Development Efforts Toward Increasing Density and Coverage of Aircraft Vertical Profile Measurements of Greenhouse Gases through Ride-along and Commercial Flight Opportunities

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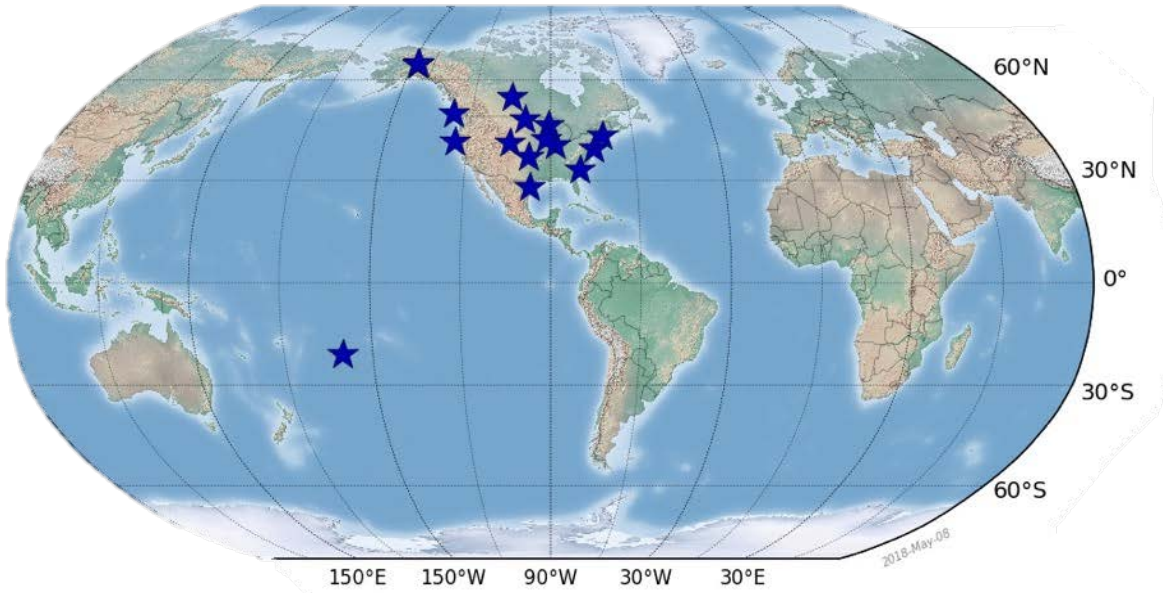
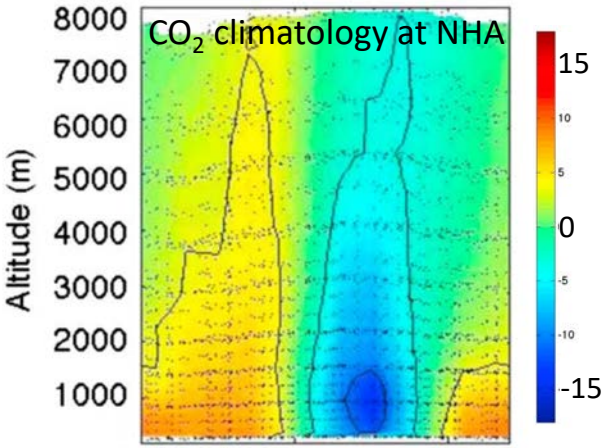
Global Monitoring Laboratory
Earth System Research Laboratories

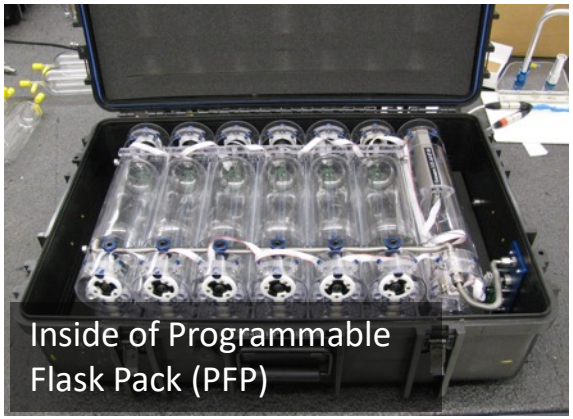
NOAA Greenhouse Gas Reference Aircraft Network



- 13 sites in N. Am. currently
- 15+ yr record at each site
- Private pilots flying small aircraft
- 1-2 profiles per month
- 12 flask samples per profile are collected at fixed altitudes
- Flask samples are analyzed for 55+ trace gases and isotopes



Sweeney et al. 2015



Aircraft vertical profile measurements are **useful** because they have:

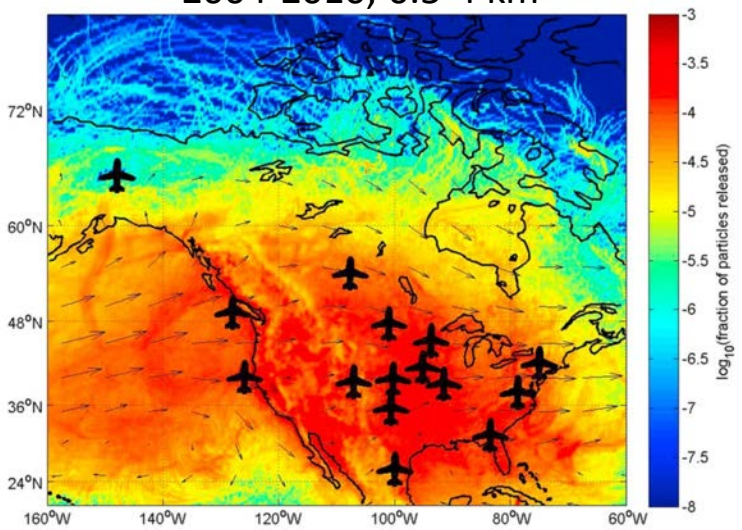
- Large scale sensitivity to surface fluxes
- Free troposphere boundary conditions
- Information about transport and vertical mixing

NOAA Aircraft Network data have been used in a large variety of **analyses**, including:

- Constraining average budgets for North America
- Evaluating modeled atmospheric transport and vertical mixing
- Evaluating satellite retrievals
- Evaluating proposed large trends in emissions

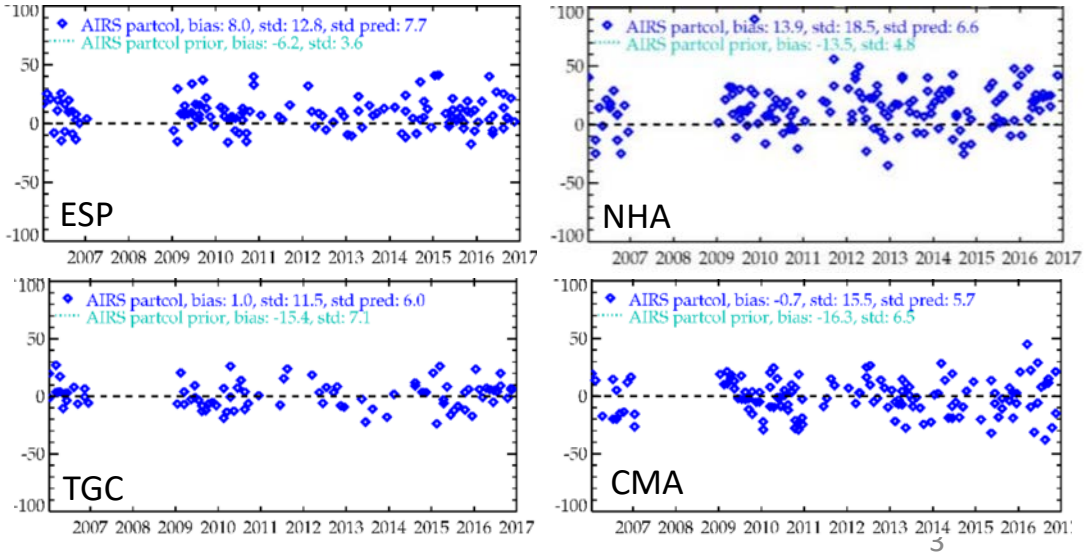
Kulawik et al. 2020 use aircraft vertical profile measurements to derive a bias correction and assess remaining uncertainties in AIRS CH_4 retrievals

Footprint of Aircraft Network
2004-2010, 0.5-4 km



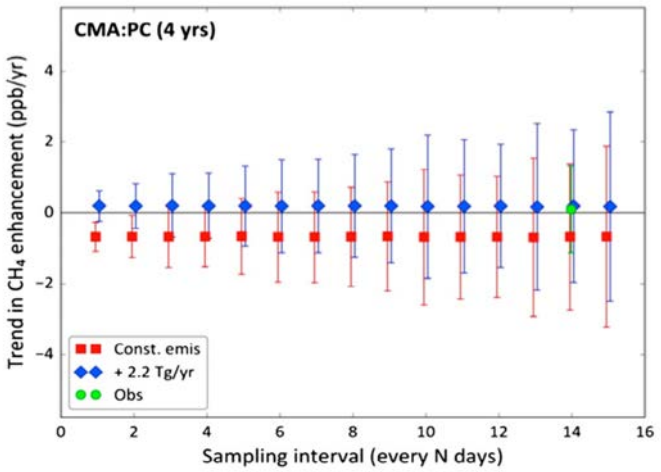
Sweeney et al. 2015

AIRS – Aircraft network,
CH_4 partial column differences



But the Aircraft Network sampling is too **sparse** and **infrequent** to detect changes in fluxes that are relevant to **policy** and **processes**

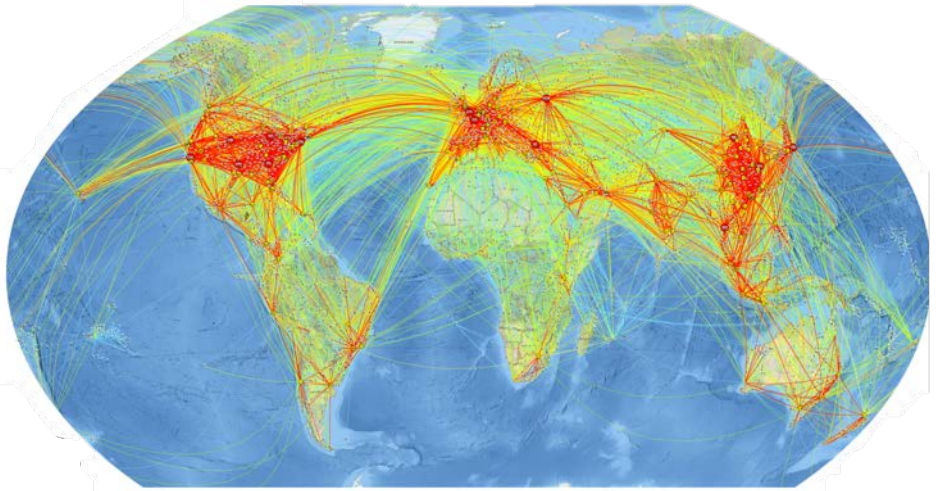
- Interannual variability
- Regional scale
- Trends with realistic magnitudes



Bruhwiler et al. 2017 found that a hypothesized trend in CH_4 emissions from U.S. oil & gas of 2.2 Tg/y would be detectable in the vertical gradient of a single site on the East Coast over 4 years only at a daily sampling frequency.

Ride-along flights present an economical opportunity to increase the coverage, density, and frequency of vertical profile measurements

- Small aircraft routinely flying in remote, under-observed, globally-important regions
- Commercial regional flights



We have amassed thousands of campaign flight hours with a semi-unattended Picarro insitu measurement system for CO_2, CH_4, CO, H_2O

General measurement strategy:

- Sample air not dried; use analyzer-specific empirical H_2O correction
- Cell pressure setpoint lowered to extend upper altitude range
- 1 or 2, 2-L insitu calibration tanks
- Simple checklist followed by an engaged person to operate

Outcomes:

- Define operational and measurement requirements
- Identify risks
- Evaluate measurement uncertainties

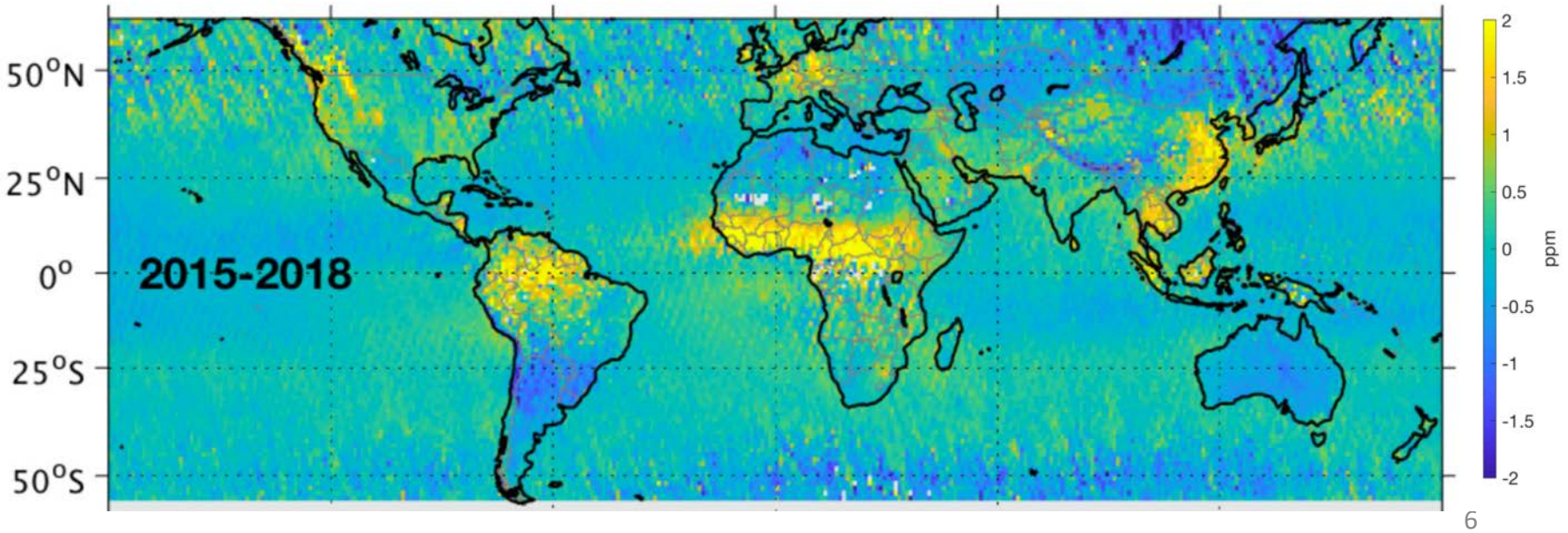
Now we are directing efforts toward ride-along and commercial flight programs

Ride-along and dedicated flights in Tropical Africa

Science goals:

- Investigate an apparent large CO_2 source indicated by the OCO-2 satellite
- Fill a major data gap in the global network

OCO-2 XCO_2 Anomaly



Hakkarainen et al. 2019

Ride-along and dedicated flights in Tropical Africa

Operational requirements:

- Easy and quick to operate
- Low maintenance
- No consumables
- Instrument rack routinely goes on and off the plane

Cessna 208B based in Kampala, Uganda

Ride-along and dedicated flights in Tropical Africa

Goal: Minimize interaction and simplify checklist

Text messages:

- OK: Instrument is “Warming”
- OK: Instrument is “Measuring”.
- GO FLY: Values are within limits.
- Check Instrument: values NOT within limits.
- Shutdown

Picarro instrument GUI (PiG)

Displays status of countdown **timers**, **GPS**, and critical **measurement parameters** in one simple window

Created by Phil Handley

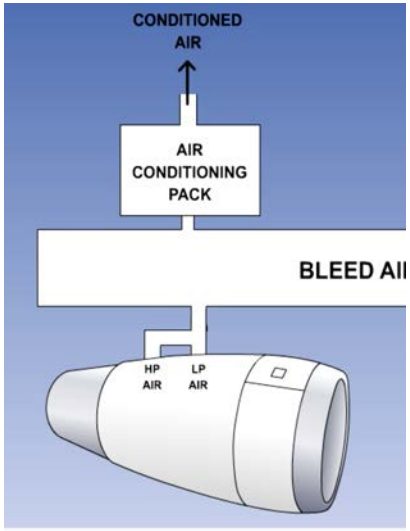
Commercial Flight Test Research Program

Goal: Identify feasible inlet configuration for commercial aircraft program

Why: Inlet type has broad implications for certification process and airline appetite / feasibility / operations

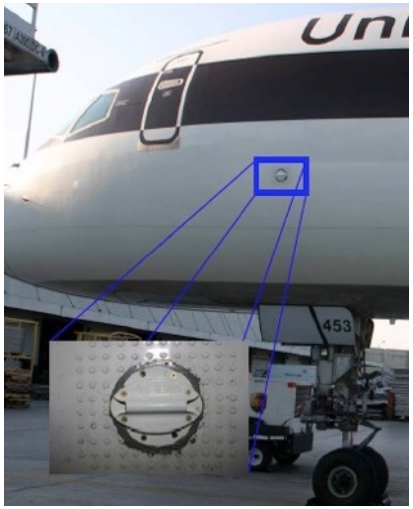
Plan: 3 inlets will be tested with 3 separate measurement systems on a new aircraft flying under experimental certification in a huge range of conditions

Engine bleed (CONTRAIL)



- No need to penetrate fuselage
- Sample at cabin pressure
- Downstream of ozone converter and dehumidifier

Flush-mount (WVSS)



- Certification should be straight forward
- Reduced operational risk for airline
- Not sampling outside of boundary layer

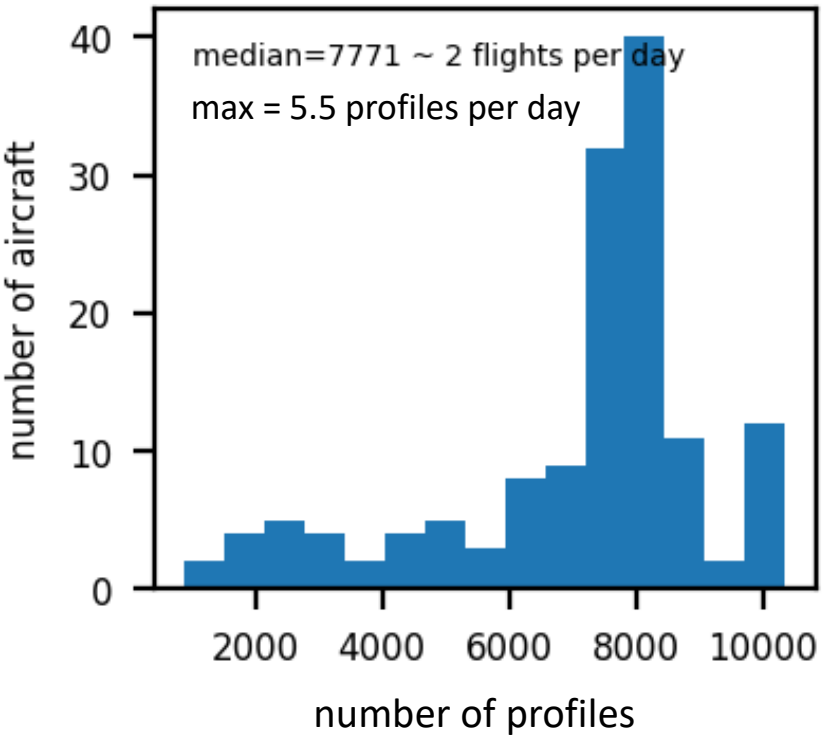
Rosemount (IAGOS)

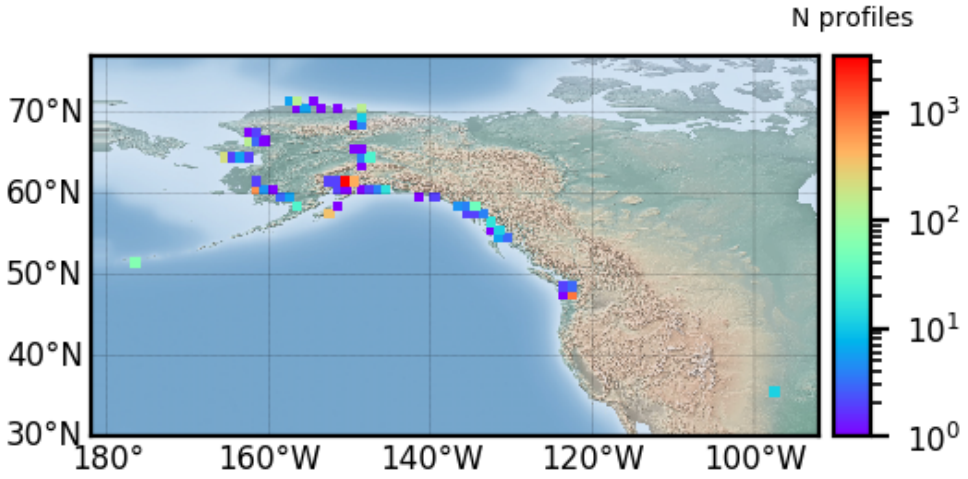
- Certified for most aircraft
- Probe no longer in production
- Needs mounting plate

Observing System Simulation Experiment (OSSE) for a hypothetical regional commercial GHG program

Observation times and locations from AMDAR (Aircraft Meteorological DAta Relay)

- Data obtained from NOAA/PSL
- Extracted all flight tracks by tail number from a target airline from 2011-2015
- Selected random sample of 10 tail numbers
- Selected stratified random samples of tail numbers flying more in certain regions





Some aircraft stay on the same routes

AMDAR data extracted Andy Jacobson

Observing System Simulation Experiment (OSSE) for a hypothetical regional commercial GHG program

Setup

- Truth fluxes: CAMS v18r3 optimized CO_2 fluxes
- TM5 transport to generate posterior concentrations from CAMS fluxes
- Synthetic data generated from concentrations for randomly selected tail numbers from AMDAR and for GV+ ObsPack (existing observations)
- CarbonTracker inversion system with TM5 transport to retrieve fluxes
- "perfect data, perfect model"

Questions

- Compare accuracy of retrieved fluxes for North America in total, smaller regions, interannual and seasonal variability
- Impact of different numbers of instrument aircraft
  - 1, 3, or 10
  - 2 with mostly Alaska routes
  - 2 with many East Coast routes

OSSE setup by Andy Jacobson

Summary

- The NOAA GGGRN Aircraft Network is unique and scientifically useful, but it does not meet the needs of science and society.
- Ride-along and commercial flights present an economical opportunity to increase the coverage, density, and frequency of vertical profile GHG measurements.
- Current efforts toward this goal:
  - Minimize operational requirements for ride-along flights
  - Identify feasible inlet configurations on commercial aircraft
  - Commercial Aircraft OSSE to quantify and articulate the impact

COVID-19 Pandemic Imperils Weather Forecast

Ying Chen ✉ **Geophysical Research Letters**

First published: 15 July 2020 | https://doi.org/10.1029/2020GL088613

- COVID-19 pandemic lockdowns led to 50-75% reduction in aircraft meteorological observations, leading to a significant deterioration in weather forecasts
- The impact over Western Europe is buffered by the high density of conventional observations

➢ A lesson for building a resilient and robust observing system