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Characterising summertime atmospheric mercury in the Southern Ocean and Antarctic Coast marine boundary layer during the 2024 MISO Voyage

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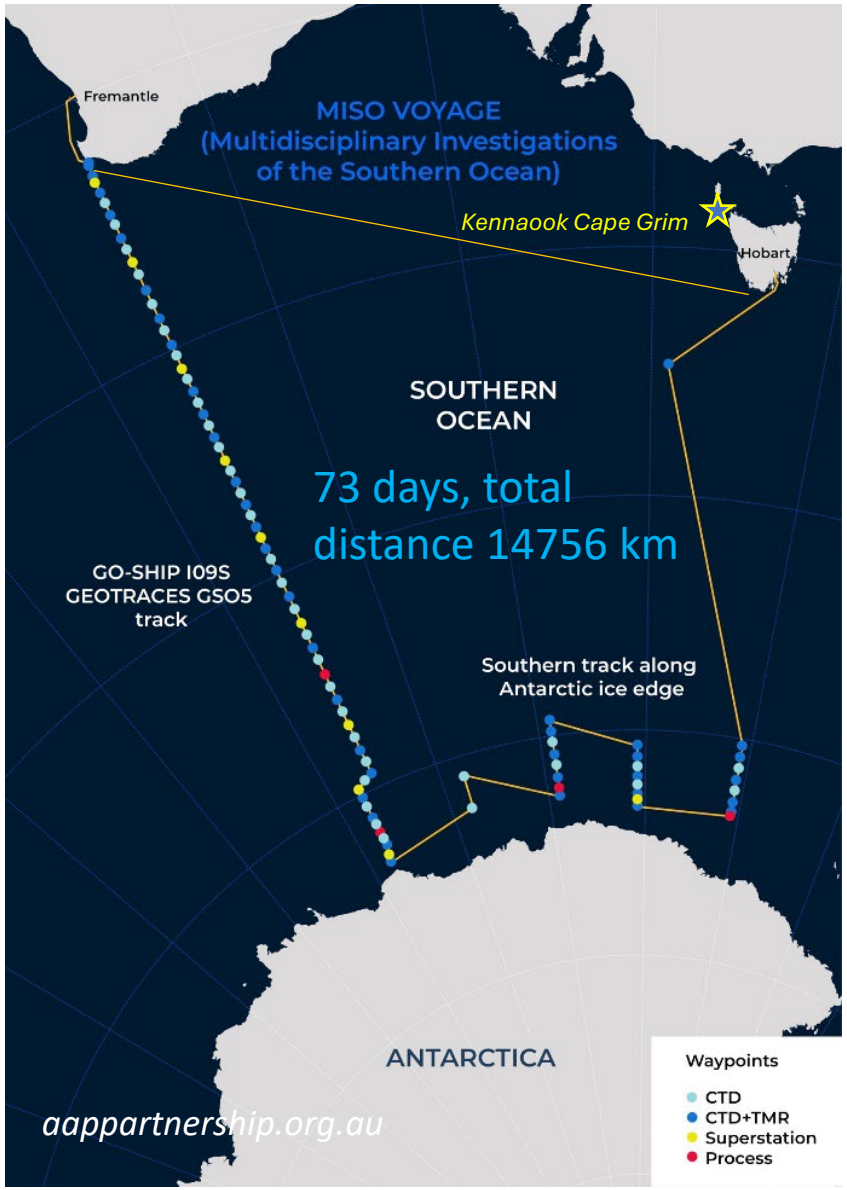
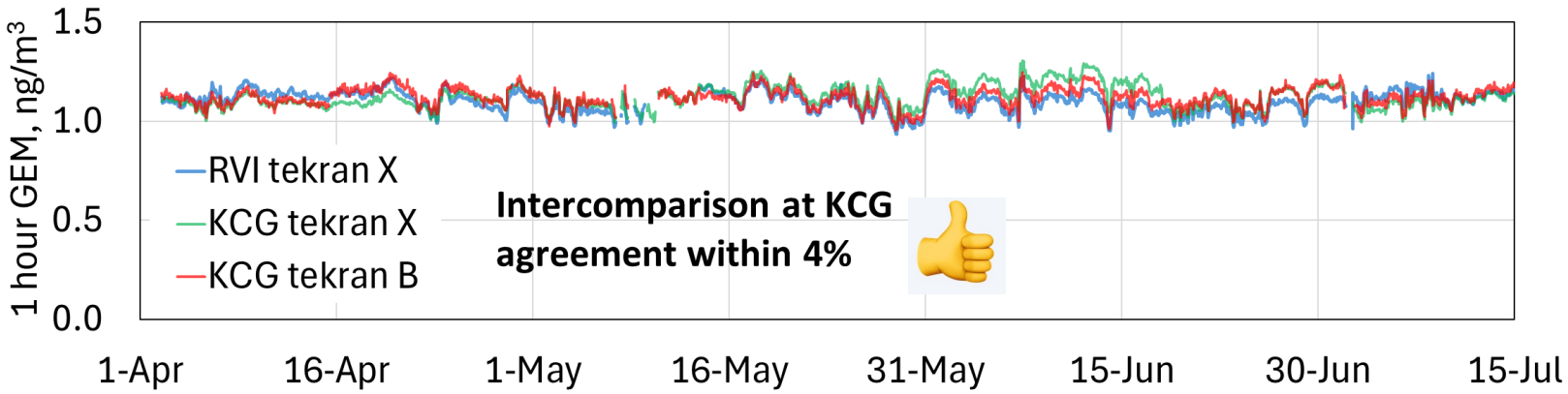
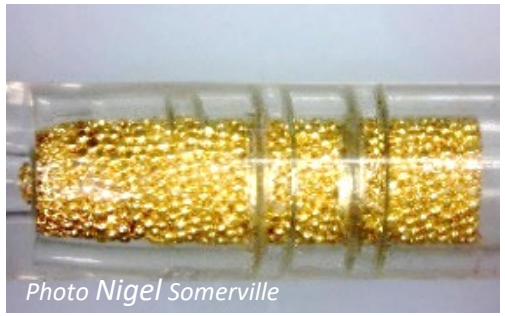
Long term measurements of the Southern Ocean

*MISO: **M**ultidisciplinary **I**nvestigations of the **S**outhern **O**cean: 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 (GEM) measurements





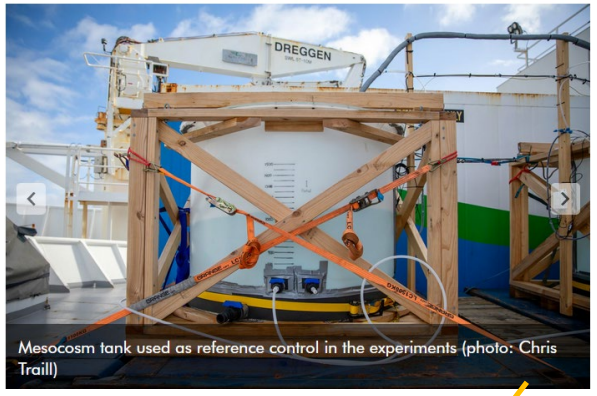
Tekran User Manual: 2537x

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

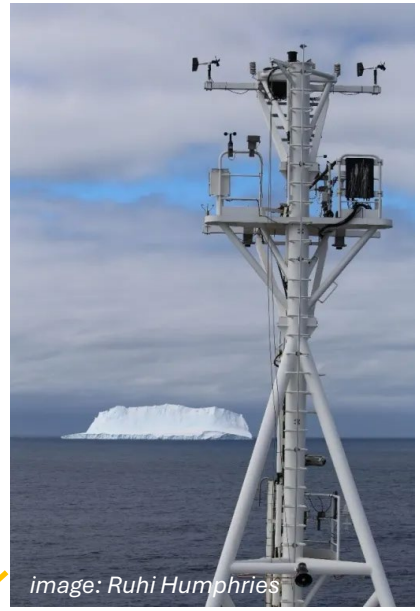
Supporting voyage measurements

Meteorological measurements and radar

Air chemistry laboratory

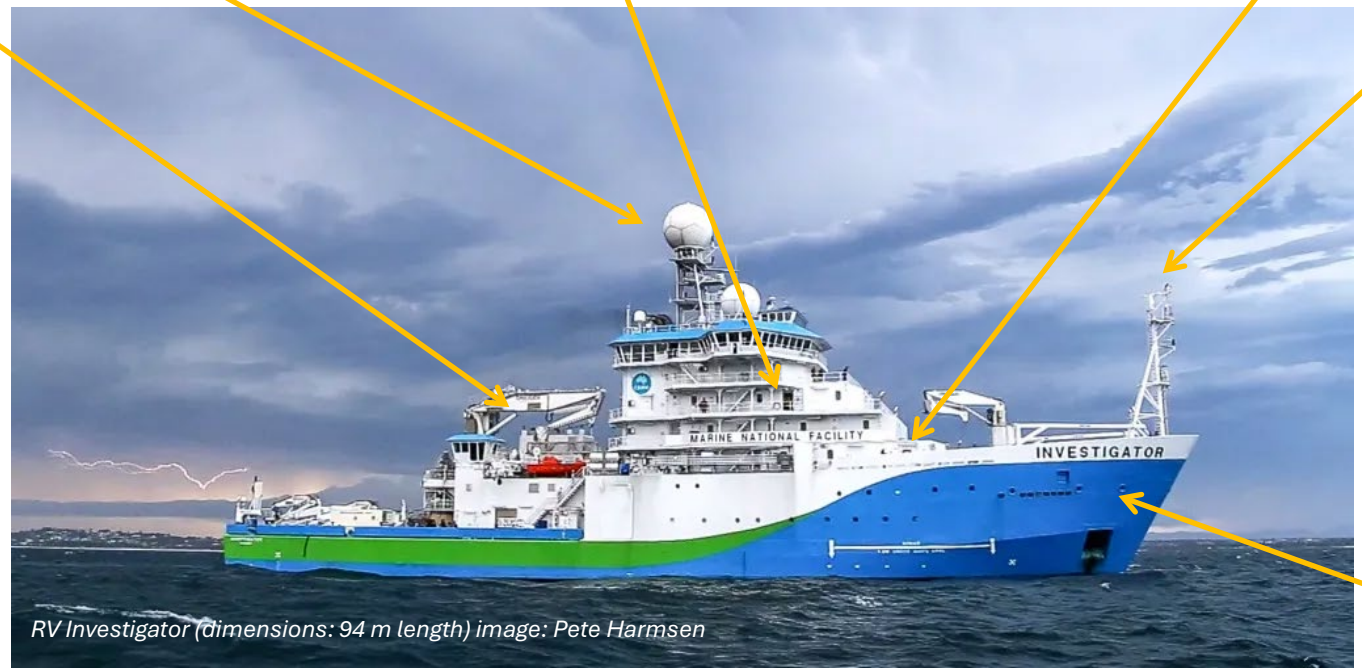


2000 L Teflon-lined mesocosm tanks



Air sample inlets

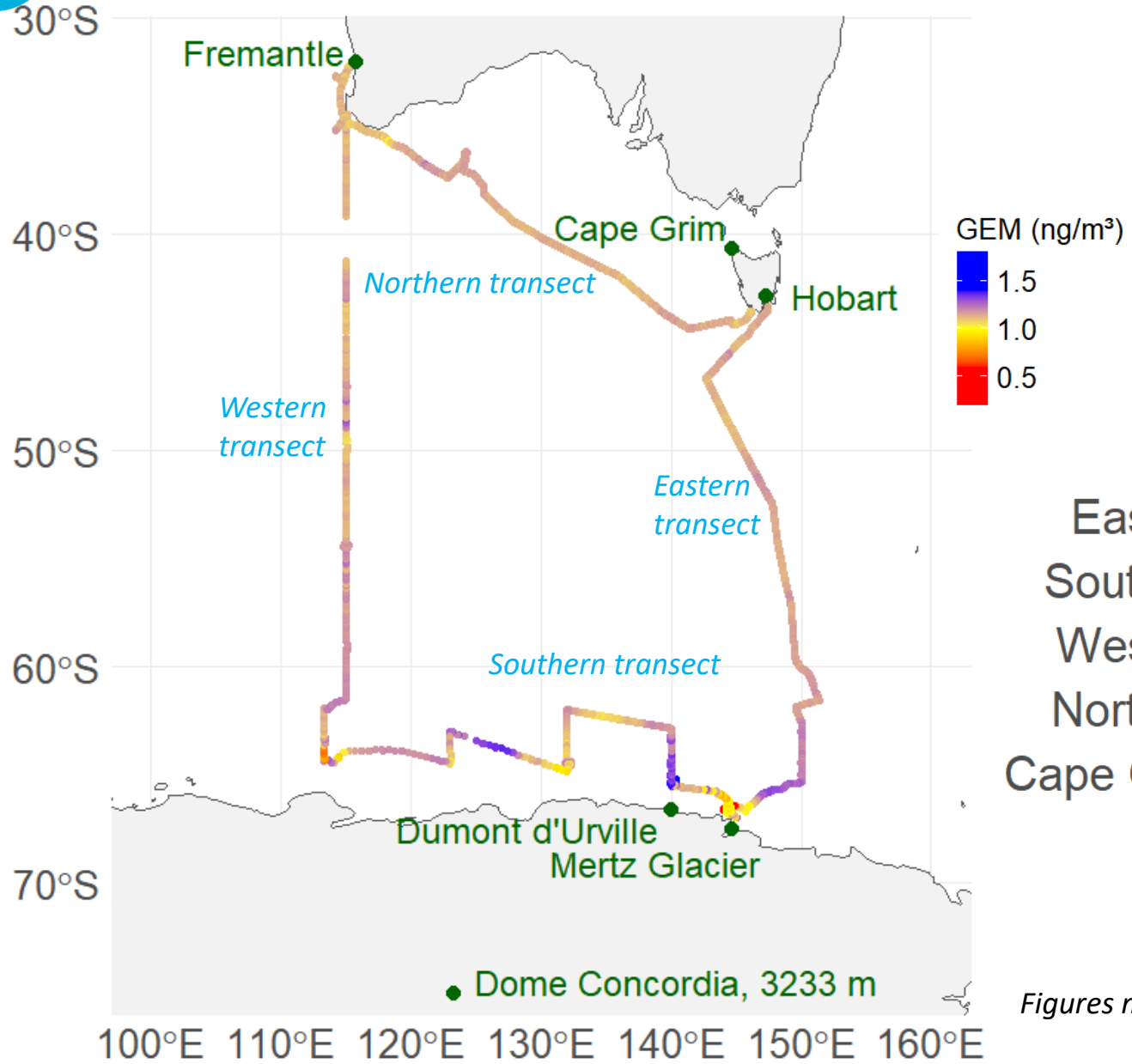
Trace metal sample collection

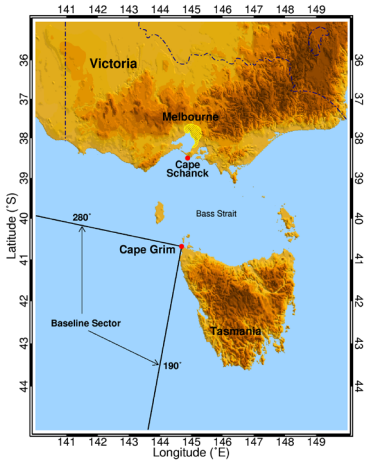


Seawater collection, marine biology, geochemistry, geophysical surveying

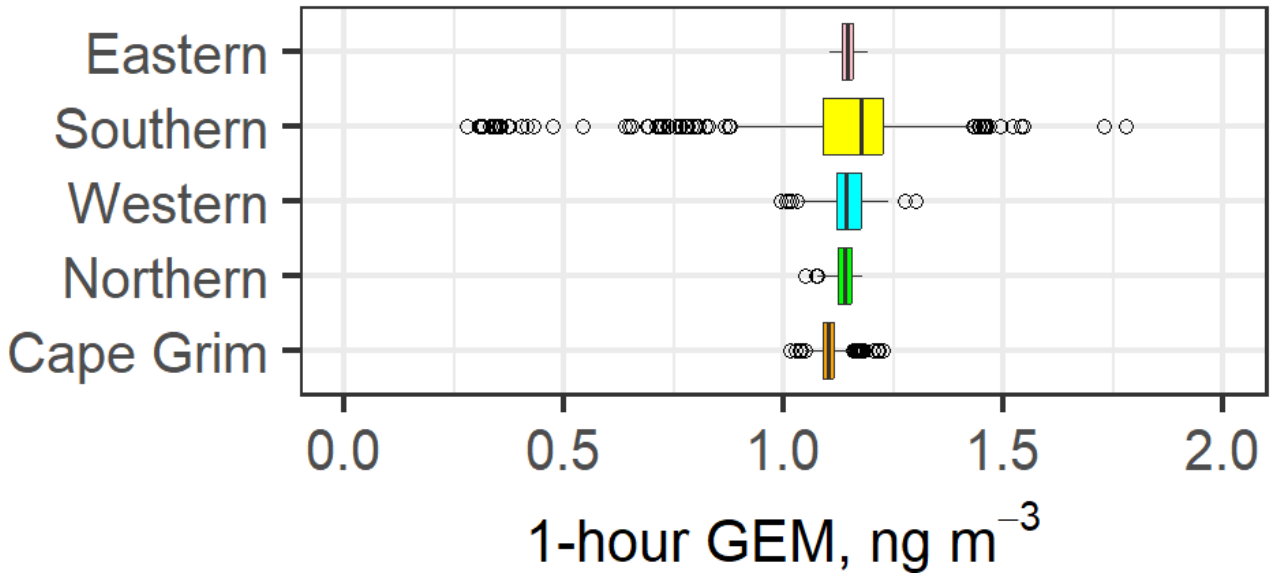
Aerosol laboratory

Voyage transect GEM concentrations



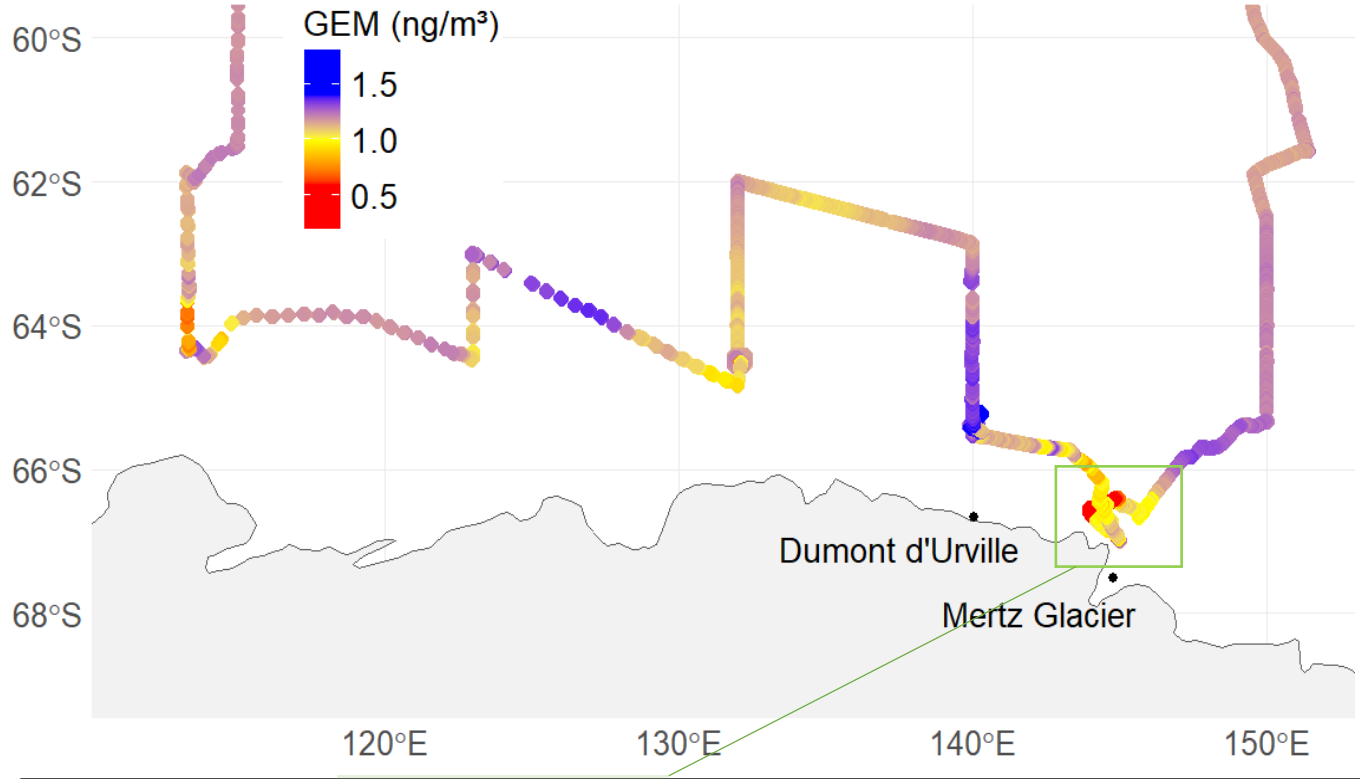


- N,W,E,KCG similar
- Southern transect much more variability → more dynamic cycling close to Antarctica



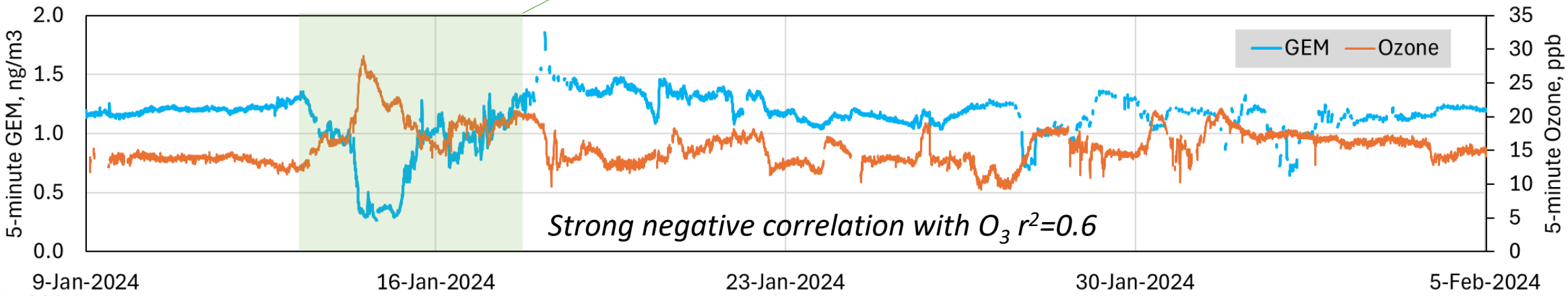
Figures made using R and openair (Carslaw and Ropkins, 2012, R Core Team 2021)

Polar transect GEM – depletion event observed

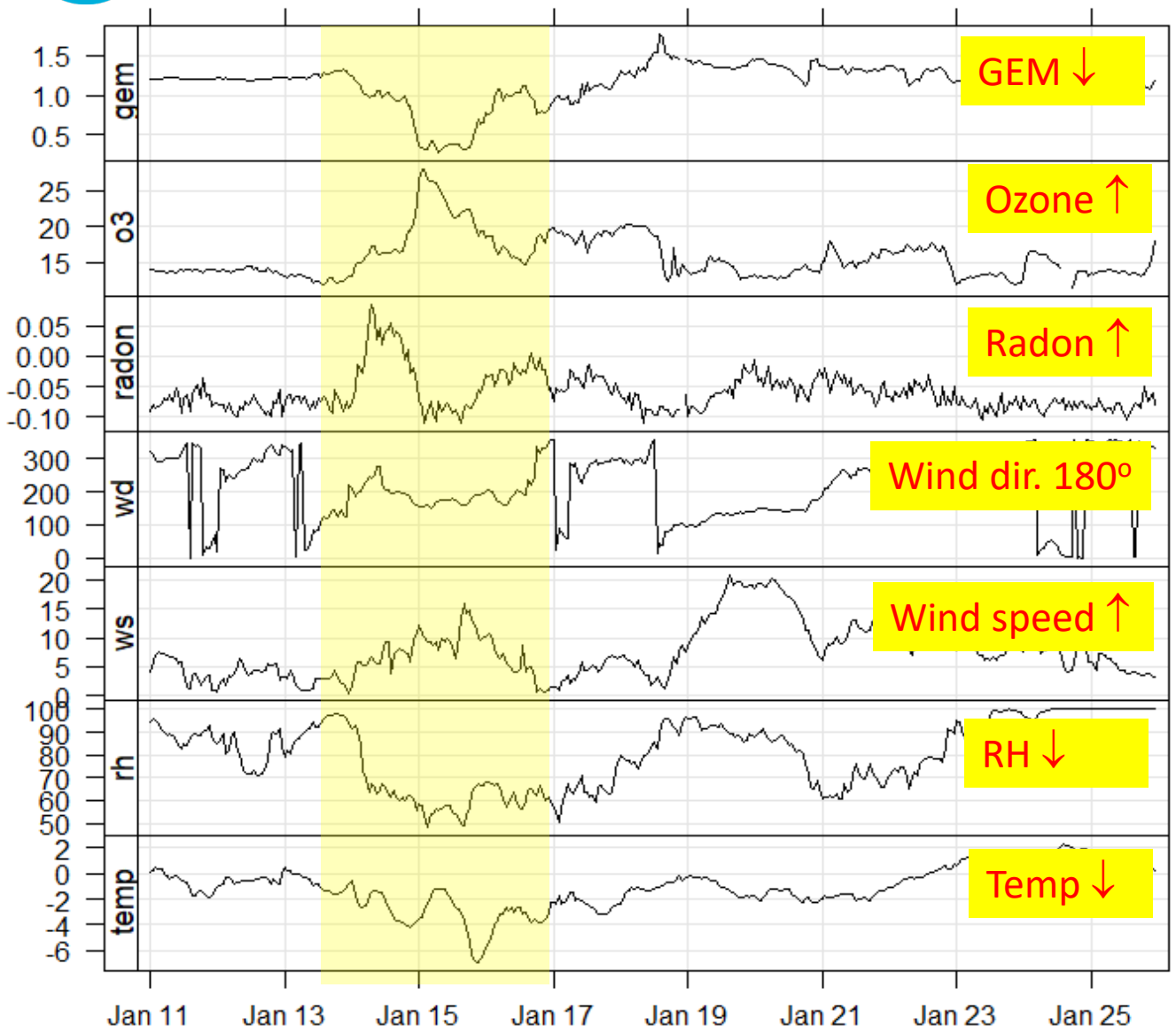


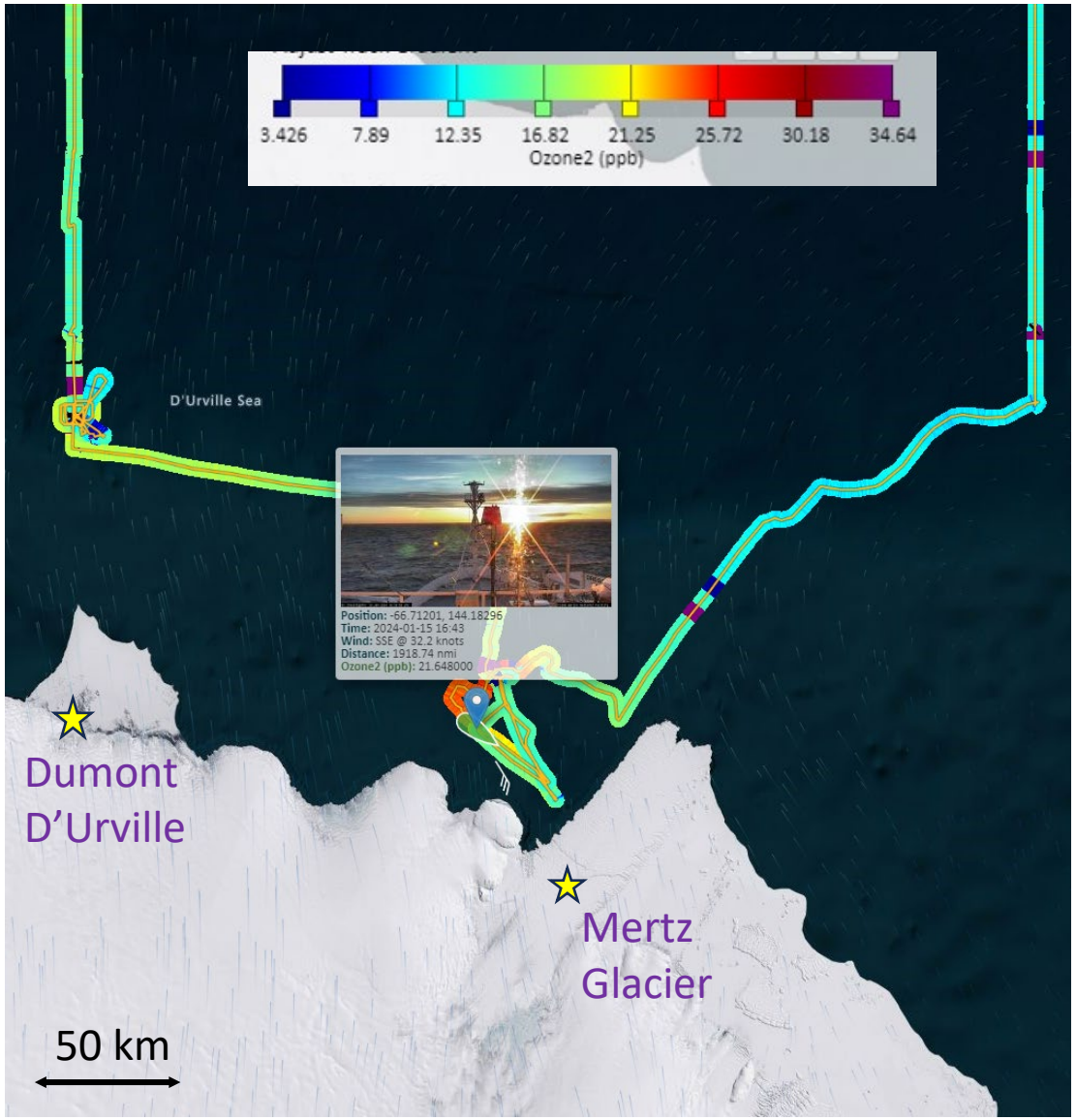
- 4-day depletion event
- < 1 ng/m³ for 32 hours
- Lowest value 0.26 ng/m³
- GOM & PBM present or deposited out?
- Negative correlation with ozone (r^2=0.6)

Map produced in R (R Core Team 2021)



What were the depletion characteristics?





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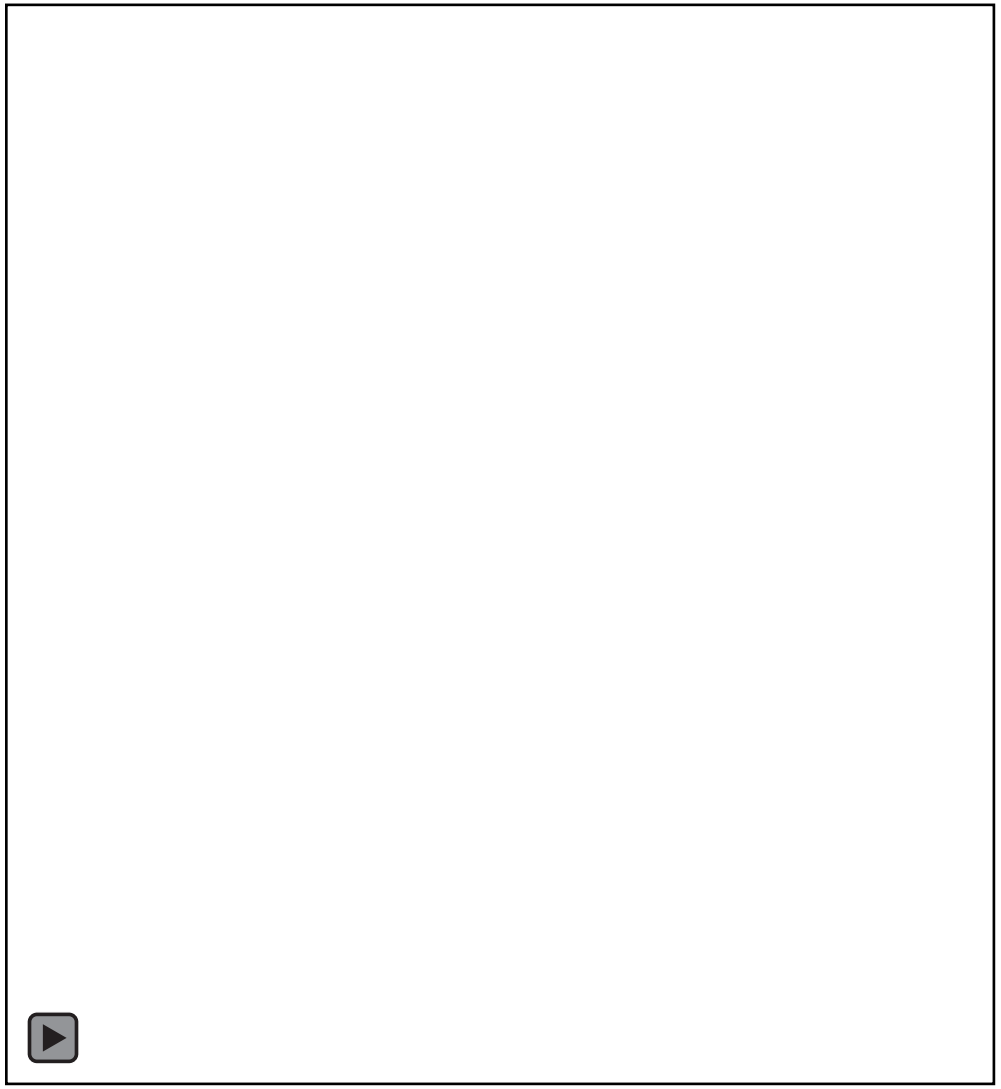
Katabatic winds transport depleted air from plateau



Katabatic winds near Mertz Glacier image: Knut Heinatz

Event was observed when the Investigator was near Adelie land (142°S), a known confluence zone for katabatic winds (Angot et al. 2016a)

Figures made using HYSPLIT model (Stein et al.., 2015)

Why is the airmass depleted?

Inland plateau origin – low GEM, high O_3

- Summertime GOM observed on plateau (Brookes 2008) attributed to high oxidative capacity in summer (NO_x, OH·, O_3, HO_2, BrO?)
- Multiday GEM depletion events observed at Concordia during stagnant airmasses/tropospheric subsidence (Angot et al 2016a)
- Katabatic winds transport airmasses with **low GEM, high GOM & high oxidants** to the coast. Events observed at:

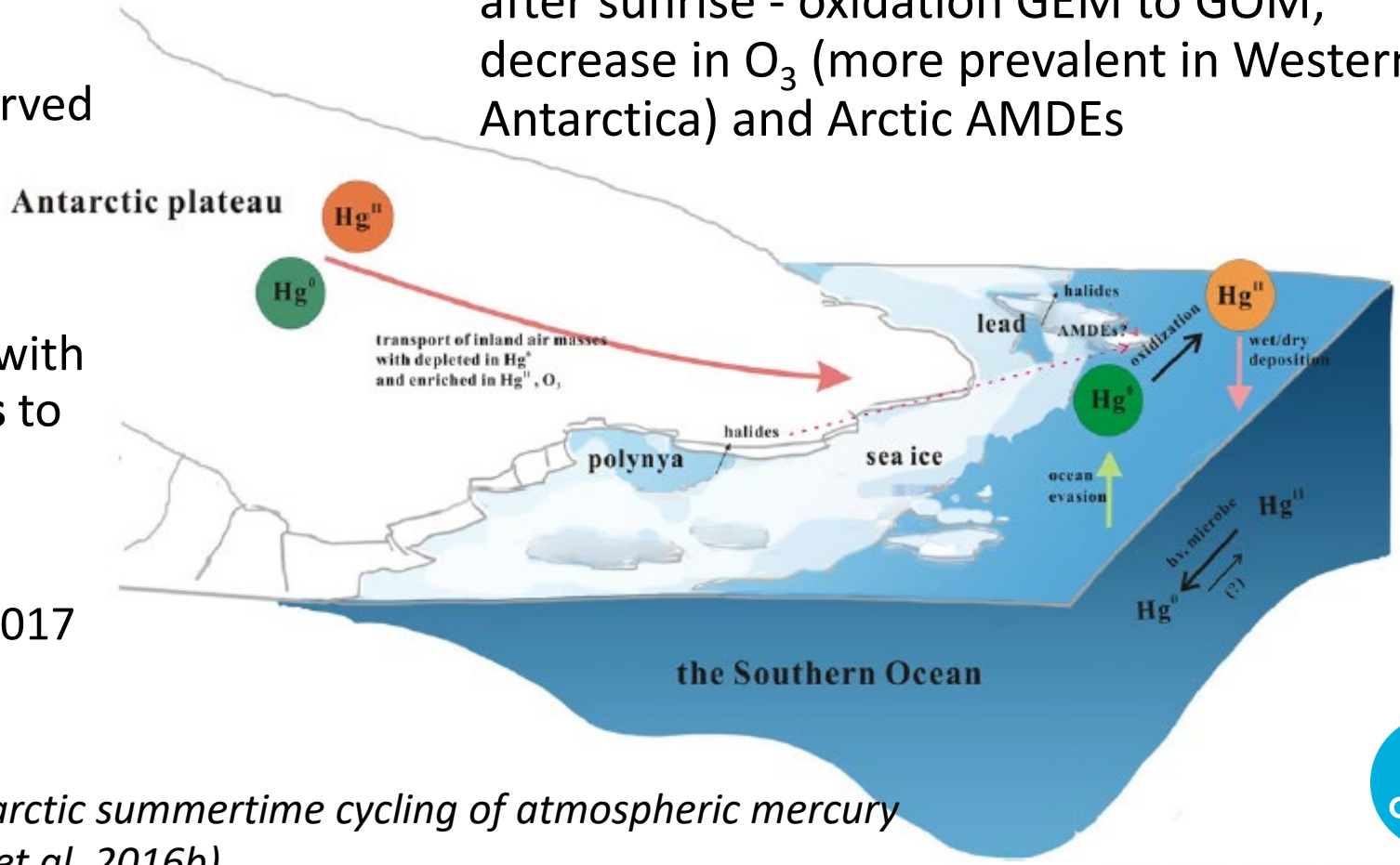
➢ Troll Pfaffhuber et al. 2012

➢ Summer voyage Ross Sea Wang et al. 2017

➢ Dumont D'Urville, Angot et al. 2016b

Coastline origin – low GEM, low O_3

- Springtime, occasionally summer/winter
- coastal sea-ice halogen Br radical activation after sunrise - oxidation GEM to GOM; decrease in O_3 (more prevalent in Western Antarctica) and Arctic AMDEs



Conceptual diagram of Antarctic summertime cycling of atmospheric mercury (Wang et al. 2017 & Angot et al. 2016b)

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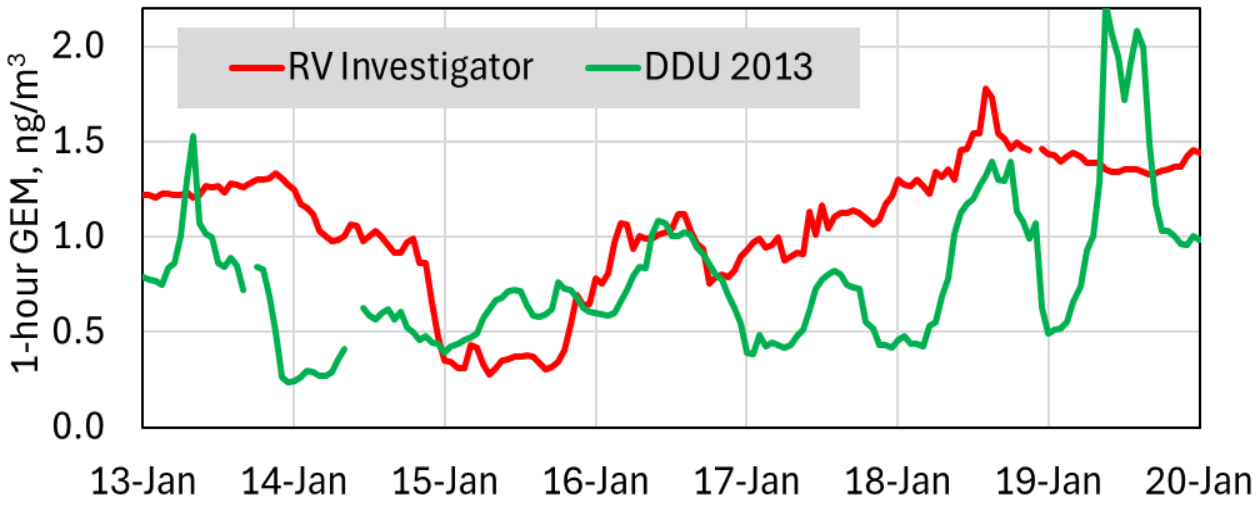
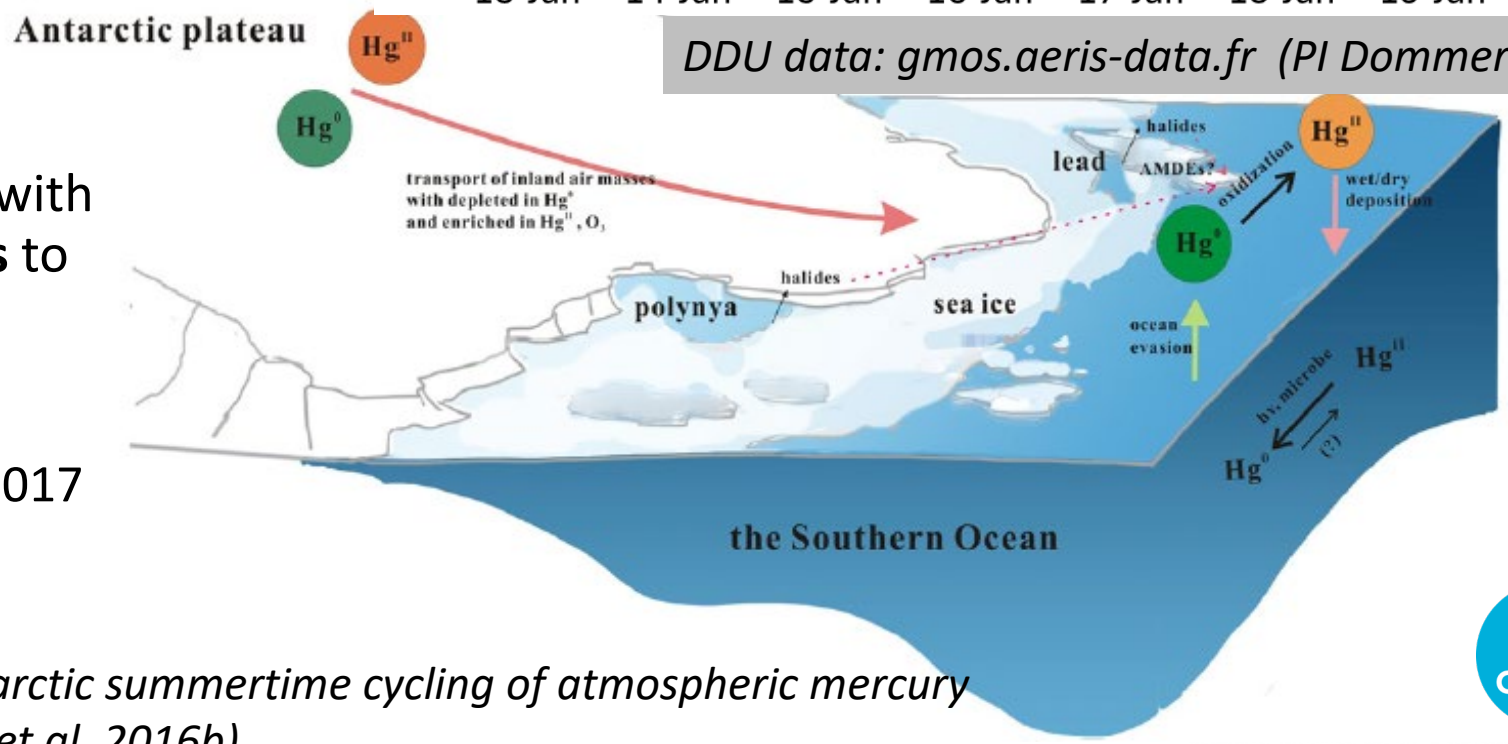
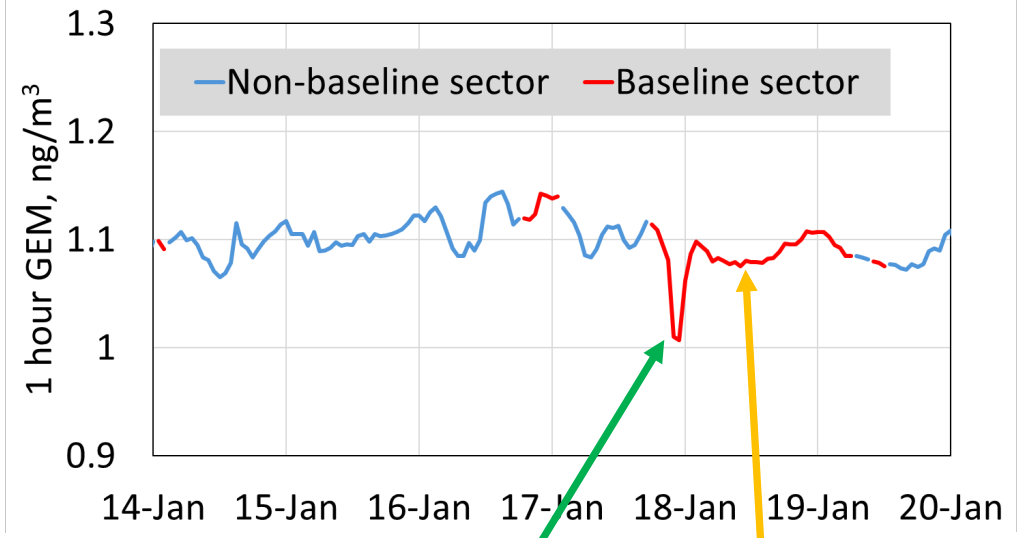


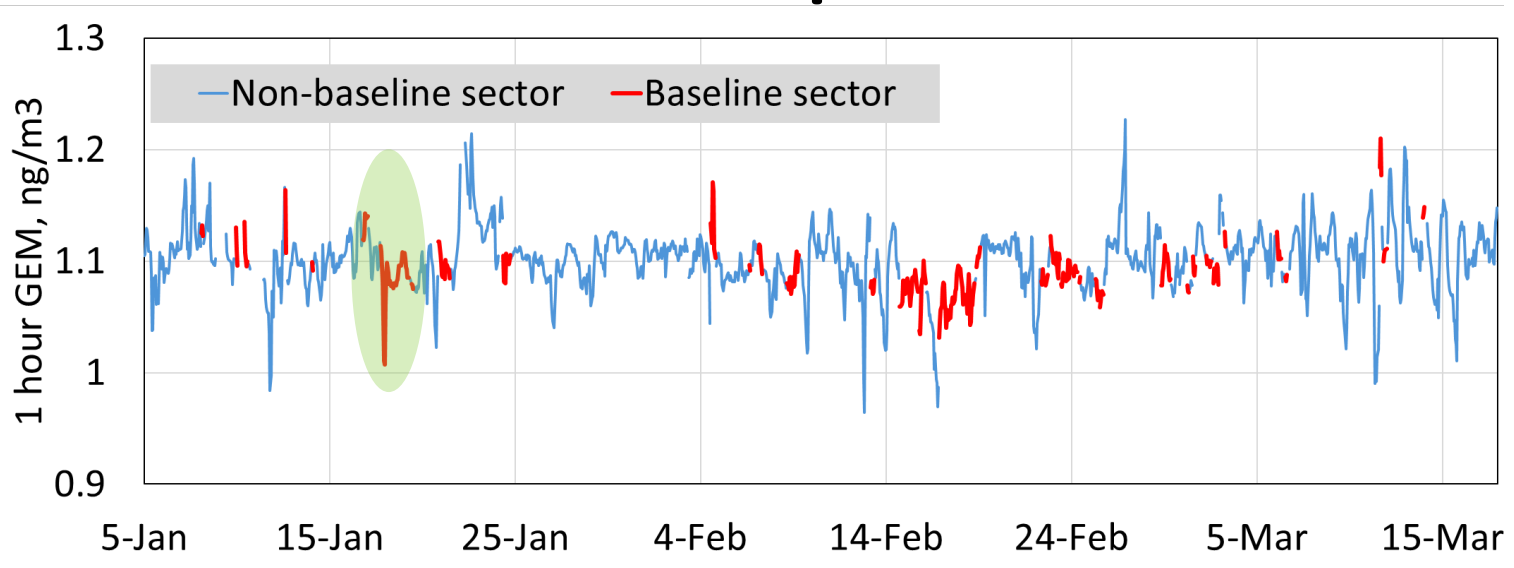
DDU data: gmos.aeris-data.fr (PI Dommergue)

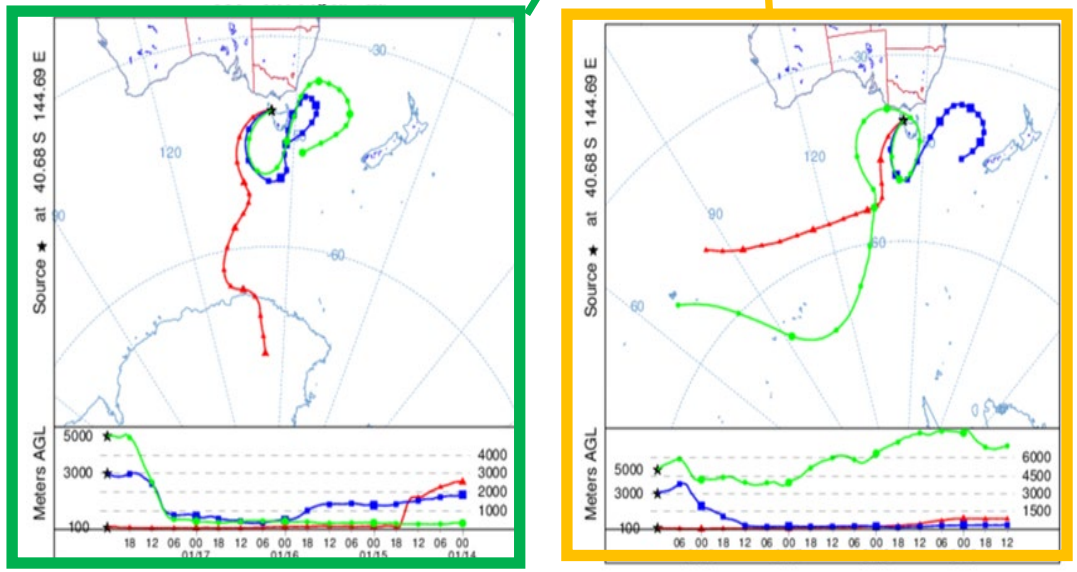


Conceptual diagram of Antarctic summertime cycling of atmospheric mercury (Wang et al. 2017 & Angot et al. 2016b)

Depletion detected at kennaook/Cape Grim?





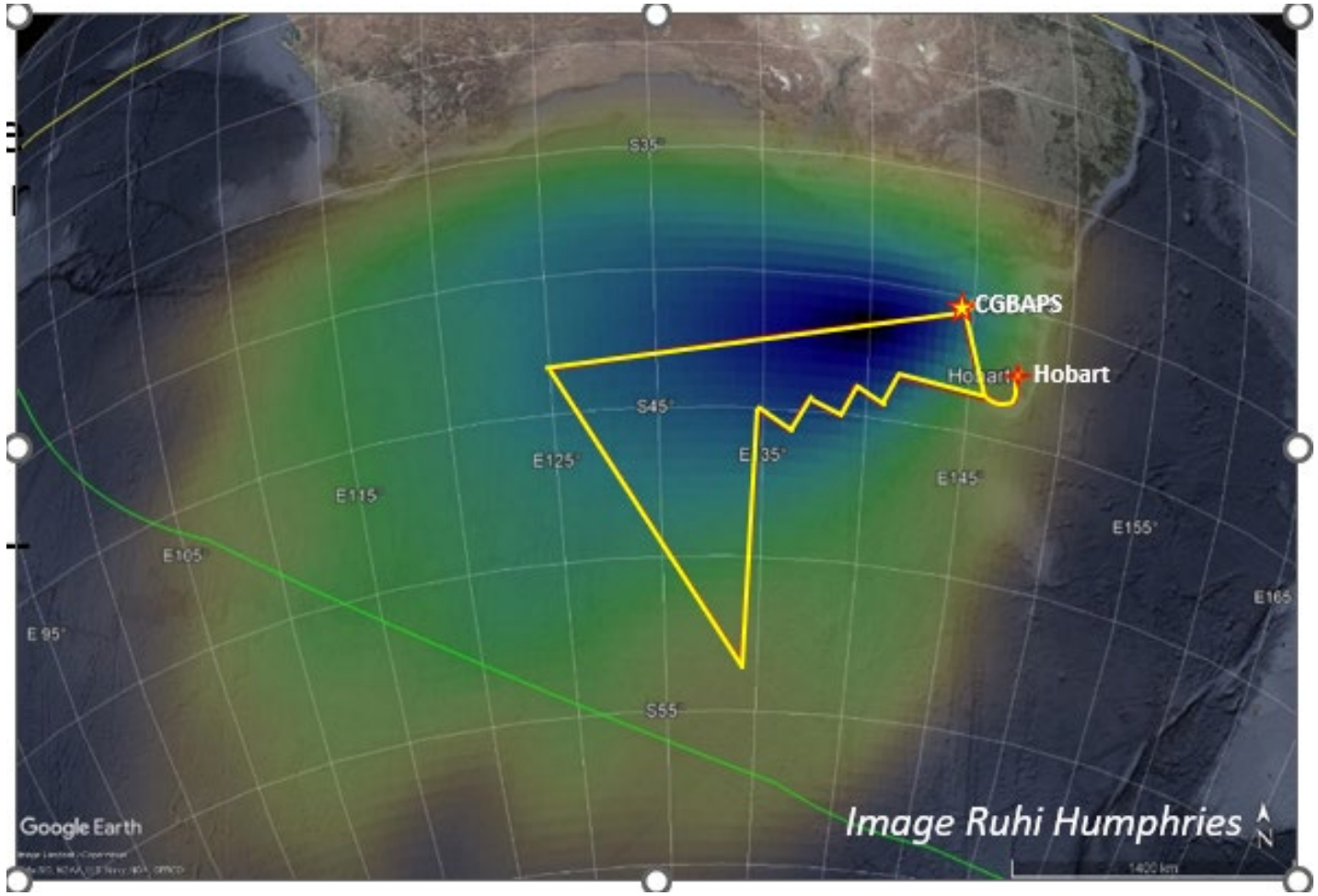


- "Baseline" = Southern Ocean origin (14% of voyage)
- 0.1 ng/m^3 (10%) drop in baseline GEM
- 6-hour event before airmass changed
- Lowest baseline gem over 74-day voyage
- Does this help to understand replenishment of depleted GEM over the Southern Ocean? So far N=1…ten years data to review!
- Aim: perform a source apportionment analysis similar one for Cape Point (Bieser et al. 2020)

NOAA Hysplit 96 hour back trajectory (Stein et al., 2015)

Southern Ocean as a source of GEM: Coast K

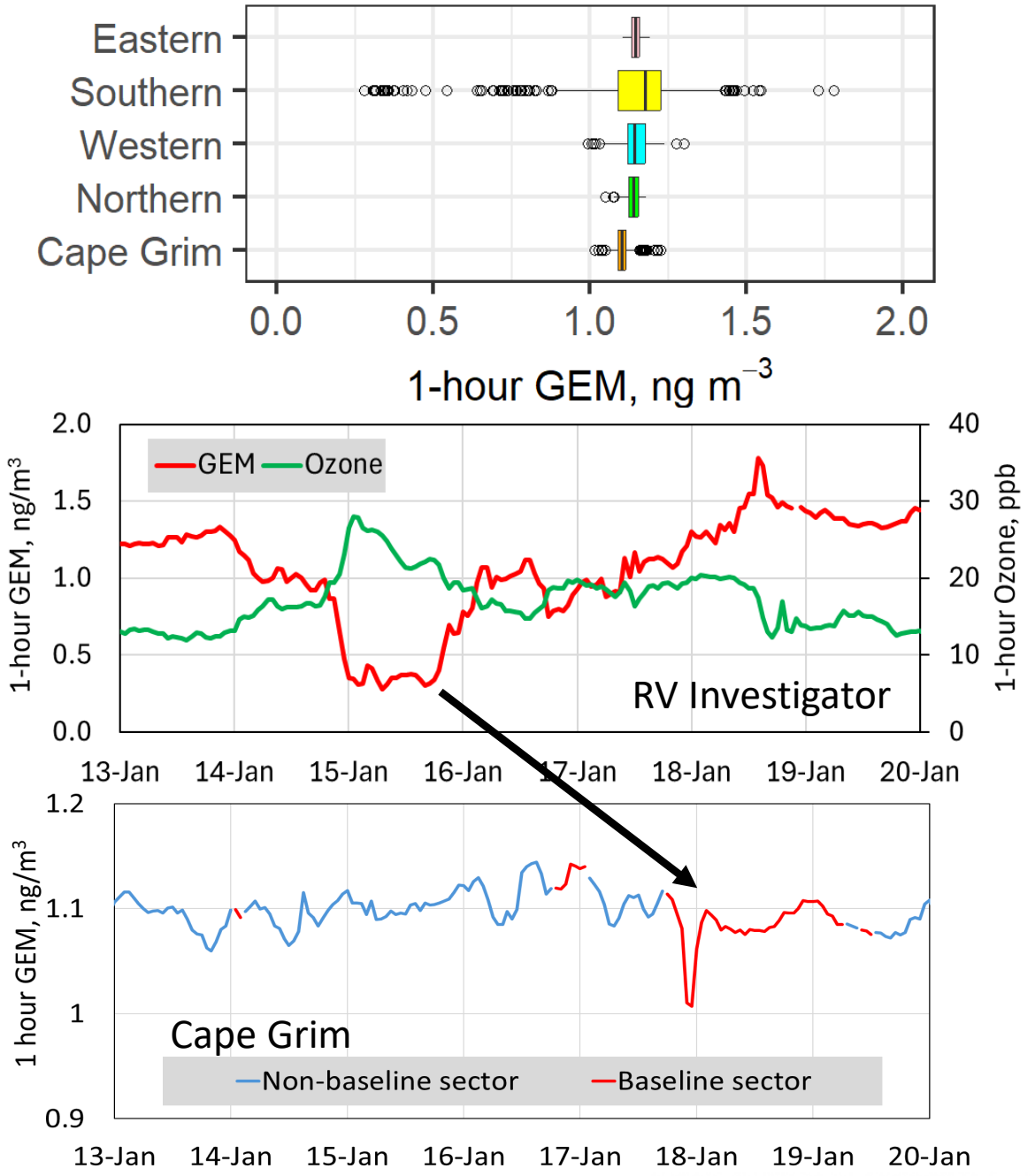
- 29 April to 18 May 2025
- Intercomparison of Cape Grim and RV Investigator GEM
- Measurements of dissolved gaseous mercury (DGM) using an equilibrator →fluxes across air-sea interface – useful for modelling
- Advice/collaboration welcome!



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.

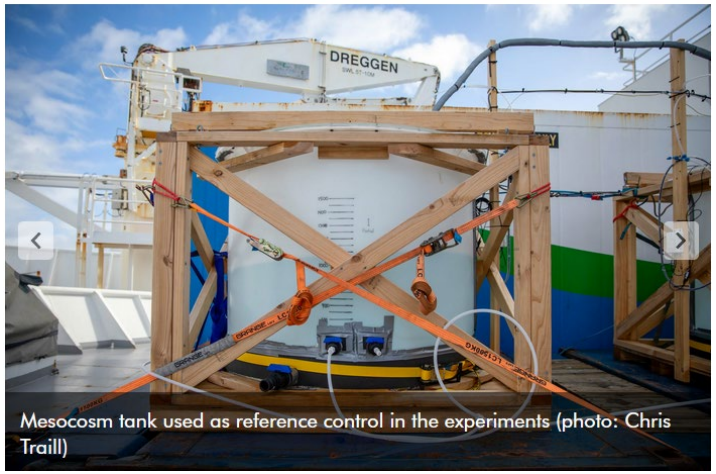
Conclusions

- Spatial transect of GEM over Southern ocean covering over 14,000 km over 73 days
- Cape Grim similar concentration range to Northern, Eastern, Western Southern Ocean transects
- Large in variation in southern transect suggesting more dynamic mercury cycling in polar region
- Multi-day gem depletion event, minima 0.26 ng/m^3 originating in Antarctic plateau, transported to coast by Katabatic flow.
- Depletion large enough to be detected at Cape Grim, 2,800 km away.
- N>1? currently reviewing 10-year record. Could inform us of replenishment of GEM in depleted airmasses by the Southern Ocean.
- Coast K voyage in 2025: plan to measure DGM/fluxes in the Southern Ocean: collaboration/advice welcome



Mercury voyage data still to explore….

5-day seawater mesocosm incubation experiments:
phytoplankton productivity and influence of iron fertilization; emissions of gases VOCs, CO_2, CH_4, GEM measured in tank headspace, Total Hg, MeHg measured in tank water (method based on Sellegri et al. 2023)



Mesocosm tank used as reference control in the experiments (photo: Chris Traill)

2000 L Teflon lined tanks, clear lid

Spatial gradients of total mercury in water compared to air
150 water samples taken at super and process stations along southern and western transects (4-8 depths per station)

Image: Helen Fry

Trace metal sampling

Influence of mercury on new particle formation:
possible link identified on previous voyage (SIPEX2) to sea-ice edge in Spring-time (Humphries et al. 2015)

Acknowledgements/References

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