Estimates of regional CH$_4$ emissions in the Surat Basin, Queensland, Australia
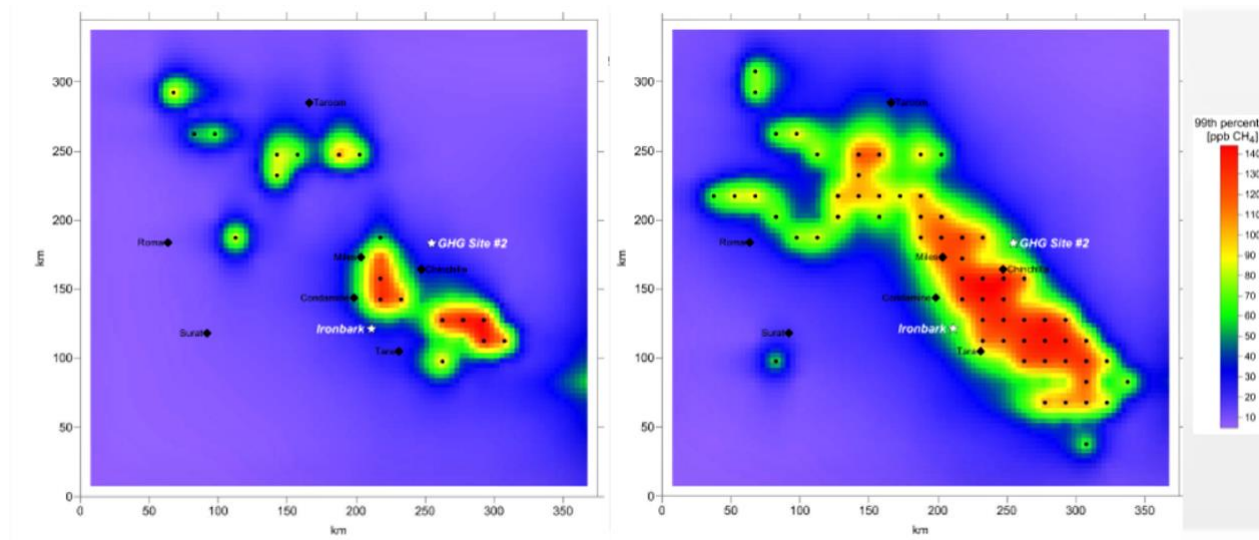
Zoë Loh, David Etheridge, Ashok Luhar, Julie Noonan

Predicted CSG well expansion: 2015 – 2018

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

	Ironbark (IBA)	Burncluith (BCA)
Instrument	Picarro G2301	Picarro G2401
Trace gases	CO_2, CH_4, (H_2O)	CO_2, CH_4, CO, (H_2O)
Intake height	10 m	10 m
Met. height (3D sonic)	5.8 m	7.6 m

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Methane inventory emissions (2015), Surat Basin
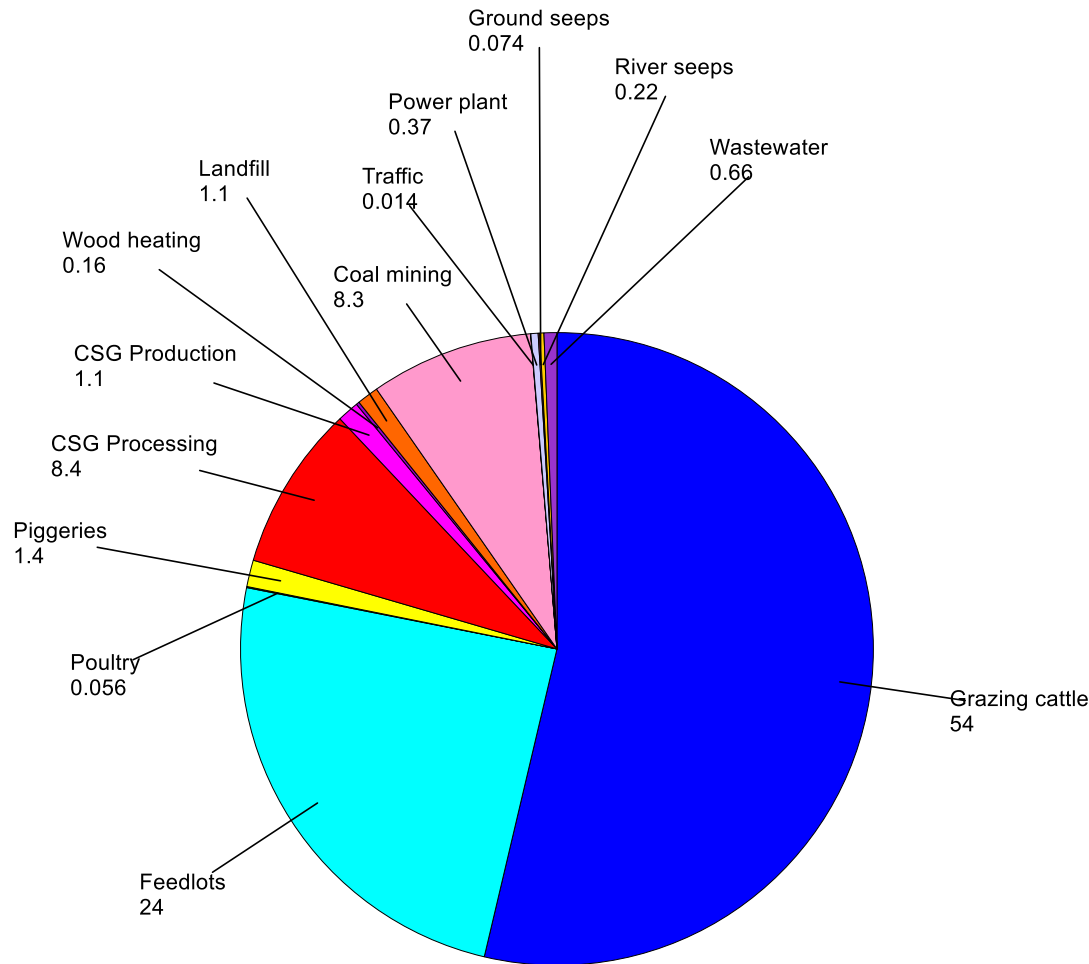
Produced by environmental consultancy, Katestone (2017)
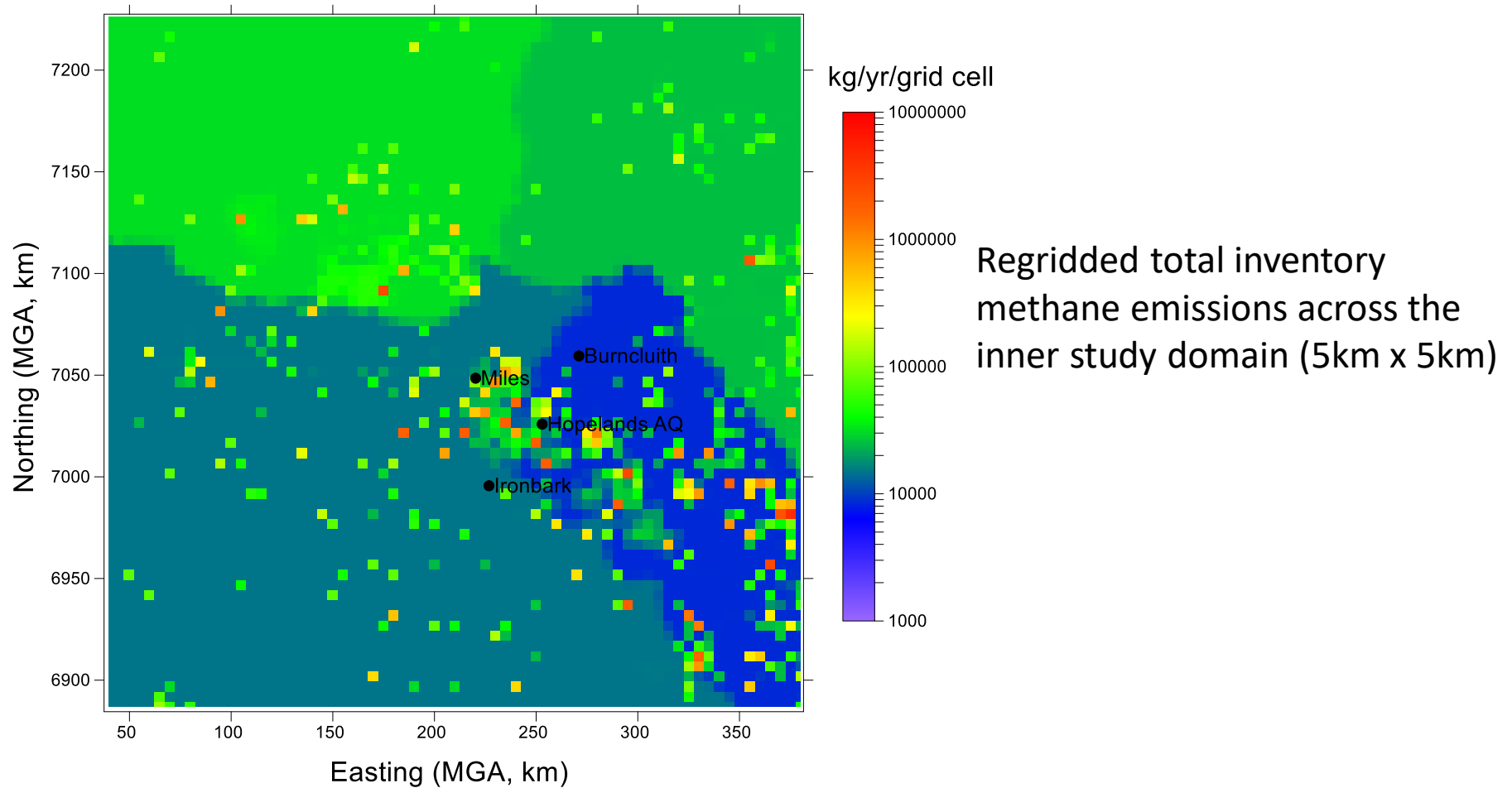
Shown as % by sector

Used in forward model run and as the prior in subsequent inversion
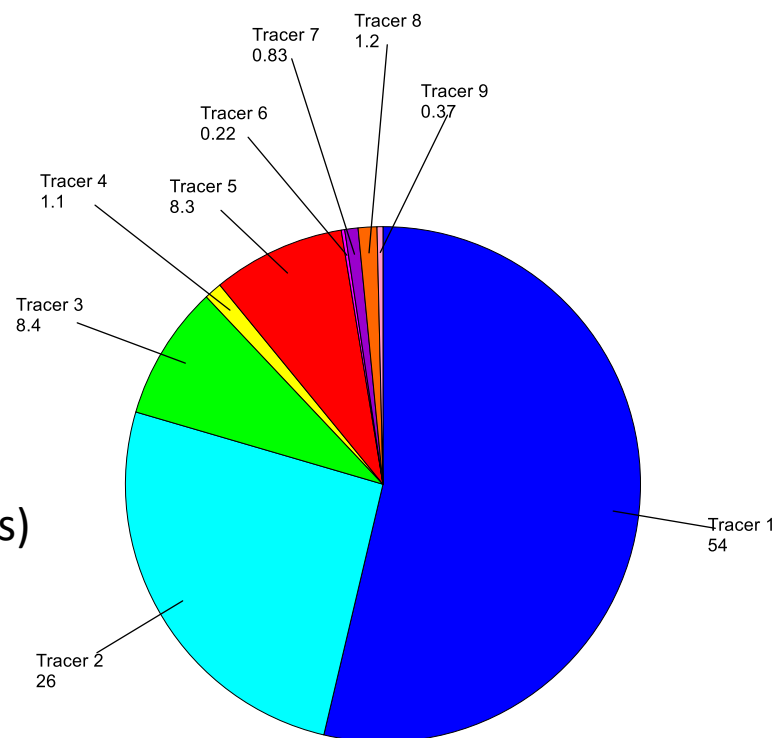
Notable exceptions:
- biomass burning
- wetlands
- fugitive CSG

Methane inventory emissions (2015), Surat Basin

Regridded total inventory methane emissions across the inner study domain (5km x 5km)
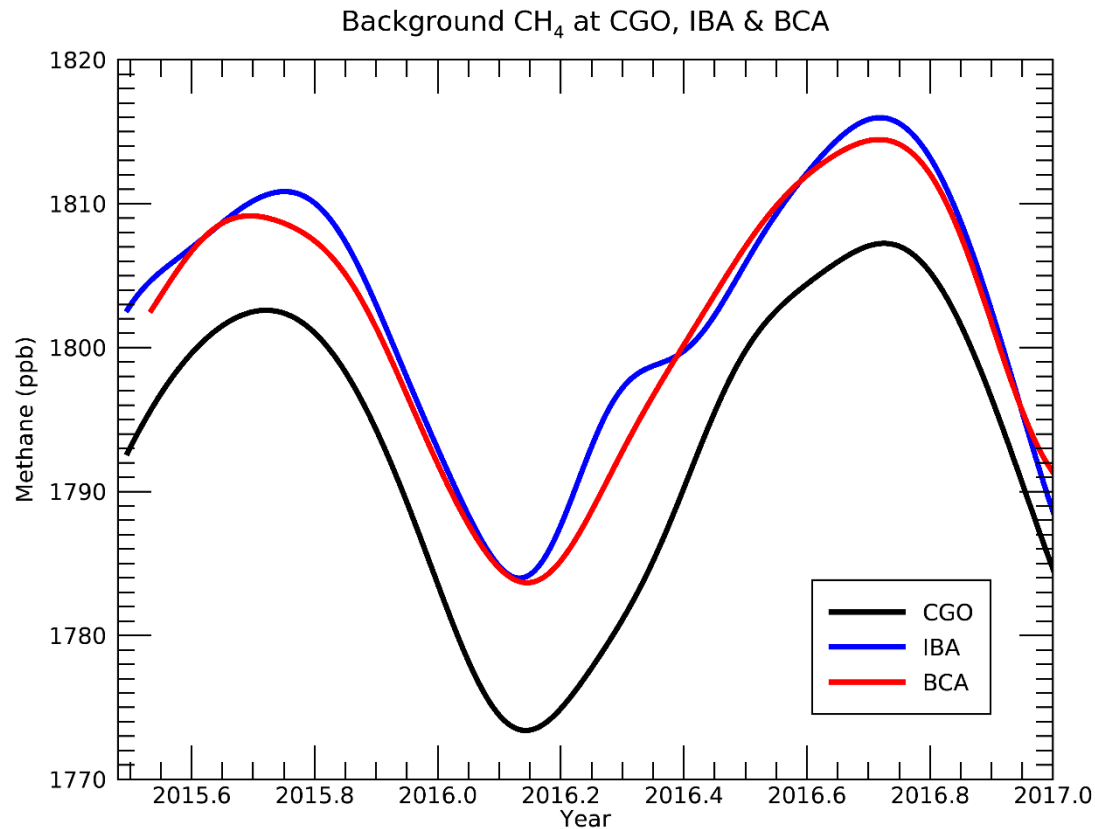
TAPM configuration (v4.0.4)

- 1 July 2015 – 31 December 2016
- Inner domain: 370 x 370 km, resolution 5 x 5 km
- Outer domain: 1110 x 1110 km, resolution 15 x 15 km
- 25 vertical levels; lowest at 10m
  - Tracer 1 (Grazing cattle)
  - Tracer 2 (Feedlot + Poultry + Piggeries)
  - Tracer 3 (CSG Processing)
  - Tracer 4 (CSG Production)
  - Tracer 5 (Mining)
  - Tracer 6 (River seeps)
  - Tracer 7 (Wastewater + Wood heating + Vehicles)
  - Tracer 8 (Landfill + Ground seeps)
  - Tracer 9 (Power stations)

Pie chart:
- Tracer 1: 54
- Tracer 2: 26
- Tracer 3: 8.4
- Tracer 4: 1.1
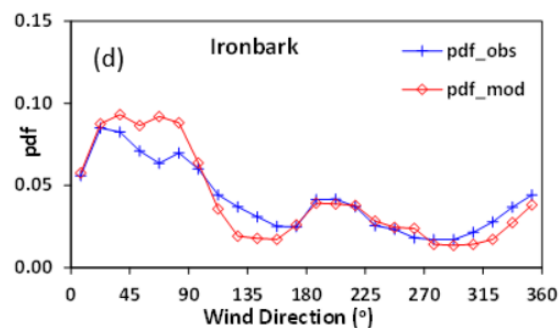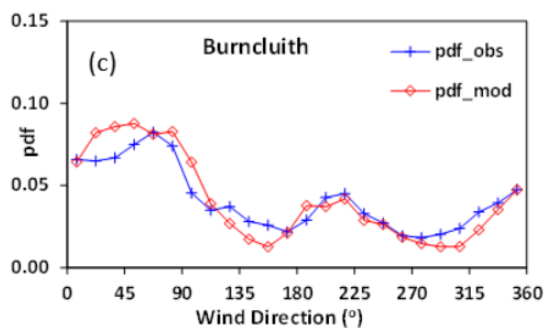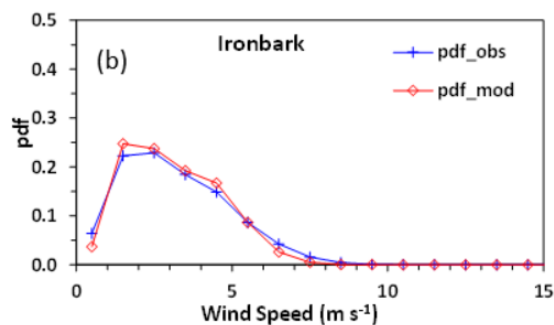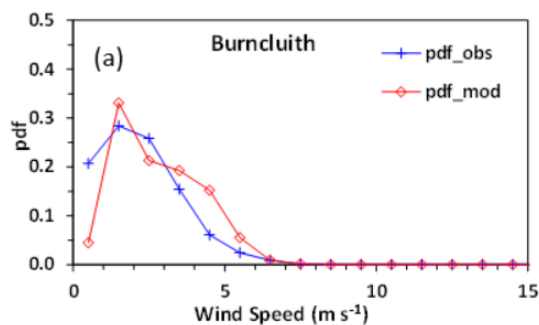- Tracer 5: 8.3
- Tracer 6: 0.22
- Tracer 7: 0.83
- Tracer 8: 1.2
- Tracer 9: 0.37

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Background methane concentration

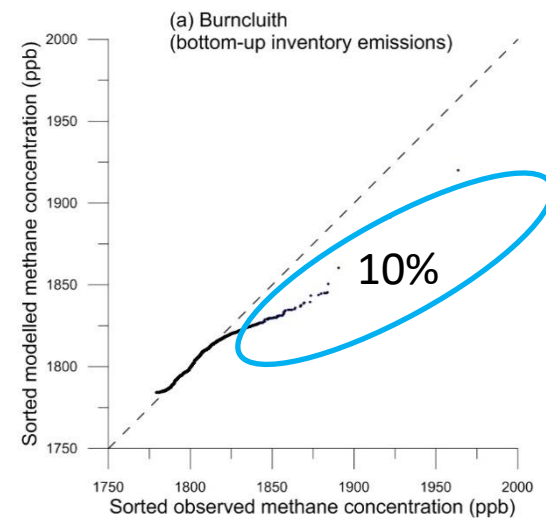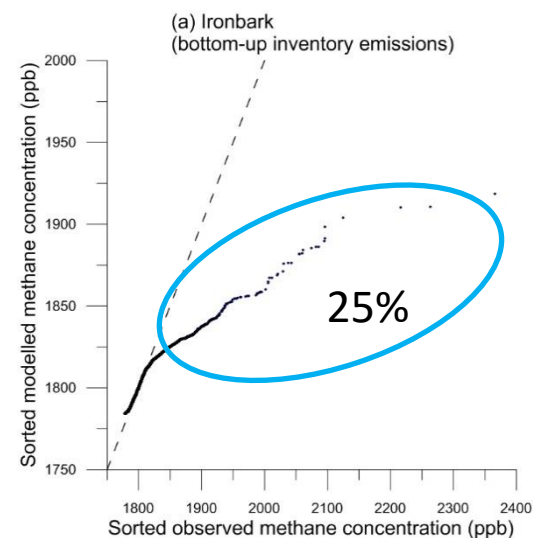Background CH$_4$ at CGO, IBA & BCA

Forward model results

Methane concentrations
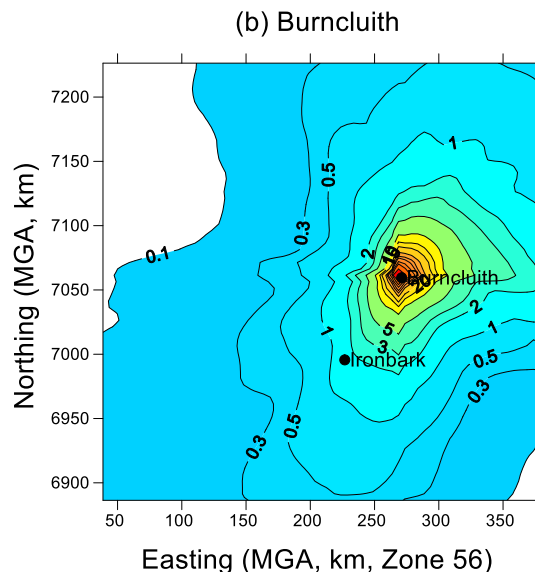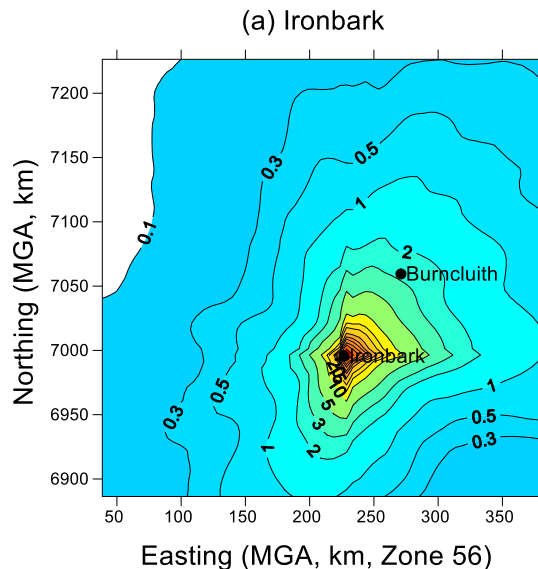
Meteorology

Inversion methodology

- Same nested domains as the forward modelling
- Tracers released from Ironbark and Burncluith (backward TAPM) to generate the source-receptor relationship required for the Bayesian analysis

(a) Ironbark   (b) Burncluith

18 month average

Low probability of adequately sampling the NW corner of the domain

Region of CSG activity best sampled (by design)

- 11 x 11 sources (see re-gridding next slide)
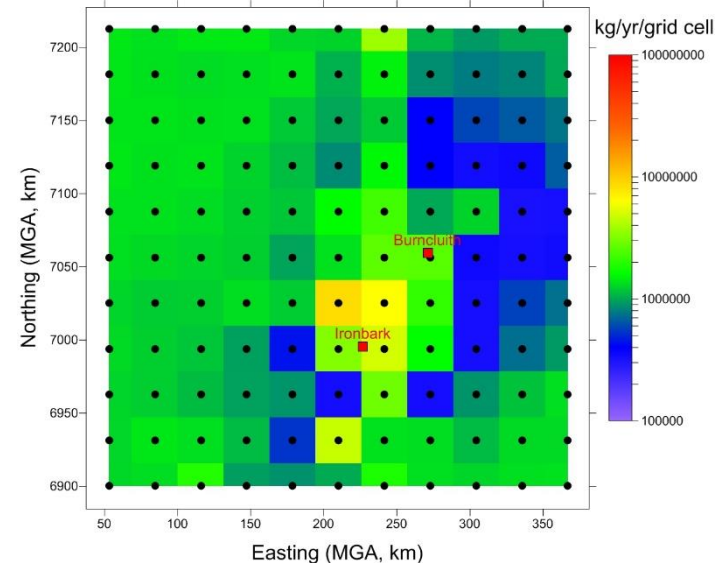- MCMC technique for posterior PDF sampling

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Synthetic inversion

- Inventory emissions re-gridded to 31 km x 31 km
  - Used to drive forward model run
    - Modelled concentration timeseries at IBA & BCA
  - Modelled timeseries + uniform prior

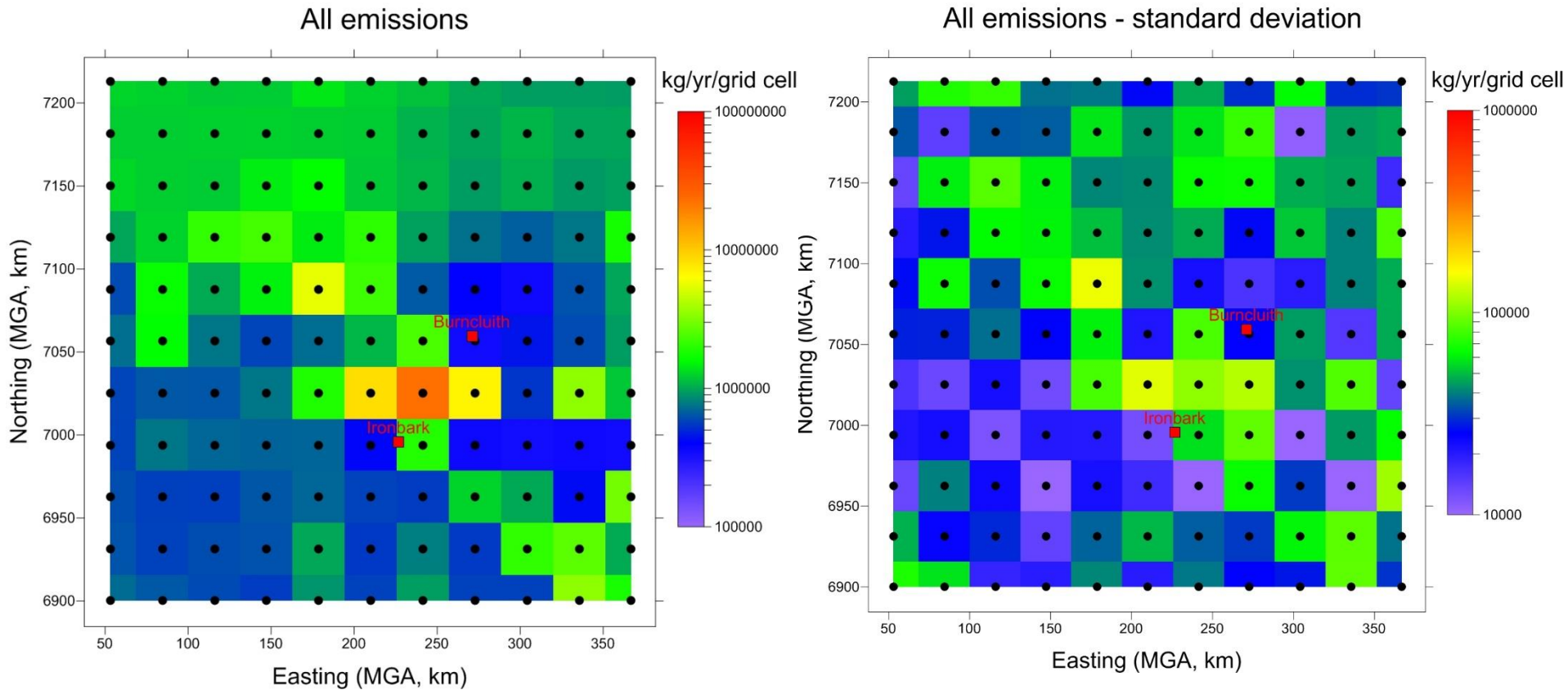Inventory emissions
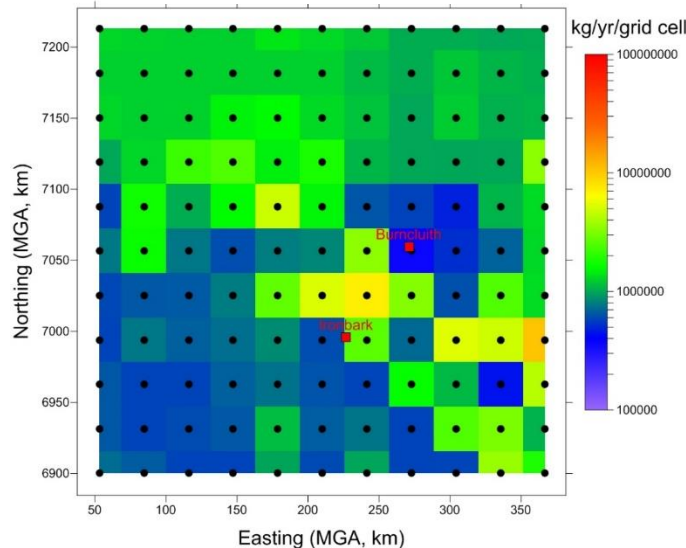
Synthetic inversion result

Total emissions 6% smaller than inventory

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Inversion methodology

- Measurements used for inversion if:
  - 1000-1700 h, i.e. daytime
  - 1800-0900 h *and* wind speed > 3 m.s^{-1}
  - At BCA if CO < 10 ppb above background
    - Screen out biomass burning signal
- Background [CH$_4$] subtracted from time-matched hourly measured concentrations (3.5 ppb uncertainty)
- Model uncertainty specified as 20%
- Three cases:
  a) Broad range of emission rates (10-10,000 g.s^{-1} per source area)
  b) Even prior (45.37 g.s^{-1} per source area), Gaussian uncertainty of 10%
 c) Bottom up inventory as prior, Gaussian uncertainty of 3%

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Inversion results

a)

Very loose bounds

Total flux 6.4% smaller than inventory

High fluxes centrally consistent with inventory, but magnitude larger

b)

Uniform prior, Gaussian uncertainty 10%

Total flux 17.7% less than inventory

Emissions distribution improved

c)

Inventory as prior, Gaussian uncertainty 3%

Total flux 4.4% less than inventory

Emissions are better distributed

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Uncertainty in inferred emissions

All emissions

All emissions - standard deviation

Take standard deviation of the 150 MCMC samples
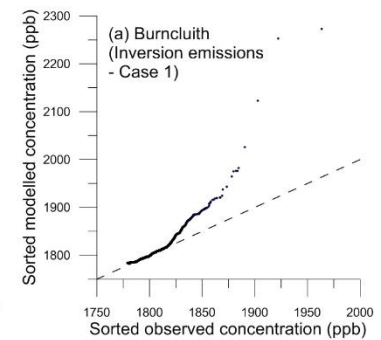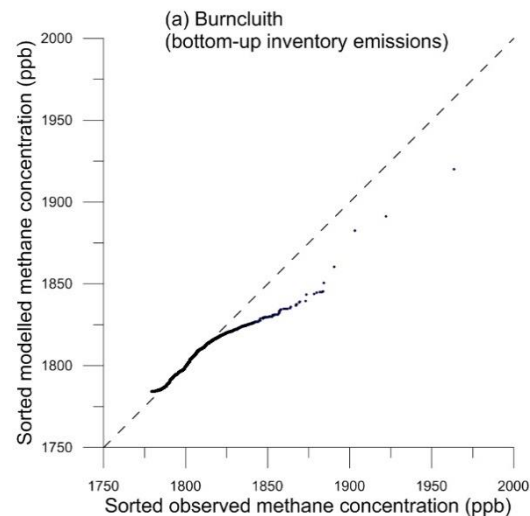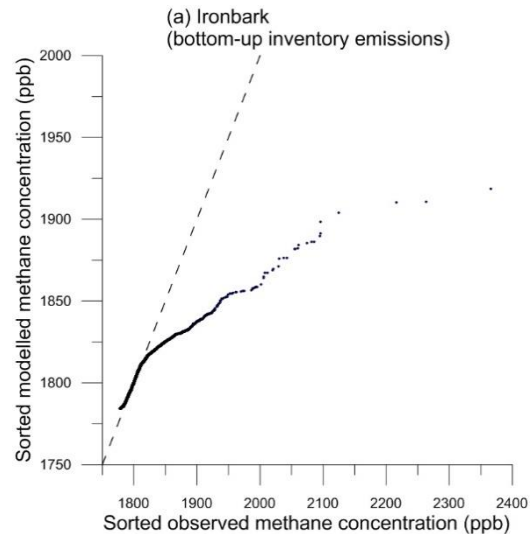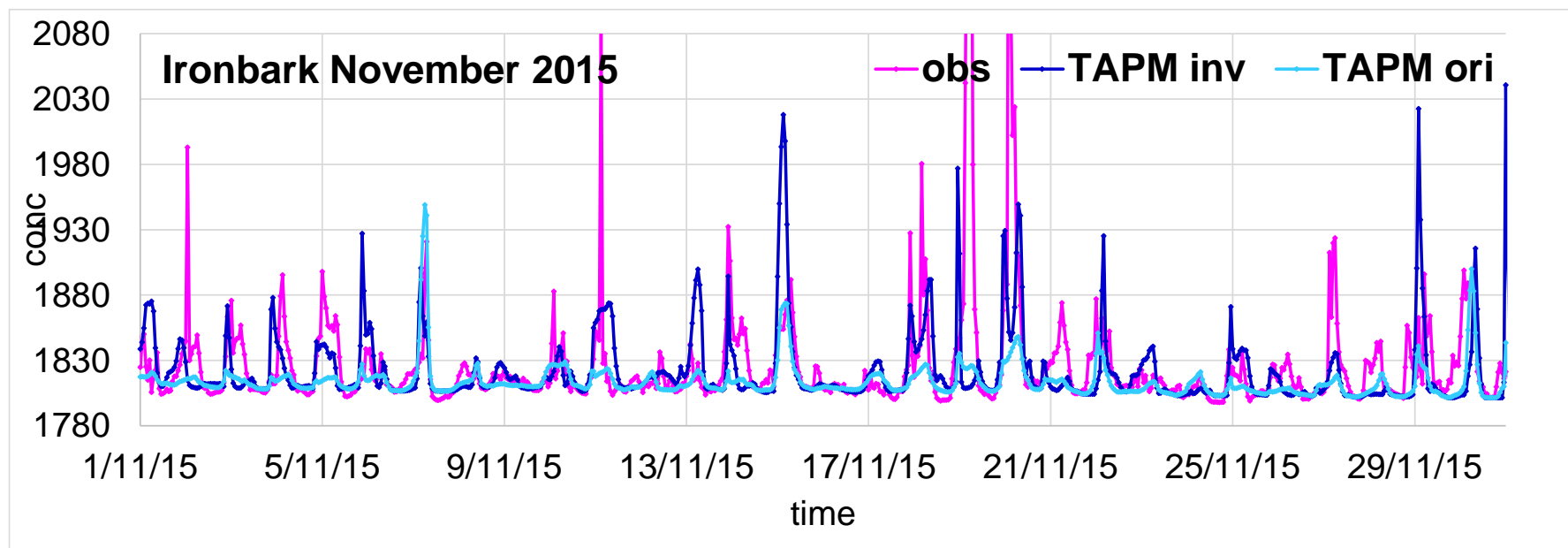The grid cell with highest emissions has relatively low uncertainty

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Inverse model validation
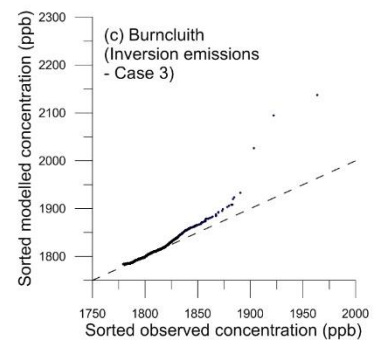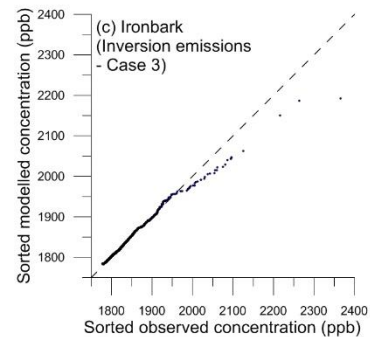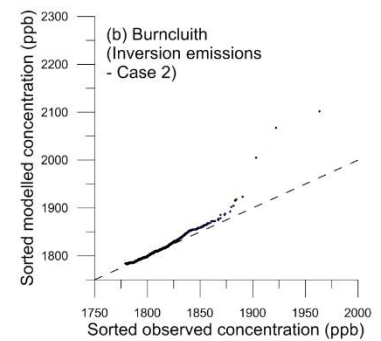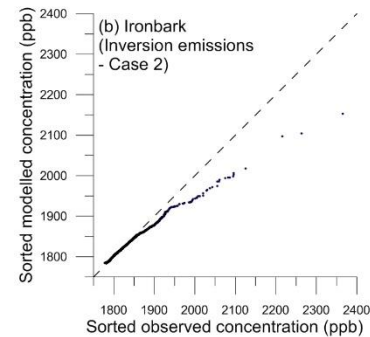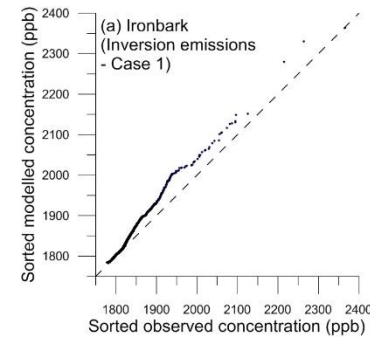
Observed and modelled timeseries

Ironbark November 2015 — obs, TAPM inv, TAPM ori

Conclusions

- A bottom-up regional methane emission inventory was compiled:

  - It yielded lower frequency and magnitude concentration peaks when used in a regional transport model, compared to measurements.

  - Possible reasons include missing or under-reported sources in the inventory, particularly near the monitoring stations.

- A top-down methodology was devised to estimate CH_4 emissions across the region:

  - combines a Bayesian inference approach, a backward setup of the regional transport model and a posterior PDF sampling scheme.

  - uses hourly observed $[CH_4]$ from two stations and the inventory as a prior with specified uncertainties.

  - results indicate that even without a prior, the measured concentrations are able to constrain the total emissions and distribution.

  - use of the inventory as a prior leads to the best emission estimates (as judged from their ability to describe the CH_4 data).

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Thank you

Postdoc position in Melbourne, Australia

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Regional methane inversion modelling (e.g. urban or CSG)

To be advertised soon

For more information, see
Cathy Trudinger, Zoë Loh or
Peter Rayner

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