Update on CLM5 progress

David Lawrence and the Land Model Working Group
International LAnd Model Benchmarking (ILAMB) package 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
• 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
What's new for CLM5

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

Hydrology: dry surf. layer, var. soil depth w/ deeper (8.5m) max soil, revised GW, canopy interc

Snow: canopy snow updates, wind effects, 'firn' model (12 layers, max 10m SWE)

Rivers: Model for Scale-Adaptive River Transport (hillslope → tributary → main channel)

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

Carbon: carbon allocation revised, deep soil decomposability increased

Fire: updates, trace gas and aerosol emissions

Vegetation: Ecosystem Demography, plant hydraulics, prognostic roots, ozone damage, stress decid phenology trigger

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

Isotopes: carbon and water isotope enabled
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Isotopes: carbon and water isotope enabled
Proposed revised timeline

WG meetings
Feb 2016

All WGs define
-final additions
-timeline
Mar. 1 2016

CESM2.0
Sessions at
Breckenridge
June 2016

Definition of
CESM2.0
Jul. 1 2016

Code Freeze
Sep. 1 2016

CESM2.0
Release
Dec 2016

Code available through developers’ access

Document impacts in coupled simulations

Pending approval by the SSC
To do list: Scientific development

- Continue to ‘tamp down’ new N-cycle
- Adjust params / parameterizations to try to resolve problems with simulations

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[Add a task]
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!
To do list: Scientific development

Parameter adjustment (tuning)

Systematic (?) parameter adjustment

- Starting from TRY database estimates for leaf longevity, SLA, leaf C:N target
  - Tuning for what variables
    - Simulation characteristics
- Separate coupled and land-only tuning
  - Fire
  - Methane (wetland distribution)
  - Dust
CLM5
CLM5 without new N
CLM4.5
CLM5 with new wood harvest
CLM5
CLM5 without new N
CLM4.5
CLM5 with new wood harvest

Global Accumulated NBP

Global WOOD_HARVESTC
CLM5
CLM5 without new N
CLM4.5
CLM5 with new wood harvest

global Accumulated NBP

global NPP

global WOOD_HARVESTC
Soil Temperature bias at Boreholes

Figure courtesy A. Slater

+15m, Nth of 65°N: CLM5.B (GSWP3) vs IPY Boreholes (10x10)

\[ Y = 0.47 + 0.73X \]

\[ R = 0.69 \]
• 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
CLM5 development report card

The good

• Strong participation from the LMWG/BGCWGs (>50 people, 15 inst.)
• Scientific basis of model is significantly improved
• Functionality is expanded
• CLM5 should permit greater breadth and quality of scientific inquiry
• >165 CLM tags since CLM4.5 (June 2013)
CLM5 development report card

The good

• Scientific basis is significantly improved
• Functionality is expanded
• CLM5 should permit greater breadth and quality of scientific inquiry

The bad

• Model improvement not readily apparent in diagnostics (yet)
### CLM5 versus CLM4.5

**ILAMB scores**

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<td><strong>Overall</strong></td>
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The bad

• Model improvement not readily apparent in diagnostics (yet)
• CLM was limiting factor (some of the time) in CESM2 testing
• Process has been chaotic, stressful (but also fun at times), inefficient (at times), long, and exhausting for CLM group
Proposed revised timeline

CLM5 fixing + tuning
Decisions on
• N-cycle config
• Prog roots
• Plant hydraulics
• Fire emissions

CLM5 final configuration

CLM5 documentation and control simulations
JAMES overview paper incl Tech Note
additional papers on N-cycle, land use, hydrology, ‘ILAMB in model dev’, ???

Feb 2016
Mar. 1 2016

June 2016
Jul. 1 2016

Sep. 1 2016
Dec 2016

WG meetings
All WGs define
-final additions
-timeline

CESM2.0 Sessions at Breckenridge
Definition of CESM2.0

Code Freeze

CESM2.0 Release
Full release
-All functionality
-CMIP6 1°

Code available through developers’ access
Document impacts in coupled simulations

Pending approval by the SSC
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
- CLM5 / CESM2

~ 40 students

- Graduate students, postdocs, early career faculty are eligible
- Acceptance criteria includes relevance to CLM/CESM project
- Students will have to secure own travel funding (no add’l registration fee)
Tropical grid [6.13°N, 288.75°E]

20 year annual mean

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CTRL

PFT-COL
CLM5 development report card

The bad

- CLM was limiting factor (some of the time) in CESM2 testing
- Process has been chaotic, stressful, inefficient (at times), long, and exhausting for CLM group, … but new management tools/methods show promise for future

Some observations

- Considerable fraction of new code came from external collaborators
  - External code was of highly variable quality
  - Somewhat successful getting external and internal scientists to utilize SVN revision control and software testing
  - Most new code broke a ‘kitchen sink’ run
- Complexity of process spurred experimentation with Project Management Tools
Tasks

Integration of the FlexCN (LBNL), LUNA (LANL) and FUN (JPL) codes into the CLMS code in preparation for Oct 1 deadline.

- **You + 3 others**: Launch a flexCN-LUNA-FUN simulation
- **You + 7 others**: Recognize change in answers for CROP when FUN is on
- **You + 7 others**: Recognize change in answers for CROP when FUN is on
- **You + 4 others**: Determine how to calculate smrn_to_plant_vr in context of FUN
- **Anyone**: Check performance of FlexCN and LUNA with OUT crops
- **Anyone**: Revisit allocation parameters
- **Anyone**: Determine appropriate respiration form for CLMS
- **Anyone**: Re-visit spinup
- **You + 1 other**: Change soil and npceal error to an end run
- **You + 7 others**: Bugs in flexCN, LUNA, FUN
- **You + 4 others**: Solve issue with crop productivity in crop x FUN x LUNA x FlexCN runs

Add a task 90 completed
CLM as a community modeling tool

Presentations with CLM in abstract or title at AGU

- Hydrology
- Ecology
- Biogeochemistry
- Cryosphere
- Societal Dimensions

LMWG CLM

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Software development guidelines

- Software developer's guide: read this for general information on the steps in the model development process including information on coding standards, maintaining a branch, testing, and working with the CLM Code Management Team
  - Coding practices
  - Using SVN to work with development branches
  - CLM testing
  - Upcoming CLM branch and trunk tags
  - Recent CLM code refactoring

- Code refactoring: more modular and object-oriented code has promise to ease development process

- Unit testing