Historical and Future Land Use and Land Cover Change in CLM5 – Preliminary Results

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1. The new Historical and SSP - RCP land use and land cover change time series have been compiled through the Land Use and Scenario Model Intercomparison Projects (LUMIP and ScenarioMIP).

2. The Global Land Model (GLM) has been extended to 12 land units to better represent dynamics of agriculture and forests. The new land units include:

   - Primary Forest
   - Secondary Forest
   - Crop C3 Annual
   - Crop C3 Nitrogen Fixing
   - Crop C4 Perennial
   - Grazing Rangeland
   - Primary Non Forest
   - Secondary Non Forest
   - Crop C3 Perennial
   - Crop C4 Annual
   - Grazing Pasture
   - Urban

3. New management information for Crops and Forests is provided with transient N Fertilizer and Irrigation prescription, and new Wood Harvest
Changes in CLM5 Transient Land Cover in 1850 – 2015: Reduced Bare Soil through MODIS LAI constraint on VCF
Changes in CLM5 Transient Land Cover in 1850 – 2015:
Increased Grass through MODIS LAI constraint on VCF
Changes in CLM5 Transient Land Cover in 1850 – 2015: Consistent Crops even with new LUMIP Crop Data
Changes in CLM5 Transient Land Cover in 1850 – 2015: Lower Tree Cover with new LUMIP Forest Data
Changes in CLM5 Transient Land Cover in 1850 – 2015: Lower Shrub Cover with new Tropical and Arctic Shrubs
New CLM5 Transient SSP (Beta) Land Use in 2016 – 2100

CLM5 Tree PFT Area (10^6 km^2)

CLM5 Crop CFT Area (10^6 km^2)

CLM5 Grass PFT Area (10^6 km^2)

CLM5 Shrub PFT Area (10^6 km^2)
New CLM5 Transient SSP Land Cover in 2016 – 2100
CLM5 Carbon Cycle impacts of Land Use Land Cover Change

1. The New Land Surface time series data were used as the basis for evaluating the Carbon Cycle response of CLM5 to LUMIP Land Use Land Cover Change (LULCC) forcing data sets for the Historical, SSP1 and SSP3 periods under changing climate and CO₂.

2. To do this CLM5 simulations with transient LULCC were compared to the same simulations performed with no LULCC over the period.

3. The Historical CLM5 simulations were performed from 1850 – 2010 with atmospheric forcing from the new Global Soil Wetness Project (GSWP3) meteorology.

4. Future CLM5 RCP 8.5 simulations were also performed for 2011 – 2100 using anomaly forcing from RCP 8.5 air temp, precip, wind, humidity and pressure added to current day (2000 – 2010) GSWP3 forcing. Atmospheric CO₂ and other transient forcing data were prescribed in all runs.

5. The CLM5 results were then compared to similar experiments run with CLM4 and the CMIP5 LULCC data sets.
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Tot Ecosys C

**CLM5 LUMIP**
- Historical: 191.5 PgC
- SSP1: 34.4 PgC
- SSP3: 145 PgC

**CLM4 CMIP5**
- Historical: 129.6 PgC
- RCP 8.5: 164.6 PgC
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Conversion C

CLM5 LUMIP
- Historical: 62.8 PgC
- SSP1: 18.6 PgC
- SSP3: 39.9 PgC

CLM4 CMIP5
- Historical: 63.6 PgC
- RCP 4.5: 9.9 PgC
- RCP 8.5: 34.2 PgC
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Wood Harvest

**CLM5 LUMIP**
- Historical: 94.2 PgC
- SSP1: 76.3 PgC
- SSP3: 95.3 PgC

**CLM4 CMIP5**
- Historical: 64.6 PgC
- RCP 4.5: 146 PgC
- RCP 8.5: 243 PgC
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – NPP

CLM5 LUMIP
Historical:  △10.4 PgC/yr
SSP1:  △20.6 PgC/yr
SSP3:  △19.3 PgC/yr

CLM4 CMIP5
Historical:  △5.4 PgC/yr
RCP 8.5:  △11.1 PgC/yr
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Fire

**CLM5 LUMIP**
- Historical: 340.3 PgC
- Hist nolu: 275.8 PgC
- SSP1: 238.4 PgC
- SSP3: 265.3 PgC
- SSP nolu: 215.8 PgC

**CLM4 CMIP5**
- Historical: 318.7 PgC
- Hist nolu: 343.6 PgC
- RCP 8.5: 208.8 PgC
- RCP 8.5 nolu: 237.4 PgC
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Het. Resp.

CLM5 LUMIP
Historical: 6385 PgC
Hist nolu: 6484 PgC
SSP1: 4417 PgC
SSP3: 4395 PgC
SSP nolu: 4462 PgC

CLM4 CMIP5
Historical: 6306 PgC
Hist nolu: 6349 PgC
RCP 8.5: 4473 PgC
RCP 8.5 nolu: 4491 PgC
New CLM5 LUMIP vs CLM4 CMIP5 LULCC – Crops

CLM5 Global Grain C to Food (Millions Tonnes/yr)

- HIST1
- HISTnolulcc1
- SSP1RCP85
- SSP3RCP85
- SSPnoLULCCRCP85
- UNFAO Equiv

Years: 1850 to 2100
CLM5 LUMIP vs CLM4 CMIP5 LULCC - Summary

1. In 1850 the new CLM5 LUMIP surface data reduced bare soil by 10 million km² to allow the BGC model to simulate grass where MODIS LAI found seasonal grasses not prescribed by MODIS VCF.

2. Crop area is very close in CLM5 LUMIP and CLM4 CMIP5 but we now have crop model with transient crop specific fertilizer and irrigation management at the grid cell.

3. Trees have been reduced overall primarily fixing a CLM4 CN phenology issue for tropical shrubs in the old data. Arctic shrubs have been reduced as well.

4. We have transient LUMIP CLM5 surface data for Historical (1850 – 2015) and beta versions of SSPs 1-5. SSP1 afforestation SSP3 crop expansion.

5. The CLM5 BGC results show larger Historical Land Use flux with LUMIP but the model also has much stronger response to CO₂ and climate than CLM4 CN. Beta versions of the SSPs show much lower wood harvest than CMIP5 RCPs.