Observations of Atmospheric Methane and Implications for Emissions

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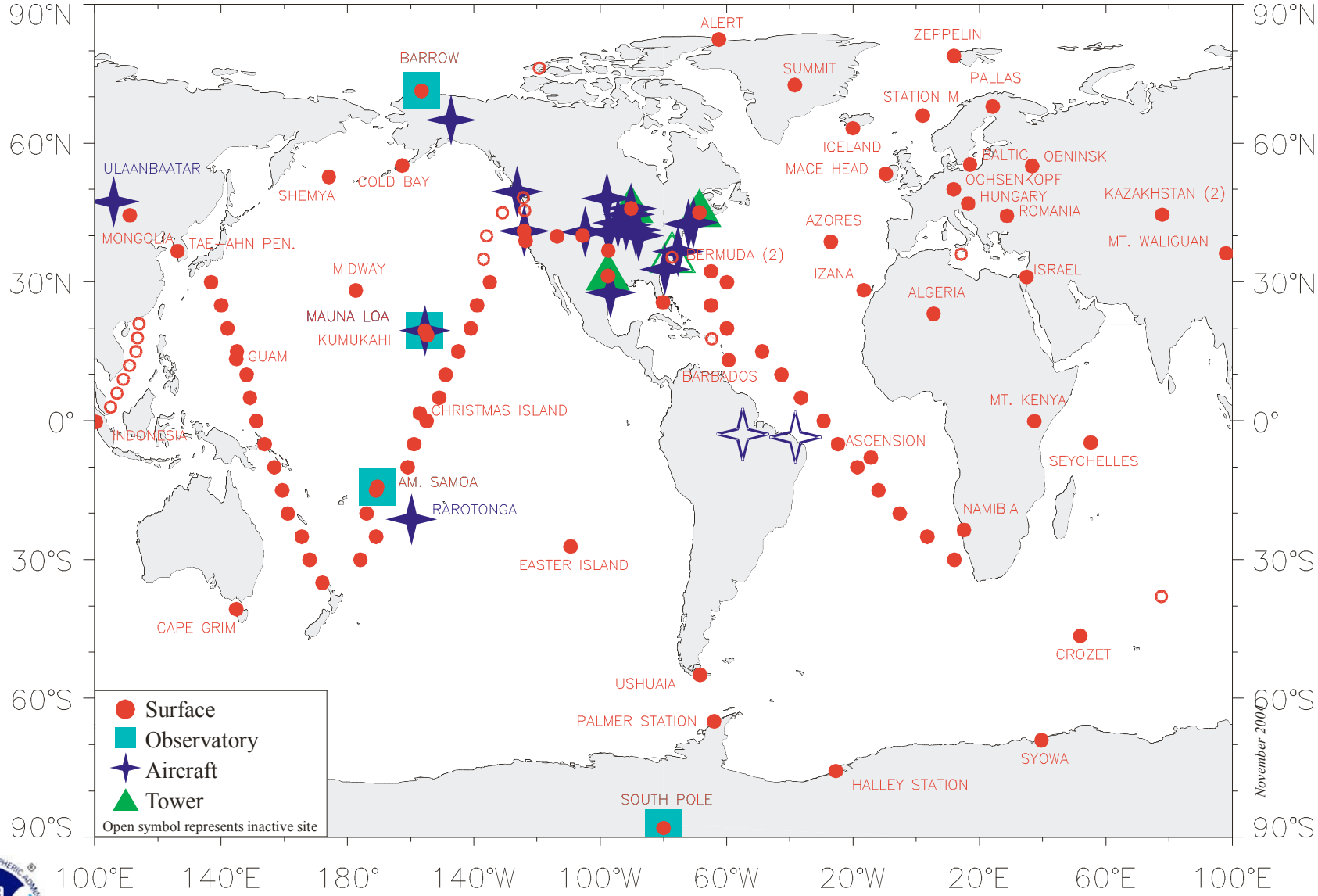
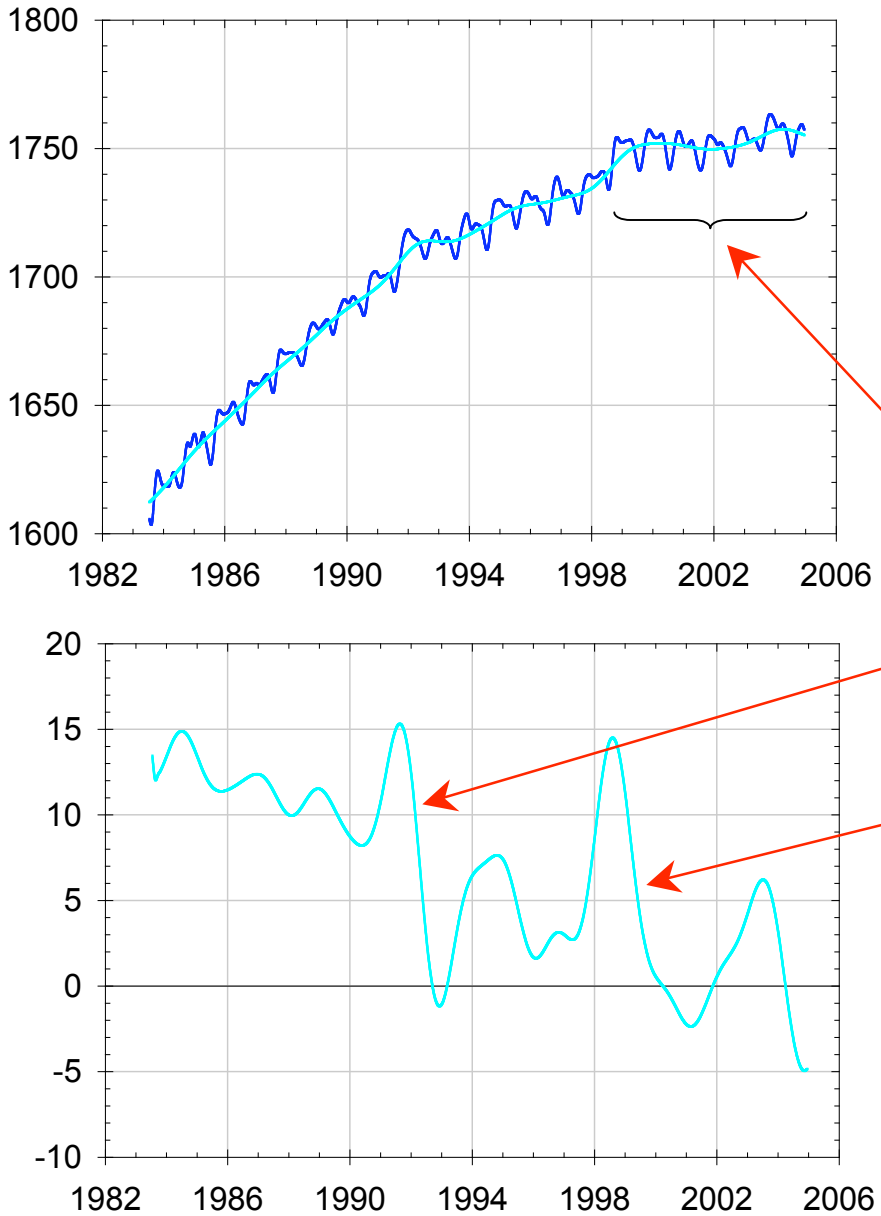
CMDL Global Cooperative Air Sampling Network



Global Methane Observations



Some Interesting Features:

Long period of little growth

1991-1992 Growth rate increase and decrease

1998 Growth rate increase

Global Burden

$[CH_4]$ (2003) = 1755 ppb → ~4900 Tg burden

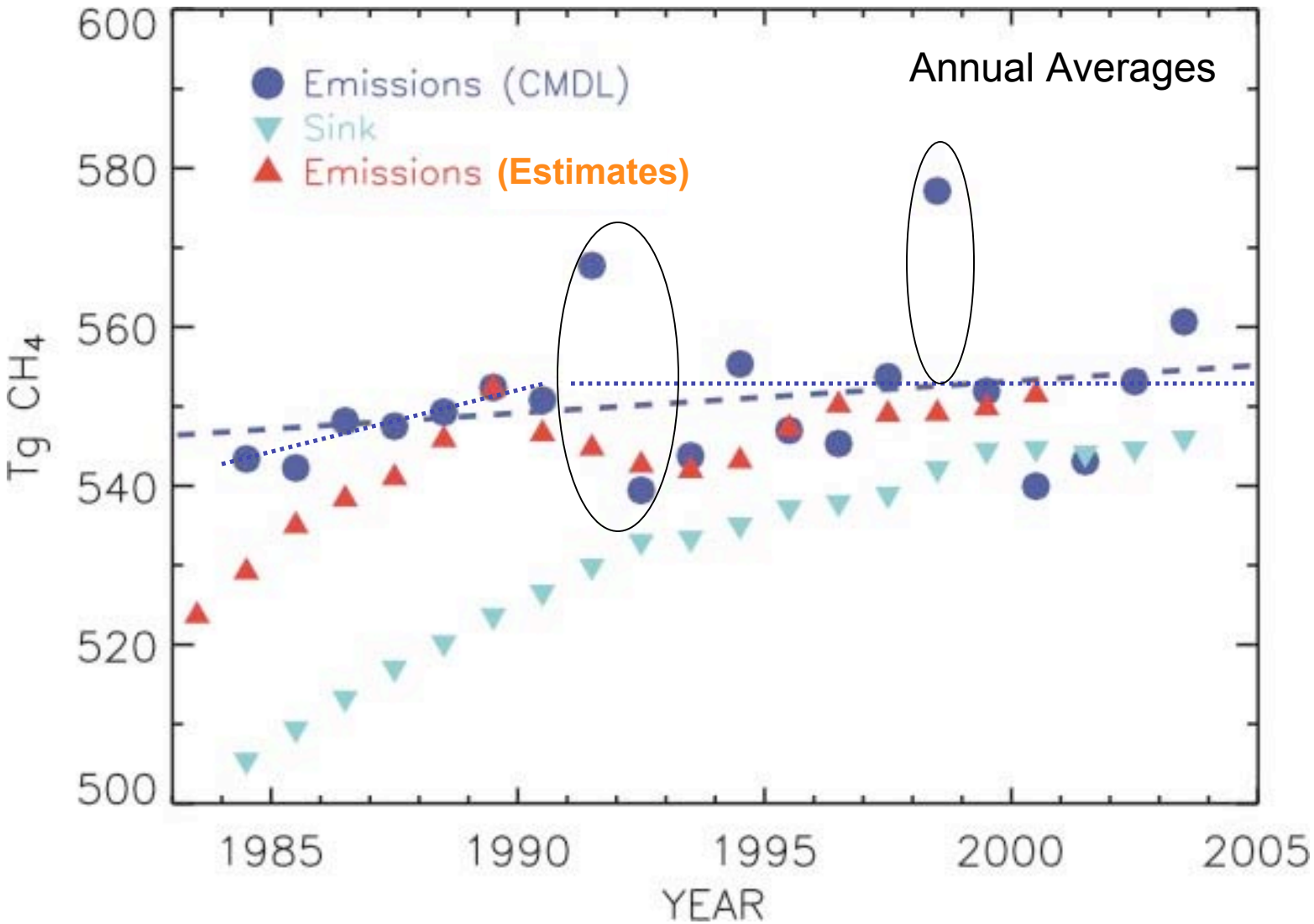
Global Emission Rate

Growth Rate = Emission Rate – Removal Rate

Emission Rate = $d[CH_4]/dt + [CH_4]/\tau$

d[CH4] /dt and [CH4] are measured

τ = CH_4 lifetime ≅ 8.9 years, due mainly to chemical removal by OH, is assumed constant



Average Emissions = 550.6 ± 9.4 Tg CH_4 yr^{-1}

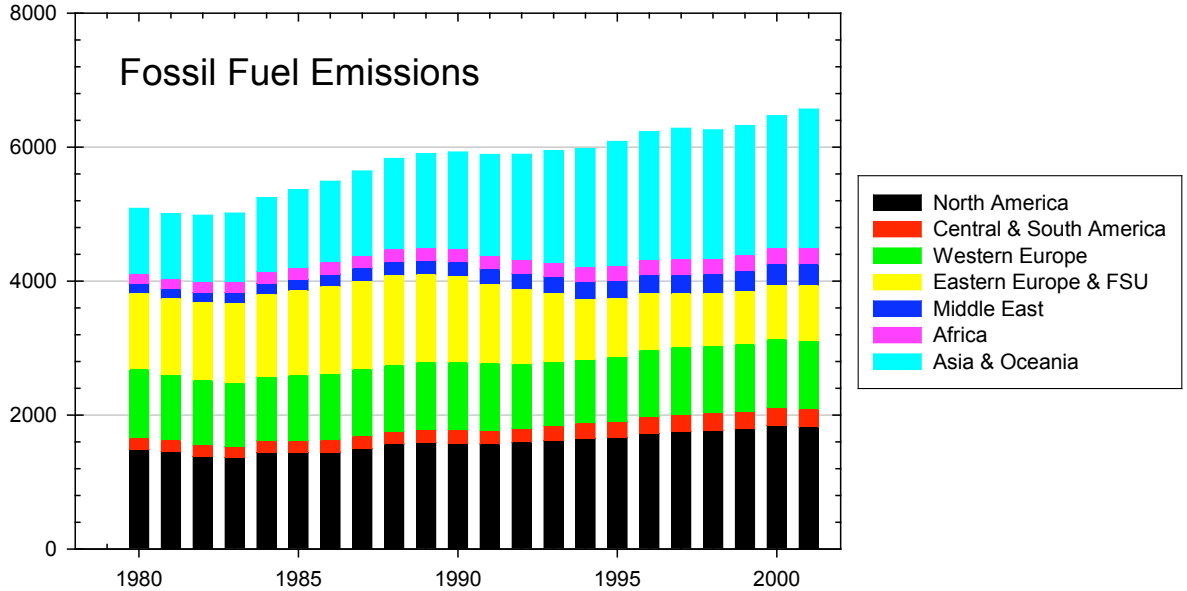
Trend (1984-2004) = 0.4 ± 0.4 Tg yr^{-1}

1991 - 1992

- The volcano Pinatubo erupted

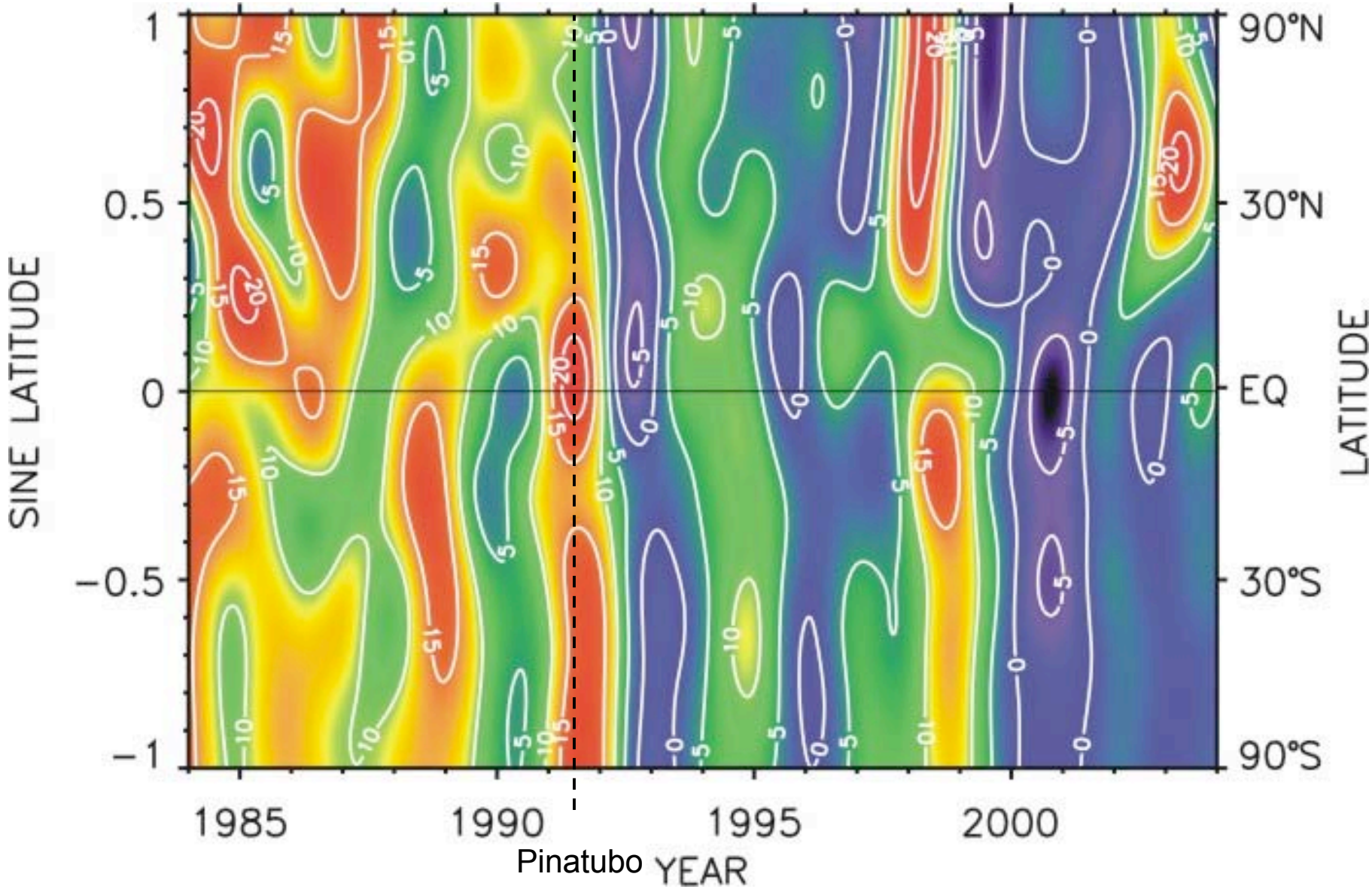
  Stratospheric SO_2 and sulfate aerosol reduced solar UV which decreased the production of OH, decreasing chemical methane loss (increased growth rate) in 2nd half of 1991. This was followed by tropospheric cooling (decreased growth rate) in 1992.

- The former Soviet Union collapsed



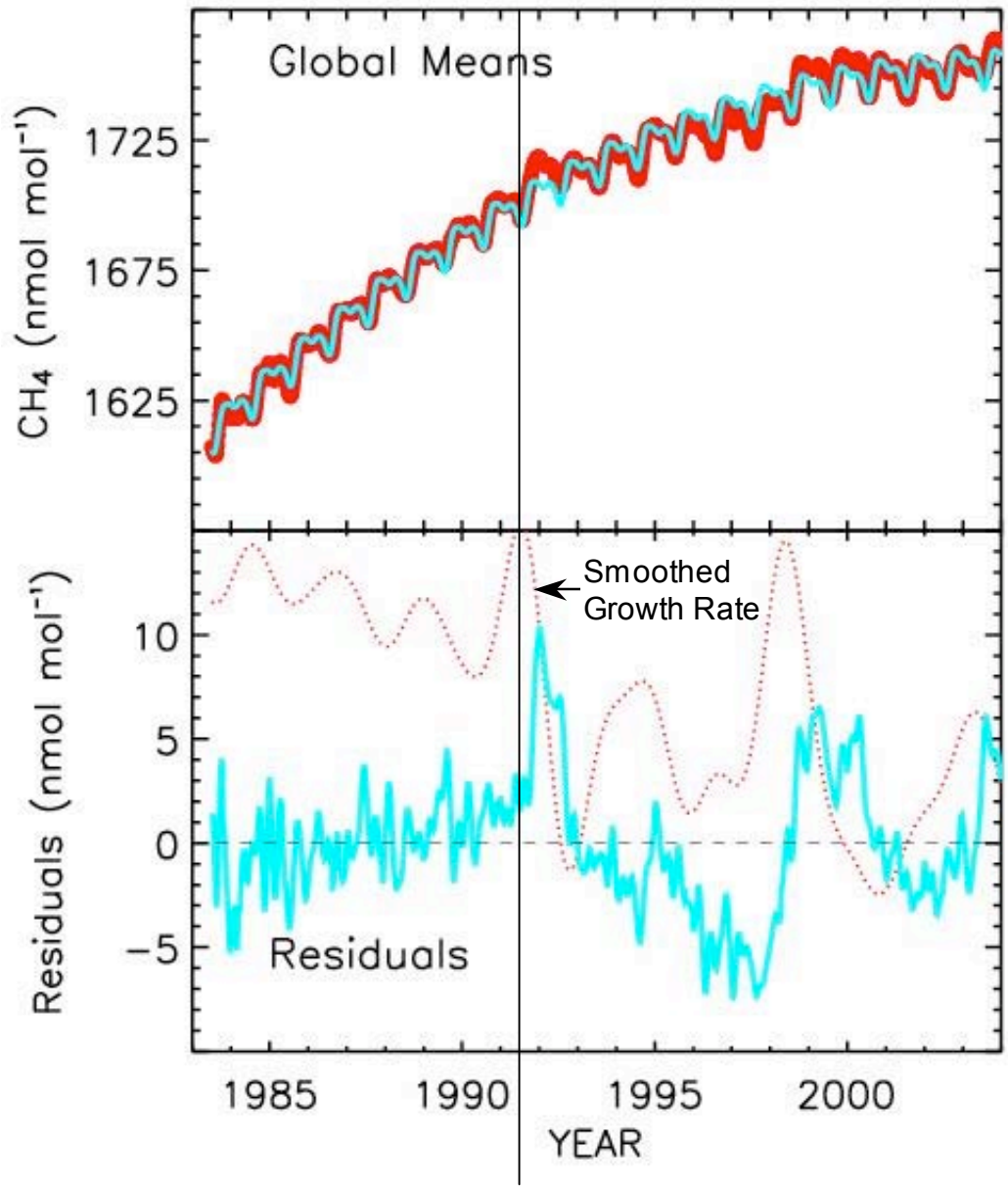
Methane Growth Rate Contours (ppb/yr)

(red is high, blue is low)



$$f(t) = a_1 + a_2 t + a_3 t^2 + \sum_{i=1}^{4} [a_{2i+2} \sin(2\pi i t) + a_{2i+3} \cos(2\pi i t)]$$

More accurate event timing using residuals



Pinatubo

Changes in CH_4 Spatial Pattern

CH_4 Growth Rate anomaly in 1992 coincident with collapse of economy in the former Soviet Union.

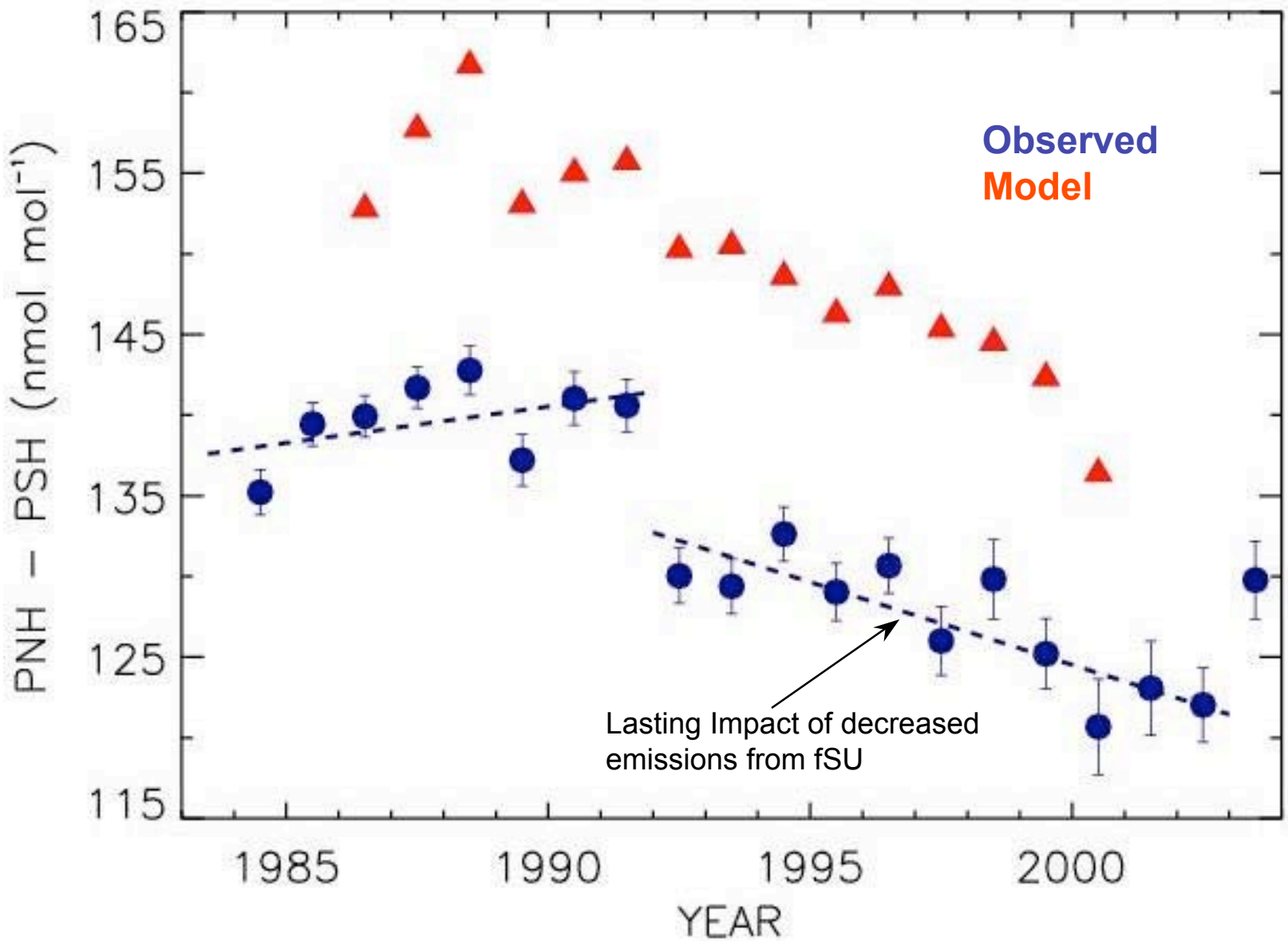
Emission Data Base suggests decreased fSU emissions from 1990 to 1995 in sectors:

- Fossil fuels
- Animals

Total decrease: 10.6 Tg CH_4

1992 also cool (post-Pinatubo) and dry – wetland emissions down.

Interpolar Difference (IPD) = (53-90N) – (53-90S)



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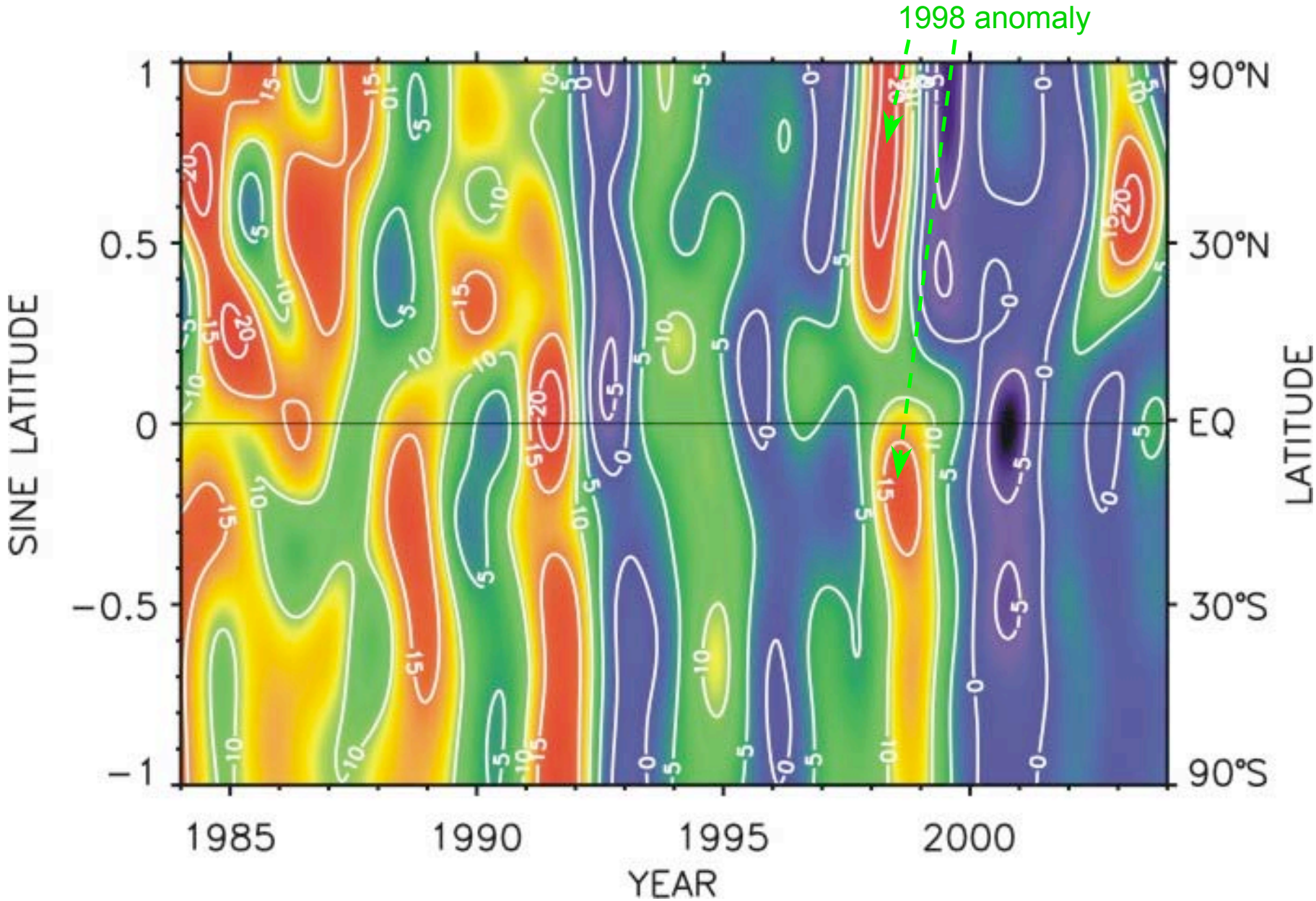


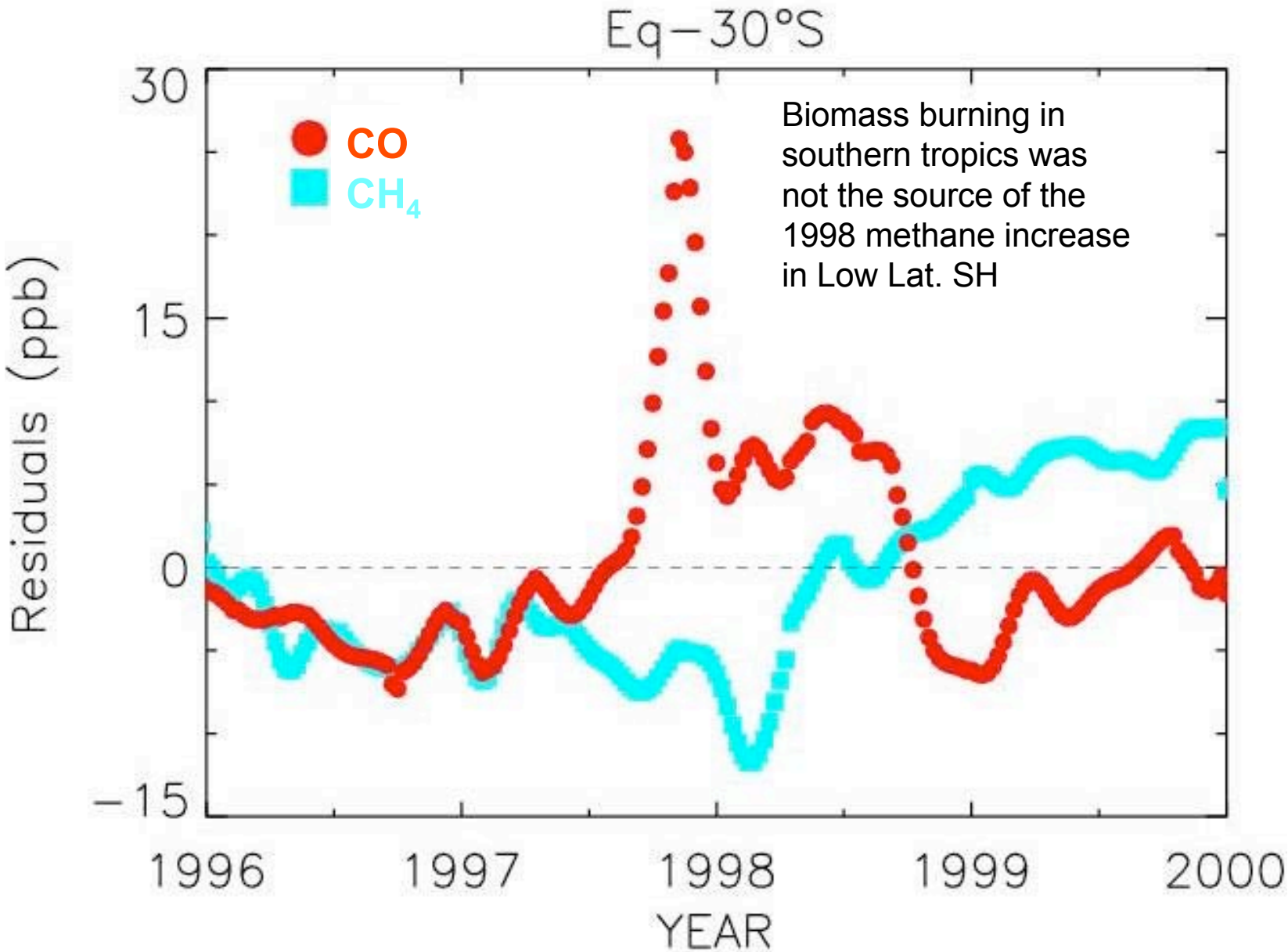
1998 Growth Rate Anomaly

Large positive growth rates observed in High NH and Low SH latitudes - ~24 Tg.

Process-based wetlands model indicated ~12 Tg each from High NH and Low SH source. In addition, boreal forest and peat fires estimated to have added ~ 6 Tg in 1998.

$^{13}CH_4$ measurements support both biomass burning and wetland sources (Morimoto et al.) as contributors to the 1998 increase in High NH.

Using Carbon Monoxide as a Tracer of Biomass Burning



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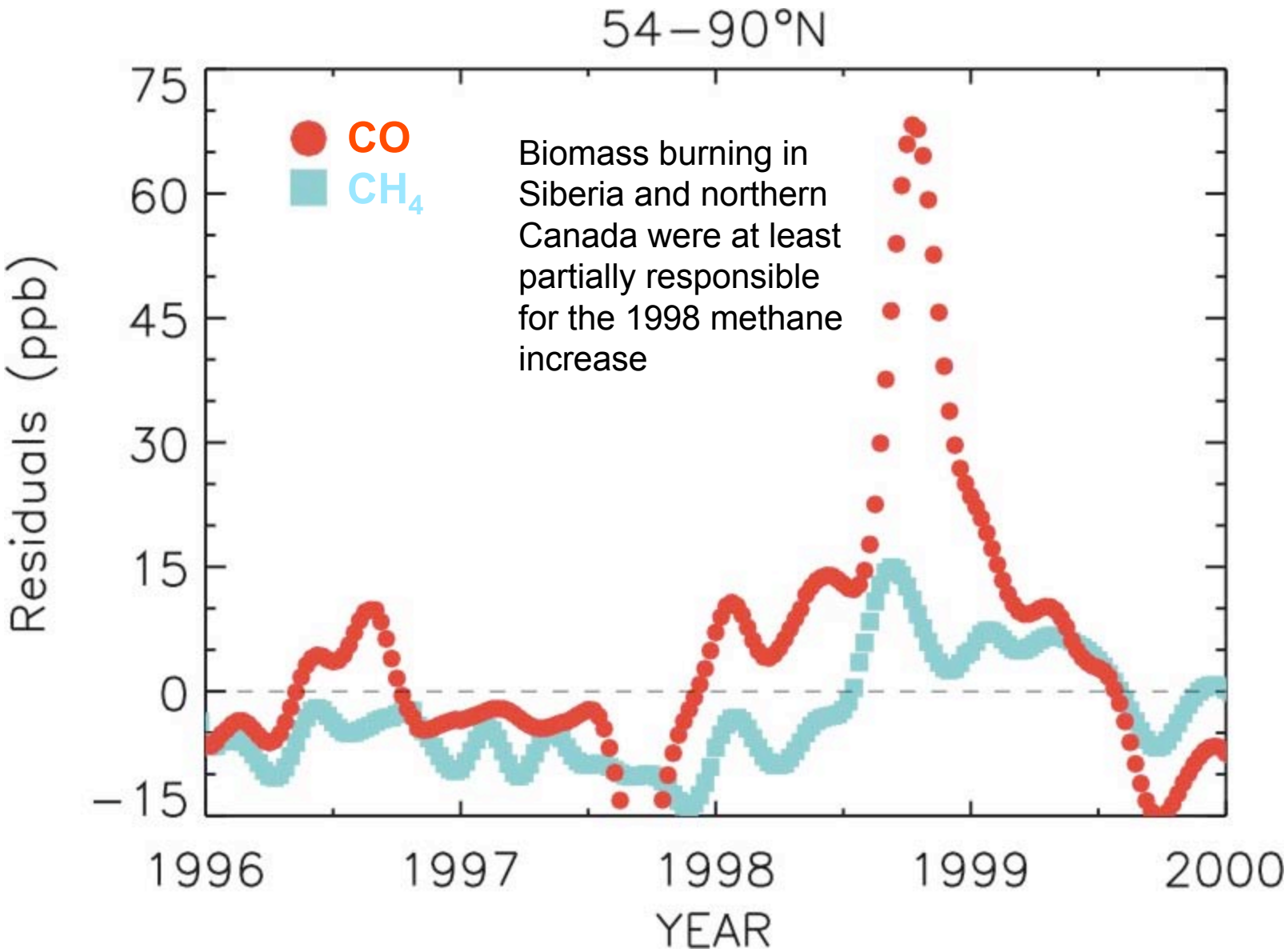


Verification

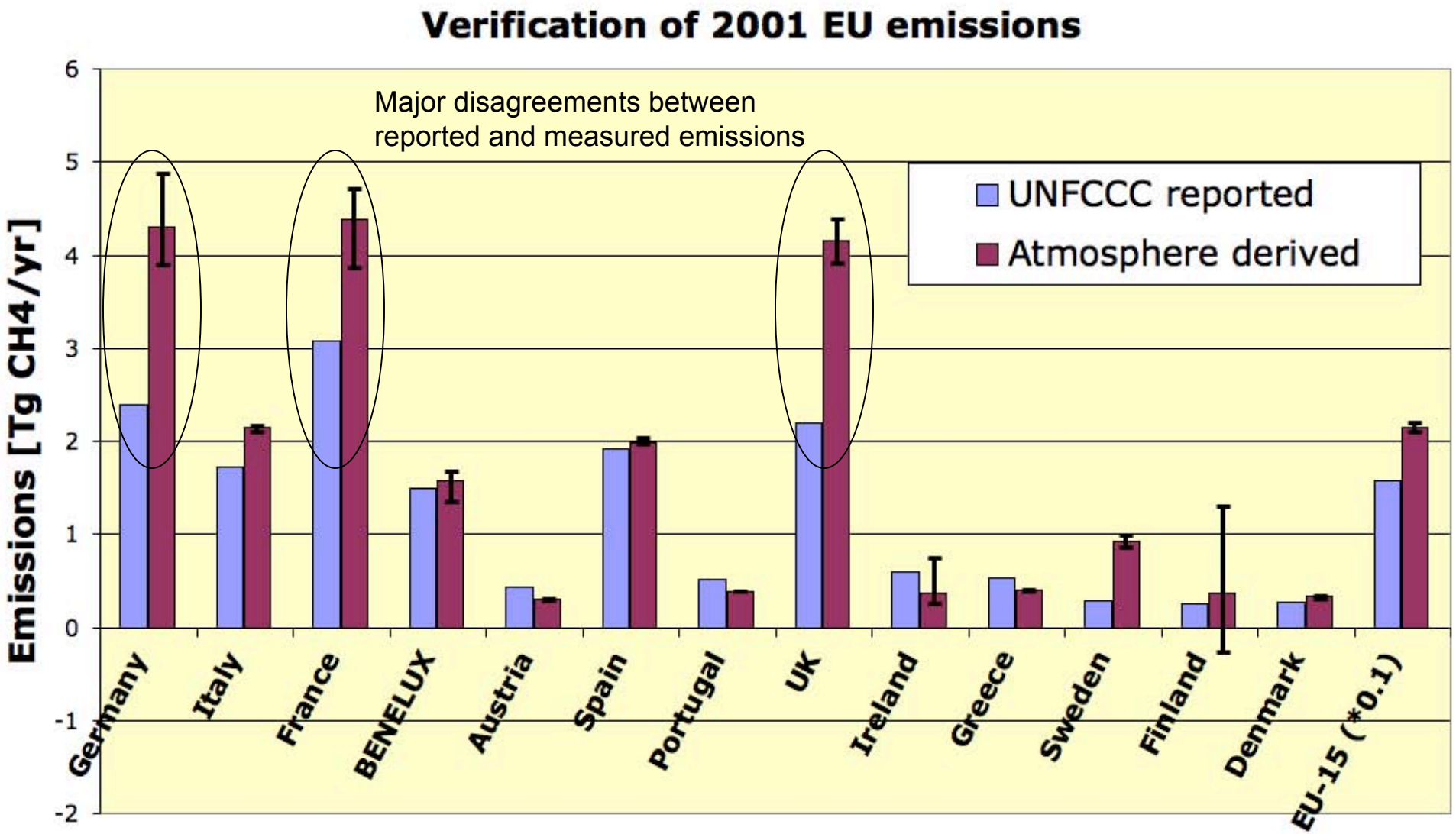
How can emissions reported to UNFCCC or under Kyoto agreement be verified?

Measurement Programs:

- NACP – North American Carbon Program.
- Meth-MonitEUr – European program.

Measurements and Inverse Models:

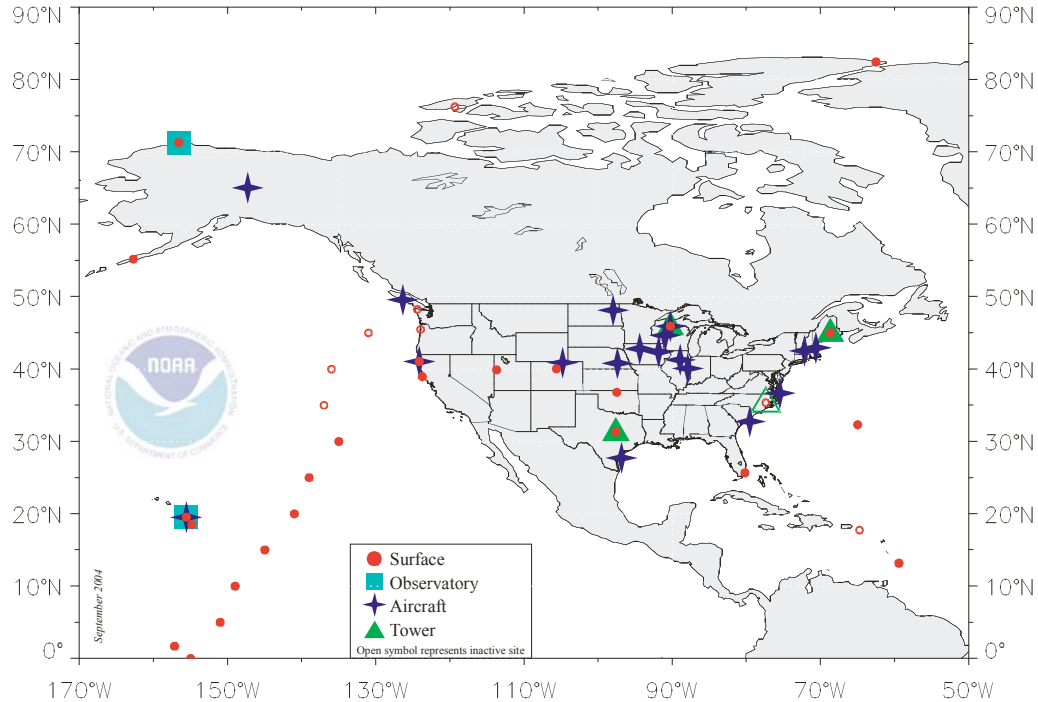
- Bergamaschi et al., Inverse modeling of national and European CH_4 emissions using the atmospheric zoom model TM5, Atmos. Chem. Phys. Discuss., 5, 1007-1066, 2005.



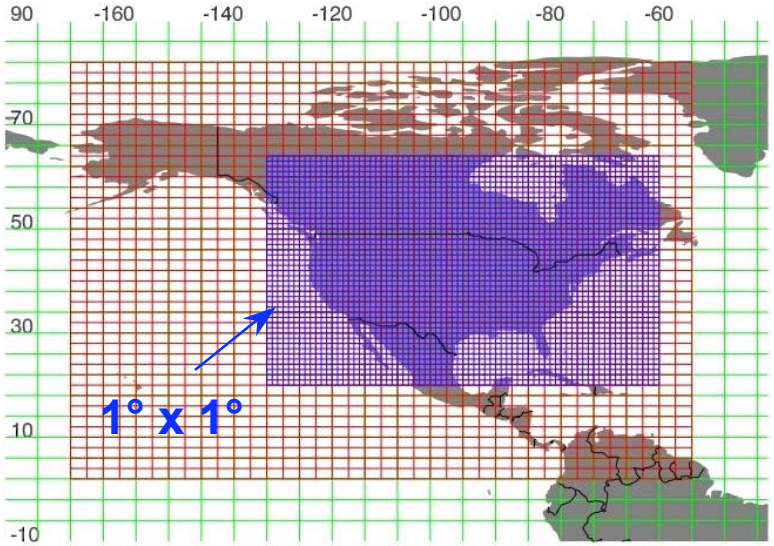
Bergamaschi et al., 2005

North America Carbon Program

Expansion of profile measurements in US, using aircraft and tall (~500 m) towers, is underway. Goal: 24 aircraft, 12 towers by 2008.



Nested grid inverse transport models will provide the needed spatial scales to utilize the new measurements in order to extract sources and sinks at higher resolution.



Summary and Conclusions

Observations provide key constraints:

Methane burden, trend, global emissions, spatial gradients, seasonal cycles.

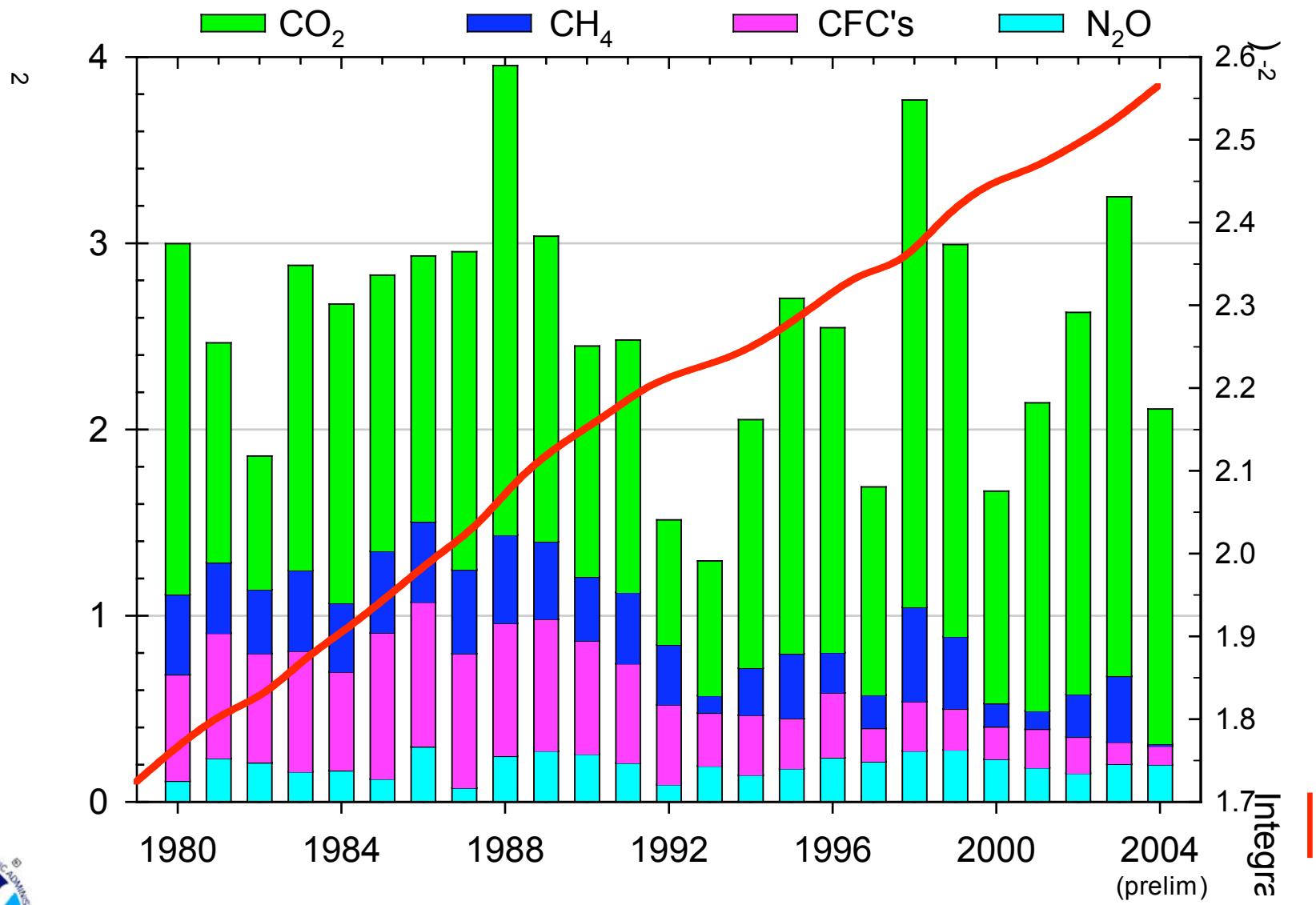
Growth rate variations and CO obs.→ Processes

Wetland emissions, biomass burning.

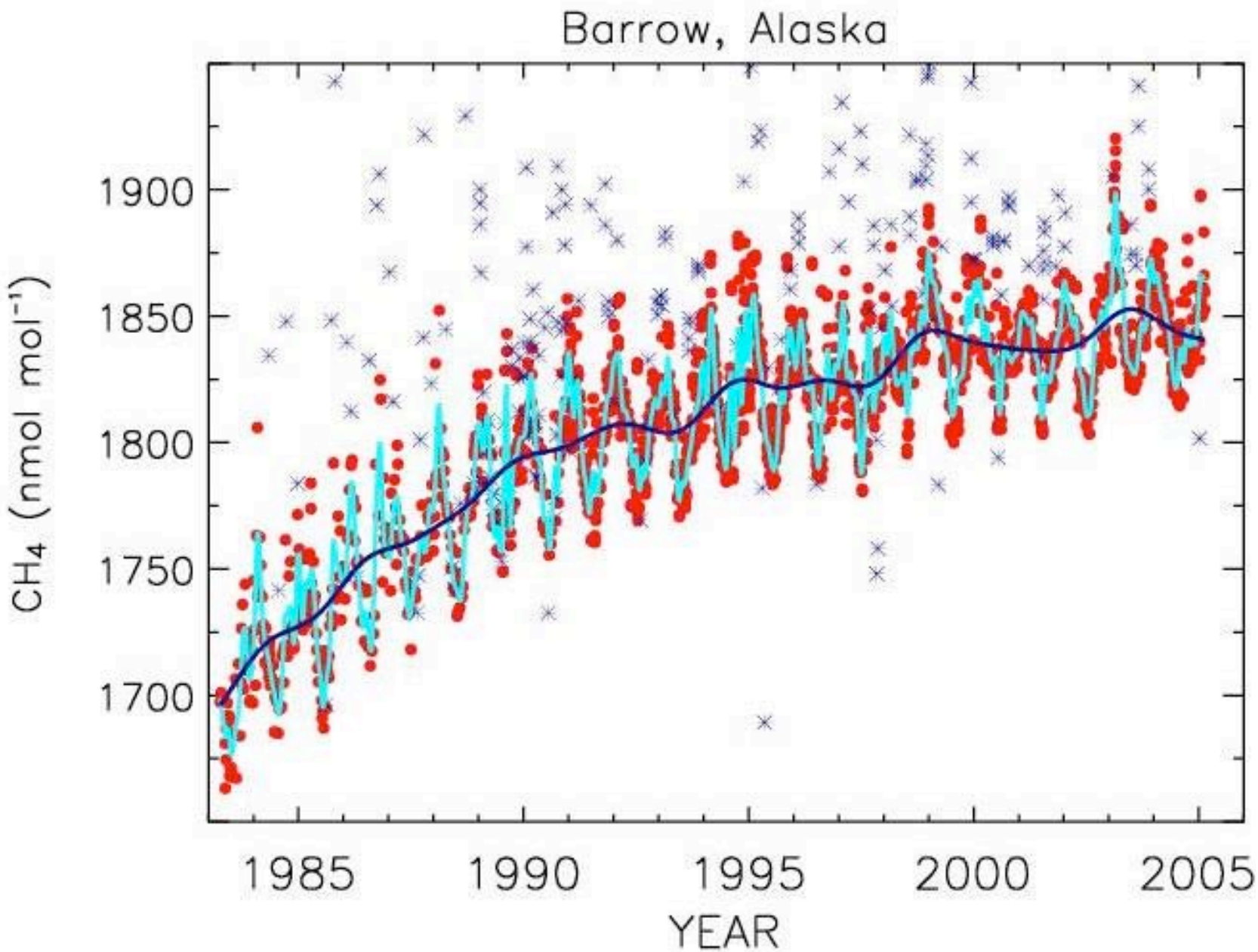
Verification

Europe ahead of US but we're working on it. Need higher density of observations and continued inverse model improvements.

Annual Variation in Global Direct Radiative Forcing by Major Greenhouse Gases in ppm EQCO2



Annual Greenhouse Gas Index


Barrow, Alaska
1900
1850
1800
1750
1700
CH4 (nmol mol-1)
1985
1990
1995
2000
2005
YEAR