Australian Government
Bureau of Meteorology

CSIRO

Atmospheric Composition & Chemistry Observations & Modelling Conference

incorporating the

Cape Grim Annual Science Meeting 2021

Abstracts

30 November – 3 December 2021

hosted by

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

Virtual Meeting



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

Citation

Author, A. B., A. B. Author and A. B. Author (2021). Abstract Title. In ‘ACCOMC incorporating the CGASM2021 [abstract]’ (30 Nov – 3 Dec 2021, online) (eds. N. Derek and P. B. Krummel) pp. 46 (BoM and CSIRO: Melbourne, Australia)

All documents are available at:

https://cloudstor.aarnet.edu.au/plus/s/jxqIxNc9Hq4vCoL

Posters

Please take the time to view the posters. If you have any questions, contact the author directly.	
Jeremy Silver	Data assimilation of atmospheric aerosols with the CSIRO CTM
Justin Takacs	Intercomparison of stratospheric ozone measurements from ground-based FTIR, satellites and ozonesondes across Australia and New Zealand

Day 1: Tuesday, 30 November 2021; 10:00-13:00

10:00	Paul Krummel	Daily welcome includes acknowledgement of traditional owners
Chair	**Paul Krummel**	**Session 1 – Oral Presentations**
50	Ian Galbally/ Suzie Molloy/Erin Dunne	Review of the Kennaook/Cape Grim Reactive Gases sub-program 2015-2021
10	Ashok Luhar	Radiative effects of improved tropospheric ozone parameterisations in the ACCESS chemistry-climate model
20	Question time	
10	Comfort break	
10	Travis Naylor	AIRBOX – A general update
10	Andrew Klekociuk	The air chemistry capability of the RSV Nuyina
60	Ann Stavert/ Elise Guerette	Aspendale Infrastructure Review

Day 2: Wednesday, 1 December 2021; 10:00-13:00

10:00	Paul Krummel	Daily welcome includes acknowledgement of traditional owners
Chair	**Matt Woodhouse**	**Session 2 – Oral Presentations**
10	Paul Fraser	HFCs in the Australian atmosphere: 1978-2020
10	Cathy Trudinger	Australian emissions of HFCs from inversion of atmospheric observations at Cape Grim
10	Michael Bertolacci	Fully Bayesian decomposition and estimation of the climatology and interannual variability of global CO_2 fluxes
10	Roger Francey	Interannual variation in global baseline CO_2 and its isotopes
10	Jocelyn Turnbull	Dramatic lockdown fossil fuel CO_2 decrease detected by citizen science supported ^{14}C observations
15	David Etheridge	Revised fossil methane emissions estimates confirmed by Law Dome $^{14}CH_4$ measurements
20	Question time	
10	Comfort break	
Chair	**Cathy Trudinger**	**Session 3 – Oral Presentations**
10	Neil Brough	Advancing the New Zealand atmospheric greenhouse gas observation network
10	Beata Bukosa	CarbonWatchNZ: regional to national scale inverse modelling of New Zealand's carbon balance
10	Sara Mikaloff-Fletcher	MethaneSAT: Towards detecting agricultural emissions from space
10	Zoë Loh	Cape Grim and urban emissions estimates
10	Nicholas Deutscher	The Total Carbon Column Observing Network – new and improved data
10	Maria Paula Pérez-Peña	Modelling the primary production of molecular hydrogen (H_2) from the photolysis of aldehydes and its implications on the H_2 tropospheric budget
20	Question time	

Day 3: Thursday, 2 December 2021; 10:00-13:00

10:00	Paul Krummel	Daily welcome includes acknowledgement of traditional owners
Chair	**Zoë Loh**	**Session 4 – Oral Presentations**
10	David Griffith	Side-by-side GHG measurements on the RV Investigator and at Cape Grim by CRDS and FTIR – can we really achieve GAW compatibility goals?
10	Elise-Andree Guerette	Improving N_2O measurement precision across CSIRO's network
10	Nicholas Deutscher	Greenhouse gas fluxes from a NSW coastal wetland and a tidal restoration site
10	Brittany Walker	Development of low-cost sensors and evaluation using high precision Fourier Transform Infrared Spectroscopy
10	Ray Langenfelds	Air standard preparation at the Cape Schanck clean air facility
20	Question time	
10	Comfort break	
Chair	**Ray Langenfelds**	**Session 5 – Oral Presentations**
10	Scott Chambers	Two-filter ^{222}Rn detector calibrations traceable to the SI
10	Stephen Wilson	Estimating the impact of front window contamination on aerosol optical depth (AOD) measurements at Cape Grim
10	Matthew Tully	An overview of the Aspendale/Laverton/Broadmeadows ozonesonde record
10	Fraser Dennison	Early vortex break-ups in the ACCESS-CM2-Chem model
10	Paul Krummel	The 2021 Antarctic ozone hole
20	Question time	

Day 4: Friday, 3 December 2021; 10:00-13:00

10:00	Paul Krummel	Daily welcome includes acknowledgement of traditional owners
Chair	**Clare Paton-Walsh**	**Session 6 – Oral Presentations**
10	Alastair Williams	Radon-derived baseline determination across the Southern Ocean
10	Neil Page	Using environmental variables to develop a predictive model for concentrations of tropospheric bromine and mercury in coastal Antarctica
10	Keita Richardson	Climate drivers of salinity in Macquarie Island lakes
10	Ruhi Humphries	PICCAASO – Partnerships Investigating Clouds and the Chemistry of the Atmosphere in Antarctica and the Southern Ocean
10	Melita Keywood	Investigating 3–11 nm particle events at Cape Grim between 2013–2020
10	Jhonathan Ramirez-Gamboa	Preliminary analysis on the secondary organic aerosol formation during the COALA-2020 campaign
20	Question time	
10	Comfort break	
Chair	**Melita Keywood**	**Session 7 – Oral Presentations**
10	Fabienne Reisen	Estimating smoke emissions using bottom-up and top-down methods
10	Jack Simmons	Smoke plume composition and relative toxicological impacts of atmospheric species from the 'Black Summer' bushfires
10	Shyno Susan John	Can we see the impact of indigenous fire management on the temporal shift in atmospheric carbon monoxide in Northern Australia?
10	Steven Utembe	Forecasting dust pollution events in Brooklyn
10	Clare Paton-Walsh	Impacts of COVID-19 lockdowns on air quality in Western Sydney
10	Amanda Wheeler	Evaluation of a residential intervention to reduce exposures to smoke events resulting from planned burns
20	Question time	

Contents

Posters: available at: https://cloudstor.aarnet.edu.au/plus/s/jxqIxNc9Hq4vCoL

Data assimilation of atmospheric aerosols with the CSIRO CTM 1
J. D. Silver, M. E. Cope, F. Riesen, K. M. Emmerson, J. Horsley and A. Wain

Intercomparison of stratospheric ozone measurements from ground-based FTIR, satellites and ozonesondes across Australia and New Zealand 2
J. Takacs

Day 1 – Tuesday, 30 November 2021

Review of the Kennaook/Cape Grim Reactive Gases sub-program 2015–2021 3
I. E. Galbally, S. B. Molloy and E. Dunne

Radiative effects of improved tropospheric ozone parameterisations in the ACCESS chemistry-climate model 4
A. K. Luhar, I. E. Galbally and M. T. Woodhouse

AIRBOX – A general update 5
T. A. Naylor, D. Dominick, J. N. R. Capnerhurst, N. M. Deutscher, A. D. Griffiths, S. R. Wilson, A. G. Williams, C. Paton-Walsh, R. Schofield and P. J. Rayner

The air chemistry capability of the RSV Nuyina 6
A. R. Klekociuk and S. P. Alexander

Aspendale Infrastructure Review 7
A. R. Stavert and E.-A. Guerette

Day 2 – Wednesday, 1 December 2021

HFCs in the Australian atmosphere: 1978-2020 8
P. J. Fraser, N. Derek, B. L. Dunse, C. M. Trudinger, P. B. Krummel, B. Mitrevski and L. P. Steele

Australian emissions of HFCs from inversion of atmospheric observations at Cape Grim 9
C. M. Trudinger, A. J. Manning, P. J. Fraser, B. L. Dunse, A. L. Redington and P. B. Krummel

Fully Bayesian decomposition and estimation of the climatology and interannual variability of global CO_2 fluxes 10
M. Bertolacci, A. Zammit-Mangion, N. Cressie, B. Bukosa, J. A. Fisher, A. Schuh and Y. Cao

Interannual variation in global baseline CO_2 and its isotopes 11
R. J. Francey

Dramatic lockdown fossil fuel CO_2 decrease detected by citizen science supported ^{14}C observations 13
J. Turnbull, L. Gatti Domingues and N. Turton

Revised fossil methane emissions estimates confirmed by Law Dome $^{14}CH_4$ measurements 14
D. M. Etheridge, V. V. Petrenko, A. M. Smith, P. D. Neff, B. Hmiel, C. M. Trudinger, E. Crosier, D. P. Thornton, R. L. Langenfelds, L. Jong, C. M. Harth, B. Mitrevski, C. Buizert, B Yang, R. F. Weiss and J. Severinghaus

Advancing the New Zealand atmospheric greenhouse gas observation network 15
N. Brough, G. W. Brailsford, M. Murphy, S. Nichol, T. Bromley, L. Gatti Domingues, S. Gray, J. McGregor, S. E. Mikaloff Fletcher, R. Moss, R. Peethambaran, P. Sperlich, K. Te Puni and J. Turnbull

CarbonWatchNZ: regional to national scale inverse modelling of New Zealand's carbon balance 16
B. Bukosa, S. E. Mikaloff-Fletcher, G. W. Brailsford, P. Sperlich, C. Nankivell, D. Smale, E. D. Keller, J. Turnbull, K. Steinkamp, M. J. Harvey, R. Moss, S. Gray, S. Moore, S. Nichol, T. Bromley and Z. Buxton

MethaneSAT: Towards detecting agricultural emissions from space 17
S. E. Mikaloff-Fletcher, A.-G. Ausseil, G. W. Brailsford, B. Bukosa, J. Benmergui, D. I. Campbell, J. E. Franklin, A. Geddes, J. P. Goodrich, S. P. Hamburg, D. Ngaru King, R. Law, J. Laubach, D. Noone, D. F. Pollard, J. Turnbull, H. Schaefer, L. A. Schipper, D. Smale and S. C. Wofsy

Cape Grim and urban emissions estimates 18
Z. M. Loh, P. B. Krummel, R. L. Langenfelds, B. L. Dunse, S. J. Fallon, X. Lu, J. Wardand N. T. Somerville

The Total Carbon Column Observing Network – new and improved data 19
N. M. Deutscher, J. L. Laughner, D. Wunch, G. C. Toon, S. Roche, T. Warneke, C. M. Roehl, D. G. Feist, D. F. Pollard, D. W.T. Griffith, C. Murphy and TCCON Partners

Modelling the primary production of molecular hydrogen (H_2) from the photolysis of aldehydes and its implications on the H_2 tropospheric budget 20
M. P. Pérez-Peña, J. A. Fisher, H. Yashiro, D. B. Millet, P. B. Krummel, R. L. Langenfelds and S. H. Kable

Day 3 – Thursday, 2 December 2021

Side-by-side GHG measurements on the RV Investigator and at Cape Grim by CRDS and FTIR – can we really achieve GAW compatibility goals? 21
D. W. T. Griffith, A. R. Stavert and Z. M. Loh

Improving N_2O measurement precision across CSIRO's network 22
E.-A. Guerette, B. Mitrevski, Z. M. Loh, P. B. Krummel, D. A. Spencer and R. L. Langenfelds

Greenhouse gas fluxes from a NSW coastal wetland and a tidal restoration site 23
N. M. Deutscher, M. J. Spann, K. Zajec-Tingle, J. Kelleway, M. Hughes, A. G. Carter, T. A. Naylor and B. T. Walker

Development of low-cost sensors and evaluation using high precision Fourier Transform Infrared Spectroscopy 24
B. Walker, N. M. Deutscher, A. Carter, D. W.T. Griffith, P. Ihnat, N. B. Jones, J. J. Kelleway and T. A. Naylor

Air standard preparation at the Cape Schanck clean air facility 25
R. L. Langenfelds, D. A. Spencer, L. P. Steele, M. V. van der Schoot, S. A. Coram and B. Mitrevski

Two-filter ^{222}Rn detector calibrations traceable to the SI 26
S. D. Chambers, S. Röttger, V. Morosh, F. Mertes, O. Sisoutham, A. D. Griffiths, A. G. Williams and A. Röttger

Estimating the impact of front window contamination on aerosol optical depth (AOD) measurements at Cape Grim 28
S. R. Wilson

An overview of the Aspendale/Laverton/Broadmeadows ozonesonde record 29
M. B. Tully, I. E. Galbally and A. R. Klekociuk

Early vortex break-ups in the ACCESS-CM2-Chem model 30
F. W. Dennison

The 2021 Antarctic ozone hole 31
P. B. Krummel, A. R. Klekociuk, M. B. Tully, P. J. Fraser and N. Derek

Day 4 – Friday, 3 December 2021

Radon-derived baseline determination across the Southern Ocean 32
A. G. Williams, S. D. Chambers, A. D. Griffiths, P. B. Krummel, Z. M. Loh, P. Sperlich, C. Labuschagne, S.-B. Hong and T. Cho

Using environmental variables to develop a predictive model for concentrations of tropospheric bromine and mercury in coastal Antarctica 34
N. Page, J. A. Fisher, S. R. Wilson, R. Schofield, R. G. Ryan, S. Gribben and A. R. Klekociuk

Climate Drivers of Salinity in Macquarie Island Lakes 35
K. Richardson, K. M. Saunders and A. D. Griffiths

PICCAASO – Partnerships for Investigating Clouds and the biogeoChemistry of the Atmosphere in Antarctica and the Southern Ocean 36
R. Humphries, M. Mallet, S. Fiddes and many others

Investigating 3-11 nm particle events at Cape Grim between 2013-2020 38
M. D. Keywood, J. P. Ward, J. N. Harnwell, Y. Lai, J. Park, Y. Sun and Y. Wang

Preliminary analysis on the secondary organic aerosol formation during the COALA-2020 campaign 39
J. Ramirez-Gamboa, C. Paton-Walsh, J. B. Simmons, M. D. Keywood, A. Mouat and J. Kaiser

Estimating smoke emissions using bottom-up and top-down methods 40
F. Reisen, M. E. Cope, J. A. Noonan, C. T. Roulston, J. C. Powell and A. K. Luhar

Smoke plume composition and relative toxicological impacts of atmospheric species from the 'Black Summer' bushfires 41
J. Simmons, C. Paton-Walsh, A. P. Mouat, J. Kaiser, R. S. Humphries, M. D. Keywood, D. W.T. Griffith, A. Sutresna, T. A. Naylor and J. Ramirez-Gamboa

Can we see the impact of indigenous fire management on the temporal shift in atmospheric carbon monoxide in Northern Australia? 42
S. S. John, N. M. Deutscher, C. Paton-Walsh and D. W.T. Griffith

Forecasting dust pollution events in Brooklyn 43
S. R. Utembe, R. Fedele, C. Bydder, J. Choi, M.-B. di Folco, G. Fisher, P. Torre and J. D. Silver

Impacts of COVID-19 lockdowns on air quality in Western Sydney 44
Y. Chen[1], C. Paton-Walsh, T. A. Naylor, N. M. Deutscher, S. D. Chambers, H. Duc, T. Trieu, S. White and J. N. R. Capnerhurst

Evaluation of a residential intervention to reduce exposures to smoke events resulting from planned burns 45
A. J. Wheeler, R. W. Allen, F. Reisen, C. T. Roulston, M. Dennekamp, N. Goodman and F. H. Johnston

Data assimilation of atmospheric aerosols with the CSIRO CTM

J. D. Silver[1], M. E. Cope[2], F. Riesen[2], K. M. Emmerson[2], J. Horsley[3] and A. Wain[4]

[1] School of Earth Sciences, University of Melbourne, Melbourne, Victoria
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[3] University of Sydney, Sydney, NSW
[4] Bureau of Meteorology, Melbourne, Victoria

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

Abstract

The CSIRO CTM (Chemistry Transport Model) is a central component of the AQFx prototype air quality forecasting system, which is being rolled out nationally in response to the 2019-2020 'Black Summer' bush fires. This model uses data on emission estimates, weather forecasts, gridded concentrations from global forecast models, and knowledge about the dynamics and chemistry of the atmosphere to predict concentrations of trace gases and aerosols across Australia or smaller regions. Air pollution observations (surface and satellite) have typically been compared with model output to quantify forecast skill, but not to adjust modelled fields. Here we consider the use of data assimilation, which harmonises observations and model forecasts in a statistically consistent framework, to the optimise the emission rates of dust and smoke.

Retrievals of aerosol optical depth (AOD), from the VIIRS instrument aboard the NASA/NOAA satellite VIIRS, were assimilated using the 'enkf-c' ensemble Kalman filter assimilation system. The ensemble of CTM runs (with 18 members) was forced with an ensemble of NWP runs from the Bureau of Meteorology's ACCESS-GE3 system. In the initial setup of this assimilation system, we use a simplified version of the CTM that simulates wind-blown dust only (without chemistry and with far fewer atmospheric species, thus allowing for faster run-times and rapid prototyping). The main control variable was spatially-varying dust emission adjustment factors that feed into the wind-blown dust emission scheme. Analysed fields of these dust emission scaling factors were propagated from one day to the next. Model output from the assimilation run was compared with hourly surface measurements of $PM_{2.5}$ and PM_{10} at monitoring sites across Australia.

The initial comparison shows that the model output overestimates the corresponding surface measurements. Furthermore, the correlation with observed aerosols was below $R = 0.5$ at many sites. Further investigation into the model configuration and additional tuning of the assimilation parameters (e.g., observation errors, localisation length-scales) is required.

However, one promising feature of the assimilation output was that during the course of the month of simulation and assimilation, the spatial pattern exhibited by the dust emission adjustment factors converged towards a relatively stable state, without a collapse in the ensemble spread for these two parameter fields. This suggests that the assimilation was showing some consistency in identifying regions that under- or over-estimated wind-blown dust.

Intercomparison of stratospheric ozone measurements from ground-based FTIR, satellites and ozonesondes across Australia and New Zealand

J. Takacs

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Science, University of Wollongong, Wollongong, NSW

[*] corresponding author: Justin Takacs [jt378@uowmail.edu.au]

Abstract

Text

Review of the Kennaook/Cape Grim Reactive Gases sub-program 2015–2021

I. E. Galbally, S. B. Molloy and E. Dunne

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale Victoria

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

Abstract

The Kennaook/Cape Grim Baseline Station (GAW Station ID: CGO) is the premier global observing station of the GAW network in the mid-latitudes of the Southern Hemisphere. The Reactive Gases sub-program at Cape Grim involves long term observations of ozone (O_3), nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The Cape Grim Science Program Governance Manual (2021) requires each subprogram to be reviewed every five years, although circumstances such as the current pandemic can modify this period. Reactive Gases is the subject of the current review and covers the period from 2015–2021.

The framework used in preparing this review was that of the Cape Grim Science Program Governance Manual (2021); and the WMO GAW Implementation Plan 2016–2023 and addresses: the conduct of long-term measurements of O_3, NO_x and VOCs; the analysis, archiving and dissemination of data; and the scientific outputs and overall contribution of the Reactive Gases sub-program in partnerships with our collaborators, to the prediction of climate, weather and air quality.

A detailed account of the work of the Reactive Gases Sub-program over the review period is presented in Galbally, Molloy and Dunne (2021). Here we present the highlights of the work and deliberations of the Reactive Gases Sub-program over the period 2015-2021 under three broad headings:

- Measurements
- Achievements
- Future directions.

References

Cape Grim Science Program Governance Manual, Version 4.1 (Draft), February 2021

Galbally, I. E., S. B. Molloy and E. Dunne (2021). Review of the Cape Grim Reactive Gases Program, CSIRO, Australia, 47 pp.

WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016-2023, GAW Report 228, World Meteorological Organization 2017, ISBN: 978-92-63-11156-2

Radiative effects of improved tropospheric ozone parameterisations in the ACCESS chemistry-climate model

A. K. Luhar, I. E. Galbally and M. T. Woodhouse

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

* corresponding author: Ashok Luhar [ashok.luhar@csiro.au]

Abstract

Ozone (O_3) is a greenhouse gas, with the third largest global warming effect after CO_2 and methane (CH_4), and thus plays an important role in the Earth's climate system. The tropospheric ozone burden is estimated to have increased by about 40% since preindustrial times as a result of increases in the emissions of ozone precursors (Young et al. 2013). According to the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC 2013), the anthropogenic component of the radiative forcing due to ozone is estimated to be 0.35 ± 0.2 W m^{-2}, of which 0.40 ± 0.2 W m^{-2} is the tropospheric ozone contribution and -0.05 ± 0.1 W m^{-2} is the stratospheric contribution. Ozone represents about 15% of the net anthropogenic radiative forcing estimated for the year 2011 (IPCC 2013).

In the troposphere, the ozone budget is determined by transport from the stratosphere, deposition at the Earth's surface, and chemical production and loss. Dry deposition is an important sink of ozone, and oxides of nitrogen (NO_x) generated from lightning play an important role by acting as a precursor to ozone. Recently, Luhar et al. (2017, 2018) developed a new process-based scheme for ozone dry deposition to the ocean, and found that when used in the ACCESS-UKCA chemistry-climate model this scheme leads to an approximately 20% decrease in the total global ozone dry deposition over the current estimates, and thus leading to an increase in atmospheric ozone in the lower troposphere. By improving lightning flash-rate parameterisations, Luhar et al. (2021) observed that the modelled global lightning-generated NO_x (LNO_x) increases from 4.8 to 6.6 Tg N yr^{-1}, the tropospheric ozone burden increases by 8.5 %, and the modelled atmospheric composition agrees better with measurements.

Here, through the use of ACCESS-UKCA, we quantify the impact of the improved ozone dry deposition and LNO_x schemes on atmospheric radiative fluxes. In particular, we examine the change in the outgoing top of the atmosphere (TOA) radiation, and incoming longwave and shortwave fluxes at the surface. This provides a measure of uncertainty in radiation arising due to natural process representation in chemistry-climate models and the amount of this can be compared with the anthropogenic radiative forcing.

References

IPCC: Climate Change 2013 (2014). The Physical Science Basis, Contribution of Working Group I to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. T. F. Stocker et al. (eds), 1535 pp. (Cambridge University Press: Cambridge, UK and New York, NY, USA). doi:10.1017/CBO9781107415324

Luhar, A. K., I. E. Galbally, M. T. Woodhouse and M. Thatcher (2017). An improved parameterisation of ozone dry deposition to the ocean and its impact in a global climate–chemistry mode. *Atmos. Chem. Phys*. 17, 3749–3767. doi:10.5194/acp-17-3749-2017

Luhar, A. K., M. T. Woodhouse and I. E. Galbally (2018). A revised global ozone dry deposition estimate based on a new two-layer parameterisation for air–sea exchange and the multi-year MACC composition reanalysis. *Atmos. Chem. Phys*. 18, 4329–4348. doi:10.5194/acp-18-4329-2018

Luhar, A. K., Galbally, I. E., M. T. Woodhouse and N. L. Abraham (2021). Assessing and improving cloud-height-based parameterisations of global lightning flash rate, and their impact on lightning-produced NOx and tropospheric composition in a chemistry–climate model, *Atmos. Chem. Phys.,* 21, 7053–7082. doi:10.5194/acp-21-7053-2021

Young, P. J., A. T. Archibald, K. W. Bowman et al. (2013). Preindustrial to end 21st century projections of tropospheric ozone from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP). *Atmos. Chem. Phys*. 13, 2063–2090. doi:10.5194/acp-13-2063-2013

AIRBOX – A general update

T. A. Naylor[1*], D. Dominick[1], J. N. R. Capnerhurst[3], N. M. Deutscher[1], A. D. Griffiths[1,2], S. R. Wilson[1], A. G. Williams[1,2], C. Paton-Walsh[1], R. Schofield[4] and P. J. Rayner[4]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW
[2] Environmental Research, ANSTO, Lucas Heights, NSW
[3] Department of Planning, Industry and Environment, Lidcombe, NSW
[4] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Melbourne, Victoria

* corresponding author: Travis Naylor [naylort@uow.edu.au]

Abstract

In September 2020 AIRBOX was homed at the New South Wales Department of Planning, Industry and Environment Air Quality Monitoring Super Site at Lidcombe. The purpose of this position was to do cross-calibration work and collect data for other colleagues using AIRBOX and guest instrumentation. AIRBOX instruments include MiniMPL Lidar, Max-DOAS, MAAP and Radon. The guest instrument is a Picarro G2301 CO_2/CH_4 sampling from a 10 m height. Instrument status updates will be provided along with hardware updates for the AIRBOX.

The last year or so of running on the site has produced some useful data but at the same time a number of instruments have experienced significant down time and the AIRBOX itself has run in a compromised mode until recently.

The purpose of this update is to provide details to the wider community and AIRBOX owners of operational issues over this time and how they have been resolved or not. It also hopes to inspire thoughts and conversation on how we as a community can better support AIRBOX when technical support and funding are limited or not available.

The air chemistry capability of the RSV Nuyina

A. R. Klekociuk* and S. P. Alexander

Australian Antarctic Division, Kingston Tasmania
Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania

* corresponding author: Andrew Klekociuk [andrew.klekociuk@aad.gov.au]

Abstract

The science capability of the Australian Antarctic Program's new icebreaker, RSV Nuyina, will be commissioned over 2021-2023. We present an overview of the potential for air chemistry science using the ship and discuss plans to establish long-term and campaign-based measurements over the coming years, highlighting the proposed Marginal Ice Zone (MIZ) voyage in 2023.

Aspendale Infrastructure Review

A. R. Stavert and E.-A. Guerette

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

* corresponding authors: Elise-Andree Guerette [elise-andree.guerette@csiro.au] & Ann Stavert [ann.stavert@csiro.au]

Abstract

CSIRO is committed to leaving its Aspendale site (which currently hosts GASLAB, ICELAB, our aerosol and reactive gases capabilities and our modelling teams) by the end of 2023. The process of imagining our new facilities is under way.

Rather than replicating the Aspendale infrastructure at a new location the decision has been made to review the nature and location(s) of the infrastructure required to support our scientific and strategic directions over the next 20+ years. We've been asked to think big – terrifying and exciting. As part of this process, we have been asked to develop an initial 'options' paper collating people's thoughts and articulating the benefits of each option.

In this session, we will be presenting the options that have been proposed so far, as well as welcome further comments and alternatives. We are especially interested in your thoughts on:

1. Where our infrastructure should be located
2. Current/future gaps in infrastructure for atmospheric science in Australia
3. The role CSIRO should/could play in filling those gaps
4. Potential internal and external partnerships/synergies
5. Our current and potential collaborators' infrastructure plans in the short/medium/long term

We are trying to gather as broad an outlook as possible on the next decades of Australian Atmospheric Science, so we encourage everyone to join in on the day, whether based at CSIRO or not.

A draft report will be circulated to participants on December 3rd, with comments expected the following week. The report will then be submitted on December 10th.

HFCs in the Australian atmosphere: 1978-2020

P. J. Fraser*, N. Derek, B. L. Dunse, C. M. Trudinger, P. B. Krummel, B. Mitrevski and L. P. Steele

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

HFCs (hydrofluorocarbons) are the fastest growing category of greenhouse gases (GHGs) in the background atmosphere and currently contribute 1-2% of global warming attributed to long-lived GHGs. HFCs are 'ozone friendly' replacements for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). CSIRO, in conjunction with the University of East Anglia, first measured HFCs in the Southern Hemisphere atmosphere in the early-1990s by gas chromatographic-mass spectrometric (GC-MS) analysis of the Cape Grim Air archive (1978–1995, Oram et al. 1996). *In situ* HFC GC-MS measurements commenced at Cape Grim in 1998 and at CSIRO Aspendale in 2006. Today, eleven HFCs (Table) are measured 12 times per day at these sites, the longest, most comprehensive HFC measurement program globally. The resultant HFC data have been used to derive global and Australian HFC emissions, published in international research papers (25) and international reviews of climate change (Myhre, Shindell et al. 2014) and ozone depletion science (Montzka, Velders et al. 2018).

The production, consumption and emissions of HFCs are controlled by the Montreal Protocol (UNEP, Kigali Amendment) and the Kyoto Protocol (UNFCCC, Doha and Paris Amendments). Australia reports annual HFC consumption and emissions (bottom-up and top-down, the latter based on CSIRO atmospheric measurements) to UNEP and the UNFCCC, fulfilling obligations under both Protocols.

The latest HFC observations from Cape Grim and Aspendale will be presented, providing qualitative information on the regional sources of HFCs in SE Australia, which will be quantified in a subsequent ACCOM presentation (Trudinger et al.)

HFCs measured at Cape Grim and Aspendale

HFC	Chemical formula	Mixing ratio (ppt, 2020)	GWP (100 yr)	Industrial source/use
HFC-23	CHF_3	33	14600	HCFC-22 ($CHClF_2$), teflon manufacture
HFC-32	CH_2F_2	21	770	air conditioning refrigerant blends
HFC-125	CHF_2CF_3	31	3740	air conditioning refrigerant blends
HFC-134a	CH_2FCF_3	107	1530	refrigeration: mobile and domestic
HFC-143a	CH_3CF_3	25	5810	air conditioning refrigerant blends
HFC-152a	CH_3CHF_2	4.8	165	aerosol propellant, foam blowing
HFC-227ea	CF_3CHFCF_3	1.7	3600	fire suppressant, aerosol propellant
HFC-236fa	$CF_3CH_2CF_3$	0.20	8690	niche refrigerant
HFC-245fa	$CHF_2CH_2CF_3$	2.9	960	foam blowing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	1.1	915	foam blowing
HFC-4310 mee	$CF_3(CHF)_2CF_2CF_3$	0.29	1600	mobile air conditioning

References

Montzka, S. A., G. J. M. Velders et al. (2018). Hydrofluorocarbons (HFCs), Chapter 2, Scientific Assessment of Ozone Depletion: 2018. Global Ozone Research and Monitoring Project – Report No. 58, 2.1–2.56. (World Meteorological Organization: Geneva, Switzerland)

Myhre, G., D. Shindell et al. (2014), Anthropogenic and Natural Radiative Forcing. Chapter 8, Climate Change 2013 – The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 659–740. (Cambridge University Press: Cambridge, UK and New York, NY, USA)

Oram, D. E., C. E. Reeves, W. T. Sturges, S. A. Penkett, P. J. Fraser and R. L. Langenfelds (1996). Recent tropospheric growth rate and distribution of HFC-134a (CF_3CH_2F). *Geophy. Res. Lett.*, 23, 1949–1952. doi:10.1029/96GL01862

Australian emissions of HFCs from inversion of atmospheric observations at Cape Grim

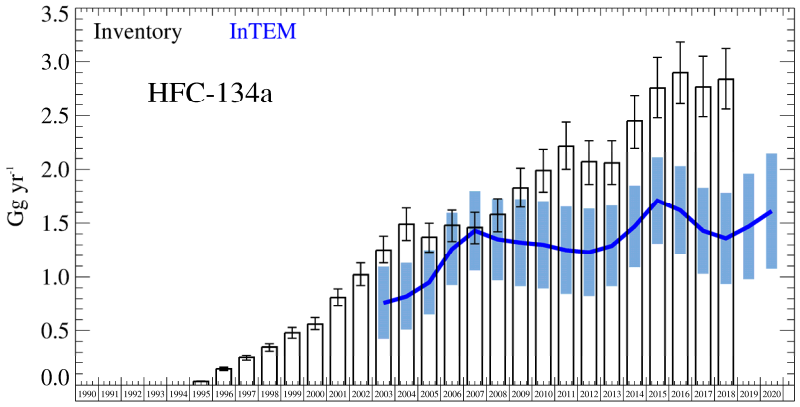
C. M. Trudinger[1*], A. J. Manning[2], P. J. Fraser[1], B. L. Dunse[1], A. L. Redington[2] and P. B. Krummel[1]

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

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

Abstract

Hydrofluorocarbons (HFCs) are replacements for ozone-depleting chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) in air conditioning, refrigeration and foam blowing, and as aerosol propellants and fire retardants. However, HFCs are potent greenhouse gases, and they are growing rapidly in the background atmosphere (Fraser et al., 2021). Atmospheric constraints on emissions of synthetic greenhouse gases such as HFCs are complementary to (and can identify errors in) "bottom-up" estimates of emissions based on import and consumption data. Here we use the UK Met Office's InTEM inversion system (Manning et al., 2011; 2021) with the NAME atmospheric transport model and HFC observations from Cape Grim to estimate HFC emissions in south-eastern Australia. These estimates are scaled up to provide emission estimates for the whole of Australia, then compared with bottom-up estimates in the National Greenhouse Gas Inventory. In this talk, we will describe the InTEM HFC calculations, uncertainties and results.



References

Fraser, P. J., N. Derek, B. L. Dunse, C. Trudinger, P. B. Krummel, B. Mitrevski and L. P. Steele (2021). HFCs in the Australian atmosphere: 1978-2020. In 'ACCOMC incorporating the CGASM2021 [abstract]' (30 Nov–3 Dec 2021, online) (eds. N. Derek and P. B. Krummel) pp. 12. (BoM and CSIRO: Melbourne, Australia)

Manning, A. J., S. O'Doherty, A. R. Jones, P. G. Simmonds and R. G. Derwent (2011). Estimating UK methane and nitrous oxide emissions from 1990 to 2007 using an inversion modeling approach. *J. Geophys. Res*. 116, D02305. doi:10.1029/2010JD014763

Manning, A. J., A. L. Redington, D. Say, S. O'Doherty, D. Young, P. G. Simmonds, M. K. Vollmer, J. Mühle, J. Arduini, G. Spain, A. Wisher, M. Maione, T. J. Schuck, K. Stanley, S. Reimann, A. Engel, P. B. Krummel, P. J. Fraser, C. M. Harth, P. K. Salameh, R. F. Weiss, R. Gluckman, P. N. Brown, J. D. Watterson, and T. Arnold (2021). Evidence of a recent decline in UK emissions of hydrofluorocarbons determined by the InTEM inverse model and atmospheric measurements. *Atmos. Chem. Phys*. 21, 12739–12755. doi:10.5194/acp-21-12739-2021

Fully Bayesian decomposition and estimation of the climatology and interannual variability of global CO_2 fluxes

M. Bertolacci[1*], A. Zammit-Mangion[1], N. Cressie[1], B. Bukosa[2], J. A. Fisher[1], A. Schuh[3] and Y. Cao[1]

[1] University of Wollongong, Wollongong, NSW, Australia
[2] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[3] Cooperative Institute for Research in the Atmosphere, Colorado State University, USA

[*]corresponding author: Michael Bertolacci [michael_bertolacci@uow.edu.au]

Abstract

We present version two of the Wollongong Methodology for Bayesian Assimilation of Trace-gases, a fully Bayesian hierarchical framework for global flux inversion. This extends version one of the framework, described by Zammit-Mangion et al. (2021), which focussed on improvements to uncertainty quantification in flux inversions. In version two, the focus is on improving the scientific interpretability of the flux estimates, while retaining the uncertainty quantification.

Version one introduced a hierarchical Bayesian statistical model to account for instrument bias, correlated measurements, and uncertainty in the prior. Markov chain Monte Carlo (MCMC) is used to obtain posterior estimates and uncertainties for all quantities of interest. Prior means for the fluxes are derived from inventories covering land and oceanic fluxes. The framework was applied to infer non-fossil-fuel CO_2 fluxes over a two-year period using column-average CO_2 retrievals from the Orbiting Carbon Observatory-2 (OCO-2) satellite.

In version two, in addition to the above features, we incorporate a time-series decomposition of the biosphere and ocean inventories that form the prior mean. This separates the prior fluxes into trend, harmonic (climatological), and residual (inter-annual variability) components. In the flux inversion, each component is parameterised separately, and their joint posterior distribution is inferred. This allows for direct uncertainty quantification of quantities related to, for example, the climatology of fluxes. Due to the nature of the decomposition, it also allows the extrapolation of the trend and harmonic components into years outside the direct study period. The framework was applied to both OCO-2 retrievals and *in situ*/flask measurements of CO_2 concentrations over a six-year period.

References

Zammit-Mangion, A., M. Bertolacci, J. Fisher, A. Stavert, M. L. Rigby, Y. Cao and N. Cressie (2021). WOMBAT v1.0: A fully Bayesian global flux-inversion framework. *Geosci. Model Develop.* doi:10.5194/gmd-2021-181

Interannual variation in global baseline CO_2 and its isotopes

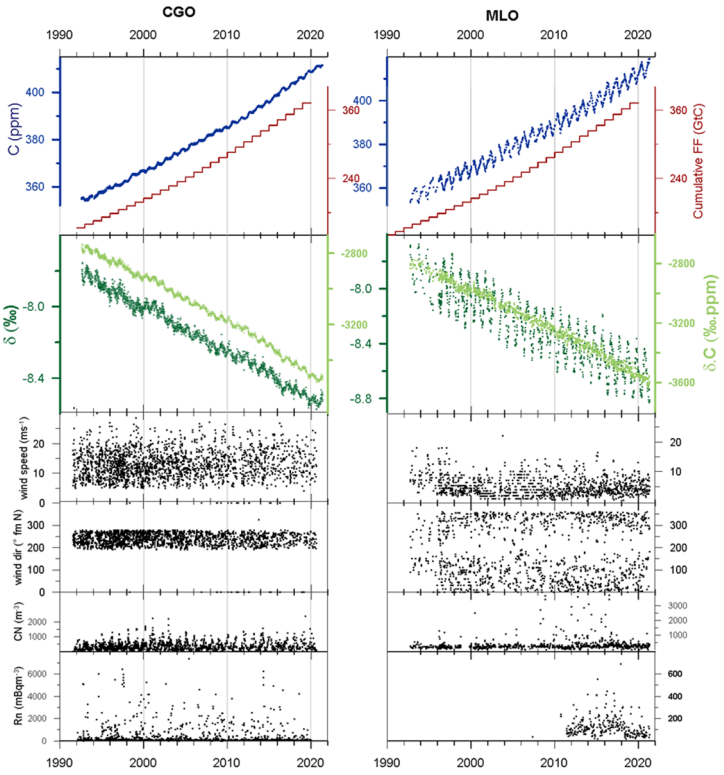
R. J. Francey

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

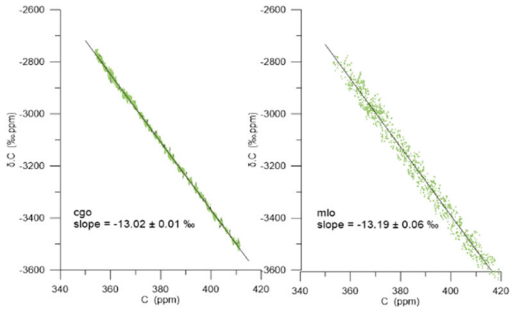
Three-decades measurements of CO_2 (C) and $\delta^{13}C$ (or δ, its normalized $^{13}C/^{12}C$ ratio) in baseline air from 11 globally distributed GASLAB sites are summarised. Particular attention to Cape Grim and Mauna Loa data reflects, in part, their comprehensive information on air-mass history. Real-time baseline measurements at Cape Grim represent the trend in accumulated global anthropogenic emissions, emitted mainly in the Northern Hemisphere and mixed globally. At Mauna Loa a larger trend represents the emissions accumulated in a smaller volume due to slow inter-hemispheric transport. In both hemispheres the $^{13}C/^{12}C$ trend, and much of the $^{13}C/^{12}C$ interannual variation, represents an equilibrium value between carbonates in surface water established by the rapid gross turnover of CO_2 through oceanic and terrestrial (mainly leaf) water. (Marginal hemispheric differences are consistent with different hemispheric distributions of oceanic and terrestrial water).



Left: For Cape Grim (cgo) and Mauna Loa (mlo):

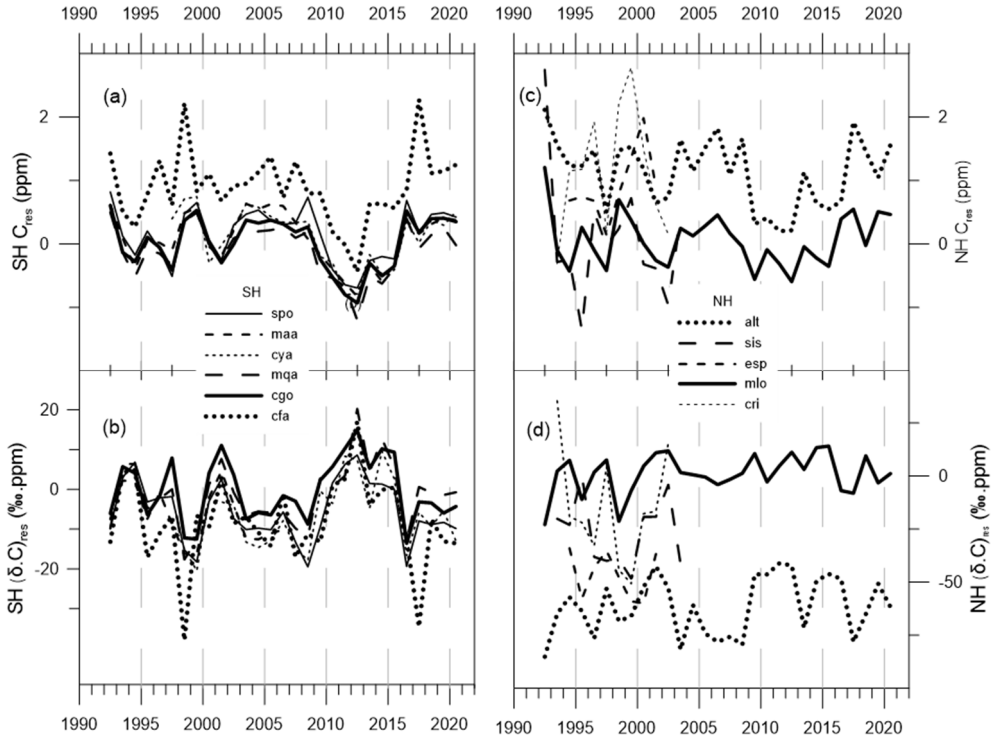
- Individual flask CO_2
- Cumulative anthropogenic emissions (red)
- Individual flask $\delta^{13}C$ (dark green)
- Individual flask $\delta^{13}C*CO_2$ (light green)
- (in black)
- Wind Speed
- Wind direction
- Condensation nuclei (CN)
- Radon

Below: Plots d*C versus C with slope showing equilibrium $^{13}C/^{12}C$ ratios in ‰ from PDB.



Quadratic fits though the Cape Grim and Mauna Loa, consistent with global cumulative emissions, provide baselines for respective hemispheres, against which within hemisphere differences are examined.

Interannual variation in annually averaged residuals from respective hemispheric baselines show considerable global coherence. The 2–3 year variation exists throughout both C and isotopic records, with similar amplitude in both hemispheres. This is consistent with an early attribution (Thomson et al. 1986) to low latitudes of the Southern Hemisphere, and recent studies showing the dominant role of semi-arid ecosystems in the trend and variability of the land CO_2 sink (Ahlström et al. 2015).



Annual average C and δ.C residuals from quadratics through Cape Grim (SH) and Mauna Loa (NH) data.

The enhanced variation at Cape Ferguson corresponding to the major El Niños in 2008/9 and 2015/16 is attributed to a regional (possibly extended wildfire) response.

However, the largest anomaly in interannual variation in both C and δ.C occurs in the period 2009-2015, when surprisingly the amplitude at Cape Grim is larger than that at Mauna Loa (but not that at Alert). Consideration of the magnitude of reported fossil emission anomalies (e.g the GFC) and terrestrial sink anomalies are far too small to explain the C and δ.C anomalies, but overestimation of global fossil emissions during the period, as reported by Saeki and Patra (2017), offers a possible explanation. (The reduced Mauna Loa difference is a possible consequence of nearby unusual inter-hemispheric transfer variation).

Acknowledgements

Ray Langenfelds and many people, from GASLAB, BoM, Antarctic Division, AIMS, NOAA, AES, and Jorgen Frederiksen, Graham Farquhar, Peter Rayner are contributing to this work.

References

Ahlström A., M. R. Raupach, G. Schurgers, B. Smith, A. Arneth, M. Jung, M. Reichstein, J. G. Canadell, P. Friedlingstein, A. K. Jain, E. Kato, B. Poulter, S. Sitch, B. D. Stocker, N. Viovy, Y-P. Wang, A. Wiltshire, S. Zaehle and N. Zeng (2015). The dominant role of semi-arid ecosystems in the trend and variability of the land CO_2 sink. *Science* 348:6237, 895–899. doi:10.1126/science.aaa1668

Saeki, T. and P. K. Patra (2017). Implications of overestimated anthropogenic emissions on East Asian and global land CO_2 flux inversion. *Geosci. Lett.* 4:9. doi:10.1186/s40562-017-0074-7

Dramatic lockdown fossil fuel CO_2 decrease detected by citizen science supported ^{14}C observations

J. Turnbull*, L. Gatti Domingues and N. Turton

GNS Science, Lower Hutt, New Zealand

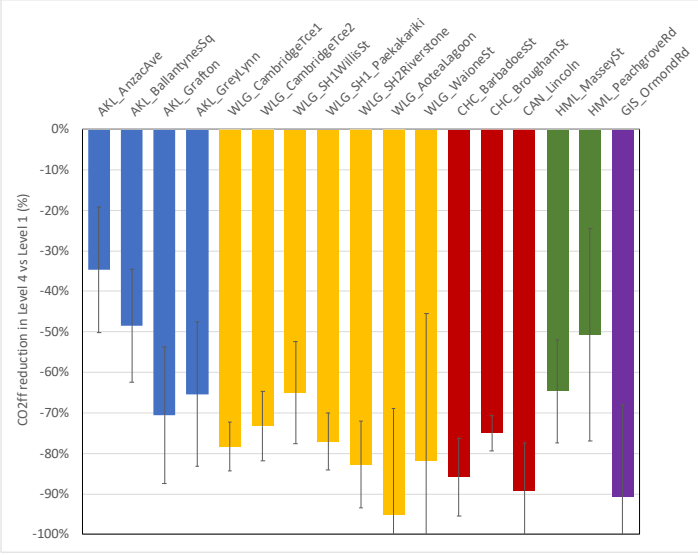
* corresponding author: Jocelyn Turnbull [j.turnbull@gns.cri.nz]

Abstract

The travel and work restrictions imposed by COVID-19 lockdowns resulted in dramatic changes in fossil fuel carbon dioxide (CO_2) emissions around the world, most prominently in the transportation sector. Yet to date, most estimates of the change in emissions have relied on proxy data, and it is difficult to evaluate emission changes from CO_2 measurements alone. Radiocarbon measurements are the gold standard for quantifying recently added fossil fuel CO_2 into the local atmosphere, since fossil fuels are devoid of radiocarbon.

We used a novel citizen science campaign to collect grass samples from around New Zealand during the 2020 and 2021 COVID-19 lockdowns, when the highly restrictive lockdowns meant that scientists could not travel to collect samples in a more traditional way. We present the methodology of measuring radiocarbon content of the grass samples and calculating the recently added, local, fossil fuel CO_2 mole fraction at the local and time period that the grass grew. We demonstrate that although there are some limitations and caveats of this method, it is possible to control for meteorological and other factors, and infer local fossil fuel CO_2 emission changes from the grass data.

Our results from 17 sites in five cities around New Zealand demonstrate dramatic reductions in traffic emissions of 75 ± 3 % during the most severe lockdown restriction period. This is consistent with sparse local traffic count information, and a much larger decrease in local traffic emissions than reported in global aggregate estimates of COVID-19 emission changes. Our results demonstrate that despite nationally consistent rules on travel during lockdown, emission reductions varied by location, with inner city sites dominated by bus traffic showing smaller decreases in emissions than sites dominated by passenger vehicle traffic.



Traffic CO_2 emission decrease during Level 4 lockdown observed from ^{14}C in grass at 17 roadside sites around New Zealand.

Revised fossil methane emissions estimates confirmed by Law Dome $^{14}CH_4$ measurements

D. M. Etheridge[1,2*], V. V. Petrenko[3], A. M. Smith[4], P. D. Neff[3,5], B. Hmiel[6], C. M. Trudinger[1], E. Crosier[3], D. P. Thornton[1,2], R. L. Langenfelds[1], L. Jong[2,7], C. M. Harth[8], B. Mitrevski[1], C. Buizert[9], B Yang[4], R. F. Weiss[8] and J. Severinghaus[8]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale Victoria
[2] Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania
[3] Department of Earth and Environmental Sciences, University of Rochester, Rochester, New York, USA
[4] Australian Nuclear Science and Technology Organisation (ANSTO), Kirrawee, NSW, Austraia
[5] Department of Soil, Water and Climate, University of Minnesota Twin Cities, Minneapolis, Minnesota, USA
[6] Environmental Defense Fund, New York, New York, USA
[7] Australian Antarctic Division, Kingston Tasmania
[8] Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA
[9] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA

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

Abstract

Methane is a powerful greenhouse gas and has significant roles in the chemistry of the atmosphere. Its global concentration has risen by 240 % since 1750 AD. Atmospheric $^{14}CH_4$ is an independent and potentially unambiguous tracer of fossil CH_4 emissions from anthropogenic and natural geologic sources, however, ^{14}C from nuclear weapons tests and $^{14}CH_4$ from nuclear power plants complicate its interpretation after the late 1950s. Measurements before then rely on air extracted from polar ice and firn. Hmiel et al. (Nature, 2020) measured $^{14}CH_4$ in air extracted from firn and ice in Greenland and Antarctica and found that the natural global fossil CH_4 source is very small (<6 Tg CH_4 /yr). This is inconsistent with bottom-up geological CH_4 emissions estimates (40-60 Tg CH_4 /yr) and implies an upward revision of anthropogenic fossil source emissions, emphasising the need for further measurements.

We present new $^{14}CH_4$ measurements of air extracted from the high accumulation site DE08-OH on the Law Dome ice sheet in 2018/19, including firn air to 81 m depth and large ice samples combined from parallel ice cores to 240 m. Measurements of trace gases confirm that the samples were uncontaminated and only minor corrections are required for sample processing. The correction for cosmogenic in-situ production of $^{14}CH_4$ is very small at DE08-OH due to its high accumulation rate and relatively low elevation. The new $^{14}CH_4$ results compare closely with the previous measurements from the other sites. An atmospheric $^{14}CH_4$ history is reconstructed from inverse modelling of the combined ice and firn data. The pre-industrial $^{14}CH_4$ level is almost identical to that expected from contemporaneous biogenic sources, confirming very minor natural fossil CH_4 emissions. $^{14}CH_4$ decreases to a minimum in about 1940 as anthropogenic fossil methane is emitted followed by an increase during the nuclear era from 1950 to present. The record since the 1950s would allow the evolution of the anthropogenic fossil source to be quantified when improved nuclear $^{14}CH_4$ emissions estimates become available. The larger emissions from anthropogenic fossil sources implied by this result suggests opportunities for methane emissions reductions.

Advancing the New Zealand atmospheric greenhouse gas observation network

N. Brough[1*], G. W. Brailsford[1], M. Murphy[1], S. Nichol[1], T. Bromley[1], L. Gatti Domingues[2], S. Gray[1], J. McGregor[1], S. E. Mikaloff Fletcher[1], R. Moss[1], R. Peethambaran[1], P. Sperlich[1], K. Te Puni[1] and J. Turnbull[2]

[1] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[2] GNS Science, Lower Hutt, New Zealand

[*] corresponding author: Neil Brough [neil.brough@niwa.co.nz]

Abstract

New Zealand has committed to greenhouse gas reductions in the future. Yet, key questions surrounding forest, grassland and urban carbon exchange remain unanswered. CarbonWatch-NZ is a five-year programme which will expand New Zealand's national observing network to eleven permanent and four field deployable stations, introduce urban and regional forest scale studies, leverage measurements of isotopes and carbonyl sulphide to understand source and sink processes, and integrate flux tower observations to understand the role of pastures. State of the art land modelling, focused field studies, sub-national inverse modelling and partnerships with indigenous groups will allow a deeper understanding of forest carbon uptake and the impact of planting strategies and land management practices on our forest carbon sink. Data from over more than 30 site years of eddy covariance measurements will be combined with land modelling and atmospheric observations to study carbon cycling in New Zealand's grasslands. National scale methane (CH_4) inverse modelling will inform New Zealand's emissions reporting and agricultural CH_4 mitigation strategy. An urban inverse model for New Zealand's largest city, Auckland, will shed new light on both emissions and the urban biosphere in this green subtropical city.

New Zealand's atmospheric greenhouse gas measurements and modelling programme is growing rapidly. New *in situ*, flask and eddy covariance observations have been added to our long-running timeseries through the CarbonWatchNZ Research Programme. In addition, New Zealand has funded a new Research Programme to use data from MethaneSAT, a methane-sensing satellite that will launch in 2022, to infer agricultural CH_4 emissions in New Zealand and around the world. Here, we present an overview of the atmospheric observation sites recently incorporated and provide an insight into some of the associated data at those platforms and plans for further observation platforms.

CarbonWatchNZ: regional to national scale inverse modelling of New Zealand's carbon balance

B. Bukosa[1], S. E. Mikaloff-Fletcher[1], G. W. Brailsford[1], P. Sperlich[1], C. Nankivell[1], D. Smale[1], E. D. Keller[2], J. Turnbull[2], K. Steinkamp[1], M. J. Harvey[1], R. Moss[1], S. Gray[1], S. Moore[1], S. Nichol[1], T. Bromley and Z. Buxton[1]

[1] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[2] GNS Science, Lower Hutt, New Zealand

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

Abstract

Atmospheric observations of carbon dioxide (CO_2) and other greenhouse gases have been widely used to constrain their flux estimates through atmospheric inverse modelling. Yet, applying these methods at national scale to verify and improve the National Inventory Report (NIR) and support the Paris agreement remains at the frontier of climate science.

We use inverse modelling to estimate New Zealand's carbon uptake and emissions (CO_2 and CH_4) using atmospheric measurements and model. This effort is part of a five-year CarbonWatch-NZ research programme, which aims to develop a complete top-down picture of New Zealand's carbon balance using national inverse modelling and targeted studies of New Zealand's forest, grassland and urban environments. Our decade long (2011-2020) CO_2 inversion results show a stronger sink relative to the NIR, pointing to a strong CO_2 uptake in Fiordland, a region covered by indigenous temperate rainforest in New Zealand's South Island. These results suggest that these environments might actually be a more efficient carbon sink than what we thought before.

We have performed several sensitivity tests and improvements with our inversion system such as updating our transport model, anthropogenic, oceanic and terrestrial prior fluxes and land-use maps, testing various background CO_2 values and adding new measurements to the inversion. A particular focus was directed towards the prior terrestrial fluxes. Using updated flux estimates and land-use maps further increased the CO_2 sink. We also performed a CO_2 diurnal cycle test, based on an observing system simulation experiment (OSSE), to identify the impact of using monthly prior terrestrial fluxes that exclude the diurnal variability in the CO_2 fluxes. The diurnal cycle test suggests a strong interannual variability in our results with both under and overestimated posterior fluxes.

MethaneSAT: Towards detecting agricultural emissions from space

S. E. Mikaloff-Fletcher[1], A.-G. Ausseil[2], G. W. Brailsford[1], B. Bukosa[1], J. Benmergui[3], D. I. Campbell[4], J. E. Franklin[3], A. Geddes[1], J. P. Goodrich[4], S. P. Hamburg[5], D. Ngaru King[1], R. Law[2], J. Laubach[2], D. Noone[6], D. F. Pollard[1], J. Turnbull[7], H. Schaefer[1], L. A. Schipper[4], D. Smale[1] and S. C. Wofsy[3]

[1] NIWA, Wellington, Aotearoa New Zealand
[2] Manaaki Whenua Landcare Research, Lincoln, Aotearoa New Zealand
[3] School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts, USA
[4] School of Science, Environmental Research Institute, University of Waikato, Hamilton, Aotearoa New Zealand
[5] MethaneSAT LLC/EDF, Austin, Texas, USA
[6] Faculty of Science, University of Auckland, Auckland, Aotearoa New Zealand
[7] GNS Science, Lower Hutt, Aotearoa New Zealand

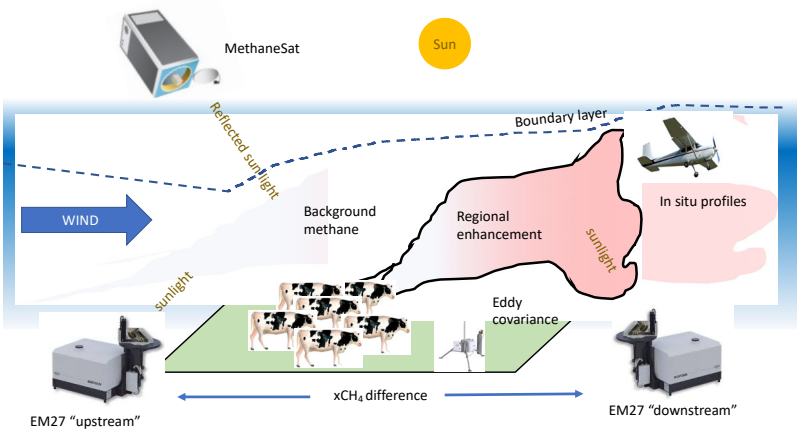
* corresponding author: Sara Mikaloff-Fletcher [sara.mikaloff-fletcher@niwa.co.nz]

Abstract

The MethaneSAT satellite, scheduled for launch in fall 2022, is a joint American and Aotearoa-New Zealand (Aotearoa-NZ) initiative, involving a partnership between Environmental Defense Fund's (EDF) subsidiary MethaneSAT LLC, and the New Zealand government. The satellite's core mission is to catalyze methane (CH_4) emission reductions around the world by measuring atmospheric CH_4 with unprecedented precision and mapping flux rates. While MethaneSAT was designed to detect emissions from oil and gas infrastructure, we hypothesize that it can also be used to measure more diffuse and thus harder to resolve agricultural CH_4 emissions. We present plans for a research programme to develop and test this capability.

Aotearoa-NZ is the ideal natural laboratory for this research due to its distance from other land areas, its greenhouse gas measurement and modelling capability and its unusual greenhouse gas emission profile. CH_4 emissions make up nearly half of its gross emissions budget, and 85% of these emissions are from agriculture. Atmospheric inverse modelling will leverage meteorology from Aotearoa-NZ's 1.5 km resolution numerical weather prediction model and inverse modelling tools being used by the MethaneSAT team. Aotearoa-NZ's long-running TCCON site at Lauder will be supplemented by observations from two EM27 instruments and aircraft-based vertical profile data.

We will develop a global observation strategy to target agricultural emissions from ruminant animals and rice agriculture. We will also identify a list of priority targets where MethaneSAT has the potential to provide valuable new emission information. Then, we will work with policy and advocacy experts to identify priority targets where mitigation solutions are practical. Thus, our strategy will consider not only where MethaneSAT can quantify emissions with the most accuracy but also where such data will be most beneficial for realizing emission reductions.



Schematic showing the field campaign design

Cape Grim and urban emissions estimates

Z. M. Loh[1], P. B. Krummel[1], R. L. Langenfelds[1], B. L. Dunse[1], S. J. Fallon[2], X. Lu[3], J. Ward[4]and N. T. Somerville[4]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[2] College of Science, Australian National University, Canberra, ACT
[3] School of Biological, Earth and Environmental Sciences, University of NSW, Kensington, NSW
[4] Cape Grim Baseline Air Pollution Station, Bureau of Meteorology, Smithton, Tasmania

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

Abstract

Cape Grim measurements from the Greenhouse Gas and Ozone Depleting Substances (GG-ODS) program have long been used to estimate Australia's emissions of many synthetic greenhouse gases (GHGs) from pollution episodes with a fetch over Greater Melbourne. The estimates are reported to the Department of Agriculture Water and the Environment (DAWE) and the Department of Industry, Science, Energy and Resources (DISER), from which they are then used in Australia's reporting to the UNFCCC.

Cities are incandescent hot spots for anthropogenic emissions of carbon dioxide (CO_2) and methane (CH_4). Internationally, demand is growing to better understand CO_2 and CH_4 emissions from urban areas, to help inform smart mitigation policies and track progress towards emissions reductions. Despite the complications of many and varying natural sources (and sinks) of these two principal GHGs, Cape Grim *in situ* data carry rich information about emissions of these species from Greater Melbourne.

This presentation will consider how we might use the Cape Grim CO_2 and CH_4 *in situ* data to understand Melbourne emissions, and what other measurements might be necessary to fully realise the value of these data for addressing this question.

The Total Carbon Column Observing Network – new and improved data

N. M. Deutscher[1*], J. L. Laughner[2], D. Wunch[3], G. C. Toon[4], S. Roche[3], T. Warneke[5], C. M. Roehl[2], D. G. Feist[6], D. F. Pollard, D. W.T. Griffith[1], C. Murphy[1] and TCCON Partners

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW
[2] Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, USA
[3] Department of Physics, University of Toronto, Toronto, Canada
[4] Jet Propulsion Laboratory, NASA, Pasadena, California, USA
[5] Institute für Umweltphysik, Univeristät Bremen, Bremen, Germany
[6] Ludwig-Maximilians-Universität München, Lehrstuhl für Physik der Atmosphäre, and Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Munich, Germany

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

Abstract

In last year's TCCON update, we gave a preliminary overview of the new TCCON version based on updated spectral processing software, GGG2020. Since then, phase 1 of the GGG2020 reanalysis has taken place, and network-wide analysis of these results has been performed.

In this presentation we give an update on the new TCCON data version, especially focusing on improvements in airmass-dependent biases and comparison to vertical in situ profiles that enable TCCON to be linked to the World Meteorological Organisation, Global Atmosphere Watch scales.

In addition, we also introduce a new instrument that is now operational at Wollongong and plans for its certification to replace the existing Wollongong TCCON instrument.

Modelling the primary production of molecular hydrogen (H_2) from the photolysis of aldehydes and its implications on the H_2 tropospheric budget

M. P. Pérez-Peña[1], J. A. Fisher[2*], H. Yashiro[3], D. B. Millet[4], P. B. Krummel[5], R. L. Langenfelds[5] and S. H. Kable[1]

[1] School of Chemistry, Faculty of Science, University of New South Wales, Sydney, NSW
[2] Centre for Atmospheric Chemistry. School of Earth, Atmospheric and Life Sciences University of Wollongong, Wollongong, NSW
[3] Earth System Division, National Institute for Environmental Studies, Tsukuba, Japan
[4] Department of Soil, Water & Climate, University of Minnesota, Falcon Heights, Minnesota, USA
[5] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

[*] corresponding author: Jenny A. Fisher [jennyf@uwo.edu.au]

Abstract

For its potential as an energy carrier, molecular hydrogen (H_2) has been previously modelled to determine its tropospheric burden and to constrain its sources and sinks (Ehhalt and Rohrer 2009; Yashiro et al. 2011). Current models consider the photodissociation of formaldehyde and glyoxal as the only atmospheric chemical sources of H_2. However, recent laboratory measurements by Harrison et al. (2019) showed that acetaldehyde photo-dissociates yielding H_2 at a 1% quantum yield. Rowell et al. (2021) calculated ground-state energies for a list of aldehydes and concluded that the primary formation of H_2 from their photolysis is possible. In this work, we tested the importance of the so far unexplored photochemical sources on the tropospheric budget of H_2 by using two photochemical models. We added new reactions for various aldehydes complementing the so far well-known chemical sources of H_2. We used the box model AtChemV1.2 with the MCM and incorporated the photolysis generation of H_2 for 16 aldehydes. We used the 1% quantum yield determined by Harrison et al. (2019) as a benchmark for all the tested aldehydes. The box model was configured for short simulations (< 12 days) at three sites with distinctive environmental conditions. Using the box modelled rates of production, we identified the aldehydes that had the biggest contribution to the primary photochemical generation of H_2: acetaldehyde, propanal, methylglyoxal and glycolaldehyde. We then implemented the GEOS-Chem model globally for a baseline and a scenario adding the photochemical reactions to only six aldehydes for a two-year simulation (2015-2016). The modelled scenario included the most important aldehydes identified with the box modelling. The new photochemistry produced a maximum of 3.58x10^3 Mg yr^-1 of H_2 over densely forested areas, for which biogenic VOCs are most relevant as precursors of the aldehydes tested here. However, the increase in the photochemical source of H_2 was balanced out by an increase in the modelled sinks. The inclusion of the new photochemistry is not likely to fix the low H_2 model bias observed in our global modelled baseline. Other processes involved in the tropospheric budget of H_2, like physical sources and sinks, must be revised in order to improve the H_2 modelling.

References

Ehhalt, D. H., and F. Rohrer (2009). The tropospheric cycle of H_2: A critical review. *Tellus, Series B: Chem. Phys. Meteorol.* 61(3), 500–535. doi:10.1111/j.1600-0889.2009.00416.x

Harrison, A. W., A. Kharazmi, M. F. Shaw, M. S. Quinn, K. L. K. Lee, K. Nauta … S. H. Kable (2019). Dynamics and quantum yields of H_2 + CH_2CO as a primary photolysis channel in CH_3CHO. *Phys. Chem. Chem. Phys.* 21(26), 14284–14295. doi:10.1039/c8cp06412a

Rowell, K. N., S. H. Kable and M. J. T. Jordan (2021). Photo-initiated ground state chemistry: How important is it in the atmosphere?. Retrieved June 2021 from https://doi.org/10.5194/acp-2021-424

Yashiro, H., K. Sudo, S. Yonemura and M. Takigawa (2011). The impact of soil uptake on the global distribution of molecular hydrogen: Chemical transport model simulation. *Atmos. Chem. Phys.* 11(13), 6701–6719. doi:10.5194/acp-11-6701-2011

Side-by-side GHG measurements on the RV Investigator and at Cape Grim by CRDS and FTIR – can we really achieve GAW compatibility goals?

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

[1] School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

In 2019 on the RV Investigator, and in 2020 at Cape Grim, we ran two greenhouse gas analysers side by side for extended periods of weeks (RVI) to months (Cape Grim). The analysers were Picarro Cavity Ringdown Spectrometers (CRDS), operated by RVI and CSIRO, and Spectronus FTIR (Wollongong). Despite good agreement in co-measuring (dry) calibration standards, in ambient air measurements we observe consistent biases of up to 0.2–0.3 ppm in carbon dioxide (CO_2) and 2 ppb in methane (CH_4). For comparison, Global Atmosphere Watch's compatibility goals for these gases are that interstation biases be less than 0.05 ppm for CO_2 in the southern hemisphere, and 2 ppb for CH_4. Meeting these goals is a challenge!

In 2021 we have run similar CRDS and FTIR instruments side by side at the University of Wollongong to investigate and quantify possible sources of these biases, including:

- Calibration gas assigned values
- Plumbing and sample handling connections
- Dealing with water vapour– removal (FTIR) vs correction (CRDS)
- Effect of a chiller used to remove excess humidity (RVI)

As a by-product we have developed a potentially more accurate method to determine the water correction to be applied to CRDS measurements in wet air. The work is still ongoing, and in this talk we will present the current state of the studies.

Acknowledgements

The author list represents the 2021 study, but we thank the many others who have contributed to the original RVI and Cape Grim measurements and provided support in Covid-straitened times. These include the teams.

Improving N_2O measurement precision across CSIRO's network

E.-A. Guerette*, B. Mitrevski, Z. M. Loh, P. B. Krummel, D. A. Spencer and R. L. Langenfelds

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

Nitrous oxide (N_2O) is a potent greenhouse gas that is accumulating in the atmosphere and contributing to both climate change and stratospheric ozone depletion.

N_2O has been measured in situ at Cape Grim since 1978, with increasing precision as new gas chromatography measurement systems have been introduced over the years under the auspices of the ALE, GAGE and AGAGE projects (SIO-16 N_2O scale).

The most recent addition at Cape Grim is a cavity ringdown instrument (CRDS) commissioned in 2019. This new instrumentation is part of the CSIRO network (NOAA/WMO 2006 N_2O scale). Two more CRDS instruments, one located at Aspendale and the other to be deployed on the Research Vessel Investigator in coming weeks, complete the CSIRO *in situ* N_2O network at present.

CSIRO has also been routinely measuring N_2O in flasks from its global network since 1992.

Both the calibration standards needed for the *in situ* measurements and the flask measurements have been made on a single GC-ECD system (Shimadzu-1), operational in GASLAB since 1991. In recent years, the performance of this instrument had been degrading and so in October 2021, Shimadzu-1 was replaced with a new GC-ECD system, which offers much increased precision.

Greenhouse gas fluxes from a NSW coastal wetland and a tidal restoration site

N. M. Deutscher[1], M. J. Spann[1], K. Zajec-Tingle[1], J. Kelleway[1], M. Hughes[1,2], A. G. Carter[1], T. A. Naylor[1] and B. T. Walker[1]

[1] School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW
[2] NSW Department of Planning, Industry and Environment, Parramatta, NSW

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

Abstract

Coastal wetlands have the ability to store large amounts of carbon compared to other vegetation. In particular, in sufficiently saline environments, methanogenesis can suppressed due to preferential sulfate reduction. Coastal wetlands therefore could play a role in climate change mitigation strategies; for example, tidal restoration projects seek to gain carbon credits by decreasing methane emissions from degraded wetlands. Here we present work from two measurement campaigns looking at greenhouse gas fluxes.

One ongoing campaign occurred at Lake Tilba Tilba, a small saltmarsh wetland that is an Intermittently Closed and Open Lake or Lagoon (ICOLL). At this site ongoing actions have been undertaken to improve water quality, and as a result regular vegetation surveys have been performed. To measure greenhouse gas fluxes, two eddy covariance towers measuring CO_2 were installed, one with a fetch over a community of *Sarcocornia quinqueflora*, a low growing succulent, and the other over a mixed community dominated by rush vegetation, *Juncus kraussii*.

Separately, a lab mesocosm experiment was undertaken from samples from a tidal restoration site at Yeramba, on the George's River in southern Sydney. Soil chambers were coupled to a Fourier Transform Infrared (FTIR) spectrometer to measure greenhouse gas fluxes from soil representative of the site inundated with brackish or saline water, and a control over a 2-month period.

Results from these two separate campaigns illustrate significant differences in CO_2 fluxes between the two vegetation communities and potential implications of tidal restoration projects on greenhouse gas budgets.

Development of low-cost sensors and evaluation using high precision Fourier Transform Infrared Spectroscopy

B. Walker[1*], N. M. Deutscher[1], A. Carter[1], D. W.T. Griffith[1], P. Ihnat[2], N. B. Jones[1], J. J. Kelleway[3] and T. A. Naylor[1]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Science, University of Wollongong, Wollongong, NSW
[2] School of Physics, Faculty of Engineering and Information Sciences, University of Wollongong, Wollongong, NSW
[3] GeoQuEST Research Centre, School of Earth, Atmospheric and Life Science, University of Wollongong, Wollongong, NSW

[*] corresponding author: Brittany Walker [btw292@uowmail.edu.au]

Abstract

Methane (CH_4) and carbon dioxide (CO_2) are important greenhouse gases, with rising emissions expected to result in drastic environmental impacts. At enhanced concentrations they can also directly impact human health, so it is therefore important to be able to effectively measure the amounts of these gases. Historically, expensive, high precision instruments have been used to determine the mole fractions of these gases; however, these instruments are not able to be widely deployed, especially in locations where funding and/or infrastructure are limited.

A module was designed that incorporated a low-cost non-dispersive infrared CO_2 sensor and two tin oxide methane sensors, with temperature, humidity, and pressure sensors. A Raspberry Pi was set up and a program developed to communicate with the sensor board and receive data, which was logged and delivered remotely daily. Three modules were evaluated and characterised by comparison to independent, high-precision measurements.

A controlled humidity injection experiment highlighted large humidity dependencies for the methane sensors, which were able to be well characterised at humidities above 5 gm^{-3}; there was little-to-no humidity dependence for the CO_2 sensors. Application of the sensors to real-world scenarios yielded mixed results. A chamber experiment showed very little sensitivity to fluxes for both methane and carbon dioxide but was limited by small signals. An ambient lab comparison showed reasonable agreement for CO_2, while when sampling from a compost bin, excellent agreement with independent data was seen. The methane sensors did not perform well at determining the methane mole fraction, despite accounting for the humidity dependence.

The CO_2 sensors, temperature, humidity, and pressure measurements could be applied to real world scenarios; however, the methane sensors performed poorly over the ranges studied and require further improvements and testing over wider methane ranges if they are to be suitable for measurements of methane mole fractions close to ambient conditions.

Air standard preparation at the Cape Schanck clean air facility

R. L. Langenfelds*, D. A. Spencer, L. P. Steele, M. V. van der Schoot^, S. A. Coram^ and B. Mitrevski

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
^ no longer at CSIRO

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

Abstract

High pressure cylinder air standards have been prepared at the Cape Schanck clean air facility since 1994. Standards may be prepared as clean, natural SH air or modified to specification for higher/lower concentrations of multiple trace gases. They are used extensively in CSIRO O&A's atmospheric measurement programs and have been supplied to numerous other users within Australia and internationally. Some unmodified samples have been retained to supplement the Cape Grim Air Archive after completion of their service as air standards.

Air is collected using an oil-free RIX-SA3 Sweet-Air compressor. Trace gas modification techniques include spiking with pure gases, chemical scrubbing, dilution with zero or CO_2-free air and blending of different whole air mixtures.

Measurements of unmodified Cape Schanck air are compared with baseline records from Cape Grim. This helps both identify artifacts relating to equipment or filling procedures and characterise the site in relation to regional trace gas exchange and air mass history.

Due to closure of the Cape Schanck site during the 2020–21 pandemic, cylinder filling operations were moved to Aspendale. These events highlight the importance of maintaining a second filling site, preferably at GASLAB's home base in bayside Melbourne.

Two-filter ^{222}Rn detector calibrations traceable to the SI

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

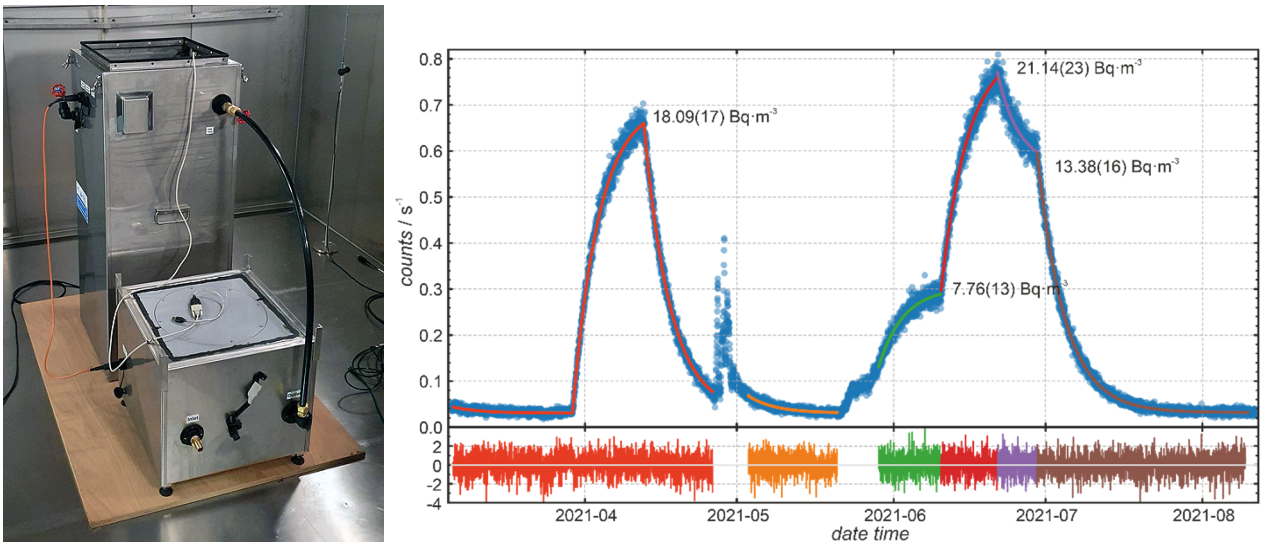
[1] NST Environmental Research, ANSTO, Lucas Heights, NSW, Australia
[2] Physikalisch–Technische Bundesanstalt (PTB), Braunschweig, Germany

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

Abstract

Radon gas is the largest source of public exposure to naturally occurring radioactivity, but its unique collection of physical characteristics also makes it an efficient and unambiguous tracer of atmospheric transport and mixing processes. Consequently, there is an overlapping need of radiation protection, climate and air quality research communities, globally, for an increased number of long-term, high temporal resolution measurements of atmospheric radon concentrations with low measurement uncertainty. While ANSTO-built dual-flow-loop two-filter detectors have long been recognised as the most reliable and sensitive radon monitors in the world (WMO, 2004; Williams and Chambers, 2016; Chambers et al. 2018), their large size (1500 L), high flow rates (80 L·min^{-1} – 100 L·min^{-1}) and slow response time (Griffiths et al. 2016) have so far made it impractical to devise and implement a calibration strategy that is traceable to the International System of Units (SI).

Recently, in collaboration with PTB and as part of the 19ENV01 *traceRadon* Project[§], ANSTO has designed and built a prototype portable (200 L) two-filter radon detector with an operating flow rate of only (10 L·min^{-1} – 15 L·min^{-1}). As a direct result of its portability and low flow rate, as well as the recent development of low level, high-accuracy calibration sources (Mertes et al. 2021), PTB researchers have successfully devised a calibration method that will enable an SI traceable calibration to be conducted at environmental radon concentrations for the first time (Röttger et al. 2021). This talk will outline the calibration experiment as well as plans to use this instrument to transfer traceable calibrations to new and existing radon monitors with contrasting operating principles in radiation protection and climate research station networks globally.



Left: Prototype 200 L dual-flow-loop two-filter radon monitor, designed and built at ANSTO, operating inside the PTB controlled climate calibration chamber. **Right:** Response of the 200 L detector (at 30-min temporal resolution) according to activity concentration levels established in the PTB calibration chamber.

References

Chambers, S. D., S. Preunkert, R. Weller, S.-B. Hong, and co-authors (2018). Characterizing Atmospheric Transport Pathways to Antarctica and the Remote Southern Ocean Using Radon-222. *Front. Earth Sci*. 6:190, 1-28. doi:10.3389/feart.2018.00190

Griffiths, A. D., S. D. Chambers, A. G. Williams and S. Werczynski (2016). Increasing the accuracy and temporal resolution of two-filter radon–222 measurements by correcting for the instrument response. *Atmos. Meas. Tech*., 9, 2689–2707. doi:10.5194/amt-9-2689-2016

Mertes, F., S. Röttger and A. Röttger (2021). Development of ^{222}Rn emanation sources with integrated, quasi 2π active monitoring. *Int. J. Environ. Res. Public Health* (submitted).

Röttger, A., S. Röttger, C. Grossi, A. Vargas, R. Curcoll, P. Otáhal, M. Á. Hernández-Ceballos, G. Cinelli, S. Chambers, S. A. Barbosa, M.-R. Ioan, I. Radulescu, D. Kikaj, E. Chung, T. Arnold, C. Yver-Kwok, M. Fuente, F. Mertes and V. Morosh (2021). New metrology for radon at the environmental level. *Meas. Sci. Technol*. 32, 124008. doi:10.1088/1361-6501/ac298d

Williams, A. G., and S. D. Chambers (2016). A history of radon measurements at Cape Grim. *Baseline Atmospheric Program (Australia) History and Recollections* (40th Anniversary Special Edition), 131–146.

WMO (2004). Summary and working group reports, WMO-GAW 1st International experts meeting on sources and measurements of natural radionuclides applied to climate & air quality studies, 3-5 June 2003, Gif sur Yvette, France, L. A. Barrie and H. N. Lee (eds.), WMO TD No. 1201, Report No. 155, 1–19.

This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19ENV01 *traceRadon* denotes the EMPIR project reference.

Estimating the impact of front window contamination on aerosol optical depth (AOD) measurements at Cape Grim

S. R. Wilson*

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

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

Abstract

The signal measured when observing the sun directly (S) at a single wavelength can be related to the signal that the instrument would observe at the top of the atmosphere (S_0) via a form of the Beer-Lambert law:

$$ln(S) = ln(S_0) - C(t) - \sum m_i \delta_i$$

The term $m_i\delta_i$ describes the decrease in intensity due to aerosol scattering, molecular scattering or molecular absorption multiplied by the path through the atmosphere as expressed as an air mass m_i, where viewing a source directly overhead will have an air mass of 1. The term *C(t)* has been added to the normal formulation to describe the impact of contamination of the front window at the measurement site, where *t* is the time since the window was cleaned.

Three ways have been identified to quantify the rate of contamination C(t) (assumed linear (=C.t)) from data collected at Cape Grim. First, the observed in situ calibration will depend on time since cleaning (I). Second, the calibration in situ can be compared to a calibration of the same instrument made at a 'clean' site (II) (see Fig. 1). Third, the retrieved AOD will also depend on the time since cleaning (III). The results for these three methods are shown in Table 1.

An estimate of C of 5 x 10^{-4} h^{-1} implies that 1 day after cleaning the retrieved AOD will be biased high at midday (summer) by 0.01 compared with a typical retrieved aod at this time of around 0.08. Note that this bias will be less when the sun is lower in the sky. Constraining this term will allow the AOD record to be filtered using the cleaning record with a determined level of uncertainty due to contamination.

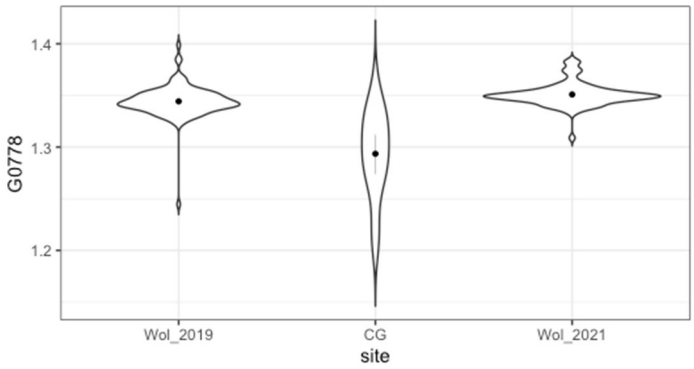


Fig 1. Calibration retrieved at Wollongong (Wol) and Kennaook/Cape Grim (CG) for one wavelength (778 nm) for use with method II. Note that the data for the CG deployment is incomplete.

Method of determination	Sunphotometer (wavelengths)	C (x 10^{-4} h^{-1})
I	SP01a (all)	4 (3,5)
II	SP02 (not 368 nm)	9 (1,10)
III	WMO#1	6.3 (6.2,6.4)
	SP01a	3.0 (2.8, 3.2)
	SP02	4.4 (4.3,4.5)

Table 1. Estimate of the contamination factor (C) for deployment at Cape Grim/ Kennaook. Note that data comes from WMO#1 (1986 – 1996), SP01a (1997 – 2006) and SP02 (2001 – 2019) for method C (and A). Numbers are estimates with 95% confidence intervals in brackets. Data for method B is incomplete.

An overview of the Aspendale/Laverton/Broadmeadows ozonesonde record

M. B. Tully[1*], I. E. Galbally[2] and A. R. Klekociuk[3]

[1] Bureau of Meteorology, Melbourne, Victoria
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[3] Australian Antarctic Division, Hobart, Tasmania

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

Abstract

Systematic launching of Balloon-borne chemical ozonesondes has been undertaken in the greater Melbourne area from 1965 to the present day. If considered as one record, it lays claim to being one of the oldest in the world and provides an invaluable history of changes in ozone in the southern hemisphere mid-latitudes in the middle and lower stratosphere and free troposphere.

Ozonesondes were first flown by CSIRO from Aspendale, now a south-eastern suburb of Melbourne, in 1965.

In 1983 responsibility for the program was transferred to the Bureau of Meteorology and the launch site moved to Laverton, in Melbourne's south-west. The location was changed again in 1999 to Broadmeadows, in Melbourne's north-west, and has remained there to the present time.

The frequency of launches has varied over this time, initially more than one per week from 1965 to 1973 but reducing thereafter. Since 1993, a schedule of one launch per week has largely been maintained.

The major equipment changes over the period took place in the early 1990s with the transition from the original Brewer-Mast sondes to the current Electrochemical Concentration (ECC) design, although other smaller changes, including to the accompanying radiosonde, also need to be accounted for in the data.

Here, the full 1965–2021 record will be presented, in a preliminary form following some initial attempts at removing instrumental inhomogeneities, including changes observed over time to the annual cycle at selected pressure levels.

Early vortex break-ups in the ACCESS-CM2-Chem model

F. W. Dennison

CSIRO, Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

Stratospheric sudden warming (SSW) events are characterised by an early breakup of the polar vortex. In the Southern Hemisphere these events are rare, only two major SSWs have been observed (in 2002 and 2019), while in the Northern Hemisphere they occur at a frequency of six per decade [Butler, 2021]. The rarity of these events mean that these events are not as well understood as their Northern Hemisphere counterparts. Also, in the Southern Hemisphere, pronounced ozone depletion – known to strengthen the vortex – may play some role in the incidence of the events. These factors make chemistry-climate models a suitable tool for investigating the phenomenon.

Using the ACCESS-CM2-Chem chemistry-climate model, two early break-up events have been identified in free-running historical simulations. While not as sudden as either of the observed SSWs, these events are similar in that the vortex break up occurs more than one month earlier than normal and the ozone hole gets displaced toward the Atlantic (similar to the observed 2019 vortex break-up). In this study, we examine the mechanisms of these early vortex break-up events in the model and compare them to the observed SSWs.

References

Butler, A. H. (2021), https://csl.noaa.gov/groups/csl8/sswcompendium/majorevents.html. Retrieved 14/6/2021

The 2021 Antarctic ozone hole

P. B. Krummel[1*], A. R. Klekociuk[2], M. B. Tully[3], P. J. Fraser[1] and N. Derek[1]

[1] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria, Australia
[2] Australian Antarctic Division, Hobart, Tasmania, Australia
[3] Australian Bureau of Meteorology, Melbourne, Victoria, Australia

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

Abstract

The 2021 ozone hole developed in earnest in early to mid-August and reached about 25 million km^2 in area in late-September/early-October. Since then and until the second week of November, the 2021 ozone hole has remained relatively large and persistent and closely mirrored the 2020 Antarctic ozone hole. This is a result of a very stable and strong polar vortex again in 2021, which is quite similar to 2020. Mid- to low-stratospheric temperatures have been colder than average for the entire ozone hole season so far due to low levels of heat transport towards the pole. These conditions are ideal for stratospheric ozone depletion chemistry. Some of the ozone hole metrics in 2021 are in the top 10 largest/deepest holes ever.

This presentation will give an update on 2021 Antarctic ozone hole season and how the 2021 ozone hole metrics compare to the historical metrics from the last 42 years of satellite measurement.

Radon-derived baseline determination across the Southern Ocean

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
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[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

We postulate that, due to the properties of ^{222}Rn (radon), there exists in the Marine Atmospheric Boundary Layer (MABL) over the central latitudes of the Southern Ocean (SO) north of the polar front, a narrow but persistent range of radon concentrations resulting from an equilibrium that forms on timescales greater than 2-3 weeks. The radon equilibrium is maintained by a balance between the average regional radon flux from the SO surface, vigorous mixing due to high wind speeds within the MABL, and radon's radioactive decay ($t_{½}$ = 3.82d). The resultant narrow range of concentrations is expected to vary little in space and time across the SO, because although there may be geographical and seasonal variations in suspended surface sediment loads (containing Ra-226, radon's particulate parent), wind speeds (modulating surface emissions by altering wave heights and breaking characteristics), MABL depth (vertical dilution) and exchange with the free troposphere (venting, modulated by clouds), all these variations are expected to be small in this region and slowly changing on timescales comparable to radon's half-life.

Superimposed upon the radon equilibrium range are short periods of elevated radon concentrations corresponding to air parcels arriving at SO measurement sites from distant landmasses on timescales of up to a few weeks. In the central latitudes of the SO, most of these events travel predominantly in the MABL (although some may enter the MABL from the free atmosphere above, via synoptic frontal injections), and carry with them greenhouse gases, ozone-depleting substances, and fine particle pollutants of continental origin, with varying sources/sinks and atmospheric residence times. Together with large-scale hemispheric, polar, and cross-equatorial circulation patterns, this direct transport in the MABL of trace species from regional terrestrial sources represents one of the most significant mechanisms contributing to the mean chemical composition (the so-called 'baseline' signal) of the SO atmosphere.

We demonstrate the existence of the SO radon equilibrium range using measurements at five widely distributed and geographically diverse Southern Ocean stations (Cape Grim CGO, Cape Point CPT, Baring Head BHD, Macquarie Island MQA and King Sejong KSG) and aboard the *RV Investigator*, and employ it to define consistent, robust and unambiguous radon-only criteria for determination of the hemispheric 'baseline' for long-lived trace species CO_2 and CH_4. Trends and seasonality in the multi-year baseline signals derived using the radon-only criteria are found to be remarkably consistent across all the SO stations for the entire study period (Figs 1&2). This indicates that the baseline signals derived for long-lived trace species across the central latitudes of the SO north of the polar front are largely location-independent, suggesting that a well-mixed airmass representing a balance between averaged sources, sinks and transport for these species exists across the entire SO region and is maintained on timescales of weeks.

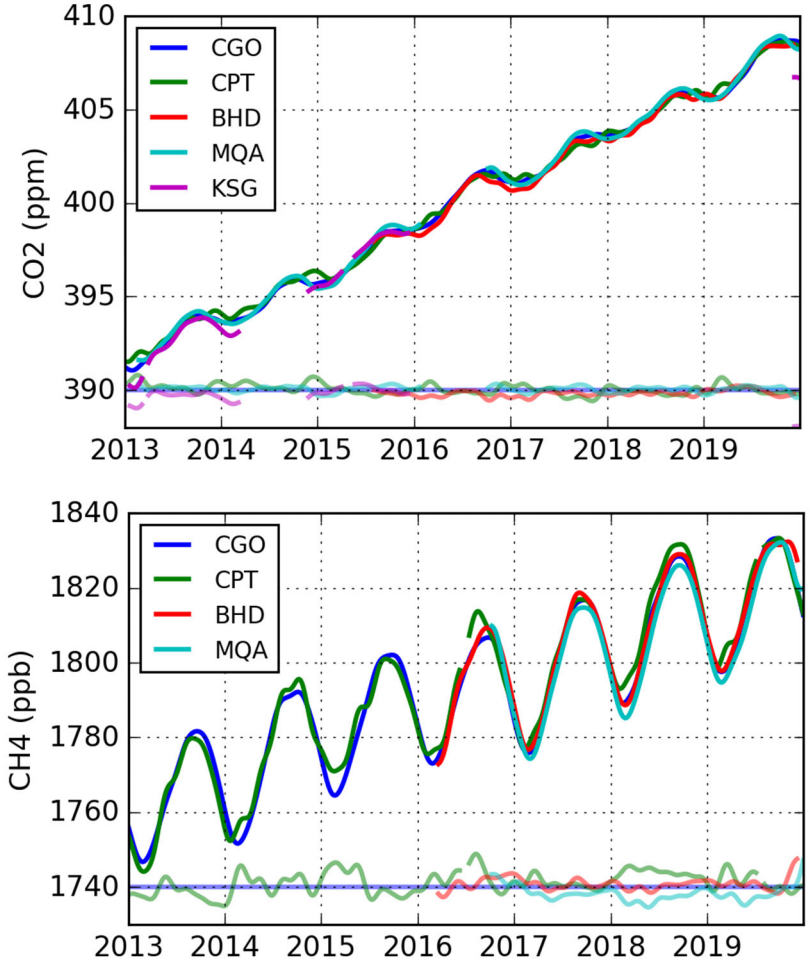


Figure 1. Baseline-selected CO_2 (upper) and CH_4 (lower) concentrations for 2013-2019, based on radon-only selection criteria with outlier removal and using the NOAA curve-fitting algorithm, for five geographically diverse Southern Ocean sites. Also shown are differences relative to Cape Grim (transparent offset curves). Note no CH_4 data for KSG.

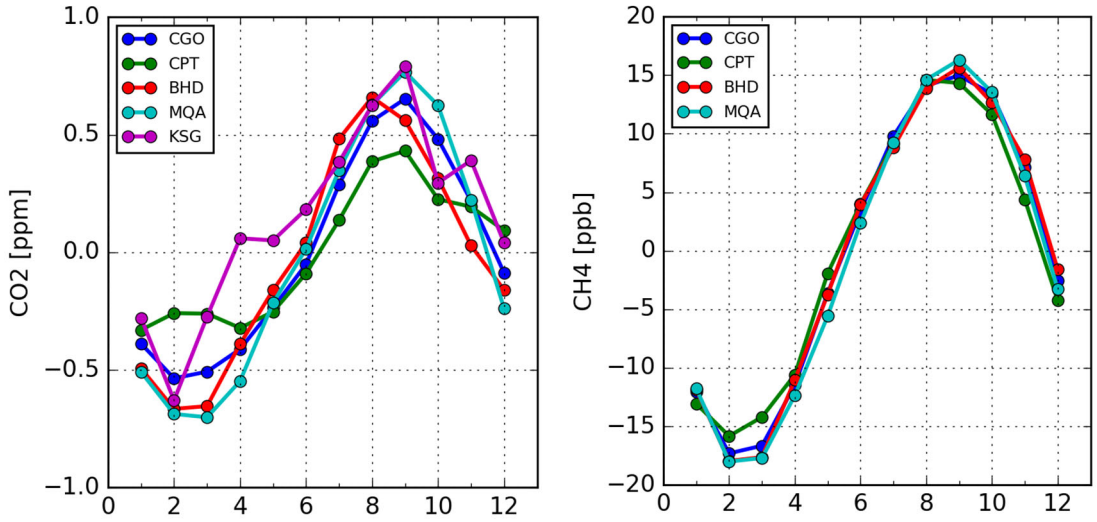


Figure 2: Seasonal variability in baseline-selected CO_2 (left) and CH_4 (right) in 2013-2019 with multi-year trend removed, for five geographically diverse Southern Ocean sites. Note no CH_4 data for KSG.

Using environmental variables to develop a predictive model for concentrations of tropospheric bromine and mercury in coastal Antarctica

N. Page[1*], J. A. Fisher[1], S. R. Wilson[1], R. Schofield[2], R. G. Ryan[2], S. Gribben[3] and A. R. Klekociuk[4]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW,
[2] School of Earth Sciences, University of Melbourne, Melbourne, Victoria
[3] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[4] Australian Antarctic Division, Kingston, Tasmania

[*] corresponding author: Neil Page [ncp532@uowmail.edu.au]

Abstract

The production and distribution of bromine radicals in coastal Antarctica affects the chemistry and oxidising capacity of the polar troposphere, removing ambient ozone and oxidising gaseous elemental mercury (Hg^0). Sea ice cover, the snowpack residing on top and sea salt aerosols are all thought to release bromine, but the relative contribution of each source is not fully understood. Additionally, the role of environmental and atmospheric conditions that control bromine and mercury cycling are poorly characterised.

MAX-DOAS (Multi-AXis-Differential Optical Absorption Spectroscopy) retrievals of atmospheric bromine monoxide (BrO) and Tekran 2537 observations of Hg^0 were made onboard the Australian icebreaker RSV Aurora Australis during the Chemical and Mesoscale Mechanisms of polar Cell Aerosol Nucleation (CAMMPCAN) campaign between October and March over a 2-year period. The campaign involved 6 research voyages spanning three seasons each year that traversed the Southern Ocean from Australia to Antarctica.

An environmental dataset for the Antarctic was created by combining meteorological observations from the Aurora Australis, meteorological fields from the Modern Era Retrospective Analysis for Research and Applications version 2 (MERRA-2), satellite observations of sea ice cover and ice contact time calculated using HYSPLIT back trajectories. Principal component analysis (PCA) was then undertaken on the environmental dataset to determine the dominant modes of variability. The PCA derived three important principal components from the environmental dataset. The first principal component (PC1) is consistent with a vertical mixing mode associated with low pressure systems. The second principal component (PC2) describes a blowing snow mode associated with high wind speeds and increased sea ice contact. The third principal component (PC3) consists of increased wind speeds, high chlorophyll concentrations in surface water and decreased sea ice cover that are consistent with an ocean biological source. The three principal components were then fitted (via principal component regression (PCR)) against the observations of BrO and Hg^0 to develop separate predictive models for BrO and Hg^0 in the Antarctic.

Results showed that the dominant Antarctic principal components could be used to predict concentrations of both Hg^0 and lower tropospheric BrO. Predictions of Hg^0 from this model had an R^2 of 0.48 against the observed Hg^0 concentrations, higher than the R^2 for BrO of 0.26. For BrO, the model reiterates the importance of sea ice cover and suggests that biological bromine sources could be of key importance during the Antarctic summer. Biological activity has also been suggested as a source for Hg^0 emissions. However, the results here suggest that the ocean biological source has a bigger influence on BrO than for Hg^0. Finally, regression analysis suggested that the most important variables for observed Hg^0 variability in coastal Antarctica were relative humidity, land contact time and the potential temperature differential in the lowest 100 m (a measure of atmospheric stability).

Climate Drivers of Salinity in Macquarie Island Lakes

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

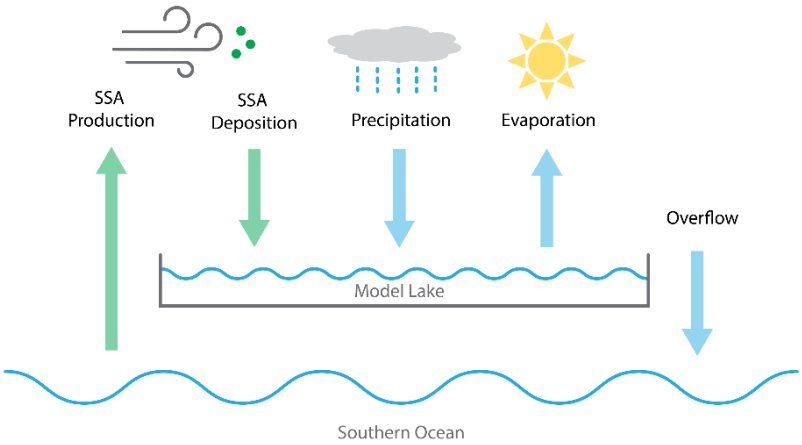
[1] ANSTO Environmental Research Theme, Lucas Heights, NSW
[2] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania
[3] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW

[*] corresponding author: Keita Richardson [richardk@ansto.gov.au]

Abstract

The Southern Ocean carbon sink is an important regulator of climate change, being currently responsible for ~43% of global anthropogenic CO_2 uptake. The capacity of this carbon sink is in turn affected by the Southern Hemisphere westerly winds (SHW), through modulation of ocean upwelling and circulation. This has motivated paleoclimatic studies of the SHW including those that concentrate on sub-Antarctic Macquarie Island lakes. A key hypothesis of these studies is that the flux of sea salt into lakes on the western side of the island is modulated primarily by SHW strength due to the location of Macquarie Island, at 54°S, in the band of the strongest SHW winds. In turn, deposition flux is proposed to be the main driver of lake salinity. As a result, proxies for salinity in lake sediment cores have been interpreted as a signal of past changes in the strength of SHW winds.

This work seeks to test the hypothesis using a simple lake model driven by observed meteorological data from Macquarie Island, which is available from 1951–present. The model is conceptualised as an evaporation pan with an input sea spray aerosol flux that matches the local production rate. The model exhibits low-frequency variability over the study period and predicts salinity values which are broadly in agreement with spot measurements. A sensitivity analysis of the model shows that long term trends in the modelled salinity are indeed driven by long-term trends in windspeed, but that other parameters are also important over the monitoring period. In particular, long-term trends in observed precipitation and humidity are of comparable importance to changes in wind speed.



Overview of the physical processes captured by our model evaporation pan with sea spray aerosol input.

References

Saunders, K. M., S. J. Roberts, B. Perren et al. (2018). Holocene dynamics of the Southern Hemisphere westerly winds and possible links to CO_2 outgassing. *Nature Geosci* 11, 650–655. doi:10.1038/s41561-018-0186-5

PICCAASO – Partnerships for Investigating Clouds and the biogeoChemistry of the Atmosphere in Antarctica and the Southern Ocean

R. Humphries[1,2*], M. Mallet[2], S. Fiddes[2] and many others

[1] Climate Science Centre, Oceans and Atmosphere Business Unit, CSIRO, Melbourne, Australia
[2] Australian Antarctic Program Partnership, University of Tasmania, Hobart, Australia

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

Abstract

The Antarctic and Southern Ocean region is one of the most pristine in the region. This relative absence of anthropogenic influence provides a unique testbed for studying natural physical and chemical processes. In the context of the impact of aerosols and cloud on the climate system, observations in these environments provide the biggest reductions of uncertainties in climate and earth system models at a global scale [Regayre et al. 2020].

The natural processes in the region are complex and multidisciplinary. The particular biodiversity of a phytoplankton population influences the magnitude of their emissions of key sulfur and organic compounds. Sulfur compounds end up in the atmosphere and after complex photochemistry, end up in the aerosol phase and drive the concentrations of CCN. Organics in aqueous phase are incorporated into sea spray aerosol, changing their composition. Aerosol properties, particularly at the low concentrations observed in pristine regions, are major controllers of cloud properties, and subsequently on precipitation and radiation.

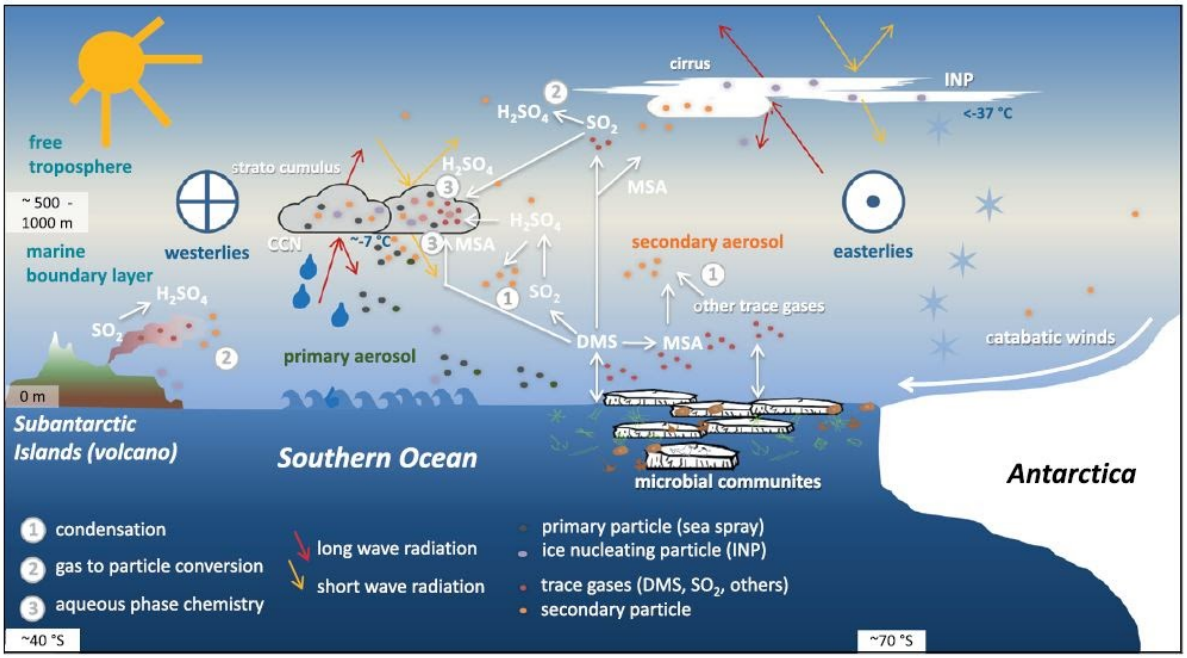
There are many outstanding questions in this research space. These questions can only be answered by increasing the number and range of observations in this remote environment, and collaborating closely with modellers. To this end, we have identified 18 fully funded or proposed campaigns in the region over the coming 5 years, which complement the 12 long-term stations in the region. Most of these projects were conceptualised independently but share common objectives.

PICCAASO is a recently formed initiative whose goal is to form a coordinated and united global effort. It encourages closer ties between the multiple disciplines that we need working in this space, in order to answer the complex scientific questions. The enhanced collaboration facilitated through PICCAASO, we hope to magnify the impact of this important science, providing the most comprehensive understanding of how life in the Antarctic and Southern Ocean region influences climate, and helping to accelerate model development to help guide us through our rapidly changing climate.

References

Regayre, L. A., J. Schmale, J. S. Johnson et al. (2020). The value of remote marine aerosol measurements for constraining radiative forcing uncertainty. *Atmos. Chem. Phys.* 20, 10063–10072. doi:10.5194/acp-20-10063-2020

Schmale, J., A. Baccarini, I. Thurnherr et al. (2019). Overview of the Antarctic circumnavigation expedition: Study of preindustrial-like aerosols and their climate effects (ACE-SPACE). *Bull. Amer. Meteorol. Soc.* 100, 2260–2283. doi:10.1175/BAMS-D-18-0187.1



Schematic of the complex processes occurring in the summertime over the Southern Ocean. Figure from Schmale et al. (2019)

Investigating 3-11 nm particle events at Cape Grim between 2013-2020

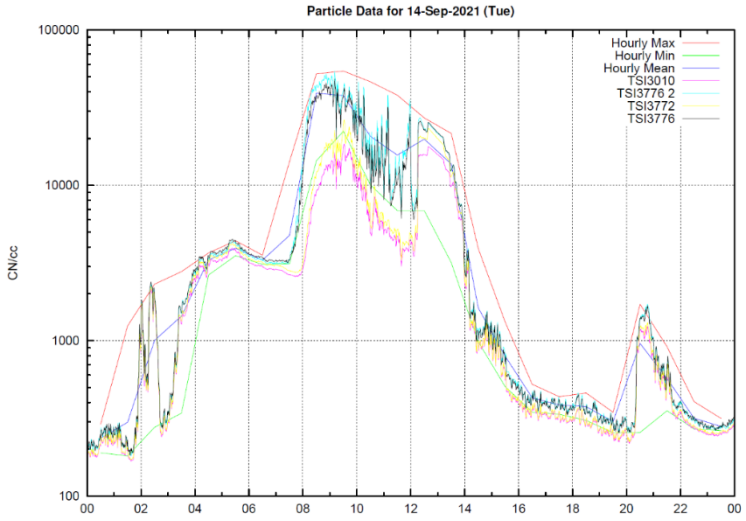
M. D. Keywood[1*], J. P. Ward[1], J. N. Harnwell[1], Y. Lai[2], J. Park[2], Y. Sun[2] and Y. Wang[2]

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

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

Abstract

The measurement of particle number concentration between for particles greater than 3 nm (CN3) and 11 nm (CN11) is a fundamental activity of the particle observations at Cape Grim, with these measurements being carried out since 1977 for CN3 and 1994 for CN11. The difference between CN3 and CN11 is a measure of the number of particles between 3–11 nm in diameter and potentially an indicator of the formation of new particles. Jimi et al. (2008) and Gras et al. (2009) investigated these particles in datasets collected in 1999 and 2000 in the baseline sector and suggested that enhancements in 3–11 nm particles were associated with the passage of cold fronts, with nanoparticles that formed at or just above the boundary layer inversion being entrained into the free troposphere after the passage of the front.



Example of enhancement in 3-11 nm particles over the course of 24 hours on 14 Sept 2021 (from CG BAPS Daily Report).

Since that work, periods of elevated 3-11 nm particle concentrations continue to be observed (Figure X) in the baseline and non-baseline sector (Figure). In this presentation we present an analysis of the climatology of these events for the period 2013-2020 to identify the conditions (season, time of day, meteorological conditions) under which these episodes occur. Inspection of the CG BAPS Daily Reports suggests that (anecdotally) these episodes may be occurring more frequently….but are they?

References

Jimi, S. I., S. T. Siems, J. L. McGregor, J. L. Gras, and J. J. Katzfey (2008). An investigation into the origin of aerosol nucleation events observed in the Southern Ocean boundary layer. *Aust. Meteorol. Mag.* 57(2), 85–93.

Gras, J. L., S. I. Jimi, S. T. Siems and P. B. Krummel (2009). Postfrontal nanoparticles at Cape Grim: observations. [Article]. *Environ. Chem.* 6(6), 508–514. doi:10.1071/EN09075

Preliminary analysis on the secondary organic aerosol formation during the COALA-2020 campaign

J. Ramirez-Gamboa[1*], C. Paton-Walsh[1], J. B. Simmons[1], M. D. Keywood[2], A. Mouat[3] and J. Kaiser[3]

[1] Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, NSW
[2] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[3] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia, USA

[*] corresponding author: Jhonathan Ramirez [jrg604@uowmail.edu.au]

Abstract

Aerosols play an important role in atmospheric processes influencing cloud formation, scattering and absorbing solar radiation, and as a part of the chemical reactions affecting the abundance of trace gases in the atmosphere. Ultimately aerosols affect the radiative balance of the earth modifying climate. Aerosols can be categorized into anthropogenic and natural aerosols depending on the source. A large fraction of aerosols is formed through chemical reactions following *"gas to particulate"* processes in the atmosphere: nucleation, condensation and growth. Biogenic Secondary Organic Aerosols (BSOA) are formed when plant produced volatile organic compounds (VOCs) react in the atmosphere through heterogeneous reactions. South-east Australia is one of the locations with high emissions of biogenic VOCs in the world given the high density and population of Eucalyptus species considered as one of the high emitters among the plant species.

During the COALA-2020 campaign many new particle formation (NPF) events were registered after the Black summer fires. Using the growth rate and the changes in the geometric diameter during the NPF along with the chemical aerosol composition, we found that the relative aerosol composition changes during the particle formation. Similar analysis using the sulphur dioxide and nitrogen oxides along with the VOC load can help to identify which factors are driving or impeding the aerosol formation in the atmosphere. This presentation provides a summary of the preliminary results of this characterization and the future work planned to characterize the aerosol formation observed during the COALA-2020 campaign.

Estimating smoke emissions using bottom-up and top-down methods

F. Reisen*, M. E. Cope, J. A. Noonan, C. T. Roulston, J. C. Powell and A. K. Luhar

CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria

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

Abstract

The quantification of emissions from fires and planned burns presents a large source of uncertainty for accurately forecasting smoke impacts. Two approaches currently see widespread use in short-term forecasting systems.

- Bottom-up approach where emissions are estimated as follows:

$$E = A \times FL \times Z \times EF \quad (1)$$

  Where A is burned area (m2), FL is the fuel load (kg fuel/m2), Z is the burning efficiency (%) and EF is the species-specific emission factor (g/kg fuel)

- Top-down approach where emissions are estimated using satellite observations of fire radiative power (FRP)

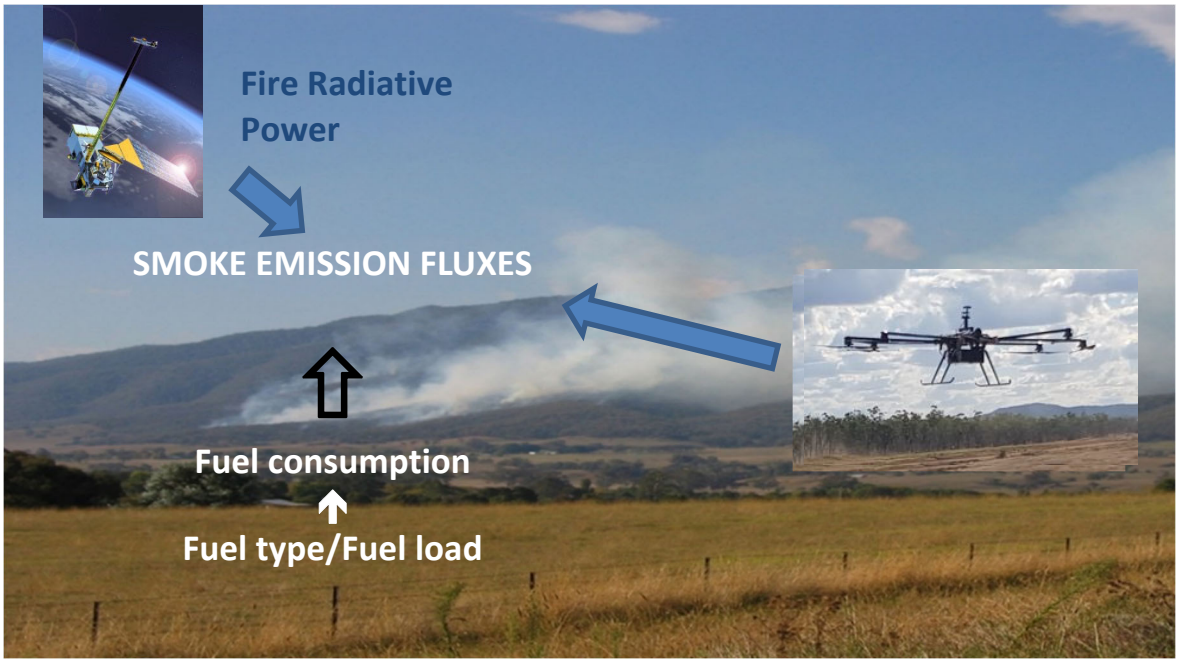
$$E = \alpha \times EF \times \int_{t1}^{t2} FRP(t)dt \quad (2)$$

  Where α is the emission coefficient (kg fuel/J), EF is the species-specific emissions factor (g/kg fuel)

Both approaches have advantages and disadvantages with (1) being dependent on accurately describing fuel load and the proportion of the available fuel that is consumed; (2) relies on the integration of a snapshot of FRP over the fire duration relying on data from polar-orbiting satellite observations.

Fortunately, recent advances in remote sensing, coupled with the development of low-cost aerial platforms (drone), and new analysis techniques based on machine learning provide a pathway for reducing emission uncertainties, and thereby improving the accuracy of smoke forecasting.

In this talk I will present the different approaches in quantifying smoke emissions, a bottom-up approach currently used in the AQFx smoke forecasting system and future implementation of top-down approaches using satellite observations of fire radiative power as well as drone technology and inverse modelling.



Smoke plume composition and relative toxicological impacts of atmospheric species from the 'Black Summer' bushfires

J. 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. A. Naylor[1] and J. Ramirez-Gamboa[1]

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

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

Abstract

The 2019-2020 Australian bushfire season was historically large, long, and intense. Smoke from fires burning in southeast Australia blanketed population centres for weeks to months. This study reports the chemical composition in the gas and aerosol phase of aged plumes measured near Wollongong, NSW in early 2020 during the COALA-2020 campaign. Enhancement ratios to CO are presented for a range of gas- and particle-phase species measured during the campaign. The relative toxicological contribution of species present in the plumes was deter-mined for dilute plume exposure at the measurement site and for concentrated plumes at a heavily impacted population centre case study using an additive toxicological class framework and are presented here. Significant contributions are observed from respirable particles, acrolein and formaldehyde.

Can we see the impact of indigenous fire management on the temporal shift in atmospheric carbon monoxide in Northern Australia?

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

Centre for Atmospheric Chemistry (CAC), University of Wollongong, Wollongong, NSW

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

Abstract

Fire is an essential global phenomenon that existed soon after the appearance of terrestrial plants and is vital for the regeneration of the plant species. Human activities have contributed to a changing climate and impacted fire regimes, resulting in more intense, frequent and severe fires. In particular, the 2019-20 bushfires in south-eastern Australia were unprecedented in their extent and intensity. However, human activities can also play a dominant role in regulating fire behaviour effectively through better 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.

Biomass burning can emit many chemical species that have an impact on human health. One of the most abundant and widely measured is carbon monoxide (CO), whose long-term exposure can lead to potential human health risk. CO is also a good proxy for emissions of other shorter-lived and harder-to-measure atmospheric constituents. This study is focussed on understanding to what extent the earlier fire season in Northern Australia impacts seasonal variability of CO measured at Darwin. Column CO data from the ground-based Total Carbon Column Observing Network site in Darwin will be used together with surface measurements, complemented by the surface mixing ratio observations from the satellite-based sensor MOPITT. 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. Overall, the results of this study will allow us to better understand the effect of local fire emissions on the surface and column CO at Darwin.

Forecasting dust pollution events in Brooklyn

S. R. Utembe[1*], R. Fedele[1], C. Bydder[1], J. Choi[1], M.-B. di Folco[1], G. Fisher[1], P. Torre[1] and J. D. Silver[2]

[1] Environment Protection Authority Victoria, Macleod, Victoria
[2] School of Earth Sciences, University of Melbourne, Melbourne, Victoria

[*] corresponding author: Steven Utembe [steven.utembe@epa.vic.gov.au]

Abstract

Dust pollution caused by industrial activities, has been a persistent problem in Brooklyn, a Melbournian suburb that is located to the west of Melbourne CBD. Dust exposure affects respiratory and pulmonary health. Large particles of dust are known to irritate the eyes, nose and throat whereas the smaller particles may get deep into the lungs and thereby cause serious health effects. In this study, machine learning is used as an early warning tool to predict next day dust forecast conditions for Brooklyn. The methodology uses predicted atmospheric variables from ACCESS-R model and measured PM10 concentrations at an EPA measurement site in Brooklyn. Using 2 years of measured PM_{10} and predicted meteorological data as training data, to predict dust conditions of the next 2 years as test data, the forecasting tool is able to predict 77% of correct forecasts, with a probability of detection of a pollution event of 0.67. This is holding much promise as an early warning tool for dust prediction in Brooklyn. The forecasts can be used by both sensitive groups and industry to take extract precautions to protect themselves from dust and minimise dust pollution, respectively. This technique identifies the potential to use machine learning to forecast dust effects in other areas throughout Australia.

Impacts of COVID-19 lockdowns on air quality in Western Sydney

Y. Chen[1], C. Paton-Walsh[1*], T. A. Naylor[1], N. M. Deutscher[1], S. D. Chambers[1,2], H. Duc[3], T. Trieu[3], S. White[3] and J. N. R. Capnerhurst[3]

[1] Centre for Atmospheric Chemistry, School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW
[2] Environmental Research, ANSTO, Lucas Heights, NSW
[3] Department of Planning, Industry and Environment, Lidcombe, NSW

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

Abstract

In this study, we investigate the variation in pollutant concentrations in the Lidcombe suburb of western Sydney during the COVID-19 lockdown periods. The study focuses on carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), ozone and particulate matter less than 2.5 µm in diameter ($PM_{2.5}$). The potential emission intensity from vehicles is analysed by comparing the daily and monthly cycles of traffic flow. Pasquill-Gifford stability classification is used to assess the atmospheric mixing state during the lockdown and non-lockdown periods, to determine the likelihood of contrasting levels of pollutant dilution. Greenhouse gases measurements and modelled boundary layer height were also compared to further understand the dilution effect of atmospheric mixing. The study found that there was no significant difference in monthly mean atmospheric stability during the lockdown and reference periods. Decreases in the ambient concentrations of CO, NO, NO_2 and $PM_{2.5}$ were observed during both lockdown periods, accompanied by a slight increase in ozone concentrations. The changes in air pollutant concentrations are most likely caused primarily by a reduction of traffic flow during lockdown. The lockdown periods provide a good natural experiment for testing the skill of air quality models to capture the changes. We plan to use the data in the near future to test the skill of the Department of Planning Industry and Environment (DPIE) air quality model for New South Wales.

Evaluation of a residential intervention to reduce exposures to smoke events resulting from planned burns

A. J. Wheeler[1,2*], R. W. Allen[3], F. Reisen[4], C. T. Roulston[4], M. Dennekamp[5], N. Goodman[6] and F. H. Johnston[2].

[1] Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Victoria
[2] Menzies Institute for Medical Research, University of Tasmania, Hobart, Tasmania
[3] Faculty of Health Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada
[4] CSIRO Oceans and Atmosphere, Climate Science Centre, Aspendale, Victoria
[5] Environment Protection Authority Victoria, McLeod,Victoria
[6] Sustainable Building Innovation Laboratory, School of Property, Construction and Project Management RMIT University, Melbourne, Victoria

[*] corresponding author: Amanda J. Wheeler [Amanda.wheeler@acu.edu.au]

Abstract

Evidence conducted internationally has demonstrated that much of the outdoor air pollutants generated from smoke emissions are able to infiltrate indoors resulting in reductions in residential indoor air quality along with increased risks of exposure (Barn et al. 2008; Wheeler et al. 2014).

Concurrent indoor and outdoor particulate matter monitoring at 9 homes during the planned burn season was completed. This was conducted over a maximum of 4-weeks to capture both smoke events and baseline measures. The air quality sensor data was made available to the research team in real time using participant's existing communications network (wifi).

A portable HEPA cleaner was installed in each of the homes to evaluate their effectiveness at reducing elevated particulate matter resulting from planned burn emissions. This allowed the research team to evaluate the efficacy of closing doors and windows as well as operating the portable HEPA cleaner. Participants were asked to switch on the portable HEPA cleaners when smoke concentrations start to increase inside their home.

Figure 1 provides an example of data collected from indoor and outdoor $PM_{2.5}$ monitors and demonstrates the range in concentrations experienced as a result of the planned burns. The figure also demonstrates the time it can take for polluted outdoor air to penetrate the building envelope and reduce air quality indoors. The data can also be used to evaluate how quickly the indoor levels can return to background once outdoor levels have diminished. These data can be important to provide guidance for when homes should be ventilated after a smoke event has cleared.

Data from the majority of homes demonstrated the successful operation of the portable HEPA cleaner to reduce indoor $PM_{2.5}$ concentrations.

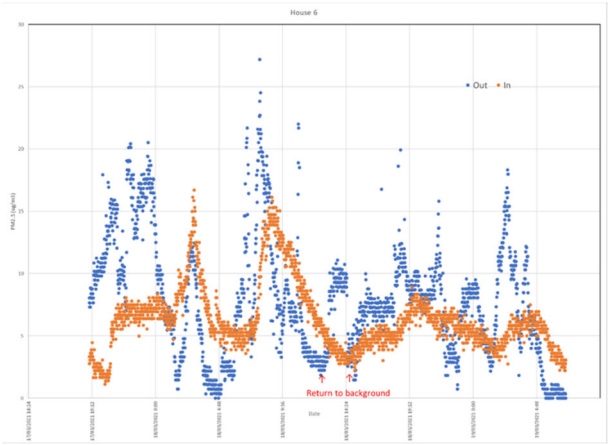


Figure 1. Example of indoor and outdoor $PM_{2.5}$ concentrations during a planned burn event.

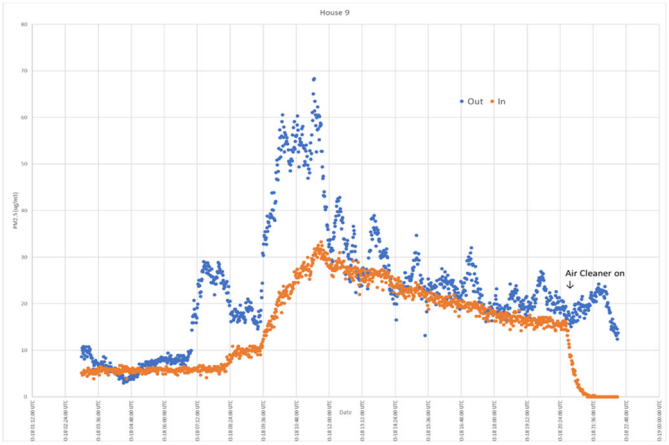


Figure 2. Example of indoor and outdoor $PM_{2.5}$ concentrations when operating a portable HEPA cleaner

References

Barn, P., T. Larson, M. Noullett,, S. Kennedy, R. Copes and M. Brauer (2008). Infiltration of forest fire and residential wood smoke: an evaluation of air cleaner effectiveness. J*. Expo. Sci. Environ. Epidemiol*. 18(5), 503–511. doi:10.1038/sj.jes.7500640

Wheeler, A. J., M. D. Gibson, M. MacNeill et al. (2014). Impacts of air cleaners on indoor air quality in residences impacted by wood smoke. *Environ. Sci. Technol*. 48(20), 12157–12163. doi:10.1021/es503144h