

Supplementary Information

Environmental and social inequities in continental France: An analysis of exposure to heat, air pollution, and lack of vegetation

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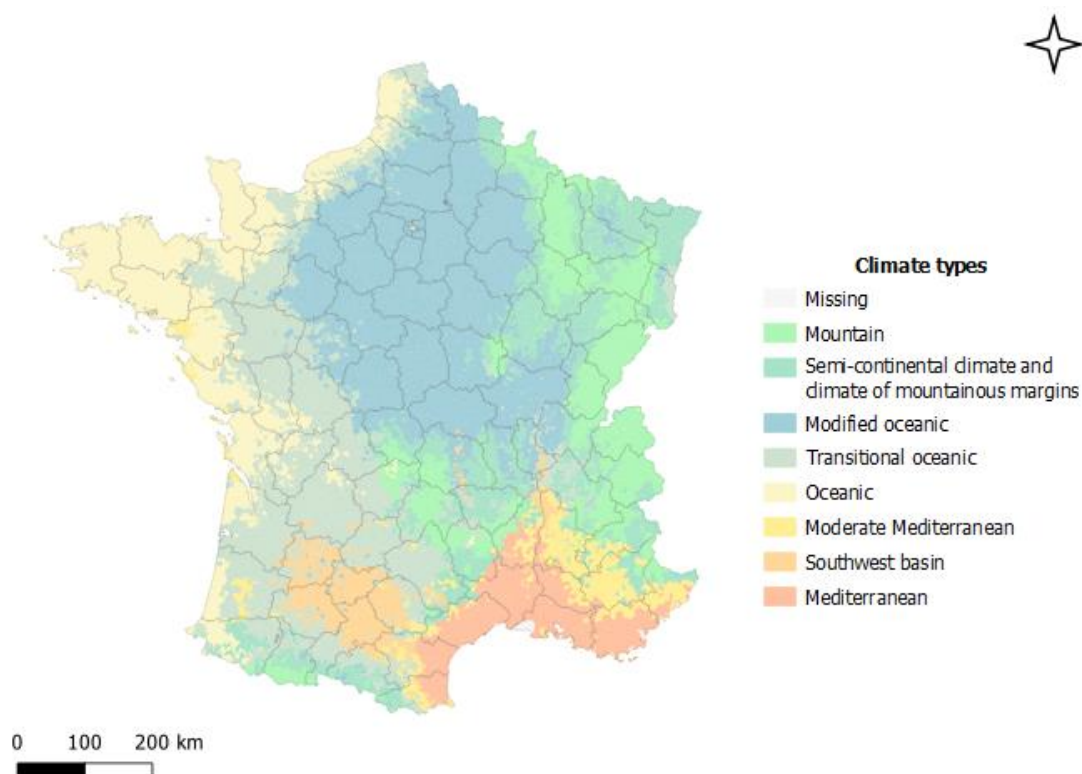
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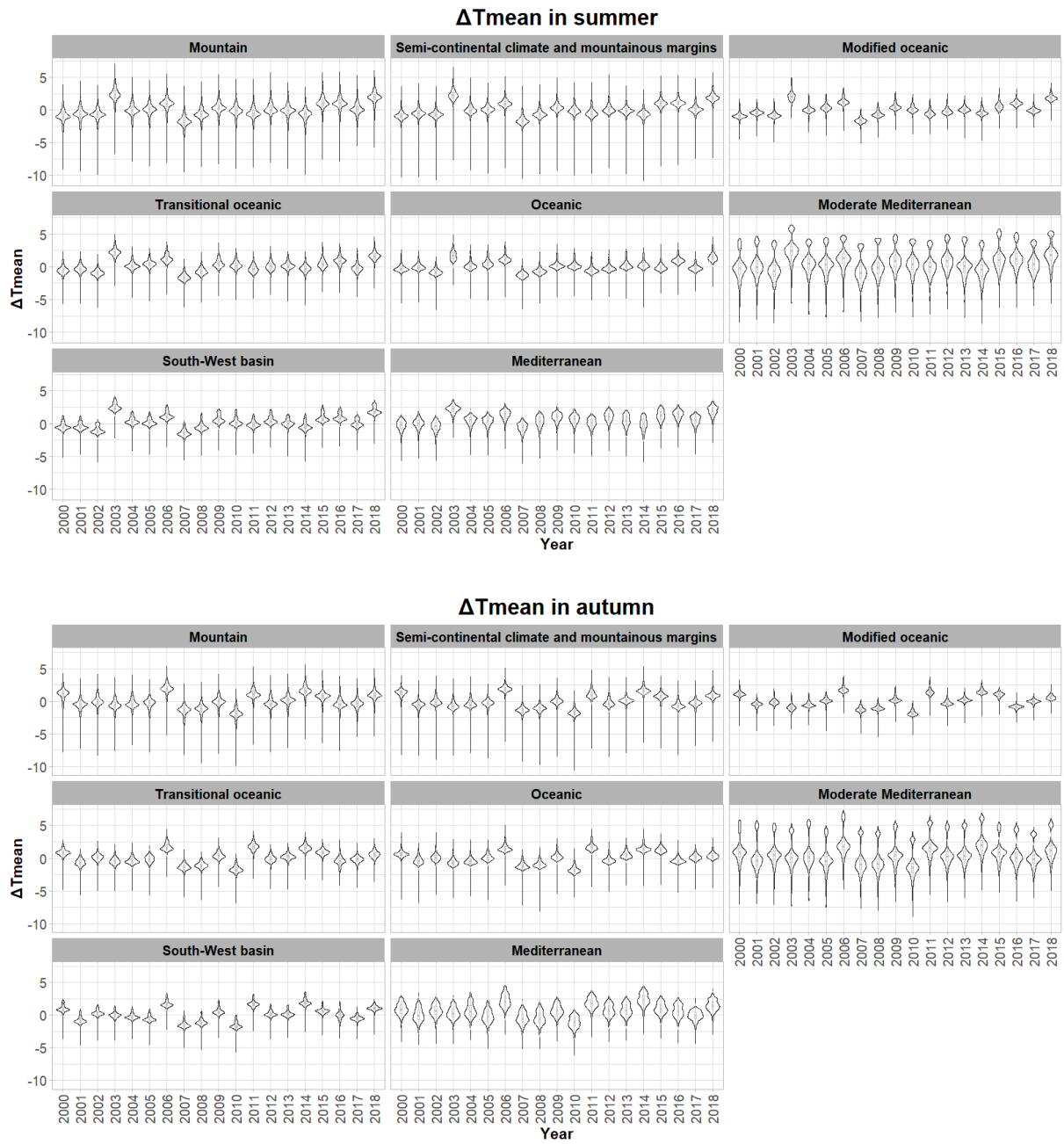
Supplementary Figure 1. Climate types* in continental France and distribution of IRIS by urbanization level and climate type



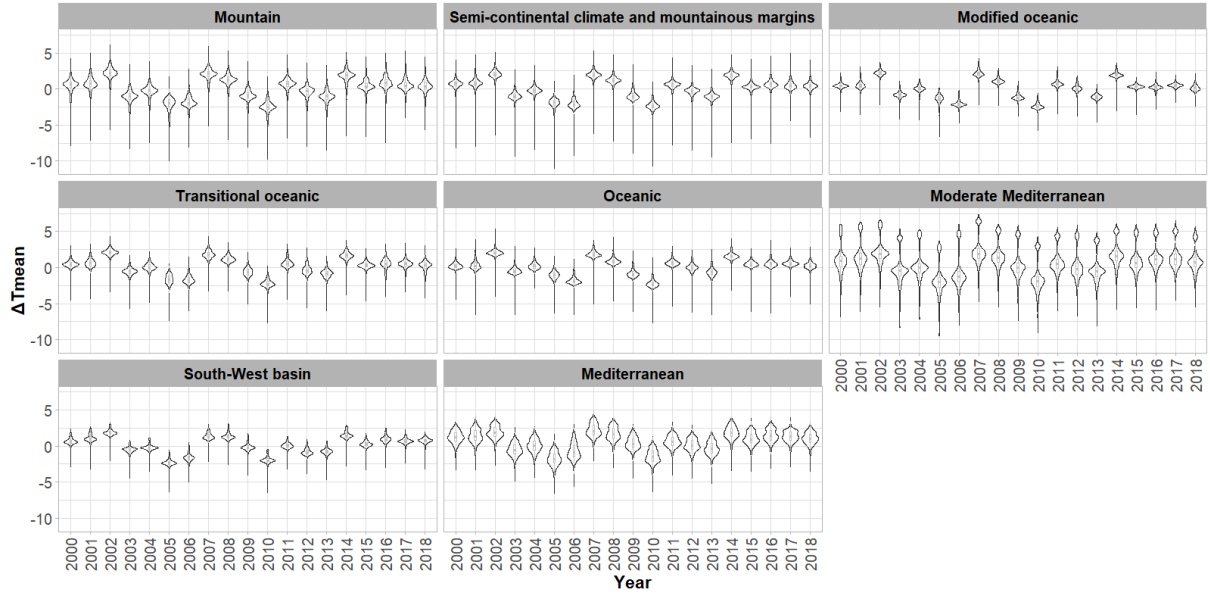
Climate type	Urban areas n (%)	Rural areas n (%)
Mountain	606 (3.4)	3,686 (12.0)
Semi-continental climate and climate of mountainous margins	1,459 (8.3)	5,214 (17.0)
Modified oceanic	6,856 (39.1)	8,906 (29.1)
Transitional oceanic	3,589 (20.4)	5,994 (19.6)
Oceanic	1,611 (9.2)	3,383 (11.0)
Moderate Mediterranean	402 (2.3)	1,036 (3.4)
Southwest basin	911 (5.2)	1,366 (4.4)
Mediterranean	2,037 (11.6)	1,048 (3.4)
Missing (no interpolation)	71 (0.4)	10 (0.03)
Total	17,652	30,643

*Adapted from Joly D, Brossard T, Cardot H, Cavailles J, Hilal M, Wavresky P. Les types de climats en France, une construction spatiale. *Cybergeog: European Journal of Geography*. 2010

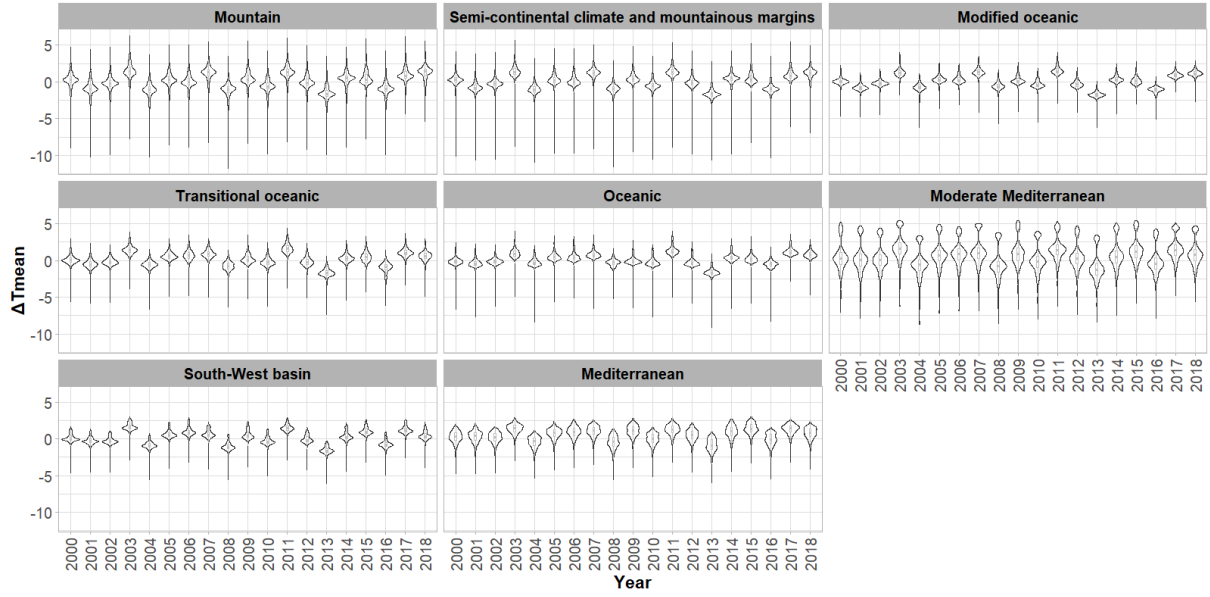
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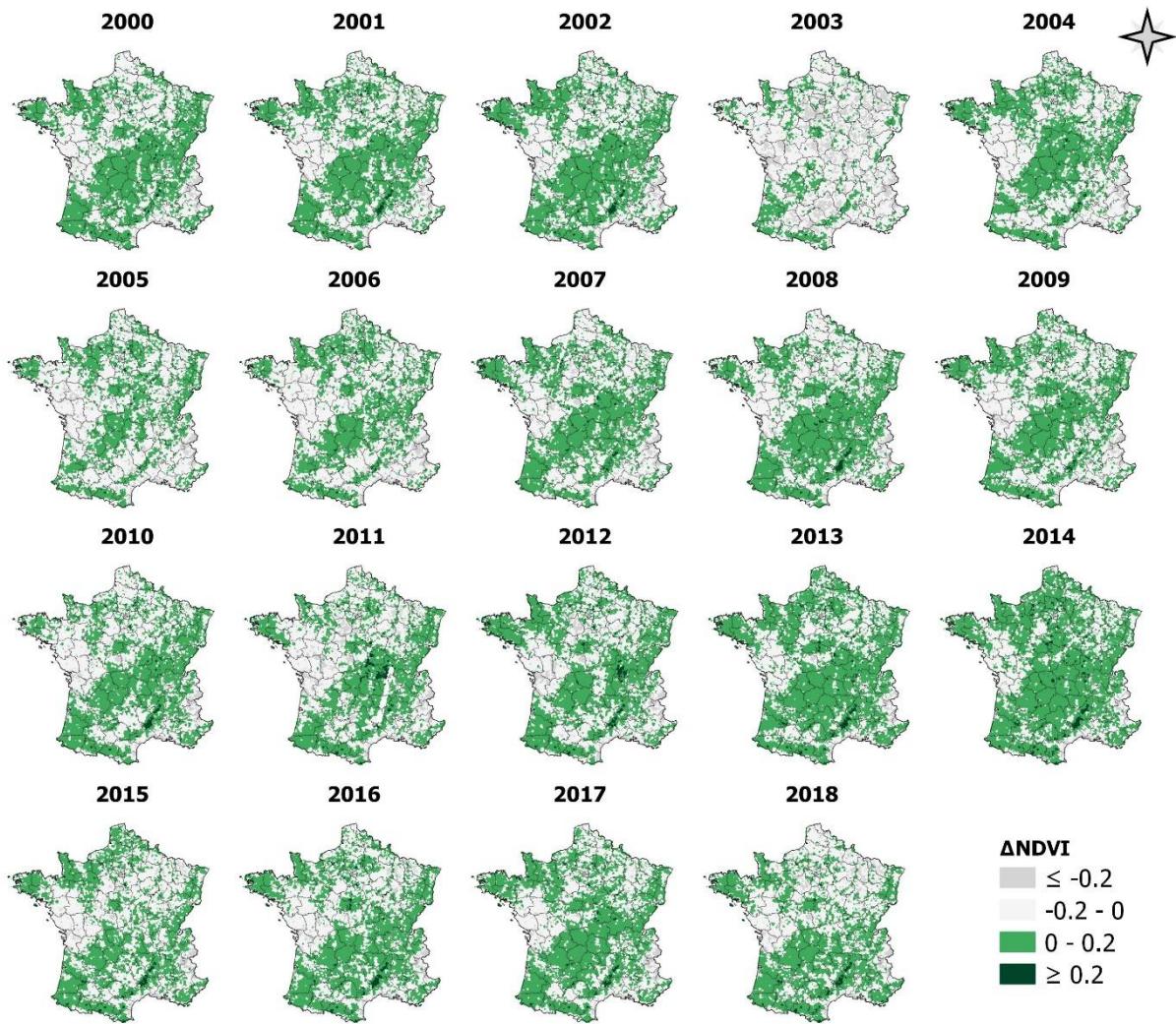
ΔT_{mean} in winter



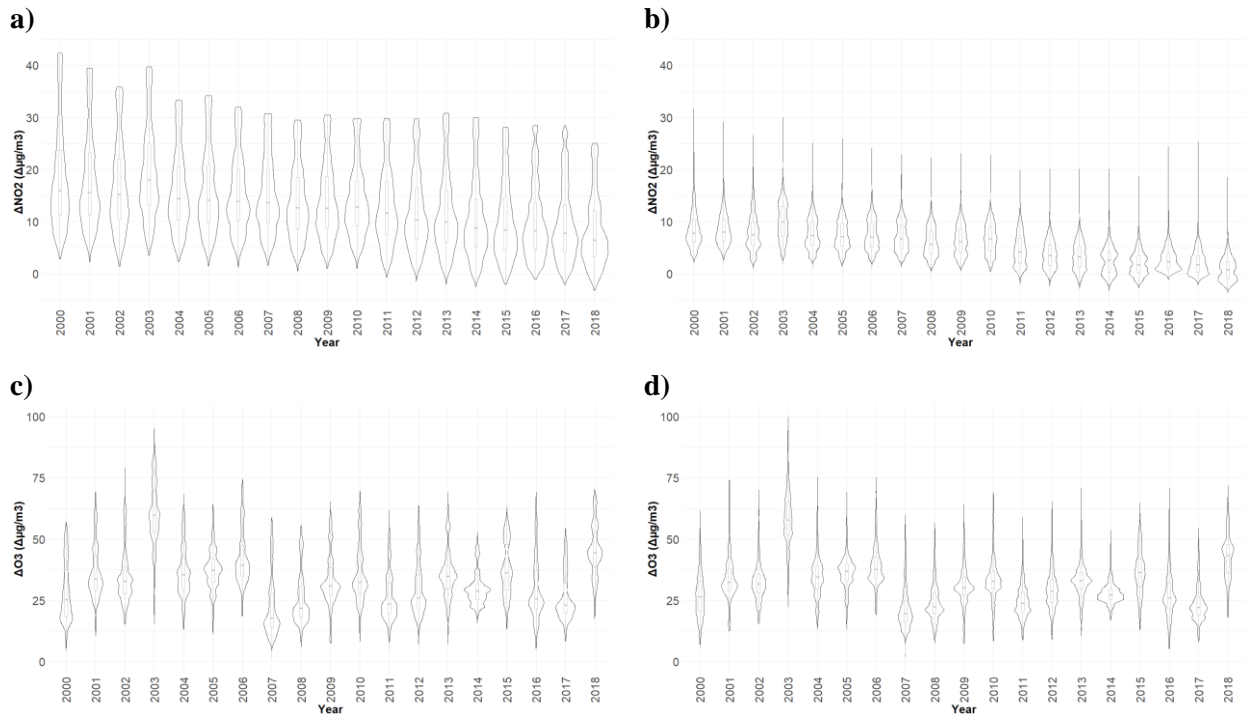
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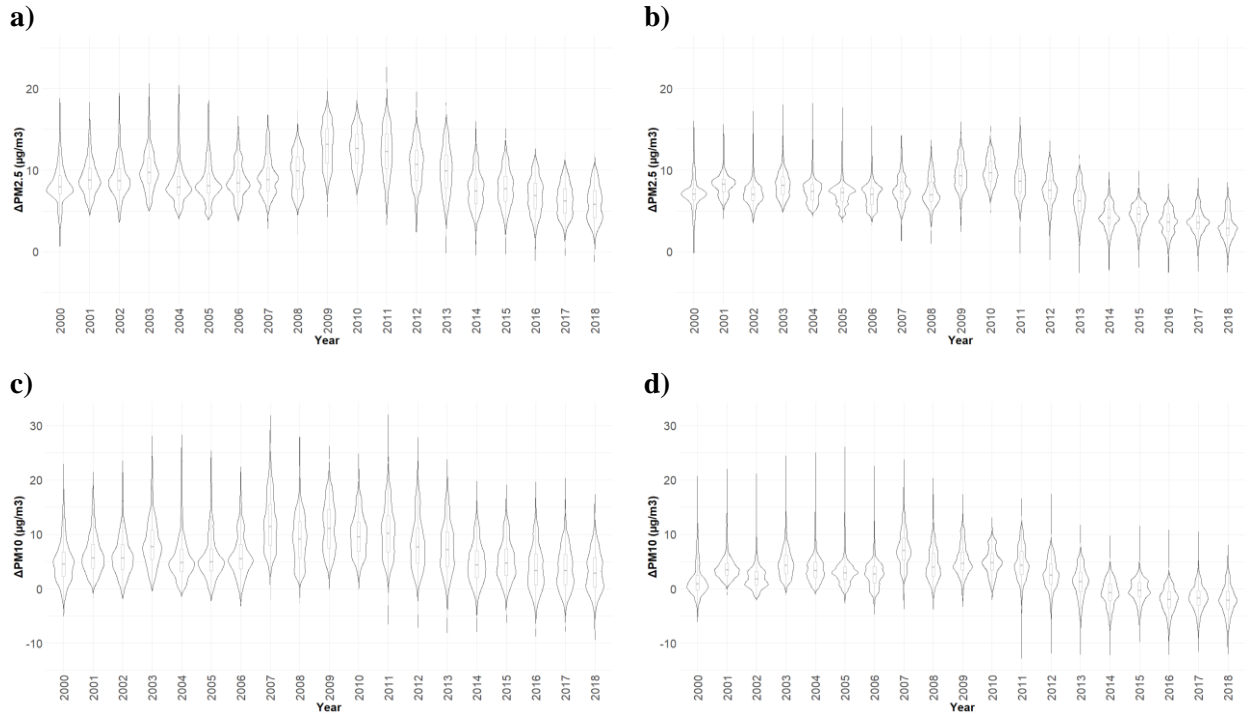
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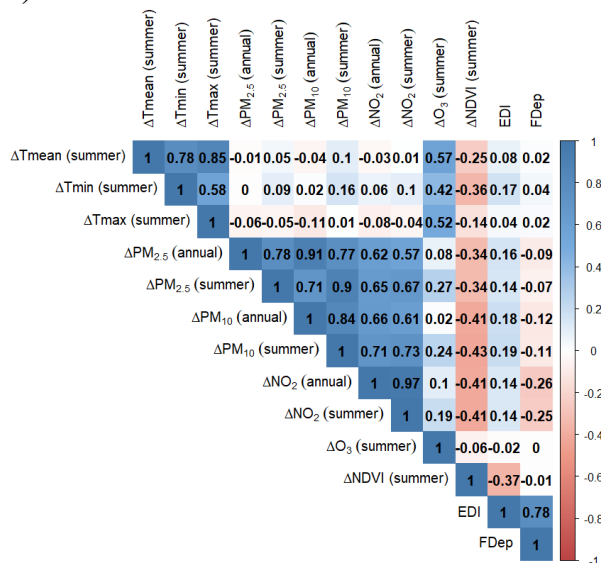


Supplementary Figure 5. Distribution of $\Delta PM_{2.5}$ (a, b) and ΔPM_{10} (c, d) concentrations between 2000 and 2018 in urban IRIS (a, c) and rural IRIS (b, d) in continental France

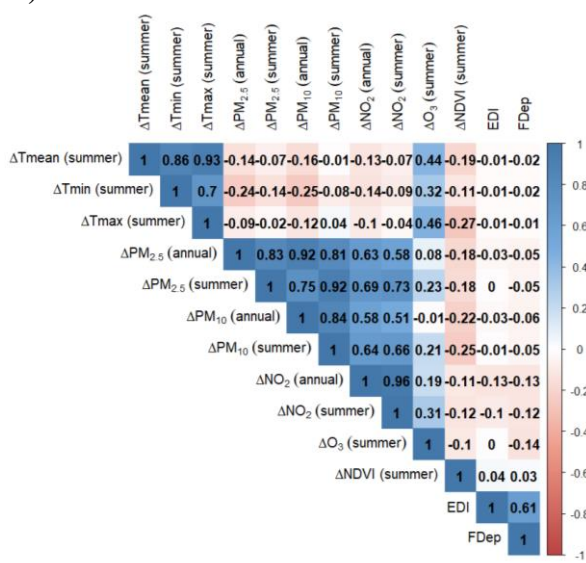


Supplementary Figure 6. Correlations between exposure indicators and social deprivation between 2000 and 2018 in urban (a) and rural (b) areas in continental France

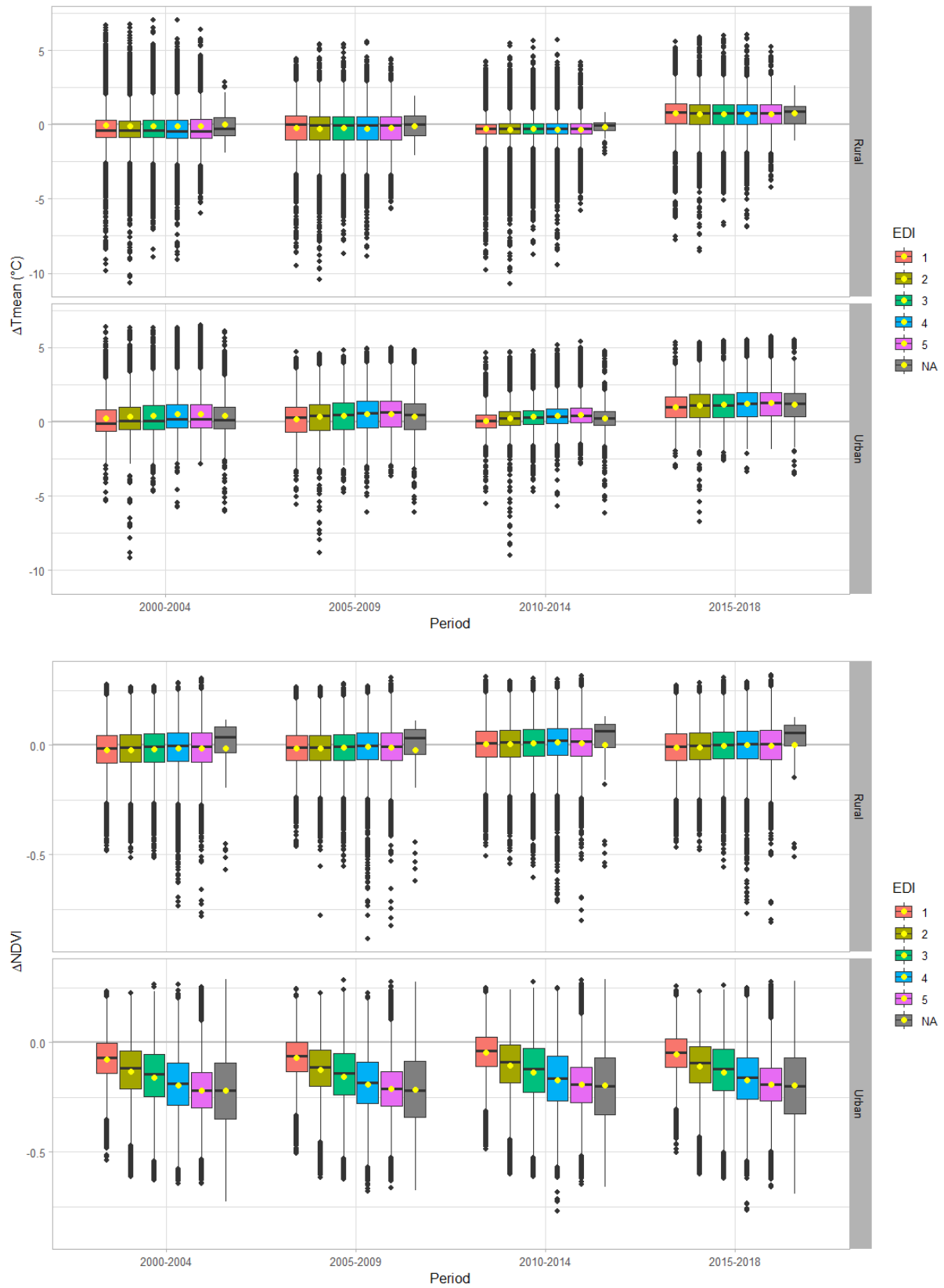
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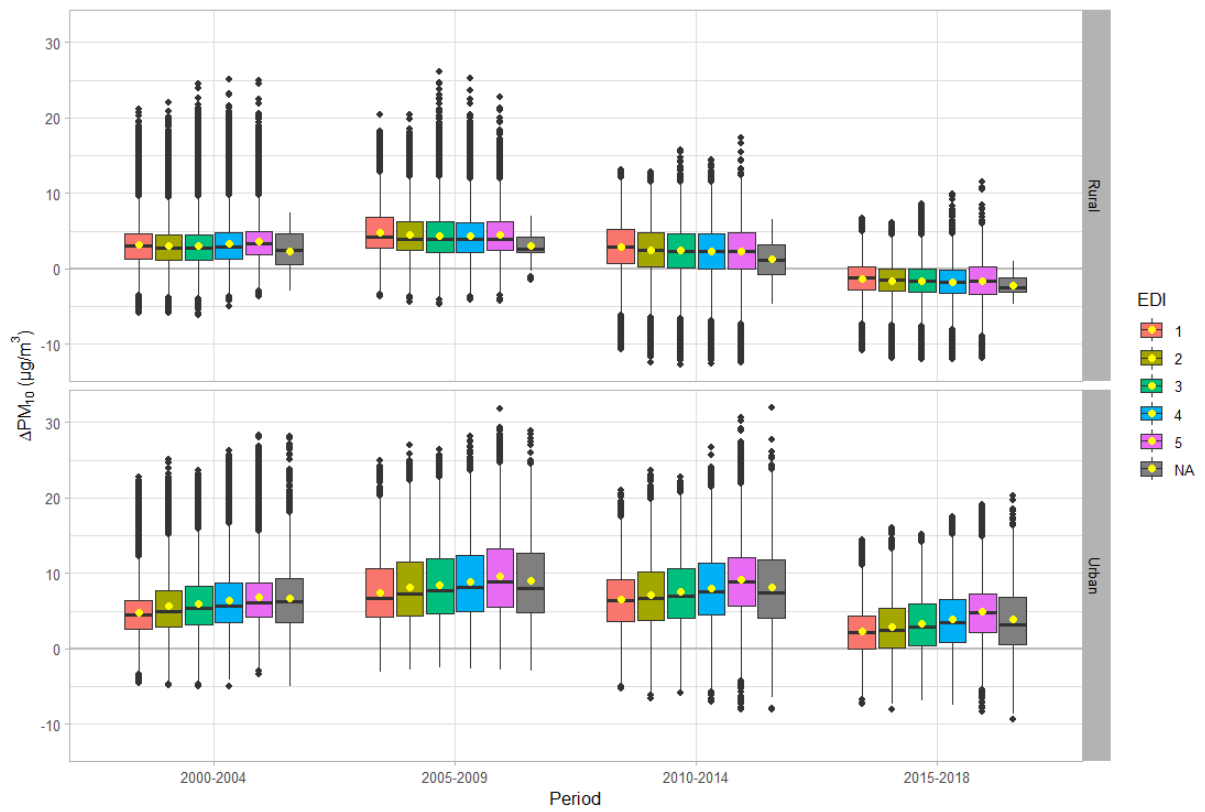
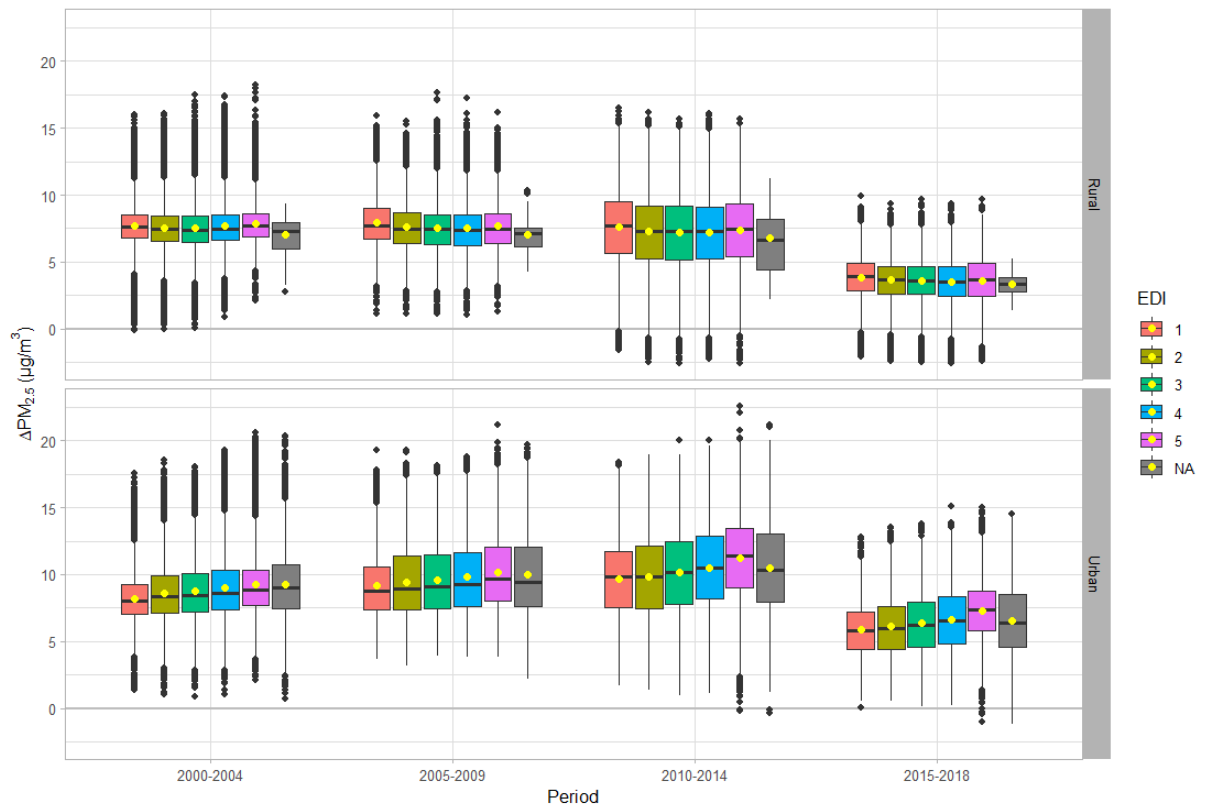


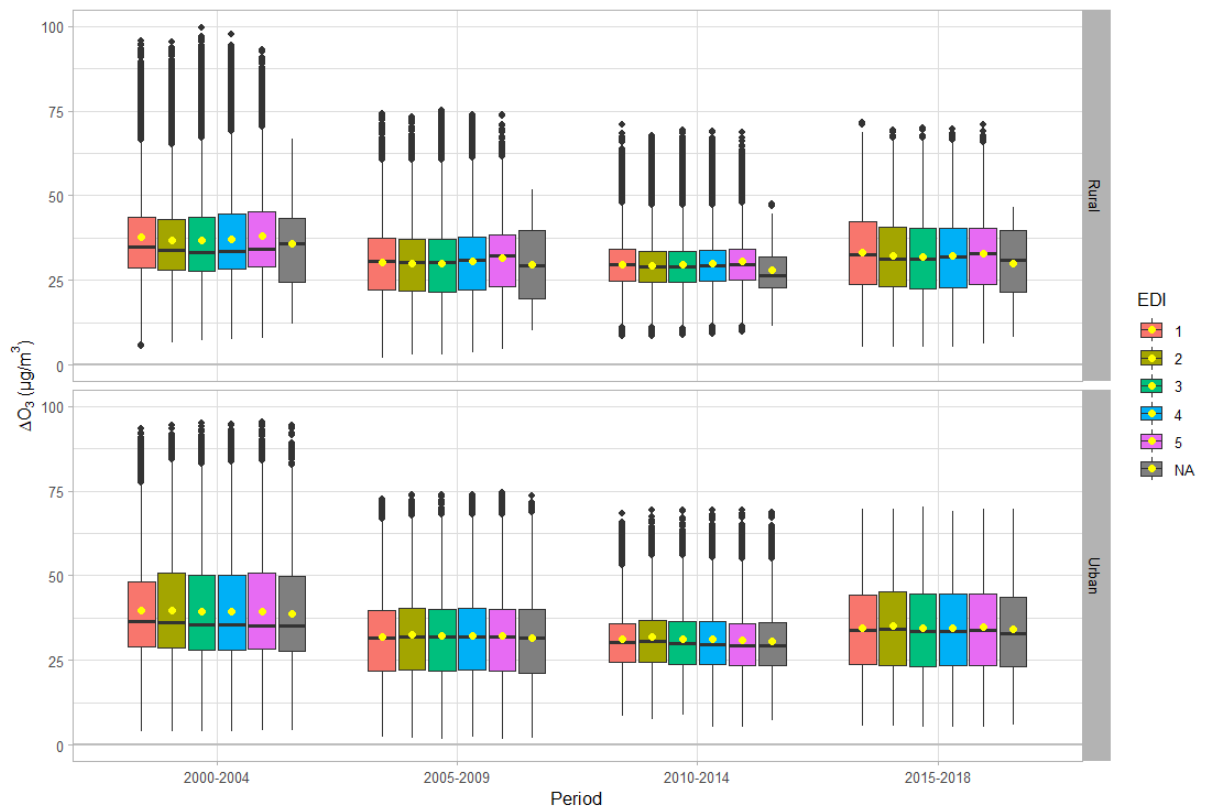
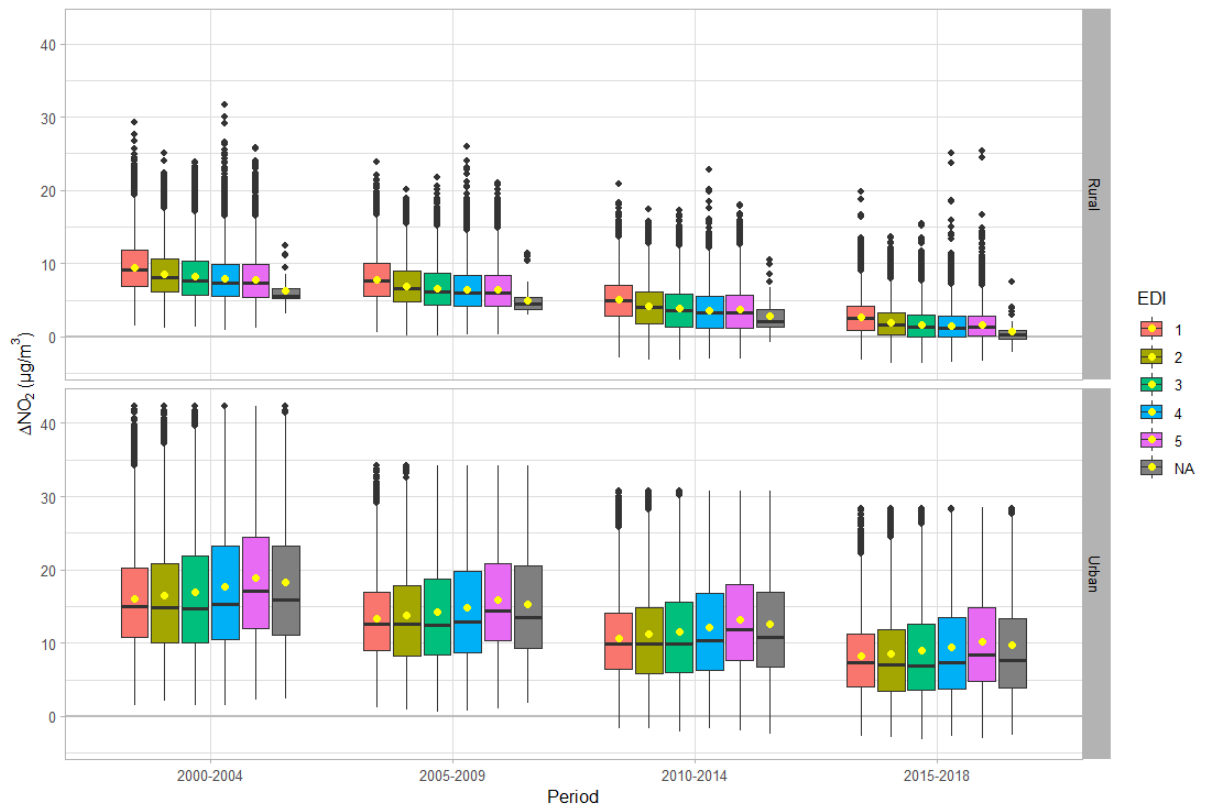
b)



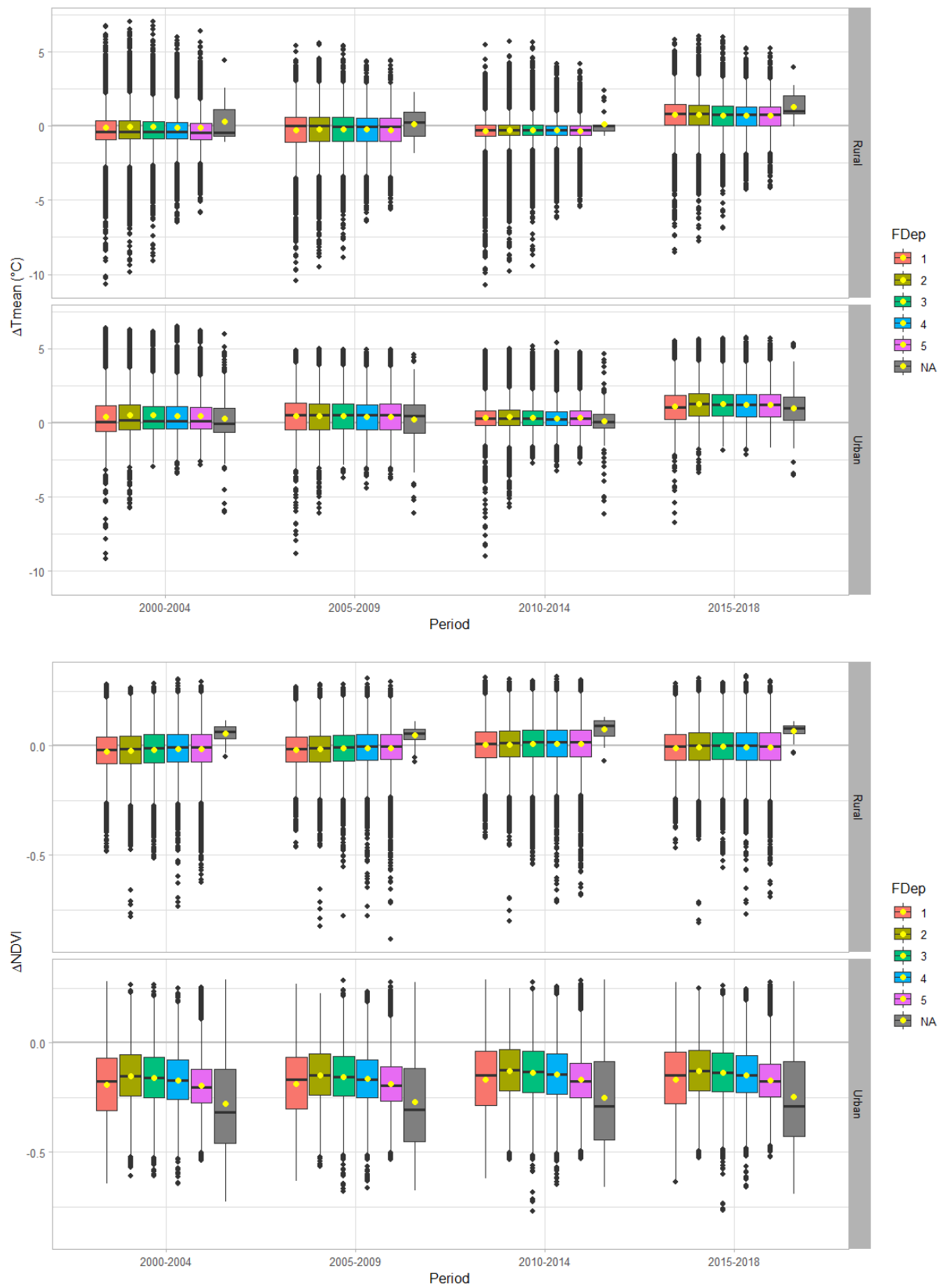
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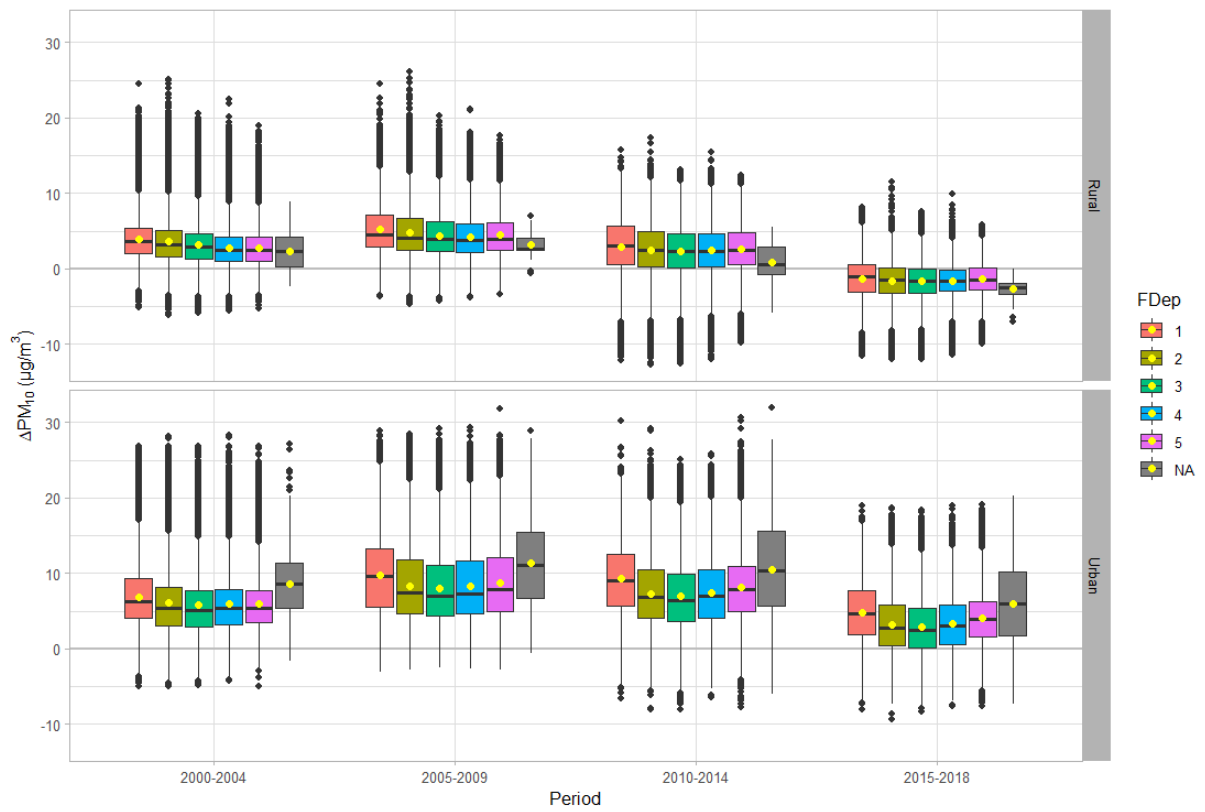
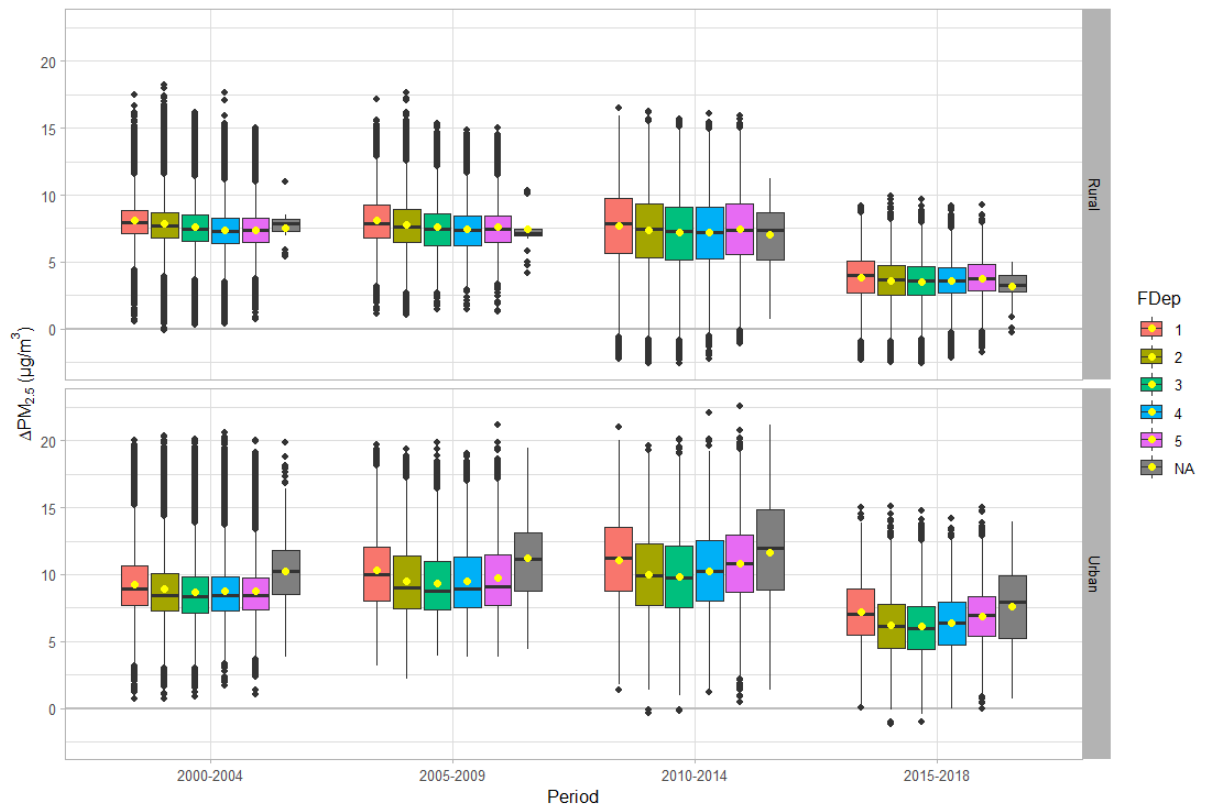


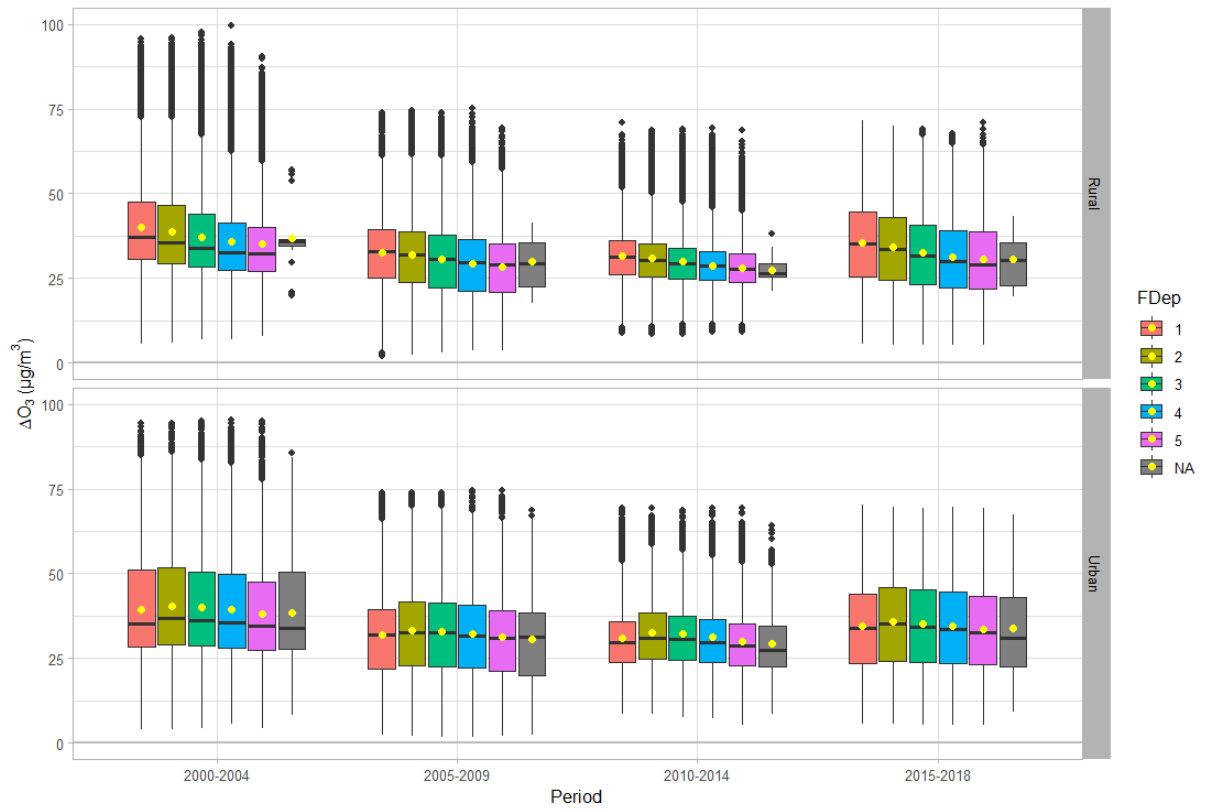
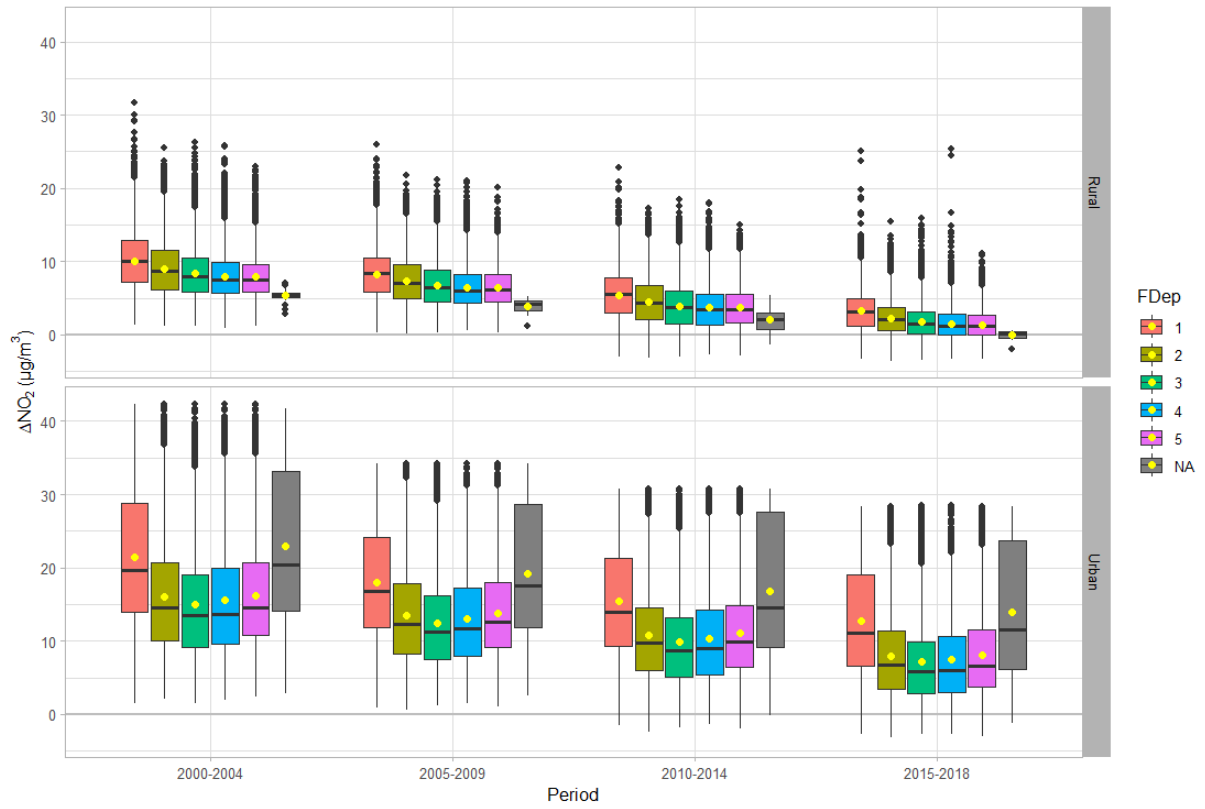




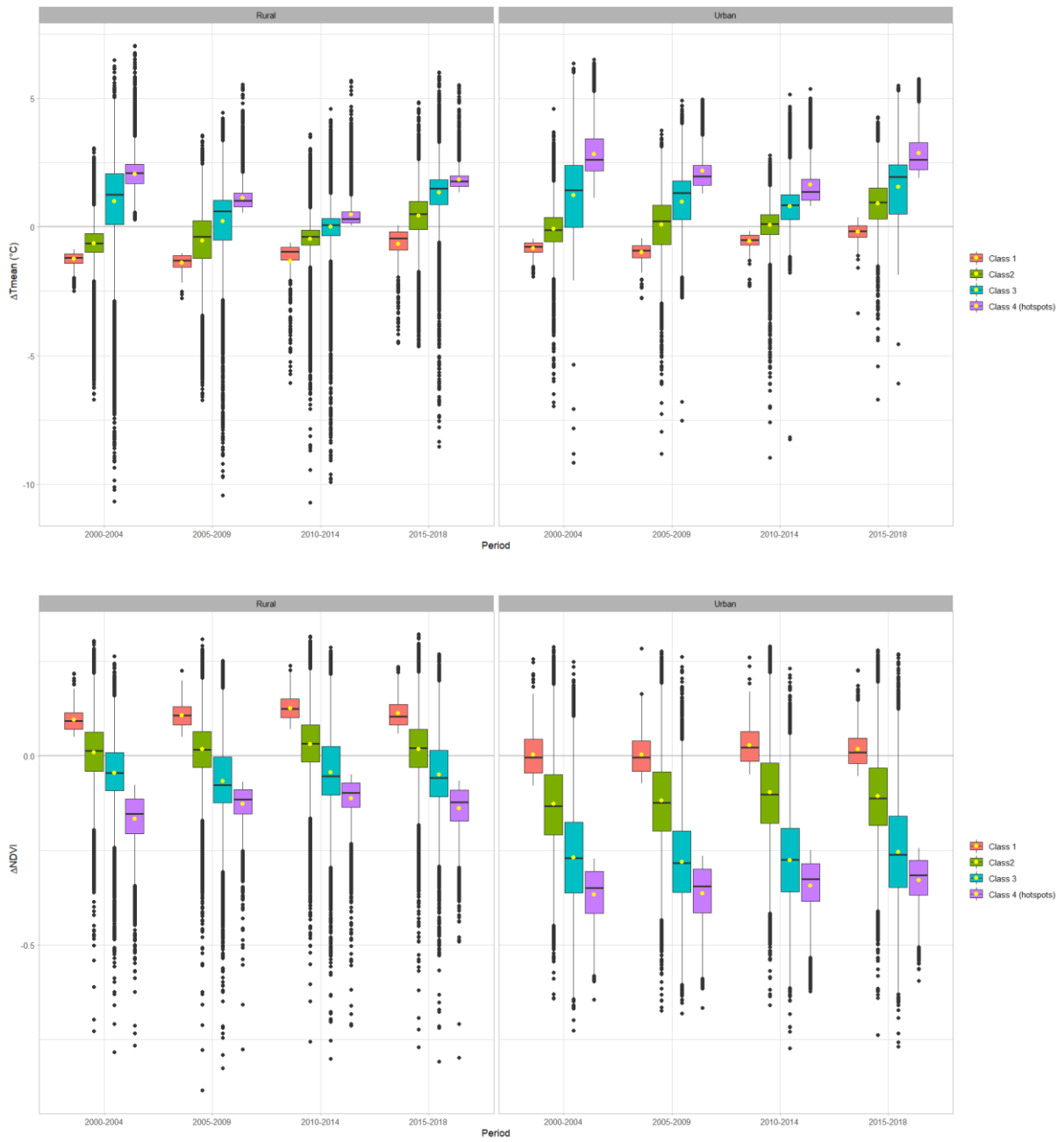
Supplementary Figure 8. Distribution of each exposure indicator by French Deprivation Index (FDep) quintiles, period, and urbanization level

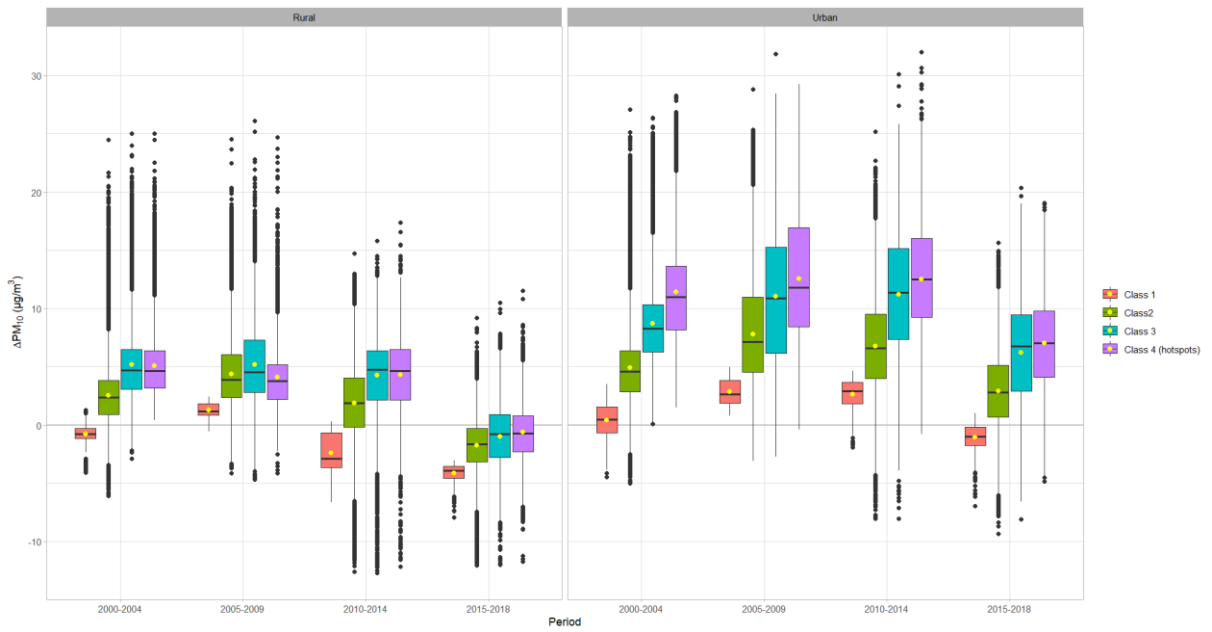
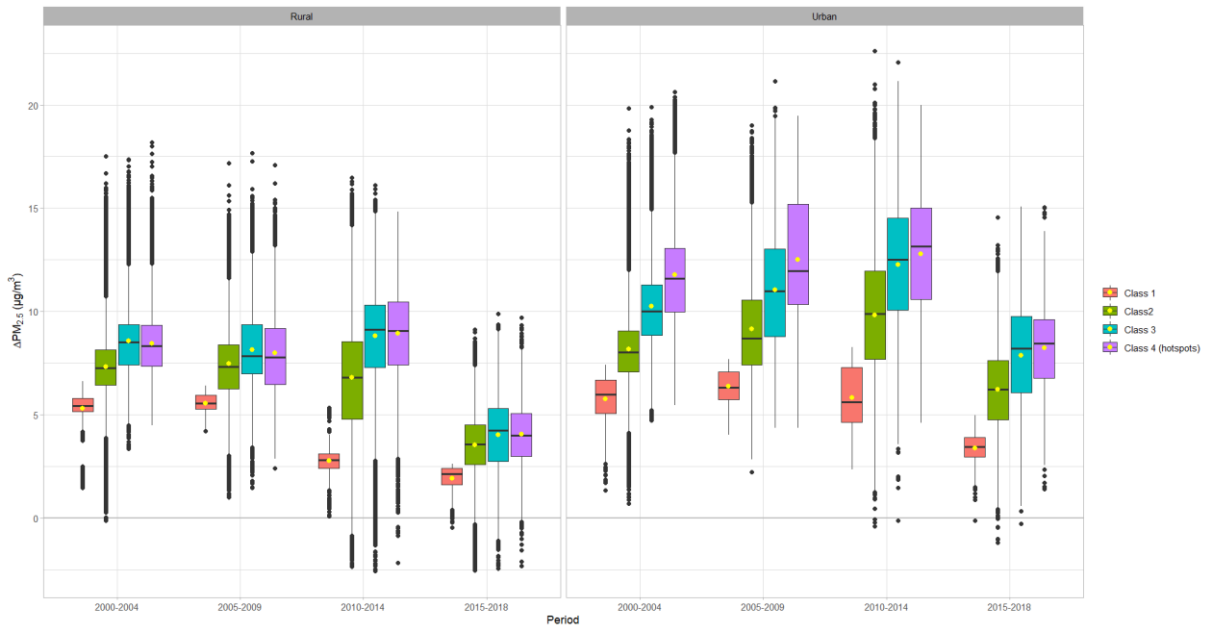


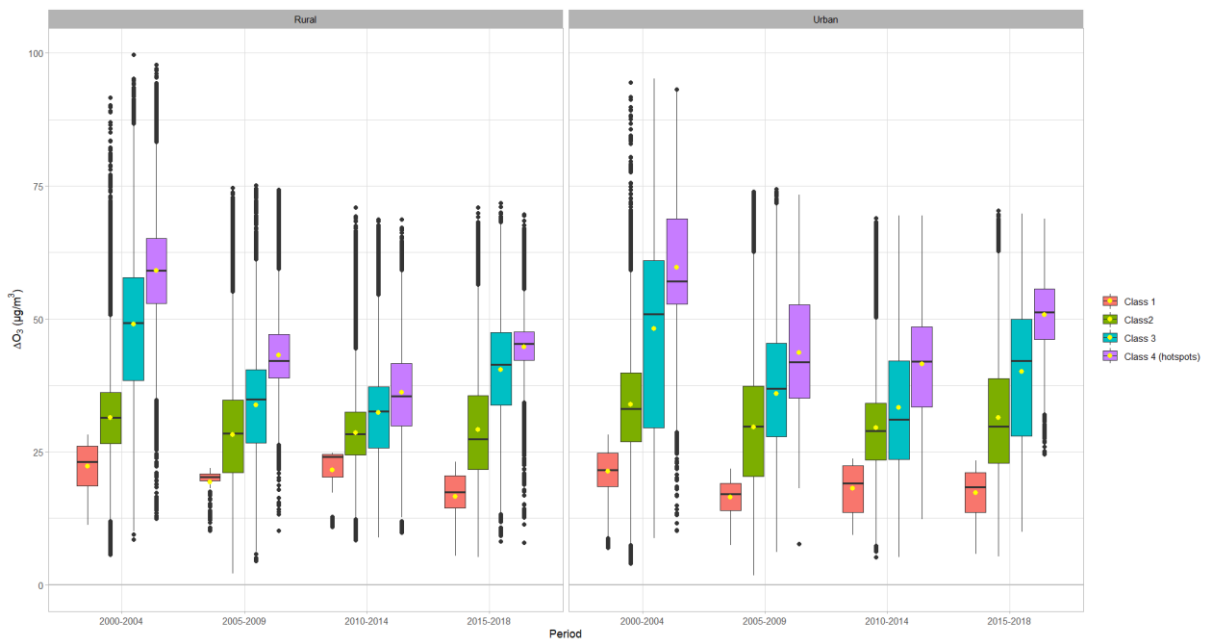
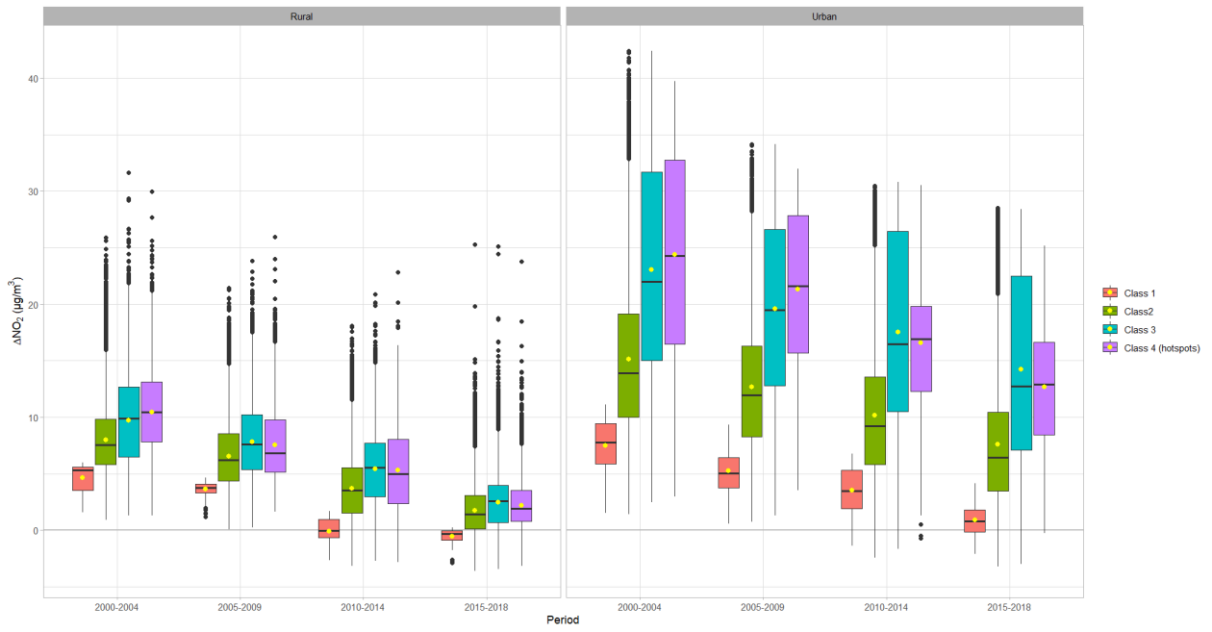




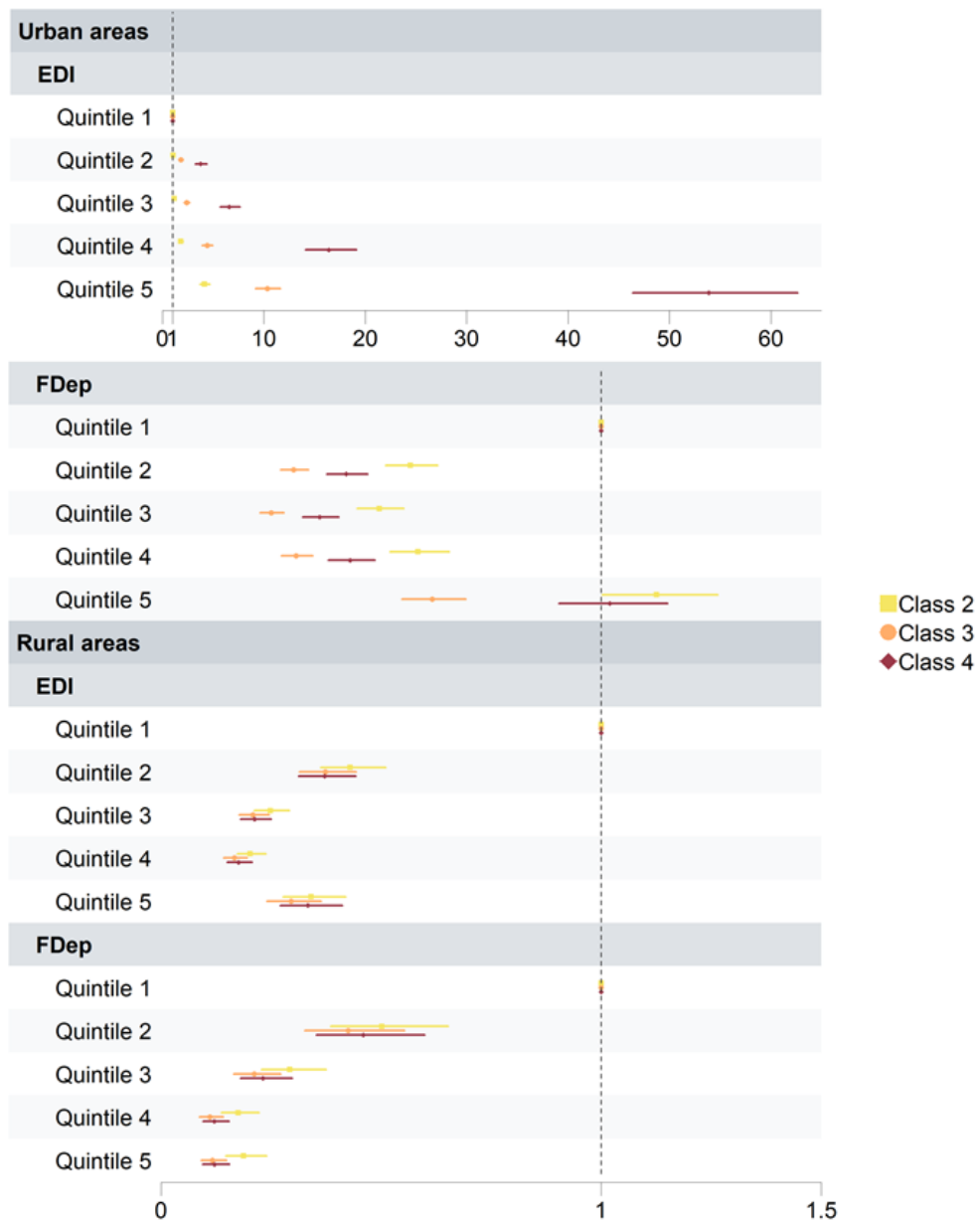
Supplementary Figure 9. Distribution of each exposure indicator by class of the cumulative exposure indicator, period, and urbanization level







Supplementary Figure 10. Associations between the cumulative exposure indicator classes and the deprivation indices (EDI and FDep) between 2000 and 2018 in urban and rural areas in continental France (OR [95% CI]*)



*OR (95% CI) estimated using non-ordinal polytomous logistic models

1 **Supplementary Table 1.** Summary of the indicators

Relative exposure indicators				
Name	Definition	Type of indicators	Categories	
ΔT_{mean} ΔT_{min} ΔT_{max}	Difference between the daily temperature and the corresponding 10-day reference values for each department and each climate type <i>Overexposure if $\Delta T_{\text{mean}}/\Delta T_{\text{min}}/\Delta T_{\text{max}} > 0$</i>	Continuous	/	
		Quartiles (ΔT_{mean} only)	During summer, by period (2000-2004, 2005-2009, 2010-2014, 2015-2018), and urbanization level (urban/rural)	
		Categorized (ΔT_{mean} only): exposure to heat during summer	Low	≤ 0
			Medium*	Urban:]0 ; 0.96[Rural:]0 ; 0.75[
High	Urban: ≥ 0.96 Rural: ≥ 0.75			
ΔNDVI	Difference between mean summer NDVI and median values of mean summer NDVI values in rural areas for each climate type <i>Overexposure if $\Delta \text{NDVI} < 0$</i>	Continuous	/	
		Quartiles	By period (2000-2004, 2005-2009, 2010-2014, 2015-2018) and urbanization level (urban/rural)	
		Categorized: exposure to lack of vegetation during summer	Low	≥ 0
			Medium*	Urban:]-0.18 ; 0[Rural:]-0.065 ; 0[
High	Urban: ≤ -0.18 Rural: ≤ -0.065			
$\Delta \text{PM}_{2.5}$	Difference between daily mean $\text{PM}_{2.5}$ concentrations and annual WHO air quality guideline values ($5 \mu\text{g}/\text{m}^3$) <i>Overexposure if $\Delta \text{PM}_{2.5} > 0$</i>	Continuous	/	
		Quartiles	By period (2000-2004, 2005-2009, 2010-2014, 2015-2018) and urbanization level (urban/rural)	
		Categorized	Low	Urban: $\leq 1.84^\dagger$ Rural: $\leq 0.45^\dagger$
			Medium*	Urban:]1.84 ; 6.50[Rural:]0.45 ; 4.89[
High	Urban: ≥ 6.50 Rural: ≥ 4.89			
ΔPM_{10}		Continuous	/	

	Difference between daily mean PM ₁₀ concentrations and annual WHO air quality guideline values (15 µg/m ³)	Quartiles	By period (2000-2004, 2005-2009, 2010-2014, 2015-2018) and urbanization level (urban/rural)						
	<i>Overexposure if $\Delta PM_{10} > 0$</i>	Categorized	Not studied						
		Continuous	/						
ΔNO_2	Difference between daily mean NO ₂ concentrations and annual WHO air quality guideline values (10 µg/m ³)	Quartiles	By period (2000-2004, 2005-2009, 2010-2014, 2015-2018) and urbanization level (urban/rural)						
	<i>Overexposure if $\Delta NO_2 > 0$</i>	Categorized	<table border="1"> <tbody> <tr> <td>Low</td> <td>≤ 0</td> </tr> <tr> <td>Medium*</td> <td>Urban:]0 ; 6.89[Rural:]0 ; 2.35[</td> </tr> <tr> <td>High</td> <td>Urban: ≥ 6.89 Rural: ≥ 2.35</td> </tr> </tbody> </table>	Low	≤ 0	Medium*	Urban:]0 ; 6.89[Rural:]0 ; 2.35[High	Urban: ≥ 6.89 Rural: ≥ 2.35
Low	≤ 0								
Medium*	Urban:]0 ; 6.89[Rural:]0 ; 2.35[
High	Urban: ≥ 6.89 Rural: ≥ 2.35								
		Continuous	/						
ΔO_3	Difference between daily maximum O ₃ concentrations during summer and peak season WHO air quality guideline values (60 µg/m ³)	Quartiles	During by period (2000-2004, 2005-2009, 2010-2014, 2015-2018) and urbanization level (urban/rural)						
	<i>Overexposure if $\Delta O_3 > 0$</i>	Categorized	<table border="1"> <tbody> <tr> <td>Low</td> <td>Urban: ≤ 15.78[†] Rural: ≤ 16.26[†]</td> </tr> <tr> <td>Medium*</td> <td>Urban:]15.78 ; 32.34[Rural:]16.3 ; 31.22[</td> </tr> <tr> <td>High</td> <td>Urban: ≥ 32.34 Rural: ≥ 31.22</td> </tr> </tbody> </table>	Low	Urban: ≤ 15.78 [†] Rural: ≤ 16.26 [†]	Medium*	Urban:]15.78 ; 32.34[Rural:]16.3 ; 31.22[High	Urban: ≥ 32.34 Rural: ≥ 31.22
Low	Urban: ≤ 15.78 [†] Rural: ≤ 16.26 [†]								
Medium*	Urban:]15.78 ; 32.34[Rural:]16.3 ; 31.22[
High	Urban: ≥ 32.34 Rural: ≥ 31.22								
Cumulative exposure indicator									
Hotspots		The three following conditions are all met:							
Class 4	IRIS in the strongest quartiles for all factors	<ul style="list-style-type: none"> i) summer ΔT_{mean} in the last quartile; ii) at least one of the four air pollutants (annual $\Delta PM_{2.5}$, annual ΔPM_{10}, annual ΔNO_2, or summer ΔO_3) in the last quartile; iii) summer $\Delta NDVI$ in the first quartile. 							

Class 3	IRIS in the strongest quartiles for two factors	Two of the following conditions are met: i) summer ΔT_{mean} in the last quartile; ii) at least one of the four air pollutants (annual $\Delta \text{PM}_{2.5}$, annual ΔPM_{10} , annual ΔNO_2 , or summer ΔO_3) in the last quartile; iii) summer ΔNDVI in the first quartile.
Class 2	IRIS in the strongest quartiles for one factor	One of the following conditions is met: i) summer ΔT_{mean} in the last quartile; ii) at least one of the four air pollutants (annual $\Delta \text{PM}_{2.5}$, annual ΔPM_{10} , annual ΔNO_2 , or summer ΔO_3) in the last quartile; iii) summer ΔNDVI in the first quartile.
Class 1	IRIS in the lowest exposure quartiles for all factors	The three following conditions are met: i) summer ΔT_{mean} in the first quartile; ii) all four air pollutants (annual $\Delta \text{PM}_{2.5}$, annual ΔPM_{10} , annual ΔNO_2 , and summer ΔO_3) in the first quartile; iii) summer ΔNDVI in the last quartile.

2 †Correspond to the 5th percentile of the distribution (to allow for sufficient statistical power)

3 *Upper bounds correspond to the median in overexposed IRIS for ΔT_{mean} , $\Delta \text{PM}_{2.5}$, ΔNO_2 , and ΔO_3 . Lower bounds correspond to the median in overexposed
4 IRIS for ΔNDVI .

5

6 **Supplementary Table 2.** Mean ΔT_{mean} , ΔT_{min} , and ΔT_{max} by period, season, and urbanization
7 level in continental France

		Urban IRIS*				Rural IRIS*			
		2000-2004	2005-2009	2010-2014	2015-2018	2000-2004	2005-2009	2010-2014	2015-2018
Summer	ΔT_{mean}	0.46	0.45	0.36	1.19	-0.09	-0.24	-0.31	0.73
	ΔT_{min}	0.86	0.84	0.62	1.33	-0.08	-0.13	-0.26	0.47
	ΔT_{max}	0.19	0.03	0.03	1.39	-0.02	-0.33	-0.38	0.89
Autumn	ΔT_{mean}	0.22	0.36	0.65	0.46	-0.23	-0.28	0.13	0.16
	ΔT_{min}	0.63	0.44	0.83	0.48	-0.02	-0.31	0.20	-0.14
	ΔT_{max}	-0.21	0.02	0.32	0.78	-0.38	-0.30	0.06	0.44
Winter	ΔT_{mean}	0.79	0.15	0.17	0.62	0.38	-0.39	-0.35	0.41
	ΔT_{min}	1.03	0.14	0.30	0.91	0.44	-0.53	-0.34	0.48
	ΔT_{max}	0.54	-0.10	-0.15	0.62	0.39	-0.28	-0.40	0.31
Spring	ΔT_{mean}	0.35	0.73	0.36	0.66	-0.19	0.09	-0.26	0.25
	ΔT_{min}	0.71	0.97	0.51	0.92	-0.12	0.13	-0.30	0.20
	ΔT_{max}	0.04	0.39	0.13	0.73	-0.19	0.06	-0.25	0.21

8

9

10 **Supplementary Table 3.** Percentage of IRIS in each class of the cumulative exposure indicator by
 11 period and urbanization level

	Urban areas				Rural areas			
	Class 1 % (n)	Class 2 % (n)	Class 3 % (n)	Class 4 % (n)	Class 1 % (n)	Class 2 % (n)	Class 3 % (n)	Class 4 % (n)
2000-2004	1.16 (1,014)	65.94 (57,839)	25.24 (22,138)	7.66 (6,719)	0.72 (1,096)	72.66 (111,327)	15.29 (23,430)	11.33 (17,362)
2005-2009	0.56 (494)	68.77 (60,319)	22.84 (20,031)	7.83 (6,866)	0.13 (194)	68.47 (104,900)	26.69 (40,889)	4.72 (7,232)
2010-2014	0.77 (678)	68.96 (60,489)	22.99 (20,164)	7.27 (6,379)	0.31 (475)	72.81 (111,559)	22.15 (33,932)	4.73 (7,249)
2015-2018	1.36 (953)	67.37 (47,272)	25.15 (17,646)	6.12 (4,297)	0.54 (659)	71.37 (87,476)	21.64 (26,532)	6.45 (7,905)

12 Class 4: hotspots with IRIS in the strongest quartiles for all three factors

13 Class 3: IRIS in the strongest quartiles for two factors

14 Class 2: IRIS in the strongest quartiles for one factor

15 Class 1: IRIS in the lowest exposure quartiles for all factors

16

17 **Supplementary Table 4.** Mean percentages of IRIS overexposed to each environmental exposure
 18 indicator by cumulative exposure indicator class and urbanization level

	Urban areas				Rural areas			
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4
Summer $\Delta T_{\text{mean}} > 0$	59.76%	64.29%	74.26%	100%	14.05%	38.91%	61.09%	100%
Summer $\Delta \text{NDVI} < 0$	40.69%	83.22%	98.19%	100%	0%	39.13%	78.54%	100%
$\Delta \text{PM}_{2.5} > 0$	99.99%	99.99%	99.98%	99.97%	99.82%	99.46%	99.84%	99.76%
$\Delta \text{PM}_{10} > 0$	79.80%	94.00%	98.51%	99.48%	43.57%	71.54%	83.23%	81.87%
$\Delta \text{NO}_2 > 0$	92.17%	98.79%	99.87%	99.99%	75.50%	92.07%	95.29%	97.80%
Summer $\Delta \text{O}_3 > 0$	100%	100%	100%	100%	100%	100%	100%	100%

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