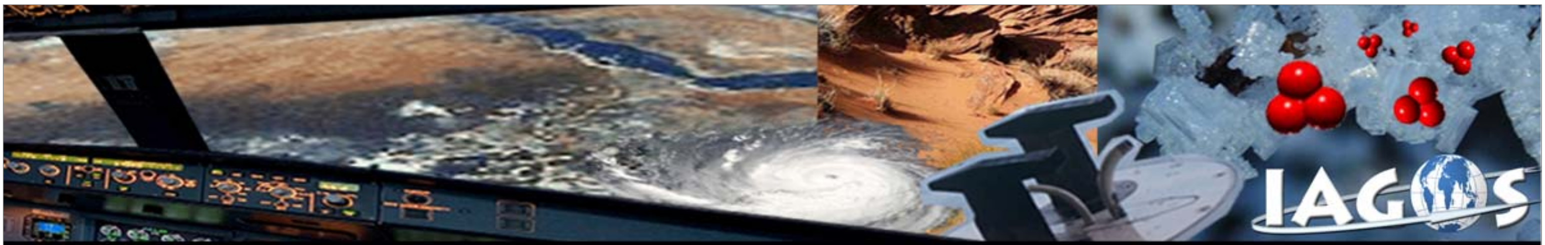

CO_2 AND CH_4 MEASUREMENTS BY COMPACT CAVITY RING-DOWN

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1. Abstract

A measurement system for the greenhouse gases CO_2 and CH_4 will be deployed **on commercial airliners** as part of the **IAGOS-ERI** project.
For this, a commercial analyzer developed by **PICARRO Inc.** (US) was redesigned to meet the requirements needed regarding design (size, weight, safety issues) and performance (long term stability, low maintenance, robustness, full automation). The analyzer is based on **cavity ring-down spectroscopy (CRDS)** and provides simultaneous measurements of **CO_2, CH_4, CO and H_2O** at high precision. A fully automated calibration system ensures that measurements are referenced to WMO standards.

3. Analyzer

- **based on the cavity ring-down spectroscopy (CRDS) technique**
- **simultaneous measurements of CO_2, CH_4, CO and H_2O**
- **insensitive to changes in ambient pressure and temperature**
- **no drying system needed**
  → water correction for dilution and pressure broadening effect
  [Chen et al., 2009, High-accuracy continuous airborne measurements of greenhouse gases (CO_2 and CH_4) using the cavity ring-down spectroscopy (CRDS) technique]

Parameter	CO_2	CH_4	H_2O	CO
Precision (1-sigma over 30 sec, vibration @ 20 Hz, 1g)	< 0.1 ppmv	< 1 ppbv	50 ppmv	< 20 ppb
Operating Range	300 to 700 ppmv	300 to 2600 ppbv	0 to 2.5%	10 – 1000 ppb
Measurement Interval	< 2 seconds	< 2 seconds	< 2 seconds	< 2 seconds

Parameter	Value
Size (W x H x D)	350mm x 300mm x 530mm
Weight	< 30 kg
Inlet gas pressure	230 – 1000 Torr
Inlet gas flow rate	0.2 – 0.45 L / min
Max. Rate of Change in Ambient Temperature	20°C in 20 minutes
Max. Rate of Change in Altitude	1000 meters per minute
Power dissipation	< 300W @ 28VDC IAGOS

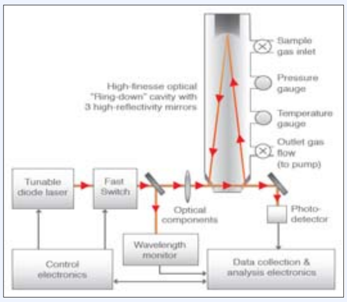


Figure 2.1: CRDS cavity configuration and sample gas flow in the Picarro analyzer

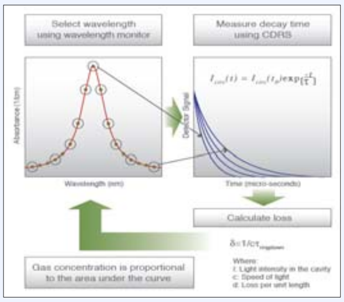
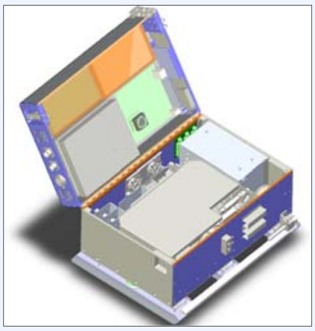


Figure 2.2: measurement principle: wavelength-scanned cavity ring-down spectroscopy

(www.picarro.com)

- **instrument developed by Picarro Inc.**
  → redesigned by enviscope to meet the IAGOS package II certification requirements



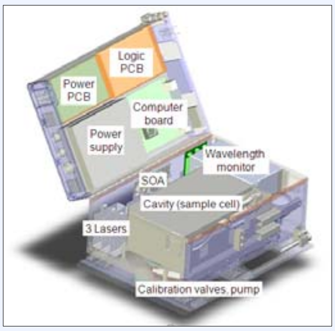


Figure 2.3 and 2.4: All components of the commercial analyzer are arranged in a specially designed frame. Some components had to be replaced due to e.g. flammability regulations.

2. Measurement System

The measurement system for CO_2 consists of an **inlet** for the sample air, a **calibration system,** and the **analyzer**.

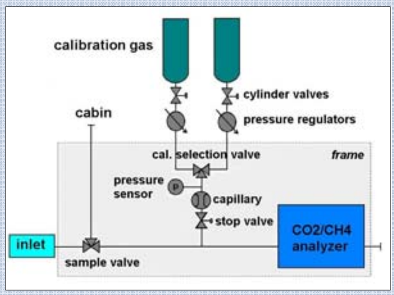


***Figure 2.1**: The pump of the analyzer supplies the instrument with sample air, which enters the system through the inlet. The air is then measured in situ by the temperature and pressure controlled analyzer. In-flight calibrations guarantee the quality of the measurements. The sample flow leaves the instrument to the atmosphere through the exhaust line, connected through the flange that carries the inlet*

different measurement modes:
- measurement of sample air
- measurement of cabin air
- calibration

to change between different modes:
→ use **signals of the aircraft** (weight on wheels, cargo door open/closed, landing gear status, also position and altitude)

4. Test Flights of the CRDS Analyzer

IMECC project (**I**nfrastructure for **M**easurements of the **E**uropean **C**arbon **C**ycle)

- validation of ground based remote sensing
- campaign in September/October 2009

→ comparison of prototype CRDS instrument against flask sample analysis
→ analyzer exceeds the targeted performance requirements

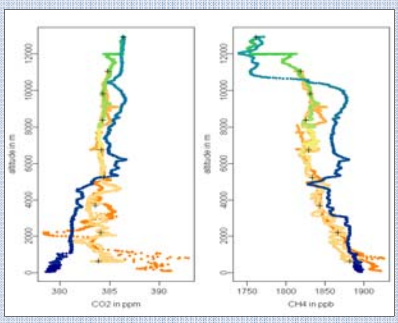


Figure 3.2: profiles of CO_2 and CH_4 mixing ratios during noon on 2nd Oct 2009 (points – in situ , crosses – flasks)

Flask - CRDS	CO_2	CH_4
precision (1-σ)	0.1 ppm	1 ppb
bias	0.05 ppm	- 0.3 ppb

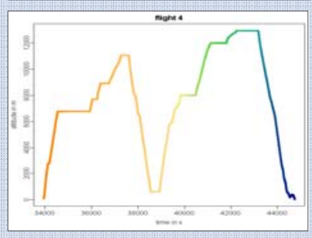


***Figure 3.1:** flight track (Karlsruhe – Orleans – Hohn)*

5. Application of Data

- **validating remote sensing** data both from ground (e.g. FTS) and from space (e.g. GOSAT)
- **improving atmospheric transport models** in simulating vertical transport (PBL mixing and moist convective transport)
- constraining **greenhouse gas budgets** at regional scale by combining vertical profiles with inverse models of atmospheric transport
  → quantification of **biogenic vs. anthropogenic influence**
- assessment of relative contributions from **long-distance transport vs. regional pollution sources**
- constraints on **stratosphere-troposphere exchange** (STE) and lower stratosphere transport
  → statistical analysis (chemical age, age distribution)