Proven Precision and Long-Term Stability: Why CRDS Is the Gold Standard for Atmospheric Monitoring

PICARRO

APPLICATION NOTE (AN043)
GREENHOUSE GAS ANALYZERS

Global deployment evidence, network-grade performance and long-term data continuity for greenhouse gas and trace-gas observations

Overview

Atmospheric greenhouse gas networks depend on small but meaningful changes in CO_2, CH_4, CO and other trace gases measured consistently over time. To support decisions across stations, countries and data products, those measurements must remain stable, traceable and comparable for years.

> **With broad network adoption, field-proven performance and established calibration workflows, Picarro CRDS has become a gold-standard platform for atmospheric monitoring.**

Picarro analyzers are already used in major atmospheric monitoring programs, including ICOS, WMO/GAW stations, NOAA reference networks, urban observatories, mobile laboratories and airborne research platforms. The Picarro G2301 and G2401 greenhouse gas analyzers provide a proven foundation for CO_2, CH_4, CO and H_2O measurements. The same Picarro CRDS measurement architecture also supports additional trace gases relevant to atmospheric science, including N_2O and NH_3, by combining stable, pressure- and temperature-controlled optical cavities with high-resolution spectroscopy, built-in water-vapor correction, and calibration workflows linked to internationally recognized atmospheric calibration scales.

The practical advantage is continuity. A new monitoring system built around Picarro extends an already established ecosystem of CRDS instrumentation, calibration workflows, audit procedures and peer-reviewed atmospheric datasets. This application note outlines the network requirements, qualification record, deployment history and analyzer-selection considerations that support Picarro CRDS for long-term atmospheric monitoring.

635
active G2401 analyzers worldwide

42
countries with active G2401 deployments

50+
ICOS atmosphere stations linked to Picarro analyzers

>97%
measurement uptime, with minimal calibration and quality control checks

Network-Grade Requirements

Long-term atmospheric monitoring is held to a higher standard than short campaigns or routine field measurements. Short-term sensitivity alone is not enough; the analyzer must support stable, traceable, high-availability measurements over multi-year operation.

WMO/GAW compatibility goals

The World Meteorological Organization Global Atmosphere Watch program defines compatibility goals for greenhouse gas measurements exchanged across the global network. For high-accuracy atmospheric monitoring, relevant goals include ±0.1 ppm for CO_2 in the Northern Hemisphere, ±2 ppb for CH_4, and ±2 ppb for CO between comparable measurements on the same calibration scale [1,2].

ICOS qualification

The Integrated Carbon Observation System (ICOS) evaluates analyzer precision, repeatability, long-term stability, water-vapor effects and field performance before network deployment. For CO_2, CH_4 and CO, ICOS requirements include 1-minute precision better than 50 ppb for CO_2, 1 ppb for CH_4 and 2 ppb for CO; 10-minute repeatability better than 50 ppb for CO_2, 0.5 ppb for CH_4 and 1 ppb for CO; independent laboratory qualification of the analyzer model; field-performance evidence; and operation with minimal maintenance and consumables [1,3].

High data coverage

Every calibration or reference-gas injection reduces the time available for measuring ambient air. ICOS's minimum requirement for a qualified CRDS analyzer is one calibration per month and one target-gas check per day [1], leaving more than 97% of the time for ambient-air measurement. This reduces data gaps, reference-gas use, cylinder logistics and operating cost.

TABLE 1

Network Performance Targets for CO_2, CH_4 and CO			
Gas	ICOS 1-minute precision	ICOS 10-minute repeatability	WMO/GAW compatibility goal
CO_2	<50 ppb	<50 ppb	±0.1 ppm†
CH_4	<1 ppb	<0.5 ppb	±2 ppb
CO	<2 ppb	<1 ppb	±2 ppb

Summary of the ICOS analyzer requirements and WMO/GAW compatibility goals described above [1–3]. *† Northern Hemisphere. Compatibility goals apply between comparable measurements on the same calibration scale.*

Picarro CRDS in Global Networks

The value of a monitoring analyzer is ultimately demonstrated in the field through the quality and continuity of the data it helps produce. Picarro CRDS analyzers have been adopted across atmospheric monitoring networks, reference stations, urban observatories, and mobile and airborne research platforms. The table below summarizes selected examples and their relevance to long-term atmospheric monitoring.

TABLE 2

Selected Deployment Record of Picarro CRDS Analyzers		
Evidence area	**Cavity Ring-Down Spectroscopy (CRDS)**	**Representative record Relevance**
ICOS data products and urban networks	ICOS Carbon Portal metadata and station records list Picarro CO_2-CH_4-CO-H_2O analyzers across the European atmospheric network, including 88 G2401, 50 G2301 and 11 G1301 analyzers linked to more than 50 atmosphere stations [4,5].	Supports use in formal European atmospheric research infrastructure, including complex regional and urban environments.
Independent ICOS evaluation	The ICOS Atmospheric Thematic Centre evaluated 47 Picarro CRDS analyzers in the laboratory and 15 analyzers in the field, including G2301 and G2401 models [6]*. More recent ICOS/GAW station studies continue to document the use of Picarro CRDS analyzers in long-term atmospheric monitoring, including Pallas-Sammaltunturi and Zugspitze [7,8].	Demonstrates that the platform has been evaluated under formal network criteria and continues to be used in long-term atmospheric monitoring programs.
WMO/GAW station operation	Published measurements include the Izaña Global GAW station, Mt. Cimone WMO/GAW station, and Pallas-Sammaltunturi GAW/ICOS station. At Pallas-Sammaltunturi, comparison of ICOS and GAW systems showed agreement in hourly means at better than 0.01 ppm for CO_2 and 0.47 ppb for CH_4 [9,10,7].	Shows sustained use in recognized atmospheric reference programs with traceability to international calibration scales.
NOAA and national reference networks	NOAA GML documents the use of CRDS instrumentation at Mauna Loa, where a CRDS-based CO_2 analyzer was installed in April 2019; NOAA's tall-tower network also provides a published example of high-accuracy CO_2, CH_4 and CO monitoring [11, 12].	Demonstrates operational use in a major national greenhouse gas monitoring program.
Mobile and airborne measurements	NASA and NSF NCAR document G2401-*m* deployments for aircraft-based CO_2, CH_4, CO and H_2O measurements [13].	Extends the same CRDS measurement approach from fixed stations to vertical profiles, regional transects and airborne campaigns.

** The ICOS ATC evaluation reported by Yver Kwok et al. (2015) includes Chris Rella, a Picarro scientist, as a co-author.*

This deployment record also matters for operational integration, especially when building or expanding monitoring networks. A Picarro-based measurement ecosystem builds on established CRDS measurement practices, calibration workflows, quality-control methods, and published atmospheric datasets already used in long-term monitoring applications. In India, for example, Picarro analyzers are increasingly being adopted by leading atmospheric and Earth-system research institutions, including IITM, PRL, NARL, ARIES and NRSC. With support from local application expertise, training and service coordination, this combination of global network adoption and regional user experience helps new stations align more easily with proven workflows rather than starting from a separate or unfamiliar platform.

Picarro G2401 global footprint: 635 analyzers in 42 countries



Figure 1. *Global adoption of the Picarro G2401 analyzer platform (October 2026). The map illustrates 635 active G2401 analyzers across 42 countries. Green bubbles represent customer locations, with bubble size indicating the number of active units associated with each location. Regional insets highlight high-density deployments across Europe and Asia. Data exclude G2401-m airborne/ mobile models, inactive and returned units, and represent primary customer locations rather than individual measurement sites.*

Matching Analyzer Design to Monitoring Objectives

Instrument design should match the measurement objective. Compact and portable analyzers can be valuable for field studies, mobile surveys, source screening, soil-gas measurements and process investigations. Continuous atmospheric monitoring places heavier demands on drift, water-vapor effects, calibration traceability and data availability.

ICOS documentation provides a useful benchmark for this distinction. Portable and ultraportable analyzers have been evaluated using ICOS test procedures, and some were reported as “not qualified so far in ICOS” [14]. This distinction is important because field portability and network qualification address different measurement needs. The table on the next page summarizes some of the key selection considerations.

TABLE 3

Analyzer Selection Considerations for Atmospheric Monitoring		
Selection criterion	**Picarro CRDS station analyzers**	**Compact and portable field analyzers**
Primary measurement role	Continuous atmospheric monitoring with high data availability over long deployments.	Field studies, mobile surveys, source screening, soil-gas measurements, compliance checks and process investigations.
Network evidence	Supported by ICOS qualification work and station metadata, WMO/GAW station records, NOAA tall-tower deployment and validated extension to complex trace gases within network infrastructure [15-18].	Network qualification evidence should be reviewed before treating the analyzer as equivalent for long-term monitoring.
Long-term performance	Demonstrated through multi-instrument laboratory evaluation and field deployments across varied environments.	Short-term field performance does not by itself demonstrate multi-year station performance.
Water-vapor handling	Supported by dry-mole-fraction correction methods and ICOS water-vapor characterization.	Water-vapor effects should be characterized to the same level expected for network-quality measurements.
Calibration and traceability	Compatible with established reference-gas, target-gas, audit and quality-control workflows.	Higher calibration demand can reduce ambient-air data coverage and increase reference-gas logistics.
Selection risk	Lower risk where continuity, comparability and recognized network evidence are required.	Higher risk unless supported by independent qualifications or comparable long-term atmospheric deployment evidence.

Key Considerations for Network Planners

For a network-quality record, analyzer specifications should focus on long-term performance, not only nominal sensitivity. The practical criteria below help distinguish instruments suited to continuous atmospheric monitoring from tools intended primarily for shorter field applications.

Recommended Selection Criteria:

- Specify network-relevant precision and repeatability at appropriate averaging times, including 1-minute and 1-hour performance where applicable.
- Require documented drift specifications over extended operation, including monthly drift performance for CO_2, CH_4 and CO where applicable, not only short-term stability over 24 hours.
- Give priority to analyzers with ICOS compliance, equivalent independent metrology evaluation, or documented long-term operation in WMO/GAW, ICOS or comparable atmospheric monitoring networks.
- Require validated water-vapor correction and a calibration strategy that preserves high ambient-air data coverage during routine operation.
- Use compact and portable analyzers as complementary tools for field surveys, mobile studies, screening or leak detection, not as replacements for the station backbone unless comparable network qualification evidence is available.

These criteria favor instruments with a documented track record. Picarro CRDS analyzers meet that expectation through field-proven performance, established calibration practice and recognized use in major monitoring networks.

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