

Software Design Documentation

FATES Dynamic Land Units

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Introduction

*What is the goal of the software? What is the problem statement?
If there are any specification documents, link them in Appendix.*

Implement FATES with multiple land unit classes.

Solutions

*Is it feasible? How much effort does it need for each approach? Pros/cons of each approach.
Document alternatives, why you made the decision and how it will affect the team and project.*

Design Considerations

Describe the issues that need to be addressed before creating a design solution.

Assumptions and Dependencies

Describe any assumptions that may be wrong or any dependencies on other things

1. There is an assumption that the pasture and rangeland will be considered vegetated land. This is currently under consideration at the CLM level.

General Constraints

Describe any constraints that could have an impact on the design of the software.

CESM workshop is week of Jun 12, 2023

During all phases, we must maintain compatibility with E3SM.

Design and Architecture

Call sequence

Calls to fates dynamics will be moved to earlier in the `clm_driver` call sequence, unless Bill or other CLM SE's think its unnecessary. The core existing FATES dynamics sequence, what is in `EDMainMod`, will be maintained, and existing disturbances such as logging, fire and treefall will be preserved. However, some of these events will be allowed to move patches across sites. Either following or preceding the `EDMain` call, another call sequence for transition based disturbances will be executed. This includes area based and/or mass based (harvesting,etc) transitions.

Both the pre-existing and newly introduced transition based area changes will be summed up and passed to CLM. Later on in development, if FATES has to exchange area with non-FATES columns (such as glaciers, urban, crop, etc) it will also pass mass fluxes that represent mass tracked on fates columns that has to disappear.

System diagram or flowchart

Interaction diagram of various inputs, outputs, sub systems and dependencies.

[Dynamic Land Units Flowchart](#)

Algorithm or Pseudo code for main components

Describe your logic in this section

Rollout Plan

1. Implement C (and N?) balance checking between FATES and CLM
 - a. <https://github.com/rgknox/ctsm/blob/clmfates-cbalance/src/biogeochem/CNBalanceCheckMod.F90>
 - b. Ryan Knox and Adrianna Foster are working on this
2. FATES represent primary and secondary land columns areas
 - a. Driven by logging module
 - b. Dictate changes in area to HLM
 - c. Pass area between primary and secondary in fates
 - d. CTSM sees changes area from FATES side (balance check off)
 - e. Grid cell areas for HLM fluxes to atm consistent w/ fates areas
 - i. CLM tracking column level terms (belowground under fates sites)

- ii. No change in below ground state variables (break conservation w/out balance check) NOT conserving mass states
 - iii. The per m² basis is wrong w/out balance check
- 3. Conserving C & N with shift in primary/secondary area
 - a. Passing fluxes patch to column (C N to HLM)
 - b. Invoking calls for dynamic area calls (column level hlm)
 - c. Conservation requires transfer of mass between columns
 - d. Handle on fates side (fates litter and harvest)
 - e. Primary shrinks and grow secondary
 - i. Trees cut on primary
 - ii. Transfer litter to secondary column (fates tracks this)
 - iii. Tracks this shift in mass on fates side
 - iv. HLM conservation needs individual pools
 - v. HLM needs soil details
 - f. Liquidation of fates LU and transformed...
- 4. Loss of nat area in fates
 - a. Column level C discretized across soil layers
 - b. Handle changes in column area for other reasons (e.g. fire disturbance)
 - c. Consider impact on soil column (fire impact on permafrost)
 - d. Sent back to HLM
 - e. Check current method - where does C go? Buried under glacier?
 - f. Consideration of exogenous vs endogenous disturbance
 - i. Fully exogenous - reading in change and implement
 - ii. Fully endogenous - fire, large blowdown, etc.
 - iii. semi-endogenous
- 5. FATES area expands
 - a. Create new patches
 - b. Include litter? (not at first)
- 6. Area change for nat veg to other non-fates LU (very different than fates to fates LU)
 - a. urban and fates on separate columns
 - i. Carve out patch,
 - ii. remove mass from fates,
 - iii. Donate mass to HLM
 - iv. Pass external boundary condition of this mass passed from fates to HLM based on the area change (dependant on transition)
 - 1. Fractions to various pools (atm, soil, etc)
 - a. PFT level parameter from file
 - b. Shijie harvest sent to product pools
 - 2. Could be in litter
 - a. Moving patches and cohorts across columns

- b. In a call sequence on fates side w/ potential for multiple fates updates, but only one HLM update
 - 3. Could be buried under urban or glacier
 - 4. Harvested product pool (goes away)
 - v. Fates can provide column level flux across soil layers
 - 1. Put into litter?
 - 2. Check current method for glacier
 - 3. Different for crop
 - vi. Normalize per patch values
 - 1. Number density, crown area, etc
 - 2. site area times patch area must equal new site area times new patch area
 - 3. This should be straightforward
 - vii. (maybe need more rewrite of current infrastructure)
7. Setup structure for handshake for dynamic LU
- a. Basic test of changing area (increase and decrease)
 - b. Turn off balance checks (do not need to pass at first)
 - c. Confirm areas sync up
 - d. Single point dataset w/ defined changes in nat veg partition
 - e. Then changes in total area of other parts
8. Frequency of updates
- a. Timing (annual, monthly, daily)
 - i. Retain ability to harvest daily and based on external timing
 - ii. Retain fire disturbance daily
 - iii. Are all transitions at same timing?
 - iv. Is it ok for FATES to carry around past dist history? This is already carried around
 - b. Handling of model fluxes
 - c. Reporting in history
 - i. Tracking mass from primary to secondary lands
 - ii. w/ annual call it is hard to determine this change
9. Controls on running model
- a. Sync up with HLM controls on dynamic LU
 - b. Decide which software module makes this decision (Big-leaf, fates, etc)
 - c. Include vector in fates param file
 - i. vectors for LU to consider, how many types of LU from data
 - ii. 111, 222, 333, etc
 - d. Set resolution for fates w/ LU
 - i. 0 = fates only; 1= primary, secondary; 2= primary, second, pasture; 3= etc
 - e. Groupings (fates does not follow LUH2 PFT designations)
 - i. Non-forest

- ii. Forested
- iii. Potential flow:
 1. Split forest from primary secondary made at patch level
 2. Identify labels and then renormalize that into fates site instance for primary and secondary
 3. Fates handles renormalization
 4. Currently all fates logic happens at fates site/column level
 5. Fates logic, but not at site level
 6. Aware of fates site on grid cell
 7. Then acting as puppeteer master of fates sites
 8. Collect these and check for ones that do not belong
 9. This happens outside of ed ecosystem dynamics - at higher level
 10. Go into site pull out patches, and then then fates does renormalization
 11. Creates new type that would do all this or a vector or subroutine that is called at grid cell level
 12. Creates vector of site types & operates at grid cell level
 13. Pull out labeled changes and then
 14. Sort, terminate, and then call fuse patches at the end
- f. Crops
 - i. Include a generic C3 & C4 crop
 - ii. Fates - one column for crop to handle crop transitions
- g. Irrigated vs non-irrigated (don't need this yet)
- h. HLM side
 - i. Most of this will happen in **clm-fates interface mod**
 - ii. Ed ecosys dynamics called from clm-fates interface
 - iii. Downstream of this is single site
 - iv. Library for check this site
 - v. To take out a patch
 1. Fuse these sites
 2. Inside dynamics drive
 3. We have copy cohort (maybe copy patch)
 - vi. Nested type within this dynamic LU
 1. Then reference module that contains unch of routines
 2. There are already nested types in here
 3. Good spot for another nested type?

Appendix

References, links to additional documentation

[FATES LUH2 Design Doc \(Charlie Koven, Bill Sacks \)](#)

This includes initial design discussions for dynamic land units as well.

[FATES-LUH2 Harmonization notes \(Ryan Knox\)](#)

[FATES-Dynamic LU meeting notes 09 Feb 2023 \(JK Shuman\)](#)

[CLM Transient Land Use Technical Documentation](#)

Review Sign-off

Reviewer(s):

Sign-off Completed on YYYY-MM-DD