

I will be at my poster:
 • Wed 7/13, 10:00-11:00 JST
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Solving scene inhomogeneity-induced errors without a slit homogenizer: application to GeoCarb

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Background/Intro

- Many scenes observed from space can be highly inhomogeneous (e.g Fig 1).
- This Scene Inhomogeneity (SI) can lead to distortions in the Instrument Spectral Response Function (ISRF or ILS) (Fig 2).
- The (generally unknown) ILS distortions will lead to retrieval errors.

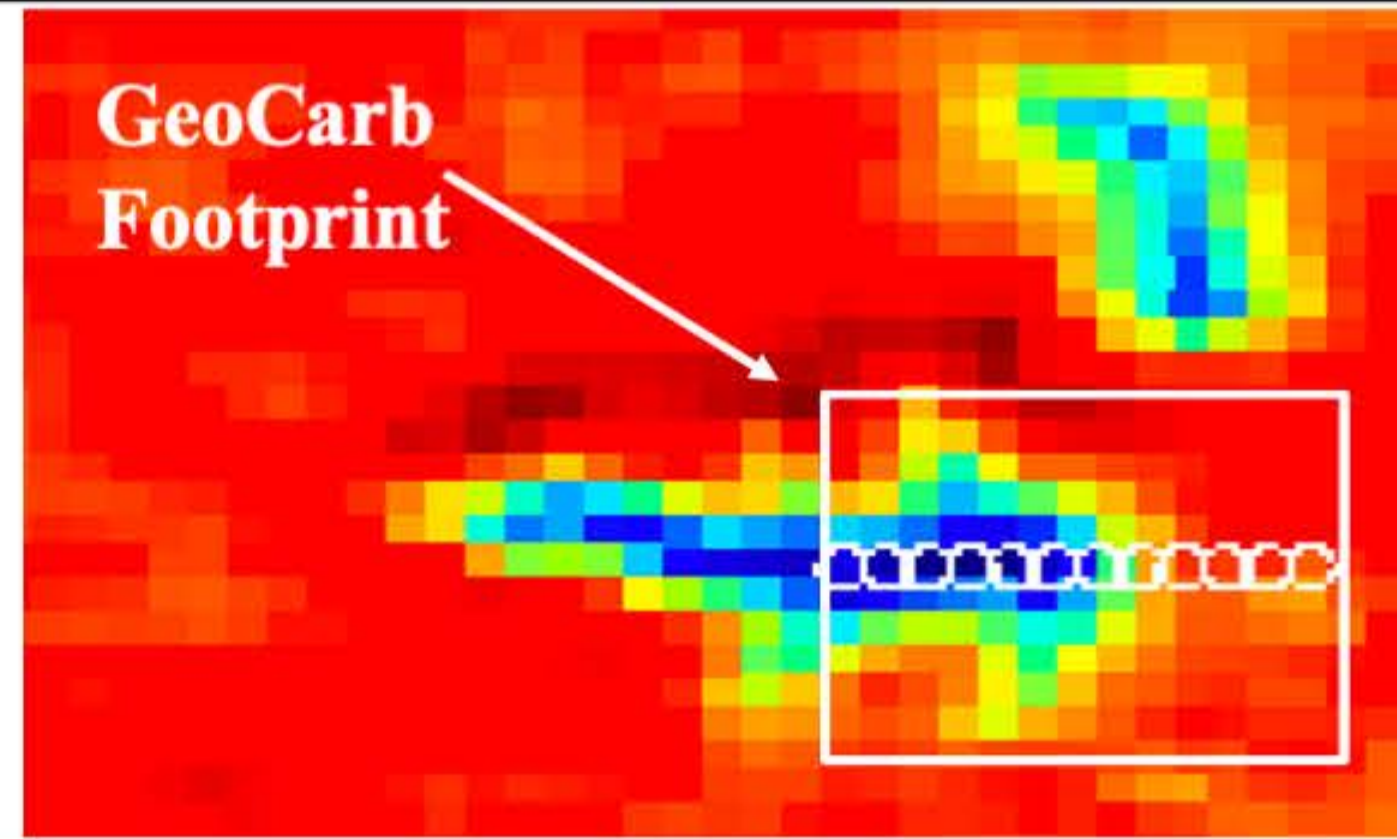
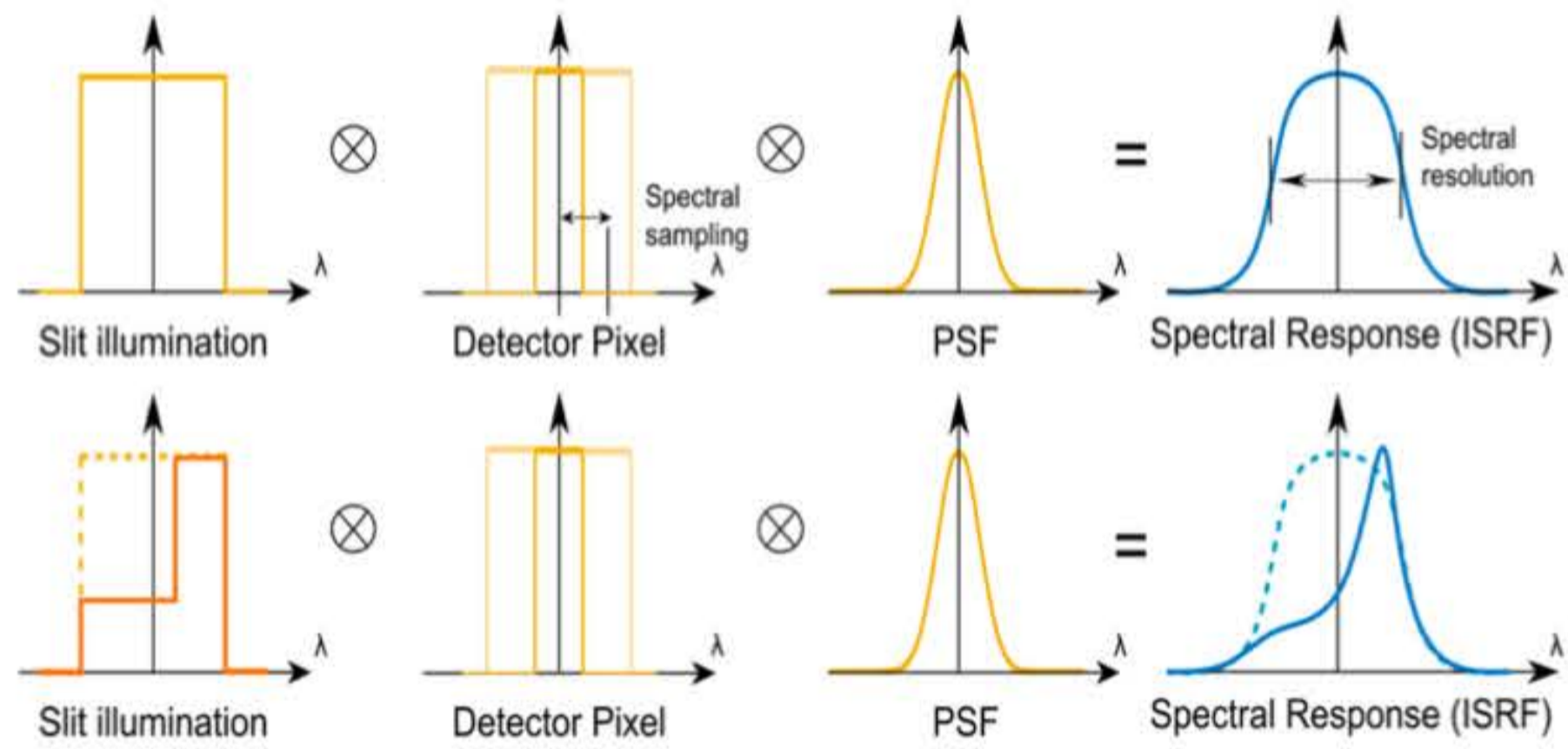


Fig 1: 870nm MODIS reflectivity at 0.5km resolution over Carter Lake Blackwell Region, OK, USA, along with a sample GeoCarb footprint with high spatial inhomogeneity

Fig 2: ISRF is the convolution of the Scene Illumination (left), the pixel function (middle), and the grating point spread function (right). Top: Uniform scene illumination; Bottom: Non-uniform scene illumination. Credit: Hummel et al., 2021.



Previous Work/Other Instruments

- First recognized for Ozone measurements on **OMI on Aura**. Solution was to fit for a single wavelength shift in the spectrum (Voors et al., 2006). Further applied to **Sentinel-4** (Noel et al., 2012).
- Did not affect **OCO-2** due to strong subscene averaging & purposeful defocusing of instrument.
- Investigated for **TROPOMI**. Perhaps due to the along-track averaging due to their pushbroom set-up, they find errors < 2% for CO (Landgraf et al., 2016) and < 0.4% for CH4 Hu et al., 2017) due to this effect.
- A “Slit Homogenizer” can be used to smooth out spatial variations before they fall on the spectrometer; such a technique will be used for OMI on Sentinel-5 (Hummel et al., 2021) and CO2M (Hummel et al., 2022).

Sim Set-up

- We simulate this effect on GeoCarb by simulating radiance spectra across the western hemisphere for 4 days of GeoCarb observations with a realistic set of GeoCarb instrument parameters.
- MODIS 0.5km resolution reflectivities are used to drive the simulation for 12 “subslits in the along-slit direction (circles in Fig 1).
- Aerosols & True Meteorology come from ERA5, clouds come from GOES16.
- The Radiative transfer is highly accurate as described in O’Brien et al (2009).

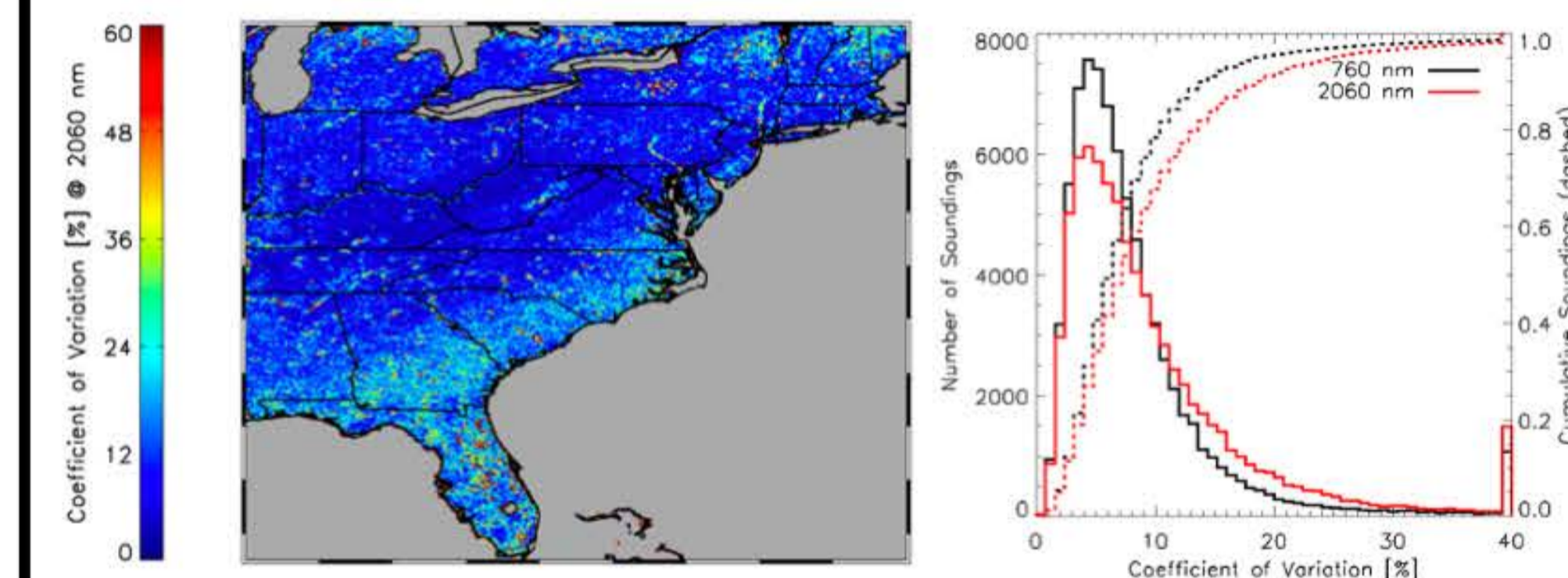
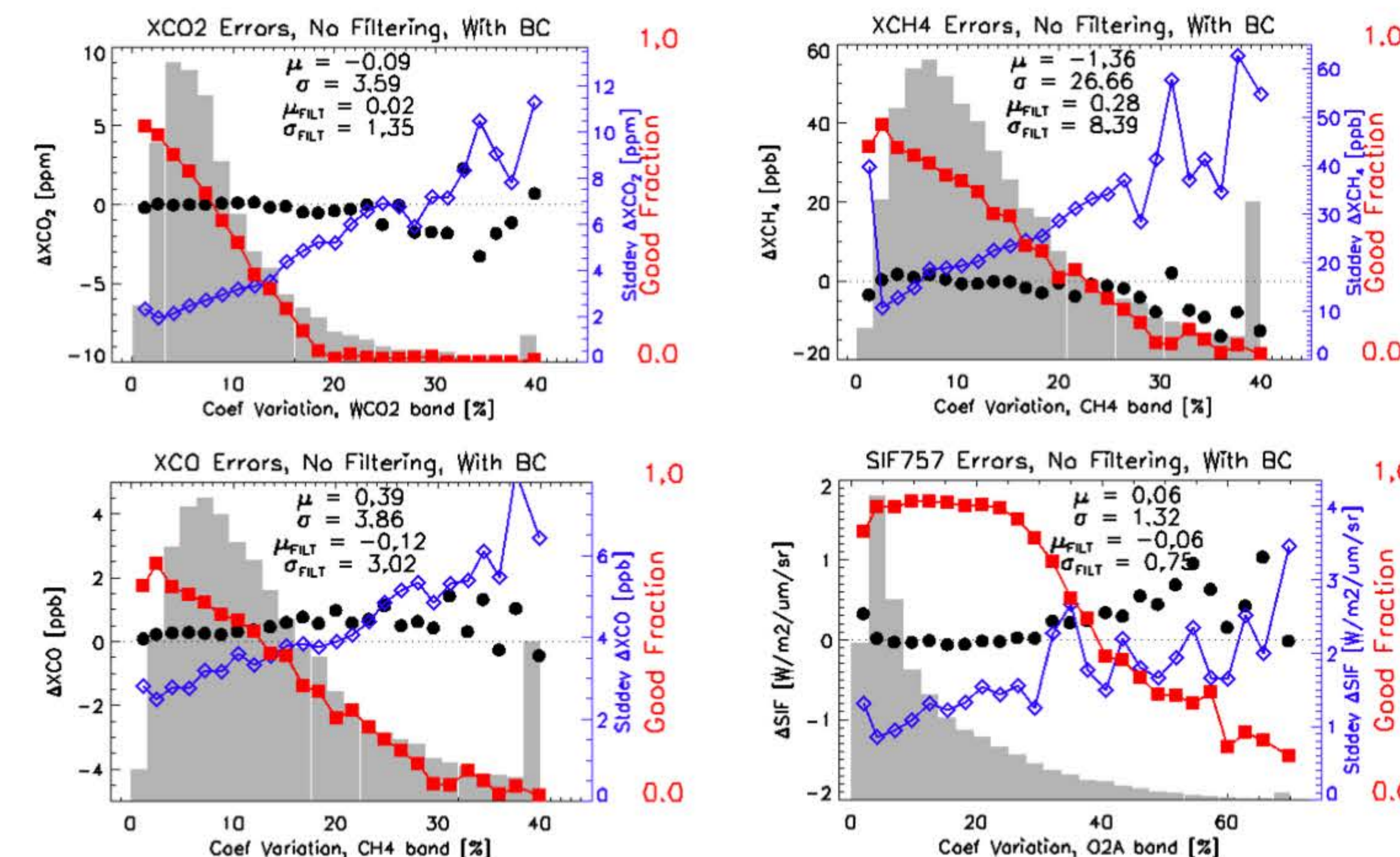


Fig 3: Left: Coefficient of Variation (Stddev/Mean) of MODIS reflectivity for at 0.76 um for the eastern US on 21 March 2016. Right: Histograms of Coefvar for the three OCO2 bands for this case.

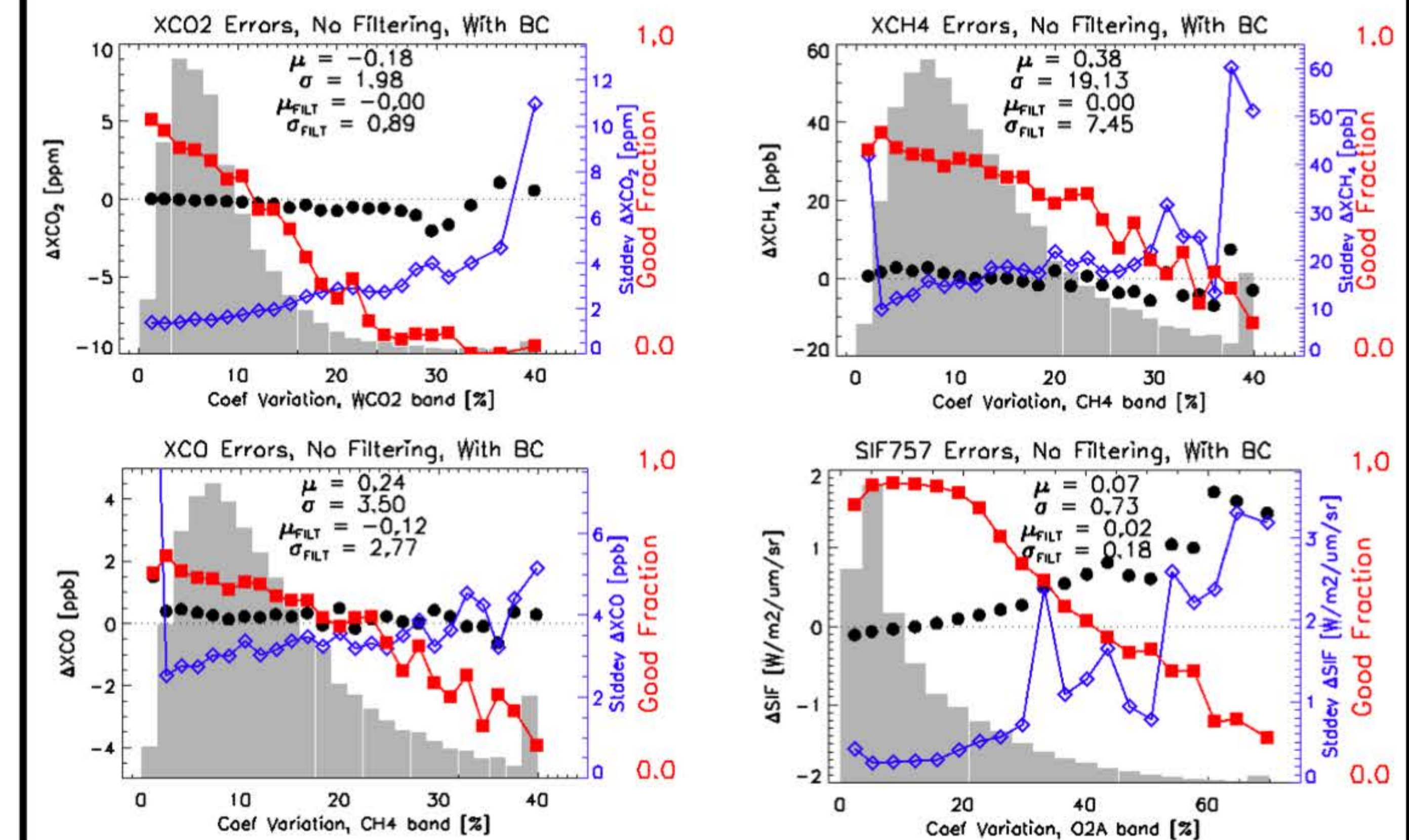
Results from Standard Retrieval

- Run standard 4-Band ACOS Retrieval (v9) on synthetic data
- Apply usual filtering & bias correction techniques



Results with ILS Fitting

- Same as standard run, but fit for an additional ILS width scaling factor for each of the four GeoCarb bands.
- Tests show that this enlarged state vector only marginally increases noise-driven uncertainty.



Conclusions

- Scene Inhomogeneity (SI) causes a reduction in “good” soundings of about 30%, and induces substantial “pseudo-noise” in XCO2 (~ 1ppm) and SIF (~0.7 Wm⁻²um⁻¹sr⁻¹).
- The SI-induced pseudo-noise is close to negligible for XCH4 (~3 ppb) and XCO (~1 ppb).
- This pseudo-noise is a strong function of the surface subscene inhomogeneity.
- Fitting an ILS width reduces the SI-induced pseudo-noise to about 0.3 ppm for XCO2 and to near 0 for SIF.
- Good Sounding loss with ILS fitting is reduced from 30% to 18% for XCO2, and from 8% to 7% for SIF.
- ILS Fitting is an excellent way to mitigate SI-induced errors