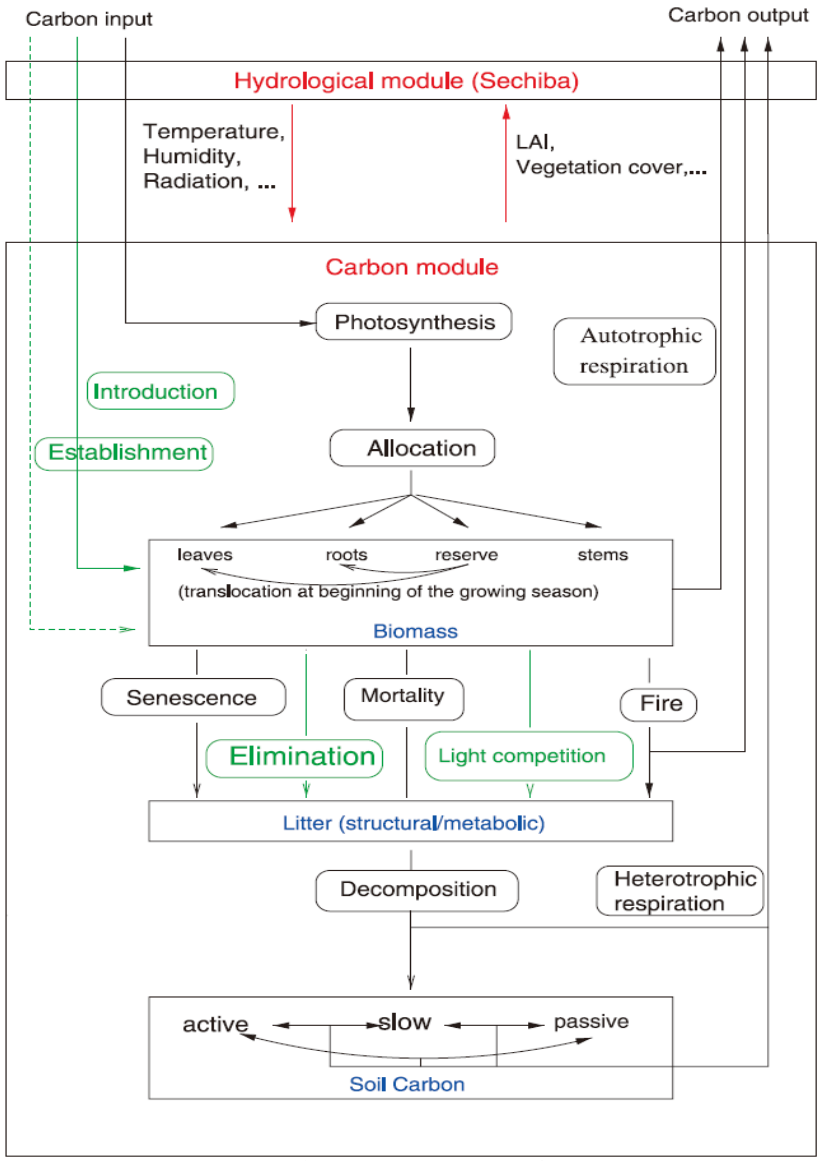
Northern vegetation dynamics calibrated and evaluated for ORCHIDEE

Dan Zhu, Shushi Peng, Philippe Ciais, Nicolas Viovy, Arsène Druel, Masa Kageyama, Gerhard Krinner, Philippe Peylin, Catherine Ottlé, Shilong Piao, Ben Poulter, Dmitry Schepaschenko

Background: DGVM



Basic structure of ORCHIDEE (Krinner et al., 2005)

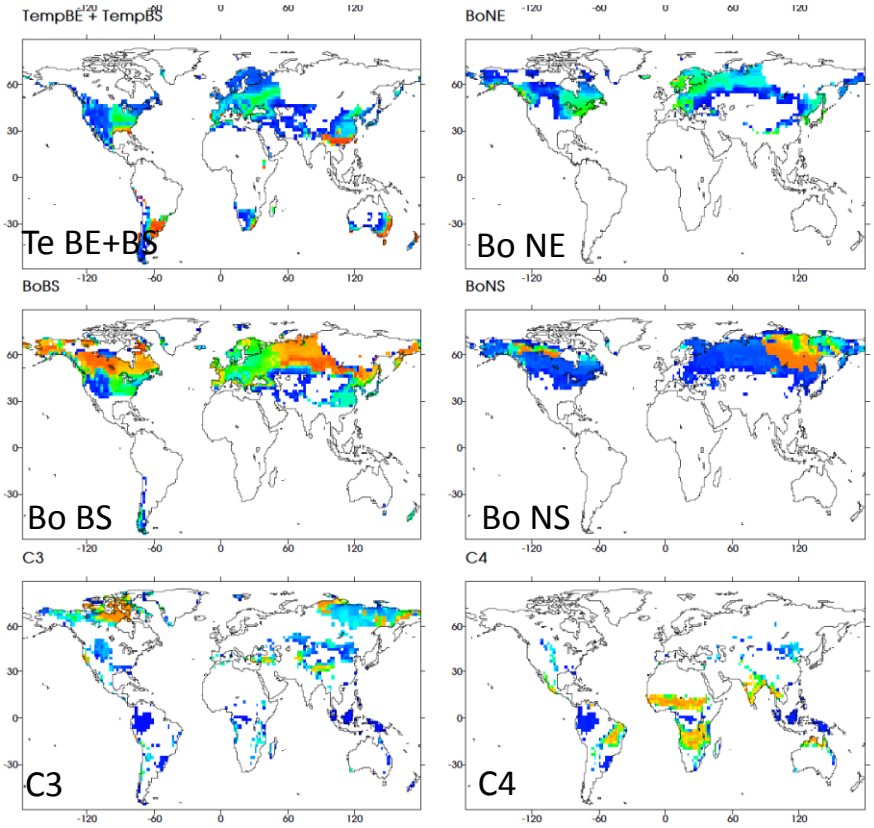
Dynamic **G**lobal **V**egetation **M**odel: simulates vegetation distribution dynamics and associated hydrological, biophysical and biogeochemical cycles in response to climate, CO_2,…

In ORCHIDEE, **vegetation dynamics** processes (green) was adapted from LPJ.

Problems in original ORCHIDEE vegetation dynamics (ORC-VD)

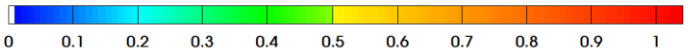
ORCHIDEE high latitude version (ORC-HL) has incorporated new or improved processes: 11-layer soil hydrology, soil freezing scheme…

But ORC-VD is not updated in pace with the rest of the model since Krinner et al. (2005), producing unrealistic results in dynamic runs:



Overestimation of BS tree in NE dominated forests

Vegetation fractions (% of grid cell)



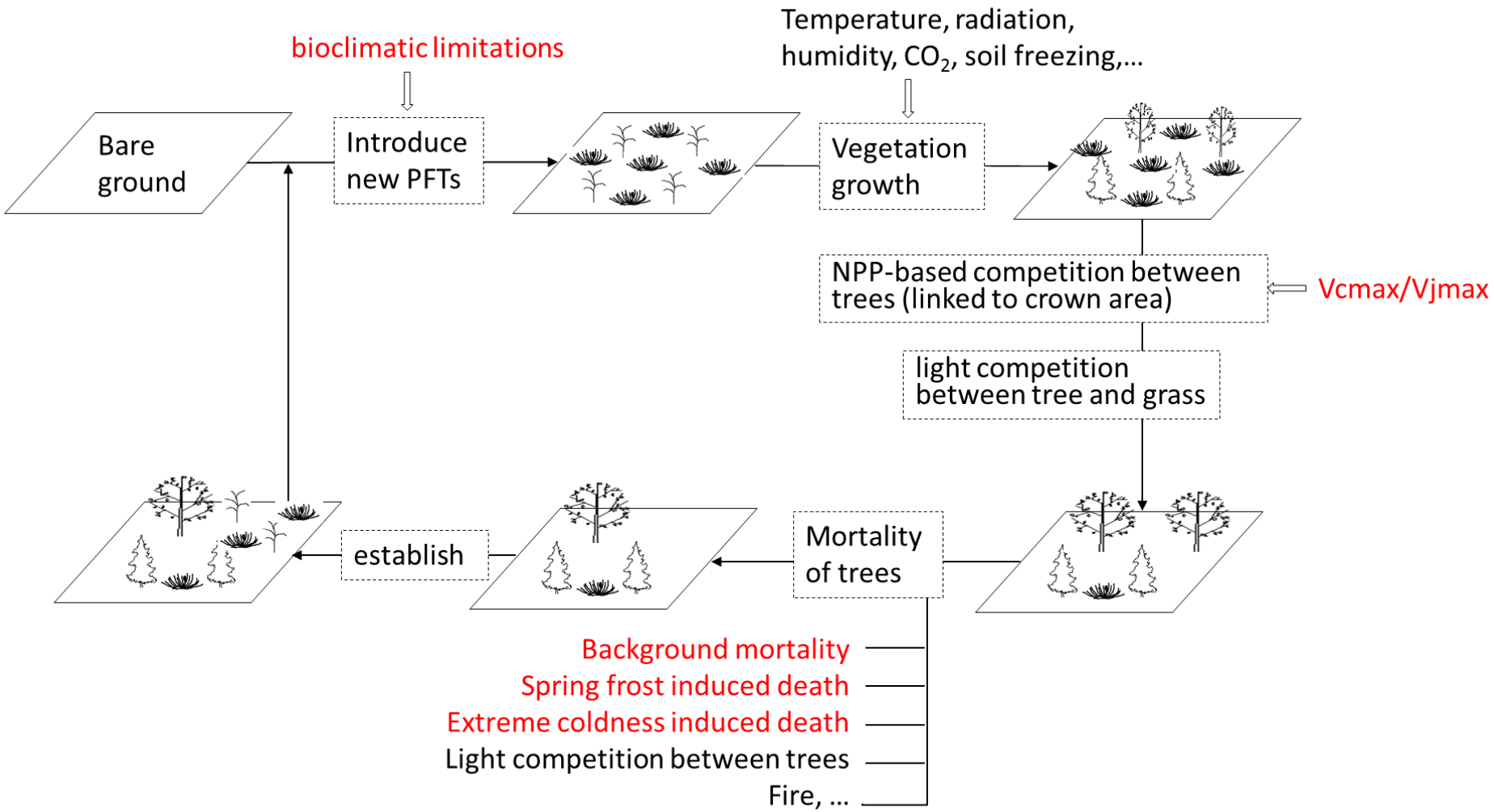
(Woillez et al., 2011)

Goals

- Improve ORC-HL-VD with a focus on northern hemisphere vegetation dynamics
- Use different set of recent observations to evaluate model performances using quantitative metrics

Methods: Modifications in ORC-VD (implemented in high latitude version)

Schematic of ORC-VD. The modifications are marked red:



Methods

Simulation protocal:

Name	Model	Module	Spinup		Simulation (1850-2010)	
			Climate forcing	CO_2 level	Climate forcing	CO_2 level
NEW	ORC-HL-NVD	Activate ORC-VD, soil freezing and fire schemes	CRUNCEP 1901~1920 cycle	285ppm	CRUNCEP 1901-2010 (from 1850-1900: randomly select from 1901~1920)	rising
OLD	ORC-HL-OVD	/	/	/	/	/

Evaluation datasets:

- Vegetation distribution: ESA CCI land cover v1.1 (ESA); GLC2000 (JRC, 2003); ISLSCP II vegetation continuous field (Defries and Hansen, 2009)
- GPP: MTE (Jung et al., 2011)
- Forest biomass: (Thurner et al., 2013)
- Soil carbon: HWSD, NCSCD (Hugelius et al., 2013)

Methods: Metrics for evaluation

- Most metrics do not consider observational uncertainty
- The choice of an observation for model evaluation may highly influence the model performance score
- In this study, a metric normalized by observational uncertainty (Skill, S) is defined

For PFT fractional abundance:

$$\beta_{c,M\_O_i} = \sqrt[2]{\sum_k^n (V_{k,c,M} - V_{k,c,O_i})^2} \; ; \beta_{c,O_i\_O_j} = \sqrt[2]{\sum_k^n (V_{k,c,O_i} - V_{k,c,O_j})^2}$$

where

$V_{k,c,M}$ / V_{k,c,O_i}: fractional cover for PFT k and for grid cell c, simulated by model or from observational dataset i;

n=11, the number of natural PFTs.

Beta diversity (β) is bound to [0,$\sqrt{2}$]. Higher values represent larger discrepancy between two PFT maps.

$$S_{V,c} = \overline{\beta_{c,O\_O}} / \overline{\beta_{c,M\_O}}$$

The $S_{V,c}$ were averaged over Northern Hemisphere to get an overall score (S_V).
Grid cells where $S_{V,c}$>1 were excluded, because in these pixels the observational data have too large uncertainties to be qualified for model evaluation.

Methods: Metrics for evaluation

For GPP and forest biomass:

$$S_{G,c} \; or \; S_{B,c} = \frac{\sigma_O}{|X_{c,M} - X_{c,O}|}$$

where

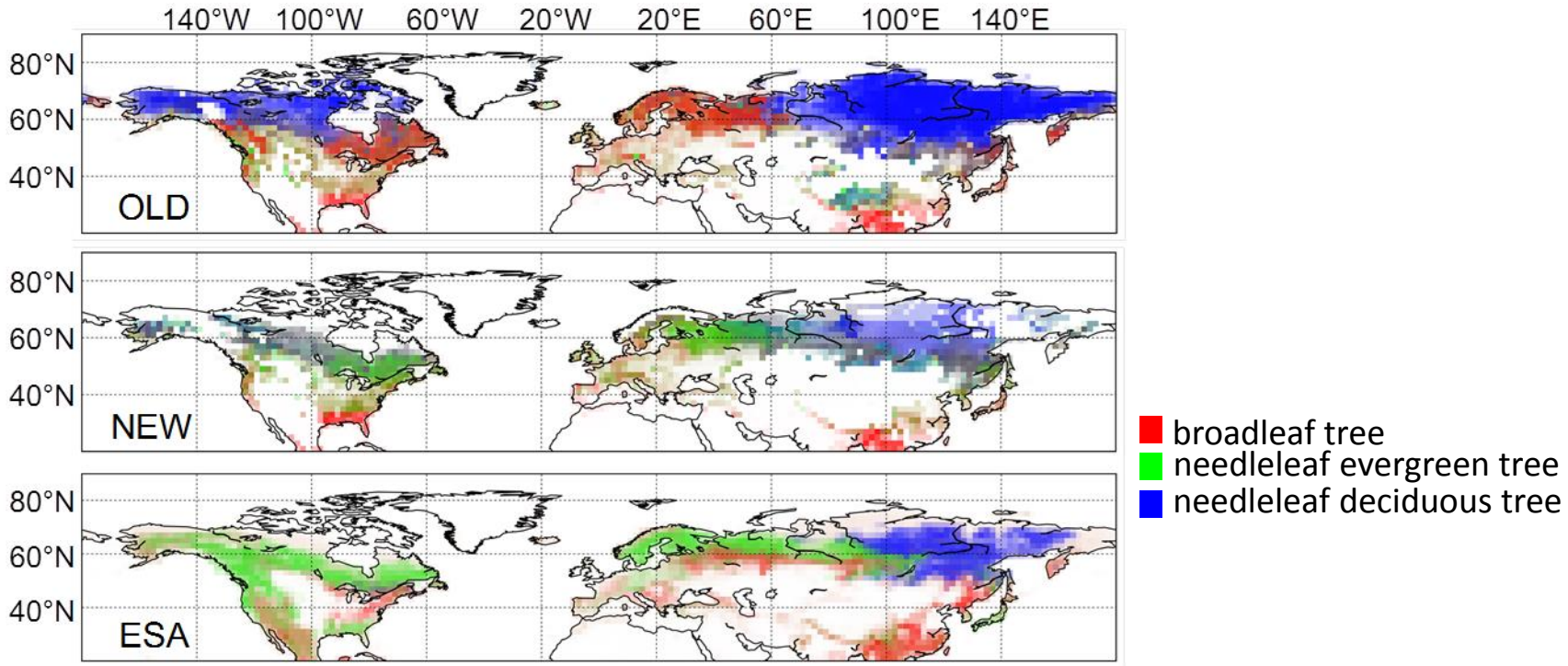
$X_{c,M}$ / $X_{c,O}$: GPP or forest biomass for grid cell c, simulated by model or from observation;

σ_O: standard deviation of observation.

In grid cells where $|X_{c,M} - X_{c,O}| < \sigma_O$, $S_{G,c}$ or $S_{B,c}$ is set to 1.

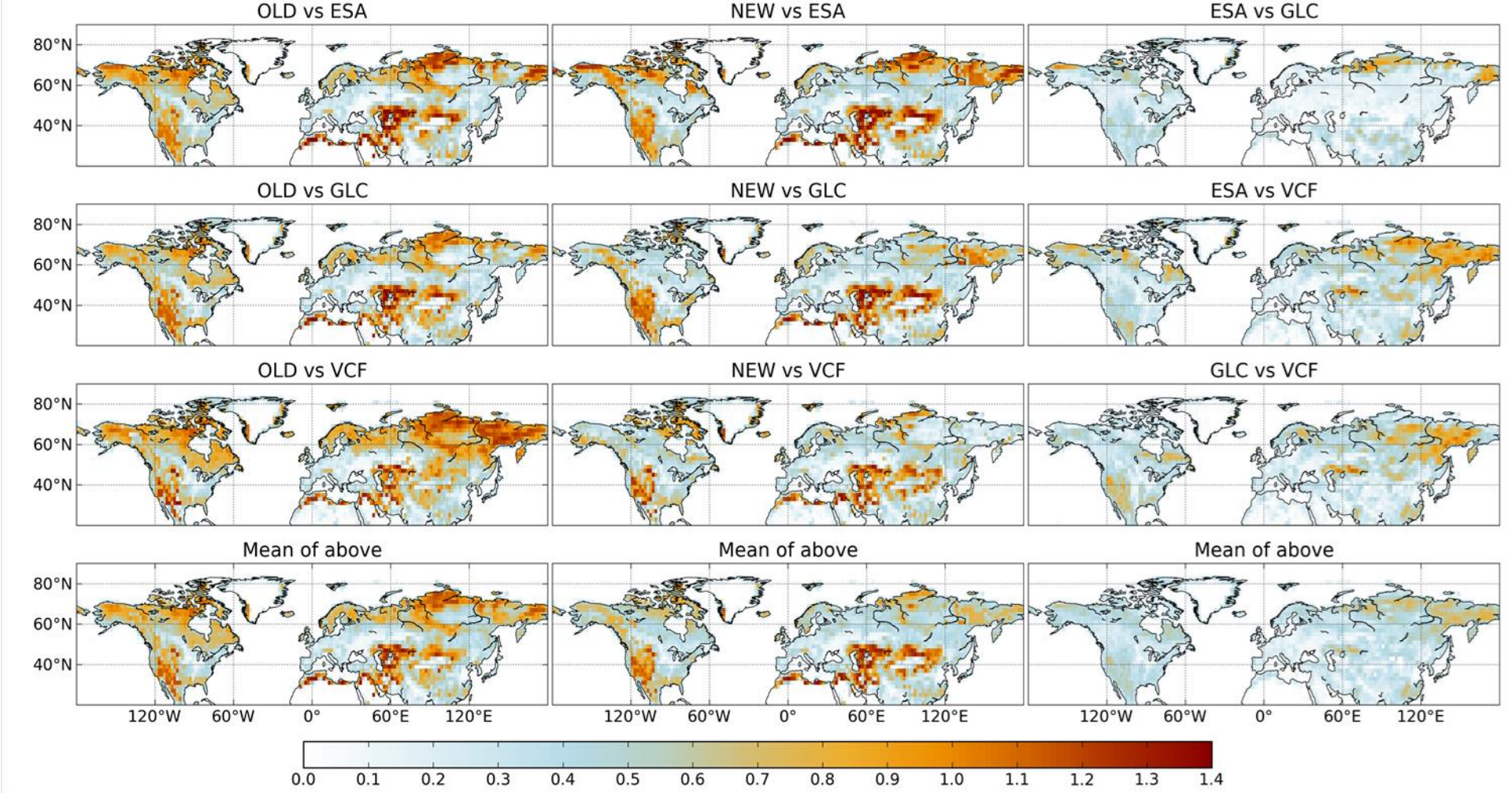
The $S_{G,c}$ or $S_{B,c}$ of each grid cell were averaged over Northern Hemisphere to get an overall score (S_G or S_B).

Results: Northern hemisphere vegetation distribution



Composite-color map of the fractional vegetation cover in OLD, NEW and observation-derived PFT map converted from ESA

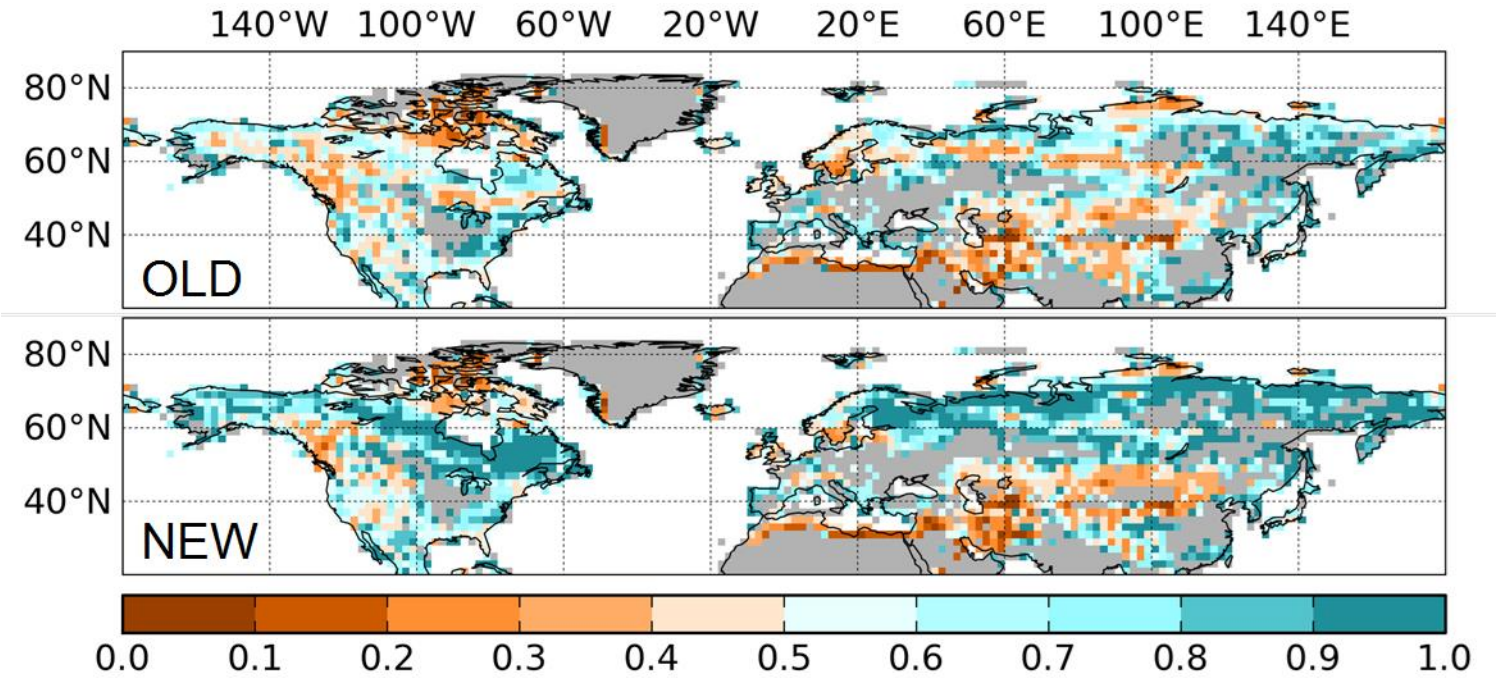
Results: Northern hemisphere vegetation distribution



β to quantify the dissimilarity in vegetation distribution. β ranges from 0 to $\sqrt{2}$, with higher values representing larger disagreement.

- The average β for NEW versus ESA, GLC and VCF are of 0.57, 0.49 and 0.48 respectively, equivalent to a 2.3%, 13% and 25% reduction (i.e. improvement) compared with OLD

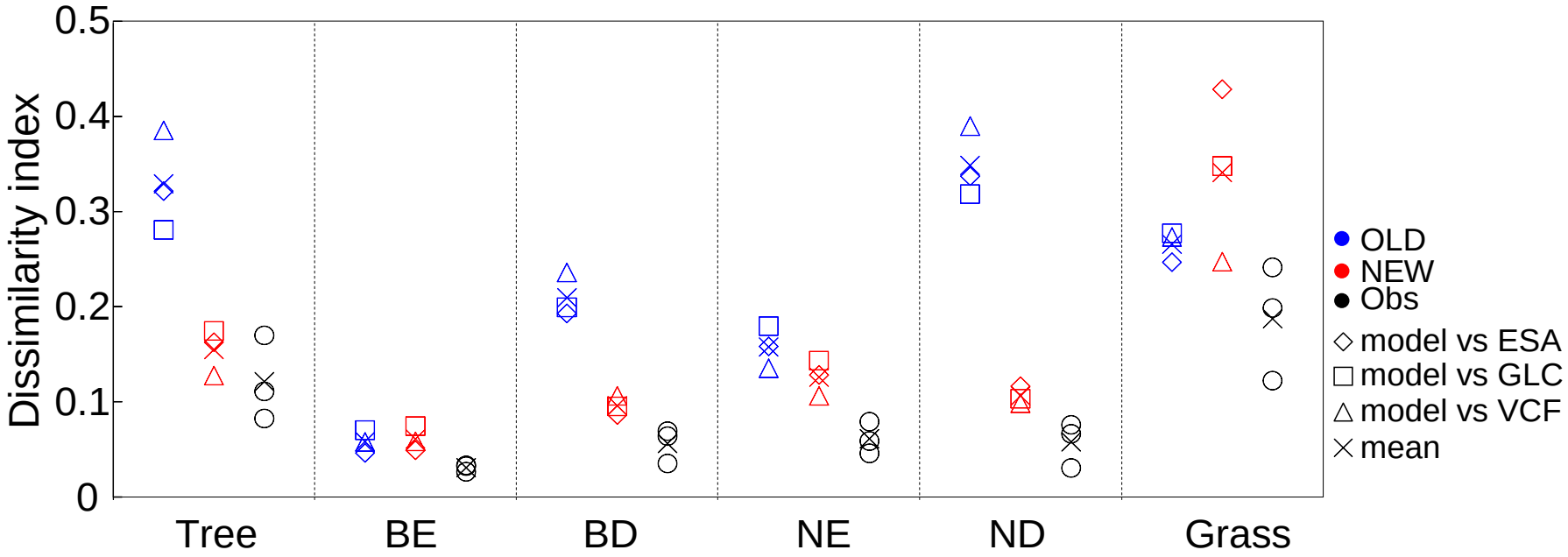
Results: Northern hemisphere vegetation distribution



Model skill to simulate vegetation distribution (S_V) for OLD and NEW. The grid cells where $S_{V,c}$>1 for both models and where crop fraction is higher than 0.5 are masked out (in grey).

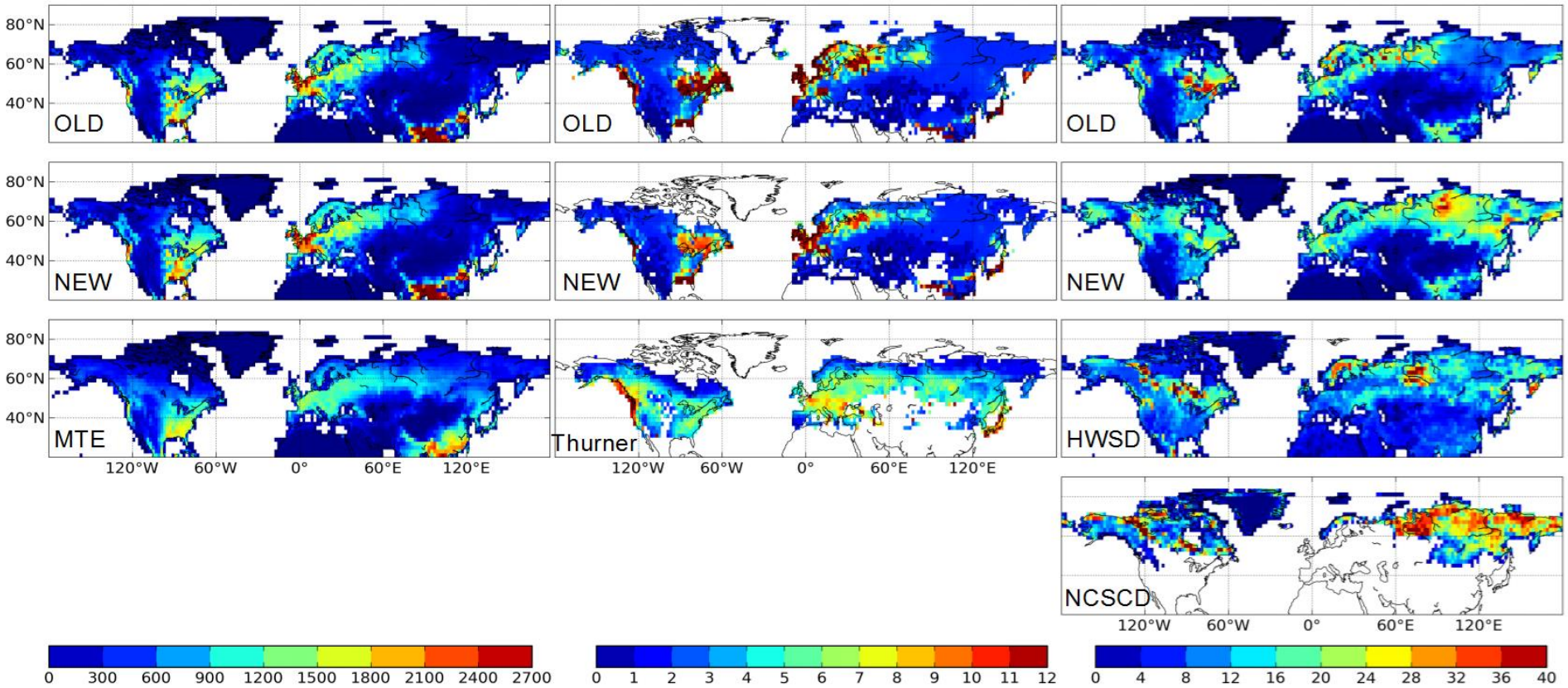
- The overall S_V for Northern Hemisphere is 0.72 in NEW compared to 0.60 in OLD (20% improvement)
- In OLD, 13% of the land grid cells have a β_{c,M_O} value less than the uncertainty between different satellite products (β_{c,O_O}); in NEW, this fraction increases to 27%.

Results: Distribution of specific groups of PFTs



Dissimilarity index (D) for fractional cover of PFT groups averaged over Northern Hemisphere (20°N-90°N). D ranges from 0 to1, with higher values representing larger disagreement. BE, broadleaf evergreen; BD, broadleaf deciduous; NE, needleleaf evergreen; and ND, needleleaf deciduous.

Results: GPP, forest biomass, total soil carbon



Northern Hemisphere (20°N-90°N)	Forest area (Mkm^2)	GPP (PgC/yr)	Forest biomass (PgC)	Total soil carbon (PgC)
OLD	26.5	43.1	117.6	265 (no peat)
NEW	17.5	44.8	77.4	382 (no peat)
Literature	17.2 (Pan et al., 2011)	42.2±2.4 (Jung et al., 2011)	79.8 (Thurner et al., 2013)	460 (NCSCD, 0~1m)

Results:

Model skills to simulate vegetation distribution (S_V), GPP (S_G) and forest biomass (S_B), averaged over different countries/regions.

		Asian Russia	European Russia	Canada	USA	Europe	China	Northern Hemisphere (20°N-90°N)
Vegetation distribution	OLD	0.68	0.64	0.53	0.60	0.56	0.66	0.60
	NEW	0.92	0.87	0.72	0.67	0.59	0.69	0.72
GPP	OLD	0.52	0.69	0.59	0.59	0.57	0.62	0.63
	NEW	0.54	0.64	0.50	0.57	0.55	0.63	0.61
Forest biomass	OLD	0.52	0.53	0.37	0.49	0.56	0.49	0.46
	NEW	0.64	0.65	0.59	0.55	0.66	0.53	0.59

Summary

- The new version of the ORCHIDEE vegetation dynamics module shows marked improvement in the simulated PFT distribution

- A new set of metrics is proposed, which integrate uncertainties in observational datasets. This multi-datasets evaluation framework could be applied to the evaluation of other DGVM models

Thanks!