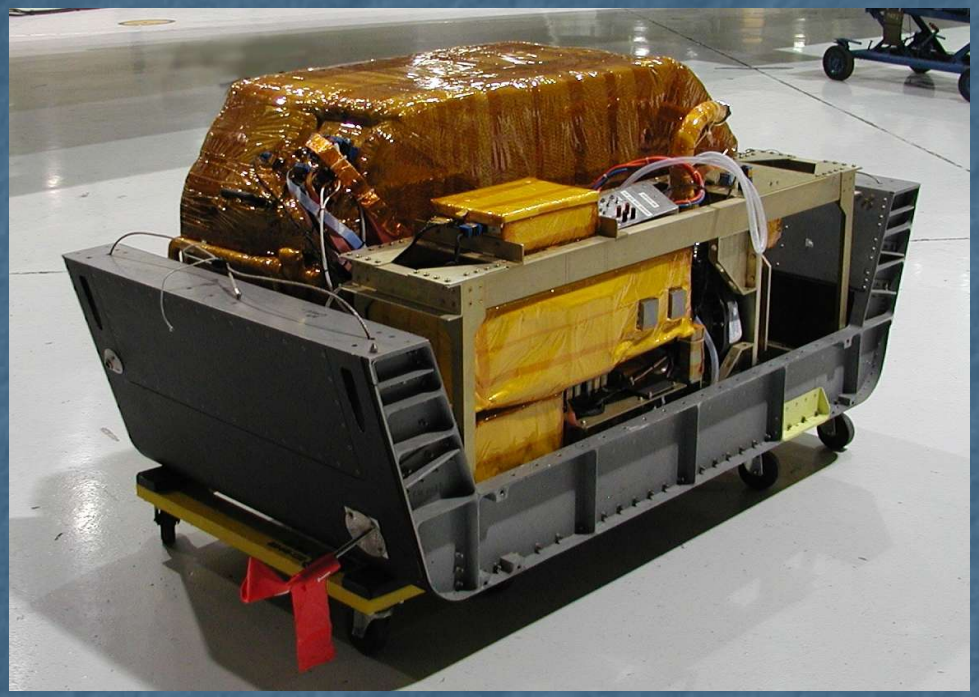
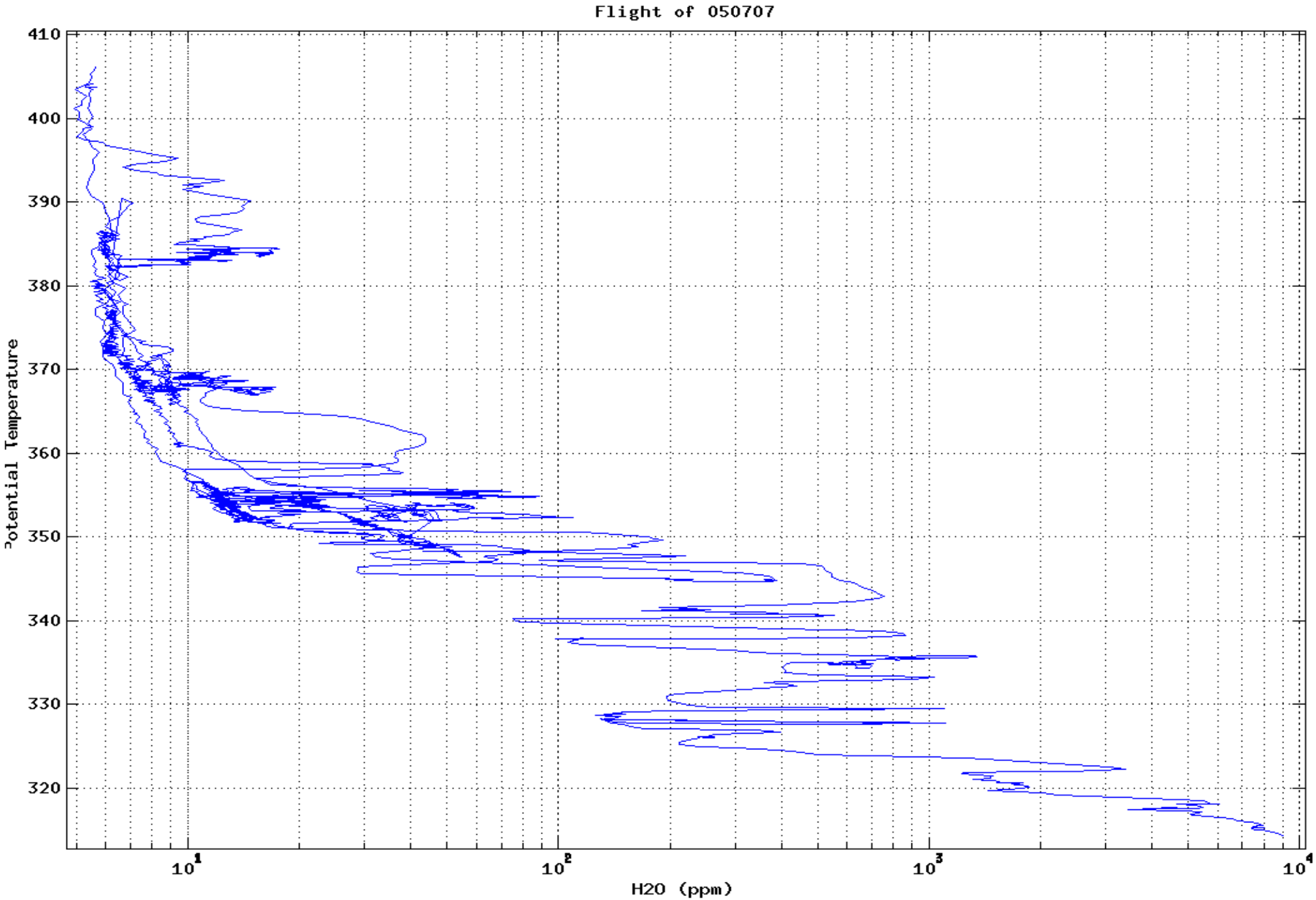
Measurement of water isotopes by the Harvard ICOS instrument:

Flight performance during the AVE-WIIF campaign



David S. Sayres, E. J. Moyer, F. N. Keutsch, N. T. Allen, J. G. Anderson
Harvard University, Dept. of Earth and Planetary Sciences

Measurement Requirements for H_2O, HDO, and $H_2{}^{18}O$



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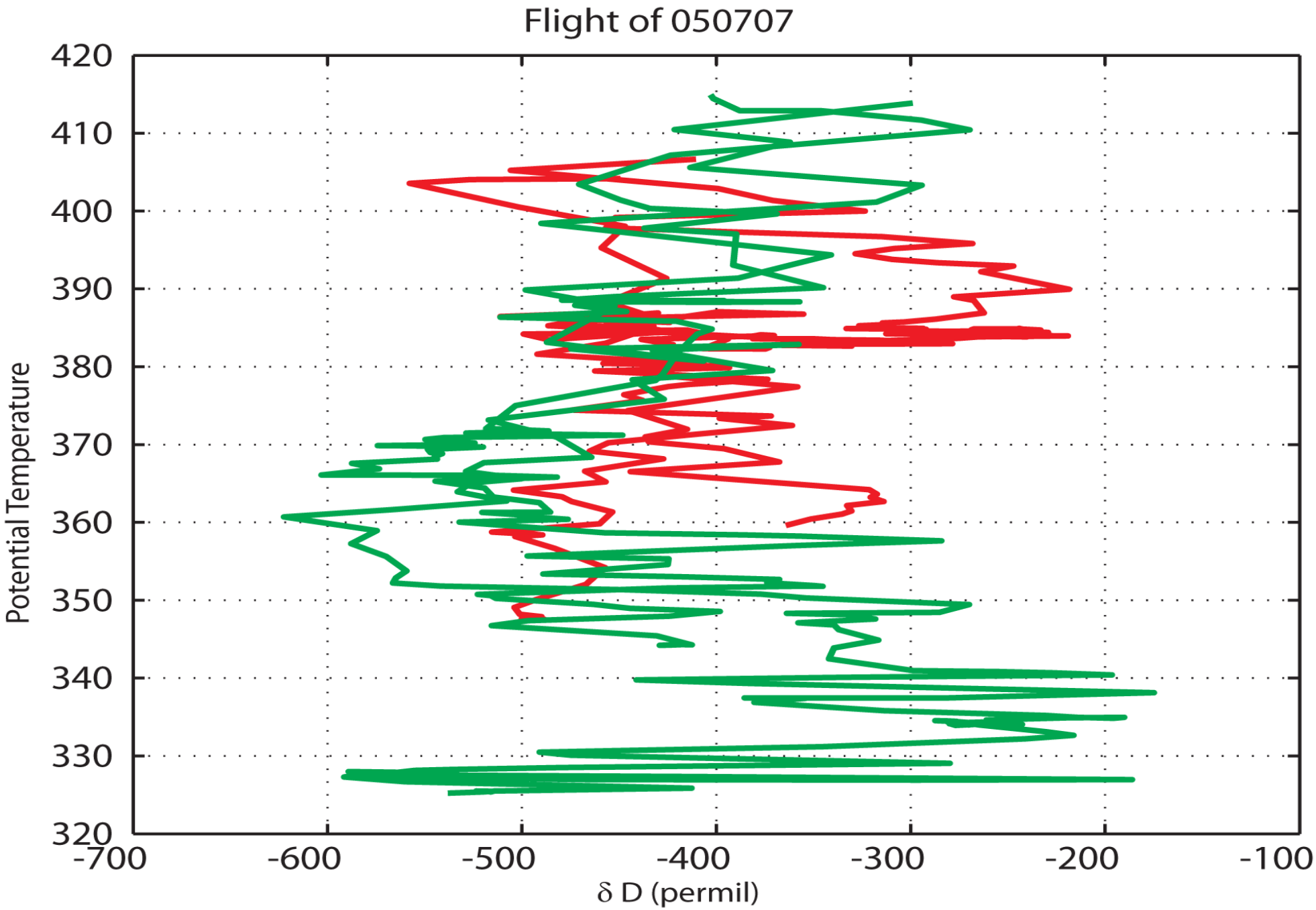

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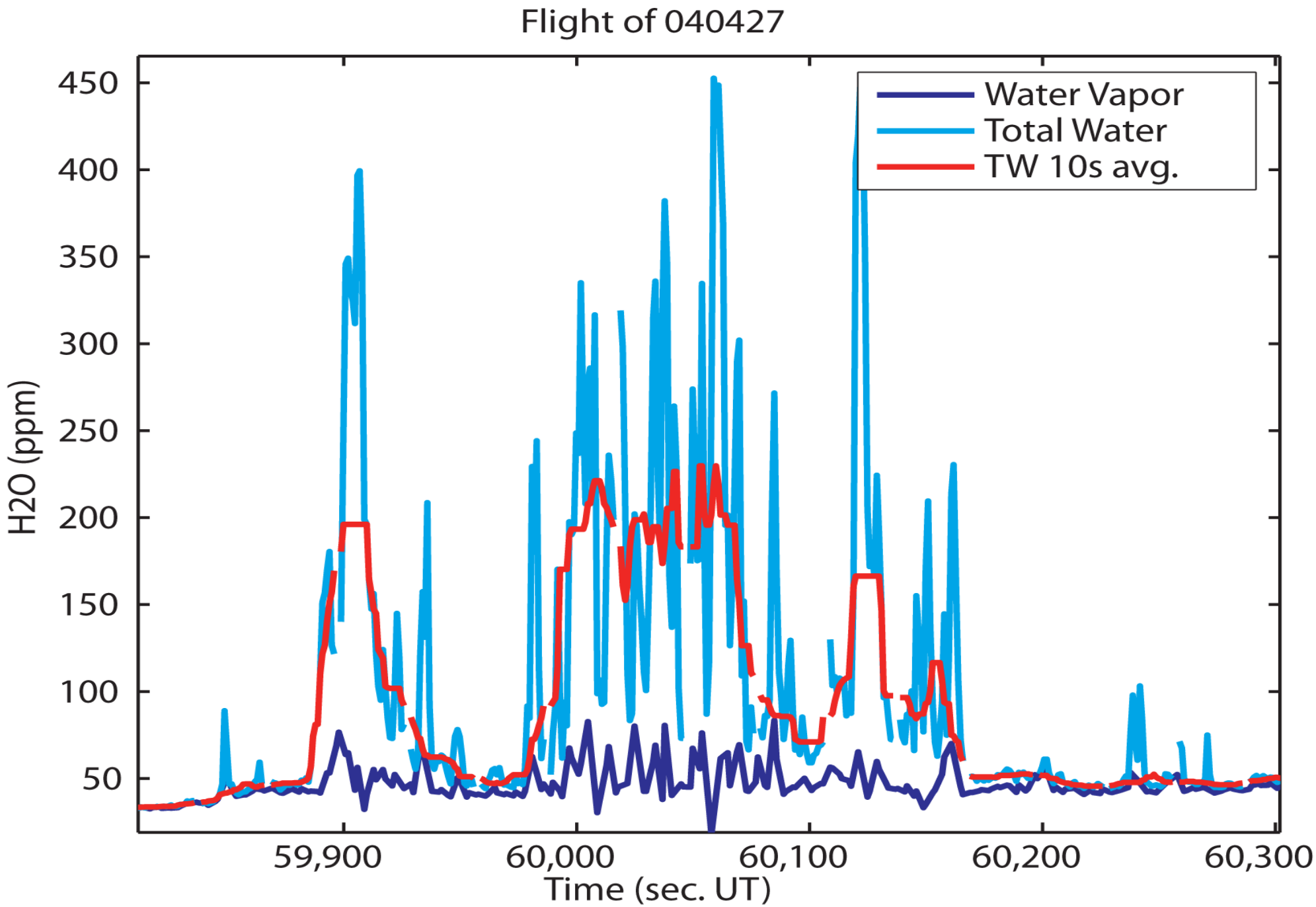

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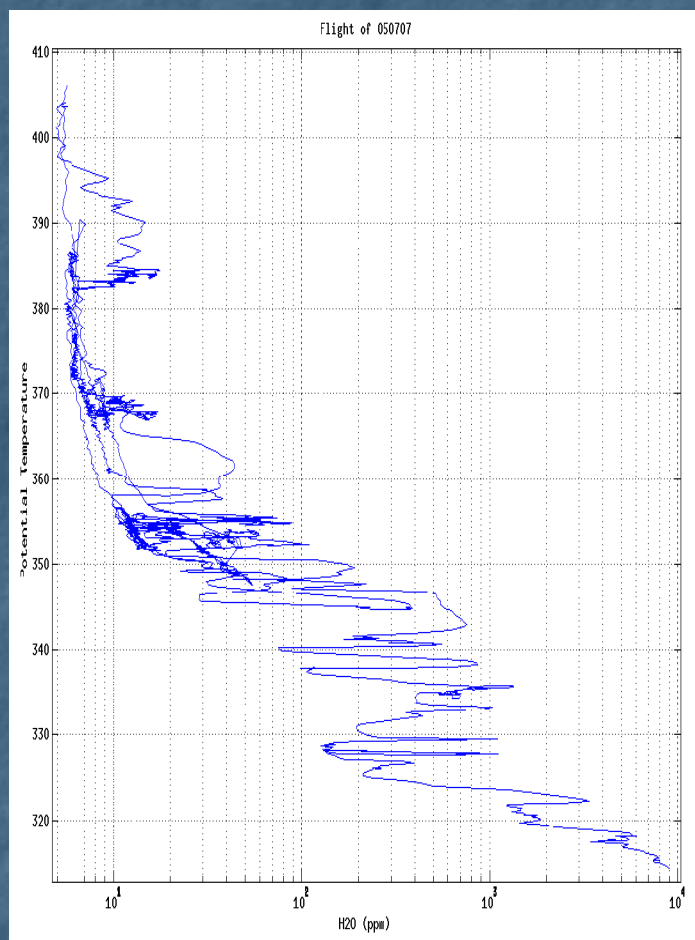
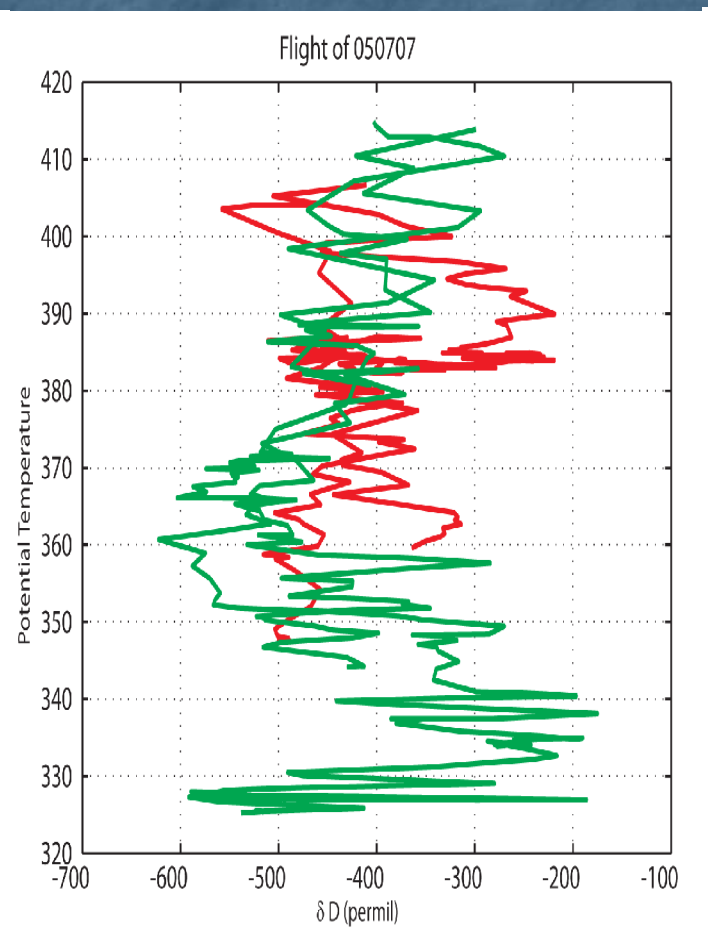
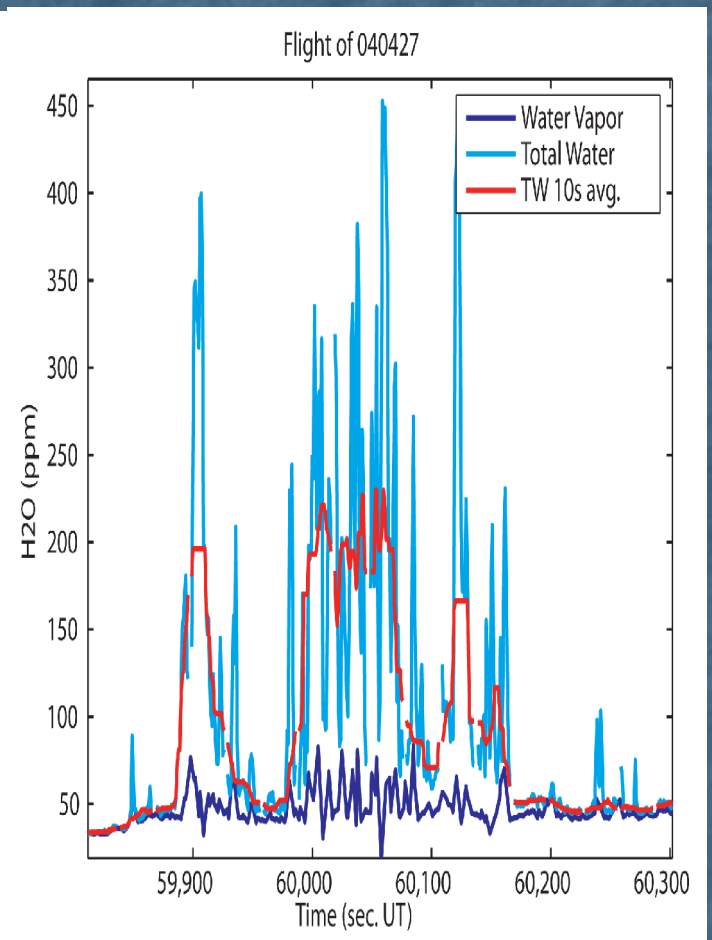
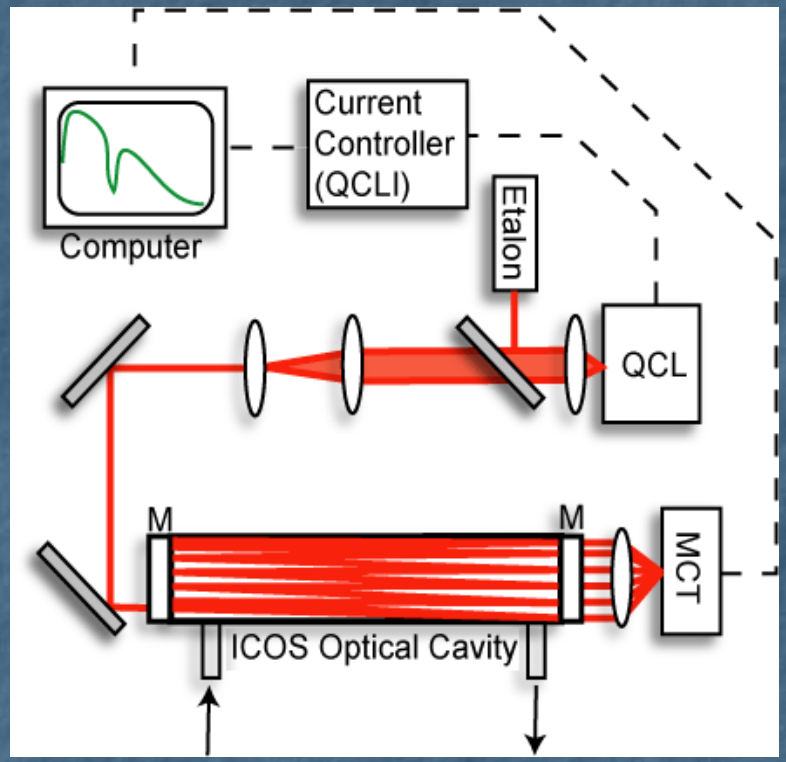






	Sensitivity	Accuracy	Precision	Resolution
H2O	< 0.5 ppm	2-3%	2%	1-5s
HDO	< 25 ppt	2-3%	2%	1-5s

Integrated Cavity Output Spectroscopy (ICOS)



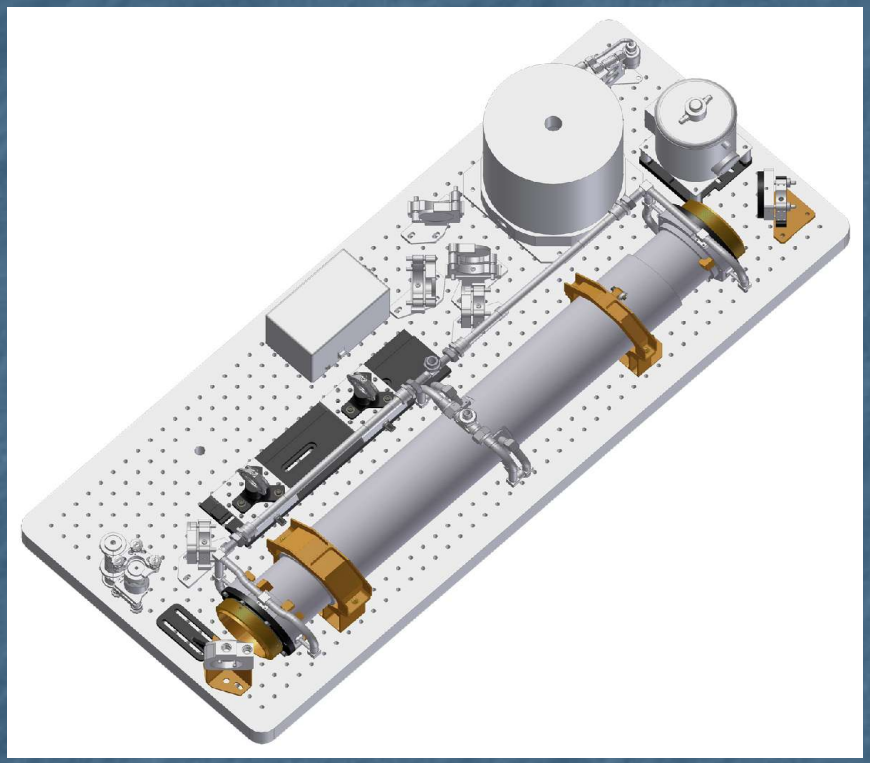
Quantum Cascade Laser (100 mW)

High-finesse Optical Cavity (215ppm mirrors)

τ = 14 µs -> L_{eff} = 14.5 km

1 meter cavity with 4" mirrors

Calibration tied to laboratory measurements of absorption cross-section



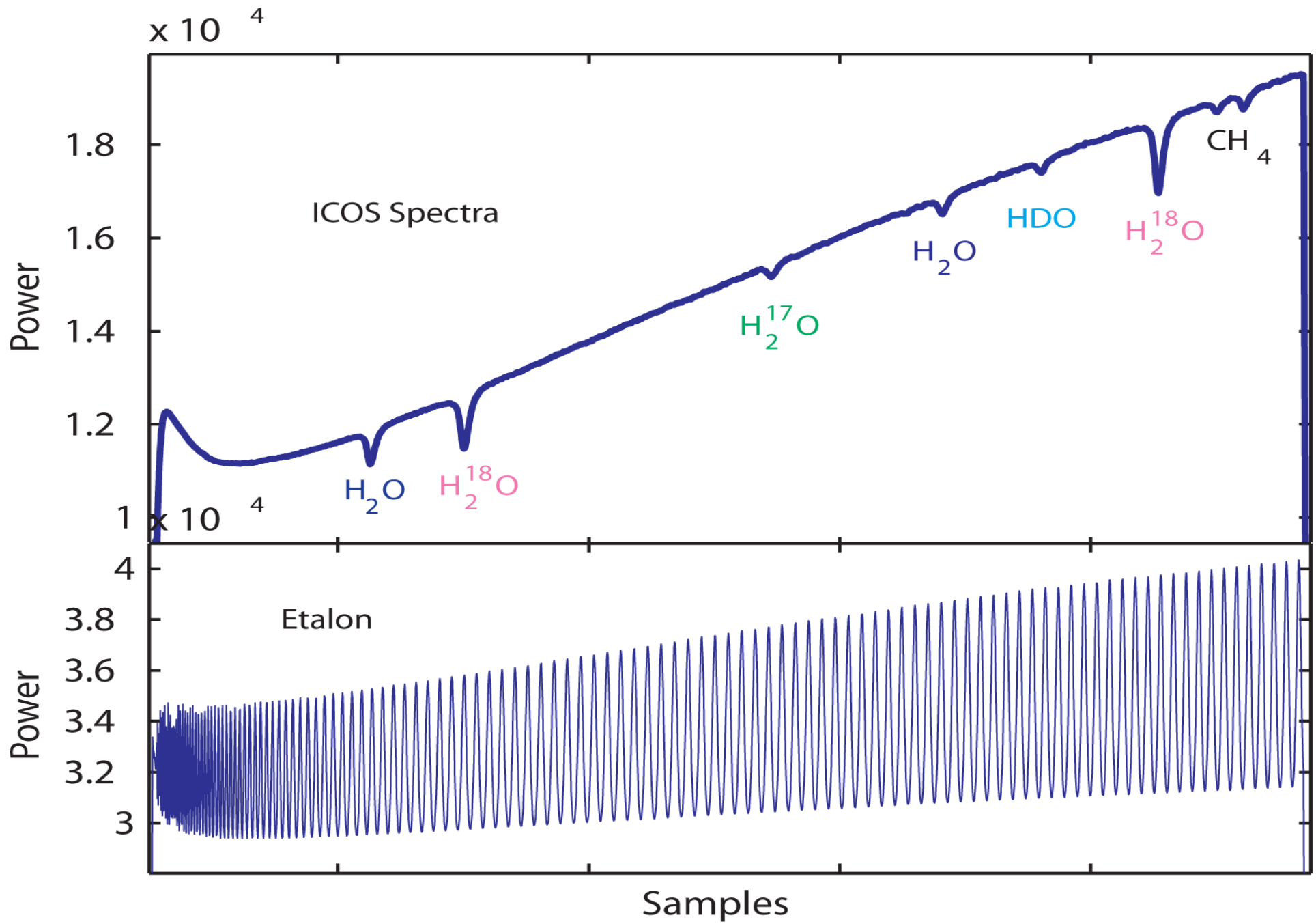
High Signal to Noise (SNR = 30 at 5ppm)

Enhanced Sensitivity

Precision

Accuracy

Analysis of Data



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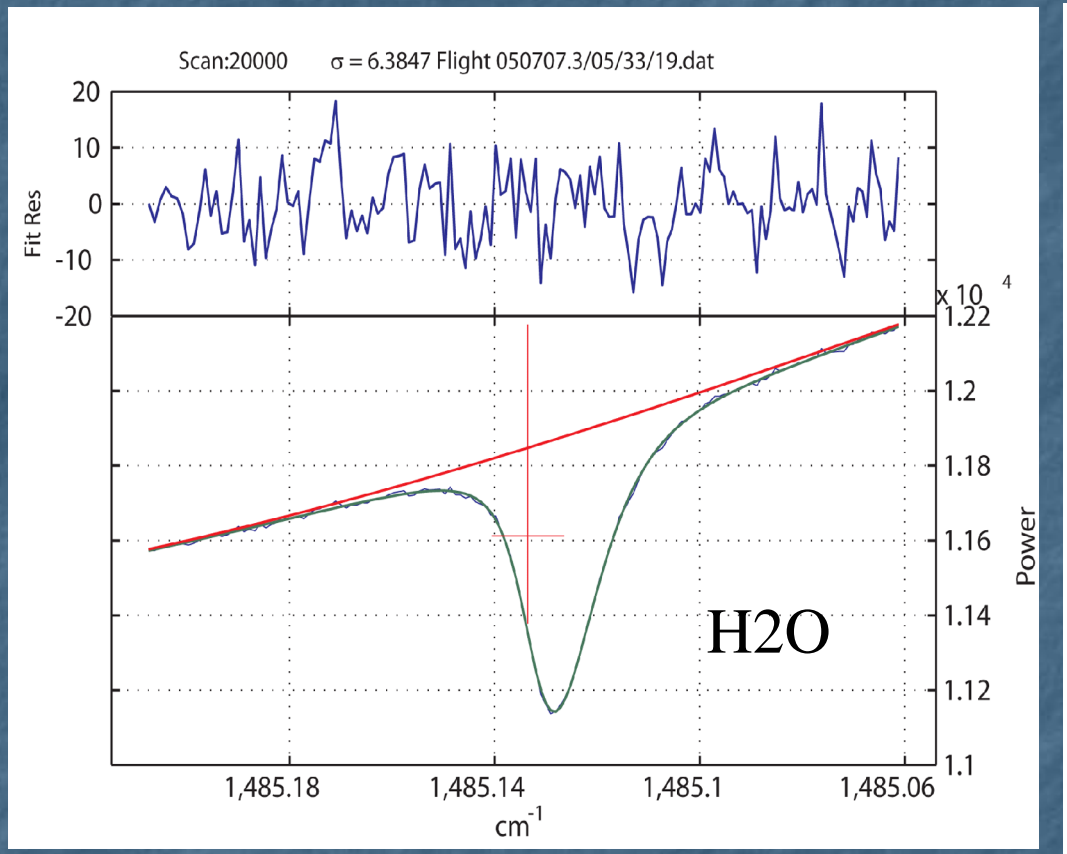
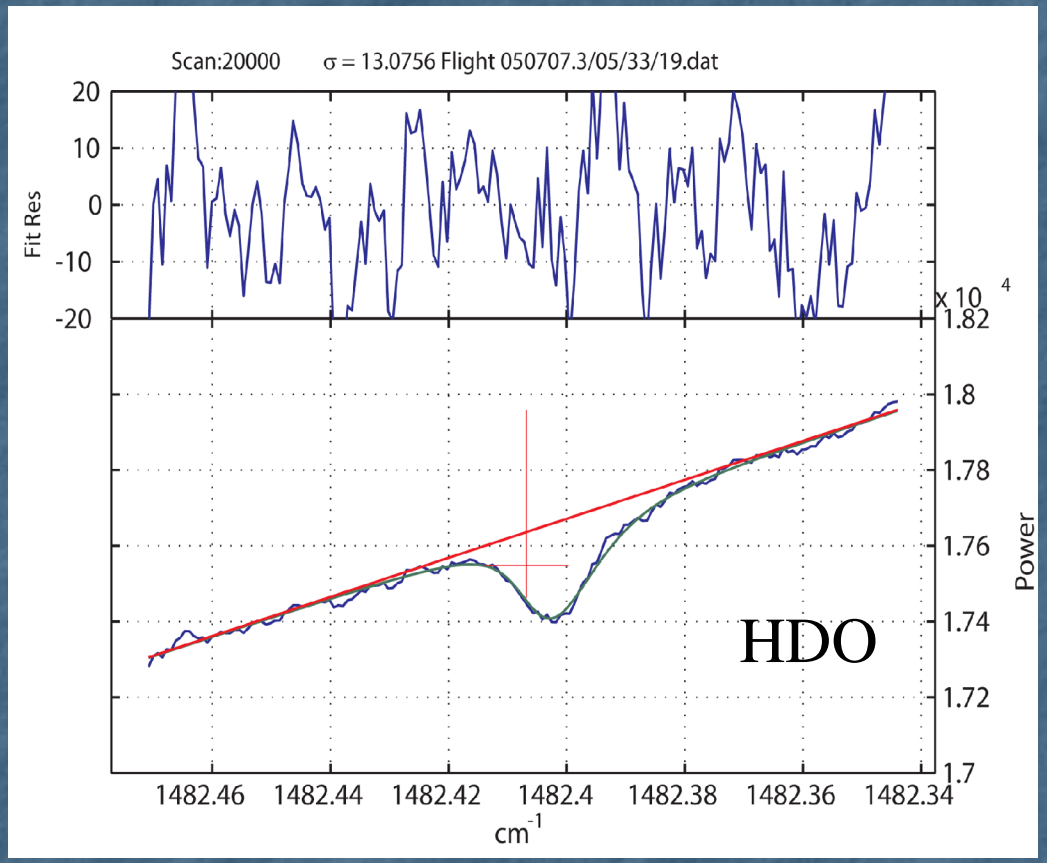




fit(spectra, baseline, etalon fit, P, T, τ, cross-section)

--> [Concentration]

Flight Performance during AVE-WIIF

Insensitive to aircraft vibrations

Regulation of cell P and T and laser dewar P

Accuracy (H_2O, HDO, H_2O^{18}): 7%

(δD, $\delta^{18}O$): 4%

Precision (3s): H_2O 3%; HDO 15% @ 5 ppm water

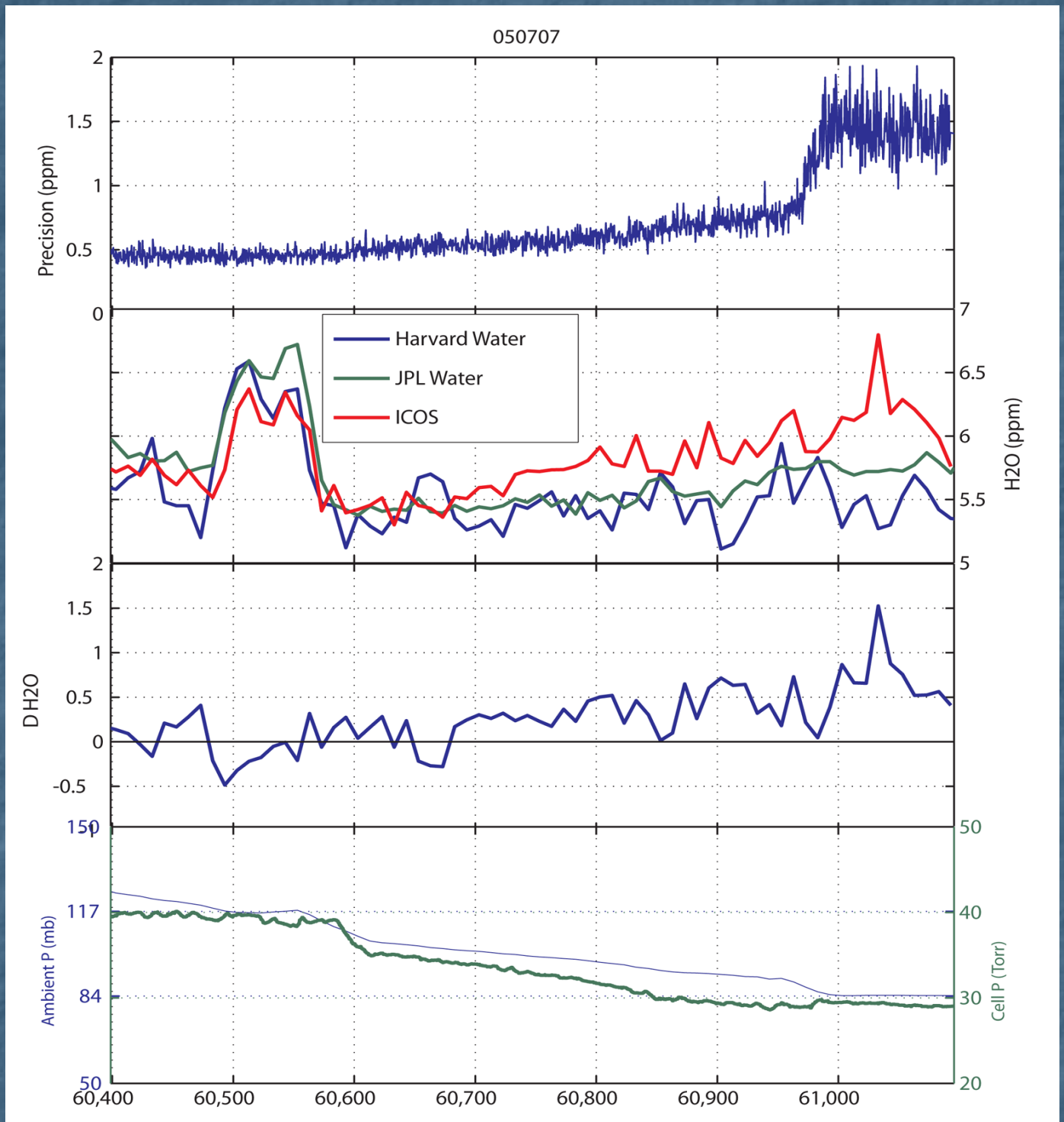
H_2O 0.15%; HDO 0.75% @ 100 ppm water

H_2O < 10 ppm: change in alignment can cause bias

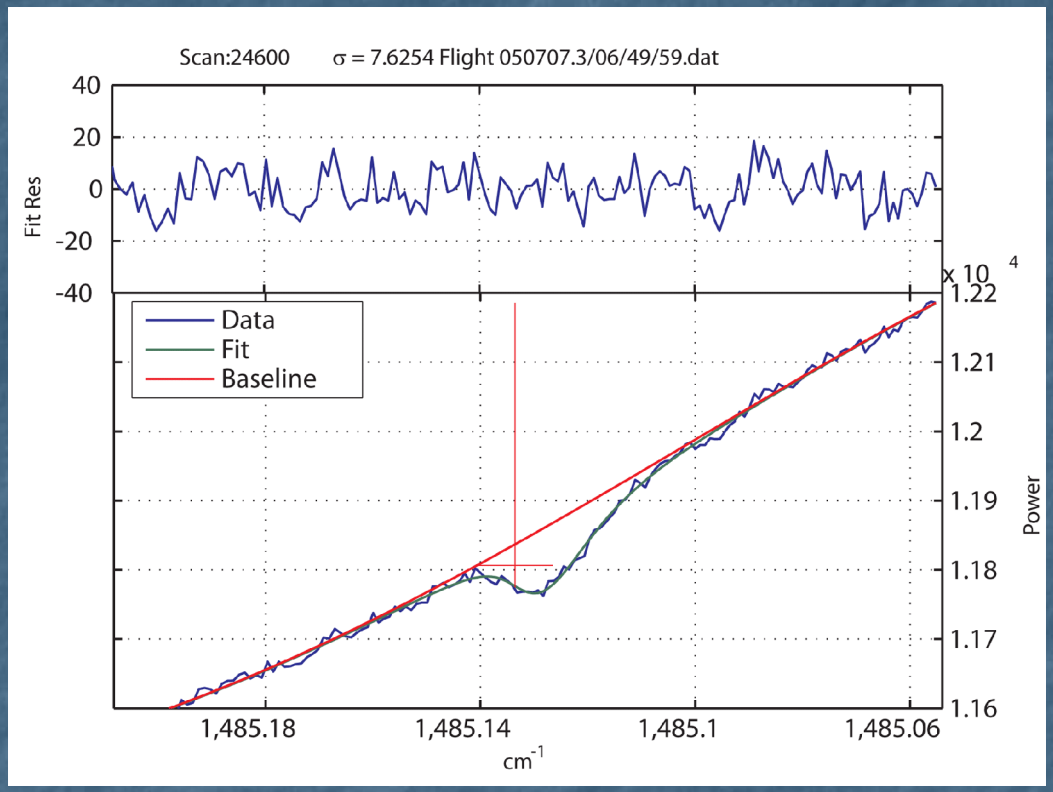
H_2O ~1ppm; HDO ~0.2 ppb; $H_2^{18}O$ ~0.4 ppb

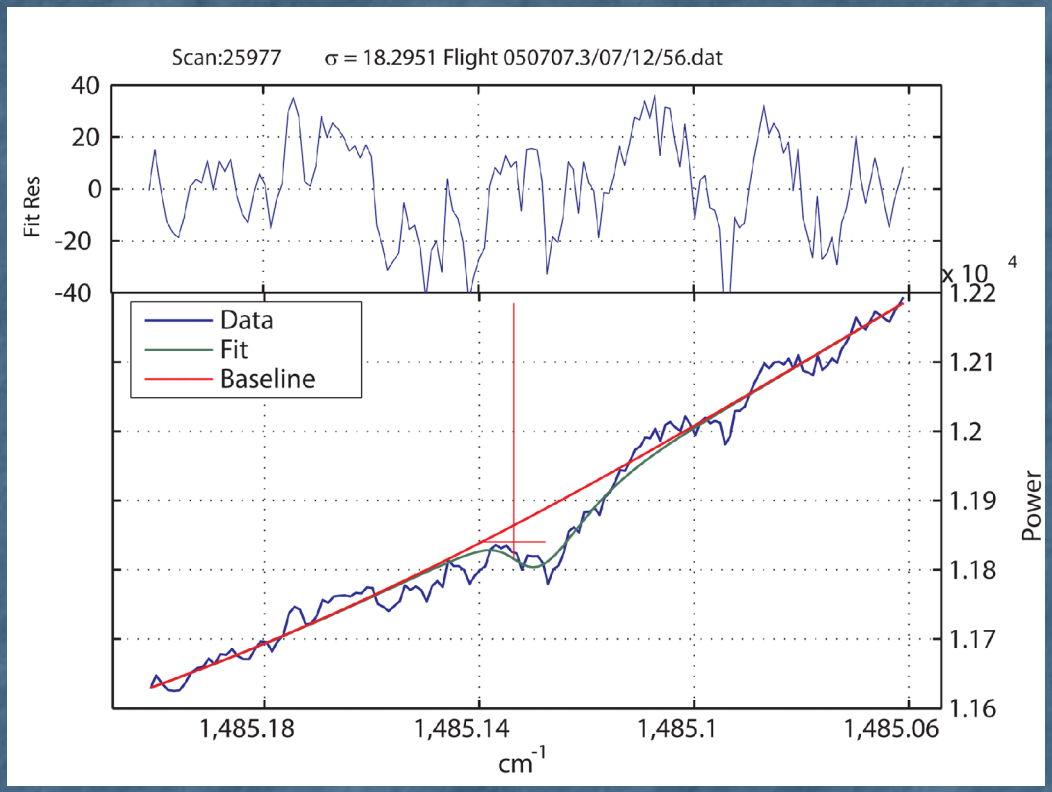
($\Delta\delta D$ ~130 permil at 5 ppm water)

Bias in Data at Low Water Concentrations



Bias in Data caused by Baseline Error





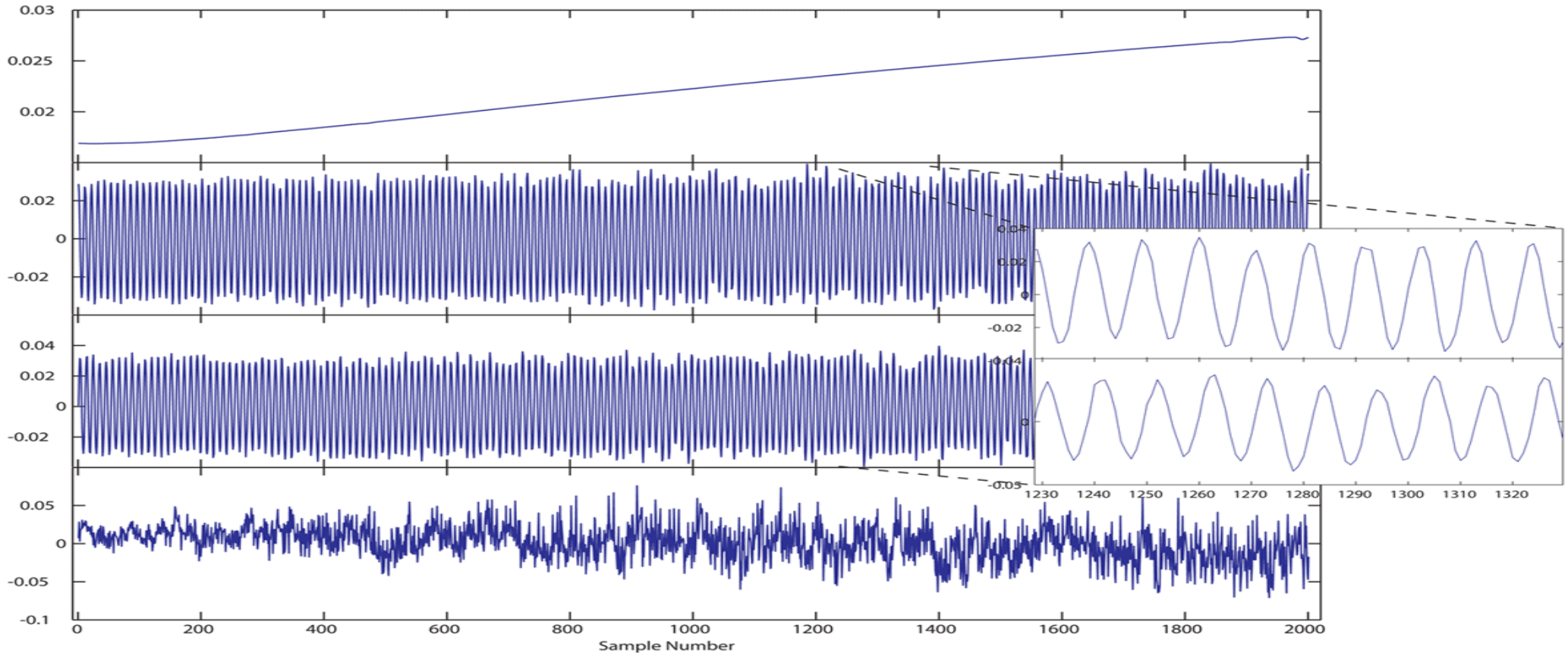
H2O @ 5.5 ppm

Approaches to Minimize Baseline Error

Experimental: Reduce operating pressure of cell

Pick alignment that is less sensitive to small changes in position

Fitting Procedure: Use orthogonal basis set to represent baseline



Changes Planned for Future Missions

Need Orthogonal Basis Set to describe baseline

Full basis set allows for full fit of data

Better understanding of how alignment changes with cell pressure

Continued laboratory calibrations (bubbler, μdroplet injector, multi-pass IR, Lyman-α)

Accuracy (H2O/HDO): 3%

Precision (H2O/HDO): 3%/10%

Thank You

WB-57 Pilots and Crew

Instrument Teams

AVE-WIIF Project Scientists