Simulation-retrieval experiments over the Western Hemisphere with the GeoCarb retrieval algorithm

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Introduction

The Geostationary Carbon Cycle Observatory (GeoCarb) mission aims to measure the spatial and temporal patterns of greenhouse gases with the ultimate goal of addressing fundamental questions in carbon cycle science, such as why and how the global carbon cycle is changing. GeoCARB will retrieve column integrated CO_2, CH_4, and CO concentrations over North and South America from shortwave-infrared measurements in four hyperspectral bands made from a geostationary satellite platform. Other facts include:

- Configurable scan blocks over the land masses to be visited multiple times a day.
- Hyperspectral bands including 0.76 (O_2-A), 1.61 (weak CO_2), and 2.06 (strong CO_2) µm (similar to OCO-2/3) in addition to a CH_4/CO band at 2.32 µm.
- The proposed spatial resolution is 4.1 km N/S and 5.4 km E/W at the sub satellite point.

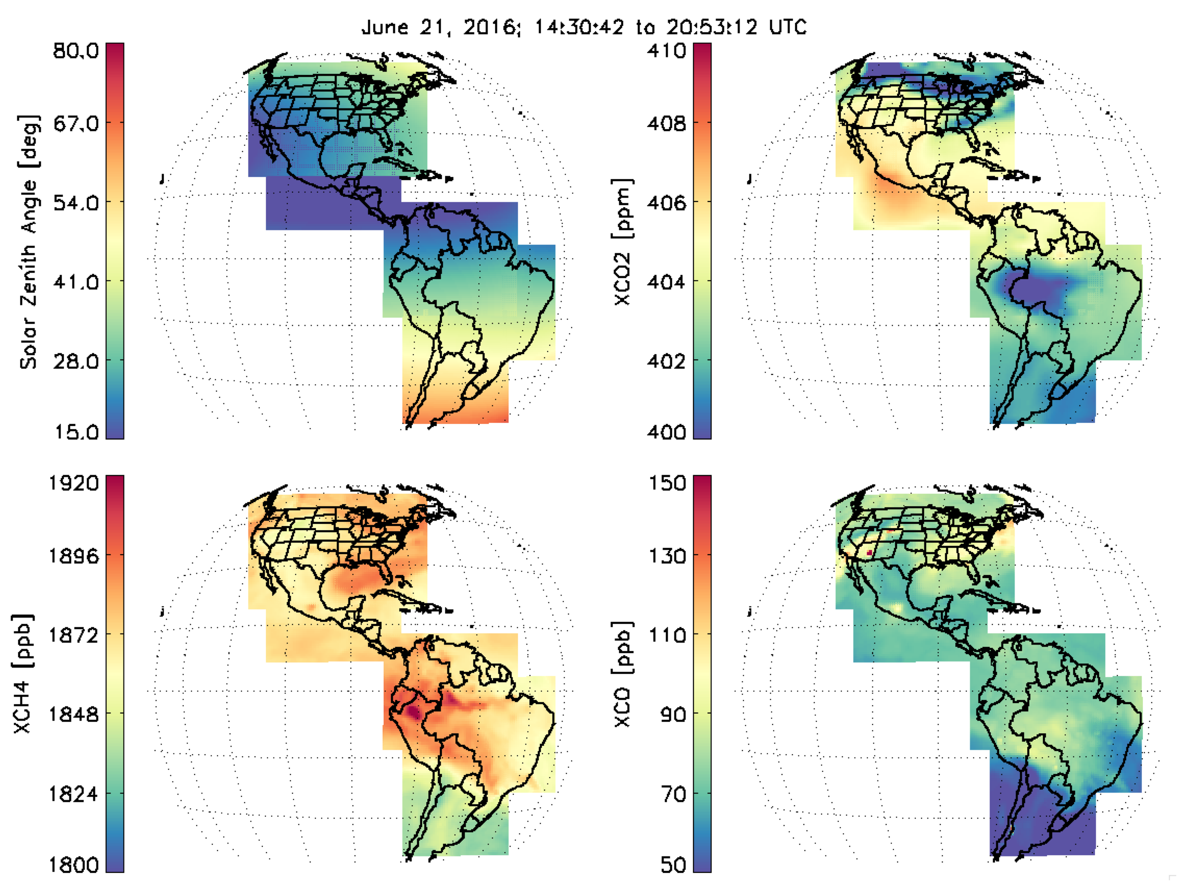
Setup

The simulation and retrieval software is based on the OCO-2/3 code and has been modified for GeoCarb's geostationary orbit and its additional band (2.32 µm) and retrieved gases (CH_4 and CO):

1. **Scene definition**: Includes meteorology, aerosols and clouds, surface BRDF, geolocation, and solar and viewing geometry. (*CSU simulator code*)
2. **Measurement simulation**: Includes radiative transfer, convolution with the ILS for each channel, and application of the instrument noise model. (*CSU simulator code*)
3. **Retrieval**: Run the retrieval on the simulated measurements without and with perturbations applied. (*OCO-2/3 L2 retrieval code adapted for GeoCarb*)

Experimental setup:

- Based on 5.4 km sampling but down sampled to 0.5°.
- 5 scan blocks per day, 1 day from each season of 2016 (Mar 21, Jun 21, Sep 21, Dec 21).
- Observations are prefiltered for particles with the OCO-2/3 A-band cloud screener.
- Simulated measurements are noise-less unless specified.



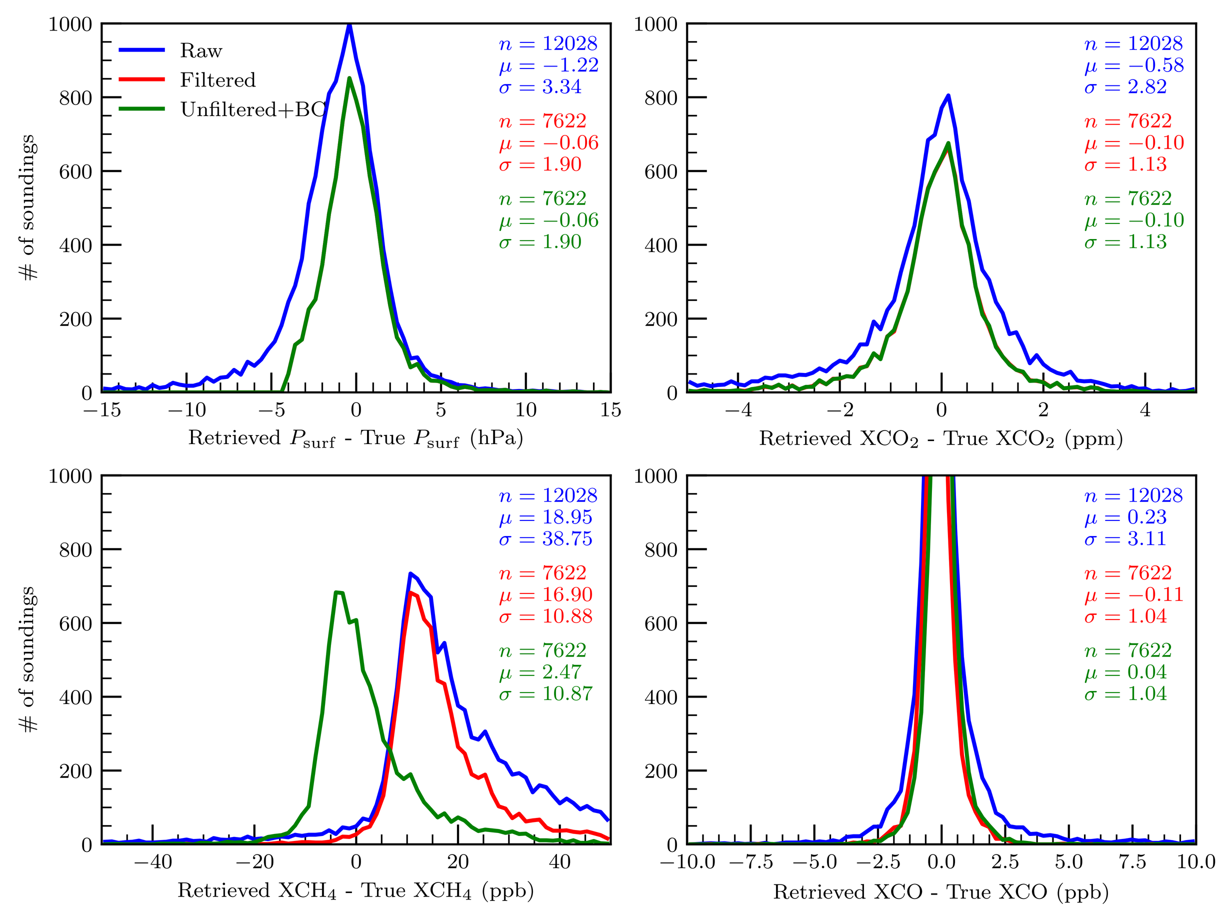
Baseline

We start by looking at retrieval results with no perturbations. Statistics reported are:

- n: The number of retrievals that converged successfully and went through post filtering.
- μ: The mean of the differences between the retrieval and the truth.
- σ: The standard deviation of the differences between the retrieval and the truth.

Here the results reported are **Raw** (unfiltered), **Filtered**, and **Filtered+BC** (bias corrected). The filtering is a series of tests based on χ^2, estimated uncertainty, and retrieved AOT. (*Results for the perturbation runs are all filtered and bias corrected.*)

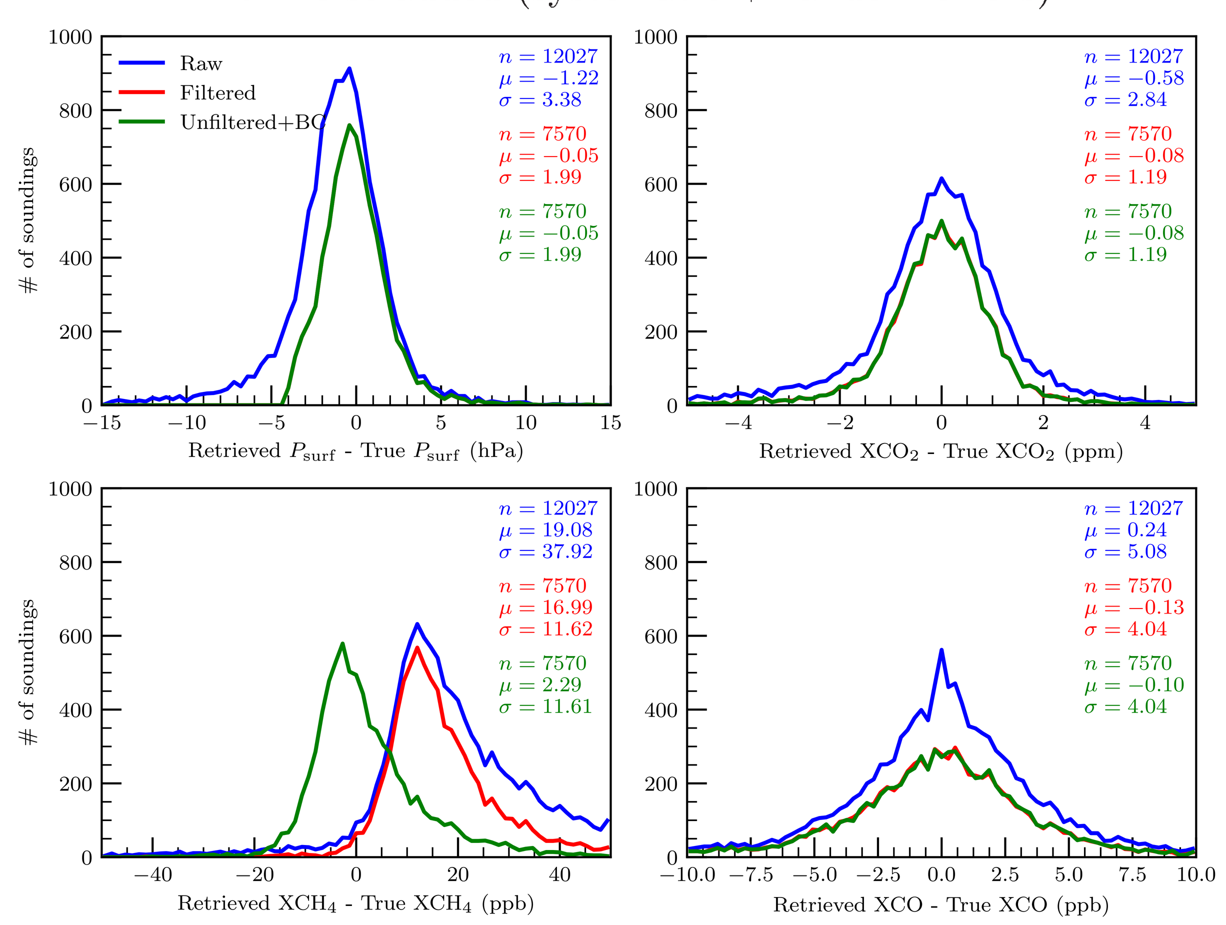
Without noise (systematic errors)



Random noise with a standard normal distribution may be applied using a proper noise model for a mapping grating spectrometer with noise coefficients for each band i:

$$\mathrm{SNR} = I/\sqrt{N_{0,i}^2 + N_{1,i} I}.$$

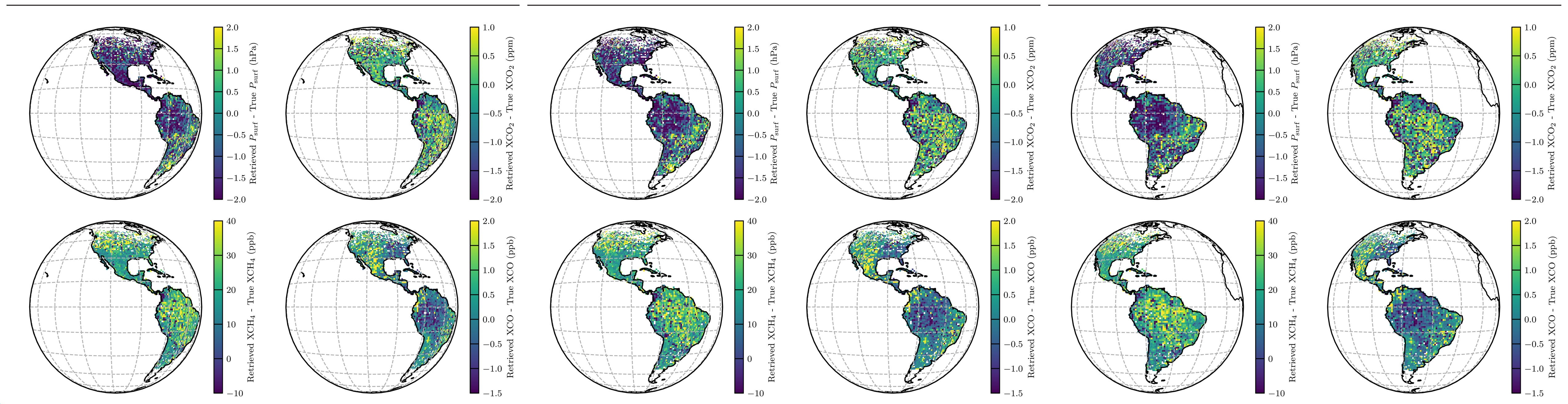
With noise added (systematic + random errors)



Alternative slots

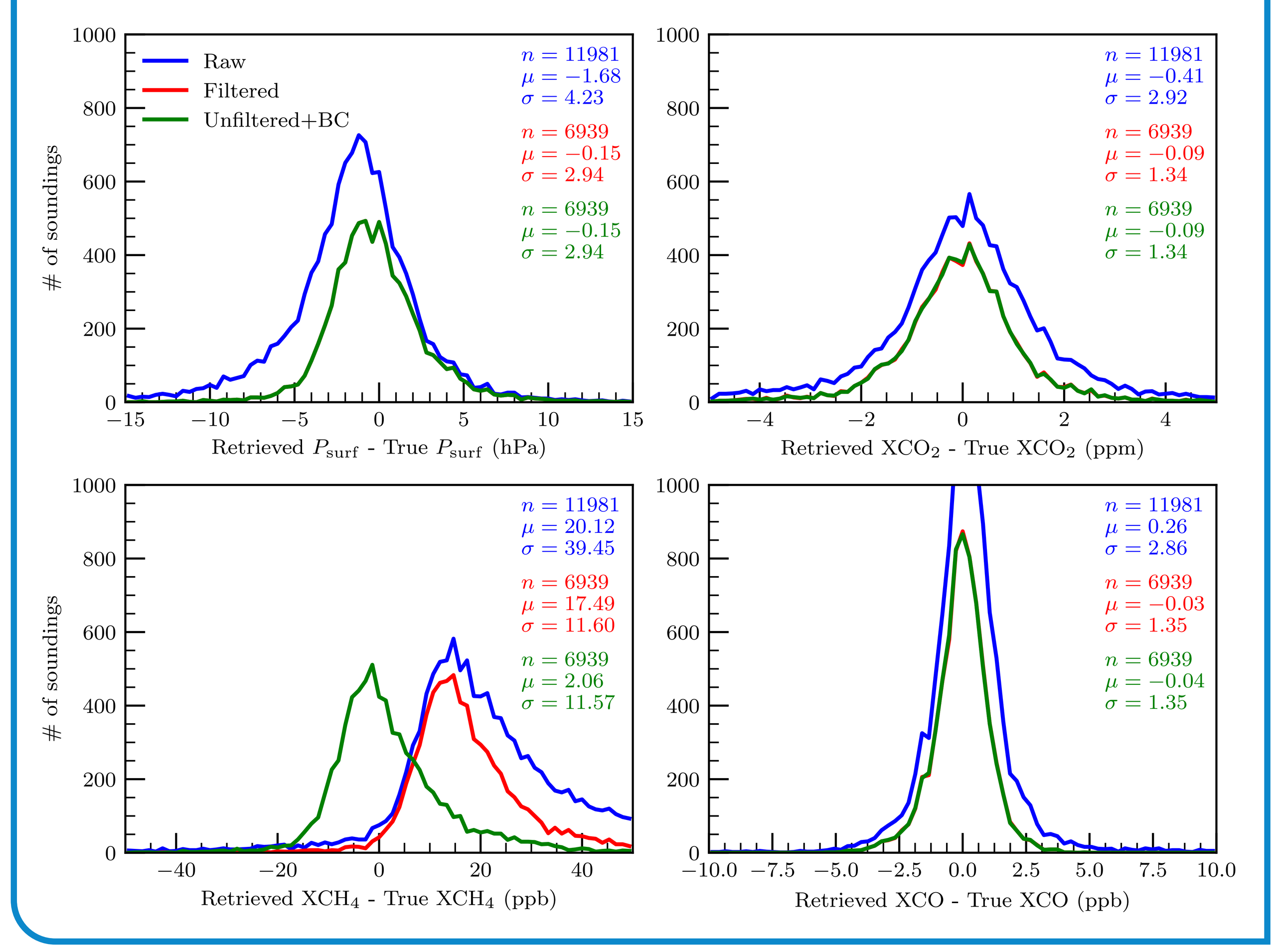
Geostationary orbits are limited to a fixed distance from the Earth above the equator. As a result, the available longitudinal positions (slots or sub satellite points) are limited to what is available at launch. The slot affects the average mass path – the amount of atmosphere between the sensor and the surface. The ideal location for North and South America also varies with slot. For GeoCarb the overall ideal position available is 87°w. Possible back-up slots include 65°w and 105°w.

105°w | 87°w | 65°w



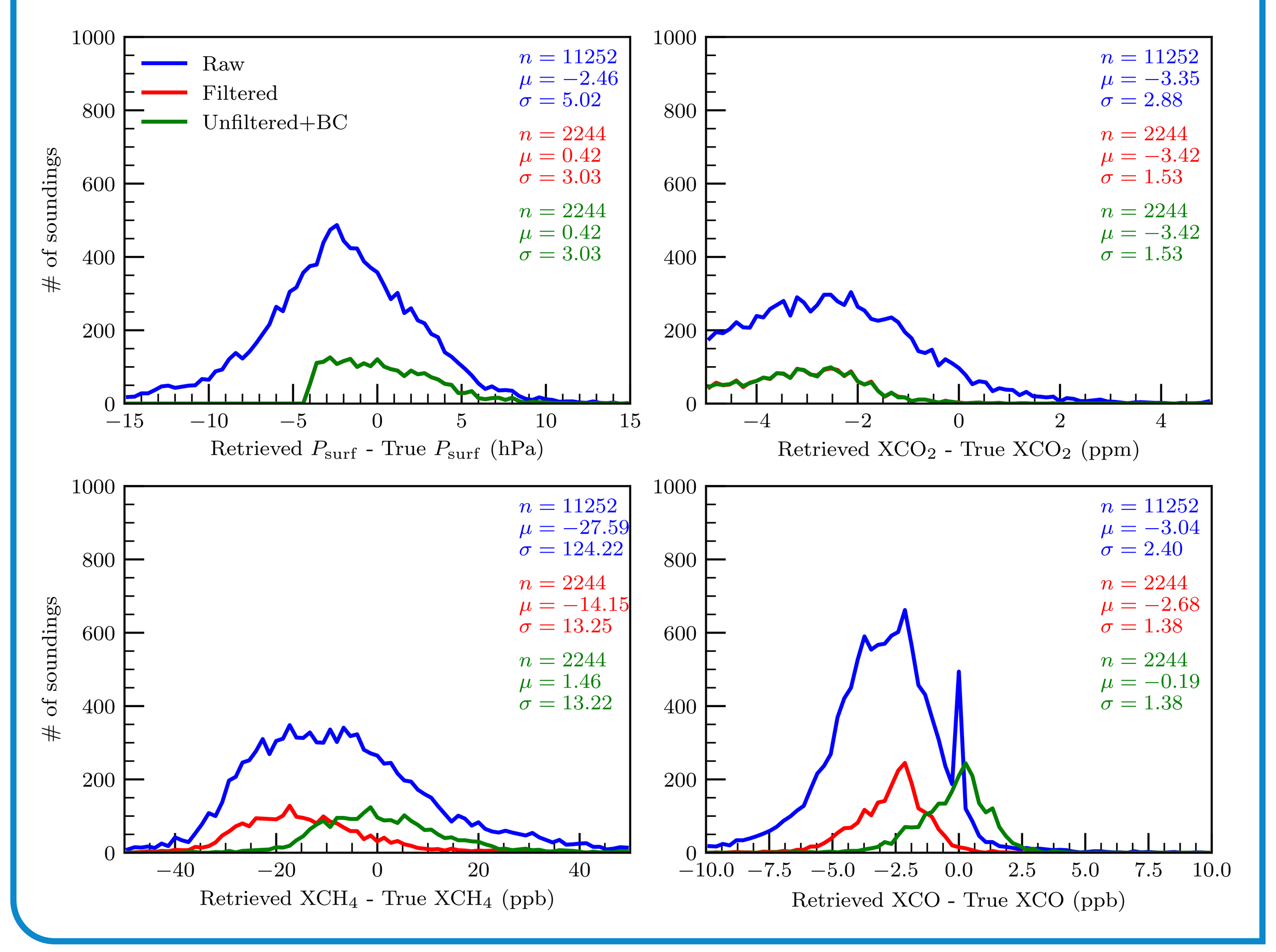
Meteorological perturbation

Meteorology for the baseline (truth) simulations is obtained from the Carbon Tracker product which is obtained from ECMWF ERA-Interim model output. The resolution is X × X°. To simulate imperfect knowledge of meteorology we use GMAO GEOS-5 FP-IT model output with a resolution of 0.3 × 0.25°.



Spectroscopic perturbation

The spectroscopic data used for the baseline (truth) is obtained from HITRAN 2016 using the MTCKD-3.2 H_2O continuum model. To simulate imperfect knowledge of spectroscopy we use data from HITRAN 2008 using the same H_2O continuum model.



Some conclusions

- **Overall points**: (1) The XCH_4 retrieval suffers from a systematic error that can be corrected through a simple bias correction. (2) Our simple filtering used for baseline filters out a relatively large amount of results in the case of spectroscopic perturbations indicating that this procedure must be tuned for different spectroscopy.
- **Alternative slots**: The change in mass path between the alternative slots of 65°w and 105°w has a small effect in our experiments indicating that, if need be, the alternative slots can be used.
- **Meteorological perturbation**: Errors due to imperfect meteorology are relatively small indicating that our sources of meteorology, whether it is ECMWF Era-Interim or GMAO GEOS-5 will be a small source of error.
- **Spectroscopic perturbation**: There is a clear systematic error in the spectroscopic perturbations that the bias correction is not resolving. Unlike with meteorology, there is a rather large random error component.