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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

Bo Huang

10.10.2020

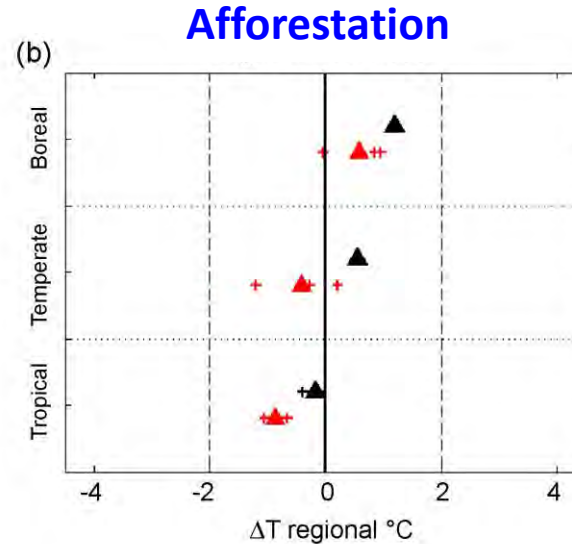
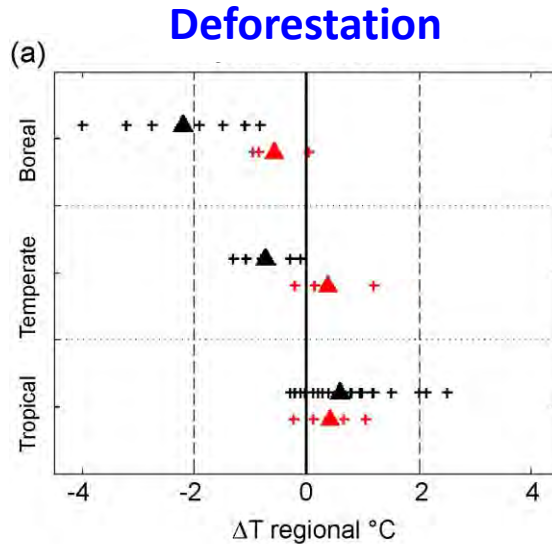
Francesco Cherubini, Xiangping Hu, Geir-Arne Fuglstad, Xu Zhou, Wenwu Zhao

AGU2020, Session GC109



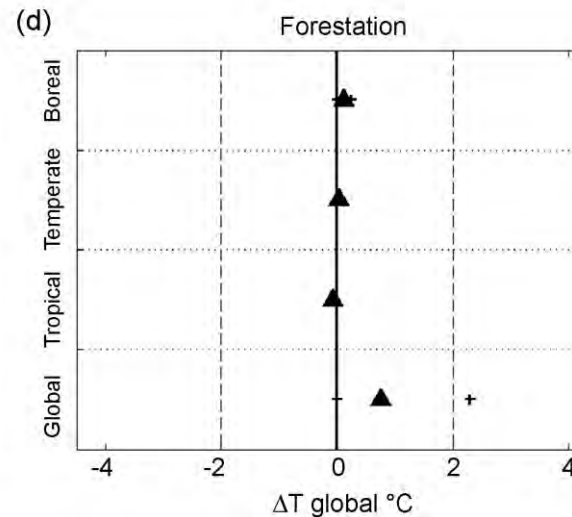
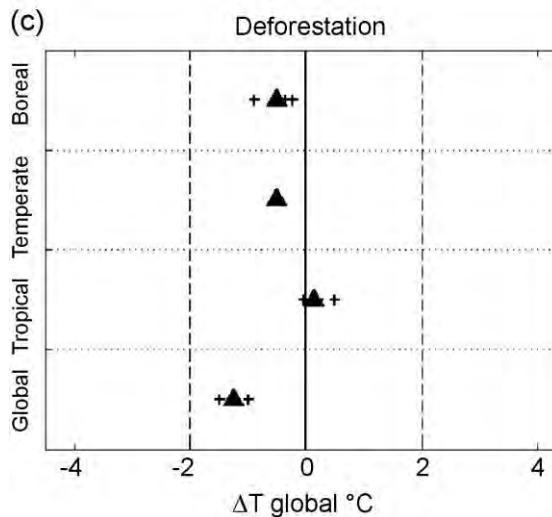
Forest changes impact on climate

Regional



+ observation
+ model
▲ obs mean
▲ model mean

Global



Perugini et al, 2017 ERL

Climate change under extreme land cover changes

FOR to BL

FOR to HV

Cooling

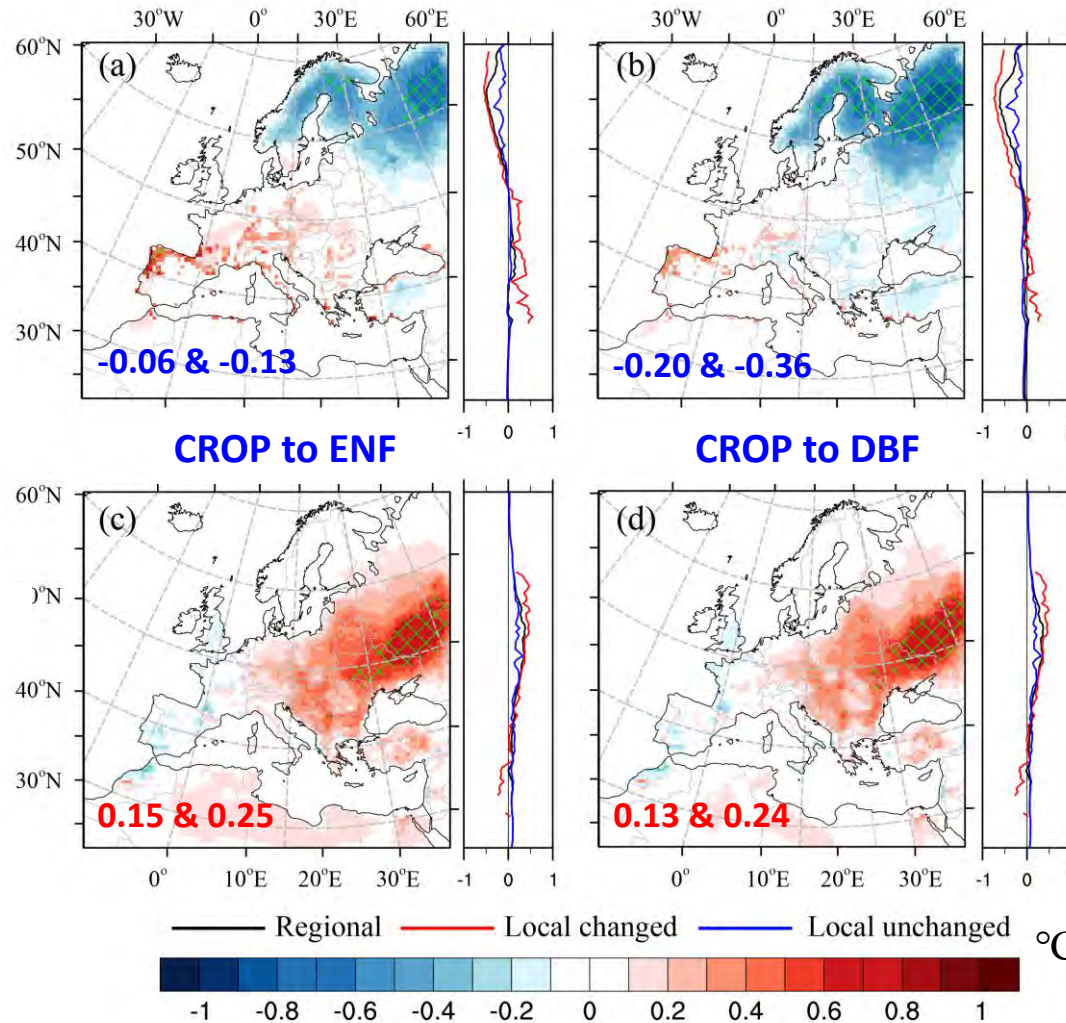
Latitudinal pattern
(50° N)

CROP to ENF

CROP to DBF

Warming

Longitudinal gradient
(10° E)



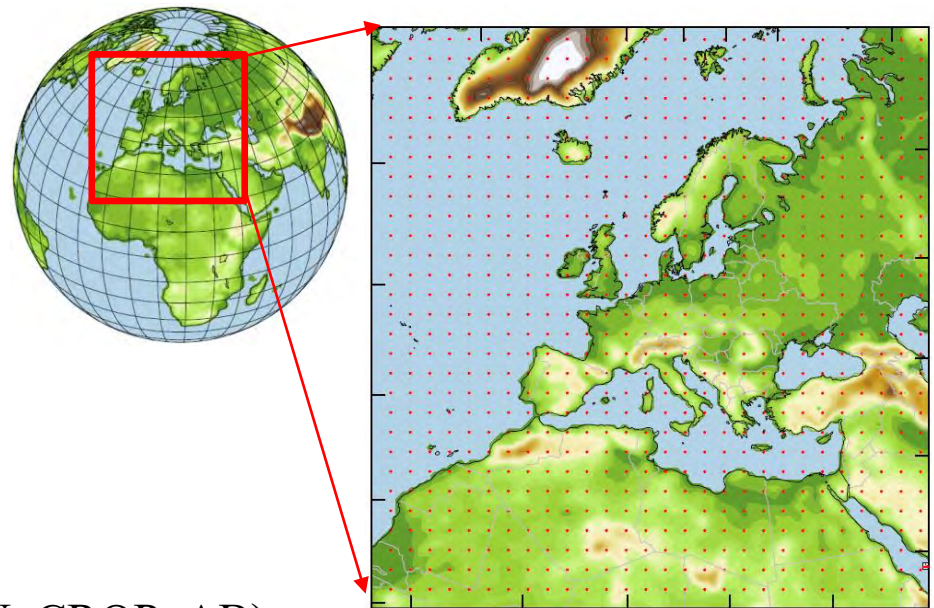
Data and model simulations

➤ Data

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

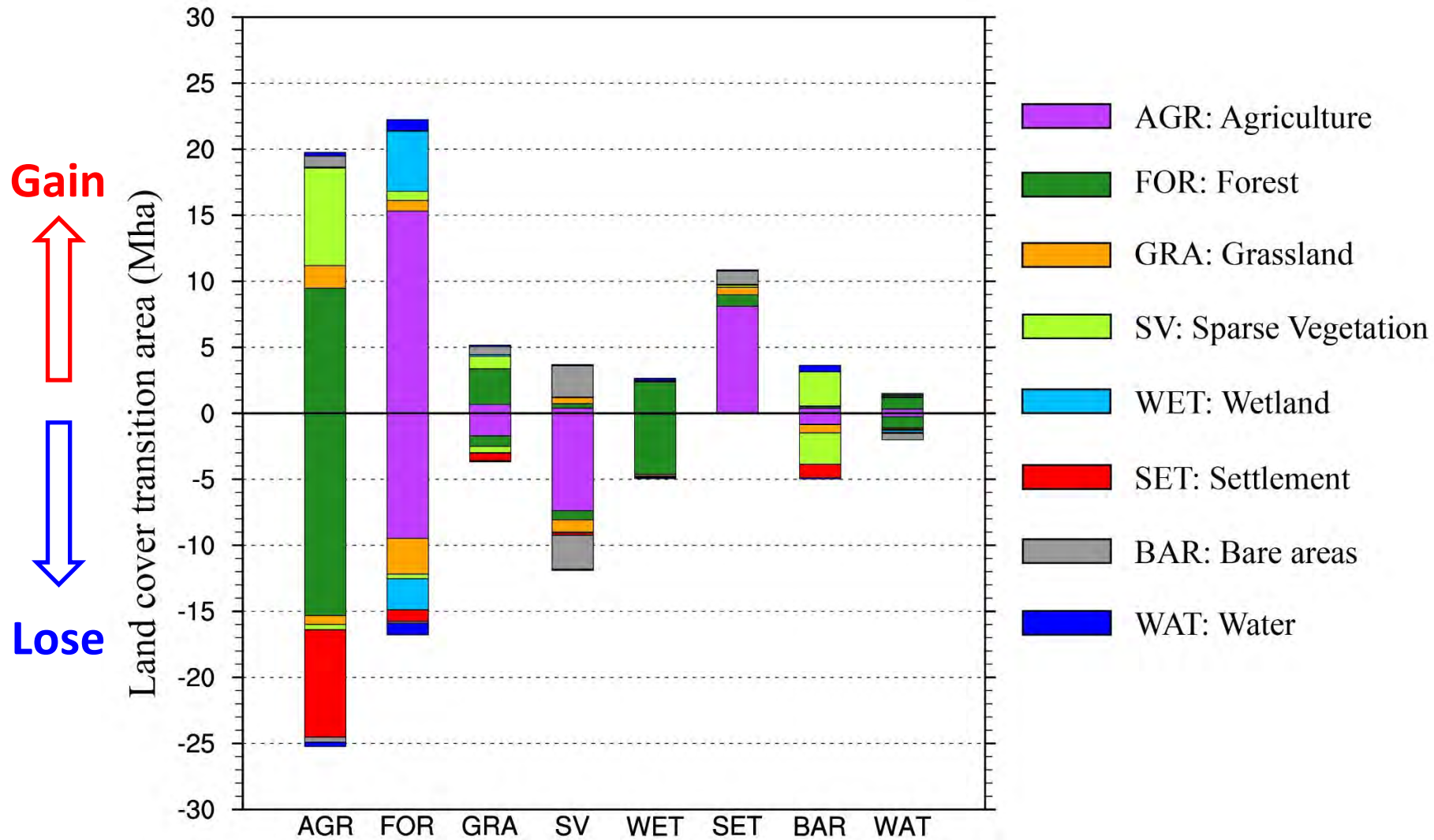
➤ Model simulation

- WRF v3.9.1, CLM4 land surfe model
- Driven data: ERA-Interim
- Horizontal resolution: 0.11° ($\sim 12\text{km}$)
- Three simulations:
 - LC1992,
 - LC2015, and
 - No Cropland abandonment (NoCROP_AB)



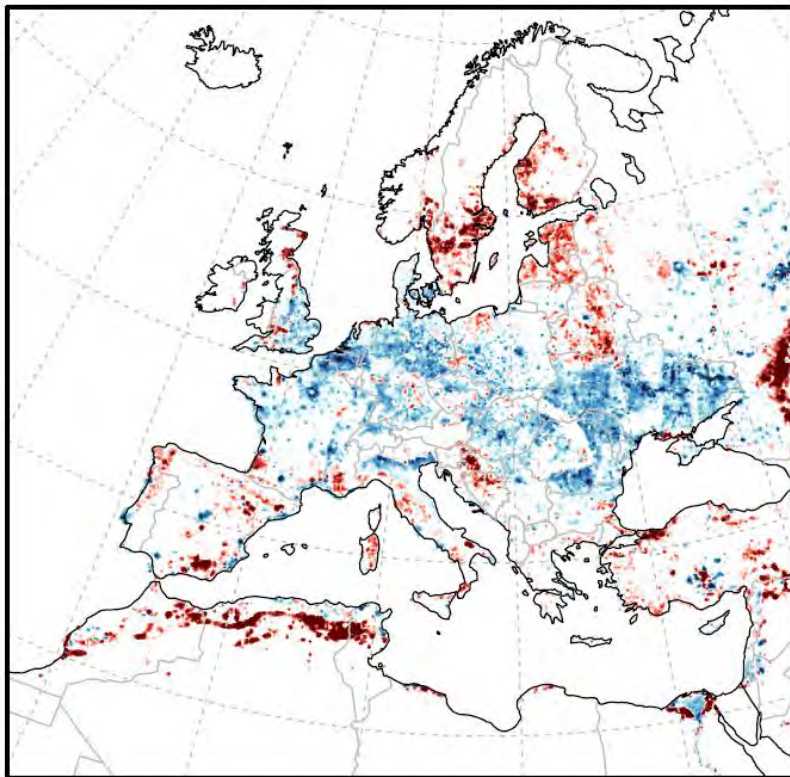
➤ Ridge-regression model

Land cover change in Europe

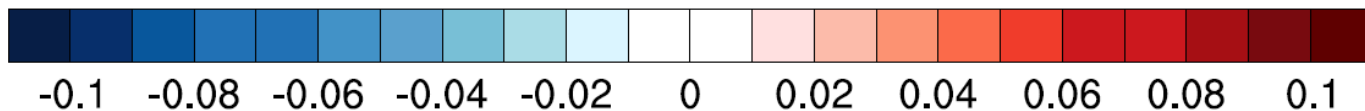
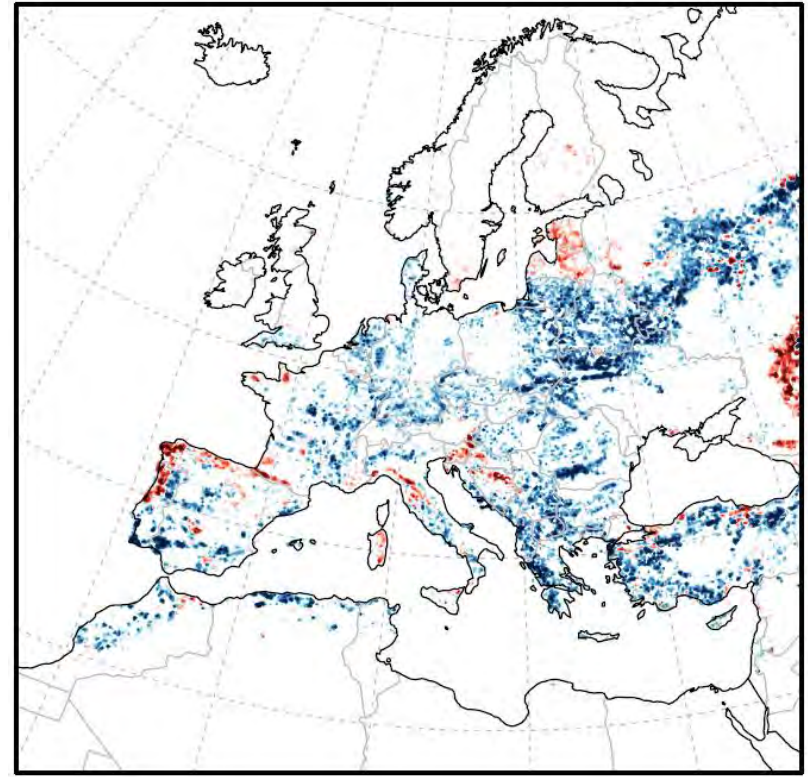


Cropland fraction difference between 2015 and 1992

Cropland

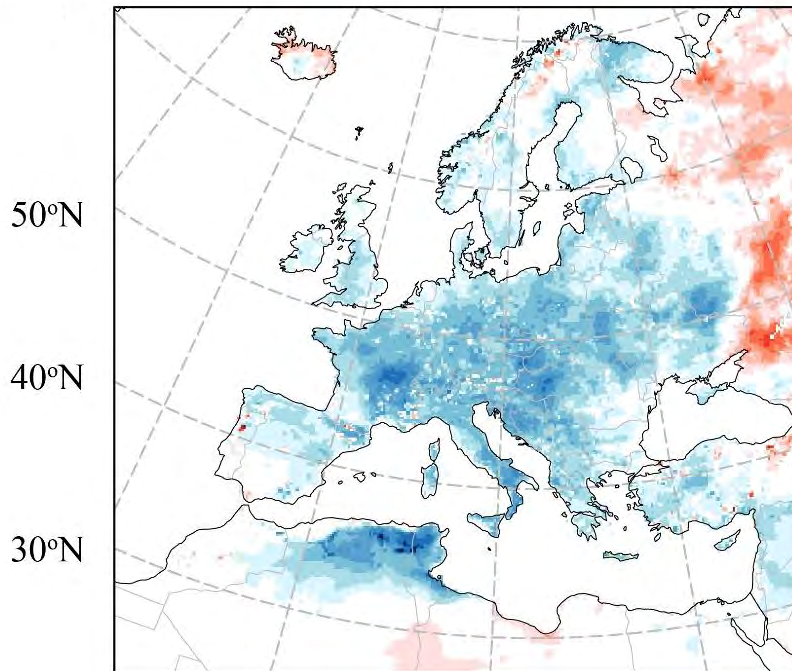


Cropland/Natural vegetation

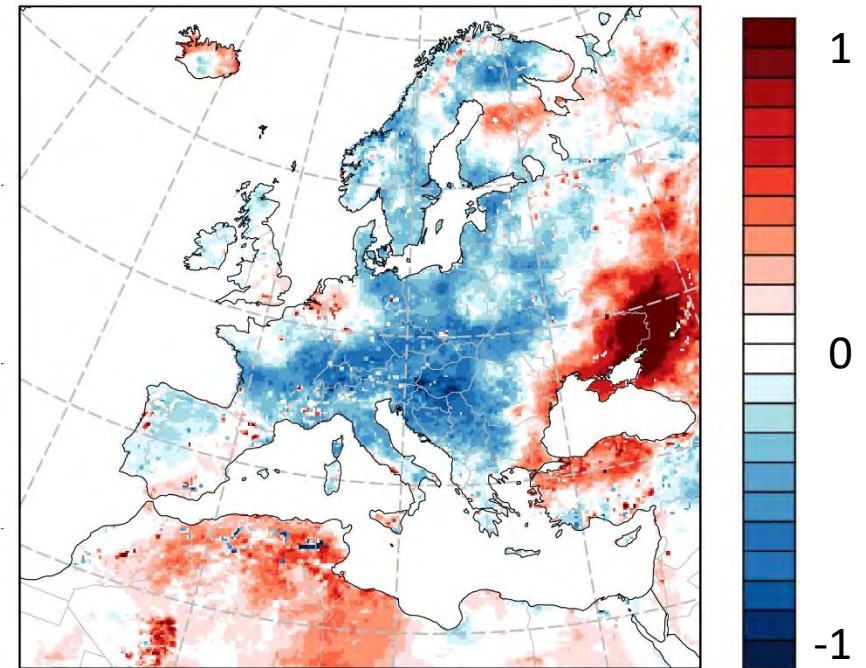


Climate change due to land cover change

Temperature



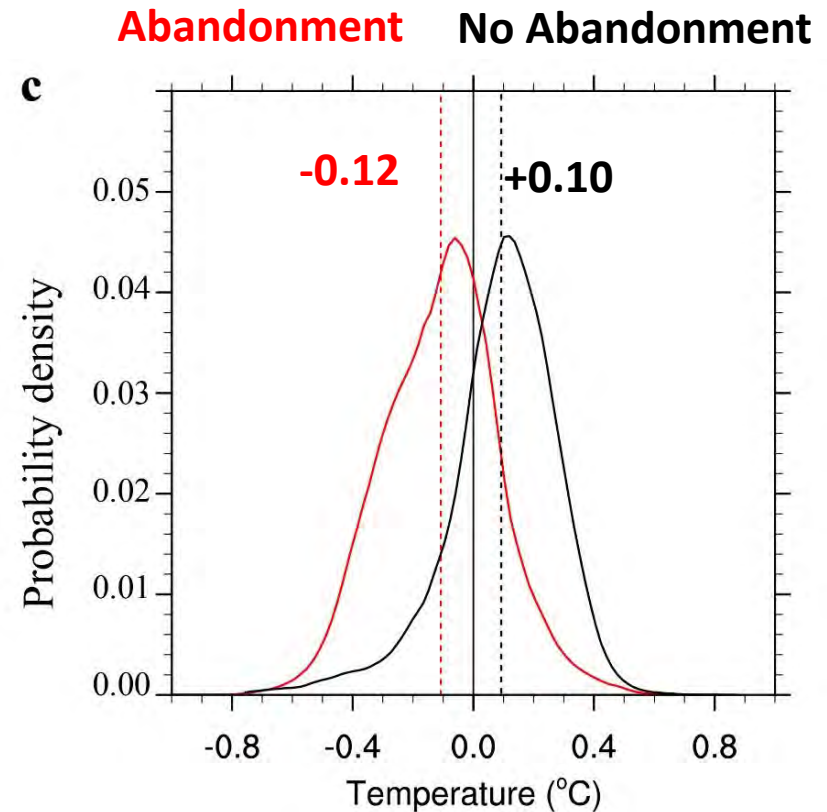
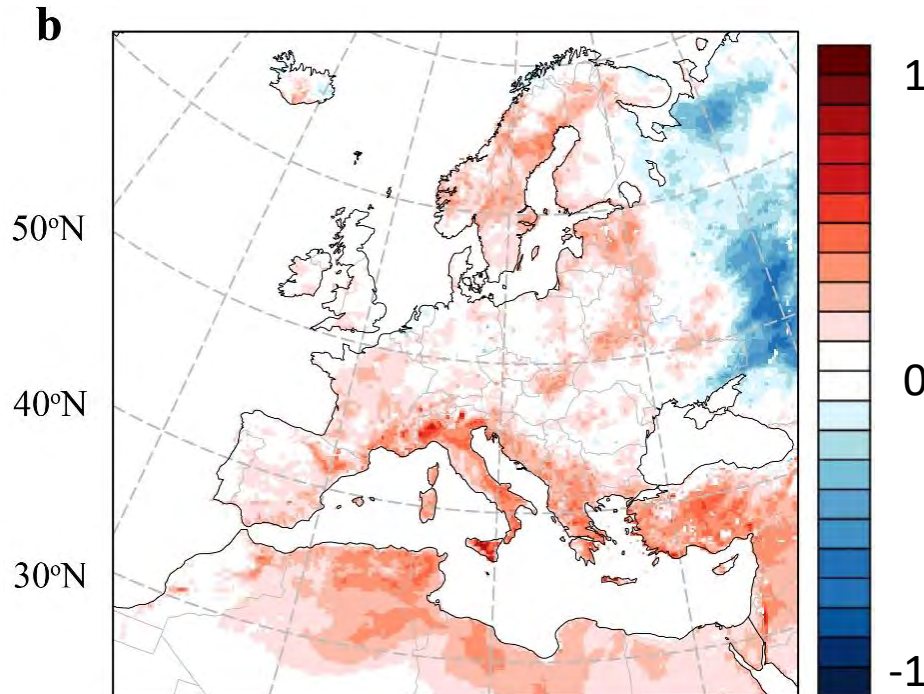
Equivalent Temperature



- 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

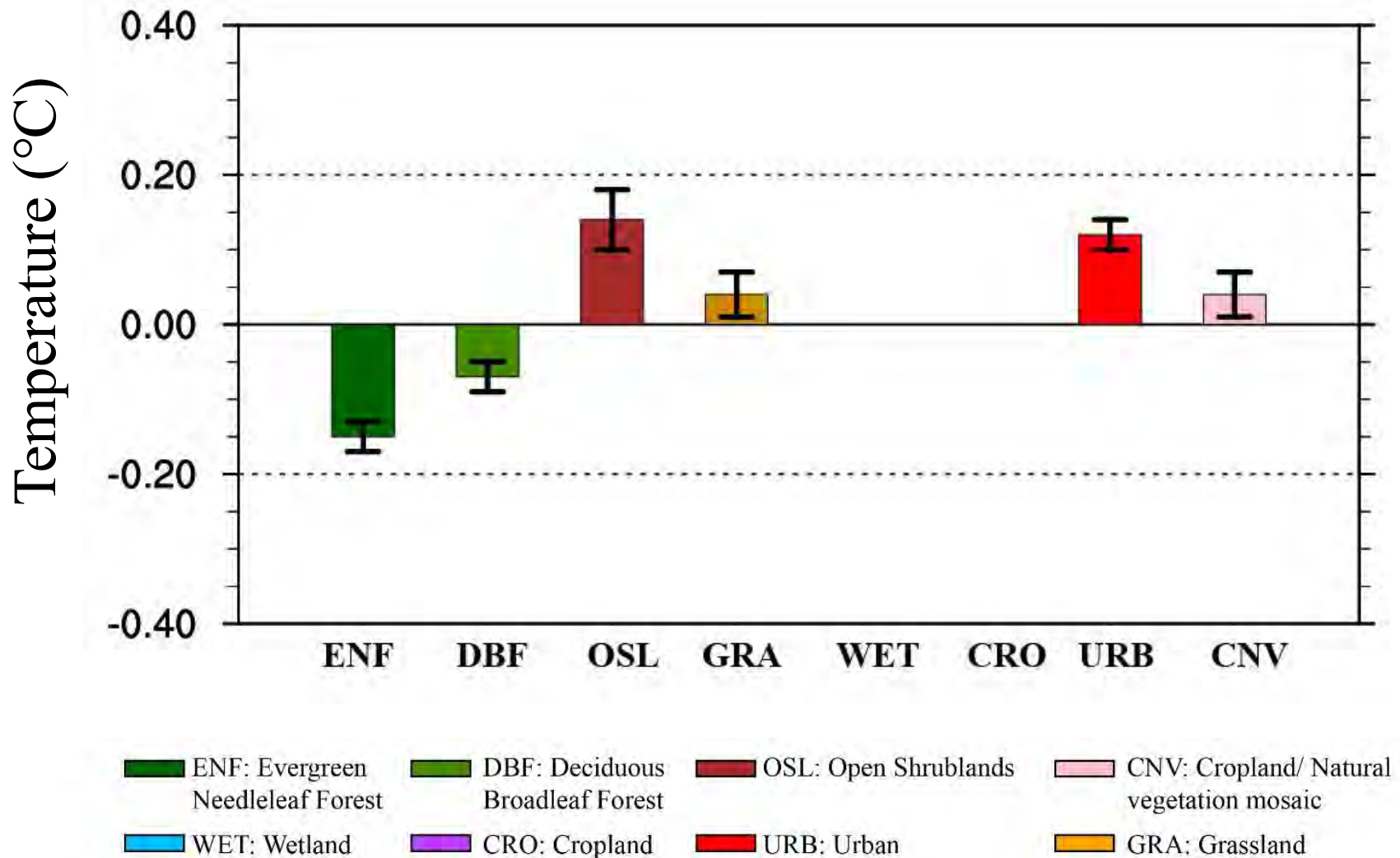
Effect of agriculture abandonment

NoCROP_AB – LC2015

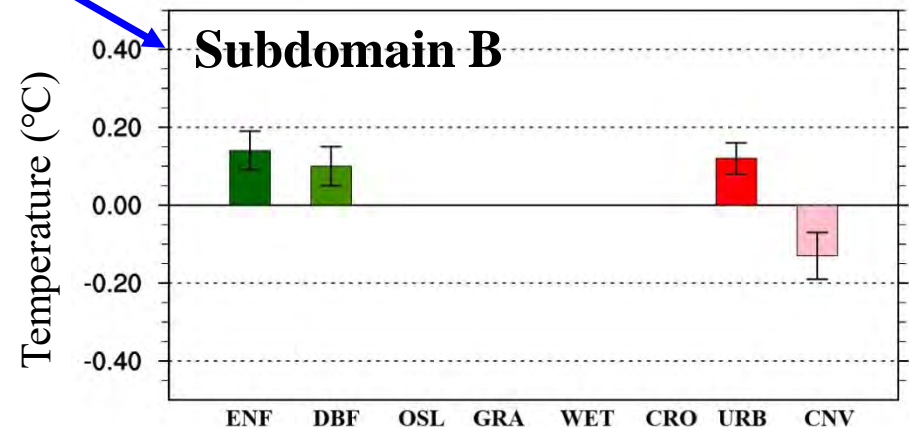
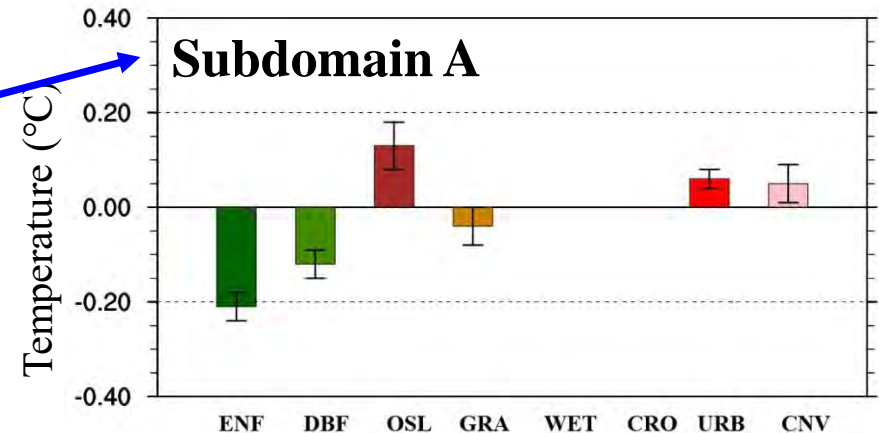
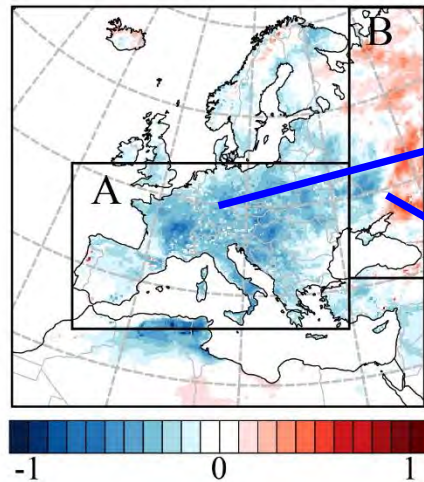


- When the transitions from **cropland to other land classes are excluded**, an annual average temperature change of **$+0.10 \pm 0.19$ °C**, with **-0.23** and **+0.33 °C** as the 5th and 95th percentile

Temperature change with cropland transition

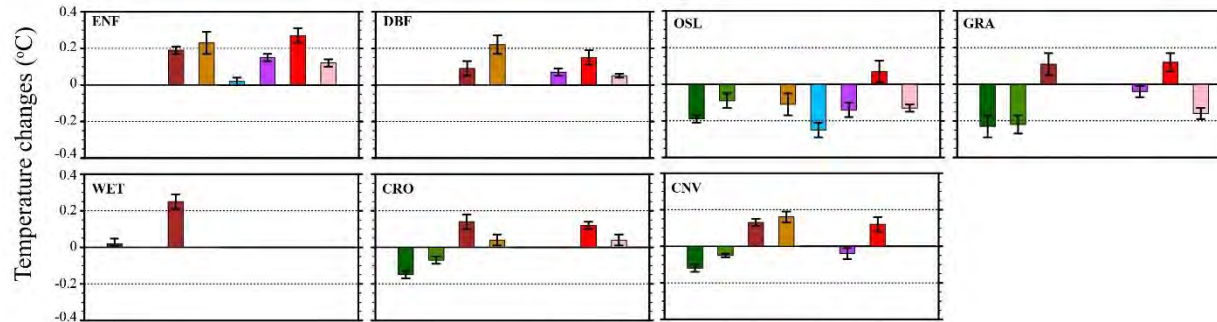


Different climate change response to cropland transition in East and West-Central Europe

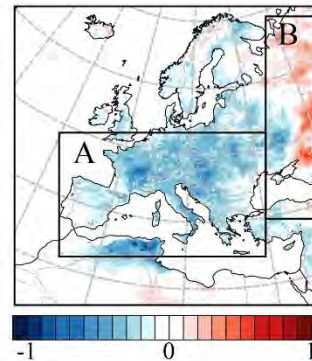


- In subdomain A, conversion of evergreen or deciduous forest to cropland results in an **average warming** of $+0.21 \pm 0.03$ °C and $+0.12 \pm 0.03$ °C
- In subdomain B, these transitions are associated with an **average cooling** of -0.14 ± 0.05 °C and -0.10 ± 0.05 °C
- This is mostly due to the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

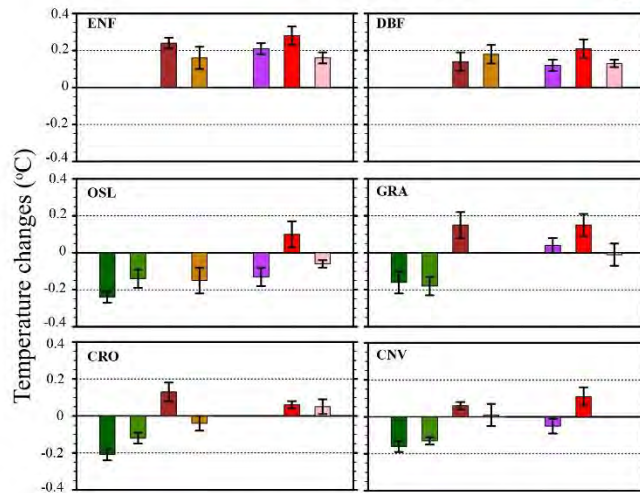
Europe



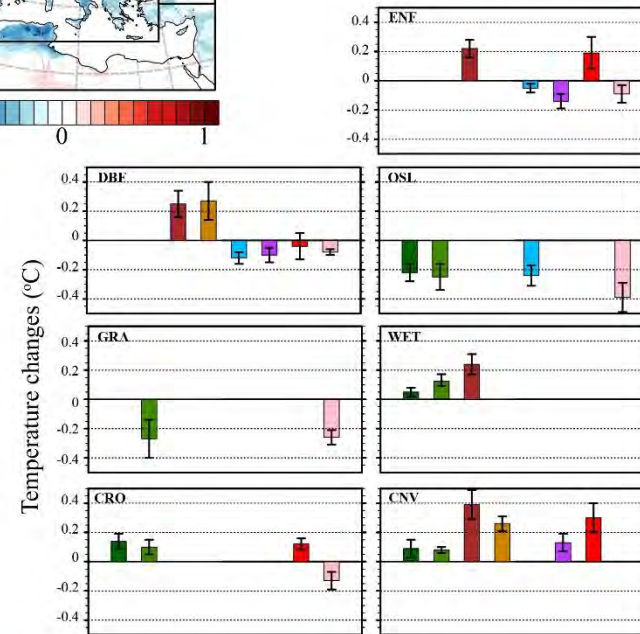
Decomposition of the temperature changes to individual land cover changes



Subdomain A



Subdomain B



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

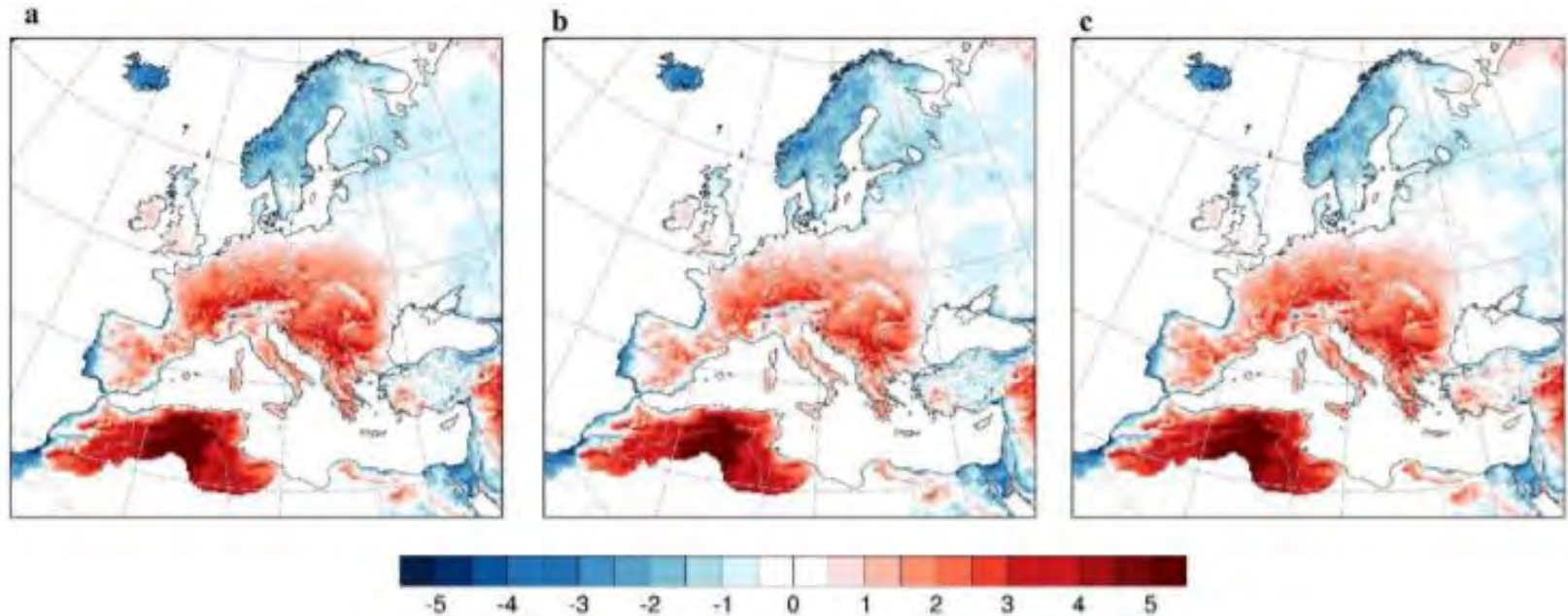
This study combines regional climate model and statistic model to decompose climate change caused by a single land cover transition in Europe.

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

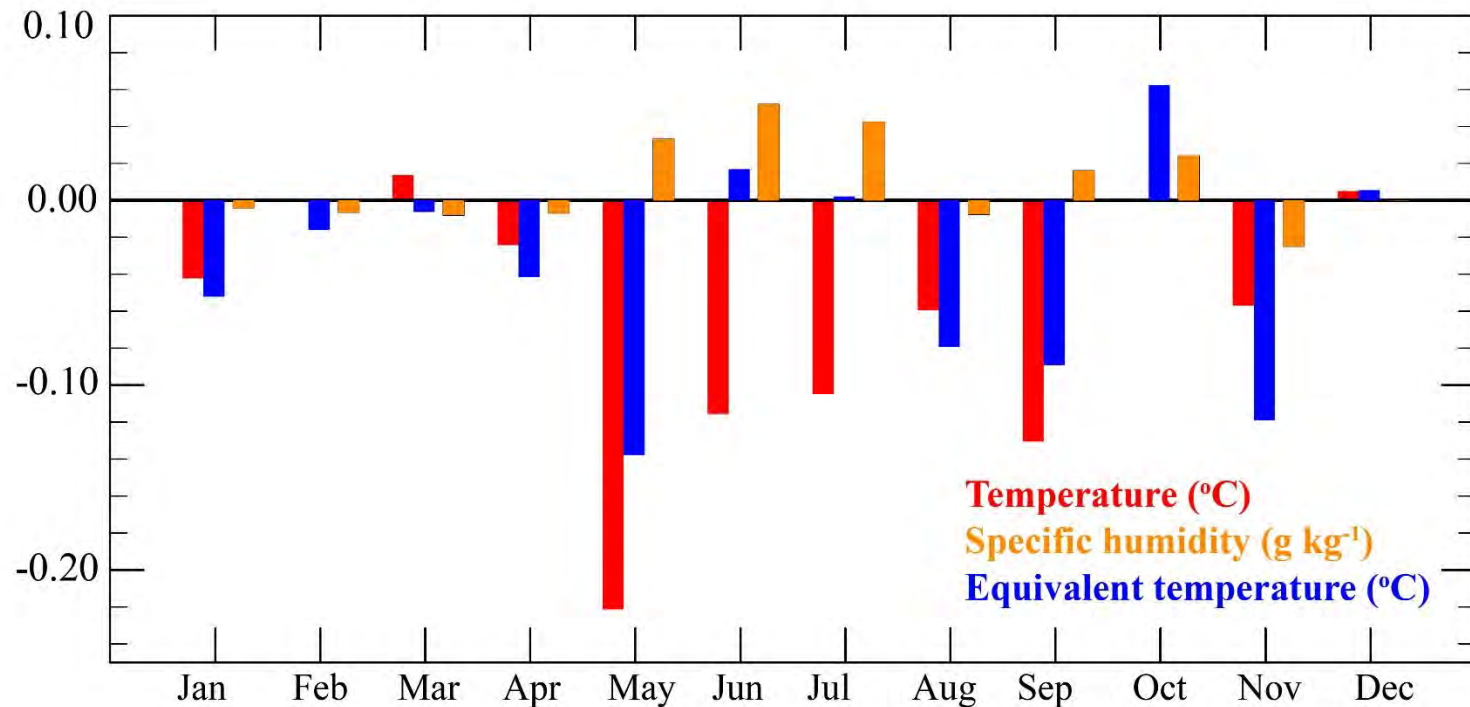
WRF3.9-CLM4 performance



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	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Evergreen Needleleaf forest	Evergreen Broadleaf forest	Deciduous Needleleaf forest	Deciduous Broadleaf forest	Mixed forest	Closed shrubland	Open shrublands	Woody savannas	Savannas	Grasslands	Permanent wetlands	Croplands	Urban and built-up	Cropland/Natural vegetation mosaic	Snow and ice	Barren or sparsely vegetated	Water	Wooded Tundra	Mixed Tundra	Barren Tundra
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	richens_and_mosses																X				
150	sparse_vegetation																X				
152	sparse_shrub																X				
153	sparse_herbaceous																X				
160	tree_cover_flooded_fresh_or_brakish_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					