Cavity Ring-Down Instrument for Nitrogen Oxides Measurements

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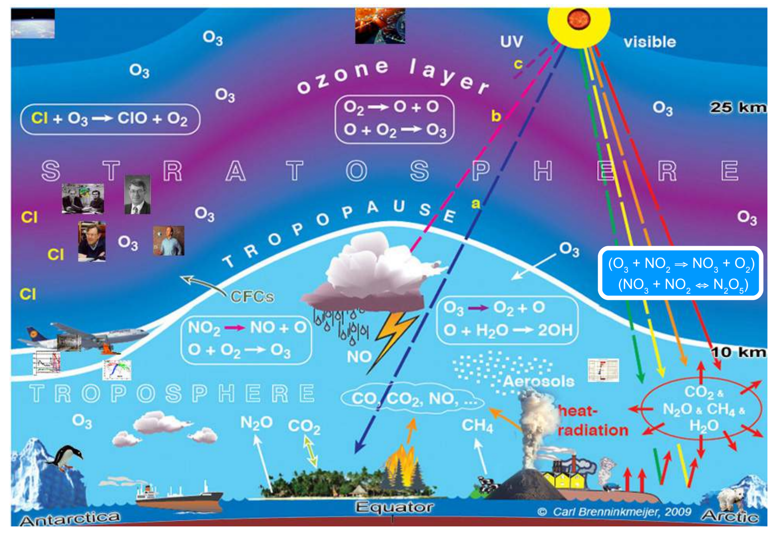
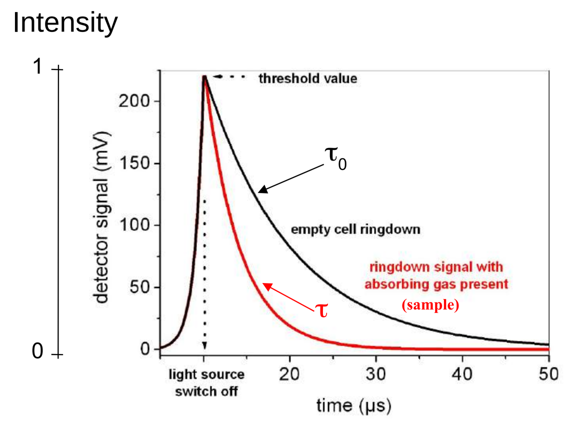
Introduction

The **aim** of this project is to build a new instrument for the in-situ detection of 4 gas species in the Upper Troposphere Lower Stratosphere: NO_3, N_2O_5, NO_2 and O_3. The instrument will be installed in the CARIBIC container [1] on board a commercial Airbus aircraft. The detection system is based on **cavity ring-down spectroscopy**, and its design is based on the instruments previously developed by our partners at NOAA [2,3]. The motivation is to study the **influence** of these species on nitrogen oxide and ozone transport and loss at night, which can show large variability as a function of the altitude [4,5]. The overall objective of the project is thus to contribute to monitor global climate change.



Methodology



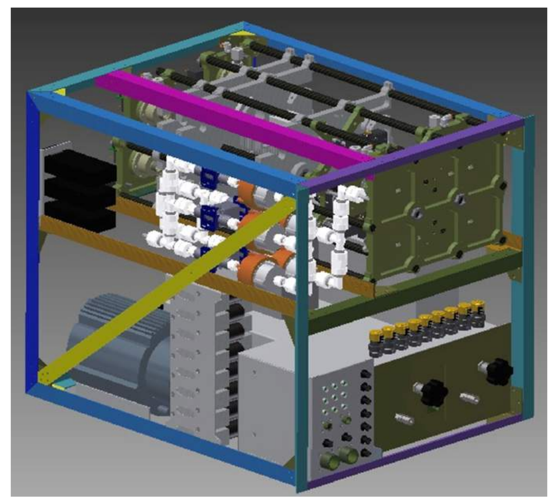
$$\alpha = \frac{L}{c}\frac{\tau_0 - \tau}{\tau_0 \tau}$$

α = Absorbance
L = Length of cavity
c = Speed of light

$$[A] = \alpha \frac{R_L}{\sigma T_E}$$

[A] absorber's concentration (mol.cm^{-3})
R_L ratio cavity length over sample length
σ absorption cross section (cm^2.mol^{-1})
T_E transmission efficiency through inlets

Design



Dimensions (WxLxH): 448 x 500 x 590 mm^3
Power consumption : 320 W
Flights duration (autonomy) : 50 hours
Weight : 60 kg

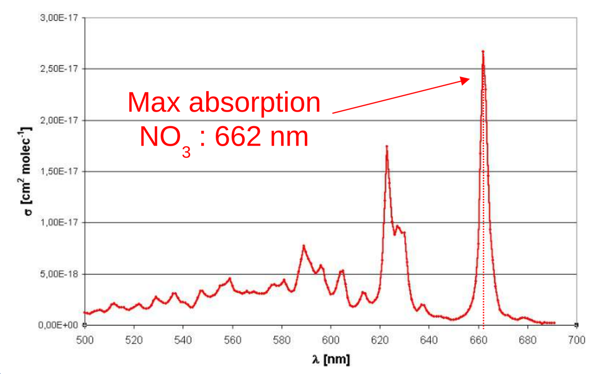
Measurement

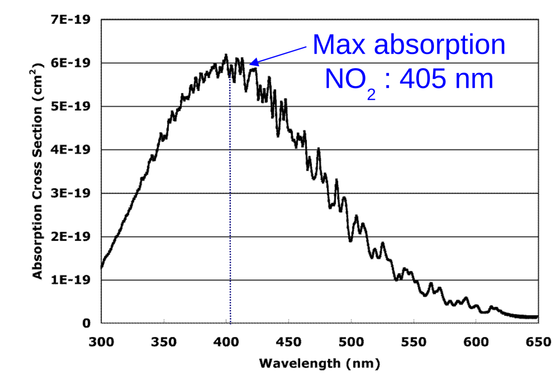
The two cavities (1) and (2) are operated at 662 nm (NO_3 and N_2O_5)

The two cavities (3) and (4) are operated at 405 nm (O_3 and NO_2)

(1) N_2O_5 (heat) → $NO_3 + NO_2$
(2) NO_3 (max absorption)
The ≠ gives N_2O_5

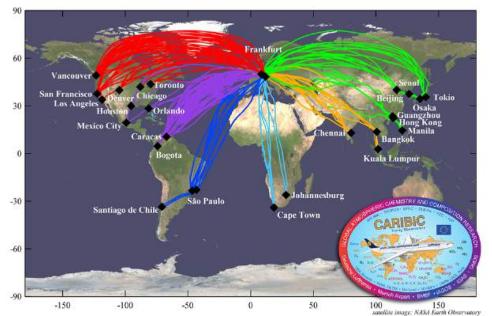
(3) $O_3 + NO \rightarrow NO_2 + O_2$
(4) NO_2 (max absorption)
The ≠ gives O_3





CARIBIC background

Container (1.6 tons), 15 instruments. About 100 gas species parameters.

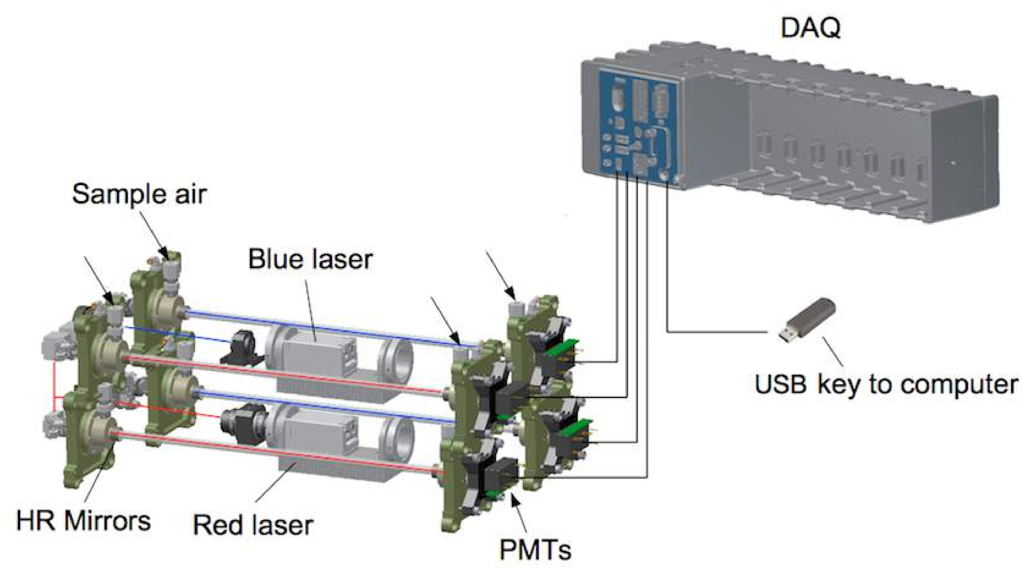


Flight routes 2004-2015 (422 flights)

Dedicated inlet system

CARIBIC hall at KIT

Experimental setup

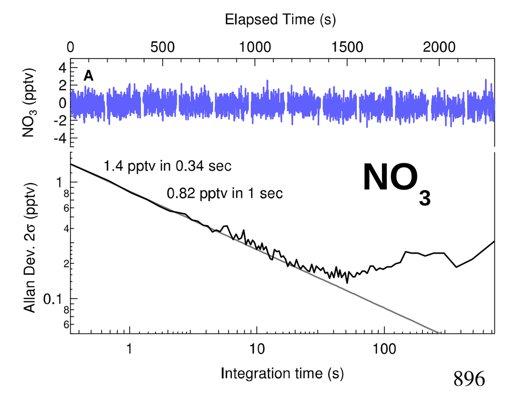


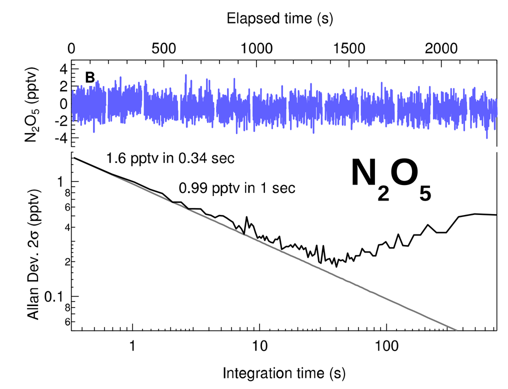
Specifications

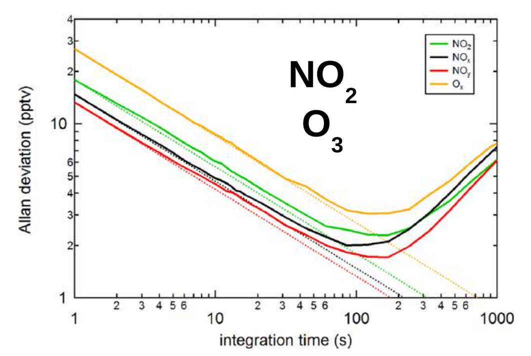
Blue laser: 405 nm
Red laser: 662 nm
HR mirrors: R = 99.999%
Time resolution: 1s (1 Hz)
DAQ: 1 MS/s

The detection is based on 4 high-finesse optical cavities (finesse ~ 627000, **path length ~ 176 km**, cavity length ~44 cm, **empty ringdown time τ_0 ~ 30 µs**).
Flow control, data collection, analysis, and zeroing procedures are fully automated and controlled by dedicated electronics and software within the device.

Expected results







	Precision	Accuracy	
NO_3	0.8 pptv (1 s), 0.2 pptv (1 min)	-9/+12 %	(Wagner et al. ACP 2011)
N_2O_5	1.0 pptv (1 s), 0.2 pptv (1 min)	-8/+11 %	(Fuchs et al. 2008)
NO_2, O_3	25 pptv (1 s), 5 pptv (1 min)	± 3 %	(Wild et al., ES&T 2014)

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Discussion and conclusion

The design of the instrument has been completed at the end of 2015, the construction is currently on-going, and the device will be tested in the lab during summer 2016. If successfully executed, the instrument is expected to be installed in the CARIBIC container during winter 2016-2017.
A preliminary estimate of the expected detection limits in the field yielded approximately 0.8 pptv (1 s) for NO_3, 1.0 pptv (1 s) for N_2O_5, 25 pptv (1 s) for NO_2, and 5 pptv (1 min) for O_3. The main limitations include inlet transmission efficiencies, ring-down time accuracy, temperature dependence of the cross-sections, sampling rate of the DAQ system, and flow-related noise in the cavities, especially for the heated channel. The instrument is expected to deliver data between 2017 and 2020.

Acknowledgement

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