detection and relative abundance results are shown in Figure 5.6.

Figure 5.6.(a) Red shows areas wheremethanewas detected at200mfrom an old explorationborenear Chinchilla. (b) Relative abundances of methane. Colourscale is shown in Figure 5.

6 Future Work

The locations of the monitoring stations and the type and precision of the measurements taken appear to be suitable to detect emissions from the Surat as predicted in the model scenarios. They have been operating reliably and remotely since installed. Continued datacollection will provide baseline atmosphericconcentrations and meteorology and form the basis for model interpretation of sources. The containers at each site are planned to soon have air quality instruments installed (by CSIRO and Ecotech for Origin Energy). These measurements may also be used as tracers of gas sources.

A variation of the GISERA Methane Seeps project (Methane Emissions Enhanced Modelling) will bring in new information that is becoming available since the Phase 2 concept. In addition to the baseline concentrations, ground survey concentration and flux data from Task 3, the enhanced project will include new station monitoring data (greenhouse gases and tracers from ground based stations including new air quality stations such as Origin's Hopelands) and information from collaborators such as the University of Melbourne and industry based monitoring if they become available. The aim is to give more detailed and betterresolved estimates of source area, type (large infrastructure sources such as gas processing plants and powerstations, feedlots, coal mines, significant seeps) and emissions.

Although most of the future work is aimed at continuous baseline monitoring using the fixed stations, we anticipate that furtherground surveys may be required from time to time to locate small scale sources (e.g. leaking boreholes, new infrastructure) to improve the model's ability to accurately locate and quantify emissions.

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