Thirty Years of Atmospheric CH_4 Monitoring: What Have We Learned?

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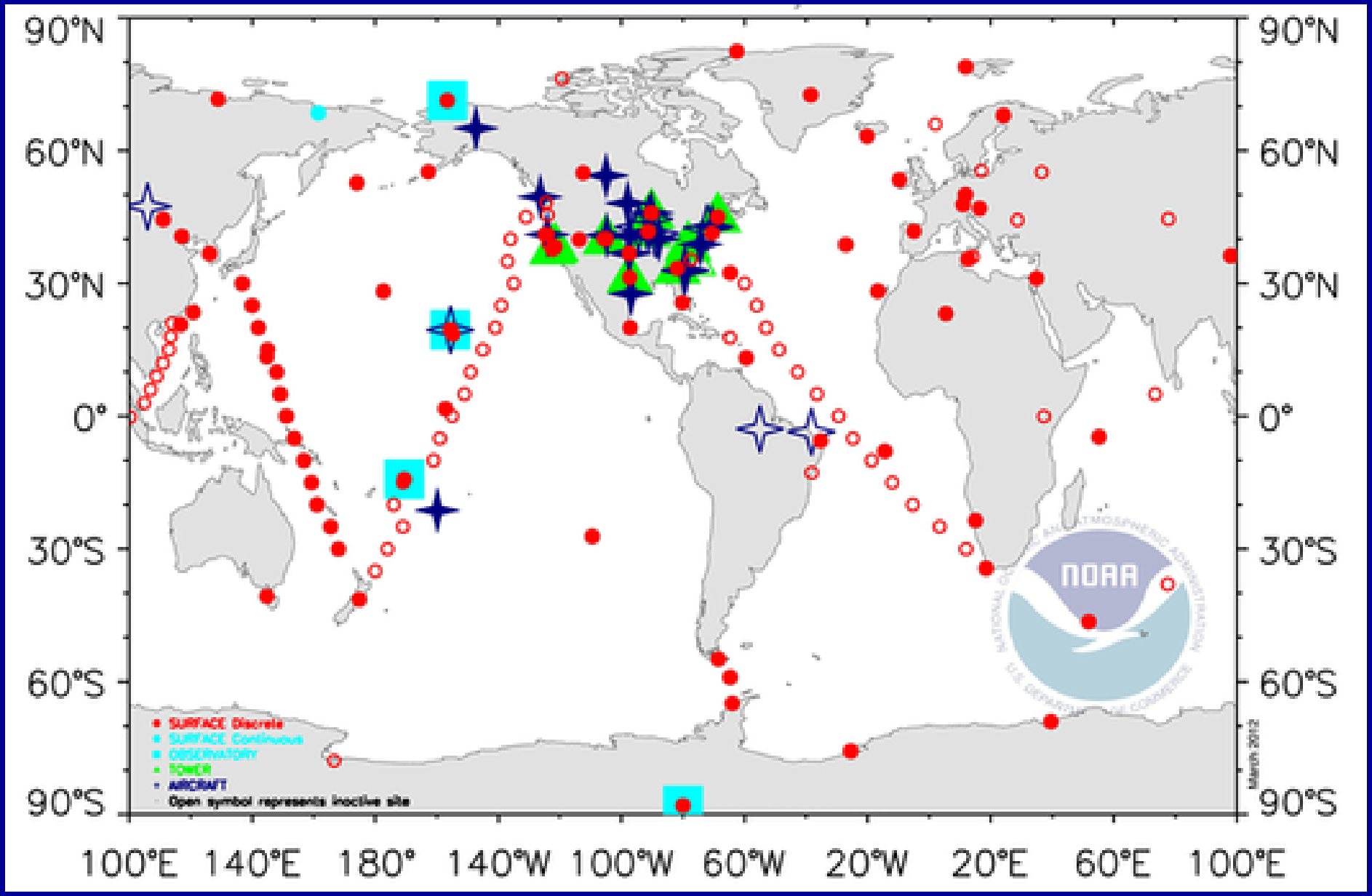
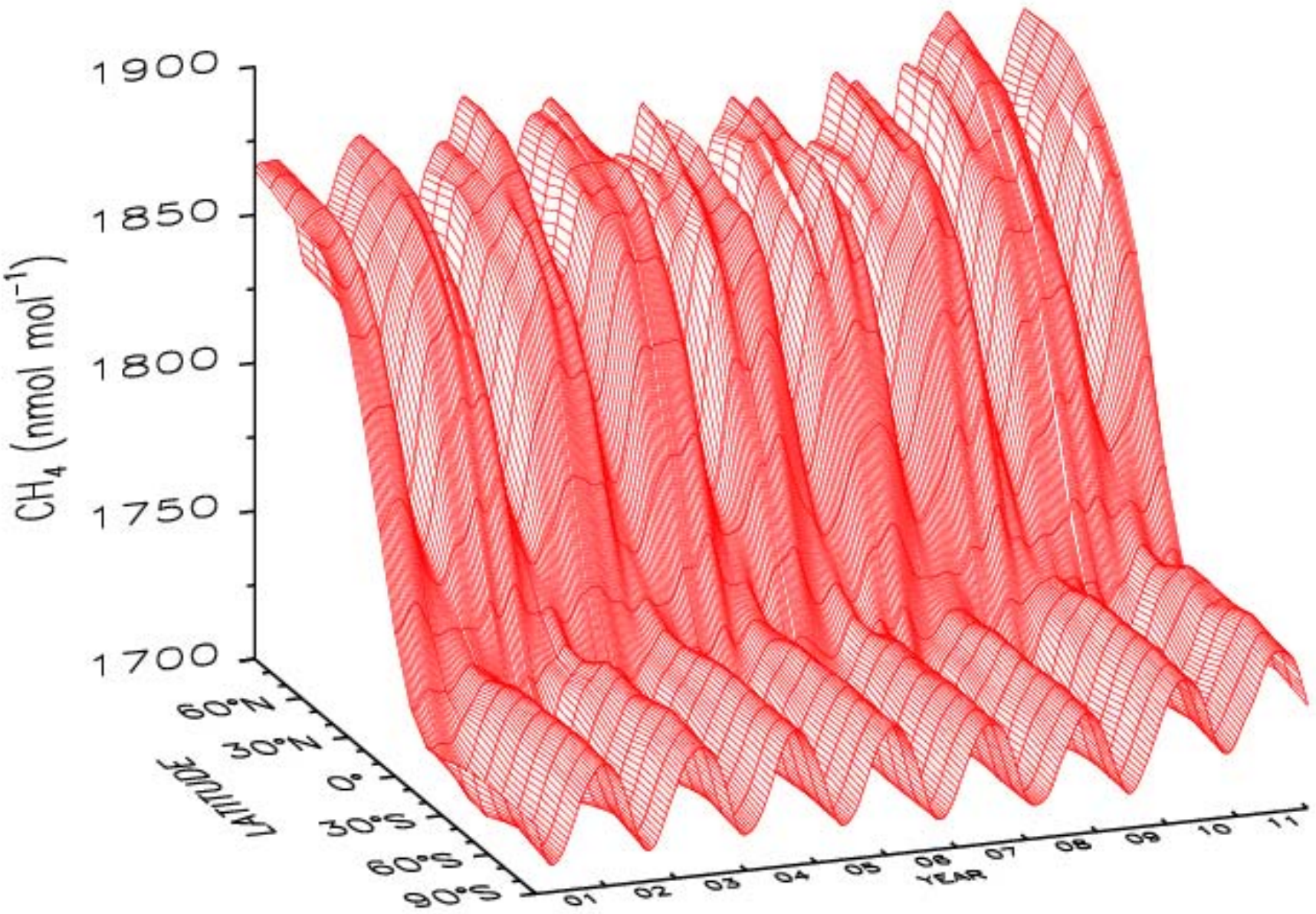
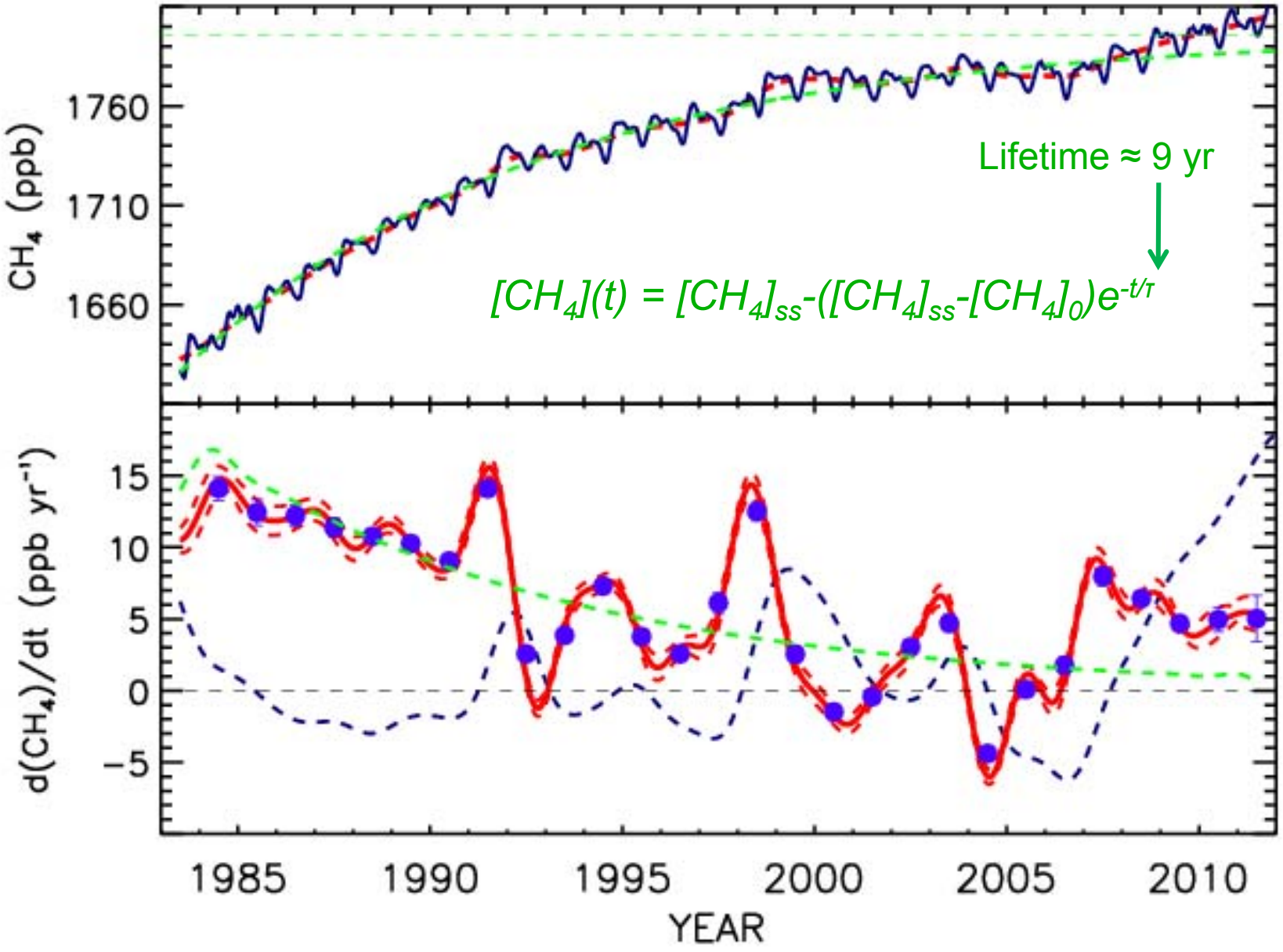
Acknowledgement: Paul Fraser and Paul Steele

www.esrl.noaa.gov/gmd/dv/iadv/

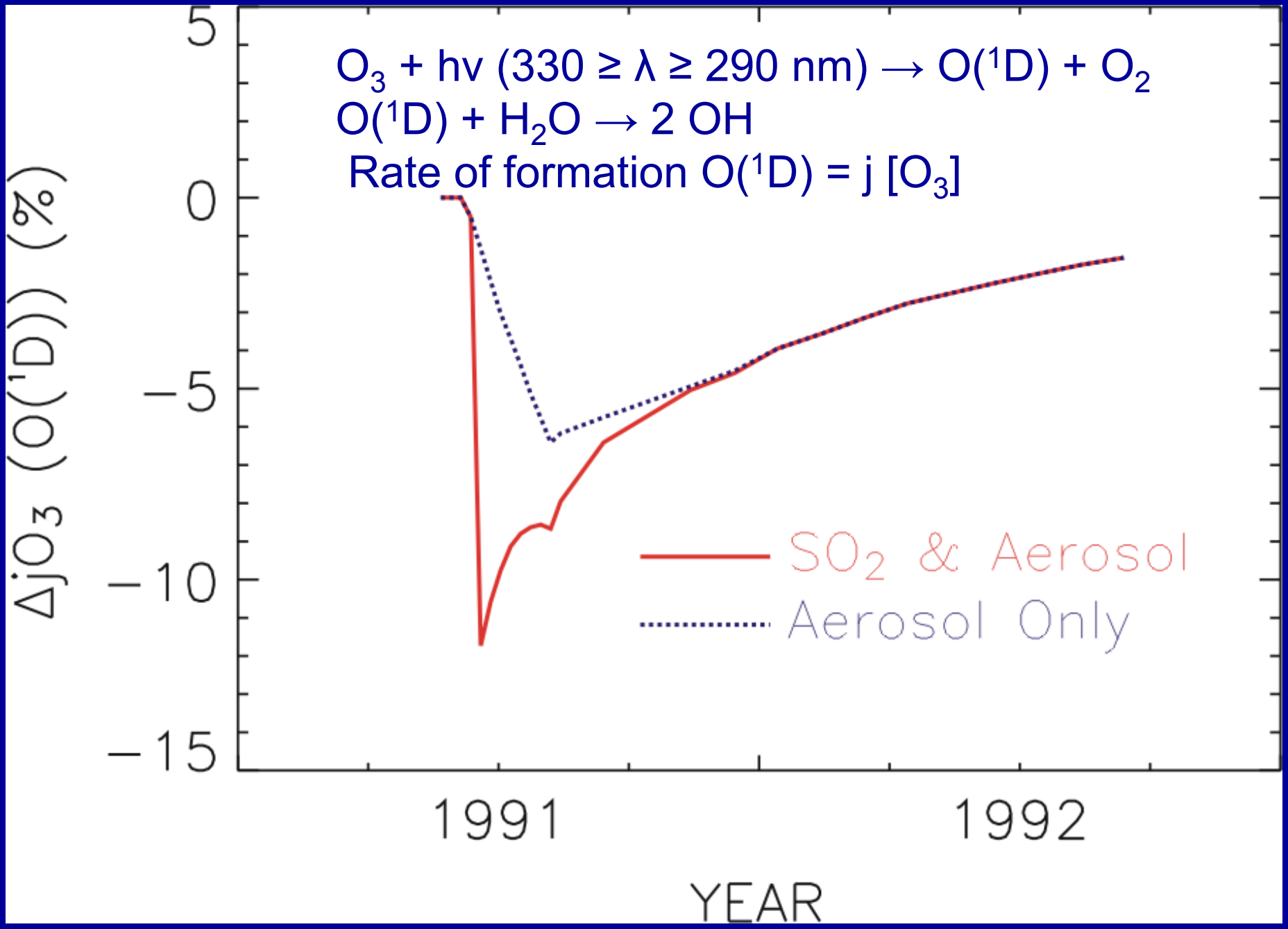


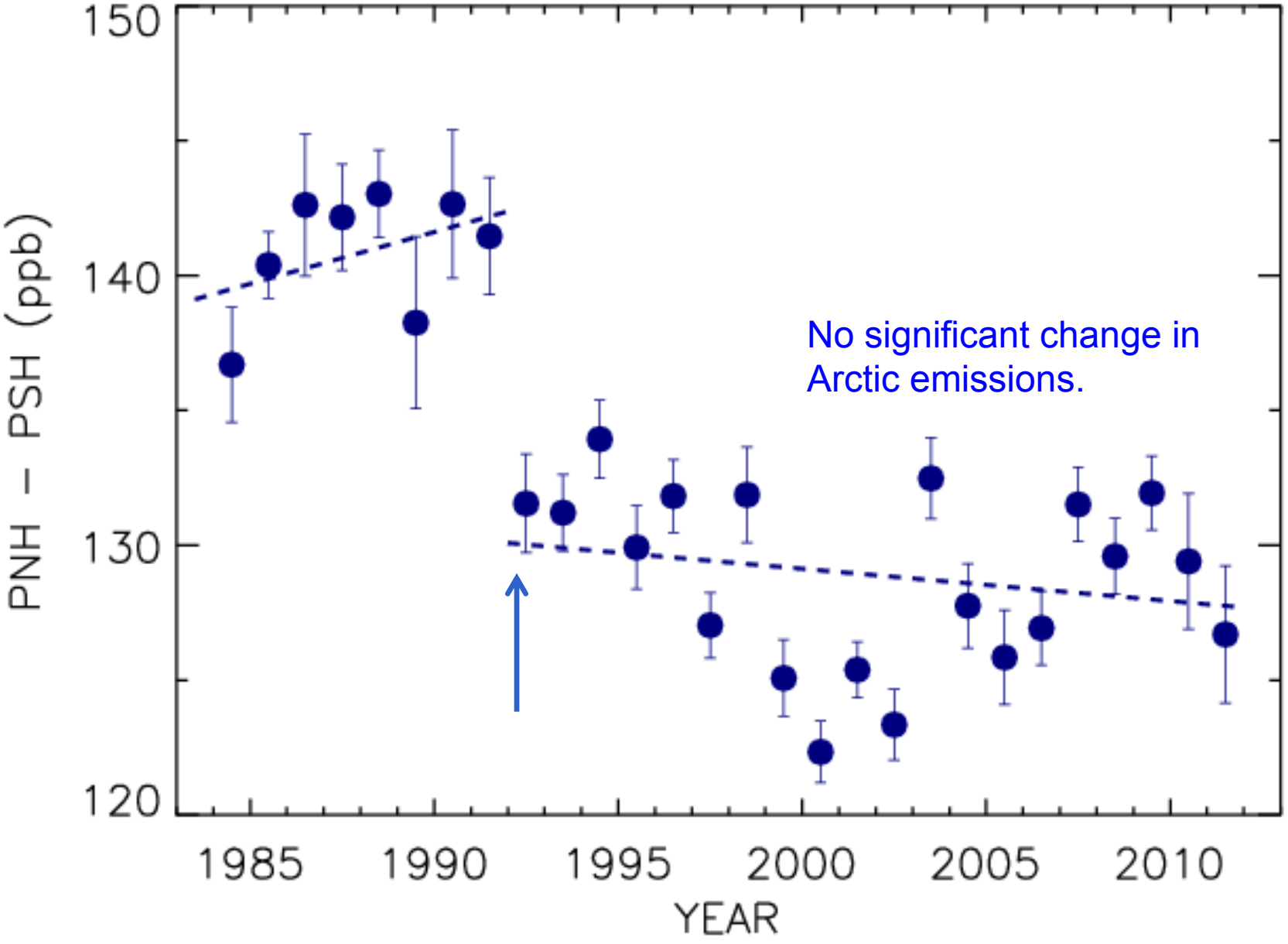

1900
1850
1800
1750
1700
CH_4 (nmol mol^{-1})
60°N
30°N
0°
30°S
60°S
90°S
LATITUDE
01
02
03
04
05
06
07
08
09
10
11
YEAR

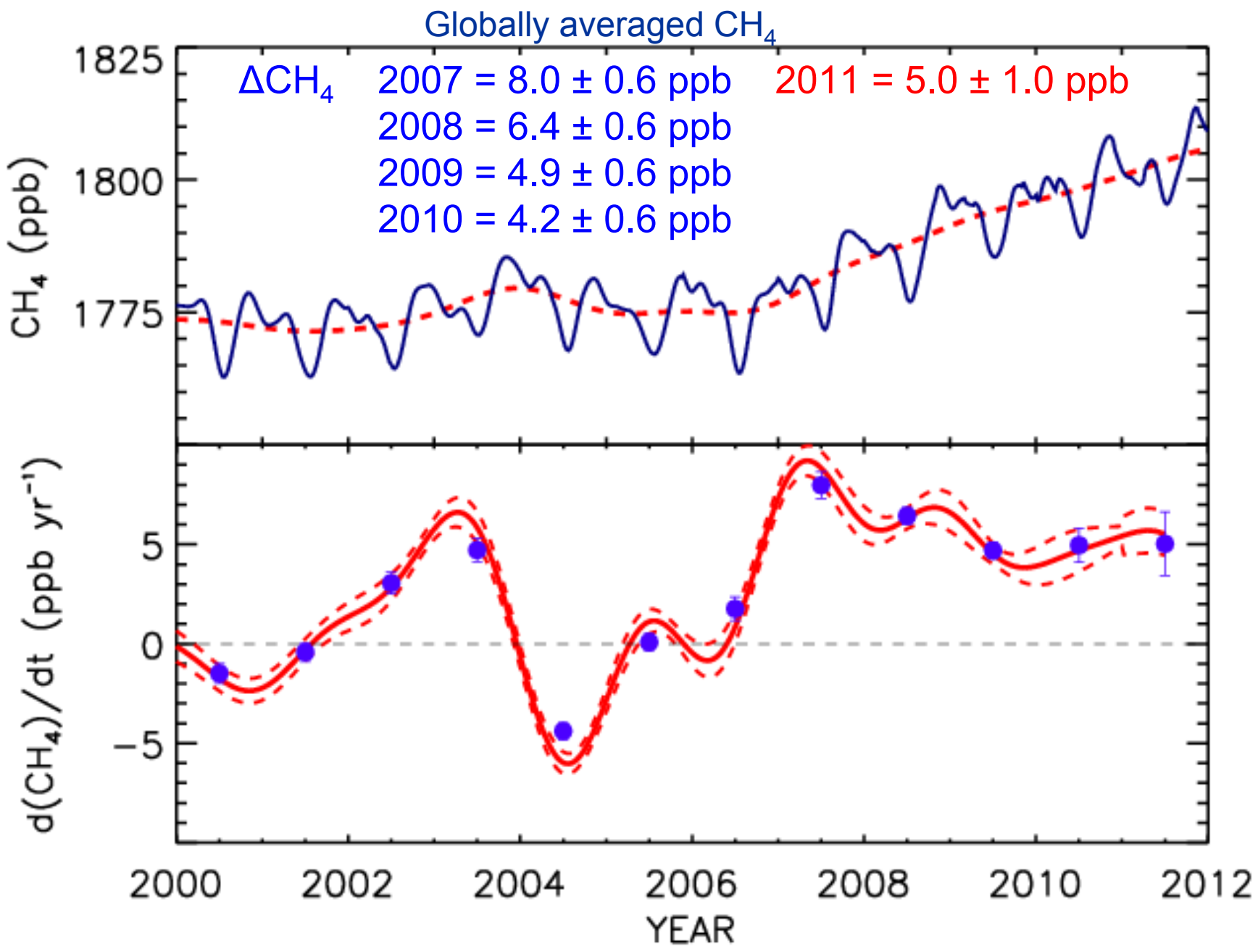

CH4 (ppb)
1760
1710
1660
Lifetime ≈ 9 yr
[CH4](t) = [CH4]ss-([CH4]ss-[CH4]0)e-t/τ
d(CH4)/dt (ppb yr-1)
15
10
5
0
−5
1985
1990
1995
2000
2005
2010
YEAR

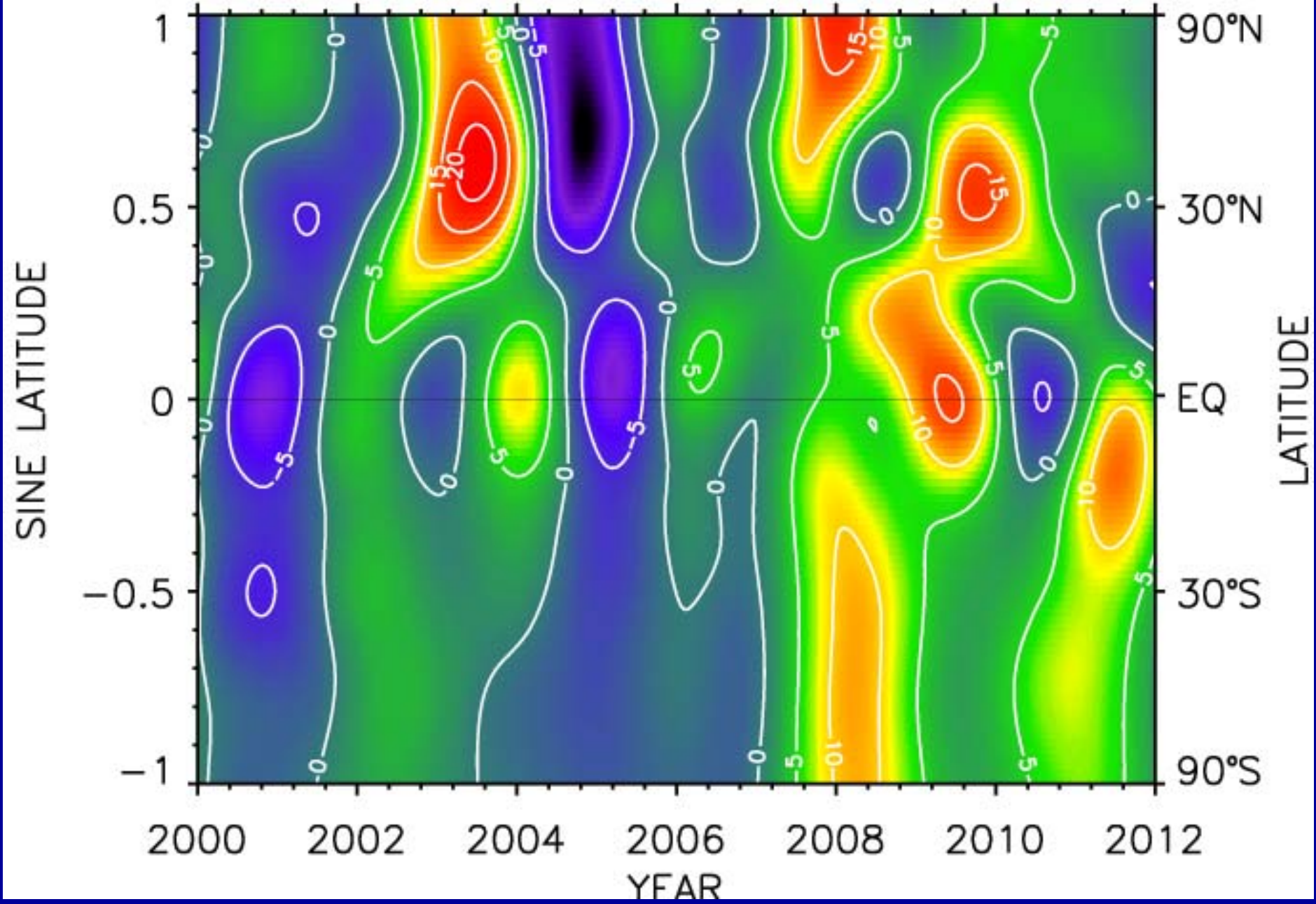
IAV: Better Process Understanding

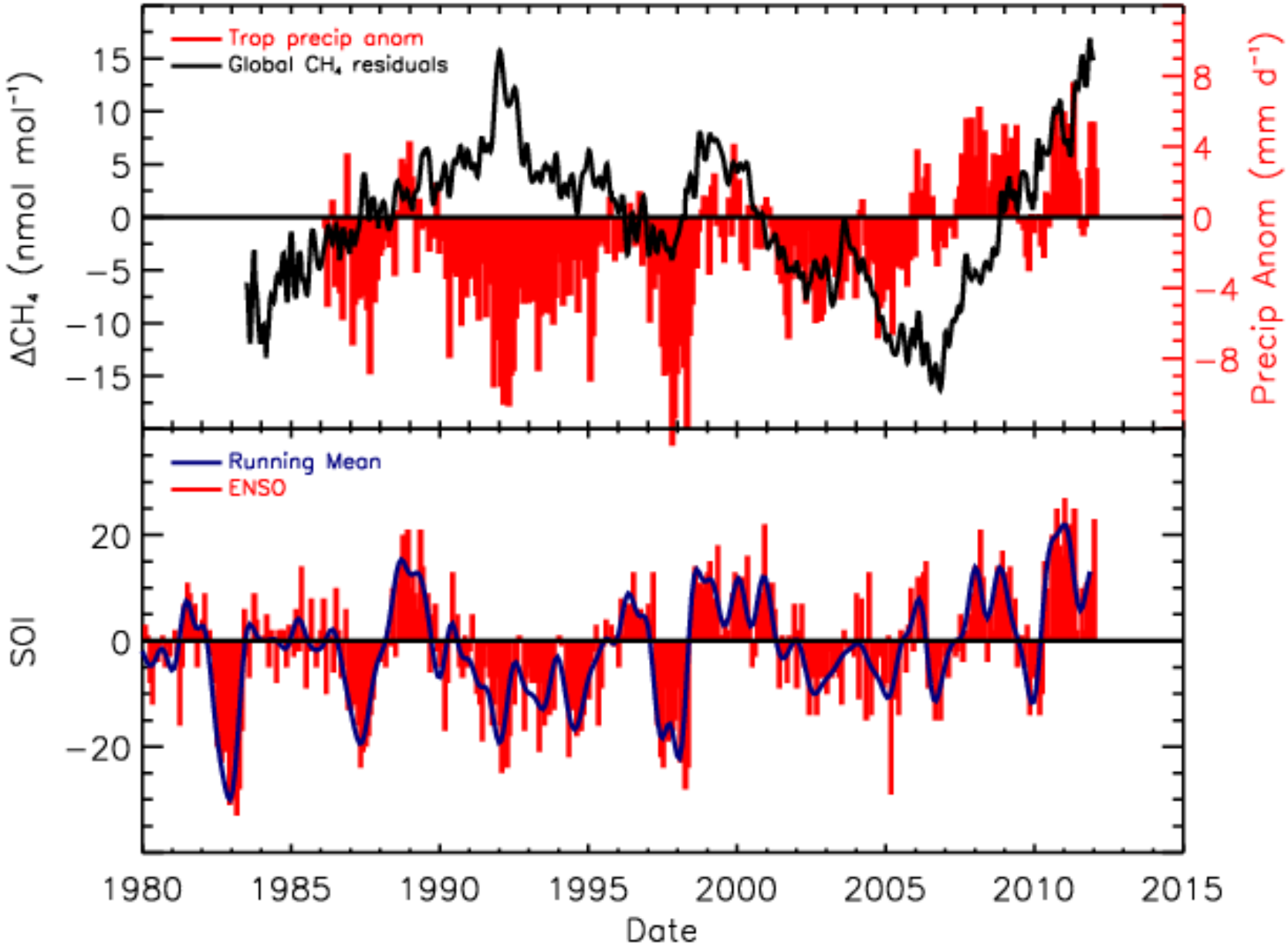
- Mt. Pinatubo and CH_4 lifetime
  - SO_2 and $SO_4^=$ affected OH production
- Economic collapse in fSU
  - Decreased emissions at high northern latitudes
- Increase since 2007
  - Tropical wetlands


$O_3 + hv\ (330 \geq \lambda \geq 290\ nm) \rightarrow O(^1D) + O_2$
$O(^1D) + H_2O \rightarrow 2\ OH$
Rate of formation $O(^1D) = j\ [O_3]$
$\Delta jO_3\ (O(^1D))\ (\%)$
5
0
−5
−10
−15
1991
1992
YEAR
SO_2 & Aerosol
Aerosol Only


150
140
130
120
PNH – PSH (ppb)
1985
1990
1995
2000
2005
2010
YEAR
No significant change in
Arctic emissions.


Globally averaged CH_4
ΔCH_4 2007 = 8.0 ± 0.6 ppb
2008 = 6.4 ± 0.6 ppb
2009 = 4.9 ± 0.6 ppb
2010 = 4.2 ± 0.6 ppb
2011 = 5.0 ± 1.0 ppb
CH_4 (ppb)
1825
1800
1775
d(CH_4)/dt (ppb yr^{-1})
5
0
−5
2000
2002
2004
2006
2008
2010
2012
YEAR

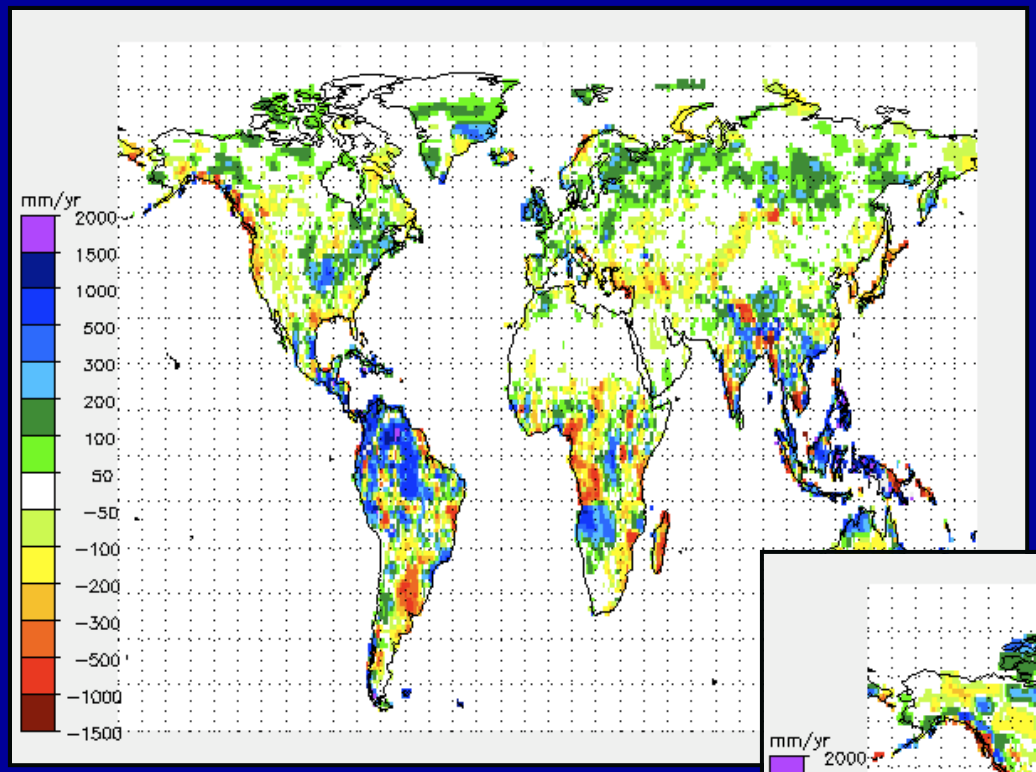

SINE LATITUDE
1
0.5
0
−0.5
−1
LATITUDE
90°N
30°N
EQ
30°S
90°S
2000
2002
2004
2006
2008
2010
2012
YEAR


Trop precip anom
Global CH4 residuals
ΔCH4 (nmol mol-1)
Precip Anom (mm d-1)
Running Mean
ENSO
SOI
Date
1980
1985
1990
1995
2000
2005
2010
2015

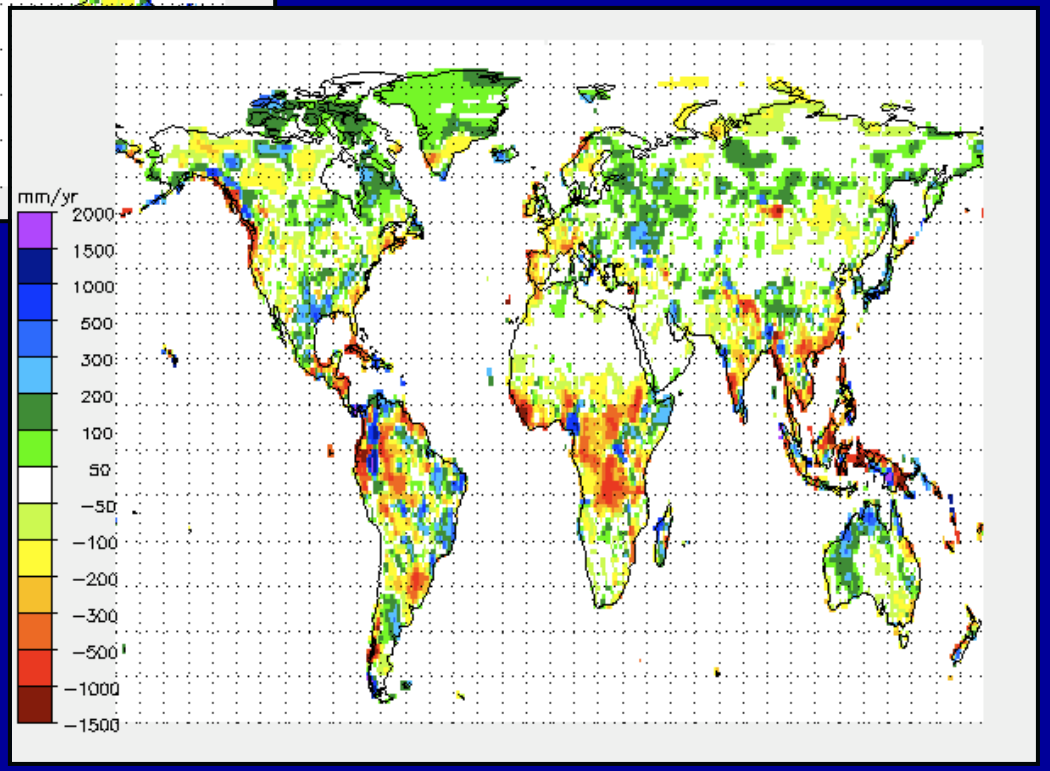
In situ CH_4 monitoring: Summary

- CH_4 approaching steady state
  - Current imbalance ~16 Tg CH_4 yr^{-1}
- Eruption of Mt. Pintubo
  - Test understanding of OH sink processes
- Economic collapse of former Soviet Union
  - Altered trajectory of atmospheric CH_4
- Tropical precipitation: wetland emissions
  - Correlates with ENSO
  - Driver of recent CH_4 increase

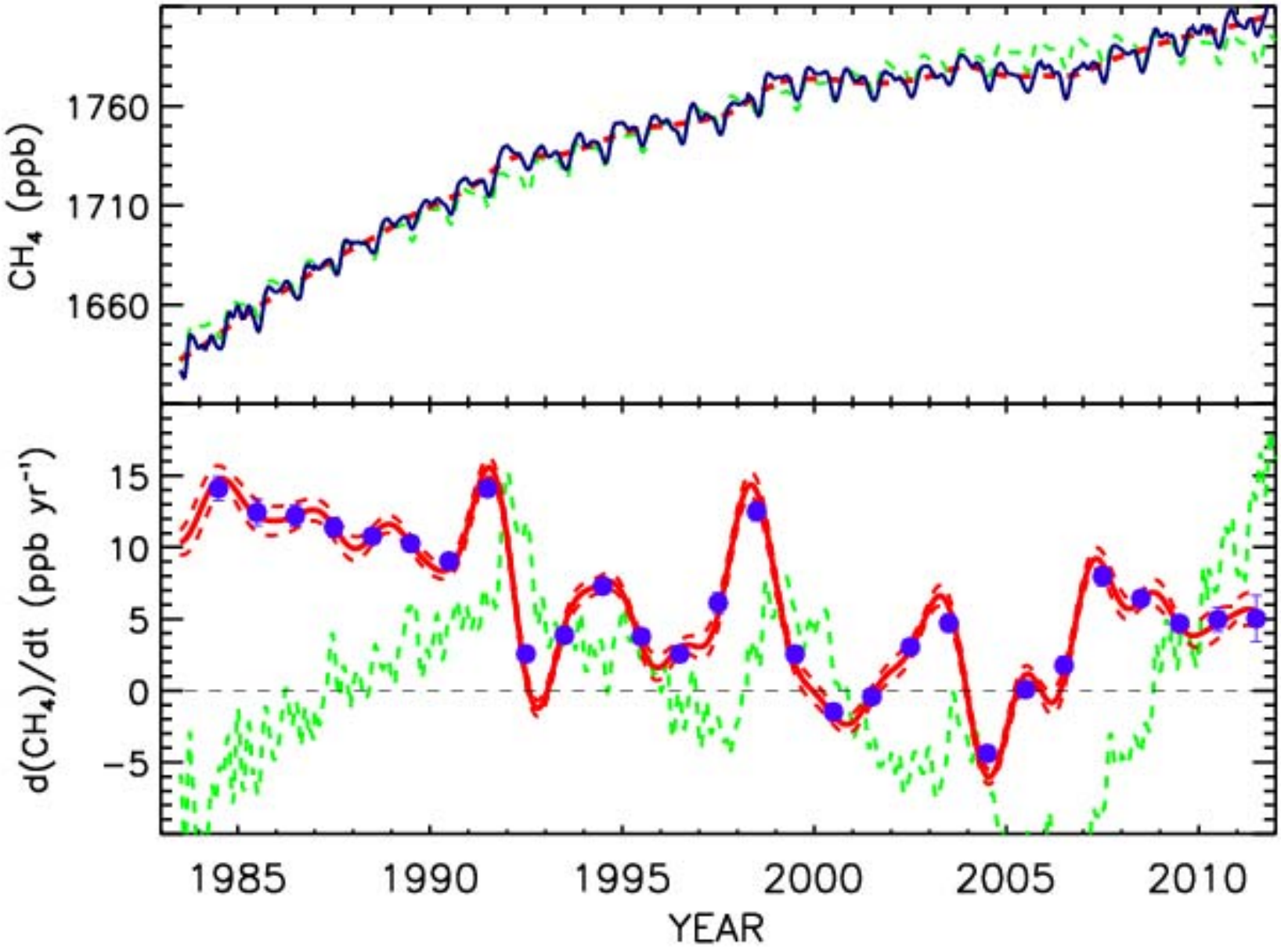
Composite Precipitation - La Niña



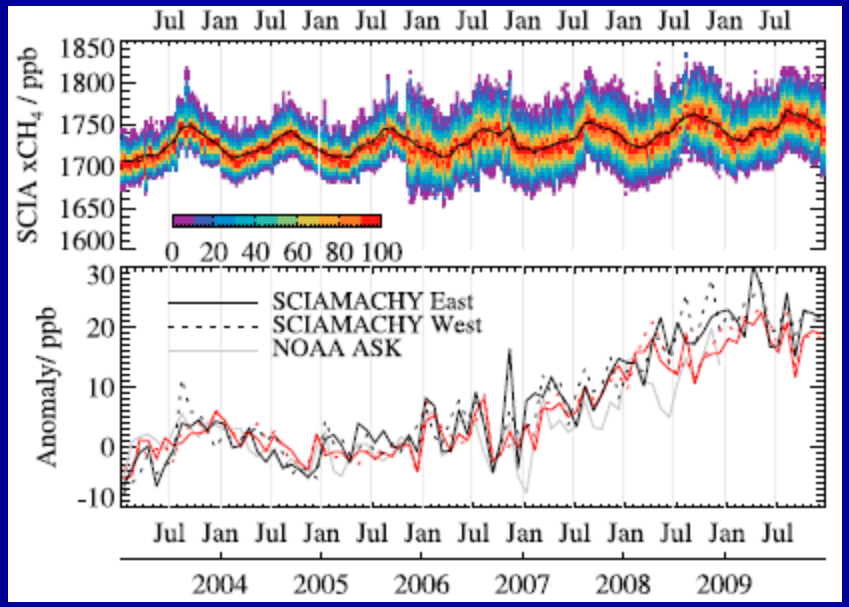
El Niño

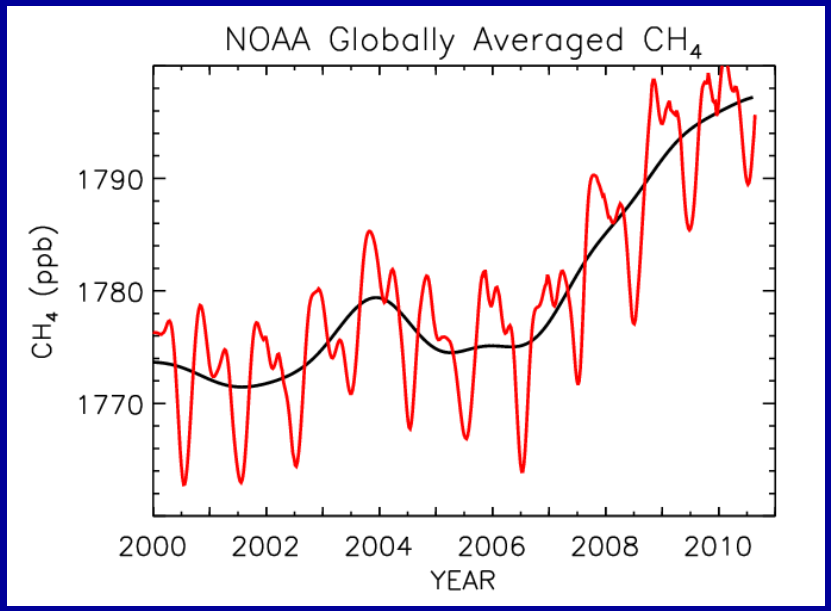


Source: GPCP


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

SCIAMACHY

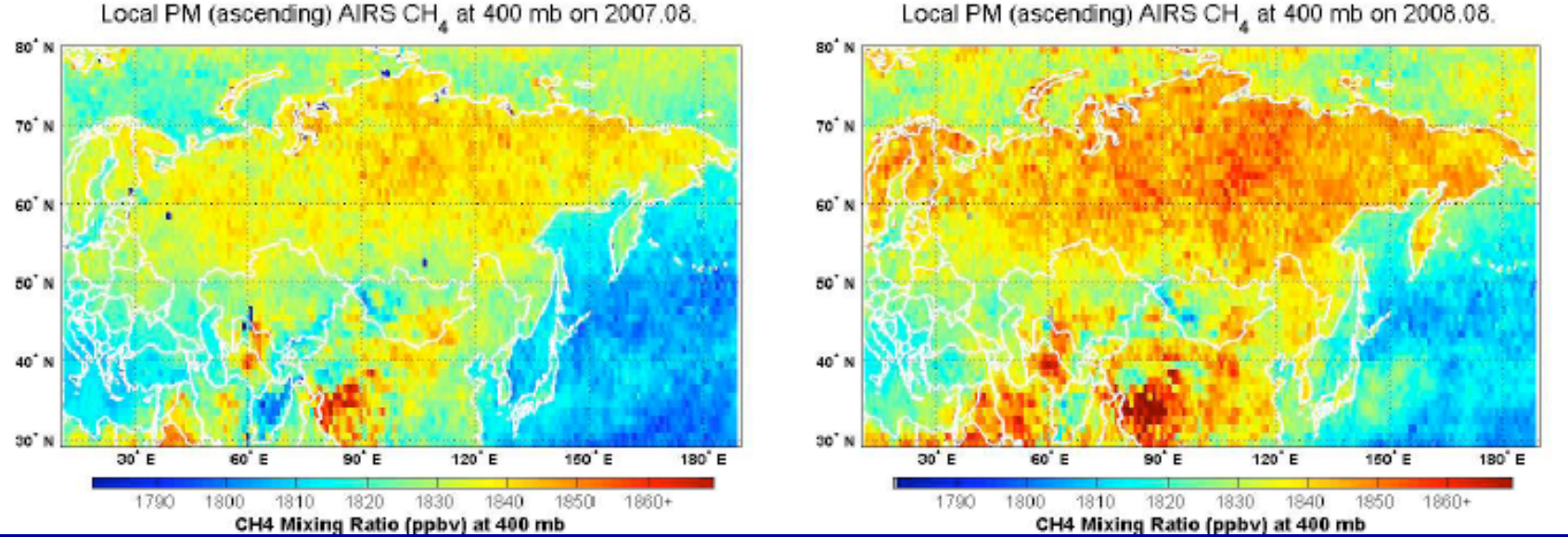


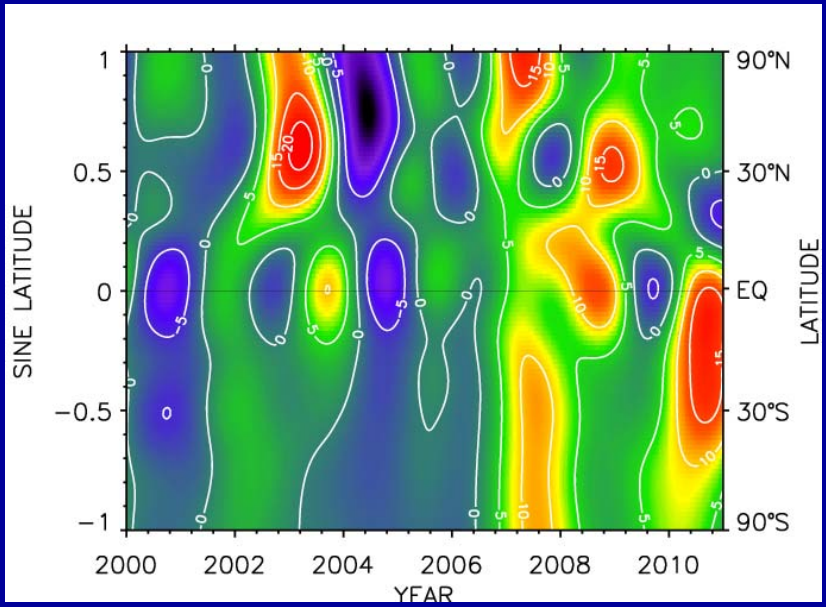


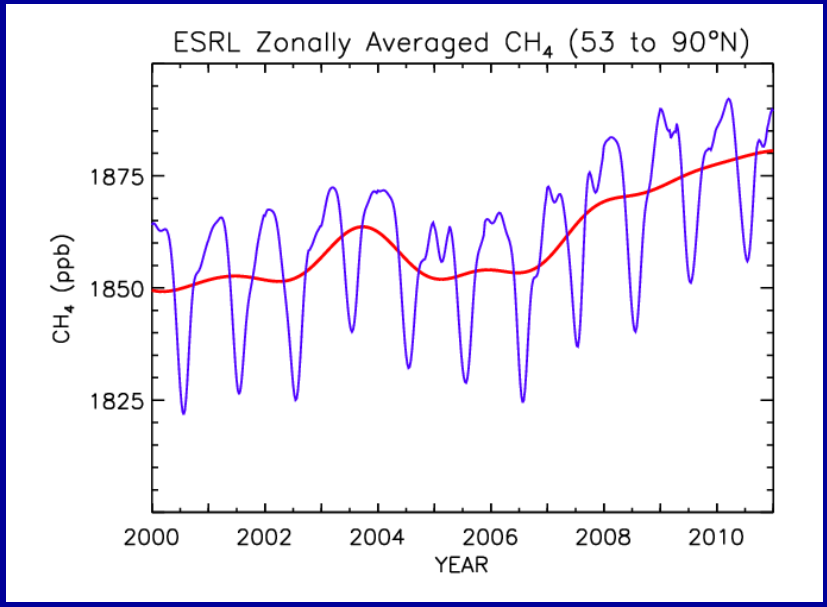
Increases in SCIA in 2007 and 2008 consistent with in situ observations.
Insufficient S/N to identify cause of recent CH_4 increase.
Frankenberg et al., JGR, 2011.

GOSAT may be better.

AIRS

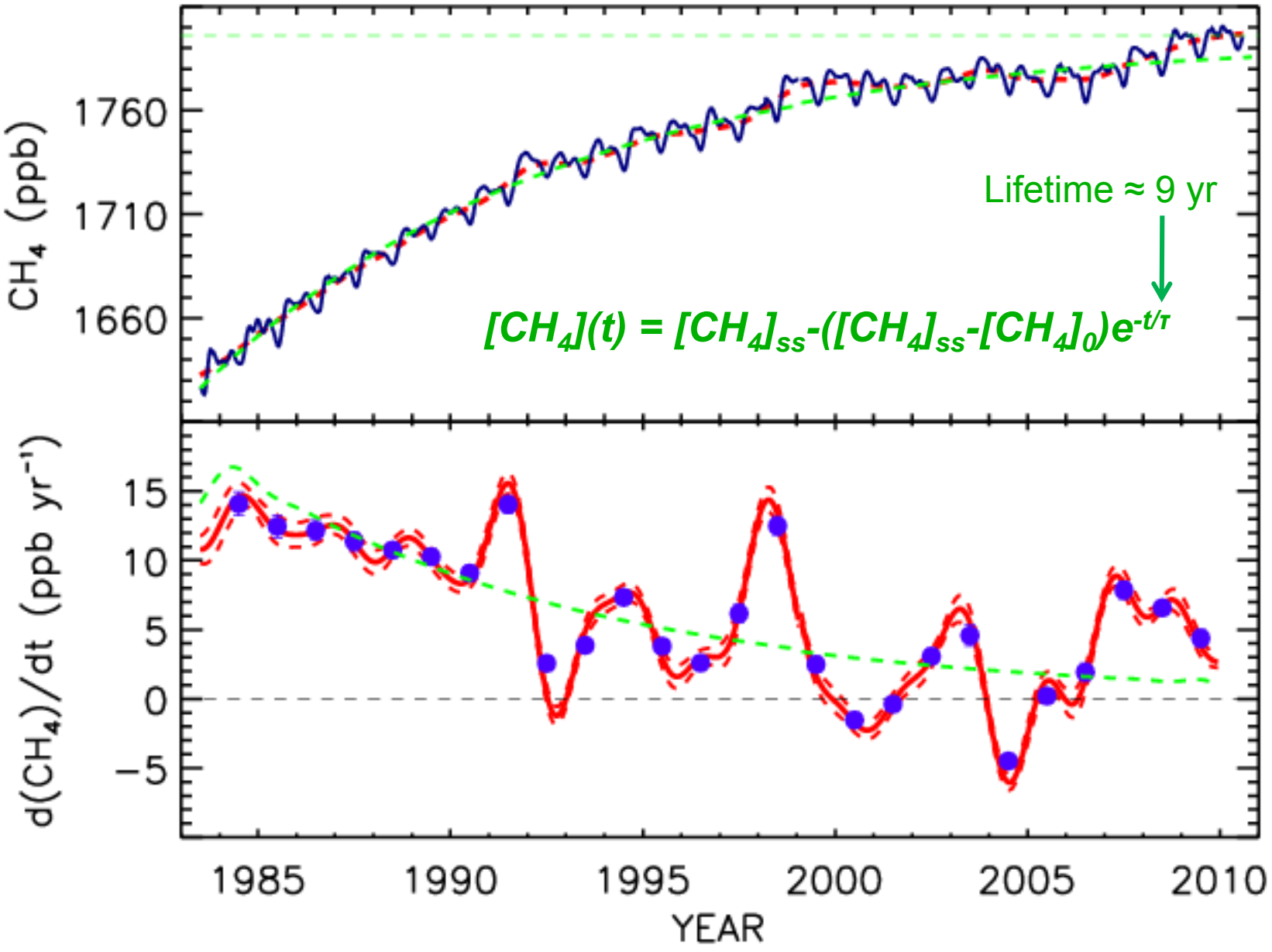

Local PM (ascending) AIRS CH4 at 400 mb on 2007.08.
Local PM (ascending) AIRS CH4 at 400 mb on 2008.08.
80° N
70° N
60° N
50° N
40° N
30° N
30° E
60° E
90° E
120° E
150° E
180° E
1790
1800
1810
1820
1830
1840
1850
1860+
CH4 Mixing Ratio (ppbv) at 400 mb


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


ESRL Zonally Averaged CH4 (53 to 90°N)
CH4 (ppb)
1875
1850
1825
2000
2002
2004
2006
2008
2010
YEAR

Conclusions

- Global CH_4 increase continues in 2010:
  - ~6.0 ppb yr^{-1} from 2007 to 2010
  - Largest, most persistent anomaly in record
- Observation-based assessment of causes:
  - T and precipitation are key drivers
- Current observation network is insufficient:
  - Satellite sensors: low S/N and disinformation
  - *In situ* measurements: increase spatial coverage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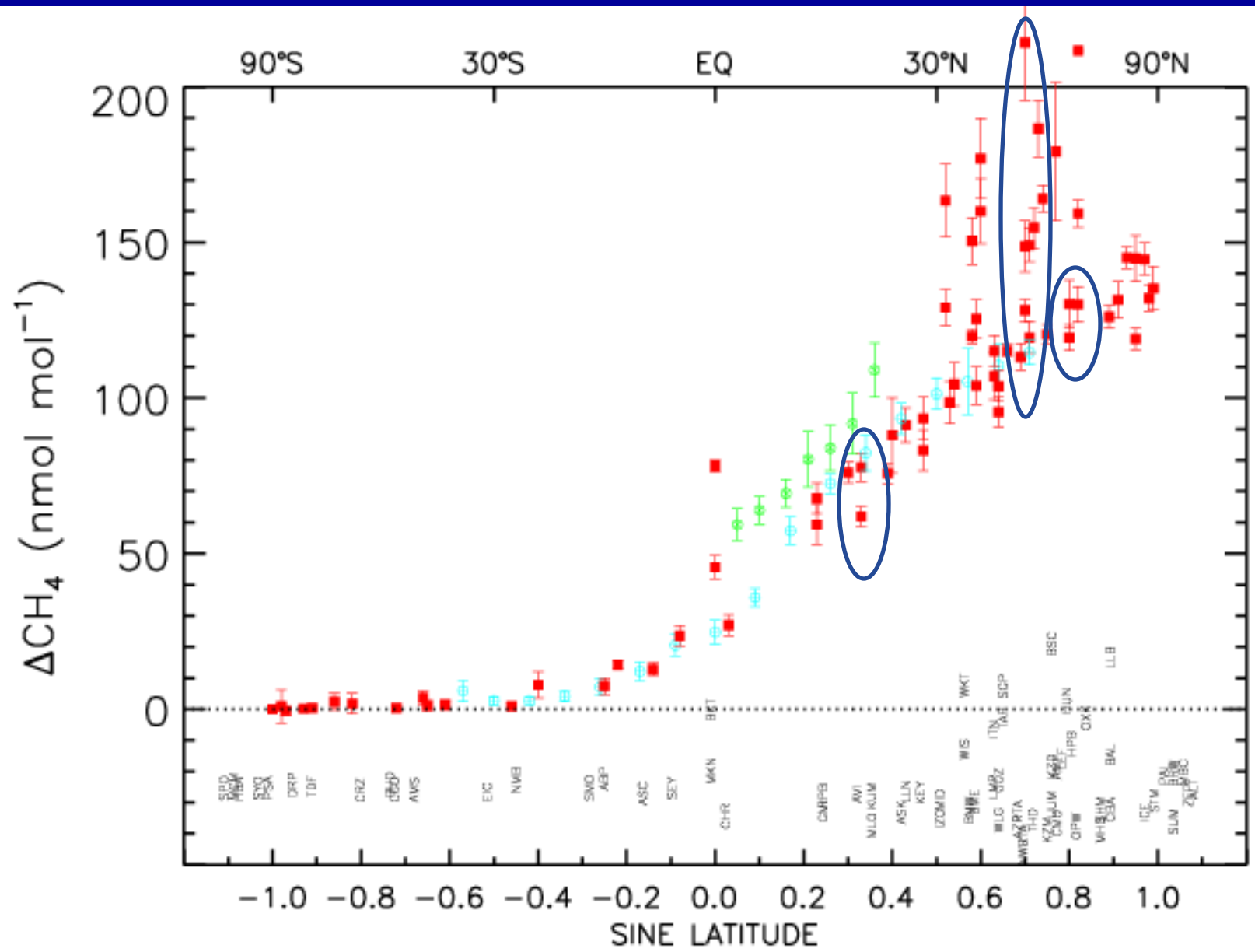
15
10
5
0
−5
1985
1990
1995
2000
2005
2010
YEAR


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.

Constraints on Global CH_4 Budget

- Globally averaged CH_4
  - Atmospheric burden: ~4990 Tg CH_4 in 2011
  - Radiative forcing (since PI): 0.5 W m^{-2}
- Rate of increase
  - Imbalance between emissions and losses
- Spatial distribution of CH_4 abundance
  - Spatial distribution of emissions
- Seasonal cycle
  - Temporal distribution of emissions