A Long-Term Perspective on Recent Increases in Atmospheric CH_4 Abundance

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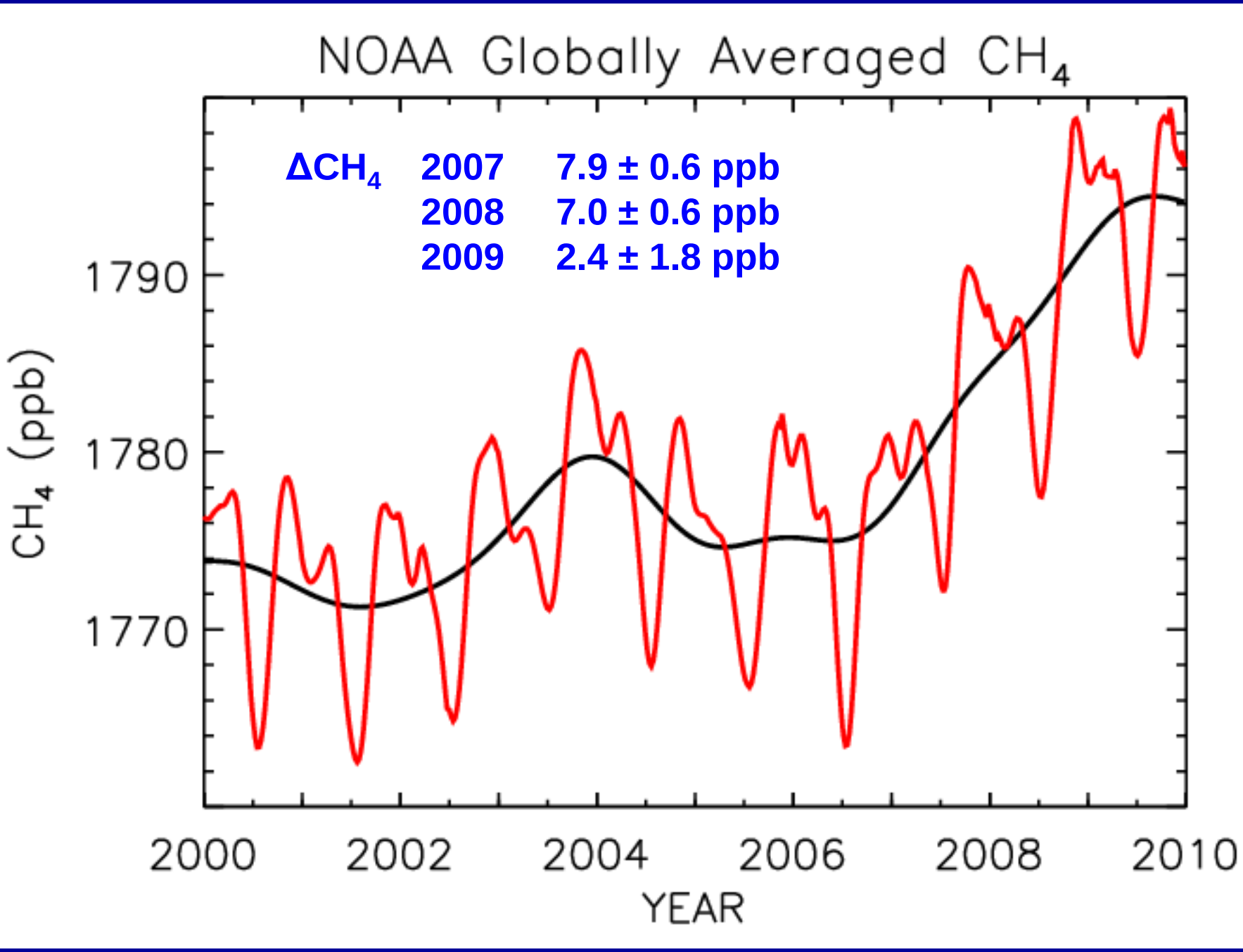
“Methane levels may see 'runaway' rise, scientists warn”

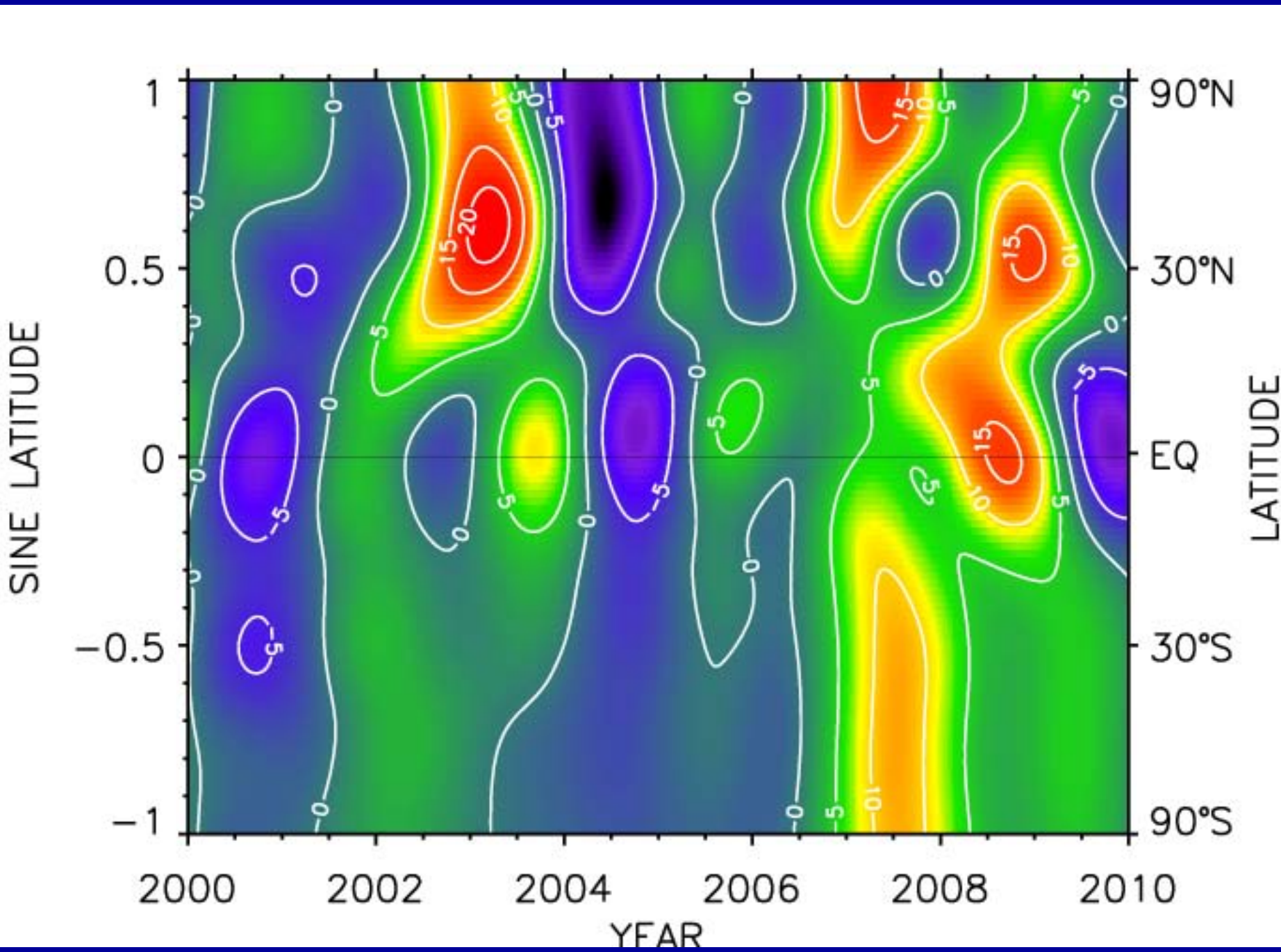
A rapid acceleration may have begun in levels of a gas far more harmful than CO_2

By Michael McCarthy, Environment Editor
The Independent, Monday, 22 February 2010

What is behind the headlines?

- Arctic climate change – T and precipitation
  - CH_4 flux from WLs T and precip. dependent
  - Destabilize permafrost and clathrates
- Arctic methane clathrate hydrates
  - 30 to 170 Pg CH_4 (1600 to 2000 Pg C globally)
  - Westbrook et al., 2009; Shakova et al., 2010
- Thermokarst formation
  - Thaw lake formation increased by climate change
  - Permafrost contains ~1000 Pg C
  - Walter et al., 2006, 2007

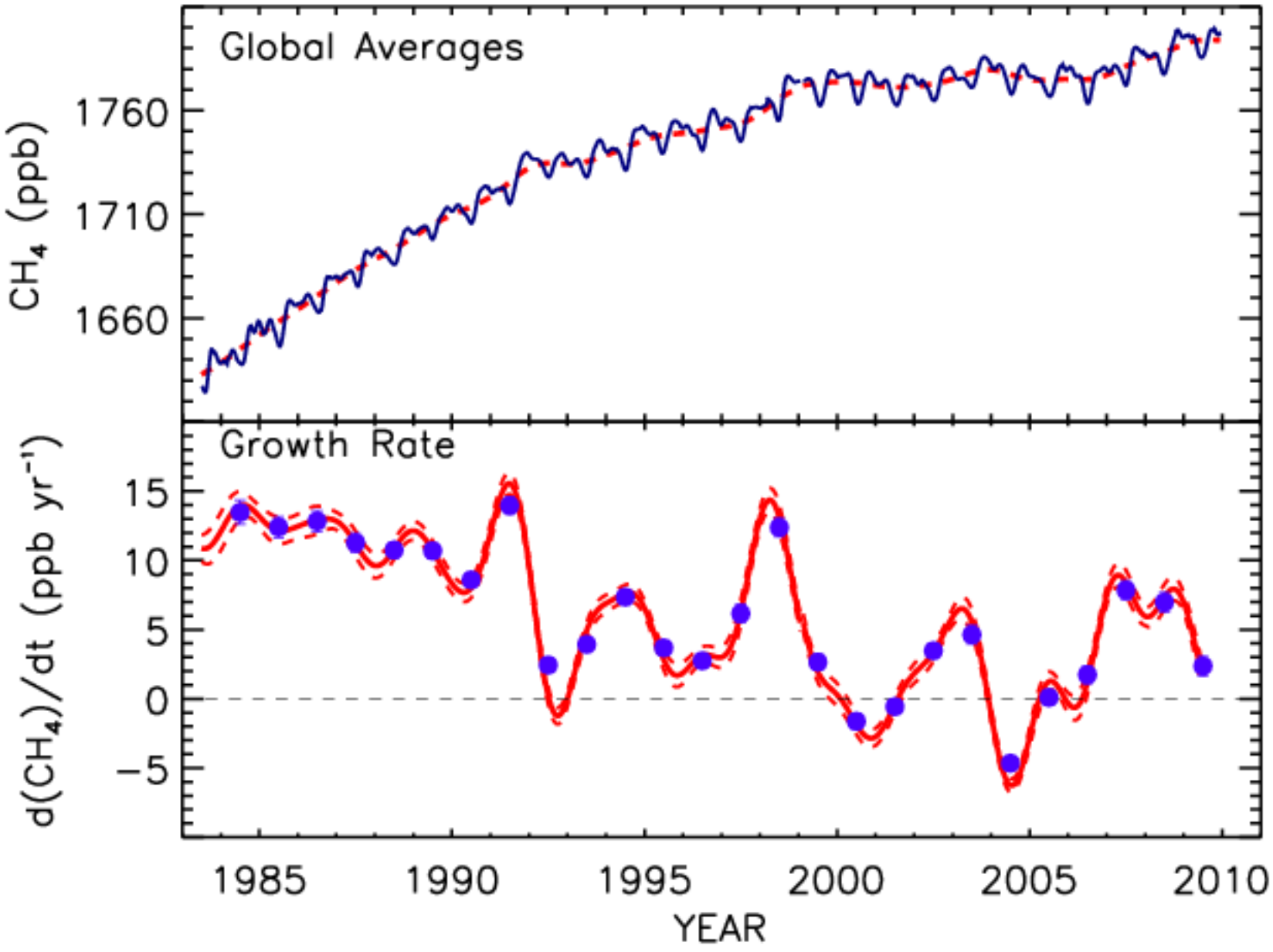

NOAA Globally Averaged CH_4
ΔCH_4 2007 7.9 ± 0.6 ppb
2008 7.0 ± 0.6 ppb
2009 2.4 ± 1.8 ppb
CH_4 (ppb)
1790
1780
1770
2000
2002
2004
2006
2008
2010
YEAR


SINE LATITUDE
1
0.5
0
−0.5
−1
LATITUDE
90°N
30°N
EQ
30°S
90°S
2000
2002
2004
2006
2008
2010
YEAR

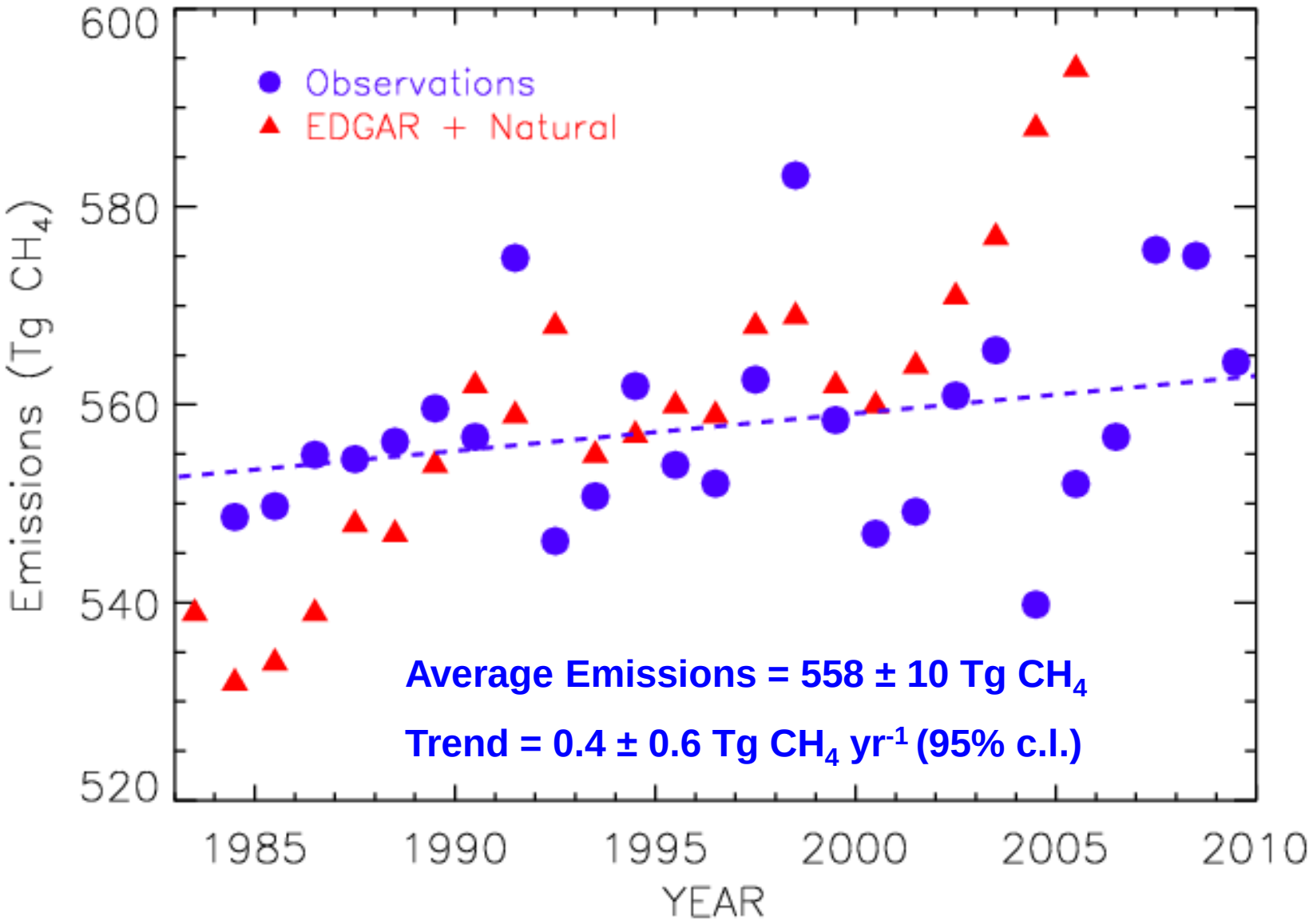
What Drove Recent Increases?

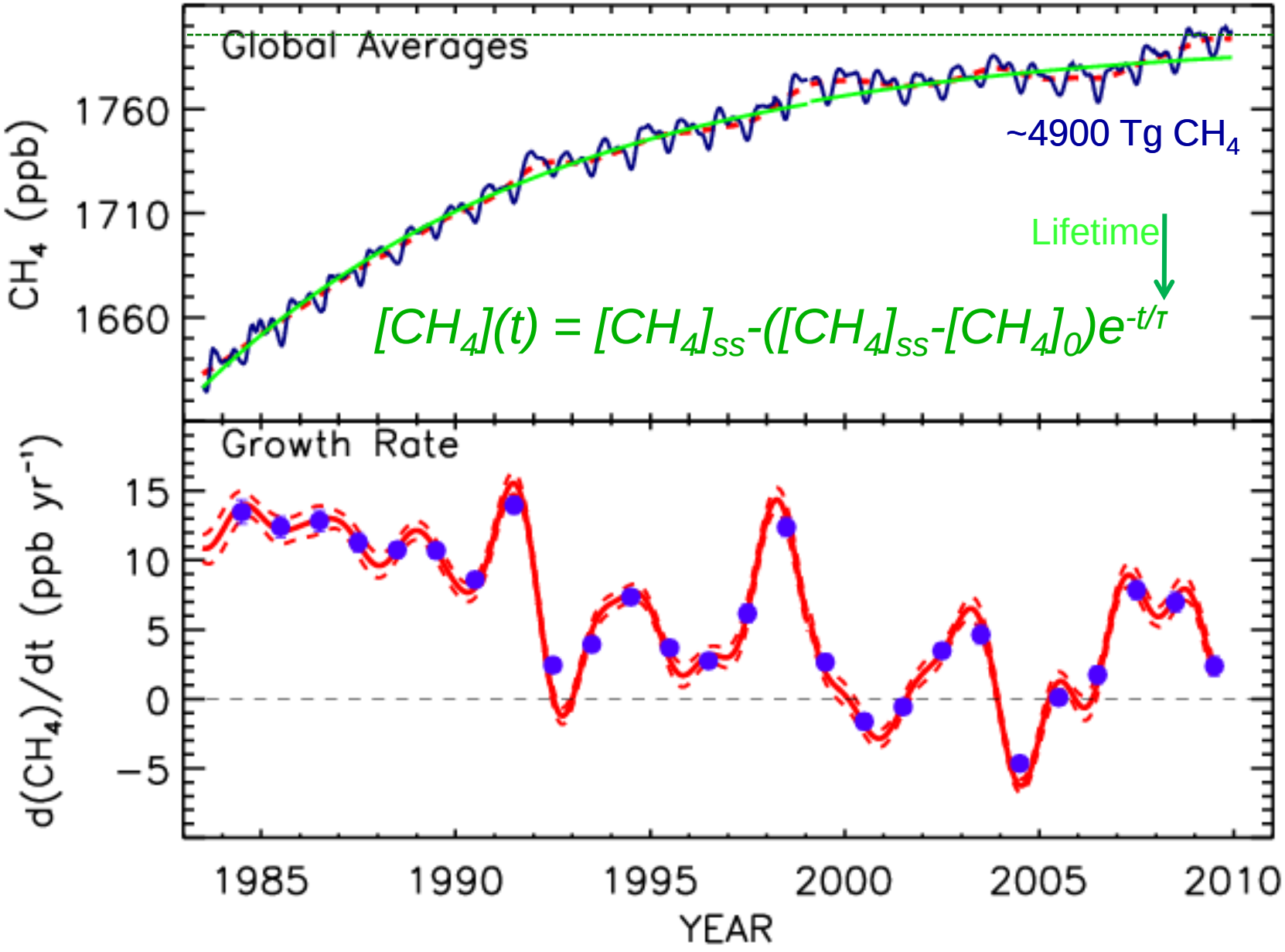
- Increased Arctic WL emissions in 2007
  - 2007: warmest year in N WL regions
  - $\delta^{13}C$ consistent with WL source
- Increased tropical WL emissions 2007/08
  - La Niña: increased tropical precipitation
  - CH_4 emissions in Amazon in 2007/8 ~50% greater than average for 2000-2006
- Biomass burning, Δ[OH] are minor

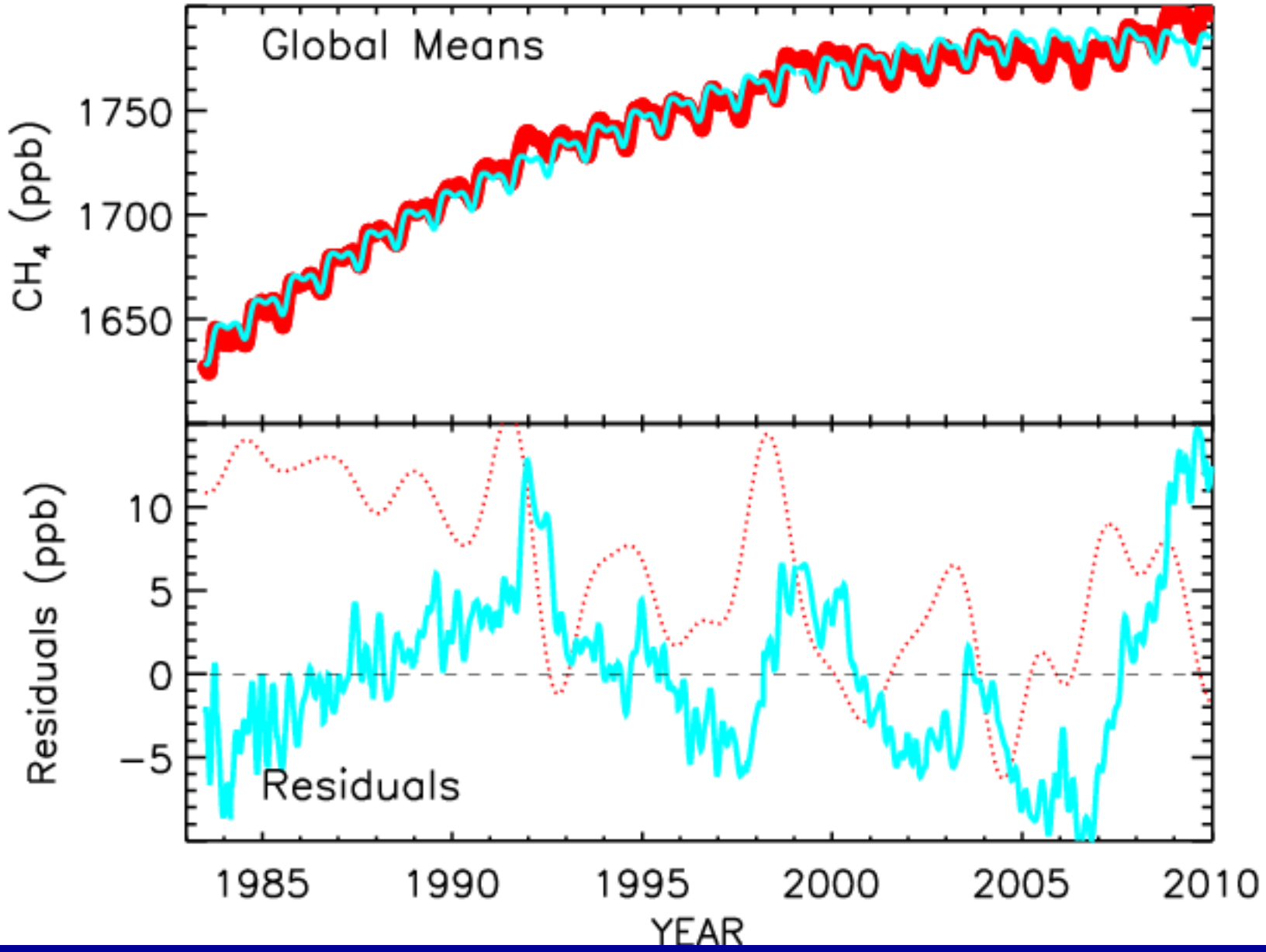
Dlugokencky et al., 2009, *GRL, 36*, doi:10.1029/2009GL039780


Global Averages
1760
1710
1660
CH4 (ppb)
Growth Rate
15
10
5
0
−5
d(CH4)/dt (ppb yr-1)
1985
1990
1995
2000
2005
2010
YEAR

Annual Emissions = $d[CH_4]/dt + [CH_4]/\tau$

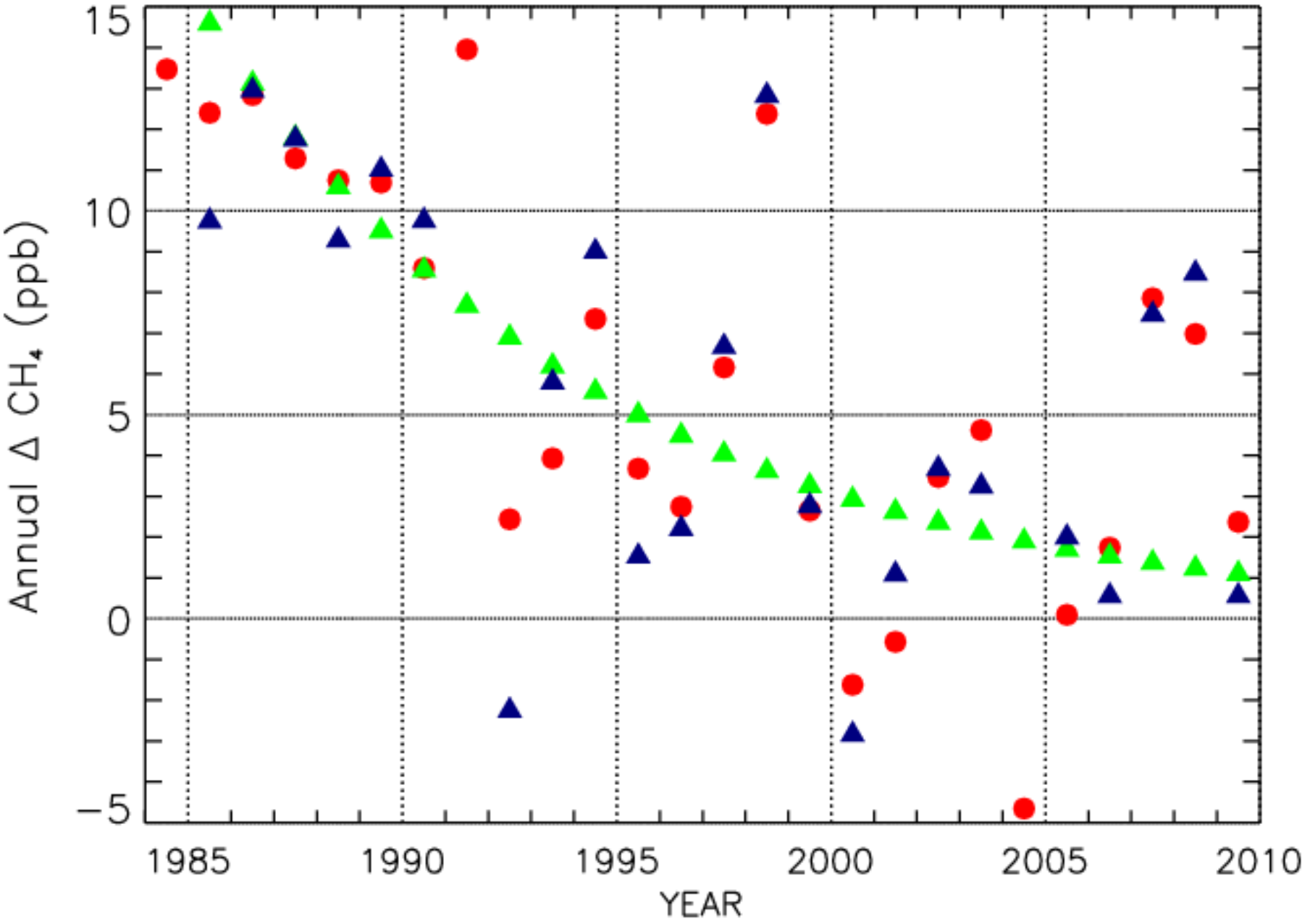



Global Averages
~4900 Tg CH_4
Lifetime
$[CH_4](t) = [CH_4]_{ss}-([CH_4]_{ss}-[CH_4]_0)e^{-t/\tau}$
CH_4 (ppb)
1760
1710
1660
Growth Rate
$d(CH_4)/dt$ (ppb yr^{-1})
15
10
5
0
−5
1985
1990
1995
2000
2005
2010
YEAR


Global Means
1750
1700
1650
CH4 (ppb)
10
5
0
−5
Residuals (ppb)
Residuals
1985
1990
1995
2000
2005
2010
YEAR

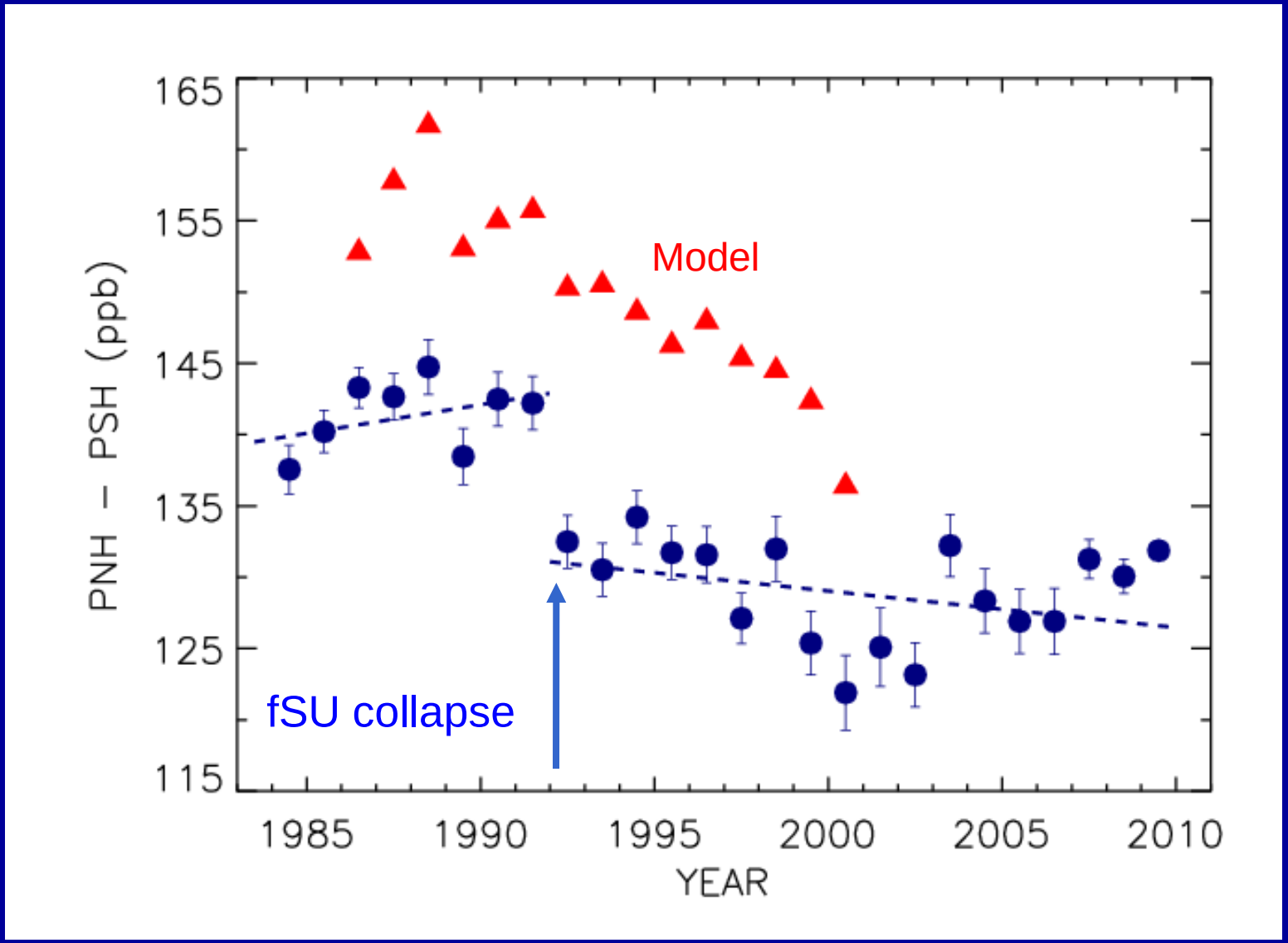
Conclusions

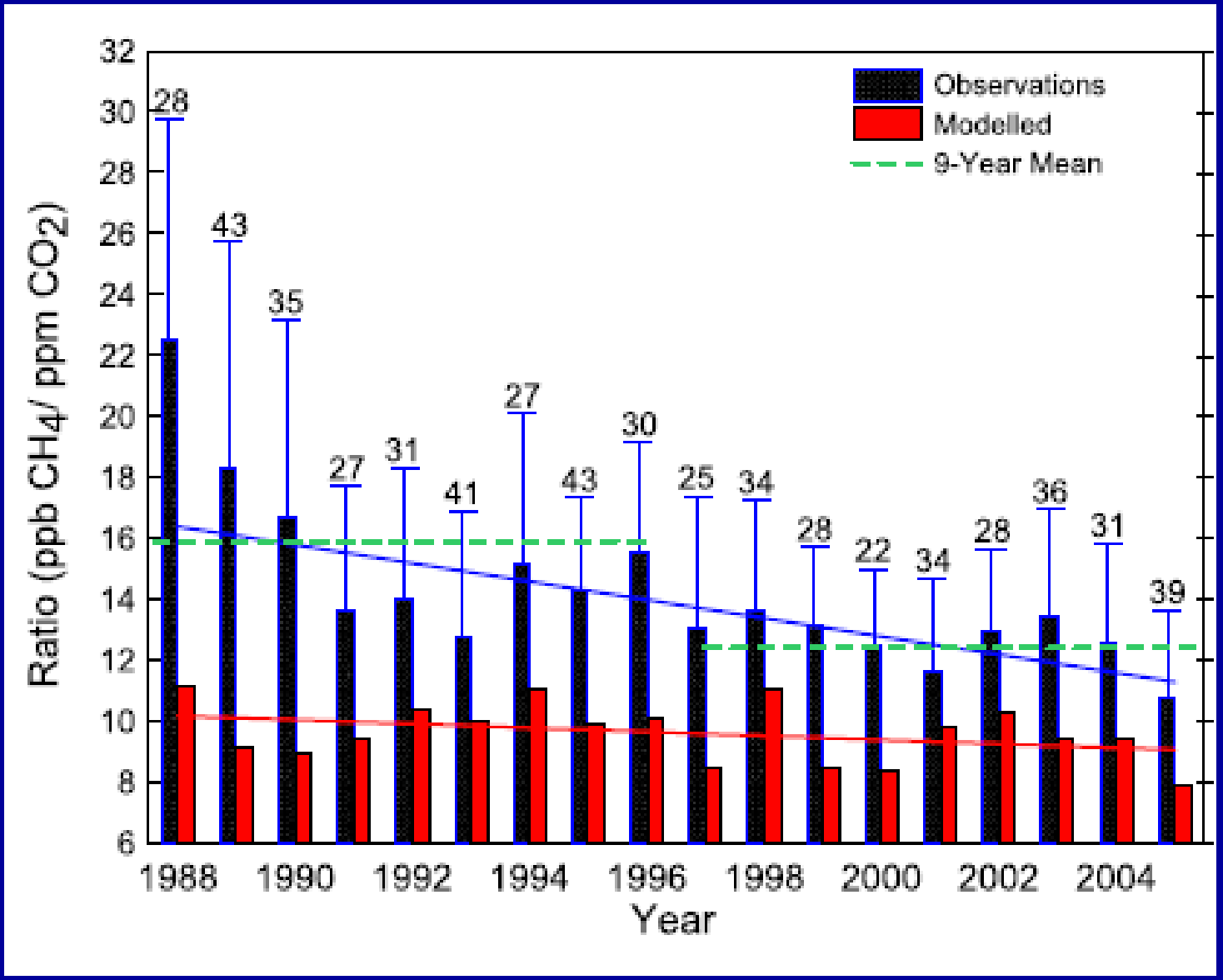
- CH_4 increased globally:
  - 7.5 ppb yr^{-1} over in 2007 and 2008
  - 2.4 ppb in 2009
- Still consistent with approach to SS:
  - Anomaly in 2007/08 is large
  - Natural IAV
- Claims about hydrates and PF exaggerated:
  - Arctic emissions lower than 20 years ago
  - Arctic emissions likely to increase, but slowly


15
10
5
0
−5
Annual Δ CH₄ (ppb)
1985
1990
1995
2000
2005
2010
YEAR

Interpolar Difference

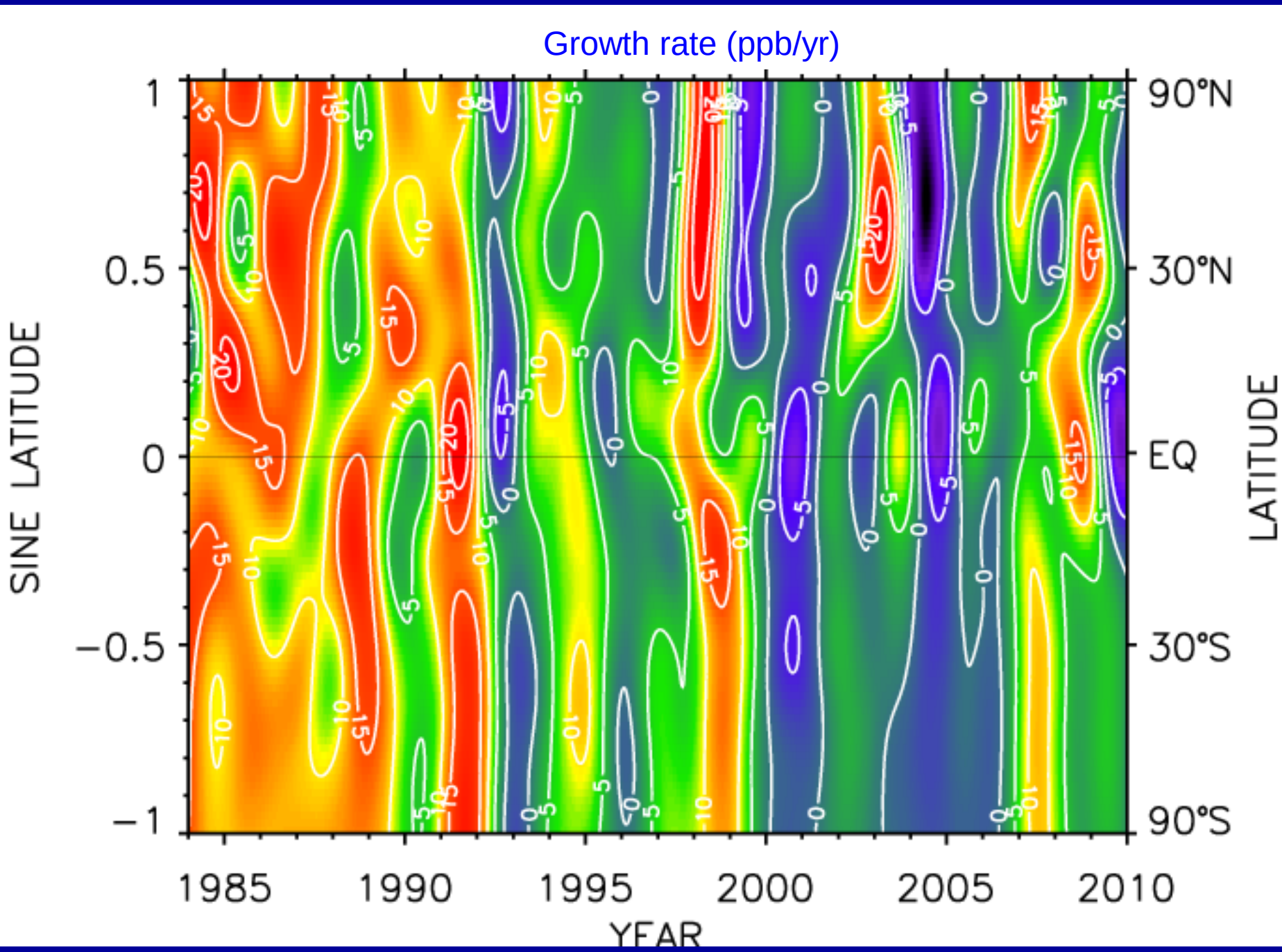
Update of: E. J. Dlugokencky, S. Houweling, L. Bruhwiler, K. A. Masarie, P. M. Lang, J. B. Miller, and P. P. Tans (2003), Atmospheric methane levels off: Temporary pause or a new steady-state?, *Geophys. Res. Lett.*, 30, 1992, doi:10.1029/2003GL018126.



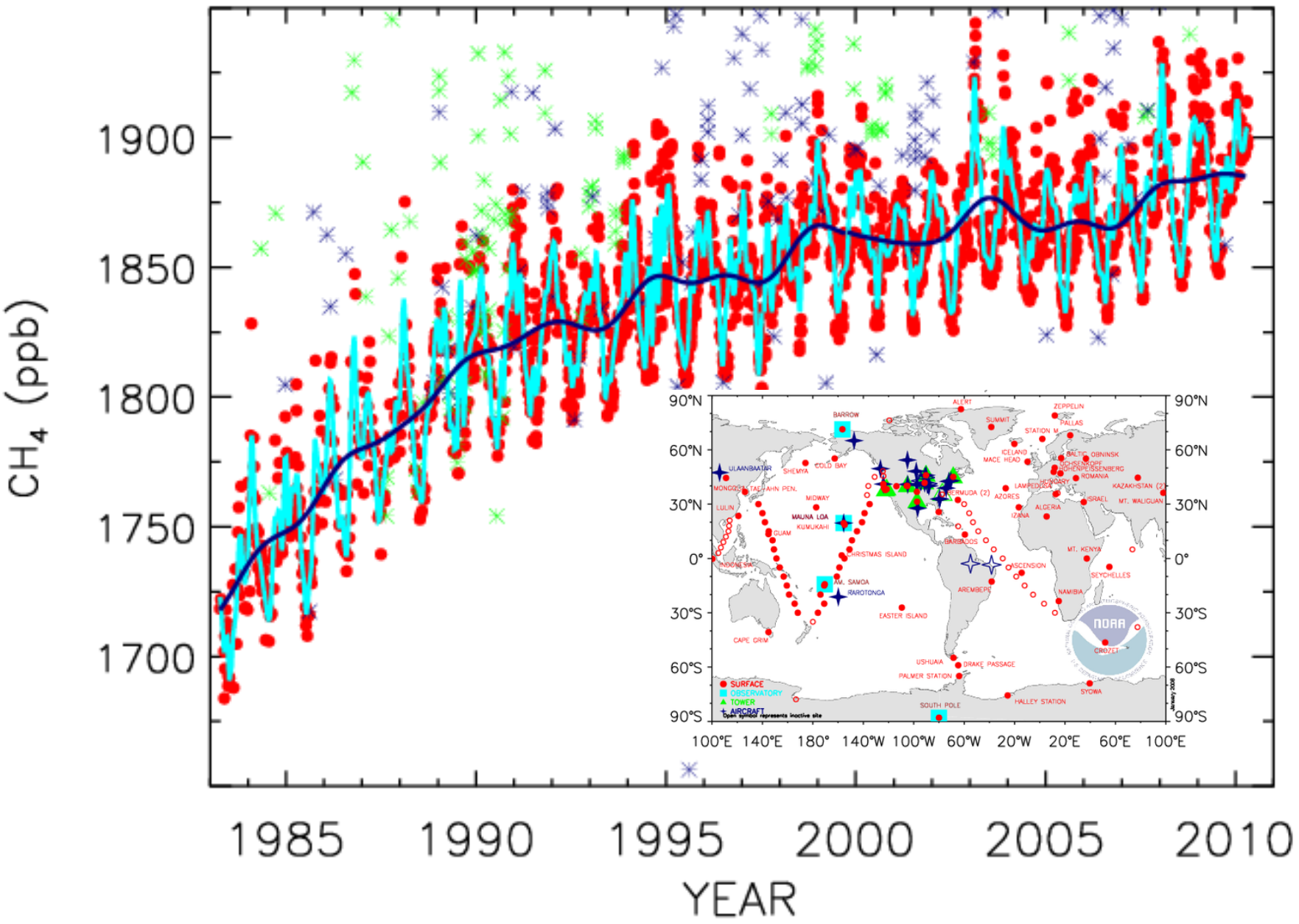


Worthy et al.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, D10301, doi:10.1029/2008JD011239, 2009


Growth rate (ppb/yr)
SINE LATITUDE
1
0.5
0
−0.5
−1
90°N
30°N
EQ
30°S
90°S
LATITUDE
1985
1990
1995
2000
2005
2010
YEAR

Barrow, AK: www.esrl.noaa.gov/gmd/ccgg/iadv/



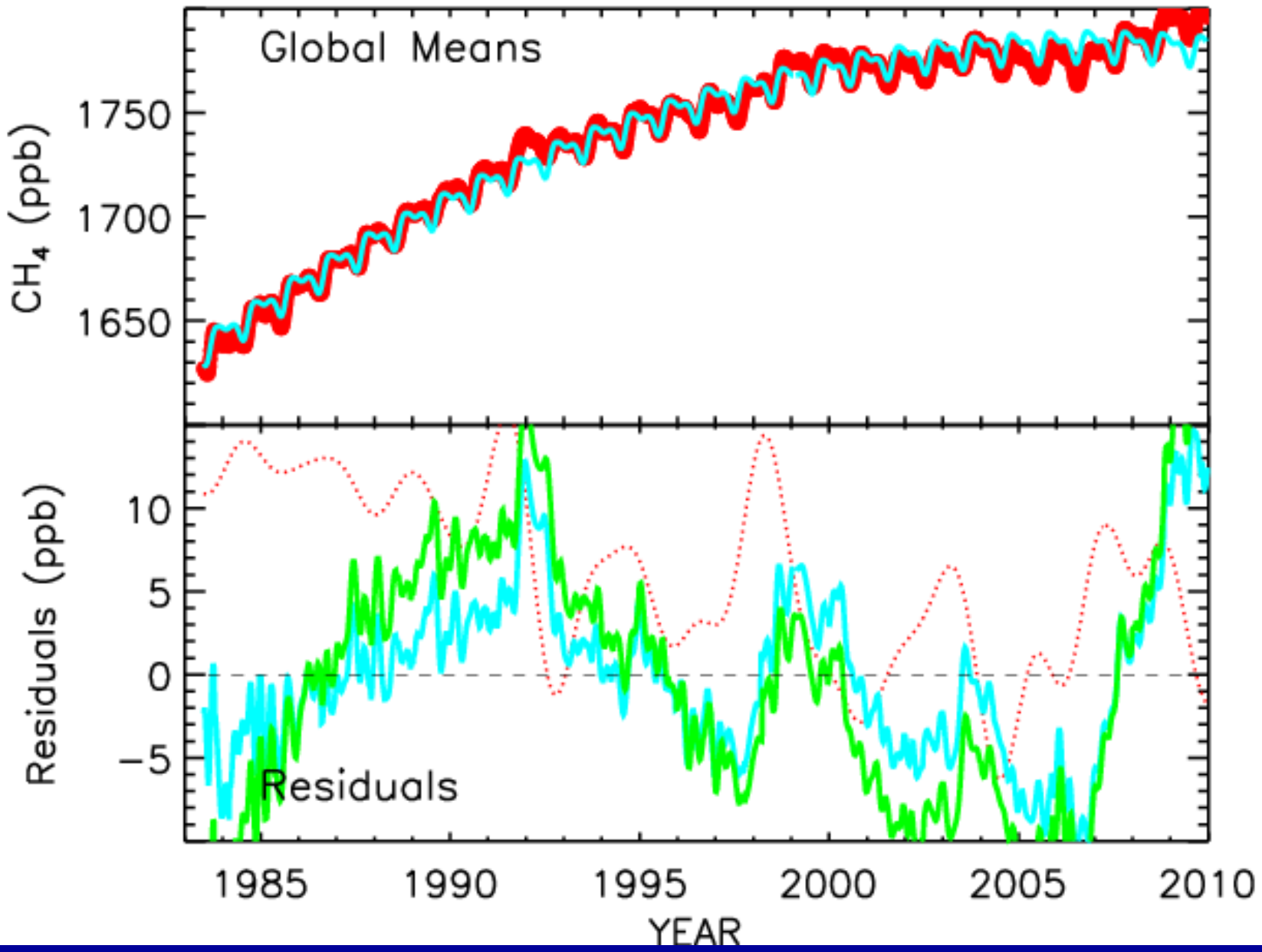
Global Annual Emissions (Top Down)

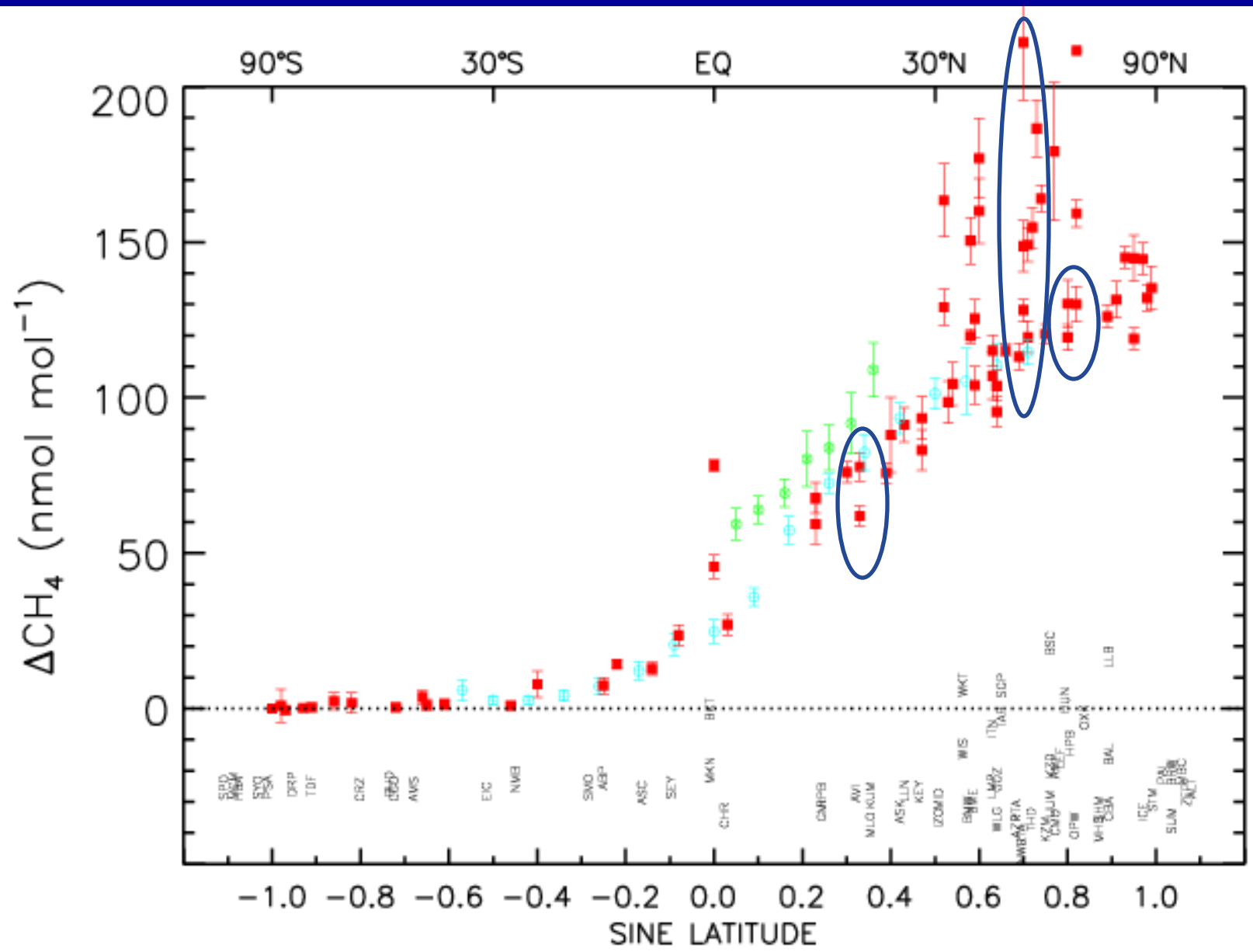
$$E = d[CH_4]/dt + [CH_4]/\tau$$

Where E = emissions

τ = CH_4 lifetime = 8.9 years

(Oxidation by OH and soil microbes)


Global Means
1750
1700
1650
CH_4 (ppb)
Residuals (ppb)
10
5
0
−5
Residuals
1985
1990
1995
2000
2005
2010
YEAR

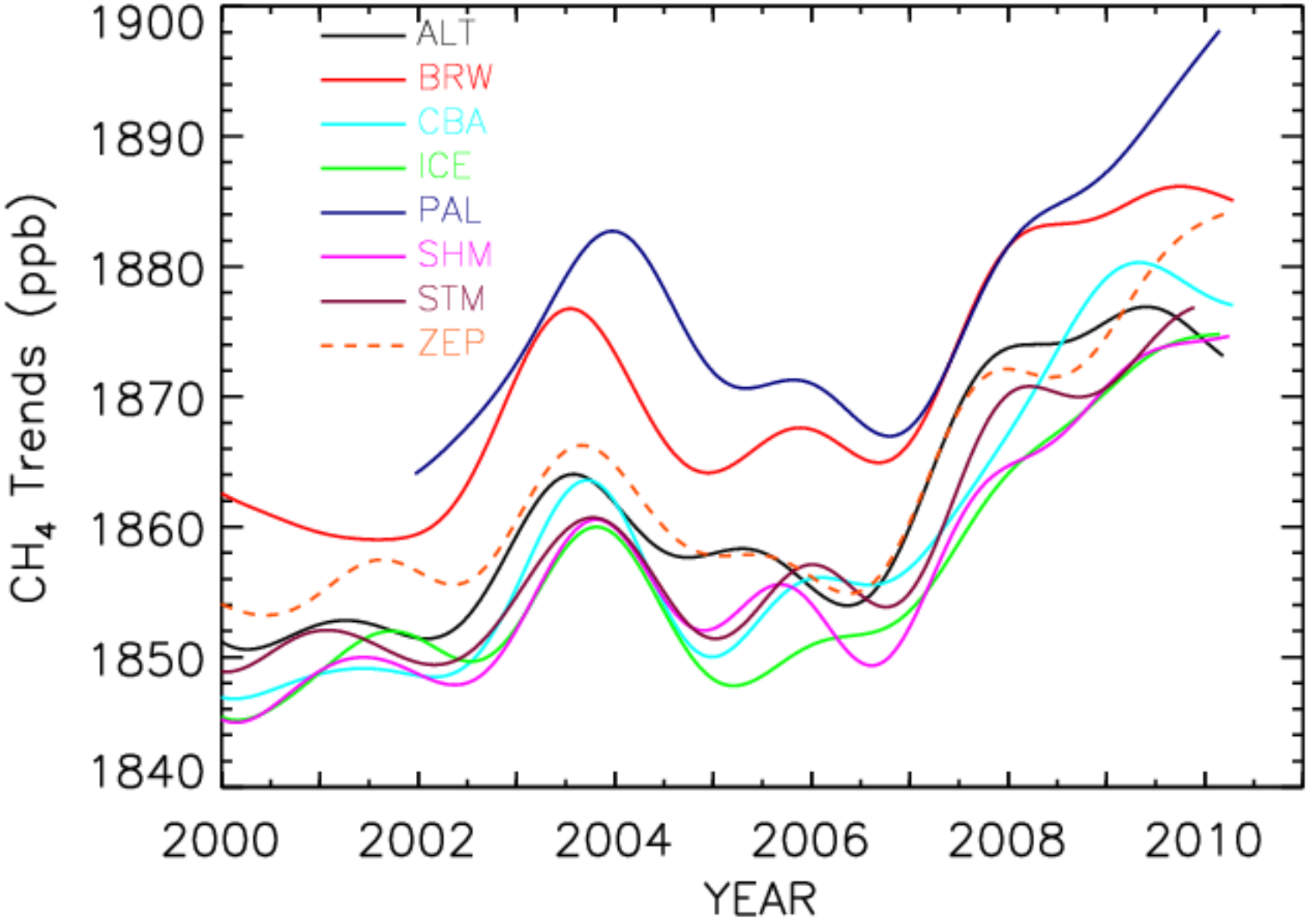

90°S
30°S
EQ
30°N
90°N
200
150
100
50
0
ΔCH4 (nmol mol−1)
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
SINE LATITUDE

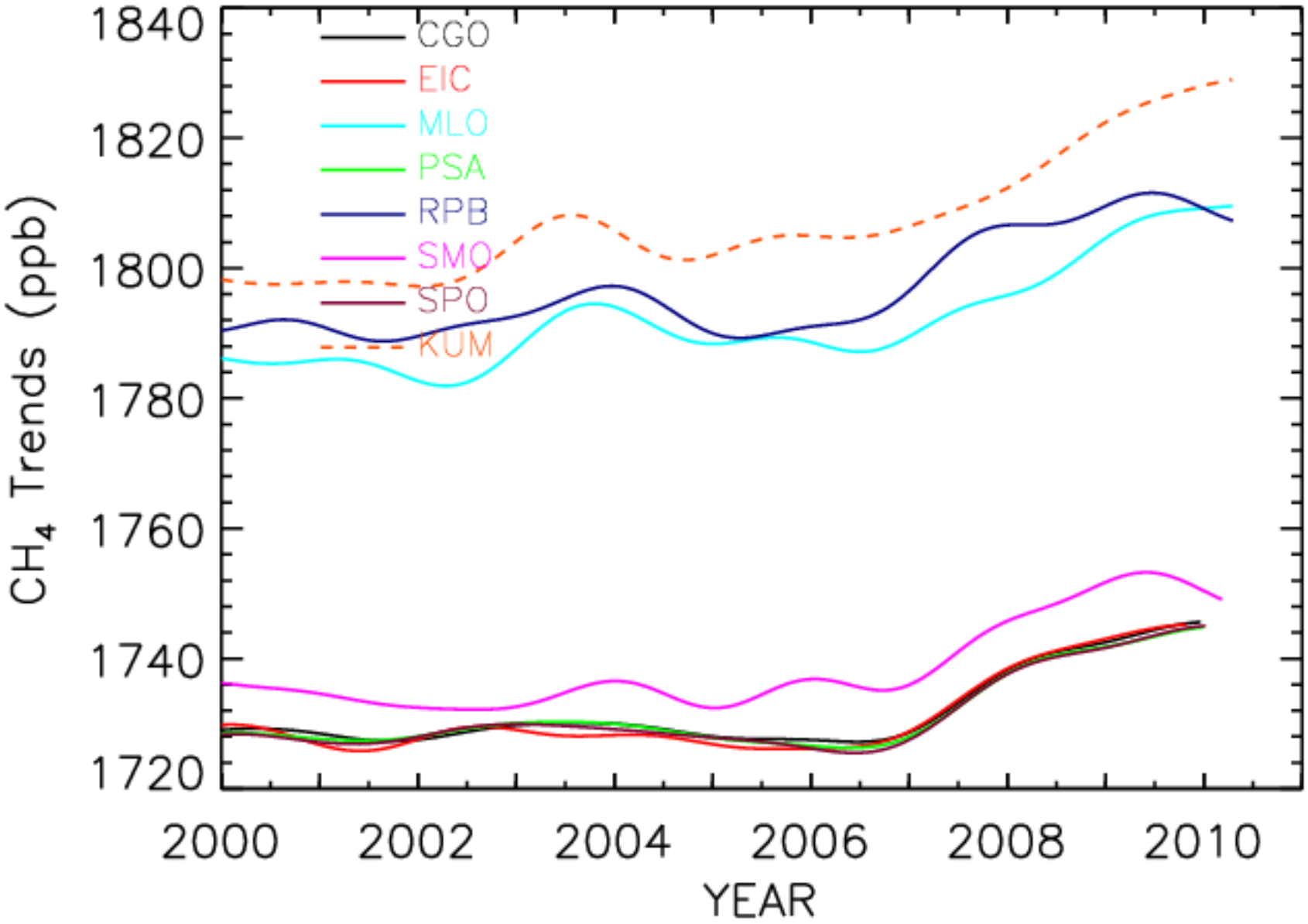
Global CH_4 Budget by Source

Source	Bousquet (Tg/yr)	IPCC Range (Tg/yr)
Anthropogenic		
Energy	110 13	74-106
Enteric fermentation	90 14	76-92
Rice agriculture	31 5	31-112
Biomass burning	50 8	14-88
Waste	55 11	35-69
Natural		
Wetlands	147 15	100-231
Termites	23 4	20-29
Oceans	19 6	4-15
Total	**525 8**	**503-610**

Sinks	Bousquet (Tg/yr)	IPCC (Tg/yr)
Troposphere	448 1	428-511
Stratosphere	37 1	30-45
Soil	21 3	26-34
Total	**506**	**492-581**

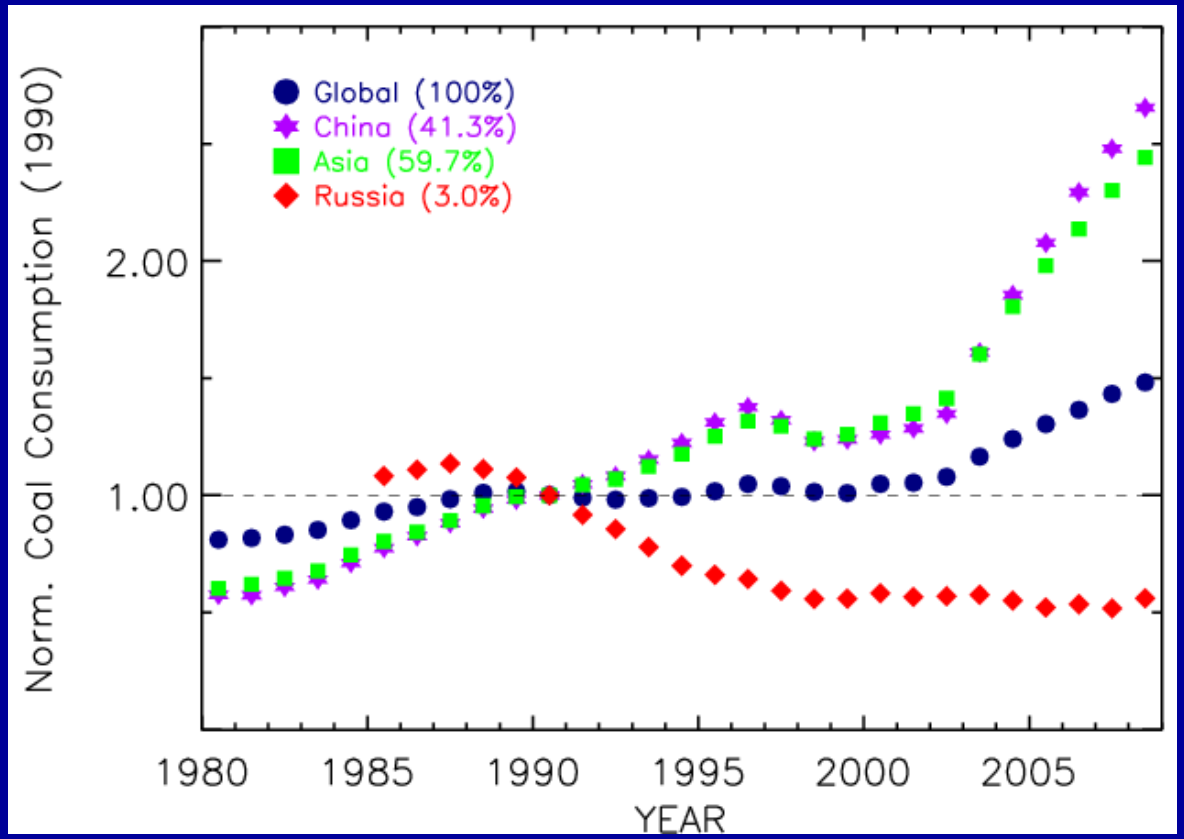
Bousquet et al., 2006, *Nature*, **443**, 439-443, doi:10.1038/nature05132.


ALT
BRW
CBA
ICE
PAL
SHM
STM
ZEP
1900
1890
1880
1870
1860
1850
1840
CH4 Trends (ppb)
2000
2002
2004
2006
2008
2010
YEAR


CGO
EIC
MLO
PSA
RPB
SMO
SPO
KUM
1840
1820
1800
1780
1760
1740
1720
CH4 Trends (ppb)
2000
2002
2004
2006
2008
2010
YEAR

Anthropogenic contribution to 2007 - 2009 CH_4 increases

- Δ Anthropogenic emissions
  - Expect gradual changes



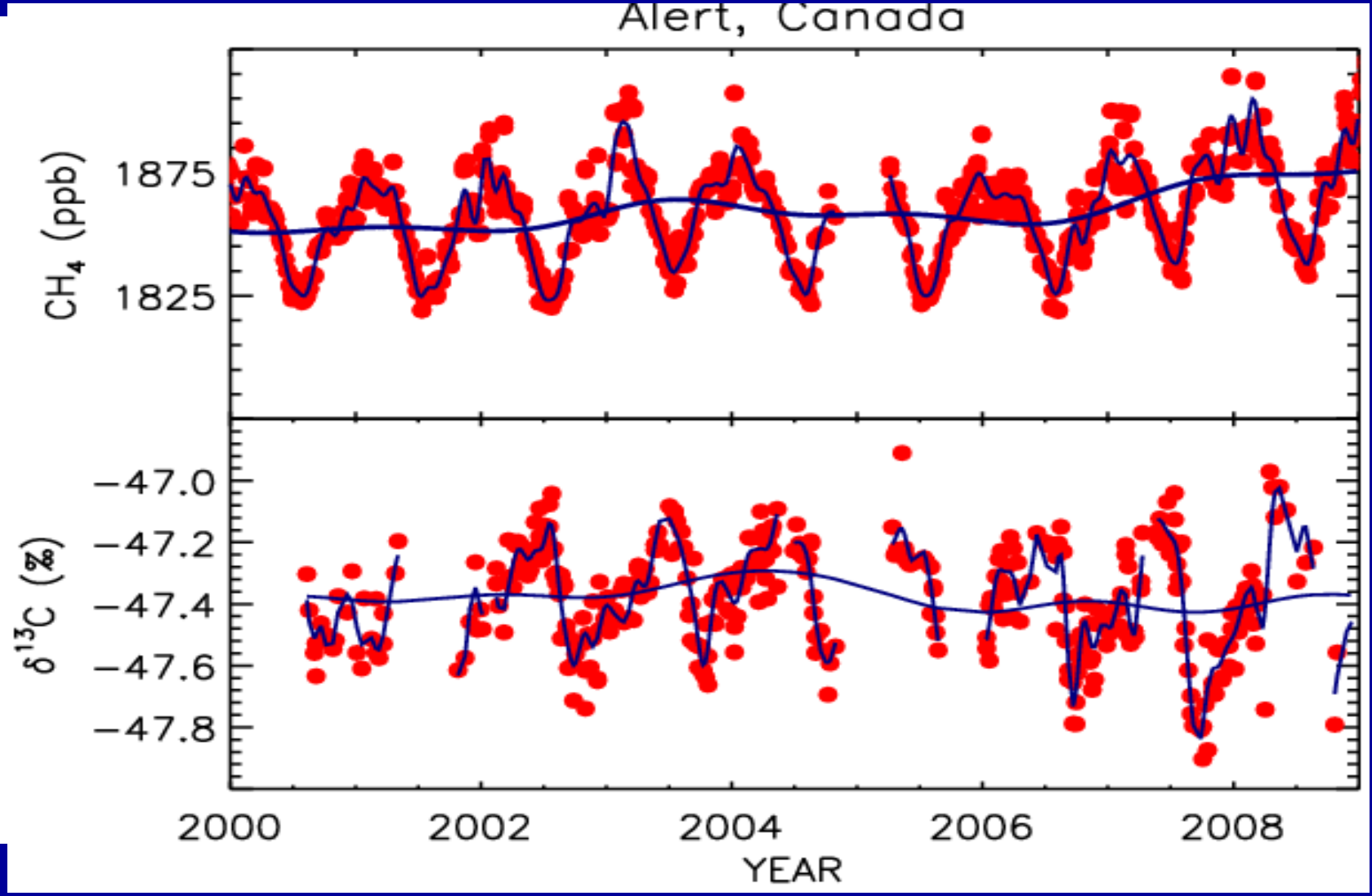
Biomass burning contribution to 2007/2008 CH_4 increases:

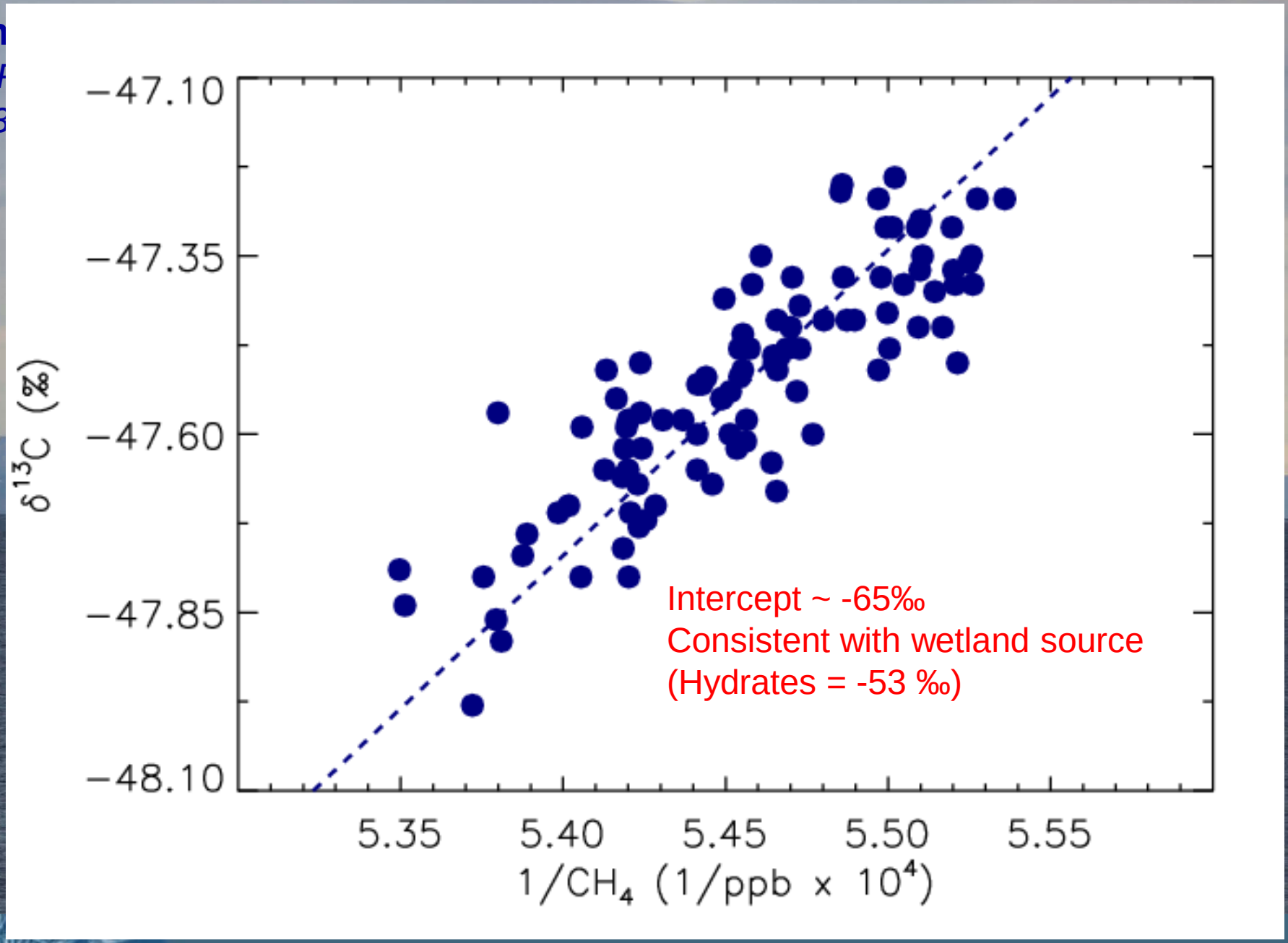
- Chloromethane, CH_3Cl (NOAA)
- Remotely sensed CO (MOPITT)
- NOAA surface CO observations

Sink contribution to 2007 - 2009 CH_4 increases

- Δ Loss rate (Δ [OH])
  - CH_3CCl_3 analysis suggests not (-2 to +1%)
  - PCE suggests not (I. Simpson, UCI)
  - CO suggests not

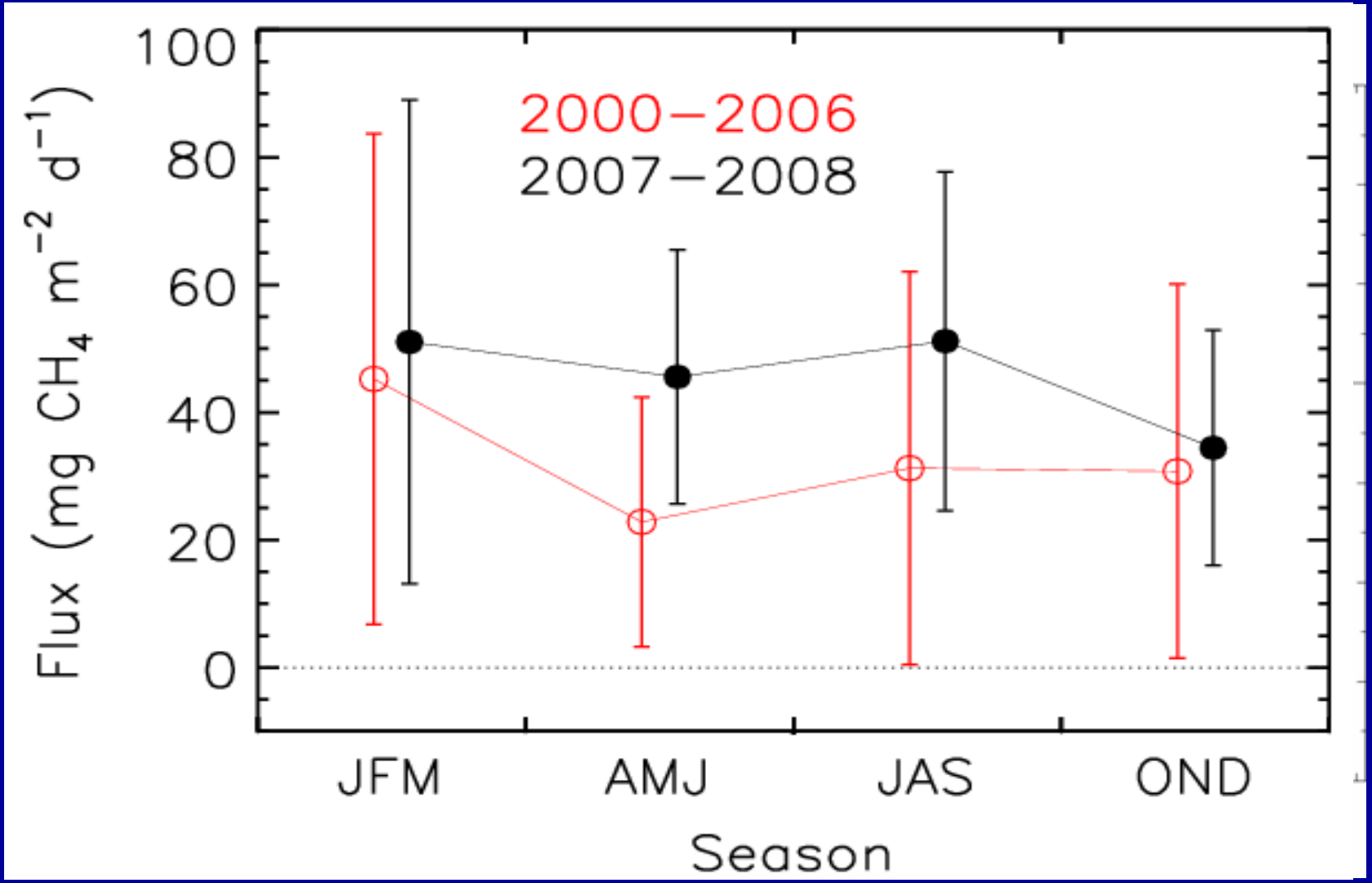
Wetland contribution to 2007/2008 CH_4 increases:

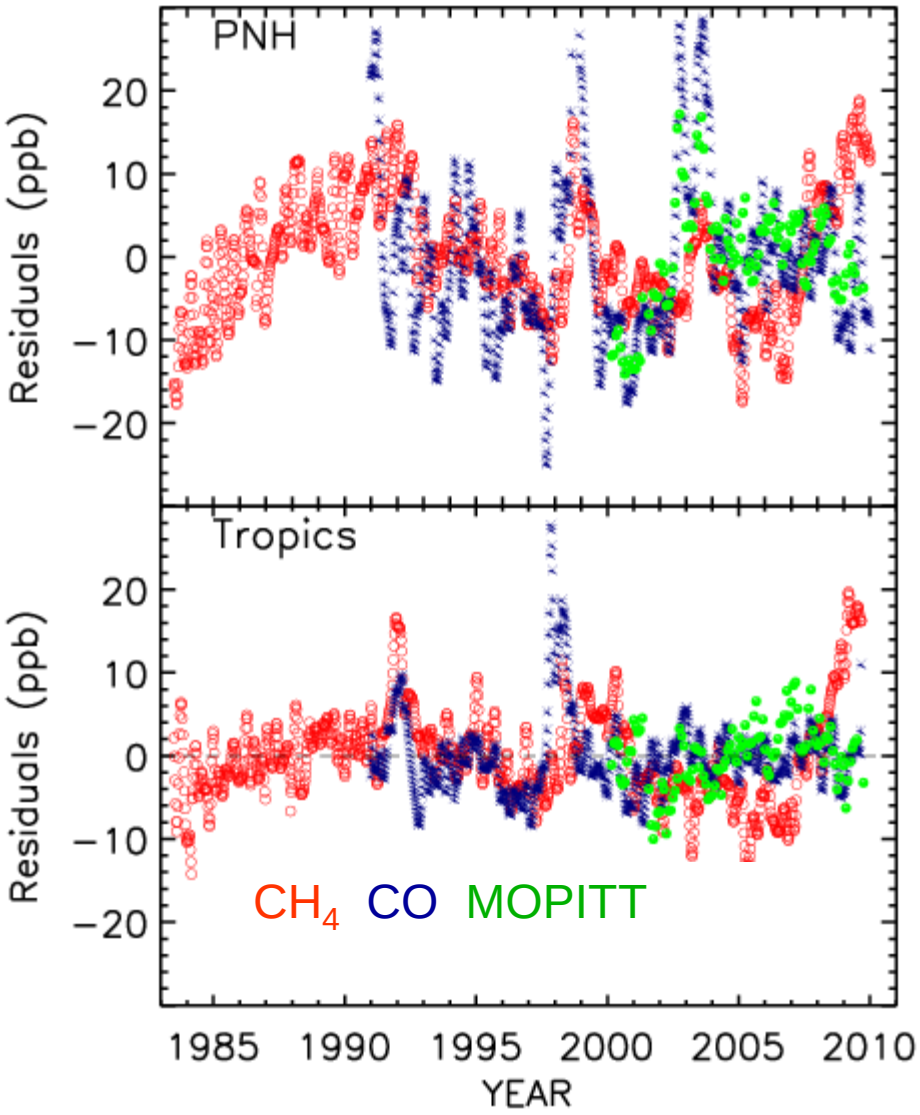




Westbrook et al., Geophys. Res. Lett, 2009

Wetland contribution to 2007/2008 CH_4 increases:





Polar northern latitudes

Tropics

MOPITT CO courtesy of Louisa Emmons, NCAR