GISERA
Gas Industry Social and Environmental Research Alliance

Regional fluxes of methane in the Surat Basin, Queensland

Stakeholder Roundtable Group meeting

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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)

October 2018

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Aim of the project

- Demonstrate the utility of an atmospheric “top-down” or inverse modelling approach to infer regional scale (~ 100 – 1000 km) methane emissions across the Surat Basin
- Monitoring from 2 stations: Ironbark and Burncluith (concurrent measurements during July 2015 – December 2016)
- Compare with “bottom-up” inventory emissions

Surat Basin


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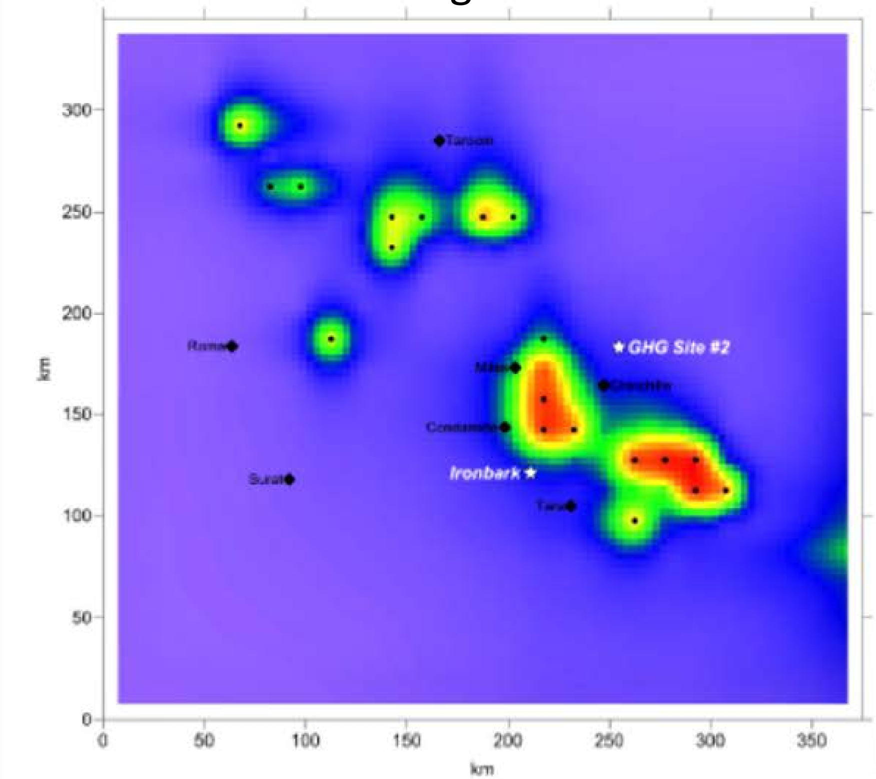
Google earth

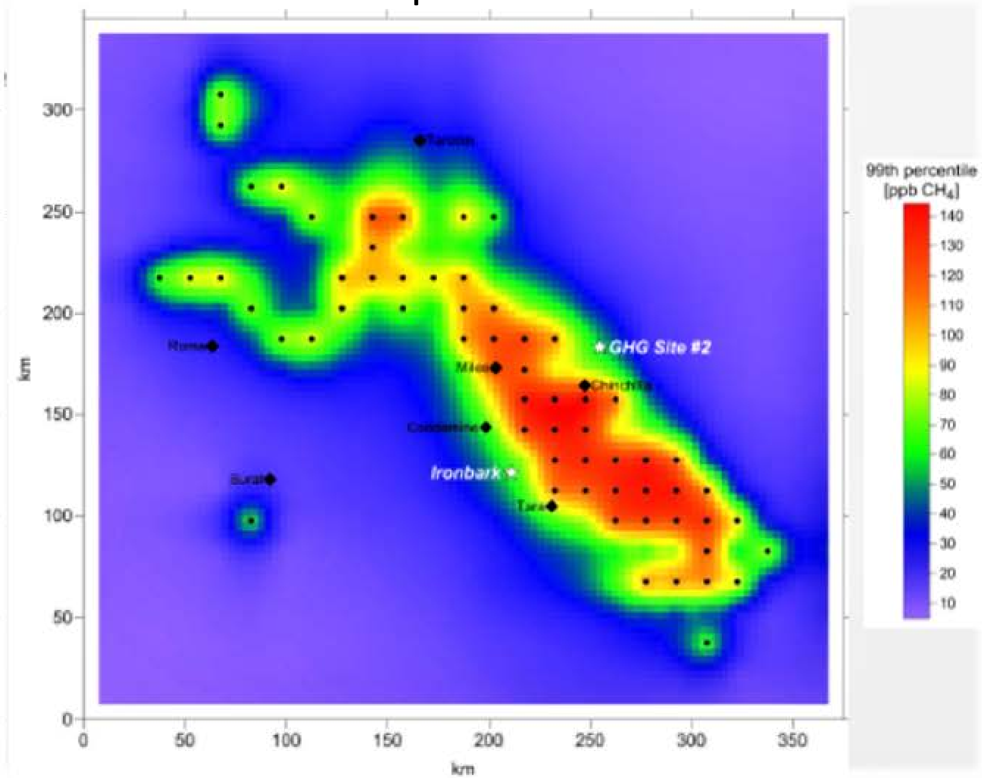
Simulated CH_4 concentrations from CSG wells 2015 – 2018 to optimise monitoring design

Modelled methane concentration signals (TAPM) from CSG operations

existing



predicted



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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%

Technical and environmental challenges

Local engagement

Concentrations at Ironbark

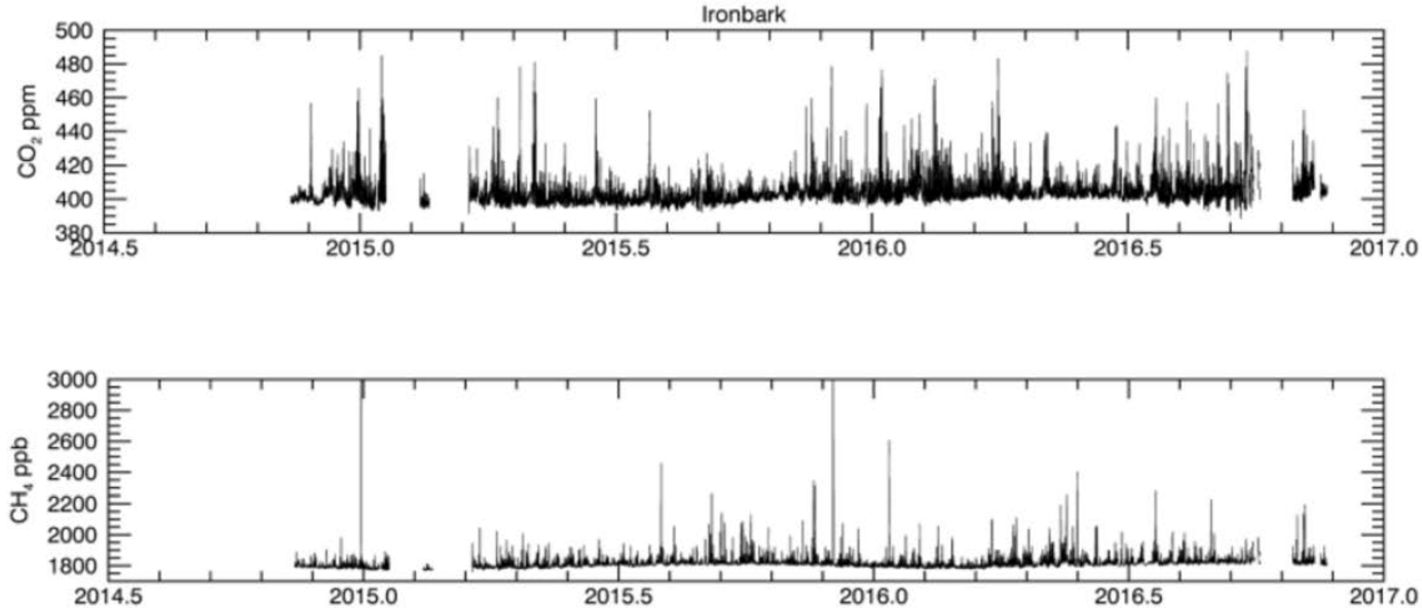


Figure 3. Measured concentration time series (hour means) of CO_2 (parts per million, ppm) and CH_4 (parts per billion, ppb) at Ironbark.

Concentrations at Burncluith

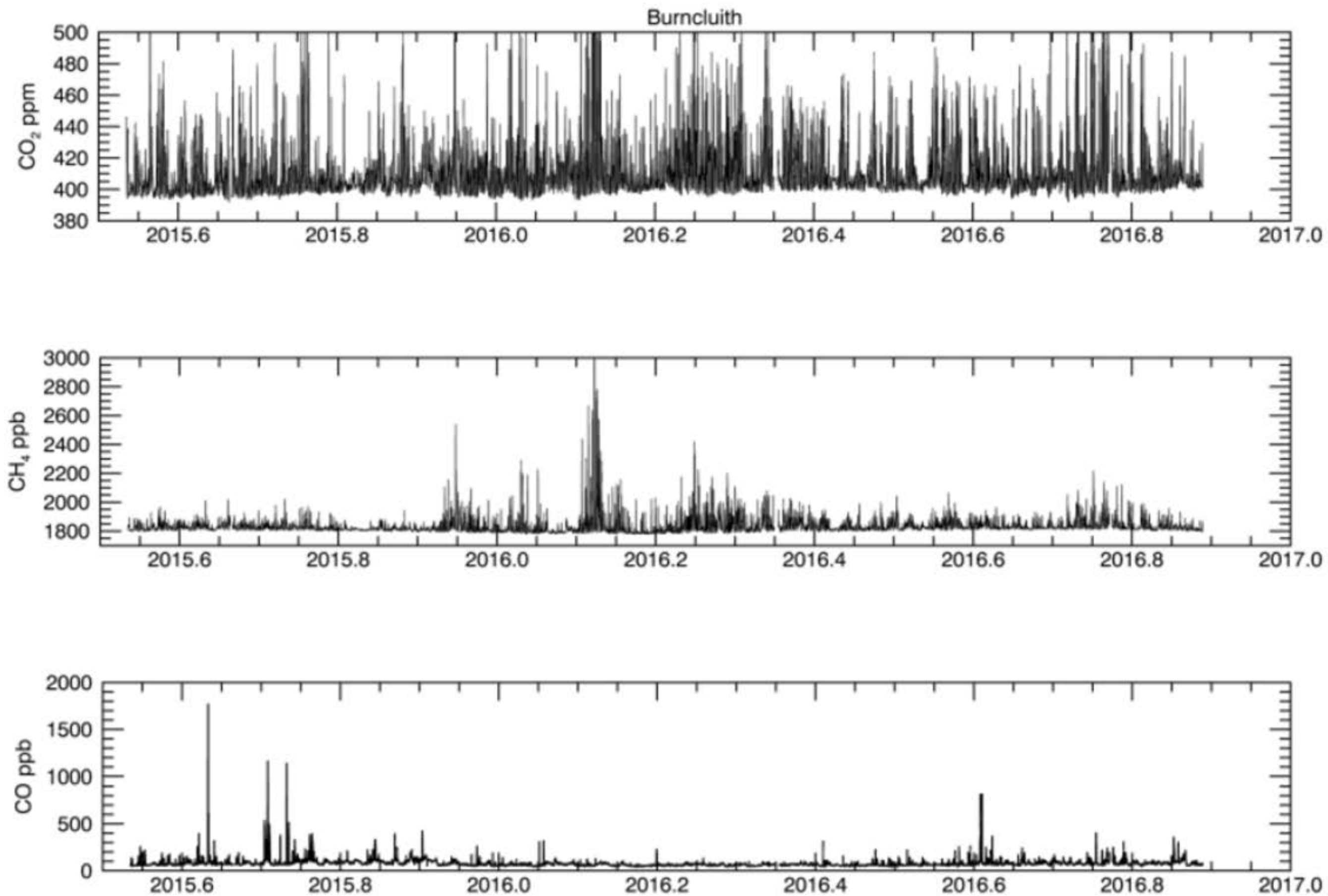


Figure 4. Measured concentration time series (hour means) of CO_2 (ppm), CH_4 (ppb) and CO (ppb) at Burncluith.

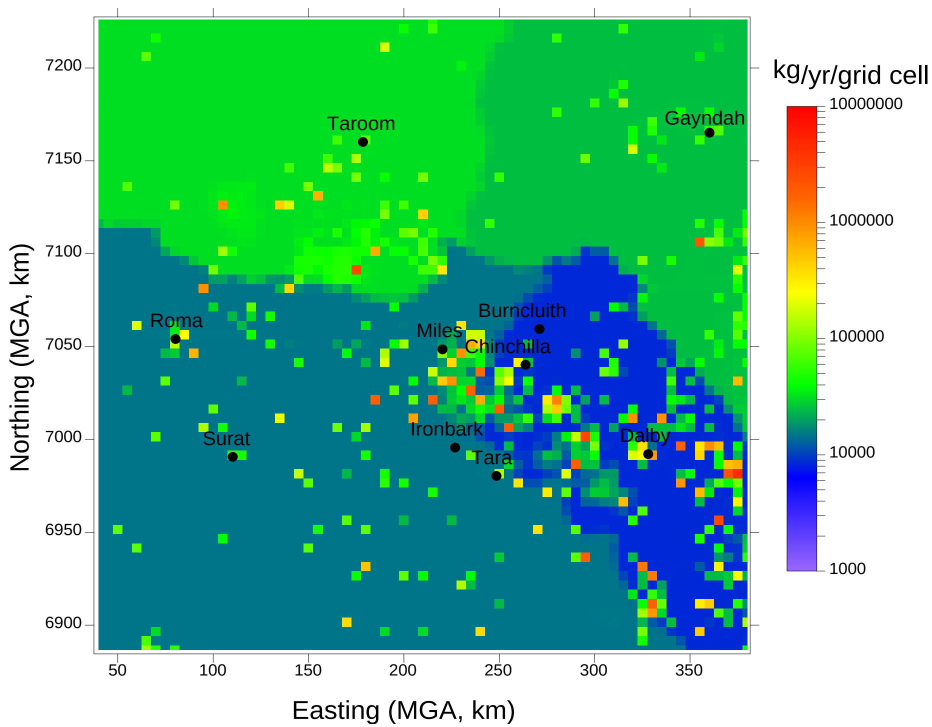
Data selection and filtering

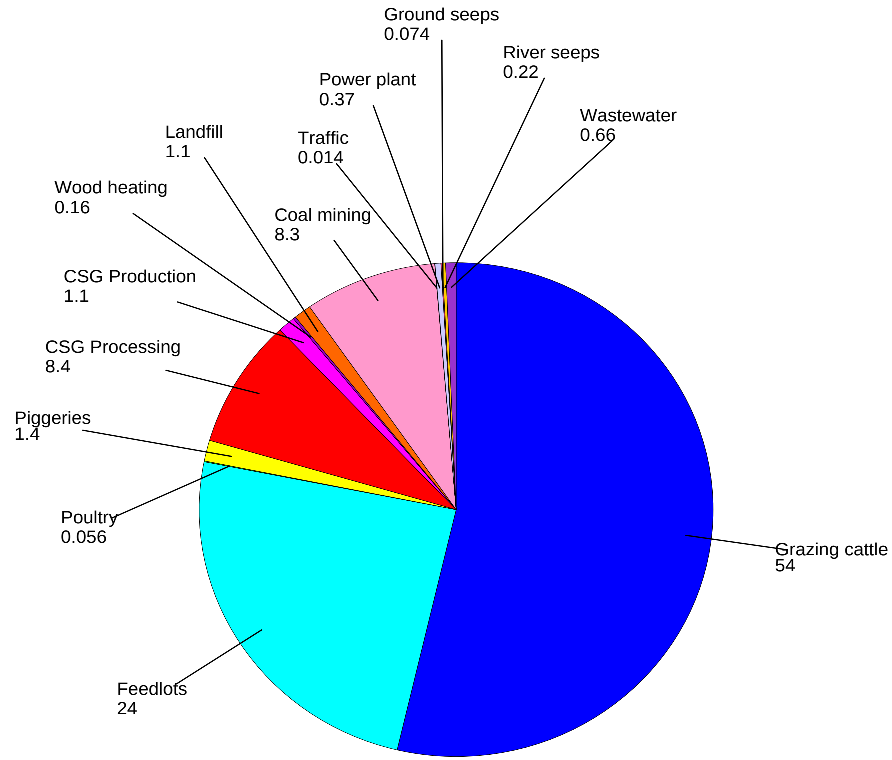
Removal of unwanted signals

- Cows near analyser inlets (detected by CO_2)
- Burning off and dwelling open fire (CO)
- Nocturnal data (high stability, low wind speeds, extreme concentration 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	

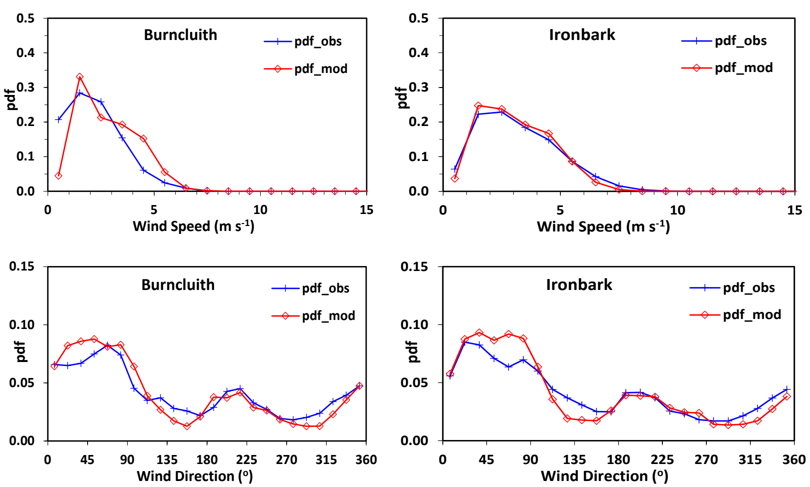
Number of Operators	Number of Gas Fields	Number of Wells^	Number of Processing Facilities
Five	16	4628	16

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

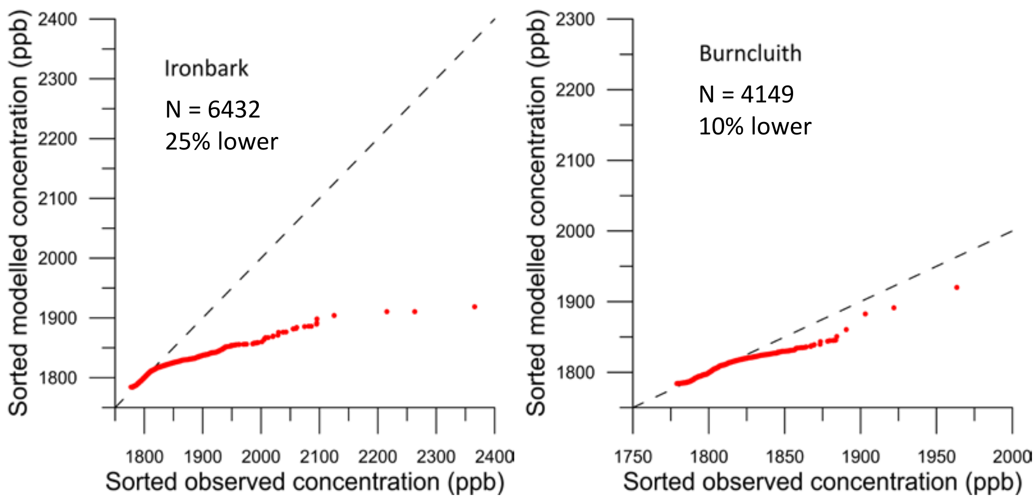
Forward modelling with bottom-up emissions

- 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 sources or under-reported emissions in the inventory

Meteorology



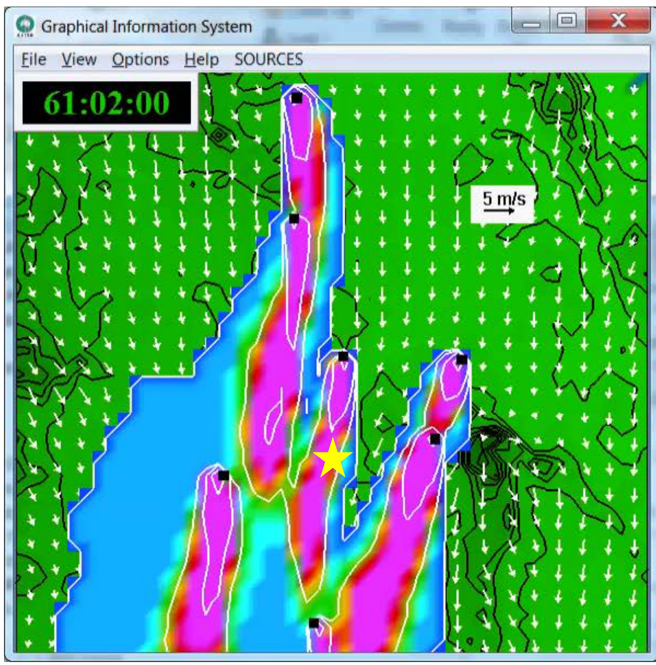
Methane concentration



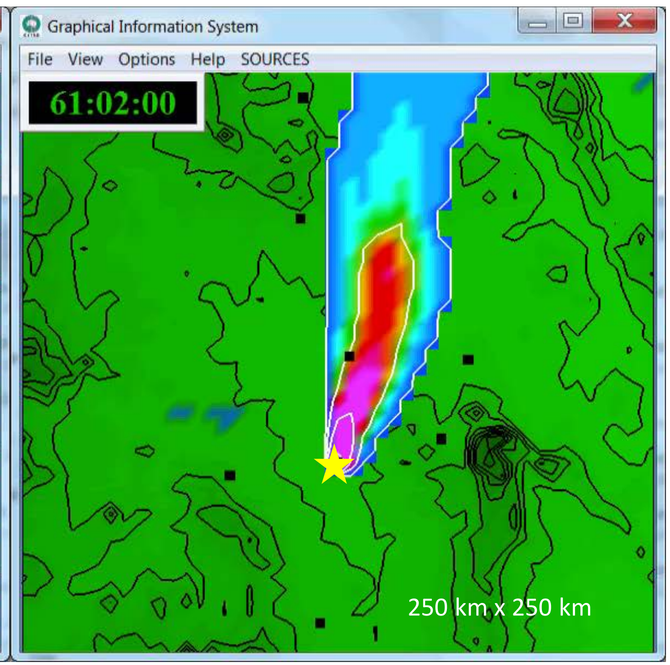
Inverse modelling at local to regional scale

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

Forward transport from sources



Backward transport from receptor (monitor)



Bayes' rule

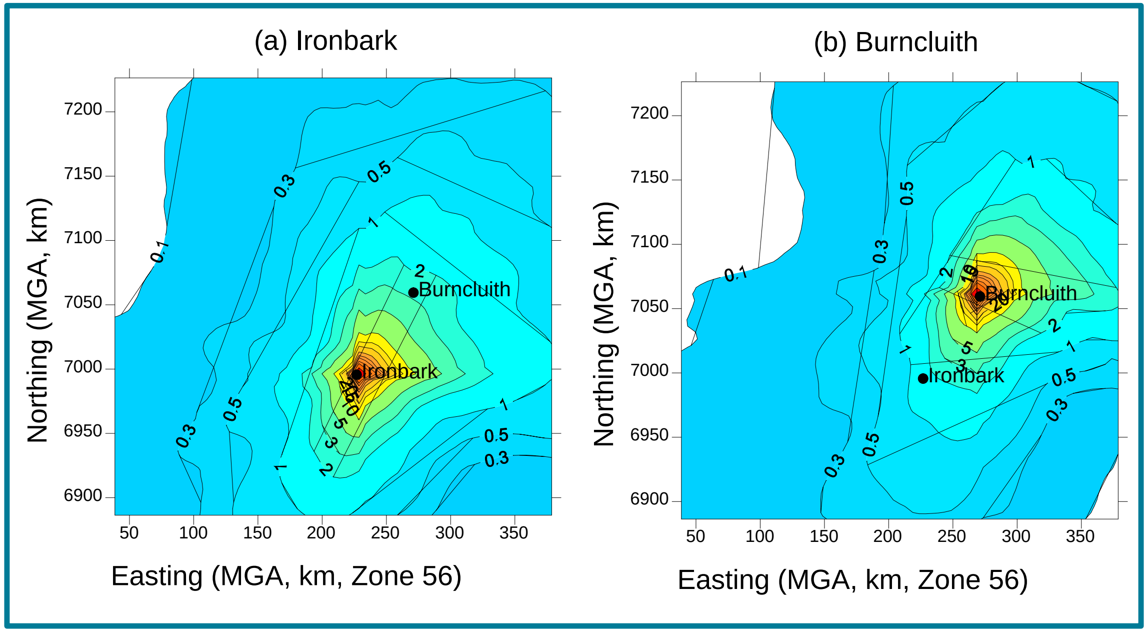
Posterior   Prior

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

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



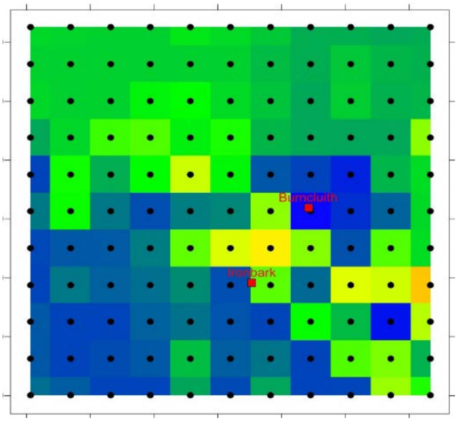
- Relatively low probability of adequately sampling the NW and SE corners of the domain
- Region of CSG activity between the two monitoring stations best sampled

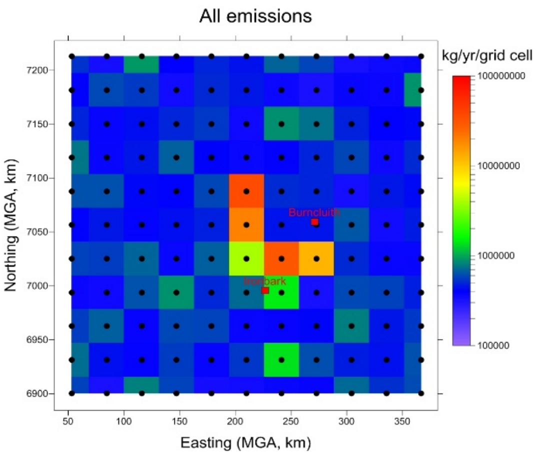
Simulation details

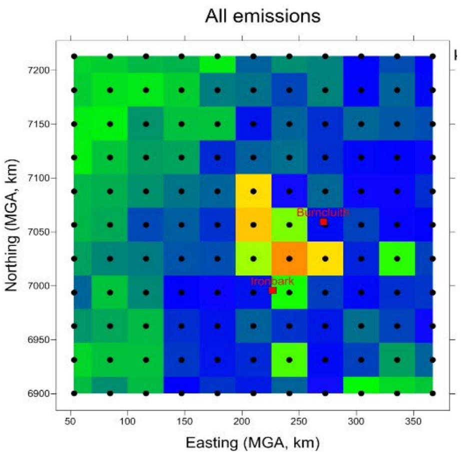
- 11 x 11 source regions considered (31 x 31 km)
- July 2015-December 2016
- Model and background methane uncertainties were accounted for
- Three cases of emission prior specified
    1) Loose bounds (10-10,000 g s^{-1} per source area) – uninformative prior
    2) Spatially uniform prior (45.4 g s^{-1}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

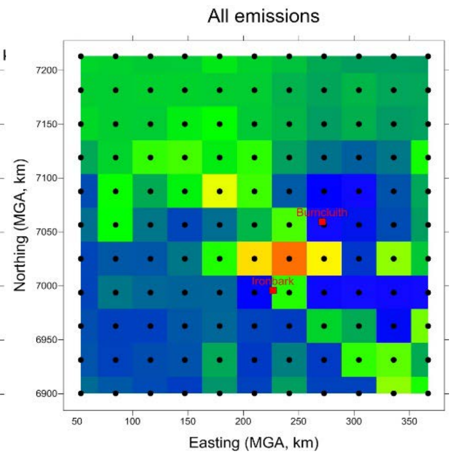
Results: inferred emissions

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

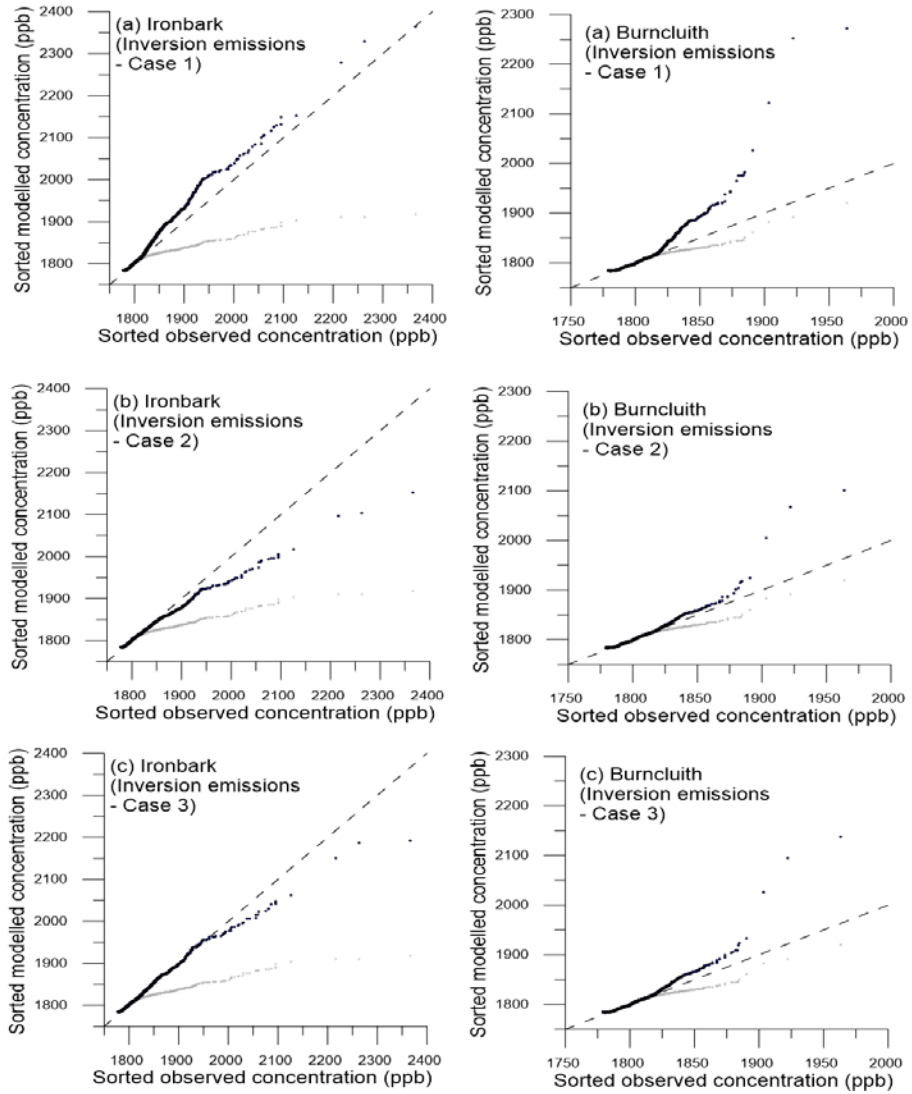
Inverse model validation

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

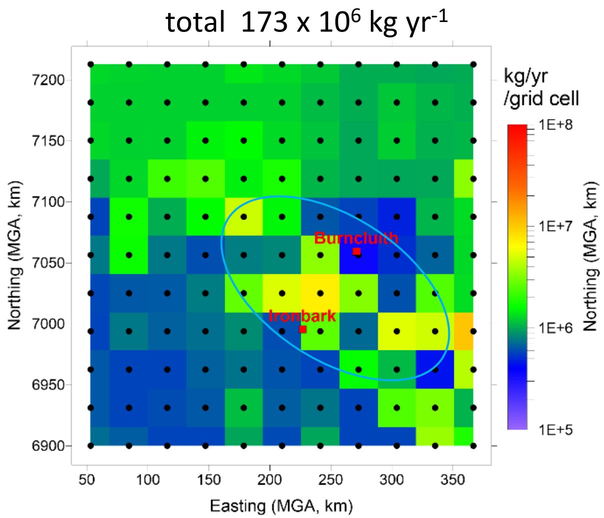
Case 3 provides the best comparison, but Case 2 is not far off

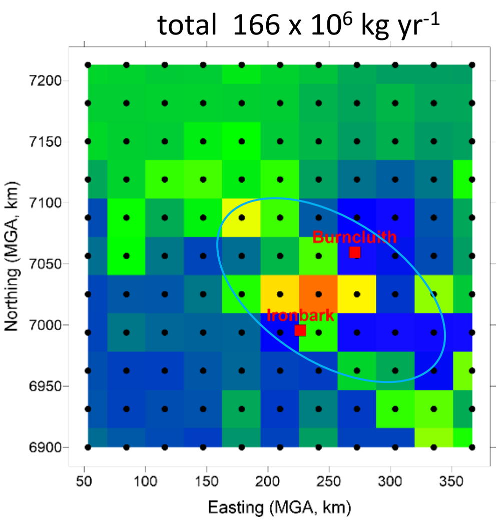


Emissions in CSG subregion

Bottom-up inventory emissions

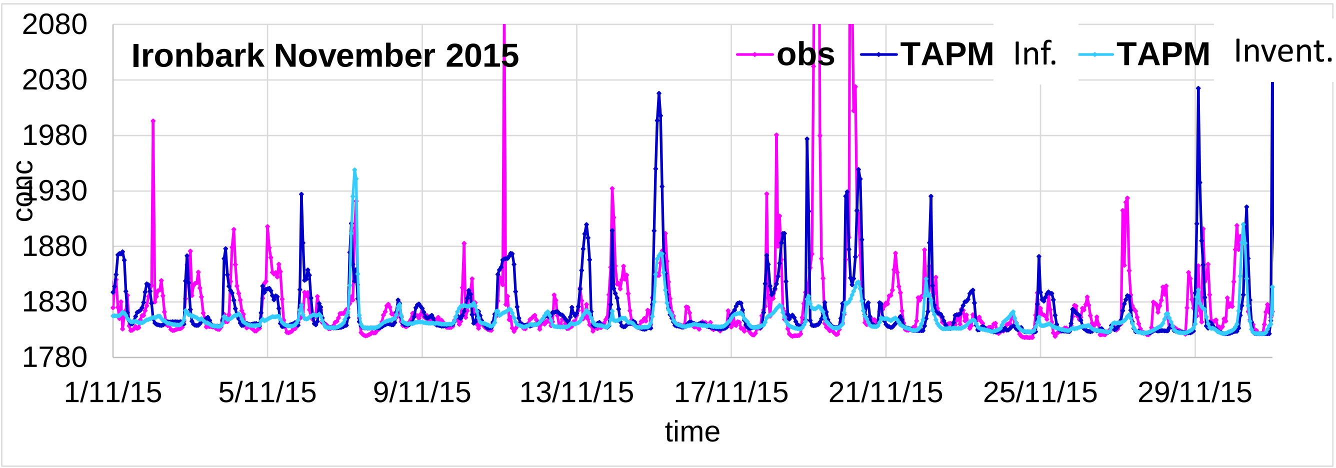
Case 3: Inversion inferred emissions





- 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%)

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, inter-calibrated CH_4 concentrations, CO_2 and CO tracers, meteorology
- Stable solution, total emissions (166 x 10^6 kg yr^{-1}) and distributions compare well to prior information and bottom up inventory (173 x 10^6 kg yr^{-1})
- In the CSG region, the inferred emissions are 30% greater than the inventory emissions
- Emissions 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 to quantify source types – 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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