Merging Multiple Instrument Measurements of Aerosol Size Distributions into a Best Estimate Aerosol Size Distribution.

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ROCKVILLE, MD
NOVEMBER 4, 2013
Motivation

- Aerosol size distributions are a necessary measurement for the understanding of the physiochemical properties of a sample of ambient aerosols.
- Making the measurement on an aircraft platform (DOE AAF G-1) presents an unique and difficult challenge:
  - Fast flight speeds create a prerequisite need for fast measurements (=>1 Hz). Optical aerosol probes can meet this need.
- Optical aerosol probes however come with a unique set of challenges:
  - Each probe covers a narrow range of sizes.
  - Sensitive to laser alignment.
  - Sensitive to contamination on the optics.
  - Accuracy in sizing is dependent on knowing the index of refraction of the measured aerosol.
- Presentation will focus on deriving a Best Estimate Aerosol Size Distribution.
Multiple Distributions?

How can this be used in a model or closure study?

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How can this be used in a model or closure study?
Ultra-High Sensitivity Aerosol Spectrometer - Airborne (UHSAS-A)
0.06 - 1.00 µm
Sampled at 1 or 10 Hz

Wiscome, W. J., 1980, Applied Optics, p1505
Rosenberg et al., 2012, A., Atmos. Meas. Tech., 5, p1147
Ultra-High Sensitivity Aerosol Spectrometer - Airborne (UHSAS-A)
0.06 - 1.00 µm
Sampled at 1 or 10 Hz
Passive Cavity Aerosol Spectrometer Probe (PCASP) – SPP200

0.10 - 3.00 μm
Sampled at 1 Hz
Passive Cavity Aerosol Spectrometer Probe (PCASP) – SPP200
0.10 - 3.00 µm
Sampled at 1 Hz
Cloud Aerosol Spectrometer (CAS)
0.60 - >10.00 μm
Sampled at 1 hz
PbP
Scattering Cross Section vs. Diameter (μm) for PSL Beads (r=1.58)

- CAS
- PCASP
- UHSAS
Methodology

The 3 aerosol probes are a complementary set

- Weakness in one instrument is filled in with another instrument

The best estimate aerosol size distribution (N) can be recovered from the merged raw counts (C) if a Kernel function (R) can be quantified:

\[ \overrightarrow{NR} = \overrightarrow{C} \]

\[
\begin{bmatrix}
  n_1 \\
  n_2 \\
  \vdots \\
  n_{j-1} \\
  n_j
\end{bmatrix}
\begin{bmatrix}
  R_{UHSAS_{11}} & R_{UHSAS_{12}} \\
  R_{UHSAS_{21}} & R_{UHSAS_{22}} \\
  \vdots & \vdots \\
  R_{UHSAS_{x-1,j-1}} & R_{UHSAS_{x-1,j}} \\
  R_{UHSAS_{x,j-1}} & R_{UHSAS_{x,j}}
\end{bmatrix}
\begin{bmatrix}
  C_{UHSAS_1} \\
  C_{UHSAS_2} \\
  \vdots \\
  C_{UHSAS_{x-1}} \\
  C_{UHSAS_x}
\end{bmatrix}
\]

Same method used to recover the size distributions from DMA measurements

Gregory R. Markowski (1987) Improving Twomey’s Algorithm for Inversion of Aerosol Measurement Data
Methodology

\[ R_{UHSAS_{i,j}} = Q_s \times t \times \varepsilon_{i,j} \]

\[ R_{PCASP_{i,j}} = Q_s \times t \times \varepsilon_{i,j} \]

\[ R_{CAS_{i,j}} = V_{TAS} \times A \times t \times \varepsilon_{i,j} \]
\[ R_{UHSAS_{i,j}} = Q_s \times t \times \varepsilon_{i,j} \]

\[ R_{PCASP_{i,j}} = Q_s \times t \times \varepsilon_{i,j} \]

\[ R_{CAS_{i,j}} = V_{TAS} \times A \times t \times \varepsilon_{i,j} \]
\[ \vec{N} \vec{R} = \vec{C} \]
Methodology
Run the Twomey routine

- Initial solution for N is calculated
- The solution for N is smoothed
- Agreement with known counts is checked
  - Smoothing Routine exits if the normalized chi-square statistic is < 1 or max number of iterations is reached
- Agreement with previous solution for N is checked for decrease in roughness
  - If it has decreased enough than routine exists; if not it repeats with the new N solution

By tweaking the smoothing value and iterations one can control the amount of smoothing
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- UHSAS
- PCASP
- CAS

$dN/d\log D_p$ (#/cm$^3$)

Diameter (μm)
Example Case

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![Graphs showing particle size distribution](image)
Summary/Future Work

- A Best Estimate Aerosol Distribution for the UHSAS-A, PCASP, and CAS was recovered using a Kernel function (R)

Future Work

- Optimizing the coefficients used in the algorithm to yield the best results for batch processing
- How to handle the overlap regions
  - Apply weighting?
- Create the BEASD for all ASDs from TCAP and BBOP
- Test the agreement of the BAESD with onboard instruments (FIMS) from BBOP and ground instruments during TCAP (UHSAS)
Data status

TCAP-2012

- UHSAS – a1….a2 available in December
- PCASP – a1….a2 will be uploaded in November
- CAS – a2….Need to derive an aerosol version

TCAP 2013

- UHSAS – a1….a2 available in January
- PCASP – a1…instrument had multiple problems…hopeful for january
- CAS – a1…. Need to derive an aerosol version…January for a2
For more information and access to data please visit:

http://www.arm.gov/sites/aaf

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