Fire in CLM

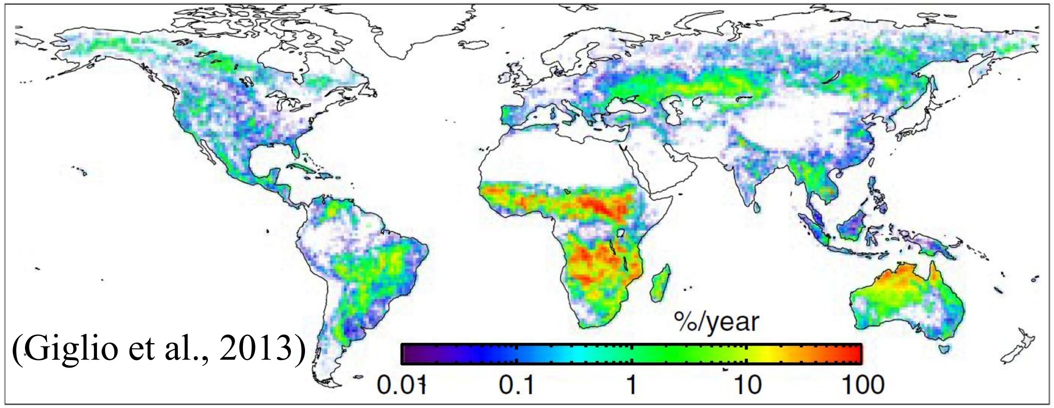
Fang Li

Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP/CAS)
E-mail: lifang@mail.iap.ac.cn office: ML-194

Ack.: S. Levis, X.-D. Zeng, F. Vitt, M. Val Martin, Q.-C. Zeng, D. M. Lawrence, R. E. Dickinson, E. Kluzek, B. Bond-Lamberty, D. S. Ward, B. Sacks…

Motivation for fire modeling

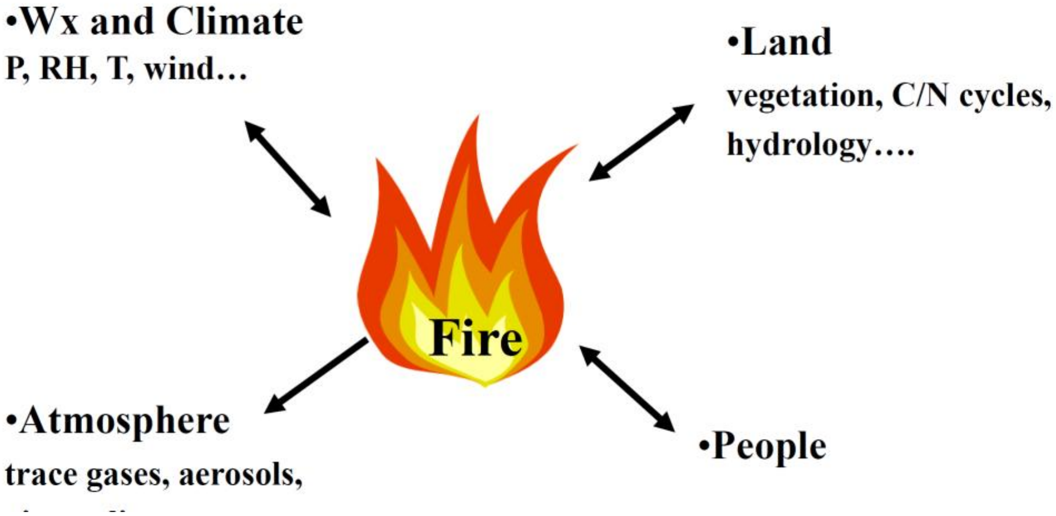
Satellite-based annual burned area fraction



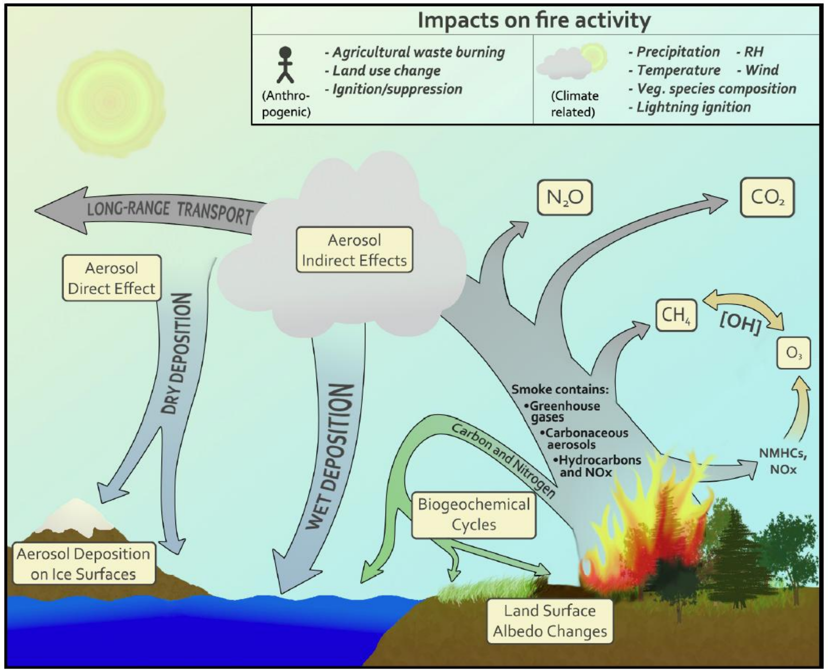
(Giglio et al., 2013)

Fire:

- **primary form of terrestrial ecosystem disturbance on a global scale**
- **affects ecosystems, and carbon cycle (fire C emis.: ~2 Pg C/yr)**
- **tightly interacts with the biosphere/atmosphere**
-

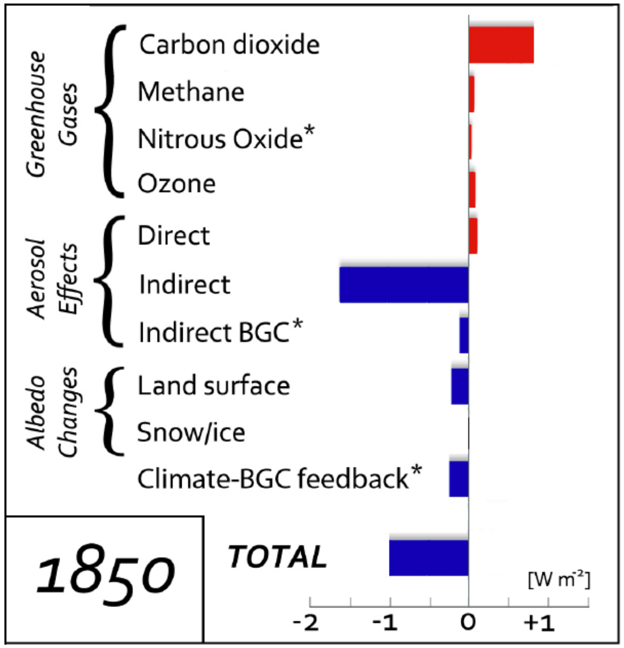


•Fire emissions



•contain key greenhouse gases, and the largest source of primary carbonaceous aerosol mass globally

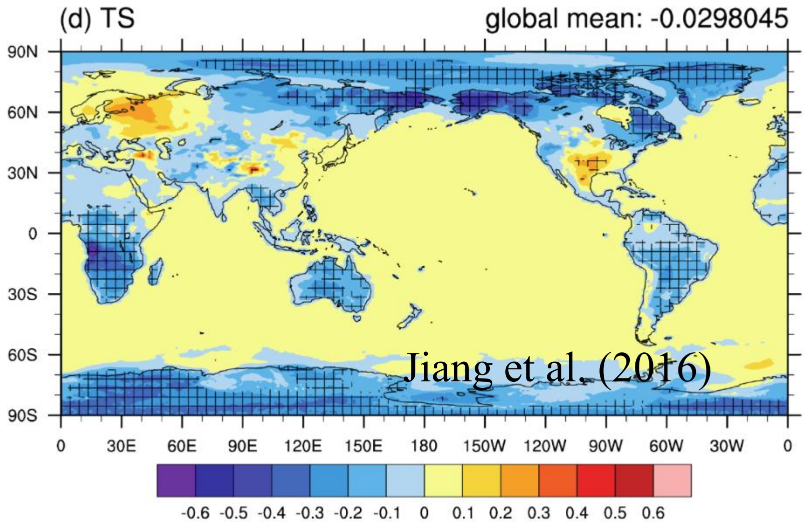
•affect global radiation balance



(Ward et al. 2012)

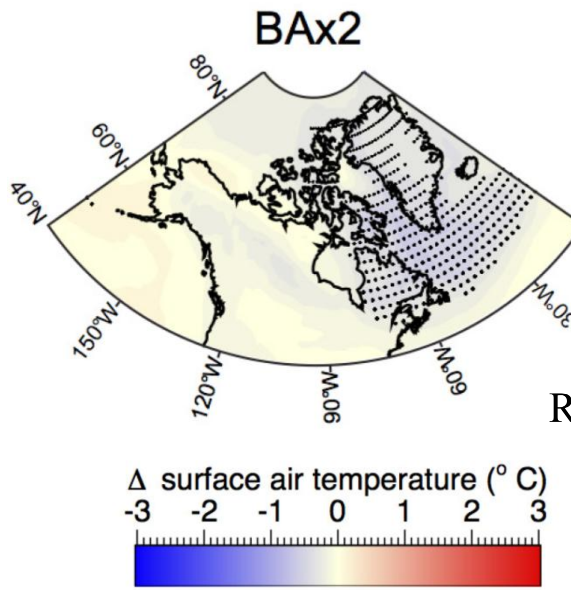
Impact on climate

By emitting fire aerosols



Jiang et al. (2016)

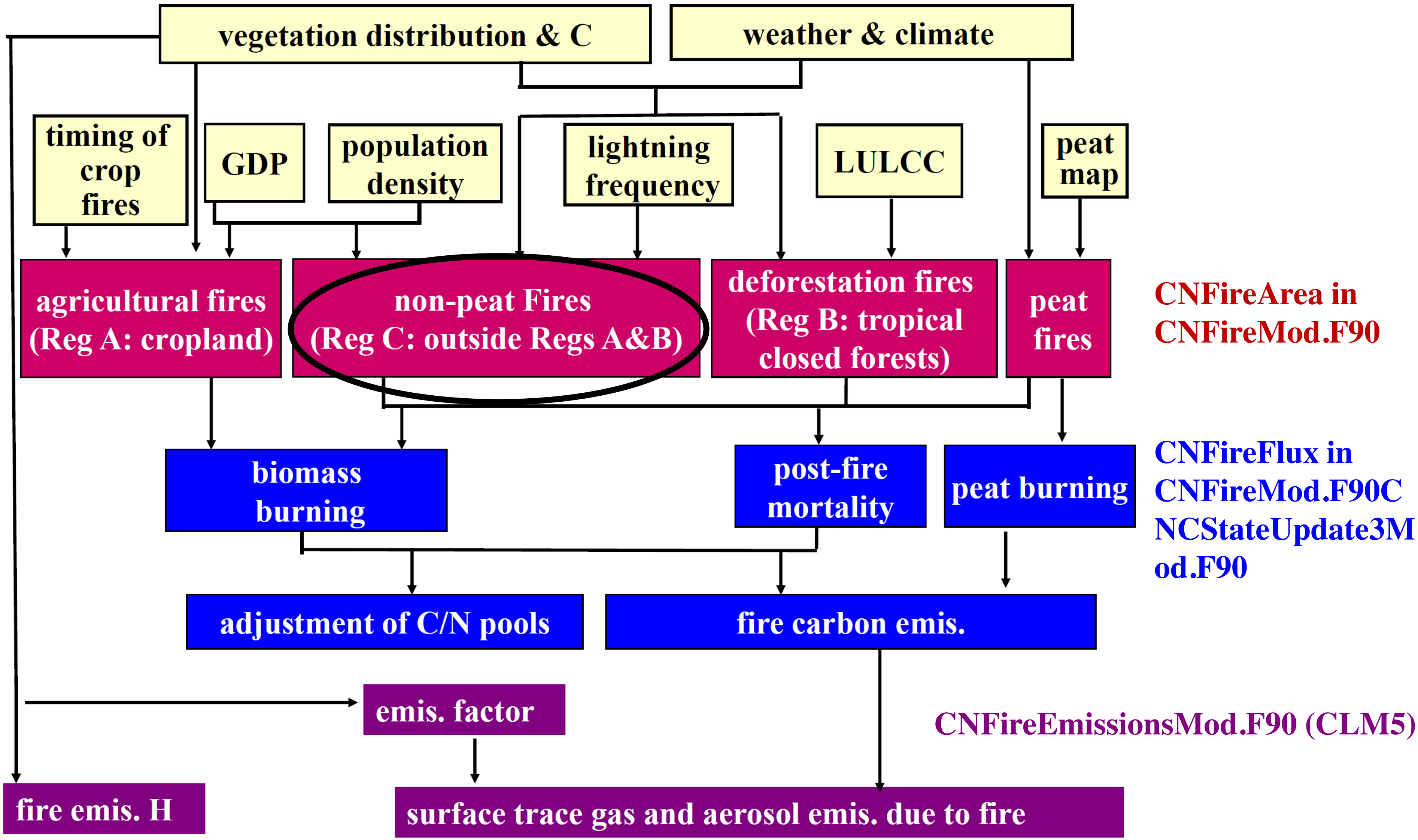
By changing ecosystems



Roger et al. (2013)

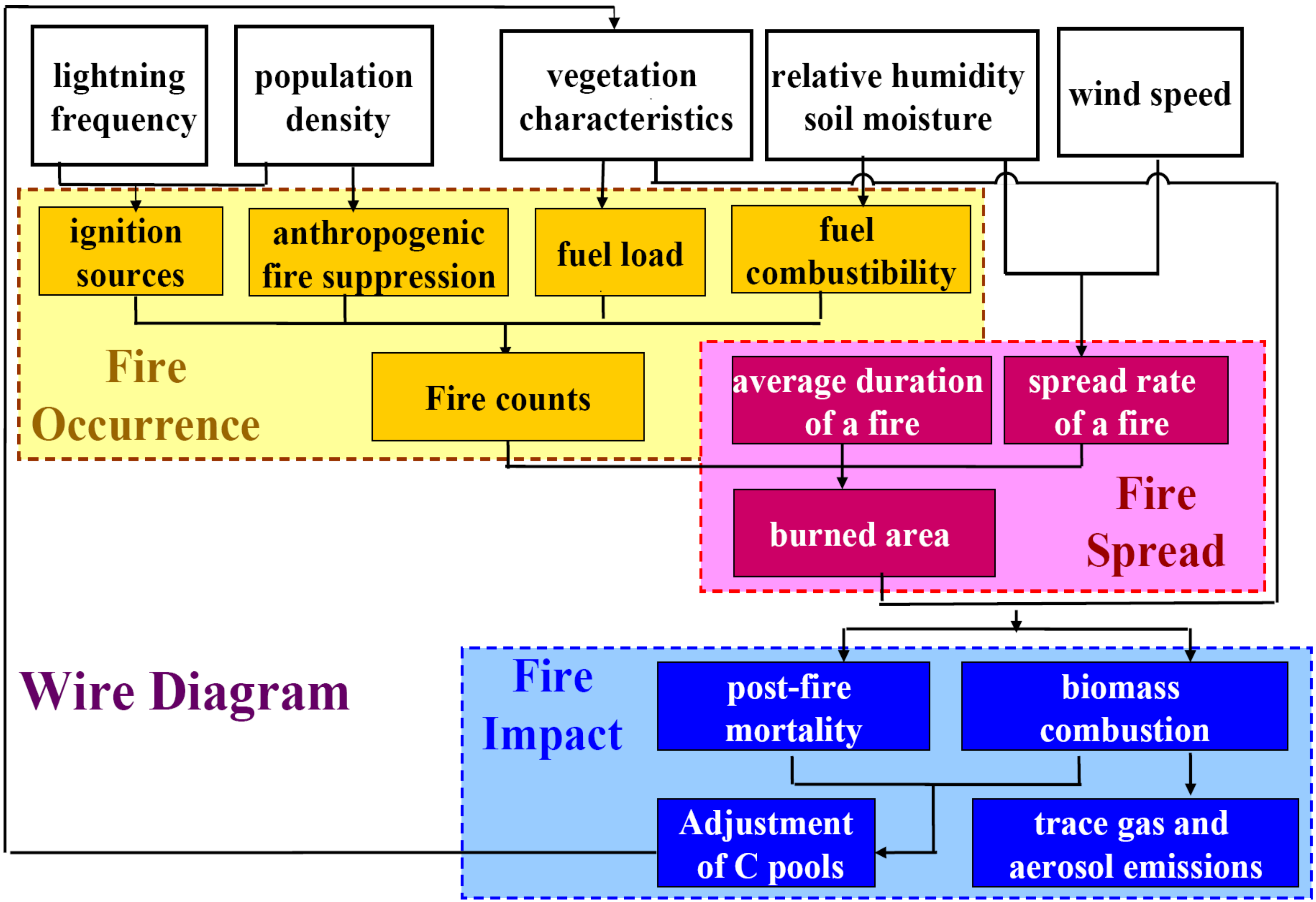
Impact on human and animal

CLM fire scheme



(Li et al., 2012, 2013; Li et al., in prep.; Val Martin et al., in prep.)

Non-peat fires in Reg. C (process-based, Intermediate)



(Li et al. 2012, Biogeosciences)

•Fire occurrence

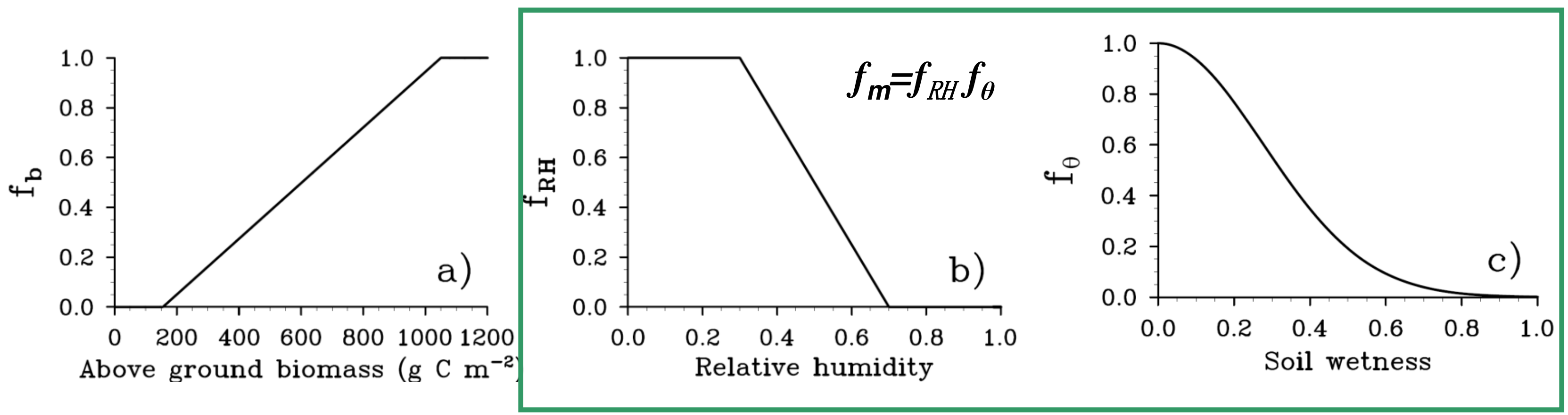
Fire counts in a grid cell :

$$N_f = N_i f_b f_m f_{ns,PD} f_{ns,GDP}$$

Fuel availability (f_b) **Fuel combustibility** (f_m)

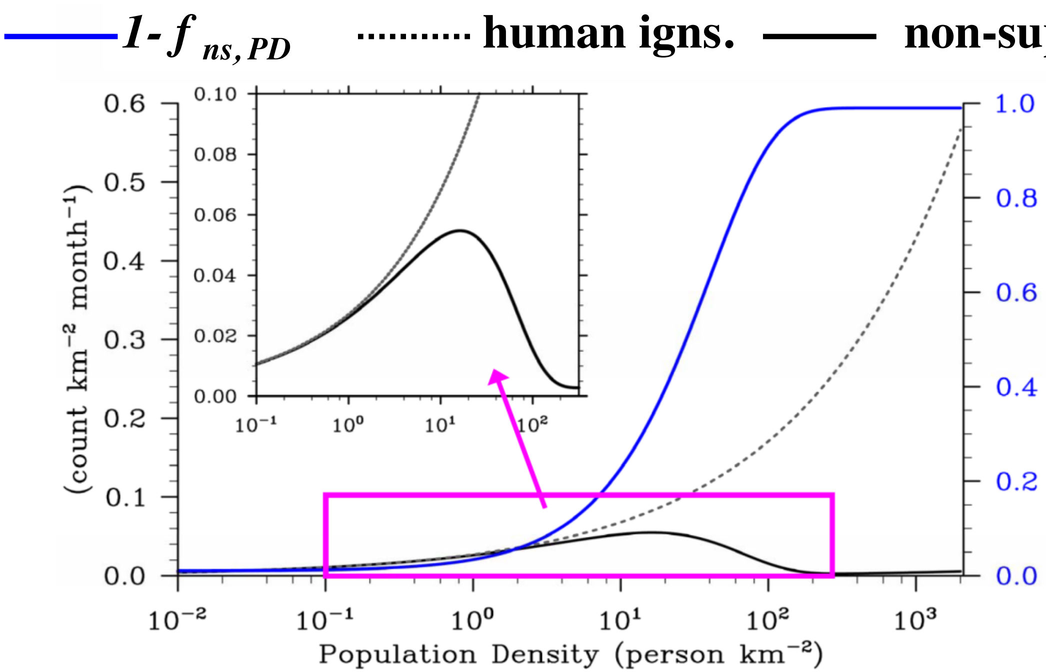
Ignition counts (N_i) **Non-suppression rate** ($f_{ns,PD} f_{ns,GDP}$)

Ignition counts: N_i= lightning ignitions + human ignitions

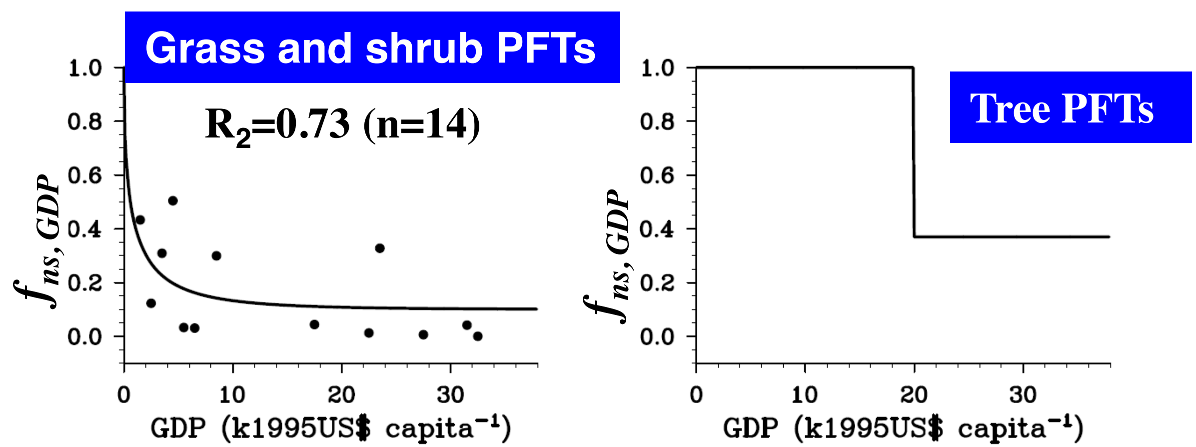


(Li et al., 2012, 2013, 2016)

Human ignitions and fire suppression

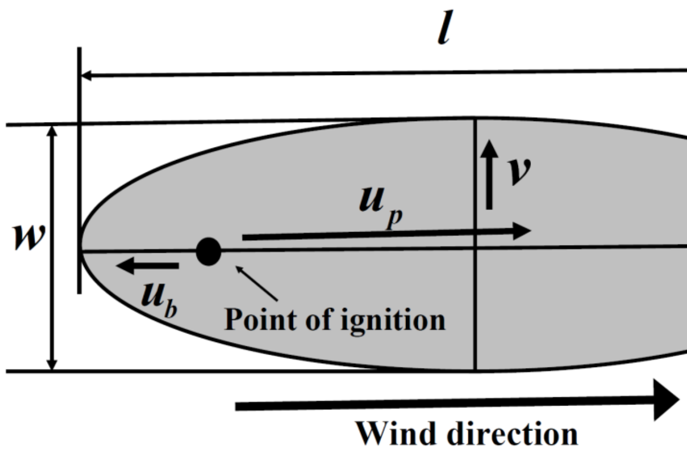


Supported by the relationship between MODIS active fire counts and pop. den /GDP



(Li et al., 2012, 2013)

•Fire spread



Average burned area of a fire without human suppression (average fire duration τ(s)=1day) :

$$a_1 = \pi \frac{l}{2}\frac{w}{2}\times 10^{-6} = \frac{\pi u_p^2 \tau^2}{4L_B}(1+\frac{1}{H_B})^2 \times 10^{-6}$$

Fire spread rate in the downwind direction:

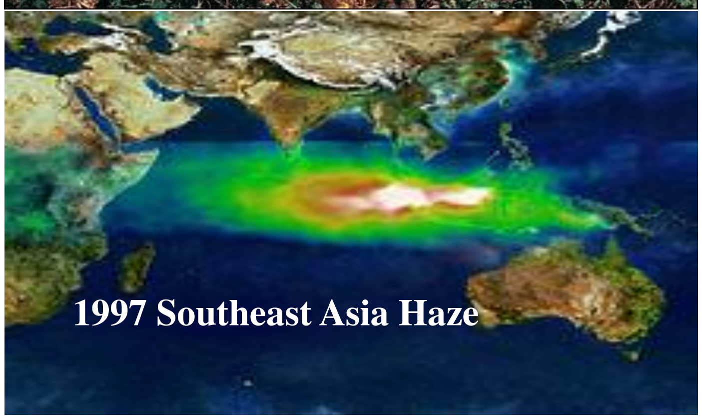
$u_p = f$ (fuel wetness) g(wind speed)

Average burned area of a fire

$$a = a_1 F_{ns,PD}\ F_{ns,GDP}$$

More developed /more densely populated → higher suppression

(Li et al., 2012, 2013)



Agricultural fires (Reg. A)

Burned area frac. — Fuel availability

$$f_{ba} = a f_b f_{se} f_t$$

Fire seasonality

Socioeconomic factor

Deforestation fires (Reg. B)

Fuel combustibility

$$f_{ba} = b f_{lu} f_{cli,d}$$

Deforestation rate

Peat fires

Fuel combustibility — Area frac. of peatland

$$f_{ba} = c f_{cli,p} (1 - f_{sat}) f_{peat}$$

Frac. area with water table at the surface or higher

(Li et al., 2013)

•Fire impact (PFT-level)

Fire C/N emissions

fire C/N emis.= C/N pools ×PFT-dependent combustion completeness factor ×burned area frac.

Fire-induced veg. mortality

whole-plant mortality= Pop. den. ×PFT-dependent individual mortality factor 1×burned area frac.

Veg. tissue mortality= C pools ×PFT-dependent tissue mortality factor 2 ×burned area frac.

Adjustment of C/N pool

Adjusted C/N pools for live veg. tissue= Original C/N pool − C/N loss due to biomass burning and mortality

Adjusted litter and CWD pools =original C/N pools − fire C/N emissions + C/N loss from fire-induced mortality

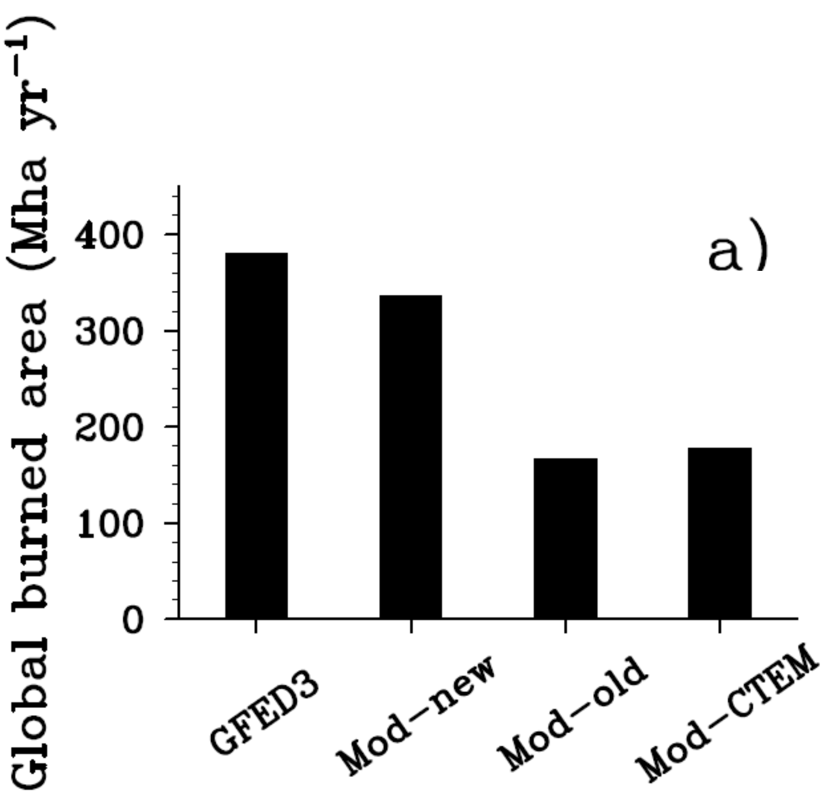
Surface trace gas and aerosol emissions due to fire (52 species)

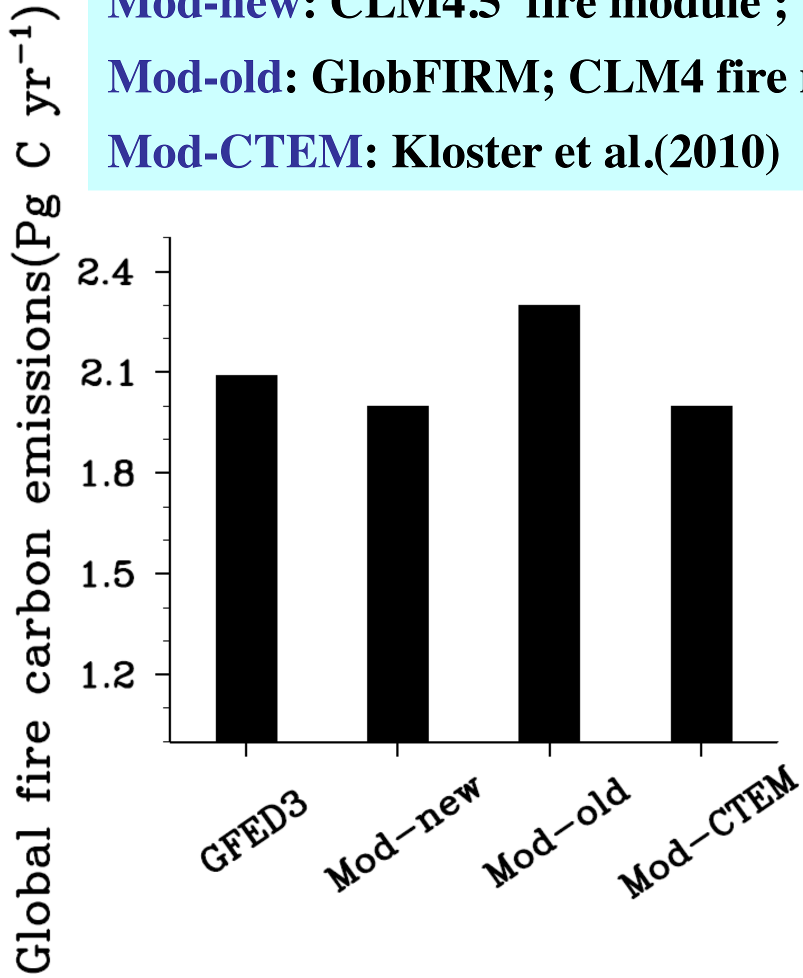
= Fire C emis. ×PFT-dependent emissions factors

Performance: CLM4.5 fire with Qian (1997-2004)

Mod-new: CLM4.5 fire module ;
Mod-old: GlobFIRM; CLM4 fire module
Mod-CTEM: Kloster et al.(2010)

- **Global total**

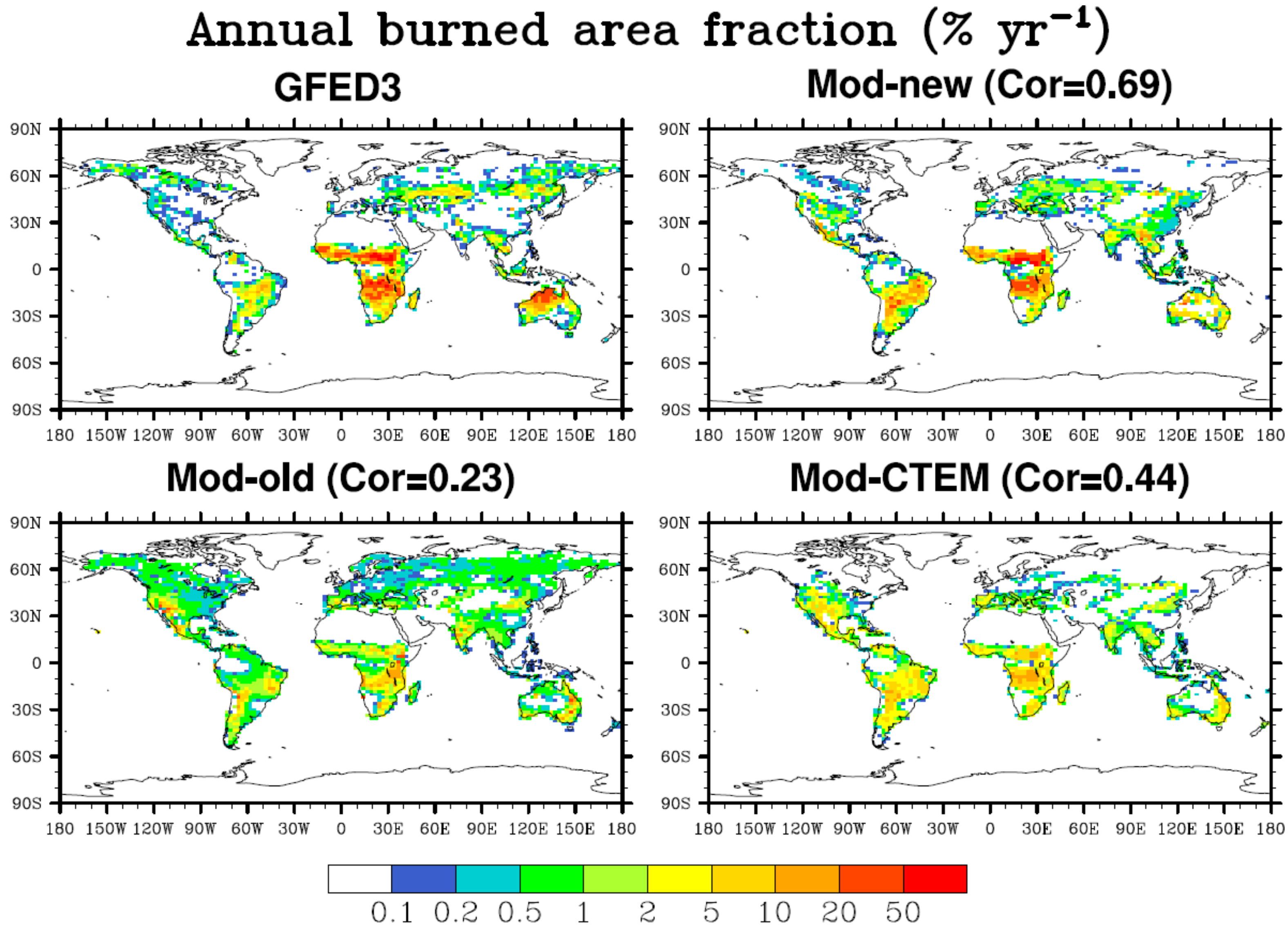




(Li et al., 2013)

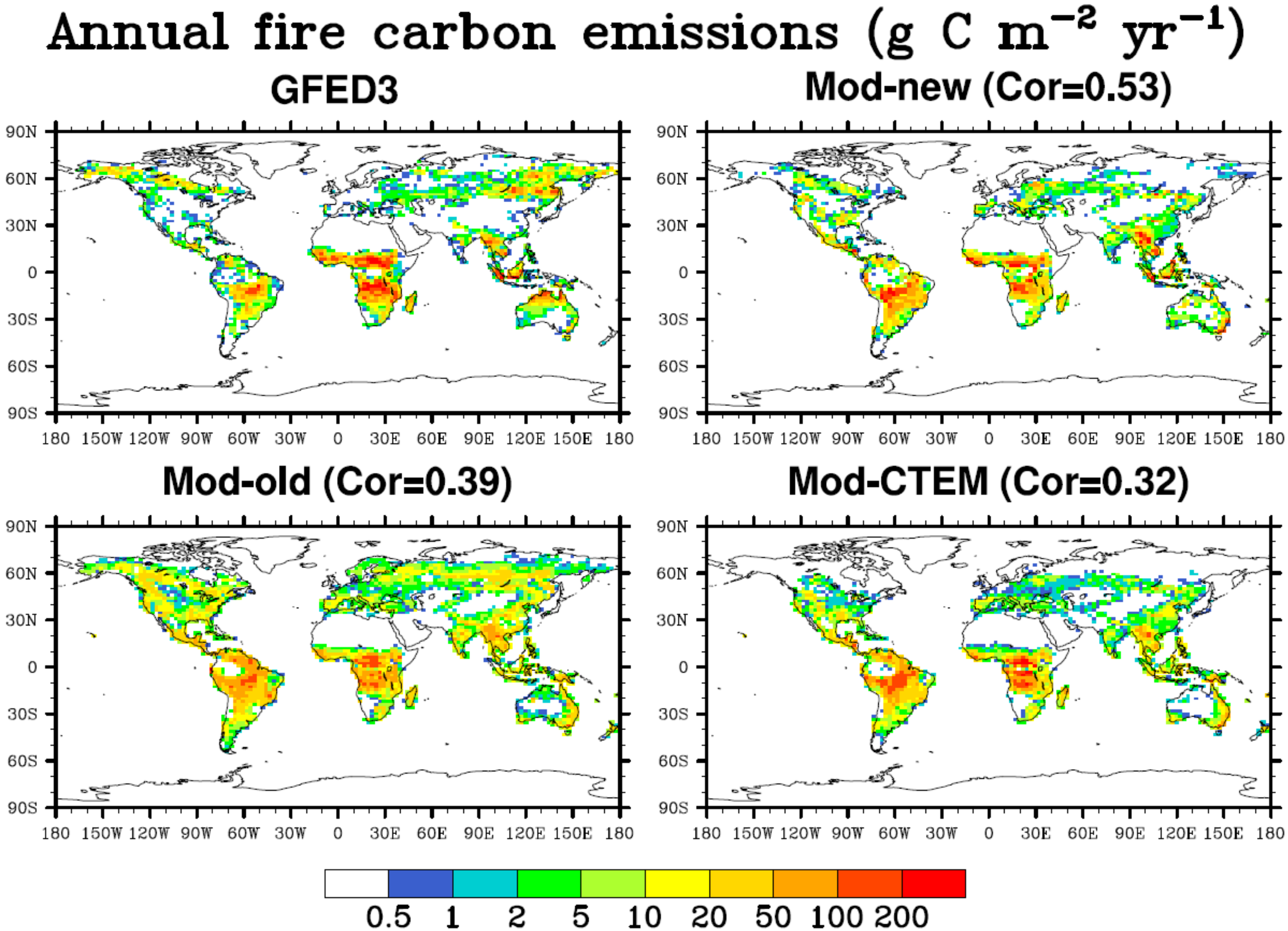
•Global spatial distribution of burned area fraction

Cor: global spatial correlation between obs and simulations



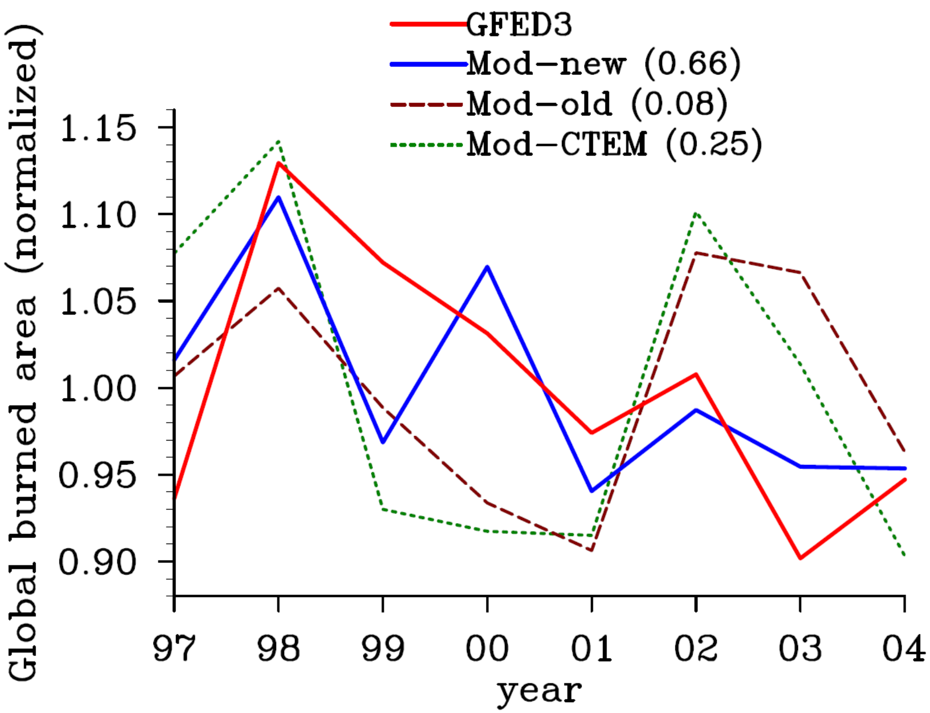
(Li et al., 2013)

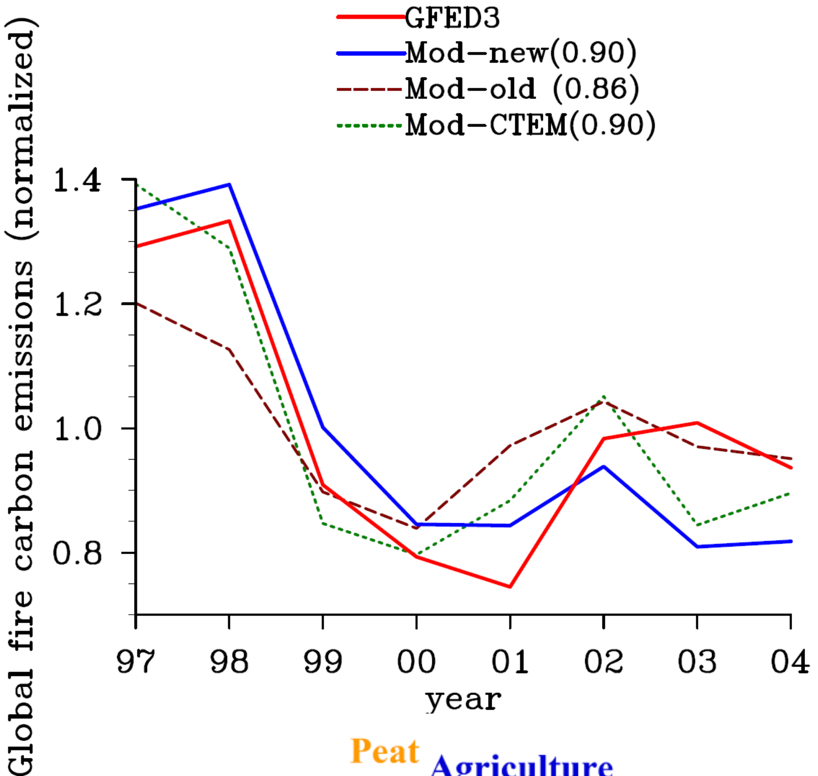
•Global spatial distribution of fire carbon emissions



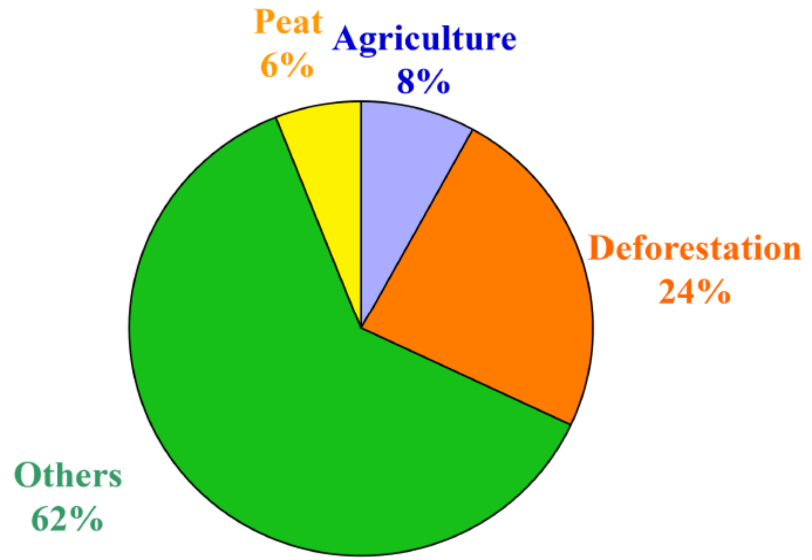
(Li et al., 2013)

•Interannual variability



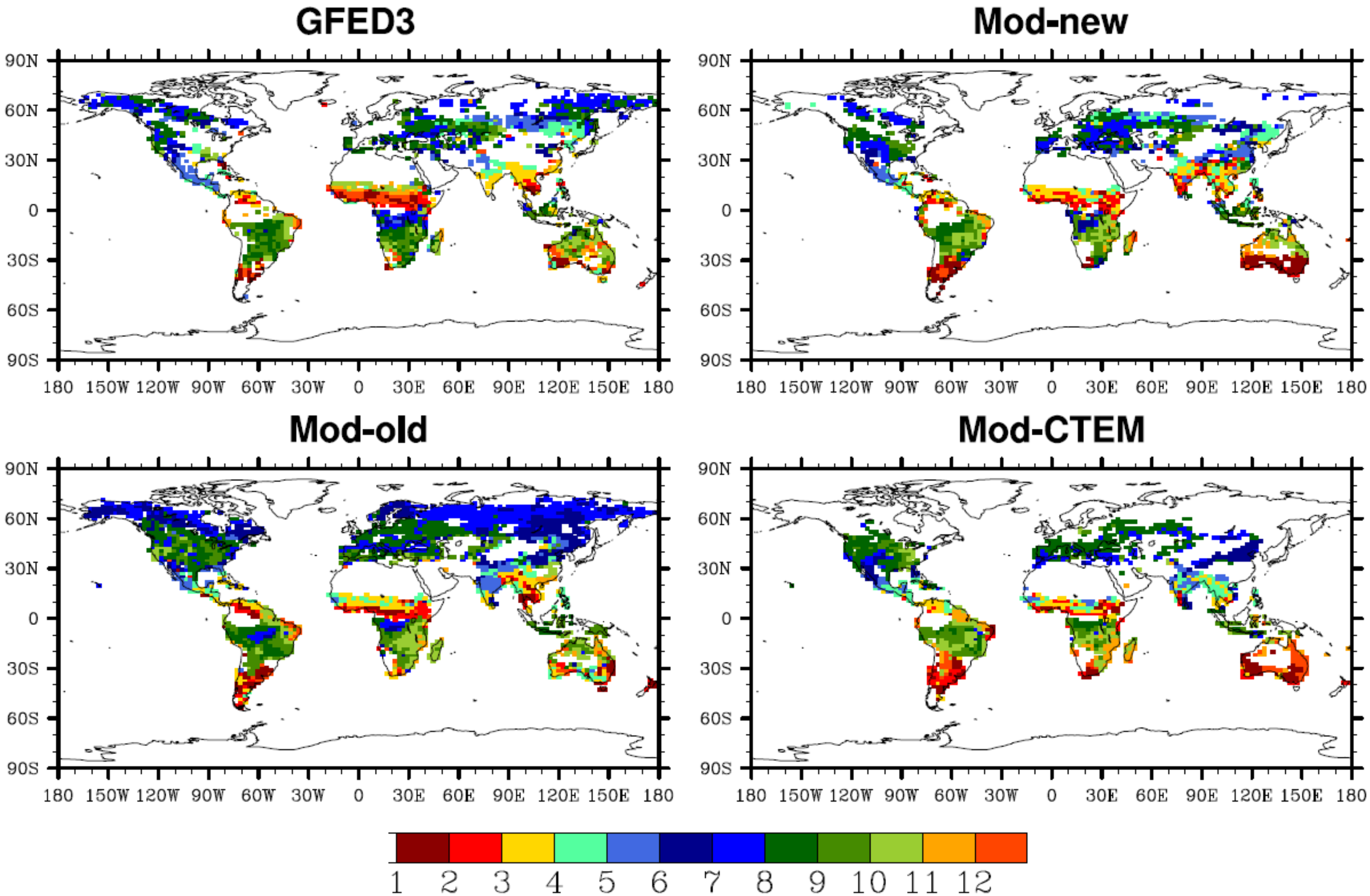


•Contributions from different sources



(Li et al., 2013)

•Seasonality of burned area fraction



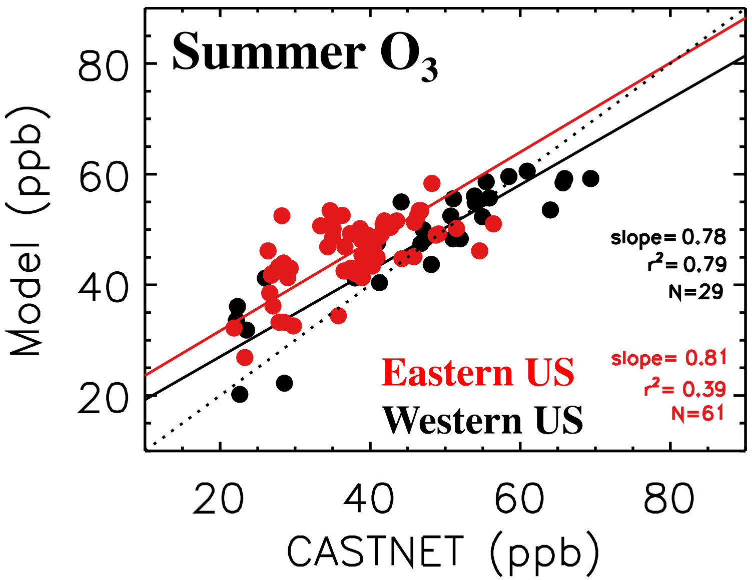
(Li et al., 2013)

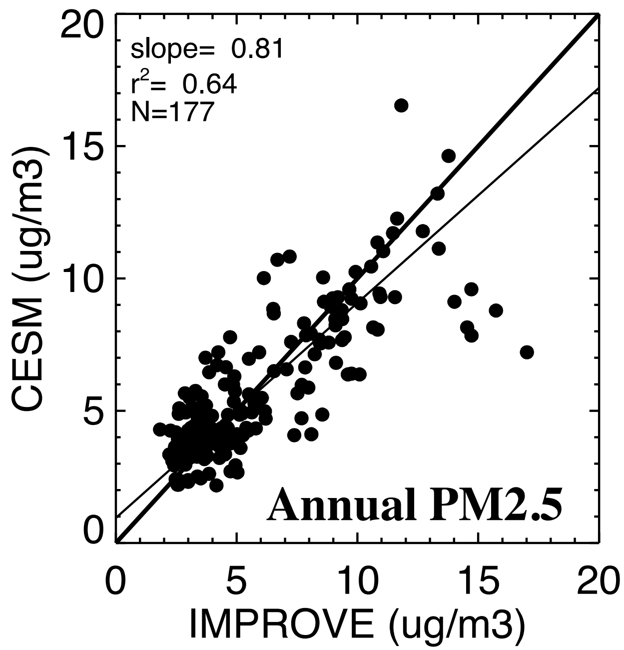
Fire Aerosol and trace gas emissions (CLM4.5 with CLM5 fire emissions)

Global Total

Species (Tg spec/yr)	CLM 2000–2005	GFED 2000–2005	FINNv1 2005–2010
CO_2	5778–8236	6460–7920	6464–7920
CO	302–430	288–394	332–409
NO	3.4–4.6	--	4–4.8
NO_x	10.5–14.6	12–16	--
SO_2	2.2–2.8	1.9–2.9	1.9–2.4
BC	1.6–2.4	1.5–1.9	1.9–2.4
OC	16–24	13–19	21–25

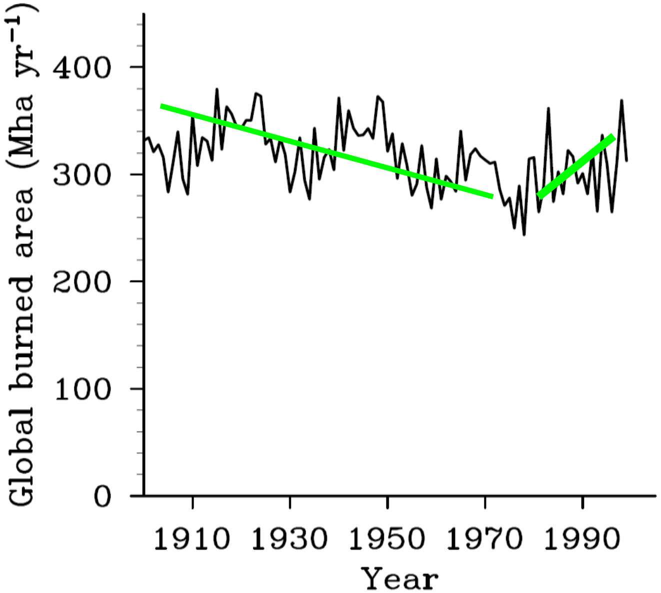
America Present-day Spatial Pattern

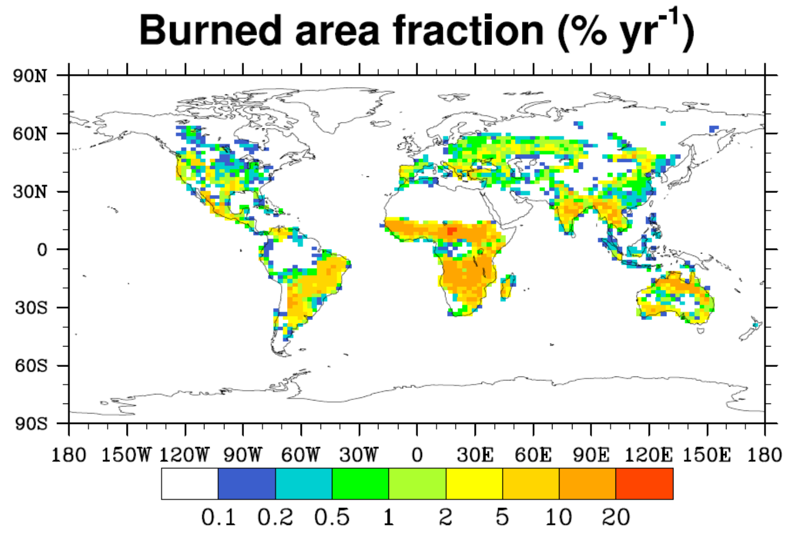




(From M. Val Martin)

• **Simulated burned area in the 20th century (CLM4.5 with Qian)**



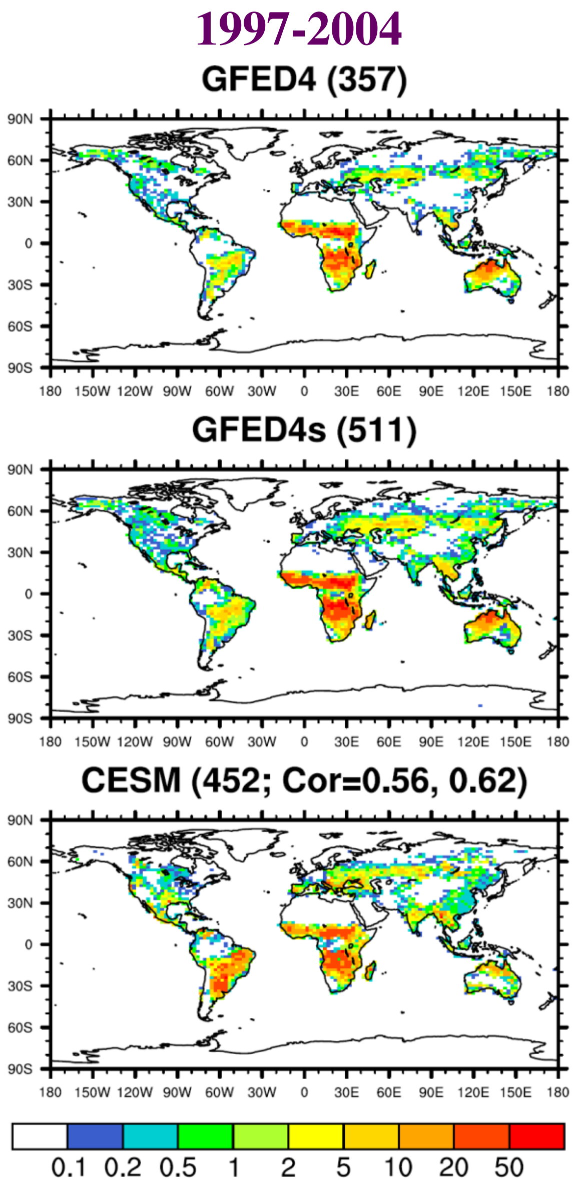


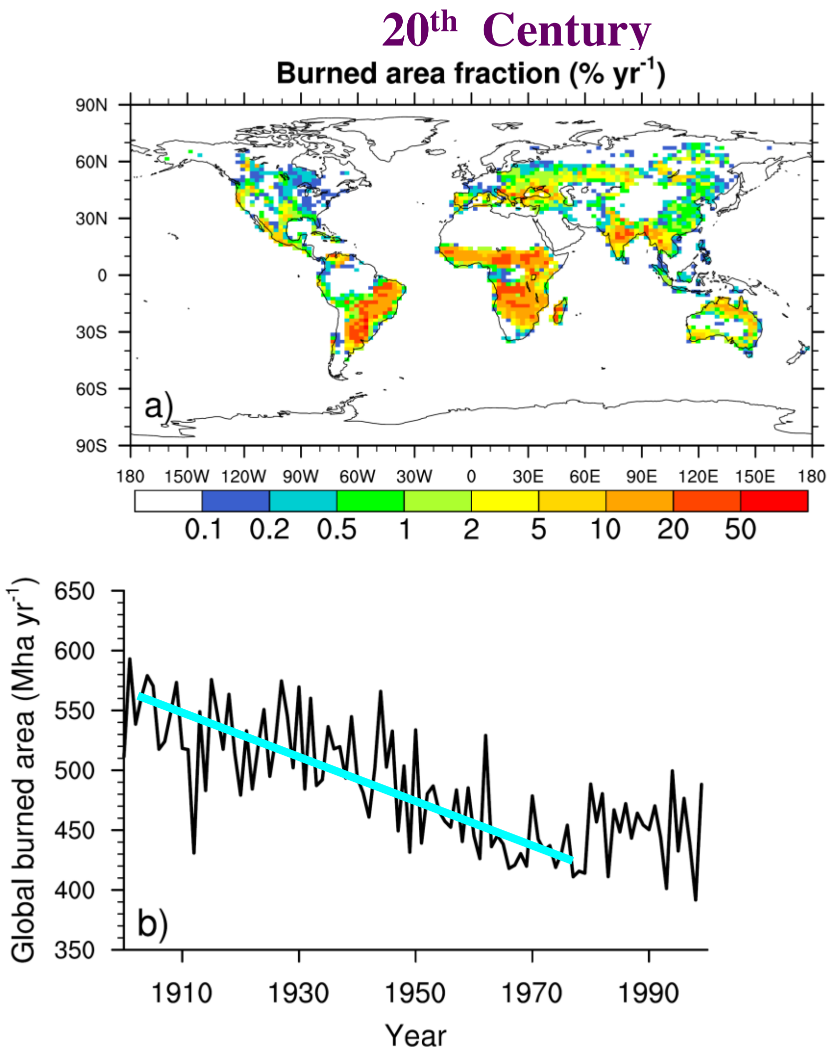
in the range of long-term trends of reconstructions

similar to that from MF05

(Li et al., 2014)

Fire simulations in CAM5.1-CLM4.5





(Li and Lawrence, JC, minor revision)

Application: Impact of fire on carbon budget (CLM4.5)

- Global total average across the 20th C

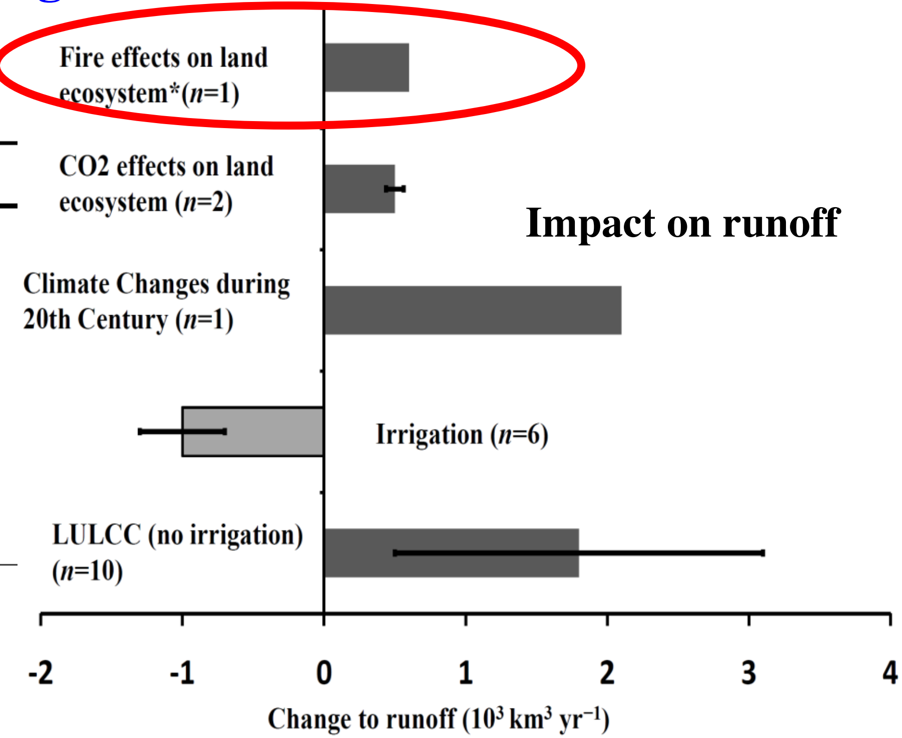
Variables	Fire-on－Fire-off	Fire-on	Fire-off
NEE	1.0*	-0.1	-1.1
Fire direct impact: **Fire carbon emissions**	1.9*	1.9	0.0
Fire indirect impact: **$-NEP+C_{lh}$**	-0.9*	-2.0	-1.1
NEP	0.8*	3.0	2.3
NPP	-1.9*	49.6	51.6
Rh	-2.7*	46.6	49.3
GPP	-5.0*	118.9	123.9
Ra	-3.1*	69.3	72.4
C_{lh}	-0.1	1.0	1.1

***diff in the means passed student t-test at α=0.05 sig. level** **Unit: Pg C/yr**

- **Fire significantly decreases net C gain by 1.0 Pg C/yr**
- **42% of fire carbon emissions (1.9) is offset by fire indirect effects (–0.9)**

(Li et al., 2014)

Impact on global annual land water/heat budget and climate due to changing ecosystems (CAM5.1-CLM4.5)



decrease ET

increase runoff

limited impact on precipitation

Variables	Fire-on−Fire-off[1]
ET	−0.6 (−1%)*
RO	+0.6 (+2%)*
Pr	+0.0 (+0%)
Et	−1.5 (−4%)*
Ec	−0.5 (−4%)*
Es	+1.4 (+5%)*

Unit: 10^3 km^3/yr, * sig. at α=0.05

(Li and Lawrence, JC, minor revision)

Warming

mainly b/c decrease in latent heat (LH)

decrease net radiation

limited impact on shortwave R.

Variable[a]	Diff	Variable	Diff
Tas (ºC)	+0.04	SLR (W m^{-2})	+0.42*
NSR (W m^{-2})	−0.02	ISR (W m^{-2})	−0.03
ALR (W m^{-2})	+0.10	RSR (W m^{-2})	−0.01
SH (W m^{-2})	−0.02	Lt (W m^{-2})	−0.82*
LH (W m^{-2})	−0.32*	Lc (W m^{-2})	−0.27*
G (W m^{-2})	+0.00	Ls (W m^{-2})	+0.78*
NLR (W m^{-2})	+0.32*	LAI (m^2 m^{-2})	−0.10*
NR (W m^{-2})	−0.34*	Veg. H (m)	−0.19*

(Li et al., GRL, under review)

Thanks!