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A gas analyzer sampling system optimized for eddy-covariance applications

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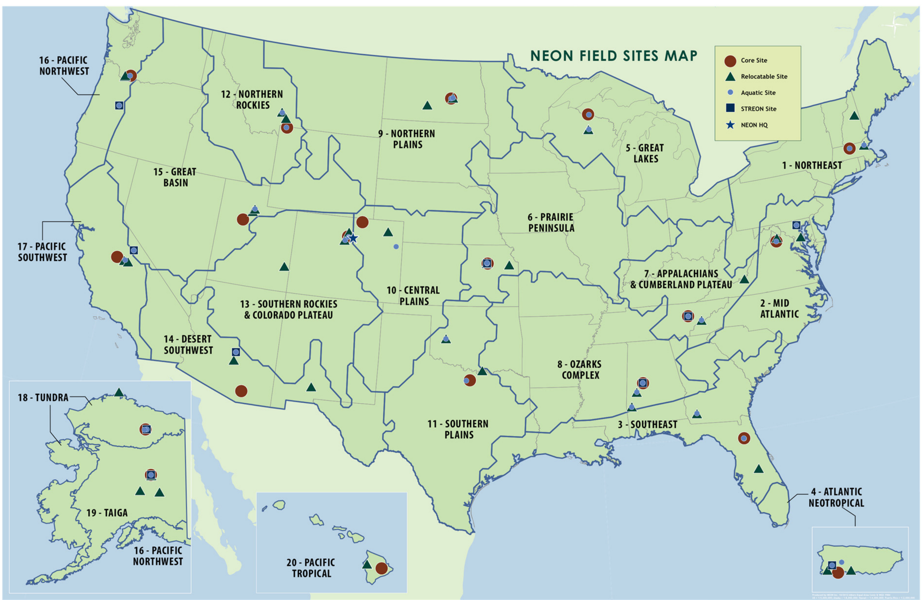
Background

The National Ecological Observatory Network (NEON) will provide free, high quality data products describing the environment. NEON is currently designing and deploying manual sampling, aircraft remote sensing, and automated measurements at 60 sites across the United States, including Alaska, Hawaii, and Puerto Rico. Among these, the surface-atmosphere exchange of momentum, heat, H_2O, CO_2 and other trace gases is monitored using eddy-covariance (EC) measurement systems.



Map of 20 NEON domains with indicators for different sites.

Objectives

To ensure comparable measurements across all sites, NEON is testing its assemblies against a set of strict, quantitative requirements to system frequency and temperature responses. In the present case, the key requirements are:

1. To minimize high-frequency spectral corrections during sampling mode, the half-power frequency response of the particle filter shall be ≥4 Hz.
2. To minimize uncertainty in the eddy-covariance flux measurements during sampling mode, high-frequency spectral corrections in post-processing of the infrared gas analyzer (IRGA) H_2O and CO_2 measurement data shall be necessary only for frequencies > 1 Hz.
3. The temperature difference between the IRGA block and the IRGA head inlet thermocouple measurement shall be maintained to within ≤15°C.
4. To enable reliable mixing ratio measurements, the temperature difference between the IRGA head inlet and outlet thermocouple measurements shall be maintained to within ≤5°C.

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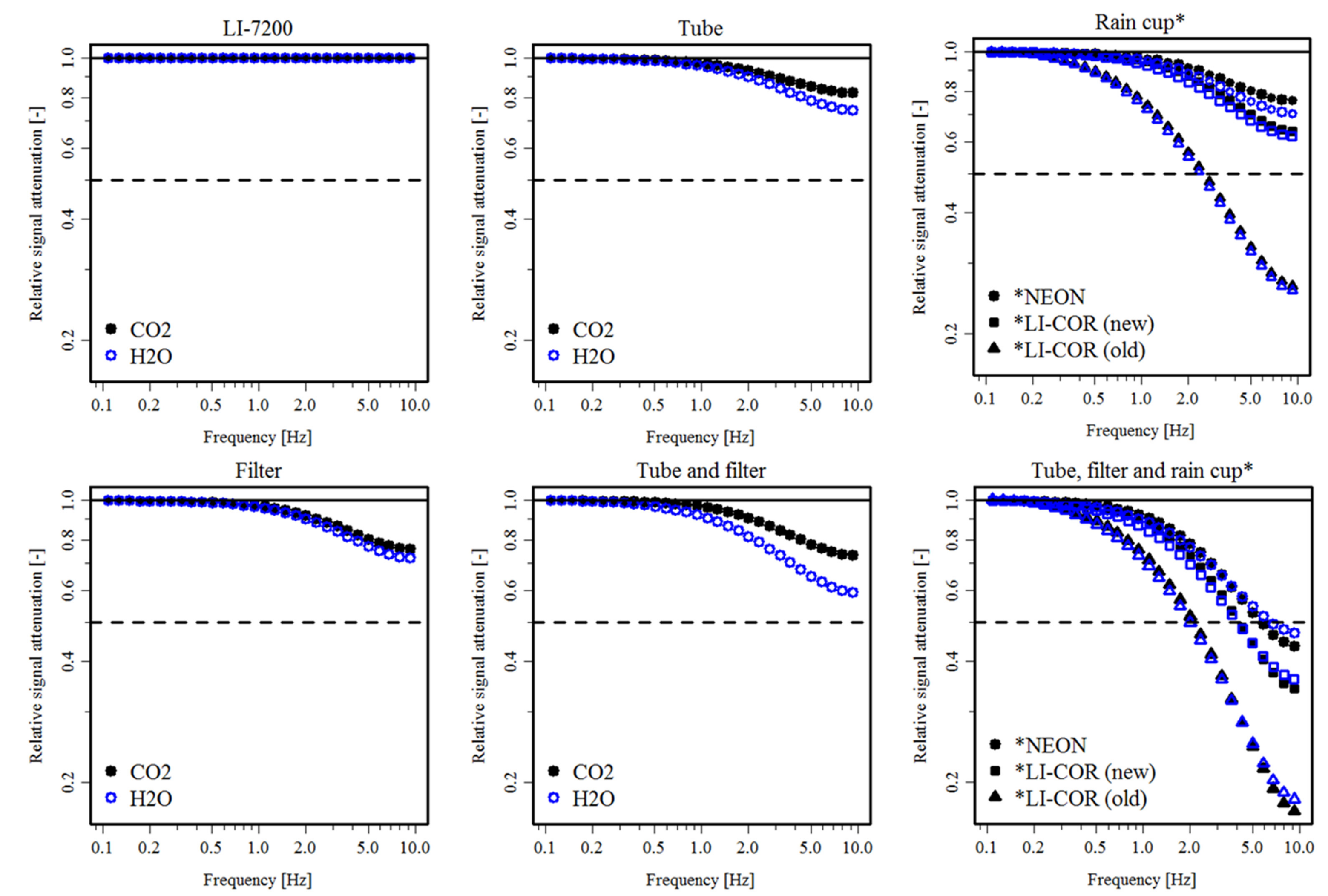
Results

Laboratory: Characterizing components

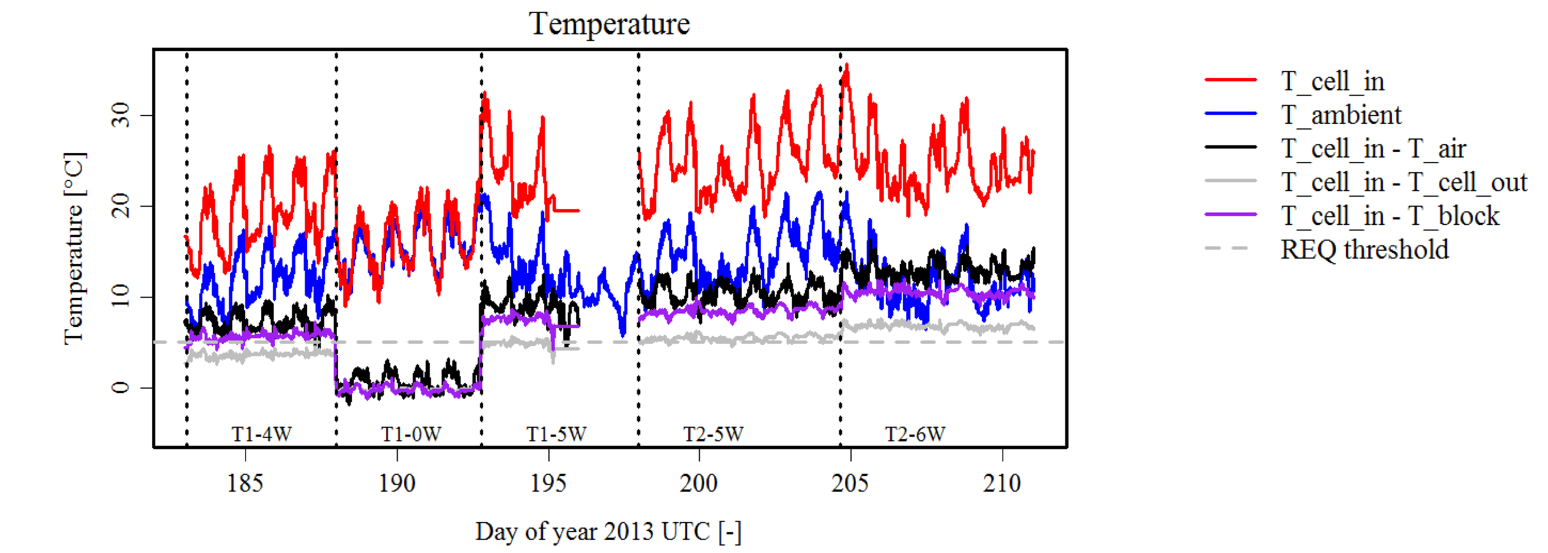


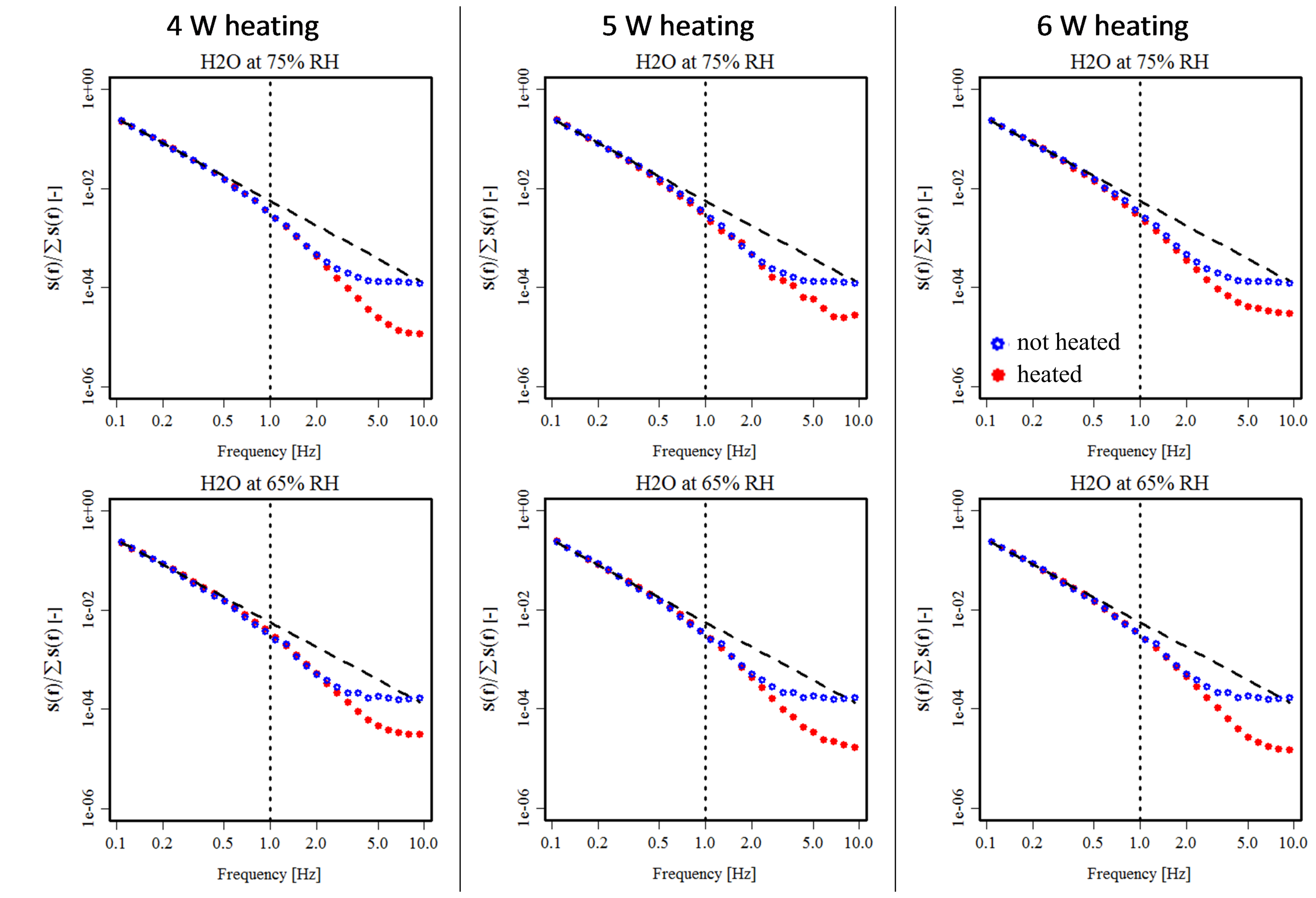
Frequencies at which the signal attenuation reaches 20% for individual infrastructure parts and combinations:

Infrastructure part	H_2O	CO_2
Tube		
70 cm stainless steel 4.8 mm ID	>10 Hz	>10 Hz
Filters		
Swagelok FW2 2µm	**≈6 Hz**	**>10 Hz**
Polypro G500	≈3 Hz	≈10 Hz
Polypro G250	≈2.5 Hz	>10 Hz
Gelman 1 µm	≈1.5 Hz	≈10 Hz
Zenpure 1 µm	≈0.6 Hz	≈4 Hz

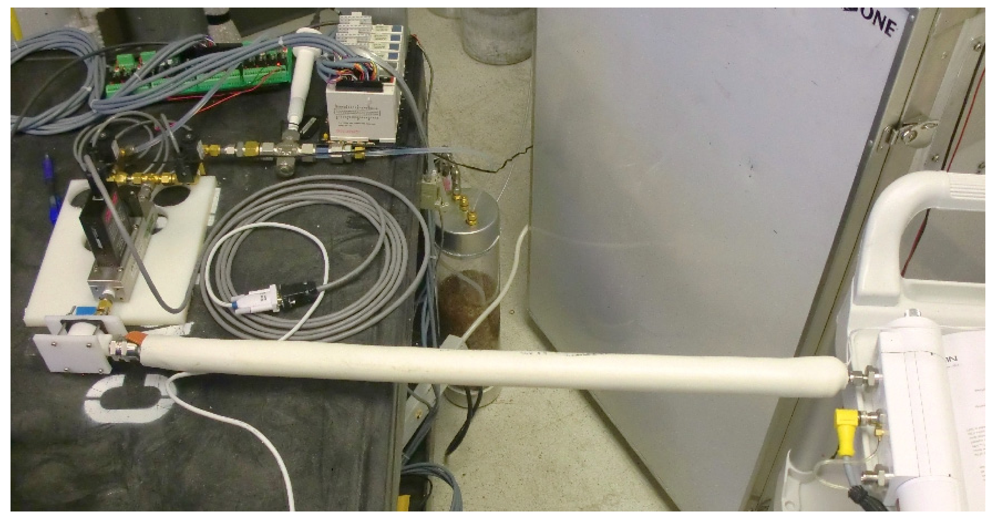
Infrastructure part	H_2O	CO_2
Rain cups		
Rain cup NEON	**≈5 Hz**	**>10 Hz**
Rain cup LI-COR (new)	≈3 Hz	≈4.5 Hz
Rain cup LI-COR (old)	≈0.8 Hz	≈0.9 Hz
Combinations		
Tube and filter Swagelok FW2	**≈3 Hz**	**≈2.5 Hz**
Tube, filter Swagelok FW2 and rain cup NEON	**≈2 Hz**	**≈2 Hz**
Tube, filter Swagelok FW2 and rain cup LI-COR (new)	≈1.5 Hz	≈1.9 Hz
Tube, filter Swagelok FW2 and rain cup LI-COR (old)	≈0.7 Hz	≈0.8 Hz

Field: Characterizing the effect of tube heating





Laboratory setup



- LI-COR LI-7200, flow rate 10.8 SLPM;
- Intake tube 70 cm of 4.8 mm ID stainless steel;
- 2 µm Swagelok pleated mesh particle filter;
- Three different rain cup designs.

Field setup

- University of Colorado Niwot Ridge AmeriFlux site;
- Intensive observation period July 2013;
- 4–6 W filter and intake tube heating.

Conclusions

- Re-designing the rain cup provided the largest margin for improving frequency response;
- The NEON and LI-COR (new) rain cups provide a six-fold and four-fold improvement over the LI-COR (old) rain cup, respectively;
- Heating improves detectability of high-frequency H_2O fluctuations;
- Intake tube and filter heating with no more than 4 W keeps temperature differential across the IRGA cell below 5°C.and enables determining H_2O and CO_2 dry mole fractions with ≤2% uncertainty;
- All NEON requirements are fulfilled.

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