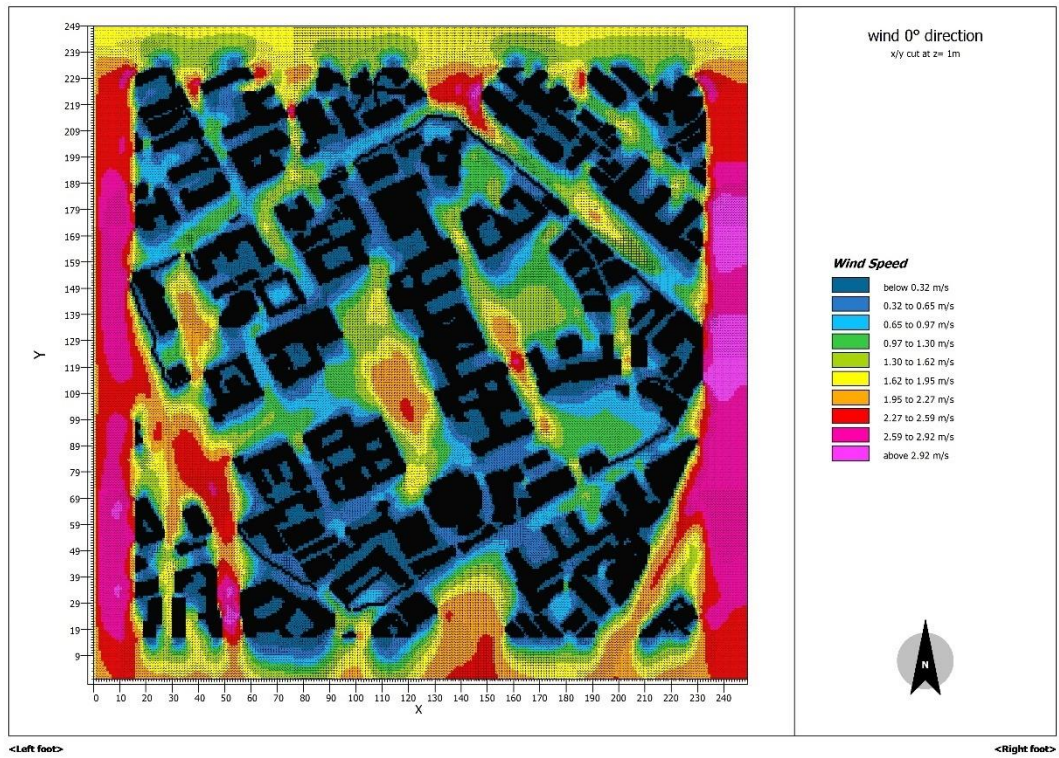# Online supplement to:

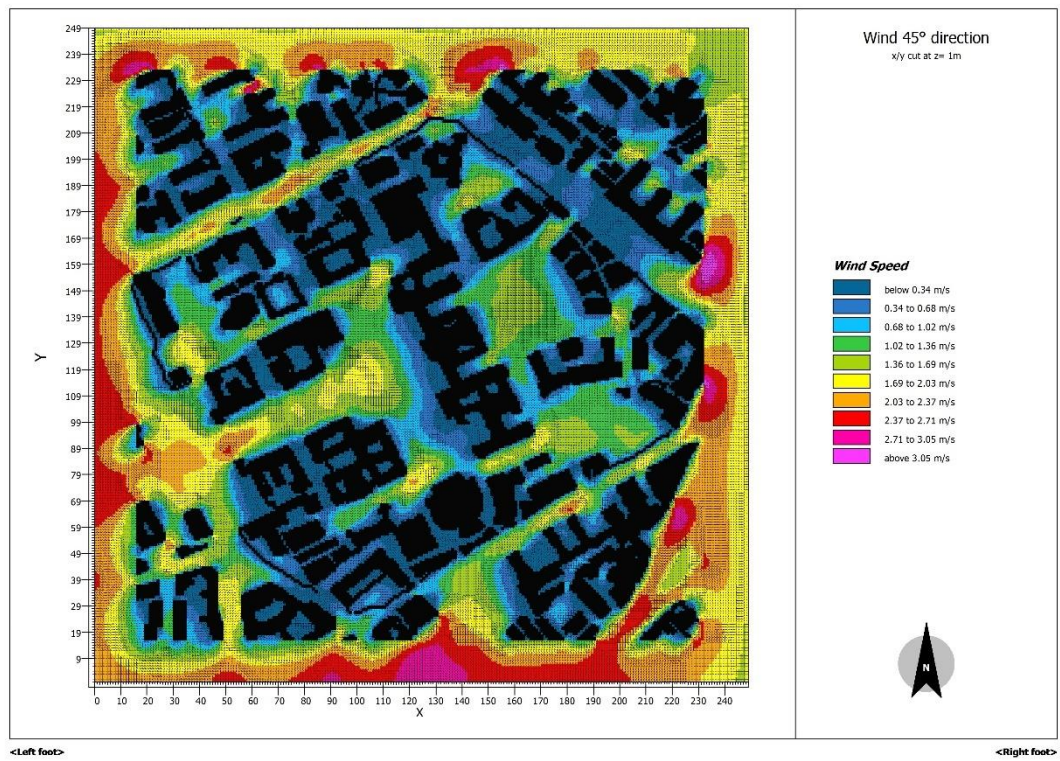## Spatio-temporal modeling of small-scale ultrafine particles variability using Generalized Additive Models

Alessandra Gaeta, Gianluca Leone, Alessandro Di Menno di Bucchianico, Mariacarmela Cusano, Raffaella Gaddi, Armando Pelliccioni, Maria Antonietta Reatini, Annalisa Di Bernardino and Giorgio Cattani

a)

wind 0° direction
x/y cut at z= 1m

Wind Speed

	below 0.32 m/s
	0.32 to 0.65 m/s
	0.65 to 0.97 m/s
	0.97 to 1.30 m/s
	1.30 to 1.62 m/s
	1.62 to 1.95 m/s
	1.95 to 2.27 m/s
	2.27 to 2.59 m/s
	2.59 to 2.92 m/s
	above 2.92 m/s

N

<Left foot>   <Right foot>

b)

Wind 45° direction
x/y cut at z= 1m

Wind Speed

	below 0.34 m/s
	0.34 to 0.68 m/s
	0.68 to 1.02 m/s
	1.02 to 1.36 m/s
	1.36 to 1.69 m/s
	1.69 to 2.03 m/s
	2.03 to 2.37 m/s
	2.37 to 2.71 m/s
	2.71 to 3.05 m/s
	above 3.05 m/s

N

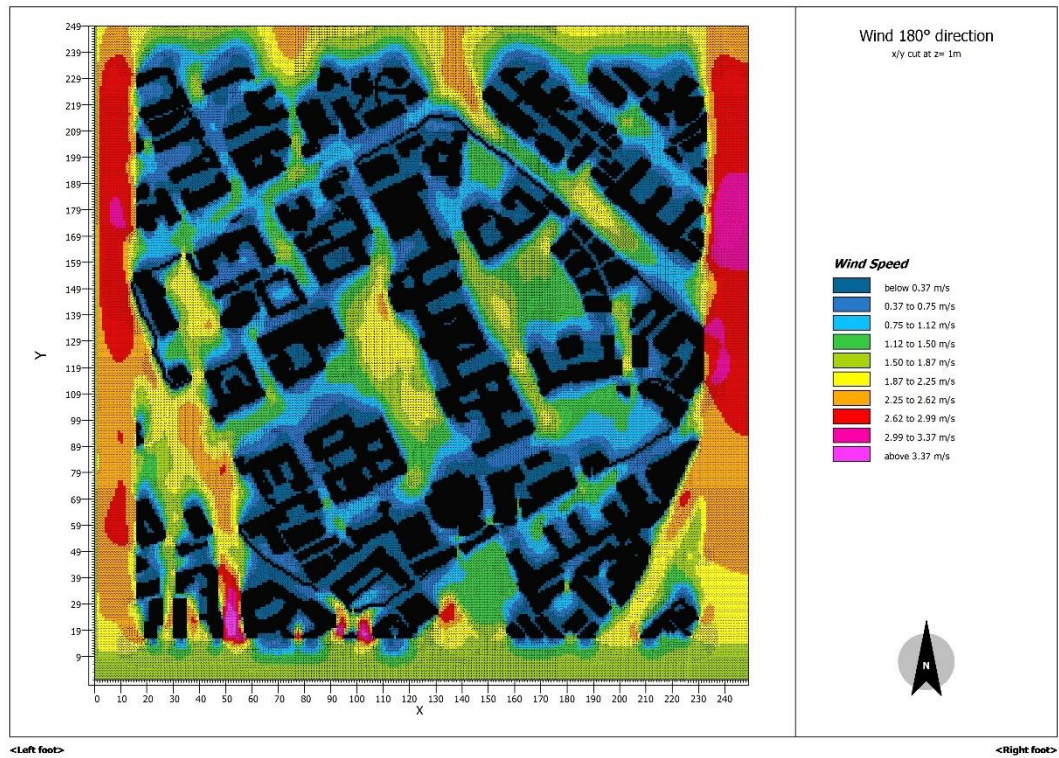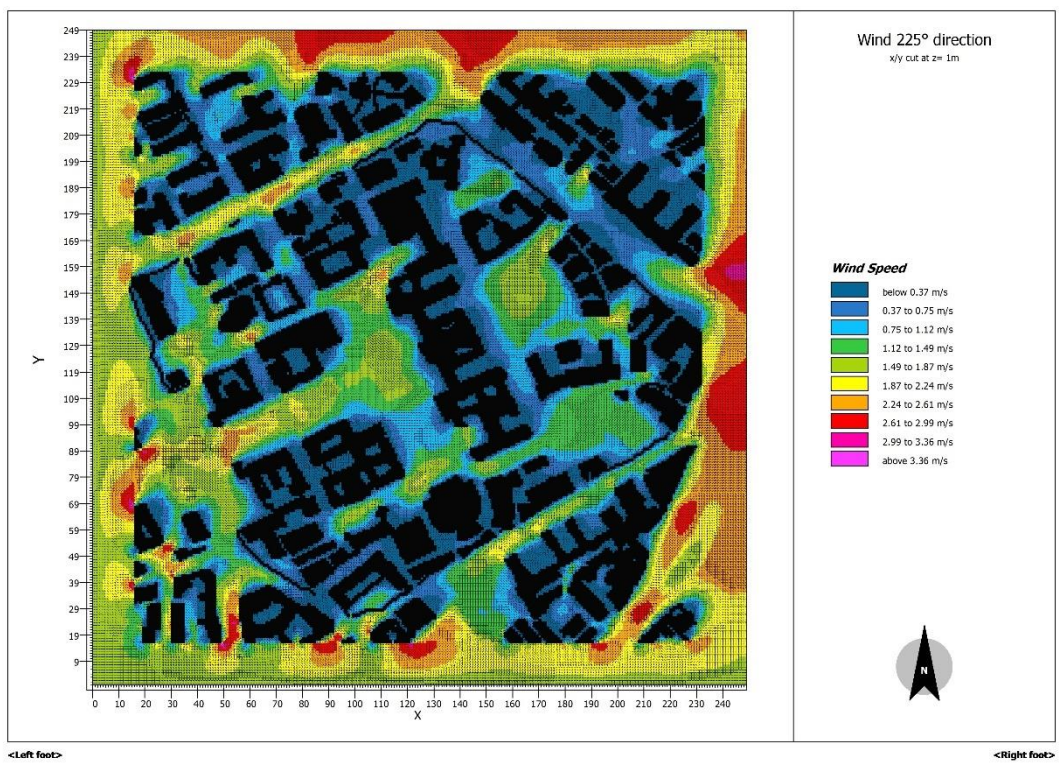<Left foot>   <Right foot>
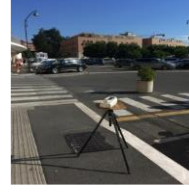
c)

d)

Figure S1. Horizontal wind intensity fields obtained by ENVIMET numerical simulations with different wind directions: a) 0°, b) 45°, c) 180°, d) 225°.

A5: Minerva monumental fountain   **A4:** Statistical sciences building (in front of)   **A3**: Info point "Ciao" (crossroad)
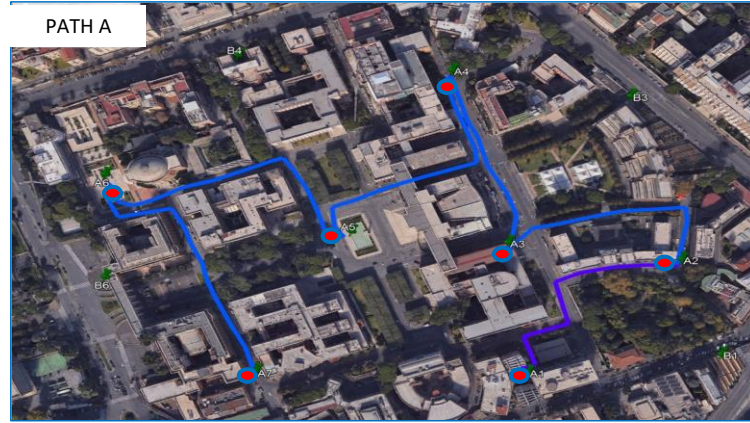

A6: Divina Sapienza chapel

A2: Sapienza botanical garden

PATH A

A7: Orthopedic clinic

A1: Physics Fermi building

Figure S2a. Measurement points selected in Path A: within Sapienza borders.

B5: v.le Policlinico n. 159

B4: v.le dell'Università n. 32   **B3:** v.le Regina Elena n. 334

B6: p.le Aldo Moro n. 5

PATH B

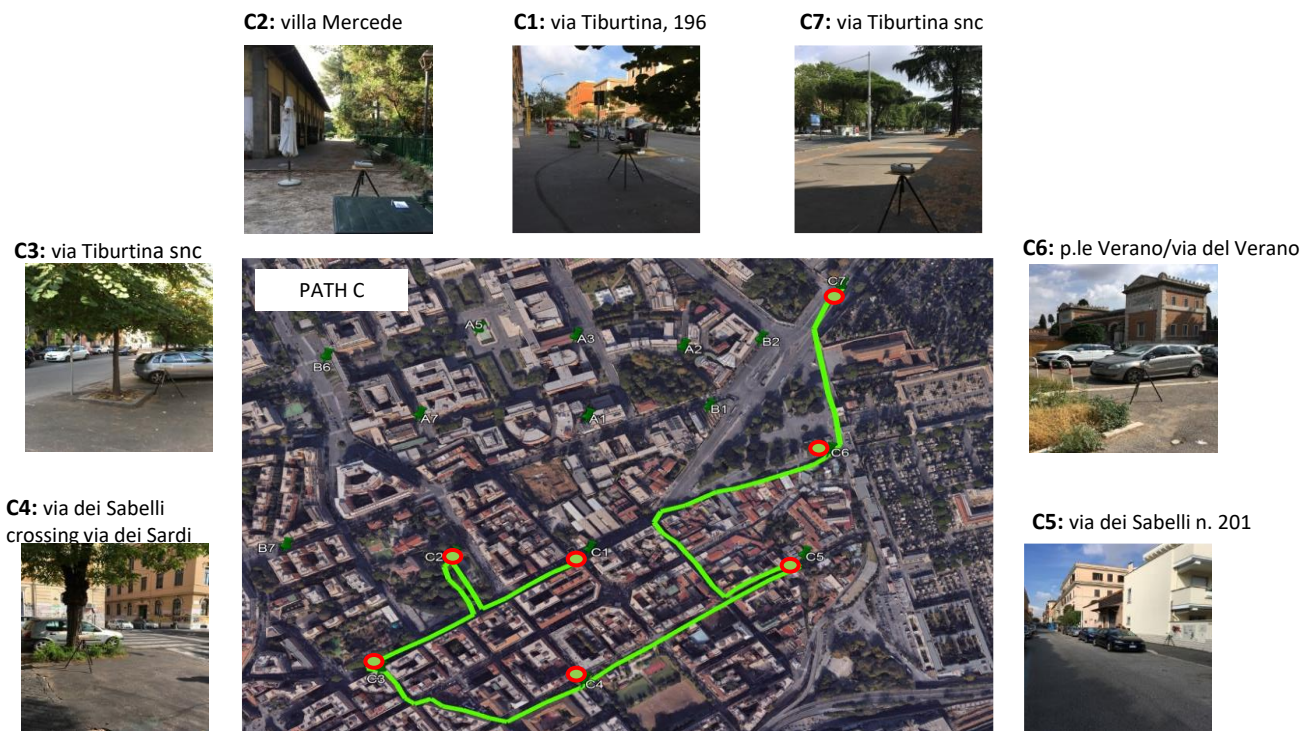**B2:** via Tiburtina snc

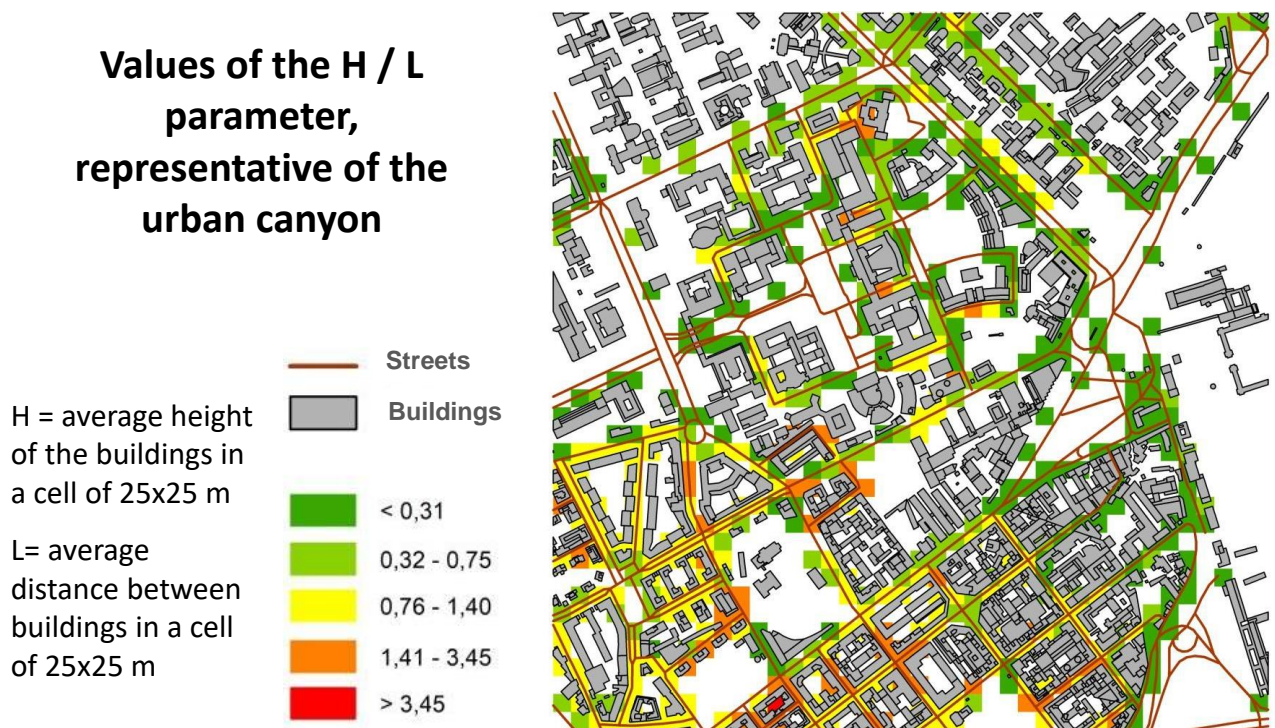**B7:** p.zza dei Siculi n. 2

B1: via C. De Lollis n. 25

Figure S2b. Measurement points selected in Path B: main roads outside Sapienza borders.

**Figure S2c.** Measurement points selected in Path C: urban area 3B - San Lorenzo.

Figure S3. H/L parameter values, representative of the urban canyon.

Table S1. First campaign, 8 - 17 November 2017. Summary statistics for two-hour PNC (particles/cm^3) measurements at 21 sites in the study area.

Site	Mean	sd	CV (%)	Min	perc 25°	Median	perc 75°	Max	n
A1	18666	6232	33%	8583	14936	16513	22792	31013	21
A2	18551	7845	42%	8042	11914	17657	23034	39896	21
A3	18576	6368	34%	8839	14504	16965	22887	30821	21
A4	19458	7459	38%	7804	15616	18379	22410	36053	21
A5	20367	7993	39%	7190	16078	19865	22525	40048	21
A6	18142	6755	37%	7718	15346	16440	20454	39018	21
A7	19163	6292	33%	7783	14722	19054	22322	31089	21
B1	38842	20264	52%	16806	25456	34467	46097	89288	21
B2	35922	22748	63%	5722	20238	29977	44142	100107	21
B3	25225	11808	47%	8331	19203	24089	30050	61017	21
B4	28582	13915	49%	8645	17091	24138	35730	62497	21
B5	28155	10455	37%	9228	22481	29688	34250	49235	21
B6	18585	6896	37%	8070	14954	17945	20816	40148	21
B7	24045	10190	42%	10496	17300	22337	26364	58242	21
C1	29530	11785	40%	17541	22355	24902	27842	62524	21
C2	18449	6386	35%	4416	15109	16860	23041	30860	21
C3	28117	9579	34%	15349	20993	25514	32712	51323	21
C4	23931	7307	31%	11800	18725	22797	26847	38867	21
C5	27197	19343	71%	7236	18618	22762	29985	101594	21
C6	18569	7102	38%	7388	14803	17511	21531	39542	21
C7	29501	11358	39%	11015	20955	27945	34162	48359	21

Table S2. Second campaign, 17 – 23 June 2018. Summary statistics for two-hour PNC (particles/cm^3) measurements at 21 sites in the study area.

Site	Mean	sd	CV (%)	Min	perc 25°	Median	perc 75°	Max	n
A1	9291	3212	35%	4850	7244	8770	11364	19135	21
A2	8717	2551	29%	4899	6468	9349	9916	14395	21
A3	8494	2766	33%	4807	6428	8312	10021	14613	21
A4	8471	2255	27%	4893	6471	8568	10165	13271	21
A5	8115	2641	33%	4335	5581	8057	9586	13665	21
A6	8107	2537	31%	5262	6117	7619	9870	14108	21
A7	8020	2787	35%	4306	5819	8141	9480	14970	21
B1	17138	7575	44%	8004	9757	14615	23716	28962	21
B2	15970	5915	37%	7982	11041	15467	19075	32483	21
B3	12274	4631	38%	5238	7792	12477	14470	22740	21
B4	14910	6580	44%	6542	9512	12443	19713	31291	21
B5	13817	6290	46%	6347	7800	12683	17701	26373	21
B6	9389	3387	36%	5943	6559	7969	11812	16339	21
B7	10730	3416	32%	5684	8270	10983	12449	19401	21
C1	14091	5985	42%	6433	9993	12589	17182	27262	21
C2	9108	3141	34%	4477	6501	8848	10632	16787	21
C3	15467	7085	46%	7312	9664	13160	21857	31444	21
C4	11774	4471	38%	5532	8271	11216	13440	23156	21
C5	9943	4478	45%	3565	6062	10850	11589	21874	21
C6	8140	3184	39%	3846	5105	7039	10152	15011	21
C7	12681	5054	40%	6497	8583	11938	14650	24153	21
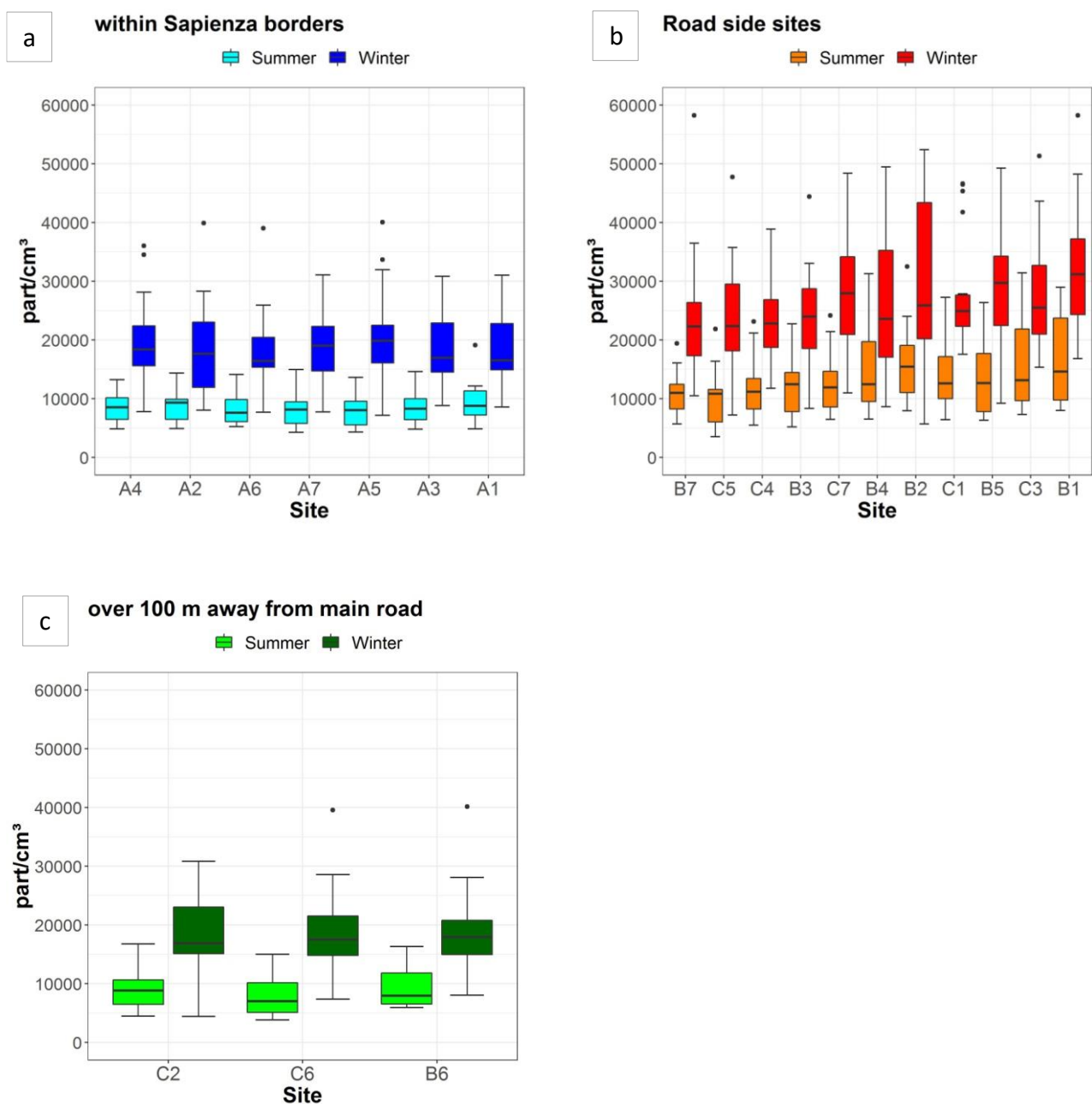
Figure S4. Comparison between average PNC values, observed in winter and in summer: a) within Sapienza borders, path A; b) in the points most affected by the greater proximity to roads with high traffic flows, (points B1, B2, B3, B4, B5 and points C1, C3, C7); c) in points relatively far from the busiest roads (B6, C2, C6).
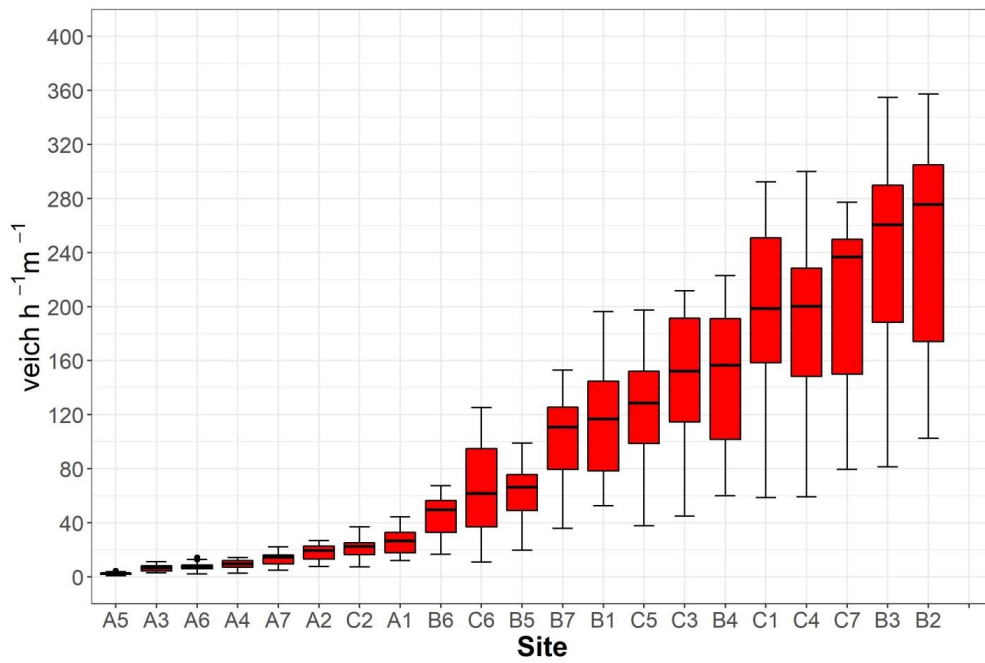
**Figure S5.** Site characterization: ratio between traffic flows on the nearest road and distance from the road.
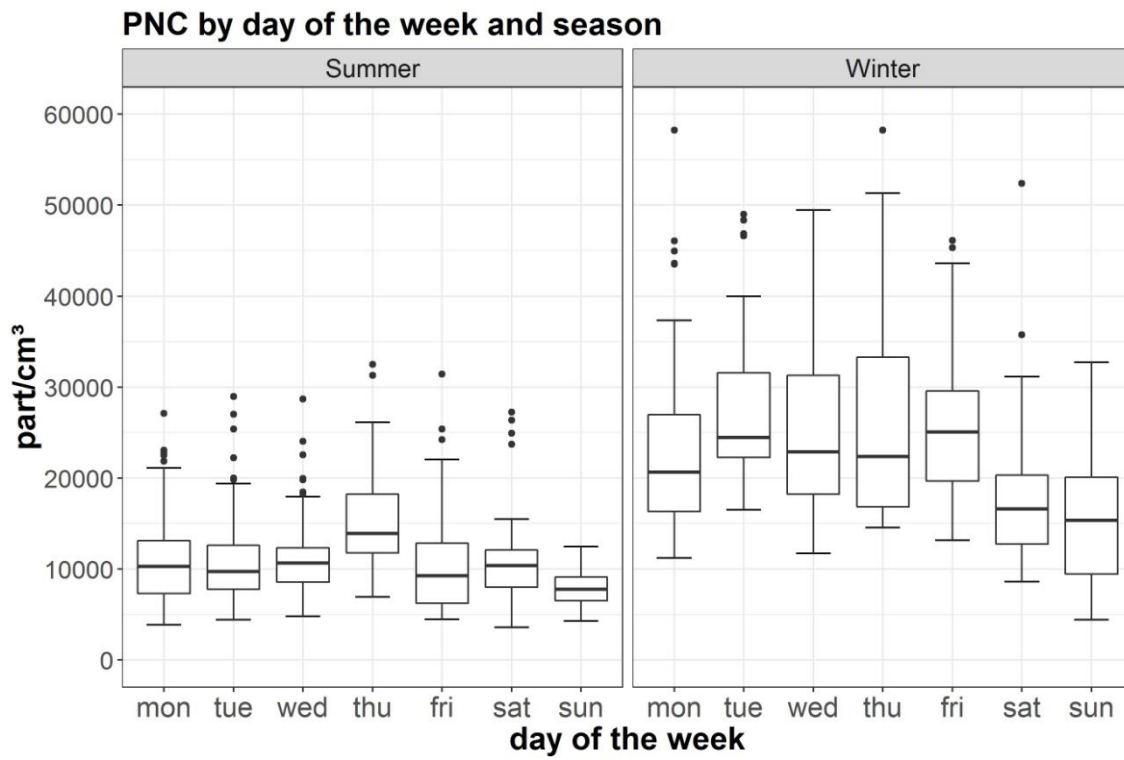
Figure S6. Distribution of average PNC values by day of the week and by season.

Table S3. Explanatory and response variables

| Variable type	Variable name	Explicative notes
Response variable	PNC	Particle Number Concentrations
Temporal variables	Tdry	Temperature (°C)
	Urel	Relative humidity (%)
	Pa	Atmospheric pressure (mbar)
	Rg	Global solar radiation (W/m^2)
	Vscal	Scalar wind speed (m/s)
	Dir	Wind direction (degrees)
	Svel	Standard deviation of the horizontal wind speed module (m/s)
	TKE_Max	Maximum turbulent kinetic energy (m^2/s^2)
	TKE_Min	Minimum turbulent kinetic energy (m^2/s^2)
	RATIO_TKE	Ratio between maximum and minimum turbulent kinetic energy
	DELTA_TKE	Difference between maximum and minimum turbulent kinetic energy (m^2/s^2)
	Hmix$_{min}$	Minimum planetary boundary layer (PBL) height (m)
	Hmix$_{average}$	Average PBL height (m)
	Hmix$_{max}$	Maximum PBL height (m)
Spatial variables	Distinv2	Inverse of the distance squared from the nearest main/busy road
	V_build12	Average volumes of buildings in a buffer with a radius of 12.5 m (m^3)
	V_build25	Average volumes of buildings in a buffer with a radius of 25 m (m^3)
	Canyon12	Ratio between H_build12 (average height of buildings in a buffer with a radius of 12.5 m) and L_build12 (distance among buildings in a buffer with a radius of 12 m)
	Canyon25	Ratio between H_build25 (average height of buildings in a buffer with a radius of 25 m) and L_build25 (distance among buildings in a buffer with a radius of 25 m)
	Imperv12	Impervious surfaces in a buffer with a radius of 12.5 m (m2)
	Imperv25	Impervious surfaces in a buffer with a radius of 25 m (m2)
	Comm_area12	Commercial, industrial and public areas in a buffer with a radius of 12.5 m (m^2)
	Comm_area25	Commercial, industrial and public areas in a buffer with a radius of 12.5 m (m^2)
Spatio-temporal variables	Traff	Total traffic flows in directions AB + BA averaged over 2 hours (vehicles/h)
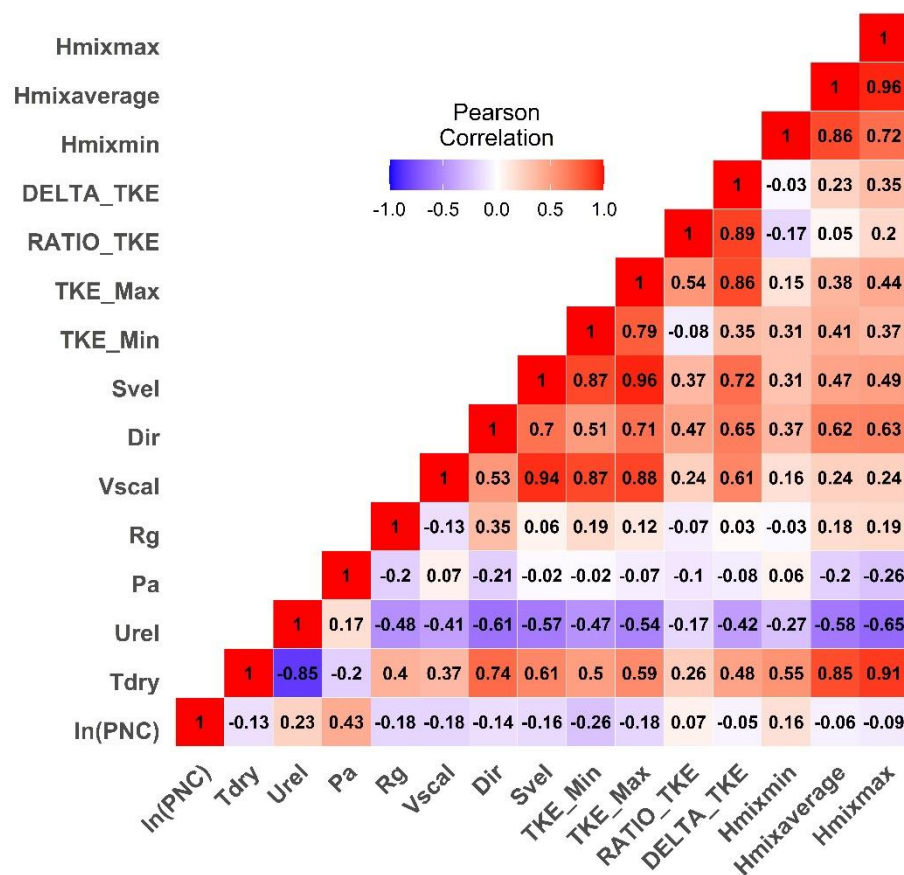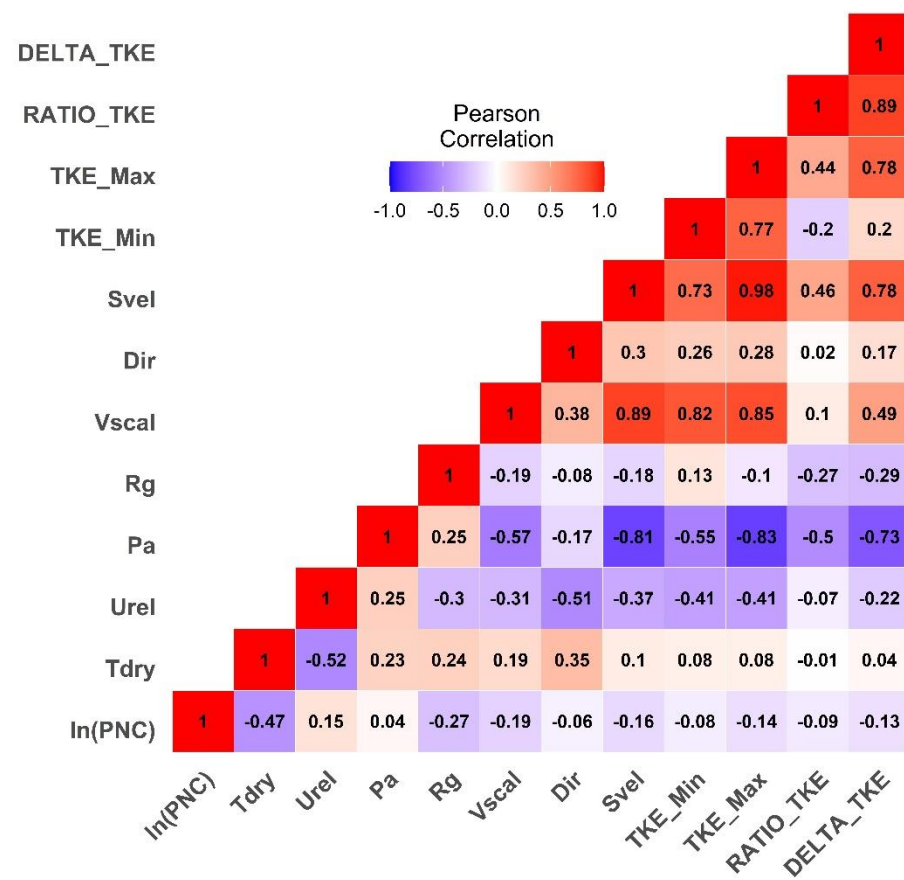
Figure S7. Correlation matrix between the natural logarithm of PNC (ln(PNC)) and the main meteorological and micrometeorological variables, in the two seasons, winter (left), summer (right).
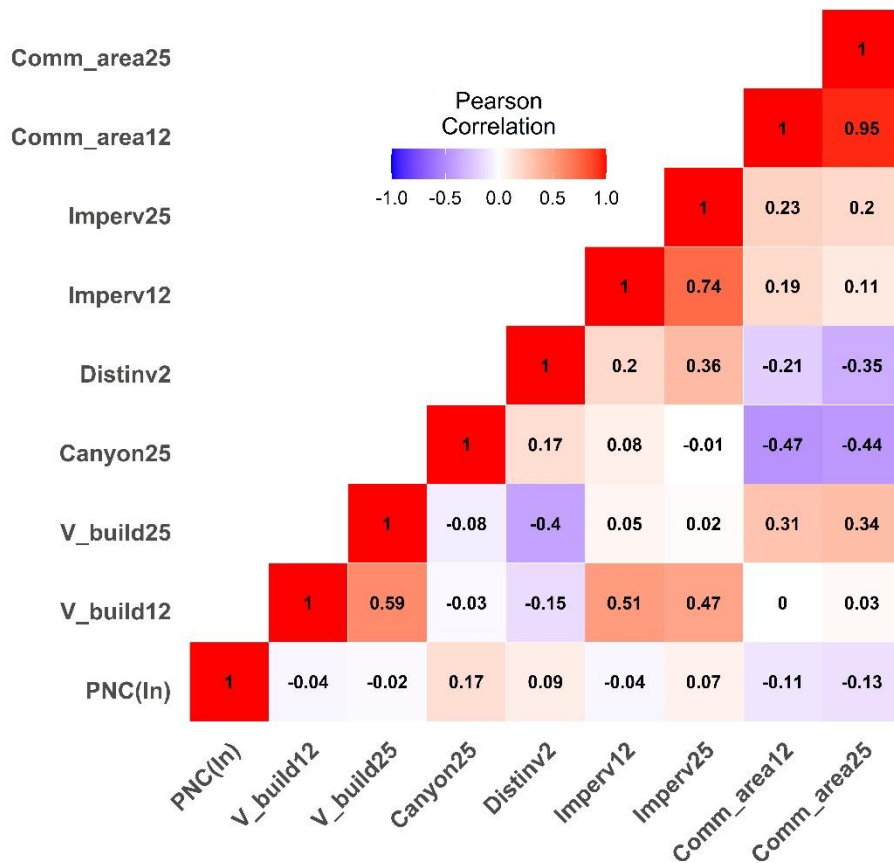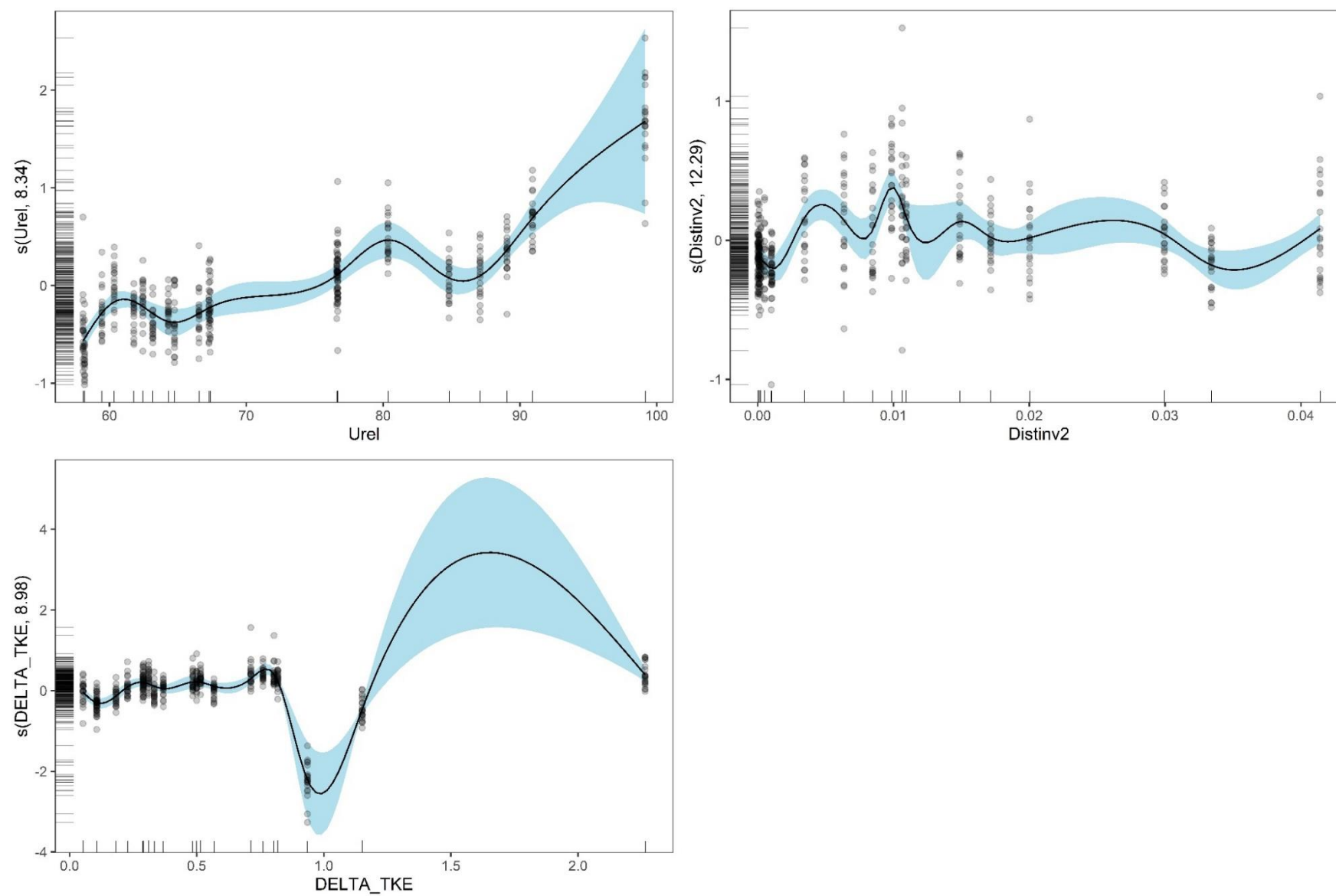
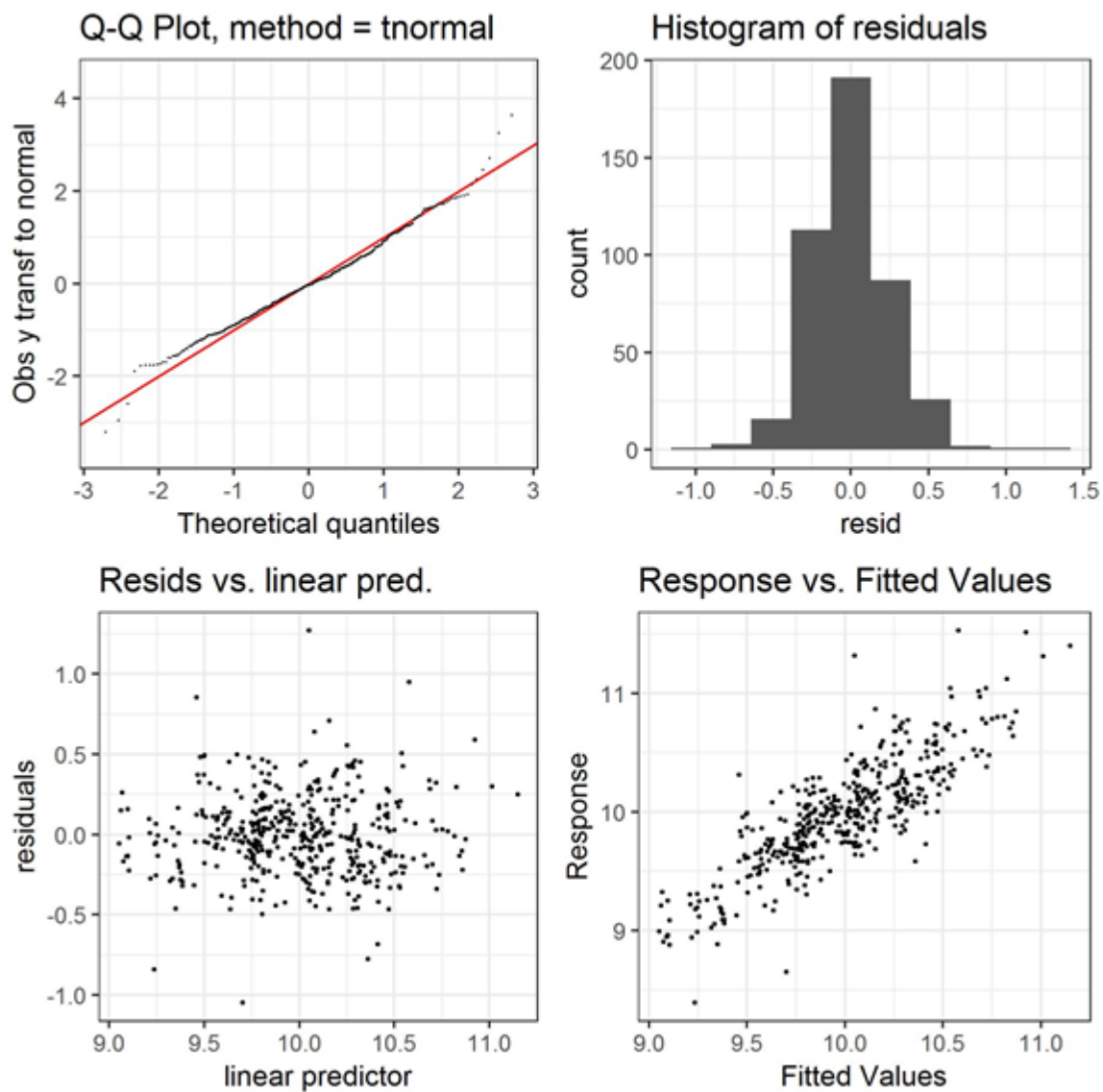**Figure S8.** Correlation matrix between the natural logarithm of PNC (ln(PNC)) and the main spatial variables.
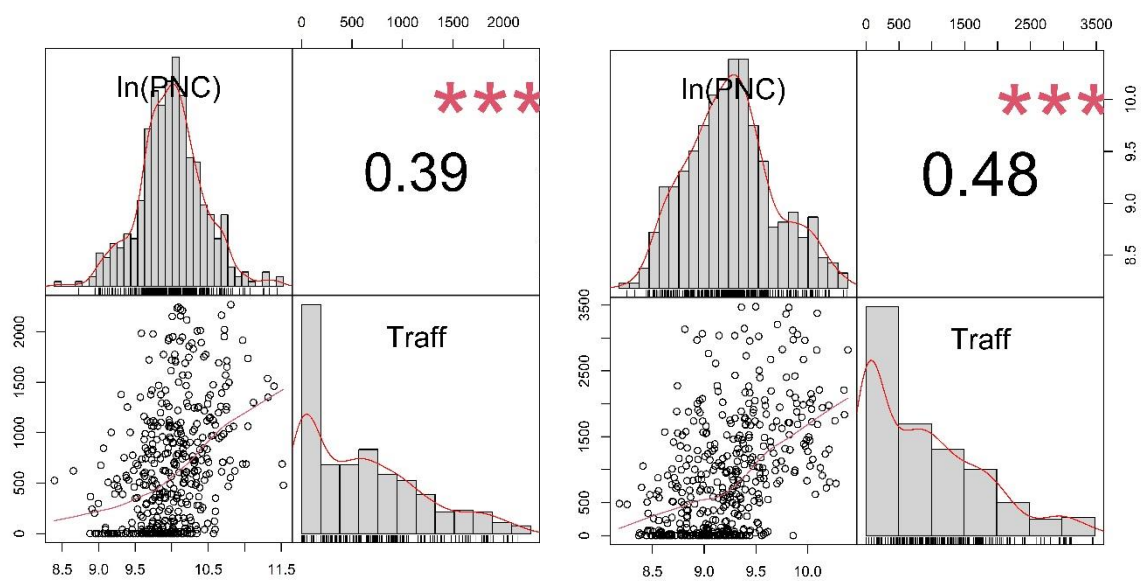
Figure S9. Correlation matrix between the natural logarithm of PNC (ln(PNC)) and the traffic flows, in winter (left) and in summer (right).
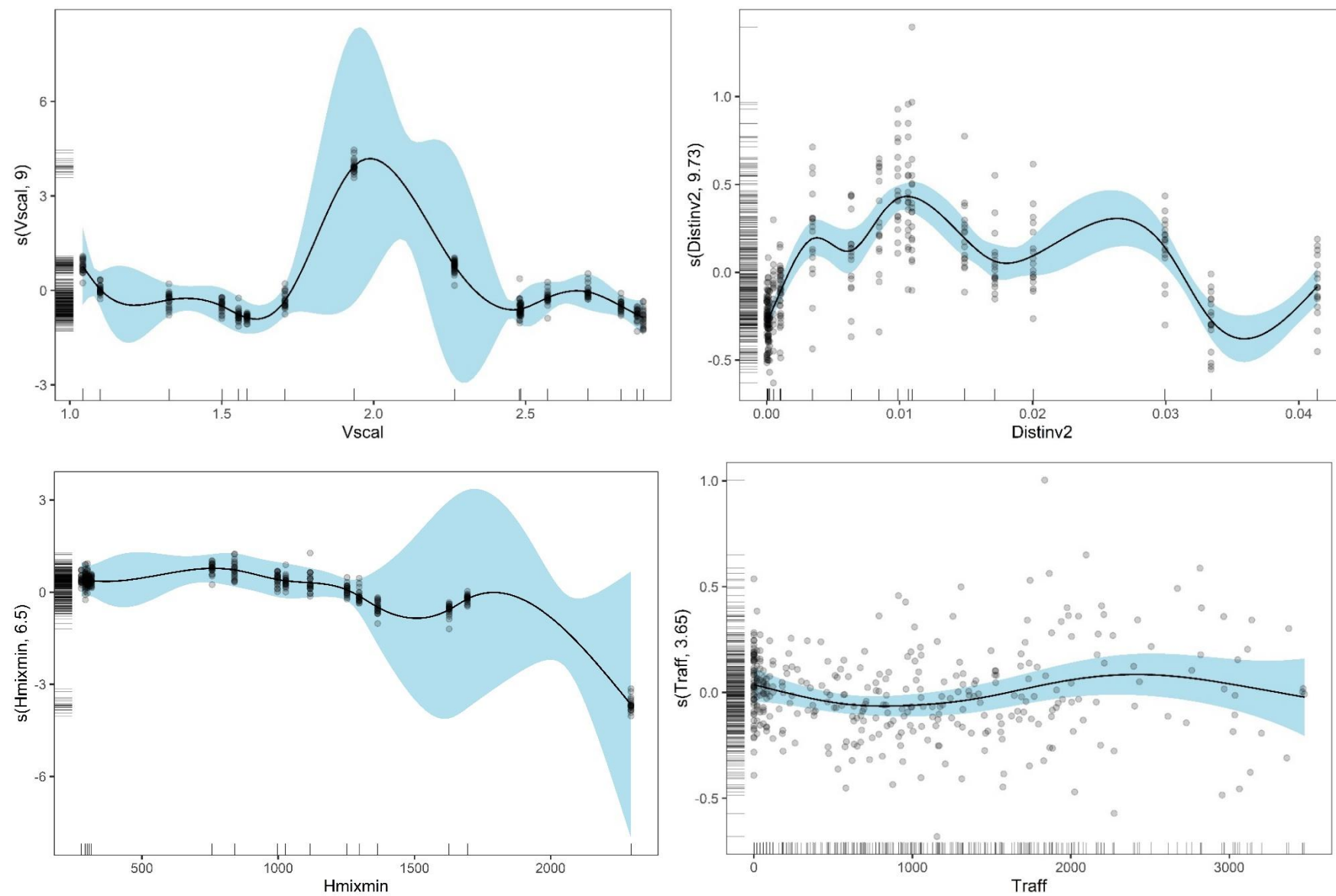
Figure S10. *November 2017 model*: trends of the spline functions for *Urel*, *Distinv2* and *DELTA_TKE* variables.
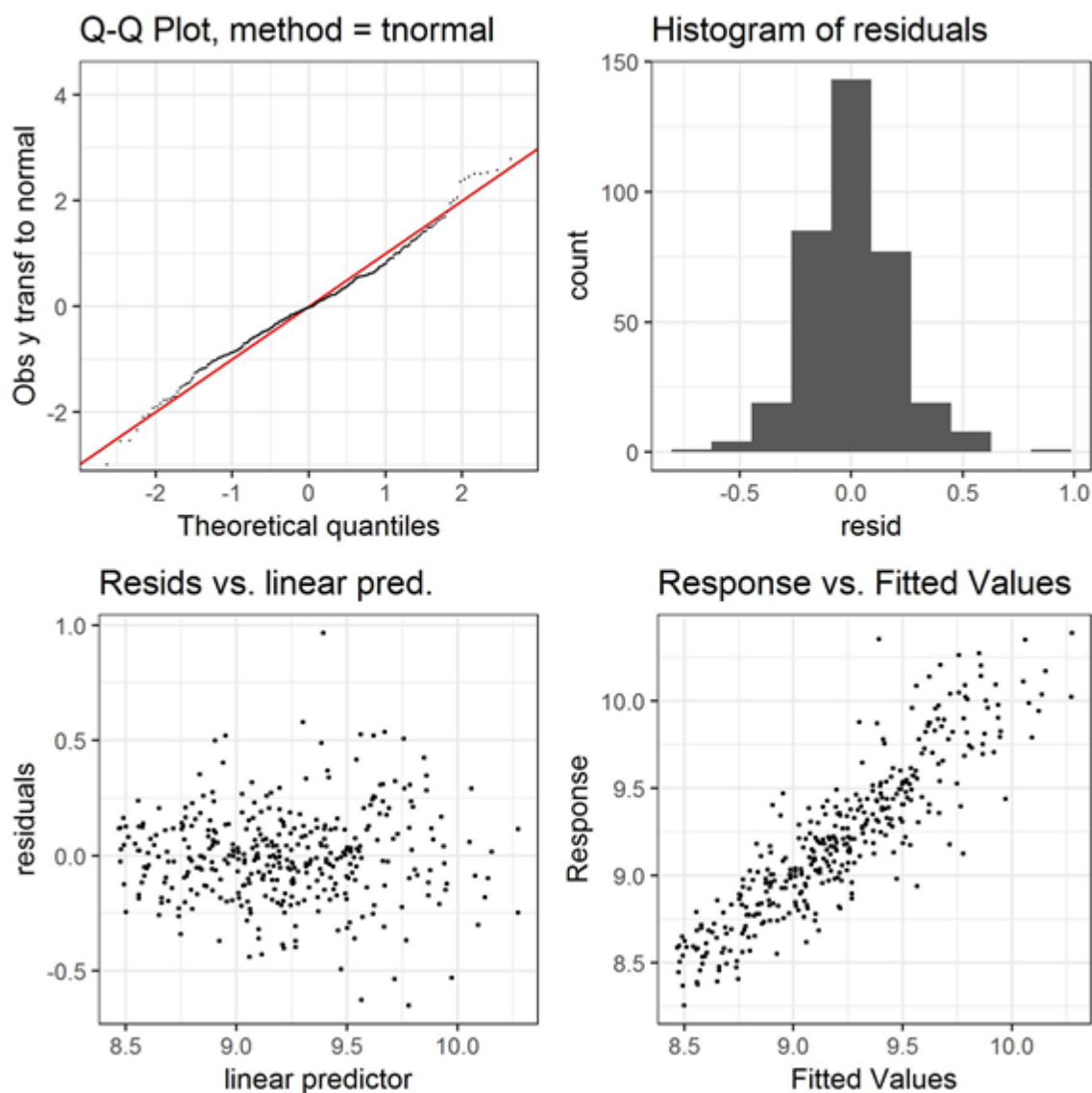
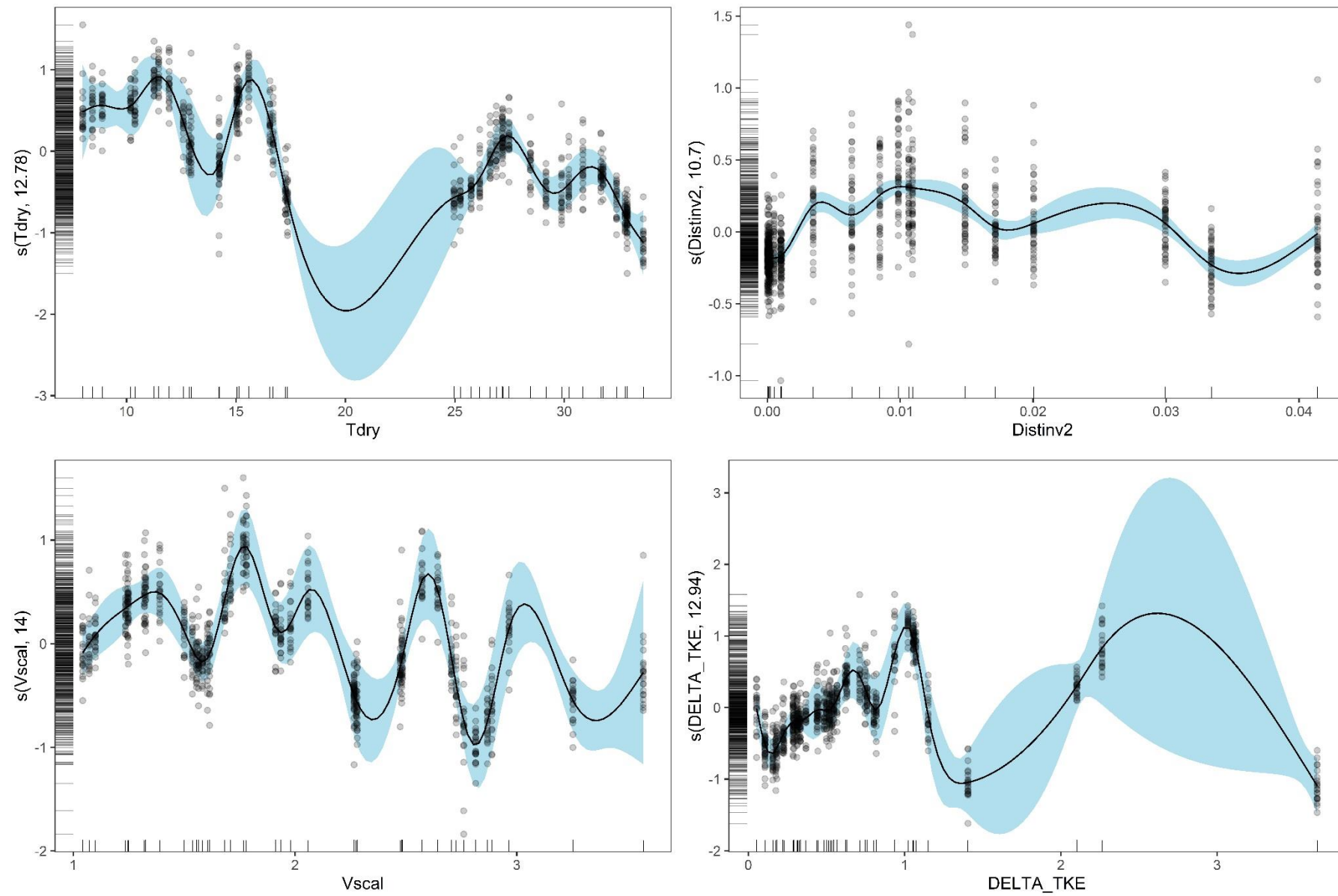**Figure S11**. Checks of the basic assumptions of the *November 2017 model*: residual analysis.

Figure S12. *June 2018 model*: trends of the splines for *Vscal, Distinv2, Hmix$_{min}$* and *Traff* variables.
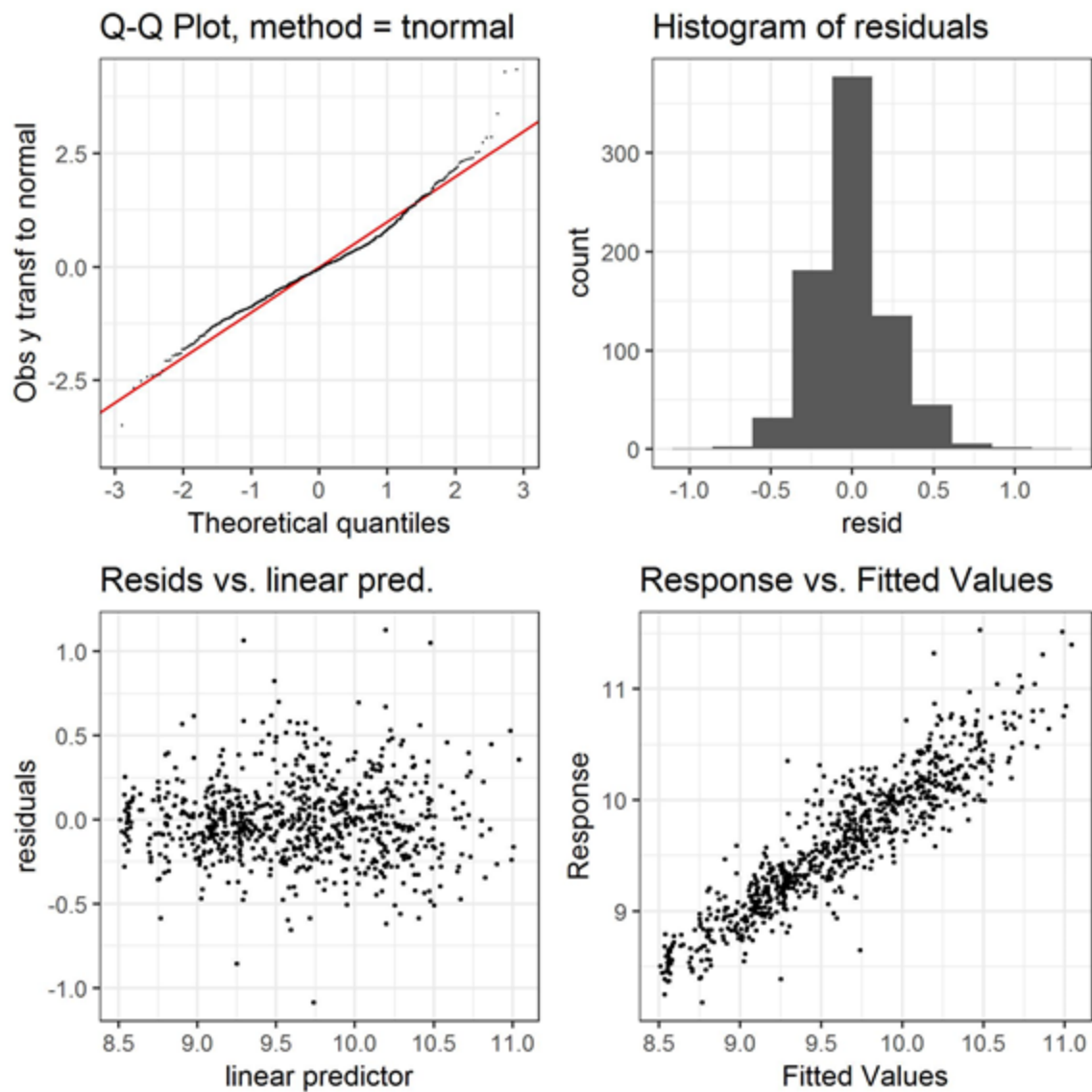
Figure S13. Checks of the basic assumptions of the *June 2018 model*: residual analysis.

Figure S14. *Overall model*: spline trends for T*dry*, *Distinv2*, *Vscal* and *DELTA_TKE*.

Figure S15. Check of the basic assumptions of the *overall model*: residual analysis.