

Measurements of trace gases with a MAX-DOAS system during a ship cruise from the Canaries to Ecuador (SO287) on board of RV Sonne



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Abstract: We present measurements of a Multi AXis Differential Optical Absorption Spectroscopy (MAX-DOAS) system installed on the research vessel Sonne during the cruise SO287 from Las Palmas (Gran Canaria, Spain) to Guayaquil (Ecuador) from the 11th of December 2021 until the 11th of January 2022. Measured differential Slant Column Densities (dSCD) have been converted to vertical concentration profiles with the inversion algorithm BOREAS. The final time series of near surface concentration and Vertical Column Densities (VCD) as well as vertical concentration profiles are shown on this poster.

Ship-based anthropogenic emissions have been identified as higher VCD and near surface concentrations of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). Both species have been found close to the surface but also in higher altitudes. On the open ocean, the frequently detected abundance of iodine monoxide (IO) emphasizes that the marine boundary layer is mainly dominated by emissions from the ocean (algae) in the absence of anthropogenic emissions. In addition to the abundance close to the ocean surface, elevated layers of IO could be identified. Formaldehyde (HCHO) has been measured close to land and in the Caribbean Sea, both, close to the surface and in higher altitudes.

Introduction

- Start of cruise: 11.12.2021 in Las Palmas, Gran Canaria, Spain
- End of cruise: 11.01.2022 in Guayaquil, Ecuador
- Vessel: RV Sonne

Measured species

- MAX-DOAS instrument:
 - NO_2
 - SO_2
 - HCHO
 - IO
 - Aerosol
 - In Situ instruments
 - NO_2 , NO_x , NO
 - SO_2
 - Black Carbon
 - CO
- In Situ data not shown!

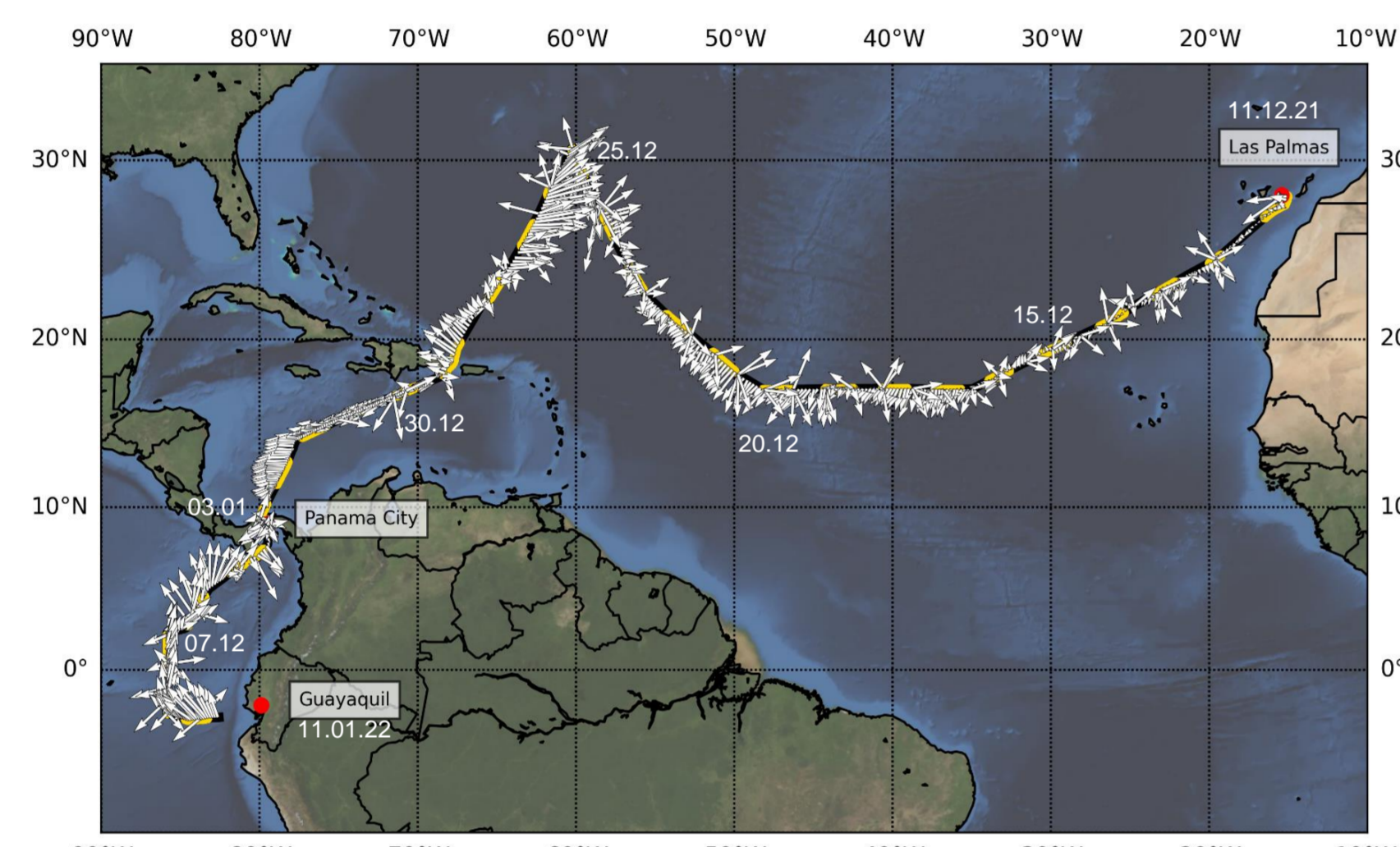
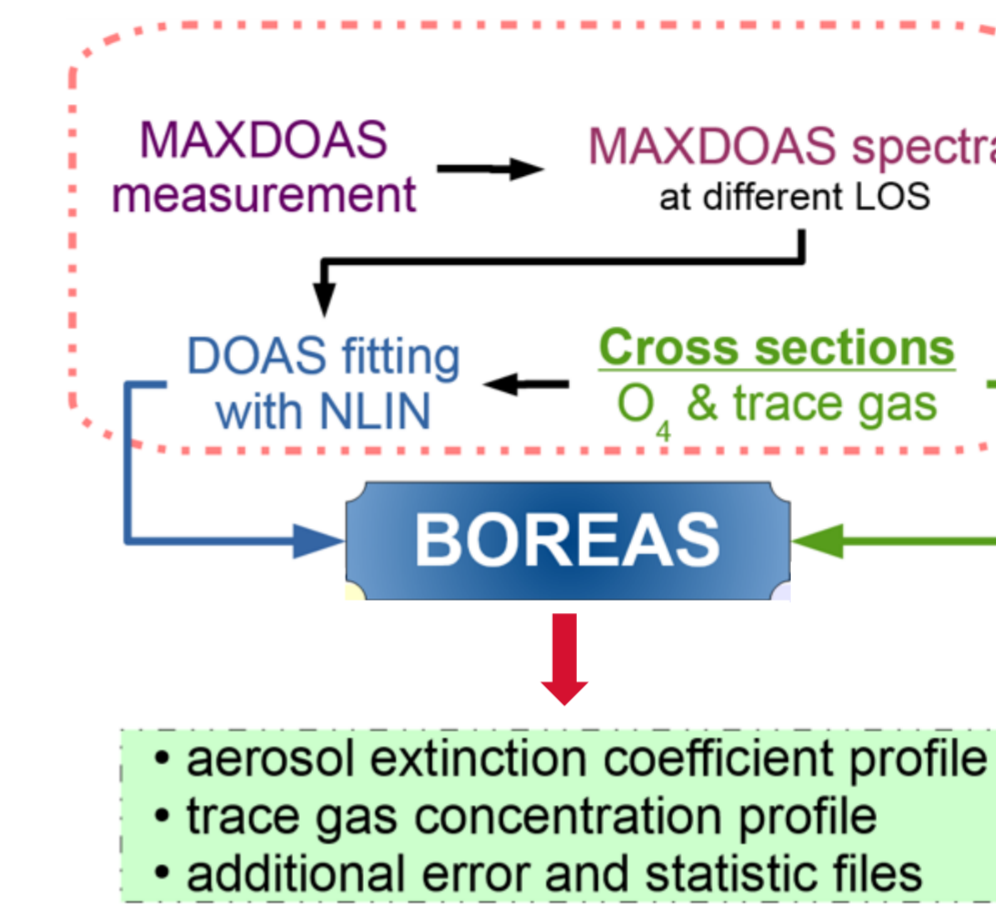


Fig. 1: Map of cruise SO287. Yellow (black) periods indicate day (night). The arrows show wind direction relative to ship movement.

Data preparation

- Spectra measured at different elevation angles
- DOAS Fits (see table) applied to retrieve differential slant column densities (dSCD) for various trace gases
- Profile retrieval algorithm BOREAS (Bösch et al. 2018) used to retrieve aerosol profiles from O_4 dSCD
- BOREAS used to retrieve trace gas profiles with aerosol from step 3



Parameter / Molecule	Value	Value	Value	Value	Reference
Fit for species:	NO_2	HCHO	SO_2	IO	
Fitting window (nm)	425 – 490	336.5 – 359	305 – 319	411.5 – 453	
Polynomial degree	5	6	6	6	
Ozone, O_3	223 K + 10 Corr.	223 K + 10 Corr.	223 K + 10 Corr. 243 K	223 K + 10 Corr.	Serduchenko et al. 2014
Oxygen-dimer, O_4	293 K	293 K	-----	293 K	Finkenzeller and Volkamer 2020
Nitrogen dioxide, NO_2	298 K + 10 Corr.	298 K + 10 Corr.	298 K + 10 Corr.	298 K + 10 Corr.	Vandaele et al. 1998
Formaldehyde, HCHO	-----	298 K	-----	-----	Meller, MPI Mainz, 1992
Sulfur dioxide, SO_2	-----	-----	294 K	-----	Vandaele et al. 1994
Iodine Monoxide, IO	-----	-----	-----	298 K	Spitz et al. 2005
Bromine Monoxide, BrO	-----	-----	223 K	-----	Fleischman, 2000
Water vapor, H_2O	293 K + 10 Corr. 293 K Cross ²	-----	-----	293 K + 10 Corr. 293 K Cross ²	HITRAN 2020
Ring effect, Const. Offset	Yes, Yes	Yes, Yes	Yes, Yes	Yes, Yes	QDOASCALC_HIGHRESSAD2010

Time series and maps

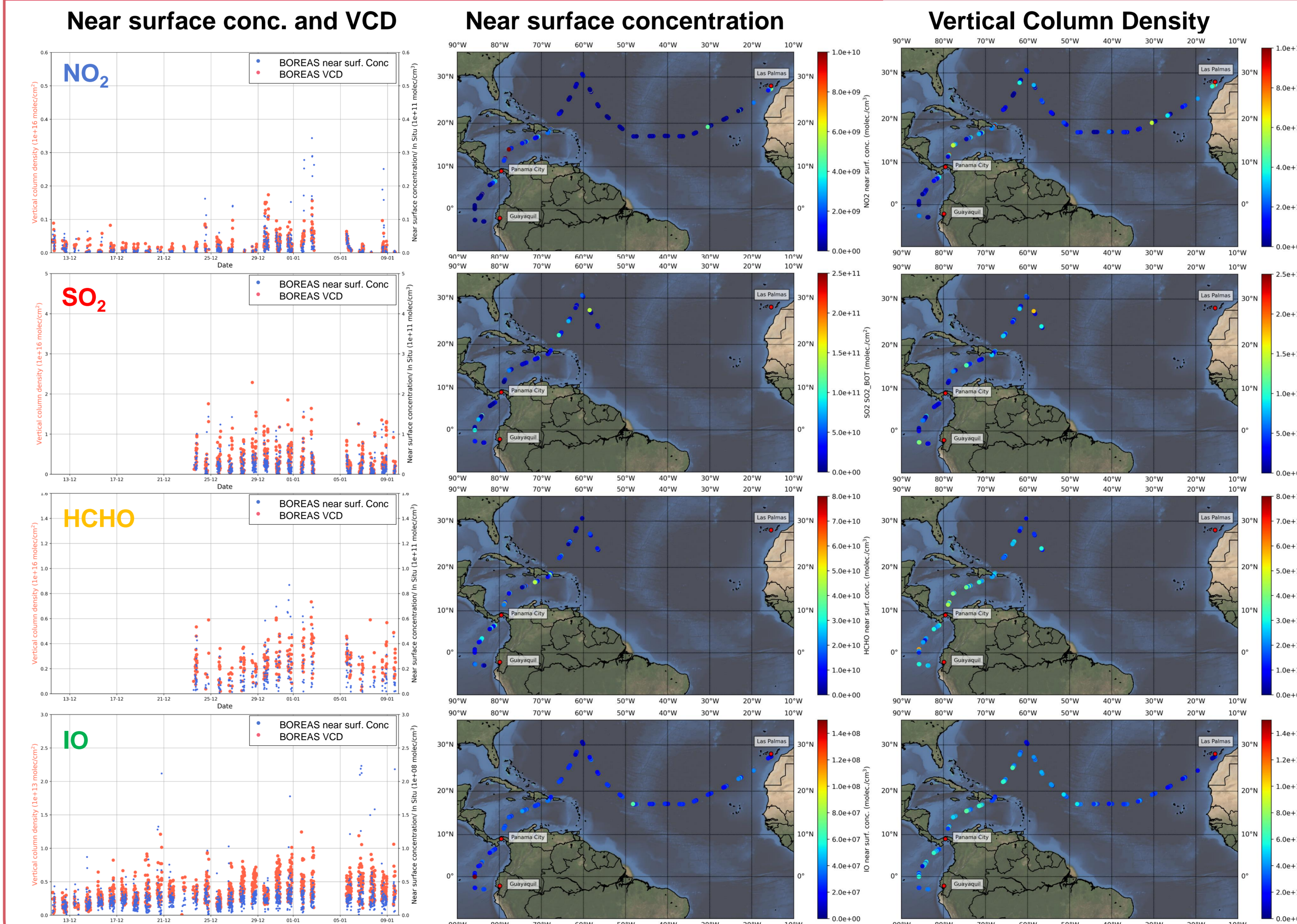


Fig. 3: Left: Time series of near surface concentration and vertical column density, Mid: Maps of near surface concentrations, Right: Maps of vertical column density. Different rows: Results for NO_2 , SO_2 , HCHO and IO .

Vertical Distribution

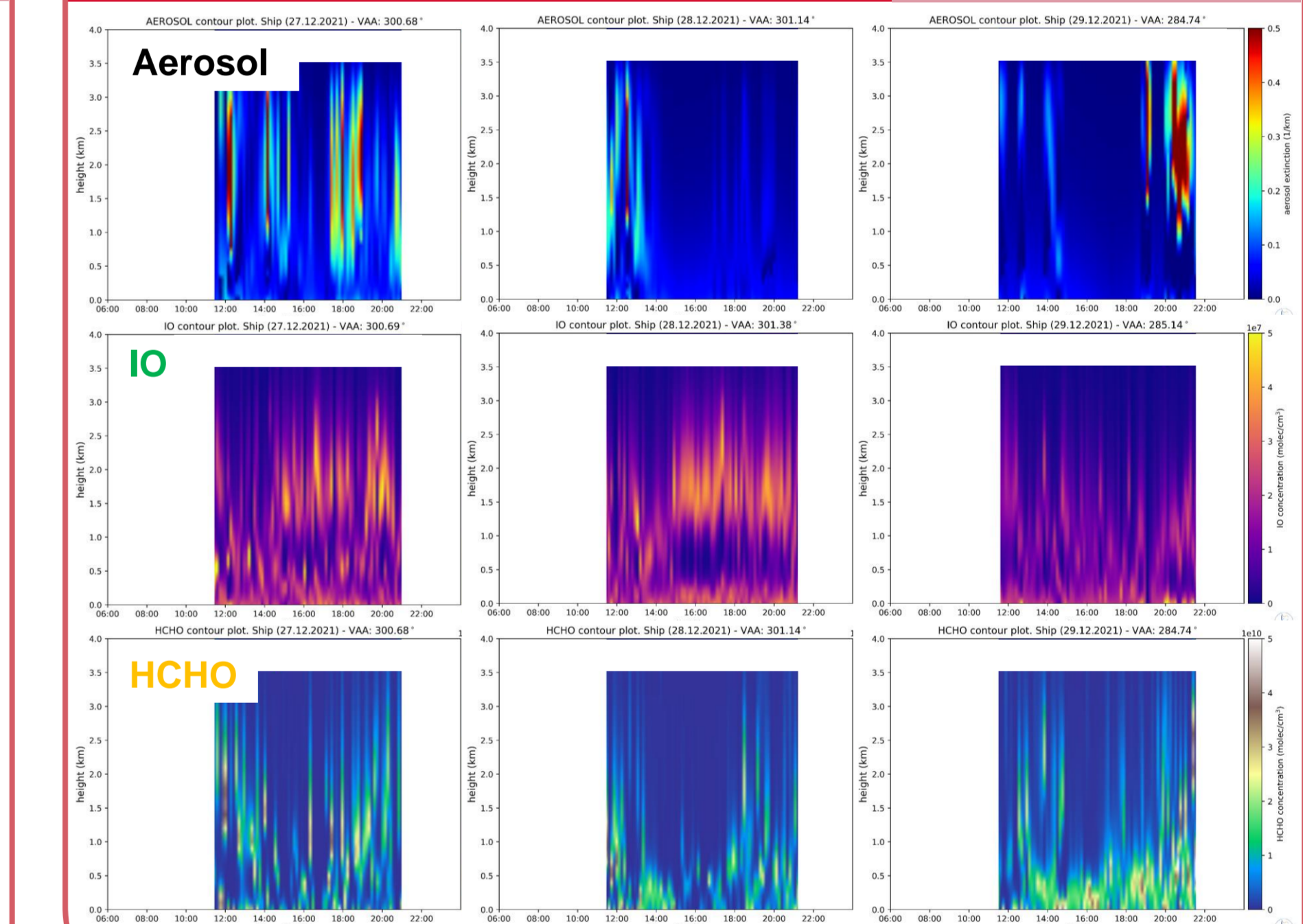


Fig. 4: Vertical concentration profiles as contour plots for three consecutive days (27.12 – 29.12) for Aerosol, IO and HCHO .

Conclusions

- Few NO_2 and SO_2 abundance in lower altitudes → Resulting from anthropogenic emissions
- HCHO concentrations high close to land. Some elevated layers can be seen, indicating transported air masses (biogenic emissions/fires)
- IO concentrations are higher in Sargasso and Caribbean Sea. High values are found close to the surface but also in higher altitudes

Acknowledgement
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Reference
Bösch et al 2018: „BOREAS – A New MAX-DOAS Profile Retrieval Algorithm for Aerosols and Trace Gases“. Atmospheric Measurement Techniques 11, Nr. 12 (21. Dezember 2018): 6833–59. <https://doi.org/10.5194/amt-11-6833-2018>



Instrumentation

MAX-DOAS systems

- Avantes system (287 – 551nm):
 - Spectrometer: AvaSpec-ULS2048x64
 - Spectral Resolution: 0.7 nm
- Rack system (UV only):
 - Spectrometer: Princeton Instruments IsoPlane SCT 320
 - Spectral Resolution: 0.05 nm
 - CCD: Princeton Instruments Pixis100 (broken → no measurements)

In Situ systems

- NO_x , NO_2 , NO : Thermo Scientific 42i, Chemiluminescence
- SO_2 : Thermo Scientific 43i, Pulsed Fluorescence
- CO : Thermo Scientific 48i, Gas Filter Correlation
- Black Carbon: Magee Scientific AE33, Aethalometer

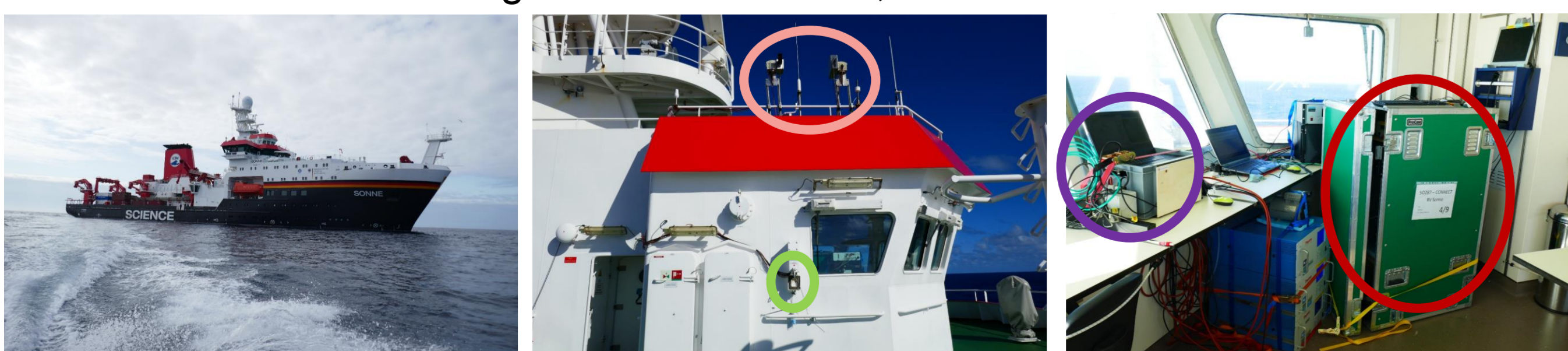


Fig. 2: Left: RV Sonne. Mid: MAX-DOAS telescopes and In Situ inlets on deck 10 and 9, respectively. Right: MAX-DOAS and In Situ systems inside measurement room on deck 9.