High Humidity-Induced Bias in Aircraft Network CO₂ Data

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Background

- NOAA GMD has routinely collected Programmable Flask Package (PFP) samples from light aircraft at a network of sites for analysis of CO₂ and many other trace gases.
- Aircraft network PFPs are filled to a pressure of 40 psi and sample air is typically not dried.
- To date, ~83,000 undried aircraft samples have been taken since 1992 from 44 different sites or projects.

Problem

- Recent measurement comparisons show a low CO₂ bias from PFPs related to high ambient H₂O.
- We hypothesize that CO₂ has dissolved into liquid water condensed on the sides of the flask at the time of analysis.

Evidence

- CO₂ measured from undried PFPs versus continuous analyzers from 3 recent projects.
- Data are filtered for insitu 1σ < 0.4 ppm.
- Low CO₂ bias appears to be approximately linear in relation to ambient H₂O at levels > ~1.7% v/v.
- Relationships from these 3 examples appear consistent, but data is either too sparse (MSH, ACT) or of unknown quality (SGP) to characterize a correction with confidence.

Next steps

Experiment to develop a correction and approximate uncertainty:
- An undried PFP sampling system was recently installed at South Carolina Tower (SCT) in parallel with the existing dried PFP system.
- During May-September, most days have H₂O > 1.7% H₂O.
- Measurements from undried PFPs will be compared to both insitu and dried PFP measurements.

Options for a long-term solution:
- Add a drier to each aircraft PFP sampling system
- Operational challenges (power, reliability, pilot burden)
- Heat flasks at analysis to evaporate water
- Potential impact to other analytes
- Fill flasks to lower pressure
- Fewer gases can be measured

Method:

H₂O data was obtained from:
- Measurements of Temperature and Relative Humidity from Vaisala probe
- Currently made routinely in the aircraft network, but ~56% of samples have no associated T/RH data
- Reanalysis data of Specific Humidity (q) and Pressure
- North American Regional Reanalysis (NARR)
  - 3-hourly and 0.3-degree resolution
  - Available from NOAA ftp server with 1-month latency
  - Domain does not cover all affected samples
- ERA-5
  - Global, 1-hourly and 0.25-degree resolution
  - Available with ~3-month latency
  - Downloading only needed hourly files
- Data are automatically imported to our database for all events and can be accessed with ccg_flask2.py

Result:

- All aircraft CO₂ measurements from PFPs filled with ambient H₂O > 1.7% v/v have been flagged.
- CO₂ measurements were flagged if H₂O > 1.7% from either measured or NARR or ERA5
- ~5% of all aircraft PFP CO₂ data is flagged and ~20% of summer boundary layer samples
- Rarotonga (RTA) and Colorado (CAR) are examples of sites with a large and small fraction of flagged data, respectively

Data Flaking

1.5 2.0 2.5

Average vertical gradient by season without and with bias correction

RRTA

RTA, bias correction

Cape Verde

Ecuador

Caribbean

Rarotonga

Sao Tome

Data are filtered for insitu 1σ < 0.4 ppm.

When the candidate correction derived from MSH is applied to RTA:
- Variability in the vertical gradient increases.
- Near-surface (alt < 500 m) values become more similar to those measured (2-hours) at SMO (14° S).
- Magnitude and seasonality of bias are consistent with those predicted by CT2017.

Testing a Candidate Correction

The Rarotonga (RTA, 21° S) sampling site has consistently high H₂O and low variability CO₂.

Average bias by altitude and season

Average bias by altitude and season

Modeled versus Measured H₂O for Aircraft PFP Samples

Modeled versus Measured H₂O for Aircraft PFP Samples