



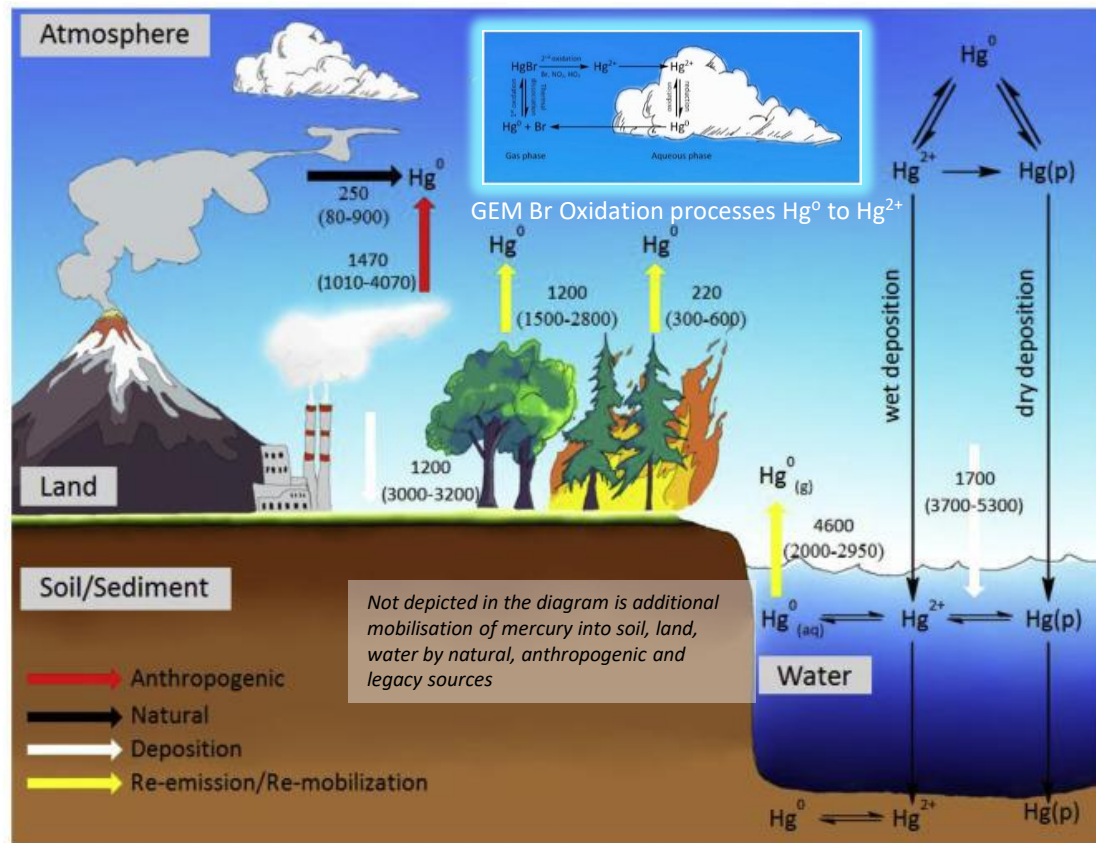
Mercury monitoring in Australia

*13th Annual
APMMN Partners
meeting*

Jennifer Powell | 4 September 2024



Atmospheric processes in mercury cycling



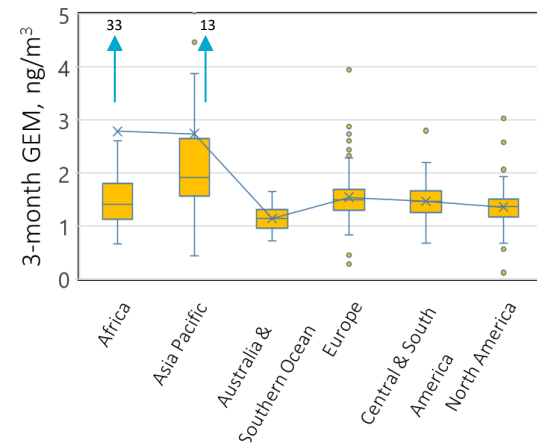
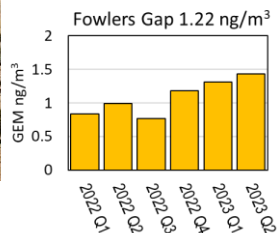
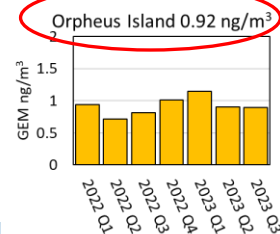
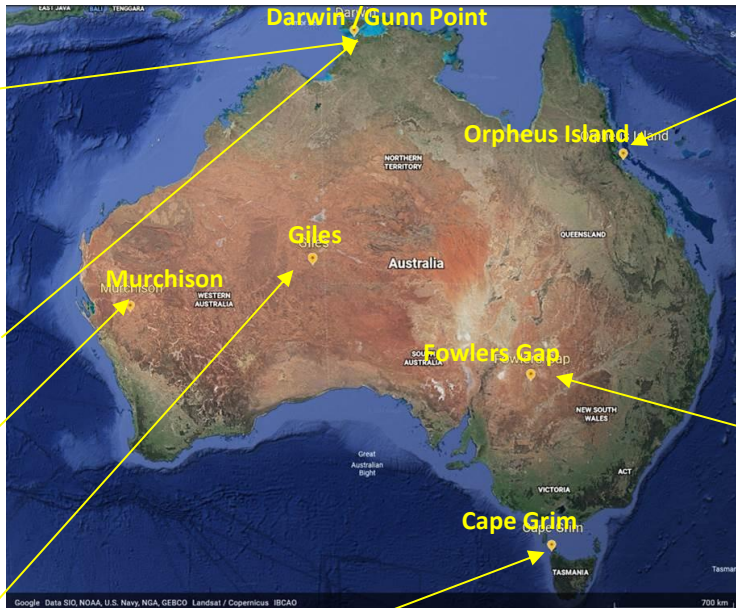
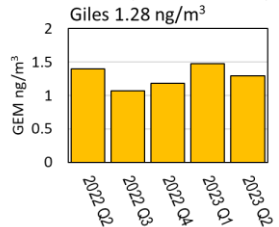
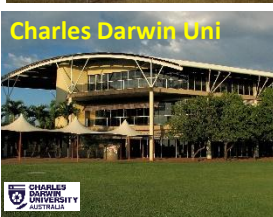
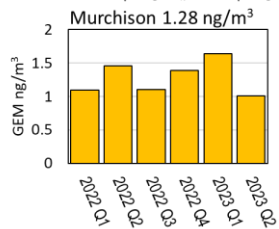
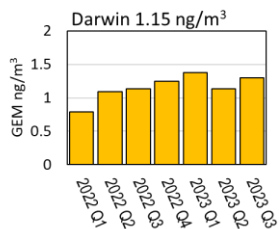
Biogeochemical cycle of mercury with estimates of global Hg^0 fluxes and the global mercury budget (shown in brackets). Gonzalez-Raymat et al 2017 <https://doi.org/10.1016/j.envpol.2017.04.101>

- Australian emissions to air mostly from natural sources: 72% soil & vegetation, 21% fires, 7% man-made (Nelson 2012). This contributes 0.4% to global emissions UNEP 2018
- Globally, atmospheric mercury **450% above natural levels** (UNEP 2018)
- Gaseous elemental mercury (GEM) comprises **95% atmospheric Hg**
- Lifetime 6-12 months → **long range transport**
- Oxidation of GEM to reactive, soluble species → **deposition of Hg^{2+} and Hg(p) into ocean**
- Mercury in ocean thermocline **150% above natural levels** (Lamborg et al 2014)
- Conversion to toxic methyl mercury in water → **bio-magnification in aquatic food web**
- Southern Hemisphere: **54% emissions from ocean** evasion of GEM
- Net effect of evasion vs deposition – is the Southern Ocean a source or sink?*



Active and passive sampling sites

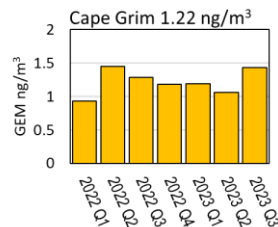
Lowest in world



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3-month sample periods, 2022-2024



Northern Australia mercury monitoring

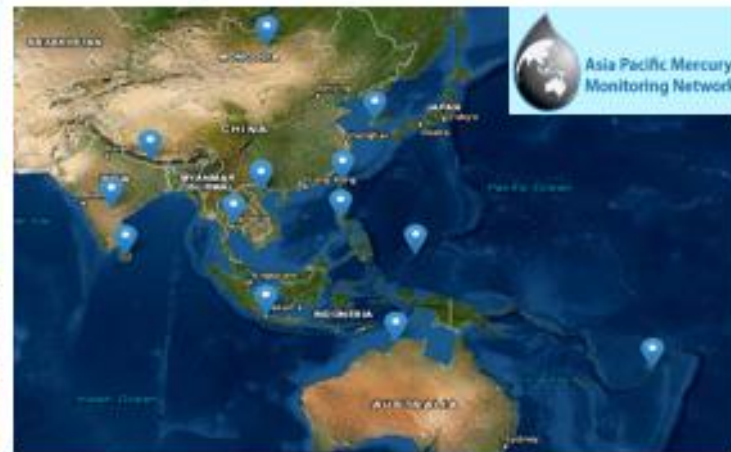
NTBAPS:
Tekran 2537x analyser
2014-2023 data
submitted for
Minamata
Effectiveness
Evaluation



APMMN Darwin site,
wet deposition
sampling, 2022 to
present



Northern Territory Baseline Air Pollution Station (NTBAPS) at Gunn Point



Charles Darwin University

1-week wet deposition samples

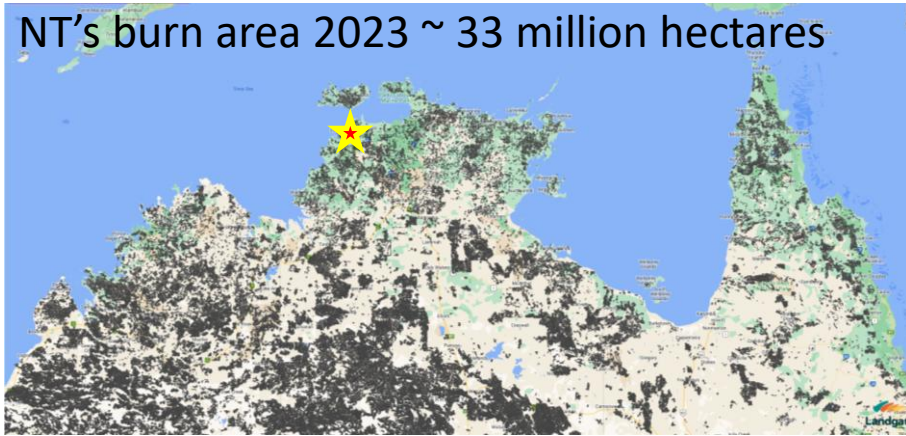
3-month Passive GEM samplers



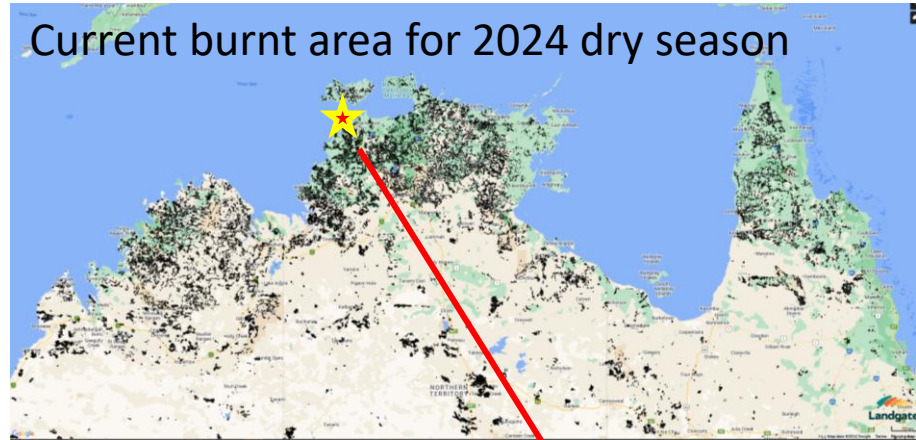


Dry season monitoring: savanna burning

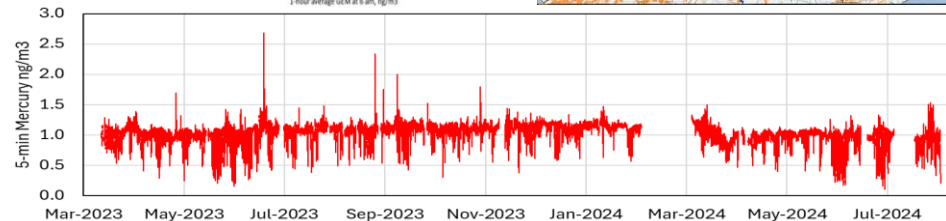
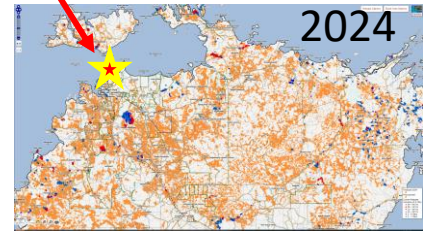
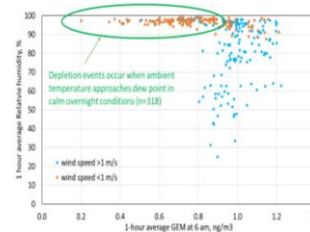
NT's burn area 2023 ~ 33 million hectares



Current burnt area for 2024 dry season

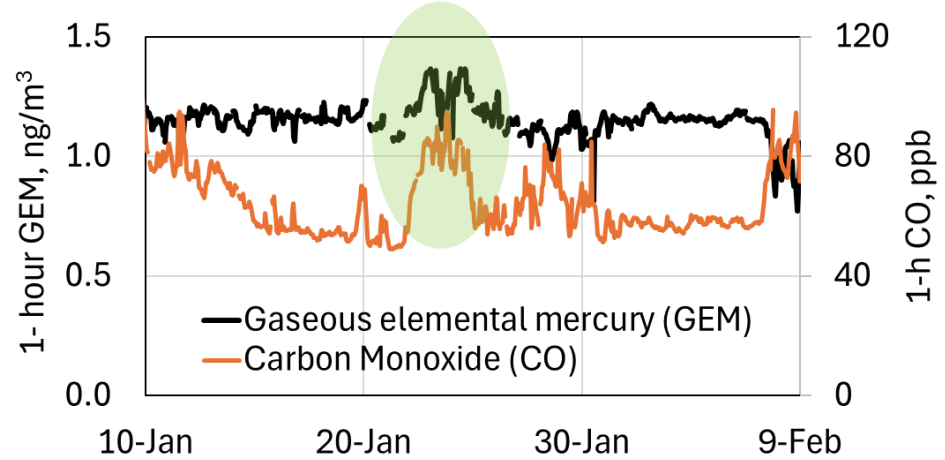
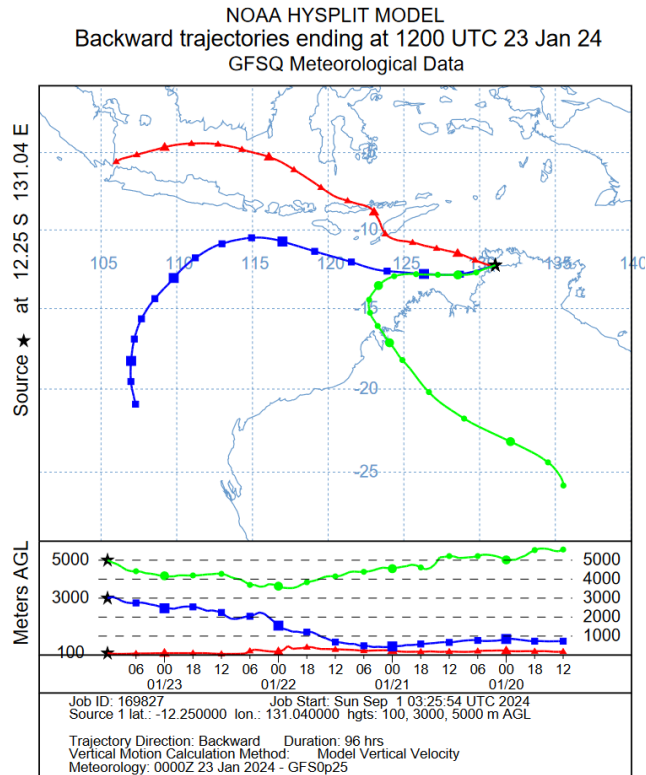


- fire events near Gunn Point used to estimate emission factors for savanna fires
- GEM at Gunn Point being used in an inverse modelling technique to constrain regional mercury emissions from biomass burning





Wet season: interhemispheric mixing events



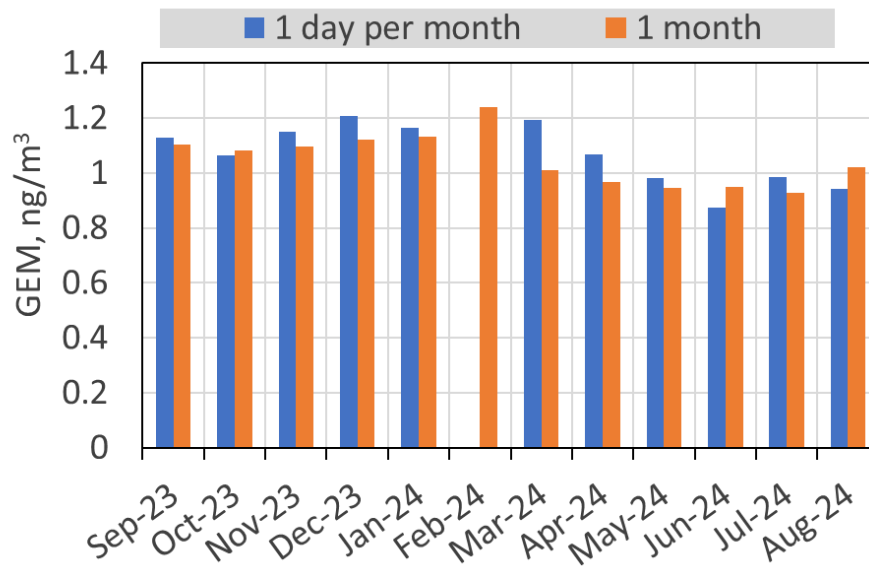
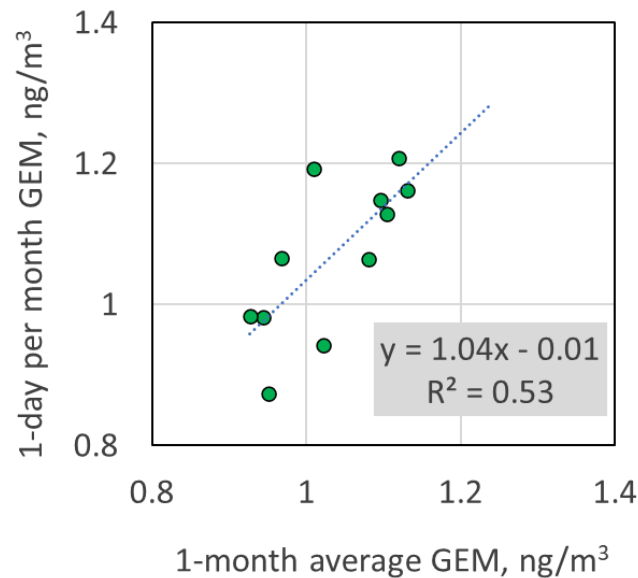
- Multiday elevation of GEM and CO in wet season
- Back trajectories show air mass originated near Jakarta
- Inter-hemispheric mixing during strong monsoonal draw-down

Hysplit Single_Particle Lagrangian Integrated Trajectory model. Hysplit 96 hour back trajectory (Stein et al., 2015)



Active sampling results on MOEJ sampling days

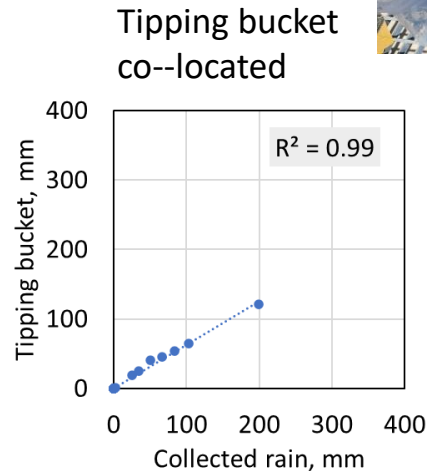
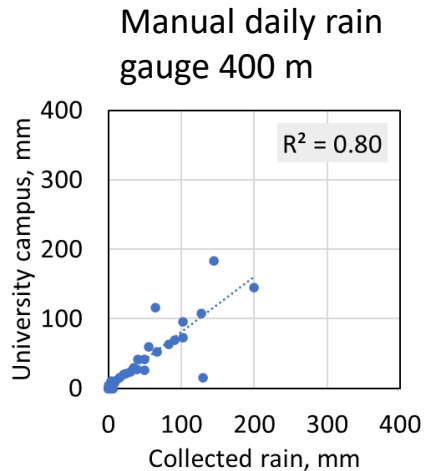
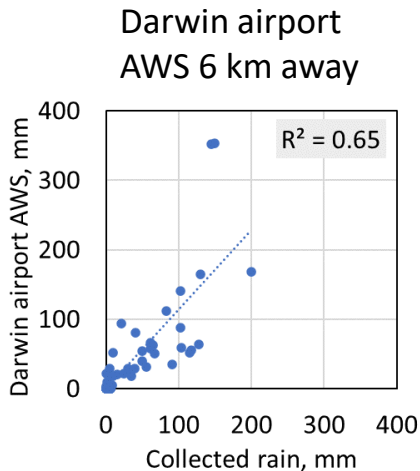
- Variation in 1 day per month sampling versus 1 month sampling
- Relative percent difference between 1-day-per-month sample and 1-month sample ranged from +8 to -16% (0.08 to -0.18 ng/m³); seasonal trend still captured, with a correlation of $R^2=0.53$





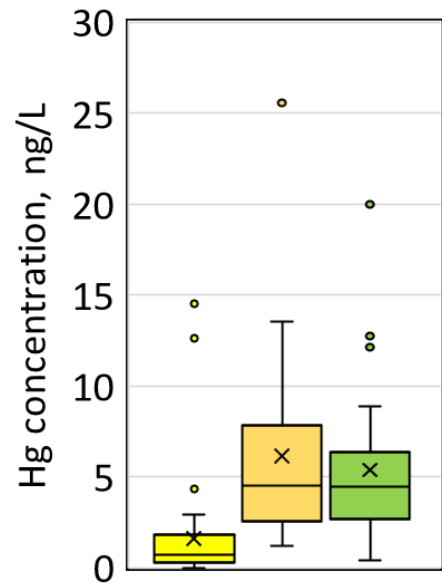
APMMN sampling

- Rainwater volume accuracy comparison:
- Closest measurements are most correlated
- Bias of 25% with co-located tipping bucket--too close to sampler or intensity too high for tipping bucket?

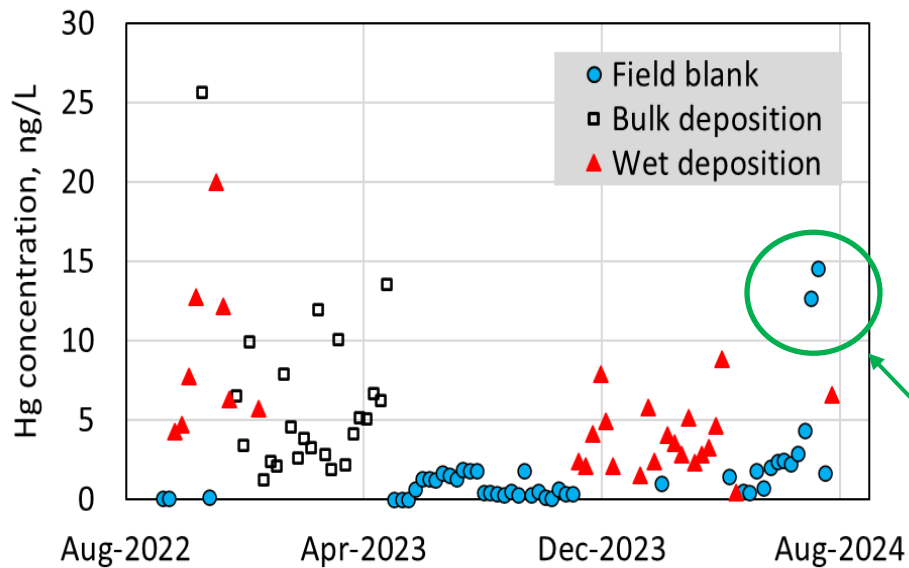




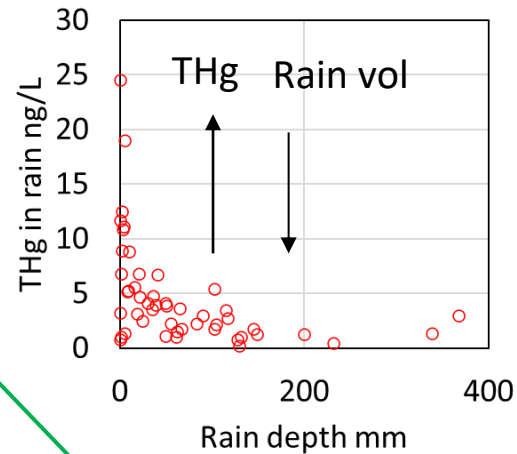
Mercury in rainwater concentrations



■ field ■ bulk ■ wet



Blank correction 1.0 ng/mL applied to flux calc



High field blanks
after lid left open
during fires

Field blank ng/L

Bulk deposition ng/L

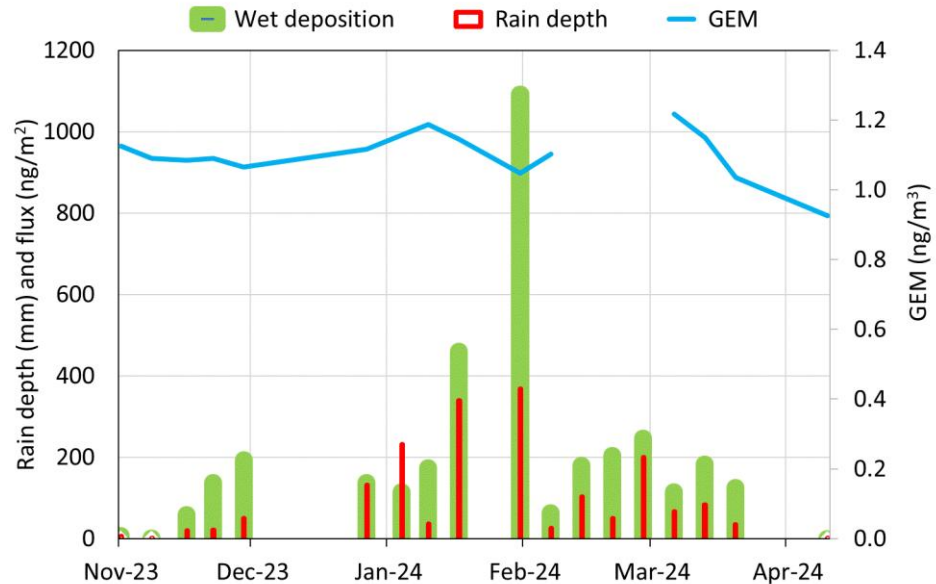
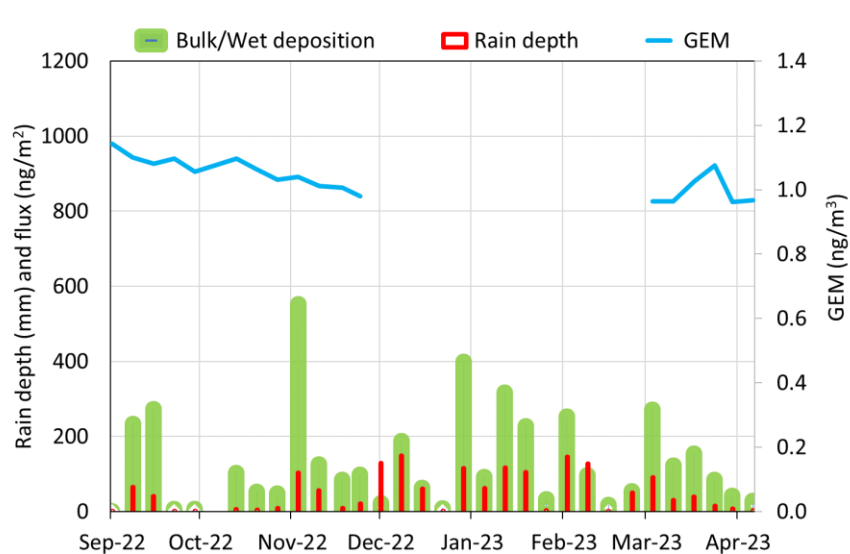
Wet deposition ng/L

1.0 ± 1.0 (n=43)

6.4 ± 5.4 (n=23)

5.4 ± 4.1 (n=28)

2022/23 and 2023/24 wet seasons



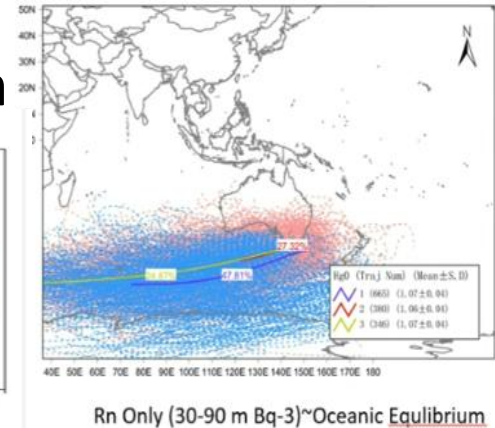
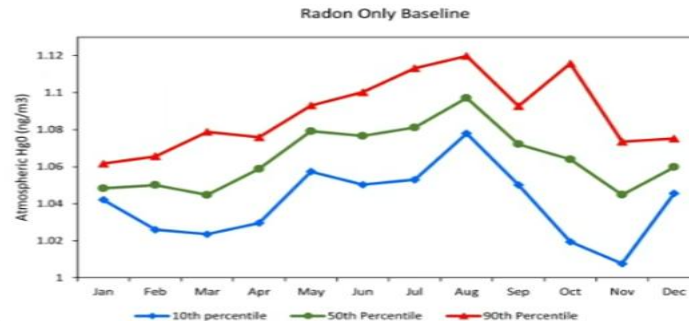
Wet season	Duration	Rainfall	Deposition flux
2022/2023	217 days	1568 mm	4.07 $\mu\text{g}/\text{m}^2/\text{yr}$
2023/2024	161 days	1763 mm	3.49 $\mu\text{g}/\text{m}^2/\text{yr}$

For comparison Cape Grim bulk deposition fluxes in 2014-2015 were 3.1–3.8 $\mu\text{g}/\text{m}^2/\text{yr}$ (Sprovieri et al 2017)



Kennaook/Cape Grim monitoring

- 2013 – 2023 GEM data submitted for Minamata Effectiveness Evaluation
- NCON wet deposition sampler purchased; sampling to beginning in November 2024
- PhD student Bakhat Rawat determined criteria for identifying oceanic airmasses using Radon (30-90 m Bq⁻³). The filtered data shows there is a seasonal pattern in GEM over the Southern Ocean

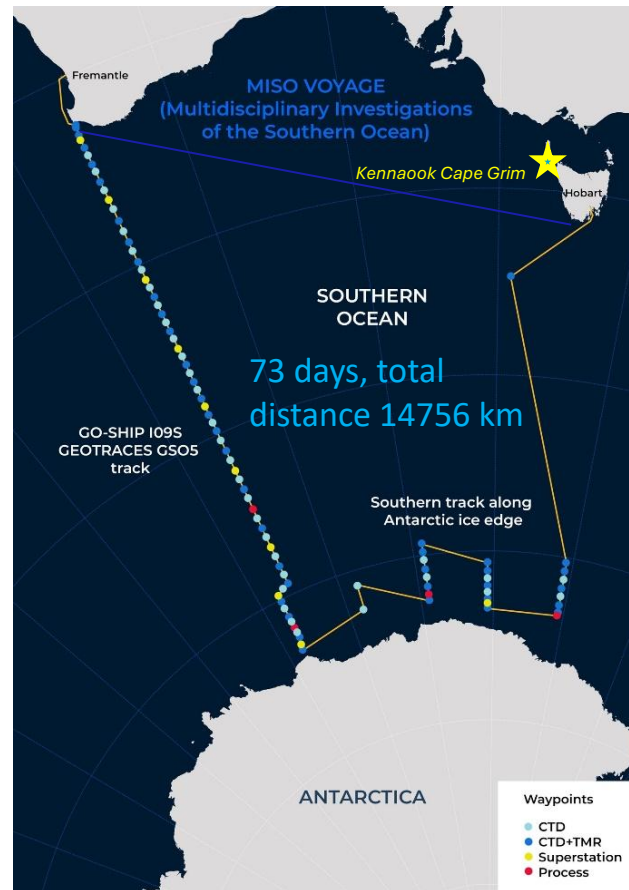




Southern Ocean observations

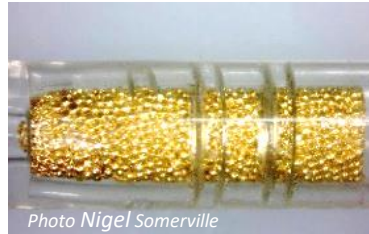
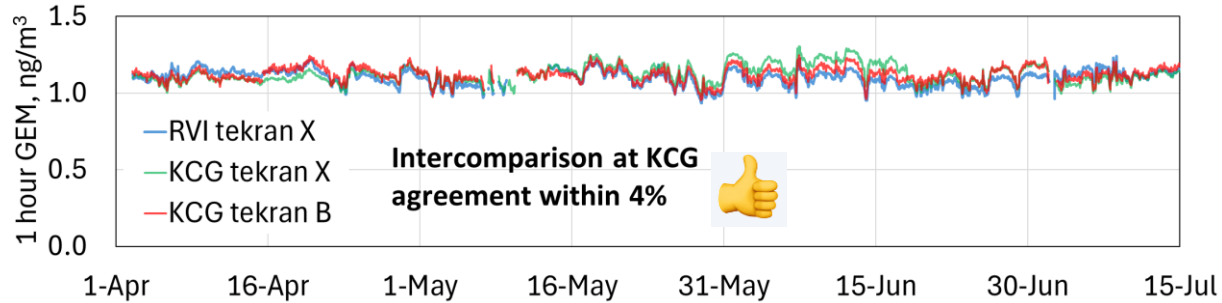


MISO: Multidisciplinary Investigations of the Southern Ocean: how physics, biogeochemistry, plankton, aerosols, clouds influence climate, Jan 5 to Mar 5 2024 + transit voyage Mar 9 to 19 Mar 2024





Gaseous elemental mercury observations



Tekran User Manual:
2537x

- Heated PFA line, 10 m mast
- Soda lime + aerosol filter = GEM (not TGM)
- Gold trap/CVAFS
- GMOS QA/QC OK
- Intercomparison OK

Supporting voyage measurements



Meteorological measurements and radar



Air chemistry laboratory



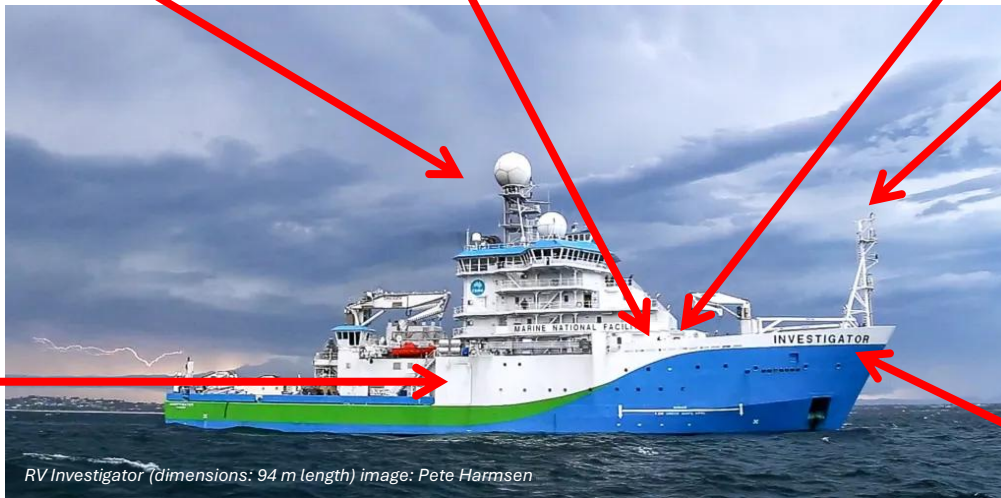
2000 L Teflon-lined mesocosm tanks



Air sample inlets



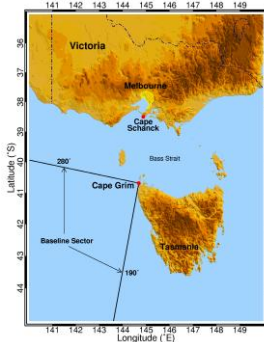
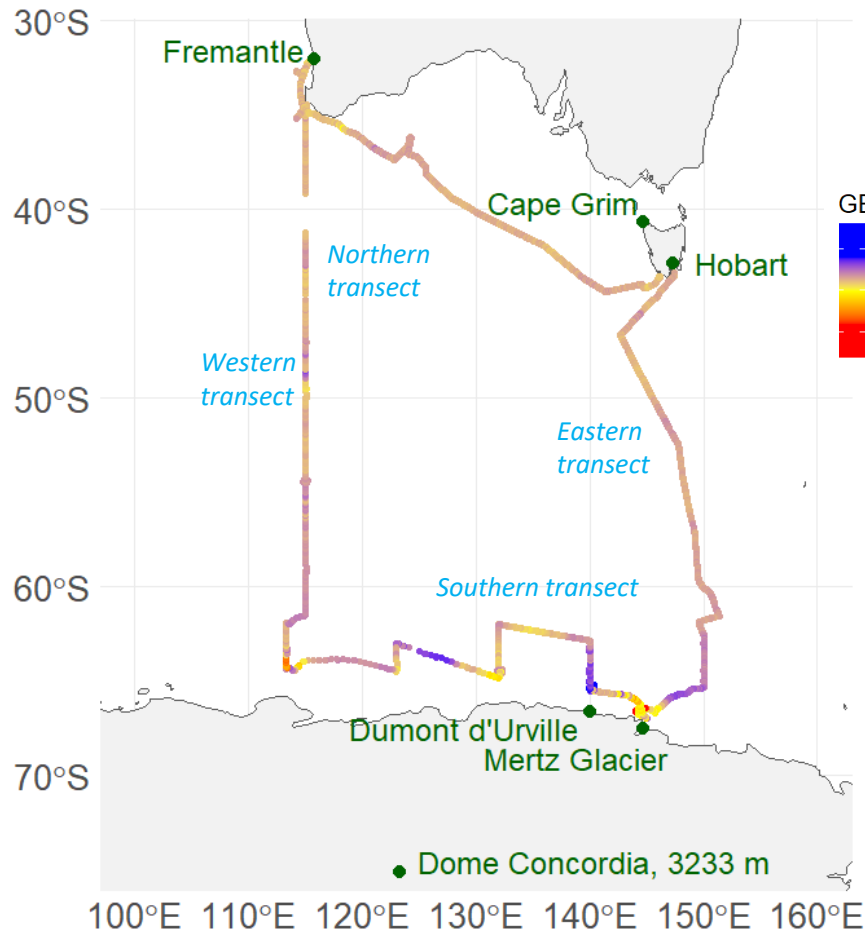
Trace metal sample collection



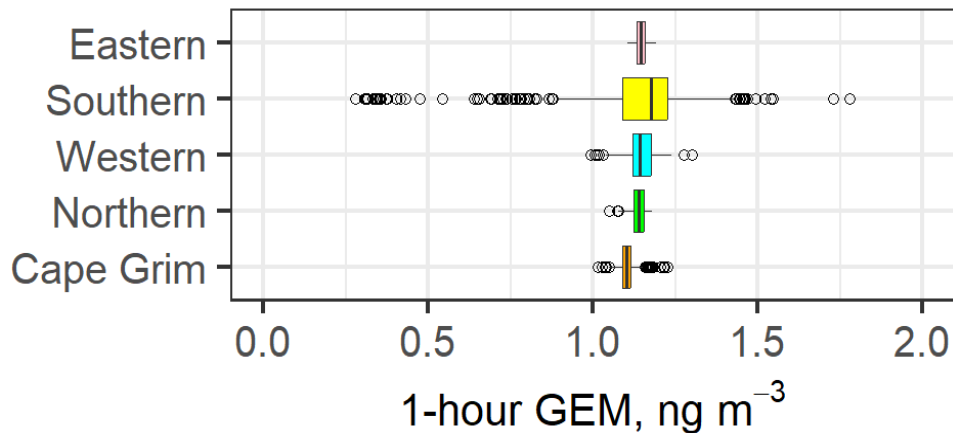
Seawater collection, marine biology, geochemistry, geophysical surveying



GEM concentrations voyage transects



- N,W,E,KCG similar
- Southern transect much more variability → more dynamic cycling close to Antarctica

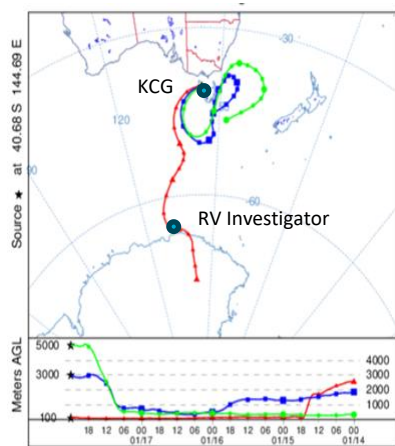
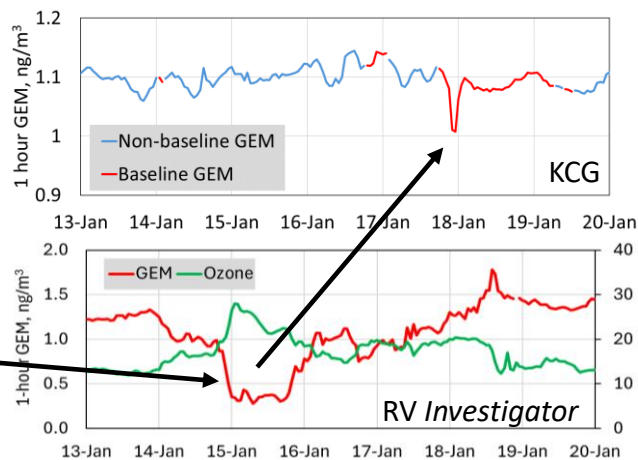
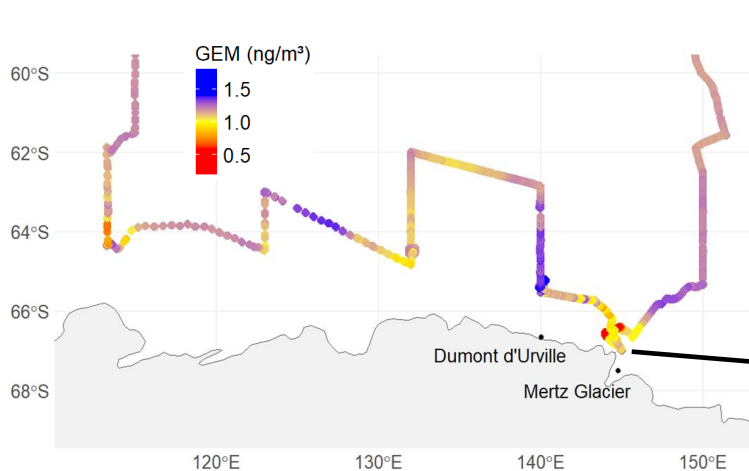


Figures made using R and openair (Carslaw and Ropkins, 2012, R Core Team 2021)



MISO and KCG mercury linkages

- Multi-day gaseous elemental mercury (GEM) depletion event originating from Antarctic plateau. Evidence of oxidation to reactive mercury species -> local deposition-> marine ecosystem methylation -> bioaccumulation
- Detection of depleted airmass at KCG -> these events are of regional magnitude
- Temporal (KCG) and spatial (RVI) observations constrain uncertainties on transport, deposition and evasion of mercury over the Southern Ocean region -> **understanding whether SO is a net source or sink is important for Multi Compartment Hg Modeling and Analysis Project -> Minamata Effectiveness Evaluation**



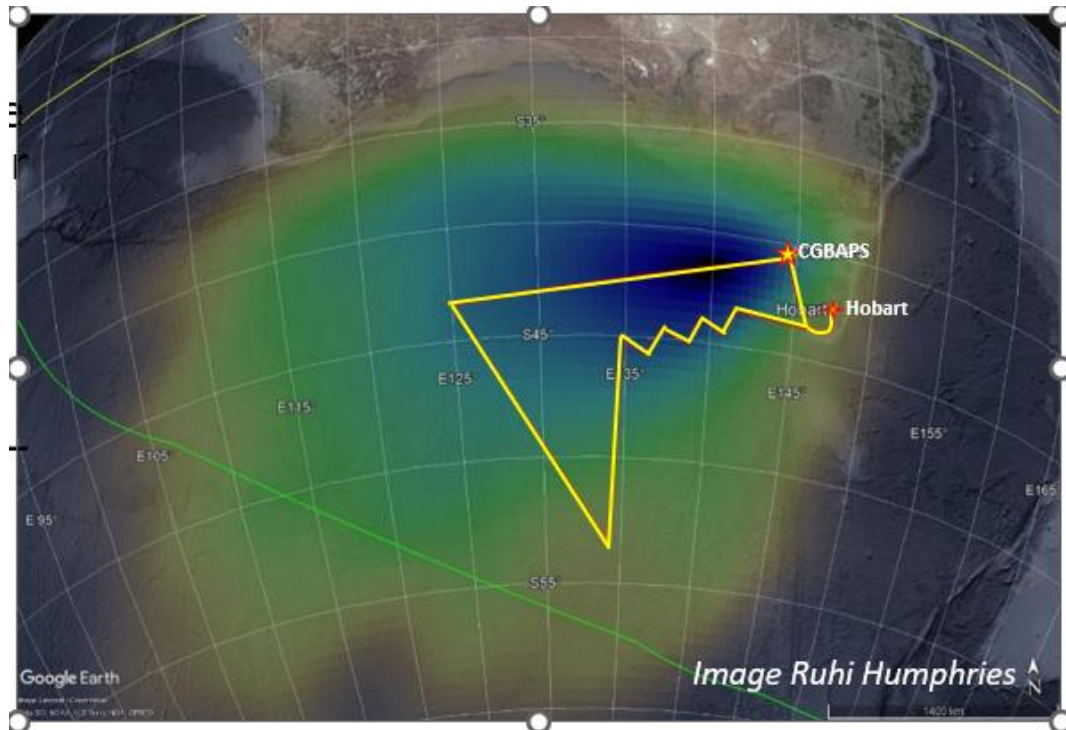
Multi-day depletion event observed on RV Investigator then at Kennako/Cape Grim

Back trajectories show the depleted airmass reached KCG; future work to assess the frequency of these events



Southern Ocean as a source of GEM: Coast K

- 29 April to 18 May 2025
- Intercomparison of Cape Grim and RV Investigator GEM
- Stretch goal: measurements of dissolved gaseous mercury (DGM) using an equilibrator → fluxes across air-sea interface – useful for modelling



Proposed voyage track overlayed a frequency map showing the likelihood of an airmass at that point will pass over Cape Grim. Blue colours indicate highest potential occurrence. Based on 3-day trajectories with GDAS meteorology.



Overview

Passive network is a cost-effective method to characterise spatial variability over a large continent. The Australia / Southern Ocean region had the lowest GEM globally.

Monitoring at **Northern Australia**, a site with a **wet and dry season**:

- wet deposition fluxes over 2 wet seasons ranged from 3.5-4.1 $\mu\text{g}/\text{m}^2/\text{yr}$
- periods of enhanced GEM observed when monsoon drawdown transports air from NH
- dry season dominated by emissions from savanna biomass burning
- fire events at Gunn Point used to estimate emission factors for savanna fires
- GEM at Gunn Point being used in an inverse modelling technique to constrain regional mercury emissions from biomass burning

Monitoring at Cape Grim, a WMO GAW station exposed to **airmasses from the Southern Ocean**

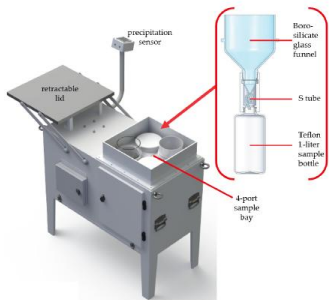
- GEM monitoring to long term trends in the Southern Ocean region
- wet deposition sampler installed at Cape Grim, sampling starts November 2024

Monitoring on RV Investigator to characterise **spatial variation and Hg cycling** in Southern Ocean

Minamata Convention activities: 2014 to 2023 GEM data from Gunn Point & Cape Grim submitted for the Minamata Effectiveness Evaluation Process



Thank-you to all of our partners & sponsors



Asia Pacific Mercury
Monitoring Network



Wet deposition sampling

- Darwin APMMN site
- Kennaook/Cape Grim WMO GAW site



Long term monitoring: Minamata
Convention Effectiveness Evaluation



Mercury cycling savanna fires & monsoons
Mercury cycling Southern Ocean

Baseline monitoring of GEM at
Tier 1 sites

- NT BAPS & CDU
- CG BAPS
- RV Investigator campaigns



MerPAS Global passive sampling network



Government
of Canada



Who we are

Australia's national science agency



One of the world's largest
multidisciplinary science
and technology
organisations



5,672+ dedicated
people working
across 53 sites in
Australia and
globally



State-of-the-art
national research
infrastructure



We delivered
\$10.2 billion of
benefit to the
nation in FY22