Australian HFC, PFC and SF_6 emissions: atmospheric verification

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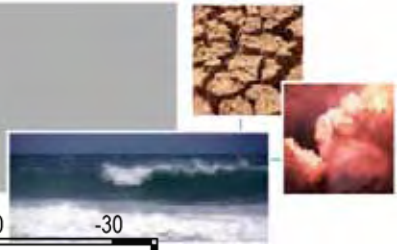
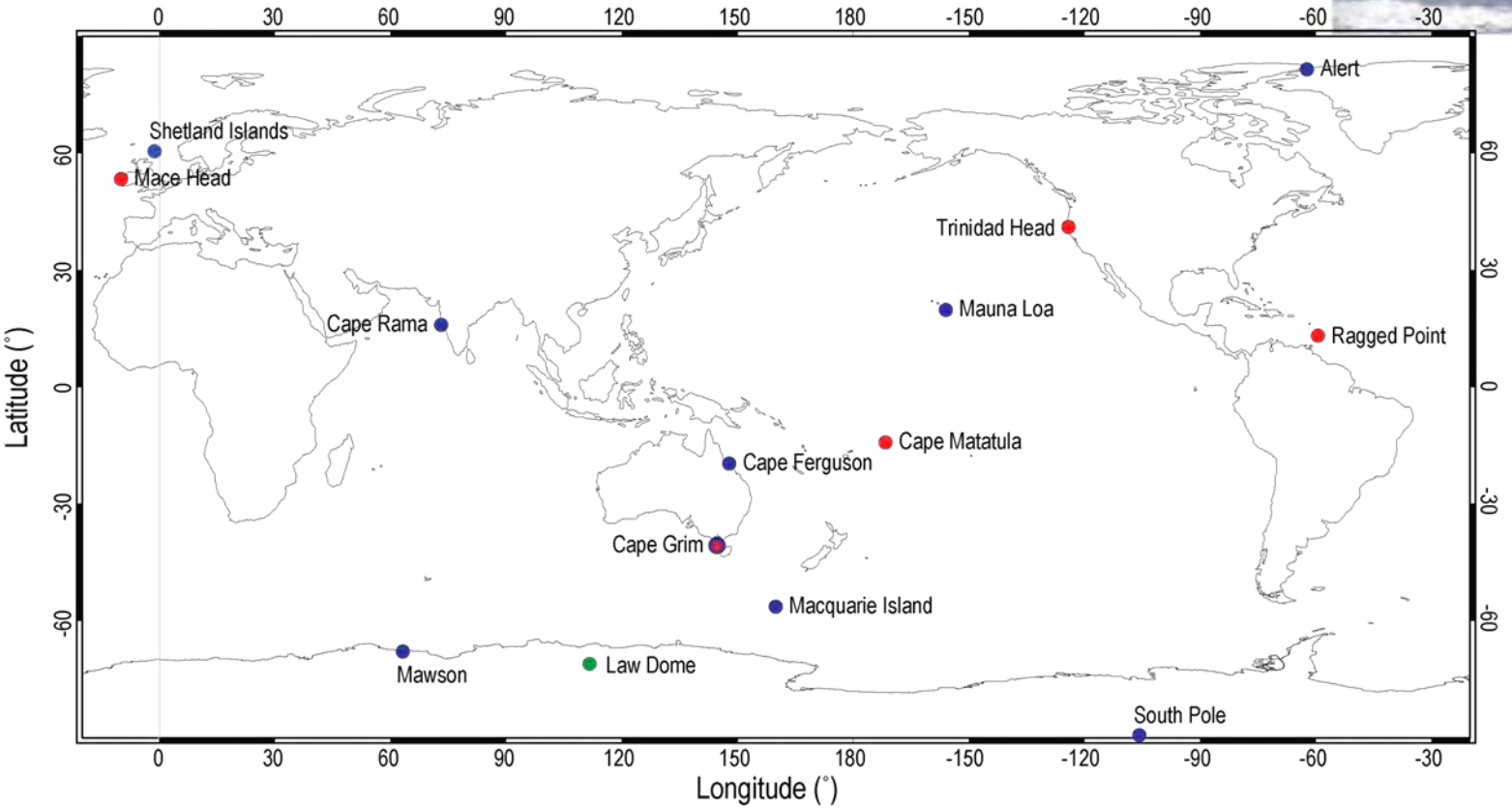
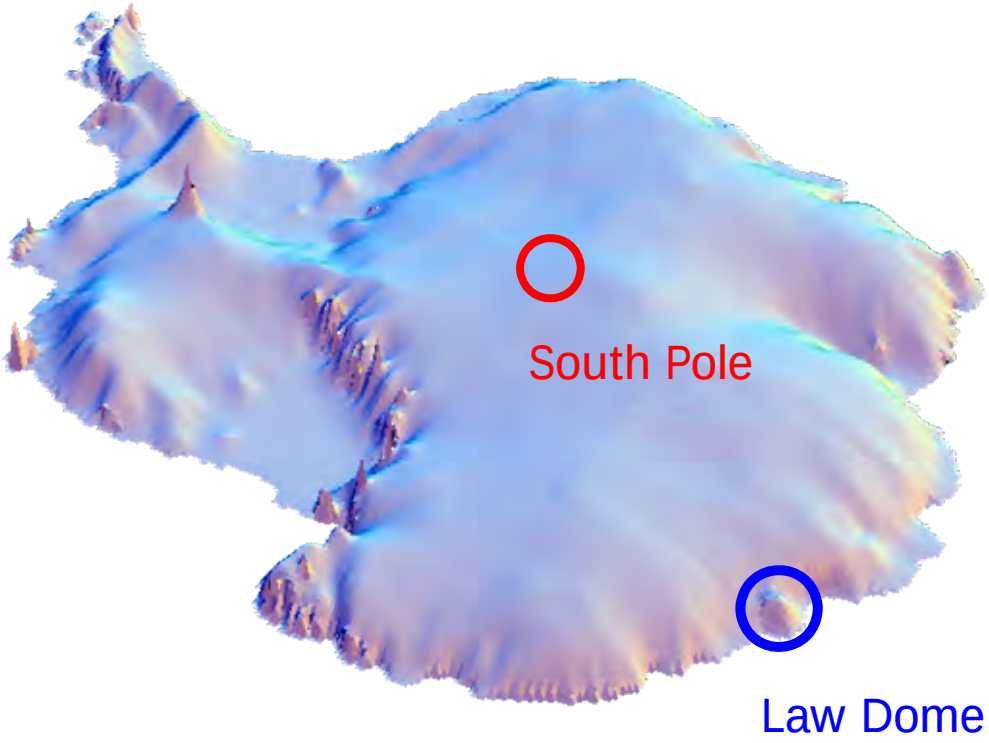
CSIRO/AGAGE global GHG network





- AGAGE & CSIRO GHG measurements since the late-1970s
- most important GHG network outside NOAA (USA)
- unlike NOAA, measures every GHG used by IPCC to define long-lived GHG radiative forcing
- Cape Grim air archive since 1978; pre-1970s data from Law Dome firn air samples
- major contribution to all 4 IPCC Climate Change Assessments

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




Cape Grim, Tasmania [41°S, 144°E]


Cape Grim air archive: 1978-2011

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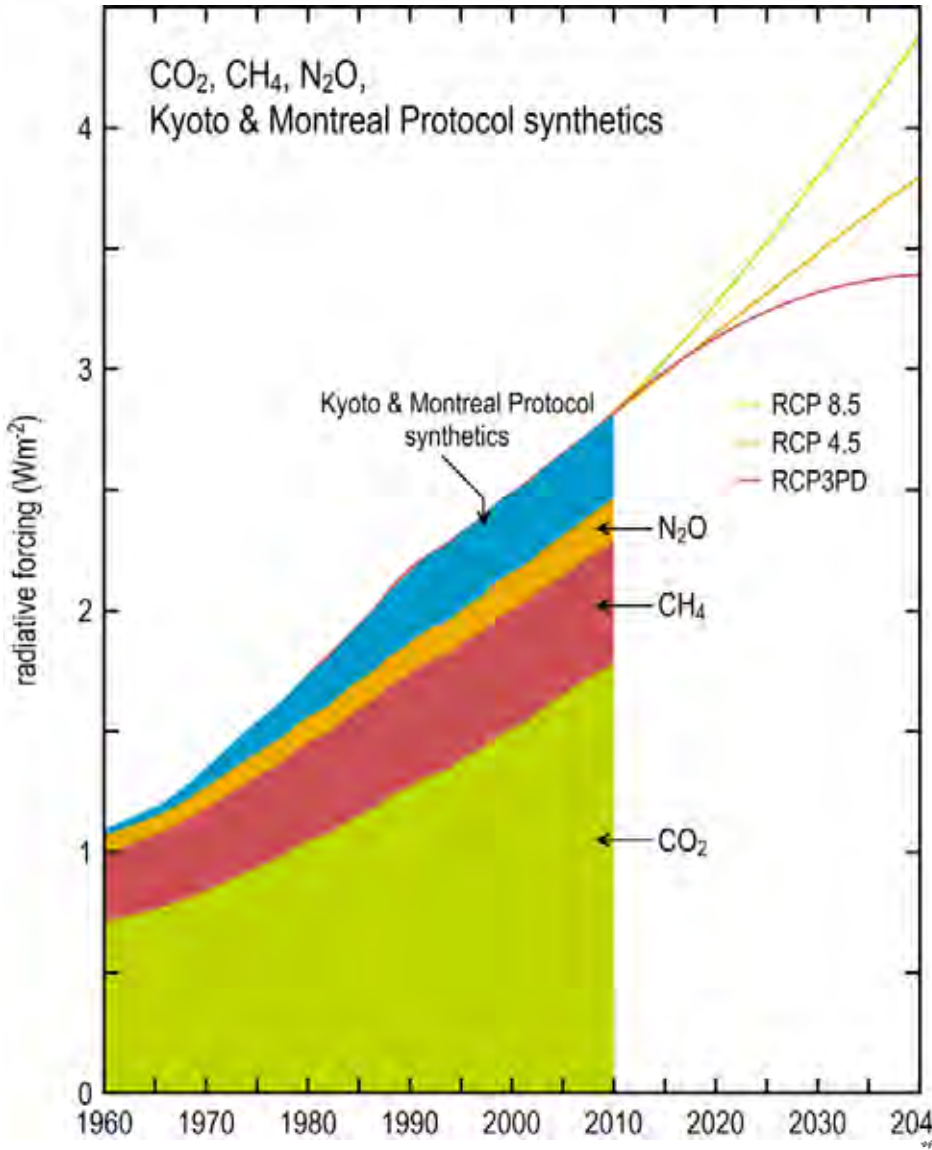
Global radiative forcing LLGHGs : CSIRO/AGAGE

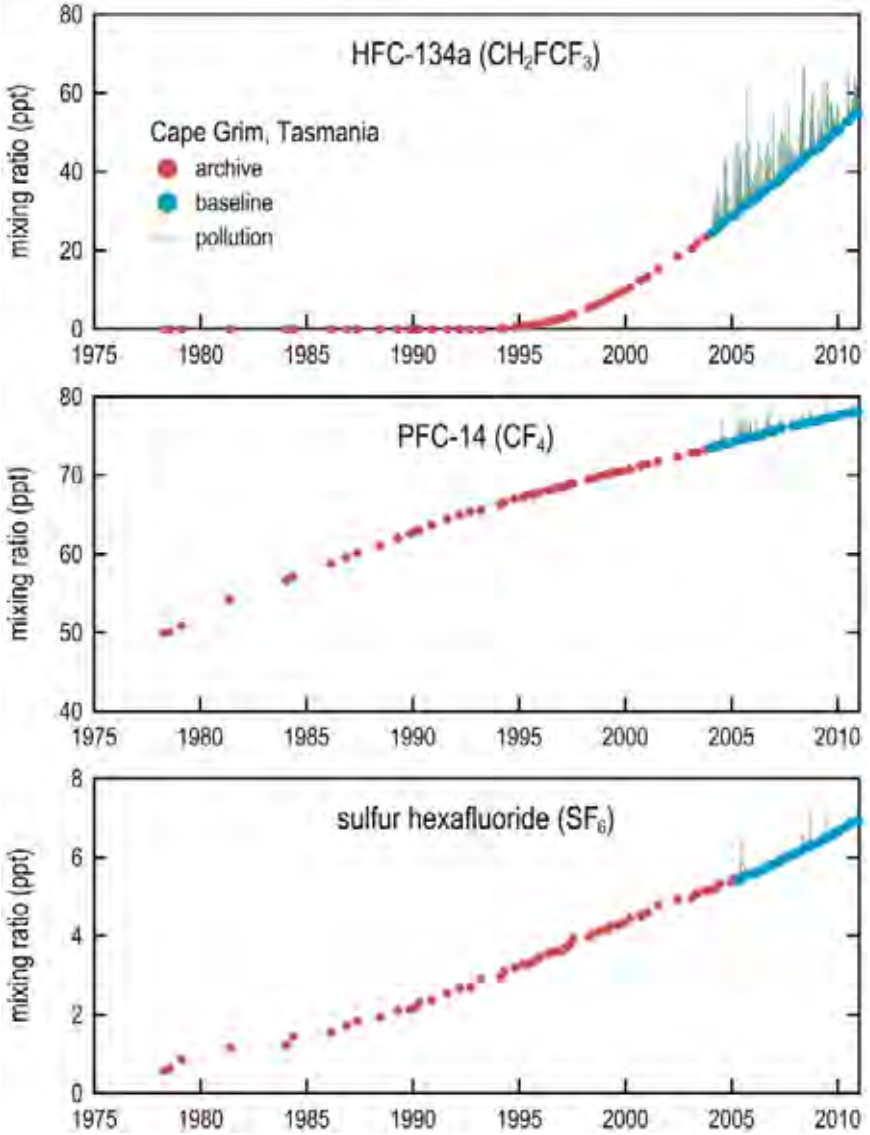


- IPCC 4th Assessment: 2005 2.64 Wm^{-2}
  CSIRO/AGAGE: 2005 2.65 Wm^{-2}
  from exactly matched GHGs (~30 gases)
- 2009 CSIRO/AGAGE: 2.77 Wm^{-2} (465 ppm CO_2-e)
- Garnaut: *Climate Change Review Update 2011*
- CSIRO: *Climate Change: science and solutions for Australia (2011)*
- KP/MP synthetics
  - faster growing GHG sector
  - up to 2010: largely CFC emissions
  - by 2050: largely HFC emissions
  - cost-effective emissions mitigation
- RCPs 3.0,4.5, 8.5: IPCC 5th Assessment

National GHG Inventory (NGGI): the Kyoto Protocol synthetics

- HFCs, PFCs, SF_6
  - currently <2% of total Australian GHG emissions
  - fastest growing sector of the NGGI (~8%/yr)
- HFCs (all refrigerants)
  - HFC-32 (CH_2F_2), HFC-125 (CHF_2CF_3), HFC-134a (CH_2FCF_3), HFC-143a (CH_3CF_3)
    - annual emissions reported in tonnes
  - unspecified HFC mix - likely HFC-152a (CH_2CHF_2), HFC-245fa ($CH_3CF_2CF_3$) + others
    - annual emissions reported as an aggregate in tonnes CO_2-e
- PFCs (aluminium & refrigeration)
  - PFC-14 (CF_4) - aluminium, PFC-116 (CF_3CF_3) – aluminium & refrigeration
    - annual emissions reported in tonnes
    - PFC-218 ($CF_3CF_2CF_3$), PFC-318 (c-C_4F_8) emissions not reported
- Sulfur hexafluoride (electricity distribution)
  - SF_6 annual emissions reported in tonnes
- newly identified GHGs: NF_3, CF_3SF_5, SO_2F_2 not reported in NGGI (to date)

HFC, PFC & SF_6 at Cape Grim



- HFC-134a: auto air-conditioning & domestic refrigeration
  - pollution episodes from Melbourne/Port Phillip
- PFC-14: aluminium smelting & electronics
  - Australia: aluminium only
  - pollution episodes from aluminium smelters
- SF_6: electricity distribution
  - pollution episodes from Melbourne/Port Phillip

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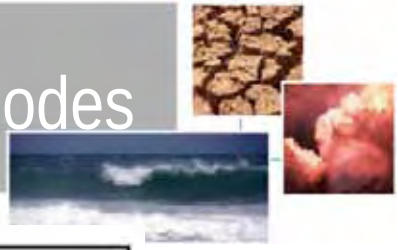
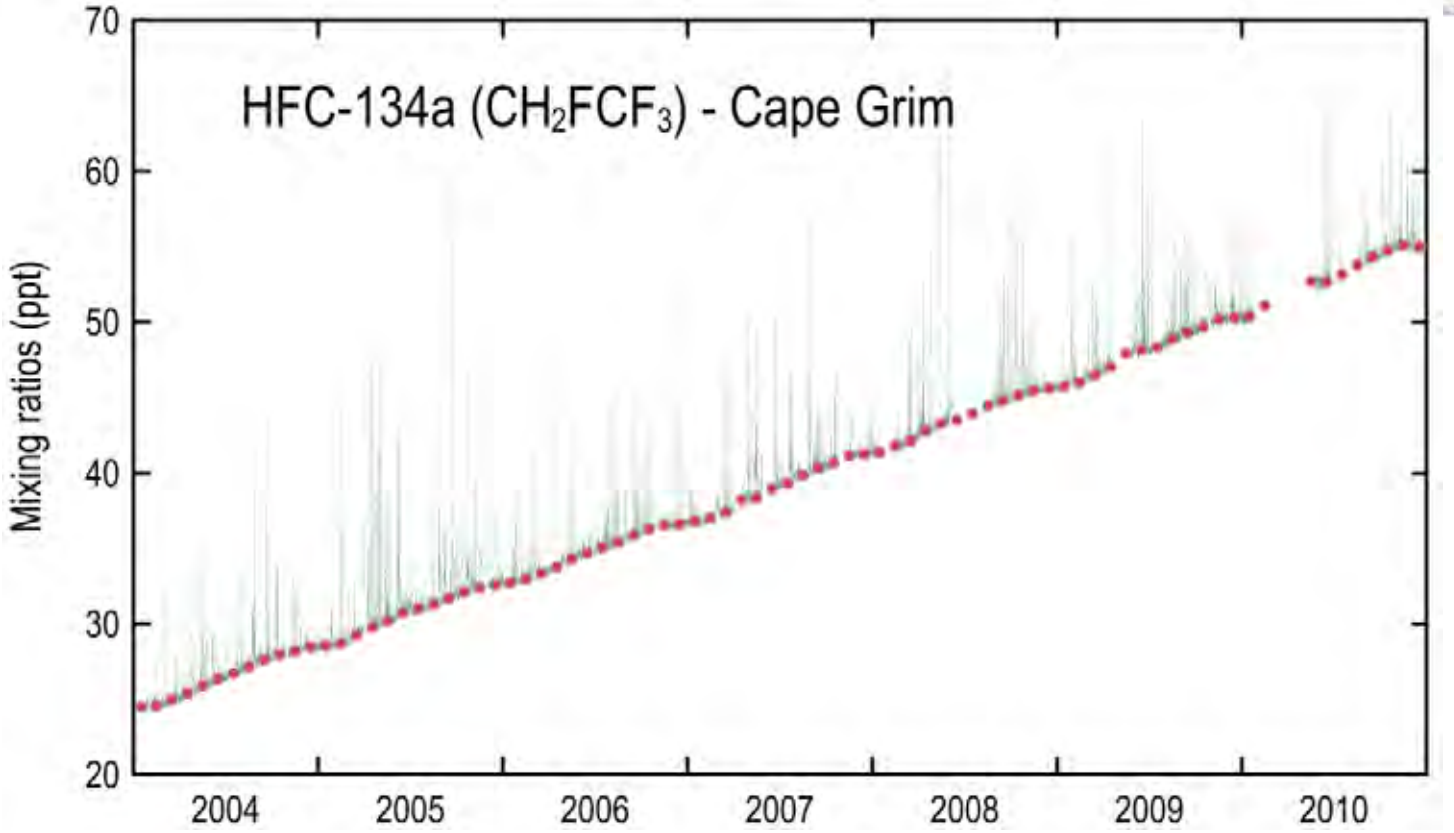
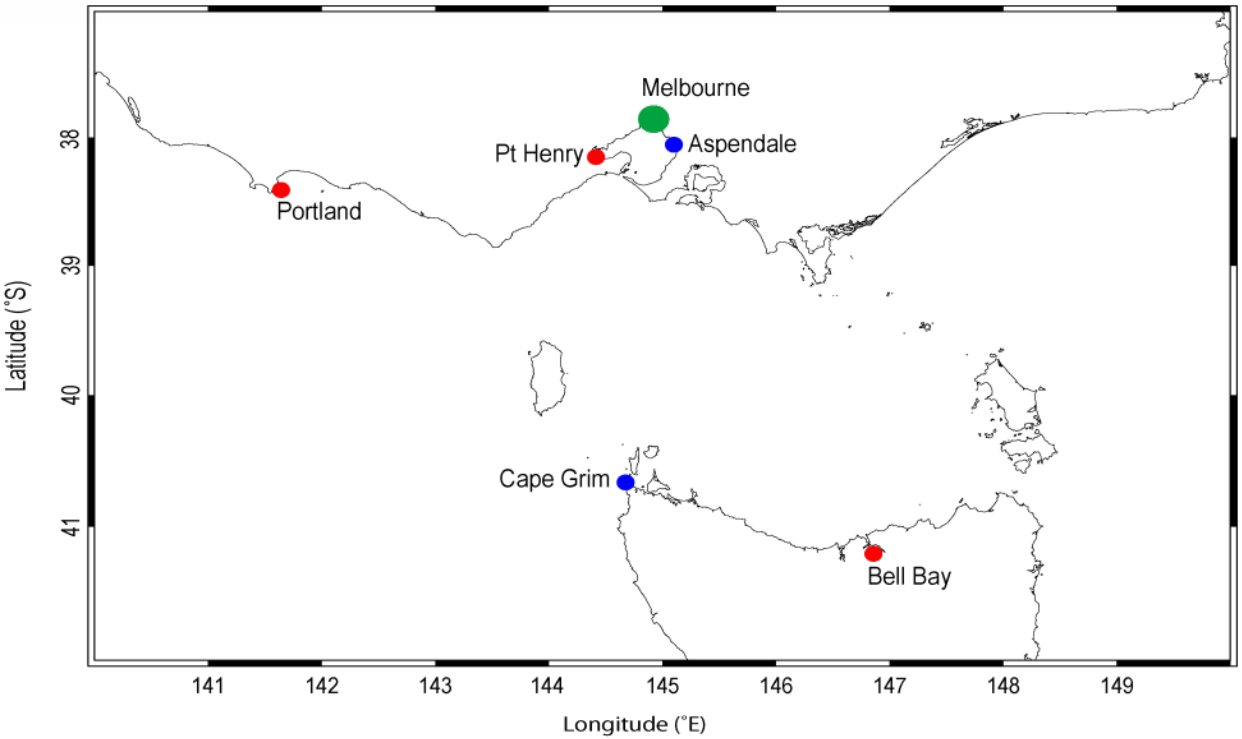
Cape Grim HFC-134a: baseline data & pollution episodes





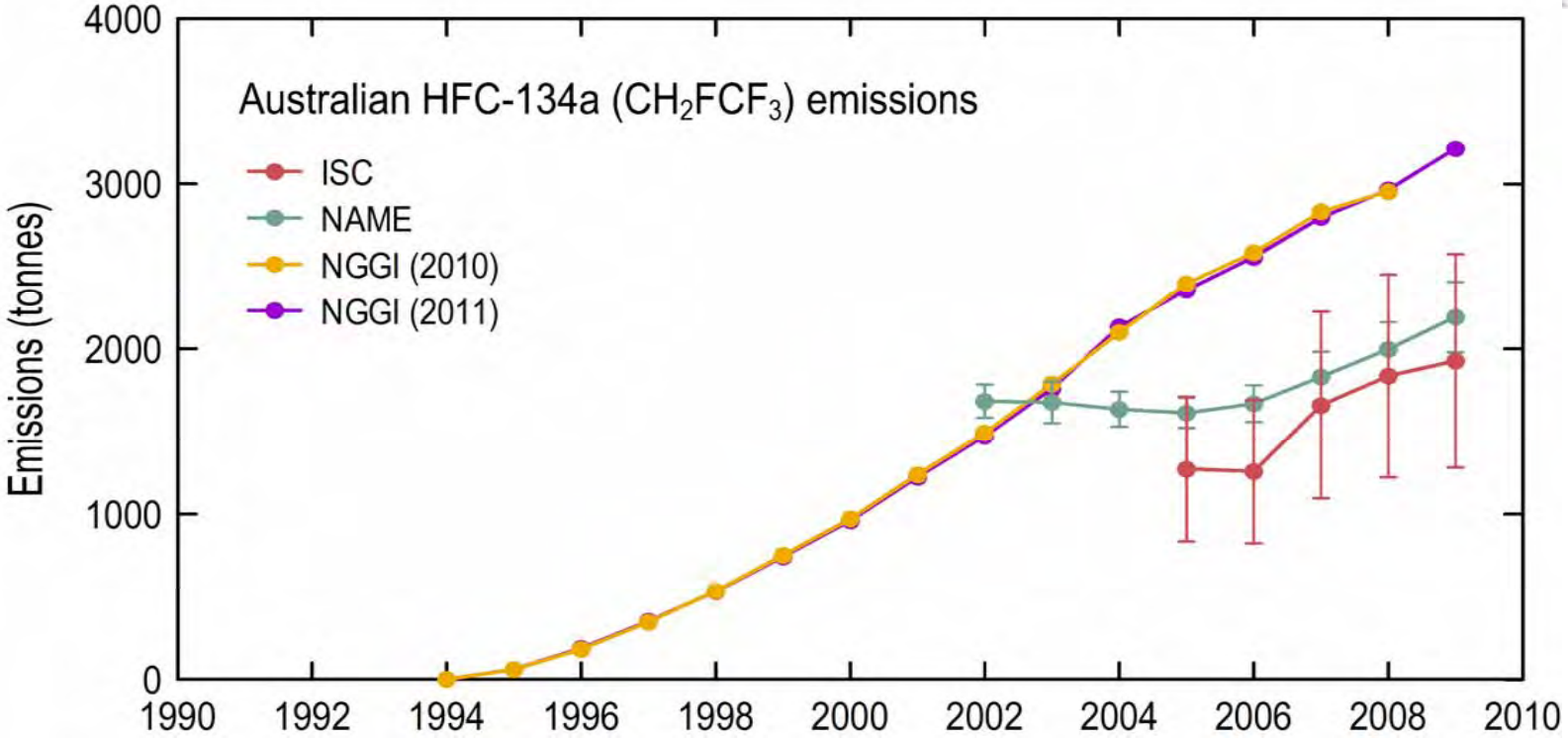
- note seasonality of pollution episodes at Cape Grim: most in winter/least in summer
- largely due to seasonality in air mass trajectories (not seasonality in emissions)

Cape Grim and local HFC, PFC, SF_6 sources



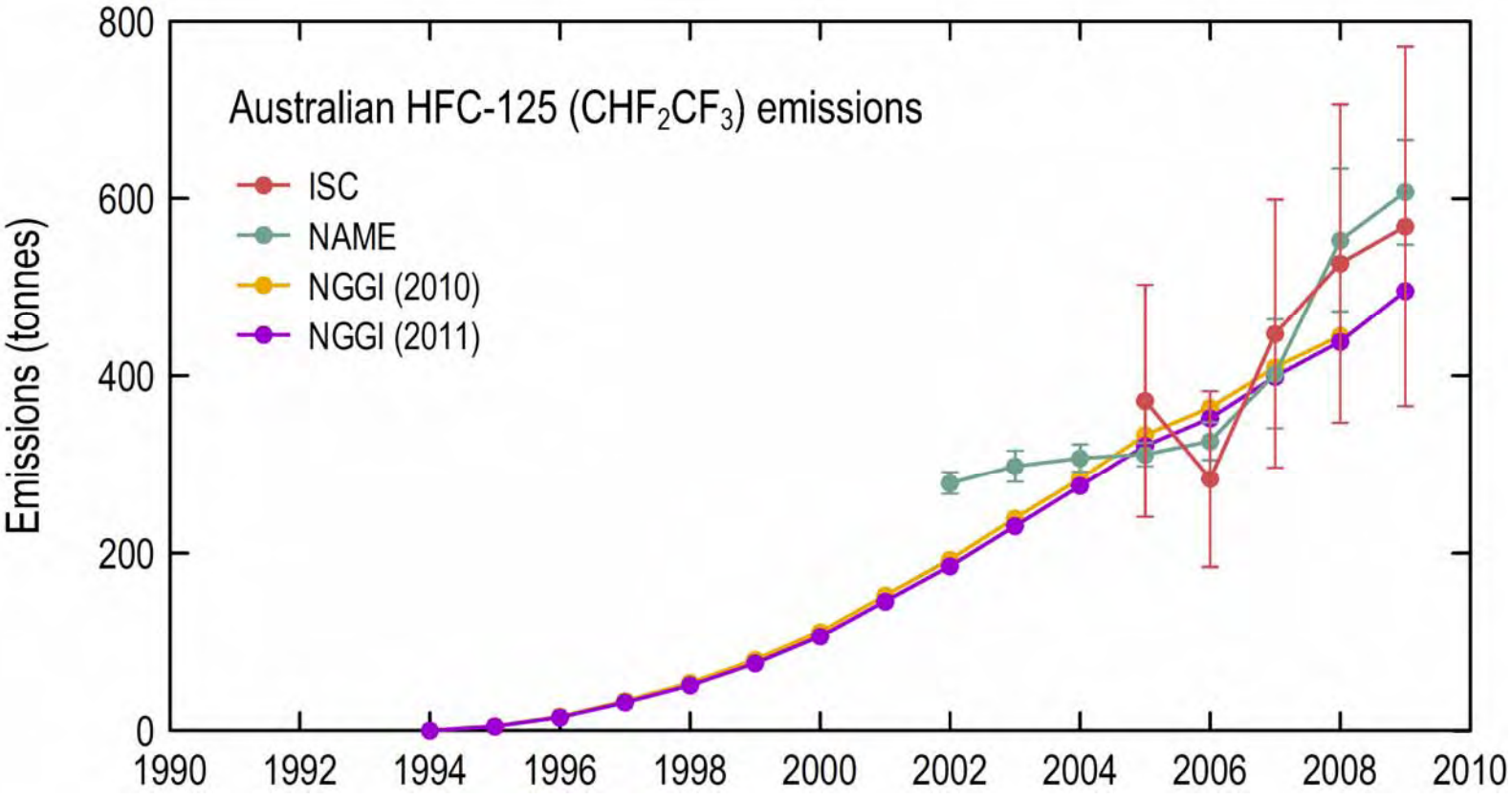
- HFC, SF_6 plumes from Melbourne/Port Phillip
- PFC plumes from aluminium smelters at Pt Henry. Portland, Bell Bay
- emissions estimated
  - by inter-species correlation (ISC) with known Port Phillip emissions of carbon monoxide
  - by inverse estimates using atmospheric transport models
    - NAME (UK Met. Office)
    - TAPM (CSIRO)

Australian HFC-134a emissions



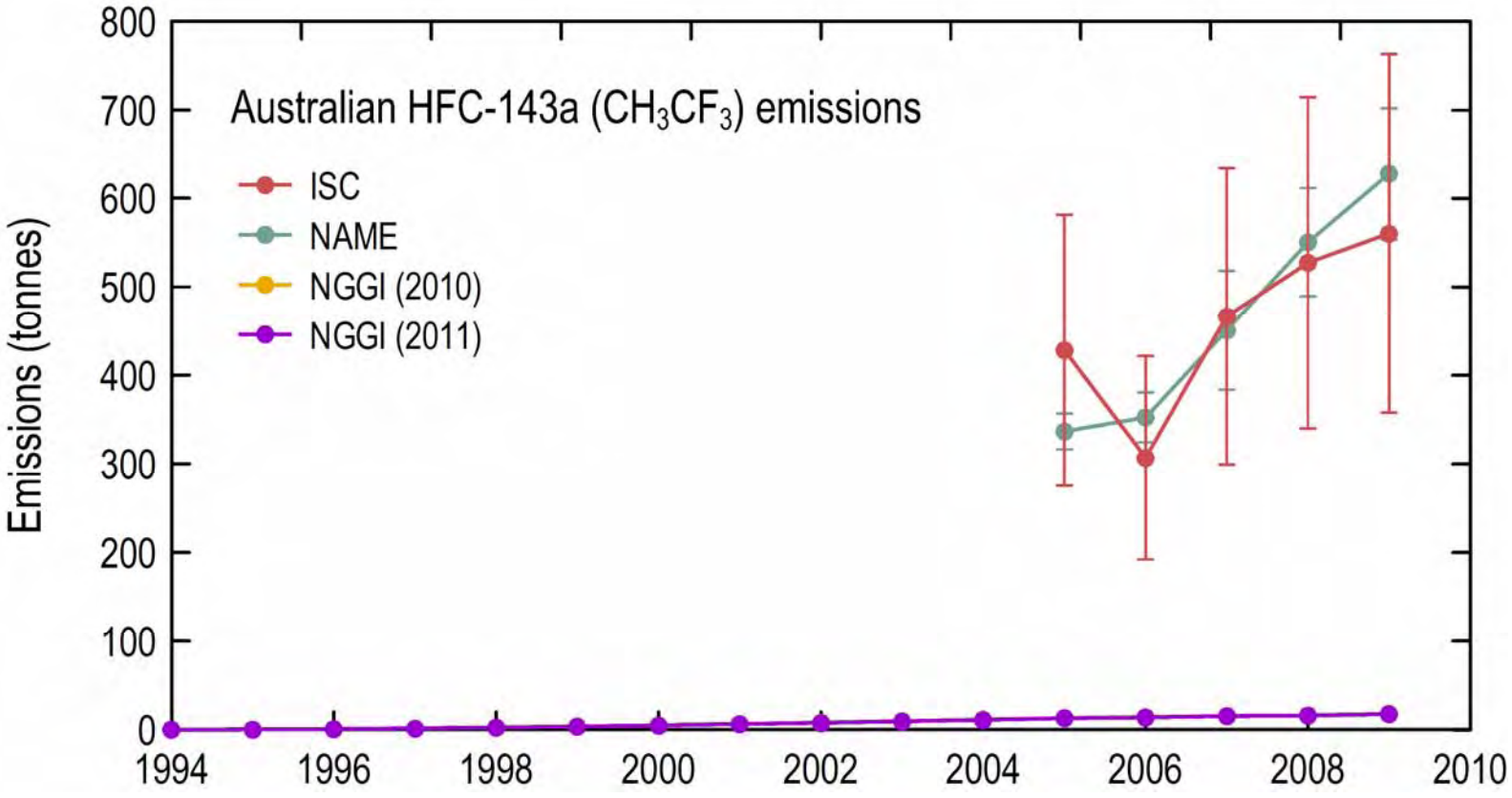
- emissions 2000-3000 tonnes/year, growing at ~10 %/year, 2-3 % of global emissions
- emissions from atmospheric observations ~70% of NGGI emissions
- HFC-134a largely from cars, trucks
  - winter bias?
  - per capita Melbourne emissions < per capita Sydney/Brisbane emissions?

Australian HFC-125 emissions



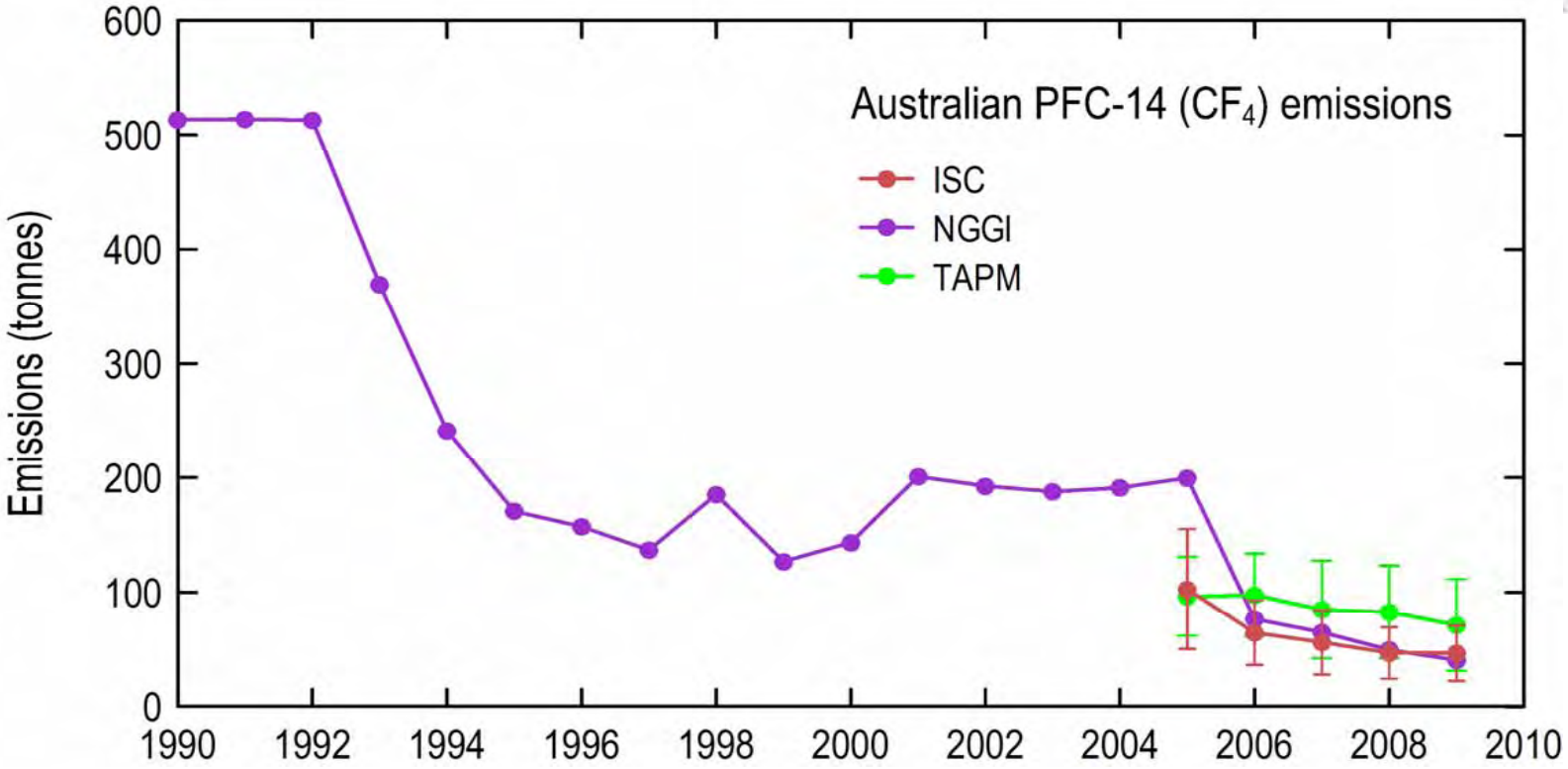
- emissions 500-600 tonnes/year, growing at ~15 %/year, 2-3% of global emissions
- excellent agreement between NGGI (what Australia reports to UNFCCC) and emissions based on atmospheric observations

Australian HFC-143a emissions



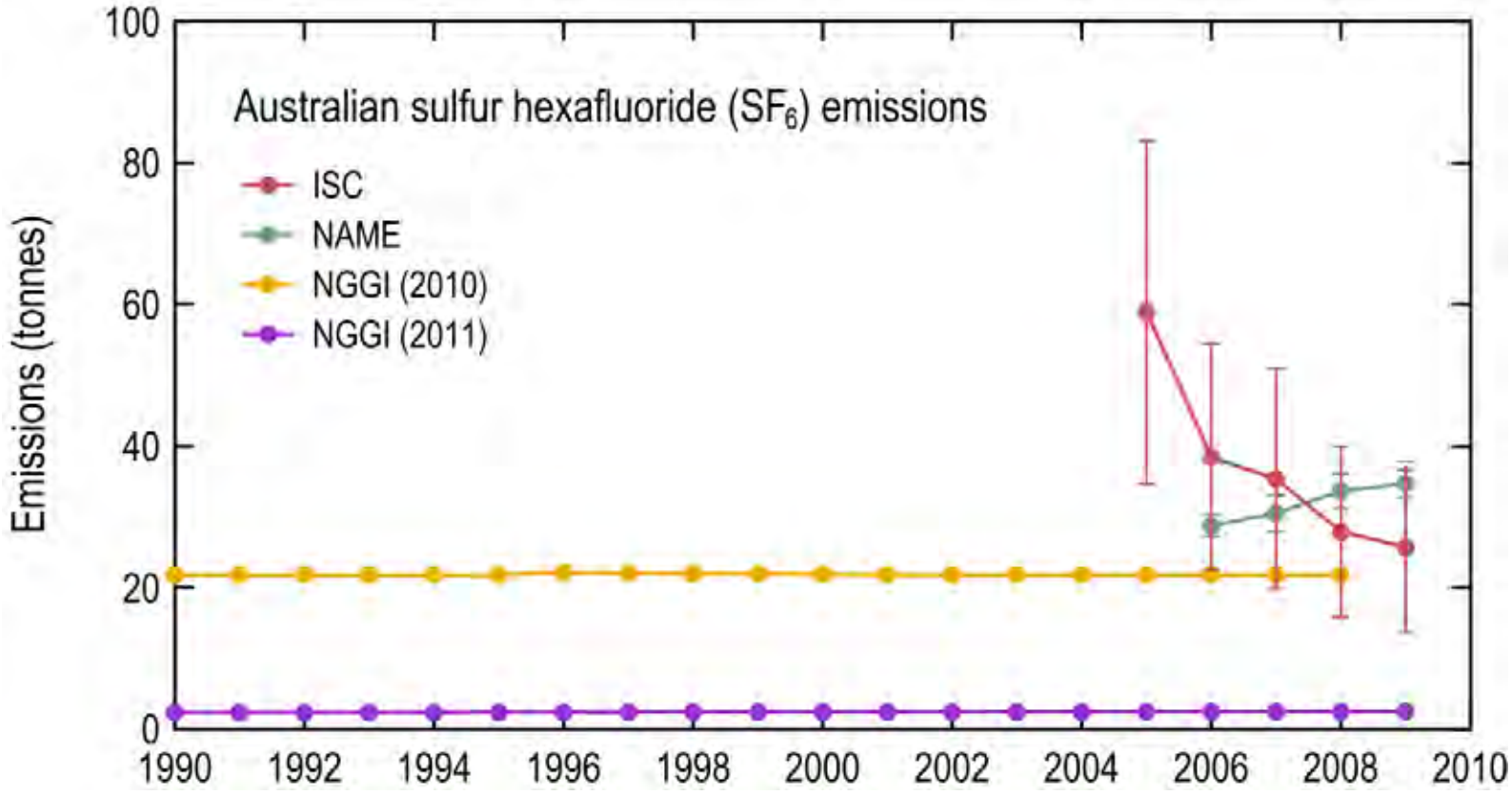
- emissions 600 tonnes/year, growing at ~10 %/year, 3 % of global emissions
- emissions not registering with NGGI (<20 tonnes per year, 0.1 % of global????)
  - could be part of the 'unspecified HFC mix'

Australian PFC-14 emissions



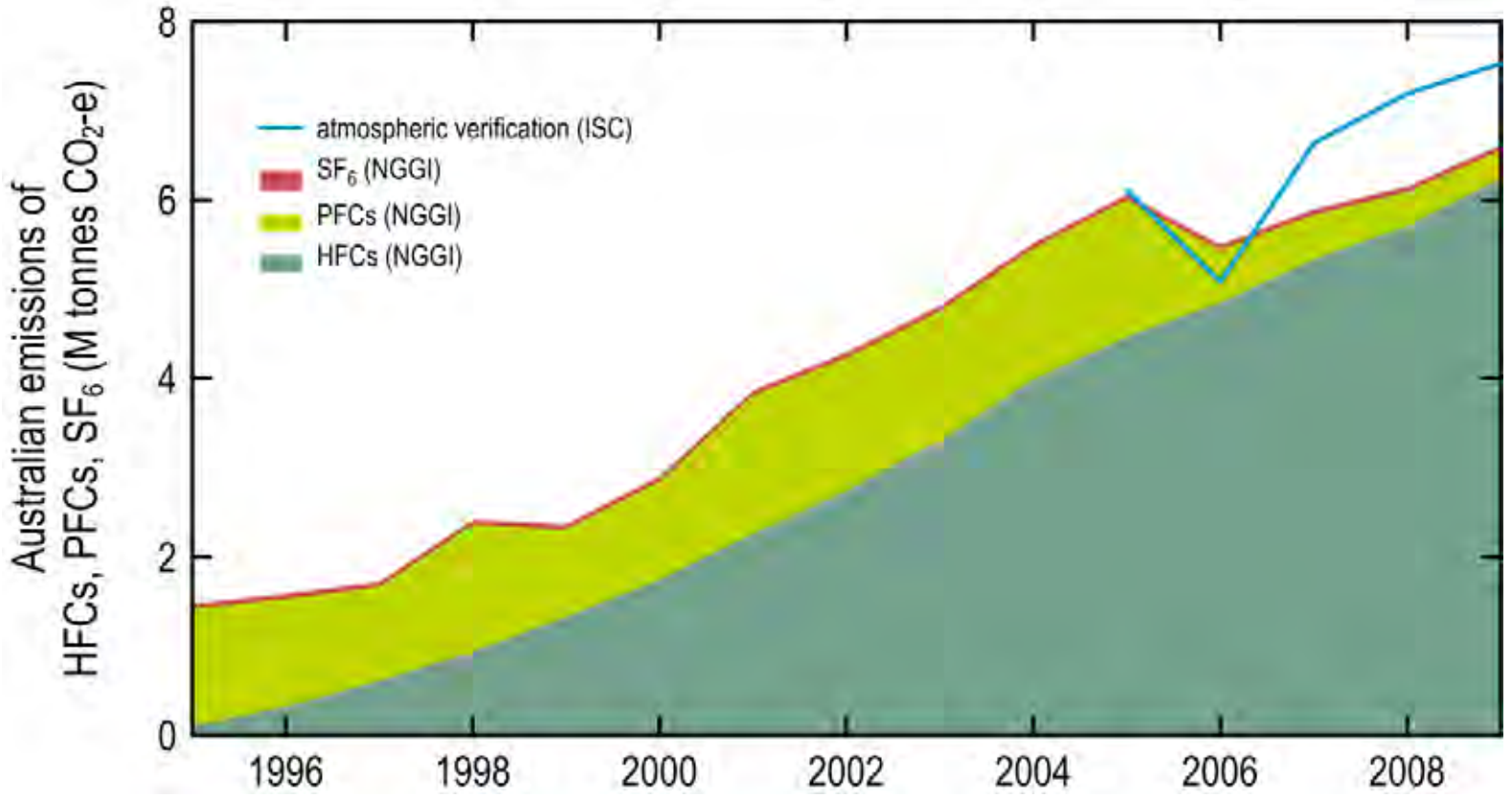
- emissions 50-70 tonnes per year, declining by 5-10% per year, 0.5 % of global
- Australian aluminium production: 5% of global
- excellent agreement between NGGI and atmospheric observations
- 2005-2006 decline in NGGI – not seen at Cape Grim – due to Hunter Valley smelter

Australian SF_6 emissions



- NGGI emissions steady at ~2 tonnes/year, <0.1% of global?????
- emissions from atmospheric observations at ~25 tonnes/year (declining), 0.5% of global

HFC, PFC, SF_6 emissions: NGGI vs atmospheric verification



- 2009 total emissions from atmospheric observations within 15% of emissions in NGGI
- 2005-2009 total emissions from atmospheric observations within 5% of NGGI

Conclusions…

- HFC emissions estimated from atmospheric data
  - ISC & NAME estimates for HFCs agree (2005-2009), to within 1% for HFC-125 & HFC-143a, within 10% for HFC-152a, within 15% for HFC-32 & HFC-134a
- excellent agreement (~97%) between total HFC emissions in 2009, expressed as CO_2-e, in the NGGI & as calculated from Cape Grim atmospheric data
- however unlikely that HFC-143 emissions are as low as ~15 tonnes/yr as reported in the NGGI; atmospheric data suggest that emissions ~500 tonnes/yr in recent years
- PFC-14 emissions 2005-2009 estimated from atmospheric data average 75±11 tonnes, in good agreement with the NGGI: 86±13 tonnes over the same period
- PFC-116 emissions 2005 – 2009 estimated from atmospheric data average 14±4 tonnes in good agreement with the NGGI data (11 tonnes) over the same period
- unlikely that SF_6 emissions are as low as 2-3 tonnes/yr as reported in the NGGI; atmospheric data indicate emissions of ~25 tonnes/yr in recent years

Conclusions…

- good agreement (better than 85%) between total HFC, SF_6 & PFC emissions in 2009 in NGGI (6.6 M tonne CO_2-e) & from atmospheric data (7.5 M tonne CO_2-e); 2005–2009: the agreement is better than 95%
- 7.5 M tonne CO_2-e = A$190M @ $25/tonne CO_2-e; reducing HFC, SF_6 emissions is not technically difficult or very costly
- CSIRO has developed technologies to independently verify, by atmospheric measurements, Australian HFC, PFC and SF_6 emissions
  - current national GHG measurement network for synthetics has ‘Cape Grim’ bias
  - reduce uncertainties by direct measurements of Sydney/Brisbane plumes
- CSIRO has developed technologies to independently measure, for example by stack measurements, GHG emissions from individual facilities, such as aluminium smelters.

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'Quantifying greenhouse gas emissions from statistical data without testing against atmospheric data is like dieting without weighing oneself'
– Nisbet and Weiss (2010)

Thank you

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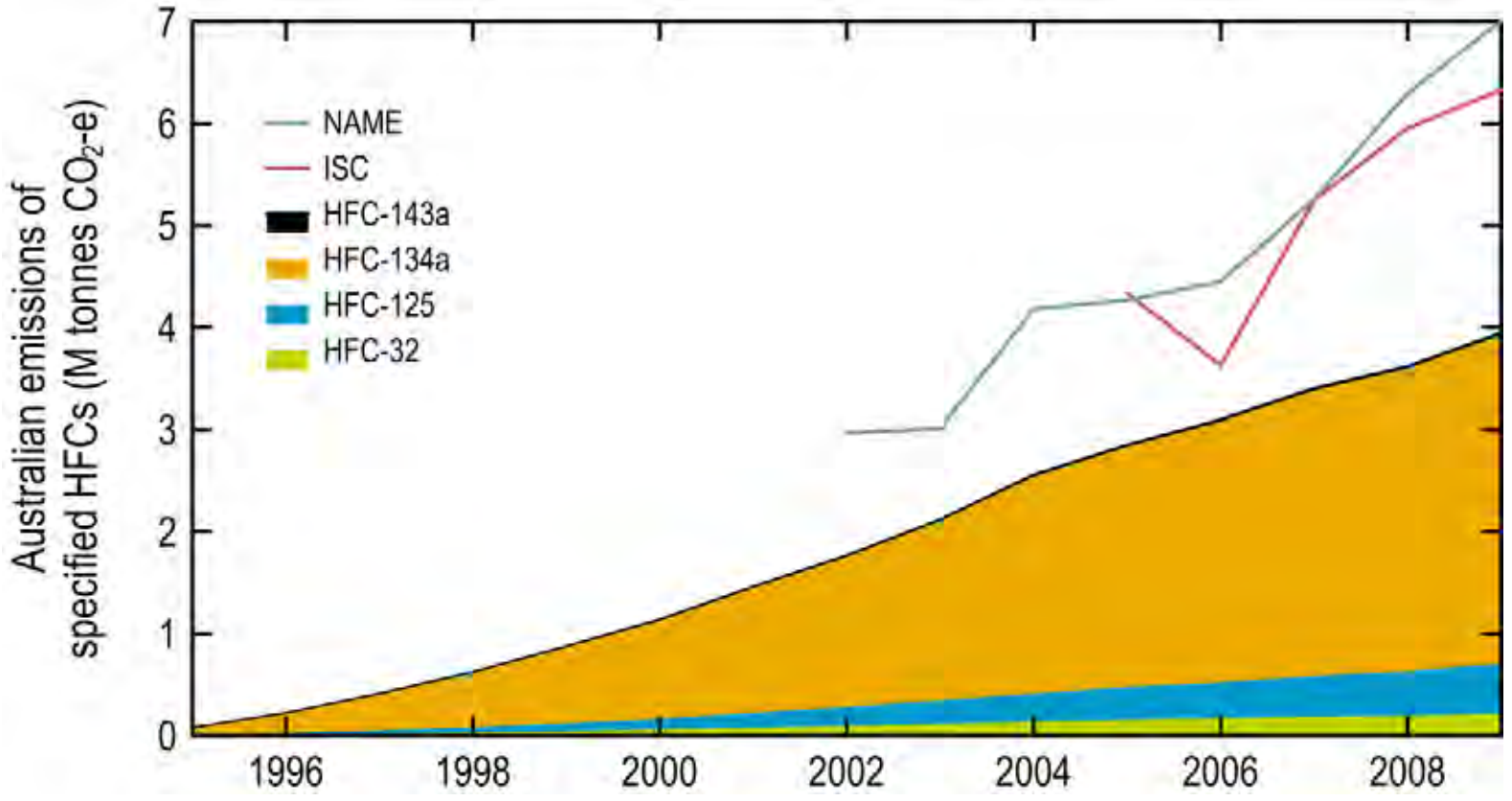
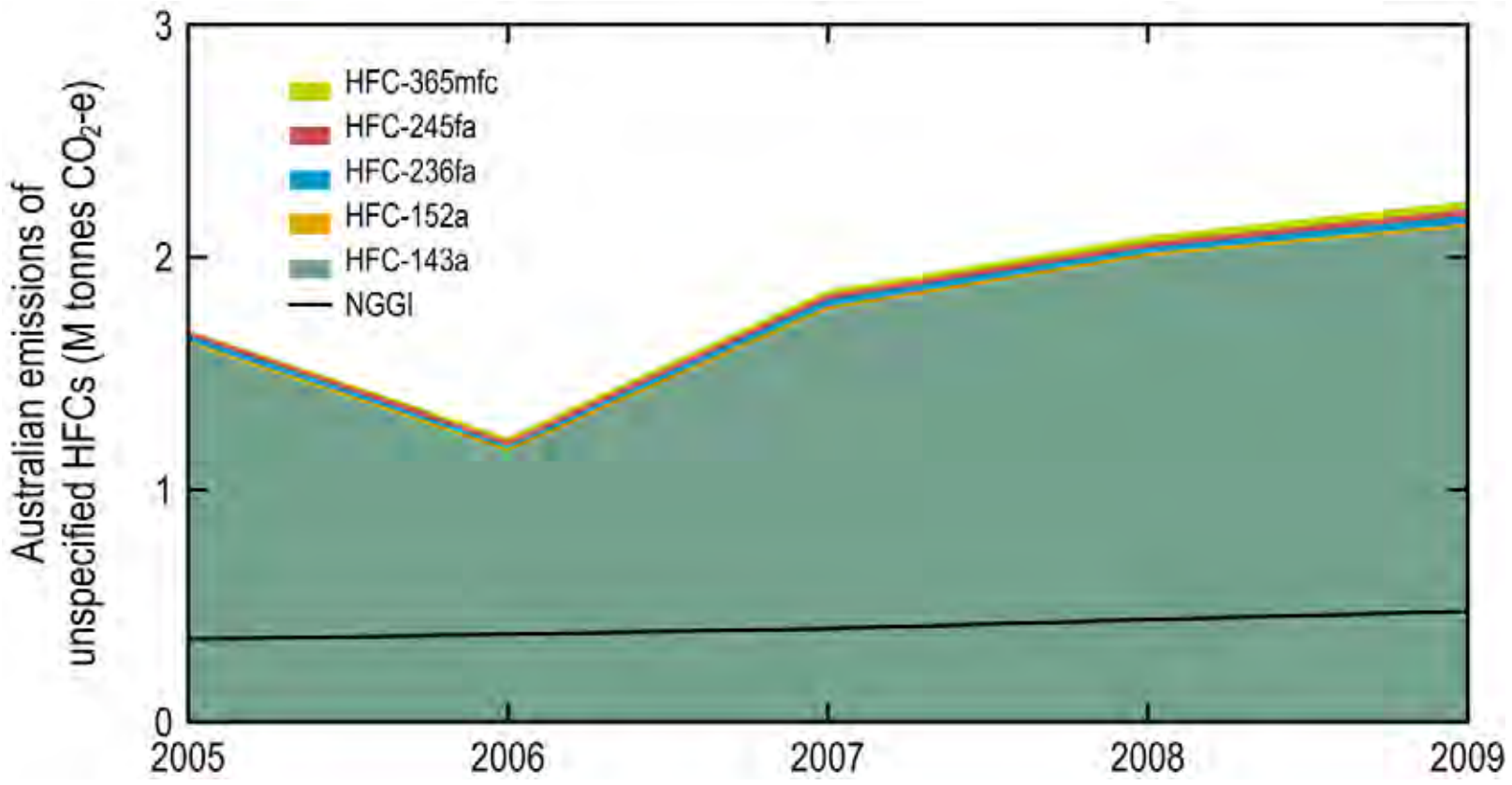
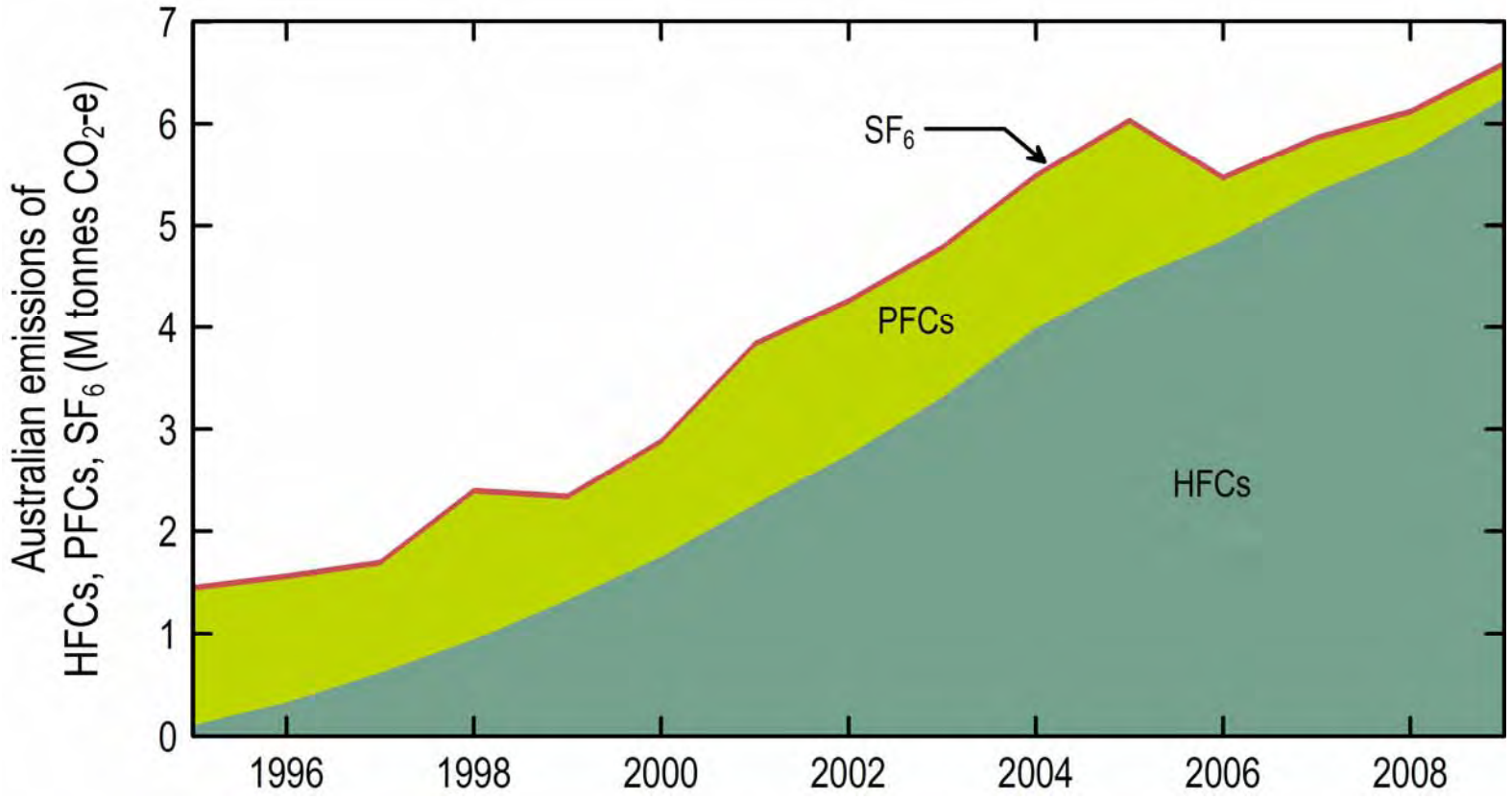
Specified HFCs: NGGI vs atmospheric verification

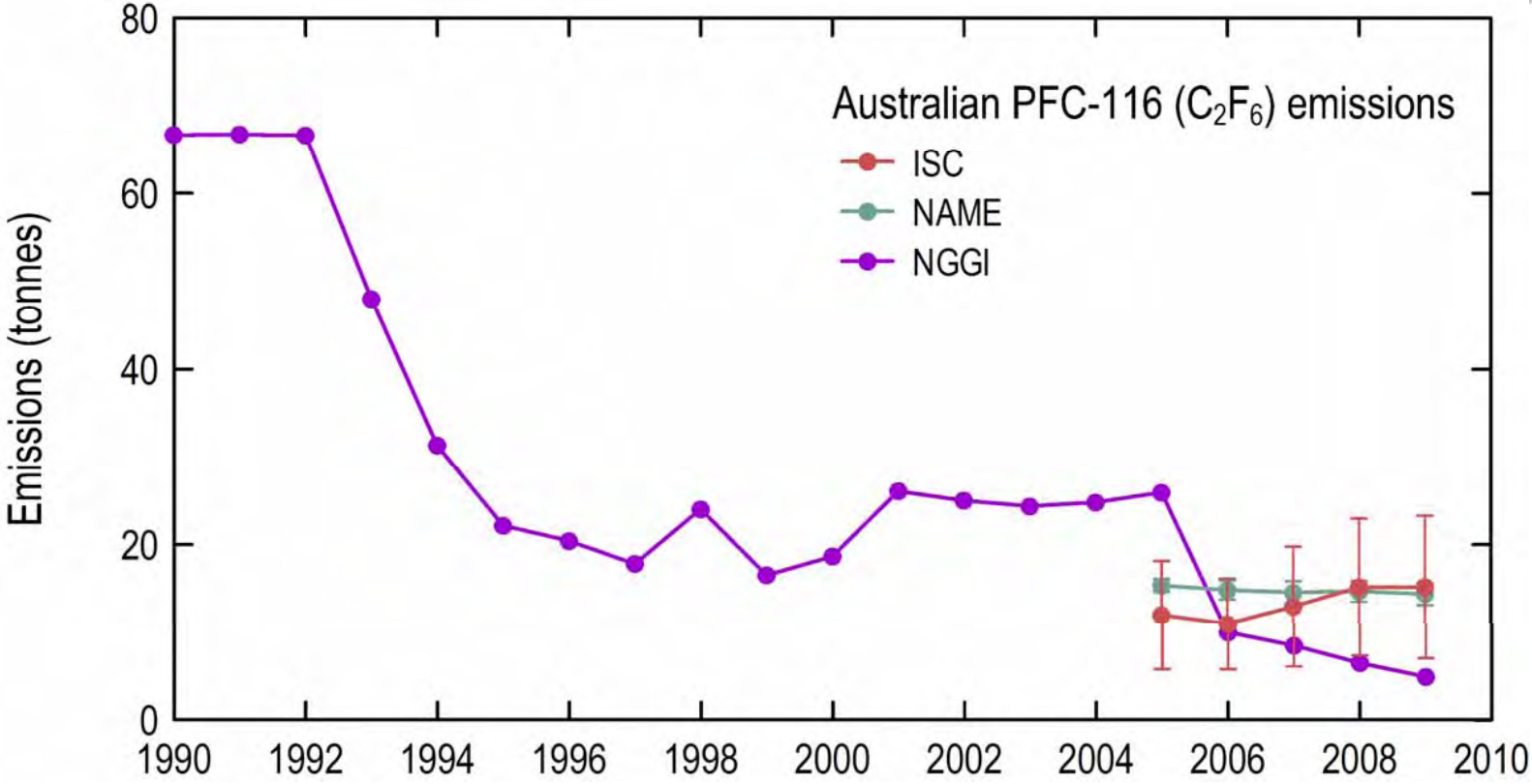



Australian emissions of unspecified HFCs (M tonnes CO_2-e)
3
2
1
0
2005
2006
2007
2008
2009
HFC-365mfc
HFC-245fa
HFC-236fa
HFC-152a
HFC-143a
NGGI

HFC, PFC, SF_6 emissions: NGGI v. atmospheric verification

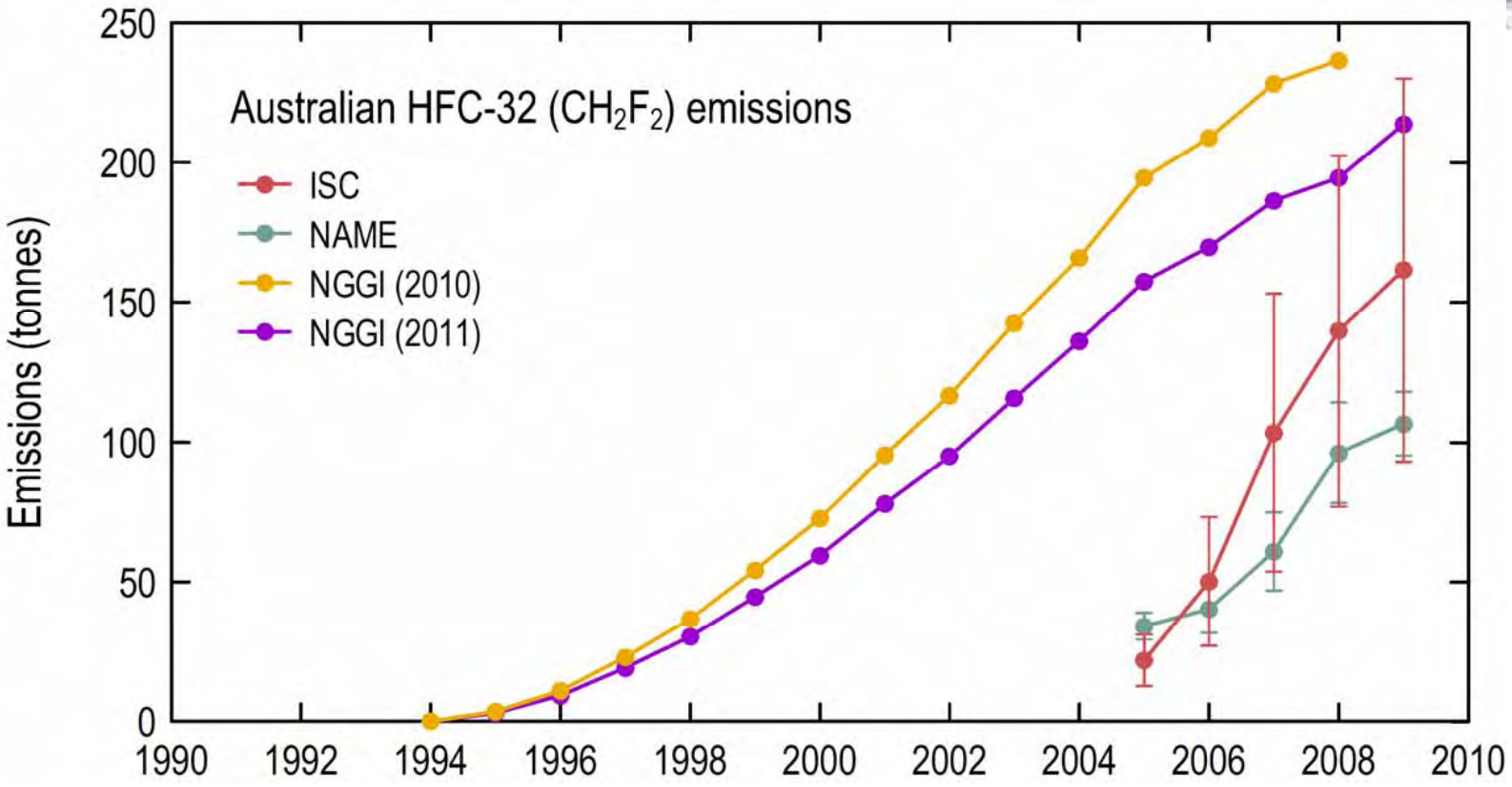


Australian PFC-116 emissions



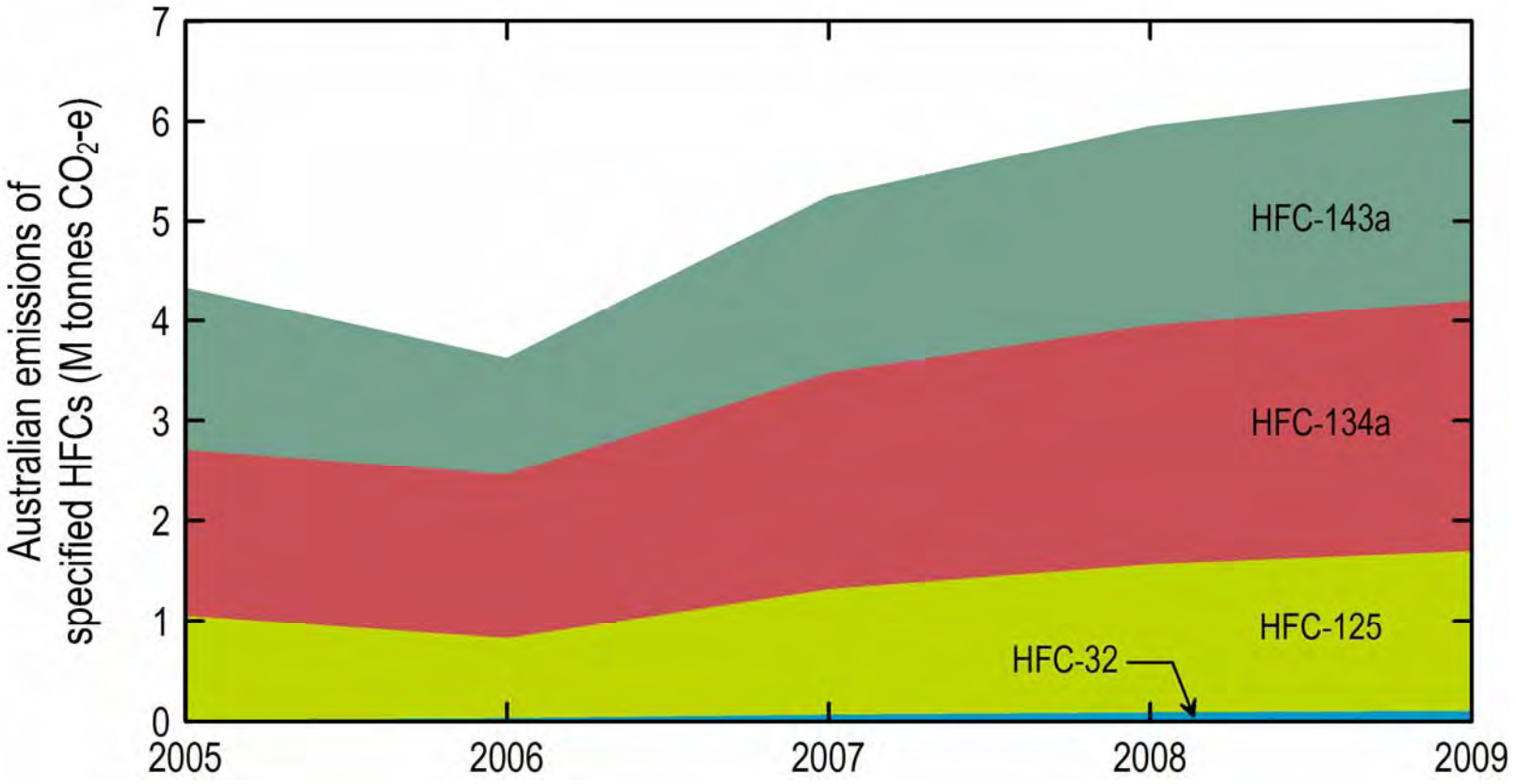
- NGGI emissions (5 tonnes/year, only Al) declining by ~20 %/year, 0.6 % of global
- emissions from atmospheric observation ~constant at 15 tonnes per year
- growing, significant refrigeration source not in NGGI?

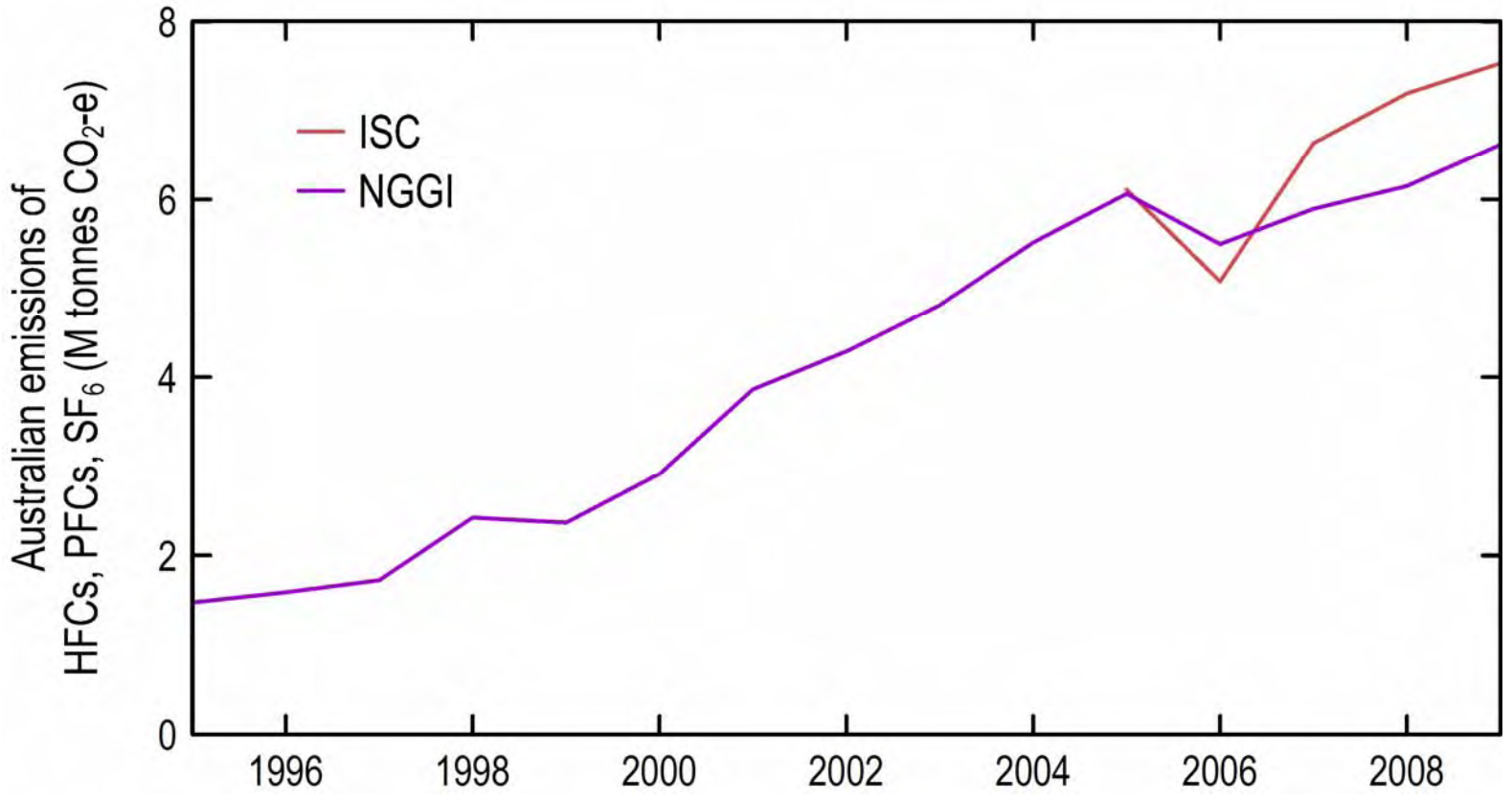
Australian HFC-32 emissions



- emissions 130-230 tonnes/year, growing at 10-15 %/year, 1-2 % of global emissions
- emissions from atmospheric observations ~60% of NGGI emissions

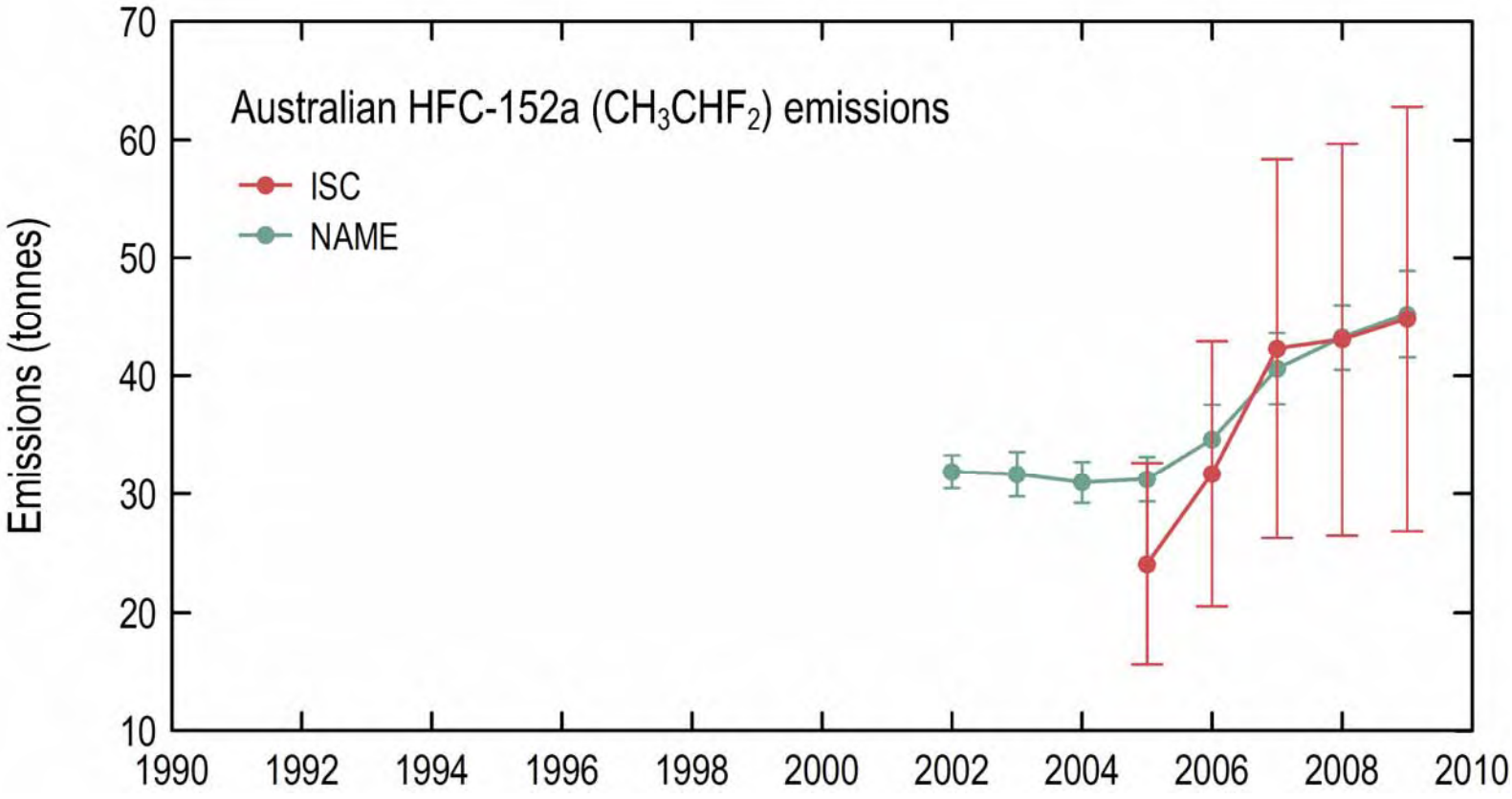
Specified HFCs: NGGI v. atmospheric verification



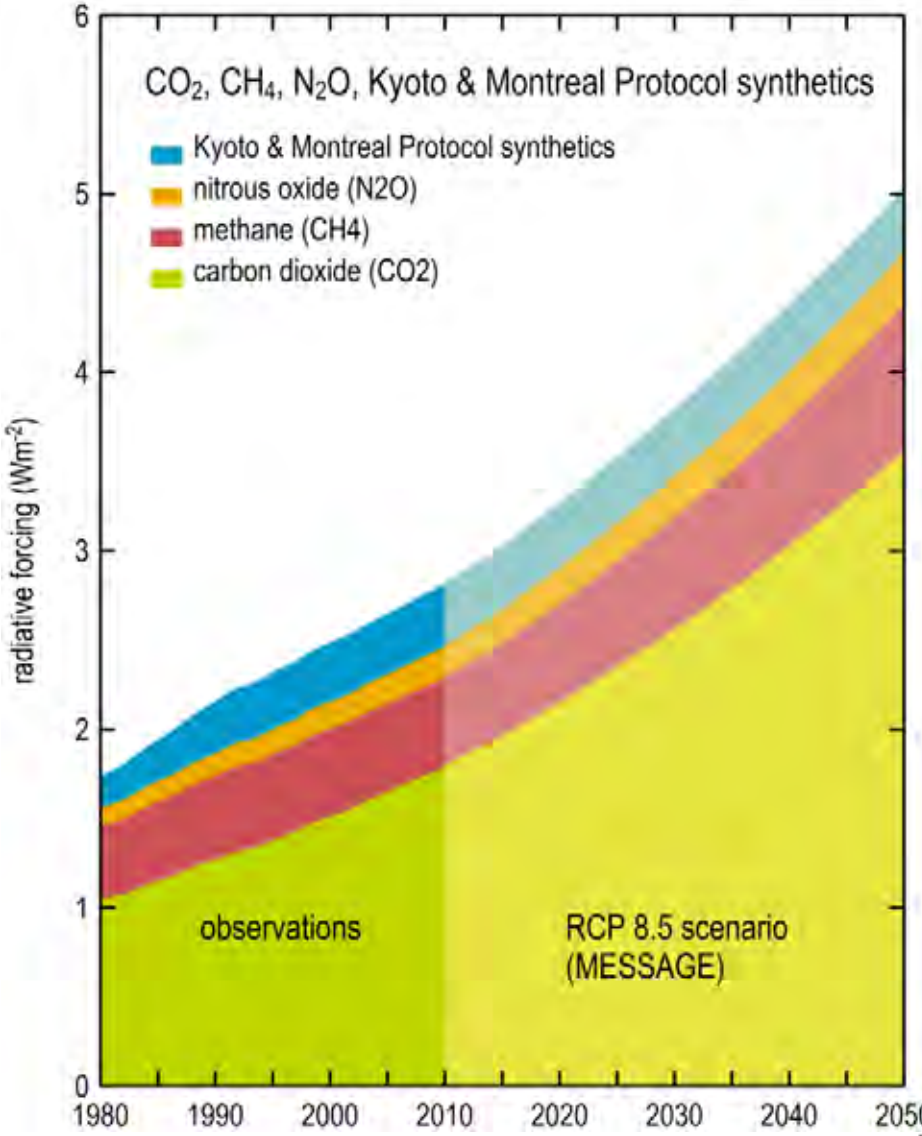

Australian emissions of
HFCs, PFCs, SF_6 (M tonnes CO_2-e)
ISC
NGGI
0
2
4
6
8
1996
1998
2000
2002
2004
2006
2008

Australian HFC, PFC, SF6 emissions from atmospheric observations

- Emissions estimated
  - by inter-species correlation (ISC) with know emissions of carbon monoxide
  - by inverse estimates from atmospheric transport models
    - NAME (UK Met. Office)
    - TAPM (CSIRO)
  - for HFCs, SF_6: Cape Grim 'sees' emissions from Melbourne/Port Phillip region
    - Australian emissions estimated by scaling based on population
  - for PFCs: Cape Grim 'sees' Bell Bay, Portland and Pt Henry aluminium smelters,
    - Australian emissions estimated by scaling based on aluminium production


Australian HFC-152a (CH_3CHF_2) emissions
ISC
NAME
Emissions (tonnes)
70
60
50
40
30
20
10
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

Global radiative forcing LLGHGs : CSIRO/AGAGE



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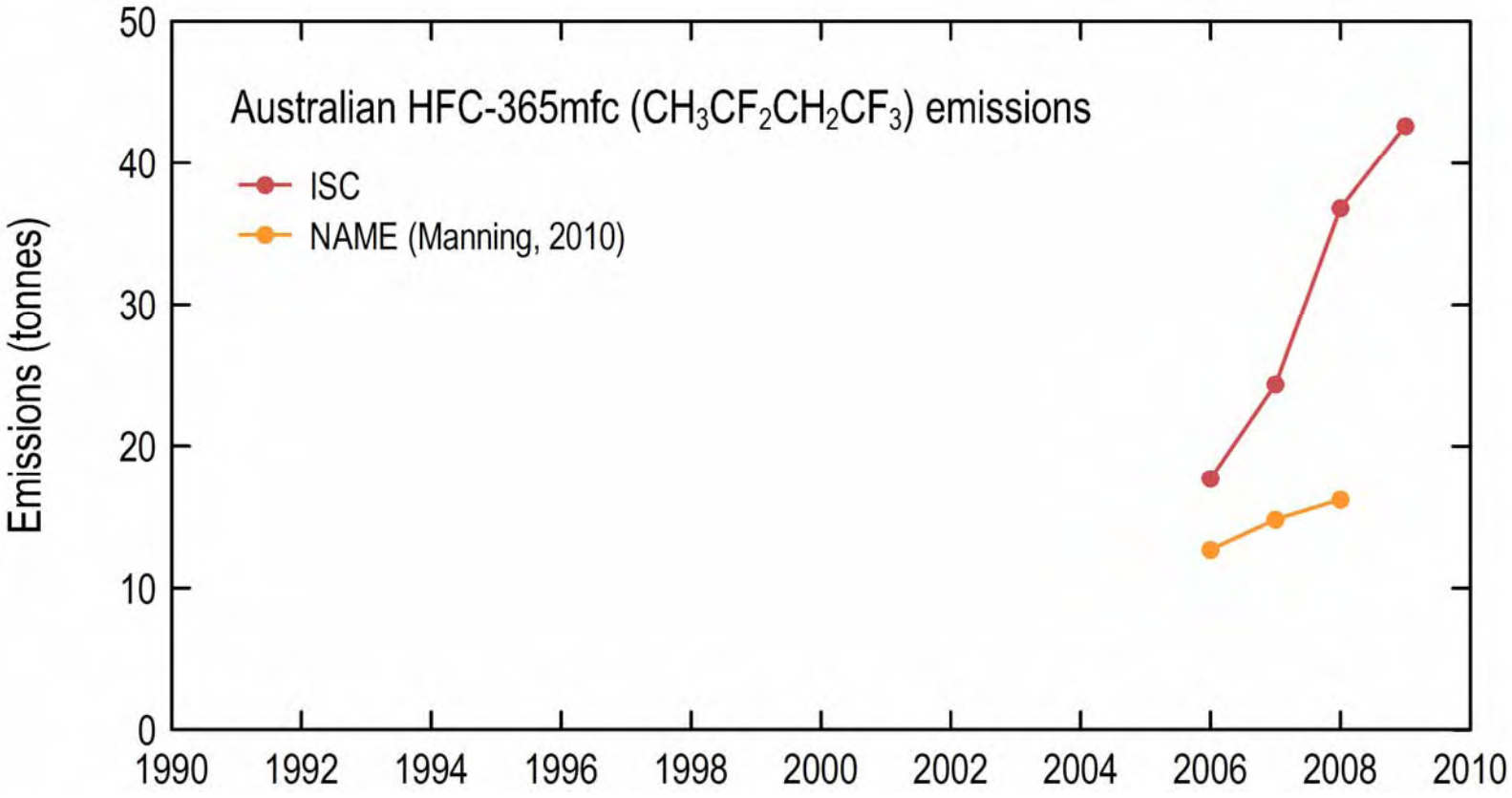
  - CSIRO: *Climate Change: science and solutions for Australia (2011)*
- KP/MP synthetics
  - up to 2010: largely CFC emissions
  - by 2050: largely HFC emissions
  - cost-effective emissions mitigation
- RCP 8.5 IPCC 5th Assessment (8.5 Wm^{-2} by beyond 2100)


Australian HFC-365mfc ($CH_3CF_2CH_2CF_3$) emissions
ISC
NAME (Manning, 2010)
Emissions (tonnes)
0
10
20
30
40
50
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010