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Towards a more detailed representation of high-latitude vegetation in the global land surface model ORCHIDEE (ORC-HL-VEGv1.0)

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Table S1: Conversion table use to obtained vegetation coverage map from the ESA CCI LCC map.

ID	CCI ESA Land Cover Class Description	Trees				Shrub				Herbaceous		NVPs	Non-vegetated				
		BE	BD	NE	ND	BE	BD	NE	ND	Natural	Crops		Bare soil	Water	Snow/Ice	Urban	No data
0	No data																100
10	Cropland, rainfed										100						
11	Herbaceous cover										100						
12	Tree or shrub cover						50				50						
20	Cropland, irrigated or post-flooding										100						
30	Mosaic cropland (>50%) / natural vegetation (<50%)	5	5			5	5	5		15	60						
40	Mosaic natural vegetation (>50%) / cropland (<50%)	5	5			7.5	10	7.5		25	40						
50	Tree cover, broadleaf, evergreen, closed to open (>15%)	90				5	5										
60	Tree cover, broadleaf, deciduous, closed to open (>15%)		50				20			30							
61	Tree cover, broadleaf, deciduous, closed (>40%)		70				15			15							
62	Tree cover, broadleaf, deciduous, open (15-40%)		30				25			45							
70	Tree cover, needleleaf, evergreen, closed to open (>15%)			50		2.5	2.5	15		30							
71	Tree cover, needleleaf, evergreen, closed (>40%)			70		5	5	5		15							
72	Tree cover, needleleaf, evergreen, open (15-40%)			30				25		45							
80	Tree cover, needleleaf, deciduous, closed to open (>15%)				50	2.5	2.5	2.5	12.5	30							
81	Tree cover, needleleaf, deciduous, closed (>40%)				70	5	5	5		15							
82	Tree cover, needleleaf, deciduous, open (15-40%)				30				25	45							

90	Tree cover, mixed leaf type (broadleaf and needleleaf)		30	20	10	5	5	5		25					
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	**7**	**15**	**4**	**5**	**8**	**15**	**6**		40					
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	**4**	**7**	**4**		**6**	**13**	**6**		60					
120	Shrubland					15	30	15		40					
121	Shrubland evergreen					30		30		40					
122	Shrubland deciduous						60			40					
130	Grassland									100					
140	Lichens and mosses									**10**	**70**	**20**			
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)		4.7	4.7	3.1		4.7	4.7	3.1	**10.0**	**45.0**	**20.0**			
151	Sparse tree (<15%)		9.4	9.4	6.2					**10.0**	**45.0**	**20.0**			
152	Sparse shrub (<15%)						7.5	7.5	5.0	**15.0**	**45.0**	**20.0**			
153	Sparse herbaceous cover (<15%)									**35.0**	**45.0**	**20.0**			
160	Tree cover, flooded, fresh or brakish water	37.5	37.5							25					
170	Tree cover, flooded, saline water	75				25									
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water						25	15		**30**	**30**				
190	Urban areas														100
200	Bare areas											100			
201	Consolidated bare areas											100			
202	Unconsolidated bare areas											100			
210	Water bodies												100		
220	Permanent snow and ice													100	

BE : Broadleaf Evergreen, BD : Broadleaf Deciduous, NE : Needleleaf Evergreen and ND : Needleleaf Deciduous.

Bold: modified values for the introduction of new boreal vegetation (i.e., shrubs, NVPs and cold climate grass PFTs)

Table S2: Description of the optimised parameters, with their initial value (prior), minimum (min), maximum (max) and the value obtained (POST). The value of the cost function is included in an indicative way.

Description (units)	**Parameters**	**prior**	**min**	**max**	**POST**
Non-Vascular Plants		(cost J(x) : before 40 880, after 28 240 (-31%))			
Stomatal conductance when irradiance is null ($Cmol.m^{-2}.s^{-1}.bar^{-1}$)	g_0	0.103	0.006	0.2	0.052
Empirical constants for conductance (-)	b_1	0.35	0.15	0.45	0.41
Senescence (day)		455	180	730	470
Maximal fraction of biomass loss (if NPP≤0) (day)	$k_{l\ max}$	0.015	0.005	0.025	0.0050
LAI seuil avant turnover	LAI_{lim}	2.5	2.3	2.7	2.4
Threshold leaf area index for turnover (day^{-1})	l_{coef}	0.007	0.0025	0.02	0.014
Root profile control parameter (-)	r_p	40	10	70	18
Offset of desiccation effect (-)	d_{off}	0.3	0.01	0.6	0.55
Maximum Leaf Area Index ($m^2.m^{-2}$)	$LAImax$	3	2	4	3.06
Maximum rate of carboxylation at 25°C ($\mu mol.m^{-2}.s^{-1}$)	$Vc_{max(25)}$	30	20	40	28
Specific Leaf Area ($m^2.gC^{-1}$)	SLA	0.017	0.004	0.03	0.0084
Maintenance respiration coefficient at 0°C ($gC.gC^{-1}.jour^{-1}$)	f_{m_resp}	0.0018	0.001	0.0026	0.0026
Boreal Shrubs		(cost J(x) : before 523 100, after 190 900 (-64%))			
Maximum height (m)	H_{max}	3	2.5	3.5	3.5
Specific Leaf Area ($m^2.gC^{-1}$)	SLA	0.02	0.012	0.028	0.027
Maximum Leaf Area Index ($m^2.m^{-2}$)	LAI_{max}	3.5	2.5	4.5	2.5
Maximum rate of carboxylation at 25°C ($\mu mol.m^{-2}.s^{-1}$)	$Vc_{max(25)}$	45	30	60	38
Residence Time (y)		30	10	50	32
Fraction of GPP which is lost as growth respiration (0-1)	f_{g_resp}	0.45	0.3	0.6	0.59
Boreal C3 Grasses		(cost J(x) : before 132 400, after 61 460 (-54%))			
Maximum rate of carboxylation at 25°C ($\mu mol.m^{-2}.s^{-1}$)	$Vc_{max(25)}$	50	30	70	40
Vc_{max} : Deactivation energy ($J.mol^{-1}$) *	E_d	195000	190000	200000	200000
Vc_{max} : Entropy constant ($J.mol^{-1}.K^{-1}.°C^{-1}$) *	b	-0.54	0	-1.08	0
Maximum rate of electron transport at 25°C					
Vj_{max} : Deactivation energy ($J.mol^{-1}$) *	E_d	195000	190000	200000	200000
Vj_{max} : Entropy constant ($J.mol^{-1}.K^{-1}.°C^{-1}$) *	b	-0.38	0	-0.76	0
Root profile control parameter (-)	r_p	7	4	10	5.6
Specific Leaf Area ($m^2.gC^{-1}$)	SLA	0.023	0.02	0.026	0.022

* J_{max} and Vc_{max} parameters, namely E_d and b, were linked for the optimisation.

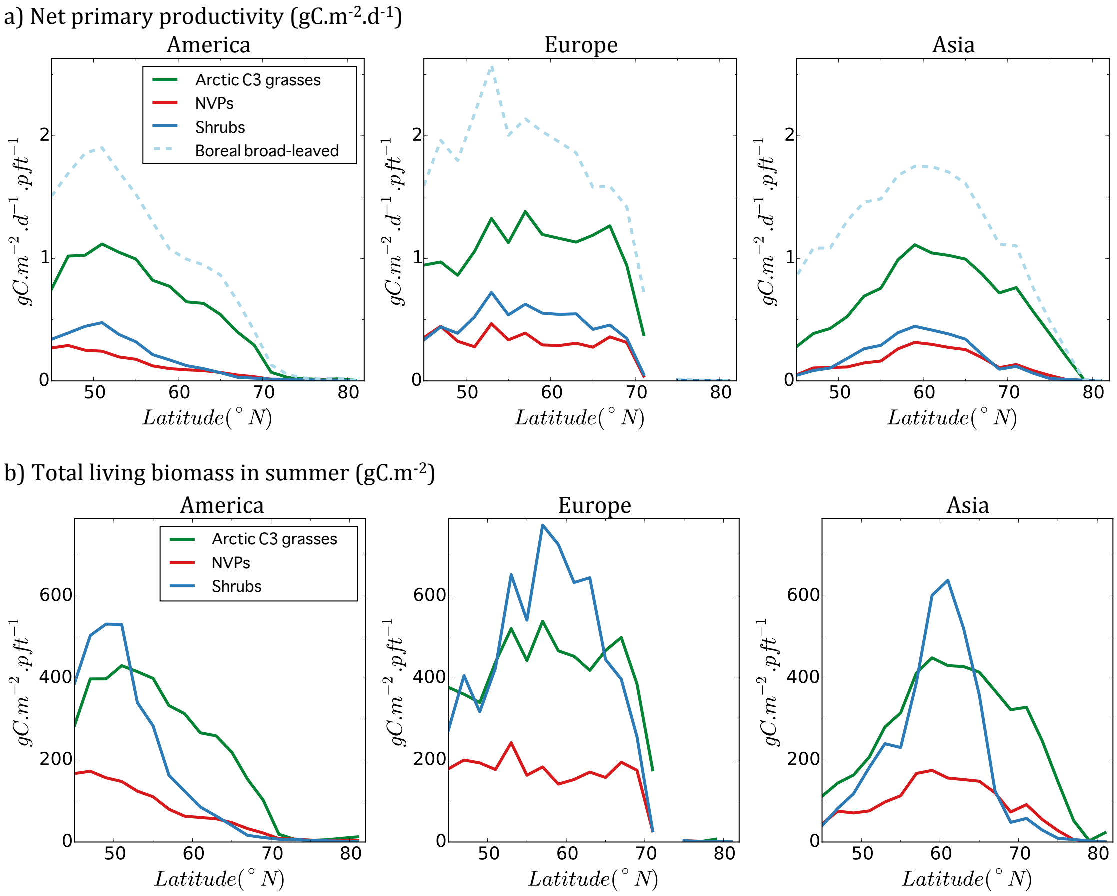

Figure S1: Latitudinal transects of the annual mean 2004-2013 net primary productivity (NPP) (a) and total living biomasses (b) of new PFTs (boreal C3 grasses, NVPs and boreal shrubs) and boreal broadleaf tree (dashed, only in a), simulated in ORC16. The results by PFT are averaged over North America (-180°E to -60°E, without Greenland), Europe (-20°E to 40°E) and North Asia (40°E to 180°E).

Figure S1 displays latitudinal transects of NPP and living biomass between 45°N and 82°N for each region. On average we obtain a similar latitudinal gradient in terms of productivity and biomass for all PFTs, with roughly a maximum in North America around 52°N (with above a continuous decrease until 72°N) and in Asia around 58°N (with a decrease until 78°N) and with a plateau in Europe between 50°N and 70°N (follow by an abrupt decrease). The shape of these latitudinal gradients is primarily controlled by the climate, especially the precipitation and temperature gradients with a strong influence of the topography. For example in Asia the precipitation gradient increases from 45°N (less than 280 mm.y^{-1}.m^{-2}) to a maximum around 55°N - 60°N (400 mm.y^{-1}.m^{-2}) and then decreases again northward, while the growing season (AMJ) mean air temperature (at 2m) decreases gradually from 45°N (+14°C) to 75°N (-7°C). For this region the decrease of precipitation from 60°N to 45°N explains the decrease of NPP and biomass. In Europe the climatic conditions are on average more favourable (e.g. +15°C at 45°N to +4°C à 70°N) which explains the higher productivity and biomasses at high-latitude (i.e. around 70°N).

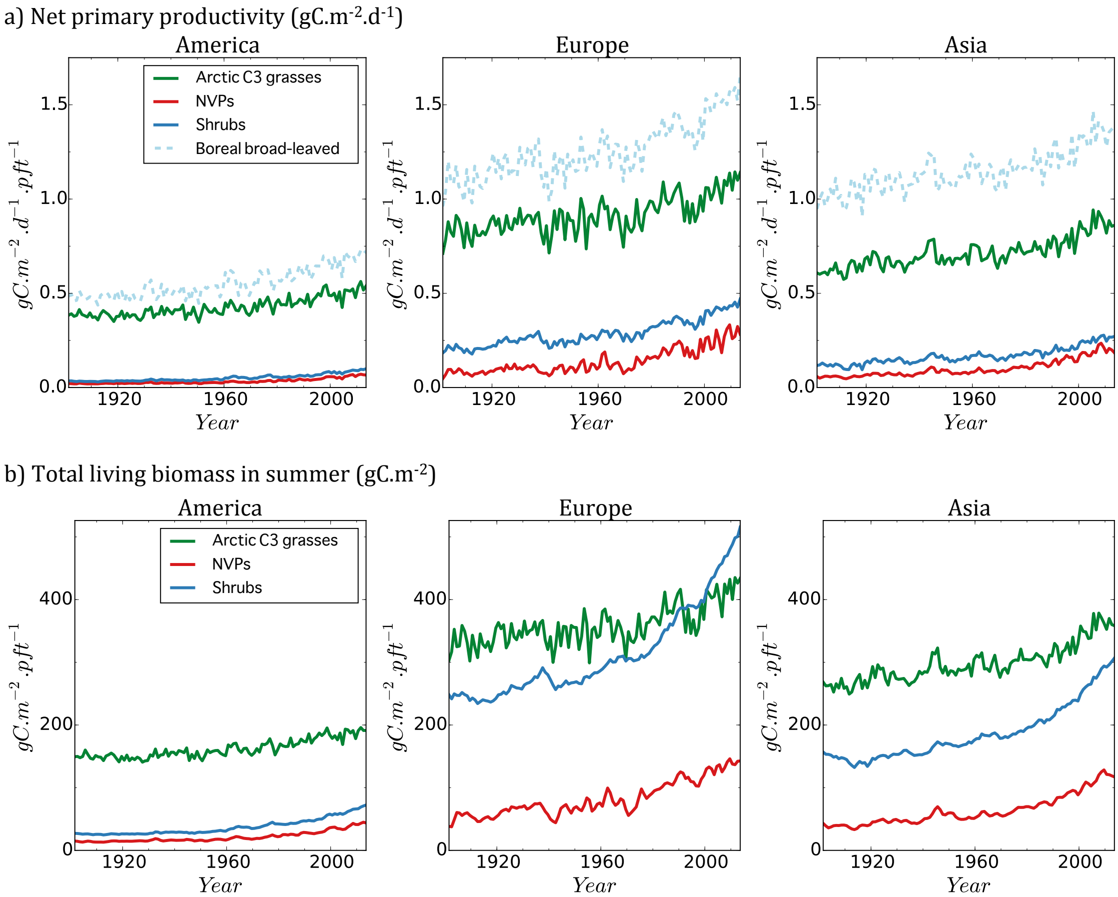

Figure S2: Time series from 1901 to 2013 and from 55°N of Net Primary Productivity (a) and total living biomass (b) of new PFTs (boreal C3 grasses, NVPs and boreal shrubs) and boreal broadleaf tree (dashed, only in a). The results are averaged over North America (-180°E to -60°E, without Greenland), Europe (-20°E to 40°E) and North Asia (40°E to 180°E).

Erreur ! Source du renvoi introuvable.shows the yearly time series from 1901 to present day for both NPP and living biomass, averaged north of 55°N. The simulated productivity increases on average for the three regions from 1950 to 2013: the increase of both NPP and biomass over the last 60 years is substantial for all PFTs, but largest for non-vascular plants and shrubs.

The combination of lower mortality and higher photosynthesis (due to temperature) in Europe, where the precipitation and the growing season temperatures are substantially larger (twice the precipitation and +6°C and + 10°C compared to America and Asia respectively), explains the higher increase in simulated biomass and NPP.

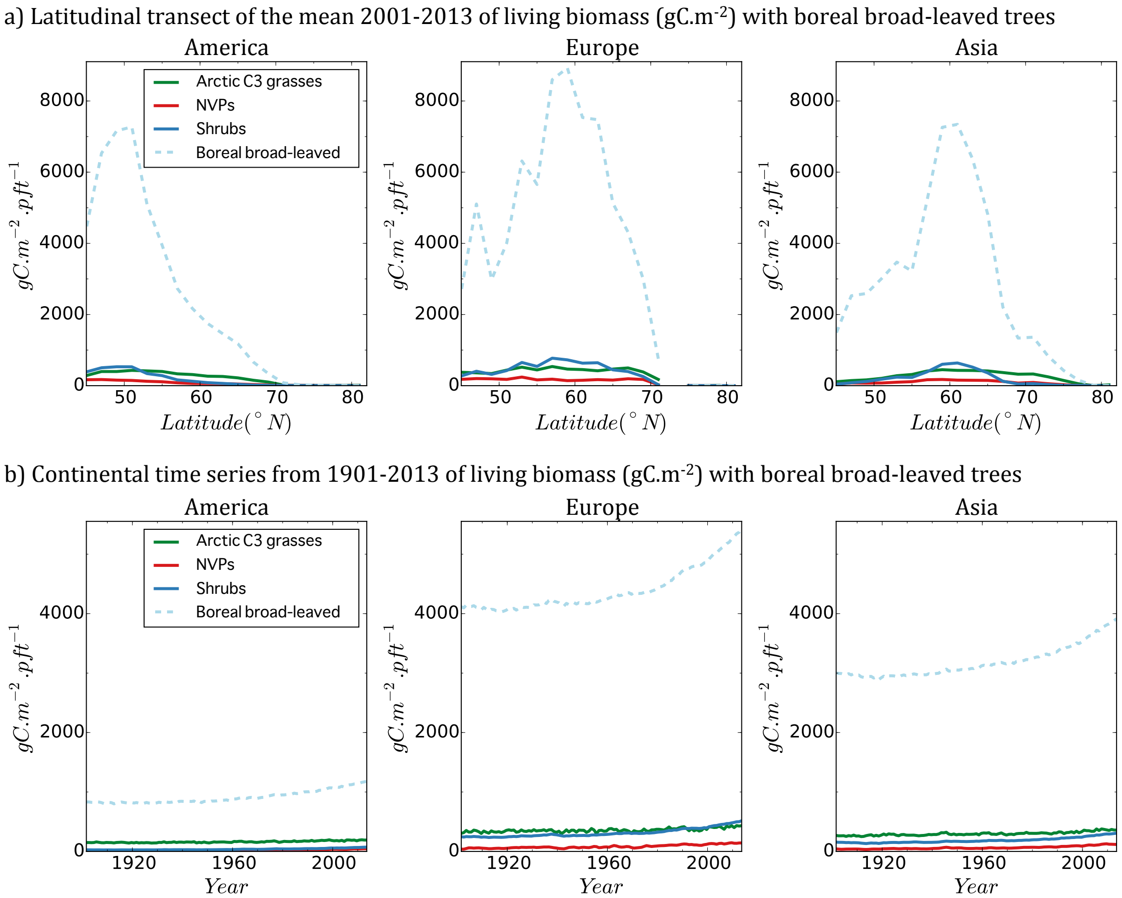

Figure S3: Latitudinal transects of the mean 2001-2013 (from 45°N) and time series from 1901 to 2013 (from 55°N) of total summer live biomass of new PFTs (cold climate C3 grasses, NVPs and boreal shrubs) and boreal broadleaf tree (dashed).

Only the new PFTs are shown (i.e., boreal C3 grasses, NVPs and shrubs), along with the boreal broad leaf deciduous trees (from which shrubs are derived).

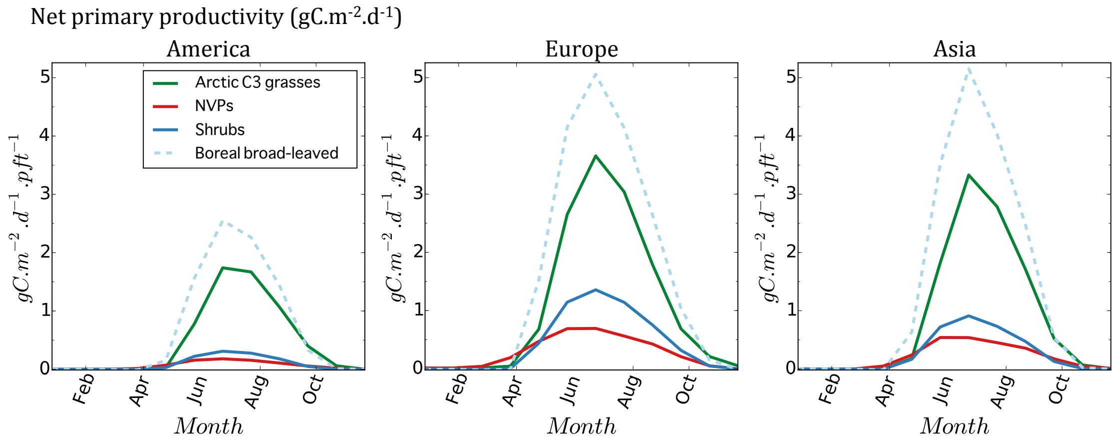

Figure S4: Inter-annual net primary productivity time series (mean 2004-2013) of new PFTs (boreal C3 grasses, NVPs and boreal shrubs) and boreal broadleaf tree (dashed).

Figure S4 displays the mean seasonal cycle of NPP for the three continental regions (mean over 2004-2013 and above 55°N). As expected, the growing season starts late spring with a sharp increase of the NPP up to July and then a slower decrease up to November, for all PFTs. The seasonality is slightly different for NVPs, for which the maximum is reached earlier (in June), with a small decrease over the summer (with sometimes locally a summer minimum in August) before the large decrease from September on.

Contrary to the other boreal PFTs, The NVPs display an earlier start of the growing season in spring (from March in Europe or April elsewhere) and a later end of season in autumn (after October) (not shown). During these two periods, more than 20% of the annual increase in NPP (Fig. S2) for NVPs occurs, while there is almost no increase for other PFTs.

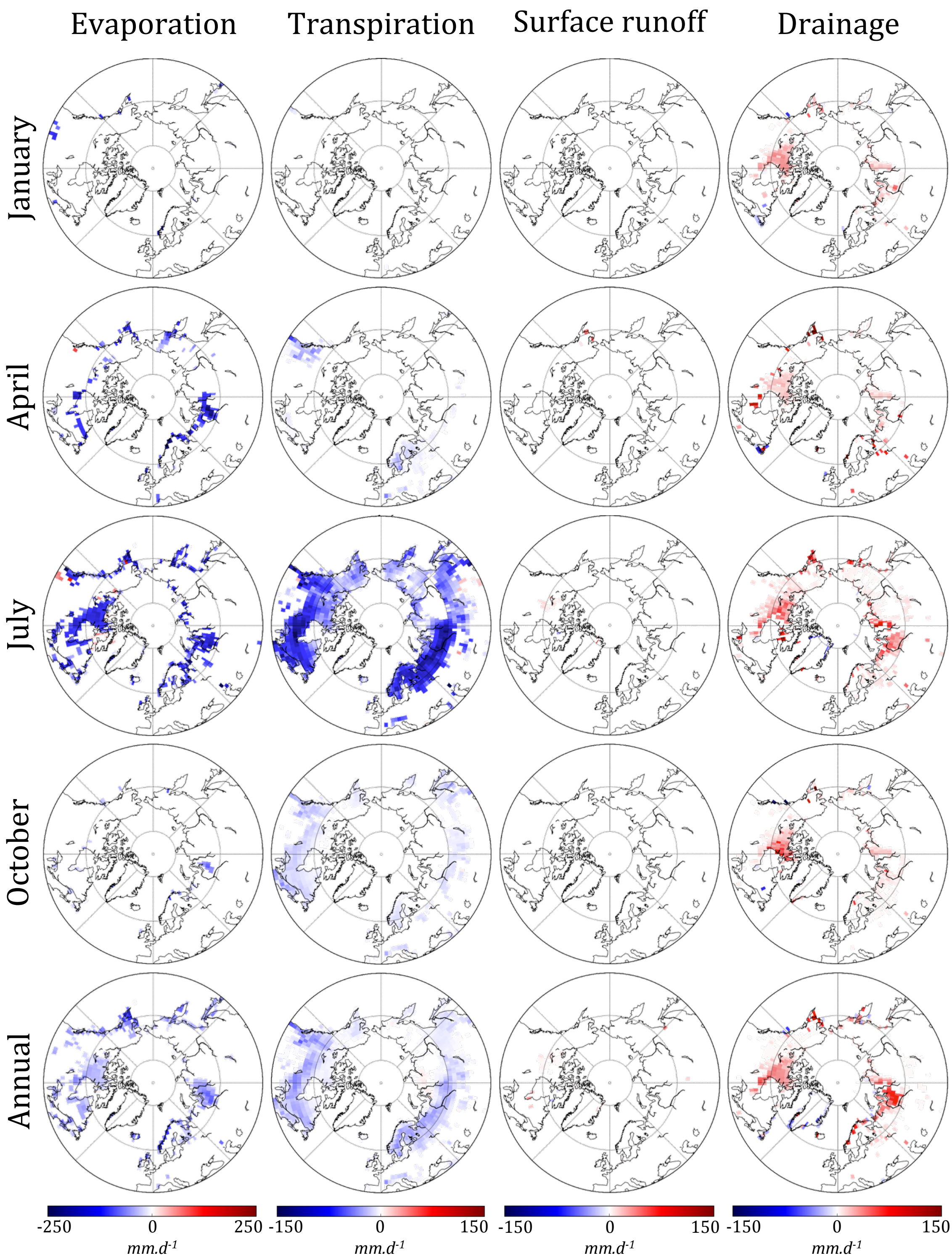

Figure S5: Maps of the significant differences (p_{value}=0.05) between the simulation with 16 PFTs (ORC16 with new boreal PFTs) and the simulation with the 13 PFTs (ORC13 standard version), for different components of the water balance: evaporation, transpiration, surface runoff and deep drainage for January, April, July, October, and the annual mean (mean over the period 2004 to 2013).