Assessing the need for O_4 correction factors for ground based MAX-DOAS during TCAP

Ivan Ortega[1,2,+] Thomas Wagner,[3] and Rainer Volkamer[1,2,*]

[1] Dept. of Chemistry and Biochemistry & [2] CIRES, University of Colorado, Boulder, CO

[3] Max-Planck Institute for Chemistry, Mainz, Germany.

+ivan.ortega@colorado.edu *rainer.volkamer@colorado.edu

University of Colorado Boulder

CIRES

Introduction

Over the past few years many ground based MAX-DOAS observations applied a collisional complex (O_2O_2, or O_4) correction factor (CF_{O4}) to improve the correlation of simulated and measured O_4 dAMF (or dSCD) – see table on the right. One potential cause of the need of the CF_{O4} was pointed out to be uncertainties in the temperature and pressure dependencies of the available O_4 cross sections. However, Spinei et al. (2015) recently showed that the uncertainties in the O_4 cross sections are significantly lower (< 3% error) than the 25 $\pm$ 10% differences reported in the literature. Furthermore, Volkamer et al. (2015) recently assessed O_4 inferred aerosol extinction using independent measurements by the aircraft NCAR/GV High Spectral Resolution LIDAR (HSRL), and did not find evidence for the need of correction factors in the presence or absence of aerosols.

Past ground based MAX-DOAS using O_4 correction factor (CF_{O4})*

Reference	Wavelength (nm)	AOD	Resolved extinction profiles?	CF_{O4}
Wagner et al. (2009)	360	0.1 – 0.2	NO	~0.78
Clémer et al. (2010)	360, 477, 577, 630	< 0.15 (360 nm)	NO	0.75 ± 0.10
Irie et al. (2011)	360, 477	0.1 – 1.0	NO	0.75 ± 0.10
Vlemmix et al. (2011)	477	0.1 – 0.7	NO	0.80
Zieger et al. (2011)	360, 477	0.1 – 0.8	Partially	~0.8

*The table might not be representative of all studies.

Scientific Synopsis & Hypothesis

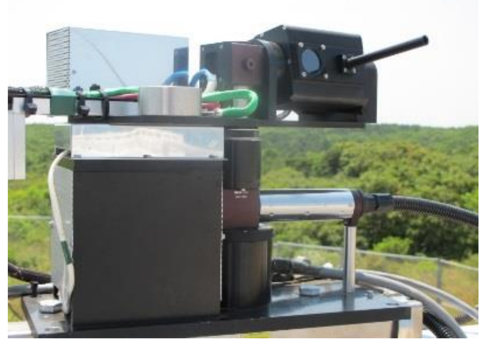
Testing O_4 dSCDs from ground-based MAX-DOAS under known aerosol profile conditions is missing in the literature. Typically simplified assumptions about aerosol profiles are made. Is the need for CF_{O4} sensitive to the assumptions about aerosol extinction profiles?

Methodology

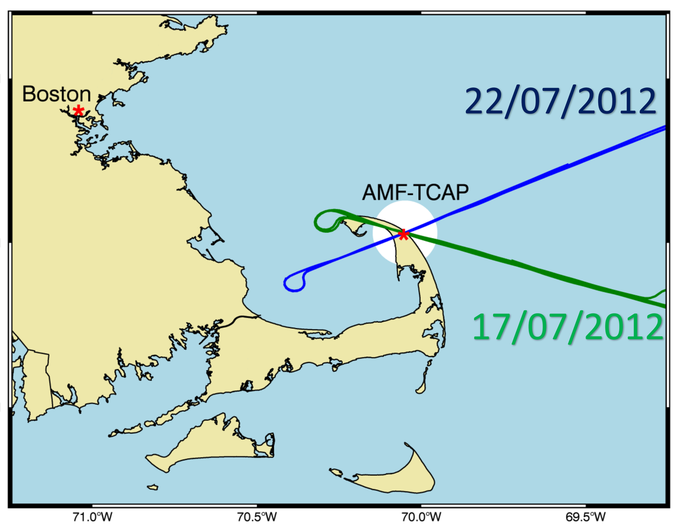
The Two Column Aerosol Project (TCAP) took place in July 2012 at Cape Cod, MA. TCAP provides a unique dataset to investigate the effect of known atmospheric conditions on the simulation of O_4 dSCD and O_4 dAMF:

Ground based instruments / products	
MFRSR	AOD and surface albedo (415, 500, 615, 673, 870, and 940 nm)
AERONET sun photometer	AOD (340, 380, 412, 440, 443, 490, 500, 532, and 555 nm)
Radiosondes	Vertical profiles of temperature, pressure and humidity (4 times/day)
Airborne instruments / products	
HSRL-2	Highly resolved aerosol extinction profiles (355, 532 nm)
UHSAS, PCASP, CAS	Aerosol size distribution (0.06 to 30.0 μm diameter)

The University of Colorado deployed the 2D-MAX-DOAS instrument (Ortega et al., 2015) to measure O_4 dSCD (360, 477 nm) in a variety of geometries.



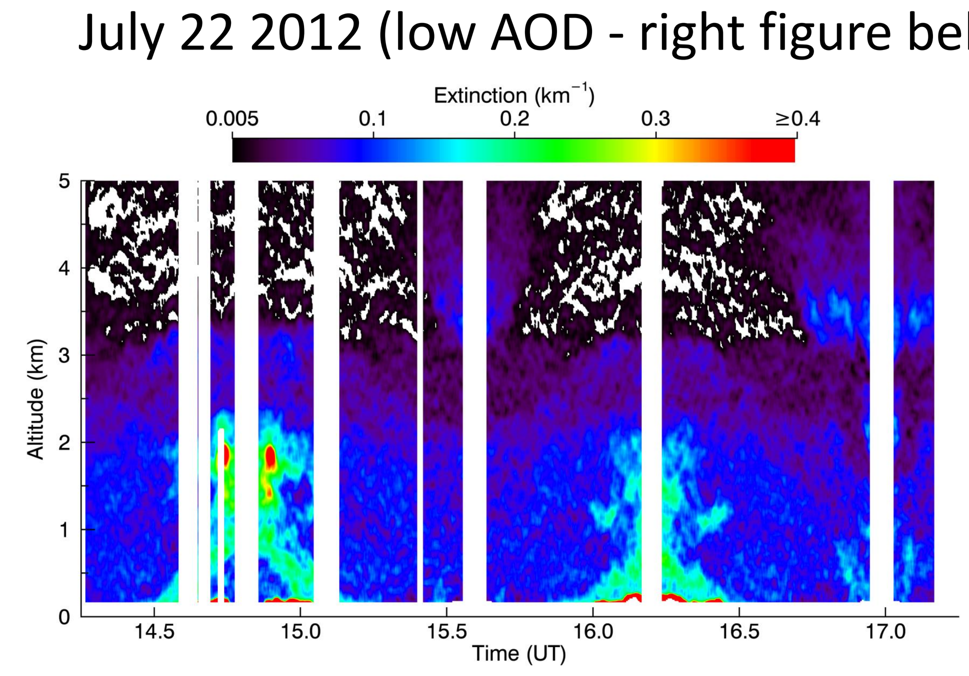
2D-MAX-DOAS deployed during TCAP (North – South)

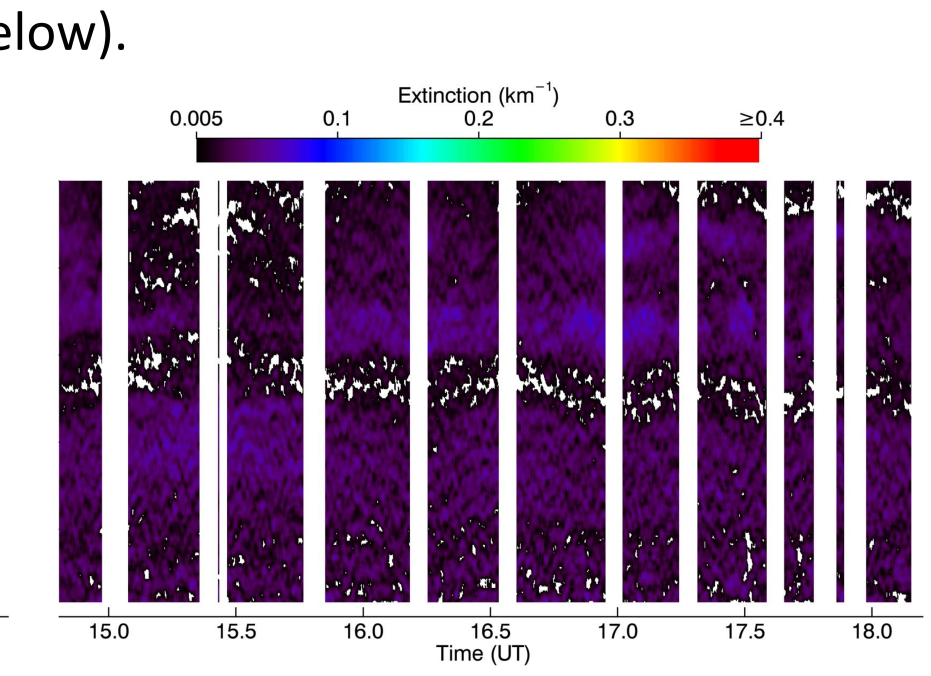


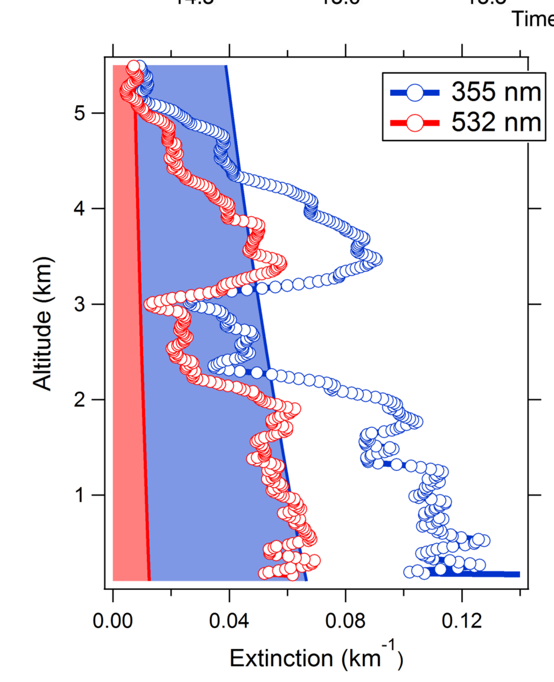
NASA's king air carried out measurements using the multispectral lidar HSRL-2

TCAP ground site and NASA's king air flight tracks

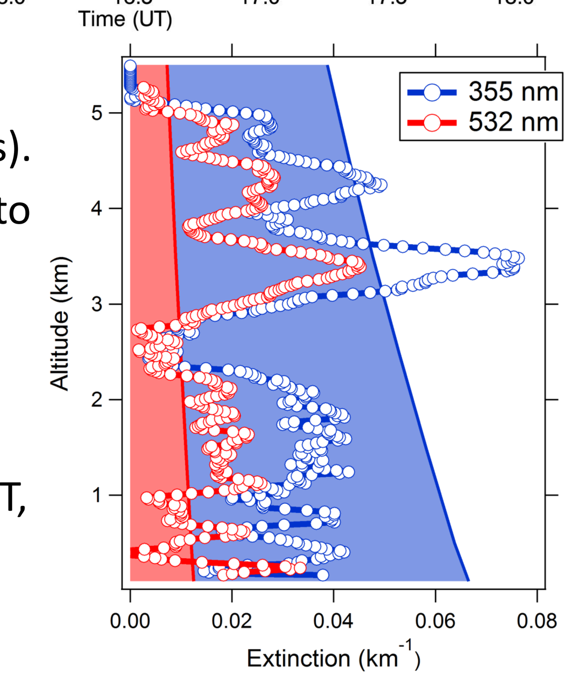
Highly resolved aerosol extinction profiles are obtained during TCAP with the NASA HSRL-2. Two days are chosen: July 17 (high AOD - left figure below), and July 22 2012 (low AOD - right figure below).



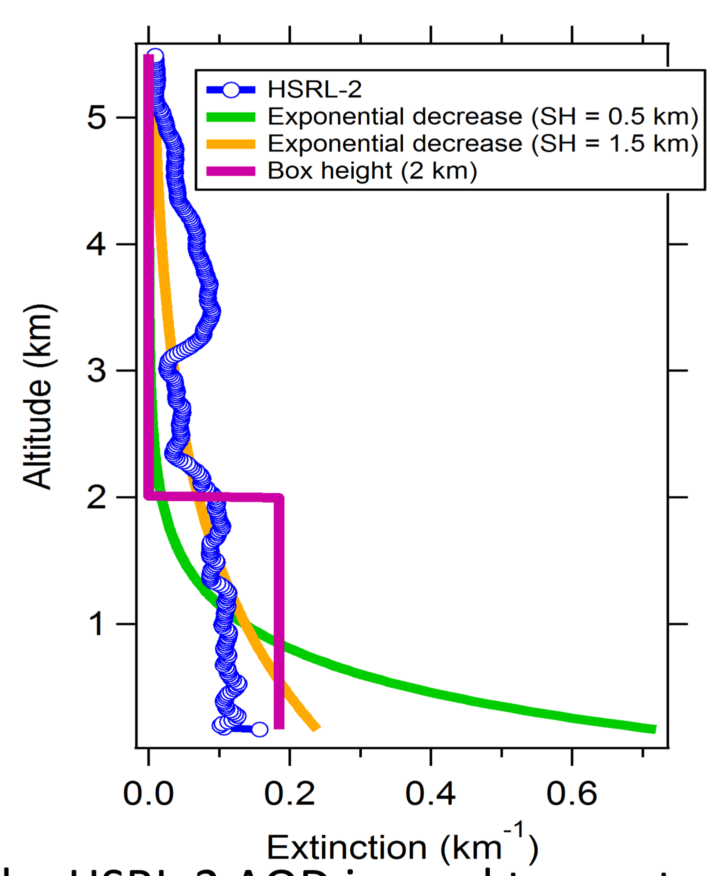




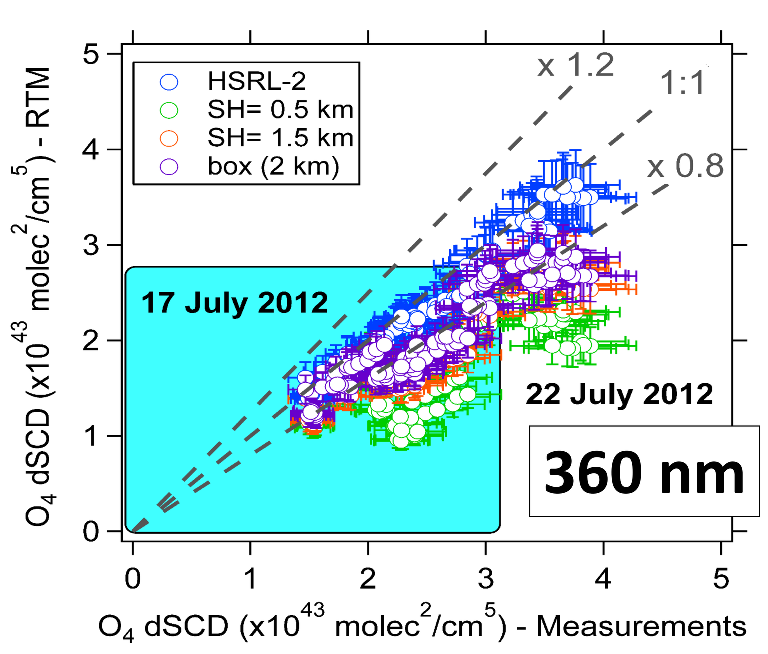
- Aerosol extinction profiles during overpasses were averaged (10km radius).
- The filled area indicates extinction due to molecular (Rayleigh) scattering.
- The comparison is limited to conditions when 2D-MAX-DOAS almucantar scans indicate homogeneous conditions.
- The AOD measured by MFRSR, AERONET, and 2D-MAX-DOAS agree within ±15 %.

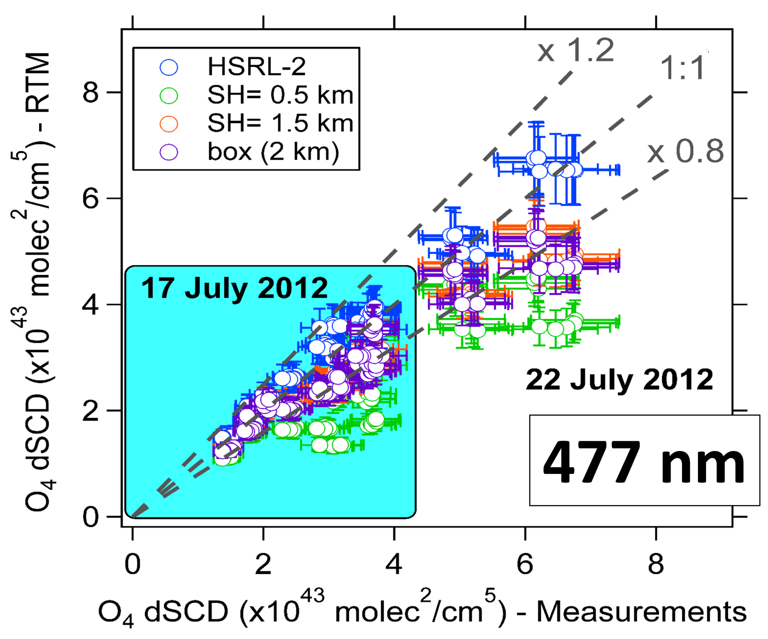


Results



- The HSRL-2 AOD is used to create aerosol extinction profiles that differ in shape, but have identical AOD.
- The above example shows profiles generated at 360 nm for July 17 2012.
- O_4 dSCDs are simulated using McArtim (Deutschmann et al., 2011)





The table shows the results from linear correlation of simulated vs measured O_4 dSCDs. The slope represents a proxy for the CF_{O4} using the different aerosol profiles as RTM input.

	HSRL-2	Exp decrease (SH=0.5 km)	Exp decrease (SH=1.5 km)	Box (2 km)
Slope (360/477 nm)	0.94/0.99	0.54/0.59	0.71/0.75	0.71/0.73
Intercept[1] (360/477 nm)	-0.008/0.18	0.32/0.37	0.12/0.39	0.20/0.34
R^2 (360/477 nm)	0.98/0.98	0.53/0.73	0.88/0.93	0.90/0.94

Conclusions

- Measured and calculated O_4 dSCDs agree within < 6% when using HSRL-2 profiles.
- No need for CF_{O4} at high and low AOD, if the aerosol profile is well known.
- Simplified aerosol profiles consistently find $O_4\ dSCD_{meas} > O_4\ dSCD_{RTM}$
- Simplified aerosol profiles need $0.54 < CF_{O4} < 0.75$.

Acknowledgments

R.V. is recipient of NSF-CAREER award ATM-0847793 to develop 2D-MAX-DOAS, and DoE award DE-SC0006080 supported the TCAP measurements. I.O. is recipient of a NASA Earth Science graduate fellowship. We thank the entire TCAP team for support during the field campaign.