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Supplement of

Intercomparison of NO_2, O_4, O_3 and HCHO slant column measurements by MAX-DOAS and zenith-sky UV–visible spectrometers during CINDI-2

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S1 MAX-DOAS regression results

This section presents detailed results from regression analyses performed for the eight MAX-DOAS data products. In each sub-section below, three plots are provided, showing respectively:

- Scatter plots of the regression between individual data sets and median reference values for all measurement days and all viewing and elevation directions (similar to Figures 10, 11 and 12 of the main manuscript).
- Overview plots of the slope, intercept and RMS from regression analysis for all measurement days and viewing directions, and for several elevation angles (1°, 3°, 5°, 8°, 15°, and 30°) (similar to Figure 15 of the main manuscript).
- Summary overview plots of the slope, intercept and RMS from regression analysis for all measurement days and all viewing and elevation directions. These summarize the details of the performance assessment results, as described in Figure 17 of the main manuscript.

S1.1 MAX-DOAS results for NO_2 in the visible range (NO2vis)

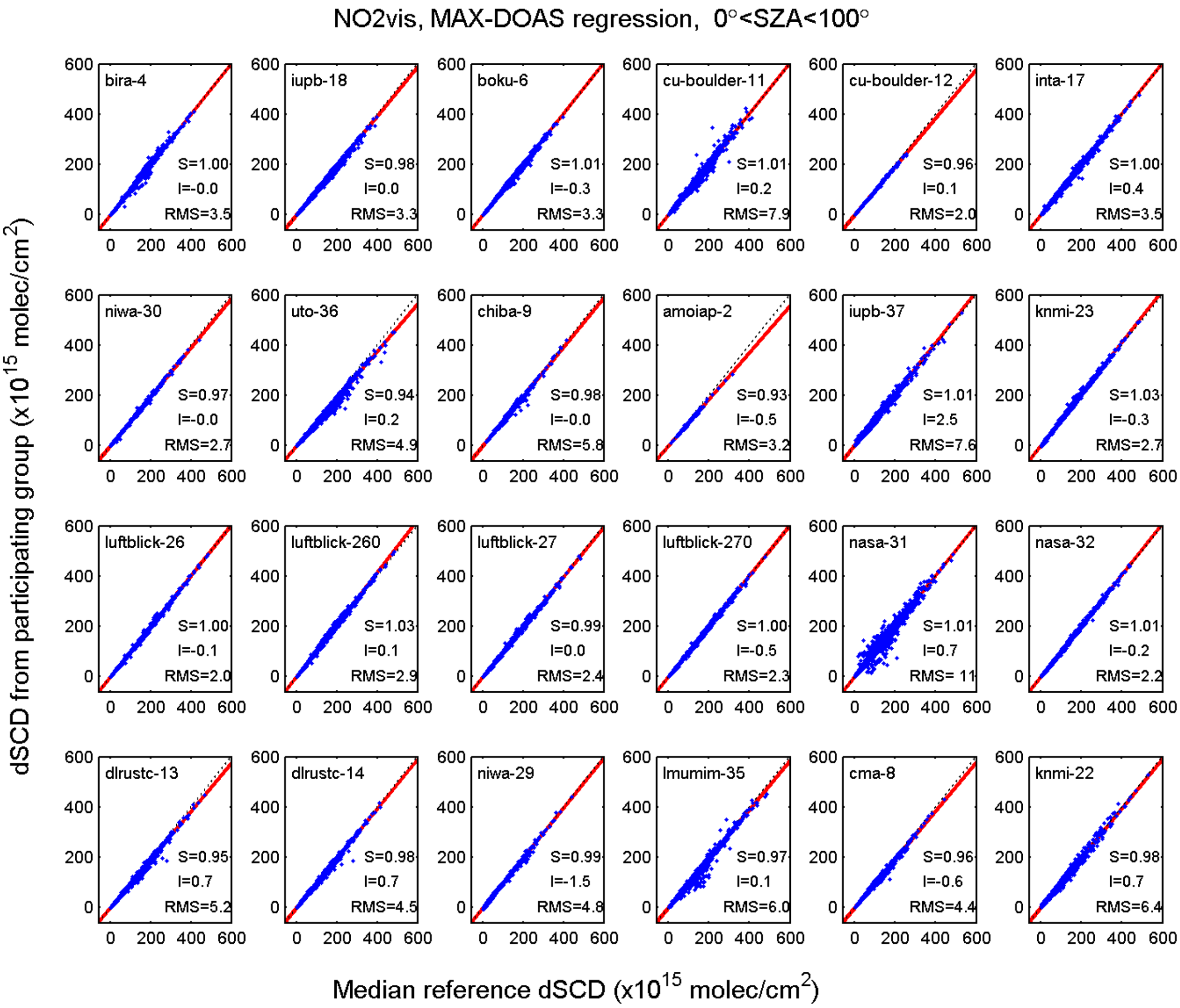


Figure S1: Regression analysis for NO_2 dSCDs (measured in the visible wavelength region), corresponding to Figure 10 in the main manuscript.

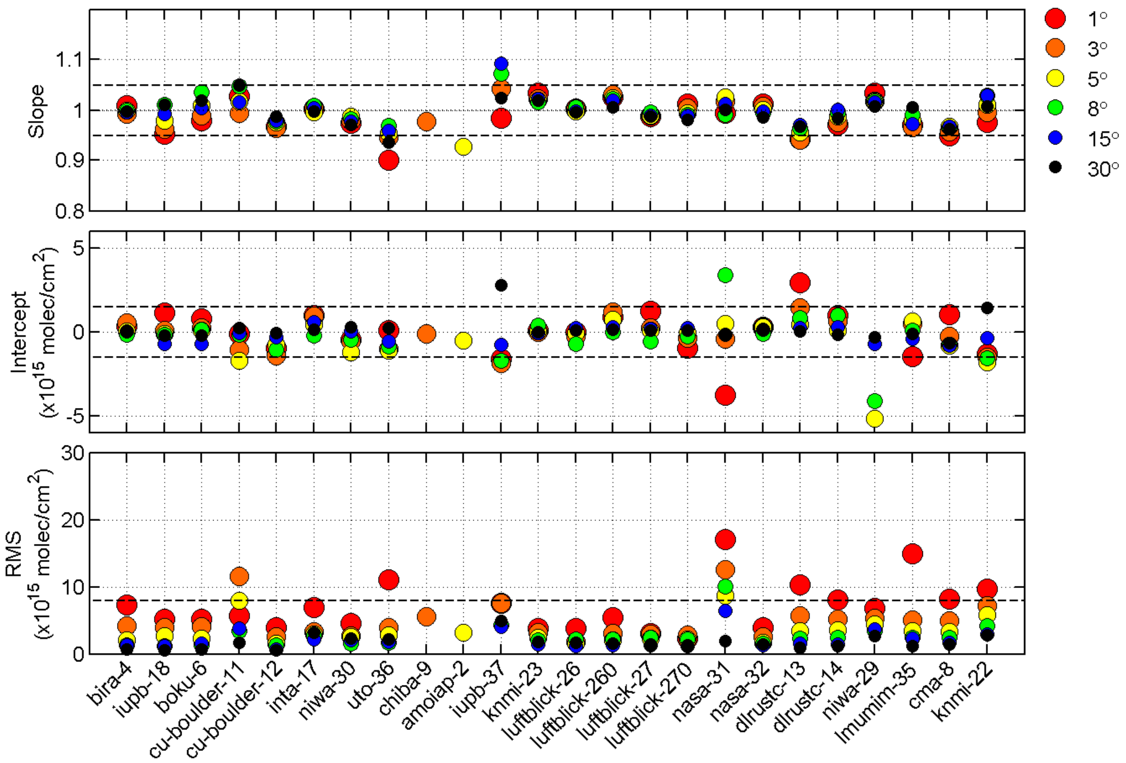


Figure S2: Slope, Intercept and RMS of NO_2 dSCDs against those of the median reference data set, for each instrument measuring NO_2 in the visible range. Colours refer to elevation angles shown top right. This figure is corresponding to Figure 17 in the main manuscript.

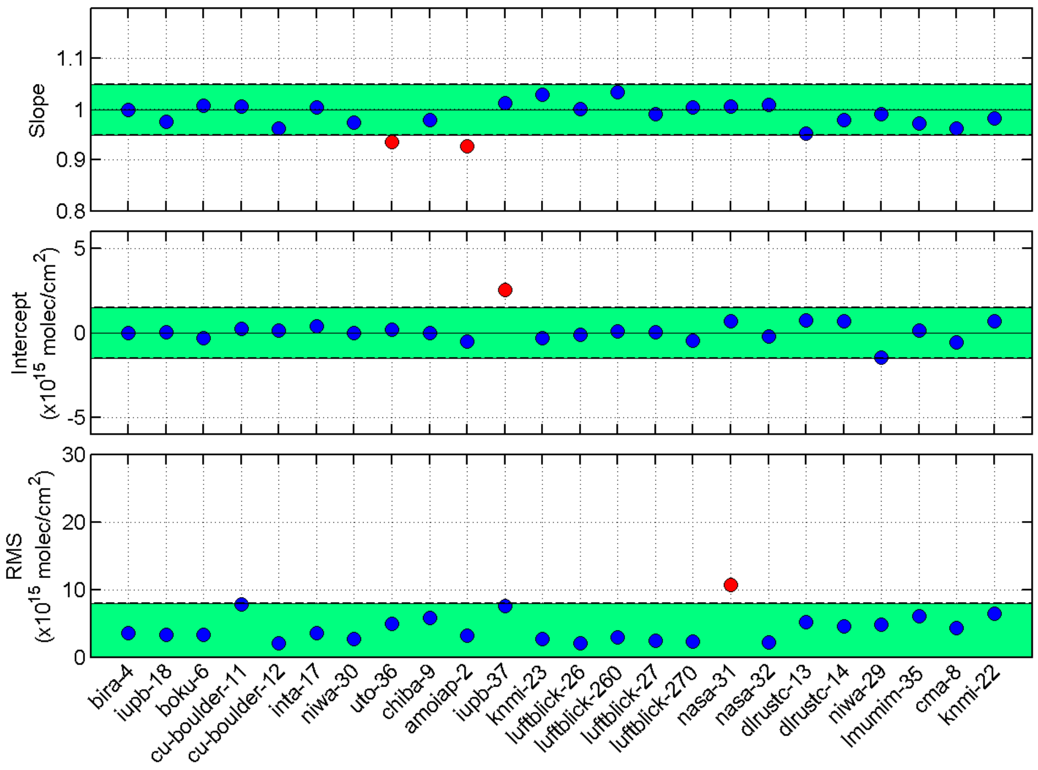


Figure S3: Summary of the regression statistic for NO_2 in the visible range, showing the slope, intercept and RMS values as displayed in Figure S1. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red. This figure is corresponding to Figure 17 in the main manuscript.

S1.2 MAX-DOAS results for NO_2 in the small visible range (NO2visSmall)

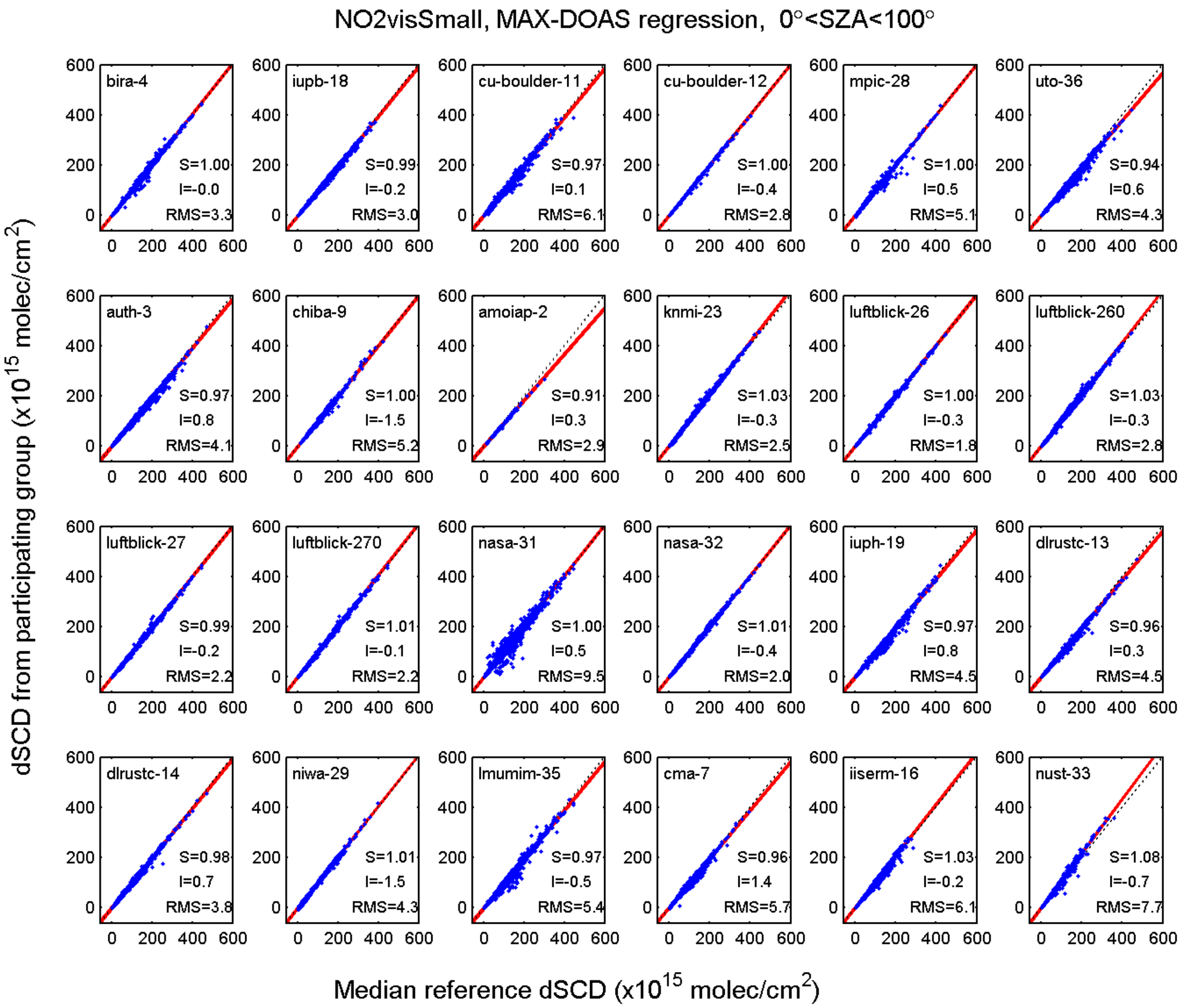


Figure S4: Regression analysis for NO_2 dSCDs (measured in the small visible wavelength region).

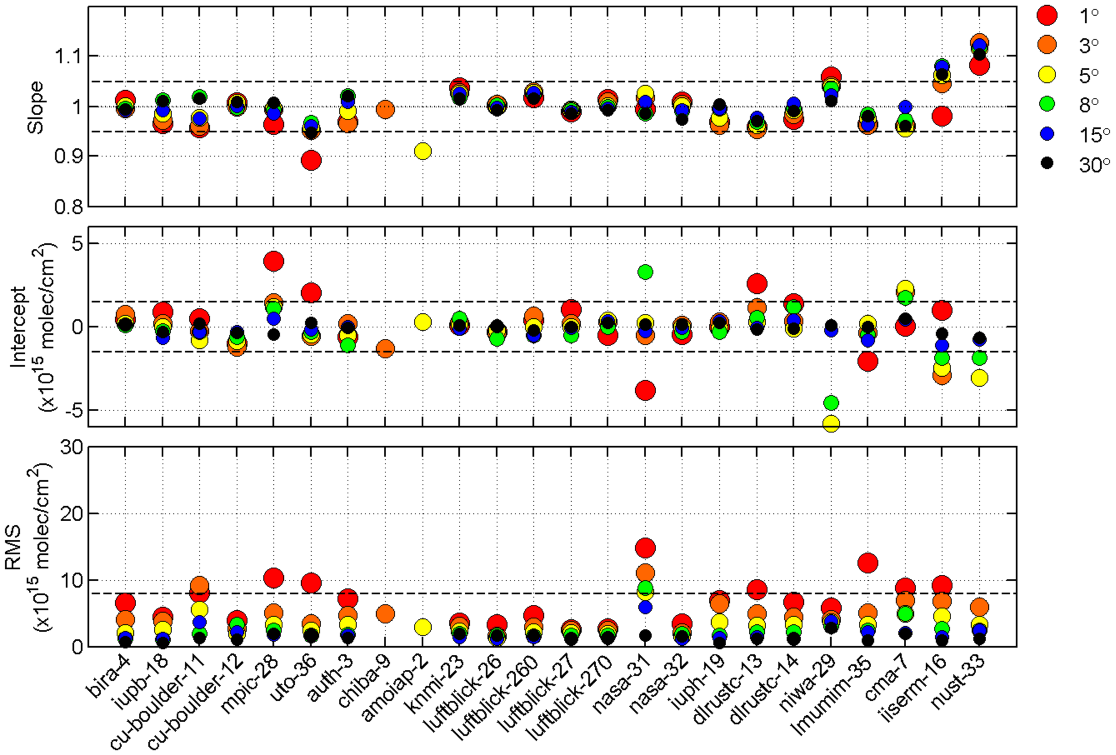


Figure S5: Slope, Intercept and RMS of NO_2 dSCDs against those of the median reference data set, for each instrument measuring NO_2 in the small visible range. Colours refer to elevation angles shown top right.

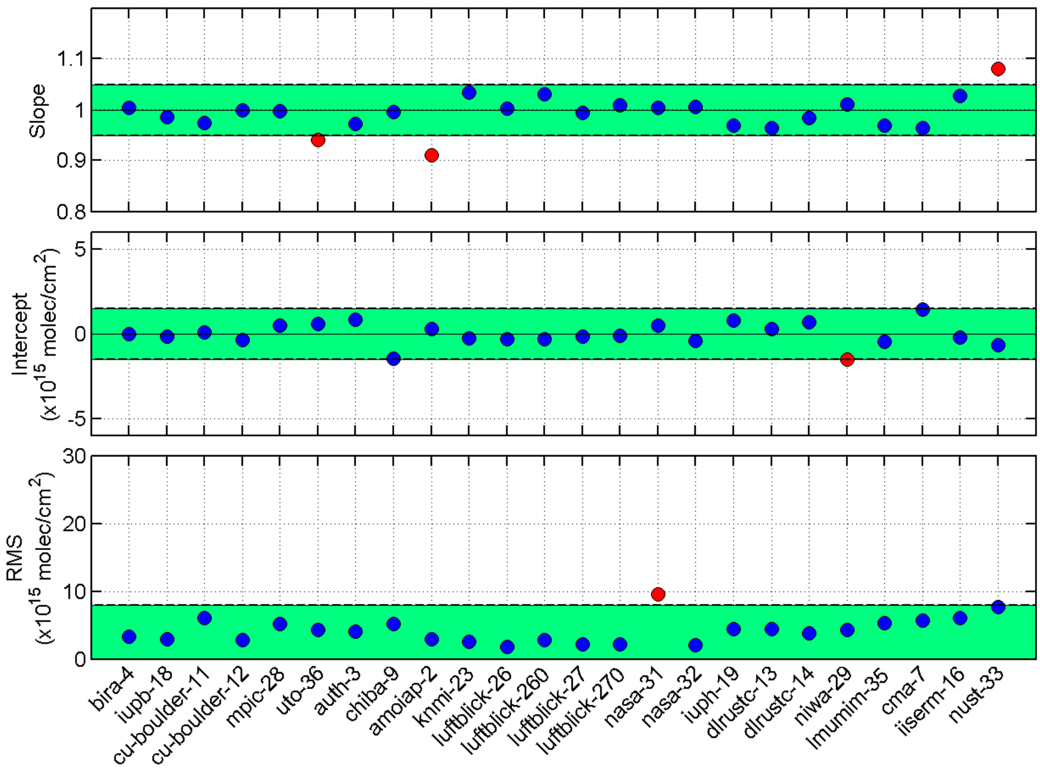


Figure S6: Summary of the regression statistic for NO_2 in the small visible range, showing the slope, intercept and RMS values as displayed in Figure S4. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.3 MAX-DOAS results for NO_2 in the UV range (NO2uv)

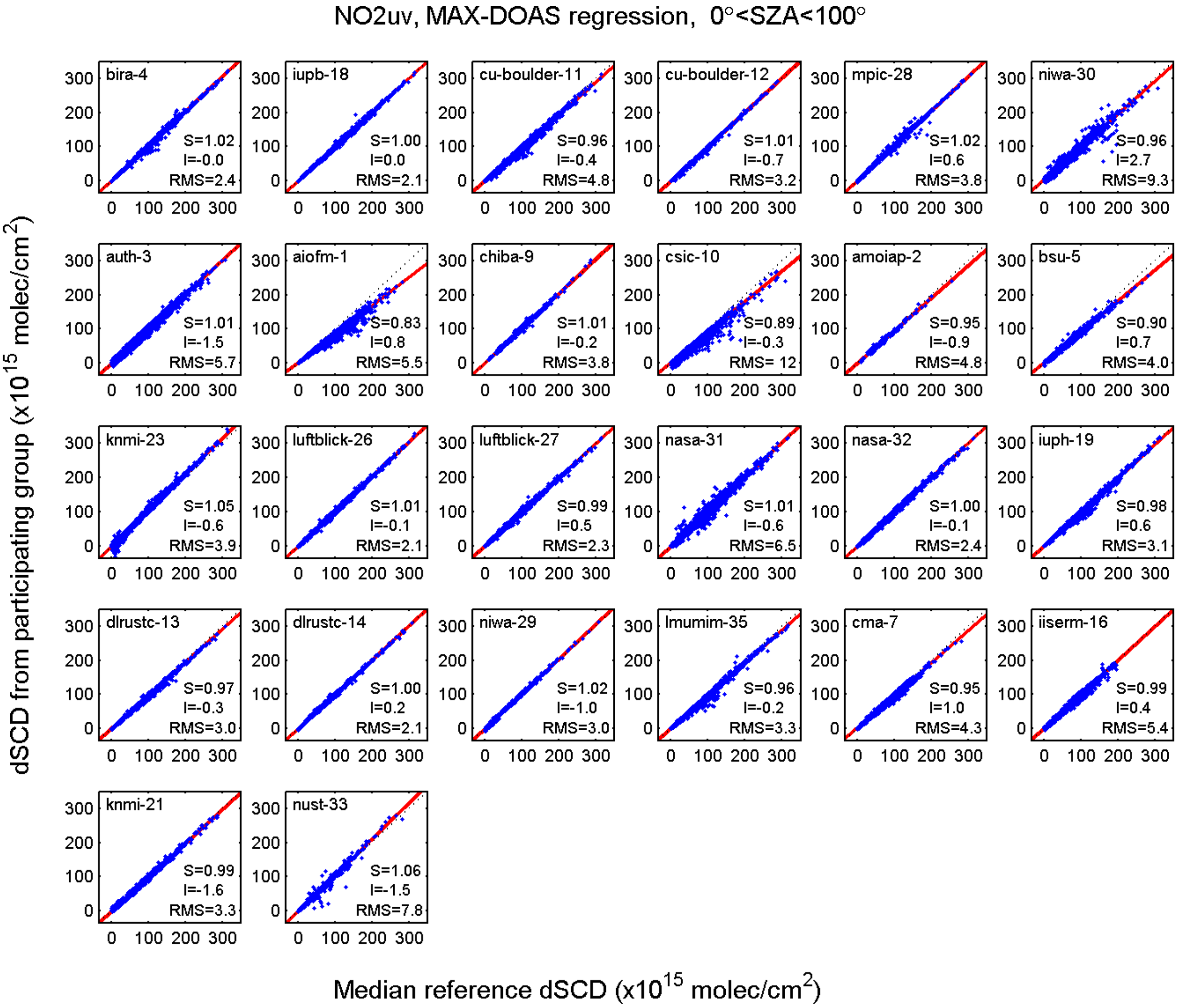


Figure S7: Regression analysis for NO_2 dSCDs (measured in the UV wavelength region).

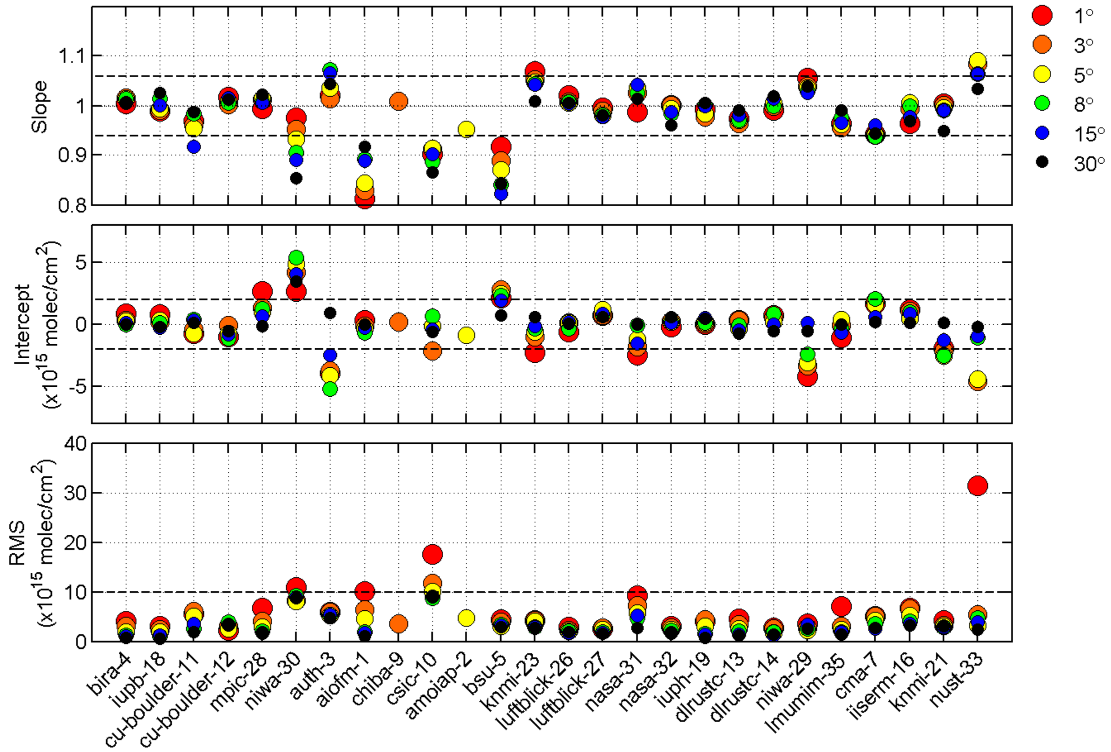


Figure S8: Slope, Intercept and RMS of NO_2 dSCDs against those of the median reference data set, for each instrument measuring NO_2 in the UV range. Colours refer to elevation angles shown top right.

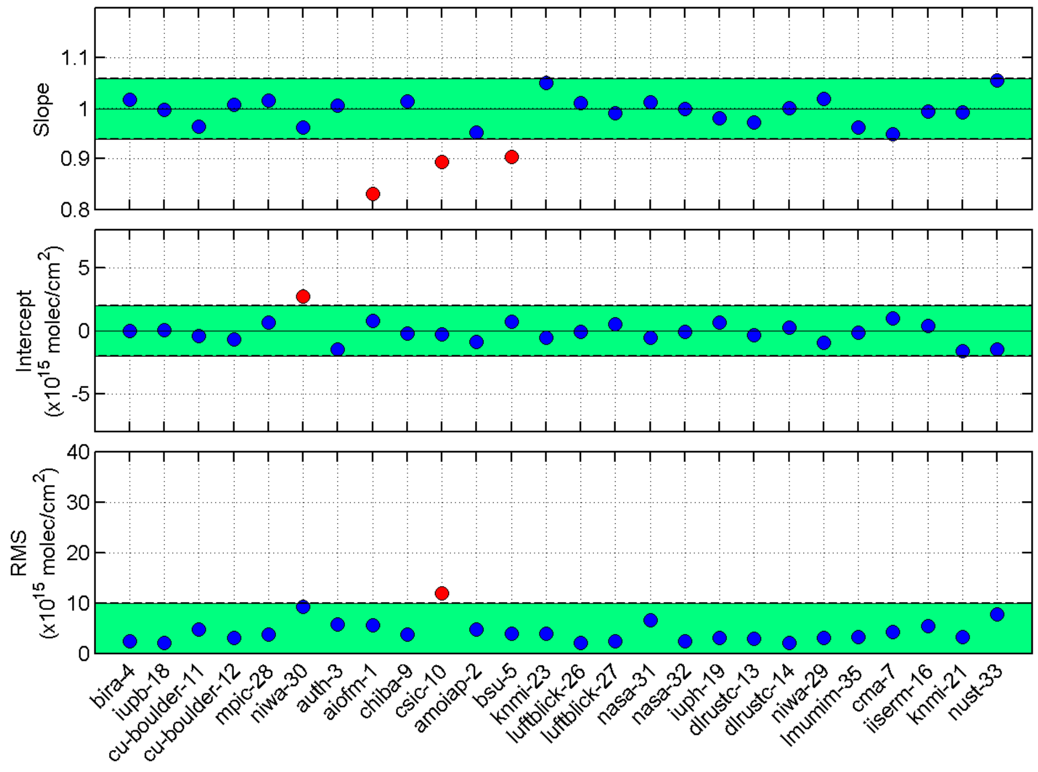


Figure S9: Summary of the regression statistic for NO_2 in the UV range, showing the slope, intercept and RMS values as displayed in Figure S7. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.4 MAX-DOAS results for O_4 in the visible range (O4vis)

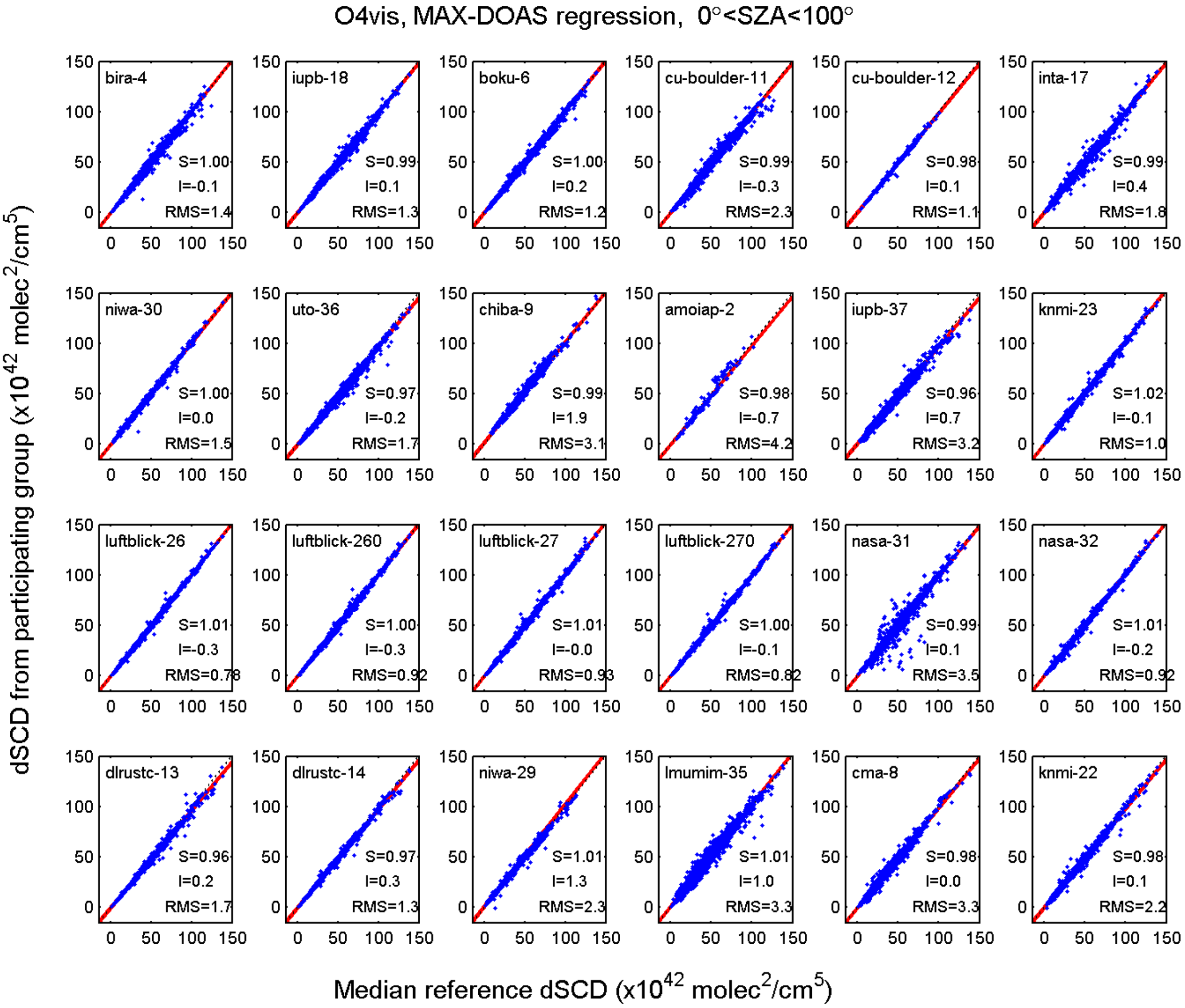


Figure S10: Regression analysis for O_4 dSCDs (measured in the visible wavelength region), corresponding to Figure 11 in the main manuscript.

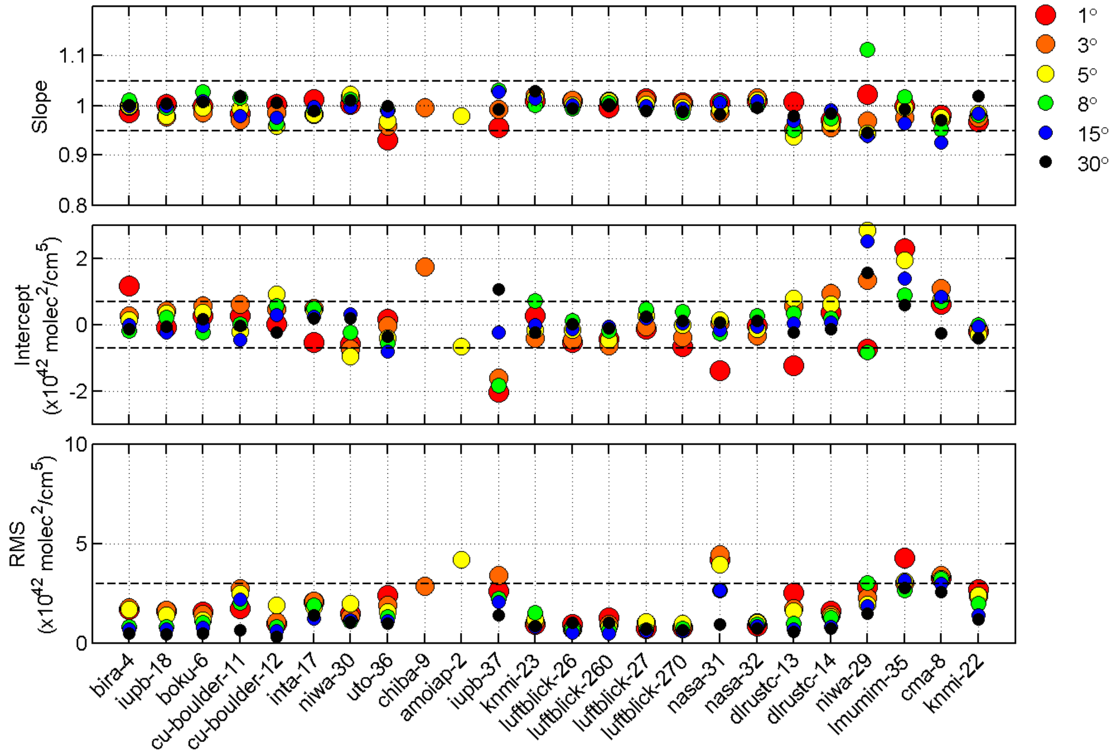


Figure S11: Slope, Intercept and RMS of O_4 dSCDs against those of the median reference data set, for each instrument measuring O_4 in the visible range. Colours refer to elevation angles shown top right.

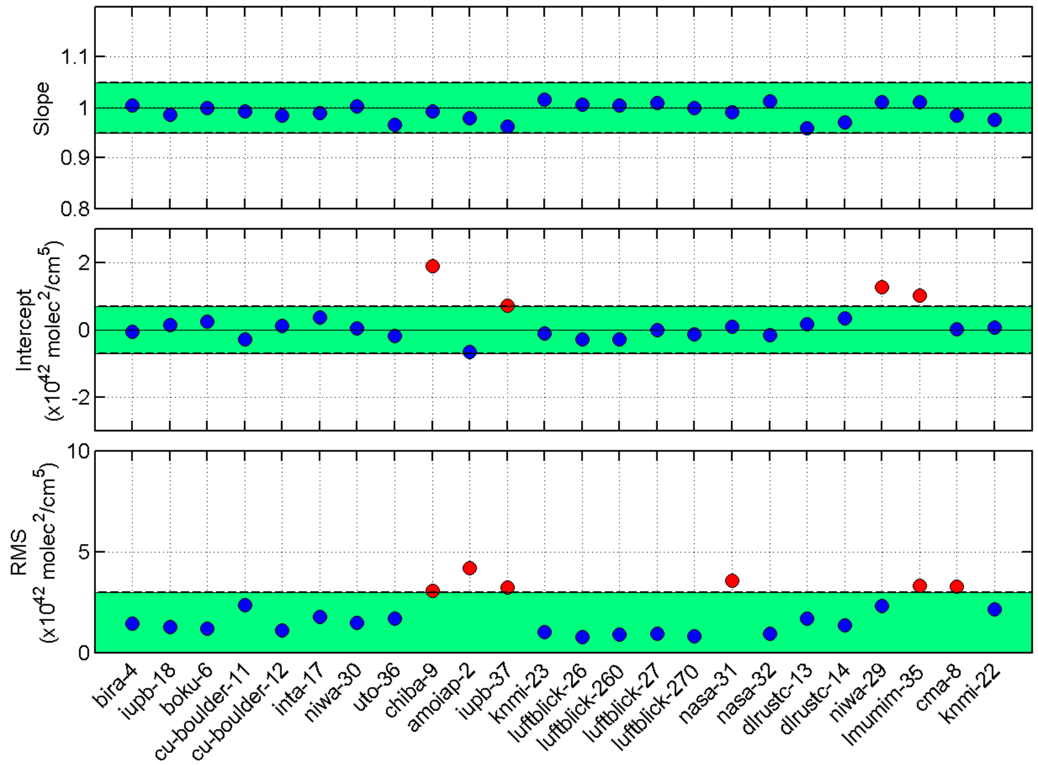


Figure S12: Summary of the regression statistic for O_4 in the visible range, showing the slope, intercept and RMS values as displayed in Figure S10. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.5 MAX-DOAS results for O_4 in the UV range (O4uv)

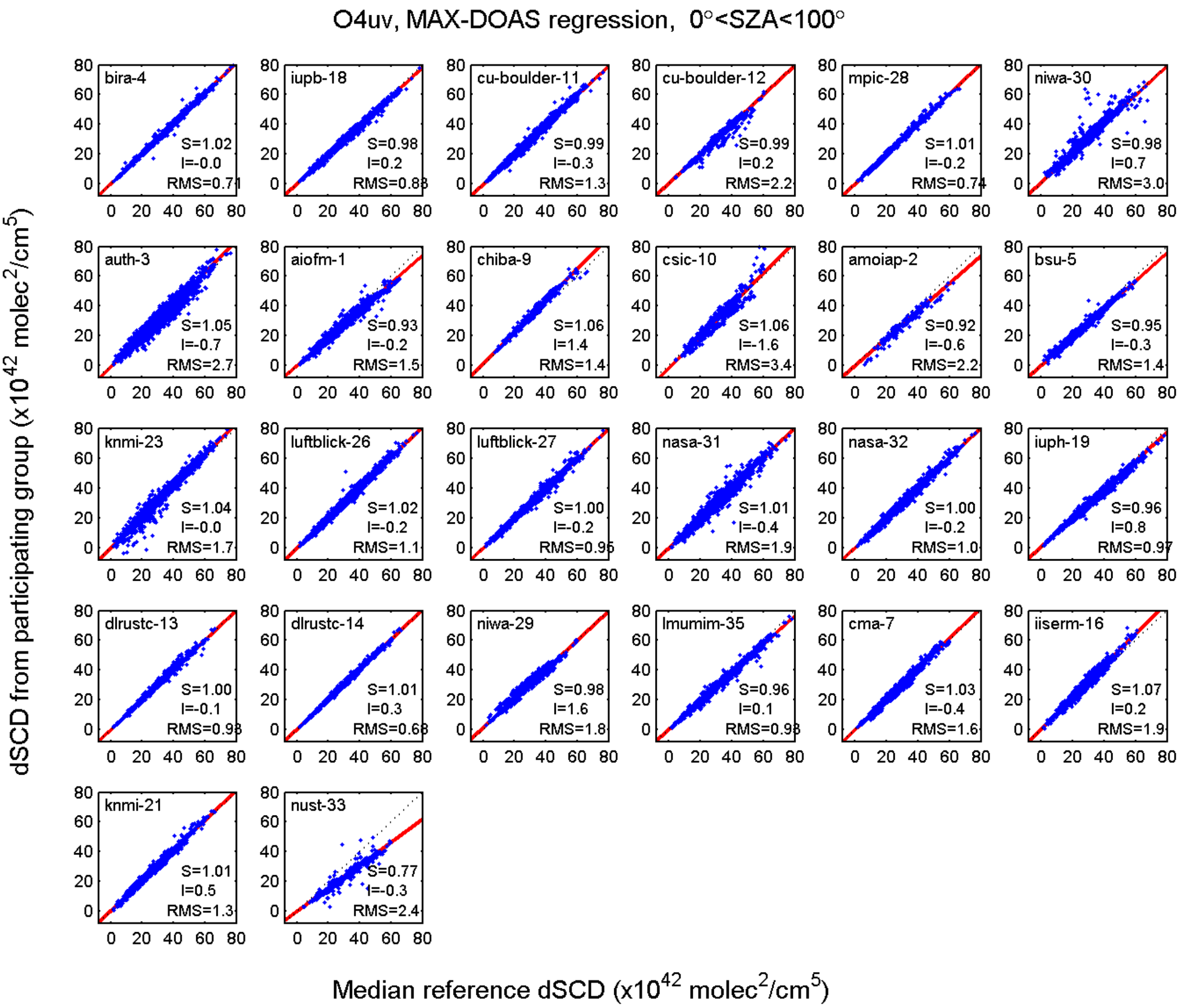


Figure S13: Regression analysis for O_4 dSCDs (measured in the UV wavelength region).

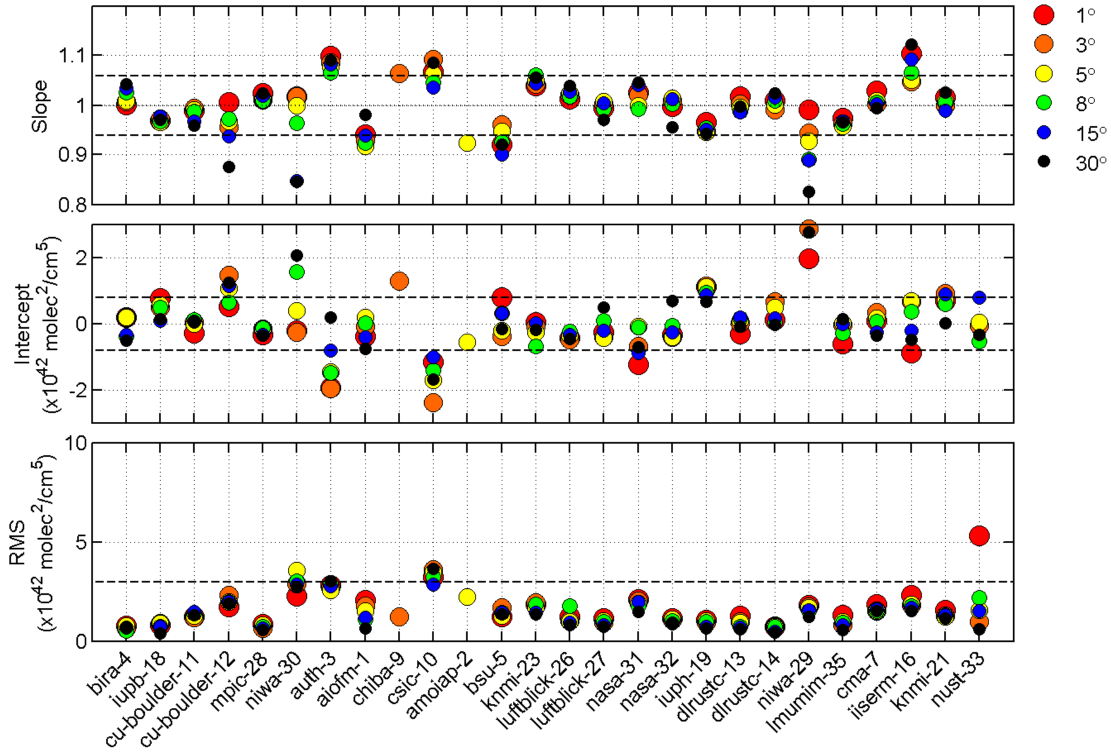


Figure S14: Slope, Intercept and RMS of O_4 dSCDs against those of the median reference data set, for each instrument measuring O_4 in the UV range. Colours refer to elevation angles shown top right.

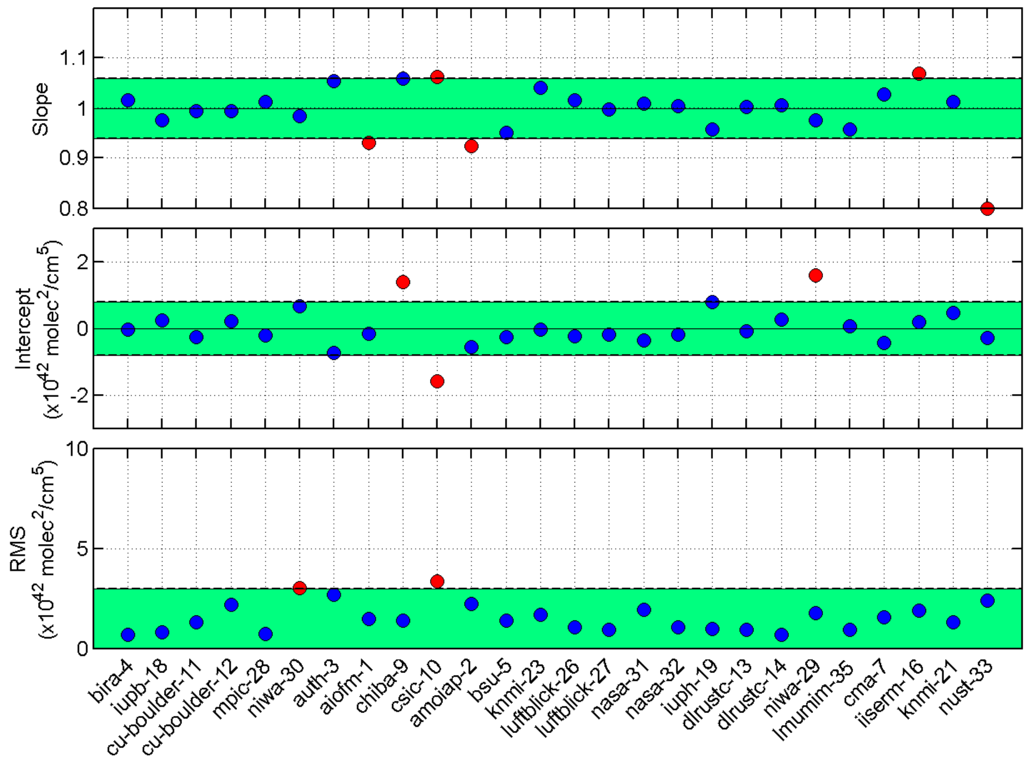


Figure S15: Summary of the regression statistic for O_4 in the UV range, showing the slope, intercept and RMS values as displayed in Figure S13. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.6 MAX-DOAS results for HCHO

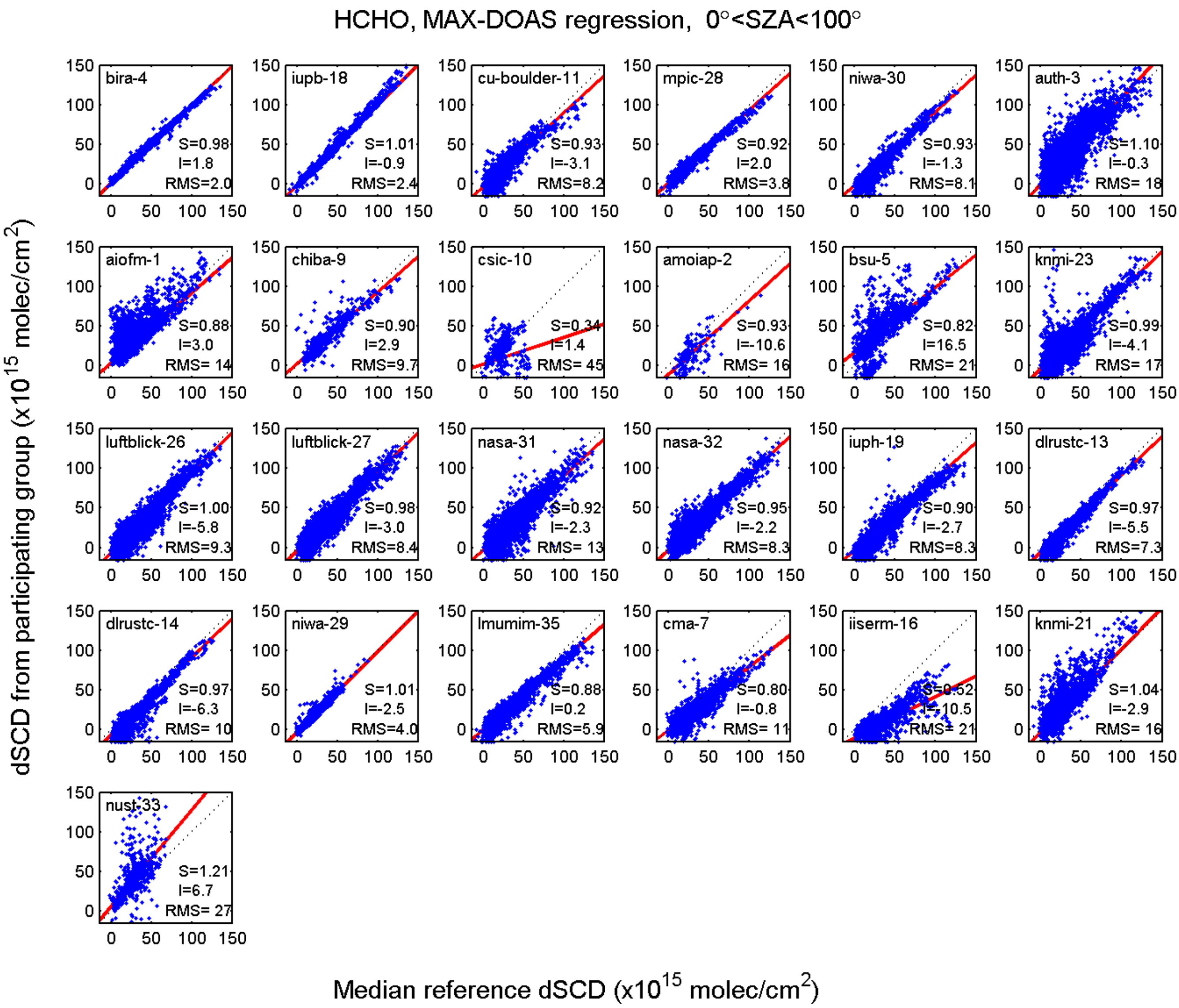


Figure S16: Regression analysis for HCHO dSCDs, corresponding to Figure 12 in the main manuscript.

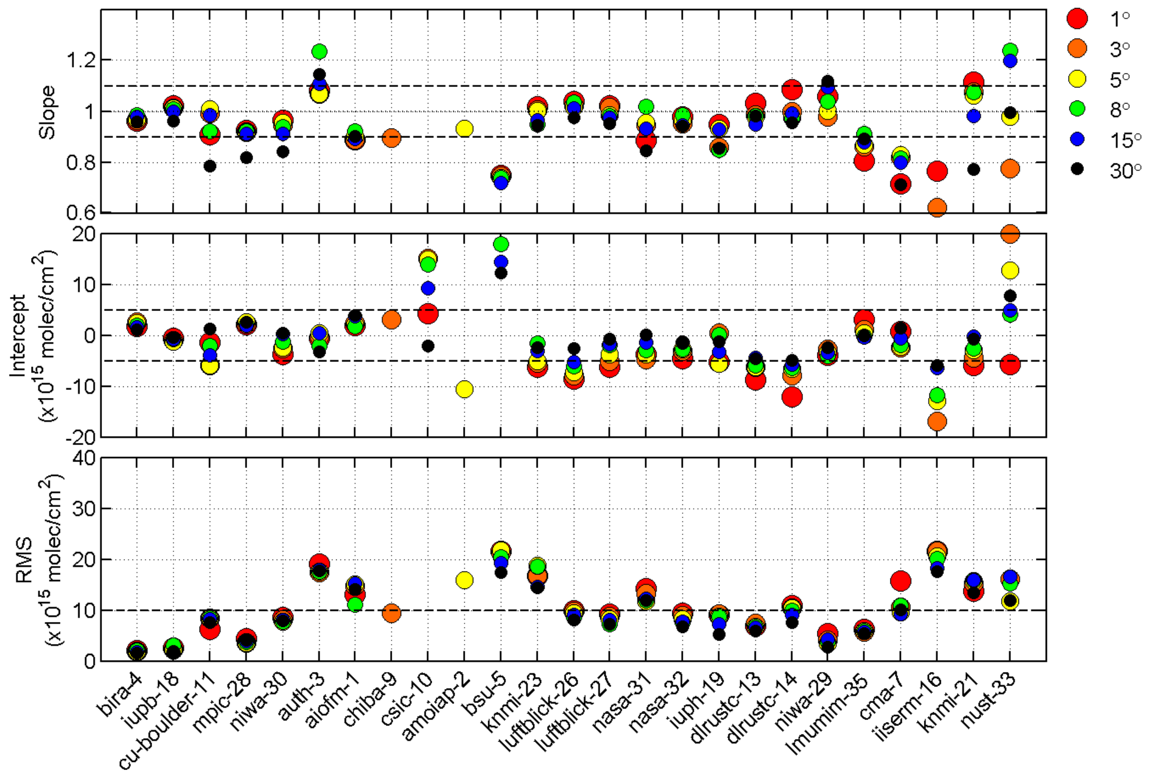


Figure S17: Slope, Intercept and RMS of HCHO dSCDs against those of the median reference data set, for each instrument measuring HCHO. Colours refer to elevation angles shown top right.

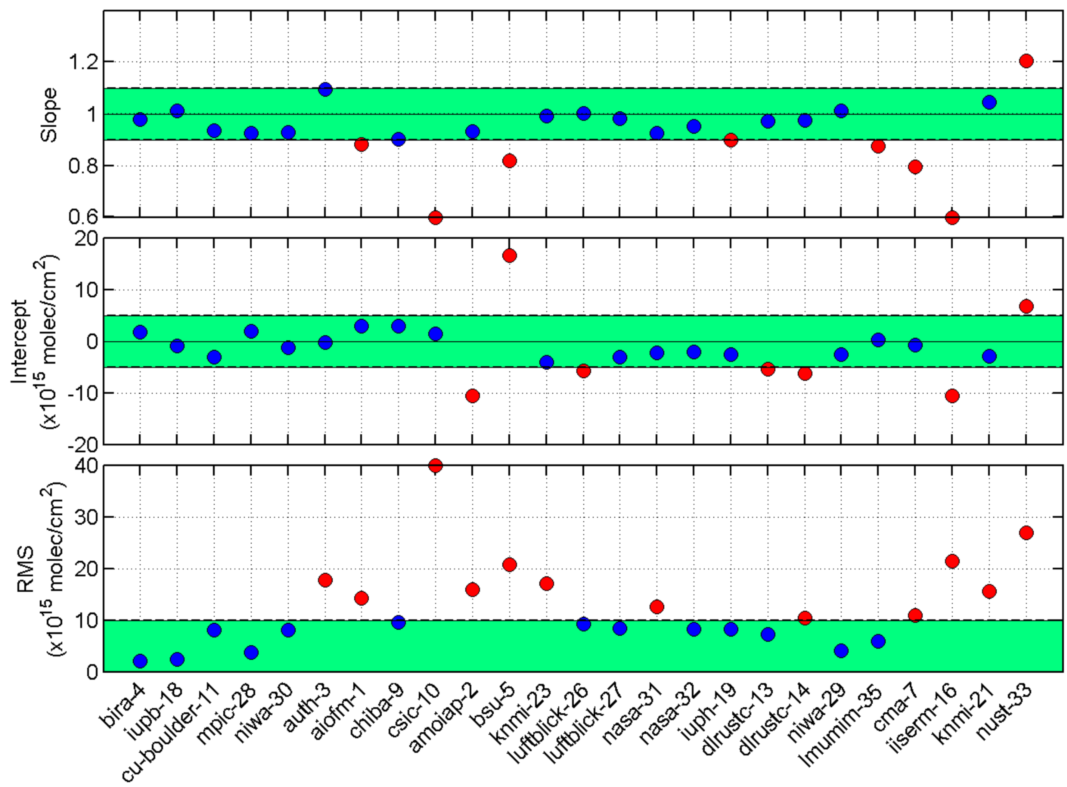


Figure S18: Summary of the regression statistic for HCHO, showing the slope, intercept and RMS values as displayed in Figure S16. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.7 MAX-DOAS results for O_3 in the visible range (O3vis)

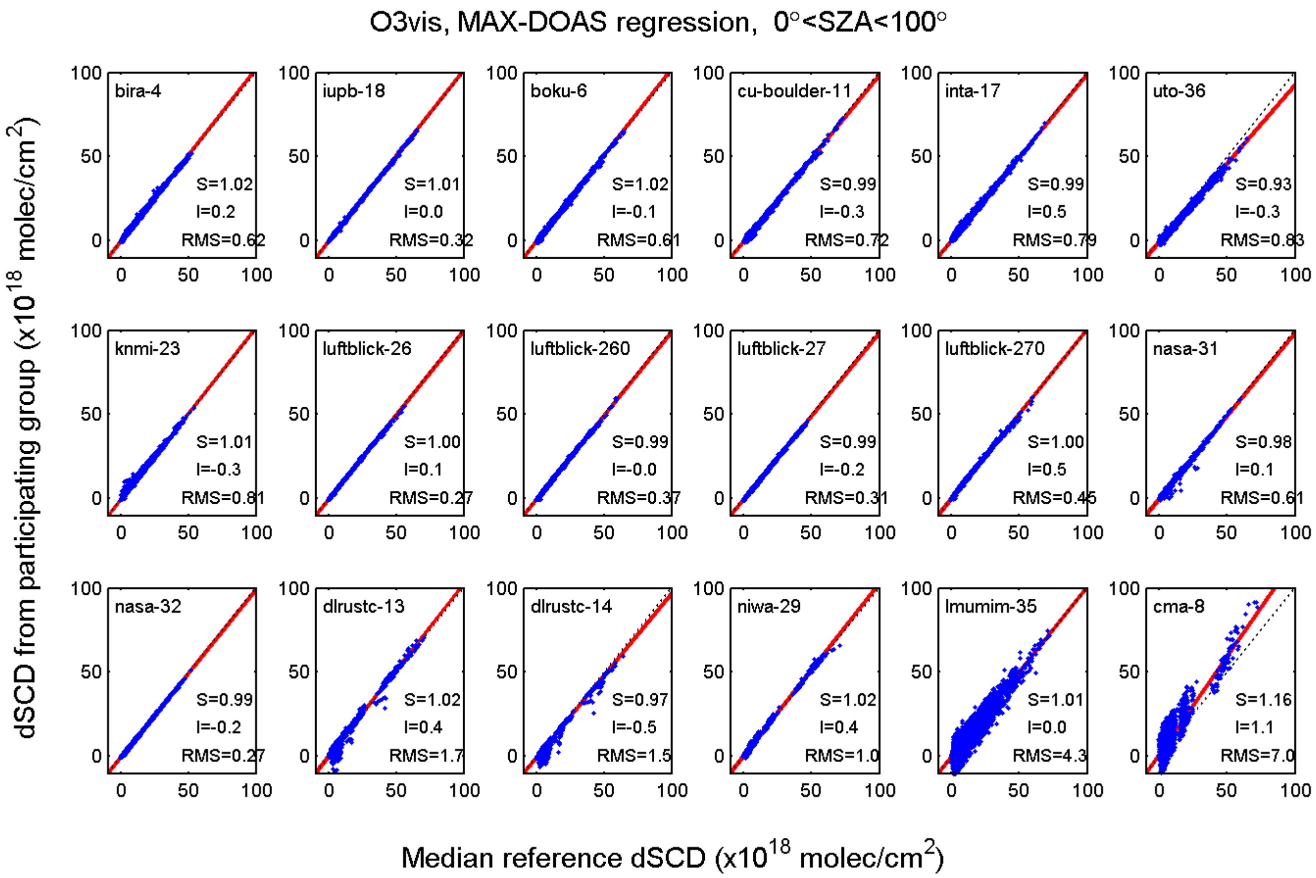


Figure S19: Regression analysis for O_3 dSCDs (measured in the visible wavelength region).

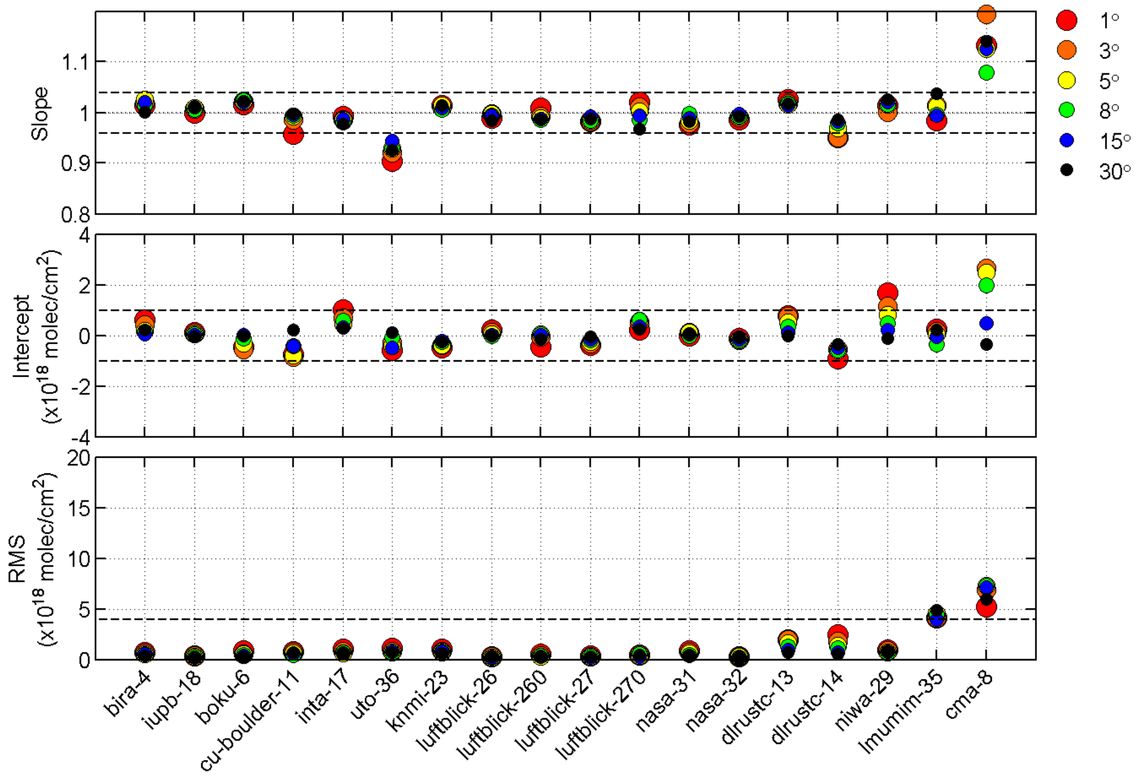


Figure S20: Slope, Intercept and RMS of O_3 dSCDs against those of the median reference data set, for each instrument measuring O_3 in the visible range. Colours refer to elevation angles shown top right.

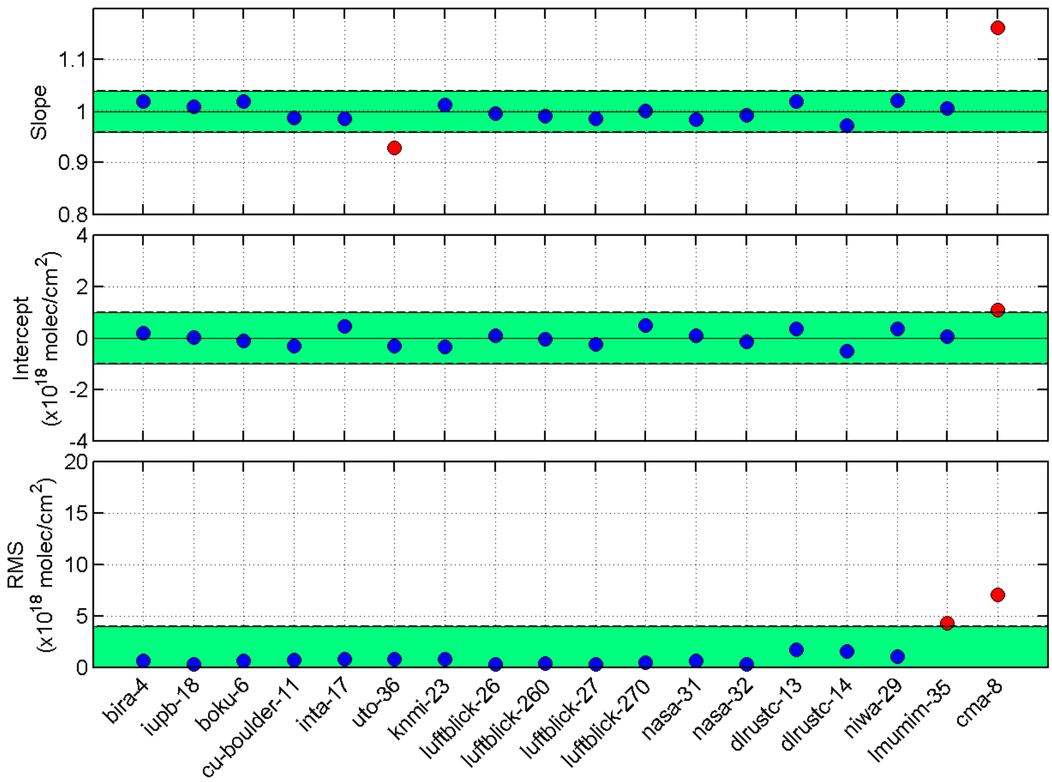


Figure S21: Summary of the regression statistic for O_3 in the visible range, showing the slope, intercept and RMS values as displayed in Figure S19. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S1.8 MAX-DOAS results for O_3 in the UV range (O3uv)

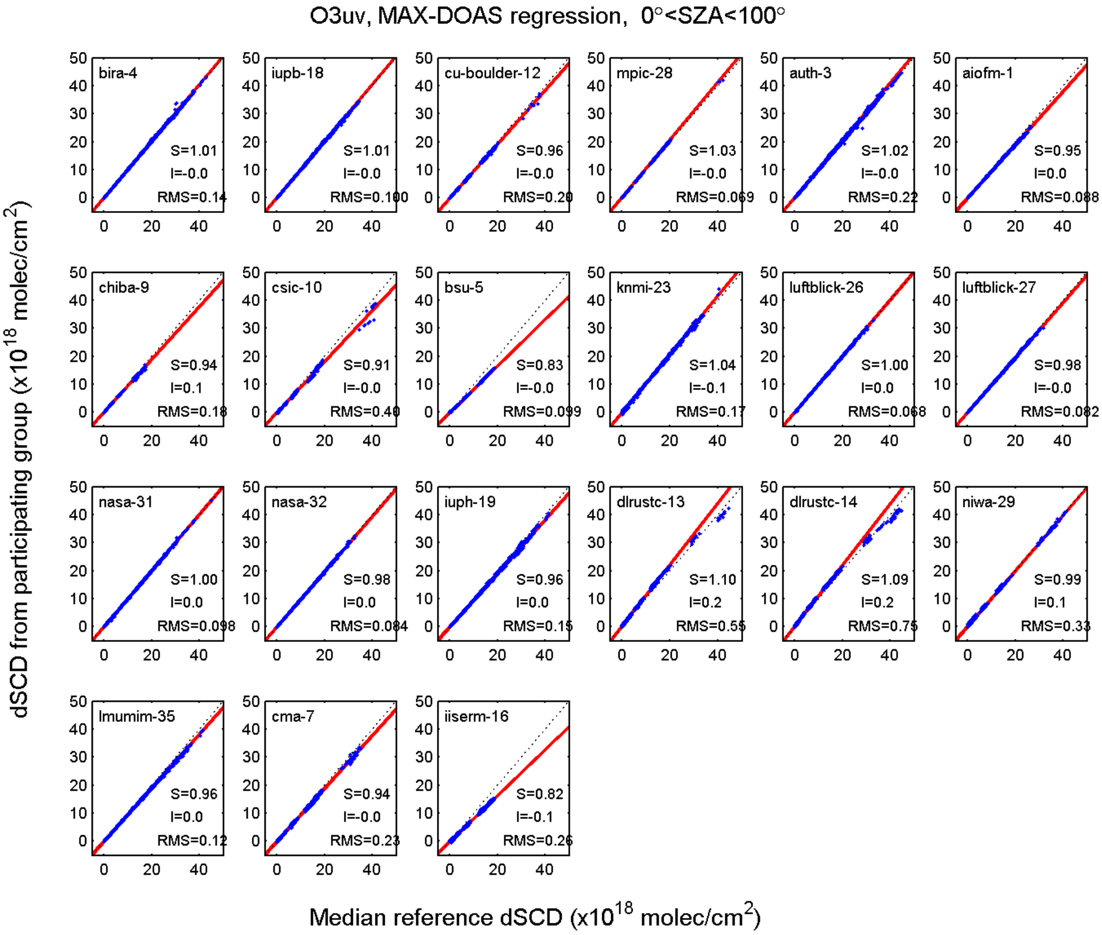


Figure S22: Regression analysis for O_3 dSCDs (measured in the UV wavelength region).

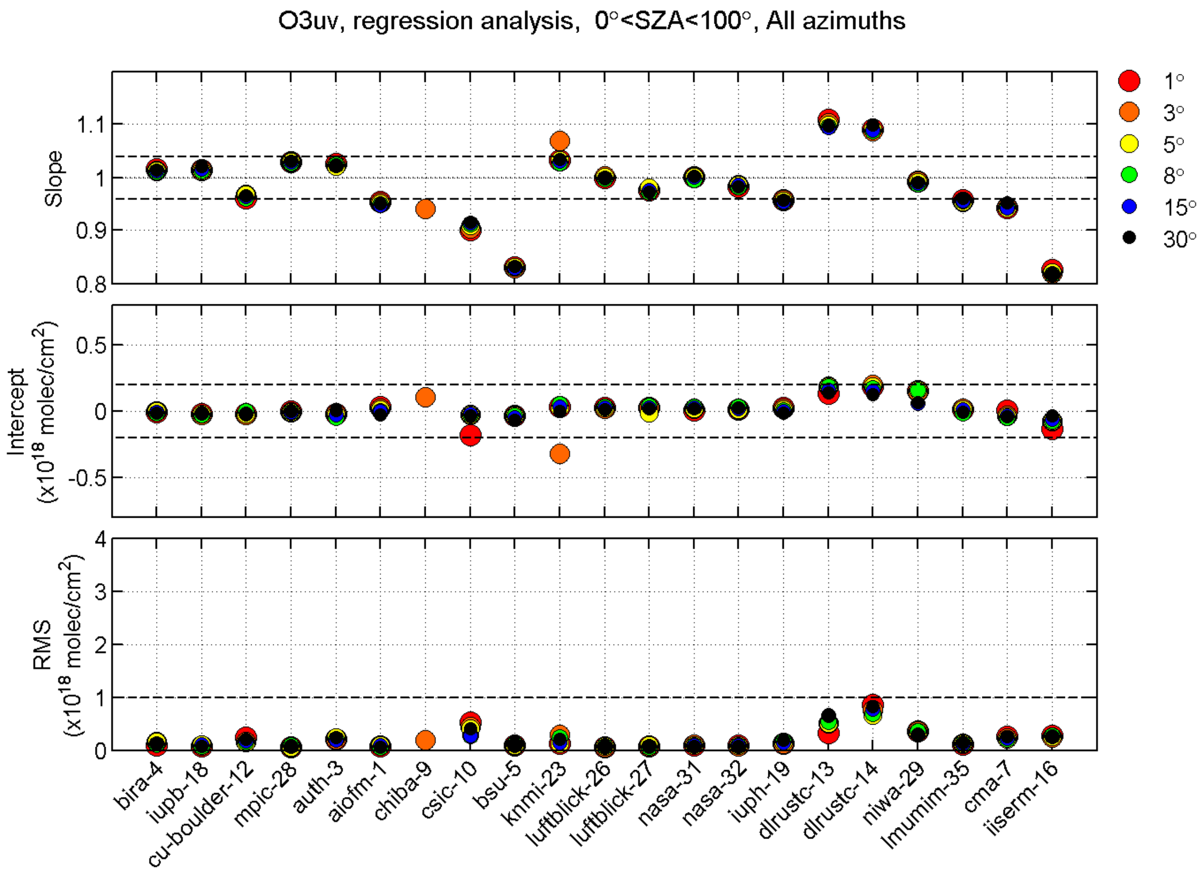


Figure S23: Slope, Intercept and RMS of O_3 dSCDs against those of the median reference data set, for each instrument measuring O_3 in the UV range. Colours refer to elevation angles shown top right.

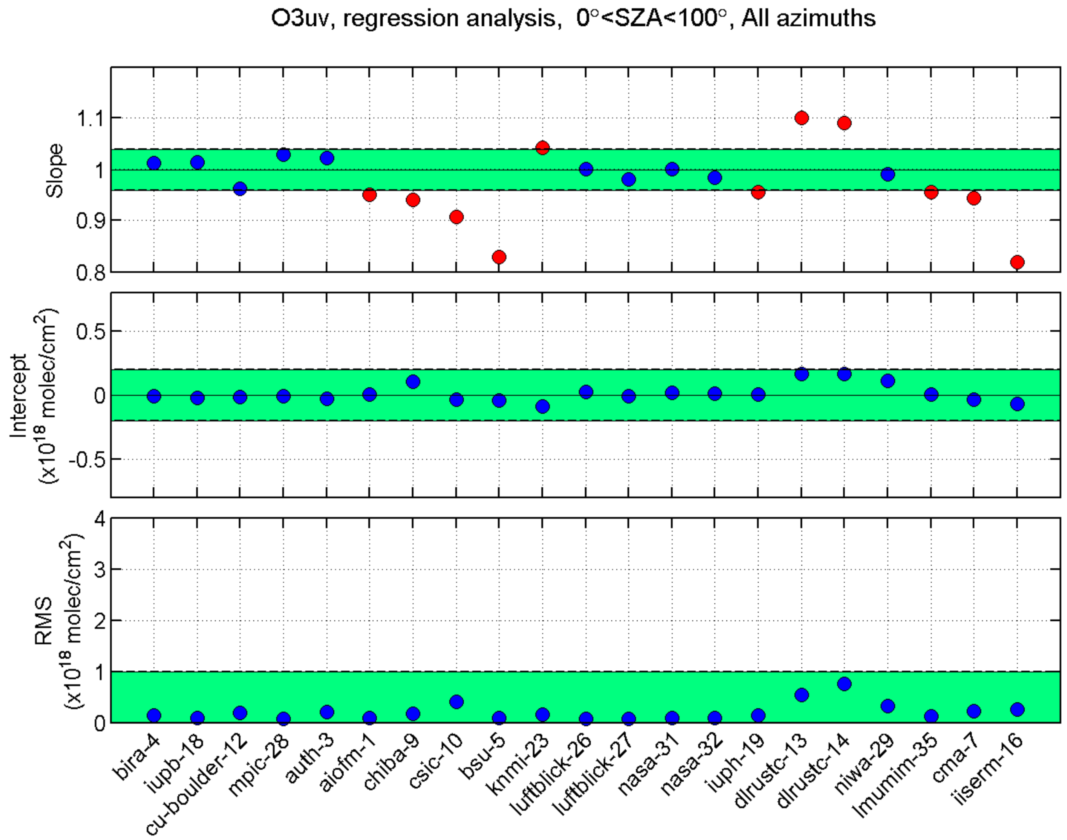


Figure S24: Summary of the regression statistic for O_3 in the UV range, showing the slope, intercept and RMS values as displayed in Figure S22. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S2 Zenith-sky twilight regression results

This section presents detailed results from regression analyses performed for the four zenith-sky twilight data products. In each sub-section below, two plots are provided, showing respectively:

- scatter plots of the regression between individual data sets and median reference values for all measurement days,
- summary overview plots of the slope, intercept and RMS from regression analysis for all measurement days. These summarize the details of the performance assessment results for zenith-sky twilight measurements as performed within NDACC.

S2.1 Zenith-sky results for NO_2 in the visible range (NO2vis)

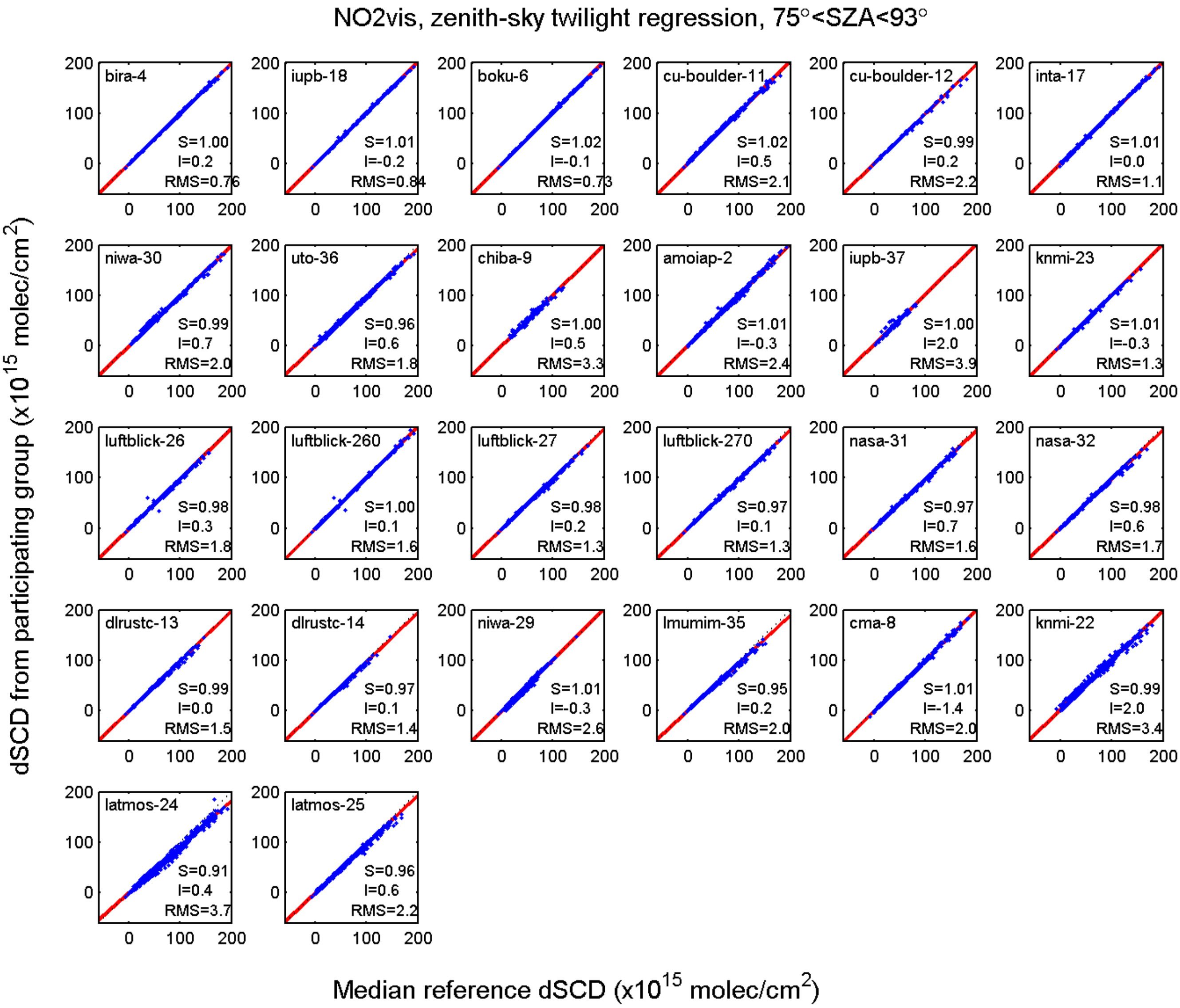


Figure S25: Regression analysis for zenith-sky NO_2 dSCDs (measured in the visible wavelength region).

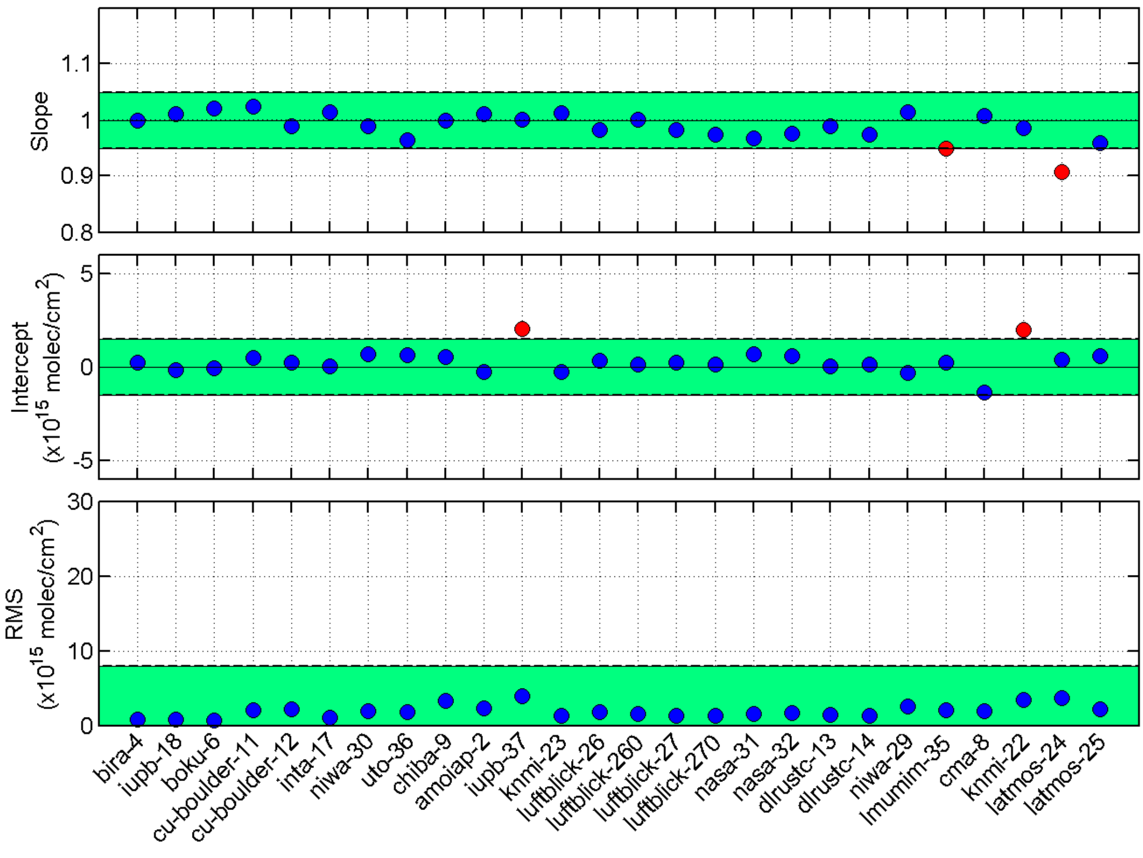


Figure S26: Summary of the regression statistic for zenith-sky NO_2 in the visible range, showing the slope, intercept and RMS values as displayed in Figure S25. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S2.2 Zenith-sky results for NO_2 in the small visible range (NO2visSmall)

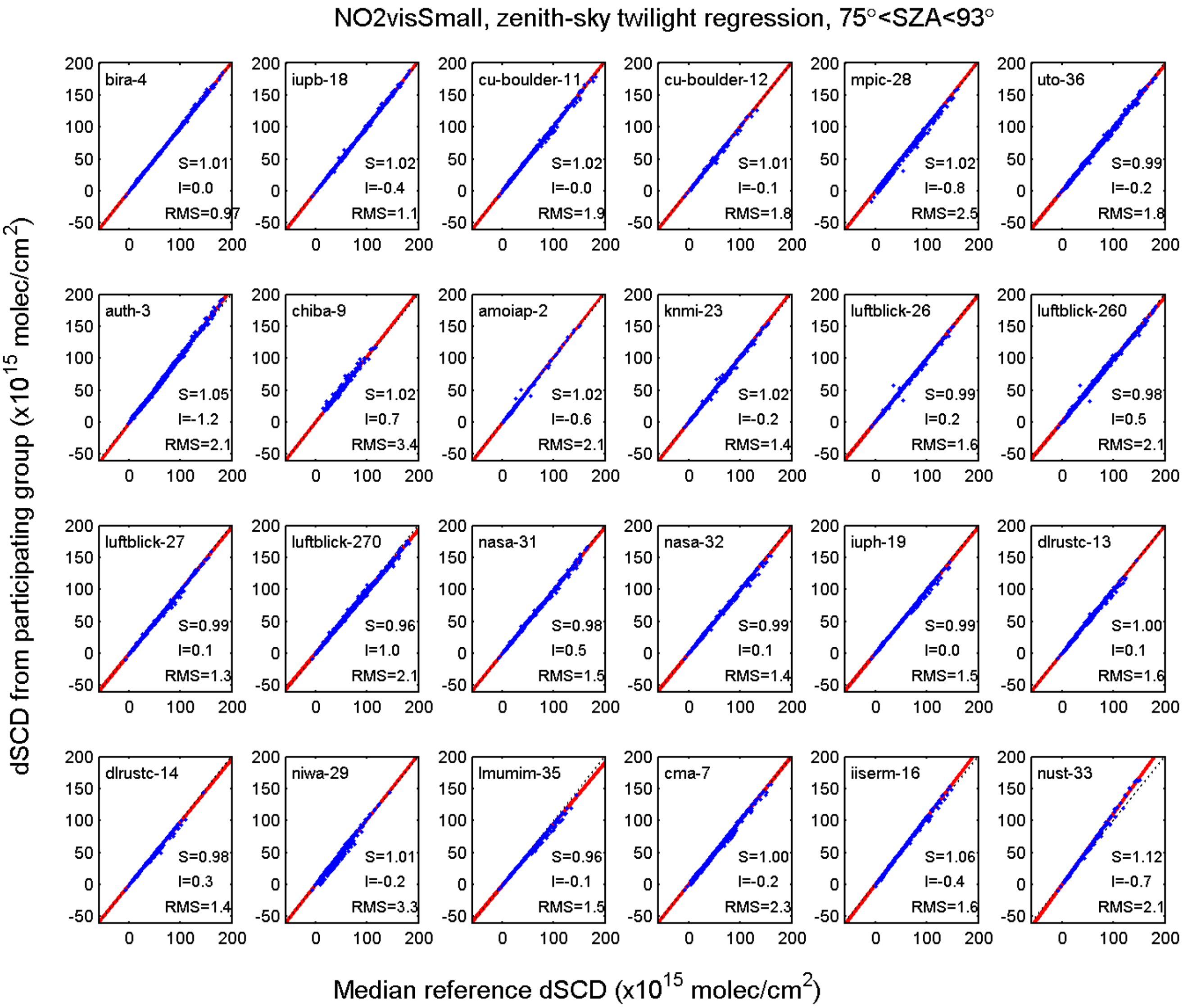


Figure S27: Regression analysis for zenith-sky NO_2 dSCDs (measured in the small visible wavelength region).

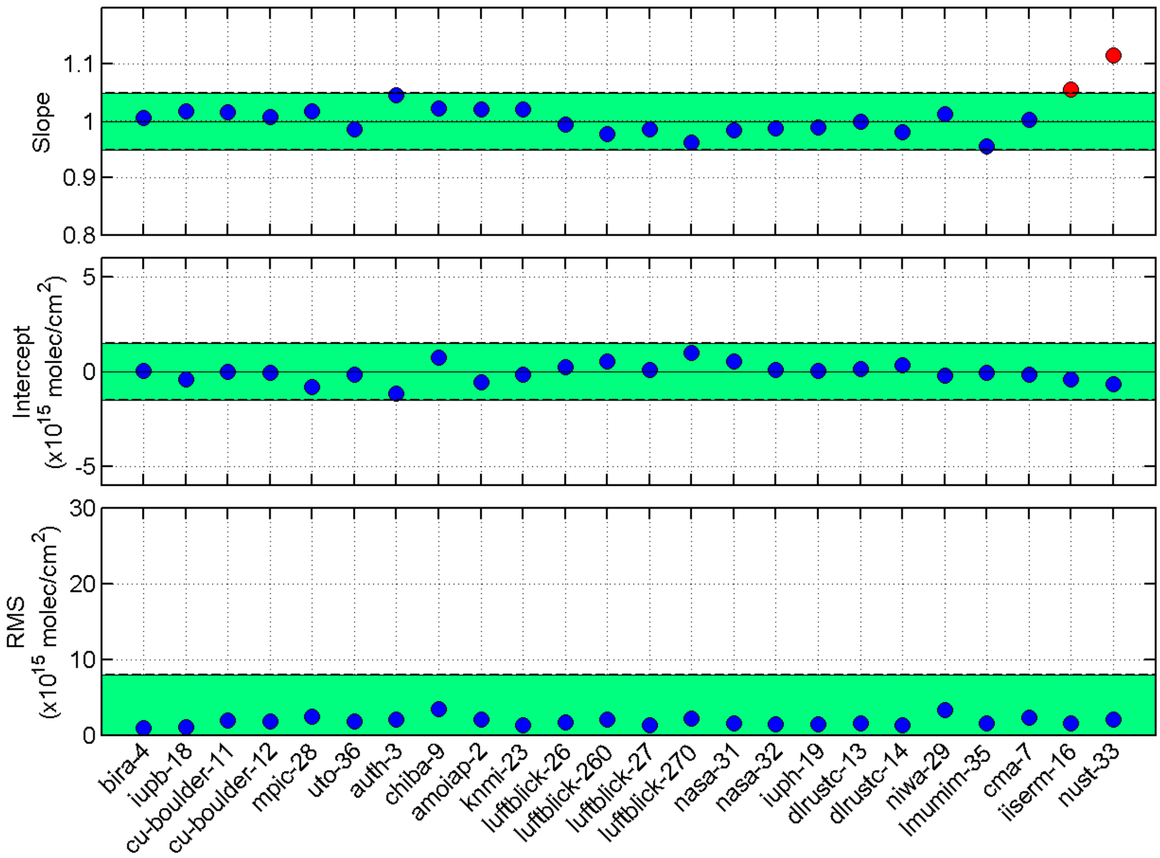


Figure S28: Summary of the regression statistic for zenith-sky NO_2 in the small visible range, showing the slope, intercept and RMS values as displayed in Figure S27. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S2.3 Zenith-sky results for NO_2 in the UV range (NO2uv)

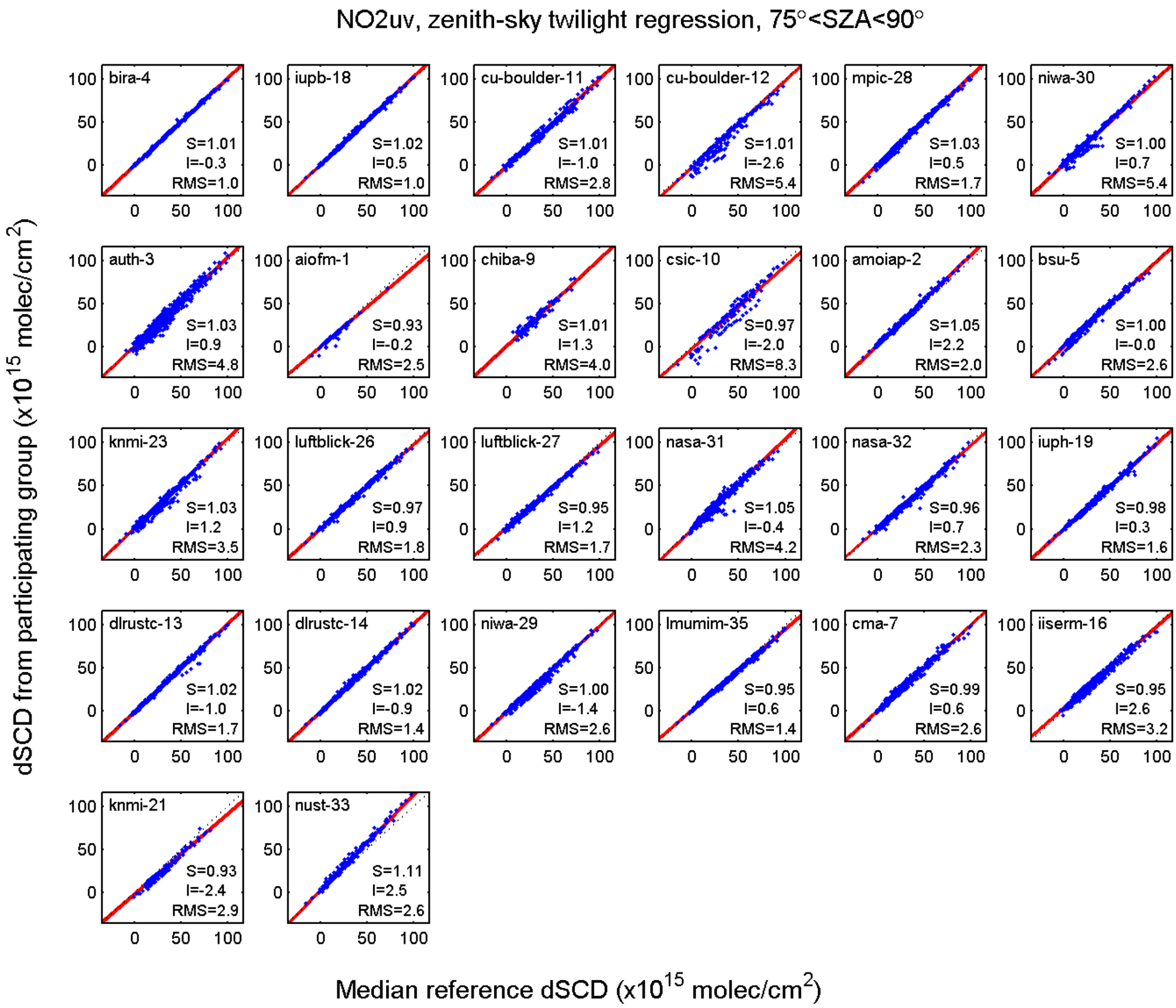


Figure S29: Regression analysis for zenith-sky NO_2 dSCDs (measured in the UV wavelength region).

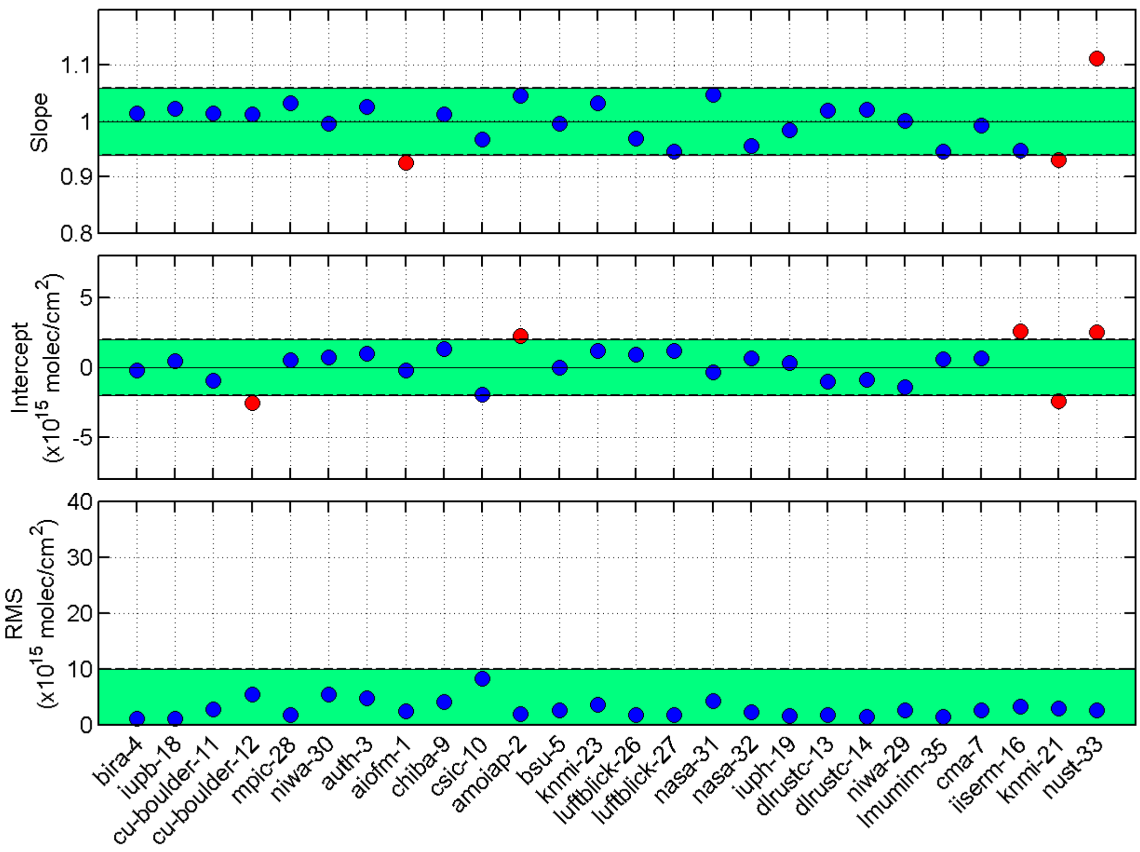


Figure S30: Summary of the regression statistic for zenith-sky NO_2 in the UV range, showing the slope, intercept and RMS values as displayed in Figure S29. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S2.4 Zenith-sky results for O_3 in the visible range (O3vis)

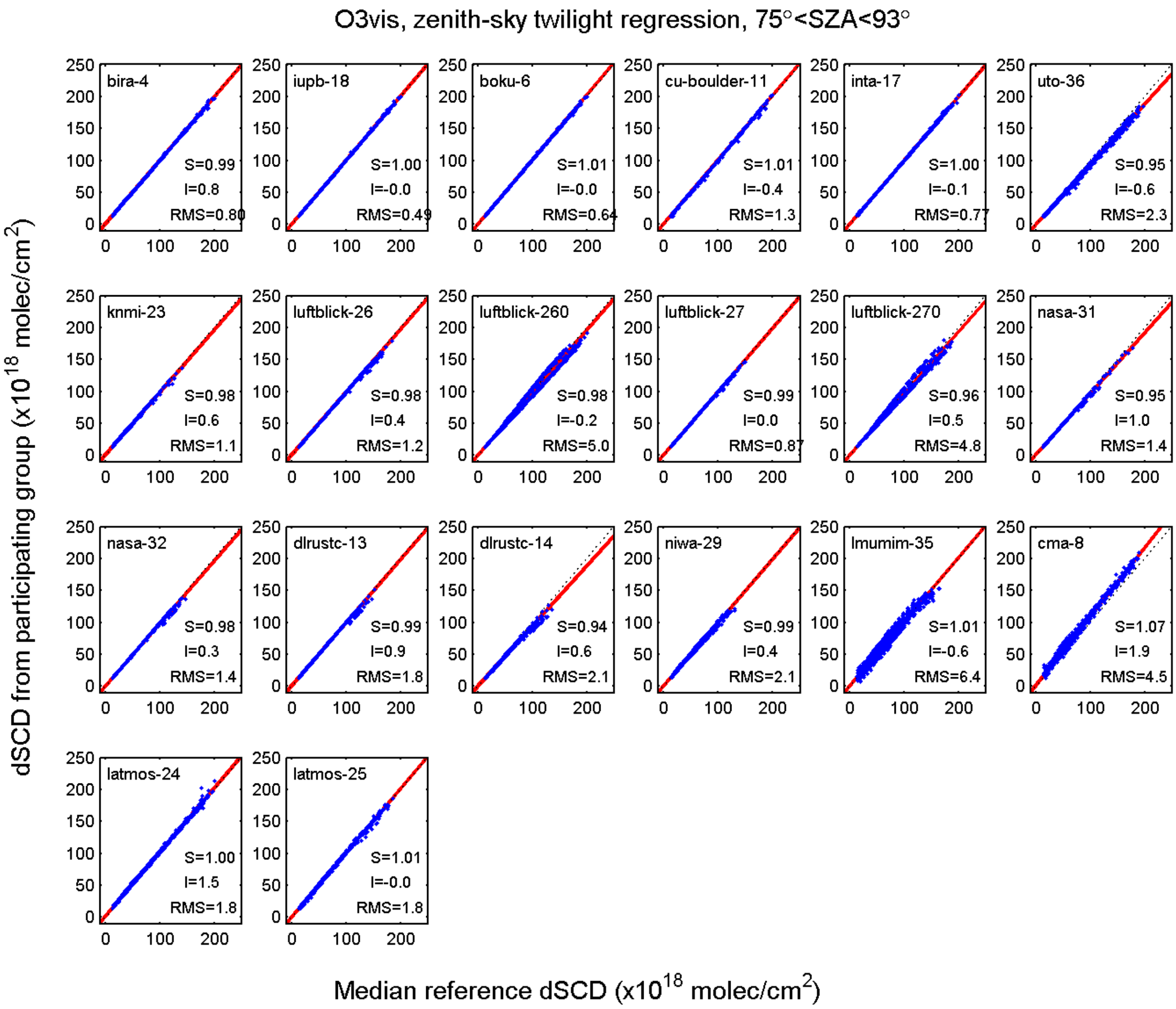


Figure S31: Regression analysis for zenith-sky O_3 dSCDs (measured in the visible wavelength region).

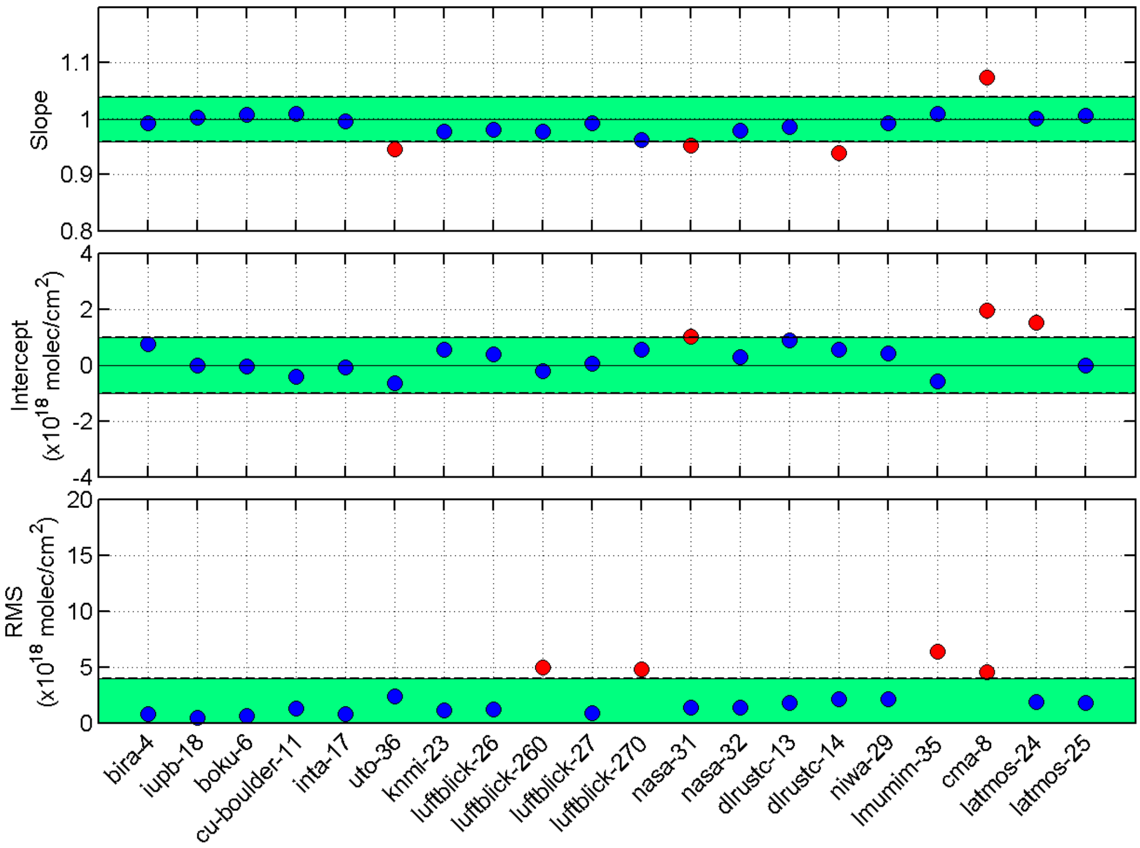


Figure S32: Summary of the regression statistic for zenith-sky O_3 in the visible range, showing the slope, intercept and RMS values as displayed in Figure S31. The dashed lines show the performance limits as defined in Table 5 of the main manuscript. The values within these limits are plotted in blue, the ones falling outside the limit in red.

S3 Description and technical characteristics of the CINDI-2 MAX-DOAS and zenith-sky DOAS systems

This section presents the description of all the participating instruments. The following colour coding is used for the different types: yellow for Zenith-sky DOAS, blue for 1D MAX-DOAS and green for 2D MAX-DOAS. The instruments are listed in alphabetical order with respect to their institute acronym which is included in the top of each instrument table as part of the institute name (see also Table 1 in the main manuscript).

Institute: Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences (**AIOFM**), Hefei, China **Responsible person(s):** Ang Li, Pinhua Xie **Contact details:** angli@aiofm.ac.cn, phxie@aiofm.ac.cn		
Instrument type: 2D MAX-DOAS	**Nr:** CINDI-2.01	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Princeton Instrument 150i **Detector type:** Princeton Instrument PIXIS-2K BUV **Optical fibers:** quartz optical fiber, length: 10 m **Filters:** ZWB3(=UG5) **Mirrors: no** **Temperature control of spectrometer/detector:** 35°C /-30°C
Instrument performance	**Spectral range/resolution:** 290-380 (adjustable)/0.35 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 0.2° **Typical integration time:** 10-60s **Typical scan duration:** 15 minutes
Calibration/characterization procedures	**Elevation angles:** inclinometer **Field of view:** scanning over a light source in the laboratory **Straylight:** **Dark signal:** by using the shutter **Line shape:** Hg lamp in the laboratory **Polarization: -** **Detector nonlinearity:** halogen lamp/dark background **Pixel-to-pixel variability**: halogen lamp/dark background
Spectral analysis software	QDOAS / WinDOAS
Supporting measurements	Video camera, inclinometer, GPS, electronic compass
Reference	Wang Yang, Li Ang, Xie Pin-Hua, Chen Hao, Xu Jin, Wu Feng-Cheng, Liu Jian-Guo, Liu Wen-Qing: Retrieving vertical profile of aerosol extinction by multi-axis differential optical absorption spectroscopy, Acta Phys. Sin., 62(18), 180705, http://dx.doi.org/10.7498/aps.62.180705, 2013.

Institute: A.M.Obukhov Institute of Atmospheric Physics (**AMOIAP**), Russian Academy of Sciences, Moscow, Russia

Responsible person(s): Alexander Borovski, Oleg V.Postylyakov

Contact details: alexander.n.borovski@gmail.com oleg.postylyakov@gmail.com

Instrument type: 2-port DOAS

Nr: CINDI-2.02

Overall design of the instrument	**Optical head including telescope:** separated; 2 telescope units (one for zenith + one for off-axis) **Spectrometer type:** Shamrock303i spectrograph with filter wheel **Detector type:** Newton CCD (DU940N-BU2, 2048×512 pxls) **Optical fibers:** standard fiber cable with two inputs and one output, length: 25 m **Filters:** Andover Corp. filter S86FG11-25 (transmittion from 320 to 700 nm) **Mirrors:** no **Temperature control of spectrometer/detector:** 35°C/-40°C
Instrument performance	**Spectral range/resolution VIS1:** 420-490 / 0.4 nm **Spectral range/resolution VIS2:** 395-465 / 0.4 nm **Spectral range/resolution VIS3:** 390-530 / 0.9 nm **Spectral range/resolution UV:** 315-385 / 0.4 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** two fixed elevation angles (one zenith and one 5°) **Field of view:** 0.3° **Typical integration time:** 1 – 10 s **Typical scan duration:** 30 – 40 s
Calibration/characterization procedures	**Elevation angles:** adjusted manually using bubble and digital levels **Field of view:** measured in the lab **Straylight:** unknown **Dark signal:** using unilluminated parts of the detector **Line shape:** Hg lamp in the lab, FWHM adjusted during spectra analysis **Polarization:** n/a (use of long depolarizing fiber bundle) **Detector nonlinearity:** unknown **Pixel-to-pixel variability**: unknown
Spectral analysis software	Andor Solis/own-developed software
Supporting measurements	n/a
Reference	I. Bruchkouski, A. Borovski, A. Elokhov, and O. Postylyakov. A layout of two-port DOAS system for investigation of atmospheric trace gases based on laboratory spectrograph, Proc. SPIE, 10035, 100353C, https://doi.org/10.1117/12.2248634, 2016.

Institute: Physics Department, Section of Applied and Environmental Physics, Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki (**AUTH**), Thessaloniki, Greece

Responsible person(s): Alkiviadis Bais, Theano Drosoglou

Contact details: abais@auth.gr, tdroso@auth.gr

Instrument type: Phaethon mini MAX-DOAS

Nr: CINDI-2.03

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048LTEC (Avantes) **Detector type:** SONY2048L (CCD linear array) **Optical fibers:** standard fiber cable with metal silicone jacketing, 800 μm fiber core diameter and overall length of 8 meters **Filters:** filter wheel: neutral density filter + ground quartz diffuser plate for direct-sun, clear aperture for sky-radiance, opaque for dark signal **Mirrors:** no mirrors, plano-convex lens **Temperature control of spectrometer/detector:** 5°C/5°C
Instrument performance	**Spectral range/resolution:** 297-452/0.3-0.4 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable, 0.125° resolution **Field of view:** 1° **Typical integration time:** 200-3000 ms (scattered light) **Typical scan duration:** 10-20 minutes for a sequence of elevation angles
Calibration/characterization procedures	**Elevation angles:** Sighting using the solar disk **Field of view:** white reflecting stripe measurements in laboratory **Straylight:** tunable-laser measurements **Dark signal:** after each scan sequence for all integration times used **Line shape:** laser lines and spectral discharge lamp measurements **Polarization:** zenith radiance measurements at different azimuth angles **Detector nonlinearity:** tunable-laser measurements with varying output **Pixel-to-pixel variability**: tungsten halogen lamp measurements
Spectral analysis software	QDOAS (currently version 2.109.3)
Supporting measurements	None during the campaign
Reference	Drosoglou, T., A. F. Bais, I. Zyrichidou, N. Kouremeti, A. Poupkou, N. Liora, C. Giannaros, M. E. Koukouli, D. Balis, and D. Melas (2017), Comparisons of ground-based tropospheric NO2 MAX-DOAS measurements to satellite observations with the aid of an air quality model over the Thessaloniki area, Greece, Atmos. Chem. Phys., 17(9), 5829-5849; http://dx.doi.org/ 10.5194/acp-17-5829-2017.

Institute: Royal Belgian Institute for space Aeronomy (**BIRA-IASB**), Brussels, Belgium

Responsible person(s): Christian Hermans and Michel Van Roozendael

Contact details: christh@aeronomie.be, michelv@oma.be

Instrument type: 2D MAX-DOAS

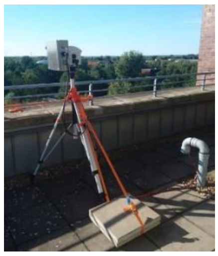
Nr: CINDI-2.04

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable; active sun tracking system **Spectrometer type UV:** Newport, model: 74086 **Spectrometer type vis:** Horiba, model: Micro HR **Detector type UV:** CCD Back-illuminated Princeton Instrument Pixis 2K **Detector type vis:** CCD Back-illuminated Princeton Instrument Pixis 100 **Optical fibers:** quartz UV chanel: monofiber (l:6m,diam:1000µm)+ bundle(length:2m, 51 fibers 100µm) Vis chanel: monofiber (l:6m,diam:800µm)+ bundle(length:2m, 37 fibers 100µm) **Filters:** UV chanel : Filter band U-340 Hoya **Mirrors:** no (for telescope we use lens in quartz) **Temperature control of spectrometer and detector UV:** 30°C/-50°C **Temperature control of spectrometer and detector vis:** 30°C/-50°C
Instrument performance	**Spectral range/resolution UV:** 300–390/0.4 nm **Spectral range/resolution vis:** 405–540/0.7 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable; resolution: <0.1° **Field of view:** <1° **Typical integration time:** total measurement t:60 sec (t min: vis 0.03s, UV 0.1s) **Typical scan duration:** 20 minutes
Calibration/characterization procedures	**Elevation angles:** digital inclinometer in telescope **Field of view:** white light source in lab **Straylight:** double monochromator fed by white light source **Dark signal:** measured as night every day **Line shape:** HgCd lamp in the lab, further adjusted using QDOAS **Polarization:** n/a (use of long depolarising fiber bundle) **Detector nonlinearity:** white light source in the lab **Pixel-to-pixel variability**: white light source in the lab
Spectral analysis software	QDOAS
Supporting measurements	Video camera
Reference	Clémer, K., Van Roozendael, M., Fayt, C., Hendrick, F., Hermans, C., Pinardi, G., Spurr, R., Wang, P., and De Mazière, M.: Multiple wavelength retrieval of tropospheric aerosol optical properties from MAXDOAS measurements in Beijing, Atmos. Meas. Tech., 3, 863-878, https://doi.org/10.5194/amt-3-863-2010, 2010.

Institute: Institute of Meteorology, University of Natural Resources and Life Sciences (**BOKU**), Vienna, Austria

Responsible person(s): Stefan Schreier

Contact details: Stefan.Schreier@boku.ac.at



Instrument type: 1 channel scientific grade elevation and azimuth scanning MAX-DOAS

Nr: CINDI-2.06

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Acton Standard Series SP-2356 Imaging Spectrograph **Detector type:** PIX100B-SF-Q-F-A **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 25m **Filters:** no **Mirrors:** no **Temperature control of spectrometer and detector:** 35°C/-60°C
Instrument performance	**Spectral range/resolution:** 419–553/0.8 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 0.8° **Typical integration time:** 30s (off-axis); 60s (zenith) **Typical scan duration:** 10 minutes for 10 elevation angles
Calibration/characterization procedures	**Elevation angles:** geometric alignment of telescope, horizon scan **Field of view:** white light source in lab **Straylight:** not yet characterized **Dark signal:** nightly measurements **Line shape:** HgCd lamp in telescope **Polarization:** - **Detector nonlinearity:** white light source in lab, characterization only **Pixel-to-pixel variability**: white light source in lab, characterization only
Spectral analysis software	NLIN
Supporting measurements	Video camera, HgCd lamp
Reference	Schreier et al., Multiple ground-based MAX-DOAS observations in Vienna, Austria – part 1: Evaluation of horizontal and temporal NO2, HCHO, and CHOCHO distributions and comparison with independent data sets, to be submitted to ACP (2019)

Institute: Belarusian State University (**BSU**), Minsk, Belarus

Responsible person(s): Ilya Bruchkouski

Contact details: bruchkovsky2010@yandex.by

Instrument type: MAX-DOAS one azimuth, catadioptric telescope / MARS-B

Nr: CINDI-2.05

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Oriel MS257 imaging spectrograph (1:4) **Detector type:** Andor DV420-OE 256*1024 pixels CCD **Optical fibers:** n/a **Filters:** red **Mirrors:** yes **Temperature control of detector:** -40°C
Instrument performance	**Spectral range/resolution:** 409-492/0.4 nm + possibly also UV **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.2° (azimuth); 1° (elevation) **Typical integration time:** 1-3s **Typical scan duration:** 1.5 minutes (12 elevation angles)
Calibration/characterization procedures	**Elevation angles:** Udo Friess method (laser level, narrow mercury lamp) **Field of view:** measured in the lab **Straylight:** N/A **Dark signal:** 485 ±6 counts **Line shape:** Gaussian **Polarization:** N/A **Detector nonlinearity:** above 25000 counts **Pixel-to-pixel variability**: ±6 counts
Spectral analysis software	Self-made + Windoas
Supporting measurements	Video camera (possibly)
Reference	I. Bruchkouski, V. Dziomin, A. Krasouski. Seasonal variability of the atmospheric trace constituents in Antarctica / I. Bruchkouski [et al.] // Abs. 35-th Canadian Symposium of Remote Sensing (IGARSS-2014), Quèbec, 13-18 July / General Chair Dr. Monique Bernier. – Quebec, 2014. – P. 4098-4100.

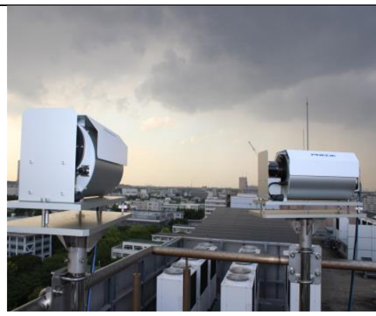
Institute: Center for Environmental Remote Sensing (CEReS), Chiba University (**CHIBA**), Chiba, Japan

Responsible person(s): Hitoshi Irie

Contact details: hitoshi.irie@chiba-u.jp

Instrument type: 1 channel scientific grade elevation and azimuth scanning MAX-DOAS

Nr: CINDI-2.09



Overall design of the instrument	**Optical head including telescope:** separated **Spectrometer type:** Ocean Optics Maya2000Pro **Detector type:** Back-thinned, 2D FFT-CCD **Optical fibers:** premium-grade UV/VIS Optical fibre, length - 10 m **Filters:** no **Mirrors:** quartz mirror **Temperature control of spectrometer and detector:** 40°C/40°C
Instrument performance	**Spectral range/resolution:** 310–515/0.4 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** set of 6 elevation angles, values can be adjusted but not the number of angles **Field of view:** <1° **Typical integration time:** 140 seconds **Typical scan duration:** 15 minutes
Calibration/characterization procedures	**Elevation angles:** Two horizontal levels embedded in the base plate and in a plate holding the reflecting mirror are used to adjust the zero angle of the reflecting mirror. A stepping motor with an angle step of 0.038) is used for controlling the mirror angle. **Field of view:** Characterized by Prede **Stray light:** Subtracted as an offset component in DOAS analysis **Dark signal:** nightly measurements **Line shape:** An asymmetry Gaussian shape is determined during the wavelength calibration. **Polarization:** - **Detector nonlinearity:** characterized by Ocean Optics **Pixel-to-pixel variability**: nightly measurements
Spectral analysis software	JM2 (Japanese MAX-DOAS profile retrieval algorithm, version 2)
Supporting measurements	none
Reference	Irie, H., H. M. S. Hoque, A. Damiani, H. Okamoto, A. M. Fatmi, P. Khatri, T. Takamura, and T. Jarupongsakul, Simultaneous observations by sky radiometer and MAX-DOAS for characterization of biomass burning plumes in central Thailand in January-April 2016, Atmos. Meas. Tech., 12, 599-606, https://doi.org/10.5194/amt-12-599-2019, January 29, 2019.

<table>
<tr><td colspan="2"><u>Institute:</u> Chinese Academy of Meteorology Science, China Meteorological Administration (CMA), Beijing, China
<u>Responsible person(s):</u> Junli Jin, Jianzhong Ma
<u>Contact details:</u> jinjunli@camscma.cn</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> Mini-DOAS Hoffmann UV (#1)</td><td><u>Nr:</u>
CINDI-2.07</td></tr>
<tr><td>Overall design of the instrument</td><td colspan="2">Optical head including telescope: integrated
Spectrometer type: Ocean Optics usb 2000
Detector type: Sony ILX511 CCD (2048 pixels)
Optical fibers: n/a
Temperature control of spectrometer/detector: n/a</td></tr>
<tr><td>Instrument performance</td><td colspan="2">Spectral range/resolution: 292-447/0.6-0.8 nm
Azimuthal scan/direct-sun capabilities: no/no
Elevation angle capability: fully configurable
Field of view: 0.8°
Typical integration time: 1-2 minutes
Typical scan duration: 15-30 minutes</td></tr>
<tr><td>Calibration/characterization procedures</td><td colspan="2">Elevation angles: horizontal scan calibration
Field of view: not yet characterized
Straylight: not characterized
Dark signal: measurement in night or measured with telescope covered, then substracted before spectra analysis
Line shape: not yet characterized
Polarization: not yet characterized
Detector nonlinearity: not yet characterized
Pixel-to-pixel variability: not yet characterized</td></tr>
<tr><td>Spectral analysis software</td><td colspan="2">WinDOAS</td></tr>
<tr><td>Supporting measurements</td><td colspan="2">none</td></tr>
</table>

Institute: Chinese Academy of Meteorology Science, China Meteorological Administration (**CMA**), Beijing, China **Responsible person(s):** Junli Jin, Jianzhong Ma **Contact details:** jinjunli@camscma.cn	
Instrument type: Mini-DOAS Hoffmann VIS (#1)	**Nr:** CINDI-2.08
Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000 **Detector type:** DET2B-vis (2048 pixels) **Optical fibers:** n/a **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer/detector:** n/a
Instrument performance	**Spectral range/resolution:** 399-712/0.6-0.8 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.8° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes
Calibration/characterization procedures	**Elevation angles:** horizontal scan calibration **Field of view:** not characterized **Dark signal:** measurement in night or measured with telescope covered, then substracted before spectra analysis **Line shape:** not yet characterized **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: not yet characterized
Spectral analysis software	WinDOAS
Supporting measurements	none

Institute: Department of Atmospheric Chemistry and Climate (AC2), Spanish National Research Council (**CSIC**), Madrid, Spain

Responsible person(s): David García, Nuria Benavent, Shanshan Wang

Contact details: dgarcia@iqfr.csic.es

Instrument type: MAX-DOAS

Nr: CINDI-2.10

Overall design of the instrument	**Optical head including telescope:** separated; elevation angles fully configurable **Spectrometer type:** Princeton Acton SP2500 **Detector type:** Pixis 2D CCD Camera, 1340x400 pixels **Optical fibers:** Multifiber UV-VIS, 10 m length **Temperature control of spectrometer and detector:** 20-25°C and 70°C
Instrument performance	**Spectral range/resolution:** 300–500/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** approx. 0.7° (estimated using white stripe method) **Typical integration time:** 0.01-1s **Typical scan duration:** 5 minutes
Calibration/characterization procedures	**Elevation angles:** 45 ° **Field of view:** lamp in telescope **Straylight:** - **Dark signal:** by using the shutter **Line shape:** Hg/Ne **Polarization:** - **Detector nonlinearity:** laboratory **Pixel-to-pixel variability**: laboratory
Spectral analysis software	QDOAS
Supporting measurements	Video camera
Reference	Prados-Roman, C., Cuevas, C. A., Hay, T., Fernandez, R. P., Mahajan, A. S., Royer, S.-J., Galí, M., Simó, R., Dachs, J., Großmann, K., Kinnison, D. E., Lamarque, J.-F., and Saiz-Lopez, A.: Iodine oxide in the global marine boundary layer, Atmos. Chem. Phys., 15, 583-593, https://doi.org/10.5194/acp-15-583-2015, 2015.

<table>
<tr><td><u>Institute:</u> University of Colorado (CU-Boulder), Boulder, Colorado
<u>Responsible person(s):</u> Rainer Volkamer, Henning Finkenzeller
<u>Contact details:</u> Rainer.Volkamer@colorado.edu, Henning.Finkenzeller@colorado.edu</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> 3D-MAX-DOAS — <u>Nr:</u> CINDI-2.11</td></tr>
</table>

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable; integrating sphere for direct sun measurements **Spectrometer type:** 2 x Acton SP2150 **Detector type:** 2 x PIXIS 400 back-illuminated CCD **Optical fibers:** Monofiber, diameter: 1.25mm, length: 25m connects to Y-type bundle, diameter: 0.145mm, length: 1m **Filters:** BG3/BG38, GG395 **Mirrors:** quartz prisms **Temperature control of spectrometer and detector:** 34°C/-30°C
Instrument performance	**Spectral range/resolution:** 327-470/0.7 & 432–678/1.2 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** 0.7 degrees (full angle) **Typical integration time:** ~20s **Typical scan duration:** ~8min (12 EA & 12 Az)
Calibration/characterization procedures	**Elevation angles:** geometric alignment, solar aureole/horizon scan **Field of view:** laser pointer backwards **Straylight:** dark areas on CCD **Dark signal:** characterized at night, and by dark areas on CCD **Line shape:** Hg/Kr lamps (external) & QDOAS for wavelength dependency **Polarization:** - **Detector nonlinearity:** Fraunhofer OD at different saturation levels of CCD **Pixel-to-pixel variability**: monitored
Spectral analysis software	QDOAS
Supporting measurements	Webcam, Hg & Kr lamp
Reference	Baidar, S., Oetjen, H., Coburn, S., Dix, B., Ortega, I., Sinreich, R., and Volkamer, R.: The CU Airborne MAX-DOAS instrument: vertical profiling of aerosol extinction and trace gases, Atmos. Meas. Tech., 6, 719-739, https://doi.org/10.5194/amt-6-719-2013 , 2013.

<table>
<tr><td colspan="2"><u>Institute:</u> University of Colorado (CU-Boulder), Boulder, Colorado
<u>Responsible person(s):</u> Rainer Volkamer
<u>Contact details:</u> Rainer.Volkamer@colorado.edu</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> ZS & MAX-DOAS (1D)</td><td><u>Nr:</u>
CINDI-2.12</td></tr>
</table>

Overall design of the instrument	**Optical head including telescope:** rotating prism, elevation angles fully configurable horizon-to-horizon across zenith **Spectrometer type:** Acton SP2356i & QE65000 **Detector type:** PIXIS 400 back-illuminated CCD & Sony CCD **Optical fibers:** Monofiber, diameter: 1.5mm, length: 10m connects to Y-type bundle, diameter: 0.145mm, length: 1m **Filters:** BG3/BG38 **Mirrors:** quartz prism **Temperature control of spectrometer/detector:** 34°C/-30°C
Instrument performance	**Spectral range/resolution:** 300-466/0.8 & 379–493/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.4 degrees (full angle) **Typical integration time:** ~30s **Typical scan duration:** ~8min
Calibration/characterization procedures	**Elevation angles:** geometric alignment, horizon scan **Field of view:** laser pointer backwards **Straylight:** dark areas on CCD **Dark signal:** characterized at night, and by dark areas on CCD **Line shape:** Hg/Kr lamps (external) & QDOAS for wavelength dependency **Polarization:** - **Detector nonlinearity:** Fraunhofer line distortion at different sat levels **Pixel-to-pixel variability**: monitored
Spectral analysis software	QDOAS
Supporting measurements	Webcam, Hg & Kr lamp
Reference	Coburn, S., Dix, B., Sinreich, R., and Volkamer, R.: The CU ground MAX-DOAS instrument: characterization of RMS noise limitations and first measurements near Pensacola, FL of BrO, IO, and CHOCHO, Atmos. Meas. Tech., 4, 2421-2439, https://doi.org/10.5194/amt-4-2421-2011 , 2011.

Institute 1: Institut fuer Methodik der Fernerkundung (IMF), Deutsches Zentrum fuer Luft- und Raumfahrt e.V. (**DLR**), Wessling, Germany

Institute 2: School of Earth and Space Sciences, University of Science and Technology of China (**USTC**), Hefei, Anhui, China

Responsible person(s): Nan Hao (DLR) and Cheng Liu (USTC)

Contact details: nan.hao@dlr.de, Chliu81@ustc.edu.cn

Instrument type: 1D MAX-DOAS EnviMeS (#1)

Nr: CINDI-2.13 CINDI-2.14

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV and Vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** none (rotatable prism for elevation angle selection) **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 296–460/0.56 nm **Spectral range/resolution vis:** 440–583/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 5 minutes
Calibration/characterization procedures	**Elevation angles:** Point-like light source and laser level **Field of view:** Point-like light source and laser level **Straylight:** Optical filters **Dark signal:** Measurement during the night **Line shape:** Atomic emission lines (Hg/Ne) **Polarization:** n/a (depolarizing fibre) **Detector nonlinearity:** Measurement of artificial light source with varying integration times **Pixel-to-pixel variability**: Halogen lamp
Spectral analysis software	DOASIS
Supporting measurements	Webcam, tilt sensor, GPS

<table>
<tr><td colspan="2"><u>Institute:</u> Indian Institute of Science Education and Research Mohali
Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research Mohali (IISERM), Punjab, India
<u>Responsible person(s):</u> Abhishek Kumar Mishra and Vinod Kumar
<u>Contact details:</u> abhishekkumar.mishra21@gmail.com, vinodkumar@iisermohali.ac.in</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> Mini-MAX DOAS Hoffmann UV (#2)</td><td><u>Nr:</u>
CINDI-2.16</td></tr>
</table>

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type UV:** Ocean Optics usb 2000+ **Spectrometer type:** CCD (2048 pixels) **Filters:** no **Mirrors:** - **Temperature control of spectrometer and detector:** Peltier cooler
Instrument performance	**Spectral range/resolution:** 316–466/0.7 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** 0.7° **Typical integration time:** 60ms **Typical scan duration:** ~5 minutes for one full elevation sequence
Calibration/characterization procedures	**Elevation angles:** - Horizon calibration (-3° – 3°) every noon, Distant point source calibration in night **Field of view:** -Point light source **Straylight:** - not characterized **Dark signal:** - Recorded every night **Line shape:** - Gaussian like **Polarization:** - Not characterized **Detector nonlinearity:** - Not characterized **Pixel-to-pixel variability**: - Not characterized
Spectral analysis software	WinDOAS and DOASIS
Supporting measurements	None

Institute: National Institute for Aerospace Technology (**INTA**), Madrid, Spain **Responsible person(s):** Olga Puentedura **Contact details:** puentero@inta.es		
Instrument type: 2D-MAX-DOAS RASAS III	**Nr:** CINDI-2.17	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Andor Shamrock SR-163i **Detector type:** IDUS Andor BU2 **Optical fibres:** Bundle 100 µm, length: 8 m **Filters:** No **Mirrors:** No **Temperature control of spectrometer/detector:** 17°C/-30ºC
Instrument performance	**Spectral range/resolution:** 420-540/0.55 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** ~1 minute/pointing direction **Typical scan duration:** ~1 minute x number of pointing directions
Calibration/characterization procedures	**Elevation angles:** Inclinometer during operation **Field of view:** Geometrical **Straylight:** HeNe LASER and optical filters **Dark signal:** Measured at constant temperature with different integration times and subtracted during analysis **Line shape:** HgCd lamp **Polarization:** Optical fibre depolarizes the signal **Detector nonlinearity:** Stable source and varying integration times **Pixel-to-pixel variability**: Halogen lamp
Spectral analysis software	LANA software
Supporting measurements	Video camera, inclinometer and GPS
Reference	Puentedura, O., Gil, M., Saiz-Lopez, A., Hay, T., Navarro-Comas, M., Gómez-Pelaez, A., Cuevas, E., Iglesias, J., and Gomez, L.: Iodine monoxide in the north subtropical free troposphere, Atmos. Chem. Phys., 12, 4909-4921, https://doi.org/10.5194/acp-12-4909-2012, 2012.

Institute: Institute of Environmental Physics (**IUP-Bremen**), University of Bremen, Bremen, Germany **Responsible person(s):** Andreas Richter **Contact details:** richter@iup.physik.uni-bremen.de		
Instrument type: 2 channel scientific grade elevation and azimuth scanning MAX-DOAS	**Nr:** CINDI-2.18	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** Acton ARC500 **Spectrometer type vis:** Acton ARC500 **Detector type UV:** Princeton NTE/CCD-1340/400-EMB **Detector type vis:** Princeton NTE/CCD-1340/400-EMB **Optical fibers:** Y-type quartz bundle, diameter: 150µm, length: 22m **Filters:** UG5 (UV only) **Mirrors:** no **Temperature control of spectrometer and detector UV:** 35°C/-35°C **Temperature control of spectrometer and detector vis:** 35°C/-30°C
Instrument performance	**Spectral range/resolution UV:** 305–390/0.5 nm **Spectral range/resolution vis:** 406–579/0.85 nm **Azimuthal scan/direct-sun capabilities:** yes/no **Elevation angle capability:** fully configurable **Field of view:** 1° **Typical integration time:** 60s; 120s for zenith **Typical scan duration:** 15 minutes for 11 elevation angles
Calibration/characterization procedures	**Elevation angles:** geometric alignment of telescope, horizon scan **Field of view:** white light source in lab **Straylight:** not yet characterized **Dark signal:** nightly measurements **Line shape:** HgCd lamp in telescope **Polarization:** - **Detector nonlinearity:** white light source in lab, characterization only **Pixel-to-pixel variability**: white light source in lab, characterization only
Spectral analysis software	NLIN
Supporting measurements	Video camera, HgCd lamp
Reference	Peters, E., Wittrock, F., Großmann, K., Frieß, U., Richter, A., and Burrows, J. P., Formaldehyde and nitrogen dioxide over the remote western Pacific Ocean: SCIAMACHY and GOME-2 validation using ship-based MAX-DOAS observations, Atmos. Chem. Phys., 12, 11179-11197, doi:10.5194/acp-12-11179-2012, 2012.

Institute: Institute of Environmental Physics (**IUP-Bremen**), University of Bremen, Bremen, Germany

Responsible person(s): Enno Peters

Contact details: Enno.Peters@iup.physik.uni-bremen.de

Instrument type: single channel scientific grade imaging-DOAS, telescope mounted on pan-tilt-head for azimuthal scans and zenith (reference) pointing, indoor parts equipped in a 19'' rack

Nr: CINDI-2.37

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Andor Shamrock 303i **Detector type:** Andor Newton DU940P-BU, 2048x512 pixel (only inner pixels used for imaging) **Optical fibers:** Fibre bundle with 69 sorted single fibres, diameter: 100µm, length: 15m **Filters:** BG39 **Mirrors:** no **Temperature control of spectrometer and detector:** 35°C/-30°C
Instrument performance	**Spectral range/resolution:** 420 – 500nm/0.8 nm **Azimuthal scan/direct-sun capabilities:** yes/n/a **Elevation angle capability:** fully configurable **Field of view:** vertically approx. 50° total, 1.5° per view, horizontally 1.2° **Typical integration time:** 10s **Typical scan duration:** 10 min for complete horizon scan (10° azimuthal steps 0-360° followed by zenith reference)
Calibration/characterization procedures	**Elevation angles:** between -5 and +30 + regular zenith-sky **Field of view:** white light source in lab **Straylight:** not yet characterized **Dark signal:** manually **Line shape:** HgCd lamp (manually) **Polarization:** - **Detector nonlinearity:** white light source in lab, characterization only **Pixel-to-pixel variability**: white light source in lab, characterization only
Spectral analysis software	NLIN
Supporting measurements	Video camera
Reference	Peters, E., Ostendorf, M.,Bösch, T., Seyler, A., Schönhardt, A., Schreier, S.F., Henzing, J. S., Wittrock, F., Richter, A., Vrekoussis, M., Burrows,J.P., Full-azimuthal imaging-DOAS observations of NO2 and O4 during CINDI-2, submitted to AMT, 2019.

Institute: Institute of Environmental Physics (**IUP-Heidelberg**), University of Heidelberg, Heidelberg, Germany

Responsible person(s): Udo Friess

Contact details: udo.friess@iup.uni-heidelberg.de

Instrument type: 2D MAX-DOAS EnviMeS (#3)

Nr: CINDI-2.19

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV and Vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** none (rotatable prism for elevation angle selection) **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 296–460/0.56 nm **Spectral range/resolution vis:** 440–583/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms - 60s **Typical scan duration:** 5 minutes
Calibration/characterization procedures	**Elevation angles:** Point-like light source and laser level **Field of view:** Point-like light source and laser level **Straylight:** Optical filters **Dark signal:** Measurement during the night **Line shape:** Atomic emission lines (Hg/Ne) **Polarization:** n/a **Detector nonlinearity:** Measurement of artificial light source with varying integration times **Pixel-to-pixel variability**: Halogen lamp
Spectral analysis software	DOASIS
Supporting measurements	Webcam, tilt sensor, GPS
Reference	Lampel, J., Frieß, U., and Platt, U.: The impact of vibrational Raman scattering of air on DOAS measurements of atmospheric trace gases, Atmos. Meas. Tech., 8, 3767-3787, https://doi.org/10.5194/amt-8-3767-2015, 2015.

Institute: Royal Netherlands Meteorological Institute (**KNMI**), De Bilt, The Netherlands

Responsible person(s): Ankie Piters

Contact details: ankie.piters@knmi.nl

Instrument type: Mini-DOAS Hoffmann UV (#3)

Nr: CINDI-2.21

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000 **Detector type:** Sony ILX511 CCD (2048 pixels) **Optical fibers:** n/a
Instrument performance	**Spectral range/resolution:** 290-443/0.6 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.45° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes
Calibration/characterization procedures	**Elevation angles:** calibration of horizon (+/-0.5 degree) via quick horizon-scan (-3 to +3, very short integration time) **Field of view:** scanning over a light source in the laboratory **Straylight**: not yet characterized **Dark signal:** characterized in the dark room as a function of detector temperature **Line shape:** determined from lamp lines (function of temperature and wavelength) **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: characterized in the dark room as a function of detector temperature
Spectral analysis software	Own software (Python-based)
Supporting measurements	none
Reference	Vlemmix, T., Piters, A.J.M., Stammes, P., Wang, P., and Levelt, P.F., Retrieval of tropospheric NO2 using the MAX-DOAS method combined with relative intensity measurements for aerosol correction, Atmos. Meas. Tech. 3, 1287-1305, 2010.

Institute: Royal Netherlands Meteorological Institute (**KNMI**), De Bilt, The Netherlands

Responsible person(s): Ankie Piters

Contact details: ankie.piters@knmi.nl

Instrument type: Mini-DOAS Hoffmann VIS (#3)

Nr: CINDI-2.22

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Ocean Optics usb 2000+ **Detector type:** Sony ILX511 CCD (2048 pixels)
Instrument performance	**Spectral range/resolution:** 400-600/0.5 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.4° **Typical integration time:** 1-2 minutes **Typical scan duration:** 15-30 minutes
Calibration/characterization procedures	**Elevation angles:** calibration of horizon (+/-0.5 degree) via quick horizon-scan (-3 to +3, very short integration time) **Field of view:** scanning over a light source in the laboratory **Straylight**: not yet characterized **Dark signal:** characterized in the dark room as a function of detector temperature **Line shape:** determined from lamp lines (function of temperature and wavelength) **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: characterized in the dark room as a function of detector temperature
Spectral analysis software	Own software (Python-based)
Supporting measurements	none
Reference	Vlemmix, T, Tropospheric nitrogen dioxide inversions based on spectral measurements of scattered sunlight, PhD Thesis, Technische Universiteit Eindhoven, DOI: 10.6100/IR719874, 2011.

Institute: Royal Netherlands Meteorological Institute (**KNMI**), De Bilt, The Netherlands **Responsible person(s):** Ankie Piters **Contact details:** ankie.piters@knmi.nl		
Instrument type: PANDORA-1S (#1)	**Nr:** CINDI-2.23	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 **Detector type:** 2048 x 64 pixel backthinned non-cooled Hamamatsu CCD **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light), attenuation filters **Mirrors:** no **Temperature control of spectrometer and detector:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 290-530/0.6 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.5° (sky mode); 2.5° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 15-30s per pointing position
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and scanning the solar disc **Field of view:** determined from scanning the solar disc **Stray light:** determined in laboratory from measuring monochromatic input at multiple wavelengths **Dark signal:** determined after each measurement **Line shape:** determined in the laboratory from measurements of several spectral lamps **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** determined in laboratory from tungsten halogen lamp measurements at different integration times **Pixel-to-pixel variability**: determined in laboratory from tungsten halogen lamp measurement
Spectral analysis software	Own software (Python-based) and Blick Software Suite (Python-based)
Supporting measurements	None
Reference	J. Herman, A. Cede, E. Spinei, G. Mount, M. Tzortziou, and N. Abuhassan, NO2 column amounts from ground-based Pandora and MFDOAS spectrometers using the direct-sun DOAS technique: Intercomparisons and application to OMI validation, J. Geophys. Res., 114, D13307, doi:10.1029/2009JD011848, 2009.

Institute: Laboratoire Atmosphère, Milieux, Observations Spatiales (**LATMOS**), Guyancourt, France **Responsible person(s):** Andrea Pazmino **Contact details:** andrea.pazmino@latmos.ipsl.fr, Manuel.pinharanda@latmos.ipsl.fr		
Instrument type: Système d'Analyse par Observation Zénithale (SAOZ)	**Nr:** CINDI-2.24	

Overall design of the instrument	**Optical head including telescope:** n/a **Spectrometer type:** Jobin-Yvon CP200 flat field **Detector type:** 1024 NMOS diode array from Hamamatsu **Optical fibers:** n/a **Filters:** no **Mirrors:** Yes **Temperature control of spectrometer and detector:** no
Instrument performance	**Spectral range/resolution:** 270–640/1.3 nm **Azimuthal scan/direct-sun capabilities:** n/a **Elevation angle capability:** n/a **Field of view:** 20° **Exposure time:** 0.19 s - 5 x measurement cycle (adjusted automatically) **Measurement cycle:** 60 s (programmable)
Calibration/characterization procedures	**Elevation angles:** n/a **Field of view:** n/a **Straylight:** n/a **Dark signal:** shutter **Line shape:** wavelength calibration based on reference spectrum **Polarization:** Est-West fixed direction of the entrance slit **Detector nonlinearity:** exposure time calibrated to 12000 counts in elementary spectrum **Pixel-to-pixel variability**: dark background
Spectral analysis software	SAM version 5.9
Supporting measurements	GPS
Reference	Pazmiño A., O3 and NO2 vertical columns using SAOZ UV-Visible spectrometer, EPJ Web of Conferences, Vol 9: ERCA 9 – From the Global Mercury Cycle to the Discoveries of Kuiper Belt Objects, p. 201-214, doi:10.1051/epjconf/201009016, 2010.

Institute: Laboratoire Atmosphère, Milieux, Observations Spatiales (**LATMOS**), Guyancourt, France

Responsible person(s): Andrea Pazmino

Contact details: andrea.pazmino@latmos.ipsl.fr, Manuel.pinharanda@latmos.ipsl.fr

Instrument type: Mini Système d'Analyse par Observation Zénithale (Mini-SAOZ)

Nr: CINDI-2.25

Overall design of the instrument	**Optical head:** separated **Spectrometer type:** Cerny-Turner, grating 600 grooves/mm **Detector type:** 2048x16 CCD back-thinned from Hamamatsu **Optical fibers:** HGC950; diameter: 950 µm; length:10 m **Filters:** OSC-UB **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 270–820/0.7 nm **Azimuthal scan/direct-sun capabilities:** n/a **Elevation angle capability:** n/a **Field of view:** 8° **Exposure time:** 0.037 s - 5 x measurement cycle (adjusted automatically) **Measurement cycle:** 60 s (programmable)
Calibration/characterization procedures	**Elevation angles:** n/a **Field of view:** n/a **Straylight:** n/a **Dark signal:** shutter **Line shape:** wavelength calibration based on reference spectrum **Polarization:** n/a **Detector nonlinearity:** exposure time calibrated to 12000 counts in elementary spectrum spectrum (semi-blind campaign) Characterisation using stable light source at different integration time (after campaign) **Pixel-to-pixel variability**: dark background
Spectral analysis software	SAOZ.gui Version 1.25-50f870
Supporting measurements	GPS
Reference	Piters, A. J. M. et al.: The Cabauw Intercomparison campaign for Nitrogen Dioxide measuring Instruments (CINDI): design, execution, and early results, Atmos. Meas. Tech., 5(2), 457-485, 2012, doi:10.5194/amt-5-457-2012, 2012.

Institute: Meteorologisches Institut, Ludwig-Maximilians-Universität München (**LMU-MIM**), Munich, Germany

Responsible person(s): Mark Wenig

Contact details: mark.wenig@physik.uni-muenchen.de, lok.chan@ physik.uni-muenchen.de

Instrument type: 2D MAX-DOAS EnviMeS (#4)

Nr: CINDI-2.35

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type UV:** Avantes AvaBench-75 **Spectrometer type vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 pixel) **Detector type vis:** Backthinned Hamamatsu CCD (2048 pixel) **Optical fibers:** Multifibre (UV), single fibre (VIS), length: 10m **Filters:** UV bandpass filters (BG3) **Mirrors:** N/A **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector vis:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 305–460/0.56 nm **Spectral range/resolution vis:** 430–650/0.54 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 15 min
Calibration/characterization procedures	**Elevation angles:** tilt sensor **Field of view:** not yet characterized **Straylight:** not yet characterized **Dark signal:** not yet characterized **Line shape:** not yet characterized **Polarization:** not yet characterized **Detector nonlinearity:** not yet characterized **Pixel-to-pixel variability**: not yet characterized
Spectral analysis software	DOASIS
Supporting measurements	Two video cameras, inclinometer
Reference	Lampel, J., Frieß, U., and Platt, U.: The impact of vibrational Raman scattering of air on DOAS measurements of atmospheric trace gases, Atmos. Meas. Tech., 8, 3767-3787, https://doi.org/10.5194/amt-8-3767-2015, 2015.

Institute: **LuftBlick**, Mutters, Austria **Responsible person(s):** Alexander Cede **Contact details:** alexander.cede@luftblick.at		
Instrument type: PANDORA-2S (#2 & #3)	**Nr:** CINDI-2.26 CINDI-2.27	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 (one for UV and one for vis) **Detector type:** 2048 x 64 pixel backthinned non-cooled Hamamatsu CCD (one for UV and one for vis) **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light), attenuation filters **Mirrors:** no **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector VIS:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 280 - 540/0.6 nm **Spectral range/resolution vis:** 380 - 900/1.1 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.5° (sky mode); 2.8° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 15-30s per pointing position
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and scanning the solar disc **Field of view:** determined from scanning the solar disc **Stray light:** determined in the laboratory from measuring monochromatic input at different wavelengths **Dark signal:** determined after each measurement **Line shape:** determined in the laboratory from measurements of several spectral lamps **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** determined in laboratory from tungsten halogen lamp measurements at different integration times **Pixel-to-pixel variability**: determined in laboratory from tungsten halogen lamp measurements
Spectral analysis software	Blick Software Suite (Python-based)
Supporting measurements	None
Reference	J. Herman, A. Cede, E. Spinei, G. Mount, M. Tzortziou, and N. Abuhassan, NO2 column amounts from ground-based Pandora and MFDOAS spectrometers using the direct-sun DOAS technique: Intercomparisons and application to OMI validation, J. Geophys. Res., 114, D13307, doi:10.1029/2009JD011848, 2009.

<table>
<tr><td colspan="2"><u>Institute:</u> Max-Planck Institute for Chemistry (MPIC), Mainz, Germany
<u>Responsible person(s):</u> Thomas Wagner
<u>Contact details:</u> thomas.wagner@mpic.de</td><td rowspan="2"></td></tr>
<tr><td><u>Instrument type:</u> TubeMAX-DOAS</td><td><u>Nr:</u>
CINDI-2.28</td></tr>
</table>

Overall design of the instrument	**Optical head including telescope:** separated; elevation angles fully configurable **Spectrometer type:** Avantes **Detector type:** CCD **Optical fibers:** quartz fibre bundle, length: 5 m **Filters:** BG3 (UV) **Mirrors:** no **Temperature control of spectrometer and detector:** 20°C/20°C
Instrument performance	**Spectral range/resolution:** 305–464/0.6 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable **Field of view:** 0.7° **Typical integration time:** 60s **Typical scan duration:** 15 minutes (depends on sequence)
Calibration/characterization procedures	**Elevation angles:** performed at the campaign using laser device or water level **Field of view:** performed at the campaign using laser device or water level **Straylight:** has to be quantified **Dark signal:** measured on site and corrected **Line shape:** almost symmetric Gaussian-like, almost not dependent on wavelength **Polarization:** - **Detector nonlinearity:** characterised in the laboratory **Pixel-to-pixel variability**: -
Spectral analysis software	Windoas and QDOAS
Supporting measurements	Video camera
Reference	Donner, S., Mobile MAX-DOAS measurements of the tropospheric formaldehyde column in the Rhein-Main region. Master Thesis, Universität, Mainz,http://hdl.handle.net/11858/00-001M-0000-002C-EB17-2, 2016.

Institute: **NASA**-Goddard (Greenbelt, Maryland) **Responsible person(s):** Jay Herman **Contact details:** jay.r.herman@nasa.gov, Elena Spinei (elena.spinei@nasa.gov)		
Instrument type: PANDORA-1S (#4 & #5)	**Nr:** CINDI-2.31 CINDI-2.32	

Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** AvaSpec-ULS2048x64 (one for 285 – 530 nm) **Detector type:** 2048 x 64 pixel backthinned non-cooled Hamamatsu CCD **Optical fibers:** single strand 400um core diameter high OH fused silica fiber, 10m long **Filters:** spectral filters (U340 and BP300 to remove visible light), attenuation filters **Mirrors:** no **Temperature control of spectrometer and detector UV:** 20°C/20°C **Temperature control of spectrometer and detector VIS:** 20°C/20°C
Instrument performance	**Spectral range/resolution UV:** 280-540/0.6 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** circular, 1.6° (sky mode); 2.8° (sun mode) **Typical integration time:** 2.4ms-300ms (sun), 20ms to 1000ms (sky) **Typical scan duration:** 15-30s per pointing position
Calibration/characterization procedures	**Elevation angles:** based on astronomical calculations and scanning the solar disc **Field of view:** determined from scanning the solar disc **Stray light:** determined in laboratory from measuring monochromatic input at multiple wavelengths **Dark signal:** determined after each measurement **Line shape:** determined in the laboratory from measurements of several spectral lamps **Polarization:** no residual polarization measured after 10m fiber **Detector nonlinearity:** determined in laboratory from tungsten halogen lamp measurements at different integration times **Pixel-to-pixel variability**: determined in laboratory from tungsten halogen lamp measurement
Spectral analysis software	Blick Software Suite (Python-based)
Supporting measurements	None
Reference	J. Herman, A. Cede, E. Spinei, G. Mount, M. Tzortziou, and N. Abuhassan, NO2 column amounts from ground-based Pandora and MFDOAS spectrometers using the direct-sun DOAS technique: Intercomparisons and application to OMI validation, J. Geophys. Res., 114, D13307, doi:10.1029/2009JD011848, 2009.

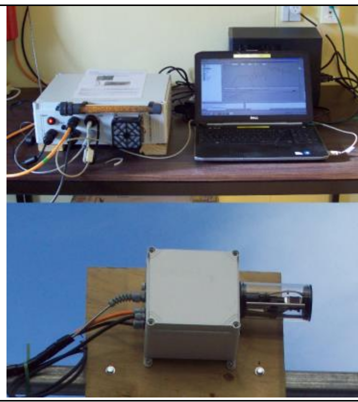
Institute: National Institute of Water and Atmospheric Research (**NIWA**), Lauder, New Zealand

Responsible person(s): Richard Querel, Paul Johnston

Contact details: richard.querel@niwa.co.nz

Instrument type: EnviMeS 1D MAX-DOAS (#3)

Nr: CINDI-2.29



Overall design of the instrument	**Optical head including telescope:** elevation angle configurable **Spectrometer type UV:** Avantes AvaBench-75 **Spectrometer type vis:** Avantes AvaBench-75 **Detector type UV:** Backthinned Hamamatsu CCD (2048 x 64 pixels) **Detector type vis:** Backthinned Hamamatsu CCD (2048 x 64 pixels) **Optical fibers:** Multifibre (6 x UV), single fibre (1 x VIS), length: 10m **Filters:** UV bandpass filter (BG3), VIS bandpass filter (BG40) **Mirrors:** Rotating glass quartz prism as entrance optic **Temperature control of spectrometer and detector UV:** 20 °C / 20 °C **Temperature control of spectrometer and detector vis:** 20 °C / 20 °C
Instrument performance	**Spectral range/resolution UV:** 305–457 nm / 0.7 nm **Spectral range/resolution vis:** 410–550 nm / 0.7 nm **Azimuthal scan/direct-sun capabilities:** no **Elevation angle capability:** fully configurable; step: 0.1° or less **Field of view:** <0.5° **Typical integration time:** 2.5ms -60s **Typical scan duration:** 60 s
Calibration/characterization procedures	**Elevation angles:** Calibrated tilt meter and level **Field of view:** not measured **Straylight:** not measured **Dark signal:** shutter blocks light path in scanning head **Line shape:** taken from Hg lamp spectra **Polarization:** 10 m fibre effectively depolarizes incoming light **Detector nonlinearity:** observations of a temperature stabilized LED with several different exposure times, assuming LED to be constant intensity. **Pixel-to-pixel variability**: Not tested
Spectral analysis software	DOASIS, STRATO
Supporting measurements	Tilt sensor (for elevation angle), PTU
Reference	Lampel, J., Frieß, U., and Platt, U.: The impact of vibrational Raman scattering of air on DOAS measurements of atmospheric trace gases, Atmos. Meas. Tech., 8, 3767-3787, https://doi.org/10.5194/amt-8-3767-2015, 2015.

Institute: National Institute of Water and Atmospheric Research (**NIWA**), Lauder, New Zealand **Responsible person(s):** Richard Querel, Paul Johnston **Contact details:** richard.querel@niwa.co.nz		 
Instrument type: Lauder Acton275 MAX-DOAS	**Nr:** CINDI-2.30	

Overall design of the instrument	**Optical head including telescope:** elevation angle configurable **Spectrometer type UV/Vis:** Acton 275 with grating control **Detector type UV/Vis:** Backthinned Hamamatsu CCD (1044 x 128pixels x 24um) **Optical fibers:** Multifibre with 100um fibres, input end circular 1mm diam, length: 12m **Filters:** **Mirrors:** Front silvered rotating mirror and quartz lens optic. **Temperature control of detector:** -20 °C
Instrument performance	**Spectral range/resolution: multi band configurable; typical two bands are: alternating** 290–363 nm and 400-460; 0.6 nm **Azimuthal scan/direct-sun capabilities:** no **Elevation angle capability:** fully configurable; step: < 0.1° **Field of view:** about 0.5° **Typical integration time:** 16ms -20s **Typical scan duration:** 60 s (but flexible)
Calibration/characterization procedures	**Elevation angles:** Bubble level on mirror and external laser level **Field of view: m**easured using laser level **Straylight:** estimated using Schott filters to cut light at shorter wavelengths.<1e-2 ? **Dark signal:** night spectra or manual scan **Line shape:** taken from Hg and other line lamp spectra **Polarization:** 12 m fibre effectively depolarizes incoming light **Detector nonlinearity:** quantified by comparing observations of a clear sky with and without neutral density filter. **Pixel-to-pixel variability**: measured with white lamp.
Spectral analysis software	STRATO (Lauder, NIWA)
Supporting measurements	GPS time, Camera possible.

Institute: National University of Sciences and Technology (**NUST**), Islamabad, Pakistan **Responsible person(s):** Muhammad Fahim Khokhar and Junaid Khayyam Butt **Contact details:** fahim.khokhar@iese.nust.edu.pk, jkb2ravian@gmail.com		
Instrument type: Mini MAX-DOAS	**Nr:** CINDI-2.33	

Overall design of the instrument	**Optical head including telescope:** integrated **Spectrometer type:** Czerny-Turner spectrometer **Detector type:** 1 dimensional CCD (Sony ILX511, 2048 individual pixels) **Optical fibers:** n/a **Filters:** n/a **Mirrors:** n/a **Temperature control of spectrometer and detector:** n/a
Instrument performance	**Spectral range/resolution:** 320–465/0.7 nm **Azimuthal scan/direct-sun capabilities:** no/no **Elevation angle capability:** fully configurable; 1 degree resolution **Field of view:** ~1.2^o **Typical integration time:** 10-60s **Typical scan duration:** 20 minutes
Calibration/characterization procedures	**Elevation angles:** water/sprit level **Field of view:** n/a **Straylight:** n/a **Dark signal:** manual procedure **Line shape:** n/a **Polarization:** n/a **Detector nonlinearity:** n/a **Pixel-to-pixel variability**: n/a
Spectral analysis software	QDOAS (version:2.111) / WinDOAS
Supporting measurements	GPS but not integrated

Institute: Department of Physics, University of Toronto (**UTO**), Toronto, Canada **Responsible person(s):** Kristof Bognar, Xiaoyi Zhao, Kimberly Strong **Contact details:** kbognar@physics.utoronto.ca, xizhao@atmosp.physics.utoronto.ca, strong@atmosp.physics.utoronto.ca	 
Instrument type: PEARL-GBS instrument (MAX-DOAS, ZSL-DOAS, and DS)	**Nr:** CINDI-2.36
Overall design of the instrument	**Optical head including telescope:** separated; elevation and azimuth angles fully configurable **Spectrometer type:** Jobin Yvon Triax-180 triple-grating spectrometer **Detector type:** back-illuminated cooled CCD with 2048 x 512 pixels **Optical fibers:** fiber bundle (37 HOH mapped fibres, spot-to-slit), spot end diameter: ~0.8 mm, length: 6 m **Filters:** Filter wheel containing one empty slot, four metallic neutral density filters (31.6%, 1%, 0.1%, 0.01% transmittance) and a UV diffuser **Mirrors:** UV-enhanced aluminum (suntracker) **Temperature control of spectrometer and detector:** 25°C/-70°C
Instrument performance	**Spectral range/resolution:** 340–560/0.75 nm **Azimuthal scan/direct-sun capabilities:** yes/yes **Elevation angle capability:** fully configurable **Field of view:** 0.6° **Typical integration time:** 50-140 s **Typical scan duration:** 12-23 minutes for 9 elevation angles
Calibration/characterization procedures	**Elevation angles:** calibrated by levelling the suntracker **Field of view:** calculated analytically **Straylight:** determined using a red filter and a halogen lamp **Dark signal:** determined from a series of closed shutter measurements **Line shape:** assumed to be Gaussian **Polarization:** determined using a polarizer and a halogen lamp; fiber bundle mostly depolarizes incoming light **Detector nonlinearity:** <0.4% as given by the CCD manufacturer **Pixel-to-pixel variability**: not characterized
Spectral analysis software	Raw data is processed using in-house MATLAB code and analysis is performed using the QDOAS software
Supporting measurements	Webcam
Reference	A. Fraser, C. Adams, J.R. Drummond, F. Goutail, G. Manney, and K. Strong. The Polar Environment Atmospheric Research Laboratory UV-Visible Ground-Based Spectrometer: First Measurements of O_3, NO_2, BrO, and OClO Columns. *J. Quant. Spectrosc. Radiat. Transfer*, **110 (12)**, 986-1004, 2009.