XCH_4 retrieval from MethaneAIR: An airborne precursor to the MethaneSAT mission

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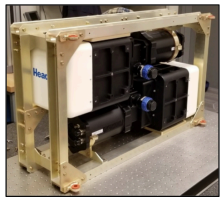
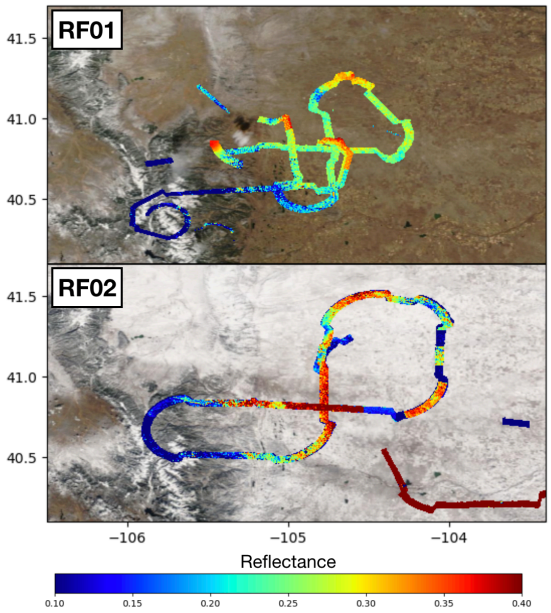
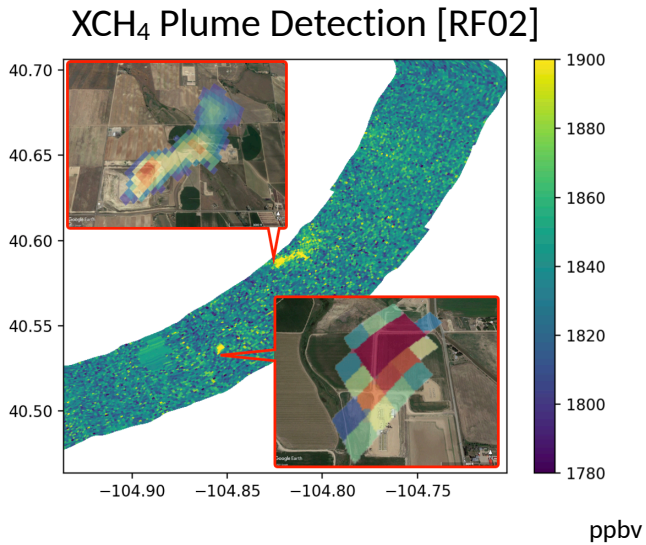
O_2 passband	1236–1319 nm
O_2 dispersion	0.08 nm/pixel
CH_4 passband	1592–1697 nm
CH_4 dispersion	0.1 nm/pixel
Swath width @ 12 km	4.99 km
Cross-track pixel @ 12 km	5.76 m
Along-track sample distance	25 m







MethaneAIR is an airborne push broom spectrometer that serves as a pre-launch testbed for MethaneSAT

Two flights were conducted over the Colorado front range in November 2019 (more planned this year over Permian basin)

Here we evaluate the performance of the proxy-XCH4 retrieval algorithm developed for MethaneSAT

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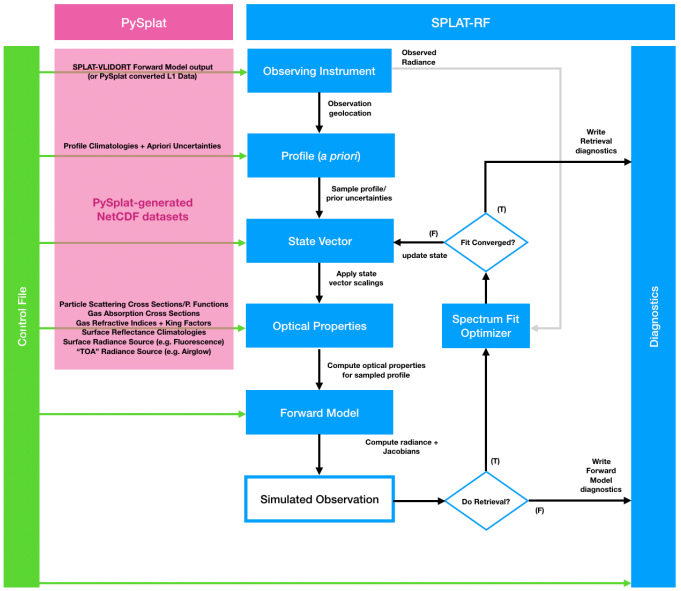
Smithsonian PLanetary ATmosphere Retrieval (SPLAT)

SPLAT Structure



Main Code: Fortran (fast) - Flexible NetCDF Interface for importing optical properties, species profiles,...

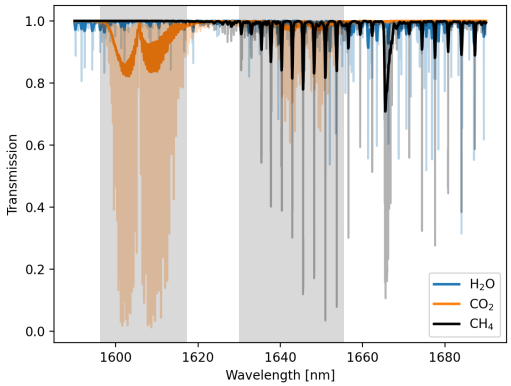
NetCDF Inputs: Generated by an auxiliary python package (PySplat)

Simulation Setup: Specified by single control File

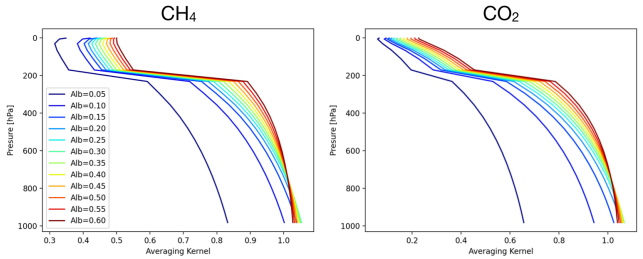
SPLAT is a flexible set of radiative transfer Tools, including an optimal estimation-based inversion scheme

SPLAT Retrieval Setup for XCH4 Proxy

State Element	Description	Prior Error	Prior Data Source
CH4	Profile scaling factors [19 Layers]	UoL Covariance Matrix / 3²	TCCON GGG2020
CO2	Profile scaling factors [19 Layers]	UoL Covariance Matrix	TCCON GGG2020
H2O	Column scaling factor	0.02 v/v	GEOS-FP
Temperature	Profile shift	5K	GEOS-FP
Surface Pressure	Sigma-profile adjustment	4 hPa	GEOS-FP w/ DEM adjustment (10x10m)
Albedo	3rd order chebyshev polynomial /window	100% a priori value	Initialized from observed radiance @ 1622.5nm
Wavelength Grid	0th order chebyshev poly, offset / window	0.05 nm	Lab calibration
ISRF Squeeze	Scaling to Tabulated ISRF wavelength grid	0.05	Lab calibration



Column Avg. Kern. [SZA=54º, VZA=5º]



Windows target 1.6 micron CO2 band and R-branch of 2v3 CH4 band (Detector QE rolloff above). Windows are jointly optimized

CH4 prior tuned based on L-curve test. Step function drop-off due to location of plane (~150 hPa)

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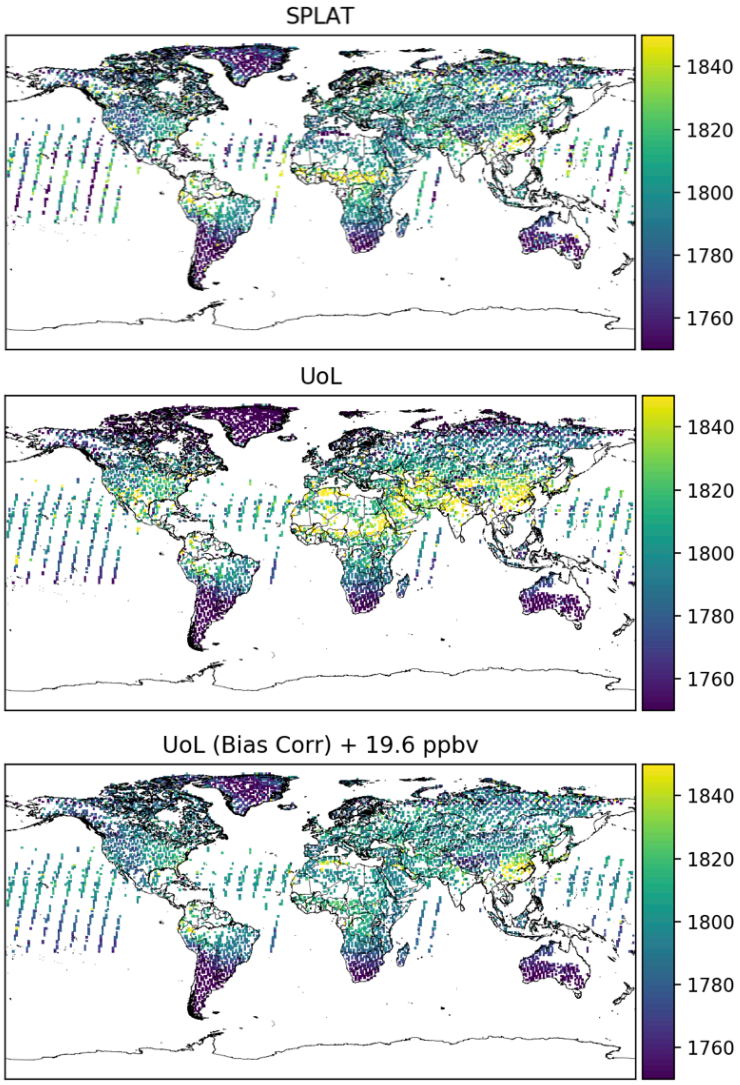
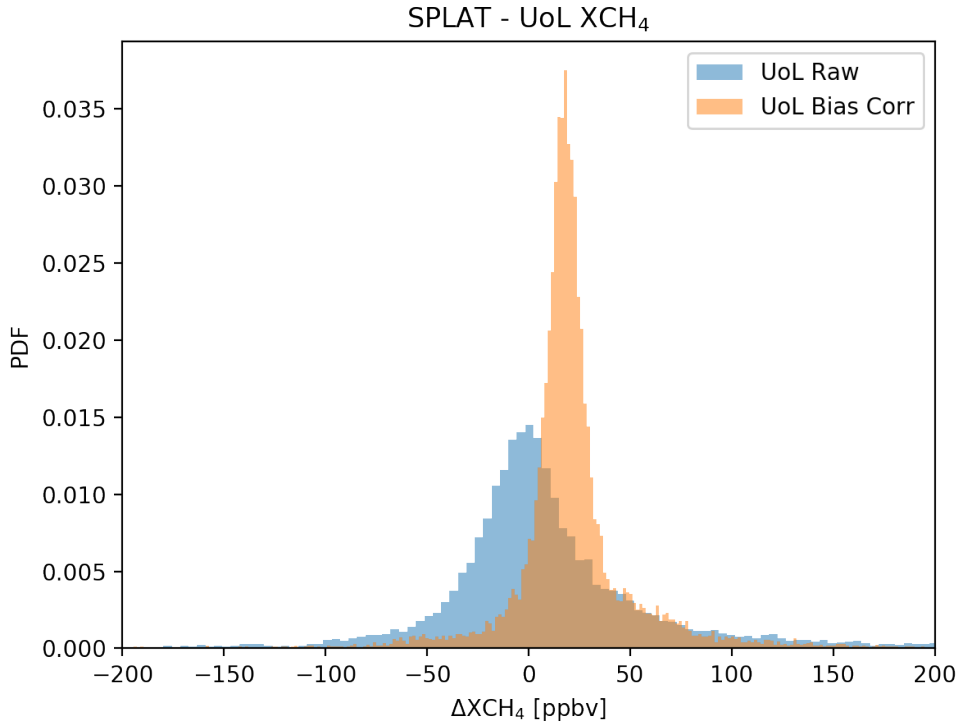
SPLAT retrieval validation using GOSAT





- SPLAT is new, therefore requires validation against a known well calibrated dataset [here GOSAT].
- Comparison against Univ. of Leicester v9.0 proxy retrieval
- Aside from offset, uncorrected SPLAT retrieval agrees well with bias corrected UoL

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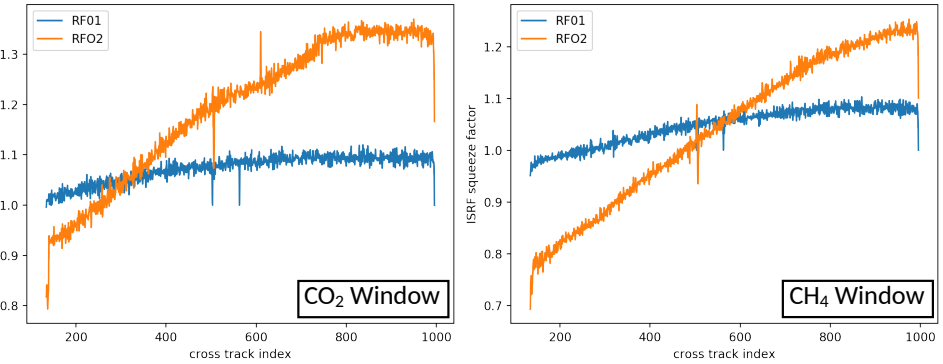
Large shifts in flight ISRF relative to calibration

ISRF width adjusted by including a squeeze factor (x) in the retrieval for each window

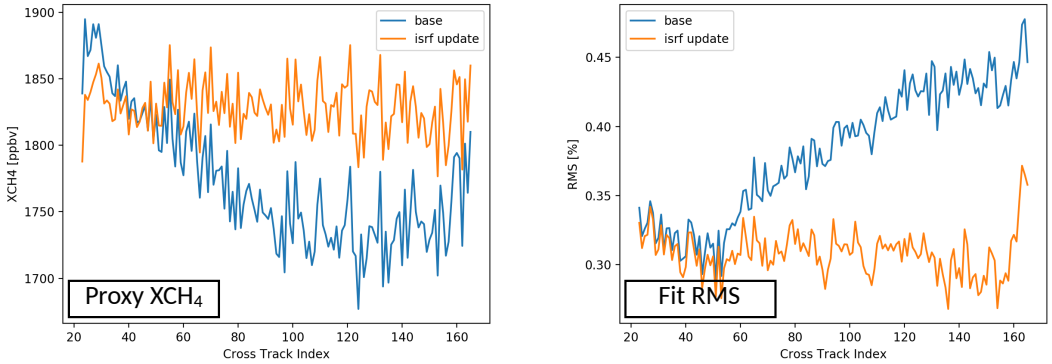
$$\Gamma(\lambda) = \Gamma_{LUT}(x\lambda)$$ **x > 1 => Narrower**

Observation Derived ISRF Squeeze Factors (Flight Median)

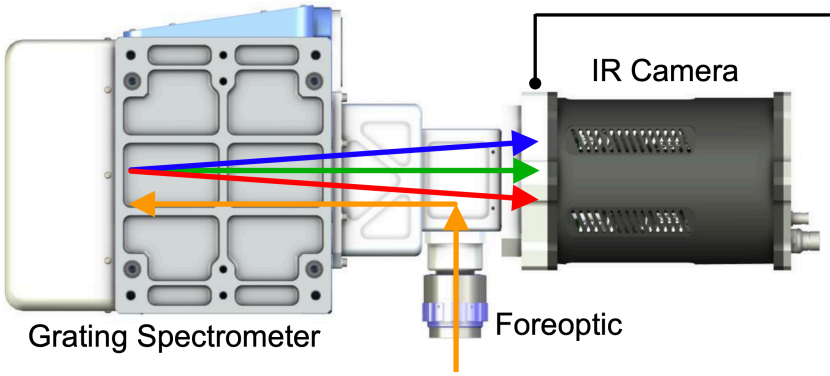


- Large change in ISRF between flights
- High-frequency structure likely due to instrument slit irregularities

Impact of ISRF Squeeze Fit on Retrieved XCH_4



- Shift corrects cross track bias (shown here for 6 cross track aggregation case)



Suspected cause: Change (relative to lab) in IR camera position from leads to ISRF defocusing. Plane landing between flights could have caused further shift

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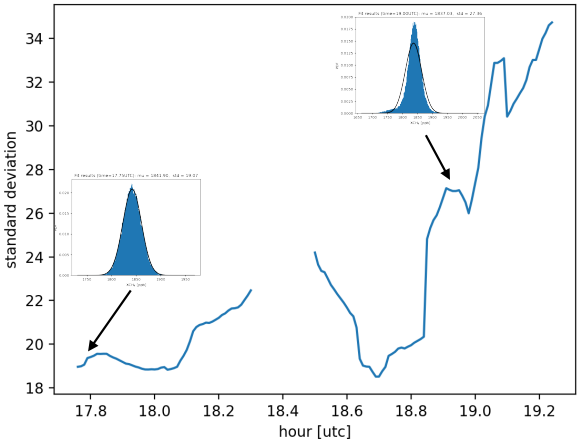
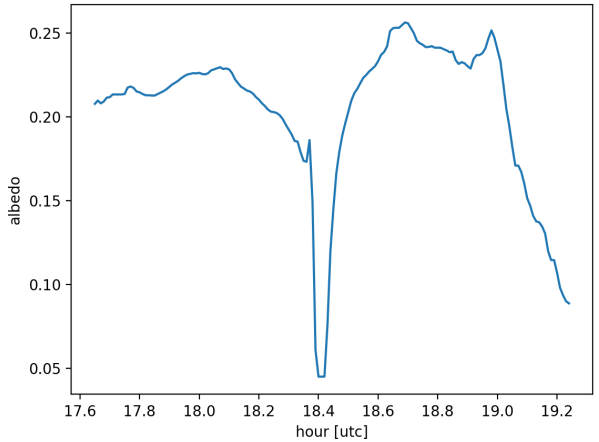
Estimating MethaneAIR retrieval precision from observations

Method 1: Standard deviation of sliding window (flat field assumption)

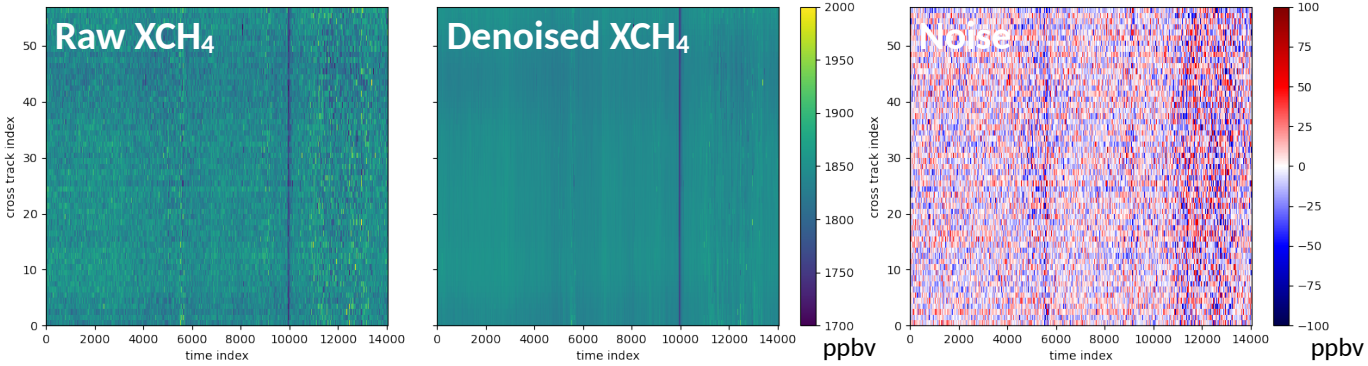




- Assumes true XCH4 is constant over averaging area
- Suggest ~20 ppbv precision for 15x3 coaxed pixel (~100x100m @ flight cruise altitude)

Method 2: Total variation denoising calibrated with J-invariance

- Use image processing algorithm (which can be calibrated using the noisy image itself)
- Standard deviation of the noise (22 ppbv) in agreement with flat field method



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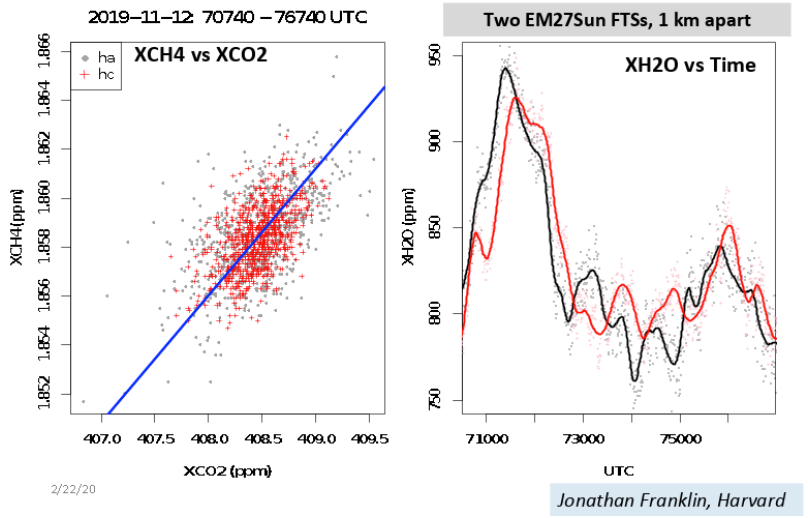
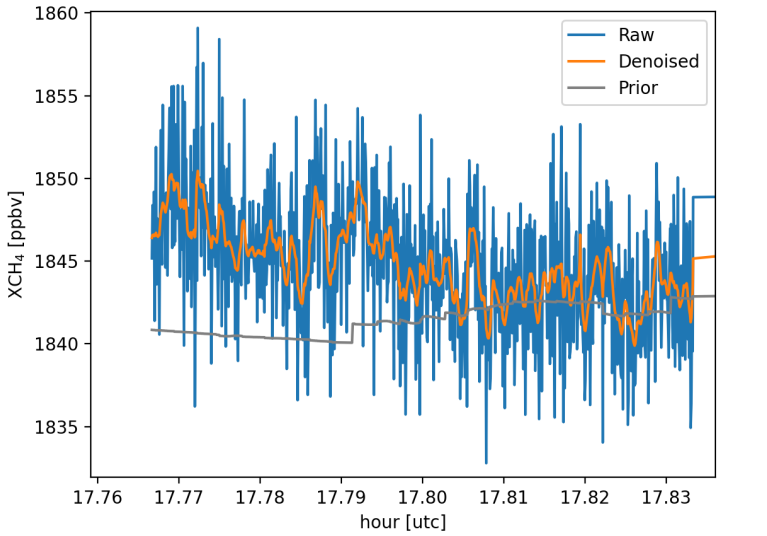
Can we detect XCH_4 gradients?

XCH4 and XCO2 (and XH2O) co-vary even in locations without strong sources



MethaneAIRAlong Track Average XCH4 [RF01]



- Field EM27 Sun data suggest wave structure in PBL
- Wave patterns of a similar amplitude (~5 ppbv) detected using MethaneAIR observations

Next Steps:

- Retrieve O2 to see if XCO2 waves correlate with those from XCH4
- 2D state vector (multi-pixel retrievals) [currently prototyping]