PM$_{2.5}$ and Water-soluble Organic Carbon (WSOC)

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Eastern U.S. PM - Overview

Average PM$_{2.5}$ Chemical Composition (2008 – 2013)

- Ammonium sulfate: 30.4%
- Ammonium nitrate: 15.1%
- Organic carbon: 37.1%
- Elemental carbon: 13.1%
- Metals: 2.4%
- Other inorganic ions: 2.0%

Data from MDE’s Essex monitoring station, compiled by Orozco et al. (*JAWMA*, 2015)
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OC made up of thousands of different compounds, many are water-soluble
What is water-soluble organic carbon “WSOC”? 

WSOC$_p$  

Semi-volatile (both)  

WSOC$_g$  

(Hodzic et al., GRL, 2014)  

Dodecane ($C_{12}H_{26}$)
Measurement Approach: WSOC\textsubscript{p} and WSOC\textsubscript{g}

SOA is oxygenated and water-soluble

• measure **Partitioning** to investigate WSOC\textsubscript{p} formation mechanisms

(Slide courtesy of R. Weber)
Hennigan Group – Organic Measurement Capabilities

Organic Measurements:
- PM$_{2.5}$ EC (45 min)
- PM$_{2.5}$ OC (45 min)
- Gas-phase water-soluble organic compounds (WSOC$_g$, 10 min)
- PM$_{2.5}$ water-soluble organic compounds (WSOC$_p$, 10 min)
  - Dry channel (5 min)
  - Ambient channel (5 min)

El-Sayed et al., *ES&T*, 2016
El-Sayed et al., *GRL*, 2015
X. Zhang et al., *JGR*, 2012
Ervens et al., *ACP*, 2011
Hennigan et al., *ACP*, 2009
Hennigan et al., *GRL*, 2008
Ambient Measurements

Measurement Site:
University of Maryland, Baltimore County
Ambient Measurements

Continuous measurements

14-min cycle:
$\text{WSOC}_g - \text{WSOC}_p - \text{WSOC}_{p,\text{dry}}$

September 2014
Feb/March 2015
April/May 2015
July/August 2015
July/August 2016
Aerosol Liquid Water - Abundance

Liquid Water: Ubiquitous Contributor to Aerosol Mass
Thien Khoi V. Nguyen,† Qi Zhang,‡ Jose L. Jimenez,§ Maxwell Pike,† and Annmarie G. Carlton‡†

Environmetal
Science & Technology
Letters
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Aerosol Liquid Water - Abundance

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[Map and chart showing aerosol liquid water abundance across different locations, with pie charts indicating the contribution of different components like water, sulfate, nitrate, and OM (organic matter).]
Aerosol Liquid Water - Abundance

(Nguyen et al., GRL, 2016)
Aerosol Liquid Water and the FRM

“Filters must be conditioned in a controlled environment of 20-23 ± 2 °C and 30 – 40 ± 5% relative humidity for at least 24 h prior to both the pre- and post-sampling weighings.”

(Noble et al., AS&T, 2001)
Aerosol Liquid Water and the FRM

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(Noble et al., AS&T, 2001)

Our Question:
How does aerosol liquid water alter the concentration and composition of organic aerosol?
The "dry" channel dries particles to: **32-42% RH**

- Not to efflorescence in most cases  (Khlystov et al., *JGR*, 2005)
- Relevant for the FRM and FEM (35% RH)
No particle losses through the 3-way valve or dryer
During fall (Sept.) – drying had NO EFFECT on $\text{WSOC}_p$
Effect of drying on $\text{WSOC}_p$ - summer

$\text{WSOM} = \text{WSOC}_p \times 1.95$
Effect of drying on WSOC\textsubscript{p} – summer 2015

(El-Sayed et al., ES&T, 2016)
Effect of drying on WSOC$_p$ – summer 2015 & 2016

(El-Sayed et al., in prep)
Drying causes evaporation of WSOC$_p$ during summer and spring

(El-Sayed et al., Atmos. Chem. Phys. Discuss., 2017)
Which factors affect $\text{WSOC}_p$ evaporation?

- Overall $\text{WSOC}_p$ concentrations
- Relative humidity
- Isoprene
- Isoprene/$\text{NO}_x$

**Isoprene: average annual profile (2011 - 2015) from MDE measurements at Essex, MD**

(El-Sayed et al., *Atmos. Chem. Phys. Discuss.*, 2017)
Effect of WSOC concentration on WSOC$_p$ evaporation

(El-Sayed et al., *ES&T*, 2016)

$\text{WSOM} = \text{WSOC}_p \times 1.95$
Effect of RH on WSOC$_p$ evaporation

(El-Sayed et al., *ES&T*, 2016)
Effect of NO$_x$/isoprene on WSOC$_p$ evaporation

(El-Sayed et al., Atmos. Chem. Phys. Discuss., 2017)
Conclusions

- **Systematic** effect of particle drying on WSOM during summer: OA evaporates with the water (analogous to semi-volatile NH$_4$NO$_3$)

- On average, 15 – 30% of WSOC$_p$ evaporated upon drying... *as high as 5-7 µg m$^{-3}$*

- Seasonal trend suggests isoprene chemistry

- Implications for measurements that implement drying (there are many, **including the FRM**)!
Implications of WSOC$_p$ evaporation

Measurement Methods that Implement Drying:
- PM mass: FRM and FEM
- f(RH)
- HTDMA
- Aerosol mass spectrometers
- Sunset Labs OCEC??
- Others...

(Shingler et al., JGR, 2016) (Saha et al., ACP, 2016)
Implications of WSOC evaporation

We **hypothesize** that the effect will be much greater in other locations in the U.S., and globally

(effect of monoterpane SOA - unknown)
Implications of WSOC evaporation

Human health effects: unknown (but worth studying)
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