# IMPACTS OF SEVERE RESIDENTIAL WOOD BURNING ON ATMOSPHERIC PROCESSING, WATER-SOLUBLE ORGANIC AEROSOL AND LIGHT ABSORPTION, IN A MEDIUM-SIZED CITY OF SOUTHEASTERN EUROPE

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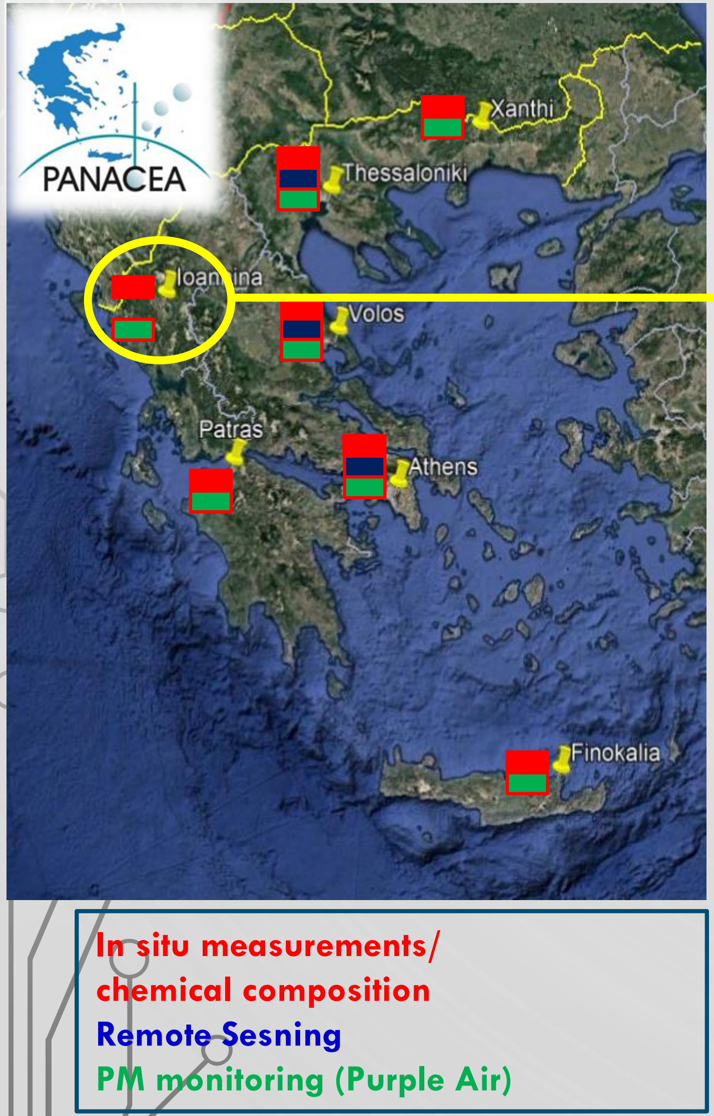
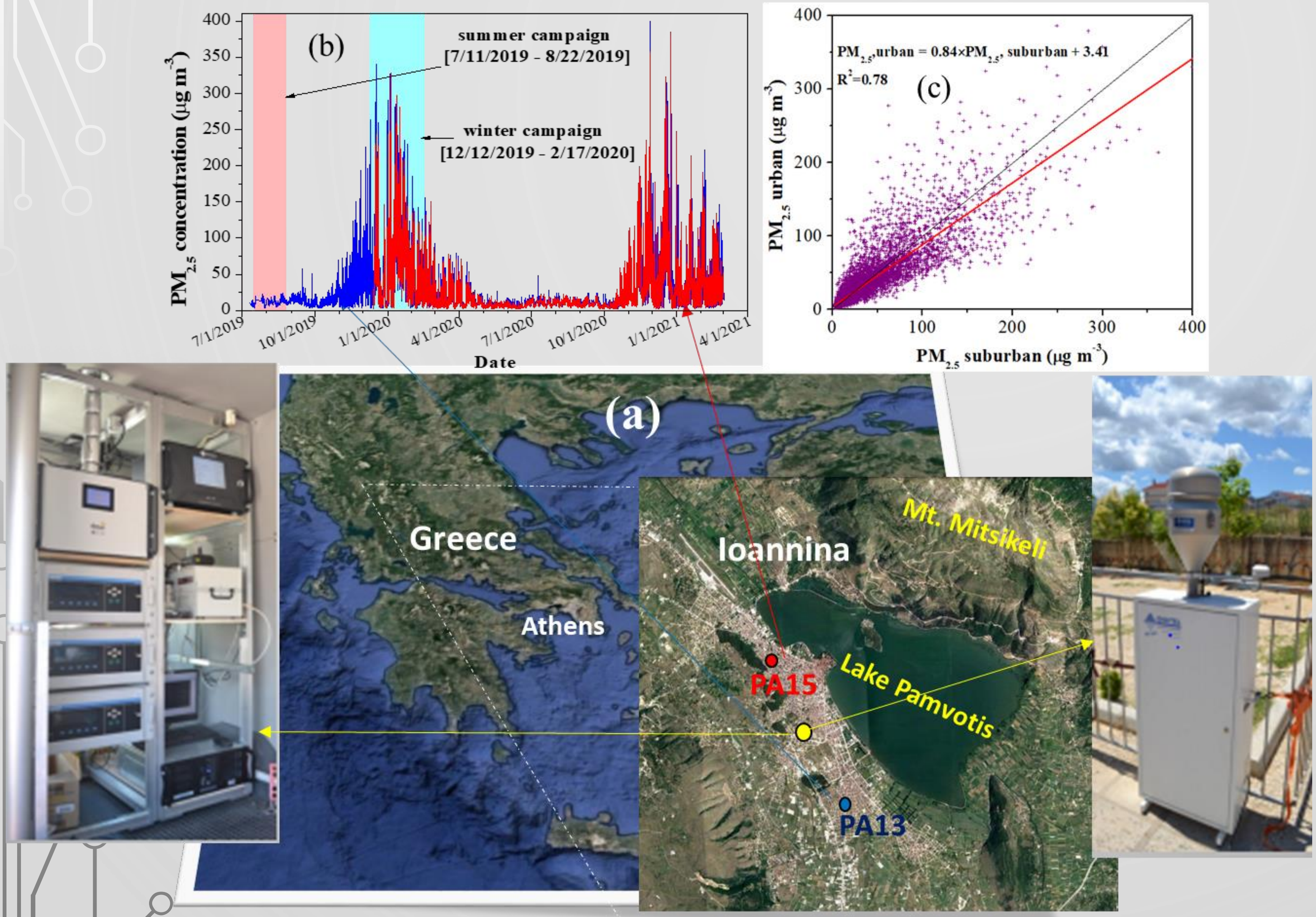
# RESEARCH CAMPAIGNS IN GREEK CITIES DURING PANACEA




- Scope: Investigation of atmospheric aerosols (physical, chemical, optical properties) & air pollution levels in Greek cities, exploring the sources and health effects.
- Ioannina Campaigns: Summer 2019 (July-August), Winter 2019/20 (December-February)
- **Measurements in Ioannina:**
- Aethalometer AE-33 [$BC_{ff}$, $BC_{wb}$, spectral absorption, AAE]
- Chemical analysis of 24-hrs $PM_{2.5}$ samples (inorganic ions, OC, EC, sugars) [Ion Chromatography for Ions, Sunset OC/EC analyzer, Shimadzu TOC-VCSH total OC analyzer for WSOC mass, High-Performance Anion Exchange Chromatography with Pulsed Amperometric Detection (HPAEC-PAD) for monosaccharide anhydrides, sugar alcohols]
- Online Purple Air monitors ($PM_{2.5}$)
- Online measurements of air pollutants ($PM_{10}$, $NO_X$, CO, $O_3$)
- Meteorological parameters (temperature, RH, rainfall, wind speed, direction)

# PM2.5 IN IOANNINA




- Sampling measurements at the urban-background site Kiafa (yellow)
- Two sites (urban-red, suburban–blue for $PM_{2.5}$ measurements
- Extremely high $PM_{2.5}$ levels (> 250 μg $m^{-3}$) in winter nights due to RWB emissions.
- High consistency of $PM_{2.5}$ levels between urban and suburban sites, indicates homogeneous pollution conditions in the Ioannina Basin
- Very low $PM_{2.5}$ levels < 25 μg $m^{-3}$ in summer

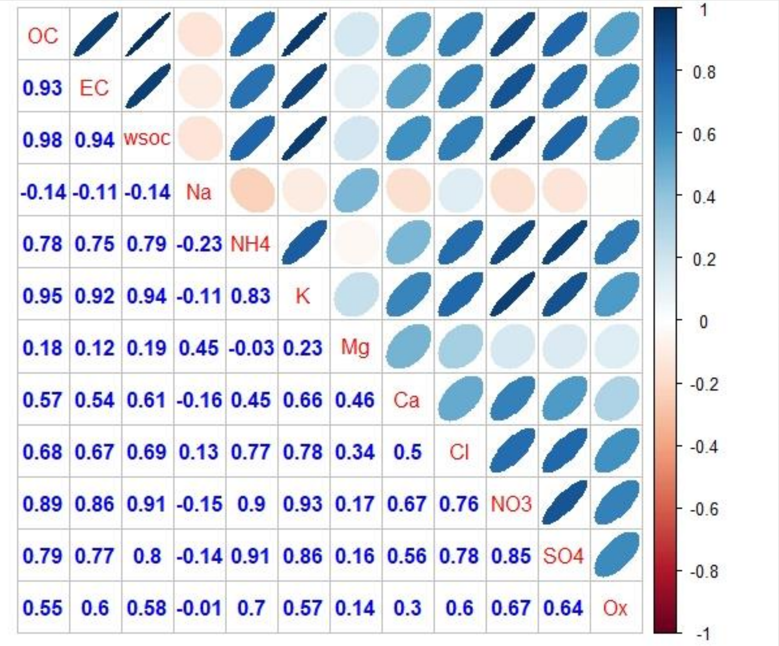
# CHEMICAL COMPOSITION OF FINE AEROSOL DURING WINTER

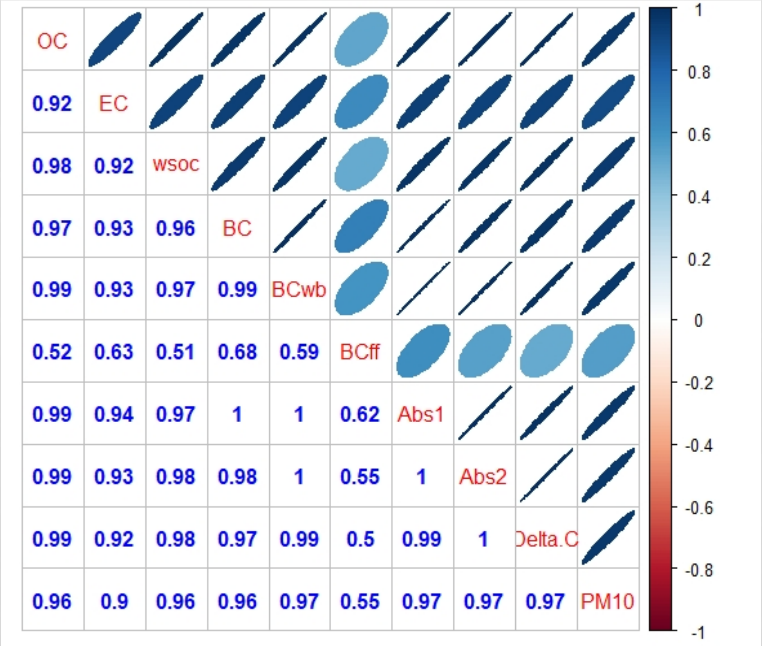
| Parameter | Winter (mean) | Summer (mean) | Ratio (mean) | Ratio (median) |
|---|---|---|---|---|
| $PM_{2.5}$ (μg $m^{-3}$) | 57.5 | 13.5 | 4.24 | 3.84 |
| BC (μg $m^{-3}$) | 5.23 | 1.04 | 5.03 | 4.49 |
| $BC_{ff}$ (μg $m^{-3}$) | 0.76 | 0.89 | 0.85 | 0.69 |
| $BC_{wb}$ (μg $m^{-3}$) | 4.47 | 0.15 | 29.8 | 30.7 |
| OC (μg $m^{-3}$) | 26.0 | 2.59 | 10.1 | 8.62 |
| EC (μg $m^{-3}$) | 2.44 | 0.41 | 5.95 | 6.11 |
| WSOC (μg $m^{-3}$) | 13.6 | 1.78 | 7.71 | 6.68 |
| WIOC (μg $m^{-3}$) | 12.3 | 0.81 | 15.2 | 12.08 |
| Levoglucosan (ng $m^{-3}$) | 6044 | 5.48 | 1103 | 1318 |
| Mannosan (ng $m^{-3}$) | 235.4 | 2.77 | 84.9 | 121.6 |
| Galactosan (ng $m^{-3}$) | 196.9 | 0.15 | 1312 | - |
| Mannose (ng $m^{-3}$) | 28.79 | 1.81 | 15.9 | 15.3 |
| Glucose (ng $m^{-3}$) | 21.11 | 8.50 | 2.48 | 2.92 |
| Inositole (ng $m^{-3}$) | 19.18 | 1.37 | 14 | 5.78 |

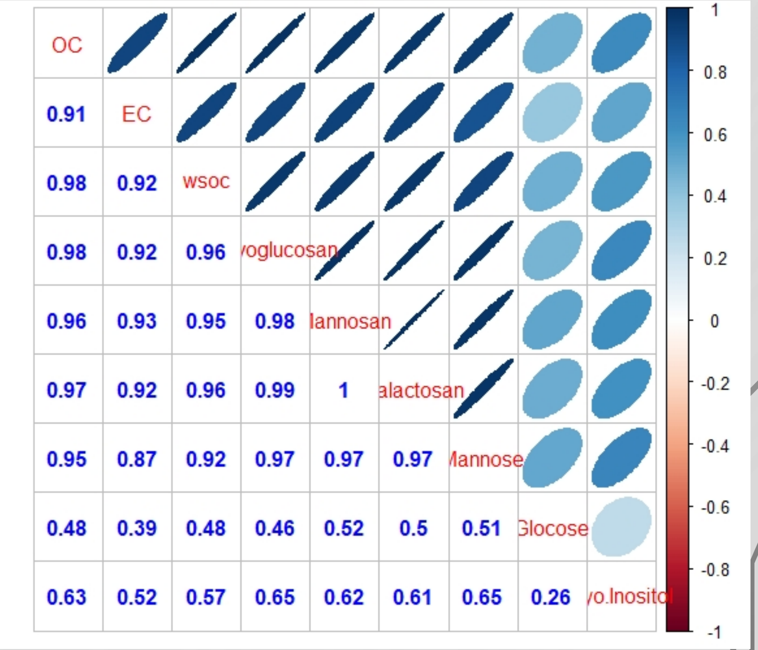
- Very high mean $PM_{2.5}$ concentrations in winter
- BB%: 79.5% in winter, 17% in summer
- Very high OC levels (26 μg $m^{-3}$) in winter; 4-5-times above the Athens levels in winter
- OC/EC ratio: 9.9 (winter), 7.0 (summer)
- WSOC/OC: 56 ± 9% (winter), 64 ± 10% (summer). High solubility of organic aerosol near to wood-burning source
- Extremely high (urban world record) levoglucosan concentrations (mean of 6 μg $m^{-3}$, daily max: 15.9 μg $m^{-3}$) in winter. Winter/summer ratio of 1100!
- Lev/OC: **22.3%** [8.14% suggested by literature for biomass-burning source]

# CORRELATION BETWEEN AEROSOL SPECIES DURING WINTER

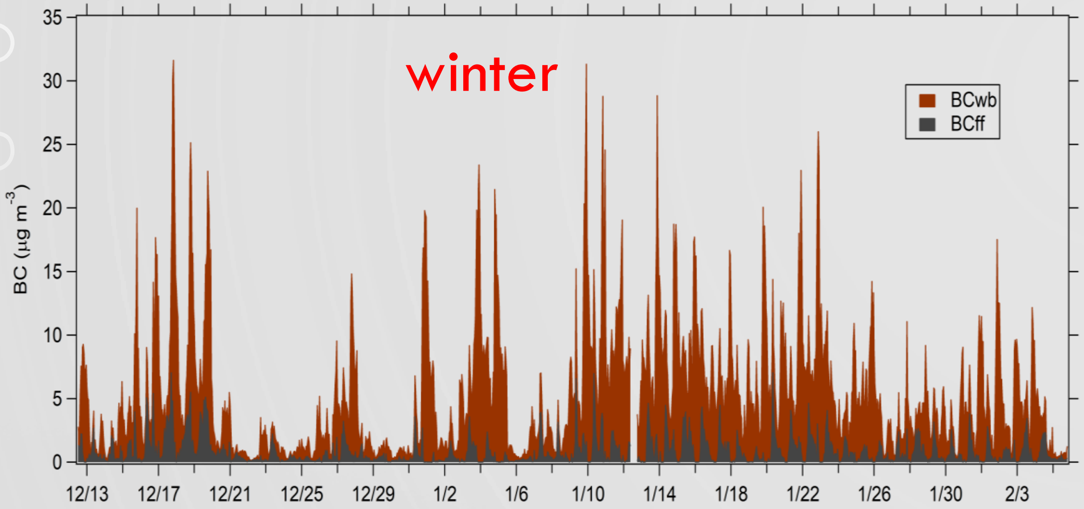
- Very high correlations of carbonaceous aerosols with inorganic species (except $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$)
- Very high correlations of OC, EC with $BC_{wb}$ (less with $BC_{ff}$), absorption at 370 nm and $PM_{10}$.
- Very high correlations between OC, EC, WSOC with sugars (Lev., Man., Gal.,) (except of glucose, Myo-inositol).
- Very low $NA^{+}$-$Cl^{-}$ (r=0.13) correlation and strong correl. of OC – $Cl^{-}$ (r=0.68): Combustion of chlorinated wood materials
- **Overall analysis reveals intense BB conditions with low contribution from traffic or any other source during winter.**

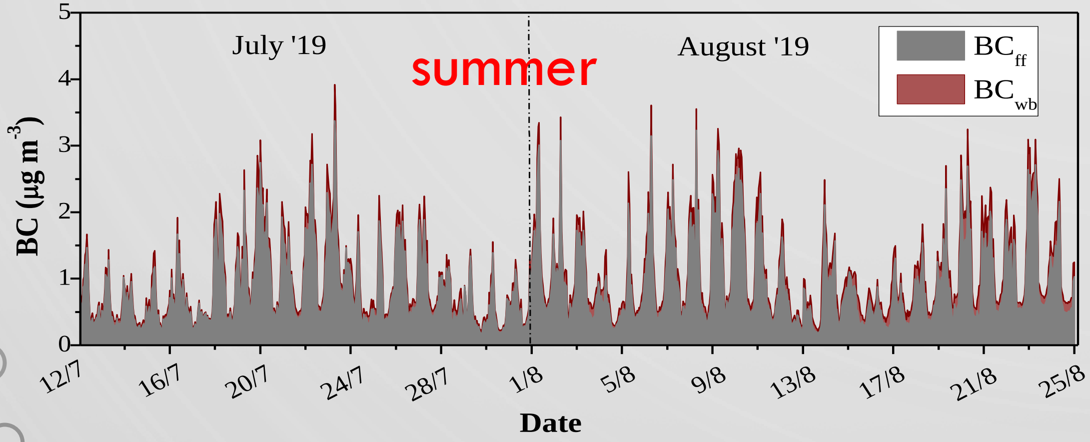


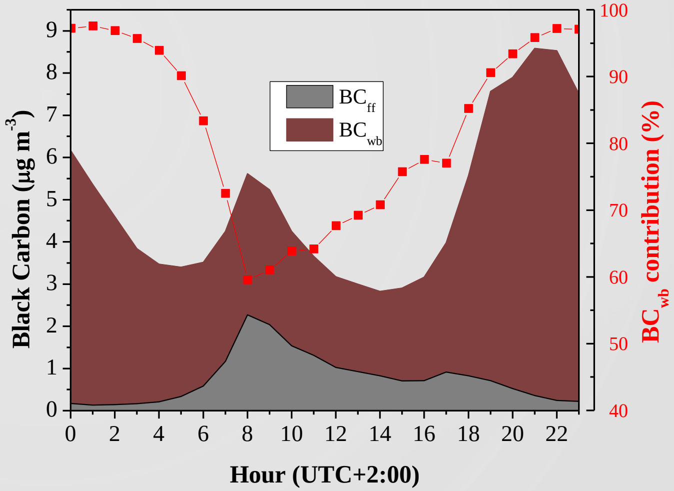



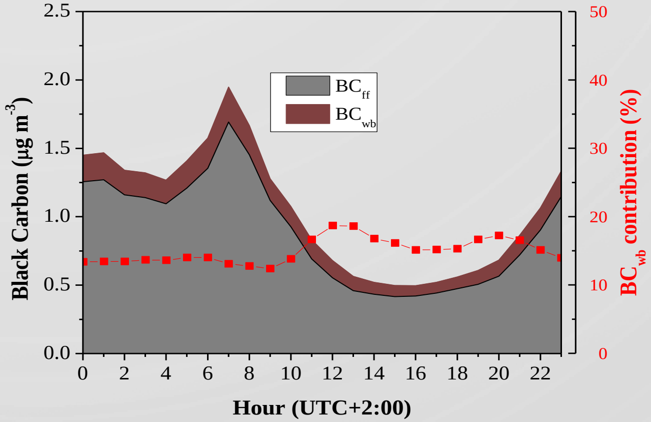



# BC CONCENTRATION AND SOURCES IN IOANNINA



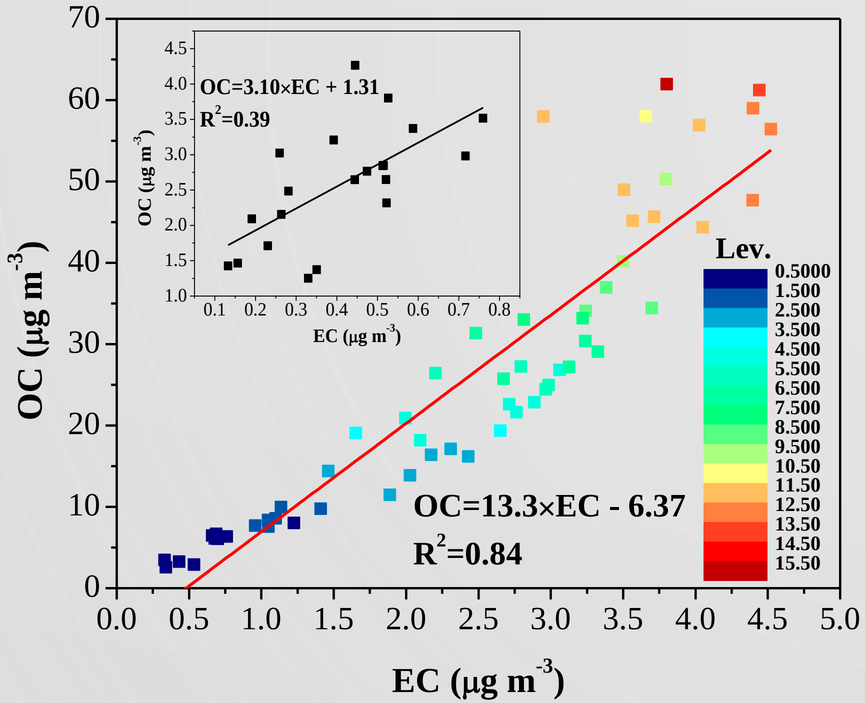



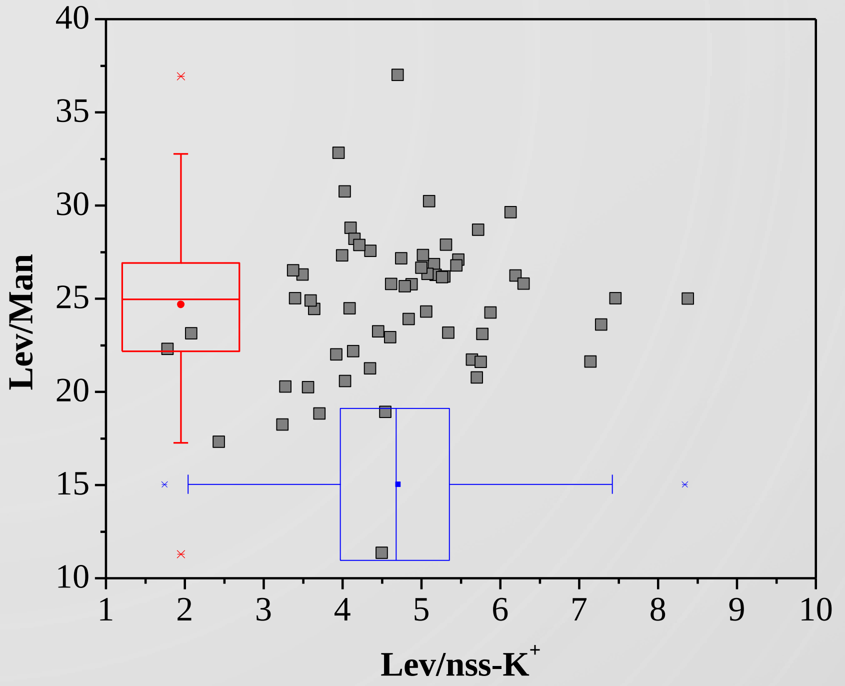




Hourly variation and diurnal cycles of $BC_{ff}$, $BC_{wb}$ in Ioannina during the winter and summer campaigns. High-resolution (1-min) AE-33 measurements.

- ❑ Clear dominance of $BC_{wb}$ throughout the day in winter, (BB% above 90% during nighttime). Traffic effect is limited during morning, with a secondary small increase during early evening.
- ❑ Predominance of $BC_{ff}$ in summer throughout the day. Nearly constant contribution of non-$BC_{ff}$ (15-18%). Increase of $BC_{ff}$ during morning rush hour and late evening/night due to traffic in summer.

# CARBONACEOUS AEROSOL (SAMPLING MEASUREMENTS)

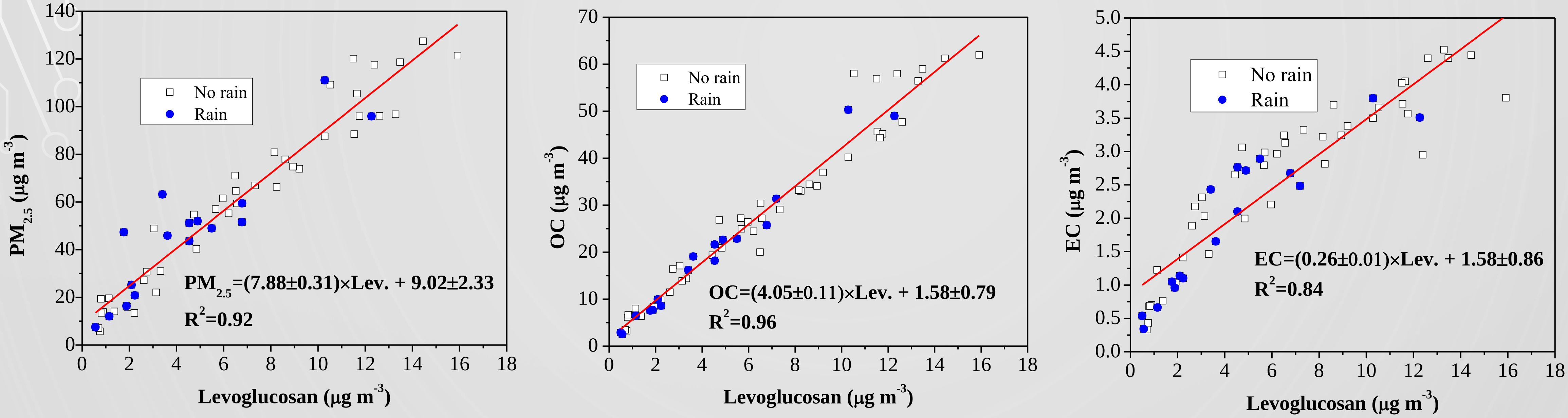



High correlation of OC – EC during winter, indicative of common combustion sources. Much lower OC –EC relationship in summer $R^2$=0.39) indicating mixing of local combustion sources (mostly traffic), with regional transported aerosols, SOC formation and biogenic OC emissions.

All winter samples fall within the hardwood burning area that is defined by Lev/Man ratios higher than 10 and Lev/nss$K^+$ ratios between 1 and 10. This indicates extensive burning of hardwood like oak, beech, yew and/or fruit trees for domestic heating. Relatively low variability of the ratio values denotes homogeneous RWB conditions during the winter campaign.

# BB CONTRIBUTION TO PM2.5 AND CARBONACEOUS AEROSOLS



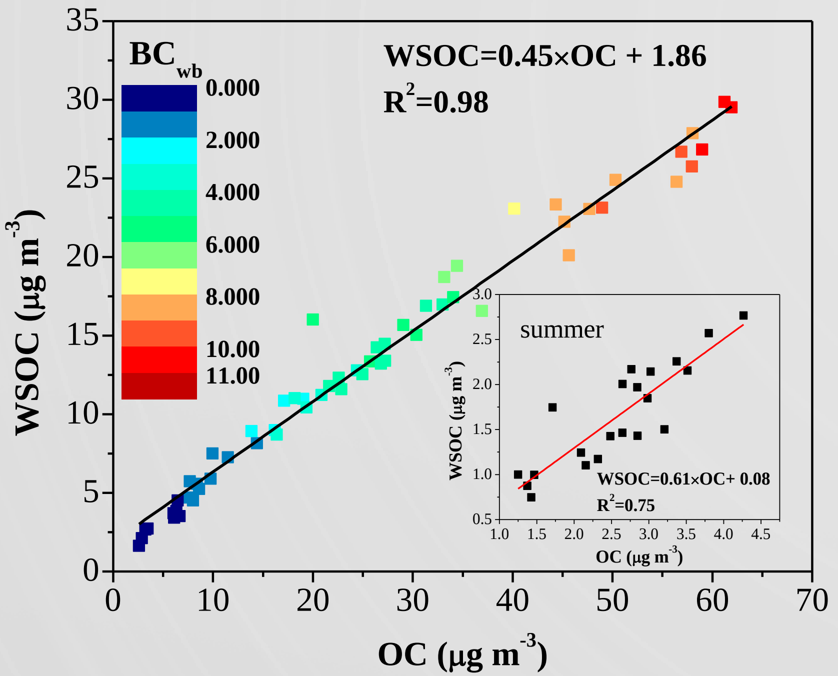

The Lev/OC ratio has been widely used to identify episodes of BB and/or to quantify BB contribution to organic mass.

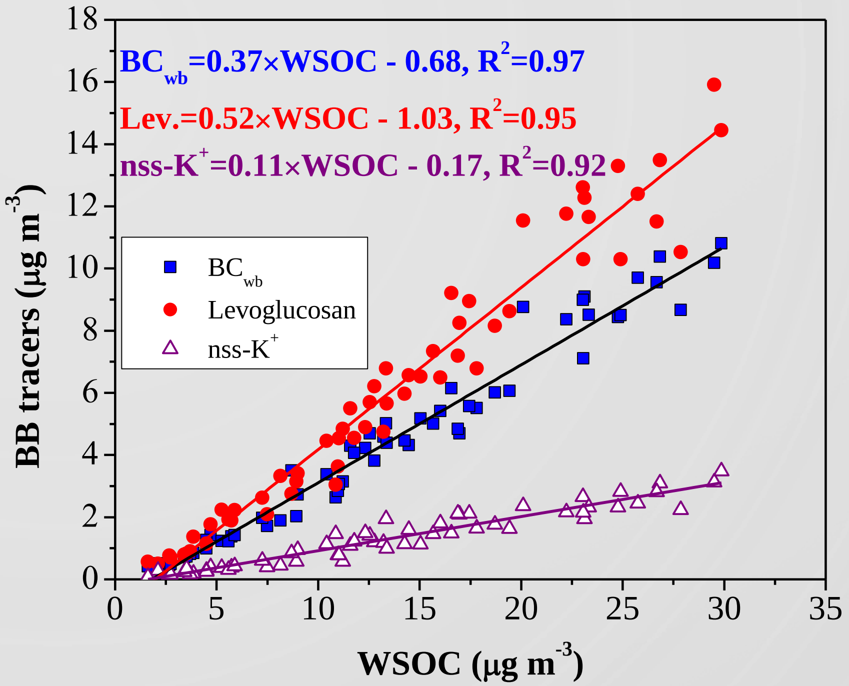
In Ioannina, the Lev/OC ratio was 22.3 ± 3.7% (range: 12.4–32.4%), much higher than global literature.

Given the very high correlations between $PM_{2.5}$, OC, EC and levoglucosan, it was possible to apply effectively the levoglucosan monotracer approach to quantify the average BB contributions, using the slopes as $(x_i/Lev)_{BB}$ source ratios.

A $PM_{2.5}$/Lev slope of 7.9 was found, while the intercept corresponds to $PM_{2.5}$ mass from non-BB sources (9 μg $m^{-3}$ or ~15.6%). So $(PM_{2.5})_{BB}$ =84-85%, **$OC_{BB}$: 92%, $EC_{BB}$: 64%.**

# WSOC – AEROSOL SOLUBILITY DURING WINTER

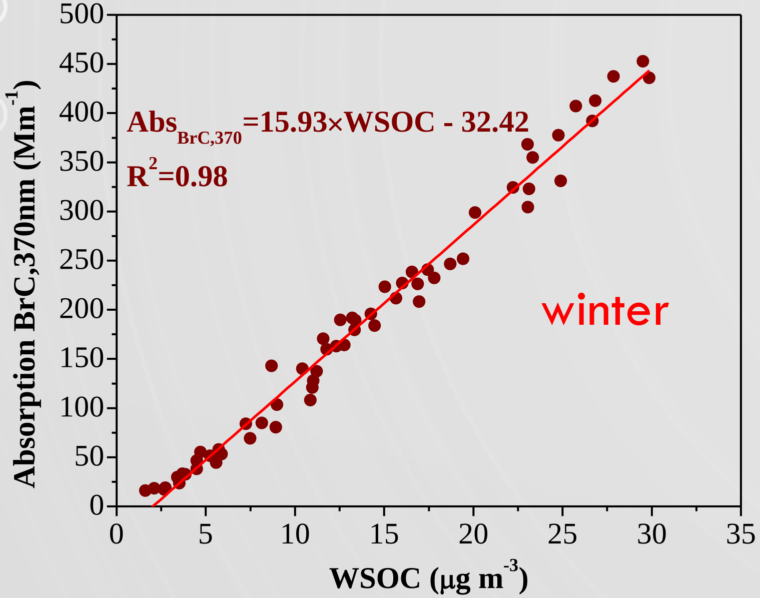


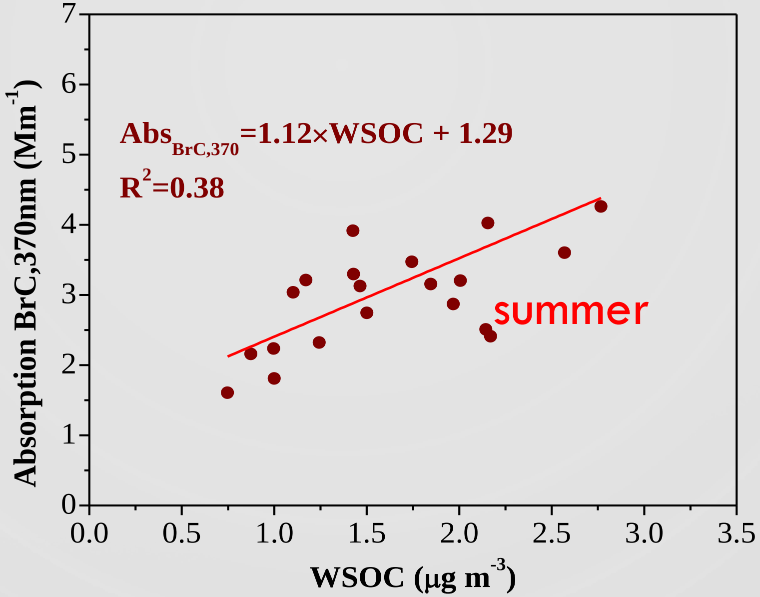



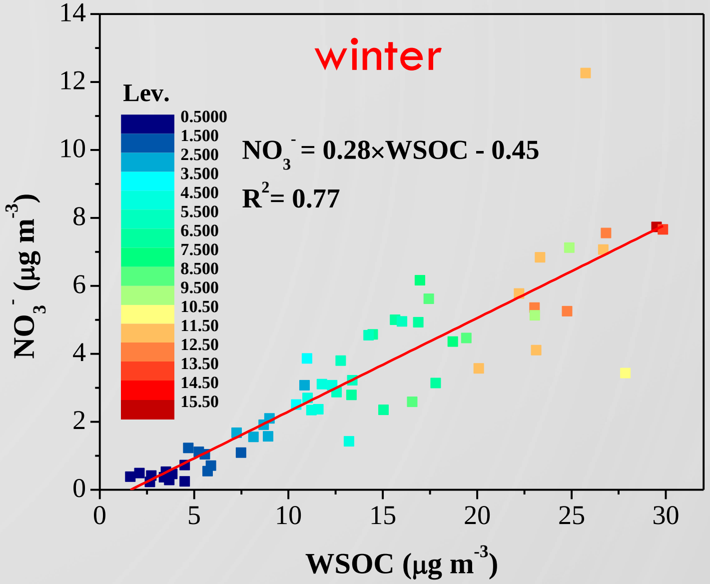

Strong linear correlation ($R^2$ = 0.98) between WSOC and OC in winter, weaker relationship in summer ($R^2$ = 0.75), indicating the impact of additional primary OC sources and a higher degree of SOA processing in summer.
WSOC in winter was strongly correlated ($R^2$ = 0.92–0.97) with BB-tracers (Lev, nss-$K^+$, $BC_{wb}$). Using the Lev-tracer method, we estimated a $(WSOC/Lev)_{BB}$ optimal ratio of 2.02 and an average $WSOC_{BB}$ of 87%.

Enhanced solubility of BB aerosols may facilitate aerosol-cloud interactions and haze/fog formation that is frequent in Ioannina during winter, favored by the presence of the lake and increased humidity.
Enhanced solubility of BB aerosols can have also a significant health impact.

# WSOC – BROWN CARBON ABSORPTION




- Very strong correlation between WSOC and BrC absorption at 370 nm (AE-33 estimated using $AAE_{BC}$=1) in winter ($R^2$ = 0.98). It suggests prevalence of water-soluble BrC chromophores from BB sources.
- In summer, a weaker relationship ($R^2$ = 0.38) exists (contribution of non-absorbing WSOC sources, SOA, photo-bleaching of the BrC chromophores, biogenic emissions).
- A strong relationship between nitrate and WSOC in winter ($R^2$ = 0.77), might suggest conditions appropriate for the formation of nitro-aromatics (co-emission of NOx and VOC under low temperatures).

<u>More analysis about WS BrC absorption in the next presentation.</u>

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# Impacts of severe residential wood burning on atmospheric processing, water-soluble organic aerosol and light absorption, in an inland city of Southeastern Europe

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