CLM Update

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with input from members of LMWG and BGCWG
Technical Description of version 4.5 of
the Community Land Model (CLM)

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CLM configurations in CESM1.2

- **CLM4.5SP**  
  Satellite phenology with new biogeophysics

- **CLM4.5BGC**  
  New biogeophysics + CENTURY-like vertically resolved soil BGC + CH$_4$ emissions, nitrogen updates

- **CLM4.5CN**  
  New biogeophysics + CN soil BGC, nitrogen

- **CLM4SP**  
  As in CCSM4/CESM1 release

- **CLM4CN**  
  As in CCSM4/CESM1 release

Note: crop and irrigation, VIC hydrology, and DGVM all optional for all BGC configurations
CLM Diagnostics Package
www.cesm.ucar.edu/experiments/cesm1.2/diagnostics/clm_diag.html

- Up to 5x faster
- Better plots
- New fields
- C-LAMP

thanks to Sheri Mickelson, Adam Phillips, Keith Oleson, and Nan Rosenbloom
Exploratory Data analysis Environment (EDEN)

EDEN is a visual analytics tool for exploring multivariate data sets. EDEN helps you see the associations among variables for guided analysis.

Download EDEN
Reduced biases in CLM4.5

ANN Latent Heat bias (obs: FLUXNET MTE)

<table>
<thead>
<tr>
<th></th>
<th>CLM4</th>
<th>CLM4.5</th>
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</thead>
<tbody>
<tr>
<td>LH (W m$^{-2}$)</td>
<td>8.9</td>
<td>5.9</td>
</tr>
<tr>
<td>GPP (gC m$^{-2}$ d$^{-1}$)</td>
<td>0.41</td>
<td>0.07</td>
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<tr>
<td>Albedo (%)</td>
<td>-0.41</td>
<td>-0.52</td>
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Soil carbon

IGBP 900-1650 PgC, to 1m

CLM4CN (650 PgC)

NCSCD soil carbon

CLM4.5BGC (to 1m; 1900 PgC)
Impact of CLM4.5 model changes on global terrestrial carbon trajectory

Koven et al., 2013

In CLM4.5, land is a C sink over latter half of 20thC, as observed

GCP estimate for land C sink
Fire model results

![Graph showing global burned area (Mha yr⁻¹) and global fire carbon emissions (Pg C yr⁻¹).](image)

Li et al. 2013
More realistic active layer hydrology and soil hydrologic response to permafrost thaw (RCP8.5)
Uncertainties in atmospheric forcing
Annual river discharge into global ocean

Forced with Qian (GPCP)
Forced with CRUNCEP (CRU)

Precip: CRUNCEP - QIAN

Total Discharge Accumulated from 90N (10^9 m^3 s^-1)

Discharge into the Global Ocean (10^9 m^3 s^-1, per degree lat)

Largest 921 Rivers
CLM4SP (yrs 1985-2004)
CLM45SP (yrs 1985-2004)
What next?

• Document CLM4.5 in a paper (or series of papers)
  – Model description
  – Metrics / benchmarks including experimental data - model comparisons
  – Atmospheric forcing uncertainty

• Code refactoring
  – Pull parameters out of code into external files, remove CPPs, pointers into associates, rationalize filters, multiple data output levels

• Refine developer protocol

• Bring Ecosystem Demography model to trunk
Science Questions

“Charge to the working groups”

- What science topics do we want to be able to address with CLM5/CESM2?
- What missing (or poorly represented) processes or biases need to be addressed to enable these studies?
Potential development targets for CLM5

– **Nutrient dynamics**
  - Plant nitrogen uptake and allocation
  - N-gas emissions
  - Leaching and riverine transport
  - Phosphorous dynamics

– **Ecosystem disturbance**
  - Ecosystem Demography model
  - Trace gas emissions from fire

– **Evapotranspiration, partitioning of ET**
  - Unrealistic hydrologic response to land cover change
  - Soil evap, canopy turbulence, canopy evap
  - Water isotopes
Potential development targets for CLM5

- **Landscape dynamics**
  - Dynamic landunits
  - iESM infrastructure

- **Hydrology**
  - Assess TOPMODEL-based vs VIC-based hydrology
  - MOSART routing model
  - Progress on lateral flow processes
  - Human management and withdrawals

- **Canopy processes**
  - Multi-layer, turbulence, optimization

- **Agriculture**
  - Extend crops to global
  - Additional crop management processes
Changes for CLM4.5 for CESM1.2

- Revised photosynthesis model, multilayer canopy, temperature acclimation, iterative calculation fix (Bonan et al., 2011, 2012; Sun et al., 2012)
- Cold region hydrology and snow fix (Swenson et al. 2012, Swenson and Lawrence, 2012)
- CENTURY-like vertically resolved soil biogeochemistry with nitrogen updates (Koven et al., in prep)
- New lake model (Subin et al., 2012)
- CH$_4$ emissions (Riley et al., 2011; Meng et al. 2012)
- Revised fire model (Li et al., 2012; 2013)
- Fertilization, irrigation, organs pool, and other updates to crop model (Drewniak et al., 2013; Levis et al., 2012; Sacks et al. 2009)
- Prognostic wetland distribution model (Swenson and Lawrence, in prep)
- CLM/RTM interactions, flooding (default off) (Swenson and Lawrence, in prep)
- VIC hydrology (alternative hydrology) (Li et al., 2012)
- $C_{13}/C_{14}$ enabled
- Multiple urban classes
- … and several minor and major bug fixes, speedup of BGC spinup
Nitrogen-cycle

Obs (preindustrial, Galloway et al. 2004)
Deposition 17; BNF 120; Denitrification 98; Export to Rivers 70; N₂O 6
Nitrogen fertilization response
Net Primary Productivity response to N fertilization

Thomas et al. 2012
Complete removal of vegetation experiments

Bare soil has higher ET than forests
CLM4.5 Performance at Tower Sites

Howland Forest Main July, 1996 NET-T

Morgan Monroe July, 2001 BDT-T

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