NOAA/GML STRATOSPHERIC SAMPLING USING AIRCORE: ROUTINE MEASUREMENTS, SATELLITE EVALUATION AND MODEL COMPARISONS

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NOAA/GML AirCore over the past decade(s)

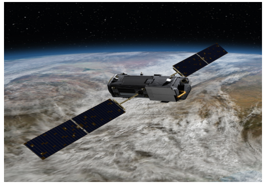
1st AirCores developed and launched by NOAA

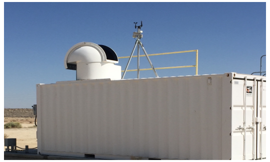
AirCore system/method patent published
Tans, 2009

AirCore comparisons to in-flight CRDS, methods published
Karion et al., 2010

Lower volume, lightweight, dual AirCores flown on single balloon payload

-AirCore remote sensing evaluation of XCO2, XCH4
-RINGO international AirCore comparison effort





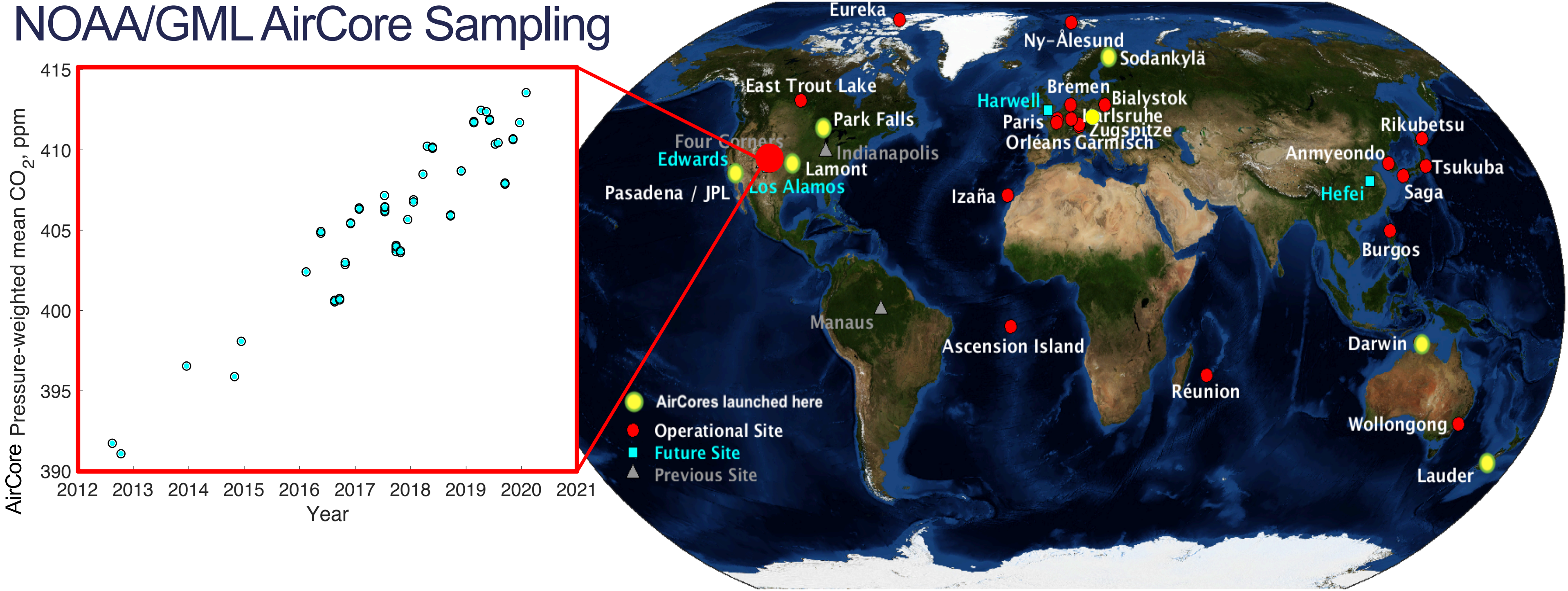
1st AirCore N_2O measurements

AirCore HORUS constructed

Expanded AirCore sampling locations, satellite evaluation efforts, new species measured

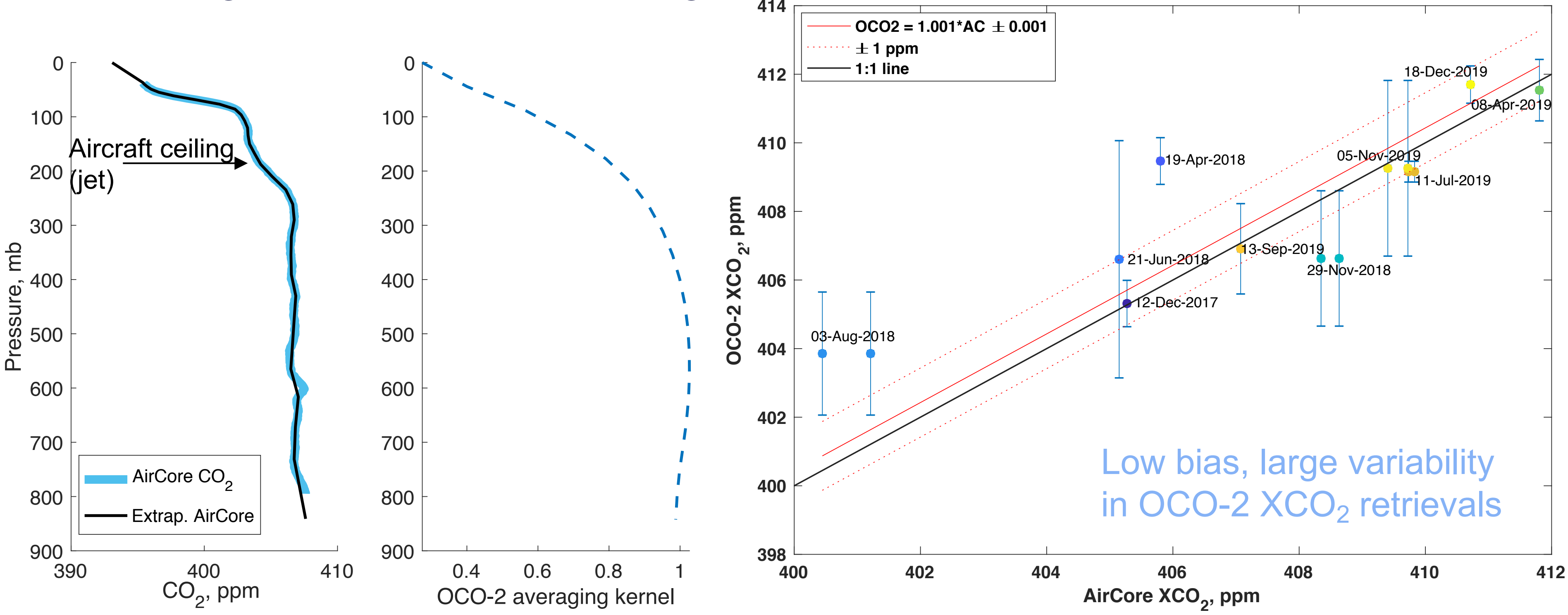
2007 2009 2010 2016 2018 2019 2020 202X

NOAA/GML AirCore Sampling



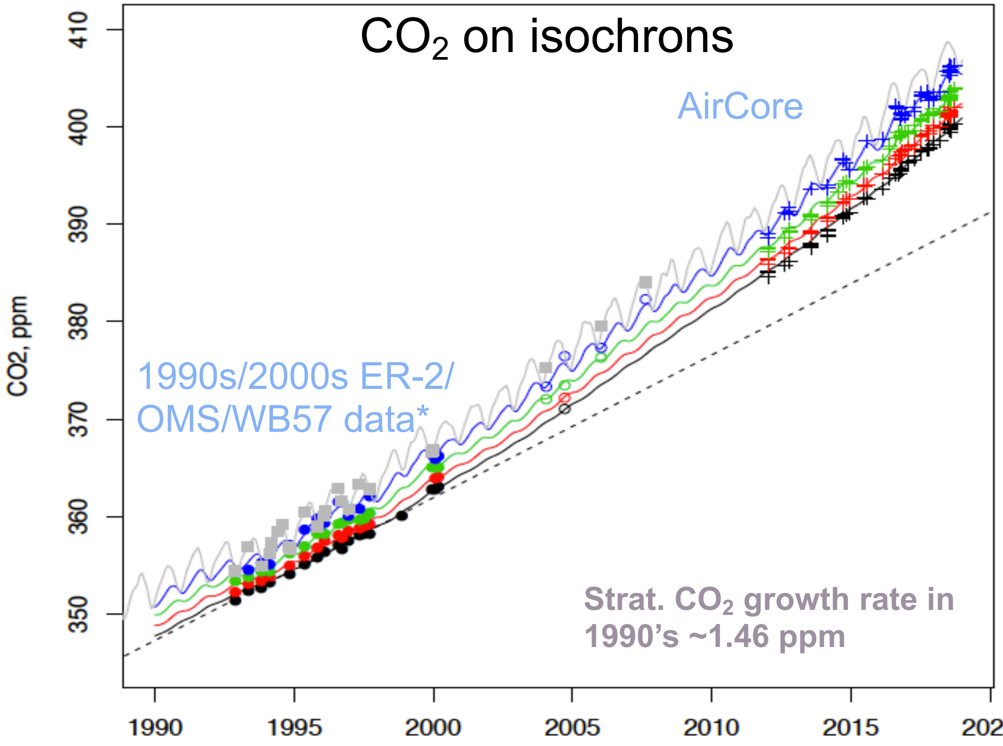
- Over a decade of NOAA/GML AirCore sampling with >100 CO_2, CH_4, CO profiles retrieved from select locations
- Routine, near-monthly balloon launches in Colorado: coordinated with A-train overpasses for OCO-2 evaluation
- Several small-scale field campaigns since 2018:
  - Remote sensing evaluation within Total Carbon Column Observing Network (TCCON) : OCO-2, ground-based FTS inter-comparisons
  - ICOS RINGO collaboration (Sodankylä, Traînou) – AirCore inter-comparisons, towards a global AirCore network

Satellite trace gas retrieval evaluation using AirCore



- Satellite trace gas retrievals cannot be calibrated, which lessens compatibility with ground-based observing networks
- Rely on resources like global TCCON, which is scaled to calibrated aircraft and AirCore GHGs traceable to WMO scales
- To-date, 11 AirCores launched coincidentally with OCO-2 overpasses in NE Colorado
- AirCores capture >98% of atmospheric column: less “extrapolation” involved, greater potential error reduction in retrievals by comparison to AirCore vs. aircraft

Stratospheric modeling efforts and comparison to AirCore



*Critical measurements made by NOAA/GML (OZWV, HATS) used to develop model stratospheric CH_4, N_2O relationships

- Accurately modelling stratospheric CO_2, CH_4 is critical for improving apriori GHG profiles for ground-based FTS retrievals (e.g. TCCON)
- Also critical for investigating age of air , stratospheric dynamics

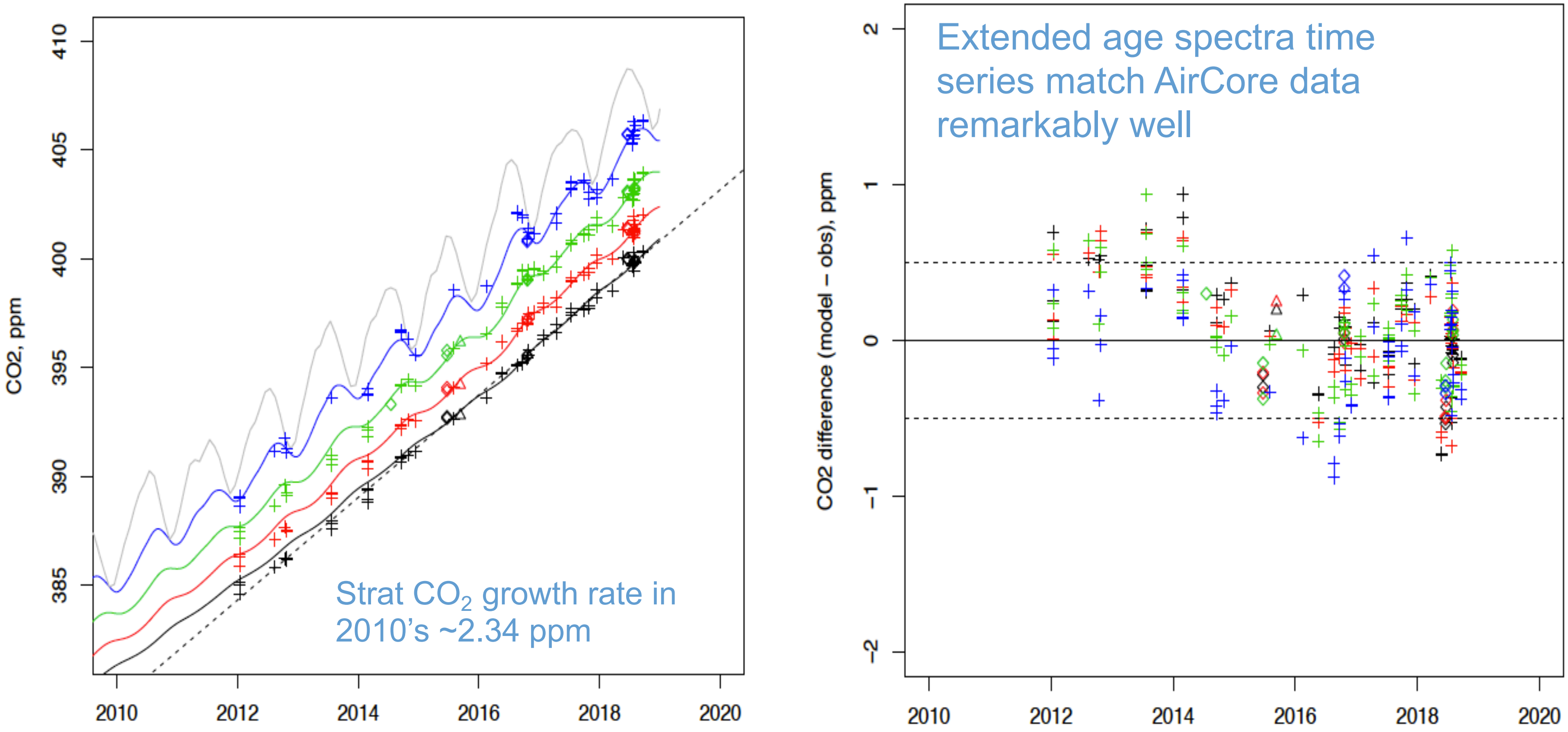
Age spectra from 2-D stratospheric model

+ CO_2 stratospheric boundary conditions (MLO, SMO)

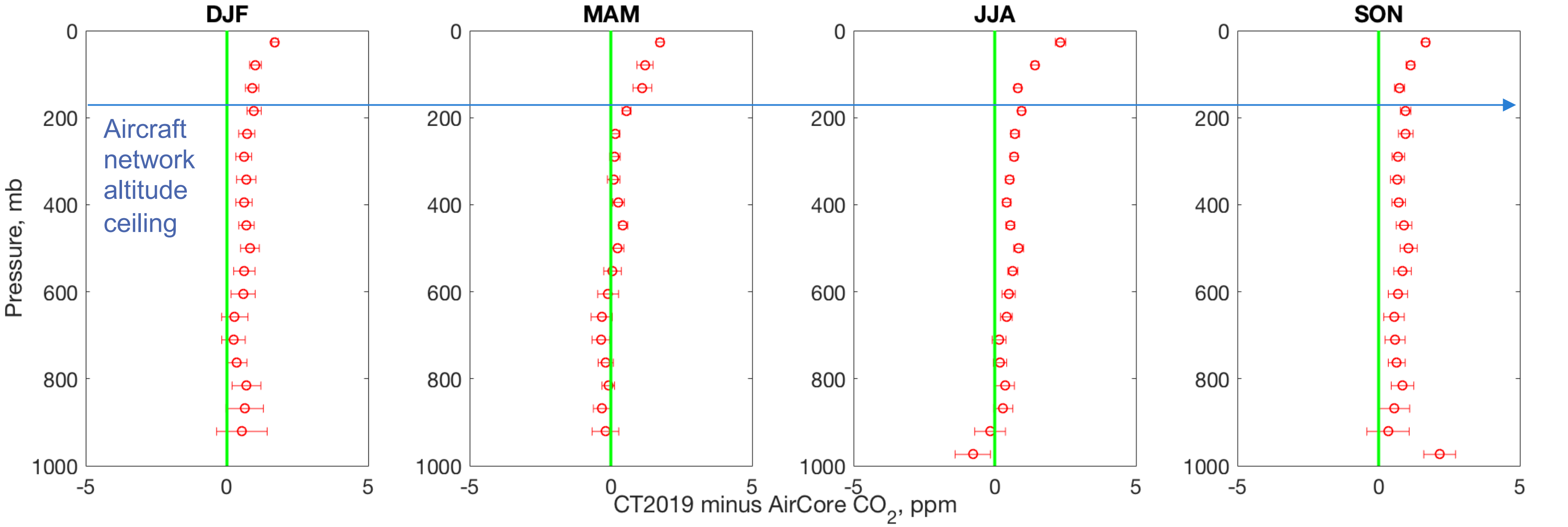
= CO_2 time series corresponding to each Mean Age

A. Andrews, with E. Fleming, F. Moore, D. Hurst, G. Dutton, J. Elkins

Stratospheric modeling efforts and comparison to AirCore



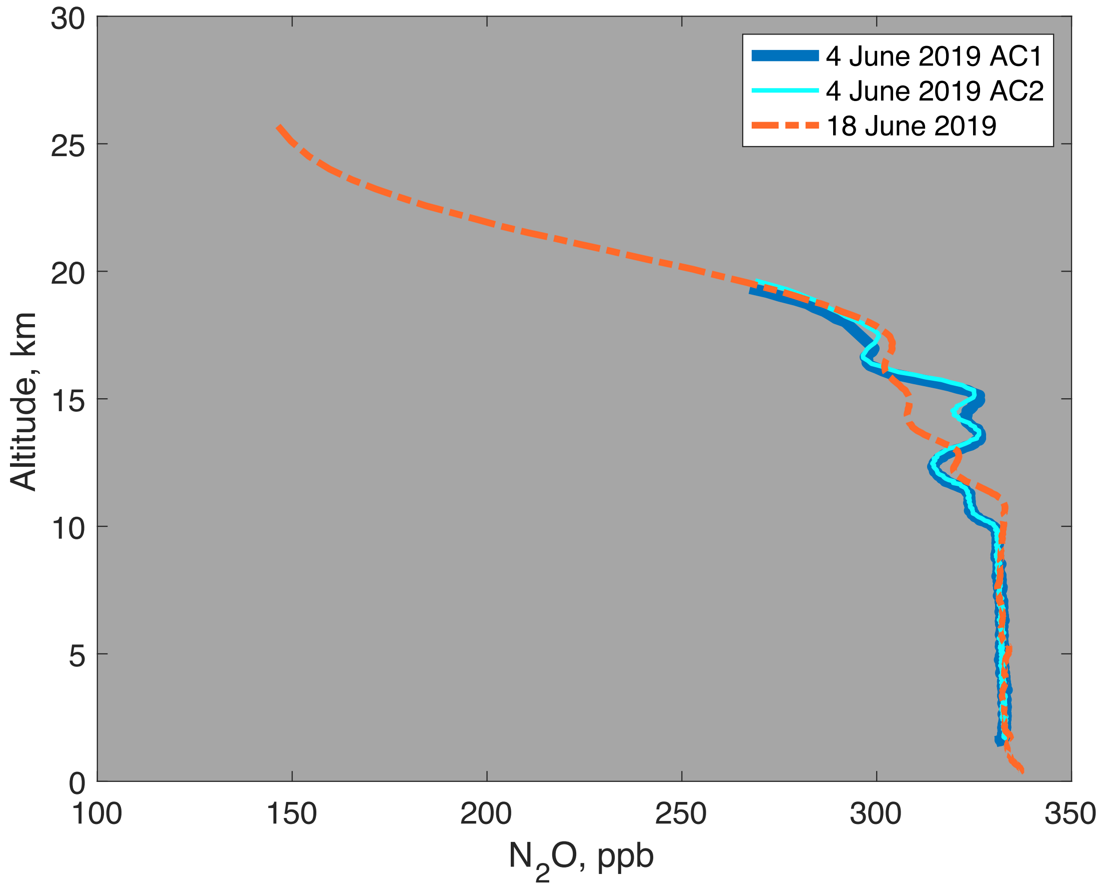
CarbonTracker (CT2019) evaluation of stratospheric CO_2 using AirCores



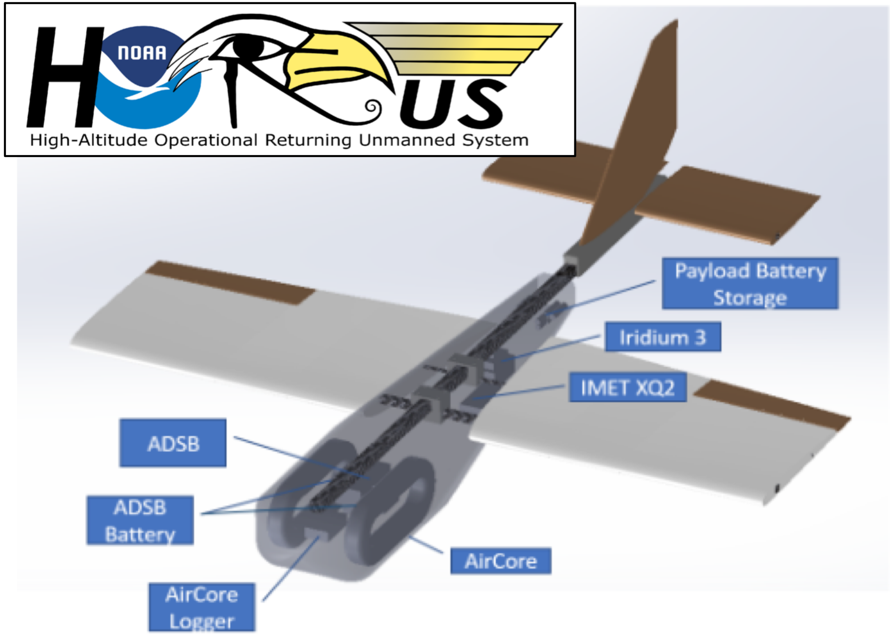
- CarbonTracker is NOAA's CO_2 inverse modeling framework for mole fraction, flux estimation (*Jacobson et al., 2020; http://www.carbontracker.noaa.gov*)
- CT assimilates routine NOAA CCGG Aircraft Network flask CO_2 measurements to ~12-13 km MSL
- AirCore samples from 2009-2020 extend to ~30km MSL, provide some of the only routine GHG measurements in UT/LS for model evaluation

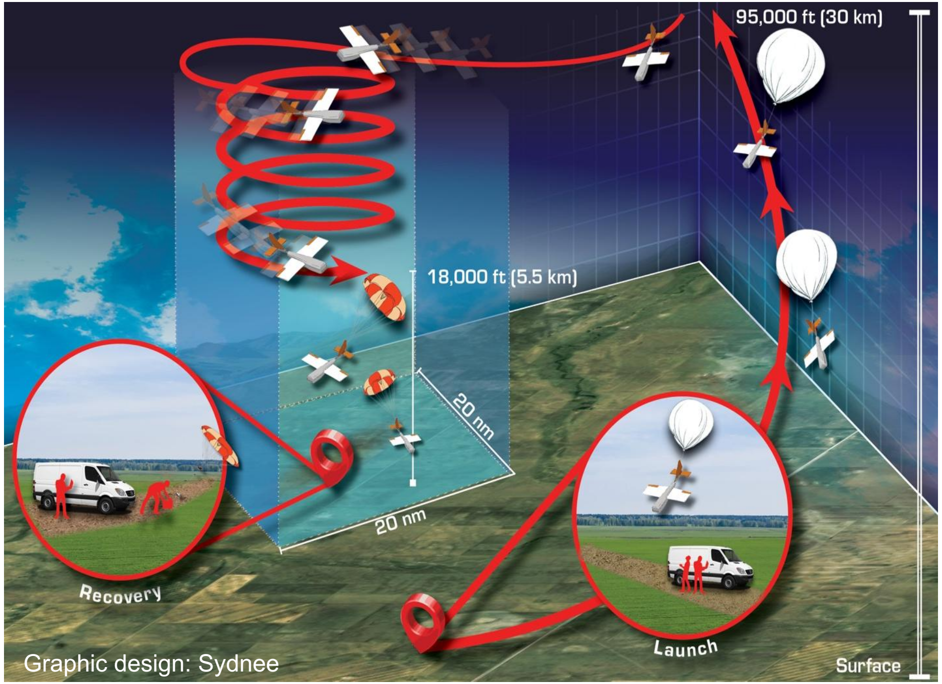
New development: measurement of N_2O in AirCores

- Nitrous oxide (N_2O) is potent GHG, long-lived: useful for investigating stratospheric circulation and change
- CO_2 + N_2O in routine AirCore samples informs stratospheric tracer-tracer relationships
- Demonstrated use of high-precision Picarro N_2O-CO + 4-channel (CO2-CH4-CO-H2O) Picarro to measure species concurrently in AirCores
- First full N_2O profiles retrieved in AirCores



New development: High-altitude AirCore sampling platform





- Biggest limitation with balloon-borne AirCore sampling is feasibility of recovery
- Custom design: portable, lightweight, optimized for AirCore and scientific payload
- **Revolutionize surface to stratosphere sampling, enhance weather forecasting capabilities, and further satellite retrieval and algorithm evaluation**

Summary

- We have a growing time series of retrieved AirCore profiles since ~2010 in Colorado
- Routine, long-term monitoring of the AirCore is useful tool in evaluating modeled greenhouse gases in the stratosphere
- As satellite community continues to grow, multiple end users in ground-, satellite-based remote sensing communities (NOAA CrIS, TROPOMI, MOPITT, A-train constellation, etc.) benefiting from routine AirCore sampling
- Collaboration between AirCore groups globally is crucial for furthering AirCore technique and working towards establishing global "AirCore Network"
- The ability to measure new species in AirCore whole-air samples opens up new possibilities for GML stratospheric observing capabilities
- As does a recoverable platform for high-altitude sampling

Funding acknowledgements:

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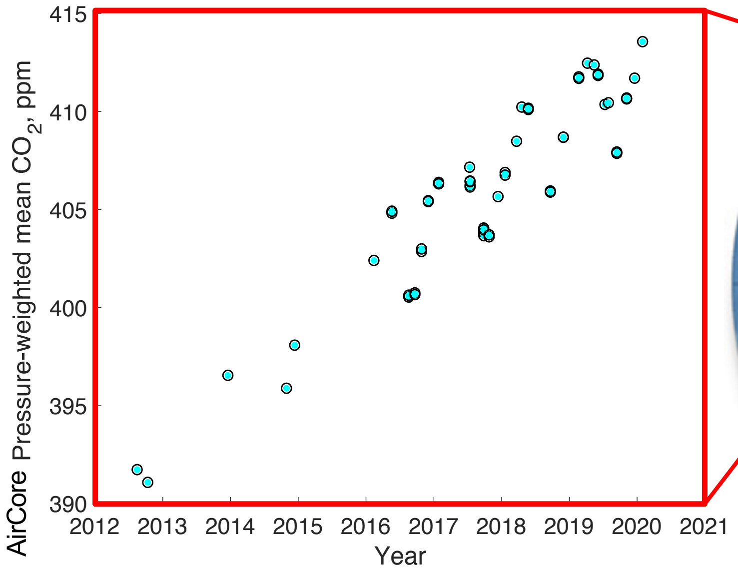
NASA ROSES, NASA Jet Propulsion Laboratory

BACKUP SLIDES

NOAA/GML AirCore Sampling



- Over a decade of NOAA/GML AirCore sampling with >100 CO_2, CH_4, CO profiles retrieved from select locations
- Routine, near-monthly balloon launches in Colorado
  - Now coordinated with A-train overpasses in NE Colorado for OCO-2 evaluation
- Several small-scale field campaigns since 2018
  - Remote sensing evaluation at U.S. TCCON stations: OCO-2, ground-based FTS inter-comparisons
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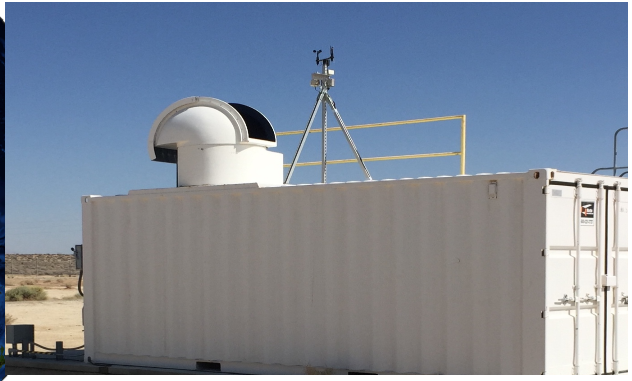
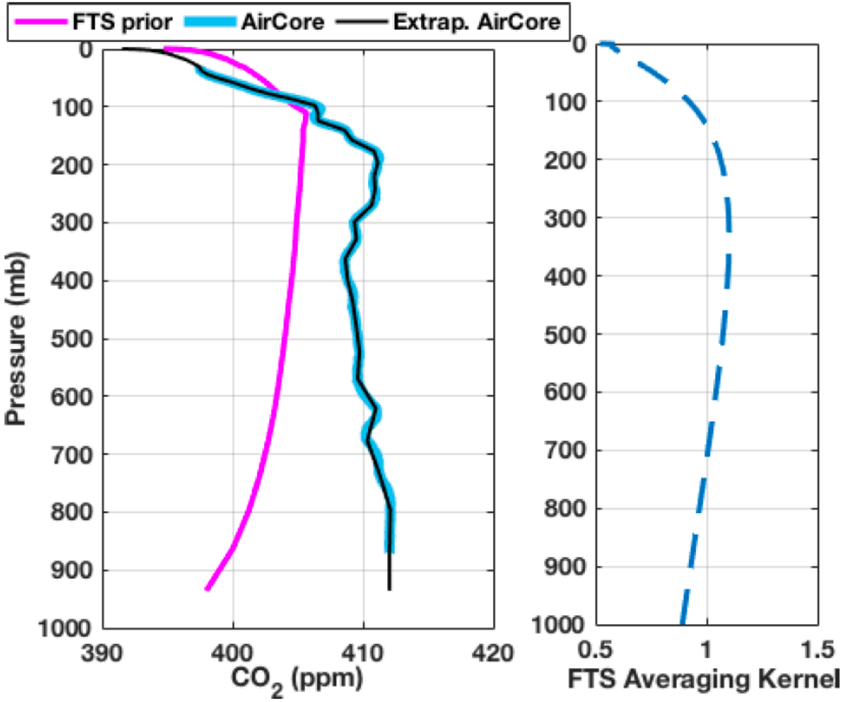
Satellite trace gas retrieval evaluation



- Total Carbon Column Observing Network (TCCON) is primary resource for evaluating satellite trace gas retrievals
- NASA's Orbiting Carbon Observatory relies heavily on TCCON total-column CO_2
- BUT ground-, satellite-based total column GHG retrievals cannot be calibrated, lessening compatibility with ground-based observing networks tied to WMO trace gas scales, and utility for GHG flux estimation

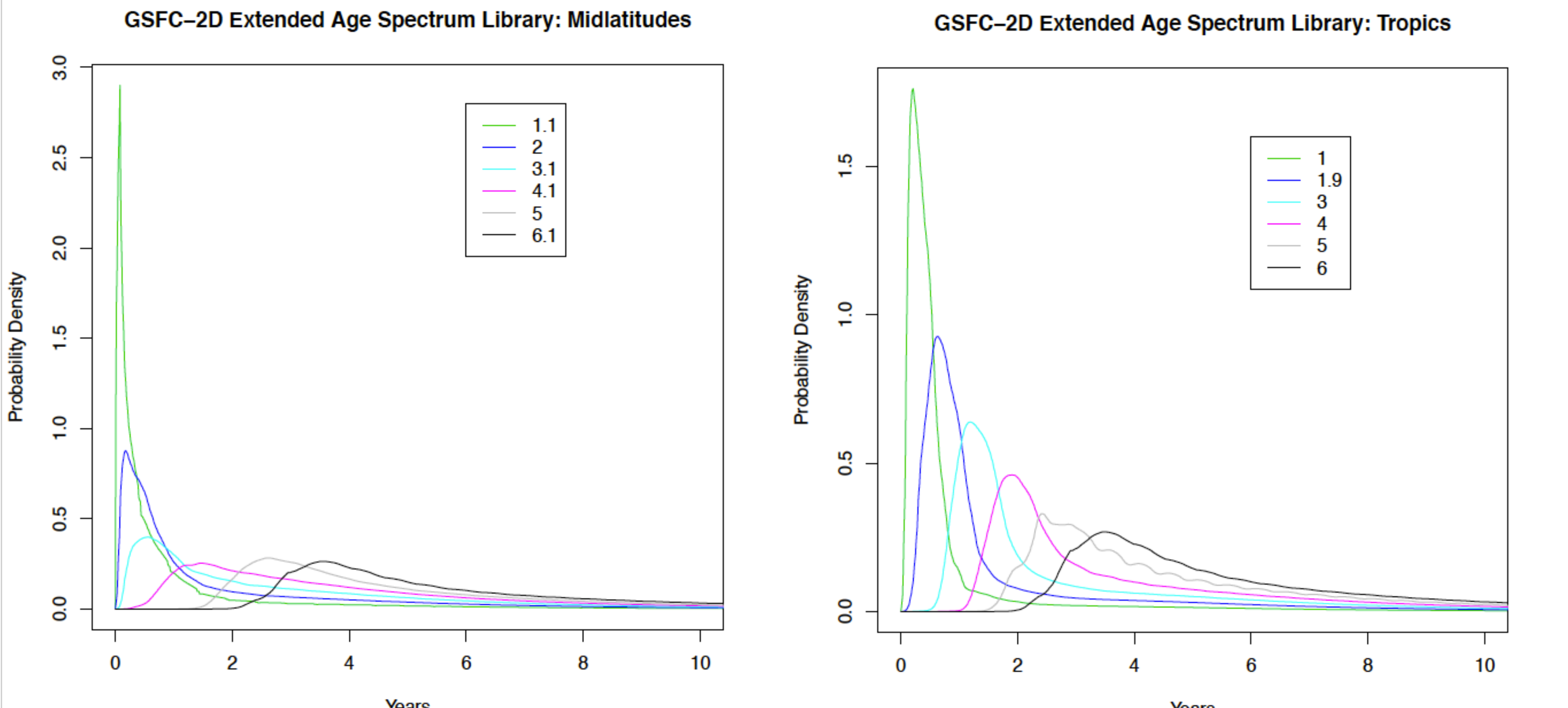
TCCON FTS remote sensing evaluation

- AirCore is low-cost, low effort pathway to sample over 98% of atmospheric column
- Spaceborne greenhouse and trace gas retrievals cannot be calibrated, which lessens compatibility with long-term, calibrated ground-based network observations
- AirCore profiles are calibrated, tied to WMO scales, which provides a link between spaceborne observations and ground-based observing networks

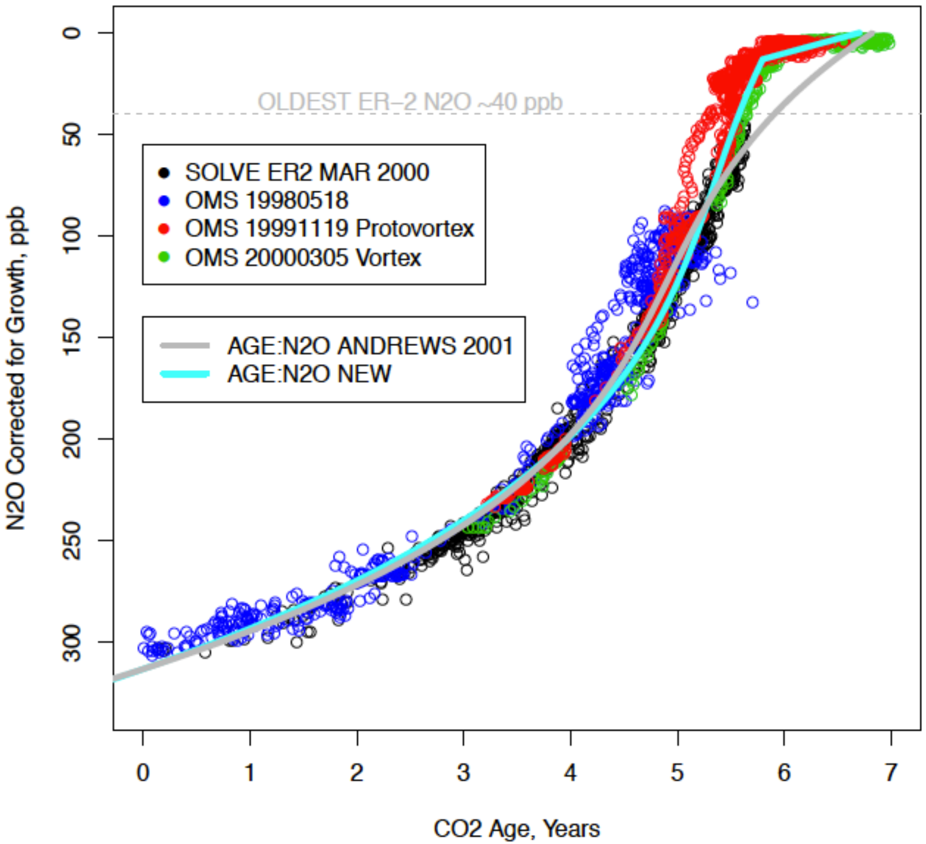


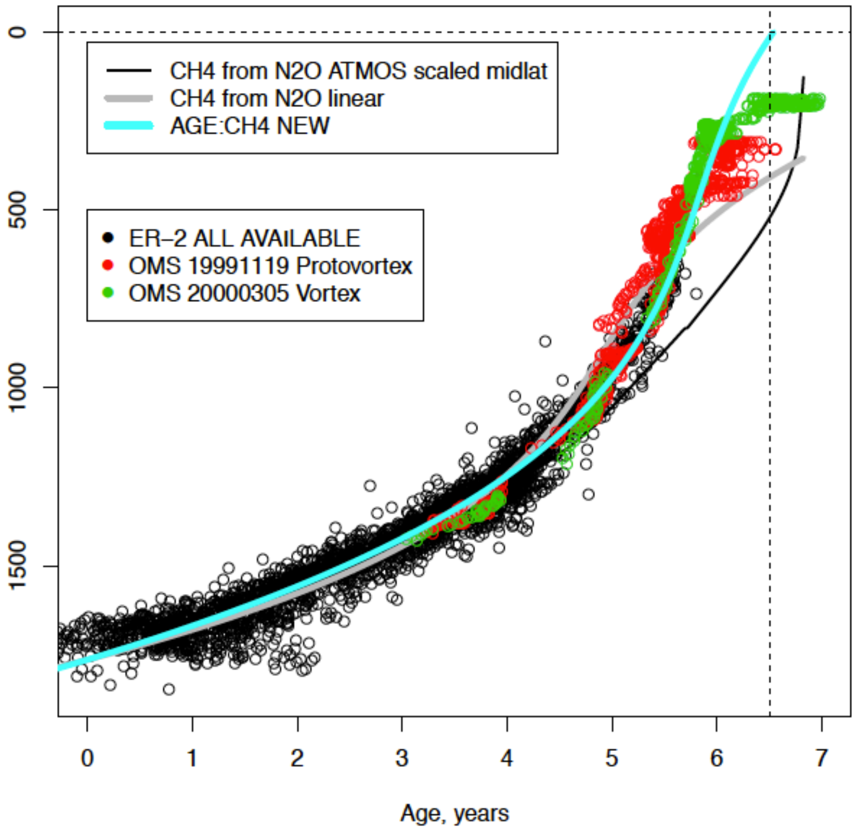
Platform	Range	Cost ($)	XCO_2 error
Small aircraft	0-8 km	1.5K	0.77-2.14 ppm
Jet	0-12 km	10K	0-0.4 ppm
AirCore	0-30km	5K (long-term)	0.1 ppm

Age Spectra are from GSFC 2D Model (Eric Fleming) that was optimized to match in situ CO2 and SF6 balloon observations from 1990s/2000s:



Mean Age versus N2O and Mean Age versus CH4 relationships are surprisingly invariant throughout the lower/middle stratosphere:





CarbonTracker evaluation of stratospheric CO_2 using AirCores

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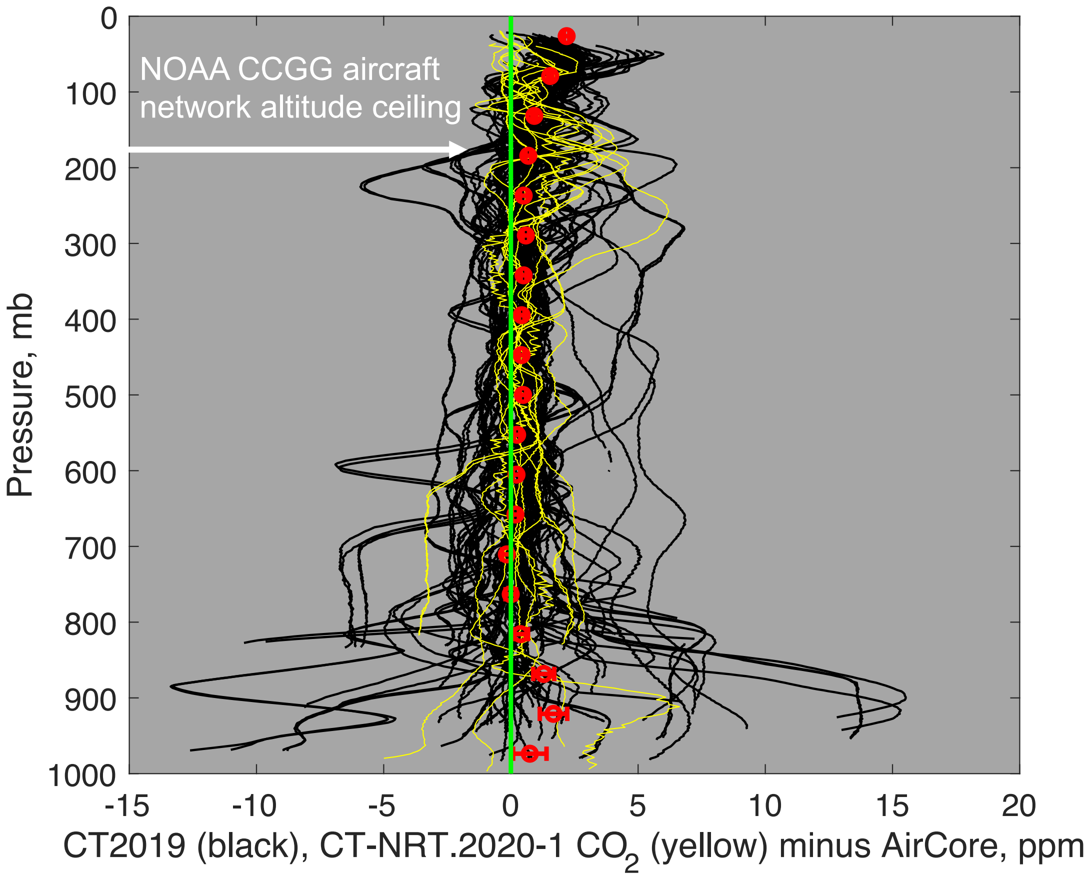
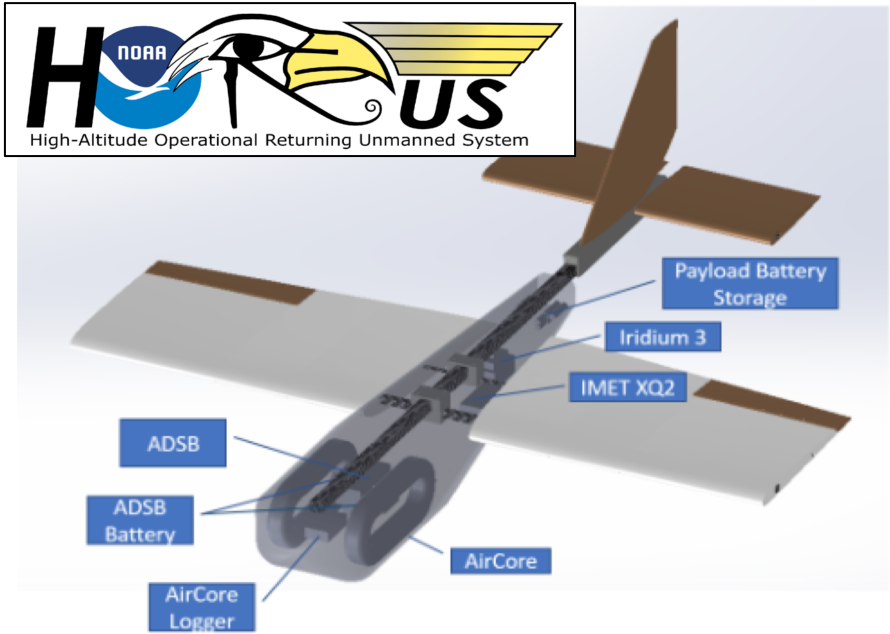


Jacobson et al., 2020, http://carbontracker.noaa.gov

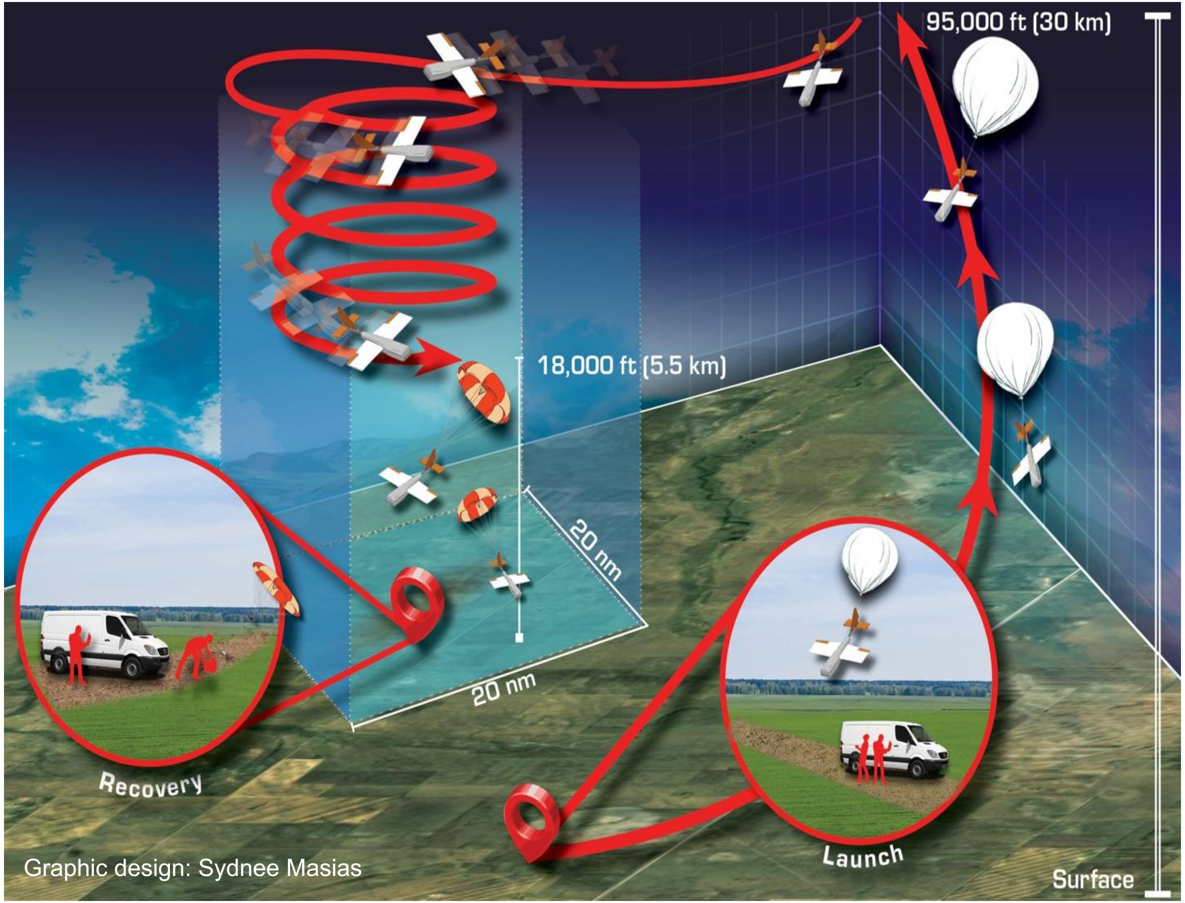
New development: High-altitude AirCore sampling platform



- Biggest limitation with balloon-borne AirCores is feasibility of recovery
  - Trees, accessibility, water all barriers to [quick] recovery and lab analysis
- Custom design: portable, lightweight, optimizes glide ratio for controlled descent rate (~10 ms^{-1}) for more efficient AirCore stratospheric sample collection, reduction in meteorological sensor hysteresis

New development: High-altitude AirCore sampling platform

- Balloon ascent, autopiloted descent
- Large payload capacity for housing multiple sensors (i.e. FPH, POPS)
- Can return e.g. high-accuracy sensors typically carried on weather balloons
- **Revolutionize surface to stratosphere sampling, enhance weather forecasting capabilities, and further satellite retrieval and algorithm evaluation**



Graphic design: Sydnee Masias