Characterisation of regional fluxes of methane in the Surat Basin, Queensland

Final report- Knowledge Transfer Session

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

Final report

Task 3: Broad scale application of methane detection, and
Task 4: Methane emissions enhanced modelling

EP185211

Report for the Gas Industry Social and Environmental Research Alliance (GISERA)

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Phase 1 Literature review
Phase 2 Pilot study of methodology to detect and quantify methane sources
Phase 3.1 Initial results from installation of continuous monitoring stations
Phase 3.2 Interim results of measurements and inverse modelling
Final Report

GISERA
Gas Industry Social and Environmental Research Alliance

Aim of the project

- Demonstrate the utility of an atmospheric “top-down” or inverse modelling approach for regional scale (~ 100 – 1000 km) for inferring methane emissions across the Surat Basin
- Two methane monitoring stations: Ironbark and Burncluith (concurrent measurements during July 2015 – December 2016)

Surat Basin

Burncluith CSIRO GHG monitor
Miles
Chinchilla
Jandowae
Brigalow
Condamine
A2
Macalister
Ironbark flux tower
Ironbark CSIRO GHG monitor
Dalby
49
A5
Tara
Image Landsat / Copernicus
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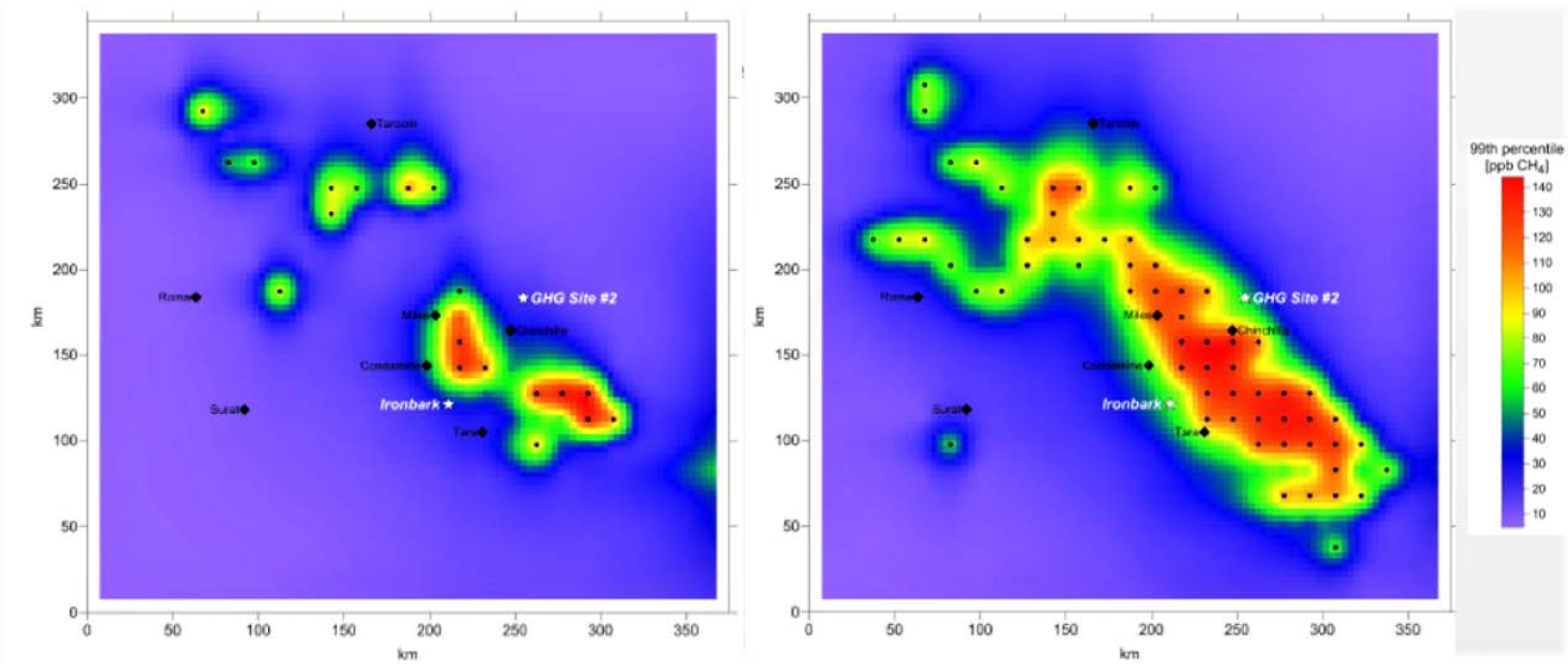
Google earth

Simulated CH_4 concentrations from CSG wells 2015 – 2018 to optimise monitoring design

Modelled methane concentration signals (TAPM) from existing (LHS) and predicted (RHS) CSG operations.



Simulated CH_4 concentrations from CSG wells 2015 – 2018

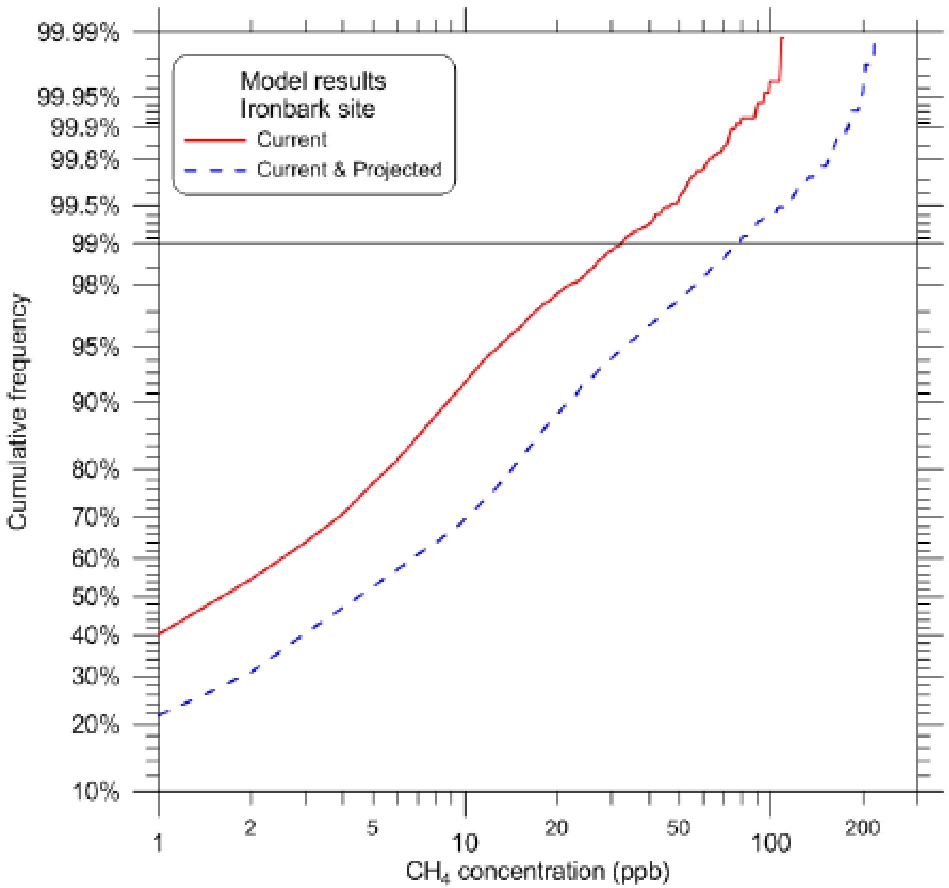


Figure 6.8. Annual cumulative frequency distribution of modelled concentrations at Ironbark monitoring site #1.

Ironbark (IBA)

CH_4 and CO_2 concentration, meteorology, eddy-covariance fluxes

Burncluith (BCA)

CH_4, CO_2 and CO concentration, meteorology
CH_4 precision of both stations ~0.2%

Concentrations at Ironbark

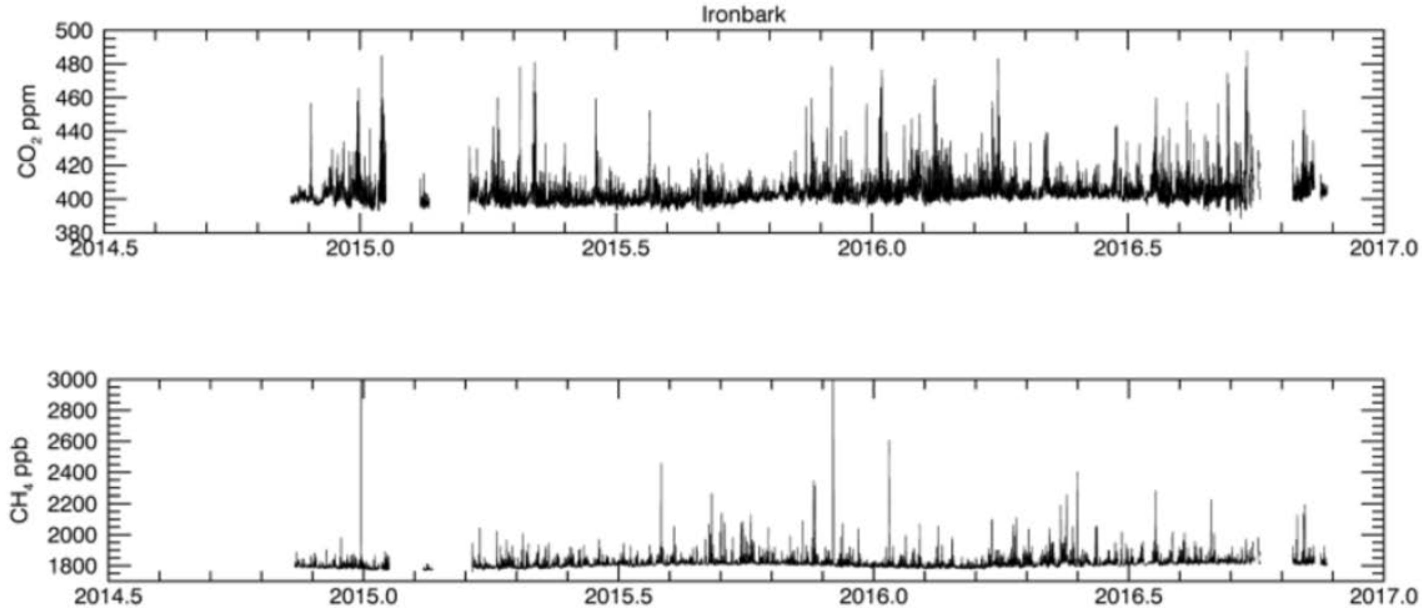


Figure 3. Measured concentration time series (hour means) of CO_2 (parts per million, ppm) and CH_4 (parts per billion, ppb) at Ironbark.

Concentrations at Burncluith

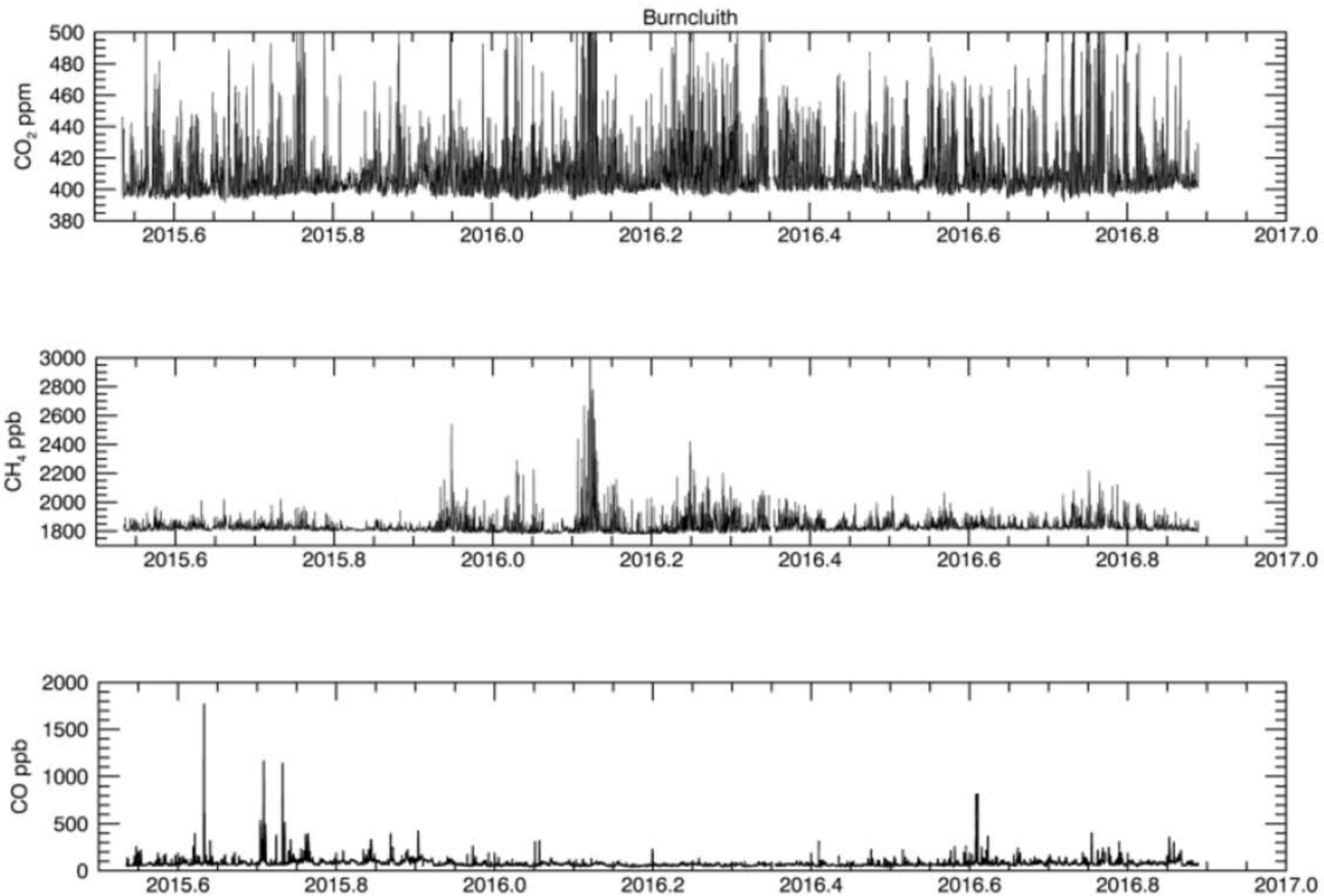


Figure 4. Measured concentration time series (hour means) of CO_2 (ppm), CH_4 (ppb) and CO (ppb) at Burncluith.

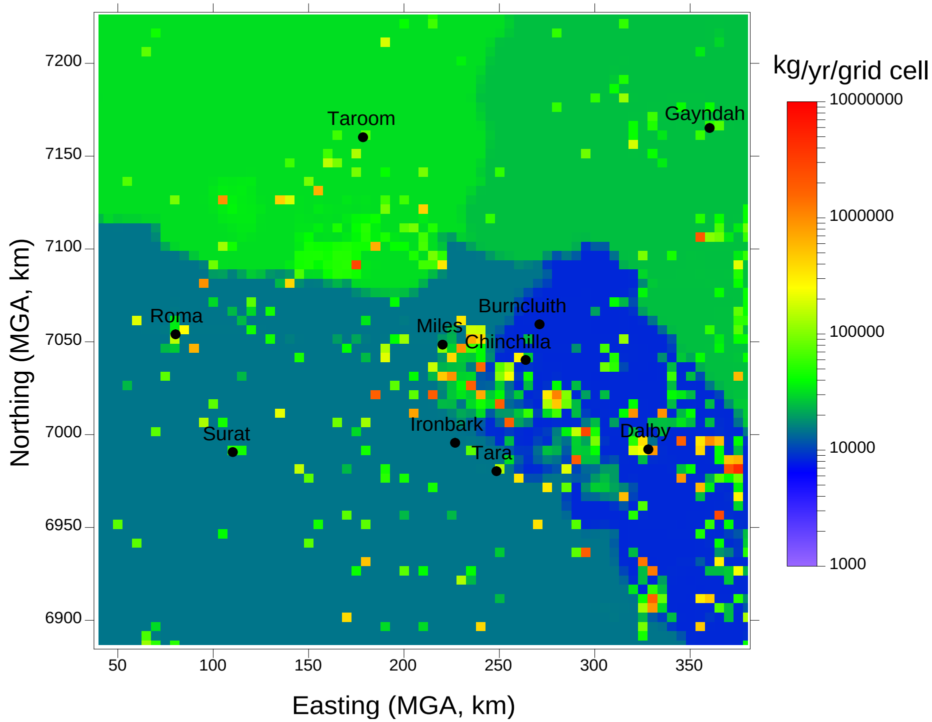
Data selection and filtering

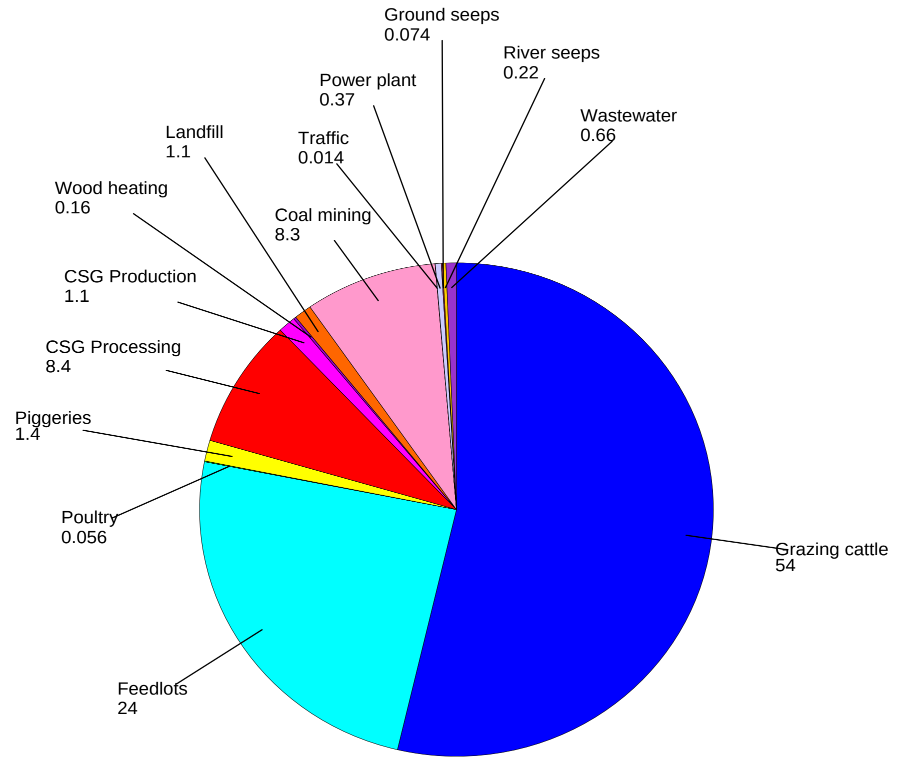
Removal of signals

- From cows near analyser inlets (CO_2 tracer)
- From burning off and dwelling open fire (CO)
- Of nocturnal measurements (high stability, extreme CH_4 gradients)

Bottom-up methane emission inventory for the region

- Prepared by Katestone Environmental with CSIRO input and feedback
- Used in forward runs and as a prior in the inverse modelling
- 1 km grid cells across 350 km x 350 km
- Total emission = 173 x 10^6 kg yr^{-1} , dominated by cattle grazing, feedlots and CSG





CSG sources (Katestone inventory)

	Emission source		Intermittent	Continuous
Production emissions	Wellhead emissions	Wellhead control equipment		X
		Separators		X
		Maintenance	X	
		Leaks	X	
	Combustion emissions	Well head pumps		X
		Flaring	X	
		Diesel used in vehicles	X	
		Backup generators	X	
	Pipeline emissions	Pipeline control equipment		X
		High point vents on produced water pipelines	X	
Processing emissions	Processing facility emissions	Compressor venting		X
		Control equipment		X
		Gas conditioning units including dehydrators		X
	Combustion emissions	Plant compressors		X
		Flaring	X	
		Diesel used in vehicles	X	
		Backup generators	X	
	Produced water	Collection and storage of produced water	X	

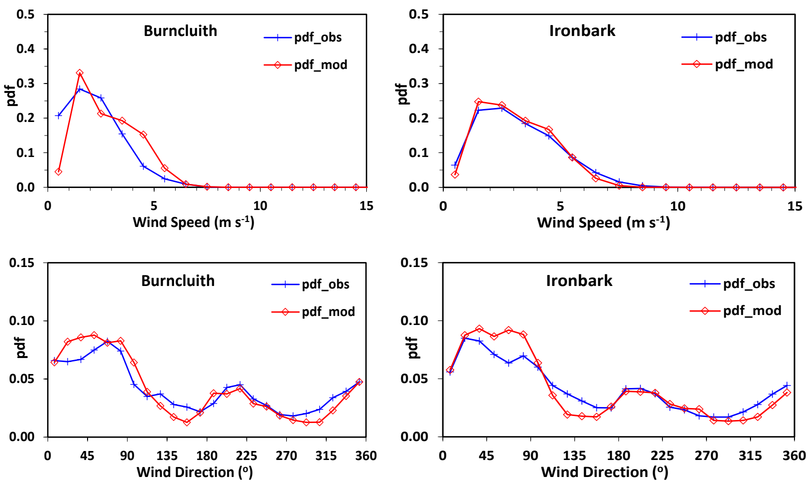
Number of Operators	Number of Gas Fields	Number of Wells^	Number of Processing Facilities
Five	16	4628	16

Table note:
^Number of wells estimated based on Queensland Government CSG production data

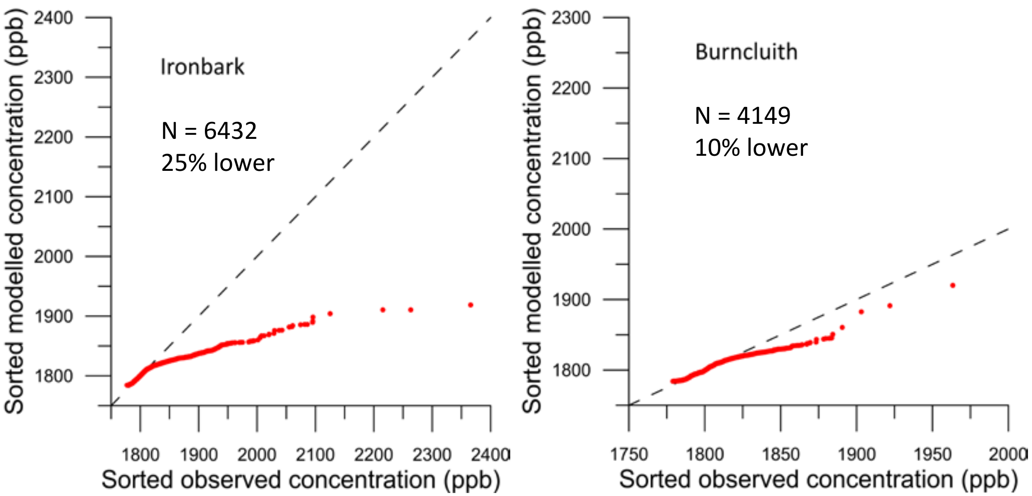
Forward modelling with bottom-up emissions

- CSIRO's forward prognostic model TAPM used
- The modelled meteorology compares well with observations
- Quantile-quantile (q-q) plots show that the model underestimates CH_4 observations suggesting missing or under-reported sources in the inventory

Meteorology



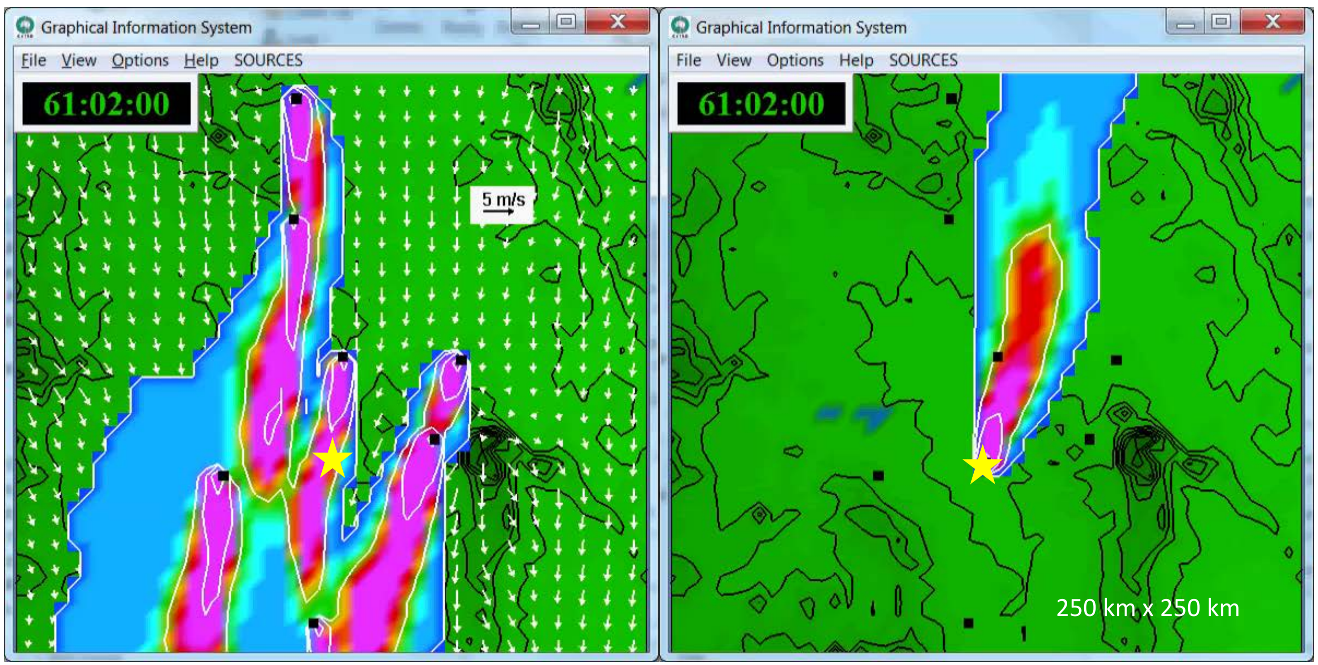
Methane concentration



Inverse modelling at local to regional scale

- Based on a Bayesian approach
- TAPM formulated in backward mode for source-receptor relationship (more efficient than forward)
- MCMC used for posterior sampling

(a) Forward transport from sources (b) Backward transport from monitor (more efficient)



Bayes' rule

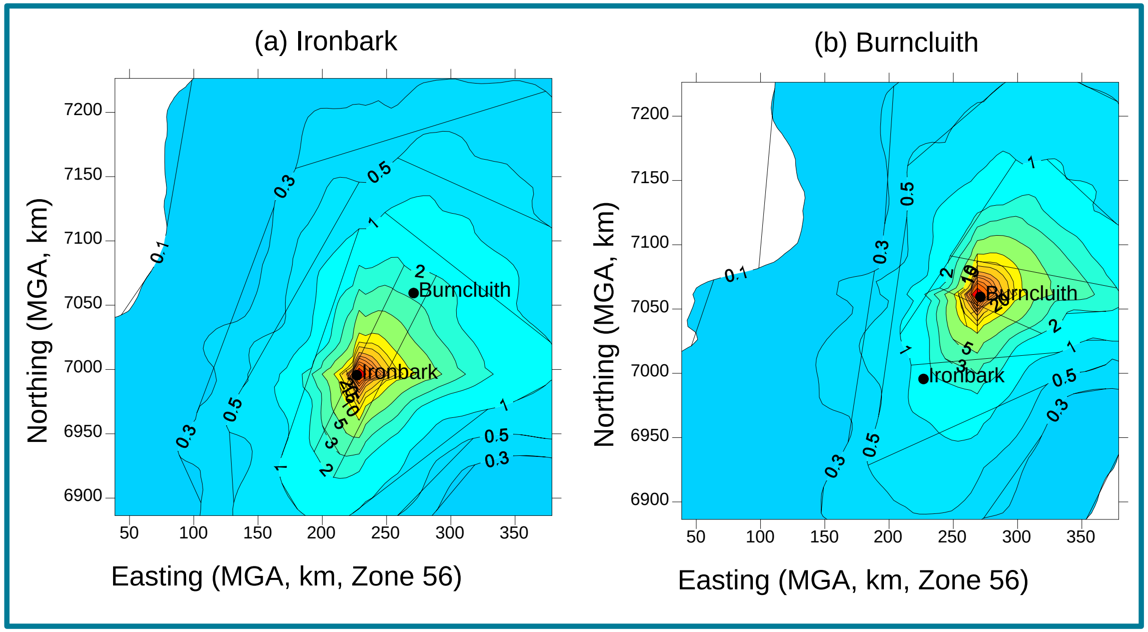
Posterior Prior

$$p(\mathbf{q}\,|\,\mathbf{c}) \propto p(\mathbf{q})\,.\,p(\mathbf{c}\,|\,\mathbf{q})$$

Likelihood function / source-receptor relationship

Inverse model application for CH_4 emissions

- Tracers released from Ironbark and Burncluith (backward TAPM) to generate the source-receptor relationship required for the Bayesian analysis



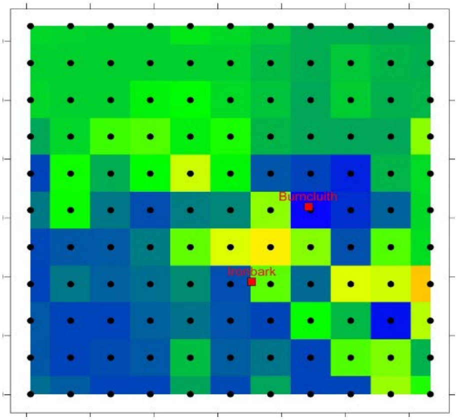
- Relatively low probability of adequately sampling the NW and SE corners of the domain
- Region of CSG activity between the two monitoring stations best sampled

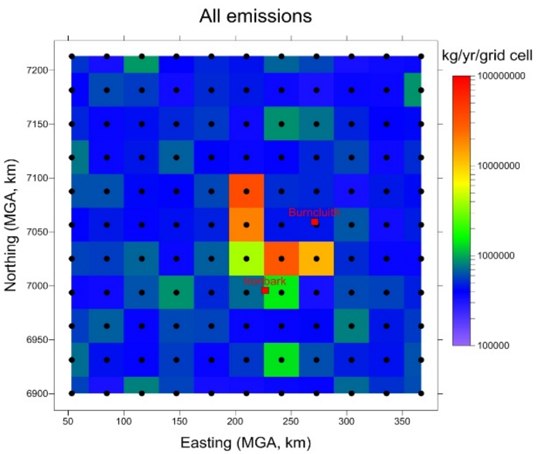
Simulation details

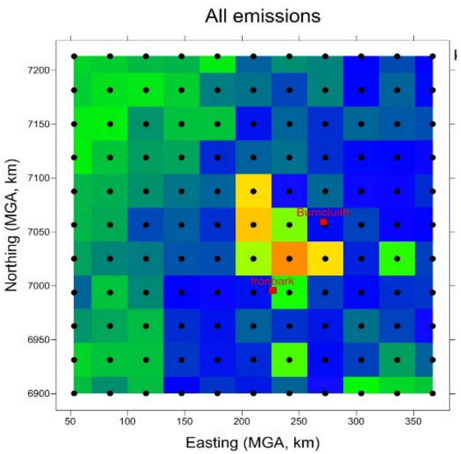
- 11 x 11 source regions considered (31 x 31 km)
- July 2015-December 2016
- Model and background methane uncertainties were accounted for
- Three cases of emission prior specified
  1) Loose bounds (10-10,000 g s^{-1} per source area) – uninformative prior
  2) Spatially uniform prior (45.4 g s^{-1} per source area), Gaussian uncertainty of 10%
  3) Bottom up inventory as prior, Gaussian uncertainty of 3%

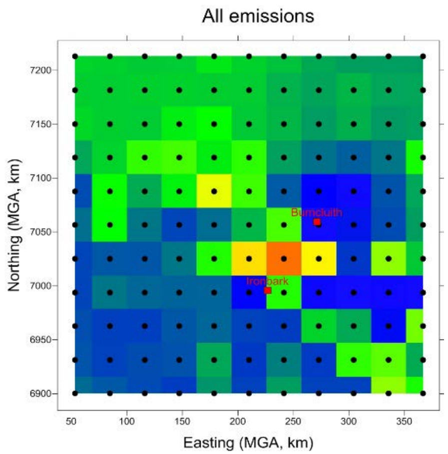
Results: inferred emissions

Inventory, 173 x 10^6 kg yr^{-1}









1) Uninformative prior

- Total emission within 6.4% of inventory
- High emissions in the centre consistent with inventory, but magnitude larger

2) Spatially Uniform prior

- Total emission within 17.7% of inventory
- Emissions distribution improved

3) Inventory as prior

- Total emission within 4.4% of the inventory
- 166 x 10^6 kg yr^{-1}
- Distribution very similar to the prior but higher emissions between the two stations

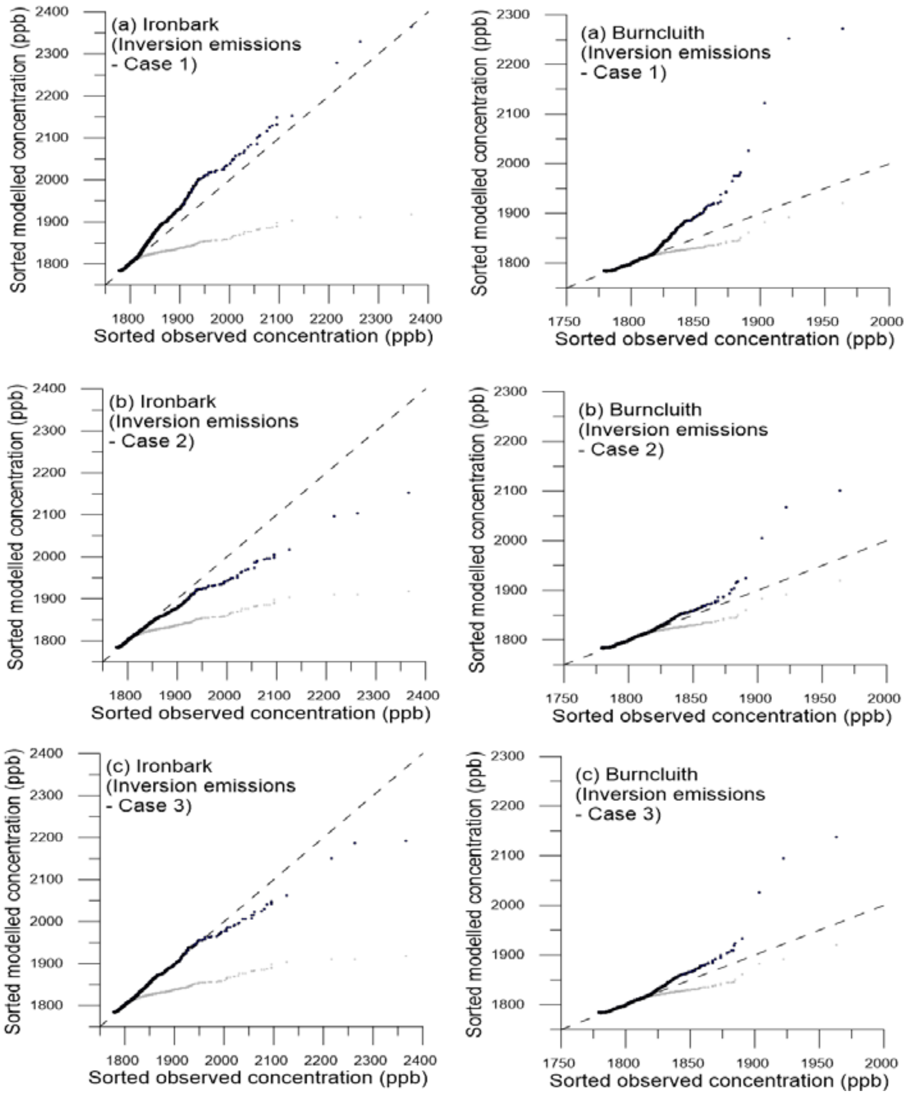
Inverse model validation

Faint symbols: with inventory emissions

Inferred emissions are used in forward TAPM to simulate methane concentrations

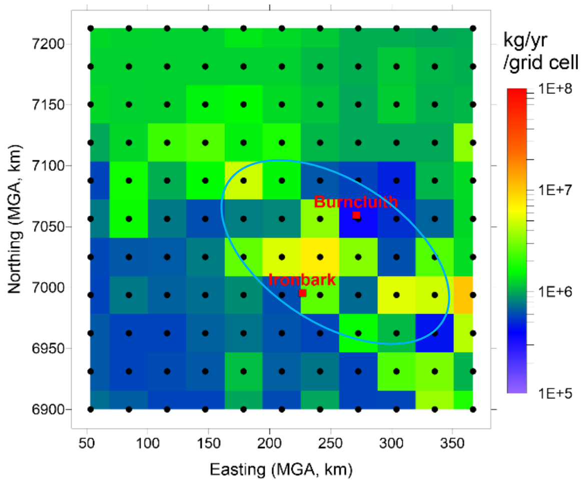
- Case 1: Loose bounds, uninformative prior
- Case 2: Spatially uniform prior
- Case 3: Bottom up inventory as prior

Case 3 provides the best comparison, but Case 2 is not far off



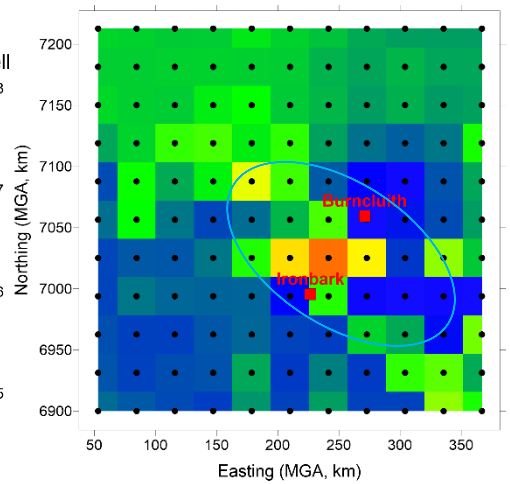
Emissions in CSG subregion

Bottom-up inventory emissions



173×10^6 kg yr^{-1}

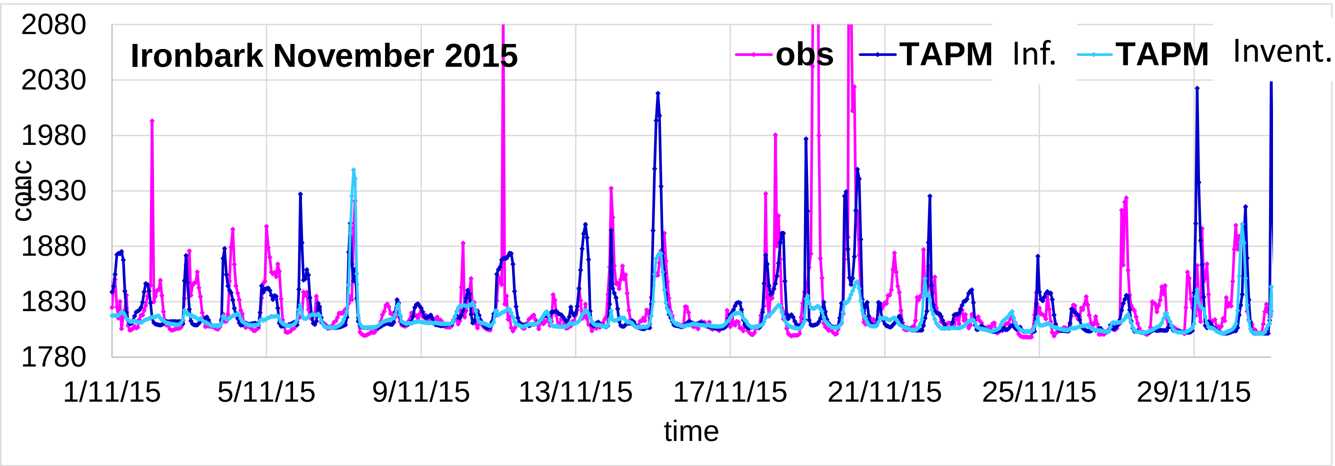
Case 3: Inversion inferred emissions



166×10^6 kg yr^{-1}

- Total inferred emissions similar to inventory, but 30% greater in the subregion
- Subregion dominated by feedlots + poultry + piggeries (30%), followed by cattle grazing (28%) and CSG processing (27%) sectors

Observed and modelled timeseries



– The inferred emissions describe the observed concentrations (timing and size of peaks) better than the bottom-up emissions

Conclusions

An atmospheric "top down" methodology was developed to estimate CH_4 emissions from local to regional scale

- Combines a Bayesian inference approach and a backward configuration of TAPM
- Applied to the Surat Basin: 2 monitoring stations across 350x350 km
- Precise, intercalibrated CH_4 concentrations, CO_2 and CO tracers, meteorology
- Stable solution, total emissions (166×10^6 kg yr^{-1}) and distributions compare well to prior information and bottom up inventory (173×10^6 kg yr^{-1})
- In the CSG region, the inferred emissions are 30% greater than the inventory emissions
- Sources inferred from inverse modelling explain the observed CH_4 concentrations better than the inventory
- Study described in full in Final Report and presented at three conferences including 2019 European Geophysical Union General Assembly

Further work

- Journal publication
- Explore value in other data – moving platforms (aircraft, vehicles), small low cost sensors, satellites
- Additional tracers – CH_4 isotopes, accompanying gases
- Follow up studies (after future growth and eventual wind down in CSG activity)
- Zone in on hot spots indicated by inversion

Acknowledgements

- CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA)

  Research reports https://gisera.csiro.au/project/methane-seepage-in-the-surat-basin

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Thank you

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