Aerosol type classification inferred by remote sensing during SEAC4RS

April 15-18 2014, Boulder, CO
Classifying aerosol type

Classifying aerosols into different types helps to quantify aerosol radiative impacts on climate, to understand aerosol sources, transformations, effects, and feedback mechanisms; and to improve accuracy of satellite retrievals.

Russell et al. [2010] shows a connection between aerosol type and several optical parameters.

We have developed a classification method that assigns an aerosol type to observations from satellite (e.g. POLDER/PARASOL), airborne (4STAR) or ground-based instruments (e.g. AERONET).

Goal is to 1. evaluate our classification method, 2. learn about the chemical composition and 3. interpret the column “effective” (i.e. non-vertically resolved) aerosol types.
Our method to classify aerosol

1. Define reference aerosol types using AERONET L2 V2 sky retrievals with filters on dates (Dubovik et al. [2002] and Cattrall et al. [2005]), aerosol depolarization$_{532}$ [Schuster et al., 2012], $\text{Vol}_{\text{fine}}/\text{Vol}_{\text{tot}}$, $\%\text{Sphere}$ and delete obs. that differ from each dominant type.

For pure marine, $\text{AOD}_{500} \leq 0.2$ and $0.1 \leq \text{EAE}_{440,870} \leq 1$ [Sayer et al., 2012] and Mie code (AERONET size distribution and modeled refractive indices)

2. Define distance $D_M$ [Mahalanobis, 1936] from data point to cluster as function of center, width and tilt of each cluster (i.e. resp. mean, std and cross-correlation)

Assign any given observation to the class (or cluster) from which it has least $D_M$ [Russell et al., sub. JGR, 2014]
Our method to classify aerosol

POLDER measures polarized radiances in different viewing directions and three channels (443, 670 and 865 nm). We use retrievals from [Hasekamp et al., 2011] and uncertainties.

POLDER aerosol types using SSA$_{491}$, EAE$_{491-863}$, RRI, SSA$_{863}$ – SSA$_{491}$ over Crete (Greece) from 2005 to 2009 [Russell et al., sub. JGR, 2014]

Our method is analogous to NASA Langley HSRL aerosol classification [Burton et al., 2012] and differs from other methods:

• Flexible algorithm with different inputs (e.g. space-borne, airborne 4STAR or ground-based AERONET)
• Objective, multidimensional measures for classification
• Effort to include marine aerosols
• Two-step classification
AERONET: Aerosol parameters over the US during SEAC4RS (08/02 – 09/23)

- Single scattering albedo (491nm)
- Extinction angstrom Exponent (491-863nm)
- Diff. in single scattering albedo (863 – 491 nm)
- Real refractive index (670 nm)

26 stations
N=282 L2 V2 (τ >=0.4) AERONET sky retrievals

- Urban Industrial 1
- Pure dust
- White smoke
- Dark smoke
- Urban Industrial 2
- Maritime
- Polluted dust

SEAC4RS obs.

Not co-located with a/c

Goals & Motivation
- Our classification method
- AERONET
- Our aerosol classification applied to AERONET
- Evaluating our aerosol types
- AERONET versus CALIOP aerosol types
- AERONET aerosol types versus DC-8 observations
- Future work
- Perspective: 4STAR
AERONET: Aerosol types over the US during SEAC4RS

Our method was applied to AERONET EAE$_{491,863}$, SSA$_{491}$, RRI$_{670}$ and dSSA$_{863,491}$ for each of the N=282 AERONET obs.

The majority (73%) of AERONET points were classified as Urban-Industrial, followed by 17% classified as biomass-burning white smoke.
# Evaluating our aerosol types during SEAC4RS

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Classification method</th>
<th>Vertical res</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CALIOP</td>
<td>Liu et al., 2010; Omar et al., 2009</td>
<td>Vertical prof.</td>
<td>Available</td>
</tr>
<tr>
<td>POLDER</td>
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<td>Full column</td>
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Active downward pointing elastic backscatter lidar, 90 m footprint, no daily global coverage

Many assumptions in CALIOP aerosol type and extinction:
feature detection scheme [Vaughan et al., 2009], feature typing [Liu et al., 2010 and Omar et al. 2009], lidar ratio assumed per aerosol type

**Only 3 AERONET L2 V2 sky retrievals (τ ≥ 0.4) within 3 hours and 100 km of CALIOP during SEAC4RS (2 on 08/31 and 1 on 09/11/2013)**
AERONET inferred aerosol type and CALIOP obs. 08/31/2013

- From National fire center (NICC): 28 large uncontained fires with largest area burned in CA (rim fire, red AQI)
- Pollution “Unhealthy for sensitive groups” (orange) in TX

Our type classification shows urban Industrial at 2 AERONET stations

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**AERONET inferred aerosol type and CALIOP obs.**

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<td>0.46</td>
<td>Urban</td>
</tr>
<tr>
<td>532 nm</td>
<td></td>
<td>0.28*</td>
<td>Polluted cont. &amp; smoke*</td>
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* *possible missing layers< detection threshold, possible misclassification |

• CALIOP detects smoke and we don’t.
• Our classification depends on the relative proportions of each type in the column.

**Goals & Motivation**

**Our classification method**

**AERONET**

**Our aerosol classification applied to AERONET**

**Evaluating our aerosol types**

**AERONET versus CALIOP aerosol types**

**AERONET aerosol types versus DC-8 observations**

**Future work**

**Perspective: 4STAR**
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Measures directly aerosol extinction and $S_a$, without ancillary aerosol meas. or assumptions on aerosol type.

Our aerosol typing was inspired by Burton et al. [2012] that uses HSRL intensive parameters (lidar ratio, back color ratio, depo., depo. scatt. ratio).

Only 3 AERONET L2 V2 sky retrievals ($\tau > 0.4$) within 1h and 15km of DC-8 valid LARGE Inistu meas. (on 08/16)
AERONET inferred aerosol type and airborne DC-8 obs.  08/16/2013

From National fire center (NICC): 38 large uncontained fires with largest area burned in Idaho (red AQI @ 3PM)

Our type classification shows urban Industrial at 3 AERONET stations
AERONET inferred aerosol type and airborne DC-8 obs.  08/16/2013

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Layers come from different regions

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<td>AERONET 440 nm</td>
<td>0.5-0.6</td>
<td>Urban industrial</td>
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* nadir, >5km, missing 1km near a/c

Need interpretation of our column “effective” aerosol types & composition
Conclusion

- We have applied our aerosol classification to AERONET sky observations (and POLDER soon) over the US during SEAC4RS
- Very few co-locations between AERONET L2 V2 clear-sky retrievals (AOD>0.4) and CALIOP within 3h/100km; even fewer co-locations with DC-8 within 1h/15km

Next steps:

- Learn about the chemical composition of our aerosol types: We will apply our aerosol classification method to airborne Insitu measurements (LARGE, PI nephelometer) and compare the inferred aerosol types to aerosol composition from PALMS (qual.), AMS (quant. small), SAGA (quant. coarse)
- Interpret our column “effective” (i.e. non-vertically resolved) aerosol types: we will apply the aerosol classification method to above aircraft-retrievals from N=42 successful 4STAR sunphotometer sky scans and compare with HSRL derived aerosol types on board the same aircraft (i.e. different proportion of aerosol types on vertical)
Perspective: 4STAR
SPECTROMETER FOR SKY-SCANNING, SUN-TRACKING ATMOSPHERIC RESEARCH

- AOD at 100s of wavelengths, Å
- Aerosol extinction profiles
- O₃, NO₂ and CWV (demonstrated);
- CO₂, CH₄, OH, Formaldehyde (desired)
- Thin cirrus cloud properties

See next talk by Yohei Shinozuka

Airborne Direct sun tracking

08/16/2013
Aged urban pollution
Aged urban pollution + aged smoke

See poster by Michal Segal-Rosenheimer, session 2

Aerosol classification using many 4STAR (see list above) and in-situ normalized quantities (e.g. OrgA, O/C ratio (AMS), CO, NOy, and O₃ (CL) and CH₂O (ISAF)) and 4STAR

See talk by Jens Redemann at 14:30

Airborne Sky scanning

- Sky Radiances
- AERONET-like aerosol size distribution, index of refraction, SSA, asymmetry factor, sphericity.

See next talk by Yohei Shinozuka