ABSTRACT

Field deployable instrumentation that measures carbon dioxide, methane, and water vapor with both high accuracy and high precision would reduce the uncertainty in the determination of terrestrial sources and sinks of these dominant greenhouse gases, and provide predictive models and a deeper understanding of the global carbon cycle. Existing atmospheric measurements based on non-dispersive infrared sensors have known problems — they are non-linear, sensitive to water vapor concentration, and have many uncorrected systematic errors and sample conditioning problems. High precision monitoring of CO2, CH4 and H2O would significantly improve the accuracy and precision of greenhouse gas measurements while reducing the operating costs of monitoring, enabling higher density deployment.

Problems with Current Atmospheric Instrumentation

The existing atmospheric measurement instrumentation based on NDIR technology has complications which must be resolved during installation and use. Device response is non-linear.

• Instruments are sensitive to water vapor concentration.

• Instruments are susceptible to measurement drift.

• Extensive modifications are often required as part of installation.

• Sample conditioning is required before the gas is presented to the instrument.

• Significant post processing is required to obtain meaningful results.

• Instruments require frequent calibration to maintain accuracy.

• Calibration standards are expensive — $1K to $2K for high accuracy.

High-precision, Carbon Dioxide, Methane and Water Vapor Analyzer

The EnviroSense 3000 is a field-deployable, real-time, ambient gas analyzer that measures atmospheric levels of methane and carbon dioxide with parts-per-billion (ppbv) sensitivity and water vapor with parts-per-million (ppmv) sensitivity while maintaining high linearity, precision, and accuracy over changing environmental conditions with minimal calibration required.

Specifications

• Precision:
  - CO2: < 200 ppbv in 5 seconds
  - CH4: < 1 ppbv in 5 seconds
  - H2O: < 100 ppmv in 5 seconds

• Maximum Drift (24 hours/month):
  - CO2: 150 ppbv / 500 ppbv
  - CH4: 1 ppbv / 3 ppbv

• Long Term Drift in the Field:
  - CO2 and H2O are continuously monitored; calibration standards are momentarily measured every 20 hours
  - Data shown at right are measurements of calibration standards after installation at Centerville, IA and Mead, NE

Need for High-precision Analyzers

• Human activity, primarily fossil fuel use, is adding roughly 3 ppmv of CO2 to the atmosphere.

• Increasing atmospheric CO2 concentrations are changing the climate.

• Globally, terrestrial ecosystems are currently removing about 1/3 of the human emissions, but the location and reasons for this buffer to climatic change are not well understood.

• Determining regional terrestrial sources and sinks of CO2 is a challenging technical problem.

Cavity Ringdown Spectroscopy

Light from a semiconductor diode laser is directed into a high finesse optical resonator cavity containing the analyte gas.

When the optical frequency matches the resonance frequency of the cavity, energy builds up in the cavity.

When the build-up is complete, the laser is shut off.

The energy decays from the cavity exponentially in time, or “rings down,” with a characteristic decay time t.

The ringdown time is measured as a function of laser wavelength. When the gas in the cavity is strongly absorbing, the ringdown time is short; when the gas does not absorb, the ringdown time is long.

Maximizing the Advantages of CRDS

• Compact, high finesse ring cavity provides ppt sensitivity with high stability.

• S5 m cavity volume? small enough for very rapid sample exchange with moderate flow while giving a pathlength of ~10 cm.

• High precision inline wavelength monitor with femtosecond resolution maximizes selectivity resulting in spectral resolution orders of magnitude higher than FT-IR.

• Accurate spectral location isolates individual spectral features? high linearity.

• Ambient sub-micron precision enables selectivity through line narrowing.

Precise temperature and sub-ppm pressure stability enhances accuracy and minimizes drift.

• Temperature controlled to 1 part in 3000, pressure to 1 part in 500

• Telecom grade DFB lasers and micro-optical components minimize reliability.

• Picarro EnviroSense 3000i is a field-deployable, real-time, ambient gas analyzer that measures atmospheric levels of methane and carbon dioxide with parts-per-billion (ppbv) sensitivity and water vapor with parts-per-million (ppmv) sensitivity while maintaining high linearity, precision, and accuracy over changing environmental conditions with minimal calibration required.

Comparison With NOAA

The trade-off between data density and the accuracy of the inversion-derived flux estimates can be determined quantitatively using field observations, thus providing guidance to future observational network designs.

Conclusions

• Field deployable instrumentation that measures carbon dioxide, methane, and water vapor with both high accuracy and high precision would reduce the uncertainty in the determination of terrestrial sources and sinks, resulting in improved predictive models and a deeper understanding of the global carbon cycle.

• The EnviroSense High-precision carbon dioxide/methane/water vapor analyzers for atmospheric inversion and Eddy Covariance Flux measurements maintain high linearity, precision, and accuracy over changing environmental conditions, with minimal calibration.

• Performance is based on a combination of the unique capabilities of the underlying optical absorption technology, and engineering designed to maximize the inherent advantages of CRDS including a high-precision wavelength monitor that ensures only the spectral absorption feature of interest is being monitored. Precise temperature and sub-ppm pressure calibration ensure excellent accuracy and precision for greenhouse gas measurements while reducing the operating costs of monitoring, enabling higher density deployment.

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• Arlyn Andrews, Jonathan Kofler, NOAA

• Picarro EnviroSense 3000i

Next generation analyzer for high precision monitoring of CO2, CH4 and H2O

Next generation analyzer for high precision monitoring of CO2, CH4 and H2O

Methane, Carbon Dioxide and Water Vapor 10 Hz Flux Analyzer

Designed specifically to enable eddy covariance flux measurements of both methane and carbon dioxide, the EnviroSense 3000i provides high precision measurements of methane, carbon dioxide and water vapor simultaneously at 10 Hz in a single, low drift analysis. The compact case design minimizes the sample exchange time enabling a response time of <0.1 seconds.

• Analyzer utilizes one laser for CO2 and one laser for CH4 and H2O

• Concentration measurements for each species interleaved and reported simultaneously at 10 Hz

Specifications

• Precision:
  - CO2 < 500 ppbv at 10 Hz
  - CH4 < 3 ppbv at 10 Hz
  - H2O < 500 ppbv at 10 Hz

• Response time at 90%: 10 Hz

• Field Results for CO2 & H2O Analyzer

• Measurement of Calibration Standards

• Location: Centerville, Iowa

• Laser Control

• Laser Control Electronics

• Patented High Finesse Cavity

• Patented Wavelength Monitor

• Compact, high finesse ring cavity provides ppt sensitivity with high stability

• Co2 and H2O are continuously monitored; calibration standards are momentarily measured every 20 hours

• Data shown at right are measurements of calibration standards after installation at Centerville, IA and Mead, NE

An ultra-sensitive, real-time CO2 and CH4 analyzer for atmospheric inversion

Precise temperature and sub-ppm pressure stability enhances accuracy and minimizes drift.

• Temperature controlled to 1 part in 3000, pressure to 1 part in 500

• Telecom grade DFB lasers and micro-optical components minimize reliability.

• Picarro EnviroSense 3000i