Impact of wood burning emissions on carbonaceous aerosols and PM in the Alpine region

H. Herich[1], M.F.D. Gianini[1], Ch. Piot[2,3], J. Cozic[2], J.L. Jaffrezo[2] , J.L. Besombes[3],
A.S.H. Prevot[4], and Ch. Hueglin[1]

[1]Empa, Swiss Federal Laboratories for Materials Science and Technology, Duebendorf, Switzerland
[2]UJF-Grenoble 1 / CNRS, LGGE UMR 5183, Grenoble, F-38041, France
[3]Université de Savoie-LCME, Le Bourget du Lac, France
[4] Paul Scherrer Institut, Laboratory for Atmospheric Chemistry, Villigen, Switzerland

Wood burning for domestic heating is an important source of carbonaceous aerosols and ambient particulate matter (PM). The importance of wood burning as a source of particulate air pollutants has been shown in many studies carried out in different countries. At locations in the Alpine region during the cold season, wood burning can be the dominating source of carbonaceous aerosols and PM (Szidat et al., 2007; Gilardoni et al., 2011; Piot, 2011).

During the past years, implemented measures for the reduction of PM emissions have been focused in many European countries on road traffic emissions. Conversely, much less attention has been paid to emissions from domestic wood burning. As shown recently by Gianini et al. (2012), average road traffic contributions to PM10 have in Switzerland declined during the past ten years, whereas the contributions from wood burning remained unchanged. As a consequence, the contribution of wood burning to PM10 is today comparable to (or even higher than) the contributions from road traffic on annual average at many locations in Switzerland. Same results are observed in France by Piot (2011).

This presentation provides an overview of the impact of wood burning emissions on carbonaceous aerosols and PM in the Alpine region. The overview is based on results of recently published studies using different methods, such as multivariate statistical models (Positive Matrix Factorization, PMF), Chemical Mass Balance (CMB), 14C-method and evaluation of the wavelength dependence of the optical aerosol absorption (Aethalometer model). In addition, available data of specific wood combustion tracers such as levoglucosan are used together with published source emission ratios and PMF-derived emission ratios in macro-tracer analyses to estimate contributions of wood burning emissions to carbonaceous aerosols and PM.

As an example, Fig. 1 shows average wood burning contributions to PM10 as derived by PMF versus average concentrations of levoglucosan at sites in Switzerland and in Milan (Northern Italy; data from Piazzalunga et al., 2011). The content of levoglucosan in PM10 from wood burning is constant for the Swiss sites that are located north of the Alps (Bern, Zurich, Payerne; levo/$PM10_{WB}$ = 0.045) and clearly lower than at the Swiss site south of the Alps (Magadino; levo/$PM10_{WB}$ = 0.069) and in Milan (Piazzalunga et al., 2011; levo/$PM10_{WB}$ = 0.059). These and other PMF-derived emission ratios are used for estimation of wood burning impacts on particulate air pollutants and for comparison with results obtained by other source apportionment approaches.

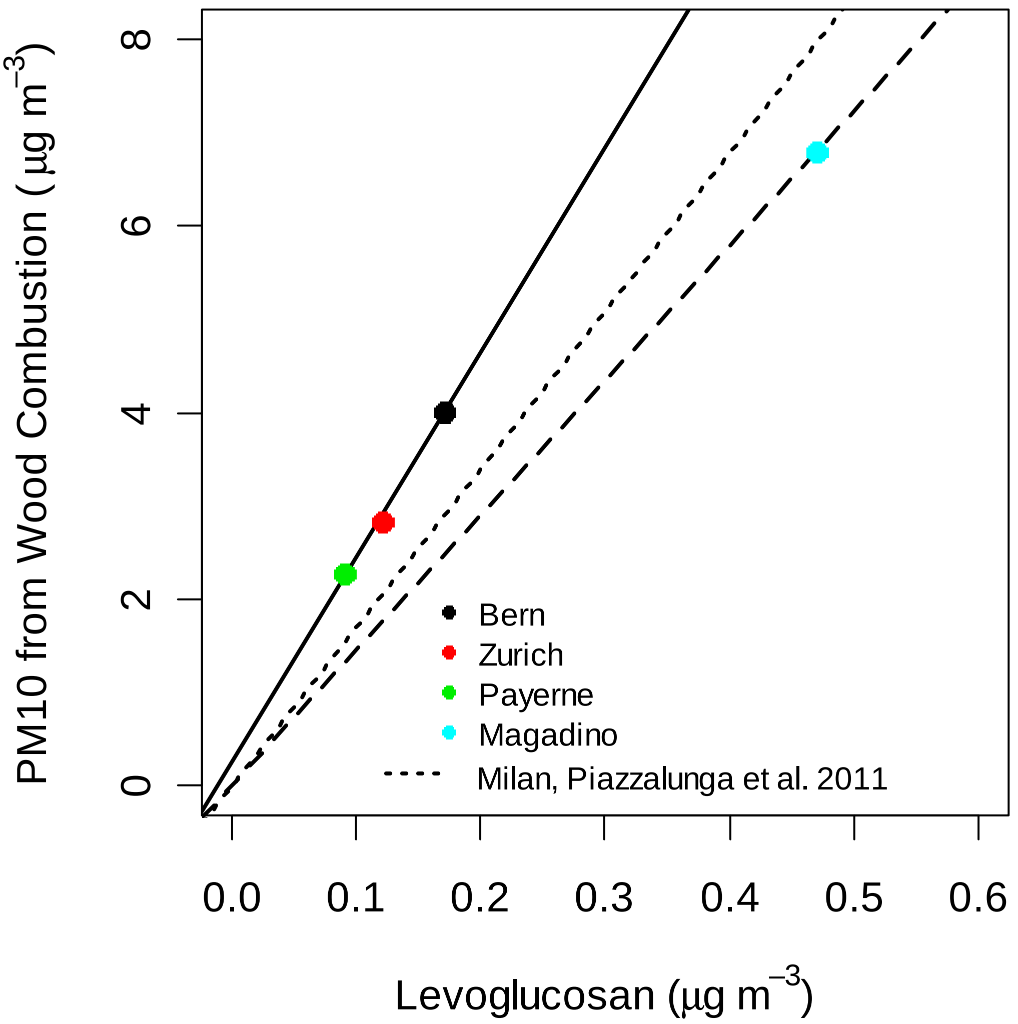


Figure 1. PMF-derived average contribution of PM10 from wood combustion versus average concentration of levoglucosan at sites in Switzerland and in Milan, Northern Italy.

References

Gianini, M.F.D., Gehrig, R., Fischer, A., Ulrich, A., Wichser, A., Piot, Ch., Besombes, J.L. and Hueglin, Ch. (2012) Atmos. Environ., 54, 149-158.

Gilardoni, S., Vignati, E., Cavalli, F., Putaud, J.P., Larsen, B.R., Stenström, K., Genberg, J., Henne, S. and Dentener, F. (2011) Atmos. Chem. Phys., 11, 5685-5700.

Piazzalunga, A., Belis, C., Bernardoni, V., Cazzuli, O., Fermo, P., Vialli, G. and Vecchi, R. (2011). Atmos. Environ., 45, 6642-6649.

Piot, C. (2011). Thesis of the University of Grenoble, 294 pp.

Szidat, S., Prevot, A.S.H., Sandradewi, J., Alfarra, M.R., Synal, H.A., Wacker, L. and Baltensperger, U. (2007) Geophys. Res. Lett., 34, L05820.

Impact of wood burning emissions on carbonaceous aerosols and particulate matter (PM) in the Alpine region

C. Hueglin[1], H. Herich[1], M.F.D. Gianini[1], Ch. Piot[2], J. Cozic[2], J.L. Jaffrezo[2], J.L. Besombes[3], A.S.H. Prevot[4]

[1] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Air Pollution and Environmental Technology, Duebendorf, Switzerland
[2] Université Joseph Fourier, CNRS-LGGE, St-Martin d'Hères, France
[3] Université de Savoie, LCME, F-73376 Le Bourget du lac, France
[4] PSI, Paul Scherrer Institut, Laboratory of Atmospheric Chemistry, Villigen, Switzerland

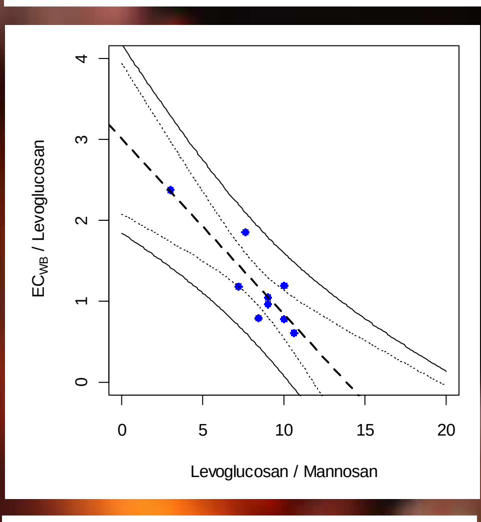
Introduction

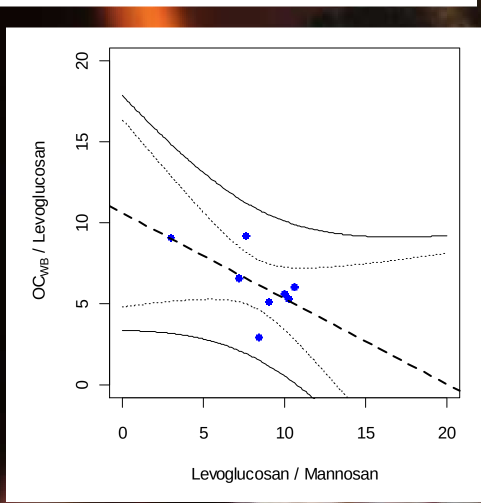
The importance of wood burning as a source of particulate air pollutants in the Alpine region is known from various studies (see references below).

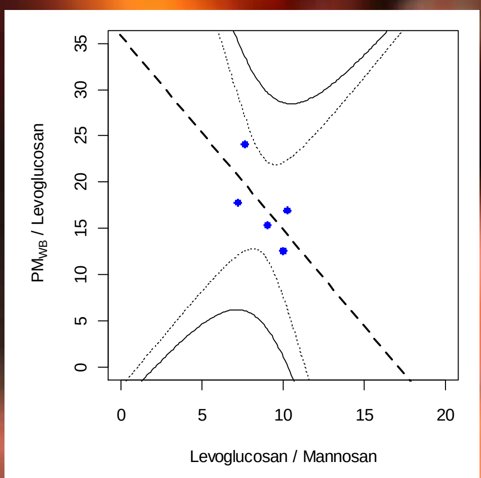
An overview of the contribution of wood burning to elemental carbon (EC_{WB}), organic carbon (OC_{WB}) and particulate matter (PM_{WB}) in the Alpine region is given,

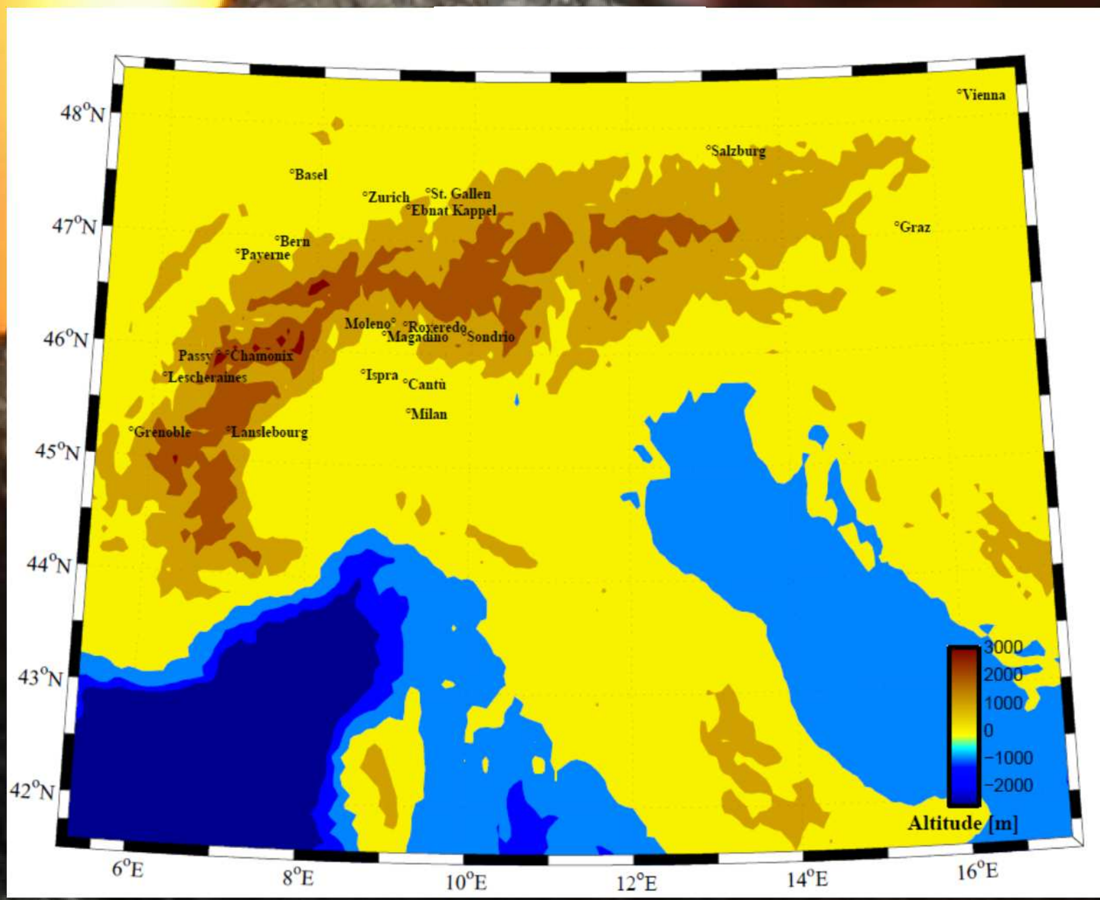
a. based on published values for EC_{WB}, OC_{WB} and PM_{WB}, and
b. based on the relation between EC_{WB}, OC_{WB} and PM_{WB} as derived from source apportionment models (PMF, aethalometer model, ^{14}C) and the measured concentrations of the specific organic tracers levoglucosan and mannosan (see figures below; broken and solid lines indicate 95% confidence- and prediction interval of linear regression calculation, uncertainties (see table) were estimated from prediction intervals).

The latter allows estimation of EC_{WB}, OC_{WB} and PM_{WB} at sites where measurements of levoglucosan and mannosan are available.









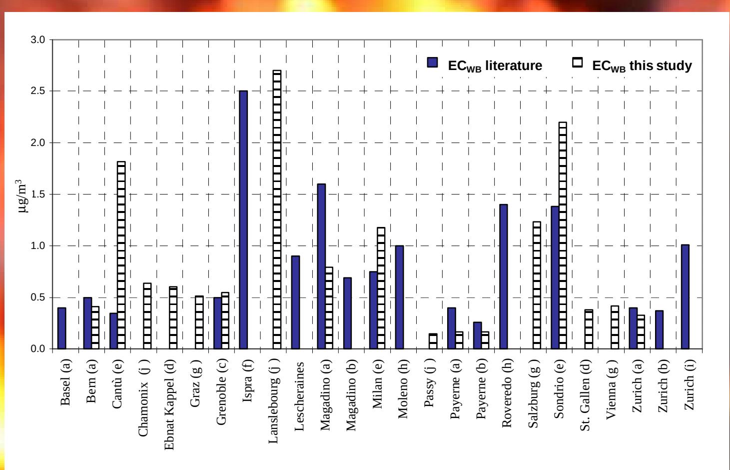
Location of sites in the Alpine region considered in this study.

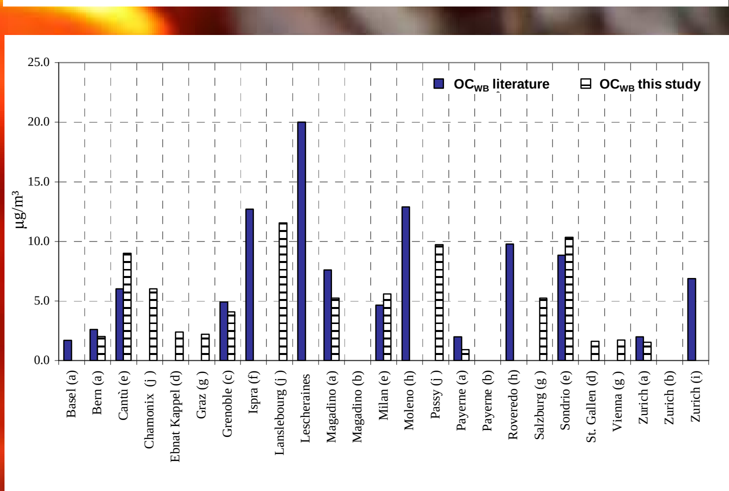
Results

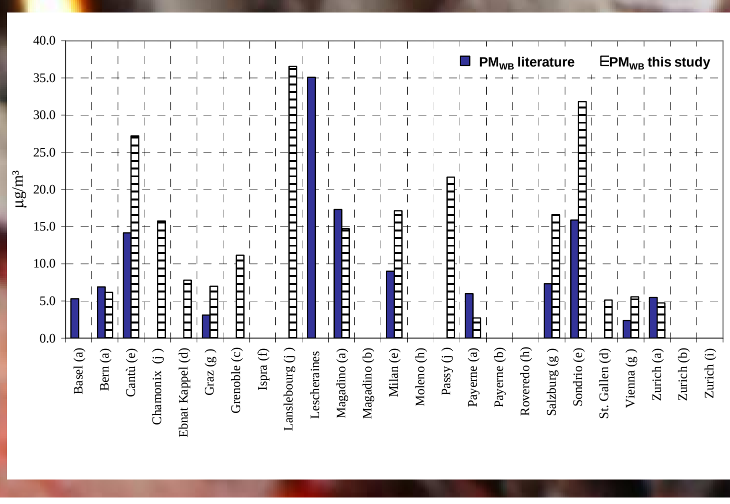
Summary of measured concentrations of levoglucosan, the ratio of levoglucosan and mannosan and estimates for the average contribution of wood burning emissions to ambient EC, OC and PM.

Site	Country	Type	PM2.5/PM10	Season	PM_{WB} (µg/m³)		OC_{WB} (µg/m³)		EC_{WB} (µg/m³)		Levo (µg/m³)	Levo/Manno	Ref.
					literature	this study	literature	this study	literature	this study			
Basel	CH	suburban	10	winter 2008/09	5.3		1.8		0.5				a
Bern	CH	urban	10	winter 2008/09	6.9	*6.1±4.3*	2.7	*2.0±1.4*	0.5	*0.4±0.2*	0.31	7.6	a
Cantù	I	urban backgr.	10	2004-2007	14.2	*27.4±19.0*	6.0	*9.1±6.4*	0.3	*1.9±1.0*	1.38	7.6	e
Chamonix	F	urban backgr.	10	Dec 07		*15.7±23.0*		*6.0±6.9*		*0.7±1.1*	1.34	11.5	j
Ebnat Kappel	CH	rural	10	winter 2010/11		*7.8±6.3*		*2.4±1.6*		*0.6±0.3*	0.31	5.1	d
Graz	A	urban/backgr.	10	winter 2004	3.1	*7.0±5.4*		*2.2±1.4*		*0.5±0.2*	0.29	5.6	g
Grenoble	F	urban backgr.	2.5	Jan 2009		*11.1±12.2*	4.9	*4.1±4.0*	0.5	*0.6±0.6*	0.82	10.6	c
Ispra	I	rural	2.5	winter 2007			12.7		2.5				f
Lanslebourg	F	rural	10	Jan 2010		*36.6±28.7*		*11.6±7.5*		*2.7±1.2*	1.51	5.5	j
Lescheraines	F	rural	10	winter 2009/10	35.1		20.0		0.9		2.00	22.1	j
Magadino	CH	rural	10	winter 2008/09	17.3	*14.7±13.6*	7.6	*5.2±4.7*	1.6	*0.8±0.8*	0.99	10.0	a
Magadino	CH	rural	2.5	winter 2008/09/10					0.7				b
Milan	I	urban backgr.	10	2004-2007	9.0	*17.2±12.0*	4.7	*5.6±3.9*	0.7	*1.2±0.6*	0.83	7.2	e
Moleno	CH	rural, motorway	10	Feb 05			12.9		1.0				h
Passy	F	urban-specific	10	Feb 2010		*21.6±65.6*		*9.8±16.2*		*0.3±2.6*	2.80	13.4	j
Payerne	CH	rural	10	winter 2008/09	6.0	*2.7±2.0*	2.0	*0.9±0.7*	0.4	*0.2±0.1*	0.16	9.0	a
Payerne	CH	rural	2.5	winter 2008/09/10					0.3				b
Roveredo	CH	rural, motorway	10	Jan/Mar 2005			9.8		1.4				h
Salzburg	A	urban/backgr.	10	winter 2004	7.3	*16.6±13.1*		*5.3±3.4*		*1.2±0.5*	0.68	5.4	g
Sondrio	I	urban backgr.	10	2004-2007	15.9	*31.9±22.5*	8.9	*10.4±7.1*	1.4	*2.2±1.1*	1.51	7.0	e
St. Gallen	CH	urban backgr.	10	winter 2010/11		*5.1±4.1*		*1.6±1.1*		*0.4±0.2*	0.21	5.4	d
Vienna	A	urban/backgr.	10	winter 2004	2.4	*5.6±4.5*		*1.7±1.1*		*0.4±0.2*	0.22	5.0	g
Zurich	CH	urban backgr.	10	winter 2008/09	5.5	*4.8±3.3*	2.0	*1.6±1.1*	0.4	*0.3±0.2*	0.23	7.2	a
Zurich	CH	urban backgr.	2.5	winter 2008/09/10					0.4				b
Zurich	CH	urban backgr.	10	Feb 03			6.9		1.0				i

a) Gianini et al. 2012, PMF (winter data only). b) Herich et al. 2011, AE-model. c) Favez et al. 2010, AE-model. d) Data provided by OstLuft. e) Piazzalunga et al. 2011, tracer approach. f) Gilardoni et al. 2011, tracer approach including ^{14}C. g) Caseiro et al. 2009, tracer approach. h) Szidat et al. 2007, ^{14}C method. i) Szidat et al. 2006, ^{14}C method. j) Piot et al. 2011, tracer approach and CMB.







Bar charts summarising EC_{WB}, OC_{WB} and PM_{WB} at the sites in the Alpine region as taken from literature and as estimated in this study.

Conclusions

- Wood burning is a main source of particulate air pollutants in the Alpine region.
- Highest contributions from wood burning can be found in Alpine valleys.
- Large variability: Relative contribution of wood burning to total OC ranged from 19-91% (for EC range is 10-70%).
- Uncertainties for PM_{WB} in our estimations are high because of small number of available "calibration points" (blue points in upper figure).

Contact: christoph.hueglin@empa.ch

Acknowledgement: Thanks to CCES-ETHZ (IMBALANCE project) for financial support.

References: a) Gianini et al. 2012, Atmos. Environ., 54, 149-158; b) Herich et al. 2011, AMT, 4, 1409-1420; c) Favez et al. 2010, ACP, 10, 5295-5314; e) Piazzalunga et al. 2011, ACP, 11, 10193-10203; f) Gilardoni et al. 2011, ACP, 11, 5685-5700; g) Caseiro et al. 2009, Atmos. Environ., 43, 2186-2195; h) Szidat et al. 2007, Geophys. Res. Lett., 34, L05820; i) Szidat et al. 2006, J. Geophys. Res., 111, D07206; j) Piot 2011, Thesis of the Univ. of Grenoble, 294 pp, http://tel.archives-ouvertes.fr/docs/00/66/12/84/PDF/35623_PIOT_2011_archivage.pdf.