Update on CLM5 progress

David Lawrence and the Land Model Working Group
What’s New for CLM5

A LOT!

More than 50 scientists and software engineers from 15 different institutions involved in development of CLM5
Hydrology: dry surf. layer, var. soil depth w/ deeper (8.5m) max soil, revised GW and canopy interc

Snow: canopy snow updates, wind effects, firn model (12 layers), glacier MEC, fresh snow dens.

Rivers: MOSART(hillslope → tributary → main channel)

Nitrogen: flexible leaf C:N ratio, leaf N optimization, C cost for N (FUN)

Carbon: revisions to carbon allocation and decomposition

Fire: updates, trace gas and aerosol emissions

Vegetation: plant hydraulics, deep tropical tree rooting, Ecosystem Demography (FATES), prognostic roots, ozone damage

Crops: global crop model with transient irrig. and fertilization (8 crop types), grain prod. pool

Land cover/use: dynamic landunits, revised PFT-distribution, wood harvest by mass, shifting cultivation

Isotopes: carbon and water isotope enabled

CLM5 default configuration

CLM5 optional feature

Included in CESM1.5 (79)

Included by July 1
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Timeline

**CLM5 fixing + tuning**
- Feb 2016

**CLM5 final configuration**
- Mar. 1 2016
- June 2016

**CLM5 documentation and control simulations**
- Sep. 1 2016
- Dec 2016
- JAMES overview paper incl Tech Note additional papers on N-cycle, land use, hydrology, ‘ILAMB in model dev’, ???
- CLM5 fixing + tuning
- CLM5 final configuration
- Code Freeze
- CESM2.0 Release

**WG meetings**
- All WGs define -final additions -timeline

**CESM2.0 Sessions at Breckenridge**
- Definition of CESM2.0

**Code available through developers’ access**

**Document impacts in coupled simulations**

**CESM2.0 Release**
- Full release -All functionality
- -CMIP6 1º CESM2 and CLM5 control simulations
Plant Hydraulic Stress

- Simple model to resolve water transport through the Soil Plant Atmosphere Continuum
- Water supply modeled via simple hydraulic framework
- Loss relative to unstressed transpiration modeled based on leaf-level water potential
- Water stress function used to calculate conductance, photosynthesis, and respiration

Slide courtesy Daniel Kennedy
Small improvements in many areas
~8% reduction in GPP RMSE in CLM5SP
**To do list: Scientific development**
Update surface dataset tool to ingest CMIP6 land use dataset.

**New History**
- Hyde 3.2 based
- Landsat F/NF
- Multiple crop types (5)
- Multiple pasture types (2)
- Updated Forest Cover/B
- Updated Wood harvest
- Updated Shifting Cultivation
- Extended time domain (850-2015)

**New Mgt. Layers**

**Agriculture**
- Fraction of cropland irrigated
- Fraction of cropland flooded
- Fraction of cropland fertilized
- Fertilizer application rates
- Fraction of cropland tilled
- Fraction of cropland for biofuels

**Crop rotations**

**Wood Harvest**
- Fraction used for industrial products
- Fraction used for commercial biofuels
- Fraction used for fuelwood

**New Future Scenarios**
- Six futures, SSP-based

**New Resolution**
- 0.25°

**New Transition Matrix**

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~ 50x information content of CMIP5!
Using tower simulation analysis to understand and optimize parameterization for drought response
2nd CLM Tutorial scheduled for September 12-16, 2016

- **Lectures** on underlying model physics, hydrology, biogeochemistry, ecology, etc
- **Practical sessions** about how to run, modify, and analyze CLM simulations
- Will present science and software of **CLM5 / CESM2**
- More than **85** applicants, 46 accepted plus 8-10 auditors
- Tutorial will (likely) be webcast
- All tutorial material including lectures and practical sessions will be available through a CLM tutorial website
International LAAnd Model Benchmarking (ILAMB) project scores for RMSE, interannual variability, pattern correlation, variable-to-variable comparisons, +

- Green: model performs better than average model
- Red: model performs worse than average model

- 2nd International ILAMB meeting in May
- New variables: runoff, runoff ratio, evap fraction, updated biomass
- New diagnostics
- ILAMBv2 operational
- Tutorial on Wednesday at 5:30 in Aspen / Blue Spruce room
Beyond CLM5

• FATES
• Multilayer canopy
• Hillslope hydrology
• …

Can we move beyond “Shantytown” syndrome?

… and the proliferation of models?

… and continue efforts to modularize and modernize the code and support tools?
A unified land model framework
for research and prediction in climate, weather, and water

Conceptual basis
• Modelers agree on many aspects of terrestrial system science
• Differences among models relate to
  - Flux parameterizations
  - Spatial discretization
  - Numerical solution

Modeling Framework
• Existing models (CLM, Noah-MP, WRF-Hydro, etc.) as special configurations
• Flexibility in
  - Process representation
  - Spatial architecture
  - Numerical solvers

Unify land models across climate, weather and water
• Multiple configurations
• Easy to modify/use
• Centralized support
Development targets for CLM5

• Land cover and land use change
  Global / transient crop capability with irrigation, fertilization, and cultivation of crops (land management) as default for historical and projection runs
  More realistic land cover change impact on water and energy fluxes

• Carbon and nutrient cycles
  Improved 20thC land carbon stocks and carbon stock trends
  Address ecological stones thrown at CLM4 (plants don’t get N for free, leaf N isn’t static, photosynthetic capacity should respond to environment, stomatal conductance not linked to N-limitation)

• Hydrology
  Hydrology representation closer to state-of-art hydrology understanding
  Increase utility for use in water resource and water-carbon interaction research

• Land-atmosphere chemistry coupling
  Enhanced interactions, fire emissions, ozone damage to plants, CH₄ emissions

• Ecosystem Demography model – future biogeochemical core of CLM
  Functional CLM5(ED) for use in studies of biome boundaries, trait filtering, etc
  CESM2 coupled runs with CLM(ED) within CMIP6 timeframe; will not be CESM2 default configuration
Improvements to fresh snow density and snow compaction

- Improved snow densities
- Cooler soil temperatures
- Eliminates spurious Antarctica snow melt
Community Nitrogen Cycle Project
Bug fixes and parameter adjustments

CLM5 (May version) – CLM5 (Feb version)

Leaf Area Index

Albedo (MAM)
Plants pay for fixed & active Nitrogen uptake (in Carbon)

Leaf Nitrogen content varies with the cost of N uptake

Contributions from 4 different institutions

Stomatal Conductance is based on N-limited photosynthesis

Photosynthetic Capacity is optimized wrt environmental drivers

CLM5.0

C FOR NUPTAKE

N UPTAKE

C UPTAKE (NPP)

VARIABLE LEAF C:N

OPTIMIZED Vc,max

NEW MOVING PARTS

C FOR NUPTAKE
To do list: Software development

- Integrate “loose-end” projects
  - Carbon / nitrogen conservation for dynamic landunits
  - Plant hydraulics
  - Dynamic roots
  - Water isotopes (BeTR)
  - Winter wheat
  - Crop tilling
  - Dynamic local river flood stage
  - Permafrost excess ice
  - Switch for PFTs on own column
  - Prescribed soil moisture code
  - ....

- Code cleanup
  - Rapid code integration for science has lead to accumulation of lots of “Technical Debt”

- Performance
  - CLM5BGC-crop costs ~5-10x over CLM4CN

- Model output rationalization
  - Over 550 fields archived by default
Tropical grid [6.13°N, 288.75°E]

20 year annual mean

|       | SW↓  | SW↑  | LW↓  | LW↑  | H    | λE   | G    | SW↓  | SW↑  | LW↓  | LW↑  | H    | λE   | G    |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| CTRL  | 207.3| 30.7 | 429.2| 468.4| 26.2 | 96.5 | 14.7 |      |      |      |      |      |      |      |      |
| PFT-COL | 207.3| 30.7 | 429.2| 470.8| 31.7 | 103.3| -0.04|      |      |      |      |      |      |      |      |

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