Papers

- Lawrence, D.M. et al., 2019. The Community Land Model version 5: Description of new features, benchmarking, and impact of forcing uncertainty. *Accepted to JAMES.*
- Lombardozi, D, et al., 2019. Simulating transient crop management in the Community Land Model version 5. *In prep*
- Lawrence, P., et al., 2019. Implementation and impacts of land cover and land-use change in CLM5. *In prep.*
- Danabasoglu, G., et al., 2019. CESM2 overview paper. *In prep*
New or updated land modeling capabilities in the CESM2/CLM5:

**Included in default CLM5**
- CN (completely updated)
- Vertically-resolved CN (permafrost)
- CH$_4$ emissions
- C isotopes
- Plant hydraulics
- Spatial explicit soil depth, dry surface layer param for soil evap, snow updates
- *No dynamic biogeography*

- Global crop model with 8 basic crop types; planting, grain fill, harvest
- Irrigation
- Industrial crop fertilization (assumed constant background manure application)
- Wood harvest (by mass)
- Urban environments (3 density classes, heating/cooling wasteheat)
- Anthropogenic fire ignition and suppression

* Temperate and tropical varieties
Heterogeneity in Community Land Model (CLM)

Subgrid landuse data available at ESGF
n.b. Full subgrid information available on request

Urban area constant at present day

Soil
- Roof
- Sun Wall
- Shade Wall
- Impervious

Crop
- Rainfed
- Irrig
- Rainfed
- Irrig

PFT
- PFT1
- PFT2
- PFT3
- PFT4
- Crop1
- Crop2
- Crop1
- Crop2

Patch

Column

Landunit
- Vegetated
- Lake
- Urban
- Glacier
- Crop

Gridcell
Set of land-only historic (1850 – 2014) simulations with one-at-a-time modification of particular aspects of land management

1. Land historical all management
2. Year 1700 instead of 1850 start
3. No LULCC change
4. Alternate land use histories
5. No shifting cultivation
6. Crop and pasture as unmanaged grassland
7. Crops with crop model but no irrigation/fertilization
8. No irrigation
9. No fertilization
10. No wood harvest
11. No grazing on pastureland
12. No human fire ignition/suppression
13. Constant 1850 CO₂
14. Constant 1850 climate

Lawrence et al., 2016
Accumulated Land Use Change Flux

- CESM2 No Land Use Change
- CESM2 Historical

CESM2 / CLM5
~180 PgC

Houghton estimate
145±16 PgC

Note that with shifting cultivation, included for TRENDY 2019, but not CMIP6, ~200 PgC

CESM1 ~120 PgC
Land carbon stock trends (RCP8.5)

CLM5

Ecosystem Carbon

Vegetation Carbon

Soil Carbon
Cumulative Land Carbon Sink

- Hoffman observations
- 4.0 CRU-NCEP
- 4.5 CRU-NCEP
- GSWP3
- 5.0 CRU-NCEP

Cumulative Land Sink (Pg C)

Year:
- 1850
- 1900
- 1950
- 2000

Approximate values:
- ~50 PgC CLM4
Bias in vegetation biomass (against GEOCARBON dataset)
Irrigation is on for all CMIP6 simulations.

Note that irrigation scheme draws water from surface water (rivers) first and then draws water diffusely from ocean.

Water for irrigation is never limited.

Work ongoing to implement reservoirs and reservoir management, groundwater pumping, and aquifers to permit water-limited irrigation.
Preliminary assessment of LULCC climate impacts

Land-hist minus land-noLU

Annual albedo

Latent Heat (JJA)

Latent Heat (MAM)
Nitrogen fertilization

Due to limitations in soil biogeochemistry scheme including representation of competition between plants and microbes for N, no confidence in N$_2$O emissions (not recommended for use)
<table>
<thead>
<tr>
<th>model</th>
<th># of models</th>
<th># of experiments</th>
<th>deforest-globe</th>
<th>esm-ssp585-ssp126Lu</th>
<th>hist-noLu</th>
<th>land-cCO2</th>
<th>land-cClim</th>
<th>land-crop-noFert</th>
<th>land-hist</th>
<th>land-hist-altStartYear</th>
<th>land-noFire</th>
<th>land-noLu</th>
<th>ssp126-ssp370Lu</th>
<th>ssp370-ssp126Lu</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCC-CSM2-MR</td>
<td>7</td>
<td>156</td>
<td>157</td>
<td>157</td>
<td>41</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CESM2</td>
<td>11</td>
<td>370</td>
<td>179</td>
<td>1298</td>
<td>172</td>
<td>172</td>
<td>172</td>
<td>24</td>
<td>172</td>
<td>161</td>
<td>427</td>
<td>427</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNRM-CM6-1</td>
<td>1</td>
<td>153</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNRM-ESM2-1</td>
<td>3</td>
<td>334</td>
<td>334</td>
<td></td>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CanESM5</td>
<td>4</td>
<td>342</td>
<td>342</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GISS-E2-1-G</td>
<td>1</td>
<td>825</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPSL-CM6A-LR</td>
<td>3</td>
<td>1369</td>
<td>1888</td>
<td></td>
<td>176</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UKESM1-0-LL</td>
<td>1</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>