Laboratory Comparison of Aerosol Optical Property Measurement Techniques

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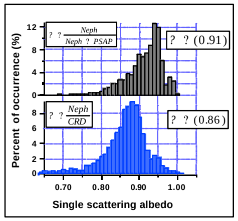
Aerosol Optical Properties (AOP)



NEAQS-ITCT unpublished data:
CRD-AES (NOAA – Baynard et al.),
Nephelometer (U of Illinois – Rood et al.),
PSAP (PMEL/UW – Covert et al.)

Extinction (s_{ep}), scattering (s_{sp}), absorption (s_{ap})

Single Scattering albedo (?); ? = s_{sp}/ s_{ep}

MOTIVATION FOR THIS STUDY

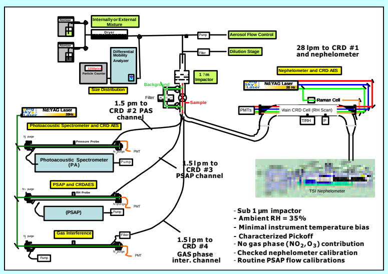
- ? values obtained from different instrument combinations can systematically differ (see NEAQS-ITCT 2004 data). These differences are significant for climate forcing estimates

GOAL

- Investigate instrument biases for AOP measurements in relation to aerosol type and composition
- Evaluate the uncertainty for the derived ? values

AOP Inter-comparison Study

SET UP



MEASURED AOP QUANTITIES

1) Extinction (s_{ep}),532 nm (NOAA CRD-AES)
$?s_{ep}$ = 1% (532 nm, sub-1 µm, dry) [1]

2) Scattering (s_{sp}),550 nm (TSI 3563 Nephelometer)
$?s_{sp}$ = 4-7% (550 nm, sub-1 µm, dry) [2]
Angle of Integration ~ 7°-170° (*truncation*), size dep. correction (Å)

3) Absorption (s_{ap}),530 nm (Radiance Research PSAP)
$?s_{ap}$ = 20-30% (sub-1 µm, dry) [3]
Response to non absorbing aerosols (*apparent absorption*)

AEROSOL TYPES (sub-1 µm, dry RH < 10%)

Calibration Polystyrene Latex Spheres (PSS) = Non dyed (? > 0.99)
Dyed (? = 0.85 - 0.90)
Non Absorbing (? > 0.99) = Inorganic salts (ammonium sulphate,~ spherical)
Organic di-carboxylic acids (succinic, adipic)
Absorbing (? < 0.99) = Nigrosin Dye (black water soluble pigment, spherical)

LOOK AT

- Spherical Particles
- Internal/External Mixtures
- Range of ?
- Non-volatile/semi-volatile

Computed ? values

- $?_{C,N} = s_{sp} / s_{ep}$ (CRD,NEPH)
- $?_{P,N} = s_{sp} /(s_{sp} + s_{ap})$ (PSAP,NEPH)

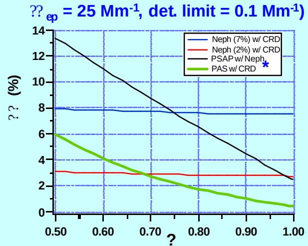
Data Processing (based on non absorbing aerosols)

- s_{sp} = truncation error, and normalization to s_{sp} (0-2%)
- s_{sp} = wavelength conversion (550 nm to 532 nm)
- s_{ap} = 'apparent absorption' correction (0 to 2 % of s_{sp})

* PAS = Photo Acoustic Spectrometer, [4]

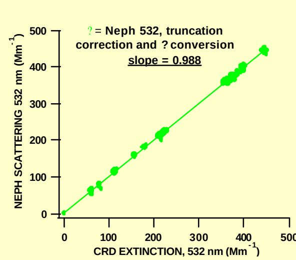
Predicted uncertainty in ?

$??_{ep}$ = 25 Mm^{-1}, det. limit = 0.1 Mm^{-1})



Non absorbing Aerosols $(NH_4)_2SO_4$

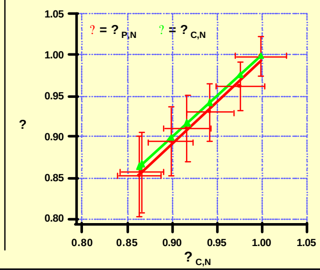
Integrated CRD-NEPH system: s_{ep} - s_{sp} < 2%; ? s_{sp} = 2-3%)



For non absorbing aerosols
s ep = ssp

$?_{C,N}$ = ssp / sep
(CRD-AES and NEPH)
IS THE REFERENCE ? IN THIS STUDY

Calibration 450 nm PSS - non absorbing and absorbing (10% dye)



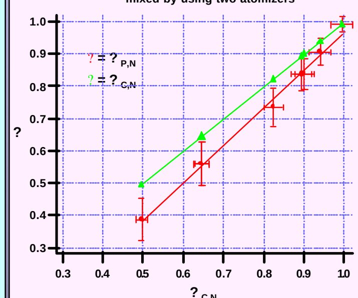
- Test aerosols (spherical, known size) good to verify instrument agreement
- External mixture ranging from 100% non dyed to 100% dyed covering the typical atmospheric aerosol ? range

AMMONIUM SULPHATE /NIGROSIN MIXTURES (AS/NSN)

Proxy for complex inorganic/organic atmospheric aerosols mixtures

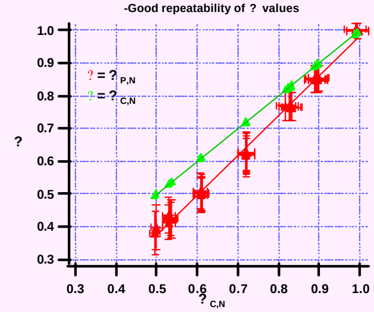
Case 1) External mixture AS/NSN

1% solutions of pure NSN and pure AS mixed by using two atomizers



Case 2) Internal mixtures (AS/NSN)

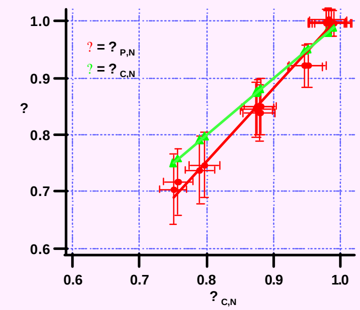
-Mixtures of known NSN fraction (pure AS to pure NSN)
-Good repeatability of ? values



- Good agreement between $?_{C,N}$ and $?_{P,N}$ for the non absorbing aerosols in both cases
- $?_{P,N}$ lower than $?_{C,N}$, discrepancy linearly increasing with the NSN % independently on filter transmission
- Not significant differences between external vs internal AS/NSN mixtures

NON ABSORBING ORGANIC ACIDS/NSN

-Di-carboxylic (succinic, adipic) acids are non absorbing, water soluble semi-volatile compounds, commonly found in ambient aerosols
- Range of NSN amount is 0 to 40%



- Similar trend of $?_{C,N}$ vs $?_{P,N}$ as for AS/NSN mixture
- Lower than expected $?_{C,N}$ values for pure succinic acid

?? ($?_{C,N}$ - $?_{P,N}$) @ ? = 0.86 (atmospheric range)

PSS	?? = 0.01
AS/NSN external	?? = 0.05
AS/NSN internal	?? = 0.045
ORGANICS/NNS	?? = 0.02

- Overestimation of absorption by NEPH,PSAP respect to the reference CRD, NEPH
- Significant discrepancies between ?? values between calibration spheres and mixtures
- Dependence of the applied correction on mixture Is a generalization possible?
- Systematic instrument biases need to be investigated under controlled conditions with laboratory generated aerosols to obtain detailed and specific correction factors before moving to atmospheric cases

For ? = 0.86, ?? = 0.05 is a too big uncertainty for accurate calculations of radiative aerosol forcing

SUMMARY

- The use of integrated CRD,NEPH approach can reduce the propagated uncertainty in ? and help evaluating filter based absorption measurement technique, e.g., PSAP
- Good closure between CRD,NEPH and PSAP,NEPH for non absorbing aerosols
- Discrepancies still remaining for absorbing aerosols indicate that recommended correction factors cause significant biases in AOP measurements – need to account for dependence of such factors on aerosol size, morphology and composition
- Need to improve AOP measurement techniques and methods

References

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