# XCH4 retrieval from MethaneAIR using the CO2-Proxy Approach: First results over major US oil and gas basins

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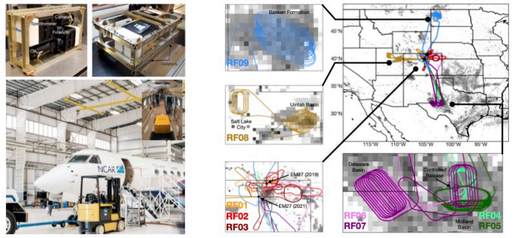
## (1) 2021/2022 Campaign

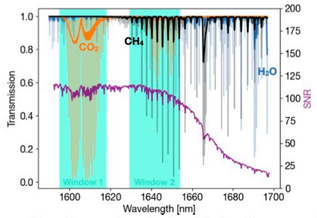





- MethaneAIR is the airborne precursor to MethaneSAT, an upcoming satellite mission commissioned to target methane emissions from the Oil and Gas (O&G) sector
- Here we present retrieved total column averaged dry air methane mixing ratios ($XCH_4$) retrieved using the $CO_2$ proxy method, the primary approach used for the satellite mission
- The campaign concluded in 2021, surveying the Bakken, Uintah, and Permian O&G production regions (top right figure)

## (2) Retrieval

**Proxy Approach:** $$XCH_4 = \frac{N_{CH_4}}{N_{CO_2}} XCO_{2(prior)}$$

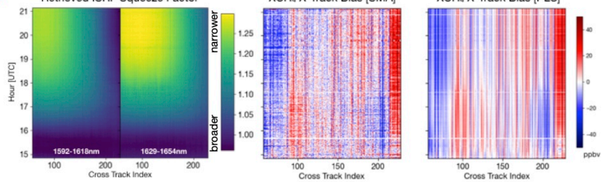



| State Vector Element | A Priori | Uncertainty |
|---|---|---|
| $CH_4$ Profile [19 Layers] | GGG2020 Priori Profile Software[1] | UoL GOSAT Proxy Covariance[2] |
| $CO_2$ Profile [19 Layers] | GGG2020 Priori Profile Software[1] | UoL GOSAT Proxy Covariance[2] |
| $H_2O$ Column | GEOS-FP[3] | 0.02 v/v |
| Temperature Profile Shift | GEOS-FP[3] | 5 K |
| Surface Pressure | GEOS-FP[3] | 4 hPa |
| Albedo | MethaneAIR Radiance | 100% |
| Wavelength Offset | 0.0 nm | 0.01 nm |
| ISRF squeeze | 1.0 | 0.2 |

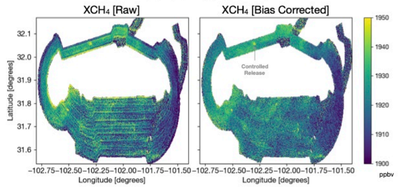
- $N_{CO2}$,$N_{CH4}$ retrieved using OE algorithm assuming non-scattering atmosphere
- Detector QE rolloff above 1654nm limits the $CH_4$ window (can be extended for MethaneSAT)
- A priori profiles based on GEOS-5, with $CO_2$/$CH_4$ calculated using GGG2020
- A priori $CH_4$/$CO_2$ covariances tuned s.t. averaging kernels are ~1 near surface
- Additional ISRF squeeze factor must be included in fit to account for unstable temperature environment

## (3) Stripe Correction

### RF05: ISRF Squeeze vs. $XCH_4$ Cross Track Bias



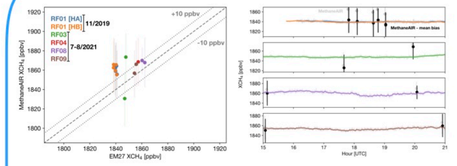

### RF05: Bias Corrected $XCH_4$




- Retrieved ISRF changes smoothly over the flight, starting from its nominal lab calibration and then gradually narrowing on one side of the detector (left figure).
- Explanation: gradual defocusing of instrument caused by temperature gradients developing across optical bench (e.g. cooling from porthole glass)
- Since squeezing the lab ISRF does not fully account for the defocus-induced change, the cross track bias pattern evolves in time (middle panel, derived using small area approx.)
- An improved stripe estimate is created via a PLS regression of the SSA derived stripes against the ISRF squeeze factors, to improve the noise (squeeze factors are more precise) and disentangle the stripe biases from other features (regularization artifacts, plumes etc).

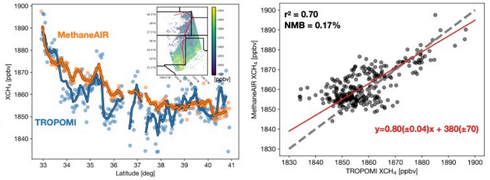
## (4) Validation

### EM27 Overpasses



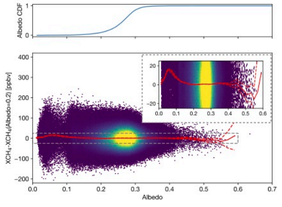

- Absolute agreement generally within 1%
- Higher $XCH_4$ bias during winter flights
- Large drift in $XCH_4$ concentrations only observed during RF03, which was due to defocusing issues caused by plane cabin temperature control

### TROPOMI Colocation [RF06]




- Figure compares MethaneAIR matched to TROPOMI data within ±1h
- Absolute mean bias is small (0.17%)
- Latitudinal gradient shallower for MethaneAIR (difference may be partially due to residual TROPOMI striping)

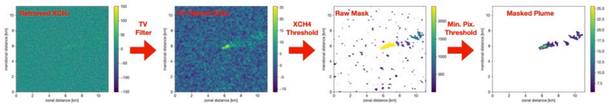
### Albedo Dependence




- $XCH_4$-albedo correlation due to interaction between aerosols and surface
- During summer campaign data impacted wildfire haze
- Figure shows the small-area $XCH_4$ anomaly as a function of reflectance using data taken over background regions
- Negative bias for albedo > 0.4 due to unfiltered clouds
- Positive for albedo <0.15 due to regularization
- The low albedo dependence is likely due to the proxy approach and the finer size of smoke aerosol not impacting the SWIR

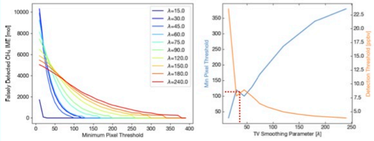
## (5) Plume Detection

### Plume Masking Procedure



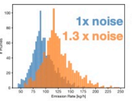

- Above schematic summarizes masking procedure based on image denoising, masking values 2 std. dev. Above background concentration, followed by filtering flagged clumps bellow min. threshold

### Tuning Plume Mask Parameters (Image Smoothing Wt. /Min Pix. Threshing)



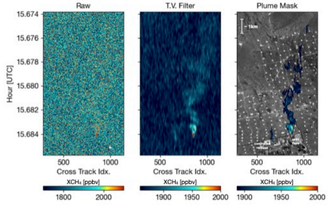

- Parameters tuned by applying plume mask to a set of synthetic background MethaneAIR images
- Right figure shows the pixel threshold required to eliminate falsely detected mass (blue) and the background variability of the denoised image (orange) vs. image smoothing
- Optimum parameter choice reduces background variance/min pix threshold (dashed red)

### Estimated Plume Detection Limit



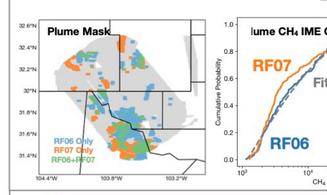

- Detection threshold estimated from1200 WRF-LES plume snapshots (left)
- Median detected emission rate ~90kg/h
- Background variance in real retrievals ~30% higher. Threshold becomes ~120kg/h
- This is consistent with the detectability threshold from controlled release overpasses

### Example over controlled release



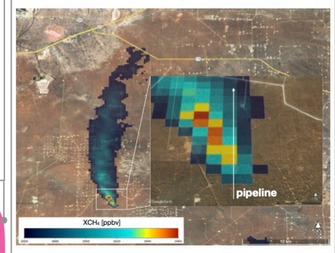

## (6) Permian Basin Case Study

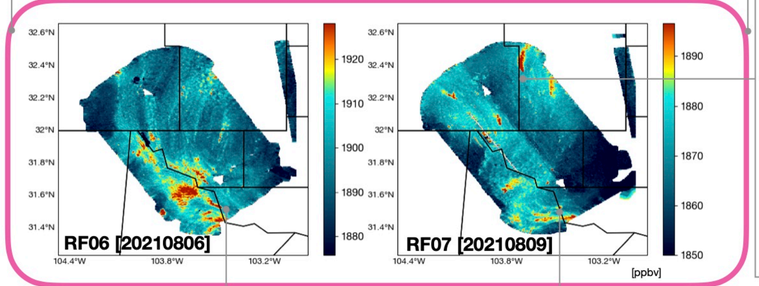
### Basin Statistics




- Two flights within spaced 3 days apart
- Basin wide probability distributions of $CH_4$ integrated mass enhancements are consistent for both flights despite high spatiotemporal variability between flights
- Skewed distributions/intermittency consistent with many previous studies

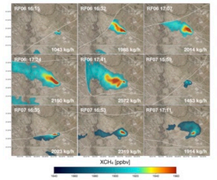
### Burst Pipeline



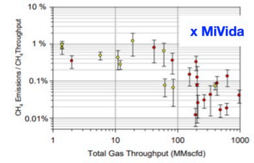




- Large plume observed over gas pipeline during RF07 extending over 20km
- ~6500 kg/h emission rate estimated using IME approach
- Estimate consistent with reported pipeline throughput (8200 kg/h)
- Leak was detected 15 days before reported by pipeline operator

### MiVida Gas Plant (Persistent Source)



- MiVida gas plant was observed multiple times on both flights, revealing persistent large source
- Changing wind conditions reveal multiple sources within plant
- Estimated emissions (1914-2572 kg/h) imply leak rate of 1.6-2.1%
- This is higher than any of those observed from a recent survey of gas facilities of its size




Marchese et al. (2015)
https://doi.org/10.1021/acs.est.5b02275