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Supplement of

Afforestation impact on soil temperature in regional climate model simulations over Europe

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Supplementary material

Table S1: Names and characteristics of the RCMs used from Davin et al. 2020.

Model name	**CCLM-TERRA**	**CCLM-VEG3D**	**CCLM-CLM4.5**	**RCA**	**RegCM-CLM4.5**	**REMO-iMOVE**	**WRFa-NoahMP**	**WRFb-NoahMP**	**WRFb-CLM4.0**
Institute ID	JLU/BTU/ CMCC	KIT	ETH	SMHI	ICTP	GERICS	IDL	UHOH	AUTH
RCM	COSMO_ 5.0_clm9	COSMO_ 5.0_clm9	COSMO_ 5.0_clm9	RCA4	RegCM4.6.1 (Giorgi et al. 2012)	REMO2009	WRF381	WRF381	WRF381
Land surface scheme	TERRA-ML (Schrodin and Heise 2002)	VEG3D (Breil et al. 2018)	CLM4.5 (Oleson et al. 2013)	(Samuelsson et al. 2006)	CLM4.5 (Oleson et al. 2013)	iMOVE (Wilhelm et al. 2014)	NoahMP	NoahMP	CLM4.0 (Oleson et al. 2008)
Land cover classes (classes effectively used in FOREST and GRASS in bold)	**1: everg. br. forest** **2: desc. broad closed** **3: desc. br. open** **4: everg. Needleleaf forest** **5: desc. needleleaf forest** 6: mixed leaf trees 7: fresh water flooded trees 8: saline water flooded trees 9: mosaic tree/natural veget. 10: burnt tree cover 11: everg. shupbs closed/open 12: desc. shrubs closed/open 13: herbac. veget. closed/open **14: grass** 15: flooded shrups or herbac. 16: cultivated and	**1: bare soil** 2: water 3: urban **4: deciduous forest** **5: coniferous forest** 6: mixed forest 7: cropland 8: special crops **9: grassland** 10: shrubland	**1: Bare Soil** **2: Needleleaf Evergreen Tree - Temperate** **3: Needleleaf Evergreen Tree - Boreal** **4: Needleleaf Deciduous Tree - Boreal** 5: Broadleaf Evergreen Tree - Tropical **6: Broadleaf Evergreen Tree - Temperate** 7: Broadleaf Deciduous Tree - Tropical **8: Broadleaf Deciduous Tree - Temperate** **9: Broadleaf Deciduous Tree - Boreal** 10: Broadleaf Deciduous	**1: bare soil** **2: open land** **3: needle leaf forest** **4: broad leaf forest**	**1: Bare Soil** **2: Needleleaf Evergreen Tree - Temperate** **3: Needleleaf Evergreen Tree - Boreal** **4: Needleleaf Deciduous Tree - Boreal** 5: Broadleaf Evergreen Tree - Tropical **6: Broadleaf Evergreen Tree - Temperate** 7: Broadleaf Deciduous Tree - Tropical **8: Broadleaf Deciduous Tree - Temperate** **9: Broadleaf Deciduous Tree - Boreal** 10: Broadleaf Deciduous	**1: tr. br. everg.** **2: tr. br. desc.** **3: temp. br. everg.** **4: temp. br. desc.** **5: everg. conif.** **6: desc. conif.** 7: everg. shrubs 8: desc. shrubs **9: C3 grasses** **10: C4 grasses** 11: tundra 12: swamps 13: C3 crops 14: C4 crops 15: urban **16: bare**	**1: everg. needleleaf** **2: desc. Needleleaf** 3: everg. Broadleaf **4: desc. Broadleaf** 5: mixed forests 6: closed shrubland 7: open shrubland 8: wooded savannah 9: savannah **10: grassland** 11: wetlands 12: cropland 13: urban and built-up 14: cropland/natural vegetation mosaic **15: snow and ice** **16: barren or sparsely vegetated** **17: water** 18: wooded tundra 19: mixed tundra 20: barren tundra 21: lakes	**1: everg. needleleaf** **2: desc. Needleleaf** 3: everg. Broadleaf **4: desc. Broadleaf** **5: mixed forests** 6: closed shrubland 7: open shrubland 8: wooded savannah 9: savannah **10: grassland** 11: wetlands 12: cropland 13: urban and built-up 14: cropland/natural vegetation mosaic **15: snow and ice** **16: barren or sparsely vegetated** **17: water** 18: wooded tundra 19: mixed tundra 20: barren tundra 21: lakes	**1: Bare Soil** **2: Needleleaf Evergreen Tree - Temperate** **3: Needleleaf Evergreen Tree - Boreal** **4: Needleleaf Deciduous Tree - Boreal** 5: Broadleaf Evergreen Tree - Tropical **6: Broadleaf Evergreen Tree - Temperate** 7: Broadleaf Deciduous Tree - Tropical **8: Broadleaf Deciduous Tree - Temperate** **9: Broadleaf Deciduous Tree - Boreal** 10: Broadleaf Deciduous

	managed 17: mosaic crop/tree/net veget. 18: mosaic crop/shrub/grass **19: bare areas** 20: water 21: snow and ice 22. artificial surface 23: undefined		Shrub - Temperate 11: Broadleaf Evergreen Shrub - Temperate 12: Broadleaf Deciduous Shrub - Boreal **13: C3 artic grass** **14: C3 grass** **15: C4 grass** 16: Crop 1 17: Crop 2		Shrub - Temperate 11: Broadleaf Evergreen Shrub - Temperate 12: Broadleaf Deciduous Shrub - Boreal **13: C3 artic grass** **14: C3 grass** **15: C4 grass** 16: Crop 1 17: Crop 2				Shrub - Temperate 11: Broadleaf Evergreen Shrub - Temperate 12: Broadleaf Deciduous Shrub - Boreal **13: C3 artic grass** **14: C3 grass** **15: C4 grass** 16: Crop1 17: Crop2
Conversion method to implement the PFT-based input vegetation maps (FOREST and GRASS)	bare soil=19 Needleleaf evergreen tree-temperate=4 Needleleaf evergreen tree-boreal=4 Needleleaf deciduous tree-boreal=5 Broadleaf evergreen tree - tropical=1 Broadleaf evergreen tree – temperate=1 Broadleaf deciduous tree – tropical=2 Broadleaf deciduous tree – temperate=2 Broadleaf deciduous tree – boreal=3 C3 arctic grass= 14 C3 grass= 14 C4 grass= 14	bare soil=1 Needleleaf evergreen tree-temperate=5 Needleleaf evergreen tree-boreal=5 Needleleaf deciduous tree-boreal=5 Broadleaf evergreen tree - tropical=4 Broadleaf evergreen tree – temperate=4 Broadleaf deciduous tree – tropical=4 Broadleaf deciduous tree – temperate=4 Broadleaf deciduous tree – boreal=4 C3 arctic grass =9 C3 grass =9 C4 grass =9	No conversion needed	Bare soil = 1 Needleleaf evergreen tree-temperate = 3 Needleleaf evergreen tree-boreal = 3 Needleleaf deciduous tree-boreal = 3 Broadleaf evergreen tree - tropical = 4 Broadleaf evergreen tree – temperate = 4 Broadleaf deciduous tree – tropical = 4 Broadleaf deciduous tree – temperate = 4 Broadleaf deciduous tree – boreal = 4 C3 arctic grass = 2 C3 grass = 2 C4 grass = 2	No conversion needed	bare soil=16 Needleleaf evergreen tree-temperate=5 Needleleaf evergreen tree-boreal=5 Needleleaf deciduous tree-boreal=6 Broadleaf evergreen tree - tropical=1 Broadleaf evergreen tree – temperate=3 Broadleaf deciduous tree – tropical=2 Broadleaf deciduous tree – temperate=4 Broadleaf deciduous tree – boreal=4 Broadleaf evergreen shrub – temperate=7 Broadleaf deciduous shrub – temperate=8 Broadleaf deciduous shrub –	Bare soil = 16 Needleleaf evergreen tree-temperate = 1 Needleleaf evergreen tree-boreal = 1 Needleleaf deciduous tree-boreal = 2 Broadleaf evergreen tree - tropical = 3 Broadleaf evergreen tree – temperate = 3 Broadleaf deciduous tree – tropical = 4 Broadleaf deciduous tree – temperate = 4 Broadleaf deciduous tree – boreal = 4 C3 arctic grass = 10 C3 grass = 10 C4 grass = 10	Bare soil = 16 Needleleaf evergreen tree-temperate = 1 Needleleaf evergreen tree-boreal = 1 Needleleaf deciduous tree-boreal = 2 Broadleaf evergreen tree - tropical = 3 Broadleaf evergreen tree – temperate = 3 Broadleaf deciduous tree – tropical = 4 Broadleaf deciduous tree – temperate = 4 Broadleaf deciduous tree – boreal = 4 C3 arctic grass = 10 C3 grass = 10 C4 grass = 10	No conversion needed

						boreal=8 C3 arctic grass=9 C3 grass=9 C4 grass=10			
Representation of sub-grid scale vegetation heterogeneity	Single class	Single class	Tile approach	Tile approach	Tile approach	Tile approach	Single class	Single class	Tile approach
Leaf Area Index	Prescribed seasonal cycle (sinus function depending on altitude and latitude with vegetation-dependent minimum and maximum values)	Prescribed seasonal cycle (sinus function depending on altitude and latitude with vegetation-dependent minimum and maximum values)	Prescribed seasonal cycle based on MODIS (Lawrence and Chase 2007)	Calculated monthly based on vegetation type, soil temperature and soil moisture	Prescribed seasonal cycle based on MODIS (Lawrence and Chase 2007)	Calculated daily based on atmospheric forcing and soil moisture state	Prescribed seasonal cycle based on lookup tables	Prescribed seasonal cycle based on lookup tables	Prescribed seasonal cycle based on MODIS (Lawrence and Chase 2007)
Total soil depth and number of hydrologically/thermally active soil layers	9 thermally active layers down to 7.5 m; first 8 hydrologically active down to 3.9 m	9 layers down to 7.5 m	15 layers for thermal calculations down to 42 m; first 10 hydrologically active down to 3.43 m	5 layers down to 2.89 m	15 layers for thermal calculations down to 42 m; first 10 hydrologically active down to 3.43 m	5 thermally active layers down to 10 m; 1 water bucket	4 layers down to 1 m	4 layers down to 1 m	10 layers down to 3.43 m
Initialisation and spin up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim except soil moisture which is based on a climatological average (Giorgi et al. 1989); 1985 as spin-up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim, 1979-1985 as spin-up	Initialization with ERA-Interim, 1983-1985 as spin-up	Initialization with ERA-Interim, 1984-1985 as spin-up
Lateral boundary formulation	(Davies 1976)	(Davies 1976)	(Davies 1976)	(Davies 1976) with a cosine-based relaxation function	(Giorgi et al. 1993)	(Davies 1976)	exponential relaxation	exponential relaxation	expotential relaxation
Buffer (No. of grid cells)	13	13	13	8	12	8	15	10	10

No. of vertical levels	40	40	40	24	23	27	50	40	40
Turbulence and planetary boundary layer scheme	Level 2.5 closure for turbulent kinetic energy as prognostic variable (Mellor and Yamada 1982)	Level 2.5 closure for turbulent kinetic energy as prognostic variable (Mellor and Yamada 1982)	Level 2.5 closure for turbulent kinetic energy as prognostic variable (Mellor and Yamada 1982)	(Vogelezang and Holtslag 1996)	The University of Washington turbulence closure model (Grenier et al. 2001; Bretherton et al. 2004)	Vertical diffusion after (Louis 1979) for the Prandtl layer, extended level-2 scheme after (Mellor and Yamada 1974) in the Ekman layer and the free atmosphere including modifications in the presence of clouds	MYNN Level 2.5 PBL (Nakanishi and Niino 2006; NAKANISHI and NIINO 2009)	MYNN Level 2.5 PBL (Nakanishi and Niino 2006; NAKANISHI and NIINO 2009)	MYNN Level 2.5 PBL (Nakanishi and Niino 2006; NAKANISHI and NIINO 2009)
Radiation scheme	(Ritter et al. 1992)	(Ritter et al. 1992)	(Ritter et al. 1992)	(Savijärvi and Savijärvi 1990), Wyser et al (1999)	Radiative transfer model from the NCAR Community Climate Model 3 (CCM 3) (Kiehl et al., 1996)	(Morcrette et al. 1986) with modifications for additional greenhouse gases, ozone and various aerosols.	Rapid Radiative Transfer Model (RRTMG) scheme (Iacono et al. 2008)	Rapid Radiative Transfer Model (RRTMG) scheme (Iacono et al. 2008)	Rapid Radiative Transfer Model (RRTMG) scheme (Iacono et al. 2008)
Convection scheme	(Tiedtke 1989)	(Tiedtke 1989)	(Tiedtke 1989)	(Bechtold et al. 2001)	(Tiedtke 1996) for cumulus convection	(Tiedtke 1989) with modifications after Nordeng (1994)	(Grell and Freitas 2014) for cumulus convection and Global/Regional Integrated Modeling System (GRIMS) Scheme (Hong et al. 2013) for shallow convection	(Kain and Fritsch 1990); no shallow convection	(Kain and Fritsch 1990); no shallow convection
Microphysics scheme	One-moment cloud microphysics scheme (Seifert and Beheng 2001)	One-moment cloud microphysics scheme (Seifert and Beheng 2001)	One-moment cloud microphysics scheme (Seifert and Beheng 2001)	Values from tables	Subgrid Explicit Moisture scheme (SUBEX) (Pal et al. 2000)	(Sundqvist 1978)(Roeckner et al., 1996)	Two-moment, 6-class scheme (Lim and Hong 2010)	(Thompson et al. 2004)	(Thompson et al. 2004)
Greenhouse gases	Historical	Historical	Historical	Historical	Historical	Historical	Historical	Constant	Constant

Aerosols	Constant (Tanré, 1984)	(Tegen et al. 1997) climatology	Constant (Tanré, 1984)	Constant	Not accounted for	Constant (Teichmann et al. 2013)	(Tegen et al. 1997) climatology	(Tegen et al. 1997) climatology	(Tegen et al. 1997) climatology

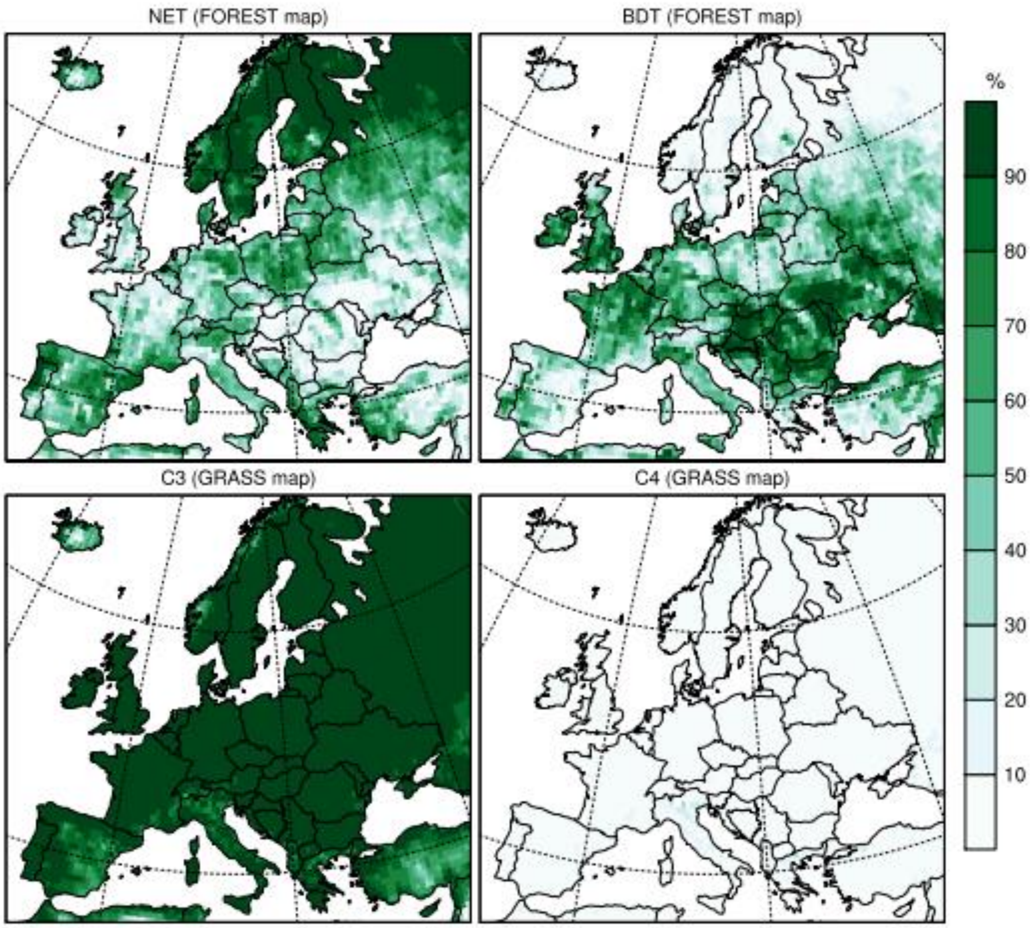

Figure S1: Vegetation maps used in the GRASS and FOREST simulations in Davin et al. 2020. NET = needleleaf evergreen trees, BDT= broadleaf deciduous trees.

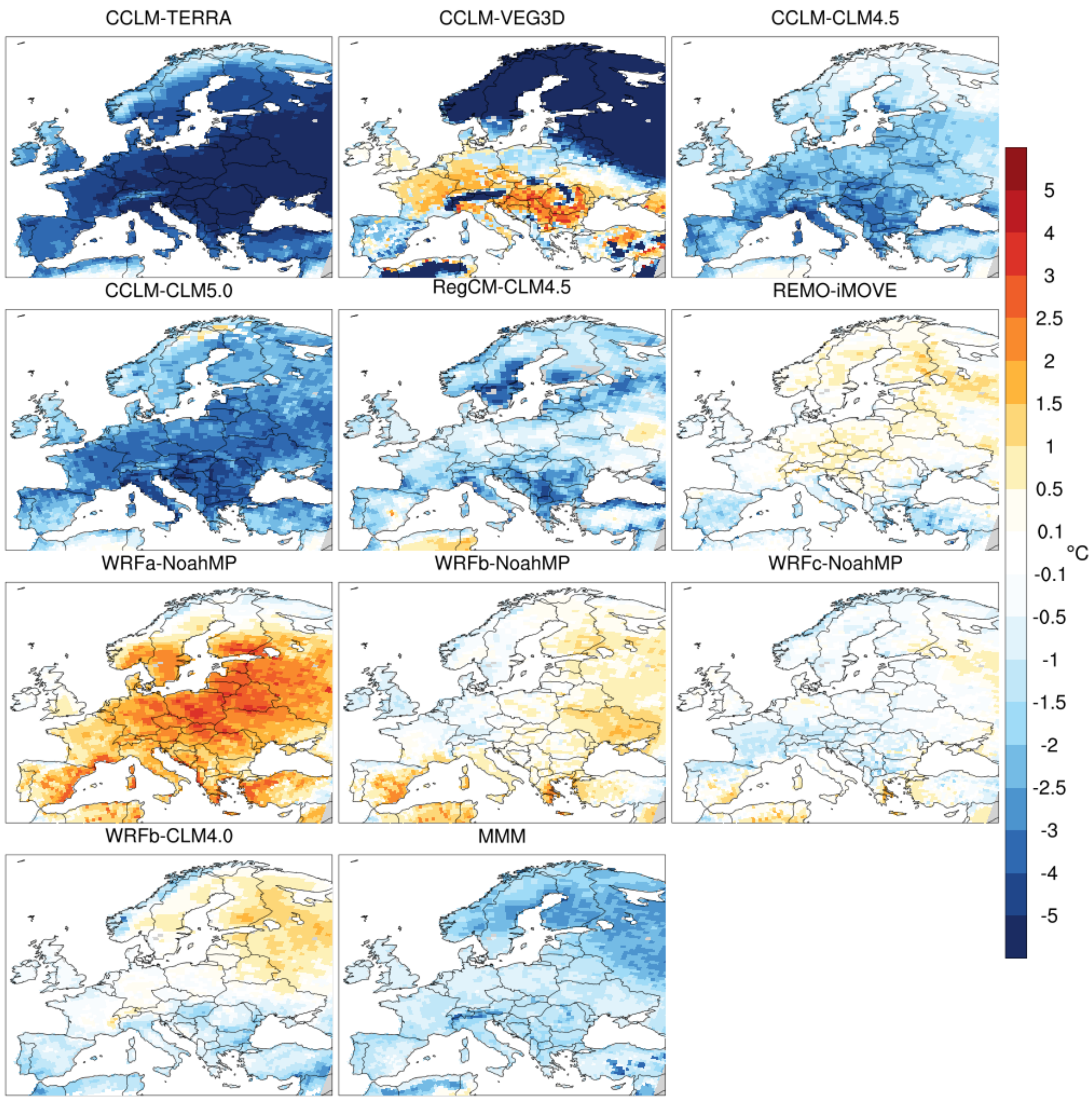

Figure S2: Afforestation (FOREST minus GRASS) impact on the annual amplitude of soil temperature (AAST) at 2 cm soil depth. MMM: Multi-Model-Mean.

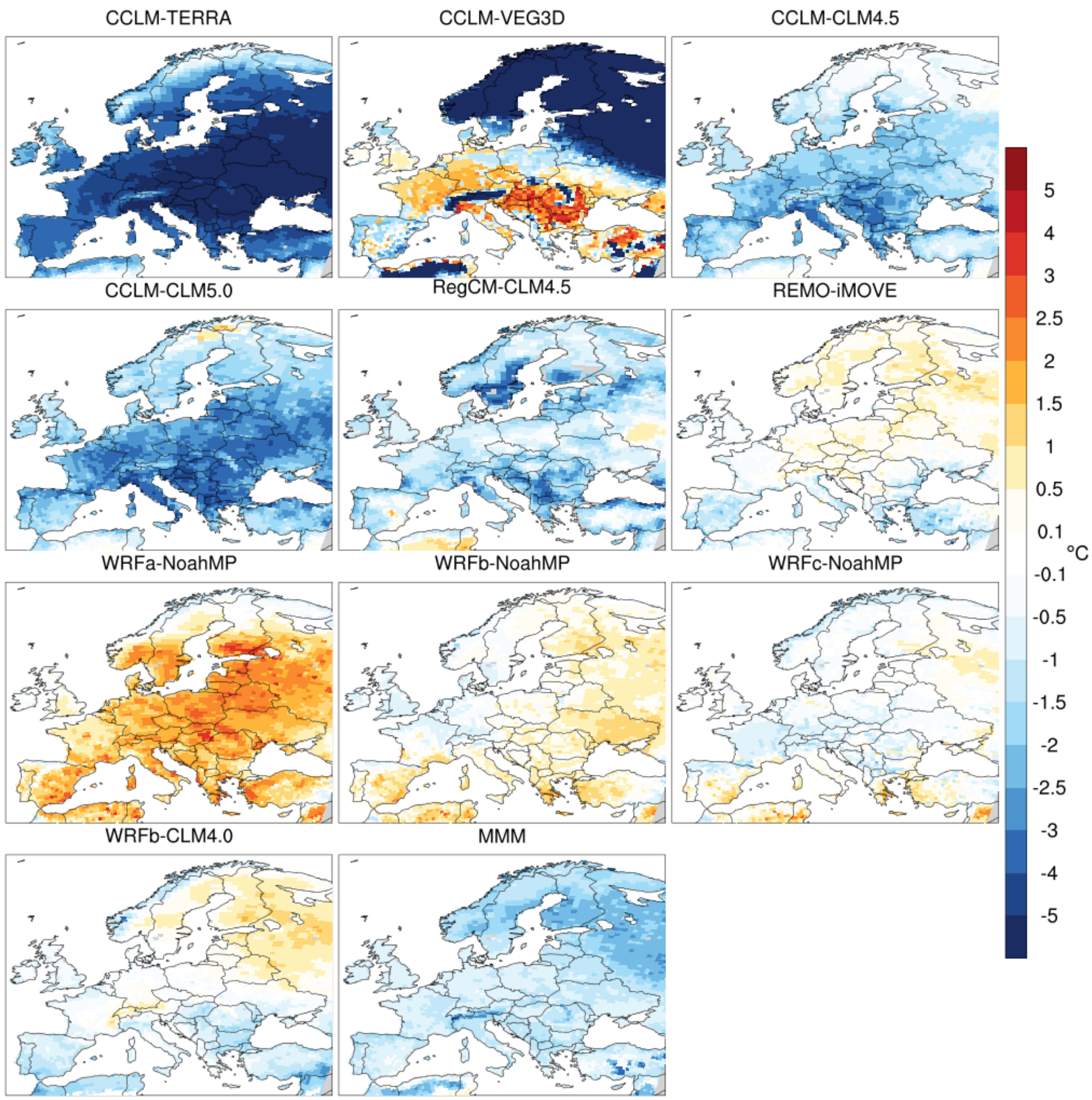

Figure S3: Afforestation (FOREST minus GRASS) impact on the annual amplitude of soil temperature (AAST) at 20 cm soil depth. MMM: Multi-Model-Mean.

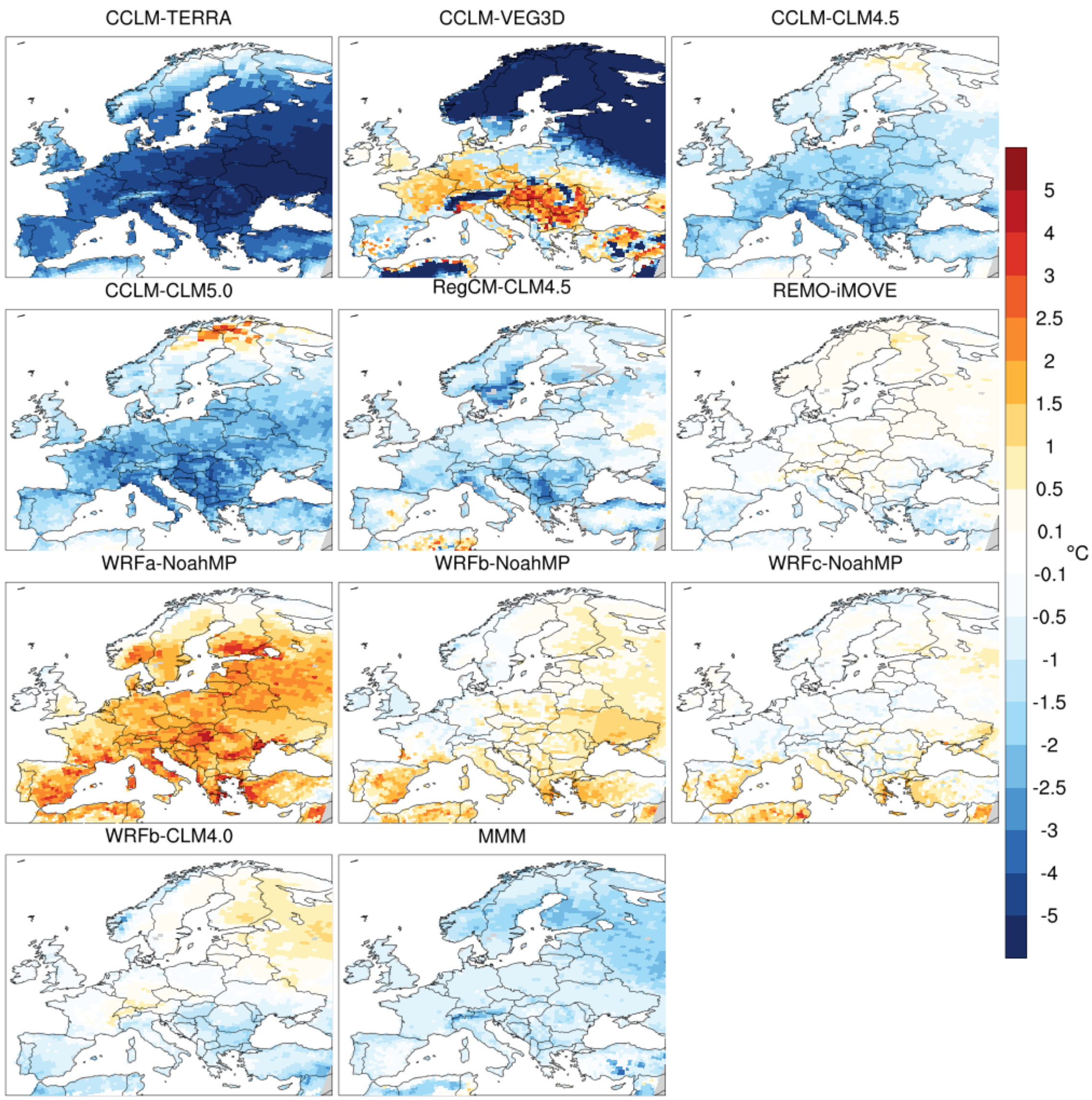

Figure S4: Afforestation (FOREST minus GRASS) impact on the annual amplitude of soil temperature (AAST) at 50 cm soil depth. MMM: Multi-Model-Mean.

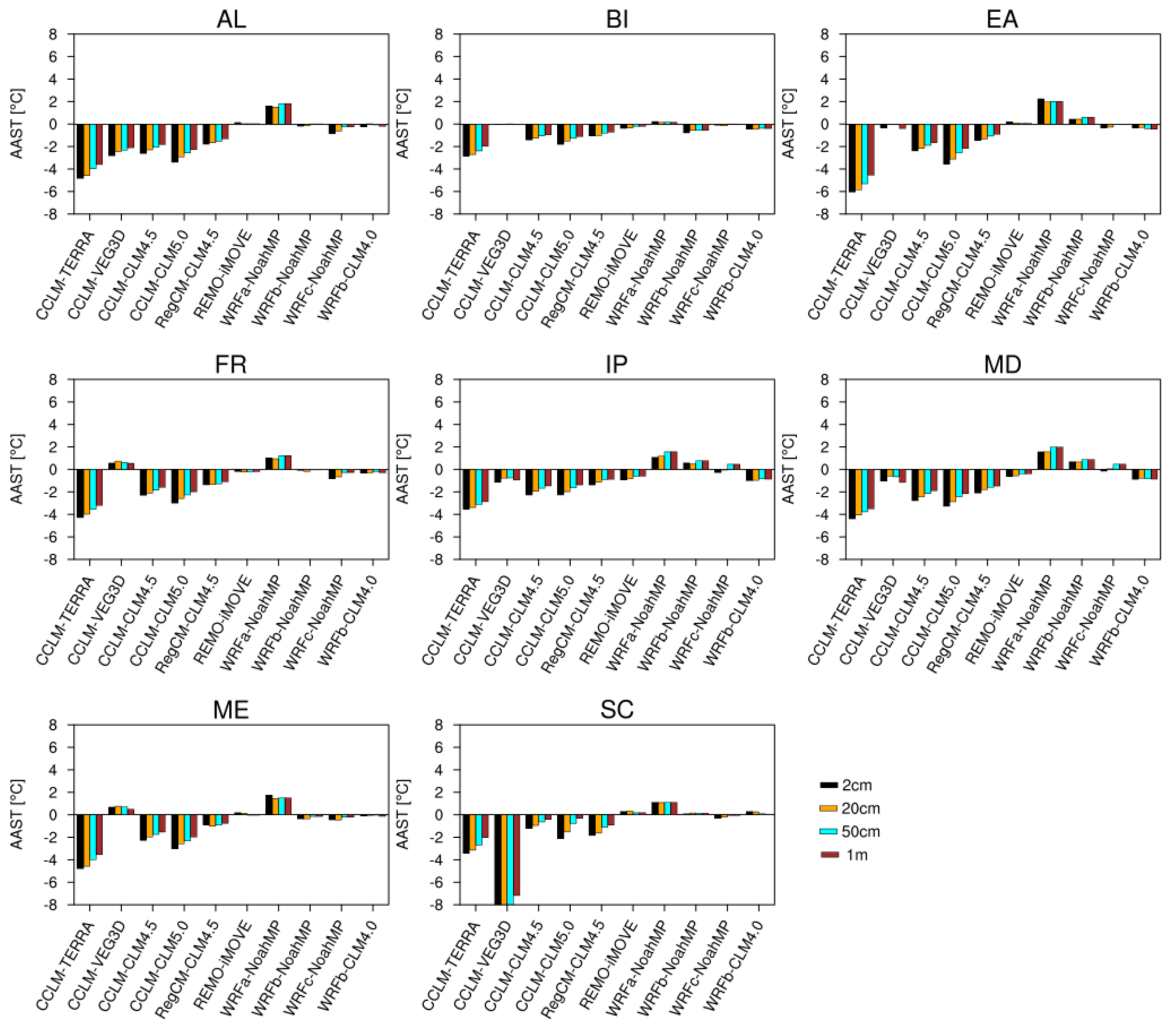

Figure S5: Afforestation (FOREST minus GRASS) impact on the annual amplitude of soil temperature (AAST) at 2cm, 20cm, 50cm and 1 meter soil depth, summarized over all European regions.

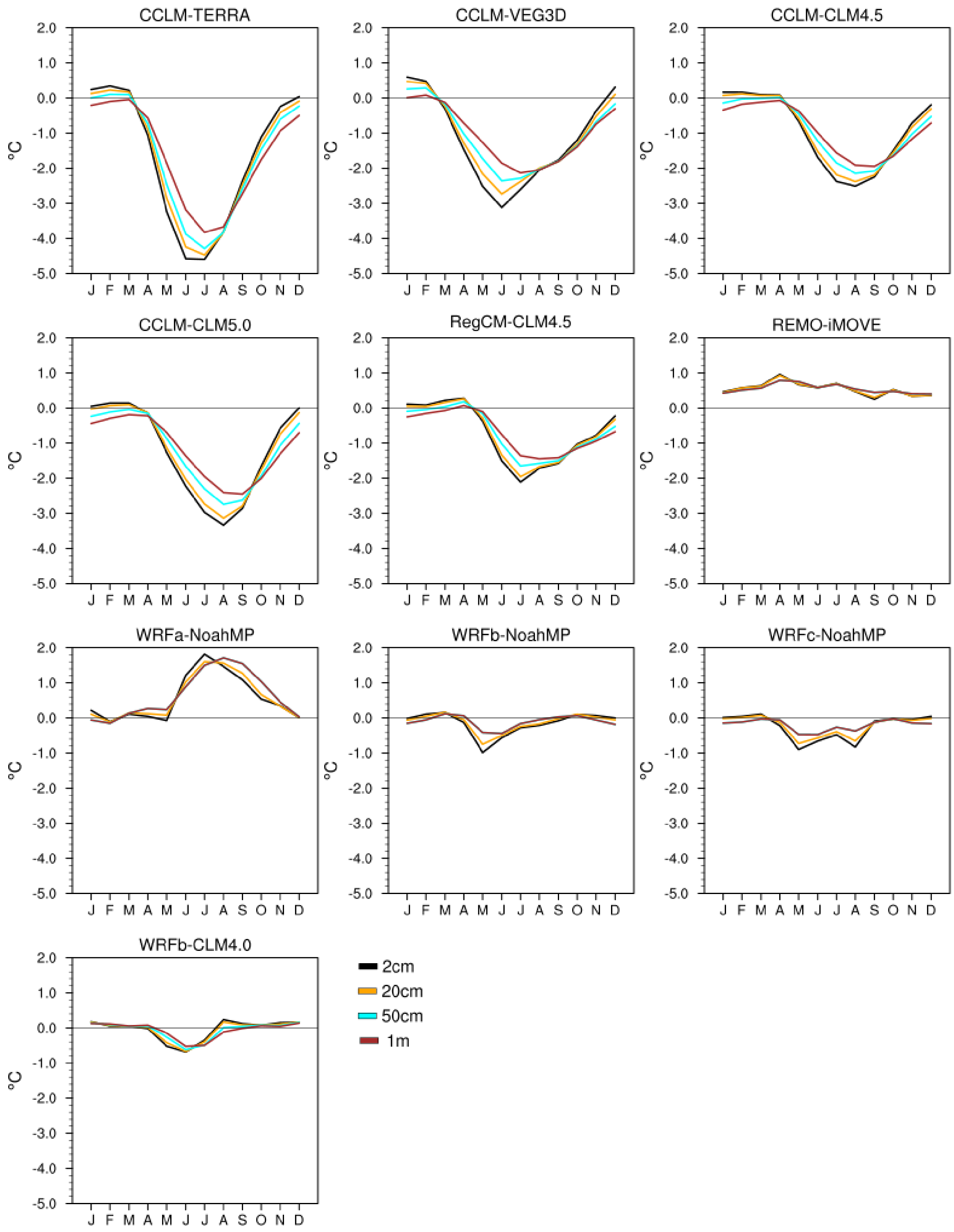

Figure S6: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over Alps.

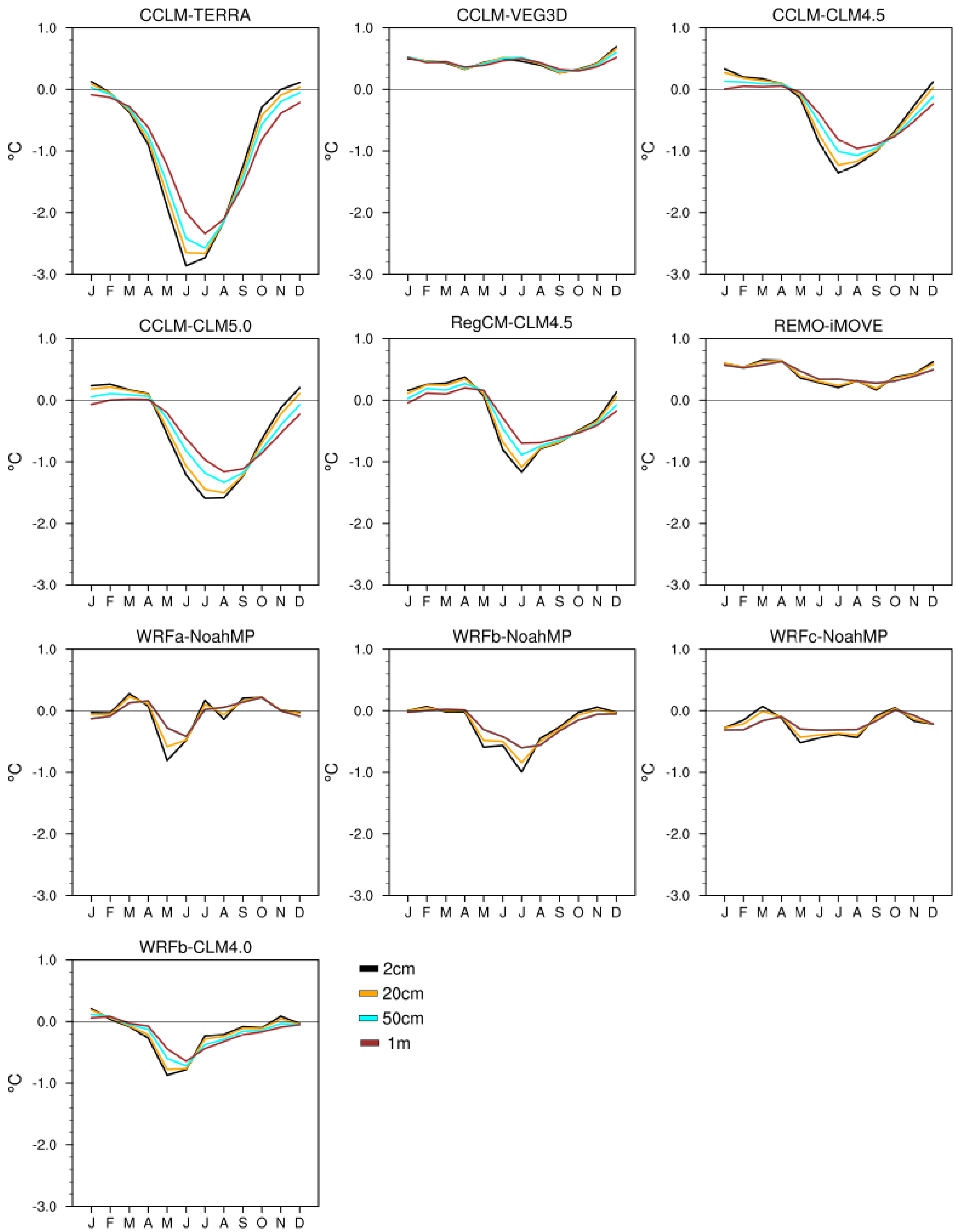

Figure S7: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over British Isles.

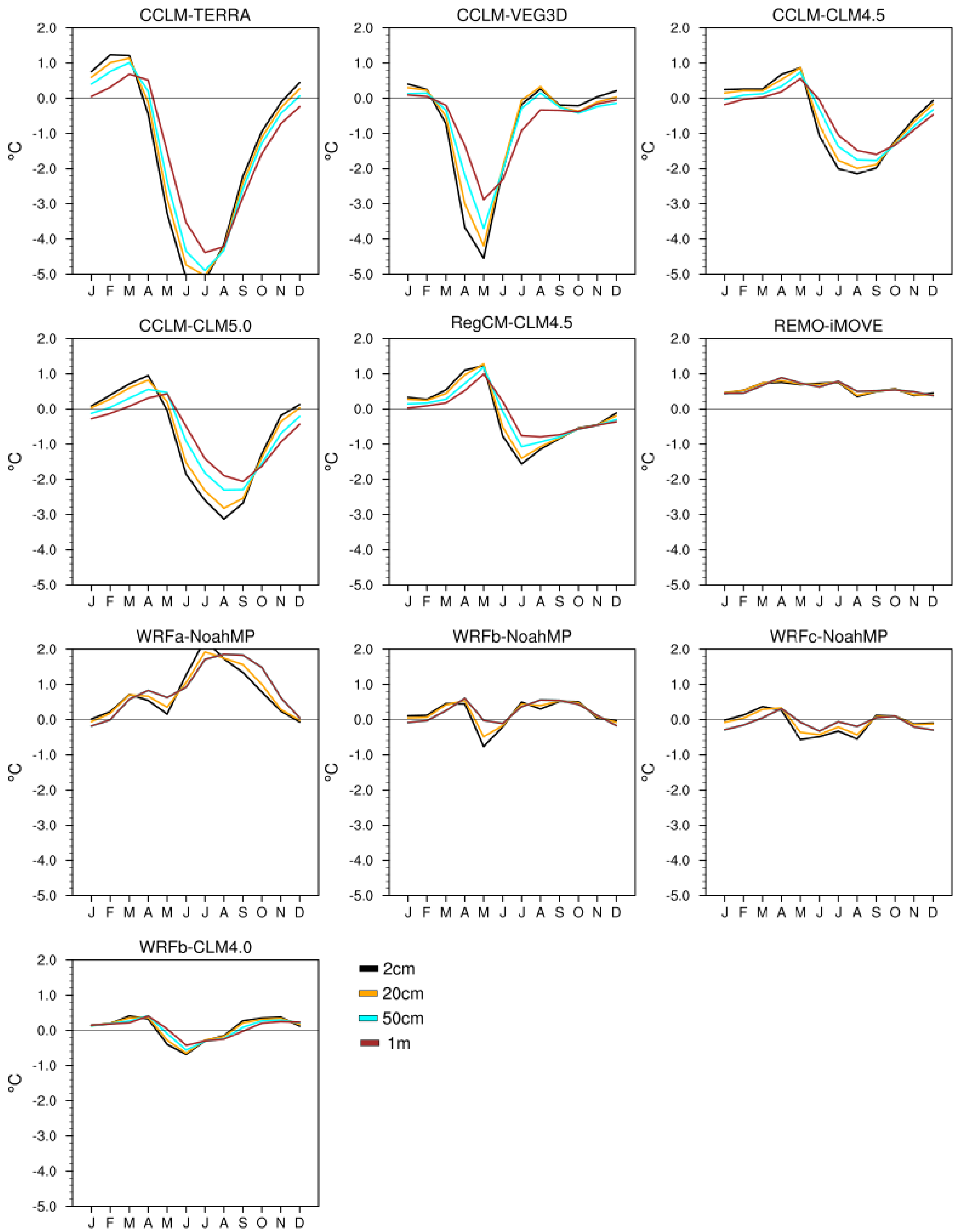

Figure S8: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over Eastern Europe.

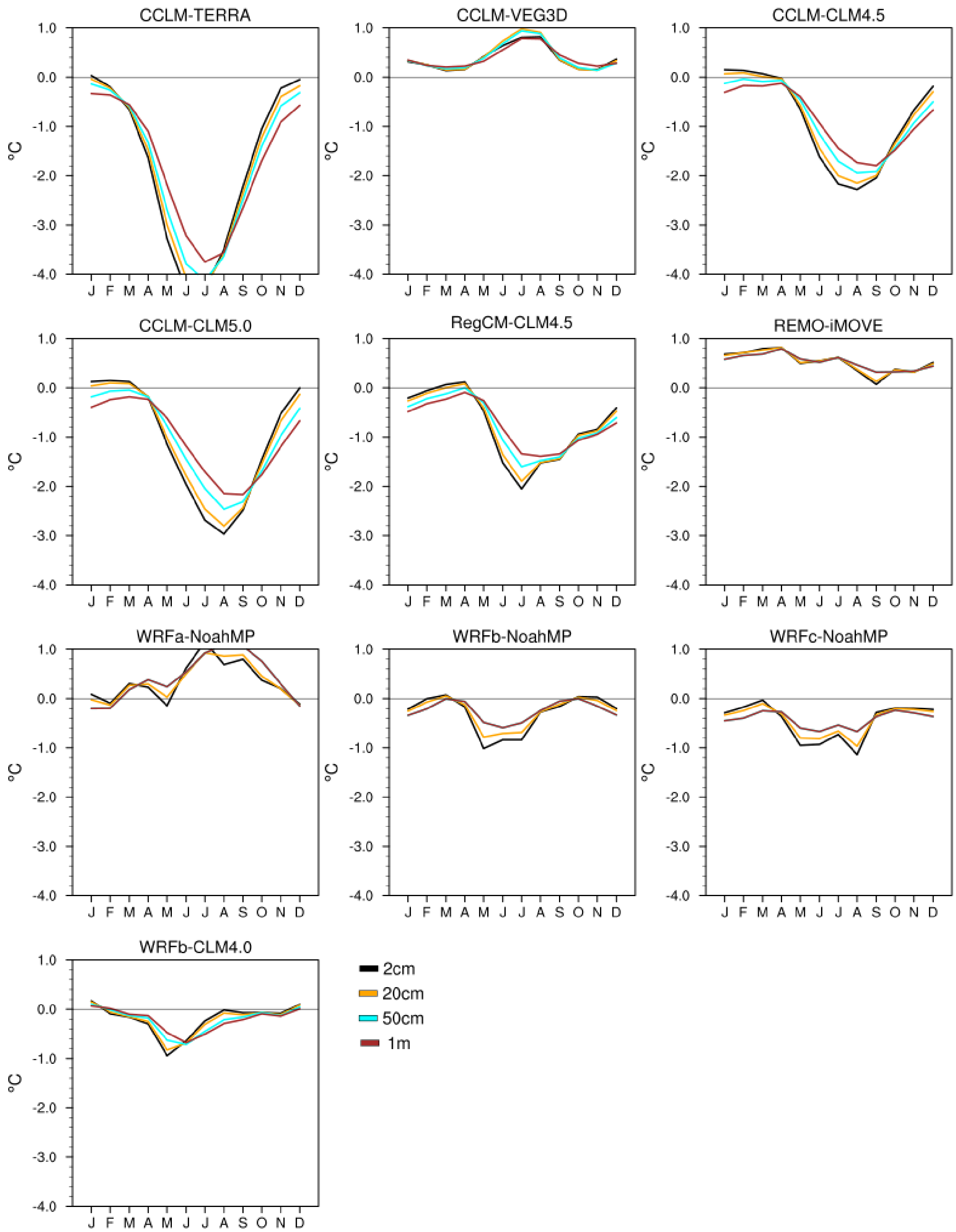

Figure S9: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over France.

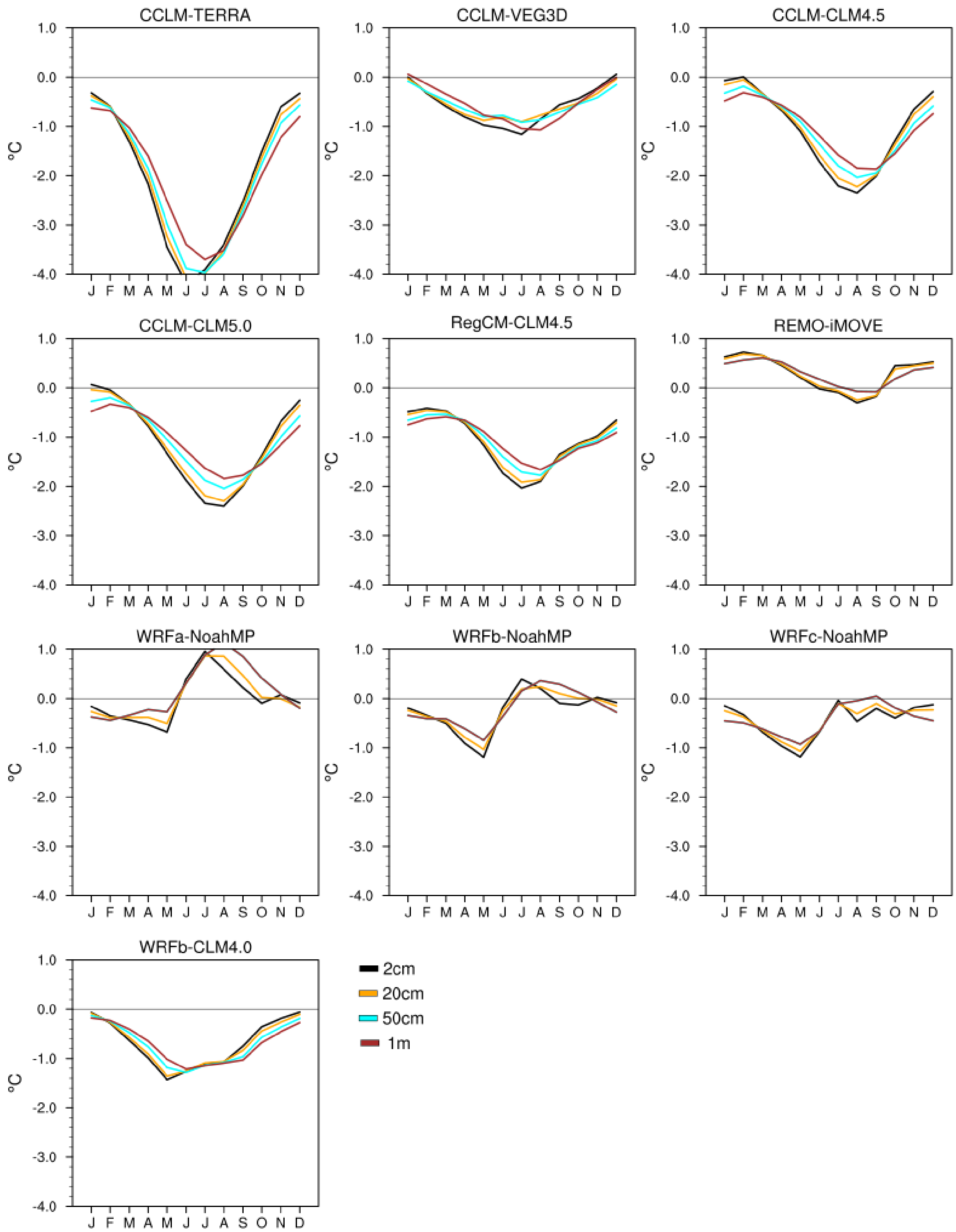

Figure S10: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over Iberian Peninsula.

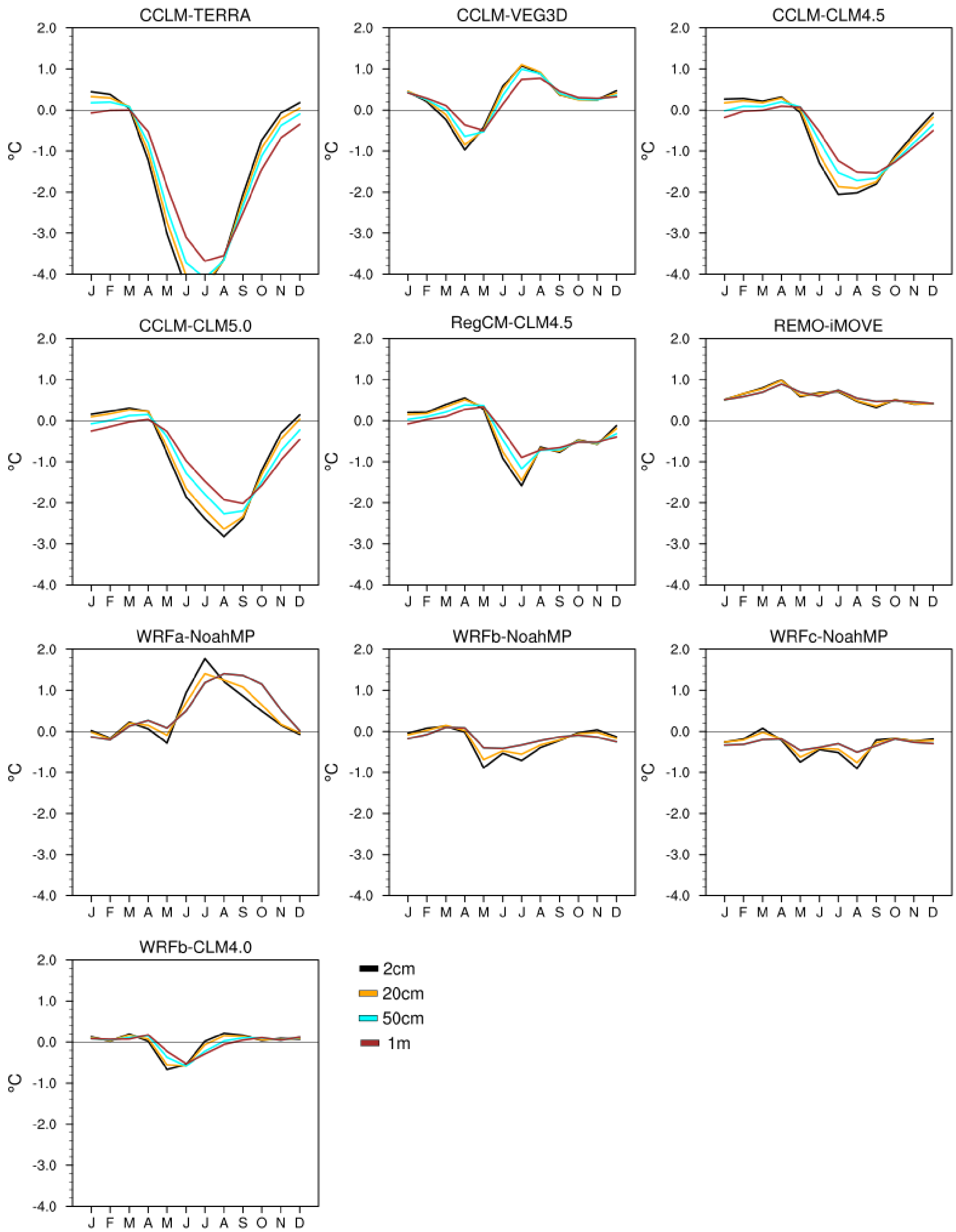

Figure S11: Afforestation impact (FOREST minus GRASS) on mean monthly soil temperature at four different soil depths over Mid-Europe.

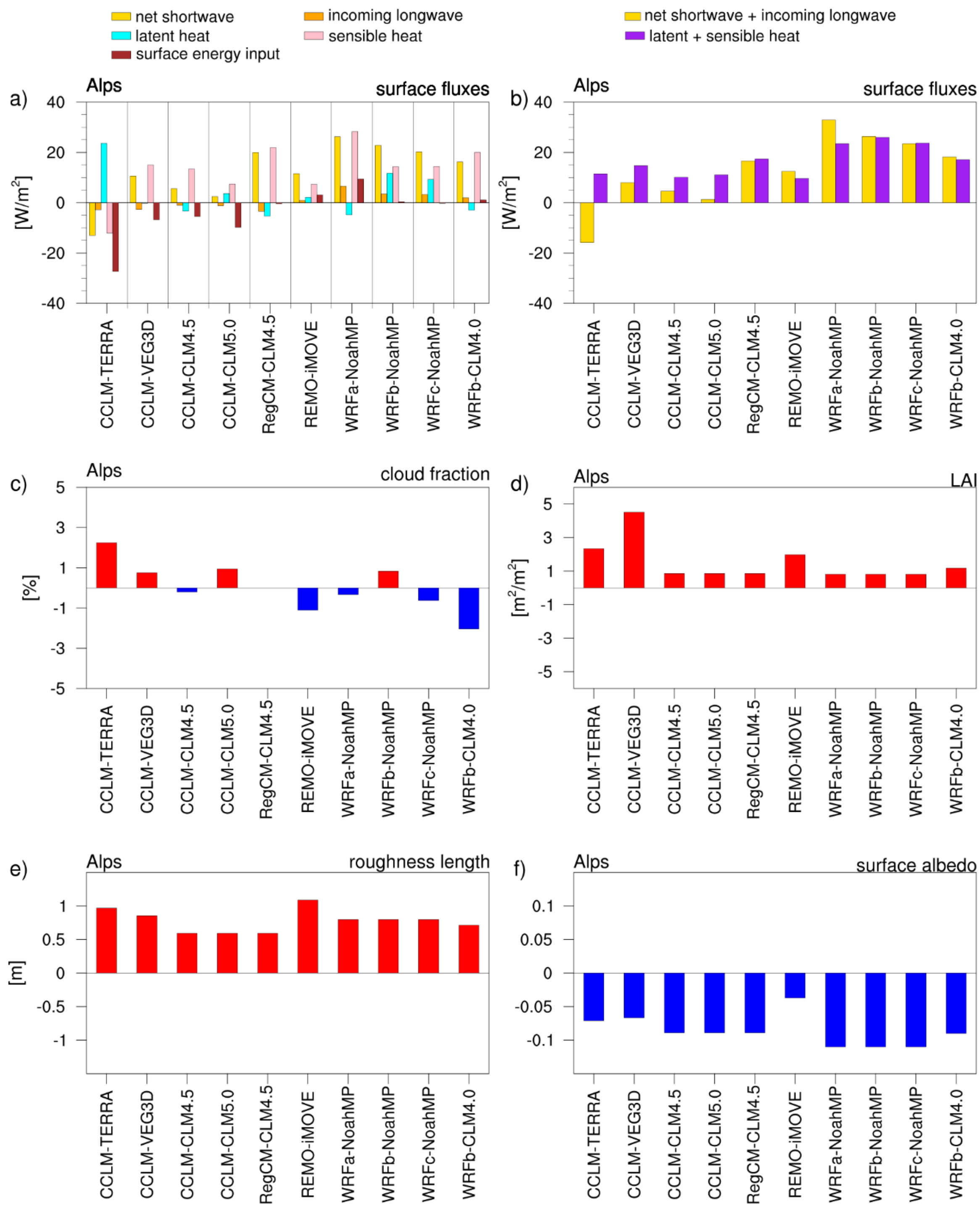

Figure S12: Changes in surface energy balance components (FOREST minus GRASS) averaged over Alps in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

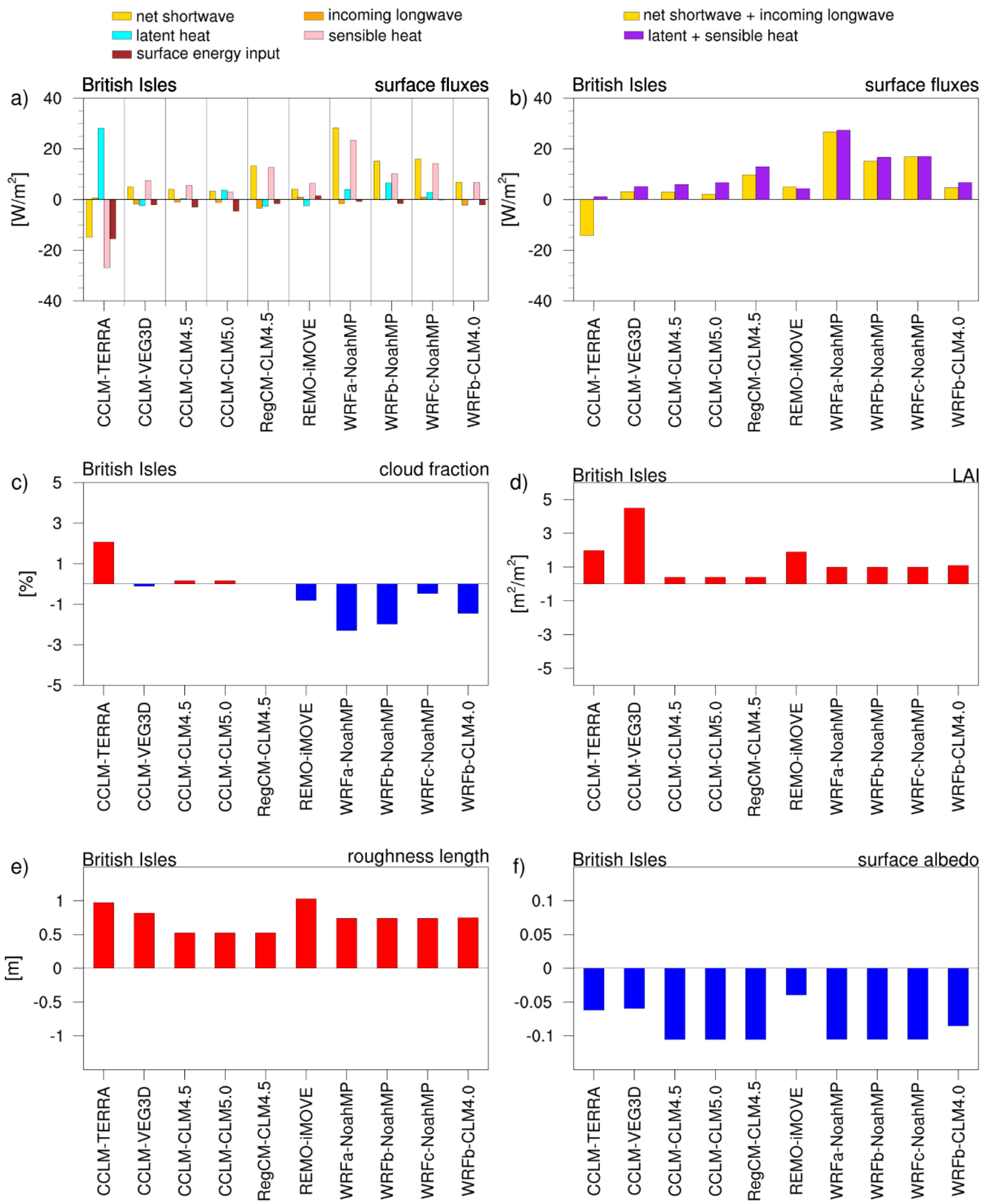

Figure S13: Changes in surface energy balance components (FOREST minus GRASS) averaged over British Isles in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

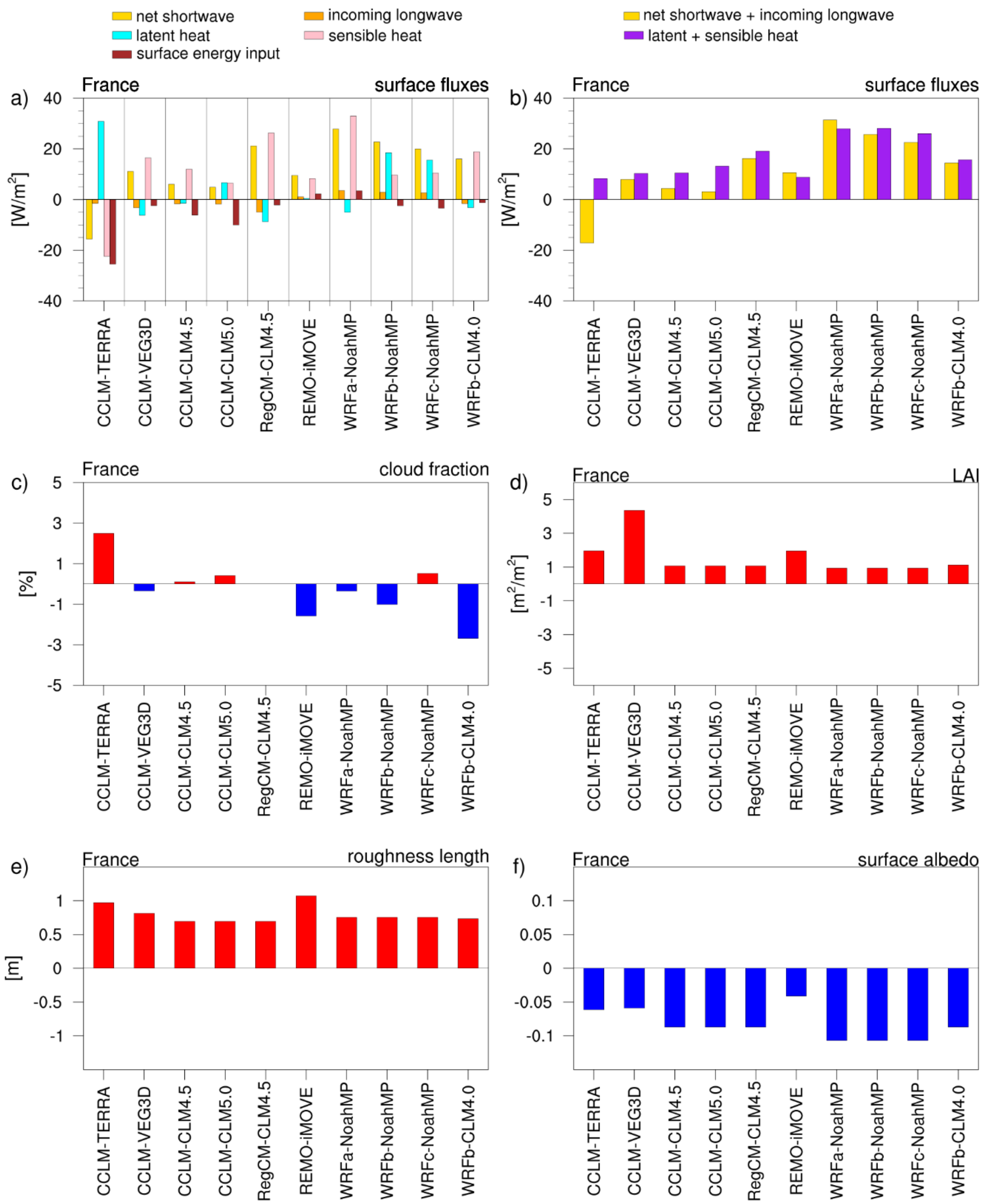

Figure S14: Changes in surface energy balance components (FOREST minus GRASS) averaged over France in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

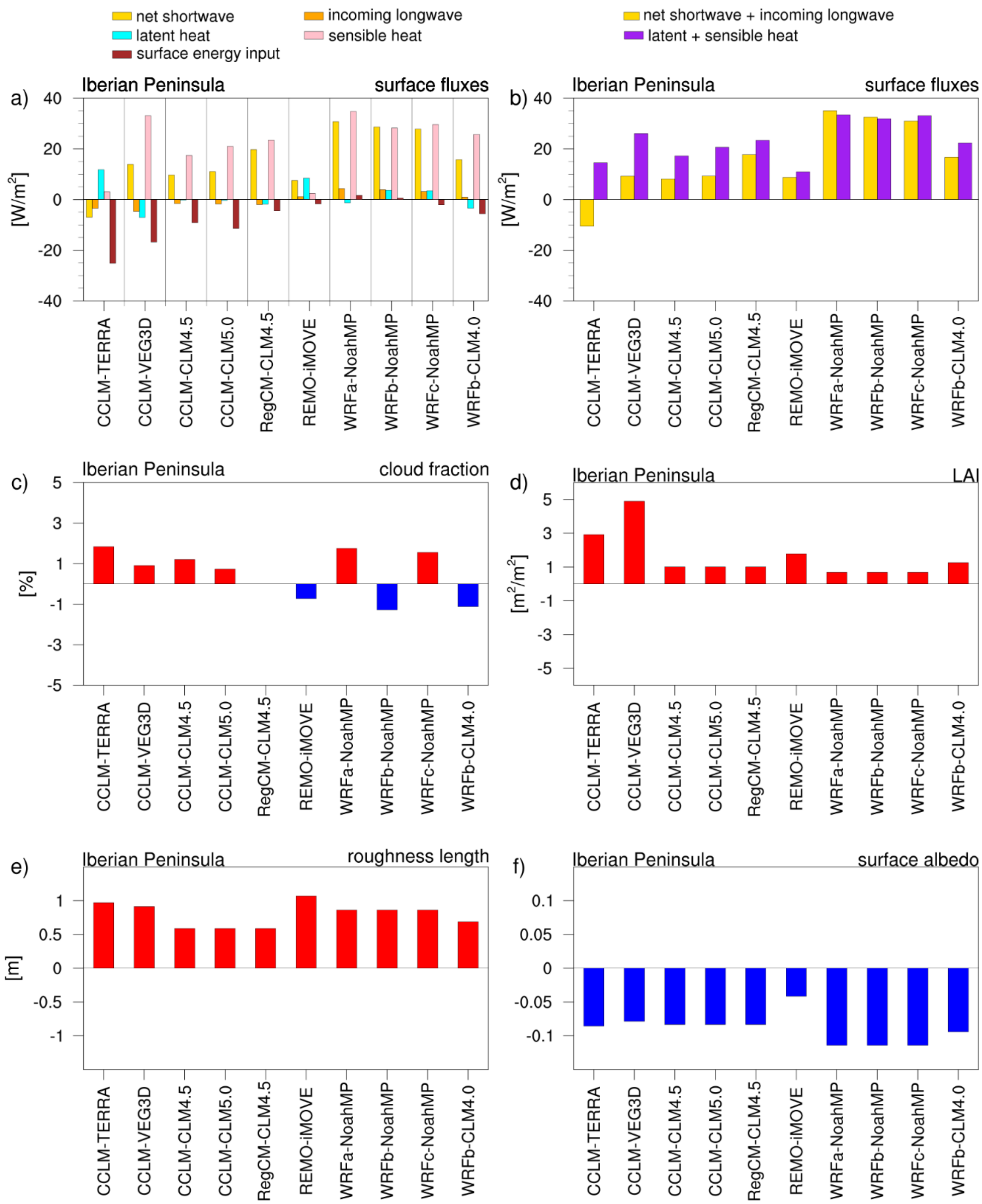

Figure S15: Changes in surface energy balance components (FOREST minus GRASS) averaged over Iberian Peninsula in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

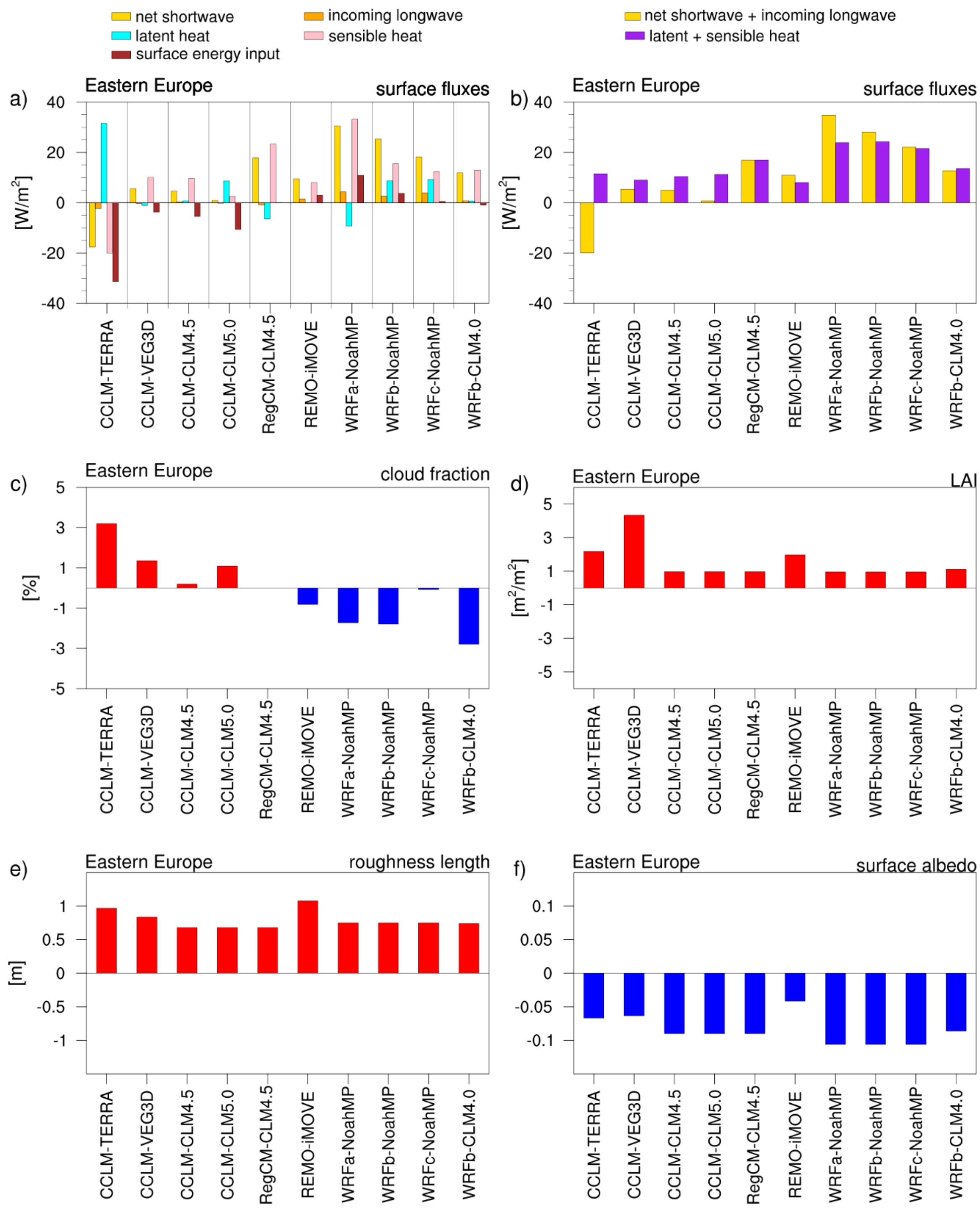

Figure S16: Changes in surface energy balance components (FOREST minus GRASS) averaged over Eastern Europe in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

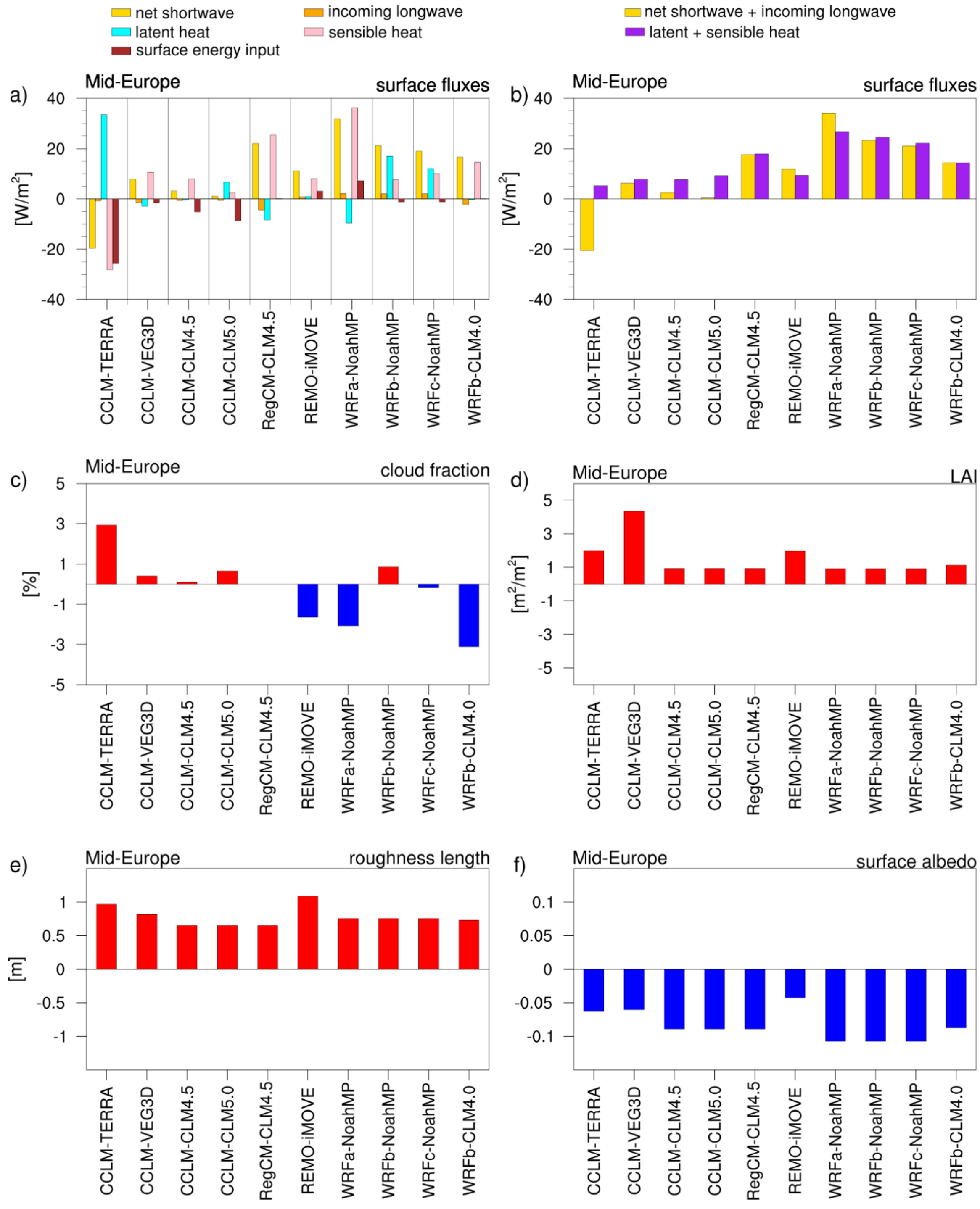

Figure S17: Changes in surface energy balance components (FOREST minus GRASS) averaged over Mid-Europe in summer, (b) The changes in available radiative energy at surface and in the sum of turbulent heat fluxes with afforestation (FOREST minus GRASS), (c) Cloud fraction response to afforestation across models, and the inter-model differences in leaf area index (LAI) (d), surface roughness (e) and surface albedo (f) in summer (yearly maximum). Positive (negative) values mean increase (decrease) with afforestation.

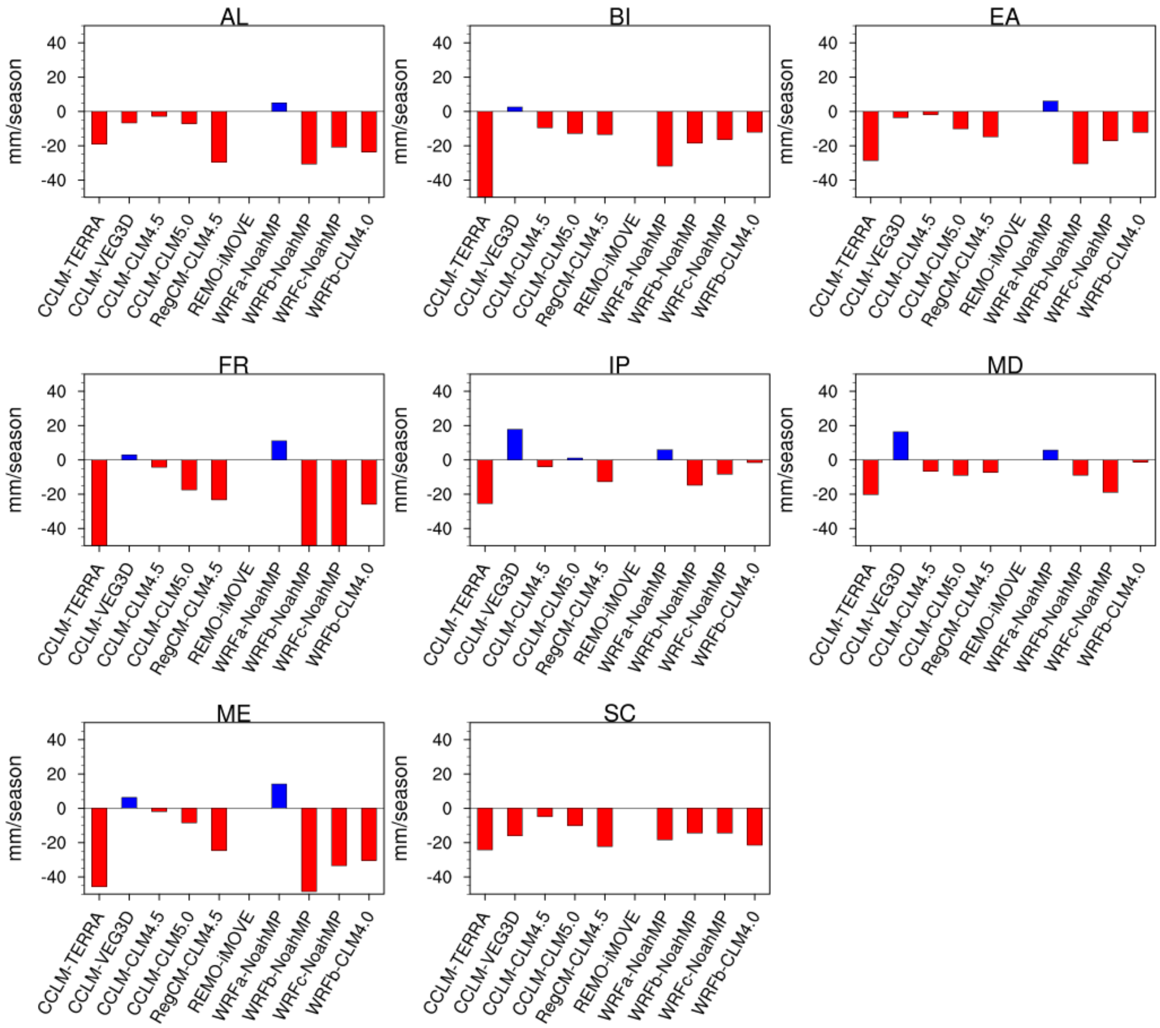

Figure S18: Afforestation (FOREST minus GRASS) impact on surface water balance, defined as the difference between precipitation and evapotranspiration, during summer season over the regions of interest.

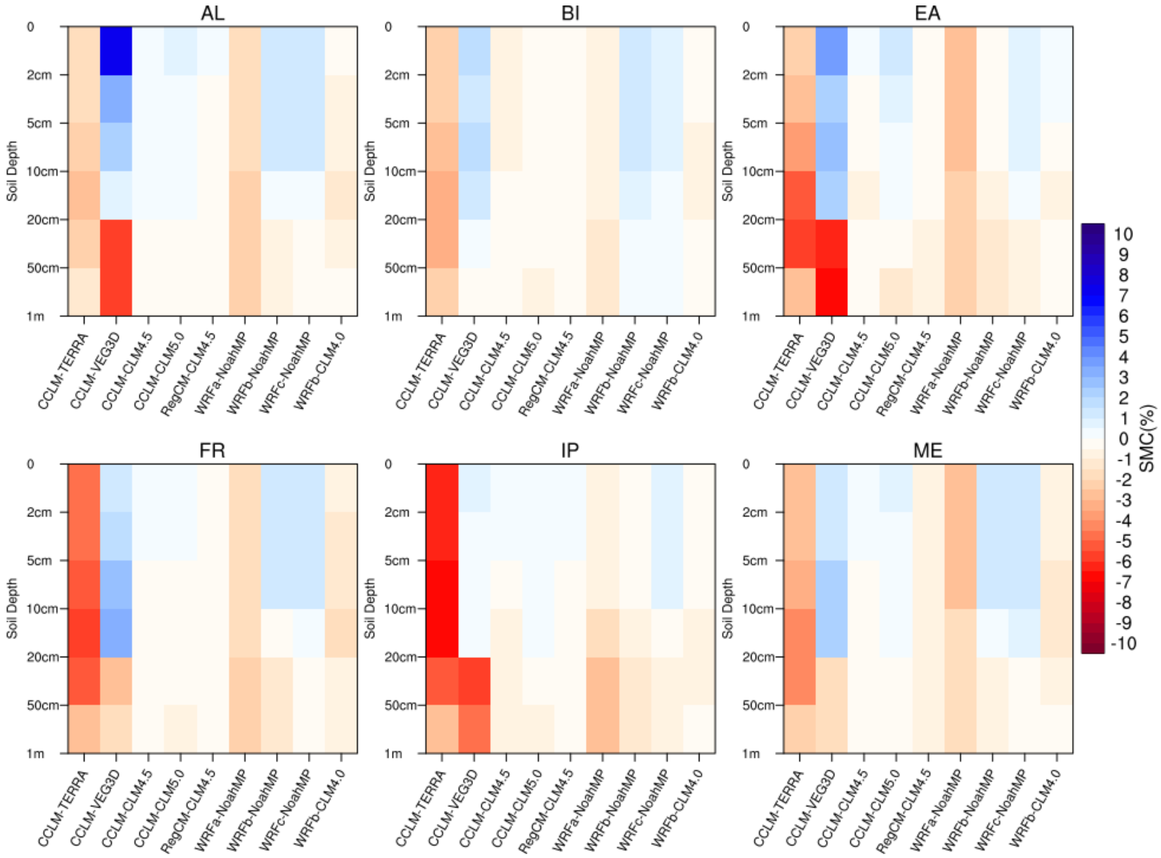

Figure S19: Summer changes in soil moisture content (SMC) due to afforestation (FOREST minus GRASS) in the top 1 meter of the soil over European sub-regions.