A comparison of biomass burning emissions and deforestation in the Legal Amazon: 2001-2009

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Junior Faculty Forum
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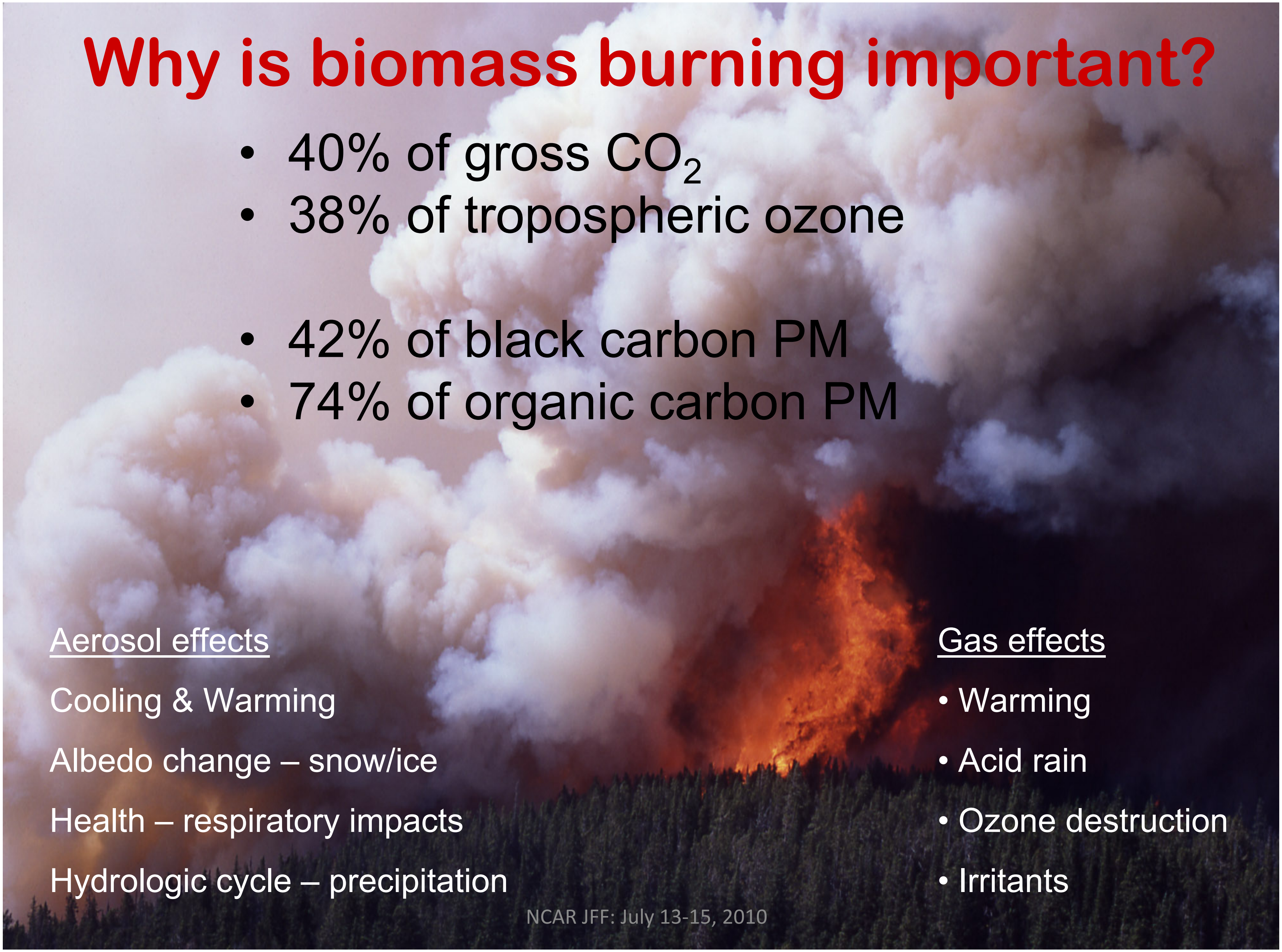
Outline

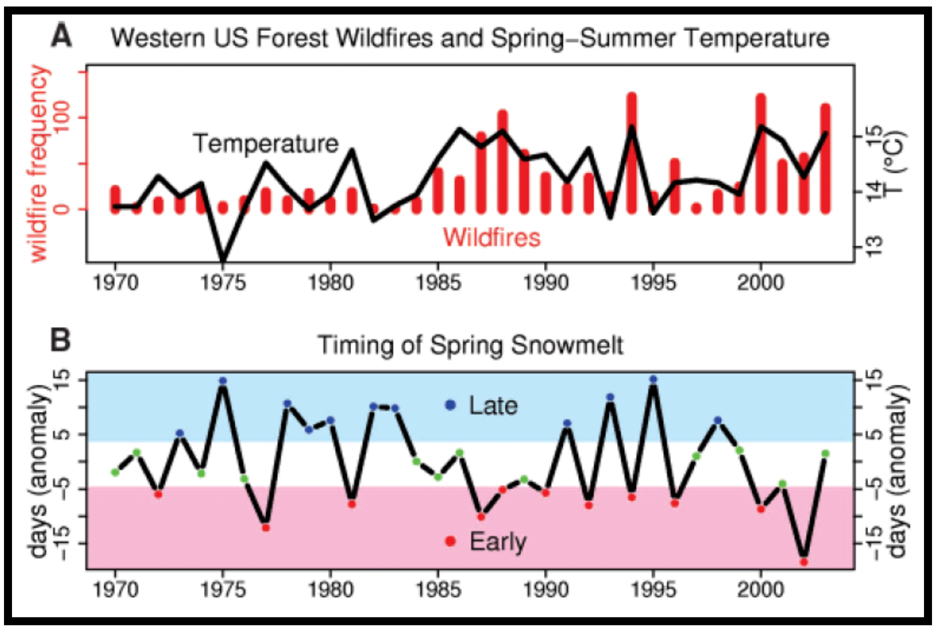
- Fire and FRP
- FRE estimation approach
- CO_2 Results
- State Trends
- Comparisons with Deforestation
- Conclusions - Discussion

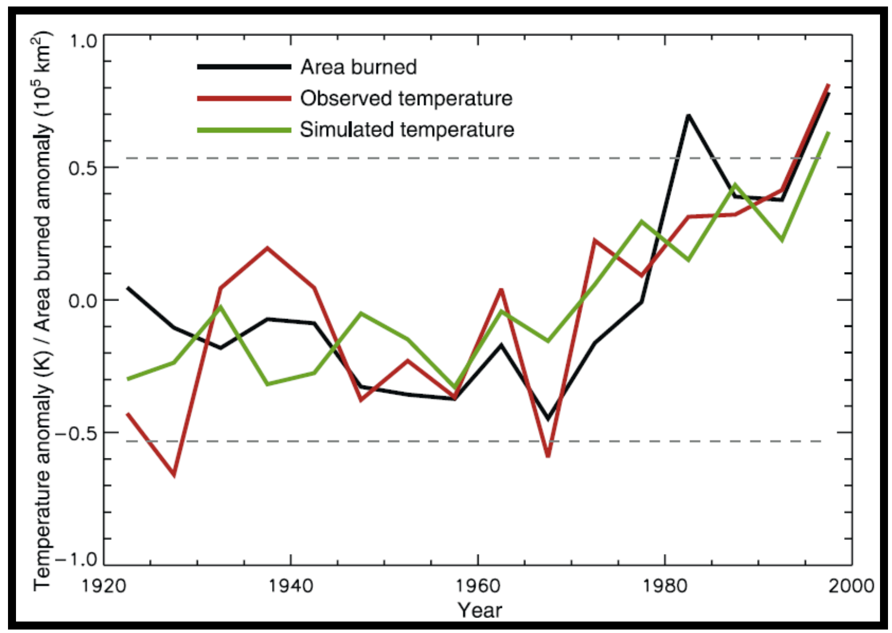

Why is biomass burning important?
• 40% of gross CO_2
• 38% of tropospheric ozone
• 42% of black carbon PM
• 74% of organic carbon PM
Aerosol effects
Cooling & Warming
Albedo change – snow/ice
Health – respiratory impacts
Hydrologic cycle – precipitation
Gas effects
• Warming
• Acid rain
• Ozone destruction
• Irritants
NCAR JFF: July 13-15, 2010

Present

Increased fire frequency over western U.S. in recent decades – related to warmer temp., earlier snow melt.

Area burned in Canada has increased since the 1960s, correlated with temp. increase.

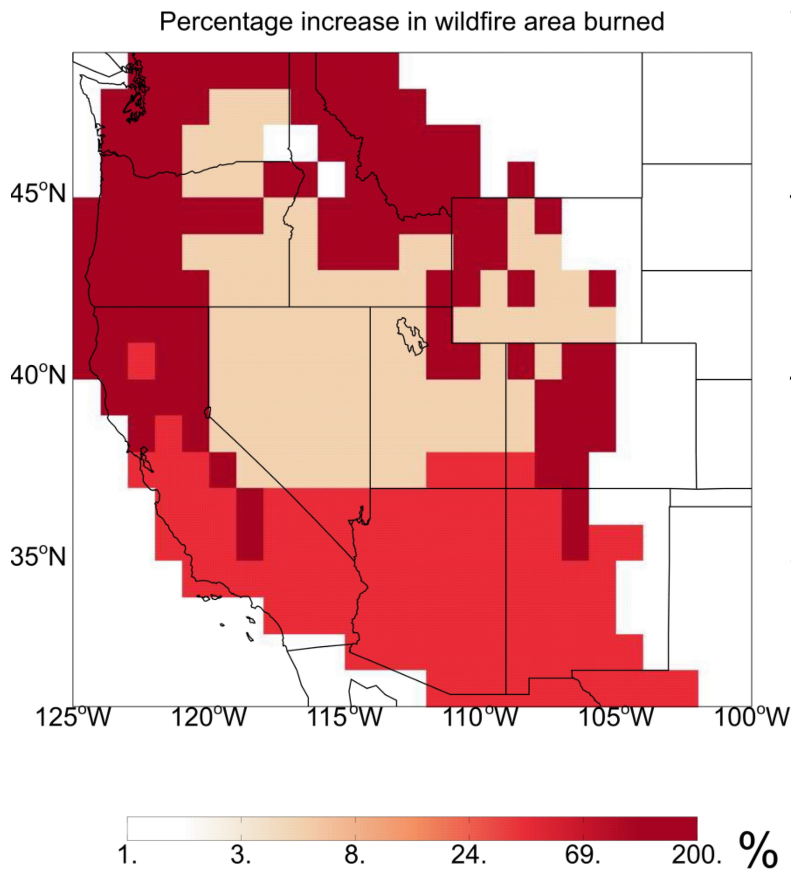




Westerling et al., 2007

Gillett et al., 2004

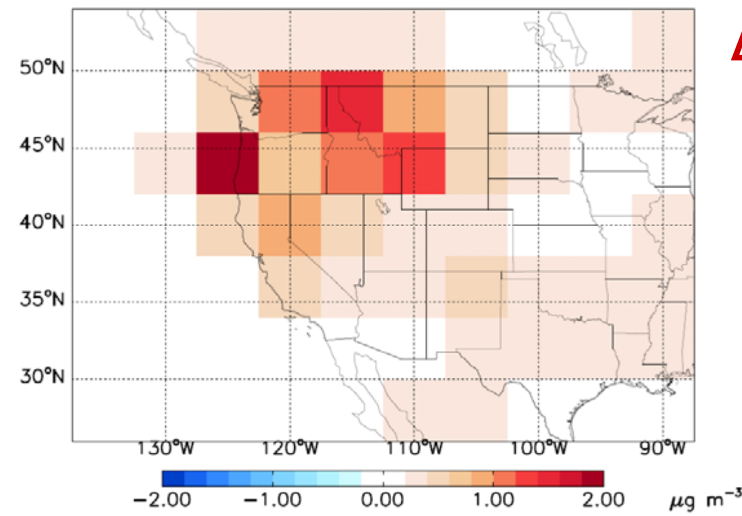
Future: This topic is not going away



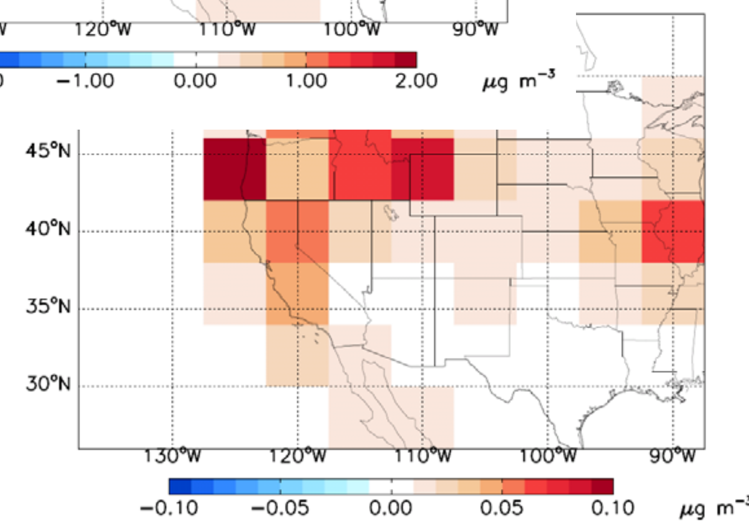
Burned area increase by 50% by 2050 and as much as 75 to 175% Pacific NW and the Rocky Mountains.

Spracklen et al. [2009]

Δ OC



Δ BC



Present day to 2050

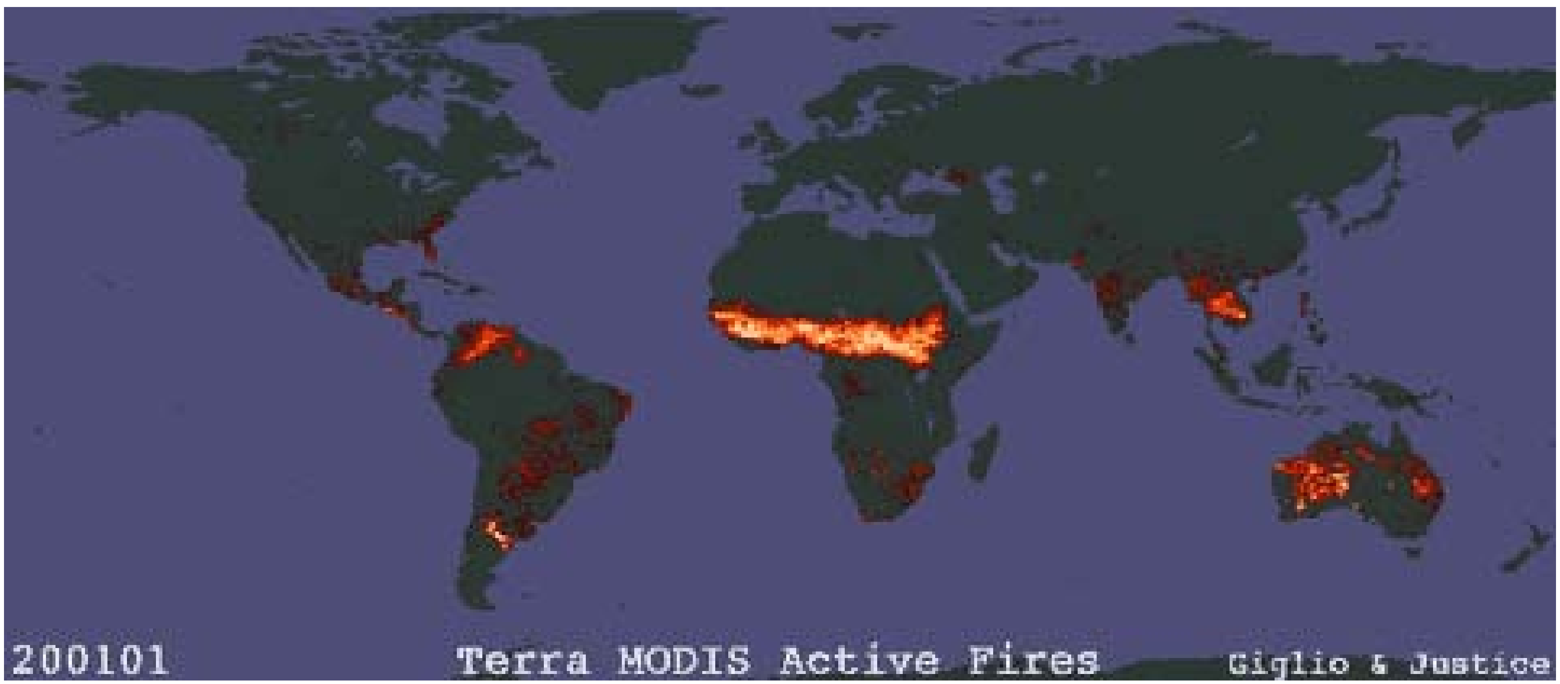
Organic carbon ↑ 40%

Black carbon ↑ 20%

Motivation

Current methods and data ["bottom up" approach] have considerable uncertainty ~50% [*van der Werf*, 2006].

Therefore we need better emission estimates



$(C_6H_{10}O_5)_n$ + O + *ignition temperature* → CO … heat

Convection

Vaporization

Radiation

Conduction

Fire Radiative Power (FRP)

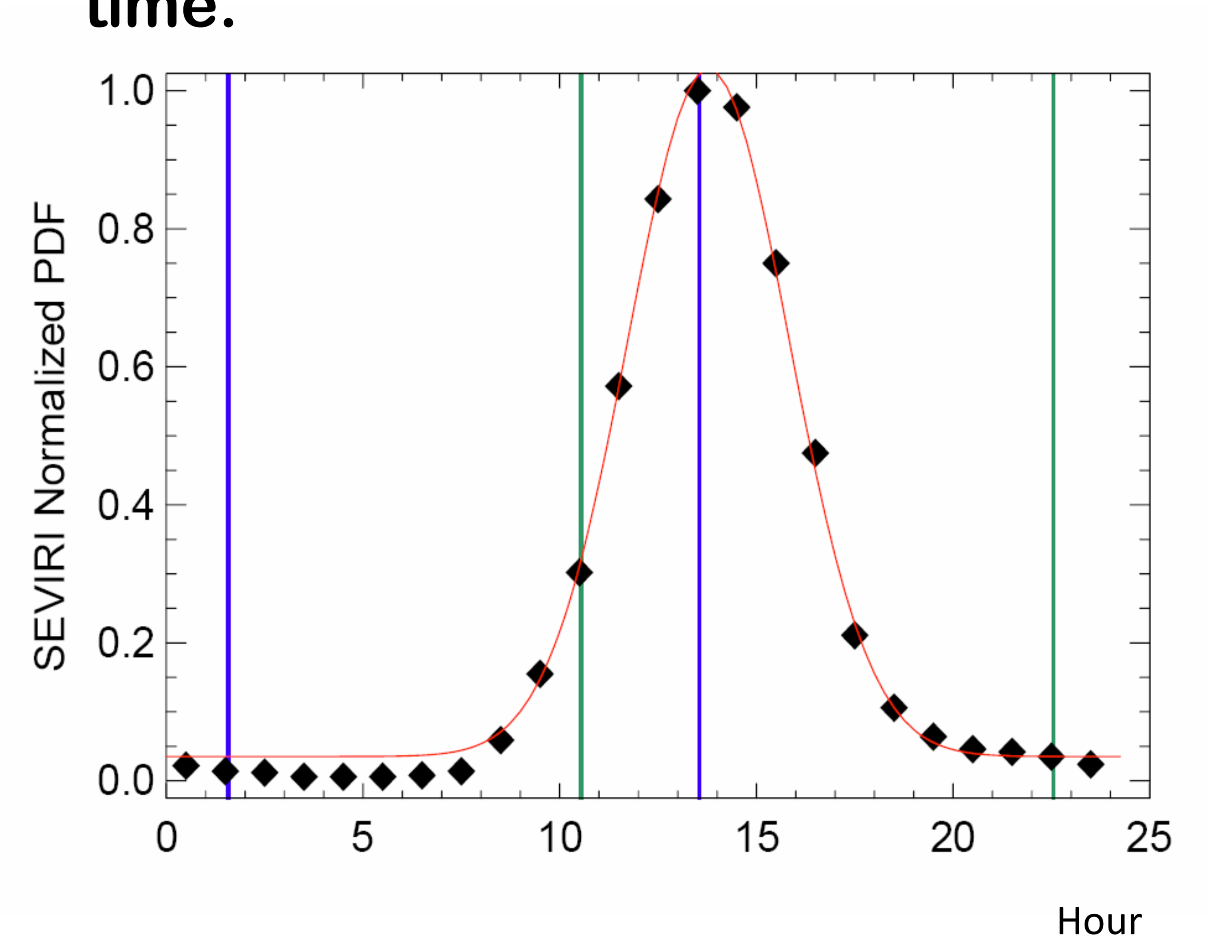
FRP – (MW) rate of fire radiative energy emitted during combustion.

FRE – (MJ) the integral of FRP over time and space

The MODIS sensor estimates the rate of radiative energy emitted from biomass burning, referred to as the fire radiative power (FRP, units in MW), using an empirical relationship relating the difference in the “fire pixel” and “background pixel” 4 μm brightness temperatures [*Kaufman et al.,* 1998].

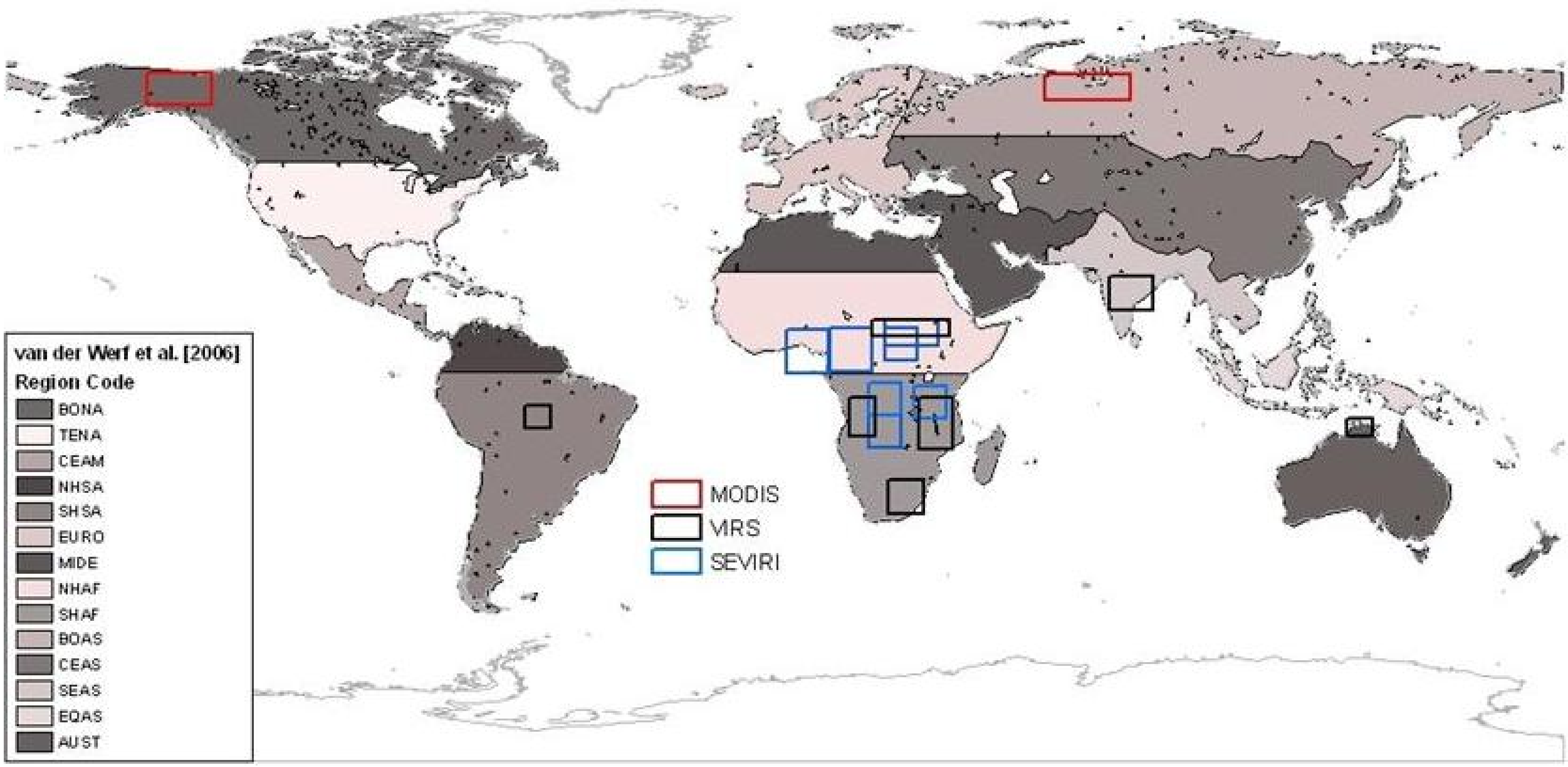
MODIS

The MODIS sensors, onboard the sun-synchronous polar-orbiting satellites Terra and Aqua, acquire four observations of nearly the entire Earth daily at 1030 and 2230 (Terra) and 0130 and 1330 (Aqua), equatorial local time.



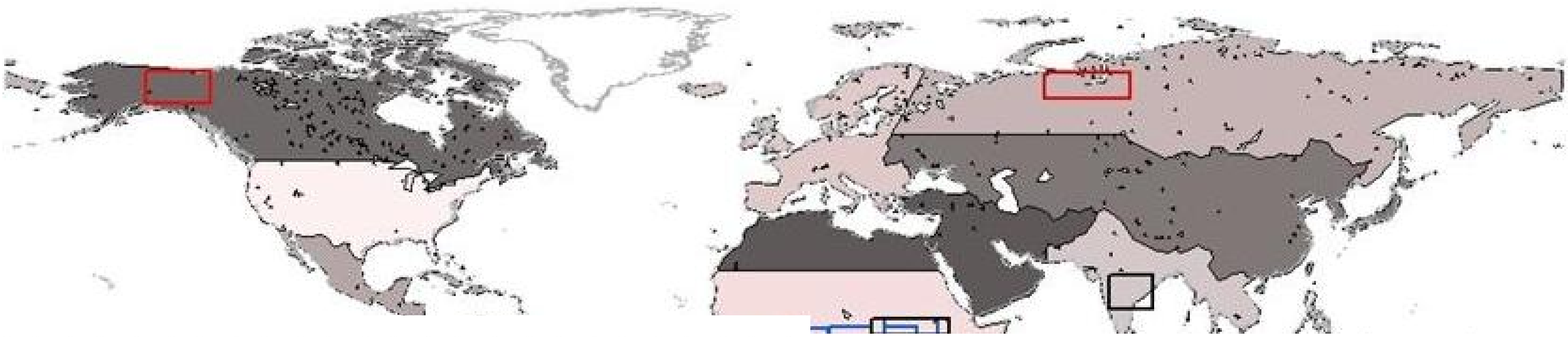
However, a current limitation is that the retrieval of fire energy from satellites is of instantaneous energy (power) over some discrete length of time and space.

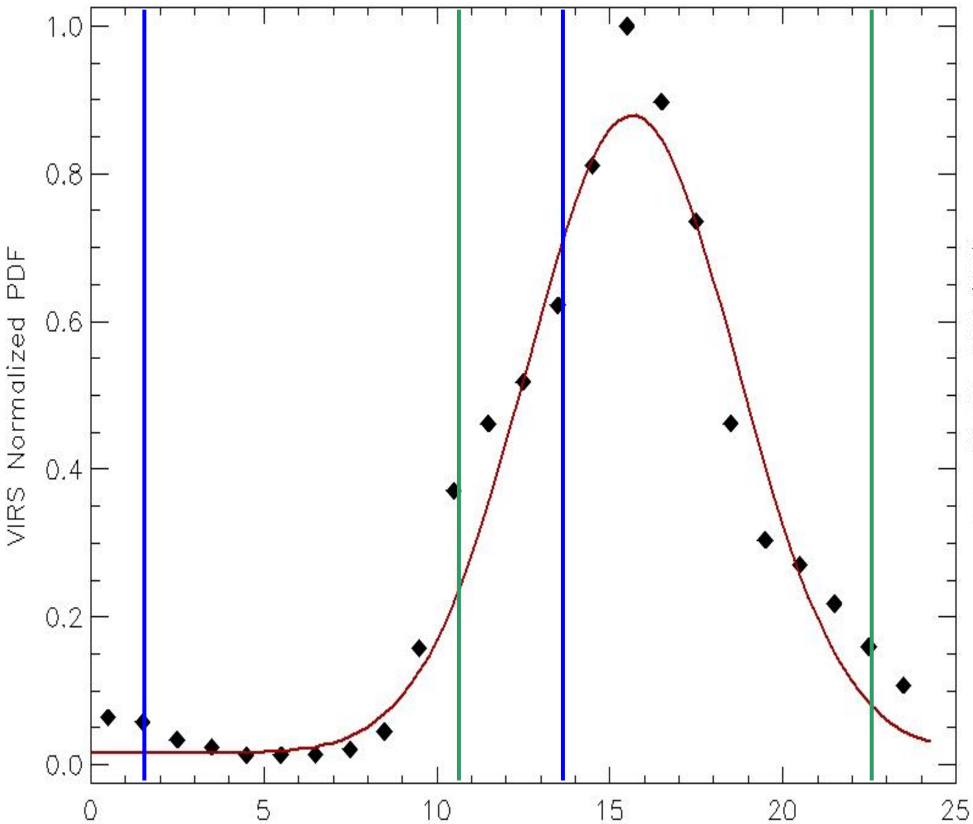
FRE

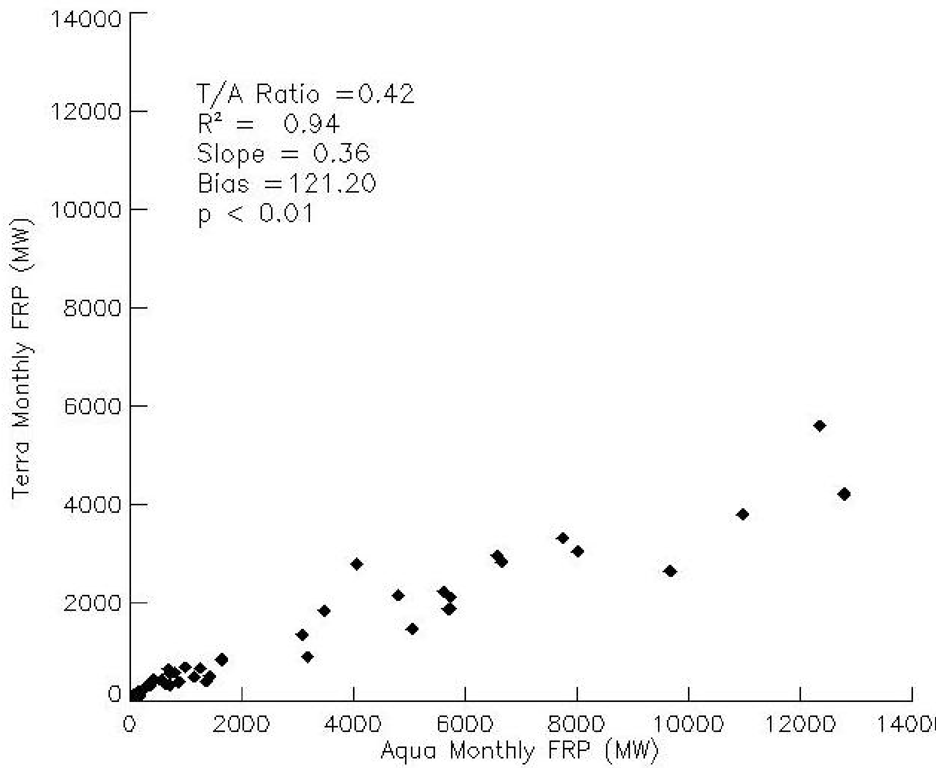


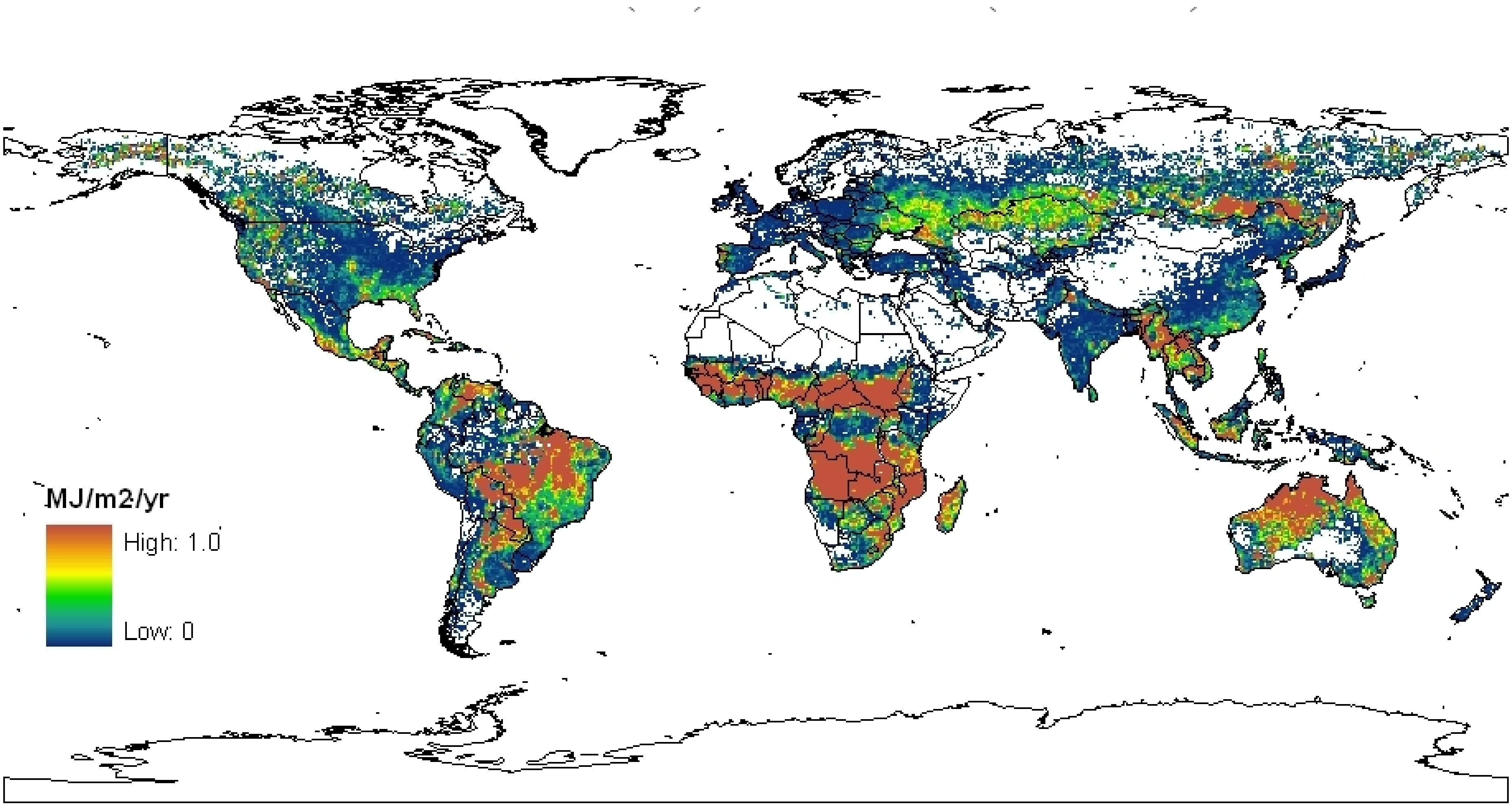
$$FRP(t) = FRP_{peak}\left(b + e^{-\frac{(t-h)^2}{2\sigma^2}}\right)$$

FRE




VIRS Normalized PDF
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25


T/A Ratio =0.42
R² = 0.94
Slope = 0.36
Bias =121.20
p < 0.01
Terra Monthly FRP (MW)
Aqua Monthly FRP (MW)
0
2000
4000
6000
8000
10000
12000
14000


MJ/m2/yr
High: 1.0
Low: 0

News of Deforestation

NY Times, August 2008
Rate of Amazon deforestation increases

ScienceDaily, January 2009
Amazon deforestation trend on the increase

Economist, June 2009
Seeing REDD in the Amazon
Saving rainforests needs both property rights and payments

Nature, July 2009:
Deforestation emissions on the rise
Amazon study suggests denser forest yields will mean more carbon release.

***Nature, August 2009*:**
Paying to save the rainforests
In Brazil, details are emerging for plans to stop deforestation. Can it serve as a model for other nations?

Peer Reviewed Literature

Monitoring and estimating tropical forest carbon stocks: making REDD a reality
– Gibbs et al., 2007, Environ Res Letters

Difficulties in tracking the long-term global trend in tropical forest area
– Grainger, January 2008, PNAS
"A better monitoring program is needed to give a more reliable trend."

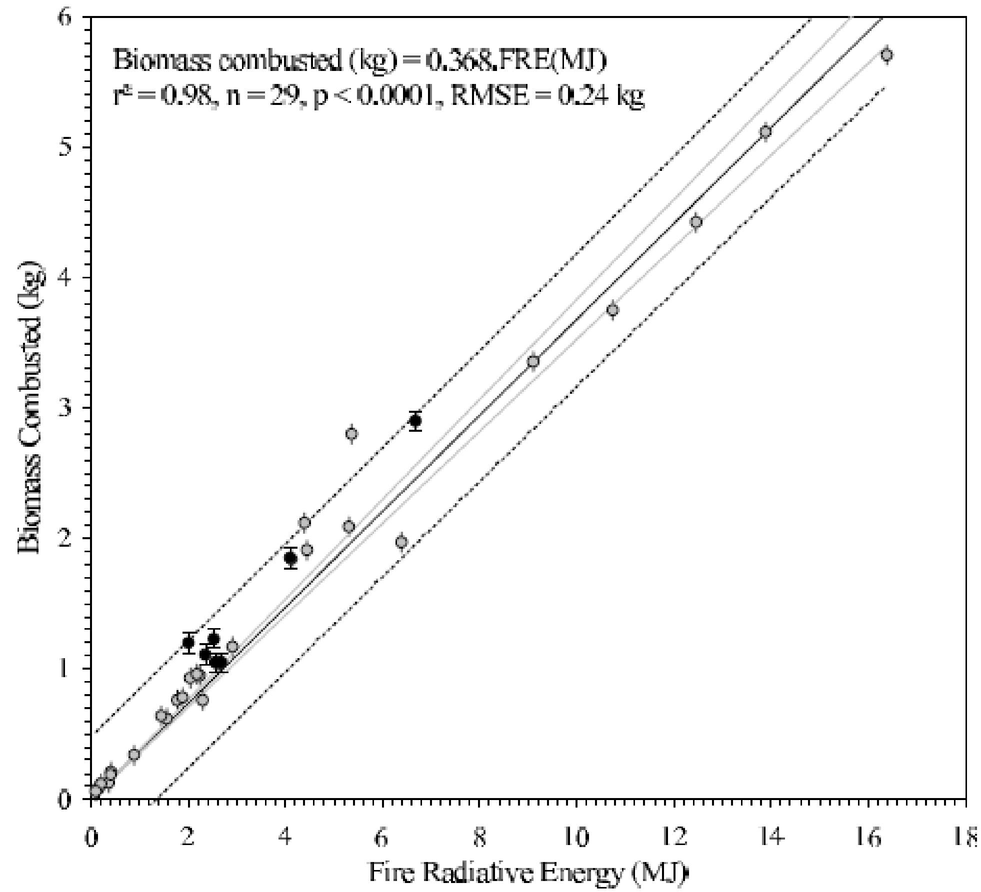
CO^2 emissions from forest loss
– van der Werf et al., November 2009, Nature Geoscience
"Following a budget reanalysis, the contribution from deforestation is revised downwards, but tropical peatlands emerge as a notable carbon dioxide source."

Boosted carbon emissions from Amazon deforestation
– Loarie et al., GRL 2009
"Although the annual rate of deforestation has not changed significantly since the 1990s the aboveground biomass lost per unit of forest cleared increased from 2001 to 2007."


The Legal Amazon
Roraima
Amapa
Amazonas
Para
Maranhao
Acre
Rondonia
Mato Grosso
Tocantins
N
W
E
S

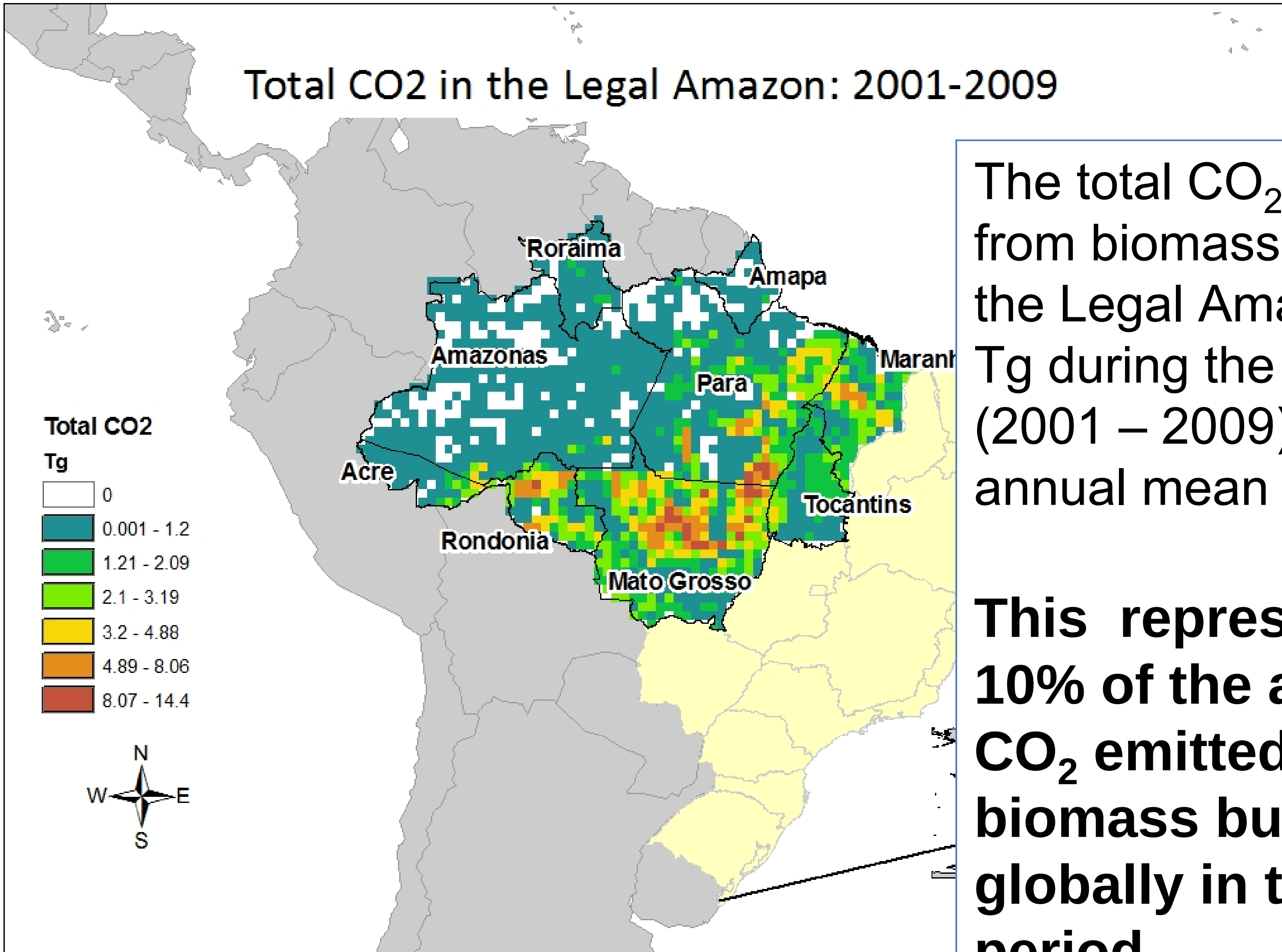
Biomass Combusted and CO_2

Field experiments have demonstrated the application of FRE to estimate biomass consumed from fire (*Wooster et al.,* 2005) and recent laboratory investigations by *Freeborne et al.* (2008) have supported the accuracy of *Wooster et al.'s* earlier work.



Wooster et al. [2005]

CO_2

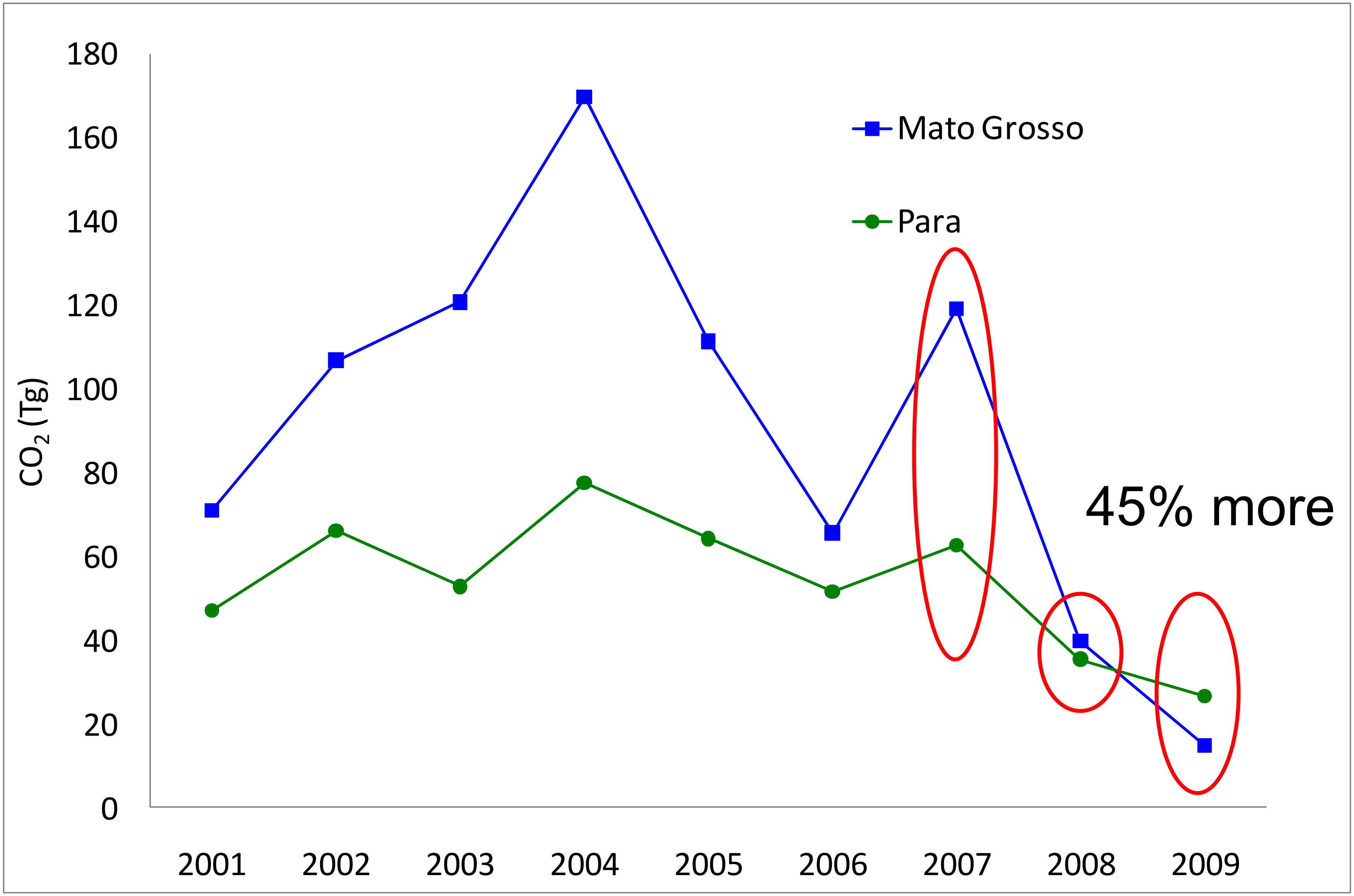


The total CO_2 generated from biomass burning within the Legal Amazon was 1970 Tg during the study period (2001 – 2009) while the annual mean was 218 Tg.

This represents roughly 10% of the annual mean CO_2 emitted from biomass burning globally in this time period.

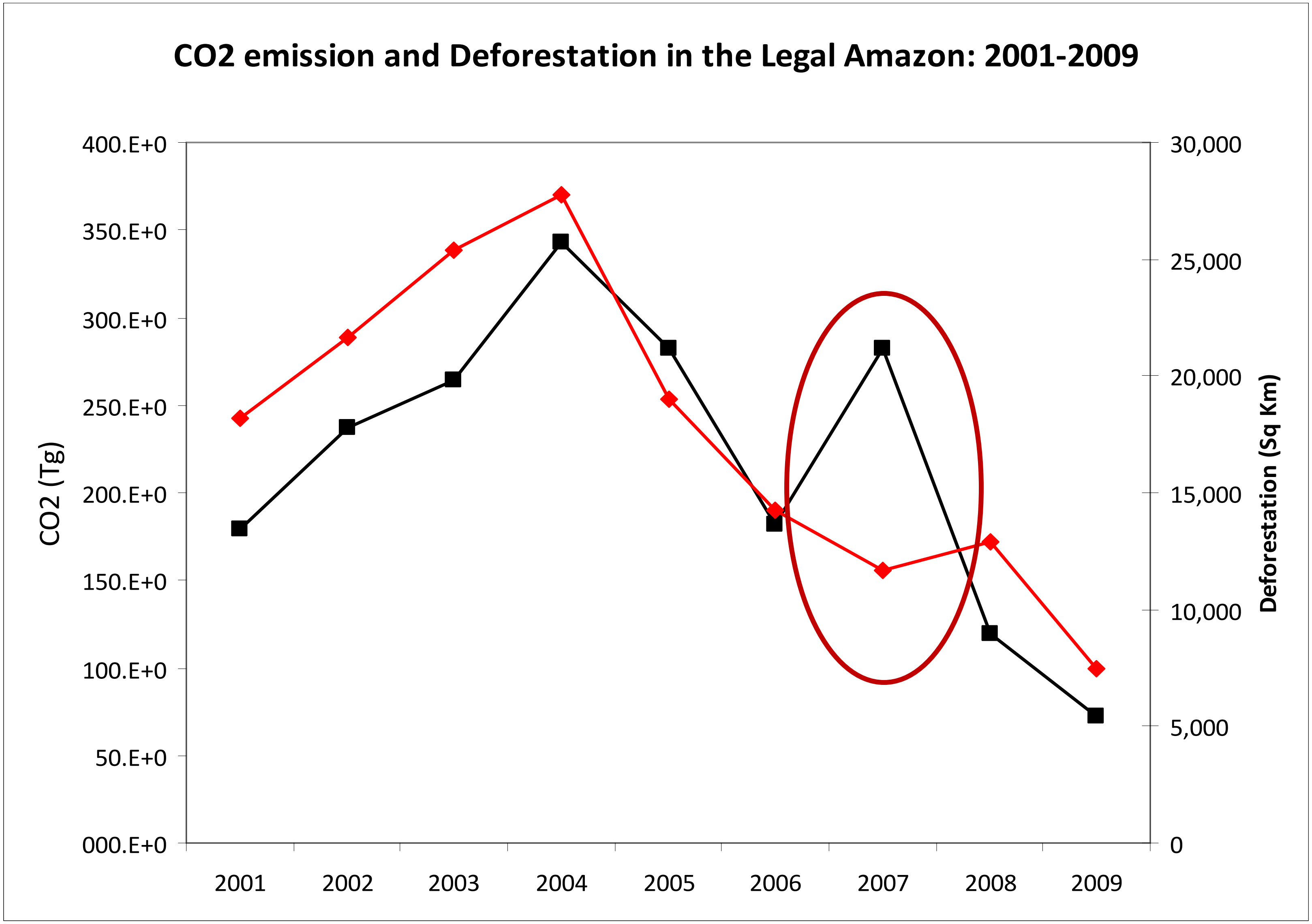
9 year total CO_2 by State

State	CO_2 (Tg)	% of total
Acre	33.66	1.7%
Amazonas	70.76	3.6%
Amapá	12.06	0.6%
Maranhão	206.33	10.5%
Mato Grosso	**818.49**	**41.5%**
Pará	**483.67**	**24.6%**
Rondônia	197.18	10.0%
Roraima	24.36	1.2%
Tocantins	123.46	6.3%
Legal Amazon	**1,969.98**	100%

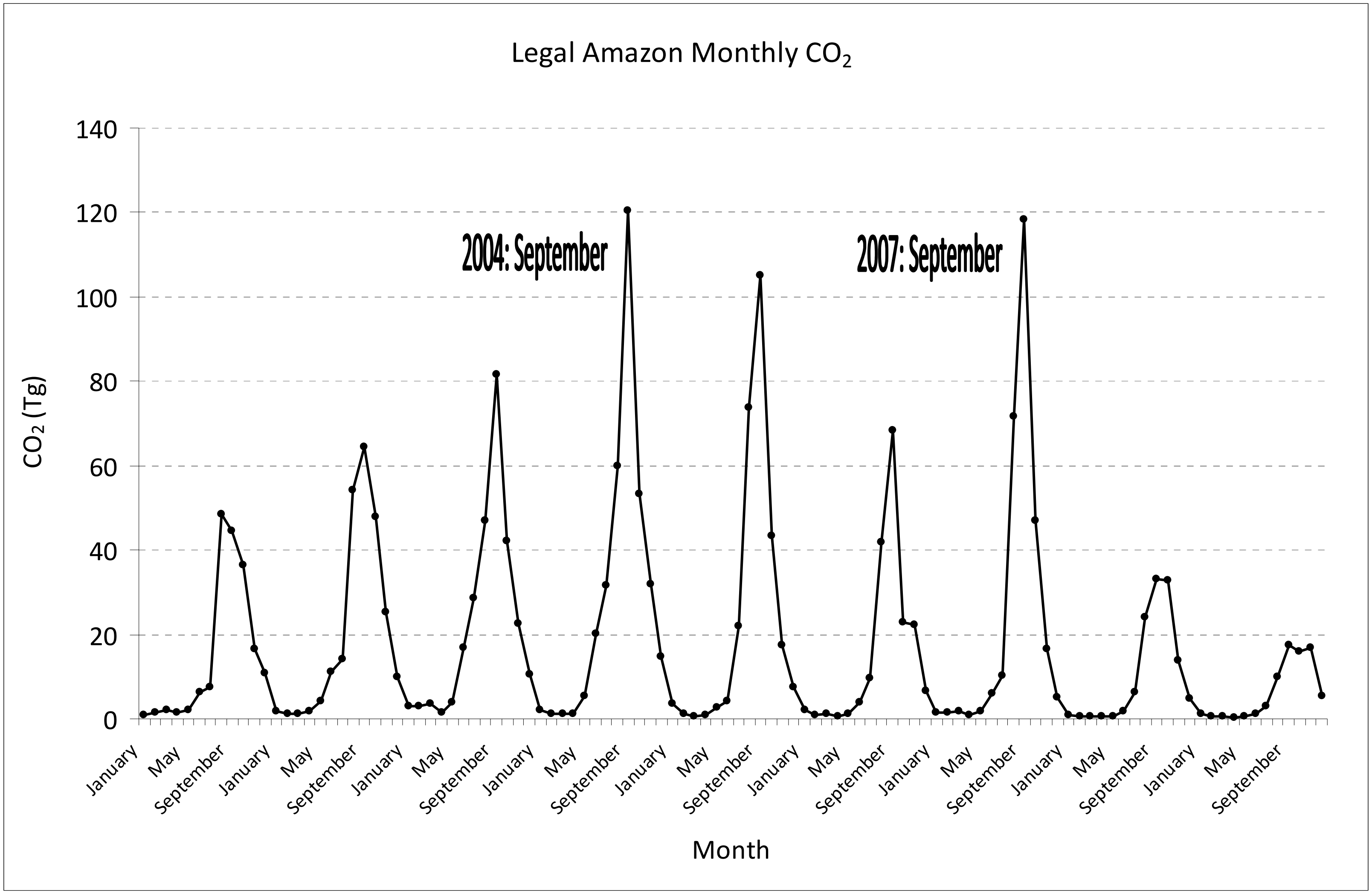


180
160
140
120
100
80
60
40
20
0
CO_2 (Tg)
Mato Grosso
Para
45% more
2001
2002
2003
2004
2005
2006
2007
2008
2009

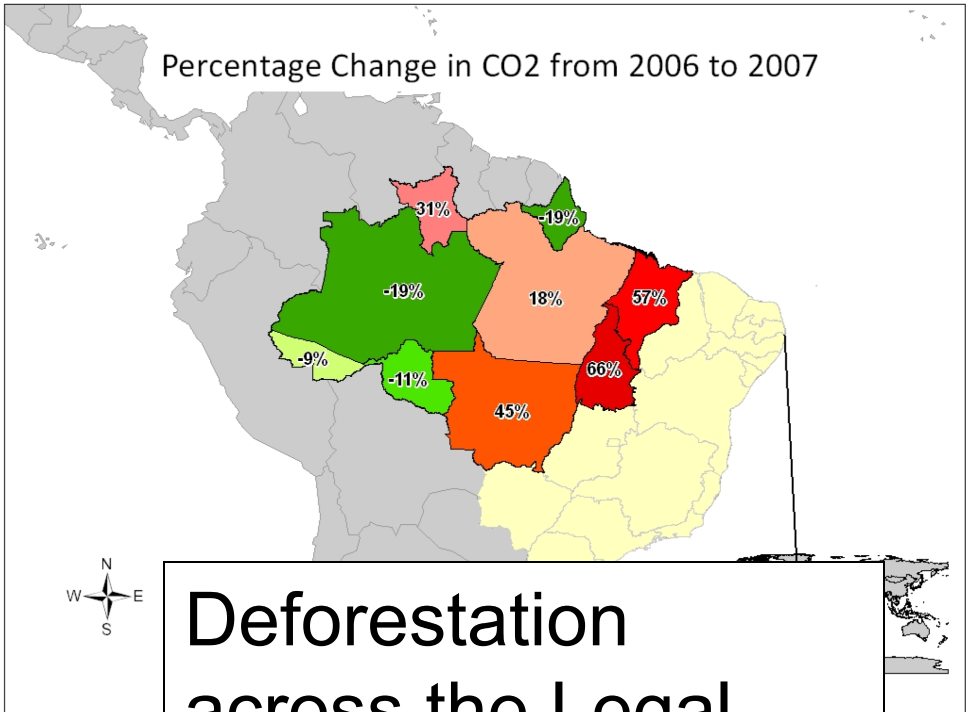
CO_2 and Deforestation



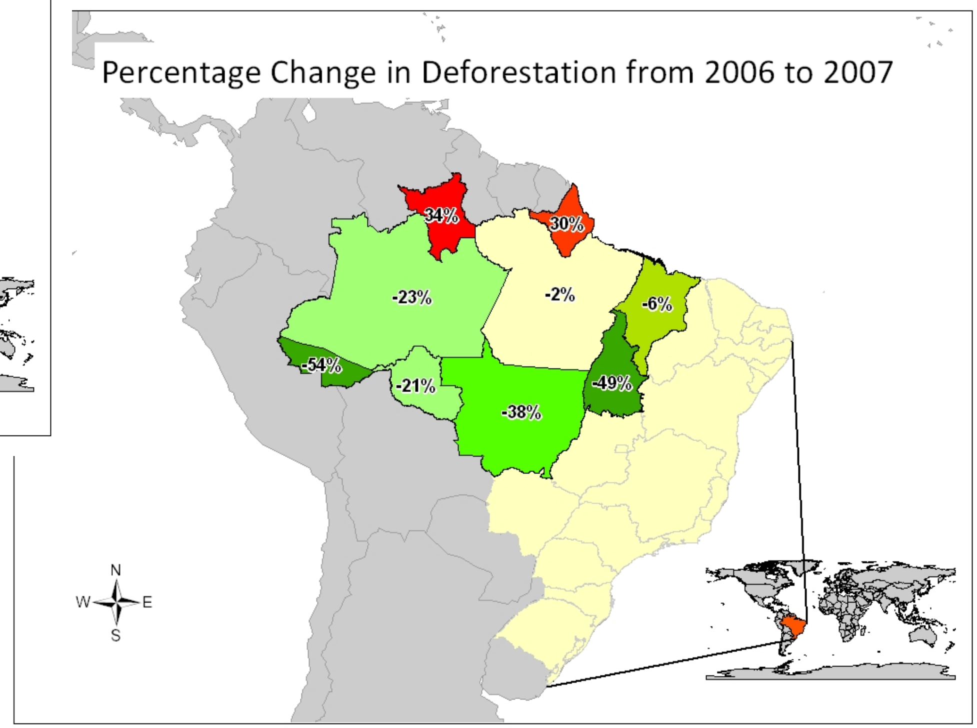
CO_2 and Deforestation



CO_2 and Deforestation



Deforestation across the Legal Amazon dropped by 18% from 2006 levels, but CO_2 increased by 35%.



CO_2 and Deforestation

Percent Change from 2006 to 2007

	CO_2	Deforestation
Acre	-9%	-54%
Amazonas	-19%	-23%
Amapá	*-19%*	*30%*
Maranhão	**57%**	**-6%**
Mato Grosso	**45%**	**-38%**
Pará	**18%**	**-2%**
Rondônia	-11%	-21%
Roraima	31%	34%
Tocantins	**66%**	**-49%**
Legal Amazon	35%	-18%

Uncertainty

Error Sources	Error estimates	Error
FRE from FRP (diurnal cycle)	Figure 7. SEVIRI comparison	19%
FRP empirical formula	*Wooster et al.,* [2005]	16%
Atmospheric effect on FRP	*Roberts & Wooster* [2008]	17%
Cloud correction FRP	*Schroeder et al.,* [2008]	11%
Conversion of FRE to biomass combusted	*Wooster et al.,* [2005]; Freeborn et al., [2008]	10%
Emission estimate	**Quadratic sum (a-e)**	**34%**

Conclusions

- Our results show large fire emissions can occur even in years of relatively low deforestation.

    - ❖ Case in point: 2007, in which fire activity as a result of drought conditions AND(?) commodity prices led to greater than normal fire activity in multiple states.

    - ❖ Much of these fires could be speculated to be a result of maintenance fires escaping and turning into larger scale events and intentional (and illegal) fires to clear land based on speculation.

- Therefore, any discussion of REDD should also consider the implications of fire as a tool for managing the land after deforestation has occurred and the influence of markets

Discussion

- Fire radiative energy (FRE) offers an additional metric by which to monitor and assess the effectiveness of emission reduction strategies.

- In addition, FRE offers a complimentary method to reduce the uncertainty in estimating atmospheric loading of GHG and aerosols from biomass burning
- Provides a supplemental metric to constrain estimates.

The Way Forward:
- Validate FRP estimates made by MODIS using higher spatial resolution data (e.g. Ikhana)
- Using higher temporal (and perhaps spatial) resolution data – validate FRE estimates
- Reconcile differences in emission estimates (e.g. GFEDv3)

Thank You

Questions?