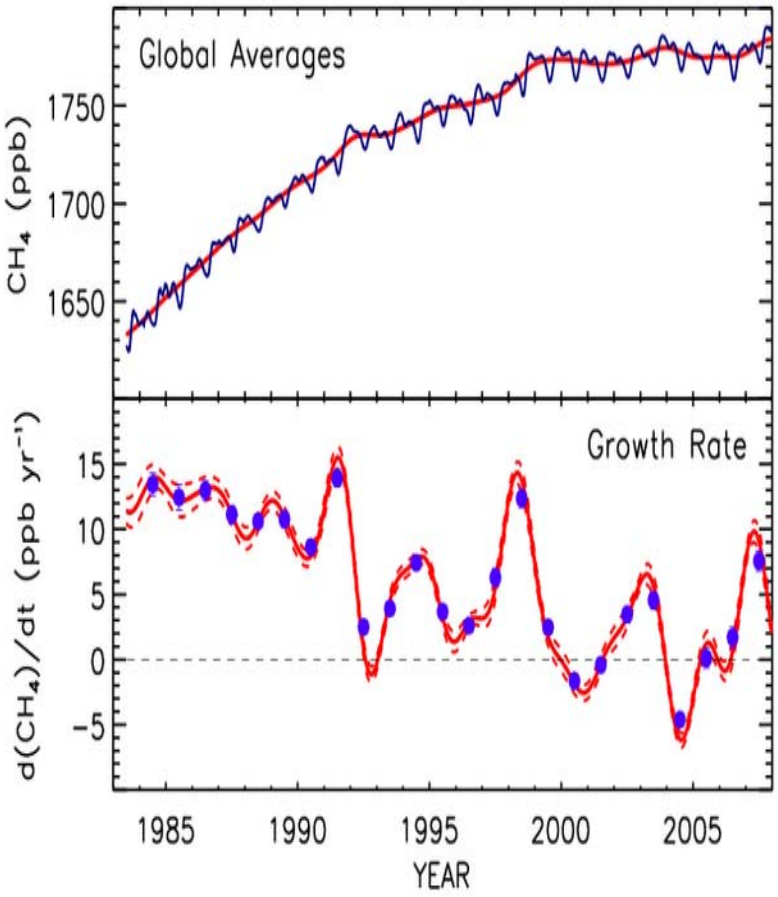
Causes of the Anomalous Atmospheric CH_4 Growth Rate During 2007

Lori Bruhwiler and Ed Dlugokencky

Earth System Research Laboratory
Boulder, Colorado

Global Growth Rate



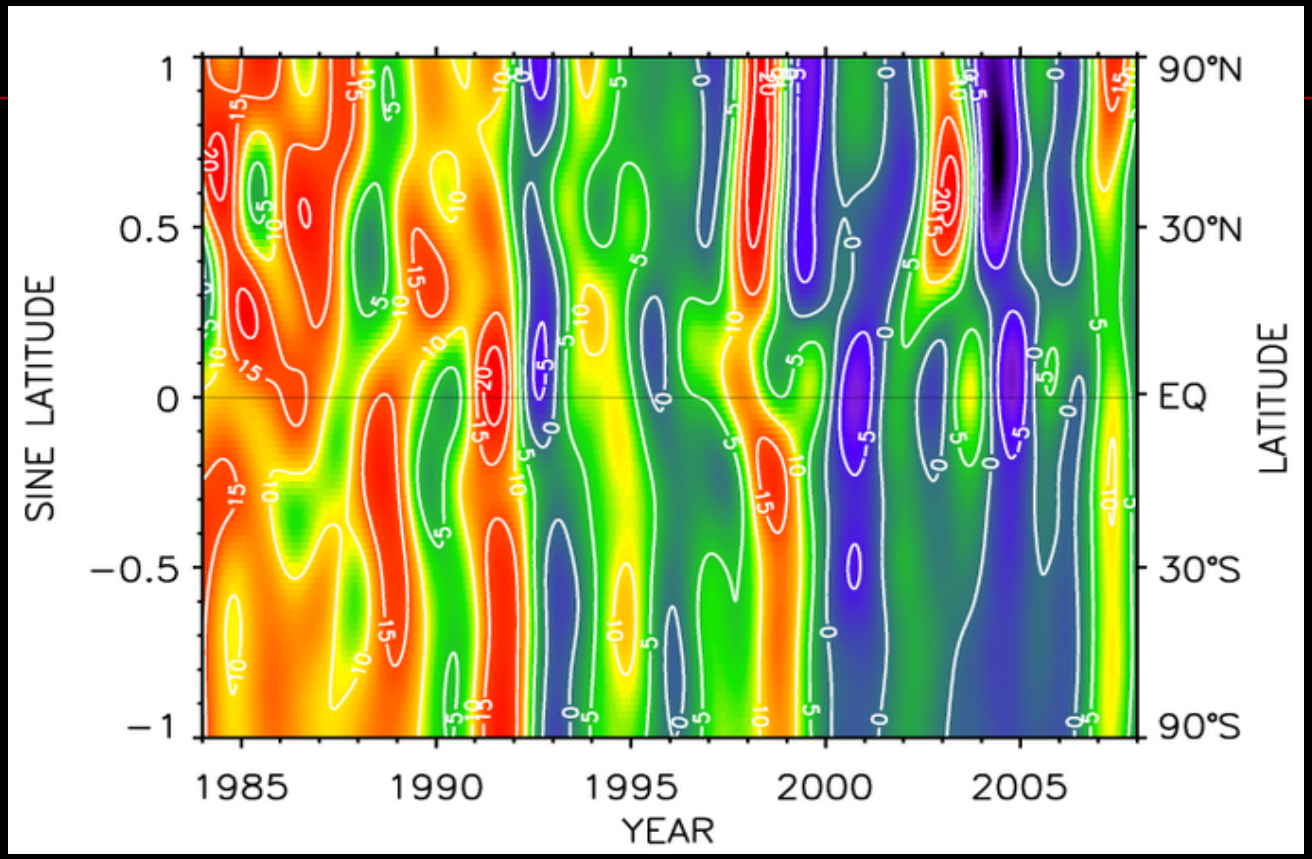
No significant Change in Growth Rate.

Methane could be approaching steady state (Dlugokencky et al., GRL, 2003) even though we think some sources may be increasing.

What causes the variability?

What happened last year?

CH_4 Growth Rate (ppb/yr)

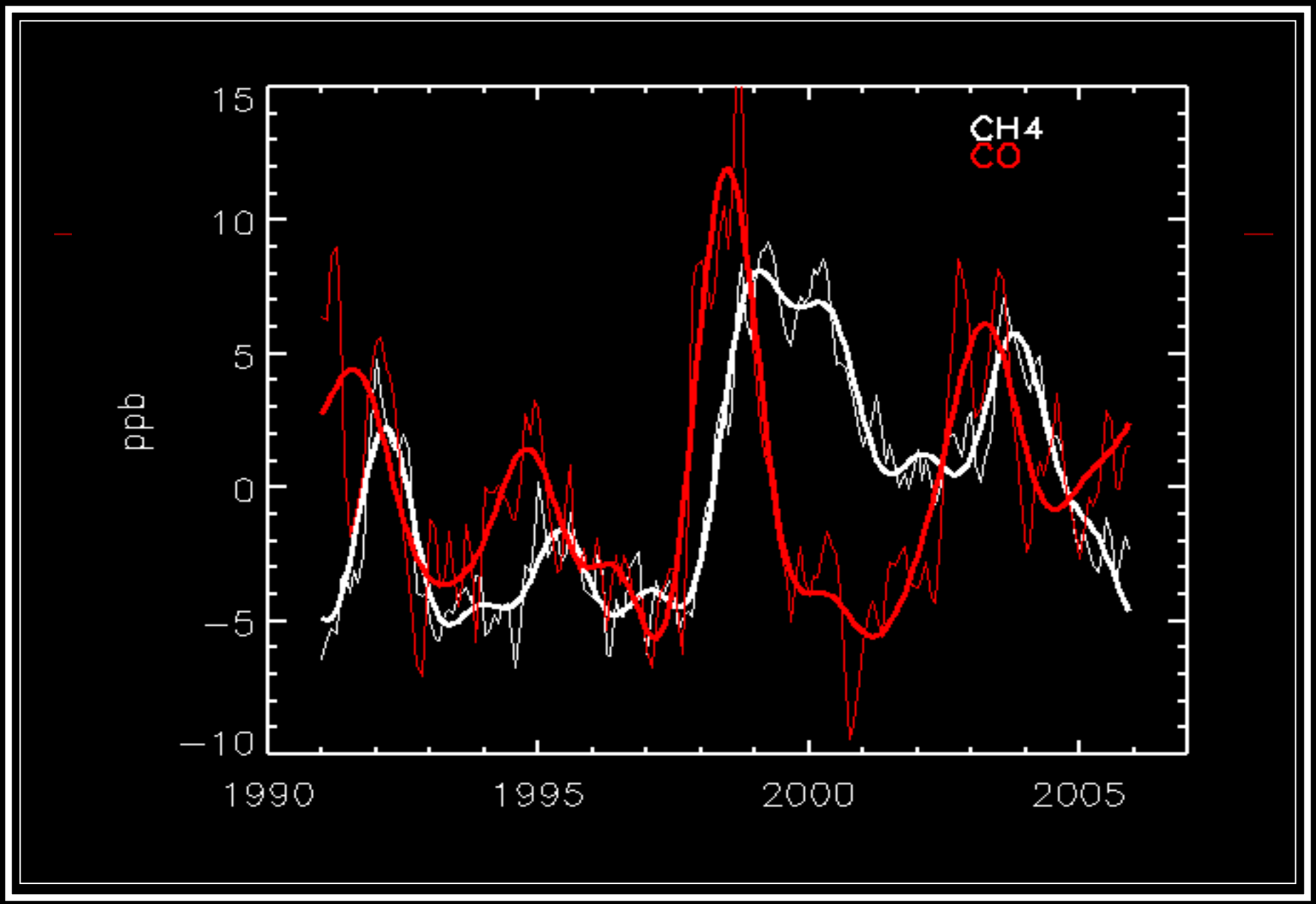


(Figure by K. Masarie)

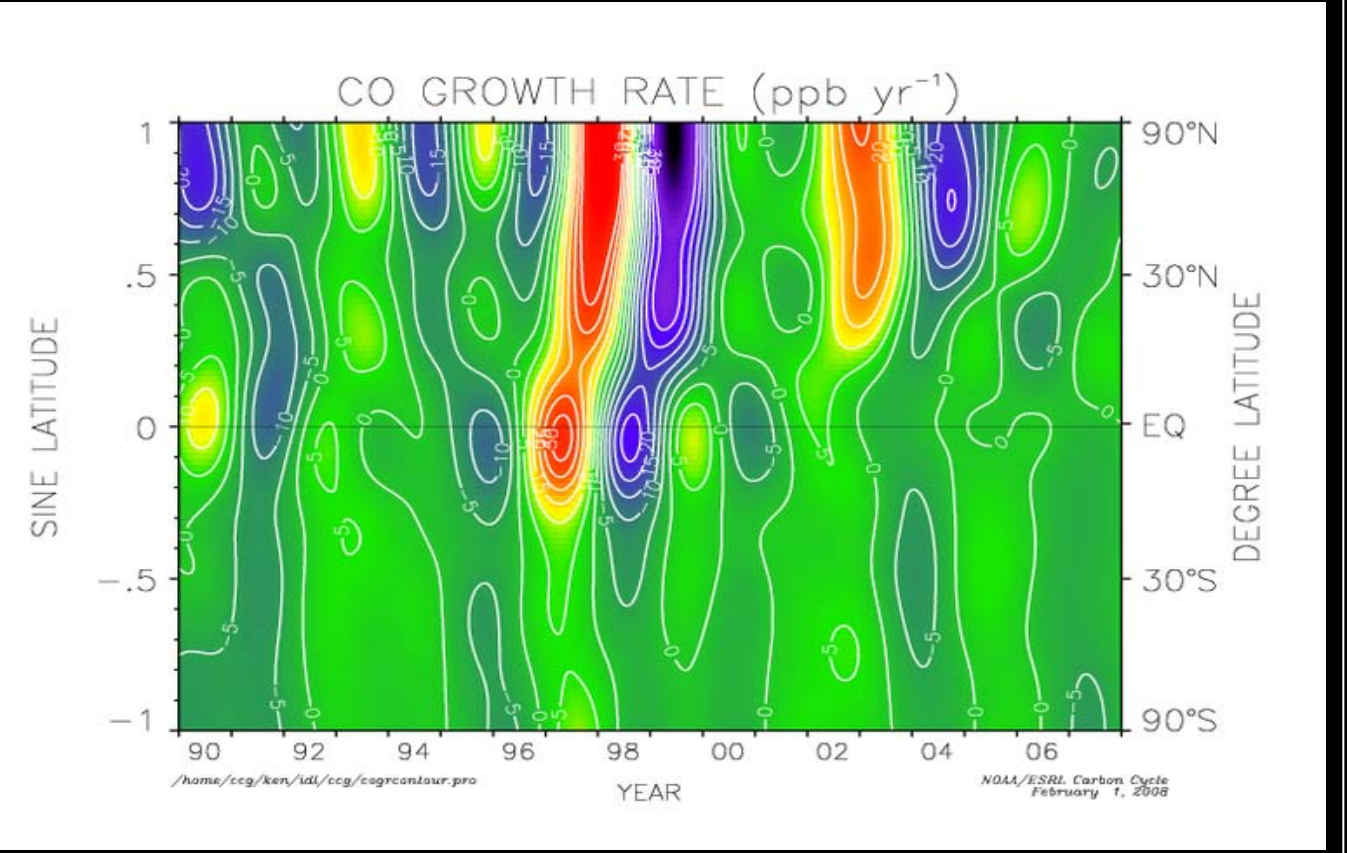
Optimized 2001 Emissions
525.63 TgCH4/yr
(Courtesy of P. Bergamaschi)

Coal	30.72	(TgCH4/yr)
Oil/Gas	50.86	
Enteric Fermentation/Manure	100.46	
Rice	59.74	
Biomass Burning	32.30	
Waste	73.62	
Wetlands	174.49	
Wild Animals	5.00	
Termites	19.23	
Soil	-37.79	
Oceans	17.00	

Fire?


CH4
CO
15
10
5
0
−5
−10
ppb
1990
1995
2000
2005

2007 was not a year with a unusually high biomass burning.



(data: Paul Novelli)

Biomass Burning Emissions:
Global Fire Emissions Database (GFEDv2)

Burned area obtained from MODIS fire counts

Vegetation and soil biomass obtained from the CASA Biosphere model

Giglio et al., 2006

Transport the Emissions with TM5 (CarbonTracker model)

Wetlands?

Wetlands

Area: 5.6×10^6 km^2 (4% Global Land Surface)

Boreal Wetlands: 50% of area, 25% CH_4 emission
Temperature-Regulated
Seasonal (Freeze, Thaw)
High Organic Matter (Peat)

Tropical/Subtropical Wetlands:
40% of area, 65% CH_4 emission
Precipitation-Regulated
Seasonal (Flooding, Water Table Rise)

Wetland Model:

(Walter,Heimann, and Matthews, 2001; Walter,Heimann and Matthews,2001)

Soil Temperature Dependence

Global Wetland Distribution of Matthews and Fung (1987)

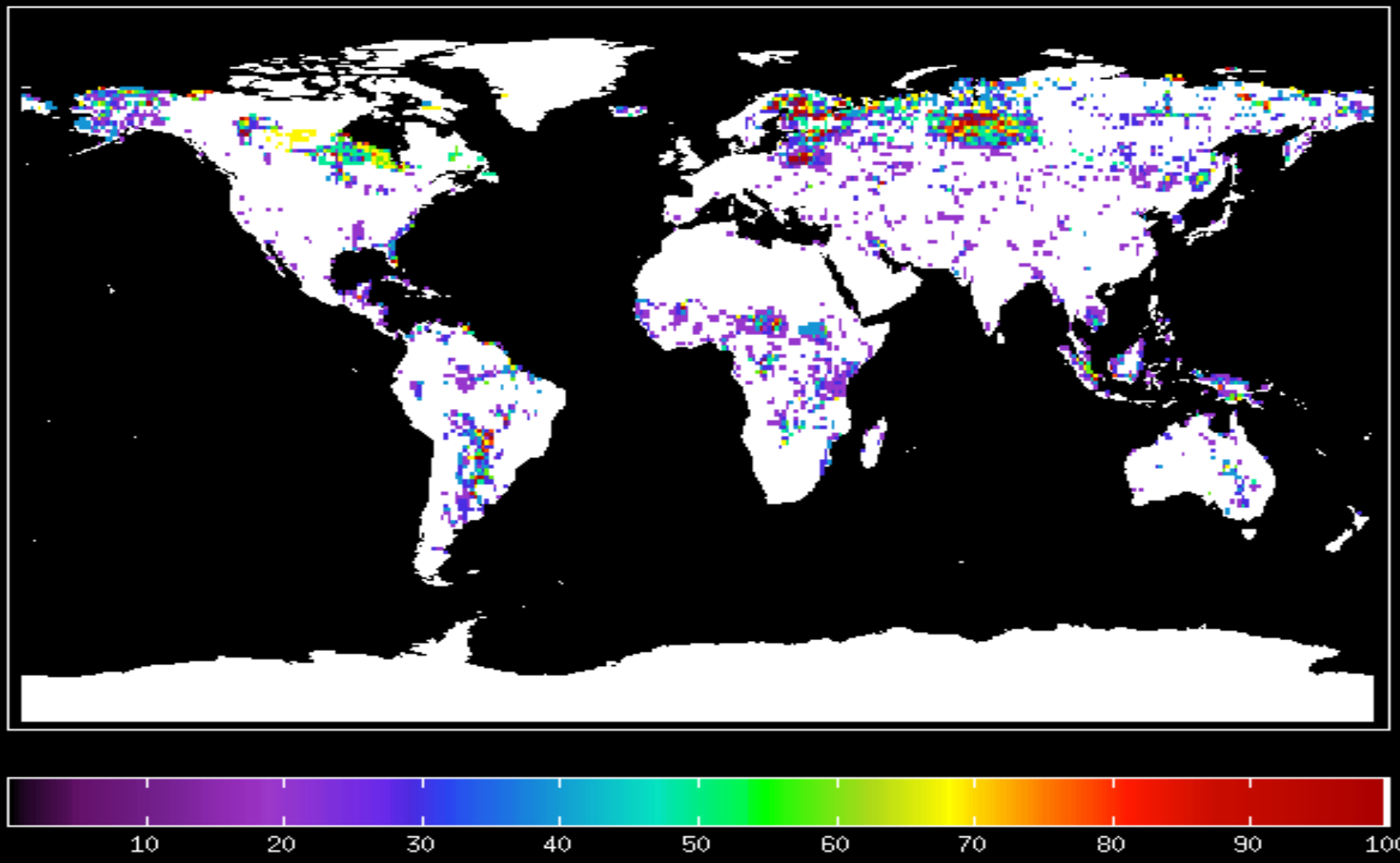
Net Primary Productivity

Water Table Calculated Using a Simple Hydrologic Model

Regression calculation used in TM5 : Δ Flux = α ΔT + β ΔP

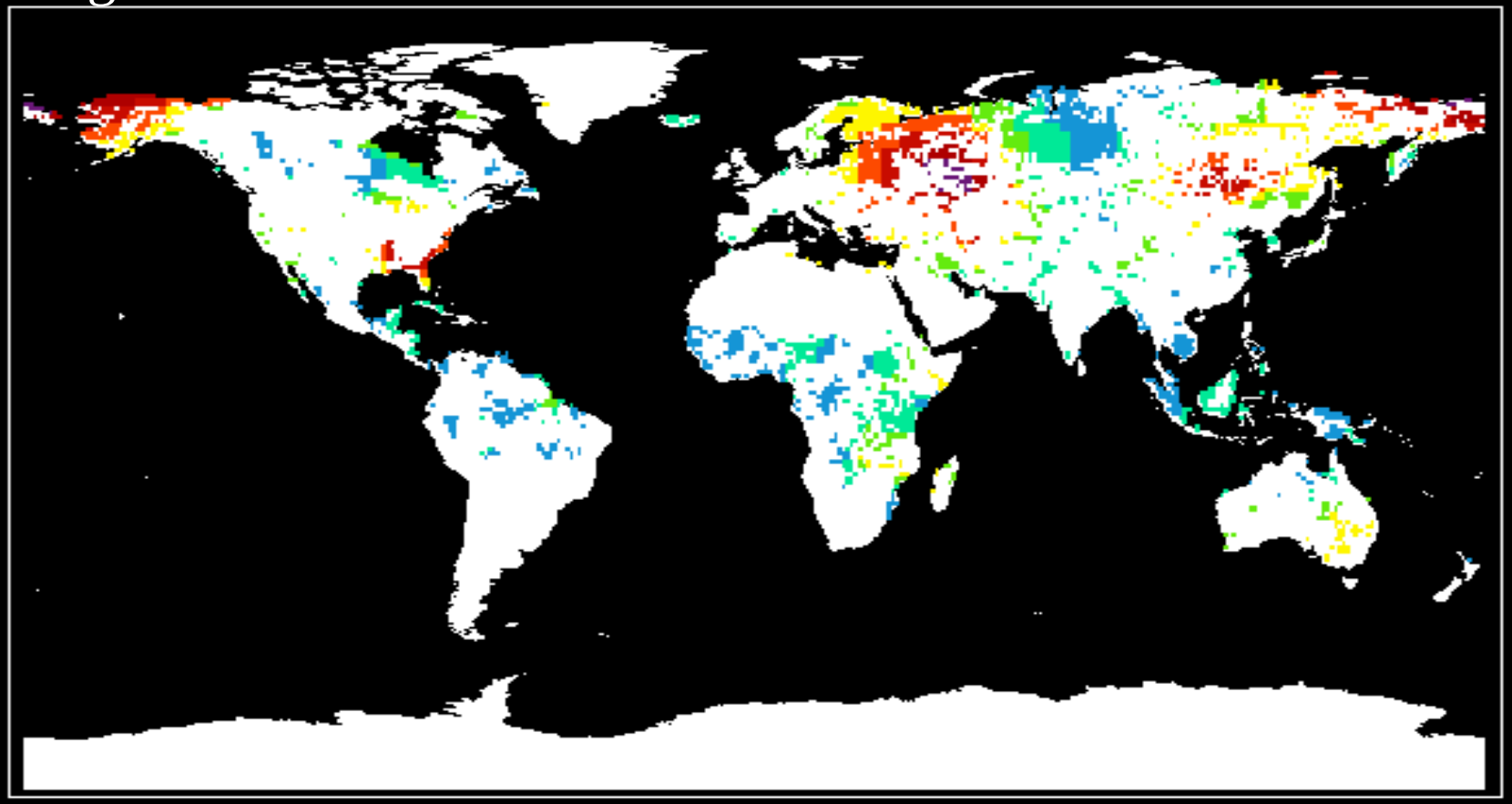
(ΔT - ERA40 Reanalysis)

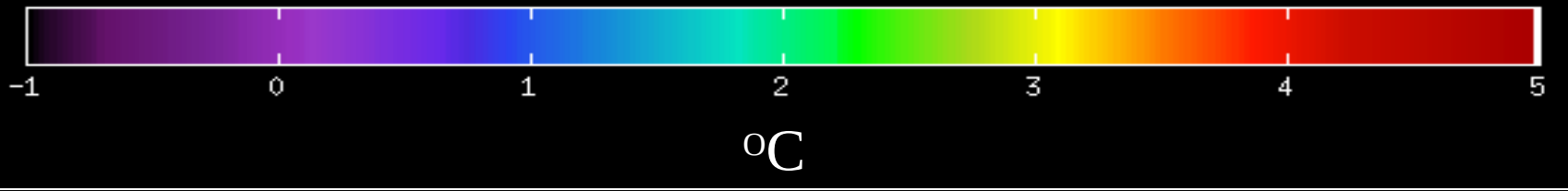
(ΔP -Rain Gauge Product, Chen et al 2002)



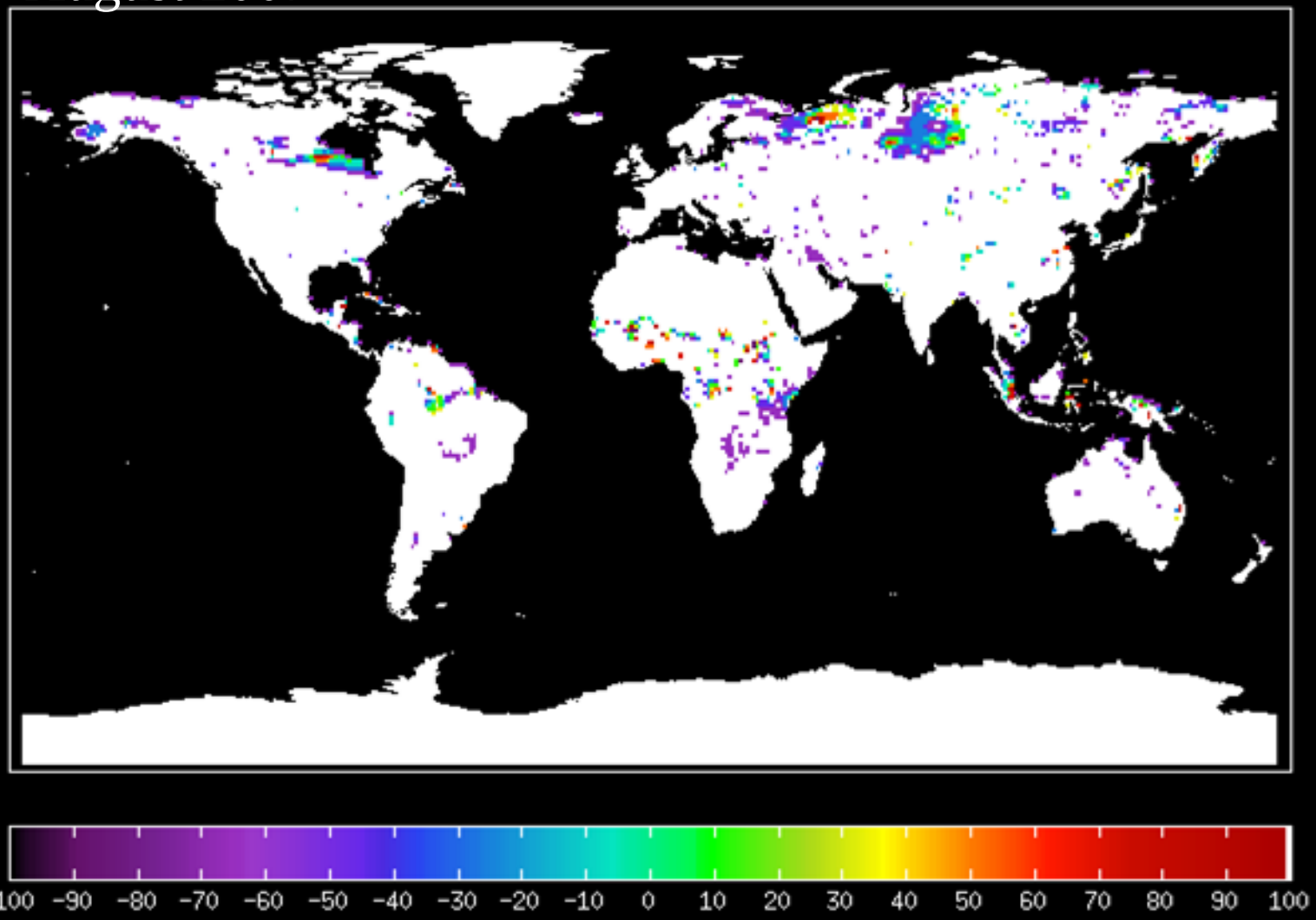
Fractional Inundation (%) - Matthews and Fung

August 2007

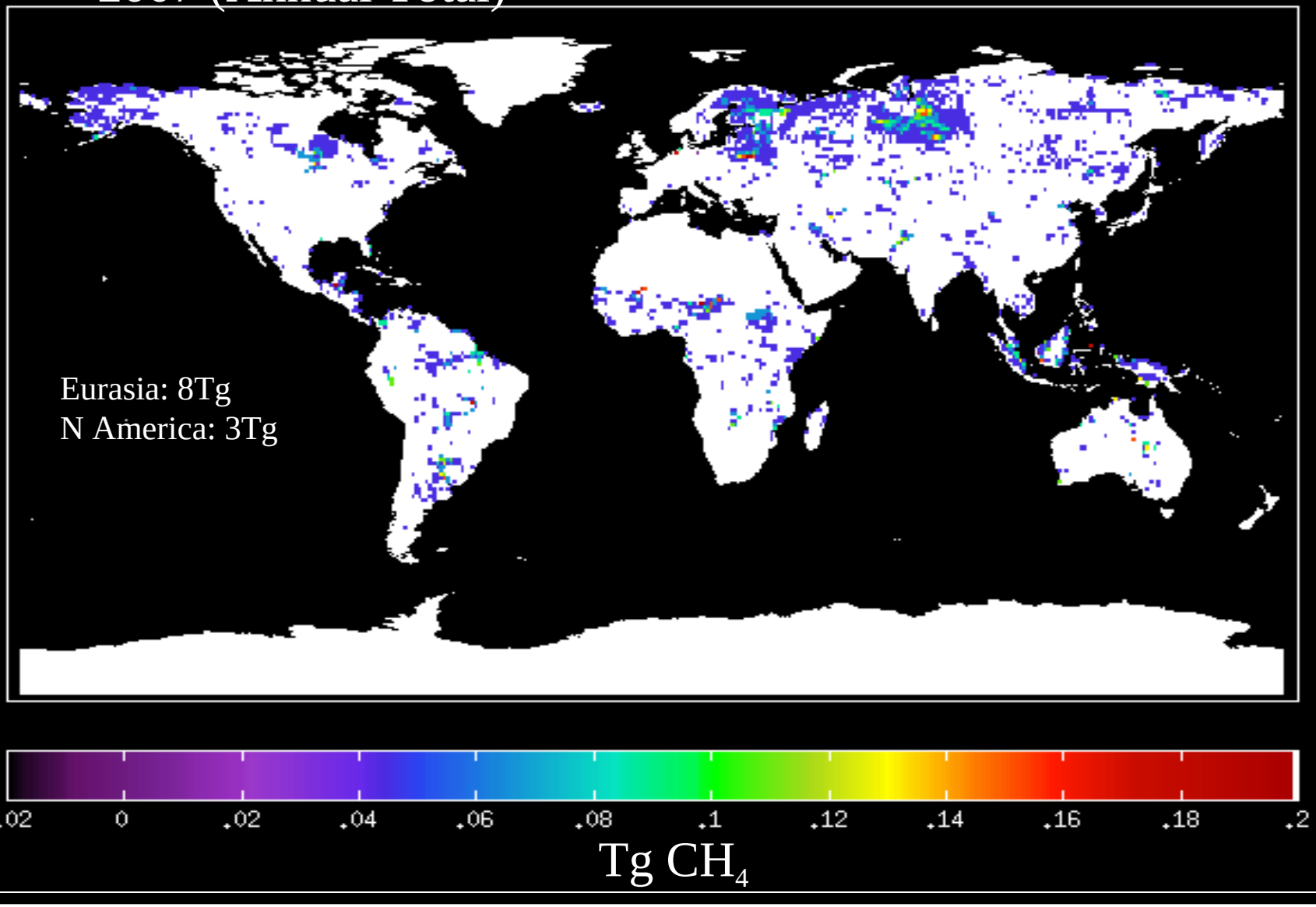


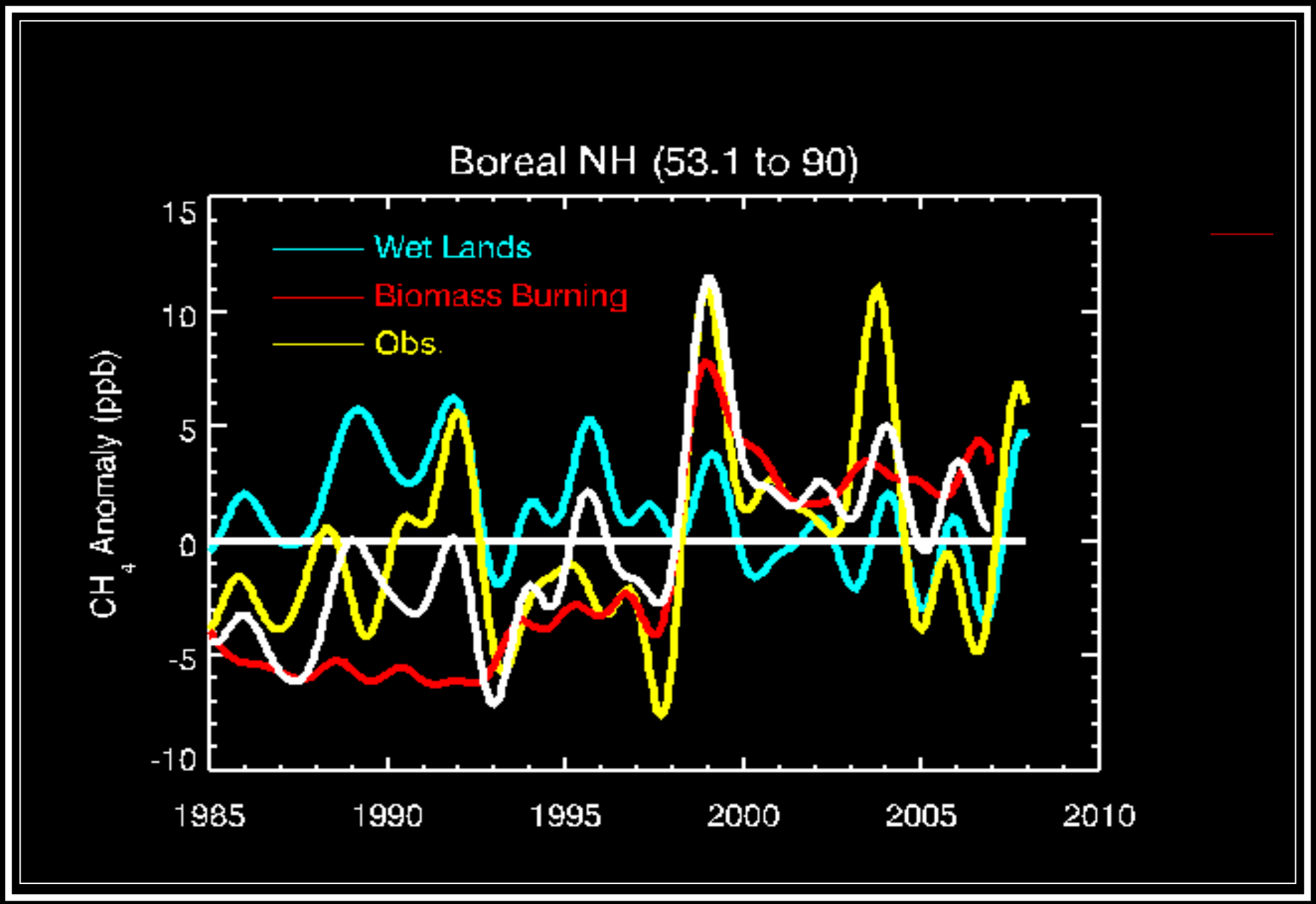


August 2007

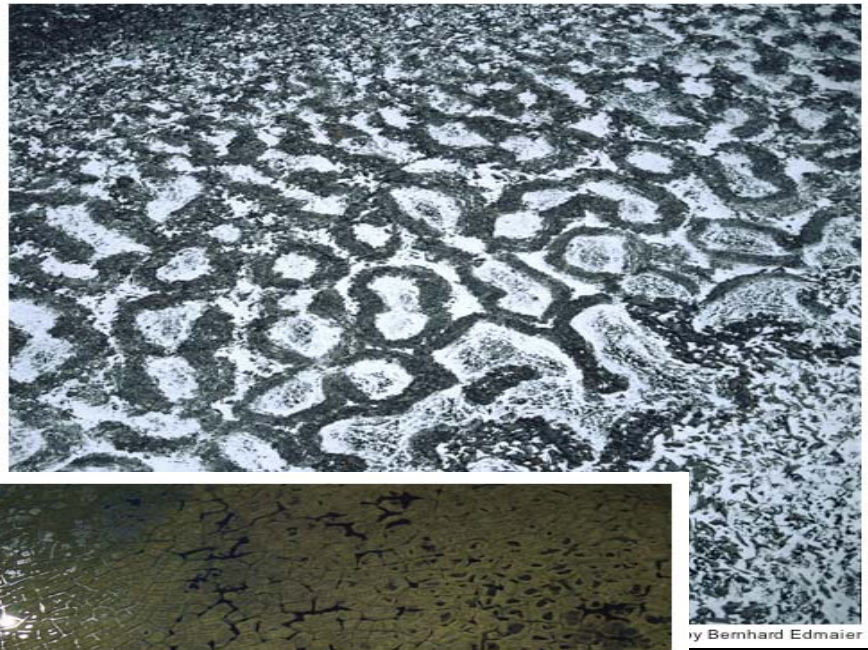

−100 −90 −80 −70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60 70 80 90 100
mm/month

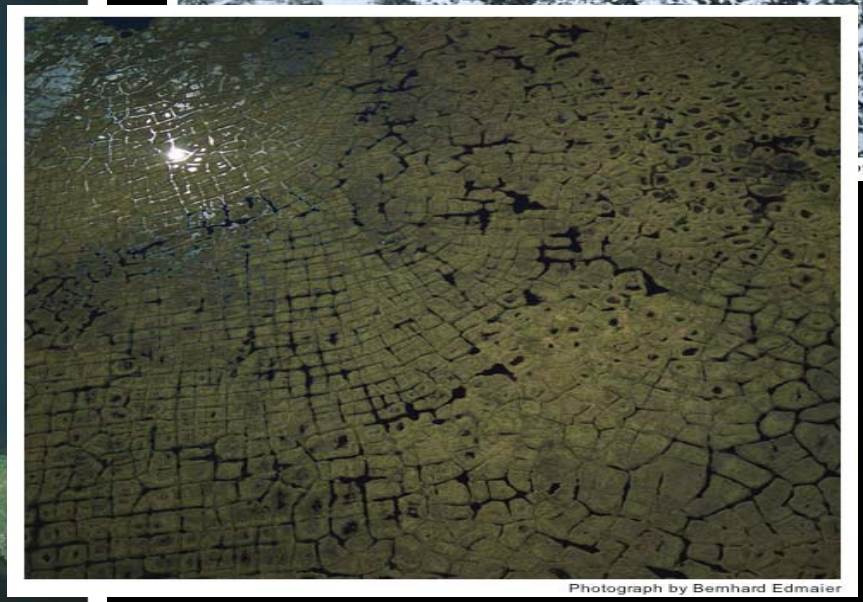
2007 (Annual Total)




Boreal NH (53.1 to 90)
Wet Lands
Biomass Burning
Obs.
CH4 Anomaly (ppb)
15
10
5
0
-5
-10
1985
1990
1995
2000
2005
2010

Permafrost Degradation?





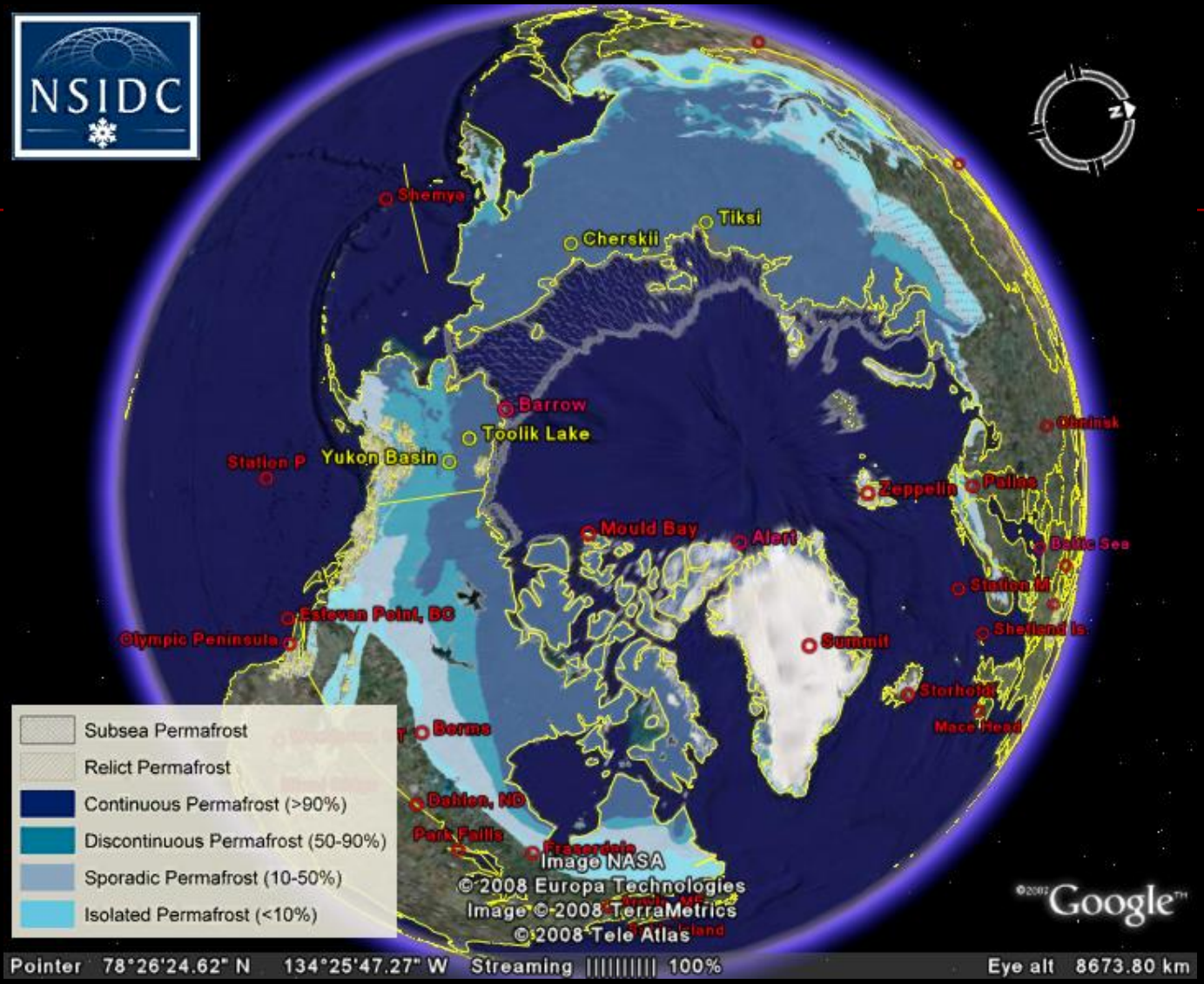
Permafrost

- Accelerating melting → thermokarst formation → Expanding wetland area.
- Longer active season.
- Increased transport DOC to Arctic Ocean.
- Soils contain 500 to 900 Pg C, implying a potential for huge CH_4 and CO_2 emissions.

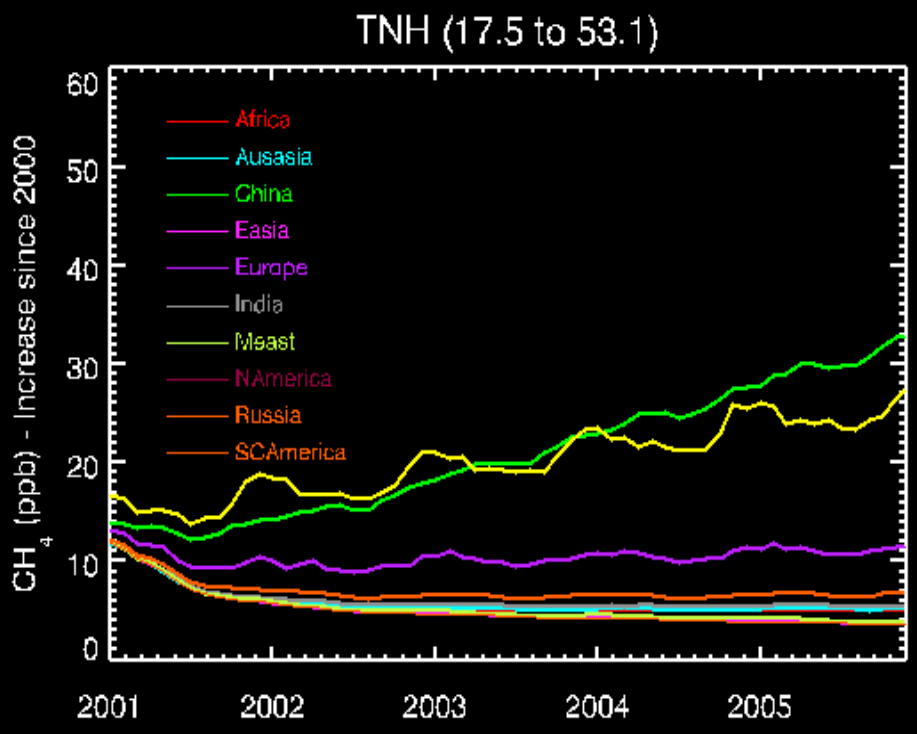
Walter et al., *Nature*, Sept. 2006

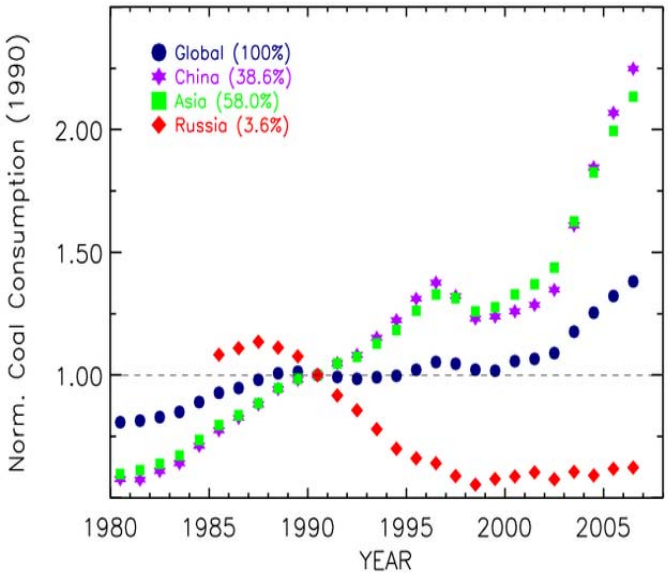
Methane Bubbling From Siberian Lakes

- **Year-round flux measurements.**
- **Remote sensing, aerial surveys quantify emissions.**
- **95% emissions from ebullition.**
- **3.8 TgCH4 yr^{-1} from Siberian thermokarst lakes**
- **Increased by 58%, from 1974 to 2000.**
- **Carbon source, 35-43k years old, d13C~-70‰.**


NSIDC
Shemya
Tiksi
Cherskii
Barrow
Toolik Lake
Station P
Yukon Basin
Zeppelin
Mould Bay
Alert
Esteven Point, BC
Olympic Peninsula
Summit
Storhofdi
Mace Head
Shetland Is.
Baltic Sea
Berms
Dahlen, ND
Park Falls
Fraserdale
Subsea Permafrost
Relict Permafrost
Continuous Permafrost (>90%)
Discontinuous Permafrost (50-90%)
Sporadic Permafrost (10-50%)
Isolated Permafrost (<10%)
Image NASA
©2008 Europa Technologies
Image ©2008 TerraMetrics
©2008 Tele Atlas
©2007 Google
Pointer 78°26'24.62" N 134°25'47.27" W Streaming 100%
Eye alt 8673.80 km

Future Trends





(See Ed Dlugokencky's Poster)

Conclusions

Methane variability is well accounted for by biomass burning inventories and parameterized wetland emissions.

2007 was anomalously warm at high latitudes and wetter than usual. This led to increased emissions from existing High Northern wetlands with a possible, but likely relatively small contribution from permafrost degradation.

Future trends may come from increases in anthropogenic sources, especially from developing economies.

Arctic Climate Change

- Accelerating T increase since early-1990s (>0.3°C decade^{-1}) resulting in warming of wetland soils.
- Decreasing snow cover and sea ice.
- Increased plant growth; northward migration of tree line.
- Increased terrestrial precipitation.
- Destabilization of permafrost.

Estimated Emission Growth
Sources: IRRI, EIA

Coal	31 TgCH4/yr	2%/yr 4.2%/yr China 2.7 %/yr India	40
Oil/Gas	51	0.4%/yr NA 2.4%/yr Russia 4.0%/yr SH/Mid-East	66
Rice	60	0.75%/yr	127
Wetlands (>60N)	45		136

Testing The Wetland Model

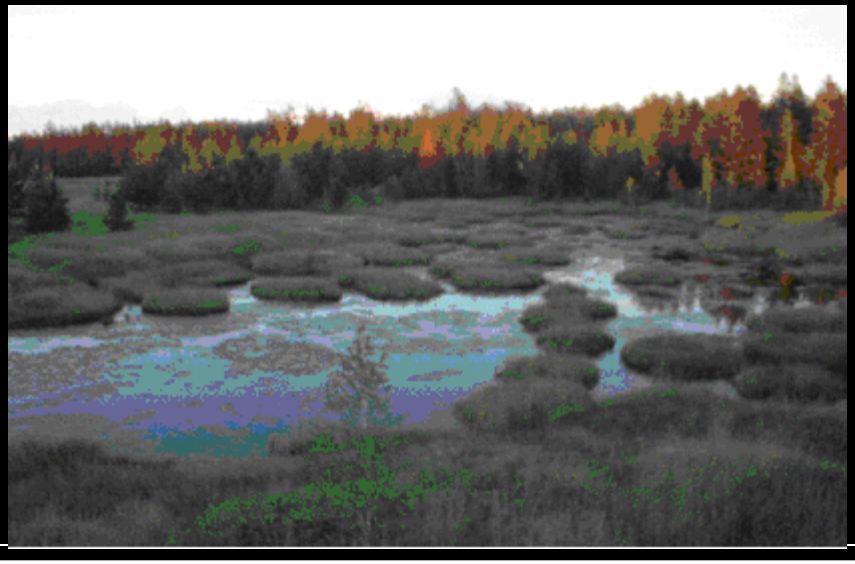
The wetland model was developed using parameterizations of wetland processes and hydrology

Calibrated/evaluated against a limited number of wetland sites (only 1 tropical site)

How well will it agree with atmospheric observations?

Thermokarst Formation

- Thermokarst (thaw) lakes migrate naturally and can be accelerated by climate change.

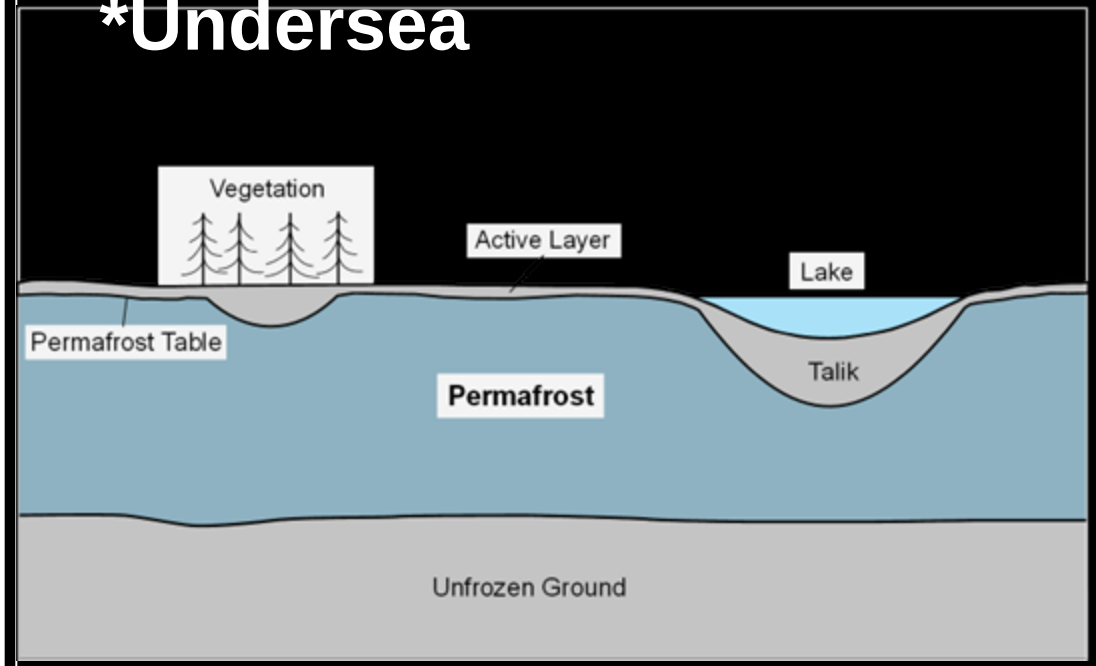


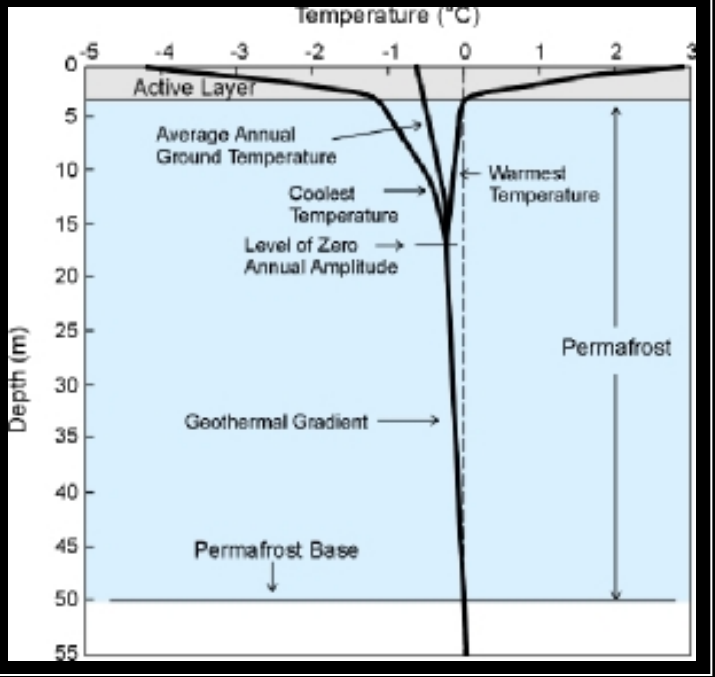
Permafrost

*Regions (dry or wet) below 0°C for two consecutive years.

*On land

*Undersea





Impacts on Infrastructure