Adaptation of a Picarro Greenhouse Gas Analyzer for Airborne Measurements with Expanded Altitude Range and Performance on Large-scale Aircraft Campaigns

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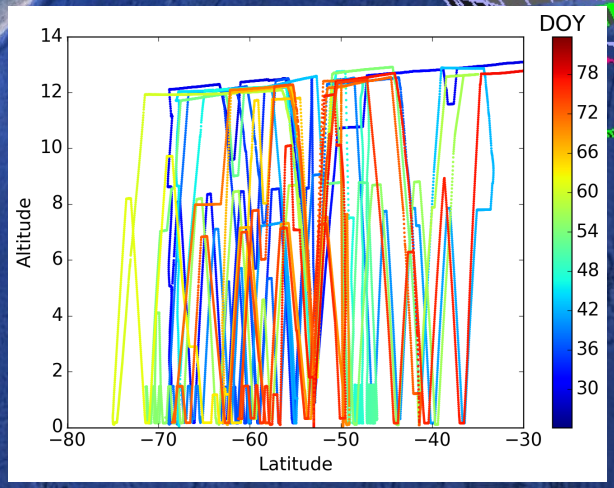
1. NOAA ESRL, 2. Picarro, 3. Scripps, 4. Harvard, 5. NASA Langley, 6. Michigan, 7. NCAR

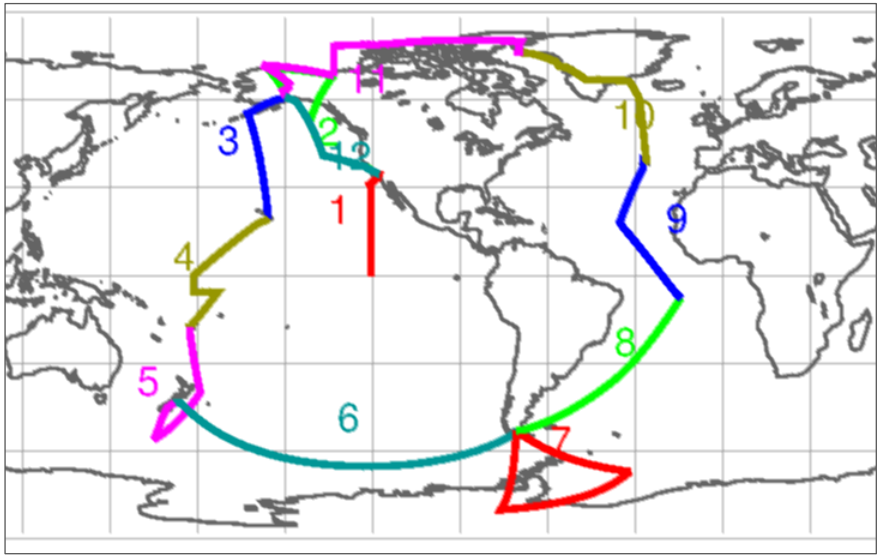
ORCAS

2016 O_2/N_2 Ratio and CO_2 Airborne Southern Ocean Study

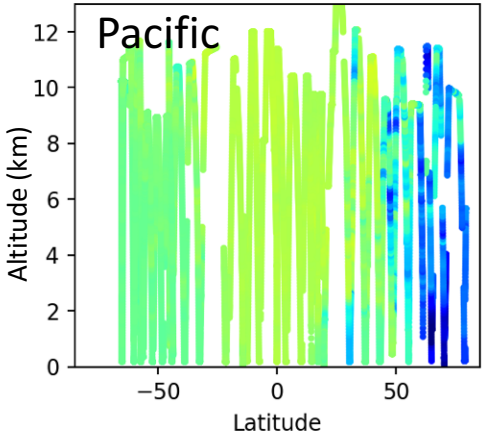
Punta Arenas, Chile
15 Jan to 29 Feb 2016
PI: B. Stephens

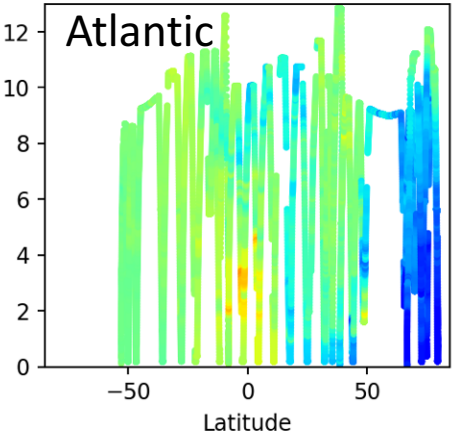


A 3-yr campaign on the NASA DC-8 to do a global survey of the remote atmosphere during each of the 4 seasons: Aug 2016, Feb 2017, Oct 2017, May 2018

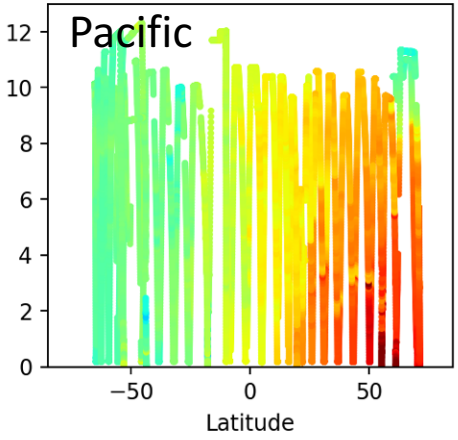


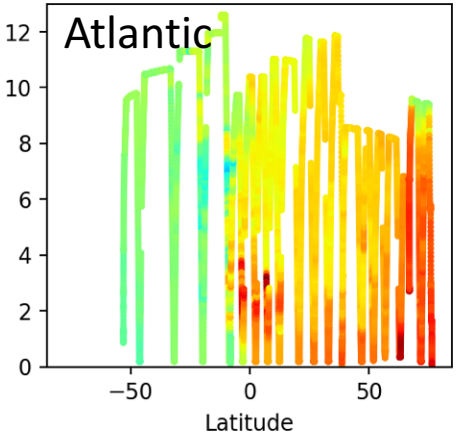
August 2016





February 2017





The altitude ceiling is determined by the minimum inlet pressure required to maintain the cell pressure setpoint

Picarro Standard Configuration:

140 torr cell pressure → ~ 7-10 km altitude ceiling

Strategies for increasing altitude ceiling:

- Increase inlet pressure via
  i. Upstream pump
  ii. Ram pressure (forward-facing inlet)

  e.g. IAGOS (Filges et al. 2015)
  +45 torr from Rosemount probe
  → 12.5 km ceiling

- Pressurizing sample stream may cause problems related to wall-effects and water condensation

The altitude ceiling is determined by the minimum inlet pressure required to maintain the cell pressure setpoint

Picarro Standard Configuration:

140 torr cell pressure → ~ 7-10 km altitude ceiling

Strategies for increasing altitude ceiling:

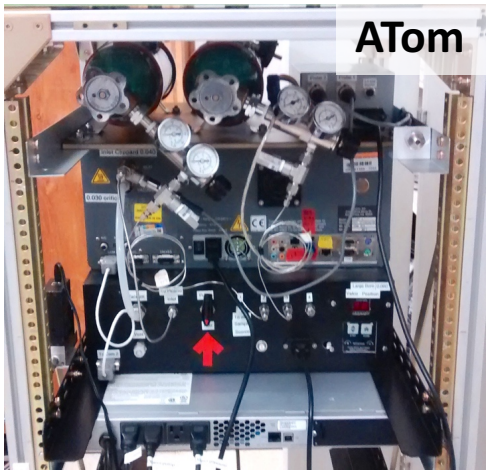
✓ Decrease cell pressure setpoint

80 torr cell pressure → ~13 km

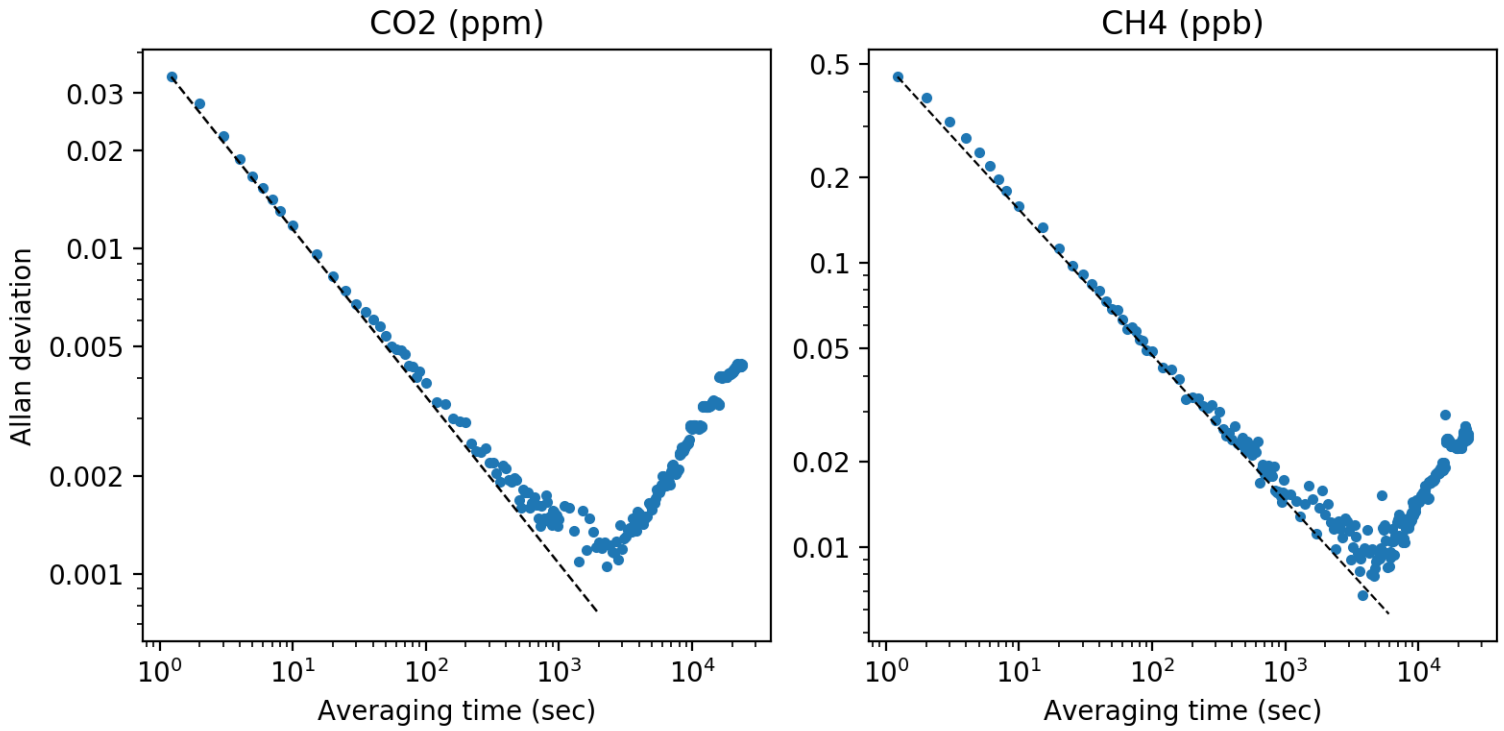
▻ Minimal interference of sample stream

Achieved with software modifications

e.g., Stowasser et al. 2014, Appl Phys B – modified a Picarro for volume-limited applications



Measurement precision degrades with decreasing cell pressure

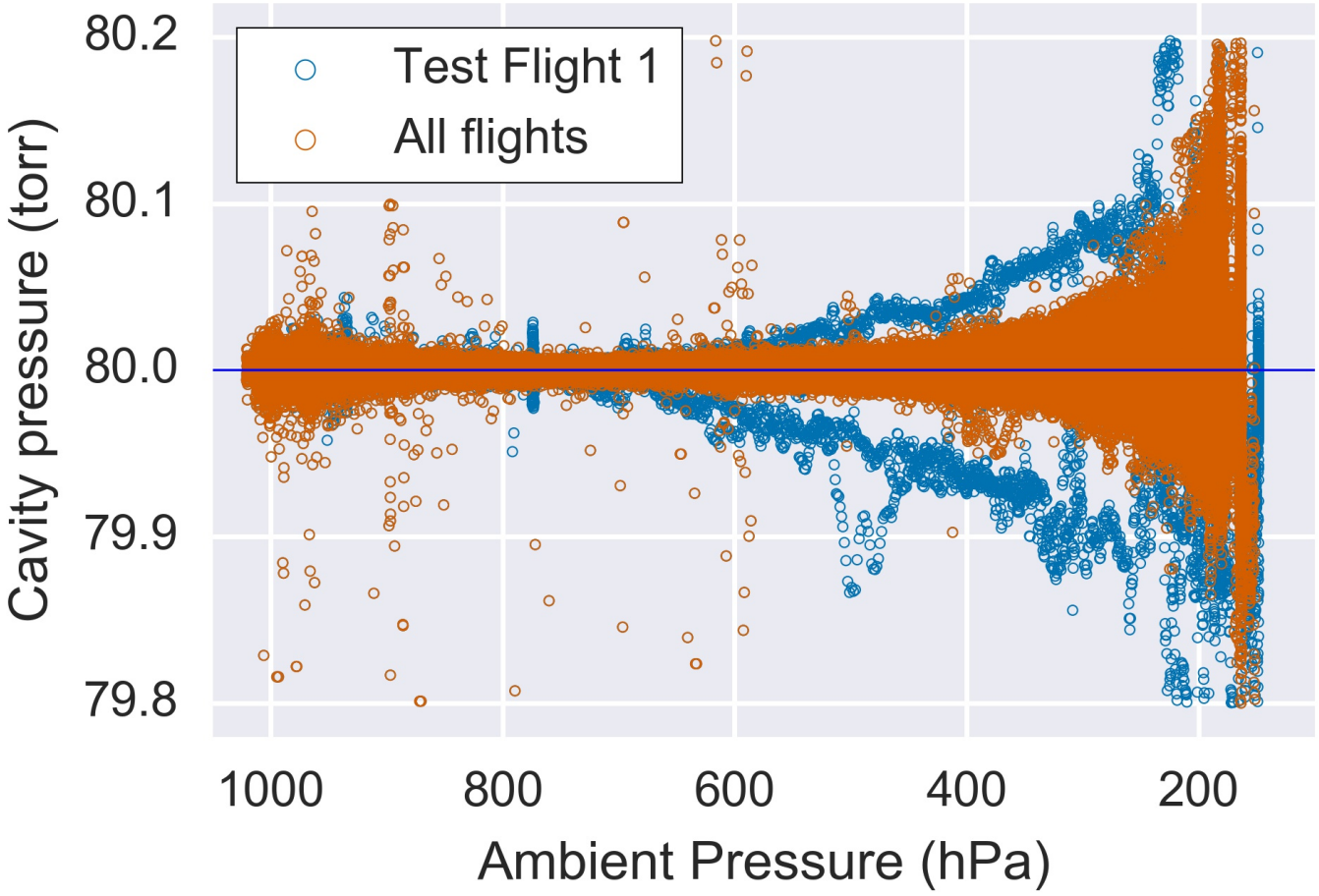


10-sec average 1σ

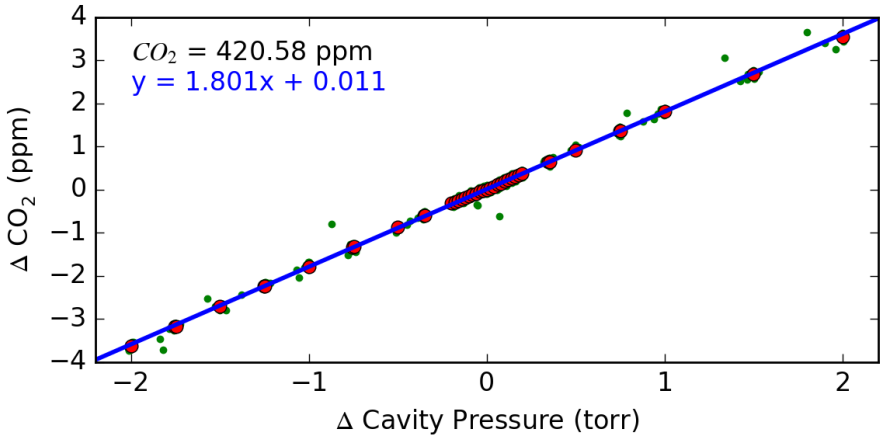
	CO_2 (ppm)	CH_4 (ppb)
140 torr	0.006	0.09
80 torr	0.01	0.16

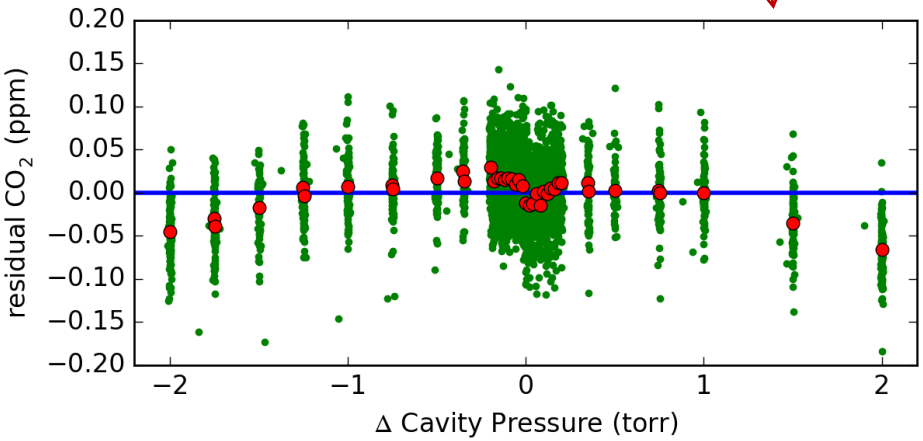
Measurement quality degrades with cell pressure instability

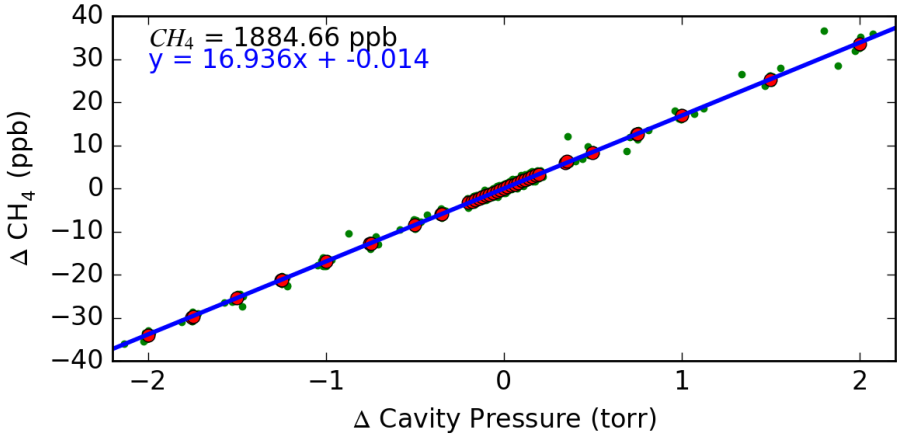
Cell pressure control loop parameters were adjusted for 80 torr mode and flight conditions

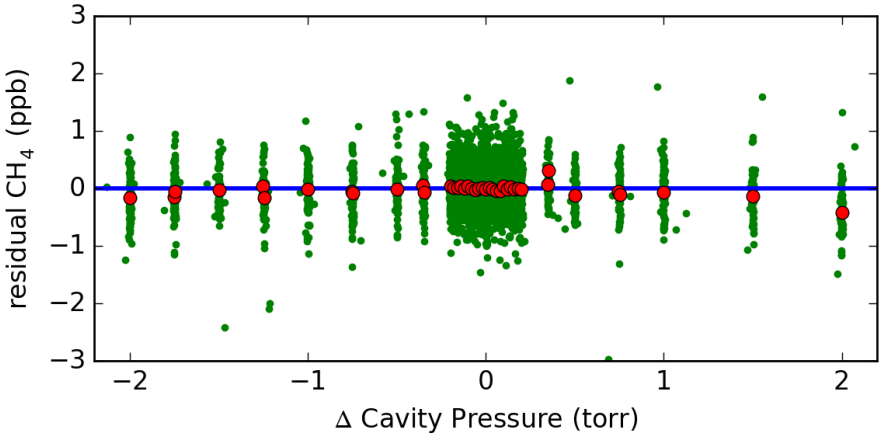


Measurement impact of cell pressure deviations is non-linear and concentration-dependent, but is correctable for small deviations









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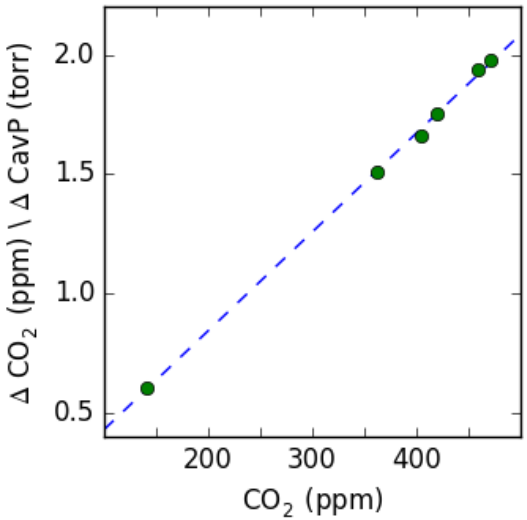
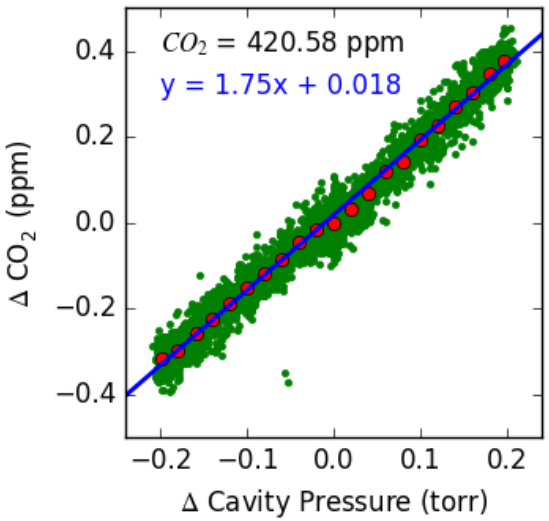
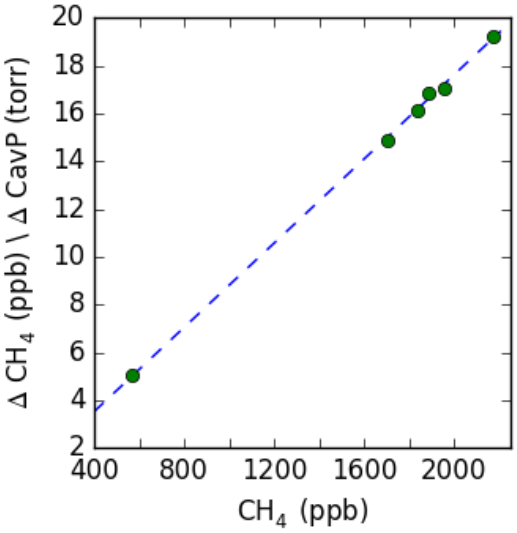
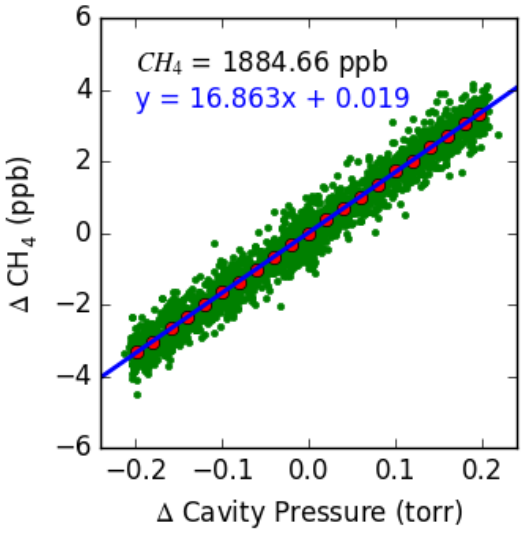






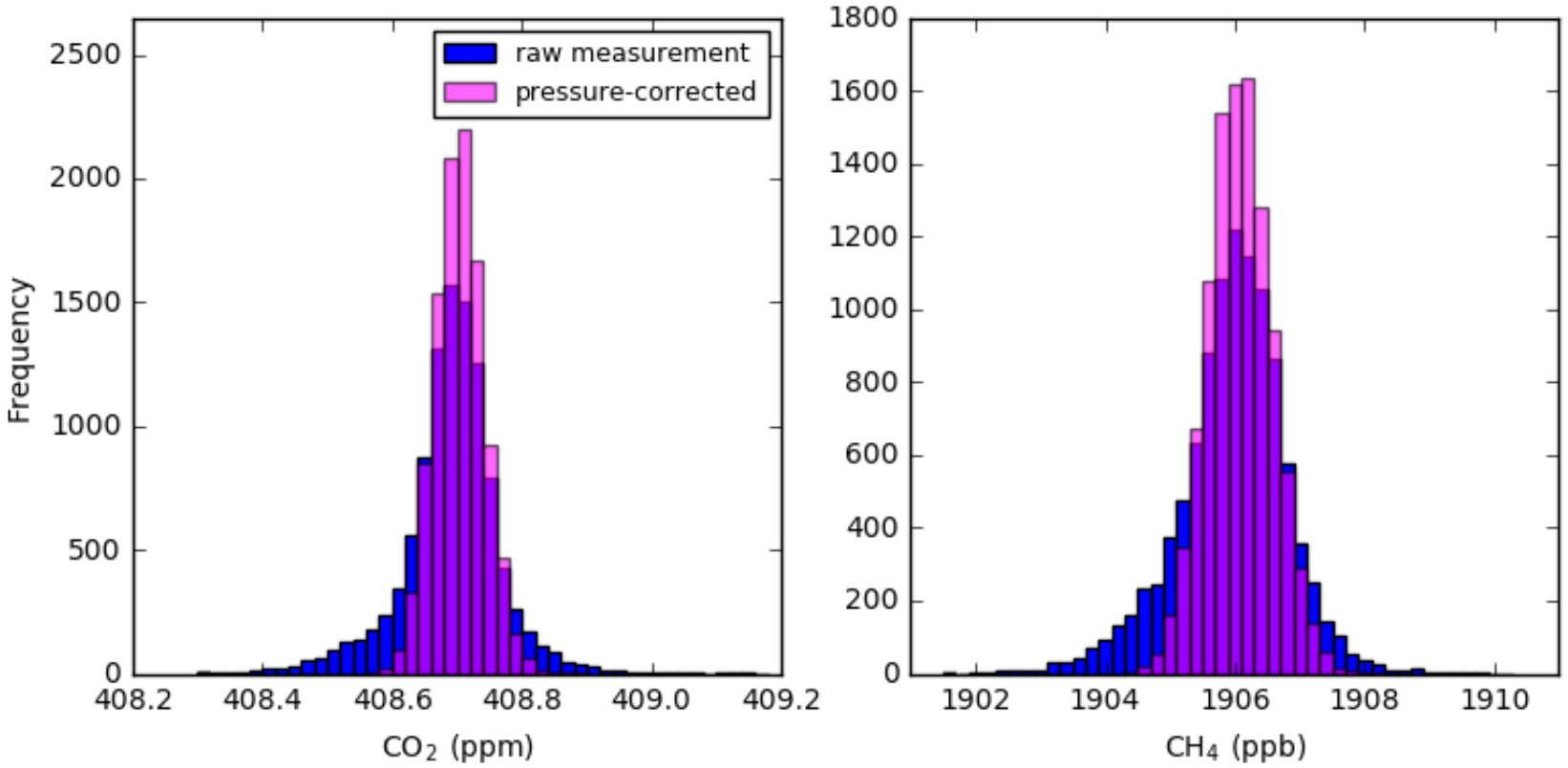


‘Null test’ of the effect of flight conditions on the measurement

ORCAS test flight

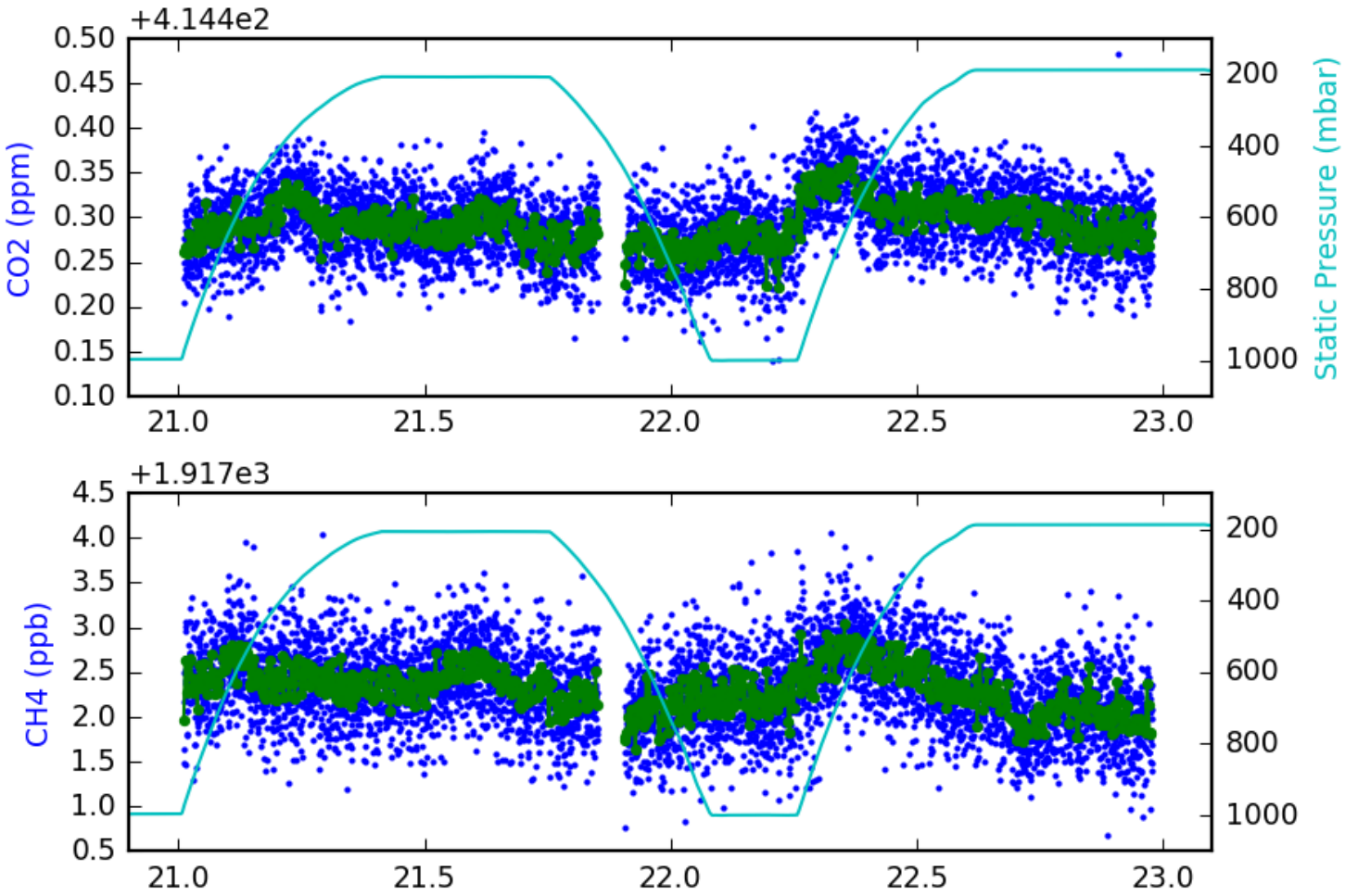
During which a tank with an unknown value was measured
at ambient pressure (~150-1000 hPa) throughout

Distribution of 1-sec measurements before and after pressure correction



‘Null test’ of the effect of flight conditions on the measurement

ATom test flight

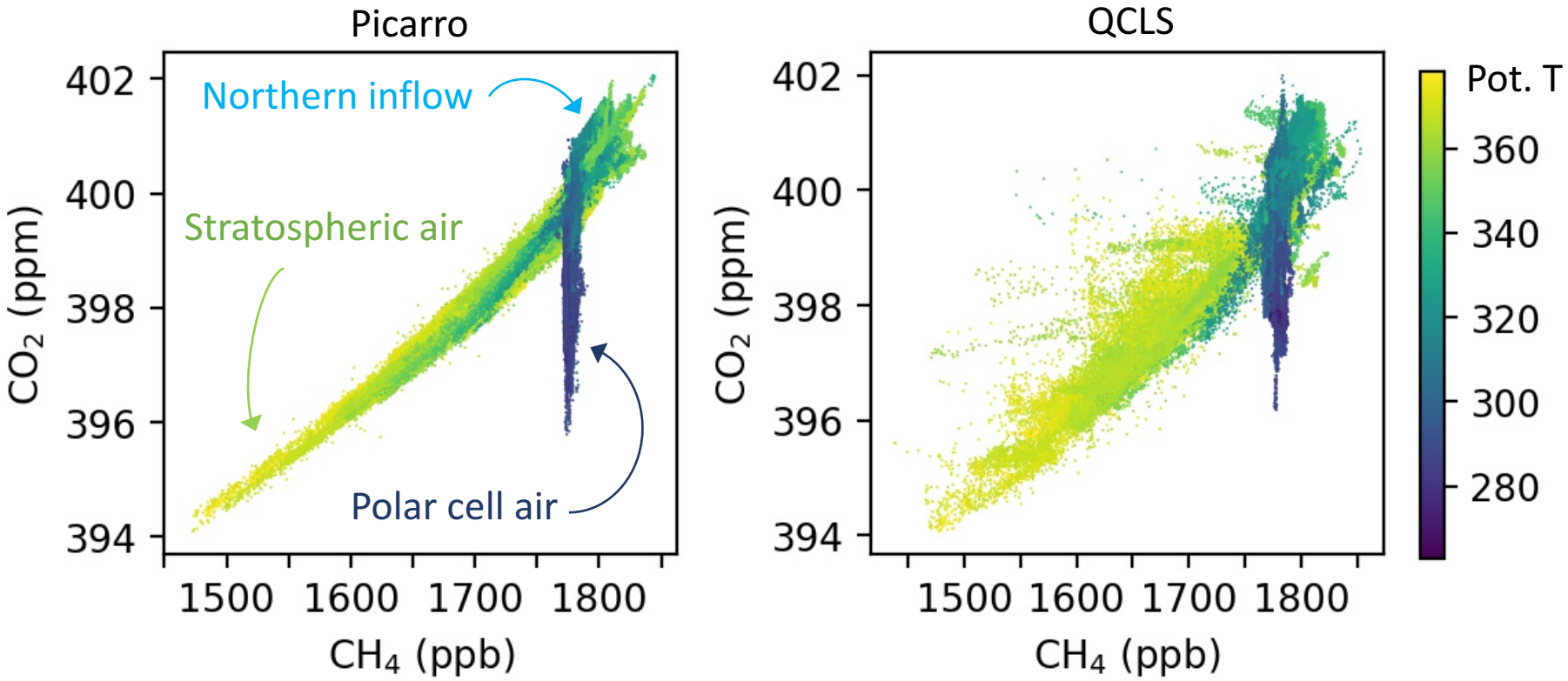


1σ raw: 0.04
1σ 10-sec: 0.02
Max range: 0.14

1σ raw: 0.44
1σ 10-sec: 0.25
Max range: 1.40

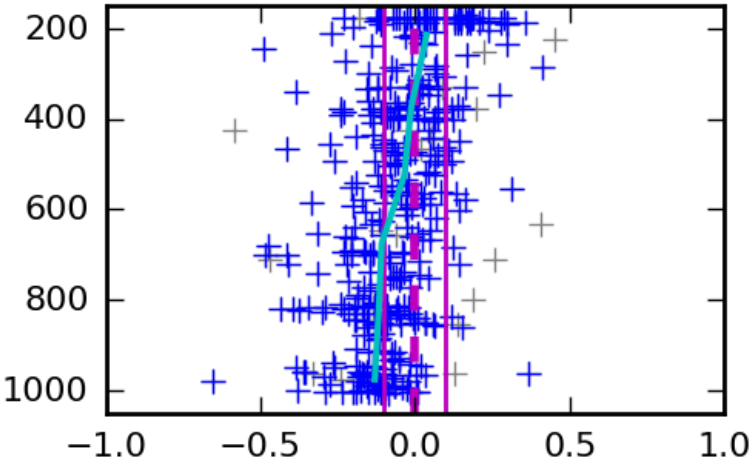
Measurement stability impacts interpretability of data

ORCAS 1-second data from all research flights

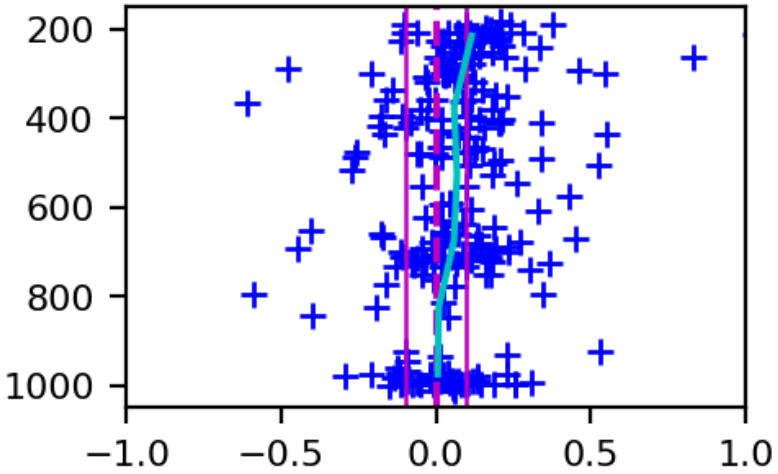


Measurement comparisons, Picarro vs Flasks

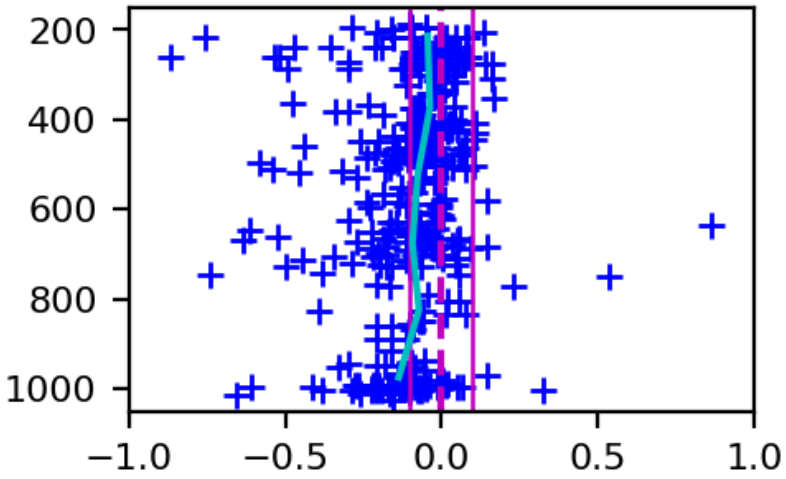
ORCAS, CO_2, Picarro-Medusa
median (1σ) = 0.07 (0.34)



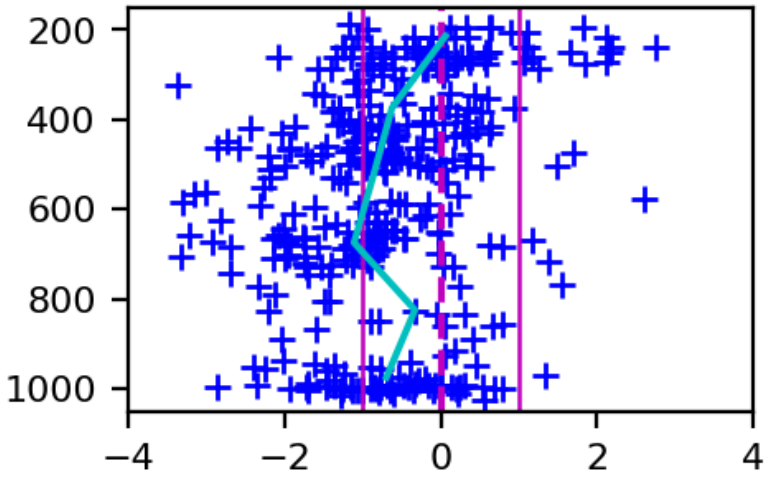
ATom1, CO_2, Picarro-Medusa
median (1σ) = 0.06 (0.20)



ATom2, CO_2, Picarro-PFP
median (1σ) = -0.07 (0.28)



ATom2, CH_4, Picarro-PFP
median (1σ) = -0.70 (1.40)



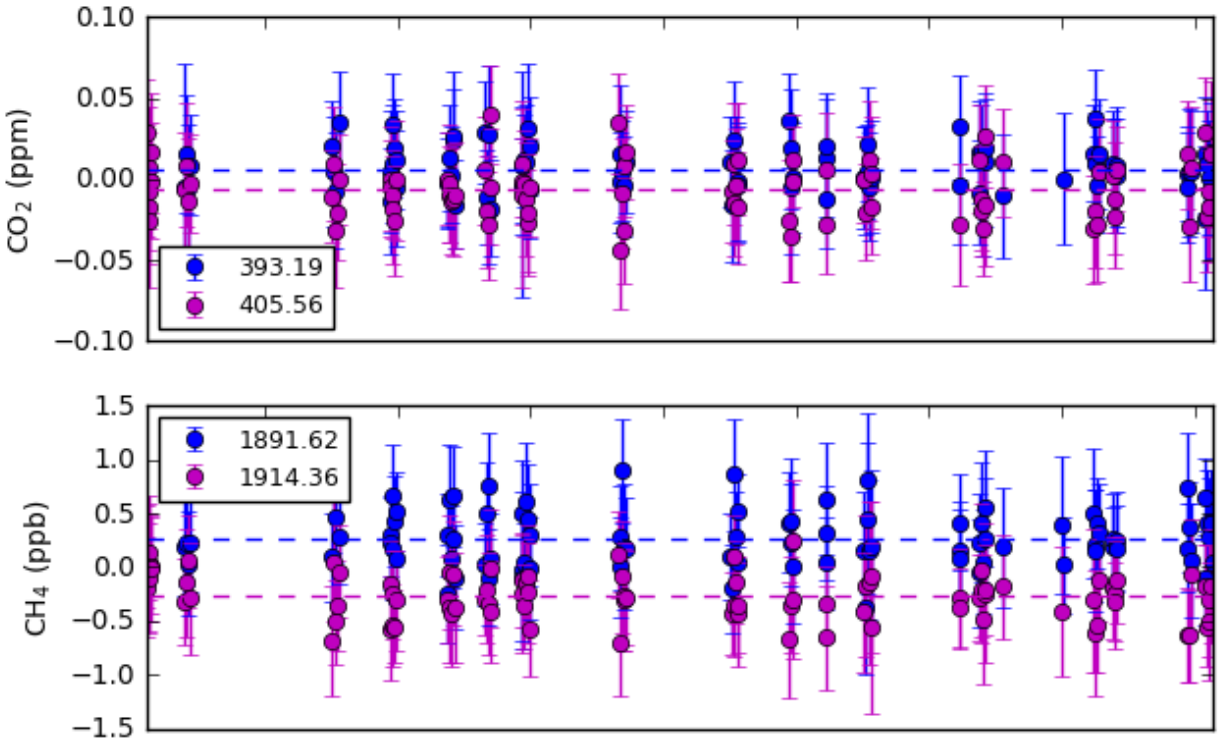
Uncertainty Analysis

Average 1σ for 1-sec measurements for each campaign

	ORCAS		ATom	
	CO_2	CH_4	CO_2	CH_4
Scale assignment	0.05	0.25	0.04	0.28
Water corr, pre vs. post	0.01	0.16	0.03	0.22
Lab cal (6-pt), pre vs. post	0.00	0.01	0.01	0.08
Inflight cal (2-pt), offset corr	0.02	0.36	0.04	0.36
Null test (precision)	0.04	0.49	0.04	0.44
Total	*0.07*	*0.68*	*0.07*	*0.70*

Residuals of in-flight calibration tank measurements

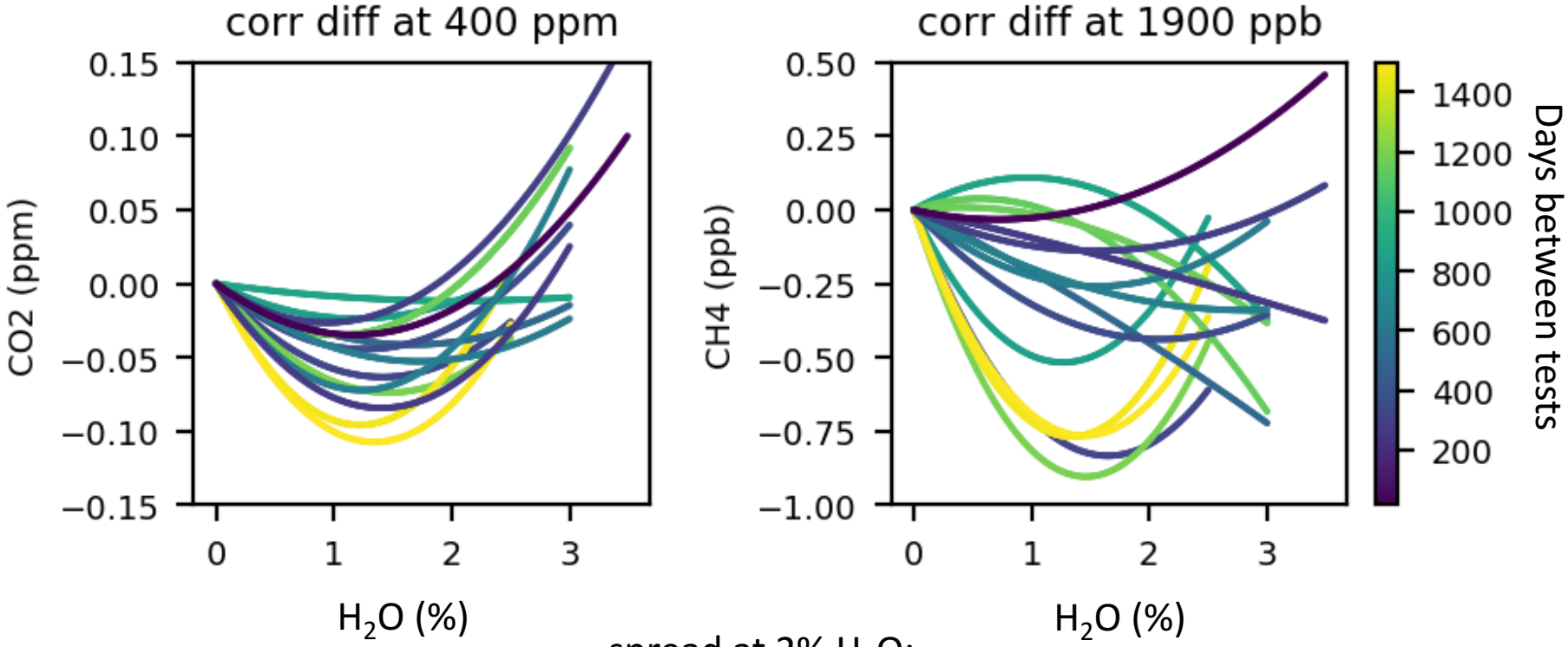
Concentration dependence?
± 0.3 ppb CH_4



Uncertainty Analysis

Reproducibility of water correction

Case study: 1 analyzer, 6 water tests, over 4 years



spread at 2% H_2O:

	CO_2 (ppm)	CH_4 (ppb)
1σ	0.03	0.25
Max-min	0.09	0.87

only slightly smaller among tests done at shorter intervals

Summary

Some aspects of the Picarro are flexible and can be modified in the software to create multiple different measurement modes to adapt individual analyzers to specific applications.

Aircraft campaigns provide a useful testbed to evaluate

- design and configuration concepts, and
- the necessity and relative impact of various QA steps,

which can be translated to monitoring-scale airborne programs.