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Supplement of

Tropospheric aerosol scattering and absorption over central Europe: a closure study for the dry particle state

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Supplementary material

The second and third air mass classification scheme are established schemes that took part in comparisons of the Cost 733 action (Philipp et al., 2010).

The Hess and Brezowsky Grosswetterlagen scheme (Cost No. 1, “HBGWL”) is a subjective method in which days are classified according to the shape of atmospheric pressure fields, with a focus on the 500 hPa geopotential surface (Hess and Brezowsky, 1952). HBGWL distinguishes three orientations of atmospheric flow over Central Europe: zonal, meridional, and mixed. According to the type of flow (cyclonic or anticyclonic) and the location of its controlling centres of high and low pressure, a total of 29 weather types are distinguished (Gerstengarbe and Werner, 2005). Daily classification data for the HBGWL scheme were retrieved for the period 2007-2011 from the German Weather Service website (www./dwd.de). The nomenclature of the Hess and Brezowsky Grosswetterlagen can be seen in Table S1, as copied from James et al. (2007).

Objective Weather Classification (Cost No. 19, “WLKC09”) is an objective weather classification scheme for Central Europe that distinguishes days according to the type of flow (cyclonic/ anticyclonic) on the 1000 hPa and the 700 hPa geopotential levels, according to the predominant wind direction on the 700 hPa geopotential level, and on the degree of moisture in the atmosphere (Dittmann, 1995). The combination of these criteria leads to a distinction of a total of 40 weather types. Daily classification data for the WLKC09 scheme were also retrieved for the period 2007-2011 from the German Weather Service website (www./dwd.de). A description of the nomenclature is given on the next page.

Table S1: Nomenclature of the Hess and Brezowsky Grosswetterlagen (HBGWL), copied from James et al. (2007).

Table 1. The 29 Grosswetterlagen with original German and translated English definitions

GWL	Original definition (German)	Translated definition (English)
01 WA	Westlage, antizyklonal	Anticyclonic Westerly
02 WZ	Westlage, zyklonal	Cyclonic Westerly
03 WS	Südliche Westlage	South-Shifted Westerly
04 WW	Winkelförmige Westlage	Maritime Westerly (Block E. Europe)
05 SWA	Südwestlage, antizyklonal	Anticyclonic South-Westerly
06 SWZ	Südwestlage, zyklonal	Cyclonic South-Westerly
07 NWA	Nordwestlage, antizyklonal	Anticyclonic North-Westerly
08 NWZ	Nordwestlage, zyklonal	Cyclonic North-Westerly
09 HM	Hoch Mitteleuropa	High over Central Europe
10 BM	Hochdruckbrücke (Rücken) Mitteleuropa	Zonal Ridge across Central Europe
11 TM	Tief Mitteleuropa	Low (Cut-Off) over Central Europe
12 NA	Nordlage, antizyklonal	Anticyclonic Northerly
13 NZ	Nordlage, zyklonal	Cyclonic Northerly
14 HNA	Hoch Nordmeer-Island, antizyklonal	Icelandic High, Ridge C. Europe
15 HNZ	Hoch Nordmeer-Island, zyklonal	Icelandic High, Trough C. Europe
16 HB	Hoch Britische Inseln	High over the British Isles
17 TRM	Trog Mitteleuropa	Trough over Central Europe
18 NEA	Nordostlage, antizyklonal	Anticyclonic North-Easterly
19 NEZ	Nordostlage, zyklonal	Cyclonic North-Easterly
20 HFA	Hoch Fennoskandien, antizyklonal	Scandinavian High, Ridge C. Europe
21 HFZ	Hoch Fennoskandien, zyklonal	Scandinavian High, Trough C. Europe
22 HNFA	Hoch Nordmeer-Fennoskandien, antizykl.	High Scandinavia-Iceland, Ridge C. Europe
23 HNFZ	Hoch Nordmeer-Fennoskandien, zyklonal	High Scandinavia-Iceland, Trough C. Europe
24 SEA	Südostlage, antizyklonal	Anticyclonic South-Easterly
25 SEZ	Südostlage, zyklonal	Cyclonic South-Easterly
26 SA	Südlage, antizyklonal	Anticyclonic Southerly
27 SZ	Südlage, zyklonal	Cyclonic Southerly
28 TB	Tief Britische Inseln	Low over the British Isles
29 TRW	Trog Westeuropa	Trough over Western Europe

The nomenclature of the WLKC09 (Dittmann, 1995) is illustrated for the case of "NWAZT" as follows:

"NW" = dominating wind direction (northwest) in Central Europe on the 700 hPa geopotential level. Other options: SW (southwest), SO (southeast), NO (northeast), X (undefined, in case no more than 2/3 of the wind vectors belong to a single sector).

"A" = anticyclonic flow in Central Europe on the 1000 hPa geopotential level, i.e. near the surface. Other option is "Z" (cyclonic)

"Z" = cyclonic flow in Central Europe on the 550 hPa geopotential level. Other option is "A" (anticyclonic)

“T” = air mass is dry (German *trocken*) with respect to the monthly mean precipitable water. Other option is “F”. i.e. The air mass is moist (German *feucht*) with respect to the monthly mean precipitable water.

Comparison of the three classification schemes

Figure S1 gives absolute frequencies of the air mass categories for the three classification schemes. It can be seen that HBGWL and WLKC09 feature many categories that occur only seldom, even over climatologically relevant periods while BCLM provides less overall categories that occur at more balanced relative frequencies.

Figure S2 provides classifications of the dry scattering coefficient σ_{sc} at 550 nm, as an illustrative example. Mean values and standard deviation of σ_{sc} are given for each of the three classification schemes. It can be seen that BCLM turns out to be the scheme with the highest predictive power. In this context, "predictive power" implies that a classification segregates high and low values of a given parameter on a statistical basis efficiently.

Concretely, BCLM (13 categories) predicts a spread of σ_{sc} between 0.22 and $1.9 \cdot 10^{-4}$ m^{-1} depending on air mass type. This corresponds to a factor of 8.4 between the extreme values. HBGWL (29 categories) predicts a maximum spread between 0.24 and $1.5 \cdot 10^{-4}$ m^{-1} corresponding to a factor of 6.2. WLKC09 (40 categories), at last, predicts a spread between 0.29 and $1.2 \cdot 10^{-4}$ m^{-1} corresponding to a factor of 4.1. As a conclusion, BCLM has the highest predictive power.

The effectiveness of BCLM appears even more superior when considering that it requires only 13 air mass type categories. HBGWL and WLKC09 provide many more possible categories, but provide only inferior predictive power for the purpose of this work. This is manifested in Figure S3, which displays mean values combined with the standard error of the dry scattering coefficient. Here, the greater sample number per category can be felt, making BCLM the apparently more reasonable classification.

We conclude that in the context of this work, BCLM is a classification scheme that is clearly superior to the two other schemes investigated. (We do not question the other two classifications as a whole; they are, of course, very reasonable in terms of characterizing the synoptic scale development of air masses over Central Europe. We just claim that they are less useful in the context of discussing ground-level aerosol concentrations.)

The reason might be that BCLM uses direct information on vertical stratification, which is of immediate relevance of aerosol measurements near the ground.

More extensive evaluations of these classifications schemes, however, are needed in the near future for other aerosol parameters.

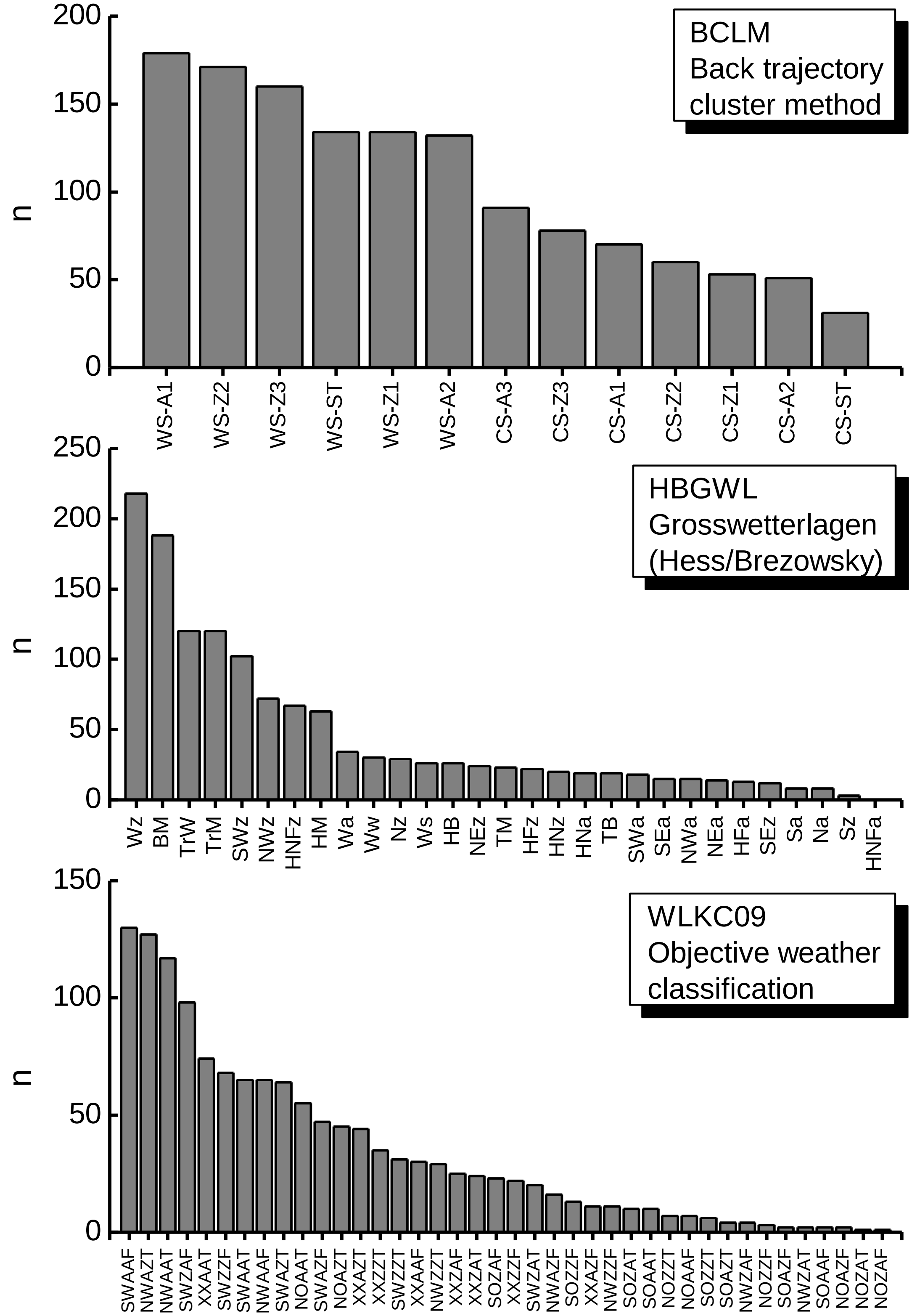

Figure S1: Absolute frequency of the air mass categories for the three classification schemes, 2007-2010. It can be seen that HBGWL and WLKC09 feature many categories that occur only seldom, even over climatologically relevant periods.

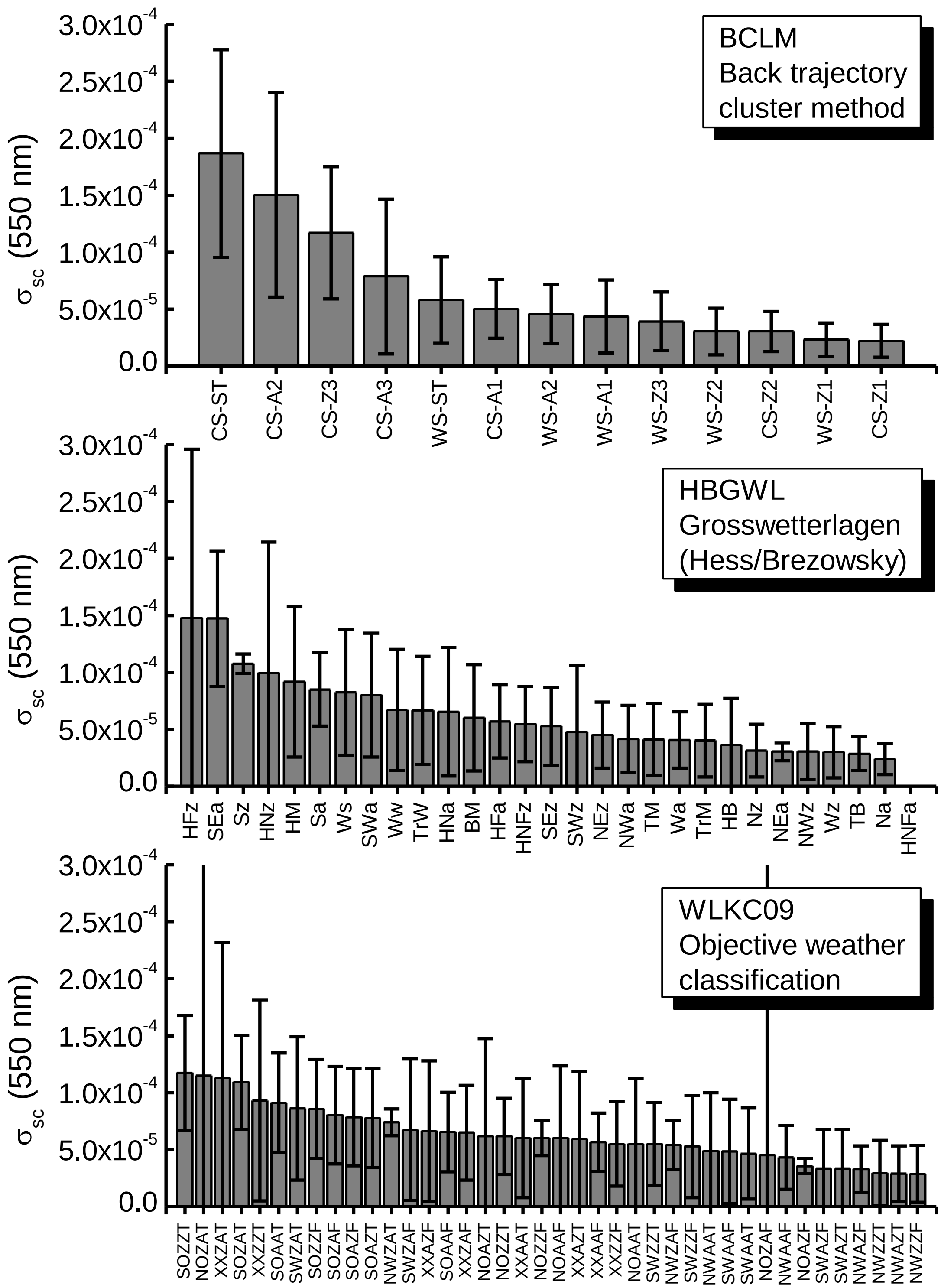

Figure S2: Mean values and standard deviation of the dry scattering coefficient at wavelength 550 nm (σ_{sc}) in m^{-1}, 2007-2010. The diagrams are sorted after descending mean value per air mass type. It can be seen that BCLM is the most superior scheme to predict differences in $\sigma_{sc.}$

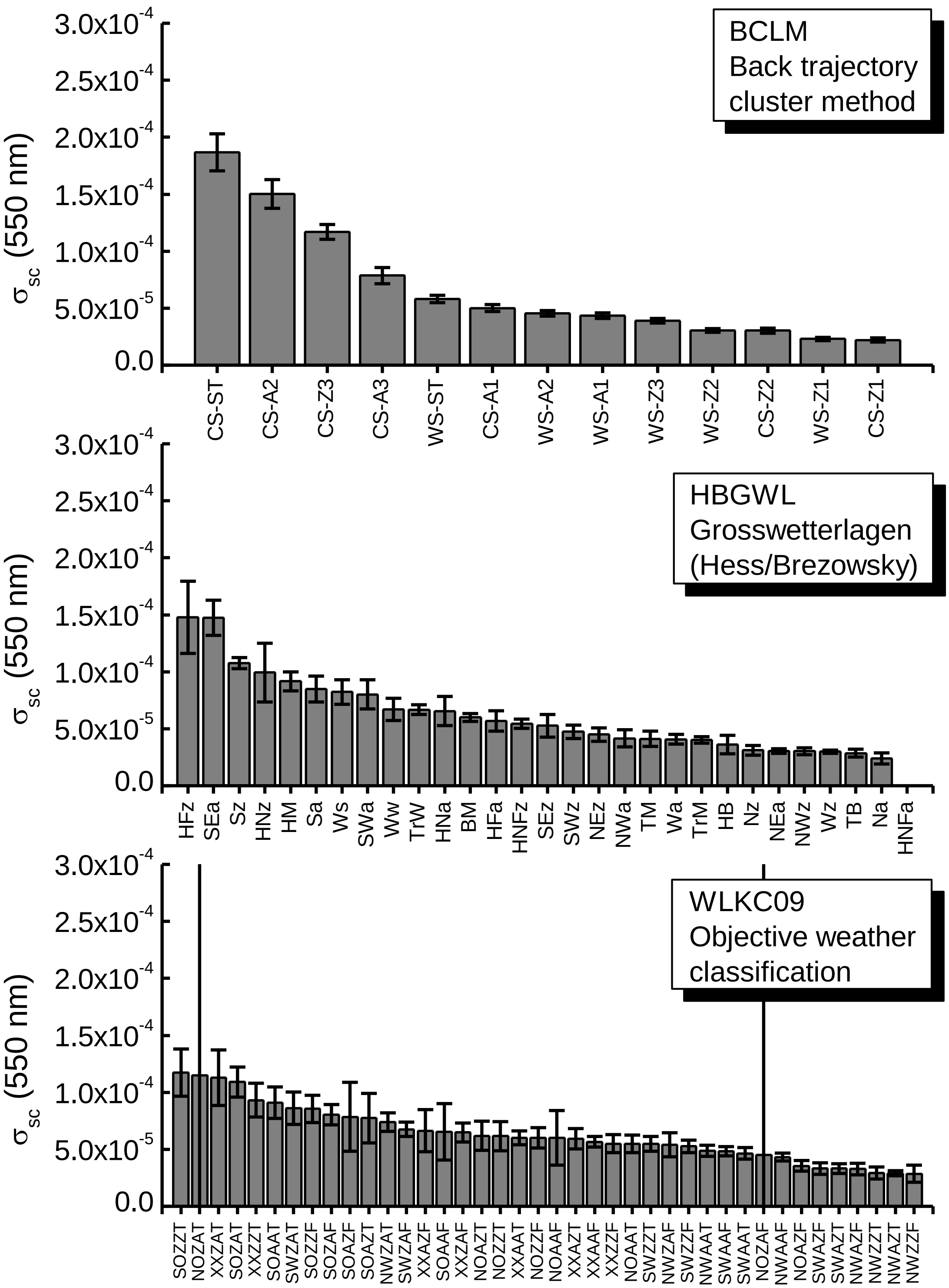

Figure S3: Mean values and standard error of the dry scattering coefficient at wavelength 550 nm (σ_{sc}) in m^{-1}, 2007-2010. The diagrams are sorted after descending mean value per air mass type. It can be seen that BCLM is the most superior scheme to predict differences in $\sigma_{sc.}$

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