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Industrial Ecology Programme
Department of Energy and Process Engineering
Faculty of Engineering

Decomposition of the effects on regional climate from recent historical land cover changes in Europe

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10.10.2020

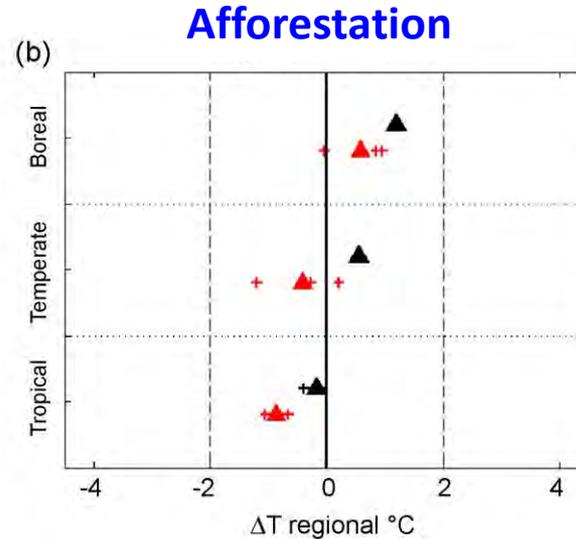
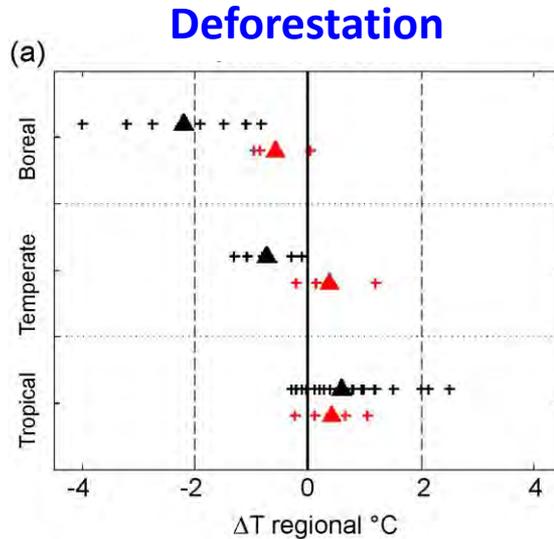
Francesco Cherubini, Xiangping Hu, Geir-Arne Fuglstad, Xu Zhou, Wenwu Zhao

AGU2020, Session GC109



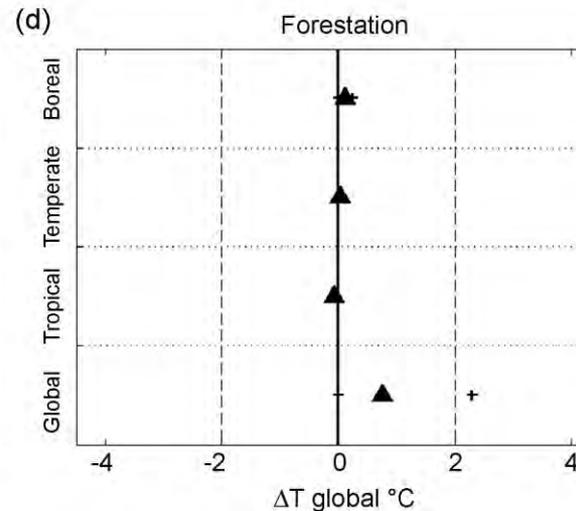
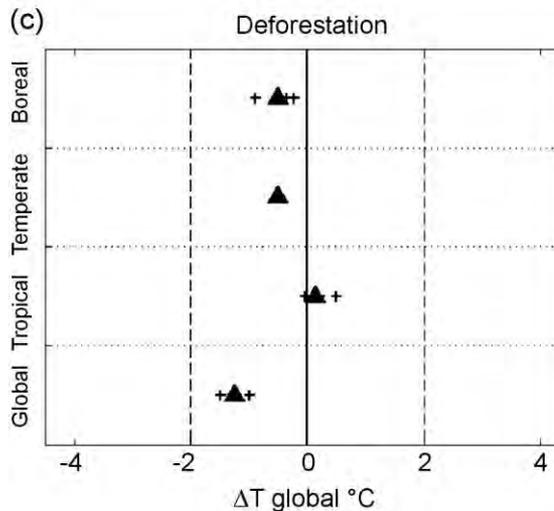
Forest changes impact on climate

Regional



- + observation
- + model
- ▲ obs mean
- ▲ model mean

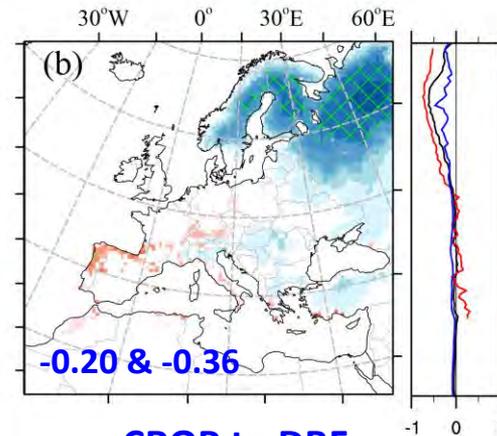
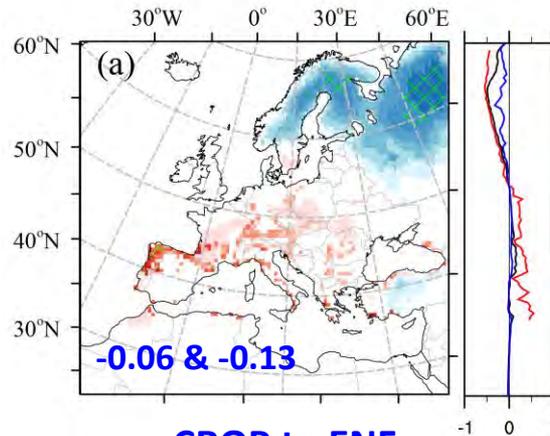
Global



Climate change under extreme land cover changes

FOR to BL

FOR to HV

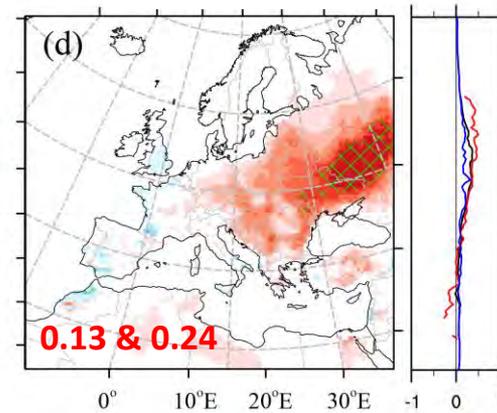
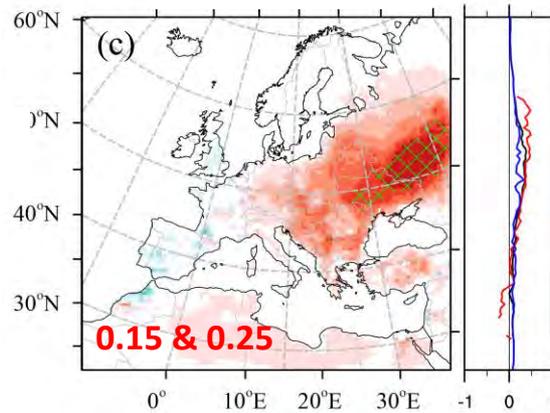


Cooling

Latitudinal pattern
(50° N)

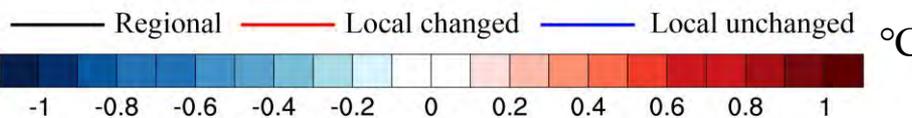
CROP to ENF

CROP to DBF



Warming

Longitudinal gradient
(10° E)



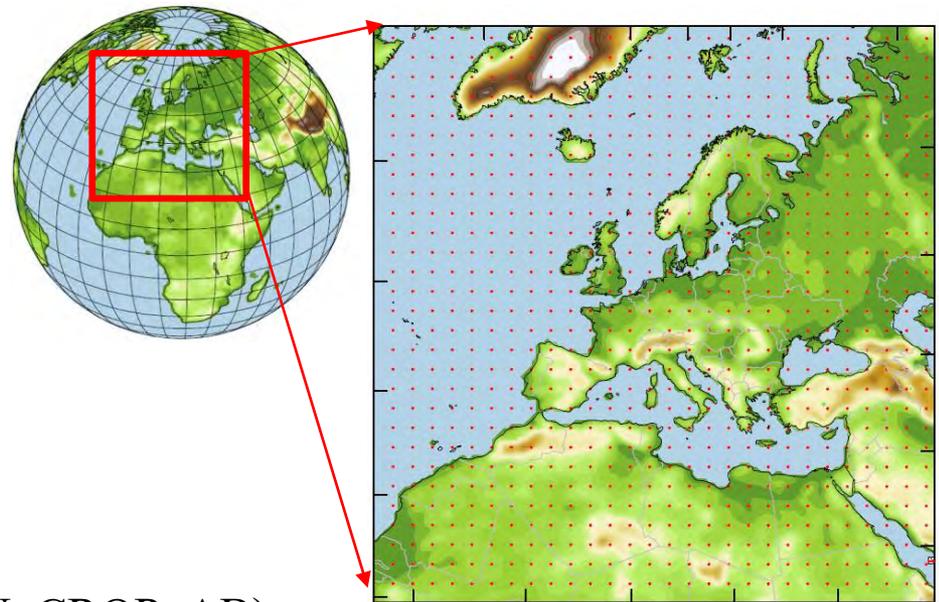
Data and model simulations

➤ Data

- European Space Agency (ESA) Climate Change Initiative (CCI) land cover 2015
- E-OBS observation
- Duveiller et al., 2018 *Sci Data*

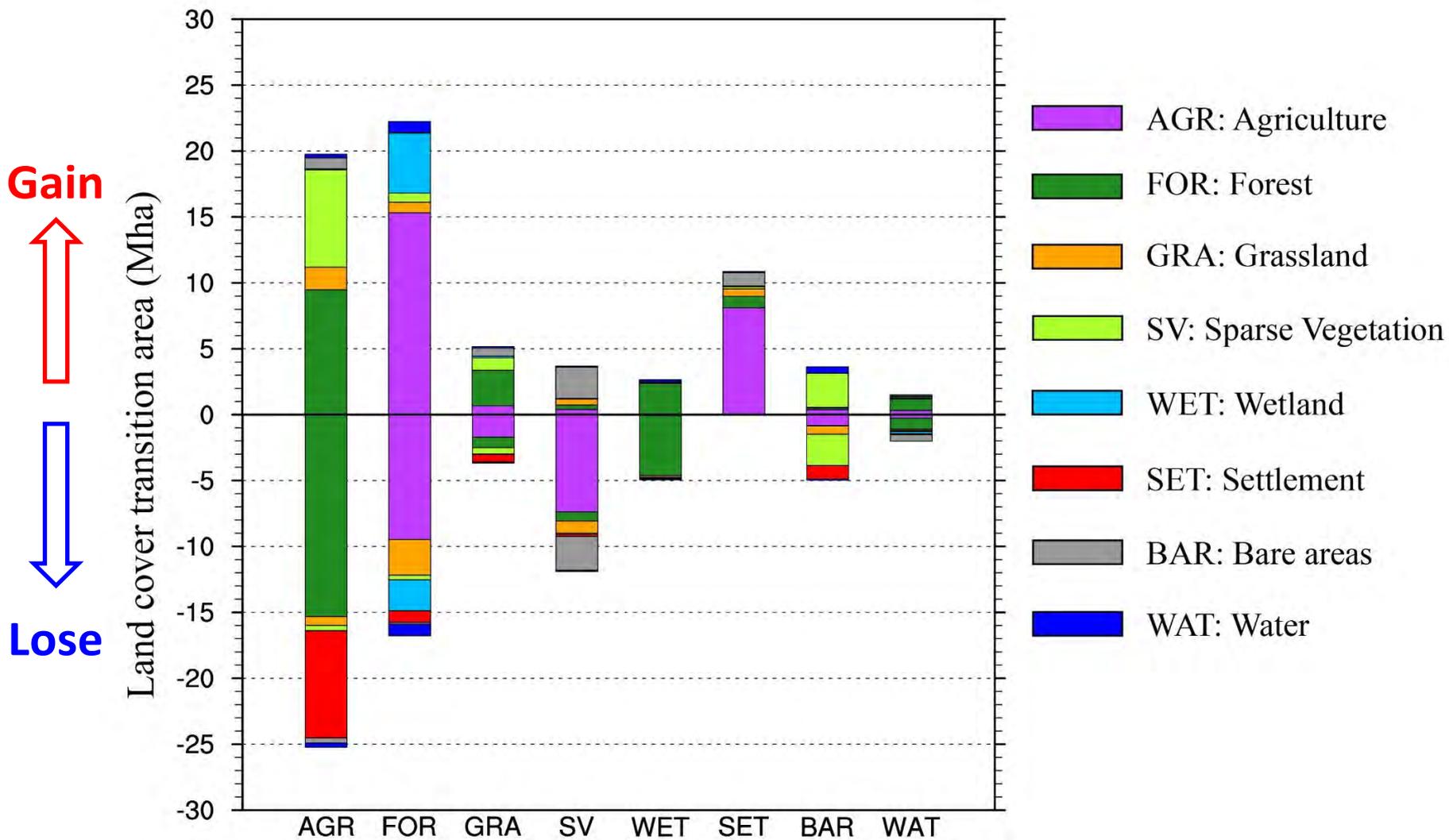
➤ Model simulation

- WRF v3.9.1, CLM4 land surface model
- Driven data: ERA-Interim
- Horizontal resolution: 0.11° (~12km)
- Three simulations:
 - LC1992,
 - LC2015, and
 - No Cropland abandonment (NoCROP_AB)



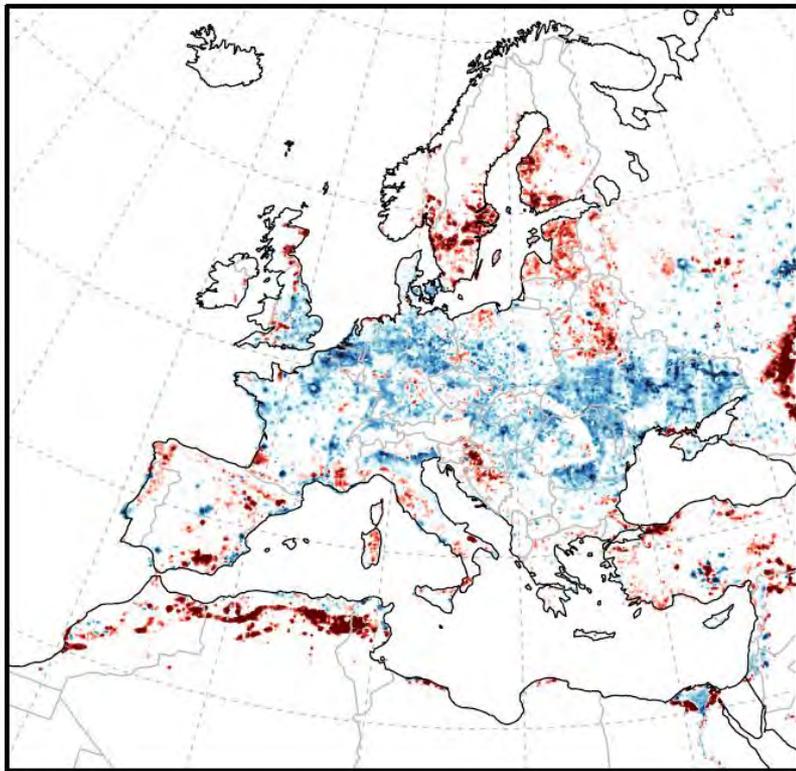
➤ Ridge-regression model

Land cover change in Europe

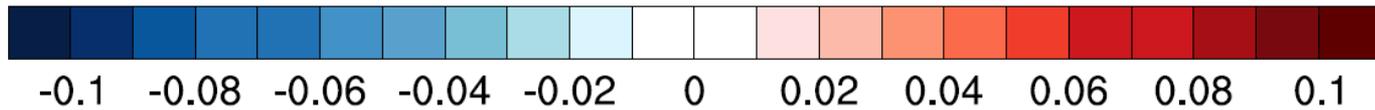
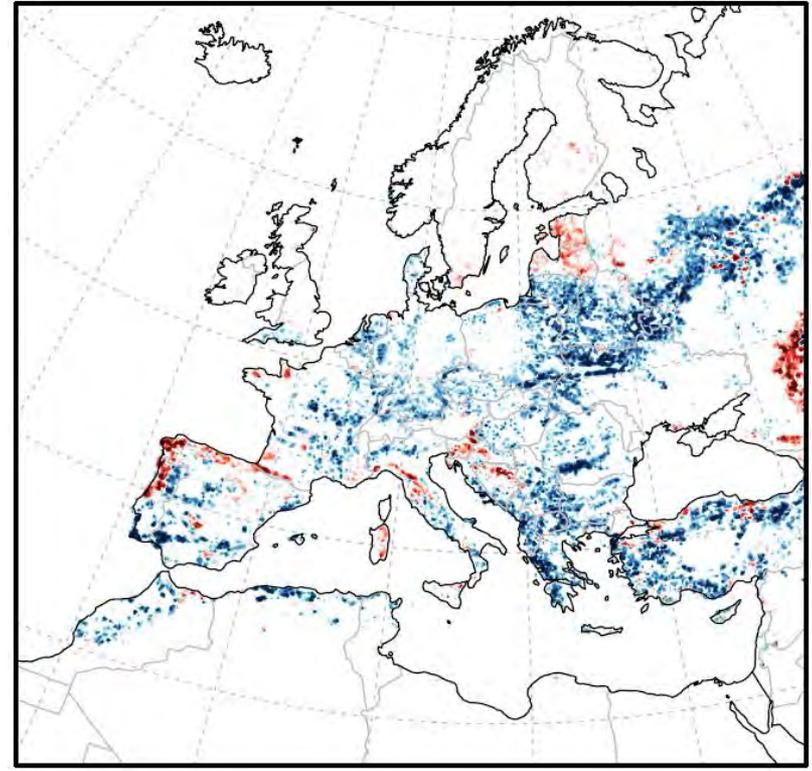


Cropland fraction difference between 2015 and 1992

Cropland

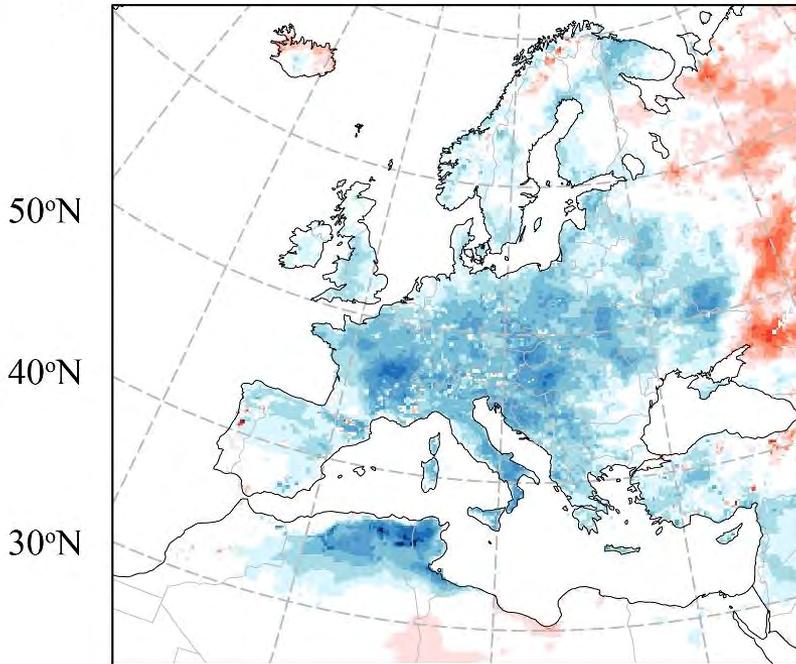


Cropland/Natural vegetation

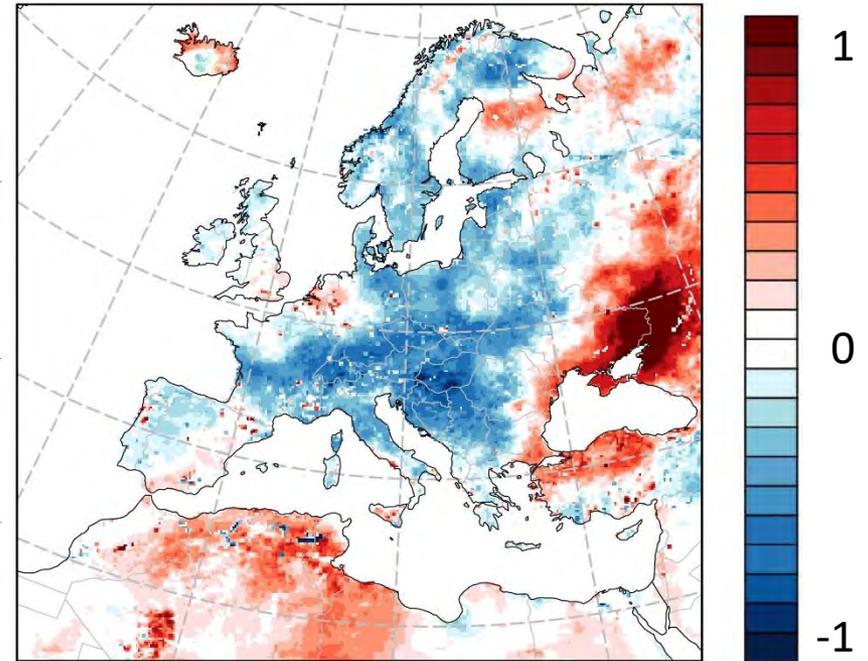


Climate change due to land cover change

Temperature



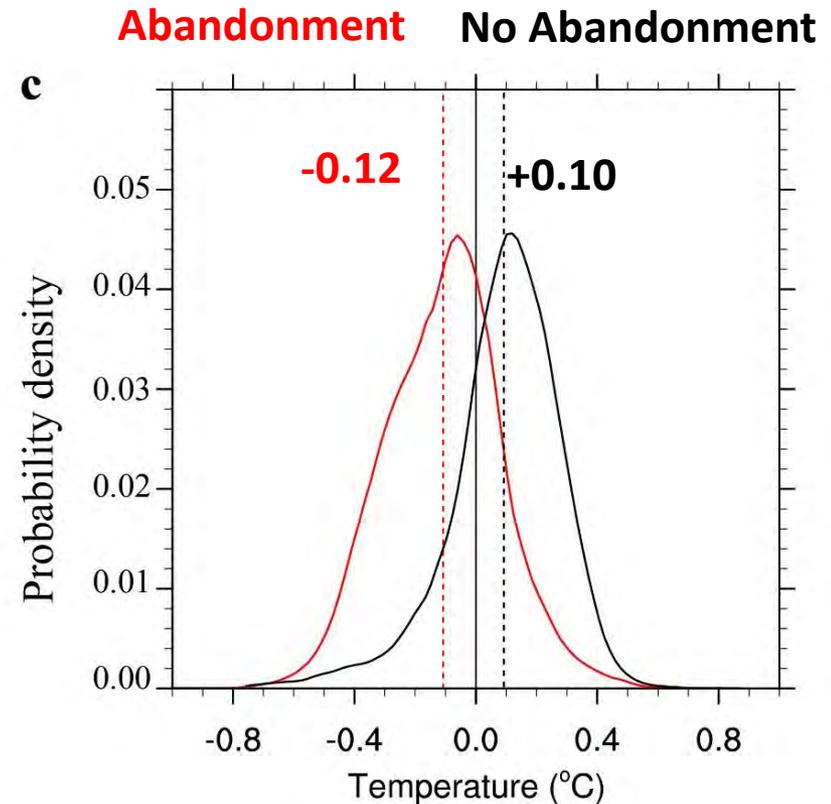
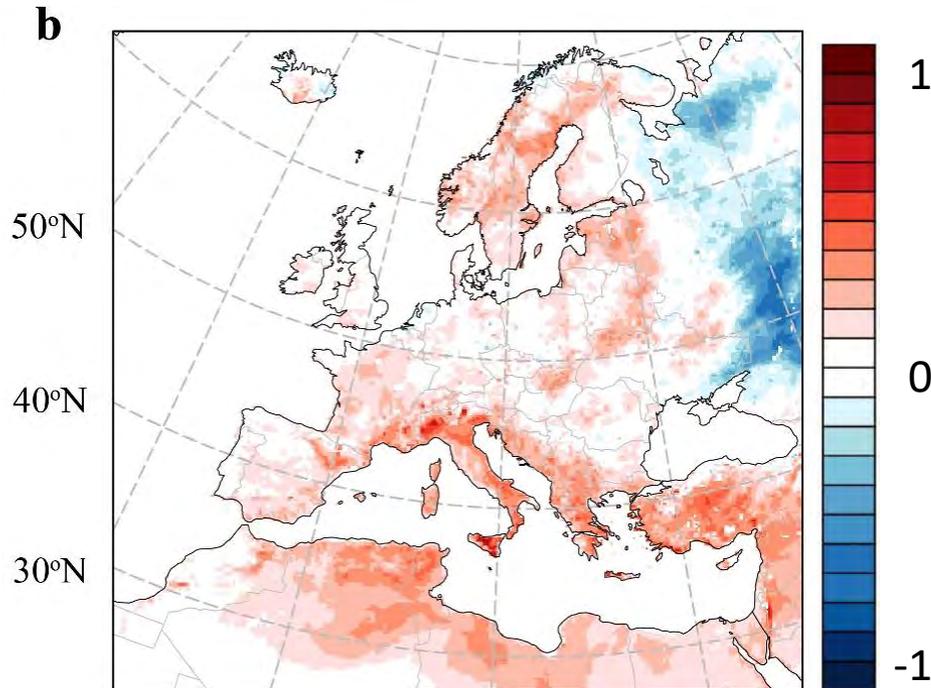
Equivalent Temperature



- an annual average temperature change of -0.12 ± 0.20 °C (mean \pm standard deviation), with -0.42 and $+0.22$ °C as the 5th and 95th percentile
- At a continental level, the average difference in T_E from the recent LCCs is -0.10 ± 0.37 °C, with $-0.58/+0.57$ °C as the 5th and 95th percentile

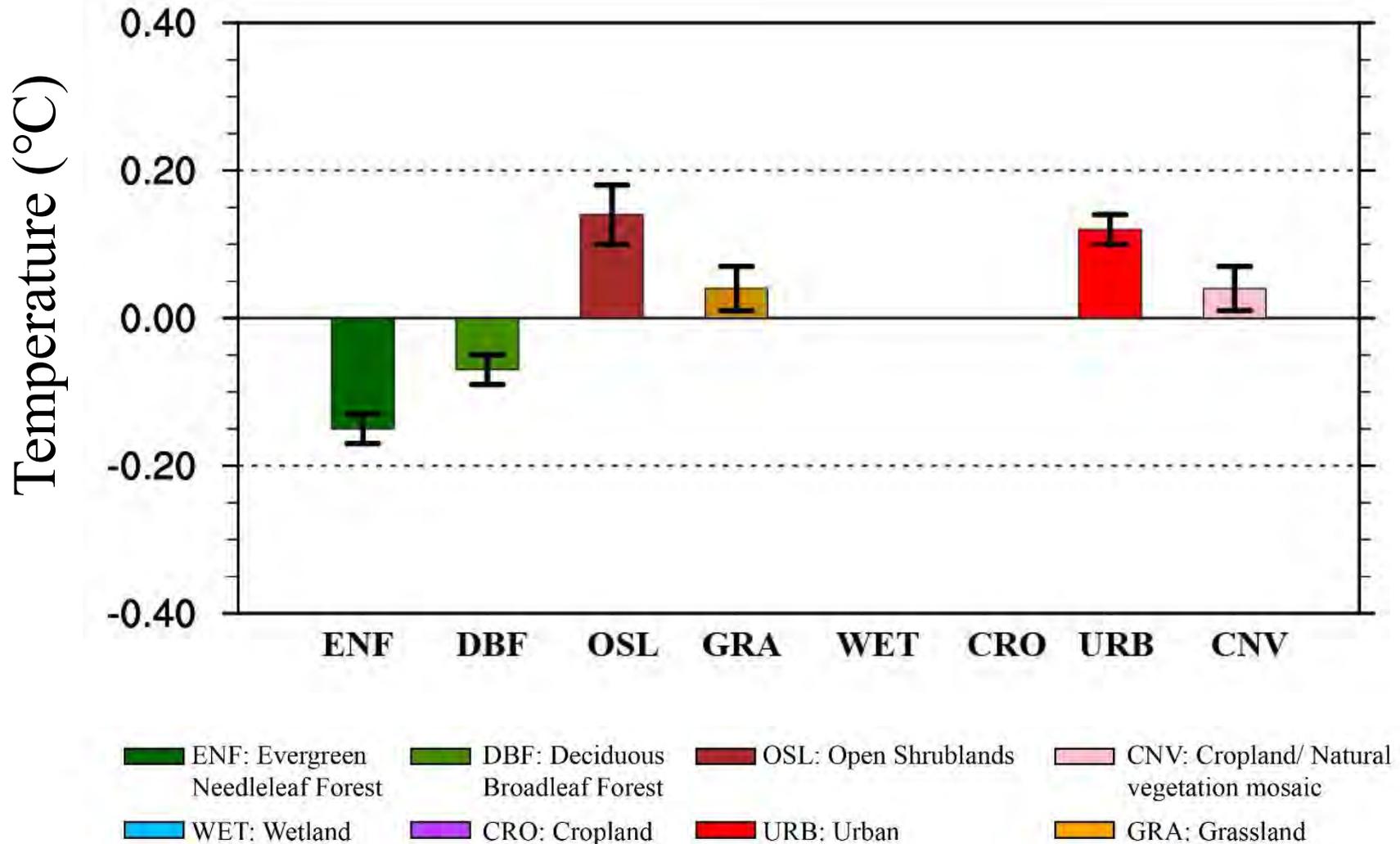
Effect of agriculture abandonment

NoCROP_AB – LC2015

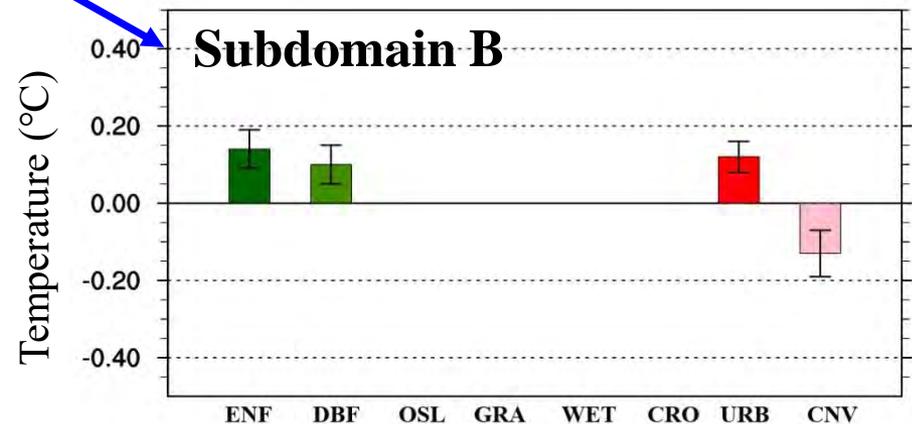
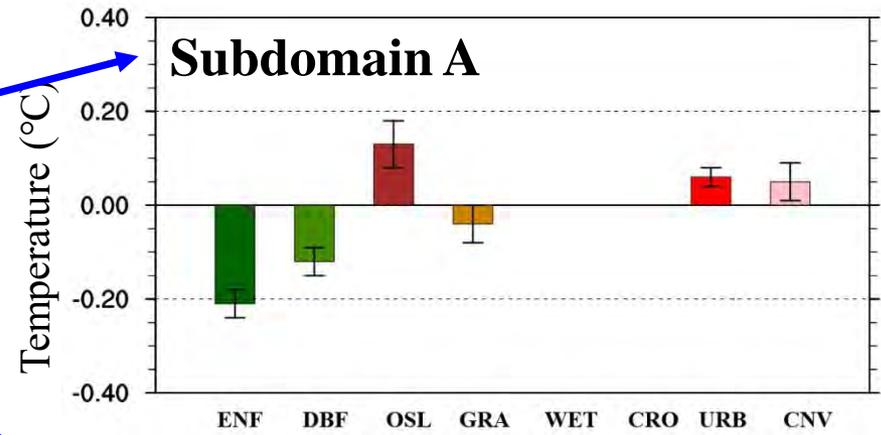
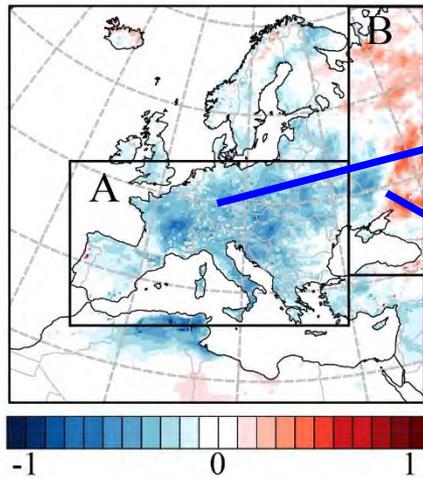


- When the transitions from **cropland to other land classes are excluded**, an annual average temperature change of **$+0.10 \pm 0.19$ °C**, with **-0.23** and **+0.33 °C** as the 5th and 95th percentile

Temperature change with cropland transition

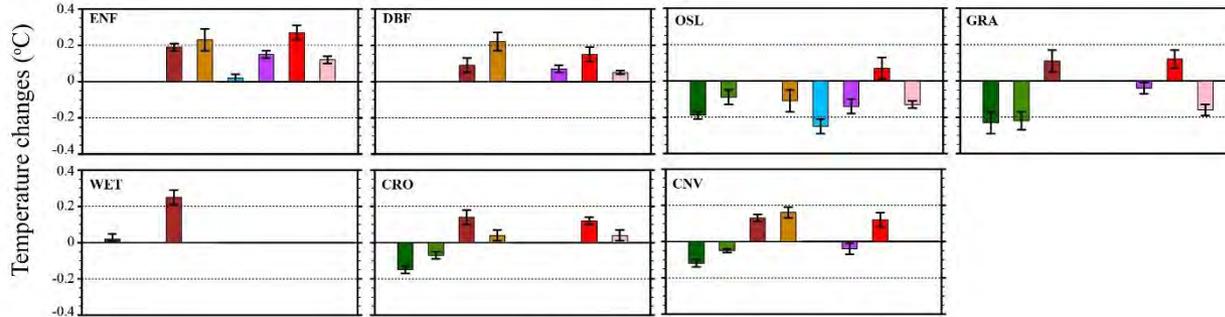


Different climate change response to cropland transition in East and West-Central Europe

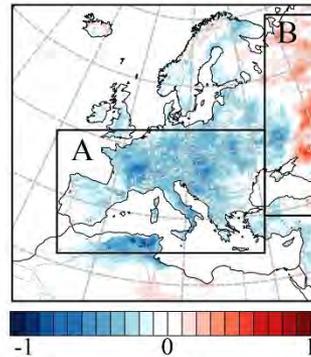


- In subdomain A, conversion of evergreen or deciduous forest to cropland results in an **average warming** of $+0.21 \pm 0.03$ °C and $+0.12 \pm 0.03$ °C
- In subdomain B, these transitions are associated with an **average cooling** of -0.14 ± 0.05 °C and -0.10 ± 0.05 °C
- This is mostly due to the **local conditions** discussed above, such as the interplay between **surface albedo changes**, **evapotranspiration** efficiencies and **soil moisture**

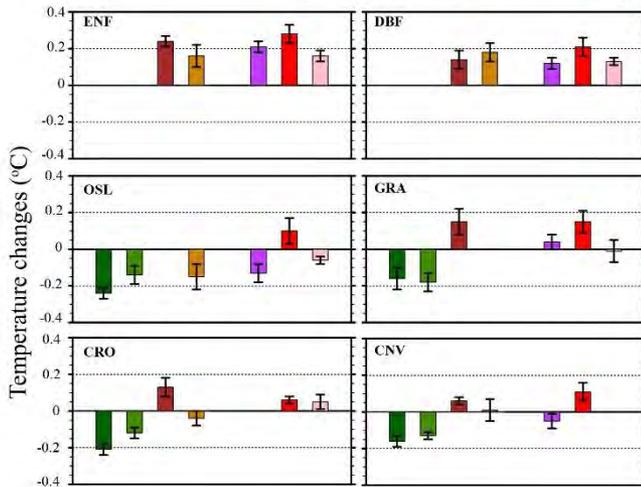
Europe



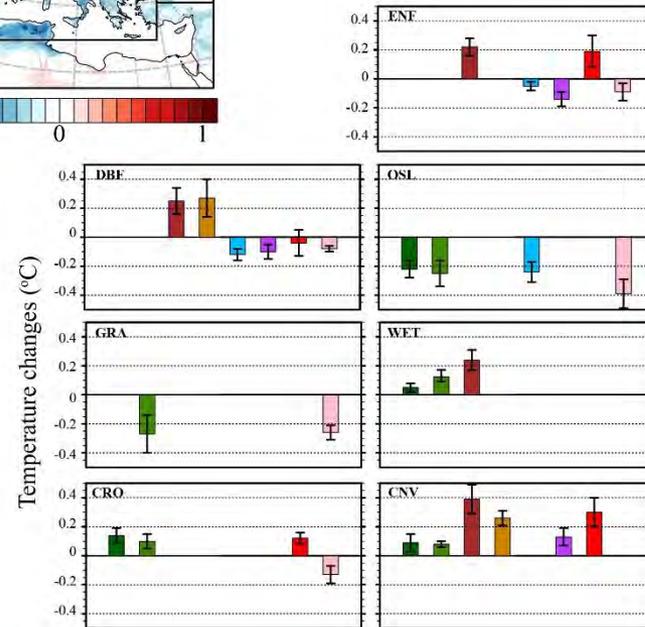
Decomposition of the temperature changes to individual land cover changes



Subdomain A



Subdomain B



- ENF: Evergreen Needleleaf Forest
- DBF: Deciduous Broadleaf Forest
- OSL: Open Shrublands
- CNV: Cropland/ Natural vegetation mosaic
- WET: Wetland
- CRO: Cropland
- URB: Urban
- GRA: Grassland

Comparison of climate change with land cover transition in observation data

Land Cover Transition	Europe		Subdomain A		Subdomain B	
	Our study	Ref.	Our study	Ref.	Our study	Ref.
ENF <=> OSL	0.19±0.04	0.20±0.08			0.22±0.12	0.18±0.12
ENF <=> GRA	0.23±0.12	0.11±0.06	0.16±0.12	0.24±0.06		
ENF <=> WET	0.02±0.04	-0.40±0.04			-0.05±0.06	-0.39±0.04
ENF <=> CRO	0.12±0.04	0.20±0.04	0.21±0.06	0.80±0.06	-0.14±0.10	-0.03±0.10
DBF <=> GRA	0.22±0.08	-0.16±0.14	0.18±0.10	-0.08±0.12	0.27±0.26	-0.29±0.10
DBF <=> WET					-0.12±0.08	-0.52±0.10
DBF <=> CRO	0.07±0.04	0.34±0.04	0.12±0.06	0.68±0.04	-0.10±0.10	-0.03±0.04
OSL <=> GRA	-0.11±0.12	0.10±0.14				
OSL <=> WET	-0.25±0.08	-0.18±0.10			-0.24±0.14	-0.17±0.10
OSL <=> CRO	-0.14±0.08	-0.27±0.06	-0.13±0.10	-0.12±0.14		
GRA <=> CRO	-0.04±0.06	0.43±0.04	0.04±0.08	0.67±0.04		

Mean ± 2stddev

Summary

- Around **70 Mha of land cover changes** occurred in Europe from 1992 to 2015
- An **average temperature cooling of -0.12 ± 0.20 °C**, with seasonal and spatial variations
- At a continental level, the mean cooling is mainly driven by **agriculture abandonment** (cropland-to-forest transitions)
- A novel Bayesian regression approach decomposed the temperature change to the individual land transitions, showing **opposite responses to cropland losses and gains** between western and eastern Europe

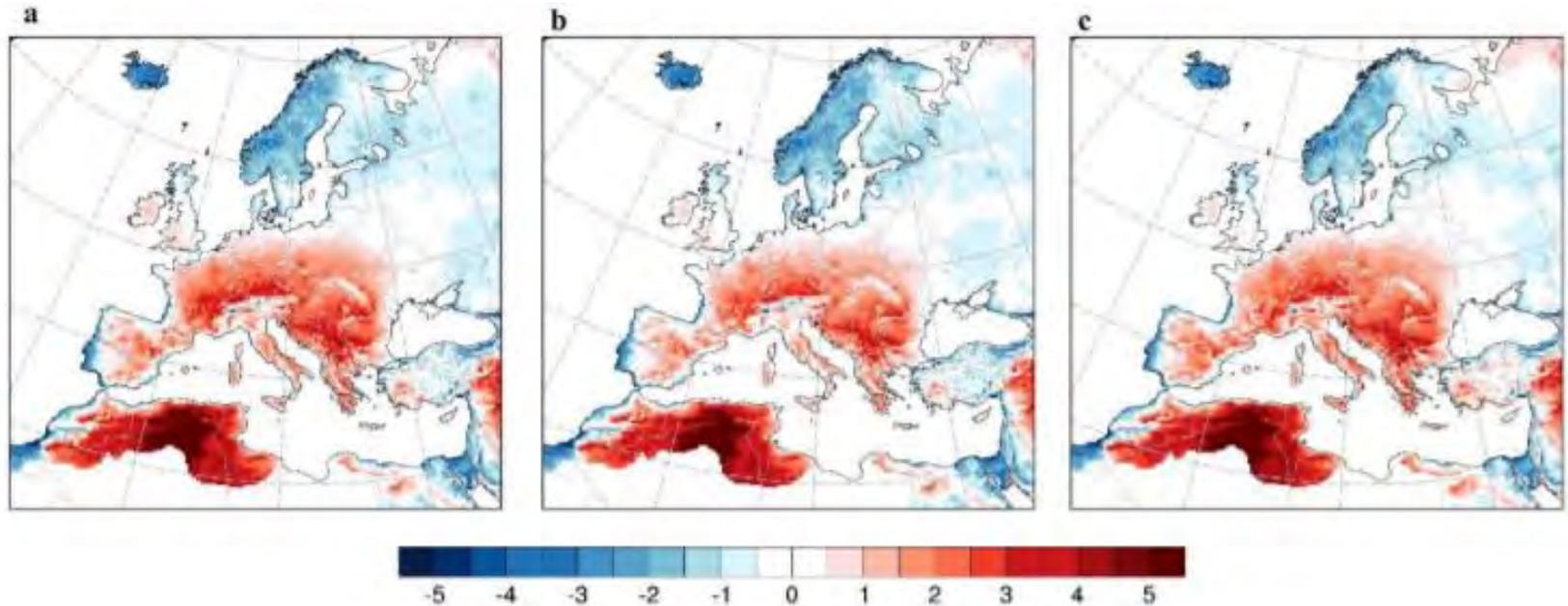
This study combines regional climate model and statistic model to decompose climate change caused by a single land cover transition in Europe.

Huang, B., X. Hu, G.-A. Fuglstad, X. Zhou, W. Zhao, and F. Cherubini, 2020: Predominant regional biophysical cooling from recent land cover changes in Europe. *Nat Commun*, **11**, 1066.



谢谢
Thank You

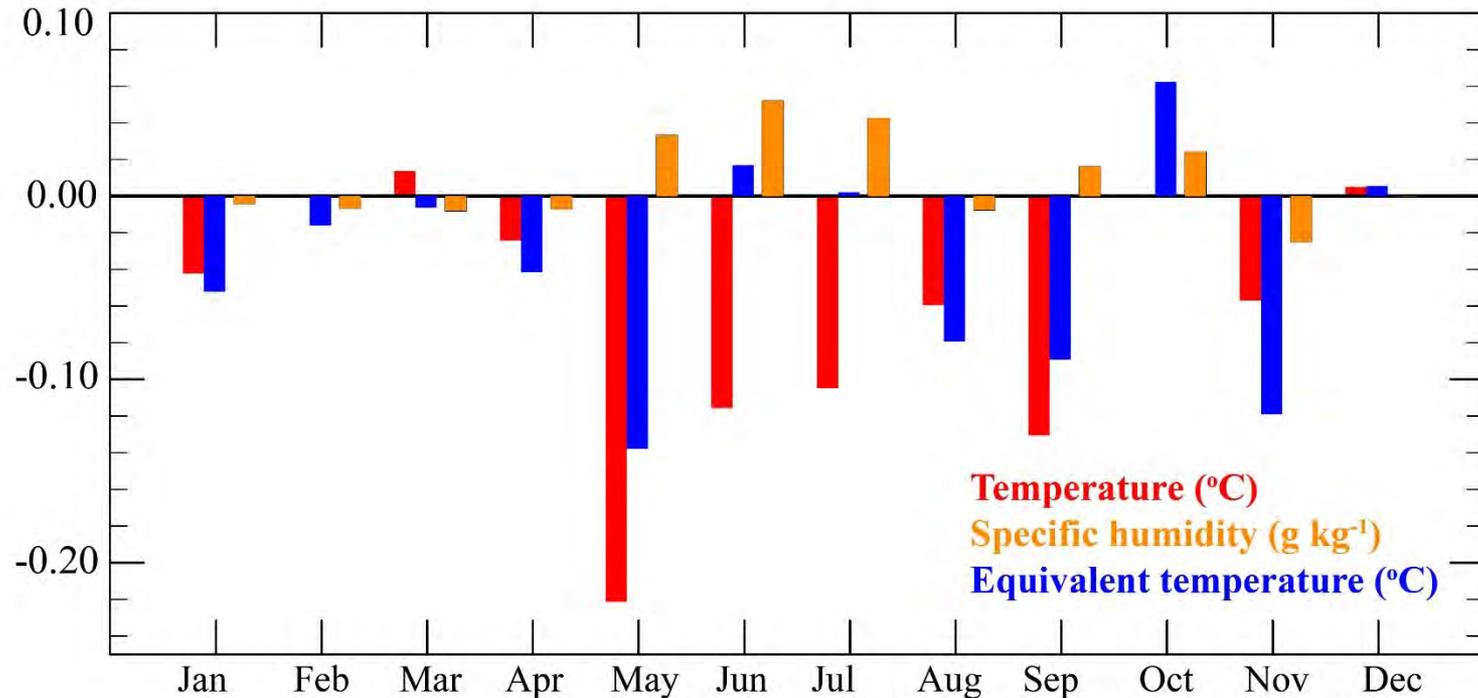
WRF3.9-CLM4 performance



Simulation	PCC	Bias (°C)	RMSE (°C)
a) LC1992 - EOBS	0.98	0.35	1.87
b) LC2015 - EOBS	0.98	0.24	1.77
c) IGBP - EOBS	0.98	0.47	1.89

Monthly climate change

LC2015 – LC1992



- T and T_E generally exhibit **similar seasonal patterns**, but T_E values are larger
- During winter and early spring, humidity is low and differences between the two variables **are small**
- As humidity increases from late spring to early fall, **differences become larger**

Supplementary Table 3 Cross-walking table provided by the ESA-CCI to convert the UNLCCS classes to the standard IPCC classes². This cross-walking table is only used for simplification and visualization purposes of the land cover changes shown in Figure 1 of the main paper.

CCI-LC		IPCC classification									
code	description	Agriculture	Forest	Grassland	Wetland	Settlement	Shrubland	Lichens and mosses	Sparse vegetation	Bare area	Water
1	0 no_data										
2	10 cropland_rainfed	X	-	-	-	-	-	-	-	-	-
3	11 cropland_rainfed_herbaceous_cover	X	-	-	-	-	-	-	-	-	-
4	12 cropland_rainfed_tree_or_shrub_cover	X	-	-	-	-	-	-	-	-	-
5	20 cropland_irrigated	X	-	-	-	-	-	-	-	-	-
6	30 mosaic_cropland	X	-	-	-	-	-	-	-	-	-
7	40 mosaic_natural_vegetation	X	-	-	-	-	-	-	-	-	-
8	50 tree_broadleaved_evergreen_closed_to_open	-	X	-	-	-	-	-	-	-	-
9	60 tree_broadleaved_deciduous_closed_to_open	-	X	-	-	-	-	-	-	-	-
10	61 tree_broadleaved_deciduous_closed	-	X	-	-	-	-	-	-	-	-
11	62 tree_broadleaved_deciduous_open	-	X	-	-	-	-	-	-	-	-
12	70 tree_needleleaved_evergreen_closed_to_open	-	X	-	-	-	-	-	-	-	-
13	71 tree_needleleaved_evergreen_closed	-	X	-	-	-	-	-	-	-	-
14	72 tree_needleleaved_evergreen_open	-	X	-	-	-	-	-	-	-	-
15	80 tree_needleleaved_deciduous_closed_to_open	-	X	-	-	-	-	-	-	-	-
16	81 tree_needleleaved_deciduous_closed	-	X	-	-	-	-	-	-	-	-
17	82 tree_needleleaved_deciduous_open	-	X	-	-	-	-	-	-	-	-
18	90 tree_mixed	-	X	-	-	-	-	-	-	-	-
19	100 mosaic_tree_and_shrub	-	X	-	-	-	-	-	-	-	-
20	110 mosaic_herbaceous	-	-	X	-	-	-	-	-	-	-
21	120 shrubland	-	-	-	-	-	X	-	-	-	-
22	121 shrubland_evergreen	-	-	-	-	-	X	-	-	-	-
23	122 shrubland_deciduous	-	-	-	-	-	X	-	-	-	-
24	130 grassland	-	-	X	-	-	-	-	-	-	-
25	140 lichens_and_mosses	-	-	-	-	-	-	X	-	-	-
26	150 sparse_vegetation	-	-	-	-	-	-	-	X	-	-
27	152 sparse_shrub	-	-	-	-	-	-	-	X	-	-
28	153 sparse_herbaceous	-	-	-	-	-	-	-	X	-	-
29	160 tree_cover_flooded_fresh_or_brakish_water	-	X	-	-	-	-	-	-	-	-
30	170 tree_cover_flooded_saline_water	-	X	-	-	-	-	-	-	-	-
31	180 shrub_or_herbaceous_cover_flooded	-	-	-	X	-	-	-	-	-	-
32	190 urban	-	-	-	-	X	-	-	-	-	-
33	200 bare_areas	-	-	-	-	-	-	-	-	X	-
34	201 bare_areas_consolidated	-	-	-	-	-	-	-	-	X	-
35	202 bare_areas_unconsolidated	-	-	-	-	-	-	-	-	X	-
36	210 water	-	-	-	-	-	-	-	-	-	X
37	220 snow_and_ice	-	-	-	-	-	-	-	-	-	-

Supplementary Table 4 Cross-walking table used to convert the CCI land cover classes to the IGBP land cover classes used as input to WRF (adapted from other references^{1,3,4}).

CCI-LC	IGBP																				
	1 Evergreen Needleleaf forest	2 Evergreen Broadleaf forest	3 Deciduous Needleleaf forest	4 Deciduous Broadleaf forest	5 Mixed forest	6 Closed shrubland	7 Open shrublands	8 Woody savannas	9 Savannas	10 Grasslands	11 Permanent wetlands	12 Croplands	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 Lake
0 no_data																					
10 cropland_rainfed												X									
11 cropland_rainfed_herbaceous_cover											X										
12 cropland_rainfed_tree_or_shrub_cover											X										
20 cropland_irrigated											X										
30 mosaic_cropland														X							
40 mosaic_natural_vegetation														X							
50 tree_broadleaved_evergreen_closed_to_open		X																			
60 tree_broadleaved_deciduous_closed_to_open				X																	
61 tree_broadleaved_deciduous_closed				X																	
62 tree_broadleaved_deciduous_open				X																	
70 tree_needleleaved_evergreen_closed_to_open	X																				
71 tree_needleleaved_evergreen_closed	X																				
72 tree_needleleaved_evergreen_open	X																				
80 tree_needleleaved_deciduous_closed_to_open			X																		
81 tree_needleleaved_deciduous_closed			X																		
82 tree_needleleaved_deciduous_open			X																		
90 tree_mixed					X																
100 mosaic_tree_and_shrub							X														
110 mosaic_herbaceous							X														
120 shrubland							X														
121 shrubland_evergreen						X															
122 shrubland_deciduous						X															
130 grassland										X											
140 lichens_and_mosses															X						
150 sparse_vegetation															X						
152 sparse_shrubs															X						
153 sparse_herbaceous															X						
160 tree_cover_flooded_fresh_or_brackish_water											X										
170 tree_cover_flooded_saline_water											X										
180 shrub_or_herbaceous_cover_flooded											X										
190 urban													X								
200 bare_areas															X						
201 bare_areas_consolidated															X						
202 bare_areas_unconsolidated															X						
210 water																X					
220 snow_and_ice														X							