High Humidity-Induced Bias in Aircraft Network CO_2 Data

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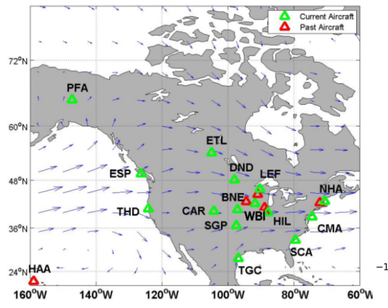
Background

- NOAA GMD has routinely collected Programmable Flask Package (PFP) samples from light aircraft at a network of sites for analysis of CO_2 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.

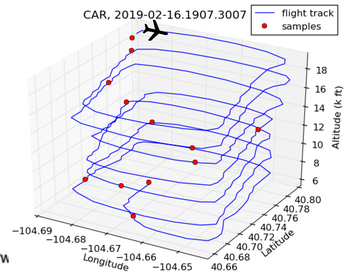
Problem

- Recent measurement comparisons show a low CO_2 bias from PFPs related to high ambient H_2O.
- We hypothesize that CO_2 has dissolved into liquid water condensed onto the sides of the flask at the time of analysis.

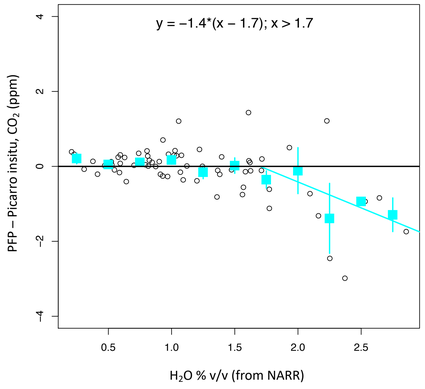
Aircraft Network sites in North America



A typical flight pattern is a downward spiral with flasks collected at a set of pre-determine altitudes to render the vertical concentration profile



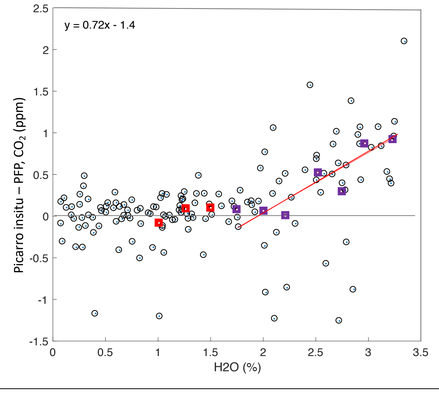
LEW & MSH tower sites during parts of 2015-2016 when PFP sample air was mistakenly not dried



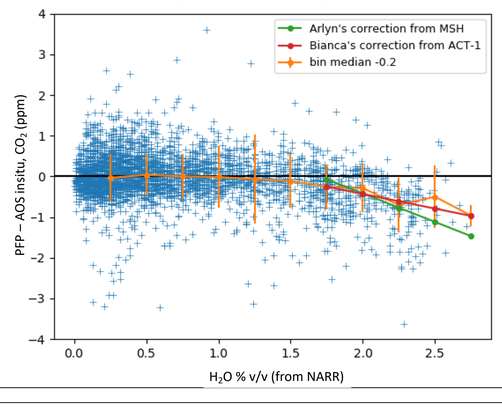
Evidence

- CO_2 measured from undried PFPs versus continuous analyzers from 3 recent projects.
- Data are filtered for insitu 1σ < 0.4 ppm.
- Low CO_2 bias appears to be approximately linear in relation to ambient H_2O 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.

ACT-1 Aircraft Campaign
before dries were added to PFP sampling system



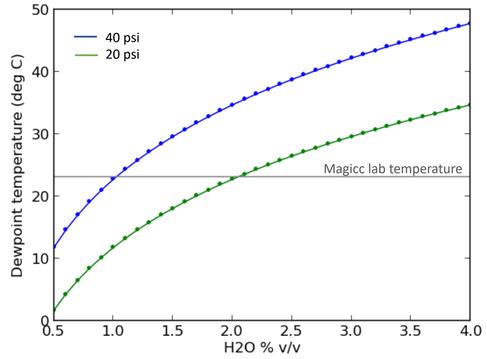
SGP Aircraft Network site
where continuous measurements were also made during 2006-2017 by S. Biraud, LBNL



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 H_2O > 1.7% H_2O.
- Measurements from undried PFPS will be compared to both insitu and dried PFP measurements.

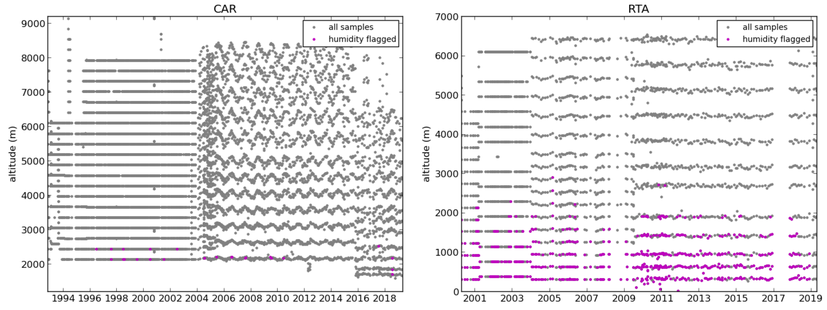
Options for a long-term solution:
- Add a drier to each aircraft PFP sampling system
  - Operational challenges (power, reliability, pilot burden)
- Heat flasks at analysis to evaporate water
  - Potential impact to other analytes
- Fill flasks to lower pressure
  - Fewer gases can be measured



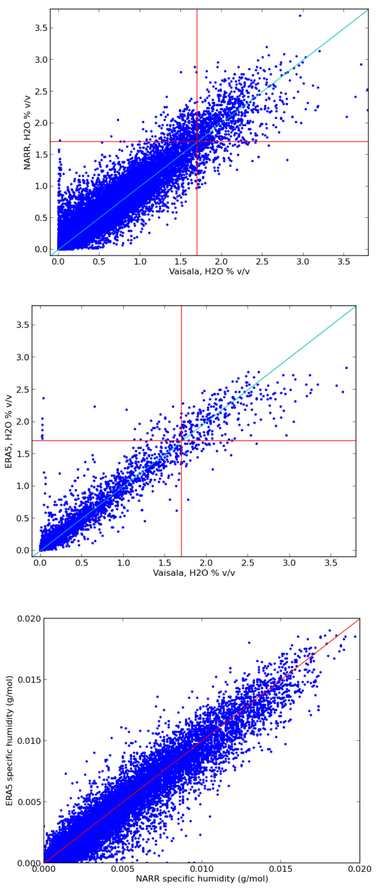
Data Flagging

Method:
H_2O 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 CO_2 measurements from PFPs filled with ambient H_2O > 1.7% v/v have been flagged.
- CO_2 measurements were flagged if H2O > 1.7% from either measured or NARR or ERA5
- ~5% of all aircraft PFP CO_2 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



Modeled versus Measured H_2O for Aircraft PFP Samples

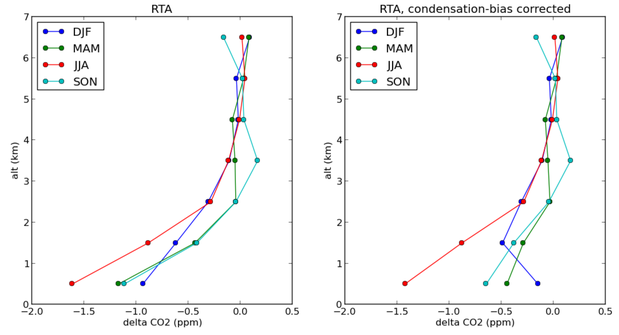


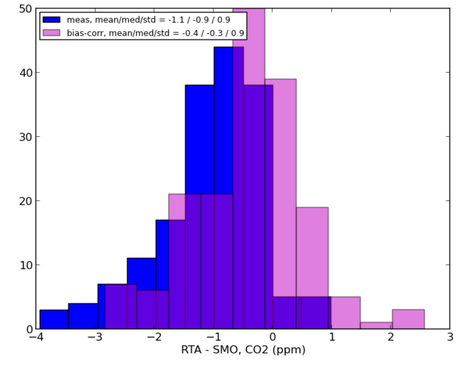
Testing a Candidate Correction

The Rarotonga (RTA, 21° S) sampling site has consistently high H_2O and low variability CO_2.

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.

Average vertical gradient by season without and with bias correction





Average bias by altitude and season