The Australian Greenhouse Gas Observation Network: Current status and vision for the future

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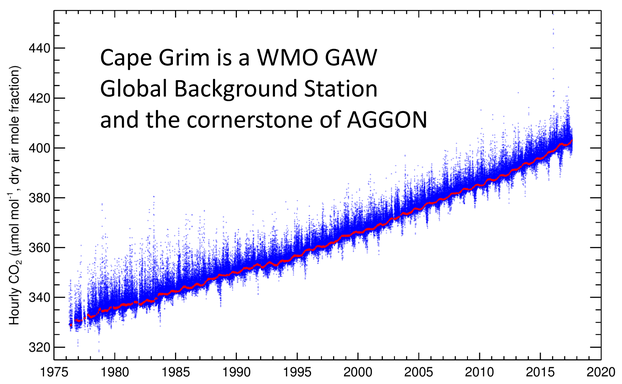

Figure 1: The 40+ year atmospheric CO_2 record from Cape Grim. Blue data are all hourly means. Red data are baseline hours.

Pristine sites

In addition to Cape Grim, Casey (Antarctica) and Macquarie Island are key sites for efforts to understand the role of the Southern Ocean in the global carbon cycle.

The RV Investigator allows us to make measurements from the ice edge, to the tropics.

Continental sites

Gunn Point was set up to address the dearth of atmospheric measurements in tropical regions.

Otway, Arcturus, Ironbark and Burncluith were all established for fugitive emissions monitoring (from geological carbon storage and coal seam gas production). Nevertheless, data from these sites are broadly valuable for validating biosphere models and for constraining regional scale greenhouse gas (GHG) emissions estimates.

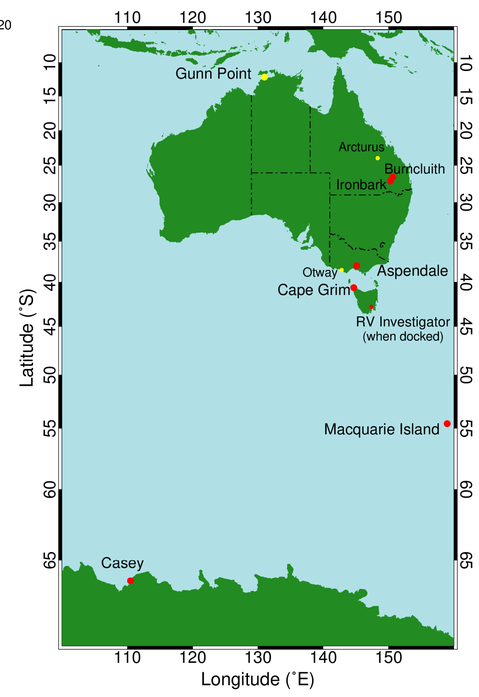

Figure 2: AGGON. Red: operational site. Yellow: decommissioned or suspended at the present time.

SITE NAME (CODE)	INTAKE HEIGHT	SPECIES	LAT/LONG	STATUS
Cape Grim (CGO)	70 m	CO_2, CH_4	40.68˚S/144.69˚E	1976 – present
Gunn Point (GPA)	20 m	CO_2, CH_4	12.25˚S/131.05˚E	2010 – 2017
Macquarie Island (MQA)	10 m	CO_2, CH_4	54.50˚S/158.94˚E	2005 – present
RV Investigator (RVI)	14 m	CO_2, CH_4	Various	2014 – present
Casey, Antarctica (CYA)	7 m	CO_2, CH_4	66.28˚S/110.52˚E	2012 – present
Aspendale (ASP)	10 m	CO_2, CH_4	38.03˚S/145.10˚E	2008 – present
Otway (OTA)	10 m	CO_2, CH_4	38.52˚S/142.82˚E	2007 – 2012
Arcturus (ARA)	10 m	CO_2, CH_4	23.86˚S/148.47˚E	2010 – 2014
Ironbark (IBA)	10 m	CO_2, CH_4	27.15˚S/150.25˚E	2014 – present
Burncluith (BCA)	10 m	CO_2, CH_4, CO	26.55˚S/150.71˚E	2015 – present

Table 1: Details of each AGGON site. At present, Cape Grim operates a LoFlo NDIR system, in parallel with a Picarro G2301. All other network sites operate Picarro G2301 or G2401 units.

Site characterisation

Figure 3 uses histograms of the standard deviation of minutely means to provide a simple way to characterise sites. The top two panels examine data from our 'pristine' sites. The lower two panels (showing long and substantial tails in their histograms) represent the continental sites.

Stavert *et al.* have successfully used the minutely standard deviation to remove the influence of local sources in the Macquarie Island data set.

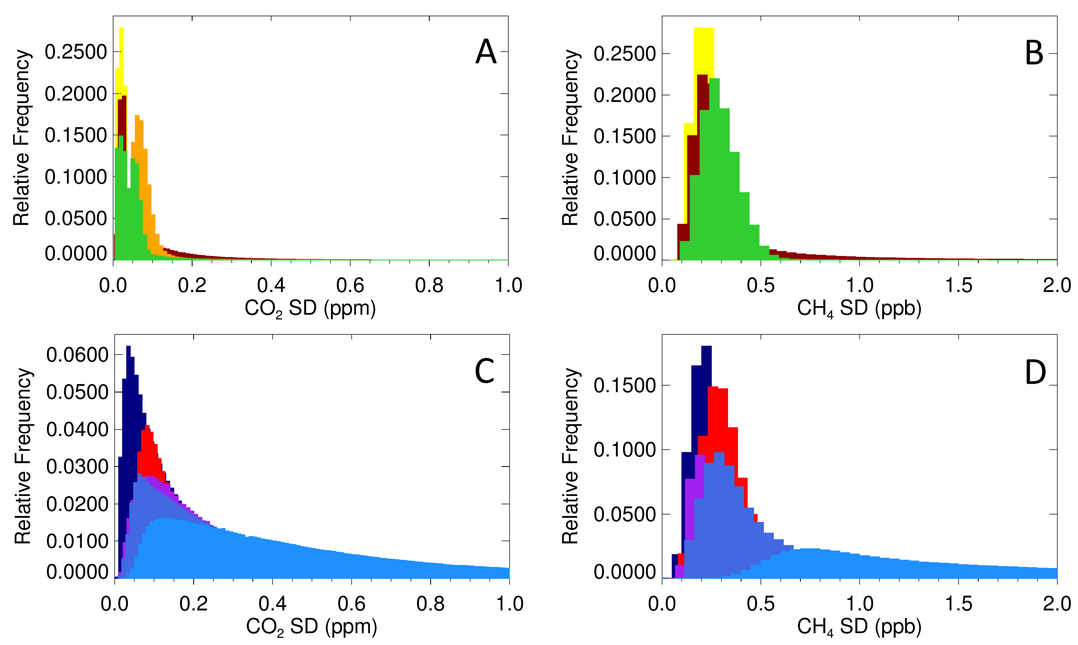

Figure 3: Frequency histograms of minutely standard deviation in **A**) CO_2 and **B**) CH_4 at **RV Investigator**, **Cape Grim**, **Macquarie Island** and **Casey**; **C**) CO_2 and **D**) CH_4 at **Ironbark**, **Gunn Point**, **Burncluith**, **Arcturus** and **Otway.** CO_2 bin size = 0.01 ppm; CH_4 bin size = 0.05 ppb.

The Australian Greenhouse Gas Observation Network (AGGON), is a network of continuous in situ instruments primarily for the measurement of CO_2 and CH_4. It is operated by CSIRO, in collaboration with the Australian Bureau of Meteorology and the Australian Antarctic Division. AGGON is designed to provide high quality data for a large portion of the Southern Hemisphere to the World Meteorological Organisation (WMO) Global Atmosphere Watch (GAW) program via the World Data Centre for Greenhouse Gases (WDCGG) as hourly means.

Calibration Strategy

Gas Chromatographs (GCs) in the CSIRO Global Atmospheric Sampling LABoratory (GASLAB) use suites of primary standards to define the WMO X2007 mole fraction scale for CO_2 and the WMO X2004A scale for CH_4. These scales are transferred to the reference and calibration standards we produce for each of our instruments. Care is taken to maintain clean air isotopic mixing ratios in the production of standards.

As shown in Figure 4, a reference standard is measured daily and used for drift correction and single point calibration. Every four to six weeks, the calibration cylinders are measured to provide a non-linearity correction. The calibration cylinders are designed to have mixing ratios spanning the range of mixing ratios generally observed at each site.

GCWerks software is used for all data processing.

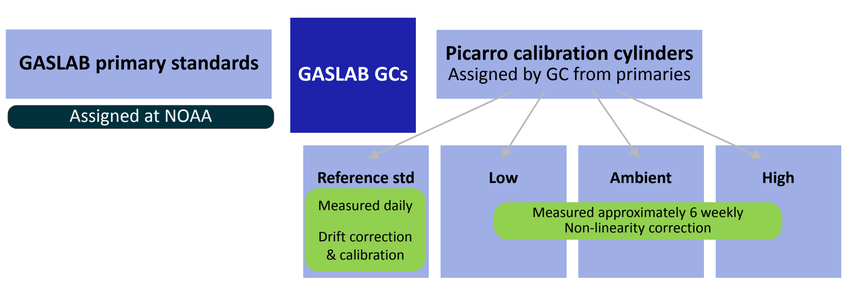

Figure 4: The calibration hierarchy for obtaining in situ measurements from field Picarro instruments on the WMO X2007 CO_2 mole fraction scale and the WMO X2004A CH_4 mole fraction scale.

Future Vision

In the wake of the Paris Agreement, our research community has a pivotal role to play in delivering the Global Stocktaking that's been foreshadowed. Each country, (including Australia), will need to provide credible national GHG budgets, with low uncertainties. Achieving this goal rapidly requires:

- Expansion of high precision GHG measurement networks;
- Investment in regional scale inverse modelling capability;
- Addition of multi-species measurements (e.g. N_2O, CO and isotopes), and;
- Better linkages between top-down and bottom-up approaches to estimating GHG emissions.

We expect that AGGON will participate in initiatives such as the WMO/UNEP driven Integrated Global Greenhouse Gas Information System, allowing Australia to:

- Quantify its progress towards Nationally Determined Contributions;
- Reduce uncertainty in emissions estimates inventories, and;
- Inform additional mitigation policies.

Despite recent set-backs (e.g. the suspension of measurements at Gunn Point), we are working towards making AGGON more robust and extensive in the medium term, by including N_2O and CO measurements at more sites and looking for opportunities to develop new sites, particularly around urban areas. A network optimisation study by Ziehn *et al.* will act as a guide.

Figure 5, below, shows the optimal locations for adding five additional sites to the base network (Cape Grim and Gunn Point, shown in brown) for CO_2, CH_4 and N_2O measurements (red, green and blue, respectively) to reduce the uncertainty in Australia's GHG emissions estimates.

Data from AGGON will be used to improve GHG emissions estimates at regional to national scale in Australia, with a view to:

- Meet our international obligations;
- Help discriminate between natural and anthropogenic emissions, and;
- Monitor natural GHG sources and sinks in response to radical decarbonisation and or negative emissions scenarios.

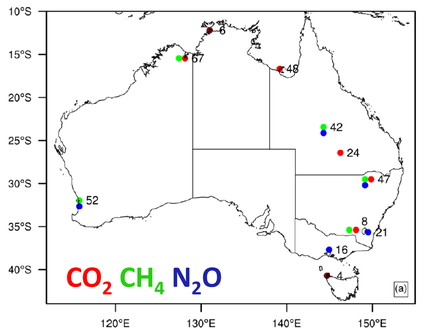

Figure 5: Optimal expanded AGGON map, taken from Ziehn *et al.* (2016).

FOR FURTHER INFORMATION

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