Land Ecosystems – Climate Interactions

Presented by

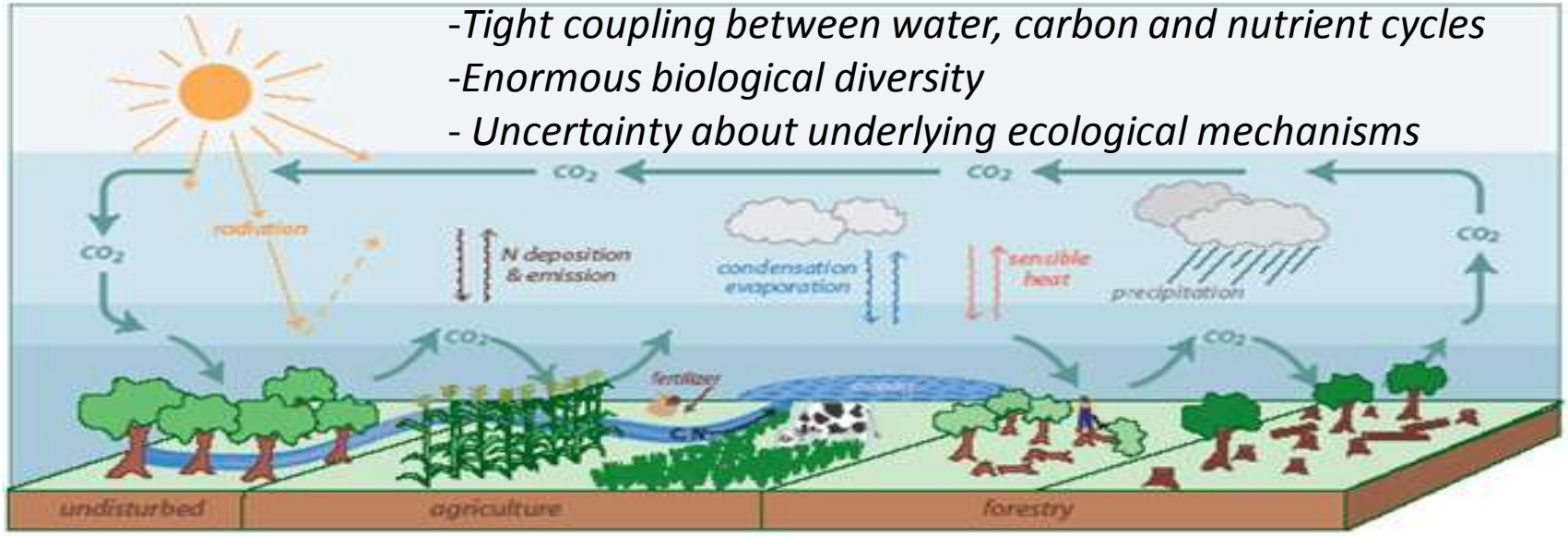
Elena Shevliakova on behalf of the GFDL land working group

Geophysical Fluid Dynamics Laboratory Review

May 20 – May 22, 2014

Overarching questions

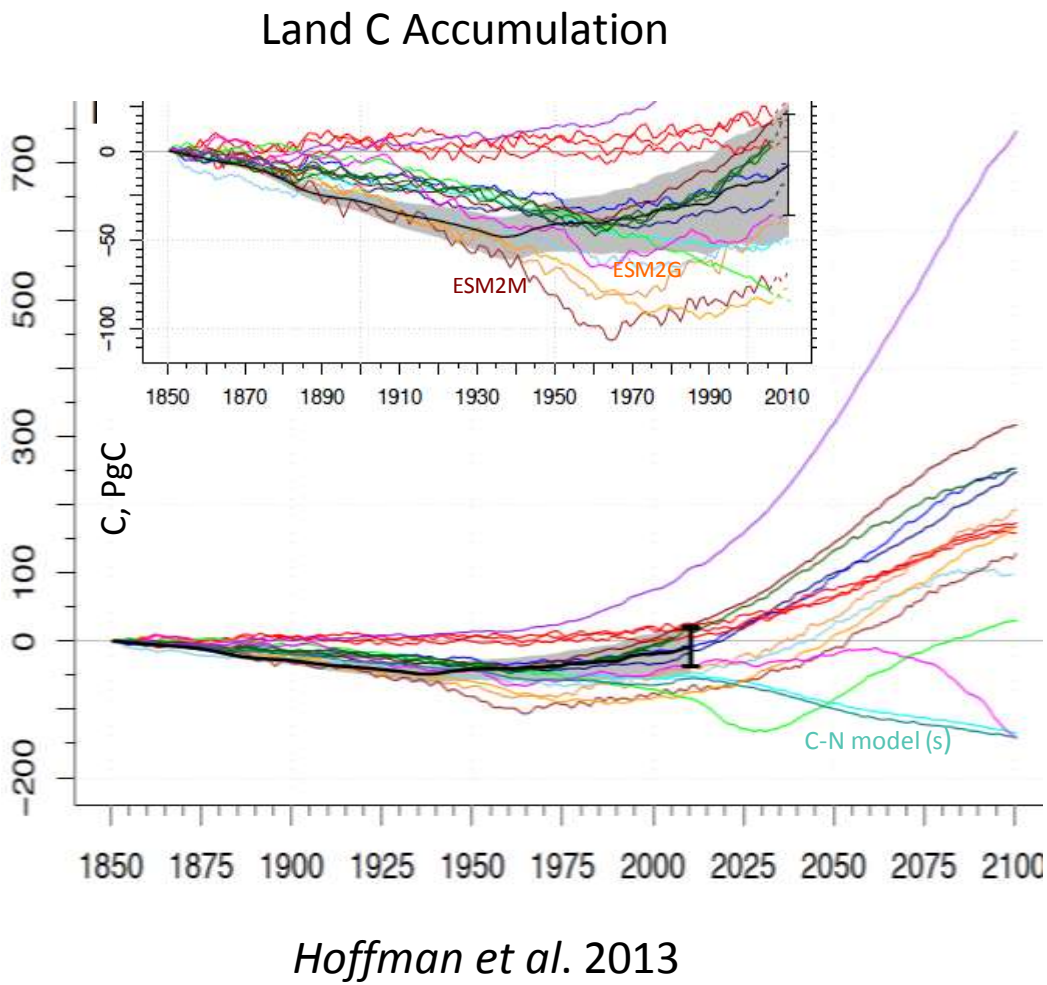
- How do changes in land ecosystem structure and functioning effect global biogeochemical cycles and climate?
- How do direct human activities and climate influence land ecosystems?



Summary of 2009-2014 land efforts

- Married LM3 ecosystem and hydrology branches
- Brought LM3 into all new GFDL GCMs and ESMs
- Developed coupled C-N land model, LM3-N
- Participated in CMIP5 ESM analyses and beyond
- Begin development of the new LM4 model
  - Comprehensive biogeochemistry in ESM: N, P, CH4, …
  - Prognostic aerosols: dust, biomass burning, …
  - Hydrological sub-grid heterogeneity & BGC
  - New age-height vegetation succession model LM3-PPA
  - Land-use management: fertilizers, water quality,…

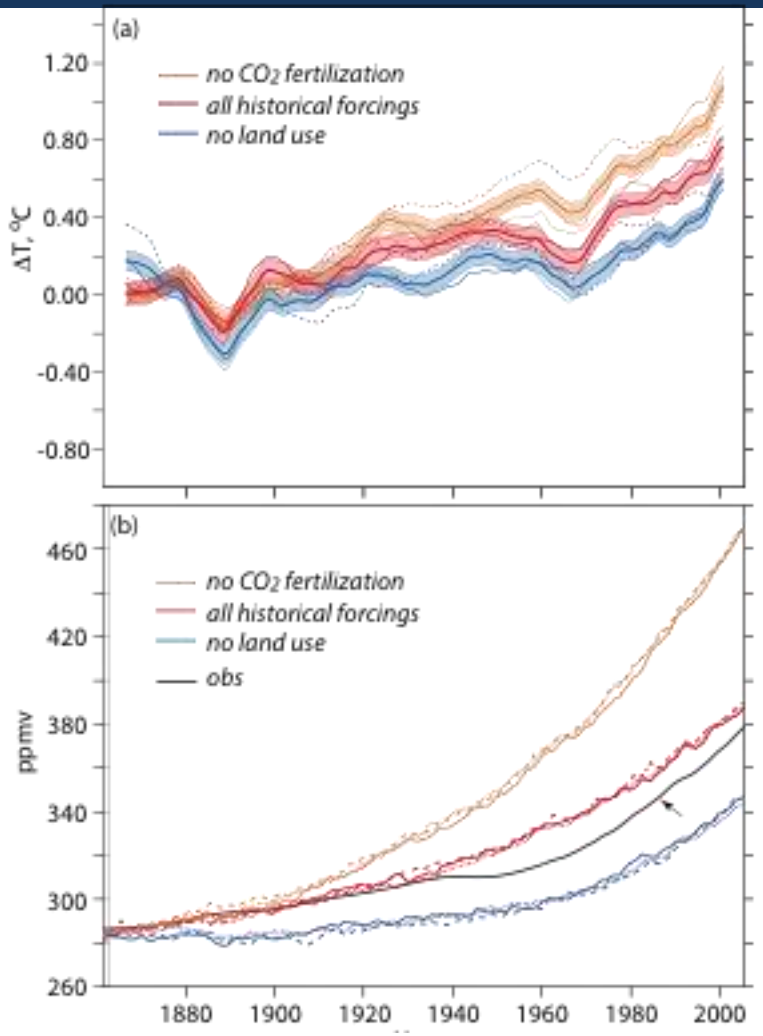
GFDL ESMs participated in CMIP5 terrestrial C studies



Hoffman et al. 2013

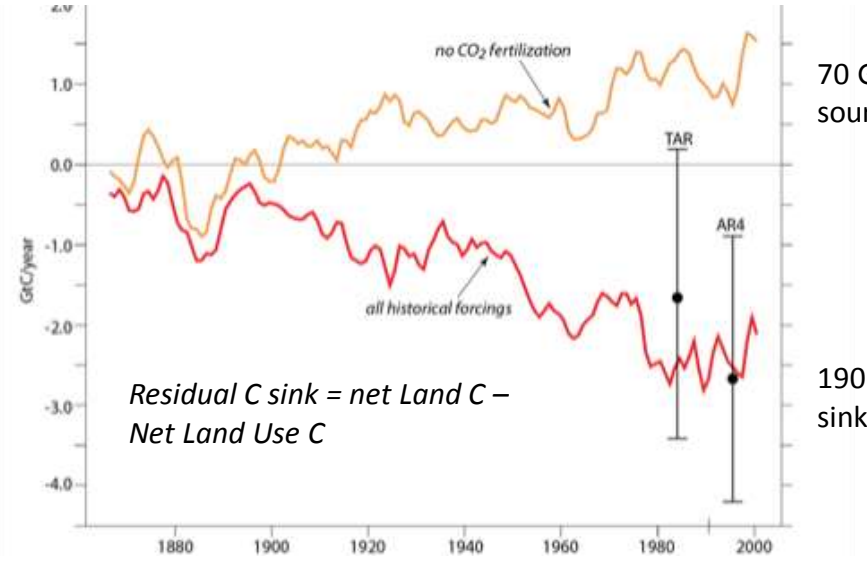
- Only 5 out 15 ESMs used prognostic biogeography
- GFDL ESMs include comprehensive land use model
- GFDL ESMs capture land C source to sink transition, but timing is delayed
- Cumulative historical land C uptake in ESM2G within observational constraints.
- Large uncertainty in future land uptake
  - nutrient limitation
  - ecosystems processes
  - climate change

Climate benefit of the enhanced land C uptake

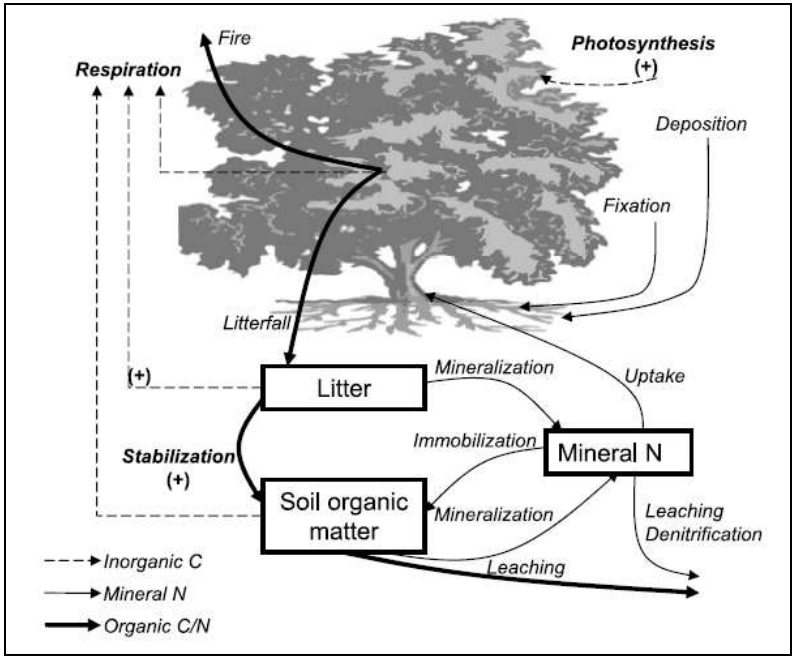


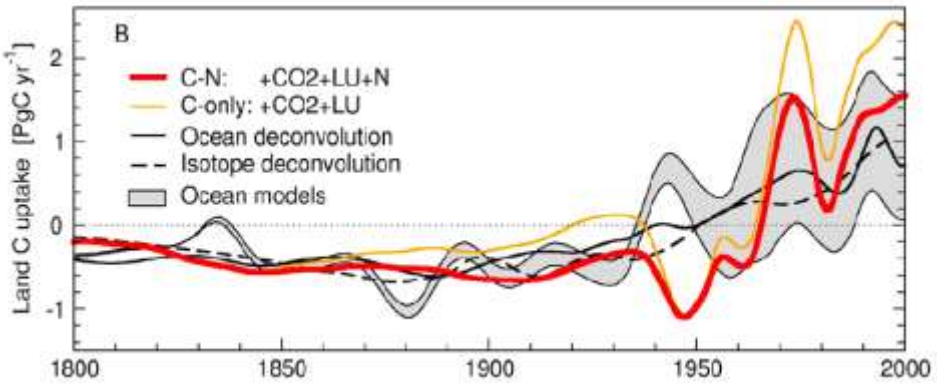
Shevliakova et al. 2013

- Land use emissions contributed ~30 ppm to the current atmospheric CO_2 increase;
- Without enhanced vegetation growth in 2005:
  - Atmospheric CO_2 would have additional 85 ppm;
  - Global surface temperature would be 0.31±0.06°C higher.



GFDL LM3-N stand alone model

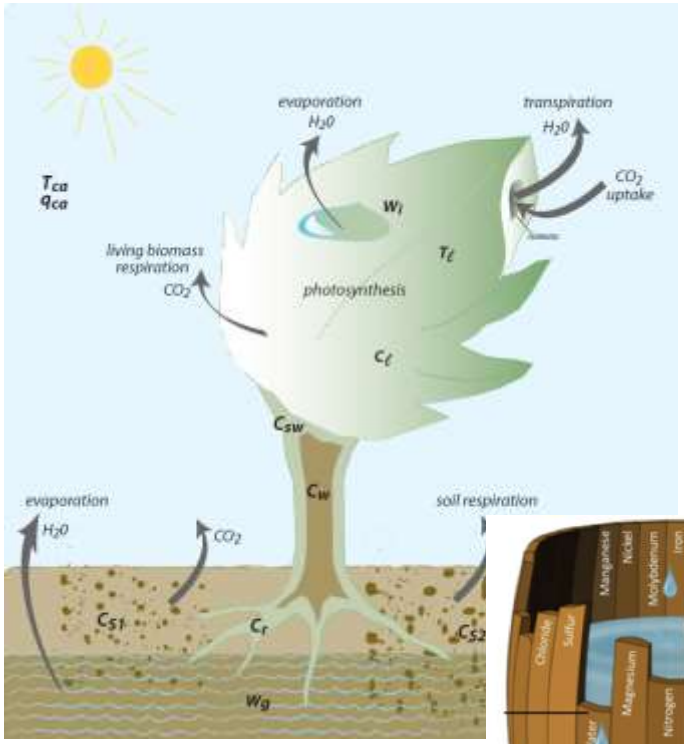


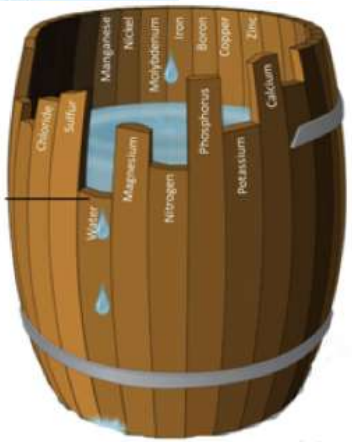


Gerber et al. 2010, 2013; Lee 2014

- Fixed C:N vegetation pools
- Prognostic biological N fixation
- 4 competing sinks of mineral N
  - plant uptake, immobilization, sorption to particles, denitrification
- Organic removal of N
  - leaching, ecosystem losses through fire
- River N cycle
- Traditional N limitation on plant growth distorts seasonal cycles of H2O and CO2=> LM3-N is not suitable for coupling with ESMs

LM3 limitations



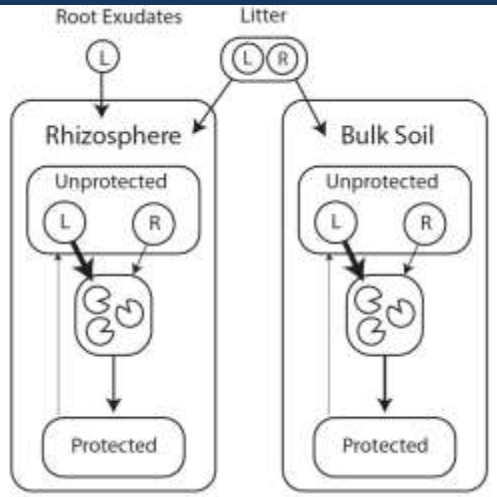


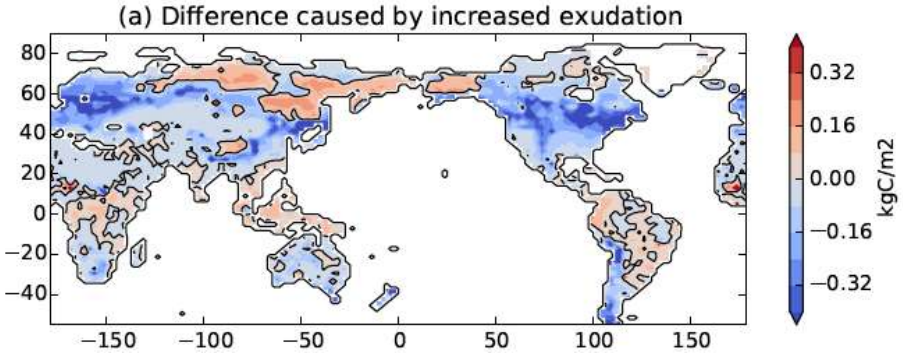
- Big soil C&N bucket with first order decays
- Liebig's Law nutrient limitation
- Fixed stoichiometry
- Fixed allocation
- No vertical canopy structure
- No explicit microbes
- Mortality via carbon starvation
- No hydrological sub-grid heterogeneity

These limitations apply to all CMIP5 land models.

Good news: we are addressing all these limitations in LM4!

Towards LM4: New soil model





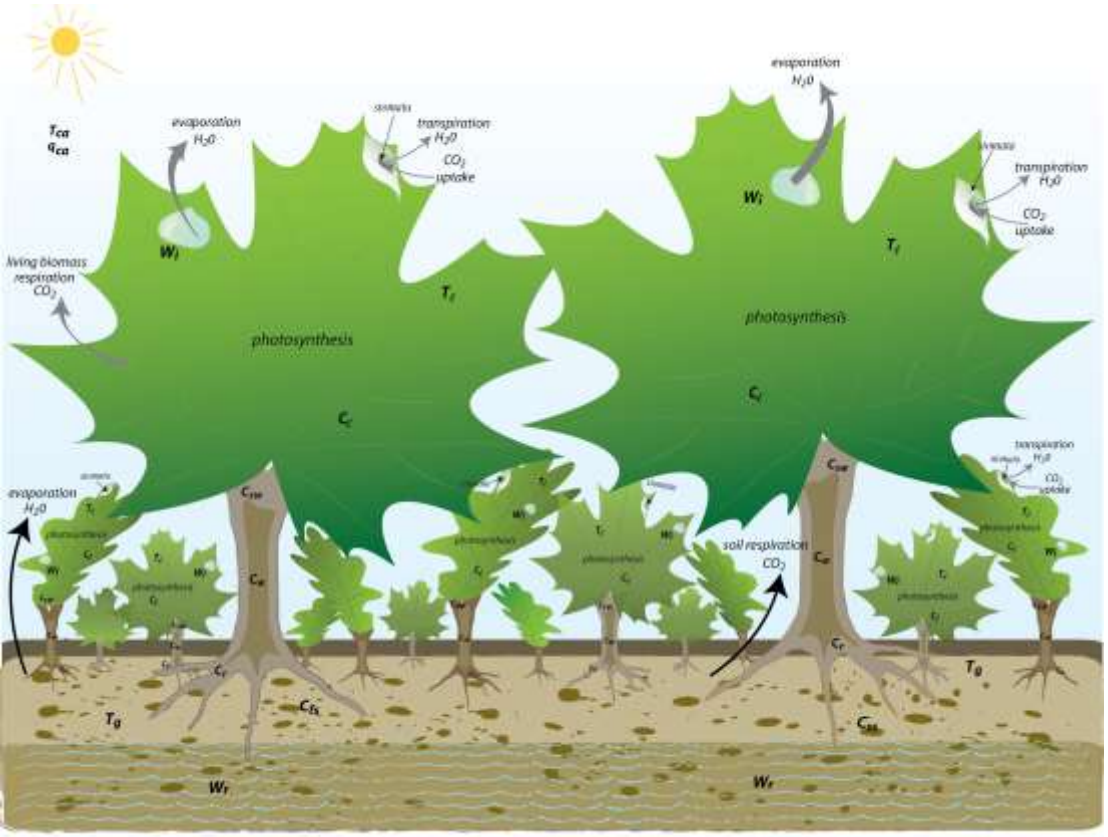
Sulman et al., submitted

Carbon, Organisms, Respiration, and Protection in the Soil Environment (LM3-CORPSE) model

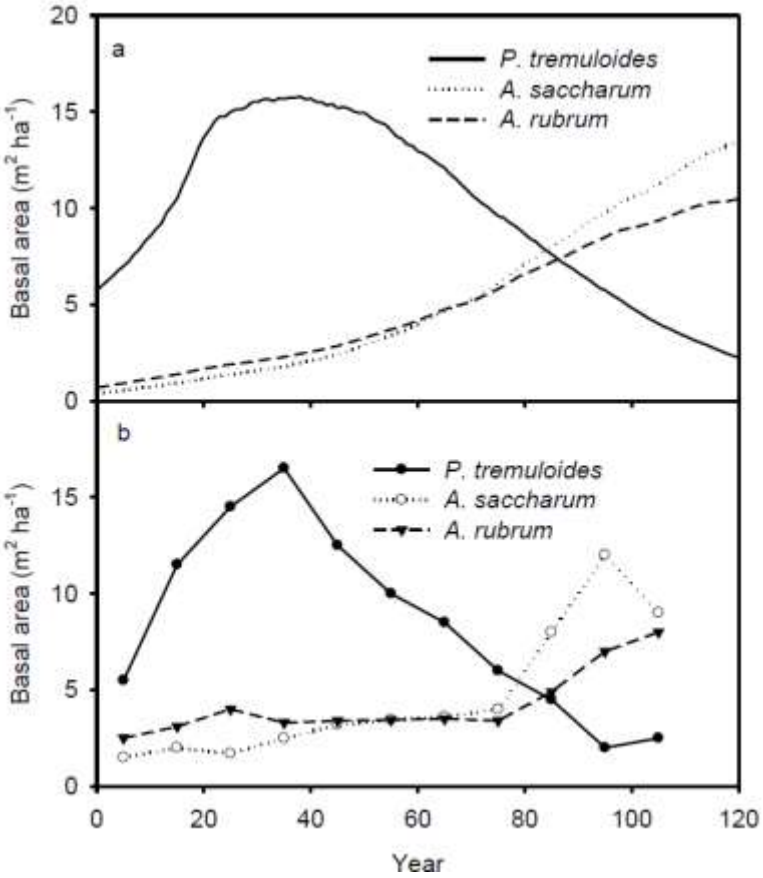
- Vertical structure
- Explicit above and below ground litter
- DOC leaching
- Dynamic microbial activity
- Protected carbon pools
- Root exudates
- Implemented in water-tiled version (LM3-TiHi)
- *Currently adding N & P*

Key uncertainty: the sensitivity of soil Carbon to changing climate

Towards LM4: Perfect Plasticity Approximation (PPA) vegetation dynamics model (LM3-PPA)



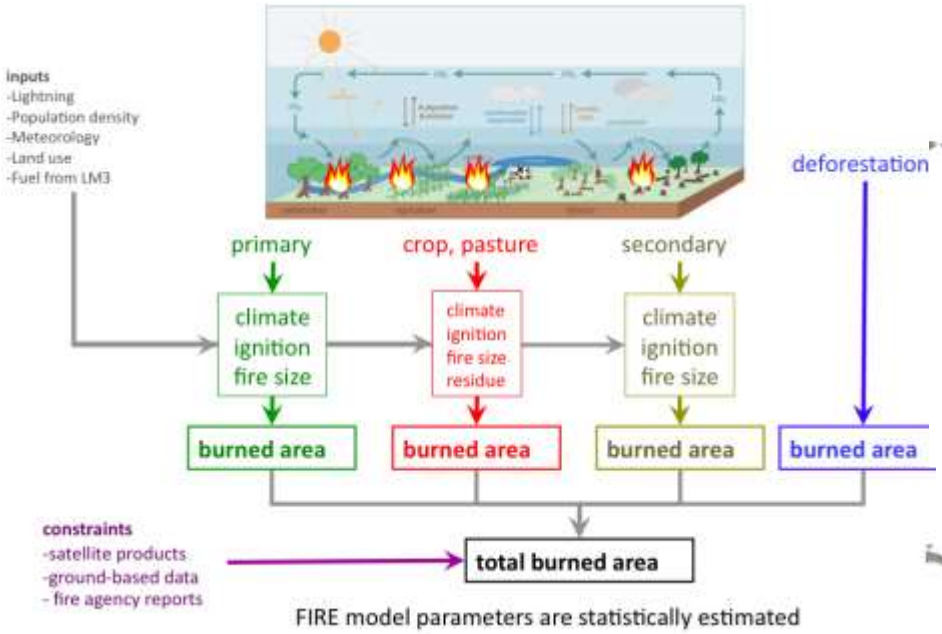
Willow Creek, WI



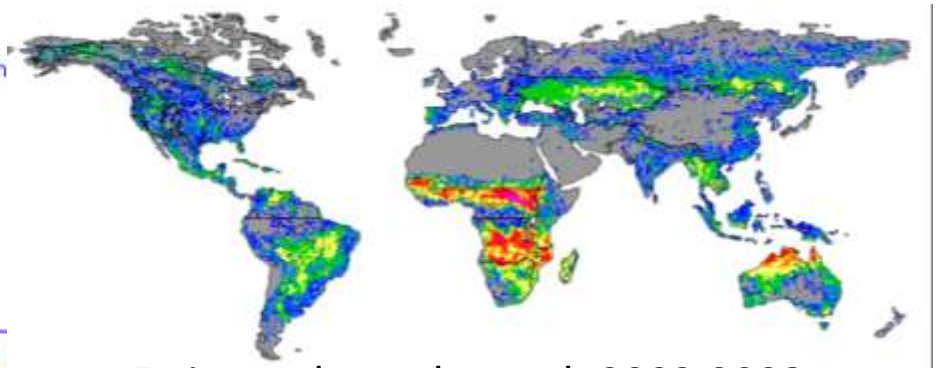
Weng et al. in prep

- *Currently expanding PPA plant diversity and evaluating globally*

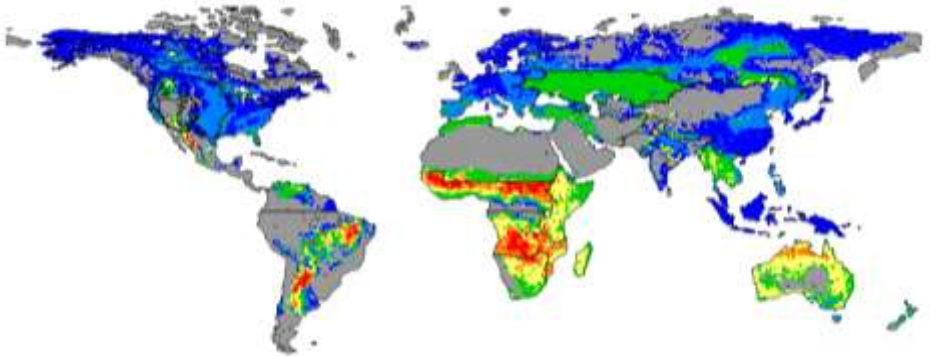
Towards LM4: new fire model



Observed area burned, 2003-2008



Estimated area burned, 2003-2008



Land-use specific fire models =>
LU-specific datasets to estimate these parameters , *Magi et al 2011*

Rabin et al. in prep

New daily fire model to enable prognostic biomass burning aerosols in CM4/ESM4

Lessons learned

- Large uncertainty remains about historical and future land C sources and sinks, particularly implications of nutrient limitations
- Exciting new LM4 developments and improvements for a number of land processes
- Collaborations with broad scientific community are essential in ongoing GFDL land model development and analysis
- Need to innovate not just tune existing CMIP5-class land models to a limited set of observations

Acknowledgements

- Princeton-GFDL CICS and Princeton CMI
- We are not a community model but we have a growing GFDL Land Model community.
- Thank you to all land working group members and our collaborators:

GFDL: Stouffer, Ginoux, Krasting, Dunne, Phillips, Sentman, John

Princeton U: Malyshev, Subin, Li, Kanter, Rabin, Medichi, Wolf, Weng, Paulot, Pacala, Jaffe, Hedin labs

USGS: Milly, Dunne

Indiana U: Sulman

UNH: Frolking

Purdue U: Smith & Dukes

CUNY: McDonald lab

U Florida: Lichstein, Gerber

U Texas: Yin, Fu, Dickinson

Columbia U: Menge

Arizona U: Russel, Saleska

To be continued !