

## ICOS: water vapor isotopes

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<http://www.arp.harvard.edu/atmobs/sciobj/instrument/cr.html>

The Harvard ICOS water isotope instrument provides rapid, highly sensitive measurements of water vapor and its major isotopologues:  $\text{H}_2\text{O}$ ,  $\text{HDO}$ ,  $\text{H}_2^{18}\text{O}$ , and  $\text{H}_2^{17}\text{O}$ . The instrument uses integrated cavity output spectroscopy (ICOS) to detect water vapor isotopologues with high precision and accuracy and fast time response.

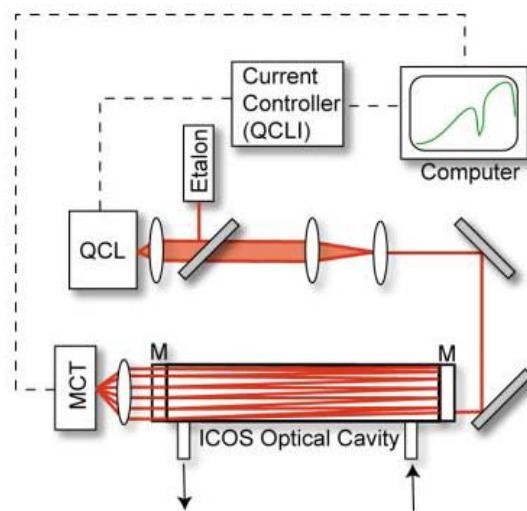


Figure 1. The Harvard ICOS instrument integrated into the WB-57 pallet is shown on the left. The schematic on the right shows the principal of operation of the ICOS technique.

ICOS is a relatively new cavity absorption technique that uses a continuous-wave (cw) tunable diode laser to probe individual rotational lines (Paul *et al.*, 2001, Baer *et al.*, 2002). In the Harvard instrument, a mid-infrared quantum cascade laser (QCL) operating at  $1484\text{ cm}^{-1}$  is used to obtain near-simultaneous measurements of  $\text{H}_2\text{O}$ ,  $\text{HDO}$ ,  $\text{H}_2^{17}\text{O}$ , and  $\text{H}_2^{18}\text{O}$ . The instrument schematic is shown in Figure 1. Light from a high-powered continuous-wave laser is injected into a high-finesse optical cavity consisting of a pair of highly reflective mirrors ( $R \approx .09998$ ) and containing the atmospheric gas to be measured. The laser wavelength is tuned over a spectral region of interest, and light bleeding out of the cavity is captured on a detector. The resulting absorption spectrum yields the number density of the absorbing gases within the cell, much as in traditional absorption spectroscopy. Because light is trapped within the optical cell for tens of microseconds, however, the effective optical pathlength is several kilometers rather than the tens of meters of a typical Herriott cell, and the instrument sensitivity correspondingly greater. The Harvard ICOS isotope instrument, with an effective optical path-length of nearly 4 kilometers, provides a detection limit of  $10\text{ pptv s}^{-1}$  ( $S/N = 1$ ) for HDO.

**Table 1.** Uncertainties of the water isotopes measured by ICOS for stratospheric conditions. Precision is determined empirically from the standard deviation of the line strength relative to fit residual. Accuracy is determined from the combined uncertainties in the laboratory calibrations. The maximum bias uncertainty is the uncertainty due to etalons in the spectrum baseline and other spectral artifacts in the data. All values are 1- $\sigma$  and for 4 s integration. [Sayres *et al.*, in preparation]

| Parameter                      | Abundance | Precision | Accuracy | Max Bias  |
|--------------------------------|-----------|-----------|----------|-----------|
| H <sub>2</sub> O               | 5 ppmv    | 0.14 ppmv | 5%       | ±0.5 ppmv |
| H <sub>2</sub> <sup>18</sup> O | 10 ppbv   | 0.16 ppbv | 5%       | ±0.6 ppbv |
| HDO                            | 1 ppbv    | 0.10 ppbv | 5%       | ±0.4 ppbv |
| δD                             | -450‰     | 50‰       | 50‰      | ±125‰     |
| δ <sup>18</sup> O              | -75‰      | 30‰       | 50‰      | ±70‰      |

### References

A detailed description of the instrument design, principle of operation, and calibration is presented in Sayres *et al.* Performance of the instrument relative to the Harvard Hoxotope and Lyman- $\alpha$  instruments is described in St. Clair *et al.* Scientific interpretation of data obtained with ICOS and Hoxotope is presented in Hanisco *et al.*

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