Identification of key aerosol types in Athens: Optical properties and the curvature effect in spectral scattering and absorption coefficients

D.G. Kaskaoutis[1,2], G. Grivas[1], I. Stavroulas[1], E. Liakakou[1], A. Bougiatioti[1], U.C. Dumka[3], K. Dimitriou[1], E. Gerasopoulos[1], N. Mihalopoulos[1,2]

[1]Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Greece
[2]Environmental Chemical Processes Laboratory, Department of Chemistry, University of Crete, Greece
[3]Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India

NATIONAL OBSERVATORY OF ATHENS
ATMOSPHERIC PHYSICS AND CHEMISTRY GROUP

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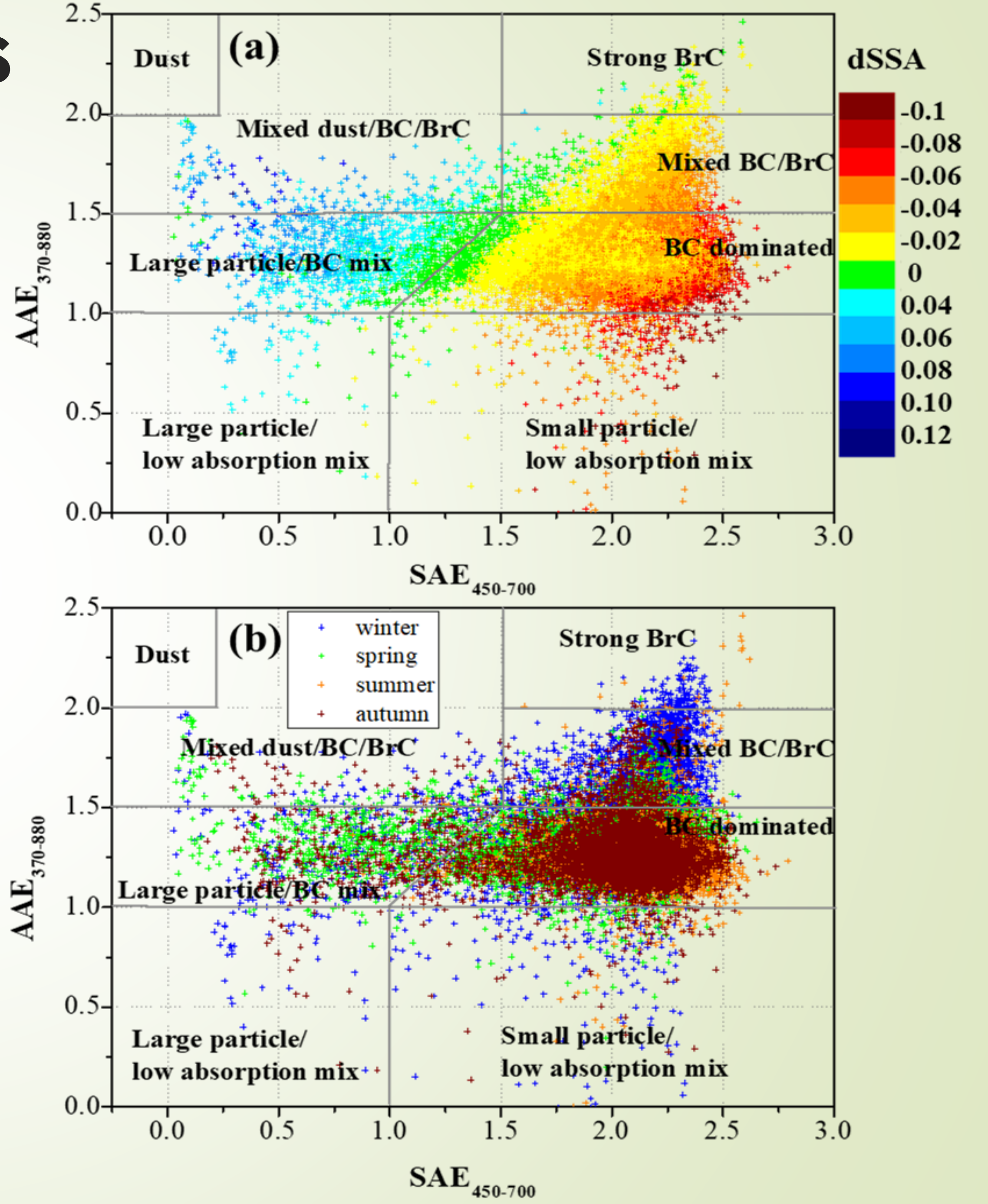
Scope and objectives

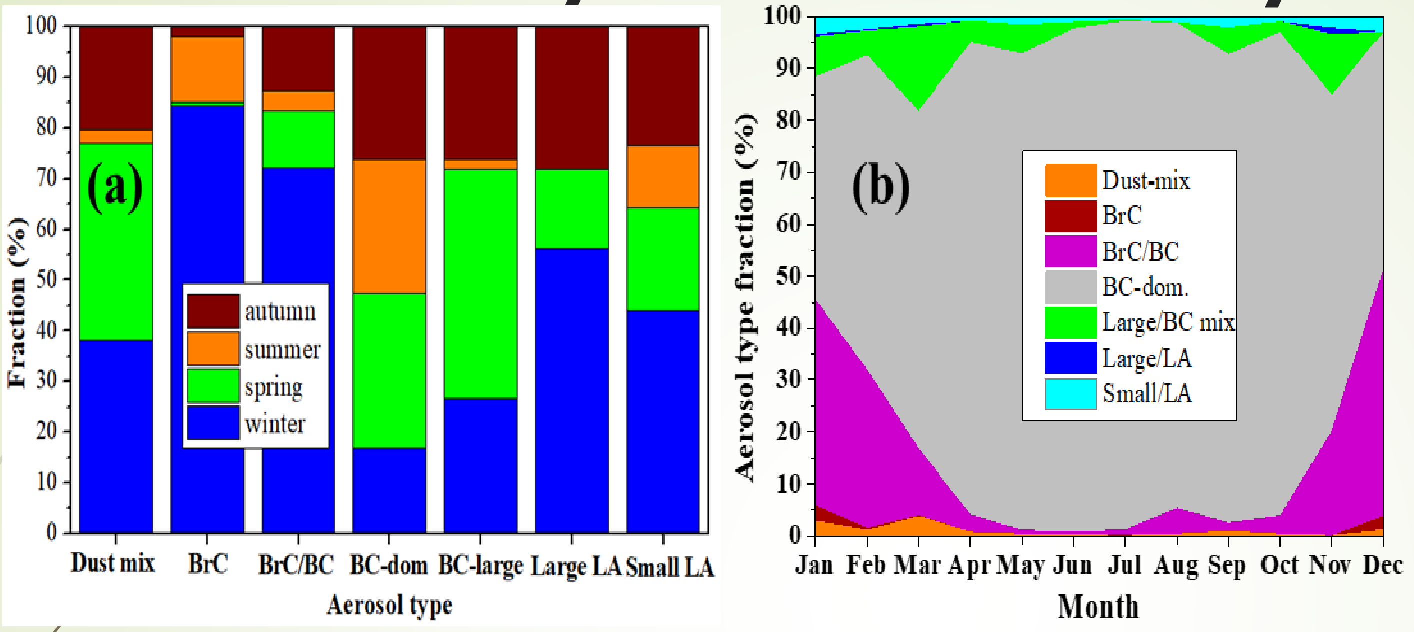
- Classification of key aerosol types in Athens based on in situ measurements (Thissio station)
- 3-year data (Oct. 2016-Sep. 2019) from Nephelometer, Aethalometer (AE-33), along with available fine-aerosol chemical composition (ACSM), meteorological observations, PM10 concentrations and trace gases (NOx, O3, CO). [hourly-averaged datasets]
- Classification matrix based on SAE vs. AAE (Cappa et al., 2016, ACP)
- Seasonality of types, monthly fractions, diurnal patterns, optical properties, chemical composition, sources and linkages with meteorology
- Examination of the curvature of spectral scattering and absorption for different aerosol types and atmospheric conditions in December 2017 and March 2018.

Identified aerosol types

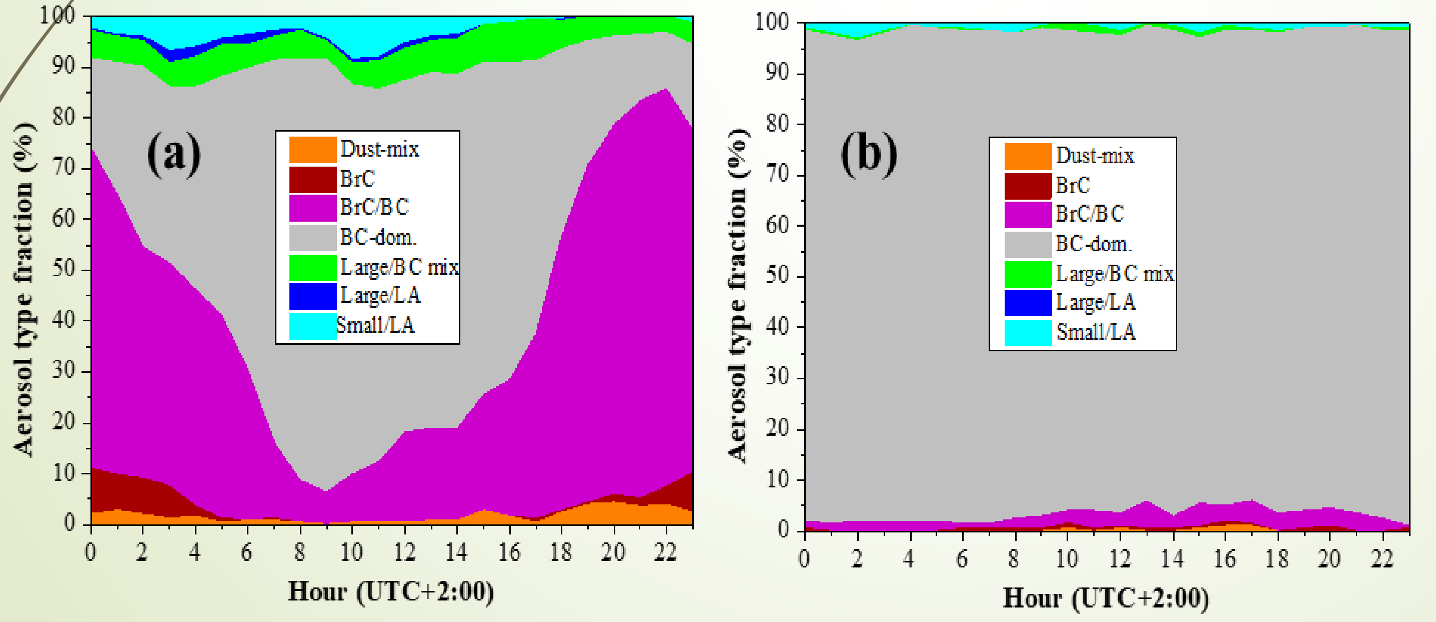
- Classification scheme $SAE_{450\text{-}700}$ vs. $AAE_{370\text{-}880}$ [Cappa et al. 2016] for identification of aerosol types in Athens, color-coded by $dSSA_{470/660}$ [SSA_{660}-SSA_{470}] (a) and season (b).
- "BC-dominated" (76.3%), "BrC/BC" (14.3%), "large/BC mix" (5.3%), "BrC" (0.65%), "dust-mix" (1.2%), small particles with low absorption efficiency (1.9%), large particles with low absorbing efficiency (0.32%).



Seasonality and diurnal cycles

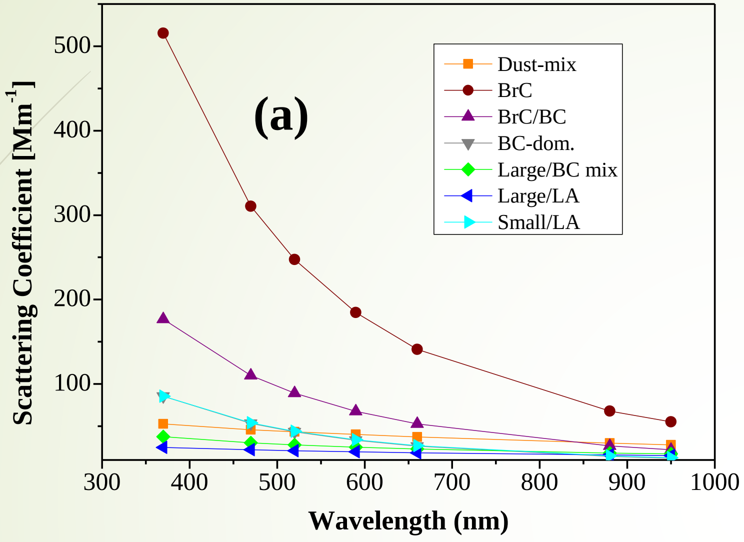


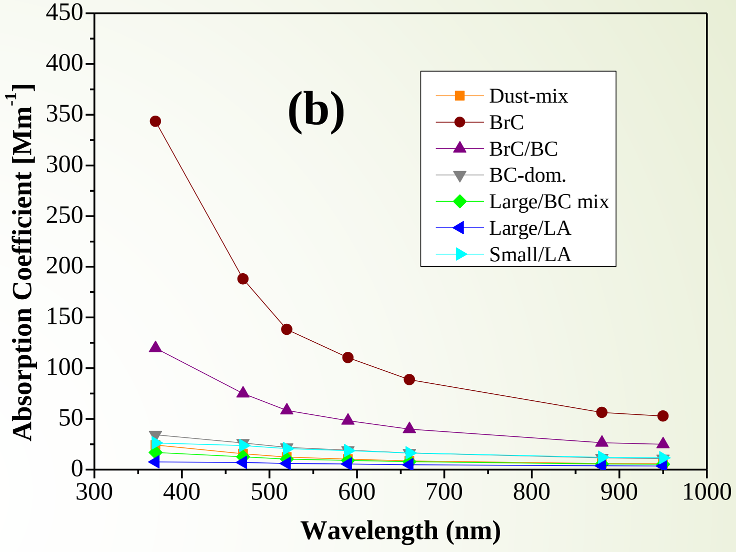
Seasonal fractions of occurrence for each aerosol type (a) and monthly variation of the cumulative percentage frequency of each aerosol type (b).

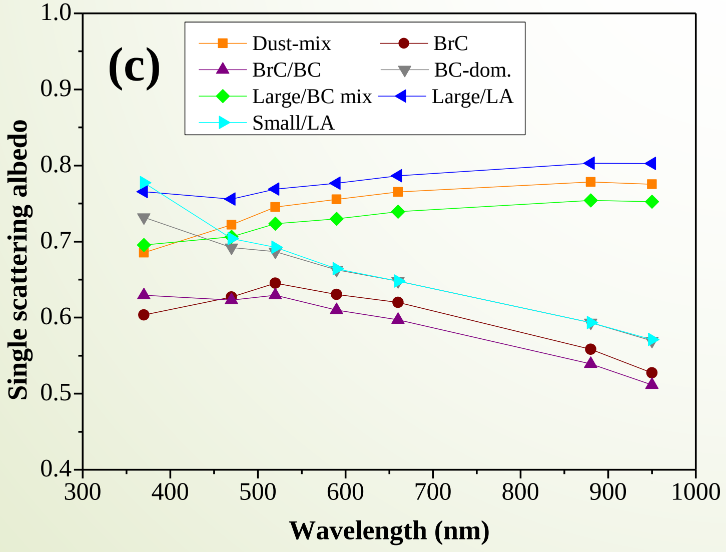


Diurnal variation of the cumulative percentage frequency for each aerosol type during winter (left) and summer (right).

Optical properties of aerosol types



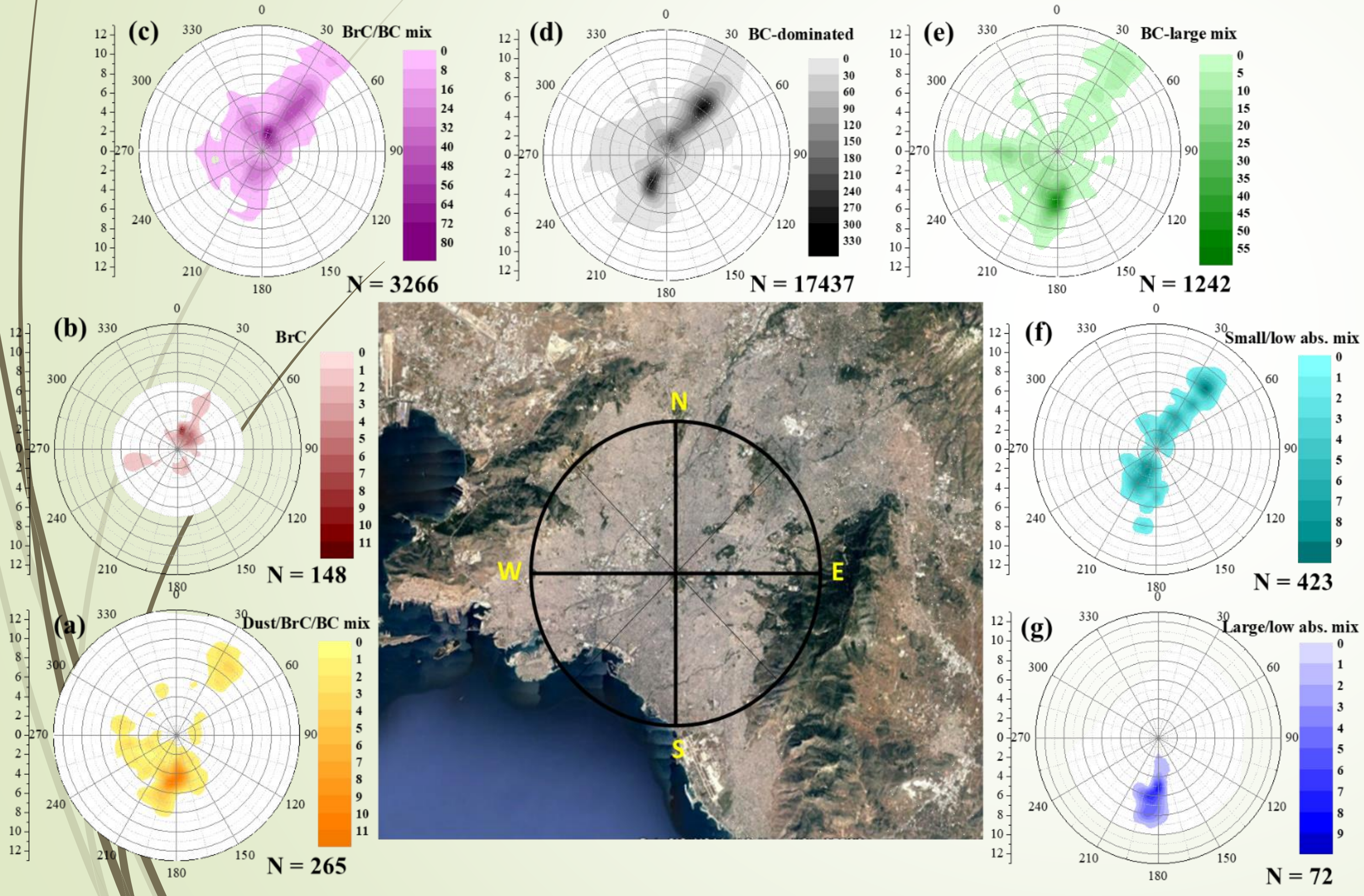




Large increase of scattering/absorption at short wavelengths for BrC and BrC/BC types (turbid conditions: strong BB-OA effect at short wavelengths).

Contrasting spectral dependence of SSA consisted with literature.

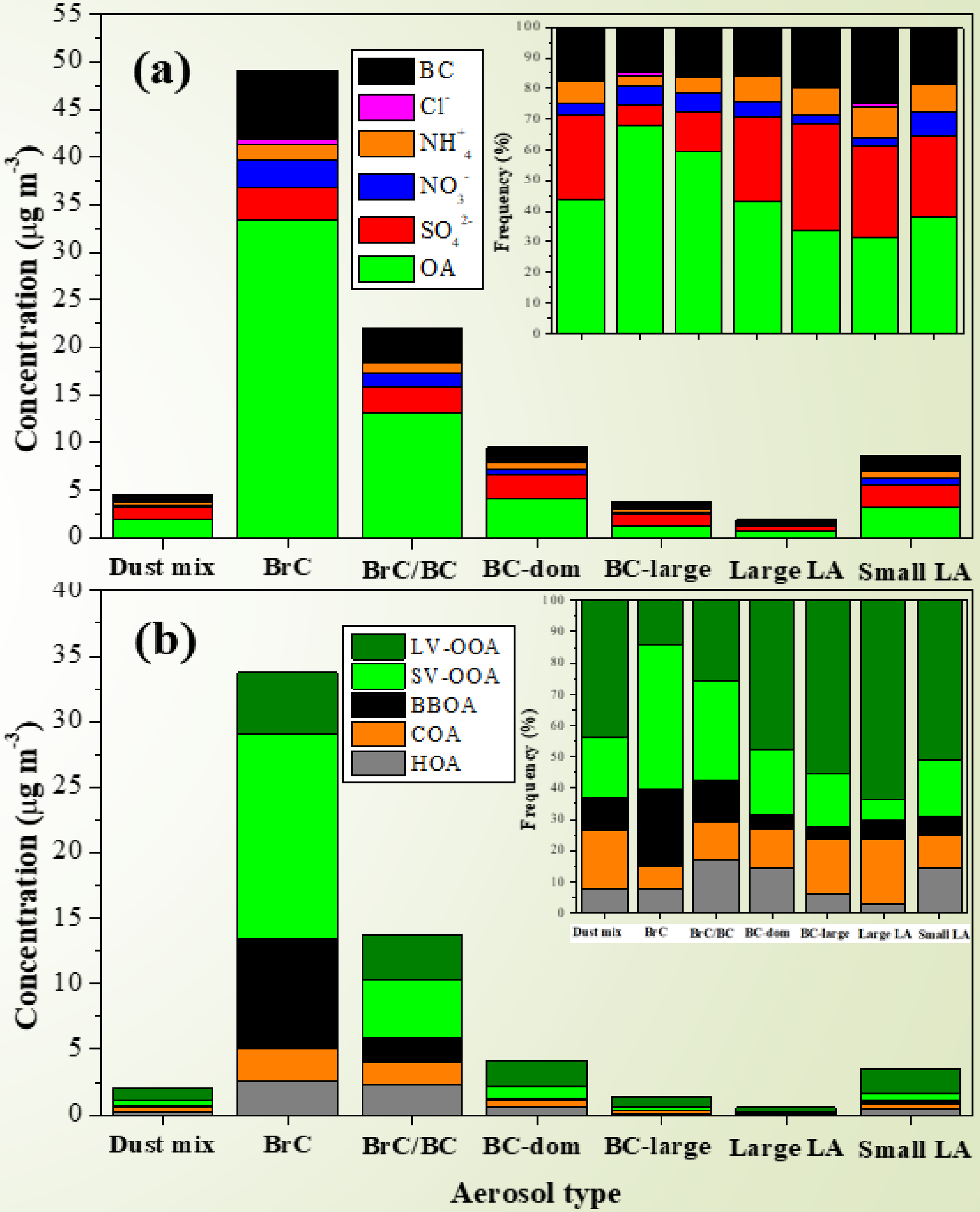
Sources, sectors and influence of meteorology



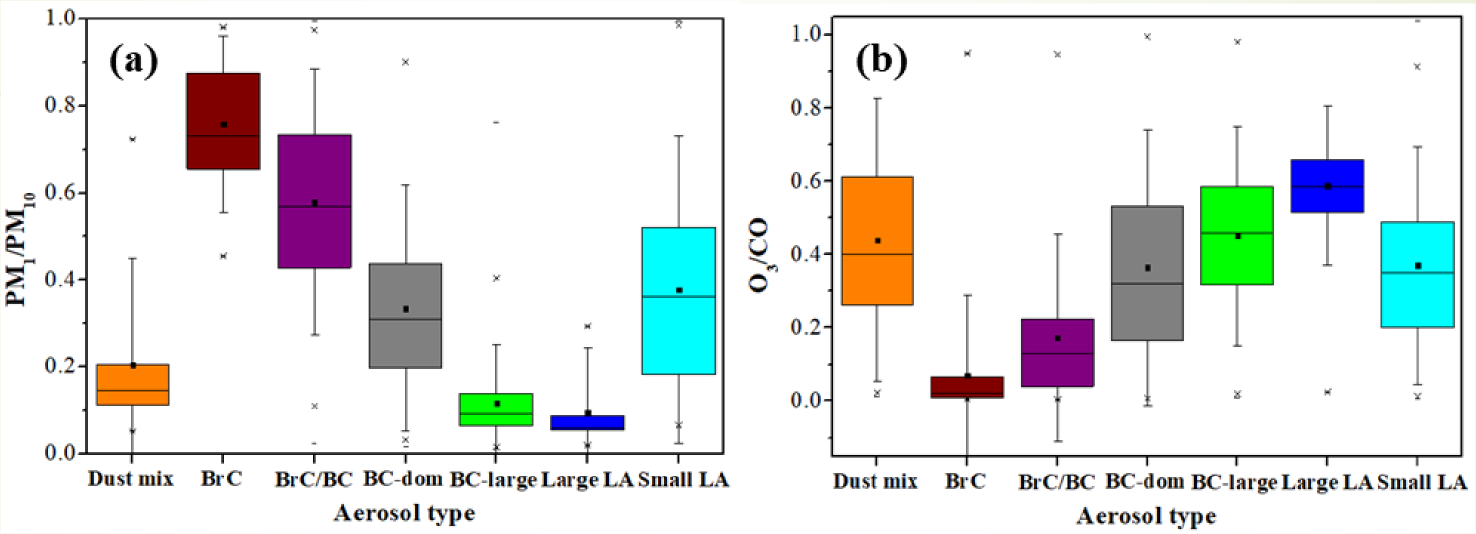
- Wind roses for the frequency of occurrence of each aerosol type. The map of the greater Athens area is shown with the centre in the monitoring site (Thissio).
- BrC, BrC/BC mix from northern directions (buildings with fireplaces in N. Athens suburbans.
- Dust-mix, from southern directions (Sahara dust plumes).
- Large/LA from southern directions (effect from marine sea salt)
- BC-dom, large/BC from several directions, effect from traffic and regional sources within and around the Athens basin.

Chemical composition of aerosol types

- Large organic and BBOA content for “BrC”, “BrC/BC” types due to residential wood burning
- Larger SO_4^{2-} for more regional types
- BC contributes 15-20% in all aerosol types
- Processed types (“large/BC mix”, “large/LA”) exhibit high LV-OOA fractions
- Highest HOA fraction for BrC/BC and BC-dom type

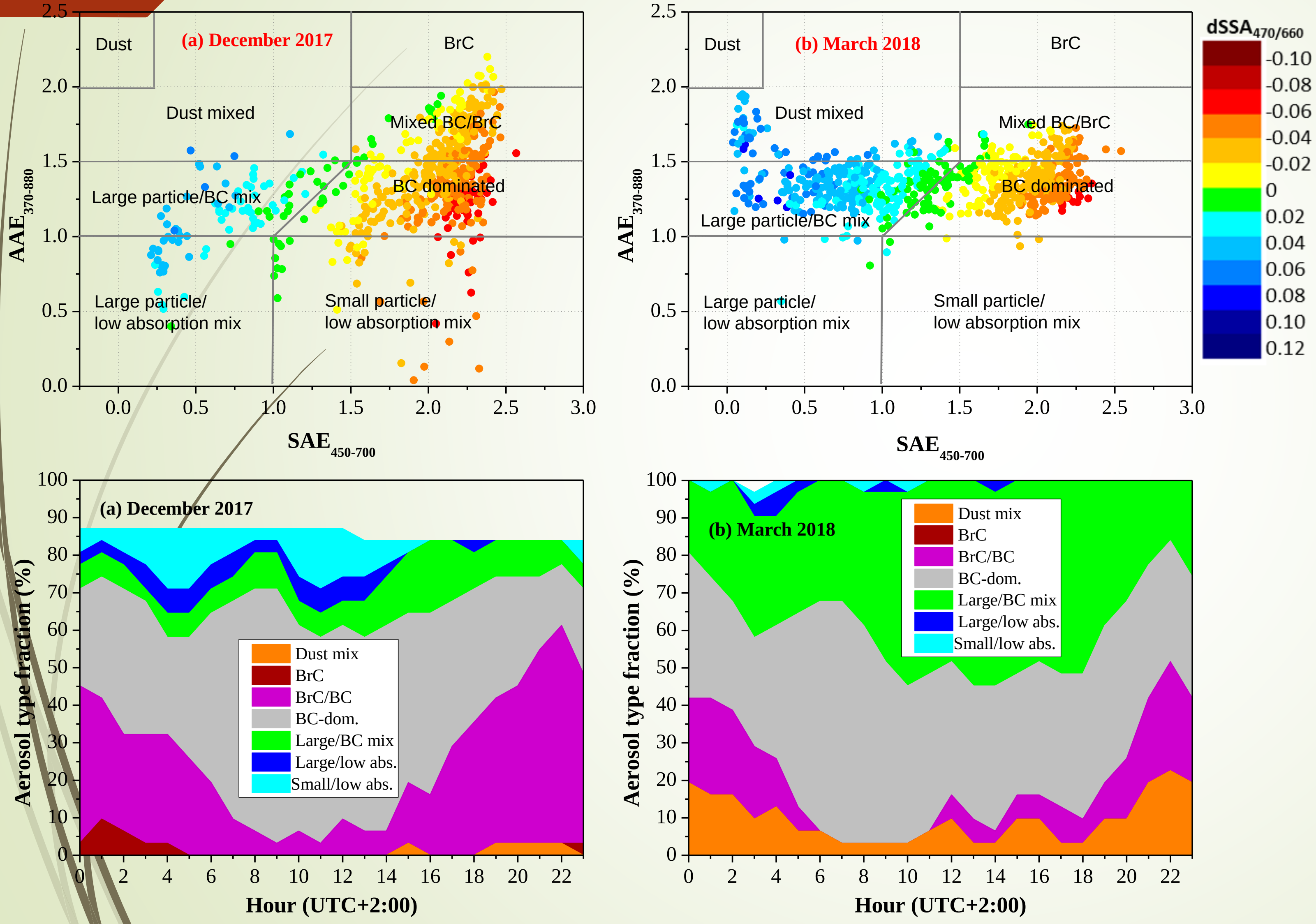


Chemical composition of aerosol types



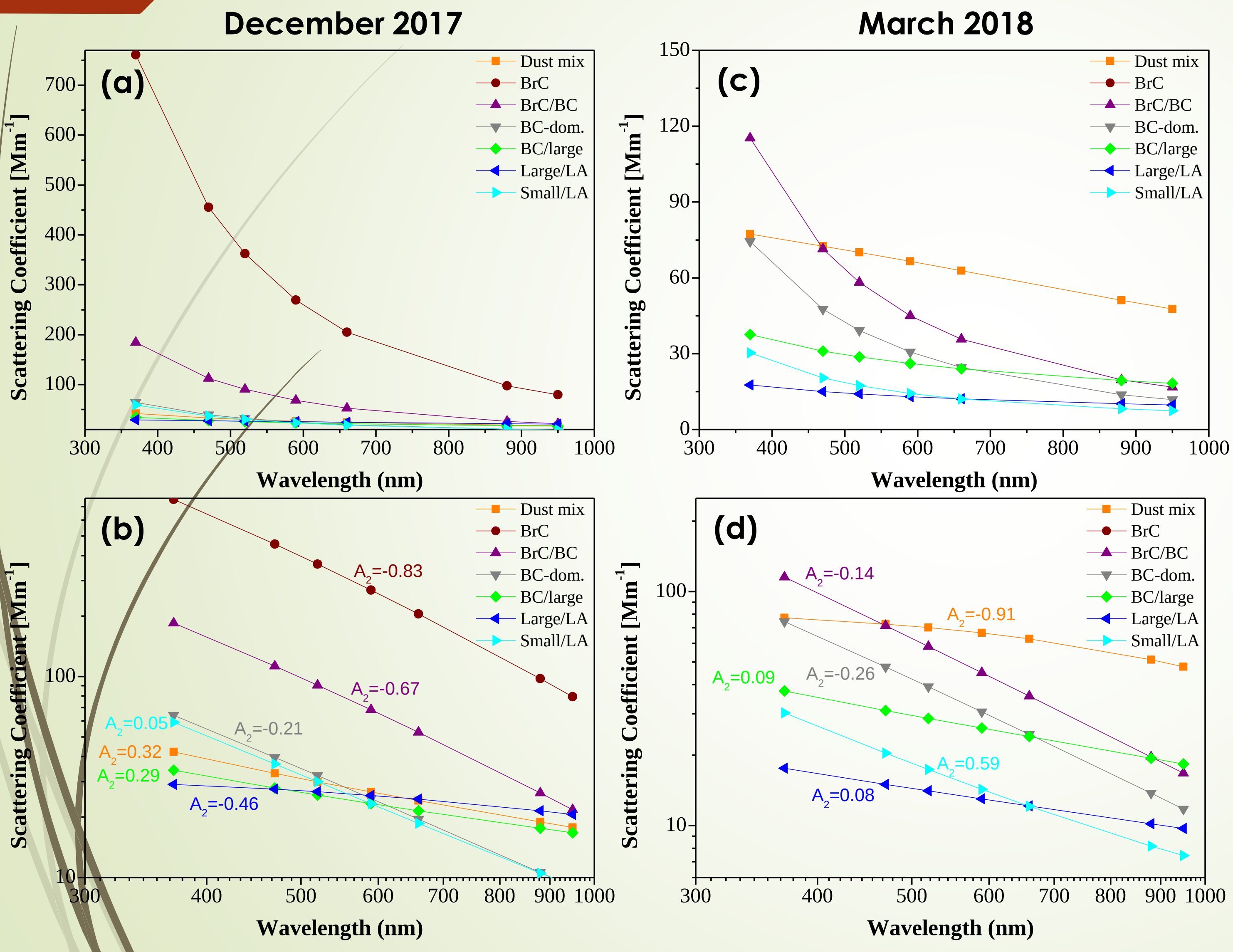
- Box-whisker plots of PM1/PM10 (a), and O3/CO (b) for the various identified aerosol types in Athens. PM1 equals the ACSM mass plus BC.
- "BrC", "BrC/BC" correspond to fine aerosols.
- Local fresh emissions for "BrC", "BrC/BC" (low O3/CO), atmospheric aging for "large/BC mix", "large/LA", "dust-mix" (high O3/CO).

Aerosol types in contrasting months



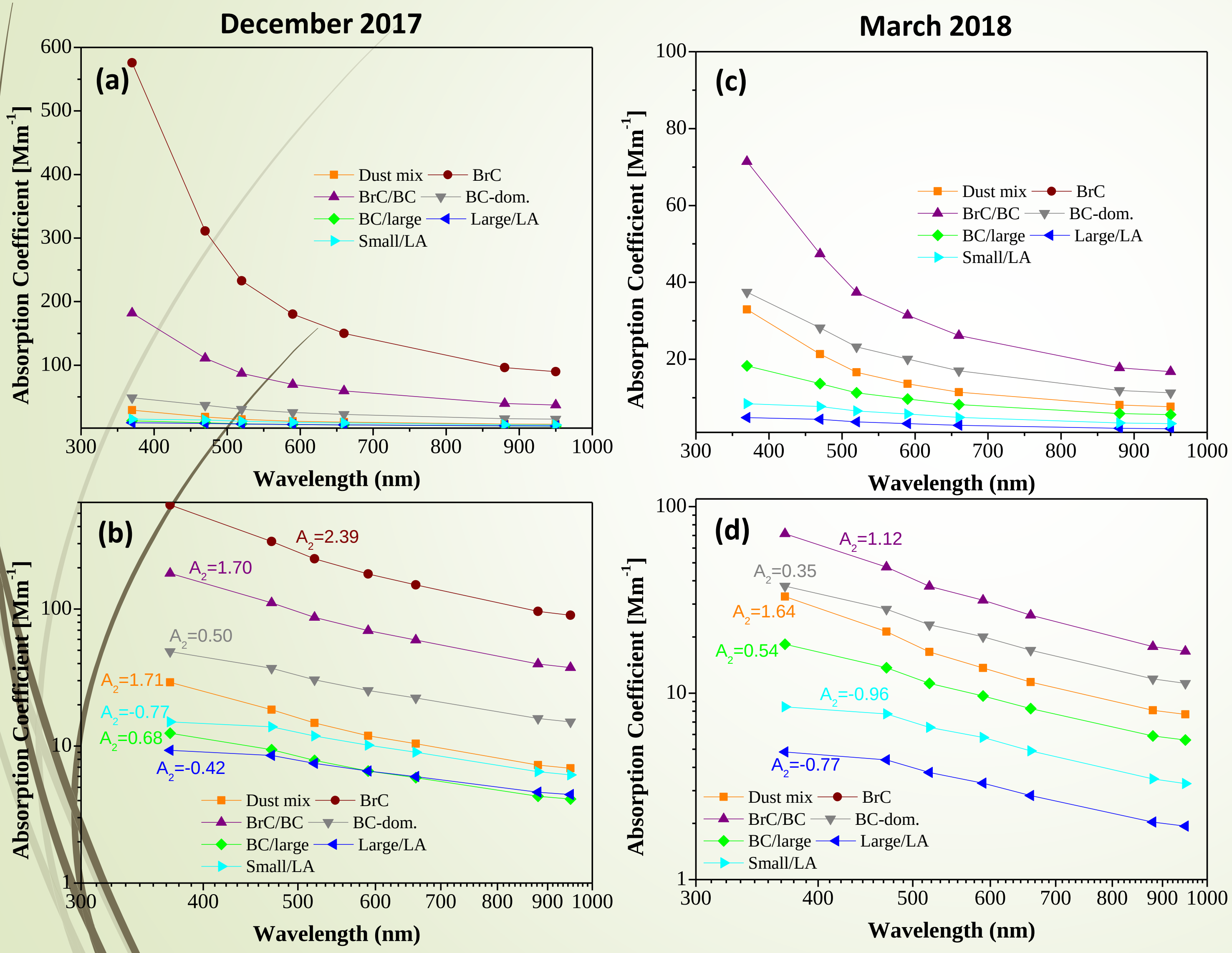
- December 2017: High wood burning emissions
- March 2018: Dusty conditions
- Presence of all aerosol types in both months
- BrC, BrC/BC mix at nights: residential wood burning effect

Spectral scattering



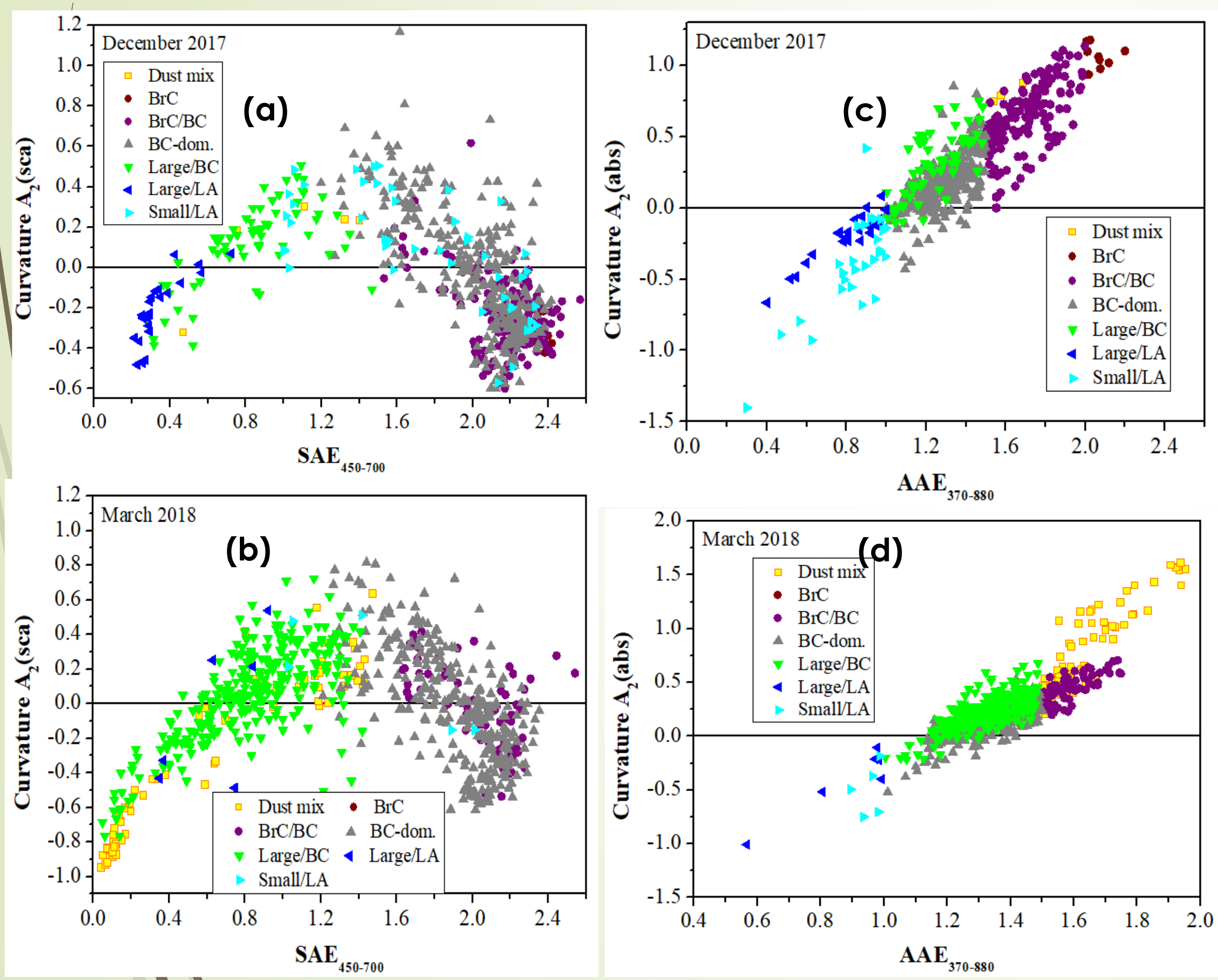
- Spectral scattering coefficient in normal and log-log coordinates for the various aerosol types in Dec. 2017 and March 2018
- Negative scattering curvature (concave curves) for the BrC/BC and BrC types.
- Negligible curvature for BC-dom aerosols
- Contrasting curvature effect for the dust-mix type
- More research is needed to examine if findings (i.e. for dust) are reproduced in other environments

Spectral absorption



- Spectral absorption coefficient in normal and log-log coordinates for the various aerosol types in Dec. 2017 and March 2018
- Positive absorption curvature (convex curves) for all aerosol types, more intense for BC, BrC types and dust.
- Negligible curvature for BC-dom aerosols
- With increased absorption at short wavelengths by presence of BrC and dust aerosols, the curvature increases

Scattering/absorption curvature for aerosol types



- Contrasting scattering curvature (A2,sca: left) with SAE values. Mostly negative (concave-type curves for BrC, BrC/BC mix, BC-dom aerosols.
- Contrasting A2,sca values for the dust-mix type in March 2018.
- The A2,abs increases with AAE, indicating large curvature and higher increasing rates of absorption at short wavelengths for dust and BrC aerosol types.
- This approach provides new insights into the differentiation of aerosol types.

Conclusions

Main characteristics of the aerosol types

BC-dominated" aerosol (76.3%): Moderate levels of scattering and absorption, low SSA (0.69), fine-mode aerosols. Mainly from fossil-fuel combustion and photo-chemical processes. Composed by organics (43%), sulfate (27%) and BC (16%).

BrC/BC" (14.3%): Dominant in winter nights, large wood burning content mixed with BC from fossil fuels. High organic content (60%).

BrC (0.65%): High turbid conditions, winter nights, calm winds, intense residential wood burning.

large/BC mix (5.3%): More frequent in spring, reflects aged processed BC mixed with coarse particles.

dust-mix (1.2%): Mixture of transported dust with urban pollution, dominant in spring, high PM10 levels, low absorption.

small/LA (1.9%): Urban aerosols with enhanced presence of sulfate and nitrate, fine aerosols, processed organics (AAE< 1).

large/LA (0.32%): Clean conditions, strong winds, weak influence of local combustion sources. High possibility to carry marine aerosols.