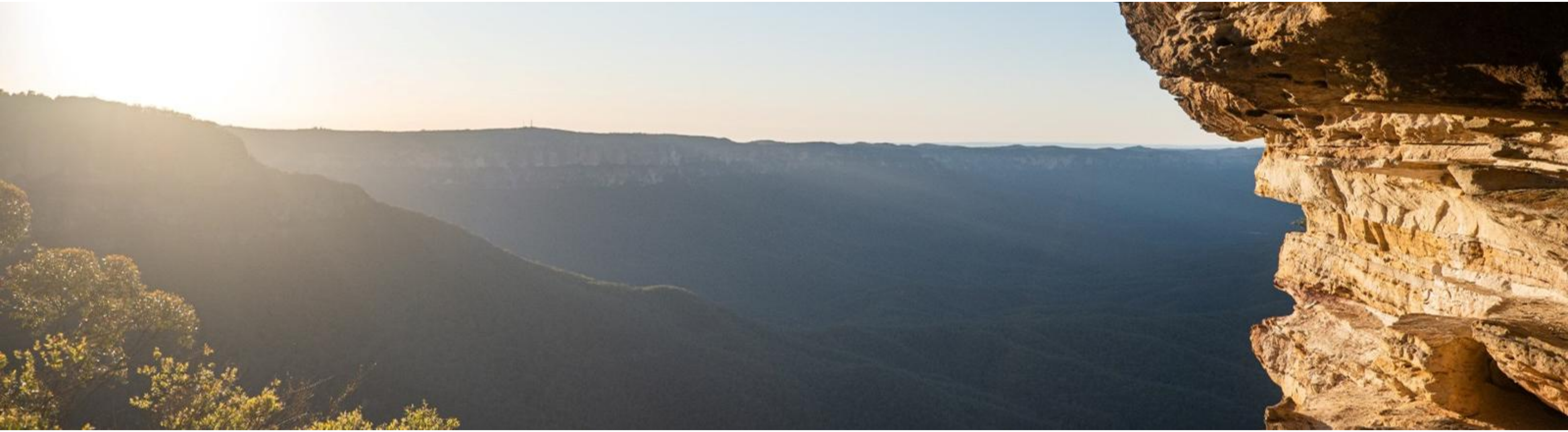


EDGAR GREENHOUSE GASES EMISSION VALIDATION USING GROUND AND REMOTE SENSING MEASUREMENTS IN UPPER HUNTER, NEW SOUTH WALES

CASANZ Clean Air Conference, Cairns QLD

31 August – 2 September 2026

H. Nguyen

Department of Climate Change, Energy the Environment and Water

Department of Climate Change, Energy the Environment and Water acknowledges the traditional custodians of the land and pays respect to Elders past, present and future.

We recognise Australian Aboriginal and Torres Strait Islander peoples’ unique cultural and spiritual relationships to place and their rich contribution to society.

Artist and designer Nikita Ridgeway from Aboriginal design agency – Boss Lady Creative Designs, created the People and Community symbol.

Emission Database for global Atmospheric research (EDGAR)

EDGAR emission for many pollutants are used in the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) air quality modelling research and forecasting for domain outside the Greater Metropolitan Region of Sydney (GMR).

Sources include power generation, combustion manufacture (industrial), aviation, shipping, road transport, railways, fuel exploitation (mining), ..

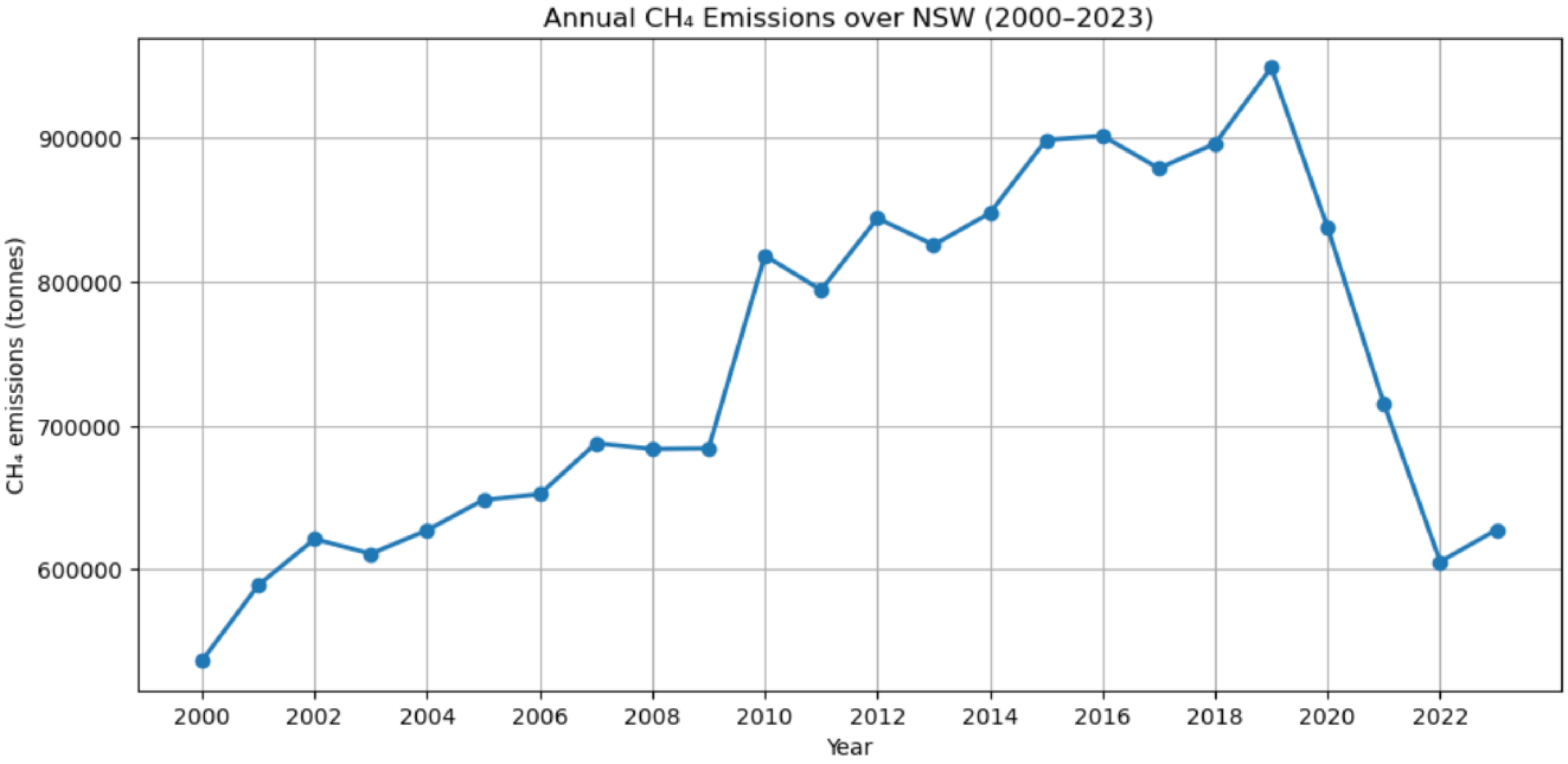
EDGAR GHG 2023

Emissions Database for Global Atmospheric Research (EDGAR) developed by the European Union has just released new version 2024

This global anthropogenic emission of greenhouse gases (CO_2, CH_4, N_2O, ..) at gridded 0.1 deg. x 0.1 deg. (about 10km x 10km), is based on countries' submission to the UN International Panel on Climate Change (IPCC) and data from the International Energy Agency (IEA)

The final emission data is then obtained through a downscaling process of national emissions using high-resolution spatial data based on spatial information and the exact location of point sources such as power stations, and industrial facilities, line sources (e.g. road network, shipping lanes, and aircraft flight paths), or area sources (e.g. populated areas and industrial areas)

EDGAR 2023 CH4 Emission in NSW



EDGAR 2023 CH_4 Emission in NSW

The trend of CH_4 emission from fuel exploitation sector from 2000 to 2023 is at first increasing from 2000 to 2019 then from 2019 the emission is declining

The change in trend from 2019 can be explained by the introduction of Safeguard Mechanism. Safeguard Mechanism was designed to make sure Australia will achieve emission target with reduction of annual emission

Spatial validation of EDGAR 2023 CH4 Emission

- EDGAR 2024 emission at 0.1 x 0.1 degrees resolution (~10km x ~10km)
- Satellite Sentinel 5P daily CH4 measurements at 7km x 3.5 km resolution
- These images can be compared using various methods such as pixel-pixel correlation, structural similarity (SSIM) or ML method such as Convoluted Neuron Network (CNN) used in image processing field
- Using ground emission data, EDGAR can also be validated

Spatial validation of EDGAR 2023 CH4 Emission

Crippa, M., Guizzardi, D., Pagani, F., Schiavina, M., Melchiorri, M., Pisoni, E., Graziosi, F., Muntean, M., Maes, J., Dijkstra, L., Van Damme, M., Clarisse, L., and Coheur, P. (2024),

Insights into the spatial distribution of global, national, and subnational greenhouse gas emissions in the Emissions Database for Global Atmospheric Research (EDGAR v8.0),

Earth Syst. Sci. Data, 16, 2811–2830, https://doi.org/10.5194/essd-16-2811-2024

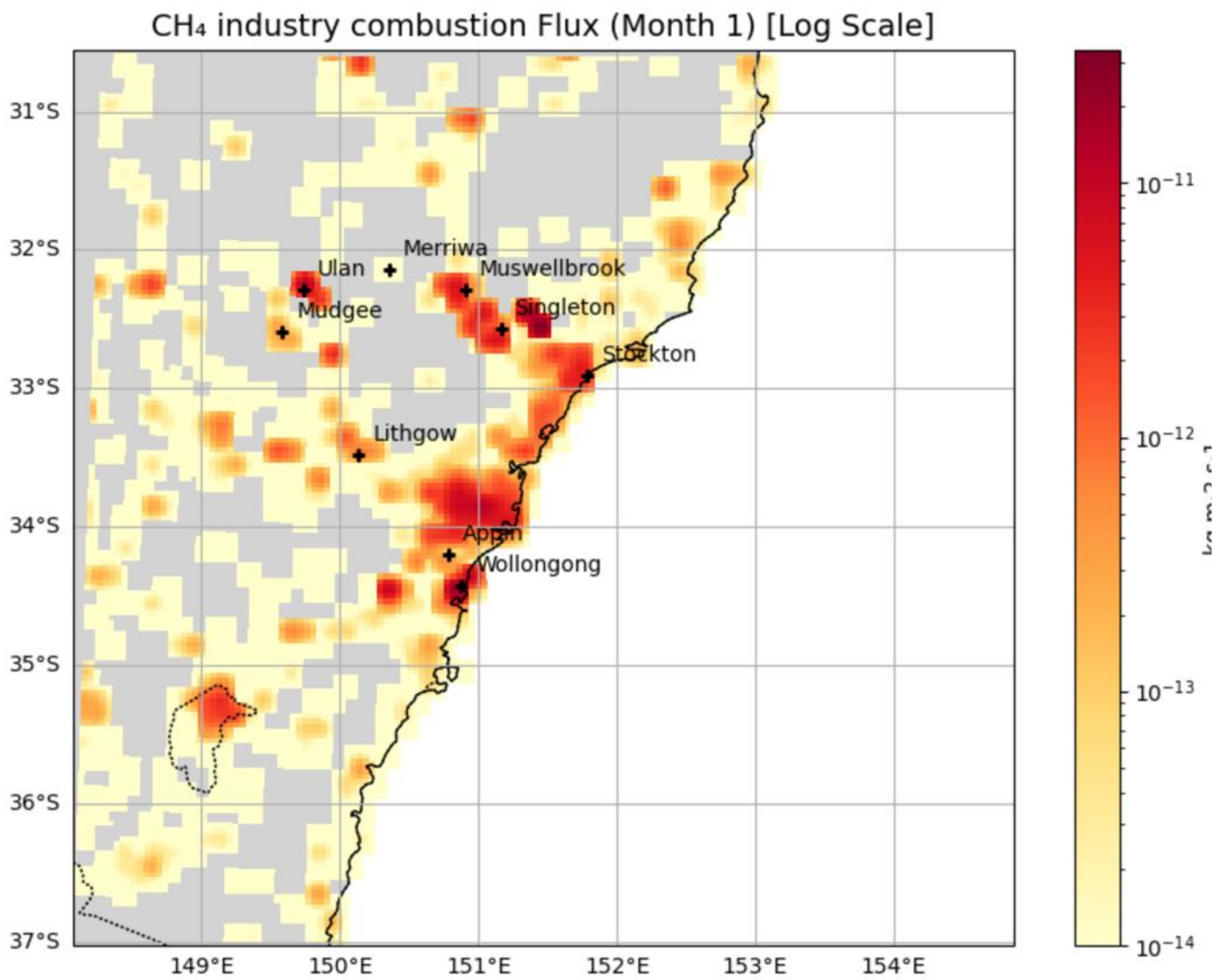
Data: Emission of CH_4 from major sectors in EDGAR

. Power Industry - Power and heat generation plants (public & autoproducers)

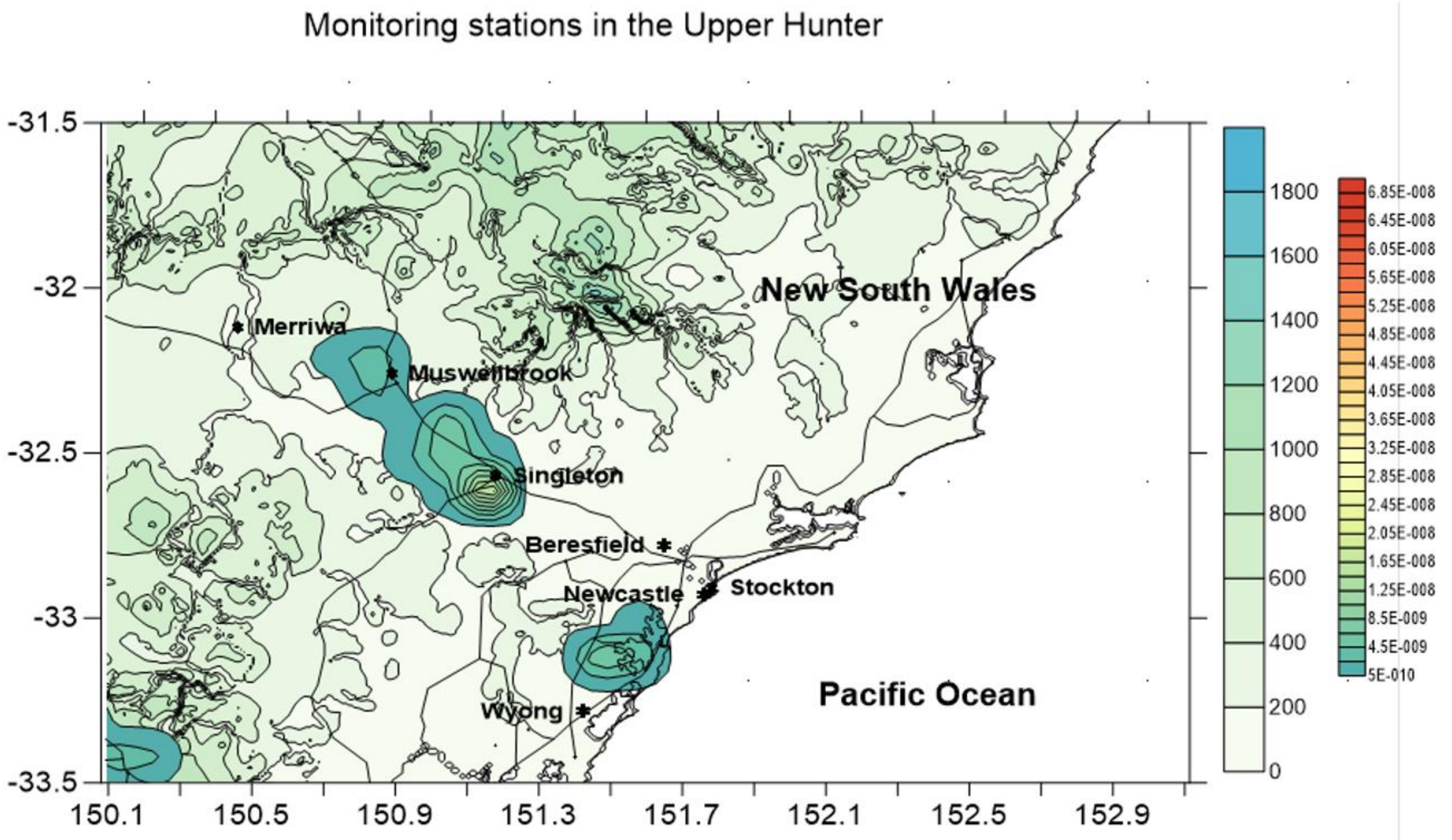
. Industrial combustion - Combustion for industrial manufacturing.

. Fuel exploitation - Production, transformation and refining of fuels

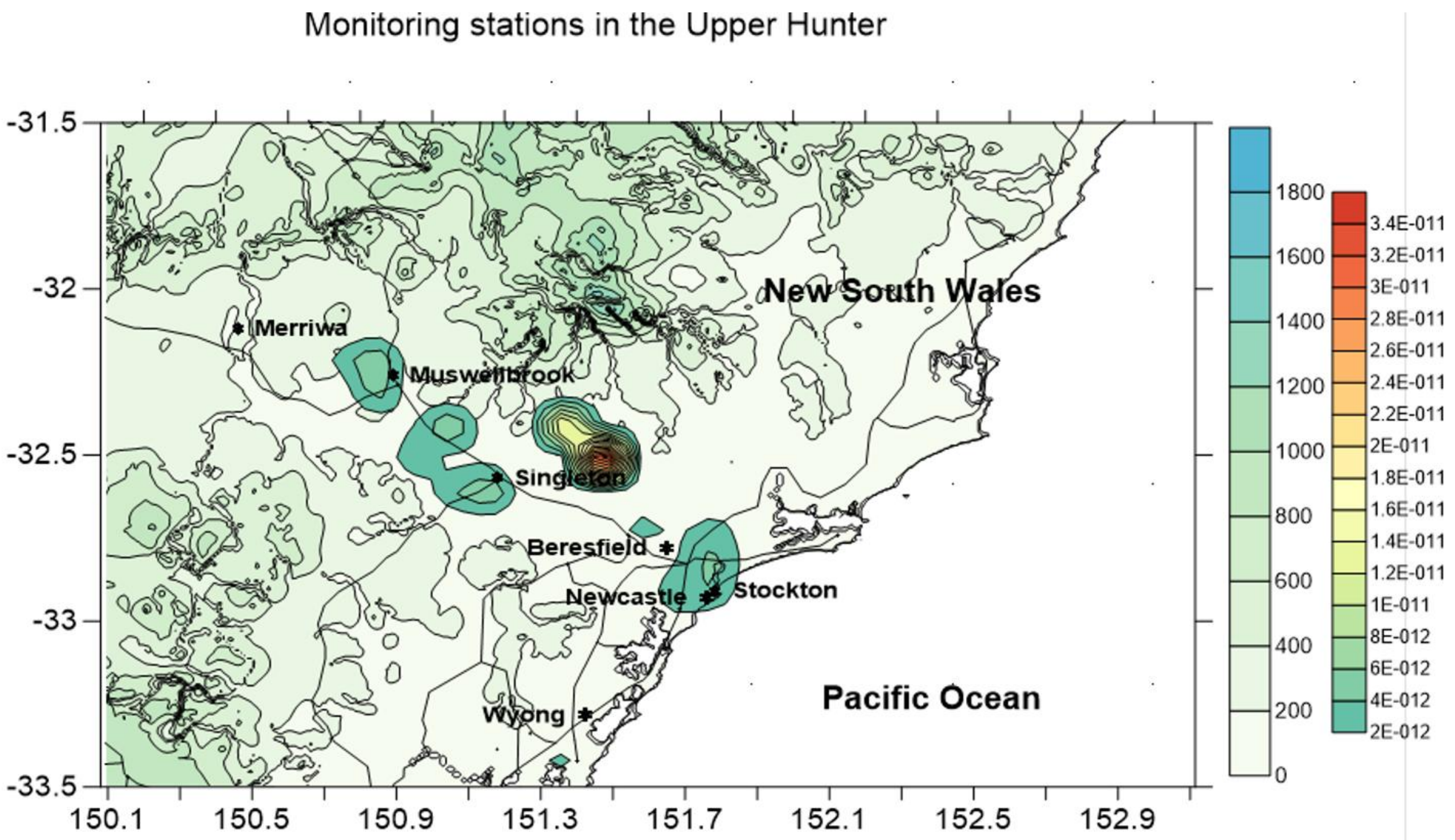
Industrial combustion CH4 fluxes in NSW (kg m-2 s-1)



CH4 flux (kg/m2/s) from mining for January



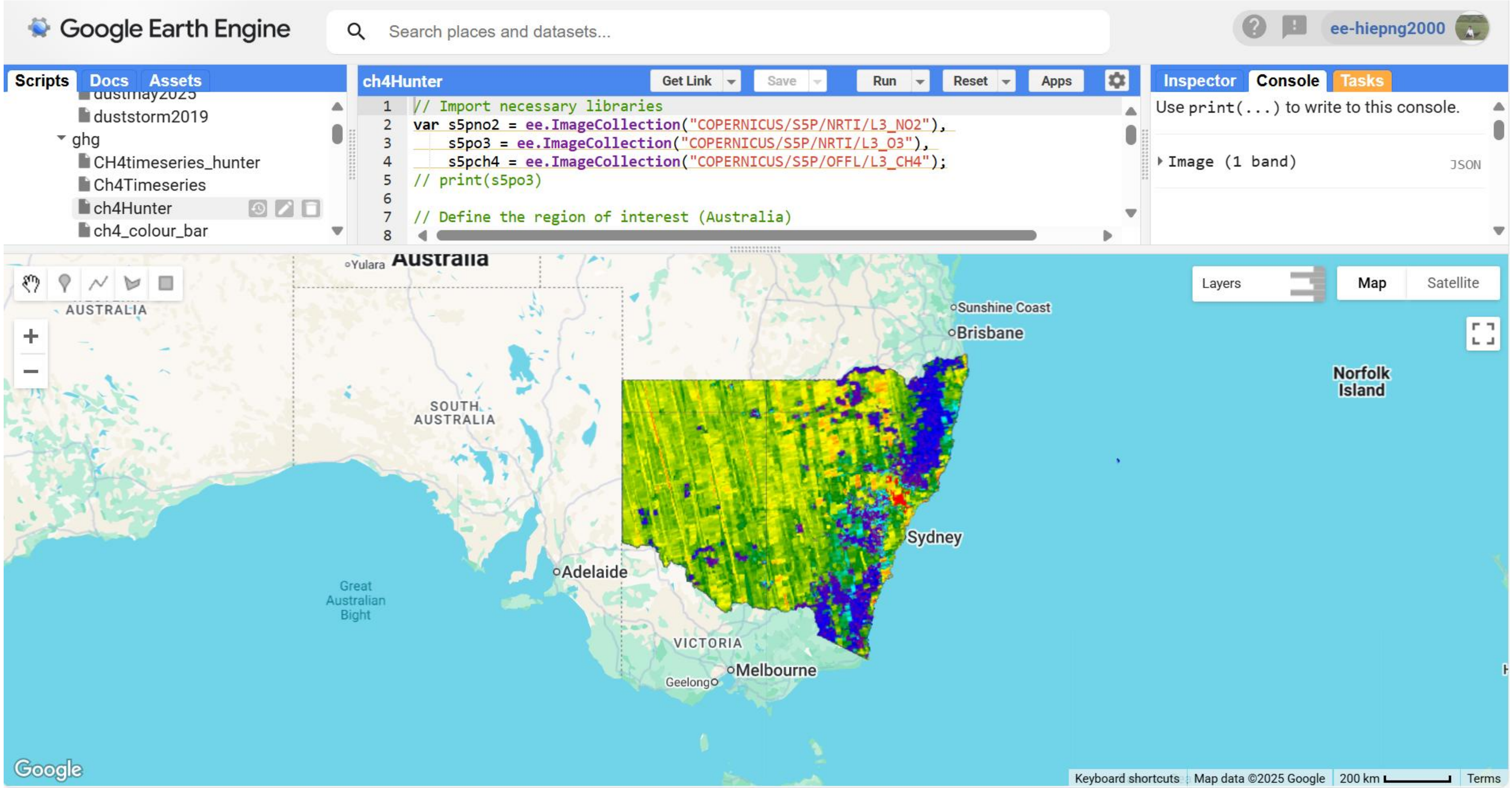
CH4 flux (kg/m2/s) from industrial combustion (January)



Sentinel 5P CH4 satellite data

- TROPOMI (Tropospheric Measurement Instrument) instrument onboard Sentienl 5P provides CH4 column concentrations with high sensitivity to the Earth's surface
- ood spatio/temporal coverage, and sufficient accuracy to facilitate inverse modelling of sources and sinks.
- https://sentinels.copernicus.eu/data-products/-/asset_publisher/fp37fc19FN8F/content/tropomi-level-2-methane
- Accessible from Google Earth Engine

Sentinel 5P CH4 satellite data



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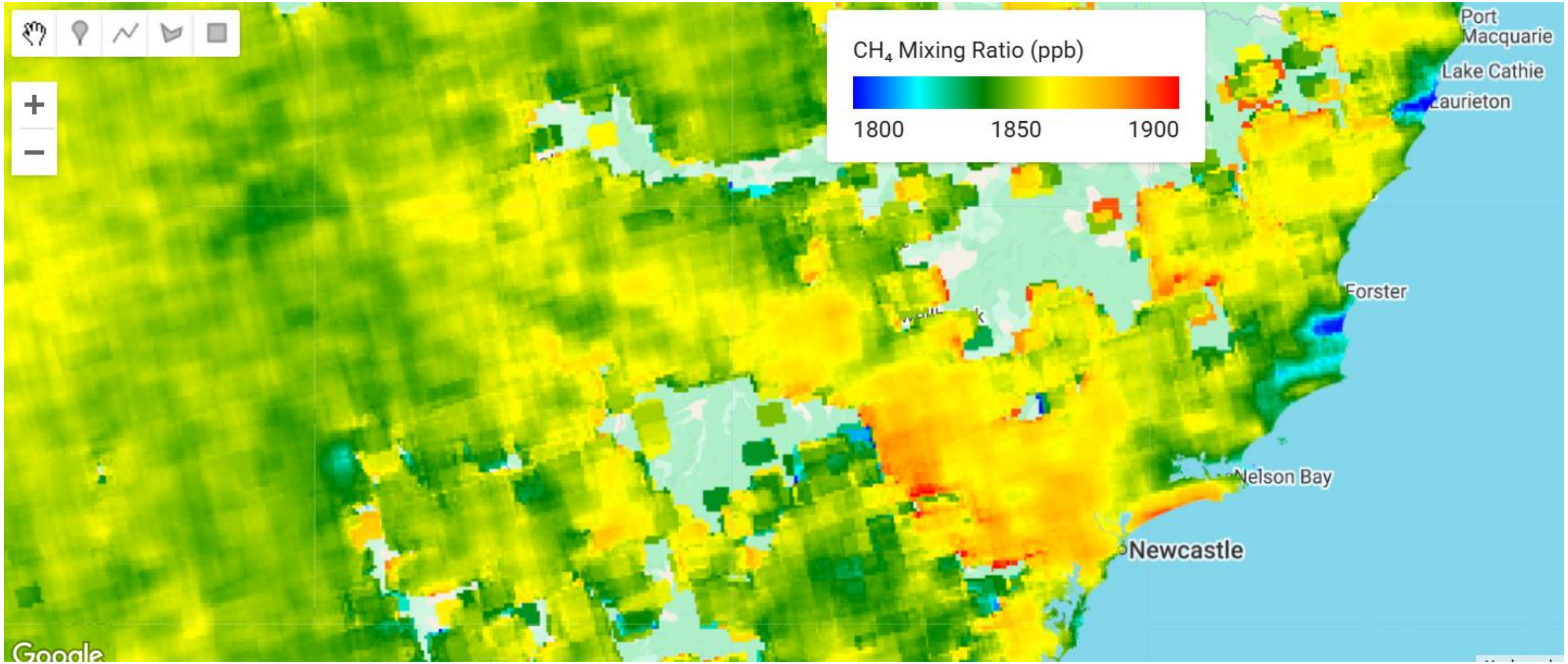
Data: Satellite Sentinel 5P



Comparison methods

- Pixel-Pixel correlation (Normalised Cross Correlation, NCC)
- Structure Similarity (SSIM)
- CNN feature similarity

These metrics compare different features of the images.

CNNs are excellent at extracting spatial patterns and textures from images.

Comparison methods

- NCC: match in terms of pixel intensity patterns — essentially, it checks whether bright and dark regions align.

$$\mathrm{NCC} = \frac{1}{N}\sum_i \frac{(A_i - \bar{A})(B_i - \bar{B})}{\sigma_A \sigma_B}$$

Vhere:

- A_i, B_i: pixel intensities in the two images
- $\bar{A}, \bar{B}$: mean pixel values
- σ_A, σ_B: standard deviations
- N: total number of pixels

Comparison methods

- Measures perceptual similarity — how structurally similar two images are in terms of luminance, contrast, and texture.

$$\mathrm{SSIM}(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

Where:

- μ_x, μ_y: average intensity of each image
- σ_x, σ_y: variance (contrast)
- σ_{xy}: covariance (structure similarity)
- C_1, C_2: constants to stabilize division

Machine Learning (ML) Convolution Neuron Network (CNN) method

- Feed each image into a pre-trained CNN (like VGG, ResNet, or a custom CNN).
- Extract feature maps from intermediate layers.
- Compute a similarity metric (e.g., cosine similarity, Pearson correlation) between the feature vectors.

Features include edges, gradients, shapes, textures. We use cosine similarity in this study.

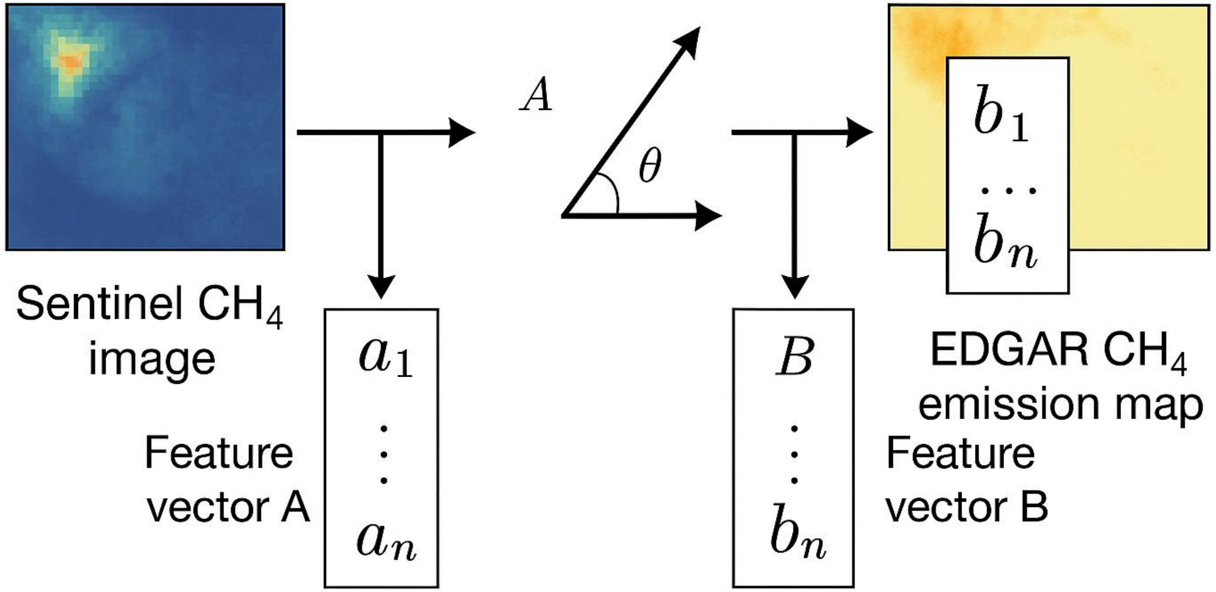
The resulting feature similarity score tells you how much the images are similar in terms of spatial patterns, not just pixel-by-pixel intensity.

Machine Learning (ML) Convolution Neuron Network (CNN) method

- Pre-trained CNN used is the VGG16 developed by the Visual Geometry Group (VGG) at the University of Oxford. It is a deep CNN with 16 weight layers trained on large database images on ImageNet with each image labelled with one of 1,000 object classes.
- VGG16 is one of the CNNs widely used in image processing.
- Downloading pre-trained model from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5

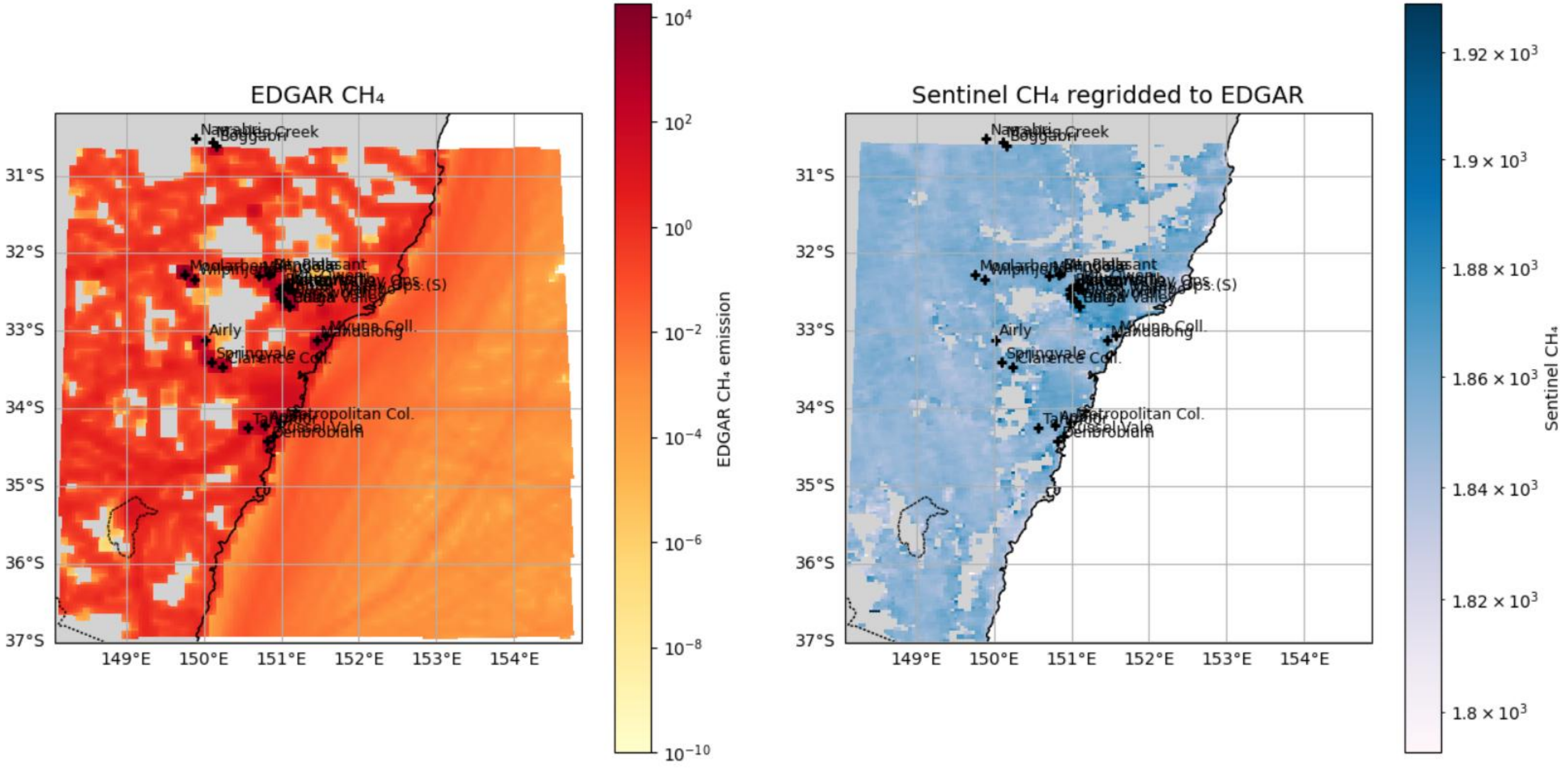
- Cosine similarity metric: A mathematical measure of how similar two vectors are — it tells you the angle between them, not their magnitude.

Cosine Similarity



$$\text{Cosine similarity} = \frac{A \cdot B}{|A||B|}$$

EDGAR CH4 Emission in eastern NSW (January) and Sentinel 5P mean CH4 columnar concentration (Jan-June 2025)



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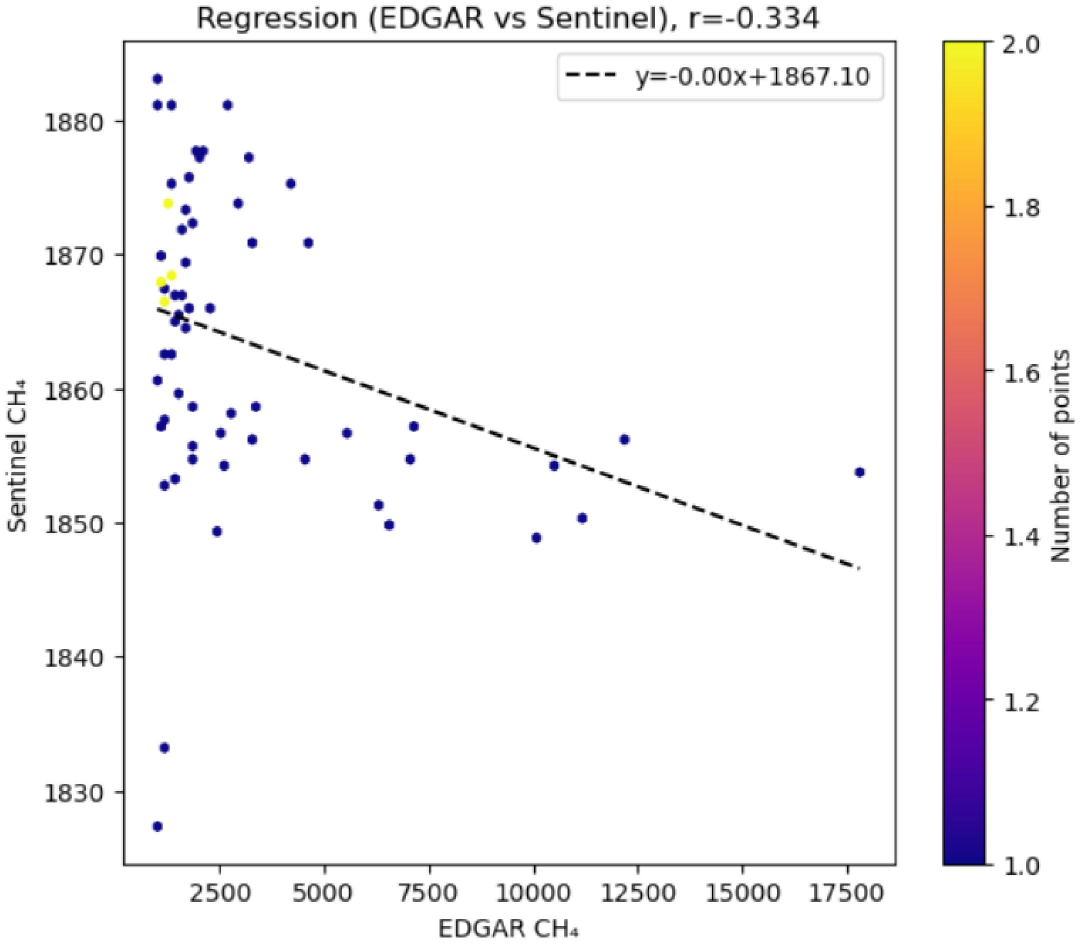
Results: Metrics of methods



Pearson r = -0.3342, p-value = 6.50e-03

SSIM similarity: 0.4909

NCC similarity: 0.0599

CNN feature similarity: 0.9301

Results

Pixel-Based Metrics

Focus on individual pixel differences

Sensitivity to scale, offset, and inverśon

A negative value: pixels disagree

Pearson r = -0,3342

Result

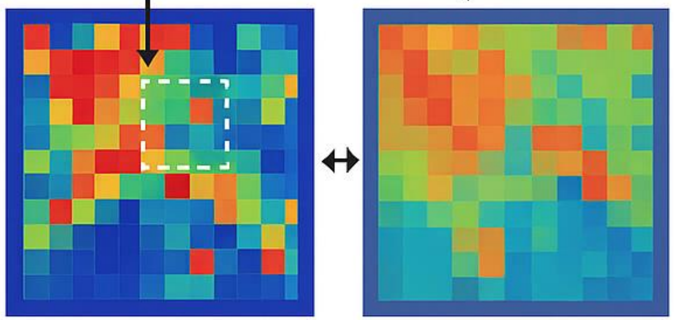
Moderate structural alignments

SSIM = 0,4909

Moderate structural alignments

EDGAR Emissions Map

Inverted Colors



EDGAR **Sentinel**

CNN feature similarity = 0,9301

CNN Feature Similarity

Focus on high-level features

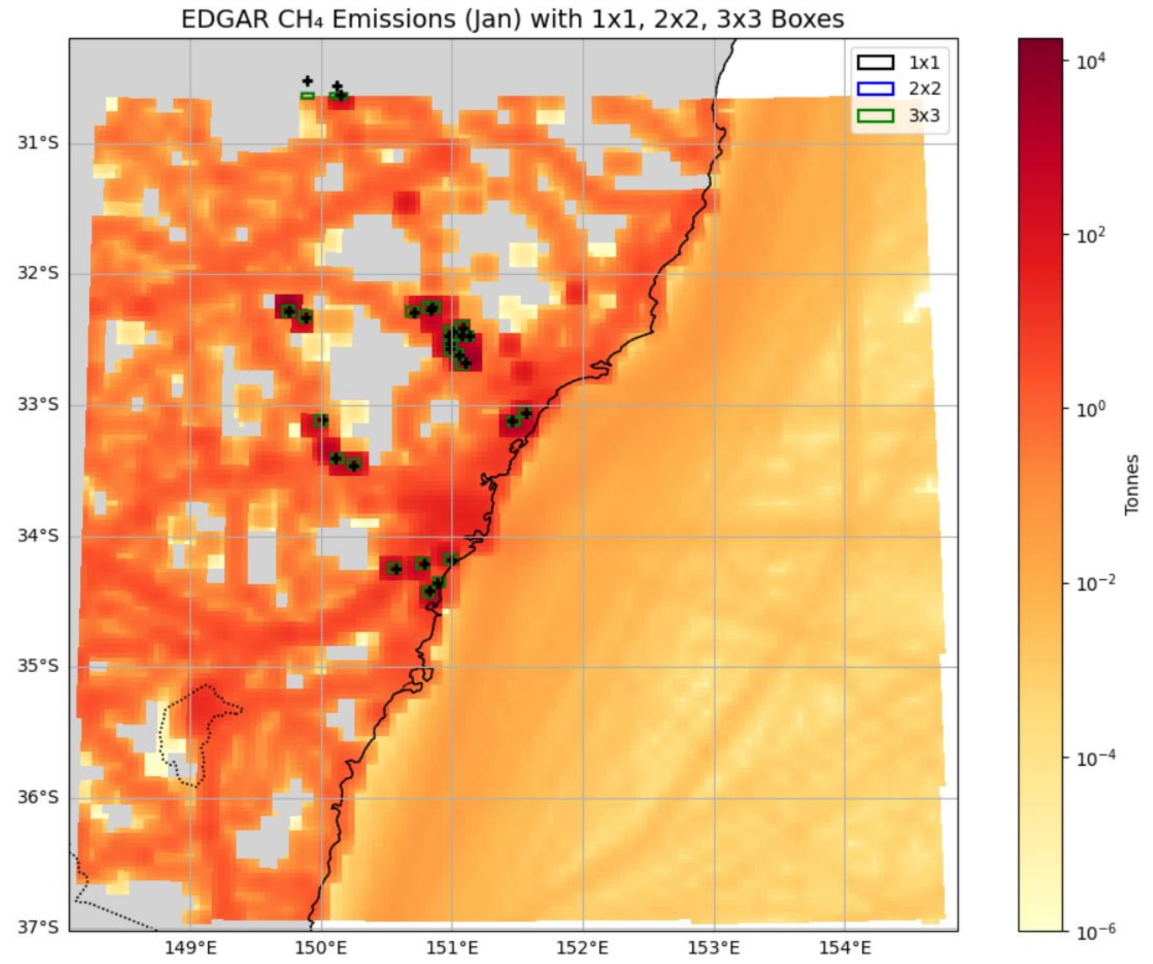
Robust to changes

CNN feature similarity = 0,9301

High-level patterns match

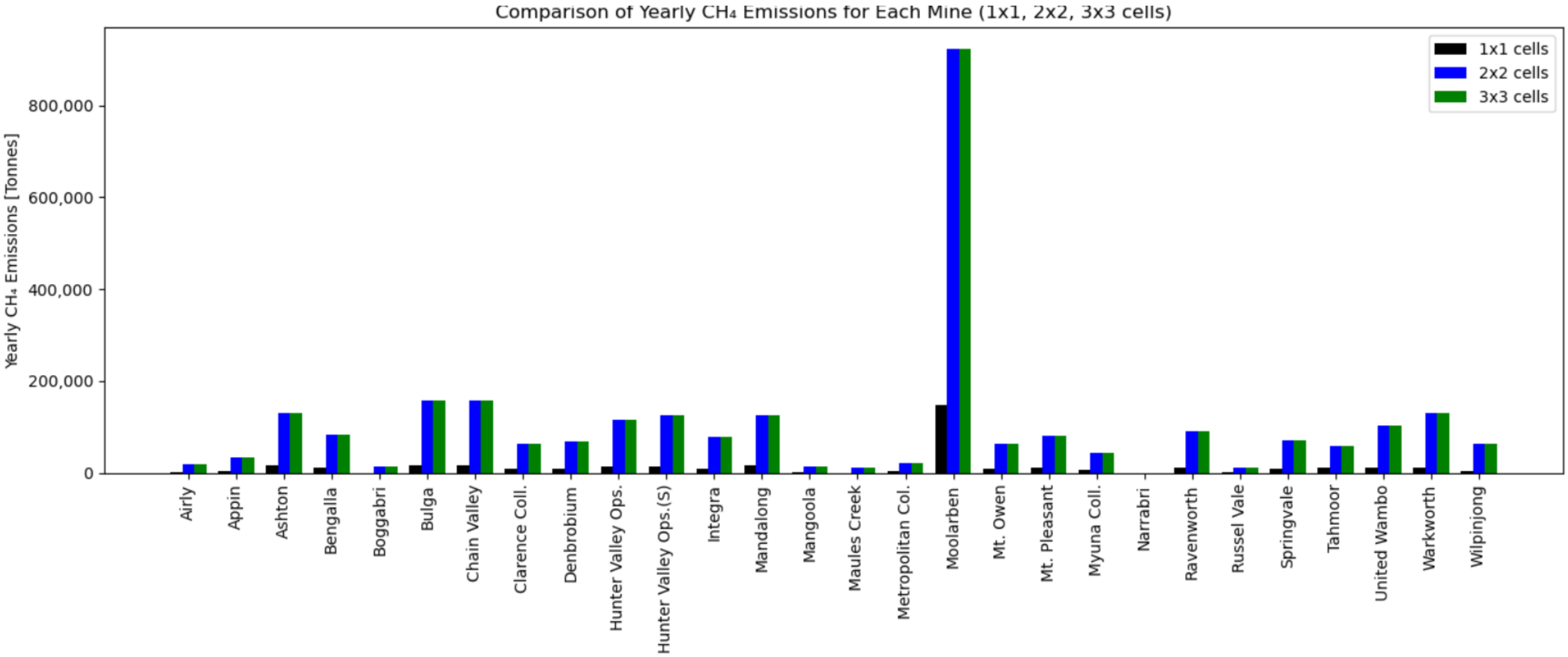
Results

Compare of point emission at NGER emission



Results

Compare of point emission from EDGAR emission



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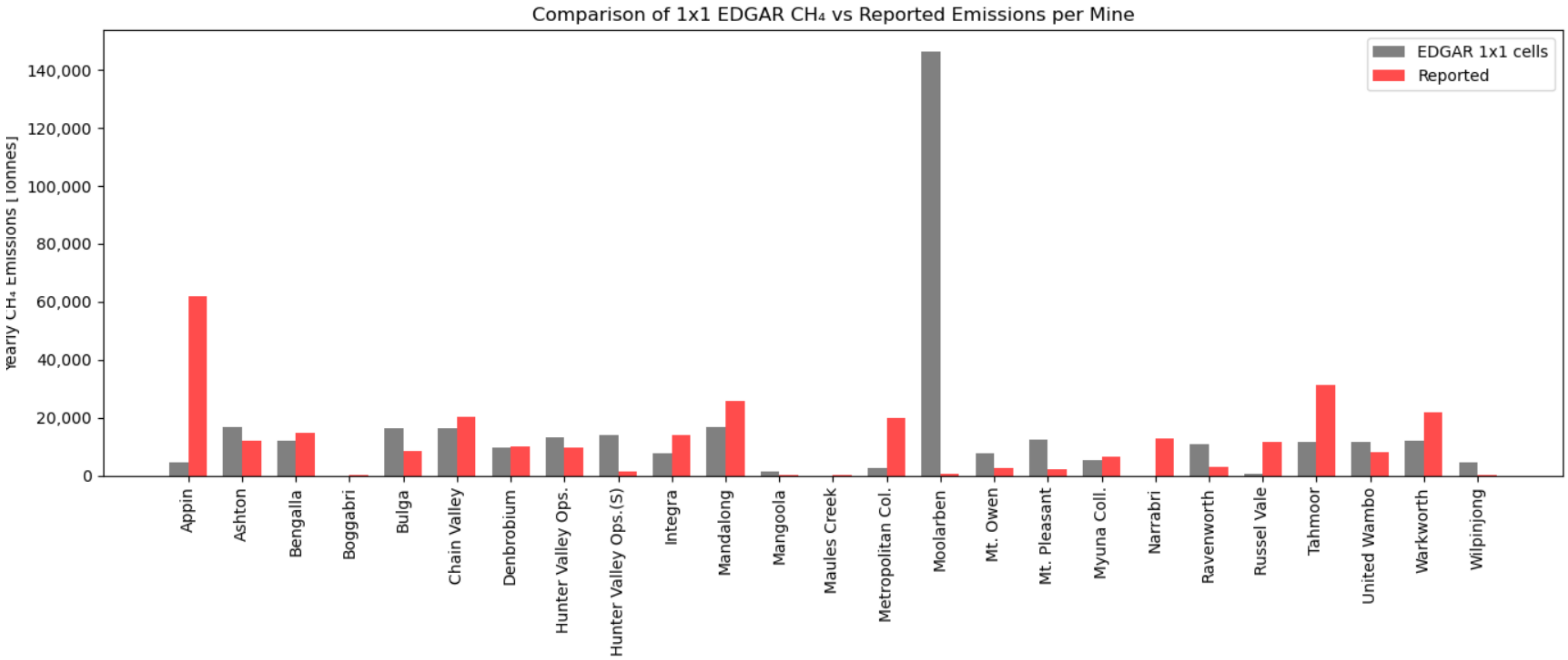
Results



Comparison of 1x1 EDGAR CH₄ vs Reported Emissions per Mine
EDGAR 1x1 cells
Reported
Yearly CH₄ Emissions [Tonnes]
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Appin
Ashton
Bengalla
Boggabri
Bulga
Chain Valley
Denbrobium
Hunter Valley Ops.
Hunter Valley Ops.(S)
Integra
Mandalong
Mangoola
Maules Creek
Metropolitan Col.
Moolarben
Mt. Owen
Mt. Pleasant
Myuna Coll.
Narrabri
Ravenworth
Russel Vale
Tahmoor
United Wambo
Warkworth
Wilpinjong

Summary of results

- Appin Safeguard mechanism baseline reported of CH_4 is higher than EDGAR
- Ulan mines of Moolarben and Wilpinjong near Mudgee have emission less than those in EDGAR
- At all other sites, the EDGAR emission is close to that of NGER reported

Results

Compare of point emission at NGER emission

Month	Appin	Ashton	Bengalla	Boggabri	Bulga	Chain Valley	Denbrobium	Hunter Valley Ops.	Hunter Valley Ops.(S)	Integra	Mandalong	Mangoola	Maules Creek	Metropolitan Col.	Moolarben	Mt. Pleasant	Mt. Owen	Myuna Coll.	Narrabri	Ravensworth	Russel Vale	Tahmoor	United Wambo	Warkworth	Wilpinjong	Springvale	Clarence Coll.	Airly
1	2708.091	10934.73	6896.311	1128.428	13145.51	13145.51	5697.781	9534.993	10530.06	6520.795	10393.5	1119.47	929.7638	1753.412	76927.64	6654.294	5241.034	3576.697	0.316084	7578.311	1006.313	4908.928	8513.42	10868.42	5228.955	5881.692	5184.835	1536.251
2	2708.081	10934.71	6896.302	1128.424	13145.5	13145.5	5697.296	9534.982	10530.05	6520.777	10393.47	1119.467	929.761	1753.41	76927.64	6654.28	5241.021	3576.655	0.316078	7578.296	1006.195	4868.674	8513.414	10868.4	5228.952	5881.679	5184.833	1536.245
3	2708.077	10934.7	6896.299	1128.423	13145.49	13145.49	5697.146	9534.979	10530.05	6520.773	10393.46	1119.466	929.7601	1753.41	76927.63	6654.275	5241.017	3576.642	0.316076	7578.292	1006.159	4856.105	8513.412	10868.4	5228.952	5881.674	5184.832	1536.243
4	2708.091	10934.73	6896.311	1128.428	13145.51	13145.51	5697.79	9534.993	10530.06	6520.795	10393.5	1119.47	929.7639	1753.412	76927.64	6654.294	5241.034	3576.698	0.316084	7578.311	1006.315	4909.607	8513.42	10868.42	5228.955	5881.692	5184.835	1536.251
5	2708.088	10934.72	6896.308	1128.427	13145.51	13145.51	5697.657	9534.99	10530.06	6520.791	10393.49	1119.469	929.7631	1753.411	76927.64	6654.29	5241.03	3576.686	0.316082	7578.307	1006.283	4898.567	8513.419	10868.41	5228.954	5881.688	5184.835	1536.25
6	2708.088	10934.72	6896.307	1128.426	13145.51	13145.51	5697.634	9534.99	10530.06	6520.79	10393.49	1119.469	929.7629	1753.411	76927.64	6654.29	5241.03	3576.684	0.316082	7578.306	1006.277	4896.699	8513.418	10868.41	5228.954	5881.688	5184.834	1536.249
7	2708.091	10934.73	6896.311	1128.428	13145.51	13145.51	5697.781	9534.993	10530.06	6520.795	10393.5	1119.47	929.7638	1753.412	76927.64	6654.294	5241.034	3576.697	0.316084	7578.311	1006.313	4908.928	8513.42	10868.42	5228.955	5881.692	5184.835	1536.251
8	2708.081	10934.71	6896.302	1128.424	13145.5	13145.5	5697.296	9534.982	10530.05	6520.777	10393.47	1119.467	929.761	1753.41	76927.64	6654.28	5241.021	3576.655	0.316078	7578.296	1006.195	4868.674	8513.414	10868.4	5228.952	5881.679	5184.833	1536.245
9	2708.077	10934.7	6896.299	1128.423	13145.49	13145.49	5697.146	9534.979	10530.05	6520.773	10393.46	1119.466	929.7601	1753.41	76927.63	6654.275	5241.017	3576.642	0.316076	7578.292	1006.159	4856.105	8513.412	10868.4	5228.952	5881.674	5184.832	1536.243
10	2708.091	10934.73	6896.311	1128.428	13145.51	13145.51	5697.79	9534.993	10530.06	6520.795	10393.5	1119.47	929.7639	1753.412	76927.64	6654.294	5241.034	3576.698	0.316084	7578.311	1006.315	4909.607	8513.42	10868.42	5228.955	5881.692	5184.835	1536.251
11	2708.088	10934.72	6896.308	1128.427	13145.51	13145.51	5697.657	9534.99	10530.06	6520.791	10393.49	1119.469	929.7631	1753.411	76927.64	6654.29	5241.03	3576.686	0.316082	7578.307	1006.283	4898.567	8513.419	10868.41	5228.954	5881.688	5184.835	1536.25
12	2709.388	10939.97	6899.619	1128.968	13151.82	13151.82	5700.364	9539.567	10535.11	6523.92	10398.48	1120.007	930.2092	1754.253	76964.57	6657.484	5243.545	3578.401	0.316233	7581.944	1006.759	4898.706	8517.505	10873.63	5231.464	5884.51	5187.323	1536.987
Year_Total	32498.33	131221.9	82758.98	13541.65	157752.3	157752.3	68373.34	114424.4	126365.7	78252.58	124726.8	13434.16	11157.6	21041.78	923168.6	79854.64	62894.84	42921.84	3.79312	90943.28	12075.56	58679.16	102165.1	130426.1	62749.95	70583.05	62220.5	18435.72

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Conclusion

- EDGAR GHG 2023 emission can be validated using remote sensing data
- Using Machine Learning CNN (Convolution Neuron Network) which is used in pattern image processing, comparison of EDGAR emission map with satellite map is applied
- Sentinel satellite daily CH_4 high resolution data is shown to validate successfully the spatial pattern of the emission

- EDGAR emission is also compared with ground emission data. It is shown these emission to be corresponding with each other.
- Inverse modelling based on monitoring data can improve these emission estimates either as area source emissions or individual emission source.
- Need higher resolution modelling to resolve individual emission from shapefiles of the open cut mines