Quantifying Greenhouse Gas Emissions from Atmospheric Measurements: A Critical Reality Check for Climate Legislation

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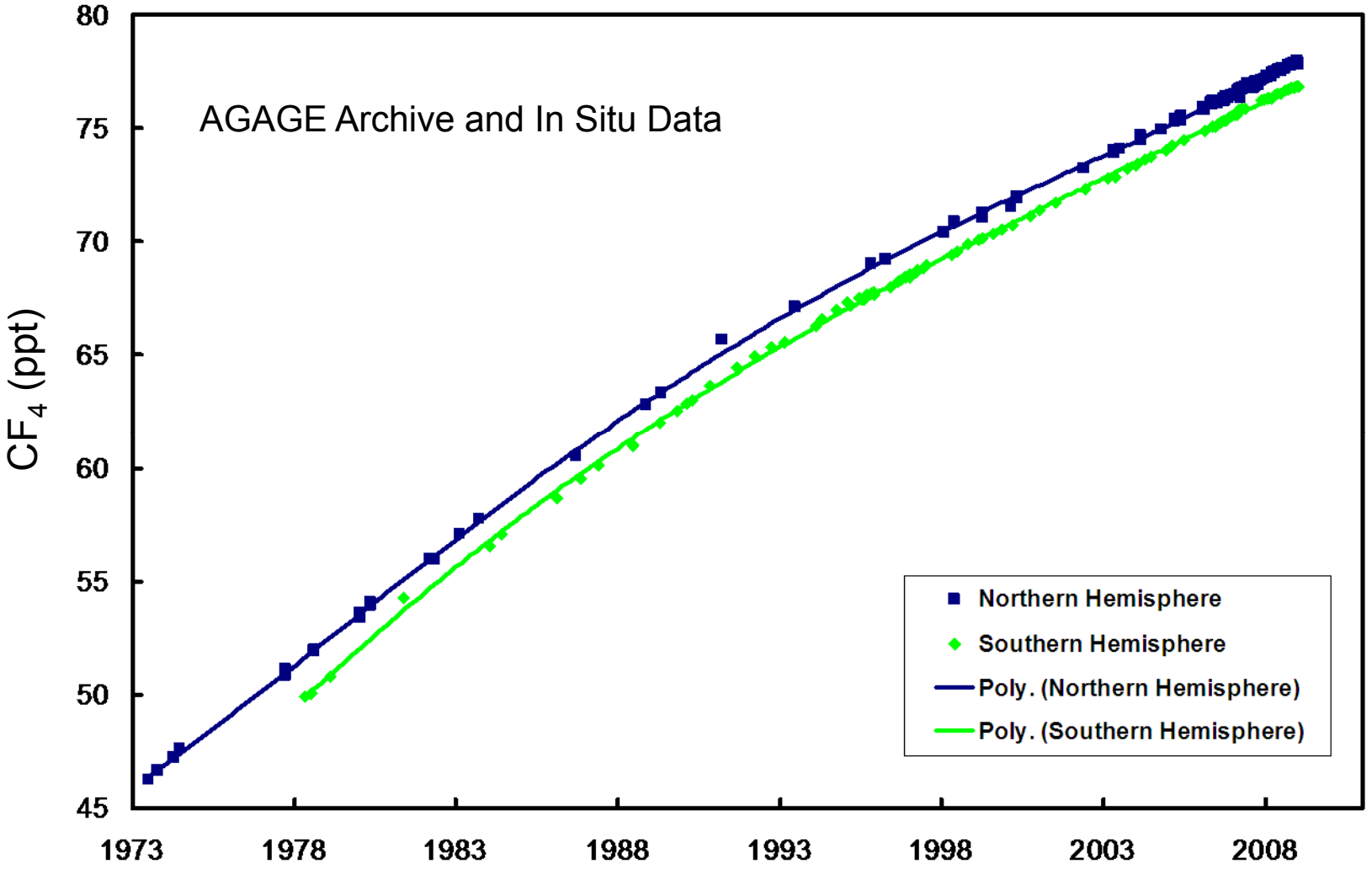
How well do "bottom-up" estimates of greenhouse gas emissions agree with "top-down" measurements of their accumulation in the global atmosphere ?

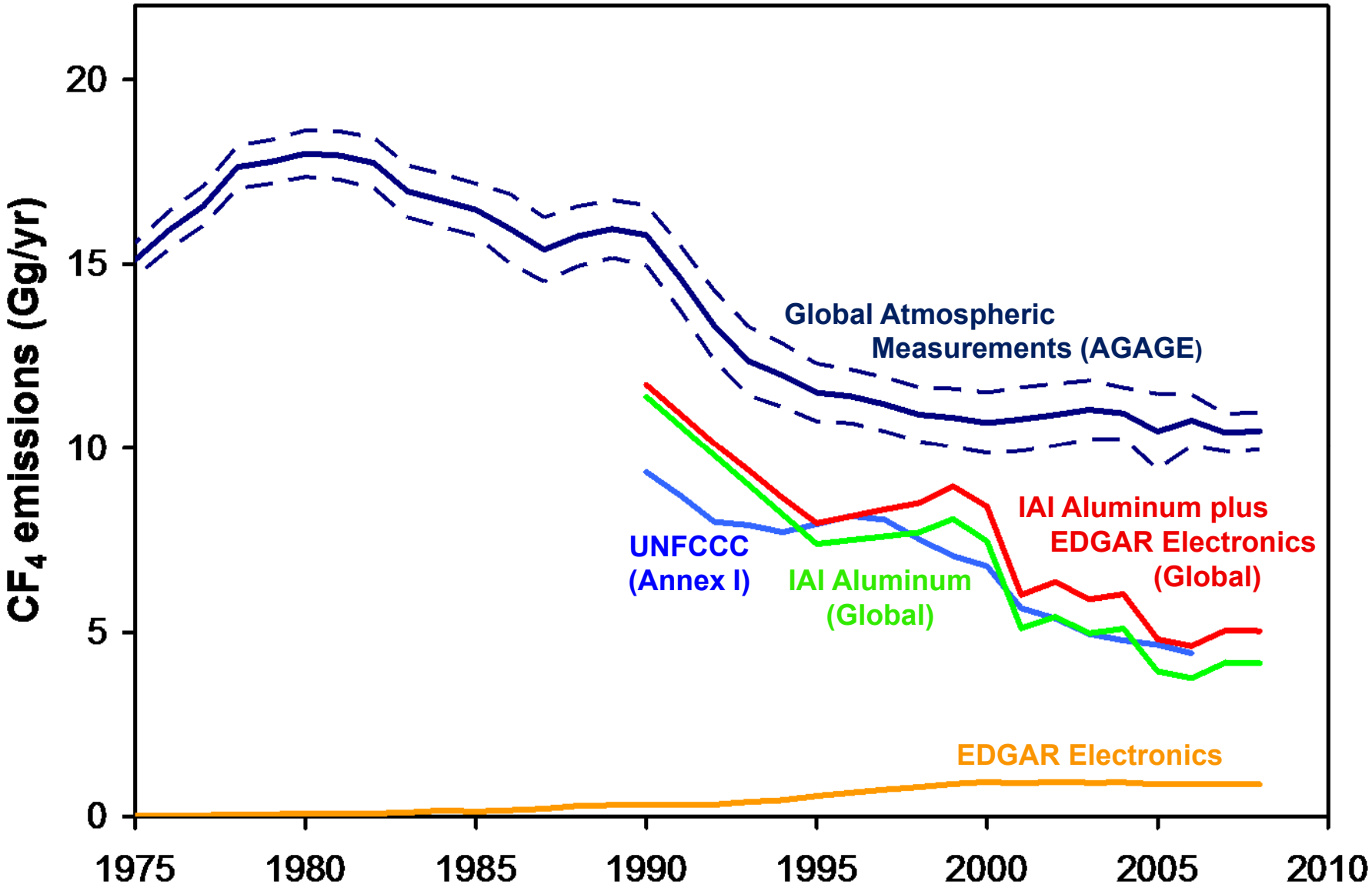
Three comparatively straightforward test cases...

Global Trends of the PFC Carbon Tetrafluoride* (CF_4, GWP=7,400)



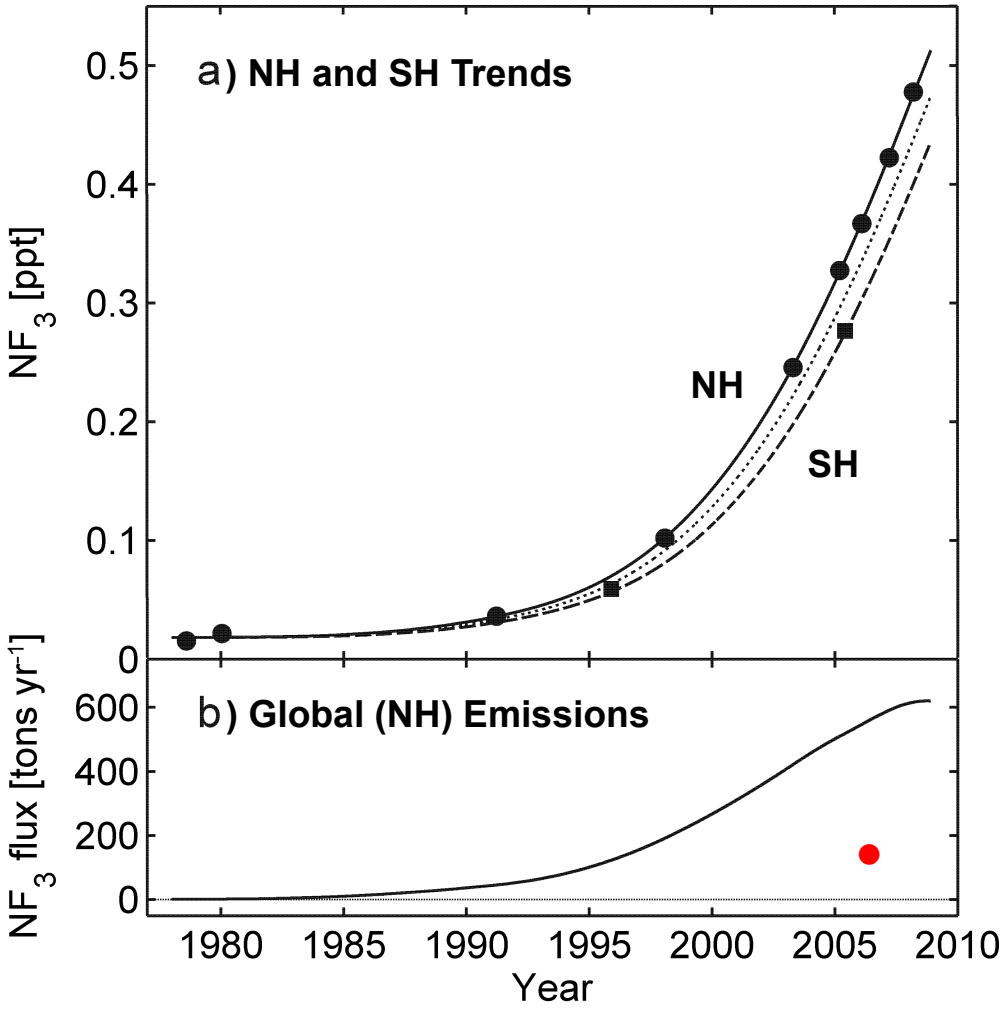
*Mühle et al., *Eos Trans. AGU*, 2009; *Atmos. Phys. Chem. Discuss*, 2010

Reported CF_4 Emissions Compared to Global Atmospheric Measurements



AGAGE data 2009

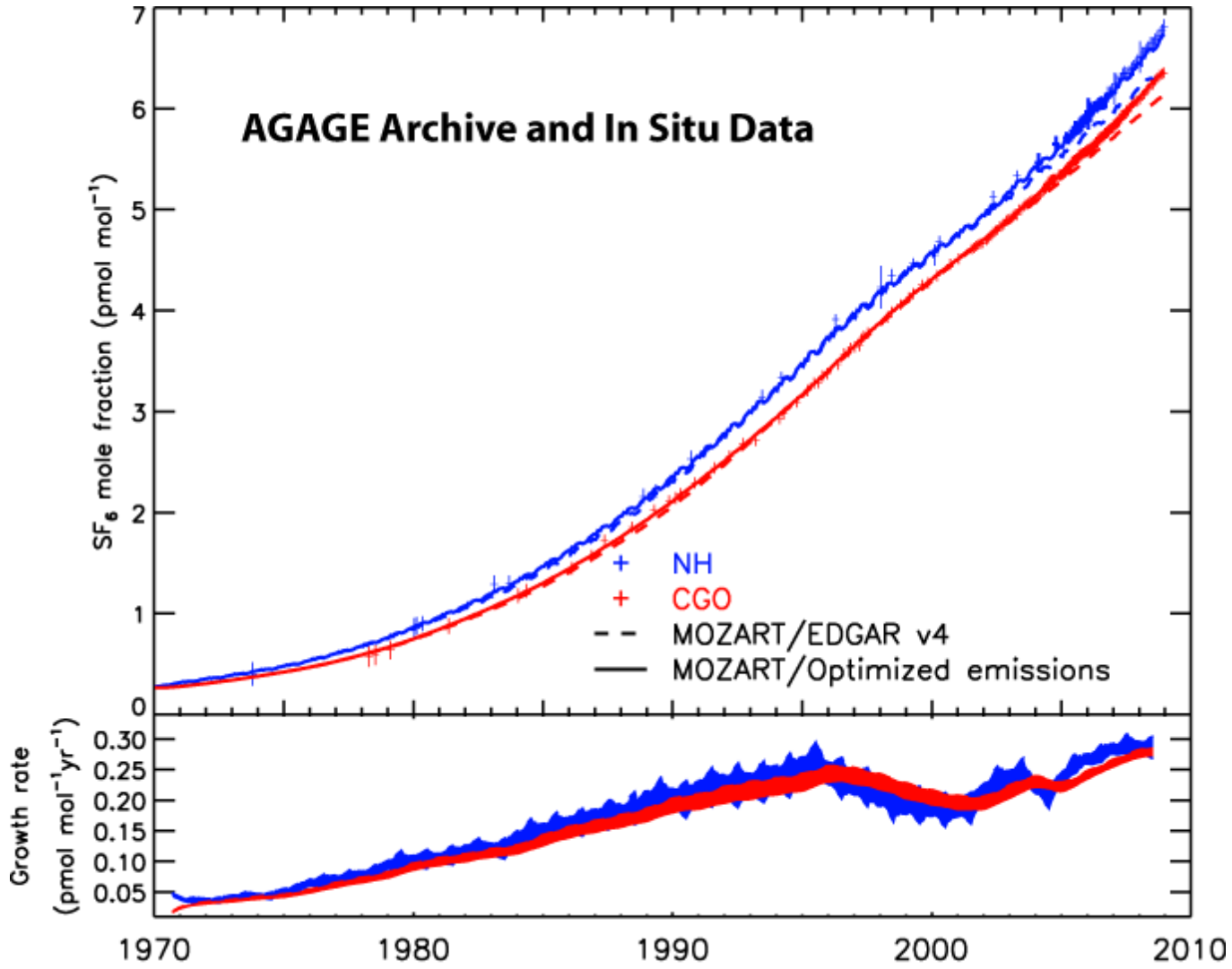
Global Trends and Emissions of Nitrogen Trifluoride * (NF_3 ,GWP = 17,000)



● = 2006 "Bottom-Up" Estimate

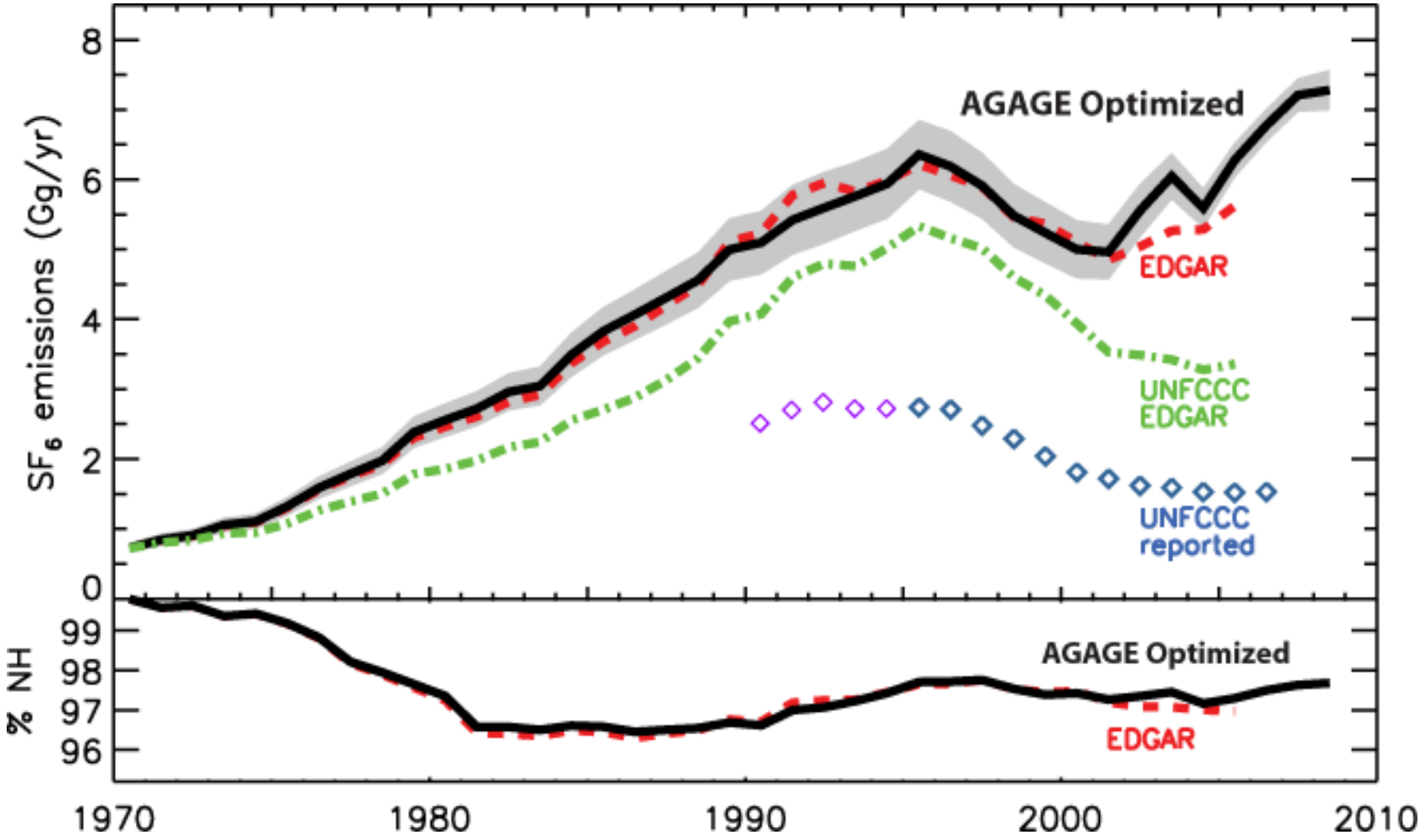
* Weiss et al., *Geophys. Res. Lett.*, 2008

Global Trends of Sulfur Hexafluoride* (SF_6 , GWP=22,800)



*Rigby et al., *Eos Trans. AGU*, 2009; *Atmos. Phys. Chem. Discuss*, 2010

SF_6 Emissions Reporting Compared to Global Atmospheric Measurements



AGAGE data 2009

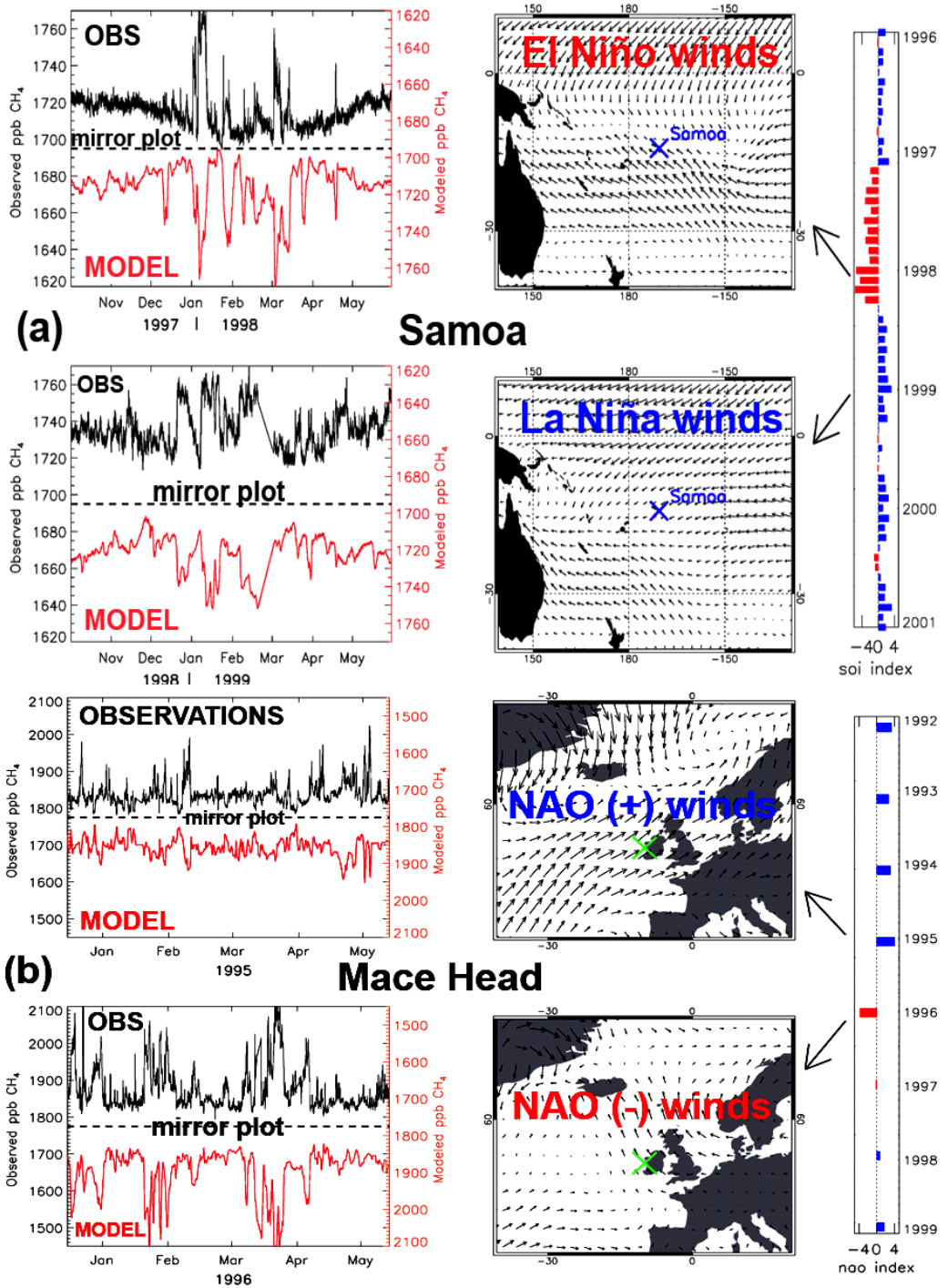
REGIONAL OPTIMAL SOURCE/SINK ESTIMATION USING MEASUREMENTS, PROCESS MODELS & 3D GLOBAL CIRCULATION MODELS

Whether Emission Reductions are claimed through Cap & Trade, Taxes, or Mandates, Reliable Estimates of Anthropogenic Emissions of Greenhouse Gas Emissions are ESSENTIAL

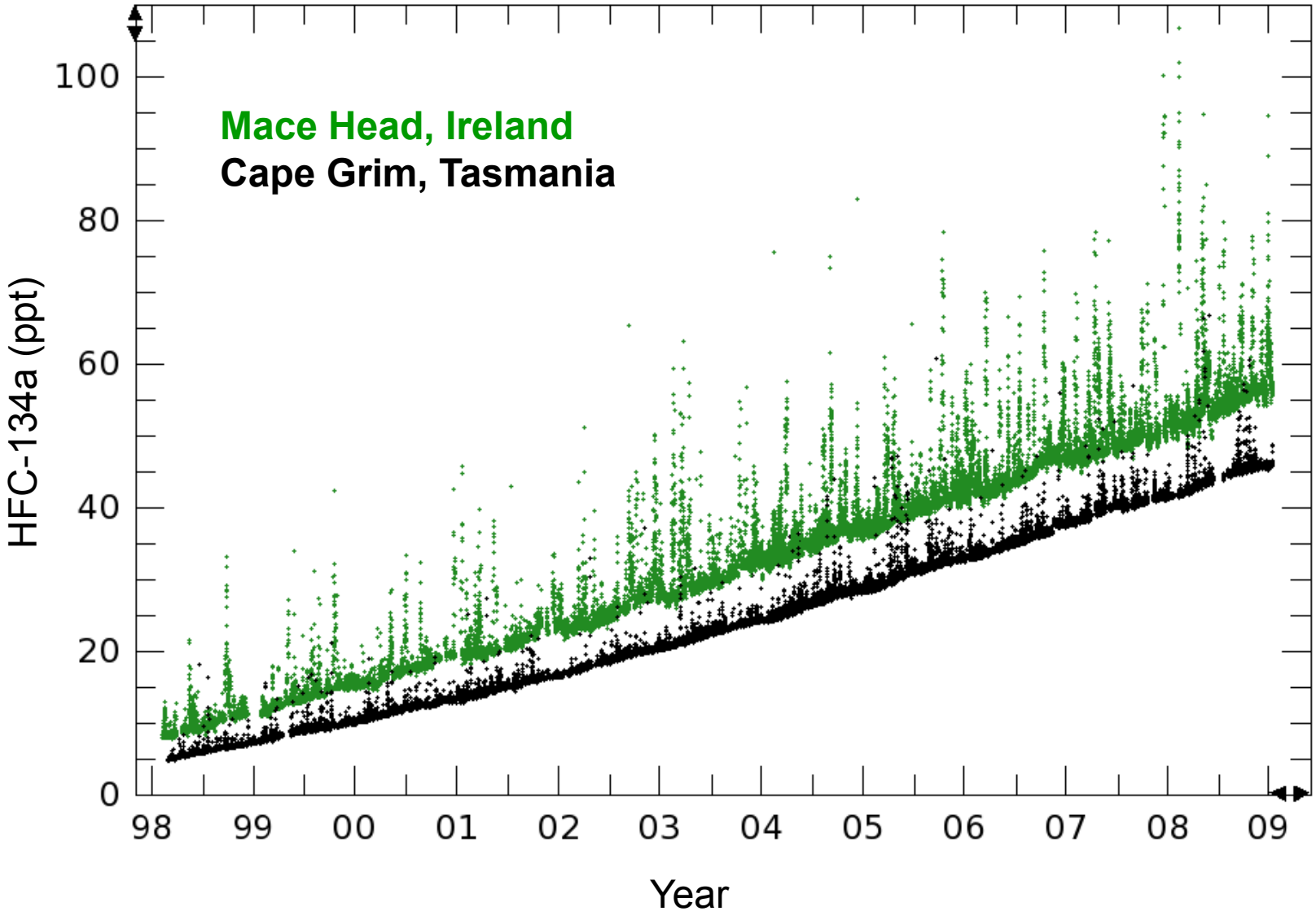
- How accurate/precise do the measurements need to be?
- How accurate/precise do the models need to be?
- What statistical methods are available & what should the criteria be for defining optimal?
- Are current capabilities adequate to verify emission claims?

HOW ACCURATE DO THE CIRCULATION MODELS NEED TO BE?

Chen & Prinn,
J. Geophys. Res., 2005



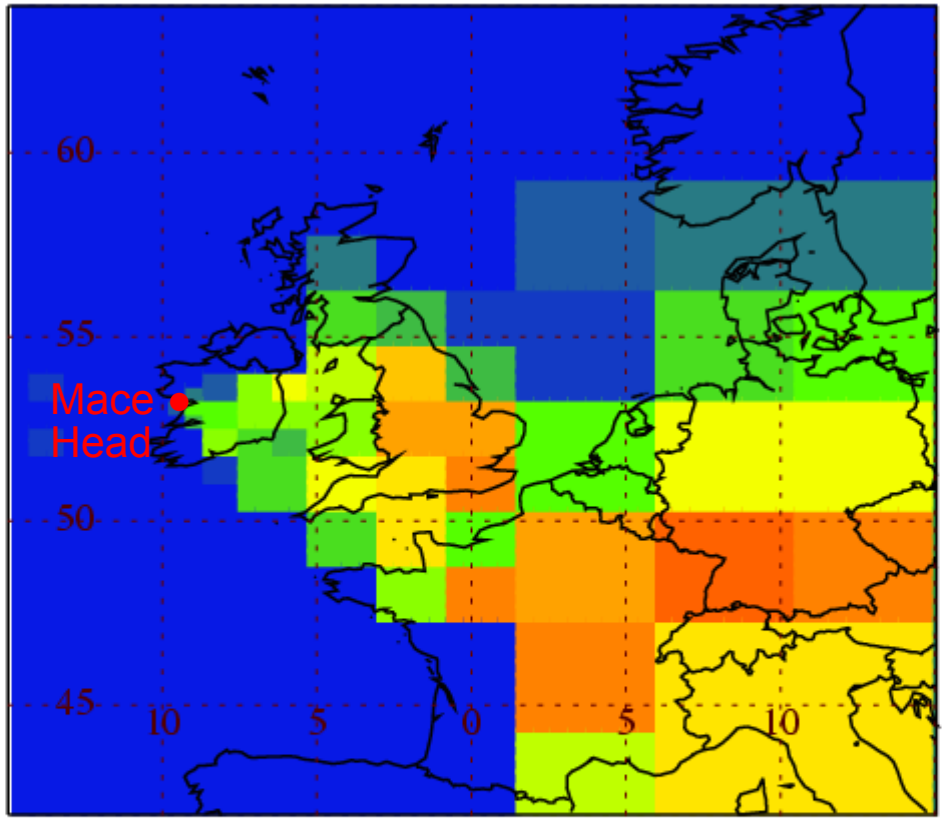
HFC-134a at two Remote Measurement Stations (CH_2FCF_3 , GWP= 1,430)



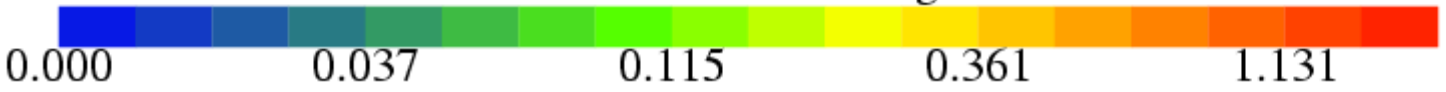
AGAGE data 2009

HFC-134a Northwestern European Emissions: Modeled * AGAGE Atmospheric Measurements at Mace Head, Ireland (2005-08)

(Per Capita and UNFCCC Reported Emissions Agree Within the ~35% Modeling Uncertainty)

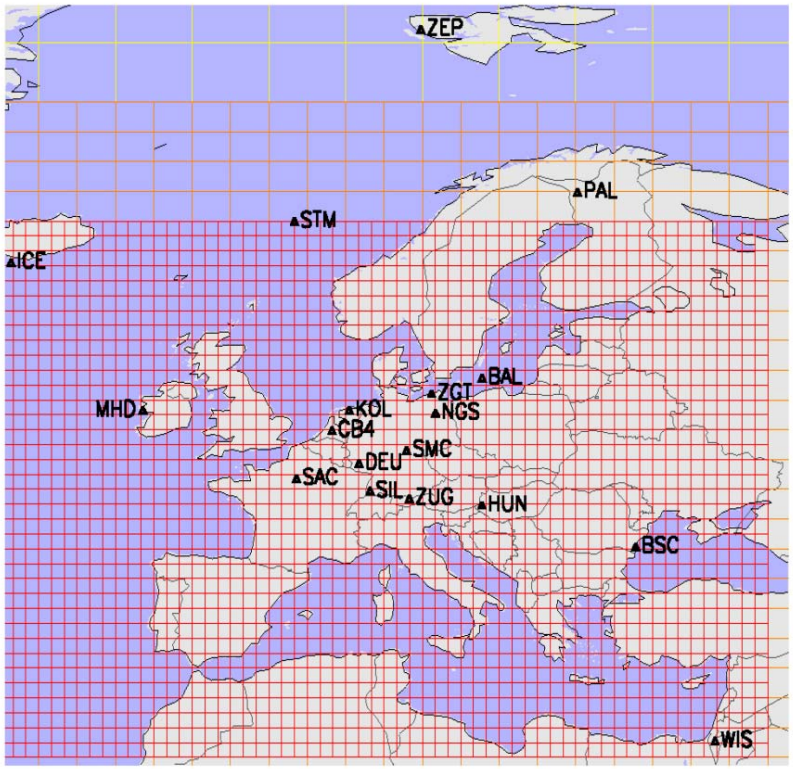


Maximum value = 1.004 ng/m^2/s

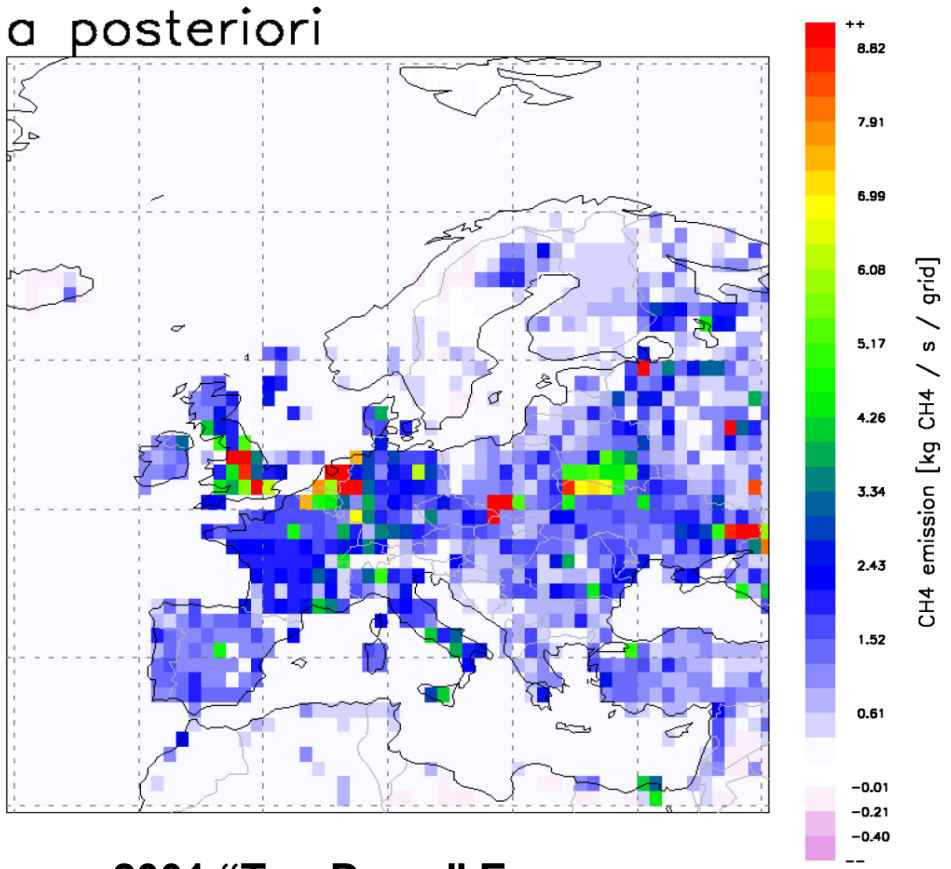


* Manning et al., *Eos Trans. AGU*, 2008 (UK Met Office Lagrangian Model)

2001 European Methane Emissions (CH_4 , GWP = 25) from a 1° Nested Atmospheric Model *



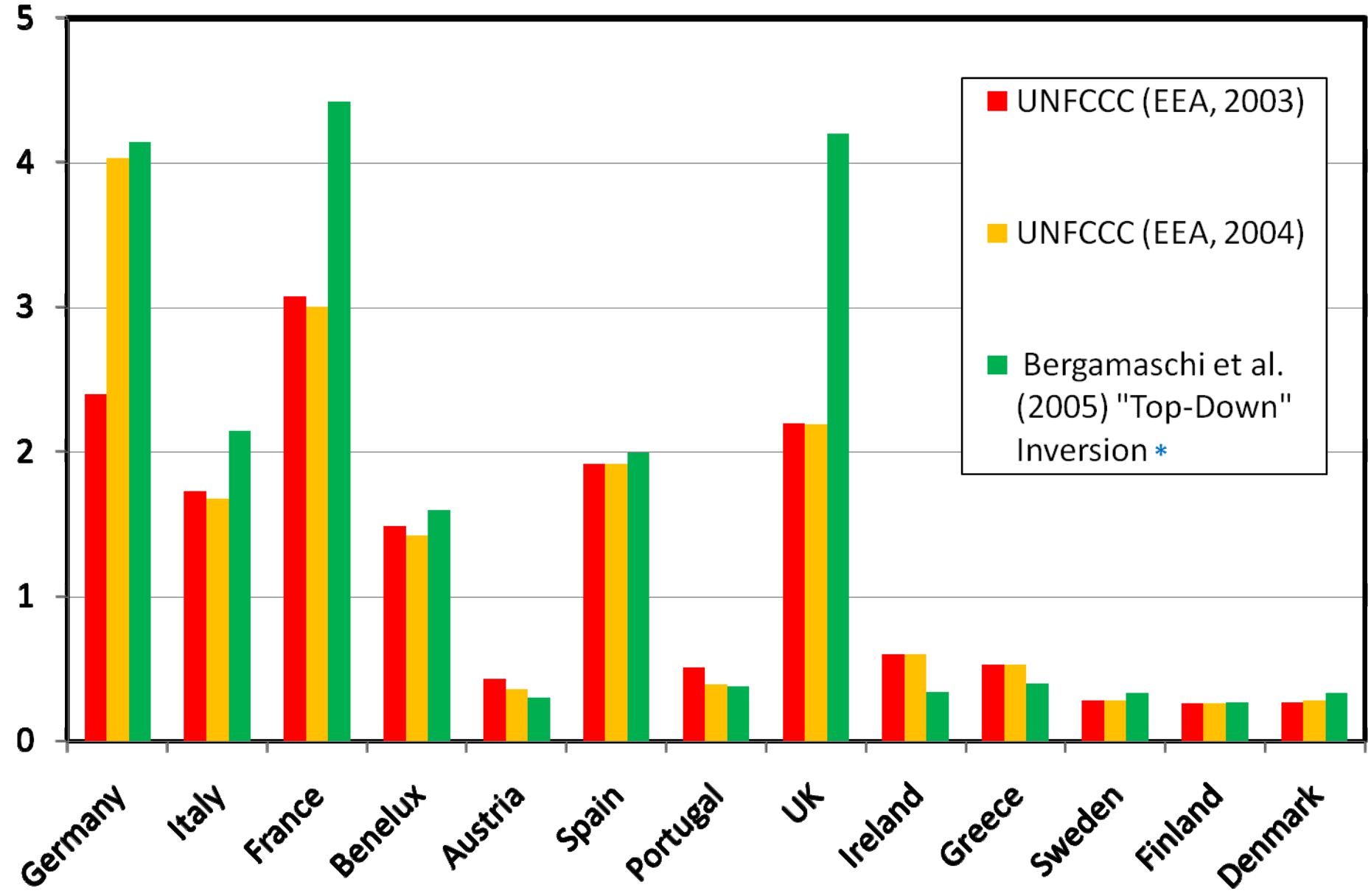
16 European Stations
Within a 56-Station Global Network



2001 "Top-Down" European
Emissions Map

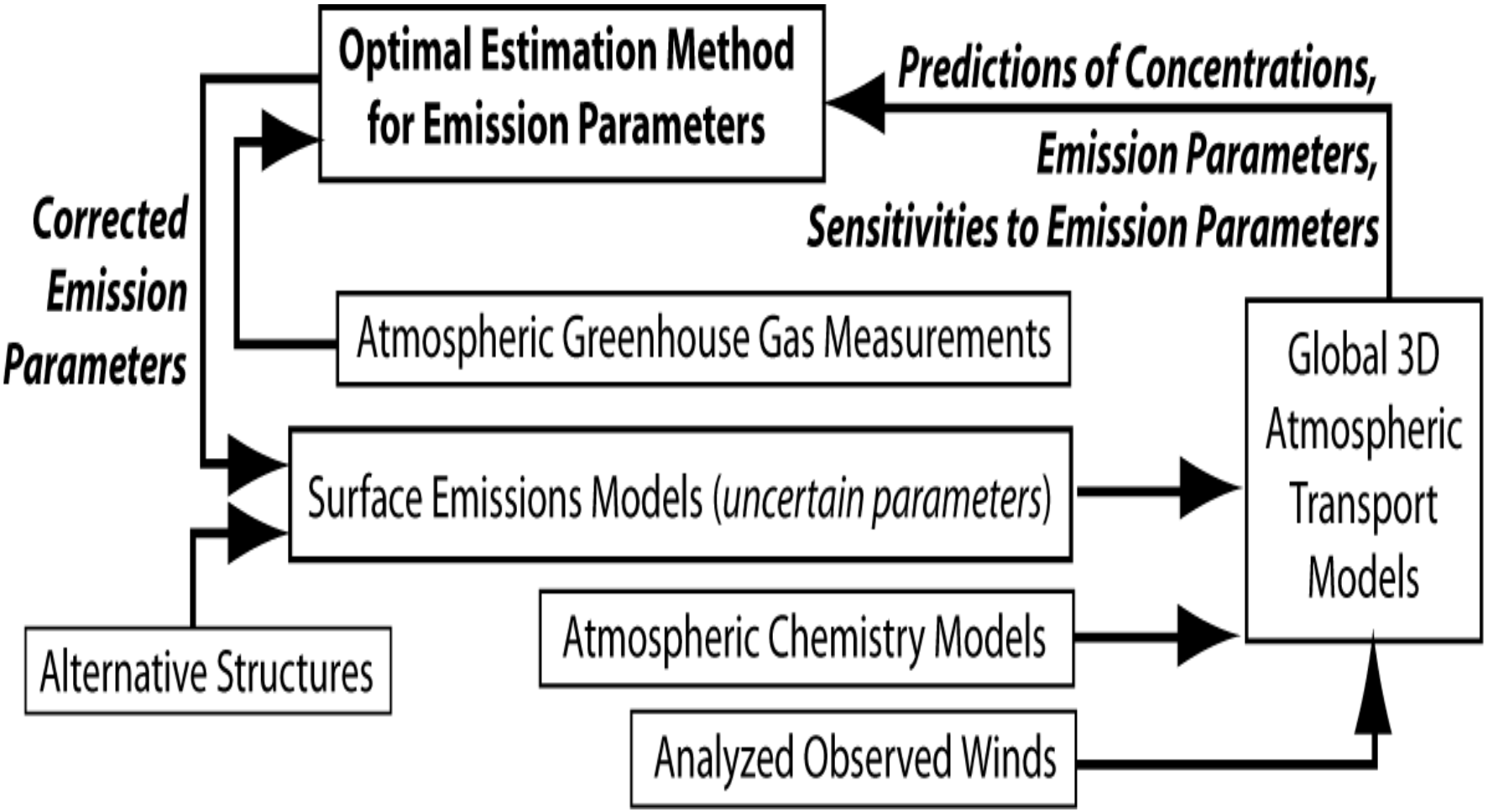
*Bergamaschi et al., *Atmos. Chem. Phys.*,5, 2431-2460, 2005

2001 Estimated European Union (EU-15) Methane Emissions in Tg/yr



*Bergamaschi et al., *Atmos. Chem. Phys.*,5, 2431-2460, 2005

The Estimation Challenge



Summary: Present Status

- There are large discrepancies for some greenhouse gases (GHGs) between global "bottom-up" emissions inventories and "top-down" global emissions as determined from atmospheric measurements.
- Under-reporting of GHG emissions appears to be more common than over-reporting, although both exist. Various factors may tend to bias toward under-reporting, including the price of emissions in carbon-equivalent trading markets and possible unidentified sources.
- Realistic regional emissions patterns, total emissions and trends can be obtained from high frequency measurements at ground based stations coupled with atmospheric inverse modeling, even when the measurement locations are sparse and are not optimally chosen, but these results do not yet meet the needs of verifying enacted emissions reduction legislation.
- Inverse models are able to assimilate measurements from many atmospheric measurement stations, thus greatly reducing uncertainties in regional emissions estimates.

Summary: Future Outlook

- There is a compelling need for increased spatial and temporal resolution of high-precision atmospheric GHG measurements, including isotopes to resolve the roles of different anthropogenic and natural processes. Modeling will continue to improve, but measurements cannot be made retrospectively.
- Improvements in inverse modeling are needed, including modeling of natural processes, in order to assimilate atmospheric GHG measurements and quantify regional emissions with sufficient accuracy to verify legislation.
- Optimal estimation and statistical methods, incorporating all information weighted by precision and accuracy, should provide a structured path to the convergence of "top-down" and "bottom-up" emissions estimates that will be required for effective implementation.
- Improved verification, achieved by investing a very small fraction of the current $100 billion investment in global carbon-equivalent trading markets, can play a significant role in stabilizing these volatile markets and thus in accelerating investment in emissions reductions.