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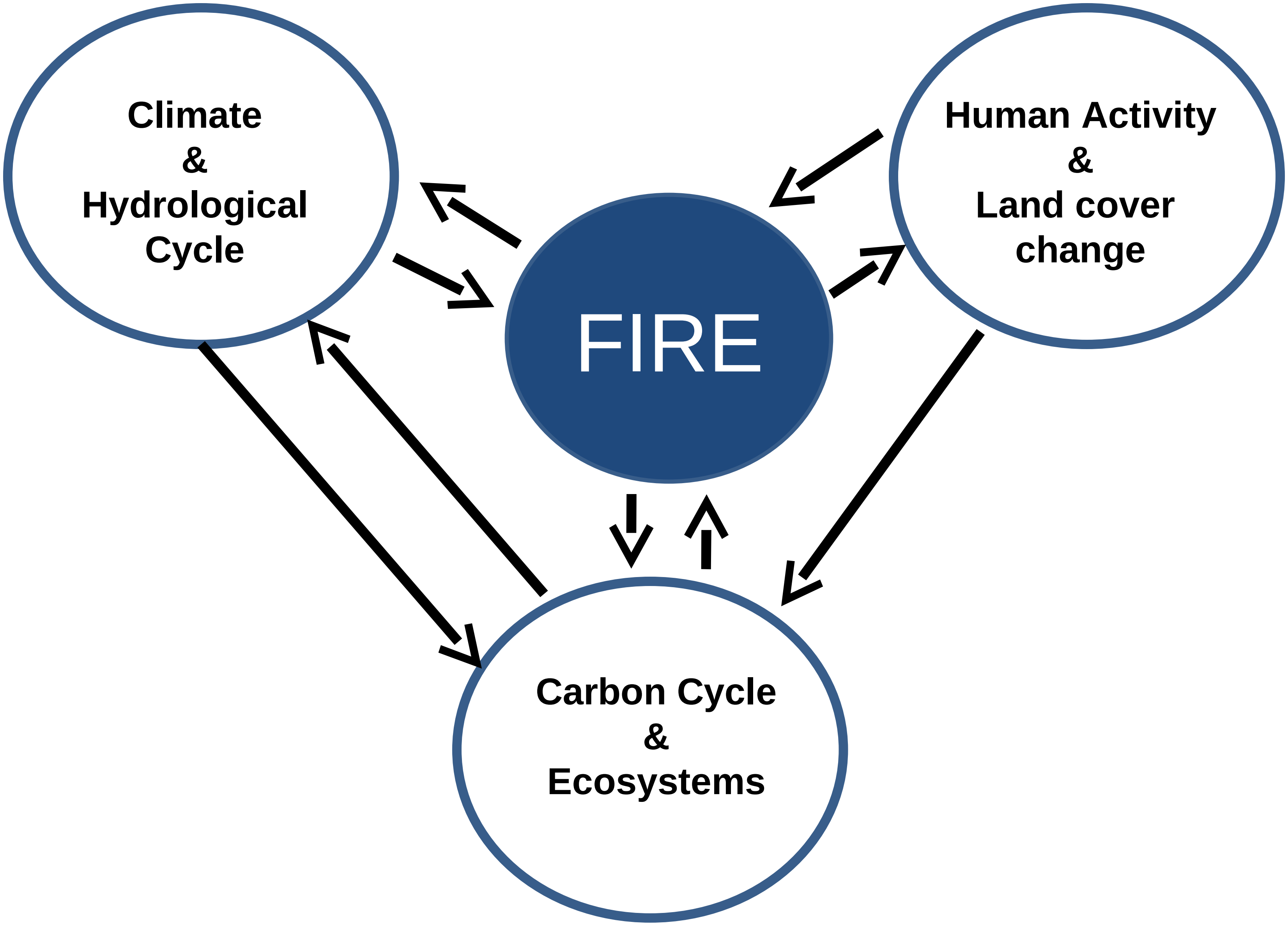
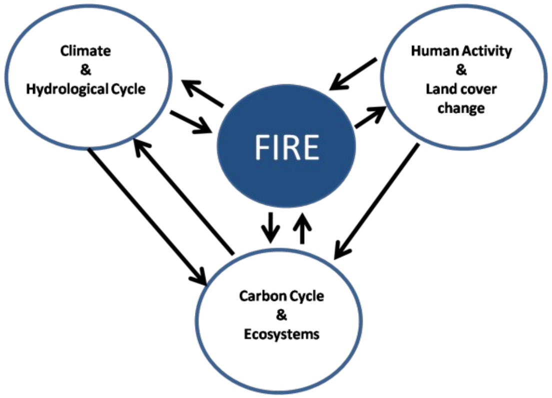
FIRE in CLM-CN

Silvia Kloster, Natalie Mahowald, Jim Randerson, Peter Thornton, Peter Hess

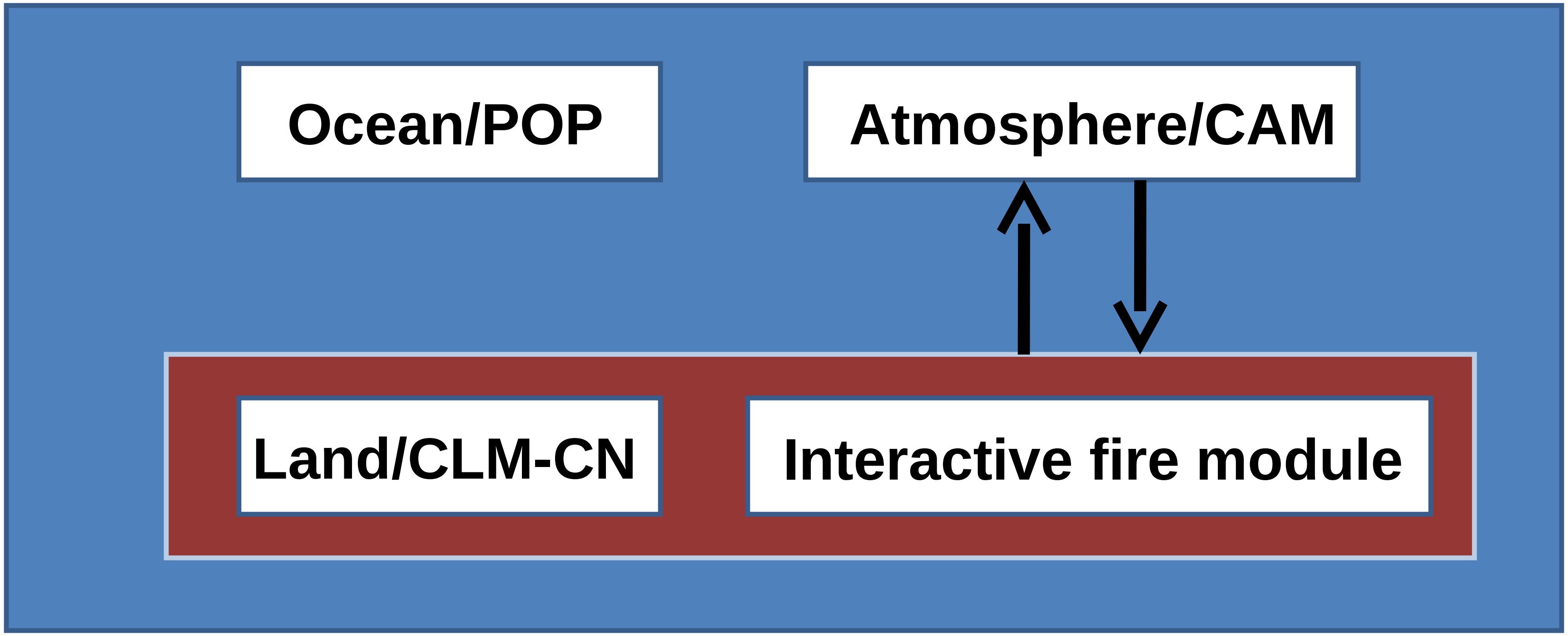
Motivation - Introduction



Motivation



Community Climate System Model
CCSM



Fire algorithm - General

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Amount of Carbon emitted during a fire:

$$EC(t) = A(t)[\sum_d C_d D_d(t) + \sum_b C_b M_b B_b]$$

dead plant material
(detritus)

Living plant material
(biomass)

- A(t) = area burned
- D(t) = dead plant material
- B(t) = living plant material
- M = Mortality factor (fraction of fuel that is killed during a fire)
- C = Combustion factor (fraction of fuel that gets combusted)
- D, B, M and C vary among the different detritus (d) and biomass (b) pools

Van der Werf et al., ACP, 2006

Model – CLM-CN

Fire algorithm:

Thonicke et al (2001)
Arora and Boer (2004)

Simulation setup:

- Offline mode
- equilibrium state representative for pre-industrial conditions

Model – CLM-CN Thonicke et al.

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CLM-CN3:

Fire algorithm based on Thonicke et al. 2001 developed for LPJ

- **Fire condition:**
  - fuel amount - dead fuel amount > 100 gC/m^2
  - temperature - T > 0 ^oC
  - moisture - $m < m_e$, m= moisture in the upper soil layer and m_e= moisture of extinction

- **Probability of occurrence of a fire at least once a day**

$$p(m) = e^{-\pi * (\frac{m}{m_e})^2}$$

- **Annual fire season length**

$$N = \sum_{n=1}^{365} p(m_n)$$

Model – CLM-CN Thonicke et al.

- **Area burned**

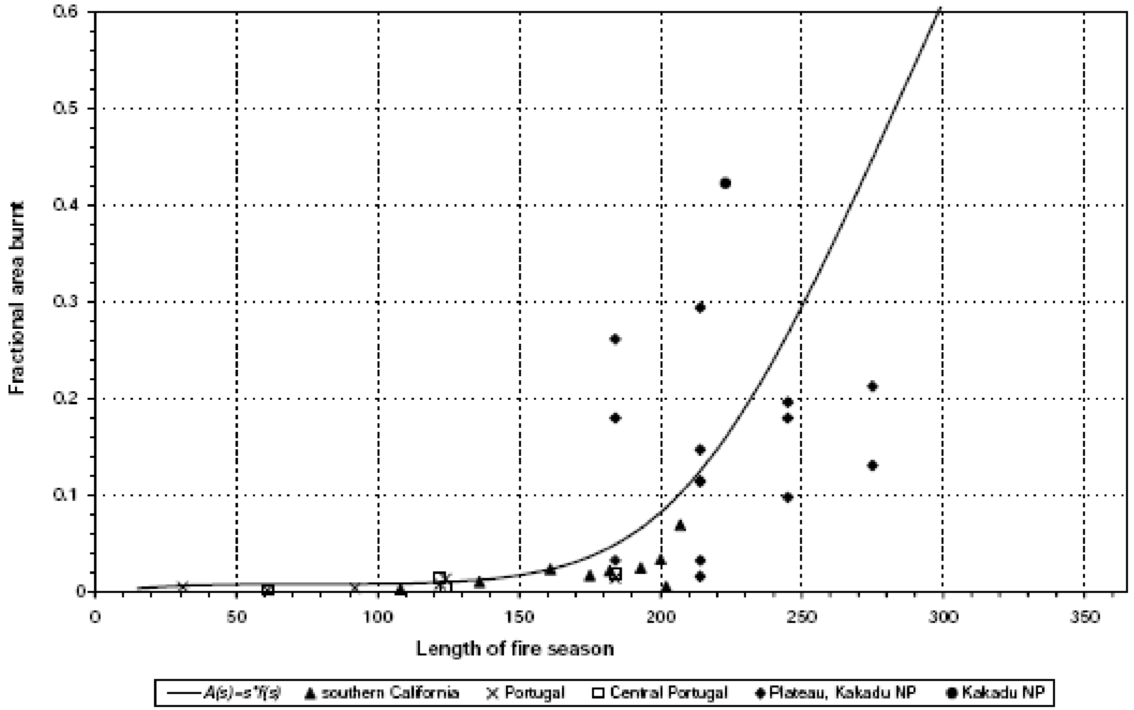
Assumption: „Annual fraction burned is a function annual fire season length“

- Annual fraction area burned:

$$A(s) = s * f(s) = s * e^{((s-1)*\alpha(s-1))}$$

with alpha derived from measurement fit.

$$s = N / 365$$



Model – CLM-CN Arora and Boer

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New fire algorithm for CLM3-CN

based on Arora and Boer, JGR, 2005 developed for CTEM

- **Fire occurrence probability:** $P_f = P_b P_m P_i$

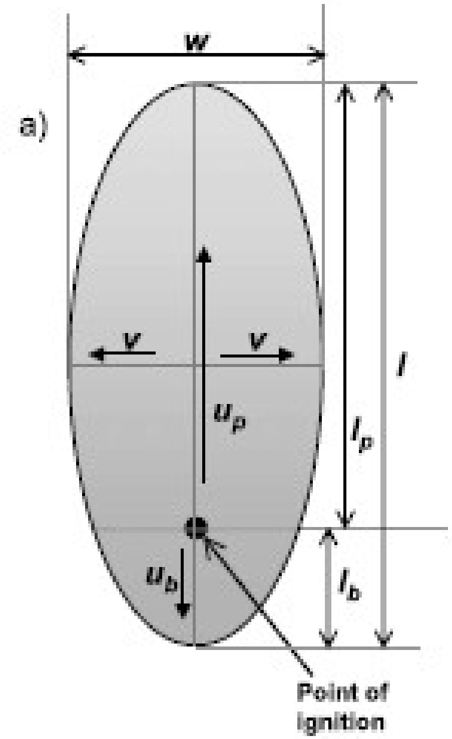
  - P_b - f(biomass available for burning)
  - P_m - f(moisture)
  - P_i - f(ignition(lightning, human))

    lightning data: monthly mean from merged LIS/OTD product

    human ignition potential: initial setup - constant globally (0.5)

Model – CLM-CN Arora and Boer

- **Potential area burned:**
  - elliptical shape $$a(t) = \pi \frac{l}{2}\frac{w}{2} = \frac{\pi}{2}(u_p + u_b)vt^2$$
  - upward and downward fire spread rate u_p , u_b
    f(wind speed, moisture)
  - length-to-breadth ratio L_b=l/w
    f(wind speed)
  - average time of burning – 1day



- **Actual Area burned: Potential area burned * Fire occurrence probability**

Model – CLM-CN area burned

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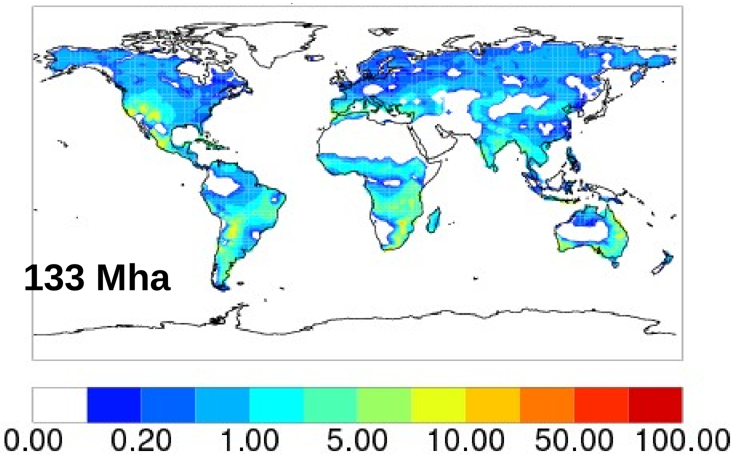
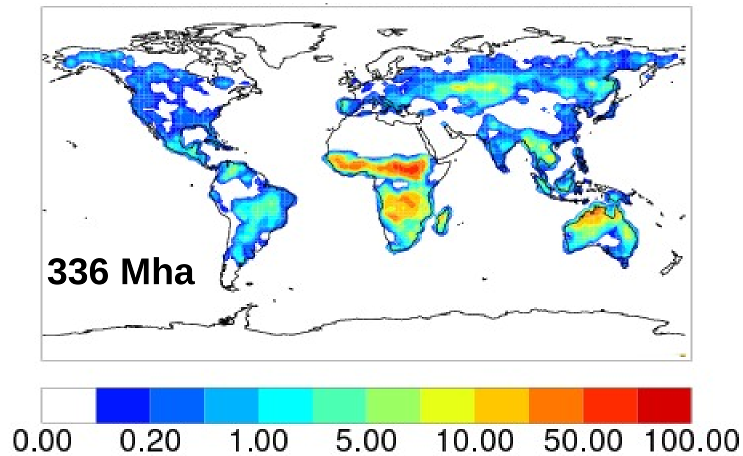
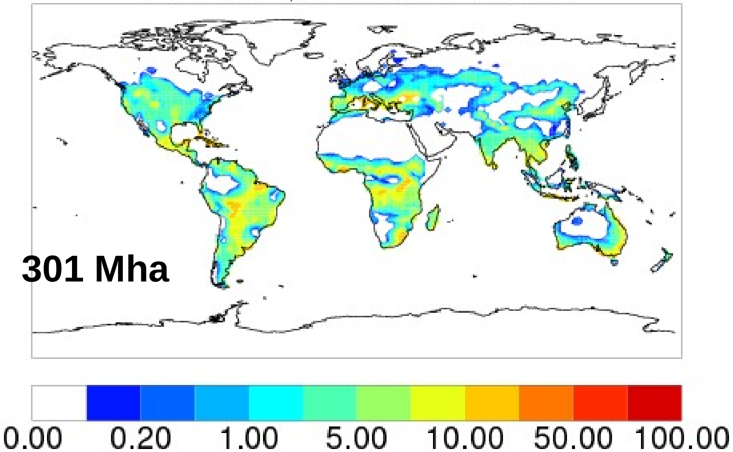
CLM – CN Thonicke et al. 2001



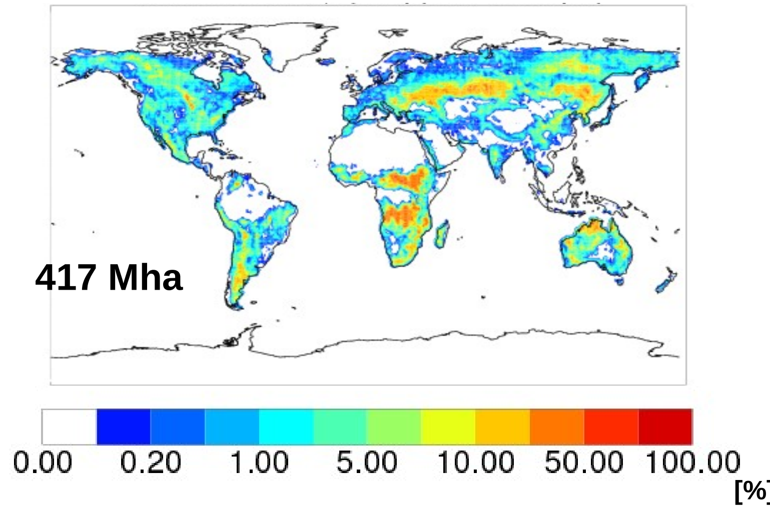
GFEDv2 (van der Werf et al., 2006) 1997 - 2004



CLM – CN Arora and Boer 2005



L3JRC (Tansey et al. 2008) 2001 - 2006



CLM-CN Carbon Emissions

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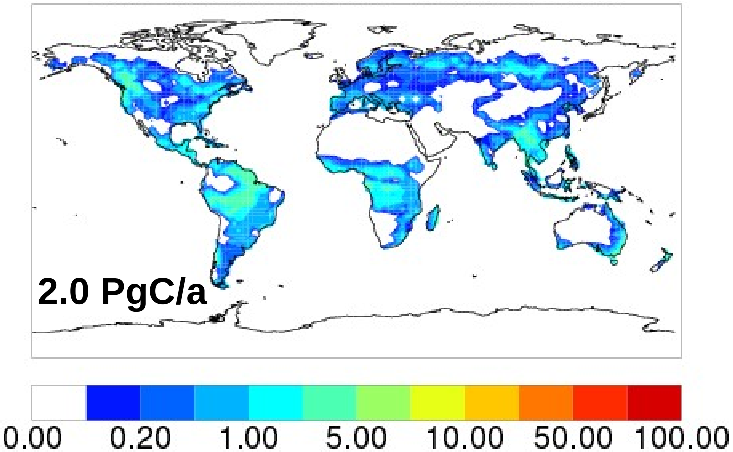
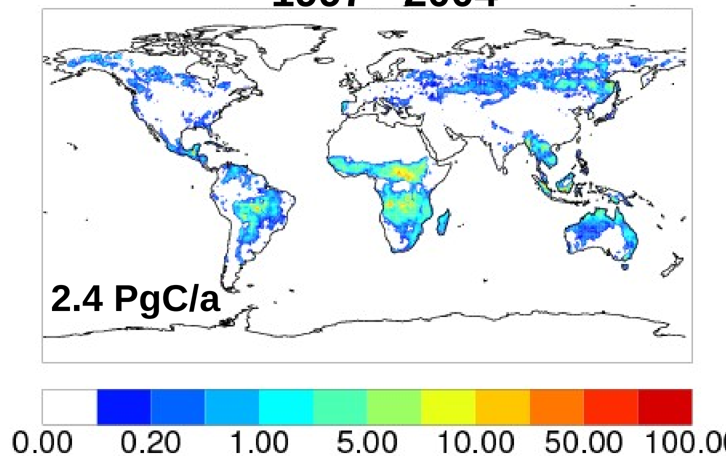
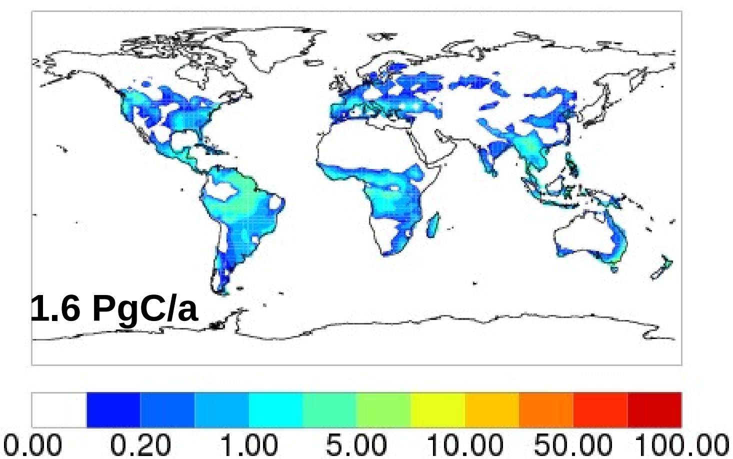
CLM – CN Thonicke et al. 2001



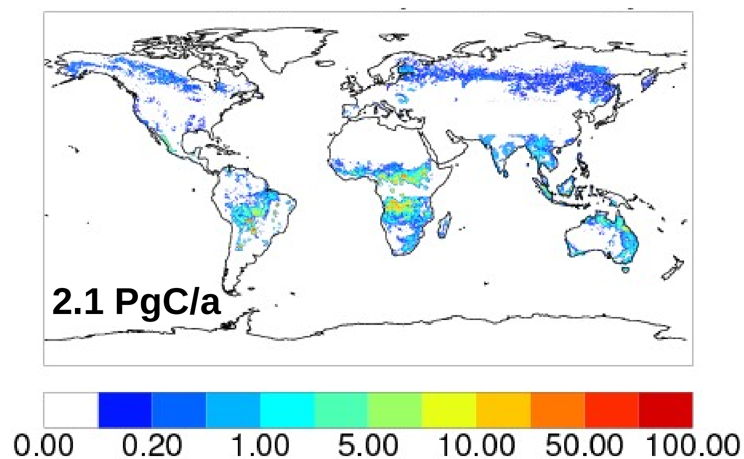
GFEDv2 (van der Werf et al., 2006) 1997 - 2004



CLM – CN Arora and Boer 2005



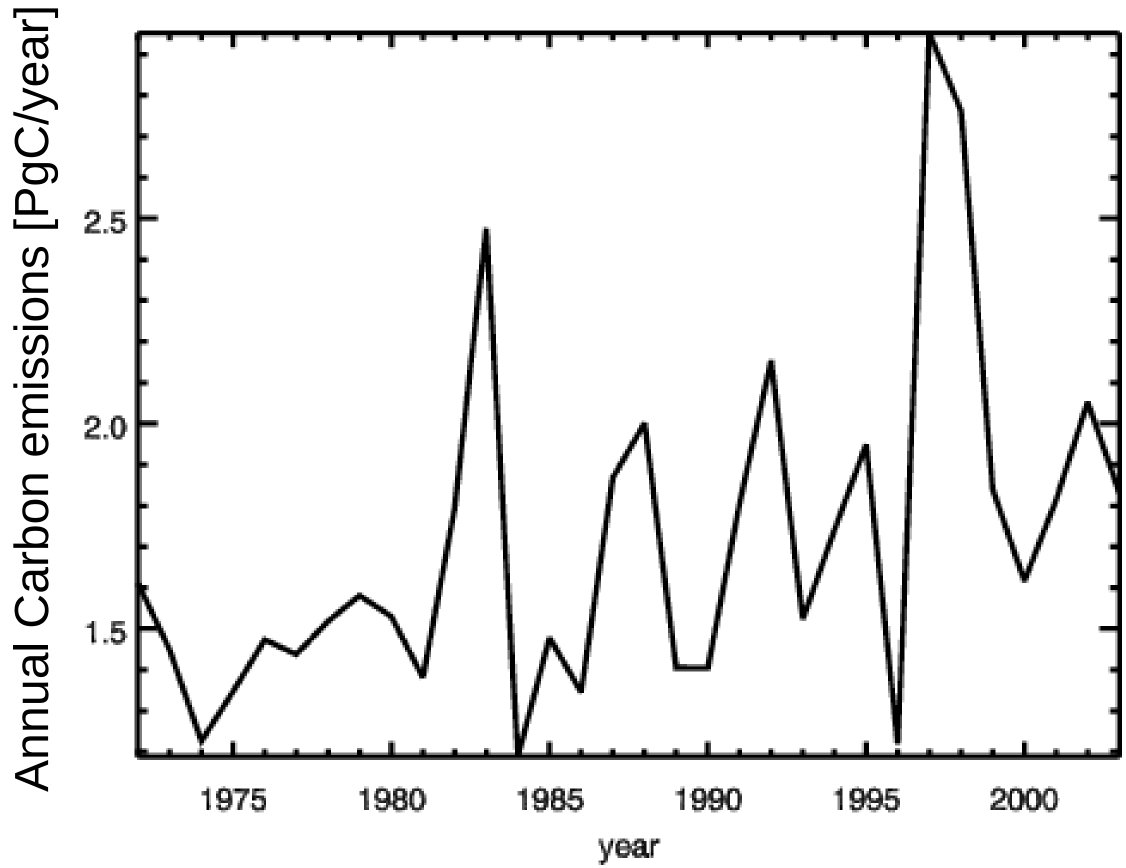
RETRO (Schulz et al., 2008) 1960 - 2000



[μg(C)/(m²s)]

Transient simulation:

- CLM-CN Arora and Boer
- Pre-industrial to present day (1798- 2004)
- Offline run using prescribed meteorological input fields (NCAR/NCEP)



Climate Response

Transient simulation:

- CLM-CN Arora and Boer
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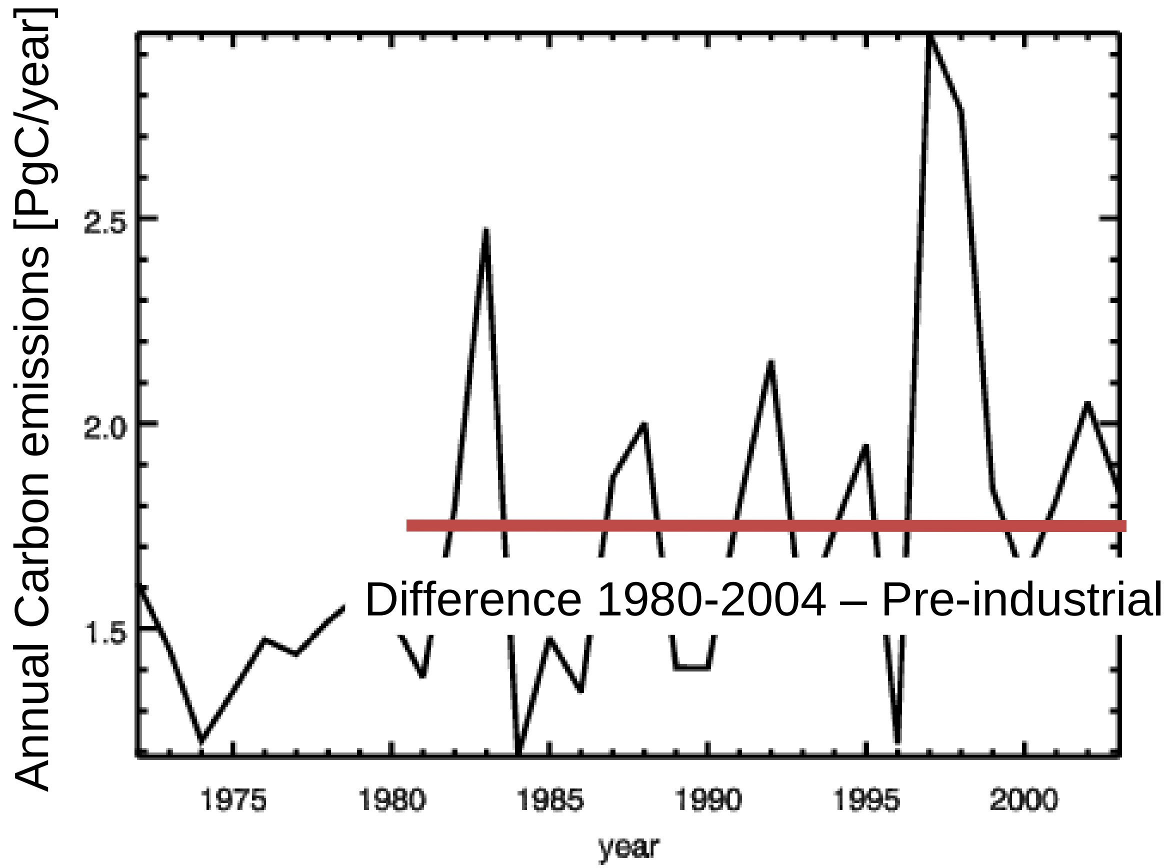

Climate Response

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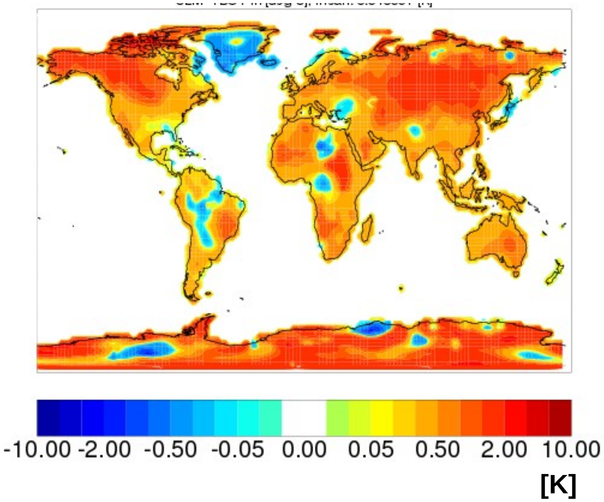
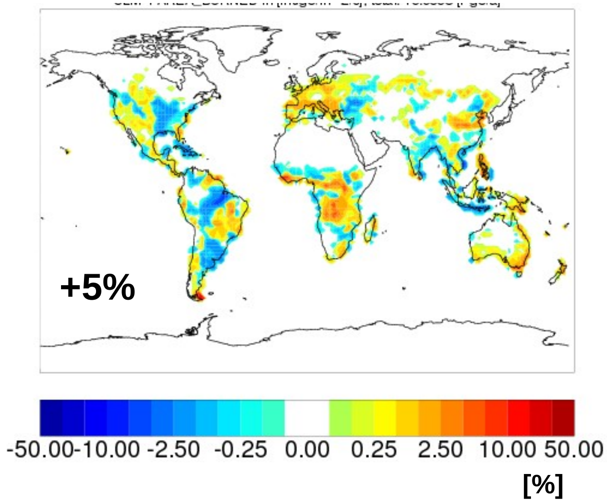
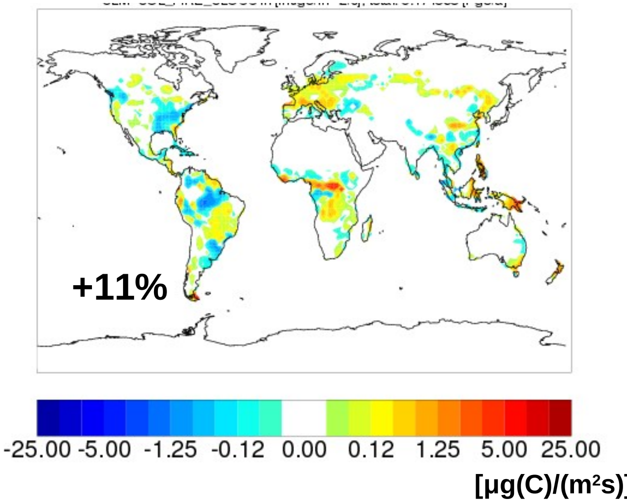
Surface Temperature [Δ0.54K]



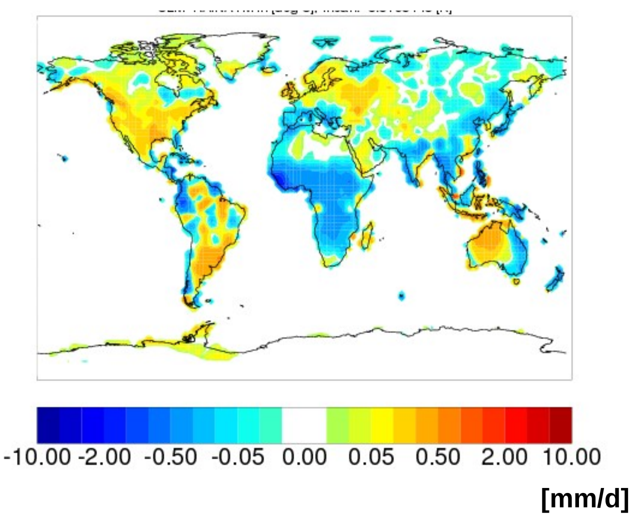
Annual area burned [Δ 15 Mha]



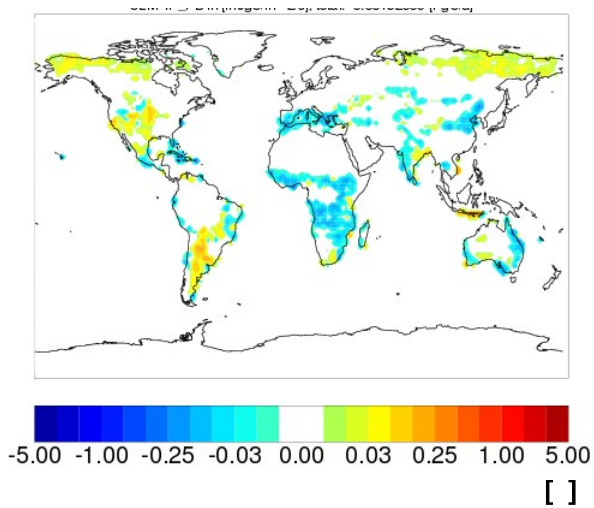
Carbon emission [Δ 0.18 PgC/a]



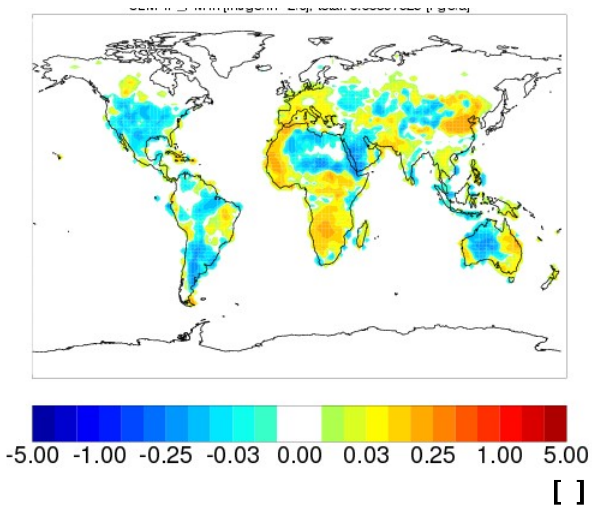
Precipitation [Δ 0.02 mm/d]



Probability biomass [Δ 0.001]



Probability moisture [Δ 0.004]



Conclusion

- Thonicke et al. 2001 implemented in CLM-CN underestimates the area burned by a factor of three

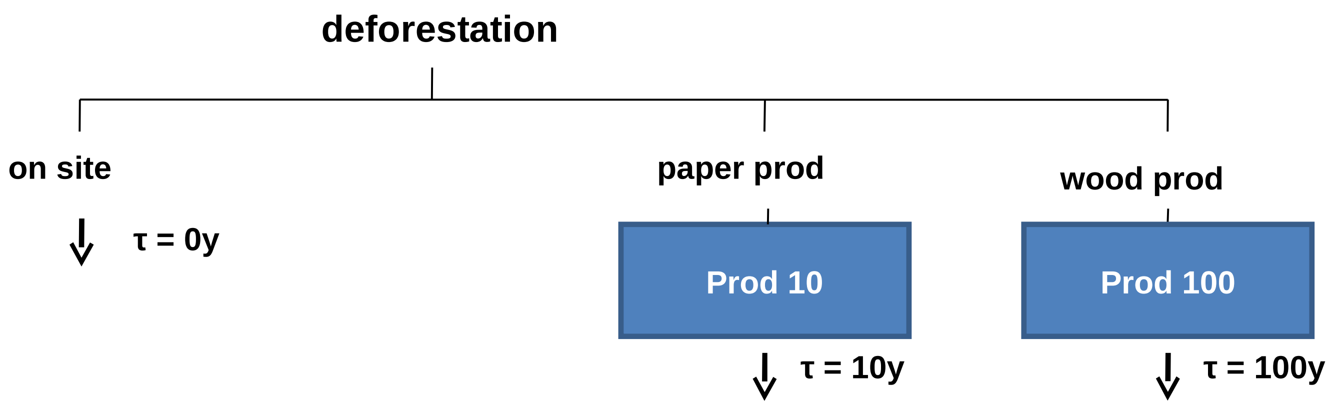
- Arora and Boer (2005) used in CLM-CN leads to better results in terms of area burned

- climate change (PD – PI) leads to an increase of the area burned by 5%; regionally the area burned increases over Africa and decreases in large parts of South America

- high human ignition potentials only in rural regions (10 inh/km**2) instead of a global constant human ignition potential of 0.5 improves the simulation over Europe and parts of South Asia

Outlook

- **deforestation fires**



Outlook

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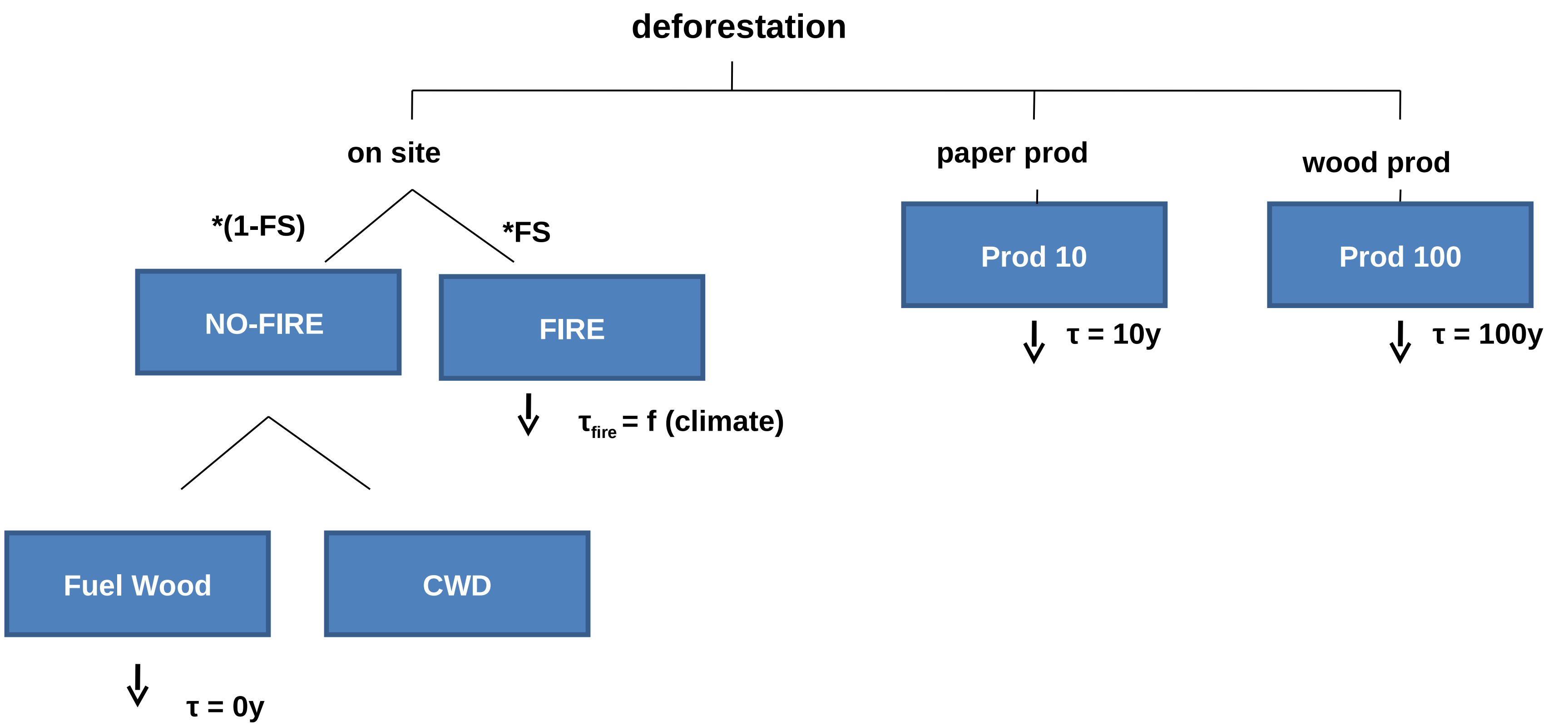

FS – Fire scalar – f(annual mean fire probability), regional varying
τ_{fire} – Rate Constant Fire pool – f(instantaneous fire probability)