Atmospheric greenhouse gas research at CSIRO: a 40 year odyssey

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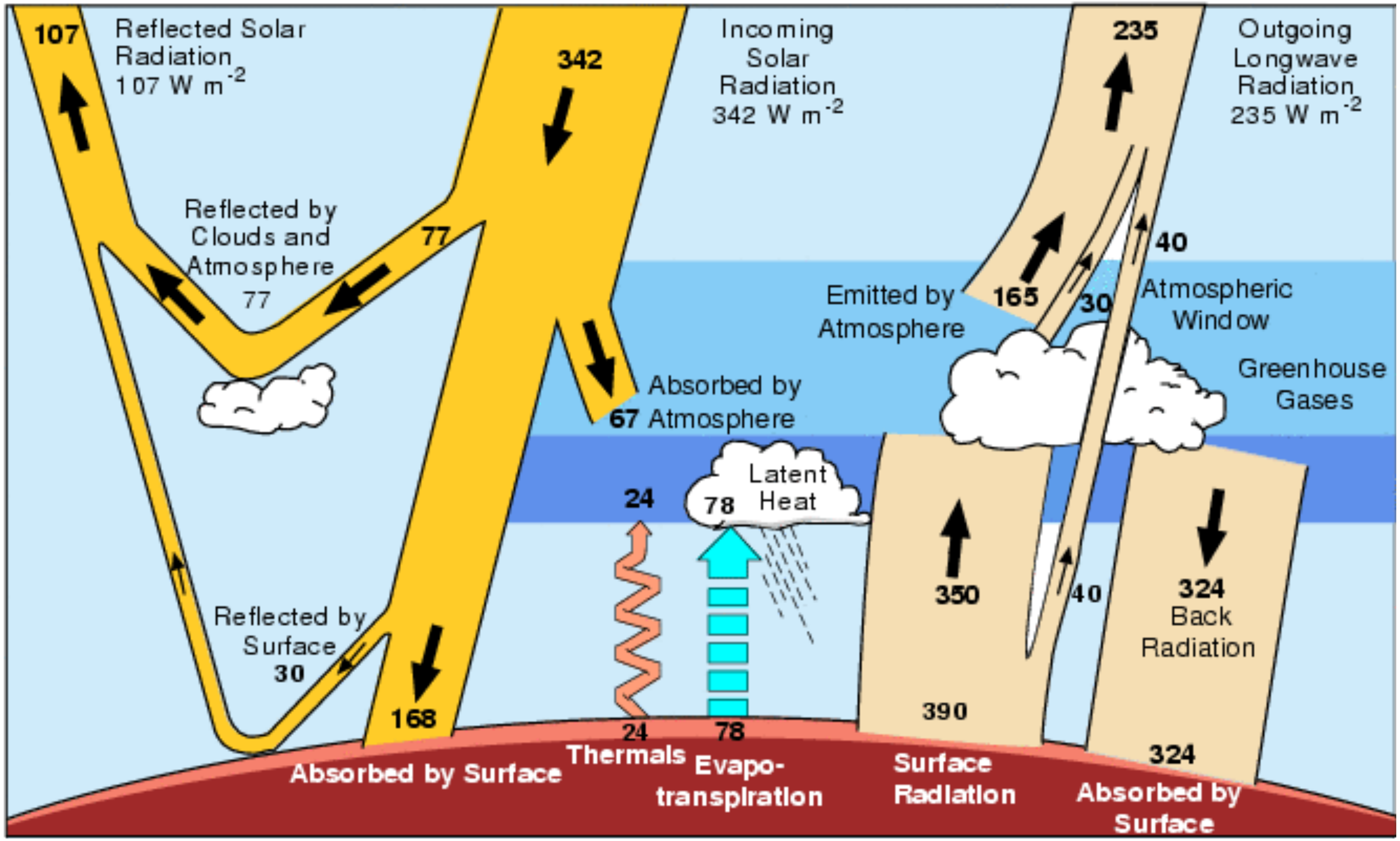
Australian Government
Bureau of Meteorology

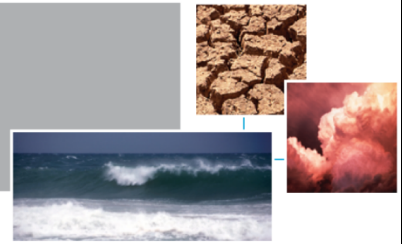
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

The Greenhouse Effect: energy flows in the atmosphere



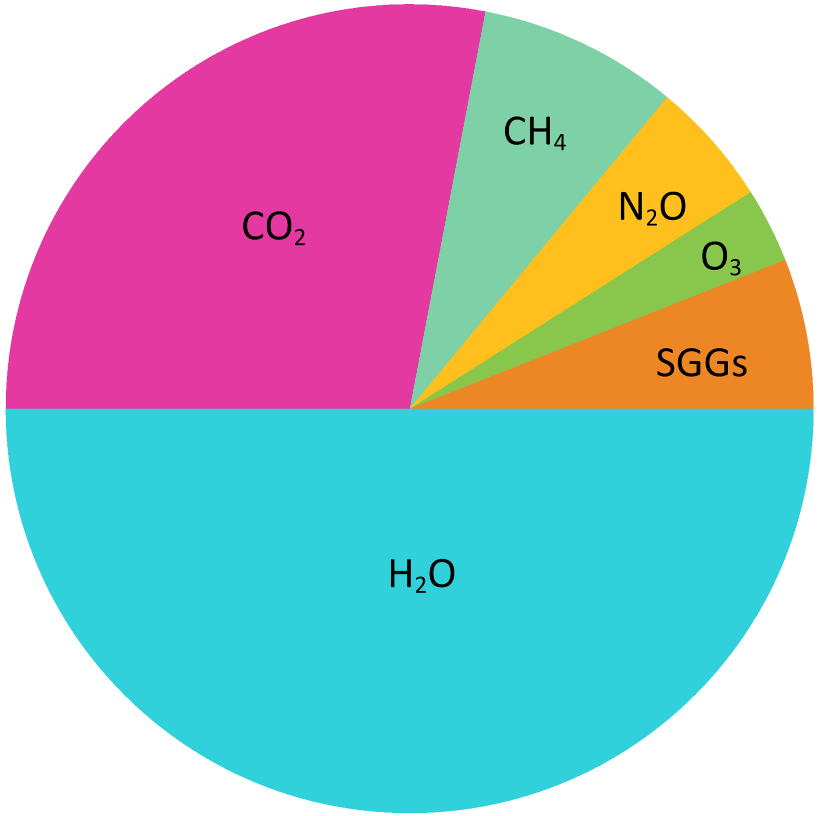
What are the atmospheric Greenhouse Gases?



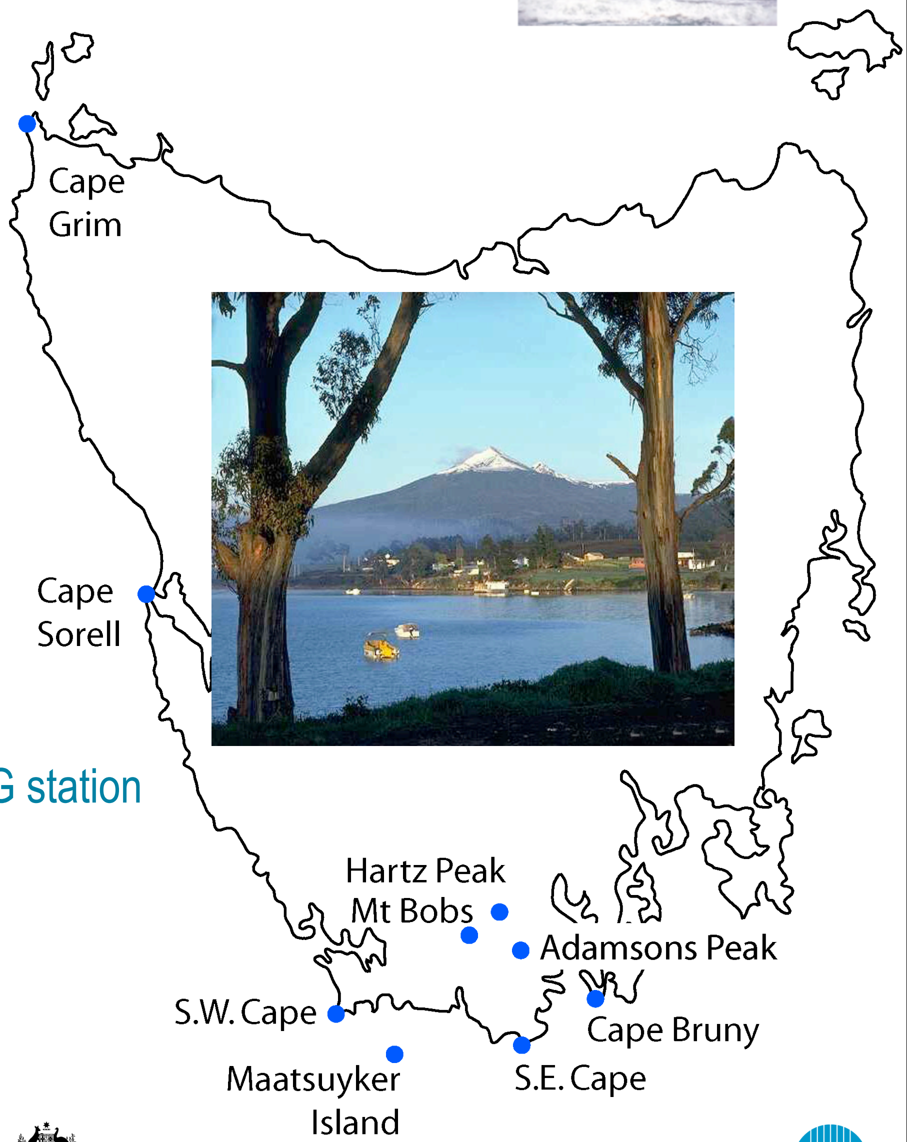
Species	Formula	Sources/Sinks
Carbon dioxide	CO_2	fossil fuel combustion, biosphere, oceans
Methane	CH_4	coal & gas, cattle, rice, wetlands
Synthetic Greenhouse	SGGs: CFCs (CCl_2F_2), HFCs	refrigeration/air-conditioning
Nitrous oxide	N_2O	soils, fertilisers, oceans
Ozone	O_3	photochemistry
Water vapour	H_2O	evaporation

Relative contributions of GHGs to climate forcing

Species	Concentration ppm	Change ppm	Radiative forcing contribution
CO_2	390	120	28%
CH_4	1.8	1.1	8%
SGGs	0.002	0.002	6%
N_2O	0.33	0.06	5%
O_3	0.02-0.1	model	3%
H_2O	4-40,000	model	~50%

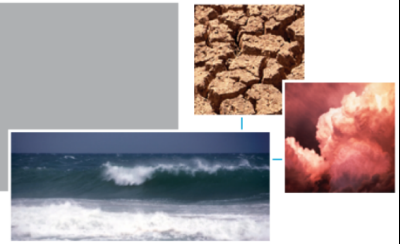


1976: Cape Grim, Tasmania - Australia's first global Baseline Station



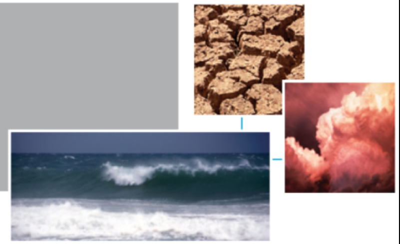
- 1972 CSIRO commenced Australia's GHG program
- 1972 Australia commits (UN): a global baseline GHG station
- 1975 Tasmania baseline site evaluations
- 1976 Cape Grim Baseline Station established
- 1976 carbon dioxide: CO_2 (NDIR)
- 1976 chlorofluorocarbons: CFCs (GC-ECD)
- 1978 nitrous oxide: N_2O (GC-ECD)
- 1980 methane: CH_4 (GC-FID)

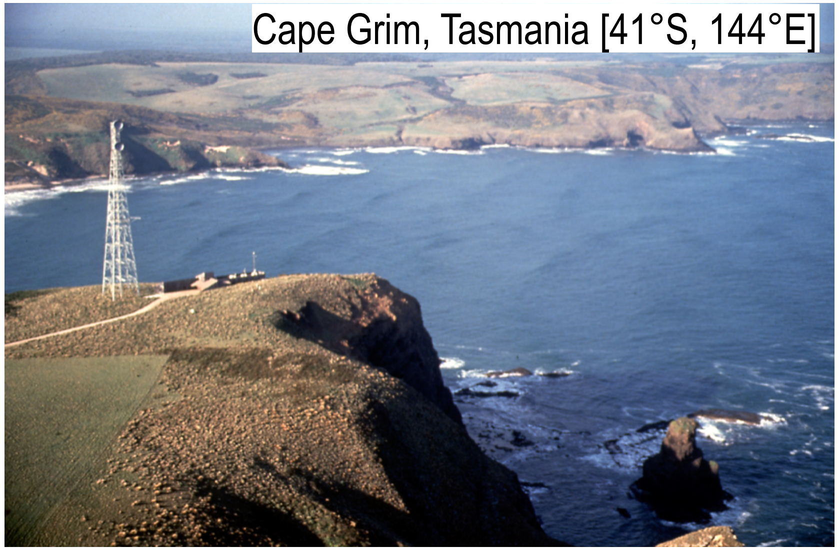
Cape Grim, Tasmania: 1981......present

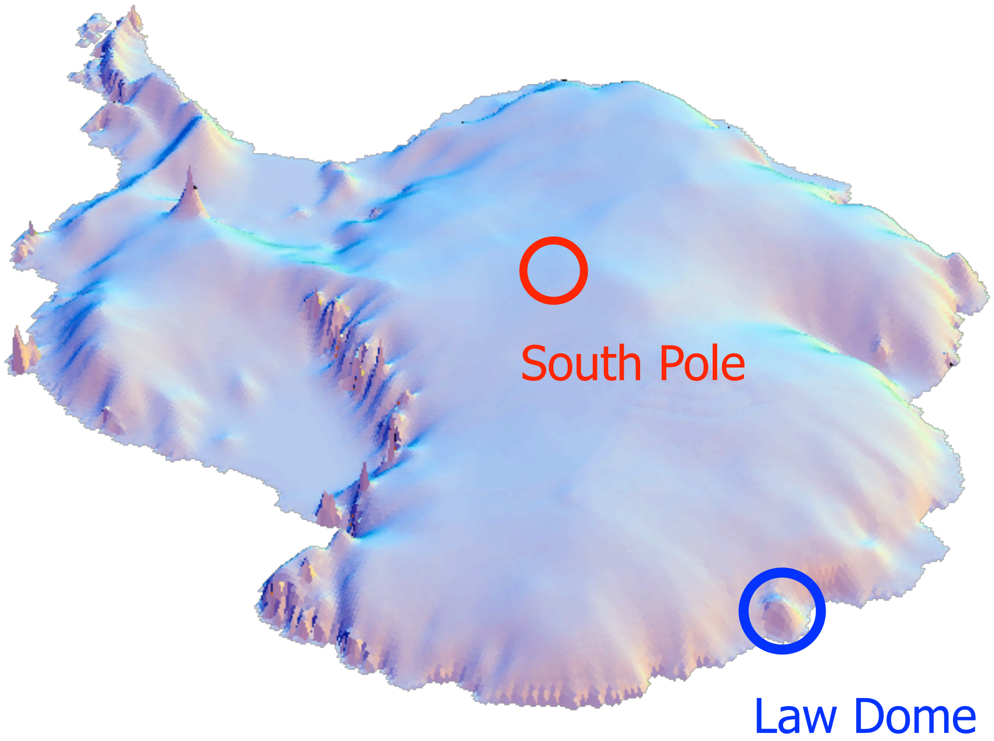


- 1981 permanent buildings
- 1982 $^{13}CO_2$ (MS)
- 1987 $^{14}CO_2$, $^{13}CH_4$ (MS)
- 1991 O_2 measured as O_2/N_2 (MS)
- 1997 minor CFCs, HCFCs, HFCs (GC-MS)
- 2001 SF_6 (GC-MS)
- 2004 PFCs (GC-MS)
- 2009 CF_3SF_5 (GC-MS)

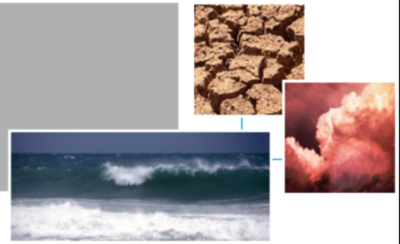
Key Australian GHG observations elements:
Law Dome, Cape Grim & the air archive

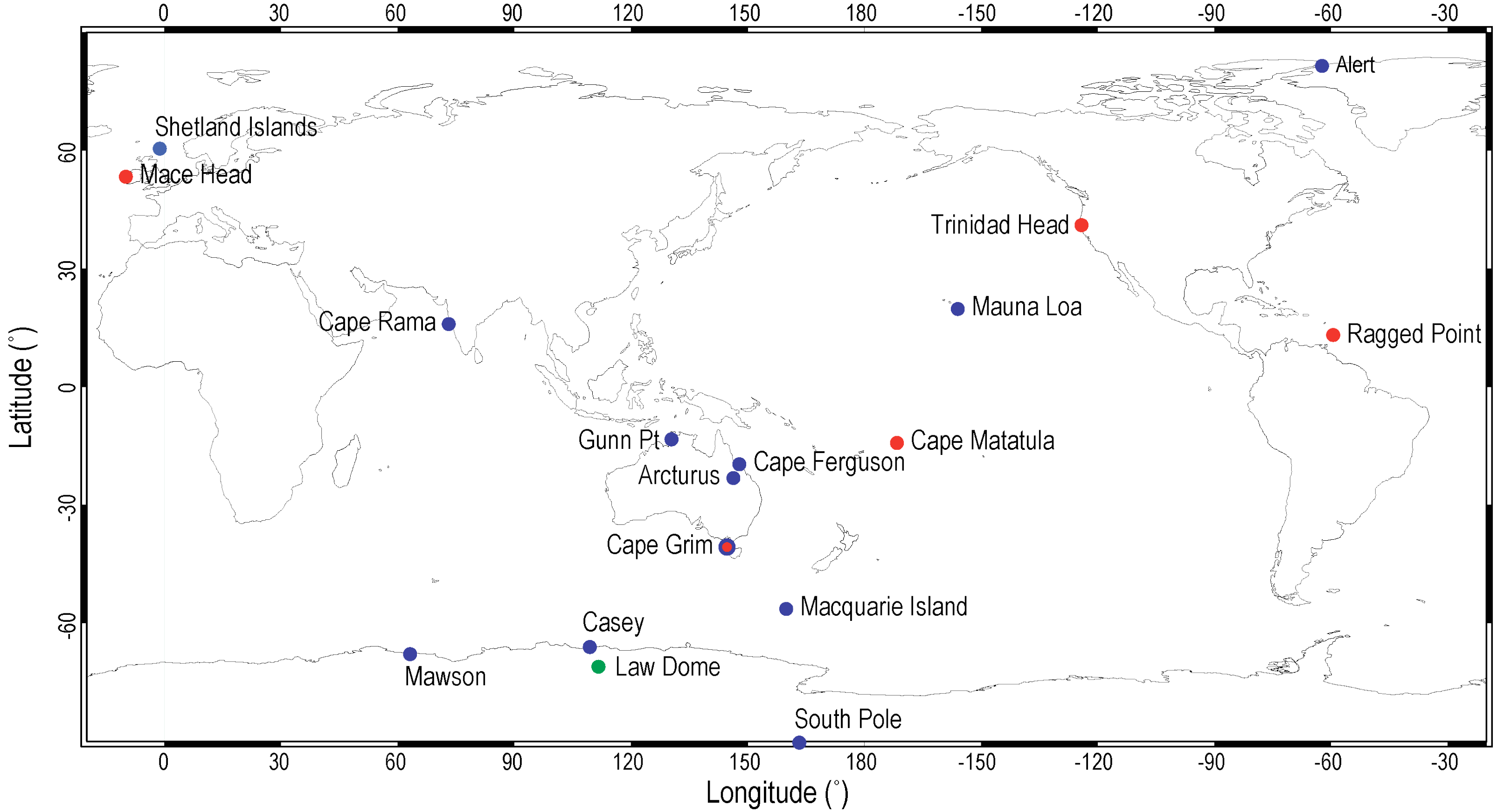






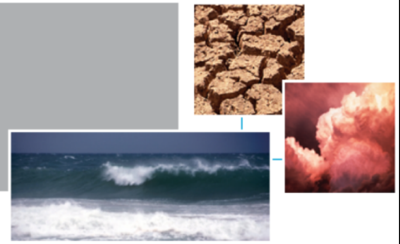
CSIRO/AGAGE global GHG network





- CSIRO (CO_2, CH_4, N_2O) & AGAGE (CFCs, HFCs etc) GHG measurements since the late-1970s
- measures every GHG used by IPCC to define long-lived GHG radiative forcing
- 2nd most important global GHG network (after NOAA USA)

1978: Cape Grim joins the NASA-funded AGAGE network for non-CO_2 GHGs



Ragged Point, Barbados

[13ºN, 59ºW]

Trinidad Head, California

[41º N, 124ºW]

Cape Matatula, American Samoa

[14ºS, 171ºW]

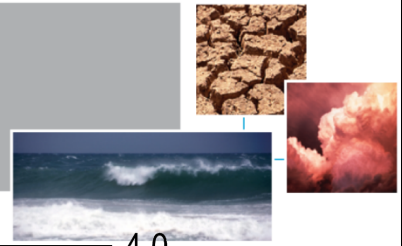
Mace Head, Ireland

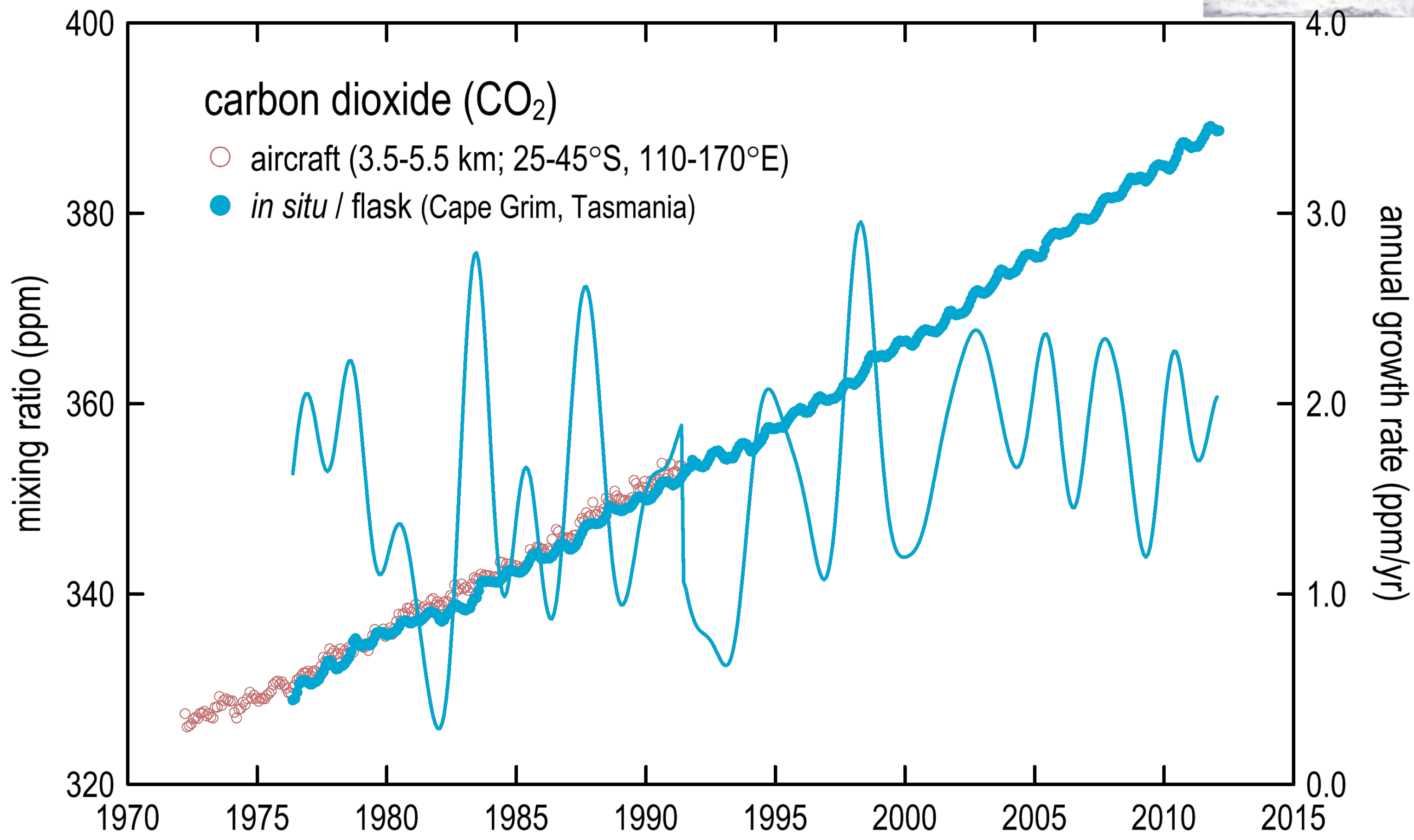
[53ºN, 10ºW]

Cape Grim, Tasmania

[41ºS, 145ºE]

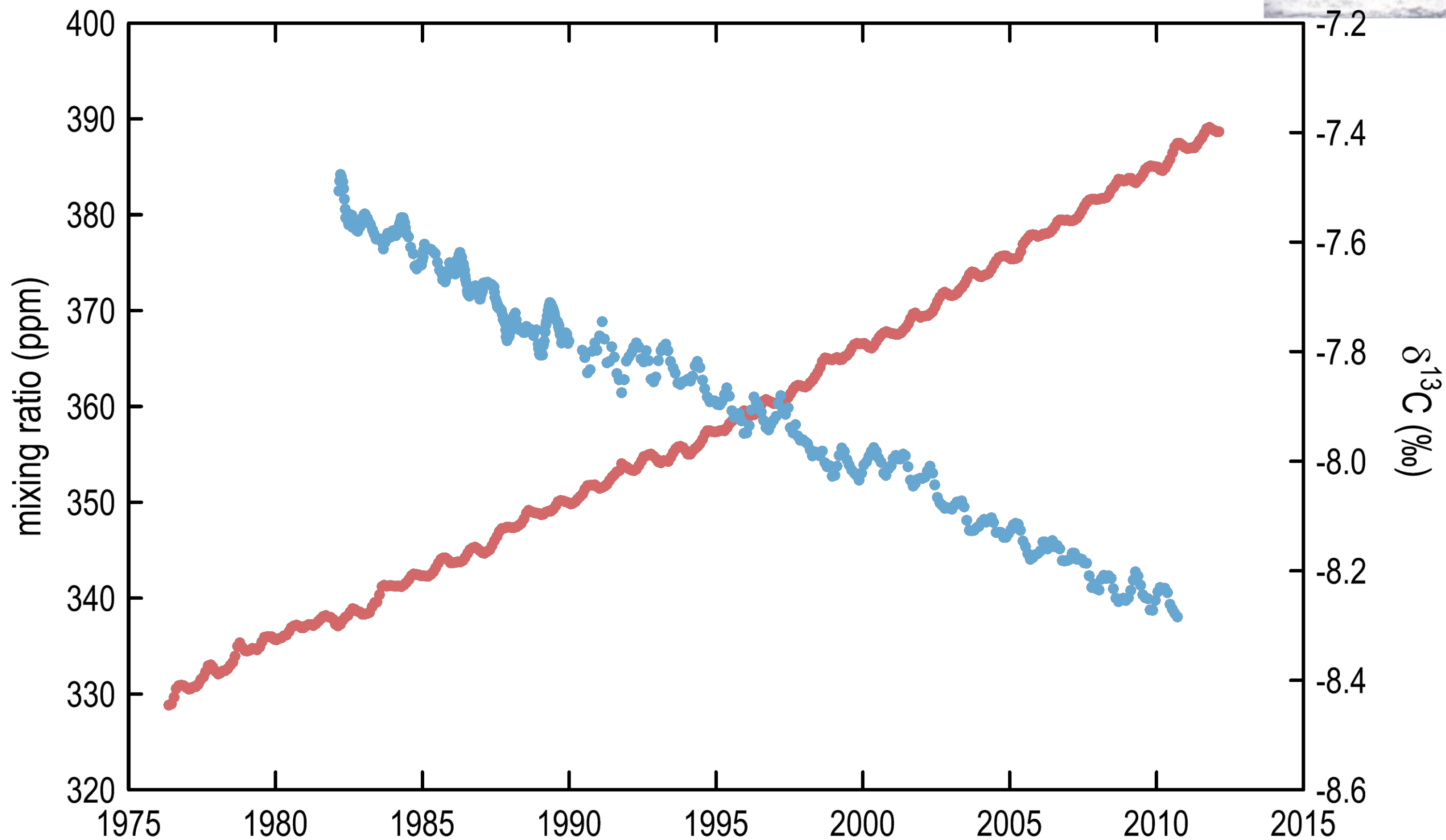
Carbon dioxide: aircraft (Bass Strait) and Cape Grim





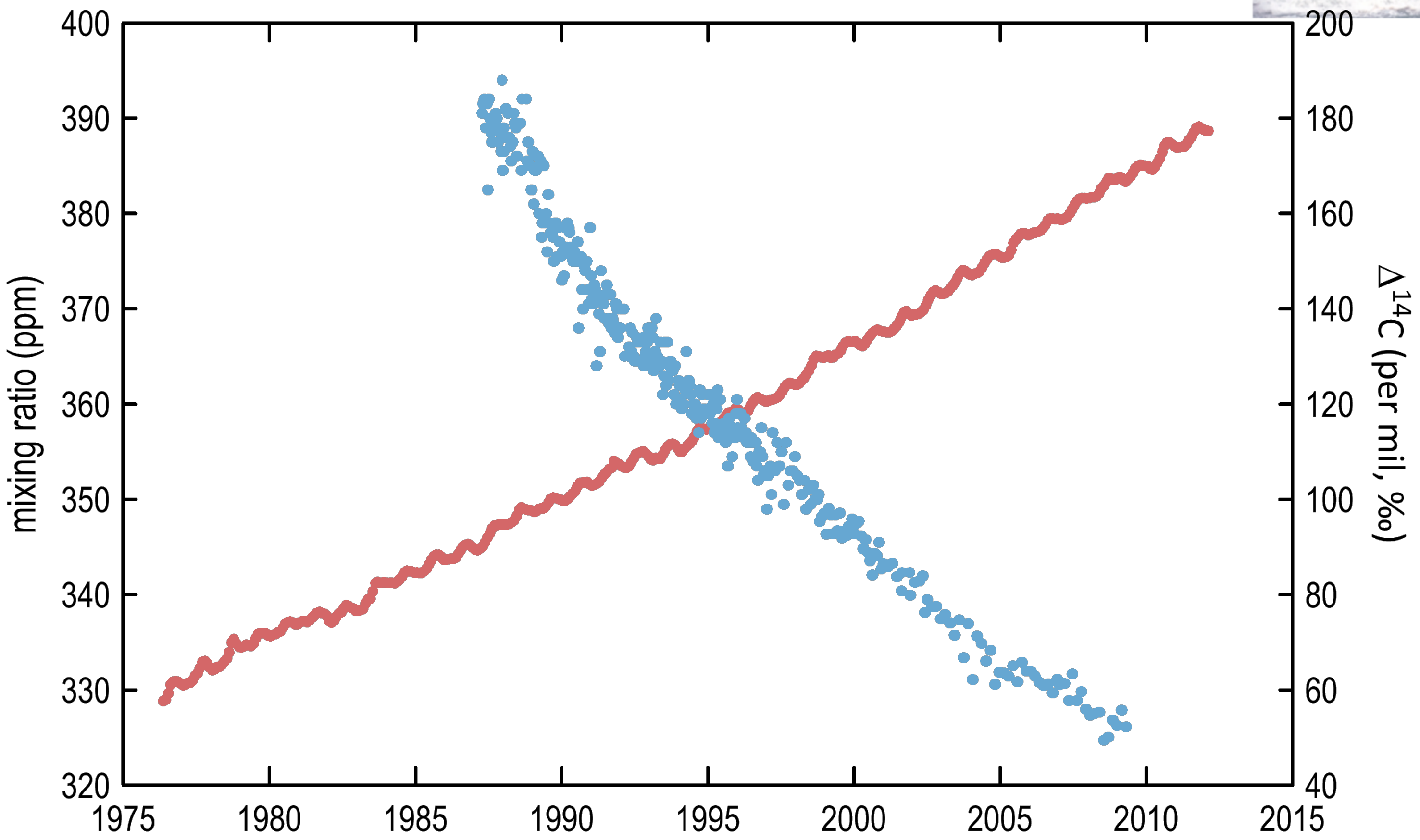
- CO_2 growth
  - Sources: burning fossil fuels, land use change/forestry (tropics), biomass burning (boreal & tropical)
  - Sinks: biosphere, oceans

Carbon dioxide and $^{13}CO_2$: Cape Grim



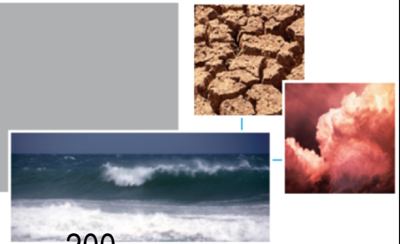
- combination of CO_2 & $^{13}CO_2$ provides significant constraints on CO_2 sources: fossil fuel, biomass burning and soil exchanges

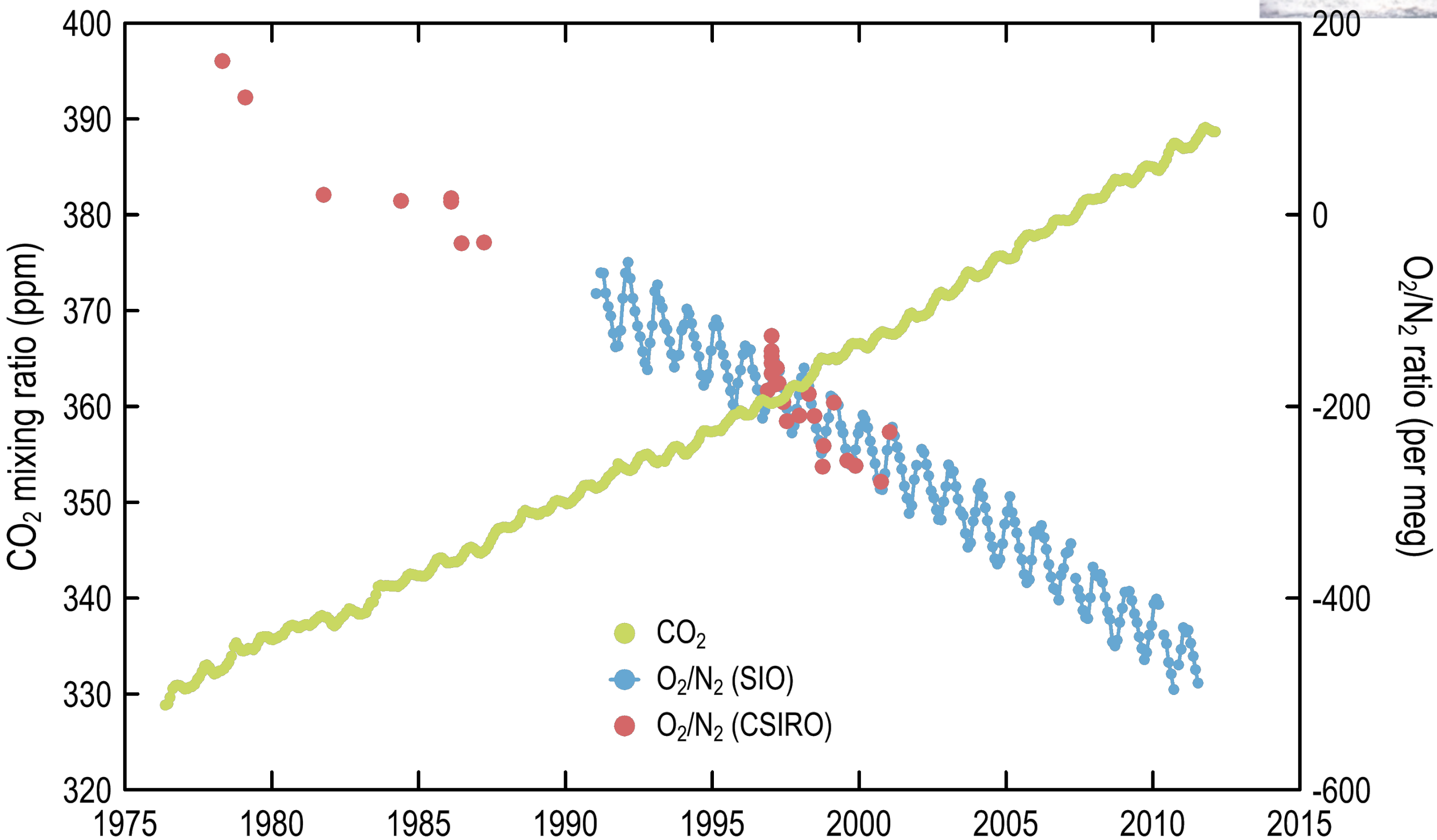
Carbon dioxide and $^{14}CO_2$: Cape Grim



- $^{14}CO_2$ decay consistent with
  - natural atmospheric $^{14}CO_2$ production
  - $^{14}CO_2$ from 1950s-1960s atmospheric nuclear weapons tests
  - $^{14}CO_2$-free source from the combustion of fossil fuels

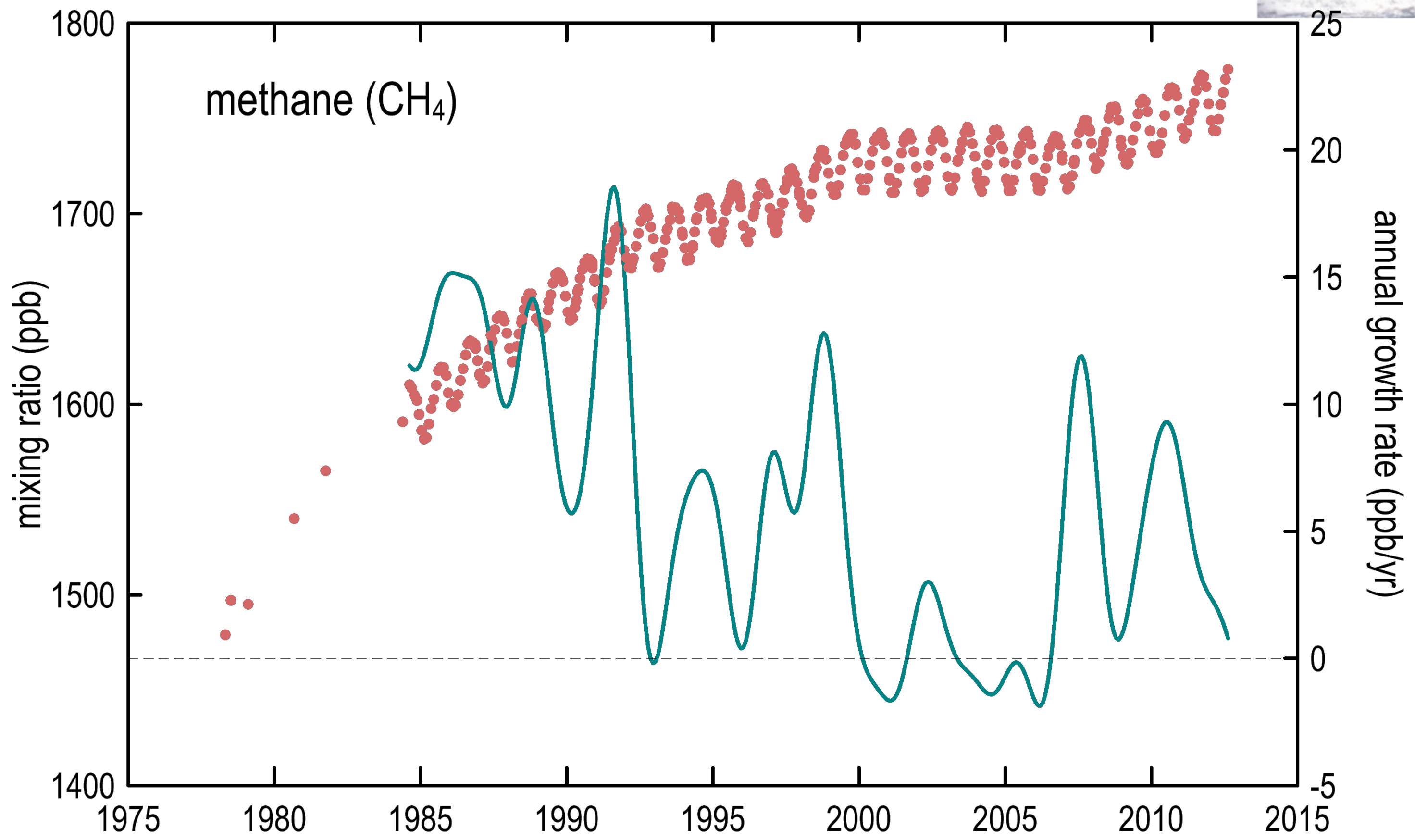
Carbon dioxide and O_2/N_2: Cape Grim





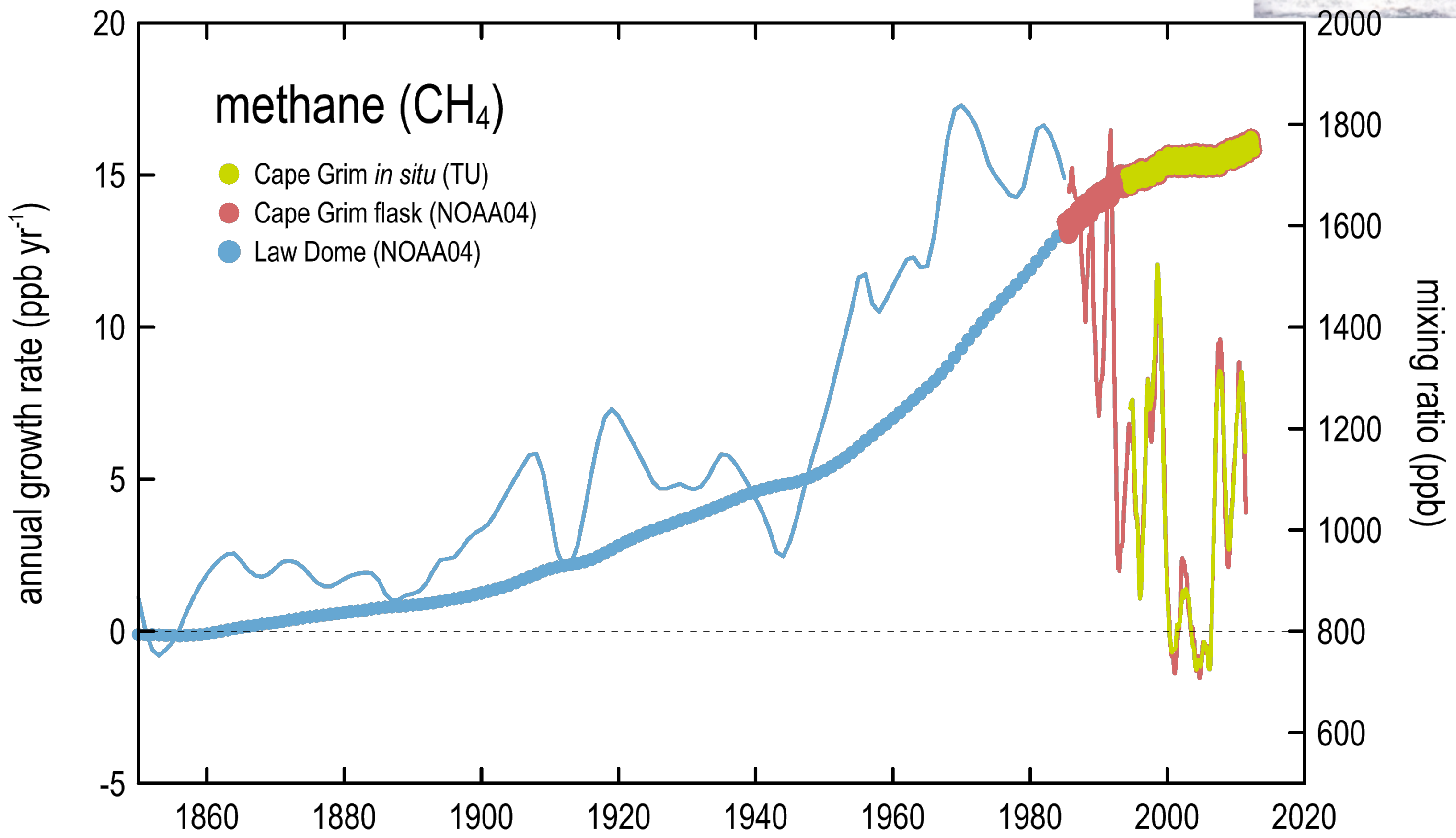
- combination of CO_2 & O_2/N_2 provides significant constraint on CO_2 sources: combustion: fossil fuel and/or biomass burning
- CO_2, $^{13}CO_2$, $^{14}CO_2$, O_2/N_2 trends can only be explained by the CO_2 increase resulting from fossil fuel combustion

Methane: Cape Grim



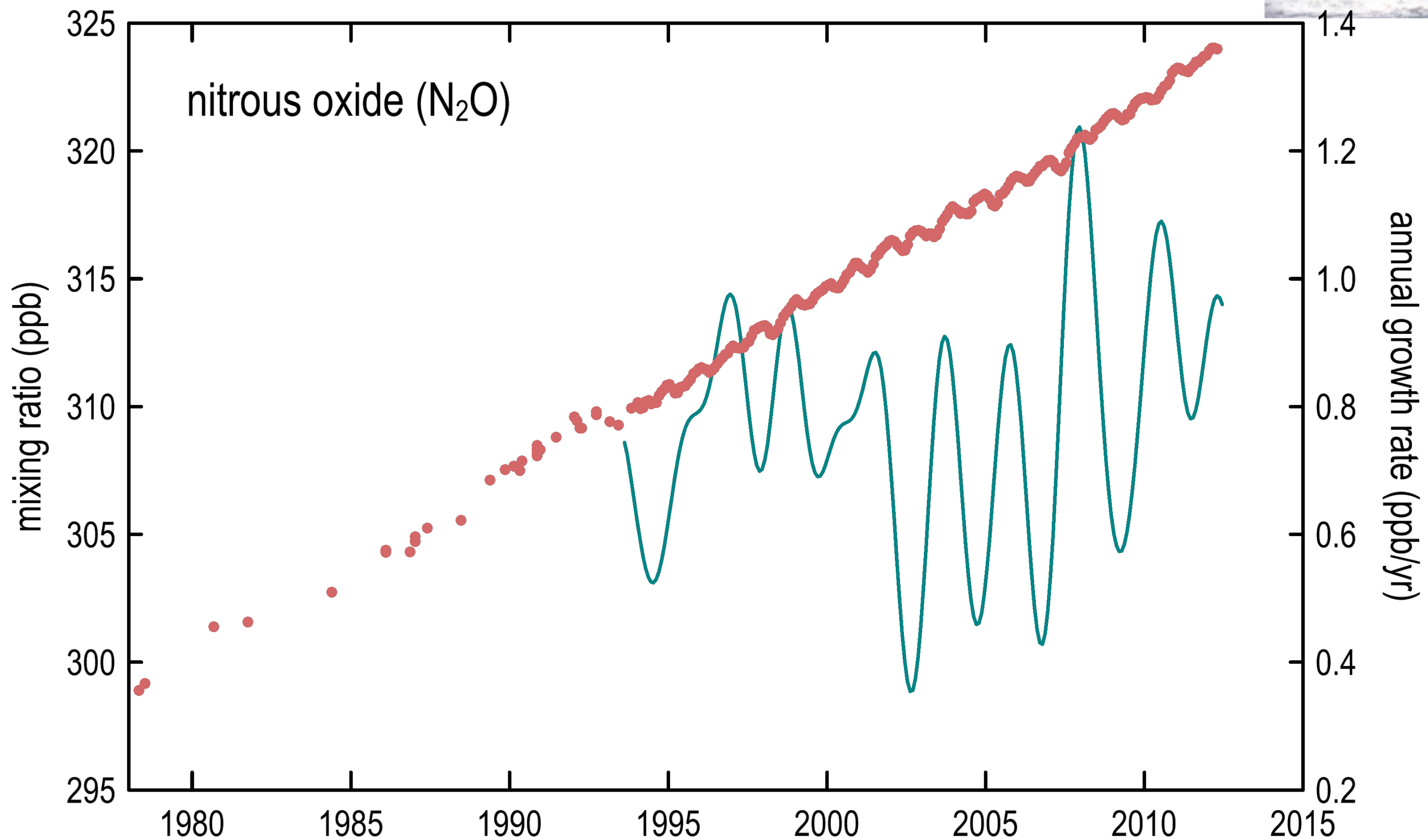
- methane growth rate slowed in the late-1990s and accelerated in the late-2000s
- overall decline in growth rate – approach to equilibrium
- recent growth : wetter than normal tropics – climate change or natural?

Methane: Cape Grim and in Antarctic ice



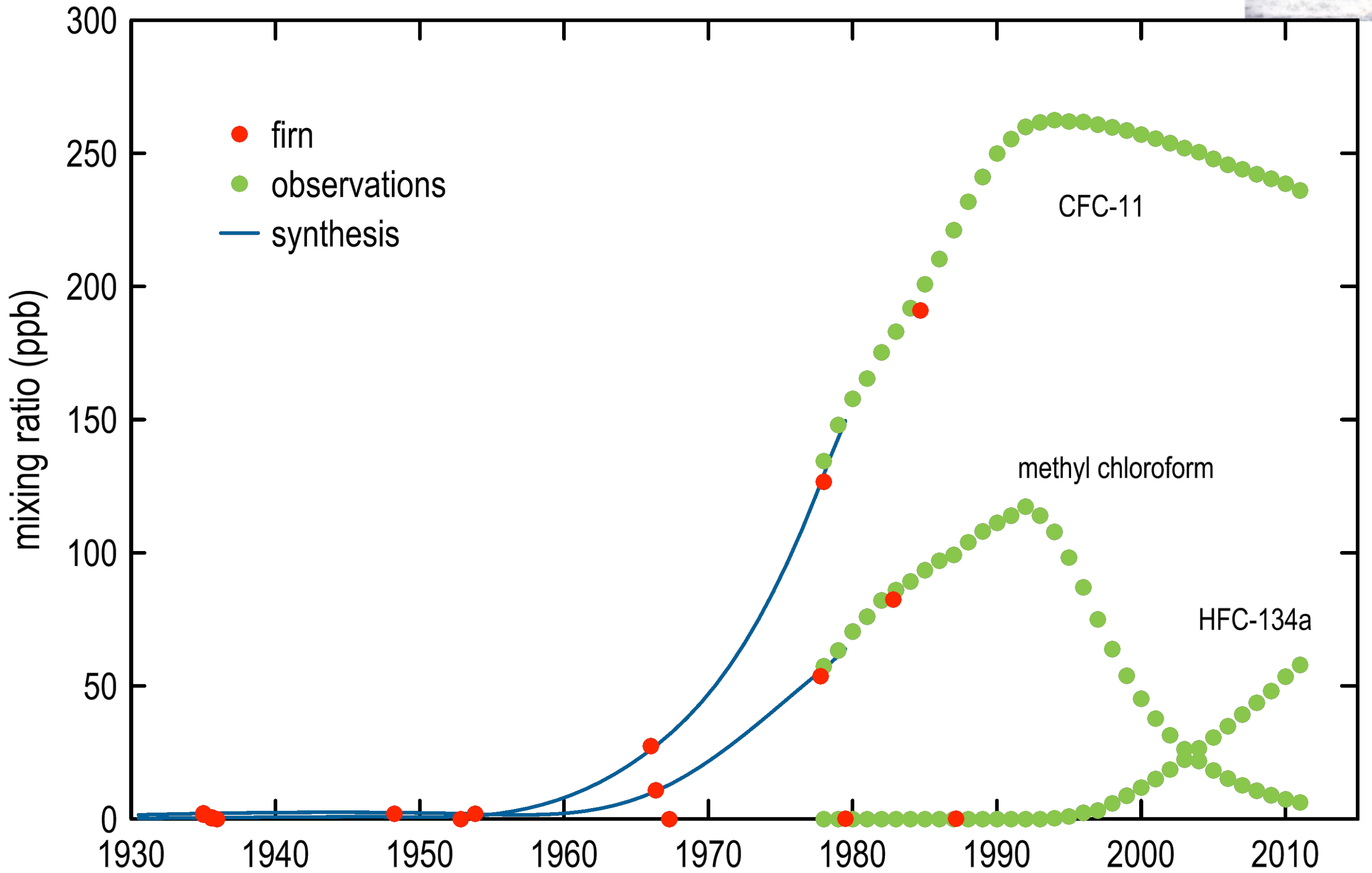
- CH_4 growth rate peaked in the early 1970s
- due to peak in fugitive natural gas emissions?

Nitrous oxide: Cape Grim



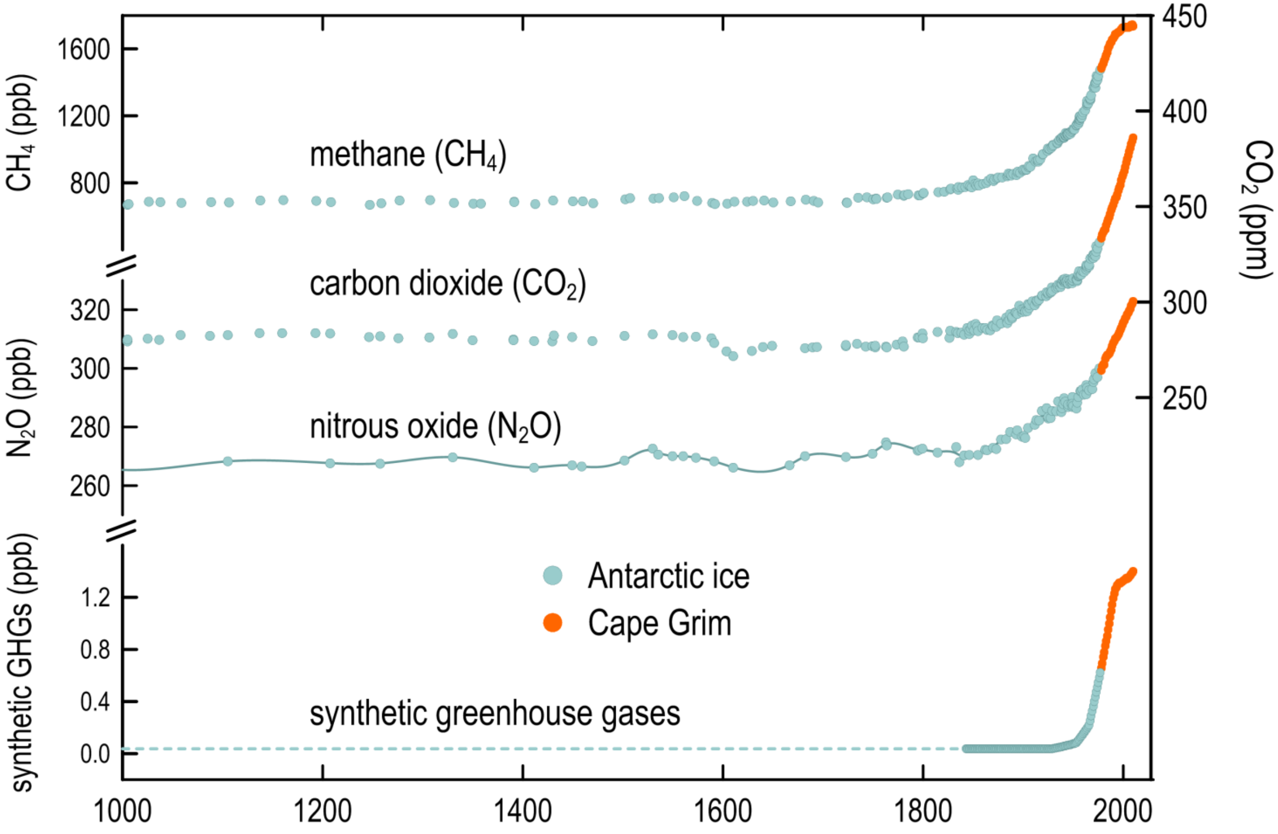
- long-term trend - increasing use of nitrogeneous fertilizers, land-use change
- growth rate variability – changes in tropical soil sources

Not all GHGs are increasing



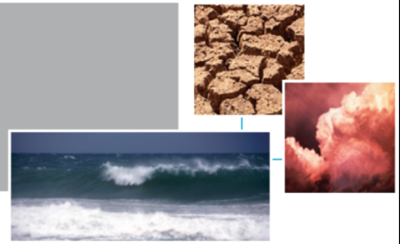
- declines in the concentrations of most of the Montreal Protocol gases: CFCs, CH_3CCl_3, CCl_4
- increases in the Kyoto Protocol synthetics: HFCs, PFCs, SF_6

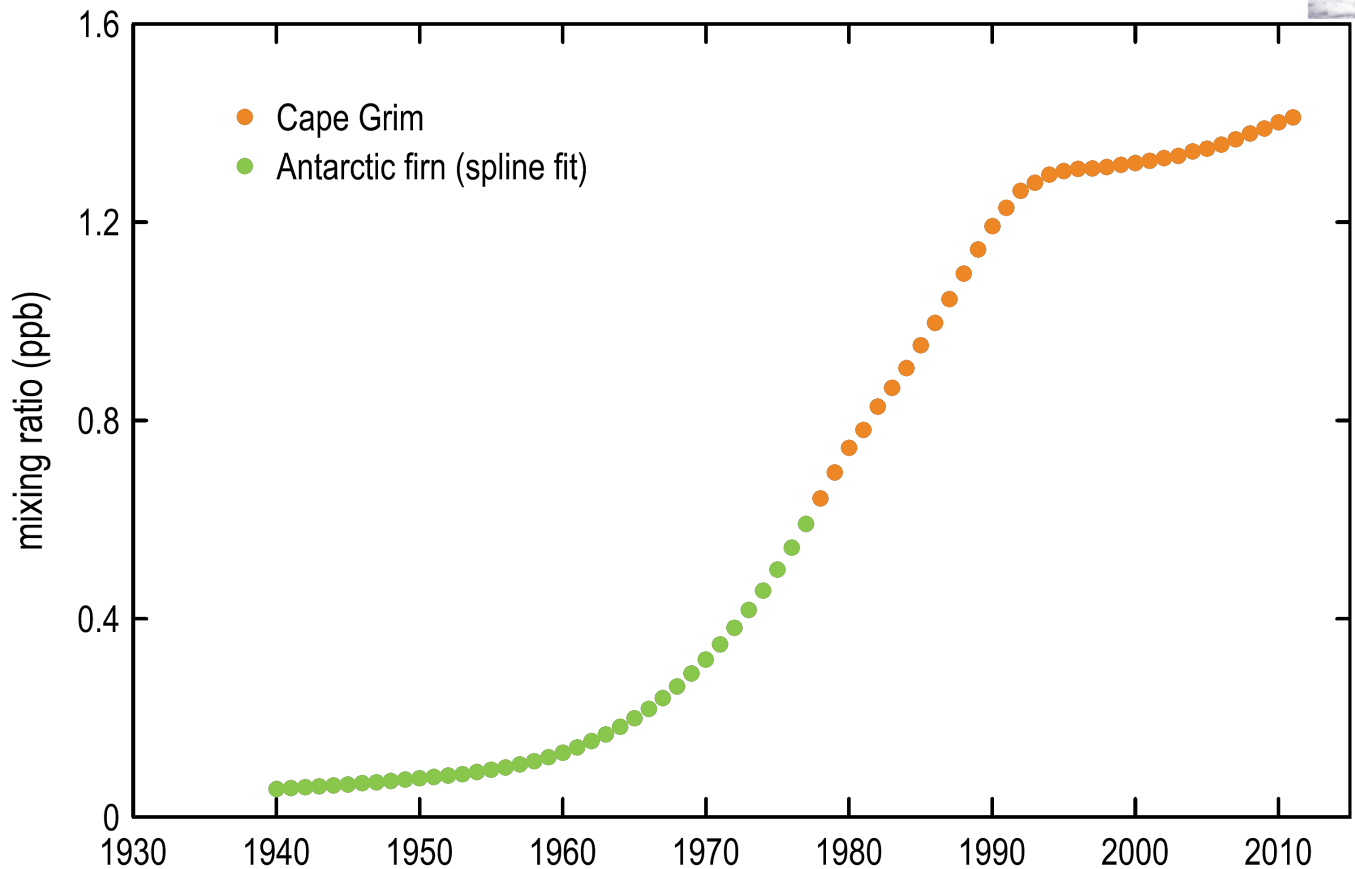
Iconic CSIRO 2000 yr records of GHGs



- the 2000-records of CO_2, CH_4 and N_2O from Cape Grim & Law Dome (Antarctica) data

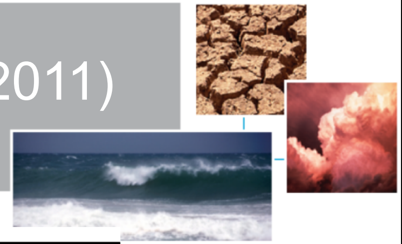
SGGs (CFCs, HCFCs, HFCs etc) at Cape Grim

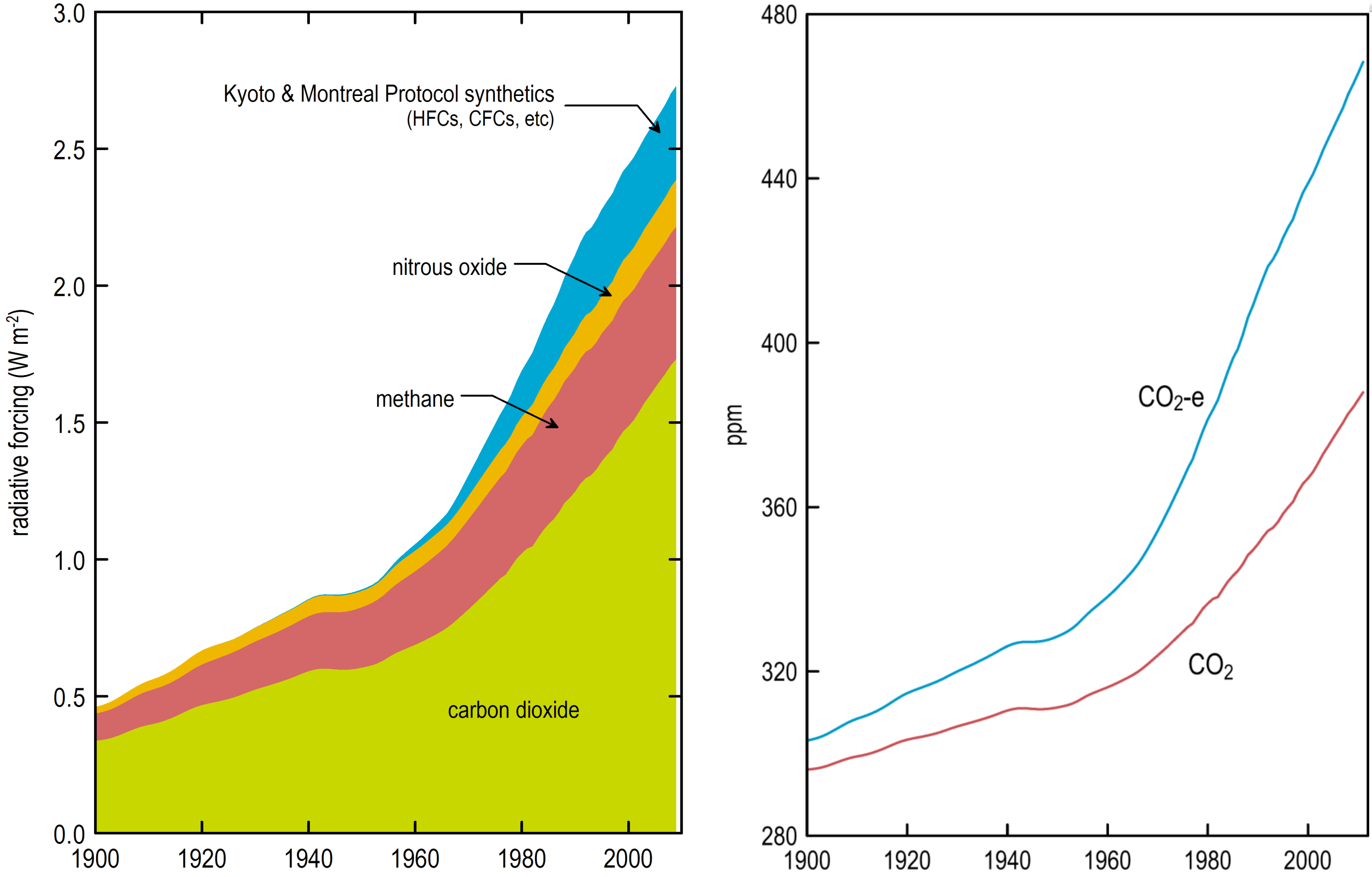




- fastest growing GHG ‘sector’
- developed to developing world transition
- now 2nd most important contributor to climate change since the 1950s
- easiest GHG ‘sector’ to regulate – already half completed (Montreal Protocol)

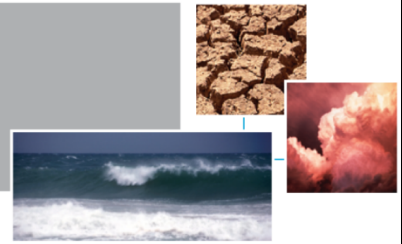
CSIRO/AGAGE long-lived GHG radiative forcing for Garnaut (2011)

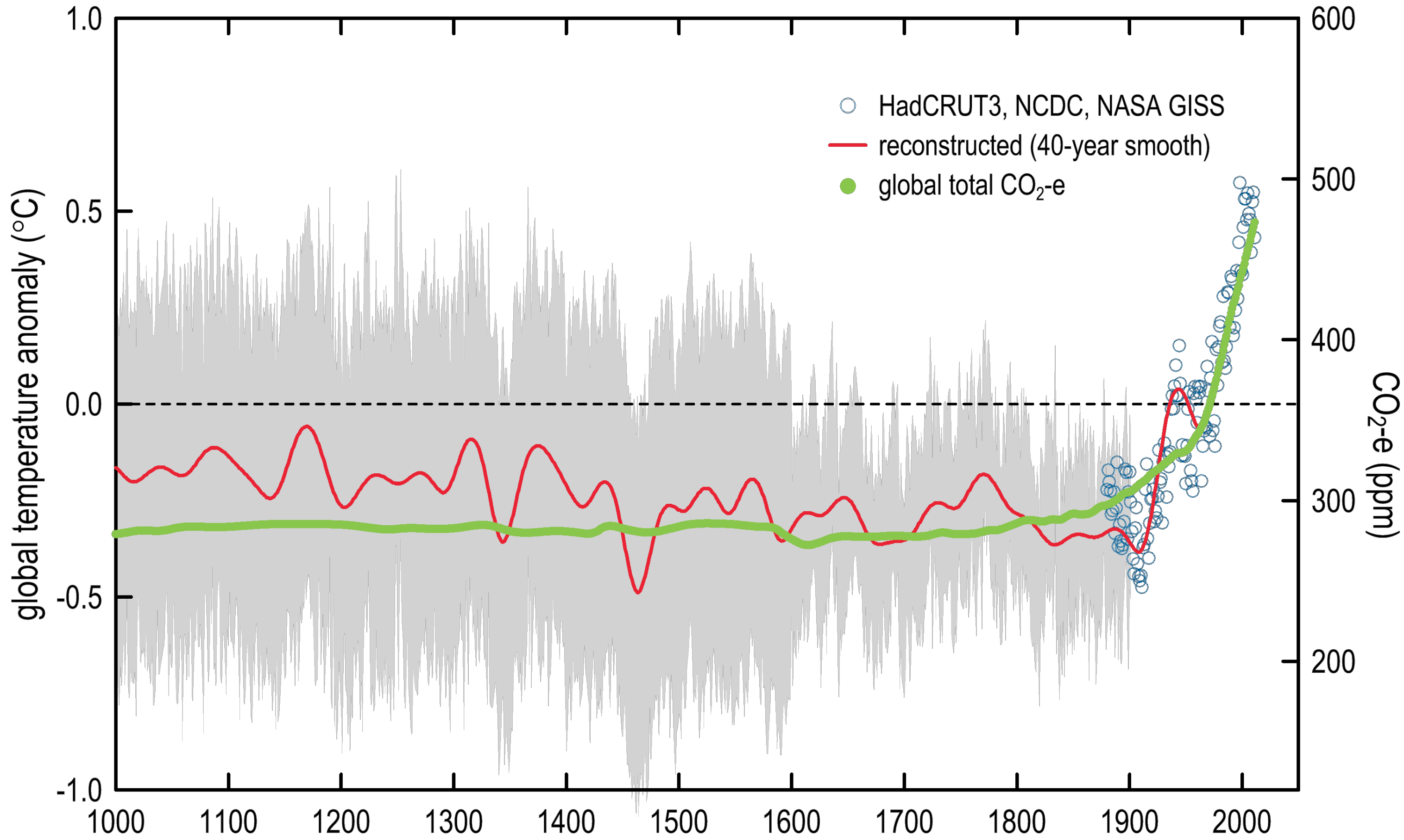




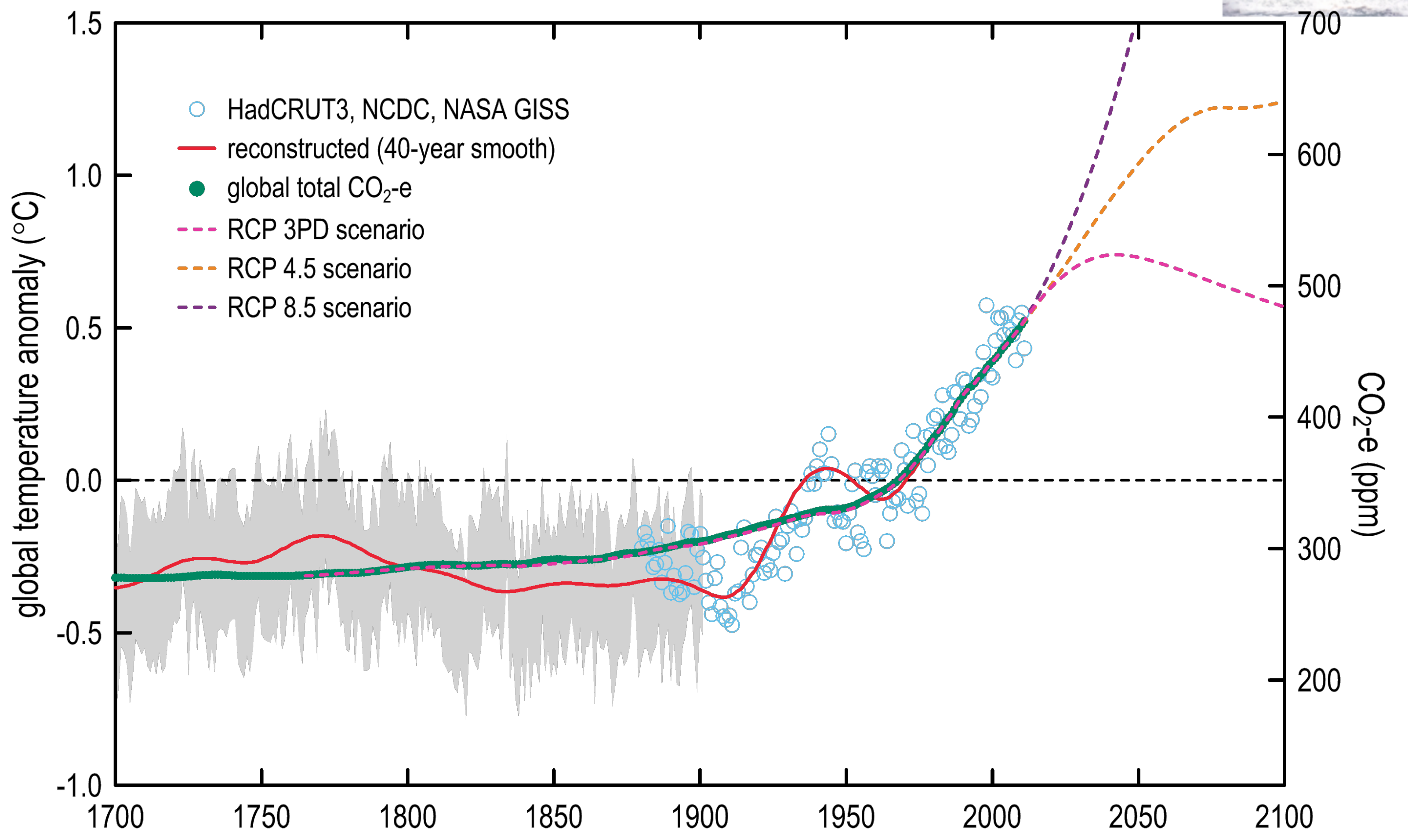
- after CO_2, the largest contributor to radiative forcing growth over the past 50 years are the SGGs: CFCs & their replacement HFCs

1000 yr global temperature record & CO_2 equivalent



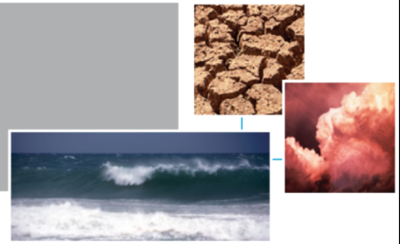


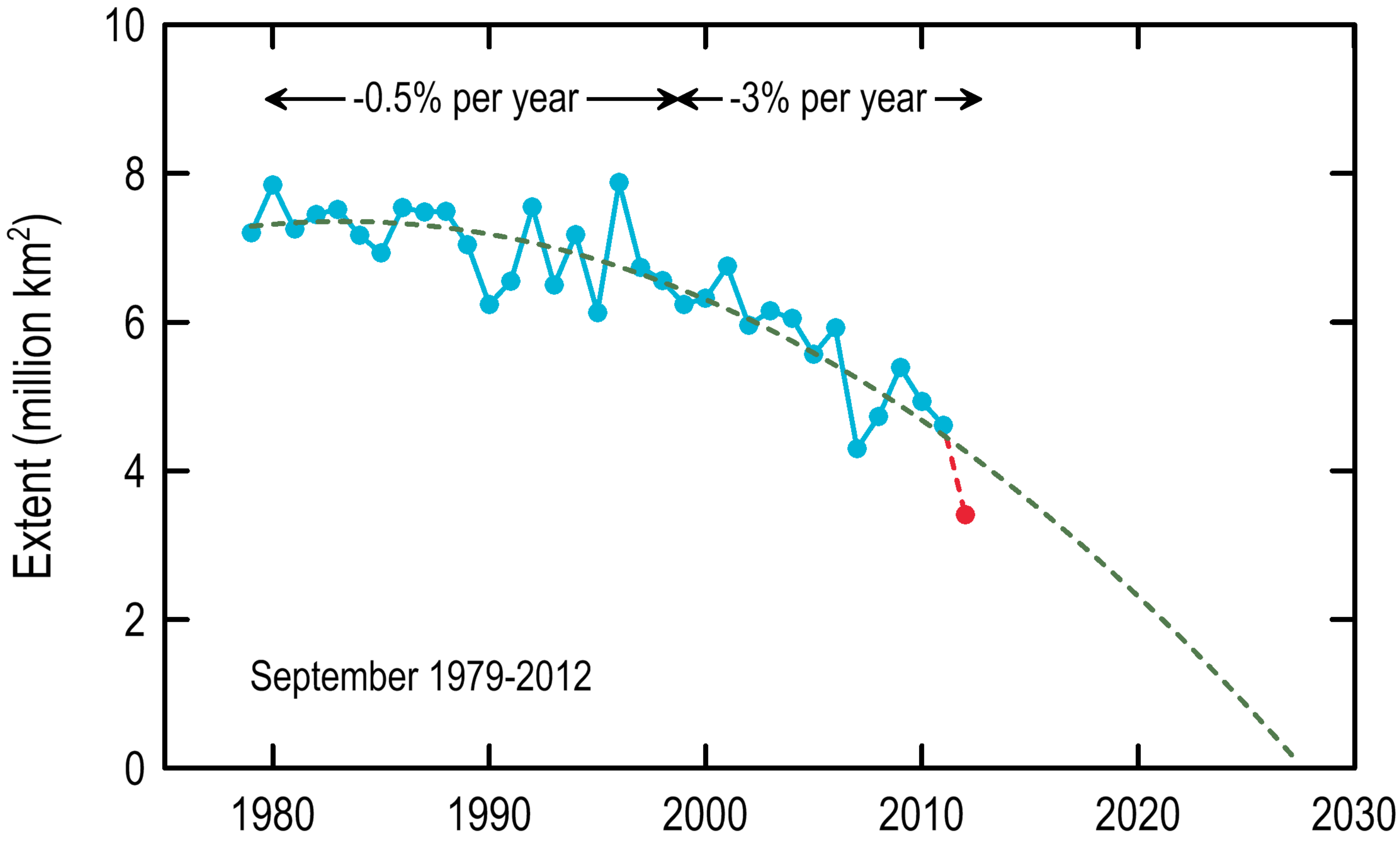
CO_2-e and temperature: past 300 years, future?



- There are important 'lags' in the temperature record

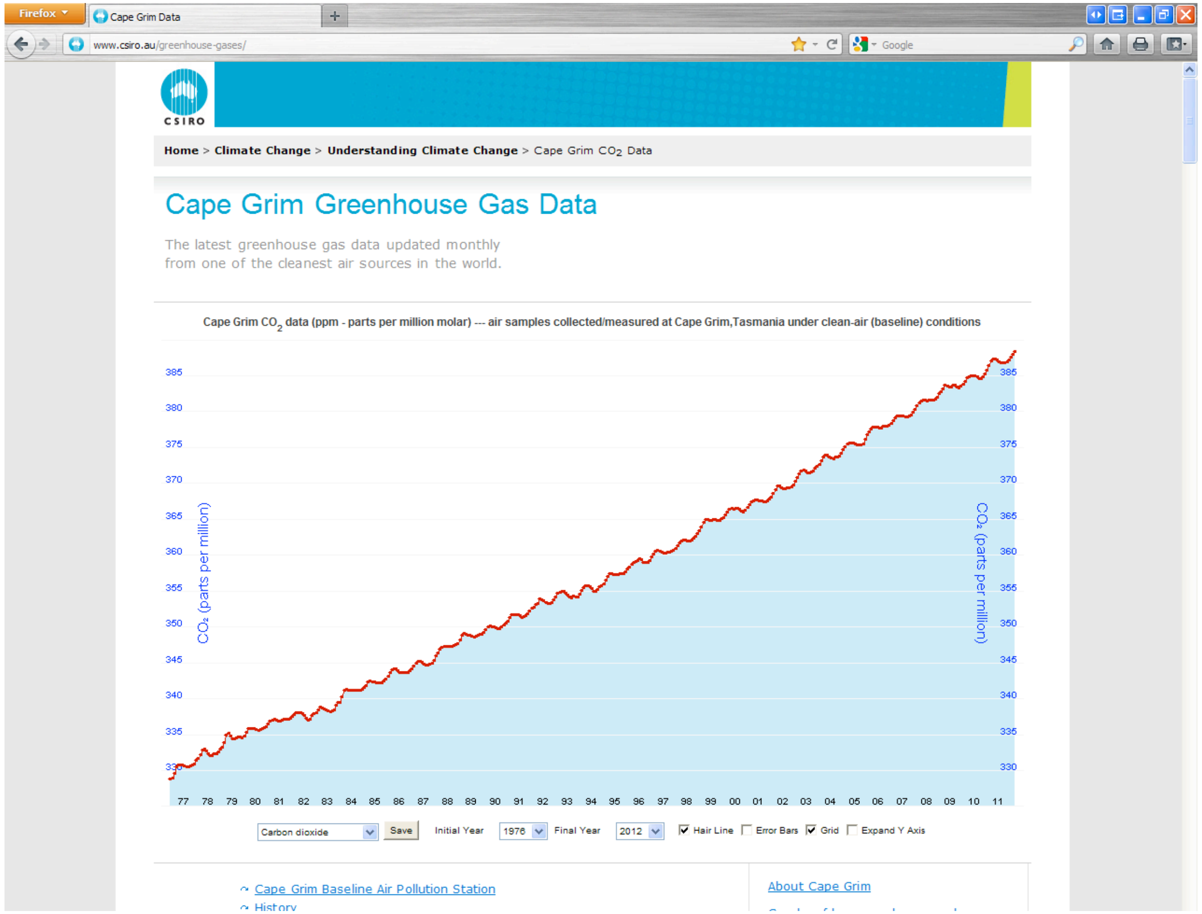
Arctic sea ice extent: a 'tipping point'?





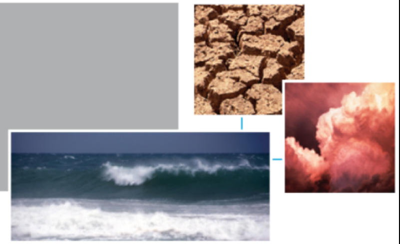
- Will the late-summer Arctic be ice-free within 20 years?

CSIRO Cape Grim GHG Website



- http://www.csiro.au/greenhouse-gases/

Summary



- CSIRO and BoM operate one of the world's most important networks for measuring GHGs in the background atmosphere
- The network measures all the important GHGs in the background atmosphere: CO_2, CH_4, SGGs (CFCs, HFCs etc), N_2O
- CO_2 drives about 60% of observed climate change, non-CO_2 GHGs about 40%
- models show that the climate change impact of GHGs is approximately doubled by the resultant water vapour feedback
- CSIRO/BoM data and research have proved that CO_2 increases in the atmosphere are driven by the combustion of fossil fuels (as have other international laboratories)
- N_2O increases are driven by agriculture (land-use change and fertilizers)
- Less certain about what drives CH_4 increases: combination of natural gas leakage, emissions from coal, agriculture and wetlands (climate change)
- Australian scientists (CSIRO, BoM, universities) are involved at all levels in the international assessments of climate change
- There is strengthening consensus that growing GHGs in the atmosphere are driving climate change
- May already be on an irreversible path to an Arctic free of summer ice

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CSIRO

CSIRO Aspendale Greenhouse Gas Team

Dr P. Fraser (Team Leader), Dr C. Allison, S. Coram, N. Derek, Dr B. Dunse, Prof. I. Enting (U. Melbourne), Dr D. Etheridge, Dr R. Francey, R. Gregory, C. Leary, P. Krummel, Dr R. Langenfelds, Dr R. Law, Dr Z. Loh, Dr. M. Rubino, D. Spencer, Dr A. Stavert, Dr P. Steele, D. Thornton, Dr C. Trudinger, Dr M. van der Schoot

Thank you

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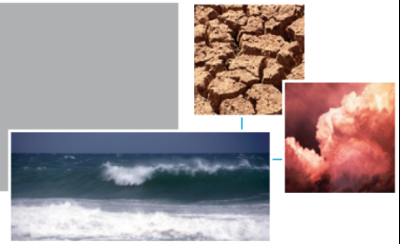
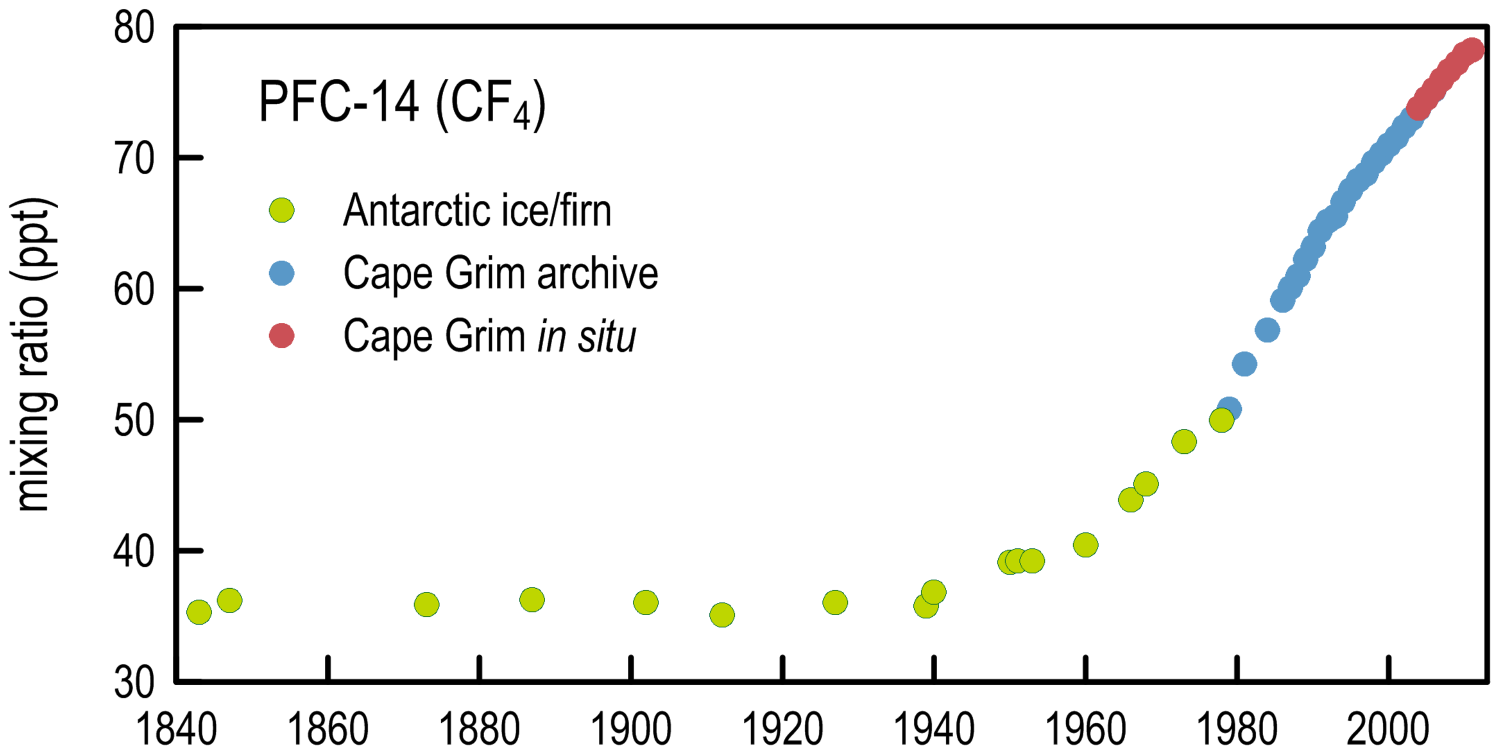
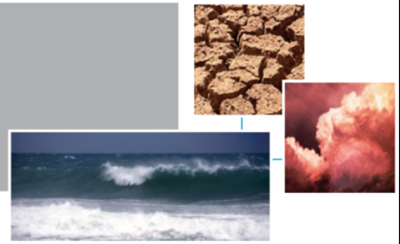
Cape Grim & Antarctic CF_4: the 'SCUBA tank' story

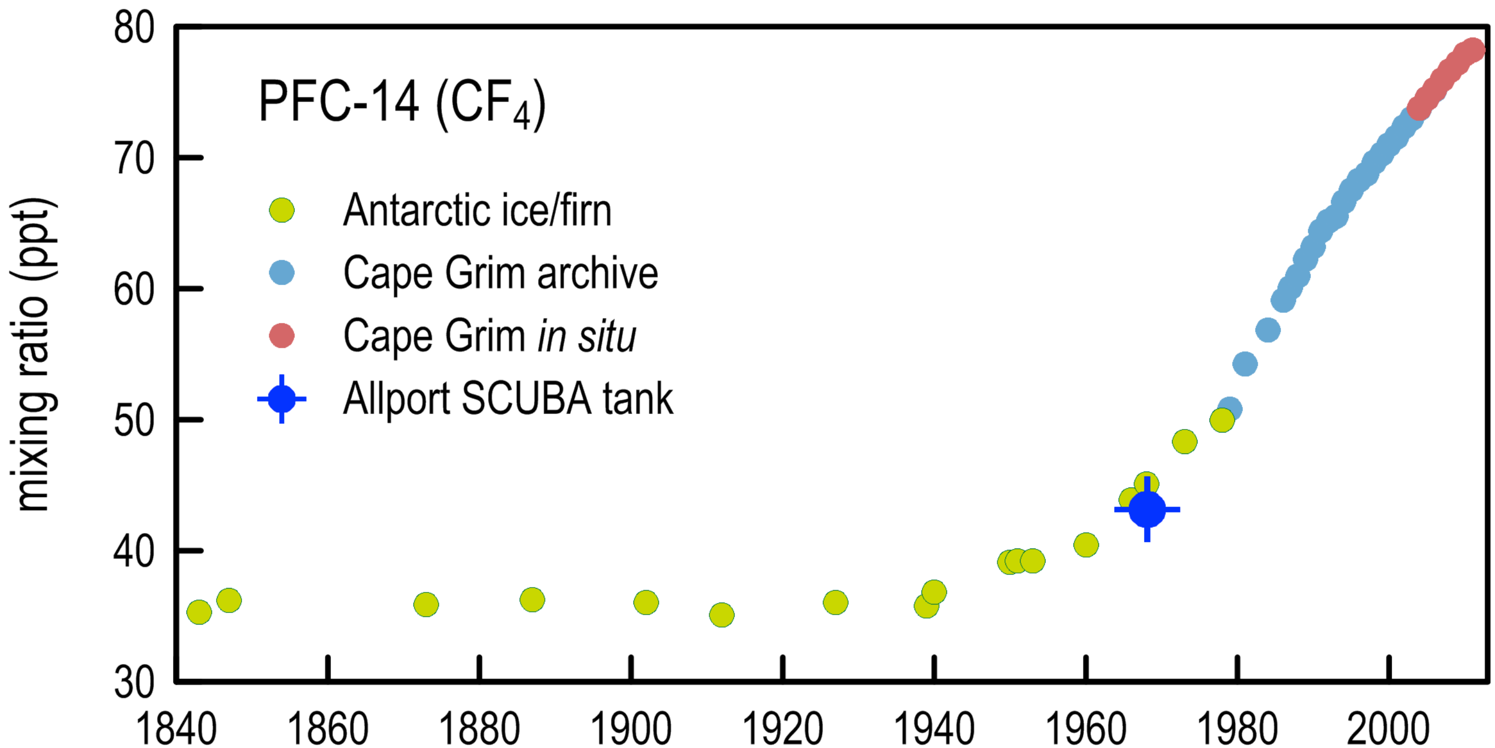




- very potent GHG
- emitted during aluminium smelting and electronic manufacture

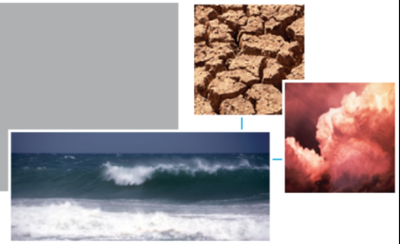
Cape Grim CF_4 & J. Allport SCUBA tank value

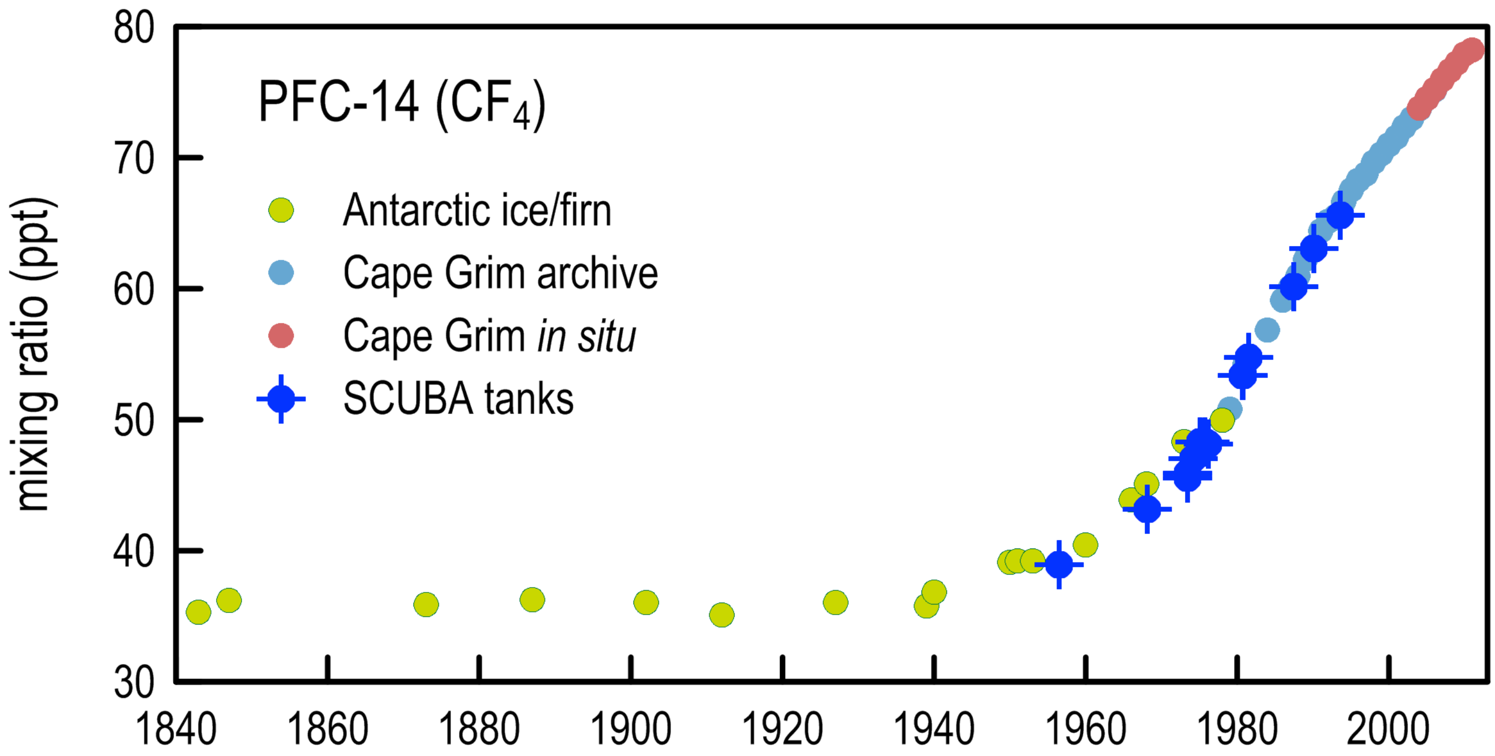




- J. Allport (Beaumaris) SCUBA tanks: 1968
- air date confirmed by diving diary and tank test date
- operational SCUBA tanks tested every 12 months
- testing date (month/year) stamped on tank

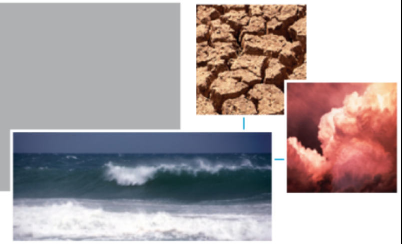
Antarctic, Cape Grim CF_4 & all SCUBA tanks

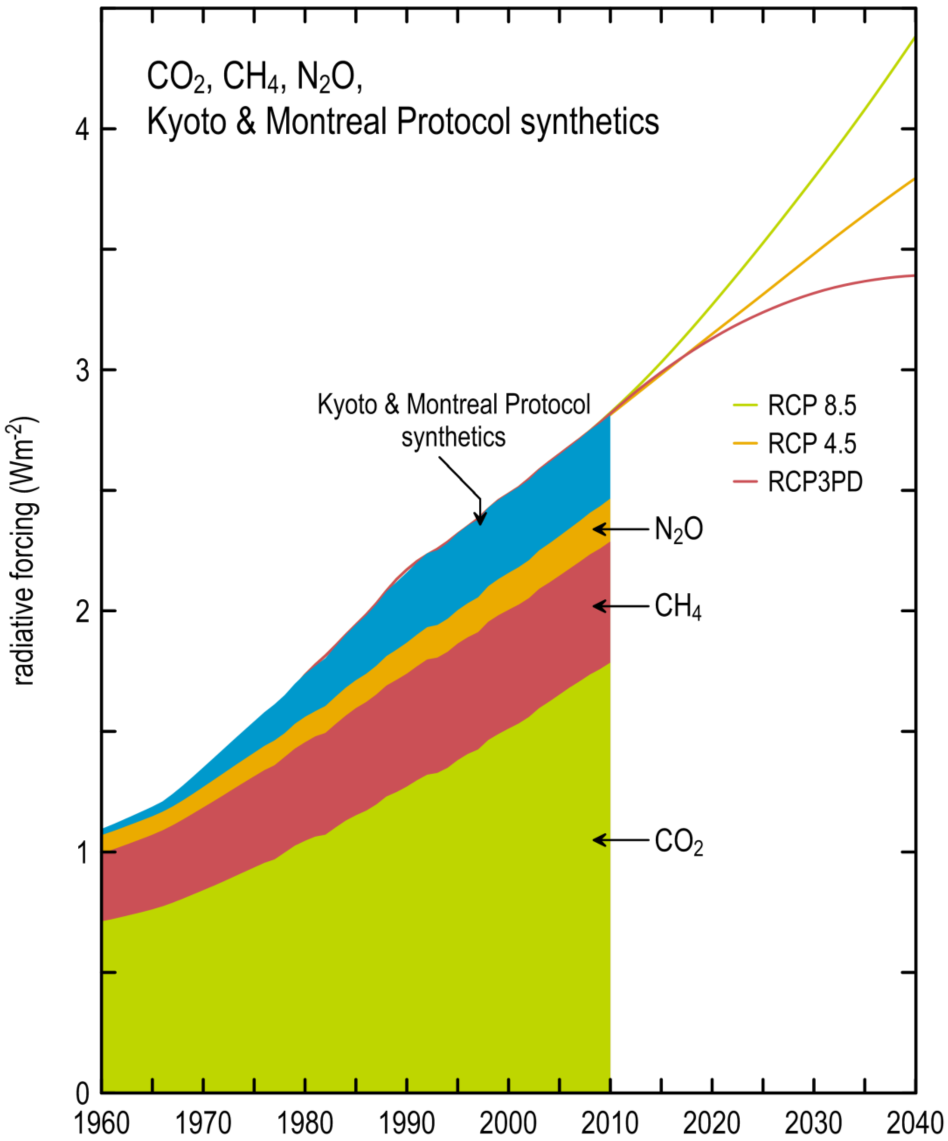




- 15 SCUBA tanks received (Qld, NSW, Vic, SA, WA)
- all contain background levels of CF_4
- useful for SH values of several SSGs (before emitted locally)

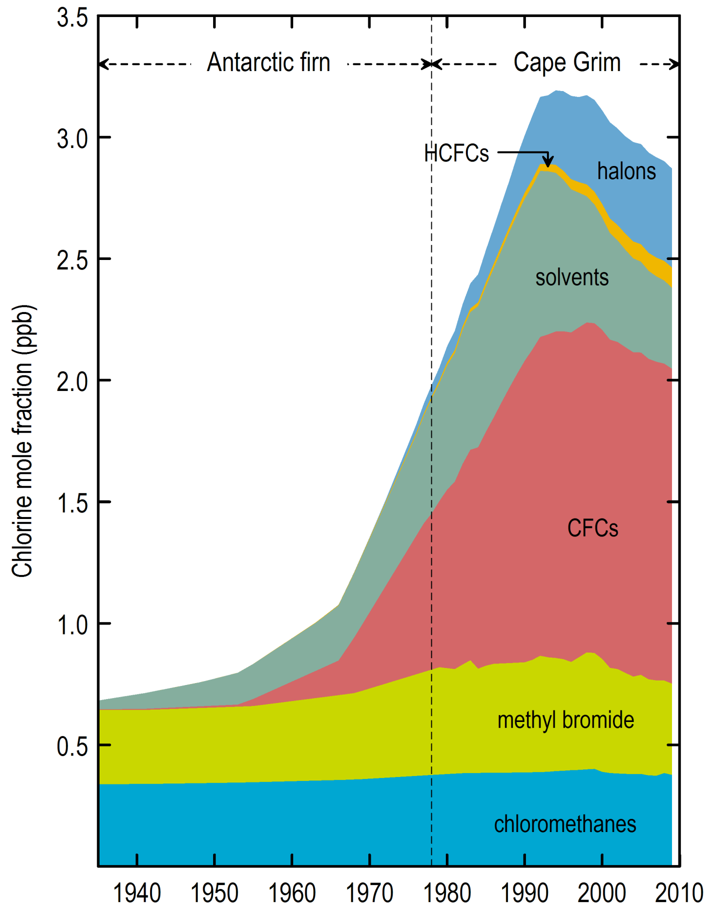
Global radiative forcing LLGHGs : CSIRO/AGAGE

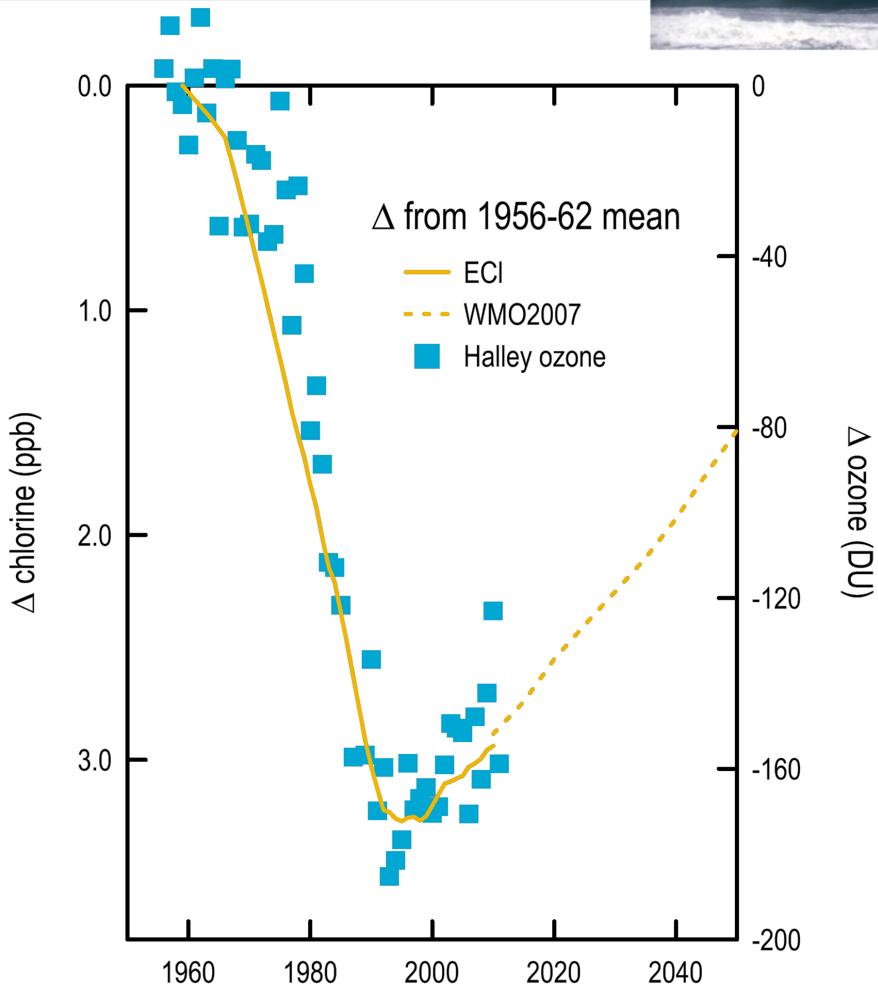




- *IPCC 4th Assessment*: 2005 2.64 Wm^{-2}
  CSIRO/AGAGE: 2005 2.65 Wm^{-2}
  from exactly matched GHGs (~30 gases)
- AGAGE/CSIRO:
  - 2009: 2.78 Wm^{-2} (467 ppm CO_2-e)
  - 2010: 2.82 Wm^{-2} (470 ppm CO_2-e)
- Garnaut: *Climate Change Review Update 2011*
- CSIRO: *Climate Change: science and solutions for Australia (2011)*
- KP/MP synthetics
  - faster growing GHG sector
  - cost-effective emissions mitigation
- RCPs 3.0,4.5, 8.5: IPCC 5th Assessment

CSIRO effective chlorine used to predict ozone recovery





- effective chlorine peaked in mid-1990s, 8% decline by 2010
- Antarctic ozone recovery underway