ICARUS

Integrated Climate forcing and Air pollution Reduction in Urban Systems

Fine Particulate Matter Composition and Sources in 6 European: The ICARUS Project

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Introduction

- ✓ PM2.5: air pollution metric widely used to assess air quality (**EU targets** for reduction in PM2.5 levels and population exposure)

- ✓ One of the major challenges for the scientific community is to **identify, quantify** and **characterize**, at the appropriate scale, **the sources of atmospheric particles** in the aspect of proposing effective control strategies to the public authorities.

- ✓ Although studies for source apportionment are rapidly spreading globally, revealing both PM local and regional origin, the comparability of results among the different sampling sites is often hampered, leading to ***the need for harmonized source apportionment outcomes from multi-city studies***.

Aim of the study

source apportionment application on **PM2.5** data collected in **six European cities** (Athens, Brno, Ljubljana, Madrid, Stuttgart and Thessaloniki)

- PM2.5 samples collected from three different sites in each city (**traffic, urban background and rural**) during winter & summer 2017
- chemical analysis for **27 PAHs**, **24 trace elements**, **anions** (Cl^-, NO_3^-, SO_4^{2-}), **cations** (Mg^{2+}, Na^+, NH_4^+), **elemental and organic carbon** (EC, OC)
- **Meteorological data** (meteorological stations at the sampling sites/the nearest station from the national meteorological networks)

- The chemical composition data was introduced in **PMFv.5 (Positive Matrix Factorization)** model with the scope of *identifying the main groups of sources* and *estimating their contribution* to PM2.5 concentrations.

Methodology

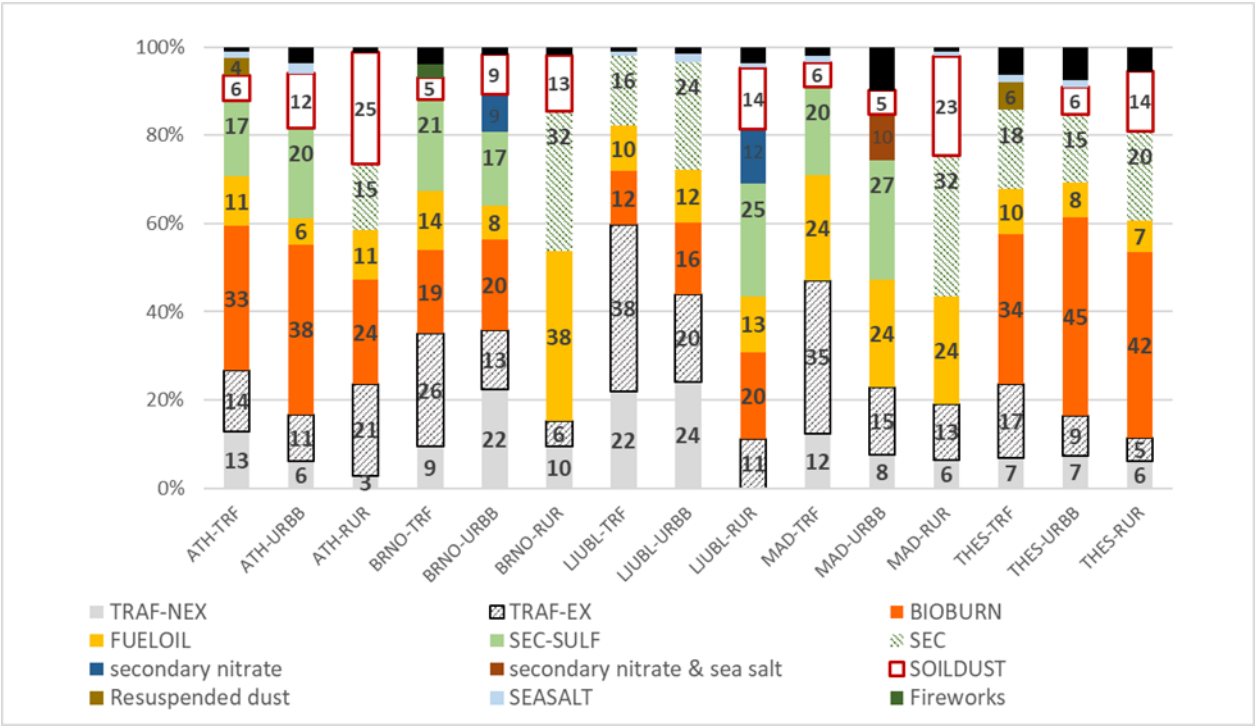
- **Receptor models** aim to *re-construct the contribution of emissions from different sources of atmospheric pollutants (e.g. particulate matter PM), based on ambient measurement data (i.e. PM chemical composition) registered at monitoring sites.*

- **Positive Matrix Factorization (PMF v.5.0)** introduces a weighting scheme taking into account errors of the data points, which are used as point-by-point weights. Adjustment of the corresponding error estimates also allows it to handle missing and below detection limit data. Moreover, non-negative constraints are implemented in order to obtain more physically meaningful factors (Paatero and Tappert, 1994)

- **Data pre-treatment** and **evaluation** of PMF solutions (Bootstrap, Displacement)

PMF Results (I)

- 5-8 factors identified by PMF at each ICARUS site:
- Main sources: traffic exhaust (TRAF-EX), traffic non-exhaust (TRAF-NEX), fuel oil combustion (FUELOIL) biomass burning (BIOBURN), soil dust source (SOILDUST), sea-salt (SEASALT), secondary aerosol (SEC)
- un-apportioned fraction of PM2.5: from <1 to 9.88%

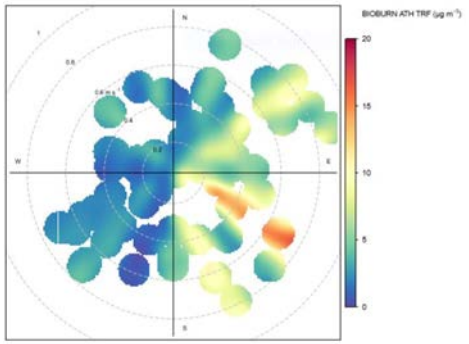


% contribution of each source to PM2.5 concentration for every site

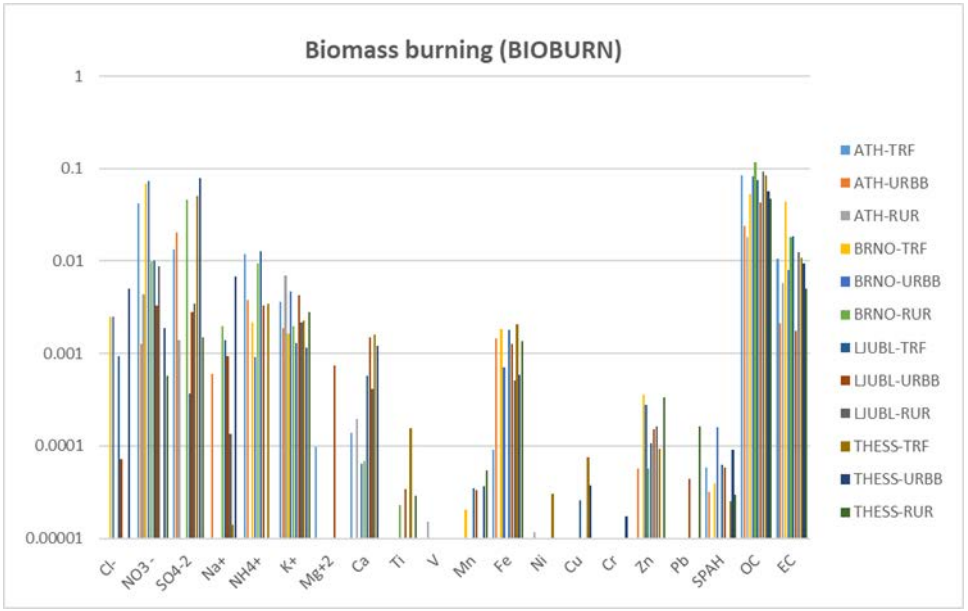
PMF Results (II)

Biomass burning (BIOBURN)

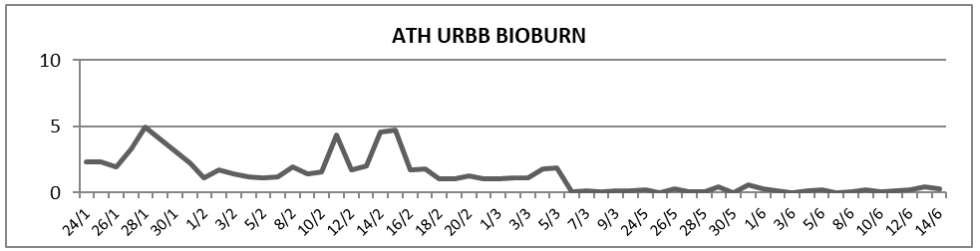
- Major tracers : (OC:30-78%; EC:3-15% of PM2.5 mass), K (7%) or K^+ (2-19%), SO_4^{2-} (3-33%), NH_4^+ (<10%) and PAHs (53-74% of measured PAHs)
- prevalence of the source **during winter** (fireplaces or wood stoves burning), without excluding biomass combustion emissions from **agricultural activities** (in cases of Athens, Ljubljana and Thessaloniki rural sites).
- BIOBURN contribution to PM2.5: 22% at traffic sites, 30% at urban background sites and 28% at rural sites
- The highest percentage of BB contribution was found in THESS-URBB (45%), while the lowest in LJUBL-TRF (12%)
- Source orientation (R-plots of Factor contribution vs wind speed and velocity) at ATH TRF (city center).



Mass profiles (μg/μg) of BIOBURN sources)



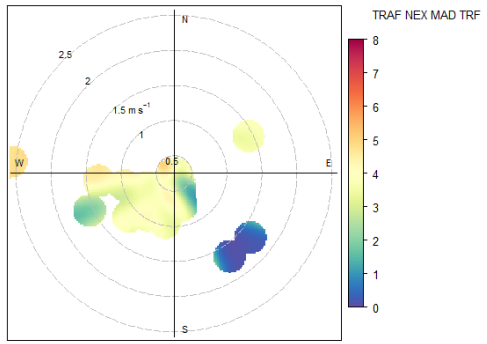
Time variation of (normalized) BIOBURN source at ATH URBB

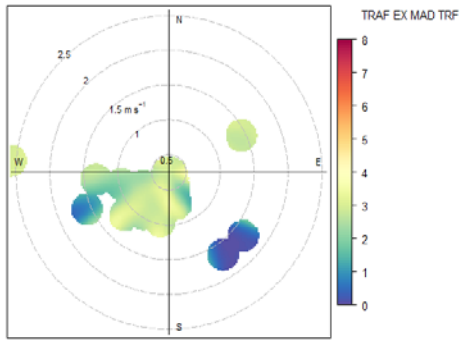


PMF Results (III)

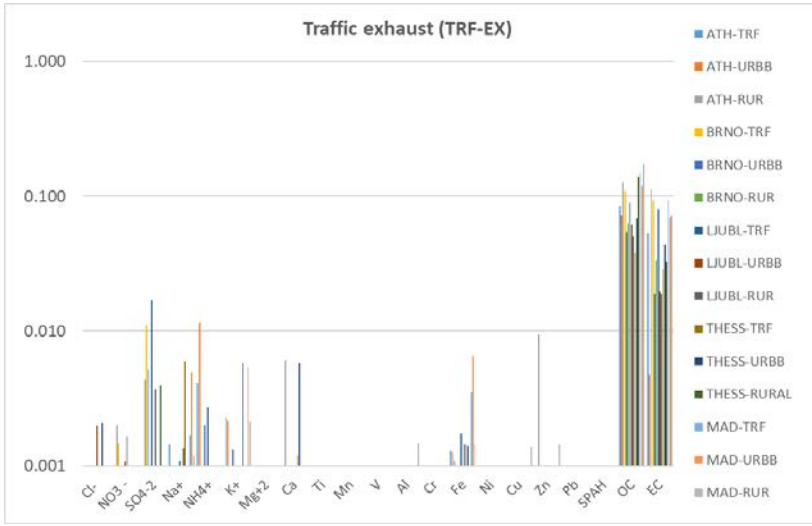
Traffic (TRAF-EX & TRAF-NEX)

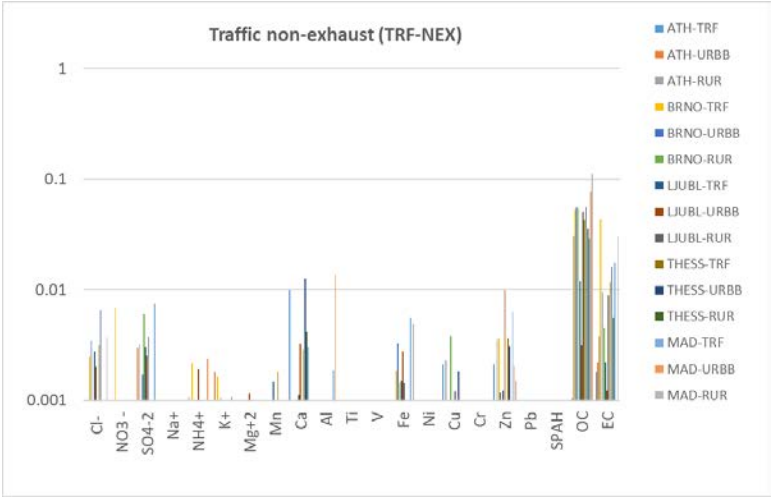
- Two traffic-related sources were distinguished in all sites: the **traffic-exhaust** source (TRAF-EX) and the **traffic non-exhaust** source (TRAF-NEX**)**
- **TRAF-EX** contribution to PM2.5 : **23.3%** at traffic sites, **13.3%** at urban background sites and **8.8%** at rural sites (excluding ATH-RUR site, where it was **21.2%** due to frequent heavy vehicles circulation)
- The highest contribution is observed at LJUBL-TRF site (37.8%) while the lowest (5.6%) at BRNO-RUR and THESS-RUR sites
- **TRA-NEX** contribution: similar levels at traffic (**12.6%**) and urban background (**13.5%**) sites while being lower (**6.1**%) at rural sites.
- TRAF-EX and TRAF-NEX: Similar source orientation (R-plots of Factor contribution vs wind speed and velocity)





Mass profiles (µg/µg) of TRAF-EX, TRAF-NEX sources)





PMF Results (IV)

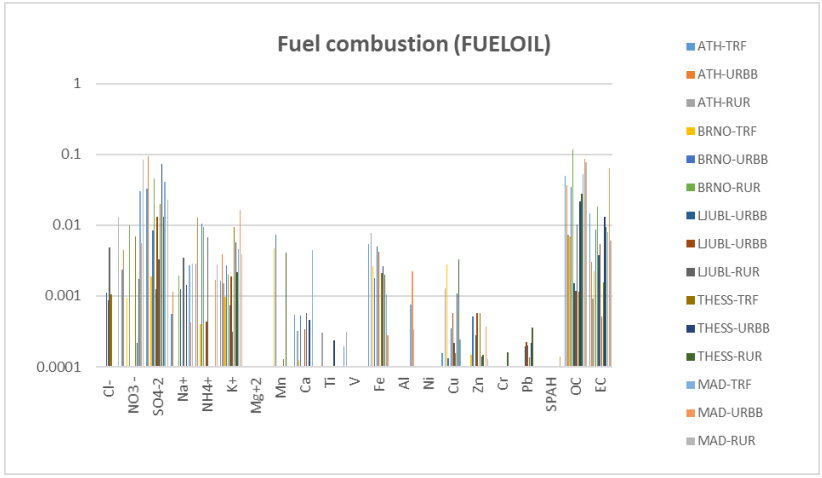
Fuel oil combustion and industry (FUELOIL)

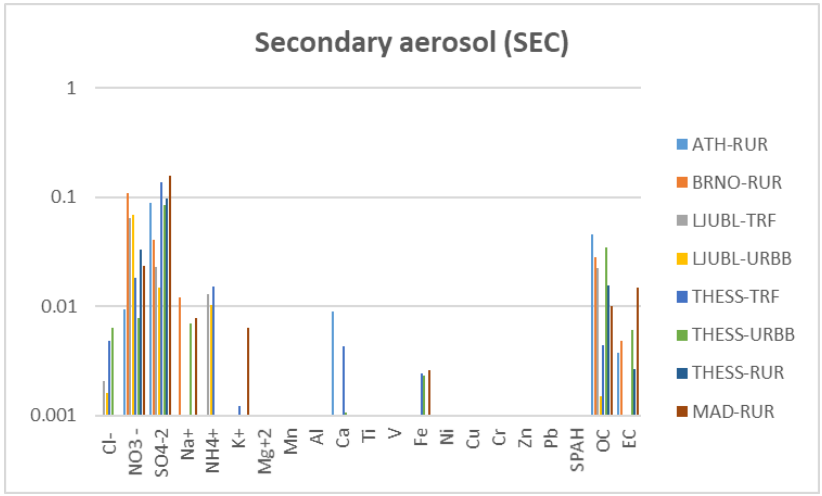
- high shares of OC, EC, SO_4^{2-}, K or K^+, as well as Ni and V
- identified in all sites either as residential fuel oil combustion (for heating) or as refinery activities or shipping exhaust emissions or a combination of them
- Not clear predominance of % contribution in a specific type of areas (13.8% at traffic, 11.6% at urban background and 18.7% at rural sites)

Secondary aerosol

- identified either as secondary sulfate and organics (SEC-SULF) or as sulfate and nitrate-rich (SEC)
- SEC accounted for the 20-27% of PM2.5 while SEC contributed for the 16-34% of PM2.5
- secondary-particle factor may represent not only the formation of secondary aerosol over relatively long distances, but also a part of traffic-related pollution

Mass profiles (µg/µg) of FUELOIL/SEC sources)



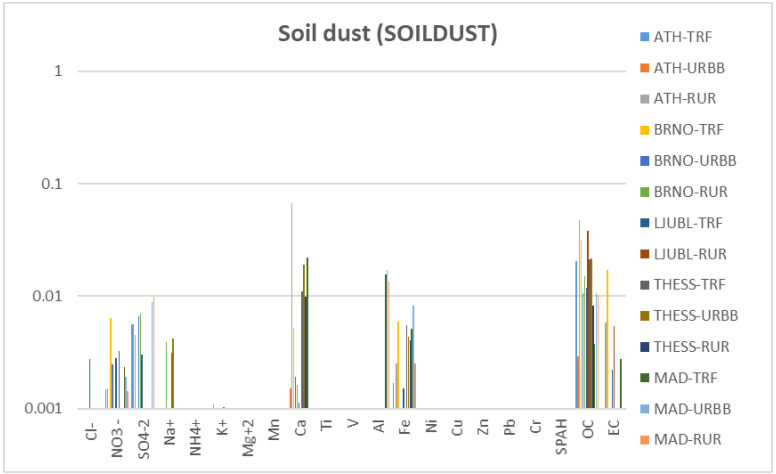


PMF Results (V)

Mass profiles (µg/µg) of SOILDUST/SEASALT sources)

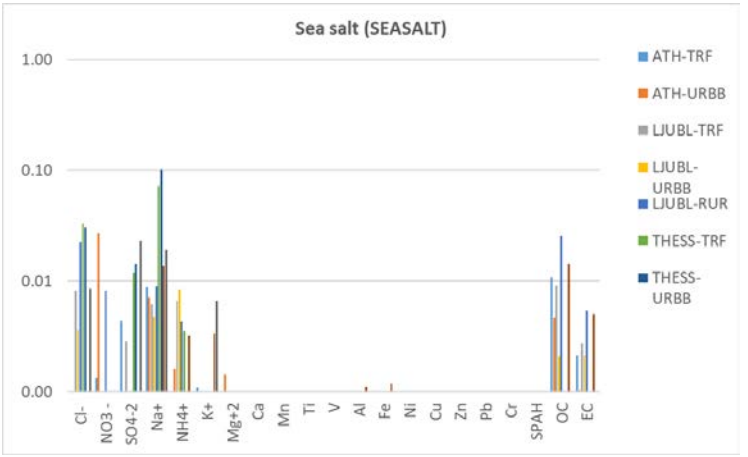
Soil dust (SOILDUST)

- SOILDUST contribution: 5% - 25%
- remarkable difference between traffic/urban background and rural sites is noticed, as SOILDUST average contribution was twofold in the latter (5% and 8% at TRF and URBB sites; 16% at rural sites)



Sea salt

- identified in Athens, Ljubljana, Madrid and Thessaloniki
- contribution 1-4%, not presenting a seasonal variation



Similarity in sources chemical profiles among the sites

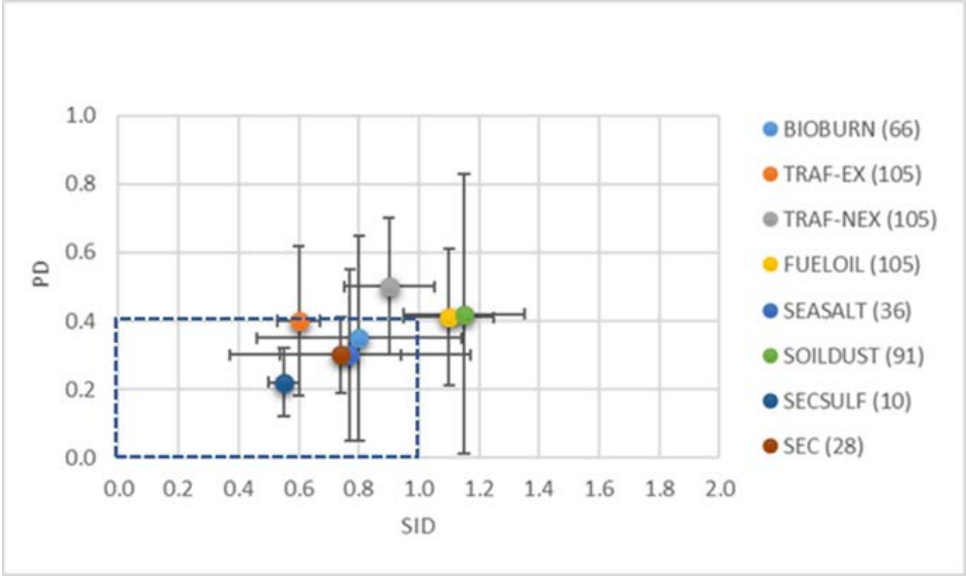
- ✓ similarity indicators : the PD (Pearson distance) and SID (standardized identity distance):

$$PD = 1 - r^2 ,$$

where r^2 is the Pearson coefficient and

$$SID = \frac{\sqrt{2}}{m} \sum_{j=1}^{m} \frac{|x_j - y_j|}{x_j + y_j},$$

where x and y is the relative mass (μg/μg) to the PM of two different sources and m the number of common specie in x and y (Weber et al., 2019). Practically, SID results from the comparison of n(n-1)/2 possible and unique pairs of profiles for each source.



Similarity plot (PD-SID space) for all pairs of profiles belonging to the same factor/source category and the acceptable area for profile similarity. The number of pairs of profiles compared for each source category is given in the parenthesis.

- ✓ Based on Pernigotti and Belis, 2018, the acceptable PD and SID values for profile similarity are: **P<0.4 and SID<1**.
- ✓ **fuel oil combustion, traffic non-exhausts** and **soil dust** source profiles are considered as dissimilar
- ✓ **biomass burning, sea salt** and **traffic exhaust** can be characterized as relatively homogenous
- ✓ **secondary aerosol** sources have been found to be characterized by similar profiles.

Conclusions – Positive Matrix Factorization

- Main sources: **traffic exhaust** (TRAF-EX), **traffic non-exhaust** (TRAF-NEX), **fuel oil combustion** (FUELOIL) **biomass burning** (BIOBURN), **soil dust** source (SOILDUST), **sea-salt** (SEASALT), **secondary aerosol** (SEC)

- *Biomass combustion* is a well-distinguished source at all sampling sites. The factor's contribution to PM2.5 indicates the **prevalence of the source during winter/fireplaces-burning periods**, without excluding biomass combustion emissions from **agricultural activities** (e.g. in cases of Athens, Ljubljana and Thessaloniki rural sites).

- **Fuel oil combustion** source presents **different temporal variation**. This is because it is associated with either residential heating or industrial emissions or shipping emissions (Thessaloniki port city) or combination of them

- In the majority of the cases, ***traffic*** is represented by two different factors: *Traffic-exhausts* and *Traffic non-exhausts*. Contrary to traffic-exhausts, there is no clear trend that traffic non-exhausts has higher share at traffic sites

- A **secondary aerosol** source was identified either as **secondary sulfate** only, either as **secondary sulfates and nitrate.** The secondary-particle factor may represent not only the formation of secondary aerosol over relatively long distances, but also a part of traffic-related pollution

- Two **natural-origin sources** were identified: **soil dust** and **sea salt**.

Thank you

for your attention