

Evaluation of vegetation cover and land surface albedo in MPI-ESM CMIP5 simulations

Victor Brovkin, Lena Boysen, Thomas Raddatz,
Veronika Gayler, Alexander Loew, Martin Claussen

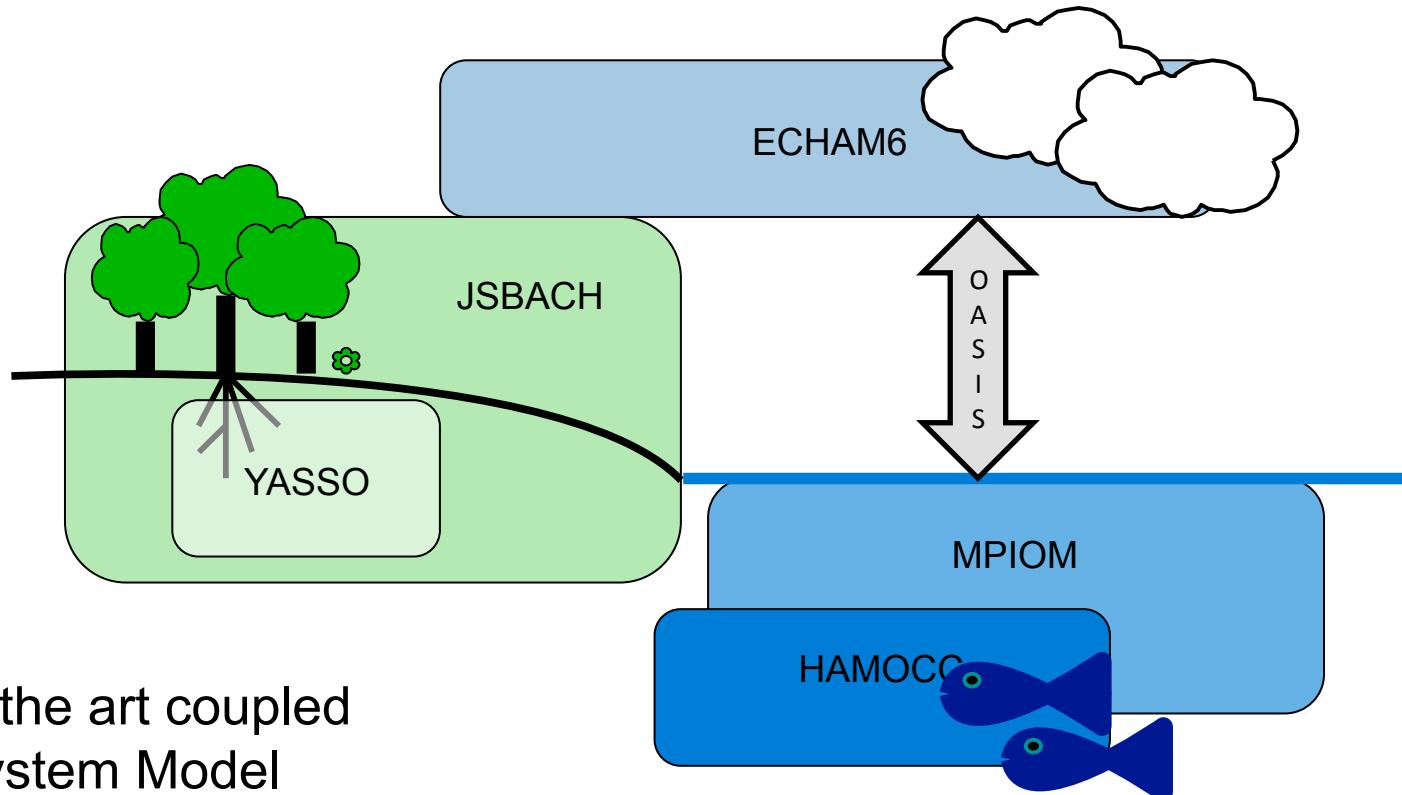
Max-Planck Institute for Meteorology, Hamburg, Germany



Why to evaluate vegetation cover and land surface albedo?

- Biogeography / offline DGVMs / ESMs simulate vegetation cover -> require datasets and metrics to evaluate their quality
- History:
 - Metrics - the Kappa statistics (Monserud and Leemans, EcoMod, 1992). For discrete classes (biomes), complications with spatial shifts of biomes
 - Reference dataset – complication with preindustrial veg map (Ramankutty and Foley, GBC, 1999, in Cramer et al., GBC, 2001, formulated in discrete classes)
- Currently:
 - Metrics – PFT-based (continuous)
 - Datasets - MODIS VCF, ESA land cover
- Albedo: affected by vegetation cover, eg snow masking effect

MPI-ESM in CMIP5/CMIP6



- State of the art coupled Earth System Model
- Developed at Max Planck Institute for Meteorology

land surface model JSBACH

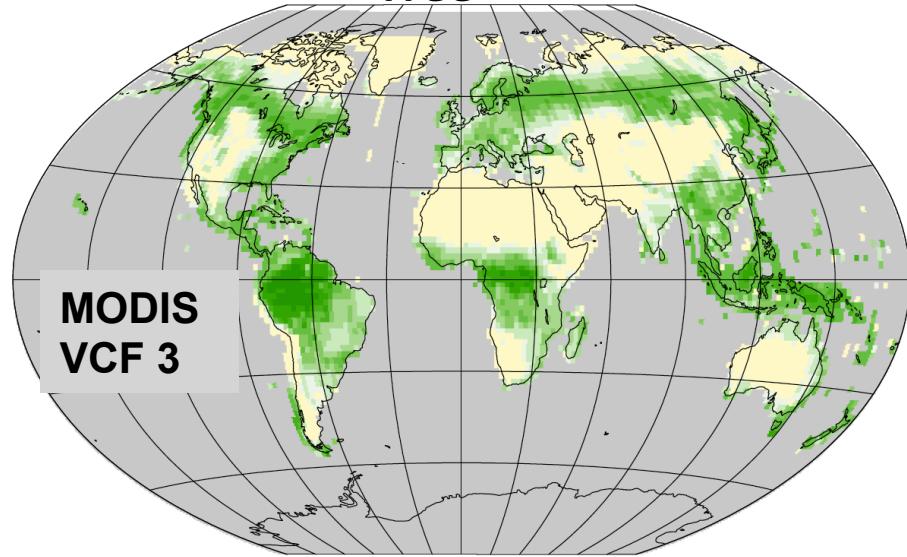
- dynamic vegetation model, landuse
- Improved 5-layer hydrology
- soil C model YASSO

Offline JSBACH extensions

- physical permafrost model (Ekici et al., 2014)
- C in permafrost
- wetland scheme
- methane transport model (Kaiser et al., GMDD, 2016)

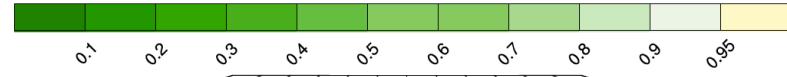
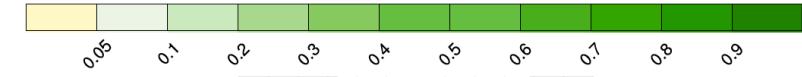
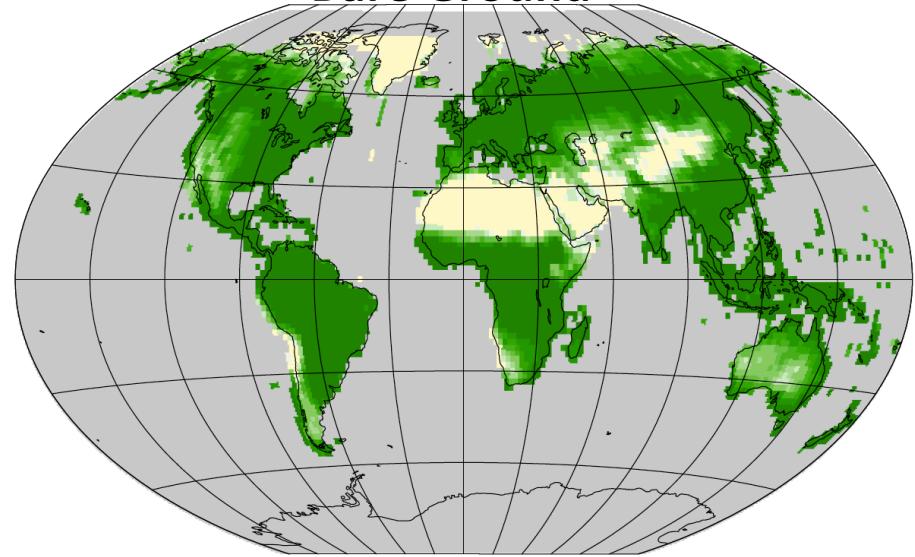
Evaluation of vegetation cover in MPI-ESM

Tree

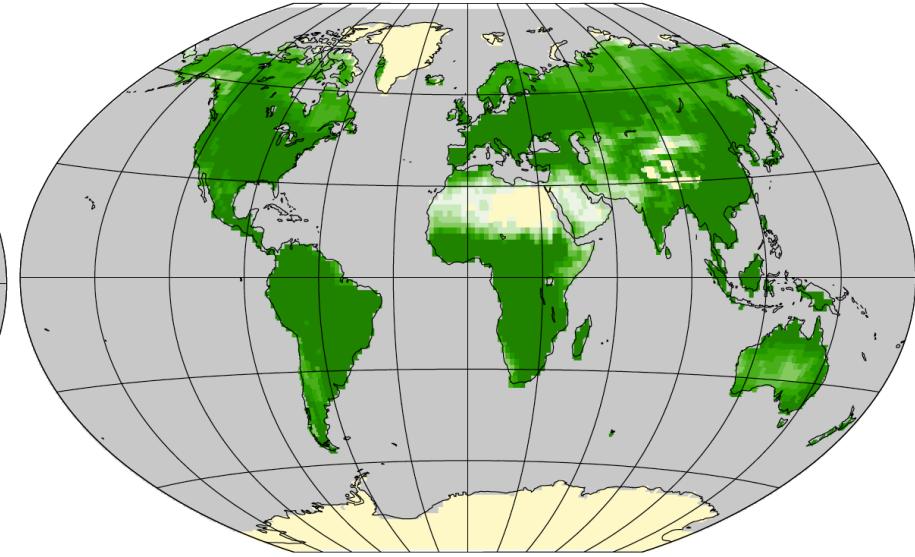
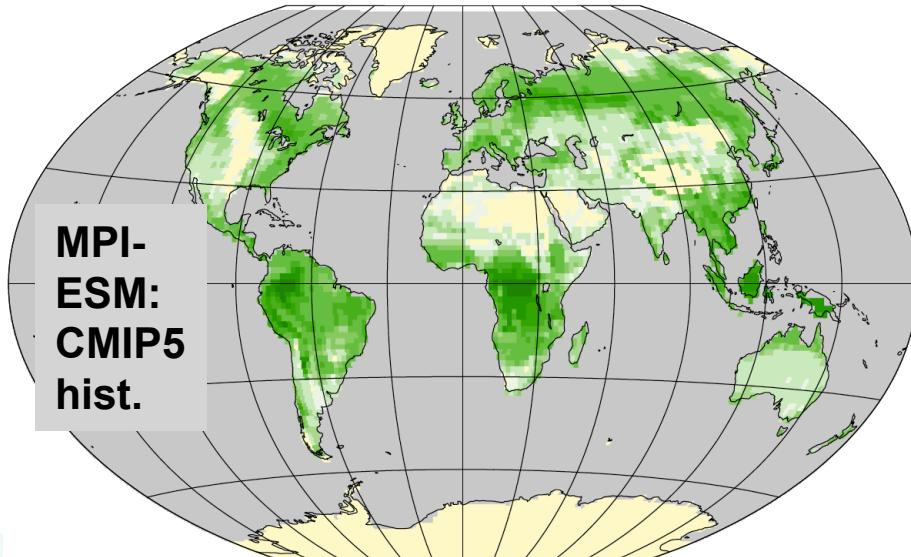


MODIS
VCF 3

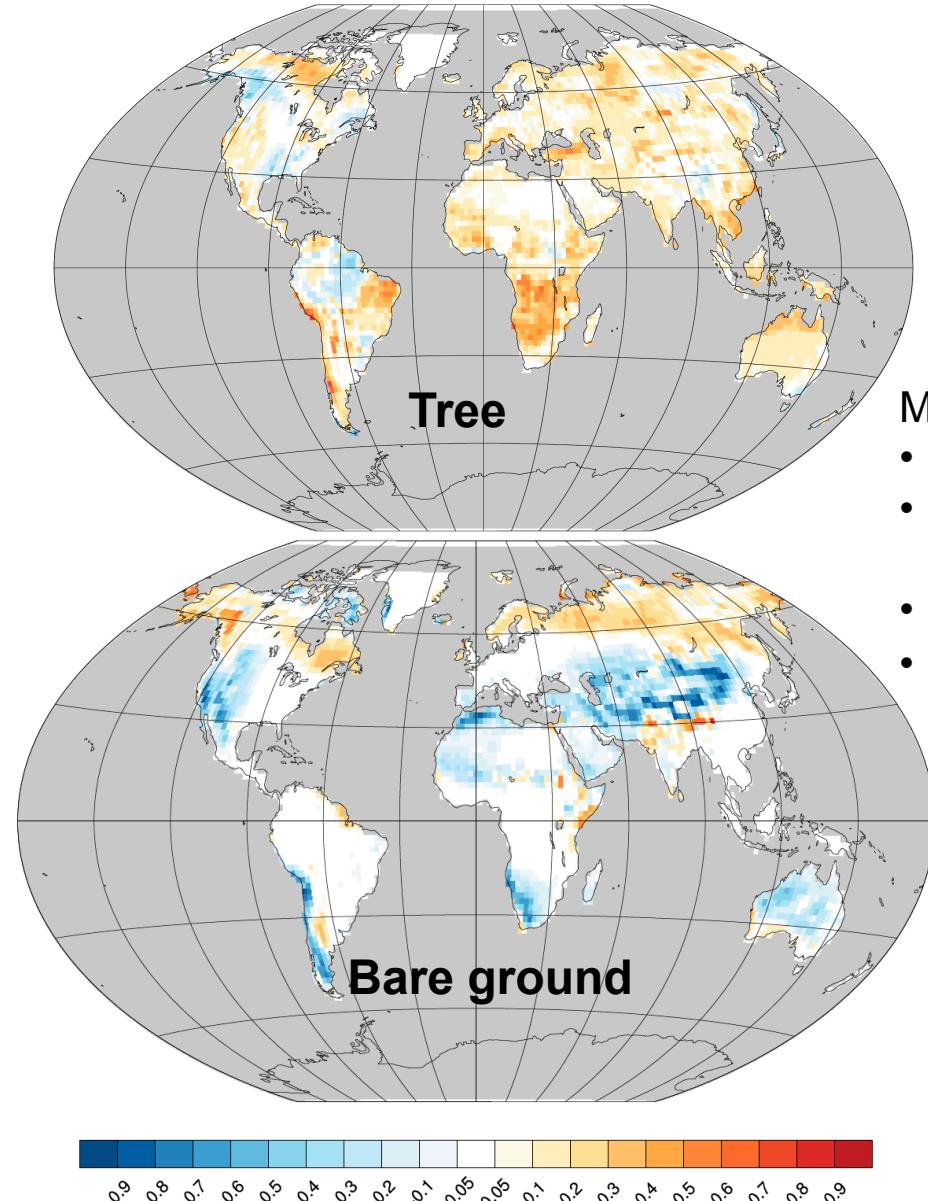
Bare Ground



MPI-
ESM:
CMIP5
hist.



Vegetation cover, MPI-ESM – MODIS VCF



MPI-ESM overestimates

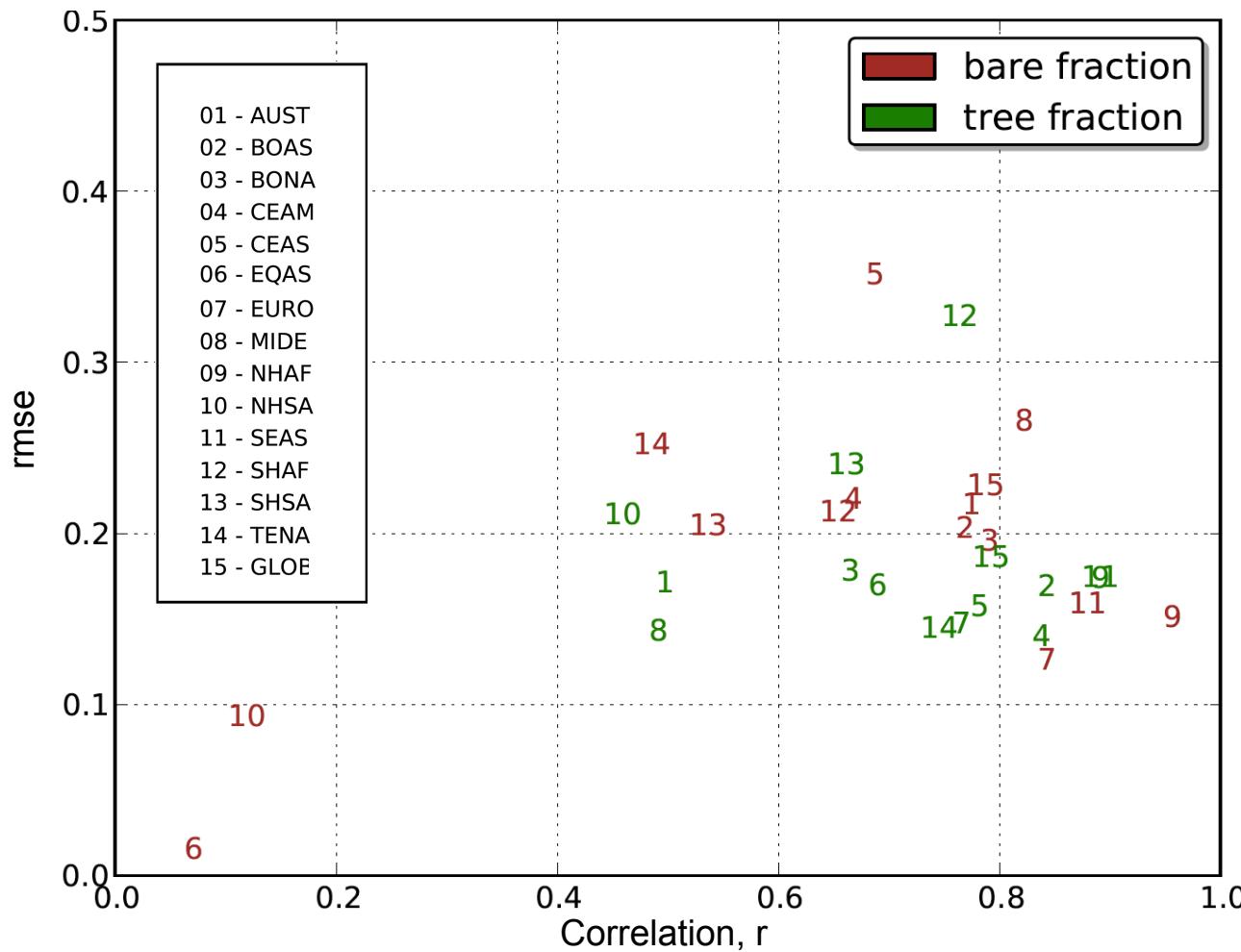
- tree cover (esp. in drylands),
- bare ground in high latitudes;
- underestimates
- tree cover in Amazon,
- bare ground in drylands.

Analysis using GFED2 regions



BONA	Boreal North America	NHAF	Northern Hemisphere Africa
TENA	Temperate North America	SHAF	Southern Hemisphere Africa
CEAM	Central America	BOAS	Boreal Asia
NHSA	Northern Hemisphere South America	CEAS	Central Asia
SHSA	Southern Hemisphere South America	SEAS	Southeast Asia
EURO	Europe	EQAS	Equatorial Asia
MIDE	Middle East	AUST	Australia and New Zealand

Regional analysis: Spatial correlation versus RMSE



Evaluation of vegetation on regional scale

GFED2 Region	Vegetation class	r^2	$rmse$	N (number of grid cells)
Australia and New Zealand (AUST)	Tree	0.23	0.17	199
	Bare ground	0.58	0.21	197
Boreal Asia (BOAS)	Tree	0.67	0.17	770
	Bare ground	0.51	0.19	754
Boreal North America (BONA)	Tree	0.44	0.17	531
	Bare ground	0.51	0.19	522
Central America (CEAM)	Tree	0.69	0.13	54
	Bare ground	0.44	0.21	52
Central Asia (CEAS)	Tree	0.60	0.15	579
	Bare ground	0.45	0.35	571
Equatorial Asia (EQAS)	Tree	0.46	0.16	44
	Bare ground	0.00	0.01	39
Europe (EURO)	Tree	0.51	0.15	199
	Bare ground	0.49	0.11	188
Middle East (MIDE)	Tree	0.23	0.13	271
	Bare ground	0.66	0.26	271
Northern Hemisphere Africa (NHAF)	Tree	0.78	0.17	361
	Bare ground	0.90	0.15	341
Northern Hemisphere South America (NHSA)	Tree	0.20	0.21	69
	Bare ground	0.01	0.09	56
Southeast Asia (SEAS)	Tree	0.76	0.17	162
	Bare ground	0.75	0.15	157
Southern Hemisphere Africa (SHAF)	Tree	0.56	0.32	228
	Bare ground	0.40	0.20	200
Southern Hemisphere South America (SHSA)	Tree	0.41	0.24	364
	Bare ground	0.29	0.19	314
Temperate North America (TENA)	Tree	0.52	0.14	228
	Bare ground	0.22	0.25	213

The color code:

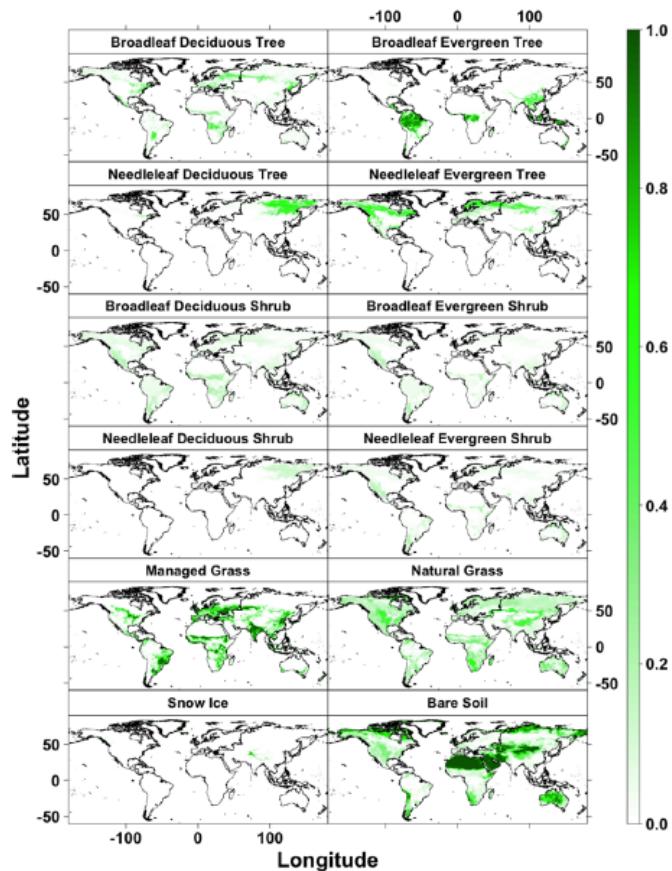
- green – high ($r^2 \geq 0.66$, $rmse \leq 0.15$),
- no color – intermediate ($0.66 > r^2 \geq 0.33$, $0.15 < rmse \leq 0.3$),
- red – low model-data agreement ($r^2 < 0.33$, $rmse > 0.3$)

Total score on the global scale: compiled but not used

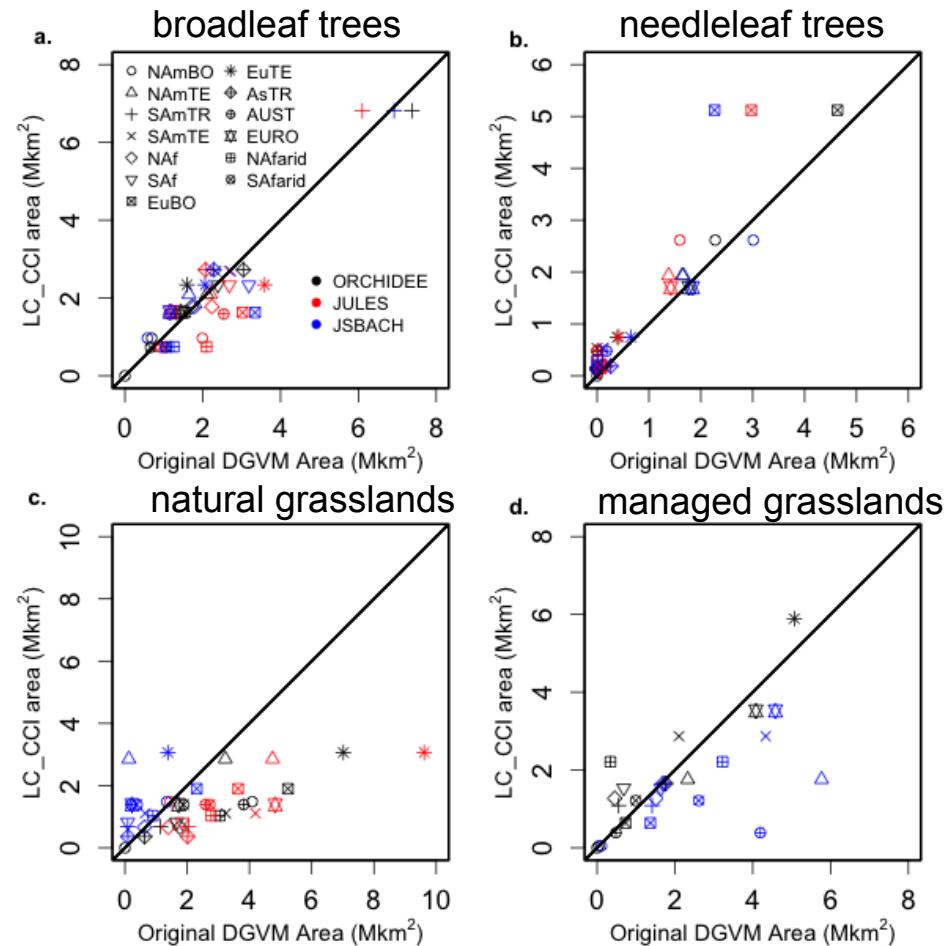
Region	Vegetation Class	r^2	RMSE
Tropics	Tree	0.63	0.21
	Bare ground	0.86	0.16
Extratropics	Tree	0.57	0.16
	Bare ground	0.43	0.27
Weighted global Score (max: 100)		0.62	0.20
Total score (max: 100)	71	62	80

Plant functional type classification for earth system models: results from the European Space Agency's Land Cover Climate Change Initiative

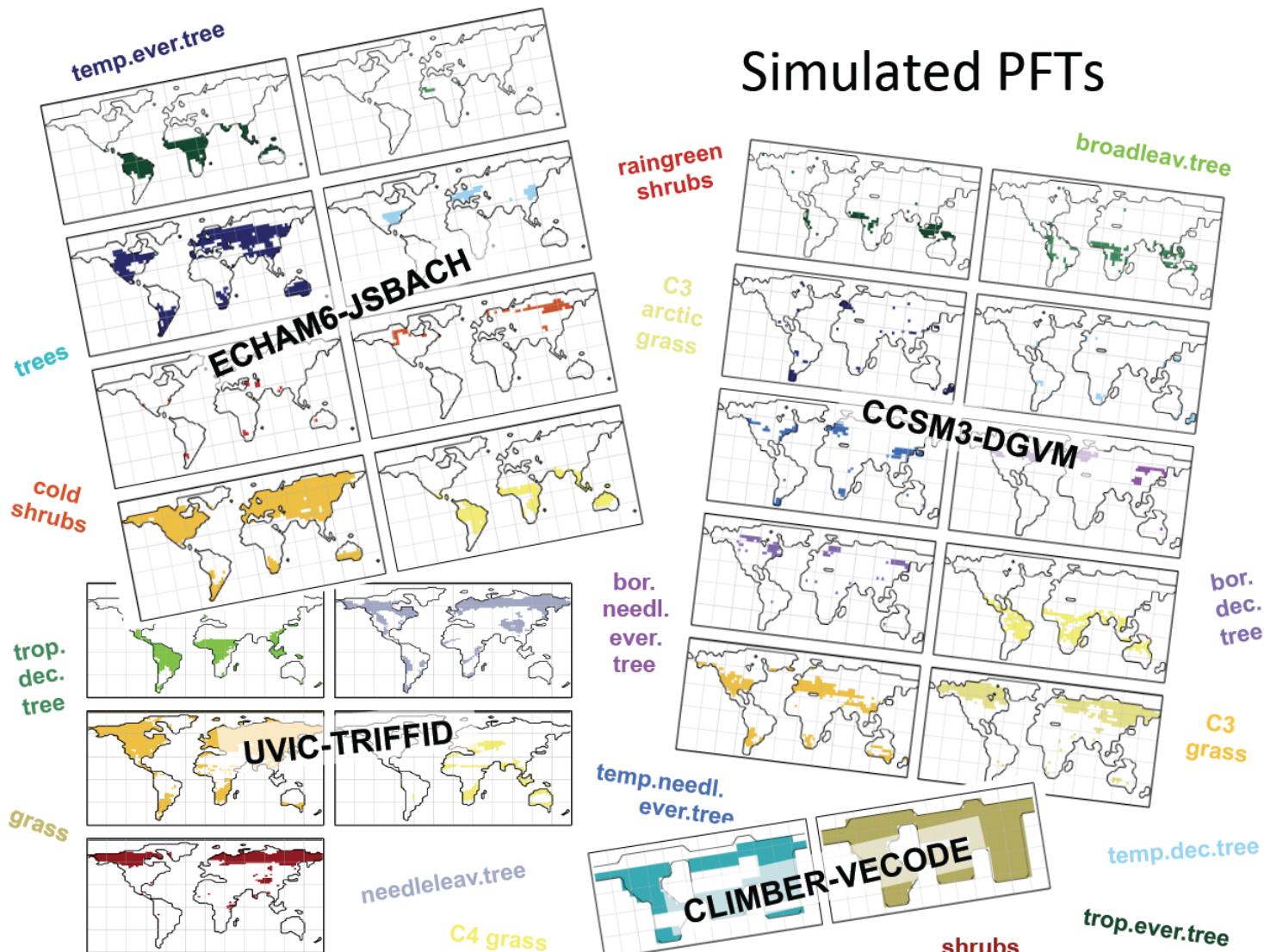
B. Poulter^{1,2}, N. MacBean¹, A. Hartley³, I. Khlystova⁴, O. Arino⁵, R. Betts³, S. Bontemps⁶, M. Boettcher⁷, C. Brockmann⁷, P. Defourny⁶, S. Hagemann⁴, M. Herold⁸, G. Kirches⁷, C. Lamarche⁶, D. Lederer⁶, C. Ottlé¹, M. Peters⁷, and P. Peylin¹



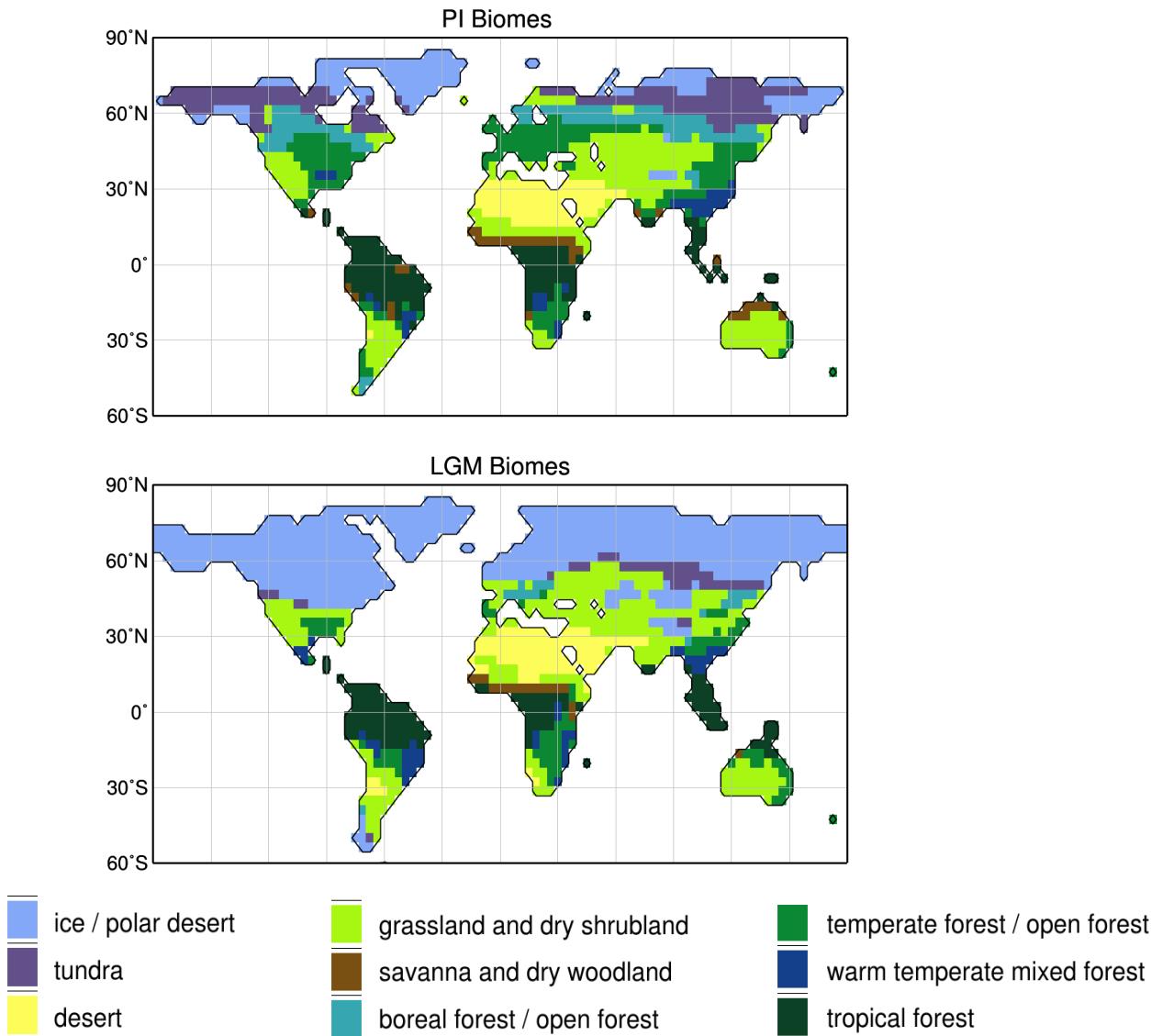
300 m, 22 classes $\rightarrow 0.5^\circ$ PFT fractions



Harmonization of vegetation cover based on mega-biomes

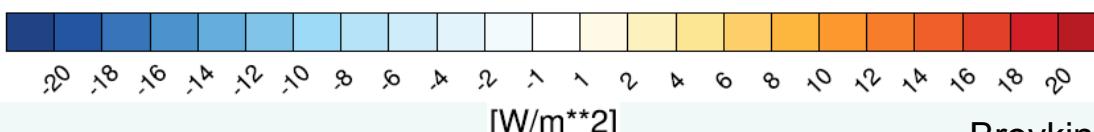
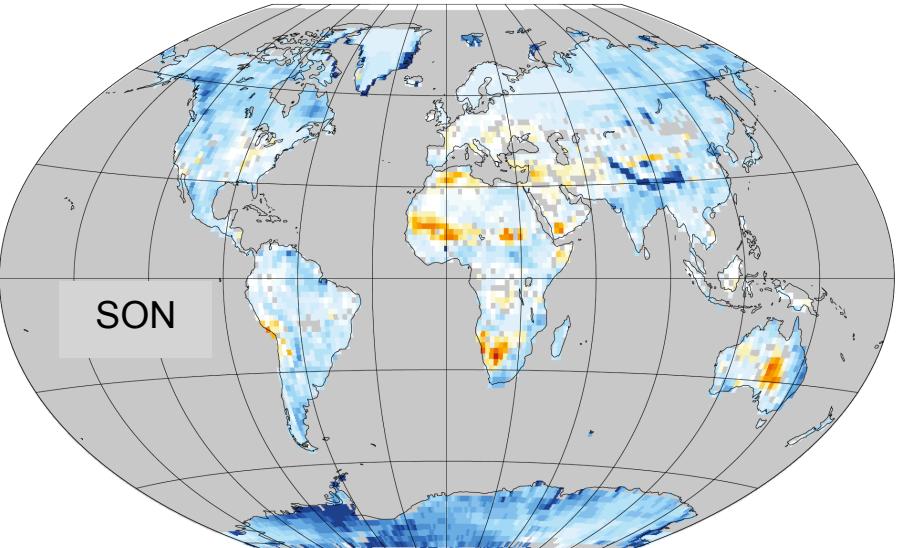
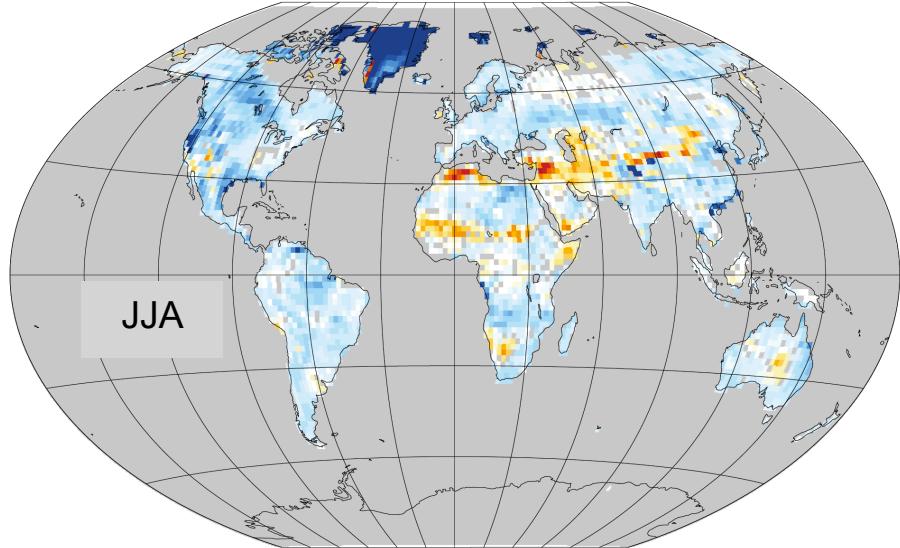
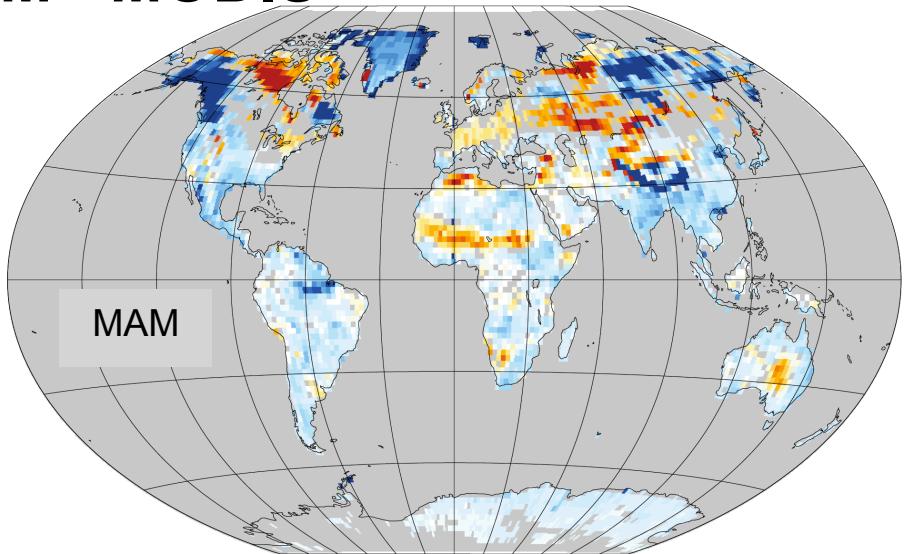
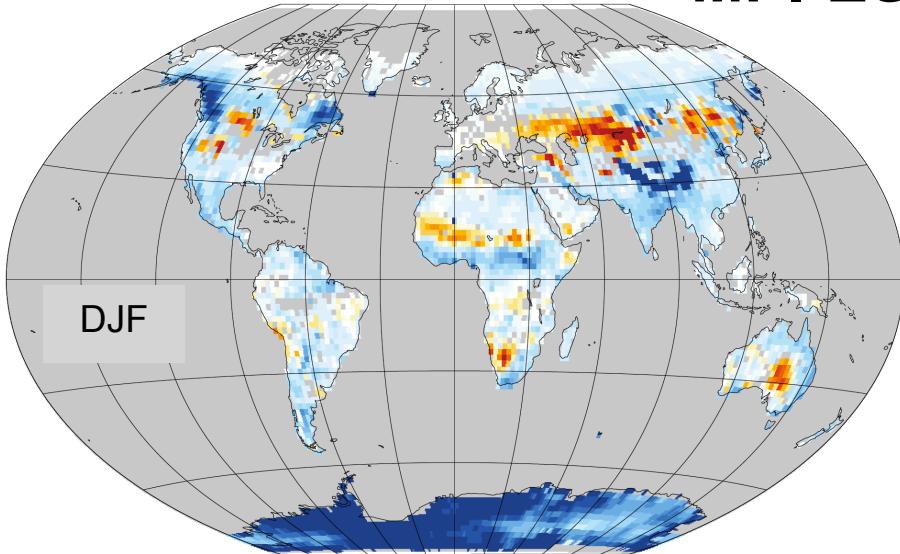


MPI-ESM veg cover converted to mega-biomes



Evaluation of albedo in terms of net surface radiation Q_{SW} ,

MPI-ESM - MODIS

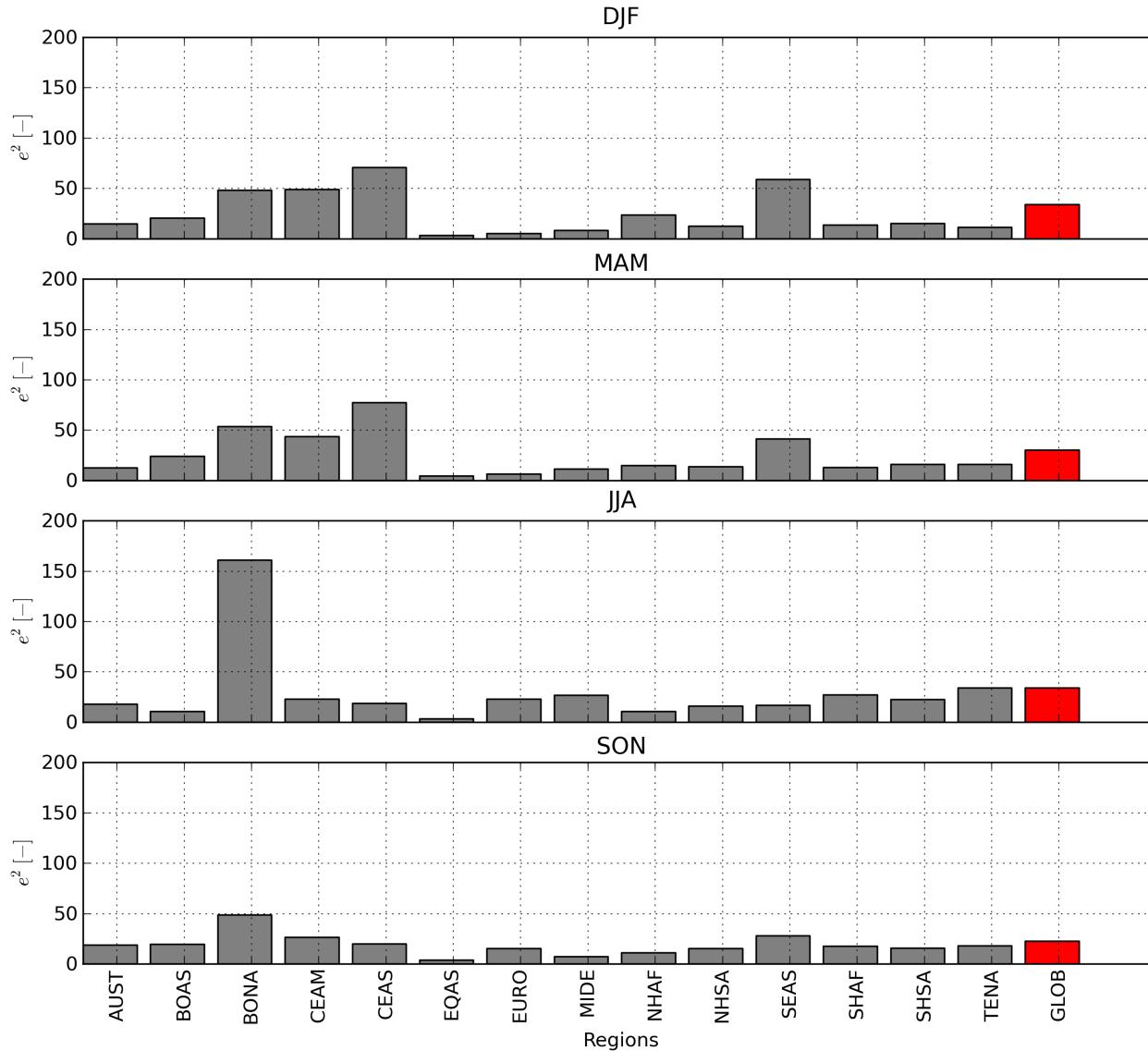


Evaluation of land-surface albedo in terms of r^2 , $rmse$, and $rmse/Q_{sw}$ on the regional scale

GFED2 Region	r^2				$rmse, W/m^2$				$rmse/Q_{sw}$			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
AUST	0.89	0.86	0.87	0.79	6.94	5.00	4.94	6.75	0.03	0.03	0.04	0.03
BOAS	0.64	0.84	0.77	0.53	5.42	13.79	8.52	7.14	0.29	0.15	0.06	0.16
BONA	0.45	0.57	0.57	0.27	9.44	23.94	22.01	9.01	0.38	0.24	0.15	0.17
CEAM	0.51	0.60	0.85	0.61	7.40	9.11	7.41	6.52	0.05	0.04	0.03	0.04
CEAS	0.21	0.46	0.88	0.80	14.86	17.92	6.65	6.71	0.18	0.10	0.03	0.05
EQAS	0.70	0.80	0.80	0.85	2.77	3.20	2.46	2.60	0.02	0.02	0.02	0.02
EURO	0.69	0.67	0.46	0.76	2.21	8.99	15.78	3.69	0.06	0.07	0.09	0.05
MIDE	0.96	0.97	0.96	0.98	4.97	5.36	6.57	3.20	0.04	0.03	0.03	0.02
NHAF	0.95	0.97	0.99	0.97	6.77	5.53	4.57	4.81	0.04	0.03	0.03	0.03
NHSA	0.82	0.82	0.72	0.83	4.96	6.05	6.45	5.98	0.03	0.03	0.03	0.03
SEAS	0.29	0.69	0.83	0.71	13.79	18.30	8.86	8.60	0.08	0.08	0.05	0.05
SHAF	0.87	0.62	0.54	0.80	5.23	4.58	5.83	5.84	0.03	0.03	0.03	0.03
SHSA	0.89	0.71	0.91	0.84	5.10	5.41	5.25	5.64	0.03	0.03	0.03	0.03
TENA	0.68	0.77	0.64	0.75	5.83	6.63	8.41	5.28	0.07	0.04	0.04	0.04
GLOB	0.88	0.83	0.90	0.96	8.50	12.49	9.49	6.29	0.09	0.08	0.07	0.06

Strong bias in northern high latitudes

Albedo evaluation – normalized error variance, e^2



Data available at the ICDC server

MODIS Percentage Forest Cove... + icdc.zmaw.de/1/daten/land/modis-vcf-forest.html hamburg icdc ICDC Sitemap Deutsch

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Integrated Climate Data Center - ICDC

MODIS Percentage Forest Cover Fraction
IAS 7.4, ICDC Klimacampus Hamburg 17–Oct–13
TIME : 01–JUL–2010 12:00
Stride: 12 in X, 14 in Y
DATA SET: Annual mean Vegetation Continuous Fraction
vegetation_area_fraction_forest (percent)

Access

UNRESTRICTED
This data set is only available for a restricted user group, please [contact us](#) if you want to access these data.

RESTRICTED only accessible in ZMAW net or via CliSAP login [What does that mean?](#)

[View data via LAS](#)
[Data access via OPeNDAP](#)
[Data access via file system /data/icdc/land/modis_forestcoverfraction](#)

Atmosphere
Ice and snow
Land
EUMETSAT Land Surface Albedo
EUMETSAT Surface Solar Irradiance
MODIS Land Surface Albedo
MODIS Land Surface Type
MODIS Percentage Forest Cover Fraction
Vegetation Cover Fraction (SPOT/PROBA-V)
FAPAR (SPOT/PROBA-V)
Land Surface Albedo (SPOT)
AMSR-E soil moisture
ASCAT soil moisture
ESA-CCI soil moisture
MODIS Land Surface Temperature
Climatology MODIS Land Surface Temperature
MODIS Vegetation Index
Leaf Area Index
MODIS Blattflächenindex / FAPAR
MODIS-SRTM Land-Water-Distribution
Harmonized World Soil Database
Soil type
Geoid EIGEN-6C2
Ocean
Society
Re-Analyses: Atmosphere
Re-Analyses: Ocean / EasyInit
Climate Indices
All data

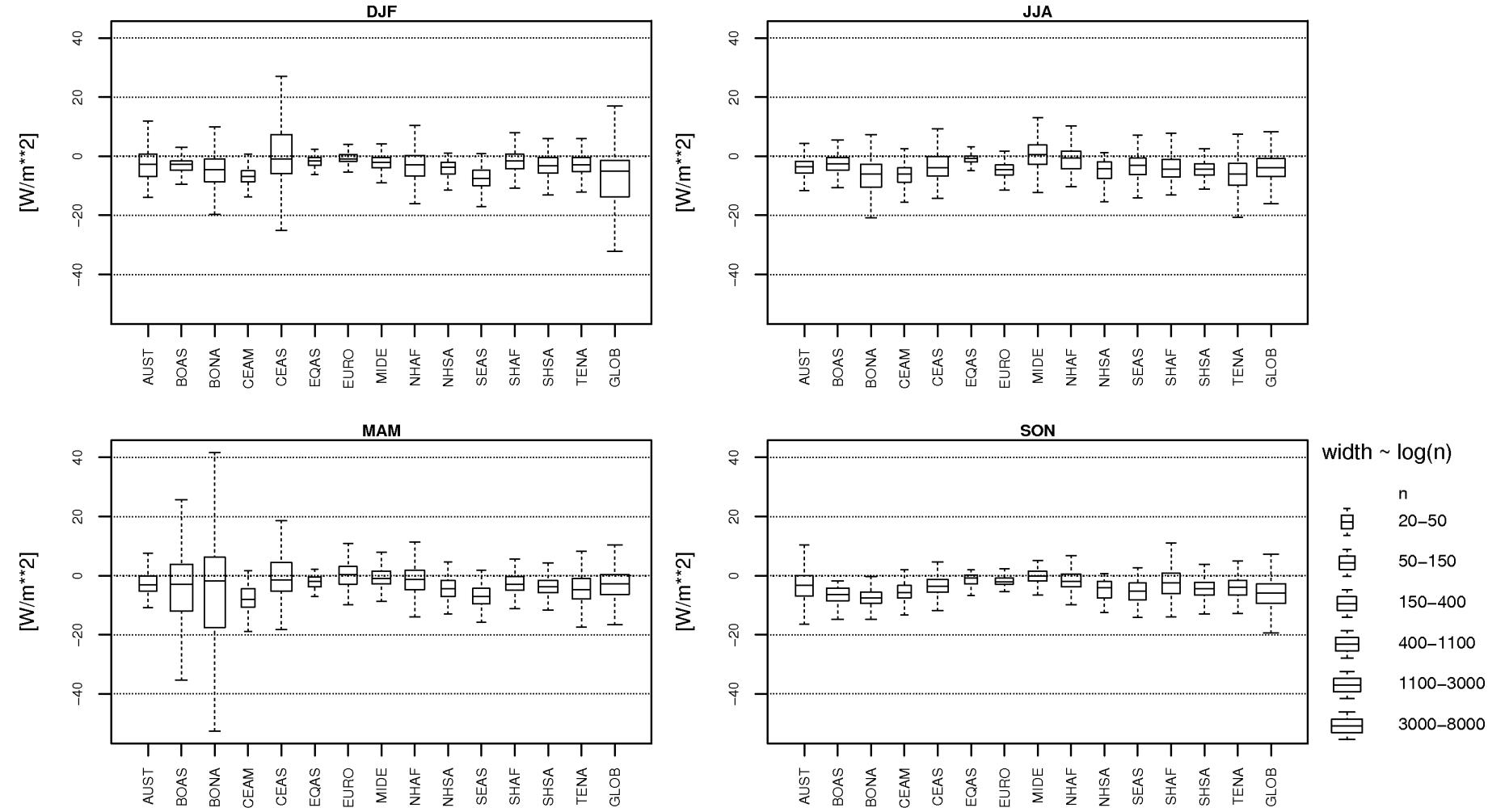


Summary

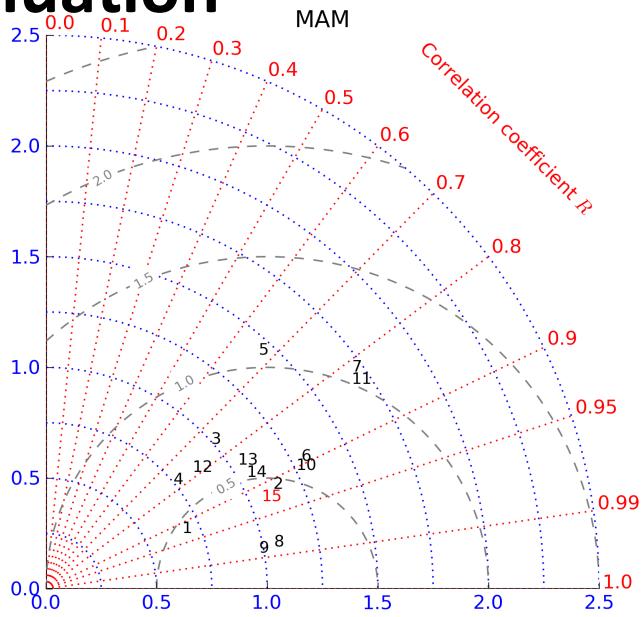
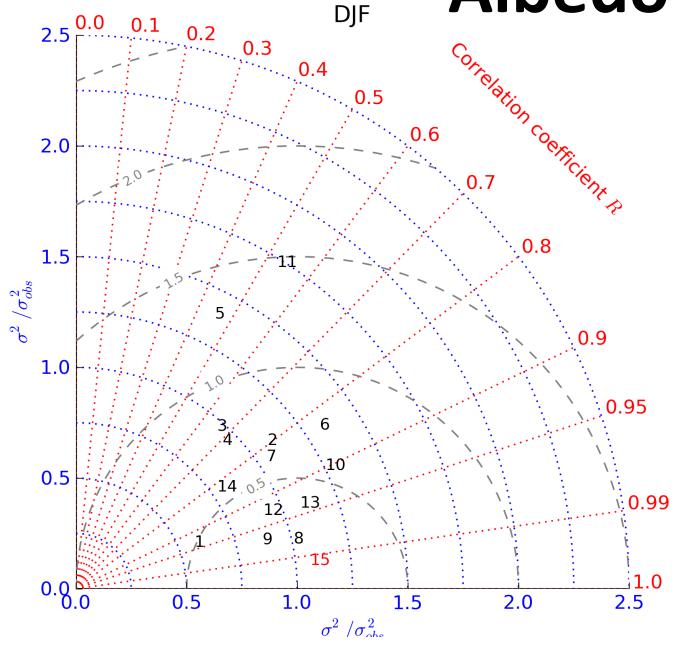
- Vegetation cover evaluation: r^2 , rmse metrics.
Tree cover patterns are simulated well by MPI-ESM (r^2 of 0.6)
 - Overestimated tree cover (esp. in drylands), while too few trees in Amazon (rainfall bias)
 - bare ground is overestimated in high latitudes and underestimated in drylands
- Land surface albedo evaluation n terms of net surface radiation, metrics: r^2 , rmse, e^2 , Taylor diagram, box-and-wiskes plots.
High correlation with data (r^2 of 0.9)
 - Main biases are in high latitudes (North America, Eurasia); partly explained by biases in tree cover and snow cover
- Data in resolution appropriate for ESMs are available at the Integrated Climate Data Centre (ICDC) in Hamburg

Albedo evaluation

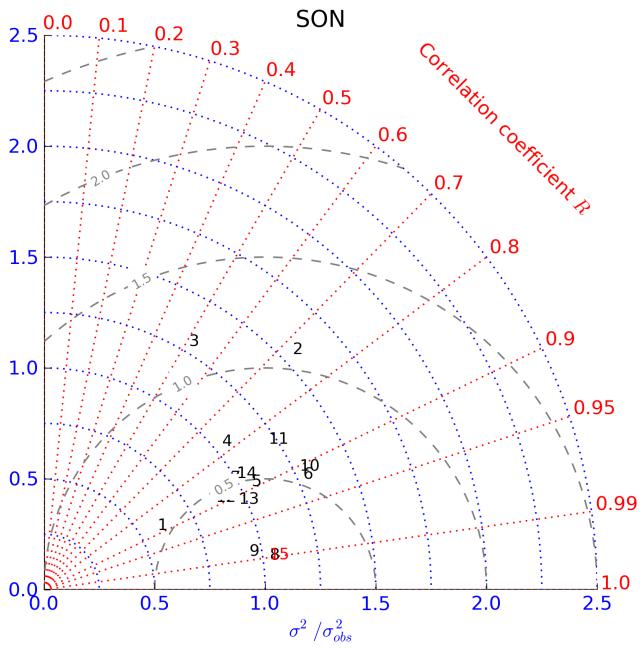
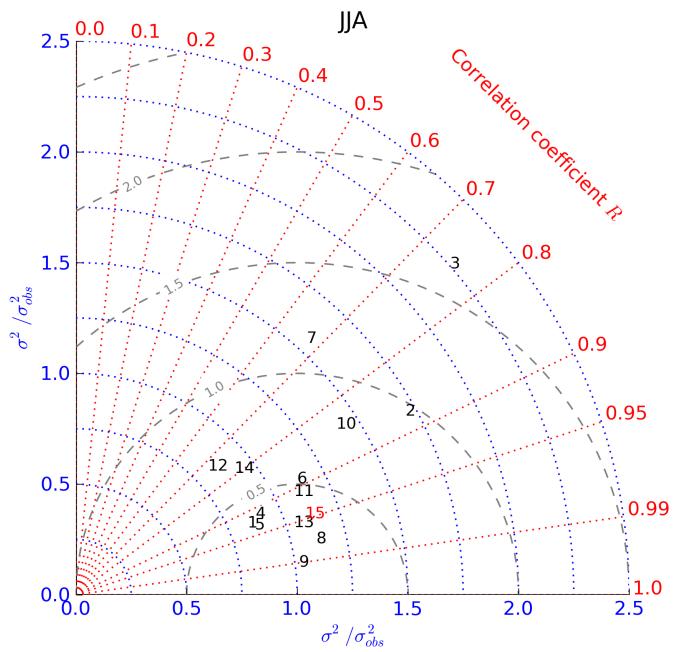
mean net surface solar radiation [W/m^{**2}] | Model – Observation



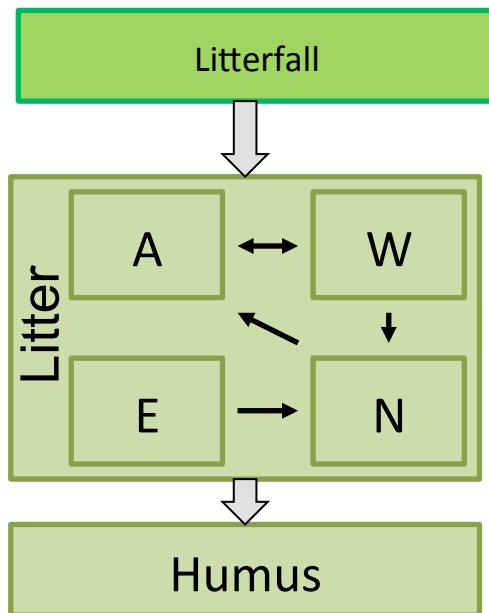
Albedo evaluation



01 - AUST
02 - BOAS
03 - BONA
04 - CEAM
05 - CEAS
06 - EQAS
07 - EURO
08 - MIDE
09 - NHAF
10 - NHSA
11 - SEAS
12 - SHAF
13 - SHSA
14 - TENA
15 - GLOB



The YASSO soil C model



- Soil C pools and parameters based on litter-bag experiments
- 4 litter pools, replicated for leaf and woody litter; above- and belowground
- 1 Humus pool, replicated for leaf and woody litter remains
- Belowground C represented as homogeneous layer at soil surface, no representation of deep C pools

Newly introduced

- **frozen C separate pools in 4 depth ranges, prescribed from NCSCDv2**
- **permafrost thaw leads to transfer to non-frozen C pools**

The Kappa-statistics

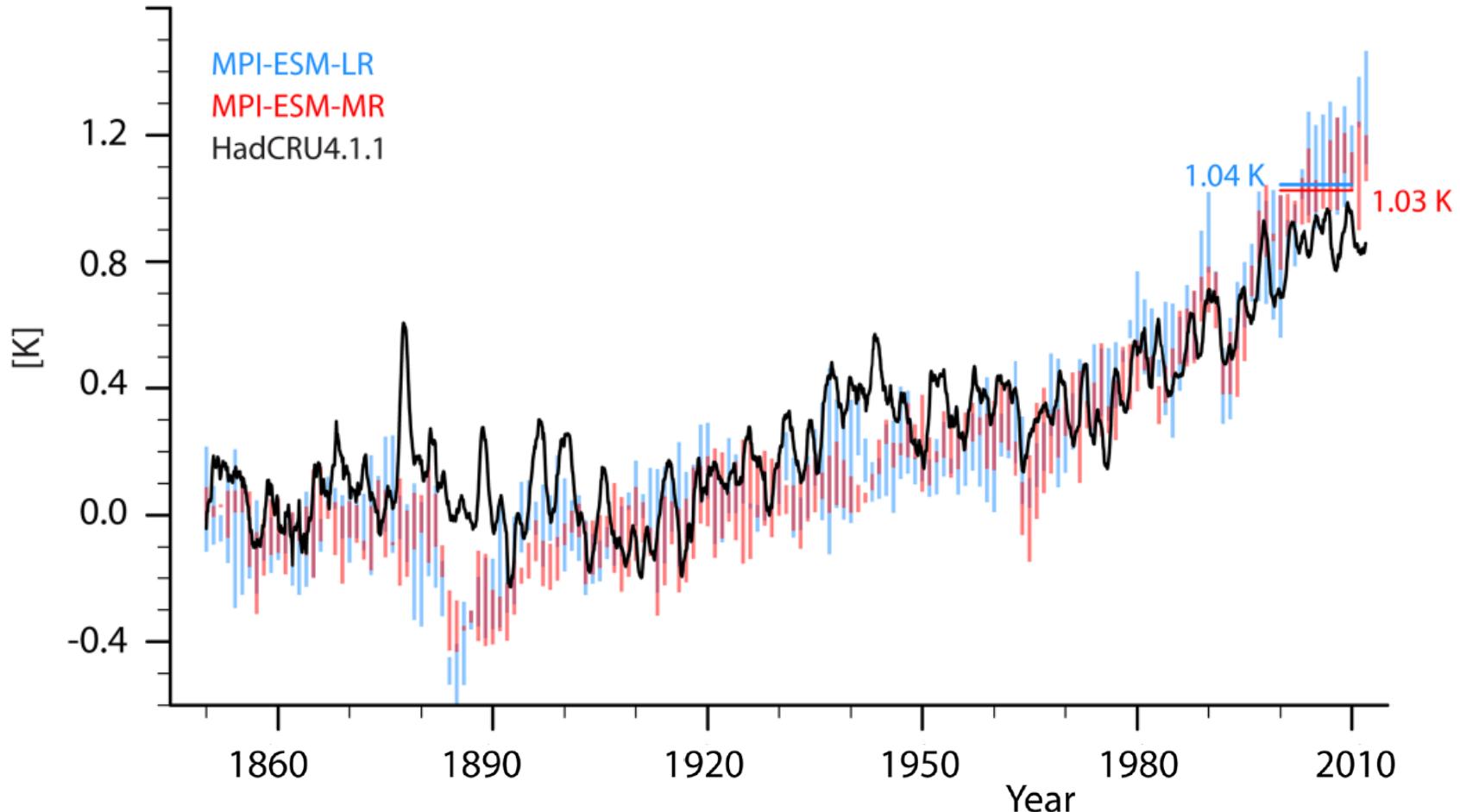
Map A	Map B		Total
	Category i	All others	
Category i	p_{ii}	$p_{i\cdot} - p_{ii}$	$p_{i\cdot}$
All others	$p_{\cdot i} - p_{ii}$	d	$1 - p_{i\cdot}$
Total	$p_{\cdot i}$	$1 - p_{\cdot i}$	1

$$\hat{\kappa}_i = \frac{p_{ii} - p_{i\cdot}p_{\cdot i}}{(p_{i\cdot} + p_{\cdot i})/2 - p_{i\cdot}p_{\cdot i}}$$

Lower bound	Degree of agreement	Upper bound
< 0.05	No	0.05
0.05	Very poor	0.20
0.20	Poor	0.40
0.40	Fair	0.55
0.55	Good	0.70
0.70	Very good	0.85
0.85	Excellent	0.99
0.99	Perfect	1.00

MPI-ESM historical run (incl. landuse): used for evaluation of vegetation cover

GIORGETTA ET AL.: CLIMATE CHANGES IN MPI-ESM



Vegetation cover, MPI-ESM – MODIS VCF

Zonal average

