Radon measurements in the Arctic: the challenges, technology and research benefits

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Arctic ^{222}Rn measurement challenges

- Northern high latitudes are characterised by frozen or waterlogged soils, often yielding small ^{222}Rn fluxes (low local radon source function)
- Air in long term equilibrium with the ocean contains 0.04 – 0.06 Bq m^{-3} of radon (less for transport over sea ice) (low ambient background radon)
- Tropospheric air subsiding over the pole can be very low in radon (e.g., <0.01 Bq m^{-3}) (admixtures with very low radon air)
- For large parts of the year outdoor radon in Arctic and subarctic environments may be characterised by concentrations ≤ 1 Bq m^{-3}
- For the best chance to reliably interpret radon observations in such environments, instruments with very low detection limits are required

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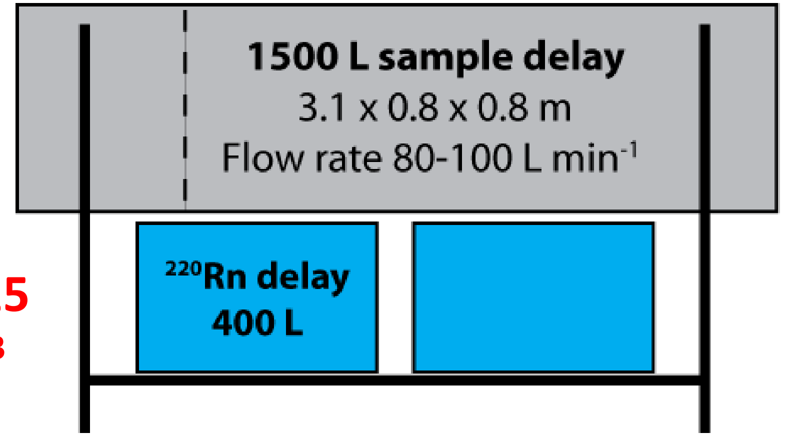
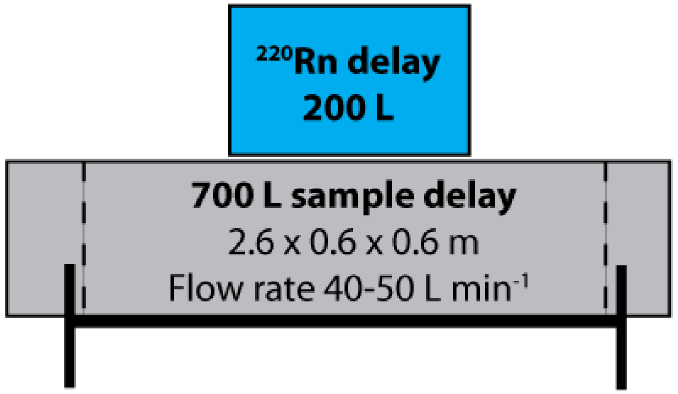
Two-filter dual-flow-loop ^{222}Rn monitors

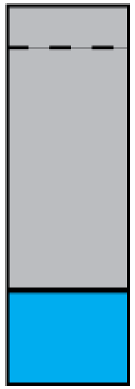
- ANSTO radon monitors were developed by progressive refinement of two-filter monitors developed in the 1970s and 1980s (detection limits 3-4 Bq/m^3)
- For over 20 years ANSTO two-filter radon monitors have been recognised as the best in the world for continuous, reliable low-level outdoor radon monitoring
- The detection limit (DL) of the 1500 L model is **0.025 Bq m^{-3}**
  30-min temporal resolution, **45-min** response time (correctable, Griffiths et al. 2016)
- Monitors provide a "direct" radon measurement: independent of sampling height, mixing state, surface characteristics, humidity and aerosol loading
  (also do not suffer tube loss effects)
- Since the DL is inversely proportional to volume (detector size), the most sensitive instruments are not readily portable (3.0 x 0.8 x 0.8 m^3; ~120 kg)

Two-filter dual flow-loop ^{222}Rn monitors

DL 0.025 Bq m^{-3}







DL 0.14 Bq m^{-3}

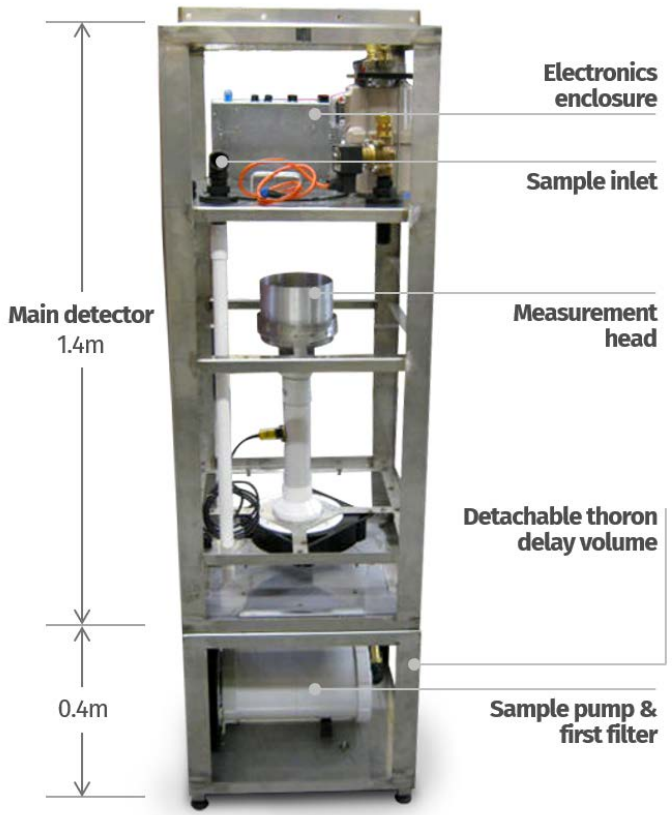
200 L sample delay
0.48 x 0.48 x 1.6 m
Flow rate 10-14 L min^{-1}

^{220}Rn delay ~70 L

Most accurate ^{222}Rn measurements in the world

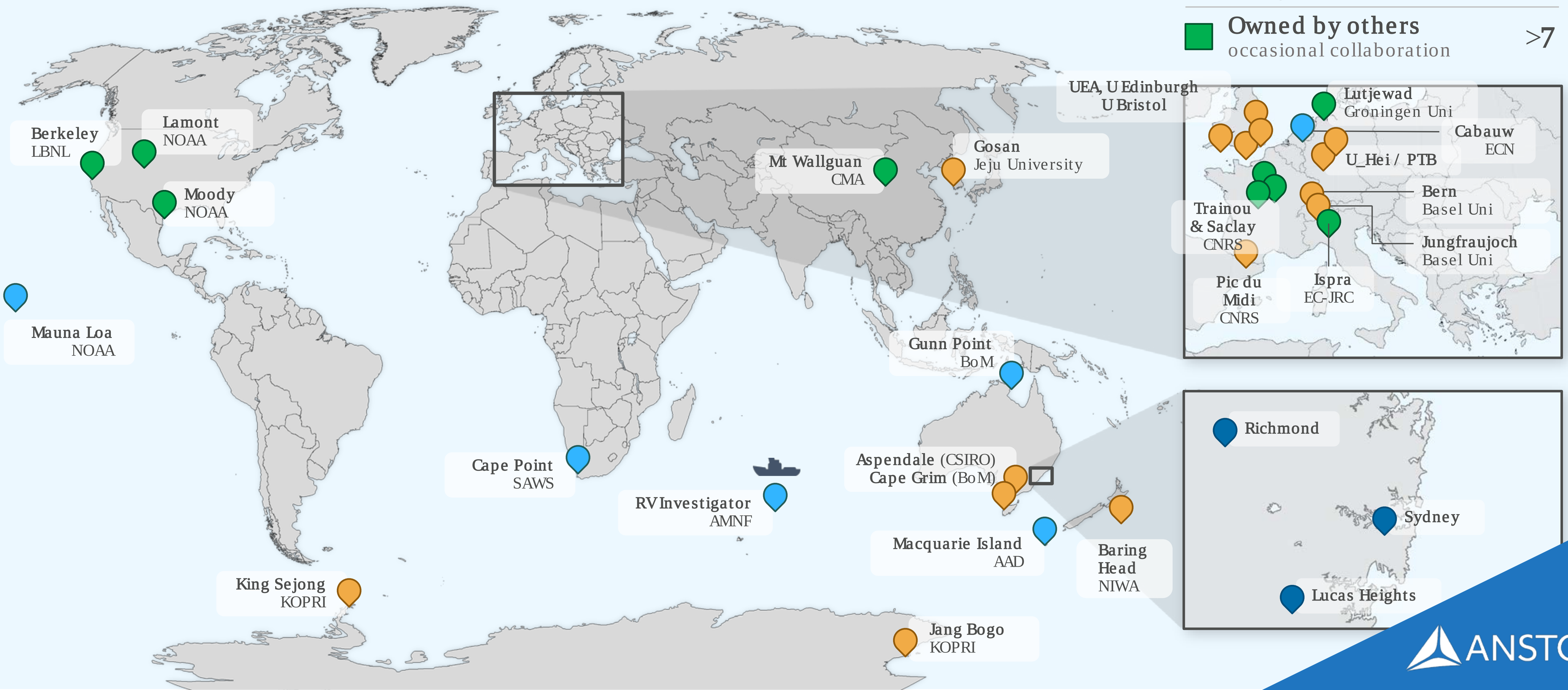
ANSTO's largest radon monitor (5000 L working volume) is located at the **Cape Grim Baseline Air Pollution Station** in Cape Grim, Tasmania.
(detection limit ~5 mBq·m^{-3} – not commercially available)

ANSTO's smallest radon monitor is the 200 L model (traceRadon)
(detection limit around 0.14 Bq·m^{-3})



Global network of ANSTO monitors

ANSTO owned and operated	3
ANSTO owned jointly operated	6
Owned by others strong collaboration	14
Owned by others occasional collaboration	>7



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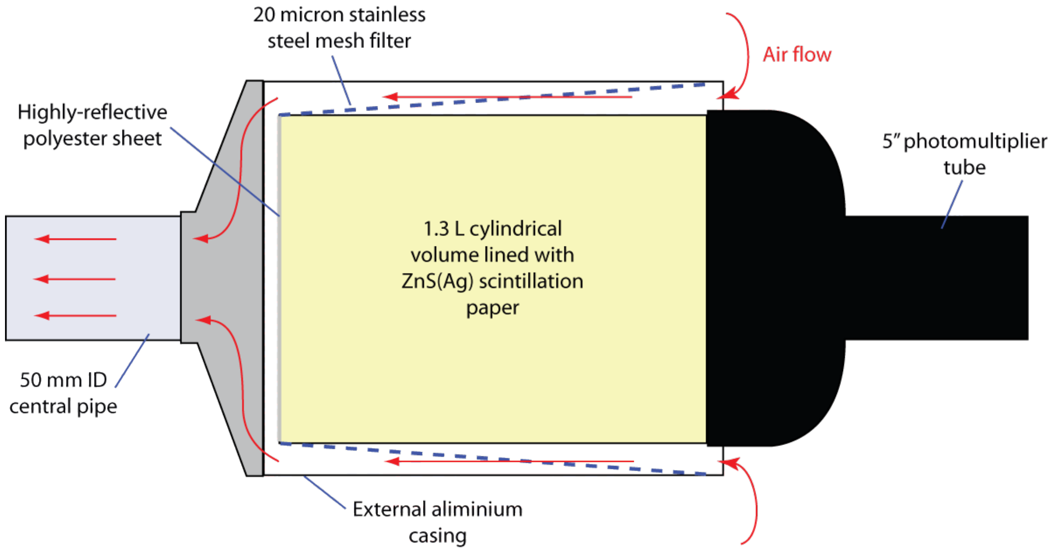
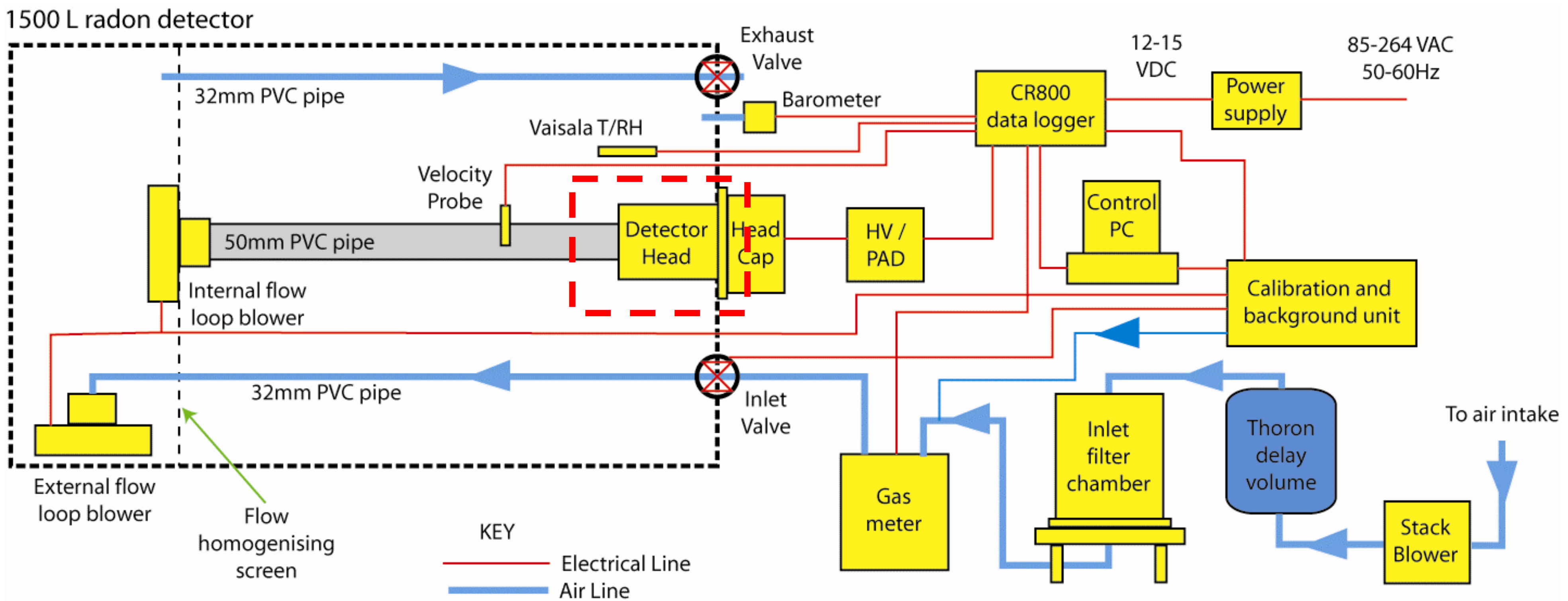
Principle of operation

- Gross α counting (not α spectra) → remove ^{219}Rn & ^{220}Rn
- Delay sample air (5 min) then filter to remove all radon progeny
- New progeny form inside the detector under controlled conditions and are captured on a 2nd filter. "zinc sulphide – PMT" assembly

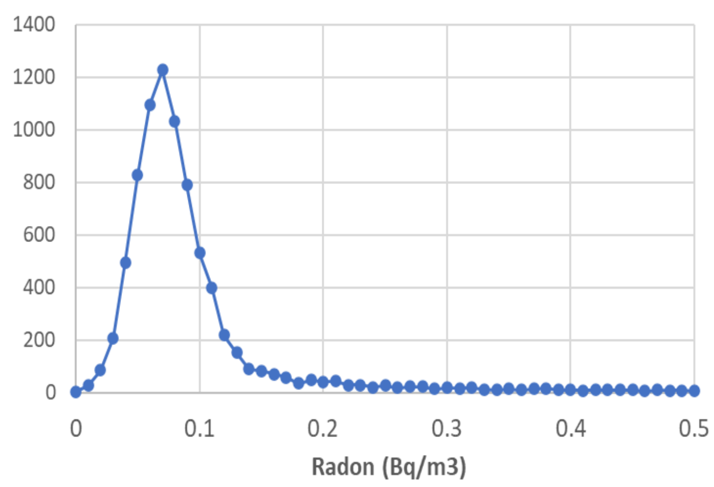




Example of high-latitude performance

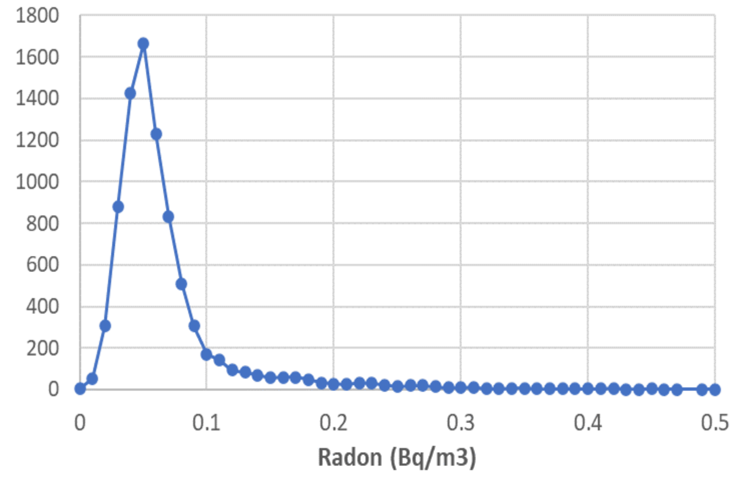
Macquarie Island

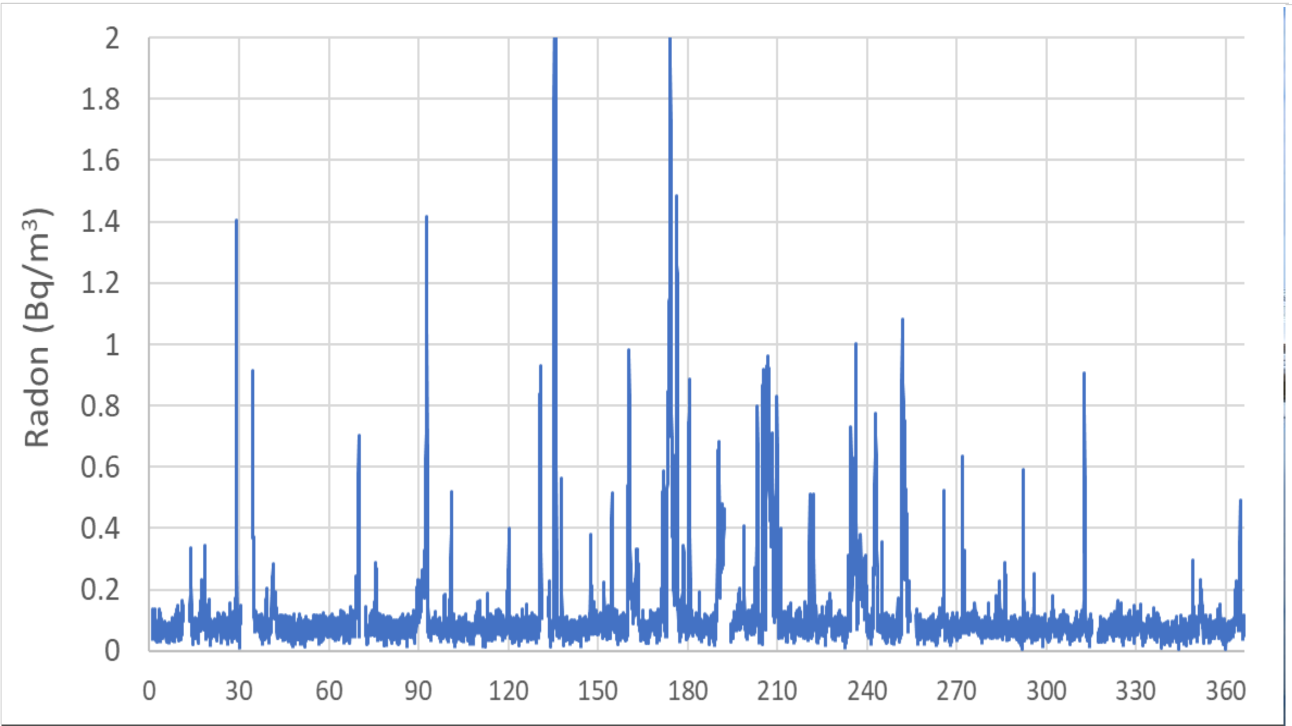
Remote oceanic site

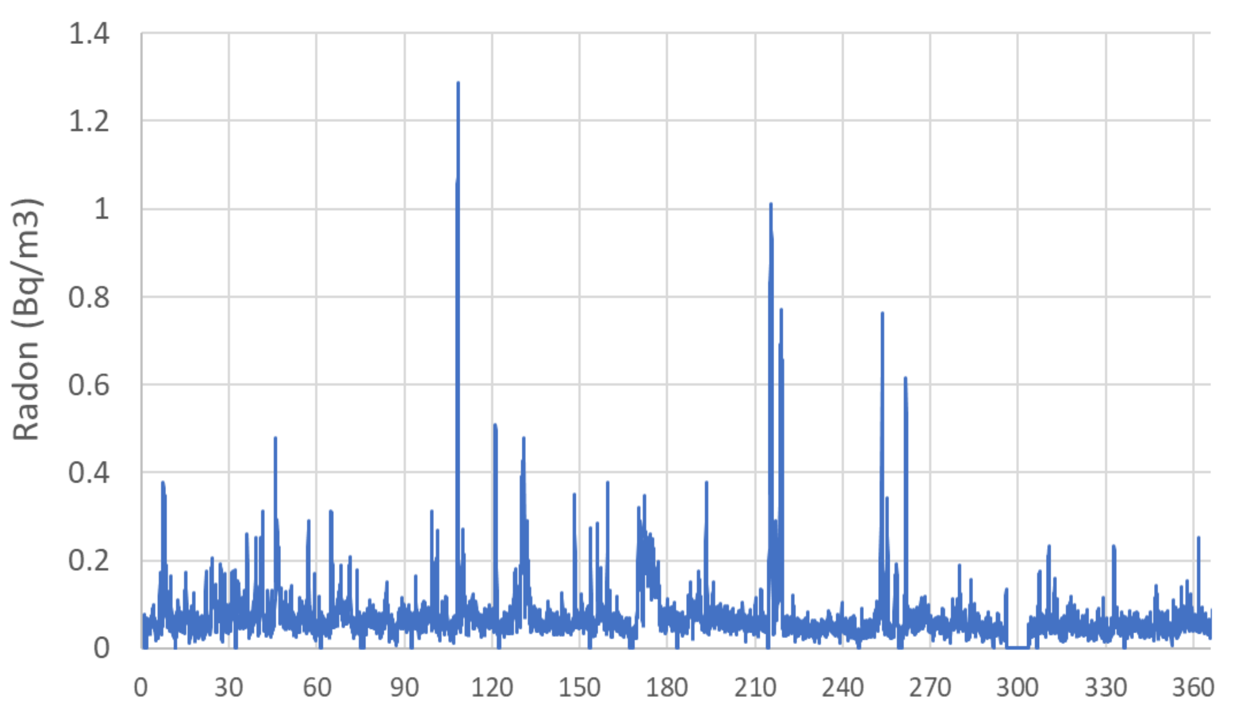


King Sejong Station

Antarctic Peninsula

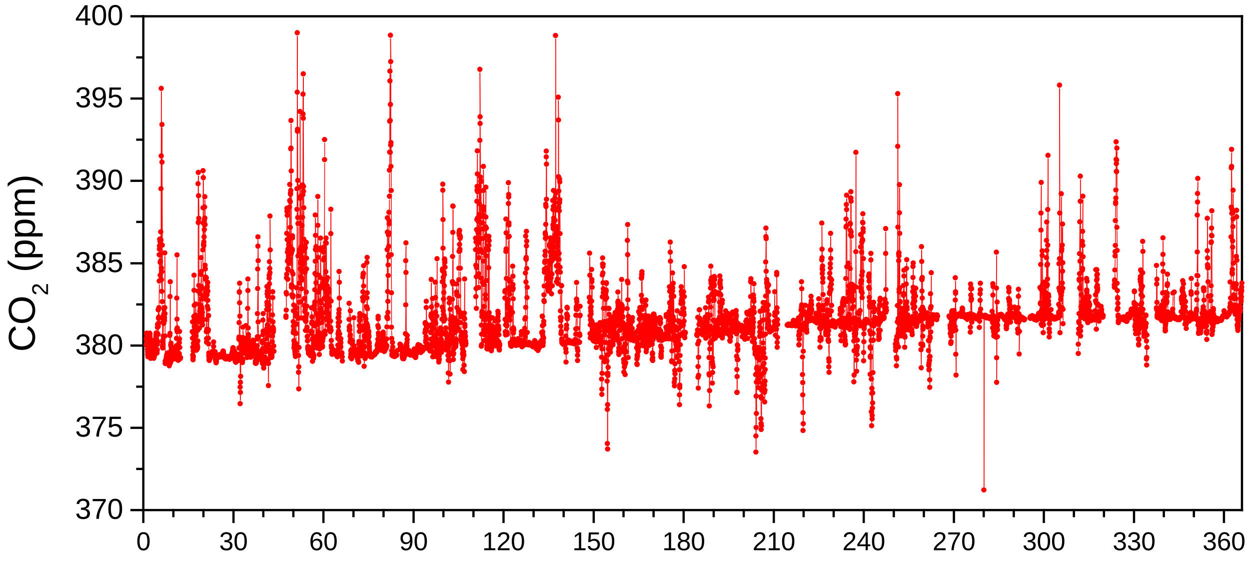


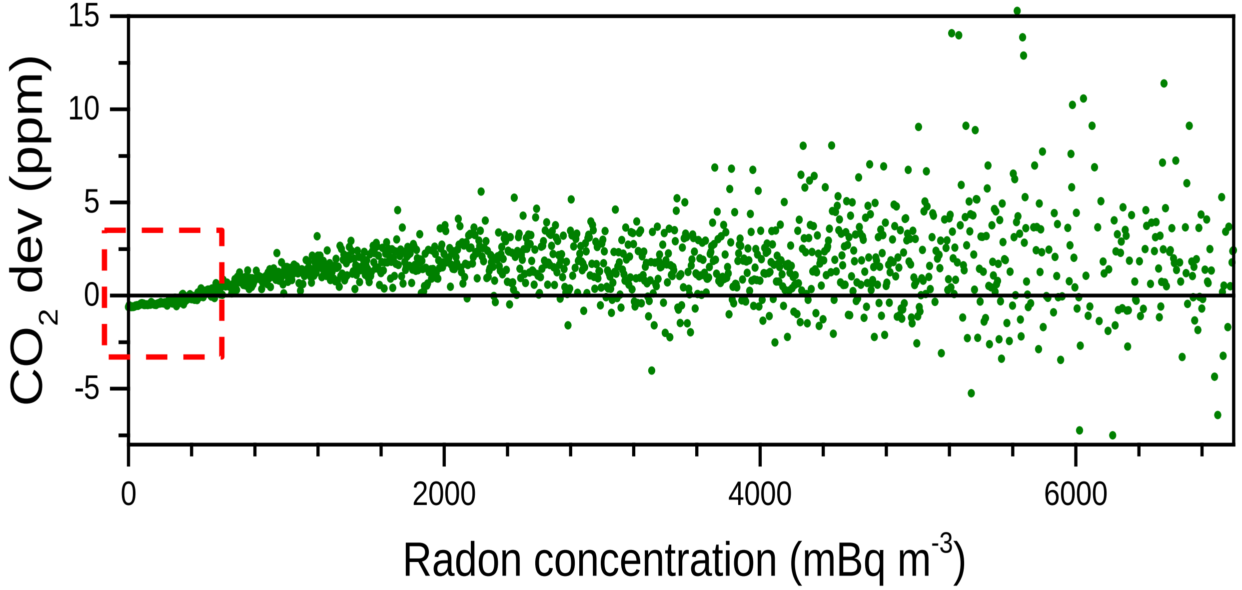




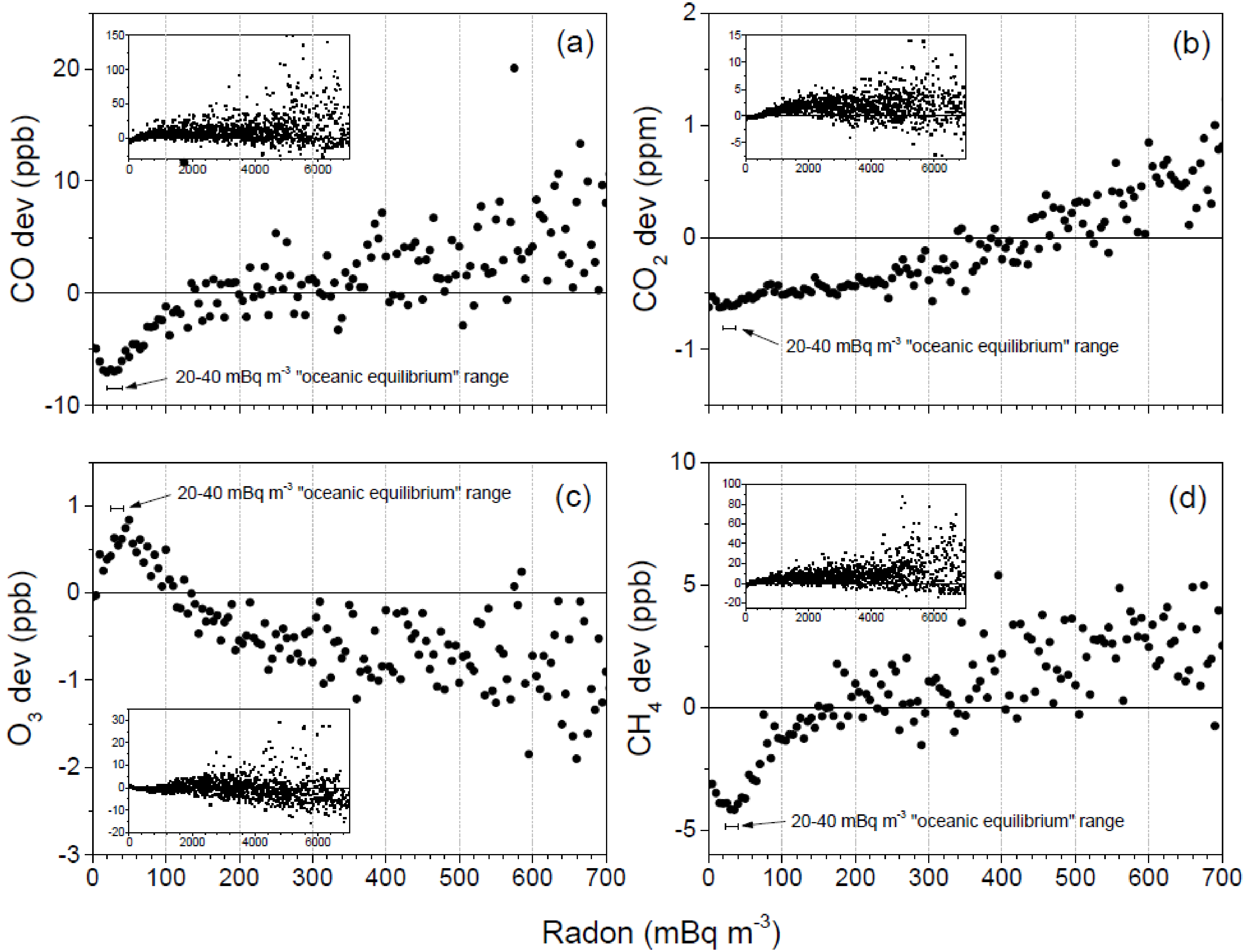
Direct applications for ICOS sites

- Characterising background (or "baseline") concentrations of GHG & ODS
- Estimation of local- to regional-scale fluxes of GHGs (radon tracer method - *traceRadon*)
- Air mass fetch analysis (in conjunction with back trajectories)
- Characterising the atmospheric mixing state (urban air quality & urban climate studies)
- Evaluate regional and global chemical transport models (transport and mixing)





Baseline characterisation of air masses



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Radon-derived baseline determination across the Southern Ocean

Alastair Williams[1], Scott Chambers[1], Alan Griffiths[1], Paul Krummel[2], Zoe Loh[2], Peter Sperlich[3], Casper Labuschagne[4], Sangbum Hong[5] and Taejin Choi[5]

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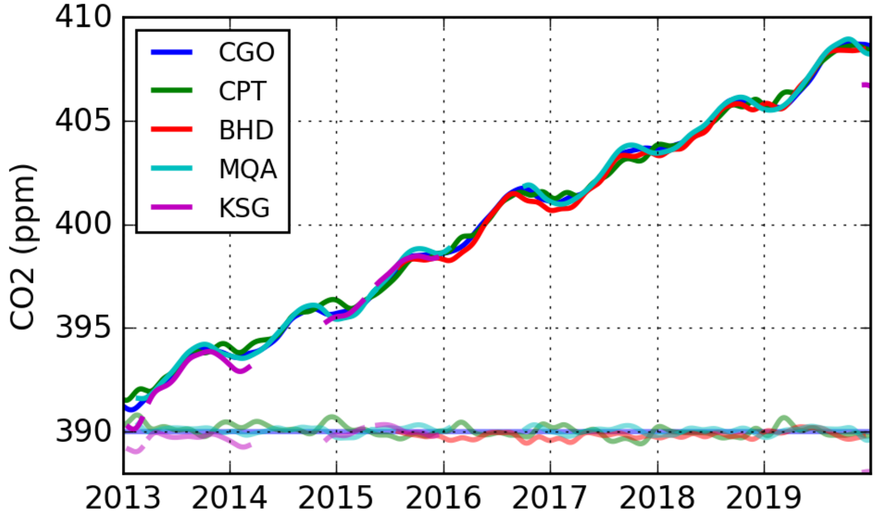
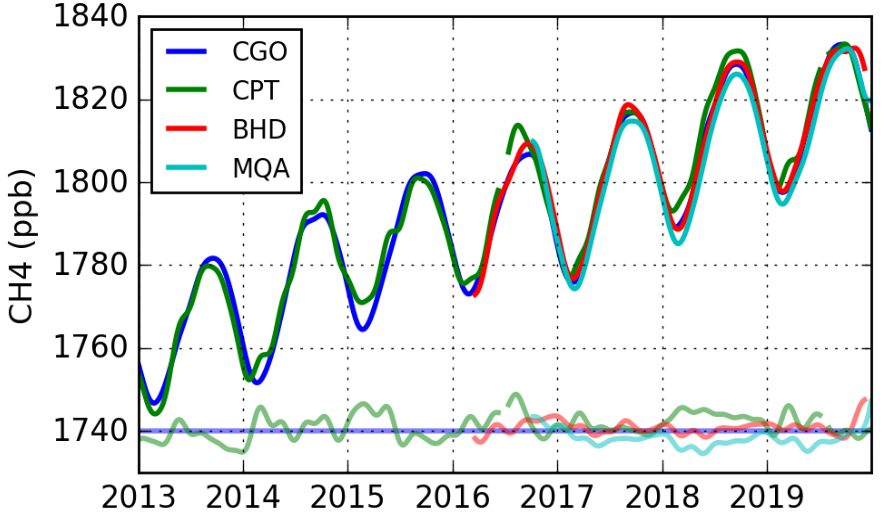
[5] *Korea Polar Research Institute (KOPRI), South Korea*

7 years of GHG (Carbon Dioxide and Methane) observations at the Cape Grim Baseline Air Pollution Station (traditionally a 6 to 9 step meteorological & statistical baseline selection process is applied – site specific)

Radon-selected "baseline" GHGs from five separated SO stations (Cape Grim, Cape Point, Baring Head, Macquarie Island, King Sejong)

Universal approach





Evaluation of Global Models

- For over 30 years ^{222}Rn has been used to evaluate transport & convection in GCMs & CTMs
- However, its efficacy depends on the quality and coverage of available radon concentration and flux measurements
- Zhang et al (2021) used radon from 51 sites globally to compare convection schemes in GEOS-CHEM – the lack of suitable observations throughout Canada, Alaska, Siberia, Greenland, Iceland & Africa was highlighted
- Accurate knowledge of radon in northern high-latitudes is currently limited to measurements from a few sites in Ireland, Finland and the Netherlands
- The present lack of suitable observations is responsible for a large uncertainty in simulated radon concentrations & fluxes in northern high latitudes (particularly Canada, AK & Siberia)
- This has necessitated an oversimplified formulation of ^{222}Rn fluxes in these regions which limits efficacy of radon as an assessment tool for convection and transport
- To better constrain seasonal & interannual variability of ^{222}Rn, long-term (multi-year) monitoring is required in these under-represented regions

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Summary

- ANSTO radon monitors are reliable, robust, accurate, with low power & maintenance requirements, and are fully remotely controllable – ideal for remote deployment
- The small (200L) model would also provide a valuable reference for public health studies
- Their measurement capabilities are well suited for characterising diurnal and seasonal changes in radon in the challenging conditions of northern high latitudes
- 35 ANSTO radon monitors are already operating worldwide (including WMO GAW and ICOS sites); with many having records for > 10 years
- Adding sites in northern high latitude regions would greatly enhance this existing capability
- Both the public health and climate research communities would benefit significantly from this enhanced capability

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The End ...