In-Flight Performance of TanSat Atmospheric Carbon Dioxide Grating Spectrometer

YANG Zhong-Dong, BI Yan-meng, WANG Qi, Cheng-Bao Liu, XU Na, Lei Yang, Song-Yan Gu, Maiyun Lin

National Satellite Meteorological Centre (NSMC), CMA, CHINA
(YANG Zhong-dong: PI of TanSat Ground Segment and Application, zhongdong.yang@icloud.com)

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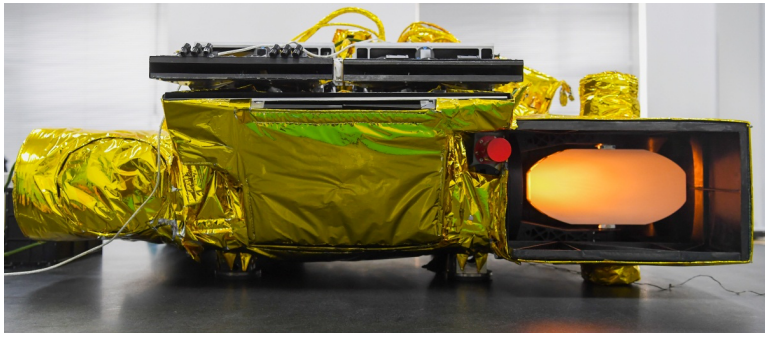
Introduction

1. The latest scientific assessment by IPCC(2013) indicates that climate warming is unequivocal. Many recent changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, snow and ice have diminished and sea level has risen. Changes such as these have resulted from positive radiative forcing caused by increased concentrations of atmospheric CO2 and CH4 make the largest contributions to radiative forcing. With concentrations now the highest for 800 000 years (IPCC, 2013), and continuing to rise, reducing the emission of these gases is the most important environmental challenge in the 21st century.
2. Reliable predictions of future levels of atmospheric CO2 require a quantitative understanding of both CO2 emissions and the specific processes and reservoirs responsible for sequestering CO2 [IPCC, 1996].
3. Measurements from a surface network are currently used to monitor atmospheric CO2. While these measurements are highly accurate, the network is too sparse to adequately characterize the geographic distribution of the CO2 sinks and the processes controlling their variability [Sarmiento and Wofsy, 1999].

Introduction



4. The TanSat is the first Chinese satellite designed dedicatedly to measure column-averaged carbon dioxide dry-air mole fraction,XCO2, with the accuracy, resolution and coverage needed to study globe climate change and distinguish CO2 sources and sinks on regional scales, which was successful launched from JiuQuan Base in Gansu Provience of China on 22 December 2016.
5. The Atmospheric Carbon dioxide Grating Spectrometer (ACGS) is a major spaceborne grating hyperspecral radiometer suite that was onboard the TanSat.

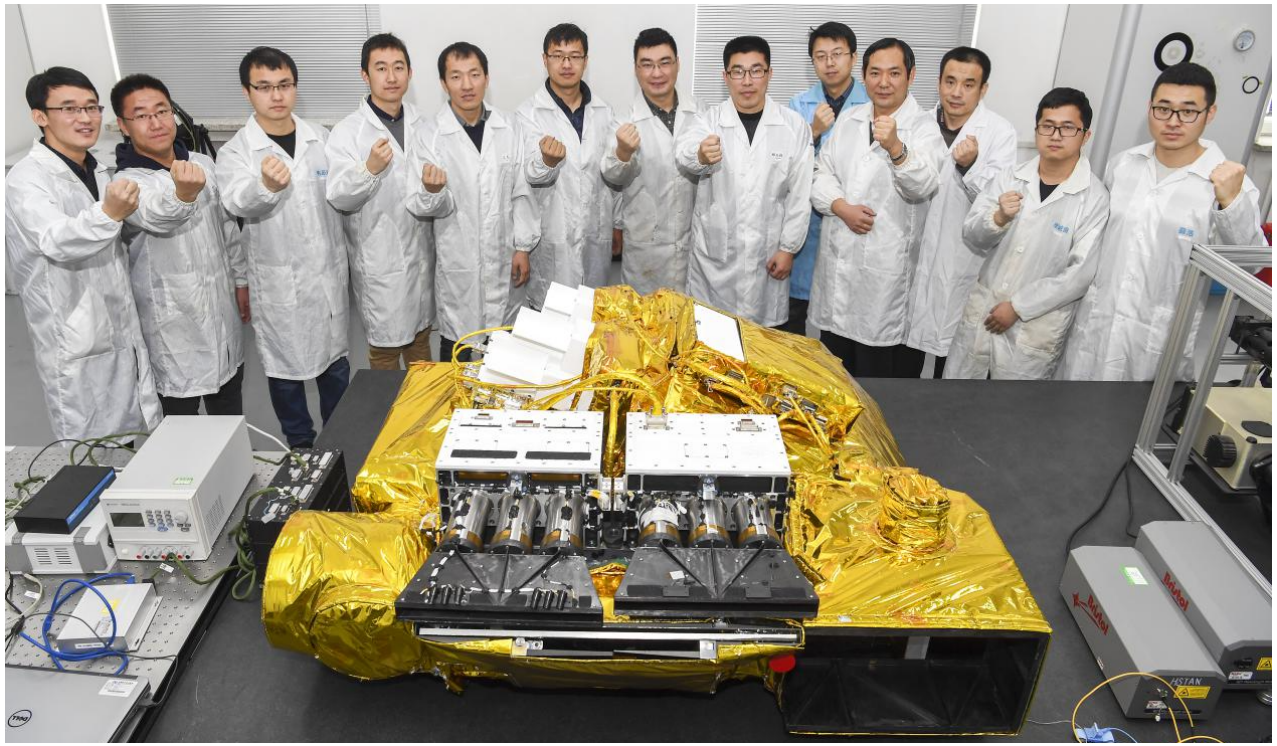
The Major Instrument of TanSat

1. The TanSat carries a three-band atmospheric carbon dioxide grating spectrometer, which is named Atmospheric Carbon dioxide Grating Spectrometer (ACGS), designed to record super-resolution, designed to record super-resolution, co-boresighted spectra of reflected sunlight within the molecular oxygen (O2) A- band at 0.765 microns and the carbon dioxide (CO2) bands at 1.61 and 2.06 microns.
2. These measurements of the ACGS are calibrated and then combined into soundings that are analyzed to retrieve spatially resolved estimates of the column-averaged CO2 dry-air mole fraction, XCO2.
3. Variations of XCO2 in space and time are then analyzed using the atmospheric transport to quantify surface sources and sinks of CO2 in regional and global scope.
4. High measurement precision is therefore essential to resolve these small variations, and high accuracy is needed because small biases in the retrieved XCO2 spatial distribution could be misunderstand as evidence for CO2 fluxes.

The Major Instrument of TanSat

5. ACGS is an grating hyperspecral instrument with three spectral bands covering visible-wave (O_2 A), near-infrared wave (WCO_2), and shortwave infrared (SCO_2) spectral bands from 13203 to 12852cm^{-1} (757.38 to 778.09nm), 6274 to 6158 cm^{-1} (1593.97 to 1623.84nm), and 4900 to 4807cm^{-1} (2040.54 to 2080.49nm) with spectral resolving power ($\lambda/\Delta\lambda$) are ∼19000, ∼12800 and ∼12250, respectively, O_2 A band with a 1242 × 320 array of FPA, WCO_2 and SCO_2 bands with 500 × 256 array of FPA.

Young People of The ACGS Manufacturing Team and The Instrument

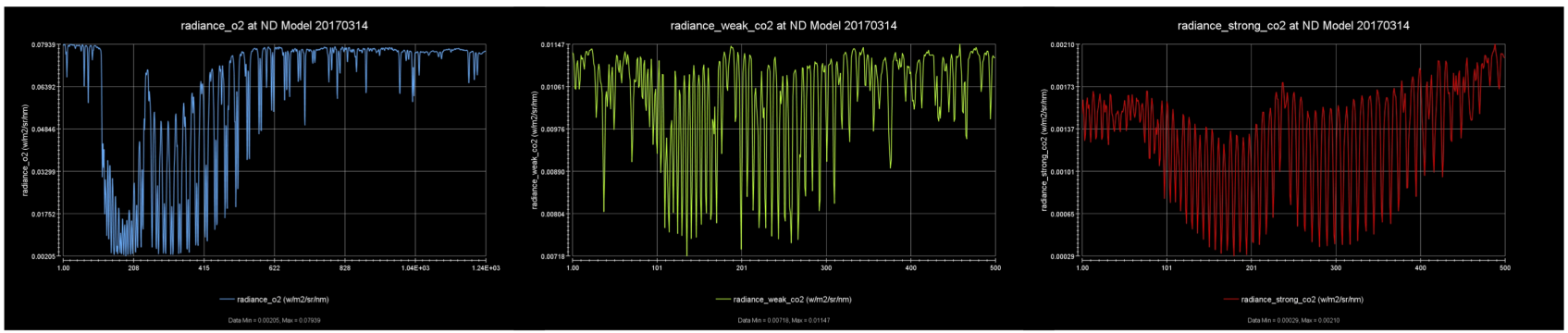


The Major Instrument of TanSat

Table: *Summary of ACGS Spectral Requirements*

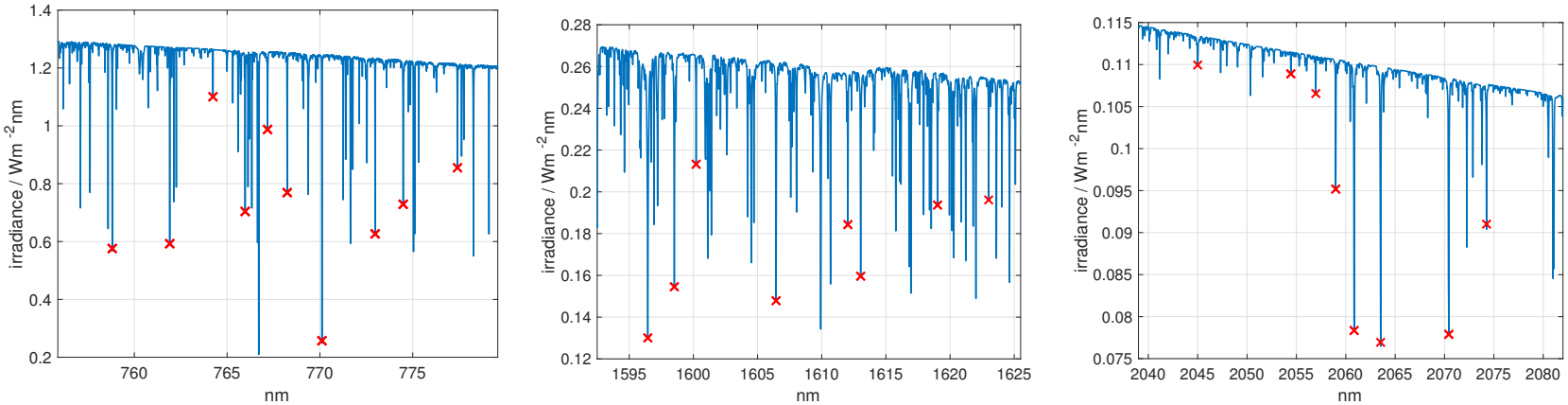
	O_2 A	WCO_2	SCO_2
Spectral Range (nm)	*758 - 778*	*1594 - 1624*	*2042 - 2082*
Spectral Resolution (nm)	*0.033 - 0.047*	*0.120 - 0.142*	*0.160 - 0.182*
Dynamic Range ($mW/m^2/sr/nm$)	*SNR=1@3.1e-02 - 362.17*	*SNR=1@7.06e-03 - 60.50*	*SNR=1@5.8e-03 - 15.50*
SNR@ xx.xx $mW/m^2/sr/nm$)	*360@15.2*	*250@2.60*	*180@ 1.10*
Abs/Rel Calibration error (%)	*<5 \ <3*		
Calibration Nonlinearity error (%)	*<2*		
Dark Current (DNs) error	*<5 DNs (After Correction)*		
Radiance Response Uniformity (%)	*>99.9 @ interior of band; >99 between bands*		
Spectral Sampling Per FWHM	*>2*		
IFOV (Km^2)	*2×2*		
Frame Rate(Hz)	*~ 3*		

Figure: The First spectrum of ACGS



On-orbital Performance of ACGS

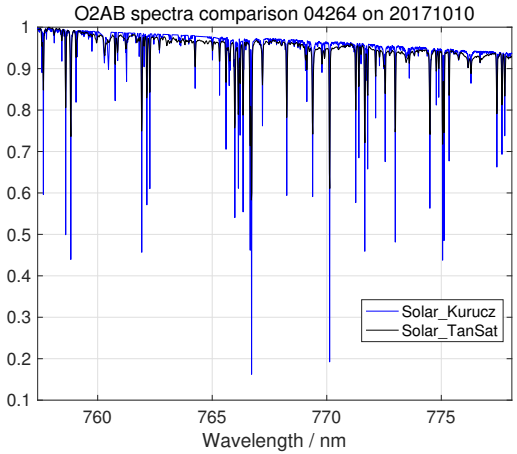
Spectroscopic: Fraunhofer Line

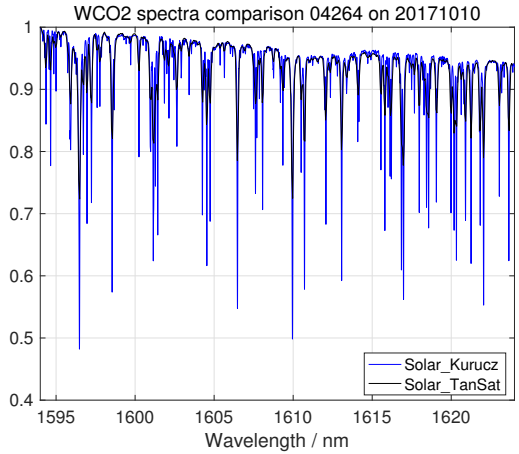


1. The red crosses mark indicate the Fraunhofer lines of solar spectrum (Kurucz, 2005, 2006)we selected at each band in this work.
2. These selected Fraunhofer lines must be deeper depth and wider of absorption to be identified by our instrument, and after to be corrected of Doppler effect.
3. We used the available Fraunhofer lines of solar spectrum acquired when solar calibration observation of TanSat, comparison with the Kurucz's solar spectrum as reference to validate spectral accuracy of centroid location. the Kurucz's solar spectrum is as a reference justly.

On-orbital Performance of ACGS

Spectroscopic: One Footprint Spectrum of ACGS





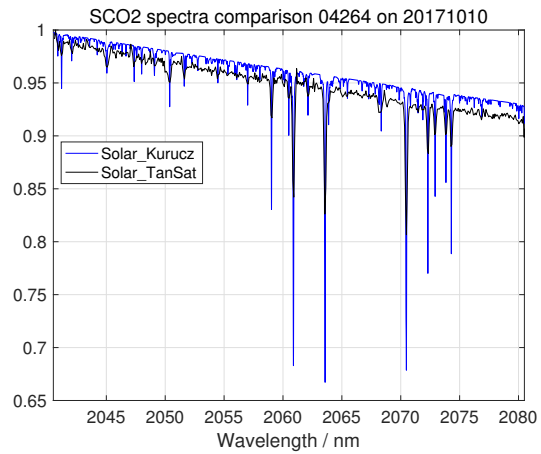


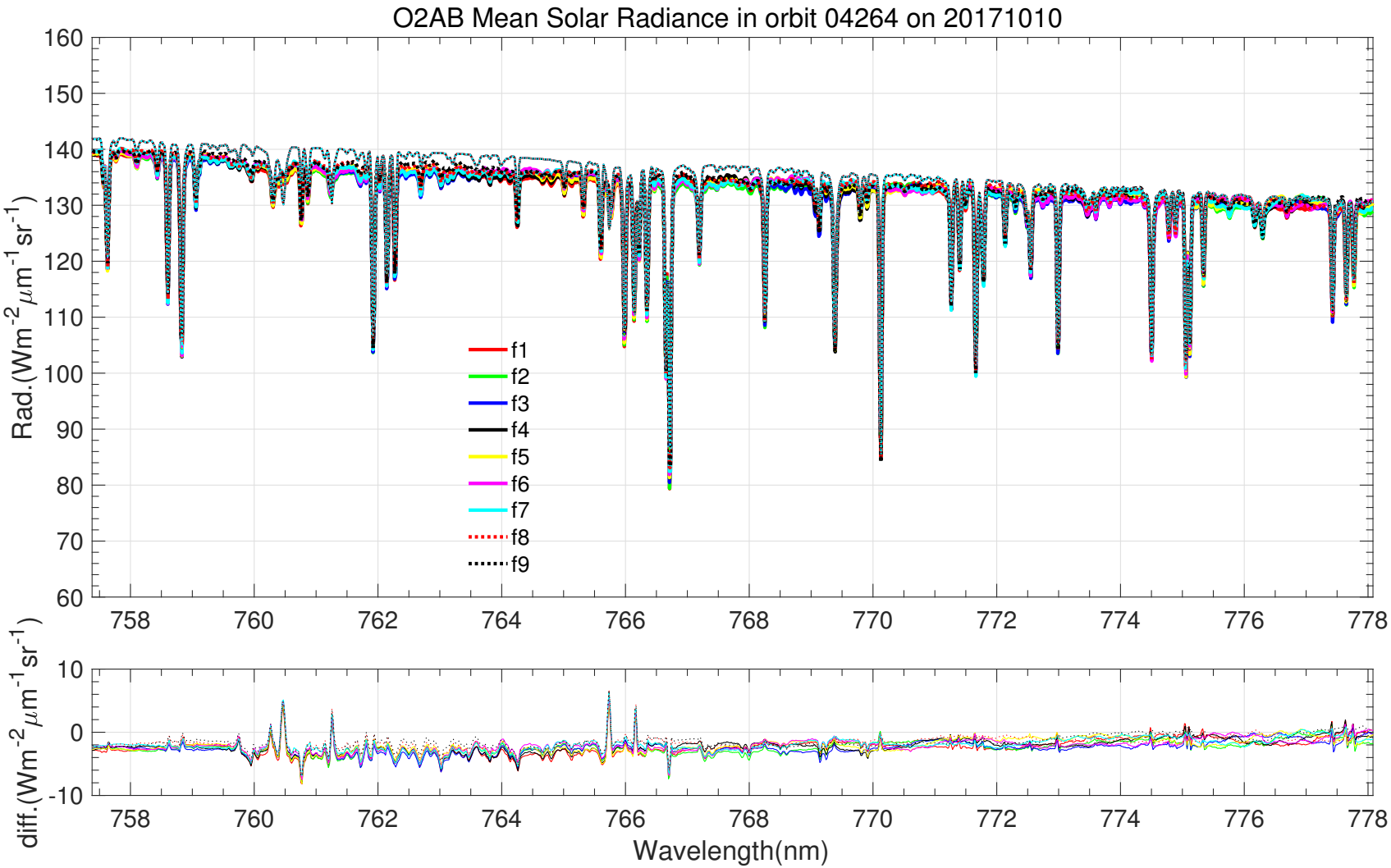
Table: *Spectral Performance on-Orbit Calibration*

	Spectral resolution	*Spectral Calibrated Performance*	*Requirement*
O_2 *A*	*0.033 - 0.047 nm*	*0.00019 nm*	*0.05 FWHM*
WCO_2	*0.120 - 0.140 nm*	*0.00027 nm*	*0.05 FWHM*
SCO_2	*0.160 - 0.180 nm*	*0.00475 nm*	*0.05 FWHM*

The spectral calibration accuracy of O_2 A band is 0.19 pm, WCO_2 band is 0.27 pm, and SCO_2 band is 4.75 pm, which all meets the requirement of 0.05 FWHM.

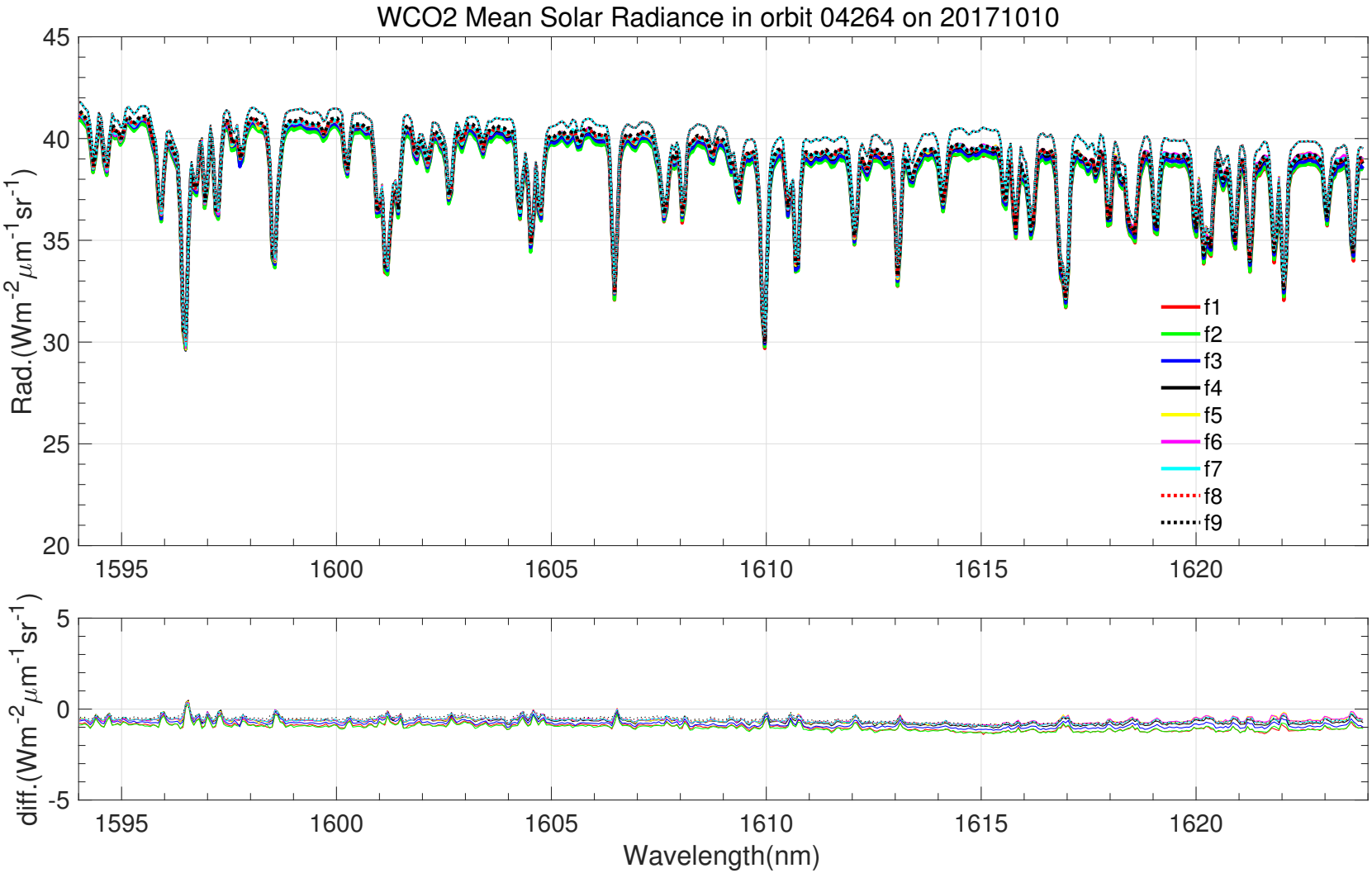
On-orbital Performance of ACGS

Spectroscopic: O_2 A band Spectrum of ACGS All 9 Footprints



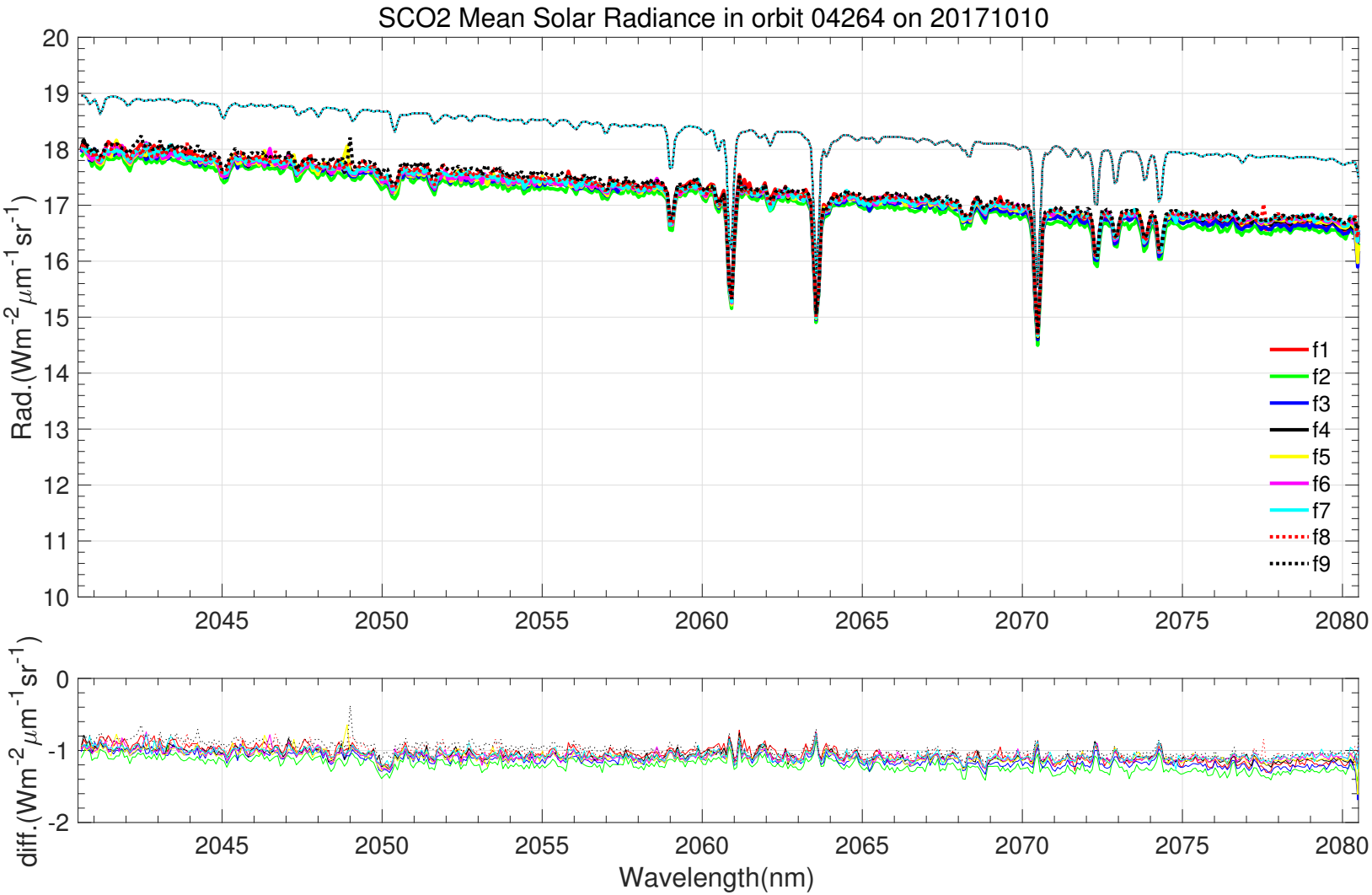
On-orbital Performance of ACGS

Spectroscopic: WCO_2 band Spectrum of ACGS All 9 Footprints



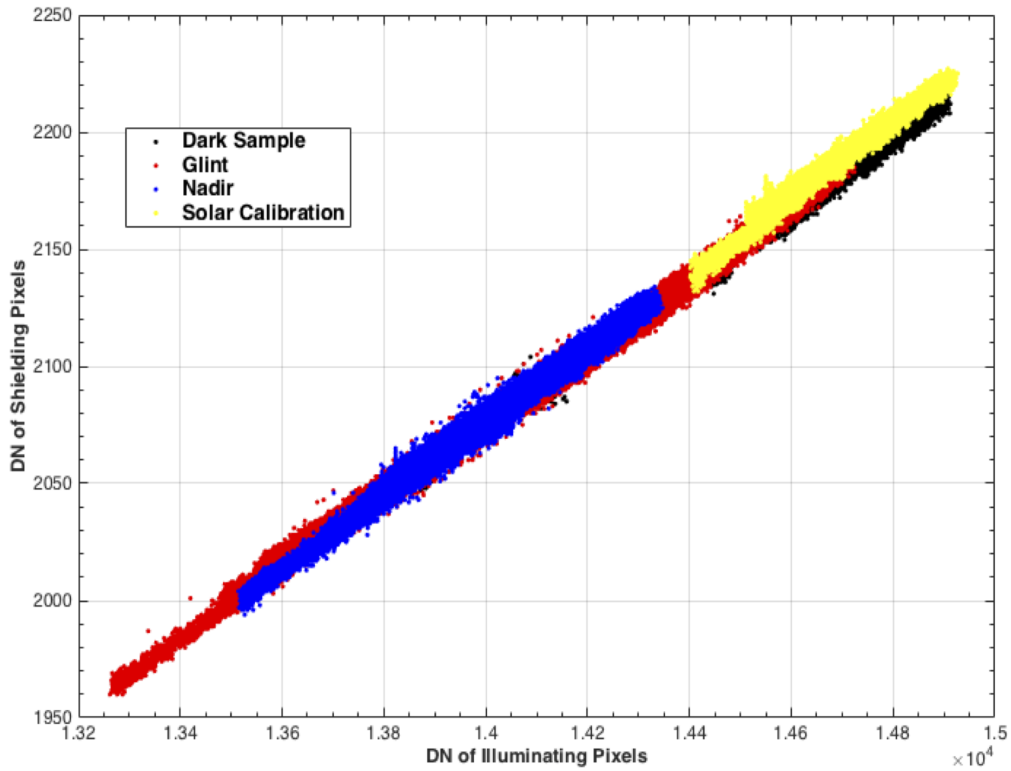
On-orbital Performance of ACGS

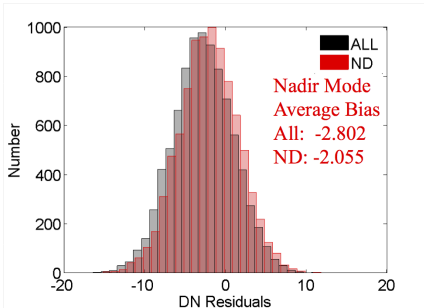
Spectroscopic: SCO_2 band Spectrum of ACGS All 9 Footprints

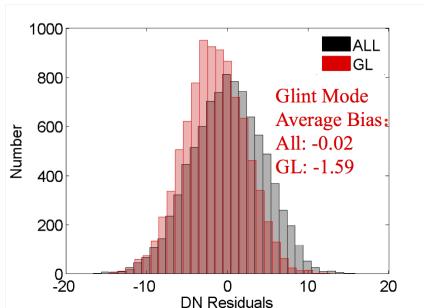


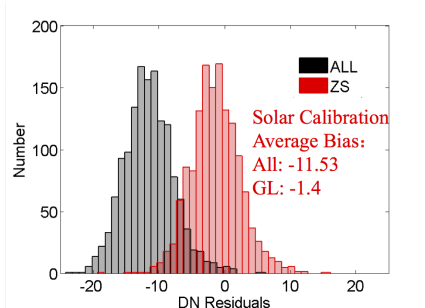
On-orbital Performance of ACGS

Radiometric: On-Orbit Dark Current Model of WCO_2



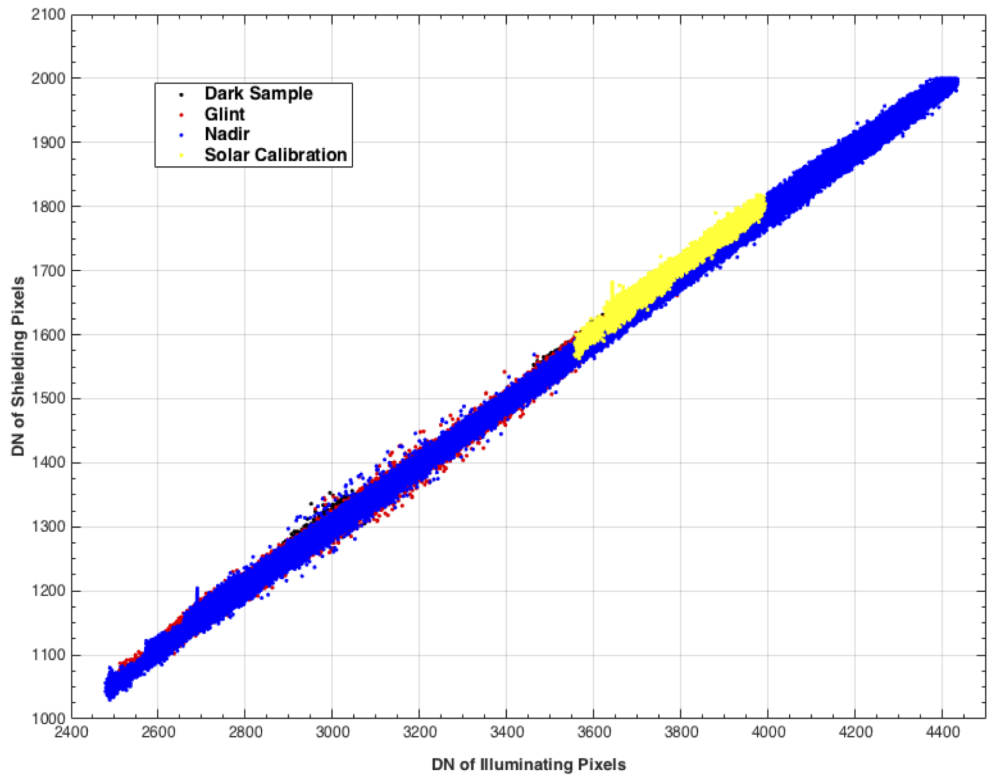


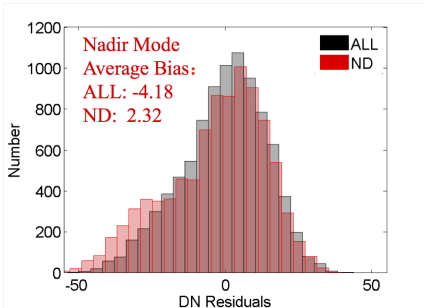


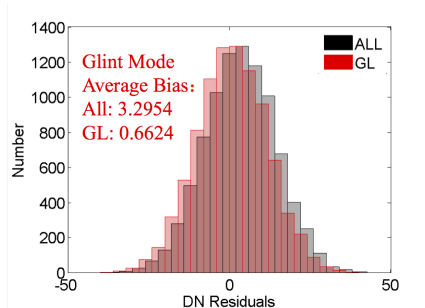


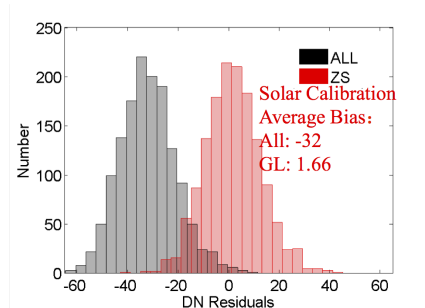
On-orbital Performance of ACGS

Radiometric: On-Orbit Dark Current Model of SCO_2



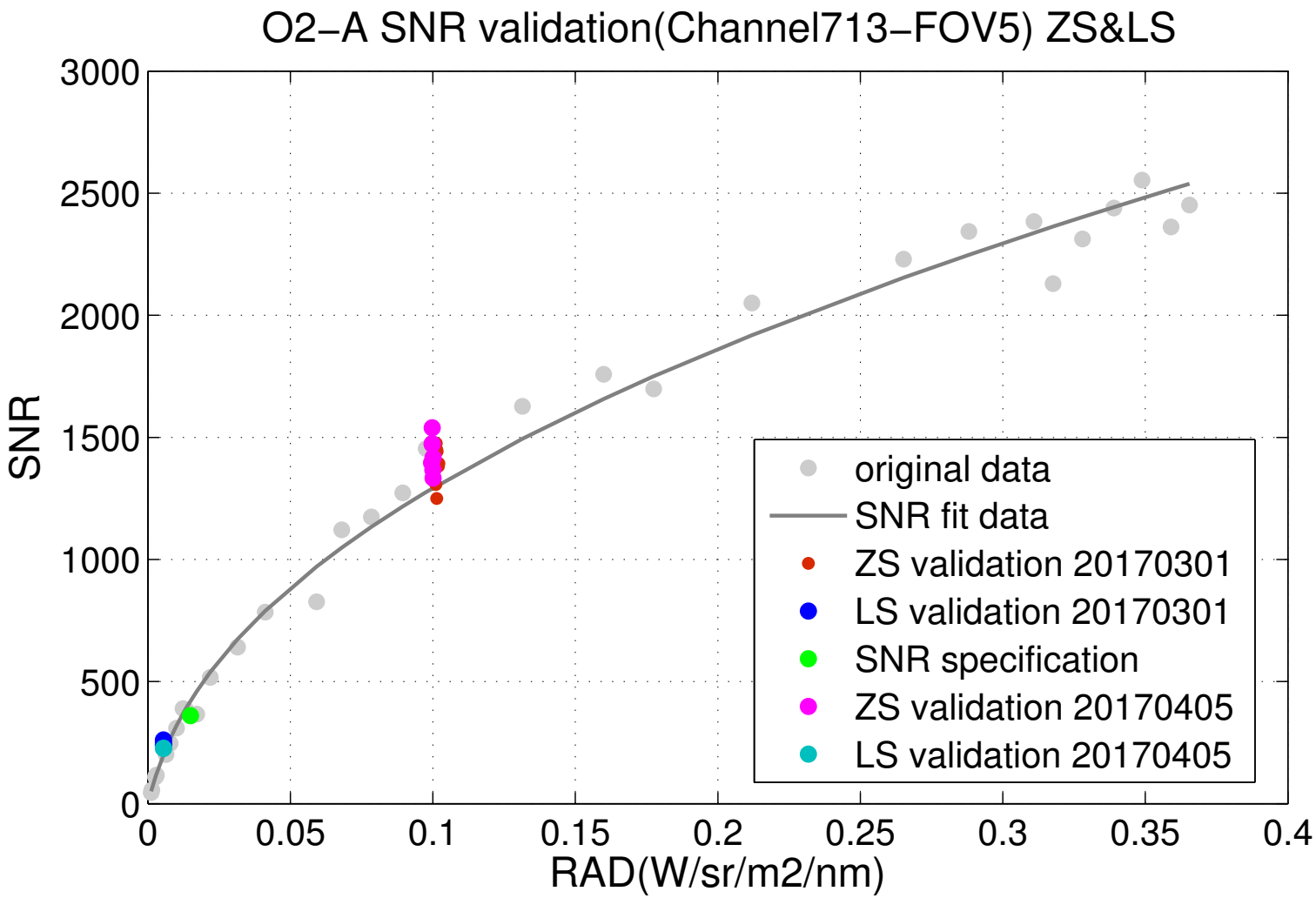






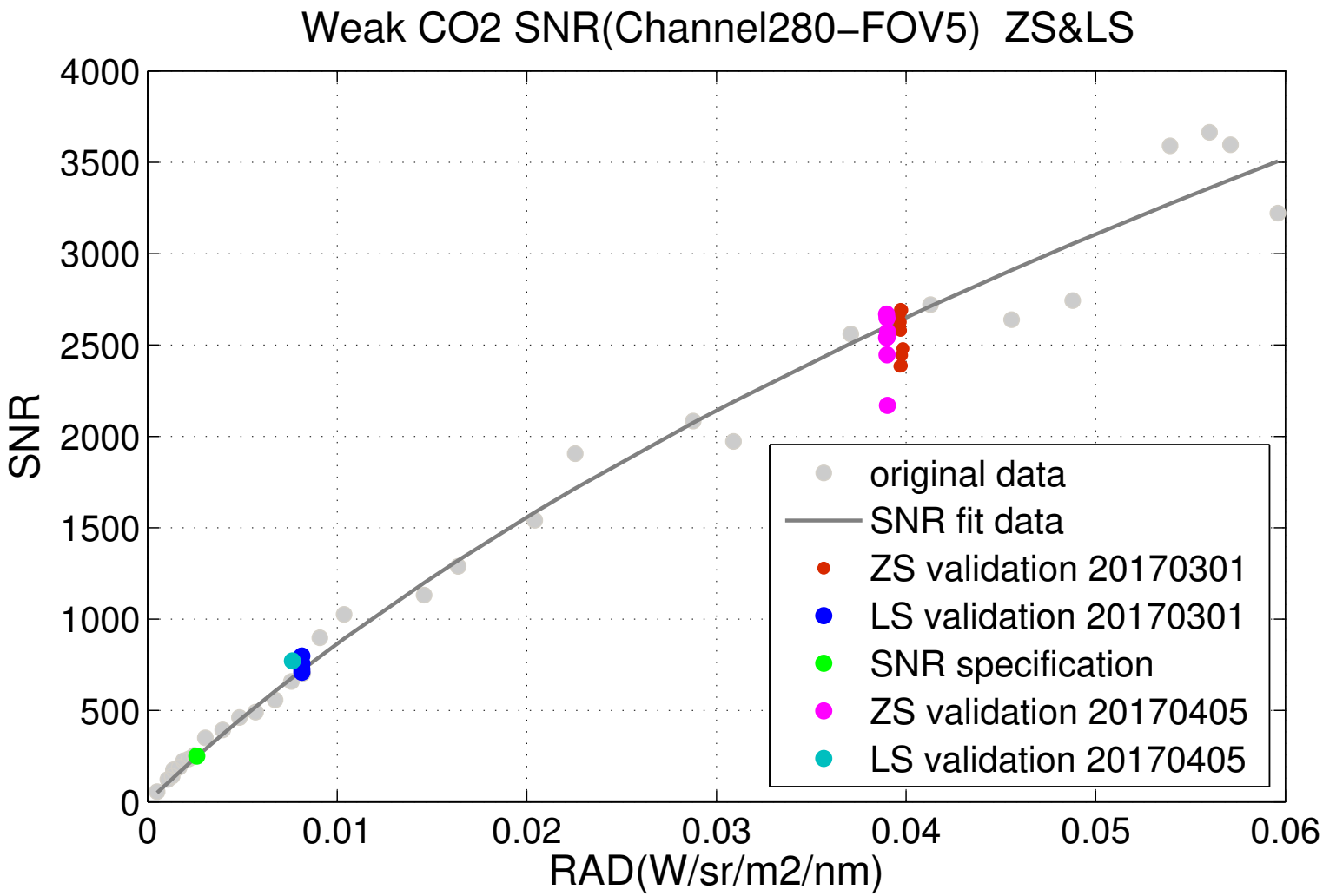
On-orbital Performance of ACGS

Radiometric: On-Orbit Signal to Noise of O_2 A band



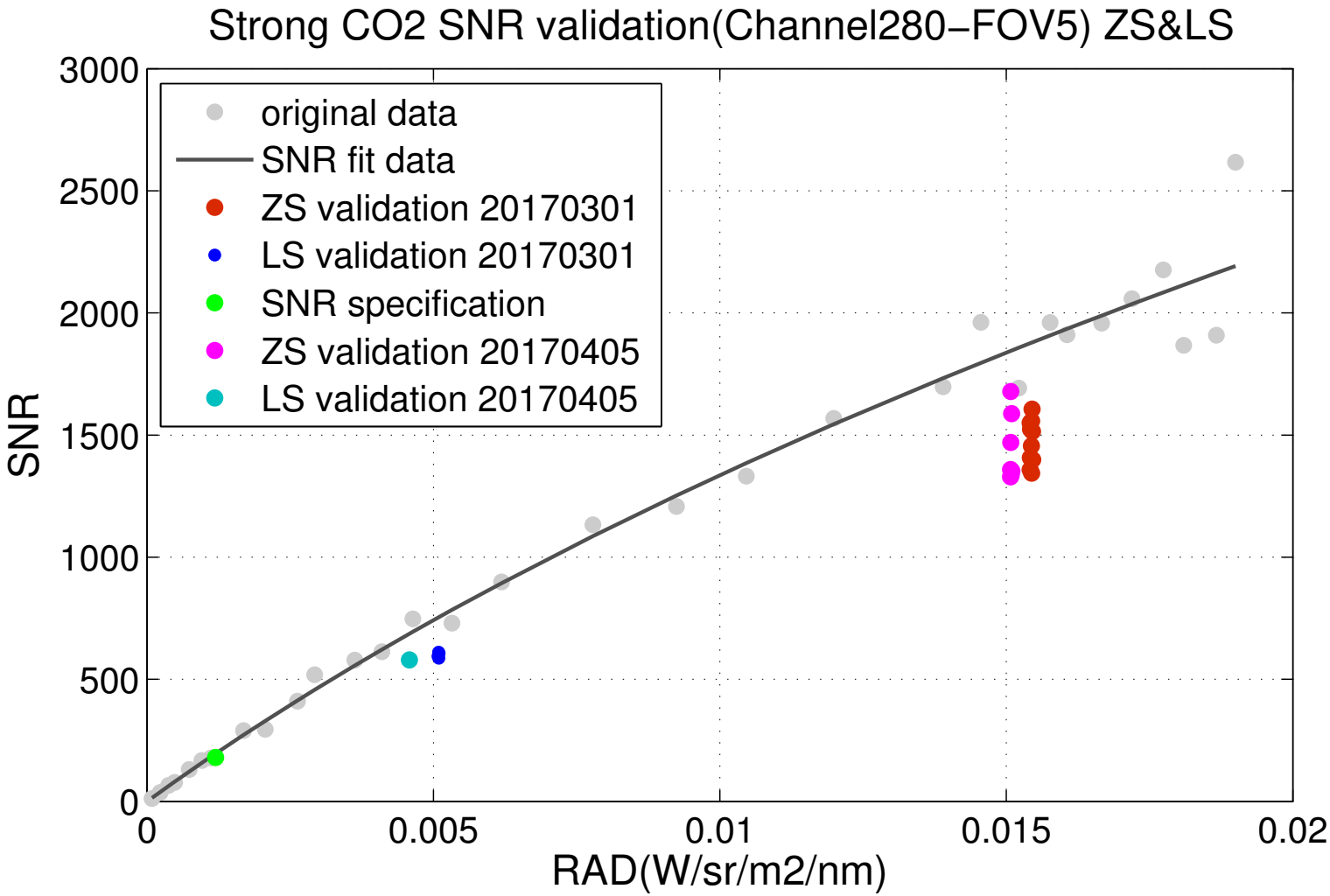
On-orbital Performance of ACGS

Radiometric: On-Orbit Signal to Noise of WCO_2 band



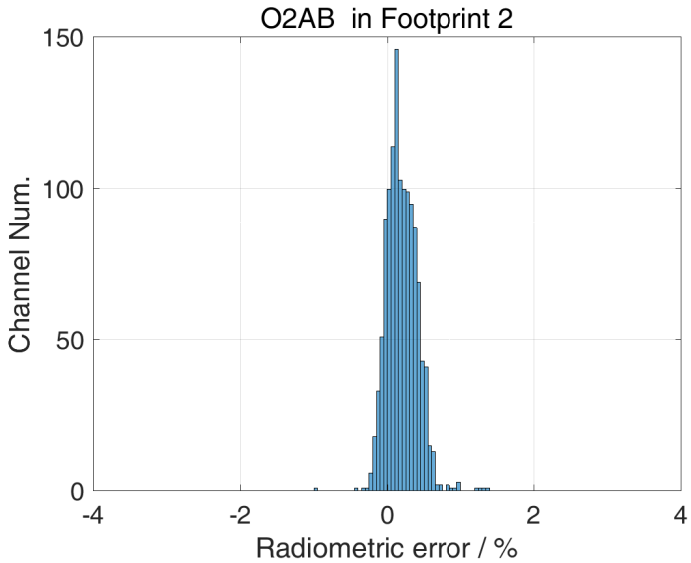
On-orbital Performance of ACGS

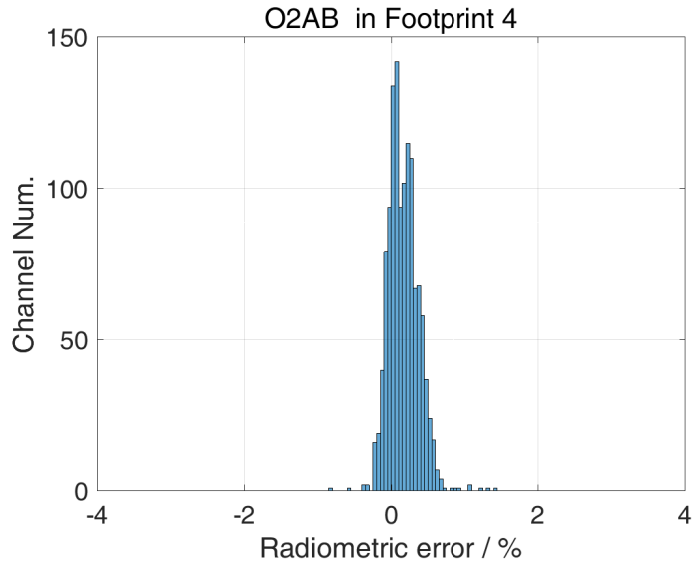
Radiometric: On-Orbit Signal to Noise of SCO_2 band

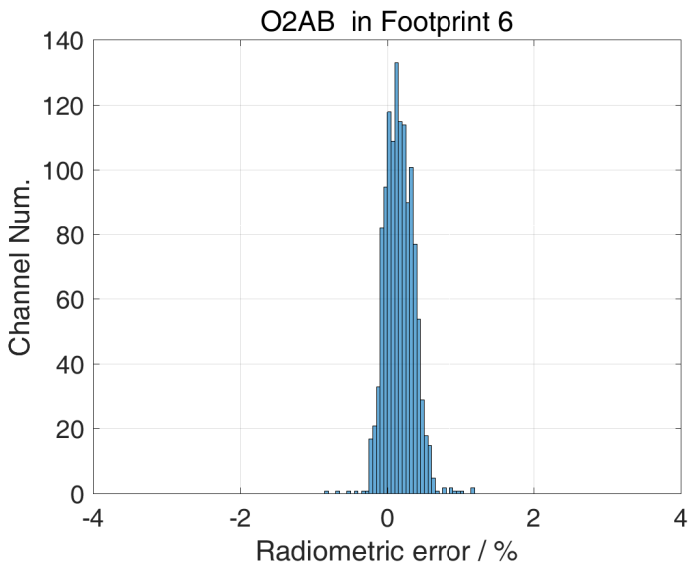


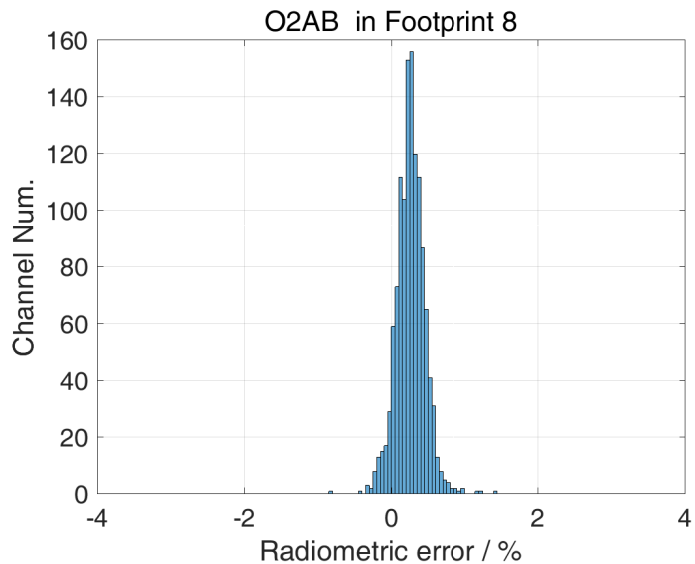
On-orbital Performance of ACGS

Radiometric: On-Orbit Radiometric Calibration Performance of O_2 A band: Bias Histogram



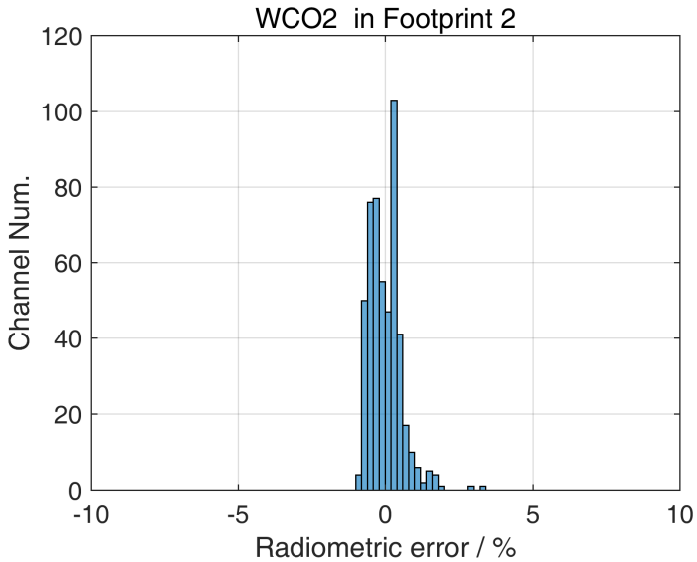


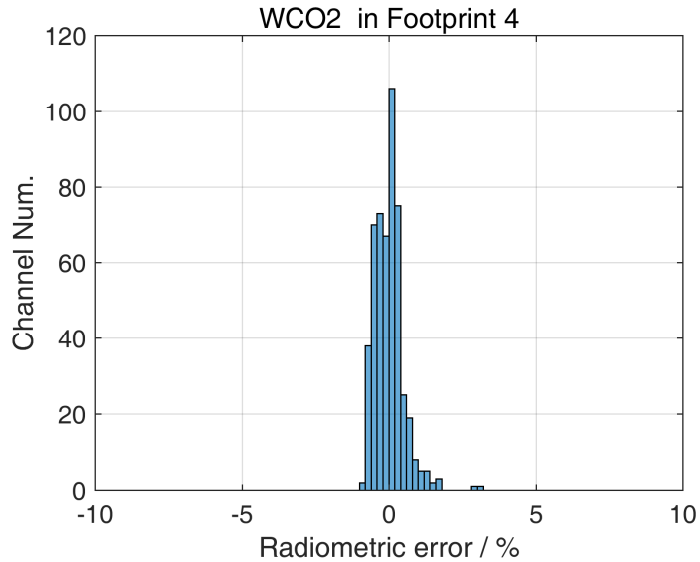


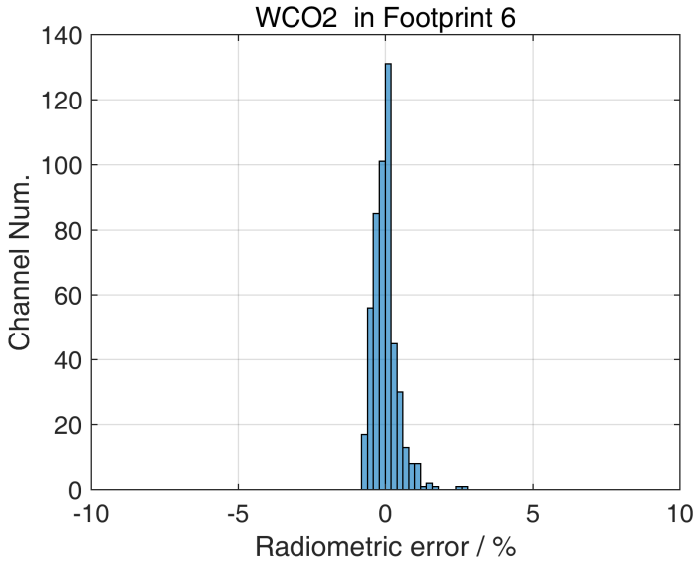


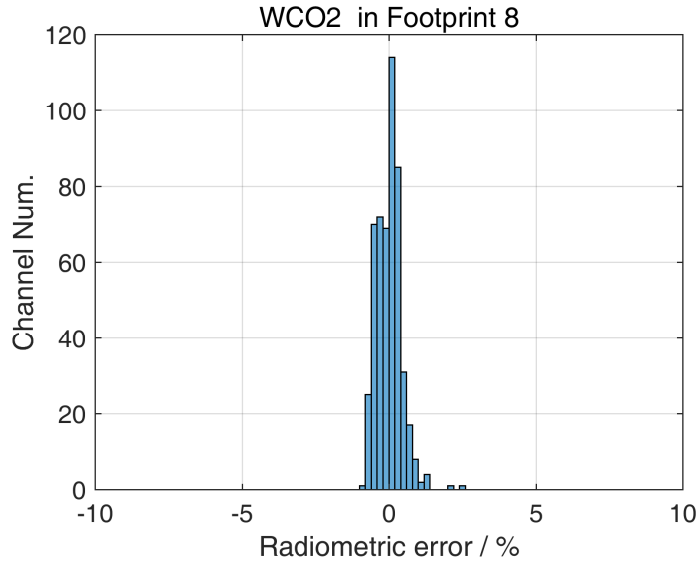
On-orbital Performance of ACGS

Radiometric: On-Orbit Radiometric Calibration Performance of WCO_2 band: Bias Histogram



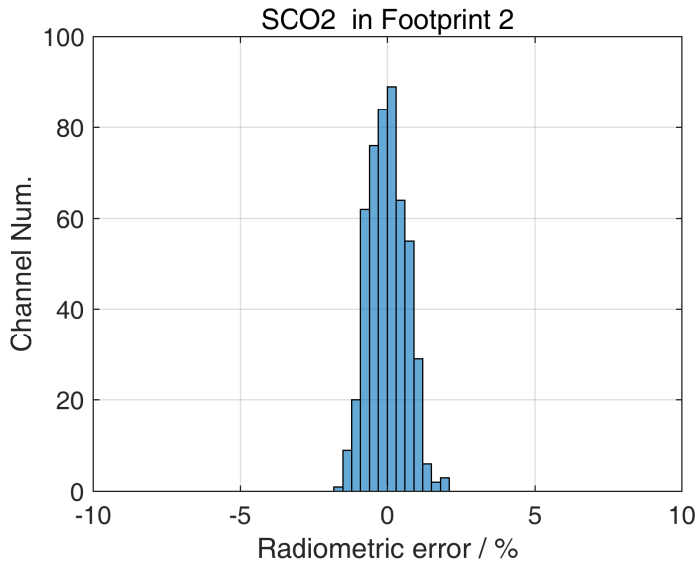


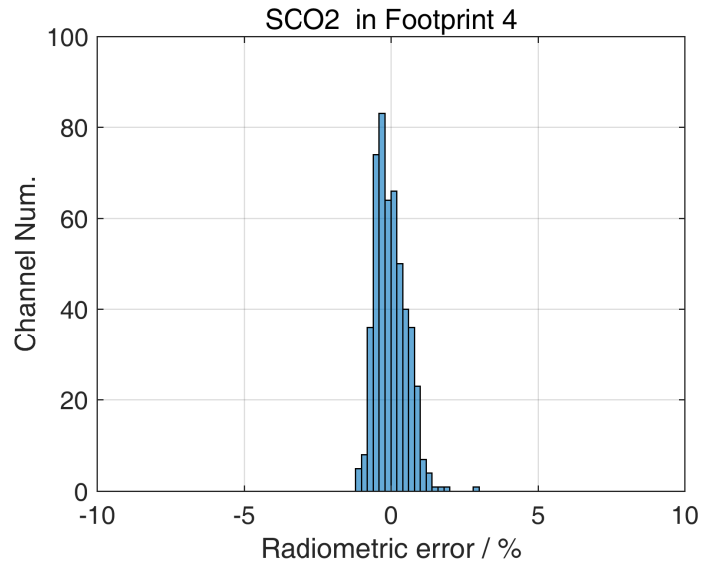


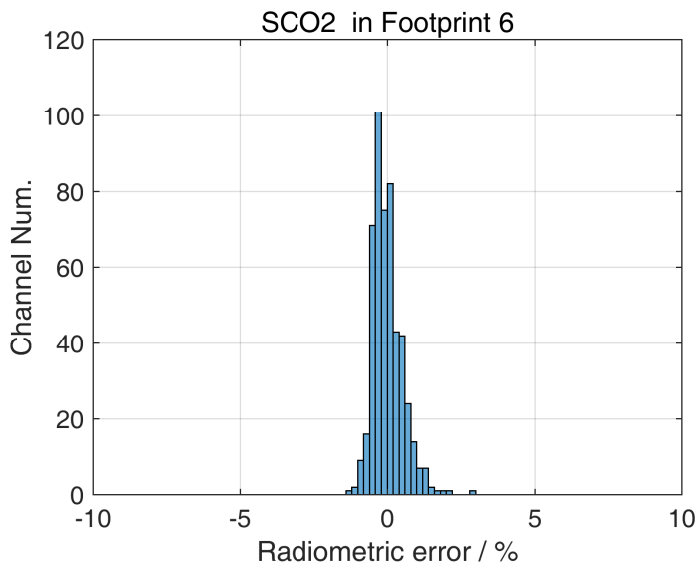


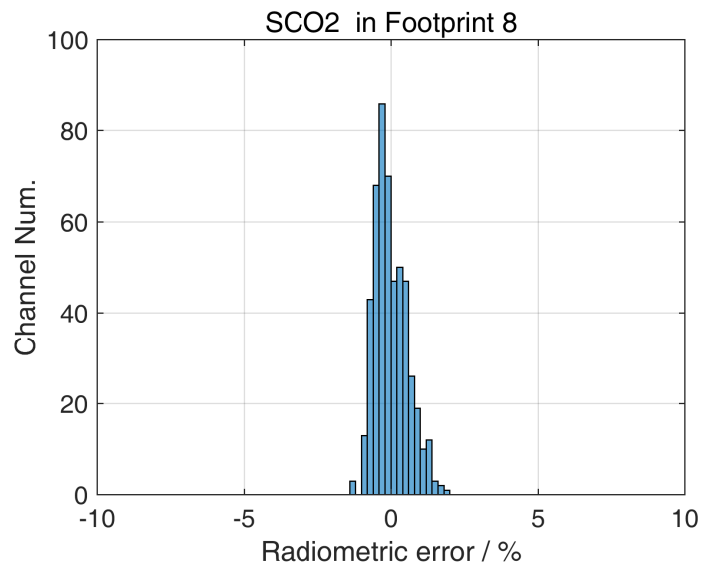
On-orbital Performance of ACGS

Radiometric: On-Orbit Radiometric Calibration Performance of SCO_2 band: Bias Histogram



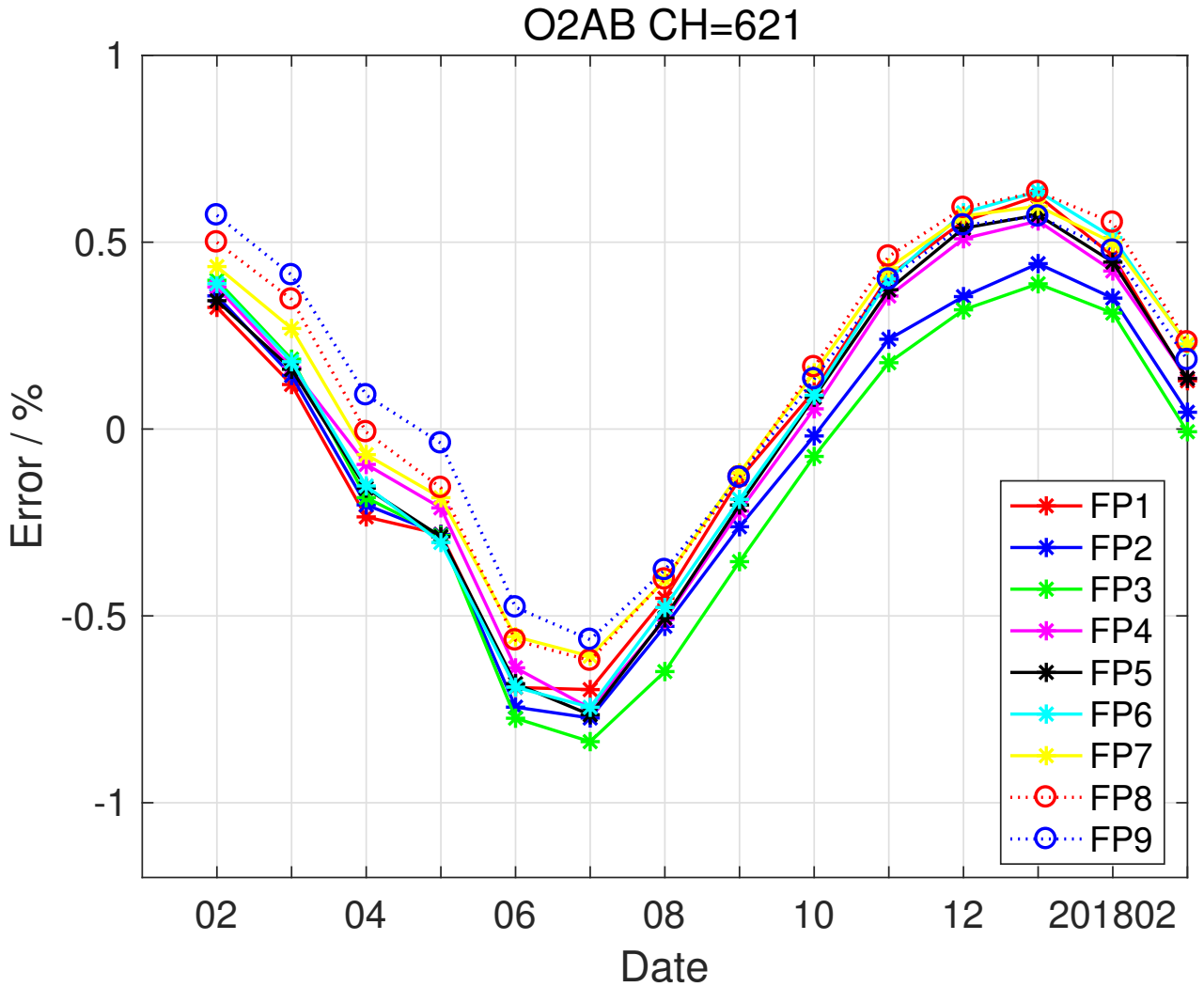






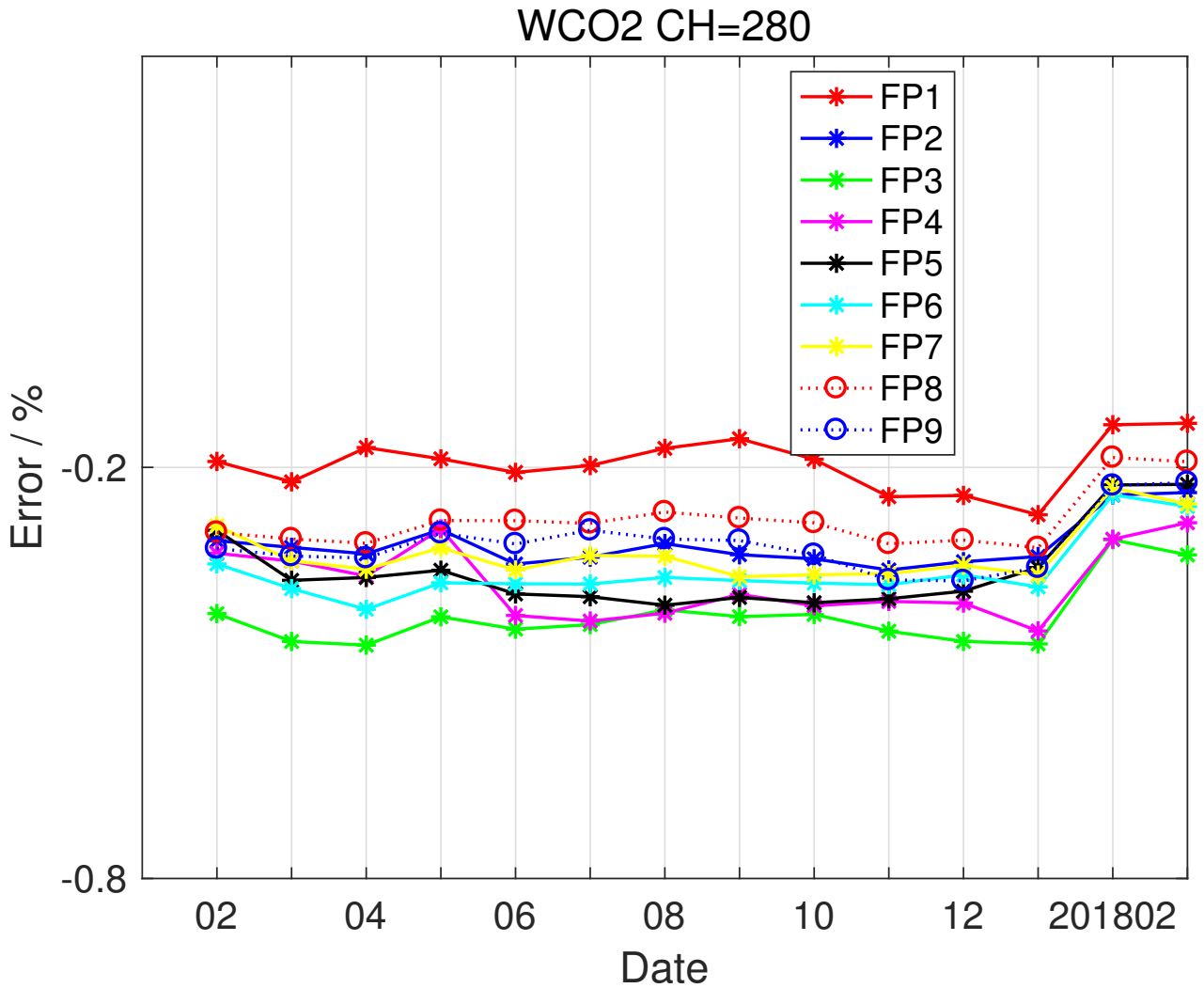
On-orbital Performance of ACGS

Radiometric: The Stability On-Orbit Radiometric Calibration Performance of O_2 A band



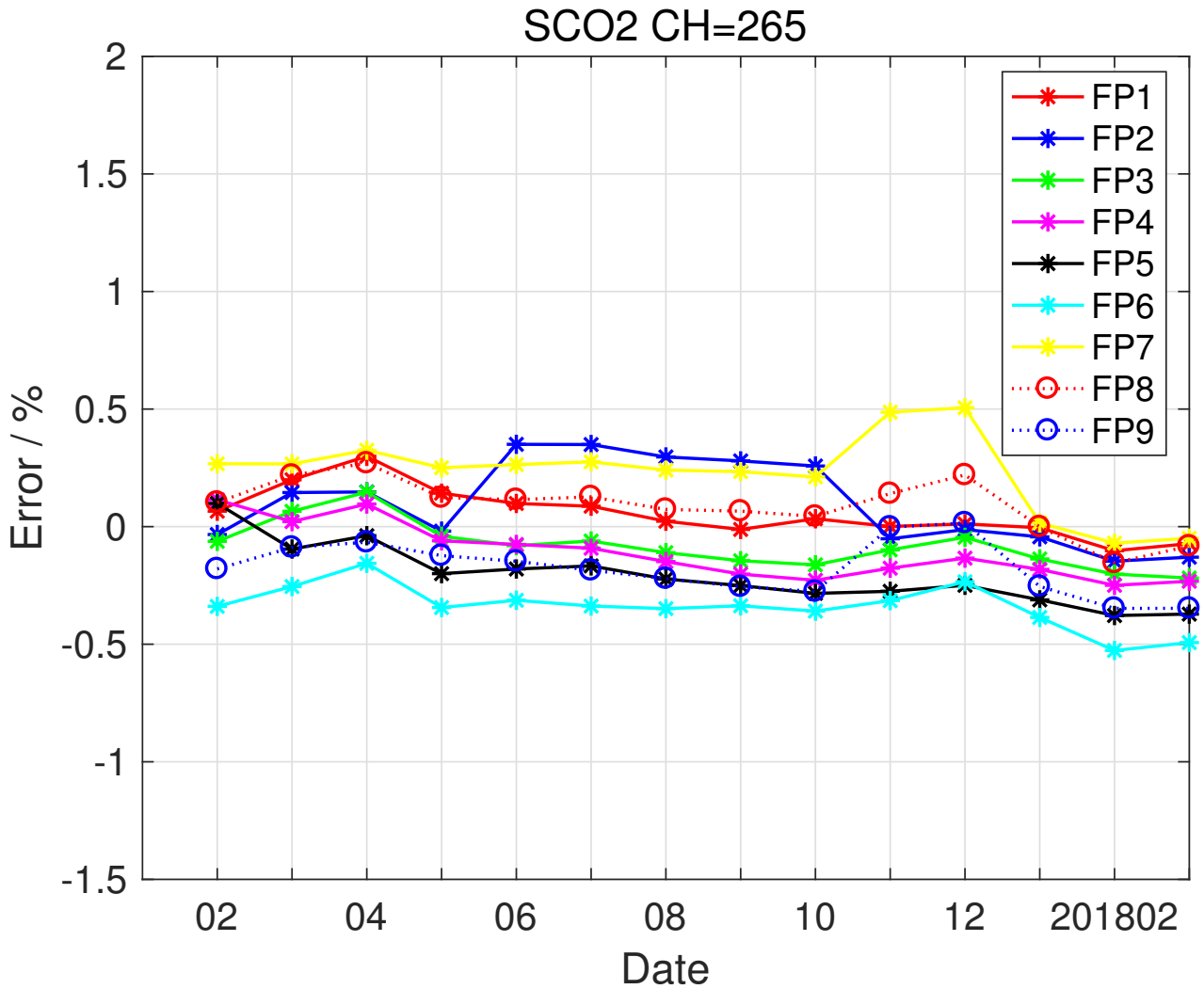
On-orbital Performance of ACGS

Radiometric: The Stability On-Orbit Radiometric Calibration Performance of WCO_2 band



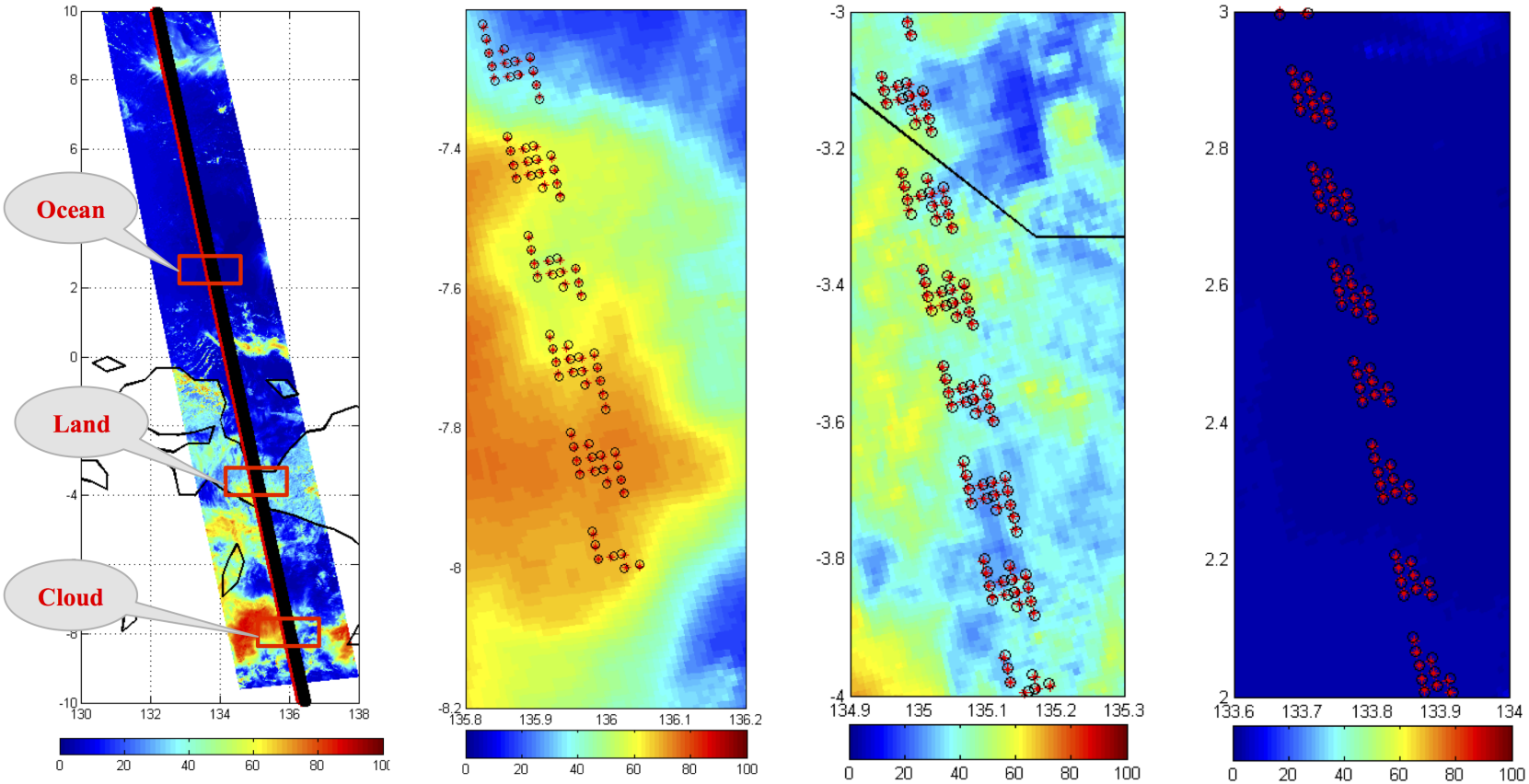
On-orbital Performance of ACGS

Radiometric: The Stability On-Orbit Radiometric Calibration Performance of SCO_2 band



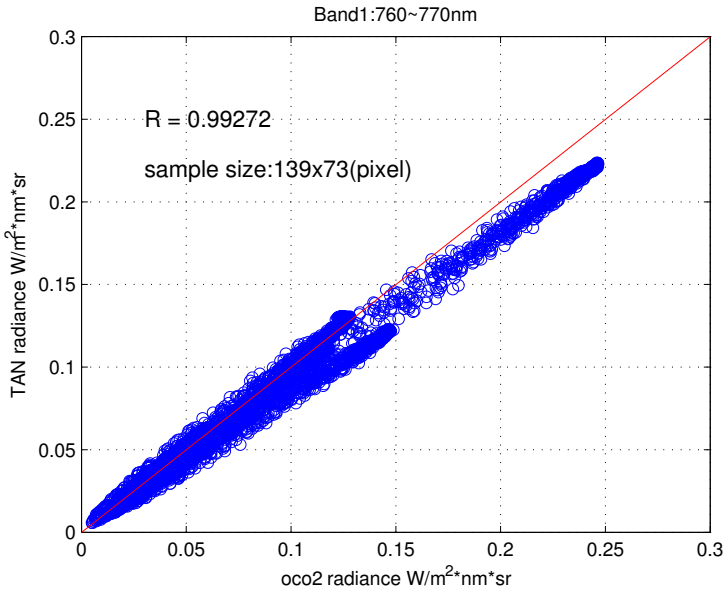
Intercomparison of L1 Product Between TanSat and OCO-2

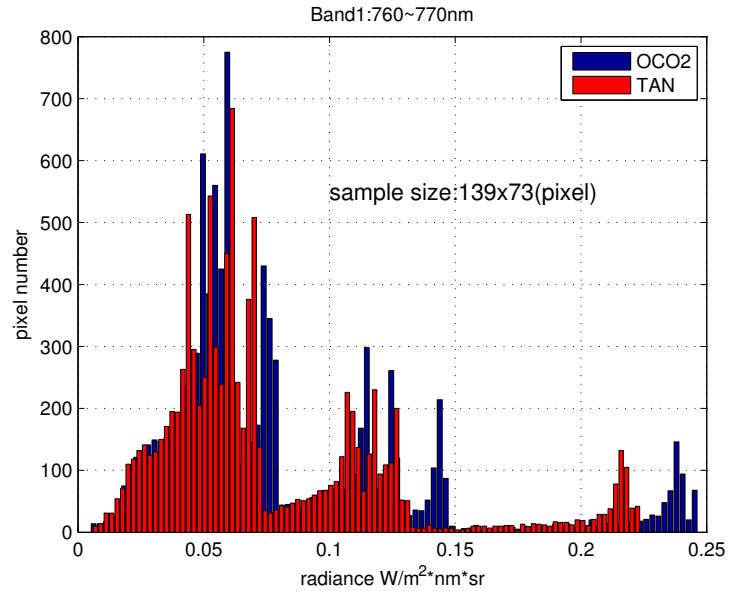
The Overlay Area of Intercomparison



Intercomparison of L1 Product Between TanSat and OCO-2

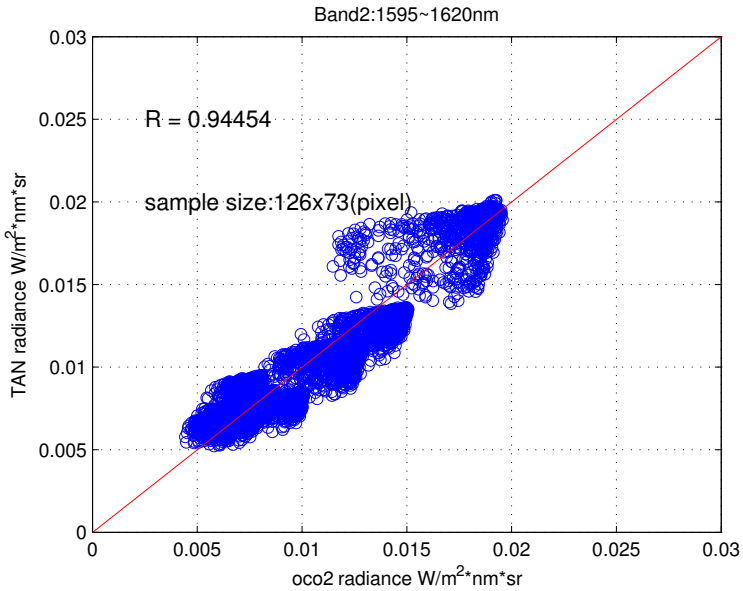
Intercomparison: Total Radiance of O_2 A band

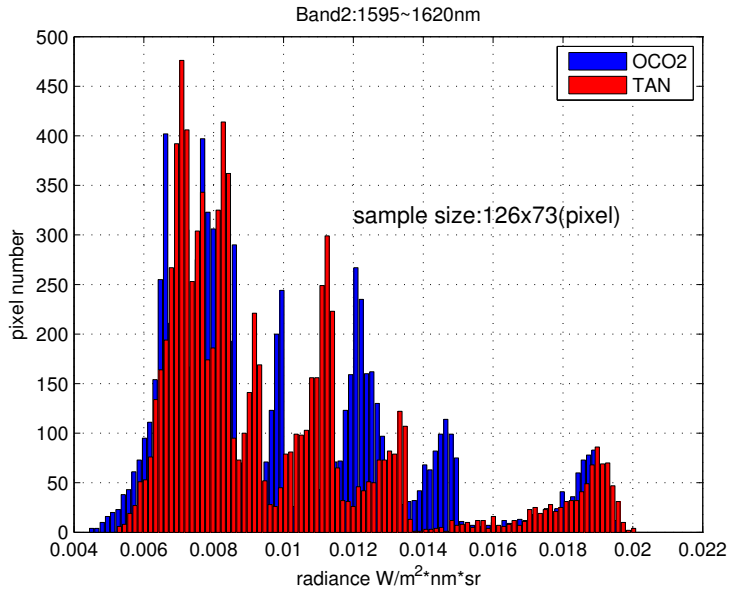




Intercomparison of L1 Product Between TanSat and OCO-2

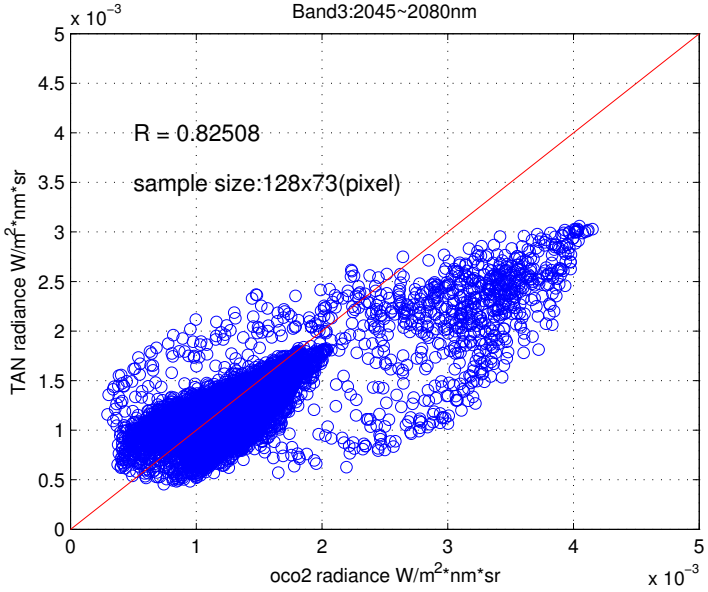
Intercomparison: Total Radiance of SCO_2 band

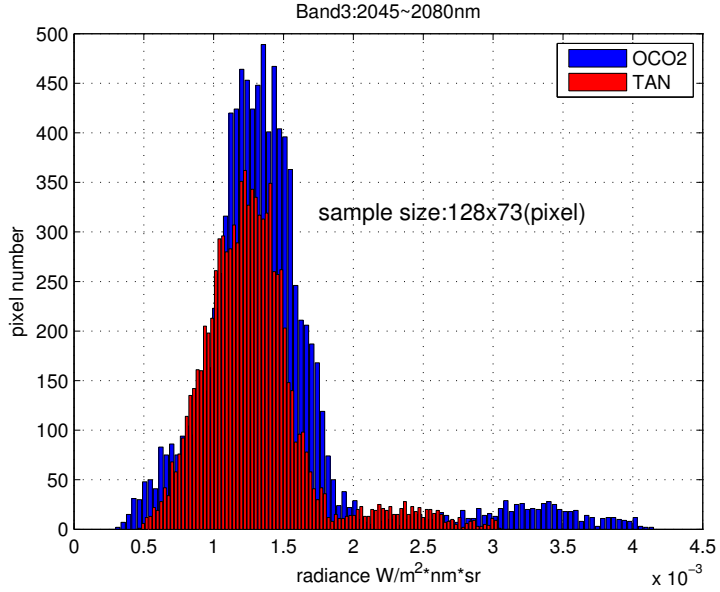




Intercomparison of L1 Product Between TanSat and OCO-2

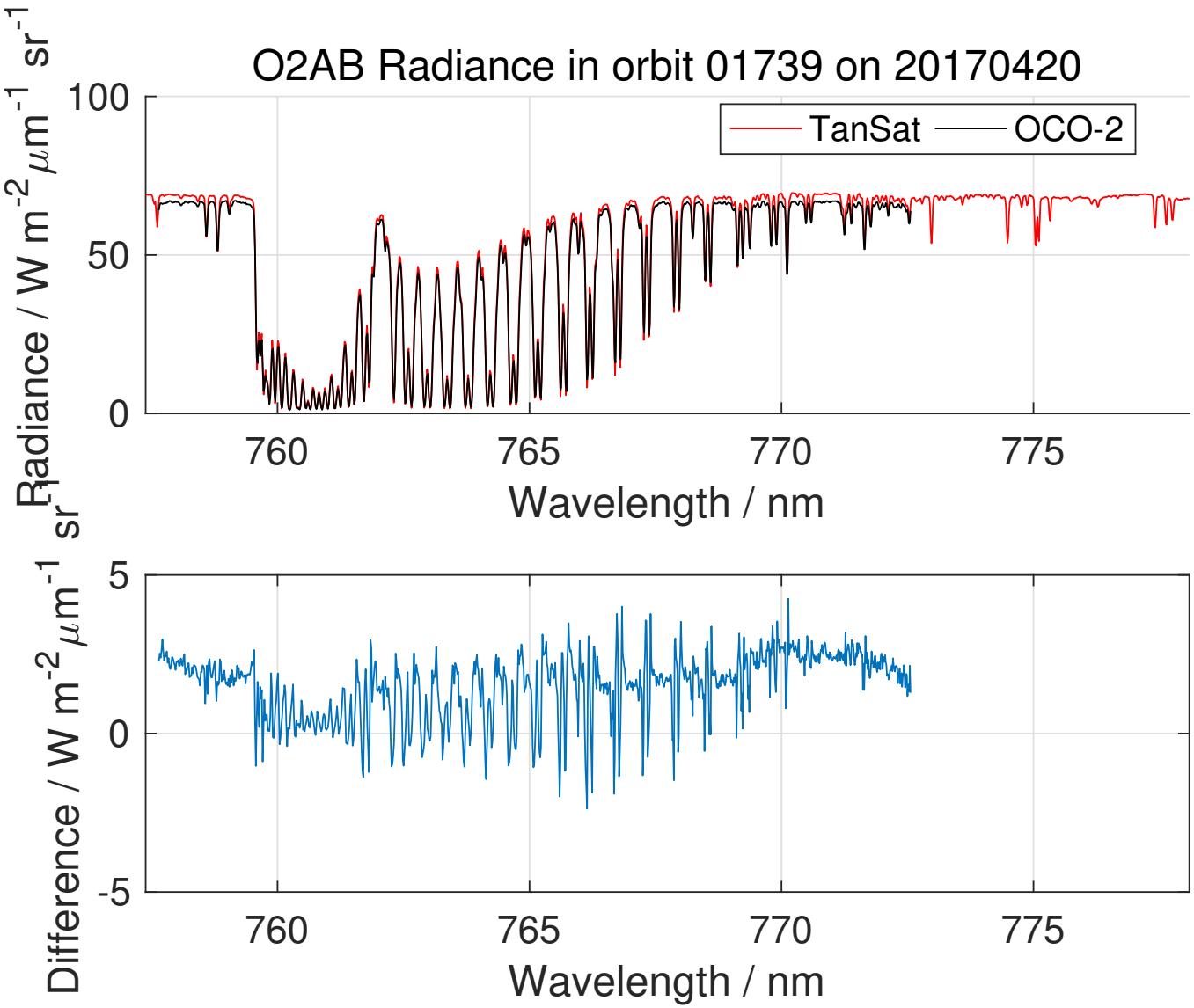
Intercomparison: Total Radiance of SCO_2 band





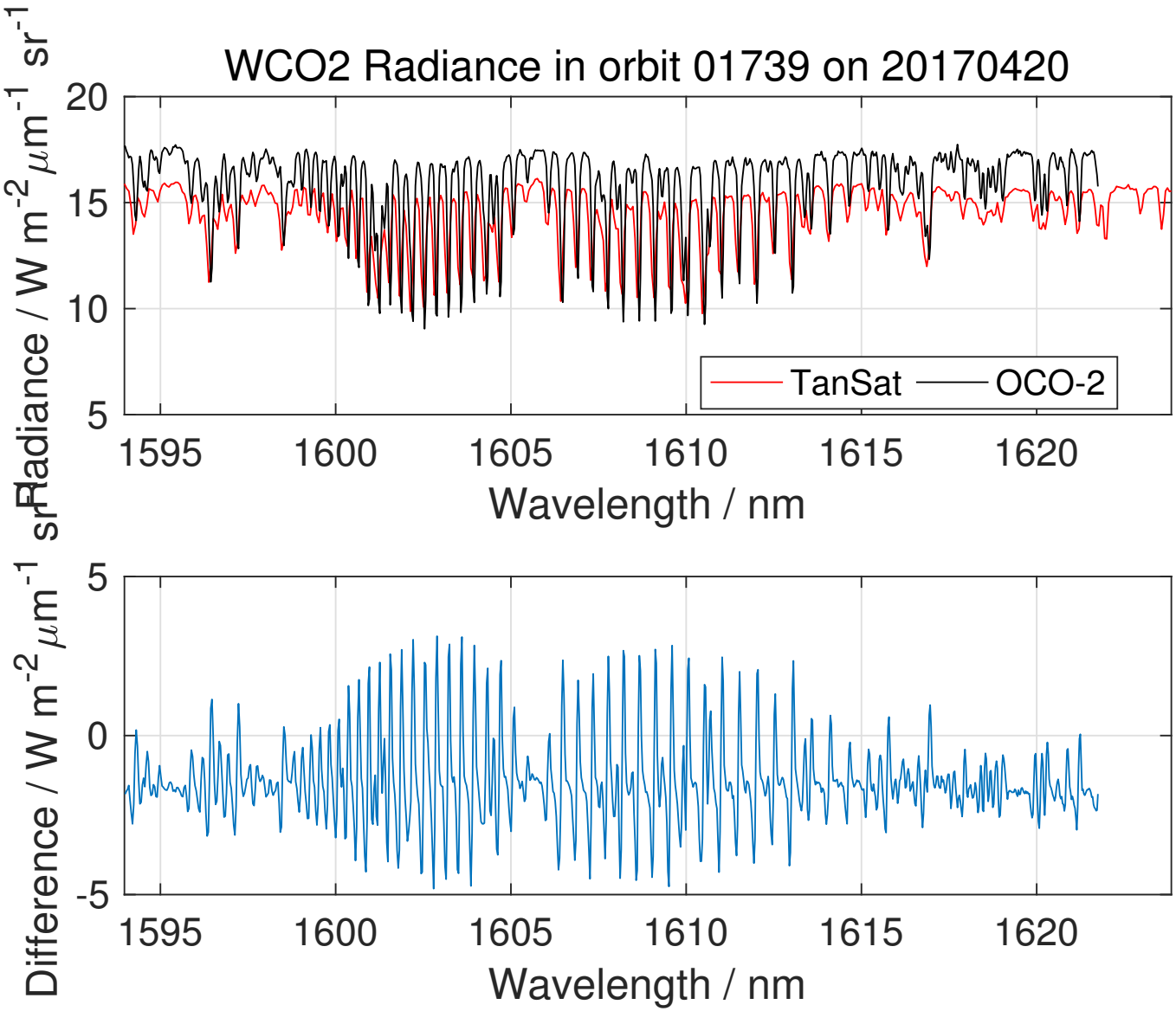
Intercomparison of L1 Product Between TanSat and OCO-2

Intercomparison: Two Spectrum of O_2 A band



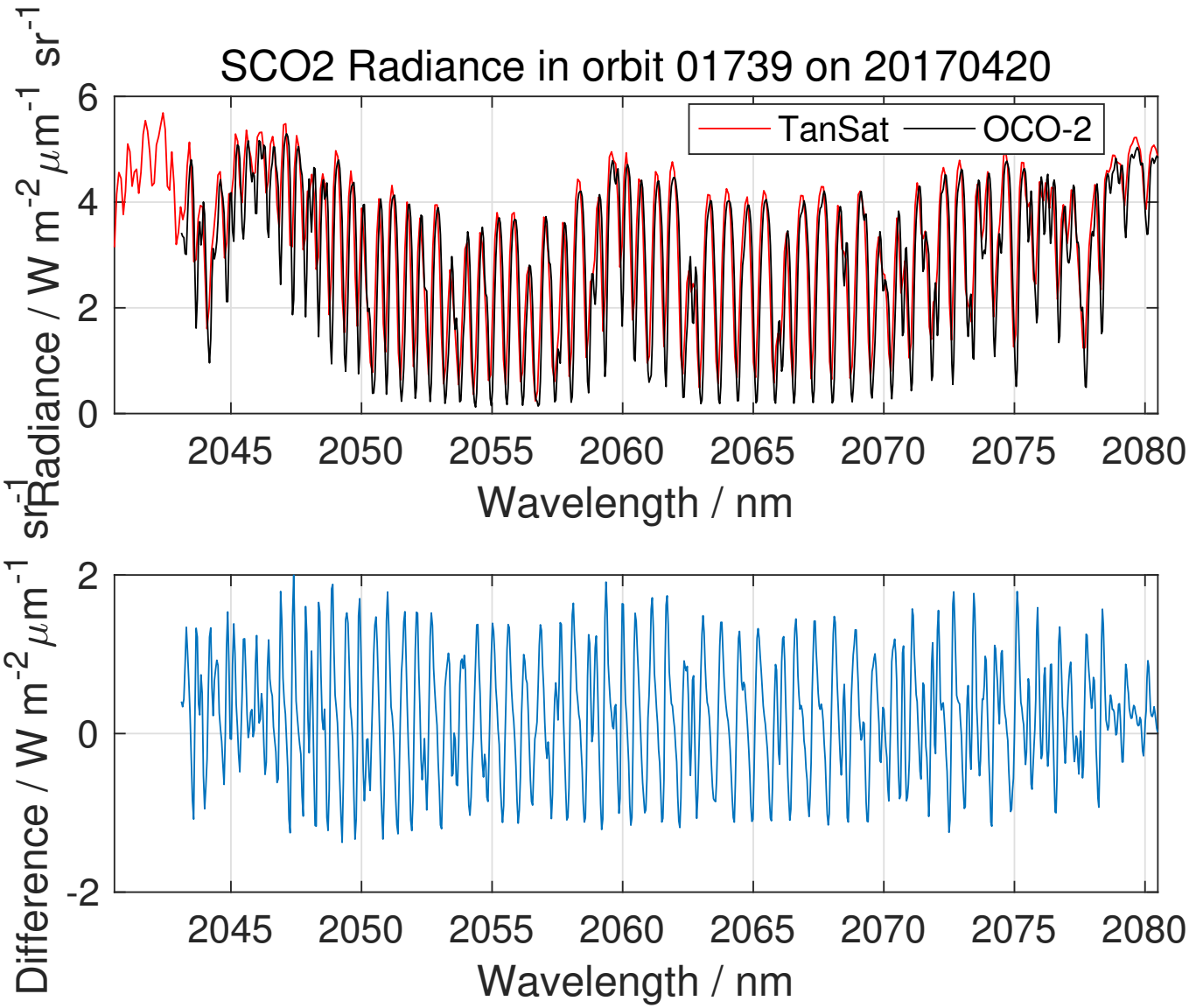
Intercomparison of L1 Product Between TanSat and OCO-2

Intercomparison: Two Spectrum of WCO_2 band



Intercomparison of L1 Product Between TanSat and OCO-2

Intercomparison: Two Spectrum of SCO_2 band



Summary

1. Since the ACGS instrument was powered up on 11 January 2017, a well-planned series of Cal/Val activities has been carried out with the goal of providing a well-calibrated and characterized level 1 product.
2. The level 1 product reached Beta maturity status on 31 May 2017 and Provisional status on 29 September 2017, we named the provisional status level 1 product as Version 1.0.
3. For Beta and Provisional Level data, the estimated absolute spectral calibration uncertainty is less than one tenth spectral resolution in the three bands, and the estimated radiometric uncertainty for all Earth scenes is less than 5% in O_2 A band and less than 3% in the WCO_2 and SCO_2 band.
4. Since 24 October 2017, we released the Ver1.0 ACGS level 1 products to around the world. 1 February 2018, L1 Products Ver2.0 were released (http://satellite.nsmc.org.cn/portalsite/default.aspx).

Thank You for Your Attention !