An Intermediate Process-based Fire Parameterization in Dynamic Global Vegetation Model (DGVM)

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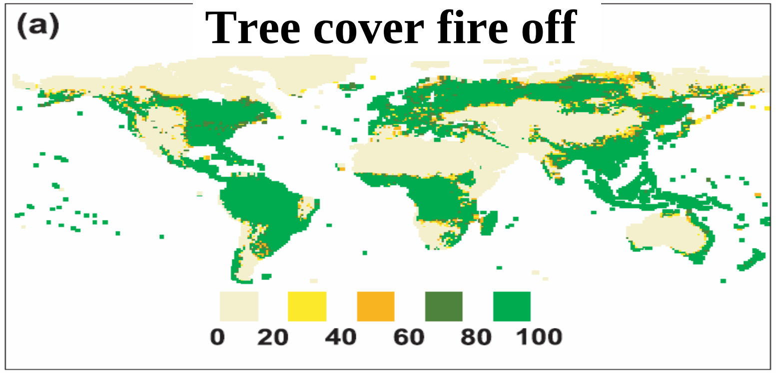
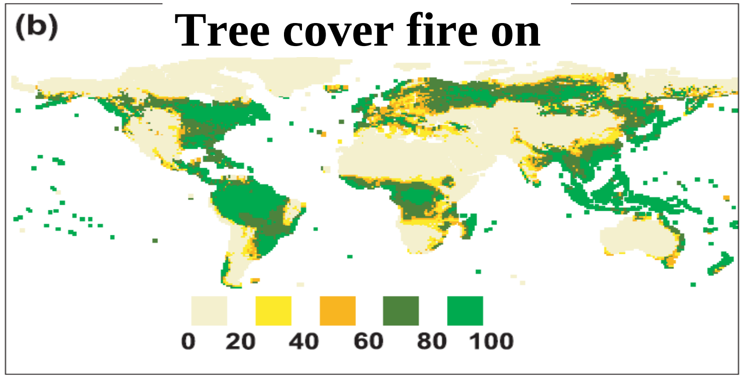
Background

- **Importance of the fire in the earth system**
  - **For vegetation: without fire, closed forests would double (27% to 56%) of vegetated grid cells for 20th century simulated by SDGVM** (Bond et al. 2004).





  - **For C/N cycle: biomass burning emits ~ 2.1PgC/yr with large interannual variability (1.4 - 3.2PgC/yr) from 1960 to 2009** (Schultz et al., 2008; Van der Werf et al. 2010)

Ref: 1980-2004 mean global net land-to-atmosphere carbon flux: **~ -0.7 PgC/yr** (IPCC 2007)

  - **For climate:**
    - **fire →vegetation, C/N cycle →climate**
    - **Biomass burning → abundant greenhouse gases, over 40% of global black carbon, ~30% of global CCN →climate** (Day, 2004; Arora and Boer, 2005,Andreae et al., 2004; Lindsey and Fromm, 2008)

- **Fire parameterization schemes in current DGVMs can be divided into three types:**
  - **constant fire loss rate/simple statistical model:** those in TRIFFID, ED, VEGAS, SDGVM, and IBIS
  - **complex process-based:** SPITFIRE in LPJ-SPITFIRE and MCFIRE in MCDGVM
  - **intermediate process-based :** **Glob-FIRM** in LPJ, SEIB-DGVM, CLM3.0-DGVM, ORCHIDEE, CoLM-DGVM, and CLM4.0-CNDV, and CTEM-FIRE in CTEM

It can capture the major processes of fire dynamics with efficient computation

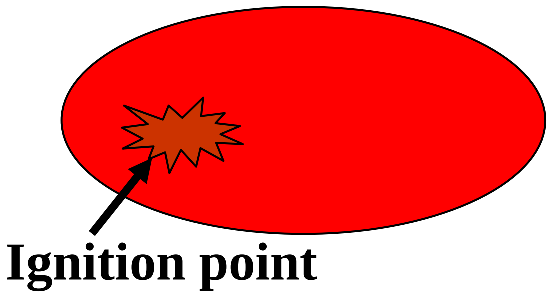
Motivation and object

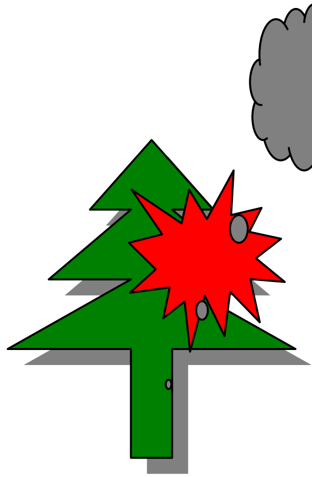
- **Existing intermediate process-based fire parameterizations have some shortcomings**:
  - **Glob-FIRM: not take into account**
    - **Availability of ignition sources**
    - **Impact of wind speed on fire spread**
    - **Combustion incompleteness of plant tissues in the post-fire region**
  - **CTEM-FIRE:**
    - **Constant probability of human-caused ignition and cloud-to-ground lightning fraction (0.5 and 0.25, globally)**
    - **self-inconsistent estimation scheme of burned area**
    - **framework of fire occurrence part →underestimate burned area in tropical savanna**.
- **Object：**

to develop an intermediate process-based fire parameterization, which overcomes the above listed shortcomings

Fire parameterization

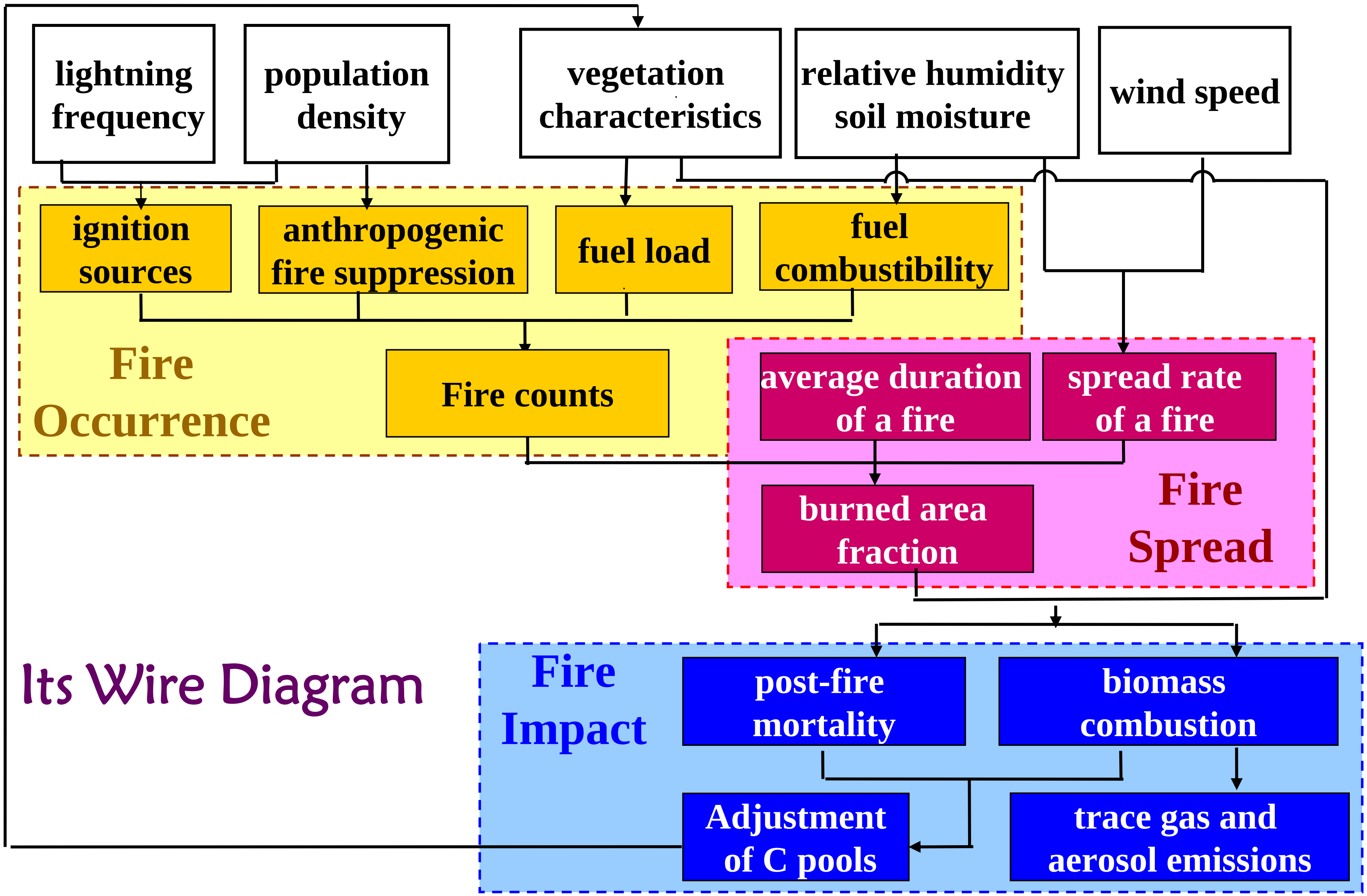
It comprises three parts: fire occurrence, fire spread, and fire impact





Fire occurrence **Fire spread** | **Fire impact**

Time-step: **hourly or daily** | **daily, monthly, annually**


lightning frequency
population density
vegetation characteristics
relative humidity soil moisture
wind speed
ignition sources
anthropogenic fire suppression
fuel load
fuel combustibility
Fire Occurrence
Fire counts
average duration of a fire
spread rate of a fire
burned area fraction
Fire Spread
Its Wire Diagram
Fire Impact
post-fire mortality
biomass combustion
Adjustment of C pools
trace gas and aerosol emissions

Model platform and Data

- **Model platform: CLM-DGVM**

CLM3.0-DGVM (Levis et al. 2004) modified by Zeng et al. (2008) and Zeng (2010)

- **Data**

Variables	Sources	Roles
Precipitation Surface air temperature Wind speed Specific humidity Air pressure Downward solar radiation Relative humidity Lightning Population density	Qian et al. (2006) NCEP, CRU NASA LIS/OTD v2.2 GPWv3	Forcing data, parameters calibration
Burned area Fire carbon emission	GFEDv3	Evaluation
Fire counts Vegetation fractional cover CPC soil moisture Fuel load	MODIS Clm4.0surfacedata CPC FCCS	Parameters calibration

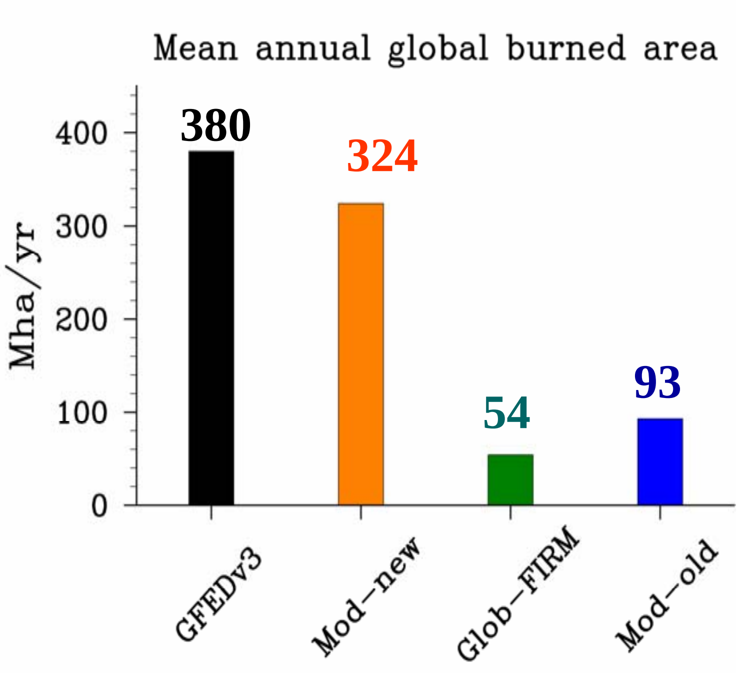
•spin-up: 880 years with repetition of 55 years (1950-2004) forcing data

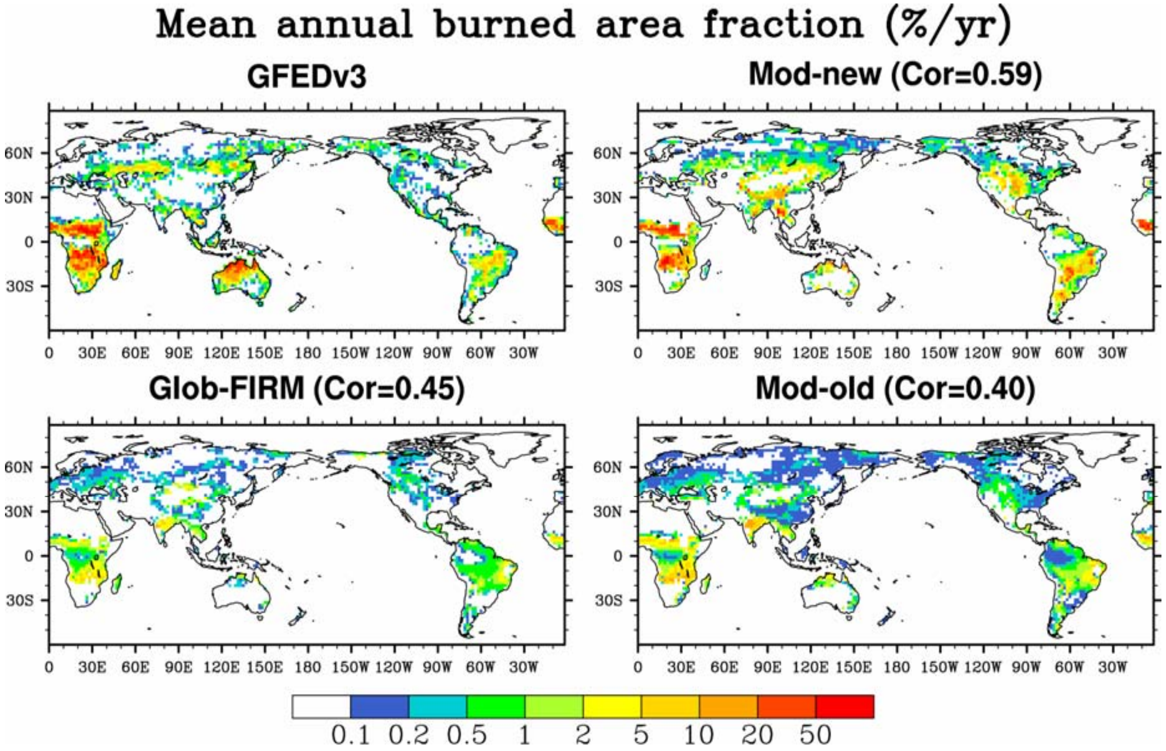
•Evaluation period: 1997-2004 (common years for GFEDv3 and forcing data)

Results (1997-2004) : Burned area

Mod-new: new fire parameterization
Glob-FIRM: Thonicke et al. 2001
Mod-old: old fire parameterization in CLM-DGVM (Levis et al. 2004)

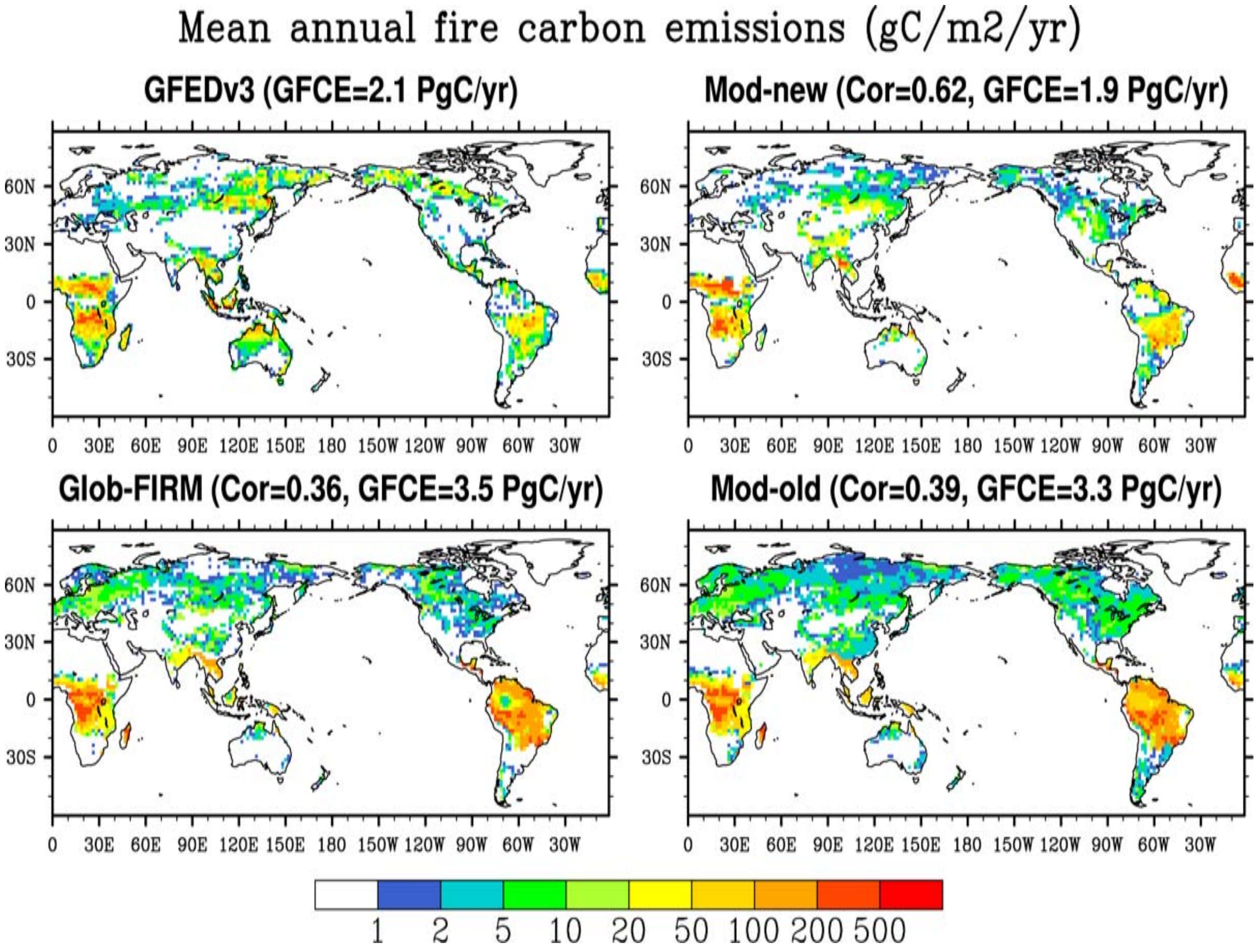
•**Cor**: global spatial **correlation** between sim and obs





• Mod-new is good agreement with observations, and more skillful than Glob-FIRM and Mod-old.
• Ref: 1997-2004 CLM-CN simulations with CTEM-FIRE (300Mha/yr, Cor=0.19) and its revised version (182Mha/yr, Cor=0.52) (Kloster et al. 2010)

• Fire Carbon emissions



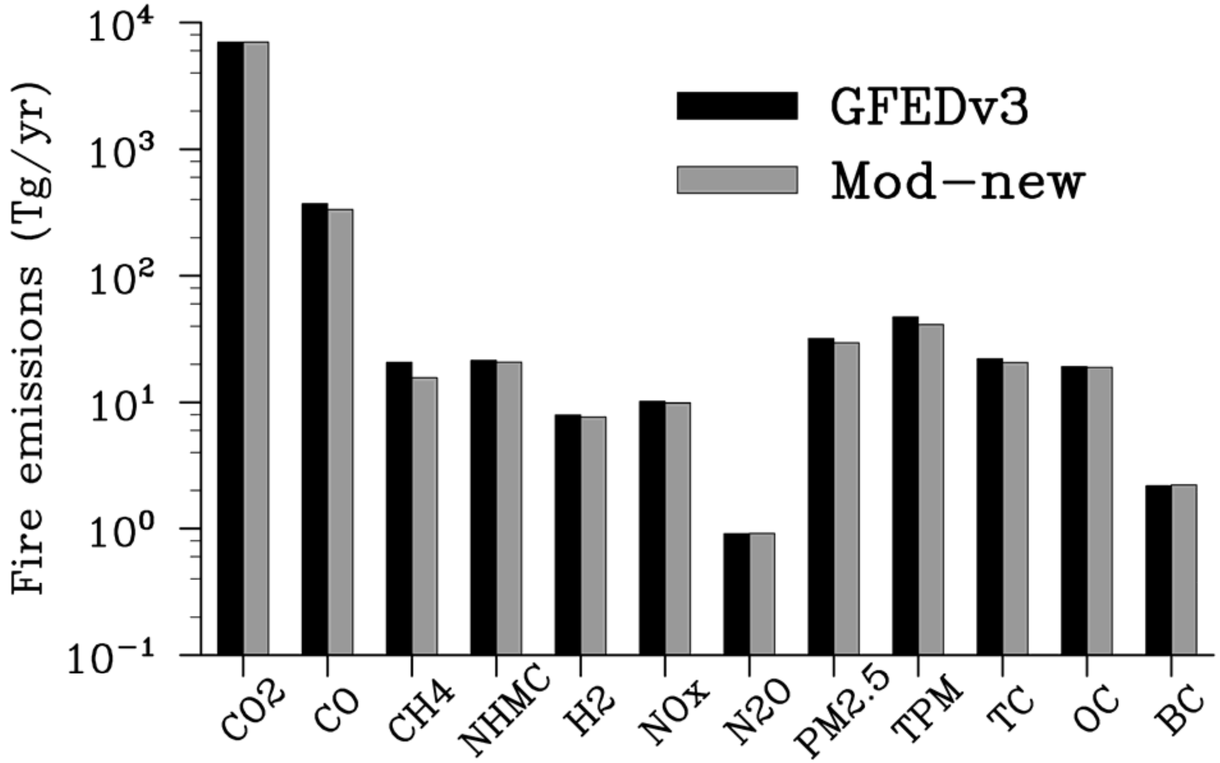
•Mod-new has more accurate global gross (GFCE) and spatial distribution than Glob-FIRM and Mod-old

•Fire carbon emission /burned area (CA, TgC /Mha):

GFEDv3:	**5.5**
Mod-new:	**5.9**
Glob-FIRM:	**64.8**
Mod-old:	**35.5**

• Ref: 1997-2004 CLM-CN simulations with CTEM-FIRE (Cor=0.25, GFCE=2.5PgC/yr, CA=8.5 TgC/Mha) and its revised version (Cor=0.45, GFCE=2.0PgC/yr, CA=9.8TgC/yr) (Kloster et al. 2010)

• Aerosol and trace gas emissions due to fire



- **Mod-new is good agreement with GFEDv3 product for all types of trace gases and aerosols emissions**
- **Average relative errors: 6.02%.**

Future plans

- **To test the fire parameterization in CLM4-CNDV after adding parameterization of impact of fires on nitrogen pools, and deforestation and cropland fires**

- **To Investigate fire-vegetation-climate interaction on a global scale from an earth system perspective with CESM as model platform.**

Thank you !