Methane: The Changing Global Budget and the Risk of Surprise

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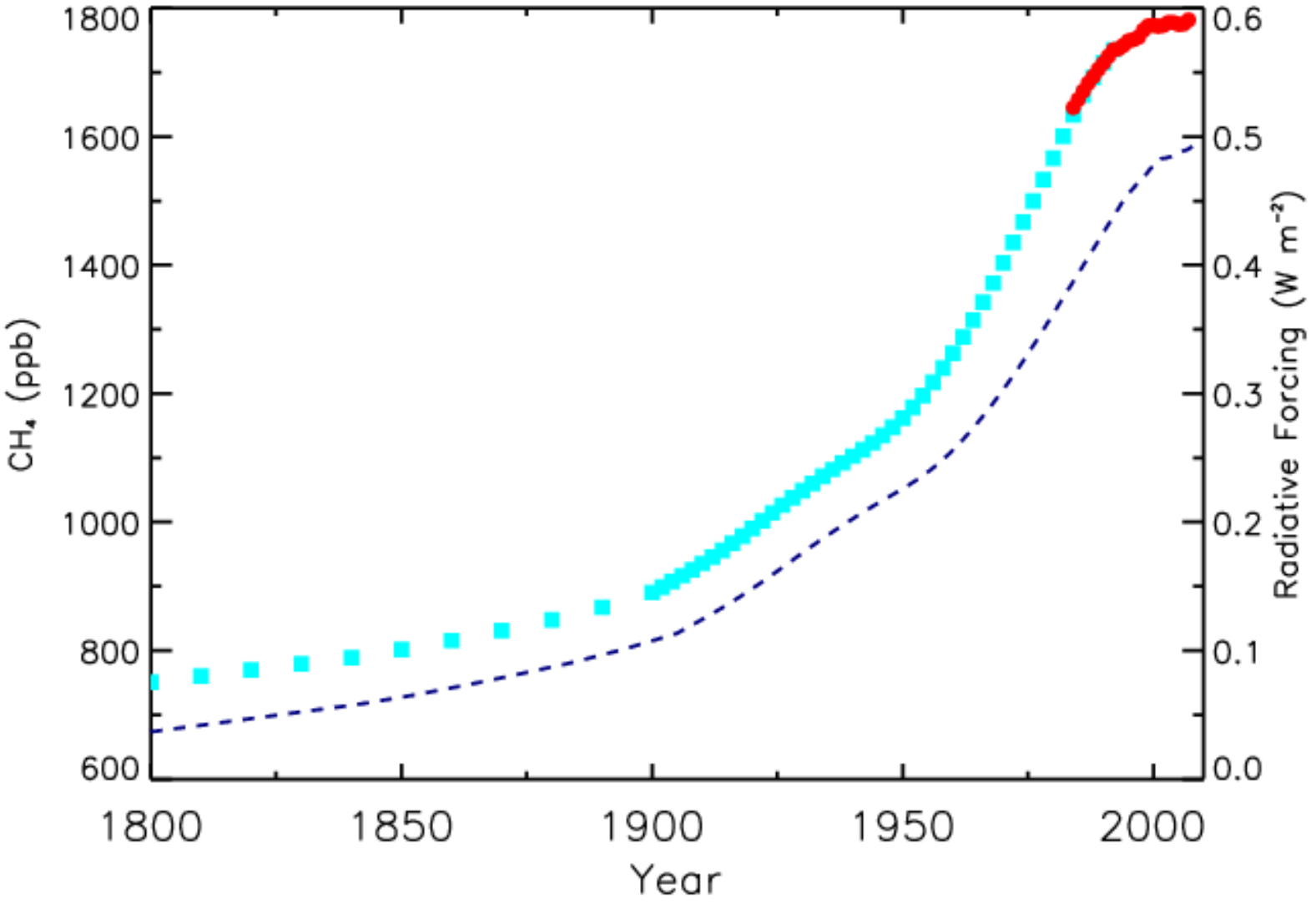
Outline

- Introduction
- Global atmospheric CH_4 observations
  - Mole fractions + isotopes
- Current CH_4 budget and its uncertainties
- What are the potential dangers?
  - Economic growth → increased CH_4 emissions
  - Strong climate feedbacks from permafrost and methane hydrates
- Conclusions

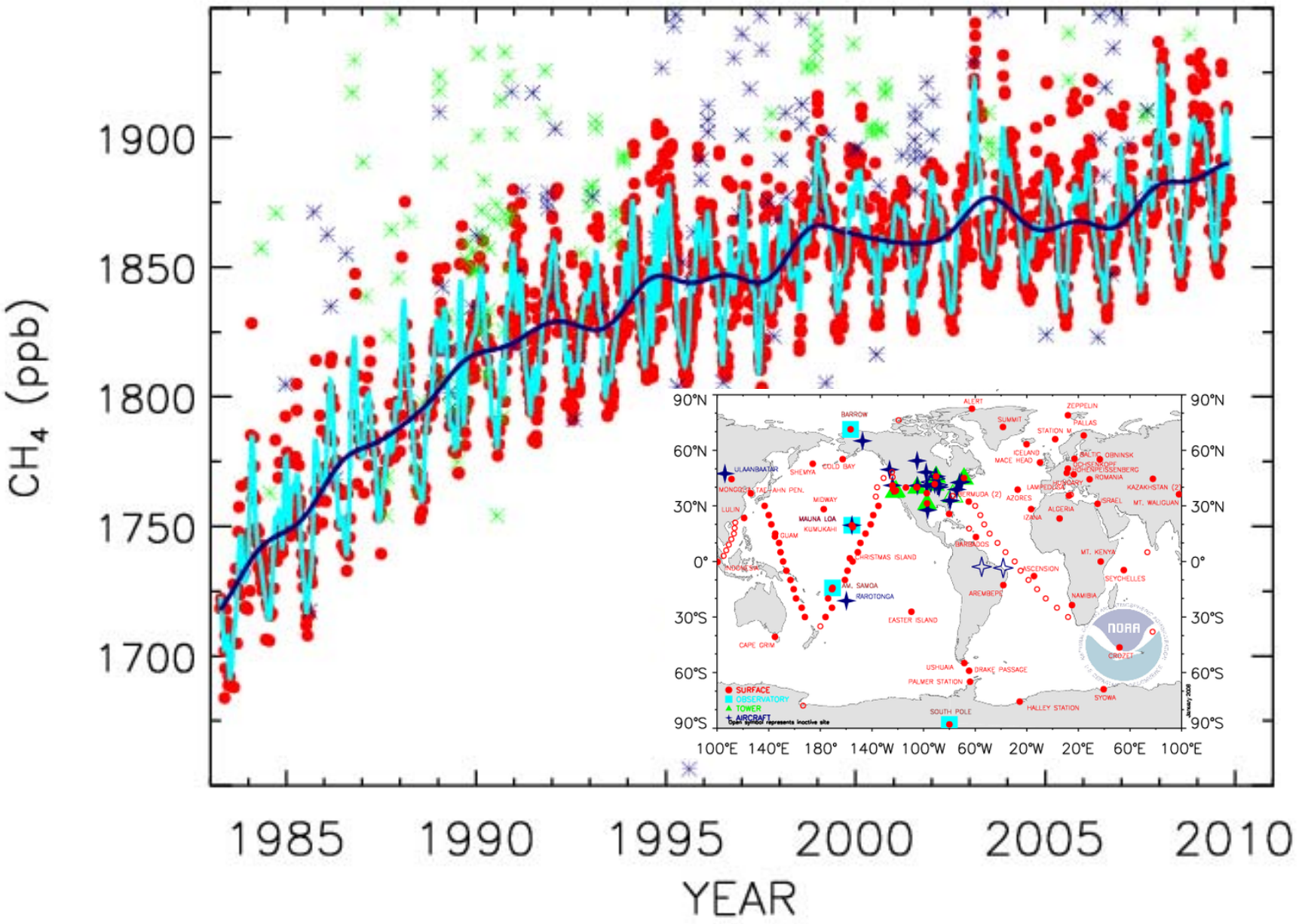
Introduction: Why is CH_4 important?

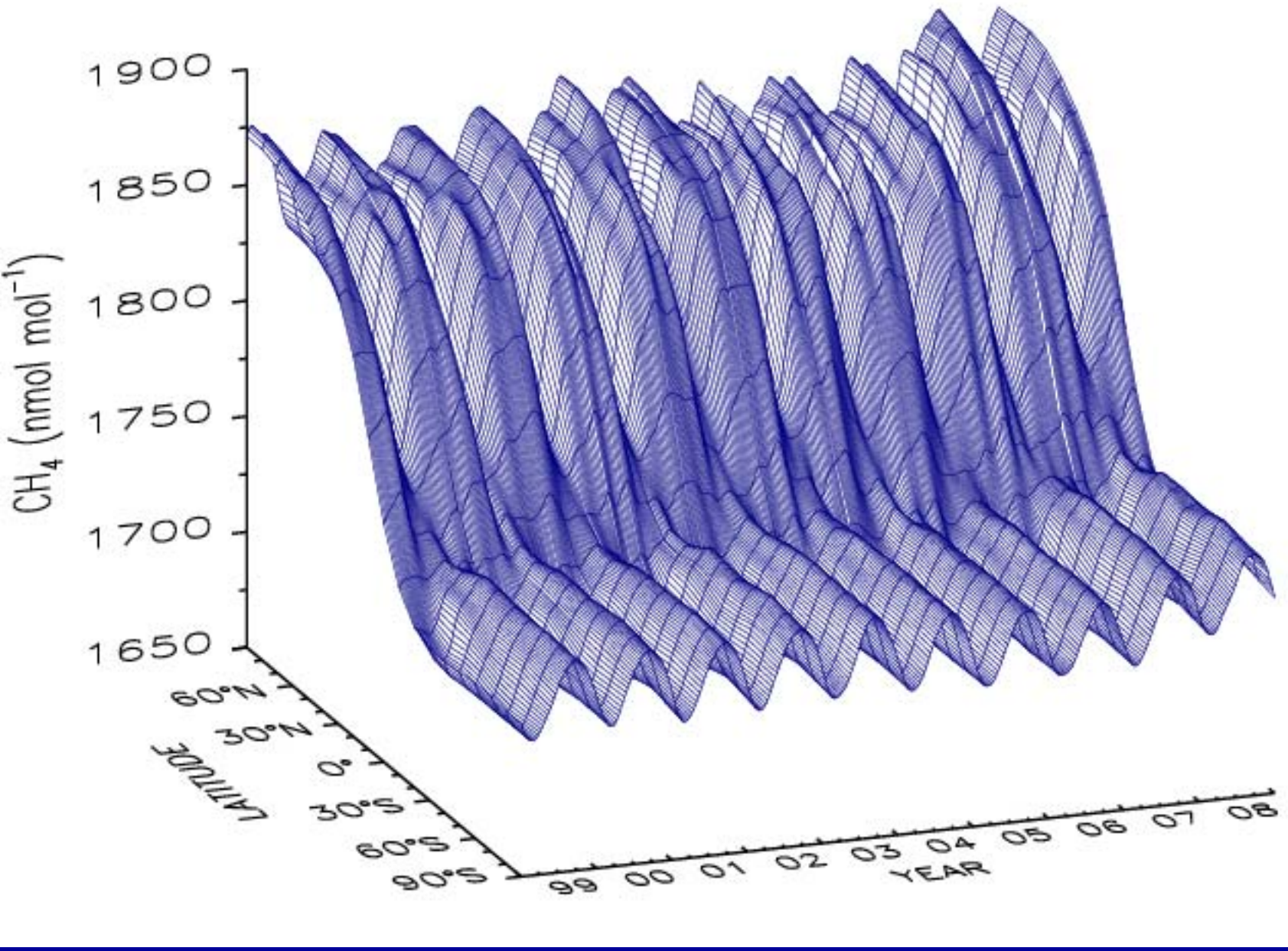
- RF = 0.5 W m^{-2} direct forcing
  - + 0.2 W m^{-2} indirect (trop. O_3 and strat. H_2O)
- Atmospheric Chemistry: OH and O_3
  - Tropospheric oxidizing capacity
- Relatively short lifetime (~9 yr)
  - GWP = 25 (100 yr), 72 (20 yr)
- Emissions reductions cost effective
  - Value = ~US$150 billion per Tg CH_4

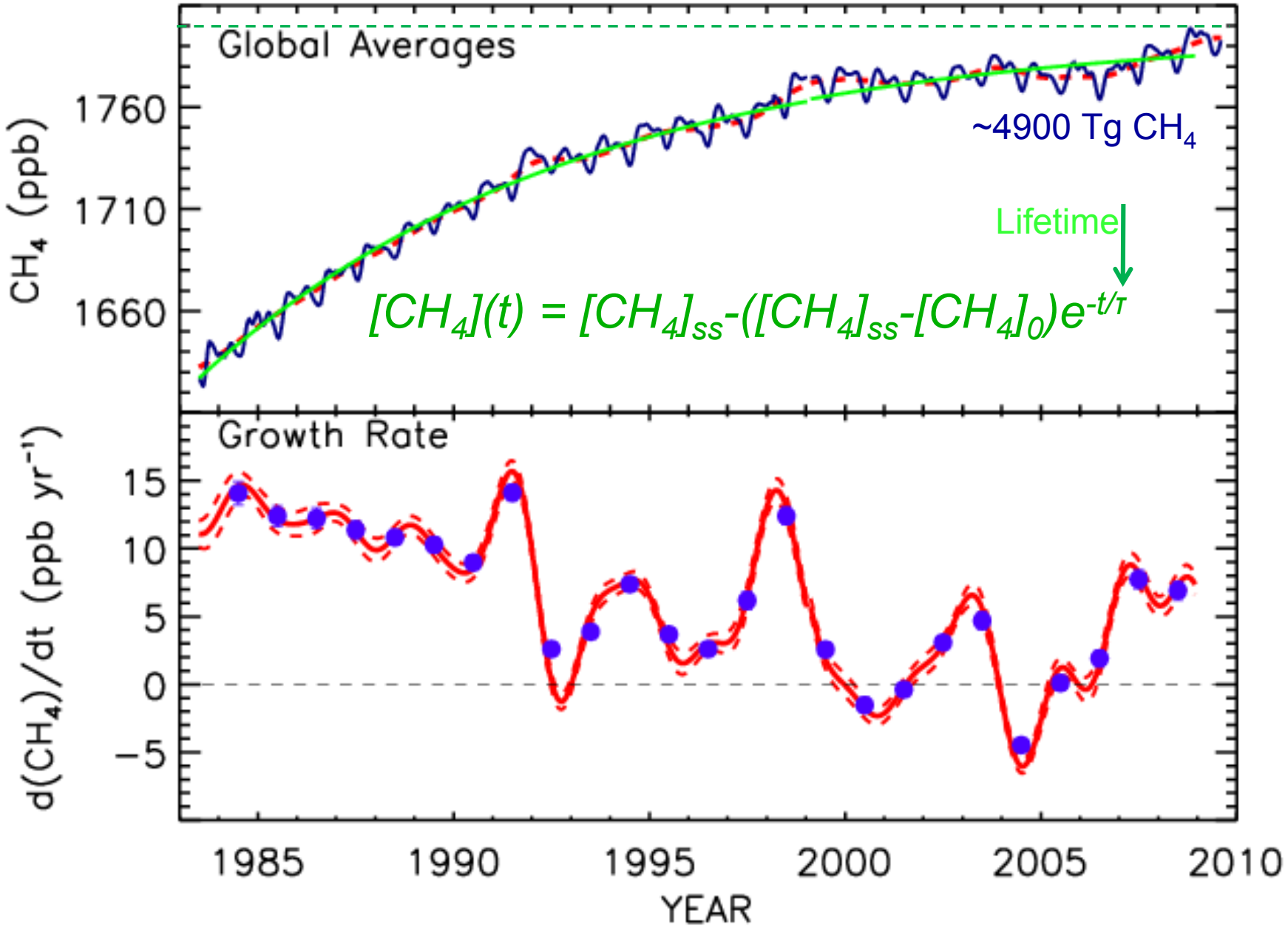
Introduction: Why is CH_4 important?



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




1900
1850
1800
1750
1700
1650
CH4 (nmol mol-1)
60°N
30°N
0°
30°S
60°S
90°S
LATITUDE
99
00
01
02
03
04
05
06
07
08
YEAR


Global Averages
~4900 Tg CH4
Lifetime
[CH4](t) = [CH4]ss-([CH4]ss-[CH4]0)e-t/τ
CH4 (ppb)
1760
1710
1660
Growth Rate
d(CH4)/dt (ppb yr-1)
15
10
5
0
−5
1985
1990
1995
2000
2005
2010
YEAR

Global Annual Emissions (Top Down)

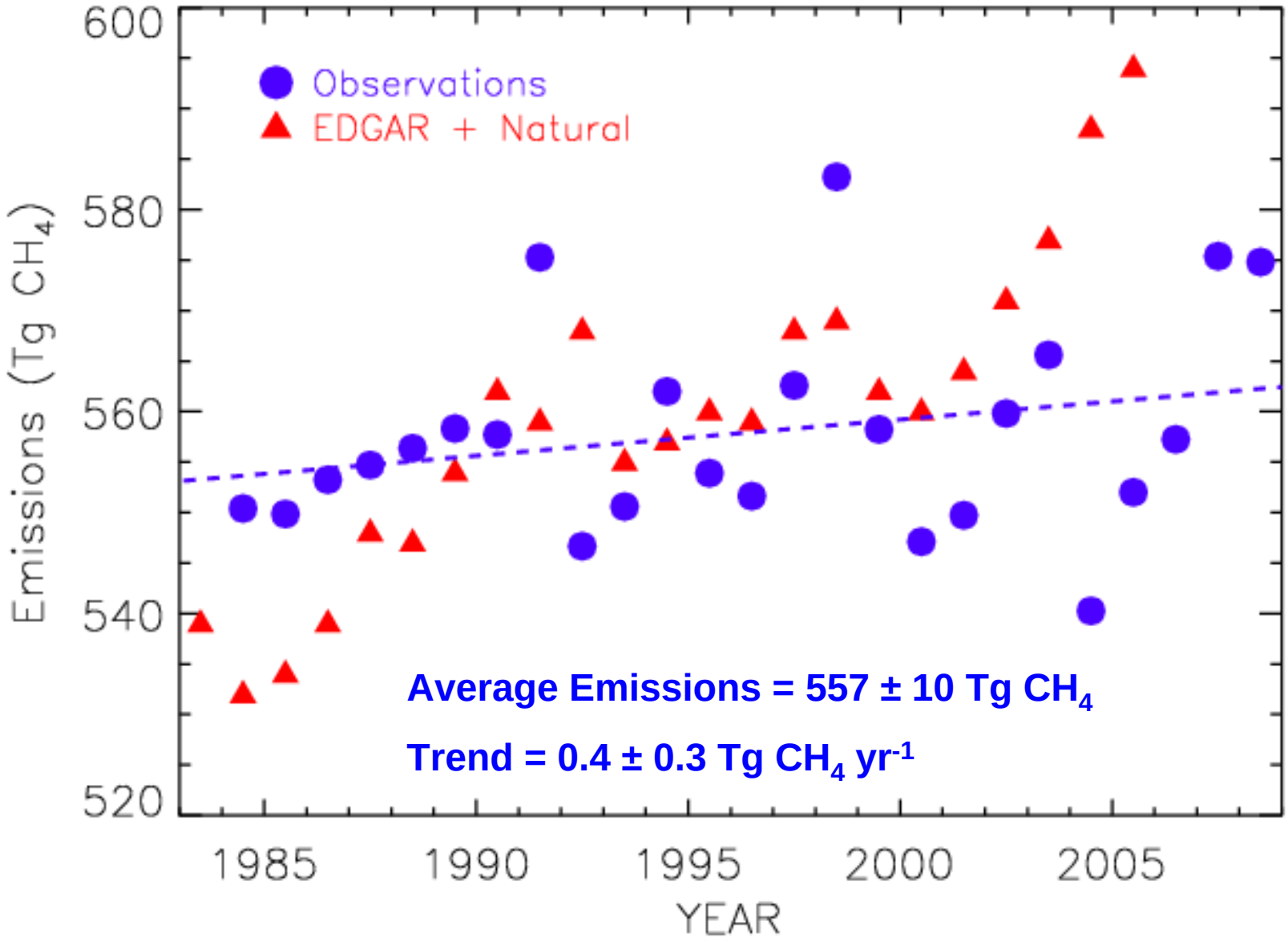
$$E = d[CH_4]/dt + [CH_4]/\tau$$

Where E = emissions

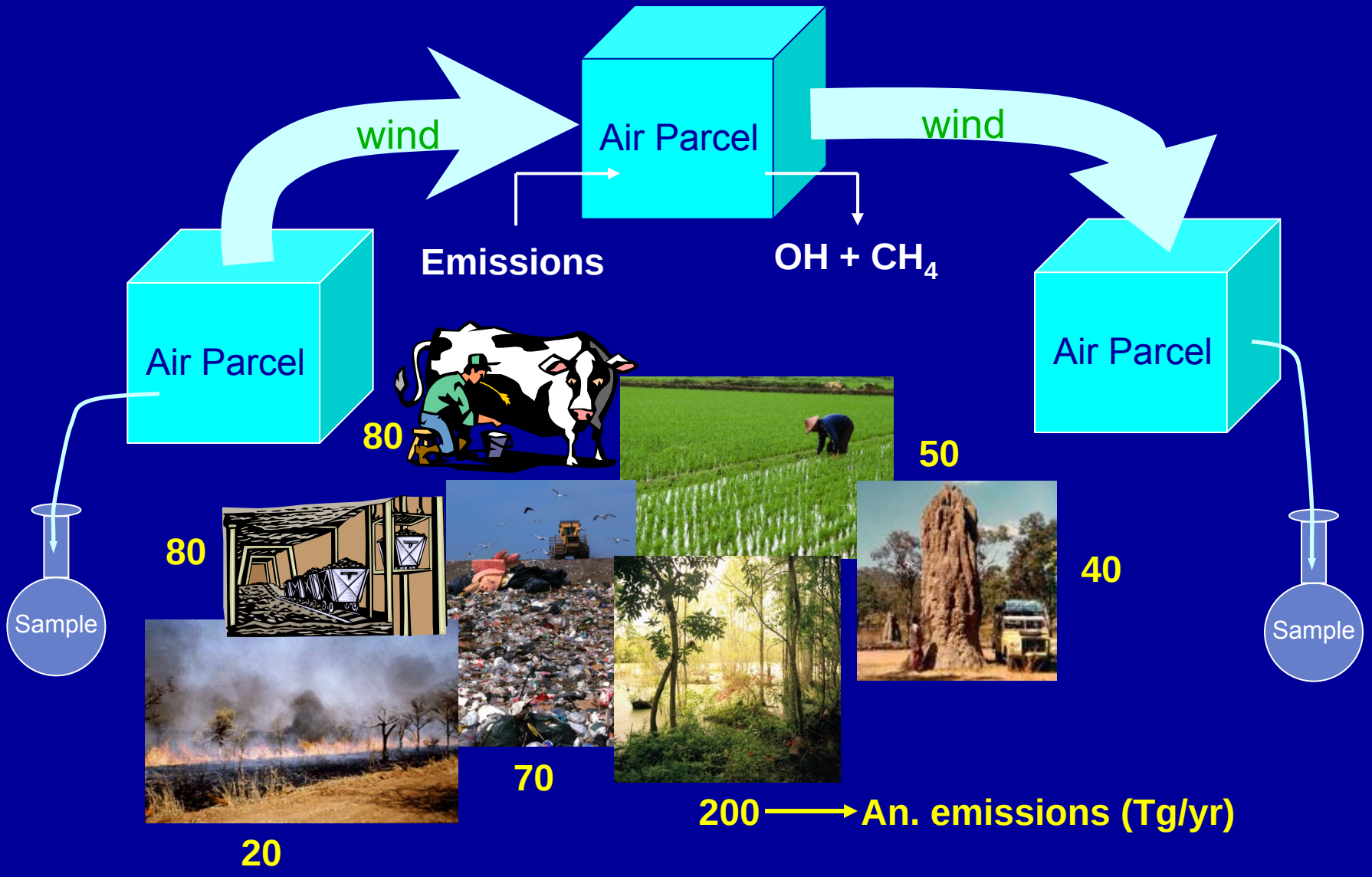
τ = CH_4 lifetime = 8.9 years

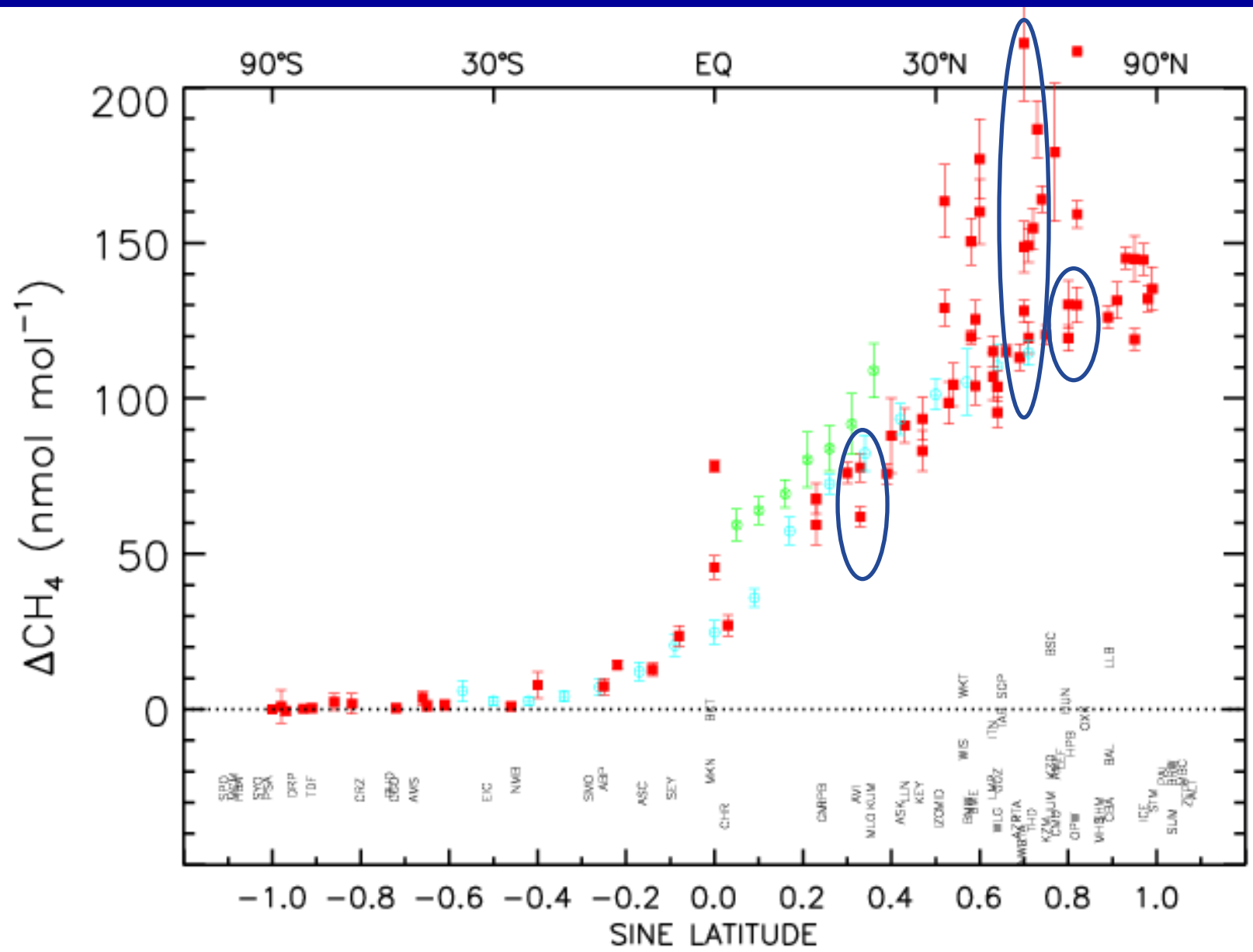
(Oxidation by OH and soil microbes)

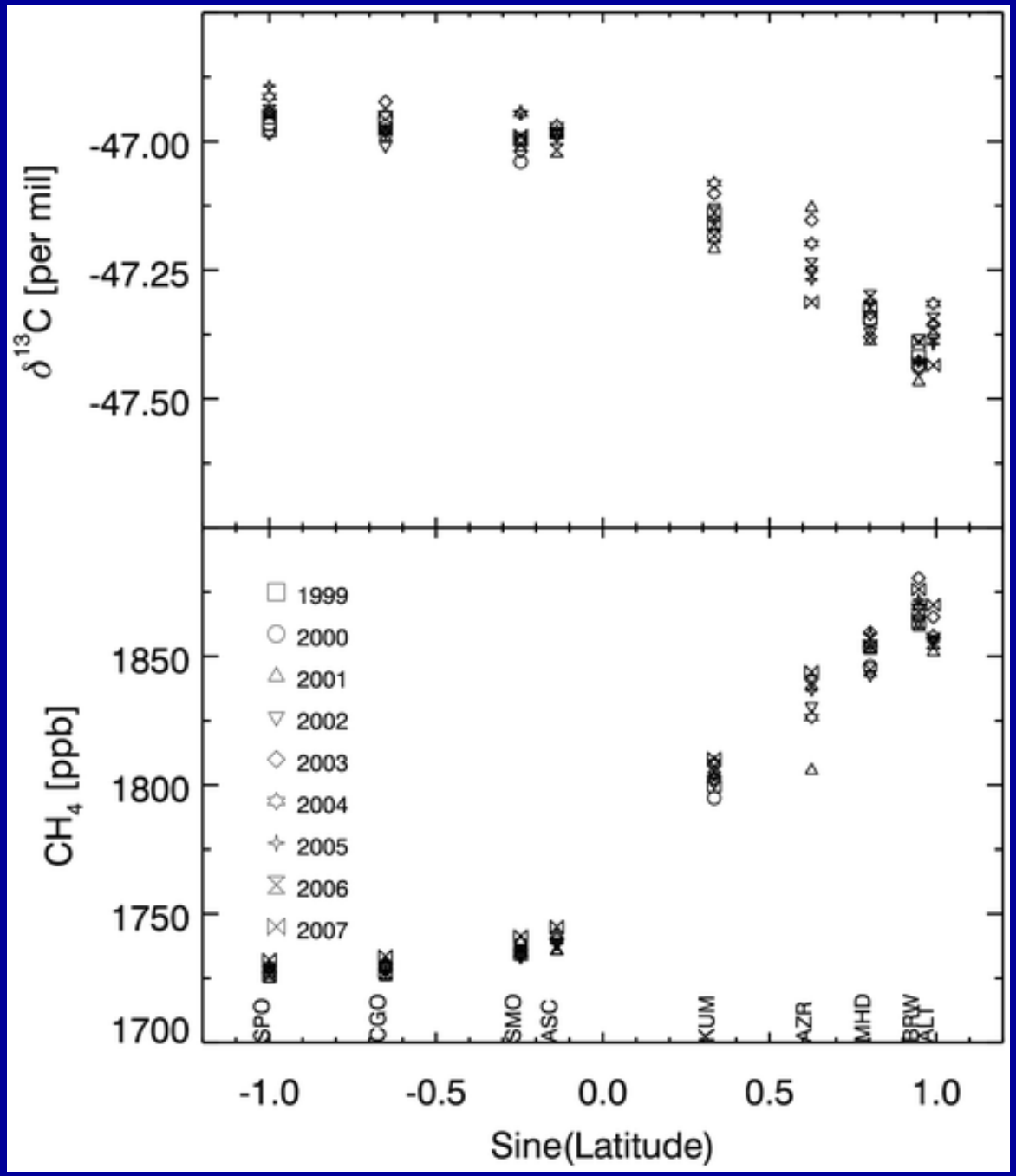
Emissions = $d[CH_4]/dt + [CH_4]/\tau$



Emissions by Source: Inverse Modeling (Top Down)




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



MBL sites

$\delta^{13}C=(R_s/R_r - 1) \times 1000‰$

$R = {}^{13}C/{}^{12}C$

s = sample, r = reference

John Miller, NOAA ESRL

Emissions by Source: Inventory (Bottom Up)

$E_i = A_i \times EF_i$

Where, for each process *i*:

E = emissions (e.g., from cows)

A = activity (no. cows)

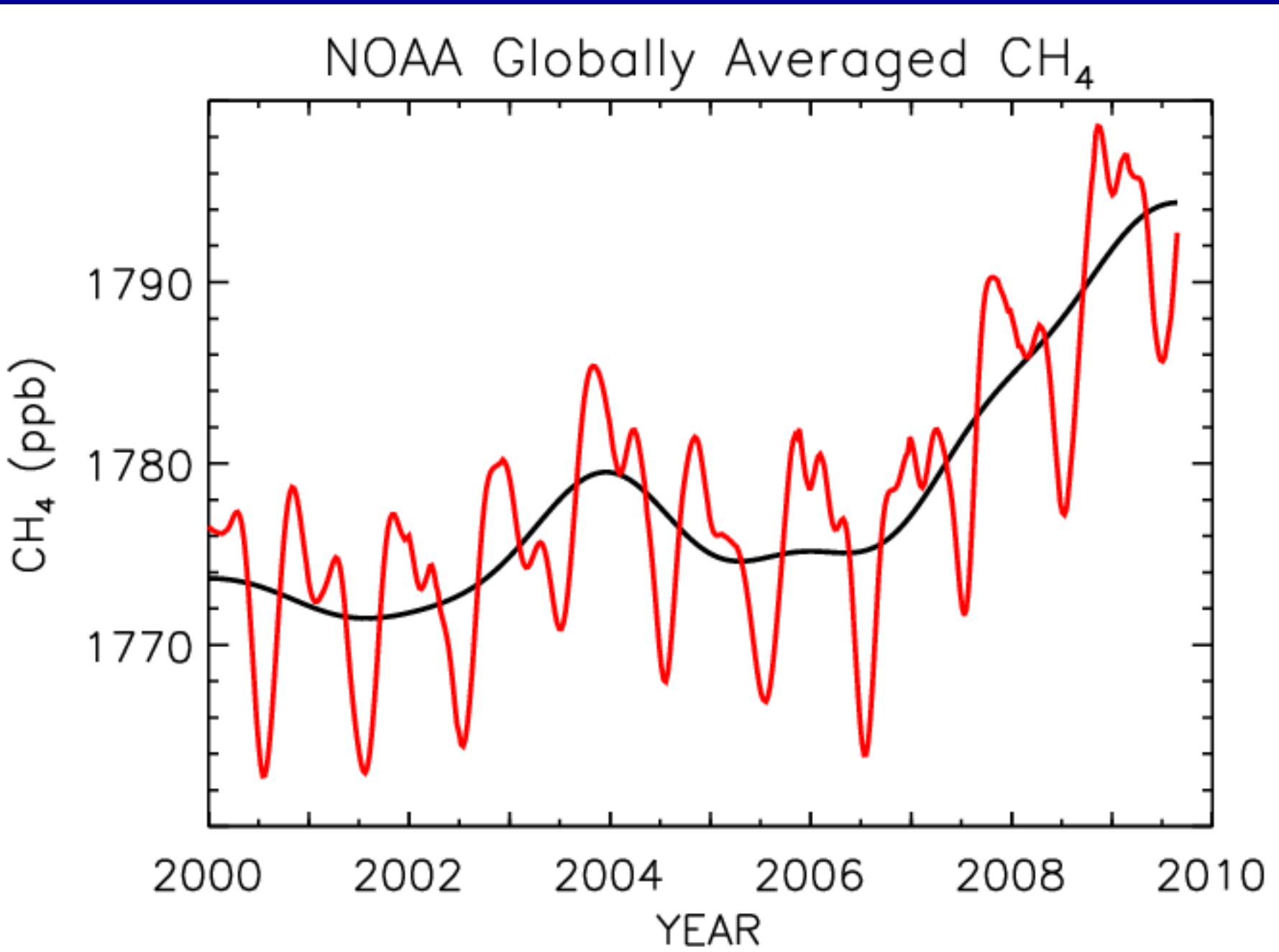
EF = emission factor (CH_4 cow^{-1})

Global CH_4 Budget by Source

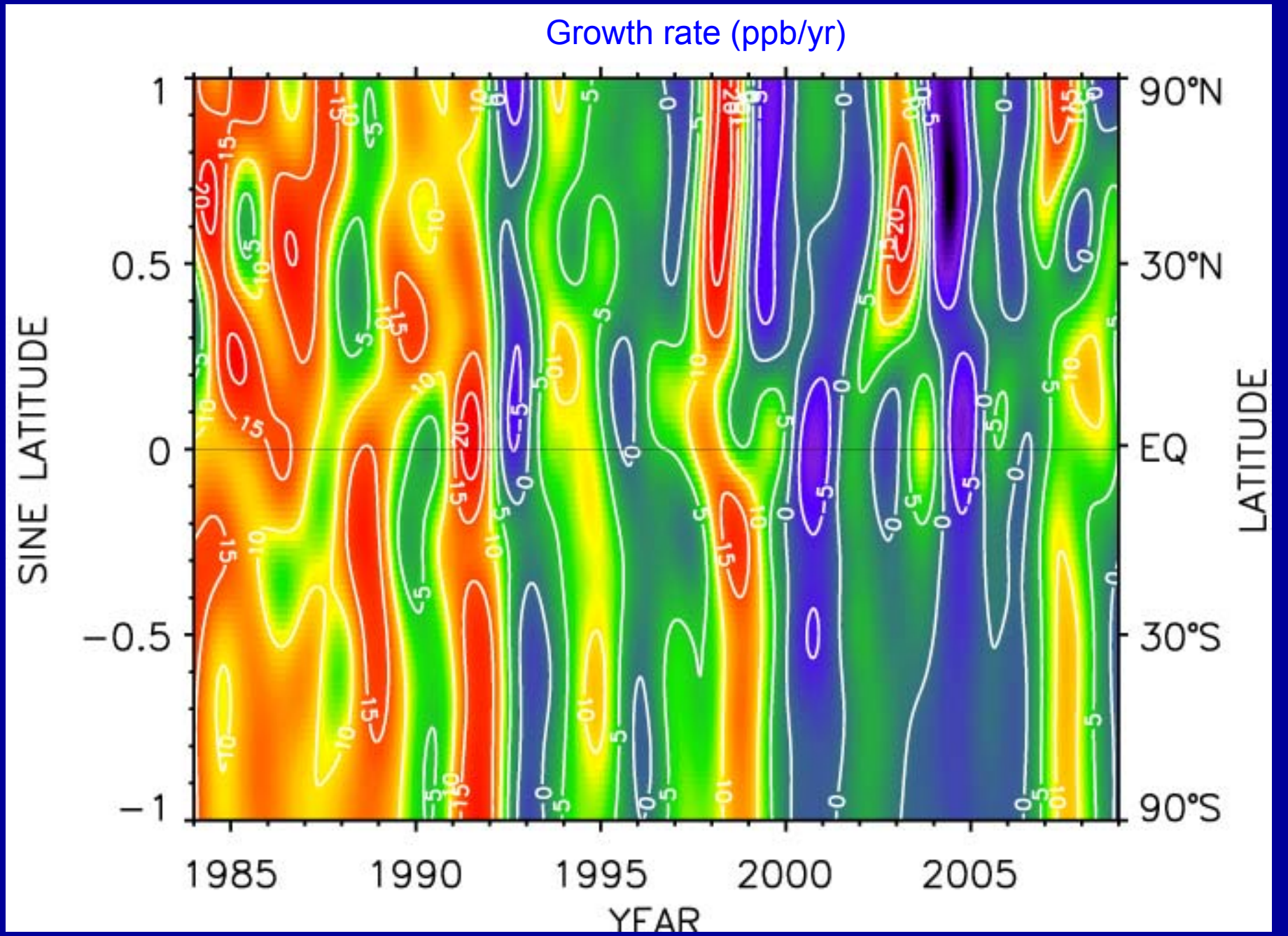
Source	Bousquet (Tg/yr)	IPCC Range (Tg/yr)
Anthropogenic		
Energy	110±13	74-106
Enteric fermentation	90±14	76-92
Rice agriculture	31±5	31-112
Biomass burning	50±8	14-88
Waste	55±11	35-69
Natural		
Wetlands	147±15	100-231
Termites	23±4	20-29
Oceans	19±6	4-15
Total	**525±8**	**503-610**

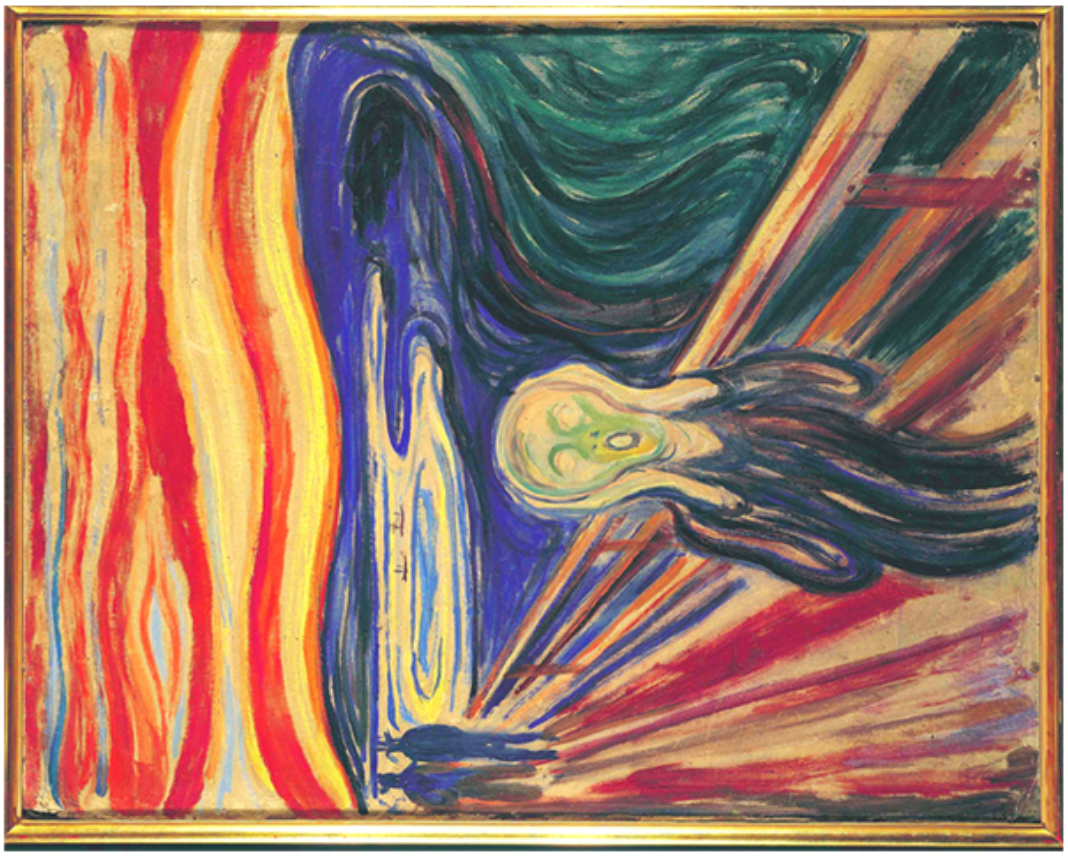
Sinks	Bousquet (Tg/yr)	IPCC (Tg/yr)
Troposphere	448±1	428-511
Stratosphere	37±1	30-45
Soil	21±3	26-34
Total	**506**	**492-581**

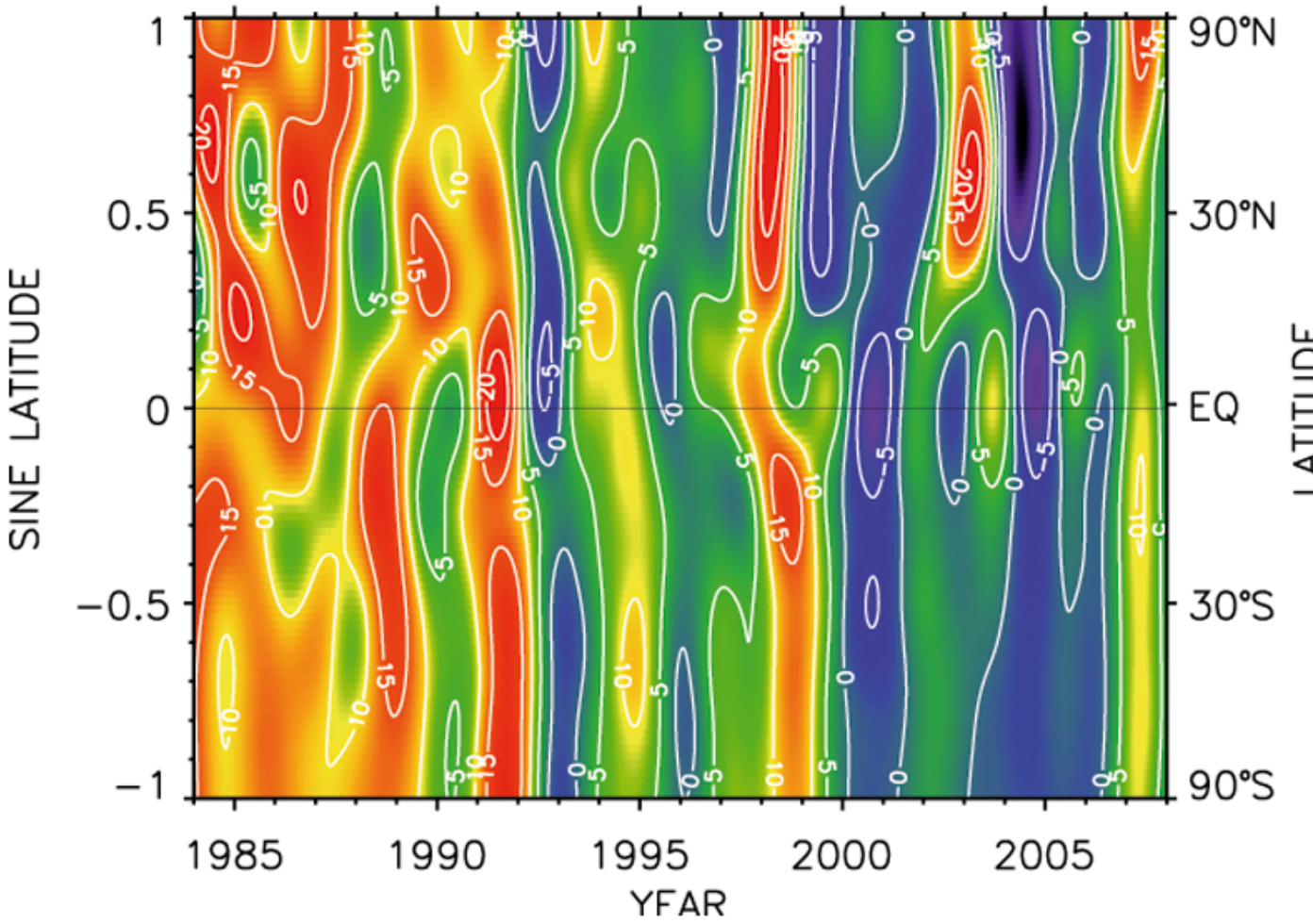
Bousquet et al., 2006, *Nature*, **443**, 439-443, doi:10.1038/nature05132.


NOAA Globally Averaged CH_4
CH_4 (ppb)
1790
1780
1770
2000
2002
2004
2006
2008
2010
YEAR

Growth rate (ppb/yr)

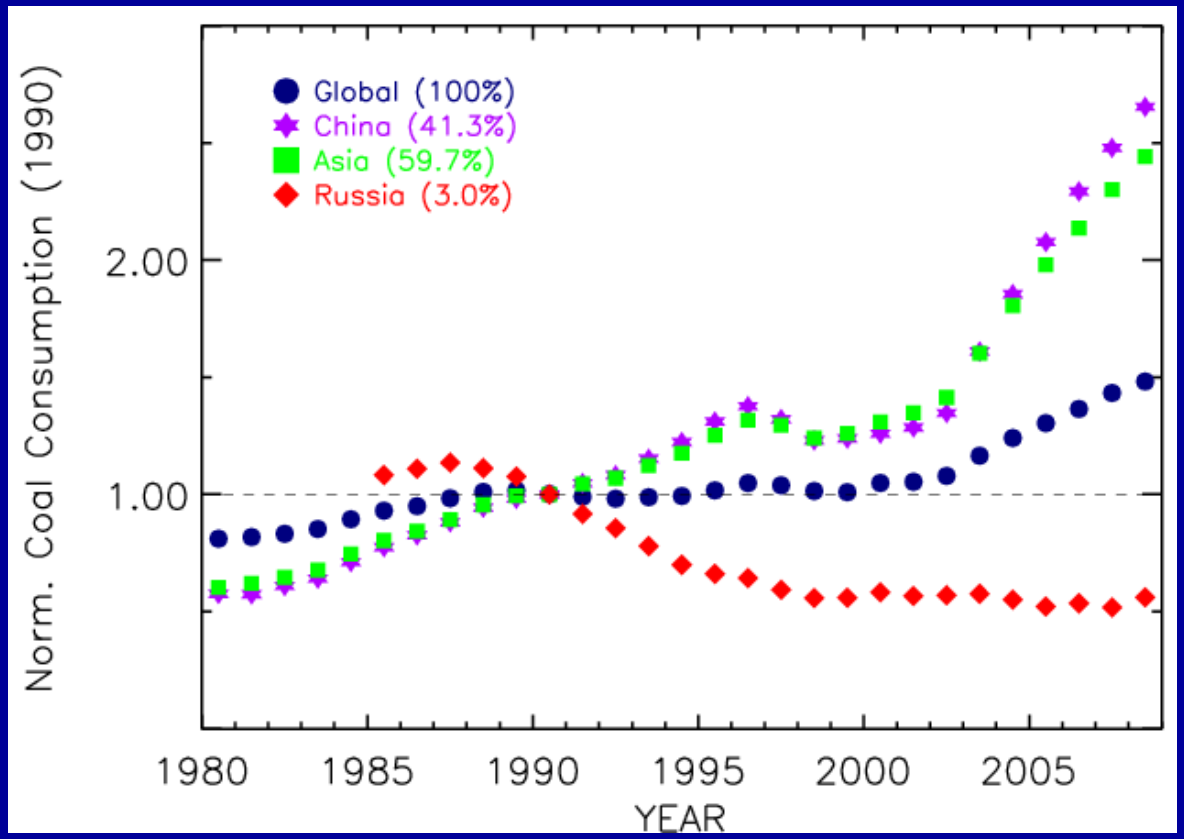





SINE LATITUDE
1
0.5
0
−0.5
−1
90°N
30°N
EQ
30°S
90°S
LATITUDE
1985
1990
1995
2000
2005
YEAR

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

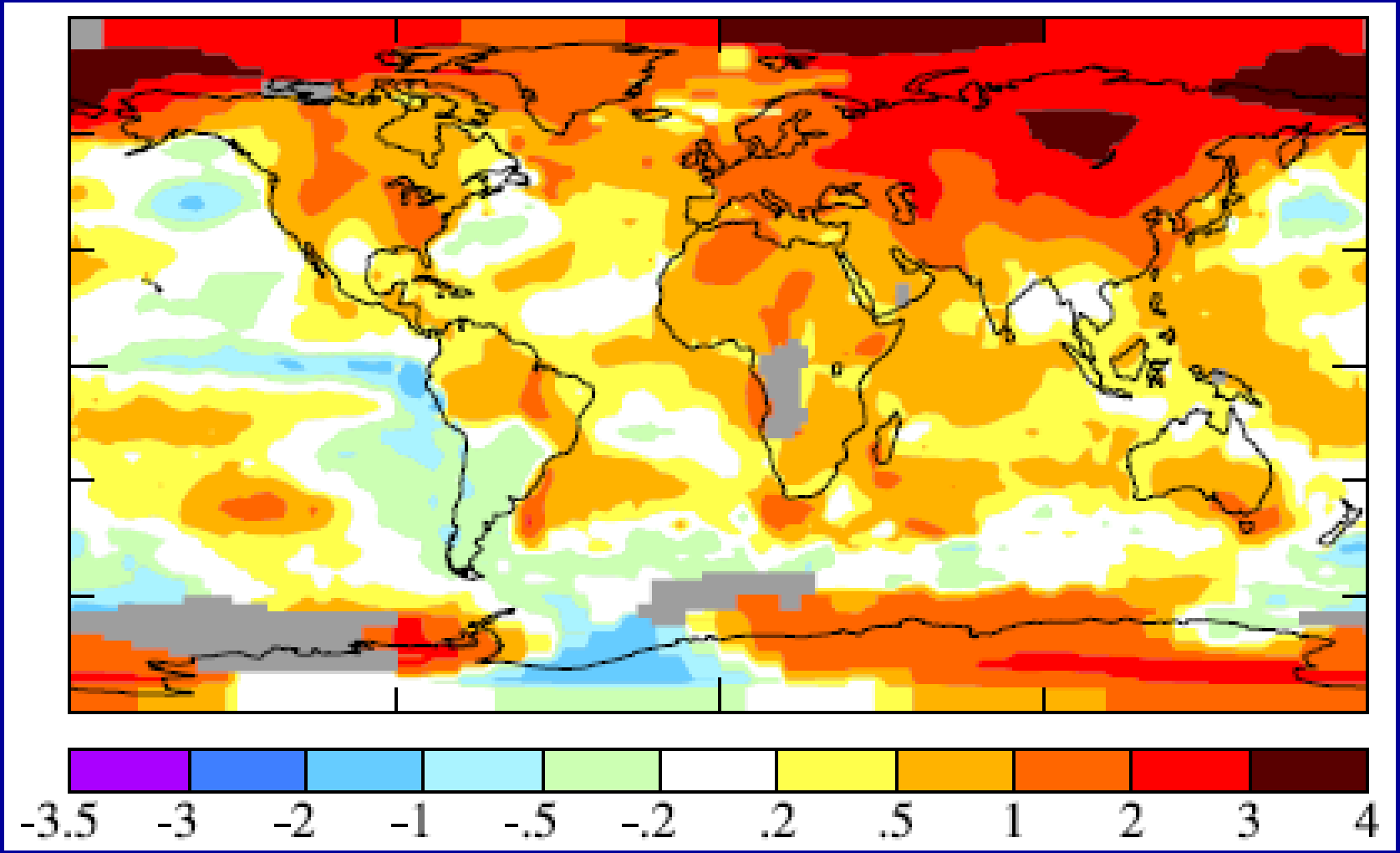
IPY Focus on Arctic Carbon

- Methane hydrates
  - 1600 to 2000 Pg C globally
- Thermokarst formation
  - Thermokarst (thaw) lakes migrate naturally and can be accelerated by climate change.
  - Permafrost contains ~1000 Pg C

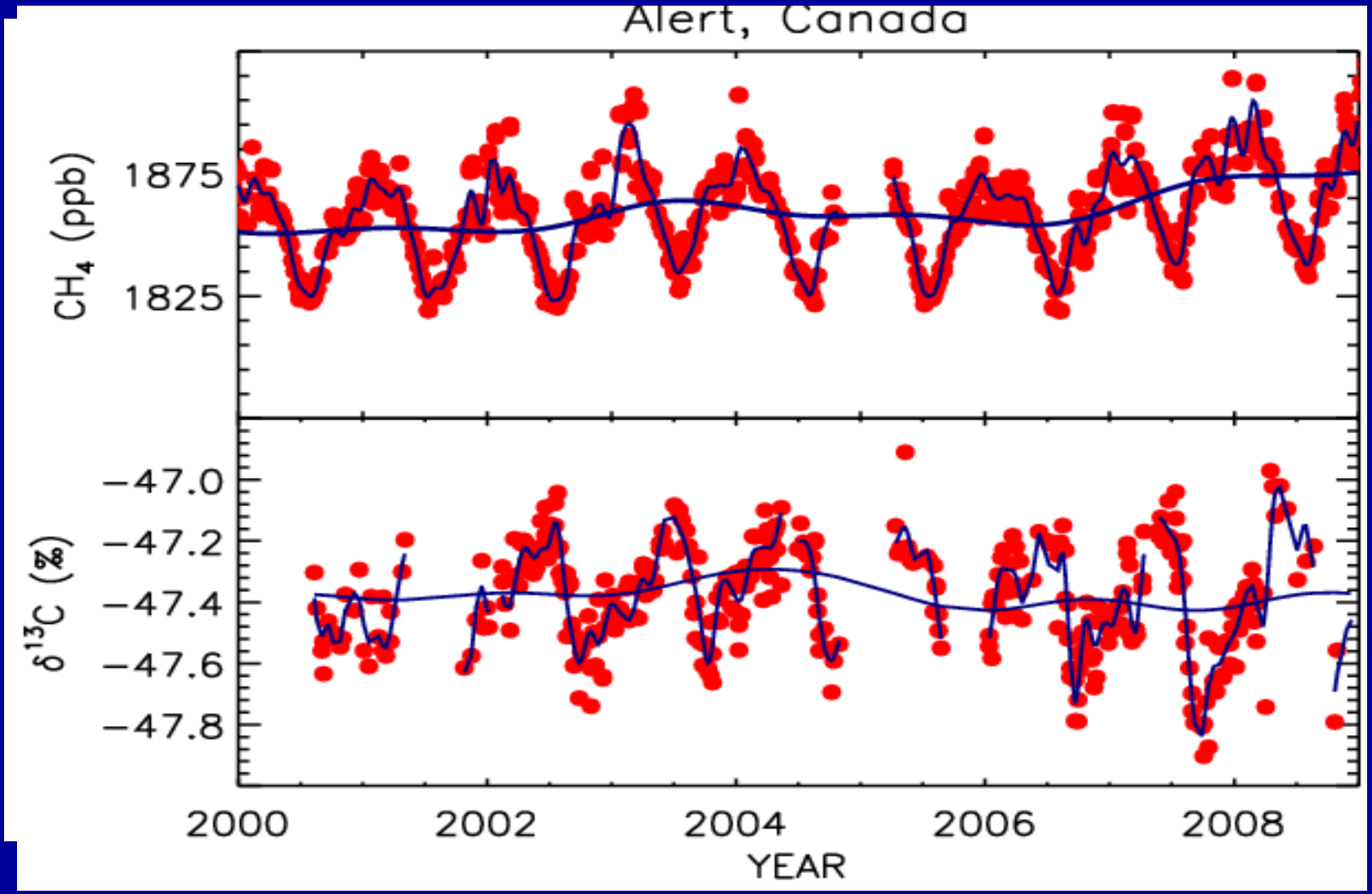
Wetland contribution to 2007/2008 CH_4 increases:

- Wetlands affected by soil T and moisture
  - 2007 warm and wet in Arctic
  - La Niña affected tropical precipitation
    - 2007 and 2008 wettest years since 1986
    - Emissions in Amazon for 2007 and 2008 ~50% greater than 2000 to 2006 average

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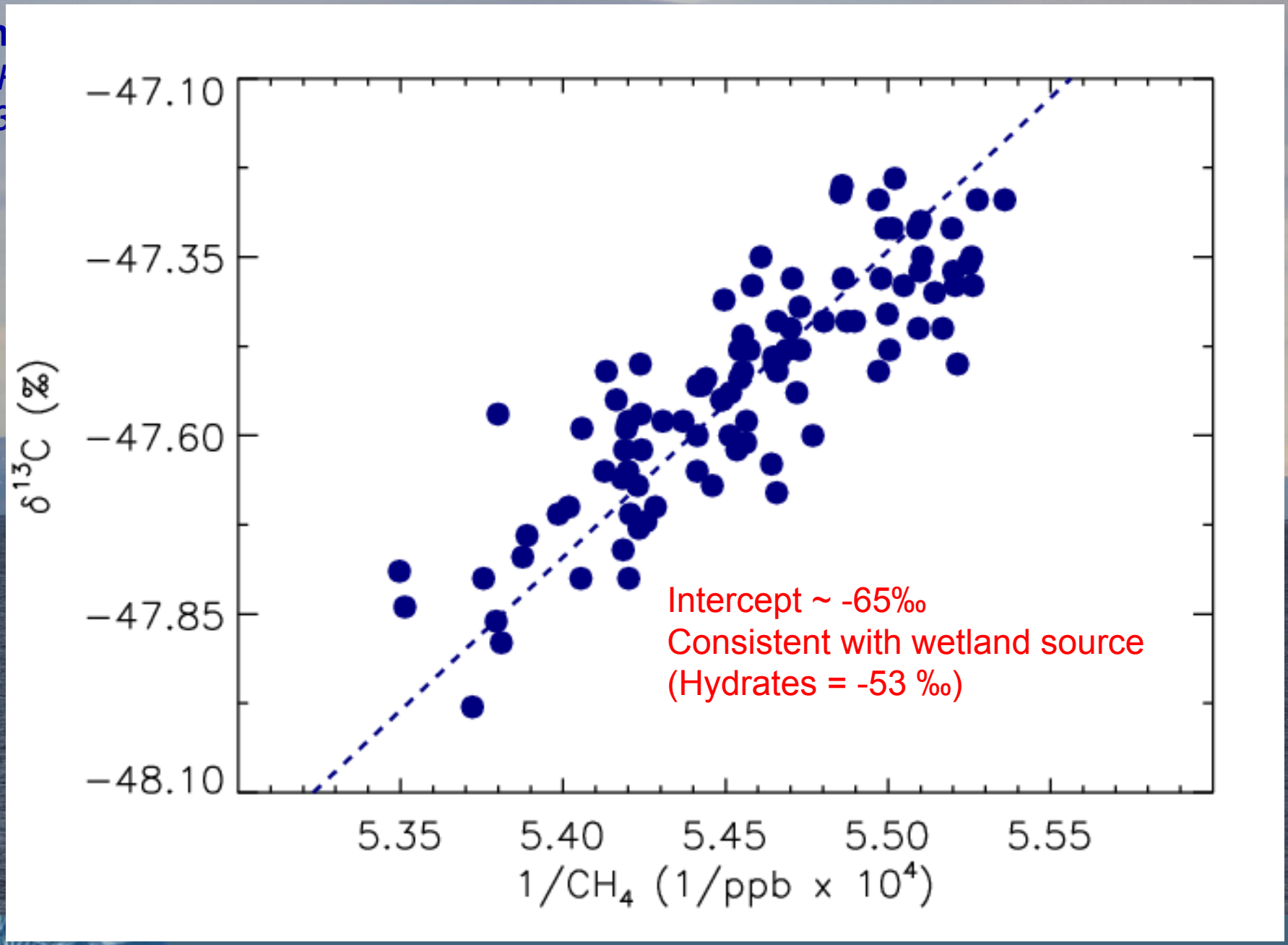
The gas hydrate puzzle - West Spitsbergen continental slope

RRS James Clark Ross

23rd August to 23rd September 2008



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

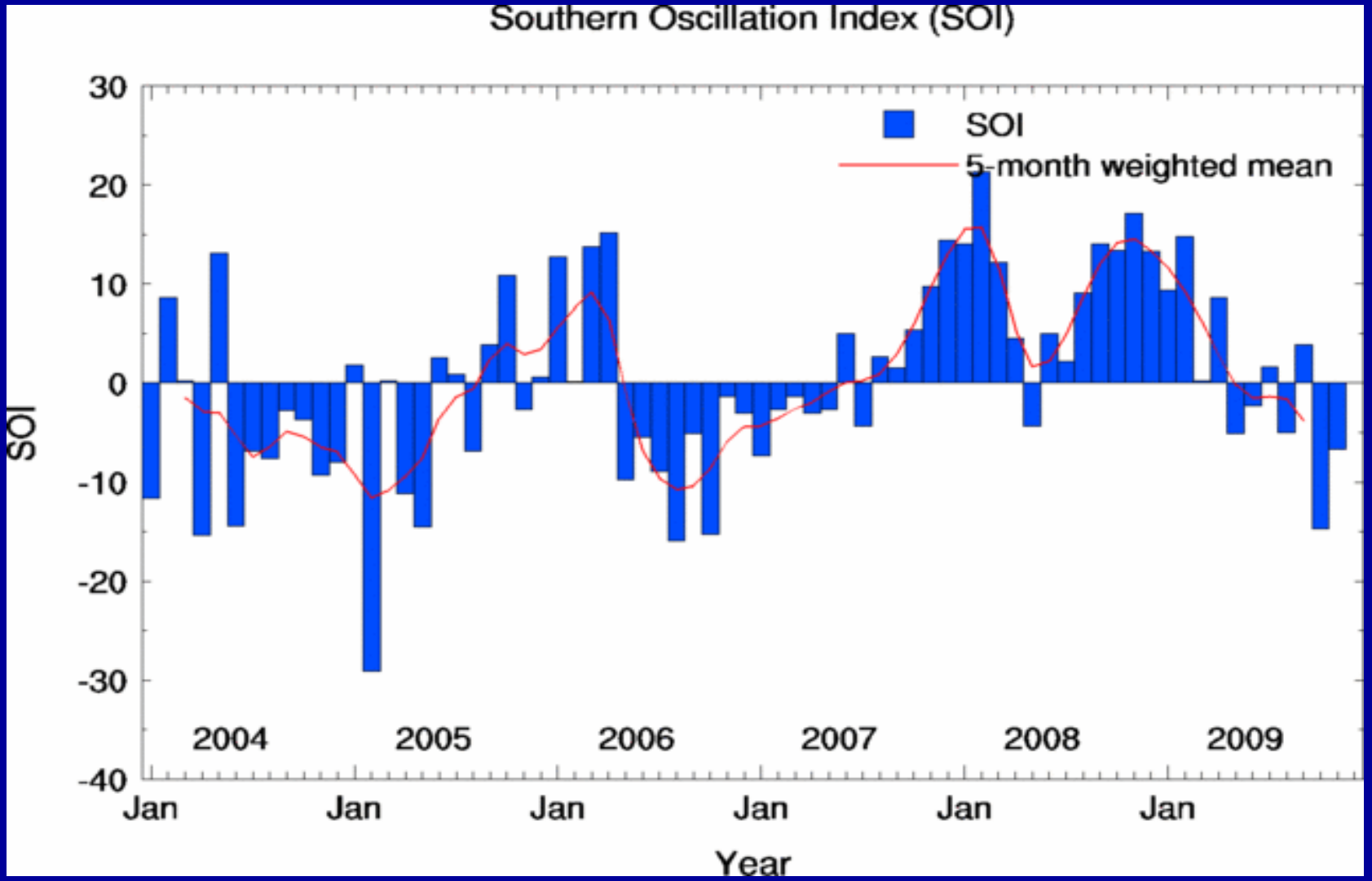


Westbrook et al., Geophys. Res. Lett, 2009

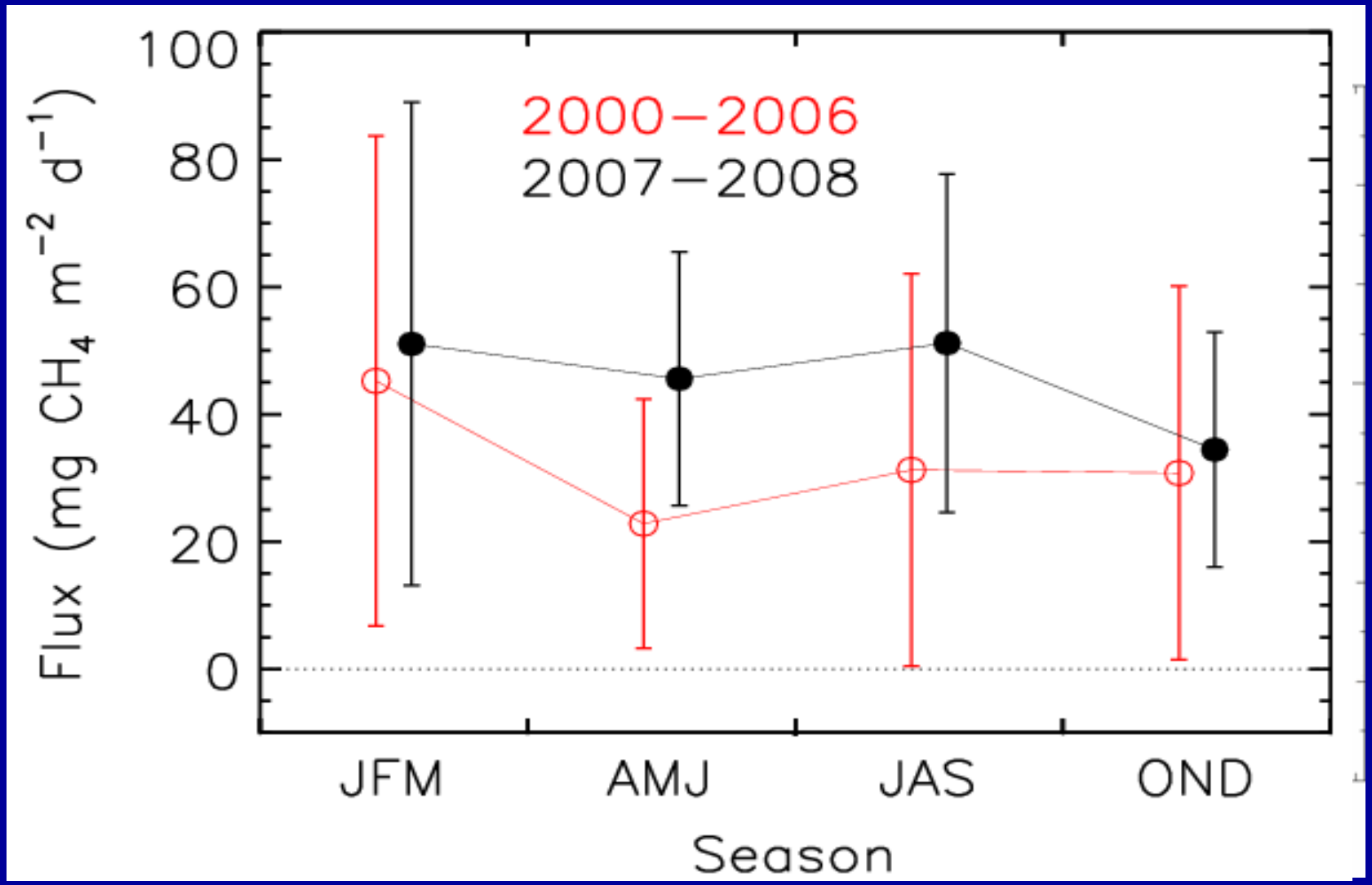
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Conclusions

- CH_4 observations → large scale features
  - Global emissions to ±15%
  - Better coverage → sources, verification (ΔE)
- Potential for climate feedbacks
  - Hydrates and permafrost thaw (1000s Pg)
  - Wetlands (tropics and Arctic)
- Not yet at Arctic tipping point
  - Observations suggest 2007 and 2008 global increases are natural IAV in emissions