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Atmospheric Composition & Chemistry Observations & Modelling Conference

incorporating the

Kennaook/Cape Grim Annual Science Meeting

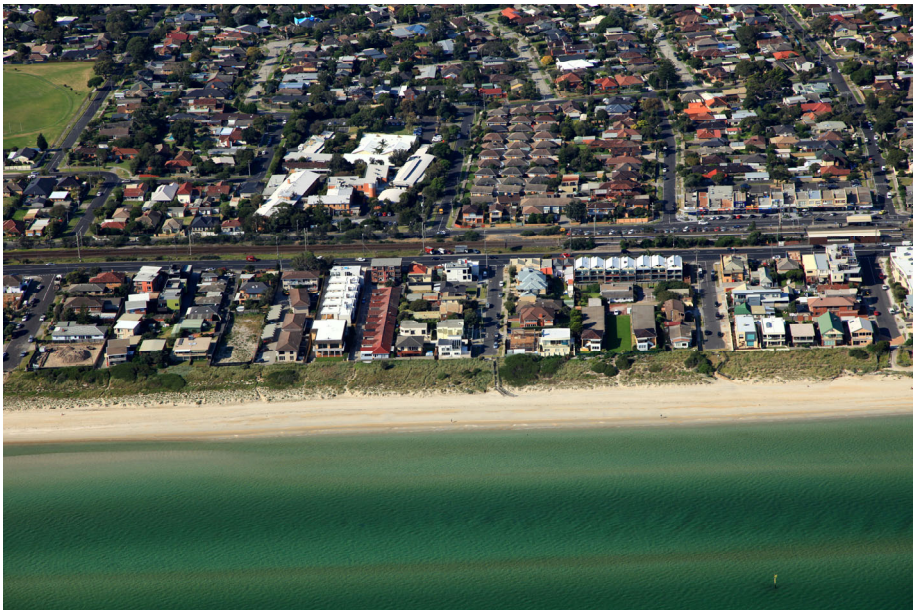
Abstracts

12–14 November 2024

hosted by

CSIRO Environment, Climate, Atmosphere and Ocean Interactions (CAOI),
Aspendale, Victoria, Australia

Priestley Lecture Theatre
Aspendale, Victoria, Australia / Virtual Meeting



Edited by: N. Derek and P. B. Krummel

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Day 1: Tuesday, 12 November 2024; 09:00–17:00

09:00	**Paul Krummel**	**Introduction**
09:05	**Sally Taylor**	**Acknowledgement of Country**

To access all documentation: click here

09:10	**Paul Krummel**	**General information on arrangements (housekeeping)**
Chair	**Kathryn Emmerson**	**Session 1 – Oral Presentations**
09:15	Melita Keywood	Aerosol chemical composition and vaporisers
09:30	Cherie Tollemache	Atmospheric particulate matter: the importance of chemical speciation and spectroscopic methods for solving this measurement challenge (20 min talk)
09:50	Jakob Pernov	Increased aerosol concentrations in the High Arctic attributable to changing atmospheric transport patterns
10:05	Erin Boedicker	Investigation into the decrease in single scattering albedo in the central United States and south-central Canada
10:20	Bruce Forgan	Progress towards an absolute terrestrial irradiance radiometer
10:35	Roger Marchand	The Cloud And Precipitation Experiment at Kennaook (CAPE-k) – an update 7 months in
10:45	Clare Murphy (Paton-Walsh) (O)	Introducing the CAPE-k Student Workshop
10:50	**Morning tea**	**Aspendale canteen**
Chair	**Ruhi Humphries**	**Session 2 – Oral Presentations**
11:15	Joel Alroe	Pursuing ocean-atmosphere links in the Southern Ocean: A 2024 MISO voyage overview
11:30	Branka Miljevic	High latitudes, high methanesulfonic acid (MSA): Tracking DMS oxidation products over the Southern Ocean
11:45	Caleb Mynard	Methanethiol is a significant contributor to volatile organosulfur concentrations over the Southern Ocean
12:00	Tahereh Alinejadtabrizi	Contributions of the synoptic meteorology to the seasonal CCN cycle over the Southern Ocean
12:15	Litai Kang	Understanding biases in E3SMv2 simulated cloud droplet number and aerosol concentrations over the Southern Ocean
12:30	Salvatore Sodano	Environmental drivers and properties of Southern Ocean aerosol and cloud formation
12:45	**Lunch**	**Aspendale canteen**
Chair	**Emily Franklin**	**Session 3 – Oral Presentations**
14:00	Ashok Luhar	Global nitrate aerosol, its impact on tropospheric composition and production from lightning
14:15	Ian Galbally	Offsets and inlet transformations in NO and NO_2 measurements at Kennaook/Cape Grim 2000–2023
14:30	Lisa Emberson	Review of vegetation assessment activities within TOAR II
14:45	Stephen MacFarlane	Impacts of aromatic peroxy radical chemistry on atmospheric ozone
15:00	Zijun Li (O)	Unravelling secondary organic aerosol formation from isoprene and toluene mixture
15:15	Cameron McNaughton	Aerial deposition of metals and polycyclic aromatic compounds in the Athabasca oilsands region
15:30	**Afternoon tea**	**Aspendale canteen**
Chair	**Dave Griffith**	**Session 4 – Oral Presentations**
16:00	Deepa Roy (O)	Simulation of monsoon low pressure system and its associated rainfall over Bangladesh using WRF Model
16:15	Esmaeel Eftekharian	CFD simulation of atmospheric wind interaction with CO_2 direct air capture
16:30	Luke Burgess	Development of hydrogen-based assessments of SSP scenarios
16:45	Akinyinka Akinnusotu (O)	Assessment of some organochlorine pesticides (OCPs) in the road dust from a metropolitan city in Nigeria: Akure as a case study
17:00	**End Day 1**	

Day 2: Wednesday, 13 November 2024; 09:00–18:30

	Paul Krummel	**Daily welcome includes acknowledgement of traditional owners**
Chair	**Luba Volkova**	**Session 5 – Oral Presentations**
09:00	Rosemary Fedele	Long range transport of $PM_{2.5}$ sources in metropolitan Melbourne
09:15	Steven Utembe	Analysis of wood heater emissions impacts in Victoria using EPA PM2.5 sensor network
09:30	Fabienne Reisen	Evaluating AQFx model accuracy: Insights from the Duck Creek fire case study
09:45	Kathryn Emmerson	Meteorological drivers of air quality in 2050: ventilation, washout and natural emissions
10:00	Emily Franklin	Effects of mechanical ventilation and Germicidal UV air disinfection devices on indoor air quality in an unoccupied setting
10:15	Svetlana Stevanovic	Pollen-humidity interactions and sub-pollen particles from native Australian species
10:30	**Morning tea**	**Aspendale canteen**
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11:00	Bakhat Rawat	Atmospheric mercury monitoring at Kennaook/Cape Grim (KCG): Insight into concentration, variability and source identification
11:15	Jennfer Powell	Atmospheric mercury in the Southern Ocean and Antarctic coast marine boundary layer during the 2024 MISO Voyage
11:30	Paul Krummel	The 2024 Antarctic ozone hole
11:45	Matt Tully	Antarctic ozone depletion measured by Davis ozonesondes 2003–2024
12:00	Poster authors	Brief poster introductions!
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Alan Griffiths		Progress towards a compact radon–222 detector for baseline air
Ruhi Humphries		Characterisation of aerosol losses of air sampling inlets from RV *Investigator* and RSV *Nuyina*
Clare Murphy		Smoke composition and toxicity: an Australian case study
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14:00	Lisa Emberson	A modelling framework to assess the future prospects for Australia's agricultural methane emissions
14:15	Chris Caldow/Zoe Loh	National to facility scale fugitive methane emissions estimation – an atmospheric science approach
14:30	Jhonathan Ramirez-Gamboa	Melbourne urban methane observation network: Expansion and current capabilities
14:45	Nasimeh Shahrokhi	Quantifying methane emissions in Melbourne, Australia: Prior estimates and urban-scale inversions
15:00	Ida Jandl	Quantification of methane emissions in the NSW coal mining region using TROPOMI data and atmospheric inversion
15:15	Hasan Nawaz (O)	Major sources of methane in Australia inferred from remote sensing observations
15:30	**Afternoon tea**	**Aspendale canteen**
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16:00	Peter Rayner	the Openmethane Platform: Status and Plans
16:15	Paul Fraser	Australian sulfur hexafluoride emissions
16:30	Cathy Trudinger	Australian emissions of perfluorocarbons
16:45	Beth Killen	Towards an accurate global model of HFO-1234ze degradation
17:00	**End of Day 2**	
18:30	**Conference dinner**	**Ciccios Woodfired Pizzeria – Nepean Hwy, Aspendale (opposite Aspendale Station; 7 min walk)**

Day 3: Thursday, 14 November 2024; 09:00–12:30

	Paul Krummel	**Daily welcome includes acknowledgement of traditional owners**
Chair	**Cathy Trudinger**	**Session 10 – Oral Presentations**
09:00	Beata Bukosa (O)	Developments in greenhouse gas measurements and modelling in Aotearoa New Zealand
09:15	Stijn Naus (O)	Resolving Auckland's CO_2 budget: urban biosphere, diurnal cycle and high-resolution modelling
09:30	Stephen Rigney	Coastal wetland greenhouse gas dynamics under changing inundation regimes
09:45	Andy Menking (O)	New measurements characterize the 1940's CO_2 slowdown and extend the Kennaook/Cape Grim record of N_2O isotopes 2005–2023
10:00	Colin Alison	40+ years of $\delta^{13}C$-CO_2 and $\delta^{18}O$-CO_2 measurements of atmospheric air at Kennaook/Cape Grim and other sites
10:15	Roger Francey	Reduced anthropogenic forcing of climate and ocean acidification between 2009 and 2015
10:30	**Morning tea**	**Aspendale canteen**
Chair	**Zoe Loh**	**Session 11 – Oral Presentations**
11:00	David Griffith	Introducing total column measurements of CO_2, CH_4 and CO at Kennaook Cape Grim
11:25	Ann Stavert	Improving the Kennaook/Cape Grim *in situ* CO_2, CH_4, N_2O and CO records
11:40	Jason Ward	The Northern Territory Baseline Air Pollution station at Gunn Point, Darwin: past, present and future
11:55	Issy Borley	Recent developments and highlights from GASLAB and related projects
12:10	Ray Langenfelds	Expanding the use of top-down methods for Australian greenhouse gas emissions accounting
12:25	**Lunch**	**End Conference**
12:45	**Interested parties**	**Discussion on GHG network expansion and Australia's contribution to WMO G3W**

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Aerosol chemical composition and vaporisers

M. D. Keywood[1*], C. Mynard[1], E. Dunne[1], R. S. Humphries[1], J. N. Harnwell[1], N. T. Sommerville[2], J. Ward[2], A. Sutresna[1], M. D. Mallett[3] and E. B. Franklin[1]

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[2] Bureau of Meteorology, KCGBAPS, Smithton, TAS, Australia
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Abstract

Marine aerosol is globally one of the most important natural aerosol systems, contributing to Earth's radiative budget, biogeochemical cycling, impacts on ecosystems and regional air quality. To fully understand these contributions, information about the chemical composition of the aerosols is just one piece of the puzzle. Aerosol chemical composition has been observed at Kennaook/Cape Grim (KCG) since the late 1980s on filters collected under baseline conditions over a weekly integrated period. In 2021 the time-of-flight Aerosol Chemical Speciation Monitor (tof-ACSM) was installed to measure the composition of nonrefractory species in aerosol < 1 µm in diameter (PM1), in real time, enhancing the time resolution of chemistry data and adding organic matter to the KCG data sets.

The tof-ACSM uses an aerodynamic aerosol sample lenses to generate narrow particle beams with high particle transmission. The particles then encounter a heated filament known as the ioniser/vaporiser system where they are then flash vaporised and ionised resulting in fragmentation before being detected by online mass spectrometry [Fröhlich et al. 2013]. The vaporiser traditionally used in the tof-ACSM, the Standard Vaporiser (SV), contributes uncertainties of around 30% to the total uncertainty of the measurement due to particles bouncing out of the vaporisers [Bahreini et al. 2009]. This particle bounce was eliminated using the Capture Vaporiser (CV), which included an external cage so that the particles were no longer able to bounce out of the vaporiser. Naturally the tof-ACSM installed at KCG included the CV to ensure minimum uncertainties.

However, our research over the past four years has highlighted some unintended consequences of using the CV, which predominately arise because the particles spend more time in the CV than in the SV and therefore spend longer time being vaporised. This changes fragmentation patterns and changes what can vaporised [Mynard et al. in prep; Sutresna et al. 2024]. This has implications for the configuration we use at KCG for long term monitoring of chemical composition of PM1. Fortunately, we have use of a second tof-ACSM so have operated two tof-ACSM side by side at KCG since May 2024 and in that time have compared the two instruments each with a CV and since September 2024, one has been operated with an SV. These experiments allow us to directly compare the influence of the different vaporisers on observations of KCG aerosol.

In this presentation, using the information generated from this comparison, we will answer the question "What vaporiser should we be using at KCG for our long-term monitoring program?"

References

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Atmospheric particulate matter: the importance of chemical speciation and spectroscopic methods for solving this measurement challenge

C. Tollemache[1,2*], H. Patel[1,2], P. Baynham[1] and B. Wells[1]

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[*] corresponding author: Cherie Tollemache [cherie.tollemache@mote.io]

Abstract

Speciation of airborne particulate matter (PM) and source apportionment is crucial for understanding the magnitude and impact of PM on the environment and human health. Identifying the emission source, regulating for decreased emissions and monitoring those mitigation efforts is best achieved when we can recognise individual particles and their concentrations within a particle population.

Early studies, regulatory standards, and current PM monitoring programs primarily focus on measuring total particle concentration and size distribution [Alfano et al. 2020; Amaral et al. 2015]. Identifying the chemical composition of particles and quantifying particles based on distinct chemical and morphological groups and their sources remains a complex challenge because environmental PM samples typically contain hundreds of thousands of unique particle species scattered randomly across sample filters. These particles originate from diverse sources, each influenced by various factors affecting their emissions profile. The surface chemistry of these particles is further affected by meteorological conditions and atmospheric chemistry changes.

In the past decade, advancements in chemical characterization and source identification of PM have been significant, driven by increased use of advanced materials chemistry techniques and improved data analysis software. Various instruments are employed to analyse PM chemistry on filters, typically using spatially averaged methods [Amaral et al. 2015; Correa-Ochoa et al. 2023; Ogrizek et al. 2022]. To identify chemical species and their emission sources from averaged data collected across multiple methods, researchers combine datasets and apply multivariate statistical methods and machine learning techniques (receptor modelling).

Hybrid instruments combining microscopes and spectroscopic techniques are powerful tools for analysing individual particles based on their morphology. These instruments can perform 2- and 3-D hyperspectral imaging in the micron and even sub-micron range. Optical and electron microscopes coupled with vibrational spectroscopy (Raman and FTIR) and have recently been used in air quality research to image single particles and scan entire filter areas with single particle resolution, obtaining molecular fingerprints of thousands of particles per filter, providing richer data sets for receptor modelling [Longoria-Rodríguez et al. 2021]. This talk aims to highlight the role these advanced instruments play in understanding and improving air quality.

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Increased aerosol concentrations in the High Arctic attributable to changing atmospheric transport patterns

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Abstract

The Arctic environment has changed profoundly in recent decades. Aerosol particles are involved in numerous feedback mechanisms in the Arctic, e.g. aerosol-cloud/radiation interactions, which have important climatic implications. To understand changes in different Arctic aerosol types and number concentrations, we have performed a trend analysis of particle number size distributions, their properties, and their associated air mass history at Villum Research Station, northeastern Greenland, in the High Arctic from 2010 to 2018. We found that, during spring, the total/ultrafine mode number concentration and the time air masses spent over the open ocean is significantly increasing, which can be ascribed to transport patterns changing to more frequent arrival from the ice-free Greenland Sea. We found that, during summer, the total/ultrafine mode number concentration, the occurrence of the Nucleation cluster (i.e. newly formed particles from gas to particle conversion), and the time air masses spent over the open ocean is significantly increasing. This can also be attributed to changing transport patterns, here with air masses arriving more frequently from Baffin Bay. Finally, we found that, during autumn, the ultrafine number concentration and the occurrence of the Pristine cluster (i.e. clean, natural Arctic background conditions) is significantly increasing, which is likely due to increasing amounts of accumulated precipitation along the trajectory path and decreasing time air masses spent above the mixed layer, respectively. Our results demonstrate that changing circulation and precipitation patterns are the factors predominantly affecting the trends in aerosol particle number concentrations and the occurrence of different aerosol types in northeastern Greenland.

Investigation into the decrease in single scattering albedo in the central United States and south-central Canada

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Abstract

During the autumn in both the central United States and south-central Canada, a significant drop in the aerosol single scattering albedo (SSA) is routinely observed. This indicates that the aerosol population is either scattering less efficiently or absorbing more. This pattern has been captured over decades of data at two long-term sites: Bondville, Illinois USA (BND) and Egbert, Ontario Canada (EGB). This work focuses on data from the last decade (2013–2023). Additionally, this decrease has been observed by a relatively new site in Dayton, Ohio USA (WPB) over the past two years (2022–2023). All three of the sites have collocated Aerosol Robotic Network (AERONET) measurements. A late year drop in column aerosol SSA at all three sites is visible in the level 1.5 AERONET data although not in the more filtered level 2.0 data. *In situ* aerosol vertical profiling above BND also measured low SSA throughout the column during this time [Sheridan et al. 2012]. This suggests a persistent source, sink, or other process that is influencing aerosol properties in the region. The cause of the autumn decrease in SSA has not been determined, but several hypotheses have been proposed including: (a) agricultural activities introducing a new source during this period and (b) increased wet scavenging from precipitation and fog preferentially removing large scattering aerosols [Delene and Ogren 2002; Sherman et al. 2015]. Neither hypothesis has been explored in detail or substantiated by other data, which is what we aim to do here.

In addition to the NFAN and AERONET systems, both BND and EGB are outfitted with a variety of other instruments. Aerosol composition measurements from the IMPROVE, NOAA/PMEL, and CAPMoN are available. Additionally, the NADP and CAPMoN provide precipitation chemistry. WPB is not directly collocated with any of these sites but lies within the densely monitored area (see Figure). At BND, October has the lowest CO concentrations, indicating that smoke from crop burning is unlikely to be the explanation for the decrease in SSA. However, increases in particulate potassium is observed during the fall, which could be from crop burning, dust, or fertilizer. Wind trajectories will need to be evaluated to explore these possible sources. At both BND and EGB a sharp decrease in particulate sulphate occurs in October, which correlates with decreased aerosol scattering. This could indicate a sink such as wet scavenging, however, the total precipitation and RH at BND do not increase during this time. Further investigation into the precipitation chemistry is therefore needed to assess this sink at BND and EGB. Data from the surrounding area will be used to determine the extent of the source, sink, or other processes causing the decrease in SSA.

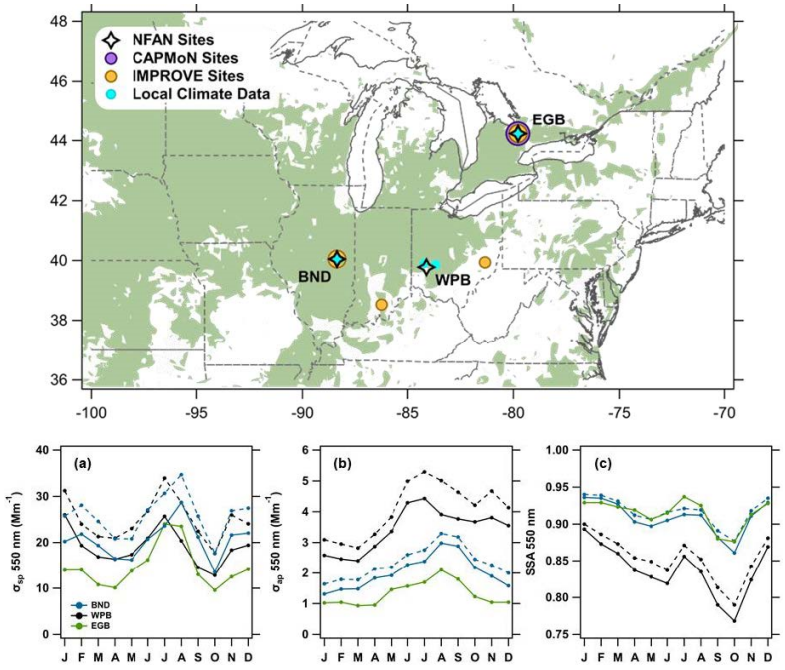


Figure: (top) Map of sites in the region of interest. Cropland coverage shown in green. (bottom) Seasonal cycles of aerosol (a) scattering, (b) absorption, and (c) SSA. PM1 data are in solid lines and PM10 data are in dashed lines.

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Progress towards an absolute terrestrial irradiance radiometer

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Abstract

Currently there is no World Meteorological Organization (WMO) endorsed absolute radiometer for monitoring downward terrestrial (infrared) irradiance and the current World Infrared Standard Group (WISG) scale is based on a group of four thermopile but domed radiometers with a known offset of ~ -4 Wm^{-2} to SI and with systematic annual variations about the mean of the order of an additional ± 2 Wm^{-2}. The Physical Meteorological Observatory in Davos/World Radiation Centre (PMOD/WRC) has terrestrial irradiance traceability to SI through its blackbody and developed relative IRIS radiometers that can be calibrated by the blackbody. However, the WMO is reluctant to define a terrestrial irradiance standard linked to a single instrument; to do so would likely recreate the problems related to WISG traceability. Reda et. al. [2012] introduced a new active cavity pyrgeometer (ACP) that did not use an optical dome but an open concentrator cavity which could be an absolute instrument traceable to SI through a least-squares (LSQ) calibration technique. Studies between 2012 and 2022 showed that the ACP produced reliable clear sky nighttime terrestrial irradiances that were traceable to SI but required recalibration every 2-3 hours with 4% variations in sensitivity. Forgan et al. [2023] showed that the ACP equation proposed in 2012 did not satisfy Kirchoff's Law and developed a new equation that showed ACPs should be very stable over months but with better understanding of convection within the open cavity especially for LSQ determination of the thermopile responsivity. The WMO Expert Team on Radiation References in 2023 established a project to demonstrate the suitability of ACPs as SI absolute radiometers and to propose their endorsement at WMO Congress in 2023. Progress has been encouraging including the establishment of a Sharepoint data base for interested researchers to access all available ACP data, reference irradiance data, climate data, and the results from annual outdoor intercomparisons at the National Renewable Energy Laboratory (NREL; Colorado, USA), 4-yearly IPgCs, long-term outdoor measurements, as well experimental studies both outdoors and indoors at PMOD/WRC, Japan Meteorological Agency (JMA) and Deutsche Wetterdienst (DWD). Such studies have indicated that the ACP can be calibrated absolutely (to SI) using several different sources including a blackbody at ambient temperature, a darkroom or shed, and with higher uncertainty, outdoors at night in clear sky conditions. Progress to submission at WMO Congress 2027 has been hampered by characterisation of ACP convection functions independent of ACPs measurements and the acceptance of a single operational equation; on the former engineering and atmospheric modelling groups have been approached to assist.

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The Cloud And Precipitation Experiment at Kennaook (CAPE-k): an update – 7 months in

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Abstract

The Baseline Air Pollution Station at Kennaook/Cape Grim (KCG) has produced the longest and most consequential record of Southern Hemisphere aerosol and gas-phase chemistry. However, cloud and precipitation measurements have not been collected there over an extended period and have been limited to campaigns at the site or aboard research vessels that typically traversed higher latitudes. These limited observations have resulted in large model uncertainty in the surface radiation budget due to clouds and precipitation in the region – a region where strong latitudinal gradients in cloud feedbacks are found. This uncertainty exists in a region where there are strong and well-documented seasonal variations in marine aerosol properties. Satellite data suggest that cloud properties covary with the seasonal cycle in aerosol in the SO, yet detailed vertically resolved measurements of cloud and precipitation in the marine boundary layer are lacking.

The Cloud And Precipitation Experiment at Kennaook (CAPE-k) is a 17 month deployment of the US Atmospheric Radiation Measurement's (ARM) Mobile Facility which consists of extensive cloud and precipitation observations to complement the extensive observational program already at KCG. CAPE-k will provide detailed cloud and precipitation observations from April 2024 to September 2025 – long enough to capture a full annual cycle as well as two winter seasons. It has also been designed to align with the COAST-k voyage aboard the RV *Investigator* currently scheduled for May 2025.

This presentation will provide an overview of the scientific objectives, the suite of instruments, and some early results in the first seven months since the launch event in April.

Introducing the CAPE-k Student Workshop

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Abstract

The Cloud And Precipitation Experiment at Kennaook (CAPE-k) involves the deployment of a huge range of state-of-the-science atmospheric instruments at the Kennaook/Cape Grim Baseline Air Pollution Station in the north west of Tasmania during 2024–2025. CAPE-k will explore cloud and aerosol interactions in the Southern Ocean to improve the parameterisation of these factors in climate models. Many experienced international scientists will be present during the intensive phases of the experiment and hence there exists a wonderful educational opportunity for the next generation of atmospheric scientists from Australia and overseas.

To take advantage of this opportunity, we have organised a student workshop to be held from 1–7 February 2025 at Stanley, Tasmania. The workshop will include a lecture series covering the physics and chemistry of aerosols delivered by the Head of WMO-GAW – World Calibration Center for Aerosol Physics Alfred Wiedensohler, and a hackathon utilising a subset of the CAPE-k observations organised by Scott Collis and Max Grover of the Argonne National Laboratory.

Students from several universities in Australia and the USA are already registered for the workshop. This short presentation will be used to highlight the workshop and advertise any remaining places that might still be available.

Pursuing ocean-atmosphere links in the Southern Ocean: A 2024 MISO voyage overview

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Abstract

The atmospheric properties and ocean-atmosphere interactions over the Southern Ocean are under increasing scrutiny due to the persistent cloud and radiation biases observed in current climate models. Much of this challenge stems from limited observational data and the complex interplay of ocean biology, atmospheric fluxes, chemistry, and dynamics that produce and transport aerosols, ultimately influencing cloud structure and precipitation. Addressing these gaps, the 2024 Multidisciplinary Investigations of the Southern Ocean (MISO) voyage was the longest and most comprehensive expedition undertaken by the RV Investigator to date, featuring extensive, cross-disciplinary measurements across ocean biology, chemistry, atmospheric composition, cloud structure, and precipitation.

This 65-day expedition traversed the Southern Ocean and Antarctic waters, with over three weeks spent in the marginal ice zone, influenced by both large phytoplankton blooms and continental outflows. We will present preliminary observations highlighting the important role of air mass history in modifying the concentration of cloud condensation nuclei. This is particularly clear when contrasting air masses that have passed over large phytoplankton blooms in contrast to continental outflow from Antarctica but is further modulated by cloud interactions and precipitation. The comprehensive suite of real-time oceanographic and atmospheric measurements collected during this voyage will be invaluable for advancing our understanding of these complex processes.

High latitudes, high methanesulfonic acid (MSA): Tracking DMS oxidation products over the Southern Ocean

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Abstract

Dimethyl sulfide (DMS) is the largest natural source of sulfur in the atmosphere, particularly in remote marine environments. The main oxidation products of DMS are sulfur dioxide (SO_2) and methanesulfonic acid (MSA), with SO_2 further oxidising into sulfuric acid (SA). SA is known to participate in particle nucleation and growth. MSA can contribute to particle growth, but so far there is no observational evidence of its role in particle nucleation. Therefore, these species are important for the formation of aerosols and clouds in the marine boundary layer. However, DMS oxidation is complex and dependent on oxidant type and availability as well as environmental conditions (T and RH), resulting in relative yields of its oxidation products being still uncertain. Polar marine environments and in particular Southern Ocean are a significant source of DMS.

This presentation will focus on gaseous MSA and SA measured during two summertime Southern Ocean voyages aboard Research Vessel (RV) *Investigator* (CAPRICORN-2, Jan–Feb 2018; MISO, Jan–March 2024) and summarise the main findings related to their trends, ratios and diurnal profiles. These species were measured using a nitrate Chemical Ionisation Mass Spectrometer (NO_3-CIMS).

There are several notable similarities between the voyages: 1) MSA increases with higher latitudes, particularly within the polar cell (see Figure), whereas SA does not show this trend; 2) during both voyages there were periods of substantially higher MSA concentrations, compared to the rest of the data (see Figure). These "high MSA" events lasted from 1 to 7 days, a pattern not observed for SA; 3) SA displayed a typical diurnal cycle with concentrations following solar radiation intensity and peaking around midday. In contrast, MSA showed no diurnal profile and exhibited similar concentrations during both day and night, suggesting that photochemical production is not the dominant mechanism for MSA formation in the Southern Ocean atmosphere; 4) MSA was negatively correlated with relative humidity (RH) and, more specifically, with absolute humidity. This relationship is not seen for SA.

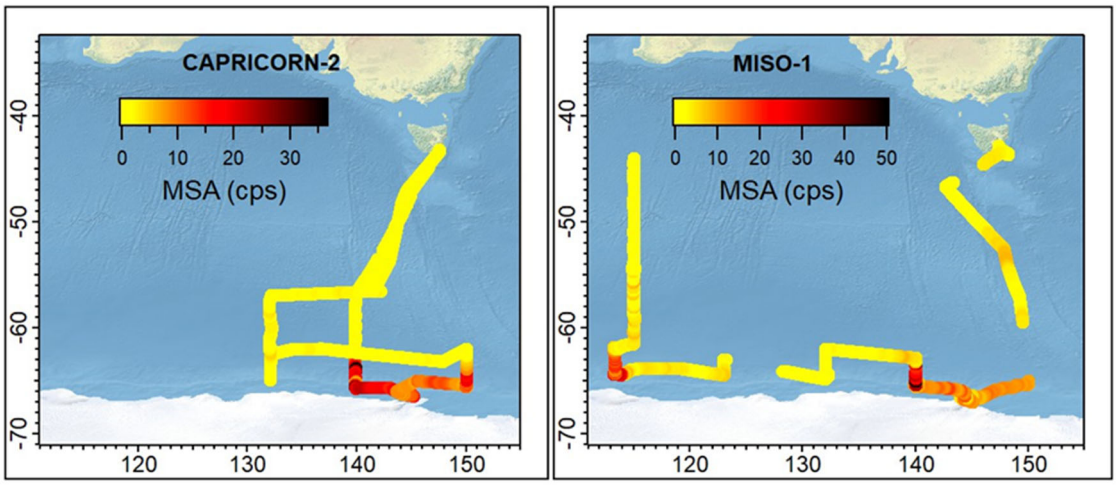


Figure: CAPRICORN-2 and MISO-1 voyage tracks colour coded by the MSA counts.

Methanethiol is a significant contributor to volatile organosulfur concentrations over the Southern Ocean

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Abstract

The persistent radiative energy biases represented in Southern Ocean climate models are largely due to a lack of understanding on how clouds form and evolve over this region (IPCC AR6). Sulfate aerosols, formed from the oxidation of sulfur-containing compounds are important for cloud formation and properties, affecting albedo and cloud lifetime. Dimethyl sulfide (DMS) has long been recognised as a key precursor to sulfate aerosol formation. DMS is oxidised to form methanesulfonic acid and sulfur dioxide (SO_2), subsequently oxidising to sulfuric acid, an important contributor to particle formation and growth. Efforts to reconcile SO_2 budgets are inconsistent with the known products from DMS oxidation. This has prompted speculation about the significance of other marine sulfur species, such as methanethiol (MeSH), that could contribute to SO_2 production. DMS and MeSH both originate from the degradation of dimethylsulfoniopropionate (DMSP) in marine microorganisms, highlighting the importance of understanding their relationship, atmospheric abundance, and oxidation pathways.

We made continuous Proton Transfer Reaction Time-of-Flight Mass Spectrometer (PTR-ToF-MS) measurements of DMS and MeSH in the Southern Ocean region. Measurements were made during baseline conditions at Kennaook/Cape Grim (KCG) and aboard the RV *Investigator* over a 60-day summertime Southern Ocean voyage as part of the Multidisciplinary Investigations of the Southern Ocean (MISO).

We report that DMS and MeSH concentrations varied significantly across seasons and regions, but with consistently strong correlations. Elevated DMS levels were observed during the MISO voyage, particularly along biologically active transects, while MeSH levels were more consistent between MISO and KCG. The MeSH:DMS ratio varied between 37-55% (R^2 = 0.6) at KCG and 17-28% on MISO (R^2 = 0.8), which was likely driven by the types of biological sources, their emission strength as modulated by changes in wind speed and temperature, their atmospheric fates, and probable coastal influences at KCG. Strong MeSH:DMS correlations in spring and summer could suggest a common biological source, while weaker correlations in autumn and winter highlight differences in seasonal and environmental drivers. These relationships and their remarkably strong correlations across the Southern Ocean region indicate the interdependence of marine MeSH and DMS emissions, which has important implications for modelling budgets of oxidation products like SO_2.

Contributions of the synoptic meteorology to the seasonal CCN cycle over the Southern Ocean

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Abstract

For over 40 years, the Kennaook/Cape Grim Observatory (KCGO) has provided critical observations of the atmospheric chemistry over the remote Southern Ocean (SO). One of KCGO's most enduring observations is that of the seasonal cycle in cloud condensation nuclei (CCN) during baseline conditions, i.e., when pristine airmasses from the SO are sampled [Ayers et al. 1997; Gras and Keywood, 2017; Humphries et al. 2023]. This seasonal cycle shows a peak CCN concentration during summer (DJF) when biogenic activity is greatest and a minimum during winter (JJA).

In this study we examine the seasonality of the synoptic meteorology over the KCGO, particularly its impact on the CCN concentration observed at KCGO during baseline conditions. Using k-means clustering, we identify six distinct synoptic regimes: three prevalent in the austral winter, when the subtropical ridge (STR) is strong and centred at lower latitudes, and three in the austral summer, when the STR shifts poleward [Larsen and Nicholls 2009]. These seasonal regimes contribute to the observed CCN cycle, with the winter baseline regime marked by heavier precipitation, a deeper boundary layer, and reduced CCN concentrations. An analysis of air mass back trajectories at the free troposphere level supports this seasonal distinction, showing that winter air masses tend to originate from higher latitudes. Across the two baseline regimes, we observe an inverse relationship between precipitation and CCN concentration, emphasizing precipitation's role in depleting CCN levels over the SO [Kang et al. 2022; Alinejadtabrizi et al. 2024].

Our findings highlight two key aspects when comparing the KCGO baseline air mass clusters with traditional baseline definitions (e.g. as used by Gras and Keywood [2017]). First, the current criteria for defining the baseline include a significant portion from wintertime high-pressure regimes. Second, and more importantly, the boundary layer structure, precipitation, and air mass origins show substantial seasonal differences (both boundary layer and free troposphere). Echoing the conclusions of Quinn and Bates [2011], a full understanding of the CCN budget over the SO is far more complex than simply an understanding of the biogenic production.

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Understanding biases in E3SMv2 simulated cloud droplet number and aerosol concentrations over the Southern Ocean

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Abstract

The accurate representation of cloud droplet number concentration (N_d) is crucial for predicting future climate. However, models often underestimate N_d over the Southern Ocean (SO), where natural sources dominate, and aerosols are composed primarily of marine biogenic sulfate and sea spray. This study uses a range of diverse datasets to evaluate and untangle biases in E3SMv2 simulated clouds, aerosols, and sulfur species. The default E3SMv2 underestimates N_d over SO by a factor of 2 when compared with observations in 3 km-resolution simulations. Updating the dimethyl sulfide (DMS) emission and chemistry leads to a better agreement between the model and the observations in N_d and boundary layer aerosols, but low biases persist in the free tropospheric aerosol concentrations larger than 70 nm, possibly attributable to insufficient particle growth. Preliminary evaluation also reveals biases in simulated sulfur species, including overestimation in DMS at high latitudes, and in simulated sulfate mass concentration, highlighting the necessity for further efforts to improve the model treatment of relevant processes.

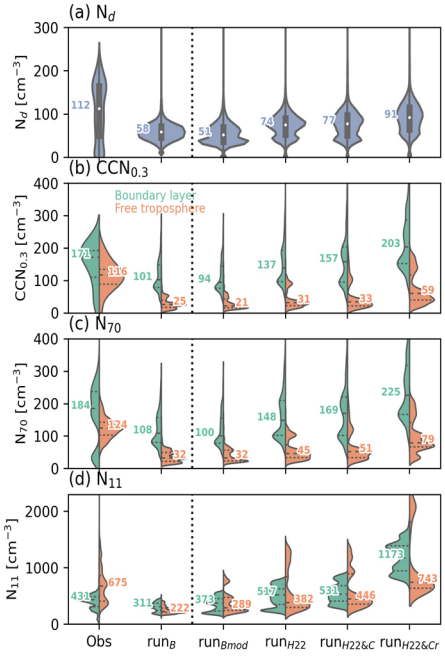


Figure: Violin plot for aircraft observed and E3SMv2 simulated (a) cloud droplet number concentration (N_d), (b) CCN at 0.3% supersaturation ($CCN_{0.3}$), (c) aerosol number concentration for particles larger than 70 nm (N_{70}), and (d) aerosol number concentration with diameters larger than 11 nm (N_{11}). Panels b,c, and d depict results in both the boundary layer (green) and the free troposphere (orange). The values alongside the violins give the median values. In panel a, the white dots represent the median value, the black bar shows the interquartile range, and the outer shape shows the distribution of the data. In panels b,c, and d, the 25th percentile, median, and 75th percentile are represented by the three dashed lines, respectively. The first violin in each panel is the aircraft observation, the second violin is the results from default run, while the rest of violins represent the different sensitivity tests.

Environmental drivers and properties of Southern Ocean aerosol and cloud formation

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Abstract

The Southern Ocean (SO) is one of the last areas of the world where atmospheric conditions are similar to the pre-industrial period [Hamilton et al. 2014; Mallet et al. 2023]. Some studies have demonstrated that synoptic-scale pollution is already altering the natural balance and dynamics [Bhatti et al. 2022]. For this reason, it is now necessary to deepen our understanding before these environments are further impacted. Considering the diversity and complexity of aerosol measurements [Reddington et al. 2017], a multidisciplinary and international effort is necessary to enhance our understanding of the interactions between aerosols, clouds, and precipitation, as well as their variability with the biosphere [Marchand et al. 2014; McFarquhar et al. 2021; Humphries et al. 2023].

This project will provide the first comprehensive, validated long-term dataset of aerosol size distribution over the Southern Ocean (SO), incorporating data collected from Kennaook-Cape Grim, the RV *Investigator*, the RSV *Aurora Australis*, and the RSV *Nuyina*. To achieve this goal, a thorough evaluation of ship exhaust will be conducted to eliminate data affected by pollutants emitted from the ship's engine.

I will present the characteristics of the exhaust filtering algorithm used and share some preliminary results obtained from the MISO voyage datasets. Additionally, I will briefly outline the Denman Marine Voyage mission, including its objectives and the expected outcomes.

The final aims are to enhance our understanding of SO aerosol and cloud formation, their role in climate, and to improve aerosol property simulations in Earth System models by providing observational constraints on aerosol size and composition.

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Global nitrate aerosol, its impact on tropospheric composition and production from lightning

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Abstract

Aerosols, liquid or solid particles in the atmosphere, have a considerable impact on Earth's energy budget and thus the climate system, and they also impact air quality. Aerosols can be emitted directly from both anthropogenic and natural sources (termed primary aerosols), or they can be chemically produced in the atmosphere from precursor gases by condensation of vapours on pre-existing particles or by nucleation of new particles (termed secondary aerosols).

Sulfate and nitrate are predominantly secondary inorganic aerosols and are often the major components of fine mode aerosol. They are strong scatterers of the incoming solar energy (the 'aerosol direct effect') and thus exert a negative radiative forcing on climate (meaning a cooling of the atmosphere). These aerosols also act as the cloud condensation nuclei (CCN), and modify cloud properties, such as cloud albedo, persistence or lifetime of clouds and precipitation rate (the 'aerosol indirect effect').

The main precursor species for the formation of fine-mode nitrate aerosol (which includes both ammonium and nitrate) are reactive gases of nitric acid (HNO_3) and ammonia (NH_3). Coarse-mode nitrate aerosol is also formed when HNO_3 condenses irreversibly onto existing sea-salt and dust aerosols. Nitrate aerosol is expected to become even more important in the future atmosphere due to the continued increase in nitrate precursor emissions (e.g. NH_3 and NO_x) and the decline in SO_2 due to stricter emissions regulations. Nitrate aerosol is often ignored in global chemistry-climate models [Tost 2017], and this may be partly due to the computational cost of simulating nitrate, combined with the chemical complexity of its formation and the semi-volatile nature of ammonium nitrate, which can reevaporate into the atmosphere. In fact, out of the ten global Earth system models with atmospheric chemistry that participated in the Aerosol and Chemistry Model Intercomparison Project (AerChemMIP) under the Coupled Model Intercomparison Project Phase 6 (CMIP6), only two models, GISS and GFDL, explicitly treated nitrate aerosol together with an interactive stratospheric and tropospheric chemistry scheme [Thornhill et al. 2021]. AerChemMIP aims to assess the effects of reactive gases and aerosols on Earth's climate.

Lightning is a major source of NO_x, particularly in the tropical to subtropical middle to upper troposphere where lightning is mostly discharged [Luhar et al. 2021]. Quantifying the role of lightning NO_x (LNO_x) production on aerosol, particularly with nitrate aerosol included, has only received very limited attention compared to its role on gaseous atmospheric composition.

Recently, a nitrate scheme has been included in the modal aerosol scheme of the Met Office's Unified Model (UM) – United Kingdom Chemistry and Aerosol (UKCA) global chemistry-climate model [Jones et al. 2021]. The aerosol scheme in UM-UKCA is a prognostic double-moment GLOMAP-mode scheme which transports both particle number and mass concentrations in size classes. (The Australian ACCESS-CM2-Chem chemistry-climate model [Dennison and Woodhouse 2023] employs both UM and UKCA but does not yet include a nitrate scheme.)

In this study, two key questions we seek to answer using UM-UKCA are: 1) what is the impact of adding nitrate to UM-UKCA on tropospheric composition fields (such as O_3, OH, methane lifetime, and aerosol), AOD and radiation, and 2) what is the dependency of these impacts on the lightning parameterisation in the model? For this purpose, we apply UM-UKCA without and with nitrate and vary LNO_x through the use two empirical parameterisations of lightning flash rate: (a) the Price and Rind [1992] (PR92) parameterisations for ocean and land which are a function of convective cloud-top height and which most global chemistry-climate models use, and (b) Luhar et al.'s [2021] flash-rate parameterisations which improve upon the PR92 parameterisation for the ocean. Simulations are also conducted with no LNO_x. Our findings show that both nitrate aerosol and LNO_x significantly impact tropospheric

composition and aerosol responses, with LNOx comparatively impacting coarse aerosol by mass the most. The inclusion of nitrate also shifts the aerosol size distribution, particularly in the Aitken and accumulation modes. Our results, described in full in Luhar et al. [2024], are based on a fast uptake rate for HNO_3 to produce NH_4NO_3 and likely represent an upper limit on nitrate effects.

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Offsets and inlet transformations in NO and NO_2 measurements at Kennaook/Cape Grim 2000–2023

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Abstract

For nitric oxide (NO) and nitrogen dioxide (NO_2) measurements made by ozone (O_3) chemiluminescence and photolytic conversion, the issues of zeroing and calibration of the instruments are straightforward [Galbally 2020; Galbally and Molloy 2024]. However, there remain two less well documented and less well understood measurement corrections, Offsets and Inlet adjustments. Instrument offsets are the difference between the true atmospheric concentration of NO or NO_2 and that measured by the analyser [Fehsenfeld et al. 1990]. These differences plague low level NO_x measurements. Inlet transformations are ongoing chemical reactions between NO, NO_2 and O_3 that occur within the inlet/photolytic convertor system and a framework for calculating these has been developed [Reimann et al. 2018]. For both Offsets and Inlet adjustments there is very little published material relating the recommended procedures to observed results. an issue critical for the pristine environment.

NO and NO_2 measurements for January 2020 to December 2023 made at Kennaook/Cape Grim are used to determine these Offsets and Inlet adjustments. The NO_2 Offsets are determined using a new approach from three different daily measurements, compiled as monthly means which vary from 9 to 52 ppt over the course of the 48 months. The correlations between the sets of the NO_2 offsets are r = 0.96, 0.93, 0.96. Offsets for NO are significantly smaller varying from -10 to 8 ppt over the course of the 48 months and with correlations between the sets of the NO offsets of r = 0.62, 0.63, 0.92. Adjustments based on chemical kinetics have been proposed separately for NO and NO_2 for ongoing chemical reactions between NO, NO_2 and O_3 that occur in the sample air in the Inlet [Reinmann et al. 2018]. Here the NO loss is directly measured during the daily calibration cycle as well as being calculated. The typical NO loss, presumably due to O_3 oxidation, is approximately 5% during late 2021 to early 2023 with, as expected, a summer minimum and winter maximum. The NO_2 transformation analysis shows a 6-7% decrease in NO_2 between the inlet and the measurement point.

These Offset and Inlet corrections are critical for reliable ppt measurements of NO and NO_2 the pristine environment.

Acknowledgements: For 2000–2023, Suzie Molloy pre-processed the raw data files; Nigel Somerville, Jeremy Ward, the author, Suzie Molloy and Emily Franklin undertook the instrument maintenance, repair and development.

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Review of vegetation assessment activities within TOAR II

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Abstract

The Tropospheric Ozone Assessment Report phase II (TOAR II) is an official activity of the International Global Atmospheric Chemistry Project (IGAC) (https://igacproject.org/activities/TOAR/TOAR-II). The goal of TOAR-II is to build on the success of TOAR-I (2014–2019) and produce an updated assessment of tropospheric ozone's global distribution and trends from the surface to the tropopause. This effort includes an analysis of the impacts of ozone on human health, crop and ecosystem productivity, and climate. This paper will concentrate on a body of work being conducted for the TOARII Vegetation Assessment paper and summarise the key findings form studies that have i). developed different methodological approaches (including flux-based dose-response relationships and process-based crop models) to assess the risk of ozone to vegetation (crops and forests); ii). applied these methodological approaches to assess the impacts of ozone on crops and forests at different scales (from national to global and for current and future climates); iii). tested the reliability of using different atmospheric chemistry transport models to estimate ozone damage via the PODy metric and finally; iv) plans to use the TOARII ozone database to assess past trends in the scale and magnitude of ozone damage to vegetation.

Impacts of aromatic peroxy radical chemistry on atmospheric ozone

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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, making it important for air quality to understand aromatic chemistry. Previous work in my PhD suggests the potential for additional aromatic peroxy radical chemical pathways to be important in low NO_x ($NO_x \equiv NO + NO_2$) environments. These additional pathways could result in the destruction of ozone, as well as an extra source of phenolic compounds, which were previously found to be underpredicted by chemical transport models (CTMs).

Here, we add these additional chemical pathways into GEOS-Chem, a global CTM, and simulate Asia from May to June 2016, and compare this to a baseline simulation without the updated chemistry. In this talk, we will show the impacts of these new chemical pathways on the atmospheric concentration of ozone and phenolic compounds between the baseline and updated simulations.

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Unravelling secondary organic aerosol formation from isoprene and toluene mixture

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Abstract

Large amounts and varieties of volatile organic compounds (VOCs) are emitted from ranges of anthropogenic and biogenic emission activities. After being emitted into the atmosphere, VOCs undergo oxidation reactions with atmospheric oxidants (i.e. O_3, OH, NO_3) and from secondary organic aerosol (SOA) particles. Most previous laboratory studies have reported SOA formation from individual anthropogenic and biogenic VOCs [Kroll et al. 2006; Ng et al. 2006, 2007]. However, the findings from those studies using single VOCs may not fully represent the SOA formation under real-world conditions in which various VOCs and their oxidation products interact. Nowadays, increasing efforts have been made to explore SOA formation from binary or ternary mixtures of VOCs. Studies using mixed VOCs have shown different findings as compared with those using single VOCs [Takeuchi et al. 2022; Liu et al. 2024]

In this study, we chose toluene and isoprene, the two most representative anthropogenic and biogenic VOCs, for study. Using an 8 m^3 atmospheric simulation chamber at QUT, we conducted photooxidation experiments at room temperature to study the SOA formation from isoprene, toluene, and isoprene-toluene mixture in the presence of neutral and acidic seed particles. A suite of real-time, high-resolution mass spectrometers was used to simultaneously measure the compositions in gas and particle phases. Furthermore, positive matrix factorization was used to deconvolute AMS data into SOA factors for further analysis to understand the evolution of SOA composition.

The Figure shows the wall-loss corrected SOA yields of isoprene, toluene, and their mixture. Compared with the neutral seed particles, acidic seed particles enhanced SOA formation regardless of VOC precursors, likely due to the acid-catalyzed effect. Comparisons in SOA yields were performed between this study and the literature. Five SOA factors were identified using PMF. In experiments using either isoprene or toluene, two factors were identified for each case. Interestingly, a unique factor was only found in the experiments using the mixture of isoprene and toluene. This indirectly suggested the chemical interactions occurring between isoprene and toluene oxidation products during SOA formation.

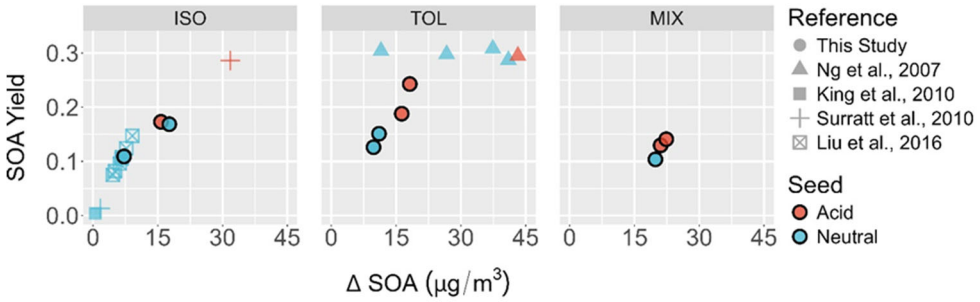


Figure: Wall-loss corrected SOA yield as a function of SOA formation for isoprene (ISO), toluene (TOL) and isoprene-toluene mixture (MIX) in the presence of acidic and neutral seeds. Circles with and without stroke colors represent data from this study and literature, respectively.

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Aerial deposition of metals and polycyclic aromatic compounds in the Athabasca oilsands region

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Abstract

Open pit oilsands mines and bitumen upgrading facilities near Fort McMurray, Alberta, Canada are large sources of air emissions including metals and polycyclic aromatic compounds (PAC). These air emissions are deposited locally to the relatively pristine boreal forest [Kelly et al. 2009; 2010]. A regional snowpack sampling program conducted as part of a federal-provincial partnership collected geochemical data that have been used to evaluate the temporal and spatial trends of metals and PAH deposition in the region [Cho et al. 2014; Manzano et al. 2016].

Here we present the results of our independent reanalysis of publicly available snowpack data: to replicate previous results; to provide new insights into the spatial and temporal patterns of metal and PAC deposition; and, to determine whether certain metals or PACs were associated with specific oil sands mining or upgrading activities [McNaughton et al. 2019].

Using geochemical ratios and a K-means clustering approach we classify snowpack data into five emissions source classes that include combustion and dust dominated sources. These source classes exhibit trends in geochemical ratios including:

- BaP Ratio = benzo(a)pyrene (BaP), divided by the sum of BaP and retene (BaP + RET).
- UNS Ratio = sum of unsubstituted “parent” PACs (unsPAC), divided by the sum of the parent plus alkylated PACs (unsPAC + alkPAC).
- DBT/dbtPAC = dibenzothiophene (DBT), divided by the sum of parent and alkylated thiophenes (dbtPAC).
- DBT Ratio = total dibenzothiophenes (dbtPAC), divided by total PACs (totPAC).

Metals ratios (e.g. vanadium to aluminum)

After classification by type, the PAC and metals data were spatially interpolated (e.g. see Figure) and contaminant loadings to the regional environment quantified for comparison to previous studies [e.g. Manzano et al. 2016].

We conclude that previous studies have over-estimated environmental loadings of PACs, their spatial extent, and direction of their trend over time. These differences are attributed to the use of arithmetic rather than geometric spatial averaging, use of an arbitrary location (AR6) to determine the regional extent of metals and PAC deposition, and because previous studies neglected to account for metals and PACs being deposited from non-oil sands sources [Peters et al. 1995]. While oil sands operators continue to reduce their emissions intensity, our work supports the emerging consensus that mitigating fugitive emissions from petroleum coke stockpiles represents the greatest opportunity to reduce environmental loadings of PACs in the Athabasca Oil Sands Region.

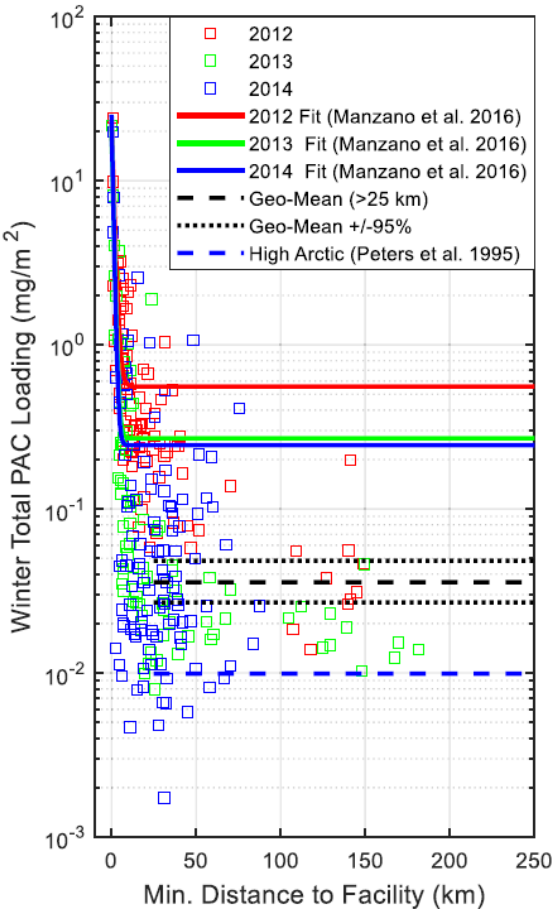


Figure: Wintertime total polycyclic aromatic compounds (PAC) loadings as a function of distance to the nearest oil sands facility.

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Simulation of monsoon low pressure system and its associated rainfall over Bangladesh using WRF Model

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Abstract

Due to its geographical position, Bangladesh experiences the highest amount of monsoon rainfall among SAARC regions and summer monsoon is the main rainy season that accounts approximately 72% of the annual rainfall in the country. In this study, an attempt had been made to simulate the monsoon low pressure system and its associated rainfall events of 14–18 June 2011 using Weather Research and Forecasting (WRF) model. The WRF model (version: 3.8) was run in a single domain of 10 km horizontal resolution. To select the best cumulus physics scheme, a sensitivity test was done using different station-wise values of mean sea level pressure, temperature, and relative humidity for the Kain-Fritsch (new Eta) Scheme, the Betts-Miller-Janjic Scheme and the Grell-Freitas ensemble Scheme. The resulting simulations were then compared with observations made by the Bangladesh Meteorological Department (BMD) and the India Meteorological Department (IMD).

Finally, the Kain-Fritsch (new Eta) scheme was selected as the best cumulus scheme for further simulation. The model was run for 24-h, 48-h, 72-h and 96-h using The National Centre for Environmental Prediction (NCEP) high-resolution Global Final (FNL) Analysis 6-hourly data using initial and lateral boundary conditions. The model performance was then evaluated analysing Mean Sea Level Pressure (MSLP), Wind Pattern, Relative Humidity, Temperature, Relative Vorticity, Vertical Wind Shear and Rainfall Distribution. The model successfully captured the low-pressure system, initial condition, propagation, landfall time and location reasonably well. Even in 96-h prediction mode, the model successfully simulated the rainfall. Overall, the model simulated rainfall amount and associated areas compared well with the observed data by BMD and the Tropical Rainfall Measuring Mission (TRMM).

Keywords: Monsoon, Low pressure system, Rainfall

CFD simulation of atmospheric wind interaction with CO_2 direct air capture

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Abstract

With the growing concern about global warming, implementing strategies to mitigate the greenhouse gases in the atmosphere is of paramount importance. Direct air capture (DAC) is one of the promising technologies that can remove CO_2 from the atmosphere, aiding towards the goal of combating global warming. Generally, there are two types of DAC technologies, namely solid or liquid absorbent systems [Abdellah et al. 2024]. The latter is the focus of the current study. DAC technology is currently at a small and experimental scale, and scaling it up is faced with many technical, environmental, and design challenges. Computational Fluid Dynamics (CFD) is a useful tool to optimise and assess the potential for upscaling DAC units.

We use large eddy simulation (LES) to investigate the impacts of the atmospheric wind on the dispersion of residual CO_2 following its discharge from a DAC unit. OpenFOAM, an open-source CFD platform, was used to solve governing thermos-fluid equations, including continuity, momentum, and species transport equations. Simulations were performed for two scenarios including dispersion of low-CO_2 plume exiting a DAC unit in no wind (still air condition) and strong wind of 11m/s. For wind modelling, an atmospheric boundary layer was introduced using a power law profile as used in our previous studies investigating wind-buoyant plume interaction [Eftekharian et al. 2019]. Our model was validated against experimental data for the flow field inside and outside of the DAC unit. This includes validation for the airflow pressure drop associated with the packing fills inside the DAC unit and that for the interaction between wind and flow exiting the DAC unit outside the unit. The modelled behaviour of the bent-over low-CO_2 plume in the presence of wind suggests that the low-CO_2 plume exiting one unit may enter another adjacent DAC unit in a large-scale DAC farm. Moreover, under strong winds, part of the low-CO_2 plume may re-enter into the same DAC unit. Both these behaviours would impact the efficiency of the removal of CO_2 by the DAC system and will thus constitute important criteria for the optimum siting of DAC units.

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Development of hydrogen-based assessments of SSP scenarios

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Abstract

In many future emission pathways, the use of hydrogen technologies will replace other forms of fossil fuel use and thereby reduce our emissions of greenhouse gases. However, the potential warming caused by leakages of molecular hydrogen into the atmosphere has not been included in assessments of these pathways. Hydrogen contributes to global warming mainly by increasing tropospheric methane lifetimes. This study examines the potential warming triggered by emissions of molecular hydrogen in the context of future SSP projections. We have developed a hydrogen-coupled atmospheric box model, calibrated this to historical concentrations and emissions and created hydrogen concentration projections as well as the first projections of methane, carbon monoxide influenced by hydrogen in SSP scenarios. The addition of hydrogen in models results in higher concentrations of methane and higher anthropogenically induced warming. We have created assessments of the global effective radiative forcing response due to hydrogen emissions while also assessing the impact of hydrogen emissions in thousands of scenarios with perturbed emissions to determine atmospheric sensitivities to hydrogen. Additional warming due to hydrogen increases even as global concentrations of methane decrease. We find that the sensitivity of tropospheric hydroxyl is larger than the previously determined sensitivity to carbon monoxide and non-methane volatile organic chemicals. Complementing other recent studies, our results emphasise the need for more dedicated research into the overall effects of a hydrogen economy if leakages cannot be avoided. While some uses of hydrogen help to replace fossil fuels, the decision of whether to invest in renewable energy and storage technologies other than hydrogen should take the additional warming due to expected hydrogen leakage into account.

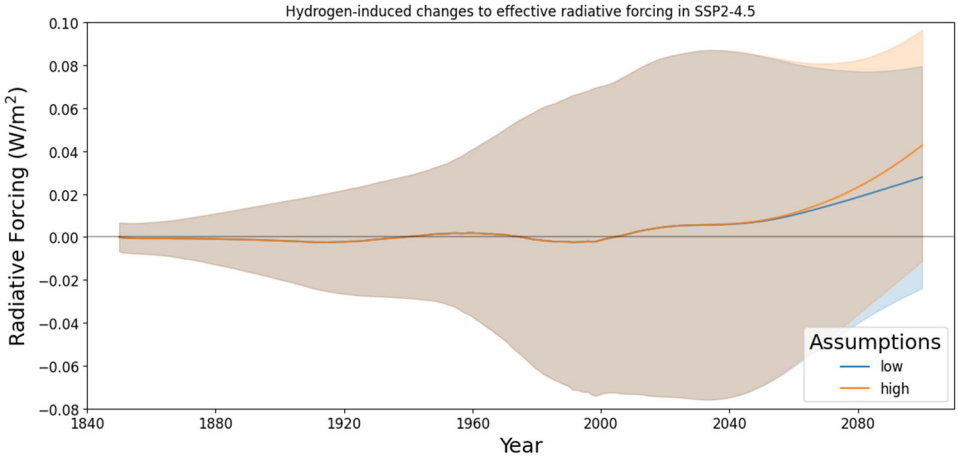


Fig. 1. Difference in effective radiative forcing between "Hydrogen" model and "No Hydrogen" model with `high' (Orange) and `low' (Blue) hydrogen assumptions in SSP2-4.5

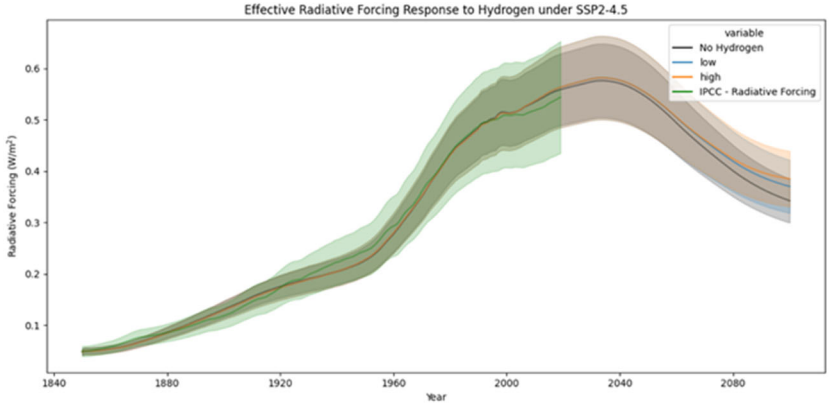


Fig. 2. Effective radiative forcing from CH$_4$ in `high' (Orange) and `low' (Blue) hydrogen scenarios for "Hydrogen" model version 1 and "No Hydrogen" (black) model version 2 in SSP2-4.5 (C). Historical ERF between 1850 and 2019 (green)

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Assessment of some organochlorine pesticides (OCPs) in the road dust from a metropolitan city in Nigeria: Akure as a case study

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Abstract

Environmental pollutants are on the rise as a result of various developments in major cities in terms of infrastructure development, road constructions, industrialization, and population shift from rural to urban areas in search of greener pastures, and industrial expansion of human activities. One of such persistent organic pollutants is organochlorine (OC) pesticides which is popularly used in the agriculture and the health sectors. Due to its numerous environmental and ecological and health risks, they have been banned by the Stockholm convection but are still in use in some developing and underdeveloped nations across the globe. There is paucity of data on the concentration of OCPs in the City under investigation, hence the need to assess their concentrations in road dust. Samples were taken from seven different locations and analysed using standard methods. The following OC pesticides congeners - α-HCH, β-HCH, γ-HCH (Lindane), and δ-HCH, popularly called the hexachlorocyclohexane were analysed from the seven sampling locations coded. They are in the following range: BDL – 2.272 µg/kg for α-HCH, BDL – 10.080 µg/kg for β-HCH, 4.872 – 31.834 µg/kg for γ-Lindane, and BDL for δ-HCH. The concentration of α-HCH was below the detection limit for all sampling locations with the exception of the sampling location 4 (2.272 µg/kg). Lindane was detected from all the sampling locations with significant concentrations. The highest is from the sampling location 7 (SL 7) while the least is from the sampling location 5 (SL 5). For δ-HCH, the concentration is below the detection limit of the instrument for all the sampling locations. The highest ∑ HCHs is from the sampling location 7 (SL 7) (41.914 µg/kg) while the least is from the sampling location 3 (SL 3) (7.146 µg/kg). The order of increase of the HCHs is SL 7>SL 3> SL 2> SL 4> SL 6> SL 5> SL 1. The presence of lindane is predominant in the road dust samples which is capable of causing several environmental and human health problems

Key words: Organochlorine pesticides, Hexachlorocyclohexane, HCHs, Road Dust, Lindane

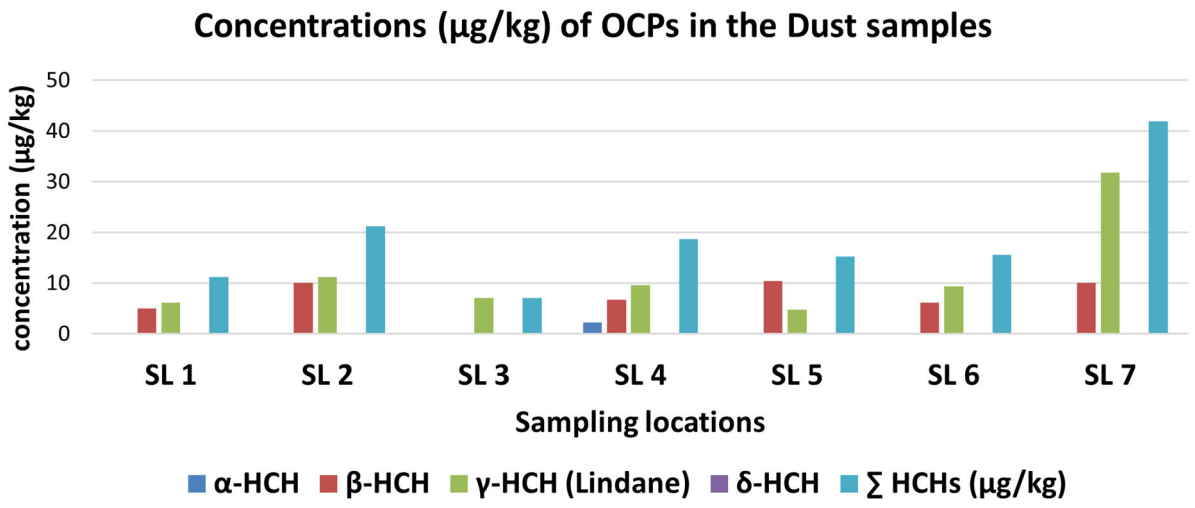


Figure: OCPs concentration (µg/kg) in the road dust samples from the locations.

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Long range transport of $PM_{2.5}$ sources in metropolitan Melbourne

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Abstract

A source apportionment study conducted in metropolitan Melbourne in 2021–2022 identified several regional sources of PM2.5. The regional sources were aged biomass burning, ammonium sulphate, nitrates and marine aerosol. Chemical composition, seasonal trends and wind analysis was enough to identify all sources except ammonium sulphate. Further investigation into the long-range transport of these sources was conducted to better understand their origins.

Four-day back trajectories were used to calculate the Potential Source Contribution Function (PSCF) probabilities for each regional source for 10 m arrival heights for each sample. Air mass back trajectories were calculated using the HYSPLIT model with GBL reanalysis meteorological files. PSCF probabilities were calculated and mapped using R statistical software and the openair package.

Long-range transport analysis highlighted significant marine influence on several regional sources: nitrates, marine aerosol and ammonium sulphate. Ammonium sulphate was also largely influenced by coal fired power stations located on the coast of NSW.

The aged biomass burning component of PM2.5, likely originating from residential wood heaters and hazard reduction burns, came from eastern Victoria, and as far as southern NSW and Tasmania.

Analysis of wood heater emissions impacts in Victoria using EPA $PM_{2.5}$ sensor network

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Abstract

This study investigates the impact of wood heater emissions on observed $PM_{2.5}$ concentrations in Victoria, Australia. Using a network of sensor measurements across Victoria, analysis of seasonal mean $PM_{2.5}$ concentrations shows winter season to be the most impacted by wood heater emissions followed by autumn season from planned burns. Among all the sites in the sensor network, Mansfield is the most impacted by wood heater emissions with winter mean concentrations peaking at 17 µg/m^3 compared to mean winter concentration of 12 µg/m^3 for the second largest impacted site in 2023. The number of hours recorded in the fair, poor and very poor air quality categories (excluding good) for Mansfield in 2021 to 2024 is consistently over 100 for each winter month (June – August). In terms of highest impacted hours of the day, the data shows the highest $PM_{2.5}$ levels are observed after 6 pm and before 9 am. This concentration trend is characteristic of WFH air emissions and attributed to when the emissions are generated and the local weather conditions of light winds, low temperatures and land features contribute to poor dispersion and build-up of $PM_{2.5}$ levels. Of all days, Saturdays record the highest $PM_{2.5}$ levels and impacts. This analysis shows that the sensor network data is an invaluable tool for analysing impacts of local sources around Victoria and should be enhanced.

Evaluating AQFx Model Accuracy: Insights from the Duck Creek Fire Case Study

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Abstract

The Duck Creek Fire occurred in the Pilliga Forest in northern New South Wales in December 2023, burning approximately 130,000 hectares of forest. On December 19, strong winds carried smoke from the fire, creating a blanket of haze over Sydney and the Hunter region, located about 500 kilometres from the fire. Air quality dropped to poor levels in Sydney's northwest, prompting health warnings for vulnerable populations. Although the smoke was expected to clear as wind patterns shifted, it caused considerable public health concerns during its peak.

The Duck Creek Fire presented an interesting case study to evaluate the performance of an updated version of the AQFx model which uses FirePixels, our new layered approach to derive emissions. The FirePixels methodology integrates a fuels-based bottom-up approach, a satellite-based top-down approach and a prognostic approach to deliver an optimal assessment of the area/fuel burnt, taking into account the accessibility and reliability of the diverse input data streams.

Our results showed that the 2-day outlook predicted the main smoke plume over the Hunter region, while the 0-day outlook accurately placed the plume over the Sydney metropolitan area, albeit with some underprediction.

Meteorological drivers of air quality in 2050: ventilation, washout and natural emissions

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Abstract

All natural emissions are driven by meteorological variables, which are likely to change in a future climate. Sea salt is wind driven; dust also depends on soil moisture and vegetation coverage; and biogenic hydrocarbons are vegetation, temperature and light dependent. Air quality processes depend on meteorology in terms of the rates of chemical reaction, rainout, dilution and transport.

We have used outputs from eight downscaled Global Climate Models (GCMs) in 2050 to drive natural emissions in the CSIRO Chemical Transport Model. The eight GCMs have been chosen to represent the plausible range of projected outcomes for Australia from a wider ensemble of CMIP6 models (Climate Model Intercomparison Project) [Grose et al. 2023]. The results tell us what the new baseline in air quality might look like in each of Australia's state and territory capitals, before we apply anthropogenic emission reduction measures. Therefore, it is the 'climate penalty' experiment that attributes how much air pollution in Australian cities could be caused by meteorological changes.

Note: smoke from bushfires is not included in this study.

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Effects of mechanical ventilation and Germicidal UV air disinfection devices on indoor air quality in an unoccupied setting

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Abstract

NOTE: Results are under embargo, do not disseminate. The abstract will be added at a later date.

Pollen–humidity interactions and sub-pollen particles from native Australian species

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Abstract

Pollinosis has been on a rising trend, with its number increasing globally [Cecchi et al. 2018]. Airborne pollen, which is the pollinosis trigger, can rupture into smaller fragments, known as Sub-pollen particles (SPPs), following exposure to moisture by the action of osmotic forces. SPPs can exacerbate allergic responses in sensitive individuals. There is a lack of clarity on the physical conditions that provoke rupturing of airborne pollen.

Numerous studies have attempted to elucidate conditions facilitating pollen rupturing [Caronni et al. 2021 etc.], with pollen hydration being a common causal factor for pollen rupturing. Pollen–humidity interactions are essentially a sub-set of pollen hydration and are not clearly understood despite their relevance considering the airborne traversal of pollen.

To gain insight into pollen-humidity interactions, our study exposed pollen grains to varying conditions of humidity (99%, 95%, 65% and 35% RH) inside a stainless-steel drum of 400L volume, based on TARDIS-Rotator [Johnson et al. 2016]. Information on the pollen grains is presented in Table 1.

Table 1. Information on pollen grains used in this work

Pollen type	Size range (µm)	Pollination method
Perennial ryegrass	24.8 – 30.4	Anemophily
Insignis pine	47.8 – 58.9	Anemophily
Early black wattle	37.6 – 42.3	Entomophily
Golden wattle	40.1 – 48.6	Entomophily

Aerosol instrumentation used in the work included particle sizers (Combustion DMS-500, 0.005 – 1 µm and GRIMM SMPS, 7.5 – 750 nm) and single particle fluorescence spectrometer (Wideband Integrated Bioaerosol Sensor WIBS-NEO, 0.5 – 30 µm). This combination of instruments enables the observation of aerosols ranging from 5 nm – 30 µm while also providing information on their fluorescent signals.

In our study, we observed pollen rupturing in cases of ryegrass and golden wattle when exposed to high humidity conditions (99% RH), causing sub-micronic SPPs in the fast particulate sizer (illustrated in the Figure) and unique fluorescent signals in the WIBS-NEO spectrometer. Ryegrass pollen ruptured at 95% RH, indicating that the dynamics of ryegrass pollen – humidity interactions demonstrate that pollen ruptures when exposed to high humidity (95-99% RH).

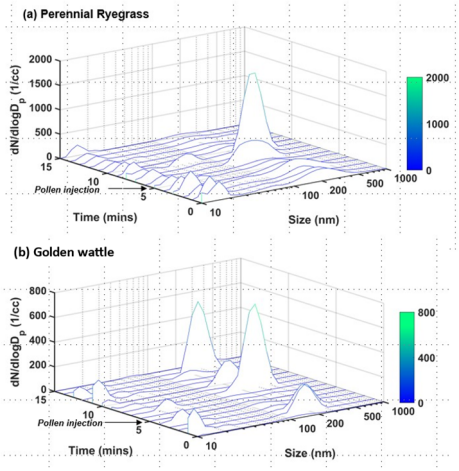


Figure: Aerosol size distribution of aerosols inside the drum following exposure to 99% RH

The novel method used in this work offers a unique opportunity to simulate pollen interactions in specific conditions during its atmospheric traversal. This study highlights the species-specific response to pollen-humidity interactions, as there was no pollen rupturing observed for Insignis pine and Early black wattle pollen. The rupturing of golden wattle pollen at very high humidity is important, considering the lack of information on the allergic potential of native Australian species and the cross-reactivity between Acacia and ryegrass allergens. The outcomes of this study would be helpful to studies from aerobiological and health perspectives.

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Atmospheric mercury monitoring at Kennaook/Cape Grim (KCG): Insight into concentration, variability and source identification

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Abstract

Atmospheric mercury is a bioaccumulative, toxic pollutant released from natural and anthropogenic sources subject to long-range transport through global air circulation. Continuous monitoring of atmospheric mercury is critical to assess whether the Minamata Convention has achieved its aims of reducing mercury in the environment and protecting human health. To date, atmospheric mercury has been sparsely measured in the Southern Hemisphere (SH), with shorter records available relative to the Northern Hemisphere (NH). Therefore, continuous monitoring of atmospheric mercury initiated in 2013 at the SH background site Kennaook/Cape Grim (KCG) in Tasmania, Australia, is particularly valuable. Instrumentation at the site was upgraded in 2017 to resolve measurement issues identified in the original data. In this study, we present an analysis of atmospheric gaseous elemental mercury (Hg^0) at KCG measured continuously with 5-min resolution from June 2017 to December 2022 using a Tekran-2537X instrument. We find the mean Hg^0 concentration at KCG over this period was 1.05 ± 0.05 ng m^{-3}, higher than the concentration previously reported for Cape Grim and more consistent with other estimates of the SH background. We find no clear seasonality in Hg^0 concentrations observed at KCG. Periods of enhanced Hg^0 at KCG are associated with increased wind speeds from the south to west, indicating that the Southern Ocean is likely an important source of Hg^0. We use coincident measurements of radon to classify the Hg^0 measurements by origin of air masses (baseline, remote, local and mainland). Our results underscore the importance of understanding mercury cycling in the Southern Ocean for interpreting the Southern Ocean as a dominant source of atmospheric mercury.

Atmospheric mercury in the Southern Ocean and Antarctic coast marine boundary layer during the 2024 MISO Voyage

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Abstract

The role of atmospheric processes in mercury cycling in the pristine Southern Ocean and Antarctic regions is important but incompletely understood, with limited observations relative to other global regions. The Multidisciplinary Investigations of the Southern Ocean (MISO) voyage, traversing 10,000 km over 60 days in early 2024, provided a unique opportunity to quantify spatial variations in mercury concentrations in the Southern Ocean and along the Antarctic coastline. Throughout MISO, ambient concentrations of gaseous elemental mercury (GEM) were continuously measured onboard the Australian research vessel RV Investigator, along with a suite of complementary atmospheric and meteorological measurements. During the voyage, air-sea interactions were additionally studied using shipboard mesocosm studies of natural seawaters collected at three process stations along the Antarctic coast transect and incubated for ~5 days each. These experiments are a novel approach to characterising air-sea interactions of trace gases (including GEM) with seawater biota, biogeochemistry and environmental conditions.

Preliminary results show little temporal or spatial variation in ambient concentrations in the open ocean segments of the voyage, with GEM similar to that observed at Australia's baseline station at Kennaook/Cape Grim, where observations of air masses from the Southern Ocean have been made for a decade. Along the Antarctic coastline however, concentrations of GEM are much more variable over time, with periods of enrichment and depletion observed. Of particular note was a depletion event observed in the D'Urville Sea. This event lasted 48 hours and coincided with elevated ozone and winds likely originating from the Antarctic plateau, which has a high capacity in summer to oxidise Hg(0) to Hg(2+).

Overall, these ambient measurements, along with small scale process studies, contribute to our understanding of sources, sinks and drivers of mercury over the pristine Southern Ocean and Antarctic regions which remain some of the most under sampled regions in the world.

The 2024 Antarctic ozone hole

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Abstract

The 2024 ozone hole developed in earnest in mid- to late-August and reached a peak of approximately 22.4 million km^2 on 28 September (see Figure). The development of the ozone hole in 2024 was about two weeks later than previous recent years, with the peak area and deficit values being below those of the large ozone holes from the last 4-years, while the daily minima metric was generally higher than recent years. The main cause for this was a considerably warmer low- to mid-stratosphere during much of July, August and September due to an increased amount of heat-flux towards the pole. September into October saw some wave activity and distortion of the ozone hole/polar vortex, interspersed by periods of stability.

This presentation will give an update on 2024 Antarctic ozone hole season and how the 2024 ozone hole metrics compare to the historical metrics from the last 45 years of satellite measurement. Overall, the 2024 Antarctic ozone hole will rank 'middle of the pack' when compared to previous years.

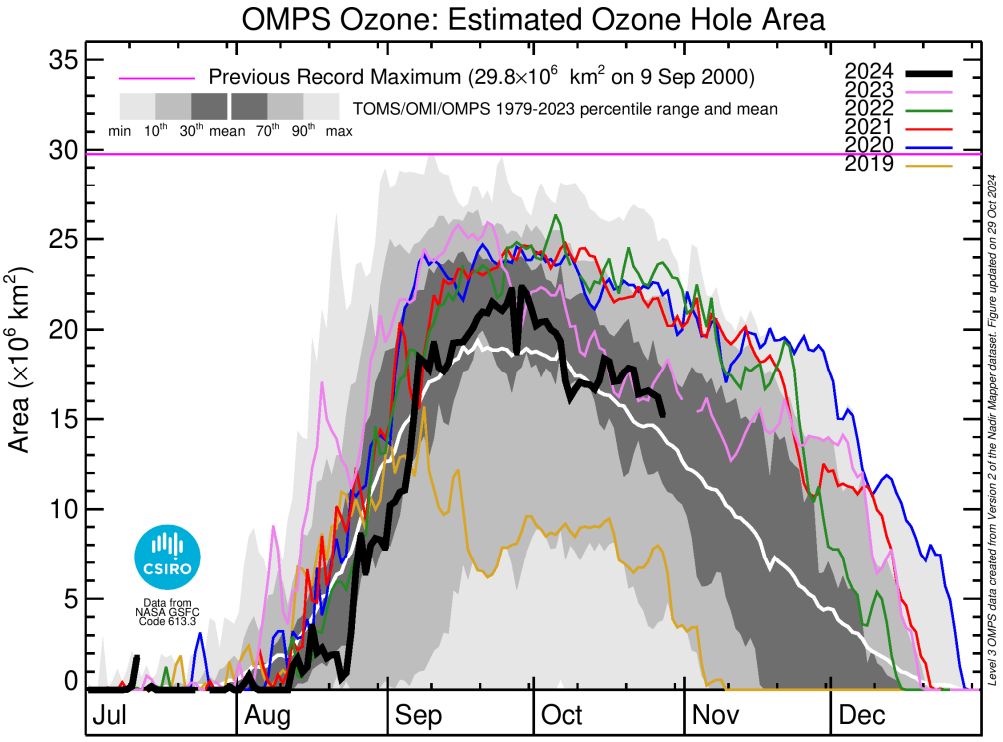


Figure: Daily Antarctic ozone hole area based on OMPS data as of 27 October 2024, along with the daily ozone hole area from the past 5-years.

Antarctic ozone depletion measured by Davis ozonesondes 2003–2024

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Abstract

We present long-term results from the ozonesonde program at the Australian Antarctic station, Davis (68.57° S 77.97° E), operated since 2003 in a partnership between the Australian Antarctic Division and the Bureau of Meteorology. Ozonesondes provide unique measurements of high resolution vertical profiles of ozone from the surface to the mid-stratosphere, along with the co-located temperature profiles. At Davis, the equipment and procedures used have remained unchanged, with the exception of updates of the radiosonde model in 2006 and in 2019, contributing greatly to the homogeneity of the dataset.

The annual cycle and interannual variability of ozone concentration at Davis over the period of record are given, including mean ozone loss rate at different time periods during winter and spring at each altitude in the depleted region. The greatest loss rates typically occur at altitudes between 40-80 hPa in early September, with minimum ozone being observed in late October. While the severity of the maximum Antarctic ozone loss in each year varies considerably with meteorological conditions in the Antarctic polar vortex, much less variability is observed in late winter and early spring before ozone loss reaches its greatest extent for the year. A statistically significant ozone recovery trend is able to be detected in this less variable late winter-early spring period.

We compare the results with those from a similar analysis using Aura-MLS overpass data (2004–2023), both at Davis and other Antarctic locations.

A modelling framework to assess the future prospects for Australia's agricultural methane emissions

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Abstract

The Australian agricultural sector produced approximately 13% of Australia's total greenhouse gas (GHG) emissions of which approximately 72% were caused by methane (CH_4) emissions [DCCEEW 2023; National Inventory Report 2021]. Around 97% of these CH_4 emissions came from enteric fermentation, and 66% from beef exports (i.e., from products consumed outside Australia). Australia has set national targets to reduce GHG emissions to 72-74% of 2005 levels by 2030 and achieve net-zero emissions by 2050 [UNFCCC 2021].

In this study we use an integrated assessment (IA) agricultural emissions model [Malley et al. 2021] to estimate Australian agricultural CH_4 emissions for the current day and 2050 based on a supply and demand of agricultural products consumed and traded with Australia. Based on a business-as-usual scenario CH_4 emissions are projected to rise to 2.2 Mt CH_4 (2030) and 2.5 Mt CH_4 (2050) compared to 2.0 Mt CH_4 (2019).

Several on-farm management interventions (improving feed digestibility, feed supplements, and higher meat value) were explored to determine their effect on emission reduction. Higher meat value (increasing the amount that each animal provides) results in the single largest CH_4 emission reduction of 15.9% (0.4 Mt CH_4) by 2050. Introducing a red seaweed (*Asparagopsis taxiformis*) feed supplement into ruminant's feed was the next best intervention resulting in an 8.6% reduction in emissions to 2.3 Mt CH_4 by 2050 followed by a higher grain diet (reducing emissions by 7.9% to 2.5 Mt CH_4) and finally, the 3-NOP feed supplement (reducing emissions by 1.9% to 2.3 Mt CH_4). A combination of management practices (the *Asparagopsis* supplement, higher meat value, and higher grain diets) result in a 29.4% (0.7 Mt CH_4) decrease in emissions by 2050.

Changes to Australia's relatively 'meat heavy' diet were also explored. If all Australians were to follow the government's recommended diet, CH_4 emissions for 2050 could be reduced by 9.6% to 2.3 Mt CH_4, compared to the modelled 2.5 Mt CH_4 were the average Australian diet to remain unchanged. If Australians followed the EAT-Lancet's recommended world health diet, CH_4 emissions would be reduced by 35.7% to 1.6 Mt CH_4, a 28.9% reduction compared to the healthy eating diet. A vegetarian diet would reduce emissions by 37.0%, and a vegan diet by 39.7% by 2050.

This study concludes by introducing a new modelling framework to estimate and evaluate CH_4 emissions from the Australian agricultural sector. This framework combines emission inventory data with atmospheric chemistry inverse modelling and satellite data assimilation to develop improved 'posterior' emissions. The framework also incorporates use of the ADOPT model [Kuehne et al. 2017] to estimate time to peak adoption and peak adoption rates to understand the barriers to implementing on-farm management CH_4 interventions. Together it is intended that this framework will help identify policy support to on-farm management that might enhance emission reductions as well as define the dietary transition that might be required to allow Australia's net zero targets to be realised.

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National to facility scale fugitive methane emissions estimation – an atmospheric science approach

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Abstract

Rapid anthropogenic methane abatement is a critical component for maintaining climate scenarios that stay within the aspirations of the Paris Agreement. The Global Methane Pledge was designed to motivate ambitious action, driving down anthropogenic methane emissions, and reaping the rewards of reduced warming within a decade, due to the relatively short (~10 yr) atmospheric lifetime of methane. However, effective emissions reduction action presupposes robust spatiotemporal knowledge of those emissions; a condition which is unlikely to be met in most regions globally. There are now many examples of discrepancies between 'bottom-up' inventory approaches to emissions estimation and that derived from atmospheric observations – the so-called 'top-down' approach. This presentation will articulate a vision for how Australia could draw on best international practices to grow our observational network to reduce uncertainties in methane emissions estimates.

We will assess the methane component of Australia's national inventory, to prioritise the areas of focus for an atmospheric science strategy to complement the national inventory. Relevant prioritisation criteria include i) the magnitude of emissions across a sector; ii) the estimated uncertainty in emission inventories for a sector; iii) the magnitude of emissions per facility; and iv) the spatial clustering of facilities (within or between sectors).

Further, we will describe how we believe a cascading approach to methane emissions estimation could be implemented with consistency and rigour from a national, through regional to facility scale assessments.

A backbone network of high-quality, ground-based *in situ* monitoring stations across the continent, tightly calibrated to the relevant World Meteorological Organisation (WMO) mole fraction scale would provide a strong constraint on continental/national scale assessments of methane emissions. Further, it would provide the appropriate boundary conditions to complement regional and facility scale emissions assessments. Such a network should include some sites with ground-based remote (column) sensing to act as a strong link to validate satellite data, which will increasingly be used to identify emissions hot spots.

Further monitoring, at regional to facility scale (possibly run by state-based authorities or facility operators) should also be calibrated to the WMO calibration scale but would not necessarily have the same precision demands as the background network to infer large fluxes within a region.

Atmospheric inverse modelling capability and capacity would need to grow to deliver timely emissions estimates from the new data streams and improve the robustness of Australia's methane emissions estimation.

This proposal offers significant co-benefits for improving emissions estimation for a range of trace gases, including anthropogenic CO_2 emissions, natural CO_2 fluxes (under a changing climate), nitrous oxide (N_2O) and hydrogen (H_2) given projected expansions in H_2 production as a green fuel source.

Finally, this proposal could form the basis for Australia to fulfill its commitment to the Global Greenhouse Gas Watch (G3W) initiative of the WMO, to which we are a signatory

Melbourne urban methane observation network: expansion and current capabilities

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Abstract

Over the past two years, we have significantly expanded the Melbourne urban methane observation network to gain a deeper understanding of the magnitude and temporal and spatial variability of methane emissions. We increased the number of *in situ* observation sites from one to five, strategically deploying methane isotope analysers at three key locations to characterize emission plumes from significant sources like water treatment plants and oil and gas refineries.

To complement these *in situ* measurements, we conducted targeted and opportunistic mobile surveys to identify potential emission sources that may not be captured by the fixed network. By integrating *in situ* and mobile observations with meteorological data and complementary tracer measurements at Aspendale, we aim to attribute emissions to specific sectors. Ultimately, these insights can be extrapolated to the entire observation network, leveraging the partial cross-capabilities at each site.

Here, we present initial results from our approach, combining *in situ* observations, mobile surveys, and isotope analysis to better understand urban methane emissions in Melbourne.

Quantifying methane emissions in Melbourne, Australia: Prior estimates and urban-scale inversions

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Abstract

Quantifying methane emissions is crucial for designing effective mitigation strategies and tracking progress in emission reductions. However, methane emission estimates remain highly uncertain, particularly in urban areas. This study quantifies methane emissions in Melbourne, Australia – an urban region with a complex spatial structure influenced by multiple emission sectors, including waste management, energy production, and nearby agricultural activities. In the absence of a national gridded methane inventory for Australia, we developed a gridded prior inventory by combining global datasets, such as the Emissions Database for Global Atmospheric Research (EDGAR), with national and regional data on sources like landfills, wastewater treatment facilities, and livestock. This approach generated emission patterns that more accurately reflect Melbourne's characteristics than those of the global dataset. Figure 1 compares the spatial distribution of the EDGAR global inventory with our prior estimates in the Melbourne region. The total annual methane emissions from all sources in the EDGAR global inventory for Victoria in 2021 was estimated at 1,134 kt [Monforti Ferrario et al. 2021; European Commission 2023], which is almost double that of the Australia's National Greenhouse Accounts [ANGA] 2021 estimate of 609 kt [ANGA 2023]. In contrast, our prior estimate suggests annual emissions in Victoria of around 900 kt. However, these prior estimates are uncertain and require validation through observational data and further refinement.

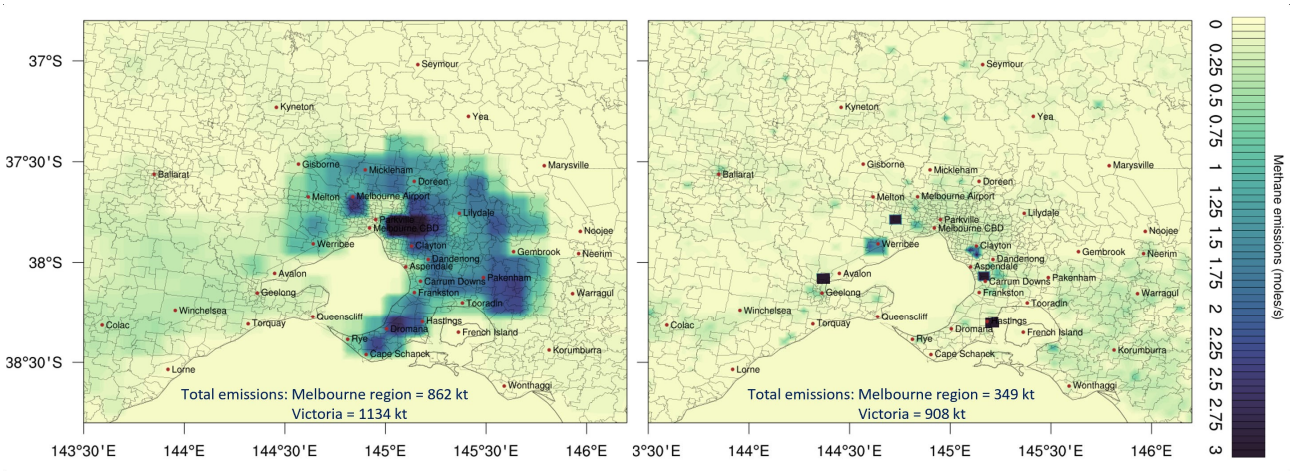


Figure 1: Spatial distribution of methane emissions (moles/s/modelling gridcell, the size of modelling gridcell is 9 km^2) in Melbourne region derived from the EDGAR global inventory (left) compared to our prior (right).

To develop more accurate emission inventories, observed methane mixing ratios are essential. Melbourne's methane *in situ* monitoring network has expanded from a single station to five *in situ* stations (shown in Figure 2). This study uses methane observations from the Kennaook/Cape Grim station and four *in situ* stations in Melbourne in 2023, supplemented with mobile drive-around measurements. Using a chemical transport model driven by prior emissions, we compared simulated methane levels with observations, highlighting the need for further model refinement to improve alignment with actual measurements. We then applied a synthesis inversion, using Bayes'

theorem, to determine scaling factors for emissions from various sectors as observed at the five stations. Additionally, a four-dimensional variational data assimilation inversion method was used to map the spatial distribution of emissions. We will present findings from the forward modelling comparison and both inversion techniques.

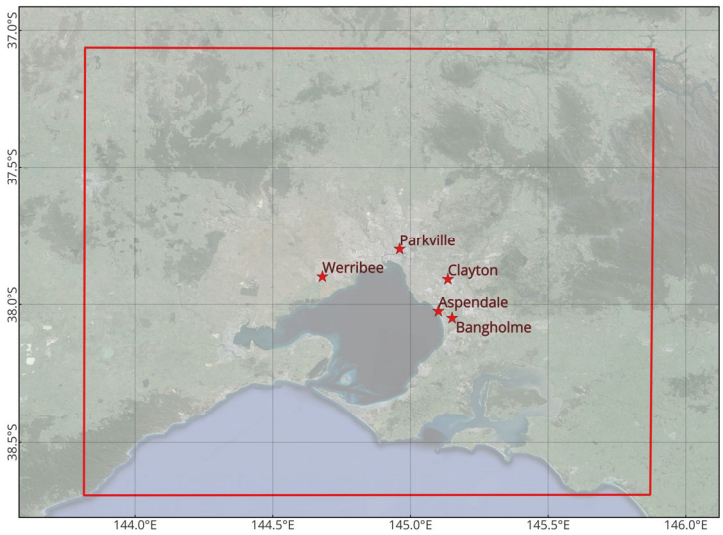


Figure 2: Location of current *in situ* methane measurement stations in Melbourne region.

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Quantification of methane emissions in the NSW coal mining region using TROPOMI data and atmospheric inversion

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Abstract

In Australia, coal mining is the second largest source of anthropogenic methane (CH_4) emissions. In particular, the New South Wales (NSW) coal mining emissions are estimated to be responsible for about 7% of the total anthropogenic methane emissions in Australia [DCCEEW 2024]. However, these emission estimates remain highly uncertain due to limited *in situ* measurements and the need for a comprehensive understanding of underlying processes. Hence, satellite measurements of CH_4, combined with atmospheric models, are used to gain additional insight into CH_4 sources. Here, we present progress on quantifying CH_4 emissions of NSW coal mining region using observations from the TROPOspheric Monitoring Instrument (TROPOMI) on the Sentinel-5P satellite and atmospheric inversion to retrieve emissions.

TROPOMI provides global daily coverage maps of CH_4 concentration since April 2018. Previous analyses of this dataset have identified surface artifacts [Barré et al. 2021] and strong cross-striping patterns [Sadavarte et al. 2021]. This study addresses these issues and applies a postprocessing filter to preserve high quality retrievals of the CH_4 column (see Figure).

Atmospheric inversion converting column information into surface emissions requires reliable wind field simulations. This study applies the Weather Research and Forecasting (WRF) model with a 2 km x 2 km spatial resolution in the NSW coal mining region. Preliminary results show a strong agreement between modelled and observed wind field data from the Bureau of Meteorology. In particular, the wind velocity comparison indicates a root mean square error (RMSE) < 3 m/s between modelled and observed datasets.

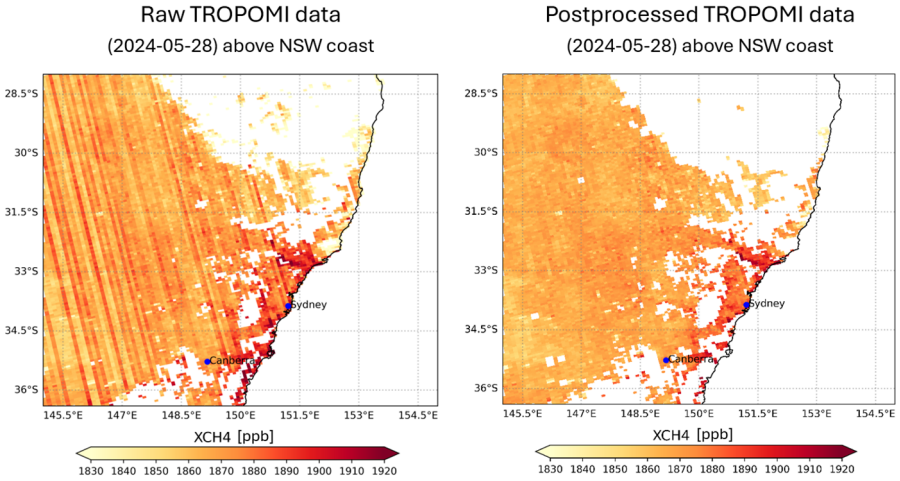


Figure: Raw TROPOMI dataset (left panel) compared with postprocessed TROPOMI dataset (right panel) from a single orbit over NSW on 2024-05-28. The postprocessing algorithm filters albedo artifacts, and striping pattern.

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Major sources of methane in Australia inferred from remote sensing observations

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Abstract

Methane (CH_4) is an important short-lived greenhouse gas that contributes to ~20% of today's global warming. Therefore, it is necessary to explore sources of CH_4 as a first step to identifying ways to reduce its emissions. This study used TROPOspheric Monitoring Instrument (TROPOMI) retrieved total column average dry air mole fractions of CH_4 to explore major sources of CH_4 in Australia during April 2018–April 2024. TROPOMI data suffers retrieval artefacts caused by surface albedo or scattering due to aerosols which makes difficult to identify real sources of CH_4. So, we apply strict data quality filters which include surface albedo and aerosol optical thickness (AOT) and observation threshold to reduce/remove the false positive contribution in CH_4 particularly over lakes and along the coastline. This study also explored spatial distribution of CH_4 over major Australian cities (i.e. Sydney, Brisbane, Melbourne, and Perth), over coal mines in Hunter Valley and Bowen Basin, and over agriculture and wetlands regions of Australia.

the Openmethane Platform: Status and Plans

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Abstract

Openmethane (https://openmethane.org) is a tool and platform to estimate and communicate Australia's methane emissions. The tool consists of a four-dimensional variational assimilation system (py4dvar) previously used for CO_2 and CO emissions. py4dvar uses a prior estimate (https://github.com/openmethane/openmethane-prior) including as much data as possible from the Australian National Greenhouse Gas Inventory combined with a range of spatial proxies. Atmospheric data are currently drawn from the TROPOMI satellite on the sentinel 5 Precursor platform. These two data sets are linked by the Community Multi-scale Air Quality (CMAQ) chemical transport model.

The platform consists of a website for interrogating and using model outputs. All input data and code are, or soon will be, publicly available.

This talk will discuss lessons learned in the first few months of operation. In particular, I will discuss our current estimates for fossil fuel emissions for the first half of 2023. I will also outline medium-term plans for integrating new data sets into the tool and upcoming features in the platform.

Australian sulfur hexafluoride emissions

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Abstract

Sulfur hexafluoride (SF_6) has an atmospheric lifetime of 3200 years and is the greenhouse gas with the highest known Global Warming Potential (GWP: 24300) over a 100-year time horizon. Signatory nations to the Kyoto Protocol (Australia for example) are obliged to report their SF_6 emissions annually to the United Nations Framework Convention on Climate Change (UNFCCC).

The major use of SF_6 globally and in Australia is as an insulating medium in high-voltage electrical equipment. SF_6 is also used in minor applications such as semi-conductor manufacture, magnesium metal production, optical surgery and as a tracer gas. The Australian government estimates Australian SF_6 emissions from industry-reported 'banks' of SF_6 in electrical equipment, applying UNFCCC-sanctioned or Australia-specific emission factors (EFs). Almost 90% of Australia's SF_6 emissions are from electrical equipment - gas insulated switchgear, transformers, circuit breakers - deployed in the national electricity generation and distribution systems. Australian SF_6 emissions for 2022 reported to the UNFCCC in 2024 were 6.7 tonnes (0.16 Mt CO_2-e).

Atmospheric observations of SF_6 at Kennaook/Cape Grim (since 2002, see Figure) are used with the UK Met Office's InTEM (Inversion Technique for Emissions Modelling) system and the NAME (Numerical Atmospheric-dispersion Modelling Environment) model to derive emissions from SE Australia. SE Australian emissions are also calculated by Inter-Species Correlation (ISC), using carbon monoxide (CO) measurements at Kennaook/Cape Grim as the emissions reference species. For both NAME-InTEM and ISC techniques, Australian emissions are estimated from SE Australian emissions by population scaling. For 2022, Australian SF_6 emissions were estimated at 28 tonnes (NAME-InTEM) and 20 tonnes (ISC), 3-4 times what has been reported to the UNFCCC. Possible causes of this discrepancy between 'bottom-up' and 'top-down' estimates of Australian SF_6 emissions are investigated. There are two wind farms (Bluff Point: 65 MW, Studland Bay: 75 MW) 2-14 km south of Kennaook/Cape Grim that deploy SF_6 in their high-voltage switch gear and circuit breakers. Their possible impact on SF_6 observations at Kennaook/Cape Grim is investigated.

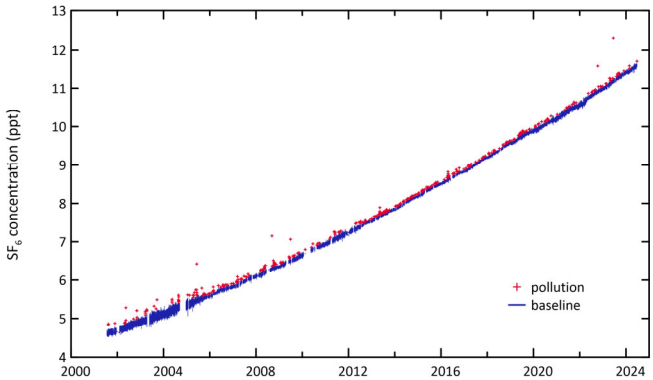


Figure: Atmospheric observations of sulfur hexafluoride (SF_6) at Kennaook/Cape Grim (since 2002). Red data are flagged pollution episodes and blue data are baseline data.

Australian emissions of perfluorocarbons

C. M. Trudinger[1*], B. L. Dunse[1], P. J. Fraser[1], A. J. Manning[2], P. B. Krummel[1] and B. Mitrevski[1]

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Abstract

Perfluorocarbons (PFCs), such as CF_4, C_2F_6 and C_3F_8, are potent greenhouse gases that are very long-lived in the atmosphere, with lifetimes on the order of thousands to tens of thousands of years. They are predominantly released to the atmosphere from aluminium production and semiconductor manufacture. PFCs are included in the Kyoto Protocol greenhouse gas basket. Emissions by signatories to the Kyoto Protocol are calculated using IPCC-approved 'bottom-up' methodologies and reported annually to the UNFCCC. Some countries, including the UK, Switzerland and Australia, also calculate PFC emissions using atmospheric observations and 'top-down' methods and compare these estimates with the bottom-up estimates.

PFCs have been measured at Kennaook/Cape Grim since 2004 and at Aspendale since 2006. In this study, we use atmospheric observations of PFCs at Kennaook/Cape Grim and Aspendale with the UK Met Office's InTEM inversion system and the NAME dispersion model to infer emissions of PFCs in SE Australia. We also use observations from Kennaook/Cape Grim with CSIRO's The Air Pollution Model (TAPM) to infer emissions. Semiconductors are not manufactured in Australia, so the inferred PFC emissions are due to aluminium production alone; SE Australian emission estimates can therefore be scaled by aluminium production to give estimates for all of Australia. We compare PFC emissions estimated using these top-down approaches with the estimates reported to the UNFCCC by the Australian government.

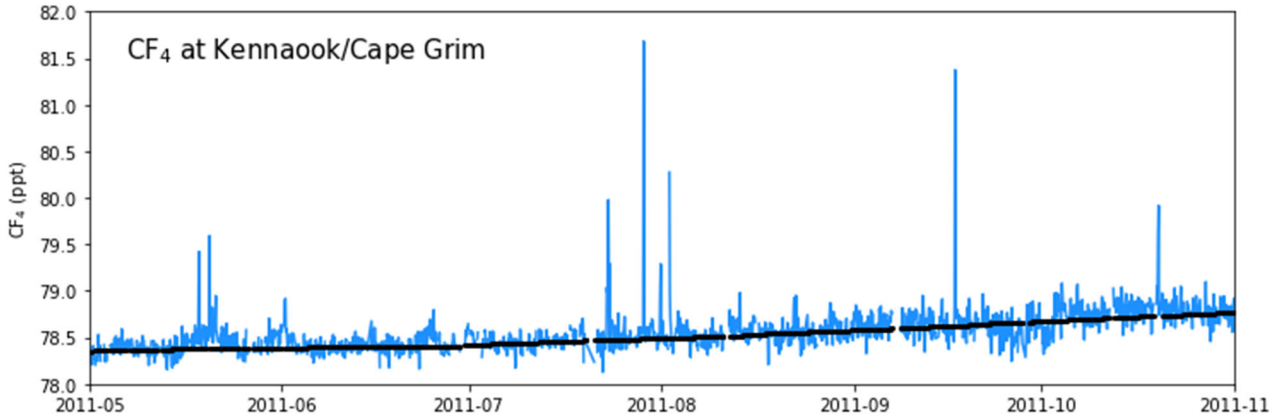


Figure: PFC-14 (CF_4) observations at Kennaook/Cape Grim for six months in 2011 (blue), showing several pollution events due to emissions from nearby aluminium smelters. The baseline curve is shown in black.

Towards an accurate global model of HFO-1234ze degradation

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Abstract

The Montreal Protocol (1988) resulted in the phase out of the first- and second-generation refrigerants (chlorofluorocarbons and hydrochlorofluorocarbons) which caused significant ozone depletion. In 2016, the Kigali Amendment ordered the phase out of the third generation (hydrofluorocarbons, HFCs) due to their high global warming potential (GWP). The leading fourth generation of refrigerants are the hydrofluoroolefins (HFOs) that possess a carbon-carbon double bond which makes them prone to oxidation by hydroxyl radicals in the troposphere. Thus, their atmospheric lifetime is short, and they are considered to have a low GWP. However, recent work has shown that these HFOs can degrade into substances with high GWP and long atmospheric lifetimes, or substances that bioaccumulate [Pérez-Peña et al. 2023; Long et al. 2022]. As a result, their continued use in the place of HFCs may have unpredicted environmental consequences. My work uses atmospheric models to investigate the degradation and transport of HFOs and their decomposition products. By supporting experiments and bridging the gap between laboratory research and atmospheric modelling, we aim to build a clear picture of the impacts that these new refrigerants have on the environment. This talk will present results from box modelling of new HFO chemistry, and ongoing work to build an up to date global 3-D transport model for their distribution [Sommariva et al. 2020].

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Developments in greenhouse gas measurements and modelling in Aotearoa New Zealand

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Abstract

Aotearoa New Zealand's measurement, modelling and research programmes are expanding. Here, we will present an overview and newest results of the main projects that contributed to this expansion: CarbonWatch-NZ, the New Zealand-NASA Catalyst project and MethaneSAT, as well as the implication of these research programmes on a global scale.

CarbonWatch-NZ utilizes inverse modelling (i.e., top-down methods) to estimate New Zealand's carbon uptake and emissions on a national, regional and urban scale. Current greenhouse gas reduction strategies rely on budget estimates that are evaluated with inventory methods (i.e., bottom-up methods). The most recent Intergovernmental Panel on Climate Change (IPCC) guidelines refinement recommends using independent methods, such as atmospheric inverse models as a tool complementary to bottom-up methods, when estimating greenhouse gas budgets. Our inverse-modelling results suggest a stronger carbon dioxide (CO_2) uptake for the last decade relative to bottom-up estimates, potentially pointing to a more efficient carbon uptake capability of indigenous forests. In contrast to CO_2 our national scale methane (CH_4) inversion suggests a good agreement with bottom-up estimates. Here, we will discuss the importance of these results, present our measurement and modelling system, as well as future plans.

The objective of the New Zealand-NASA Catalyst project is to demonstrate that NASA's Orbiting Carbon Observatory-2 (OCO-2) and OCO-3 satellites can effectively estimate CO_2 fluxes in smaller countries, using New Zealand as an ideal testing ground due to our geographic isolation, dense ground based observing network, and advanced national-scale modelling capability. Improving CO_2 flux estimates based on satellite data for smaller-scale countries is a challenging task. These challenges include the limitations of satellite-based data in terms of spatial and temporal resolution, measurement biases, source attribution, as well as uncertainties related to atmospheric transport models. Here, we will present results and future plans of our collaborative research project with NASA's Jet Propulsion Laboratory (JPL) to enhance the accuracy of satellite top-down CO_2 flux estimates and provide critical advancements in satellite validation, setting the stage for a more comprehensive and reliable national-scale emissions verification system that can be applied to smaller countries worldwide.

MethaneSAT is a recently launched novel satellite designed to detect targeted CH_4 emissions. It was developed as a CH_4 reduction strategy by detecting CH_4 emissions from oil and gas leaks (i.e., point sources), globally. The New Zealand team's aim is to develop an agricultural CH_4 emission (i.e., diffuse sources) estimation capability using data from the satellite. MethaneSAT is an American-New Zealand partnership (Environmental Defense Fund (EDF), MethaneSAT LLC and the New Zealand government) that includes collaborative work between NIWA and Harvard University. It is estimated that 85% of New Zealand's CH_4

emissions are from agricultural processes which enables unique testing opportunities. Here, we will discuss the importance of this satellite mission and present modelled and measured CH_4 scans for agricultural targets across New Zealand.

Resolving Auckland's CO_2 budget: urban biosphere, diurnal cycle and high-resolution modelling

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Abstract

New Zealand has set ambitious greenhouse gas emission reduction targets, and its largest city, Auckland, will play a key role in achieving those reductions as it houses over 25% of the national population. To meet reduction targets, it is vital to understand current emissions and monitor the impact of implemented policies. For these reasons, we are developing the first observation-constrained, urban-scale emission estimation framework for Auckland. This work is part of the New Zealand CarbonWatch-NZ project that also includes emission estimation at the national scale.

A new atmospheric observation network is operated in and around Auckland to monitor carbon dioxide (CO_2) concentrations, in addition to other tracers, including isotopes of CO_2 ($^{14}CO_2$, $^{13}CO_2$, $CO^{18}O$), carbon monoxide, carbonyl sulfide (COS) and methane. Information from these atmospheric measurements will be used to estimate both anthropogenic and biospheric fluxes in Auckland. Estimating both separately is important for Auckland: a green city with a year-round growing season. High-resolution bottom-up emission estimates have been developed specifically for anthropogenic (Mahuika-Auckland [Keller et al. 2023]) and biospheric (UrbanVPRM) CO_2 fluxes in Auckland. We combine these bottom-up estimates and atmospheric CO_2 observations in an inverse emission estimation framework that includes atmospheric transport simulations with the Lagrangian NAME III model [Jones et al. 2007], driven by meteorological data from the 333-m horizontal resolution Auckland Numerical Weather Prediction model [Safaei Pirooz et al. 2021]. Use of such high-resolution meteorological data is unique and helps interpret atmospheric measurements in the heterogeneous landscape of Auckland, especially when combined with our high-resolution bottom-up estimates. Finally, we explore the value and difficulties of including the full diurnal cycle of CO_2 data. The resulting emission product will be a policy-relevant instrument that can help evaluate and meet New Zealand's emission reduction targets.

First results from a synthetic data experiment, based only on CO_2, indicate a limited ability to separate biospheric from anthropogenic fluxes, and including nighttime observations provides valuable constraints on nighttime fluxes and morning rush hour. Future work, funded through CarbonWatch-Urban, will focus on incorporating additional tracers, as well as start the use of real-world data. Ideally, lessons learned for Auckland will be translated to emission estimates for other New Zealand cities.

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Coastal wetland greenhouse gas dynamics under changing inundation regimes

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Abstract

Coastal wetland ecosystems are long-term carbon sinks capable of sequestering carbon for millennia (termed 'blue carbon'). Consequently, their preservation and restoration are increasingly popular climate change mitigation solutions. However, for coastal wetlands to have a net cooling effect on the atmosphere, their carbon storage must exceed their emissions. Also, the conditions that facilitate sequestration of carbon dioxide (CO_2) may also favour the production of potent greenhouse gases (GHGs), including methane (CH_4) and nitrous oxide (N_2O). These gases may be modulated by several interconnected environmental variables, including salinity, temperature, and water-level dynamics. While coastal wetland CO_2 emissions are well understood globally, little research has been conducted on the drivers of CH_4 and N_2O, particularly within the Australian context. My honours work measuring CO_2, CH_4 and N_2O fluxes across a tidal inundation gradient showed they were highly dynamic, showing distinct differences between vegetation communities, and in some cases, switching seasonally between source and sink. Also, the selected physicochemical parameters poorly described variation in sediment GHG fluxes. In summer 2024, sediment GHG fluxes were measured at a low-salinity coastal wetland (Everlasting Swamp, Northern NSW) which has been identified as a potential future restoration site, but it is unclear how tidal reinstatement will impact the radiative balance of the wetland. It is also unclear how the radiative balance of coastal wetlands will respond to sea-level rise. My research aims to answer the following questions: 1) How do intertidal-supratidal wetland GHG fluxes (CO_2, CH_4, and N_2O) vary across physicochemical gradients? 2) How do intertidal-supratidal wetland GHG fluxes (CO_2, CH_4, and N_2O) vary at the estuary scale? 3) Can coastal wetland GHG fluxes be projected under changing inundation regimes? I will present results from my honours work, preliminary results from the Everlasting Swamp case study as well as outline a general plan for my PhD research.

New measurements characterize the 1940's CO_2 slowdown and extend the Kennaook/Cape Grim record of N_2O isotopes 2005–2023

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Abstract

New measurements of ice core samples from Law Dome significantly increase the temporal resolution of records characterizing the slowdown in atmospheric CO_2 growth rate between 1938–1947. CO_2 growth rate decreased by 0.3 ppm yr^{-1} to a minimum of 0.15 ppm yr^{-1}. Possible causes of the CO_2 slowdown are reviewed in the context of new $\delta^{13}C$-CO_2 data spanning the same time period. Bottom-up estimates of CO_2 fluxes are also evaluated using a 14-box model of the carbon cycle.

All CSIRO ice and firn $\delta^{13}C$-CO_2 (and $\delta^{18}O$-CO_2) data spanning the last millennium were updated with a revised link to VPDB, as well as new firn effective ages and isotopic diffusion corrections accounting for artefacts due to gas transport in firn. The updated data are compiled and submitted as forcing data for the Climate Model Intercomparison Project (CMIP) 7.

In early 2024, new measurements of the Kennaook/Cape Grim Air Archive (CGAA) extended the record of N_2O stable isotope data from 2005. N_2O concentration increased by 18 ppb during the period 2005-2023. The increase was accompanied by a -0.8 ‰ decrease in $\delta^{15}N$-N_2O, a continuation of the trend identified since the 1940's that is attributed to an invigorated nitrogen cycle in agricultural environments resulting from widespread use of fertilizers. Some CGAA samples collected prior to 2005 were also measured to verify calibration procedures and check overlap with existing data. N_2O concentration and $\delta^{15}N$-N_2O trends are well-replicated back to 1978, but the trend previously resolved in $\delta^{18}O$-N_2O was not. We ask whether N_2O (or its stable isotopes) is a potential tracer of variations in stratospheric-tropospheric exchange, including an analysis of the new data for seasonal trends.

40+ years of $\delta^{13}C$-CO_2 and $\delta^{18}O$-CO_2 measurements of atmospheric air at Kennaook/Cape Grim and other sites

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Abstract

For more than 40 years, CSIRO has measured the concentration and stable carbon and oxygen isotopic composition of atmospheric CO_2 at Kennaook/Cape Grim, Tasmania, and at several global sites. During that time, in addition to measuring ambient air, air collected during different Antarctic measurement programs has allowed us to produce a millennium record of atmospheric CO_2 isotopes.

Various analytical and calibration issues have been encountered and addressed over this long period which ensures that all measurements are traceable to the international VPDB-CO_2 scale. While the final records are not fully resolved, the current state of the records will be discussed with comparison to other, similar, records produced by other laboratories.

Reduced anthropogenic forcing of climate and ocean acidification between 2009 and 2015

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Abstract

A major anomaly in the global carbon cycle, between 2009 and 2015, is detected in co-measurements of carbon dioxide (CO_2) concentration and stable isotope ratio in baseline air collected since 1992 at globally distributed surface sites. The anomaly is evident as a departure from smooth functions that describe the three decade CO_2 concentration increase and isotopic decrease attributable to fossil fuel emissions. It coincides with anomalous behaviour in the CO_2 interhemispheric difference [Francey et al. in press]. On an annual basis, it also coincides with an anomaly in the lagged response to ENSO forcing of tropical air-surface exchange.

In the Southern Hemisphere, where air-surface exchange is dominated by upper troposphere interhemispheric exchange of fossil CO_2 from the Northern Hemisphere, annual residuals from the exponential growth are uniform over 71° of latitude. The anomaly is most precisely measured and validated at Kennaook/Cape Grim, where isotopic data exclude a significant air-sea exchange contribution. The Southern Hemisphere background data closely track variations in the Northern Hemisphere fossil emissions and their interhemispheric exchange in near real time. Interannual variation in ENSO forcing of equatorial air-surface exchange has minimal contribution from north of the ITCZ. Corrected for ENSO variation, Fig. 1 shows just two significant multi-year anomalies emerge over the three decades, 2009–2015, also the early 1992–1995 reduction attributed to Pinatubo ejecta (with isotope data indicating a significant terrestrial biosphere contribution).

Anomalies in interhemispheric transport indices [Frederiksen and Francey 2018] coincide with the onset and end of the 2009–2015 CO_2 anomaly. Variations in emissions due to the GFC and the anticipation of improved national carbon accounting, are possible contributors.

We conclude that the 2009-2015 anomaly provides a unique opportunity to improve inverse modelling of the national emission estimates by global carbon budgets that fail to report the anomaly [e.g. Freidlingstein et al. 2021]. Recent inversion studies of CO_2 growth rate during the 2009-2015 period are identified, where atmospheric transport data indicate possible alternate explanations [e.g. Peters et al. (2012), Birner et al. 2023; Schuh et al. 2020; Gruber et al. 2023].

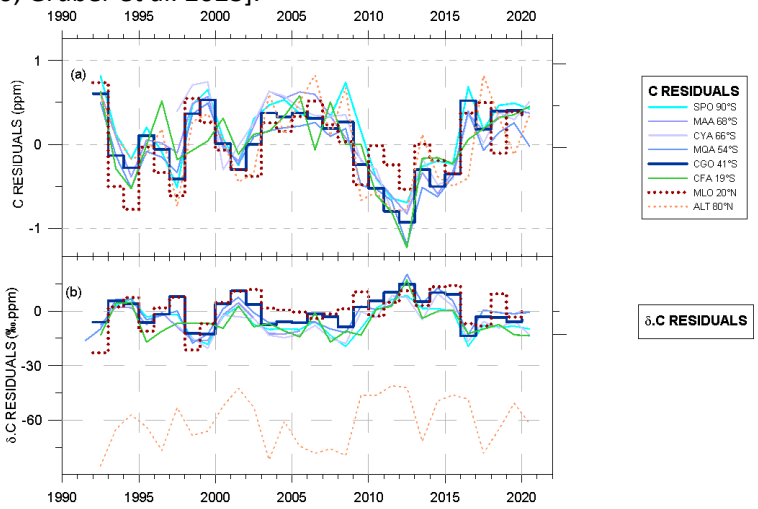


Fig. 1. (a) Comparison of the annual C residuals (C_{res}) in ppm at CGO (blue), MLO (red dash), and ALT (purple dot) on the left axis, with ENSO variation, using SOI* = SOI for the previous year, (black line, right axis).

(b). Variability of C* (left axis), the C residual adjusted for SOI influence using the slope of a linear regression through CGO C residuals and SOI* variation. Detrended global terrestrial (green) and ocean (light blue) flux interannual variations (right axis) with units scaled from the observed decadal trend).

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Introducing total column measurements of CO_2, CH_4 and CO at Kennaook/Cape Grim

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Abstract

Total column measurements of atmospheric trace gases complement *in situ* measurements – they integrate and average mole fractions through the full depth of the atmosphere and are less influenced by local and regional effects in the boundary layer. The rapid expansion of satellite-based total column measurements of greenhouse gases in recent years has provided global mapping of their total column amounts with a repeat time of the order of days and a spatial resolution of the order of kilometres. Total column mole fractions provide a valuable extension to global *in situ* measurements such as those in Global Atmospheric Watch (GAW) and Advanced Global Atmospheric Gases Experiment (AGAGE) networks, and provide additional, independent constraints on global inverse models of GHG sources and sinks.

To compare and combine total column and *in situ* measurements in models, both must be linked to the same calibration scales to avoid spurious biases. Ground based total column measurements provide this link for satellite measurements, historically through the Total Carbon Column Observing Network (TCCON) at around 30 fixed global sites, and more recently through an expanding network of lower resolution, mobile instrumentation, mainly the Cooperative Carbon Column Observing Network (COCCON).

Both TCCON and COCCON use solar Fourier Transform Spectroscopy (FTS) instruments which measure the near infrared spectrum of the direct solar beam from which trace gas amounts can be retrieved. These instruments require weather protection and/or significant laboratory space and have to date been considered impractical for implementation at Kennaook/Cape Grim (KCG) for reasons of severe weather exposure and laboratory space requirements. At the University of Wollongong, we have developed a compact mobile FTS system coupled by fibre-optic cable to a weatherproof solar tracker which allows only the tracker to operate on the roof in all weather, with the compact FTS located indoors in a laboratory below. This system enables total column measurements at KCG for the first time.

We installed a prototype system at KCG in early October 2024 as a pilot study to assess data quantity and quality obtainable and the value and practicality of a future long-term programme at Kennaook/Cape Grim. The system is planned to operate over the 2024–2025 summer for initially up to one year. In this talk we present the principles and instrument for the measurements, the first month of data, and comparisons to the established *in situ* measurements.

Improving the Kennaook/Cape Grim *in situ* CO_2, CH_4, N_2O and CO records

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Abstract

Greenhouse gas (GHG) monitoring networks are essential for tracking both global and regional long-term trends in atmospheric GHG concentrations. However, the use of these measurements in inversion based flux quantification and source/sink attribution requires that gradients between sites are driven by temporal and spatial changes in GHG sources and sinks, not by measurement biases and errors. Consequently, great care is taken to minimise and characterise any such issues.

Here we outline work conducted over the last year to improve the calibration and water corrections applied to the Kennaook/Cape Grim CO_2, CH_4, CO and N_2O records reducing instrumental biases and errors. This work builds on the on-going CRDS/FTIR side-by-side comparison, CSIRO and NOAA flask vs. *in situ* comparisons and the CSIRO network cylinder intercomparison program (ICP).

In particular we will focus on:

- The updated water corrections applied to the CRDS CO_2 and CH_4 records showing their consistency between years and quantifying the effect of changes in these over time.
- Further investigation of the N_2O and CO CRDS water correction in particular its response to changes in N_2O concentration and the potential for water correction driven biases.
- The improvement in calibration, non-linearity and drift correction for the CRDS CO record and its effect on FTIR and flask comparisons and the ICP data.
- Preliminary work comparing dried and undried ambient air measurements made with the FTIR and CRDS.

The Northern Territory Baseline Air Pollution Station at Gunn Point, Darwin: past, present and future

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Abstract

The Northern Territory Baseline Air Pollution Station (NTBAPS) is CSIRO's key baseline air pollution facility for northern Australia. The NTBAPS was established by the CSIRO in 2010 at a site on the Gunn Point peninsula, 30 km northeast of Darwin. Improvements to data quality, particularly in recent years, have enhanced the record of important air pollution and climate related parameters.

The region is characterised by tropical savanna- a mixture of grasslands and sparse trees. There are also a diverse range of aquatic habitats from freshwater wetlands to mangrove coastlines. The airmass passing over the NT BAPS has a distinct seasonality. Dry season south-easterly winds in the winter have a large continental fetch and pass over many wetland habitats on their way to the facility, whereas monsoonal north-westerlies bring an oceanic airmass from the Arafura Sea (and beyond) in the summer months.

The region is strongly impacted by biomass burning in the Dry to early Wet season, with over 400 000 km^2 of tropical savannah burn annually [Meyer et al. 2012], and the associated emissions dominate aerosol and gaseous concentrations during these times. Indeed, since the early 2000s there has been worsening impact on Darwin's air quality during the early Dry season due to changes in these burning activities [Jones et al. 2022].

There are four continuous measurement programs at the NT BAPS monitoring greenhouse gases, aerosols, radon, and gaseous elemental mercury. An adjacent weather station also provides meteorology. Historical aspects of the facility and new additions will be highlighted, recent data from the measurement programs will be presented and discussed, and plans for the facility will be proposed.

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Recent developments and highlights from GASLAB and related projects

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Abstract

GASLAB (or Global Atmospheric Sampling LABoratory) has been operating since the early 1990s, measuring Greenhouse Gases (GHG) and other trace gases changes within our atmosphere. Throughout the years, instrumentation and analytical techniques have stayed largely the same, with some adaptation to include gases such as sulfur hexafluoride (SF_6) and upgrading equipment. The laboratory facilitates multiple projects; measuring flask and ice core samples across the globe, establishing multiple *in situ* monitoring stations across Australia and Antarctica, and maintaining the Air Archive filled at Kennaook/Cape Grim. This talk intends to briefly describe the main functions of GASLAB and developments, as well as discuss the laboratory's achievements in precision, intercomparison, and long-term data analysis of the global greenhouse gas trends.

Expanding the use of top-down methods for Australian greenhouse gas emissions accounting

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Abstract

Over the last two years, various groups within the Australian Composition & Chemistry Observations & Modelling (ACCOM) community have been working to expand the use of top-down atmospheric methods for quantifying Australia's greenhouse gas emissions. This has led to new observational programs operating at facility-to-regional scales, and inverse modelling of methane emissions up to the national scale [Rayner 2024]. A proposal to expand the Australian Greenhouse Gas Observing Network (AGGON) with 12 or more new *in situ* monitoring sites [ACC 2023; Rayner et al. 2023; Figure] has been presented to government and associated entities and is under consideration.

This presentation will describe some of the developments in this space over the last 12 months. The focus will be on the AGGON proposal, the 2024 renewal of Australia's National Science and Research Priorities [DISR 2024], recommendations made in the Climate Change Authority's review of the National Energy and Greenhouse Reporting (NGER) scheme [CCA 2023], and the government's response to those recommendations [DCCEEW 2024].

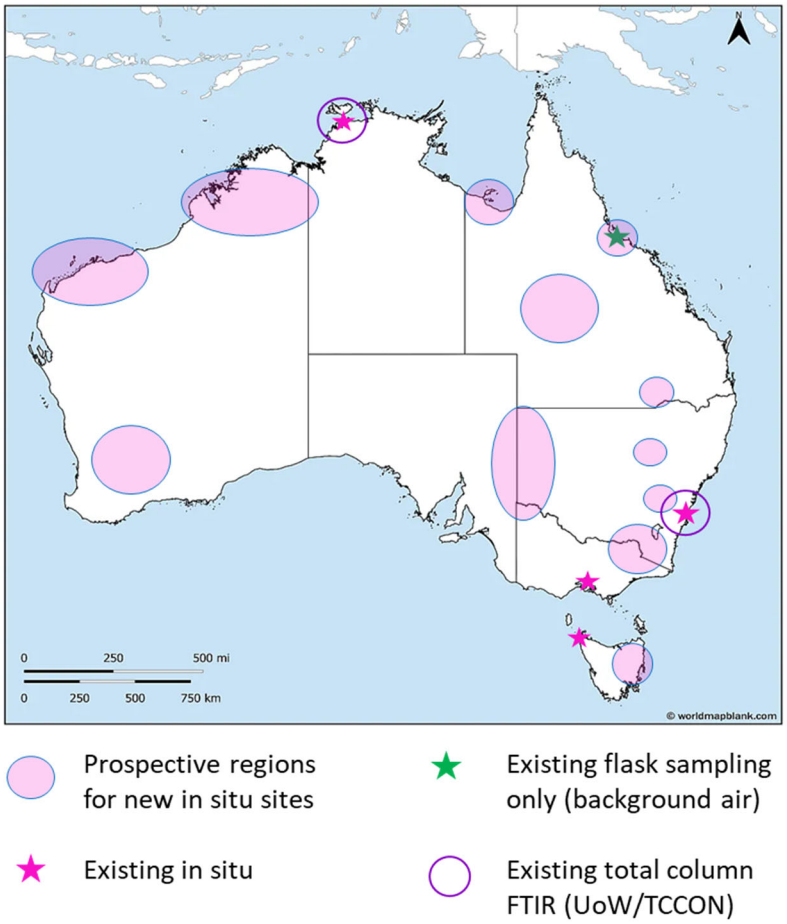


Figure: A proposed AGGON network including existing *in situ* sites and prospective regions for new sites.

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Diurnal cloud and precipitation over the Great Barrier Reef during the coral bleaching season

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Abstract

Mass coral bleaching events (CBEs) are increasing in frequency over the Great Barrier Reef and identified as a key risk for Australia with impacts on the global marine ecosystem. Caused by anomalously warm water temperatures, mass CBEs are strongly modulated by local-scale cloud cover – a key driver of the surface radiative budget. This research presents a characterization of the cloud and rainfall diurnal cycles over north-east Queensland during the coral bleaching season, aiming to provide the first step in untangling the complex relationships between clouds, precipitation, local-scale processes and the surface energy budget for this significant region.

High-resolution Himawari-8 satellite-derived brightness temperature and C-band radar datasets were analysed alongside BARRA-2 reanalysis data, to investigate observed cloud and rainfall diurnal cycles and their interactions with the local environment. A multi-year analysis over north-east Queensland coastal land, ocean and open ocean regions was conducted. Results found that background wind fields significantly impact observed cloud and rainfall diurnal cycles, although some features remain consistent. In general, over land cloud and rainfall peaks during the afternoon-early evening, over coastal ocean during the late evening-early morning, and little diurnal signal is observed over open ocean. The local-scale processes likely involve the land-sea breeze, topographical flows and daytime boundary layer development, with stronger diurnal signals and enhanced offshore propagation under westerly wind regimes. Observational and reanalysis surface radiation limitations highlight that convective-permitting high-resolution simulations will be key to further insights on the mechanisms involved in convection initiation and propagation over this region.

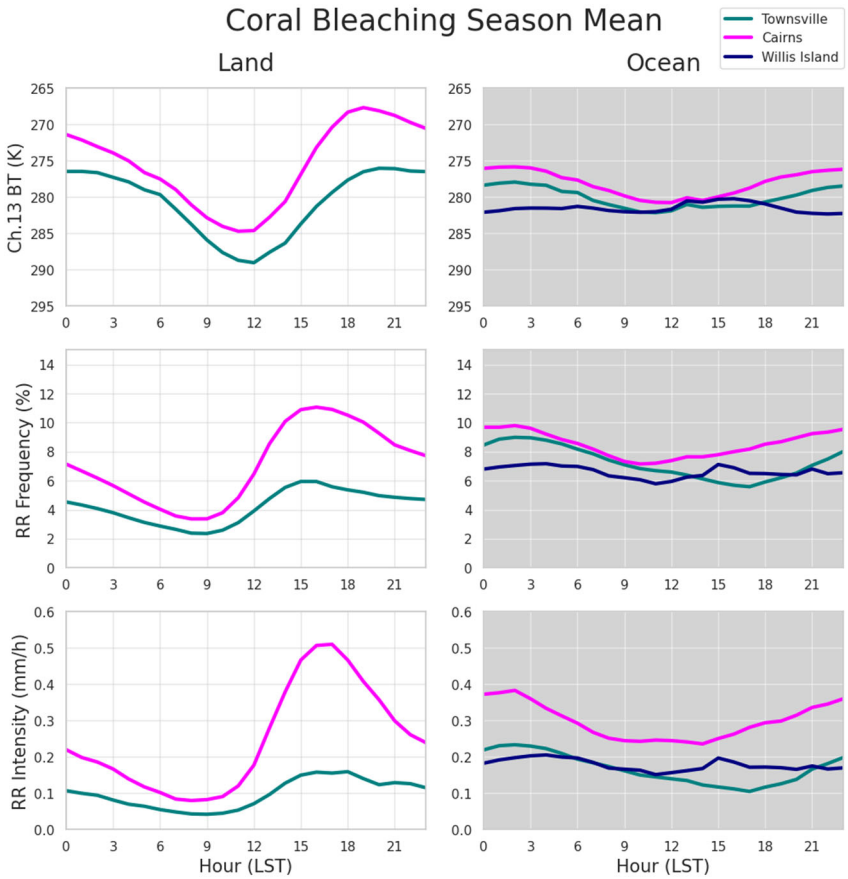


Figure: Diurnal cycle plots of Himawari-8 satellite channel 13 Brightness Temperature (BT), radar retrieved rain rate frequency and rate intensity calculated from hourly means over the coral bleaching season. The cloud BT axis is inverted, so that peaks in the diurnal cycle indicate colder BTs. Townsville (green), Cairns (pink) and Willis Island (blue) diurnal cycles are shown. The subplots in the left column show the cycles of the cloud proxy and rain rate variables for the coastal land, whereas the right column show Townsville and Cairns coastal oceans and the Willis Island open ocean region. Rain rate intensity is calculated for all periods of valid data (not just raining periods). The peak in Willis Island rain rate frequency and intensity at 15 LST can be explained by missing data at this hour, which has positively skewed (increased rain rate) the observations.

The RUSH Project: Analysing Australia NSW Bushfire Smoke for Improved Air Quality Forecasting and Firefighter Safety

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Abstract

Bushfire smoke poses a significant risk to public health and firefighter safety. The complex chemical makeup of smoke includes toxic gases and hazardous particulate matter. The Research for Understanding Smoke Hazards (RUSH) project investigates the composition of NSW bushfire smoke to address two critical objectives:

i. Enhanced Forecasting: Smoke composition data will be integrated into the NSW DPE air quality forecasting model and other chemical transport models, refining their predictions and supporting better public health warnings.

ii. Firefighter Protection: We will assess the toxicity of bushfire smoke to inform the development of safer working practices and reduce firefighters' exposure risks on the fireground.

The RUSH project is ongoing, but we present preliminary results of fuel- and moisture-dependent woodburning emissions, and some planned research topics. We anticipate our research will significantly improve smoke hazard assessments and contribute to vital protection measures for both firefighters and the wider community.

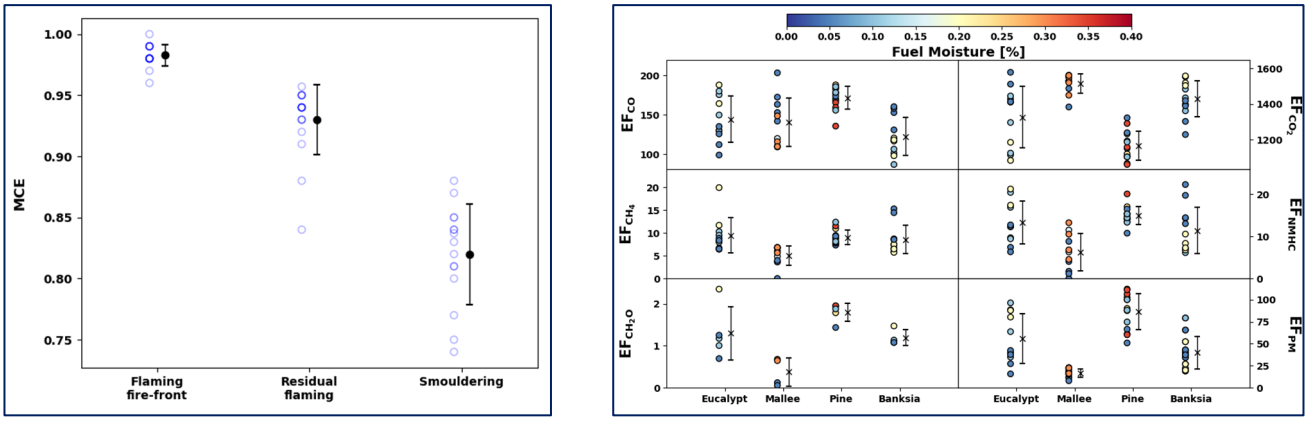


Figure: Left: MCE vs burning stages from eucalypt burning at the CSIRO Pyrotron. Right: Emission factors vs fuel types, coloured by moisture content, from burn experiments at the CSIRO laboratory in Highett, VIC.

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Progress towards a compact radon–222 detector for baseline air

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Abstract

With the goal of building a much smaller dual-flow-loop two-filter radon–222 detector, we previously developed a concept for a higher sensitivity detector head [Griffiths et. al. 2019]. This would permit the use of a smaller delay volume in a detector with the same overall sensitivity and hence, because the radon detector is mostly taken up by its delay volume, this would mean a smaller radon detector overall. An experimental proof of concept (POC) of the head has now been built and is undergoing its second round of testing.

The detector head is a combined filtration and alpha detection unit with a theoretical maximum efficiency of about 0.25 detected counts per alpha particle. Improving the head efficiency is the one improvement which has the largest potential to increase the measurement sensitivity [Griffiths et. al. 2016] and the new design, in theory, can approach an efficiency of 100%.

In the 2019 concept: a diffusion channel was specified for filtration; a ZnS(Ag) scintillator coupled to wavelength-shifting optical fibres and silicon photomultipliers were proposed for alpha particle detection. For the initial proof of concept, currently under test, we have elected to use a standard photomultiplier tube for light detection but in other aspects the POC attempted to follow the original design.

The test system has successfully produced counts, but only when using alternative configurations which avoid the use of wavelength shifting (WLS) optical fibres. These alternatives are difficult to scale up to the size needed to process the target flow rate so a design using WLS fibres is still preferred. The absence of detection when using WLS fibres appears to be down to a combination of low light throughput and excessive noise in the pulse detection electronics, rather than any fatal flaw in the design. Work is now focussed on an upgraded electronics system along with improvements to the optical system.

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Characterisation of aerosol losses of air sampling inlets from RV *Investigator* and RSV *Nuyina*

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Abstract The RV *Investigator* and RSV *Nuyina* both frequent the Southern Ocean and waters around Antarctica, providing a wealth of information about this unique and under-sampled environment. The *Investigator* has been contributing atmospheric composition and chemistry data to the World Meteorological Organization's Global Atmosphere Watch (WMO GAW) programme since 2018, being recognised as the world's first mobile station. Following suit, the RSV *Nuyina* is gearing up for a similar atmospheric capability, being able to venture into the sea-ice region which is distinct atmospherically from those the *Investigator* can typically reach.

For many atmospheric components, measurements are done by pulling ambient air through sampling inlets and feeding it into continuously-measuring, laboratory-housed instruments. Aerosols, or particulates, in the atmosphere have very particular sampling requirements, resulting in significant inlet infrastructure on the vessels. Ensuring the highest quality data is being fed to the world data centres, characterisation of the sample losses from these inlets is necessary to be able to report corrected data that is representative of the ambient atmosphere.

A major experiment was recently conducted wherein the size-dependent aerosol sample losses through each of the vessels' inlets was characterised. The RV *Investigator* inlet was characterised both before and after being cleaned, to understand the impact of exhaust and sea salt soiling on the inlet's inner walls. Both inlets were also tested at a range of flow rates – both those to which the inlets were designed to ensure laminar flow, and higher flow rates, simulating worse-case scenarios where additional flows are added during specific voyages. This presentation will show initial results from the project.

20 years of air pollution exceedance events in Melbourne and Sydney

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Abstract

This study evaluated long-term air quality changes in Melbourne and Sydney from 2000 to 2024, focusing on compliance to national and state standards and World Health Organization (WHO) guidelines. We examined the frequency, spatial distribution, and types of air pollution exceedance events in both cities. The data indicate a decrease in nitrogen dioxide (NO_2) levels, an increase in ozone (O_3) concentrations, and year-to-year fluctuations in $PM_{2.5}$ and PM_{10} levels since 2000. While Melbourne's air quality more often complies with the national and state standards than Sydney's, both cities consistently fail to comply of meeting WHO air quality guidelines and frequently experienced multiple-pollutant events. Multi-pollutant exceedance events, primarily involving combinations of NO_2, $PM_{2.5}$, and PM_{10}, were prevalent in both cities. For single-pollutant exceedances, NO_2 events accounting for approximately 80% of all single-pollution events. High frequencies of NO_2 and $PM_{2.5}$ exceedances were recorded near central business districts (CBDs), while PM_{10} and O_3 exceedances were more common in areas farther from CBDs. The long-term air quality assessment was limited by poor spatial and temporal data coverage, especially in Melbourne, where most monitoring stations operated for short periods and did not measure all criteria pollutants. Since 2017, only five stations have remained active in Melbourne, compared to 20 in Sydney. This study underscores the need for further investigation into the health and environmental effects of multi-pollutant exceedance events, as well as the expansion of Melbourne's air quality monitoring network.

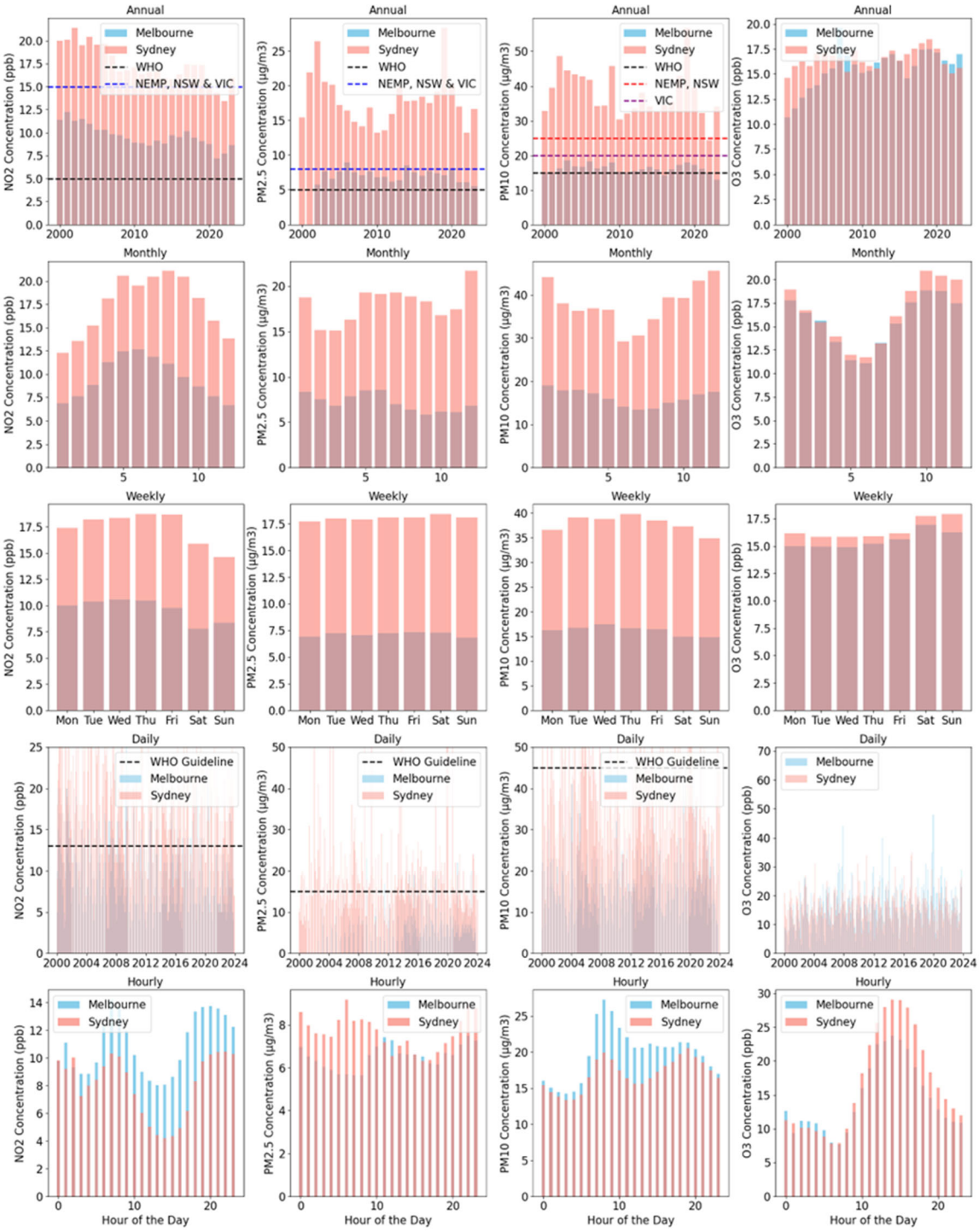


Figure: The evaluation of 24 years of annual, monthly, weekly, daily and hourly average air quality concentrations in Melbourne and Sydney in relation to NEMP, EPA-NSW, EPA-VIC standards, and WHO guidelines. Melbourne is depicted in sky blue, whereas Sydney is depicted in salmon.

Smoke composition and toxicity: an Australian case study

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Abstract

Smoke plumes from forest fires contain a large array of chemical compounds in both gas and aerosol phase. Negative health impacts from exposure to bushfire smoke is well established, but much of the focus has been on the impact of enhanced levels of $PM_{2.5}$ (e.g. [Johnston et al. 2021]). In this poster presentation we outline measurements of the gas phase composition of smoke plumes from southeast Australian forest fires and use these observations to determine the most important air toxics that are present [Guérette et al. 2018; MacSween et al. 2020].

We assess the toxicological classes of these key pollutants found in smoke and consider the likely additive effects of the multiple pollutants present in bushfire smoke and implications for health and safety on the fire-ground and for air quality downwind of the fires [MacSween et al. 2020; Simmons et al. 2022; Vyskocil et al. 2007]. We find that gaseous pollutants in smoke may cause upper and lower respiratory tract disorders, eye irritation, disruption of oxygen transport and cancer. Further study is needed to assess the changes in toxicity as the smoke ages and consider the chemical composition and toxicity of the aerosol phase emissions. In the meantime, the health impacts of the toxic gases should be considered alongside the $PM_{2.5}$ health impact of smoke.

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