ICON – A NEW IN-SITU CAPABILITY FOR O_2/N_2-MEASUREMENTS FROM AIRBORNE PLATFORMS

Julia Steinbach*, Christoph Gerbig, Karl Kübler, Reimo Leppert, Frank Voigt, Bernd Schlöffel
Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, 07745 Jena, Germany
** Corresponding author: jstein@bgc-jena.mpg.de.*

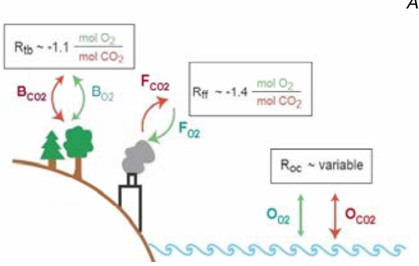
Introduction

Here we present a new device for in-situ measurements of atmospheric oxygen onboard research aircrafts. These measurements are challenging because variations on ppm level have to be detected relative to the large background concentration of ~ 21%. Therefore, only a few methods are able to realize the necessary measurement precision, most of these requiring heavy instruments (e.g. mass spectrometers) and hence not being suitable for measurements onboard research aircrafts. The instrument presented here is based on the ROXAN-VUV-analyzer developed by B.Stephens [*Stephens et al, Tellus 2003*], but is using a two-cell design for simultanous measurement of sample and reference gas and a a pressure regulation based on matching the two cell pressures instead of stabilizing the absolute pressure.

Background: Why measure atmospheric oxygen?

Measurements of O_2, together with CO_2

- allow partitioning of global oceanic and terrestrial sinks of anthropogenic CO_2
- help identifying local source/sink patterns using the local O_2/CO_2-ratio

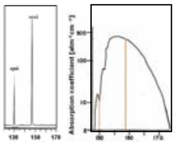


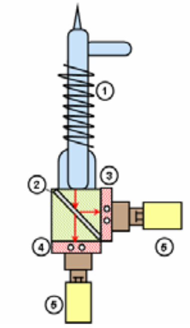
Airborne O_2 Measurements

- important complement to surface stations
- access to different spatial and temporal scales
- testing/evaluating of atmospheric transport models
- get detailed information on regional budgets

Measurement Principle

This instrument detects changes in the oxygen concentration by absorption of VUV (vacuum ultraviolet) radiation. As light source we use the 147nm emission line (shown on the right) of a Xenon resonance line lamp.





The two-cell design (see left) allows for simultaneous measurement of sample and reference gas:

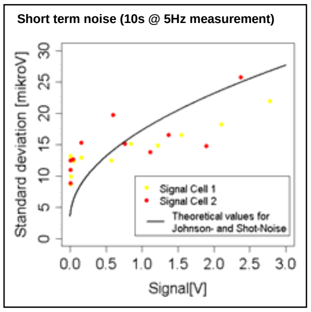
The UV-light of the lamp (1) is split up by a beamsplitter (2), located in a nitrogen-flushed housing. Light passing the two measurement cells (3 & 4) is detected by two solarblind phototube detectors (5), afterwards the signal is converted to a measurable voltage by an amplifying circuit with a noise level near the theoretical limit for Shot- and Johnson noise.

Data acquisition

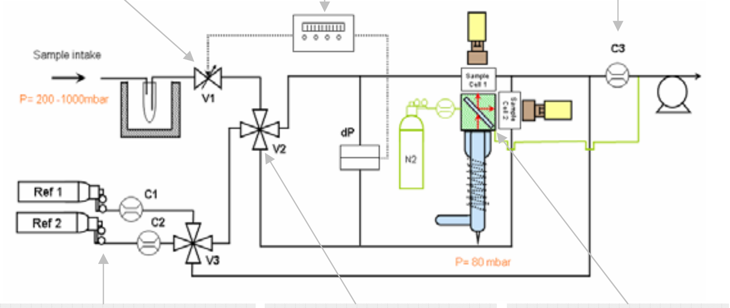
Measuring O_2 with the targeted precision of 2 per meg (corresponding to 0.4 ppm) at a time resolution of ≤10s requires high resolution and low noise levels of the detectors (~ 25μV in a 10V signal).

Our amplified signal is recorded by a customized Microcontrol CAN-module, connected to a CR1000 datalogger (Campbell).

This 23Bit detection system already provided a resolution of 2μV, but showed noise levels with amplitudes around 100μV, even the dark current of the detector. Modifications in the internal power supply and teflon housing of the sensitive amplification circuit reduced this noise by a factor of 6. The resulting noise levels for short term fluctuations are shown in the plot.


Short term noise (10s @ 5Hz measurement)

Gashandling



The only active control in the system is the proportional valve V1 which regulates the intake flow in the sample line.

V1 is controlled by a customized PID control module, driven by the pressure difference between the two cells which is measured by a 1mbar full-scale differential pressure sensor (dP).

The absolute pressure in the measurement cells is set by the capillary C3 upstream of the vacuum pump.

The gas in the reference line is supplied from one of two calibration tanks chosen by the cross-over-valve V3. Capillaries C1& C2 control the flow passively.

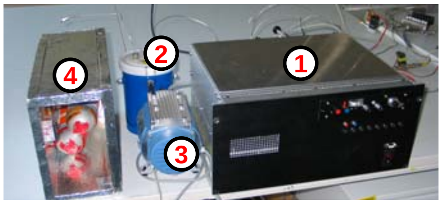
The cross-over-valve V2 is used to switch sample and reference gas periodically between the two cells.

The beamsplitter housing between the lamp and the measurement cells is flushed with nitrogen at low pressure to avoid absorption.

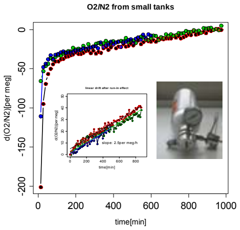
Instrument Design

With a weight of less than 15 kg and dimensions of 44 cm x 36 cm x 23 cm, i.e. fitting into a standard 19“/6HE rack, the instrument (1) can be easily used onboard small research aircrafts. External parts are a dry-ice cold trap for drying the sample air (2), a small vacuum pump (3) and a temperature stabilized box with two calibration tanks and a nitrogen tank for flushing the beamsplitter housing (4).

Due to low sample flows of ~10 sccm/min only small tanks are required for the external reference gases. We use lightweight 1l cartouches (AirLiquide, GER) filled with a pressure of 12 bar, combined with miniaturized regulators (Gloor, CH) who provide an output pressure of 1.5 bar.



In-flight Calibration

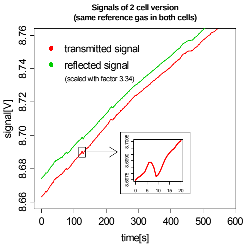

O2/N2 from small tanks

Reference tanks delivering reproducable O_2/N_2 ratios tracable to international scales are an essential component. Normally this means large tanks and regulators which conflicts with the size and weight requirements on board small research aircrafts. Laboratory analysis showed the lightweight tanks chosen for our system can at least be used for short-term calibration during a measurement flight (~3h). After a run-in time of ~1h, the tanks show a linear drift of 2.5-5 per meg/h. Therefore independent measurement of the tanks before and after each flight is required.

Current Status and Outlook

The targeted precision of the device is in the order of few per meg. This target has shown to be achievable with respect to individual components' performance, but further laboratory tests are required to determine the timescales for temporal stability and calibration intervals for the system.

Currently, two problems remain to be solved: Although at first sight the two signals seem well correlated, differences arise due to non-equal division of the light by the beamsplitter and due to the fact that the data acquisition system does not sample both signals exactly at the same time.


Signals of 2 cell version
(same reference gas in both cells)

In addition, since repackaging the device to the airborne design, peaks in the order of a few hundred per meg are occuring frequently in the signals of both channels (see plot). The reasons for these disturbances are still under investigation.

Further laboratory test are currently in progress. As as soon as the device shows reliable performance, we plan to test it on board a research aircraft, e.g. the ECO dimona from METAIR AG (Switzerland).