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Source characterization of ambient fine aerosol in Singapore during a haze episode in 2015

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Recurring transboundary haze from Indonesia peatland fires in the previous decades has significantly elevated particulate matter (PM) concentration in Southeast Asia, particularly during the 2015 El Niño event. Previous studies have investigated chemical composition of particles emitted during haze episodes; however, they were limited to time-integrated samples and the number of identified compounds. Low time-resolution measurement results in covariance of PM sources; therefore, higher time-resolution measurement is important in PM source apportionment. Between October 10-31, 2015, Aerodyne Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) was deployed for real-time chemical characterization of ambient submicron PM (NR-PM_1) in Singapore. Simultaneously, $PM_{2.5}$ filter samples were collected for molecular-level organic aerosol (OA) constituents, organic carbon (OC), elemental carbon (EC) and water-soluble OC (WSOC) analyses. OA constituents were quantified by gas chromatography interfaced to electron ionization mass spectrometry (GC/EI-MS) and ultra-performance liquid chromatography interfaced to electrospray ionization high-resolution quadrupole time-of-flight mass spectrometer operated in the negative ion mode (UPLC/(-)ESI-HR-Q-TOFMS). OA and SO_4^{2-} are dominant components of the haze particles, accounting for ∼77% and ∼12% of the total NR-PM_1 mass, respectively. OC/EC ratio of 4.8 might indicate formation of secondary OA (SOA) and aerosols from biomass burning, including those from peat burning. OA fraction from ToF-ACSM measurements was analyzed for source apportionment using a bilinear model through multi-linear engine algorithm (ME-2) in graphical user interface SoFi (Source Finder). Five OA factors were identified: hydrocarbon-like OA (HOA), biomass burning OA (BBOA), peat burning OA (PBOA), low-volatility oxygenated OA (LV-OOA), and semi-volatile oxygenated OA (SV-OOA). The HOA factor shows a distinct diurnal profile peaking in the morning and evening, suggesting traffic influences. The BBOA factor was identified based on factor profile of wood burning particles and correlated with known biomass burning tracers (i.e. levoglucosan and mannosan). The PBOA factor was identified based on factor profile of laboratory-generated peat burning particles. This factor would be further identified with OA constituents in peat burning particles, such as brown carbon constituents. The LV-OOA and SV-OOA factors peak in the afternoon indicating they were likely formed through photochemistry. The LV-OOA factor might be a product of biomass burning aerosol aging as indicated by temporal trend correlations with BBOA and PBOA factors (r^2 = 0.7–0.8). Contributions of the HOA and SV-OOA factors to OA mass are ∼12% and ∼21%, respectively. The biomass burning-related factors (BBOA and PBOA) account for ∼29% of OA mass, which likely indicates a lower-bound estimate of the transboundary impacts of primary emissions from peatland fires. The transboundary impacts of secondary aerosol from peatland fires might be represented by the LV-OOA factor accounting for ∼37% of OA mass. Overall, the transboundary haze could contribute to ∼66% of OA concentration, suggesting the strong influence of Indonesia peatland fires on the air quality of Singapore.