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Frequency Response of the TGA300 Series

Session: AS2.2 – Air-Land Interactions (General Session)

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Sharing is encouraged

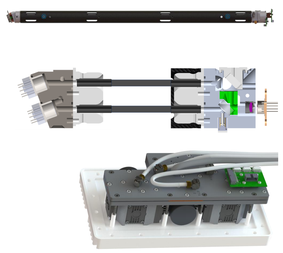
Introduction and Objectives

Campbell Scientific has developed trace gas analyzers (TGA100(A), TGA200(A)) for over 30 years to measure CH_4 and N_2O fluxes. Traditional closed-path systems rely on large, AC-powered pumps to achieve the frequency response required for eddy covariance, limiting deployment in remote or power-constrained locations. The TGA300 series addresses this by using a small sample cell (10 mL) and low flow rate (1.8 L min^{-1}) to achieve the necessary frequency response with a typical power consumption of ~40 W, enabling more flexible and cost-effective field deployments.

An impulse-response technique as described in Sargent[1], was used to measure the frequency response and lag-time in a laboratory setting of the new TGA300 series.

TGA300 Series & Test Configuration





Sample Gas Flow: 1.8 SLPM
λ N2O : 3221 nm
Reference Gas Flow: 10 ml/min
Sample Pressure: 30 kPa
Intake: 4m of Nafion® tube 2.2 mm ID

Test Equipment:
- TGA320 N_2O Analyzer
- CR1000X Datalogger (Campbell Scientific)
- Spike and Hold Driver (The Lee CO: IECX0501350A)
- MiniStac tubing assy (The Lee CO TUTC321690L).
- Valve (The Lee CO INKX0514300A)
- 0.014” orifice nozzle (The Lee CO INZA4710975H)

Preliminary Specifications

Sync Jitter: ±10 ms
Power: <50 W
Volume: 10ml
Residence time: 99 ms at 1.8 standard LPM flow and 30 kPa pressure.
Noise CH4 : <5 ppb typical (Allan deviation with 100ms averaging time)
Noise N2O : <1 ppb typical (Allan deviation with 100ms averaging time)
λ CH4 : 4534 nm
λ N2O : 3221 nm

Methods

- Inject fast pulses of N_2O into sample flow (ambient air) every 10 seconds.
- Sample the TGA320 response at 50 Hz with a CR1000X datalogger
- Impulse response
  - Remove trend (10s moving average)
  - Overlay the pulse
  - Compute the ensemble average
  - Calculate the lag time
- Frequence response
  - Fourier transform the impulse response
  - Normalize to 1 at low frequency
  - Graphically determine the half-power bandwidth ƒ
  - Calculate the characteristic time: $\tau_c = \frac{1}{2\pi f}$
  - Use a first-order model corresponding to the residence time (99 m/s).
- Inject pulses at the upstream of the inlet and upstream of the dryer with and without a 5Hz digital filter.

Optional References / Notes

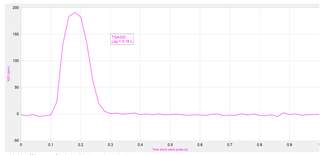
1. Sargent, S. (2012) Quantifying Frequency Response of a Low-power, Closed-path CO_2 and H_2O Eddy-covariance System. *https://s.campbellsci.com/documents/us/technical-papers/cpec200_frequency_response.pdf/*
2. Horst, T.W. (1997) A simple formula for attenuation of eddy fluxes measured with first-order-response scalar sensors. *Boundary-Layer Meteorol*. **82**: 219-233.

Measured response

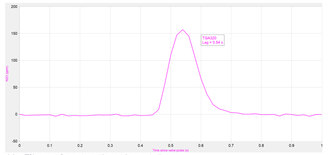
Main finding
Frequency response remains in the ~3–4 Hz range, with only modest losses from the dryer and digital filtering.

Time-lag response

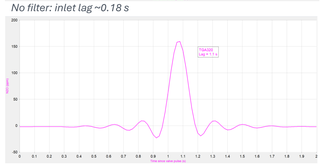
Lag time is repeatable and increases predictably when the 4 m dryer/intake volume is included.



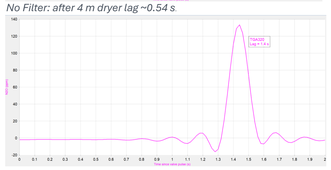
No filter: inlet lag ~0.18 s



No Filter: after 4 m dryer lag ~0.54 s.



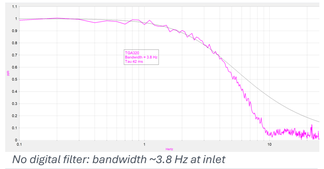
5 Hz digital filter: inlet lag ~1.07 s



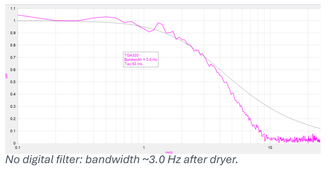
5Hz digital filter: after 4 m dryer ~1.43 s.

Frequency response

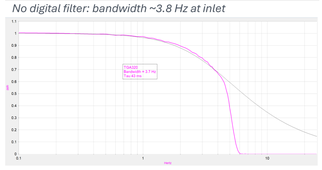
Half-power (-3 dB) bandwidth remains sufficient for eddy covariance; the dryer causes ~20% bandwidth reduction.



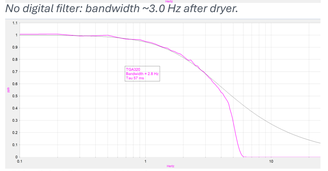
No digital filter: bandwidth ~3.8 Hz at inlet



No digital filter: bandwidth ~3.0 Hz after dryer.



5 Hz digital filter: bandwidth ~3.7 Hz at inlet



5Hz digital filter: ~2.8 Hz after dryer.

Summary of measured bandwidth

Configuration			
Inlet, filter off	**3.8 Hz**	42 ms	Baseline response
4 m dryer, filter off	**3.0 Hz**	53 ms	~20% lower bandwidth
Inlet, 5 Hz filter	**3.7 Hz**	43 ms	Minor attenuation
4 m dryer, 5 Hz filter	**2.8 Hz**	57 ms	Worst tested case

What the plots show

Design takeaway: ~40 W operation does not require sacrificing EC-scale response.

Flux Attenuation

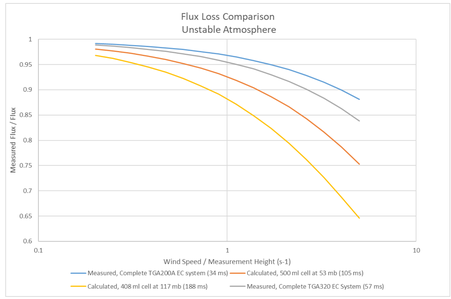
A simple model from Horst[2] computes a flux attenuation as a function of the time constant τ_c, measurement height z, and mean wind speed ū.

$$\frac{F_m}{F} = \frac{1}{1 + (2\pi n_m \frac{\bar{u}}{z} \tau_c)^{\alpha}}$$

n_m is 0.085 and α is 7/8 for unstable conditions

The ratio of measured flux to true flux is plotted as a function of wind speed/measurement height.

The TGA200A system and two sample cells assumed to have time constants equal to their residence times are shown for comparison.
Flow rates for comparison data are 15 SLPM. Flow rate for TGA320 is 1.8 SLPM



Conclusions

- The TGA300 achieves a frequency response of 3.8Hz with a 42 ms characteristic time constant.
- Adding the 4m dryer reduces frequency response to 3.0 Hz.
- Frequency response is degraded slightly with the addition of the digital filter.
- Frequency response is achieved with only 1.8 SLPM and 40W of power due to the design of a 10ml volume sample cell.
- Under unstable conditions and wind speed approximately equal to measurement height, the TGA320 shows >95% flux captured.

Future Work

- Continued development to optimize the system (dryer and intake assembly) to take advantage of the small sample cell and further improve frequency response.
- Further field verification of system performance.

Take-home message

The TGA300 provides eddy covariance–ready frequency response with a power budget that makes remote CH_4 and N_2O flux sites far easier to deploy.