

# New Transient Land Surface Data Sets for CLM5

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# 1. CLM4 CMIP5 – Land Surface Data Sets

1. CMIP5 protocol has Land Cover Change as a component of climate forcing for the 1850 – 2005 Historical period and for the 2006 – 2100 Representative Concentration Pathway (RCP) periods
2. For each Historical and RCP period land use and land cover change were described through harmonized annual changes from the Global Land Model (GLM) of the four basic land units of:
  - Primary Vegetation (Prior to Human Disturbance)
  - Secondary Vegetation (Disturbed then abandoned or managed)
  - Cropping
  - Pasture (Grazing Lands)
3. Harvesting of biomass was also prescribed for both primary and secondary vegetation land units both in terms of fraction of area and total carbon harvested for old and young forests and for non forest.

# 1. CLM 4 Transient CMIP5 Transient Land Surface Data

1. To include the historical and RCP land cover change pathways in CLM4 we needed to take the annual changes in the GLM land units and make an annual time series of changing Plant Functional Types
2. To make this transition we described the PFT composition of the individual GLM land units of each grid cell based on our Current Day and Potential Vegetation CLM 4.0 parameters for that grid cell
3. Current Day (2000) CLM 4 land surface parameters are derived from MODIS satellite data as described in *Lawrence and Chase (2007)*
4. Potential vegetation CLM 4 parameters are bio-climatically modeled as described in *Lawrence and Chase (2010)*
5. Wood harvest parameters on Tree PFTs also were calculated from the five harvest prescriptions.

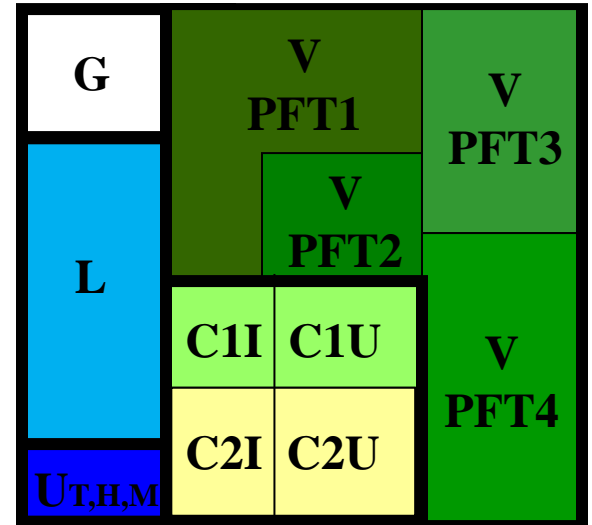
## 2. CLM5 CMIP6 – New Land Surface Data Sets

1. For CLM5 and the CMIP6 climate simulations there will be new Historical and SSP - RCP land use and land cover change data sets which are currently being compiled for through the Land Use Model Intercomparison Project (LUMIP).
2. The new time series will include new functionality following lessons learned through CMIP5 and to include new developments in CLM5.
3. 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
4. New management information for Crops and Forests is provided with transient N Fertilizer and Irrigation prescription, and new Wood Harvest

Gridcell



CLM 5 Crop subgrid tiling



Landunit



Vegetated



Lake



Urban

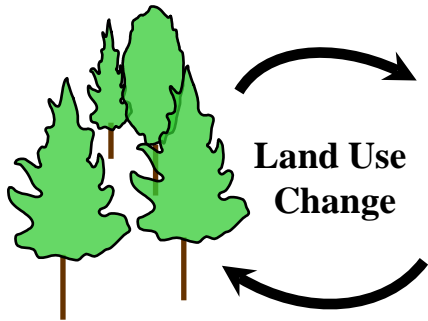


Glacier



Crop

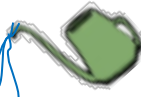
Crop Model



Planting



Leaf emergence



Irrig / Fertilize



Grain fill



Harvest



Unirrig



Irrig



Unirrig



Irrig



Crop1



Crop1



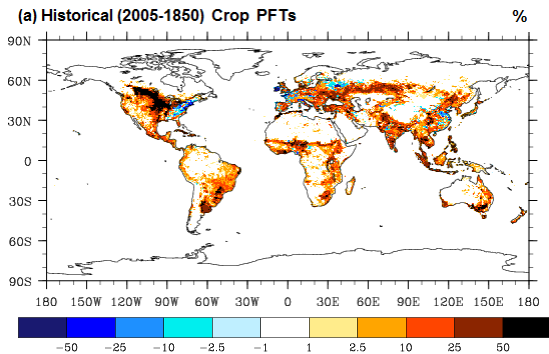
Crop2



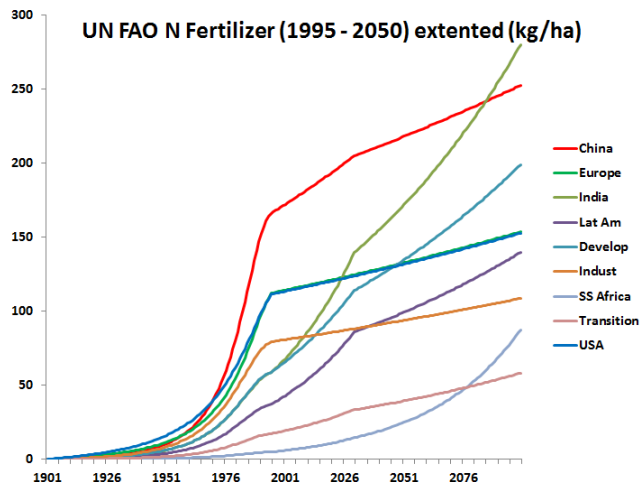
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# CLM 5 Land Surface Data Sets Forests and Crop – Scenario

GLM Land Unit Area LUMIP scenario



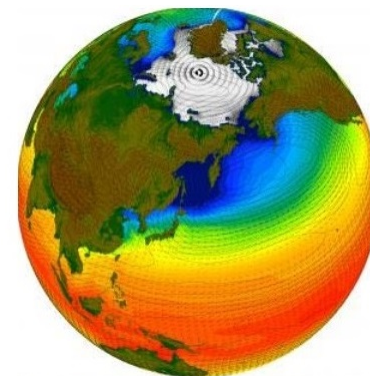
Crop Type / Irrigation time series  
GLM and Portmann et al. (2010)



Global CLM 5 Scenario

- Plant FT
- Crop FT
- Year
- Area
- Fertilizer
- Irrigation
- Wood Harvest

CESM 2.0 Climate / Carbon Simulation

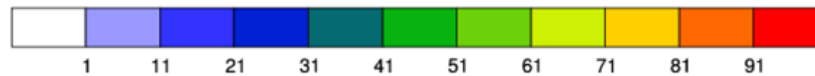
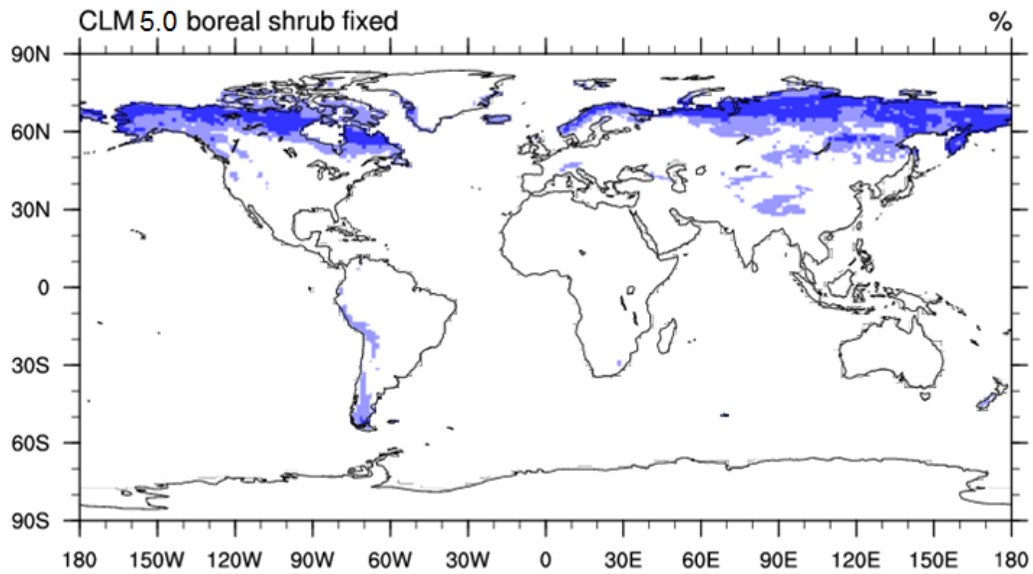
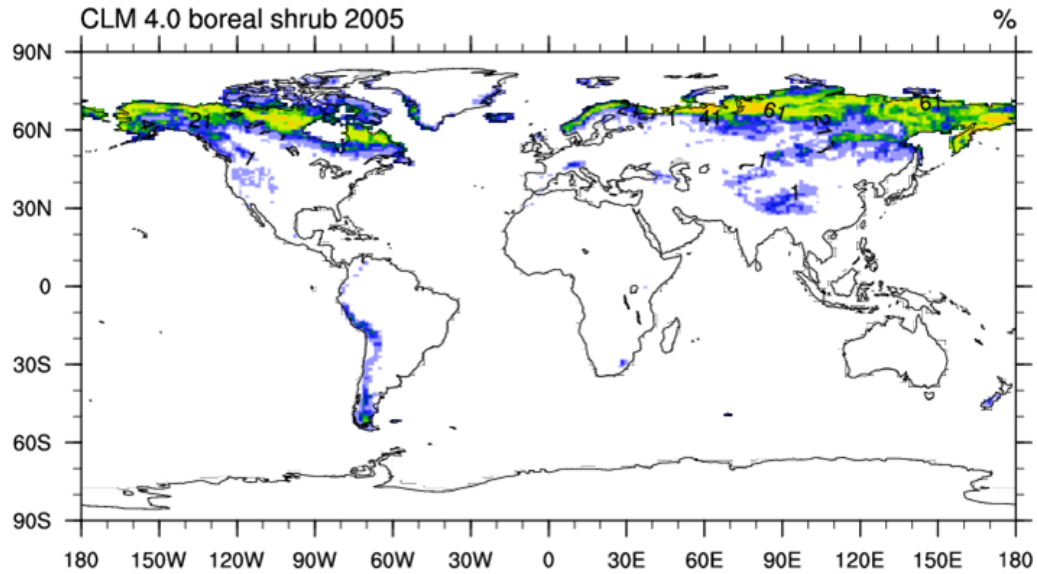


### 3. CMIP6 Transient Land Cover in CLM 5 Land Surface Data Sets

1. MODIS Land Cover, Vegetation Continuous Fields, Leaf Area Index and Albedo will be used to describe Primary and Secondary Forested and Non Forested land units as well as Rangelands and Pasture.
2. CLM 4 had a number of issues that were identified from CMIP5 simulations
3. In CLM4, current day Arctic Shrubs PFTs were directly prescribed from the MODIS Land Cover product. Comparing the CLM4 arctic shrub density to pan arctic studies by Walker et al 2005 and Taper et al 2006 found this interpretation was around four times the field observed shrub density.
4. Reducing the shrub fraction and replacing the fraction with Arctic C3 grass to be consistent with the field studies has large impacts on Arctic climate through substantially higher albedo. In the fully coupled CESM this results in arctic cooling with impacts on sea ice extent and thickness.



# CMIP6 CLM5 Current Day Boreal Shrub PFT

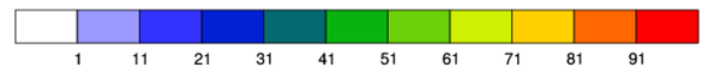
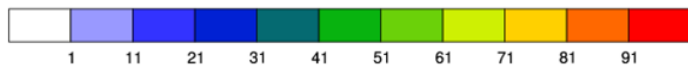
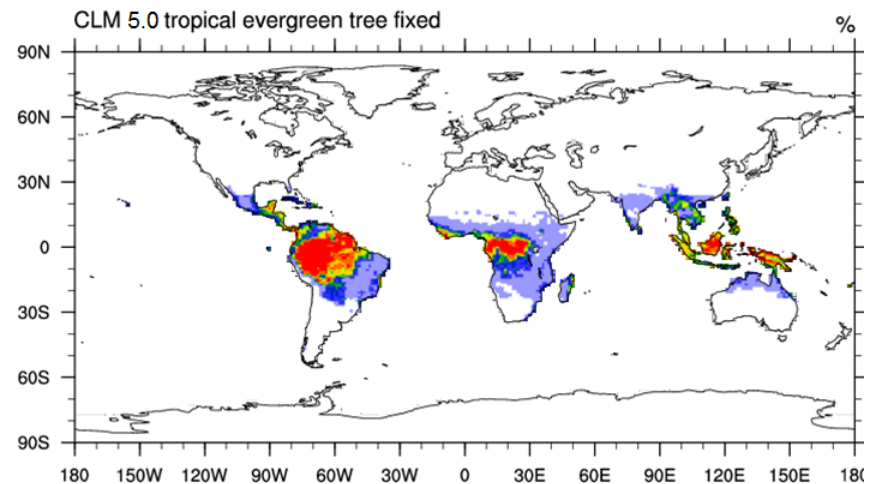
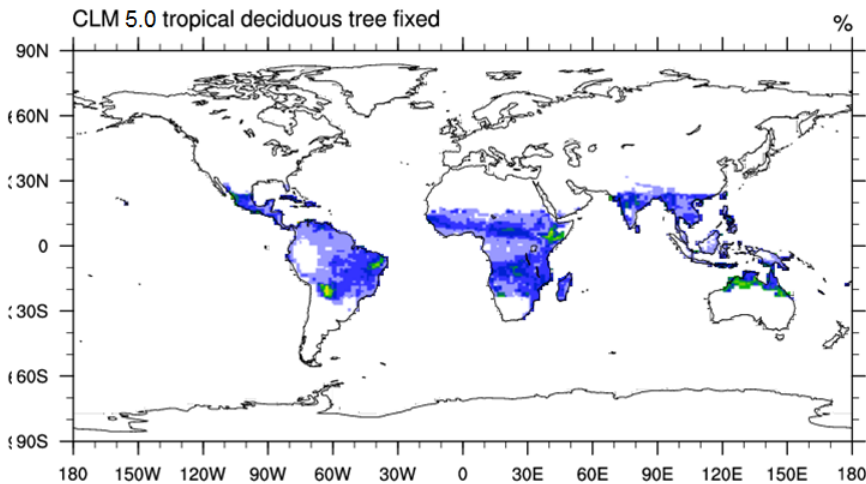
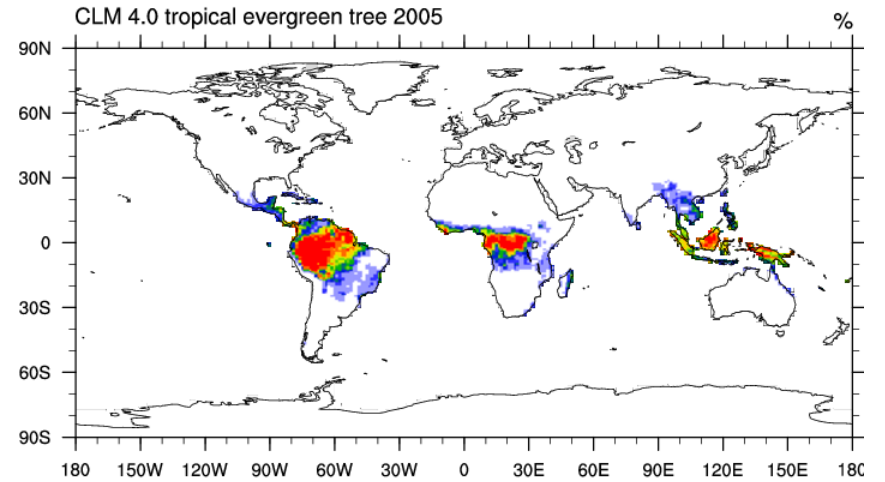
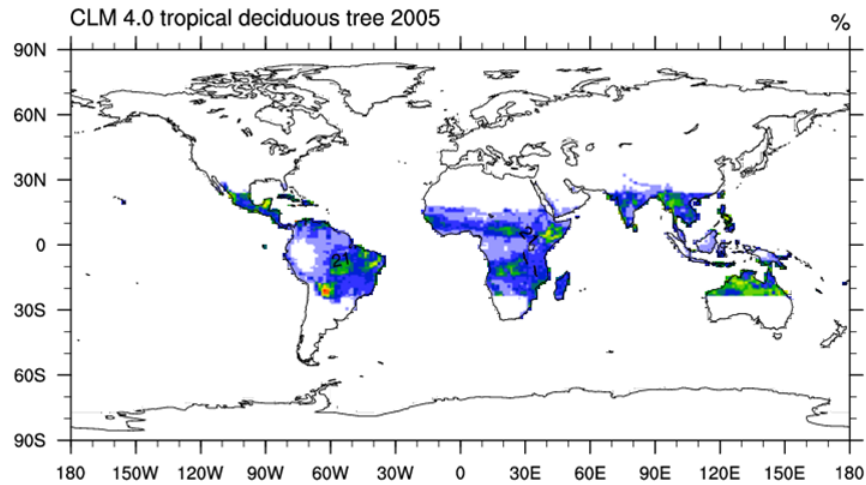




### **3. CMIP6 Transient Land Cover in CLM 5 Land Surface Data Sets**

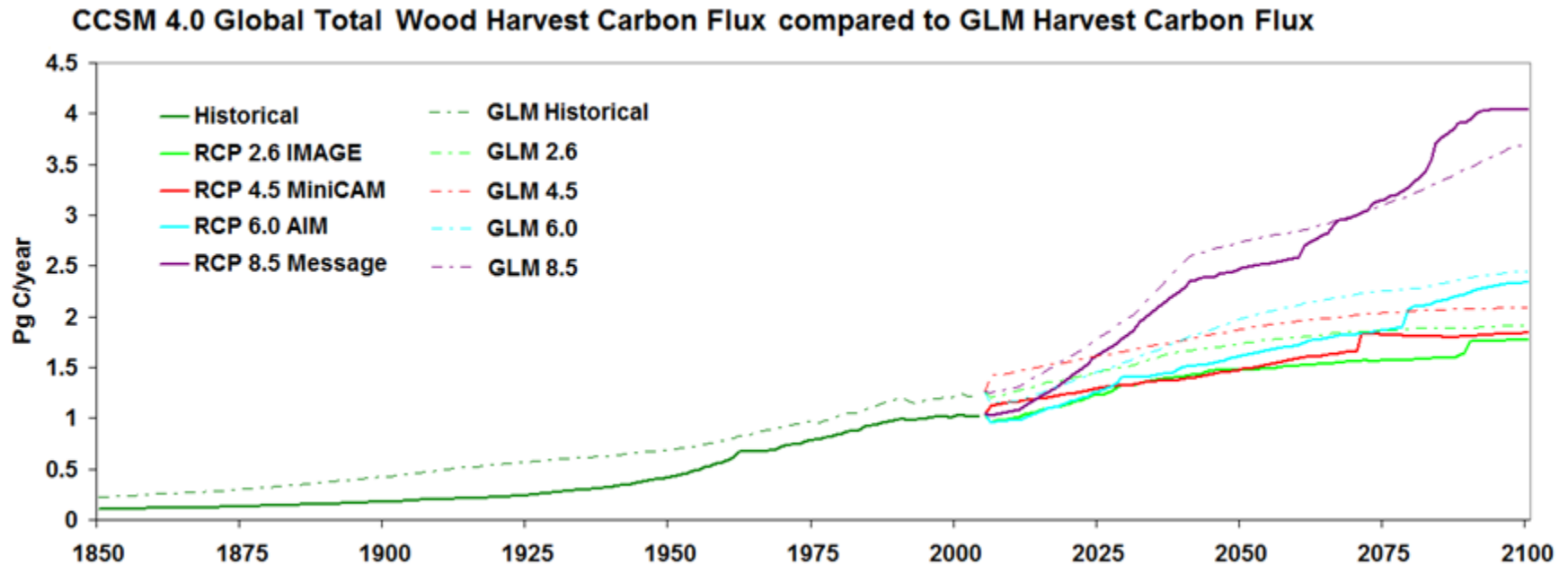
1. In CLM4, Broadleaf Deciduous Tropical (BDT) Tree PFTs were prescribed from the MODIS Vegetation Continuous Fields tree fraction and the AVHRR Continuous Fields Broadleaf and Deciduous tree data.
2. Recently Dahlin et al 2015 found that CLM4 had difficulty in simulating the BDT leaf phenology when compared to satellite LAI. While changing the phenology of BDT had some improvement in CLM4 the minimum LAI values from satellite indicated that CLM4 prescribed too much BDT in many areas.
3. For CLM5 the prescription of current day BDT tree PFTs are now guided by MODIS LAI with the BDT trees being replaced with Broadleaf Evergreen Tropical (BET) Tree PFTs

# CMIP6 CLM5 Current day Broadleaf Tropical Tree PFTs



## 4. CMIP6 Transient Wood Harvest in CLM5

1. In CLM4 Transient Wood Harvest was prescribed as the fraction of tree PFTs to be harvested for each year. The wood harvest flux took the time step interpolated fraction of the dead stem carbon pool for trees and placed it in the 10 and 100 year product pools. Other tree carbon pools had the same fraction transferred to the litter pool.
2. In CMIP5 this implementation resulted in differences in the expected carbon wood harvest flux simulated in the GLM model and in CLM due to different carbon densities between the two models



## 4. CMIP6 Transient Wood Harvest in CLM5

6. To overcome this inconsistency between prescribed Wood Harvest carbon flux and the intended flux from GLM we have rewritten the Wood Harvest code so that the annual flux of carbon is now prescribed in  $\text{gC}/\text{m}^2/\text{year}$ .
7. In the new CLM5 code the flux is used with the carbon density found in the dead stem carbon pool of the tree PFTs. This gives a fraction of the tree PFT to be harvested that will result in a wood harvest flux that is the same as was simulated in the GLM model.
8. By calculating the wood harvest fraction in the model, the transfer of other carbon pools to the litter pool are done consistently with the CMIP6 protocol.

## 5. Conclusions for CLM5 Land Surface Data Sets for CMIP6

1. Currently developing new transient Land Surface Data Sets for CLM5
2. New Data Sets will allow for better prescription of both Natural and Human Managed Landscapes
3. The New Data Sets leverage new functionality in CLM 5 such as transient Crops as well as prescribed N Fertilizer and Irrigation.
4. We are also addressing issues that arose through the CMIP5 process in terms of the describing current day vegetation in terms of boreal shrubs and broadleaf deciduous tropical trees.
5. Finally we have addressed the issue of Wood Harvest dependence on carbon density by rewriting the code to work on carbon fluxes rather than tree fraction.