Global and regional emissions estimates for HCFC-22

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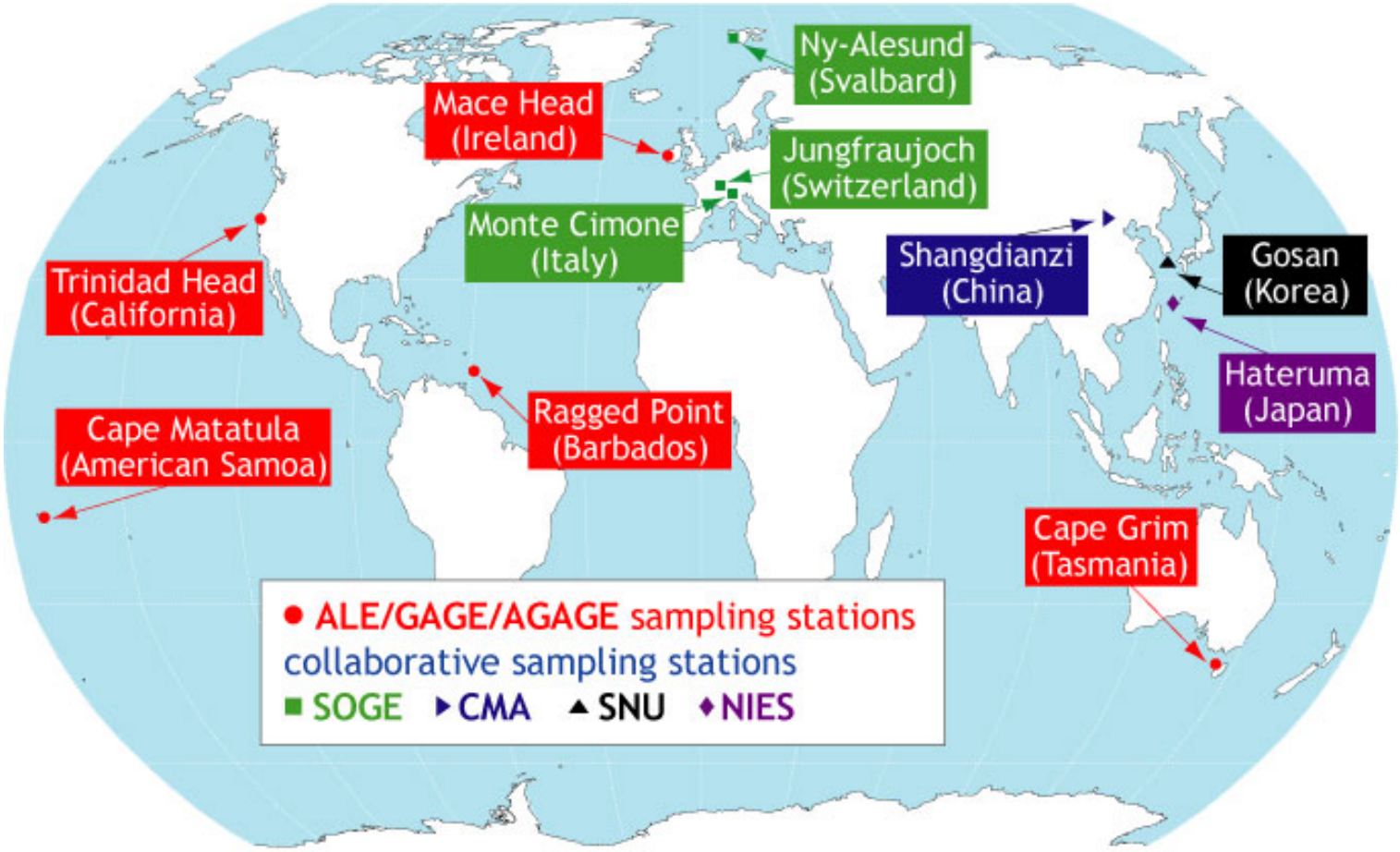
Importance of HCFC-22 ($CHClF_2$)

- Major Greenhouse Gas
  - Global Warming Potential: 1810
- Ozone-Depleting Substance: Regulated by the Montreal Protocol
  - Developed countries already started regulation (cease production by 2030, 99.5% by 2020)
  - Developing countries start in 2013
- Atmospheric lifetime: 11.9 years (primary sink - OH)
- Used for commercial refrigeration, air conditioning, and foam industries.

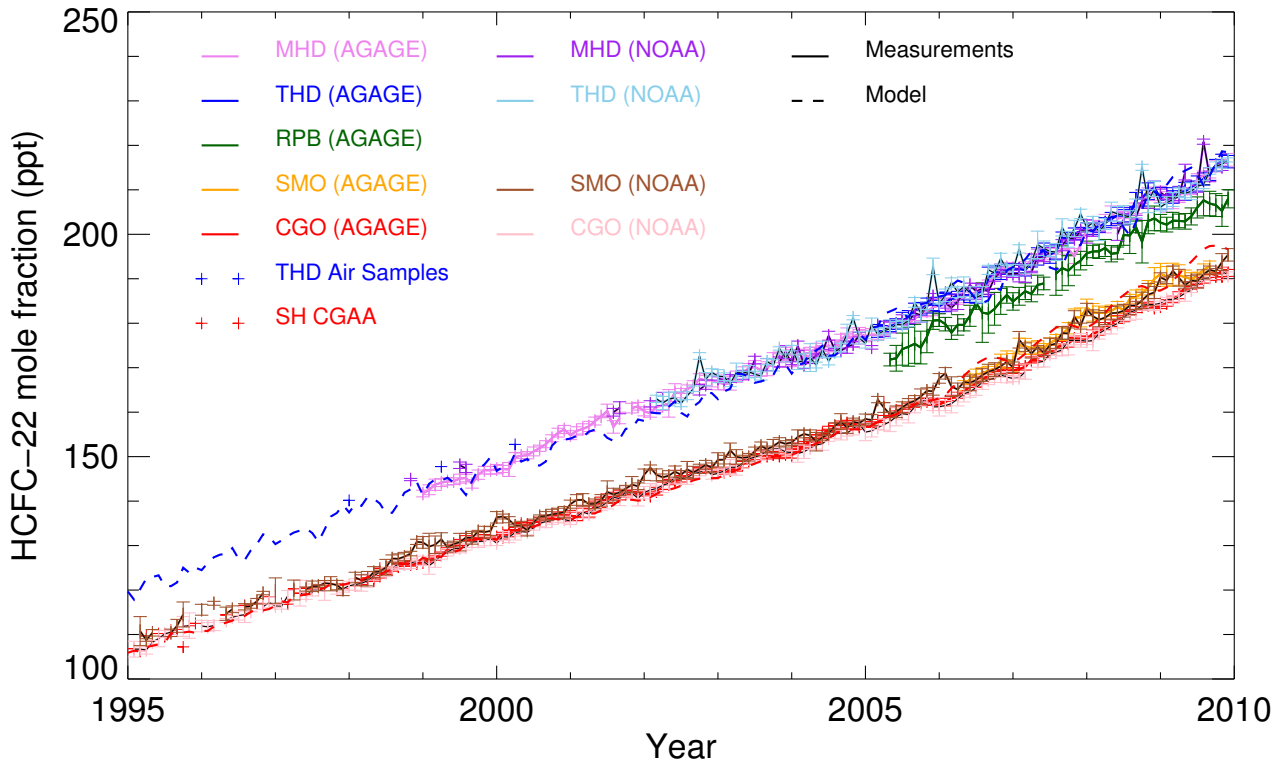
HCFC-22 Mixing Ratio Measurements

Advanced Global Atmospheric Gases Experiment Network



HCFC-22 Mixing Ratio Increasing

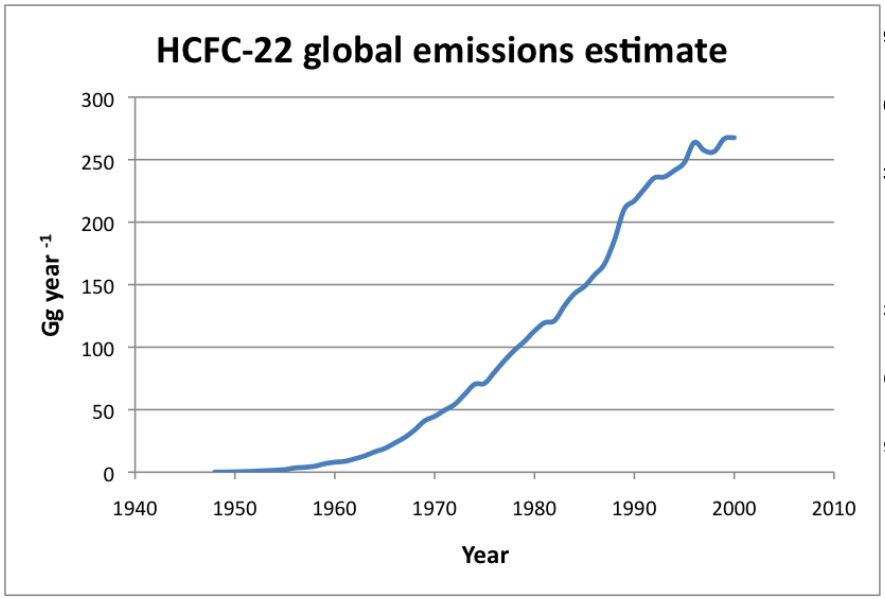
- No atmospheric mixing ratio in pre-industrial times

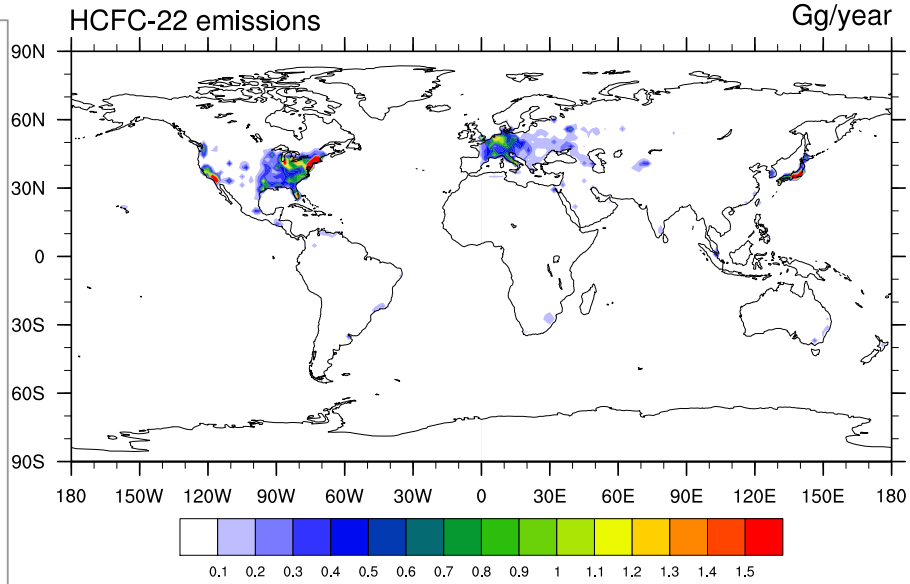


Source: AGAGE, NOAA, CGAA, and THD air samples

Source and Magnitude of HCFC-22 Emissions

- Source: Only anthropogenic





Source: McCulloch et al., 2003

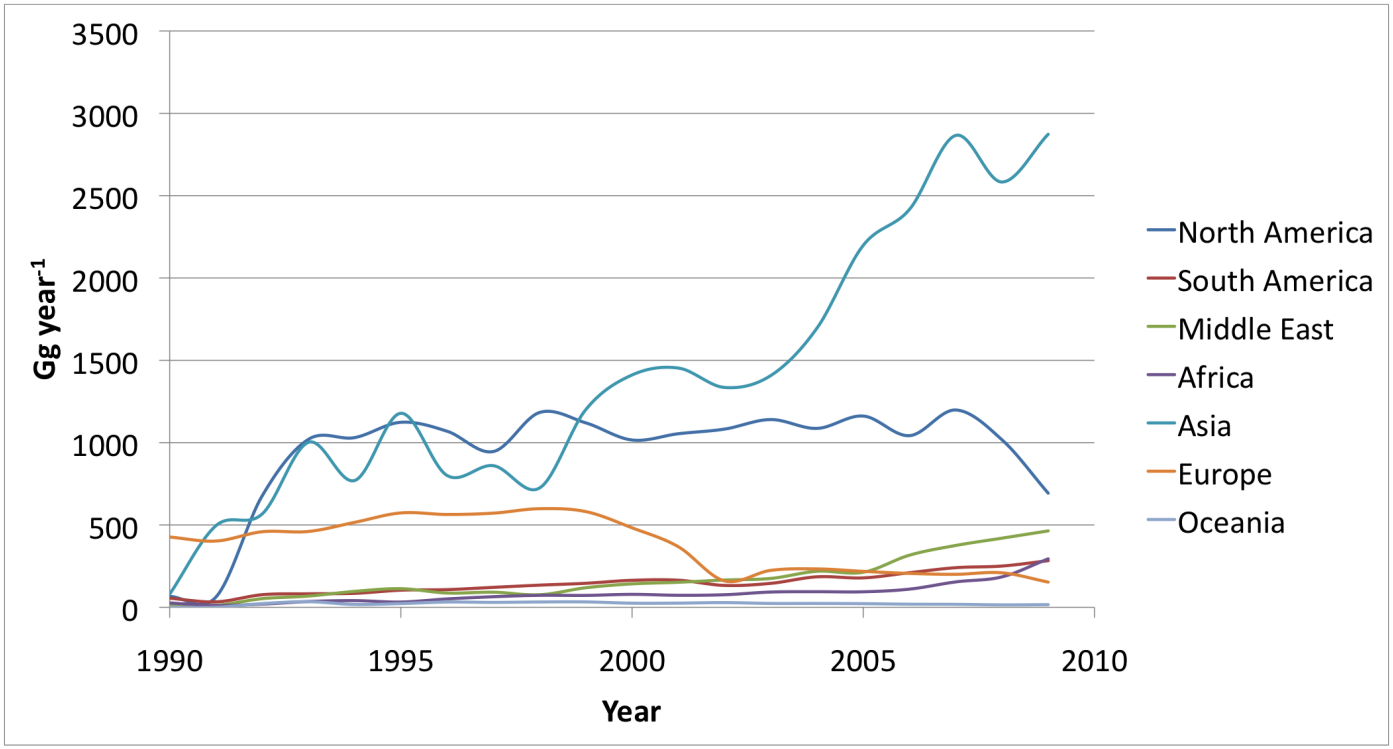
Methods

- Global 3-dimensional chemical transport model MOZART v4
- Conducted 2 simulations:
  - 1st simulation: Global, 1995-2009
  - Horizontal resolution: 5° latitude x 5° longitude
  - 2nd simulation: Regional, 2005-2009
  - Horizontal resolution: 1.9° latitude x 2.5° longitude
- 56 vertical levels from the surface to approximately 2mb
- meteorological field: MERRA
- Bayesian weighted least-squares:
  - Minimizing the following cost function with respect to x:

$$J = (y - Hx)^T W^{-1}(y - Hx) + x^T S^{-1} x \qquad (1)$$

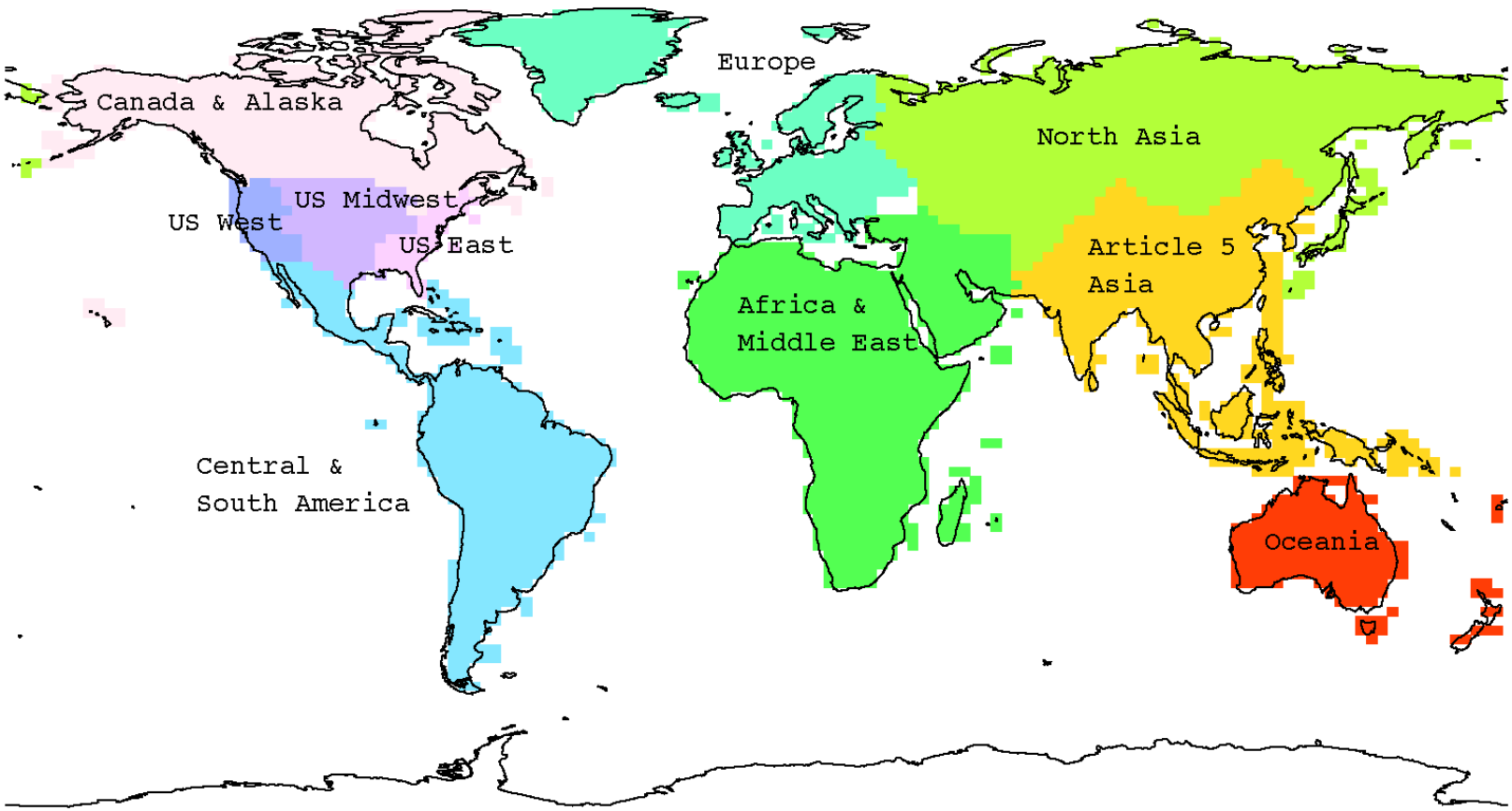
A priori emissions

- McCulloch et al. (2003): 1995-2000.
- Consumption data submitted to United Nations: 2001-2009.

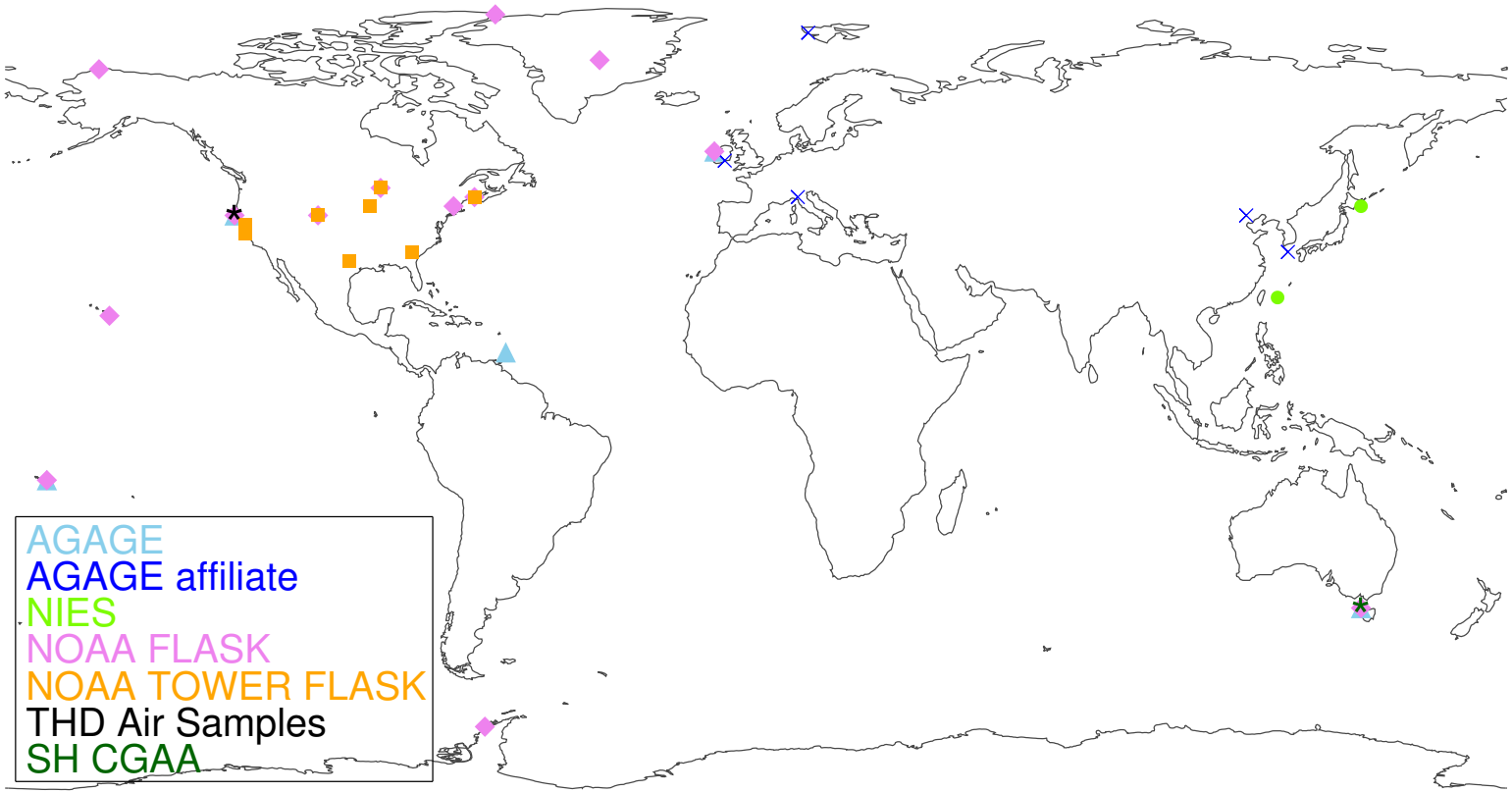


Source: UNEP

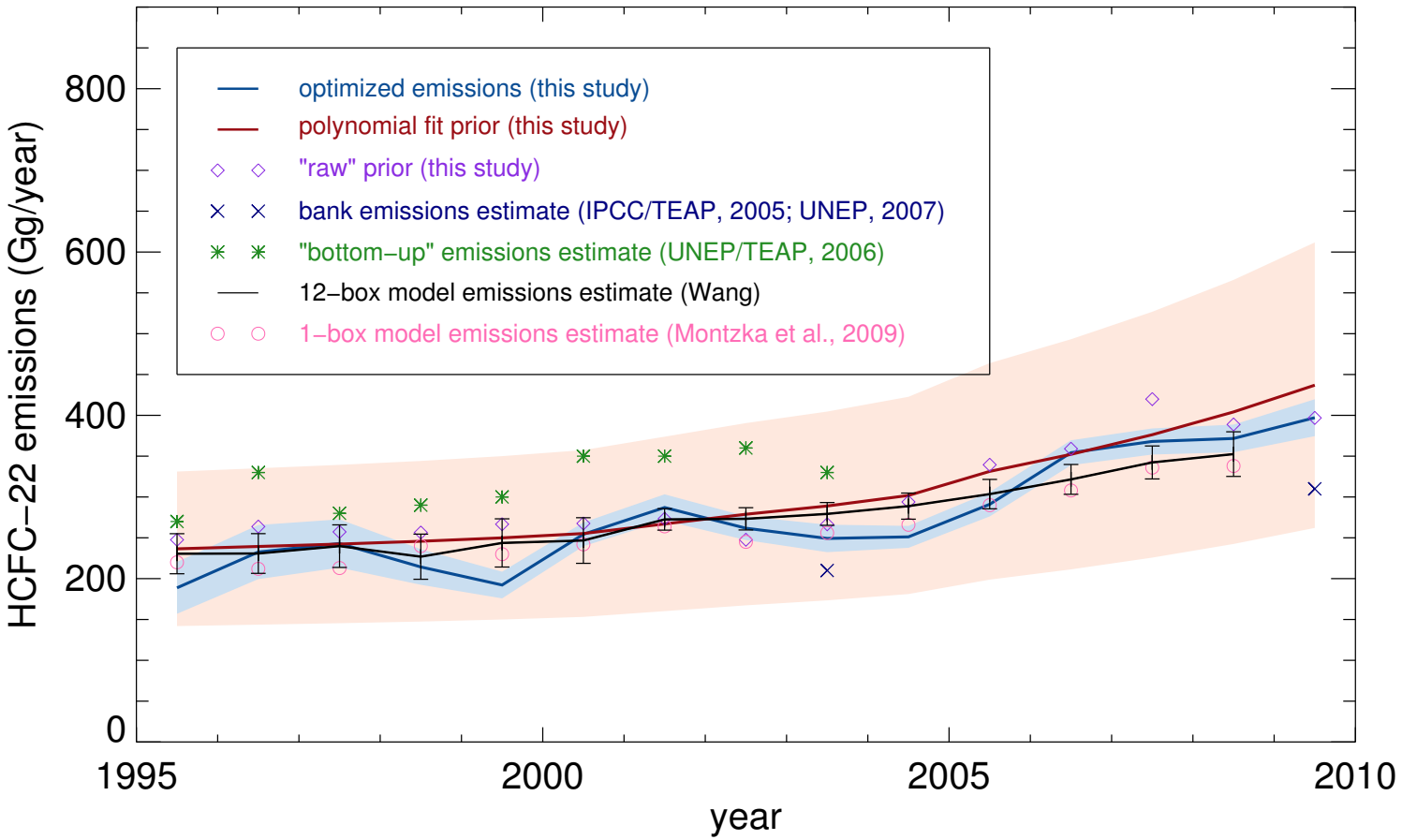
10 Regions used for the inversion



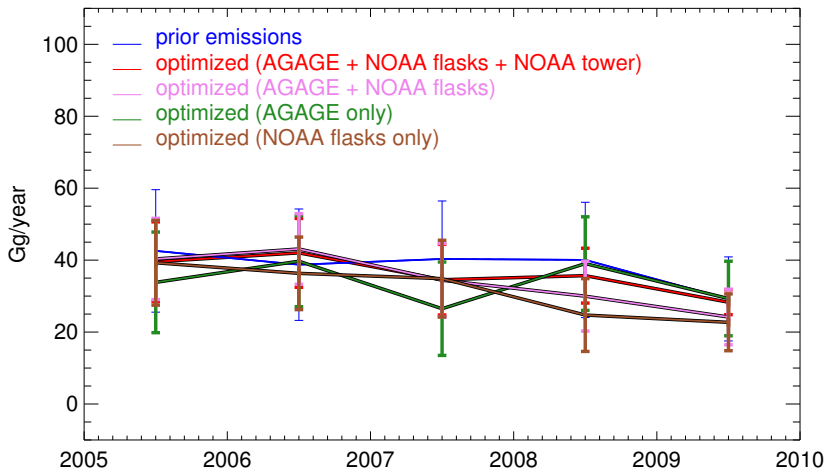
Observational Data

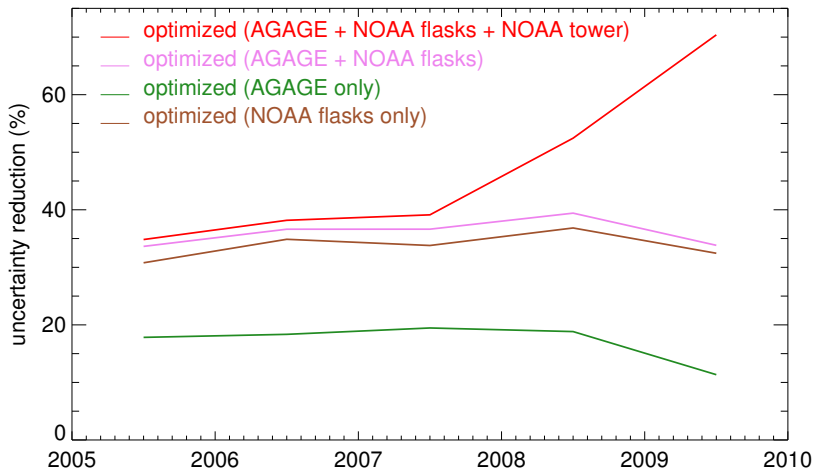


Global HCFC-22 emissions estimated from inversion



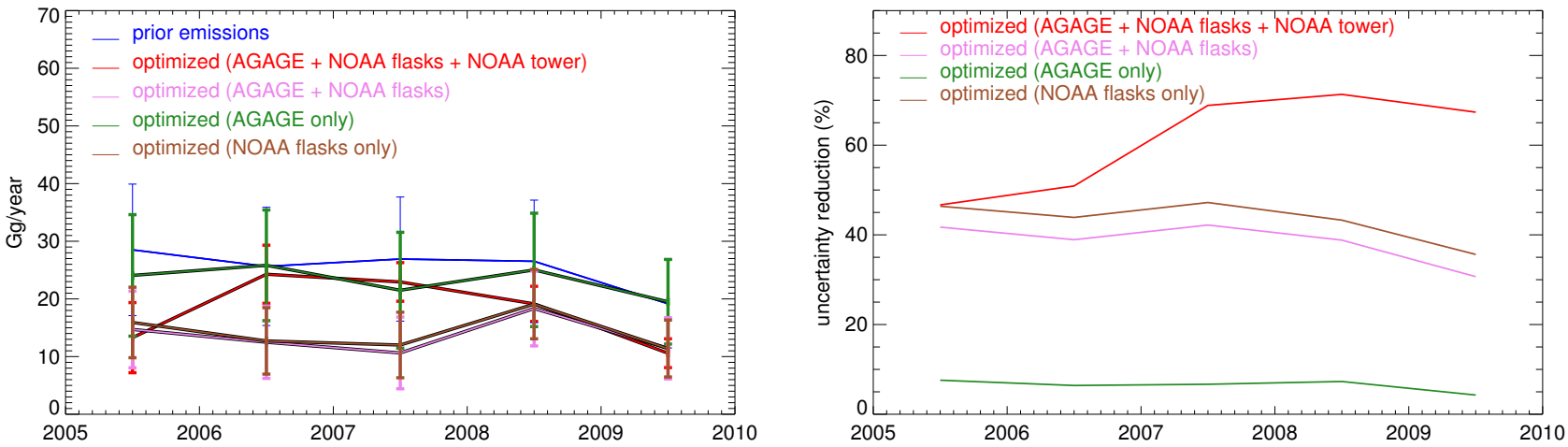
Results: Regional Emissions





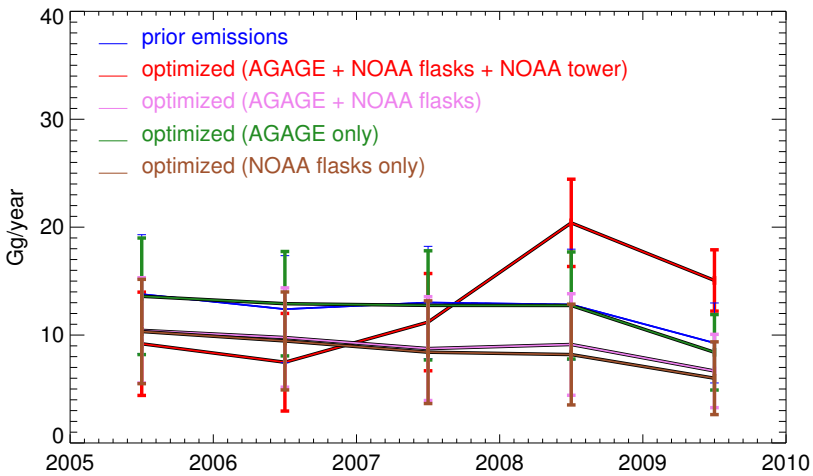
(a) US East

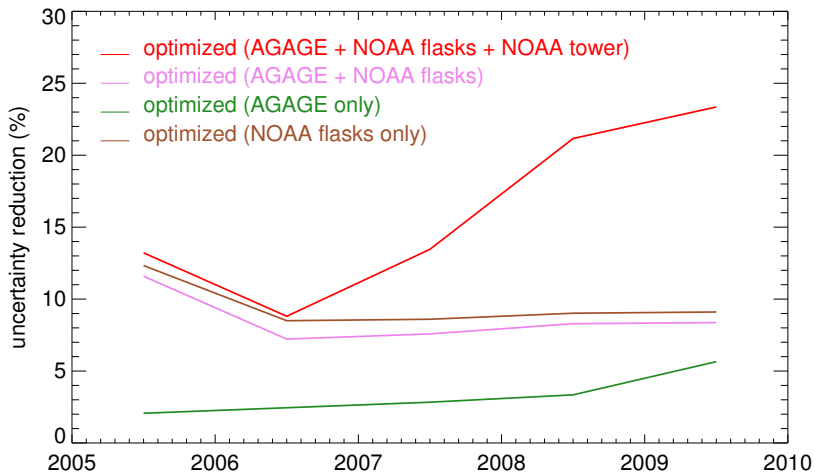
Results: Regional Emissions



(b) US Midwest

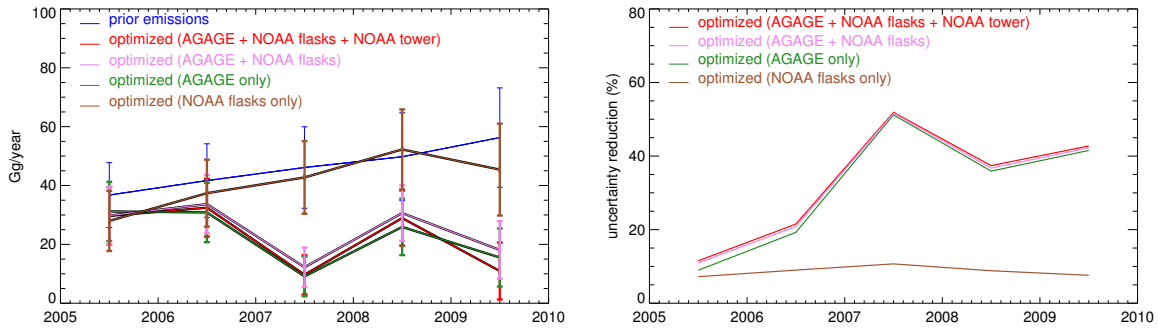
Results: Regional Emissions



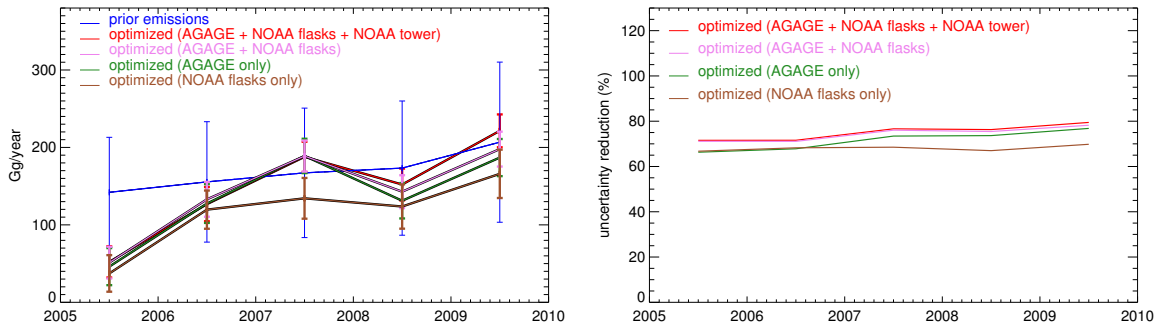


(c) US West

Results: Regional Emissions



(d) North Asia



(e) Article 5 Asia

Comparison with other models - Global

Global HCFC-22 emissions (Gg year^{-1})

- AFEAS (1997): 225 Gg year^{-1} in 1995
- This study: 169$\pm$45.69 Gg year^{-1} in 1995

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- This study: 272$\pm$78 Gg year^{-1} for 2005 and 2006
- Montzka et al. (2009) - global emissions increasing by 93 Gg from 2004-2007 & emissions shift towards low latitude in NH
- This study: 251$\pm$13.3 Gg year^{-1} in 2004 to 368$\pm$15.9 Gg year^{-1} in 2007.

Comparison with other models - Regional

- United States HCFC-22 emissions (Gg year^{-1})
  - Miller et al. (2009): 46 Gg year^{-1} for 2005 and 2006
  - EPA bottom-up estimates: 83Gg year^{-1} in 2004
  - This study: 67.9$\pm$20.6 Gg year^{-1} for 2005 and 2006

Comparison with other models - Regional

- Regional HCFC-22 emissions for 2005 and 2006 (Gg year^{-1})
  - This study:
    - North America: 75±35 Gg year^{-1}
    - Europe: 7.3±2.0 Gg year^{-1}
    - Asia: 121±31 Gg year^{-1}
    - Oceania: 1.5±0.4 Gg year^{-1}
  - Stohl et al., 2010:
    - North America: 80 Gg year^{-1}
    - Europe: 24 Gg year^{-1}
    - Asia: 149 Gg year^{-1}
    - Australia: 12 Gg year^{-1}

Conclusion

- We conducted a global and a regional inversion study for estimating HCFC-22 emissions.
- Our model results indicate an increase in global emissions from 1995 to 2009, with a large growth from 1999 to 2001 and from 2004 to 2006.
- In recent years, emissions are mostly flat in developed countries.
- We find a rapid emissions increase in Asia in the recent years.

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