

1. Intensive parameters in literature

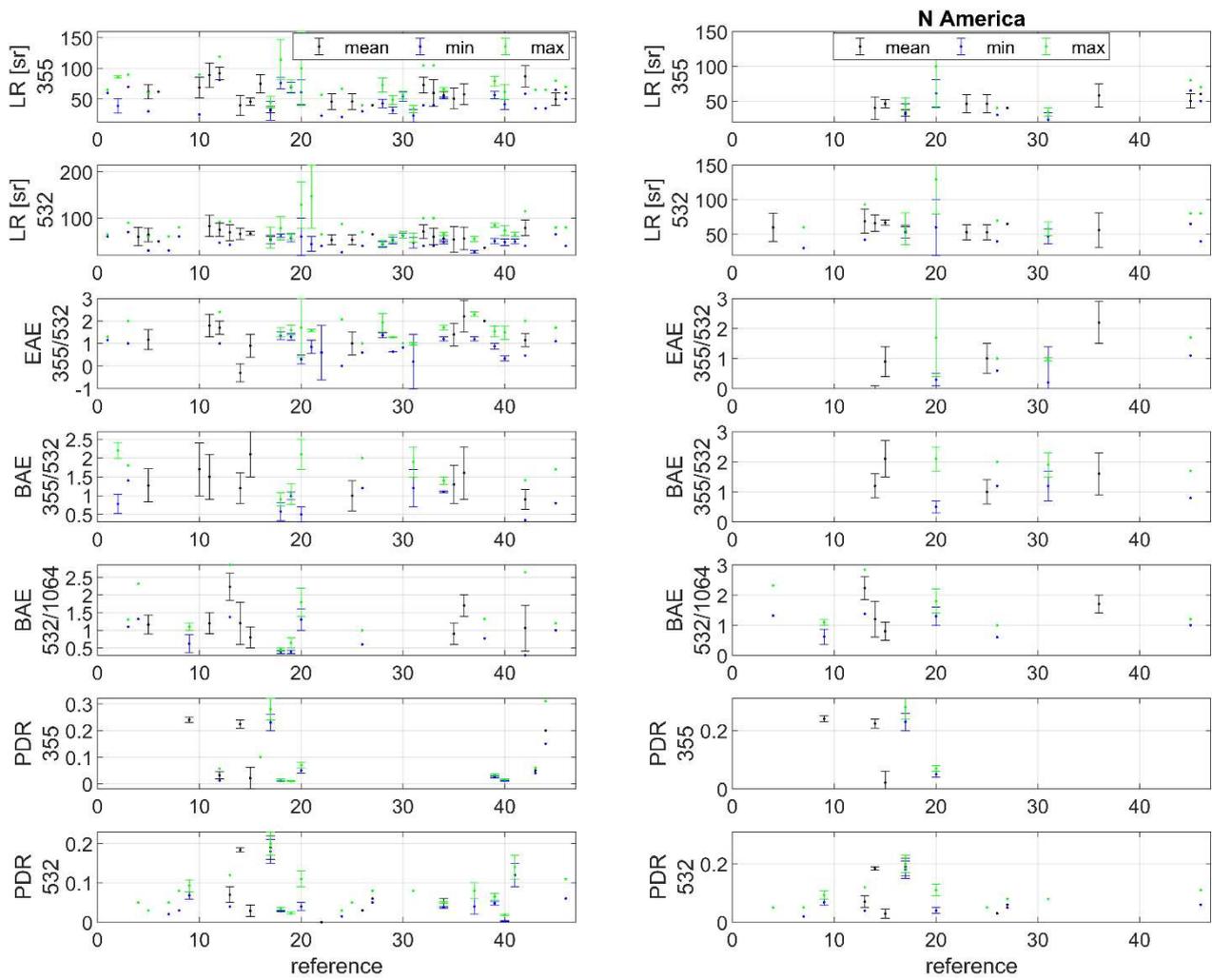


Figure S1. Intensive parameters for biomass burning, as reported in literature. The reference number corresponds to the references in Table S2.

Table S2. References for biomass burning intensive parameters

1. Alados-Arboledas, L., D. Müller, J. L. Guerrero-Rascado, F. Navas-Guzmán, D. Pérez-Ramírez, and F. J. Olmo, Optical and microphysical properties of fresh biomass burning aerosol retrieved by Raman lidar, and star-and sun-photometry, *Geophys. Res. Lett.*, 38, L01807, doi:10.1029/2010GL045999, 2011.
- 5 2. Amiridis, V., D. S. Balis, E. Giannakaki, A. Stohl, S. Kazadzis, M. E. Koukouli, and P. Zanis, Optical characteristics of biomass burning aerosols over Southeastern Europe determined from UV-Raman lidar measurements, *Atmos. Chem. Phys.*, 9, 2431–2440, 2009, www.atmos-chem-phys.net/9/2431/2009/.
- 10 3. Amiridis, V., C. Zerefos, S. Kazadzis, E. Gerasopoulos, K. Eleftheratos, M. Vrekoussis, A. Stohl, R.E. Mamouri, P. Kokkalis, A. Papayannis, K. Eleftheriadis, E. Diapouli, I. Keramitsoglou, C. Kontoes, V. Kotroni, K. Lagouvardos, E. Marinou, E. Giannakaki, E. Kostopoulou, C. Giannakopoulos, A. Richter, J.P. Burrows, N. Mihalopoulos, Impact of the 2009 Attica wild fires on the air quality in urban Athens, *Atmos. Environ.*, 46, 536-544, doi:10.1016/j.atmosenv.2011.07.056, 2012.
- 15 4. Ancellet, G., J. Pelon, J. Totems, P. Chazette, A. Bazureau, M. Sicard, T. Di Iorio, F. Dulac, and M. Mallet, Long-range transport and mixing of aerosol sources during the 2013 North American biomass burning episode: analysis of multiple lidar observations in the western Mediterranean basin, *Atmos. Chem. Phys.*, 16, 4725–4742, doi:10.5194/acp-16-4725-2016, 2016.
5. Baars, H., A. Ansmann, D. Althausen, R. Engelmann, B. Heese, D. Müller, P. Artaxo, M. Paixao, T. Pauliquevis, and R. Souza, Aerosol profiling with lidar in the Amazon Basin during the wet and dry season, *J. Geophys. Res.*, 117, D21201, doi:10.1029/2012JD018338, 2012.
- 20 6. Balis, D. S., V. Amiridis, C. Zerefos, E. Gerasopoulos, M. Andreae, P. Zanis, A. Kazantzidis, S. Kazadzis, A. Papayannis, Raman lidar and sunphotometric measurements of aerosol optical properties over Thessaloniki, Greece during a biomass burning episode, *Atmos. Environ.*, 37, 4529-4538, doi:10.1016/S1352-2310(03)00581-8, 2003.
- 25 7. Burton, S. P., R. A. Ferrare, C. A. Hostetler, J. W. Hair, R. R. Rogers, M. D. Obland, C. F. Butler, A. L. Cook, D. B. Harper, and K. D. Froyd, Aerosol classification using airborne High Spectral Resolution Lidar measurements – methodology and examples, *Atmos. Meas. Tech.*, 5, 73–98, doi:10.5194/amt-5-73-2012, 2012.
8. Burton, S. P., R. A. Ferrare, C. A. Hostetler, J. W. Hair, R. R. Rogers, M. D. Obland, C. F. Butler, A. L. Cook, D. B. Harper, and K. D. Froyd, Aerosol classification using airborne High Spectral Resolution Lidar measurements – methodology and examples, *Atmos. Meas. Tech.*, 5, 73–98, doi:10.5194/amt-5-73-2012, 2012.
- 30 9. Burton, S. P., J. W. Hair, M. Kahnert, R. A. Ferrare, C. A. Hostetler, A. L. Cook, D. B. Harper, T. A. Berkoff, S. T. Seaman, J. E. Collins, M. A. Fenn, and R. R. Rogers, Observations of the spectral dependence of linear particle depolarization ratio of aerosols using NASA Langley airborne High Spectral Resolution Lidar, *Atmos. Chem. Phys.*, 15, 13453–13473, doi:10.5194/acp-15-13453-2015, 2015.

10. Giannakaki, E., D. S. Balis, V. Amiridis, and C. Zerefos, Optical properties of different aerosol types: seven years of combined Raman-elastic backscatter lidar measurements in Thessaloniki, Greece, *Atmos. Meas. Tech.*, 3, 569–578, doi:10.5194/amt-3-569-2010, 2010.
11. Giannakaki, E., A. Pfüller, K. Korhonen, T. Mielonen, L. Laakso, V. Vakkari, H. Baars, R. Engelmann, J. P. Beukes, P. G. Van Zyl, M. Josipovic, P. Tiitta, K. Chiloane, S. Piketh, H. Lihavainen, K. E. J. Lehtinen, and M. Komppula, One year of Raman lidar observations of free-tropospheric aerosol layers over South Africa, *Atmos. Chem. Phys.*, 15, 5429–5442, doi:10.5194/acp-15-5429-2015, 2015.
12. Giannakaki, E., P. G. van Zyl, D. Müller, D. Balis, and M. Komppula, Optical and microphysical characterization of aerosol layers over South Africa by means of multi-wavelength depolarization and Raman lidar measurements, *Atmos. Chem. Phys.*, 16, 8109–8123, doi:10.5194/acp-16-8109-2016, 2016.
13. Groß, S., M. Esselborn, B. Weinzierl, M. Wirth, A. Fix, and A. Petzold, Aerosol classification by airborne high spectral resolution lidar Observations, *Atmos. Chem. Phys.*, 13, 2487–2505, doi:10.5194/acp-13-2487-2013, 2013.
14. Haarig, M., Ansmann, A., Baars, H., Jimenez, C., Veselovskii, I., Engelmann, R., and Althausen, D.: Depolarization and lidar ratios at 355, 532, and 1064 nm and microphysical properties of aged tropospheric and stratospheric Canadian wildfire smoke, *Atmos. Chem. Phys.*, 18, 11847–11861, <https://doi.org/10.5194/acp-18-11847-2018>, 2018.
15. Haarig, M., Ansmann, A., Baars, H., Jimenez, C., Veselovskii, I., Engelmann, R., and Althausen, D.: Depolarization and lidar ratios at 355, 532, and 1064 nm and microphysical properties of aged tropospheric and stratospheric Canadian wildfire smoke, *Atmos. Chem. Phys.*, 18, 11847–11861, <https://doi.org/10.5194/acp-18-11847-2018>, 2018.
16. Heese, B., and M. Wiegner, Vertical aerosol profiles from Raman polarization lidar observations during the dry season AMMA field campaign, *J. Geophys. Res.*, 113, D00C11, doi:10.1029/2007JD009487, 2008.
17. Hu, Q., P. Goloub, I. Veselovskii, J.-A. Bravo Aranda, I. Popovici, T. Podvin, M. Haeffelin, A. Lopatin, C. Pietras, X. Huang, B. Torres, and C. Chen, A study of long-range transported smoke aerosols in the Upper Troposphere/Lower Stratosphere, *Atmos. Chem. Phys. Discuss.*, <https://doi.org/10.5194/acp-2018-655>, 2018.
18. Janicka, L., I. S. Stachlewska, Properties of biomass burning aerosol mixtures derived at fine temporal and spatial scales from Raman lidar measurements: Part I optical properties, *Atmos. Chem. Phys. Discuss.*, <https://doi.org/10.5194/acp-2019-207>, 2019.
19. Janicka, L., I. S. Stachlewska, Properties of biomass burning aerosol mixtures derived at fine temporal and spatial scales from Raman lidar measurements: Part I optical properties, *Atmos. Chem. Phys. Discuss.*, <https://doi.org/10.5194/acp-2019-207>, 2019.
20. Janicka, L., I. S. Stachlewska, I. Veselovskii, H. Baars, Temporal variations in optical and microphysical properties of mineral dust and biomass burning aerosol derived from daytime Raman lidar observations over Warsaw, Poland, *Atmos. Environ.*, 169, 162–174, <http://dx.doi.org/10.1016/j.atmosenv.2017.09.022>, 2017.

21. Mariano, G.L., F.J.S. Lopes, M.P.P.M. Jorge, E. Landulfo, Assessment of biomass burnings activity with the synergy of sunphotometric and LIDAR measurements in São Paulo, Brazil, *Atmos. Res.*, 98, 486-499, doi:10.1016/j.atmosres.2010.08.025, 2010.
22. Mattis, I., A. Ansmann, U. Wandinger, and D. Müller, Unexpectedly high aerosol load in the free troposphere over central Europe in spring//summer 2003, *G.R.L.*, 30, 2178, doi:10.1029/2003GL018442, 2003.
23. Mattis, I., D. Müller, A. Ansmann, U. Wandinger, J. Preißler, P. Seifert, and M. Tesche, Ten years of multiwavelength Raman lidar observations of free-tropospheric aerosol layers over central Europe: Geometrical properties and annual cycle, *J. Geophys. Res.*, 113, D20202, doi:10.1029/2007JD009636, 2008.
24. Müller, D., I. Mattis, U. Wandinger, A. Ansmann, D. Althausen, and A. Stohl, Raman lidar observations of aged Siberian and Canadian forest fire smoke in the free troposphere over Germany in 2003: Microphysical particle characterization, *J. Geophys. Res.*, 110, D17201, doi:10.1029/2004JD005756, 2005.
25. Müller, D., A. Ansmann, I. Mattis, M. Tesche, U. Wandinger, D. Althausen, and G. Pisani, Aerosol-type-dependent lidar ratios observed with Raman lidar, *J. Geophys. Res.*, 112, D16202, doi:10.1029/2006JD008292, 2007.
26. Müller, D., A. Kolgotin, I. Mattis, A. Petzold, and A. Stohl, Vertical profiles of microphysical particle properties derived from inversion with two-dimensional regularization of multiwavelength Raman lidar data: experiment, *Appl. Opt.*, 50, 2069-2079, 2011.
27. Murayama, T., D. Müller, K. Wada, A. Shimizu, M. Sekiguchi, and T. Tsukamoto, Characterization of Asian dust and Siberian smoke with multiwavelength Raman lidar over Tokyo, Japan in spring 2003, *Geophys. Res. Lett.*, 31, L23103, doi:10.1029/2004GL021105, 2004.
28. Nicolae, D., A. Nemuc, D. Müller, C. Talianu, J. Vasilescu, L. Belegante, and A. Kolgotin, Characterization of fresh and aged biomass burning events using multiwavelength Raman lidar and mass spectrometry, *J. Geophys. Res. Atmos.*, 118, 2956–2965, doi:10.1002/jgrd.50324, 2013.
29. Nicolae, D., A. Nemuc, D. Müller, C. Talianu, J. Vasilescu, L. Belegante, and A. Kolgotin, Characterization of fresh and aged biomass burning events using multiwavelength Raman lidar and mass spectrometry, *J. Geophys. Res. Atmos.*, 118, 2956–2965, doi:10.1002/jgrd.50324, 2013.
30. Noh, Y. M., D. Müller, D. H. Shin, H. Lee, J. S. Jung, K. H. Lee, M. Cribb, Z. Li, Y. J. Kim, Optical and microphysical properties of severe haze and smoke aerosol measured by integrated remote sensing techniques in Gwangju, Korea, *Atmos. Environ.*, 43, 879–888, doi:10.1016/j.atmosenv.2008.10.058, 2009.
31. Ortiz-Amezcuca, P., J. L. Guerrero-Rascado, M. J. Granados-Muñoz, J. A. Benavent-Oltra, C. Böckmann, S. Samaras, I. S. Stachlewska, Ł. Janicka, H. Baars, S. Bohlmann, and L. Alados-Arboledas, Microphysical characterization of long-range transported biomass burning particles from North America at three EARLINET stations, *Atmos. Chem. Phys.*, 17, 5931–5946, doi:10.5194/acp-17-5931-2017, 2017.

32. Mylonaki, M., A. Papayannis, R. Mamouri, A. Argyrouli, P. Kokkalis, G. Tsaknakis and O. Soupiona, Aerosol optical properties variability during biomass burning events observed by the EOLE-AIAS depolarization lidars over Athens, Greece (2007-2016), 28th ILRC, Bucharest, Romania (2017).
33. Mylonaki, M., A. Papayannis, R. Mamouri, A. Argyrouli, P. Kokkalis, G. Tsaknakis and O. Soupiona, Aerosol optical properties variability during biomass burning events observed by the EOLE-AIAS depolarization lidars over Athens, Greece (2007-2016), 28th ILRC, Bucharest, Romania (2017).
34. Nepomuceno Pereira, S., J. Preißler, J. L. Guerrero-Rascado, A. M. Silva, and F. Wagner, Forest Fire Smoke Layers Observed in the Free Troposphere over Portugal with a Multiwavelength Raman Lidar: Optical and Microphysical Properties, *Scientific World, Journal*, 2014, Article ID 421838, 11 pages, <http://dx.doi.org/10.1155/2014/421838>.
35. Preißler, J., F. Wagner, J. L. Guerrero-Rascado, and A. M. Silva, Two years of free-tropospheric aerosol layers observed over Portugal by lidar, *J. GEOPHYS. RES.*, 118, 3676–3686, doi:10.1002/jgrd.50350, 2013.
36. Preißler, J., F. Wagner, J. L. Guerrero-Rascado, and A. M. Silva, Two years of free-tropospheric aerosol layers observed over Portugal by lidar, *J. GEOPHYS. RES.*, 118, 3676–3686, doi:10.1002/jgrd.50350, 2013.
37. Samaras, S., D. Nicolae, C. Böckmann, J. Vasilescu, I. Biniotoglou, L. Labzovskii, F. Toanca, A. Papayannis, Using Raman-lidar-based regularized microphysical retrievals and Aerosol Mass Spectrometer measurements for the characterization of biomass burning aerosols, *Journal of Computational Physics* 299, 156–174, <http://dx.doi.org/10.1016/j.jcp.2015.0>, 2015.
38. Sicard, M., M Mallet, D. Garc´ia-Vizca´ıno, A Comer´on, F Roca-denbosch, P Dubuisson and C Mu˜noz-Porcar, Intense dust and extremely fresh biomass burning outbreak in Barcelona, Spain: characterization of their optical properties and estimation of their direct radiative forcing, *Environ. Res. Lett.* 7, 034016 (6pp), doi:10.1088/1748-9326/7/3/034016, 2012.
39. Stachlewska, I. S., O. Zawadzka and R. Engelmann, Effect of HeatWave Conditions on Aerosol Optical Properties Derived from Satellite and Ground-Based Remote Sensing over Poland, *Remote Sens.*, 9, 1199; doi:10.3390/rs9111199, 2017.
40. Stachlewska, I. S., M. Samson, O. Zawadzka, K. M. Harenda, L. Janicka, P. Poczta, D. Szczepanik, B. Heese, D. Wang, K. Borek, E. Tetoni, E. Proestakis, N. Siomos, A. Nemuc, B. H. Chojnicki, K. M. Markowicz, A. Pietruczuk, A. Szkop, D. Althausen, k. Stebel, D. Schuettemeyer and C. Zehner, Modification of Local Urban Aerosol Properties by Long-Range Transport of Biomass Burning Aerosol, *Remote Sens.*, 10, 412; doi:10.3390/rs10030412, 2018.
41. Sugimoto, N., B. Tatarov, A. Shimizu, I. Matsui, and T. Nishizawa, Optical Characteristics of Forest-Fire Smoke Observed with Two-Wavelength Mie-Scattering Lidars and a High-Spectral-Resolution Lidar over Japan, *SOLA*, 6, 093–096, doi:10.2151/sola.2010-024, 2010.

42. Tesche, M., D. Müller, S. Gross, A. Ansmann, D. Althausen, V. Freudenthaler, B. Weinzierl, A. Veira and A. Petzold, Optical and microphysical properties of smoke over Cape Verde inferred from multiwavelength lidar measurements, *Tellus*, 63B, 677–694, DOI: 10.1111/j.1600-0889.2011.00549.x, 2011.
43. Vaughan, g., A. P. Draude, H. M. A. Ricketts, D. M. Schultz, M. Adam, J. Sugier, and D. P. Wareing, Transport of Canadian forest fire smoke over the UK as observed by lidar, *Atmos. Chem. Phys.*, 18, 11375–11388, <https://doi.org/10.5194/acp-18-11375-2018>, 2018.
44. Vaughan, g., A. P. Draude, H. M. A. Ricketts, D. M. Schultz, M. Adam, J. Sugier, and D. P. Wareing, Transport of Canadian forest fire smoke over the UK as observed by lidar, *Atmos. Chem. Phys.*, 18, 11375–11388, <https://doi.org/10.5194/acp-18-11375-2018>, 2018.
45. Veselovskii, I, D. N Whiteman, M. Korenskiy, A. Suvorina, A. Kolgotin, A. Lyapustin, Y. Wang, M. Chin, H. Bian, T. L. Kucsera, D. Pérez-Ramírez, and B. Holben, Characterization of forest fire smoke event near Washington, DC in summer 2013 with multi-wavelength lidar, *Atmos. Chem. Phys.*, 15, 1647–1660, doi:10.5194/acp-15-1647-2015, 2015.
46. Wandinger, U., D. Müller, C. Böckmann, D. Althausen, V. Matthias, J. Bösenberg, V. Weiß, M. Fiebig, M. Wendisch, A. Stohl, and A. Ansmann, Optical and microphysical characterization of biomassburning and industrial-pollution aerosols from multiwavelength lidar and aircraft measurements, *J. Geophys. Res.*, 107, NO. D21, 8125, doi:10.1029/2000JD000202, 2002.