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Abstracts

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Aspendale, Victoria, Australia

Priestley Lecture Theatre
Aspendale, Victoria, Australia / Virtual Meeting



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

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Day 1: Tuesday, 22 November 2022; 09:00-17:00

09:00	**Paul Krummel**	**Introduction**
09:05	**Janine Richardson**	**Welcome to Country**

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09:15	**Paul Krummel**	**General information on arrangements (housekeeping)**
Chair	**Melita Keywood**	**Session 1 – Oral Presentations**
09:20	Stephen Wilson	Aerosol Optical Depth at Kennaook/Cape Grim 1986 – 2021
09:35	Joanna Turner	Twenty years of atmospheric solar radiation research at the University of Southern Queensland
09:50	Kathryn Emmerson	Evaluating the skill of grass pollen forecasts in Australia
10:05	Chamari Buddhika Mampage	Characterization of airborne pollen fragments, fungal spores, and bacterial endotoxins during rain events in midwestern United States
10:20	Betsy Stone	Influences of convective storms on bioaerosols in a semi-arid grassland
10:35	**Morning tea**	**Aspendale canteen**
Chair	**Erin Dunne**	**Session 2 – Oral Presentations**
11:05	Melita Keywood	Particle and Multiphase Atmospheric Chemistry Program Review: 2016-2021
11:35	Ian Galbally	Progress with studies of reactive nitrogen oxides at Kennaook/Cape Grim
11:50	Martin Cope	Smoke forecasting- a deep dive into model performance for the 19/20 bushfire season
12:05	Jeremy Silver	Data assimilation to quantify biomass burning emissions
12:20	Jack Simmons	Greenhouse gas flux chamber measurements using low- and high-resolution techniques
12:35	**Lunch**	**Aspendale canteen**
Chair	**Elise-Andree Guerette**	**Session 3 – Oral Presentations**
14:00	Betsy Andrews	Aerosol optical properties during fresh and aged wildfire smoke events in Colorado
14:15	Shyno Susan John	Impact of indigenous fire management on the annual cycle of carbon monoxide over northern Australia
14:30	Adhitya Sutresna	Interference of sea salt to conventional biomass burning marker in CV-ToF-ACSM field measurements
14:45	Clare Paton-Walsh	Emissions of biogenic VOCs from a mature Scribbly Gum tree
15:00	Stephen MacFarlane	Impacts of aromatic chemistry on the global atmosphere
15:15	Sean Gribben	Towards replacing chemistry schemes in atmospheric models
15:30	**Afternoon tea**	**Aspendale canteen**
Chair	**Kathryn Emmerson**	**Session 4 – Oral Presentations**
16:00	Paolo Sebastianelli	Kinetic modelling of formaldehyde photophysical oxidation
16:15	Maria Paula Pérez Peña	Modelling the atmospheric fate of trifluoroacetaldehyde (CF_3CHO) a product of HFO-1234ze
16:30	Jennifer Powell	Long term monitoring of mercury in ambient air in the Australian region
16:45	Dominique Kpokro	Impacts of Artisanal and Small-Scale Gold Mining in Cote d'Ivoire: Mercury contamination in atmospheric telluric and aquatic ecosystems
17:00	**End Day 1**	

Day 2: Wednesday, 23 November 2022; 09:00-18:30

	Paul Krummel	**Daily welcome includes acknowledgement of traditional owners**
Chair	**Zoë Loh**	**Session 5 – Oral Presentations**
09:00	Colin Allison	Thirty years of same-air flask comparisons at Kennaook/Cape Grim (with emphasis on the stable isotopes of CO_2)
09:15	Roger Francey/Ray	Celebrating 3-decade GASLAB monitoring of the global CO_2 background
09:45	Alastair Williams	Construction of the Southern Ocean baseline for long-lived trace species
10:00	Elise-Andree Guerette	A first look at sulfur hexafluoride (SF_6) measurements from GASLAB
10:15	Ann Stavert	CRDS bias hunting in the CSIRO S.O. network
10:30	**Morning tea**	**Aspendale canteen**
Chair	**Cathy Trudinger**	**Session 6 – Oral Presentations**
11:00	Jessie Boylan	Beyond the visible: Communicating atmospheric change through art
11:15	Ian Enting	CO_2 equivalence of methane emissions – Evolving approaches
11:30	Zoë Loh	Atmospheric methane
11:45	David Stevenson (O)	COVID-19 lockdown emission reductions have the potential to explain over half of the coincident increase in global atmospheric methane
12:00	Sougol Aghdasi	Toward an inversion of atmospheric methane sources in Gippsland
12:15	**Lunch/Celebrations**	**Aspendale canteen/Lecture Theatre for Aspendale Staff**
		Session 7 – Poster session in the library; **To access posters:** https://cloudstor.aarnet.edu.au/plus/s/WyNPIITLK9i8gOc
Akinyinka Akinnusotu		Source, distribution, and risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in sediment samples from River Owan, Edo State, Nigeria
Erin Dunne		Air-sea fluxes of biogenic VOCs and their relationship with ocean biogeochemistry
Sonja Fiddes/ Matt Woodhouse		Does the model ever get it right? Understanding cloud and radiative biases in a nudged ACCESS-AM2 simulation over the Southern Ocean
Alan Griffiths		Is sea spray aerosol production in balance with deposition at Macquarie Island?
Ruhi Humphries		Measurement Report: Understanding the seasonal cycle of Southern Ocean aerosols
Rebecca Jackson		Can marine cloud brightening prevent coral bleaching in the Great Barrier Reef?
Blagoj Mitrevski		Measuring atmospheric hydrogen ahead of the Anticipated Hydrogen Economy
Caleb Mynard		Measuring marine volatile organic compounds with a proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS)
Chris Roulston		Developing emission factors for residual smouldering combustion of coarse woody debris – filling an important data gap
Haydn Trounce		CCN Climatology of the Great Barrier Reef
Matt Woodhouse		Modelling the impacts of future hydrogen emissions
Chair	**Clare Paton-Walsh**	**Session 8 – Oral Presentations**
14:15	Ray Langenfelds	Developing an Australian Greenhouse Gas Observing Network (AGGON)
14:30	Chris Caldow	The Australian Greenhouse Gas Observing Network (AGGON): What can we learn from the European Integrated Carbon Observing System (ICOS)?
14:45	Nicholas Deutscher/ David Griffith	Australian AirCore – the 2022 Broken Hill campaign and beyond
15:15	Sabina Assan (O)	Coal Mine Methane – Filling in the gaps
15:30	Nasimeh Shahrokhi	How do the current atmospheric measurements help to improve methane emission estimates for Melbourne?
15:45	**Afternoon tea**	**Aspendale canteen**
Chair	**Chris Caldow**	**Session 9 – Oral Presentations**
16:15	Beata Bukosa	Developments in greenhouse gas measurements and modelling in Aotearoa New Zealand
16:30	Cathy Trudinger	Atmospheric constraints on Australian emissions of synthetic greenhouse gases and ozone depleting substances
16:45	Scott Chambers	The Radon Tracer Method for GHG emission estimates – recent progress of the traceRadon project
17:00	**Interested parties**	**Discussion on expanded GHG Network & AirCore**
19:00	**Conference dinner**	**MordiHQ – Pimms Room** (information available on conference site)

Day 3: Thursday, 24 November 2022; 09:00-13:00

	Paul Krummel	**Daily welcome includes acknowledgement of traditional owners**
Chair	**Matt Woodhouse**	**Session 10 – Oral Presentations**
09:00	Matthew Tully	Water vapour injection into the stratosphere by Hunga Tonga-Hunga Ha'apai
09:15	Paul Krummel	The 2022 Antarctic ozone hole
09:30	Guang Zeng (O)	Attribution of historical ozone changes in CMIP6 models
09:45	Fraser Dennison	ACCESS-CM2-Chem: Evaluation of Southern Hemisphere ozone and its impact on climate
10:00	Matthew Tully	Total Column Ozone projections for Australia and New Zealand from a state-of-the-art Coupled Chemistry Climate Model
10:15	Olaf Morgenstern (O)	Comparison of Arctic and Antarctic stratospheric climates in chemistry versus no-chemistry climate models
10:30	**Morning tea**	**Aspendale canteen**
Chair	**Ruhi Humphries**	**Session 11 – Oral Presentations**
11:00	Daniel Marno (O)	CAFE-Pacific (Chemistry of the Atmosphere Field Experiment in the Pacific) airborne measurement campaign
11:25	Zoran Ristovski	Seasonality in sources of CCN over the Southern Ocean
11:40	Stephanie Cowling	Understanding the atmospheric conditions for aerosol formation in the Southern Ocean
11:55	Marc Mallett	Untangling the influence of Antarctic and Southern Ocean life on clouds
12:10	Tahereh Alinejadtabrizi	Evidence of wet deposition in mesoscale cellular convection over the Southern Ocean
12:25	Gerald Mace (O)	The Clouds and Precipitation Experiment at Kennaook (CAPE-K)
12:40	Lilani Toms-Hardman	A methodology comparison of atmospheric boundary layer characterisation using miniMPL data
12:55	David Etheridge	A Preliminary record of changes in Southern Hemisphere atmospheric OH abundance from ^{14}CO in glacial ice (Law Dome, Antarctica, 1870 AD to present)
13:10	**Lunch**	**End Conference**
14:00	**Interested parties**	**Continued discussions on Network Expansion, AirCore, or other topics – if needed**

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Contents

Day 1 – Tuesday, 22 November 2022

Aerosol Optical Depth at Kennaook/Cape Grim 1986 – 2021 1
S. R. Wilson

Twenty years of atmospheric solar radiation research at the University of Southern Queensland 2
J. Turner, B. A. V. Parisi, C. N. Downs, D. A. Amar and E. H. Butler

Evaluating the skill of grass pollen forecasts in Australia 3
K. M. Emmerson and the AusPollen team

Characterization of airborne pollen fragments, fungal spores, and bacterial endotoxins during rain events in midwestern United States 4
C. B. A. Mampage, D. D. Hughes, L. M. Jones, N. Metwali, P. S. Thorne and E. A. Stone

Influences of convective storms on bioaerosols in a semi-arid grassland 5
E. A. Stone, T. K. Feldman, C. B. A. Mampage, N. Bryan, J. Creamean, J. Escobedo, N. M. Falk, S. W. Freeman, B. Heffernan, T. C. Hill, G. Leung, A. Mazurek, C. Mignani, C. A. Neumaier, M. Nieto-Caballero, D. Veloso-Aguila, P. J. DeMott, L. D. Grant, S. M. Kreidenweis, R. J. Perkins and S. C. van den Heever

Particle and Multiphase Atmospheric Chemistry Program Review: 2016-2021 6
M. D. Keywood, E. Dunne, R. S. Humphries, F. Reisen, S. Taylor, N. Derek, J. P. Ward, J. N. Harnwell and J. C. Powell 6

Progress with studies of reactive nitrogen oxides at Kennaook/Cape Grim 7
I. E. Galbally, S. B. Molloy, M. D. Keywood, F. Reisen, P. B. Krummel, Z. M. Loh, J. P. Ward, N. T. Somerville, S. B. Baly, J. Ward and A. G. Williams

Smoke forecasting – a deep dive into model performance for the 19/20 bushfire season 8
M. E. Cope, F. Reisen, J. A. Noonan, S. A. Young, R. L. Gregory, D. Lynton and A. G. Wain

Data assimilation to quantify biomass burning emissions 9
J. D. Silver, M. E. Cope, F. Reisen and J. A. Noonan

Greenhouse gas flux chamber measurements using low- and high-resolution techniques 10
J. B. Simmons, C. Paton-Walsh, A. P. Mouat, J. Kaiser, R. S. Humphries, M. D. Keywood, D. W. T. Griffith, A. Sutresna, T. Naylor and J. Ramirez Gamboa

Aerosol optical properties during fresh and aged wildfire smoke events in Colorado 11
E. Andrews, L. Schmeisser, P. J. Sheridan, A. G. Hallar, D. A. Jaffe and J. P. Sherman

Impact of indigenous fire management on the annual cycle of carbon monoxide over Northern Australia 12
S. S. John, N. M Deutscher, C. Paton-Walsh and D. W. T. Griffith

Interference of sea salt to conventional biomass burning marker in CV-ToF-ACSM field measurements 13
A. R. Sutresna, M. D. Keywood, C. Paton-Walsh, J. B. Simmons, Q. Dang, M. Mochida, S. Ohata, S. Afsana, B. Kunwar, K. Kawamura, C. Mynard, R. S. Humphries, K. M. Emmerson, A. D. Griffiths, R. Schofield[1] and P. J. Rayner

Emissions of biogenic VOCs from a mature Scribbly Gum tree 14
C. Paton-Walsh, I. E. Galbally, J. Ramirez Gamboa, J. B. Simmons, M. Possell, A. Guenther, A. Mouat, Y. Peng and J. Kaiser

Impacts of aromatic chemistry on the global atmosphere 15
S. M. MacFarlane, J. A. Fisher, L. Xu, K. Ball, J. Crouse, P. Wennberg and H. Pye

Towards replacing chemistry schemes in atmospheric models 16
S. Gribben* and K. M. Emmerson 16

Master Equation modelling: Formaldehyde Photophysical Oxidation 17
P. Sebastianelli, M. J. T. Jordan, K. N. Rowell, M. Corrigan, B. A. Welsh and S. H. Kable

Modelling the atmospheric fate of trifluoroacetaldehyde (CF_3CHO) a product of HFO-1234ze 18
M. P. Pérez-Peña, J. A. Fisher and S. H. Kable

Long term monitoring of mercury in ambient air in the Australian region 19
J. C. Powell, M. D. Keywood, J. P. Ward, J. N. Harnwell, E. Dunne, D. Howard, N T. Somerville, M. Miller, P. Nelson, T. Morrison and J. A. Fisher

Severity and impacts of mercury use in Artisanal and Small-Scale Gold Mining (ASGM) in Cote d'Ivoire 20
D. Bally Kpokro, J. A. Fisher, L. Schneider and C. Paton-Walsh

Day 2 – Wednesday, 23 November 2022

Thirty years of same-air flask comparisons at Kennaook/Cape Grim (with emphasis on the stable isotopes of CO_2) 22
C. E. Allison, S. E. Michel, E-A. Guerette and R. L. Langenfelds

Celebrating 3-decade GASLAB monitoring of the global CO_2 background 23
R. J. Francey, R. L. Langenfelds, L. P. Steele and E-A. Guerette

Construction of the Southern Ocean baseline for long-lived trace species 25
A. G. Williams, S. D. Chambers, A. D. Griffiths, P. B. Krummel, Z. M. Loh, P. Sperlich, C. Labuschagne, S.-B. Hong and T. Choi

A first look at sulfur hexafluoride (SF_6) measurements from GASLAB 27
E-A. Guerette, R. L. Langenfelds, B. Mitrevski and C. Caldow

CRDS bias hunting in the CSIRO S.O. network 28
A. R. Stavert, D. W. T. Griffith, Z. M. Loh and D. M. Spencer

Beyond the visible: Communicating atmospheric change through art 29
J. Boylan

CO_2 equivalence of methane emissions – Evolving approaches 30
I. G. Enting and N. Clisby

Atmospheric Methane 32
Z. M. Loh, P. B. Krummel, A. R. Stavert, D. A. Spencer, E-A. Guerette, A. J. Swan, N. Shahrokhi, C. M. Trudinger, C. T. Roulston and C. Caldow

COVID-19 lockdown emission reductions have the potential to explain over half of the coincident increase in global atmospheric methane 33
D. S. Stevenson, R. G. Derwent, O. Wild and W. J. Collins

Toward an inversion of atmospheric methane sources in Gippsland 34
S. Aghdasi, P. J. Rayner, N. M. Deutscher and J. D. Silver

Developing an Australian Greenhouse Gas Observing Network (AGGON) 35
R. L. Langenfelds, Z. M. Loh, P. B. Krummel, D. M. Etheridge, C. M. Trudinger, C. Caldow, Y. Villalobos Cortes, P. Canadell, E-A. Guerette, A. R. Stavert, P. J. Fraser, N. Shahrokhi, B. L. Dunse, T. Ziehn and R. M. Law

The Australian Greenhouse Gas Observing Network (AGGON): What can we learn from the European Integrated Carbon Observing System (ICOS)? 36
C. Caldow and R. L. Langenfelds

Australian AirCore – the 2022 Broken Hill campaign and beyond 38
N. M. Deutscher, J. B. Simmons, T. A. Naylor, D. W. T. Griffith, C. Paton-Walsh, N. B. Jones, D. A. Pollard, D. Noone, B. C. Baier, T. Newberger, J. A. Higgs, C. Sweeney and S. Wolter

Coal Mine Methane – Filling in the gaps 39
S. Assan

How do the current atmospheric measurements help to improve methane emission estimates for Melbourne? 41
N. Shahrokhi, C. M. Trudinger, P. J. Rayner, Z. M. Loh, A. R. Stavert and S. Thomas

Developments in greenhouse gas measurements and modelling in Aotearoa New Zealand 42
B. Bukosa, S. E. Mikaloff-Fletcher, G. W. Brailsford, A. Geddes, D. Kennett, P. Sperlich, D. Smale, E. D. Keller, R. C. Moss, S. Gray, S. Moore, S. Nichol, T. Bromley, M. Kirschbaum, D. Giltrap, L. L. Liáng, J. Turnbull, D. Noone, J. Benmergui and S. Wofsy

Atmospheric constraints on Australian emissions of synthetic greenhouse gases and ozone depleting substances 43
C. M. Trudinger, A. J. Manning, P. J. Fraser, B. L. Dunse, R. L. Langenfelds, A. Redington and P. B. Krummel

The Radon Tracer Method for GHG emission estimates – recent progress of the traceRadon project 45
S. D. Chambers, A. D. Griffiths, A. Röttger, S. Röttger, A. G. Williams, F. Mertes, V. Morosh, O. Sisoutham, G. Kettlewell and the *traceRadon* Consortium

Day 3 – Thursday, 24 November 2022

Water vapour injection into the stratosphere by Hunga Tonga-Hunga Ha'apai 46
M. B. Tully, H. Vömel and S. Evan

The 2022 Antarctic ozone hole 47
P. B. Krummel, M. B. Tully, P. J. Fraser and N. Derek

Attribution of historical ozone changes in CMIP6 models 48
G. Zeng, O. Morgenstern, J. H. T. Williams, F. M. O'Connor, P. T. Griffiths, J. Keeble, M. Deushi, L. W. Horowitz, V. Naik, L. K. Emmons, N. L. Abraham, A. T. Archibald, S. E. Bauer, B. Hassler, M. Michou, M. J. Mills, L. T. Murray, N. Oshima, L. T. Sentman, S. Tilmes, K. Tsigaridis and P. J. Young

ACCESS-CM2-Chem: Evaluation of Southern Hemisphere ozone and its impact on climate 50
F. W. Dennison and M. T. Woodhouse

Total Column Ozone projections for Australia and New Zealand from a state-of-the-art Coupled Chemistry Climate Model ... 51
M. B. Tully, F. W. Dennison and M. T. Woodhouse

Comparison of Arctic and Antarctic stratospheric climates in chemistry versus no-chemistry climate models 52
O. Morgenstern, D. E. Kinnison, M. Mills, M. Michou, L. W. Horowitz, P. Lin, M. Deushi, K. Yoshida, F. M. O'Connor, Y. Tang, N. L. Abraham, J. Keeble, F. W. Dennison, E. Rozanov, T. Egorova, T. Sukhodolov and G. Zeng

CAFE-Pacific (Chemistry of the Atmosphere Field Experiment in the Pacific) airborne measurement campaign 54
D. Marno, B. J. Lelieveld and C. J. Curtius

Seasonality in sources of CCN over the Southern Ocean 55
L. T. Cravigan, J. Alroe, R. Brown, R. S. Humphries, P. W. Selleck, M. D. Keywood and Z. D. Ristovski

Understanding the atmospheric conditions for aerosol formation in the Southern Ocean 56
S. Cowling, C. Paton-Walsh, S. Marx, S. D. Chambers, A. D. Griffiths, A. G. Williams, R. S. Humphries and M. D. Keywood

Untangling the influence of Antarctic and Southern Ocean life on clouds 57
M. D. Mallet, R. S. Humphries, S. L. Fiddes and the PICCAASO team

Evidence of wet deposition in mesoscale cellular convection over the Southern Ocean 58
T. Alinejadtabrizi, F. Lang, L. Ackermann, Y. Huang, S. T. Siems, M. J. Manton, M. D. Keywood, R. S. Humphries, G. P. Ayers and P. B. Krummel

The Clouds and Precipitation Experiment at Kennaook (CAPE-K) 59
G. G. Mace, R. T. Marchand, M. D. Keywood, R. S. Humphries and A. Protat

A methodology comparison of atmospheric boundary layer characterisation using miniMPL data 60
L. Toms-Hardman and R. Schofield

A Preliminary record of changes in Southern Hemisphere atmospheric OH abundance from ^{14}CO in glacial ice (Law Dome, Antarctica, 1870 AD to present) 61
D. M. Etheridge, V. V. Petrenko, P. D. Neff, A. M. Smith, E. Crosier, B. Hmiel, D. P. Thornton, L. Jong, R. Beaudette, C. M. Harth, R. L. Langenfelds, B. Mitrevski, T. van Ommen, M. A. J. Curran, C. Buizert, L. Murray, C. M. Trudinger, M. Dyonisius, J. Ng, J. P. Severinghaus[7] and R. F. Weiss

Posters – Wednesday, 23 November 2022

Source, distribution, and risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in sediment samples from River Owan, Edo State, Nigeria 62
A. Akinnusotu, J. E. Ukpebor and F. E. Okieimen

Air-sea fluxes of biogenic VOCs and their relationship with ocean biogeochemistry 63
M. Rocco, E. Dunne, M. Peltola, N. Barr, J. Williams, A. Colomb, K. Safi, A. Saint-Macary, A. Marriner, S. Deppeler, J. N. Harnwell, C. Law and K. Sellegri

Does the model ever get it right? Understanding cloud and radiative biases in a nudged ACCESS-AM2 simulation over the Southern Ocean 64
S. L. Fiddes, M. T. Woodhouse, M. D. Mallet, A. Protat and S. P. Alexander

Is sea spray aerosol production in balance with deposition at Macquarie Island? 65
A. D. Griffiths, K. Richardson, K. M. Saunders, S. D. Chambers and A. G. Williams

Measurement Report: Understanding the seasonal cycle of Southern Ocean aerosols 66
R. S. Humphries, M. D. Keywood, J. P. Ward, J. N. Harnwell, S. P. Alexander, A. R. Klekociuk, K. Hara, I. M. McRobert, A. Protat, J. Alroe, L. T. Cravigan, B. Miljevic, Z. D. Ristovski, R. Schofield, S. R. Wilson, C. J. Flynn, G. R. Kulkarni, G. G. Mace, G. M. McFarquhar, S. D. Chambers, A. G. Williams and A. D. Griffiths

Can marine cloud brightening prevent coral bleaching in the Great Barrier Reef? 68
R. Jackson, M. T. Woodhouse and M. Baird

Measuring atmospheric hydrogen ahead of the Anticipated Hydrogen Economy 69
B. Mitrevski, E-A. Guerette, R. L. Langenfelds, M. T. Woodhouse, D. A. Spencer, P. B. Krummel and L. P. Steele

Measuring marine volatile organic compounds with a proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS) 70
C. Mynard, A. Patti, E. Dunne, R. S. Humphries and S. T. Siems

Developing emission factors for residual smouldering combustion of coarse woody debris – filling an important data gap 71
C. T. Roulston, J. C. Powell, S. Taylor, S. B. Molloy and F. Reisen 71

CCN Climatology of the Great Barrier Reef 72
H. Trounce, Z. D. Ristovski, L. Cravigan, J. Alroe, B. Miljevic, E. Horchler, R. S. Humphries and D. Harrison

Modelling the impacts of future hydrogen emissions 74
M. T. Woodhouse, F. W. Dennison, J. A. Noonan, Z. Nicholls, J. Lewis, R. Burdon and M. Meinshausen

Aerosol Optical Depth at Kennaook/Cape Grim 1986 – 2021

S. R. Wilson*

Centre for Atmospheric Chemistry, SEALS, University of Wollongong, Wollongong, NSW, Australia

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

Abstract

Measurements of Aerosol Optical Depth (AOD) at Kennaook/Cape Grim began in 1978 with manual sunphotometers. At the start of 1986 automated measurements began, that have continued until the present. The automated instruments are more stable and give a much greater data coverage. However, these instruments are then permanently outside, with the viewing window exposed to the (marine) environment. The resulting salty deposit leads to a decrease in signal which affects both *in situ* calibrations and estimates of AOD.

The data records for the sunphotometer installed on the roof deck (WMO#1, 1986 – 1997) and those in the radiation enclosure next to the access road (SPO1a, SP02 various, 1997 – 2021) have been assessed, looking at both the dependence of the retrieved calibration and AOD on time since cleaning. No wavelength dependence has been found, but the rate of contamination for the instruments in the enclosure was 50% higher than that of the roof deck. For the instruments in the enclosure this means a winter bias of around 20% in AOD 24 hours after cleaning.

Data from 1986 – 2021 have been recalibrated correcting for the average contamination rate, and this has been submitted to the World Data Centre for Aerosols. This is the longest record in the database for the southern hemisphere. This record shows the large impact of the Mount Pinatubo eruption and significant annual cycle as noted before [Wilson and Forgan 2002], and variations broadly in line with those predicted for spring and summer [Bhatti et al 2022] over the 35 years. No significant trend is observed when considering the entire record. Removing the period of the Pinatubo eruption gives a small linear increase of the order of 0.01 for the entire period. The annual cycle shows a peak in small (fine) particle AOD in August and a minimum in winter, and the large (coarse) particle AOD showing a weaker cycle with a minimum in winter.

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Twenty years of atmospheric solar radiation research at the University of Southern Queensland

J. Turner*, B. A. V. Parisi, C. N. Downs, D. A. Amar and E. H. Butler

Centre for Applied Climate Science, University of Southern Queensland,
Toowoomba, QLD, Australia

* corresponding author: Joanna Turner [Joanna.turner@usq.edu.au]

Abstract

The Solar Radiation Research group at the University of Southern Queensland (UniSQ) has been involved in solar radiation measurements and atmospheric monitoring since the early 2000s. The research group, currently aligned with the Centre for Applied Climate Sciences and the Centre for Astrophysics at UniSQ, has been working on numerous projects using data collected from several instruments located at the UniSQ Toowoomba, Queensland campus. The key data supporting this research include spectral global and diffuse solar ultraviolet (UV) radiation, broadband erythemal global and diffuse UV radiation and broadband UVA radiation measurements; in addition to total sky images that have been taken every minute to estimate the cloud cover. Additionally, other instrumentation that are installed onsite include total solar radiation, photosynthetically active radiation (PAR) and blue light sensors.

The data has contributed to many research projects, including but not limited to personal UV radiation exposure measurements with existing and developed chemical dosimeters, influence of clouds on solar UV radiation, reflectance of UV irradiance in the built environment, measuring and modelling the influence of shade on UV radiation exposure, influence of dust and aerosols on UV radiation measurements, modelling UV radiation exposure to elite athletes, and adapting smartphones to measure UV radiation.

The solar radiation group is currently working on developing a data management system that enables this long-term data collection and future data to be available to the public.

Evaluating the skill of grass pollen forecasts in Australia

K. M. Emmerson[1*] and the AusPollen team[#]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Kathryn Emmerson [kathryn.emmerson@csiro.au]

Abstract

Grass pollen is a chief cause of hay fever and asthma in the spring. Providing an accurate pollen forecast to the public is important for the self-management of symptoms and is wholly dependent on pollen counts being available. The AusPollen Partnership was set up in 2016 to link the various university groups measuring pollen in Australia and standardise the process. Pollen forecasts up to 6 days ahead began to emerge from Brisbane, Canberra, Melbourne and Sydney with various levels of sophistication. The ability to correctly predict a 'high' or 'extreme' grass pollen day is the target of much research.

This talk will take you through how different the grass pollen seasons can be in each of these capital cities, and how this causes simplicity or difficulties for the forecasts. In 2019, the AusPollen partnership started an exercise to evaluate how accurate each of the forecasts were and compared the outcomes to naïve forecasts using persistence and pollen climatology techniques [Emmerson et al 2022]. The results have underpinned the importance of increasing the pollen measurement network and started the conversation towards developing a national pollen forecasting system.

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[#] Many authors are listed in the reference above

Characterization of airborne pollen fragments, fungal spores, and bacterial endotoxins during rain events in midwestern United States

C. B. A. Mampage[1], D. D. Hughes[1], L. M. Jones[1], N. Metwali[2], P. S. Thorne[2] and E. A. Stone[1,3*]

[1] Department of Chemistry, University of Iowa, Iowa City, IO, USA
[2] Department of Occupational and Environmental Health, University of Iowa, Iowa City, IO, USA
[3] Department of Chemical and Biochemical Engineering, University of Iowa, Iowa City, IO, USA

[*] corresponding author: Elizabeth A. Stone [betsy-stone@uiowa.edu]

Abstract

Bioaerosols like pollen grains (10-100 µm), fungal spores (1-30 µm), and bacteria (0.25-8 µm) can affect human respiratory health as allergens, pathogens, and inflammatory agents. Pollen fragments (< 2.5 µm) are released by the rupturing of intact pollen grains. Due to their smaller size, pollen fragments can have longer atmospheric lifetime and can deposit throughout the airways inducing inflammation and allergic responses. During the spring tree pollen season in Iowa City, Iowa, in the Midwestern United States, we assessed the size distribution and temporal variation of pollen fragments, fungal spores, and bacterial endotoxins in the atmosphere using online single-particle fluorescence spectroscopy (Hughes et al. 2020) and offline analysis of chemical tracers [Mampage et al. 2022]. The concentration of fructose (a chemical tracer of pollen) in particles < 2.5 µm was elevated during rainy sampling periods, especially during thunderstorms, with the highest concentration occurring on a day when a tornado struck. Concurrently, submicron fluorescent particle concentration also increased during thunderstorms. The size-resolved concentrations of fructose and a birch pollen allergen (Bet v 1) indicated that the pollen fragment diameters span < 0.25 to 2.5 µm. Meanwhile, the concentration of mannitol (a chemical tracer of fungal spores) was primarily elevated in particles > 1.0 µm on warm and dry days following rain, in agreement with intact spore diameters. Endotoxin was enhanced on rainy days primarily in particles > 1.0 µm. Even though the concentrations of fructose, mannitol, and endotoxins all increased on rainy days, the highest relative increase of concentration in particles < 1.0 µm was observed for pollen tracers. Overall, this study provides new insight on the use of chemical tracers to track the pollen rupturing events in the atmosphere and provides evidence for release of allergen-loaded pollen fragments during tree pollen season in the Midwestern United States in response to extreme weather conditions.

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Influences of convective storms on bioaerosols in a semi-arid grassland

E. A. Stone[1*], T. K. Feldman[1], C. B. A. Mampage[1], N. Bryan[2], J. Creamean[2], J. Escobedo[2], N. M. Falk[2], S. W. Freeman[2], B. Heffernan[2], T. C. Hill[2], G. Leung[2], A. Mazurek[2], C. Mignani[2], C. A. Neumaier[2], M. Nieto-Caballero[2], D. Veloso-Aguila[2], P. J. DeMott[2], L. D. Grant[2], S. M. Kreidenweis[2], R. J. Perkins[2] and S. C. van den Heever[2]

[1] Department of Chemistry, University of Iowa, Iowa City, IA, USA
[2] Atmospheric Sciences, Colorado State University, Fort Collins, CO, USA

[*] corresponding author: Elizabeth A. Stone [betsy-stone@uiowa.edu]

Abstract

Bioaerosols, such as pollen, fungal spores, and bacteria, may carry allergens that can trigger allergic airway diseases and can also influence cloud formation and precipitation processes by triggering cloud droplet and ice crystal nucleation. The composition, concentration, and size distribution of bioaerosols are affected by environmental conditions, including rainfall, wind, temperature, and humidity. In the Bioaerosols and Convective Storms (BACS) study, our goal is to quantitatively assess the fluxes of biological material between the Earth's surface and atmosphere under changing meteorological conditions and to examine how bioaerosols may impact clouds and precipitation. Our objectives are to quantify the fluxes and concentrations, and characterize the identities of bioaerosols. We specifically target intact pollen, sub-pollen particles, fungal spores and bacteria released and transported during convective storm updrafts, storm-generated cold pools of evaporatively-cooled negatively-buoyant air, and compare them to quiescent conditions.

Samples were collected in May-June 2022 in a semi-arid grassland region at the Central Plains Experimental Range in Northern Colorado in the United States, which contains a National Science Foundation National Ecological Observatory Network (NSF NEON) flux measurement site. During the measurement campaign, twenty-three cold pools were observed along with several convective storms. This presentation will focus on flux-tower based measurements of individual fluorescent particles using a Wideband Integrated Bioaerosol Sensor (WIBS-5). On 7 June, for example, light rain occurred in the early evening, followed by a cold pool passage. Both weather events increased fluorescent particle concentrations by an approximate factor of two, with rain increasing those in the submicron size range and the cold pool increasing fluorescent particles in the supermicron size range. In contrast, some cold pools had little to no influence on fluorescent particle concentrations. Further bioaerosol classification will be enabled by ground-based measurements of size-resolved aerosol samples and rainwater for quantification of sucrose and fructose as tracers for pollen, mannitol as a tracer for fungal spores, endotoxin from gram negative bacteria, and DNA analysis. These off-line measurements complement high-time resolution measurement platforms and will support understanding of how different types of bioaerosols are affected by convection and cold pools.

Particle and Multiphase Atmospheric Chemistry Program Review: 2016-2021

M. D. Keywood*, E. Dunne, R. S. Humphries, F. Reisen, S. Taylor, N. Derek, J. P. Ward, J. N. Harnwell and J. C. Powell

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

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

Abstract

The Particle and Multiphase Atmospheric Chemistry Program (PMAC) focuses on the observation of aerosol microphysical, optical and chemical properties, precipitation composition, gaseous elemental mercury and persistent organic pollutants (POPs). PMAC formed in 2016 as a result of the merging of the Particle and MAC Programs following the recommendation of the 2015 Particle Program review. The MAC program was reviewed independently in 2017. This presentation has been prepared in response to the request from the Management Group that the Particle and Multiphase Atmospheric Chemistry (PMAC) Program be reviewed in 2022. This will be the first review of the combined PMAC program.

The presentation will include information on the goals of the program and the methods used.

Major achievements include the continued generation of long-term records including:

- A 44-year record of ultrafine particle number concentration (CN3)
- A 32-year record of particle number concentration (CN10)
- A 25-year (1981-2006) manual baseline CN record (monthly median CCN (1.23%, 0.96%, 0.71%, 0.47% and 0.23 %SS) 2-6 days per month measured in baseline wind sector (190-280°)
- A 14-year record of cloud condensation nuclei concentration (CCN) measured continuously (0.5%SS)
- A 30 -year record of black carbon concentrations (BC) (aerosol absorption)
- A 15-year record of forward aerosol scattering at 3 wavelengths
- A 45-year record of soluble ion concentrations in ~ PM10 including MSA, sea-salt and non-sea salt sulfate (NSSS)
- A 19-year record of gravimetric mass and soluble ion concentrations in PM2.5 for MSA, sea salt and NSSS
- A 36-year record of soluble ion concentrations in weekly baseline rainfall including sea salt and NSSS
- 18-year record of annual passive POPs concentrations (GAPS network, a collaborative program with Environment Canada)
- ~10-year record of gaseous elemental mercury via continuous measurement

These and other achievements will be described during the presentation which will also include a summary of future plans for PMAC.

Progress with studies of reactive nitrogen oxides at Kennaook/Cape Grim

I. E. Galbally[1*], S. B. Molloy[1], M. D. Keywood[1], F. Reisen[1], P. B. Krummel[1], Z. M. Loh[1], J. P. Ward[1], N. T. Somerville[2], S. B. Baly[2], J. Ward[2] and A. G. Williams[3].

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Kennaook/Cape Grim Baseline Air Pollution Station, Bureau of Meteorology, Smithton, TAS, Australia
[3] Australian Nuclear Science and Technology Organisation, Kirrawee DC, NSW, Australia

[*] corresponding author: Ian Galbally [ian.galbally@csiro.au]

Abstract

Measurements of nitric oxide (NO) and nitrogen dioxide (NO_2) which combined are represented by NO_x, plus limited measurements of total reactive gaseous nitrogen oxides (NO_y) over the period 2016-2022 at the Kennaook/Cape Grim GAW Station are presented. These nitrogen oxides are key to the reactive chemistry of the atmosphere regulating aerosol production and methane removal. This is a report on ongoing work.

The data processing for these measurements has been undertaken with custom software written in R. Output of the software includes simple statistics of the measurements of the three nitrogen oxide species along with about a dozen other parameters which are critical to the quality of the measurements. A brief overview of these steps will be presented.

In the marine atmosphere as defined by 'baseline' primarily using radon [Molloy and Galbally 2014] previous NO_x measurements at Cape Grim have shown low NO_x levels of the order of tens of ppt [Galbally et al. 2000]. The measurements here indicate similar levels, but more work needs to be done on instrument artifacts before conclusive results are achieved at these low levels.

The main focus of the current work is on unravelling the influence from bushfire, urban, and rural landscape NO_x emissions on the NO_x concentrations observed at Cape Grim. Black carbon, radon, carbon monoxide and ozone are used as explanatory tracers.

The year 2016 was one of extreme fire conditions in Tasmania, the major fires commenced with a massive lightning storm on 13 January 2016. Two major areas of fires in the northwest of Tasmania, with direction in the quadrant south to east of Cape Grim were the Wuthering Heights and the Mawbanna fires.

Results will be presented of the NO_x, NO_y and associated atmospheric records at Cape Grim from 10 – 13 February 2016 when a major smoke plume traversed the station. Other results will include the levels of NO_x in the rural atmosphere in the absence of large fires.

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Smoke forecasting – a deep dive into model performance for the 19/20 bushfire season

M. E. Cope[1*], F. Reisen[1], J. A. Noonan[1], S. A. Young[1], R. L. Gregory[1], D. Lynton[1] and A. G. Wain[2]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Australian Bureau of Meteorology, Melbourne, VIC, Australia

[*] corresponding author: Martin Cope [martin.cope@csiro.au]

Abstract

AQFx is a Bureau of Meteorology (BoM) operational air quality forecasting platform which was initially developed for the Victorian Department of Environment, Water, Land and Planning (DELWP), following the Victorian Royal Commission investigation into the 2009 Black Saturday fires.

The major elements of the platform are 1- ACCESS 36 – 72 h meteorological forecasts for the Australian region, for Victoria-Tasmania, and for NSW (the latter for use by the NSW Rural Fire Service); 2- anthropogenic air emissions inventories including smoke from domestic wood combustion; feeds of bushfires and prospective or current prescribed burns from DELWP and RFS; satellite thermal anomaly processing to identify fires in other regions of Australia; chemical transport modelling for smoke emission, transport and transformation; and cloud-based visualisation for stakeholder use.

The AQFx capability was leveraged throughout Australia during the 2019/2020 extreme bushfire season with forecasts of fine particle ($PM_{2.5}$) exposure due to smoke being used by many of the state and territory environment agencies, by fire agencies, and by BoM in support of aviation and ADF visibility advisories. Application of AQFx at the national scale for large and persistent bushfire smoke plumes necessarily stretched the design capabilities of the platform.

Following the Royal Commission into National Natural Disaster Arrangements, funding was made available through the Department of Home Affairs to support the development of a truly national air quality forecasting capability, and this platform is called the National Prototype Air Quality Forecasting System (AQFx_p).

A key component of the AQFx_p development work is a deep dive into the robustness of the platform for forecasting smoke impacts during extreme bushfire events as experienced in 2019/2020. Our exploration of this robustness includes an assessment of the platform's science algorithms, using observational data selected (as much as possible) to enable the modelled individual emission/transport/transformation processes to be tested in isolation.

In this presentation we will demonstrate this diagnostic verification approach, by focussing on two case studies (5-9 Jan 2020- smoke impacts in Sydney; 13th Jan 2020- smoke impacts in Melbourne). The presentation will summarise our current investigations into the capabilities of AQFx_p for modelling bushfire smoke emission rates, smoke plume rise, smoke particle morphology and smoke transport for these case studies.

Data assimilation to quantify biomass burning emissions

J. D. Silver[1,2*], M. E. Cope[2], F. Reisen[2] and J. A. Noonan[2]

[1] University of Melbourne, Parkville, VIC, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Jeremy Silver [jeremy.silver@unimelb.edu.au]

Abstract

'Data assimilation' involves updating model variables or parameters in geophysical simulations based on relevant observations. We present a data assimilation system focussing on atmospheric aerosols that aims to estimate smoke emissions from forest fires. It has been set up for the CSIRO Chemistry-Transport Model (CTM), which was reconfigured to simulate only the contribution from forest fires. These biomass burning aerosols are represented in a highly simplified manner, as inert aerosol tracers (subject to transport, dispersion, emission and wet and dry deposition, but not other physical or chemical aerosol processes) for a single size bin (<2.5 μm). To compare with measurements of total aerosols, other aerosol sources are estimated using a CTM simulation with emissions from all other emission sectors and aerosol types.

We used an ensemble-based assimilation scheme, which represents model uncertainty as an array of perturbed simulations. This captures the flow-related dependencies in the three-dimensional aerosol field, particular to the prevailing weather situation. Each CTM ensemble member is forced by meteorological outputs from a corresponding member of an ensemble of weather model runs, either the Bureau of Meteorology's ACCESS-GE ensemble or WRF model simulations with stochastic physics. An ensemble of 18 weather model runs was available. The array of 18 CTM simulations was expanded to create a larger ensemble, by representing bushfire smoke using inert aerosol tracer and perturbing emissions by treating parameters within the C-SEM smoke emission scheme probabilistically. Satellite aerosol retrievals (namely aerosol optical depth, or AOD, from the MODIS sensors) and surface $PM_{2.5}$ concentrations were assimilated.

We consider results from two baseline runs: without assimilation and with assimilation, and a range of variants on the 'with assimilation' baseline run. The analysis focuses on the 'Black summer' bushfires of 2019-2020 in eastern Australia. Results are compared against independent data, including AOD retrievals from a different satellite (VIIRS) or surface PM2.5 data that were not assimilated. The benefits of ensemble modelling are also considered.

Greenhouse gas flux chamber measurements using low- and high-resolution techniques

J. B. Simmons[1*], C. Paton-Walsh[1], A. P. Mouat[2], J. Kaiser[2,3], R. S. Humphries[4], M. D. Keywood[4], D. W. T. Griffith[1], A. Sutresna[4], T. Naylor[1] and J. Ramirez Gamboa[1]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, Australia
[2] School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA, USA
[3] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA
[4] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Jack B. Simmons [jsimmons@uow.edu.au]

Abstract

Although hard to imagine after two years of continuing wet weather, historical landscape dryness contributed to large and severe bushfires across eastern Australia [Nolan et al 2020] during the Austral summer of 2019-2020 known as the 'Black Summer'. Smoke-influenced air quality impacts were observed in population centres along the east coast including Sydney, Wollongong, Canberra and Melbourne for period of weeks to months [Borchers Arriagada et al 2020] Chemical composition of aged smoke plumes from 'Black Summer' fires in both the aerosol and gaseous phase was measured near Wollongong, NSW in January and February 2020 as part of the COALA-2020 campaign. Enhancement ratios for aerosol and gaseous species to carbon monoxide were determined and will be presented. Enhancement ratios reported here can be used in plume modelling of landscape-scale fires and assist in concentration estimates of infrequently measured atmospheric pollutants. The relative toxicological contribution of species present in the plumes was determined for plume exposure at the measurement site, and for concentrated plumes at a population centre case study. These toxicological contributions provide a reminder of the risks of exposure to toxic gases found in aged smoke plumes, not only particles. This presentation will draw heavily from the publication [Simmons et al 2022].

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Aerosol optical properties during fresh and aged wildfire smoke events in Colorado

E. Andrews[1,2*], L. Schmeisser[1,3], P. J. Sheridan[3], A. G. Hallar[4], D. A. Jaffe[5] and J. P. Sherman[6]

[1] University of Colorado/CIRES, Boulder, CO, USA
[2] NOAA/GML, Boulder, CO, USA
[3] Rocky Mountain Institute, Boulder, CO, USA
[4] University of Utah, Salt Lake City, UT, USA
[5] University of Washington, Bothell, WA, USA
[6] Appalachian State University, Boone, NC, USA

[*] corresponding author: Elisabeth Andrews [betsy.andrews@noaa.gov]

Abstract

The devastating 2020-2021 fire season in the American West generated intense plumes of wildfire smoke providing the opportunity to study the properties of aerosols in smoke plumes. We have analysed in-situ surface measurements of aerosol optical properties and size distribution at the Table Mountain monitoring site near Boulder, in northeast Colorado. These measurements offer insight into the influence of wildfires on downstream air quality as well as how aerosol properties change with age.

Fig. 1 shows the relationship between scattering Ångström exponent and absorption Ångström exponent overlaid on a modified aerosol typing matrix originally developed by Cappa et al. (2016). Measurements influenced by different wildfire events are highlighted in pink and blue, with pink indicating fresh smoke plumes and blue indicating plumes that have undergone long range transport. The plot shows that fresh smoke tends to have large spectral dependence suggesting an aerosol dominated by small, organic particles. We utilise the 2020 aerosol observations at Table Mountain in an attempt to develop a metric to identify fresh and aged smoke. We test the metric on the 2021 smoke observed at Table Mountain and then at other smoke-impacted sites in NOAA's Federated Aerosol Network across the US.

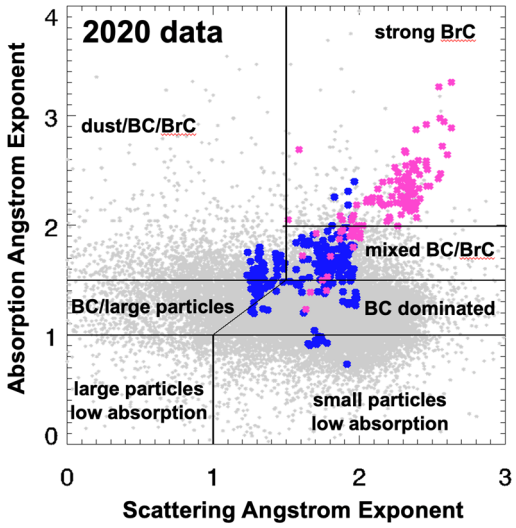


Fig. 1. Relationship between scattering Ångström exponent and absorption Ångström exponents for hourly surface in-situ aerosol observations at Table Mountain during 2020. Fresh smoke events are coloured in pink, while aged smoke events are represented by blue points.

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Impact of indigenous fire management on the annual cycle of carbon monoxide over Northern Australia

S. S. John*, N. M Deutscher, C. Paton-Walsh and D. W. T. Griffith

Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW, Australia

* corresponding author: Shyno Susan John [ssj703@uowmail.edu.au]

Abstract

The 2019-20 bushfires in south-eastern Australia were unprecedented in their extent and intensity. Human activities can regulate fire behaviour effectively through good fire management practices. In Northern Australia, indigenous fire managers use prescribed burns during the early dry season to prevent large late dry season fires, which shifts the overall temporal distribution of fire activity earlier during the primary biomass burning season. This increasing trend of prescribed burns has helped to significantly reduce the size and extent of the intense late dry season fires, indicating that such fire management practices can be effective at managing wildfires in savannas. This study examines whether the earlier fire season in Northern Australia impacts seasonal variability of carbon monoxide (CO) measured at Darwin. Column CO data from the ground-based Total Carbon Column Observing Network (TCCON) site in Darwin is used together with surface measurements and observations from the satellite-based sensor MOPITT (Measurement of Pollution in the Troposphere).

Observed trends from TCCON and MOPITT column data over Darwin indicate that CO increases during the early dry season and decreases in the late dry season, which could be attributed to the prevalence of prescribed burning practices. In addition, the observed CO trends shown by different global biomass burning inventories match with those of the TCCON and MOPITT column CO. The shift to earlier burning results in fires that burn at cooler temperatures, reducing the amount of biomass burned (or CO_2 emitted), but increasing the proportion of fire emissions from incomplete combustion. In addition, we see a seasonal pattern in CH_4 : CO emissions from the fires, indicating that reductions in CO_2 might be offset by increased emissions of CH_4. We also found significant difference between the annual CH_4 emissions reported from the global biomass burning inventories with that of the emissions estimated based on the CH_4 /CO enhancement ratio obtained from the surface in situ measurements at Darwin. The GEOS-Chem CO tagged tracer modelling capability will be used in order to disentangle the CO emitted from the study region from that measured from remote emissions coupled with long-range transport.

Interference of sea salt to conventional biomass burning marker in CV-ToF-ACSM field measurements

A. R. Sutresna[1,2*], M. D. Keywood[2], C. Paton-Walsh[3], J. B. Simmons[3], Q. Dang[3], M. Mochida[4], S. Ohata[4], S. Afsana[4], B. Kunwar[5], K. Kawamura[5], C. Mynard[2], R. S. Humphries[2], K. M. Emmerson[2], A. D. Griffiths[6], R. Schofield[1] and P. J. Rayner[1]

[1] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, Australia
[4] Nagoya University, Nagoya, Aichi, Japan
[5] Chubu University, Kasugai, Aichi, Japan
[6] Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW, Australia

[*] corresponding author: Adhitya R. Sutresna [asutresna@student.unimelb.edu.au]

Abstract

The Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) is a mass spectrometry technique that estimates aerosol composition using fragmentation calculations. Development of the capture vapouriser (CV) has reduced uncertainties associated with particle bounce in ToF-ACSM measurements, though using the CV introduces changes to measurements including being able to measure refractory species like sea salt and changing the fragmentation patterns of many organic molecules. One example is the marker for biomass burning organic aerosols (BBOA) m/z 60 is also being a marker for sea salt, which was not previously observed with the standard vapouriser as it could not easily measure sea salt. This study analyses measurements conducted in Southeast Australia during Black Summer bushfires illustrate the contributions of both sources to m/z 60, as well as other markers of BBOA.

CV-ToF-ACSM measurements were collected during the Characterising Organic Aerosols Loading over Australia (COALA-2020) campaign which was located around 50 km southwest of Sydney during the Black Summer bushfires. These field measurements were compared to the mass spectra of levoglucosan and synthetic sea salt standards, as well as being correlated with collocated measurements of radon, a marker for terrestrial air. Ions that were expected markers for BBOA (m/z 26, 42, 56, 68, 73, and 96) [Hu et al 2018] were positively correlated with radon, while some ions that were expected markers for sea salt (m/z 23, 25, and 36) [Freney et al 2021] were negatively correlated, suggesting a marine source. However, other ions that were expected sea salt markers (m/z 37, 38, and 58) [Freney et al 2021] had more similar correlations with radon to the expected BBOA markers, which can be explained by their presence in the levoglucosan standard mass spectra. For m/z 60, its correlation with radon did not resemble either the BBOA or sea salt sources, suggesting an even contribution from both sources. This indicates that m/z 60 is not an appropriate marker for BBOA when measuring using a CV-ToF-ACSM.

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Emissions of biogenic VOCs from a mature Scribbly Gum tree

C. Paton-Walsh[1*], I. E. Galbally[1,2], J. Ramirez Gamboa[1], J. B. Simmons[1], M. Possell[3], A. Guenther[4], A. Mouat[5], Y. Peng[5] and J. Kaiser[5,6]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] School of Life and Environmental Sciences, University of Sydney, Sydney, NSW, Australia
[4] University of California, Irvine, CA, USA
[5] School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA, USA
[6] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA

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

Abstract

Biogenic volatile organic compounds (BVOCs) are of particular significance to atmospheric chemistry in the relatively clean Southern Hemisphere. Despite their importance only a few Australian studies have been undertaken to measure emissions from native tree species. The Characterising Organics and Aerosol Loading in Australia 2020 (COALA-2020) campaign took place from 17 January to 23 March in 2020 at Cataract Scout Park (34°14'44"S, 150°49'26" E) in an area of open dry sclerophyll forest dominated by *Eucalyptus* trees, including *Eucalytpus haemastoma* (commonly known as Scribbly Gum trees).

BVOC emissions were measured using a proton-transfer-reaction-time-of-flight-mass spectrometer (PTR-TOF-MS) at 30 second resolution from three separate branches of a mature Scribbly Gum tree, each contained in a dynamic branch enclosure for approximately one day and night of the experiment. The PTR-TOF-MS was configured to draw sample via a bypass pump at 1 litre per minute on rotation from three separate lines:

1. 10 minutes sampling ambient air from a 10 m mast
2. 10 minutes from the enclosure containing the branch of the Scribbly Gum (with a separate pump running 12 litres/minute through the enclosure)
3. 10 minutes sampling from open line in midst of scribbly gum branches

with concentrations of BVOCs determined from 30 second averages of the mass spectra and then averaged over the 10 minutes. In this talk an initial assessment of these BVOC emissions as a function of temperature and photosynthetic active radiation will be presented along with plans for further analyses.

Impacts of aromatic chemistry on the global atmosphere

S. M. MacFarlane[1*], J. A. Fisher[1], L. Xu[2], K. Ball[3], J. Crouse[3], P. Wennberg[3] and H. Pye[4]

[1] University of Wollongong, Wollongong, NSW, Australia
[2] National Oceanic and Atmospheric Administration, Boulder, CO, USA
[3] California Institute of Technology, Pasadena, CA, USA
[4] United States Environmental Protection Agency, Research Triangle Park, NC, USA

[*] corresponding author: Stephen MacFarlane [smm997@uowmail.edu.au]

Abstract

Aromatics are an important subset of volatile organic compounds (VOCs), emitted mostly by anthropogenic sources such as vehicle exhaust, industry, and solvent usage [Cabrera-Perez et al 2016]. These sources make them particularly important in urban environments, accounting for up to 60% of total VOCs in urban and semi-urban areas [Cabrera-Perez et al 2016]. Aromatic species can undergo atmospheric oxidation resulting in significant contributions to both ozone and secondary organic aerosol (SOA) production [Seinfeld and Pandis 2016], making it important for air quality to understand aromatic chemistry. The impacts of aromatic chemistry can be examined using Chemical Transport Models (CTMs) that simulate atmospheric processes. However, CTMs are only useful if they can be trusted to provide an accurate description of the real atmosphere.

Here, we evaluate a new aromatic chemistry mechanism recently implemented in GEOS-Chem, a global CTM. The new aromatic mechanism includes new reactions, species, and products. However, it has not yet been evaluated using atmospheric observations. To evaluate the new aromatic mechanism, we compare GEOS-Chem model simulations to measurements from the Korea-United States Air Quality (KORUS-AQ) aircraft campaign, during which a variety of aromatic species and their oxidation products were measured around the Korean Peninsula from May to June 2016. In this presentation, we will provide a preliminary analysis of model ability to reproduce observed aromatic concentrations and variability during the campaign. We will also discuss implications for atmospheric composition in aromatic influenced regions and plans for future model development.

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Towards replacing chemistry schemes in atmospheric models

S. Gribben* and K. M. Emmerson

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Sean Gribben [sean.gribben@csiro.au]

Abstract

Approximately 90% of the computational time used by chemical transport models is taken up via processing the chemical mechanism. The chemical mechanism is the 'recipe' that breaks down pollutants emitted to the atmosphere and allows us to predict how much ozone and fine particles will be formed in the air as a result. Machine learning has been put forward as a technique that could one day replicate a chemical mechanism. The technique has the potential to speed up the chemical process by orders of magnitude, and will enable modellers to use the efficiencies gained in other areas, e.g. by increasing the spatial resolution of urban simulations to the sub-kilometre scale. These improvements are necessary for the next generation of urban air quality and health studies.

Thousands of outputs from a chemical box-model are used as the training dataset. The training data aims to replicate all conditions in atmospheric space - different concentrations of pollutants, different temperatures and pressures, times of day (and latitudes, for photolysis outcomes). Using the normalized values of these data as input, an Encoder-Decoder network was built and trained to potentially replace the computationally expensive chemistry scheme. Testing showed the network achieved a mean squared error of 0.003 when compared to the chemistry scheme's values.

Master Equation modelling: Formaldehyde Photophysical Oxidation

P. Sebastianelli[1*], M. J. T. Jordan[2], K. N. Rowell[2], M. Corrigan[2], B. A. Welsh[1] and S. H. Kable[1]

[1] School of Chemistry, University of NSW, Sydney, NSW, Australia
[2] School of Chemistry, University of Sydney, Sydney, NSW, Australia

[*] corresponding authors: Paolo Sebastianelli [p.sebastianelli@unsw.edu.au]
Meredith Jordan [meredith.jordan@sydney.edu.au], Scott Kable [s.kable@unsw.edu.au]

Abstract

For H_2CO photolysis, IUPAC reports quantum yields for radical formation by photons with 10 kJ/mol less energy than that required to form radicals (i.e. < 363 kJ/mol) [IUPAC 2013]. A hypothesis that the reaction between formaldehyde and O_2 could occur after absorption of light, with energy below that required for production of radicals, by a light-driven mechanism is proposed and the following process (R1) is analysed:

$$H_2CO^* + O_2 \rightarrow HO_2 + HCO \qquad (R1)$$

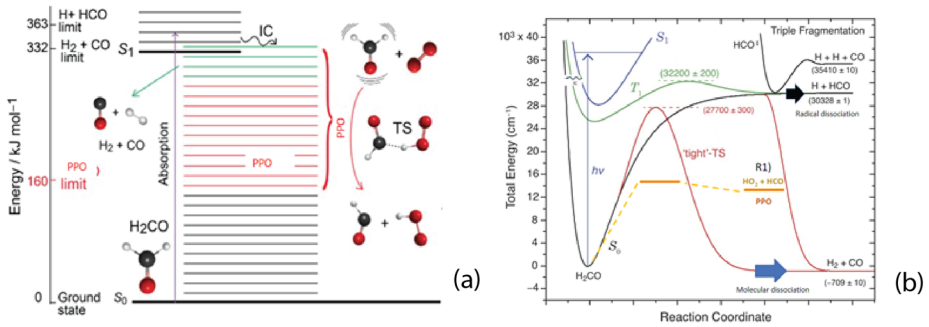


Fig. 1. (a) H_2CO^* production after absorption of a near-UV photon [Jordan, Kable, Fisher ARC(DP22)]. (b) ME simulated processes [modified from Quinn 2017]

Molecular oxygen would react with parent carbonyl molecules providing a new HO_2 source. This process is named Photophysical Oxidation (PPO). PPO reaction of the simplest carbonyl, H_2CO, is examined computationally and experimentally.

A Master Equation (ME) model was developed taking into account four processes illustrated in Fig. 1b (i) Internal Conversion (IC) from $H_2CO(S_1)$ to $H_2CO(S_0)$, (ii) molecular and (iii) radical dissociation and (iv) formaldehyde PPO. Rate coefficients for the various reactions were predicted using RRKM theory or Barker and co-workers' semimicrocanonical transition state theory [Maranzana 2007]. These were used within master equation models to assess the importance of (R1) and to simulate recent experimental results. The atmospheric implications of (R1) are also discussed.

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Modelling the atmospheric fate of trifluoroacetaldehyde (CF_3CHO) a product of HFO-1234ze

M. P. Pérez-Peña[1*], J. A. Fisher[2] and S. H. Kable[1]

[1] School of Chemistry. Faculty of Science, University of New South Wales, Sydney, NSW, Australia
[2] Centre for Atmospheric Chemistry. School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, Australia

[*] corresponding author: Maria Paula Pérez-Peña [m.perez_pena@unsw.edu.au]

Abstract

The use of human-made refrigerants and blowing agents have by now a long record of restrictions because of the impacts their emissions have had on the atmospheric composition and climate. One of the most resent alternatives for replacing some of the harmful and banned refrigerants and blowing agents are hydrofluoroolefins (HFOs). An example of this is HFO-1234ze, proposed as a replacement for HCFC-141b in the polyurethane foam industry. HFO-1234ze has an atmospheric lifetime of ~16 days and reacts almost exclusively with OH to produce formyl fluoride (HC(O)F) and trifluoroacetaldehyde (CF_3CHO) [Wang et al. 2021]. However, the photodissociation of CF_3CHO to fluoroform HFC-23 (CHF_3), a potent greenhouse gas that has a GWP-100 yr of 12,690, has been shown to be a possible channel. Although the HFC-23 channel has been reported to have a small quantum yield (~0.3% [Sulbaek Andersen and Nielsen 2022]), it still needs to be accounted for since the HFC-23 has a lifetime of 222 years, making it the HFC with the highest GWP [Seinfeld and Pandis 2016]. In this study we use a box model for 30 days to determine how much HFC-23 can be produced from the photolysis of CF_3CHO under real atmospheric conditions. We tested constant emission rates of the HFO-1234ze as the only sources of CF_3CHO for two years, 2015 and 2050. We also account for the physical removal of CF_3CHO based on its hydrogenated equivalent (CH_3CHO) by obtaining a range of deposition values using GEOS-Chem. The main chemical sink of CF_3CHO is photolysis with the radical channel being responsible for at least 64% of the CF_3CHO loss, while the HFC-23 channel accounts for ~1% of the CF_3CHO removal. We find that over one month, an upper limit of 1.0×10^{-2} ppt of HFC-23 can be produced from HFO-1234ze through CF_3CHO photolysis. This implies that the HFC-23 photolysis channel explored here could be responsible for up to ~12% of the current HFC-23 growth rate. Further studies are needed to include other sources of CF_3CHO and to explore its chemical properties since we use CH_3CHO as a benchmark for its deposition estimates.

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Long term monitoring of mercury in ambient air in the Australian region

J. C. Powell[1*], M. D. Keywood[1], J. P. Ward[1], J. N. Harnwell[1], E. Dunne[1], D. Howard[2], N T. Somerville[3], M. Miller[4], P. Nelson[5], T. Morrison[5] and J. A. Fisher[6]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] University of Colorado, Boulder, CO, USA
[3] Kennaook/Cape Grim Baseline Air Pollution Station, Bureau of Meteorology, Smithton, TAS, Australia
[4] EPA ESAT, USA
[5] Macquarie University, Macquarie Park, NSW, Australia
[6] University of Wollongong, Wollongong, NSW, Australia

[*] corresponding author: Jennifer Powell [jennifer.powell@csiro.au]

Abstract

The Minamata Convention is a global treaty whereby signatory countries, including Australia, have committed to reducing anthropogenic emissions of mercury. Evaluation of the effectiveness of the convention requires monitoring levels of mercury in biota and core environmental media, including air. Long term observations of mercury in ambient air at the Kennaook/Cape Grim Baseline Air Pollution Station and the Northern Territory Baseline Air Pollution Station will be used in this process. Both sites are impacted by continental and marine airmasses and are among only a handful of sites in the Southern Hemisphere with observations spanning more than 5 years, which is the minimum required for trend analysis. In this presentation we will discuss the measurement program, characteristics of both sites and a recent expansion of the network to include passive sampling and wet deposition sites.

Severity and impacts of mercury use in Artisanal and Small-Scale Gold Mining (ASGM) in Cote d'Ivoire

D. Bally Kpokro[1], J. A. Fisher[2], L. Schneider[3] and C. Paton-Walsh[4]

[1] University of Wollongong, Wollongong, NSW, Australia
[2] University of Wollongong, Wollongong, NSW, Australia
[3] Australian National University, Canberra, ACT, Australia
[4]University of Wollongong, NSW, Australia

[*] corresponding author: Dominique Bally Kpokro [bkdfk511@uowmail.edu.au]

Abstract

Artisanal and Small-Scale Gold Mining (ASGM) sector has become the largest anthropogenic source of mercury releases worldwide (UNEP 2018). The environmental and health-related impacts of mercury use in artisanal and small-scale mining (ASGM) which have been extensively reviewed by environmental and health scientists over the past three decades [Salomons 1995; Rodrigues Filho and Maddock 1997; Meech et al 1997; Bannerman et al 2003; Wickre et al 2004; Qiu et al 2019; Mason et al 2019; Niane et al 2019]. Minamata Convention on Mercury, a global treaty entered into force in 2017 that aims to eliminate mercury's use in industry, foremost ASGM, remains by far the most comprehensive move actually to eliminate mercury use at ASGM for environment and health reasons in sub-Saharan Africa. By considering mercury emissions and the associated transboundary contamination with ASM activities, my research seeks to map the circulation and pathways of mercury supplies in ASGM, the different actors engaged in its distribution, and the ancillary economic activities it gives rise to; pinpointing contamination 'hotspots', and to modeling pollution pathways to later define intervention scenarios from existing regulations and/or policies at regional and global level constitute the major activities to cover in that research. Therefore, my contribution will be to provide a comprehensive analysis of transboundary networks responsible for ASGM mercury distribution and supplies in West Africa, as well as associated hotspots and exposure pathways taking the case of Côte d'Ivoire. Thereby, identifying mercury ASGM sites as well as non-mercury ASGM site for establishing mercury environmental contamination remains a priority step. Air, soils, sediments and mines tailings have been sampled in ASGM sites and their surroundings for analysis. The obtained results will contribute to providing further guidance of sustainable interventions to address mercury pollution from ASM sector.

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Thirty years of same-air flask comparisons at Kennaook/Cape Grim (with emphasis on the stable isotopes of CO_2)

C. E. Allison[1*], S. E. Michel[2], E-A. Guerette[1] and R. L. Langenfelds[1]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, USA

[*] corresponding author: Colin Allison [colin.allison@csiro.au]

Abstract

For more than thirty years, air has been collected in glass flasks at Kennaook/Cape Grim (CGO) for a same-air measurement comparison between CSIRO GASLAB and NOAA GML/INSTAAR for trace gas amount fractions and stable isotopes of CO_2. The same-air nature of this comparison acts as a baseline for co-located comparisons at other sites (e.g. Alert, Canada) and provides a reference framework for atmospheric measurement comparison programs between other laboratories.

Over the thirty years, the agreement (difference) between the two laboratories has varied from excellent agreement to poor agreement but has never been used to adjust measurements made in one laboratory. Rather, observed differences have been used by one or both laboratories to investigate measurement and processing in their own laboratories.

In recent years, for the stable isotopic composition of atmospheric CO_2, both CSIRO and INSTAAR have synchronised their link to the hypothetical reference material, VPDB, by adopting the JRAS-06 procedure developed at MPI-BGC. With this revised link, the atmospheric CO_2 stable isotope records of the 'same-air' at CGO have been assessed against the WMO GAW compatibility targets and now appear to be compatible at the target level of 0.01 ‰.

This presentation will describe the program, summarise results, and speculate on broader implications.

Celebrating 3-decade GASLAB monitoring of the global CO_2 background

R. J. Francey*, R. L. Langenfelds, L. P. Steele and E-A. Guerette

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Roger Francey [roger.francey@csiro.au]

Abstract

GASLAB measurement methods that differ from those used in other CO_2 background monitoring programs throughout 1992-2021 are described and unique strengths identified.

The three-decade CO_2 (C) trends in flask air are dominated by accumulated long-lived emissions from power generation, over 95% released in the Northern Hemisphere. In the extreme baseline conditions sampled, Kennaook-Cape Grim (CGO) records these emissions mixed globally. Co-monitored Radon confirms that SH air-surface annual exchanges are negligible in comparison to the accumulated emissions transported from the NH. While the C emission lifetime is of order 50 years, the co-monitored isotope ratio $\delta^{13}C$ (δ) is rapidly equilibrated (within ~1 year) by gross CO_2 surface exchange to a value between the -25‰ of Fossil fuel and 0‰ of ocean carbonates.

Quadratic C and δ.C fits to 3-decade trends at CGO (41°S), and at Mauna Loa (MLO, 20°N), consistent with cumulative fossil emission trends, are used as hemispheric baselines. Annually averaged residuals from the respective quadratics exhibit remarkably similar interannual variation globally, lagging ENSO by one year, but with anomalous behaviour in 1993-4 after Pinatubo, and more markedly between 2010 and 2015. In all cases there is a near consistent anti-correlation with equilibrated terrestrial isotopes and mainly indicating climate forcing of the equatorial biosphere.

The onset of the 2010-2015 anomaly is attributed to a combined influence of the global financial crisis with the unprecedented contraction of interhemispheric exchange in 2010. Over at least 70° of Southern latitudes, the reduced C residuals persist to 2015 before rapid restoration, representing an anomaly total of order 12 PgC. At MLO there is minimal deviation from ENSO, but at Alert (ALT, 83°N) the residual reduction more resembles the SH. A possible explanation for this puzzle involves sensitivity of low latitude NH sites to inter-hemispheric exchange. The only known flux to explain the magnitude and duration of the SH 2010-2015 anomaly is the 3-4 PgC annually exchanged between hemispheres. In the absence of persisting IH exchange contraction, a significant overestimation of NH fossil emissions is necessary. The coincidence of regularised national accounting of emissions at COP21 is of possible relevance.

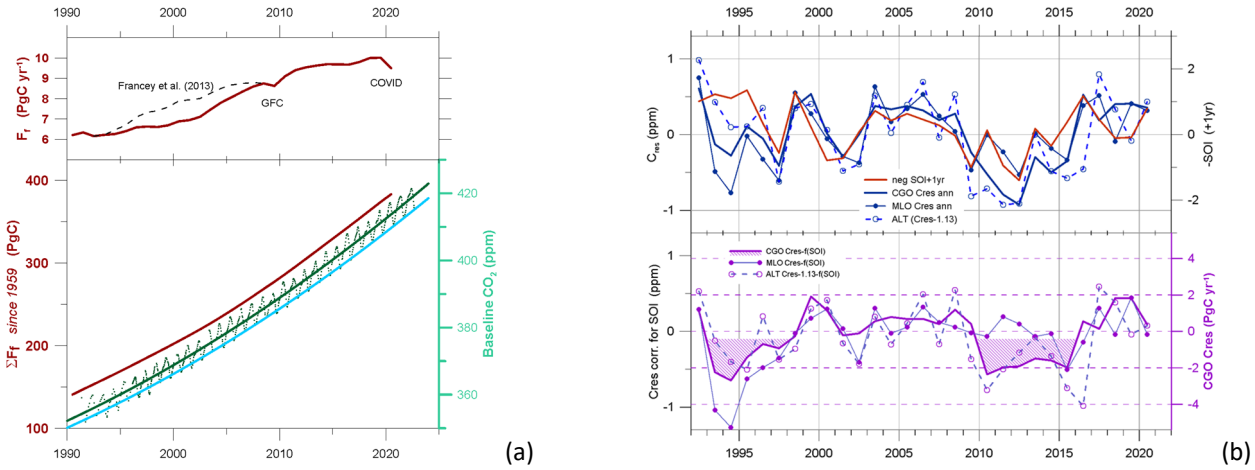


Fig. 1. (a) A comparison of F_f and ΣF_f with 3-decade baseline CO_2 quadratic trends at Kennaook-Cape Grim and Mauna Loa, (b) Residuals, including Alert, from hemispheric quadratics compared with SOI (at year +1) top, and residuals corrected for SOI, bottom. Anomalies are shaded.

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Construction of the Southern Ocean baseline for long-lived trace species

A. G. Williams[1*], S. D. Chambers[1], A. D. Griffiths[1], P. B. Krummel[2], Z. M. Loh[2], P. Sperlich[3], C. Labuschagne[4], S.-B. Hong[5] and T. Choi[5]

[1] ANSTO Environmental Research, Lucas Heights, NSW, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[4] South African Weather Service, Stellenbosch, South Africa
[5] Korea Polar Research Institute, Incheon, South Korea

[*] corresponding author: Alastair Williams [agw@ansto.gov.au]

Abstract

Baseline time series for long-lived trace species derived using radon-only criteria are location-independent across the central latitudes of the Southern Ocean north of the polar front [Williams et al 2021]. This suggests that a well-mixed airmass representing a balance between averaged sources, sinks and transport for such species exists across the entire Southern Ocean region and is maintained on timescales of weeks. But how is this baseline airmass constructed, and how is it maintained? Characteristics of the residual signal (raw data minus baseline) provide insights into this process.

In this study, residual time series from monitoring stations at remote Southern Ocean sites are contrasted with those from sites around the continental margins. At all stations, residuals are found to exhibit highly variable seasonal behaviour depending on the specific location. With the baseline signal removed, the residuals characterise the composition of measured air parcels that have been in recent contact with nearby landmasses, in the case of continental margin sites (marked by radon concentrations well in excess of the baseline range), or transported relatively quickly and directly from distant land masses, in the case of remote Southern Ocean locations. The latter events are characterised by radon concentrations that are small but nevertheless significantly elevated above the baseline values at the remote site (sometimes called 'radonic storms'). Such events represent 'terrestrial injections', in which air masses that have passed over continental regions relatively recently continue to penetrate deep into the Southern Ocean before eventually being incorporated into the baseline signal (defined in this study by radon dropping below an upper threshold of 80 mBq m^{-3}).

Focusing on CO_2 and CH_4 measurements, we present the observed distributions and seasonality of residual signals at selected continental and remote Southern Ocean sites (e.g., Fig. 1 compares Kennaook / Cape Grim with Macquarie Island), and discuss some high frequency characteristics of the radon and trace gas signals at Macquarie island that may represent evidence of the mixing process in action incorporating distant terrestrial signals into the Southern Ocean baseline.

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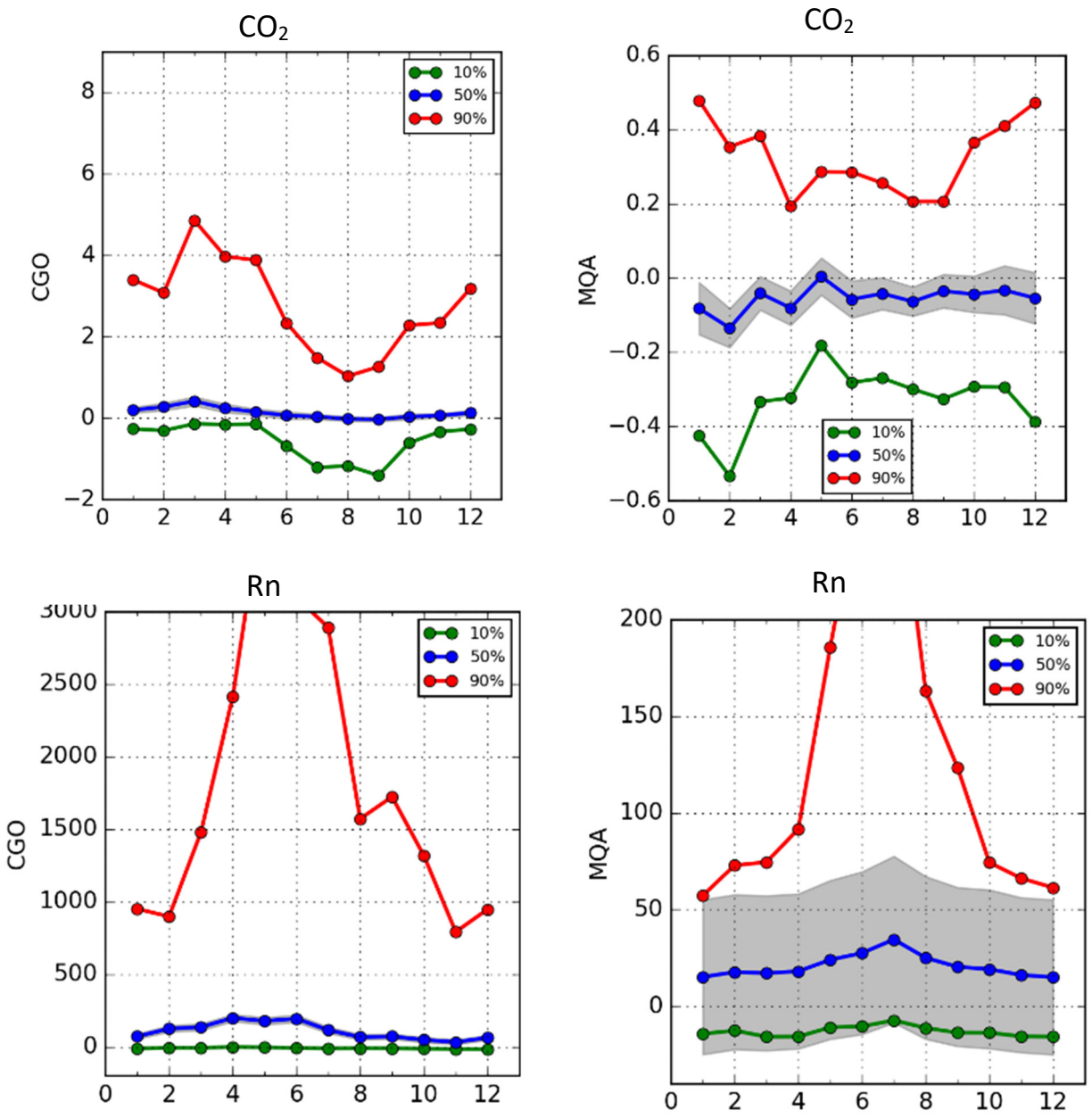


Fig. 1. Seasonal variability in residuals from raw data after removal of baseline, for 2013-2019 at Kennaook / Cape Grim (CGO, left) and Macquarie Island (MQA, right). Upper: CO_2 [ppm]; lower: radon [mBq m^{-3}]; note big changes in scale from CGO (left) to MQA (right). Plotted curves are monthly 10th (green), 50th (blue) and 90th (red) percentiles. Grey shaded areas around the median indicate instrumental uncertainty.

A first look at sulfur hexafluoride (SF_6) measurements from GASLAB

E-A. Guerette*, R. L. Langenfelds, B. Mitrevski and C. Caldow

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Elise-Andree Guerette [elise-andree.guerette@csiro.au]

Abstract

Sulfur hexafluoride (SF_6) is a potent greenhouse gas of mainly anthropogenic origin. The distribution of its sources makes it a useful tracer of interhemispheric transport [Maiss et al 1996].

The commissioning of a new gas chromatograph with electron capture detector (GC-ECD) in GASLAB in October 2021 has enabled routine measurement of SF_6 in flask samples from GASLAB's global network.

A year on, we celebrate this new data stream by:

- looking into instrument performance
- presenting preliminary time series data from our flask sampling sites
- when possible, comparing GASLAB data to that of other laboratories

The presentation will also explore the potential to extend the time series back in time using compressed air cylinders filled at Cape Schanck and at Kennaook/Cape Grim.

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CRDS bias hunting in the CSIRO S.O. network

A. R. Stavert[1*], D. W. T. Griffith[2], Z. M. Loh[1] and D. M. Spencer[1]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] University of Wollongong, Wollongong, NSW, Australia

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

Abstract

The Southern Ocean (S.O.) is a large global scale sink of CO_2, estimated to absorb approximately –0.53 ± 0.23 petagrams C/yr (net uptake) south of 45°S during the period 2009–2018 [Long et al. 2021]. However, the physical breadth of the sink means that ocean sink driven spatial gradients between CO_2 *in situ* observation locations in the S.O. region are small. This makes a high level of within network accuracy and precision essential with the WMO recommending a southern hemisphere network compatibility goal of 0.05 ppm CO_2 [WMO, 2018].

While CRDS instrumentation can achieve this level of repeatability with dry air cylinders clear biases between co-located CRDSs and co-located CRDS and FTIR instrumentation (between -0.4 and +0.3 ppm CO_2) when measuring 'wet' air have been identified. Biases in CH_4 measurements are also evident ranging between -1.0 and 0.5 ppb.

In this presentation we:

- Show examples of these biases – CRDS vs CRDS and CRDS vs FTIR
- Detail a series of experiments to identify the source of these biases – chilling/drying, calibration and CRDS water correction. These experiments indicate that the most likely source of the bias is the CRDS water correction.
- Outline an automated prototype method to correct for water driven biases.
- Show the effect that the use of the prototype method has on CO_2 and CH_4 biases for ambient air measurements at Aspendale.

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Beyond the visible: Communicating atmospheric change through art

J. Boylan*

RMIT University, Melbourne, VIC, Australia

* corresponding author: Jessie Boylan [jessie.boylan@student.rmit.edu.au]

Abstract

This presentation will give an overview of my PhD project, which, through using photography, slow-cinema techniques, multi-channel video and sound, explores the incommunicability of global atmospheric change through the Kennaook/Cape Grim Baseline Air Pollution Station in north-west Lutruwita/Tasmania. My work draws from research on slow emergencies, which are forms of harm and damage that are not acute but occur gradually and imperceptibly to most of us—like environmental pollution and radiation. Yet despite remaining largely unseen over time, the effects of slow emergencies are palpable, their relative invisibility rendering the harm they wreak all the more entrenched and difficult to address. The visual and sound work made as a result of my research employs an intentionally slow, observational approach and uses slow aesthetic techniques to respond to the slow science carried out on site and to the slow violence of climate change. Through art, science and technology, I am interested in looking at how changes in air quality and changes in human and non-human health are interdependent, while also showing how the pervasive, slow and violent effects of climate change and global warming are still being perceived as if they are yet to come.

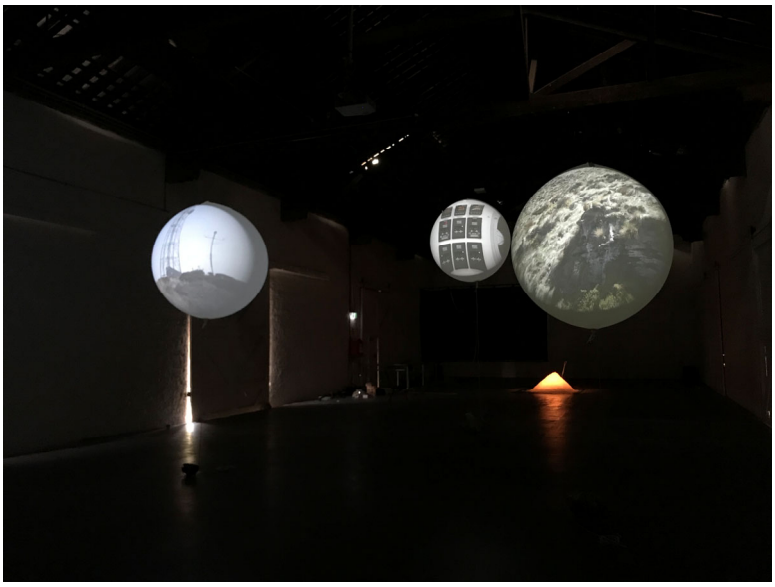


Fig. 1. 'The Smallest Measure' Installation, Castlemaine Festival, 2021, Castlemaine, Victoria.

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CO_2 equivalence of methane emissions – Evolving approaches

I. G. Enting[1*] and N. Clisby[2]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Department of Mathematics, Swinburne University of Technology, Hawthorn, VIC, Australia

[*] corresponding author: Ian Enting [ian.g.enting@gmail.com]

Abstract

Stabilising global temperatures requires that radiative forcing from anthropogenic greenhouse gases be stabilised. Achieving a given temperature target for the least cost requires the ability to compare reductions in different gases. The two most significant anthropogenic greenhouse gases are carbon dioxide and methane. Comparing them is difficult as they have dramatically different atmospheric lifetimes and consequent time profiles of radiative forcing.

Wigley [1998] specified equivalent emissions as having equal radiative forcing over time (termed the Forcing Equivalent Index: FEI), specified by

$$a_{\mathrm{CH4}} \int_0^t S_{\mathrm{CH4}}(t') R_{\mathrm{CH4}}(t-t')\,dt' = a_{\mathrm{CO2}} \int_0^t S_{\mathrm{FEIequiv}}(t') R_{\mathrm{CO2}}(t-t')\,dt'$$

where respectively, a_{CH4} and a_{CO2} are radiative forcings per unit mass and R_{CH4} and R_{CO2} are their impulse response functions. The different timescales of the response functions means that no simple multiplier such as GWP or GTP can give FEI-equivalence in all contexts. There is a spectrum from perfect equivalence in terms of radiative forcing to approximations involving simple metrics that still capture the historical context.

Formally, the process of converting a CH_4 emission history to the FEI CO_2 equivalent can be expressed as
For **CH_4 source history** $S_{CH4}(t)$, integrate to get **CH_4 concentration** then scale to get **CO_2 equivalent concentration** and finally, invert to get **CO_2 equivalent source** $S_{FEIequiv}(t)$

The last step is deducing CO_2 sources from concentrations, e.g. as in the analysis of CO_2 data from ice cores.

A visual way of understanding the relation, and also for analysing approximations to FEI is to consider the different timescales in terms of frequency responses as shown in the Fig. 1. To bring CO_2 and CH_4 into alignment requires applying what would be called an equaliser in audio systems. This is given by the ratio of the CO_2 and CH_4 frequency responses as shown in the rightmost panel.

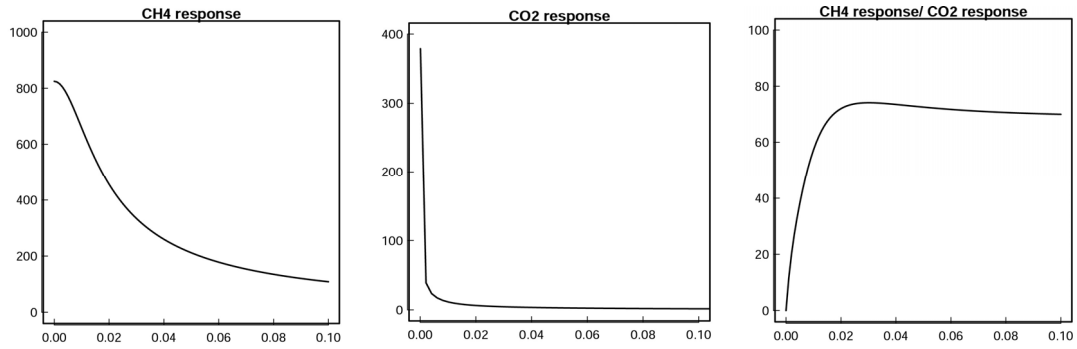


Fig. 1. Frequency responses against cycles per year. Left: CH_4 scaled by radiative forcing per kg relative to CO_2. Centre: CO_2 frequency response. Right: Ratio of these i.e. the 'equaliser'. Metrics can be assessed in terms of how well they reproduce this curve [cf Enting and Clisby 2021].

At low frequencies the ratio of responses is approximately proportional to frequency, implying that the equaliser is approximately differentiation of the methane source history. A climate-neutral index dominated by rates of change of methane emissions can also be understood from a stocks and flows perspective. For a 'flow' gas a constant source leads to equilibrium. In contrast for a 'stock' gas constant sources lead to continually increasing concentrations and equilibrium requires zero emissions. The equivalence with zero rate of change in emissions of a flow gas equivalent to zero emissions of a stock gas suggests the CO_2 equivalents for flow gases should be proportional to the rates of change of emissions of these gases.

Metrics that defined CO_2 equivalents in terms of rates of change of CH_4 emissions were proposed by Smith et al [2012], Lauder et al [2013] and Allen et al [2016] who used the 100-year GWP as a reference point for relating CH_4 rates of change to CO_2-equivalent emissions. Various refinements [Allen et al 2018; Lynch et al 2020; Enting and Clisby 2021] have been considered. These can be interpreted as aiming to fit the ratio of frequency responses more closely than a linear fit. Enting and Clisby [2021] plotted various metrics in terms of timescale dependence using Laplace transforms, rather than the Fourier transforms shown here.

Equivalence based on radiative forcing is slowly gaining acceptance. Although the IPCC AR6 fails to explicitly endorse the concept, the representative concentration profiles for stabilisation have zero CO2 emissions and constant but non-zero CH_4 emissions. Dr Bradley Ridoutt (CSIRO, Agriculture and Food) analysed emissions from Australia's livestock production, firstly directly in terms of radiative forcing, analysing historical CH_4 emissions without reference to a metric and also in terms of the GWP* metric [Ridoutt 2021, and references therein]. The use of metrics that capture the historical context of short-lived gases through analysis that captures changes in radiative forcing is essential for efficient achievement of climate-neutrality.

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Atmospheric Methane

Z. M. Loh*, P. B. Krummel, A. R. Stavert, D. A. Spencer, E-A. Guerette, A. J. Swan, N. Shahrokhi, C. M. Trudinger, C. T. Roulston and C. Caldow

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Zoë Loh [zoe.loh@csiro.au]

Abstract

The success of efforts to contain global warming to (well) less than 2°C above the pre-industrial average in line with the aspirations of the Paris Agreement rely on a combination of rapid reductions in anthropogenic greenhouse gas (GHG) emissions, coupled with longer term reductions in the atmospheric abundance of the major GHGs. With an atmospheric lifetime of hundreds of years, reductions in CO_2 rely on negative emissions technologies. In contrast, methane has an atmospheric lifetime of only around a decade, so efforts to reduce emissions have the potential to substantially rein in radiative forcing on a shorter timescale. This is the motivation for the Global Methane Pledge which aims to reduce methane emissions by at least 30% (relative to 2020 emissions) by 2030.

Unfortunately, as illustrated by the monthly mean baseline data from Kennaook/Cape Grim in Fig. 1, the growth rate of atmospheric methane over the last two years has been accelerating, exceeding 17 parts per billion per year (ppb/yr) since 2020. In contrast, the decadal growth rate for 2010-2019 was less than 8 ppb/yr. This talk explores the likely drivers of that growth, and the sort of targeted science our community can deliver to support methane emissions reductions in the near term.

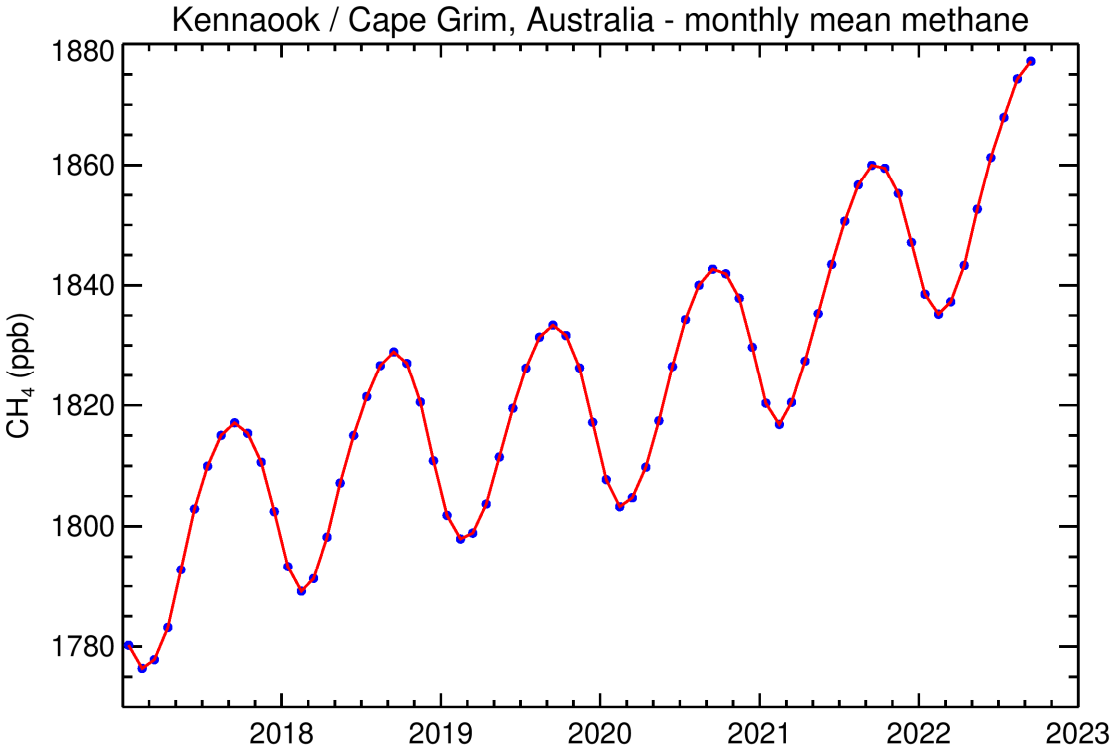


Fig. 1. Monthly mean baseline mole fraction of CH_4 (ppb) measured at Kennaook/Cape Grim Baseline Air Pollution Station

COVID-19 lockdown emission reductions have the potential to explain over half of the coincident increase in global atmospheric methane

D. S. Stevenson[1*], R. G. Derwent[2], O. Wild[3] and W. J. Collins[4]

[1] School of GeoSciences, University of Edinburgh, Edinburgh, UK
[2] rdscientific, Newbury, UK
[3] Lancaster Environment Centre, Lancaster University, Lancaster, UK
[4] Department of Meteorology, University of Reading, Reading, UK

[*]corresponding author: David Stevenson [David.S.Stevenson@ed.ac.uk]

Abstract

Compared to 2019, measurements of the global growth rate of background (marine air) atmospheric methane rose by 5.3 ppb/yr in 2020, reaching 15.0 ppb/yr. Global atmospheric chemistry models have previously shown that reductions in nitrogen oxide (NO_x) emissions reduce levels of the hydroxyl radical (OH), and lengthen the methane lifetime. Acting in the opposite sense, reductions of carbon monoxide (CO) and non-methane volatile organic compound (NMVOC) emissions increase OH and shorten methane's lifetime. Using estimates of NO_x, CO and NMVOC emission reductions associated with COVID-19 lockdowns around the world in 2020, together with model-derived regional and aviation sensitivities of methane to these emissions, we find that NOx emissions reductions led to a 4.8 (3.8 to 5.8) ppb/yr increase in the global methane growth rate. Reductions in CO and NMVOC emissions partly counteracted this, changing (reducing) the methane growth rate by -1.4 (-1.1 to -1.7) ppb/yr (CO) and -0.5 (-0.1 to -0.9) ppb/yr (NMVOC), yielding a net increase of 2.9 (1.7 to 4.0) ppb/yr. Uncertainties refer to ±1 standard deviation model ranges in sensitivities. Whilst changes in anthropogenic emissions related to COVID-19 lockdowns are probably not the only important factor that influenced methane during 2020, these results indicate that they have had a large impact, and that the net effect of NO_x, CO and NMVOC emissions changes can explain over half of the observed 2020 methane changes. Large uncertainties remain in both emissions changes during the lockdowns and methane's response to them; nevertheless, this analysis suggests that further research into how atmospheric composition changed over the lockdown periods will help us to interpret past methane changes and to constrain future methane projections.

The observed change in the methane growth rate showed strong latitudinal differences, with large changes seen at Northern Hemisphere sites in 2020, but much smaller changes in the south. Further analysis of the latitudinal and temporal evolution of the methane changes is likely to place further constraints on the processes involved.

For more details see Stevenson et al. [2022].

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Toward an inversion of atmospheric methane sources in Gippsland

S. Aghdasi[1*], P. J. Rayner[1], N. M. Deutscher[2] and J. D. Silver[3]

[1] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC, Australia
[2] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW, Australia
[3] School of Mathematics and Statistics, University of Melbourne, Parkville, VIC, Australia

[*] corresponding author: Sougol Aghdasi [saghdasi@student.unimelb.edu.au]

Abstract

This presentation describes preliminary steps toward an inversion of atmospheric methane sources in Gippsland. The inversion uses a variational assimilation system (Py4dvar). The aforementioned includes an offline Community Multiscale Air Quality (CMAQ) model with inputs derived from the meteorological model (Weather Research and Forecasting, WRF) and Emissions Database for Global Atmospheric Research (EDGAR) with a resolution of 2 km. The measurements considered in this work include those from an in-situ FTIR trace gas analyser, the Spectronus (located at Dutson Downs), and two Cavity RingDown Spectrometers, Picarro G2301s (based at Churchill and Yarram). Data synthesis on in-situ datasets was made by applying different filters (such as wind speed filtering and daily filtering), and overall, there is enough reliable data for an inversion. The performance of WRF was verified against several weather station observations of wind speed and direction as well as temperature. Generally, WRF is found to perform reasonably well for the task with better agreements between the WRF outputs and observations in lower elevations compared to mountains regarding wind speed and direction. Also, the prior emissions (EDGAR) are downscaled based on the Gridded Population of the World (GPW) datasets to produce the flux prior at a suitable resolution for the inversion. In the next step, the main objective is to run the Py4dvar system using the *in situ* observations.

Developing an Australian Greenhouse Gas Observing Network (AGGON)

R. L. Langenfelds[1*], Z. M. Loh[1], P. B. Krummel[1], D. M. Etheridge[1], C. M. Trudinger[1], C. Caldow[1], Y. Villalobos Cortes[2], P. Canadell[2], E-A. Guerette[1], A. R. Stavert[1], P. J. Fraser[1], N. Shahrokhi[1], B. L. Dunse[1], T. Ziehn[1] and R. M. Law[1]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Black Mountain, ACT, Australia

[*] corresponding author: Ray Langenfelds [ray.langenfelds@csiro.au]

Abstract

Australia is a signatory to international greenhouse gas (GHG) emissions reduction agreements and is responsible for reporting its national emissions. Until now reported emissions have been determined mainly through bottom-up methods that can be subject to large uncertainties and which fail to account for unidentified sources. National emissions could be better defined by complementary use of atmospheric top-down methods. Expanded application of such methods for global measurement of GHG emissions at nation scale resolution has recently been proposed by the World Meteorological Organization [WMO; media release 27-Jun-2022].

The ACCOM/Kennaook/Cape Grim community has established expertise in GHG measurement and inverse modelling of fluxes, and a proven track record in applying top-down methods on global and regional scales. Contributions to national emissions verification are presently limited by sparsity of observations. A capability for ongoing monitoring of national emissions could include:

- an expanded ground-based network adapted from earlier network design studies [Ziehn et al. 2016] providing continuous analysis of the concentrations and isotopic composition of the main GHGs (CO_2, CH_4, N_2O) and related tracers
- discrete sampling at selected sites for key gases/isotopes not able to be monitored continuously
- definition of vertical gradients using total column measurements, AirCore, or other platforms
- flux inversions constrained by direct atmospheric measurements and satellite-based data.

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The Australian Greenhouse Gas Observing Network (AGGON): What can we learn from the European Integrated Carbon Observing System (ICOS)?

C. Caldow* and R. L. Langenfelds

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Christopher Caldow [christopher.caldow@csiro.au]

Abstract

The latest United Nations Environment Programme Emissions Gap Report predicts that the world is on track for 2.8 degrees of warming by the end of this century, which is now less than 80 years away [UNEP 2022]. At the same time, commitments towards net zero emissions are ramping up with more than 70 countries now with net zero targets, covering about 76% of global emissions [UN 2022]. There are also more than 1000 cities and 1200 companies, including about half of the ASX 200, with net zero commitments. In order to mitigate climate change and truly reach net zero, accurate accounting of greenhouse gas sources and sinks is essential.

Australia's National Greenhouse Gas Accounts include inventories that are used to meet emissions reporting requirements under the Paris Agreement, UNFCCC and Kyoto Protocol. However, it has been shown recently that such inventories can be substantially inaccurate, with emissions being underestimated by factors ranging from 2 to 10 [Assan et al. 2022; Neininger et al. 2021; Plant et al. 2022]. Such studies highlight the need for independent and accurate estimates of greenhouse gas sources and sinks at scales ranging from industrial sites to cities to nations. This is vital for the development and verification of effective greenhouse gas mitigation strategies and policies.

The European Integrated Carbon Observing System (ICOS) was established to provide a high quality, standardised, and long-term greenhouse gas observation system to support scientists, decision makers and other members of society to predict and mitigate climate change. It formed around 2008 and built off the success of European studies that demonstrated how collaborative and co-ordinated greenhouse gas networks could be utilised to estimate continental-scale greenhouse gas fluxes [Luyssaert et al. 2010; Vetter et al. 2008; Schulze et al. 2009; Heiskanen et al. 2022]. ICOS covers three distinct domains (Atmosphere, Ecosystem and Ocean) and consists of about 150 measurement stations across 14 European countries. The ICOS atmosphere station network includes 39 stations in 14 countries, as well as an Atmospheric Thematic Centre and Central Analytical Laboratories.

This presentation will provide an overview of ICOS, focussing on aspects expected to be highly relevant for the development of an Australian Greenhouse Gas Observation Network. This includes the formation and initialisation of ICOS, along with network design and the infrastructure employed to ensure that high-quality greenhouse gas information is delivered.

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Australian AirCore – the 2022 Broken Hill campaign and beyond

N. M. Deutscher[1*], J. B. Simmons[1], T. A. Naylor[1], D. W. T. Griffith[1], C. Paton-Walsh[1], N. B. Jones[1], D. A. Pollard[2], D. Noone[3], B. C. Baier[4,5], T. Newberger[4,5], J. A. Higgs[5], C. Sweeney[5] and S. Wolter[4,5]

[1] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW, Australia
[2] National Institute for Water and Atmospheric Research, Lauder, NZ
[3] Department of Physics, University of Auckland, Auckland, NZ
[4] Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, USA
[5] NOAA Global Monitoring Laboratory, Boulder, CO, USA

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

Abstract

AirCore is a passive *in situ* atmospheric sampling system, able to provide vertical profiles of atmospheric composition. After many years of preparations, the first Australian AirCore campaign took place at Broken Hill, NSW, from 27 September–7 October 2022 featuring a team from the University of Wollongong, NIWA, and NOAA. Five successful AirCore launches and retrievals occurred, while four portable low spectral resolution solar FTIRs were operated. The FTIRs comprised two EM27/SUNs operating to standard COCCON (Collaborative Carbon Observing Network) procedures, an EM27 coupled to a fibre optic, and a IRCube coupled to a fibre optic; the latter two instruments are developmental alternatives that could offer operational advantages over the standard COCCON instruments.

This series of talks will be split between multiple presenters covering complementary aspects of AirCore and the Broken Hill campaign. We will describe the background of our AirCore system, the campaign and preliminary results. We will present the preliminary AirCore profiles, and comparison to and between the ground-based solar FTIRs.

The session is intended to remind the audience of the principles and value of AirCore, prior to discussion of its place in a future Australian greenhouse gas observing network.

Coal Mine Methane – Filling in the gaps

S. Assan*

Ember-Climate, London, UK

* corresponding author: Sabina Assan [sabina@ember-climate.org]

Abstract

Australian coal mines released 898,000 tonnes of methane into the atmosphere in 2019, equating to more than two-thirds (68%) of Australia's energy sector methane; more than the oil and gas industries combined [AGEIS 2021].

In order to limit global temperature rise to 1.5°C, the International Energy Agency (IEA) estimates that methane emissions from the coal mining industry must be reduced by 75% by 2030 [IEA 2021]. This decline needs a steep reduction in thermal coal use for electricity and an increase in the deployment of coal mine emissions reduction measures. Mitigation measures will be particularly necessary for metallurgical coal, which will still provide more than half of iron and steel energy input in 2030 [IEA 2022].

This study analysed data submitted to Australia's greenhouse gas emission inventory and compared it with other sources, including corporate annual reports and IEA estimates. It presents a pathway in which Australia's coal mines could reduce annual methane emissions by approximately 770,000 tonnes by 2030. This is equivalent to 18% of Australia's total methane emissions in 2020.

The pathway shows that more than half of the reductions in coal mine methane can be achieved by phasing out thermal coal used for electricity generation and thermal coal exports (410,000 tonnes a year by 2030). The remainder is achieved by reducing methane pollution from both thermal and metallurgical mines (370,000 tonnes a year by 2030). By 2030, the remainder of emissions are from the metallurgical coal sector, after the implementation of mitigation technologies.

The analysis found that not only will reducing Australia's methane emissions be severely hindered if the Government's strategy continues to allow new coal mines or expansions, but that there is also a huge risk that coal mine methane (CMM) emissions are already much greater than currently reported. The IEA estimated that Australian coal mines emitted 1.8 million tonnes of methane in 2021, double the officially reported figures, whilst TROPOMI satellite data measured emissions from one open-cut mine to be ten times larger than it was officially reporting [ACCR 2022].

The first step in implementing CMM reductions is to improve the quality of emissions data. This talk will cover an introduction to CMM emissions in Australia and discuss where the gaps in understanding these emissions currently lie. It aims to highlight the importance of direct measurements from both active and inactive mines, and discuss some of the methods the new EU Methane Regulation is proposing to improve the monitoring, reporting and verification (MRV) mechanisms for coal mines in Europe.

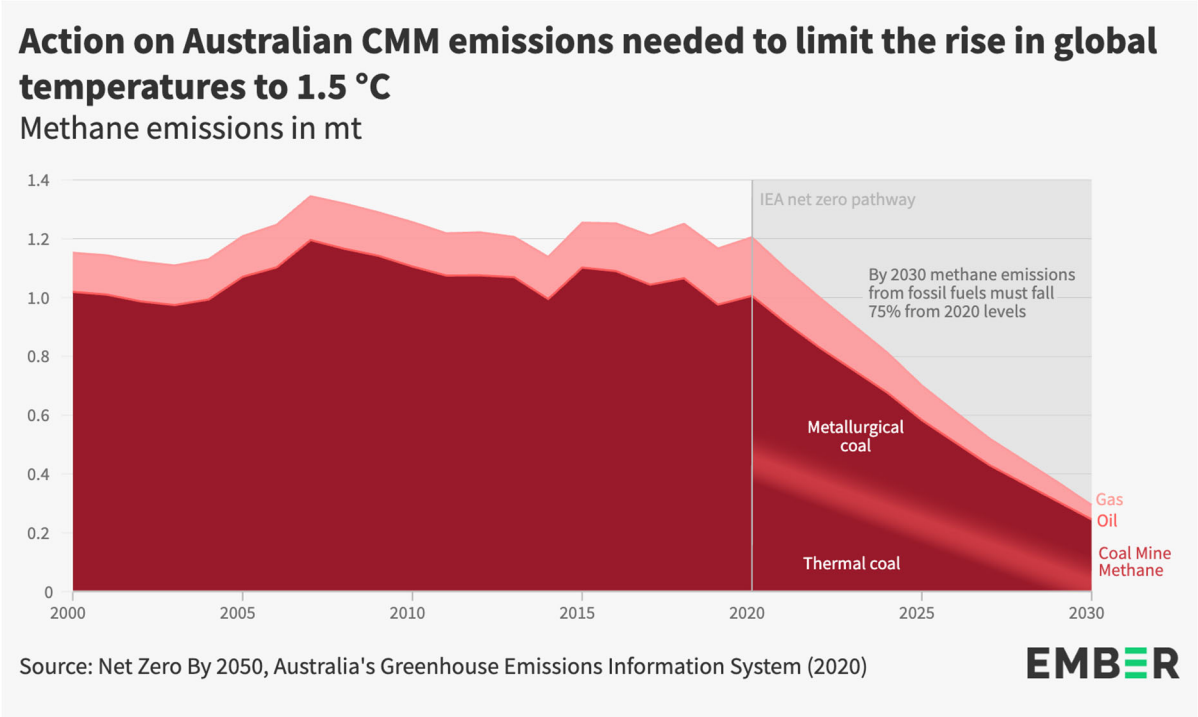


Fig. 1. Actions on Australian CMM emissions needed to limit the rise in global temperatures to 1.5

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How do the current atmospheric measurements help to improve methane emission estimates for Melbourne?

N. Shahrokhi[1*], C. M. Trudinger[1], P. J. Rayner[2,3], Z. M. Loh[1], A. R. Stavert[1] and S. Thomas[2]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC, Australia
[3] Melbourne Climate Futures Academy, University of Melbourne, Parkville, VIC, Australia

[*] corresponding author: Nasimeh Shahrokhi [Nasimeh.shahrokhi@csiro.au]

Abstract

Methane (CH_4) is a greenhouse gas and the second most significant contributor to global warming after carbon dioxide. Improving forecasts of atmospheric methane requires precise and accurate emission estimates; however, previous studies indicate a mismatch between current emission estimates and atmospheric observations. Here, we use prior emissions from different sectors to model methane mixing ratios in Melbourne, Australia, to estimate the mismatch with measurements. The prior anthropogenic emissions are downscaled from EDGAR[1] database, fire emissions are derived from GFAS[2] dataset and biogenic emissions are estimated from MEGAN[3] model. As boundary conditions play a significant role in regional scale modelling, we adjusted boundary conditions for this study using Kennaook/Cape Grim *in situ* measurements and the WACCM[4] dataset. The modelled mixing ratios using prior emissions show an averaged mismatch around 70 ppb with Aspendale *in situ* measurements during June 2021. To minimise the mismatch, we used a combination of *in situ* measurements of methane from Aspendale station and a variational inversion approach based on Bayes' theorem to refine urban-scale methane emission estimates. The comparison with assimilated data shows improvements in modelling methane mixing ratios in Aspendale and a bias reduction to 3 ppb (Fig. 1). However, to obtain a more comprehensive improved emission inventories in Melbourne, more in-situ stations are required in this area. The results of this study are used to identify potential hot-spots in Melbourne and to expand the methane monitoring network for this city.

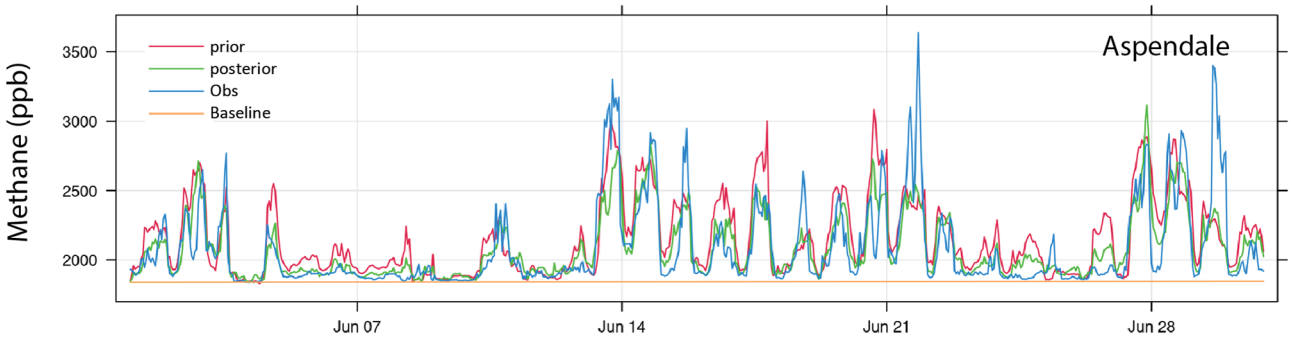


Fig. 1. Comparison of prior and posterior modelled methane mixing ratios with *in situ* observations at Aspendale, June 2021.

[1] EDGAR: The Emissions Database for Global Atmospheric Research

[2] GFAS: The Global Fire Assimilation System

[3] MEGAN: The Model of Emissions of Gases and Aerosols from Nature

[4] WACCM: The Whole Atmosphere Community Climate Model

Developments in greenhouse gas measurements and modelling in Aotearoa New Zealand

B. Bukosa[1*], S. E. Mikaloff-Fletcher[1], G. W. Brailsford[1], A. Geddes[2], D. Kennett[1], P. Sperlich[1], D. Smale[2], E. D. Keller[3], R. C. Moss[1], S. Gray[1], S. Moore[1], S. Nichol[1], T. Bromley[1], M. Kirschbaum[4], D. Giltrap[4], L. L. Liáng[4], J. Turnbull[3], D. Noone[5], J. Benmergui[6] and S. Wofsy[6]

[1] National Institute for Water and Atmospheric Research (NIWA), Wellington, New Zealand
[2] National Institute for Water and Atmospheric Research (NIWA), Lauder, New Zealand
[3] GNS Science, Lower Hutt, New Zealand
[4] Manaaki Whenua Landcare Research, Palmerston North, New Zealand
[5] University of Auckland, Auckland, New Zealand
[6] Harvard University, Boston, MA, USA

[*] corresponding author: Beata Bukosa [beata.bukosa@niwa.co.nz]

Abstract

Aotearoa New Zealand's measurement and modelling programme is expanding. Here, we will present an overview and newest results of the two research programmes that contributed to this expansion, CarbonWatchNZ and MethaneSAT.

CarbonWatchNZ utilizes inverse modelling to estimate New Zealand's carbon uptake and emissions on a national scale. Our decade long carbon dioxide (CO_2) inversion (2011-2020) suggests a stronger uptake relative to previous estimates. The additional sink appears in regions that are covered by indigenous forests, suggesting a more efficient carbon uptake capability of these environments. In contrast to CO_2 our national scale methane (CH_4) inversion (2017-2020) suggests a good agreement with prior estimates. Here, we will present the newest updates to our measurement network and explore the improvements and sensitivity tests made to our CO_2 modelling approach. We have performed sensitivity tests to our inversion system based on the main inversion components including the prior flux estimates and their uncertainties (biosphere, ocean and fossil fuel), transport model, background CO_2 values, CO_2 measurements from a new site, flux estimates for updated regions, constraining the gross primary productivity and respiration components as well a CO_2 diurnal cycle effect.

MethaneSAT is a yet to be launched novel satellite designed to detect targeted CH_4 emissions. It was developed as a CH_4 reduction strategy by detecting CH_4 emissions from oil and gas leaks (i.e., point sources), globally. The Aotearoa New Zealand team's aim is to develop an agricultural CH_4 emission (i.e., diffuse sources) estimation capability using data from the satellite. MethaneSAT is an American-New Zealand partnership (Environmental Defense Fund (EDF), MethaneSAT LLC and the New Zealand government) and the methods for the CH_4 emission estimation are built on a collaborative work between NIWA and the Harvard University. 85% of Aotearoa New Zealand's CH_4 emissions are from agricultural processes which enables unique testing opportunities. Here, we will present preliminary results of modelled CH_4 scans for the main agricultural targets across country. We will show a set of synthetic/modelled column averaged values as observed by the MethaneSAT satellite using the NAME III Lagrangian dispersion model and discuss the advantages and limits of such data products.

Atmospheric constraints on Australian emissions of synthetic greenhouse gases and ozone depleting substances

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

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Met Office Hadley Centre, Exeter, UK

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

Abstract

Synthetic greenhouse gases (SGGs) like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) are man-made chemicals used in refrigeration, air conditioning, fire-fighting, foam blowing and more, sometimes as replacements for ozone depleting substances (ODSs) like chlorofluorocarbons (CFCs) or halons. Although the abundance of SGGs in the atmosphere is currently much less than the naturally occurring greenhouse gases CO_2, CH_4 and N_2O, SGGs generally have a much higher global warming potential and can have very long lifetimes, so are of significant concern. Emissions of ODSs are mainly from so-called 'banks' due to prior use (e.g. old refrigerators, air conditioning and fire-fighting systems in old buildings), but can also be due to new production that is inconsistent with the Montreal Protocol [e.g. Montzka et al 2018; Rigby et al 2019]. Global atmospheric changes of some SGGs and ODSs are significantly greater than expected from global inventory estimates of their emissions, so atmospheric observations and regional inversions are important tools to understand current emissions, and to track progress as we reduce emissions in the future.

We use atmospheric observations of SGGs and ODSs from Kennaook/Cape Grim in the UK Met Office's InTEM inversion system [Manning et al., 2011; 2021] to infer emissions of these gases for SE Australia (mainly Victoria and Tasmania). The SE Australian emission estimates are scaled up using population to provide emission estimates for the whole of Australia, which can then be compared with bottom-up estimates from the Australian National Greenhouse Gas Inventory (based on import data and emission factors, DISER 2022). We will describe the Australian InTEM inversions and compare results with inventory estimates (e.g. Fig. 1).

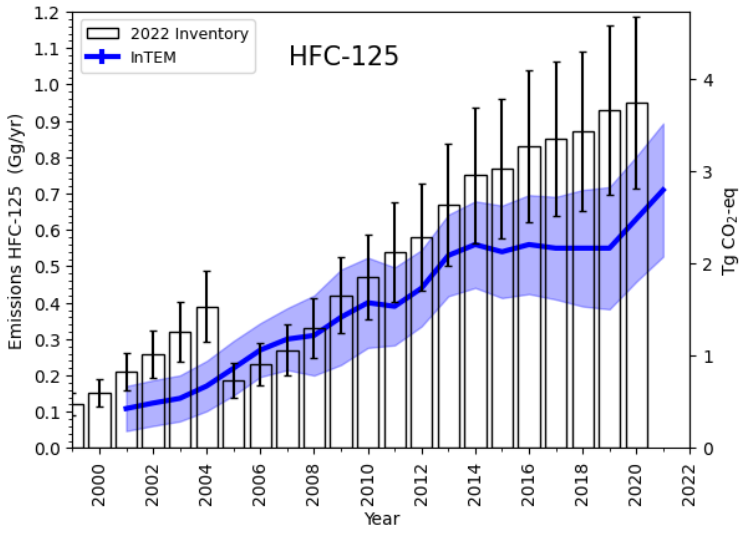


Fig. 1. Australian emissions of the refrigerant HFC-125. Inventory emissions are from the Australian National Greenhouse Gas Inventory [DISER 2022], with assumed uncertainties of 25%. InTEM emissions were inferred for SE Australia from observations at Kennaook/Cape Grim using the InTEM inversion system and have been scaled up to all of Australia using population. Manning et al [2021] describes how InTEM calculates uncertainties.

Hu et al. [2017] estimated emissions of several SGGs and ODSs for the USA using flask samples from a network of tall towers and aircraft vertical profiles. They found that the *per capita* emissions for some gases varied considerably for different parts of the country, sometimes by up to a factor of 3 or 4. For example, emissions of foam-blowing agents used in building insulation (e.g. HCFC-142b) were higher (*per capita*) in the north where the climate is cooler, and emissions of refrigerants used in air conditioning (e.g. HFC-125 and HFC-32) were higher (per capita) in the south where the climate is warmer. Per capita emissions are likely to also vary around Australia, leading to errors in our Australian estimates when scaled up by population from SE Australia. For example, if per capita emissions of the refrigerant HFC-125 are higher in the warmer northern parts of Australia, our top-down estimates based on SE Australia are likely to be underestimates (this might explain why the InTEM estimates are lower than the inventory estimates in recent years, see Fig. 1).

To improve our Australian estimates of SGGs and ODSs, we need additional measurement sites to be able to sample the main population centres (we are particularly missing Sydney and Brisbane at present). Emissions of many SGGs and ODSs are predominantly from populated areas, and we don't have to worry about natural fluxes like we do for CO_2, CH_4 and N_2O. However, measurements of SGGs and ODSs require a more complicated measurement system (like the Medusa system), severely limiting the number of in situ measurement sites that would be possible. Satellite observations of SGGs and ODSs are also very limited. We will look at where we could measure to improve Australian estimates of SGG and ODS emissions, and discuss issues like site selection and the value of in situ vs flask measurements. Some of the gases measured on the Medusa system could also be useful tracers for inversions of CO_2 or CH_4 (e.g. ethane that is sometimes co-emitted with CH_4, or synthetic gases that would indicate when air has been influenced by populated regions).

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The Radon Tracer Method for GHG emission estimates – recent progress of the traceRadon project

S. D. Chambers[1*], A. D. Griffiths[1], A. Röttger[2], S. Röttger[2], A. G. Williams[1], F. Mertes[2], V. Morosh[2], O. Sisoutham[1], G. Kettlewell[1] and the *traceRadon*[#] Consortium

[1] ANSTO, Lucas Heights, NSW, Australia
[2] Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

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

Abstract

Scientific interest regarding the continuous, reliable monitoring of atmospheric greenhouse gases (GHGs) and emission strengths has grown over the past 60+ years; particularly in recent years given the need for compliance checking of policy-driven regulations on emissions related to the Paris Climate Agreement. While GHG emissions have often been estimated using bottom-up techniques, the quality of such results is closely linked to the accuracy of emissions reporting. One alternative that has been explored is the use of top-down approaches, including the combined use of observations and inverse models to constrain regional emission strengths. Another top-down approach is the so-called Radon Tracer Method (RTM) [Levin et al. 1999]. Since Radon-222 (radon) has a relatively consistent and well-defined terrestrial source function, with unique physical characteristics that make it an ideal tracer for atmospheric mixing and transport, ratios of collocated observations of radon and GHGs with similarly distributed sources can be used to infer local- to regional-scale emissions of these GHGs. The accuracy of this approach, however, depends strongly on (i) the ability to accurately measure radon at low activity concentrations typical of outdoor environments at high temporal resolution, and (ii) the degree of understanding of spatial and temporal variability in the terrestrial radon source function [Levin et al. 2021]. Among the primary goals of the EMPIR 19ENV01 Project 'traceRadon' [Rottget et al. 2021], are (i) the traceable calibration of research-grade atmospheric radon monitors for concentrations between (1 – 100) Bq m^{-3}, (ii) improving the spatial and temporal uncertainty of radon flux maps, and (iii) developing a standard protocol for application of the RTM at monitoring sites across Europe. Here we will discuss recent advances in radon detector calibration traceability, calibration transfer between detectors of observation network sites, improvement in long-term radon flux monitoring, and how these developments may benefit a national GHG observing network in Australia.

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Water vapour injection into the stratosphere by Hunga Tonga-Hunga Ha'apai

M. B. Tully[1*], H. Vömel[2] and S. Evan[3]

[1] Australian Bureau of Meteorology, Melbourne, VIC, Australia
[2] National Centre for Atmospheric Research, Boulder, CO, USA
[3] LACy, Laboratoire de l'Atmosphère et des Cyclones, UMR8105, CNRS, Université de la Réunion, Météo-France, Saint-Denis, La Réunion, France

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

Abstract

The remarkable eruption of the submarine volcano Hunga Tonga-Hunga Ha'apai in January 2022 injected unprecedented amounts of water vapour directly into the stratosphere. In the days following the eruption, the stratospheric concentration of water vapour in the plume was enhanced by several orders of magnitude and was large enough to be detected by operational Vaisala RS41 radiosondes. As the plume moved eastwards over Australia, ten of the Bureau of Meteorology's upper air stations across northern Australia were able to provide high resolution vertically-resolved measurements of the water vapour enhancements, enabling an estimate to be made of the total amount of water vapour injected of 50 teragrams [Vömel, Evan and Tully 2022].

We show details of the initial stages of the injection as the plume travelled across Australia, and then its subsequent circuits of the globe over the next two months, as measured by radiosondes and balloon-borne cryogenic frostpoint hygrometers. We conclude with satellite measurements from the following months which now show enhanced stratospheric water vapour extending across the southern mid-latitudes to the edge of the polar vortex.

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The 2022 Antarctic ozone hole

P. B. Krummel[1*], M. B. Tully[2], P. J. Fraser[1] and N. Derek[1]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Australian Bureau of Meteorology, Melbourne, VIC, Australia

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

Abstract

The 2022 ozone hole developed in earnest in mid- to late-August and reached over 26 million km^2 in area in early-October (Fig. 1). Since then and until the first week of November, the 2022 ozone hole has remained relatively large and persistent and has closely mirrored the 2020 and 2021 Antarctic ozone holes. This is a result of: a relatively stable and strong polar vortex again in 2022, similar to 2020 and 2021; mid- to low-stratospheric temperatures have been colder than average for the majority of the ozone hole season so far due to low levels of heat transport towards the pole; and the potential influence from the Hunga Tonga-Hunga Ha'apai volcanic eruption in January 2022 which only injected an average amount of sulphate aerosol into the stratosphere compared with other volcanic eruptions, but injected an unprecedented amount of water vapour into the stratosphere in terms of both the magnitude and height reached (57 km - the mesosphere) (Millán et al. 2022; Vömel et al. 2022). These conditions are ideal for stratospheric ozone depletion chemistry.

This presentation will give an update on 2022 Antarctic ozone hole season and how the 2022 ozone hole metrics compare to the historical metrics from the last 43 years of satellite measurement.

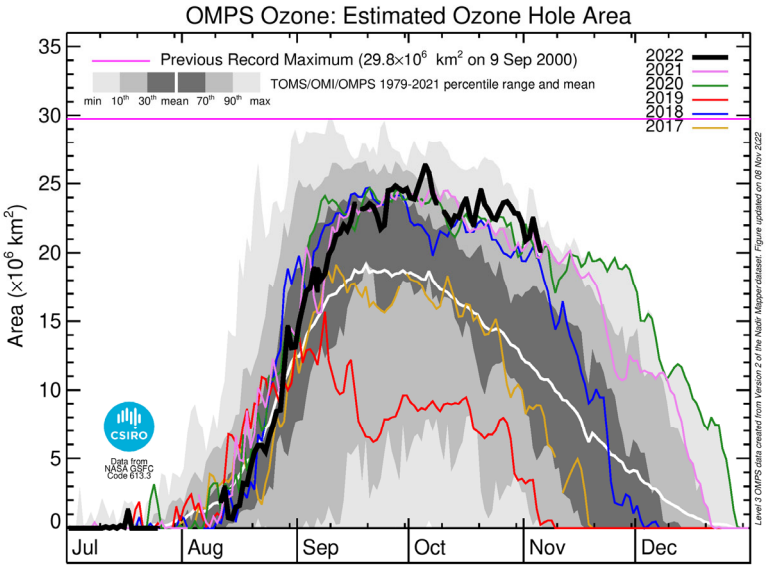


Fig. 1. Daily Antarctic ozone hole area based on OMPS data as of 5 November 2022, along with the daily ozone hole area from the past 5-years.

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Attribution of historical ozone changes in CMIP6 models

G. Zeng[1*], O. Morgenstern[1], J. H. T. Williams[1], F. M. O'Connor[2], P. T. Griffiths[3,4], J. Keeble[3,4], M. Deushi[5], L. W. Horowitz[6], V. Naik[6], L. K. Emmons[7], N. L. Abraham[3,4], A. T. Archibald[3,4], S. E. Bauer[8,9], B. Hassler[10], M. Michou[11], M. J. Mills[7], L. T. Murray[12], N. Oshima[5], L. T. Sentman[6], S. Tilmes[7], K. Tsigaridis[8,9] and P. J. Young[13]

[1] National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand
[2] Hadley Centre, Met Office, Exeter, UK
[3] National Centre for Atmospheric Science, Cambridge, UK
[4] Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, UK
[5] Meteorological Research Institute (MRI), Tsukuba, Japan
[6] GFDL, National Oceanic and Atmospheric Administration, Princeton, NJ, USA
[7] National Center for Atmospheric Research (NCAR), Boulder, CO, USA
[8] NASA Goddard Institute for Space Studies (GISS), New York, NY, USA
[9] Center for Climate Systems Research, Columbia University, New York, NY, USA
[10] DLR, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
[11] CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France
[12] University of Rochester, Rochester, NY, USA
[13] Lancaster Environment Centre, Lancaster University, Lancaster, UK
[14] Centre of Excellence for Environmental Data Science,
Lancaster University and UK Centre for Ecology and Hydrology, Lancaster, UK

[*] corresponding author: Guang Zeng [guang.zeng@niwa.co.nz]

Abstract

We quantify the impacts of halogenated ozone-depleting substances (ODSs), greenhouse gases (GHGs), and short-lived ozone precursors on ozone changes between 1850 and 2014 using single-forcing perturbation simulations from several Earth system models with interactive chemistry participating in the CMIP6 Aerosol and Chemistry Model Intercomparison Project (AerChemMIP). We present the responses of ozone to individual forcings and an attribution of changes in ozone columns and vertically resolved ozone to these forcings. The results show that whilst substantial ODS-induced ozone loss dominates the stratospheric ozone changes since the 1970s, increases in tropospheric ozone due to increases in short-lived ozone precursors and methane since the 1950s make increasingly important contributions to total column ozone (TCO) changes (Fig. 1). Increases in methane also lead to substantial extra-tropical stratospheric ozone increases when the ODS loading is high. Impacts of nitrous oxide and carbon dioxide on stratospheric ozone are significant but their impacts on TCO are small overall due to several opposing factors and are also associated with large dynamical variability. The multi-model mean (MMM) results show a clear change in the stratospheric ozone trends after 2000 due to now declining ODSs, but the trends are generally not significantly positive, except in the extra-tropical upper stratosphere, due to relatively small changes in forcing over this period combined with large model uncertainty. Although the MMM ozone compares well with the observations, the inter-model differences are large primarily due to the large differences in the models' representation of ODS-induced ozone depletion [Zeng et al. 2022].

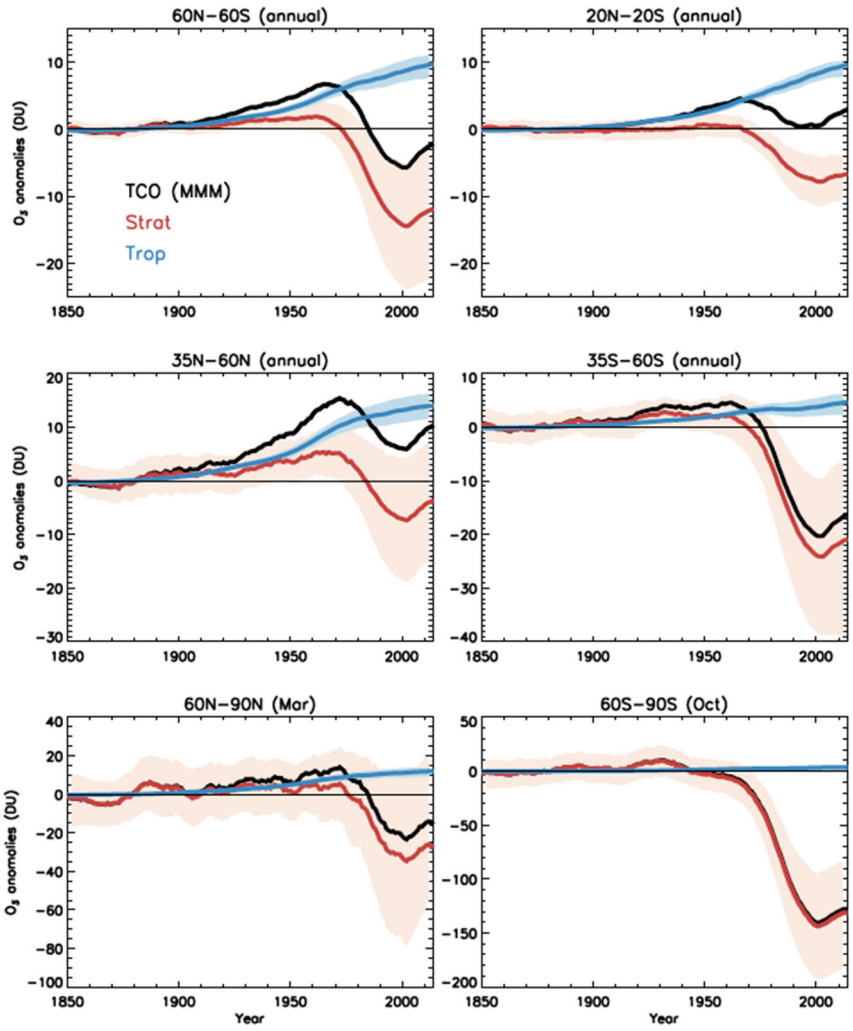


Fig. 1. Multi-model mean (MMM) deviations of total, stratospheric, and tropospheric column ozone from the mean values of 1850–1900 regionally averaged for six regions. Coloured thick lines: Smoothed MMM deviations using a 20-year boxcar filter. Shaded areas: Annually resolved model uncertainty (expressed as the mean absolute deviation, MAD) for stratospheric and tropospheric columns. The tropopause is defined using the World Meteorological Organization lapse rate definition in each model. Four models (CESM2-WACCM, MRI-ESM2-0, UKESM1-0-LL, and GFDL-ESM4) are included in the ensemble mean.

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ACCESS-CM2-Chem: Evaluation of Southern Hemisphere ozone and its impact on climate

F. W. Dennison* and M. T. Woodhouse

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

* corresponding author: Fraser Dennison [fraser.dennison@csiro.au]

Abstract

Chemistry-climate models are important tools for forecasting the evolution of climate. Of particular importance is the simulation of Antarctic ozone depletion due to its effect on the Southern Annular Mode (SAM). In this presentation we evaluate the chemistry-climate model ACCESS-CM2-Chem. We find the simulation of stratospheric ozone by ACCESS-CM2-Chem to be significantly improved relative to its predecessor, ACCESS-CCM, and as good as the best of the contemporary chemistry-climate models. We also find that the trend in summertime SAM is simulated well by ACCESS-CM2-Chem when compared to the ERA5 reanalysis. Further, we show that this trend is more sensitive to changes in ozone depletion forcing in ACCESS-CM2-Chem than the equivalent model with prescribed ozone. Many recent studies have identified the important role of feedbacks between interactive ozone chemistry and climate. This phenomenon will be crucial to understand future projections where the recovery of stratospheric ozone will interact with increasing greenhouse gas driven warming. Based on the performance demonstrated here, ACCESS-CM2-Chem is a good model with which to further this line of research.

Total Column Ozone projections for Australia and New Zealand from a state-of-the-art Coupled Chemistry Climate Model

M. B. Tully[1*], F. W. Dennison[2] and M. T. Woodhouse[2]

[1] Australian Bureau of Meteorology, Melbourne, VIC, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

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

Abstract

As part of the Coupled Chemistry Model Initiative Phase 2, CSIRO has recently completed model runs defined by the project using the state-of-the-art ACCESS-CM2-Chem chemistry-climate model. The modelling experiments include a hindcast simulation (REF-D1) from 1960-2018 which uses forcings following as nearly as possible the estimated historical values, and a future simulation using a baseline scenario run to 2100.

Choosing a number of locations across Australia and New Zealand, we firstly compare total column ozone values from the hindcast simulation with those observed in the satellite era from the SBUV Merged Ozone Dataset [Frith et al. 2014], considering both the mean and distribution of daily values for each month. We then present the projected evolution of total column ozone over the 21st century at the same locations, with an emphasis on the projections of low ozone values in January.

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Comparison of Arctic and Antarctic stratospheric climates in chemistry versus no-chemistry climate models

O. Morgenstern[1*], D. E. Kinnison[2], M. Mills[2], M. Michou[3], L. W. Horowitz[4], P. Lin[5], M. Deushi[6], K. Yoshida[6], F. M. O'Connor[7,8], Y. Tang[7], N. L. Abraham[9,10], J. Keeble[9,10], F. W. Dennison[11], E. Rozanov[12,13,14], T. Egorova[12], T. Sukhodolov[12,14,15] and G. Zeng[1]

[1] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[2] National Center for Atmospheric Research, Boulder, CO, USA
[3] Centre National des Recherches Météorologiques (CNRM), Toulouse, France
[4] Geophysical Fluid Dynamics Laboratory (GFDL), National Oceanic and Atmospheric Administration (NOAA), Princeton, NJ, USA
[5] Program in Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ, USA
[6] Meteorological Research Institute (MRI), Japan Meteorological Agency, Tsukuba, Japan
[7] Hadley Centre, MetOffice, Exeter, UK
[8] Department of Mathematics and Statistics, Global Systems Institute, University of Exeter, UK
[9] Department of Chemistry, University of Cambridge, Cambridge, UK
[10] National Centre for Atmospheric Science, University of Cambridge, Cambridge, UK
[11] Commonwealth Scientific and Industrial Research Organization, Aspendale, VIC, Australia
[12] Physikalisch-Meteorologisches Observatorium, World Radiation Centre, Davos, Switzerland
[13] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[14] St. Petersburg State University, St. Petersburg, Russia
[15] Institute of Meteorology and Climatology, University of Natural Resources and Life Sciences, Vienna, Austria

[*] corresponding author: Olaf Morgenstern [olaf.morgenstern@niwa.co.nz]

Abstract

Using nine chemistry-climate and eight associated no-chemistry models, we investigate the persistence and timing of cold episodes occurring in the Arctic and Antarctic stratosphere during the period 1980–2014. We find systematic differences in behaviour between members of these model pairs. In a first group of chemistry models whose dynamical configurations mirror their no-chemistry counterparts, we find an increased persistence of such cold polar vortices, such that these cold episodes often start earlier and last longer, relative to the times of occurrence of the lowest temperatures. Also, the date of occurrence of the lowest temperatures, both in the Arctic and the Antarctic, is often delayed by 1–3 weeks in chemistry models, versus
their no-chemistry counterparts (Fig. 1). This behaviour exacerbates a widespread problem occurring in most or all models, a delayed occurrence, in the median, of the most anomalously cold day during such cold winters. In a second group of model pairs there are differences beyond just ozone chemistry. In particular, here the chemistry models feature more levels in the stratosphere, a raised model top, and differences in non-orographic gravity wave drag versus their no-chemistry counterparts. Such additional dynamical differences can completely mask the above influence of ozone chemistry. The results point toward a need to retune chemistry-climate models versus their no-chemistry counterparts [Morgenstern et al. 2022].

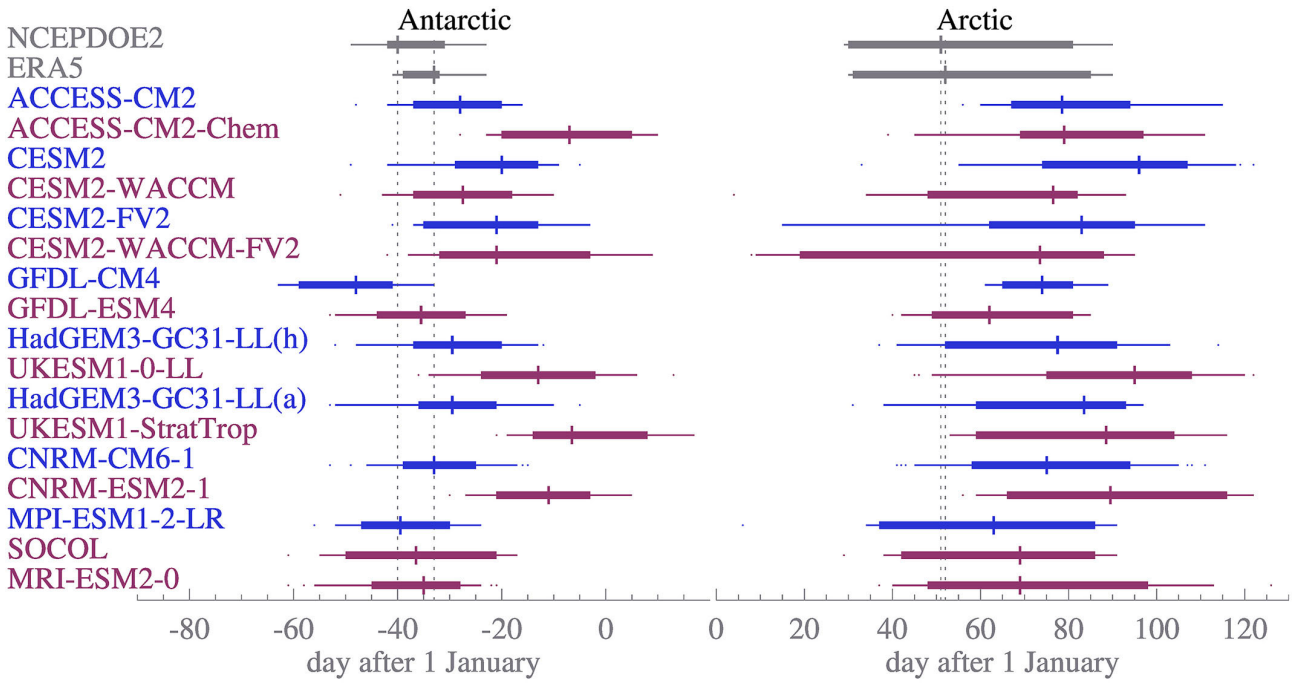


Fig. 1. Date of occurrence of lowest temperatures in years with the minimum of the 15-day filtered 70 hPa polar-mean temperature anomaly in the lowest 20%. Left: Antarctica (75–90°S). Right: Arctic (75–90°N). Vertical bars: Median day. Thick lines: 16 to 84-percentile range. Thin lines: 2.5 to 97.5-percentile range. Dots: Outliers outside the 2.5 to 97.5 percentiles. Note that the NCEP-DOE2 and 5th European Centre for Medium-Range Weather Forecasts Reanalysis (ERA5) reanalyses and the GFDL-CM4 simulations only have 7 such cold winters each in this 20% category (out of a total of 34, for the period of September 1980–August 2014). The long dashed vertical lines mark the medians of the coldest days in the two reanalyses. Chemistry models are represented in red, no-chemistry models in blue. '(h)' stands for the 'historical' ensemble of HadGEM3-GC31-LL, '(a)' for AMIP.

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CAFE-Pacific (Chemistry of the Atmosphere Field Experiment in the Pacific) airborne measurement campaign

D. Marno[1*], B. J. Lelieveld[1] and C. J. Curtius[2]

[1] Max-Planck-Institute for Chemistry, Mainz, Germany
[2] Goethe University, Frankfurt, Germany

[*] corresponding author: Daniel Marno [daniel.marno@mpic.de]

Coordinated by the Max Planck Institute for Chemistry and the Goethe University, Frankfurt, the CAFE-Pacific mission will be the second in a triad of measurement campaigns investigating photochemical and aerosol processes in the tropical troposphere using the High Altitude – Long Range (HALO) aircraft. HALO has been uniquely equipped with a custom designed payload by three departments of the MPIC and partner institutes. It consists of a suite of highly sensitive mass spectrometric and optical instrumentation, which are capable of measuring a range of chemical species from reactive radicals to large volatile organic compounds and aerosol particles. This ensemble of measurements enables the comprehensive characterization of atmospheric oxidation mechanisms, as well as their control of particle production and growth throughout the troposphere.

The tropical region is of particular relevance on Earth because it represents a large fraction of the troposphere where oxidation processes are most efficient, and directly connects to the stratosphere through the upward motion generated by the formation of deep convective clouds. For example, about 80 – 90% of atmospheric methane oxidation takes place in the tropics, even though the largest fraction is emitted at higher latitudes. The tropical troposphere is referred to as the 'wash room' of the atmosphere. Moreover, tropical atmospheric chemistry and aerosol processes have been much less studied compared to the extra-tropics.

The main objective of the CAFE missions is to investigate tropical tropospheric oxidant photochemistry in combination with aerosol particle formation and growth under clean, pristine conditions over land, and contrast the results with those in marine and polluted conditions. The measurements constrain computer models that represent chemical processes, environmental feedback mechanisms up to the Earth system, in order to generalize the results to regional and global scales. The data support studies of the atmospheric oxidation capacity and the abundance of fine particulate matter in relation to clouds, climate and planetary health. The studies of unpolluted, pristine conditions provide a reference for human-induced perturbations in the Anthropocene, as well as constraints on atmospheric conditions in the Earth's history.

Seasonality in sources of CCN over the Southern Ocean

L. T. Cravigan[1], J. Alroe[1], R. Brown[1], R. S. Humphries[2], P. W. Selleck[2], M. D. Keywood[2] and Z. D. Ristovski[1*]

[1] School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, QLD, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Zoran Ristovski [z.ristovski@qut.edu.au]

Abstract

Over the SO a strong shortwave radiation bias has been consistently observed in climate model output, particularly in the austral summer months. The SO bias has been attributed to poor representation of summertime low-to-mid level cloud. The contribution from sea spray aerosol to cloud condensation nuclei (CCN) is important over the high latitude Southern Ocean [Quinn et al 2017] and has been observed to make an important contribution to cloud droplet number concentrations in this region [McCoy et al 2015].

Here we will present results from measurements taken during three *in situ* voyages over the SO on board the RV Investigator providing seasonal and zonal context. Cold-Water Trial was a zonal transect of the SO south of Hobart in Jan/Feb 2015; CAPRICORN voyage was in the mid latitudes SO during Mar/ Apr 2016; and Ice-Edge to Equator voyage was a zonal transect from the edge of the Antarctic sea ice to the equator in May/June 2016. Measurements of the aerosol size distributions (0.01 – 10 µm), volatility, composition and water uptake properties (sub-saturated and super-saturated) were taken to characterise the aerosol sources and their contribution to CCN concentrations.

The contribution of the nascent sea spray aerosol (SSA) mode to CCN was lowest during the summer, 48% of the CCN at 0.2% supersaturation in January, and increased to 79% in May, as shown in Figure 2. The number concentration of nascent SSA CCN decreased only slightly from January to May, indicating that the seasonal change in contribution to CCN is driven by a seasonally varying secondary component. Seasonality in CCN contributions over the Southern Ocean have previously been observed from remote sensing measurements (McCoy et al. 2015). The data reported here display good agreement with the seasonality observed from remote sensing measurements, and therefore provide valuable in-situ validation. Across all three Southern Ocean voyages the CCN contribution from SSA was greater at higher Southern Ocean latitudes, in particular beyond 50°S, which is also consistent with previous observations from remote sensing.

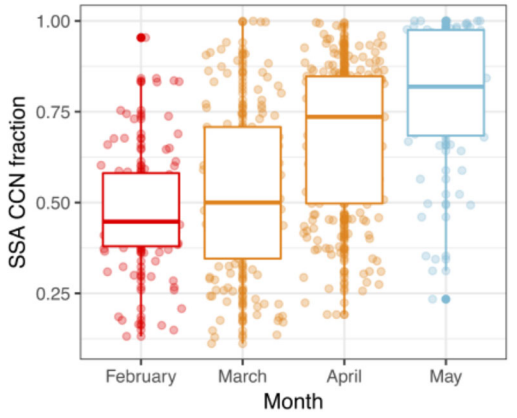


Fig. 1. Seasonality in fraction of CCN (0.2% SS) from sea spray mode.

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Understanding the atmospheric conditions for aerosol formation in the Southern Ocean

S. Cowling[1*], C. Paton-Walsh[1], S. Marx[1], S. D. Chambers[2], A. D. Griffiths[2], A. G. Williams[2], R. S. Humphries[3] and M. D. Keywood[3]

[1] University of Wollongong, Wollongong, NSW, Australia
[2] ANSTO, Lucas Heights, NSW, Australia
[3] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Stephanie Cowling [sc590@uowmail.edu.au]

Abstract

Atmospheric processes at Kennaook/Cape Grim Baseline Air Pollution Station and on the RV *Investigator* were analysed from 2018-2021 to address which atmospheric conditions are optimal for new particle formation event occurrence, growth rate and particle concentration during baseline conditions in this under-researched region. Datasets were filtered for baseline conditions to observe clean Southern Ocean air. SMPS data was equipped to visualise formation events with the lognormal fitting of mode distributions: nucleation, Aitken and accumulation. Identified events were classified and correlated with meteorological and terrestrial contamination variables. New particle formation events were optimal with low relative humidity, low wind speed and high terrestrial contaminants. These findings demonstrated that a collection of variables at an ideal level are required for a new particle formation event to occur in baseline Southern Ocean air. These particle formation events can influence natural climate processes on a global scale, rendering information on their mechanisms and processes vital knowledge. These observations will provide much-needed information to improve the accuracy of climate and chemical transport models. Future studies include predicted interactions of the variables found to hold significant correlations with atmospheric particle formation processes.

Untangling the influence of Antarctic and Southern Ocean life on clouds

M. D. Mallet[1*], R. S. Humphries[2,1], S. L. Fiddes[1] and the PICCAASO team

[1] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Marc D. Mallet [marc.mallet@utas.edu.au]

Abstract

Recent targeted field campaigns [Fossum et al 2018; McFarquhar et al 2021; Schmale et al 2019; Sellegri et al in press] have measured aerosol, vapours, and clouds around the Southern Ocean. Findings from these campaigns have shown that biological organisms in Southern Ocean surface waters and Antarctic sea-ice have a potentially large influence on our atmosphere. But the campaigns also highlighted major gaps in our understanding of complex processes influenced by these organisms. New observations and modelling efforts are needed. In this presentation we outline major gaps in our knowledge, emerging research priorities, and upcoming opportunities and needs. We then give an overview of some of the large-scale measurement campaigns planned across Antarctica and the Southern Ocean in the next five years (see Fig. 1) that will address the key issues.

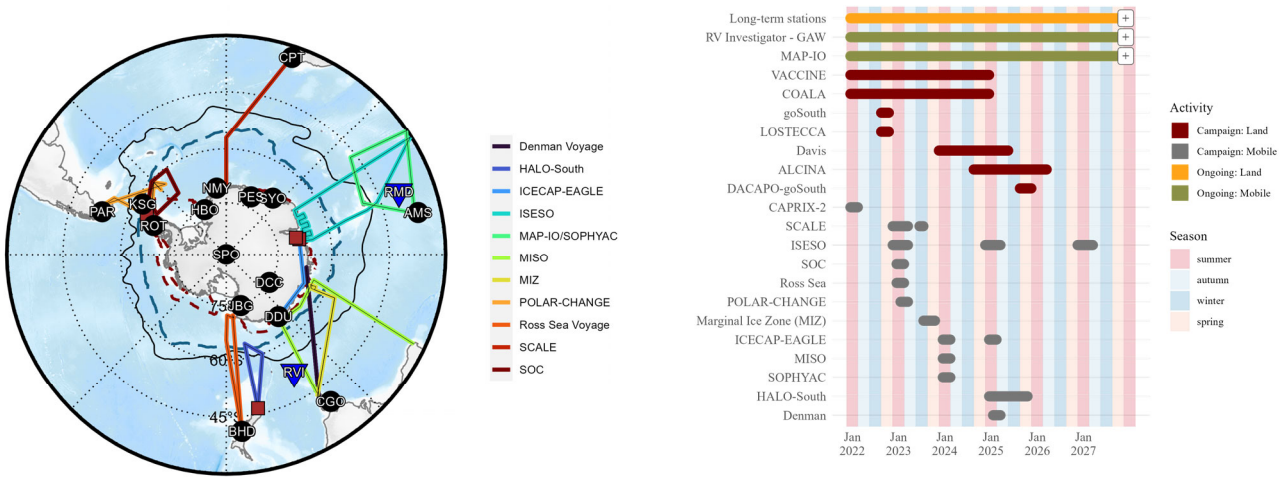


Fig. 1. Upcoming measurement programs in the Southern Ocean and Antarctica targeting biogeochemistry-atmosphere measurements. Further details can be found at www.piccaaso.org.

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Evidence of wet deposition in mesoscale cellular convection over the Southern Ocean

T. Alinejadtabrizi[1,2*], F. Lang[1], L. Ackermann[3], Y. Huang[2,4], S. T. Siems[1,2], M. J. Manton[1], M. D. Keywood[5], R. S. Humphries[5], G. P. Ayers and P. B. Krummel[5]

[1] School of Earth, Atmosphere and Environment, Monash University, Clayton, VIC, Australia
[2] Australian Research Council Centre of Excellence for Climate Extremes (CLEX), Melbourne, VIC, Australia
[3] Bureau of Meteorology, Observations and Data Science Section, Melbourne, VIC, Australia
[4] School of Earth Sciences, University of Melbourne, Parkville, VIC, Australia
[5] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

[*] corresponding author: Tahereh Alinejadtabrizi [tahereh.alinejadtabrizi@monash.edu]

Abstract

Southern Ocean (SO) air is amongst the most pristine air anywhere on Earth, particularly during winter when the lowest concentrations of cloud condensation nuclei (CCN) are observed. Historically, there has been an on-going focus on the production of dimethyl sulfide, a precursor gas, as an explanation for the observed seasonal cycle in CCN and in support of the 'CLAW' hypothesis. This hypothesis, however, has been found to be incomplete, necessitating the study of other processes that may help define the CCN budget. Coalescence scavenging (drizzle formation) is one such process that may be particularly relevant over the SO, the region of Earth with the highest frequency of occurrence of drizzle and light rain.

Using a boundary layer cloud climatology built off Himawari-8 observations, CCN observations from Kennaook/Cape Grim and nearby precipitation observations, we find a statistically significant difference in CCN concentration between when the upwind meteorology (baseline conditions) is dominated by open MCC and closed MCC. When open MCC is dominant upwind of Cape Grim, a lower median CCN concentration (68.9 cm^{-3}) has been found compared to when closed MCC (88.5 cm^{-3}) is dominant. Periods of open MCC are seen to precipitate more heavily (1.92 $mm.day^{-1}$) than the closed MCC (0.24 $mm.day^{-1}$).

The relationship between CCN concentration and precipitation can be further examined across a diurnal cycle, particularly during the summer season when solar forcing is most intense. As before, we observe a negative relationship precipitation and CCN concentration. We see, however, the precipitation cycle leading the CCN cycle by 1 – 2 hours, suggesting precipitation changes may be driving the changes in the CCN concentration.

The Clouds and Precipitation Experiment at Kennaook (CAPE-K)

G. G. Mace[1*], R. T. Marchand[2], M. D. Keywood[3], R. S. Humphries[3] and A. Protat[4]

[1] Department of Atmospheric Sciences, University of Utah, Salt Lake City, UT, USA
[2] Department of Atmospheric Sciences, University of Washington, Seattle, WA, USA
[3] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[4] Australian Bureau of Meteorology, Melbourne, VIC, Australia

[*] corresponding author: Jay Mace [jay.mace@utah.edu]

Abstract

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program will augment ongoing measurements at the Kennaook/Cape Grim Baseline Air Pollution Station (KCGBAPS) with components of the second ARM Mobile Facility (AMF2) in a deployment called the Cloud And Precipitation Experiment at Kennaook (CAPE-K). CAPE-K will provide detailed cloud and precipitation observations over a period from mid-April 2024 through mid-September 2025 in order to capture two winter seasons and to align with complementary high value-add activities planned by Australian colleagues. Located at Kennaook/Cape Grim on the northwestern tip of Tasmania (40.68°S, 144.69°E), the station has produced the longest and most consequential record of Southern Hemisphere aerosol and gas-phase chemistry, however extensive cloud and precipitation measurements have not been collected there. CAPE-K is motivated by the fact that model uncertainty in the surface radiation budget due to clouds and precipitation is large in this region – a region where strong latitudinal gradients in cloud feedbacks are found. This uncertainty exists in a region where there are strong and well-documented seasonal variations in marine aerosol properties. We identify three science objectives that the CAPE-K deployment will enable:

1. Document the seasonal cycle of SO low-cloud and precipitation properties and examine how they co-vary with aerosol and with dynamical and thermodynamical factors.
2. Compare and contrast these relationships with observations from other surface sites and campaigns including other ARM sites.
3. Study aerosol-cloud-precipitation interactions in pristine marine low clouds and explore how these interactions can best be represented in models at various scales

We will describe our approach to addressing these science questions with the combined ARM AMF2 instrumentation collected synergistically with the ongoing long-term aerosol measurements at Kennaook/Cape Grim

A methodology comparison of atmospheric boundary layer characterisation using miniMPL data

L. Toms-Hardman[1,2*] and R. Schofield[2]

[1] Defence Science and Technology Group, Perth, WA, Australia
[2] University of Melbourne, Parkville, VIC, Australia

[*] corresponding author: Lilani Toms-Hardman [lilani.tomshardman@unimelb.edu.au]

Abstract

The influence of the atmospheric boundary layer (ABL) on air quality is known to follow an inverse correlation between aerosol number concentration and ABL height (Su, 2018; Miao 2019). To gain a deeper understanding of this relationship and to better inform air quality assessment and modelling, the ABL must be continuously monitored and its height accurately characterised.

Radiosounding techniques using the parcel method are widely accepted as a reference standard for ABL height measurements but are typically only performed 2-4 times per day with a minimum of 1.5-3 hours between measurements (Seibert, 2000). In contrast, the sampling frequency of LiDAR techniques is much greater, producing averaged vertical profiles of photon backscatter from a pulsed laser in minutes to seconds. Additionally, LiDAR can run effectively autonomously, allowing continuous data retrieval over extended periods.

Many algorithms exist to calculate ABL heights from the vertical backscatter profiles, with varying reliability depending on the atmospheric conditions at the time the profile was retrieved. Here we compare some of the more notable approaches by implementing them on data collected with a Droplet Laboratories mini micro pulse LiDAR (miniMPL) situated on the roof of a 12-story building near Melbourne CBD.

This work forms part of my four-month graduate secondment from Defence Science and Technology Group at The University of Melbourne.

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A Preliminary record of changes in Southern Hemisphere atmospheric OH abundance from ^{14}CO in glacial ice (Law Dome, Antarctica, 1870 AD to present)

D. M. Etheridge[1,2*], V. V. Petrenko[3], P. D. Neff[3,4], A. M. Smith[5], E. Crosier[3], B. Hmiel[3], D. P. Thornton[1,2], L. Jong[6,2], R. Beaudette[7], C. M. Harth[7], R. L. Langenfelds[1], B. Mitrevski[1], T. van Ommen[6,2], M. A. J. Curran[6,2], C. Buizert[8], L. Murray[3], C. M. Trudinger[1,2], M. Dyonisius[3], J. Ng[7], J. P. Severinghaus[7] and R. F. Weiss[7]

[1] Climate Science Centre, CSIRO Oceans and Atmosphere, Aspendale, VIC, Australia
[2] Australian Antarctic Program Partnership, Hobart, TAS, Australia
[3] Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY, USA
[4] Department of Soil, Water, and Climate, University of Minnesota Twin Cities, Saint Paul, MN, USA
[5] Australian Nuclear Science and Technology Organisation, Kirrawee DC, NSW, Australia
[6] Australian Antarctic Division, Hobart, TAS Australia
[7] Scripps Institution of Oceanography, La Jolla, CA, USA
[8] College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

[*] corresponding author: David Etheridge [david.etheridge@csiro.au]

Abstract

Hydroxyl (OH) is the main tropospheric oxidant and determines the lifetime of methane and most other trace gases in the atmosphere, thereby controlling the amount of greenhouse warming produced by these gases. Changes in OH concentration ([OH]) in response to large changes in reactive trace gas emissions during the industrial period and into the future are uncertain. Measurements of ^{14}C-containing carbon monoxide (^{14}CO) and other tracers such as methyl chloroform have been successfully used to monitor changes in average [OH] over the last ~25 years but there are no observational constraints on [OH] further back in time. Reconstructions of ^{14}CO from ice cores can extend the record further back in time but requires sites with very high snow accumulation rates to limit in-situ production of ^{14}CO by cosmic rays directly in the ice and enormous quantities of ice. A joint US and Australian team sampled and measured firn air and ice at Law Dome, Antarctica (2018-19 season, site DE08-OH, 1.2 m a^{-1} ice-equivalent snow accumulation), to a depth of 240 m. Each air sample was extracted from ~500 kg of parallel ice cores using an on-site large-volume ice melting system. Ice core air sample ages span from the 1870s to the early 2000s. Firn-air samples from the snow surface to 81 m depth capture air from the early 2000s to present. Analyses of [CO] and halocarbons in the samples show a relatively low and stable procedural CO blank and demonstrate that the samples are unaffected by ambient air inclusion. ^{14}CO analyses in these firn and ice core air samples have been successfully completed. Corrections for *in situ* ^{14}CO production, validated against direct atmospheric measurements for the more recent samples, have allowed us to develop a preliminary ^{14}CO history. This history will be interpreted with the aid of the GEOS-Chem chemistry-transport model to place the first observational constraints on the variability of Southern Hemisphere [OH] since ~1870 AD.

Source, distribution, and risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in sediment samples from River Owan, Edo State, Nigeria

A. Akinnusotu[1,2,3*], J. E. Ukpebor[2] and F. E. Okieimen[2]

[1] Department of Science Laboratory Technology, Rufus Giwa Polytechnic, Owo, Nigeria
[2] Department of Chemistry, University of Benin, Benin City, Nigeria
[3] Department of Environmental Toxicology and The Institute of Environmental and Human Health (TIEHH), Texas Tech University, Lubbock, TX, USA

* corresponding author: Akinyinka Akinnusotu [akinyinka_akinnusotu@rugipo.edu.ng; aakinnus@ttu.edu]

Abstract

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous environmental pollutants with various human and environmental concerns. We determined the concentration of the 16 priority PAHs, 1-Methyl naphthalene, and 2-Methyl naphthalene in sediment samples from River Owan, Edo State, Nigeria. Gas chromatography equipped with flame ionization detector (GC-FID) was used for the determination. Our study revealed that 1-Methyl naphthalene and 2-Methyl naphthalene were present in all sediment sampling locations: 1-Methyl naphthalene = 0.013 – 0.084 µg/kg and 2-Methyl naphthalene = 0.009 – 0.042 µg/kg. The ∑LMWPAHs were in the range of 0.093 – 0.250 µg/kg; ∑HMW PAHs was 0.107 – 0.579 µg/kg. The range of total ∑PAHs in the sediment samples was 0.280 - 0.810 µg/kg (Concentration order of increase: ∑PAHs SE5>SE4>SE3>SE6>SE1>SE2>SE7). Sediment quality assessment showed that the total concentration of PAHs was lower than the regulatory values of sediment quality guidelines (SQG) for effects range-low and effects range-mean (ERL and ERM), which suggests that no toxic effects should occurrence in this area at present. The percentage of petrogenic to pyrogenic in the ratio of Ant/(Ant + Phe) in the sediment was 0.57. The ratio of Flt/(Flt + Pyr) in sediment samples was above 0.1 revealing that they are from pyrogenic sources. The percentage of LMW/HMW PAHs of petrogenic to pyrogenic sources is 29% - 71%. The diagnostic ratio indicates that the sources are more of pyrogenic than petrogenic.

Air-sea fluxes of biogenic VOCs and their relationship with ocean biogeochemistry

M. Rocco[1], E. Dunne[2*], M. Peltola[1], N. Barr[3], J. Williams[4], A. Colomb[1], K. Safi[3], A. Saint-Macary[3,5] A. Marriner[3], S. Deppeler[3], J. N. Harnwell[2], C. Law[3,5] and K. Sellegri[1]

[1] Université Clermont Auvergne, CNRS, Laboratoire de Météorologie Physique (LaMP), Clermont-Ferrand, France
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[4] Department of Atmospheric Chemistry, Max Planck Institute for Chemistry, Mainz, Germany
[5] Department of Marine Science, University of Otago, Dunedin, New Zealand

[*] corresponding author: Erin Dunne [erin.dunne@csiro.au]

Abstract

Evidence suggests that in the Southern Ocean, a lack of understanding of the role of marine biological emissions on aerosol formation and subsequent cloud formation and processes are a significant source of the observed bias in the radiative balance of current numerical weather predictions for this region [Vallina et al 2006; Law et al 2017; McFarquhar 2021]. Dimethyl sulphide (DMS) is considered a key precursor of interest in marine organic aerosol formation, however progressive studies have revealed a larger diversity in marine emissions of organic gases [e.g. Rocco et al 2021; Davie-Martin et al 2020]. Here we report sea-to-air fluxes of a range of biogenic VOCs from a series of in situ mesocosm studies of natural seawaters during the Sea2Cloud voyage in the SW Pacific Ocean (Sellegri et al 2022, accepted BAMs). The composition of fluxes varied between seawaters of differing origin (frontal, sub-tropical, sub-Antarctic) with several species exhibiting fluxes of similar order of magnitude or greater than that of DMS. Significant associations were observed between the composition of fluxes and phytoplankton class and dynamics in the seawater. Studies such as these provide important information on the sources and drivers of emissions of climatically relevant marine organic gases that may enable the use of satellite oceanographic maps of marine biological productivity to improve the representation of these emissions in chemistry-climate models.

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Does the model ever get it right? Understanding cloud and radiative biases in a nudged ACCESS-AM2 simulation over the Southern Ocean

S. L. Fiddes[1], M. T. Woodhouse[2,1*], M. D. Mallet[1], A. Protat[3,1] and S. P. Alexander[4,1]

[1] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Science, University of Hobart, Hobart, TAS, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] Bureau of Meteorology, Melbourne, VIC, Australia
[4] Australian Antarctic Division, Kingston, TAS, Australia

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

Abstract

Like many climate models, the Australian Community Climate and Earth System Model (ACCESS) – Atmosphere only Model (AM2) has biases in clouds and radiation over the Southern Ocean. In a meteorologically-constrained simulation, we evaluate daily cloud and radiation fields against satellite products. Our analysis is split into cloud types determined by k-means clustering to understand if there are conditions in which the model performs well. We find that, predominantly, the model is simulating a different cloud to the satellite, despite the constrained meteorology. The incorrectly simulated cloud type has a large effect on the radiative properties of the clouds, impacting the radiation budget. We also examine days where the model has simulated the same cloud type as the satellite and find that in most of these instances, the cloud microphysics and radiative properties remain biased. This implies that even if the model can simulate the correct cloud type for the large-scale conditions, significant work remains to represent the radiative properties correctly.

To understand how cloud biases are impacting the radiative bias further, we employ machine learning combined with feature importance metrics. These methods allow us to isolate the contributions of cloud biases to the radiative bias. For example: we find that bias in the liquid water path is the largest contributor to cloud radiative bias over the Southern Ocean. Applying a perturbation to slow ice crystal growth decreases the liquid water bath bias and reduces the role it plays in the cloud radiative bias.

Is sea spray aerosol production in balance with deposition at Macquarie Island?

A. D. Griffiths[1,2*], K. Richardson[1], K. M. Saunders[1,3], S. D. Chambers[1,2] and A. G. Williams[1,2]

[1] ANSTO, Lucas Heights, NSW, Australia
[2] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW, Australia
[3] University of Tasmania, Hobart, TAS, Australia

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

Abstract

Biological and geochemical indicators in lake sediment cores from sub-Antarctic Macquarie Island have been used to develop palaeo-records of lake salinity over the last ~12ka [Saunders et al 2018]. Located at 54.5°S, within a latitude band dominated by the Southern Ocean and intense westerly winds, it is reasonable to suppose that low-frequency variability in the salinity record is governed by changes in ocean/atmosphere processes over climatic timescales, particularly any changes in westerly wind strength. A simple interpretative model has been developed which considers the production of sea spray aerosol (SSA), deposition into a lake, evaporation, and overflow processes with the aim of demonstrating which parameters drive lake salinity [Richardson et al. 2021].

A significant assumption in the model, which is desirable as it permits the model to be run over extended time periods, is that annual total SSA deposition is in equilibrium with local production. Here, we test this assumption using an atmospheric dispersion model over the period 2009-18 (Flexpart, driven by ERA-Interim winds, with wet and dry deposition). After validating the model's low-frequency variability using in situ radon-222 observations [Williams et al. 2021, e.g.], potential mechanisms for the decoupling of local SSA production and deposition are identified. In the model world, when considering a running 1-year average, the upstream SSA production region is offset northwards for both wet and dry deposition, with the offset being larger for wet deposition. This places the SSA source region outside the centre of the Southern Hemisphere westerly wind jet, meaning that wind speeds in the SSA production region are consistently lower than those at Macquarie Is. The degree of meridional transport determines the magnitude of the difference in wind speed, meaning that changes in the strength of meridional flow have the potential to affect the deposition rate of SSA at Macquarie Is. In spite of this complication, the main low-frequency signals over the monitoring period are not sensitive to the choice between upstream or local SSA (especially for dry deposition) and the model, with caution, may still be suitable for palaeo-record interpretation.

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Measurement Report: Understanding the seasonal cycle of Southern Ocean aerosols

R. S. Humphries[1,2], M. D. Keywood[1,2], J. P. Ward[1], J. N. Harnwell[1], S. P. Alexander[3,2], A. R. Klekociuk[3,2], K. Hara[4], I. M. McRobert[5], A. Protat[6,2], J. Alroe[7], L. T. Cravigan[7], B. Miljevic[7], Z. D. Ristovski[7], R. Schofield[8], S. R. Wilson[9], C. J. Flynn[10], G. R. Kulkarni[11], G. G. Mace[12], G. M. McFarquhar[13], S. D. Chambers[14], A. G. Williams[14] and A. D. Griffiths[14]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Melbourne, VIC, Australia
[2] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia
[3.] Australian Antarctic Division, Kingston, TAS, Australia
[4] Department of Earth Science System, Faculty of Science, Fukuoka University, Jyonan, Fukuoka, Japan
[5] CSIRO National Collections and Marine Infrastructure, Engineering and Technology Program, Hobart, TAS, Australia
[6] Australian Bureau of Meteorology, Melbourne, VIC, Australia
[7] School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, QLD, Australia
[8] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC, Australia
[9] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, Australia
[10] School of Meteorology, University of Oklahoma, Norman, United States of America
[11] Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory, Richland, WA, USA
[12] Department of Atmospheric Science, University of Utah, Salt Lake City, UT, USA
[13] Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, OK, USA
[14.] Environmental Research, ANSTO, Lucas Heights, NSW, Australia

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

Abstract

The remoteness and extreme conditions of the Southern Ocean and Antarctic region have meant that observations in this region are rare, and typically restricted to summertime during research or resupply voyages. Observations of aerosols outside of the summer season are typically limited to long-term stations, such as Kennaook/Cape Grim (KCG, 40.7°S, 144.7°E) which is situated in the northern latitudes of the Southern Ocean, and Antarctic research stations, such as the Japanese operated Syowa (SYO, 69.0°S, 39.6°E). Measurements in the mid-latitudes of the Southern Ocean are important, particularly in light of recent observations that highlighted the latitudinal gradient that exists across the region in summertime. Here we present two years (March 2016 - March 2018) of observations from Macquarie Island (MQI, 54.5°S, 159.0°E) of aerosol (condensation nuclei larger than 10 nm, CN_{10}) and cloud condensation nuclei (CCN at various supersaturations) concentrations. This important multi-year data set is characterised, and its features are compared with the long-term data sets from KCG and SYO together with those from recent, regionally relevant voyages. CN_{10} concentrations were the highest at KCG by a factor of 50% across all non-winter seasons compared to the other two stations which were similar (summer medians of 530 cm^{-3}, 426 cm^{-3} and 468 cm^{-3} at KCG, MQI and SYO, respectively). In wintertime, seasonal minima at KCG and MQI were similar (142 cm^{-3} and 152 cm^{-3}, respectively), with SYO being distinctly lower (87 cm^{-3}), likely the result of the reduction in sea spray aerosol generation due to the sea-ice ocean cover around the site. CN10 seasonal maxima were observed at the stations at different times 15 of year, with KCG and MQI exhibiting January maxima and SYO having a distinct February high. Comparison of CCN0:5 data between KCG and MQI showed similar overall trends with summertime maxima and wintertime minima, however KCG exhibited slightly (~10%) higher concentrations in summer (medians of 158 cm^{-3} and 145 cm^{-3}, respectively), whereas KCG showed Richland ~40% lower concentrations than MQI in winter (medians of 57 cm^{-3} and 92 cm^{-3}, respectively). Spatial and temporal trends in the data were analysed further

by contrasting data to coincident observations that occurred aboard several voyages of the RSV *Aurora Australis* and the RV *Investigator*. Results from this study are important for validating and improving our models, highlight the heterogeneity of this pristine region, and the need for further long-term observations that capture the seasonal cycles.

Can marine cloud brightening prevent coral bleaching in the Great Barrier Reef?

R. Jackson[1*], M. T. Woodhouse[2] and M. Baird[3]

[1] CSIRO Oceans and Atmosphere, Black Mountain, ACT, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] CSIRO Oceans and Atmosphere, Hobart, TAS, Australia

[*] corresponding author: Rebecca Jackson [rebecca.jackson@csiro.au]

Abstract

Climate change is adversely affecting coral reef ecosystems and has led to more frequent and severe coral bleaching events (Heron et al., 2016). Modelling predicts that sea surface temperatures will continue to rise, even under optimistic future emission scenarios (Fox-Kemper et al., 2021), increasing the need for additional interventions to conserve coral reefs. The Great Barrier Reef (GBR) has experienced six mass thermal bleaching events since 1998, four of which have occurred since 2016 and have affected more than 98% of reefs [Hughes et al 2021]. The Reef Restoration and Adaptation Program (RRAP) aims to help the GBR resist, adapt to, and recover from the impacts of climate change through the development and assessment of intervention technologies. Marine cloud brightening is one intervention which may prevent coral bleaching by reducing acute heat and light stress in corals during high-risk bleaching periods (Tollefson, 2021). Using a regional atmospheric model, we simulate the impacts of injecting submicron sea salt particles over the reef to brighten low-lying clouds and determine the potential to mitigate coral bleaching during the 2016 bleaching event. Injecting sea salt at a rate of 0.2 ug m^{-2} s^{-1} over the central GBR during the 2015-16 summer enhanced aerosol direct and first indirect effects, and reduced surface incoming short-wave radiation by an average of 12 W m^{-2} over the summer months. The reduction in surface radiation could reduce surface temperature by an average of ~0.3°C [Harrison et al 2019], potentially mitigating coral bleaching in the GBR.

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Measuring atmospheric hydrogen ahead of the Anticipated Hydrogen Economy

B. Mitrevski*, E-A. Guerette, R. L. Langenfelds, M. T. Woodhouse, D. A. Spencer, P. B. Krummel and L. P. Steele

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

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

Abstract

The continuous population and economy growth demands more energy, currently provided predominantly by burning of fossil fuels. However, the depletion of fossil fuel resources and the detrimental environmental impacts of burning fossil fuels are driving the public opinion and governments towards renewable energy (RE) sources. Solar and wind power are the most promising, but its reliability is shadowed by their weather dependence. Hydrogen is considered as a very promising energy carrier which can overcome the limitations of the existing RE sources. Producing hydrogen at the solar panel fields or incorporating water electrolysers within wind turbines will smooth the energy supply, and even reduce the energy transport. If the hydrogen economy takes effect as anticipated, then the hydrogen impact on the climate needs to be re-assessed. In order to simulate future hydrogen concentrations, it is necessary to build a model which can simulate present day hydrogen emissions and sinks, and resultant atmospheric concentrations, which are currently infrequently measured. Building a history of hydrogen measurements opens up possibilities in the future to determine background and pre-existing hydrogen sources, and gives a baseline before the switch to a hydrogen economy.

Historically, Reduction Gas Analysers (RGA) were the workhorse in the laboratory and field, where reductive gasses like hydrogen or carbon monoxide release mercury gas by passing along a heated solid mercuric oxide bed, which in turn is analysed by ultraviolet (UV) absorption. The method is well established but lacks linear response and stability. CSIRO is working on novel methods for more accurate and precise hydrogen measurement. The Pulsed Discharge Helium Ionization Detector, or simply PDD, is an alternative to the RGA. CSIRO has been operating a PDD for hydrogen at Cape Grim (along with the classic RGA) for 7.5 years using shared calibration tanks. The mean difference between them (50,000+ matched data points, when pollution events are removed) is just 0.02 ppb, proving PDD's incredible compatibility with the established RGA technique. The PDD also has a demonstrated superior precision and linearity compared to the RGA. Another two PDD systems are operational at Aspendale measuring urban hydrogen since 2019 and 2021. The later one is to be deployed at the CSIRO Clayton site, where Aspendale will relocate to in 2025. Another PDD system is in a development stage, able to measure not just hydrogen, but many other atmospheric gases (CH_4, CO_2, N_2O, Kr, Xe). The inability of optical instruments to measure hydrogen (homonuclear diatomic molecule) will mean that there will be an increased demand for RGA or PDD measurements of hydrogen in the future.

Measuring marine volatile organic compounds with a proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS)

C. Mynard[1,2*], A. Patti[2], E. Dunne[1], R. S. Humphries[1] and S. T. Siems[3]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] School of Chemistry, Monash University, Clayton, VIC, Australia
[3] School of Earth, Atmosphere and Environment, Monash University, Clayton, VIC, Australia

[*] corresponding author: Caleb Mynard [caleb.mynard@csiro.au]

Abstract

Gas-phase organic compounds, such as volatile organic compounds (VOCs), play a significant role in the atmosphere through photochemical reactions resulting in the production of ozone, and other critical reactions with hydroxyl and nitrate radicals, nitrogen oxides, chlorinated compounds and ozone, which results in their oxidation to lower-vapour-pressure oxygenated VOCs (OVOCs) and eventually their growth into secondary organic aerosol (SOA) [Koppman et al 2020]. Significant uncertainties exist in our understanding of atmospheric aerosol and reactive gas processes, such as the persistent, significant challenges in characterising their sources, composition, chemistry, and fates, which suggests the need for information on a wide range of organic compounds in different environments. Since VOCs are poorly constrained in marine environments, such as the Southern Ocean region and its absence of long-term in-situ measurements, this provides many opportunities for advancements in this area of atmospheric chemistry [Yu et al 2021].

The scope of this PhD project is based on measuring known and unknown trace-level marine VOCs and OVOCs that could be important marine aerosol precursors (e.g. amines, organosulfur, halides, and terpenoids) with the proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS), which has shown to be an important and versatile real-time online technique for conducting in-situ measurements due to its ability to generate full mass scan information at 1 Hz with high mass resolving power ($m/\Delta m \sim 4000$) of isobaric interferences [Müller et al 2014]. PTR-ToF-MS measurements of VOCs and aerosol (using the newly developed CHemical Analysis of aeRosol ON-line (CHARON) inlet system [Müller et al 2017]) will provide unparalleled identification and characterisation of organic compounds in aerosol and gas-phase found in coastal (Kennaook/Cape Grim, Tasmania) and remote ocean (Southern Ocean) environments, which may be used to help further understand the processes and precursors which drive SOA formation.

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Developing emission factors for residual smouldering combustion of coarse woody debris – filling an important data gap

C. T. Roulston*, J. C. Powell, S. Taylor, S. B. Molloy and F. Reisen

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia

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

Abstract

Records of emission factors (EFs) for residual smouldering combustion of coarse wood debris (CWD) remain an important data gap. Using fire average EFs that are dominated by lofted emissions of flaming combustion can substantially underestimate emissions for burn areas dominated by CWD. As emissions during smouldering are not lofted by strong fire-induced convection, the smoke typically remains at or close to ground level and can significantly impact local air quality. Emission estimates can be improved by applying separate EFs to represent the various combustion stages of flaming and smouldering combustion.

To improve quantification of emissions during smouldering combustion of CWD, we carried out field measurements at planned burns in Victoria during autumn 2020 and 2021 using a portable backpack sampler. Sampling focused on combustion of heavy fuels (d > 7.5 cm), mainly decaying logs, branches and stumps on the forest ground. Additional measurements were taken from freshly felled tree trunks, smouldering bark on living trees and stumps of grasstrees and pine.

We derived particle emission factors and chemical characteristics as a function of combustion conditions and temperature. Findings from the field-based measurements will contribute to refine the algorithms in the AQFx smoke forecasting system.

CCN Climatology of the Great Barrier Reef

H. Trounce[1*], Z. D. Ristovski[1], L. Cravigan[1], J. Alroe[1], B. Miljevic[1], E. Horchler[1], R. S. Humphries[2] and D. Harrison[3]

[1] School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, QLD, Australia
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[3] National Marine Science Centre, Southern Cross University, Coffs Harbour, NSW, Australia

[*] corresponding author: Haydn Trounce [h.trounce@qut.edu.au]

Abstract

Atmospheric aerosols play an important role in the global energy balance by absorbing or scattering solar radiation in what is known as 'aerosol-radiation interactions', and by acting as cloud condensation nuclei (CCN) in 'aerosol-cloud interactions' [Boucher et al 2013]. CCN concentrations affect cloud albedo, fraction and lifetime, which in turn affects surface temperatures, and is important for ecosystems such as the Great Barrier Reef (GBR) Marine Park. Despite this, characterisation of aerosols in the GBR remains incomplete [Cropp et al 2018].

This work aims to characterise sources and transport of CCN over the GBR Marine Park. The work combines measurements collected during six voyages – two aboard Australia's RV Investigator (IN2016_v05, IN2019_T02), one aboard Schmidt Ocean Institute's RV Falkor (FK201122) and three taken as part of the Reef Restoration and Adaptation Program (RRAP) Cooling and Shading sub-program. The voyage details are shown in Table 1.

Table 1. Details of voyages analysed by this work. Aside from Darwin (located in the Northern Territory, Australia), all locations are in Queensland, Australia.

Voyage Code	Vessel	Dates	Location
IN2016_V05	RV Investigator	26/09/2016 – 26/10/2016	Brisbane – Cairns
IN2019_T02	RV Investigator	04/10/2019 – 14/10/2019	Brisbane – Darwin
FK201122	RV Falkor	22/11/2020 – 22/12/2020	Brisbane – Gladstone
2021_03_CS02	RV Magnetic	12/03/2021 – 25/03/2021	Broadhurst Reef
2021_12_CS07	RV Guardian	02/12/2021 – 17/12/2021	Broadhurst Reef
2022_02_CS02	RV Magnetic/RV Guardian	27/01/2022 – 22/02/2022	Broadhurst Reef

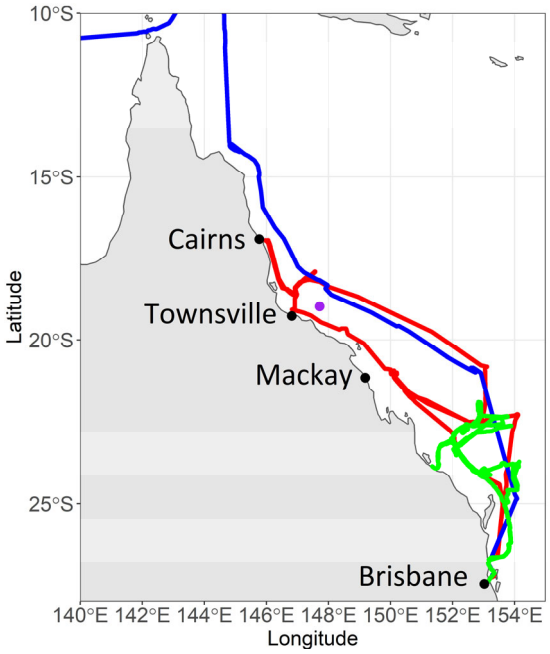


Fig. 1 (right): Voyage track Voyage tracks of campaigns analysed by this work. The red, blue, and green tracks represent IN2016_v05, IN2019_T02 and FK201122, respectively. The purple dot shows the location of Broadhurst Reef (2021_03_C02, 2021_12_CS07, 2022_02_CS02)

Aerosol-cloud interactions have a large uncertainty in climate models (Boucher et al., 2013). Observations collected during these campaigns can be used to improve climate models in the region and predictions of the longevity of the reef. In addition, data collected over the GBR will be utilised within the RRAP to examine the inherent sensitivity in cloud radiative forcing over the GBR to CCN.

Particle number concentration, size distributions, CCN concentrations and activation diameters, and particle composition measurements are analysed across the six campaigns to develop a CCN climatology of the Great Barrier Reef marine park. Local shipping emissions and continental outflow were found to contribute significantly to the region's aerosol budget.

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Modelling the impacts of future hydrogen emissions

M. T. Woodhouse[1*], F. W. Dennison[1], J. A. Noonan[1], Z. Nicholls[2], J. Lewis[2], R. Burdon[2] and M. Meinshausen[2]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, VIC, Australia
[2] Climate Resource, Melbourne, VIC, Australia

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

Abstract

One possibility to move away from a carbon-based economy is to transition to hydrogen. Hydrogen itself isn't an energy source, but various hydrogen species are under consideration for use in energy storage and transport. The potential impact of some candidate hydrogen species, molecular hydrogen and ammonia for example, is beginning to be understood. A notable gap, and obvious next step, is to explore future (out to 2100) scenarios covering possible adoption pathways.

In the project outlined here, we are developing the capabilities needed to inform our understanding of the future implications of transitioning to a hydrogen-based economy. The project has three core goals:

1. Generate future scenarios of hydrogen emissions for use in global and Australian model simulations, spanning a range of climate states and hydrogen adoption pathways
2. Support the maintenance and development of CSIRO's molecular hydrogen observation network, specifically collecting high quality data from Kennaook/Cape Grim, Aspendale, and Clayton sites. These data will be integrated with the global flask network dataset, to provide a baseline knowledge of molecular hydrogen concentrations and trends
3. Develop and deploy future hydrogen projection tools (models) at the global and regional Australian scale to determine the possible impacts of transitioning to a hydrogen-based economy

In this poster, I provide an overview of the chosen emission scenarios, and describe the model configurations and anticipated simulations. The end result of the project will be a suite of tools and data to begin to form and answer policy-relevant questions about the impacts on climate and air quality of switching to a hydrogen-based economy.