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Atmospheric Composition & Chemistry Observations & Modelling Conference

in conjunction with the

Australian New Zealand Aerosol Assembly

incorporating the

Kennaook/Cape Grim Annual Science Meeting

Abstracts

2 – 5 December 2025

hosted by

The University of Wollongong | Faculty of Science, Medicine and Health
School of Science | Environmental Futures

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Wollongong, New South Wales, Australia / Virtual Meeting

Edited by: M. Desservettaz, C. Paton-Walsh, P. Krummel, and M. Keywood

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ACCOMC 2025: Online & Hybrid Attendance

We are delighted to offer a hybrid experience for the ACCOMC ANZAA 2025 conference. All oral sessions will be broadcast live via Zoom for our registered virtual attendees.

Join the Conference via Zoom

All four days of the conference will use the same Zoom meeting link.

Zoom
Join ACCOMC & ANZAA

Day 1: Tuesday, 2 December 2025; 09:00–16:50

This day is dedicated to methane, with sessions covering observations, quantification, and mitigation strategies.

09:00	**Clare & Max**	**Introduction & Acknowledgement of Country**

Chair	**Paul Krummel**	**Session 1 – Methane Monitoring & Remote Sensing**
09:10	Sara Mikaloff-Fletcherr (Online)	Quantifying agricultural CH_4 emissions using MethaneSAT and MethaneAIR
09:30	David Frank Pollard	Ground-Based Validation of MethaneSAT XCH_4 Observations Over New Zealand Agricultural Regions
09:50	Harrison O'Sullivan-Moffat (Online)	MethaneSAT Verification Campaign: Canterbury, New Zealand
10:10	Peter Sperlich	Towards accurate quantification of New Zealand's methane emissions from waste and agriculture
10:30	Clare Murphy (Paton-Walsh)	Recent trends in methane in the Southern Hemisphere
10:50	**Morning tea**	**Building 20 - Foyer**
11:20	Nicholas Deutscher	Methane Hunter
11:40	Ida Jandl	Forward modelling atmospheric methane in the coal mining region of New South Wales
12:00	Kaydy Pinetown	Development of the NSW Greenhouse Gas Monitoring and Verification Program
12:20	Hasan Nawaz	Satellite validation of XCH_4 over Australia and New Zealand
12:40	**Lunch**	**Building 20 - Foyer**
13:40	Timothy Bedin	Observing methane plumes in geostationary satellite data can improve our understanding of the spatiotemporal dynamics of super-emission events
Chair	**Hasan Nawaz**	**Session 2 – Methane Sources & Mitigation**
14:00	Mark Lunt	Empowering methane mitigation through science: actionable data from methane science studies in Australia
14:20	Johannes Dittmann	Resolving Ghost Forest tree methane pathway, origin, and age using a novel ^{14}C-CH_4 approach
14:40	Christopher Caldow	Fugitive methane monitoring using top-down approaches: policy and mitigation informed by the best available science
15:00	**Afternoon tea**	**Building 20 - Foyer**
15:30	Leigh Fleming (Online)	CarbonWatch-Urban Mobile Laboratory for estimating urban emissions across Aotearoa New Zealand
15:50	Jhonathan Ramirez Gamboa	Melbourne urban methane: Network status and integrating facility scale observations
16:10	Nasimeh Shahrokhi (Online)	Methane emissions in Melbourne inferred from ground-based measurements with a synthesis inversion
16:30	Cathy Trudinger	Methane emissions from two wastewater treatment plants in Melbourne: A network design study
16:50	**End Day 1**	

Day 2: Wednesday, 3 December 2025; 09:00–16:40

A deep dive into Southern Ocean dynamics, research from the CAPE-k campaign, aerosol properties, and regional atmospheric chemistry & air quality.

Chair	**Melita Keywood**	**Session 3 – Southern Ocean & Aerosol Precursors**
09:00	Caleb Mynard	Linking ocean productivity and air mass history to variability in volatile methylated sulfur species across the Southern Ocean
09:20	Abithaswathi Muniraj Saraswathy	High gaseous MSA events during CAPRICORN II and MISO Southern Ocean voyages
09:40	Alanah Chapman	A model sensitivity analysis of aerosol precursor emissions related to Antarctic sea-ice
10:00	Branka Miljevic	Aerosol Acidity Controls Methanesulfonic Acid Evaporation from Aerosols During Antarctic Continental Outflow
10:20	Joel Alroe	Regional and meteorological influences on atmospheric composition and cloud structure from the MISO voyage
10:40	**Morning tea**	**Building 20 - Foyer**
Chair	**Alanah Chapman**	**Session 4 – Aerosol Properties & Chemistry**
11:10	Melita Keywood	Aerosol properties measured during the Cloud And Precipitation Experiment at Kennaook (CAPE-K)
11:30	Jakob Boyd Pernov	CAPE-K CHEM: New Particle Formation and Precursors Vapours at Kennaook Cape Grim
11:50	Robert Ryan	The impact of ship sulfate emission regulations on solar radiation and coral bleaching severity at the Great Barrier Reef
12:10	Stephen MacFarlane	Impacts of Aromatic Chemistry on the Global Atmosphere
12:30	**Lunch**	**Building 20 - Foyer**
Chair	**Max Desservettaz**	**Session 5 – Air Quality & Urban Aerosols**
13:30	Kathryn Emmerson	What atmospheric composition changes can we expect at Kennaook Cape Grim and Wollongong in 2050?
13:50	Robyn Schofield	Update on observations from AirLab and AIRBOX
14:10	Emily Franklin	Aerosol Chemistry and Source Apportionment in Urban Australia
14:30	Hamesh Patel	An Automated SEM Analysis of Airborne Elongated Mineral Particles in an Urban Community
14:50	**Afternoon tea**	**Building 20 - Foyer**
15:20	Sudharsun Venkatesan	The influence of simulated thunderstorm conditions on pollen rupturing
15:40	David Anene	Face masks: Friend or foe?
Chair	**Brittany Walker**	**Session 6 – Special Program Review**
16:00	Scott Chambers & Alan Griffiths	The radon measurement program at Kennaook/Cape Grim 2019-2025
16:40	**End Day 1**	

Day 3: Thursday, 4 December 2025; 09:00–16:00

Sponsored by the NSW Bushfire and Natural Hazards Research Centre, this day focuses on fire events, smoke impacts, and atmospheric modelling techniques.

Chair	**Clare Murphy**	**Session 7 – Fire, Smoke & Emissions Characterisation**
09:00	Max Desservettaz	Research for Understanding Smoke Hazards (RUSH): Recent Findings, Model Integration, and Future Directions
09:20	Fabienne Reisen	Biomass Burning Impacts at Kennaook/Cape Grim: Insights for AQFx Module Improvement
09:40	Steve Petrie	Finding fires: Estimating ignition locations and times through satellite imaging of smoke plumes and fire extent
10:00	Deepa Roy	Impact of fuel type and moisture content on emission variability
10:20	Christopher Roulston	The new Pyrotron Emissions and Greenhouse Gas Analysis System (PEGGASys)
10:40	**Morning tea**	**Building 20 - Foyer**
Chair	**Deepa Roy**	**Session 8 – Smoke Impacts & Modelling**
11:10	Eleni Dovrou (Online)	Switching regimes in wildfire plumes: Environmental implications
11:30	Ray Langenfelds	Using CO and H_2 variability in SH background air as tracers of wildfire emissions
11:50	Zijun Li (Online)	Using data-driven approaches to understand O_3 formation and the impact of wildfire emissions in Queensland
12:10	Samantha Lee	Comparison of measured and modelled pollutant concentrations in aged smoke in Southeast Australia
12:30	Steven Utembe	Changes to Air Quality at Melbourne's Station Pier
12:50	**Lunch**	**Building 20 - Foyer**
Chair	**Jenny Fisher**	**Session 9 – Atmospheric Modelling & Inversion Techniques**
13:50	Matt Woodhouse	Composition modelling in the ACCESS suite
14:10	Ashok Luhar	A higher-order inverse modelling approach for improved source estimation, with application to a controlled methane release
14:30	Josh Jacobson	WOMBAT v2.S: A Bayesian inversion framework for CO_2 flux attribution from multiprocess satellite data
14:50	Daemon Kennett (Online)	Atmospheric Inverse Modelling of CO_2 Fluxes in New Zealand at National and Urban Scales
15:10	Beth Killen	Short-lived refrigerants, long-term impacts: quantifying budgets of the HFO-1234ze degradation cascade
15:30	**Afternoon tea**	**Building 20 - Foyer**
16:00 onwards		**Tour of UOW labs (optional)** **Side Meetings and Discussion** **Time off before dinner**
18:00	**Conference Dinner**	**Wollongong Golf Club – The VUE Room**

Day 4: Friday, 5 December 2025; 09:00–13:00

The final day highlights insights from long-term observational programs, including from Kennaook/Cape Grim, and discusses global atmospheric trends before concluding the conference.

Chair	**Emily Franklin**	**Session 10 – Kennaook Cape Grim Long-Term Observations**
09:00	Ann Stavert	The problem with water and the benefits of friends - Using comparisons between co-located GHG instrumentation to identify and rectify sources of error
09:20	David Griffith	Total column measurements of greenhouse gases at Kennaook Cape Grim
09:40	Erin Dunne	An update from the Kennaook - Cape Grim Reactive Gases Program
10:00	Andy Menking (Online)	Extending the Kennaook/ Cape Grim record of N_2O stable isotopes 1978-2025
10:20	Bakhat Rawat	Atmospheric mercury (Hg^0) in Kennaook/Cape Grim (KCG): Insight into concentration, variations and source attribution
10:40	**Morning tea**	**Building 20 - Foyer**
Chair	**Nicholas Deutscher**	**Session 11 – Long-Term Trends & Global Change**
11:10	David Etheridge	First observational evidence of changes in atmospheric hydroxyl concentration in the Southern Hemisphere over the Anthropocene
11:30	Justin Takacs	Long-term Trends and Variability in the Wollongong NDACC record
11:50	Brittany Walker	The impact of climate drivers on trace gases at Southern Hemisphere TCCON sites
12:10	Ian Enting	GWP*: What and Why?
12:30	Paul Krummel	The 2025 Antarctic ozone hole
12:50	**Lunch & Departure**	**Building 20 - Foyer**

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Jun-Oh Bu	Characterization of the Physical, Optical, and Chemical Properties of Wildfire Aerosols: A Case Study of the 2023 Hongseong Wildfire in South Korea
Cherie Tollemache	What is that particle and whose particle is it? Advancing single-particle characterisation of atmospheric PM
Saima Iram	Investigating $PM_{2.5}$ Toxicity: The Initial Comprehensive OP Study in Australia Utilising Various Acellular Assays
Jing Kong	Ten-year trend of NH_3 and its impact on secondary inorganic aerosols and $PM_{2.5}$ in Newcastle, Australia

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Quantifying agricultural CH_4 emissions using MethaneSAT and MethaneAIR

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Abstract

The MethaneSAT satellite, launched in March 2024, is a joint American and Aotearoa-New Zealand initiative, involving a partnership between Environmental Defense Fund's (EDF) subsidiary MethaneSAT LLC, and the New Zealand government. The satellite's core mission is to support CH_4 emission reductions around the world by measuring atmospheric CH_4 with an unprecedented combination of precision, resolution, and imaging area. While MethaneSAT was designed to detect emissions from oil and gas infrastructure, it can also be used to measure agricultural methane emissions. Although contact was lost with the satellite earlier this year, it collected 97 measurements over agricultural targets in its lifetime. In addition, we have analysed over 200 agricultural scenes form MethaneAIR, a precursor instrument designed to map methane emissions from aircraft. We will present preliminary results demonstrating MethaneSAT and MethaneAIR's capability to detect and quantify both dispersed emissions from pastoral agriculture and discrete emissions from intensive agriculture.

New Zealand is the ideal test case for dispersed pastoral agricultural emissions, due to its high CH_4 emissions, approximately 85% of which are from agriculture. We will show MethaneSAT data collected from key agricultural regions across New Zealand. These measurements are in agreement with modelled XCH_4 modelled using 1.5 km spatial resolution, New Zealand specific bottom-up CH_4 fluxes and the Numerical Atmospheric dispersion Modelling Environment (NAME III), driven by meteorological input from the New Zealand Convective Scale Model (NZCSM, 1.5 km spatial resolution) Numerical Weather Prediction (NWP) model. Then, we will show XCH_4 measurements and emissions estimates from intensive agricultural systems in the US (e.g. dairies and feedlots) from MethaneAIR, an airborne precursor instrument. MethaneAIR data collected over more than 200 individual scenes have been processed using wavelet analysis and emissions have been quantified using a divergence integral approach. 68% of all agricultural scenes were found to have at least one agricultural plume present and 40% of all agricultural scenes have robustly detected plumes. MethaneAIR and MethaneSAT observations will be compared for facilities observed by both instruments.

Ground-Based Validation of MethaneSAT XCH_4 Observations Over New Zealand Agricultural Regions

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Abstract

This study describes field campaigns conducted as part of the MethaneSAT New Zealand Agricultural Methane project focussing on initial efforts to validate level three estimates of the column averaged dry-air mole fraction of methane (XCH_4) derived from satellite measurements.

Launched on 4 March 2024, MethaneSAT [Chan et al., 2023] was designed to measure atmospheric methane concentrations with high precision, primarily targeting emissions from oil and gas infrastructure. The New Zealand agricultural methane project aims to extend this capability to quantify emissions from the agricultural sector.

Between August 2024 and March 2025, two field campaigns were conducted, deploying up to four ground-based EM27/SUN spectrometers [Gisi et al., 2012] across key regions to capture spatial gradients in XCH_4.

This work represents one of the first validation activities for MethaneSAT and a rare opportunity to validate a satellite borne instrument with multiple ground-based instruments within individual captured scenes, Fig. 1.

MethaneSAT's high spatial resolution (100 x 400 m pixels with a swath width of 260 km) necessitates a novel approach to spatial and temporal coincidence criteria, accounting for the viewing geometry of both measurement systems. Additionally, by taking account of coincident wind observations, the advection of the spatially resolved satellite scenes and the temporal evolution of the ground-based point measurements can be used to consider a multi-dimensional validation.

Following the loss of communication with MethaneSAT in June 2025, the data presented here form a valuable tool for interpreting and exploiting the measurements that were acquired during the mission and the techniques developed will be relevant to the next generation of high spatial resolution greenhouse gas observing satellites.

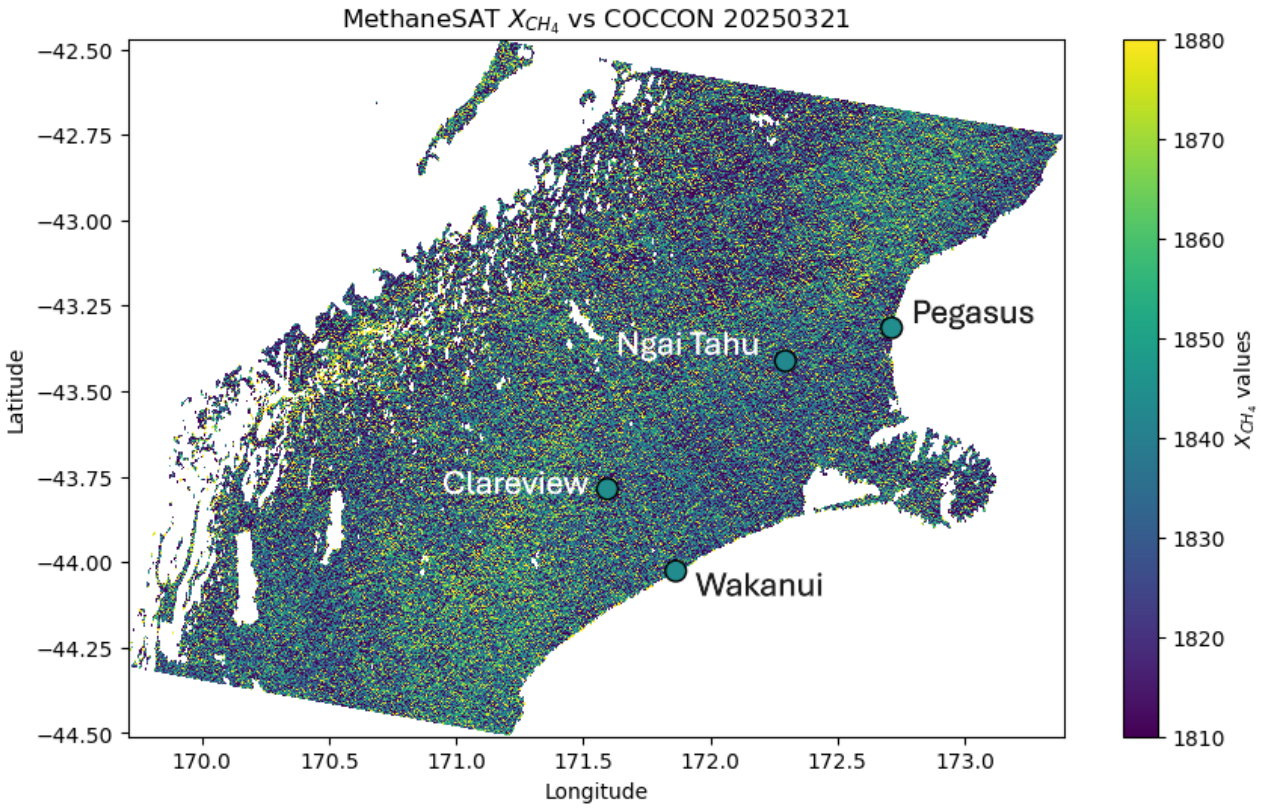


Fig. 1. Comparison of MethaneSAT L3 XCH4 image with ground-based EM27/SUN spectrometer retrievals on 21st March 2025 over the Canterbury region of New Zealand. Labelled black circles show the location of the ground-based sites and their fill colour represents the ground-based measurement on the same colour scale.

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MethaneSAT Verification Campaign: Canterbury, New Zealand

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Abstract

Canterbury, on New Zealand's South Island, is a key region of pastoral agriculture and a major contributor to New Zealand's methane (CH_4) emissions [Ministry for the Environment, 2025]. New Zealand's greenhouse gas emission inventory is well-defined for agricultural emissions making Canterbury the ideal place to estimate CH_4 emissions. This field campaign was conducted in February/March 2025 to coincide with multiple overpasses of the MethaneSAT satellite, a high precision CH_4 sensing satellite launched in March 2024 [MethaneSAT, 2025].

We deployed four EM27/SUN Fourier Transform Spectrometers [Gisi et al., 2012], to obtain total column-averaged dry air mole fractions of CH_4 (XCH_4). Using spatial gradients derived from the upwind and downwind EM27/SUN total column estimates and information about atmospheric transport from the NAME III (Numerical Atmospheric-dispersion Modelling Environment) model to use in a box-modelling framework, we have been able to derive an estimate of regional emissions.

These synchronous measurements of different types enable comparison between box-model fluxes, MethaneSAT fluxes, and inventory-derived emissions. In this talk, we present preliminary results that enhance understanding of CH_4 emissions in Canterbury and provide insight into MethaneSAT's capability to detect and quantify diffuse emission sources. This is the first time in the literature that EM27/SUNs have been deployed at this spatial scale (10's of kilometres) to measure diffuse emissions.

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Towards accurate quantification of New Zealand's methane emissions from waste and agriculture

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Abstract

Methane emissions from waste and agriculture account for 46.6 % of Aotearoa New Zealand's (ANZ) gross greenhouse gas emissions in 2023. Despite the significance of methane emissions, the only way to estimate their magnitude is based on emission factor methods, which include large uncertainties. We will show our newly developed tools using mobile observation platforms (Figure 1) to directly measure methane emissions at facility scale and report on the results of our first trials. The accuracy of this method is directly quantified through measurements of known quantities within a controlled release experiment, as well as through comparison via co-located measurements on research farms using industry-leading technology. Both methods show excellent agreement, providing much needed assurance of analytical performance. While currently limited to methane, future developments may incorporate other greenhouse gases as well. Our tools support ANZ's farmers and waste managers to better understand current emissions, as well as to assess the efficacy of investments into emission mitigation. Additional tests explore new isotope techniques with the goal to quantify methane fluxes from different components within a plant, for example methane derived from digestors versus methane derived from biosolids in wastewater treatment systems, or methane from the open face of a landfill versus emissions from an area that is covered.



Fig. 2. Mobile measurement platforms used for methane emission quantification.

Recent trends in methane in the Southern Hemisphere

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Abstract

Methane (CH_4) is a potent greenhouse gas with a warming potential ~80 times greater than carbon dioxide (Masson-Delmotte et al. 2021). The dominant sources of CH_4 are natural wetland emissions and anthropogenic sources from agriculture, fossil fuels and waste (Kirschke et al. 2013). CH_4 undergoes oxidation by hydroxyl radicals in the troposphere with a lifetime of approximately 11 years, so the atmospheric burden responds relatively rapidly to changes in the emissions compared to carbon dioxide. This has made it a target for policy makers wishing to reduce near future warming of the climate.

Global atmospheric CH_4 has typically been increasing at rates of around 6-7 ppb per year since 1980, with a period of stabilisation between 2000-2007 and an increased growth rate of ~12 ppb per year from 2019-2023(Feng et al. 2022; He et al. 2025; Yin et al. 2021). Here we will present trends in column-average dry air mole fractions of CH_4 (XCH4) from long-term records from three TCCON sites in the Southern Hemisphere and two sites in the Northern Hemisphere (showing contrasting trends). We will also show trends from 3 sites measuring surface concentrations of CH_4 in the Southern Hemisphere and discuss possible contributing factors to these trends.

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Methane Hunter

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Abstract

In this presentation we give an overview of campaigns undertaken to quantify methane emissions from open-cut coal mines in the Upper Hunter Valley. The work will focus on measurements using ground-based solar remote sensing with a network of EM27/SUNs, which can be used to quantify total column averages of methane (X_{CH4}) and carbon dioxide (X_{CO2}). These measurements form part of an increasing number of atmospheric methane measurements in the Upper Hunter Valley, including from aircraft and mobile land-based platforms. These measurements enable estimates of methane emissions using top-down measurements, which can be compared to bottom-up emissions reported by facilities. We will present enhancements seen in the time series and initial derivations of methane emission rates.

Forward modelling atmospheric methane in the coal mining region of New South Wales

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Abstract

National greenhouse gas inventories rely on activity-based information or source specific models [DCCEEW, 2024]. Additional information on emissions can come from top-down frameworks, including inversion techniques, which use atmospheric transport models, observations and prior fluxes to infer emissions [Saunois et al. 2025, Villalobos et al. 2025]. The choice of the prior fluxes influences the inversion [Wang et al. 2025]. Increasing the spatial resolution of the prior could help differentiating between the methane (CH_4) emission sources [Tibrewal et al. 2024]. Here, we test our forward model with different prior fluxes and compare the simulated column methane mole fraction (XCH_4) with atmospheric observations in the New South Wales (NSW) coal mining region.

We develop a gridded methane emission inventory by integrating nationally reported data with available national and regional information on methane sources within the study region. Our prior is based on the Open Methane prior [Open Methane, 2025], but we improved the prior fluxes for coal mining and waste sectors. For coal mining we increased the spatial resolution of the Open Methane prior using polygons based on active mining regions and coordinates for the ventilation shafts. For waste we differentiated between landfills and wastewater treatment plants using Geoscience Australia datasets. The magnitude of the emissions for the sectors is based on Australia's National Greenhouse Accounts emission estimates for states and Safeguard emission estimates for facilities.

With better representation of spatial and sectoral distribution, this prior serves as an important component of the regional inversion framework. In this study, we use the coupled Weather Research Forecasting (WRF) Community Multiscale Air Quality (CMAQ) transport model to simulate hourly methane mole fraction with a spatial resolution of 2km x 2km in the NSW coal mining region. We compare the simulated XCH_4 with atmospheric XCH_4 observations and assess how well observations are represented by the forward model driven by the prior emission inventories.

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Development of the NSW Greenhouse Gas Monitoring and Verification Program

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Abstract

Methane is emitted from several Environmental Protection Authority (EPA) regulated facilities in NSW, which include coal mining operations, oil and gas extraction, processing and distribution, agricultural activities, and waste management and wastewater treatment facilities. Many facilities report their annual emissions under the National Greenhouse Emissions Reporting Scheme (NGERS). Recent studies (e.g. Borchardt, *et.al.* (2025)) have highlighted possible discrepancies between atmospheric measurements of methane emissions, particularly from Australian coal mines and solid waste landfill sites, and the NGERS reported emissions. Since the NSW Government relies on emissions data reported through NGERS, potential discrepancies and underreporting will impact the government's ability to accurately track progress against the emissions reduction targets under the Climate Change Act, and to implement the NSW EPA's Climate Change Action Plan.

To address this issue, the Climate and Atmospheric Science branch within the NSW DCCEEW has been tasked with establishing a Greenhouse Gas (GHG) Monitoring and Verification program for NSW. This would leverage the existing, statewide Air Quality Monitoring Network currently operated by the branch, one of the most extensive networks of its kind in the southern hemisphere. The program will enable the collection of fundamental GHG data to help ground truth GHG emissions inventories, identify under-regulated or unregulated GHG emissions, inform regulation, provide for ongoing tracking, and independently gather GHG emissions data that is not reliant on industry reporting. The key objectives of the program over the pilot phase from June 2025 to June 2027 are to (1) establish a monitoring network in the Upper Hunter region of NSW, (2) design and implement a data and modelling framework for inventory verification, and (3) plan for ongoing operation and future expansion of the program across NSW.

Since the program's commencement progress has been made on several tasks. This presentation will provide background information and an overview of the program, focussing on

- the key sources of emissions in the Upper Hunter region of NSW from facilities that are regulated by the NSW EPA,
- the existing NSW Air Quality Monitoring Network,
- existing methods for quantifying and associated inventories, and,
- initial top-down emission estimation approaches that are being investigated.

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Satellite validation of XCH4 over Australia and New Zealand

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Abstract

Satellite-based observations of methane (CH_4) provide essential data for detecting and monitoring large scale CH_4 emission sources. However, these observations require validation against ground-based solar remote sensing measurements for accurate quantification of CH_4 and intercomparability to in-situ calibration scales. Two spaceborne instruments i.e., TROPOspheric Monitoring Instrument (TROPOMI) onboard Sentinel-5P satellite and Infrared Atmospheric Sounding Interferometer (IASI) onboard Meteorological Operational satellite are providing high-resolution CH_4 data with daily global coverage. Likewise, the ground-based Total Carbon Column Observing Network (TCCON) sites are also delivering continuous CH_4 measurements that can be used for satellite-validation.

Satellite-based CH_4 data has mostly been validated in the Northern Hemisphere because there is a denser network of ground-based instruments in the Northern Hemisphere compared to Southern Hemisphere. Ignoring validation in Southern Hemisphere may induce several uncertainties in the CH_4 retrievals. Therefore, this study presents the validation results of TROPOMI and IASI derived total column dry air mole fraction of CH_4 (XCH_4) with ground-based observations from TCCON sites in Australia (Darwin and Wollongong) and New Zealand (Lauder). We also review the capability of ground-based portable EM27/SUN spectrometers to validate space-borne XCH_4 measurements. These EM27/SUN instruments were deployed during field campaigns in Australia and New Zealand at different times of year (see Table 1) to have XCH_4 measurements.

Lastly, we also compared AirCore measurements with TROPOMI and IASI XCH_4 data. AirCore is an atmospheric sampling system consisted of a thin long tube used to sample surrounding air and a trace gas analyser usually Picarro used to convert trace gas (CO_2/CH_4) profile into mole fraction. More information and schematic diagram can be found in (Karion et al., 2010)

Table 1. Methane emissions and quantification field campaign in Australia and New Zealand

Country	Location	Dates
Australia	Broken Hill	Sep 27 – Oct 7, 2022
	Hunter Valley	May 20 – June 28, 2024
	Hunter Valley	Nov 5 – 21, 2024
New Zealand	Waikato region, North Island	Aug 1 – 28, 2024
	Christ Church, South Island	Feb 10 – Mar 24, 2025

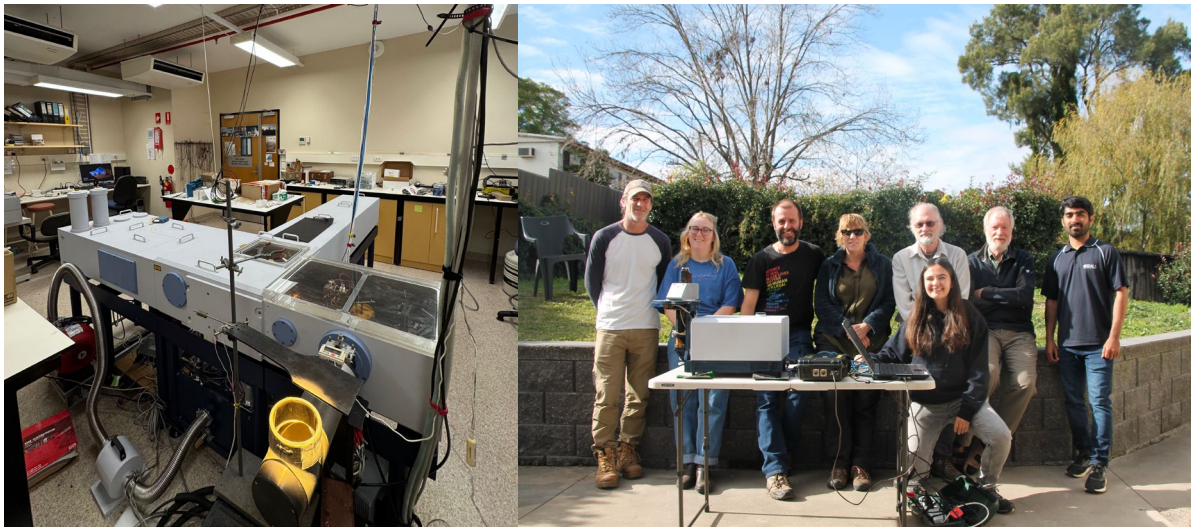


Fig. 3. TCCON Wollongong site (left) and Methane Hunter Team with EM27/SUN instrument (right).

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Observing methane plumes in geostationary satellite data can improve our understanding of the spatiotemporal dynamics of super-emission events

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Abstract

Satellite instruments such as GOSAT and Sentinel 5P/TROPOMI are widely used in observing atmospheric methane, particularly at regional to continental scales. However, their limited revisit time makes their use in identifying transient events limited. Combining data from these methane-specific instruments with other satellite products allows improved temporal coverage, enhancing the ability to quantify emissions for large, transient methane sources. Here we investigate the use of geostationary satellite imagery to improve our understanding of the temporal dynamics of methane super-emission events.

We have developed a band-differencing algorithm that allows geostationary data to be used to image methane super-emission events. We then use it to image methane events from the Copernicus methane hotspot explorer [CAMS, 2025]. Our algorithm builds upon the work of Varon et al. 2021 and Watine-Guiu et al. 2023, who used non-methane specific instruments to observe methane concentrations. We have so far applied our technique to GOES geostationary data and aim to extend this to the closely related Himawari geostationary satellites to apply this method in an Australian context.

Here, we will present some initial work that shows methane plumes in the data from these geostationary satellites and describe how even though their spectral coverage may not be optimised for methane detection, they have an important role to play in constraining methane emission rates for large transient point sources. Our results show that the better temporal completeness of these measurements (15-minute rather than one-day revisit periods) mean that they are useful in the case of very large transient emissions, even though the methane concentrations required for observation are higher than for Sentinel 5P / TROPOMI.

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Empowering methane mitigation through science: actionable data from methane science studies in Australia

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Abstract

Open, reliable and actionable measurement-based data is essential to understand the magnitude and location of methane emissions globally and to demonstrate progress towards emissions reduction goals. The United Nations Environment Program's International Methane Emissions Observatory (UNEP's IMEO) is responding to this need, providing reliable policy-relevant data to facilitate actions to reduce methane emissions. A key component of this initiative are scientific studies, of which several have recently been conducted in Australia. Using airborne measurements, these studies have focused on key methane sources at the facility level in Australia including Bowen Basin coal mines and liquefied natural gas (LNG) export terminals. Here, we will provide an overview of these studies and recent accompanying publications (e.g. Borchardt et al. 2025, Lunt et al. 2025). We will discuss the ability of different remote sensing and in-situ measurements deployed on Airborne Research Australia's ECO-Dimona aircraft to detect, quantify and attribute methane emissions from industrial facilities such as coal mines and LNG terminals. In addition, we will demonstrate how carbon dioxide can be used as a tracer of opportunity to estimate methane emissions from LNG terminals both accurately and efficiently. Finally, we will discuss the importance of measurement method validation, the ways this can be achieved and the scientific opportunities to drive tangible methane reductions in Australia.

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Resolving ghost forest tree methane pathway, origin, and age using a novel ^{14}C-CH_4 approach

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Abstract

Freshwaters and inland waters are major sources of methane (CH_4) (Saunois et al., 2020). Wetland tree stems have high CH_4 emissions, but most research focuses on living wetland tree emissions. Dead trees can also emit CH_4 (Carmichael et al., 2018). Consequently, new lines of research are focusing on the so-called "ghost forest" CH_4 emissions (Carmichael et al., 2018). Ghost forests are the result of forest dieback events that can occur due to land use-change, natural disasters and/or climate change.

This study aims to understand CH_4 emissions from a ghost forest created by reservoir construction, and determine the importance of this previously unaccounted-for CH_4 source. The objectives of this study are to: 1) refine and confirm the ^{14}C- CH_4 extraction method; and 2) determine the source, age and pathways of the CH_4 emissions using radiocarbon ^{14}C-CH_4 isotopes.

Once knowing these ^{14}C signatures, we can address the following research questions:

1. Are the trees emitting CH_4 derived from fresh young carbon flushed into the lake?

2. Are the trees emitting CH_4 derived from deeper old soil carbon?

3. Are the trees emitting CH_4 derived from the decomposition of the wood?

Field campaigns revealed that ghost forest trees are a substantial CH_4 emission source (+15%) to the total reservoir CH_4 budget. For ^{14}C-CH_4 analysis, we collected gas samples from flooded ghost forest trees (n = 10) and ebullition (n = 3), soil cores (n = 6), and wood cores (n = 18) were incubated to measure potential CH_4 production. For ^{14}C analysis, we first separated CH_4 and CO_2 from the gas samples, then graphitised these along with the soil samples for analysis on the ANSTO accelerators, values are pending.

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Fugitive methane monitoring using top-down approaches: policy and mitigation informed by the best available science

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Abstract

Methane has risen by record amounts over recent years, and it is the second greatest contributor (~16%) to global radiative forcing of all long-lived greenhouse gases. Methane's global warming potential is 81 times greater than carbon dioxide over 20 years (GWP-20) and it has a relatively short lifetime (12 years), which means that reducing emissions can significantly reduce radiative forcing over relatively short timescales. For such reasons, a large swathe of climate commitments, legislation and regulations require the reduction of anthropogenic methane emissions. This includes international climate agreements such as the Global Methane Pledge and the Paris Agreement on which Australia is a signatory. Within Australia, this includes the National Greenhouse and Energy Reporting Scheme and associated Safeguard Mechanism, as well as a range of State and Territory legislation such as the NSW Climate Change (Net Zero Future) Act 2023.

Fugitive methane emissions have recently attracted significant attention both internationally and within Australia, for the following reasons:

1. They are a significant contributor (~ 25%) to total anthropogenic methane emissions.

2. There is a substantial and growing body of evidence suggesting that fugitive emissions are both significantly underestimated and highly uncertain (e.g. Luhar et al. 2020; Borchardt et al. 2025). Importantly, this includes emissions estimates derived using the IPCC (bottom-up) methodologies that are applied globally and by countries such as Australia, to report their national greenhouse gas inventories to the UNFCCC.

3. Recent assessments (e.g. IEA 2024) have shown that most fugitive methane emissions can be reduced using currently available technology, and that around half can be reduced at low cost or even net-negative cost (i.e. cost beneficial), through techniques such as leak detection and repair.

It is vital that emissions and their uncertainties are accurately quantified as this fundamentally informs all decision making related to effective mitigation, including policy development. This presentation will provide an overview of recent work by CSIRO that was commissioned by the NSW EPA (NSW EPA and CSIRO 2025). It provided (a) the identification of priority sources of NSW methane emissions and their uncertainties, (b) a review of bottom-up and top-down methods including those that could be applied to enhance fugitive methane emission monitoring, and (c) recommendations for enhanced fugitive methane monitoring to be applied to different sectors. Finally, this presentation will provide a brief update on progress related to the development of an Australian Greenhouse Gas Observing Network (AGGON).

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CarbonWatch-Urban Mobile Laboratory for estimating urban emissions across Aotearoa New Zealand

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Abstract

Carbon dioxide from fossil fuel burning (CO_2ff) in urban areas contributes 40% of Aotearoa New Zealand's gross emissions. Concurrently, urban vegetation absorbs and releases CO_2 (CO_2bio) by photosynthetic uptake and respiration. Initial data suggests CO_2bio is a net sink that offsets 10-60% of urban CO_2ff, but insufficient data is available in New Zealand, or indeed for urban areas worldwide. To bridge this gap in data, the CarbonWatch-Urban research programme aims to produce high-resolution emissions information, mapped across space, time, and sector, for every urban centre in New Zealand, verified by atmospheric measurements. To help achieve this, a mobile laboratory measuring carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), black carbon (BC), radon-222 (^{222}Rn), radiocarbon ($^{14}CO_2$), carbonyl sulphide (COS), and meteorological and GPS parameters, has been built. The mobile laboratory will be visiting towns and cities that span a range of New Zealand's topography, meteorology, climate and urban size each season for the next three years, implementing the following sampling strategies: 1. Stationary flask samples to determine $^{14}CO_2$ and CO_2ff from which spot check comparisons with modelled fluxes can be made; 2. Mobile measurements for observing on-road emissions and emission rates; 3. Mobile measurements to map methane emission sources ; 4. Stationary nocturnal measurements for radon tracer method of CO_2 fluxes.

We will discuss the design and set-up of the instrumentation and sampling strategies and show preliminary data from the first South Island field measurements

Melbourne urban methane: Network status and integrating facility scale observations.

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Abstract

Urban methane emissions remain poorly constrained, resulting in unreliable emission inventories that fail to accurately represent sector-specific contributions or capture source variability. Addressing this issue is challenging due to the complex and overlapping mix of urban sources. Over the past three years, we have substantially expanded our Melbourne urban observation network from one site to six sites and developed a robust mobile measurement capability to inform and drive our modelling system, with the goal of producing a more accurate and reliable emissions inventory for the region.

Within our fixed network, three sites are equipped with methane isotopic analysers ($\delta^{13}C\text{-}CH_4$), which are critical for effective source attribution. Initial isotopic analyses showed a strong biogenic influence (likely from the Eastern Treatment Plant) over the eastern domain during prevailing easterly winds. In contrast, a thermogenic signature was consistently observed from northerly directions, particularly during the winter months, and this was corroborated by data from two sites in the same area. On the western side of the network, the dominance of a biogenic signature remains pronounced. To optimize the network, an isotope analyser was relocated from Bangholme to the Parkville site. This central deployment is designed to capture a broader regional plume footprint for more effective analysis.

Complementing the urban network, mobile surveys have been extensively used to characterize the spatial distribution of sources and to inform the monitoring design of the Western Treatment Plant (WTP). These campaigns have provided high-resolution data that enable detailed characterization of WTP emission sources. Here, we present key insights from the updated network data collected over the past three years, describe the spatial distribution of emission sources within the WTP, and outline plans to integrate this facility-scale data into the broader urban network.

Methane emissions in Melbourne inferred from ground-based measurements with a synthesis inversion

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Abstract

Quantifying methane (CH_4) emissions in urban areas is challenging due to the complex mix of sources, overlapping emissions, and gaps in existing inventories. We developed a sector-specific gridded prior inventory for Melbourne using global, national, and regional datasets. Simulated methane mole fractions based on this inventory were compared with observations from five sites: four within Melbourne (Aspendale, Bangholme, Clayton, Parkville) and the Kennaook/Cape Grim site in Tasmania. The model captured the timing of methane variations reasonably well but consistently underestimated the observed mole fractions, suggesting that emissions in the prior inventory were too low.

To improve these estimates, we applied a synthesis inversion framework using in situ atmospheric measurements and a Bayesian approach. This method included both linear (Gaussian) and non-negative (constrained) inversions, observational data selection, and uncertainty analysis using randomised ensemble spreads and posterior covariance. The inversion showed that prior emissions were underestimated, especially from landfills, gas infrastructure, and wastewater treatment. Posterior estimates showed improved agreement with observations, with reduced RMSE, stronger correlations, and lower bias across all sites.

Diagnostic metrics, including the chi-squared parameter, confirmed appropriate choices for observational and model error settings. Sensitivity tests demonstrated the robustness of the inversion system, although source attribution remained uncertain in areas with overlapping emissions or limited observational coverage. Overall, this study highlights the value of synthesis inversion for urban CH_4 quantification and its potential to support targeted mitigation and improve emissions reporting in Australian cities. The findings also suggest that urban infrastructure offers greater potential for CH_4 abatement than suggested by the prior inventory.

Methane emissions from two wastewater treatment plants in Melbourne: A network design study

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Abstract

Wastewater Treatment Plants (WWTPs) can be significant sources of methane (CH_4) in urban areas. Accurately quantifying methane emissions from WWTPs allows us to prioritise mitigation efforts and track progress in emissions reduction. Melbourne Water operates two large WWTPs that together process more than 800 ML/day of sewage to serve a population of around 4.8 million people across Greater Melbourne. Melbourne Water has pledged to reach net zero emissions by 2030. Here, we look at the potential for using atmospheric methane measurements at fixed ground-based sites to quantify the facility-wide methane emissions from these WWTPs over the timescale of 5-10 years.

We first used mobile surveys in and around the WWTPs and atmospheric transport modelling to characterise the spatial and temporal variability of methane in the atmosphere near the WWTPs (Fig. 1). The mobile surveys showed that the WWTPs are significant emitters of methane within the urban region, and that plumes of methane measuring tens to hundreds of ppb can be detected at least 12 km downwind of the WWTPs, depending on atmospheric conditions. Seasonality in the predominant winds causes seasonality in the directions most often influenced by the plumes. Plumes very close to the TPs contain fine-scale variability due to the complex spatial pattern of emissions within the WWTPs, but the plumes smooth out and decrease in magnitude with increasing distance away. Modelled methane plumes using prior estimates of emissions were reasonably similar to the measured plumes, but with scope for improvement of the WWTP emissions.

We then used atmospheric modelling to identify optimal measurement locations in a network design study. This involved forward model simulations as well as inversion calculations using pseudo-observations in a synthesis inversion framework. One challenge in this work is to separate the influence of the WWTP emissions from other nearby sources such as landfills, agriculture and gas leaks – measurement locations were selected to minimise these other influences. There is some diurnal, seasonal and episodic temporal variability in WWTP emissions due to weather and operational processes, so we identified locations that are most frequently influenced by the downwind plume to provide maximum information for constructing the average emission estimate. We considered locations with existing infrastructure that could support instrument installation. We also considered distance from the WWTP to balance the influence of small-scale structure in the methane plume (that could be difficult to simulate with the model) with decreasing magnitude of the plume.

Following this network design study, Melbourne Water has begun installation of instruments to measure methane, nitrous oxide (N_2O, another greenhouse gas emitted from wastewater treatment) and relevant meteorological parameters at suggested locations. The measurements will be used in an inversion framework to estimate WWTP methane (and, at a later stage, nitrous oxide) emissions over the next 5-10 years.

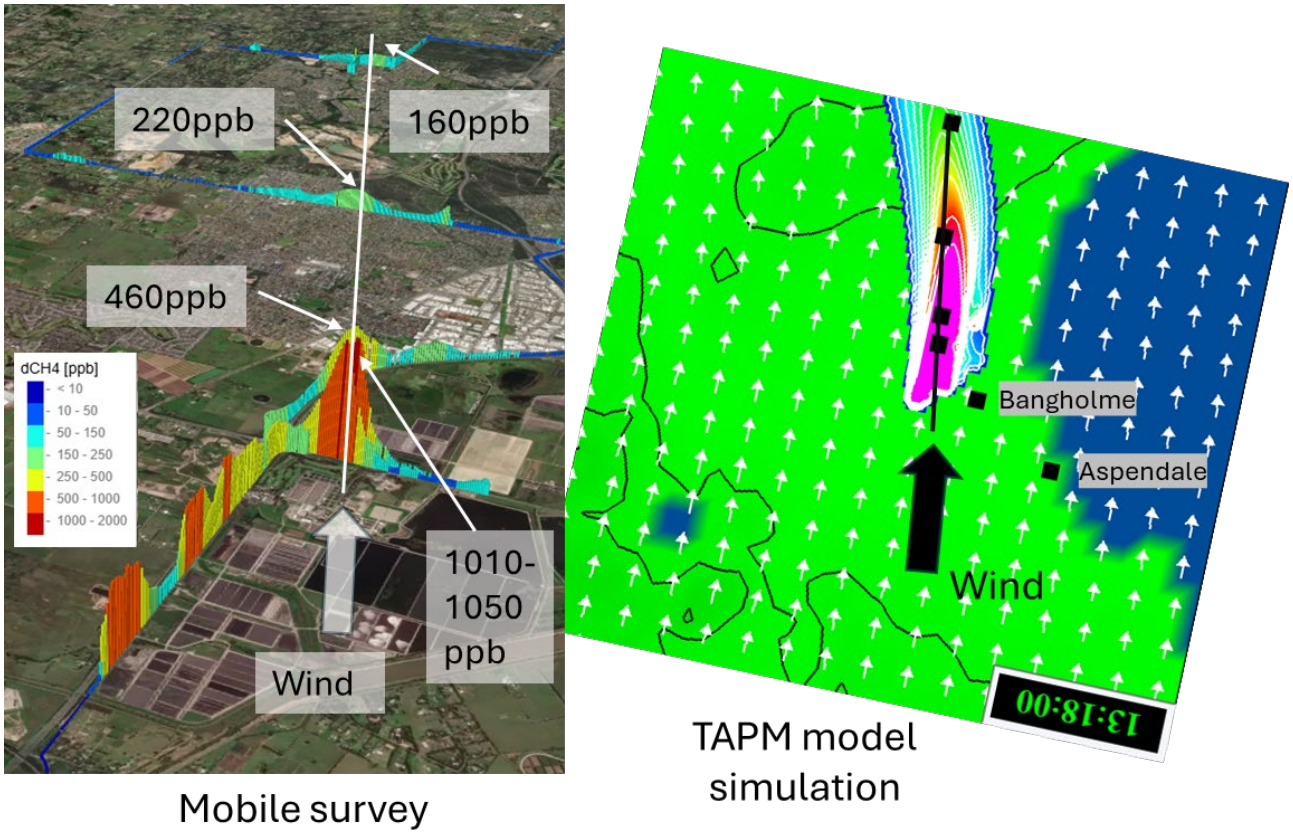


Fig. 4.Results from a mobile survey (left) and model simulation (right) of atmospheric methane downwind of the WWTP in Melbourne's eastern suburbs on 13 August 2024. The model simulation used TAPM (CSIRO's The Air Pollution Model). The black squares on the map of model results show the existing measurement sites at Aspendale and Bangholme and the locations where the mobile survey crosses the methane plume.

Linking ocean productivity and air mass history to variability in volatile methylated sulfur species across the Southern Ocean

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Abstract

Marine phytoplankton play an important role in the marine sulfur cycle through the production of volatile methylated sulfur species (VMS). In the Southern Ocean, dimethyl sulfide (DMS) and methanethiol (MeSH) are known to be important drivers of climate-cooling aerosol formation, with both VMS species sharing the common biological precursor dimethylsulfoniopropionate (DMSP). Yet the biogeochemical drivers and atmospheric pathways governing their emission, transformation, and oxidation remain poorly constrained. These uncertainties limit representation of VMS source strengths and atmospheric processing in models, and current climatologies fail to capture the strong spatial and temporal variability observed across the Southern Ocean and Antarctic coast. Improving our understanding of these pathways is therefore essential for constraining VMS-aerosol relationships and their climatic implications.

Using parallel atmospheric VMS and biogeochemical measurements coupled with 12-hour backward trajectories from the 2024 austral summer Multidisciplinary Investigations of the Southern Ocean (MISO), we establish the dominant controls on VMS across Southern Ocean productivity regimes. Air mass exposure to biologically productive waters was the strongest predictor of DMS near the Antarctic coast (62° S-67° S), where elevated DMS was mirrored in enhanced oxidation products, dimethyl sulfoxide (DMSO) and methanesulfonic acid (MSA), consistent with a high-latitude oxidation environment in which cold temperatures favour the OH-addition oxidation pathway and halogen-mediated oxidation becomes important. In the open ocean (32° S-62° S), DMS was decoupled from productivity, with variability instead linked to humidity, boundary layer structure and oxidant availability. MeSH was weakly tied to productivity at the ice-edge and over the open ocean despite its consistently strong relationship with DMS. After removing biological influence, VMS residuals demonstrated a strong relationship to wind speed as a dominant driver of sea-air transfer. Together, our findings suggest that spatial variability in VMS across the Southern Ocean reflects shifting dominance between biological production, air mass history and temperature-dependent oxidation, with each species responding to a distinct balance of source and sink processes.

High gaseous MSA events during CAPRICORN II and MISO Southern Ocean voyages

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Abstract

The study of natural aerosols is important to establish a baseline for measuring the impact of anthropogenic aerosols on Earth's climate. The Southern Ocean provides a pristine setting to study biogenic marine aerosols and its precursors such as dimethylsulphide (DMS) and its oxidation products. DMS is the largest source of natural sulfur in the atmosphere and during austral summer the polar sector of the Southern Ocean has the highest concentrations of aqueous DMS on the planet [Hulswar et al., 2022]. DMS originates from marine phytoplankton and is emitted into the atmosphere through air-sea exchange processes. After its emission, DMS is oxidised by atmospheric oxidants through different pathways producing sulfuric acid (SA; H_2SO_4) and methanesulfonic acid (MSA; CH_3SO_3H). SA has been shown to be involved in new particle formation (nucleation) and particle growth. MSA has been shown to assist in particle growth, but there is yet no evidence of MSA influence on nucleation. Therefore, these species are climate-relevant compounds as they are important for the formation of aerosols and clouds in the marine boundary layer. This presentation reports the observations of aerosols and trace gas measurements made aboard the RV Investigator during the CAPRICORN II (Jan-Feb 2018) and MISO voyages (Jan-Mar 2024) in the Southern Ocean during austral summer. The RV investigator traversed the western Pacific sector of the Southern Ocean between (110° E - 150° E). During both voyages periods of elevated concentration of gaseous MSA were observed at higher latitudes (> 62°S). These "high MSA" periods contain the highest reported concentrations of gaseous MSA in the coastal Antarctic region [Miljevic et al., 2025], with MISO voyage showing a higher gaseous MSA levels than CAPRICORN II. Air-mass back trajectory analysis during the high MSA periods for both the voyages show consistent cold, dry air flowing from the Antarctic continent. During all high gaseous MSA periods particle composition was dominated by species of biogenic origin (SO_4^{2-}, MS^-). This biogenically enriched air also correlated with a prominent increase in the measured CCN concentrations. These results suggest that long-range transport of biogenically enriched aerosols contribute to the observed high CCN concentrations consistent with the findings during CAPRICORN II [Mallet et al., 2025].

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A model sensitivity analysis of aerosol precursor emissions related to Antarctic sea-ice

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Abstract

The complex interactions between radiation, clouds and aerosol remains the largest source of uncertainty in estimates of climate sensitivity to anthropogenic emissions. In the remote Southern Ocean far from anthropogenic sources, climate models significantly underestimate the number of aerosol particles, which importantly affect cloud properties, precipitation and radiation (Fiddes et al., 2024). Efforts to improve aerosol representation have so far shown limited success, highlighting issues with the aerosol to cloud microphysical processes within climate models. Recent work suggests that improving natural aerosol processes may be a key part to improving the modelling for this region.

We explore aerosol and climate responses to an Antarctic sea-ice associated source of the natural aerosol precursor gas dimethyl sulfide (DMS). Studies over Antarctic sea-ice regions have observed direct sea-ice to atmosphere DMS fluxes, alongside high DMS seawater concentrations associated with sea-ice melt; with neither of these processes captured in current climate models (Burke et al., 2024). Control and DMS perturbation simulations are performed with the ACCESS-AM2 (Australian Community Climate and Earth-System Simulator - Atmospheric Model v2) climate model between 2016-2024, covering a comprehensive set of recent observations. The additional source of DMS is examined for impacts on cloud processes and the subsequent surface radiation budget, which is important for estimates of climate sensitivity.

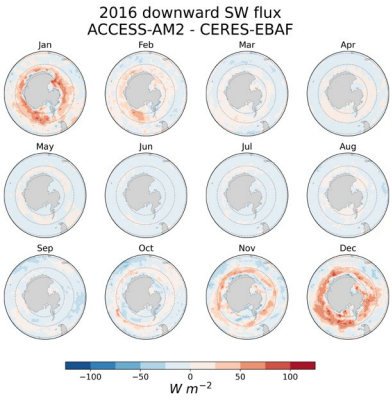


Fig. 5. ACCESS-AM2 surface shortwave downward flux from the control simulation compared with the CERES-EBAF satellite product reveals a positive austral summer polar bias.

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Aerosol Acidity Controls Methanesulfonic Acid Evaporation From Aerosols During Antarctic Continental Outflow

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Abstract

Methanesulfonic acid (MSA), a key oxidation product of dimethyl sulfide (DMS), plays a crucial role in the atmospheric sulfur cycle and in the formation of cloud condensation nuclei (CCN). MSA contributes significantly to aerosol growth and, potentially, the modulation of cloud microphysical properties, particularly in remote marine and polar regions where CCN concentrations are relatively low. This presentation will focus on elevated gaseous MSA periods observed along the coastal region of East Antarctica during CAPRICORN-2 (2018) and MISO (2024) voyages that coincided with air masses coming from the Antarctic continent. The periods of high gaseous MSA coincided with a sharp and sustained decrease in both absolute humidity and temperature. Such dry and cold air masses are frequently associated with Antarctic katabatic outflow. This outflow also brings biogenically dominated, highly acidic aerosols and we show that elevated gaseous MSA observed at the same time results from evaporation off the surface of these aerosol particles. While MSA evaporation is promoted by a decrease in relative humidity, we show that aerosol acidity is the primary driver of this process. These results provide new insights into processes involved in the marine sulfur cycle, which should be taken into account when using observations of DMS oxidation products to guide model evaluation and development.

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Regional and meteorological influences on atmospheric composition and cloud structure from the MISO voyage

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Abstract

Persistent cloud and radiation biases over the Southern Ocean remain a key uncertainty in global climate models, driven in part by incomplete understanding of the sources and transformations of aerosols that influence cloud formation. The 2024 Multidisciplinary Investigations of the Southern Ocean (MISO) voyage aboard the RV *Investigator* provided a rich and comprehensive dataset to address this challenge, combining continuous ship-based measurements of aerosol and gas-phase composition with oceanographic and meteorological observations across the Southern Ocean and coastal Antarctic regions.

Here we present an expanded analysis of these atmospheric observations, focusing on how aerosol size distributions, chemical composition, and cloud condensation nuclei (CCN) properties vary with air mass origin and synoptic meteorology. Air mass trajectories have been classified according to whether they predominantly traversed Antarctic, Australian, or open-ocean regions during the five days preceding arrival at the ship. Distinct changes in compositional and microphysical properties are evident for different air mass origins and synoptic regimes, reflecting contrasting influences from marine biogenic emissions, long-range continental transport, and local atmospheric processing.

Preliminary comparisons with output from the UM Regional model will be presented, focusing on a notable period of transient atmospheric conditions near the Antarctic coastline. Together, these results provide valuable insight into the interplay between regional sources and atmospheric dynamics and their potential to inform the representation of these processes in climate models.

Aerosol properties measured during the Cloud And Precipitation Experiment at Kennaook (CAPE-K)

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Abstract

The Cloud And Precipitation Experiment at Kennaook (CAPE-K) took place at Kennaook/Cape Grim (KCG) between April 2024 and October 2025. This international collaboration between the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) program, CSIRO, and the Australian Bureau of Meteorology has integrated KCG's long-term aerosol datasets with ARM's suite of remote sensing instruments, including radar and lidar systems, to provide comprehensive observations of low cloud and precipitation processes.

CAPE-k data will be used to improve the representation of aerosol-cloud-precipitation interactions in climate models and reduce persistent radiative biases in Earth system models over the Southern Ocean. These biases are associated with an overestimation of regional warming, largely attributed to the misrepresentation of low cloud cover. The inter-model spread in low cloud projections is especially pronounced near 40°S (Zelinka et al., 2020) introducing substantial uncertainty into climate projections and, by extension, into policy frameworks for mitigation and adaptation.

This presentation provides an overview of aerosol measurements collected during CAPE-K, with a focus on baseline periods. Particular attention is given to aerosol microphysical properties (e.g., size distributions, particle number concentrations, cloud condensation nuclei), optical characteristics (e.g., absorption and scattering coefficients), and chemical composition. These data are important for constraining model parameterizations and improving climate model simulations in the Southern Ocean region.

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CAPE-K CHEM: New Particle Formation and Precursors Vapours at Kennaook Cape Grim

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Abstract

Understanding the pre-industrial atmosphere is imperative for investigating anthropogenic climate change and the Southern Ocean is representative of the pre-industrial atmosphere. New particle formation (NPF) represents a large contribution to aerosol loading and cloud condensation nuclei globally, both in the preindustrial and present-day atmosphere.

As part of the larger Clouds and Precipitation Experiment at Kennaook (CAPE-k) campaign, CAPE-k CHEM performed online measurements of aerosol precursor vapors using a high-resolution nitrate chemical ionization mass spectrometer (CIMS) and particle number size distributions (PNSDs) using a neutral and air ion spectrometer (NAIS). Measurements were performed in the U.S. Department of Energy Atmospheric Radiation Management (ARM) Mobile Facility (AMF2) at Kennaook/Cape Grim from October 2024 to May 2025. CAPE-k CHEM represents the first-time deployment of this instrumentation at Kennaook/Cape Grim.

We investigated the meteorological conditions, precursor vapors, and air mass history for Non-event days, Undefined days, and NPF event days as defined by the Nanoparticle Ranking Analysis from Aliaga et al. (2023). NPF event days occur around 11% of the time, predominately from the non-baseline sector, without a seasonal cycle over the campaign period. NPF event days were drier with higher pressures and lower wind speeds with more fluctuating temperatures over the diurnal cycle. On NPF days, sulfuric/oxalic/malonic acids and Highly Oxidized Molecules (HOMs) peak earlier and higher, iodic Acid and IO_2 peak in the morning only, and C1+C2 Amines elevated the morning and night before.

NPF event day air masses spend more time closer to Tasmania and arrived from higher aloft. CAPE-k CHEM offers a unique opportunity to examine NPF from marine as well as anthropogenic sources.

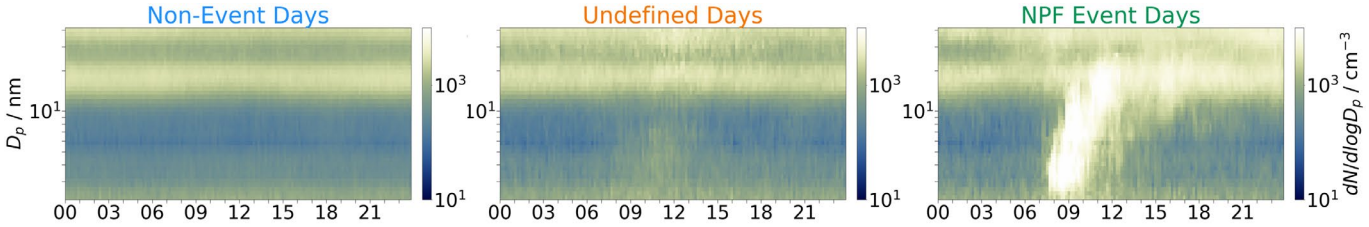


Fig. 6. Diurnal mean of Non-event, Undefined, and NPF events days as defined by the Nanoparticle Ranking Analysis by Aliaga et al. (2023).

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The impact of ship sulfate emission regulations on solar radiation and coral bleaching severity at the Great Barrier Reef

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Abstract

In 2020, the International Maritime Organization (IMO) introduced regulations limiting the sulfur content of shipping fuel to <0.5% to mitigate air pollution in port cities. This change is significant because ships are the dominant anthropogenic source of sulfate aerosol over the oceans. Ship-emitted aerosols not only contribute to air pollution and human health impacts but also influence Earth's radiation budget through both direct scattering and indirect cloud effects. Recent global modelling studies suggest that the IMO's sulfur reduction may have led to a substantial shift in Earth's radiation balance. The decline in maritime sulfate aerosol has likely reduced both cloud albedo and direct aerosol scattering, allowing more solar radiation to reach the ocean surface and effectively "unmasking" part of the global warming previously offset by these aerosols. In this study, we assess the impact of the IMO's 2020 regulation on Australia's Great Barrier Reef (GBR), which faces increasing thermal stress due to climate change. Rising ocean temperatures are the primary cause of coral bleaching, but recent research indicates that elevated incoming solar radiation may also act as a trigger. Using the Weather Research and Forecasting model coupled with chemistry (WRF-Chem), we estimate that the 80% decline in sulfate aerosol following the 2020 regulation increased downward shortwave radiation over the GBR by approximately 11 W m^{-2} relative to pre-2020 conditions, during the lead-up to the 2022 La Nina mass coral bleaching event. This represents a large fraction of the ~14 W m^{-2} shortwave "masking" previously provided by ship emissions. Sustained increases in shortwave radiation of this magnitude would likely induce an additional three degree heating weeks of coral thermal stress. However, we find that in periods dominated by cloudy weather or strong south-easterly trade winds, the advection of aerosol away from the GBR substantially decreases the impact of the aerosol reduction. This highlights that the most effective masking effect of ship sulfate aerosols was felt when corals were already most vulnerable to bleaching.

Impacts of Aromatic Chemistry on the Global Atmosphere

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Abstract

Aromatics are an important subset of volatile organic compounds (VOCs), emitted mostly by anthropogenic sources such as vehicle exhaust, industry, and solvent usage (Cabrera-Perez et al. 2016). These sources make them particularly important in urban environments, accounting for up to 60% of total VOCs in urban and semi-urban areas. Aromatic species can undergo atmospheric oxidation resulting in significant contributions to both ozone and secondary organic aerosol (SOA) production (Seinfeld and Pandis 2016). Aromatic oxidation also forms different species depending on the oxidant, either OH or NOx, with different impacts on air quality, such as higher SOA formation potential or higher toxicity. It is therefore important for air quality to understand aromatic chemistry. Previous work in my PhD examined the impacts of aromatic chemistry by quantifying the atmospheric budget of phenolic compounds in South Korea using a Chemical Transport Model (CTM), a region with high anthropogenic emissions. However, the impacts of aromatic chemistry may be different elsewhere in the world, for example in regions where biomass burning is prevalent, which brings a different emission profile and complex chemistry that was not present in South Korea. It is therefore important to quantify the atmospheric budget in other regions to better understand the impacts of aromatic chemistry on a global scale.

Here, we quantify the global and regional atmospheric budget of several aromatic species through a global high-resolution simulation using the GEOS-Chem High Performance model (GCHP). In this talk, we will provide an analysis of the global atmospheric budget of key phenolic compounds, a comparison of regional budgets, and what this implies about the impacts of aromatic chemistry.

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What atmospheric composition changes can we expect at kennaook Cape Grim and Wollongong in 2050?

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Abstract

Natural emissions from vegetation, sea salt and dust emissions are driven by meteorological variables, which will change in a future climate. Natural emissions can dominate air quality in Australia, particularly when high emissions from eucalypt trees promotes smog formation in summer. Therefore, quantifying how natural emissions might change is important. This study uses 4 downscaled Global Climate Models (GCMs) under 2 shared socioeconomic pathways in the 2050s to drive natural emissions at 20km spatial resolution in the CSIRO Chemical Transport Model (C-CTM).

The results from this modelling study have been explored for Australia's state and territory capital cities, but not for sites important to our community. This talk will show the predicted meteorological and atmospheric chemical changes for our meeting host site and at KCG in 2050.

I will also talk about results from the recent National Climate Risk Assessment, where this modelling was also used to calculate health risk outcomes in 2050. The increases predicted from natural emissions contributed to additional deaths and poor health outcomes in 2050, including respiratory and cardiovascular complaints.

Update on observations from AirLab and AIRBOX

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Abstract

AirLab (established in 2022) on the roof of the Redmond Barry building on the urban Parkville campus of the University of Melbourne north of Melbourne's CBD. At an elevation of 43m this is a well-mixed urban boundary layer background observing site.

With a Nephelometer and a filter system for particulate matter we have been participating in the grassroots Surface Particulate Matter Network (SPARTAN). Recent work by Ren et al., 2025 has developed our understanding black carbon for cities globally. Ultrafine particle size and number density observations with a Scanning Mobility Particulate Sizer were made since June 2023-2024, compared with cities across Australisia. Picarro Greenhouse Gas instruments have been monitoring CO_2, CH_4 and CO concentrations since February 2023. MAXDOAS observations have been conducted since 2023. Pollen data from AirLab made with a WIBS instrument has contributed to recent study by Mampage et al., 2025.

AIRBOX is now located at the University of Melbourne Dookie campus, and is being commissioned to run with meteorological instruments, a MAXDOAS and the Radon instrument. This presents us with a unique opportunity to compare rural and urban air quality observations within Victoria.



Fig. 7. Spartan instruments on the rooftop platform above the AirLab laboratory.

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Aerosol Chemistry and Source Apportionment in Urban Australia

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Abstract

Fine particulate matter poses significant risks to public health, contributing to a range of health conditions for vulnerable populations including seniors and young children. Recent studies in the Northern Hemisphere have identified that as anthropogenic pollution sources such as traffic and industry become more tightly regulated, previously unaccounted for sources of air pollution such as cooking and volatile chemical products now constitute significant contributors to urban air. The Southern Hemisphere has been comparatively understudied by techniques capable of distinguishing complex organic sources; the extent to which these emerging source classes influence urban air pollution in Australia therefore is unknown. During Austral winter 2025, a broad suite particulate matter and complementary oxidant and VOC measurements were commenced in a suburb of Melbourne, Australia.

Preliminary results indicate that background particulate matter pollution levels are extremely low as a result of the movement of pristine Southern Ocean marine airmasses through the Melbourne airshed. However, wintertime submicron particulate matter frequently exceeds 40 µg/m3, particularly overnight. These elevated pollution levels typically persist into the late morning, a cause for particular concern as this overlaps with the time window in which children commute to school. Extreme pollution events typically occur under abnormally cold and still conditions and are most pronounced on weekends, with woodheaters and outdoor firepits likely contributing to observed phenomena. Wintertime fine particulate matter is dominantly (>75%) organic, with secondary nitrate contributing between 10 and 20% of observed particulate matter. Significant nitrate aerosol events are frequently observed and typically follow but lag significant smoke events, highlighting the potential importance of interactions between primary and secondary sources in driving the total submicron particulate matter burden experienced by communities.

The expansion of aerosol chemistry techniques broadly applied across the Northern Hemisphere to Southern Hemisphere urban centres creates unique opportunities to compare and contrast dynamics driving urban aerosol formation and fate in the Southern Hemisphere.

Quantifying Airborne Elongated Mineral Particles in Communities Using a Novel Automated Scanning Electron Microscope Methodology

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Abstract

Zeolitic elongated mineral particles (EMP's) can be released into the atmosphere through a series of different emissions pathways posing a risk to nearby communities. One of these pathways includes earthworks associated with urban development and infrastructure improvements in developing cities. Current techniques (such as phase contrast microscopy) offer some insight but provide indefinite chemical and elemental particle characterisation. Their manual nature increases costs and processing times, thus limits their scalability when assessing a large number of filters from dense community filter networks.

Here we present a novel approach to automatically identify EMP's on lab spiked and real-world samples from a developing community in Auckland, New Zealand. Automated scanning electron microscope with energy dispersive spectroscopy (SEM-EDS) was used to quantify particles within a morphological and elemental criteria. Final classification was undertaken with transmission electron microscopy with selected area electron diffraction (TEM-SAED). Our performance evaluation standards demonstrated linear relationship ($R^2 = 0.98^{***}$) and detection limit of 7.4 f/cc. Automated analysis of real-world community samples identified 449 zeolitic EMP's with 29 EMP's exhibiting elemental structures consistent with erionite, a carcinogenic zeolite. Further analysis of EMP's from real-world samples using TEM-SAED confirmed that none of the EMP's were indeed erionite.

This work presents the results from a first-of-its-kind, cost-effective, filter community network combined with tiered, automated analytical techniques. The results highlight although the risk to carcinogenic erionite is low, other EMP's do exist in the ambient air. This work provides a foundation for ongoing studies to determine environmental and occupational exposure limits for EMP's, less well understood using current analysis toolkits.

The influence of simulated thunderstorm conditions on pollen rupturing

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Abstract

Pollen allergies are on the rise globally, with climate extremes contributing to longer and more intense pollen seasons. Under certain conditions in the atmosphere, pollen grains, that are otherwise too large to enter the lower respiratory tract, can fragment into smaller particles that are called subpollen particles (SPPs). SPPs are frequently in respirable size range. Specifically, during thunderstorms, SPPs, can be released at very high amounts, and trigger more severe allergic reactions, intensifying conditions like Thunderstorm Asthma (TA) [1].
The exact mechanism behind TA remains unclear. While physical factors such as osmotic and mechanical forces are typically recognised as primary contributors to pollen rupture, emerging evidence highlights the potential role of electrical charges during storm events in influencing this process [2], [3].

This study investigates the role of electrical charges in pollen rupturing during stormy conditions by simulating pollen-charge interactions for wind-pollinated pollen grains from the Lolium (Perennial Ryegrass) family. These simulations were conducted within the house-made, novel 'Environmental Chamber for High Voltage and Oxidative Air Pollutants'(ECHO). Pollen-charge interactions were examined under various voltage differences: static electric fields (10, 20, 30, and 40 kV)/9.5 cm and arcing (31-35 kV)/4.5 cm, replicating the charge regimes within clouds during thunderstorms. The testing procedure for this study involves exposing to varying charge regimes under two conditions of humidity: dry (35 – 40 %) and wet (90-95 % RH) to clearly demarcate the influence of humidity on airborne pollen. Aerosol sampling is done using the aerosol instrumentation which encompasses detection and characterisation of wide range of aerosols with size ranges from 60 nm – 35 µm.

The Figure is showing that after pollen was introduced between the electrodes, we observed a sudden surge in the concentration of submicronic particles (Figure 2). A sharp increase in particle concentration indicates the onset of pollen fragmentation, triggered by the presence of electrical field. We observed that the extent of rupturing increases with increasing the strength of electric field and that the rupturing increases significantly under high humidity conditions. Following arcing, a sharp surge in particle release occurs, peaking higher and persisting longer at 95% RH, indicating that humidity enhances pollen rupture and aerosolisation. These findings suggest that electric fields and high humidity significantly influence airborne allergen dispersion, with potential implications for respiratory health and environmental studies.

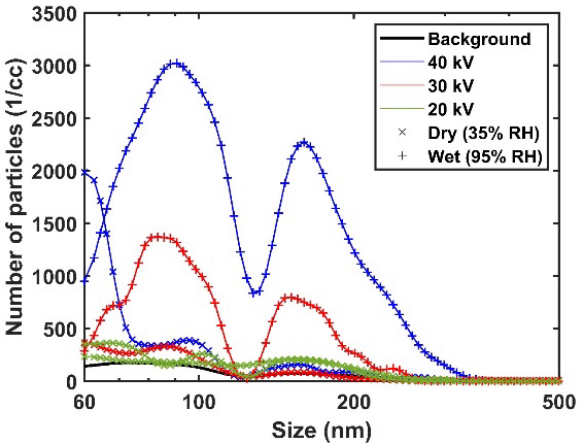


Figure. Size distribution of formed SPP, recorded at 35% and 95% RH at three different strengths of electric field

References:

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Face masks: Friend or foe?

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Abstract

Face masks (FMs) are important personal protective equipment (PPE) used to maintain occupational health and safety (OHS). However, recent evidence suggests that FMs, especially those made from polypropylene, may release microplastics (MPs) and chemical additives during use (Bogush and Kourtchev, 2024; Xie et al., 2022). This research examines how FM usage behaviour in the workplace influences exposure to MPs. It also investigates the effects of released MPs on human health.

A mixed-methods approach was used for this research. Data were collected through a cross-sectional survey based on the Theory of Planned Behaviour (TPB) from 331 respondents across various occupational sectors. Results showed that surgical masks were the most common type (60%), with an average wear time of < 2 hours/day. Healthcare workers reported significantly longer wear durations (> 5 hours), indicating a higher chance of chronic MP exposure. Insights from the behavioural study were then applied to optimise ongoing cytotoxicity experiments using human cell lines representing oral, nasal, and dermal exposure routes. Dynamic light scattering and Zetasizer measurements confirmed the size distribution and surface charge characteristics of the polypropylene MPs. Kinetic plots from the DCFH-DA assay revealed a rapid increase in ROS generation within the first 10 minutes of MP exposure, while MTT assay results showed a corresponding decrease in cell viability compared to the control.

The study provides evidence of potential human health effects linked to MPs released from FMs. Combining behavioural data with environmental toxicology creates a framework for estimating real-world exposure in occupational settings. The findings have important implications for public health and environmental policies, emphasising the need for safer, more sustainable FM materials and workplace guidelines that account for cumulative MP exposure. This research uncovers a critical paradox: protective equipment designed to safeguard health may, through material degradation, introduce new and often overlooked risks.

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Acknowledgment

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The radon measurement program at Kennaook/Cape Grim 2019-2025

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Abstract

From its establishment in 1980, the radon sub-program has measured atmospheric concentrations of this radioactive noble gas, primarily as a definitive tracer of terrestrial influence. As is still the case today, there was no commercially available radon detector sufficiently sensitive to measure concentrations typical of remote baseline sites, so a distinguishing feature of the program was the invention and construction of an in-situ radon detector to meet this need. The design of this instrument, which became most sensitive radon detector in the world, has undergone several generations of improvement and continues to evolve.

Periodically, sub-programs at Kennaook/Cape Grim (KCG) are reviewed to ensure that they are well managed, producing good science, and meeting the needs of the community. Since the last scientific review, the radon program has seen a change in personnel, a change in leadership, and changes to equipment while the overall goals of the program – high-quality measurements, research, and instrument development – have remained largely the same.

The main achievements of the last five years include: publication of a harmonised 25-year data set (1992-2016); design and delivery of a new calibration system; new control software; the addition of a development "test bed" radon detector at KCG; the publication of a guideline document for radon tracer:tracer techniques, extension of a consistent radon-based baseline definition to measurement sites throughout the Southern Ocean; and preliminary work towards a new high-efficiency detector head. This occurred within the context of a growing network of ANSTO radon detectors, especially at GAW and European ICOS network sites, with the radon detector onboard *RV Investigator* being particularly noteworthy due to the COAST-K intercomparison voyage. Over the same period, the sub-program has dealt with issues associated with a change in lead scientists and a 40% reduction in ANSTO personnel associated with radon work.

An upcoming challenge for the program is the anticipated end-of-life of the one-of-a-kind 5000L radon detector (HURD3, the 3rd generation HUge Radon Detector). Our technical goal over the next 5-years is to build a replacement detector that is less complex (reducing future maintenance costs), compact enough to be installed indoors (substantially reducing maintenance time and effort), with an improved measurement quality. An important science goal is to capitalise on multi-year measurements from around the Southern Ocean network, in addition to KCG, to better characterise atmospheric transport patterns and how these are changing.

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Research for Understanding Smoke Hazards (RUSH): Recent Findings, Model Integration, and Future Directions

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Abstract

The Research for Understanding Smoke Hazards (RUSH) project, sponsored by the NSW Bushfire and Natural Hazards Research Centre (BNHRC), aims to improve the characterisation of bushfire smoke to enhance air quality forecasting and mitigate health risks for firefighters and the public. This presentation will provide a comprehensive update on the project's recent achievements and future research directions.

A major recent output is a comprehensive review paper (Desservettaz et al., 2025) addressing specific health and safety concerns raised by Australian firefighters via the 2023 Fulbright report. This work synthesizes the current knowledge on smoke composition, toxicity, dermal exposure pathways, and the efficacy of personal protective equipment (PPE).

In collaboration with traditional burning practitioners on the NSW South Coast, we have also conducted new exposure monitoring. Preliminary analysis of personal Carbon Monoxide (CO) monitoring data indicates that practitioners of traditional burning techniques are exposed to significantly lower levels of air toxics, with cumulative CO exposure up to four times lower than that observed during typical hazard reduction burns.

The RUSH project integrates targeted research from PhD and Masters students, which will also be presented separately at this conference. Key student projects include: (1) a re-analysis of the CSIRO 2008 fire experiment dataset to quantify the impact of fuel moisture content on emission factors, particularly for $PM_{2.5}$ from eucalypt fuels (D. Roy); and (2) a model intercomparison study evaluating the performance of regional air quality models (CSIRO's AQFx, NSW DCCEEW's CMAQ) and global models (NCAR's MUSICA) against observational data from the 2019/20 Black Summer smoke plumes (COALA campaign) (S. Lee).

Future work will focus on filling critical data gaps. We are currently planning a major laboratory campaign at the University of Tasmania's Firelab3 a shared fire research facility to characterise emissions from Australian peat fuels, which are poorly constrained in current emission inventories.

We are also planning a large multi-institute Study at the Forschungszentrum Jülich Simulation of Atmospheric PHotochemistry In a large Reaction Chamber (SAPHIR), to study the aging (oxidation) of biogenic and smoke under varied atmospheric conditions.

The combined outputs from these project streams will deliver improved, locally relevant emission factors and a deeper understanding of smoke chemistry to support the next generation of air quality models and firefighter safety guidelines.

Biomass Burning Impacts at Kennaook/Cape Grim: Insights for AQFx Module Improvement

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Abstract

Biomass burning events significantly influence atmospheric composition and air quality, posing challenges for accurate smoke forecasting. Reliable and timely forecasts are critical for protecting public health, supporting emergency responses, and mitigating impacts on vulnerable communities. A key challenge in smoke forecasting is the accurate and timely estimation of fire emissions.

AQFx is a modular, multi-tiered air quality forecasting system developed in 2016 through collaboration between CSIRO, the Bureau of Meteorology, and partner universities. It integrates meteorological forecasts, satellite observations, emissions inventories, fire behaviour models, and a chemical transport model to produce 72-hour forecasts of $PM_{2.5}$ and other pollutants.

Since AQFx's development, several significant biomass burning events have impacted the Kennaook/Cape Grim station, including the 2019/20 summer bushfires and the most recent fires occurring in February 2025.

We explore how high-resolution observational data from Kennaook/Cape Grim can be leveraged to evaluate and improve key AQFx modules. By identifying and characterizing periods influenced by biomass burning, we assess the representation of emissions, transport, and chemical transformation processes within AQFx. These insights will guide refinements to model inputs and parameterisations, enhancing AQFx's predictive capabilities for future smoke pollution events.

Finding fires: Estimating ignition locations and times through satellite imaging of smoke plumes and fire extent

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Abstract

As climate change continues to increase the frequency and intensity of bushfires, new techniques are required to detect and contain fires more rapidly, in order to more effectively protect people, property, wildlife, and ecosystems. Rapid detection and notification of fires is important for effective firefighting, particularly in the case of large bushfires. However, bushfires sometimes burn for hours before fire authorities are notified. Existing hotspot-based fire detection algorithms are useful for satellite-based bushfire monitoring (Xu & Zhong, 2017), however high-resolution hotspot detection requires satellites with revisit times that are not frequent enough for rapid bushfire detection. Alternatively, geostationary hotspot algorithms with high temporal frequency are based on thermal infrared imagery with 2km resolution, so it takes some time for a bushfire to become large enough to be detectable at that resolution. Here we outline initial investigations into using 500m resolution geostationary satellite imagery to detect bushfire smoke plumes and distinguish them from clouds. We also outline a novel technique to obtain high-accuracy bushfire ignition times and locations for historical fires.

Bushfire smoke plume detection: Our initial exploratory work on smoke plume detection has focused on processing geostationary Himawari and GOES imagery. The algorithm uses the highest resolution band (500m red band) to detect smoke/cloud pixel blobs that are anchored to a consistent geographic location. The algorithm is able to detect smoke plumes within around 10-30 minutes of ignition, with some false positive contamination from clouds. In future work we intend to incorporate lower resolution (1-2km) infrared bands to enhance differentiation of smoke plumes from clouds, potentially enabling our algorithm to be scaled up to detect fires across large areas. We expect that such a scale-up will require development of a machine learning algorithm to process large amounts of EO data and disentangle cloud from smoke, without compromising accuracy.

High-accuracy ignition times and locations: We have also developed a novel technique to obtain high-accuracy bushfire ignition times and locations for historical fires. The technique combines high spatial resolution imagery from low-Earth orbit satellites with high temporal frequency imagery from geostationary satellites, to obtain high-accuracy ignition locations and times. We use the aforementioned smoke plume analyses pipeline to provide accurate estimates of ignition times and wind conditions around the time of ignition. We then combine these estimates with high-resolution burn scar imagery generated using Sentinel-2 data to infer high-accuracy ignition locations under certain conditions: i.e. when a smoke plume is visible, when there is consistent wind direction around ignition time, and when the imaged burn scar shape includes an apex that is located upwind. Comparing this to historical ground-truth data on fires and wildfires supplied by fire authorities suggests that our method is able to provide more accurate wildfire ignition locations, as well as independent validation of ground-truth fire extents. The high-accuracy, independently validated data on ignition locations and times generated using this technique are useful for generating high quality training data for machine learning algorithms for fire detection and quantification, or to test the accuracy of existing fire detection algorithms.

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Impact of fuel type and moisture content on emission variability

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Abstract

Increasing intensity and frequency of wildfires in Australia are impacting air quality, with emissions varying based on types of vegetation and the moisture content present in those. Accurate estimation of emission factors (EFs) is essential for better air quality modelling, yet the combined effects of fuel type and moisture content on emission variability has received limited attention. In this study, we analyzed data from controlled laboratory combustion experiments to quantify emission factors for trace gases and particulate matter from four types of vegetation: Eucalyptus leaf litter, Mallee heath, Pine needles, and Banksia. Each fuel type was tested under moisture conditions ranging from 5% to 30%, representing both wildfire and planned burn scenarios.

Emissions of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), non-methane hydrocarbons (NMHCs), formaldehyde (CH2O), and particulate matter were measured using continuous gas analyzers and filter-based techniques. Our statistical analyses showed that vegetation type was the main driver of emission variability, explaining between 20% and 59% of the variance depending on the pollutant. While overall fuel moisture explained less than 5% of the variance when all fuels were combined, important fuel-specific trends were observed for Eucalyptus, showing clear sensitivity to moisture—each 1% increase in fuel moisture led to roughly 3.3% higher CO emissions and 8.5% higher PM2.5 emissions, alongside lower CO_2 output, indicating reduced combustion efficiency. This study highlights the need to account for the complex interaction between fuel type and moisture to improve the precision of air quality modelling for Australian fire events.

Keywords:
Emission factors, fuel type, Eucalyptus, fuel moisture, particulate matter, Australian wildfires.

The new Pyrotron Emissions and Greenhouse Gas Analysis System (PEGGASys)

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Abstract

Quantifying greenhouse-gas (GHG) and particulate emissions from vegetation fires remains essential for improving inventories and atmospheric models. The Pyrotron Emissions and Greenhouse Gas Analysis System (PEGGASys) was developed within a recent pilot project to provide high-precision, synchronised measurements of combustion emissions under controlled laboratory conditions. The system integrates a stainless-steel exhaust manifold, clean-air dilution subsystem, and coordinated analyser suite (ICOS for CO_2, CO, CH_4; DustTrak II for $PM_{2.5}$), enabling co-located, high-frequency sampling of multiple species from a common airstream.

PEGGASys was applied to twenty-two burns in the CSIRO Pyrotron using eucalypt canopy branchlets, eucalypt litter, and ryegrass with two combustibility treatments achieved via fuel-moisture manipulation. Modified Combustion Efficiency (MCE = 0.93–0.98) indicated flaming-dominated combustion, with emission factors for CH_4 and $PM_{2.5}$ increasing as MCE decreased, indicating the dilution system operated correctly. Comparative results showed high-combustibility fuels yielded higher CO_2 emissions, while low-combustibility fuels produced proportionally more CO and other species. These results validate the system's sensitivity to combustion phase and fuel condition.

Integration with pre- and post-burn hyperspectral imaging creates a new dataset linking spectral change, combustion efficiency, and emission composition. This provides a pathway for scaling laboratory emissions to regional and continental models and for improving satellite product validation and carbon-budget assessments.



Fig. 8. Experimental burns at the Pyrotron.

Switching regimes in wildfire plume: Environmental implications

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Abstract

Wildfire events present a rising frequency in recent years, especially in regions dominated by elevated temperatures, dry and windy conditions (Donahue et al., 2009; Hodshire et al., 2019). During such events, the generated fire plume contains a mixture of gaseous and particulate species (Fig. 1), driving the chemical processing during the initial and aging stage. Organic aerosols comprise a large portion of the available chemical species inside a fire plume and their fate is primarily determined by two competing regimes (Dovrou et al., 2025; Garofalo et al., 2019): (1) oxidation-driven condensation and (2) dilution-driven evaporation.

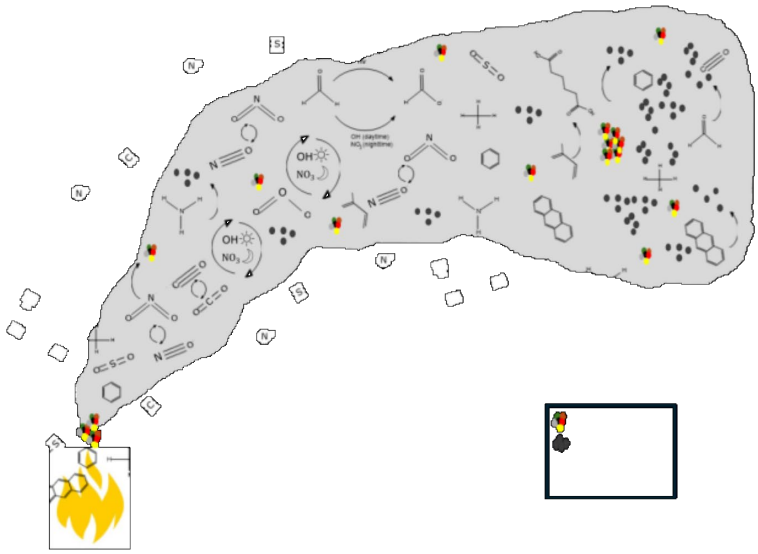


Fig. 1. Simple representation of chemical species and their interconnection in a fire plume.

In this work we evaluate the conditions of prevalence of each regime, identifying the oxidation-driven condensation as the driving mechanism in fresh plumes and the dilution-driven evaporation in aged plumes. The balance of these two regimes is associated with the black and brown carbon levels and thus the differentiation of the chemical reactions in the center and at the edges of the plume (dark vs light chemistry). Data obtained from FIREX-AQ flights (Warneke et al., 2023) are used to examine the conditions affecting and favoring each regime, considering the vegetation and meteorological profile of northwestern area in the US. The effect and differentiation between the two regimes are also investigated in regional model simulations, focusing on the Mediterranean area, and simulating two air quality scenarios. Regional models tend to be biased, depending on the supported chemical speciation and mechanisms, favoring the oxidation-driven condensation regime. Thus, targeting specific fire events will allow for in-depth analysis

and evaluation of the regional model representation of fire plume chemical evolution, with implications for better understanding the signature of wildfires on atmospheric composition and climate.

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Using CO and H_2 variability in SH background air as tracers of wildfire emissions

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Abstract

Interannual variability of carbon monoxide (CO) and hydrogen (H_2) in southern hemisphere (SH) background air has previously been linked to biomass burning (e.g. Langenfelds et al. [2002]). Large wildfire events in recent years, including the Australian Black Summer fires of 2019/20, led to significant perturbations of CO and H_2 in baseline air at Kennaook/Cape Grim (Fig. 1). CO emissions from the Australian 2019/20 event were estimated using observed anomalies in background air together with the GEOS-Chem chemical transport model.

More recent data show elevated CO in mid-late 2024 and H_2 through 2024-25. The H_2 signal is particularly unusual relative to the 15-year record in Fig. 1. It raises a question of whether H_2 emissions might be linked to its growing industrial use. A preliminary analysis of CO and H_2 responses to wildfires during 2023-24 suggests that the fires can account for much, if not all of the atmospheric signal.

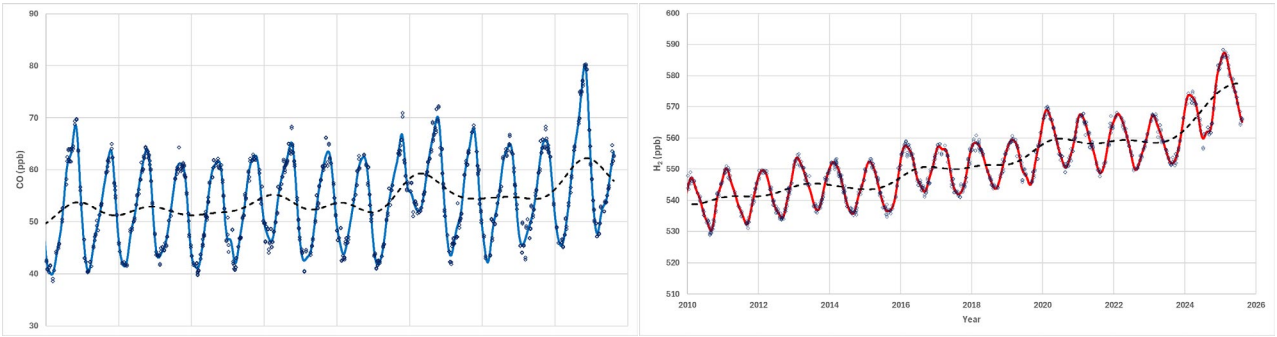


Fig. 9. CSIRO records of CO (upper panel) and H_2 (lower) at Kennaook/Cape Grim since 2010. Flask data (◊) were selected for baseline winds and data quality. Smoothed (solid) and deseasonalised trend (dashed) curves were calculated using the curve-fitting routines of Thoning et al. [1989].

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Using data-driven approaches to understand O_3 formation and the impact of wildfire emissions in Queensland

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Abstract

Knowledge on the long-term impact of wildfire emissions on urban air quality is limited in the Southern Hemisphere as compared to the Northern Hemisphere. During the downwind transportation, wildfire emissions can interact with the local urban nitrogen oxides (NOx) emissions and likely enhance the production of urban ozone (O3)(Rickly et al., 2023). Australia is one of the most wildfire-prone countries in the Southern Hemisphere(Boer et al., 2020; Knorr et al., 2017), with wildfires responsible for 7-8% of global annual biomass burning reactive carbon emissions(Guérette et al., 2018). This underscores a pressing need to evaluate the impacts of wildfire emissions on the urban O_3 concentrations.

Here, we analysed nearly 10 years of in-situ air quality data collected using two differential optical absorption spectroscopy (DOAS) instruments in parallel at two Eastern Australian sites from 2011 to 2020. The datasets of hourly time resolution contain not only three commonly measured pollutants, fine particulate matter ($PM_{2.5}$), O_3, and nitrogen dioxide (NO_2), but also formaldehyde (HCHO) and benzene, toluene, and xylene (BTX). A trajectory-fire interception method, TIFM, was used to identify wildfire periods (Schneider et al., 2021). A XGBoost (Chen and Guestrin, 2016) machine learning (ML) model was developed to assess the contribution of wildfire to local O3 formation.

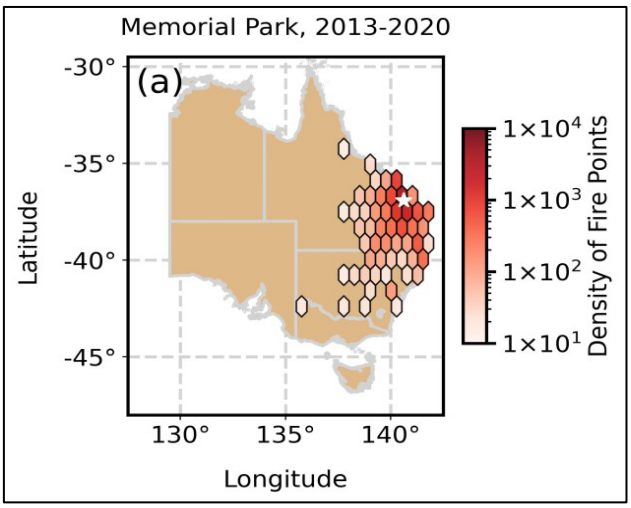


Fig. 1. Spatial density distribution of wildfire points intercepted by air mass back trajectories at Memorial Park in 2013-2020.

Notable increases in air-trajectory-fire interceptions and wildfire-affected hours were observed since 2018. Figure 1 shows an example of the spatial distribution of TFIM-identified wildfire points for Memorial Park in 2013-2020. The ML model indicates that average increases of 0.3 ppb and 1.04 ppb in net O_3 change at

Memorial Park and Springwood, respectively. We future analyse the sensitivity of net O_3 change against proxies for O_3 precursors, HCHO and NO_2. We found that net daytime O_3 change varied with the HCHO-to-NO_2 ratio, and the degrees of net daytime O_3 change to wildfire emissions differed between sites.

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Comparison of measured and modelled pollutant concentrations in aged smoke in Southeast Australia

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Abstract

Smoke from bushfires (wildfires) poses significant health hazard to first responders and the general public, while also contributing to the emissions of greenhouse gases and other pollutants. The increasing use of modern climate models to project concentrations of these species necessitates validation against point-based measurements. During the 2019-2020 Australian summer, the COALA-2020 measurement campaign in south-east NSW captured extensive data on many chemical species during the largest fire event recorded in the region, creating one of the most comprehensive smoke datasets for Australia.

This talk will discuss the comparison between simulated concentrations of key atmospheric chemical species of interest from multiple models (AQFx, CESN-MUSICA and WRF-CMAQ) and COALA-2020 point-based measurements from December 2019 to February 2020.

Models will be evaluated for their quantitative accuracy in simulating the measured concentrations of the two species. They will also be assessed based on the qualitative accuracy of predicting exceedances of health safety limits. These evaluations will utilise standard community benchmarks for atmospheric chemistry.

This research into weather models against COALA-2020 measurements for an exceptional fire event in southeast Australia will influence future work and direction on smoke simulations for key pollutants.

* COALA – Characterising Organics and Aerosols Loading over Australia
* CESM-MUSICA – Community Earth System Model - Multi-Scale Infrastructure for Chemistry Modeling
* AQFx – Air Quality Forecasting system
* WRF-CMAQ– Weather Research and Forecasting - Community Multiscale Air Quality model systemn

Changes to Air Quality at Melbourne's Station Pier

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Abstract

Port Melbourne's Station Pier is the premier cruise ship terminal in Melbourne Victoria having as many as 100 ship visits every cruise season. This presentation analyses air quality measured at Station Pier in Port Melbourne and the surrounding EPA sites. This presentation assesses the air quality impact after the introduction of low sulphur marine fuel and the relocation of Tasman ferry services both of which occurred in 2020. We compare the data measured in the 2016 and 2017 (pre-period) with the data collected between 1 December 2023 to 31 December 2024 (post-period).

The results show that the measured concentrations of PM_{10} and NO_2 are similar for the two periods with $PM_{2.5}$ concentrations slightly reduced in the post period. SO_2 shows the largest reduction in the post period showing that port activity was the largest source of SO_2. Overall, the air quality has improved around the local Port Melbourne's Station Pier area. EPA also conducted a source apportionment study between May 2021 and May 2022, 3 kms from Station Pier in the commercial Melbourne Port. The study showed shipping emission impacts were localised to area near shipping activities and not a major contributor to ground level $PM_{2.5}$ in the general area.

Composition modelling in the ACCESS suite

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Abstract

The Australian Community Climate and Earth System Simulator (ACCESS) is actually a suite of models covering different domains in the earth system. The atmospheric component of ACCESS, the Unified Model (UM), includes the United Kingdom Chemistry and Aerosol (UKCA) framework for handling various aspects of atmospheric composition, including emission, atmospheric processing, and deposition of aerosol and gas-phase constituents. With UKCA, the UM can simulate the role of atmospheric composition across a range of scales, including effects on radiation, dynamics, cloud, and precipitation.

In this presentation, the various composition-resolving configurations and capabilities within ACCESS are described, with a view to encouraging uptake and collaboration. The configurations include a global full chemistry model with optional coupled ocean, all the way to a relocatable high-resolution convection-resolving limited area model with aerosol and cloud microphysics.

With infrastructure support from ACCESS-NRI, and a recent bloom in the number and quality of measurements, there is a golden opportunity to expand high quality composition modelling activities in Australia.

A higher-order inverse modelling approach for improved source estimation, with application to a controlled methane release

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Abstract

Hourly-averaged atmospheric concentration measurements are widely used for inverse modelling of emission sources, but they capture only limited information about the variability in observed plumes. Recent advances in high-frequency, near-instantaneous in-situ sensors now provide both hourly means and measures of concentration fluctuations, offering additional information that can potentially improve source attribution. To utilise this richer dataset, we propose an inverse modelling framework that incorporates the full concentration probability distribution function (PDF) rather than relying solely on hourly means. The PDF is represented using percentiles derived from a left-shifted clipped-gamma parameterisation, requiring only three inputs: mean, variance, and intermittency (Yee and Chan 1997). The mean concentration was estimated with a Lagrangian particle-puff model and variance with an Eulerian formulation from CSIRO's The Air Pollution Model (TAPM) (Hurley et al. 2005), with intermittency expressed as a function of the first two (Yee and Chan 1997). A backward implementation of the mean and variance models was used to enhance computational efficiency.

The methodology was evaluated using methane measurements from a controlled local-scale release experiment carried out in 2011 at the Otway carbon capture and storage site in Victoria, Australia (Luhar et al. 2014). Traditional inverse modelling with only hourly mean concentrations produced reasonable source location estimates but underestimated emission rates by about 25%. In contrast, replacing means with higher-order percentiles from the full PDF recovered the true emission rate and reduced directional uncertainty, although the accuracy of source location decreased slightly. Lower-order percentiles, especially the median, degraded performance due to interference from background methane variability, highlighting that higher-order percentiles carry the strongest source signal.

The success of the approach depends on accurate predictions of both the mean and variance. While mean concentrations were reliably predicted, variance was underpredicted, partly due to the Eulerian model's sensitivity to turbulence and plume meander. This suggests that models accounting for plume meandering or using eddy-resolving simulations such as large-eddy simulation could improve performance.

Overall, this percentile-based framework demonstrates significant potential to enhance inverse source estimation by leveraging the full concentration distribution available from high-frequency measurements.

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WOMBAT v2.S: A Bayesian inversion framework for CO_2 flux attribution from multiprocess satellite data

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Abstract

Contributions from photosynthesis and other natural components of the carbon cycle present the largest uncertainties in our understanding of carbon dioxide (CO_2) sources and sinks. While the spatiotemporal distribution of Earth's net surface flux (the sum of all contributions) can be inferred from atmospheric CO_2 concentrations through flux inversion, attributing the net flux to its individual components remains challenging. The advent of solar-induced fluorescence (SIF) satellite observations provides an opportunity to separate natural components by isolating gross primary productivity (GPP), the photosynthetic component of the net flux. Here, we introduce a novel statistical flux-inversion framework that simultaneously assimilates observations of SIF and CO_2 concentration, extending WOMBAT v2.0 (WOllongong Methodology for Bayesian Assimilation of Trace-gases, version 2.0) with a hierarchical model of spatiotemporal dependence between GPP and SIF processes.

We call the new framework WOMBAT v2.S, and we apply it to SIF and CO_2 data from NASA's Orbiting Carbon Observatory-2 (OCO-2) satellite and other instruments to estimate natural fluxes over the globe during a recent six-year period. In a simulation experiment that matches OCO-2's retrieval characteristics, the inclusion of SIF improves accuracy and uncertainty quantification of component flux estimates. Comparing estimates from WOMBAT v2.S, v2.0, and the independent FLUXCOM initiative, we observe that linking GPP to SIF has little effect on net flux, as expected, but leads to stronger seasonal cycles and a shifted zonal distribution in natural flux components.

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Atmospheric Inverse Modelling of CO_2 Fluxes in New Zealand at National and Urban Scales

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Abstract

Accurate estimates of anthropogenic and biospheric carbon dioxide (CO_2) fluxes are essential for verifying greenhouse gas emissions reduction strategies and informing effective climate policy. Atmospheric inversion models combine atmospheric mole fraction observations and an atmospheric transport model to derive the spatiotemporal distribution of surface fluxes.

Here we describe the development of two inversion systems in New Zealand for estimating CO_2 fluxes; a national-scale system and a high-resolution urban-scale system for Auckland. Both systems make use of high-resolution transport modelling, specially developed bottom-up prior flux estimates, and dedicated observing networks.

The national-scale system assimilates observations from a five-site in situ network, together with XCO_2 observations from the Orbiting Carbon Observatory (OCO-2 and OCO-3) satellites. The urban-scale system for Auckland assimilates observations from a newly established four-site in situ network. Initial synthetic data experiments demonstrate the potential of both systems to constrain CO_2 fluxes across scales.

Future work will focus on improving flux partitioning between anthropogenic and biospheric components by jointly assimilating additional tracers (CO, COS, $^{14}CO_2$), and improved error characterisation. Together, these systems provide a foundation for policy-relevant quantification of CO_2 fluxes in New Zealand.

Short-lived refrigerants, long-term impacts: quantifying budgets of the HFO-1234ze degradation cascade

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Abstract

Fourth-generation refrigerants (HFOs) are rapidly replacing HFCs following the Kigali Amendment to the Montreal Protocol. However, their atmospheric degradation may produce long-lived greenhouse gases and persistent environmental contaminants that could undermine their intended benefits. 1,2 This study uses the GEOS-Chem 3-D transport model to quantify the formation of HFC-23 (GWP100 = 14,600) from HFO-1234ze degradation through its primary intermediate, trifluoroacetaldehyde (CF3CHO).

We implemented comprehensive HFO-1234ze chemistry in GEOS-Chem, including pressure-dependent quantum yields for CF_3CHO photolysis. Using sensitivity tests with Henry's Law constants (K*H) spanning 10-10^6 M atm^{-1}, we evaluated how depositional loss affects CF_3CHO fate. Based on these tests, we conducted a year-long simulation using K*H = 10^5 M atm^{-1} and an observationally constrained global emissions inventory to quantify HFC-23 production and atmospheric distributions.

We calculate an HFC-23 molar yield from CF_3CHO and compare with recent experimental measurements.1,4 This results in an indirect GWP_{100} for HFO-1234ze that we compare to direct radiative forcing values and regulatory thresholds. Our simulations indicate that deposition accounts for a large proportion of CF3CHO loss, potentially yielding significant quantities of trifluoroacetic acid (TFA). While HFO-1234ze's contribution to HFC-23 burden appears minimal, TFA formation from deposited CF_3CHO represents an unquantified environmental concern. As HFO usage increases globally, accurate quantification of their indirect impacts becomes increasingly important for comprehensive assessments.

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The problem with water and the benefits of friends - Using comparisons between co-located GHG instrumentation to identify and rectify sources of error.

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Abstract

Long term records of GHG (greenhouse gases) and related tracers are powerful tools for tracking and understanding global and local GHG sources and sinks. However, it is essential that patterns in these datasets are driven by changes in GHG fluxes rather than instrumental or calibration driven biases and errors. Here we outline efforts to identify and remove such issues from the Kennaook/Cape Grim CRDS (cavity-ringdown spectroscopy) N_2O and GC-RGA (gas chromatography reduction gas analyser) CO records. Key to this are comparisons between these and co-located in situ and flask measurements. In situ measurements used in our comparisons include, for N_2O FTIR (Fourier transform infrared spectroscopy) & GC-ECD (gas chromatography electron capture detector) and for CO CRDS, while flask measurements of CO and N_2O made by both CSIRO and NOAA are also used.

A poorly characterised water correction on the N_2O CRDS analyser was identified as the key driver of systematic discrepancies between N_2O records. A series of experiments was conducted to better quantify the instrument specific water response. Preliminary comparisons using these results show a reduction in average CRDS-FTIR differences from -0.2 ppb to 0.0 ppb N_2O for the period 2023 to 2025 (Fig. 1). Similar improvements in CRDS less GC-ECD mean bias, from -0.4 ppb to -0.2 ppb for 2018-2023, and CRDS less CSIRO flask biases, from -0.3 ppb to 0.0 pbb N_2O for 2022-2025 were also noted. It is also important to note that the GC-ECD data are linked to the SIO-16 scale, while other CGO N_2O data sets (CRDS, FTIR and flask) are anchored to the NOAA-2006A scale. The NOAA-2006A N_2O scale is typically lower than SIO-16, with an average difference over the past two years of 0.4 ppb, this offset will affect any comparisons.

Co-located measurements of CO have been made at Kennaook/Cape Grim using in situ GC-RGA and GASLAB analysed glass flasks since 1993. Previous efforts to characterise and adjust for the GC-RGA non-linearity improved the agreement between flask and in situ records for the 2006-2025 period, reducing it from ~2 ppb to ~0.5 ppb [CO]. Here we will focus on the on-going re-evaluation of the earlier record (1993-2006). This will include the use of updated non-linearity fitting and drift correction functionalities alongside the limitations of working with historic datasets.

Total column measurements of greenhouse gases at Kennaook Cape Grim

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Abstract

Measurements of the total column of greenhouse gases from the surface to the top of the atmosphere can be made by solar Fourier Transform Infrared Spectroscopy (Solar-FTS) in clear sun conditions. They provide a valuable complementary product to in situ measurements at the surface by vertically integrating over the whole atmospheric column – they are less influenced by local sources and sinks in the boundary layer, represent a larger spatial footprint, and are commonly used to validate top-down satellite total column measurements such as from OCO-2, OCO-3, GOSAT and TROPOMI. Globally, there have been very few such ground based total column measurements made at baseline clean air sites that also have GAW-compatible continuous in situ measurements. We aim to explore and learn from modelling of the surface-total column comparisons in future work.

From October 2024 to October 2025 we ran a 1-year pilot study of solar FTS measurements at KCG with a low (0.5 cm^{-1}) resolution FTS setup developed at UoW and similar to those used in the COCCON network. Unlike COCCON instruments, which must be located outdoors and would be difficult to implement at Cape Grim, the FTS is located indoors in the chemistry lab and coupled to a weatherproof solar tracker on the roof platform via a 20m quartz optical fibre. Despite the well known cloudiness at Cape Grim, we obtained over 125,000 valid 1-minute measurements over the year, on average over 2400 per week with very few weeks with no data.

In this talk we present the full year of total column measurements of CO_2, CH_4 and CO at Cape Grim and compare them to the in situ records and from coincident satellite overpasses.

An update from the Kennaook-Cape Grim Reactive Gases Program

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Abstract

The Kennaook-Cape Grim (KCG) tropospheric ozone record extends over 40+ years and is the longest record of its kind in the Southern Hemisphere mid-latitudes. Here we will present an update with the 2024 data recently been added to the record from 1982 onwards in the World-Data Centre for Reactive Gases. The 1982 – 2020 data KCG data was also included in the recent TOAR II ozone over the global oceans and polar regions datasets along with data from 15 RV Investigator voyages (2017 – 2019) (Kanaya et al 2025). We will also present a first look at the intercomparison between KCG and RVI ozone data collected during the recent COAST-k voyage when the RVI was offshore from KCG.

Measurements of oxides of nitrogen (NOx) have been collected almost continuously at KCG for over 15 years. Significant improvements have been made in instrument developments, QA/QC methods and data analysis approaches. However, quantification of NOx in baseline conditions remain an analytical challenge, particularly in relation to determination of offsets and calibration uncertainty. Here we report on recent efforts towards development of the NO calibration methodology for GAW traceability and the resulting KCG NO calibration history (Galbally et al, Baseline 2014-16), and approaches to reducing limits of quantification.

The annual cycles of several GAW target VOCs including acetaldehyde, acetone, isoprene, benzene and DMS will be presented for the first time from a KCG pilot study of the application of proton-transfer-reaction mass spectrometry at KCG running since 2023. It has been over 25 years since the coherence between marine DMS, its aerosol oxidation products, and cloud processes was empirically demonstrated for the Southern Ocean atmosphere via in situ data collected at Kennaook-Cape Grim (KCG) (Ayers & Gillet et al 2000 and references within). Given the renewed focus on Southern Ocean aerosol cloud interactions in the context of the 2024/25 Cape-k campaign, here we will particularly focus on seasonality of DMS and its cousin methanethiol (Mynard et al 2025).

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Extending the Kennaook/ Cape Grim record of N_2O stable isotopes 1978-2025

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Abstract

New measurements of the Kennaook/ Cape Grim air archive and Cape Schanck archive extend the record of N_2O stable isotope data ($\delta^{15}N$-N_2O and $\delta^{18}O$-N_2O) from 2005 to 2023. Additional subsamples were measured to fill in resolution and gaps in the existing record before 2005. A small number of firn air samples were re-measured to verify long-term trends back to 1940, and South Pole flask samples were measured to extend the record to 2025. Subsamples of the Kennaook/ Cape Grim air archive were also measured at EMPA for inter-laboratory comparison.

N_2O concentration increased by 19 ppb during the period 2005-2025. The increase was accompanied by a 1.0 ‰ decrease in $\delta^{15}N$-N_2O, a continuation of the trend identified since the 1940's attributed to widespread use of synthetic agricultural fertilizers. N_2O concentration and $\delta^{15}N$-N_2O trends are well-replicated back to 1978 in the recent measurements, but the trend previously resolved in $\delta^{18}O$-N_2O was not. Prior work showed $\delta^{15}N$-N_2O and $\delta^{18}O$-N_2O varied on seasonal timescales in a manner that was anti-correlated to seasonal N_2O concentration fluctuations, possibly consistent with seasonal mixing of stratospheric air into the troposphere. With the addition of the new data, the seasonal signal is no longer significant in $\delta^{15}N$-N_2O or $\delta^{18}O$-N_2O. Simple box modelling suggests if stratospheric-tropospheric exchange was wholly responsible for the N_2O seasonality, the influence on $\delta^{15}N$-N_2O would be ~ 0.02 ‰ peak to trough, which is smaller than our measurement precision (~ 0.05 ‰). We assess whether interannual variability in N_2O growth rate is correlated to variations in CFC-11 and CFC-12, which also have a stratospheric sink.

Atmospheric mercury (Hg^0) in Kennaook/Cape Grim (KCG): Insight into concentration, variations and source attribution

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Abstract

Long-term measurement of background conditions of any trace gases is critical to understand how the natural and anthropogenic effects on the mean state of the global or hemispheric environment, and to evaluate the efficiency of current mitigation strategies. Few high temporal resolution measurements of atmospheric Hg^0 are not sufficient in understanding mercury biogeochemistry. Therefore, this study provides insight into the concentration, seasonal variability, and source attribution of Hg^0 at an ocean-influenced southern hemisphere mid-latitude site (KCG).

The 2017-2022 mean Hg^0 concentration at KCG was 1.05 ± 0.05 ng m^{-3}, higher than the concentration previously reported in 2015 (Slemr et al., 2015) and more consistent with other estimates of the Southern Hemisphere background (Sprovieri et al., 2010). The trend over this period was constant or slightly increasing at 0.01 ng m^{-3} y^{-1} ($p < 0.1$). We observed weak to negligible seasonality in Hg^0 at KCG, likely attributable to the background marine influence, with generally mild conditions and relatively consistent air masses influenced by the marine boundary layer. The air masses from South/Southwest with increase wind speed enhanced atmospheric Hg^0, indicating that Southern Ocean is a major source of atmospheric Hg^0.

We use radon in the range 30-50 mBq m^{-3} to identify oceanic contributions to air masses. However, this range does not exclusively represent atmospheric Hg^0 as both high Hg^0 and low-Hg^0 regimes can still occur, which are influenced from long-range transport and vertical mixing (air-sea exchange process). The mid-range provides a better representation of atmospheric Hg^0 influenced from Oceanic sources. We applied a Generalised additive model (GAM), which can explain 37% of atmospheric Hg^0 variability with day of year (DOY) and temperature becoming the dominant factors influencing atmospheric Hg^0 from Oceanic sources.

Our results suggest that further mechanistic and modelling studies combined with additional observational variables such as ozone, sea surface temperature, and chlorophyll are needed to explain variability in ocean-influenced Hg^0 concentration and improve global estimates of air-sea exchange.

First observational evidence of changes in atmospheric hydroxyl concentration in the Southern Hemisphere over the Anthropocene

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Abstract

The lifetime of methane and many other trace gases in the atmosphere and hence their climate impact is determined by hydroxyl, OH, the main tropospheric oxidant. Changes in OH concentration in response to large changes in reactive trace gas emissions are uncertain. Measurements of 14C-containing carbon monoxide (14CO) and other tracers such as methyl chloroform over the last ~30 years have been successfully used to infer changes in average OH, but there are no observational constraints on OH further back in time. Air occluded in polar ice can potentially provide a 14CO record if the snow accumulation rate is sufficiently high to limit in-situ production of 14CO in the ice by cosmic rays. Further, the 14CO measurement requires much larger sample size than conventional ice coring can provide.

In 2018-19, a joint Australian-US team sampled and measured air extracted from firn and ice at the east side of Law Dome, Antarctica where the accumulation rate is 1.3 m a-1 ice equivalent, many times the Antarctic average. Air was extracted on-site from combined ice samples using a large-volume melting system. 14CO analyses in these air samples have been corrected for in-situ 14CO production and validated against direct atmospheric measurements for the more recent samples to produce a finalized atmospheric 14CO history.

The 14CO reconstruction shows stable values from 1866 to 1997 and subsequently a smoothed variation driven by changing atmospheric production in the better age-resolved firn samples. The 14CO history is interpreted with the aid of the GEOS-Chem chemical transport model, which indicates that time-averaged 14CO at Law Dome is sensitive to hemispheric-scale OH concentration. The long-term Southern Hemisphere OH change over the anthropogenic era inferred from our 14CO record is similarly small, indicating that OH has been stable despite large changes in the emissions of reactive species.

Long-term Trends and Variability in the Wollongong NDACC record

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Abstract

The NDACC network provides observations of a number of chemical and physical parameters of the atmosphere at sites around the globe. This includes remote sensing of trace gas total columns and profiles from Fourier-Transform Infrared Spectroscopy, with ground-based FTIR sites observing chemical changes with high temporal resolution and validating satellite observations. The record of retrieved atmospheric profiles of 12 trace gases from the Wollongong NDACC FTIR site extends from 1996 to 2025 for some species, allowing long-term trends and significant events to be observed. The trends and seasonal variations of the 12 species in the NDACC public archive were examined, as well as year-to-year variability and the correlations between species such as those produced from biomass burning.

The information from the retrievals is limited by the noise in the recorded spectra, information on the temperature profile and forward model errors. The limits this imposes on the determination of both partial and total column values for each gas were considered, as well as the effect of assumptions such as the estimates used for the a priori profiles.

The long-term trend and seasonality of the retrieved total columns, as well as selected tropospheric and stratospheric partial columns where possible, are compared to results from previous studies in the Southern Hemisphere, and in the case of some gases such as methane, to well-known global trends with generally good agreement.

The impact of climate drivers on trace gases at Southern Hemisphere TCCON sites

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Abstract

Greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) continue to increase in concentration in the earth's atmosphere, which has led to increasing global temperatures, an increase in the severity of weather events and the global warming of oceans (IPCC, 2023). The increase in greenhouse gases is largely attributed to anthropogenic sources, however natural sources also contribute to the variability of trace gases in the atmosphere (Yue et al. 2018). Sustained wet or dry periods influence natural sources of trace gases such as the extent of wetlands and the likelihood and severity of bushfires, impacting emissions of CH_4, nitrous oxide (N_2O) and carbon monoxide (CO) (Cao et al. 2024, Cunningham et al. 2024).

The Southern Hemisphere is impacted by multiple climate drivers such as the El Nino Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and the Southern Annular Mode (SAM), which influence the climate and drive weather patterns. This talk discusses the influence of Southern Hemisphere climate drivers on trace gases observed from the 4Total Carbon Column Observing Network (TCCON) sites in the Southern Hemisphere.

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GWP*: What and Why?

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Abstract

The large contributions of CO2 (carbon dioxide) and CH4 (methane) mean that reductions in emissions of each of them will be needed in order to prevent increasingly large changes in climate. In this context, it is desirable to have a way of comparing the relative importance of such reductions.

There is a long history of noting that GWP (Global Warming Potential) is a poor way of comparing greenhouse gases, particularly when aiming for stabilisation targets and particularly when trying to define a CO_2-equivalents for short-lived atmospheric constituents, (e.g. Wigley 1998). While there have been suggestions that emissions of short-lived and long-lived constituents should be reported separately It would still be valuable to have a way of comparing the climatic effect of all emissions.

Wigley (1998) proposed an equivalence relation FEI (Forcing Equivalent Index) based on radiative forcing. The relation for two constituents is

$$a_1 \int_0^t S_1(t') R_1(t-t')\, dt' = a_2 \int_0^t S_2(t') R_2(t-t')\ dt' \qquad (1)$$

where a_1, a_2 are the radiative forcing per unit mass of pollutants 1 and 2, and $R_1(t), R_2(t)$ are the respective impulse response functions, i.e. the proportion of a release that remains in the atmosphere after time t. This is an equivalence of the whole time-histories of the two pollutants, or more specifically small perturbations in emissions since for some constituents (especially CO_2 and CH_4) the amount of forcing depends non-linearly on the concentration. At first glance the FEI relation (1) appears too complicated to be used as an equivalence metric. Much of this complication disappears if FEI is unpacked, as done, for example by Allen et al (2016).

Expressing the FEI relation for CO_2 and CH_4 in terms of concentration changes due to small changes in emissions gives:

$$a_{CH4} \times \mathrm{CH_4MODEL}[S_{CH4}] = a_{CO2} \times \mathrm{CO_2MODEL}[S_{CO2}\mathrm{eq}] \qquad (2)$$

implies that the source relation is

$$S_{CO2}\mathrm{eq}(t) = (a_{CH4}/a_{CO2}) \times \mathrm{INVERSE\text{-}CO_2\text{-}MODEL}[\mathrm{CH_4\text{-}MODEL}[S_{CH4}] \qquad (3)$$

Inverse modelling of the carbon cycle is something that has been undertaken extensively over many years, particularly in the interpretation of CO_2 concentrations measured in ice cores. Particularly relevant are the inversions based on simple parameterisations of the inverse CO_2 model (Trudinger 2000). Further discussion of simple parameterisation of forward and inverse CO2 models is given by Enting (2022).

Simple versions of a metric, derived more directly, have suggested defining CO_2-equivalence in terms of rates of change of sources of short-lived constituents (eg Smith et al, 2102, Lauder et al, 2013). Mathematically, this reflects the fact that the CO_2 inversion is dominated by the derivative (Enting and Mansbridge, 1987).

Cain et al (2019) proposed a metric of the form:

$$S_{CO2}eq(t) = G_{100} [4\ S_{CH4}(t) - 3.75\ S_{CH4}(_t\text{-}20)] \quad (4)$$

where G_{100} is the 100 year GWP for CH_4.

This represents a compromise between inability to calculate an `instantaneous' rate of change and the concern (Allen et al 2018) that full FEI equivalence would, in principle, depend on the full history of CH_4 emissions. Enting and Clisby (2021) analysed the Cain et al metric (4) in terms of timescale dependence (i.e. the Laplace transform) and showed that it gave results very close to idealised FEI.

Smith et al (2021) revisited relation (4), in terms of radiative forcing, bring their approach closer to the FEI analysis described above, in contrast to earlier work largely based on climate model runs, and gave a slightly modified form of (4), applicable to any constituent x as

$$S_{CO2}eq(t) = G_{100}[4.53\ S_x(t)\text{-}4.25\ S_x(t\text{-}20)] \quad (5)$$

where G_{100} is now the 100 year GWP for constituent x.

The GWP* concept has encountered a degree of resistance (ref???). Some of this appears to be based on misunderstandings. Hopefully, a simple direct description will facilitate he more accurate comparison between CO_2, CH_4 and other short-lived constituents.

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The 2025 Antarctic ozone hole

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Abstract

This presentation will give an overview of the development and recovery of the 2025 Antarctic ozone hole using several ozone hole metrics based on satellite total column ozone data. The stratospheric meteorological conditions will also be shown as these are one of the main drivers of year-to-year variability in the size and depth of the ozone hole. The 2025 ozone hole metrics will be compared to the historical metrics from the last 46 years of satellite measurement.

The historical ozone hole metrics will in turn be compared with Equivalent Effective Stratospheric Chlorine (EESC) as a simple measure to look at ozone hole recovery. The EESC data are based entirely on Kennaook/Cape Grim Air Archive, Antarctic firn and Advanced Global Atmospheric Gases Experiment (AGAGE) global measurements of ozone depleting substances (ODSs). EESC is a metric used to quantify the total chlorine and bromine loading in the stratosphere that is available to destroy ozone. Thanks to the Montreal Protocol on Substances that Deplete the Ozone Layer, EESC has fallen approximately 13% since peaking around the year 2002. However, due to the long atmospheric lifetimes of many of the ODSs, their levels are not expected to recover to pre-1980 levels until the late 2080s in the Antarctic stratosphere.

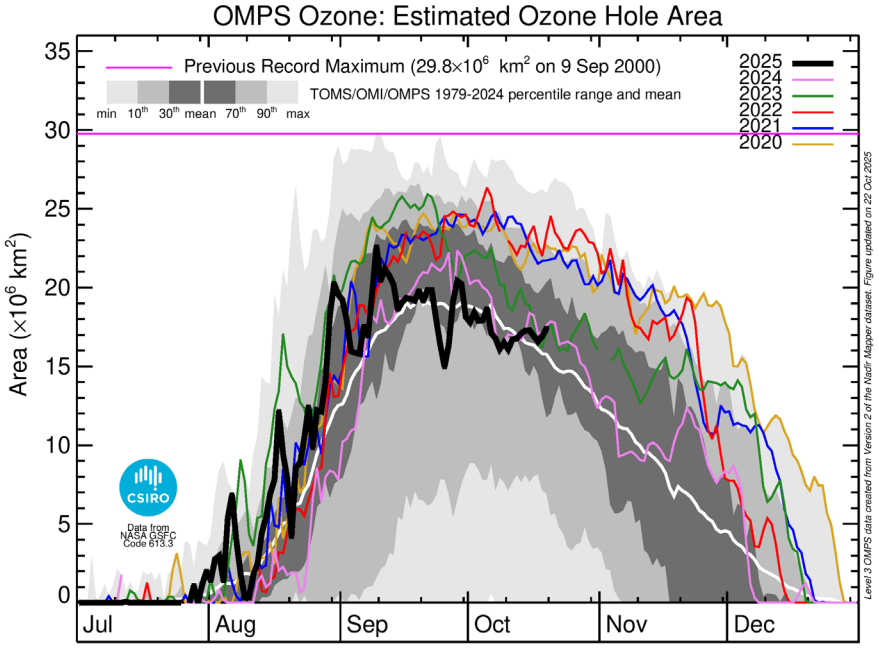


Fig. 10. Daily Antarctic ozone hole area based on OMPS data as of 19 October 2025, along with the daily ozone hole area from the past 5-years.

Characterization of the Physical, Optical, and Chemical Properties of Wildfire Aerosols: A Case Study of the 2023 Hongseong Wildfire in South Korea

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Abstract

This study characterized the aerosol changes during the April 2023 Hongseong wildfire in Chungcheongnam-do, Korea, using physical, optical, and chemical data from the Anmyeon-do Global Atmosphere Watch station. The observation period was divided into three distinct phase: immediately after the wildfire (Period I), during precipitation (Period II), and the re-entry of wildfire smoke after precipitation (Period III).

During Periods I and III, the PM_{10} mass concentrations were 75.7±31.2 and 98.2±55.6 μg/m^3, respectively, which were approximately 2.4 and 3.1 times higher than the 2023 annual average (31.8 μg/m^3) at the Anmyeon-do site. Aerosol scattering coefficients increased by factors of 4.0 and 6.9, and absorption coefficients by 5.5 and 4.2, respectively.

Analysis of PM_{10} and $PM_{2.5}$ filter samples showed biomass burning markers, such as K^+ and $C_2O_4^{2-}$, increased by 5.5-31.4 times compared with those in Period II. Elevated levels of combustion-related elements, including S, K, V, and Pb, further confirmed the influence of wildfire smoke on air quality during the affected periods.

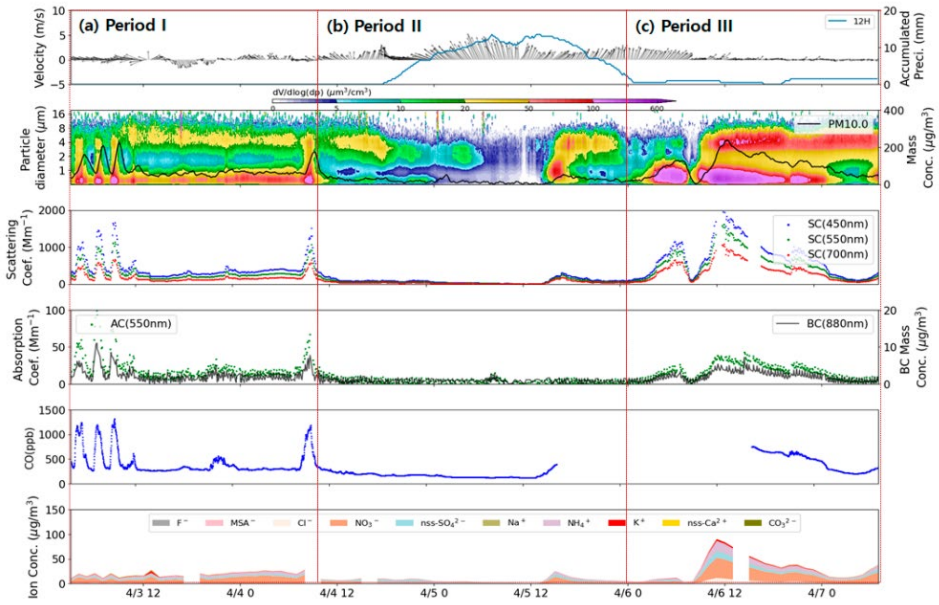


Fig. 11. Hourly variations in atmospheric parameters at the Anmyeon-do GAW station from 3 to 7 April 2023.

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What is that particle and whose particle is it? Advancing single-particle characterisation of atmospheric PM

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Abstract

Accurately determining the composition and sources of airborne particulate matter (PM) remains one of the central challenges in atmospheric chemistry. Last year, we introduced the concept of a multi-modal analytical framework combining optical photothermal infrared spectroscopy (O-PTIR), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), and synchrotron-based microspectroscopy to advance single-particle chemical speciation. This year, we report substantial progress toward a reproducible, scalable methodology for cross-modal particle identification and source attribution.

We have implemented coordinated measurement workflows across O-PTIR, SEM-EDS, and synchrotron IRM/XFM platforms, enabling integration of vibrational and elemental fingerprints from individual particles <10 µm. Using reference materials and field samples from industrial, coastal, and agricultural environments, we demonstrate improved discrimination between organic and inorganic particle types and the identification of compositional markers linked to specific emission sources (e.g., feed-derived organics in poultry dust, combustion soot in urban and industrial zones). Preliminary Surface-Enhanced Raman Spectroscopy (SERS) results also show promise for extending detection limits in mixed matrices.

Synchrotron datasets are now being used to validate low-cost filter substrates and moderate-cost laboratory techniques, establishing defensible correlations between high-resolution elemental and vibrational fingerprints. Current work focuses on feature selection and probabilistic classification using Bayesian inference, paving the way for a legally robust, high-resolution framework to support regulatory air-quality management and climate-relevant aerosol research.

Investigating $PM_{2.5}$ Toxicity: The Initial Comprehensive OP Study in Australia Utilising Various Acellular Assays

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Abstract

The oxidative potential (OP) of $PM_{2.5}$, an indicator of its cellular harm, is now considered more relevant for establishing health impacts of PM exposure than mass concentration alone. Research indicates that OP varies with source contributions and chemical composition, emphasising the need for detailed site-specific characterisation (Xing et al. 2023). Extensive studies on $PM_{2.5}$ OP have been conducted in the Northern Hemisphere, particularly in Asia, Europe, and North America, i.e. (Calas et al. 2018). However, there is a notable research gap in the Southern Hemisphere, especially in Australia, with its distinct emission sources, meteorological conditions, and seasonal patterns in its urban environments. This study addresses this gap by investigating $PM_{2.5}$ OP in an Australian urban setting using three acellular assays. It provides essential insights for air quality management and public health in the Southern Hemisphere by analysing $PM_{2.5}$ metals and organic components and comparing them to oxidative potential, temporal and seasonal variations. In the present study, sampling was conducted from May 2021 to May 2022 at two metropolitan sites around 2 km apart. The study found that all three OP measurements were not strongly correlated with $PM_{2.5}$ mass concentration.

Our analysis showed a complimentary nature of all three OP assays, each providing unique insights into PM2.5 toxicity. The DTT assay showed the highest variation in oxidative potential (OP) values among PM2.5 samples at both sites. DTT readings had a higher amplitude than AA and DCFH assays, suggesting that DTT may be more sensitive to oxidising agents that change over time or that PM components interacting with DTT have larger temporal fluctuation at these sites. While the AA assay was likewise variable, the DCFH assay is the least variable across all samples at both monitoring locations. Seasonal analysis demonstrated clear patterns, with DTT activity reaching its peak during the winter months due to an increase in residential wood heating and AA exhibiting maximum responses in autumn as the peak time for hazard reduction burns of the year, whereas DCFH exhibited no seasonal pattern. The analysis of transition metals demonstrated notable correlations with OP measurements, especially for Fe and Cu, with these relationships exhibiting variability across different seasons and locations. Significant correlations were observed between OP values and carbonaceous species across all assays (r = 0.52-0.77). These relationships are particularly noteworthy as black carbon (BC) and organic carbon (OC) constitute on average 60% of $PM_{2.5}$ in the studied regions.

The findings will enhance our understanding of the influence of various emission sources and weather conditions on the oxidative potential of $PM_{2.5}$, thereby aiding the development of more effective air quality control strategies in the Australian urban environment.

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Ten-year trend of NH_3 and its impact on secondary inorganic aerosols and PM2.5 in Newcastle, Australia

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Abstract

Ammonia (NH_3) is a key precursor of secondary inorganic aerosols (SIAs) such as ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO3), which form an important component of fine particulate matter ($PM_{2.5}$). Understanding its long-term variation and atmospheric effects is essential for improving air quality management. This study investigates the ten-year (2015–2024) trend of NH_3 concentrations in Newcastle, Australia, and quantifies its impact on SIA formation and $PM_{2.5}$ levels. By integrating continuous ground-based measurements with meteorological and emission data, we explore the seasonal and interannual dynamics of NH_3 and examine its interactions with temperature, relative humidity, and gaseous precursors (NO_x and SO_2). Machine Learning (ML) results demonstrate that NH_3 concentrations substantially contribute to the formation of ammonium aerosols, intensifying $PM_{2.5}$ pollution under stagnant and high-temperature conditions. These findings emphasize the growing importance of NH_3 in regulating urban and regional particulate pollution and underscore the need to incorporate ammonia emission control into air quality management frameworks. The study provides new insights into the atmospheric chemistry of NH_3 and its implications for achieving sustainable air quality improvement in industrial coastal cities like Newcastle.