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Forests, savannas, and grasslands: bridging the knowledge gap between ecology and Dynamic Global Vegetation Models

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Supplementary S1

Bimodality analysis of the three DGVMs in an intermediate rainfall range

Methods

The bimodality test was performed with the "flexmix" package in R for finite mixture models regression (Grün and Leisch, 2007; Hirota et al., 2011; Yin et al., 2014), which assumes that each distribution is formed by a mixture of a number of normal distributions. The program implements the finite mixtures of regression models by the expectation–maximization (EM) algorithm (Grün and Leisch, 2007). To select the best fitting distribution, while being parsimonious at the same time, we use the integrated completed likelihood criterion (ICL), and the Akaike information criterion (AIC, Akaike, 1974) and we test one to four potential class models, following Yin et al. (2014). The lowest value of the ICL and AIC identify the best model. If the two indices identified different models, the differences between the resulting distributions are analysed further. In most of the cases the analyses showed that ICL is a better indicator (see also Yin et al. 2014). In some cases the algorithm could not find solutions by adding more normal distributions. In those cases, fewer than four classes are reported.

We performed the bimodality test for the three models output in different mean annual rainfall range. If bimodality was observed in a certain mean annual rainfall range, the sensitivity of this finding to set range boundaries was tested by choosing more narrow rainfall ranges. If in that case no bimodality was observed, the bimodality observed in the wider rainfall range was probably due to a shift of the distribution from a state to another along the gradient. This reduction of the rainfall range was performed only down to at least 100 model points.

Results

According to the bimodality analysis of JSBACH outputs on tree cover, the forest is unimodally distributed for mean annual rainfall between 800 and 1200 mm y^{-1}. According to ICL, three ranges were identified where bimodality occurs (400-800, 500-1000 and 400-900 mm y^{-1}). For those ranges, the AIC identified three or four Gaussians as the best fit for the distribution (see Table S1.1 and Fig. S1.1). More detailed analysis, however, showed that the peaks of the bimodal distribution (recognized as the best fit by ICL) were actually not well separated. Thus no bimodality was assessed in JSBACH model output. Please note that the range of mean annual rainfall could not be narrowed down further for this model because too few points would then be selected (JSBACH has 1.9x1.9^{o} spatial resolution, lower than the other two models).

Table S1.1 ICL and AIC values for JSBACH tree cover output in different mean annual rainfall intermediate ranges. Values in bold represent the minimum value (i.e. the best model according to that index).

Range (mm y^{-1})	ICL				AIC				Comments on differences between ICL and AIC
	1	2	3	4	1	2	3	4	
800-1200	**-88**	-74	-16	42	-94	**-105**	-100	-94	Unimodal (small separation between the peaks)
400-800	-24	**-34**	-4	46	-30	-60	**-68**	-63	(%) The two peaks are not well separated, the fit with three (four) Gaussians captures extra peak(s) in between the other two
500-1000	-55	**-60**	-35	-22	-61	-94	-101	**-105**	(%)
400-900	-33	**-41**	5	72	-39	-71	**-75**	-69	(%)

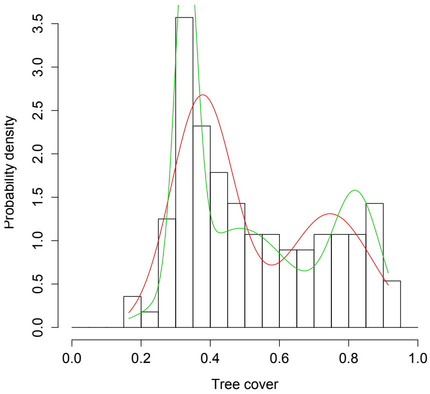

Fig. S1.1 Probability density distribution of tree cover for the JSBACH output, for mean annual precipitation between 400 and 800 mm y^{-1} mean annual rainfall. Red line represents bimodal distribution (i.e. it is fitted significantly better by a superposition of two normal distributions, according to ICL), denoting not very well separated peaks. Green line represents trimodal distribution (given by a superposition of three gaussians, best fit according to AIC), which captures the non-separateness of the bimodal distribution fitting a third peak in between.

When performing the analysis for LPJ-GUESS-SPITFIRE tree cover data, we observed a bimodality of grassland and forest when considering a quite wide rainfall range (e.g. 400 to 1200 mm y^{-1}, 500-1000 see Table S1.2). However, when splitting this rainfall range into smaller ranges, the bimodality reduced to unimodality. In one case (600-800 mm y^{-1}), we still observed bimodality of grassland (~ 15% tree cover) and forest (~ 70% tree cover). It must be noticed that this bimodality was observed in a very narrow rainfall range only, and it did not represent the bimodality of savanna and forest we are interested in. Thus, we can state that LPJ-GUESS-SPITFIRE does not display bimodality of savanna and forest.

Table S1.2 ICL and AIC values for LPJ-GUESS-SPITFIRE tree cover output in different mean annual rainfall intermediate ranges. Values in bold represent the minimum value (i.e. the best model according to that index).

Range (mm y^{-1})	ICL				AIC				Comments on differences
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
500-1000	77	-535	**-583**	-434	-86	-602	-689	**-717**	(*) Kind of bimodality between forest and grassland: three peaks, middle peak with very low density, and fourth peak is basically coincident
800-1200	**-1350**	-1204	-1196		-1359	-1404	**-1424**		($) Unimodal (coincident peaks)
400-1200	236	-657	**-757**	-697	226	-717	-929	**-1027**	As **(*)**
1000-1200	**-756**	-630			-763	**-772**			As ($)
400-700	97	-91	**-136**	-119	90	-129	-210	**-235**	Three peaks (fourth peak coincides)
800-1000	**-702**	-602	-580	-585	-709	-718	**-726**		As ($)
600-800	-62	**-234**	-234		-69	-254	**-283**		As (*)

For aDGVM, we performed the analysis for several ranges of rainfall, and we observed bimodality of intermediate (i.e. savanna) and high (i.e. forest) cover values in all of the intermediate rainfall values chosen. See Tab. S1.3 for indices values. In Figure S1.2 we depicted the bimodality for data with mean annual rainfall between 800 and 1200 mm y^{-1}.

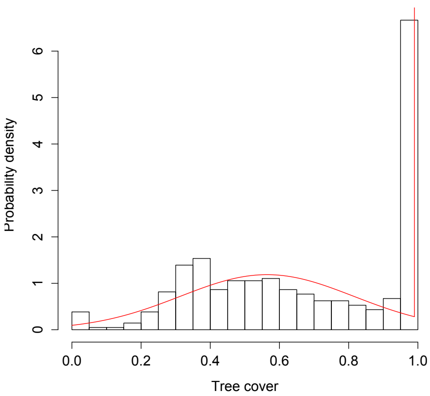

Fig. S1.2 Probability density distribution of tree cover for the aDGVM output, for mean annual precipitation between 800 and 1200 mm y-1 mean annual rainfall. The distribution is bimodal between savanna and forest (i.e. it is fitted significantly better by a superposition of two normal distributions).

Table S1.3 ICL and AIC values for aDGVM tree cover output in different mean annual rainfall intermediate ranges. Values in bold represent the minimum value (i.e. the best model according to that index).

Range (mm y^{-1})	ICL				AIC				Comments on differences between ICL and AIC
	1	2	3	4	1	2	3	4	
1000-1200	78	**-1412**	-1275		71	**-1429**	-1423		-
800-1200	157	**-2634**	-2330	-2469	149	-2654	-2648	**-2715**	(Δ) Four peaks are not well separated (coincide with 2)
800-1000	83	**-1213**	-1168	-1172	77	-1230	-1244	**-1251**	As (Δ)
700-1400	343	**-4185**			334	**-4207**			-
500-1500	616	**-4906**			606	**-4931**			-
1000-1300	139	**-2102**	-1878		131	**-2121**	-2115		-
500-800	137	**-540**	-504		129	-559	**-594**		As (Δ)

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Table S1

The coefficient *b* of the quantile nonlinear regression curves for the model and observational data. Values for the 90th and 99th quantile are reported.

Data series	**Figure and panel**	***b*, 90th quantile** [mm^2 y^{-2}]	***b*, 99th quantile** [mm^2 y^{-2}]
Field observation	Fig. 1A	5.8E+05	3.0E+05
MODIS observation	Fig. 1B	4.1E+05	1.9E+05
JSBACH/DYNVEG	Fig. 2A	1.4E+05	6.1E+04
LPJ-GUESS-SPITFIRE	Fig. 2B	6.1E+04	4.4E+03
aDGVM	Fig. 2C	3.9E+04	5.4E+03