

An overview of CSIRO/CAWCR Greenhouse Gas (GHG) observation activities in Australia

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Centre for Australian Weather and Climate Research/CSIRO Marine and Atmospheric Research

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Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology



Presentation Outline



An overview of greenhouse gas (GHG) observation networks and GHG research activities conducted by CAWCR/CSIRO in Australia will be presented:

1. The CSIRO Global Atmospheric Sampling LABORatory (GASLAB) flask network
2. Proposed expanded Australian GHG network with high precision *in situ* analysers
3. The Cape Grim GHG program and associated cooperative programs – how these contribute to WMO GAW
4. GHG inter-comparison activities undertaken at Cape Grim

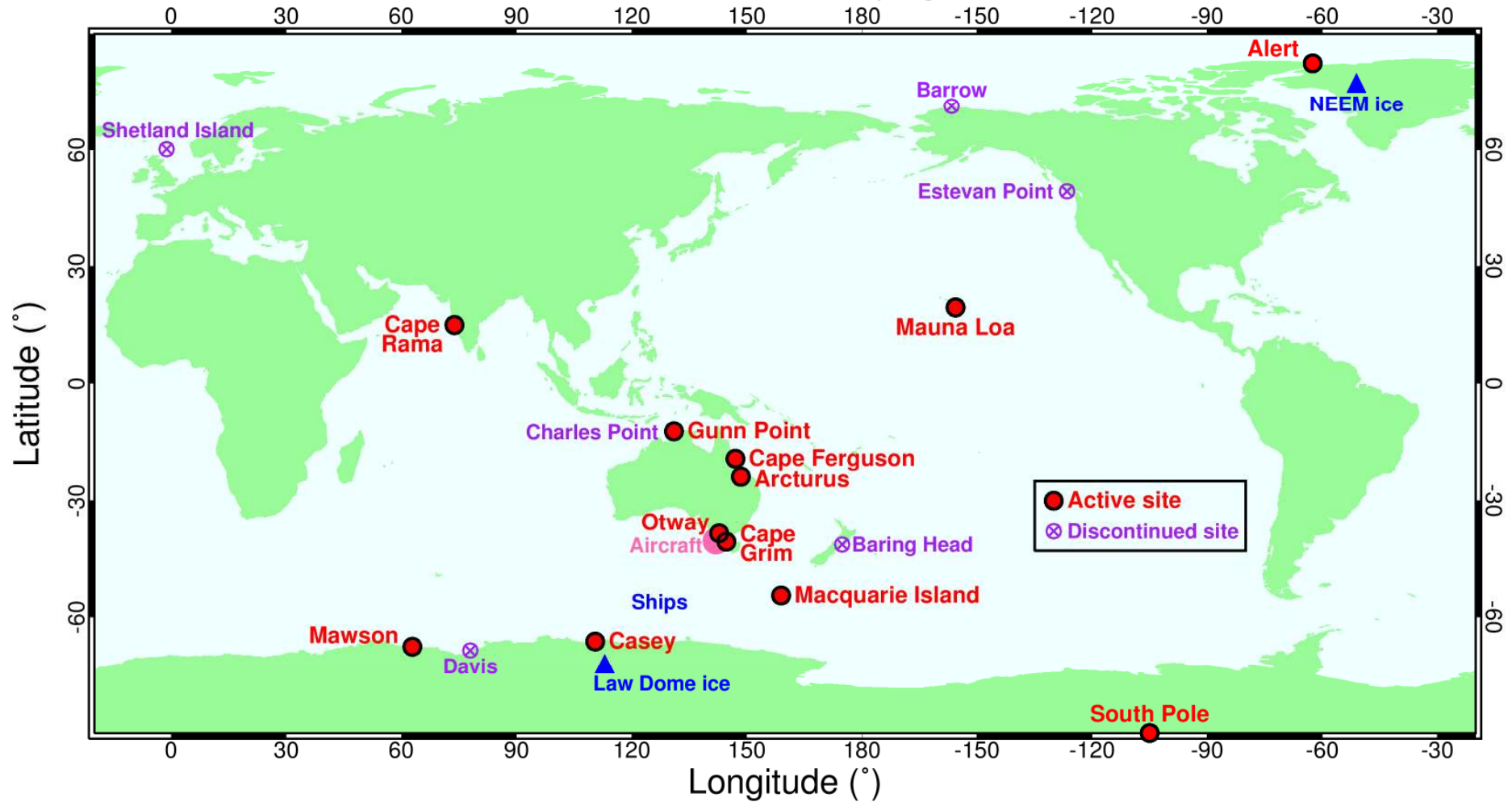
The CSIRO Global Atmospheric Sampling Laboratory (GASLAB) flask network



The CSIRO Global Atmospheric Sampling Laboratory (GASLAB) flask network



CSIRO GASLAB Flask Sampling Network



The CSIRO Global Atmospheric Sampling Laboratory (GASLAB) flask network

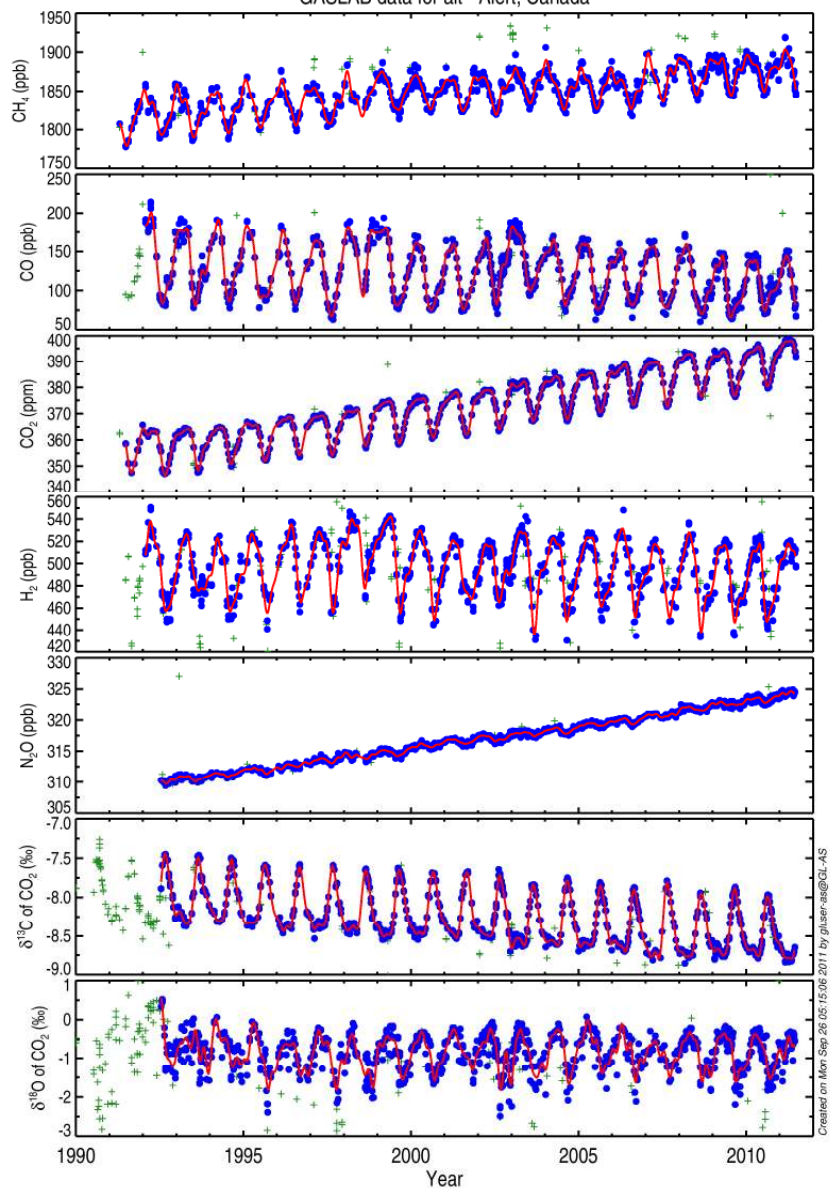


- 2nd largest flask network in the world behind the extensive NOAA ESRL network
- Southern Hemisphere focus
- Operational since 1991
- 0.5 litre glass flasks (some 5 litre glass flasks from South Pole)
- Analysed for CO₂, CH₄, N₂O, CO & H₂ using gas chromatography with three different detectors: FID, ECD and MRD
- Analysed for ¹³CO₂ & C¹⁸OO using mass spectrometry
- Small sample size (30-50 ml) – important for flask air sharing programs & ice-core measurements
- Not possible without in kind support from many other institutions/observatories
- Data submitted to WMO GAW WDCGG each year
- Data used in major national and international assessments, annual WMO GHG bulletin
- Facility needs major upgrade

The CSIRO Global Atmospheric Sampling Laboratory (GASLAB) flask network



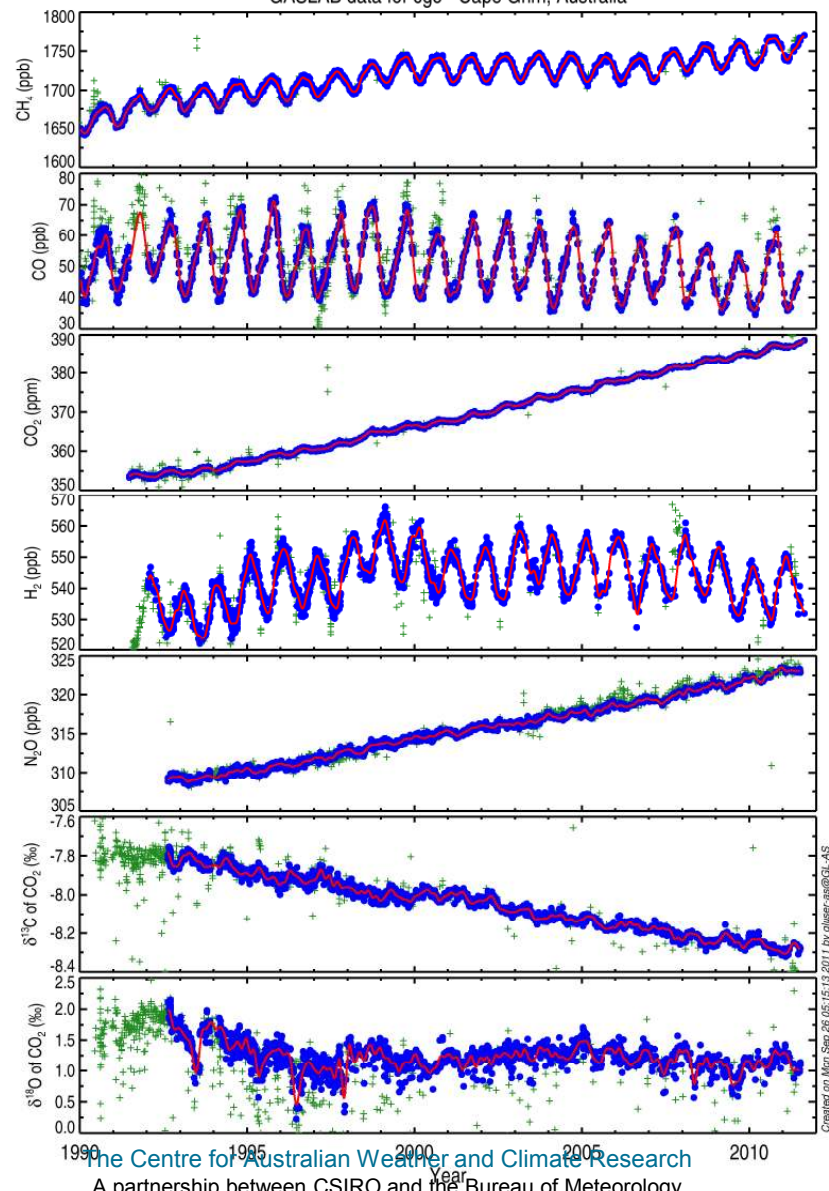
GASLAB data for alt - Alert, Canada



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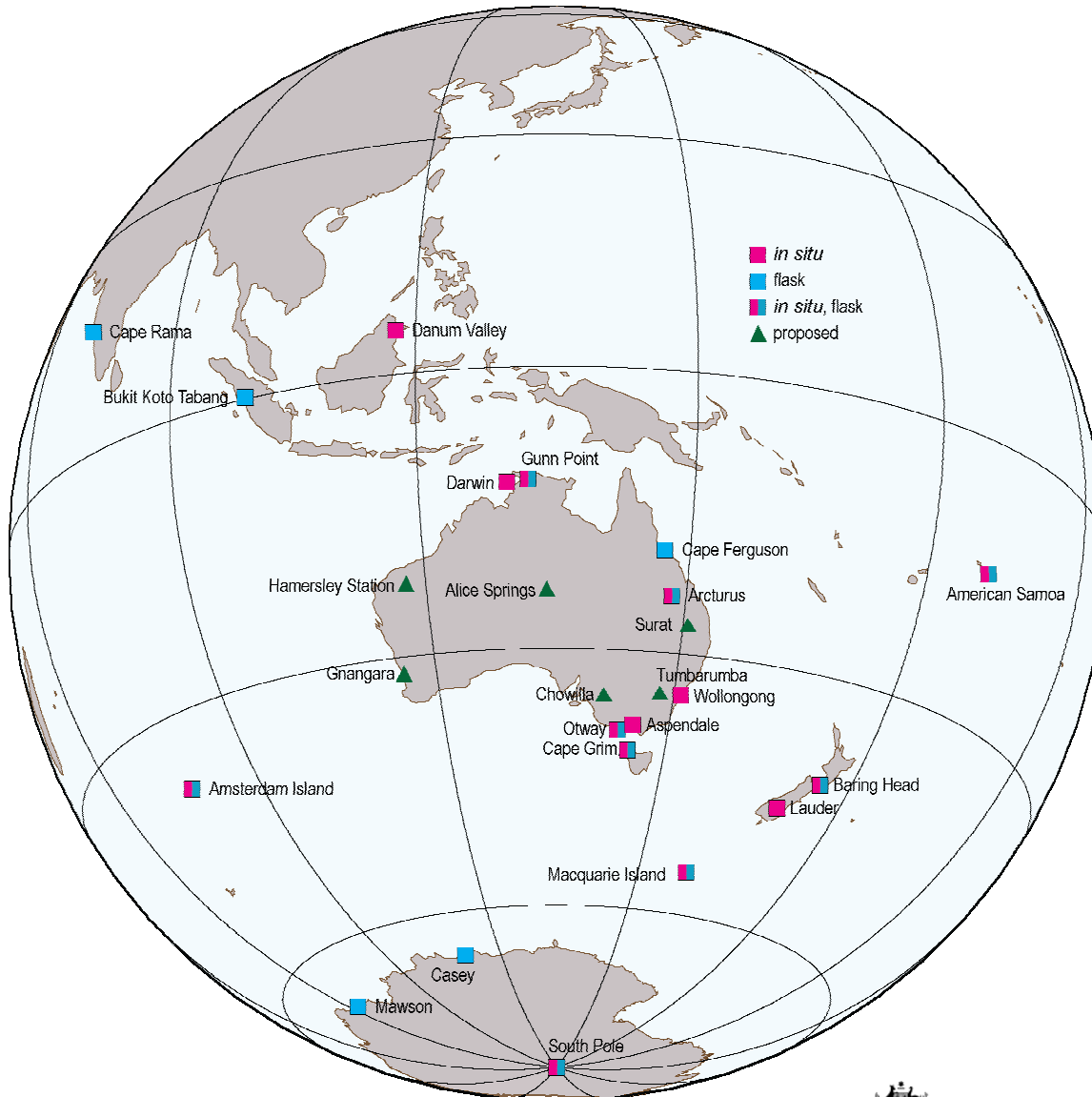


GASLAB data for cgo - Cape Grim, Australia



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Proposed expanded Australian GHG network with high precision *in situ* analysers



■ Operational and proposed surface GHG observing sites (*in situ*, flask) in the Australian region (CSIRO, TCCON, CSS, international: AGAGE and WMO GAW).

■ Tropics and central/western Australia under sampled.

The Cape Grim GHG program



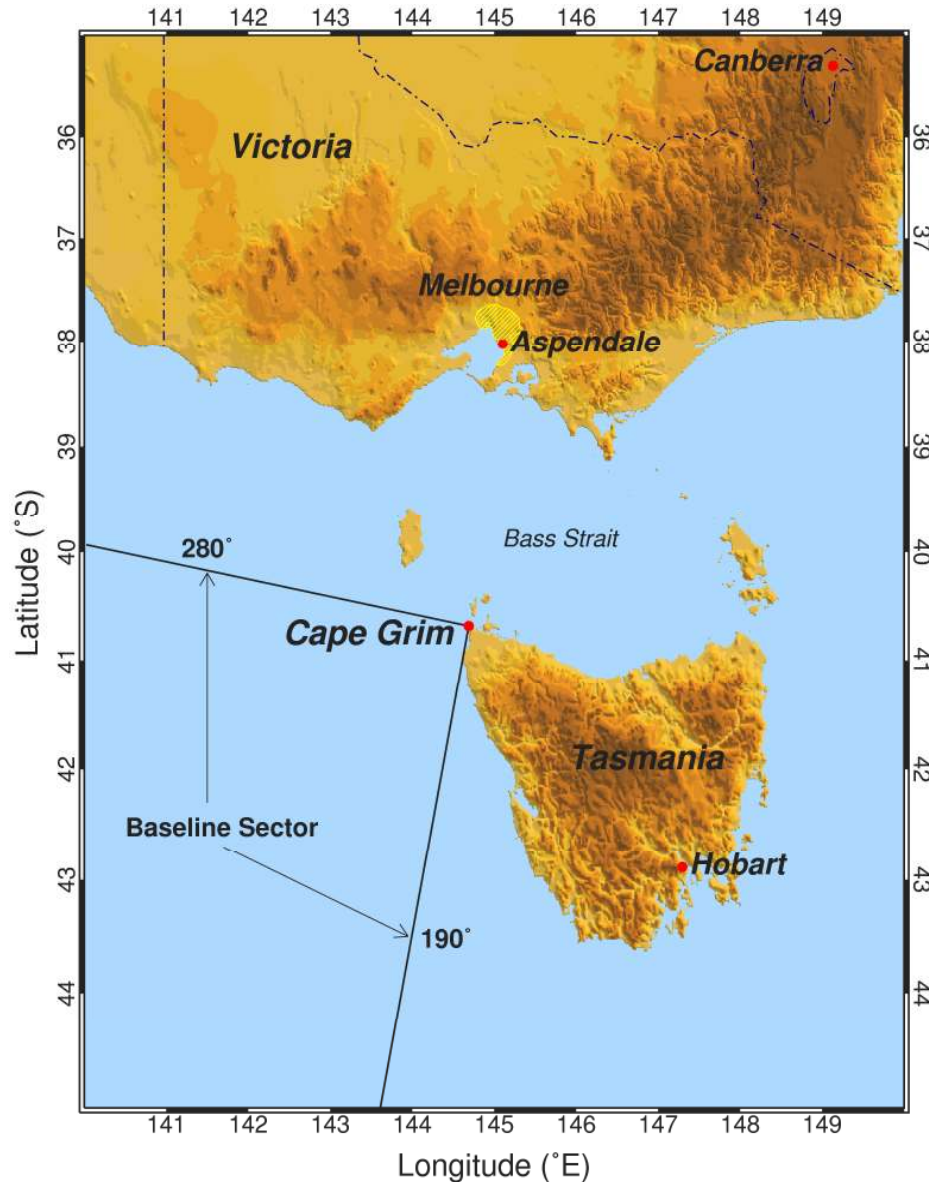
The Cape Grim GHG program



The Cape Grim GHG program



The Cape Grim GHG program



- In continuous operation since 1976 – one of the longest sites in the world.
- Located on north-west tip of Tasmania, atop 94 m cliff
- Representative mid-latitudes southern hemisphere and located in roaring forties: ~30% of air is in baseline sector.
- Station is operated and funded by Australian Bureau of Meteorology
- The scientific management is a joint responsibility of the Bureau and CSIRO Marine and Atmospheric Research

Cape Grim GHG program – scientific objectives



- Contribute to Australia's obligations to WMO-GAW to operate a global baseline monitoring station
- Provide 'state-of-the-art' data on all the important GHGs & ODSs at the mid-latitudes of the Southern Hemisphere
- Maintain the resultant data in stable, publically-available, user-friendly data archives
- Derive temporal (diurnal to decadal), atmospheric variability of GHGs and ODSs
- Provide data to national & international atmospheric modelling teams (often collaboratively) to derive regional & global GHG and ODS emissions & understand important sink processes
- Publish the data, trends, cycles, global & regional emissions & sinks in high-quality national/international peer-reviewed journals
- In particular compare/verify these 'top-down' estimates of GHG emissions to national /international 'bottom-up' emission estimates that constitute the legal obligations as signatories to the UNFCCC (meeting Kyoto Protocol commitments)
- Submit data & research findings to all important national and international periodic reviews of climate change & ozone depletion science (IPCC & UNEP/WMO)

Cape Grim Greenhouse Gases Program



■ Three Sub-Programs

- Carbon Dioxide (CO₂) & CO₂ isotopes (¹³CO₂, C¹⁸OO)
- Non-CO₂ Greenhouse Gases (GHGs) & Ozone Depleting Substances (ODSs)
 - All Kyoto gases: methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), nitrogen trifluoride (NF₃) & related species under consideration: trifluoromethyl sulfurpentafluoride (CF₃SF₅), sulfuryl fluoride (SO₂F₂)
 - All important Montreal gases: chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, methyl bromide (CH₃Br), methyl chloroform (CH₃CCl₃), carbon tetrachloride (CCl₄)
 - Other halocarbons (CH₃Cl, CH₂Cl₂, CHCl₃ etc)
 - Carbon monoxide (CO), hydrogen (H₂), carbonyl sulfide (COS)
 - Hydrocarbons: ethane (C₂H₆), propane (C₃H₈), benzene (C₆H₆), toluene (C₇H₈)
- Cape Grim Air Archive – more than 85 whole air samples since 1976
- In 2004 Cape Grim became the first Baseline Station in the Southern Hemisphere to monitor all the important GHGs & ODSs involved in the Kyoto & Montreal Protocols
- The inventory of measured species continues to grow, currently about 65

Cape Grim Greenhouse Gases Program



■ Past and present Co-operative Sub-Programs

- Empa (Switzerland): HFCs
- LSCE (France): CO₂ & isotopologues, CH₄, N₂O, CO, H₂
- NIES (Japan): halocarbons
- NOAA-ESRL (USA): CO₂ & isotopologues, CH₄, N₂O, halocarbons, SF₆, CO, H₂
- U. California/SIO (USA): O₂/N₂, halocarbons, SF₆
- U. Heidelberg & MPI-BGC (Germany): SF₆, CO₂ & isotopologues, CH₄, N₂O, CO, H₂
- U. East Anglia (UK): halocarbons, SF₆
- U. Princeton (USA): O₂/N₂
- U. Tohoku: CO₂ & isotopologues, CH₄, CO

Instrumental Methods



- GC-MD (1993-present): 10 species
- GC-ECD (2001-2009): 1 species (SF₆)
- GC-MS-ADS (1998-2004): ~25 species
- GC-MS-Medusa (2004-present): >50 species
- LoFlo Mk 1 & 2 (NDIR) CO₂ (2001-present)
- GASLAB flasks (1991-present): GC 5 species; IRMS 2 CO₂ isotopologues

- Data submitted to WMO GAW WDCGG each year for most species
- New Cape Grim GHG webpage available:
 - www.csiro.au/greenhouse-gases
 - Plan to update the data on this website on a monthly basis

- Importance of good data management and QA/QC procedures to produce long-term high quality datasets.

Benefit of doing long-term high quality GHG measurements: last 10 years (2000-2010) publications using Cape Grim data



■ 110 peer-reviewed papers since 2000

■ CO ₂ /isotopes	33%
■ CH ₄ , N ₂ O	27%
■ Kyoto Protocol synthetics (HFCs etc)	13%
■ Montreal Protocol gases (CFCs etc)	17%
■ other halomethanes (CH ₃ Cl, CH ₃ I, CHCl ₃ etc)	15%
■ other gases	5%
■ international journals	95%
■ 9 in <i>Science</i> or <i>Nature</i>	8%
■ ~2,400 citations	23 per paper
■ national/international modelling collaborations	60%

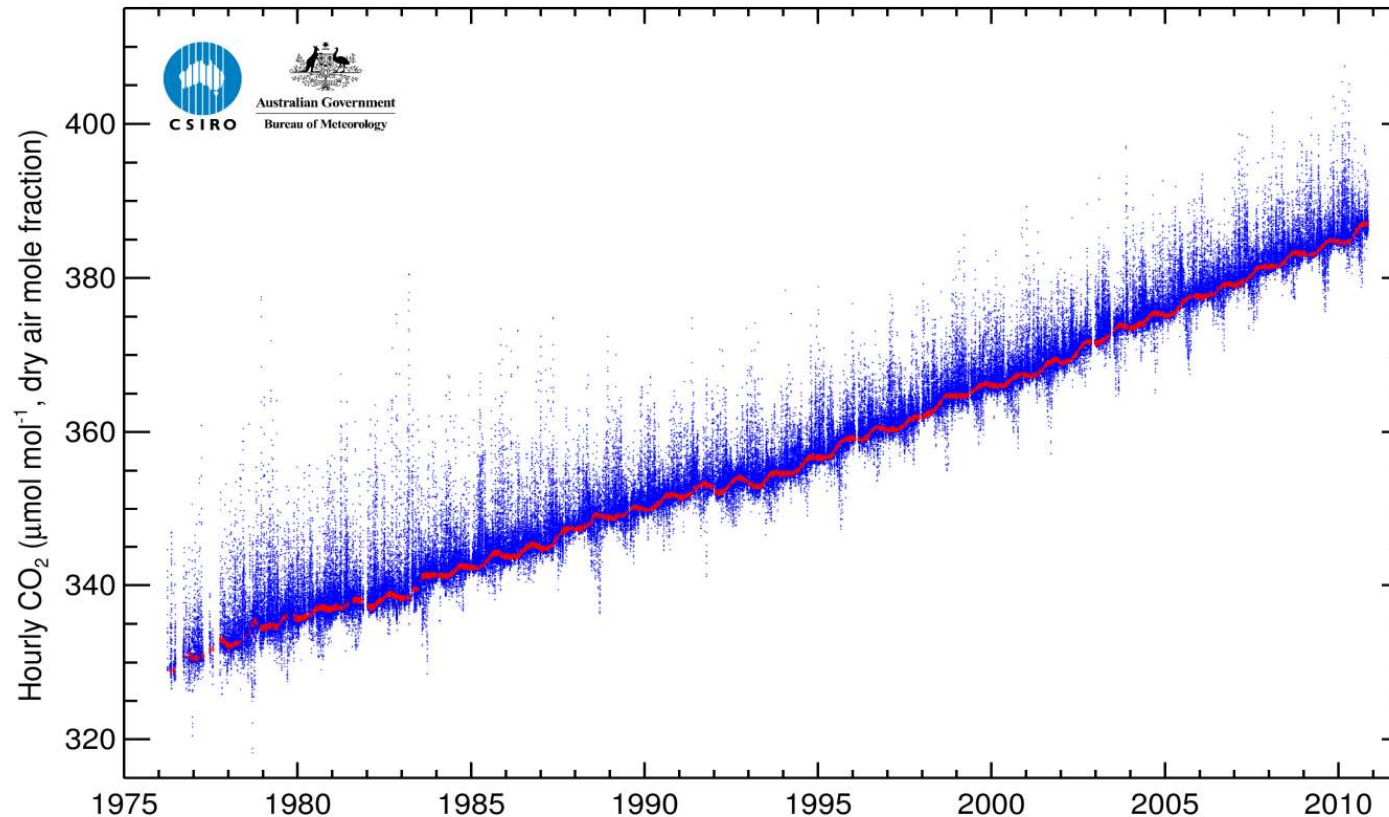
■ ~250 conference papers

- 90 at international conferences outside Australia

■ 16 national & international reviews

- *IPCC 4th Assessment* (2007) – Cape Grim GHG data in 7 of first 8 Figures of Chapter 2
- *UNEP/WMO Ozone Assessment* (2007) – first 9 Figures of Chap. 1: Cape Grim ODS data

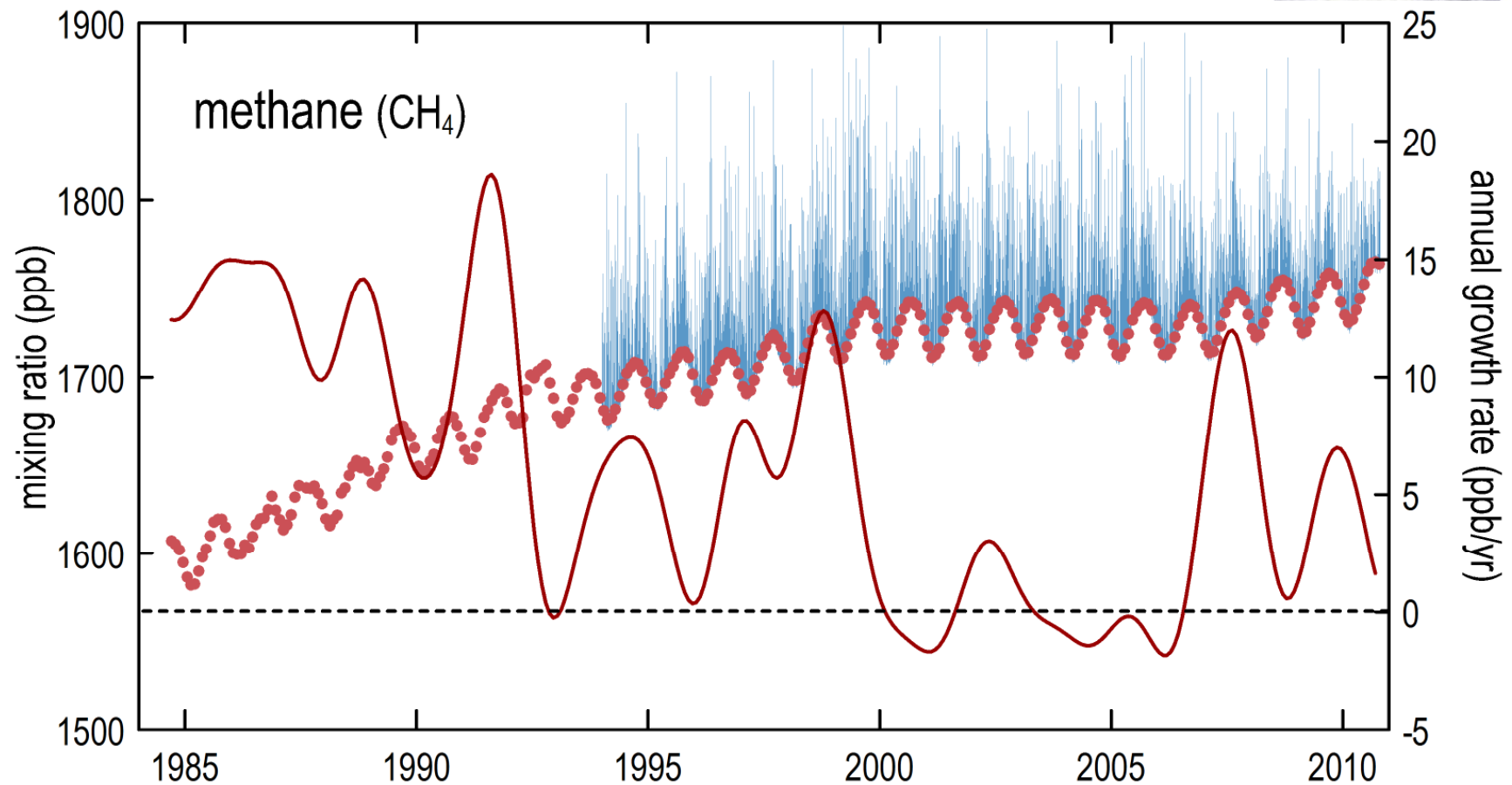
Cape Grim Greenhouse Gases Program: carbon dioxide



- Roles of tropical terrestrial emissions, biomass burning, & the Southern Ocean, in global variability of atmospheric CO₂ – Battle *et al.*, 2000; Langenfelds *et al.*, 2002; Le Quéré *et al.*, 2003, 2007; Pak *et al.*, 2003; Roy *et al.*, 2003; Francey *et al.*, 2005; Patra *et al.*, 2006, Stephens *et al.*, 2007; Law *et al.*, 2008; Rayner *et al.*, 2008
- Differences in fossil fuel emissions of CO₂ via ‘top-down’ and ‘bottom-up’ methodologies – Francey *et al.*, 2010



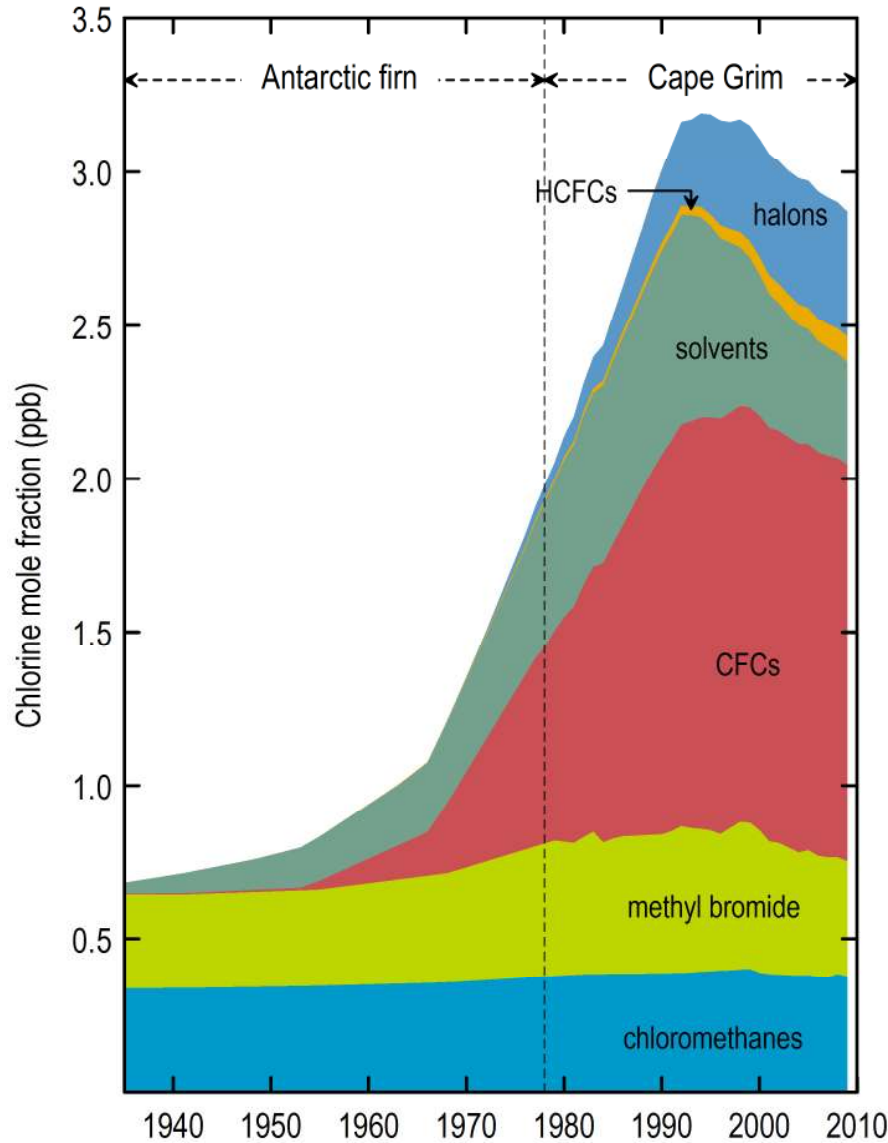
Cape Grim Greenhouse Gases Program: methane



■ Methane growth rate slowing in the late-1990s and acceleration in the late-2000s

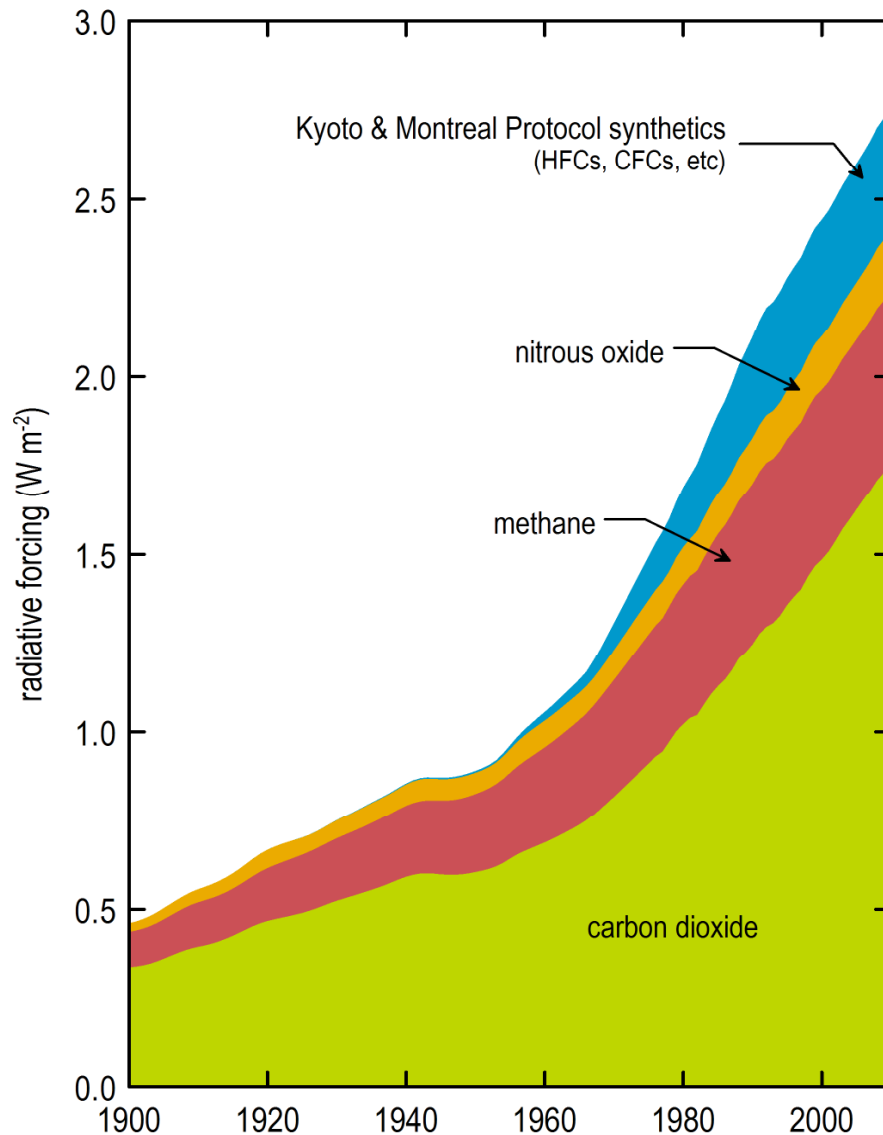
- Cunnold *et al.*, 2002; Langenfelds *et al.*, 2002; Bousquet *et al.*, 2006, 2010; Rigby *et al.*, 2008; Patra *et al.*, 2009

Cape Grim effective chlorine



- Unique record based entirely on observations – Antarctic firn, Cape Grim air archive, flasks & *in situ* measurements
- Effective chlorine peaked in mid-1990s, 11% decline by 2009

Cape Grim long-lived GHG radiative forcing



- Unique record based entirely on observations – Antarctic ice-core & firn, Cape Grim air archive, flasks & *in situ* measurements
- After CO_2 , the largest contributor to radiative forcing growth over the past 50 years are the CFCs & their replacement HFCs

Data Comparison Activities



- There have been, and continue to be, comprehensive comparison activities involving Cape Grim GHG data
- WMO GAW considers Cape Grim as one of three designated global GHG comparison sites (super-sites), only one in the Southern Hemisphere
- Why undertake comparisons of independent measurements?:
 - allows reliable integration of atmospheric data from independent laboratories and/or measurement techniques;
 - becomes a powerful tool in the early identification of problems that may have gone undiagnosed for longer;
 - provides a stringent quality control test of individual laboratories experimental methods and internal calibration schemes
 - gives you an idea of the uncertainty estimate on the datasets when merging data

Data Comparison Activities – WMO recommendation



- Item 11 General Recommendations For Quality Control Of Atmospheric Trace Gas Measurements from 15th WMO experts meeting (Jena, 2009):
- *‘(c) Besides round-robin comparisons, more frequent and ongoing comparison activities between pairs of laboratories which incorporate the analyses of actual air samples are strongly recommended. The tremendous benefit of ongoing same-air comparisons has been demonstrated (Masarie et al., 2001) and is reinforced. Mutual exchange of air in glass flasks is encouraged as a means to detect experimental deficiencies. The comparison experiment at Alert involving multiple laboratories at a single site has proven to be extremely valuable. Similar multi-lab comparisons have been conducted at Cape Grim. Comparisons of measurements from co-located in-situ instruments and co-located discrete samples and in-situ instruments are also strongly recommended’*
- and *“(g) Flask sampling programmes shall be implemented where possible at observational sites making continuous measurements. This will provide ongoing quality control and help determine measurement uncertainty and eventually allow merging data sets from different laboratories.”*

Data Comparison Activities - **same air (flask)**

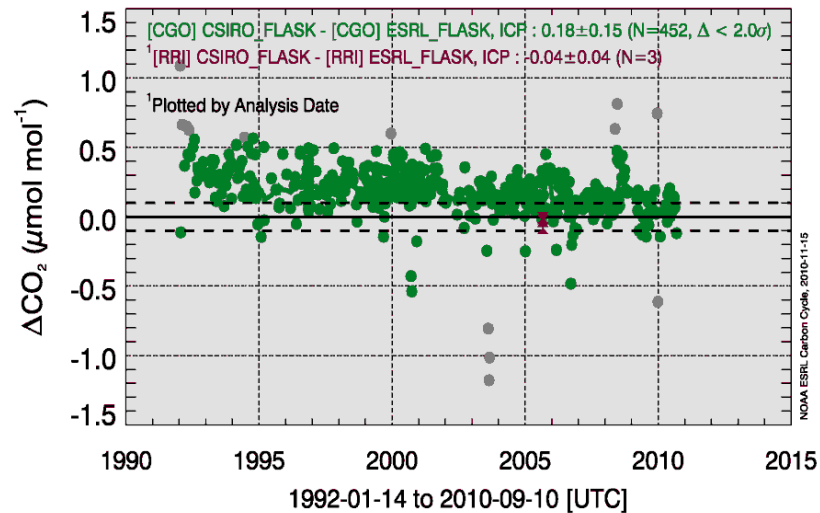
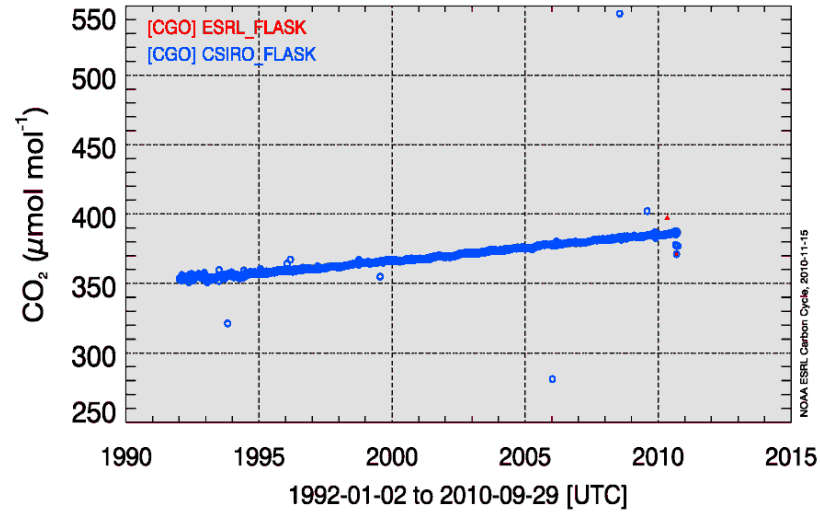


- NOAA flasks 1992-present: 7 species
 - Flasks filled at Cape Grim for NOAA measured by CSIRO GASLAB and NOAA.
 - Data exchanged via automated process
 - Comprehensive set of comparisons automatically generated
- LSCE and U. Heidelberg/MPI-GBC flasks:
 - Similar process
 - Comparisons take place on an ad-hoc basis
- GASLAB participates in the WMO round robin exercises.
- GASLAB also participates in the European based sausage and cucumber inter-comparison activities

Data Comparison Activities



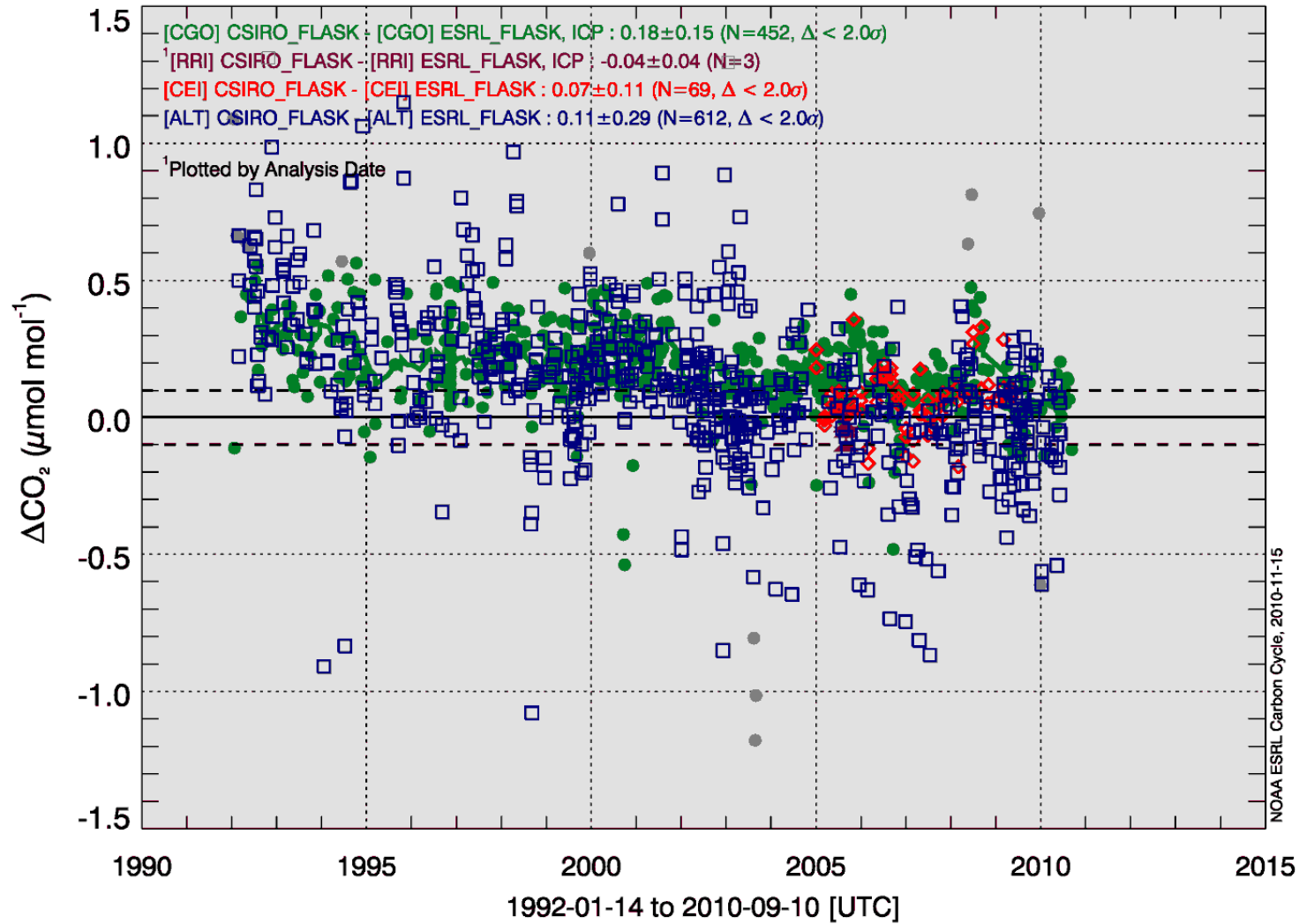
CSIRO/NOAA Same-Air ICP
Cape Grim, Tasmania



Data Comparison Activities



CSIRO/NOAA Comparisons

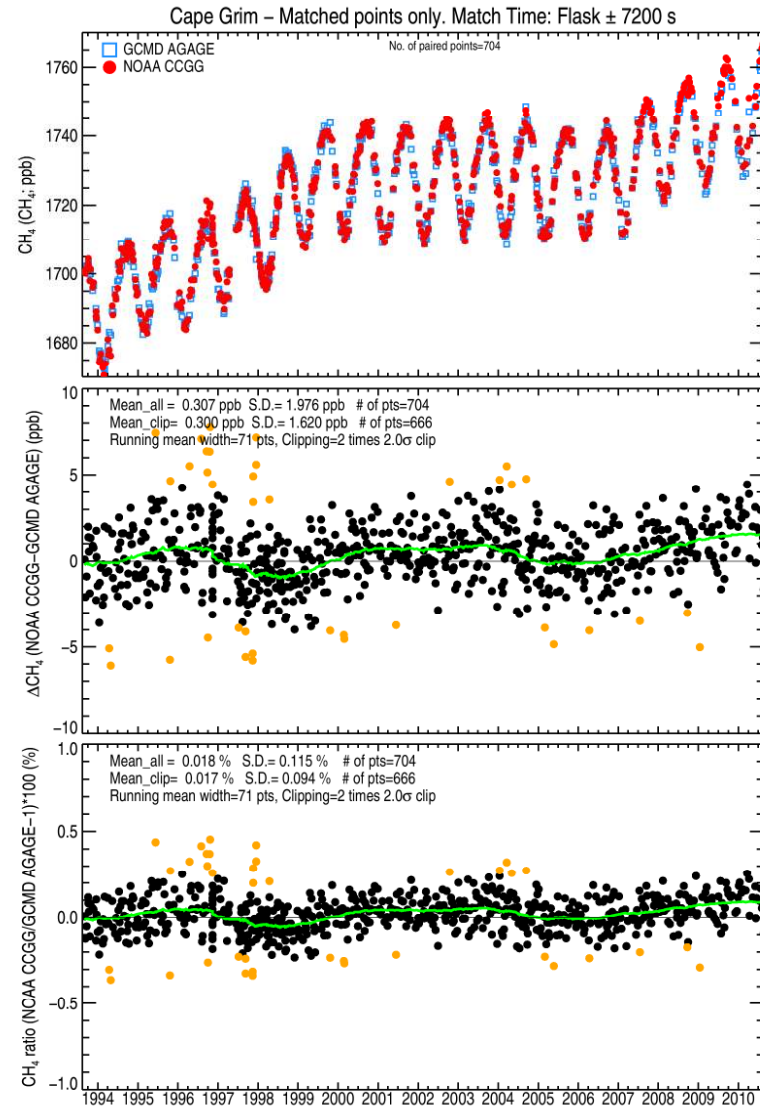
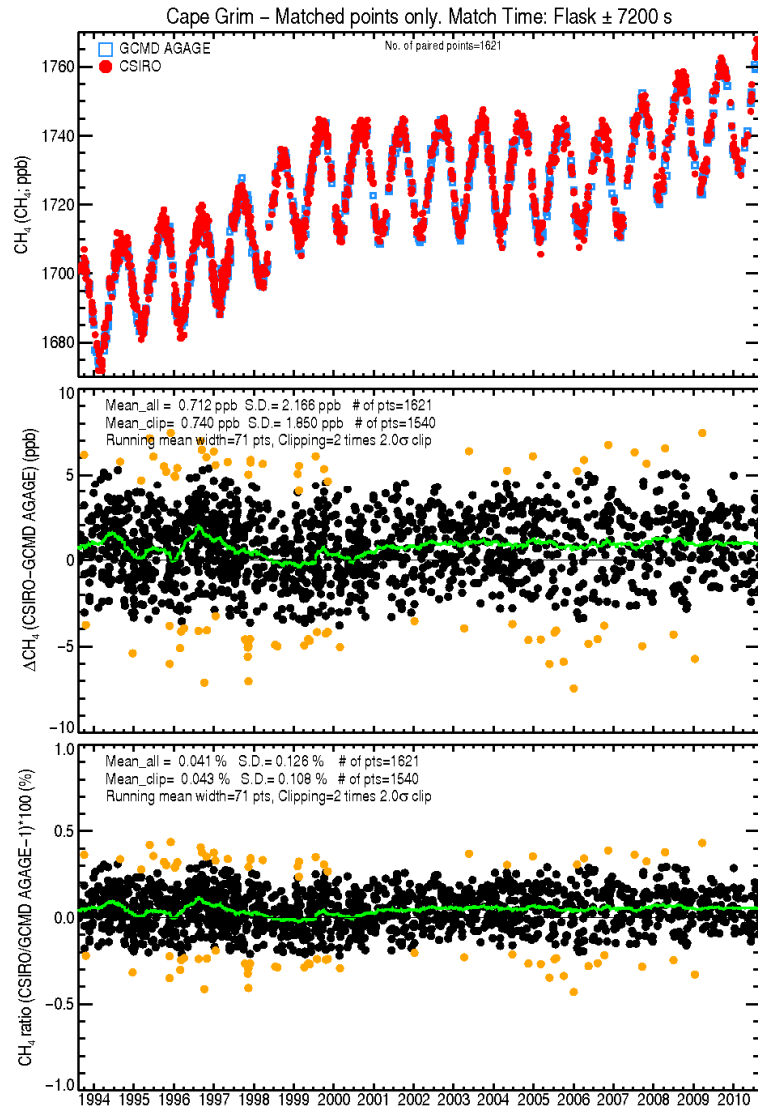


Data Comparison Activities – **flask/in situ**

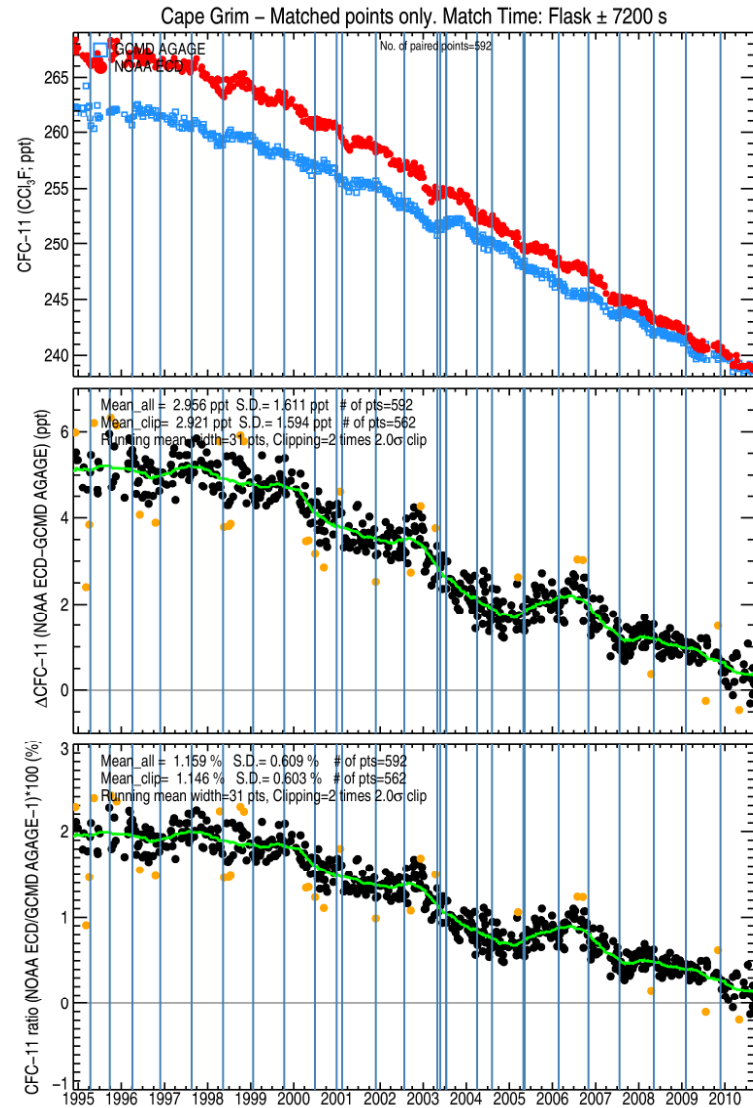
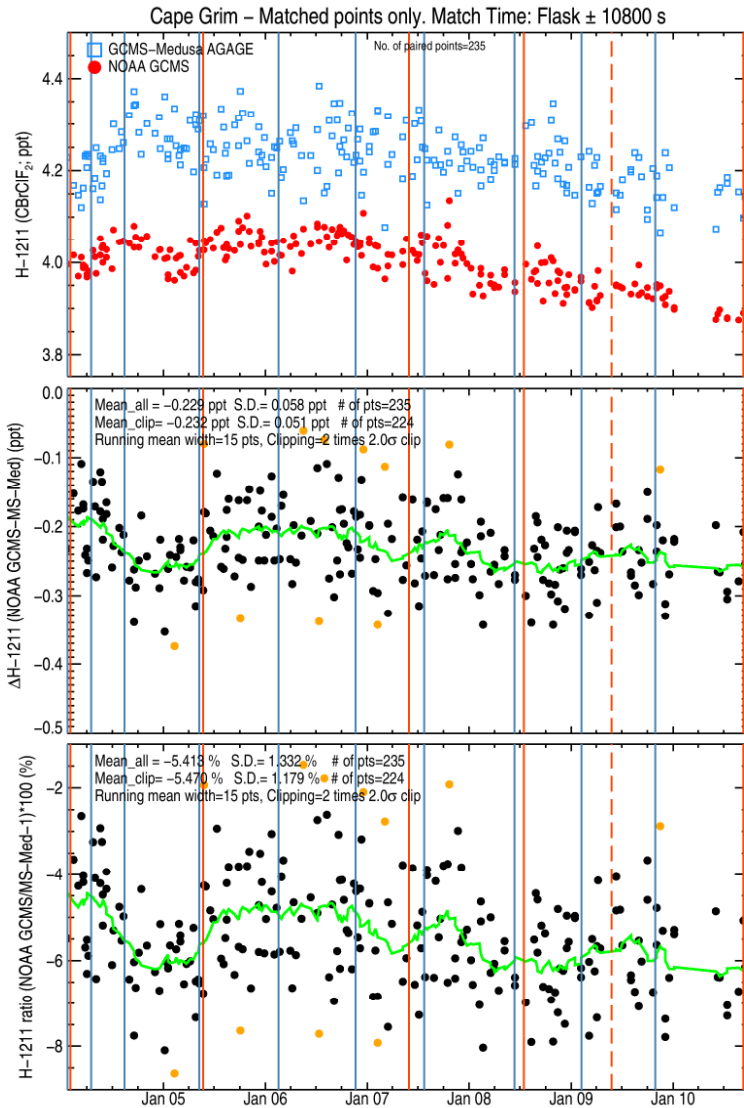


- Since 1999, comparisons between flask data and *in situ* measurements have been undertaken on a regular basis on Cape Grim data
- Comprised of:
 - CSIRO flasks, 5 species
 - NOAA flasks, ~32 species
 - U Heid flasks, 1 species
 - NIES flasks, 12 species
 - SIO flasks, 6 species
 - UEA flasks, 24 species

Data Comparison Activities: CH₄



Data Comparison Activities: H-1211 & CFC-11

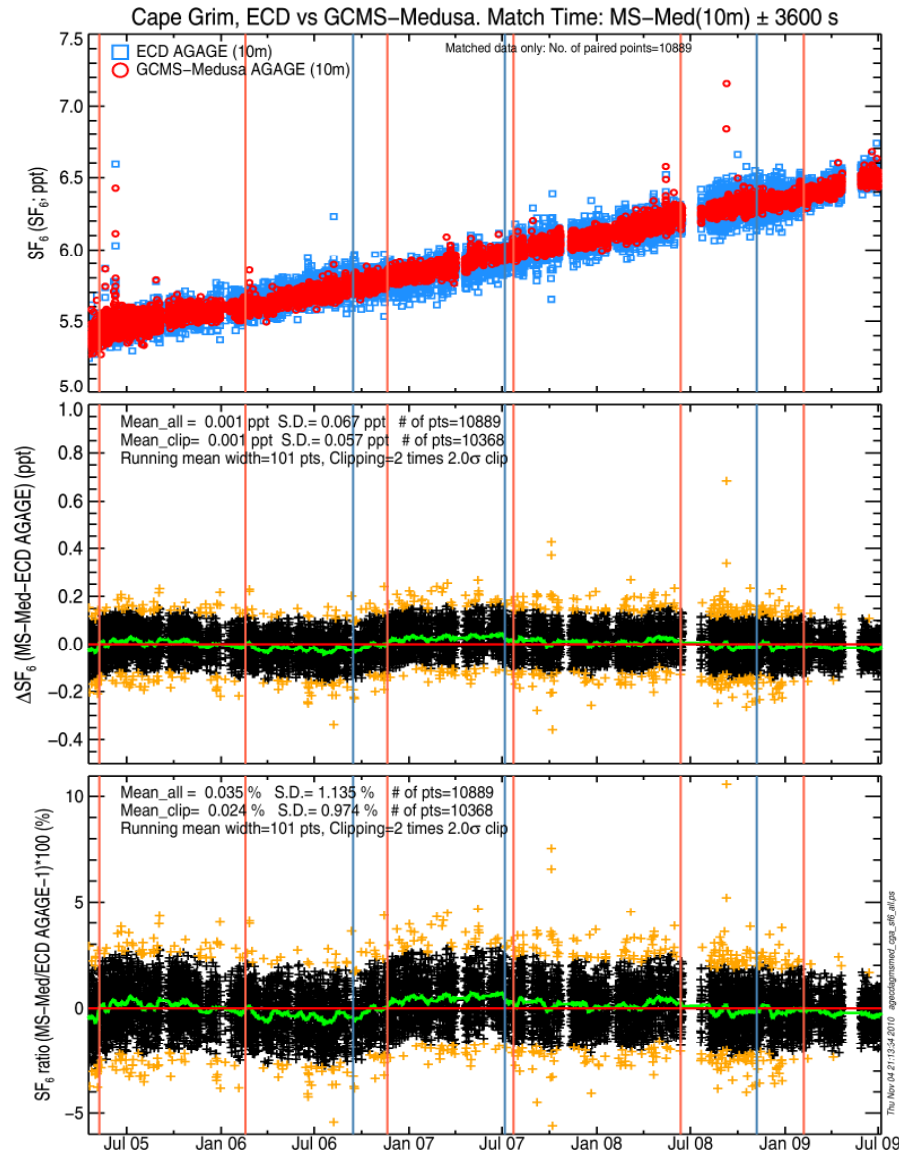


Data Comparison Activities – *in situ* *in situ*



- comparisons between *in situ* instruments measuring the same trace gas species are undertaken:
 - overlap experiments of instrumental upgrades
 - during dedicated experiments to compare different measurement techniques
 - as part of routine comparisons in the AGAGE program

Data Comparison Activities: SF₆



Acknowledgements



■ Past and present staff

- Cape Grim Baseline Air Pollution Station
 - in particular the late Laurie Porter
- Bureau of Meteorology
 - in particular Bruce Forgan & Peter Price
- CSIRO Atmospheric/Marine and Atmospheric Research
 - in particular former Lead Scientists: Graeme Pearman & Roger Francey

■ AGAGE

- R. Prinn (MIT), R. Weiss, P. Salameh, J. Muhle, C. Harth (SIO), P. Simmonds, S. O'Doherty (U. Bristol), R. Wang, the late D. Cunnold (GIT)

■ NOAA (USA)

- J. Elkins, S. Montzka, P. Tans, E. Dlugokencky, K. Masarie, T. Conway

■ NASA (USA)

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Thank you

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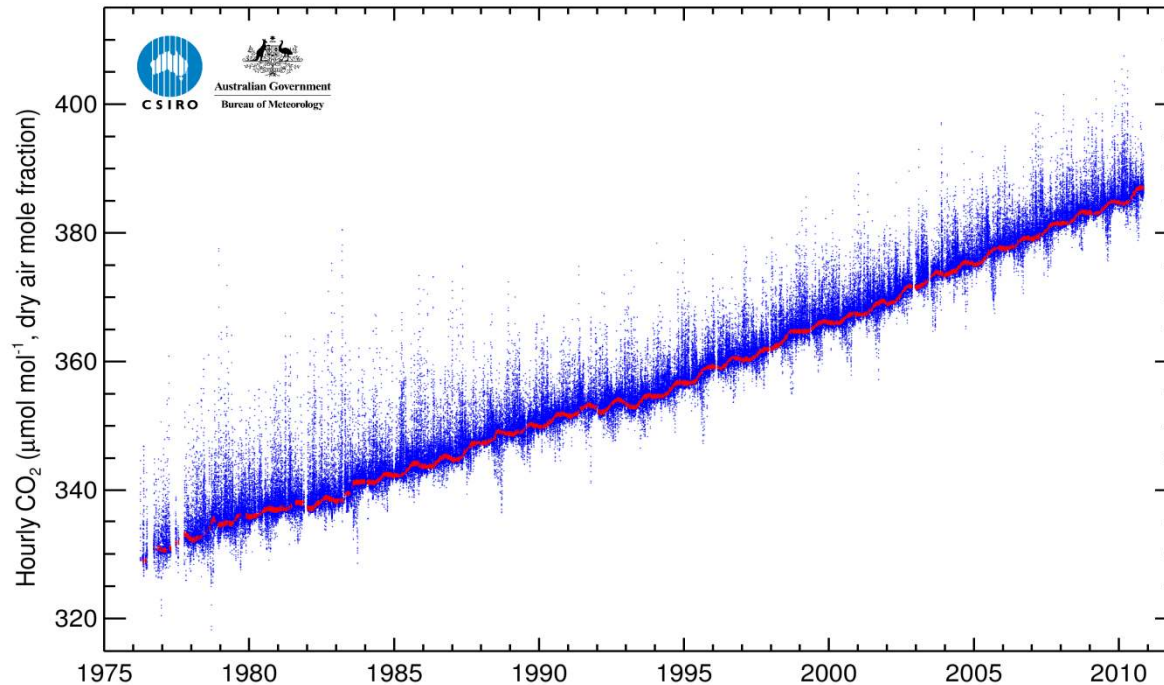


Cape Grim Greenhouse Gases Program



- In 2004 Cape Grim became the first Baseline Station in the Southern Hemisphere to monitor all the important GHGs & ODSs involved in the Kyoto & Montreal Protocols
- The inventory of measured species continues to grow, currently about 65
 - Kyoto Protocol
 - CO₂, ¹³CO₂, ¹⁴CO₂, C¹⁸OO, O₂/N₂ (5)
 - CH₄, N₂O, N₂O major isotopologues (7)
 - HFCs (11)
 - PFCs (9)
 - SF₆, CF₃SF₅, SO₂F₂, (NF₃)
 - Montreal Protocol
 - CFCs (6)
 - HCFCs (5)
 - Halons (3)
 - CCl₄, CH₃CCl₃, CH₃Br, (CH₃CH₂CH₂Br)
 - other halocarbons: CH₃Cl, CH₂Cl₂, CHCl₃, CHBr₃ etc (10)
 - CO, H₂, COS
 - other hydrocarbons: C₂H₆, C₃H₈, C₆H₆, C₇H₈ (4)

Cape Grim Greenhouse Gases Program: carbon dioxide



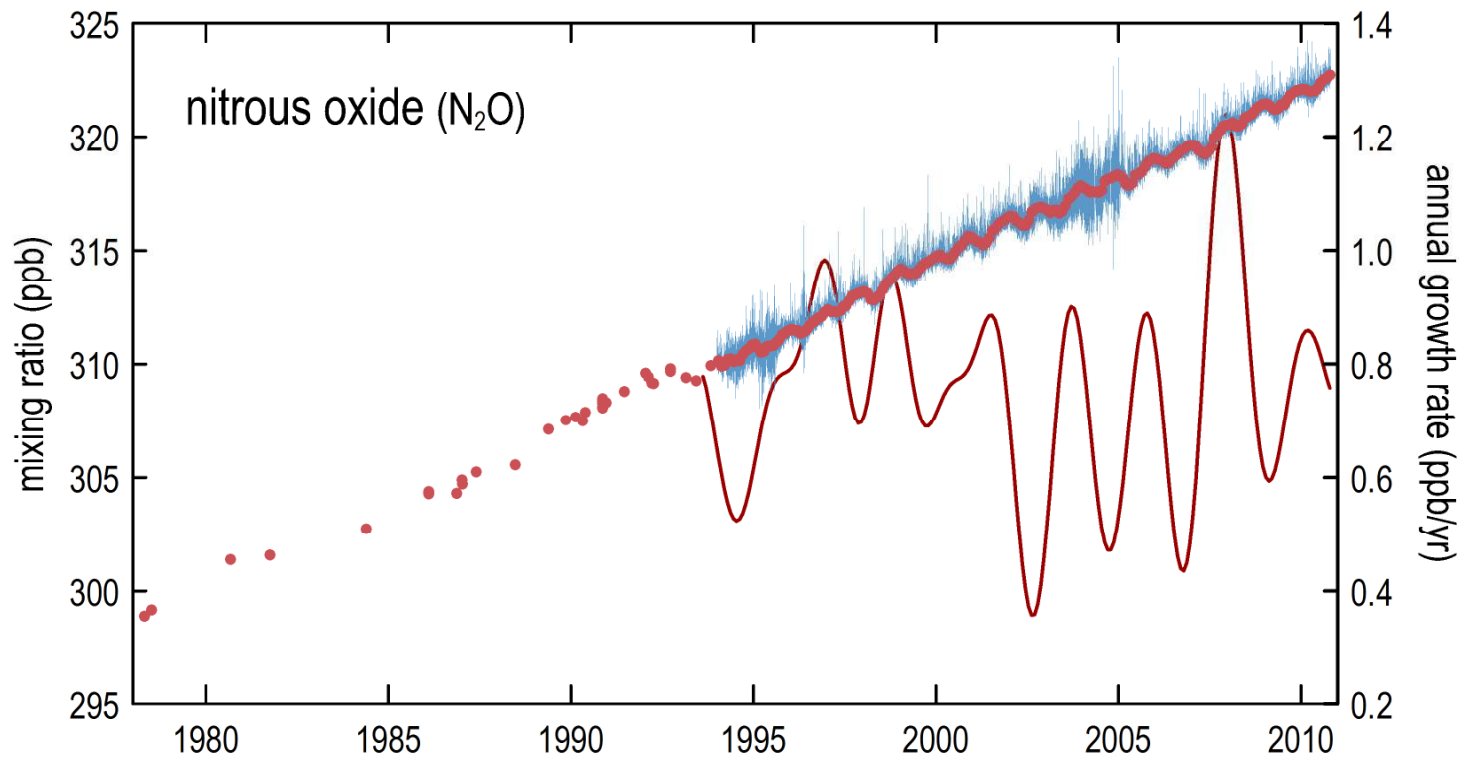
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■ Differences in fossil fuel emissions of CO₂ via 'top-down' and 'bottom-up' methodologies

- Francey *et al.*, 2010

Cape Grim Greenhouse Gases Program: nitrous oxide



- New global budget for N_2O – dominant sources terrestrial tropics, the roles of stratosphere-troposphere exchange & ocean biosphere in seasonal cycles
 - Nevison *et al.*, 2005, 2010; Huang *et al.*, 2009; Ishijima *et al.*, 2010

Data Processing Methods



■ *in situ* CO₂

- “Classical” NDIR CO₂ (1976-2004) processed via customised Fortran/Perl code; and re-processing via IDL & Microsoft SQL database
- LoFlo CO₂ (2001-present) processed with customised C++ code; and re-processing via Microsoft SQL database

■ CSIRO GASLAB Flasks

- processed and stored via Microsoft SQL database

■ non-CO₂ GHG (AGAGE)

- Software (GCWerks) designed specifically for *in situ* instrument control and integrated data processing/re-processing, storage and visualisation
- Linked in to global AGAGE network with common methods and rigorous calibration protocols
- Critical data review by peers every six months

Importance of good data management and QA/QC procedures to produce long-term high quality datasets