Using NOAA AirCore vertical profiles to evaluate satellite retrievals and establish WMO traceability: applications to NASA's OCO-2 program and implications for future work

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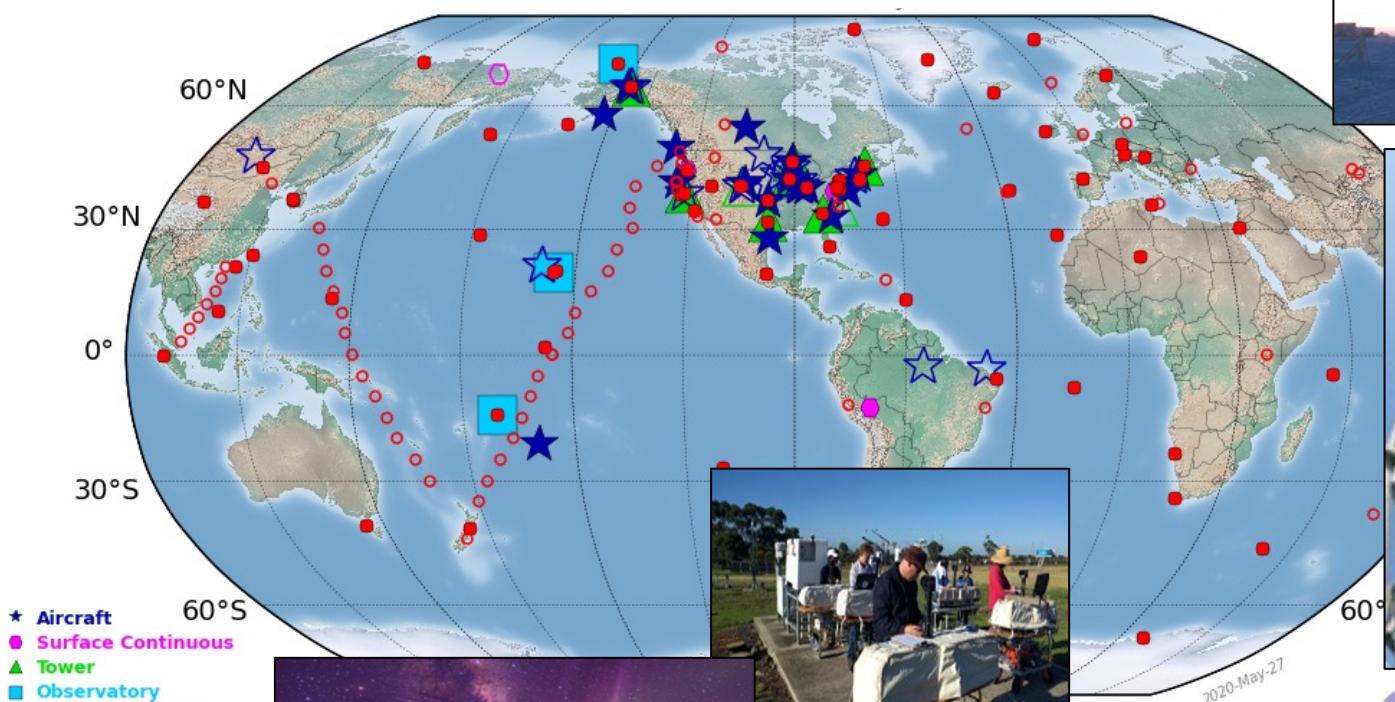
Integrated spaceborne and surface GHG observing

- Understanding global carbon cycle relies on integrated earth observing system that is fully compatible
- High-quality surface in situ observations tied to WMO trace gas standard scales
- Sparse data coverage

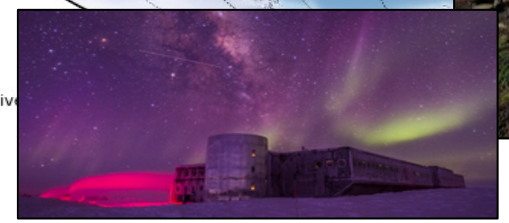
NOAA Global Greenhouse Gas Reference Network



Balloon

Aircraft

Tower



Ground

Figure credit: https://ocov2.jpl.nasa.gov/observatory/

Integrated spaceborne and surface GHG observing

- Satellites like NASA's OCO-2 offers global coverage of XCO2

- For retrievals to be useful for advancing our knowledge of CO_2 variability and fluxes , missions must incorporate evaluation programs that scale to WMO trace gas standard scales

Balloon

Aircraft

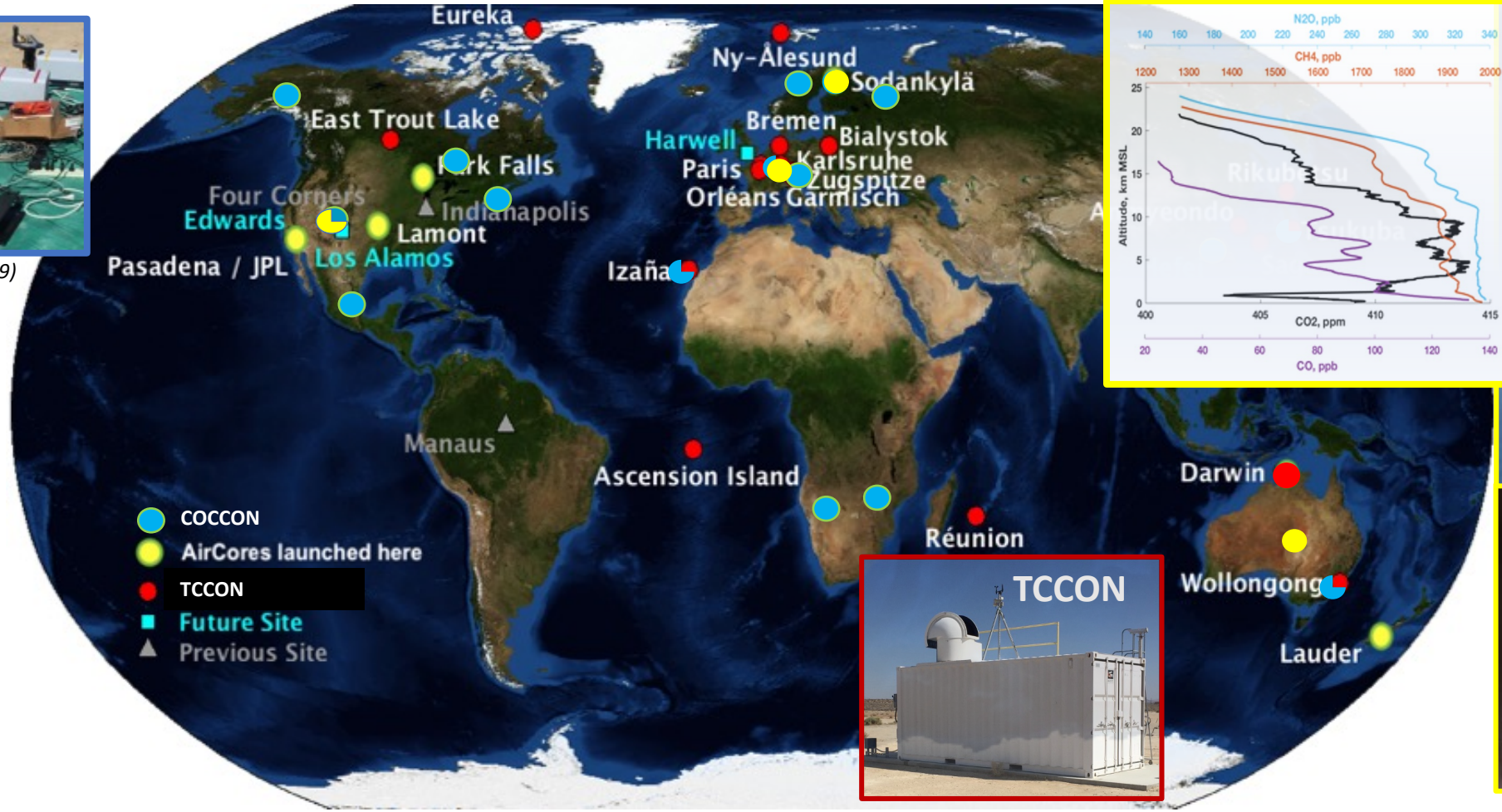
Tower

Ground

Figure credit: https://ocov2.jpl.nasa.gov/observatory/, https://disc.gsfc.nasa.gov/datasets/OCO2_L2_Lite_FP_9r/summary

AirCore remote sensing evaluation

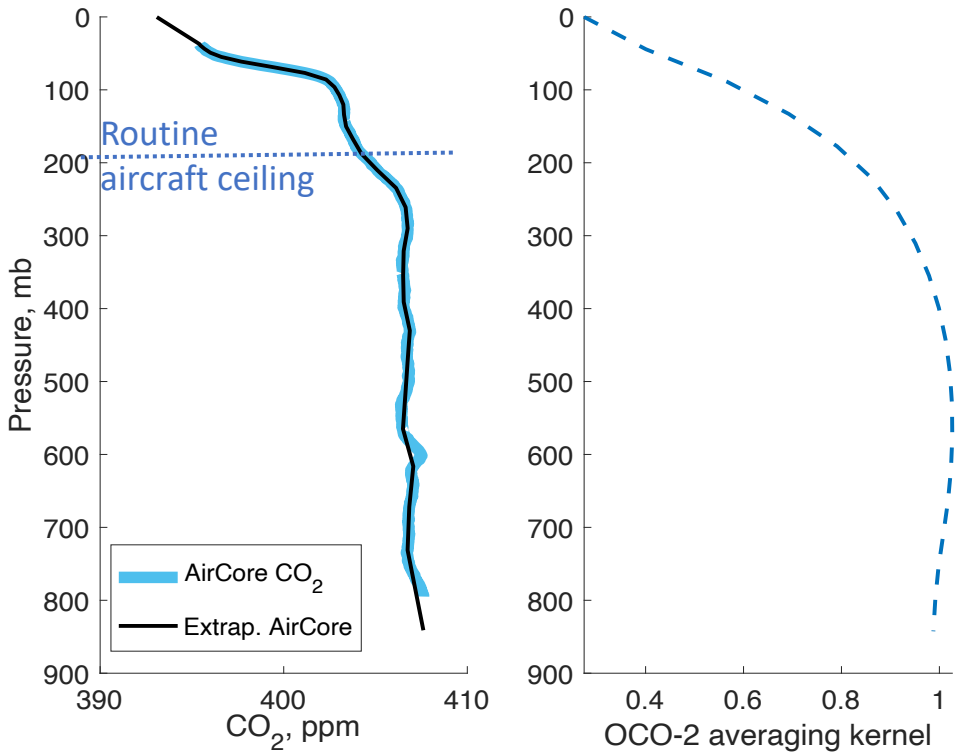
(EM27/SUN, Frey et al., 2019)

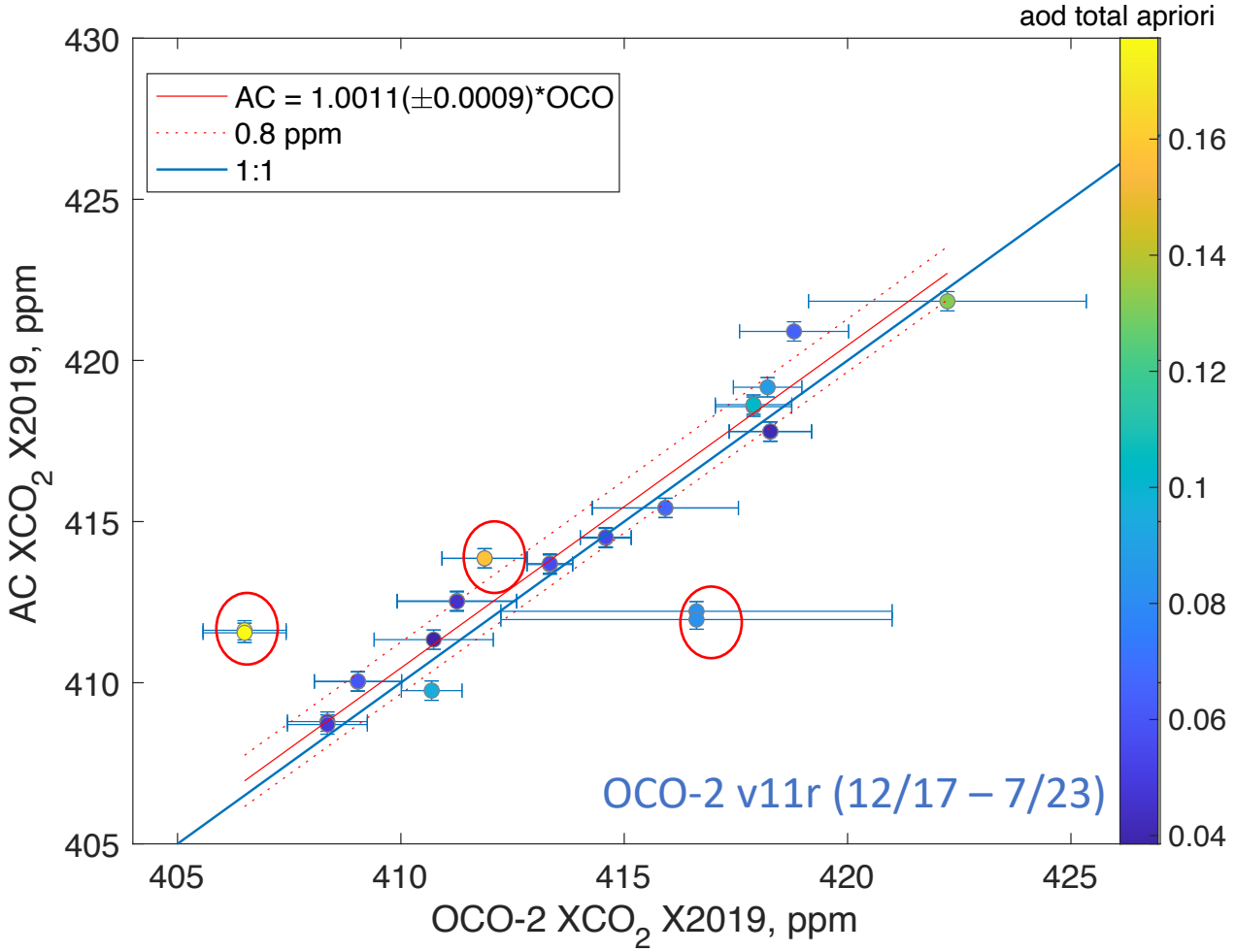


(Karion et al.,2010; Tans, 2022)

- AirCore a **low-cost** in situ method for capturing > 95% of atmosphere, greater potential for error reduction in XCO_2 relative to aircraft

1. AirCore-OCO-2 comparisons 2018-2023: NE Colorado

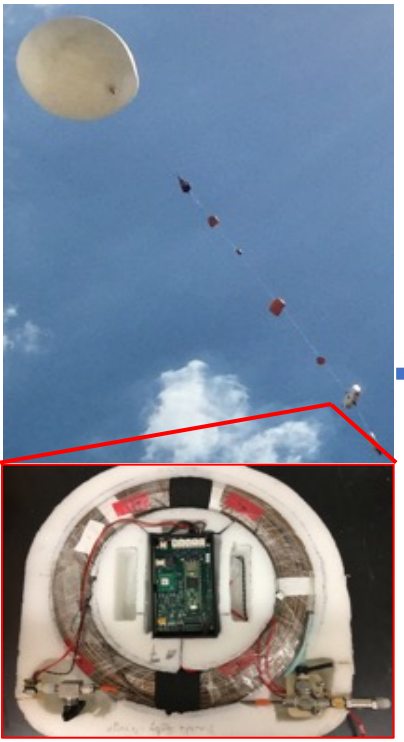




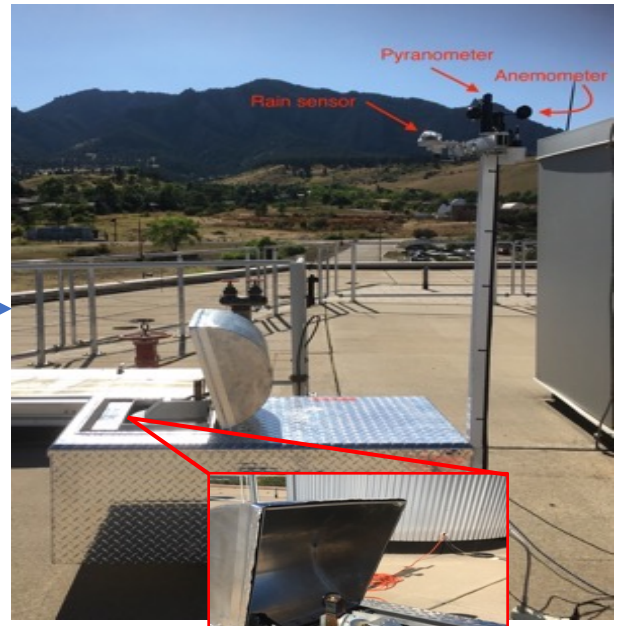
- AirCores launched on ~monthly basis
- Long-term evaluation efforts required to:
  - Establish robust scaling for OCO-2
  - Maintain WMO compatibility across standard scales and observing networks
  - Evaluate new data product releases

- Large outliers seen during wildfire events
- Error bars: 1σ in OCO-2 XCO_2 over colocation time period (1° lat/lon, and +\- 1.5 h surrounding AirCore landing time)
- Not a lot of comparison data!

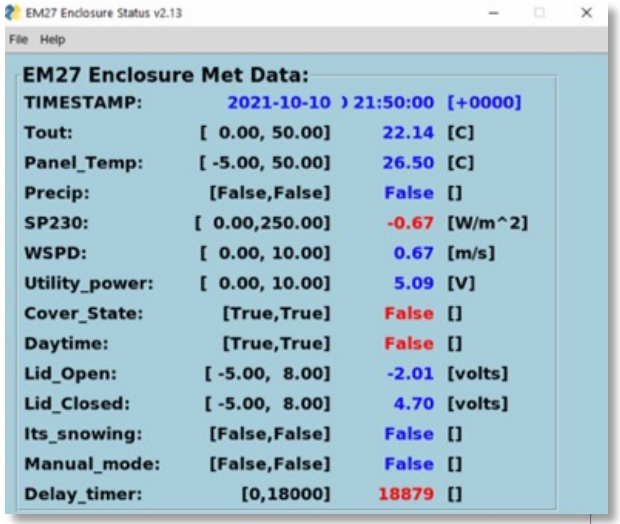
2. Use of portable EM27/SUN as “transfer standard”

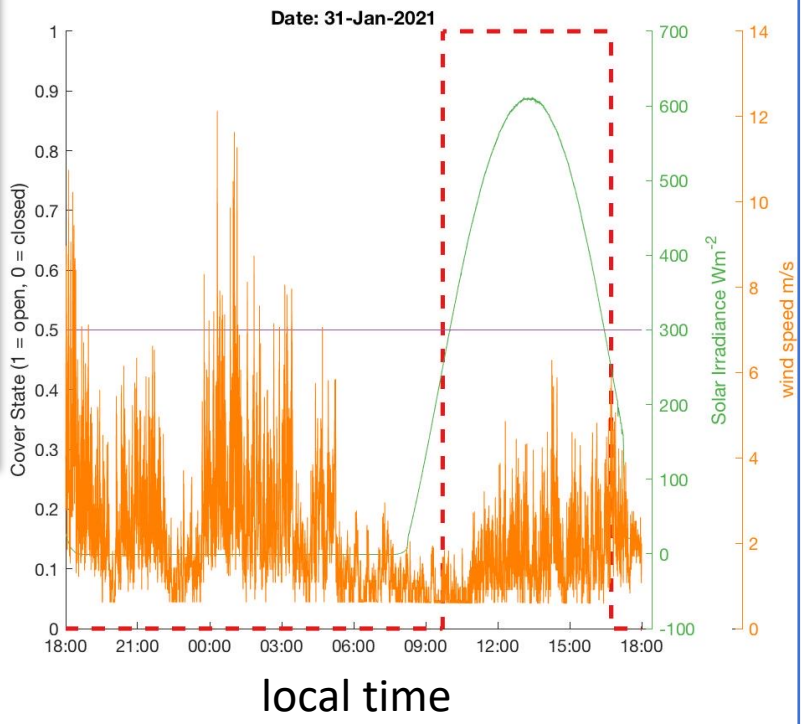


AirCore (calibrated)



Deitrich et al., 2021

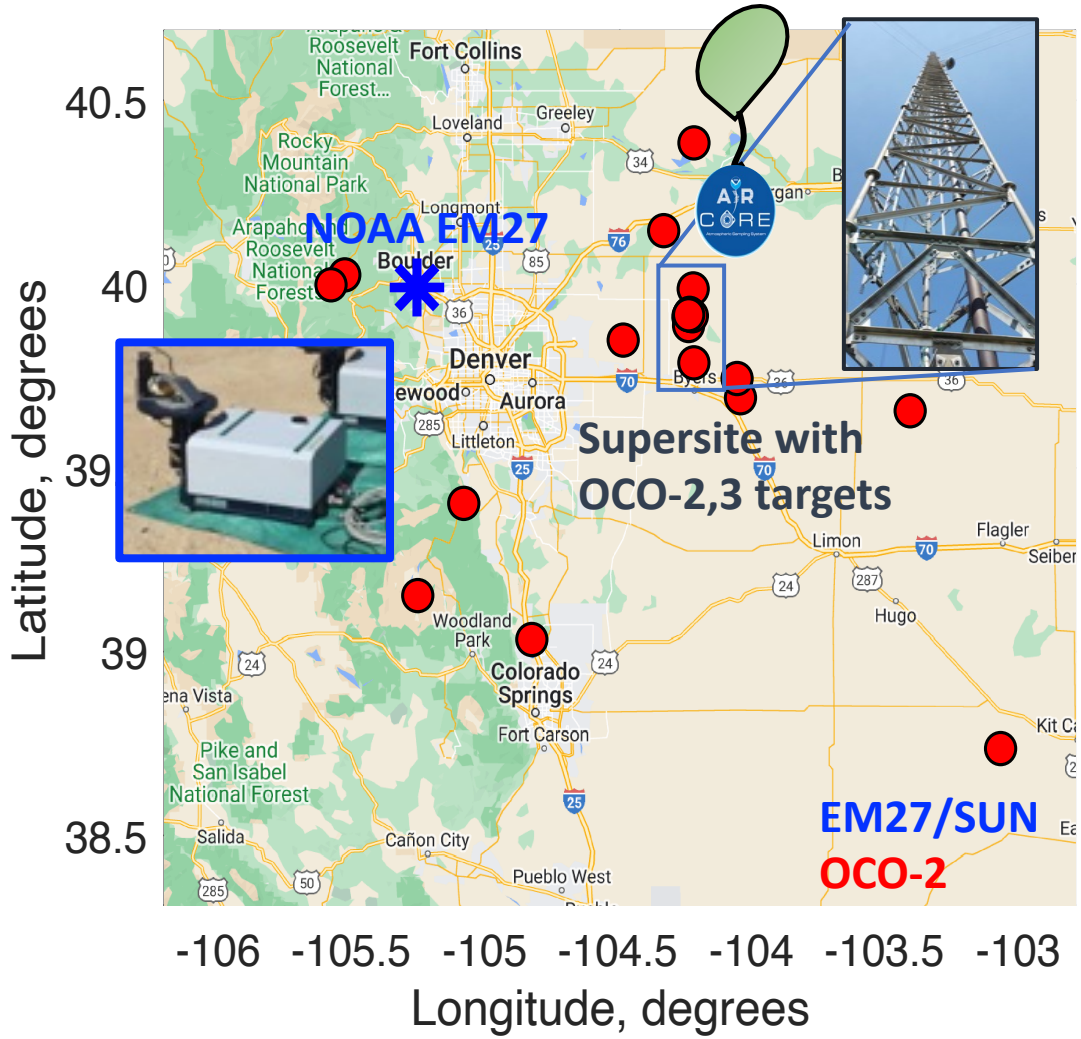


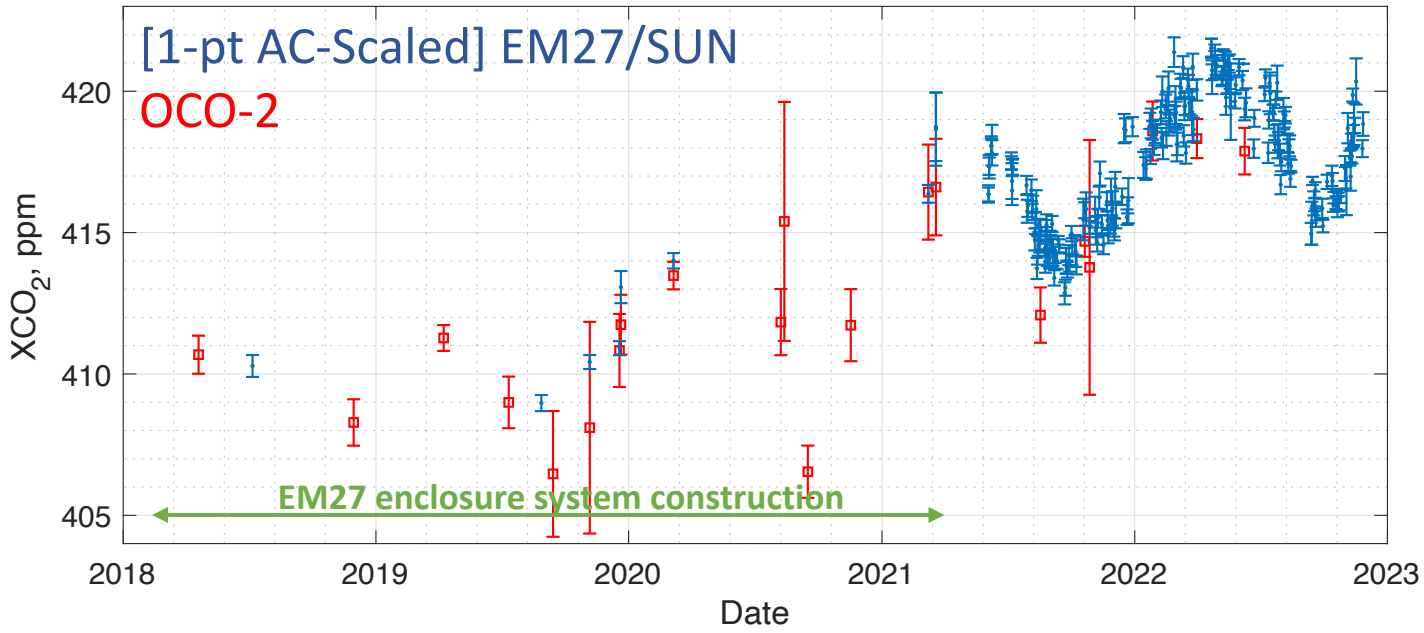


Autonomous EM27 at OCO-2 target location

- Use AirCore-scaled EM27/SUN retrievals as a “transfer standard” for OCO-2 WMO traceability
- EM27/SUN enclosure system allows for near-autonomous measurements

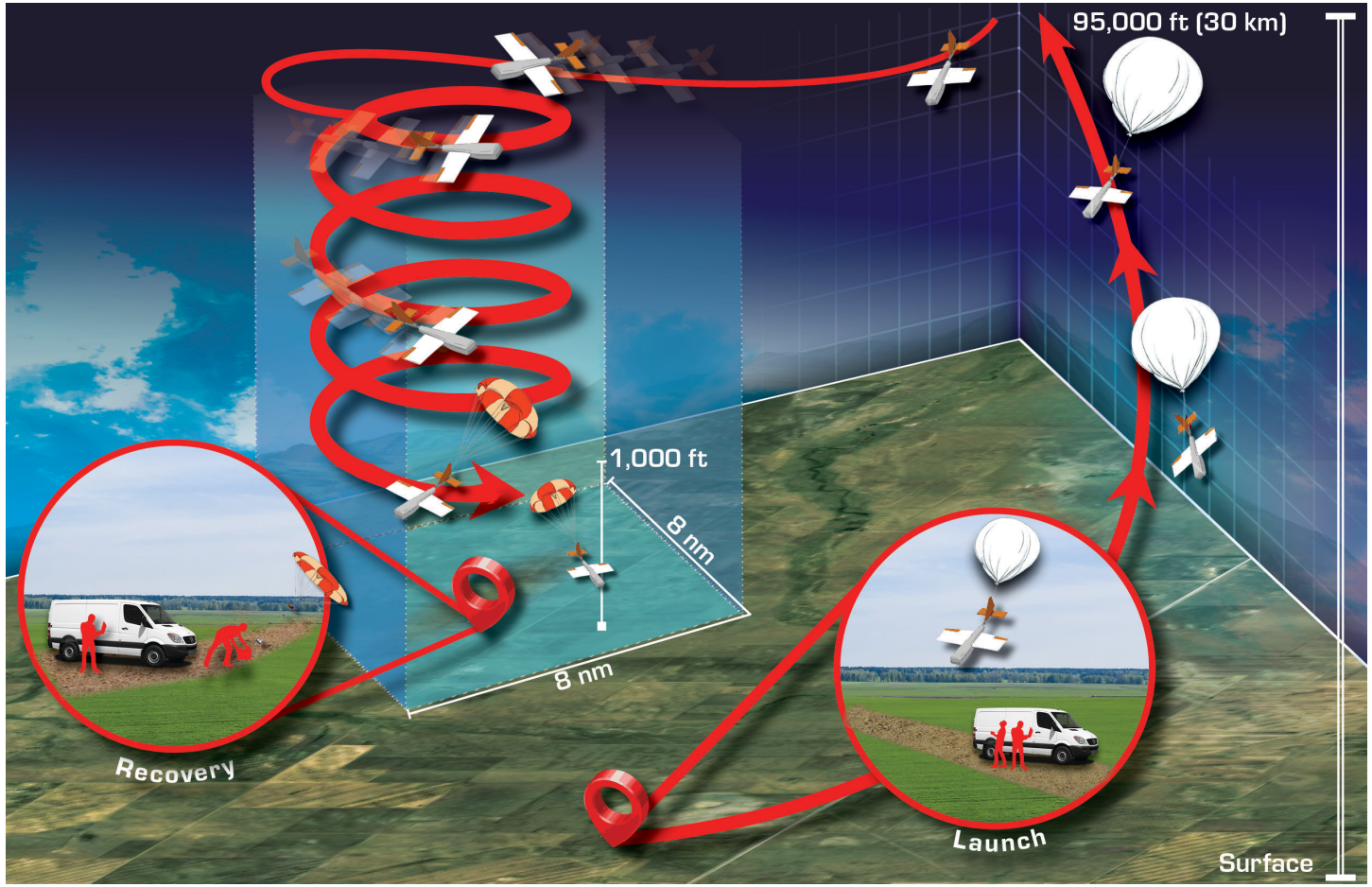
2. Use of portable EM27/SUN as “transfer standard”





- AirCore-scaled retrievals of stationary, autonomous FTS allow for **more frequent comparisons to OCO-2** over direct AirCore comparisons
- Colorado Atmospheric Observatory tower “supersite” prime example of satellite evaluation site

Scaling with High-altitude Operational Returning Uncrewed System



- HORUS platform enables recovery of up to two AirCore samplers from ~ 25 km to ground, deployment in climate-critical or hard-to-reach regions (high latitudes, tropics, or from ships)
- Payload: AirCore CO_2, CH_4, CO, N_2O; O_3; Aerosol number concentration and size distribution; Vaisala T, P, RH

3. AirCore evaluation of v10 OCO2 Model Intercomparison Project

Model	Contact	Institution	Transport Model	Meteorology	Inverse Method
Ames	Matthew Johnson and Sajeev Philip	NASA Ames Research Center	GEOS-Chem	MERRA-2	4D-Var
CAMS	Frédéric Chevallier	LSCE France	LMDz	ERA-interim	4D-Var
COLA	Zhiqiang Liu				
CMS-Flux	Junjie Liu	NASA JPL	GEOS-Chem	GEOS-FP	4D-Var
CSU	Andrew Schuh	Colorado State University	GEOS-Chem	MERRA-2	Bayesian synthesis
CT	Andy Jacobson	University of Colorado and NOAA GML	TM5	ERA-interim	EnKF
JHU	Scot Miller				
LoFI	Brad Weir				
NIES	Shamil Maksyuotov				
OU	Sean Crowell	University of Oklahoma	TM5	ERA-interim	4D-Var
PCTM	David Baker	Colorado State University	PCTM	MERRA-2	4D-Var
TM5-4DVAR	Sourish Basu	University of Maryland and NASA GMAO	TM5	ERA-interim	4D-Var
UT	Feng Deng	University of Toronto	GEOS-Chem	GEOS-FP	4D-Var
WOMBAT	Michael Bertolacci, Andrew Zammit Mangion, Noel Cressie	University of Wollongong	GEOS-Chem	MERRA-2	MCMC

- OCO-2 MIP incorporates multiple models that assimilate OCO-2 XCO_2 identically, but use different transport/inverse methods
- 10-year AirCore record serves as independent evaluation metric throughout column

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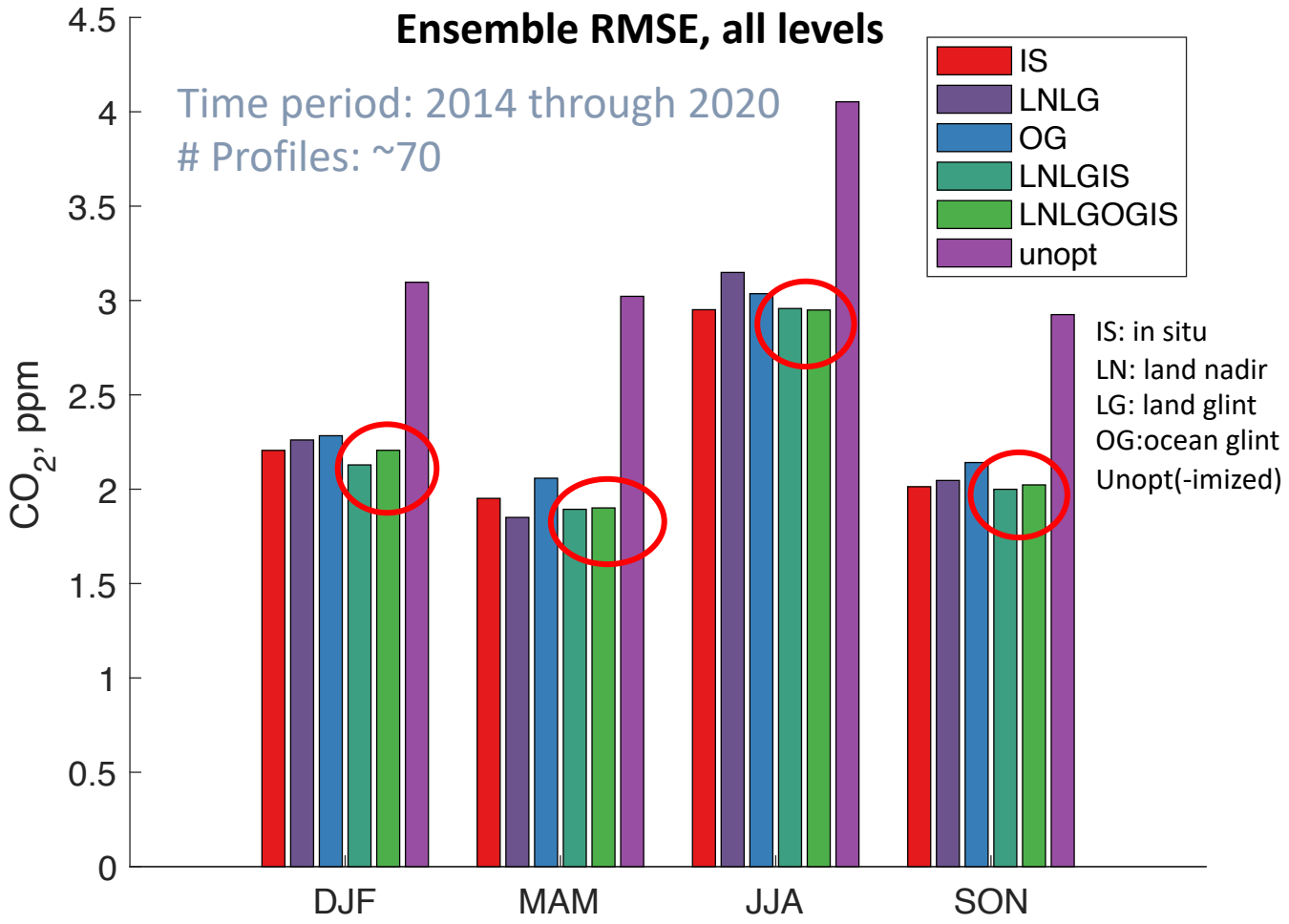
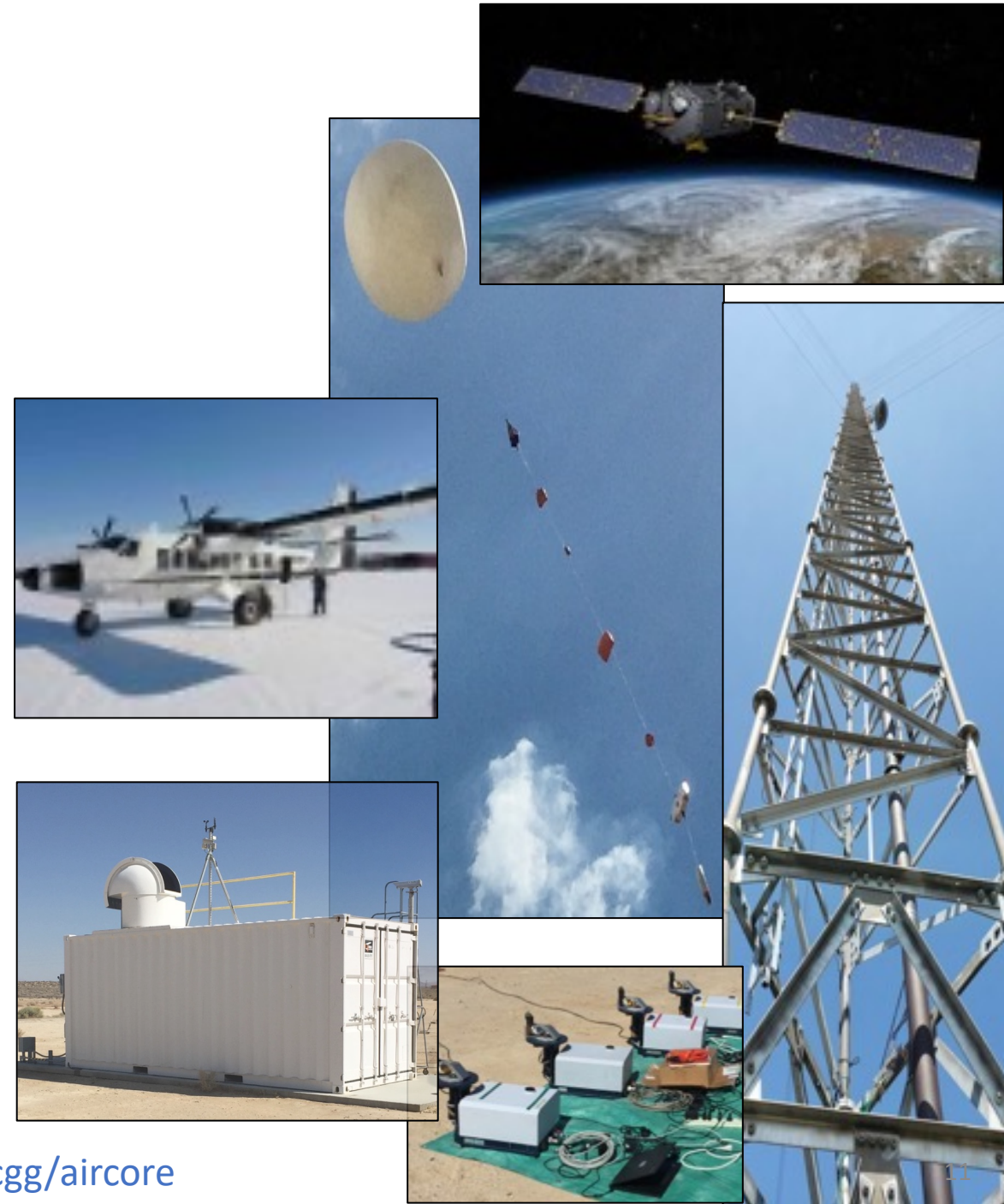


In all seasons, RMSE improves relative to AirCore with combination of remote sensing, in situ observations

Summary

- AirCore applications for OCO-2 evaluation:
  1. Direct balloon-satellite comparisons (infrequent)
  2. Scaling of EM27/SUN, TCCON as a “transfer standard”
  3. Inverse model evaluation using OCO-2-assimilated data

- New platform for expanding profiling capabilities
- Need for incorporating airborne (aircraft, AirCore) scaling of ground-based remote sensing instrumentation within the expanding TCCON, COCCON networks used as primary satellite cal/val sites



bianca.baier@noaa.gov, gml.noaa.gov/ccgg/aircore

Our team is hiring!

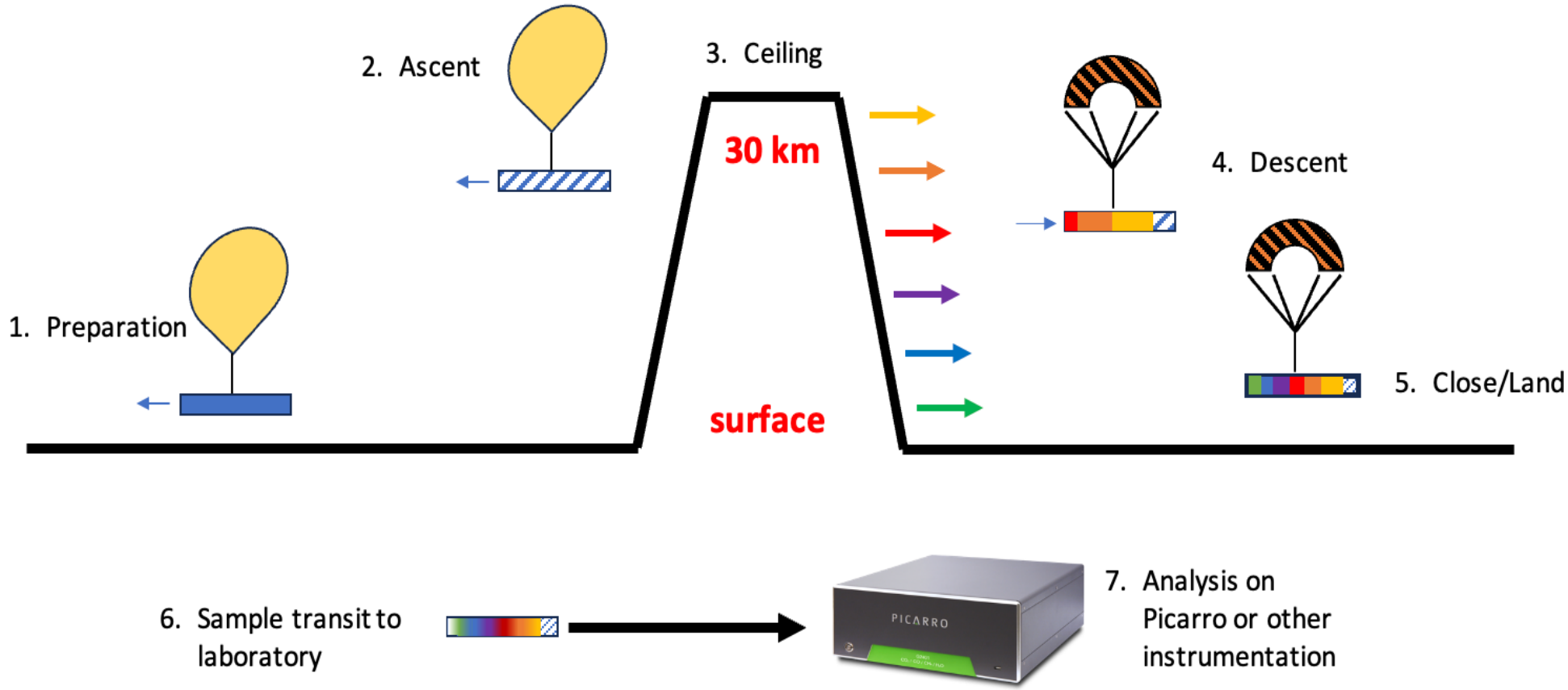
CIRES/ NOAA GML Technology Transfer, Engineering and Applications (TTEA) AirCore Program Postdoctoral Associate

https://jobs.colorado.edu/jobs/JobDetail?jobId=56410

Backup slides

AirCore passive sampling system for profiling the atmosphere

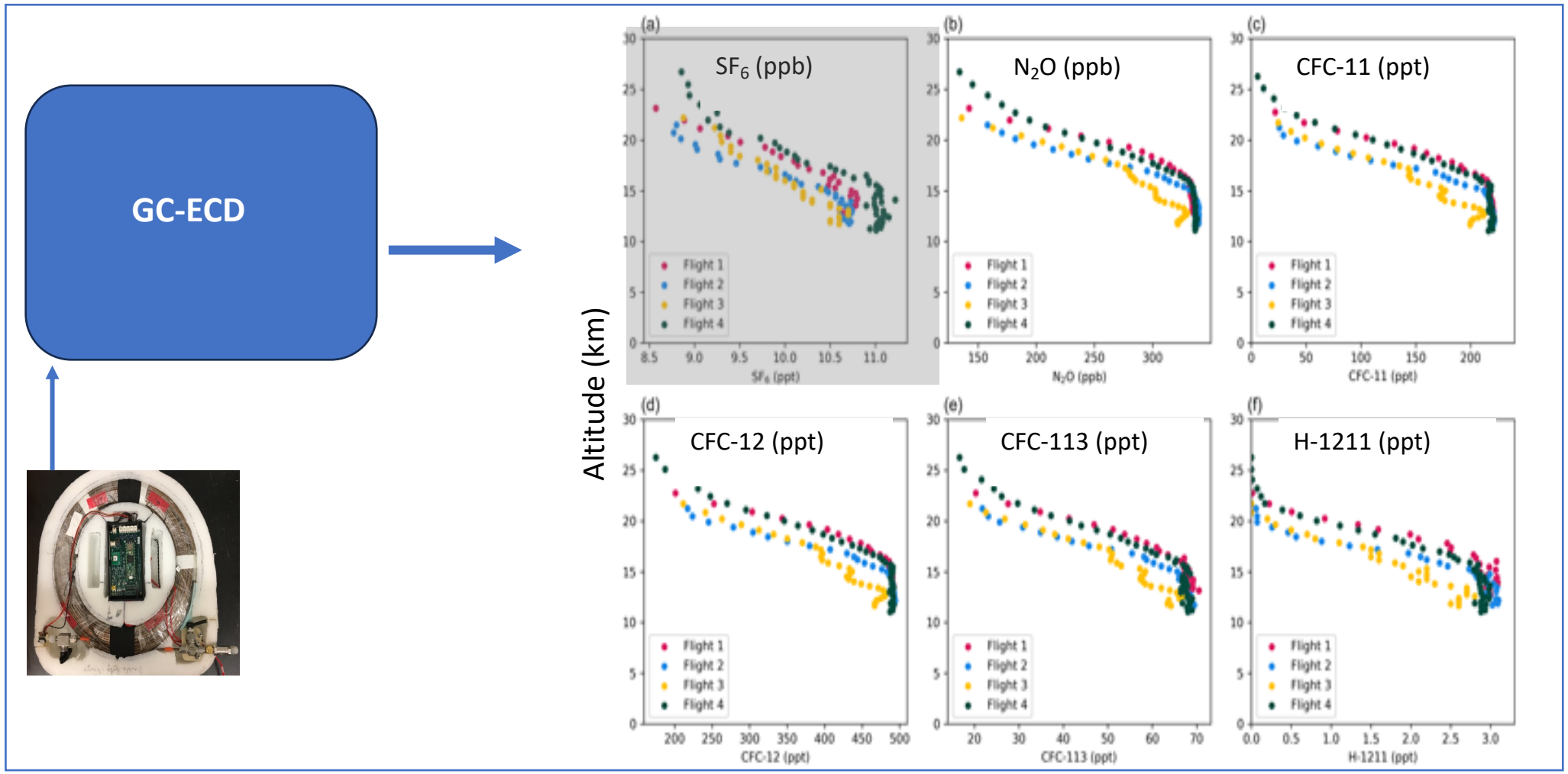
- Small balloons a low-cost way to observe near-total atmosphere from surface to stratosphere
- GML-patented AirCore technology, a long, coiled tube, passively collects air from balloon burst to ground
- Air sample measured for long-lived atmospheric species to provide profiles



CO_2, CH_4, and CO profiles registered with altitude using dynamical model

(Karion et al., 2010; Tans et al., 2022)

3. AirCore model evaluation – transport



Li et al., 2023

- New, SF_6 partial profiles from GC-ECD measurements of AirCores could help to constrain model vertical mixing

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