FIRE in CLM-CN

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Motivation - Introduction

FIRE

Climate & Hydrological Cycle

Human Activity & Land cover change

Carbon Cycle & Ecosystems
Amount of Carbon emitted during a fire:

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

- \( A(t) \) = area burned
- \( D(t) \) = dead plant material (detritus)
- \( B(t) \) = living plant material (biomass)
- \( M \) = 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
Fire algorithm:

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

Simulation setup:

- Offline mode
- equilibrium state representative for pre-industrial conditions
CLM-CN3:
Fire algorithm based on Thonicke et al. 2001 developed for LPJ

• Fire condition:
  • fuel amount - dead fuel amount > 100 gC/m²
  • temperature - \( T > 0 \, ^\circ\text{C} \)
  • 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
  \[ p(m) = e^{-\pi^* \left( \frac{m}{m_e} \right)^2} \]

• Annual fire season length
  \[ N = \sum_{n=1}^{365} p(m_n) \]
• Area burned

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

• Annual fraction area burned:

\[ A(s) = s \cdot f(s) = s \cdot e^{(s-1) \cdot \alpha(s-1)} \]

with alpha derived from measurement fit.

\[ s = \frac{N}{365} \]
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)
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** \( u_p, u_b \)
  \[f\text{(wind speed, moisture)}\]

- **Length-to-breadth ratio** \( L_b = l/w \)
  \[f\text{(wind speed)}\]

- **Average time of burning** – 1 day

**Actual Area burned:** Potential area burned * Fire occurrence probability
Model – CLM-CN area burned

CLM – CN Thonicke et al. 2001

133 Mha

CLM – CN Arora and Boer 2005

301 Mha

GFEDv2 (van der Werf et al., 2006)

1997 - 2004

336 Mha

L3JRC (Tansey et al. 2008)

2001 - 2006

417 Mha
CLM-CN Carbon Emissions

CLM – CN Thonicke et al. 2001

2.0 PgC/a

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

2.4 PgC/a

CLM – CN Arora and Boer 2005

1.6 PgC/a

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

2.1 PgC/a
Climate Response

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

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Climate Response

Surface Temperature \([\Delta 0.54K]\)

Annual area burned \([\Delta 15 \text{ Mha}]\)

Carbon emission \([\Delta 0.18 \text{ PgC/a}]\)

Precipitation \([\Delta 0.02 \text{ mm/d}]\)

Probability biomass \([\Delta 0.001]\)

Probability moisture \([\Delta 0.004]\)
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

![Diagram](image)

- On site
  - \( \tau = 0 \text{y} \)
- Paper production
  - Prod 10
    - \( \tau = 10 \text{y} \)
- Wood production
  - Prod 100
    - \( \tau = 100 \text{y} \)
**Outlook**

- deforestation fires

![Diagram of deforestation process]

- **NO-FIRE**
  - *FS*
  - Fuel Wood
    - $\tau = 0y$

- **FIRE**
  - *(1-FS)*
  - CWD
    - $\tau = 0y$

- **paper prod**
  - Prod 10
    - $\tau = 10y$

- **wood prod**
  - Prod 100
    - $\tau = 100y$

*FS* – Fire scalar – f(annual mean fire probability), regional varying

$\tau_{fire}$ – Rate Constant Fire pool – f(instantaneous fire probability)