CROP & FIRE modeling in the Community Land Model

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Terrestrial Sciences Section
CLM Tutorial 2014

Outline

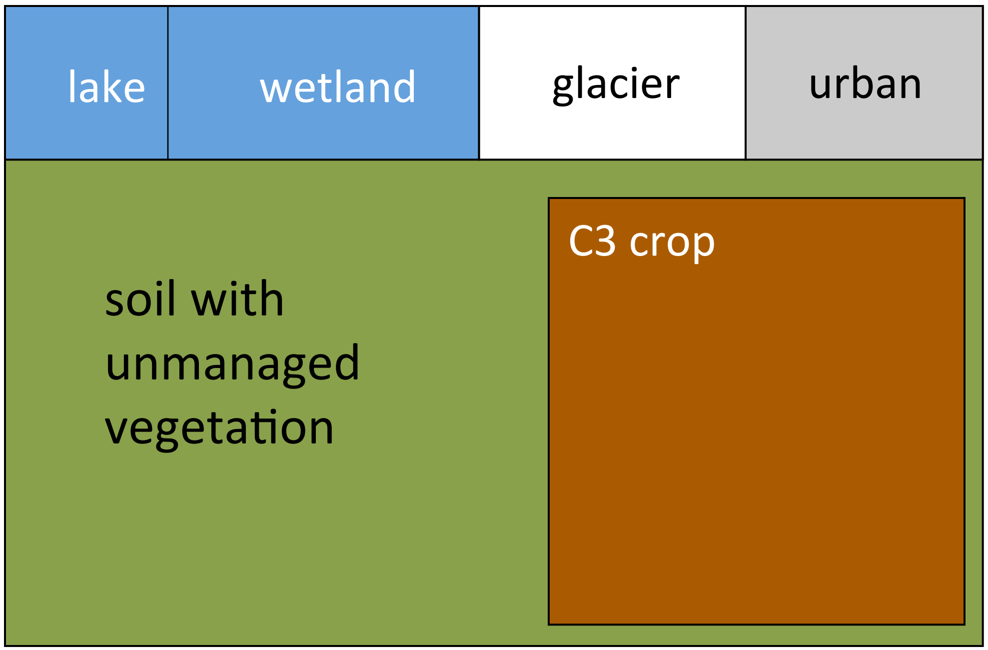
1. The CROP model
2. The FIRE model

} Algorithms & Simulations

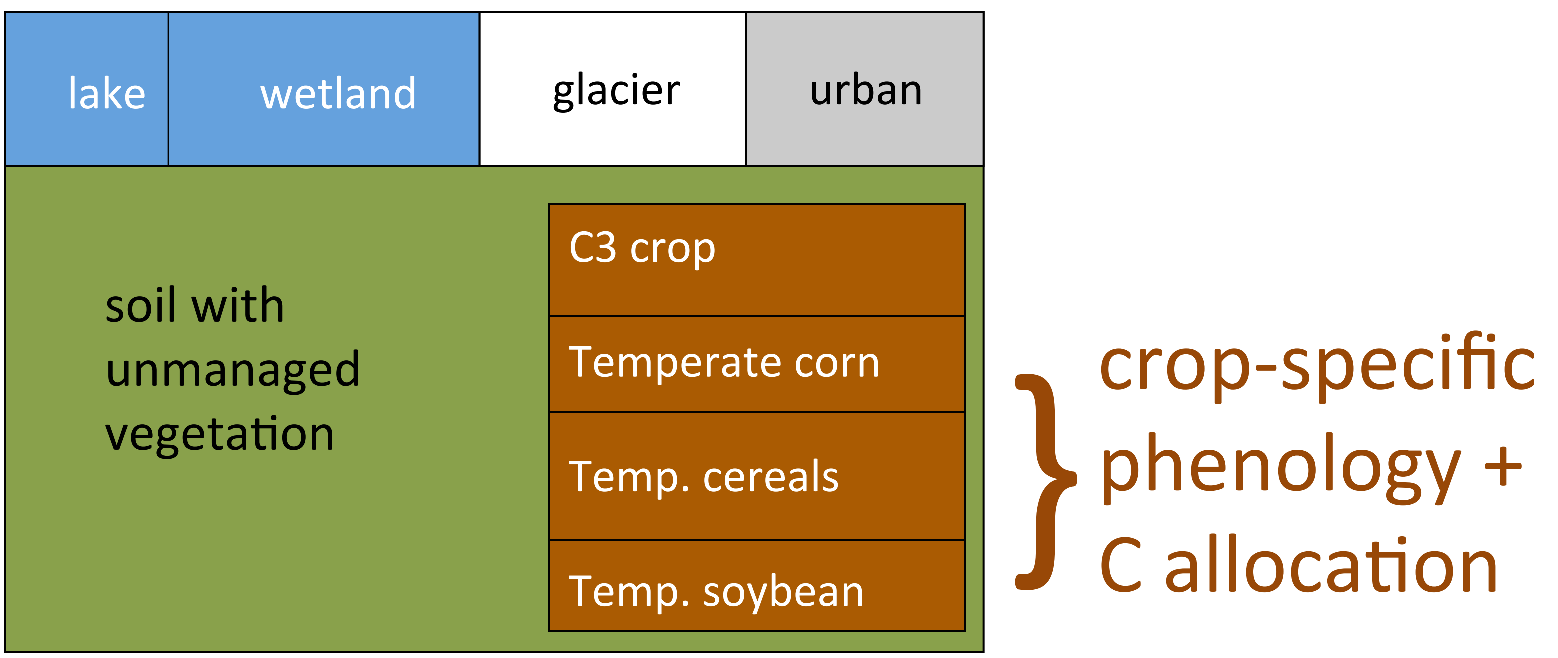
Motivation for crop modeling

- Food supply ...crop yields
- Fuel supply ...biofuels
- Land-atm interactions ...climate change
  - Biogeophysical
  - Biogeochemical

a CLM grid cell (default)



a CLM grid cell
with interactive crop management



Interactive Crops in the CLM

<u>Following AgroIBIS</u> (Kucharik & Brye, 2003)

Temperate corn, soybean, spring wheat:

Phenology by GDD accumulators ➔

Planting, leaf emergence, grain fill, maturity, harvest

C allocation + N limitation ➔

Leaf area, height, crop yield

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Simple fertilization (Drewniak et al.) and irrigation (Sacks et al.) schemes

CLM4

Temp. corn

Temp. cereals

Temp. soybean

effects on atm.

Levis et al. (2012)

CLM4

Temp. corn

Temp. cereals

Temp. soybean

effects on atm.

Levis et al. (2012)

CLM4.5

w/ options to fertilize & irrigate

Oleson et al. (2013)

enhanced soil C decomposition

Levis et al. (2013)

CLM4	CLM4.5	post4.5
Temp. corn Temp. cereals Temp. soybean	w/ options to fertilize & irrigate	plus… Trop. corn Trop. soybean Sugarcane Rice Cotton
effects on atm. Levis et al. (2012)	Oleson et al. (2013) enhanced soil C decomposition Levis et al. (2013)	A. Badger (GMU)

CLM4 & 4.5:

Ramankutty and Foley (1998)

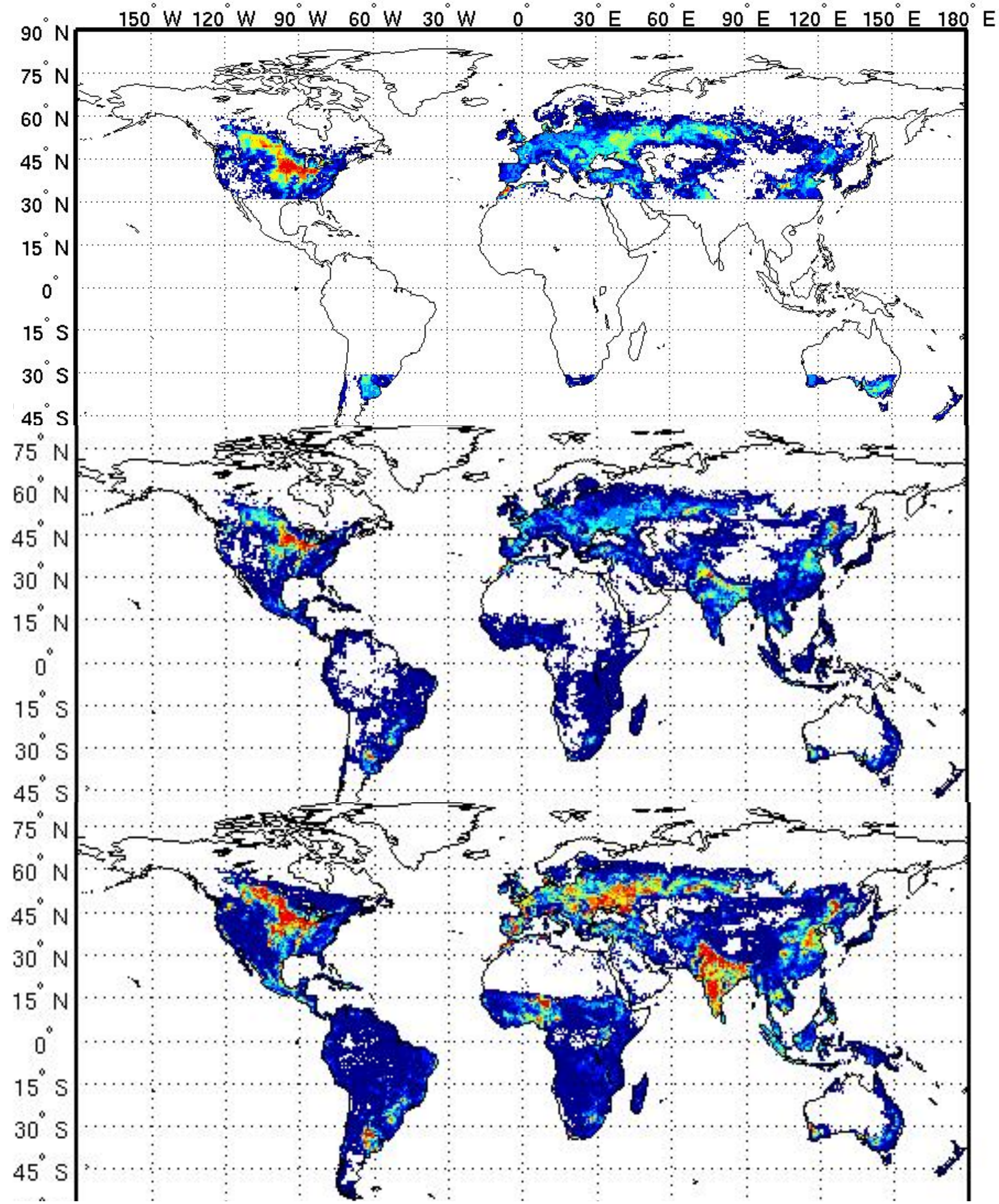
Portman *et al.* (2010)

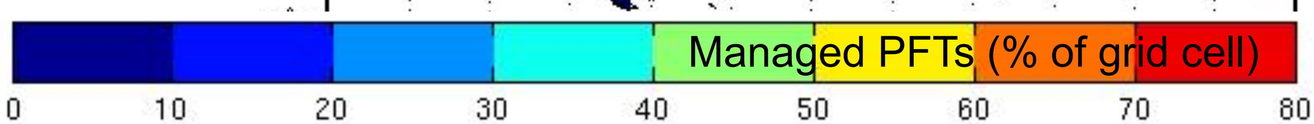
post4.5:

Portman *et al.* (2010)

all crops:

Portman *et al.* (2010)





CLM4 & 4.5:

Ramankutty and Foley (1998)

Portman *et al.* (2010)

post4.5:

Portman *et al.* (2010)

all crops:

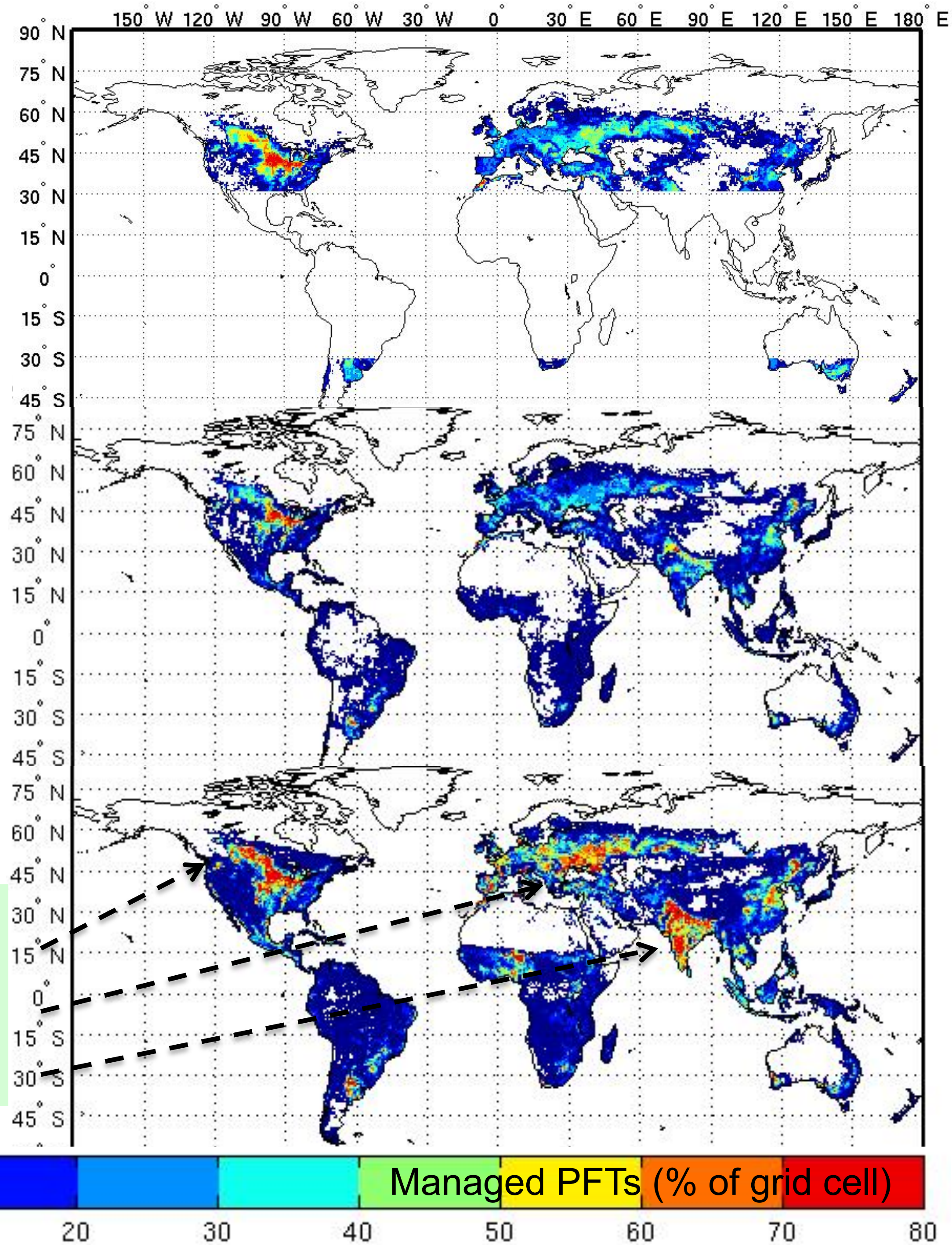
Portman *et al.* (2010)

…still missing

Canada foddergrass

Russia sunflower and foddergrass

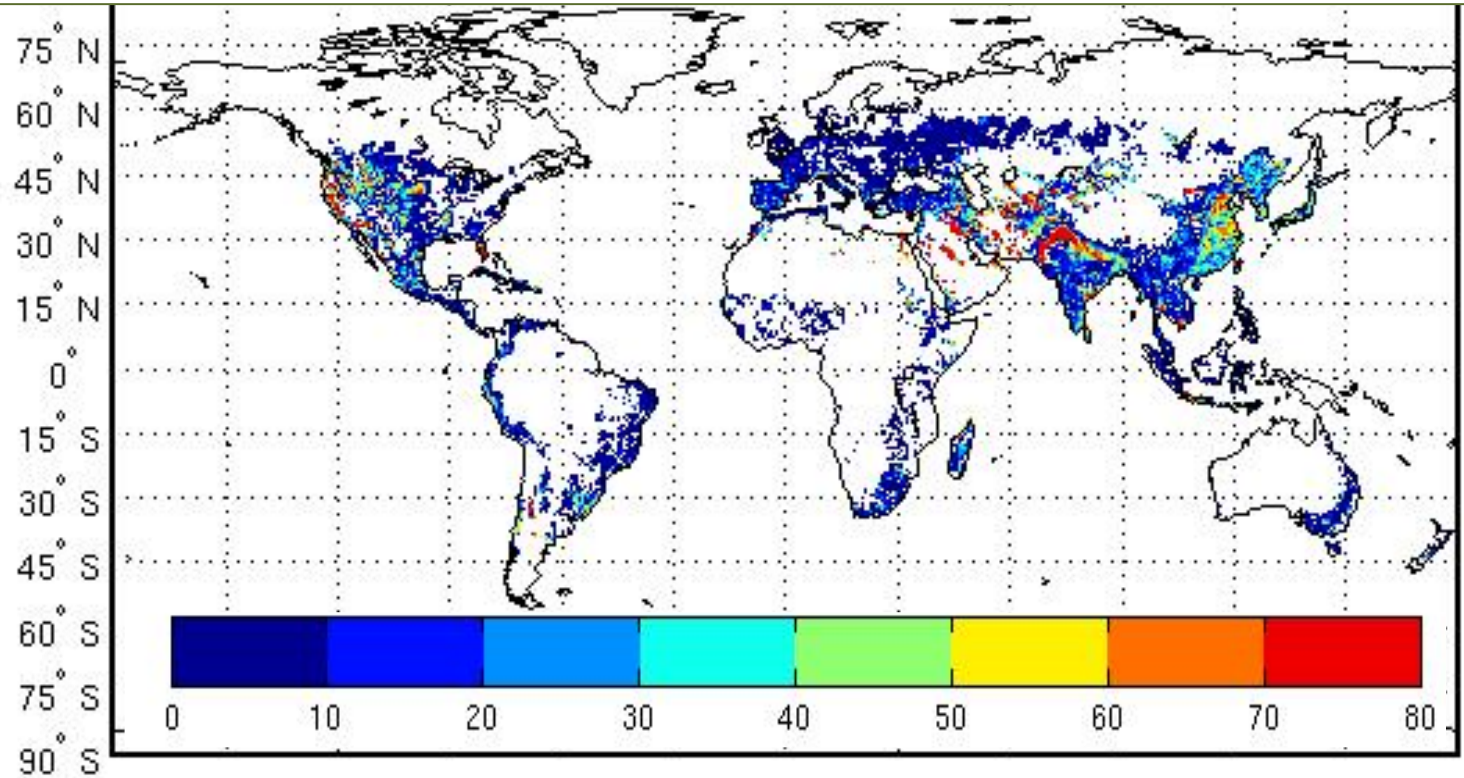
India sorghum, pulses, millet, pnuts



CLM **input files with crop-relevant info**

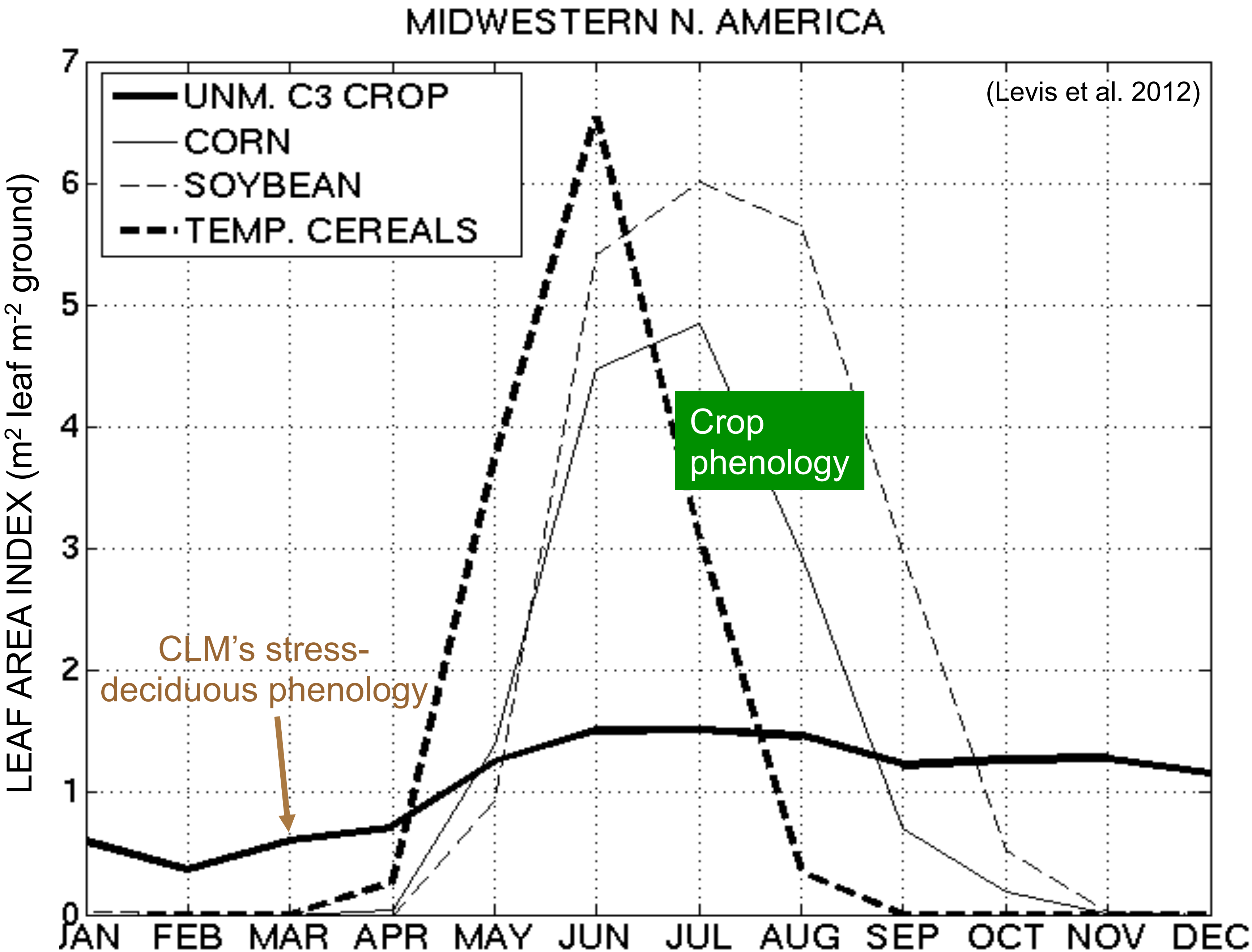
- **fsurdat**: % area of rainfed and irrigated crops
- **clm_params**:
  - min/max planting dates
  - min/max planting temperature
  - nitrogen in fertilizer
  - etc.

% of crops equipped for irrigation (Portmann et al. 2010)



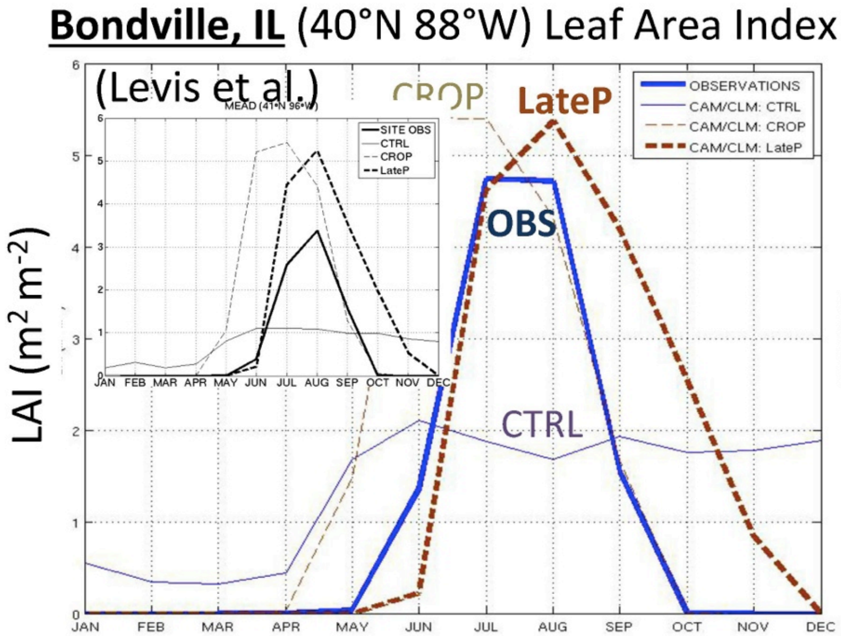
Cooling mainly in US & SE Asia < 1K
Greater by day than night
Positive cloud feedback contributes ~equally
Volume & area of irrigation affect result most

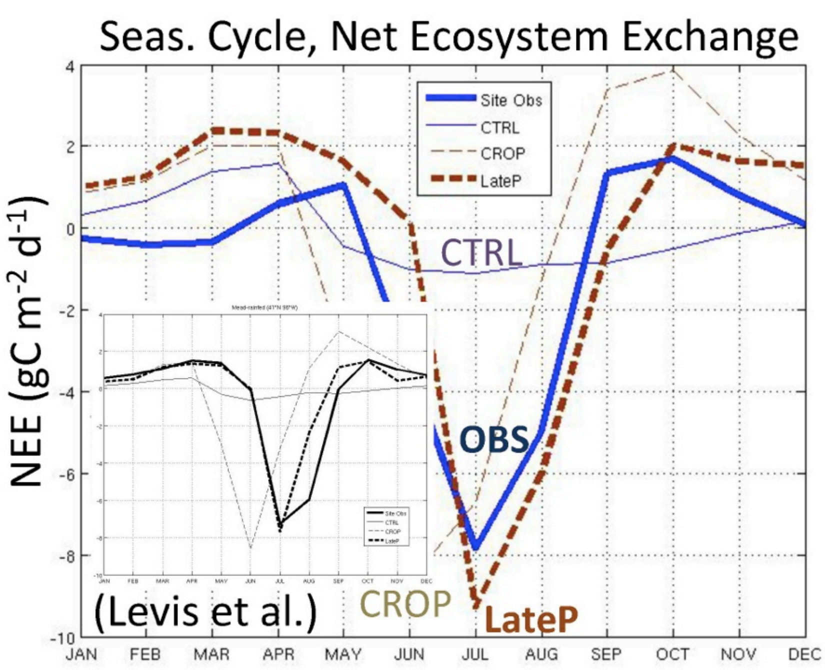
Warming in N high lats from circulation chg
So little global average effect
Similar order as the effects of LU locally
(Sacks et al. 2008)

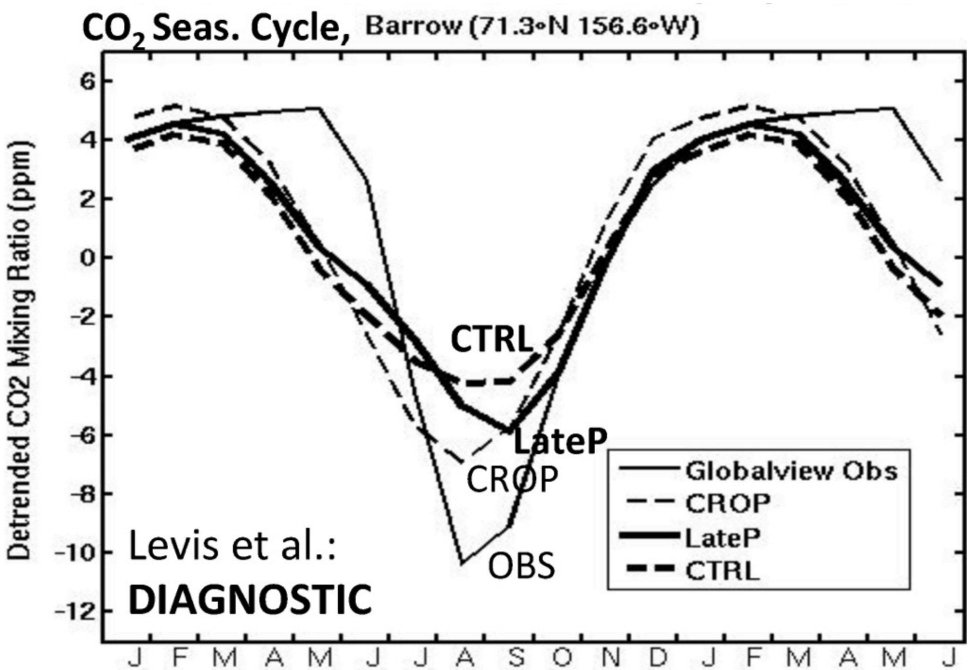


MIDWESTERN N. AMERICA
LEAF AREA INDEX (m² leaf m⁻² ground)
UNM. C3 CROP
CORN
SOYBEAN
TEMP. CEREALS
(Levis et al. 2012)
Crop phenology
CLM's stress-deciduous phenology
0
1
2
3
4
5
6
7
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

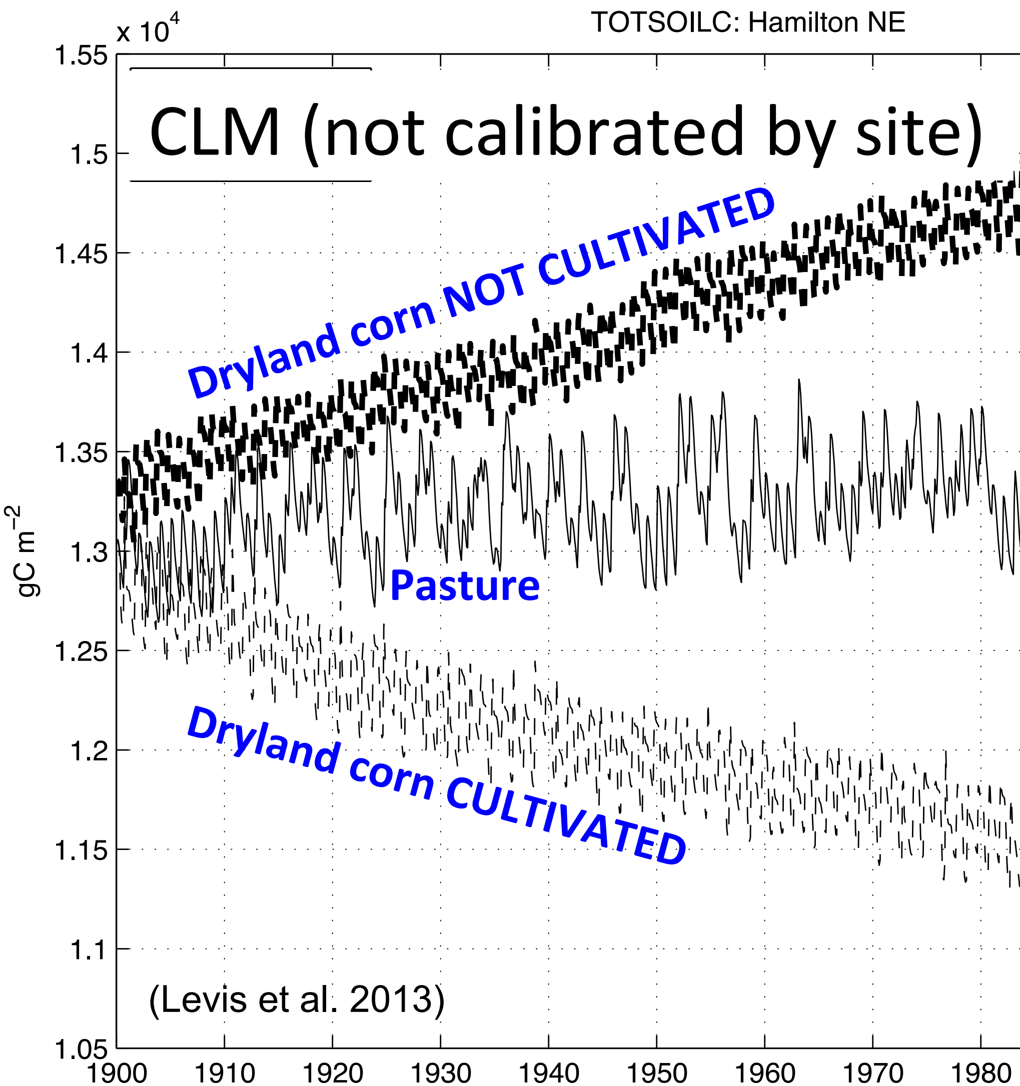
Effects on the <u>atmosphere</u>







Enhanced soil C decomposition



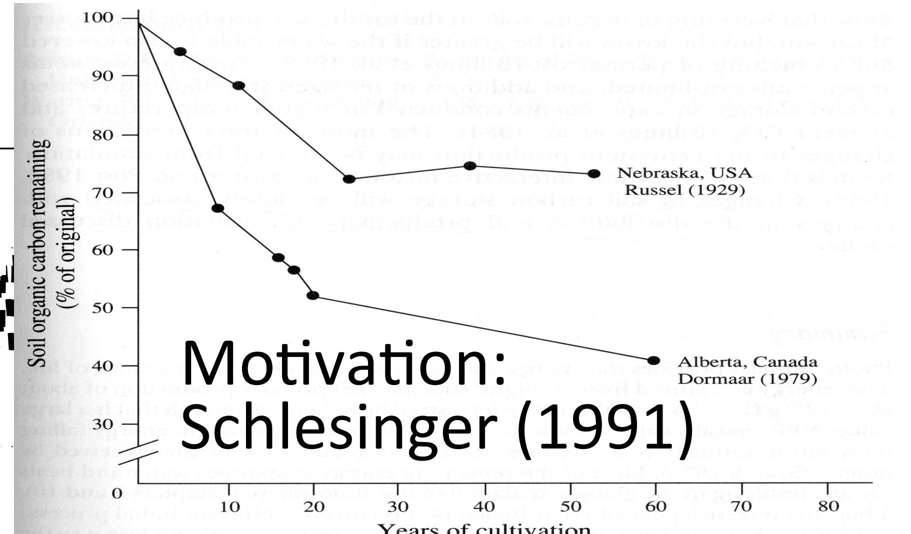
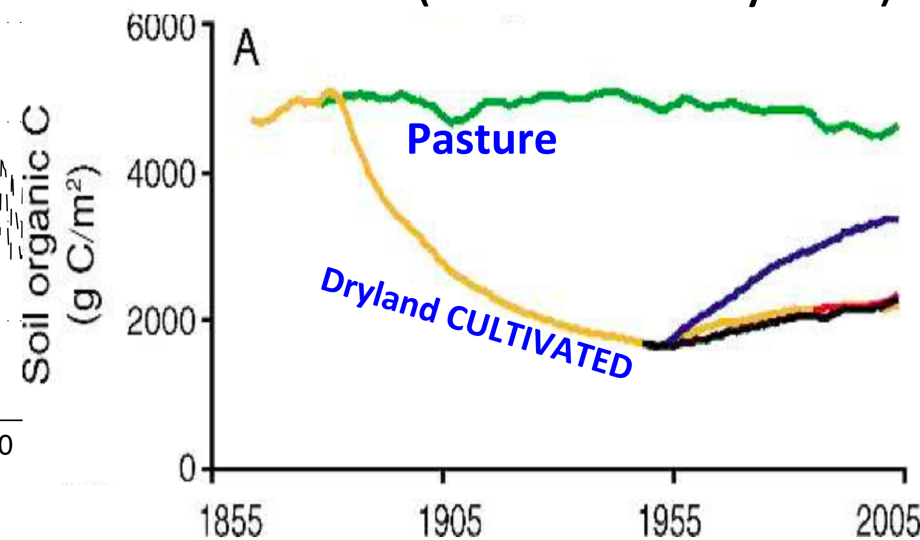


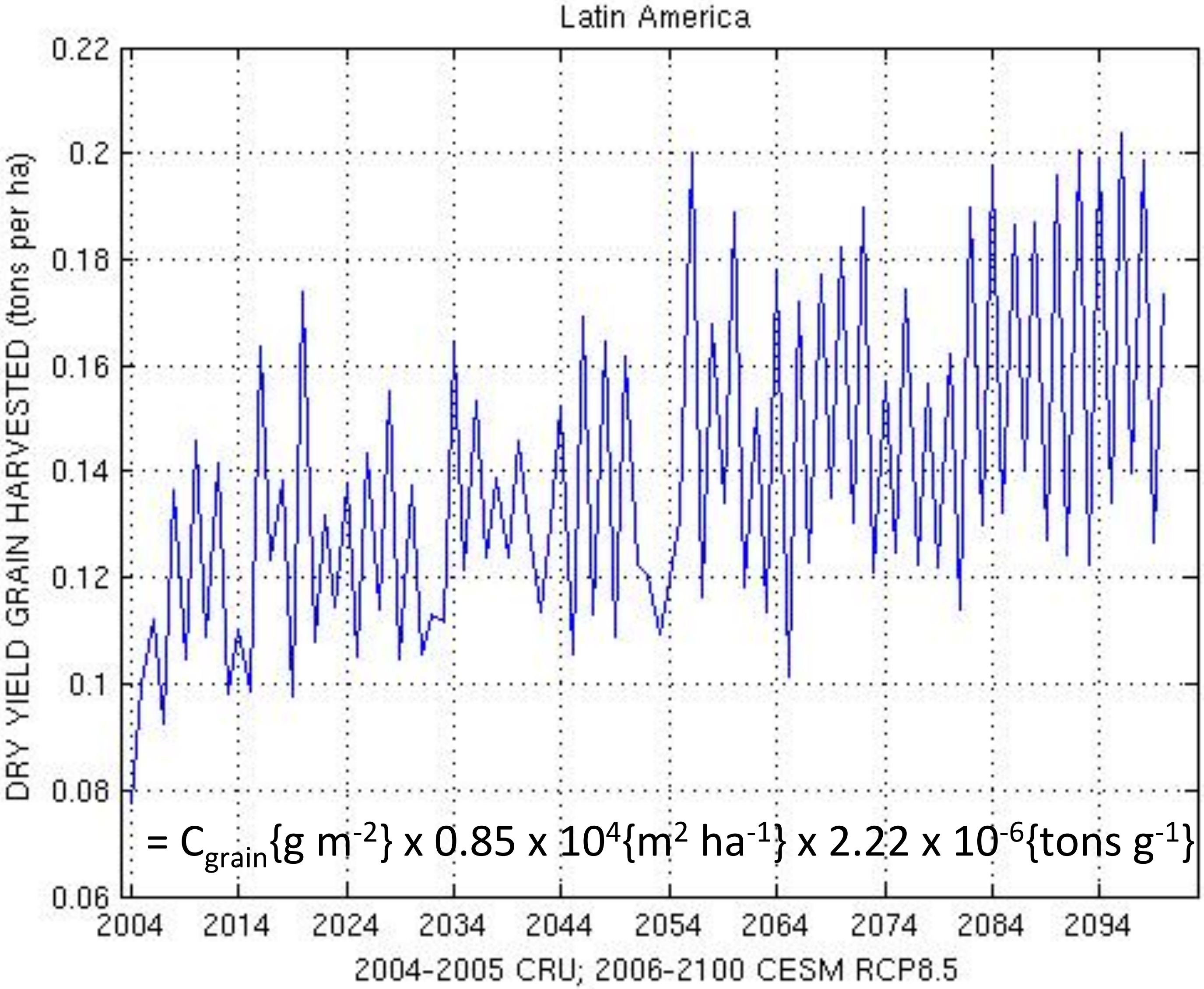
Figure 5.18 Decline in soil organic matter following conversion of native soil to agriculture for two grassland soils.

Hamilton County, Nebraska

DAYCENT (calibrated by site)



Yield: all CLM crops



2004 obs (tons ha^{-1})

Botswana	0.3
…	
USA	6.9
…	
Belgium	9.2

http://data.worldbank.org

1st Summary & Conclusions

- **Interactive crop management in the CLM**
  - Better simulated annual cycle of crop LAI
  - Better annual cycle of the NEE (and CO_2)
  - Promising for simulations with interactive CO_2
  - Better summer precip over MW N. America, too
  - More forms of mgmt: crop rotation, multi-cropping

- **Human dimensions: new frontier in CESM research**
  - LULM & urbanization: steps in that direction
  - Still also resolving more basic issues: biogeophys. & bgc
  - Coupling ESMs and IAMs in the not so distant future…

Fire dynamics in the CLM

Li* & Levis, et al. papers (2012, 2013)

*Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

•Wx and Climate
P, RH, T, wind…

•Land
vegetation, BGCs, hydrology….

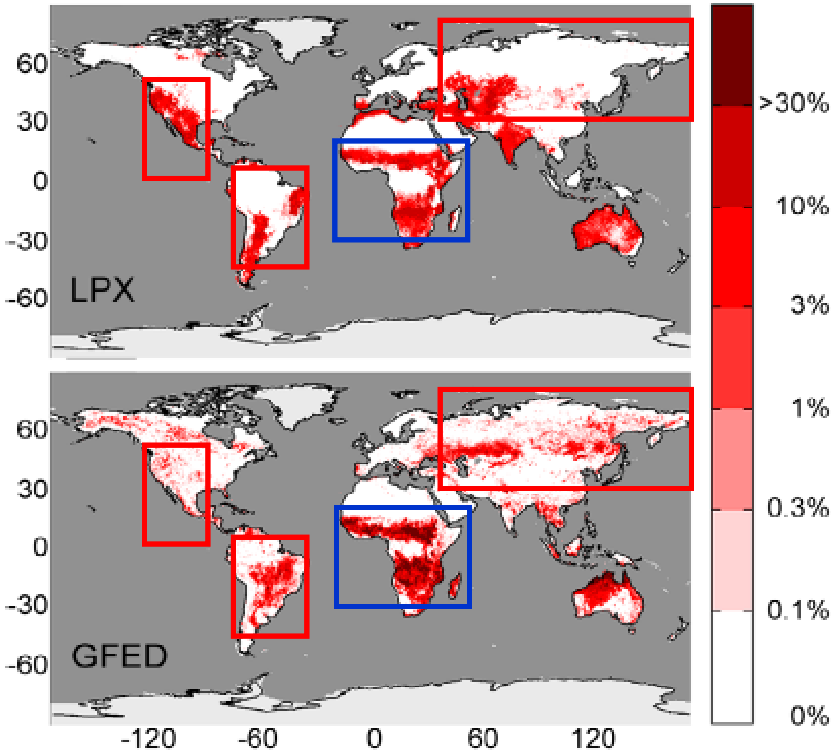
•Atmosphere
trace gases, aerosols, air quality…

•People

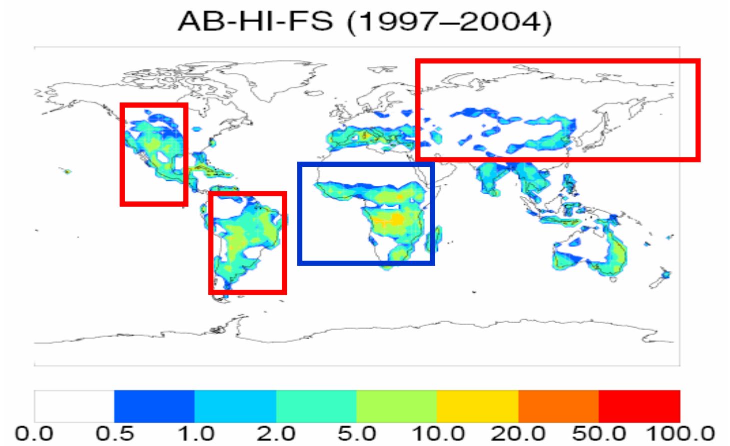
Three types of global fire parameterizations

1. Complex process-based (e.g. SPITFIRE [Thonicke et al. 2010])

1997-2005 average annual fractional burnt area from improved LPJ-SPITFIRE (LPX) and GFED3 (Prentice et al. 2011)



Intermediate process-based/CLM-CN with revised CTEM-FIRE (Kloster et al. 2010)

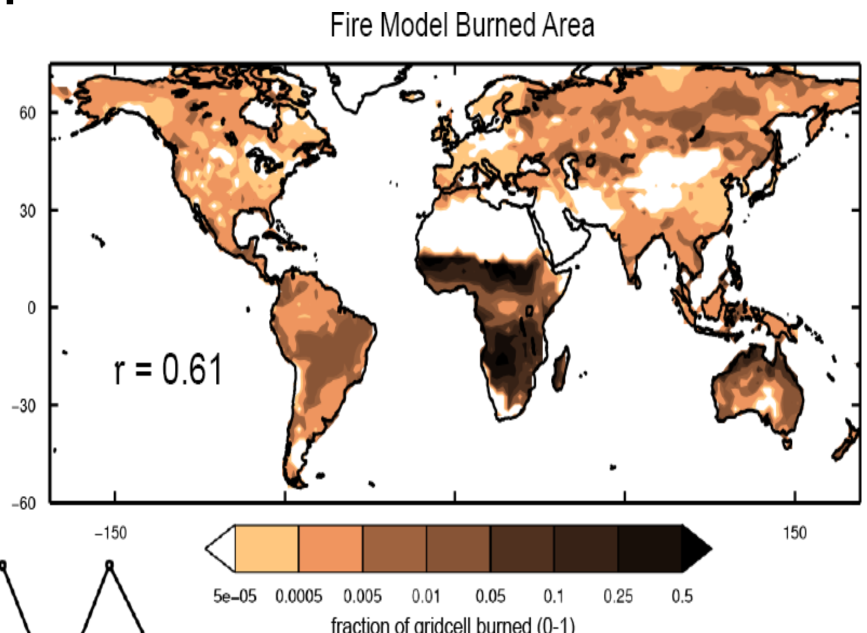


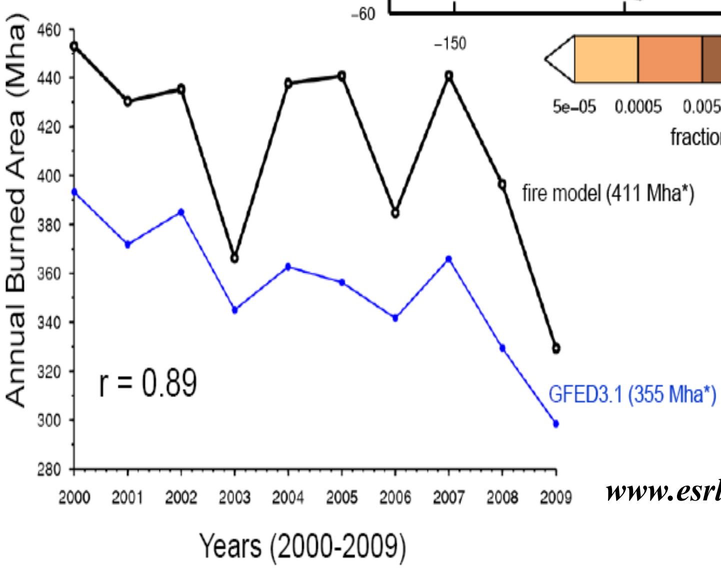
on a global scale，SPITFIRE hasn't shown the benefit of it's complex design

2. Statistical model:

– **Constant fire loss rate**

Future fire parameterization in GFDL land model (Magi et al.)





Key Points

•Spatial correlation with GFED3.1 is 0.61

•Burned area simulated by the fire model is within the range (285-408 Mha*) of satellite-based estimates from GFED3.1, L3JRC, GLOBCARBON, and MCD45

•**effect of fuel load on fire not accounted for**

•**statistical model not coupled in any land model, yet**

www.esrl.noaa.gov/gmd/annualconference/slides/55-110415-A.pdf

3. Intermediate Process-Based

Examples from the CLM:

- **Glob-FIRM (Thonicke et al., 2001)**

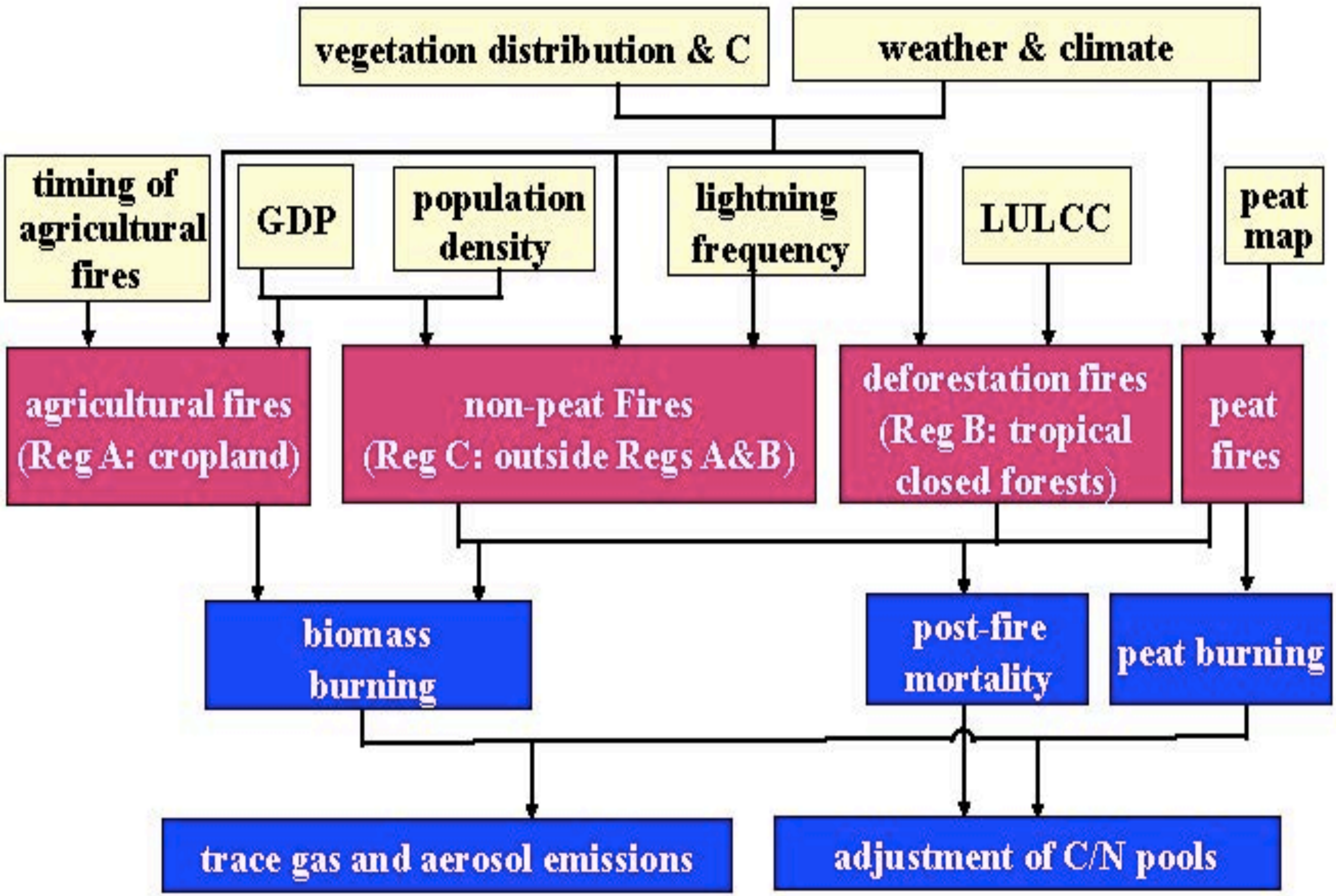
  modified version introduced to the CLM by N. Mahowald

- **CTEM-FIRE (Arora and Boer, 2005)**

  modified version introduced to the CLM by (Kloster et al. 2010) includes anthropogenic ignition and fire suppression (Pechony and Shindell, 2009) + deforestation fires + effect on nitrogen dynamics

- **CLM4.5 fire model (Li et al. 2012 and 2013)**

  new fire occurrence & spread calcns (parameter-calibration from obs) w/ anthropogenic ignition and fire suppression (Pechony and Shindell, 2009) + parameterization for trace gas and aerosol emissions from fire + deforestation fires + ag. fires + socioeconomic impact on fires + peat fires


vegetation distribution & C
weather & climate
timing of agricultural fires
GDP
population density
lightning frequency
LULCC
peat map
agricultural fires (Reg A: cropland)
non-peat Fires (Reg C: outside Regs A&B)
deforestation fires (Reg B: tropical closed forests)
peat fires
biomass burning
post-fire mortality
peat burning
trace gas and aerosol emissions
adjustment of C/N pools

Region A: agricultural fires

Managed crops:

- **Fire counts per km^2:**

$$N_f\text{=f(fuel load)g(GDP)}$$

- **Burned area fraction: aN_f**

a: global average burned area per agriculture fire derived from satellite data

- **Fire seasonality:**

assume agricultural fires occur at the next time step of harvest

Korontzi et al. (2006): most agricultural fires occur after or during harvesting

- **Fire impact:**

Litter combusted, litter C pool adjusted

CURRENTLY IMPLEMENTED ONLY FOR CROP not active => no harvest date => ag. waste burned on first rainless time step in peak month of crop fire emissions

data: van der Werf et al. (2010)

Effect of fire on crops same as for grass PFTs

Region A: agricultural fires

Higher GDP → smaller fire counts per km^2 cropland area

mechanical management of agricultural waste rather than burning

Region B: deforestation fires

Tropical forests

Deforestation fires: started by humans
Degradation fires: loss of control…

A function of human & natural influences
- Lightning
- Climate
- Population density

Region C: ALL fires BUT… agricultural, deforestation, and peat

Higher GDP ⟶ higher ability to suppress fires ⟶ shorter fire duration

Economic impact on tree PFTs is smaller than grasses and shrubs

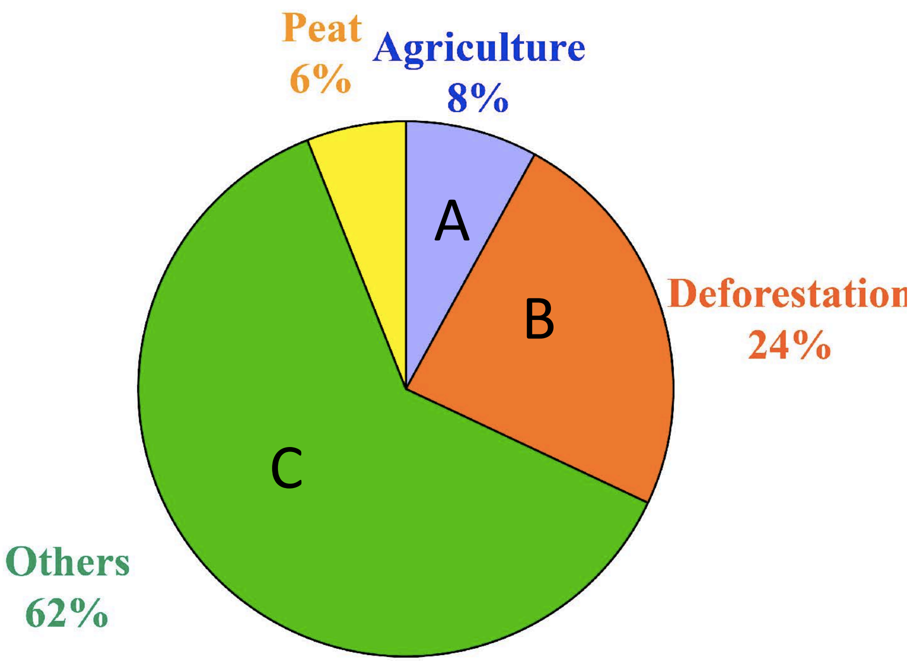
- **20th century simulations (1850-2004)**

  transient land cover, CO_2, and aerosol deposition

- **DATA:**

Types	Variables	Sources
Forcing data	Precipitation Surface air temperature Wind speed Specific humidity Air pressure Downward solar radiation	Qian et al. (2006)
	Relative humidity	NCEP/NCAR CRU
	Lightning frequency	NASA LIS/OTD v2.2
	Peak month for ag. fires	van der Werf et al. (2010)
	Population density	GPWv3, HYDE v3.1
	Gross domestic product	van Vuuren et al. (2006)
	peat map	Giglio et al. (2009) GLWD
Evaluation data	Burned area & Fire emissions	GFED3 (1997-2004)

Clm4.5 fire model, 1997-2004 averages



CLM4.5 global fire C emissions

Table 4. Annual burned area (Mha) for Africa

	GFED3	Mod-new	Mod-old	Mod-CTEM
NHAF	134	116	18	24
SHAF	124	83	38	45

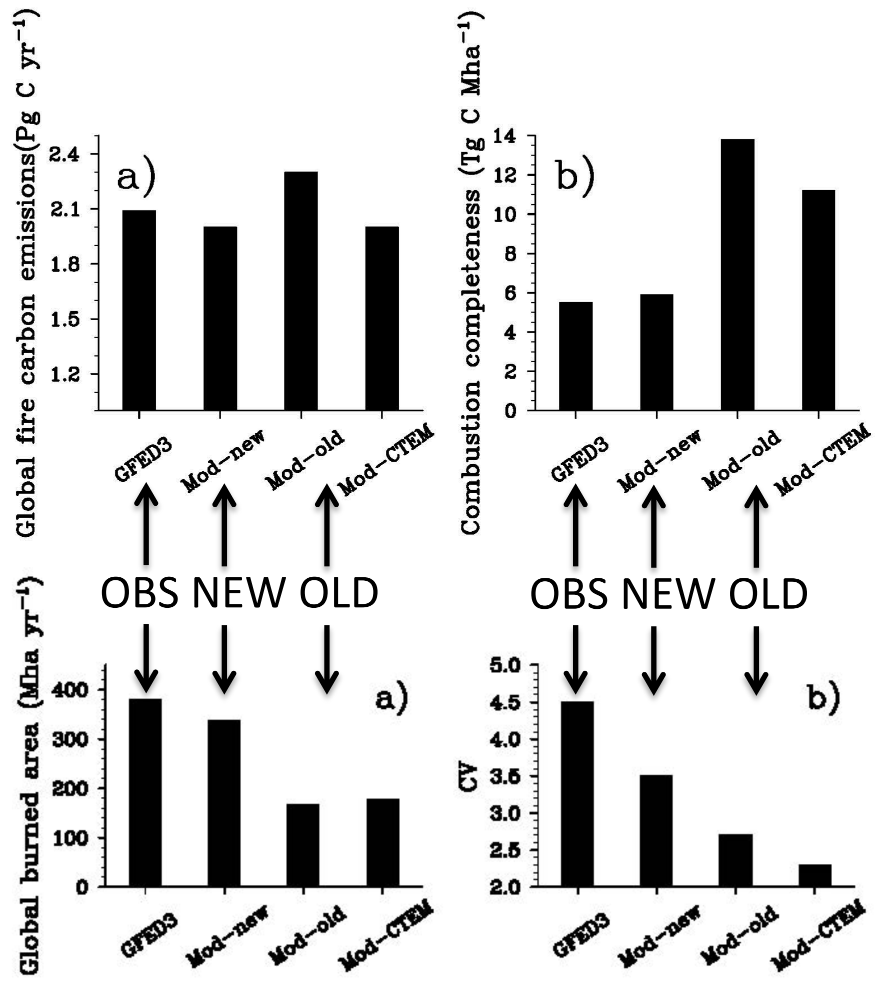
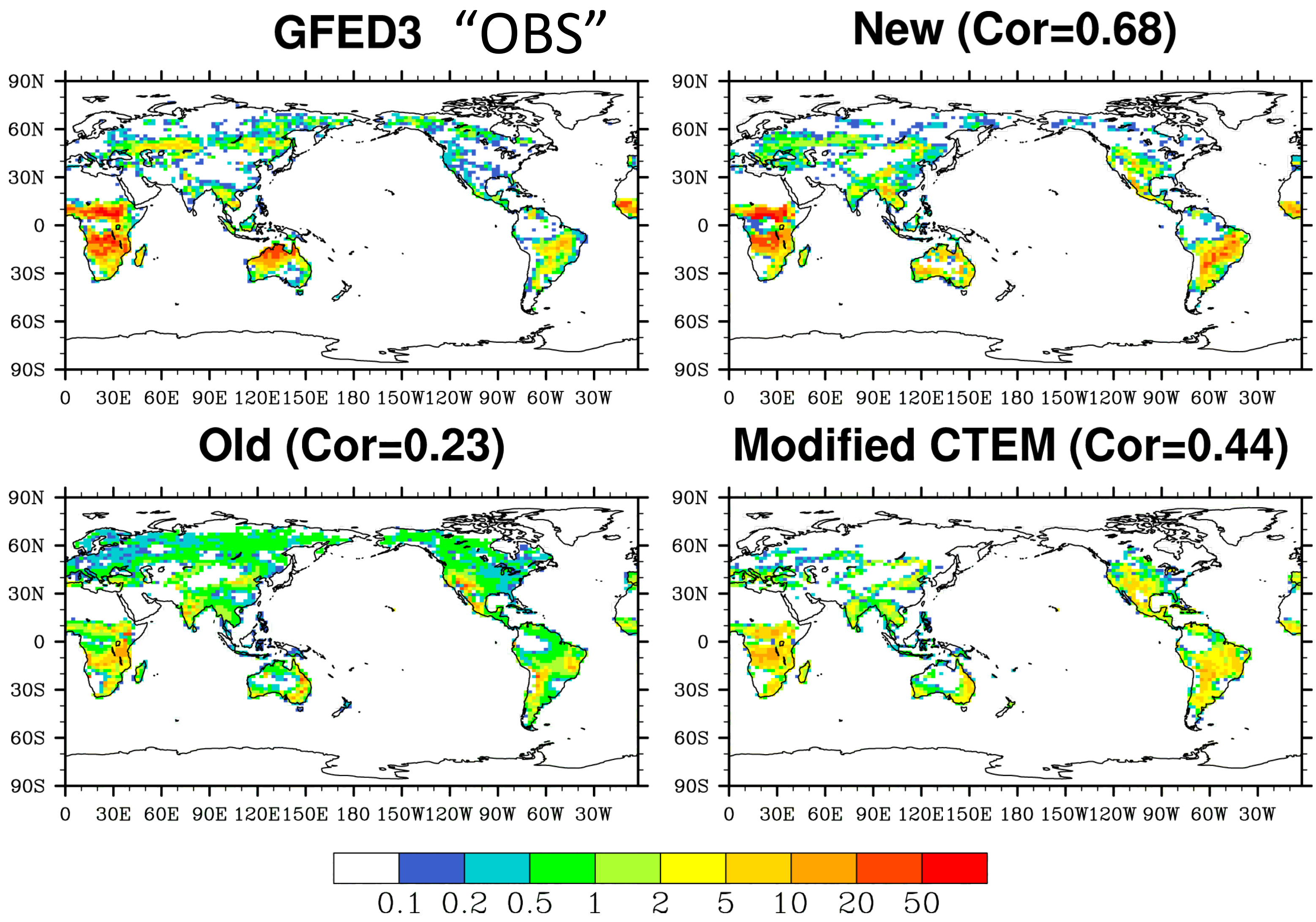


Fig. 8. 1997–2004 average **(a)** global annual burned area and **(b)** spatial dispersion of annual burned area fraction on global land surface grids quantified by coefficient of variation CV from GFED3

Global spatial distribution of burned area fraction

Cor: global spatial correlation between obs and simulations



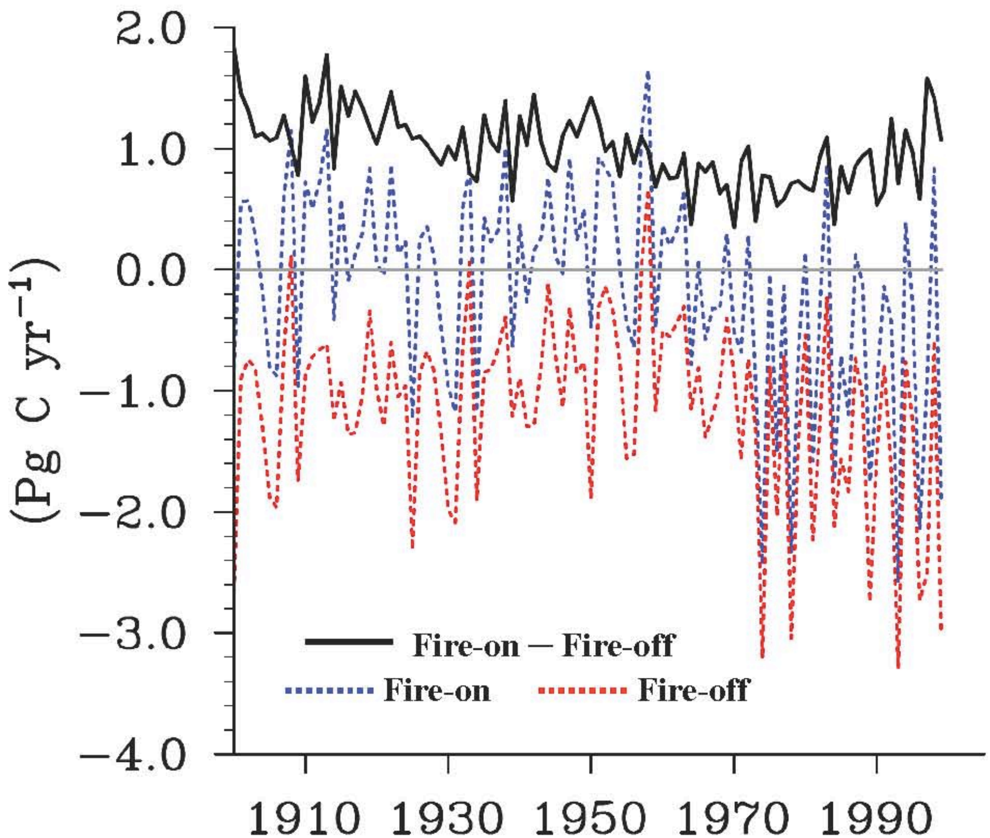
Summary of results (1997-2004)

	GFED3 "OBS"	New CLM	Old CLM	Modified CTEM
Global burned area (Mha/yr)	380	344	167	178
Spatial Correlation… annual burned area fraction	1.0	0.68	0.23	0.44
Temporal Correlation… annual global burned area	1.0	0.78	0.08	0.25
Spatial Correlation… st.d. of annual burned area	1.0	0.45	0.14	0.26
Global emissions (Pg C yr^{-1})	2.1	2.0	2.3	2.0
& their Spatial Correlation	1.0	0.61	0.39	0.32
Emissions per burned area (Tg C/Mha)	5.5	5.8	13.6	11.2

Fire decreases the net carbon gain of global terrestrial ecosystems by 1.0 Pg C yr^{-1} in the 20th c.

NEE

…direct effect = 1.9PgCyr^{-1} …indirect effect = −0.9PgCyr^{-1}



2nd summary and conclusions

CLM4.5 simulates improved fire dynamics

- Improved spatial and temporal representation
- Promising for atm. chemistry & aerosol transport simulations

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- Fire decreases the net carbon gain of global terrestrial ecosystems by 1.0 Pg C yr^{-1} averaged across the 20th century

(Li et al. 2013)

Questions?