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Interactive comment on "Performance of a low-cost methane sensor for ambient concentration measurements in preliminary studies" by W. Eugster and G.W. Kling

General Comments

This work reports on the evaluation of a non-specific solid state sensor for the measurement of methane concentrations in air. Measurements of this kind are important and have the potential to initiate a new direction in sensor developments; it would be a breakthrough if low cost solid state sensors could be used to measure the low atmospheric concentrations with sufficient precision. However, if the issues of gas species cross-sensitivity, temperature dependence, and relative humidity sensitivity of these solid state sensors (and others) cannot be solved or if their performance leads to unacceptable results, it might encourage the development of alternative low-cost optical sensor technology. Although the presented research has several shortcomings it might stimulate discussion about suitable sensor technology for atmospheric research.

The authors report on atmospheric methane measurements. Methane is an important greenhouse gas. Unfortunately the authors do not discuss this importance in sufficient detail and therefore fail to provide the basis for the important contribution that their work might have for measuring this greenhouse gas. For example, methane could be compared to carbon dioxide and concentrations versus heat trapping capabilities could be briefly mentioned. Another important aspect is the short chemical lifetime (about 12 years) of methane in the atmosphere. Methane might have significant implications for the Earth's climate future because rising concentrations have been reported from different monitoring stations over the last few years. Increased release from Arctic regions or tropical wetlands could drive a feedback mechanism. Methane released from hydrates on the ocean floor and the implications of such an event might also be shortly addressed. These points might be referenced in addition to those already mentioned by Dr. Peter Werle.

Another important aspect missing in the paper is the clear outline of requirements for atmospheric methane measurements. Atmospheric methane concentrations are low; in the 2 parts-per-million range. The challenge for atmospheric methane sensors is to measure the concentration accurately but also to measure small changes in methane concentration, i.e. changes in the 10-parts-per-billion range (or below). This is a challenge even for high performance optical sensors. The “signal-to-noise characteristics” of an optical sensor must be in the 1:1000 range to be suited for atmospheric methane measurements.

The authors report decent results that they achieve with “low-cost” solid state sensors operating in the field. These sensors are not intended to measure extremely small concentration changes of methane. Therefore the presented study represents a first approach to evaluate such sensors for such demanding tasks. Only relative measurements are possible with the solid state sensors and calibration measurements require a high performance methane analyzer. However, the argument using many low-cost sensors for large area coverage is attractive. Two solid state sensors based on the Figaro TGS 2600 were run parallel and the results compared to a high performance optical methane sensor from Los Gatos Research. Main problems of the solid state sensors are outlined as cross-sensitivity to other gas species as well as temperature and relative humidity sensitivity. Cross-sensitivity to other gas species is discussed in detail. However, the measurement location in Alaska essentially eliminates cross-sensitivity.

Temperature and relative humidity sensitivity of the sensor seems critical. This is addressed and the data have been corrected for both. An important aspect here is that the “methane sensor” used for the presented work consists of the Figaro TGS 2600 sensor head and also other components. How was this sensor operated? Important details are missing in the description of the experimental setup. How is the temperature/humidity sensor placed? How well does it reflect the temperature of the sensor head? What are the specifications for the temperature and relative humidity measurements? Are they relevant at the sensor head location? What are expected uncertainties? The expected achievable measurement precision based on the determined temperature and relative humidity sensitivity should be discussed. The

“methane sensor” presented here is the sum of multiple components and, due to the strong sensitivity of the TGS 2600 to temperature and humidity, the overall sensing system might be limited by the ability to measure temperature and relative humidity with sufficient precision. This is only speculation, but the TGS 2600 might not have been the limiting component of the sensor.

Specific Comments

This work reports the performance of a solid state based methane sensor during field measurements. These evaluations are important, however, before a sensor is ready for these evaluations thorough testing in the laboratory under defined conditions should be performed. Questions of how stable the sensor is and what the limiting parameters are can be more easily addressed in the laboratory than in the field. For example the question of sensor pressure dependence is not addressed at all.

What does low-cost mean? As mentioned above, a “complete” sensor should be discussed and not only a component of this sensor. What would be an estimate for a methane sensor based on a TGS 2600 element? How does it compare to an optical sensor, for example the Los Gatos Research FMA 100?

A paragraph where optical sensors are compared to solid state sensors would be helpful. The current trend is to replace solid state sensors with more reliable optical sensors.

How well is the FMA from Los Gatos suited for atmospheric methane measurements? What are the specifications of this device?

I recommend avoiding the term ‘cross-sensitivity’ for temperature and relative humidity and reserve this expression to refer to ‘different gas species’.

Sentence in line 19/20: This sentence should be reformulated. Not just *increases* in the atmospheric concentration of methane contribute to global warming; the current atmospheric concentration itself is also a contributing factor.

2.2 Principle of Operation: The TGS 2600 is mounted in a TO5 package. This package is well known in the laser community and might be a better description than used by the authors.

Figure 5: How can the mean diurnal cycle data be so good with such small error bars so as to fall within the size of the marker? How were these data extracted? The Fig. 4 data suggest much larger errors because the data vary between 1.87 ppm and 1.98 ppm.

Two TGS 2600 sensor heads were run parallel. The agreement shown in Figures 4 and 5 are impressive. Does that result from temperature and RH measurements being measured with the same device? In that case uncertainties in temperature and relative humidity determination would be propagated in the same way into the measurement results. This might indicate that the TGS 2600s are better than they appear in the presented measurements, i.e. when results are compared with the Los Gatos instrument. A different set-up where every TGS 2600 has its own temperature and RH measurement device might lead to completely different results.

The traces in Figure 1 are too thick to reveal any sensitivity for methane in the low ppm concentration range. A look at Figaro's web site reveals that sensitivity.

The Figures 4 and 5 show data with surprisingly good agreement of the solid state sensor data with the Los Gatos instrument. On the other hand the authors report less favorable results for the pairwise agreement of all data points from the TGA 2600 sensor with the Los Gatos instrument. A graph with less favorable data would help understand the real performance of the solid state methane sensor.

Discussion of the temperature and RH dependence of the TGS 2600

From (5) it can be concluded that R_0/R_s changes by 0.0288 per ppm CH_4. The reported diurnal cycle difference is in the range of 0.01 ppm. For 0.01 ppm CH_4 R_0/R_s should change by 0.000288.

According to (3) R_0/R_s changes by 0.0072 per % RH. What can the CS215-L12 measure? Although the output resolution is specified as 0.03% the given short term hysteresis of < 1% RH might indicate that this sensor cannot measure the relative humidity with better than 1% precision in the long term. That would imply that the sensor cannot resolve changes smaller than 0.5ppm based on the implemented measurement capability for the relative humidity.

According to (3) R_0/R_s changes by 0.0246 per °C. How precise and reproducible can the temperature be measured? Resolving 0.01 ppm methane would require determining the temperature with a precision of 0.01 °C in the long term. What are the specifications on the long-term temperature precision? The temperature in the sensor head is probably relevant. How realistic reflects the recorded temperature the temperature of the sensor head?

These simple considerations show that very high precision in determining the temperature and the relative humidity are required. The question remains why the solid state methane sensor can measure effects of a 10 ppb concentration variation? Does the averaging compensate for temperature and humidity uncertainties?

In conclusion, the presented results seem to indicate that simple solid state sensors are capable of monitoring the variation of very low concentrations of methane. Open questions remain which must be addressed in further detailed studies.