Supplement of Atmos. Chem. Phys., 18, 13639–13654, 2018
https://doi.org/10.5194/acp-18-13639-2018-supplement

Atmospheric Chemistry and Physics
Open Access
EGU

Supplement of

Simulation of the size-composition distribution of atmospheric nanoparticles over Europe

David Patoulias et al.

Correspondence to: Spyros N. Pandis (spyros@chemeng.upatras.gr)

S1. Information about the measurement stations

The Aspvreten (ASP) site (58° 48' 0" N, 17° 23' 0" E) is located 70 km south west of Stockholm. The station is considered to be representative of the regional background in Mid-Sweden and is situated about 2 km from the coast in a rural area surrounded by forest. A DMPS was used to measure the number size distribution of particles in the size range of 10 to 410 nm.

The Birkenes (BIR) station (58° 23' 18" N, 8° 15' 7" E) is located in the boreal forest with mixed conifer and deciduous trees. The nearest local emission source is the city of Kristiansand (65,000 inhabitants), located 25 km south/south-west of the station having minor or negligible influence on the air quality at the site. A DMPS was used to measure the number size distribution of particles in the size range of 10 to 550 nm.

The Cape Corsica (COR) is located in Ersa (42° 58' 10" N, 9° 22' 49" E) near the northern tip of Corsica. The Cape Corsica peninsula is a remote site ensuring that its measurements are not affected by local anthropogenic pollution. An SMPS was used to measure the number size distribution of particles in the size range of 11 to 580 nm.

The Finokalia (FIN) station is located in Crete (35° 19' N, 25° 40' E) the largest Greek island, in the southeast part of Greece. The sampling site is located in a remote coastal area, 50 km away from Heraklion (150,000 inhabitants) and at an elevation of 230 m above the sea surface level. The station is characterized as a remote background site without human activity within a radius of approximately 15 km. An SMPS was used to measure the number size distribution of particles in the size range of 9 to 850 nm.

The Meteorological Observatory Hohenpeissenberg (HOH) (47° 48' 0" N, 11° 1' 0" E) is located on a solitary hill in the rural countryside of southern Bavaria (980 m. above sea surface level), approximately 40 km north of the Alpine mountain range. An SMPS was used to measure the number size distribution of particles in the size range of 10 to 800 nm.

The Hyytiala (HYY) Station for Measuring forest Ecosystem-Atmosphere Relations II (SMEAR II) (61° 51' 0" N, 24° 17' 0" E) is located in Southern Finland. The site represents typical regional background conditions for higher latitudes of Europe, and the air masses are usually influenced by European pollution or clean Arctic air. A DMPS was used to measure the number size distribution of particles in the size range of 3 to 1000 nm.

The Ispra (ISP) station (45° 48' 0" N, 8° 38' 0" E) is located in a semi-rural area by the Eastern shore of a sub-alpine lake in Northern Italy, at a height of 2960 m above sea level. The

station is several tens of kilometers away from large emission sources like intense road traffic or big factories. A DMPS was used to measure the number size distribution of particles in the size range of 10 to 800 nm.

The K-Puszta (KPU) station is situated in the clearing of a mixed coniferous/deciduous forest on the Great Hungarian Plain (46° 58' 0" N, 19° 35' 0" E) about 80 km SE of Budapest. This rural site is free of local anthropogenic pollution. A DMPS was used to measure the number size distribution of particles in the size range of 6 to 800 nm.

The Mace Head (MAC) station (53° 19' 12" N, 9° 52' 48" W) is located on the west coast of Ireland on a hilly area (height around 35 m) surrounded by a number of small lakes and is exposed to the North Atlantic Ocean. It is located 90 km west of Galway (population approximately 60000) which is the nearest major city. An SMPS was used to measure the number size distribution of particles in the size range of 20 to 500 nm.

The Melpitz station (MEL) (51° 31' 48" N, 12° 55' 48" E) is located in eastern Germany near the city of Torgau 50 km northeast of Leipzig. The site is surrounded by flat, agricultural pastures, forests and semi-natural grasslands. A TDMPS was used to measure the number size distribution of particles in the size range of 5 to 800 nm.

The Patras (PAT) station is located 7 km northeast of the city center (38° 18' N, 21° 47' E) in the Institute of Chemical Engineering Science (ICE-HT/FORTH) at an elevation of 85 m above sea surface level. The area is surrounded by olive trees while the coast is approximately 3 km away. A major road is at a distance of 1 km away. An SMPS was used to measure the number size distribution of particles in the size range of 11 to 500 nm.

The Schneefernerhaus (SCH) station (47° 25' N, 10° 58' 46" E) is located near the top of Zugspitze, which is the highest mountain in Germany, at a height of 2960 m above sea level. UFS is a nine-story building, constructed into the southern flank of the Zugspitze. An SMPS was used to measure the number size distribution of particles in the size range of 10 to 510 nm.

The San Pietro Capofiume (SPC) measurement station (44° 39' 0" N, 11° 37' 0" E) is located on a flat, homogeneous terrain of harvested fields, about 40 km north east of Bologna and 30 km south of the Po River. An SMPS was used to measure the number size distribution of particles in the size range of 10 to 800 nm.

The Thessaloniki (THE) station is located at the suburbs of Thessaloniki (40° 37' N, 23° 02' E). Thessaloniki is the second largest city of Greece, with a population of 1.1 million

inhabitants, and is situated in the northern part of the country. The sampling site is located at Eptapyrgio and is considered as a suburban background site. The site is 5 km northeast of the city center, with possible local air pollution sources a major road at a distance of approximately 1 km and an industrial region located at a distance of approximately 12 km. An SMPS was used to measure the number size distribution of particles in the size range of 10 to 470 nm.

The Vavihill (VAV) site is located at Southern Sweden (56° 1' 0" N, 13° 9' 0" E). There are no local pollution sources in the immediate vicinity of the site. The densely populated areas of Malmo, Copenhagen, and Helsingborg southwest to west of the station are 45, 40 and 25 km away, respectively. An DMPS was used to measure the number size distribution of particles in the size range of 3 to 860 nm.

The Waldhof site (WAL) (52° 48' 8" N, 10° 45' 34" E) is surrounded by forest in all directions. Measurements here are considered as representative of the background in the North German low lands. An SMPS was used to measure the number size distribution of particles in the size range of 10 to 800 nm**.**

Table S1: Vertical height for each simulated layer.

Layer number	Bottom height (m)	Top height (m)
1	0	60
2	60	150
3	150	260
4	260	400
5	400	590
6	590	820
7	820	1100
8	1100	1670
9	1670	2300
10	2300	2950
11	2950	3650
12	3650	4900
13	4900	6200
14	6200	7500

Table S2: Boundary and initial conditions of the simulation.

	Boundary conditions (all sides)	Initial conditions
SO_2 (ppb)	0.01	0.01
O_3 (ppb)	30	30
HNO_3 (ppb)	0.01	0.01
HCHO (ppb)	0.05	0.05
NH_3 (ppb)	0.01	0.01
CO (ppb)	50	50
Dust ($\mu g\ m^{-3}$)	0.001	0.001
Sulfate ($\mu g\ m^{-3}$)	0.001	0.001
SOA ($\mu g\ m^{-3}$)	0.001	0.001
Number conc. (cm^{-3})	50	50

Table S3: Details of atmospheric measurement sites in Europe for AMS PM_1 composition.

Station	Name	Country	Longitude	Latitude	Altitude (m)
FIN	Finokalia	Greece	35.3167	25.6667	250
PAT	Patra	Greece	38.2980	21.8092	85
BOL	Bologna	Italy	44.4833	11.3333	0
SPC	San Pietro Capofiume	Italy	44.6553	11.6236	11

Table S4: Predicted (PMCAMx-UF) and observed (AMS) average PM_1 concentrations of organics, sulfate, ammonium and nitrate in different locations.

Station	Sulfate		Ammonium		Nitrate		Organics	
	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)
FIN	3.95	3.4	1.55	1.1	0.9	0.15	1.07	2.16
PAT	2.38	3.36	1.06	0.95	0.53	0.1	1.05	3.81
BOL	1.89	2.51	0.94	0.9	0.78	0.61	2.32	5.77
SPC	2.03	1.81	0.98	0.88	0.87	1.2	2.04	3.98

Table S5: Details of atmospheric sites in Europe for $PM_{2.5}$ composition measurements from filters.

Station	Name	Country	Longitude	Latitude	Altitude (m)
CH02	Payerne	Switzerland	46.8131	6.9447	489
DE44	Melpitz	Germany	51.5301	12.9339	86
ES1778	Montseny	Spain	41.7667	2.3500	700
FI09	Utö	Finland	59.7792	21.3772	7
FI17	Virolahti II	Finland	60.5267	27.6861	4
FI36	Pallas (Matorova)	Finland	68.0000	24.2372	340
GB36	Harwell	United Kingdom	51.5731	-1.3167	137
GB48	Auchencorth Moss	United Kingdom	55.7922	-3.2429	260
IT04	Ispra	Italy	45.8000	8.6333	209
NO56	Hurdal	Norway	60.3724	11.0781	300
PL05	Diabla Gora	Poland	54.1500	22.0667	157
SI08	Iskrba	Slovenia	45.5667	14.8667	520

Table S6: Predicted (PMCAMx-UF) and observed (filters) average $PM_{2.5}$ sulfate, ammonium nitrate, and organic aerosol concentrations

Station	Sulfate		Nitrate		Ammonium		Organics	
	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Observed ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)	Predicted ($\mu g\ m^{-3}$)
DE44	1.92	2.17	2.17	0.47	1.48	0.94	2.23	1.96
FI09	1.63	1.11	3.44	0.38	0.87	0.34		
FI17	1.15	0.68	1.89	0.09	0.58	0.15		
FI36	0.17	0.43	0.33	0.01	0.07	0.08		
GB36	2.10	1.45	2.24	0.79	1.38	0.39		
GB48	1.89	0.94	2.31	0.53	1.12	0.50		
PL05	1.94	1.66	1.45	0.16	1.27	0.39	2.02	2.83
SI08	2.80	3.22	1.61	0.10	1.66	1.26	2.56	4.65
IT04							3.53	4.00
CH02							0.91	1.97
ES78							3.11	3.52
NO56							0.91	1.20

Table S7: Predicted impact (%) of boundary conditions and emissions change in particle number concentrations in Europe during 20 days in June 2012.

Change		$N_{1\text{-}10}$	N_{10}	$N_{10\text{-}50}$	$N_{50\text{-}100}$	N_{100}
Boundary conditions	Aerosol (-50%)	-0.7	-0.1	-0.1	-0.2	-0.1
	Gas (-50%)	-2.3	-5.8	-4.1	-0.7	-0.1
	SO_2 (-50%)	3.1	-2.6	-2	-0.4	-0.1
	SO_2=0	-2.3	-11	-7.6	-1.2	-1.2
Emissions	Aerosol (-50%)	22.1	11	3.4	-7.9	-12.1
	Gas (-50%)	-15.5	-13.1	-17.2	-16.7	-33.4
	SO_2 (-50%)	-14.8	-11.4	-14.7	-14.5	-30
	SO_2=0	-68.2	-52.6	-51.9	-40.7	-70.5

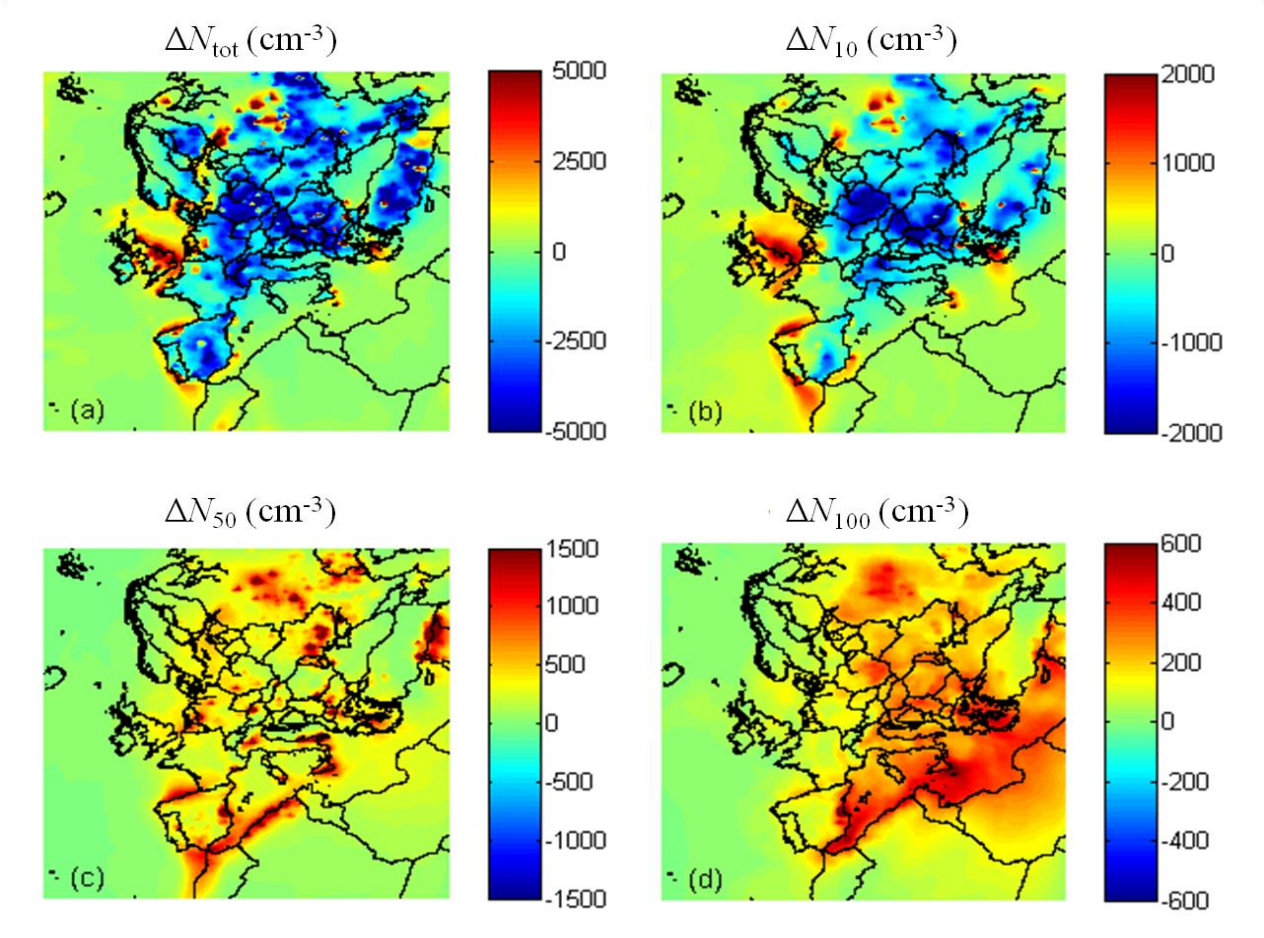

Figure S1: Ground level average increase of number concentration (cm^{-3}) due to the condensation of organics species predicted during 5 June – 8 July 2012 for: (a) all particles (ΔN_{tot}); particles above (b) 10 nm (ΔN_{10}); (c) 50 nm (ΔN_{50}); and (d) 100 nm (ΔN_{100}). Different scales are used.

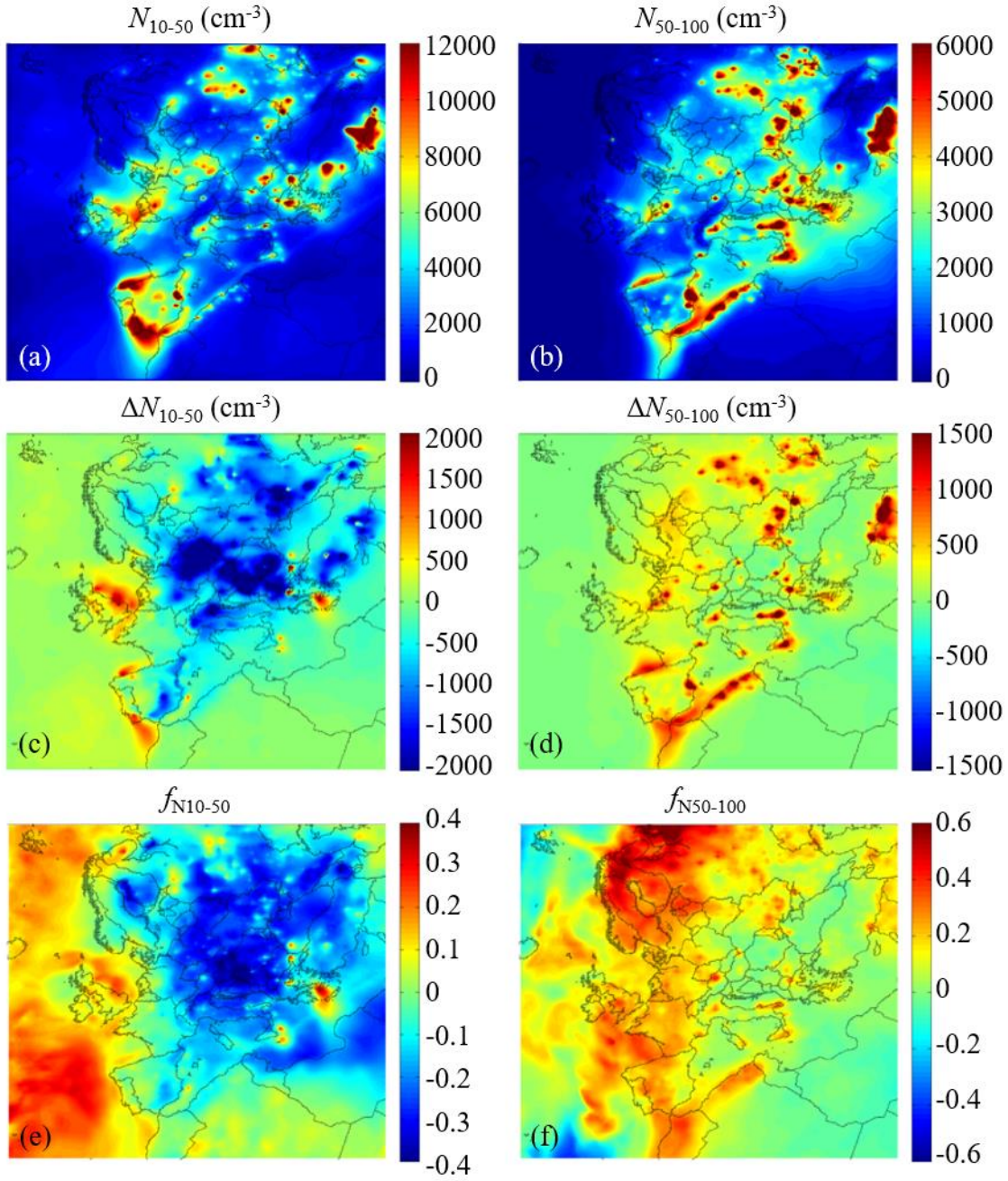

Figure S2: Ground level average number concentrations (cm^{-3}) (a-b), increase of number concentration (cm^{-3}) (c-d) and fractional increase (f_{Nx}) of number concentration (e-d) due to the condensation of organics species predicted during 5 June – 8 July 2012 for: (a-c-e) particles between 10 nm and 50 nm ($N_{10\text{-}50}$); (b-d-f) particles between 50 nm and 100 nm ($N_{50\text{-}100}$). Different scales are used.

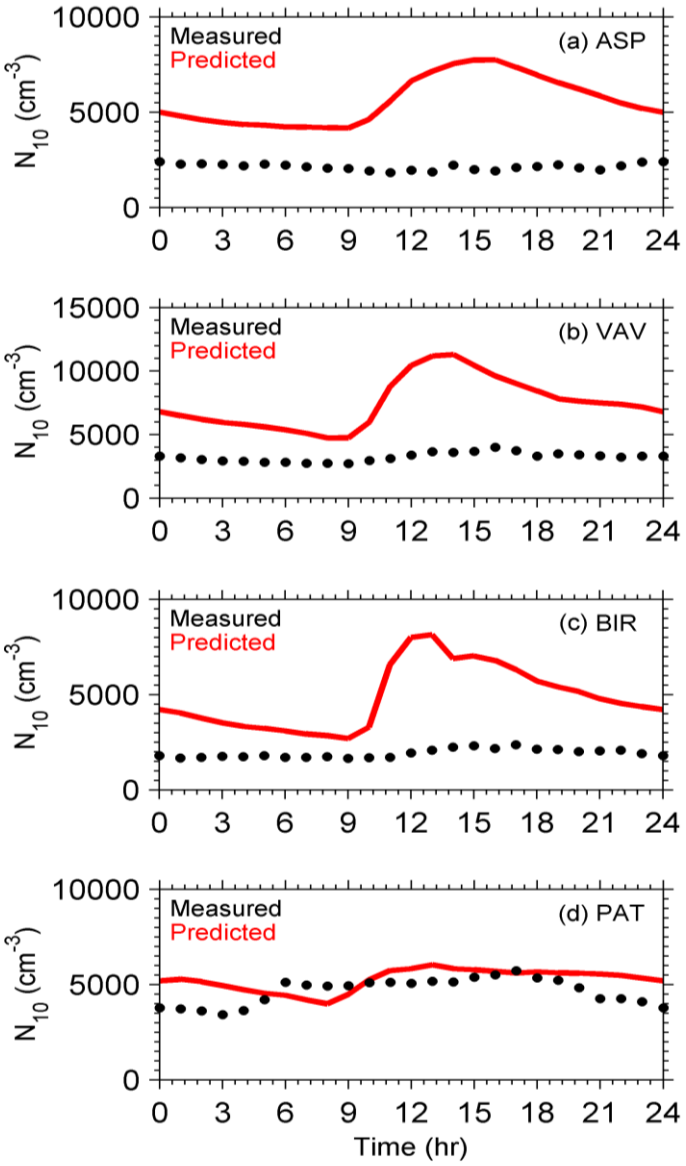

Figure S3: Average diurnal profiles of particle number concentrations (cm^{-3}) above 10 nm in: (a) Aspvreten (Sweden); (b) Vavihill (Sweden); (c) Birkenes (Norway) and (d) Patras (Greece) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

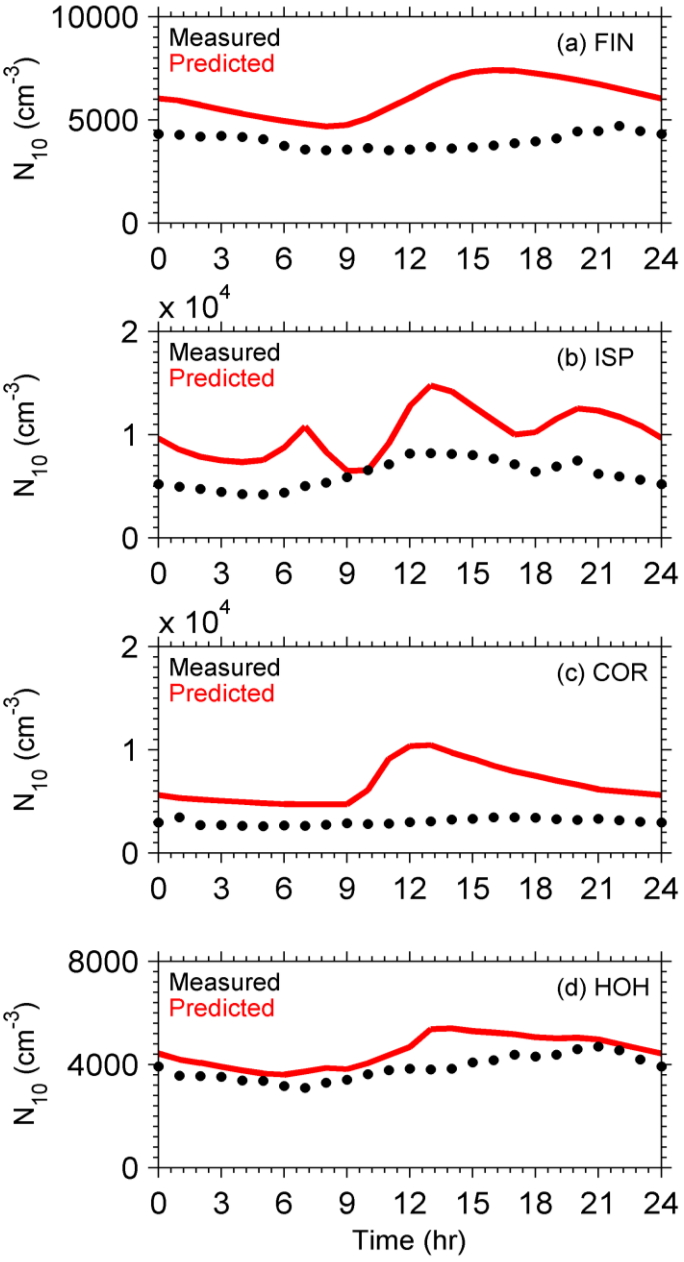

Figure S4: Average diurnal profiles of particle number concentrations (cm^{-3}) above 10 nm in: (a) Finokalia (Greece); (b) Ispra (Italy); (c) Corsica (France) and (d) Hohenpeissenberg (Germany) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

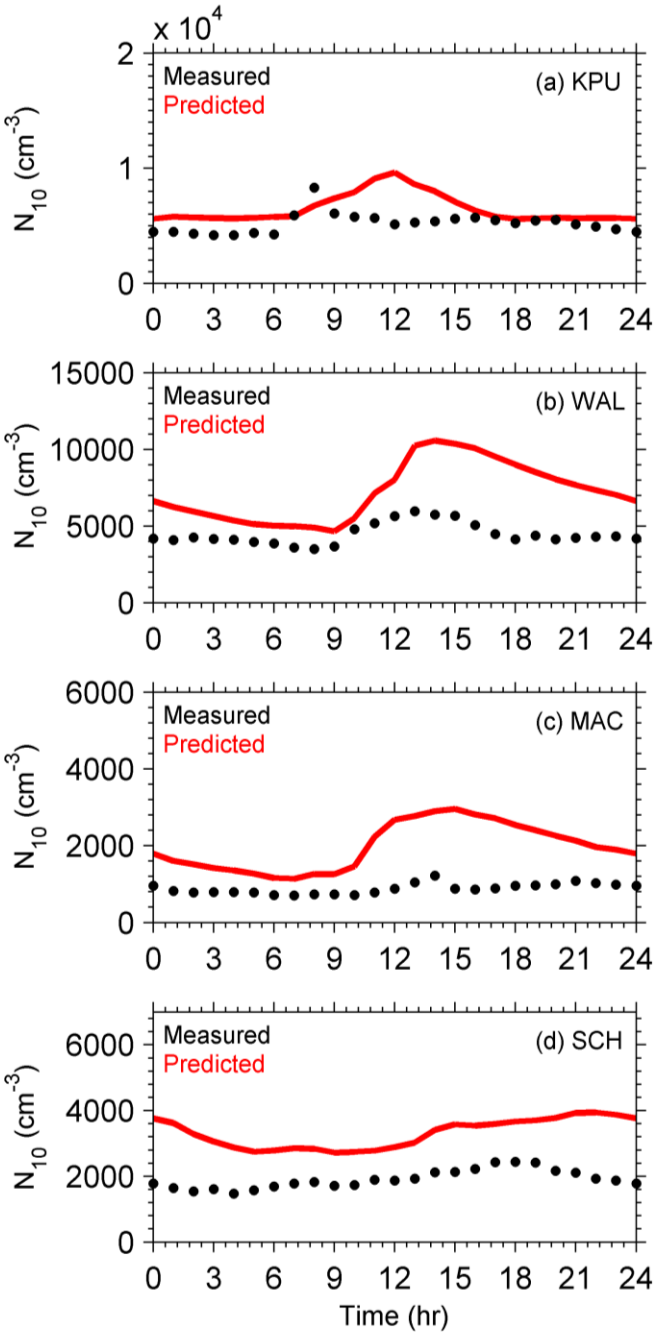

Figure S5: Average diurnal profiles of particle number concentrations (cm^{-3}) above 10 nm in: (a) K-Puszta (Hungary); (b) Waldhof (Germany); (c) Mace Head (Ireland) and (d) Schneefernerhaus (Germany) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

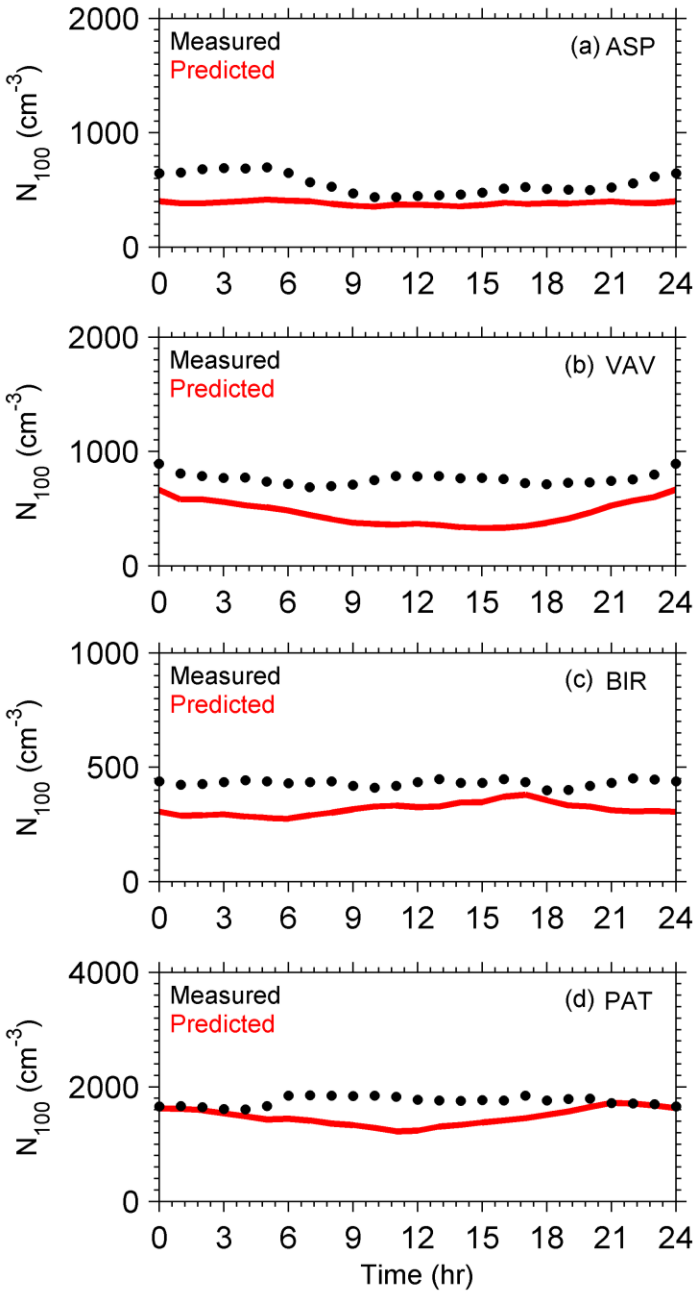

Figure S6: Average diurnal profiles of particle number concentrations (cm^{-3}) above 100 nm in (a) Aspvreten (Sweden); (b) Vavihill (Sweden); (c) (a) Birkenes (Norway) and (d) Patras (Greece) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

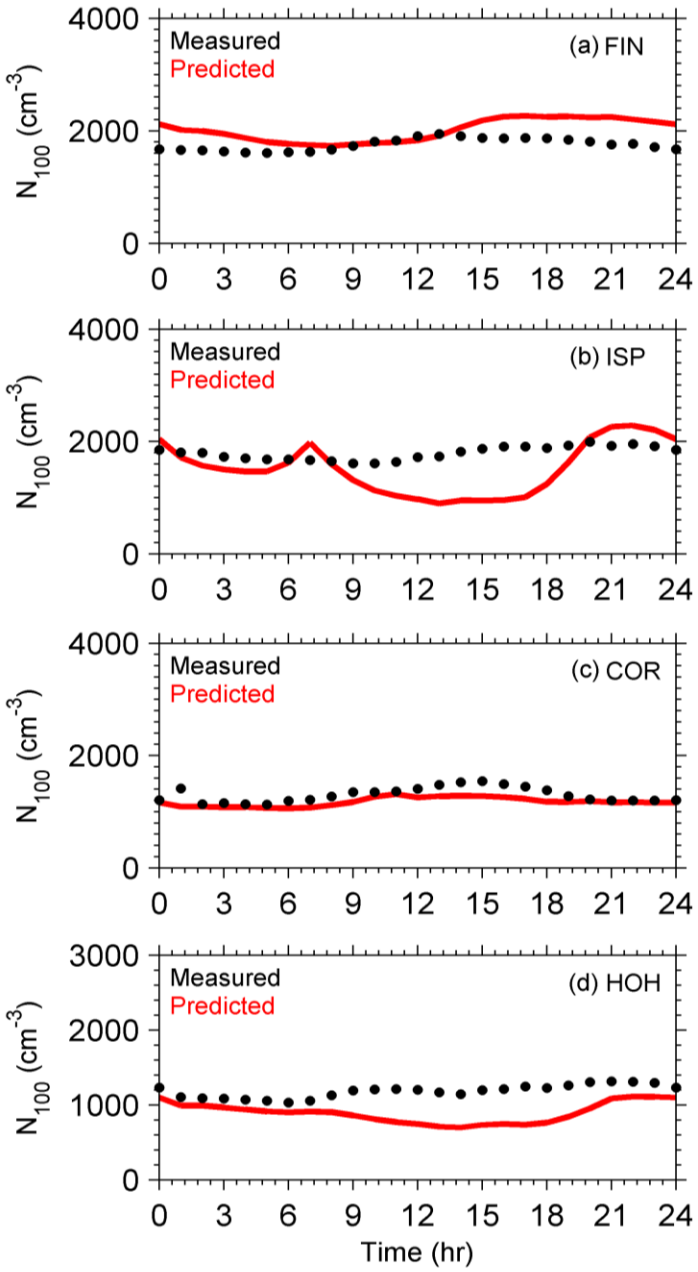

Figure S7: Average diurnal profiles of particle number concentrations (cm^{-3}) above 100 nm in: (a) Finokalia (Greece); (b) Ispra (Italy); (c) Corsica (France) and (d) Hohenpeissenberg (Germany) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

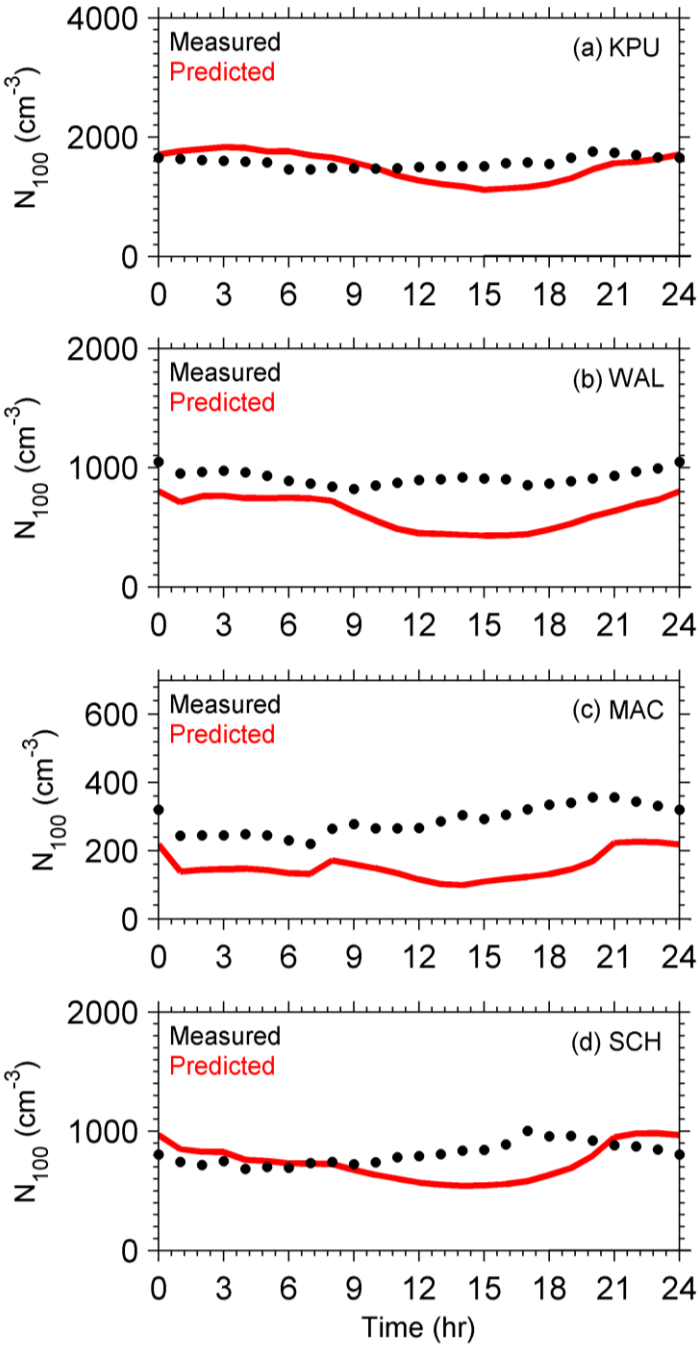

Figure S8: Average diurnal profiles of particle number concentrations (cm^{-3}) above 100 nm in: (a) K-Puszta (Hungary); (b) Waldhof (Germany); (c) Mace Head (Ireland) and (d) Schneefernerhaus (Germany) during 5 June – 8 July 2012. Red lines correspond to predictions and black symbols to observations.

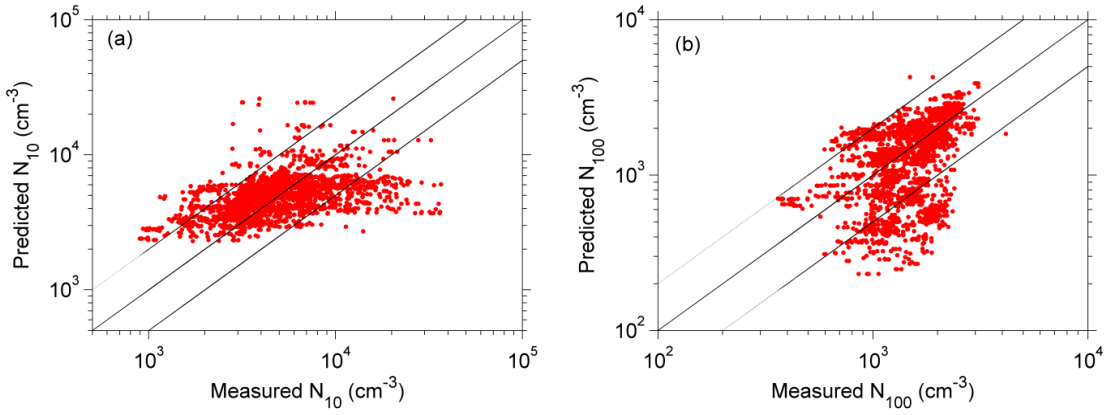

Figure S9: Comparison of predicted (with organics) versus observed (Zeppelin) particle number concentrations (in cm^{-3}) for (a) N_{10} and (b) N_{100} of 25 flights over the Po Valley during the PEGASOS campaign. Also shown the 1:1, 2:1 and 1:2 lines.

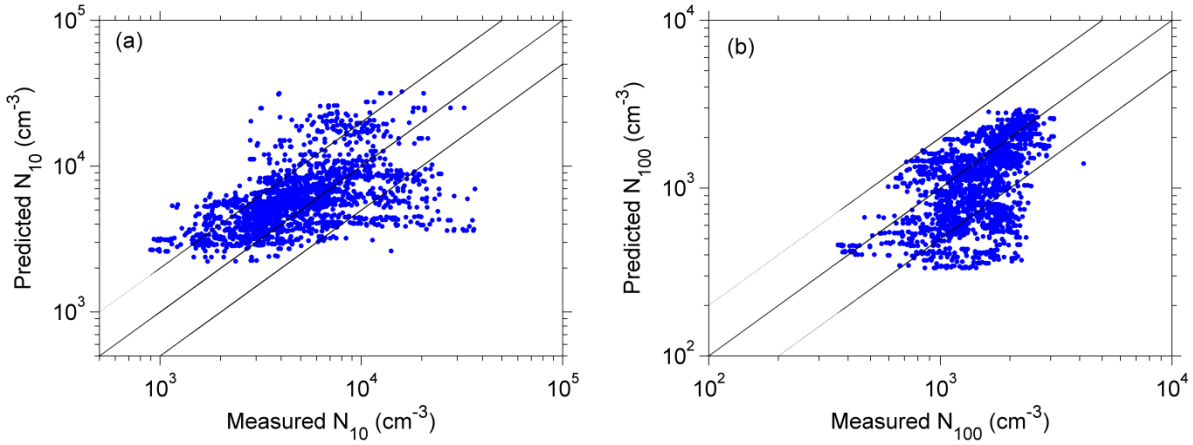

Figure S10: Comparison of predicted without organics versus observed of Zeppelin particle number concentrations (cm−3) for (a) N_{10} and (b) N_{100} of 25 flights over the Po Valley during the PEGASOS campaign. Also shown the 1:1, 2:1 and 1:2 lines.

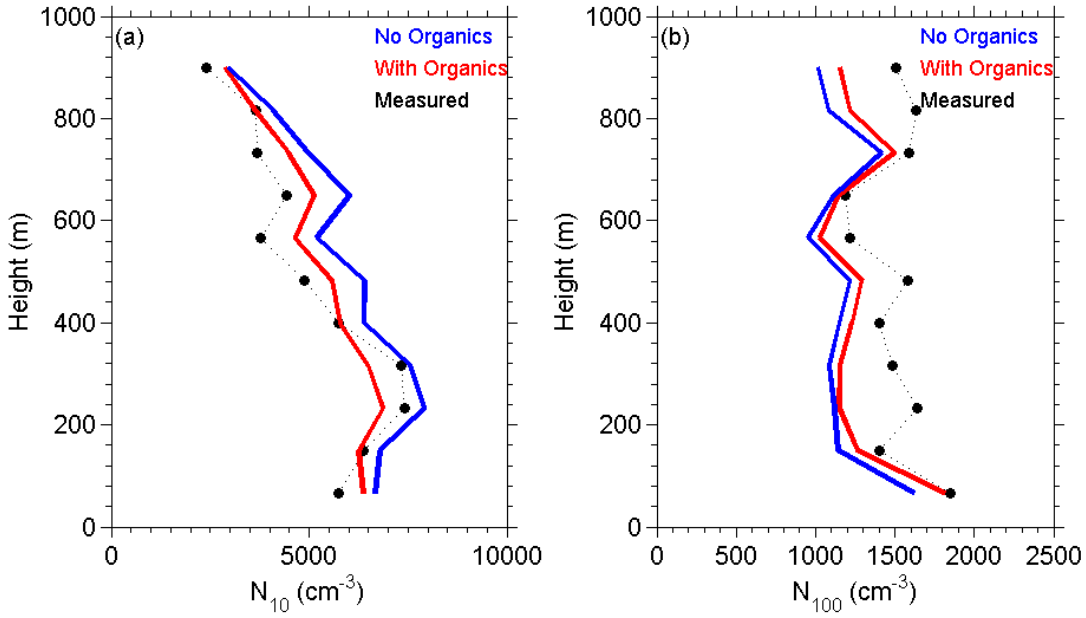

Figure S11: Comparison of predicted PMCAMx-UF (red line: with organics; blue line: without organics) vs. observed (black dots) vertical profiles of averaged particle number concentrations for (a) N_{10} and (b) N_{100} of 25 flights over the Po Valley during the PEGASOS campaign.