

Interactive comment on “Spatio-temporal variability and principal components of the particle number size distribution in an urban atmosphere” by F. Costabile et al.

F. Costabile et al.

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We appreciate the referees' valuable comments, especially for what concerns the suggestion to refer to previous studies in a more proper way. To this aim we have prepared the following table.

On the other hand, the referee mentions that Figure 3 and 5 are hard to follow. In fact, we have thought a lot about how to change the display of this information. As for Figure 3, there would be no alternative than omitting some of the case studies. Nevertheless, we find the 6 case studies distinct enough from each other; they reveal the richness of the data set, and represent information other researchers can immediately relate to. Moreover, despite the amount of graphics shown, we find that each case study itself

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is rather clearly presented straightforward to follow. As for Figure 5, we also see no alternative than omitting some of the statistical runs. Again, however, the subfigures seem distinct enough from each other; they span and illustrate the whole range of variations across time/space that can be gathered from the data available to us. Again, each subfigure is rather straightforward to follow. In conclusion we keep to prefer Figures 3 and 5 as they are, since all the conclusions written throughout the text and in the conclusions section are actually referring to these Figures. It is probably worth to note that in the final layout the subfigures will appear nicely and pairwise on one A4 page, and will therefore appeal to the reader more than in the present one-page ACPD discussion layout.

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Particle mode ⁽¹⁾	Diameter (nm)	Description	Method ⁽²⁾	Observation site ⁽³⁾	Study
NM_I	3–7	Emission from point sources	UCP–CPC	RS	Alam et al., 2003
	5	Non volatile core after thermodenuder	Max of the PNSD	RS	Rönkkö et al., 2007
	3–7.5	Nucleation1: OC 90%, sulfuric acid 5%, ammonium sulphate 5%	Max of the PNSD	RS	Pohjola et al. 2007
	<5	Fresh roadside NM	Modal size range by multisite PCA	RS	This work
	3–10	Collision-controlled nucleation	Increase of measured and theoretical PNSD for 3–10 nm aerosols	UB	McMurry et al., 2000
	3–8	Recently formed particles	Particles in the 3–8 nm size-range	UB	Williams et al., 2000
	3–9	Fresh nucleation mode	Log–normal fit	RB	Birmili et al., 2001
	3–10	Photochemically driven collision-controlled nucleation	Mode of PNSD	UB	Woo et al., 2001
NM_II	3–7	Homogeneous nucleation within the atmosphere	UCPC–CPC	UB	Alam et al., 2003
	3–7.5	Nucleation1: OC 68%, EC 19%, sulfuric acid 7%, ammonium sulphate 6%	Max of the PNSD	UB	Pohjola et al., 2007
	<5	Fresh urban background NM	Modal size range by multi-site PCA	UB, RB	This work
	9, 13	Nuclei mode: background and local sources, urban and freeway	DGN	RS, UB	Whitby, 1978
	8–13	Nuclei mode from diesel engine	Mode of PNSD	RS	Kittelson et al. 1998
	6–25	Freeway emissions	Mode of PNSD	RS	Zhu et al. 2002
	<10	Fresh diesel aerosol with nucleation mode	Mobile lab: mode of PNSD	RS	Bukowiecki et al., 2002
	7–20	Downwind the highway	Modal shapes of PNSD	RS	Zhang et al., 2004
	9–12, <15	Nucleation mode	Lognormal mode, GMD	RS	Hussein et al., 2005
NM_III	6–11	Nuclei mode of diesel exhaust aerosol	Mode of on road PNSD	RS	Kittelson et al. 2006
	~10	Emissions from light- or heavy- duty vehicles	Mode of PNSD	RS	Yao et al. 2006
	9	Photochemical nucleation	Modal diameter by fitting PC to log-normal PNSD	RS	Chan and Mozurkewich, 2007a,b
	7.5–43	Nucleation2 : OC 68 %, EC 19%, sulfuric acid 7%, ammonium sulphate 6%	Max of the PNSD	RS	Pohjola et al., 2007
	4–20	Urban roadside NM	Modal size range by multi-site PCA	RS	This work

⁽¹⁾ NM=Nucleation mode, AM= Aitken mode, MM= Accumulation mode. ⁽²⁾ PNSD= particle number size distribution, PC= principal component, PCA= principal component analysis, DGN=geometric number mean size, GMD= geometric mean diameter. ⁽³⁾ RS= roadside, RB=regional background, UB=urban background. ⁽⁴⁾ At UB but believed to be of regional origin.

Table 1. Continued on next page

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Particle mode ⁽¹⁾	Diameter (nm)	Description	Method ⁽²⁾	Observation site ⁽³⁾	Study
NM_IV	10	Transient nuclei mode	Mode of dN/dLogDp	UB	Willeke and Whitby, 1975 Whitby, 1978
	14	Nuclei mode: urban average, background and aged urban plume	DGN	UB	
	10–20	Urban ambient air with nucleation mode	Mobile lab: mode of PNSD	UB	Bukowiecki et al., 2002 Wehner and Wiedensohler, 2003
	10–18	Nucleation mode	Lognormal modes	UB	
	8.9	Fresh nucleation mode	GMD of the mode fitting parameters	UB	Hussein et al., 2004 Stanier et al., 2004
	3–10	nuclei mode particle - marker for nucleation	Increase in the number of 3–10 nm particles	UB	
	4.8–22.8	Nucleation mode particles in a highly polluted megacity	Lognormal GMD	UB	Mönkkönen et al., 2005 Stolzenburg et al., 2005 Hussein et al., 2005
	9.8	Nucleation mode	Lognormal mode, GMD	UB	
	9,12	Photochemical nucleation	Modal diameter by fitting PC to log-normal PNSD	UB	
	NM_V	3–15	Urban background NM	Modal size range by multi-site PCA	UB
15		Nuclei mode: average background	DGN	UB	Whitby, 1978
10–17		Nucleation mode	GMD	RB	Mäkelä et al., 2000
3–11		Freshly formed particles	PNSD during NPF events	RB	Birmili et al., 2003
10		Nucleation mode	Mode of PNSD	RB	Ketzel et al., 2004
14.3		Nucleation mode	Lognormal parameter of the mean PNSD	UB	Hussein et al., 2005
3–20		Freshly formed particles	Mode of PNSD	RB	Laaksonen et al., 2005
9,12		Photochemical nucleation	Modal diameter by fitting PC to log-normal PNSD	RB	Chan and Mozurkewich, 2007a,b
5–20		Rural background NM	Modal size range by multi-site PCA	RB	This work

⁽¹⁾ NM=Nucleation mode, AkM= Aitken mode, AcM= Accumulation mode. ⁽²⁾ PNSD= particle number size distribution, PC= principal component, PCA= principal component analysis, DGN=geometric number mean size, GMD= geometric mean diameter. ⁽³⁾ RS= roadside, RB=regional background, UB=urban background. ⁽⁴⁾ At UB but believed to be of regional origin.

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Particle mode ⁽¹⁾	Diameter (nm)	Description	Method ⁽²⁾	Observation site ⁽³⁾	Study
NM_VI	25	Traffic influenced aerosol	Mode of volume size distribution	UB	Hidy, 1975
	20–40	Gasoline exhausts and Aging of well-mixed urban aerosol	Mode of PNSD	RS, UB	Morawska et al., 1999
	9–30	Aged nucleation mode	Lognormal fitting parameter	RB	Birmili, 2001
	10–35	Unknown, but possibly fossil fuel source	Mode of PNSD	UB	Woo et al. 2001
	~20	Nano-size range particles in connection with diesel vehicles	Peak of average PNSD	RS	Wählin et al. 2001
	25–50	Decay of freeway emissions	Mode of PNSD	RS,UB	Zhu et al., 2002
	14–26	Very small particles at high vehicle speeds	Mode of PNSD	RS	Kittelson et al., 2004
	17.7	Nucleation mode	GMD of the mode fitting parameters	UB	Hussein et al., 2004
	15–20	Mode of the traffic-related PNSD	Particle number count	UB	Stanier et al., 2004
	10–50	Fresh emissions from the traffic	PC mode by PCA	RS	Janhäll et al. 2004
	20–30	Nucleation mode	Mode of PNSD	UB,RB	Ketzel et al., 2004
	20–50	Downwind the highway	Modal shapes of PNSD	RS	Zhang et al., 2004
	22	Nucleation mode particles from exhaust gas cooling	Max concentration measured	RS	Imhof et al., 2005
	~20	Emissions from heavy-duty diesel vehicles	Mode of PNSD	RS	Yao et al., 2006
	15–19	Photochemical nucleation	Modal diameter by PC to log-normal PNSD fitting	RB, UB	Chan and Mozurkewich, 2007a,b
	27–30	–	Max of moving average correlation coefficient	UB	Gramotnev et al., 2007
	7.5–43	Nucleation2: OC 68%, EC 19%, sulfuric acid 7%, ammonium sulphate 6%	Mode of the PNSD	UB	Pohjola et al. 2007
AkM_I	11–30	Aged nucleation	Mode of 11–30 nm particles	RB	Charron et al., 2007
	18	Young Aitken mode	Lognormal modal parameters of PNSD	RS, UB	Birmili et al., 2008
	10–50	Aged urban NM	Modal size range by multi-site PCA	RB,UB	This work
	62	Accumulation mode: urban and freeway	DGN	UB, RS	Whitby, 1978
	200	Traffic influenced aerosol	Mode of volume size distribution	RS	Morawska et al., 1998
	40–100			RS	Kittelson et al., 2000
	50–100	Decay of freeway emissions	Mode of PNSD	RS,UB	Zhu et al., 2002
	50–200	Downwind the highway	Modal shapes of PNSD	RS	Zhang et al., 2004
	15–60	Aitken mode	GMD of highway PNSD	RS	Hussein et al., 2005
	50–300	Soot aggregates from incomplete combustion	Mode of PNSD	RS	Imhof et al., 2005
	~50	Emissions from light-duty vehicles	Mode of PNSD	RS	Yao et al., 2006
80	–	Max of moving average correlation coefficient	UB	Gramotnev et al., 2007	
43.2–122	Aitken: OC 27 %, EC 64%, mineral dust 7%, ammonium sulphate 2.2%, ammonium nitrate 0.3%	Max of the PNSD	RS	Pohjola et al. 2007	
53–81	Aitken mode	Lognormal modal parameters of PNSD	RS, UB	Birmili et al., 2008	
30–200	Urban soot AkM	Modal size range by multi-site PCA	RS	This work	

⁽¹⁾ NM=Nucleation mode, AkM= Aitken mode, AcM= Accumulation mode. ⁽²⁾ PNSD= particle number size distribution, PC= principal component, PCA= principal component analysis, DGN=geometric number mean size, GMD= geometric mean diameter. ⁽³⁾ RS= roadside, RB=regional background, UB=urban background. ⁽⁴⁾ At UB but believed to be of regional origin.

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Particle mode ⁽¹⁾	Diameter (nm)	Description	Method ⁽²⁾	Observation site ⁽³⁾	Study
	54	Accumulation mode: urban average	DGN	UB	Whitby, 1978
	20–40	Nuclei mode of urban-influenced aerosol	Mode of PNSD	UB	Morawska et al., 1999
	39–68	–	Lognormal modes	UB	Wehner and Wiedensohler, 2003
	43.8–48.1	Aitken mode	GMD of the mode fitting parameters	UB	Hussein et al., 2004
	30–100	Growing and coagulating of nucleated particles. Primary particles growing by condensation	Particle number count	UB	Stanier et al., 2004
AkM_II	40–50	Aitken mode	Mode of the PNSD	UB	Ketzel et al. 2004
	33.6–60.5	Aitken mode	Lognormal GMD	UB	Mönkkönen et al., 2005
	55	–	Max of moving average correlation coefficient	UB	Gramotnev et al., 2007
	43.2–122	Aitken: sulphuric acid 21%, OC 24.5%, EC 19%, mineral dust 12%, sea salt 2.5%, ammonium nitrate 21.3%	Max of the PNSD	UB	Pohjola et al. 2007
	30–90	Urban background AkM	Modal size range by multi-site PCA	UB	This work
	76	Accumulation mode: average background	DGN	RB	Whitby, 1978
	44–65	Aitken mode	GMD	RB	Mäkelä et al., 2000
	30–110	Aitken mode	Lognormal fitting (45–74, 60–88, 52–85, 50–83, 48–80 nm)	RB	Birmili et al., 2001
AkM_III	50–60	Aitken mode	Mode of the PNSD	RB	Ketzel et al. 2004
	25	–	Lognormal mode	UB ⁽⁴⁾	Hussein et al., 2004
	60	Aitken mode	–	RB	Laaksonen et al., 2005
	20–70	Rural background AkM	Modal size range by multi-site PCA	RB	This work
	250	Traffic influenced aerosol	Mode of volume size distribution	UB	Hidy, 1975
	200	Suburban aerosol	Mode of volume size distribution	RB	Meszaros, 1977
AcM_I	200	Suburban background aerosol	Mode of PNSD	RB	Morawska et al., 1999
	228, 384	Regional pollution	Modal diameter by fitting PC to log-normal PNSD	RB	Chan and Mozurkewich, 2007a,b
	>200	Long-range transport	Modal size range by multi-site PCA	RS,RB,UB	This work

⁽¹⁾ NM=Nucleation mode, AkM= Aitken mode, AcM= Accumulation mode. ⁽²⁾ PNSD= particle number size distribution, PC= principal component, PCA= principal component analysis, DGN=geometric number mean size, GMD= geometric mean diameter. ⁽³⁾ RS= roadside, RB=regional background, UB=urban background. ⁽⁴⁾ At UB but believed to be of regional origin.

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Particle mode ⁽¹⁾	Diameter (nm)	Description	Method ⁽²⁾	Observation site ⁽³⁾	Study
AcM_II	180–220	Condensation mode	Mass median aerodynamic diameter		Hering and Friedlander, 1982
	200	Condensation mode			Meng and Seinfeld, 1994
	171–207	Accumulation mode	GMD	RB	Mäkelä et al., 2000
	150–250	Accumulation mode	Lognormal fitting (160–250, 150–240, 150–210 nm)	RB	Birmili et al., 2001
	180–236	Accumulation mode	Lognormal modes	UB	Wehner and Wiedensohler, 2003
	~150	Accumulation mode	GMD of the mode fitting parameters	UB	Hussein et al., 2004
	50–170	Aged air masses not originating directly from traffic	PC mode by PCA	RS	Janhäll et al. 2004
	100–200	Accumulation mode	GMD of PNSD	RS,UB,RB	Hussein et al., 2005
	117–163	Accumulation mode	Lognormal GMD	UB	Mönkkönen et al., 2005
	110–240	–	Max of moving average correlation coefficient	UB	Gramotnev et al., 2007
	171, 178	Accumulation mode	Modal diameter by fitting PC to log-normal PNSD	UB	Chan and Mozurkewich, 2007a,b
	122–321	Accumulation1: sulphuric acid 21%, OC 24.5%, EC 19%, mineral dust 12%, sea salt 2.5%, ammonium nitrate 21.3%	Max of the PNSD	UB	Pohjola et al. 2007
	100	Organic aerosol mode	Mode of particle mass distribution	RB,UB,RS	Schneider t al., 2008
	100–200	Small-mode organics	Size resolved mass loadings	UB	Cubison et al. 2008
	134–208	Accumulation mode	Lognormal modal parameters of PNSD	RS, UB	Birmili et al., 2008
90–250	Condensation AcM	Modal size range by multi-site PCA	RS,RS,UB	This work	
AcM_III	500	Background aerosol	Mode of volume size distribution	UB	Hidy, 1975
	700	Droplet mode, aqueous phase chemical reactions	Aerodynamic diameter		Hering and Friedlander, 1982
	700	Droplet mode from cloud processing	Aerodynamic diameter		John et al., 1990
	700	Droplet mode, activation of condensation mode, cloud-fog drops, aqueous phase chemistry	Aerodynamic diameter		Meng and Seinfeld, 1994
	200–400	Background aerosol	Mode of volume size distribution	RB	Le Canut et al, 1996
	>300,	Sea spray or droplet mode. Accumulation mode 2	Lognormal fitting (240–320, 280–330, 280–370,280–440,300–470 nm)	RB	Birmili et al., 2001
	240–470	accumulation mode			
	200–300	accumulation2: sulphuric acid 21%, OC 24.5%, EC 19%, mineral dust 12%, sea salt 2.5%, ammonium nitrate 21.3%	Max of the PNSD	RB	Ketzel et al. , 2004
	321–1250	Large-mode organics, total inorganics	Size resolved mass loadings	UB	Pohjola et al. 2007
	200–400	Droplet AcM	Modal size range by multi-site PCA	RS,RS,UB	Cubison et al. 2008
	300–800				This work

⁽¹⁾ NM=Nucleation mode, AkM= Aitken mode, AcM= Accumulation mode. ⁽²⁾ PNSD= particle number size distribution, PC= principal component, PCA= principal component analysis, DGN=geometric number mean size, GMD= geometric mean diameter. ⁽³⁾ RS= roadside, RB=regional background, UB=urban background. ⁽⁴⁾ At UB but believed to be of regional origin.

Table 1. Experimental evidence on physical aerosol particle modes in the atmosphere: Comparison between this work's results and literature reports.

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