Australian Government
Bureau of Meteorology

CSIRO

2026

Atmospheric Composition & Chemistry Observations & Modelling Conference

incorporating the

Kennaook/Cape Grim Annual Science Meeting

Program & Abstracts

18 – 20 November 2026

hosted by

Kennaook/Cape Grim Baseline Air Pollution Station
*celebrating **50 years***
of continuous atmospheric composition measurements

Tall Timbers Hotel
Smithton, Tasmania, Australia
and Online

AUSTRALIA'S ATMOSPHERIC COMPOSITION & CHEMISTRY
ACCOM
accom.org
OBSERVATIONS & MODELLING CONFERENCE

Edited by: M. Desservettaz, P. Krummel, and S. Prior

Citation

Author, A. B., A. B. Author, and A. B. Author (2026). Abstract Title. In ‘2026 ACCOMC incorporating the KCGASM [abstracts]’ (18–20 November 2026, hybrid| Smithton, TAS, Australia) (eds. M. Desservettaz, P. B. Krummel, S. Prior). (BoM and CSIRO), x, 77 pp.

ACCOMC 2026: Online & Hybrid Attendance

We are delighted to offer a hybrid experience for the ACCOMC 2026 conference. All oral sessions will be broadcast live via Zoom for our registered virtual attendees.

Join the Conference via Zoom

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

zoom
Join ACCOMC 2026

Day 1: Wednesday, 18 November 2026; 09:00–16:50

09:00	**Max, Sarah, Sally, & Paul**	**Conference Opening Remarks & Acknowledgement of Country**
Chair	**Paul Krummel**	**SESSION 1: WMO GAW & Kennaook / Cape Grim 50th Anniversary**
09:20	Sergi Moreno Valero (WMO)	An Overview of the WMO Global Atmosphere Watch Programme
09:35	Johannes Laube (FZ Jülich, Germany - Online)	The Cape Grim Air Archive – a unique resource for atmospheric "Triple-C" studies
09:50	Paul Fraser (CSIRO Environment)	50 years of GHG measurements at Kennaook-Cape Grim: In the beginning .....
10:05	David Etheridge (CSIRO; UTas)	Atmospheric composition before Kennaook/Cape Grim- a review of the ice and firn record from Law Dome
10:20	Stephen R. Wilson (UOW)	Nearly 50 years of Aerosol Optical Depth measurements at KCG – what have we learnt?
10:35	**Morning tea & Posters**	
Chair	**Duncan Quevedo**	**SESSION 2: Southern Ocean Aerosols, Marine Atmosphere & CAPE-k Campaign**
11:05	Ruhi Humphries (CSIRO)	COAST-K and CAPE-K: Cross-Platform Observations of Southern Ocean Aerosols, Clouds, and Precipitation
11:20	Melita Keywood (CSIRO)	Aerosol Variability Across Two Contrasting Winters During CAPE-K
11:35	Jakob Boyd Pernov (QUT)	Overview of aerosol precursors and chemical composition during CAPE-k CHEM
11:50	Deepa Roy (UOW)	A Multi-Instrument View of Transported Wildfire Smoke at Kennaook/Cape Grim during the CAPE-k Campaign
12:05	David Corporal (QUT)	Investigating an Underutilised Mass Spectrometry Technique and Its Application to Marine Atmospheric Science
12:20	Alanah Chapman (Univ. of Melbourne)	Assessing the role of Antarctic sea ice dimethyl sulphide emissions on Southern Ocean CCN, cloud and radiation
12:35	**Lunch**	
Chair	**Max Desservettaz**	**SESSION 3: Stratospheric Ozone, Halocarbons & Global Budgets**
13:35	Roger Francey (CSIRO Alumni)	Cape Grim/Kennaook's critical role in correcting current models of the global carbon budget.
13:50	Cathy Trudinger (CSIRO)	Australian emissions of synthetic greenhouse gases inferred from atmospheric measurements at Kennaook/Cape Grim
14:05	Paul Krummel (CSIRO)	The 2026 Antarctic ozone hole
14:20	Matt Tully (Bureau of Meteorology)	Long-term Evolution of Total Column Ozone in Australia – the Melbourne Dobson Record 1972-2025
14:35	David Oram (Univ. of East Anglia, UK)	Long-term observations of atmospheric halocarbons from sites in East and South-East Asia - addressing a gap in our global networks
14:50	**Afternoon tea & Posters**	
Chair	**Ruhi Humphries**	**SESSION 4: Aerosol-Cloud Interactions, High-Latitude Modelling & Global Observatories**
15:20	Matt Woodhouse (CSIRO)	Interactive aerosol and cloud microphysics in the Australian regional atmospheric model
15:35	Zhangcheng Pei (AAPP / UTas)	Implementing Marine Aerosol Ice Nucleation Parametrizations in the Unified Model: Mitigating the Cloud Radiative Bias During a Case Study Over the Southern Ocean
15:50	Sonya Fiddes (Univ. of Tasmania)	High resolution modelling over Southern Ocean field campaigns
16:05	Alan Griffiths (ANSTO)	Atmospheric Processes Affecting sub-Antarctic Island Mercury Deposition
16:20	Dagmar Kubistin (DWD, Germany)	Over 25 Years of Continuous Observations of Atmospheric Composition within GAW, ACTRIS and ICOS at Hohenpeissenberg, Southern Germany
16:35	Sang-Woo Kim (Seoul National Univ., Korea)	Decrease in nucleated particles and cloud condensation nuclei observed across a range of environments
16:50	**End Day 1**	

Day 2: Thursday, 19 November 2026; 09:00–17:00

Chair	Eric Saboya	SESSION 5: Hydroxyl Radical (OH), Firn Air & Isotopic Tracers
09:00	Peter D. Neff (Univ. of Minnesota; Online)	Stable Southern Hemisphere Atmospheric Hydroxyl (OH) During the Industrial Era Reconstructed from 14CO in Glacial Firn and Ice (Law Dome, Antarctica, 1870-present AD)
09:15	Lee Thomas Murray (Univ. of Rochester; Online)	Constraining spatial, seasonal and temporal variability in OH with ^{14}CO
09:30	Michael N. Dyonisius (INSTAAR; Online)	Atmospheric Δ14CH4 constraints on fossil methane emissions
09:45	Steve Montzka (NOAA GML, USA)	Insights into the magnitude and variability of trace-gas sources and sinks from globally-distributed measurements of long-lived trace gases
10:00	Luke Western (MIT, USA)	A novel method for emissions-free derivation of hemispheric hydroxyl radical anomalies using measured halocarbons
10:15	Andrew Smith (ANSTO)	ANSTO's micro-14C capability: contributions to understanding the composition of the past & present atmosphere
10:30	**Morning tea & Posters**	
Chair	**Ida Jandl**	**SESSION 6: Atmospheric Instrumentation, Calibration Standards & Remote Sensing**
11:00	Ann Stavert (CSIRO)	Further investigation into CRDS water corrections – CO2, CH4, N2O and CO.
11:15	David Griffith (UOW)	The Methane Isotope Round Robin: Lab differences, reference gas needs and improvements to calibration of optical isotopic measurements
11:30	Nicholas Deutscher (UOW)	Solar Remote Sensing Observations in Australia and Atmospheric Developments
11:45	Hasan Nawaz (UOW)	Validation of TROPOMI and IASI XCH4 with AirCore and EM27/SUN measurements over Australia and New Zealand
12:00	Scott D. Chambers (ANSTO)	Prototyping a portable radon calibration transfer standard for GAW and ICOS stations
12:15	Blagoj Mitrevski (CSIRO)	A decade-long overlapping experiment: reduction gas analyser versus pulsed discharge helium ionization detector for ambient hydrogen
12:30	**Lunch**	
Chair	**Hasan Nawaz**	**SESSION 7: Methane & Regional Emissions: Plumes, Facilities & Inversions**
13:30	Jhonathan Ramirez Gamboa (CSIRO)	A multi-platform atmospheric network for greenhouse gas emissions at Melbourne's Western Treatment Plant
13:45	Ida Jandl (Univ. of Melbourne / CSIRO)	Coal mine methane emissions in NSW – Atmospheric inverse modelling
14:00	Kirstin Gerrand (Earth Sciences NZ; Online)	Inverse modelling of agricultural methane in Aotearoa New Zealand using MethaneSAT
14:15	Leigh Fleming (Earth Sciences NZ)	CarbonWatch: In situ and flask sampling network in Auckland for quantifying urban emissions
14:30	Timothy Bedin (Swinburne / CSIRO)	Imaging very large transient methane emission plumes using the GOES-19 and Himawari-9 satellites
14:45	Mackenzie Purtill-Wright (UOW)	Quantifying Methane Fluxes Through Fourier Transform Infrared Spectrometry and Atmospheric Transport Modelling
15:00	**Afternoon tea & Posters**	
Chair	**Robert Ryan**	**SESSION 8: Biomass Burning, Smoke Chemistry & Fire Plumes**
15:30	Max Desservettaz (UOW)	Investigating Photochemical Aging and Rapid Ozone Formation in Simulated Wildfire Plumes: Preliminary Findings from the SAPHFIRE 2026 Campaign
15:45	Clare Murphy (Paton-Walsh) (UOW)	Emissions from Australian Peat: a first look at results from the ASPECT campaign
16:00	Mango Parker (AWRI)	VOCs that damage winegrapes: fresh emissions from controlled burns in the Mount Lofty Ranges
16:15	Fabienne Reisen (CSIRO)	Rapid Update Cycle Smoke Forecasting: Insights from a Recent Case Study
16:30	Luba Volkova (Univ. of Melbourne)	Testing AQFx Sensitivity to variation in Coarse Woody Debris loads - a Wildfire Case Study
16:45	Aiko Jackson (Adelaide / AWRI; Online)	Observations of smoke aging from Kennaook 2025
18:00	**Conference dinner**	**Tall Timbers BBQ in Function room area**

Day 3: Friday, 20 November 2026; 09:00–11:15

Chair	**Jakob Pernov**	**SESSION 9: Regional Aerosols, Marine Atmosphere & Southern Ocean**
09:00	Salvatore Sodano (IMAS / UTas / CSIRO)	Environmental drivers and properties of Southern Ocean aerosol and cloud formation
09:15	Robert Deas (Uni. Auckland/Mote; Online)	Marine Aerosols Modified by Urban Environments
09:30	Hamesh Patel (Mote Networks; Online)	Black Carbon Aethalometer Optimisation and Source Apportionment
09:45	Robert Ryan (Univ. of Melbourne)	AEROSPAN update: 25 years of Australian aerosol optical depth measurements.
10:00	**Morning tea & Posters**	
Chair	**Deepa Roy**	**SESSION 10: Urban Air Quality, Emissions & Health Impacts**
10:30	Kathryn Emmerson (CSIRO)	The oxidising capacity of Australia's cities in 2050
10:45	Simon W. Mkasimongwa (Univ. of Melbourne)	Evaluating the Health Burden of Multi-Pollutant Air Pollution in Sydney, Australia (2000–2025)
11:00	Robert Ryan (Univ. of Melbourne)	How much air pollution are data centres adding to Melbourne’s atmosphere?
11:15	Diego Roberto Rojas Neisa (Univ. of Melbourne)	Towards Melbourne urban air quality modelling: a WRF-Chem sensitivity study
11:30	**Conference Closing**	

This page was left blank intentionally

Day 1 – Wednesday, 18 November 2026

An Overview of the WMO Global Atmosphere Watch Programme 14
Sergi Moreno Valero[1*]

The Cape Grim Air Archive – a unique resource for atmospheric "Triple-C" studies 15
J. C. Laube[1,2*], D. E. Oram[2,3], K. E. Adcock[2], P. J. Fraser[4], R. L. Langenfelds[4], and P. B. Krummel[4]

50 years of GHG measurements at Kennaook-Cape Grim: In the beginning 16
P. Fraser[1*]

Atmospheric composition before Kennaook/Cape Grim- a review of the ice and firn record from Law Dome 18
D. M. Etheridge[1,2], C.M. Trudinger[1], R.L. Langenfelds[1], J.A. Menking[1,2], M. Rubino[3] A.M. Smith[4]., P.B. Krummel[1], C.E. Allison[1], D.A. Spencer[1], E. Andree-Guerette[1], G.I. Pearman[1], R. J. Francey[1], P.J. Fraser[1], L.P. Steele[1], I.G. Enting[1], P.J. Rayner[5], V.V. Petrenko[6], P. Neff[7], C. Buizert[8], L. Murray[6], X. Faïn[9], P. Martinerie[9], T. van Ommen[10,2], V. Morgan[10], V. Levchenko[4], J.W.C. White[11], D.F. Ferretti[12], H. Schaefer[12,18], D.C. Lowe[12], K. Lassey[12], D. Baggenstos[10,2], C.M. MacFarling Meure[1], D. Thornton[1], C.G.R. Caldow[1], M.K.Vollmer[13], W.T. Sturges[14], L.K. Fifield[15], S. Park[16], and T. Blunier[17].

Nearly 50 years of Aerosol Optical Depth measurements at KCG – what have we learnt? 20
S.R. Wilson[1]

COAST-K and CAPE-K: Cross-Platform Observations of Southern Ocean Aerosols, Clouds, and Precipitation 21
Ruhi S. Humphries[1,2], Gerald G. Mace[3], Roger Marchand[4], Melita D. Keywood[1,2], Alain Protat[5,2], Robyn Schofield[6], Yi Huang[6], Suzie Molloy[1], Branka Miljevic[7], J. Sulo[7], Alan Griffiths[8], I. McRobert[9], H. Crawford[9], W. Ponsonby[9], Paul B. Krummel[1], Zoe M. Loh[1], C. Murphy[10], Jessie Creamean[11], S. Greeney[11], Steven Siems[12], Tahereh Alinejadtabrizi[12], A. Chapman[6], Andreas Schmitt[13], Ottmar Möhler[13], Luis Ackermann[5], D. Kubistin[14], Erin Dunne[1], Emily Franklin[1], James Harnwell[1], Sally Taylor[1], Jason Ward[1], N. Somerville[5], Sarah Prior[5].

Aerosol Variability Across Two Contrasting Winters During CAPE-K 23
Melita D. Keywood[1,2] Ruhi S. Humphries[1,2], Gerald G. Mace[3], Roger Marchand[4], Alain Protat[5,2], Suzie Molloy[1], Jacob Pernov[6], Branka Miljevic[6], Alan Griffiths[7], Jessie Creamean[9], S. Greeney[9], Steven Siems[10], Tahereh Alinejadtabrizi[10], Andreas Schmitt[11], Ottmar Möhler[11], Luis Ackermann[5], Erin Dunne[1], Emily Franklin[1], James Harnwell[1], Sally Taylor[1], Jason Ward[1], N. Somerville[5], Sarah Prior[5].

Overview of aerosol precursors and chemical composition during CAPE-k CHEM 25
J.B. Pernov[1,*], J. Sulo[1], C. Mynard[2], E. Franklin[2], J. Alroe[1], Z. Li[1], E. Dunne[2], R. Humphries[2], Suzie Molloy[2], Z. Ristovski[1], and B. Miljevic [1]

A Multi-Instrument View of Transported Wildfire Smoke at Kennaook/Cape Grim during the CAPE-k Campaign 27
Deepa Roy[1,2*], Maximilien Desservettaz[1,2], Ruhi Humphries[3], Melita Keywood[3], Caleb Mynard[3], Fabienne Reisen[3], Erin Dunne[3], Suzie Molloy[3], Scott Collis[4], Janek Uin[4], Art Sedlacek[4], Rob Newsom[4], Raghu Krishnamurthy[4], Damao Zhang[4], Evan Keeler[4], John Shilling[4], Gary Hodges[4], Jenni Kyrouac[4], Clare Paton-Walsh[1,2]

Investigating an Underutilised Mass Spectrometry Technique and Its Application to Marine Atmospheric Science 28
D. Corporal[1*], W. Hu[1], S. Brydon[1], N. Demarais[2], S. Blanksby[1], B. Miljevic[1]

Assessing the role of Antarctic sea ice dimethyl sulphide emissions on Southern Ocean CCN, cloud and radiation 29
Alanah Chapman[1,2,3,4*], Sonya Fiddes[2], Matt Woodhouse[3], Yi Huang[1,4] and Robyn Schofield[1]

Cape Grim/Kennaook's critical role in correcting current models of the global carbon budget. 30
Roger J. Francey[1*] and Jorgen S. Frederiksen[2]

Australian emissions of synthetic greenhouse gases inferred from atmospheric measurements at Kennaook/Cape Grim 31
C. M. Trudinger[1*], B. L. Dunse[1], P. J. Fraser[1], P. B. Krummel[1], A. J. Manning[2], and B. Mitrevski[1]

The 2026 Antarctic ozone hole 32
P. B. Krummel[1*], A. R. Klekociuk[2,3], M. B. Tully[4], P. J. Fraser[1], and C. M. Trudinger[1]

Long-term Evolution of Total Column Ozone in Australia – the Melbourne Dobson Record 1972-2025 33
M. B. Tully[1*], S. K. Rhodes[1], and D. G. Body[1]

Long-term observations of atmospheric halocarbons from sites in East and South-East Asia - addressing a gap in our global networks 34
David Oram[1,2,*], Karina Adcock[2], Johannes Laube[3], Charles Chou[4], To Thi Hien[5], Tran Hoang Minh[5], Cao Ha Phuc Duy[5], Bui Duy Anh Tong[5], Nguyen Dang Minh Khoa[5], and Ahmad Amin Abdullah[6]

Interactive aerosol and cloud microphysics in the Australian regional atmospheric model 35
M. T. Woodhouse[1*], R. L. Jackson[2], S. L. Fiddes[3,4]

Implementing Marine Aerosol Ice Nucleation Parametrizations in the Unified Model: Mitigating the Cloud Radiative Bias During a Case Study Over the Southern Ocean 36
Zhangcheng Pei[1*], Sonya L. Fiddes[1], Marc D. Mallet[2], Matthew T. Woodhouse[3], Simon P. Alexander[4, 1], Alain Protat[5, 1], Kalli Furtado[6], and Paul Field[7]

High resolution modelling over Southern Ocean field campaigns 37
Sonya L. Fiddes[1], Matthew T. Woodhouse[2], Rebecca Jackson[2], Zhangcheng Pei[1], Alanah Chapman[3,1], Yi Huang[3], Marc D. Mallet[4], Alain Protat[4,1], Simon P. Alexander[5,1]

Atmospheric Processes Affecting sub-Antarctic Island Mercury Deposition 38
A. D. Griffiths[1*], P. Sebastianelli[2], M. A. Schneider[3], J. A. Fisher[4], S. D Chambers[1], and L. Schneider[3]

Over 25 Years of Continuous Observations of Atmospheric Composition within GAW, ACTRIS and ICOS at Hohenpeissenberg, Southern Germany 39
D. Kubistin[1], A. Claude[1], A. Filges[1], H. Flentje[1], R. Holla[1], F. Klein[1], T. Koch[1,2], M. Lindauer[1], J. Mueller-Williams[1], B. Nassl[1], W. Thomas[1], S. Wraase[1], and C. Plass-Duelmer[1]

Decrease in nucleated particles and cloud condensation nuclei observed across a range of environments 40
Sang-Woo Kim[1*], Do-Hyeon Park[2], and co-authors

Day 2 – Thursday, 19 November 2026

Stable Southern Hemisphere Atmospheric Hydroxyl (OH) During the Industrial Era Reconstructed from ^{14}CO in Glacial Firn and Ice (Law Dome, Antarctica, 1870-present AD) 41
Peter D. Neff[1,2*], Vasilii Petrenko[2], David Etheridge[3,4], Andrew M. Smith[5], Christo Buizert[6], Lee Murray[2], Cathy Trudinger[3], Mingjian Shi[2], Edward Crosier[2], Benjamin Hmiel[2], David Thornton[3,4], Lenneke Jong[7], Tas van Ommen[7], Marc Curran[7], Ross Beaudette[8], Christina Harth[8], Ray Langenfelds[3,4], Blagoj Mitrevski[3,4], Michael Dyonisius[2], Jessica Ng[8], Jeffrey Severinghaus[8], Ray Weiss[8]

Constraining spatial, seasonal and temporal variability in OH with ^{14}CO 42
L. T. Murray[1]*, A. Chattopadhyay[1], S. S. Miller[1], E. E. Thomson[1], K. R. Hall[1], S. Ahn[1], M. Scholer[1], A. C. Ihle[1], V. V. Petrenko[1], I. Usoskin[2], S. Poluianov[2], A. M. Smith[3], B. Yang[3], A. Amatya Joshi[3], B. Thomas[4], R. Burgener[4], A. Colton[4], M. Doneghey[4], R. M. Chewitt-Lucas[5], E. Blades[5], A. Borges[6], N. C. Machín[6], P. Soriano[6], M. Leitch[7], H. Schaefer[7], G. W. Brailsford[7], O. Magand[8], D. Combemale[8], P. Hernandez[8], E. Golubic[8], A. J. Turner[9]

Atmospheric $\Delta^{14}CH_4$ constraints on fossil methane emissions 43
M. N. Dyonisius[1*], S. J. Lehman[1], J. B. Miller[2], H. Schaefer[3,5], A.M. Smith[4], J.C. Turnbull[5], Y. Oh[2], R. Moss[5], S. Gray[5], V. V. Petrenko[6], C. Buizert[7], P. Neff[8], D. Etheridge[9,10], C. Trudinger[9], L. Bruhwiler[2], C. Wolak[1], S. Morgan[1], P. Cappa[1], J. Southon[11]

Insights into the magnitude and variability of trace-gas sources and sinks from globally-distributed measurements of long-lived trace gases 46
S. A. Montzka[1*], I. Vimont[1], G. Dutton[1,2], M. Crotwell[1,2], L. Western[3], M. Chipperfield[4], Z. Wang[4]

A novel method for emissions-free derivation of hemispheric hydroxyl radical anomalies using measured halocarbons 47
Luke. M. Western[1*], Candice Chen[2], Paul B. Krummel[3], Chris R. Lunder[4], Stephen A. Montzka[5], Jens Mühle[6], Simon O'Doherty[7], Ronald G. Prinn[1], Matthew Rigby[7], Martin K. Vollmer[8], Dickon Young[7]

ANSTO's micro-^{14}C capability: contributions to understanding the composition of the past & present atmosphere 49
A. M. Smith[1*], A. Amatya Joshi[1], G. W. Brailsford[2], M. N. Dyonisius[3], D. M. Etheridge[4,5], B. Hmiel[6], V. A. Levchenko[1], Q. Hua[7], V. Morgan[8], L. Murray[9], P. D. Neff[10], V. A. Petrenko[9], C.M. Trudinger[4], and B. Yang[1]

Further investigation into CRDS water corrections – CO_2, CH_4, N_2O and CO. 50
Ann R. Stavert[1*], Paul B. Krummel[2], Darren A. Spencer[2], Jeremy Ward[3], Zoë M. Loh[2], Issy N. Borley[2], and David W. T. Griffith[4]

The Methane Isotope Round Robin: Lab differences, reference gas needs and improvements to calibration of optical isotopic measurements 51
David Griffith[*1], Peter Sperlich[2], Gordon Brailsford[2], Sylvia Englund-Michel[3], Ben Riddell-Young[3], and 16 Round Robin participant labs

Solar Remote Sensing Observations in Australia and Atmospheric Developments 52
N. M. Deutscher[1*], D. W. T. Griffith[1], N. B. Jones[1], C. Paton-Walsh[1], H. Nawaz[1], D. Roy[1], and M. A. Purtill-Wright[1]

Validation of TROPOMI and IASI XCH_4 with AirCore and EM27/SUN measurements over Australia and New Zealand 53
H. Nawaz[1*], N. M. Deutscher[1*], C. Paton-Walsh[1], D. F. Pollard[2], L. Ventress[3], C. Alberti[4], B. Baier[6], M. Desservettaz[1], A. Geddes[2], D. W. T. Griffith[1], S. J. Harris[5], F. Hase[4], J. Higgs[7], N. B. Jones[1], B. J. F. Kelly[5], T. Naylor[1], T. Newberger[6], H. O'Sullivan-Moffat[2], J. Robinson[2], J. Simmons[1], C. Sweeney[6], B. T. Walker[1], and S. Wolter[6]

Prototyping a portable radon calibration transfer standard for GAW and ICOS stations 54
S. D. Chambers[1*], A. D. Griffiths[1], V. Oeser[2], A. Kostjukevich [2], O. Sisoutham[1], and S. Röttger[3]

A decade-long overlapping experiment: reduction gas analyser versus pulsed discharge helium ionization detector for ambient hydrogen 55
Blagoj Mitrevski[1*], Ray Langenfields[1], and Paul Krummel[1]

A multi-platform atmospheric network for greenhouse gas emissions at Melbourne's Western Treatment Plant 56
J. Ramirez-Gamboa[1,*], Z. M. Loh[1], C. G. R. Caldow[1], C. M. Trudinger[1], N. Shahrokhi[1], D. Spencer[1], C. T. Roulston[1], I. N. Borley[1], and N. Crosbie[2]

Coal mine methane emissions in NSW – Atmospheric inverse modelling 57
Jandl[1,2*], N. Shahrokhi[2], C. Trudinger[2], P. Rayner[3], N. Deutscher[4], M. Garthwaite[5], H. Nawaz[4], N. Jones[4], R. Hynes[6], and R. Schofield[1]

Inverse modelling of agricultural methane in Aotearoa New Zealand using MethaneSAT 58
K. Gerrand[1,5*], B. Bukosa[1], S. Mikaloff-Fletcher[1], E. D. Keller[1,5], D. Kennett[1], R. Law[2], A. Geddes[1], J. Benmergui[3,4], M. Knapp[3,4], and S. C. Wofsy[3]

CarbonWatch: In situ and flask sampling network in Auckland for quantifying urban emissions 59
L. S. Fleming[1*], L. Balzer[1], G. Brailsford[1], L. Domingues[1], S. Gray[1], T. W. Hilton[1], M. Hertoghs[1], E. Macapagal-Taluban[1], V. Monteiro[1], S. Nichol[1], J. Parry-Thompson[1], J. Turnbull[1], and H. Young[1]

Imaging very large transient methane emission plumes using the GOES-19 and Himawari-9 satellites 60
T Bedin[1,2*], N Shahrokhi[2], R Allen[1], C Trudinger[2], and S Petrie[1]

Quantifying Methane Fluxes Through Fourier Transform Infrared Spectrometry and Atmospheric Transport Modelling 61
Mackenzie A. Purtill-Wright[1,2], Nicholas M. Deutscher[1], Nicholas Jones[2], Hasan Nawaz[1], Bryce F.J. Kelly[3], Stephen J. Harris[3,4], and the Methane Hunter Team[5]

Investigating Photochemical Aging and Rapid Ozone Formation in Simulated Wildfire Plumes: Preliminary Findings from the SAPHFIRE 2026 Campaign 62
M. Desservettaz[1,2*], C. Murphy[1,2], G. Gkatzelis[3], Merched Azzi[4], Kathryn Emmerson[5], The SAPHFIRE team[3,6,7,8]

Emissions from Australian Peat: a first look at results from the ASPECT campaign 63
Maximilien Desservettaz[1,2], Deepa Roy[1,2], Owen Price[1,2], **Clare Paton-Walsh (Murphy)[1,2*]**, Meagan Porter[3], Scott Foyster[3], Mark Hovenden[3], Judith Rosentreter[4], Malcolm Possell[5], and Sally Taylor[6]

VOCs that damage winegrapes: fresh emissions from controlled burns in the Mount Lofty Ranges 64
M. Parker[1,2*], B. Williams[3], K. Abley[3], M. J. Herderich[1,2], and F. Reisen[4]

Rapid Update Cycle Smoke Forecasting: Insights from a Recent Case Study 65
Fabienne Reisen[1*], Julie Noonan, Martin Cope

Testing AQFx Sensitivity to variation in Coarse Woody Debris loads - a Wildfire Case Study 66
Luba Volkova[1], Martin Cope, and Kylle Quinn

Observations of smoke aging from Kennaook 2025 67
A. Jackson[1,2,4], M. J. Herderich[1,2], C. Kidman[3], F. Reisen[4*], and M. Parker[1,2]

Environmental drivers and properties of Southern Ocean aerosol and cloud formation 68
Salvatore Sodano[1,2*], Marc Mallet[1], Sonya Fiddes[1], Andrew Bowie[1], Melita Keywood[2], Ian McRobert[3], Hanuman Crawford[3], Jason Ward[2], and Ruhi Humphries[2]

Day 3 – Friday, 20 November 2026

Environmental drivers and properties of Southern Ocean aerosol and cloud formation 64
Salvatore Sodano1,2*, Marc D. Mallet1, Sonya L. Fiddes1, Andrew Bowie1, Melita D. Keywood2, Ian McRobert3, Hanuman Crawford3, Jason Ward2, and Ruhi S. Humphries2

Marine Aerosols Modified by Urban Environments 65
Robert Deas1, Anushka Elangasinghe2,3, Cherie Tollemache1,3, Hamesh Patel2,4,5, Daniel Lynch3, Paul Baynham3, Joel Rindelaub1, Alexander Elliott1, Brett Wells3, Jennifer Salmond2, David Williams1,3, and Duncan McGillivray1

Black Carbon Aethalometer Optimisation and Source Apportionment 66
Anushka Elangasinghe1,2*, Jennifer A. Salmond1, Paul Baynham2, Erika Macapagal-Taluban3, Perry Davy3, Jocelyn Turnbull3, and Hamesh Patel4,5

AEROSPAN update: 25 years of Australian aerosol optical depth measurements. 67
Robert Ryan1*, David Barker2, Fraser Dennison1, Ruhi Humphries2, and Robyn Schofield1

Evaluating the Health Burden of Multi-Pollutant Air Pollution in Sydney, Australia (2000–2025) 68
Simon William Mkasimongwa 1*, Robert G. Ryan2, Stephen J. Livesley2, and Robyn Schofield3

How much air pollution are data centres adding to Melbourne's atmosphere? 69
Robert Ryan1*, Diego Rojas Niesa1, Jeremy Silver2, Annabelle Workman3, Rachel Tham4, Steven Utembe5, Geoffrey Browne6, Clare Walters1, and Robyn Schofield1

Towards Melbourne urban air quality modelling: a WRF-Chem sensitivity study 70
D. R. Rojas-Neisa1*, R. Ryan1, and R. Schofield1

Posters

Optimisation and implementation of a continuous flow analysis system to measure methane in ice cores 78
S. Callaghan[1*], A. Menking[2], D. Baggenstos, T. Vance[1], and C. Plummer[2]

Quantifying California HFC Emissions with the AGAGE Network 79
Duncan Quevedo[1*], Jooil Kim[2], Jens Mühle[2], Robert Rhew[2], Ray Weiss[2], and Luke Western[1]

A vehicle-mounted platform for mobile surveys of methane and nitrous oxide - PiLogger 80
C. T. Roulston[1*], J. Ramirez-Gamboa[1], D. Spencer[1], N. Crosbie[2], C. G. R. Caldow[1], and Z. M. Loh[1]

Joint inversions of HCFC-22 and HFC-23 for partitioning emission sources of HCFC-22 in eastern China (2021-2024) 81
Eric Saboya[1*], Sunyoung Park[2,3], Luke M. Western[1], and Ronald G. Prinn[1]

An Overview of the WMO Global Atmosphere Watch Programme

Sergi Moreno Valero[1*]

[1] World Meteorological Organisation, Geneva, Switzerland

[*] corresponding author: Sergi Moreno Valero [smoreno@wmo.int]

Abstract

The World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) Programme provides the international framework for observing and understanding the chemical composition of the atmosphere and its long-term changes.

Through a global network of measurement stations, contributing networks, calibration centres, and world data centres, GAW delivers high-quality observations of greenhouse gases, aerosols, reactive gases, ozone, precipitation chemistry and UV radiation.

By integrating long-term observations from surface-based and other measurement platforms, the programme provides essential information for detecting changes in atmospheric composition, identifying emerging environmental issues, evaluating atmospheric models, and supporting international environmental assessments and policy development. This overview introduces the main objectives, structure, observational activities, data systems, and scientific contributions of the WMO GAW Programme, highlighting its role in maintaining consistent, high-quality atmospheric observations and strengthening international cooperation in atmospheric science.

The Cape Grim Air Archive – a unique resource for atmospheric "Triple-C" studies

J. C. Laube[1,2*], D. E. Oram[2,3], K. E. Adcock[2], P. J. Fraser[4], R. L. Langenfelds[4], and P. B. Krummel[4]

[1] Institute for Climate and Energy Systems: Stratosphere (ICE-4), Forschungszentrum Jülich, Jülich, North Rine-Westphalia, Germany.
[2] School of Environmental Sciences, City, University of East Anglia, Norwich, Norfolk, UK
[3] National Centre for Atmospheric Science, University of East Anglia, Norwich, Norfolk, UK
[4] CSIRO Environment, Aspendale, Victoria, Australia

[*]corresponding author: J. C. Laube [j.laube@fz-juelich.de]

Abstract

Having started the collection and storage of large air samples in 1978, the Cape Grim Air Archive (CGAA) remains a powerful asset for studies of atmospheric composition, chemistry, and circulation ("Triple-C") to date. Looking back at a collaboration between CSIRO and the University of East Anglia (and more recently also Forschungszentrum Jülich, FZJ) that has spanned more than three decades, we will present some highlight examples that illustrate the scientific significance of this ongoing effort. These examples will reflect the changing nature of atmospheric composition, such as the transition of anthropogenic emissions away from ozone-depleting chlorofluorocarbons. They will also focus on wider implications for chemical and dynamical processes in the troposphere and stratosphere, such as effects related to chlorinated very short-lived substances, or connections to large-scale circulation patterns.

50 years of GHG measurements at Kennaook-Cape Grim: In the beginning ……

P. Fraser[1*]

[1] CSIRO Environment, Aspendale, Victoria, Australia

[*] corresponding author: Paul Fraser [paul.fraser@csiro.au]

Abstract

Increases in the global baseline concentrations of long-lived greenhouse gases (carbon dioxide – CO_2, methane – CH_4, nitrous oxide – N_2O and synthetic halogenated gases such as chlorofluorocarbons – CFCs) since pre-industrial times are significant drivers of recent climate change (Myhre and Shindell, 2014). Australian baseline measurements of CO_2, from air samples collected in the mid-troposphere, commenced in 1972 (Garratt and Pearman, 1973) and in the marine boundary layer (MBL) at Kennaook-Cape Grim, using an *in situ*, German-sourced URAS (Ultra-Rot Absorptions Schreiber) non-dispersive infrared (NDIR) gas analyser, commencing in April 1976 (Pearman *et al.*, 2017).

April 1976 also marked the first measurements of non-CO_2 greenhouse gases at Kennaook-Cape Grim, namely the synthetic halogenated species CFC-11 (CCl_3F), methyl chloroform (CH_3CCl_3) and carbon tetrachloride (CCl_4) (Fraser *et al*., 1983, 2018). These measurements were made using a gas chromatograph (GC) equipped with a tritium (H^3)-based electron capture detector (ECD), donated in 1975 by the ECD inventor, James Lovelock (Bowerchalke, UK), who made the first measurements of these species in the Southern Hemisphere Atlantic Ocean MBL in 1971-72 (Lovelock *et al*., 1973).

N_2O measurements at Kennaook-Cape Grim commenced in mid-1978 with the installation of a Hewlett-Packard GC equipped with a Ni^{63}-based ECD, after CSIRO was invited to join a global (Ireland, USA, Barbados, Samoa, Tasmania) network (ALE – Atmospheric Lifetime Experiment – Prinn *et al*., 1983) of such instruments measuring several CFCs, CH_3CCl_3, CCl_4, chloroform ($CHCl_3$) and N_2O. The ALE GC-ECD instrument at Kennaook-Cape Grim was funded by the Chemical Manufacturers Association (CMA, USA) in partnership with the Massachusetts Institute of Technology (MIT, USA). N_2O proved to be a difficult species to measure at a precision that enabled improved definition of source-sink relationships. The N_2O chromatography was improved and sampling frequency increased in 1981. The resultant N_2O data underwent intense quality control procedures, and the first 10 years of N_2O data at Kennaook-Cape Grim were published in 1990 (Prinn *et al*., 1990).

The first CH_4 measurements at Kennaook-Cape Grim were made in 1980 on air samples collected in glass flasks and stainless-steel tanks (air archive), analysed on a CSIRO Aspendale-based Carle GC fitted with a flame ionization detector (FID). The Carle GC was on loan from Washington State University (Rei Rasmussen) and was being evaluated by CSIRO as an instrument capable of making CO_2 measurements on small volume air samples (ml) compared to the NDIR instruments which required litre air samples. The resultant CH_4 data revealed unequivocal increases in the Southern Hemisphere and the very distinctive CH_4 annual cycle (Fraser *et al.*, 1981, 2018). The Carle-FID instrument subsequently yielded excellent CH_4 and CO_2 data from small air samples extracted from Antarctic ice and firn (Pearman et al., 1986)

References

Fraser, P. J., A. K. Khalil, R. A. Rasmussen and A. J. Crawford (1981). Trends of atmospheric methane in the Southern Hemisphere, *Geophys. Res. Letts.,* vol. 8, pp. 1063-1066.

Fraser, P., P. Hyson, I. Enting and G. Pearman (1983). Global distribution and Southern Hemisphere trends of atmospheric CCl_3F, *Nature*, vol. 302, pp. 692-695.

Fraser, P. J., G. I Pearman and N. Derek (2018). CSIRO non-carbon dioxide greenhouse gas research. Part 1: 1975-90. *Historical Records of Australian Science*, vol. 28, pp. 1-13. https://doi.org/10.1071/HR17016.

Garratt, J. R. and G. I. Pearman (1973), Large-scale CO_2 fluxes in the Southern Hemisphere troposphere, *Nature*, vol. 242, pp. 54-55.

Lovelock, J. E., R. J. Maggs and R. J. Wade (1973). Halogenated hydrocarbons in and over the Atlantic, *Nature*, vol. 241, pp. 194-196.

Myre, G. and D. Shindell (2014). Anthropogenic and Natural Radiative Forcing, Chapter 8 in *Climate Change 2013 – The Physical Science Basis*, eds. T.F. Stucker *et al.*, Cambridge University Press, UK/New York, USA, pp. 659-740.

Pearman, G. I., D. M. Etheridge, F. R. De Silva and P. J. Fraser (1986). Evidence of changing concentrations of atmospheric CO_2, N_2O and CH_4 from air bubbles in Antarctic ice, *Nature,* vol. 320, pp**.** 248-250.

Pearman, G. I., P. J. Fraser and J. R. Garratt, CSIRO high-precision measurement of atmospheric CO2 concentration in Australia. Part 2: Cape Grim, surface CO2 measurements and carbon cycle modelling, *Historical Records of Australian Science*, vol. 28, pp. 126-139. https://doi.org/10.1071/HR17015.

Prinn, R., P. Simmonds, R. Rasmussen, R. Rosen, F. Alyea, C. Cardelino, A. Crawford, D. Cunnold, P. Fraser and J. Lovelock, The Atmospheric Lifetime Experiment: 1. Introduction, Instrumentation and Overview, *J. Geophysical Research*, vol. 88, pp. 8353-8376.

Prinn, R., D. Cunnold, R. Rasmussen, P. Simmonds, F. Alyea, A. Crawford, P. Fraser and R. Rosen (1990). Atmospheric emissions and trends of nitrous oxide deduced from 10 years of ALE-GAGE data, *J. Geophysical Research*, vol. 95, pp.18369-18385.

Atmospheric composition before Kennaook/Cape Grim- a review of the ice and firn record from Law Dome

D. M. Etheridge[1,2], C.M. Trudinger[1], R.L. Langenfelds[1], J.A. Menking[1,2], M. Rubino[3] A.M. Smith[4]., P.B. Krummel[1], C.E. Allison[1], D.A. Spencer[1], E. Andree-Guerette[1], G.I. Pearman[1], R. J. Francey[1], P.J. Fraser[1], L.P. Steele[1], I.G. Enting[1], P.J. Rayner[5], V.V. Petrenko[6], P. Neff[7], C. Buizert[8], L. Murray[6], X. Faïn[9], P. Martinerie[9], T. van Ommen[10,2], V. Morgan[10], V. Levchenko[4], J.W.C. White[11], D.F. Ferretti[12], H. Schaefer[12,18], D.C. Lowe[12], K. Lassey[12], D. Baggenstos[10,2], C.M. MacFarling Meure[1], D. Thornton[1], C.G.R. Caldow[1], M.K.Vollmer[13], W.T. Sturges[14], L.K. Fifield[15], S. Park[16], and T. Blunier[17].

Current or former affiliation:
[1] CSIRO, Aspendale, Victoria, Australia
[2] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia
[3] Department of Mathematics and Physics, Università della Campania "Luigi Vanvitelli", Caserta, Italy
[4] Centre for Accelerator Science, Australian Nuclear Science and Technology Organisation [ANSTO], Lucas Heights, NSW, Australia
[5] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, Victoria, Australia
[6] Department of Earth and Environmental Sciences, University of Rochester, Rochester, New York, USA
[7] Department of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota, USA
[8] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA
[9] University Grenoble Alpes, CNRS, INRAE, IRD, Grenoble INP, IGE, 38000 Grenoble, France
[10] Australian Antarctic Division, Kingston, Tasmania, Australia
[11] Institute of Arctic and Alpine Research University of Colorado Boulder, Boulder, Colorado, USA
[12] Earth Sciences New Zealand (formerly NIWA), Wellington, New Zealand
[13] Empa, Laboratory for Air Pollution and Environmental Technology, Duebendorf, Switzerland
[14] Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich, UK
[15] Department of Nuclear Physics and Accelerator Applications, Research School of Physics, Australian National University, Canberra, ACT, Australia
[16] Kyungpook Institute of Oceanography, Kyungpook National University, Daegu, Republic of Korea
[17] Center for Ice and Climate, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
[18] Royal Society Te Apārangi, Wellington, New Zealand

* corresponding author: David M. Etheridge [david.etheridge@csiro.au; david.etheridge219@gmail.com]

Abstract

Five years after atmospheric monitoring began at Cape Grim, work started on extending the record of atmospheric composition back in time by measuring air enclosed in Antarctic ice. The Australian ice core measurements in the 1980s focussed on the past few centuries to quantify the natural background concentrations of the main greenhouse gases and their subsequent evolution. At hand were legacy ice cores drilled from Law Dome, a coastal ice cap near Casey Station where the glaciology had been extensively characterised since the 1960s by the Australian Antarctic Program. The accumulation rates, dynamics and age-depth profile measured at the ice core sites allowed the ages of the air enclosed in bubbles to be determined. Analytical capability came from the gas chromatography systems at CSIRO Atmospheric Research. Despite some limitations of the ice core quality and the early air extraction and measurement systems, the concentrations of carbon dioxide, methane and, for the first time, nitrous oxide were measured from pre-industrial time to the 1960s.

The use of Law Dome as an archive of atmospheric composition rapidly developed. Field experiments, laboratory measurements and modelling tracked the movement of air through the firn layer and into bubbles in ice and quantified the resulting air age, air age distribution and the possible effects on composition. Ice cores specifically for atmospheric composition were drilled at DE08, on the high accumulation eastern side of the dome, where the

air is enclosed with narrow age resolution and overlaps with direct atmospheric measurements. Improvements were made in techniques to dry-extract air from ice and the measurement of trace gas concentrations and the isotopic ratios of carbon dioxide, methane and nitrous oxide at CSIRO and at collaborating laboratories (ANSTO, NIWA New Zealand, IGE/CNRS France, Australian and overseas Universities). Measurements of species demanding minimal sample handling or large air sample volumes, such as carbon monoxide, ultra-trace halogenated gases and carbon-14 methane, were made on air pumped directly from the permeable firn layer, notably from the low accumulation site DSSW20K on the west side of the dome. Close links to the measurements and calibrations at Casey and Kennaook-Cape Grim allowed comparisons to scrutinise possible artefacts of ice and firn air, especially important for the more reactive and difficult to measure trace gases and isotopes. Measurements of the DSS ice core, from near the summit of Law Dome, extended the records further back in time. With no gaps or artificial jumps between the ice core air, firn air, Kennaook-Cape Grim archived air and direct atmospheric observations in the resulting time series, models can reliably infer emissions and uptake over this crucial period.

This presentation will review some of the outcomes from these long-term measurements and modelling, including: the climate forcing of IPCC CMIP simulations; the temperature sensitivity of the terrestrial biospheric carbon uptake; the upward revision of fossil methane emissions and the evidence of mitigation of emissions of some key gases. It will look at atmospheric composition questions that might still be addressed by ice cores and the future of Australian ice core gas measurements as the capability is being transferred from CSIRO and enhanced at a new centre at IMAS at the University of Tasmania.

Nearly 50 years of Aerosol Optical Depth measurements at KCG – what have we learnt?

S.R. Wilson[1]

[1] School of Science, University of Wollongong, Wollongong, NSW, Australia

[*] corresponding author: Stephen Wilson [swilson@uow.edu.au]

Abstract

Aerosol attenuation of sunlight as it passes through the atmosphere, as measured by Aerosol Optical Depth (AOD), is both a significant factor in the radiation balance and one of the most poorly quantified parts of that balance, and there is a need for it to be well quantified in as many environments as possible.

The first recorded Aerosol Optical Depth (AOD) measurements at KCG were on 24 January 1978 and have continued in various forms and locations ever since (see Fig 1). What have we learned? The median AOD at 500nm over the entire record is 0.068 (0.064, 0.072). The impacts of large volcanic eruptions (El Chichón, Mt Pinatubo) are clear in the record. A clear annual cycle has been observed, with a minimum of around 0.04 in June and maxima in September and January [Wilson and Forgan, 2002].

Is there a significant long-term trend in AOD? To answer this question requires much more careful consideration of the calibration of the instrument, and consideration of the possible biases that might change over the years.

The changes in the measurements over the years, and some of the factors that have driven those changes, will be outlined. These include the shift from manual to automated measurements, the changes in the sun photometer design and data collection protocol and the location of the measurements.

Recent efforts to identify, quantify and correct for the impact of front window contamination will be presented.

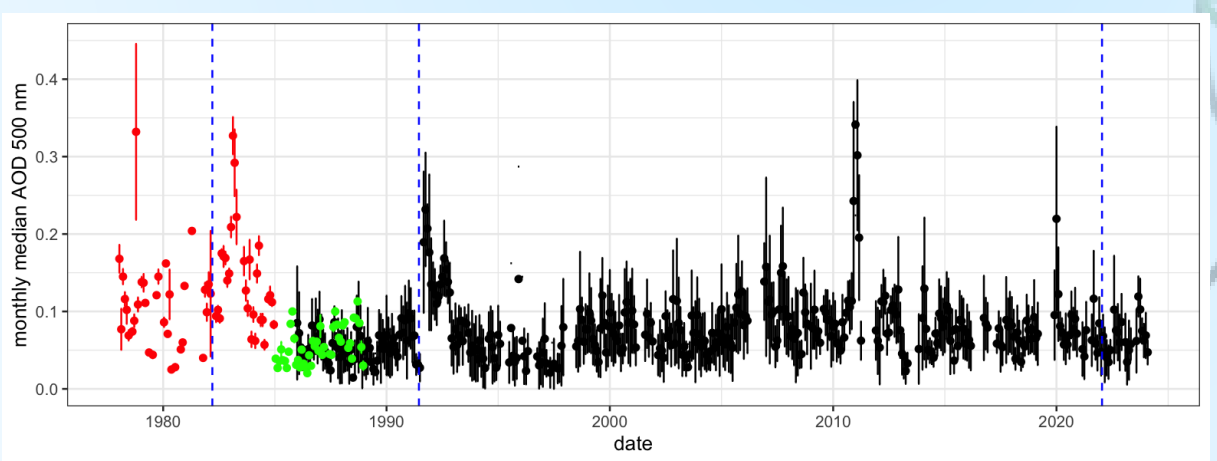


Fig. 1. Monthly AOD at 500 nm as derived from all AOD data. Plotted are the median and the mad (median absolute deviation) scaled to a standard deviation. The vertical lines mark major volcanic eruptions (El Chichon, Mt Pinatubo and Hunga Tonga–Hunga Ha'apai). Red data points were measured using an Eppley handheld sunphotometer, the measurements in green were made with an EKO handheld sunphotometer. The black measurements are made with a number of automatic sunphotometers.

References

Wilson, S.R., Forgan, B.W. (2002). Aerosol optical depth at Cape Grim, Tasmania, 1986 - 1999. J. Geophys. Res. 107, 4068. https://doi.org/10.1029/2001JD000398

COAST-K and CAPE-K: Cross-Platform Observations of Southern Ocean Aerosols, Clouds, and Precipitation

Ruhi S. Humphries[1,2], Gerald G. Mace[3], Roger Marchand[4], Melita D. Keywood[1,2], Alain Protat[5,2], Robyn Schofield[6], Yi Huang[6], Suzie Molloy[1], Branka Miljevic[7], J. Sulo[7], Alan Griffiths[8], I. McRobert[9], H. Crawford[9], W. Ponsonby[9], Paul B. Krummel[1], Zoe M. Loh[1], C. Murphy[10], Jessie Creamean[11], S. Greeney[11], Steven Siems[12], Tahereh Alinejadtabrizi[12], A. Chapman[6], Andreas Schmitt[13], Ottmar Möhler[13], Luis Ackermann[5], D. Kubistin[14], Erin Dunne[1], Emily Franklin[1], James Harnwell[1], Sally Taylor[1], Jason Ward[1], N. Somerville[5], Sarah Prior[5].

[1] CSIRO Environment, Melbourne, Australia
[2] Australian Antarctic Program Partnership, University of Tasmania, Hobart, Australia
[3] Department of Atmospheric Sciences, University of Utah, Salt Lake City, UT, USA
[4] Department of Atmospheric and Climate Science, University of Washington, Seattle, WA, USA
[5] Australian Bureau of Meteorology, Melbourne, Australia
[6]University of Melbourne, Melbourne, Australia
[7] Queensland University of Technology, Brisbane, Australia
[8] ANSTO, Lucas Heights, Australia
[9] CSIRO National Collections and Marine Infrastructure, Hobart, Australia
[10] University of Wollongong, Wollongong, Australia
[11] Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA
[12] Monash University, School of Chemistry, Clayton/Melbourne, Australia
[13] Karlsruhe Institute of Technology, Karlsruhe, Germany
[14] German Meteorological Service, Hohenpeissenberg, Germany

[*] corresponding author: Ruhi Humphries [ruhi.humphries@csiro.au]

Abstract

Low-level clouds and aerosols over the Southern Ocean represent a leading source of uncertainty in global climate models. Reducing this uncertainty has motivated many international research projects over the previous decade. Most observations have occurred during summer months when weather conditions allow easier access, however this creates a significant observational bias. While aerosol observations have continued at Kennaook/Cape Grim (KCG) for several decades, high resolution cloud and precipitation observations have remained sporadic. The Clouds and Precipitation Experiment at Kennaook (CAPE-K) addressed this gap by deploying the Atmospheric Radiation Measurement (ARM) Mobile Facility alongside long-term baseline aerosol records at the KCG station in Tasmania over a period of 18 months, from 15 April 2024 to 15 October 2025 – long enough to cover a full seasonal cycle and importantly, two winter periods when data is most scarce.

Coincidentally, a similarly instrumented voyage aboard the RV Investigator occurred during the late autumn of 2025, overlapping perfectly with CAPE-k and creating an important spatial dimension to the dataset. The COAST-k (Clean Ocean Air Sampling upwind of Tasmania-Kennaook) voyage had two primary goals. The first was to test the spatial representativeness of long-term observations at Kennaook/Cape Grim which have been assumed for decades to represent a large area of the Southern Ocean. The coincident timing, and overlapping instrument suite due to deployments of guest cloud and precipitation instrumentation, meant that this concept could be further expanded to CAPE-K. The second aim of COAST-k was to undertake the world's first direct full-station intercomparison of two platforms in the Global Atmosphere Watch (GAW) programme. Executing this aim involved bringing the mobile platform of the RV Investigator as close as safely possible to the coast off Kennaook/Cape Grim, allowing simultaneous measurements of the same airmass at both stations. It was during this period where the vessel was alongside the station, that both platforms captured the CAPE-K experiment's flagship case study, occurring 6 May 2025. During this period, a major cold-front passed KCG, initiating over 60 hours of pristine post-frontal flow. Both platforms captured the transition from deep frontal clouds and rain to shallow post-frontal cellular convection using radiosondes, cloud radars, lidars, disdrometers, and filter samplers. Initial regional

modelling (ACCESS-rAM3) demonstrates the capacity of these paired observations to constrain cloud microphysics and precipitation efficiency.

These datasets provide invaluable benchmark data that will be utilised in the coming years to reduce major uncertainties and improve aerosol–cloud–precipitation parameterisations in Earth system models.



Figure 1: Top: Kennaook / Cape Grim as seen from the RV Investigator, with the vessel's instrumented foremast shown in the foreground. Bottom: RV Investigator as seen from the fields at Kennaook / Cape Grim, with CAPE-K instrumentation shown in the foreground.

Aerosol Variability Across Two Contrasting Winters During CAPE-K

Melita D. Keywood[1,2] Ruhi S. Humphries[1,2], Gerald G. Mace[3], Roger Marchand[4], Alain Protat[5,2], Suzie Molloy[1], Jacob Pernov[6], Branka Miljevic[6], Alan Griffiths[7], Jessie Creamean[9], S. Greeney[9], Steven Siems[10], Tahereh Alinejadtabrizi[10], Andreas Schmitt[11], Ottmar Möhler[11], Luis Ackermann[5], Erin Dunne[1], Emily Franklin[1], James Harnwell[1], Sally Taylor[1], Jason Ward[1], N. Somerville[5], Sarah Prior[5].

[1] CSIRO Environment, Melbourne, Australia
[2] Australian Antarctic Program Partnership, University of Tasmania, Hobart, Australia
[3] Department of Atmospheric Sciences, University of Utah, Salt Lake City, UT, USA
[4] Department of Atmospheric and Climate Science, University of Washington, Seattle, WA, USA
[5] Australian Bureau of Meteorology, Melbourne, Australia
[6] Queensland University of Technology, Brisbane, Australia
[7] ANSTO, Lucas Heights, Australia
[9] Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA
[10] Monash University, School of Chemistry, Clayton/Melbourne, Australia
[11] Karlsruhe Institute of Technology, Karlsruhe, Germany

[*] corresponding author: Melita Keywood [melita.keywood@csiro.au]

Abstract

The Southern Ocean plays a vital role in the Earth system, yet Earth system models exhibit significant radiative biases, leading to overestimated warming in this region. This discrepancy affects climate projections and, consequently, policy decisions on mitigation and adaptation. The largest model biases occur near the latitude of Kennaook/Cape Grim (KCG), where low-level clouds are poorly represented.

The Cloud And Precipitation Experiment at Kennaook (CAPE-K), conducted from April 2024 to October 2025, was a collaboration between the US Department of Energy's Atmospheric Radiation Measurement (ARM) program, CSIRO, and the Bureau of Meteorology. The deployment of the ARM Mobile Facility 2 at KCG enabled detailed investigation of seasonal variability in low clouds and precipitation, and their interactions with aerosols and atmospheric dynamics.

In this presentation, we focus on preliminary aerosol observations from CAPE-K in the context of the cloud and precipitation measurements described in the CAPE-K overview paper (Mace et al., submitted to *BAMS*). CAPE-K spanned two contrasting winters. Winter 2024 was dominated by high-pressure ridges and was characterised by relatively warm, stable conditions, whereas Winter 2025 was dominated by frequent low-pressure systems and was cooler and more dynamically active.

Significant differences in CCN properties, aerosol composition and aerosol size distributions were observed between the two winters. Relative to Winter 2024, Winter 2025 was characterised by lower low-supersaturation CCN activation ratios, lower concentrations of aerosol chloride, sulfate and organics, fewer particles in the 100-300 nm size range, and a smaller geometric mean diameter of the larger fitted aerosol mode. These changes are consistent with a shift in the aerosol population towards reduced low-supersaturation CCN activation, reflecting differences in both particle size distribution and composition. While the relative contributions of these factors cannot be independently quantified, the observed aerosol differences indicate distinct aerosol-cloud interaction environments between the two winters.

The aerosol differences are examined in the context of cloud and precipitation characteristics observed during the two contrasting winter periods, providing insights into the role of aerosols in shaping Southern Ocean cloud and precipitation processes.

References

Gerald G. Mace; Roger Marchand; Melita Keywood; Tahereh Alinejadtabrizi; Ruhi Humphries; Alain Protat; Heath Powers; John Bilberry; Peter May; Steven Siems; Yi Huang; Min Deng; Sonya Fiddes; Jessie Creamean; Branka Miljevic; Jakob B. Pernov; Matthew D. Lebsock; Kerri Pratt; Sally Benson; Tiffany Smallwood; Luis Ackermann; Simon P. Alexander; Stuart Baly; Anna Bardin; Scott D. Chambers; Scott Collis; Thomas L. Day; Erin Dunne; Emily Barnes Franklin; Paul Gregory; Alan D. Griffiths; James Harnwell; Carson Hume; Mathew Lipson; Ottmar Möhler; Suzie Molloy; Benjamin J. Murray; Caleb Mynard; David Noone; Jennifer Powell; Andreas Schmitt; Robyn Schofield; Alexander Smirnov; Sally Taylor; Adam Theisen; Maria Vazquez; Jason Ward; Bethan White; Francis J. Zurek. The Clouds and Precipitation Experiment at Kennaook (CAPE-K): Multi-Season Observations of Southern Ocean Clouds, Aerosols, and Precipitation at 40°S submitted to the Bulletin of the American Meteorological Society " (BAMS-D-26-0027) 3 October 2026.

Overview of aerosol precursors and chemical composition during CAPE-k CHEM

J.B. Pernov[1,*], J. Sulo[1], C. Mynard[2], E. Franklin[2], J. Alroe[1], Z. Li[1], E. Dunne[2], R. Humphries[2], Suzie Molloy[2], Z. Ristovski[1], and B. Miljevic [1]

[1]School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, Australia
[2]CSIRO, Aspendale, Australia

[*]corresponding author: Jakob Pernov [Jakob.pernov@qut.edu.au]

Abstract

Earth system models struggle to properly represent the amount of downwelling solar radiation in the Southern Ocean, likely due to a misrepresentation of aerosol processes (Mallet et al., 2023), however, there is a dearth of gas- and aerosol-phase chemical measurements from Southern Ocean. Kennaook/Cape Grim is an ideal location for investigating aerosol precursors and aerosol chemical composition due to the diverse air masses experienced by the station including pristine Southern Ocean, terrestrial, and coastal.

As part of the larger Clouds and Precipitation Experiment at Kennaook (CAPE-k) campaign, CAPE-k CHEM performed online measurements of aerosol precursor vapours using a high-resolution nitrate chemical ionization mass spectrometer (CIMS) and bulk non-refractory aerosol chemical composition using a high-resolution time-of-flight aerosol mass spectrometer (HR-TOF-AMS). Measurements were performed in the U.S. Department of Energy Atmospheric Radiation Management (ARM) Mobile Facility (AMF2) at Kennaook/Cape Grim from October 2024 to May 2025. CAPE-k CHEM represents the first-time deployment of this instrumentation at Kennaook/Cape Grim.

In this presentation, we will showcase results from CAPE-k CHEM regarding gas-phase aerosol precursors and aerosol-phase chemical composition including the temporal patterns, relationship with meteorological and air mass history variables, and source regions for both the baseline sector of the natural pristine Southern Ocean and the terrestrially and anthropogenically influenced non-baseline sector. Figure 1. displays the diurnal cycles of gas and aerosol phase species, highlighting the influence of wind sector on temporal patterns and magnitude. This presentation will provide insight into the sources and dynamics of gas- and aerosol-phase chemical species in an understudied yet important region.

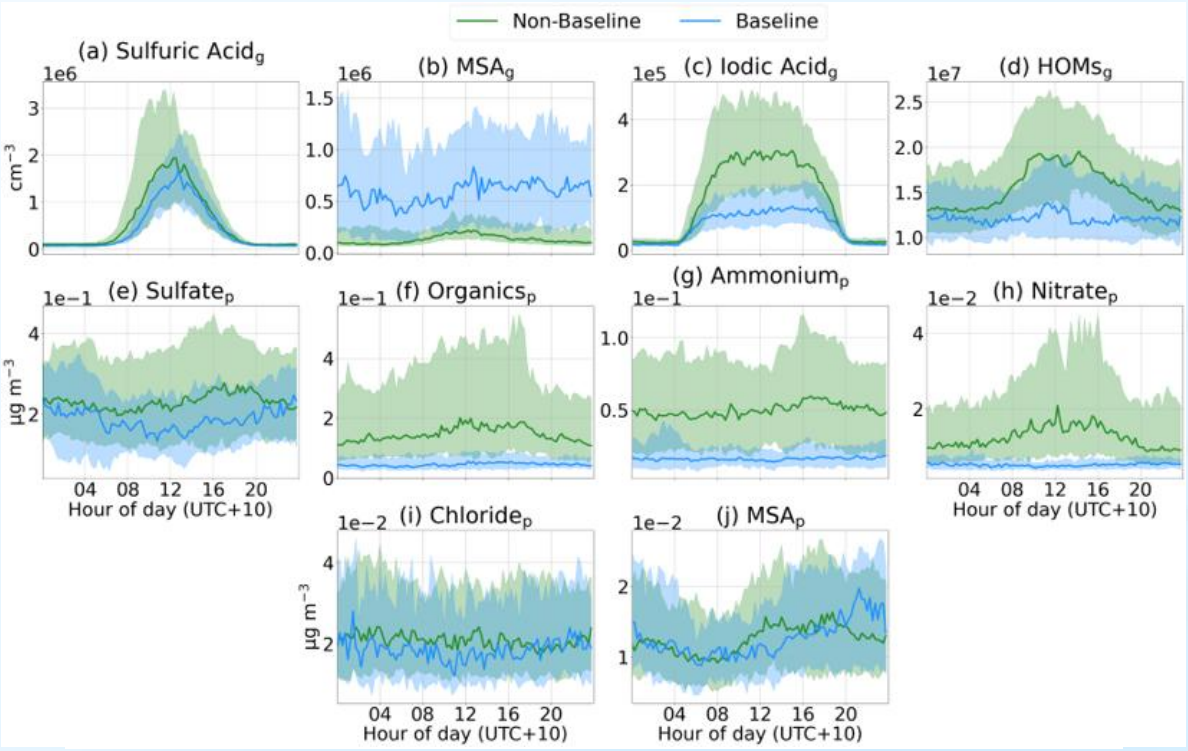


Fig. 2. Diurnal cycles of gas phase species from the nitrate CIMS (a-d, top row) and aerosol phase species from the HR-TOF-AMS (e-j, bottom two rows) split by non-baseline (green) and baseline (blue) sectors. The thick line represents the median, and the shading represents the interquartile range. The subscripts g and p represent the gas and particle phase respectively.

References

Mallet, M. D., Humphries, R. S., Fiddes, S. L., Alexander, S. P., Altieri, K., Angot, H., Anilkumar, N., Bartels-Rausch, T., Creamean, J., Dall'Osto, M., Dommergue, A., Frey, M., Henning, S., Lannuzel, D., Lapere, R., Mace, G. G., Mahajan, A. S., McFarquhar, G. M., Meiners, K. M., … Woodhouse, M. T. (2023). Untangling the influence of Antarctic and Southern Ocean life on clouds. *Elementa: Science of the Anthropocene*, *11*(1), 00130. https://doi.org/10.1525/elementa.2022.00130

A Multi-Instrument View of Transported Wildfire Smoke at Kennaook/Cape Grim during the CAPE-k Campaign

Deepa Roy[1,2]*, Maximilien Desservettaz[1,2], Ruhi Humphries[3], Melita Keywood[3], Caleb Mynard[3], Fabienne Reisen[3], Erin Dunne[3], Suzie Molloy[3], Scott Collis[4], Janek Uin[4], Art Sedlacek[4], Rob Newsom[4], Raghu Krishnamurthy[4], Damao Zhang[4], Evan Keeler[4], John Shilling[4], Gary Hodges[4], Jenni Kyrouac[4], Clare Paton-Walsh[1,2]

[1] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW, Australia
[2] New South Wales Bushfire and Natural Hazards Research Centre, Australia
[3] Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
[4] Atmospheric Radiation Measurement (ARM) User Facility, U.S. Department of Energy, USA

*Corresponding author: Deepa Roy [dr977@uowmail.edu.au]

Abstract

The Kennaook/Cape Grim Baseline Air Pollution Station (KCG), located on the north-west coast of Tasmania, is a remote site with clean background air, free from nearby anthropogenic emission sources, making it well suited for detecting transported air masses such as wildfire smoke. During the Cloud and Precipitation Experiment at Kennaook (CAPE-k), the existing measurements at KCG were supported by additional instruments from the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Mobile Facility. The campaign provided simultaneous measurements of trace gases, volatile organic compounds (VOCs), aerosol composition, black carbon and meteorology, together with remote-sensing measurements of the vertical structure of the atmosphere. Although CAPE-k focused on Southern Ocean clouds and aerosol–cloud interactions, this rich suite of instruments also offered a rare opportunity to study transported pollution events in detail.

Here, we use this multi-instrument view to investigate two wildfire-smoke events that reached KCG on 7-8 May 2024 and 5 February 2025. Surface observations of trace gases, VOCs measured by PTR-MS, aerosol composition and black carbon were analysed together with ceilometer, Doppler lidar and radiosonde measurements. These observations were further supported by HYSPLIT back-trajectory analyses and satellite-derived fire detections.

Both smoke events were characterised by elevated concentrations of combustion-related tracers. However, the relationships between gaseous and particulate components differed substantially in how their gas and aerosol components related to one another, and in the vertical structure of the atmosphere during their passage. These contrasts show that smoke arriving at the same remote site can carry very different signatures and highlight the value of interpreting surface chemistry together with vertical structure. The events provide useful case studies for evaluating fire emissions, transport and chemistry within atmospheric models.

Keywords:

Kennaook/Cape Grim; CAPE-k; wildfire smoke; multi-instrument observations; atmospheric composition; trace gases; aerosols; PTR-MS; boundary layer.

Investigating an Underutilised Mass Spectrometry Technique and Its Application to Marine Atmospheric Science

D. Corporal[1*], W. Hu[1], S. Brydon[1], N. Demarais[2], S. Blanksby[1], B. Miljevic[1]

[1] Queensland University of Technology, Brisbane, Queensland, Australia
[2] Syft Technologies, Christchurch, Canterbury, New Zealand

[*] corresponding author: David Corporal [david.corporal@hdr.qut.edu.au]

Abstract

Historically and in the present day, humanities understanding of atmospheric science has been constrained by the instruments and methods available to the scientific community [Lehtipalo et. al. 2024]. In marine environments particularly, instrument options are further limited due to the need to be portable for field campaigns [Lee et. al. 2014]. This field work is often needed to study short-lived chemical species.

Here, we investigate an established-but-not-routine technique in marine atmospheric research, selected-ion flow tube mass spectrometry (SIFT-MS). Although SIFT-MS has previously been reported on in atmospheric studies for over a decade [Prince et. al. 2010] [Hwang et. al. 2020], it remains underutilised in marine field campaigns relative to nitrate or hydronium chemical ionisation MS [Zhang et. al. 2023]. The fast reagent ion switching of this technique, allowing for detection selectivity beyond that of proton transfer reaction MS, merit further application to this field [Sovová et. al. 2010].

We deployed our SIFT-MS instrument onboard the CSRIO's research vessel Investigator from July to August 2026, for a 24-day voyage over the Southern Great Barrier Reef (GBR). Now, this voyage data is being analysed with follow up lab studies being planned.

This talk will provide a brief introduction to mass spectrometry in atmospheric science, discuss how SIFT-MS differs from other mass spectrometry techniques, describe the GBR voyage undertaken, and provide preliminary results from our investigation.

References

Hwang, K., J. G. An, S. Lee, W. Choi and U. H. Yim (2020). A Study on the Ozone Formation Potential of Volatile Organic Compounds in Busan using SIFT-MS. *Journal of Korean Society for Atmospheric Environment* 36. doi:10.5572/KOSAE.2020.36.5.645

Lee, B. H., F. D. Lopez-Hilfiker, C. Mohr, T. Kurtén, D. R. Worsnop and J. A. Thornton (2014). An Iodide-Adduct High-Resolution Time-of-Flight Chemical-Ionization Mass Spectrometer: Application to Atmospheric Inorganic and Organic Compounds. *Environmental Science & Technology* 48, 6309-6317. doi:10.1021/es500362a

Lehtipalo, K., T. Nieminen, S. Schobesberger, M. Ehn, M. Kulmala and V. Kerminen (2024). How the understanding of atmospheric new particle formation has evolved along with the development of measurement and analysis methods. *Journal of Aerosol Science*, 184, 106494 doi:10.1016/j.jaerosci.2024.106494

Prince, B. J., D. B. Milligan and M. J. McEwan (2010). Application of selected ion flow tube mass spectrometry to real-time atmospheric monitoring. *Rapid Communications in Mass Spectrometry* 24, 1763-1769. doi:10.1002/rcm.4574

Sovová, K., K. Dryahina, P. Španěl, M. Kyncl and S. Civiš (2010). A study of the composition of the products of laser-induced breakdown of hexogen, octogen, pentrite and trinitrotoluene using selected ion flow tube mass spectrometry and UV-Vis spectrometry. *Analyst* 135, 1106-1114. doi:10.1039/b926425f

Zhang, Y., R. Liu, D. Yang, Y. Guo, M. Li and K. Hou (2023). Chemical ionization mass spectrometry: Developments and applications for on-line characterization of atmospheric aerosols and trace gases. *TrAC Trends in Analytical Chemistry* 168, 117353. doi:10.1016/j.trac.2023.117353

Assessing the role of Antarctic sea ice dimethyl sulphide emissions on Southern Ocean CCN, cloud and radiation

Alanah Chapman[1,2,3,4*], Sonya Fiddes[2], Matt Woodhouse[3], Yi Huang[1,4] and Robyn Schofield[1]

[1] School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Parkville, VIC, Australia
[2]Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia
[3] CSIRO Environment, Aspendale, VIC, Australia
[4] ARC Centre of Excellence for 21st Century Weather, Melbourne, VIC, Australia

[*] Corresponding author: Alanah Chapman [alanahc@student.unimelb.edu.au]

Abstract

Representation of aerosol-cloud interactions over the Southern Ocean is known to be one of the largest sources of uncertainty for projections of future climate change. The Australian Community Climate and Earth System Simulator Atmosphere Model v2 (ACCESS-AM2) underrepresents cloud condensation nuclei during the period of largest surface shortwave radiation bias by more than 50%. We test the sensitivity of ACCESS-AM2 CCN, cloud, and radiation properties to a sea-ice associated source of the biogenic aerosol precursor dimethyl sulphide (DMS), to determine whether this brings simulation results in line with a series of comprehensive aerosol observations.

The control simulation, which uses the Hulswar et al. (2022) DMS seawater climatology, with no additional sea ice associated DMS source best reproduces atmospheric DMS concentrations measured by five ship campaigns and at three Antarctic coastal sites. However, CCN (evaluated over eight ship campaigns, at two Antarctic sites and one sub-polar site), cloud, and radiation properties are misrepresented, and are improved with the addition of a sea ice source of DMS. Our results indicate that climate models adequately represent atmospheric surface DMS concentrations, but the modelled pathways to sulphate aerosol production are contributing to the low CCN bias. Along with other recent studies, our results show that the simple 3-reaction DMS oxidation scheme is inadequate for producing the observed levels of Southern Ocean CCN, with implications for cloud and radiation in the region.

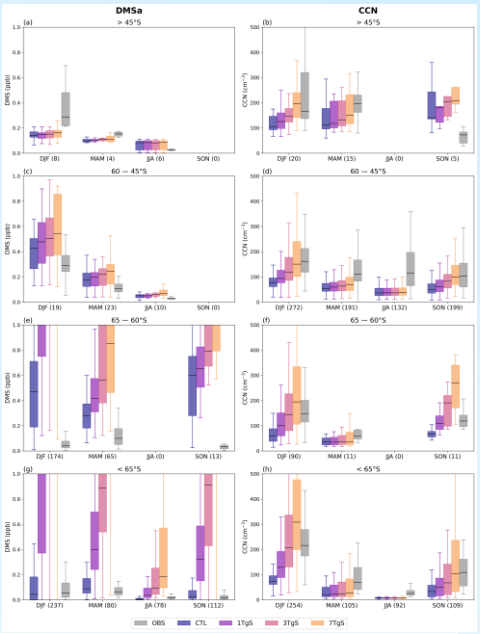


Fig. 3. Box plots of (a,c,e,g) atmospheric DMS over five voyage and three station campaigns, and (b,d,f,h) CCN over nine voyage and three station campaigns compared with model simulations. Daily data is grouped by season and latitudinal bands (a-b: >45°S; c-d: 60-45°S; e-f: 65-60°S; g-h: <65°S). Observations (OBS) and the CTL, 1TgS, 3TgS and 7TgS simulations are differentiated by colour: grey, blue, purple, pink and orange respectively. The number of sample days are shown in the x-axis tick label parentheses. Y-axis limits are limited in (e.g.) for readability.

Cape Grim/Kennaook's critical role in correcting current models of the global carbon budget.

Roger J. Francey[1]* and Jorgen S. Frederiksen[2]

[1] CSIRO Alumni, Canberra, ACT, Australia
[2] School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Parkvillle, VIC., Australia

* corresponding author: Roger Francey [roger.francey@bigpond.com]

Abstract

Anomalously low CO_2 mixing ratio, associated with the Global Financial Crisis (GFC) and expressed as a residual from the Cape Grim (CGO, 41°S) smooth exponential CO_2 increase, is sustained between 2010 to 2015 throughout the Southern Hemisphere. In the Northen Hemisphere, residuals from the Mauna Loa (MLO, 19°N) smooth exponential CO_2 increase demonstrate the global extent of the anomalous behaviour. However, this global response has not been reported in widely used global carbon modelling studies that rely on the integration of fluxes derived from globally distributed growth rate data. Additionally, Southern Hemisphere ^{13}C isotopic variations are consistent with transported fossil emissions from the Northern Hemisphere, but inconsistent with recent model estimates of Southern Hemisphere terrestrial or ocean carbon sinks. Also inconsistent are aircraft profiles of the CO_2 and $^{13}CO_2$ to between 6 to 8 km above Cape Grim (CGO, 41°S) which show minimal vertical gradients. These data support recent studies suggesting an overestimation of modelled air-surface exchange fluxes, which in turn, implies a longer atmospheric lifetime of fossil CO_2 emissions. Shortcomings in the widely accepted global carbon cycle models are identified as the inadequate representation of CO_2 interhemispheric exchange in inversion modelling and in the interpretations based on CO_2 growth rates. Significant improvement in this modelling is anticipated if it is more effectively constrained to match the effective absence of scatter in widespread measurements of precise baseline Southern Hemisphere CO_2 and $^{13}CO_2$ mixing ratios. With increasing global climate instability there is urgency in clarifying the demonstrable shortcomings in the CO_2 models currently used by governments around the world to address anthropogenic climate change.

References

Francey R.J. and Frederiksen J.S. Systematic anomalies in the recent global atmospheric CO_2 concentration. *PLOS Clim* 4(8), e0000682 (2025). https://doi.org/10.1371/journal.pclm.0000682

Australian emissions of synthetic greenhouse gases inferred from atmospheric measurements at Kennaook/Cape Grim

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

[1] CSIRO Environment, Aspendale, Victoria, Australia
[2] Met Office Hadley Centre, Exeter EX1 3PB, United Kingdom

[*] corresponding author: Cathy Trudinger [cathy.trudinger@csiro.au]

Abstract

Synthetic greenhouse gases (SGGs), also known as fluorinated gases (F-gases), include hydrofluorocarbons (HFCs) used predominantly as refrigerants, perfluorocarbons (PFCs) produced during aluminium production, and sulfur hexafluoride (SF_6) used in electrical transmission. Although present in the atmosphere at low concentrations, most SGGs have high global warming potentials and, in some cases, extremely long atmospheric lifetimes. As a result, they are covered by emission reduction targets under the Paris Agreement.

For more than 25 years, atmospheric observations from Kennaook/Cape Grim (KCG) have been used with inverse modelling to estimate Australian emissions of SGGs. The measurements capture both background concentrations and regional pollution events. Emissions inferred for southeastern Australia using the KCG observations and the InTEM inversion framework are scaled to derive national emission estimates. These atmospheric, or "top-down", estimates are compared with Australian National Greenhouse Gas Inventory estimates, which are derived using activity and import data and emission factors ("bottom-up" estimates). Both sets of estimates are reported annually to the United Nations Framework Convention on Climate Change.

Total Australian SGG emissions have more than doubled since 2005. Top-down emission estimates for many HFCs are broadly consistent with the Inventory until around 2010. Thereafter, Inventory estimates continue to rise, while top-down estimates increase much more slowly, resulting in a growing divergence between the two. More recently, however, top-down estimates indicate a marked increase in emissions for many HFCs, although more data are required to confirm this trend. The major PFCs (CF_4 and C_2F_6) show reasonable agreement between top-down and Inventory emission estimates, with similar long-term trends. In 2023, large PFC pollution peaks were measured at KCG, driven by increased emissions during operational instability at the Portland aluminium smelter following electricity supply disruptions. SF_6 pollution peaks are small and often difficult to distinguish from measurement noise.

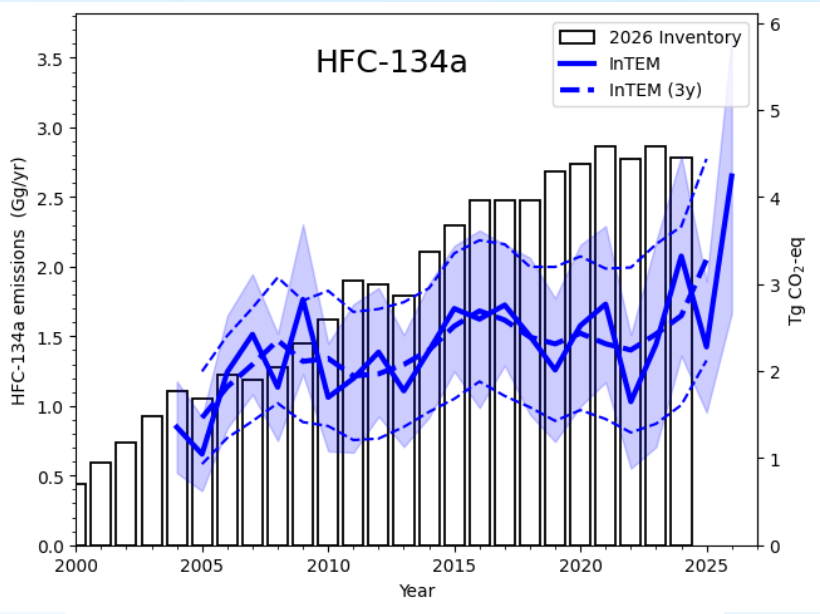


Fig. 1. Estimated Australian HFC-134a emissions from the Inventory and using atmospheric measurements (InTEM).

The 2026 Antarctic ozone hole

P. B. Krummel[1*], A. R. Klekociuk[2,3], M. B. Tully[4], P. J. Fraser[1], and C. M. Trudinger[1]

[1] CSIRO Environment, Aspendale, Victoria, Australia
[2] School of Physics, Chemistry and Earth Sciences, University of Adelaide, Adelaide, Australia
[3] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Victoria, Australia
[4] Australian Bureau of Meteorology, Melbourne, Victoria, Australia

[*] corresponding author: Paul Krummel [paul.krummel@csiro.au]

Abstract

This presentation will give an overview of the development and recovery of the 2026 Antarctic ozone hole using several ozone hole metrics based on satellite total column ozone data. The stratospheric meteorological conditions will also be shown as these are one of the main drivers of year-to-year variability in the size and depth of the ozone hole. The 2026 ozone hole metrics will be compared to the historical metrics from the last 47 years of satellite measurement.

The historical ozone hole metrics will in turn be compared with Equivalent Effective Stratospheric Chlorine (EESC) as a simple measure to look at ozone hole recovery. The EESC data are based entirely on Kennaook/Cape Grim Air Archive, Antarctic firn and Advanced Global Atmospheric Gases Experiment (AGAGE) global measurements of ozone depleting substances (ODSs). EESC is a metric used to quantify the total chlorine and bromine loading in the stratosphere that is available to destroy ozone. Thanks to the Montreal Protocol on Substances that Deplete the Ozone Layer, EESC has fallen approximately 14% since peaking around the year 2002. However, due to the long atmospheric lifetimes of many of the ODSs, their levels are not expected to recover to pre-1980 levels until the late 2080s in the Antarctic stratosphere.

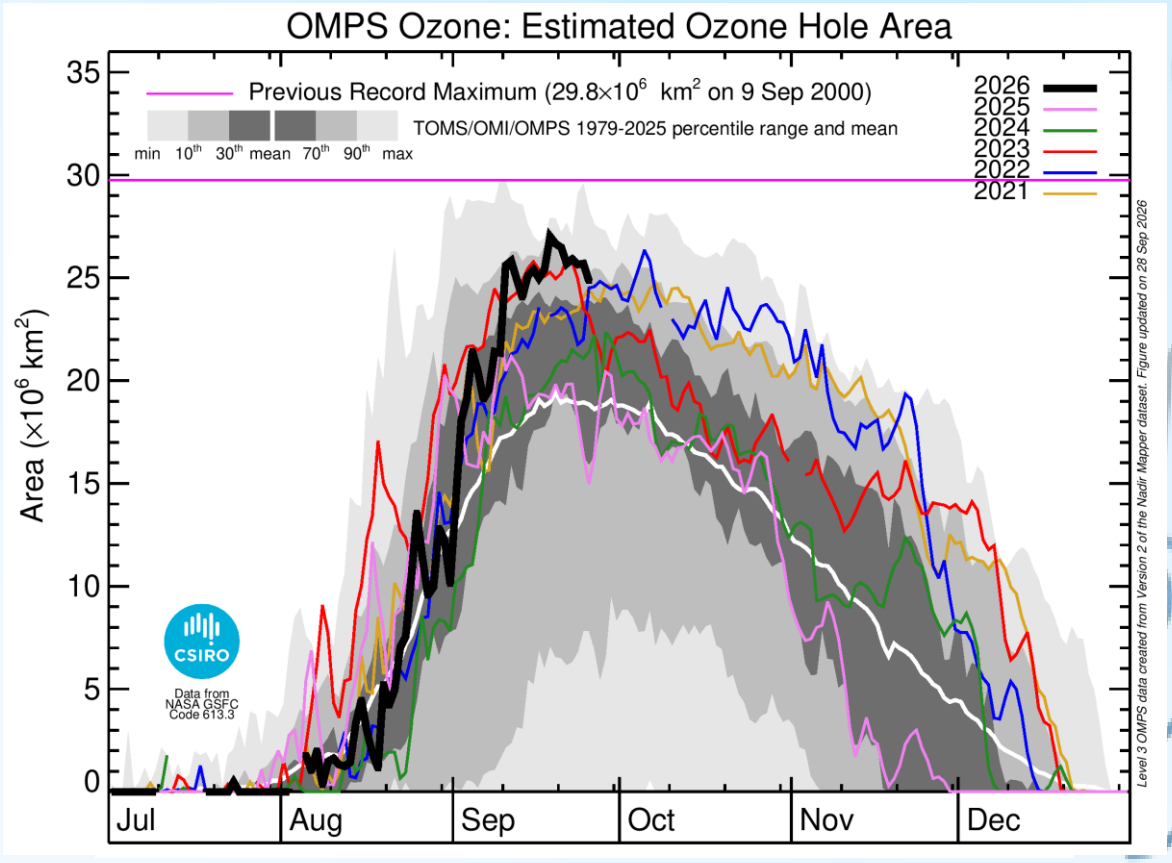


Fig. 1. Daily Antarctic ozone hole area based on OMPS data as of 25 September 2026, along with the daily ozone hole area from the past 5-years.

Long-term Evolution of Total Column Ozone in Australia – the Melbourne Dobson Record 1972-2025

M. B. Tully[1*], S. K. Rhodes[1], and D. G. Body[1]

[1] Bureau of Meteorology, Melbourne, Victoria, Australia

[*] corresponding author: Matt Tully [matt.tully@bom.gov.au]

Abstract

The Bureau of Meteorology continued long-term Dobson spectrophotometer measurements of total column ozone in the Melbourne area from 1983 to 2025, extending the long-term record originally begun by CSIRO at Aspendale in July 1955. From 1972 onwards the measurements are traceable to the World Standard Dobson. The Dobson program was ended in November 2025, with long-term ozone monitoring continuing in the suburb of Broadmeadows with a Brewer spectrophotometer.

We will present the Dobson data record from 1972 to 2025 which has now been reprocessed in a fully consistent manner.

A relatively rapid decline in total ozone in the 1970s and 1980s is evident, followed by a statistically significant slow recovery in total ozone since the late 1990s. The decadal trends in ozone are consistent with the long-term rise and fall of Equivalent Effective Stratospheric Chlorine (EESC) due to actions taken under the Montreal Protocol. The large seasonal influence on total ozone of broadscale climate patterns such as the Quasi-Biennial Oscillation (QBO) will be shown, in addition to the impact of one-off events such as the eruption of the Hunga volcano in Tonga in January 2022.

We will also compare the Dobson record against long-term satellite data and consider the spatial representativeness of measurements made at this location.

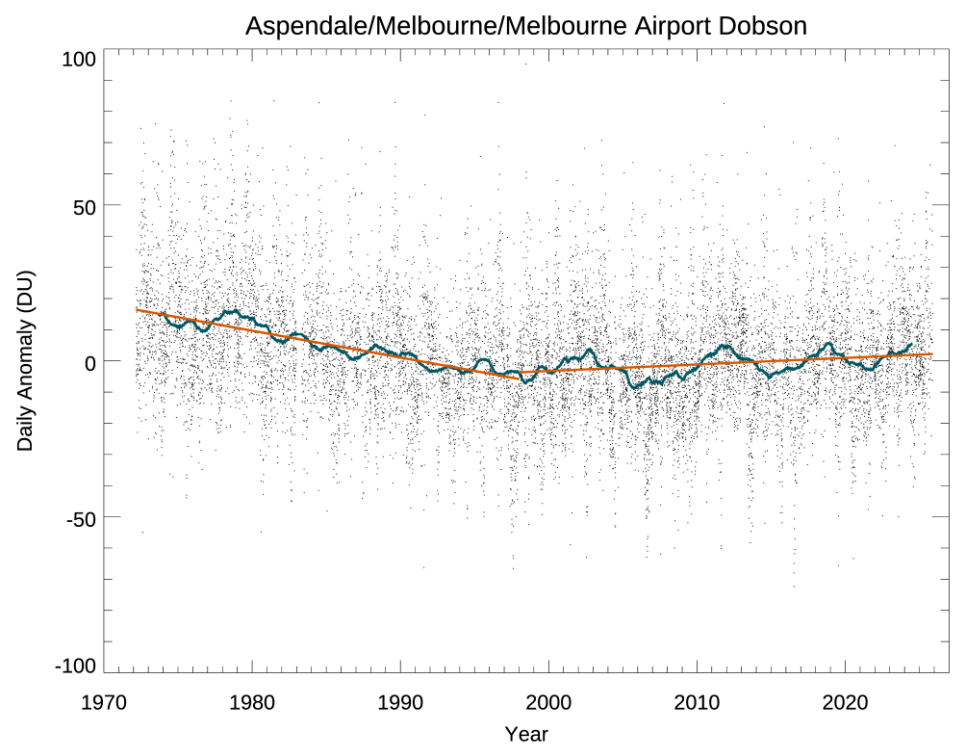


Fig. 4. Daily total ozone anomalies 1972-2025 as measured by the Dobson. The blue curve is a two year running mean. The orange lines represent the pre- and post- 1997 raw linear trends.

Long-term observations of atmospheric halocarbons from sites in East and South-East Asia - addressing a gap in our global networks

David Oram[1,2,*], Karina Adcock[2], Johannes Laube[3], Charles Chou[4], To Thi Hien[5], Tran Hoang Minh[5], Cao Ha Phuc Duy[5], Bui Duy Anh Ton[5], Nguyen Dang Minh Khoa[5], and Ahmad Amin Abdullah[6]

[1]National Center for Atmospheric Science, School of Environmental Sciences, University of East Anglia, UK
[2]Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, UK
[3]Institute for Climate and Energy Systems: Stratosphere (ICE-4), Forschungszentrum Jülich, Jülich, Germany
[4]Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan
[5]Faculty of Environment, University of Science, Vietnam National University, Ho Chi Minh City, Vietnam
[6]Institute of Ocean and Earth Sciences, University of Malaya, Kuala Lumpur, Malaysia

[*] corresponding author: David Oram [d.oram@uea.ac.uk]

Abstract

Halocarbons are the major drivers of stratospheric ozone depletion, and some are powerful greenhouse gases. Following the Montreal Protocol, the atmospheric abundances of many halocarbons are in decline, whilst many others are still increasing. The regional distribution of halocarbon emissions has also changed significantly over the last few decades, with emissions of many legacy compounds declining in Europe and North America but increasing in parts of Asia as industrial production and demand for refrigeration, etc has expanded. Atmospheric measurements have become increasingly important for identifying these changing source regions and assessing the effectiveness of international regulations. However, there are significant gaps in the global observation networks, not least in East and SE Asia, where historical measurements are sparse and present-day emissions are strong. To help address this gap, since 2014 we been collecting seasonal whole air samples at sites around the South China Sea, including in Taiwan, Malaysia and Vietnam.

We will present observations of a wide range of halocarbons, including both established ozone-depleting substances and their replacements. We will examine changes in atmospheric abundances over time and enhancements above background levels and compare observations between sites to investigate regional differences in emissions. We will also investigate the influence of atmospheric transport and identify periods associated with enhanced regional pollution.

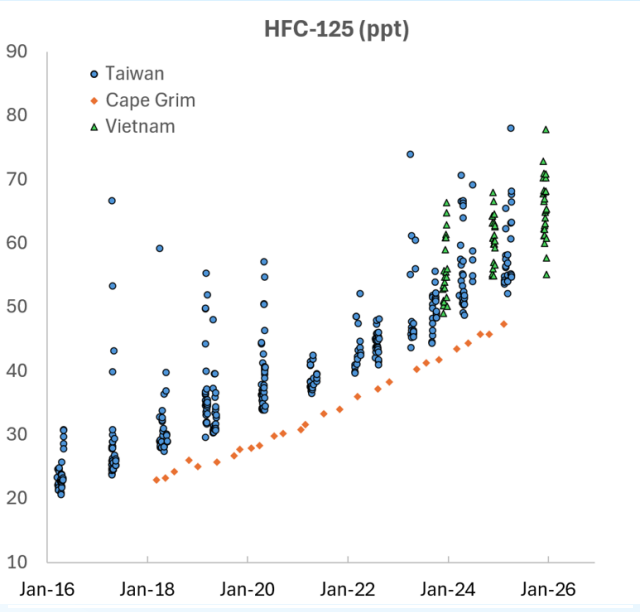


Fig. 5. Increasing atmospheric abundance of HFC-125 (CF_3CHF_2)

Interactive aerosol and cloud microphysics in the Australian regional atmospheric model

M. T. Woodhouse[1*], R. L. Jackson[2], S. L. Fiddes[3,4]

[1] CSIRO Environment, Aspendale, Victoria, Australia
[2] CSIRO Environment, Black Mountain, ACT, Australia
[3] Australian Antarctic Program Partnership, Hobart, Tasmania, Australia
[4] Institute for Marine and Antarctic Science, University of Tasmania, Hobart, Tasmania, Australia

[*] corresponding author: Matt Woodhouse [matthew.woodhouse@csiro.au]

Abstract

The ACCESS-rAM3 high-resolution atmospheric model allows for simulation across convection-permitting and convection-resolving resolutions, courtesy of flexible nested domains. It is being used for a variety of research applications including high impact weather. This standard configuration is being widely adopted by the Australian atmospheric community, and is being supported by the ACCESS-NRI (Australian Community Climate Earth System Simulator – National Research Infrastructure). While very capable, the standard configuration of ACCESS-rAM3 model is unaware of the variable influence of aerosol on clouds and radiation, and is restricted by a fixed cloud droplet number concentration.

In this work, an enhanced configuration of the ACCESS-rAM3 model including detailed aerosol microphysics is presented: ACCESS-rAM3-aer. The new configuration brings interactive aerosol emissions, deposition and microphysics from the GLOMAP-mode aerosol scheme (Mann et al., 2010; 2012), following the work done by Gordon et al (2023) and Jackson et al (2026). In ACCESS-rAM3-aer the aerosol is also coupled to the CASIM cloud microphysics scheme and can influence radiation, cloud microphysics, precipitation and dynamics, opening up new possibilities to study microphysical scale processes including the role of aerosol.

The intriguing possibility for the composition community is to be able to simulate aerosol processes at high resolution and make the most of the data and insights from the recent boom in southern hemisphere voyages and campaigns.

References

Gordon et al, 2023. NUMAC: Description of the Nested Unified Model With Aerosols and Chemistry, and Evaluation With KORUS-AQ Data. Journal of Advances in Modeling Earth Systems. https://doi.org/10.1029/2022MS003457

Jackson et al, 2026. A high-resolution coupled atmosphere-ocean model of the Great Barrier Reef: ACCESS-EMS-GBR v1.0. Under review in Geoscientific Model Development https://egusphere.copernicus.org/preprints/2026/egusphere-2026-2761/

Mann et al., 2010. Description and evaluation of GLOMAP-mode: A modal global aerosol microphysics model for the UKCA composition-climate model. Geoscientific Model Development. https://doi.org/10.5194/gmd-3-519-2010

Mann et al, 2012. Intercomparison of modal and sectional aerosol microphysics representations within the same 3-D global chemical transport model. Atmospheric Chemistry and Physic https://doi.org/10.5194/acp-12-4449-2012

Implementing Marine Aerosol Ice Nucleation Parametrizations in the Unified Model: Mitigating the Cloud Radiative Bias During a Case Study Over the Southern Ocean

Zhangcheng Pei[1*], Sonya L. Fiddes[1], Marc D. Mallet[2], Matthew T. Woodhouse[3], Simon P. Alexander[4, 1], Alain Protat[5, 1], Kalli Furtado[6], and Paul Field[7]

[1] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
[2] Bureau of Meteorology, Hobart, Australia
[3] Environment, CSIRO, Aspendale, Australia
[4] Australian Antarctic Division, Kingston, Australia
[5] Bureau of Meteorology, Melbourne, Australia
[6] National Oceanography Centre, Southampton, UK
[7] Met Office, Exeter, UK

[*] corresponding author: Zhangcheng Pei [zhangcheng.pei@utas.edu.au]

Abstract

Mixed-phase clouds over the Southern Ocean profoundly influence Earth's radiative balance, yet climate models persistently exhibit a positive surface shortwave radiation bias driven by over-glaciation in mixed-phase clouds. Addressing this bias requires accurate representation of ice-nucleating particles (INPs). This study presents the first online implementation of aerosol-aware marine INP parametrizations derived interactively from sea spray and marine organic aerosols within the high-resolution Unified Model. Using CAPRICORN-2 shipborne observations, we demonstrate that the default INP scheme overestimates INP concentrations by up to four orders of magnitude, causing a severely underestimated liquid water path. In contrast, empirical Antarctic and deterministic marine INP schemes reproduce the low INP concentrations typical of the pristine Southern Ocean, improving cloud and radiative properties. Crucially, microphysical and radiative responses to these INP reductions are strongly regime-dependent.

In deep, pre-frontal mixed-phase clouds, suppressing INP concentrations effectively inhibits cloud glaciation, significantly enhancing supercooled liquid water and largely mitigating the surface shortwave radiation bias. However, in shallow, post-frontal stratocumulus clouds, altering INP parametrization yields negligible improvements. Radiosonde evaluations reveal this insensitivity is driven by several model deficits, including systematically smoothed boundary layer inversions leading to excessive dry air entrainment, exacerbated by underestimated cyclonic moisture transport. Consequently, these shallow clouds are thermodynamically starved of water vapor, rendering microphysical INP adjustments ineffective. Ultimately, fully resolving Southern Ocean cloud-radiation biases requires synergistic advancements in representing aerosols, boundary layer physics and large-scale meteorological forcings.

References

Pei, Z., Fiddes, S. L., Mallet, M. D., Woodhouse, M. T., Alexander, S. P., Protat, A., Furtado, K., and Field, P. R.: Implementing Marine Aerosol Ice Nucleation Parametrizations in the Unified Model: Mitigating the Cloud Radiative Bias During a Case Study Over the Southern Ocean, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2026-3541, 2026.

High resolution modelling over Southern Ocean field campaigns

Sonya L. Fiddes[1], Matthew T. Woodhouse[2], Rebecca Jackson[2], Zhangcheng Pei[1], Alanah Chapman[3,1], Yi Huang[3], Marc D. Mallet[4], Alain Protat[4,1], Simon P. Alexander[5,1]

[1] Australian Antarctic Program Partnership, Institute of Marine and Antarctic Studies, University of Tasmania, Hobart, Tas, Australia
[2] Environment, Commonwealth Scientific and Industrial Research Organisation, Aspendale, Australia
[3] Bureau of Meteorology, Melbourne, Vic, Australia
[4] Australian Antarctic Division, Hobart, Tas, Australia
[5] School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Melbourne, Vic, Australia

[*] corresponding author: Sonya Fiddes [sonya.fiddes@utas.edu.au]

Abstract

The interaction of biologically derived aerosol with clouds and sunlight over the Southern Ocean is of large uncertainty, in part due to a lack of comprehensive observations. This has resulted in significant biases in models for this region, impacting the global energy balance. Observations are now available, extending from Kennaook-Cape Grim (Tasmania) through to the ice edge. These observations range from the sea state and biological productivity; the production of aerosol relevant gases; the size and composition of aerosol; to the microphysical properties of the cloud including its phase and depth.

In this work we will evaluate ACCESS-rAM3, a high-resolution regional model, which includes double moment cloud physics, with an additional coupling to the GLOMAP-mode aerosol scheme. We have made further changes from the default that are key to the Southern Ocean, including updating the ice-nucleating parameterisation to be location specific, updating the dimethyl sulphide ancillary to the newest climatology and ensuring the sea ice, sea surface temperature and chlorophyll-*a* fields are accurate. Each of these changes has made incremental improvements to how we model this complex system.

Utilising the observations from campaigns we will evaluate the UM and provide a benchmark from which we can test changes to the model to better represent the Southern Ocean aerosol-cloud system.

Atmospheric Processes Affecting sub-Antarctic Island Mercury Deposition

A. D. Griffiths[1*], P. Sebastianelli[2], M. A. Schneider[3], J. A. Fisher[4], S. D Chambers[1], and L. Schneider[3]

[1] ANSTO, Lucas Heights, NSW, Australia
[2] University of Wollongong, Wollongong, Australia
[3] Australian National University, Canberra, ACT, Australia
[4] James Cook University, Douglas, QLD, Australia

[*] corresponding author: Alan Griffiths [Alan.Griffiths@ansto.gov.au]

Abstract

Processes driving mercury deposition, to sub-Antarctic Macquarie Island, were investigated with the aim of guiding interpretations of lake sediment records on a timescale of up to the length of the Holocene (12 ka). At this scale, sediment records of salinity proxies indicate that ocean/atmosphere processes can drive fluctuations in lake salinity. This happens because changes in mean wind speed drive changes in sea spray aerosol (SSA) production and hence deposition.

To test if a similar mechanism is important for mercury deposition, and to assess its magnitude, we employed short 5-year runs of the GEOS-Chem model using a pre-industrial emissions scenario along with modern day wind fields. To represent past changes, spatially local mean-state perturbations were introduced in the model for (1) surface-level winds, (2) surface ocean mercury concentration, and (3) SSA aerosol interactions. These were targeted changes, affecting only to the model components responsible for calculating surface fluxes while leaving transport unaffected. The resulting changes in deposition support the hypothesis of a link between atmospheric processes and changes in mercury deposition, however it is a relatively weak effect. It appears plausible for these changes to drive a change in mercury deposition in the 5-10% range, whereas other mechanisms need to be considered, separately or in addition, to drive larger changes in deposition rate.

Over 25 Years of Continuous Observations of Atmospheric Composition within GAW, ACTRIS and ICOS at Hohenpeissenberg, Southern Germany

D. Kubistin[1], A. Claude[1], A. Filges[1], H. Flentje[1], R. Holla[1], F. Klein[1], T. Koch[1,2], M. Lindauer[1], J. Mueller-Williams[1], B. Nassl[1], W. Thomas[1], S. Wraase[1], and C. Plass-Duelmer[1]

[1] Hohenpeissenberg Meteorological Observatory, Deutscher Wetterdienst, 82383 Hohenpeissenberg, Germany
[2] Max Planck Institute for Biogeochemistry, 07745 Jena, Germany

* corresponding author: Dagmar Kubistin [dagmar.kubistin@dwd.de]

Abstract

Long-term atmospheric observations are essential for understanding trends in atmospheric composition, evaluating changes in emissions, and assessing the effectiveness of air quality and climate policies. At the Hohenpeissenberg Meteorological Observatory, operated by the German Meteorological Service (DWD), key atmospheric constituents have been measured continuously since the mid-1990s within the WMO/GAW programme and, more recently, as part of the European Research Infrastructures ICOS and ACTRIS.

Covering a broad range of species, from reactive gases to long-lived greenhouse gases, these long-term observations provide a unique record of atmospheric composition in Central Europe and support the assessment of ozone trends, atmospheric self-cleaning capacity, chemical processes, and changes related to anthropogenic emission regulations. They form the observational basis for science-for-services applications, such as Germany's Integrated Greenhouse Gas Monitoring System (ITMS), which combines atmospheric observations with modelling to provide independent estimates of greenhouse gas emissions and sinks in support of the implementation of the Paris Agreement.

Here, we present the observatory's long-term measurement programme, its contributions to atmospheric research and monitoring services, and recent developments towards improved data quality and near-real-time data provision.

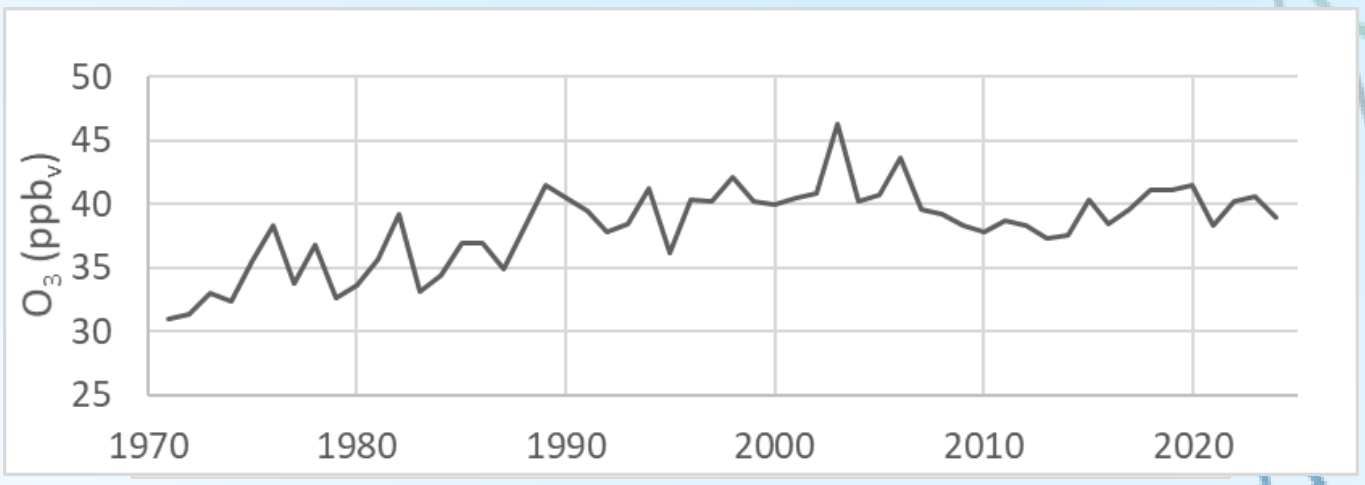


Fig. 1. Annual mean of surface ozone at the Hohenpeissenberg Meteorological Observatory.

Decrease in nucleated particles and cloud condensation nuclei observed across a range of environments

Sang-Woo Kim[1*], Do-Hyeon Park[2], and co-authors

[1]School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea
[2]Center for Climate and Carbon Cycle Research, Korea Institute of Science and Technology, Seoul, Korea

[*]corresponding author: Sang-Woo Kim [sangwookim@snu.ac.kr]

Abstract

Understanding new particle formation (NPF) and the fate of nanoparticles is crucial because of their close links to air quality, cloud formation, and climate. These effects vary spatially and temporally owing to diverse aerosol sources and their relatively short atmospheric lifetime. Here, we present a comprehensive analysis of long-term trends in NPF-associated nucleation-mode particles and cloud condensation nuclei (CCN) concentrations across diverse observation environments using quality-controlled particle number size distribution (PNSD) and CCN data from 37 sites, primarily from Global Atmosphere Watch (GAW) stations.

We identify declining decadal trends in both NPF occurrences and nucleated particle concentrations across most site types, with the strongest declines in urban areas. We observe simultaneous reductions in both CCN concentrations and in nucleation-mode particles, suggesting that newly formed particles are a potential source of CCN. This in turn suggests that cloud microphysical properties and radiative effects can be indirectly influenced through aerosol-cloud interactions that modify cloud droplet formation. These findings indicate that decreasing anthropogenic emissions could influence the climate forcing potential of aerosol-cloud interactions, with important implications for future climate projections.

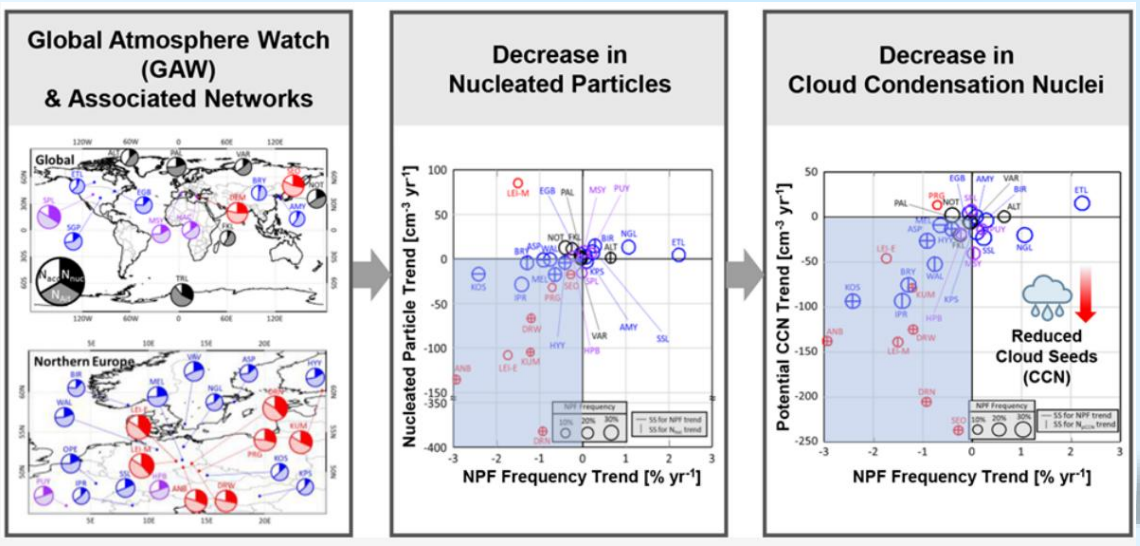


Fig. 6. Decreasing nucleated particles and cloud condensation nuclei

References

Park, D.-H., P. Laj, E. Andrews, C. Rose, A. Benedetti, M. Kulmala, I. Zabala, E. Ahlberg, A. Alastuey, E. Asmi, O. Bath, T. W. Chan, J.-S. Choi, M. Collaud Coen, S. Conil, S. Martins Dos Santos, K. Eleftheriadis, M. Fiebig, M. I. Gini, A. G. Hallar, A.-P. Hyvärinen, L. Järvi, N. Kalivitis, M. Keywood, J. E. Kim, S. Kim, J. Kontkanen, G. Kouvarakis, A. Kristensson, C. Kuang, M. Lee, H. Lihavainen, Y. Lin, C. Lunder, A. Matsuki, O. L. Mayol-Bracero, M. Merkel, N. Mihalopoulos, C. Lund Myhre, J. Park, M. Park, R. Park, T. Petäjä, J.-P. Putaud, A. Schwerin, K. Sellegri, E. Swietlicki, T. Tuch, P. Tunved, V. Vakkari, P. Villani, S. Vratolis, K. Weinhold, A. Wiedensohler, Y. J. Yoon, S. S. Yum, V. Ždímal, J. A. Ogren and S.-W. Kim (2026). Decrease in nucleated particles and cloud condensation nuclei observed across a range of environments. Environmental Science & Technology 60, doi:10.1021/acs.est.5c18035.

Stable Southern Hemisphere Atmospheric Hydroxyl (OH) During the Industrial Era Reconstructed from ^{14}CO in Glacial Firn and Ice (Law Dome, Antarctica, 1870-present AD)

Peter D. Neff[1,2*], Vasilii Petrenko[2], David Etheridge[3,4], Andrew M. Smith[5], Christo Buizert[6], Lee Murray[2], Cathy Trudinger[3], Mingjian Shi[2], Edward Crosier[2], Benjamin Hmiel[2], David Thornton[3,4], Lenneke Jong[7], Tas van Ommen[7], Marc Curran[7], Ross Beaudette[8], Christina Harth[8], Ray Langenfelds[3,4], Blagoj Mitrevski[3,4], Michael Dyonisius[2], Jessica Ng[8], Jeffrey Severinghaus[8], Ray Weiss[8]

[1]Department of Soil, Water, and Climate, University of Minnesota Twin Cities, Saint Paul, MN, USA
[2]Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY, USA
[3] CSIRO Environment, Aspendale, Victoria, Australia
[4]Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania, Australia
[5] Centre for Accelerator Science, Australian Nuclear Science and Technology Organisation [ANSTO], Lucas Heights, NSW, Australia
[6]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA
[7]Australian Antarctic Division & Antarctic Climate & Ecosystems Coop. Res. Centre, Hobart, Australia
[8]Scripps Institution of Oceanography, La Jolla, CA, USA

[*] corresponding author: Peter D. Neff [pneff@umn.edu]

Abstract

Hydroxyl, OH, is the main tropospheric oxidant and determines lifetime of methane and other trace gases in the atmosphere, thereby controlling warming from these gases. Changes in OH concentration ([OH]) in response to large changes in reactive trace gas emissions are uncertain. Measurements of 14C-containing carbon monoxide (14CO) and other tracers over the last ≈25 years have been successfully used to monitor changes in average [OH], but observations have not extended further back in time. Reconstructions of 14CO concentration ([14CO]) from ice cores at sites with high snowfall rates can provide constraints, as rapid snow burial limits in-situ production of 14CO.

A US-Australian team sampled firn air and ice at Law Dome, Antarctica (2018-19, DE08-OH, 1.3 m a-1 ice-equivalent snow accum.), to 240 m depth. Ice core air ages span from the 1870s to the early 2000s, and firn-air samples from 0 m to 81 m depth capture air from the early 2000s to present. [14CO] was analyzed in these air samples and corrections for in-situ 14CO production, validated against direct atmospheric measurements for more recent samples, allowed development of a [14CO] history.

Paleoatmospheric [14CO] is stable from ≈1866 - 1997. From 2003 - 2012, firn air captures a smoothed [14CO] oscillation driven by an 11-year solar cycle. [14CO] history is interpreted using GEOS-Chem, which indicates [14CO] samples at Law Dome are surprisingly sensitive to hemispheric-scale [OH]. The Law Dome record overlaps with direct atmospheric observations of OH proxies (e.g., methyl chloroform) for the past three decades, and indicates small (a few percent) variability in Southern Hemisphere [OH], in agreement with other studies.

The long-term Southern Hemisphere [OH] variability over the industrial transition inferred from our [14CO] record is similarly small, indicating [OH] was stable even at times of large changes in abundances of reactive species.

Constraining spatial, seasonal and temporal variability in OH with ^{14}CO

L. T. Murray[1]*, A. Chattopadhyay[1], S. S. Miller[1], E. E. Thomson[1], K. R. Hall[1], S. Ahn[1], M. Scholer[1], A. C. Ihle[1], V. V. Petrenko[1], I. Usoskin[2], S. Poluianov[2], A. M. Smith[3], B. Yang[3], A. Amatya Joshi[3], B. Thomas[4], R. Burgener[4], A. Colton[4], M. Doneghey[4], R. M. Chewitt-Lucas[5], E. Blades[5], A. Borges[6], N. C. Machín[6], P. Soriano[6], M. Leitch[7], H. Schaefer[7], G. W. Brailsford[7], O. Magand[8], D. Combemale[8], P. Hernandez[8], E. Golubic[8], A. J. Turner[9]

[1] University of Rochester, Rochester, NY, USA
[2] Sodankylä Geophysical Observatory (Oulu Unit), University of Oulu, Finland
[3] Center for Accelerator Science, Australian Nuclear Science and Technology Organisation, Australia
[4] National Oceanic and Atmospheric Administration Global Monitoring Laboratory, USA
[5] Caribbean Institute for Meteorology and Hydrology, Barbados
[6] Izaña Atmospheric Research Center, Tenerife, Spain
[7] National Institute of Water and Atmospheric Research, New Zealand
[8] Université de la Réunion, La Réunion, France
[9] University of Washington, Seattle, WA, USA

* corresponding author: Lee T. Murray [lee.murray@rochester.edu]

Abstract

The hydroxyl radical (OH) governs the oxidative capacity of the troposphere and controls the lifetime of methane and many reactive trace gases. However, global atmospheric chemistry models show substantial disagreement in both the mean abundance of OH and its variability from seasonal to decadal timescales. Constraints have traditionally relied on the decay of methyl chloroform, but declining atmospheric concentrations now limit its diagnostic value, motivating alternative observational proxies.

We implement radiocarbon monoxide (^{14}CO) in the GEOS-Chem chemical transport model as an independent constraint on OH. ^{14}CO is produced primarily by cosmic-ray spallation in the polar upper troposphere and lower stratosphere, with secondary production from the oxidation of $^{14}CH_4$, biogenic volatile organic compounds, and biomass burning. Primary production is parameterized using time-varying solar modulation, geomagnetic field intensity, and atmospheric pressure, while secondary sources are driven by historical $^{14}CH_4$, $^{14}CO_2$, and fire emission inventories.

The forward simulation reproduces the observed meridional gradient, seasonal cycle, and interannual variability of ^{14}CO with high skill (R = 0.86; n = 1,808), indicating robust representation of cosmogenic production and transport. Most observational sites are dominated by the well-constrained primary source, though tropical regions exhibit greater sensitivity to uncertainties in secondary production. We assimilate observations from a new global ^{14}CO monitoring network using a nonlinear analytical inversion to optimize the four-dimensional OH distribution. The inversion indicates that the prior OH climatology underestimates the amplitude of the seasonal cycle of OH in response to incoming solar radiation, and that global mean OH decreased between 2021 and 2024. Comparison with a new 26-year 4D-VAR methyl chloroform inversion highlights complementary tracer sensitivities to hemispheric and temporal structure in OH.

Atmospheric $\Delta^{14}CH_4$ constraints on fossil methane emissions

M. N. Dyonisius[1*], S. J. Lehman[1], J. B. Miller[2], H. Schaefer[3,5], A.M. Smith[4], J.C. Turnbull[5], Y. Oh[2], R. Moss[5], S. Gray[5], V. V. Petrenko[6], C. Buizert[7], P. Neff[8], D. Etheridge[9,10], C. Trudinger[9], L. Bruhwiler[2], C. Wolak[1], S. Morgan[1], P. Cappa[1], J. Southon[11]

[1] Institute of Arctic and Alpine Research University of Colorado Boulder, Boulder, Colorado, USA
[2] National Oceanic Atmospheric Administration Global Monitoring Laboratory, Boulder, Colorado, USA
[3] Royal Society Te Apārangi, Wellington, New Zealand
[4] Australian Nuclear Science and Technology Organization, Lucas Heights, New South Wales, Australia
[5] Earth Sciences New Zealand, Wellington, New Zealand
[6] Dept. Earth and Environmental Sciences University of Rochester, Rochester, New York, USA
[7] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA
[8] Dept. of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota, USA
[9] Commonwealth Scientific and Industrial Research Organisation, Aspendale, Victoria, Australia
[10] Institute of Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia
[11] W. M. Keck Carbon Cycle Accelerator Mass Spectrometer Facility, University of California, Irvine, Irvine, California, USA

[*] corresponding author: Michael N. Dyonisius [michael.dyonisius@colorado.edu]

Abstract

Atmospheric methane mole fraction ($x$$CH_4$) today is ~160% higher than preindustrial levels (MacFarling Meure et al., 2006) and accounts for ~17% of total anthropogenic radiative forcing (Forster et al., 2021). Despite international pledges to reduce emissions, $x$$CH_4$ continues to rise, and large uncertainties remain in the global CH_4 budget (Saunois et al., 2025). Measurements of the relative abundance of ^{13}C vs. ^{12}C in atmospheric CH_4 (commonly expressed with the isotopic delta notation "$\delta^{13}CH_4$") can be used to better constrain the CH_4 budget (e.g., Michel et al., 2024). However, atmospheric inversions that use both CH_4 and $\delta^{13}CH_4$ as observational constraints (i.e., "dual-tracer" inversions) yield substantially different source attributions than CH_4-only inversions. Dual-tracer inversions tend to infer higher fossil emissions and attribute the recent $x$$CH_4$ rise almost entirely to microbial sources (e.g., Basu et al., 2022; Michel et al., 2024), whereas CH_4-only inversions tend to infer lower fossil emissions and attribute the recent $x$$CH_4$ rise to both fossil and microbial sources (e.g., Pendergrass et al., 2025; Zhang et al., 2022). It has been argued that uncertainties in $\delta^{13}CH_4$ source isotope signatures and kinetic isotope effects (KIEs) from atmospheric removals may limit the reliability of the dual-tracer results (Thanwerdas et al., 2024).

Radiocarbon (^{14}C) measurements of atmospheric CH_4 ($\Delta^{14}CH_4$) provide complementary constraints on the CH_4 budget (e.g., Lassey et al., 2007) in a system that is arguably simpler than the ^{13}C system. ^{14}C is naturally produced in the upper atmosphere via nuclear reactions between cosmic rays and nitrogen. The newly produced ^{14}C atom is then quickly oxidized to $^{14}CO_2$ and assimilated into the carbon cycle. Biogenic CH_4 sources such as wetlands, biomass burning, and agriculture all emit CH_4 with a $\Delta^{14}C$ signature that follows the contemporary atmospheric $\Delta^{14}CO_2$ with a certain time lag ("τlag," also commonly referred to as biospheric turnover time), which is the delay between the assimilation of environmental carbon and its release as CH_4. Meanwhile, CH_4 from fossil sources contains no ^{14}C ($\Delta^{14}C_{fos}$ = -1000‰). Unlike $\delta^{13}CH_4$, atmospheric $\Delta^{14}CH_4$ is not sensitive to uncertainties in the KIEs of CH_4 sinks.

Here we present a new, ~10 years record of very high precision atmospheric $\Delta^{14}CH_4$ measurements (±2.7‰ reproducibility on authentic extraction and measurement pairs, 1σ) from an Arctic background site, Utqiaġvik (formerly Barrow), Alaska (BRW; 71.32°N, 156.61°W) between 2012-2022, complemented by $\Delta^{14}CH_4$ measurements from two Southern Hemisphere background sites: Baring Head, New Zealand (BHD; 41.41°S, 174.87°E) and Arrival Heights, Antarctica (ARH; 71.83°S, 166.20°E) over the same time period. We also present new $\Delta^{14}CH_4$ measurements from firn air and ice cores collected from Law Dome, Antarctica, during the 2018-2019 austral summer (DE08-OH; 66°44'S, 112°50'E). We use all available paleo and historical contemporary $\Delta^{14}CH_4$ data to provide an updated constraint on the turnover time of biogenic CH_4 (τlag = 2-3yr). Using an updated bottom-up inventory of direct $^{14}CH_4$

emissions from nuclear power plants (Laemmel and Szidat, 2025), our preliminary analysis indicates that present-day fossil CH_4 emissions must be higher than the ~100-110 Tg/yr estimates from many CH_4-only inversions (e.g., He et al., 2026; Pendergrass et al., 2025) and more consistent with fossil CH_4 emissions estimates of ~120-140 Tg/yr derived from atmospheric $\delta^{13}CH_4$ data (e.g., Basu et al., 2022; Schwietzke et al., 2016).

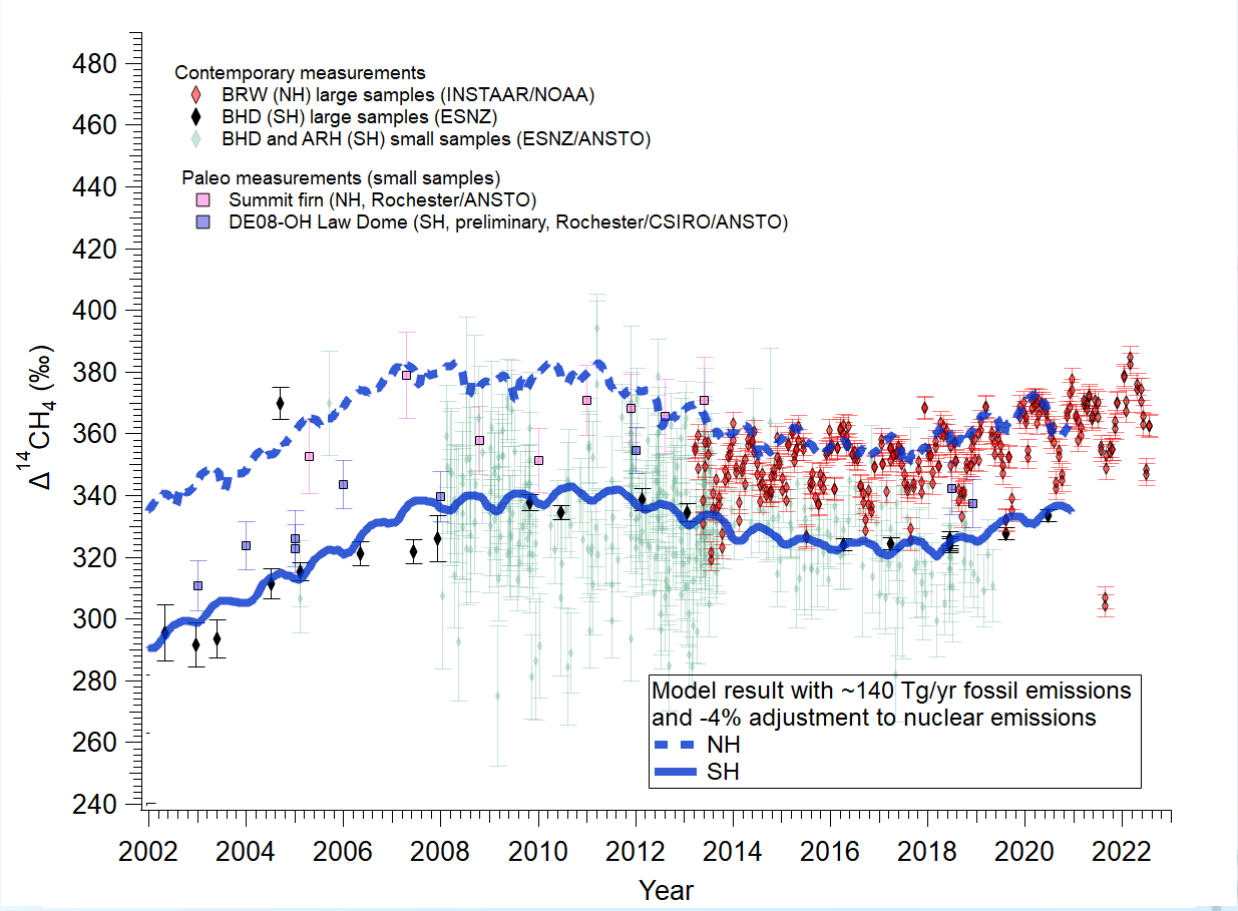


Fig.1. Contemporary atmospheric $\Delta^{14}CH_4$ measurements (diamonds) and paleo measurements (squares), compared with our "best-fit" modeled Northern Hemisphere (NH; dashed blue line) and Southern Hemisphere (SH; solid blue line) $\Delta^{14}CH_4$ from 2002-present. The result shown uses ~140 Tg/yr fossil CH_4 emissions, a 2-yr biospheric turnover time (τlag), and a small (−4%) adjustment to the bottom-up nuclear $^{14}CH_4$ emission inventory of Laemmel and Szidat (2025).

References

Basu, S., Lan, X., Dlugokencky, E., Michel, S., Schwietzke, S., Miller, J. B., Bruhwiler, L., Oh, Y., Tans, P. P., Apadula, F., Gatti, L. V., Jordan, A., Necki, J., Sasakawa, M., Morimoto, S., Di Iorio, T., Lee, H., Arduini, J., and Manca, G.: Estimating emissions of methane consistent with atmospheric measurements of methane and $\delta^{13}C$ of methane, *Atmospheric Chemistry and Physics*, 22, 15351–15377, https://doi.org/10.5194/acp-22-15351-2022, 2022.

Forster, P., Storelvmo, T., Armour, K., Collins, W., Dufresne, J.-L., Frame, D., Lunt, D. J., Mauritsen, T., Palmer, M. D., Watanabe, M., Wild, M., and Zhang, H.: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity, edited by: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R., and Zhou, B., , Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change923–1054https://doi.org/10.1017/9781009157896.009, 2021.

He, M., Jacob, D. J., Estrada, L. A., Varon, D. J., Sulprizio, M., Balasus, N., East, J. D., Penn, E., Pendergrass, D. C., and Chen, Z.: Attributing 2019–2024 methane growth using TROPOMI satellite observations, *Science Advances*, 12, eadz9007, 2026.

Laemmel, T. and Szidat, S.: Compilation of annual nuclear electricity production per reactor from 1954 to 2024, https://doi.org/https://doi.org/10.5281/zenodo.15828962, n.d.

Lassey, K. R., Lowe, D. C., and Smith, A. M.: The atmospheric cycling of radiomethane and the "fossil fraction" of the methane source, *Atmospheric Chemistry and Physics*, 7, 2141–2149, https://doi.org/10.5194/acp-7-2141-2007, 2007.

MacFarling Meure, C., Etheridge, D., Trudinger, C., Steele, P., Langenfelds, R., van Ommen, T., Smith, A., and Elkins, J.: Law Dome CO2, CH4 and N2O ice core records extended to 2000 years BP, *Geophys. Res. Lett.*, 33, L14810, https://doi.org/10.1029/2006GL026152, 2006.

Michel, S. E., Lan, X., Miller, J., Tans, P., Clark, J. R., Schaefer, H., Sperlich, P., Brailsford, G., Morimoto, S., Moossen, H., and Li, J.: Rapid shift in methane carbon isotopes suggests microbial emissions drove record high atmospheric methane growth in 2020–2022, *Proceedings of the National Academy of Sciences*, 121, e2411212121, https://doi.org/10.1073/pnas.2411212121, 2024.

Pendergrass, D. C., Jacob, D. J., Balasus, N., Estrada, L., Varon, D. J., East, J. D., He, M., Mooring, T. A., Penn, E., Nesser, H., and Worden, J. R.: Trends and seasonality of 2019–2023 global methane emissions inferred from a localized ensemble transform Kalman filter (CHEEREIO v1.3.1) applied to TROPOMI satellite observations, *Atmospheric Chemistry and Physics*, 25, 14353–14369, https://doi.org/10.5194/acp-25-14353-2025, 2025.

Saunois, M., Martinez, A., Poulter, B., Zhang, Z., Raymond, P. A., Regnier, P., Canadell, J. G., Jackson, R. B., Patra, P. K., Bousquet, P., Ciais, P., Dlugokencky, E. J., Lan, X., Allen, G. H., Bastviken, D., Beerling, D. J., Belikov, D. A., Blake, D. R., Castaldi, S., Crippa, M., Deemer, B. R., Dennison, F., Etiope, G., Gedney, N., Höglund-Isaksson, L., Holgerson, M. A., Hopcroft, P. O., Hugelius, G., Ito, A., Jain, A. K., Janardanan, R., Johnson, M. S., Kleinen, T., Krummel, P. B., Lauerwald, R., Li, T., Liu, X., McDonald, K. C., Melton, J. R., Mühle, J., Müller, J., Murguia-Flores, F., Niwa, Y., Noce, S., Pan, S., Parker, R. J., Peng, C., Ramonet, M., Riley, W. J., Rocher-Ros, G., Rosentreter, J. A., Sasakawa, M., Segers, A., Smith, S. J., Stanley, E. H., Thanwerdas, J., Tian, H., Tsuruta, A., Tubiello, F. N., Weber, T. S., van der Werf, G. R., Worthy, D. E. J., Xi, Y., Yoshida, Y., Zhang, W., Zheng, B., Zhu, Q., Zhu, Q., and Zhuang, Q.: Global Methane Budget 2000–2020, *Earth System Science Data*, 17, 1873–1958, https://doi.org/10.5194/essd-17-1873-2025, 2025.

Schwietzke, S., Sherwood, O. A., Bruhwiler, L. M. P., Miller, J. B., Etiope, G., Dlugokencky, E. J., Michel, S. E., Arling, V. A., Vaughn, B. H., White, J. W. C., and Tans, P. P.: Upward revision of global fossil fuel methane emissions based on isotope database, *Nature*, 538, 88–91, https://doi.org/10.1038/nature19797, 2016.

Thanwerdas, J., Saunois, M., Berchet, A., Pison, I., and Bousquet, P.: Investigation of the renewed methane growth post-2007 with high-resolution 3-D variational inverse modeling and isotopic constraints, *Atmospheric Chemistry and Physics*, 24, 2129–2167, https://doi.org/10.5194/acp-24-2129-2024, 2024.

Zhang, Z., Poulter, B., Knox, S., Stavert, A., McNicol, G., Fluet-Chouinard, E., Feinberg, A., Zhao, Y., Bousquet, P., Canadell, J. G., Ganesan, A., Hugelius, G., Hurtt, G., Jackson, R. B., Patra, P. K., Saunois, M., Höglund-Isaksson, L., Huang, C., Chatterjee, A., and Li, X.: Anthropogenic emission is the main contributor to the rise of atmospheric methane during 1993–2017, *National Science Review*, 9, nwab200, https://doi.org/10.1093/nsr/nwab200, 2022.

Insights into the magnitude and variability of trace-gas sources and sinks from globally-distributed measurements of long-lived trace gases

S. A. Montzka[1*], I. Vimont[1], G. Dutton[1,2], M. Crotwell[1,2], L. Western[3], M. Chipperfield[4], Z. Wang[4]

[1] Global Monitoring Laboratory, NOAA, Boulder, Colorado, U.S.A.
[2] CIRES, Univ. of Colorado, Boulder, Colorado, U.S.A.
[3] Center for Sustainability Science and Strategy, Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A.
[4] School of Earth and Environment, Univ. of Leeds, Leeds, U.K.

[*] corresponding author: Steve Montzka [Stephen.A.Montzka@noaa.gov]

Abstract

Deciphering the underlying causes for changes in the atmospheric abundances of long-lived trace gases remains a major challenge for the atmospheric science community. Understanding the role of international policy versus atmospheric processes on measured changes is an essential step for assessing the effectiveness of international protocols designed to limit global environmental damage, for example. Precise trace-gas measurements at globally-distributed sites conducted to ensure a high-degree of site-to-site consistency, *e.g.*, flask collection at distributed sites followed by analysis on a common instrument, provide a means to reliably characterize and monitor even small mole fraction gradients that are the tell-tail signs of these processes.

Here, we will explore multiple approaches for isolating the influences of emissions, loss, and transport on a range of gases controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer. These approaches have provided an improved understanding of year-to-year changes in, for example, CFC emissions, and they allow estimates of hydroxyl radical abundance on near-global scales independent of inventory-based emission estimates.

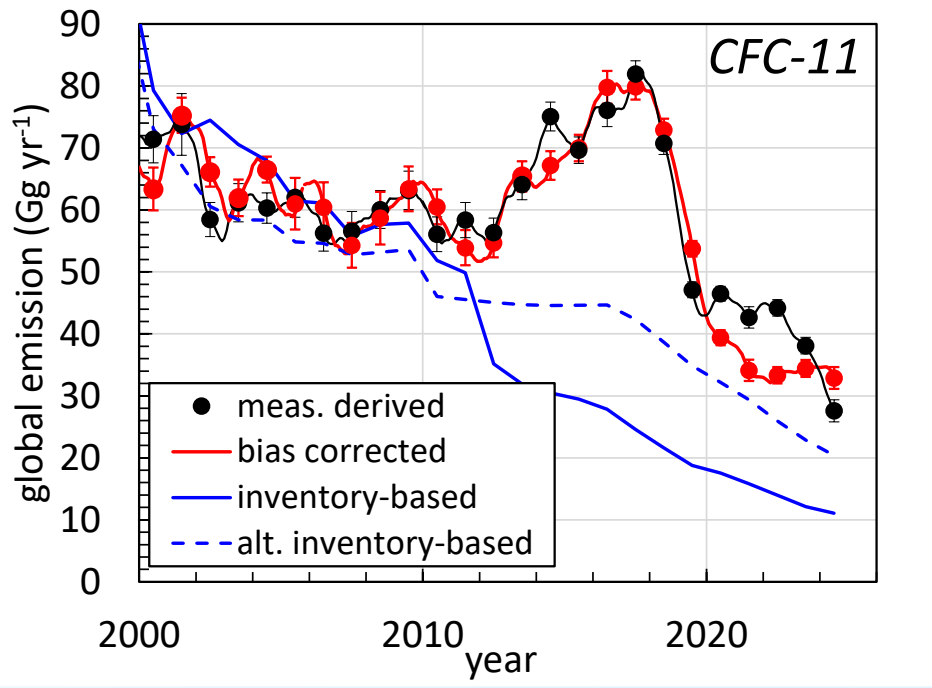


Fig. 17. Global CFC-11 emissions inferred from atmospheric measurements and an inventory-based analysis of production and consumption. Global emissions assuming a constant global loss frequency (1/50 y^{-1}; black lines and points) are shown alongside estimates after accounting for interannual changes in air transport, particularly exchange between the troposphere and stratosphere (red points and lines). Two inventory-based expectations are shown (blue lines), with the dashed line being derived from a slightly longer and distributed timescale associated with release from foams at their end of life. CFC-11 was banned for use in foams in 2010.

A novel method for emissions-free derivation of hemispheric hydroxyl radical anomalies using measured halocarbons

Luke. M. Western[1*], Candice Chen[2], Paul B. Krummel[3], Chris R. Lunder[4], Stephen A. Montzka[5], Jens Mühle[6], Simon O'Doherty[7], Ronald G. Prinn[1], Matthew Rigby[7], Martin K. Vollmer[8], Dickon Young[7]

[1] Center for Sustainability Science and Strategy, Massachusetts Institute of Technology, Cambridge, MA, USA
[2] Department of Earth Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA
[3] CSIRO Environment, Aspendale, Victoria, Australia
[4] NILU, Kjeller, Norway
[5] NOAA Global Monitoring Laboratory, Boulder, CO, USA
[6] Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA
[7] School of Chemistry, University of Bristol, Bristol, UK
[8] Laboratory for Air Pollution/Environmental Technology, Empa, Dübendorf, Switzerland

[*] corresponding author: Luke Western [lwestern@mit.edu]

Abstract

The atmospheric lifetimes of many atmospheric pollutants, ozone depleting substances and greenhouse gases, including methane, are controlled primarily by the hydroxyl radical (OH). Quantifying the tropospheric OH abundance and distribution is central to determining the budgets of these gases. We present a novel method to infer hemispheric OH anomalies from observations of HFCs and methyl chloroform (CH_3CCl_3) from the AGAGE global monitoring network (Prinn et al., 2018), combined with transport tracers, which are inert in the troposphere, to separate chemistry from dynamics.

An example of the hemispheric OH anomaly using this approach is shown in Figure 1. The inclusion of HFC-constraints, in addition to CH_3CCl_3, which has long been used to estimate OH abundances, are necessary because CH_3CCl_3 abundances have declined to levels that limit its utility (Liang et al., 2017, Duncan et al., 2024). Other proposed methods using halocarbons as an alternative to CH_3CCl_3 have required simultaneous inference of emissions and losses of gases (Liang et al., 2017; Thompson et al., 2024), creating an ill constrained problem (Naus et al., 2019).

Instead, we present a method which only assumes that the growth in emissions in each hemisphere is smooth over time, and targets interannual variability in OH rather than long-term trends. The use of multiple transport tracers to derive the interhemispheric transport timescales also allows uncertainty arising from the transport to be propagated into the end estimate. We will discuss changes in the OH anomaly in the Northern and Southern Hemispheres over the past two decades, the implications for lifetimes and measured anomalies of trace gases, and motivation for the use of alternatives to CH_3CCl_3.

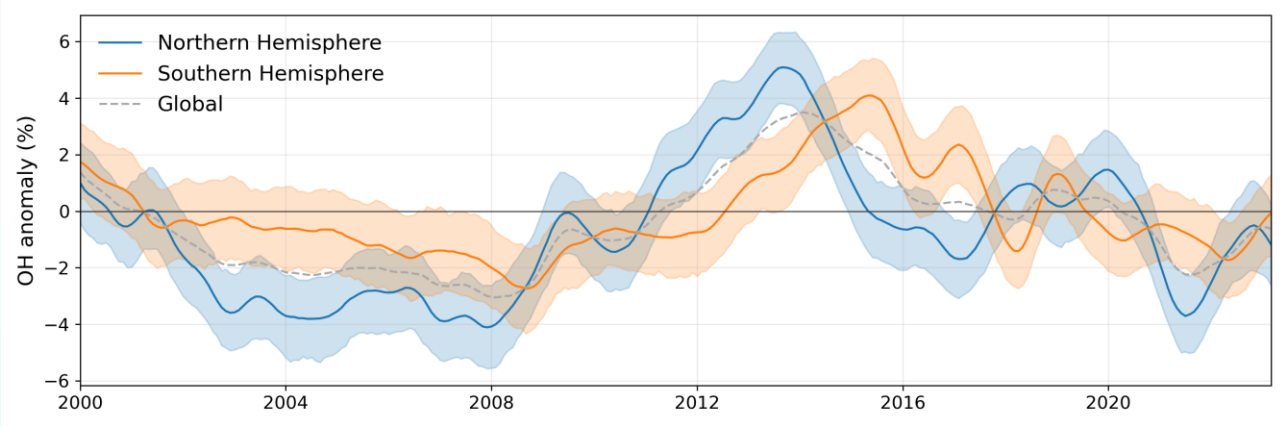


Fig. 1. The OH anomaly derived from 10 HFCs and methyl chloroform for the Northern and Southern Hemispheres, and the global mean.

References

Duncan, B.N., Anderson, D.C., Fiore, A.M., Joiner, J., Krotkov, N.A., Li, C., Millet, D.B., Nicely, J.M., Oman, L.D., St. Clair, J.M., Shutter, J.D., Souri, A.H., Strode, S.A., Weir, B., Wolfe, G.M., Worden, H.M., Zhu, Q., 2024. Opinion: Beyond global means – novel space-based approaches to indirectly constrain the concentrations of and trends and variations in the tropospheric hydroxyl radical (OH). Atmos. Chem. Phys. 24, 13001–13023. https://doi.org/10.5194/acp-24-13001-2024

Liang, Q., Chipperfield, M.P., Fleming, E.L., Abraham, N.L., Braesicke, P., Burkholder, J.B., Daniel, J.S., Dhomse, S., Fraser, P.J., Hardiman, S.C., Jackman, C.H., Kinnison, D.E., Krummel, P.B., Montzka, S.A., Morgenstern, O., McCulloch, A., Mühle, J., Newman, P.A., Orkin, V.L., Pitari, G., Prinn, R.G., Rigby, M., Rozanov, E., Stenke, A., Tummon, F., Velders, G.J.M., Visioni, D., Weiss, R.F., 2017. Deriving Global OH Abundance and Atmospheric Lifetimes for Long-Lived Gases: A Search for CH3 CCl3 Alternatives. JGR Atmospheres 122. https://doi.org/10.1002/2017JD026926

Naus, S., Montzka, S.A., Pandey, S., Basu, S., Dlugokencky, E.J., Krol, M., 2019. Constraints and biases in a tropospheric two-box model of OH. Atmos. Chem. Phys. 19, 407–424. https://doi.org/10.5194/acp-19-407-2019

Prinn R. G., Weiss, R. F., Arduini, J., Arnold, T., DeWitt, H. L., Fraser, P. J., Ganesan, A. L., Gasore, J., Harth, C. M., Hermansen, O., Kim, J., Krummel, P. B., Li, S., Loh, Z. M., Lunder, C. R., Maione, M., Manning, A. J., Miller, B. R., Mitrevski, B., Mühle, J., O'Doherty, S., Park, S., Reimann, S., Rigby, M., Saito, T., Salameh, P. K., Schmidt, R., Simmonds, P. G., Steele, L. P., Vollmer, M. K., Wang, R. H., Yao, B., Yokouchi, Y., Young, D., and Zhou, L., 2018. History of chemically and radiatively important atmospheric gases from the Advanced Global Atmospheric Gases Experiment (AGAGE), Earth Syst. Sci. Data, 10(2), 985-1018, https://doi.org/10.5194/essd-10-985-2018.

Thompson, R.L., Montzka, S.A., Vollmer, M.K., Arduini, J., Crotwell, M., Krummel, P.B., Lunder, C., Mühle, J., O'Doherty, S., Prinn, R.G., Reimann, S., Vimont, I., Wang, H., Weiss, R.F., Young, D., 2024. Estimation of the atmospheric hydroxyl radical oxidative capacity using multiple hydrofluorocarbons (HFCs). Atmospheric Chemistry and Physics 24, 1415–1427. https://doi.org/10.5194/acp-24-1415-2024

ANSTO's micro-^{14}C capability: contributions to understanding the composition of the past & present atmosphere

A. M. Smith[1*], A. Amatya Joshi[1], G. W. Brailsford[2], M. N. Dyonisius[3], D. M. Etheridge[4,5], B. Hmiel[6], V. A. Levchenko[1], Q. Hua[7], V. Morgan[8], L. Murray[9], P. D. Neff[10], V. A. Petrenko[9], C.M. Trudinger[4], and B. Yang[1]

[1]Centre for Accelerator Science, Australian Nuclear Science and Technology Organisation [ANSTO], Lucas Heights, NSW, Australia
[2]Earth Sciences New Zealand, Wellington, New Zealand
[3]Institute of Arctic and Alpine Research University of Colorado Boulder, Boulder, Colorado, USA
[4]CSIRO Environment, Aspendale, Victoria, Australia
[5]University of Tasmania, Institute of Marine and Antarctic Studies, Tasmania, Australia
[6]Air Pollution Control Division, Colorado Department of Public Health and the Environment, Glendale, CO, USA,
[7]Environment Research, Australian Nuclear Science and Technology Organisation [ANSTO], Lucas Heights, NSW, Australia
[8]Australian Antarctic Dvision, Kingston, Tamsnia, Australia
[9]Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY, USA
[10]Department of Soil, Water, and Climate, University of Minnesota Twin Cities, Saint Paul, MN, USA.

*corresponding author: A. M. Smith [ams@ansto.gov.au]

Abstract

The Centre for Accelerator Science (CAS) has been measuring the radiocarbon (^{14}C) activity of extremely small carbon samples by accelerator mass spectrometry (AMS) – 'micro-^{14}C AMS' – for several decades. We have the capability to process radiocarbon targets from a wide variety of sample types and to measure the $^{14}C/^{12}C$ ratio accurately for cathodes that may contain only a few micrograms of carbon – or less. In CAS we employ solid ion sources, so all purified CO_2 is converted to graphite using reactors that have been optimized for small samples, in particular, laser heated and micro-conventional furnaces. Micro-^{14}C samples are measured on the ANTARES 10 MV tandem accelerator, using a modified HVE 846B ion source that permits movement of the sample under the cesium beam. Along with this technical capability, we have procedures in place to correct for the addition of extraneous carbon during processing and graphitisation, and for isotopic fractionation with decreasing sample size.

This micro-^{14}C capability has allowed research that hitherto was impossible. Early work focused on measurement of the 'bomb-pulse' in carbon dioxide extracted from firn air and ice core bubbles at Law Dome, used as a constraint for tuning the firn air diffusion and trapping models developed by CSIRO. This helped link the instrumental record with the ice core record. Later work focused on research into past sources of greenhouse gas methane and more recently on its main sink, the hydroxyl radical. Measurement of $^{14}CH_4$ allows to constrain fossil and biogenic sources. Atmospheric hydroxyl concentrations are inferred from the loss of ^{14}CO, naturally produced by cosmic radiation in the atmosphere. Studies on the palaeo-climate utilized past atmospheric gas trapped in the Arctic and Antarctic ice sheets, in both firn air and occluded air bubbles in the ice. Interpretation of the measurements requires a full understanding of the production of *in situ* ^{14}C in the ice sheet, its conversion into ^{14}CO, $^{14}CO_2$ and $^{14}CH_4$ and of its retention in the firn and ice core bubbles. Studies on the present atmosphere utilise a global network of air sampling stations to obtain air samples. Methane (CH_4) and carbon monoxide (CO) are separated by our colleagues from air samples and converted to carbon dioxide (CO_2) for shipment to our laboratories at ANSTO where it is converted to graphite for AMS measurement. With the small carbon masses available for these gases when extracted from ice sheets this work is challenging. Underpinning this analytical work are the numerical modelling studies that provide insight into the measurements enabled by our team and which will be presented by others at this meeting.

Further investigation into CRDS water corrections – CO_2, CH_4, N_2O and CO.

Ann R. Stavert[1*], Paul B. Krummel[2], Darren A. Spencer[2], Jeremy Ward[3], Zoë M. Loh[2], Issy N. Borley[2], and David W. T. Griffith[4]

[1] CSIRO Environment, Black Mountain, ACT, Australia
[2] CSIRO Environment, Aspendale, VIC, Australia
[3] BoM, Cape Grim, TAS, Australia
[4] UoW, Wollongong, NSW, Australia

[*] corresponding author: Ann R. Stavert [ann.stavert@csiro.au]

Abstract

Greenhouse gas (GHG) monitoring networks are essential for tracking long and short-term trends in atmospheric GHG concentrations at both global and regional scales. 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, and not by measurement biases and errors. As such, great care is taken to minimise and characterise any such issues.

Recent advances in cavity ring-down spectroscopy (CRDS) technology have led to a rapid uptake of such instruments, for CO_2, CH_4, N_2O and CO, within global and national networks. While these instruments are robust and relatively simple to deploy, their measurements are affected by changes in the water content of a sample. This "error" can be avoided by drying the air-sample prior to analysis (minimising the size of the water correction required) or removed by applying an optimised water correction.

However, recent work has suggested that offsets exceeding or close to their respective WMO compatibility guidelines may still occur when drying or when using some water correction approaches. In this talk we:

- Validate an improved method for quantifying the water correction
- Use data collected at Kennaook/Cape Grim to examine the use of a chilling system to stabilise the sample water content
- Explore the effect of varying the water content of the gas standard on sample mole fractions
- Investigate the CRDS pressure sensor sensitivity to H_2O as identified in earlier studies (Reum, 2019).

References

F. Reum, C. Gerbig, J. V. Lavric, C. W. Rella and M. Göckede (2019) Correcting atmospheric CO_2 and CH_4 mole fractions obtained with Picarro analyzers for sensitivity of cavity pressure to water vapor *Atmos. Meas. Tech.* Vol. 12 Issue 2 Pages 1013-1027 DOI: 10.5194/amt-12-1013-2019

The Methane Isotope Round Robin: Lab differences, reference gas needs and improvements to calibration of optical isotopic measurements

David Griffith[*1], Peter Sperlich[2], Gordon Brailsford[2], Sylvia Englund-Michel[3], Ben Riddell-Young[3], and 16 Round Robin participant labs

[1] University of Wollongong, Australia
[2] Earth Sciences New Zealand, New Zealand
[3] INSTAAR, Boulder, Colorado

[*] corresponding author: David Griffith, griffith@uow.edu.au

Abstract

The blind measurement phase of a methane isotope round robin exercise led by Earth Sciences NZ (NIWA) and INSTAAR has recently been completed. Four tanks of air containing methane with a range of mole fractions, $\delta^{13}C$ and $\delta^{2}H$ were circulated among 17 laboratories and analysed using both isotope ratio mass spectrometry (IRMS) and optical techniques. We present a preliminary overview of the results, which show significant interlaboratory and inter-technique differences and point to the need for a common reference standard scale.

Results from the optical techniques, particularly from Picarro CRDS analysers, show significant dependence on mole fractions and isotopic delta values and greater scatter than the IRMS results. We also present here a reanalysis of the CRDS results from the ESNZ lab using a calibration scheme independent of the inbuilt Picarro calibration which removes almost all of the mole fraction and delta biases and achieves much improved agreement, in line with the IRMS results. The method can in principle be applied to other optical measurements in the round robin exercise and the instruments used by those laboratories in general.

References

D. W. T. Griffith, Calibration of isotopologue-specific optical trace gas analysers: a practical guide, Atmos. Meas. Tech. 2018 Vol. 11 Issue 11 Pages 6189-6201, DOI: 10.5194/amt-11-6189-2018

Solar Remote Sensing Observations in Australia and Atmospheric Developments

N. M. Deutscher[1*], D. W. T. Griffith[1], N. B. Jones[1], C. Paton-Walsh[1], H. Nawaz[1], D. Roy[1], and M. A. Purtill-Wright[1]

[1] Environmental Futures Research Centre and School of Science, Faculty of Science, Medicine and Health, University of Wollongong, Wollongong, NSW, Australia

[*] corresponding author: Nicholas Deutscher [ndeutsch@uow.edu.au]

Abstract

The University of Wollongong's solar remote sensing program has reached 30 years of measurements in 2026, across the Network for Detection of Atmospheric Composition Change (NDACC), the Total Carbon Column Observing Network (TCCON) (Wunch et al, 2011), and more recently in supporting measurements using more portable and/or less expensive solar remote sensing instruments. In this presentation we will present an update on the state of solar remote sensing in Australia and its contribution to related programs.

References

Wunch D, Toon GC, Blavier JF, Washenfelder RA, Notholt J, Connor BJ, Griffith DW, Sherlock V, Wennberg PO. The total carbon column observing network. Philos Trans A Math Phys Eng Sci. 2011 May 28;369(1943):2087-112. doi: 10.1098/rsta.2010.0240.

Validation of TROPOMI and IASI XCH_4 with AirCore and EM27/SUN measurements over Australia and New Zealand

H. Nawaz[1*], N. M. Deutscher[1*], C. Paton-Walsh[1], D. F. Pollard[2], L. Ventress[3], C. Alberti[4], B. Baier[6], M. Desservettaz[1], A. Geddes[2], D. W. T. Griffith[1], S. J. Harris[5], F. Hase[4], J. Higgs[7], N. B. Jones[1], B. J. F. Kelly[5], T. Naylor[1], T. Newberger[6], H. O'Sullivan-Moffat[2], J. Robinson[2], J. Simmons[1], C. Sweeney[6], B. T. Walker[1], and S. Wolter[6]

[1] Environmental Futures Research Centre, School of Science, University of Wollongong, NSW, 2500, Australia
[2] Earth Sciences New Zealand, Omakau, Private Bag 50061, New Zealand
[3]Rutherford Appleton Laboratory Space, National Centre for Earth Observation, Oxford University, UK
[4]Institute of Meteorology and Climate Research (IMK-ASF), Karlsruhe Institute of Technology (KIT), Germany
[5]School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW, Australia
[6]NOAA Earth System Research Laboratory Global Monitoring Division, Boulder, CO, USA
[7]Cooperative Institute for Research in Environmental Sciences, University of Colorado-Boulder, Boulder, CO, USA

* corresponding author: Hasan Nawaz [hn487@uowmail.edu.au] and Nicholas M. Deutscher [ndeutsch@uow.edu.au]

Abstract

Satellite-based column-averaged dry-air mole fractions of methane (XCH_4) have been predominantly validated in the Northern Hemisphere due to the higher density of ground-based measurement networks, leaving Southern Hemisphere observations less well constrained. This study validated satellite-based XCH_4 from the TROPOspheric Monitoring Instrument (TROPOMI) and the Infrared Atmospheric Sounding Interferometer (IASI) against EM27/SUN spectrometers and AirCore measurements over Australia and New Zealand. Satellite observations were co-located with EM27/SUN measurements within 50 km and ±1 h, while AirCore profiles from Broken Hill were compared within 100 km and ±6 h. EM27/SUN XCH_4 observations were scaled to Total Carbon Column Observing Network (TCCON) XCH_4 from Wollongong site before comparing to TROPOMI and IASI retrievals. TROPOMI exhibited a systematic difference of −0.13 ± 0.70% relative to EM27/SUN, compared with −0.26 ± 0.97% for IASI after excluding short-term local enhancements (std>5 ppb). The corresponding network-mean random errors were 0.70 ± 0.14% and 0.86 ± 0.13%, respectively.

Both satellite products show good agreement with EM27/SUN XCH_4, although TROPOMI exhibited lower scatter and greater consistency than IASI. Likewise, after smoothing the AirCore CH_4 profiles using the respective satellite averaging kernels, the mean relative differences were −0.05 ± 0.14% for TROPOMI and 0.24 ± 0.56% for IASI. The TROPOMI–EM27/SUN results are consistent with previous global validation studies, which reported mean relative differences of −0.26 ± 0.56% against TCCON (Sha et al., 2021) and +0.09 ± 0.37% against EM27/SUN (Sha et al., 2025). The present study extends these global assessments by providing validation across multiple sites and field campaigns in Australia and New Zealand, a Southern Hemisphere region that has previous relied only on TCCON sites (Darwin, Wollongong and Lauder) for satellite XCH_4 validation.

References

Sha, M. K., S. Das, M. M. Frey, et al. (2025). Fiducial reference measurements for greenhouse gases (FRM4GHG): Validation of satellite (Sentinel-5 Precursor, OCO-2, and GOSAT) missions using the COllaborative Carbon Column Observing Network (COCCON). *Remote Sensing* **17**, 734. doi:10.3390/rs17050734

Sha, M. K., B. Langerock, J. F. L. Blavier, et al. (2021). Validation of methane and carbon monoxide from Sentinel-5 Precursor using TCCON and NDACC-IRWG stations. *Atmospheric Measurement Techniques* **14**, 6249–6304. doi:10.5194/amt-14-6249-2021

Prototyping a portable radon calibration transfer standard for GAW and ICOS stations

S. D. Chambers[1*], A. D. Griffiths[1], V. Oeser[2], A. Kostjukevich[2], O. Sisoutham[1], and S. Röttger[3]

[1] ANSTO ERTG, Lucas Heights, NSW, Australia
[2] SARAD GmbH, Dresden, Saxony, Germany
[3] Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

[*] corresponding author: Scott D Chambers [szc@ansto.gov.au]

Abstract

The current global benchmark for environmental radon monitoring is the ANSTO 1500 L two-filter dual flow-loop radon monitor [Whittlestone & Zahorowski, 1998]. While employed at numerous Global Atmosphere Watch (GAW) and Integrated Carbon Observation System (ICOS) stations, their size and high sampling flow rates prevent calibration in controlled climate chambers and make traceable *in situ* calibration difficult. To solve this problem, the EMPIR 19ENV01 traceRadon Project developed, traceably calibrated, and tested a 200 L two-filter dual flow-loop radon monitor as a calibration transfer standard [Röttger et al. 2026]. Although transportable in a standard vehicle, this two-piece monitor was 1.65 m tall, 0.48 m wide and weighed ~80 kg.

Recently, as part of the ANSTO Graduate Research Program, a "suitcase sized" (100 L) two-filter dual flow-loop radon monitor was developed. Since this monitor stands ~0.9 m tall and weighs <18 kg, it is more readily portable [Hariharan et al. 2026]. It has a flow rate of ~5 $L \cdot min^{-1}$, sensitivity of ~0.02 $s^{-1} \cdot (Bq \cdot m^{-3})$, 30-minute temporal resolution, response time of 45 minutes, and detection limit ~0.3 $Bq \cdot m^{-3}$. It is presently being traceably calibrated at PTB (Braunschweig, Germany) to determine its suitability for use as a calibration transfer standard prior to design optimisation for possible future commercialisation. We report on development and initial testing of the new prototype at ANSTO and at SARAD GmbH (Germany).

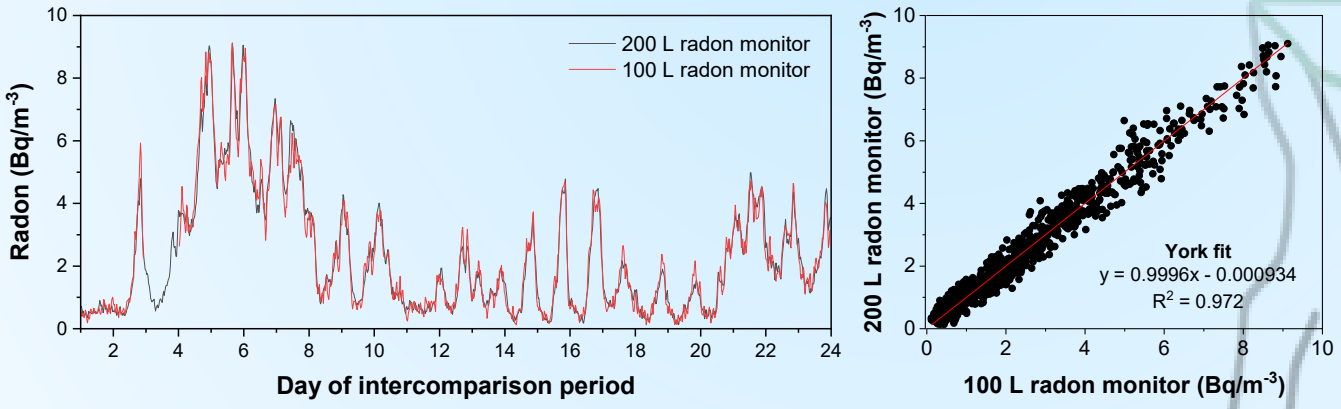


Fig. 1. 3-week comparison of 200 L & 100 L two-filter dual flow-loop radon monitors on campus at ANSTO, Dec-2025.

References

Hariharan R., C. Leung, A. D. Griffiths, O. Sisoutham and S. D. Chambers (2026). T-Rex: the transportable radon-222 explorer for environmental or public health studies. *J Env. Rad.*, 300, 108169, **Error! Hyperlink reference not valid.**.

Röttger S., F. Mertes, S. Chambers, A. Griffiths, R. Curcoll, A. Vargas, J.-L. Gutiérrez Villanueva, A. Röttger (2026). Traceable in-situ calibration of low activity concentration radon detectors. *Appl. Radiat. Isot.*, 231, 112485, **Error! Hyperlink reference not valid.**.

Whittlestone, S. and W. Zahorowski (1998). Baseline radon detectors for shipboard use: development and deployment in the first aerosol characterization experiment (ACE 1). *J. Geophys. Res.*, 103, 16743–16751, **Error! Hyperlink reference not valid.**.

A decade-long overlapping experiment: reduction gas analyser versus pulsed discharge helium ionization detector for ambient hydrogen

Blagoj Mitrevski[1*], Ray Langenfields[1], and Paul Krummel[1]

[1] CSIRO Environment, Aspendale, Vic, Australia

[*] corresponding author: Blagoj Mitrevski [blagoj.mitrevski@csiro.au]

Abstract

Molecular hydrogen (H_2), although not a direct greenhouse gas, can exert an indirect influence on climate through its effects on atmospheric chemistry. Increasing atmospheric H_2 reduces the availability of hydroxyl radicals (OH), thereby extending the atmospheric lifetime of methane (CH_4), while H_2 oxidation also influences tropospheric ozone and stratospheric water vapour. Consequently, accurate long-term measurements of atmospheric H_2 are becoming increasingly important, particularly in the context of the emerging hydrogen economy and the potential for increased anthropogenic H_2 emissions.

The Kennaook / Cape Grim station provides one of the longest continuous records of atmospheric H_2, with measurements extending back to 1993. For many years, H_2 and carbon monoxide (CO) at Kennaook / Cape Grim have been measured using gas chromatography coupled to a Reduction Gas Analyser (RGA). The RGA is a well-established and highly sensitive technique for the measurement of reducing gases at ambient atmospheric mole fractions. However, detector non-linearity and temporal drift necessitate frequent calibration to maintain measurement accuracy and long-term consistency.

Since 2015, CSIRO has operated an alternative gas-chromatographic H_2 measurement system based on a pulsed-discharge helium ionisation detector (PDHID/PDD). A decade of concurrent RGA and PDD measurements at Kennaook / Cape Grim enables direct comparison of the two techniques in terms of H_2 mole fractions, precision, stability and long-term trends. The results of this comparison will be presented.

A multi-platform atmospheric network for greenhouse gas emissions at Melbourne's Western Treatment Plant

J. Ramirez-Gamboa[1,*], Z. M. Loh[1], C. G. R. Caldow[1], C. M. Trudinger[1], N. Shahrokhi[1], D. Spencer[1], C. T. Roulston[1], I. N. Borley[1], and N. Crosbie[2]

[1] CSIRO Environment, Aspendale, VIC, Australia
[2] Melbourne Water, Docklands, VIC, Australia

[*] Corresponding author: Jhonathan Ramirez-Gamboa [jhonathan.ramirezgamboa@csiro.au]

Abstract

Wastewater treatment can be an important source of methane (CH_4) and nitrous oxide (N_2O), with emissions arising from a range of biological treatment processes and often distributed across large and spatially complex facilities. This makes facility-scale emissions difficult to characterise using conventional point measurements alone. Melbourne Water's Western Treatment Plant (WTP), located west of Melbourne, treats approximately half of the city's sewage and incorporates extensive lagoon-based treatment systems across a large area. The distributed nature of these processes, together with temporal variability in treatment conditions and meteorology, creates a challenging environment for quantifying greenhouse gas emissions and identifying the contribution of individual source regions.

To improve the understanding and quantification of greenhouse gas emissions from the WTP, Melbourne Water and CSIRO are developing a multi-platform atmospheric observation network for CH_4 and N_2O. The core of the network is a 40 m instrumented tower providing continuous greenhouse gas observations at 20 and 40 m above ground level, together with meteorological measurements for characterising atmospheric transport and boundary-layer conditions. These observations are complemented by a relocatable, solar-powered monitoring trailer equipped with a 13 m mast, greenhouse gas analysers and meteorological instrumentation. Targeted mobile surveys provide additional spatial information by characterising concentration enhancements and plume structure across and downwind of the treatment plant.

This presentation describes progress in the design, deployment and commissioning of the Melbourne Water greenhouse gas observation network, including the 40 m tower, relocatable monitoring trailer and mobile measurement platform. We present observations collected to date and initial insights into the spatial and temporal variability of CH_4 and N_2O around the WTP, including the influence of changing meteorological conditions and source regions across the facility. These measurements will subsequently be incorporated into chemical transport modelling and used as observational constraints for inverse modelling approaches aimed at estimating the magnitude and spatial distribution of greenhouse gas emissions from the WTP. Together, the fixed, relocatable and mobile measurements provide a framework for progressively improving facility-scale emission estimates and our understanding of emissions from this large and spatially complex wastewater treatment system.

Coal mine methane emissions in NSW – Atmospheric inverse modelling

Jandl[1,2*], N. Shahrokhi[2], C. Trudinger[2], P. Rayner[3], N. Deutscher[4], M. Garthwaite[5], H. Nawaz[4], N. Jones[4], R. Hynes[6], and R. Schofield[1]

[1] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC, Australia
[2] CSIRO Environment, Aspendale, VIC, Australia
[3] The Superpower Institute, Melbourne, VIC, Australia
[4] School of Science, and Environmental Futures Research Centre, University of Wollongong, NSW, Australia
[5] CSIRO Space and Astronomy, Canberra, ACT, Australia
[6] Climate and Atmospheric Science, NSW Department of Climate Change, Energy, the Environment and Water, Sydney, Australia

[*] corresponding author: Ida Jandl [ijandl@student.unimelb.edu.au]

Abstract

Reducing anthropogenic methane emissions is important to slow down climate change. In Australia, the agriculture, coal mining and waste sectors are the most dominant anthropogenic methane emission sources. However, previous studies (Sadavarte et al., 2021; Palmer et al., 2021; Borchardt et al., 2025; Harris et al., 2026) show a mismatch between sector reported emissions and those determined based on atmospheric observations. In this study, we retrieve methane emissions in New South Wales (NSW) incorporating satellite observations in a Bayesian approach.

We simulate column averaged dry-air mole fraction of atmospheric methane (XCH4) with a python-based four-dimensional variational assimilation technique Py4DVar using the WRF-CMAQ forward model together with the CMAQ adjoint model. Our study domain covers the six coalfields of NSW with 2 km spatial resolution for the year 2024. To constrain our model, we use daily observations of XCH4 measured by the TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5P satellite. Our inversion framework is validated by comparing the simulated XCH4 using optimized emissions with independent ground-based total column EM27/SUN observations deployed in the Upper Hunter Valley coal mining region, as well as Total Carbon Column Observing Network observations in Wollongong.

References

Sadavarte, P., Pandey, S., Maasakkers, J. D., Lorente, A., Borsdorff, T., Denier van der Gon, H., Houweling, S., and Aben, I (2021). Methane Emissions from Superemitting Coal Mines in Australia Quantified Using TROPOMI Satellite Observations. *Environmental Science & Technology*, 55, 16 573–16 580. https://doi.org/10.1021/acs.est.1c03976

Palmer, P. I., Feng, L., Lunt, M. F., Parker, R. J., Bösch, H., Lan, X., Lorente, A., and Borsdorff, T. (2021). The added value of satellite observations of methane for understanding the contemporary methane budget. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 379, 20210 106. https://doi.org/10.1098/rsta.2021.0106

Borchardt, J., Harris, S. J., Hacker, J. M., Lunt, M., Krautwurst, S., Bai, M., Bösch, H., Bovensmann, H., Burrows, J. P., Chakravarty, S., Field, R. A., Gerilowski, K., Huhs, O., Junkermann, W., Kelly, B. F. J., Kumm, M., Lieff, W., McGrath, A., Murphy, A., Schindewolf, J., and Thoböll, J. (2025). Insights into Elevated Methane Emissions from an Australian Open-Cut Coal Mine Using Two Independent Airborne Techniques. *Environmental Science & Technology Letters*, 12, 397–404. https://doi.org/10.1021/acs.estlett.4c01063

Harris, S. J., Krautwurst, S., Hacker, J., Lunt, M., Jakob, B., Bai, M., Boesch, H., Brain, T., Burrows, J. P., Chakravarty, S., Field, R. A., Fisher, R. E., France, J. L., Gerilowski, K., Huhs, O., Junkermann, W., Kelly, B. F. J., Kumm, M., Lanoisellé, M., Lieff, W., McGrath, A., Murphy, A., Röckmann, T., Salmon, Z., Schindewolf, J., Thoböll, J., van der Veen, C., and Bovensmann, H. (2026). Evaluation of coal mine methane inventory methods using aircraft-based approaches in the Bowen Basin, Australia. *EGUsphere*, 2026, 1–41. https://doi.org/10.5194/acp-26-10043-2026

Inverse modelling of agricultural methane in Aotearoa New Zealand using MethaneSAT

K. Gerrand[1,5*], B. Bukosa[1], S. Mikaloff-Fletcher[1], E. D. Keller[1,5], D. Kennett[1], R. Law[2], A. Geddes[1], J. Benmergui[3,4], M. Knapp[3,4], and S. C. Wofsy[3]

[1] Earth Sciences New Zealand, New Zealand
[2] Manaaki Whenua Landcare Research, Bioeconomy Science Institute, New Zealand
[3] Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA
[4] Environmental Defense Fund, New York, NY, USA
[5] Antarctic Research Centre, Te Herenga Waka Victoria University of Wellington, Wellington, New Zealand

[*] corresponding author: Kirstin Gerrand [kirstin.gerrand@earthsciences.nz]

Abstract

Methane (CH_4) is a highly potent greenhouse gas that exists in high concentrations in the Earth's atmosphere. Agriculture accounted for approximately 40% of global anthropogenic CH_4 emissions in the 2010-2019 period, making accurate quantification of these sources crucial for meeting climate targets. Agricultural emissions are, however, often diffuse and small scale, making them more difficult to quantify than point-source fossil emissions.

The MethaneSAT satellite was designed to detect and quantify anthropogenic CH_4 emissions from both fossil fuels and agricultural sources. Here, we use an inverse model with input data from MethaneSAT to quantify agricultural CH_4 emissions on a regional scale in New Zealand. New Zealand is an ideal candidate for this work, with a CH_4 emission profile dominated by agriculture (~85%) and comprehensive ground-based monitoring and reliable national inventories for validation. The inverse model used here is an analytical Bayesian system that employs the Numerical Atmospheric dispersion Modelling Environment (NAME III) as the transport model driven by meteorology from the New Zealand Convective Scale Model (NZCSM) at a 1.5 km resolution. The model uses a spatially resolved prior, also at a 1.5 km resolution.

We will present CH_4 emission estimates for the Canterbury region of the New Zealand South Island, an area of high agricultural activity and complex topography. Results will be compared against a national scale bottom-up inventory over the same domain and the official MethaneSAT inversion model: the Column Observations to Regional Emissions (CORE) algorithm [The MethaneSAT Science and Engineering Team., 2026]. By providing the first satellite-based flux estimates of diffuse agricultural CH_4 in New Zealand, this work will contribute to improved CH_4 inventories and therefore better inform climate policy and mitigation efforts.

References

The MethaneSAT Science and Engineering Team. (2026). MethaneSAT Level-4 Dispersed Emissions Product: Algorithm Theoretical Basis Document (Version 1.0). Zenodo. https://doi.org/10.5281/zenodo.21842560

CarbonWatch: In situ and flask sampling network in Auckland for quantifying urban emissions

L. S. Fleming[1*], L. Balzer[1], G. Brailsford[1], L. Domingues[1], S. Gray[1], T. W. Hilton[1], M. Hertoghs[1], E. Macapagal-Taluban[1], V. Monteiro[1], S. Nichol[1], J. Parry-Thompson[1], J. Turnbull[1], and H. Young[1]

[1] Earth Sciences New Zealand, Wellington, New Zealand

[*] corresponding author: Leigh Fleming [leigh.fleming@earthsciences.nz]

Abstract

Auckland is responsible for approximately 26% of Aotearoa New Zealand's (NZ) industry and household carbon dioxide (CO_2) emissions. Therefore, quantifying Auckland's emissions is a necessary step in supporting measures for greenhouse gas (GHG) emissions reduction in NZ. A greenhouse gas measurement network was established in Auckland in 2021 as part of the CarbonWatch programme. This network consists of 4 in-situ sites equipped with a Picarro G2401 CRDS analyser, continuously measuring CO_2, carbon monoxide (CO) and methane (CH_4). Hourly integrated flask samples are also collected weekly at each site and measured for CO_2, CO, CH_4, and radiocarbon content of CO_2 ($\Delta^{14}C$-CO_2) for quantification of fossil fuel CO_2 (CO_2ff) emissions.

I will discuss the measurement network set-up, data processing, measurement performance and data quality procedures. I will also present our resulting time-series data from the network and discuss the trends and variability in each species.

Imaging very large transient methane emission plumes using the GOES-19 and Himawari-9 satellites

T Bedin[1,2*], N Shahrokhi[2], R Allen[1], C Trudinger[2], and S Petrie[1]

[1] Space Technology and Industry Institute, Swinburne University of Technology, Hawthorn, Victoria, Australia
[2] CSIRO Environment, Aspendale, Victoria, Australia

[*] corresponding author: Timothy Bedin [tbedin@swin.edu.au]

Abstract

Low earth orbit (LEO) satellite instruments such as GOSAT and Sentinel 5P/TROPOMI are used to observe atmospheric methane concentrations, particularly at regional to continental scales. These instruments are complemented by facility-scale, targeted instruments that can image plumes with high sensitivity to methane and small ground sample distance. However, at both scales, the revisit time is at least a day, somewhat limiting their ability to detect and image transient events that may occur over sub-daily time scales, or those that occur before facility-scale instruments can be retargeted. Here we investigate the use of geostationary satellite imagery to supplement our understanding of the temporal dynamics of methane super-emission events and allow us to better locate their emission points.

We developed a band-differencing algorithm that allows geostationary data to be used to image methane super-emission events. We use this algorithm to image methane events previously detected by the CAMS Methane Hotspot Explorer [CAMS, 2025]. Our algorithm builds upon the work of [Varon et al. 2021] and [Watine-Guiu et al. 2023], who used non-methane specific instruments to observe methane concentrations. We are applying our technique to GOES geostationary data and the closely related Himawari geostationary satellites, to apply this method in an Australian context. Here, we will present work that shows the spatiotemporal dynamics of large methane plumes in the data from these geostationary satellites. We will describe how even though the satellites' spectral coverage may not be optimised for methane detection, they have an important role to play in constraining methane emission rates and emission locations for the largest transient sources. Our results show that the better temporal completeness of these measurements (15-minute rather than one-day revisit periods) mean that they are useful for better understanding the spatiotemporal dynamics of very large transient emissions, even though the sensitivity of the instrument is lower than for Sentinel 5P/TROPOMI.

References

Copernicus Atmosphere Monitoring Service (CAMS). (2025). Methane Hotspot Explorer. Retrieved October 31, 2025, from https://apps.atmosphere.copernicus.eu/methane-explorer

Varon, D. J., Jervis, D., McKeever, J., Spence, I., Gains, D., & Jacob, D. J. (2021). High- frequency monitoring of anomalous methane point sources with multispectral Sentinel-2 satellite observations. Atmospheric Measurement Techniques, 14(4), 2771–2785. https://doi.org/10.5194/amt-14-2771-2021

Watine-Guiu, M., Varon, D. J., Irakulis-Loitxate, I., Balasus, N., & Jacob, D. J. (2023). Geostationary satellite observations of extreme and transient methane emissions from oil and gas infrastructure. Proceedings of the National Academy of Sciences, 120(52). https://doi.org/10.1073/pnas.2310797120

Quantifying Methane Fluxes Through Fourier Transform Infrared Spectrometry and Atmospheric Transport Modelling

Mackenzie A. Purtill-Wright[1,2], Nicholas M. Deutscher[1], Nicholas Jones[2], Hasan Nawaz[1], Bryce F.J. Kelly[3], Stephen J. Harris[3,4], and the Methane Hunter Team[5]

[1] Centre for Atmospheric Chemistry, School of Science, University of Wollongong, Wollongong, NSW, Australia
[2]Centre for Atmospheric Chemistry, School of Mathematics & Physics, University of Wollongong, NSW, Australia
[3]School of Biological Earth & Environmental Sciences, University of New South Wales, NSW, Australia
[4]UNEPS's International Methane Emissions Observatory, Paris, France
[5]All team members who contributed to instrument setup, data collection and analysis

[*] corresponding author: Mackenzie A. Purtill-Wright [mpw093@uowmail.edu.au]

Abstract

Methane is the second most significant anthropogenic greenhouse gas after carbon dioxide, and its atmospheric abundance has increased substantially since pre-industrial times (Luther et al. 2019; Sadavarte et al.2021; Liu et al. 2023). In Australia, fugitive methane emissions from open-cut coal mines constitute a significant component of the nation's total emissions. However, bottom-up reporting methods developed under the National Greenhouse and Energy Reporting scheme are not routinely validated against atmospheric observations, where multiple studies have identified discrepancies between bottom-up inventories and top-down atmospheric measurements (Sadavarte et al. 2021; Borchardt et al. 2025; Harris et al. 2026).

Atmospheric composition measurements are obtained using a network of EM27/SUN Fourier transform infrared spectrometers that can determine the total column-averaged dry-air mole fractions of methane. These observations are combined with atmospheric transport models to simulate methane transport and dispersion from open-cut coal mines across the study region. Several approaches, including Gaussian Plume Modelling and Lagrangian Plume Dispersion Modelling, can quantify methane emission fluxes and attribute them to their underlying sources. Integrating atmospheric transport models with an inversion framework that tracks particles backward in time establishes source-receptor sensitivity relationships and enables more accurate estimates of methane emission fluxes (Luther et al. 2022). These methods provide an independent assessment of methane emissions and allow top-down estimates to be compared with bottom-up, industry-reported inventories, supporting improvements in the accuracy of Australia's greenhouse gas reporting.

Together, these approaches will use top-down estimates to verify bottom-up methane emission inventories and support greater transparency and accuracy in industry-reported methane emissions.

References

Borchardt, J., Harris, S. J., Hacker, J. M., Lunt, M., et al. (2025). Insights into Elevated Methane Emissions from an Australian Open-Cut Coal Mine Using Two Independent Airborne Techniques. *ESTL*, *12*(4), 397–404. https://doi.org/10.1021/acs.estlett.4c01063

Harris, S. J., Krautwurst, S., Hacker, J., Lunt, M., et al. (2026). Evaluation of coal mine methane inventory methods using aircraft-based approaches in the Bowen Basin, Australia. *ACP*, *26*(13), 10043–10069. https://doi.org/10.5194/acp-26-10043-2026

Liu, Y., Paris, J. D., Vrekoussis, M., Quéhé, P. Y., Desservettaz, M., et al. (2023). Reconciling a national methane emission inventory with in-situ measurements. *Science of the Total Environment*, *901*. https://doi.org/10.1016/j.scitotenv.2023.165896

Luther, A., Kleinschek, R., Scheidweiler, L., Defratyka, S., et al. (2019). Quantifying CH4 emissions from hard coal mines using mobile sun-viewing Fourier transform spectrometry. *Atmospheric Measurement Techniques*, *12*(10), 5217–5230. https://doi.org/10.5194/amt-12-5217-2019

Luther, A., Kostinek, J., Kleinschek, R., Defratyka, S., et al. (2022). Observational constraints on methane emissions from Polish coal mines using a ground-based remote sensing network. Atmospheric Chemistry and Physics, 22(9), 5859–5876. https://doi.org/10.5194/acp-22-5859-2022

Sadavarte, P., Pandey, S., Maasakkers, J. D., Lorente, A., Borsdorff, T., Denier van der Gon, H., Houweling, S., & Aben, I. (2021). Methane Emissions from Superemitting Coal Mines in Australia Quantified Using TROPOMI Satellite Observations. *Environmental Science and Technology*, *55*(24), 16573–16580. https://doi.org/10.1021/acs.est.1c03976

Investigating Photochemical Aging and Rapid Ozone Formation in Simulated Wildfire Plumes: Preliminary Findings from the SAPHFIRE 2026 Campaign

M. Desservettaz[1,2*], C. Murphy[1,2], G. Gkatzelis[3], Merched Azzi[4], Kathryn Emmerson[5], The SAPHFIRE team[3,6,7,8]

[1] University of Wollongong, NSW, Australia
[2] NSW Bushfire and Natural Hazard Research Centre, NSW, Australia
[3] Forschungszentrum Jülich, Jülich, Germany
[4] NSW Department of Climate Change, Energy, the Environment and Water, Sydney, Australia
[5] CSIRO Environment, Aspendale, Australia
[6] IRCELYON, CNRS / Université Claude Bernard Lyon 1, Villeurbanne, France
[7] NOAA Chemical Sciences Laboratory, Boulder, CO, USA
[8] University of Patras, Department of Chemical Engineering, Patras, Greece

[*] corresponding author: Max Desservettaz [mdesserv@uow.edu.au]

Abstract

Wildfire smoke emissions impact on regional air quality, radiative forcing, and human health. As biomass burning plumes age downwind, complex photochemical reactions involving reactive volatile organic compounds (VOCs) and nitrogen oxides (NOx) frequently drive rapid production of secondary pollutants, most notably tropospheric ozone (O_3) and secondary organic aerosol (SOA). However, disentangling the specific chemical drivers of photochemical ozone formation within chemically heterogeneous, rapidly evolving real-world plumes remains a major challenge for atmospheric models.

To address these mechanisms under controlled, highly instrumented conditions, the SAPHFIRE (SAPHIR Fire Inventory for Representation of Emissions and Secondary Pollution) campaign was conducted in mid-2026 within the SAPHIR atmospheric simulation chamber at Forschungszentrum Jülich. The campaign utilized four targeted synthetic VOC mixtures as chemical proxies for diverse wildfire smoke regimes. These mixtures systematically varied key compound classes, including oxygenated VOCs (OVOCs), furanoids & phenolics, organic acids, and reactive hydrocarbons, across a spectrum of ambient-relevant oxidation conditions and NOx regimes.

Here, we present initial results from photochemical aging experiments conducted during the SAPHFIRE campaign. Preliminary analysis reveals distinct oxidation trajectories across the fuel mixtures. These early findings will provide new benchmarks for evaluating chemical mechanism representations (such as MCM and condensed chemical solvers) in biomass burning smoke and offer new mechanistic constraints on the ozone production potential of wildfire emissions during plume transport.

References

Koss, A. R., Sekimoto, K., Gilman, J. B., Selimovic, V., Coggon, M. M., Zarzana, K. J., ... & de Gouw, J. (2018). Non-methane organic gas emissions from biomass burning: identification, quantification, and emission factors from PTR-ToF-MS during the FIREX 2016 laboratory experiment. Atmospheric Chemistry and Physics, 18(5), 3299–3319. https://doi.org/10.5194/acp-18-3299-2018

Gkatzelis, G. I., Coggon, M. M., Stockwell, C. E., Hornbrook, R. S., Allen, H., et al. (2024). Parameterizations of US wildfire and prescribed fire emission ratios and emission factors based on FIREX-AQ aircraft measurements. Atmospheric Chemistry and Physics, 24(2), 929–956. https://doi.org/10.5194/acp-24-929-2024

Emissions from Australian Peat: a first look at results from the ASPECT campaign

Maximilien Desservettaz[1,2], Deepa Roy[1,2], Owen Price[1,2], **Clare Paton-Walsh (Murphy)[1,2*],** Meagan Porter[3], Scott Foyster[3], Mark Hovenden[3], Judith Rosentreter[4], Malcolm Possell[5], and Sally Taylor[6]

[1] Environmental Futures, University of Wollongong, Wollongong, NSW, Australia
[2] New South Wales Bushfire and Natural Hazards Research Centre, Australia
[3] University of Tasmania, Hobart, Tasmania, Australia
[4] Southern Cross University, East Lismore, NSW, Australia
[5] Centre for Carbon Water and Food, University of Sydney, NSW, Australia
[6] Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

[*] corresponding author: Clare Paton-Walsh (Clare Murphy) [clarem@uow.edu.au]

Abstract

As the climate warms peat fires are becoming an increasing likely hazard in numerous ecosystems around the world, including in Australia [*Turetsky et al.*, 2014]. Current fire emissions inventories within Australian air quality models use emission factors based primarily on measurements of tropical peat fires. The Australian Smoke Peat Emission Characterization and Toxicity (ASPECT) campaign took place at the University of Tasmania's FireLab3 facility during March and April 2026. Amongst the aims of the campaign was to determine gas-phase and particulate emissions factors (EFs) for Australian peat samples and compare them with literature values from international peat fire events, with a view to assessing whether the default international values were appropriate for Australian peat fires or not.

This presentation will describe the experimental design and how we measured emissions from peat sample from Tasmania, New South Wales, Queensland and Western Australia. We will show some preliminary results including evidence that particulate phase emissions are filtered by the ash layer that forms as the peat burns, echoing earlier findings from Malaysian peat fires [*Roulston et al.*, 2018].

References

Roulston, C., C. Paton-Walsh, T. E. L. Smith, É. A. Guérette, S. Evers, C. M. Yule, G. Rein, and G. R. Van der Werf (2018), Fine Particle Emissions From Tropical Peat Fires Decrease Rapidly With Time Since Ignition, *Journal of Geophysical Research: Atmospheres*, *123*(10), 5607-5617, doi:10.1029/2017JD027827.

Turetsky, M., B. Benscoter, S. Page, G. Rein, G. Werf, and A. Watts (2014), Global vulnerability of peatlands to fire and carbon loss, *Nature Geoscience*, *8*, 11-14, doi:10.1038/ngeo2325.

VOCs that damage winegrapes: fresh emissions from controlled burns in the Mount Lofty Ranges

M. Parker[1,2*], B. Williams[3], K. Abley[3], M. J. Herderich[1,2], and F. Reisen[4]

[1] Adelaide University, Adelaide, SA, Australia
[2] Australian Wine Research Institute, Urrbrae, SA, Australia
[3] Department of Environment and Water, Adelaide, SA, Australia
[4] CSIRO, Clayton, VIC, Australia

[*] corresponding author: Mango Parker [mango.parker@awri.com.au]

Abstract

Smoke has caused billions of dollars in losses to the wine industry worldwide since first reported in 2003 (Høj, 2003, Krstic et al., 2021). Volatile phenols are produced by pyrolysis of lignin during biomass burning, and guaiacol, syringol, *o*-cresol, *m*-cresol and *p*-cresol, can be taken up by grapes, and together with their glycosidic metabolites that form in grapes, can result in quality downgrades due to unpleasant smoky, medicinal and ashy flavours in the wine (Hayasaka et al., 2010, Krstic et al., 2015).

The presence of smoke in a vineyard does not always result in measurable impact on winegrapes. It is difficult to ascertain the conditions under which smoke is likely to affect winegrape quality because impact-causing smoke exposure scenarios have been so diverse in their nature, ranging from half an hour of exposure to smoke from a small local fire, to smoke that drifted 110 km from distant fires and settled in a valley for days. On the other hand, there have been instances of visually observed smoke in vineyards which had no measurable impacts on grapes. The concentration of volatile phenols in smoke depends on multiple parameters such as fuel type, fire behaviour, combustion conditions, plume dispersion, and degradation driven by reactions with hydroxyl radical during the day and nitrate radicals at night. Although the fundamental processes are reasonably well understood, and advanced chemical transport models have been developed, a key knowledge gap remains regarding the concentrations of the specific volatile phenols in smoke that damage wine grapes.

In this study, the potential for fresh smoke to damage grapes was assessed using smoke samples collected during prescribed burns in the Mount Lofty Ranges. Burns were conducted by SA Dept of Environment and Water in the autumn of 2026, targeting stringybark heathland with high to extreme fuel load, conducted as low intensity backing fires. The concentrations of volatile phenols were quantified in fresh smoke using active sampling and TDU-GC-MS analysis, providing robust quantitative data on these important and understudied components. Results from the fresh smoke sampling will be presented. These measurements provide a baseline for future sampling comparing volatile phenol concentrations and smoke taint risk in fresh and atmospherically aged smoke.

References

Hayasaka, Y., G. A. Baldock, M. Parker, K. H. Pardon, C. A. Black, M. J. Herderich and D. W. Jeffery (2010). Glycosylation of smoke-derived volatile phenols in grapes as a consequence of grapevine exposure to bushfire smoke. *J Agric Food Chem*, 58 (20): 10989-10998. DOI: 10.1021/jf103045t

Høj, P. (2003). The Australian Wine Research Institute annual report.

Krstic, M., J. Culbert, M. Parker and M. Herderich 2021. Smoke taint and climate change. *In:* Reynolds, A. G. (ed.) *Managing Wine Quality.* Woodhead Publishing.

Krstic, M. P., D. L. Johnson and M. J. Herderich (2015). Review of smoke taint in wine: smoke-derived volatile phenols and their glycosidic metabolites in grapes and vines as biomarkers for smoke exposure and their role in the sensory perception of smoke taint. *Aust J Grape Wine Res*, 21: 537-553. DOI: 10.1111/ajgw.12183

Parker, M., W. Jiang, E. Bilogrevic, D. Likos, J. Gledhill, A. D. Coulter, G. D. Cowey, C. A. Simos, I. L. Francis and M. J. Herderich (2023). Modelling Smoke Flavour in Wine from Chemical Composition of Smoke-Exposed Grapes and Wine. *Aust J Grape Wine Res*, 2023: 1-14. DOI: 10.1155/2023/4964850

Rapid Update Cycle Smoke Forecasting: Insights from a Recent Case Study

Fabienne Reisen[1*], Julie Noonan, Martin Cope

[1] CSIRO Environment RU, Clayton, VIC, Australia

[*] corresponding author: Fabienne Reisen [Fabienne.reisen@csiro.au]

Abstract

As bushfires become more frequent and severe, there is an increasing need for timely smoke and air quality forecasts. Early warning of smoke impacts is critical for reducing population exposure and supporting public health responses. The national Air Quality Forecasting System (AQFx) currently produces 96-hour forecasts, using observed fire activity during the first day and projected emissions thereafter.

Rapid Update Cycle (RUC) systems can provide updates as frequently as every hour. This allows forecasts to better capture rapidly changing fire behaviour, smoke dispersion and fast-moving fires such as grassfires. Frequent updates also enable the inclusion of new fires that ignite on the day a forecast is produced. In contrast, the current AQFx system relies on satellite fire detections from the previous day so that forecasts can be generated overnight. The RUC capability is expected to improve both situational awareness and short-term forecasting. Stakeholders have identified this capability as a priority for supporting operational decision-making during fire events.

To address this need, we have developed a RUC extension to AQFx. The system integrates near real-time fire detections from hourly geostationary satellite observations, supplemented by six-hourly low Earth orbit satellite data and agency incident information. A fire behaviour model is then used to simulate fire progression and estimate burned area and smoke emissions. The resulting RUC forecasts are blended with the existing AQFx ensemble forecasts to produce updated smoke predictions.

This presentation describes the RUC system architecture and demonstrates its performance through a recent Australian smoke event case study. We highlight the benefits of high-frequency forecast updates for capturing rapidly evolving smoke impacts and discuss key challenges associated with uncertainty communication, and operational implementation at the national scale.

Testing AQFx Sensitivity to variation in Coarse Woody Debris loads - a Wildfire Case Study

Luba Volkova[1], Martin Cope, and Kylle Quinn

[1] University of Melbourne, Melbourne, Victoria, Australia

* corresponding author: Mango Parker [mango.parker@awri.com.au]

Abstract

In April 2025, a prescribed burn near Daylesford, Victoria, bridged containment and developed into a wildfire. Coincidentally, this area had been established as one of our research sites, where the loads of coarse woody debris (CWD) and their combustion efficiency were empirically measured for integration into Australia's Air Quality Forecasting system (AQFx).

This event created a rare opportunity to evaluate the sensitivity of the AQFx model to variations in CWD load and combustion efficiency, and to compare top-down and bottom-up approaches for estimating smoke emissions.

The top-down assessment used the FirePixels model, which integrates fire radiative power and satellite observations from MODIS, NASA/NOAA platforms, and Himawari-9, to derive estimates of smoke production and fire intensity. In contrast, the bottom-up approach relied on fuel load and combustion parameters—using both default values and the site-specific measurements collected on the site.

This case study offers new insights into how local-scale fuel dynamics influence large-scale smoke and carbon emission predictions. The findings are expected to improve parameterisation within AQFx and enhance the accuracy of national air quality and fire behaviour forecasting.

Observations of smoke aging from Kennaook 2025

A. Jackson[1,2,4], M. J. Herderich[1,2], C. Kidman[3], F. Reisen[4*], and M. Parker[1,2]

[1] Adelaide University, Adelaide, SA, Australia
[2] Australian Wine Research Institute, Urrbrae, SA, Australia
[3] Treasury Wine Estates, Coonawarra, SA, Australia
[4] CSIRO, Clayton, VIC, Australia

[*] corresponding author: Aiko Jackson [aiko.jackson@adelaide.edu.au]

Abstract

Volatile organic compounds (VOCs) in bushfire smoke, such as guaiacol, syringol, *o*-, *m*-, and *p*- cresol, are known to be taken up by wine grapes and result in a loss of wine grape quality (Hayasaka *et al.* 2010). As a result of the 2019/2020 bushfires, an estimated $655 million was lost by the wine industry due to loss of crop and tourism (Parker 2022, Robinson *et al.* 2020).

Guaiacol, syringol and cresols are highly reactive towards atmospheric components, particularly the hydroxyl radical during the day and nitrate radical at night, with atmospheric lifetimes expected to be in the order of several hours. However, due to the complex nature of the smoke matrix and the countless simultaneous reactions occurring, it can be difficult to predict the concentration of VOCs in a given smoke plume during aging/transport. Chemical transport models, coupled with weather prediction and dispersion models, can approximate smoke movement and aging but require ground-based truthing. A complete suite of measured smoke parameters from aged smoke is difficult to generate or come by.

In February 2025, several fires in Tasmania generated smoke that was measured at the CSIRO Kennaook/Cape Grim Observation centre. Data from the KCG station included black and brown carbon, ozone, and VOC estimates from PTR-MS. This data set presented a unique opportunity to investigate smoke of different ages from multiple fires across Tasmania. HYSPLIT, a back trajectory model for wind, was used to estimate the ages of smoke from different fire sources. The results provide unique insight to the aging of smoke and inform future work in both the atmospheric chemistry of smoke and prediction of smoke taint in vineyards.

References

Hayasaka, Y., Baldock, G. A., Pardon, K. H., Jeffery, D. W., Herderich, M. J. 2010. Investigation into the Formation of Guaiacol Conjugates in Berries and Leaves of Grapevine Vitis vinifera L. Cv. Cabernet Sauvignon Using Stable Isotope Tracers Combined with HPLC-MS and MS/MS Analysis. *J. Agric. Food Chem.* 58(4): 2076–2081.

Parker, M. 2022. *Understanding and mitigating the impact of smoke exposure on grape and wine composition and wine sensory properties final report to Wine Australia*. Adelaide, Australia: Australian Wine Research Institute.

Robinson, E., Beames, K., Krstic, M., Burgan, N., Cuijvers, A., et al. 2020. *The Australian Wine Research Institute Annual Report 2020*. Adelaide, Australia: Australian Wine Research Institute.

Environmental drivers and properties of Southern Ocean aerosol and cloud formation

Salvatore Sodano[1,2*], Marc Mallet[1], Sonya Fiddes[1], Andrew Bowie[1], Melita Keywood[2], Ian McRobert[3], Hanuman Crawford[3], Jason Ward[2], and Ruhi Humphries[2]

[1] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
[2] CSIRO Environment, Melbourne, Australia
[3] CSIRO National Collections and Marine Infrastructure, Hobart, Australia

* Corresponding author: S. Sodano [Salvatore.sodano@utas.edu.au]

Abstract

The Southern Ocean (SO) is one of the last regions where atmospheric conditions remain comparable to those of the pre-industrial period ((Hamilton et al., 2014)). However, major gaps persist in in situ aerosol observations (Humphries et al., 2023; Mallet et al., 2023), while synoptic-scale transport of anthropogenic pollution is already affecting the natural atmospheric balance and dynamics of the region (Bhatti et al., 2022)

This study presents the first long-term, harmonized aerosol size distribution dataset for the Australian sector of the SO, synthesizing shipborne observations collected aboard the RV Investigator and RSV Nuyina between 2015 and 2025. The measurements were standardized, quality-controlled (QA/QC), and validated to provide an essential observational basis for characterizing aerosol populations, investigating aerosol–cloud interactions, and constraining their representation in Earth system models (Fiddes et al., 2022; Reddington et al., 2017). A reproducible method for identifying stack-exhaust events and removing measurements contaminated by the research vessels' own emissions is presented. The method developed to identify and correct instrumental drift in the GRIMM SMPS operated aboard the RV Investigator is also described. Together, these procedures provide a consistent QA/QC framework that can support the detection and treatment of platform-generated contamination and instrumental artifacts in future shipborne atmospheric datasets.

Keywords: Aerosol size distribution, Southern Ocean, Platform exhaust identification, Aerosol-cloud interaction

References

Bhatti, Yusuf. A., Revell, Laura. E., & McDonald, Adrian. J. (2022). Influences of Antarctic Ozone Depletion on Southern Ocean Aerosols. Journal of Geophysical Research: Atmospheres, 127(18), e2022JD037199. https://doi.org/10.1029/2022JD037199

Fiddes, S. L., Protat, A., Mallet, M. D., Alexander, S. P., & Woodhouse, M. T. (2022). Southern Ocean cloud and shortwave radiation biases in a nudged climate model simulation: does the model ever get it right? Atmospheric Chemistry and Physics, 22(22), 14603–14630. https://doi.org/10.5194/ACP-22-14603-2022

Hamilton, D. S., Lee, L. A., Pringle, K. J., Reddington, C. L., Spracklen, D. V, & Carslaw, K. S. (2014). Occurrence of pristine aerosol environments on a polluted planet. Proceedings of the National Academy of Sciences, 111(52), 18466–18471. https://doi.org/10.1073/pnas.1415440111

Humphries, R. S., Keywood, M. D., Ward, J. P., Harnwell, J., Alexander, S. P., Klekociuk, A. R., Hara, K., Mcrobert, I. M., Protat, A., Alroe, J., Cravigan, L. T., Miljevic, B., Ristovski, Z. D., Schofield, R., Wilson, S. R., Flynn, C. J., Kulkarni, G. R., Mace, G. G., Mcfarquhar, G. M., … Griffiths, A. D. (2023). Measurement report: Understanding the seasonal cycle of Southern Ocean aerosols. Atmos. Chem. Phys, 23, 3749–3777. https://doi.org/10.5194/acp-23-3749-2023

Mallet, M. D., Humphries, R. S., Fiddes, S. L., Alexander, S. P., Altieri, K., Angot, H., Anilkumar, N., Bartels-Rausch, T., Creamean, J., Dall'Osto, M., Dommergue, A., Frey, M., Henning, S., Lannuzel, D., Lapere, R., Mace, G. G., Mahajan, A. S., McFarquhar, G. M., Meiners, K. M., … Woodhouse, M. T. (2023). Untangling the influence of Antarctic and Southern Ocean life on clouds. In Elementa (Vol. 11, Number 1, pp. 6237–6271). University of California Press. https://doi.org/10.1525/elementa.2022.00130

Reddington, C. L., Carslaw, K. S., Stier, P., Schutgens, N., Coe, H., Liu, D., Allan, J., Browse, J., Pringle, K. J., Lee, L. A., Yoshioka, M., Johnson, J. S., Regayre, L. A., Spracklen, D. V., Mann, G. W., Clarke, A., Hermann, M., Henning, S., Wex, H., … Zhang, Q. (2017). The Global Aerosol Synthesis and Science Project (GASSP): Measurements and Modeling to Reduce Uncertainty. Bulletin of the American Meteorological Society, 98(9), 1857–1877. https://doi.org/10.1175/BAMS-D-15-00317.1

Evaluating the Health Burden of Multi-Pollutant Air Pollution in Sydney, Australia (2000–2025)

Simon William Mkasimongwa [1]*, Robert G. Ryan[2], Stephen J. Livesley[2], and Robyn Schofield[3]

[1] School of Geography Earth and Atmospheric Science, University of Melbourne, Parkville, VIC 3010, Australia.
[2] School of Agriculture, Food and Ecosystem Sciences, Burnley Campus, University of Melbourne, 500 Yarra Boulevard, Richmond, VIC 3121, Australia.

*Corresponding author: Simon William Mkasimongwa [simonwilliam140293@gmail.com]

Abstract

Urban populations in Sydney and Melbourne are exposed to multiple pollutants that simultaneously exceed World Health Organization (WHO) air quality guidelines despite generally complying with Australian national air quality standards. However, the mortality burden associated with short- and long-term multi-pollutant exposure remains poorly quantified. This study evaluated temporal patterns of multi-pollutant air pollution across Sydney and Melbourne between 2000 and 2025 using a multi-pollutant Air Quality Health Index (AQHI).

The associated mortality burden was quantified using established concentration–response relationships. Sydney experienced multi-pollutant events on 14% of monitored days, compared with 8% in Melbourne. WHO guideline exceedances for NO_2 occurred on 52% of monitored days in Sydney and 47% in Melbourne, while $PM_{2.5}$ exceedances occurred on 13% and 4% of monitored days, respectively. Long-term assessment highlighted substantial challenges associated with inconsistent spatial and temporal monitoring coverage, particularly in Melbourne, where many monitoring stations operated for limited periods or did not measure all key pollutants throughout the study period. Short-term multi-pollutant exposure was estimated to contribute 18,438 premature deaths (95% CI: 16,057–20,837), equivalent to an average of 709 deaths annually. Across Sydney and Melbourne during 2000–2025, long-term exposure accounted for an estimated 69,603 deaths (95% CI: 48,242–90,355), averaging 2,784 deaths per year. The relative contribution of ozone (O_3) increased steadily since 2000 and became the dominant contributor to mortality in 2025 as contributions from nitrogen dioxide (NO_2) and particulate matter declined, indicating a shift towards a pollution profile increasingly influenced by secondary photochemical pollutants.

These findings demonstrate that compliance with current regulatory standards can mask a substantial multi-pollutant health burden. A health-based multi-pollutant AQHI would provide more meaningful public health information and strengthen air quality management, risk communication, and environmental health policy in Australia.

Keywords: Air Quality Health Index (AQHI), multi-pollutant events, multi-pollutant exposure, air pollution mortality risk, tropospheric ozone.

How much air pollution are data centres adding to Melbourne's atmosphere?

Robert Ryan[1*], Diego Rojas Niesa[1], Jeremy Silver[2], Annabelle Workman[3], Rachel Tham[4], Steven Utembe[5], Geoffrey Browne[6], Clare Walters[1], and Robyn Schofield[1]

[1] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Melbourne, Australia
[2] Melbourne Statistical Consulting Centre, Faculty of Science, School of Mathematics and Statistics, University of Melbourne, Melbourne, Australia
[3] Melbourne Climate Futures, Melbourne Law School, University of Melbourne, Melbourne, Australia
[4]Melbourne School of Population and Global Health, Dentistry and Health Sciences, Department of Medicine, University of Melbourne, Melbourne, Australia
[5] Victorian Environment Protection Authority, Melbourne, Australia
[6] Faculty of Architecture, Building & Planning, University of Melbourne, Melbourne, Australia

[*] corresponding author: Robert Ryan [rryan1@unimelb.edu.au]

Abstract

Data centres (DCs) are recognised as critical infrastructure for Australia's digital economy and AI-enabled future. These facilities are rapidly expanding in size and number throughout Australia's cities, with associated serious energy systems and water consumption challenges. Most DCs rely on diesel generators for back-up power which may amount to a significant new source of urban air pollution. Yet global literature on the public health impact of these emerging and extensive urban air pollution sources is lacking.

In this work we outline the development of an emission inventory for air pollutants from diesel generators providing backup power to DCs in Melbourne. We also outline the development of a methodology to test the impact of DC generators on air pollutant exposure and health risk in Melbourne, and deliver the results in an accessible way to policy makers and the community. The greater Melbourne area is now home to 30 DCs, with at least a further 19 planned. The power capacity of recently built DCs, and especially those planned in the near future, is very large (often exceeding 100 MW). Because their business model is to provide secure computing and storage resources all the time, they are equipping these centres with enough diesel-powered generators to supply complete redundancy. While total failure of Melbourne's energy supply is unlikely, meaning that the risk of all DCs turning all generators on at once is low, generators must be tested regularly to ensure they are functioning as designed. Here we outline the likely emissions from these testing schedules based on the latest available information and compare these emissions with existing urban sources.

Currently, emissions from diesel generators at data centres are only assessed, if at all, during the planning application stage on a case-by-case basis without adequately considering the cumulative effect of multiple new emission sources. Diesel generator emission factors for toxic pollutants such as particulate matter (PM), nitrogen oxides (NOx) and carbon monoxide (CO) are larger, per mass of fuel burnt, than for diesel vehicles and even coal-fired power stations. Since DCs are bringing multiple (in some cases hundreds of) new diesel generators into urban areas, it is crucial that potential impacts are identified and mitigated early.

AEROSPAN update: 25 years of Australian aerosol optical depth measurements.

Robert Ryan[1*], David Barker[2], Fraser Dennison[1], Ruhi Humphries[2], and Robyn Schofield[1]

[1] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Melbourne, Victoria, Australia
[2] CSIRO Environment, Melbourne, Victoria, Australia

[*] corresponding author: Robert Ryan [rryan1@unimelb.edu.au]

Abstract

Aerosol optical depth (AOD) is an essential climate variable quantifying the amount of aerosol in the atmospheric vertical column. AOD observations are crucial for constraining the Earth's surface radiation balance, due to the importance of aerosol in scattering and absorbing incoming sunlight. A range of satellite and surface-based AOD measurement techniques exist. Ground-based AOD observations, with highest sensitivity to the surface from which aerosol is emitted, are critical for constraining satellite retrievals, as well as for validating atmospheric chemistry and climate model outputs. Compared to many parts of the world, Australia's long-term AOD observation network is sparse. This makes the available sun photometer sites providing long-term AOD data, coordinated through the Australian-led AEROSPAN network and the US-run Aerosol Robotic Network (AERONET), extremely valuable.

Recent work has updated the data processing code for AEROSPAN to be accessible to the wider research community in Python. This has provided an opportunity to explore the quarter of a century of AEROSPAN data available from 22 sites. In this study, we report on the long-term timeseries of AOD at these sites, spanning the breadth of Australia's environments: inland and coastal, remote and urban, arid, tropical and mid-latitude. We examine the seasonal and diurnal characteristics of AOD at different sites, comparing our results with Australian AEROSPAN data published in 2017 (Mitchell et al., 2017) and AERONET data published in 2021 (Yang et al., 2021). We also examine the performance of reanalysis and satellite AOD (respectively, the Modern-Era Retrospective analysis for Research and Applications, (MERRA2) and the Moderate Resolution Imaging Spectroradiometer, (MODIS)).

References

Mitchell, R. M., Forgan, B. W., & Campbell, S. K. (2017). The climatology of Australian aerosol. *Atmospheric Chemistry and Physics*, *17*(8), 5131-5154.

Yang, X., Zhao, C., Yang, Y., & Fan, H. (2021). Long-term multi-source data analysis about the characteristics of aerosol optical properties and types over Australia. *Atmospheric Chemistry and Physics*, *21*(5), 3803-3825.

Towards Melbourne urban air quality modelling: a WRF-Chem sensitivity study

D. R. Rojas-Neisa[1*], R. Ryan[1], and R. Schofield[1]

[1] School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Parkville, VIC, Australia

[*] corresponding author: D. R. Rojas-Neisa [drrojas@student.unimelb.edu.au]

Abstract

The use of chemical transport models (CTMs) for studying air quality and its different impacts on society is well known. However, urban areas, where most people live, pose a significant challenge for these models in accurately representing the complexity of urban canopy and different types of urban surfaces. This leads to the misrepresentation of local phenomena such as the urban heat island and urban canyon effects. Most air quality modeling studies in Australia using CTMs have focused on broader scales rather than the urban scale, using domain resolutions too coarse for capture the complexity of the urban environment. This study aims to perform an urban-focused air quality simulation for the city of Melbourne using the WRF-Chem model and evaluate the sensitivity of pollutant concentrations and their spatial distribution.

We use of multilayer urban canopy model with a 17-category urban surface dataset compared to conventional single layer scheme with 1-4 urban surface types used in most of WRF-Chem studies. The WRF-Chem simulation consists of four nested domains centered in the Melbourne metropolitan area, with spatial resolutions of 13.5 km, 4.5km, 1.5 km and 0.5 km, respectively. 30 days of winter (June) and summer (mid-December-mid January) periods were selected to assess the model's performance under different emission and meteorology regimes. The chemical mechanism used was Regional Atmospheric Chemistry Mechanism (RACM) coupled with the Modal Aerosol Dynamics model for Europe (MADE) and the Volatility Basis Set (VBS) for secondary organic aerosol formation. Anthropogenic emission inputs were processed using the Emission Database for Global Atmospheric Research (EDGAR) global inventory. Biomass burning emissions were taken from Fire Inventory from NCAR (FINN). Biogenic emissions are computed online using the Model of Emissions of Gases and Aerosols from Nature (MEGAN). Two scenarios were run for this study: a control run using a single layer urban canopy model and USGS land use data (4 urban surface types), and a sensitivity run using a multilayer urban canopy model with Local Climate Zone land use data (17 urban surface types).

Compared to EPA Victoria air quality monitoring stations, winter control run showed good agreement for ozone, nitrogen oxides and carbon monoxide during daytime while overpredicting concentrations during nighttime. Particulate matter and sulphur dioxide were overestimated across all sites for this period. The nighttime pollutants overestimation was significantly influenced by shallower boundary layer heights predicted by WRF-chem compared to observations. The results of this study determine the importance of refinement urban environment data when running CTMs at sub kilometre scales for urban applications in the region.

Black Carbon Aethalometer Optimisation and Source Apportionment

Anushka Elangasinghe[1,2*], Jennifer A. Salmond[1], Paul Baynham[2], Erika Macapagal-Taluban[3], Perry Davy[3], Jocelyn Turnbull[3], and Hamesh Patel[4,5]

[1] School of Environment, Faculty of Science, University of Auckland, Private Bag 92019, Auckland, New Zealand
[2] Mote Limited, 40a George Street, Mount Eden, Auckland, New Zealand
[3] Earth Sciences New Zealand, Lower Hutt, New Zealand
[4] Mote Limited, 240 Queen Street, Brisbane, QLD 4000, Australia
[5] International Laboratory for Air Quality & Health (ILAQH), Queensland University of Technology, 2 George Street, Brisbane, Queensland, 4000, Australia

[*] corresponding author: Anushka Elangasinghe [anushka.elangasinghe@mote.io]

Abstract

Black carbon (BC) is a significant contributor to $PM_{2.5}$ globally, emanating from the incomplete combustion of fossil fuel and biomass and has a significant impact on human health and climate (Davy and Trompetter, 2018; Patel et al., 2024). Multi-wavelength aethalometers provide an avenue to estimate contributions from BC fossil fuel (BC_{ff}) and BC biomass burning (BC_{bb}) based on the aerosol optical properties and absorption dependencies (Sandradewi et al., 2008). The Aethalometer model uses default values of 1 and 2 for the two source-specific parameters, known as the absorption angstrom exponents (AAEs), representing fossil fuel combustion and biomass burning, respectively. However, the separation is sensitive to these assumed AAE values which can differ significantly across air sheds due to various source contributions (Grange et al., 2020). Here we present a data-driven approach to optimise the AAEs using regulatory air quality and meteorological data from traffic dominated, mixed urban and winter biomass home heating influenced sites across New Zealand.

Hourly measurements of BC, nitrogen oxides (NO_x), PM_1, $PM_{2.5}$, PM_{10}, and meteorological variables were obtained from regulatory authorities responsible for air quality monitoring, and the Aethalometer model was used to separate BC_{ff} and BC_{bb} using 370nm and 880nm channels. Optimisation was undertaken by maximising correlations between BC_{ff} and NO_x and BC_{bb} and PM_1.

At roadside sites, the default AAE values significantly overestimated contributions from BC_{bb} whilst the optimised values corrected this overestimation. The reduction in attributed BC_{bb} and its reattribution to BC_{ff} at these sites were consistent with what we would expect at these urban environments. At sites influenced by residential heating, the optimisation attributed a greater proportion of BC to BC_{bb} during winter nights, as expected at these sites. The improved separation highlights the need for more robust and systematic approaches to optimise default AAEs used in BC air quality monitoring instruments. These methods provide a practice approach to improving aethalometer-based BC source separation from regulatory monitoring stations and provides a scalable approach for real-time source-specific contributions to support operational air quality management.

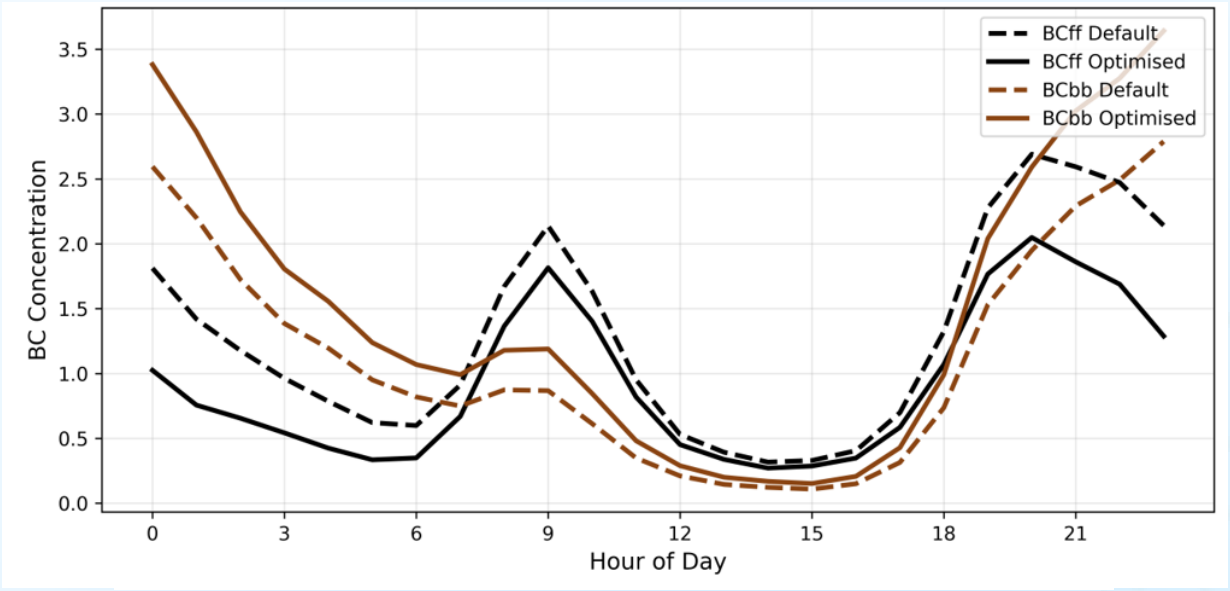


Figure 1: Default and optimised BC_{ff} (black line) and BC_{bb} (brown line). aethalometer measurements from Christchurch in the winter.

References

Davy, P. K. and W. J. Trompetter (2018). Black Carbon in New Zealand. (GNS Science Consultancy Report No. 2017/122), Institute of Geological and Nuclear Sciences, Lower Hutt (NZ).

Grange, S. K., Lötscher, H., Fischer, A., Emmenegger, L., & Hueglin, C. (2020). Evaluation of equivalent black carbon source apportionment using observations from Switzerland between 2008 and 2018. *Atmospheric measurement techniques*, *13*(4), 1867-1885. https://doi.org/10.5194/amt-13-1867-2020

Patel, H.; Baynham, P.; Wells, B.; Martin, H.; Davy, P.; (2024). Black Carbon Monitoring Feasibility Report. Prepared by Mote Limited for The Ministry for the Environment. Auckland (NZ). Mote Limited consultancy report 2024/002

Sandradewi, J., Prévôt, A. S., Szidat, S., Perron, N., Alfarra, M. R., Lanz, V. A., Weingartner, E., & Baltensperger, U. (2008). Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contributions to particulate matter. *Environmental science & technology*, *42*(9), 3316-3323.

Marine Aerosols Modified by Urban Environments

Robert Deas[1], Anushka Elangasinghe[2,3], Cherie Tollemache[1,3], Hamesh Patel[2,4,5], Daniel Lynch[3], Paul Baynham[3], Joel Rindelaub[1], Alexander Elliott[1], Brett Wells[3], Jennifer Salmond[2], David Williams[1,3], and Duncan McGillivray[1]

[1] School of Chemical Sciences, Faculty of Science, University of Auckland, Auckland, New Zealand
[2] School of Environment, Faculty of Science, University of Auckland, Auckland, New Zealand
[3] Mote Limited, 40a George Street, Mount Eden, Auckland, New Zealand
[4] Mote Limited, 240 Queen Street, Brisbane, Queensland, Australia
[5] International Laboratory for Air Quality & Health (ILAQH), Queensland University of Technology, 2 George Street, Brisbane, Queensland, Australia

[*] corresponding author: Robert Deas [robert.deas@auckland.ac.nz]

Abstract

Particulate matter (PM) in coastal cities are dominated by marine aerosols. The surface chemistry of marine aerosols is known to change through acid displacement interactions with biogenic and anthropogenic contaminants, as particles age during atmospheric transport (Su B. et al 2025). As a result, individual marine aerosol particles are unique, and their elemental composition may detail where and what they have travelled through (Dang C. et al 2022). This can provide valuable insights into pollutant interactions at atmospheric system processing through coastal regions. In this study we analyse individual marine aerosols from a clean air (West coast marine) and urban air (Auckland city) environment, collected from Auckland, New Zealand.

We investigate morphological and elemental compositions at individual particle level through particle characterisation with scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS) and X-ray fluorescence microscopy (XFM) to examine individual particle morphology and trace level elemental profiles respectively. SEM-EDS identified morphology classifications that were binned into cube or non-cube shaped particles. Cube shaped particles were generally dominated by Na and Cl corresponding to marine aerosols crystals. Compared to the clean air environment, Na-Cl containing particles from urban air showed larger deviations from the ideal Na:Cl ratio for pure seawater, consistent with acid displacement Cl depletion. XFM revealed that clean marine aerosols were generally associated with traces of Ca and K whilst marine aerosols from urban environments demonstrated elevated concentrations trace metals associated with combustion. As such, machine learning was used to classify individual ambient particles based on their elemental compositions.

Classification confirmed that both the West coast marine and Auckland city samples were dominated by seawater-like particles (marine aerosols), with the urban air (Auckland city) sample, showing a significant increase in the fraction of urban-modified or “dirty” seawater particles (Figure 1). These findings demonstrate the feasibility of single-particle characterisation using complementary high-throughput SEM-EDS and XFM to provide an in-depth understanding of marine aerosol characterisation and atmospheric mixing within urban atmospheres and act as a tool to better understand anthropogenic impacts on environments.

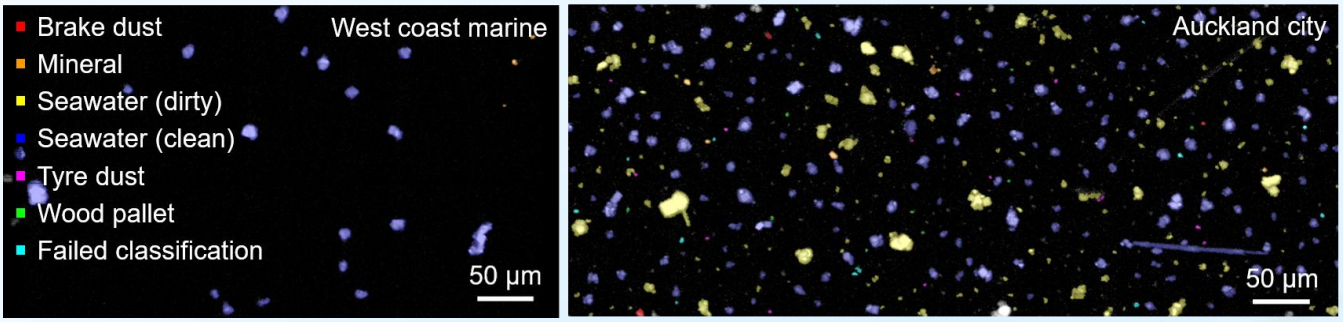


Figure 1: Greyscale XFM images of particles sampled from clean (West coast marine) and urban (Auckland city) air. Particles have been colourised according to their machine learning classification.

References

Dang C., Segal-Rozenhaimer M., Che H., Zhang L., Formenti P., Taylor J., Dobracki A., Purdue S., Wong P-S., Nenes A., Sedlacek III A., Coe H., Redemann J., Zuidema P., Howell S. and Haywood J. 2022, 'Biomass burning and marine aerosol processing over the southeast Atlantic Ocean: a TEM single-particle analysis', *Atmospheric Chemistry and Physics,* **22**(14): 9389–9412.

Su B., Wang T., Zhang G., Liang Y., Lv C., Hu Y., Li L., Zhou Z., Wang X., Bi X., 2022, 'A review of atmospheric aging of sea spray aerosols: Potential factors affecting chloride depletion', *Atmospheric Environment*, **290**: 119365.

Optimisation and implementation of a continuous flow analysis system to measure methane in ice cores

S. Callaghan[1*], A. Menking[2], D. Baggenstos, T. Vance[1], and C. Plummer[2]

[1] University of Tasmania, Hobart, TAS, Australia
[2] Australian Antarctic Program Partnership, Hobart, TAS, Australia
[3]Australian Antarctic Division, Hobart, TAS, Australia

[*]Corresponding author: Solita Callaghan [solc@utas.edu.au]

Abstract

The IMAS ice core laboratory implemented a continuous flow analysis (CFA) system designed to produce high-resolution methane records in preparation for the Million-Year Ice Core (MYIC) Project. Ice cores from the DSS0506 site at Law Dome were used to fully test the system. Results bore strong resemblance to discrete Law Done methane profiles and continuous measurements from the Northern Hemisphere NEEM site for the same period. The system has a resolution of 3.34 cm. The performance of a new system can be characterised by the degree of signal smoothing that occurs as the gas moves through the system and the extraction efficiency of the degassing components (Rhodes et al., 2013). CFA is a relatively novel method of measuring ice core gases; there are few off-the-shelf parts optimised to fulfill their unique requirements. Finding a suitable module is a core step in optimising a CFA system. We assessed the aptitude of 6 different degassers by performing step tests to determine the amount of smoothing and signal dampening each module introduced to the system. We found the 362 µL Darwin Microfluidics Bubble Trap had the highest precision (σ =1.5e-03 ppm) and fastest response time.

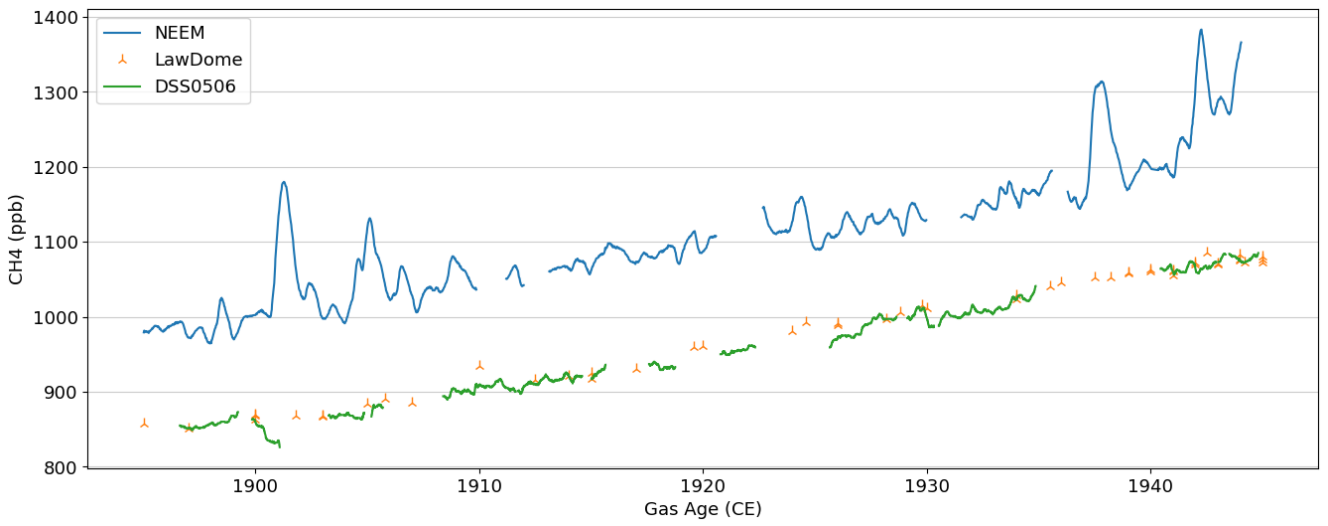


Fig. 1 Comparison of the IMAS determined DSS0506 methane concentrations to a discreate Law Dome (MacFarling et al. 2026) dataset and a continuous dataset from the NEEM site in the Northen Hemisphere (Rhodes et al. 2012). Datasets have been corrected for solubility; both continuous data sets have been integrated over a period of ~5s

References

MacFarling M., C. Etheridge, C. Trudinger, P. Steele, R. Langenfelds, T. van Ommen, A. Smith, and J. Elkins. (2006). Law Dome CO2, CH4 and N2O Ice Core Records Extended to 2000 years BP. *Geophysical Research Letters*, 33 (14), L14810. doi: 10.1029/2006GL026152

Rhodes, R. H., X. Faïn, C. Stowasser, T. Blunier, J. Chappellaz, J. R. McConnell, D. Romanini, L. E. Mitchell, E. J. Brook. (2013). Continuous methane measurements from a late Holocene Greenland ice core: Atmospheric and in-situ signals. *Earth and Planetary Science Letters*, 368, 9-19. doi: 10.1016/j.epsl.2013.02.034

Quantifying California HFC Emissions with the AGAGE Network

Duncan Quevedo[1*], Jooil Kim[2], Jens Mühle[2], Robert Rhew[2], Ray Weiss[2], and Luke Western[1]

[1] Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
[2] Scripps Institution of Oceanography, San Diego, California, USA

[*] corresponding author: Duncan Quevedo [quevedod@mit.edu]

Abstract

Introduced as benign replacements for ozone-depleting CFCs and HCFCs, HFCs are potent greenhouse gases that are released into the atmosphere from a variety of human activities, including refrigeration, air conditioning, and foam blowing. Although occurring in trace abundances, global CO2-equivalent emissions are equivalent to around two-thirds of current global methane emissions from the oil and gas sector.

Top-down HFC emissions estimates inferred from observations of atmospheric abundances often fundamentally disagree with bottom-up HFC emissions inventories inferred from industrial activity data. Some bottom-up estimates report static or decreasing emissions while top-down emission estimates are increasing. In either case, atmospheric abundances of most major HFCs are still increasing, which is a concern given the strong global warming potential of many HFCs.

Due to data sparsity, there are limited regional top-down emissions estimates of HFC emissions. Leveraging long-term monitoring stations of the AGAGE network in California at Trinidad Head and the Scripps Institution of Oceanography, we present a regional-scale top-down estimate of HFC emissions in California and comparison with bottom-up inventories. This quantification serves to evaluate regional bottom-up HFC emissions inventories for California and the Western United States and to demonstrate the utility and importance of long-term, high-resolution monitoring of halogenated GHGs.

A vehicle-mounted platform for mobile surveys of methane and nitrous oxide - PiLogger

C. T. Roulston[1*], J. Ramirez-Gamboa[1], D. Spencer[1], N. Crosbie[2], C. G. R. Caldow[1], and Z. M. Loh[1]

[1] CSIRO Environment, Aspendale, Victoria, Australia
[2] Melbourne Water, Docklands, Victoria, Australia

[*] corresponding author: Christopher T. Roulston [chris.roulston@csiro.au]

Abstract

Vehicle-based surveys with fast-response analysers are an efficient way to locate and characterise methane sources [von Fischer et al. 2017; Weller et al. 2018]. However, a survey is only as useful as its supporting data: every concentration needs an accurate time, a position and, ideally, a wind vector. We present a mobile monitoring platform built around a Raspberry Pi. It combines LI-COR LI-7810 (CH_4/CO_2/H_2O) and LI-7820 (N_2O/H_2O) analysers, an LI-550 ultrasonic anemometer and two independent GNSS receivers. Measuring N_2O alongside CH_4 helps distinguish biogenic CH_4 sources from natural gas mains leaks: natural gas contains no N_2O, so a coincident N_2O enhancement points to a biogenic origin [Fries et al. 2018]. Each instrument is logged raw to hourly files, and a synchronised 1 Hz summary combines gas, position and motion-corrected wind for live display in a web application. The platform is designed for non-specialist drivers: one button starts and stops a survey, after which the data upload automatically to a version-controlled repository.

Two corrections are essential. First, air takes several seconds to reach the analyser from the inlet (14 s in a puff test on our set-up), enough to misplace a plume by about 190 m at 50 km/h. The platform records a lag-corrected gas position alongside the instantaneous one, and the operator can adjust the delay in the web application. Second, the anemometer reports wind relative to its own body [LI-COR Biosciences n.d.], so vehicle motion must be removed and the result rotated to an earth frame, as on other moving platforms [Edson et al. 1998]. Its built-in magnetic compass is suitable only for stationary use [LI-COR Biosciences n.d.] and proved unreliable on a vehicle, so wind direction is derived from the GNSS course and the sensor's mounting angle. As that angle can change with each set-up, it is set per run in the web application.

Funded primarily by Melbourne Water, the platform has been tested and used mainly at its Western and Eastern Treatment Plants. The poster shows map views, example CH_4 and N_2O enhancement events, lessons learned and open problems, including anemometer data quality at highway speeds.

References

Edson, J. B., A. A. Hinton, K. E. Prada, J. E. Hare and C. W. Fairall (1998). Direct covariance flux estimates from mobile platforms at sea. *Journal of Atmospheric and Oceanic Technology* 15, 547-562. doi:10.1175/1520-0426(1998)015<0547:DCFEFM>2.0.CO;2

Fries, A. E., L. A. Schifman, W. D. Shuster and A. Townsend-Small (2018). Street-level emissions of methane and nitrous oxide from the wastewater collection system in Cincinnati, Ohio. *Environmental Pollution* 236, 247-256. doi:10.1016/j.envpol.2018.01.076

LI-COR Biosciences (n.d.). LI-550 mounting options and considerations. *LI-550 TriSonica Mini online documentation*. https://licor.com/env/support/LI-550/topics/mounting.html (accessed 30 September 2026).

von Fischer, J. C., et al. (2017). Rapid, vehicle-based identification of location and magnitude of urban natural gas pipeline leaks. *Environmental Science & Technology* 51, 4091-4099. doi:10.1021/acs.est.6b06095

Weller, Z. D., et al. (2018). Vehicle-based methane surveys for finding natural gas leaks and estimating their size: validation and uncertainty. *Environmental Science & Technology* 52, 11922-11930. doi:10.1021/acs.est.8b03135

Joint inversions of HCFC-22 and HFC-23 for partitioning emission sources of HCFC-22 in eastern China (2021-2024)

Eric Saboya[1]*, Sunyoung Park[2,3], Luke M. Western[1], and Ronald G. Prinn[1]

[1] Center for Sustainability Science and Strategy, Massachusetts Institute of Technology, Cambridge, MA, USA
[2] Kyungpook Institute of Oceanography, Kyungpook National University, Daegu, Republic of Korea
[3] Department of Oceanography, Kyungpook National University, Daegu, Republic of Korea

* corresponding author: Eric Saboya [esaboya@mit.edu]

Abstract

Emissions verification of controlled substances, such as HFC-23 and HCFC-22, is needed to ensure compliance with the Montreal Protocol and its amendments, and greenhouse gas emission reduction goals. Atmospheric trace gas measurements are often used to infer surface emissions through inverse modelling (e.g., Saboya et al., 2024). HFC-23 emissions are thought to predominantly arise as a byproduct of HCFC-22 production (which is used as a refrigerant and as a feedstock). Recent observation-inferred HFC-23 emissions for eastern China were found to be substantially higher than 2020-2022 emissions reported for the whole of China, the world's largest HCFC-22 producer (Adam et al., 2024; Park et al., 2023). The cause of this large discrepancy remains unexplained. However, constraining HCFC-22 emissions from production vs. usage/end-of-life could add constraints on the cause of the HFC-23 emissions discrepancy and improve our understanding of how emissions of these two species are interlinked.

Here, we developed an inverse method for partitioning production and usage/end-of-life HCFC-22 emissions by using HFC-23 as a tracer for HCFC-22 production emissions – linked through an adjustable HCFC-22-HFC-23 emissions ratio factor. We will present inversion results for 2010 to 2023 for eastern China for HFC-23 and HCFC-22 using two different inverse frameworks in our model, ARTEMIS (Atmospheric Regional Trace gas Emissions Modelling Inverse System), with atmospheric HFC-23 and HCFC-22 measurements from the AGAGE (Advanced Global Atmospheric Gases Experiment) network. We will show how using a multi-species inverse method changes the observation-inferred HFC-23 and HCFC-22 emission magnitudes and spatial distributions for eastern China compared to when a single-species inverse method is used. An advantage of the multi-species approach is that it will impose additional constraints on the partitioning of HCFC-22 emission sources and on our understanding of the HCFC-22 production and HFC-23 emissions relationship.

References

Adam, B., Western, L. M., Mühle, J., Choi, H., Krummel, P. B., O'Doherty, S., Young, D., Stanley, K. M., Fraser, P. J., Harth, C. M., Salameh, P. K., Weiss, R. F., Prinn, R. G., Kim, J., Park, H., Park, S., & Rigby, M. (2024). Emissions of HFC-23 do not reflect commitments made under the Kigali Amendment. *Communications Earth and Environment*, *5*(1). https://doi.org/10.1038/s43247-024-01946-y

Park, H., Kim, J., Choi, H., Geum, S., Kim, Y., Thompson, R. L., Mühle, J., Salameh, P. K., Harth, C. M., Stanley, K. M., O'Doherty, S., Fraser, P. J., Simmonds, P. G., Krummel, P. B., Weiss, R. F., Prinn, R. G., & Park, S. (2023). A rise in HFC-23 emissions from eastern Asia since 2015. *Atmospheric Chemistry and Physics*, *23*(16). https://doi.org/10.5194/acp-23-9401-2023

Saboya, E., Manning, A. J., Levy, P., Stanley, K. M., Pitt, J., Young, D., Say, D., Grant, A., Arnold, T., Rennick, C., Tomlinson, S. J., Carnell, E. J., Artioli, Y., Stavart, A., Spain, T. G., O'Doherty, S., Rigby, M., & Ganesan, A. L. (2024). Combining Top-Down and Bottom-Up Approaches to Evaluate Recent Trends and Seasonal Patterns in UK N_2O Emissions. *Journal of Geophysical Research: Atmospheres*, *129*(14). https://doi.org/10.1029/2024JD040785