Influence of forest-age structure on land-atmosphere fluxes in the land surface model JSBACH

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1. Introduction

Globally the majority of forests are under some form of human use, often with an influence on their age structure. Although forests of different ages have different land-atmosphere fluxes, many **land surface models neglect age effects** by assuming ageless or mean-age forests.

We present our implementation of age cohorts in the land surface model JSBACH and investigate the impact on different land properties and land-atmosphere fluxes.

Summary and outlook

JSBACH4 simulations with and without our newly implemented age cohorts show large differences in land properties and land-atmosphere fluxes. Particularly simulated carbon stocks differ strongly, underlining the need to **account for forest-age structures when investigating land-use effects** in land surface models**.** Global simulations as well as assessments of the effect on the carbon cycle in coupled applications of the ICON Earth System Model are still pending.

4. Experiment set-up

We conducted 5 simulations (Tab. 1) of a grid box in Canada (lat 48; lon -73; T63), covered mainly by JSBACH's evergreen (**ETE** - 50.5%) and deciduous (**ETD** - 45.7%) extra-tropical PFTs; running 150 years (1860-2010) using GSWP3 forcing data [3]. Harvest in **mean-age**/ **cohorts** was such that the grid-cells 2010 mean-ages (E: 71; D: 70)/age distributions (Fig. 4) matched those from a global age distribution map [4]. In **H** and **H+R** we harvested annual fractions as in the cohorts simulation. **default** and **H** are without regrowth.

	default	H	H+R	mean-age	cohorts
harvest (H)	N	annual	annual	once	annual
regrowth (R)	N	N	Y	Y	Y
cohorts	N	N	N	N	Y

Tab. 1 Conducted simulations: columns, used processes: rows

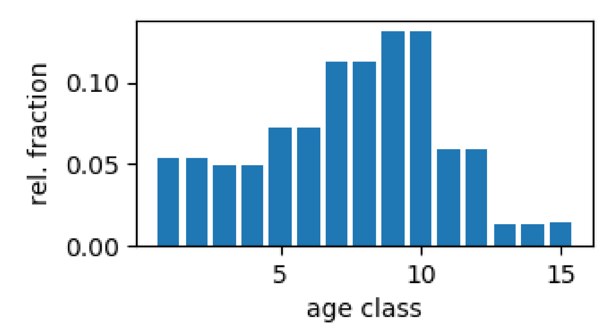

Fig. 4 Relative distribution into 10-year age classes taken from the global map [4].

** shown for evergreen, but almost identical for deciduous*

2. Implementation of regrowth

Previous versions of JSBACH assumed an ageless forest with a climatically driven leaf area index (LAI) not coupled to the available leaf carbon. We replaced the prescribed constant maximum leaf area index (LAI_{max}) with an interactively simulated leaf area, based on the self-thinning rule and an allometric relationship between biomass and leaf biomass per individual (Fig. 1).

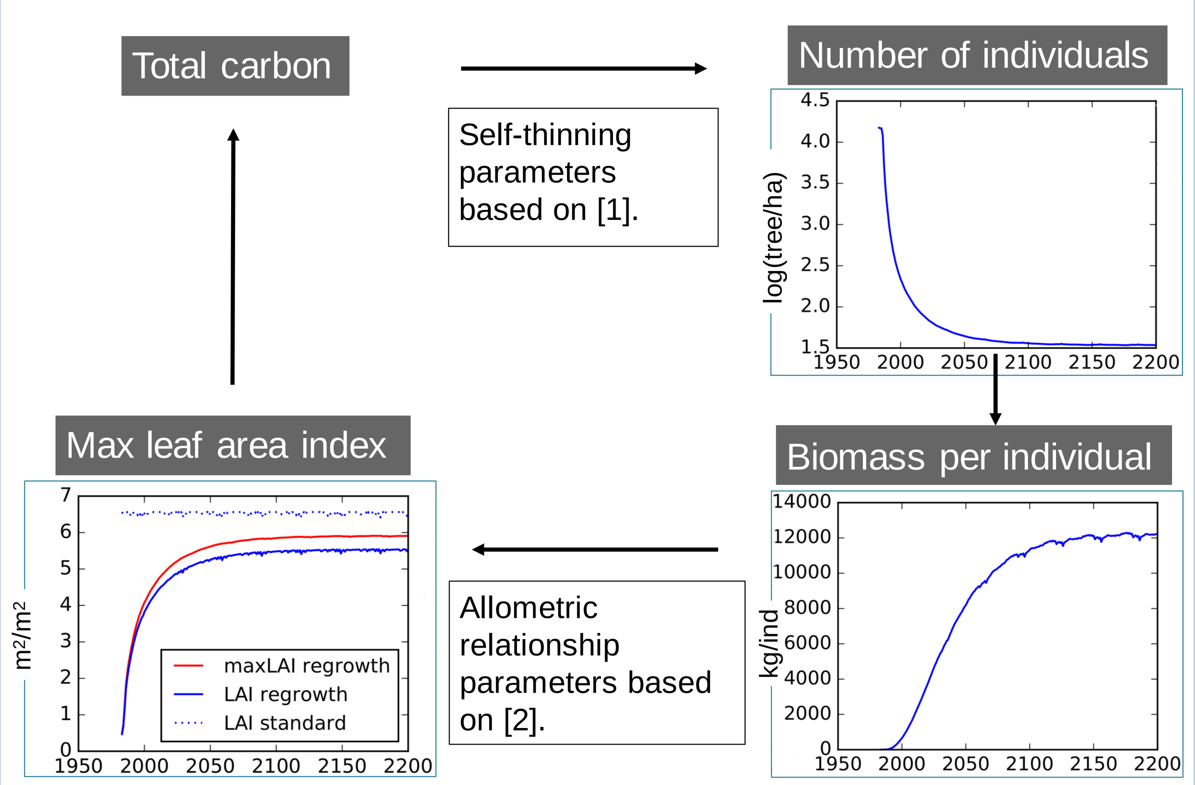

Fig. 1 Overview of the forest regrowth implementation, with example data for the tropical evergreen PFT at -14ºN/-55ºW.

3. Implementation of forest age in JSBACH4

JSBACH is currently reimplemented for use within ICON-ESM, the new Earth System Model of the Max Planck Institute for Meteorology. In the reimplementation the old flat tile structure is replaced with a hierarchical tile structure (Fig. 2) which facilitates a cohort implementation.

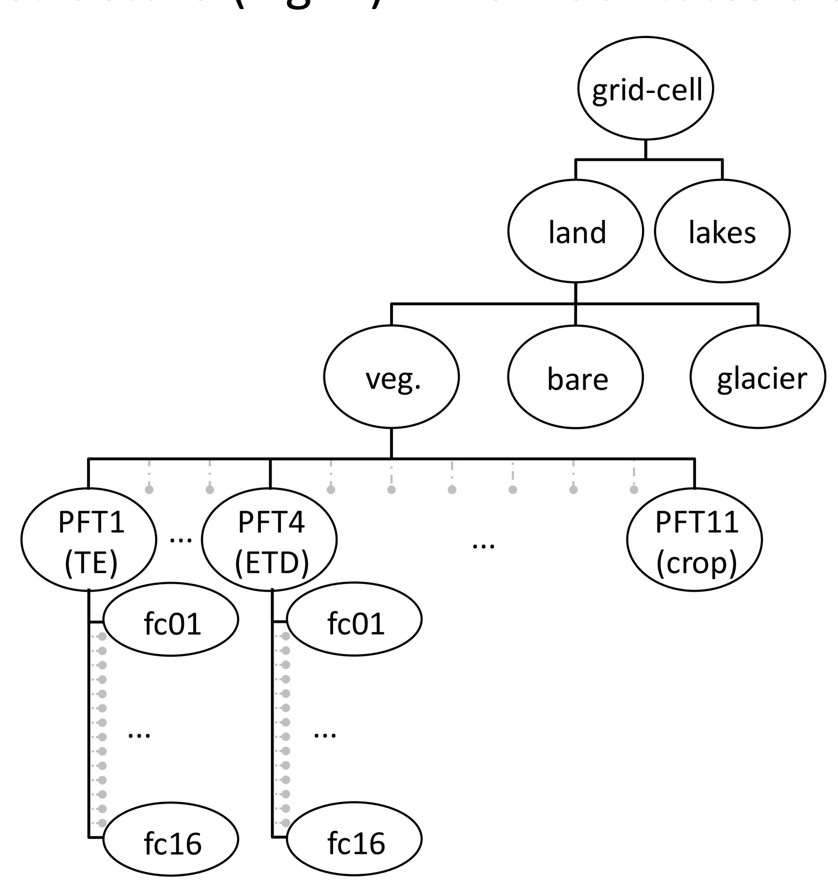

Fig. 2 JSBACH4's tile structure amended with cohorts. The default set-up has eleven plant functional types (PFTs), of which 4 are forest types: Evergreen and deciduous tropical (TE and TD) and evergreen and deciduous temperate (ETE and ETD).

The number of cohorts in a land surface model is a compromise between computational complexity and accuracy. This compromise is alleviated by fully tracking the exact age fractions, making use of the hierarchical tile structure: The administration of the cohorts is done on the associated PFT (Fig. 3).

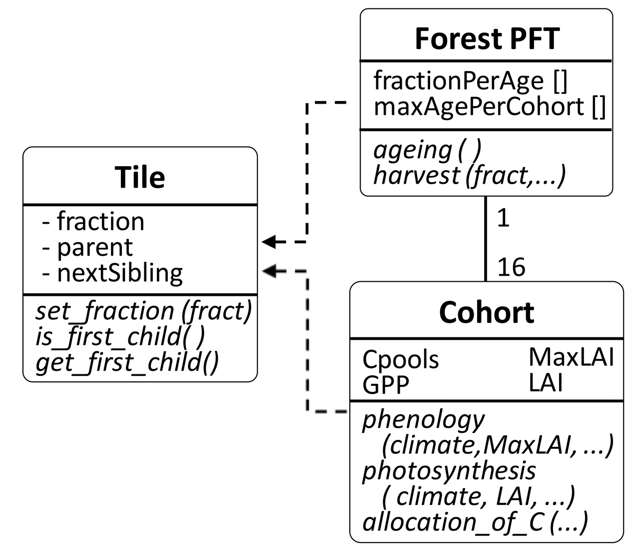

Fig. 3 PFTs and cohorts are distinct types of tiles in JSBACH4, hosting different state variables and processes. Depicted state variables and processes are exemplarily.

5. Results and evaluation

The simulations differ strongly in the temporal development of gross primary production (GPP), LAI and wood carbon (Fig. 5).

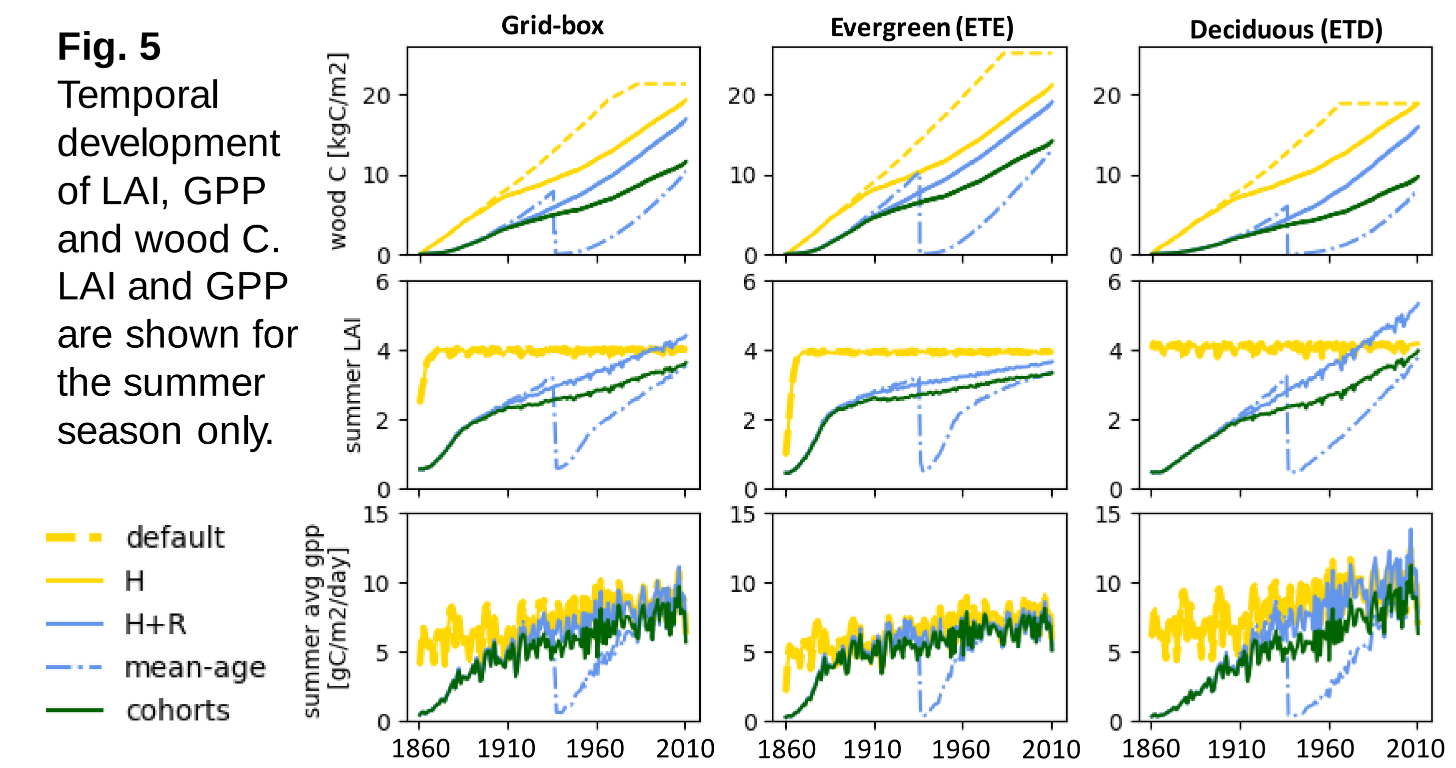

Fig. 5 Temporal development of LAI, GPP and wood C. LAI and GPP are shown for the summer season only.

We evaluated our regrowth and forest age scheme comparing simulated 2010 GPP, LAI and aboveground carbon (AGC) with data products (Tab. 2).

With the **H** simulation as reference – which is most representative of how JSBACH is used in CMIP6 – the LAI and GPP mean of the **cohorts** simulation have slightly improved for the evergreen (ETE) but not for the deciduous PFT (ETD). Whilst AGC significantly improved, it is still too high compared to the data.

		default	H	H+R	mean-age	cohorts [min,max]	data	source
LAI	ETE	3.96	3.96	3.66	3.37	3.34 [0.37-3.90]	2.62	[5]
	ETD	4.28	4.28	5.48	3.85	4.06 [0.45-6.28]	5.27	
GPP $[gC/m^2/d]$	ETE	7.12	7.12	6.85	6.30	6.41 [0.37-6.95]	5.33	[5]
	ETD	9.30	9.30	10.64	8.54	8.53 [0.49-10.75]	10.86	
AGC $[kgC/m^2]$		15.49	13.94	12.20	7.55	8.45	4.16	[6, 7]

Tab. 2 Comparison of simulation output and data. LAI and GPP from simulations and data [5] stem from day 212 of the year 2010. For AGC DOY 212 from the simulations was compared to the 2010 data value [6,7].

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