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Lunar calibration for a multi-band sensor onboard RISESAT and its validation activity with LANDSAT-8 data

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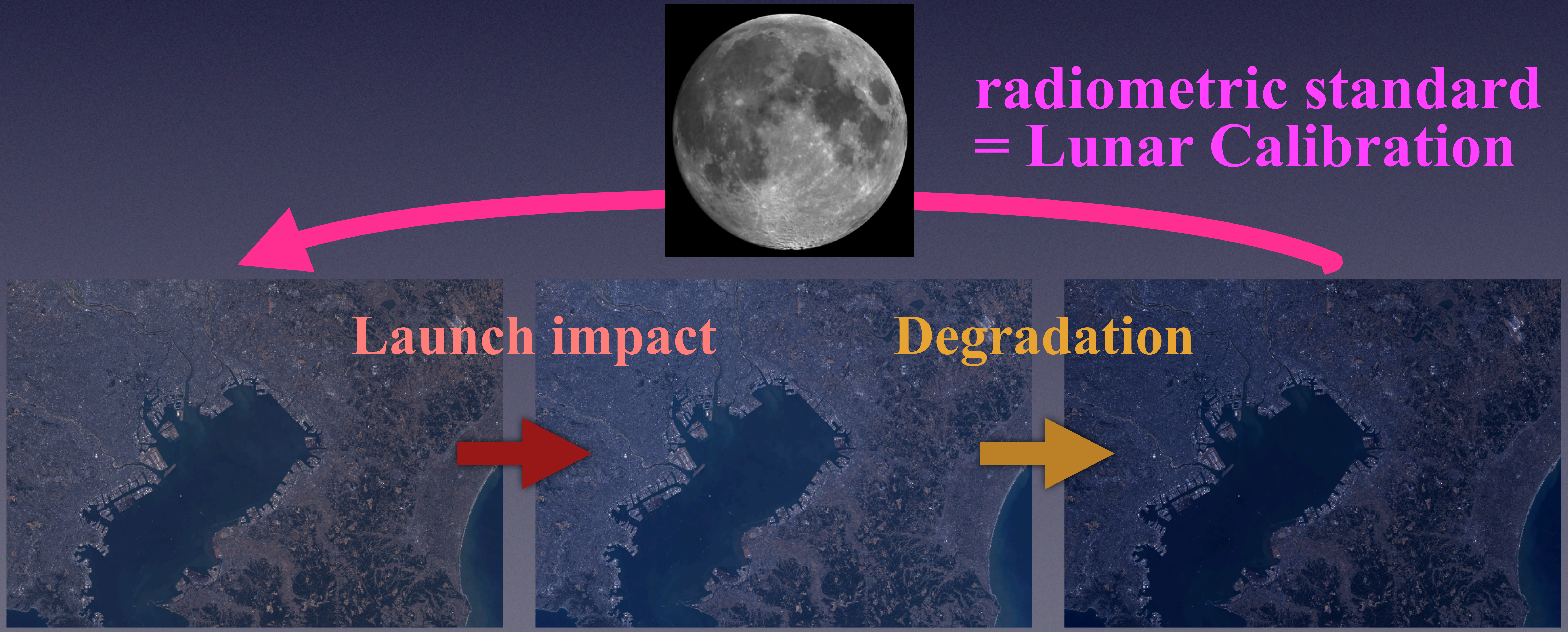
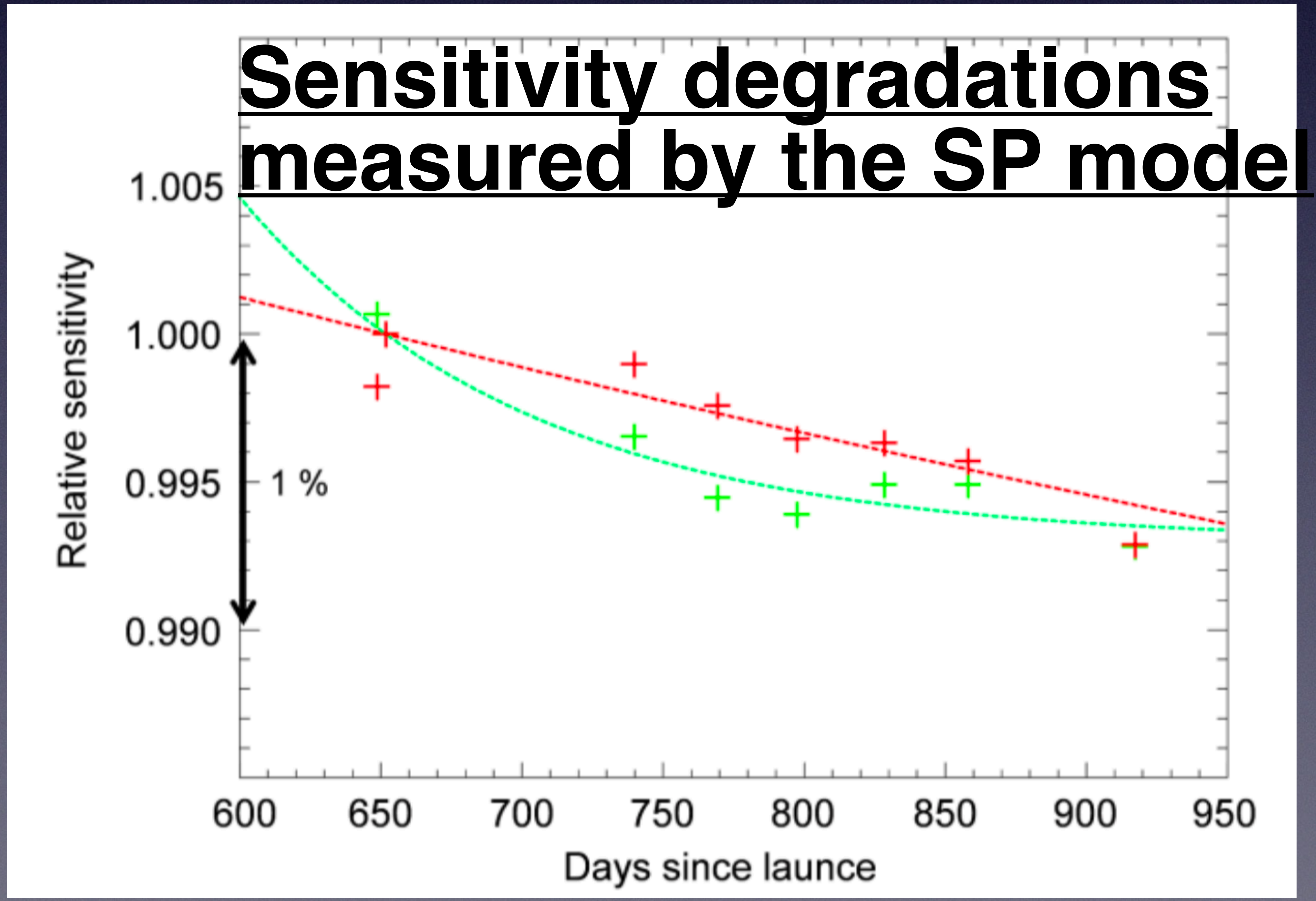
Introduction

- Radiometric calibration is strongly desired during the operation in space to evaluate the true performance and to maintain compatibility with other remote-sensing data.
- We developed the SP model (Spectrum Profiler onboard SELENE) and try to establish a convenient and reliable Lunar calibration method, especially for micro-satellites.

Recover the original performance!

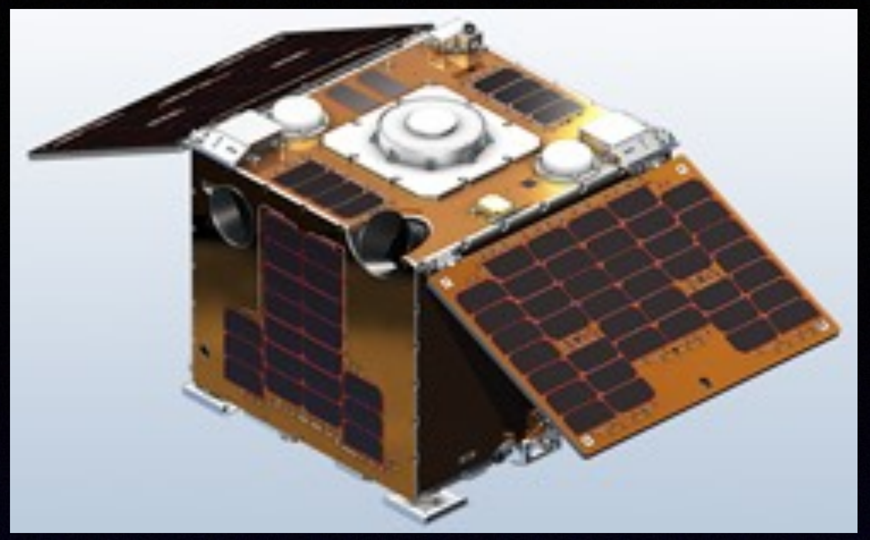




[Kouyama et al., 2016]

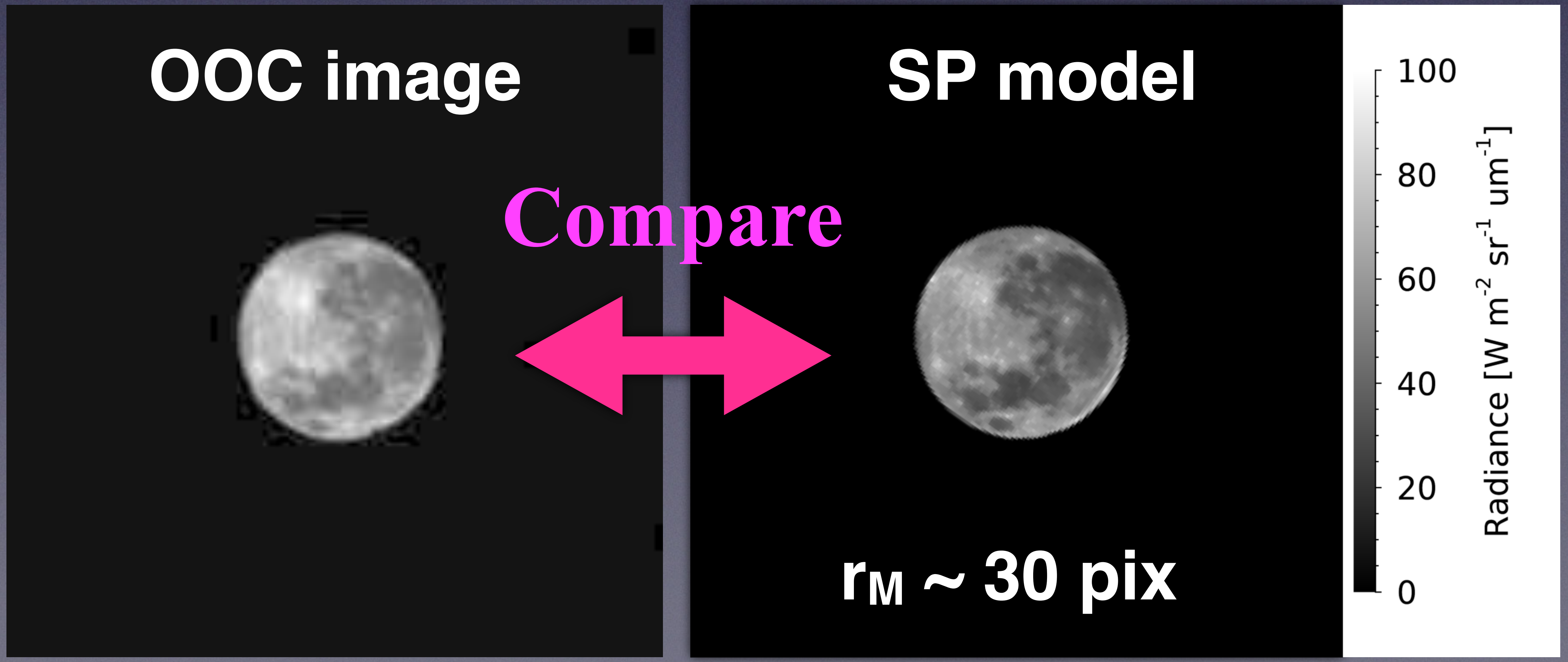
Moon observation with RISESAT/OOC

- Lunar Calibration by using ROLO and SP models are in progress for the Ocean Observation Camera (OOC) onboard RISESAT micro-satellite.
- Our target is to achieve multi-band imaging with < 1% precision for investigating the abundance of chlorophyll and the Colored Dissolved Organic Matter.
- RISESAT/OOC monthly observes the Moon from August 2019 when the absolute phase angle was about 10° (± 2.5°) to get the highest SN ratio avoiding the opposition surge.



RISESAT

OOC

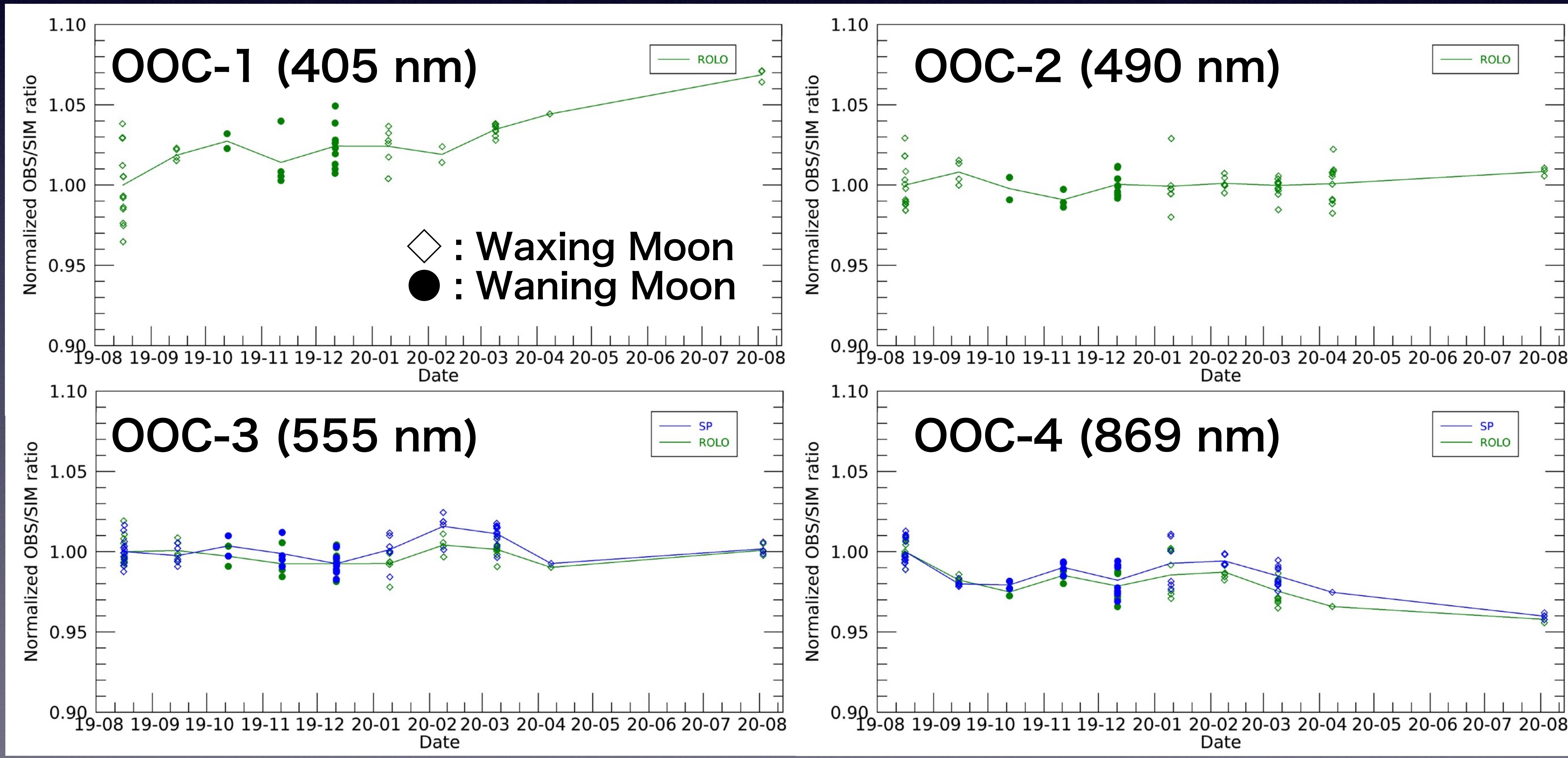


RISESAT	Mass	59.3 kg
	Size	50 cm cube
	Developer	**Tohoku** and **Hokkaido** Univ., Japan
	Orbit	Sun-synchronous orbit with 500 km alt., ~1.5 hour period
OOC	Focal length	50 mm
	Spectral bands	405, 490, 555, 869 nm (FWHM ~10 nm)
	Imaging size	659 x 494 pixels
	FOV	5.6 x 4.2 deg (48 x 36 km at nadiar)
	Spatial resolution	74 m at nadiar
	Quantization	10 bit

Results 1: Temporal changes in the Moon irradiance

- OOC's sensitivity degradation seems < 3% over 8 months (excepting Aug. 2020).
- Relatively large standard deviations were due to the small phase angle (< 9°), and another reason could be the instrument <u>temperature variation</u>.

- Using both positive and negative phase angles should be a minor impact.
- The difference between the ROLO and SP is ~1%, which is reasonable considering 1% of inclusive modeled irradiance errors.

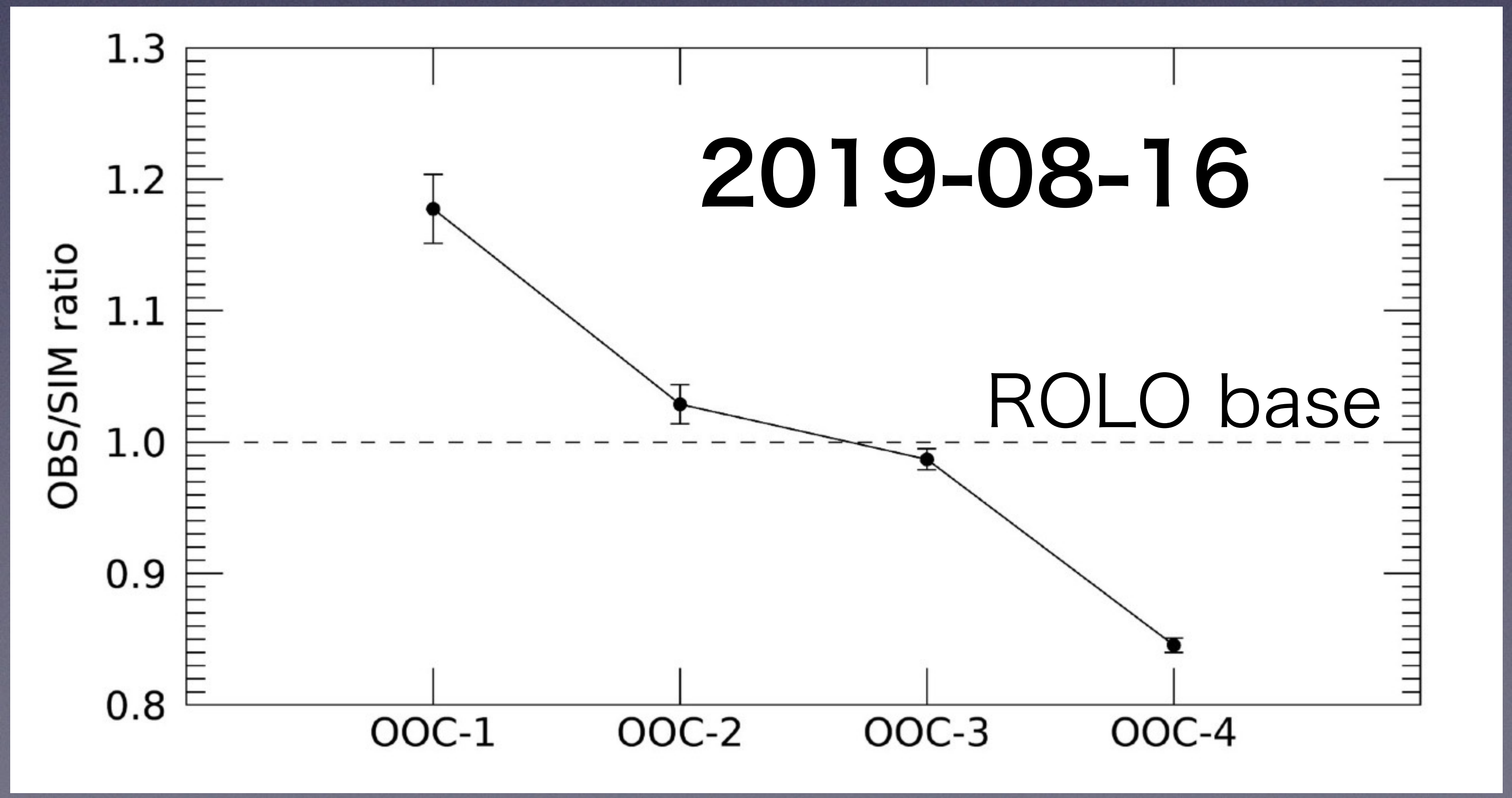


* SP model covers > 500 nm

Results 2: Inter-band ratio

- By comparing the observation and simulation, the discrepancy of the current band-to-band ratio against the pre-launch calibration can be tested.
- While OOC's sensitivity degradation is small, the launch impact and the severe environment might alter the inter-band ratio.
- Revealed bluing trend must be critical for OOC's science targets.
- After the validation, OOC's Moon observations can contribute to prepare re-calibration data.

405 490 555 869 nm



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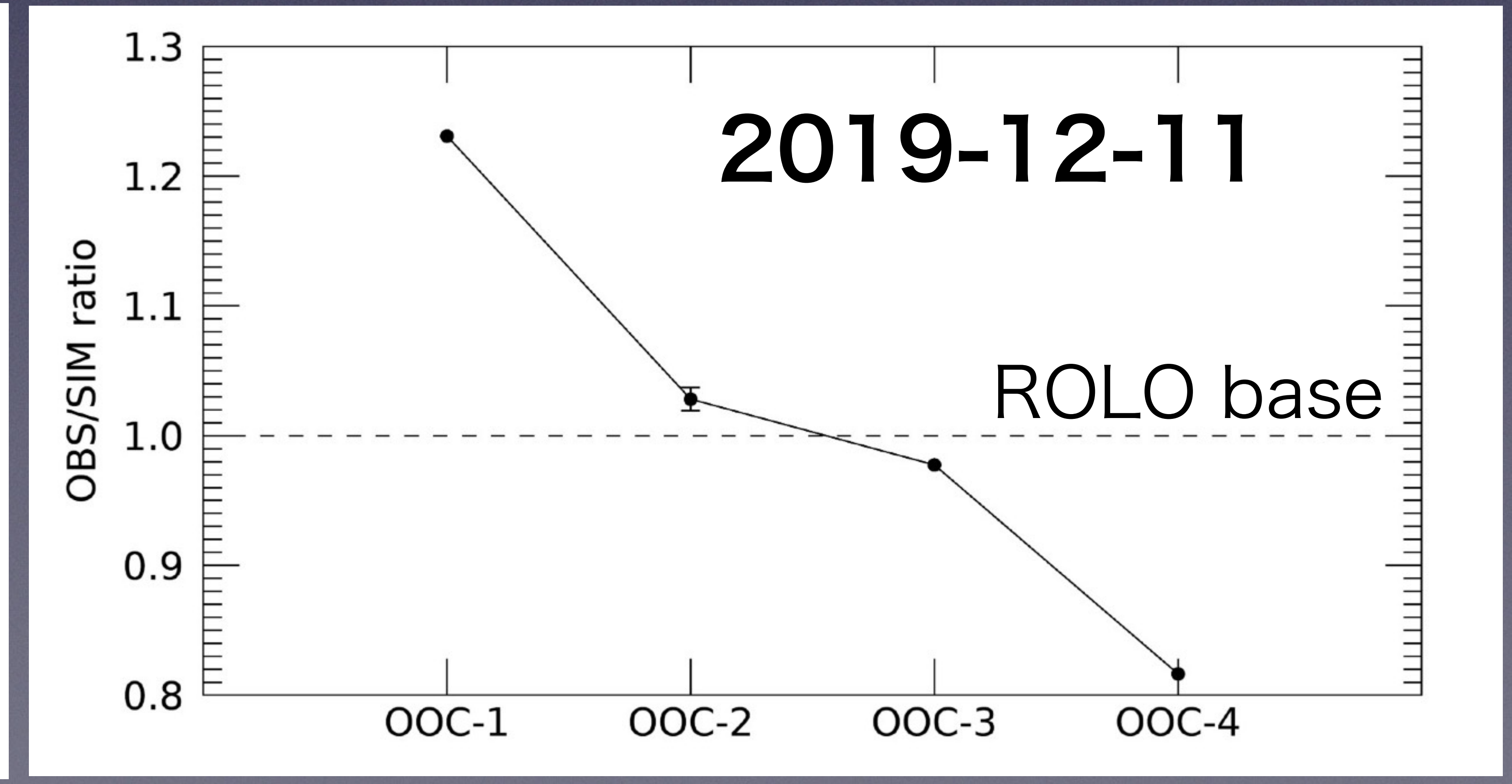

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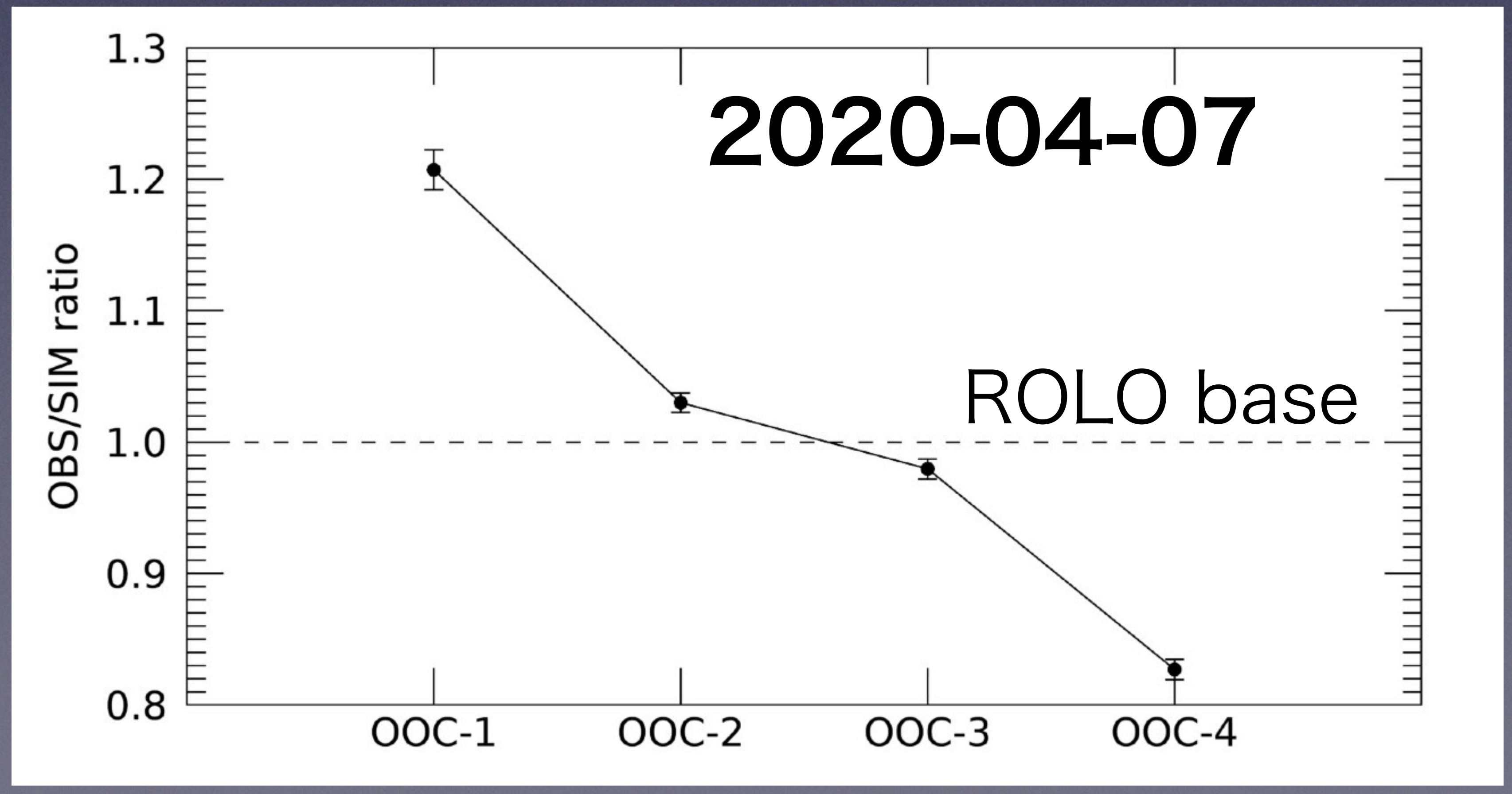
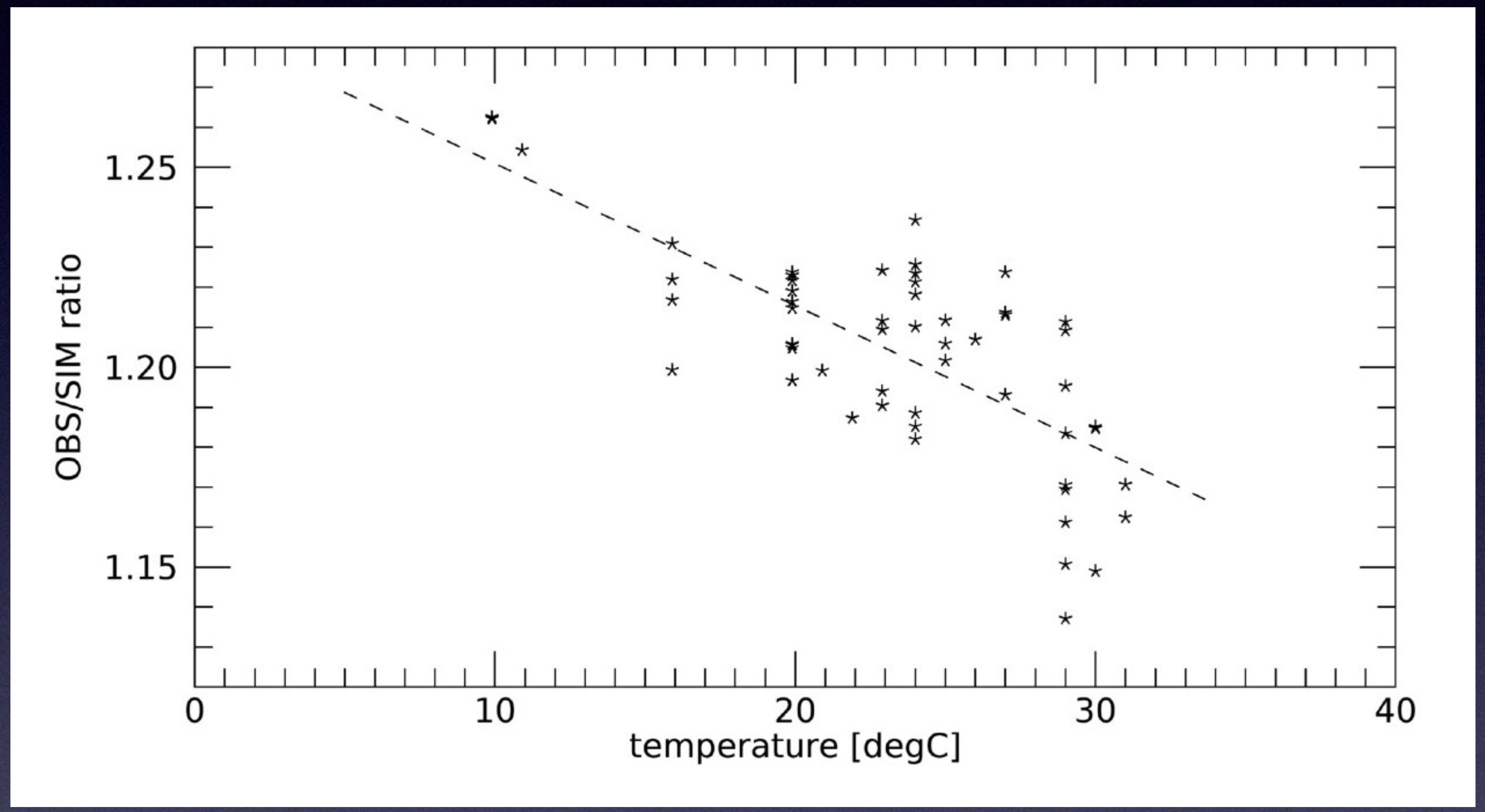


Discussion 1-1: Sensor sensitivity degradation

- Although, rather small temporal changes can be confirmed in the Moon irradiance ratio, the instrument temperature might affect the sensor sensitivity.
- Similar dependence was confirmed by the inflight calibration of Hayabusa-2's optical navigation camera.

OOC-1 (405 nm)



OOC-2 (490 nm)

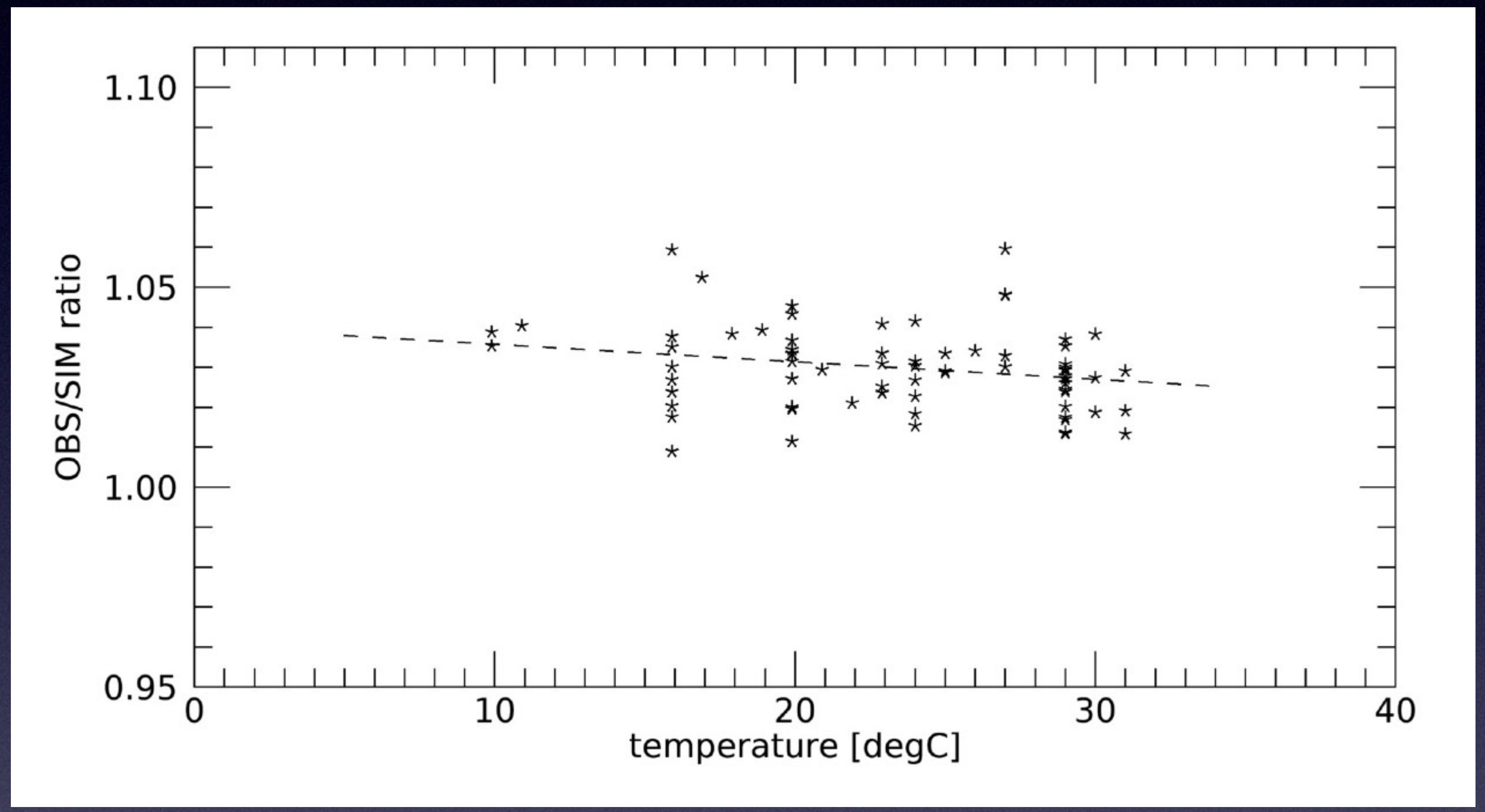
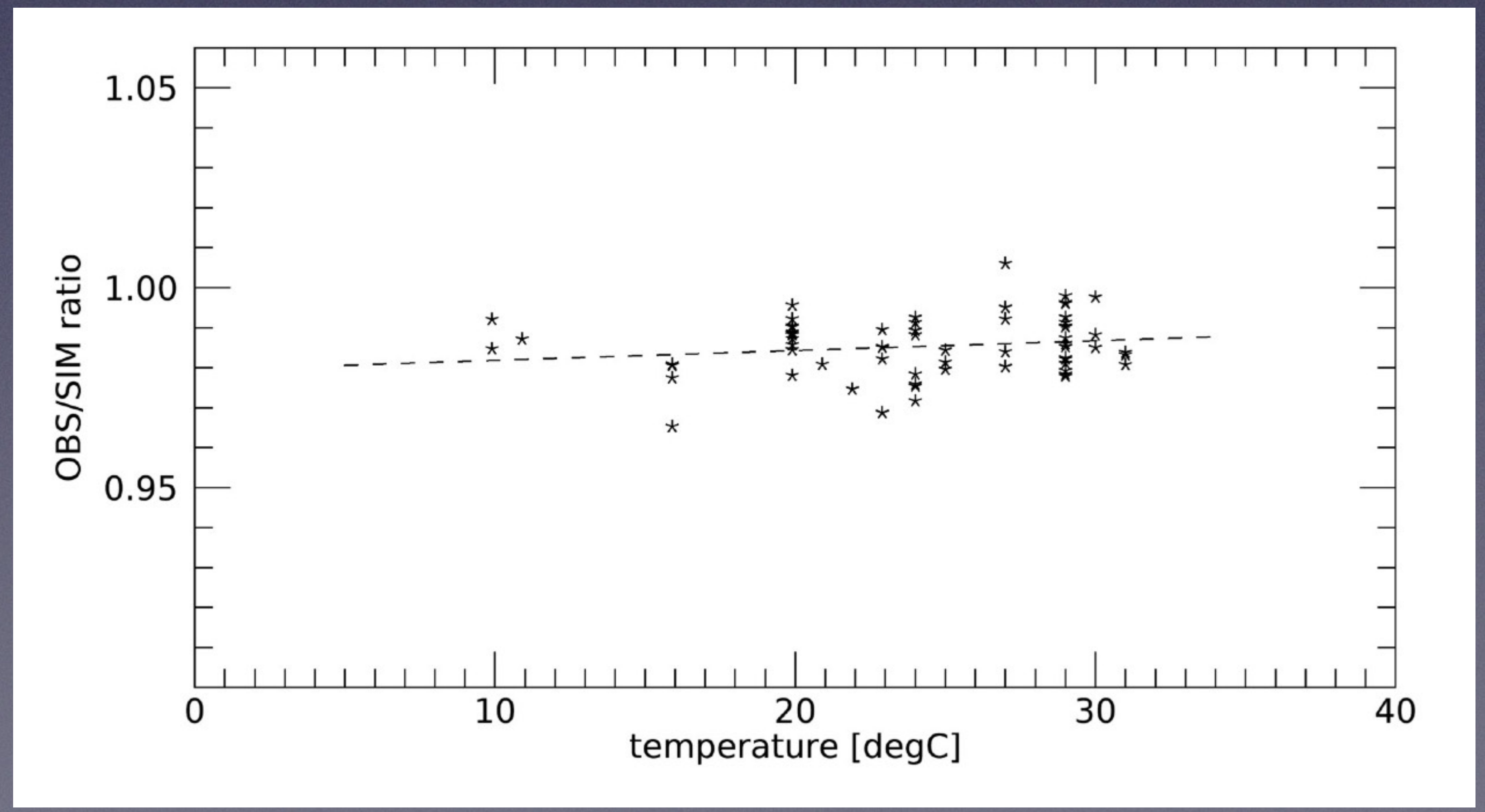


Table 3.8
Sensitivity dependence from CCD temperature for all band-pass-filters. The errors cited are the 2-σ errors.

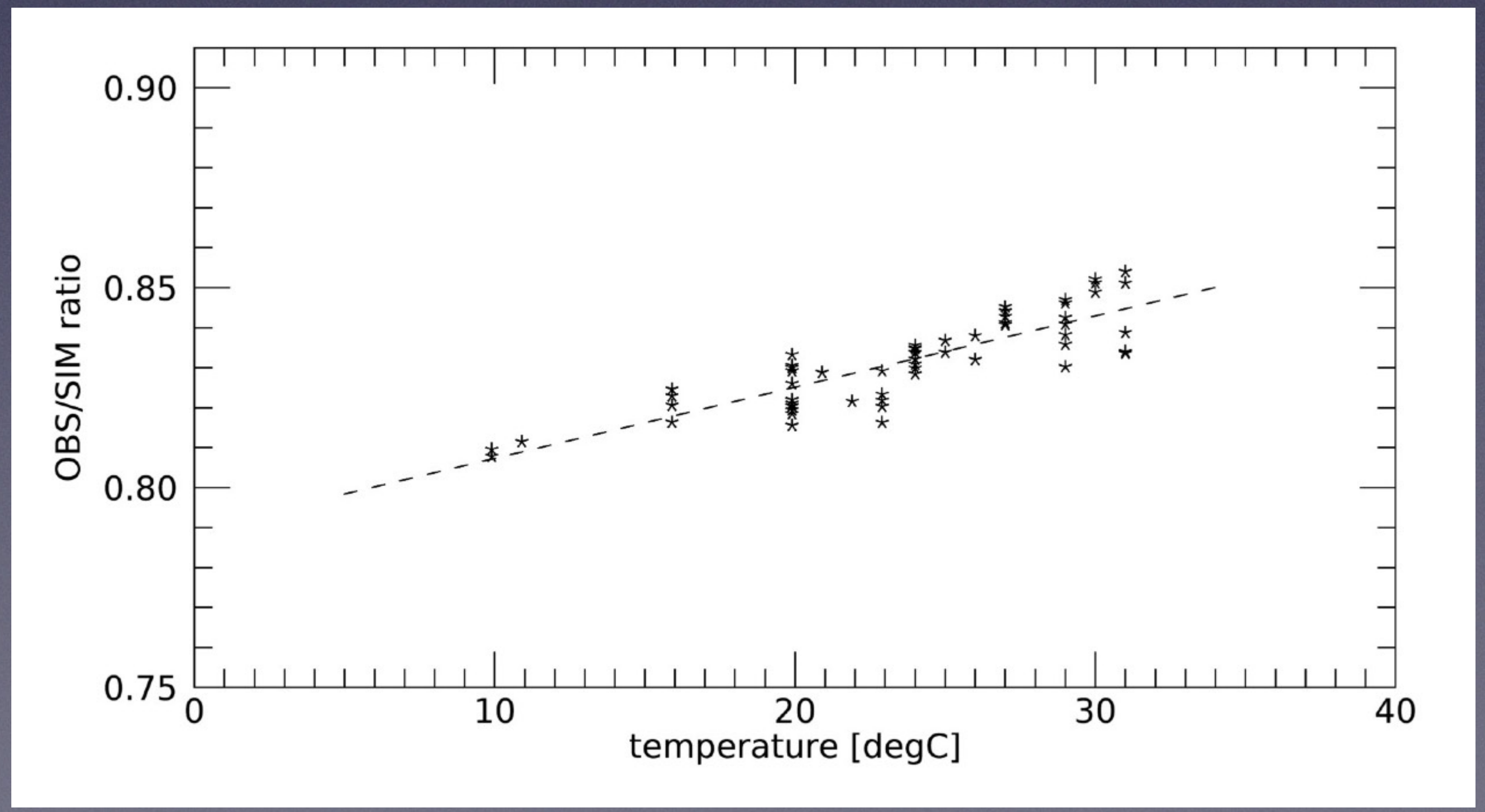
Band	$a_{CCD,\,n}$ [/˚C]
ul (0.40 µm)	−0.001449 ± 0.000244
b (0.48 µm)	−0.000968 ± 0.000108
v (0.55 µm)	−0.000814 ± 0.000090
Na (0.59 µm)	−0.000866 ± 0.000154
w (0.70 µm)	−0.000355 ± 0.000112
x (0.86 µm)	0.001771 ± 0.000158
p (0.95 µm)	0.004201 ± 0.000202

[Tatsumi et al., 2019]

OOC-3 (555 nm)



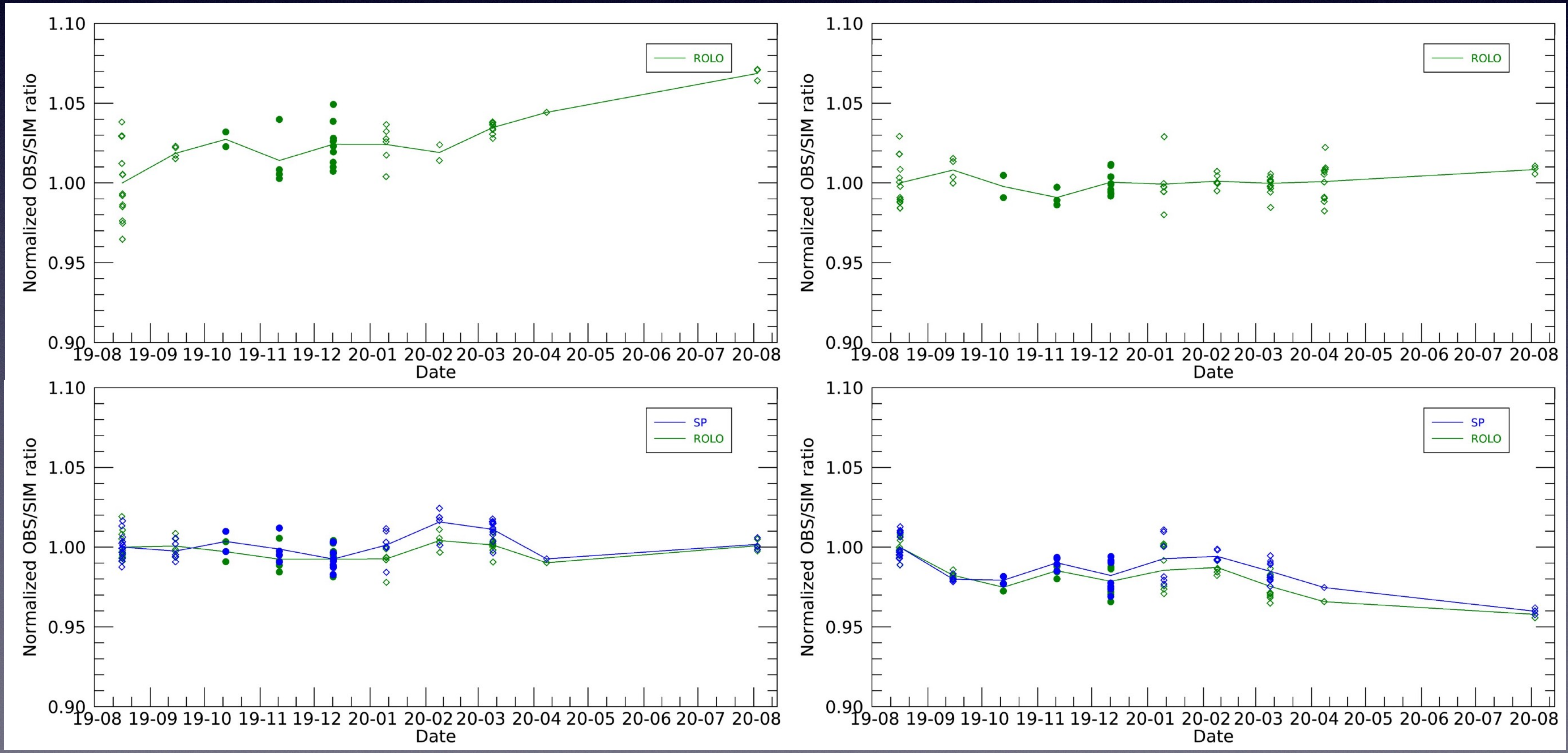
OOC-4 (869 nm)



Discussion 1-2: Sensor sensitivity degradation

- Since OOC doesn't measure the sensor temperature directly, the sensitivity dependence on the temperature should be carefully investigated…

- However, when we take the possible temperature—sensitivity dependence into the account, OOC's sensitivity degradation might be < 1 %.



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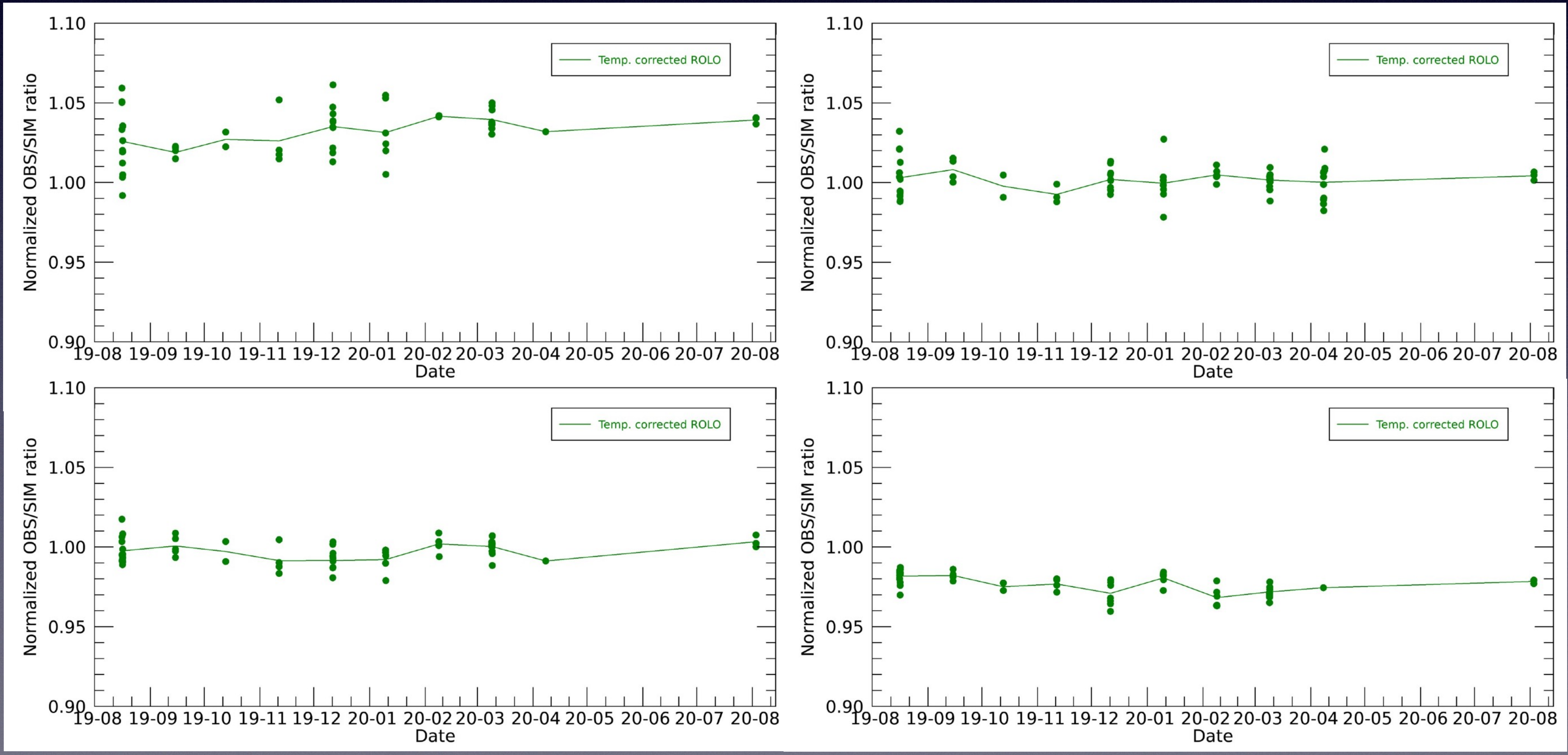
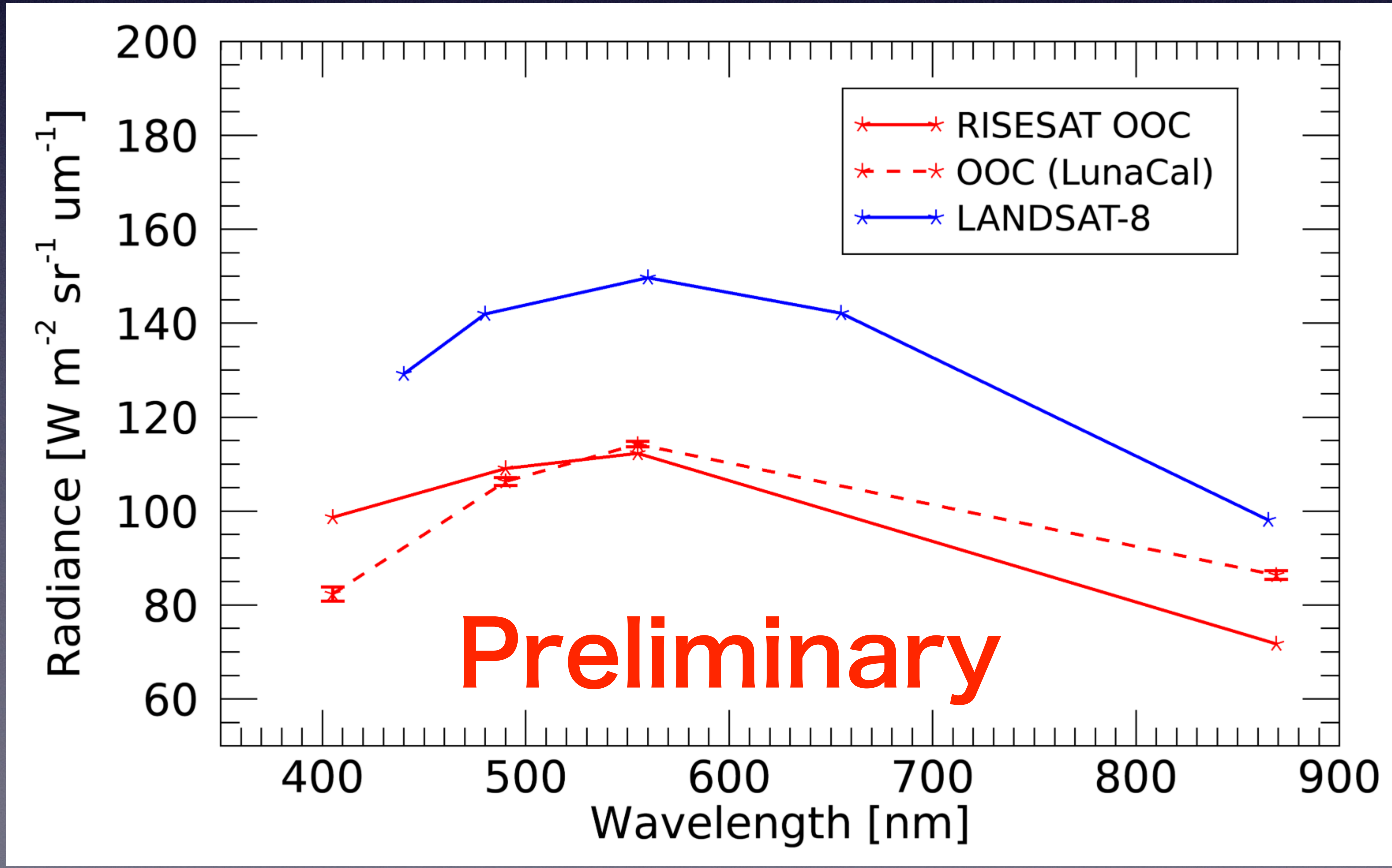
- Further moon observations over the wide temperature range could provide the detail effect of temperature variation.



Discussion 2: Validation of inter-band ratio

- The confirmed OOC's bluing trend is under investigation by the cross-calibration with LANDSAT-8.
- Our preliminary result of Railroad Valley observation is not ideal to validate the measured discrepancy, and further observation will be conducted Nov 17.

Railroad Valley



Summary and Future work

- Our RISESAT/OOC experiments demonstrated the Moon observation can provide a convenient method to investigate the sensor degradation with at least ~1% accuracy and discrepancy in the inter-band ratio.
- The lunar calibration can be a promising candidate for a common radiometric calibration method among hundreds of nano/micro-satellites, which usually have strict weight and cost restrictions.

- To achieve the precise calibration (< 1%), sensitivity dependence on the sensor temperature must be critical, and our experiment indicates the importance of measuring the sensor temperature and pre-launch experiment is important even for the micro-satellite remote-sensing.
- Further validation of our Lunar Calibration is on going by using the inter-satellite comparison result with LANDSAT-8.
- Our next step is establishing the calibration method among the instruments (OOC and other on-boards) and inter-satellite comparison.