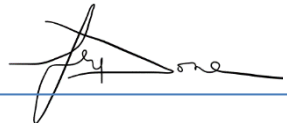
Technical Note on MOS Radiometric Assessment

Author(s):  ***Samantha Lavender***
Task 2 Mission Expert

Approval:  ***Fay Done***
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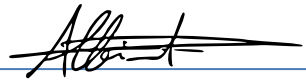
Accepted:  ***Clement Albinet***
EDAP Technical Officer

EDAP.REP.069 *Issue: 1.0* *11/03/2022*

AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
0.1	17/11/2020	First draft version for review.
1.0	11/03/2022	Final version

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1. INTRODUCTION

The primary objective of this activity was to undertake a preliminary assessment into whether the data from the Marine Observation Satellite (**MOS**) instruments could be radiometrically calibrated. Currently, the Multispectral Electronic Self-Scanning Radiometer (**MESSR**) and Visible and Thermal Infrared Radiometer (**VTIR**) data is generated as GeoTIFFs that are geometrically corrected, but with Digital Numbers (DN) as the radiometric values.

MOS-1 was launched and operated by the National Space Development Agency of Japan (**NASDA**), which joined the formation of the Japan Aerospace Exploration Agency (**JAXA**) in 2003, in February 1987 and was followed by its successor, MOS-1b, in February 1990, which generated data until 1995.

1.1 Reference Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

[RD.1] Robert, B. and Wiebe, K. 1989. Geometric and Radiometric Correction of MOS-1 Imagery in a Canadian Processing System, https://a-a-r-s.org/proceeding/ACRS1989/Papers/DP289-5.htm

[RD.2] Henry, P. and Begni, G. 1989. MOS-1 absolute calibration using SPOT1 as an intermediate radiometer. The Third Symposium on MOS-1 Verification Program, page 436, Earth Observation Center, National Space Development Agency of Japan.

[RD.3] MOS-1 MESSR CCT Format Specifications, Release 0.2, ESA\EARTHNET March 1989

[RD.4] Arai, K. 1990. Results From Marine Observation Satellite-1 (MOS-1) Operation, IEEE Transactions on Geoscience and Remote Sensing, 28(4).

[RD.5] Majumdar, T. J. and Mohanty, K. K. 1998. Derivation of land surface temperatures from MOS-1 VTIR data using split-window channel computation technique, Int. J. Remote Sensing, 19(2), pp. 287-294

[RD.6] Arai, K. 1988. Preliminary assessment of radiometric accuracies for MOS-1 sensors, International Journal of Remote Sensing, 9(1), pp. 5-21

1.2 Glossary

The following acronyms and abbreviations have been used in this report:

AVHRR	Advanced Very-High-Resolution Radiometer
CCRS	Canadian Centre for Remote Sensing
CCT	Computer Compatible Tapes
ESA	European Space Agency
IPF	Instrument Processing Facility

JAXA	Japan Aersopace Exploration Agency
MESSR	Multispectral Electronic Self-Scanning Radiometer
MOS	Marine Observation Satellite
NASDA	National Space Development Agency of Japan
RD	Reference Document
SST	Sea Surface Temperature
TC	Time Correlation
TM	Thematic Mapper
VISSR	Visible and Infrared Spin Scan Radiometer
VTIR	Visible and Thermal Infrared Radiometer

2. LITERATURE REVIEW

The Canadian Centre for Remote Sensing (**CCRS**) acquired MOS-1 data, and Mac Donald Dettwiler was commissioned to develop a prototype system capable of performing radiometric and geometric corrections [RD.1].

2.1 MESSR

The CCRS assessment of MESSR data identified artefacts introduced by the operation and electronics of the sensor [RD.1]. Vertical striping took two forms: random striping caused by differences in the gains and dark current offsets of adjacent CCD elements and periodic striping caused by the even-odd shift registers of the CCD. The random striping was mainly removed by the absolute calibration of the data using NASDA supplied calibration coefficients, while the periodic even-odd striping was not as easily removed.

The CCRS converted input pixels to physical units (typically radiance) using telemetry data and in-flight and pre-flight calibration data supplied by NASDA. As there was no in-flight absolute calibration capability, the work of Henry et al. [RD.2] compared MESSR with near-simultaneous SPOT data that could achieve absolute radiometric calibration with an uncertainty as low as 10%.

Reviewing the European Space Agency (**ESA**) ESRIN MESSR Computer Compatible Tapes (**CCT**) Format Specifications [RD.3], which covers system corrected (based on pre-flight and on-board correction parameters) files, it states the Radiometric Ancillary record contains:

"… decompression conversion tables used to convert the raw data into calibrated data (must be compressed from 8-bit to 6-bit during the transmission). The MESSR system (01 or 02) and processing system is given at bytes 21 to 28. The gain status (normal or high gain) and temperatures for each band are also included in this record."

In terms of the data currently stored by ESA, it is in a Level 0 SAFE format that is a folder containing binary measurement payload correction data files. The inputs used for this study were Level 1 data generated using the MOS Instrument Processing Facility (**IPF**) from this Level 0 data.

Arai [RD.4] assessed that the radiometric accuracy of MESSR was 0.45-0.75 quantisation levels pixel-to-pixel and 0.18-0.45 quantisation levels line-to-line. The dark current contribution to the radiometric calibration was determined using nighttime data. The signal-to-noise ratio was found to be 41-45 dB by normalising the standard deviation with the average MESSR signal in homogeneous areas.

2.2 VTIR

For VTIR, CCRS detected radiometric artefacts in the form of horizontal striping particularly noticeable in band 4 and slight vertical striping noise almost periodic in nature [RD.1].

CCRS converted the raw digital numbers to radiance using both in-flight calibration data obtained by viewing a reference black body and deep space, as well as pre-flight data [RD.1]. Majumdar and Mohanty [RD.5] include a figure, see Figure 2-1, that shows that the gain step controls the spectral response of the radiometer in each band. Arai [RD.6] had a figure showing the adjustable range of gain for VTIR visible band; see Figure 2-2

Therefore, when assessing whether radiometric calibration is possible, it will be essential to have the thermal and visible gain information, which is unfortunately not available at this time.

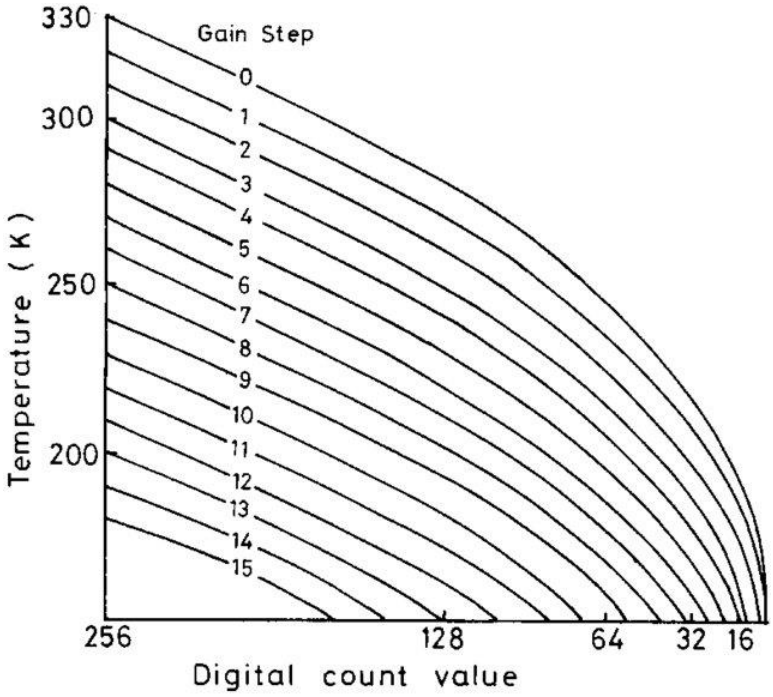

Figure 2-1: Spectral response of the radiometer in each VTIR thermal band as controlled by the gain step; from [RD.5].

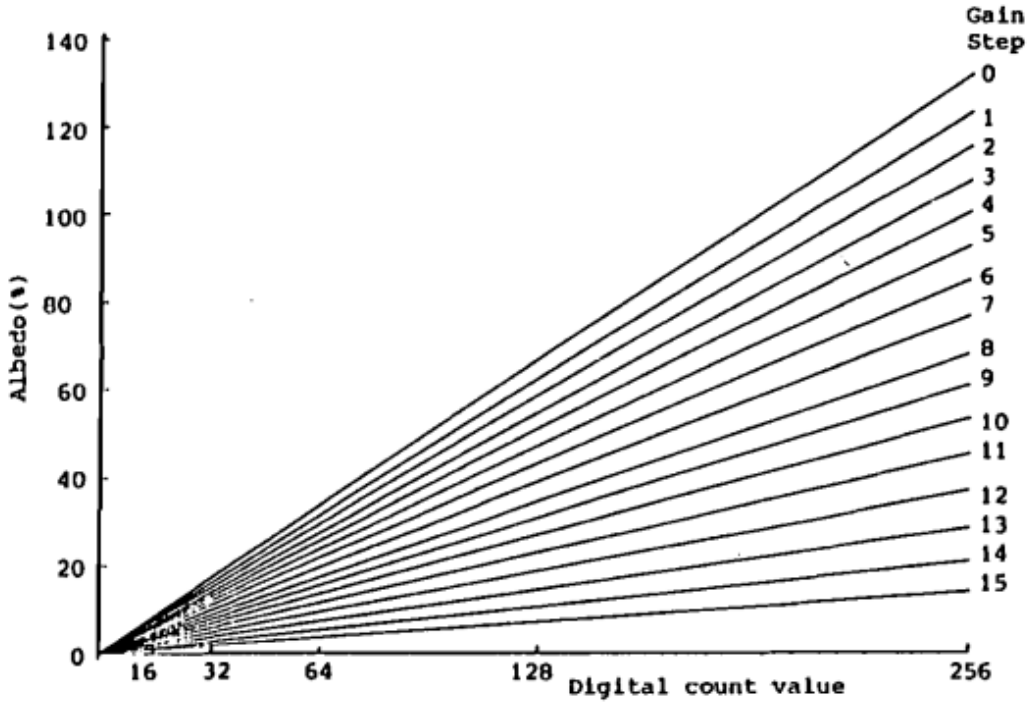

Figure 2-2: Adjustable range of gain for VTIR visible band; from [RD.6].

Arai [RD.4] determined the radiometric accuracy of the VTIR sensor to be one quantisation level with a signal-to-noise ratio in the range of 40-54 dB. Cross-correlation coefficients

between VTIR and Visible and Infrared Spin Scan Radiometer (**VISSR**) of the Geostationary Meteorological Satellite showed high correlations for bands 3 and 4. CRRS also mentioned cross-calibration with the Advanced Very-High-Resolution Radiometer (**AVHRR**) data [RD.1], the proposed approach for the ESA dataset.

Majumdar and Mohanty [RD.5] also took the processing of the thermal data a step further by converting the VTIR radiance in the thermal bands (brightness temperature) to Sea Surface Temperature (**SST**) using a split-window channel technique.

3. DETAILED MESSR ASSESSMENT

3.1 Visual Assessment

The radiometry assessment is being performed over the desert as it is assumed that the site is pseudo-invariant. Hence, a gap of a few days between the MESSR and comparison satellite mission is not critical.

A selection of orbits were processed using version 3.02 of the IPF as a test dataset for verifying the processor. This limited dataset was made available as the full MOS-1/-1b dataset has not been fully processed, which is occurring in parallel to this activity.

Although the subset of the full MESSR dataset that is being processed was searched, further matching scenes over the chosen desert location could not easily be located. There was a promising orbit overlapping this geographic region, but the geometry was inaccurate; see Figure 3-1. Therefore, no ground control points could be found by the IPF and used to improve the geolocation further.

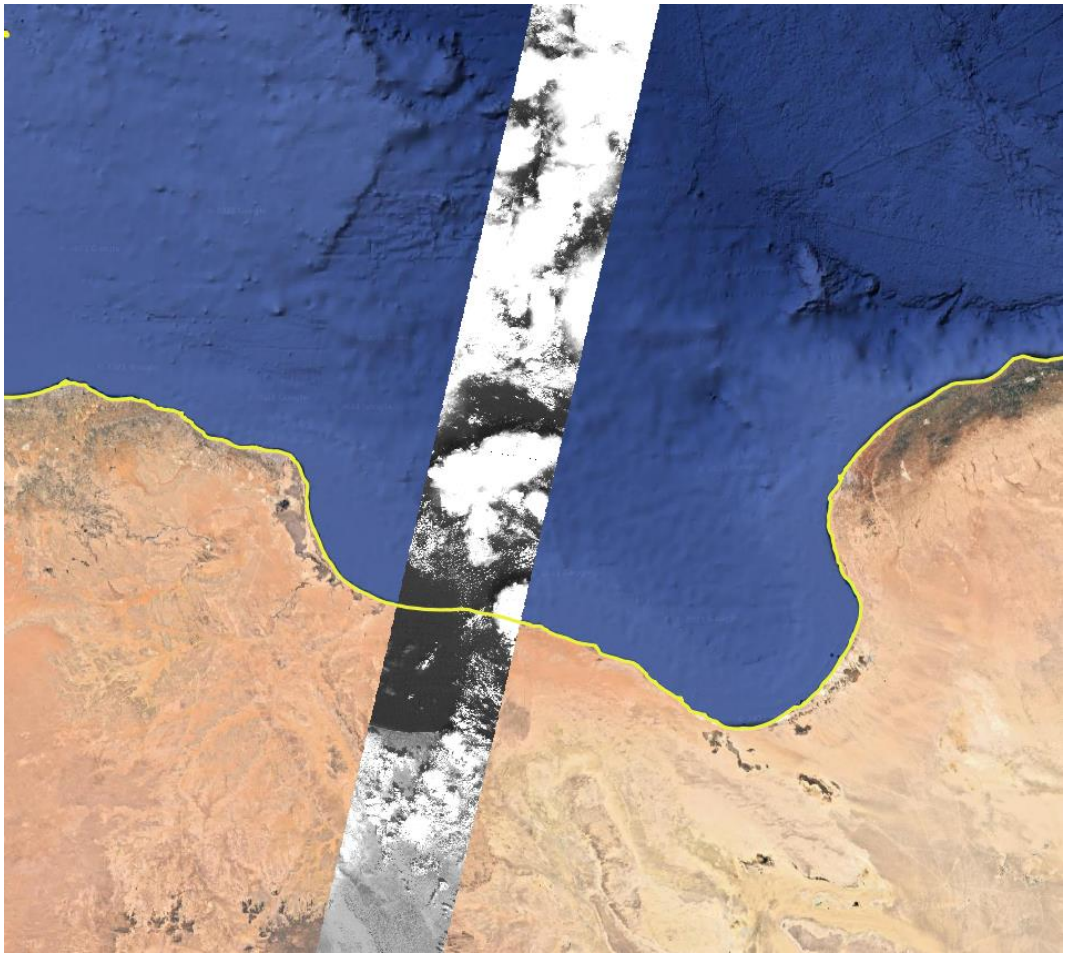

Figure 3-1: Example MESSR orbit with poor geometric accuracy.

This problem occurs when the Time Correlation (**TC**) information is not close to the orbit processed. For the reprocessing exercise, this geometric error will be reduced by reprocessing orbits with poor geolocation that are close in time to orbits with a good TC that can provide improved auxiliary TC inputs.

Therefore, Figure 3-2 shows the test dataset orbits that were used for this preliminary assessment.

Figure 3-2: The MESSR orbits for the scenes investigated, with the zoomed-in region of interest shown in the bottom left.

3.2 Radiometric Assessment

The characteristics of the MESSR and VTIR instruments are shown in Table 3-1. The orbital altitudes of both MOS missions were around 900 km, and so the missions had revisit periods of 17 days. MOS-1b was launched into the same orbit as MOS-1 but approximately eight days out of phase [RD.4].

Table 3-1: MESSR & VTIR instrument characterises

Instrument	Band No.	Wavelength Range [nm]	Spatial Resolution [m]	Swath Width [km]
MESSR	1	510 – 590	50	100

	2	610 – 690	50	100
	3	720 – 800	50	100
	4	800 – 1 100	50	100
VTIR	1	500 – 700	900	1 500
	2	600 – 700	2 700	1 500
	3	10 500 – 11 500	2 700	1 500
	4	11 500 – 12 500	2 700	1 500

Figure 3-3 shows the MESSR data overlaid on near-simultaneous Landsat-5 Thematic Mapper (**TM**) scenes. The MESSR scenes were acquired around 09:30 to 09:36 UTC, while the Landsat-5 overpasses were acquired around 08:40 to 08:46 UTC, so both were morning overpasses, although the missions had a time gap of three to five days.

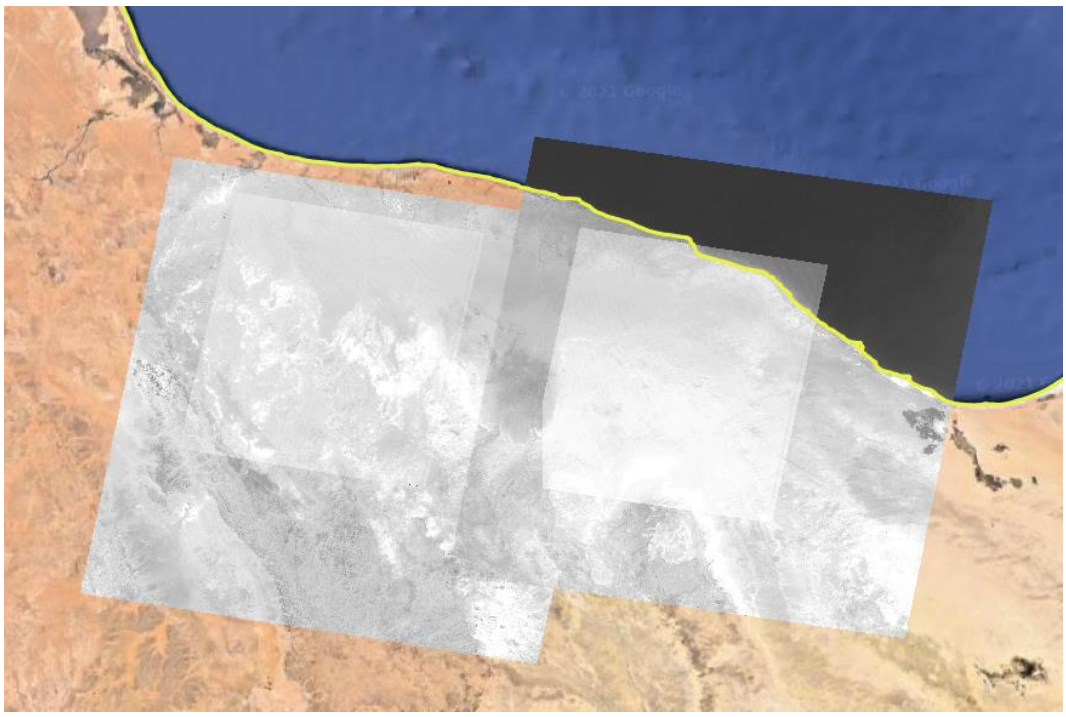

Figure 3-3: Example of the MOS 20 and 19 June 1990 (left to right) band 1 scenes overlaid on the Landsat TM-5 23 and 16 June 1990 band 2 scenes.

Random points were generated for the extent of the MESSR scenes, including the no data extent, and then the values extracted from both the MESSR and Landsat scenes; see Figure 3-4. Water was excluded from the extraction by deleting the random points that ended up over the sea, and where there was no valid data (i.e. only digital number values greater than zero) the extraction points were ignored.

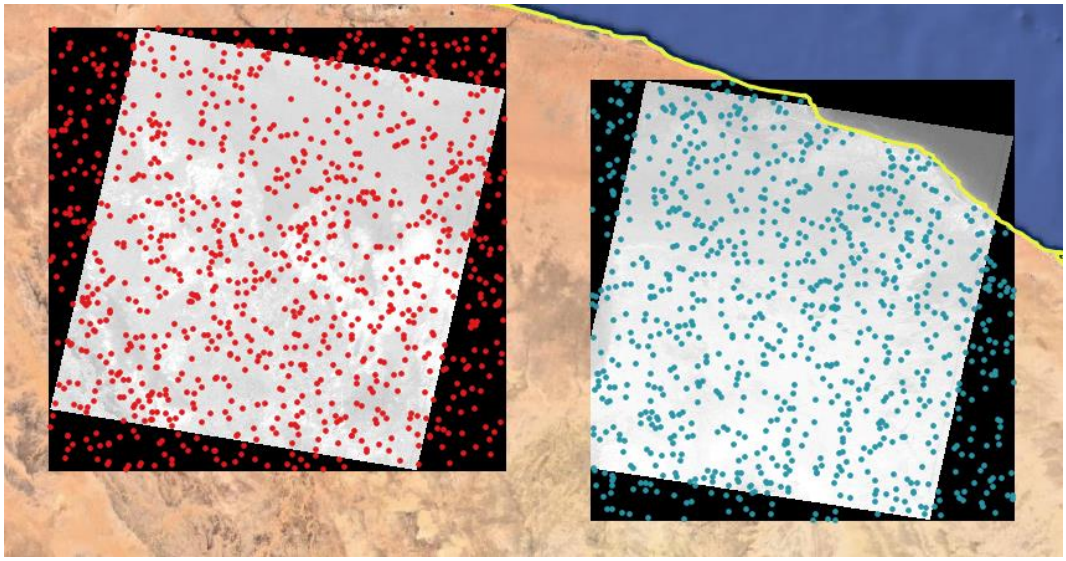

Figure 3-4: Generation of random points for the calibration assessment.

Figure 3-5 shows a regression between the MESSR and Lansat-5 TM data for the band1/2 and 2/3 combinations with the data plotted for both sets of scenes. Both sets of bands have a correlation between the two missions, and the shown regression lines could be used to convert the MOS digital numbers to radiance values.

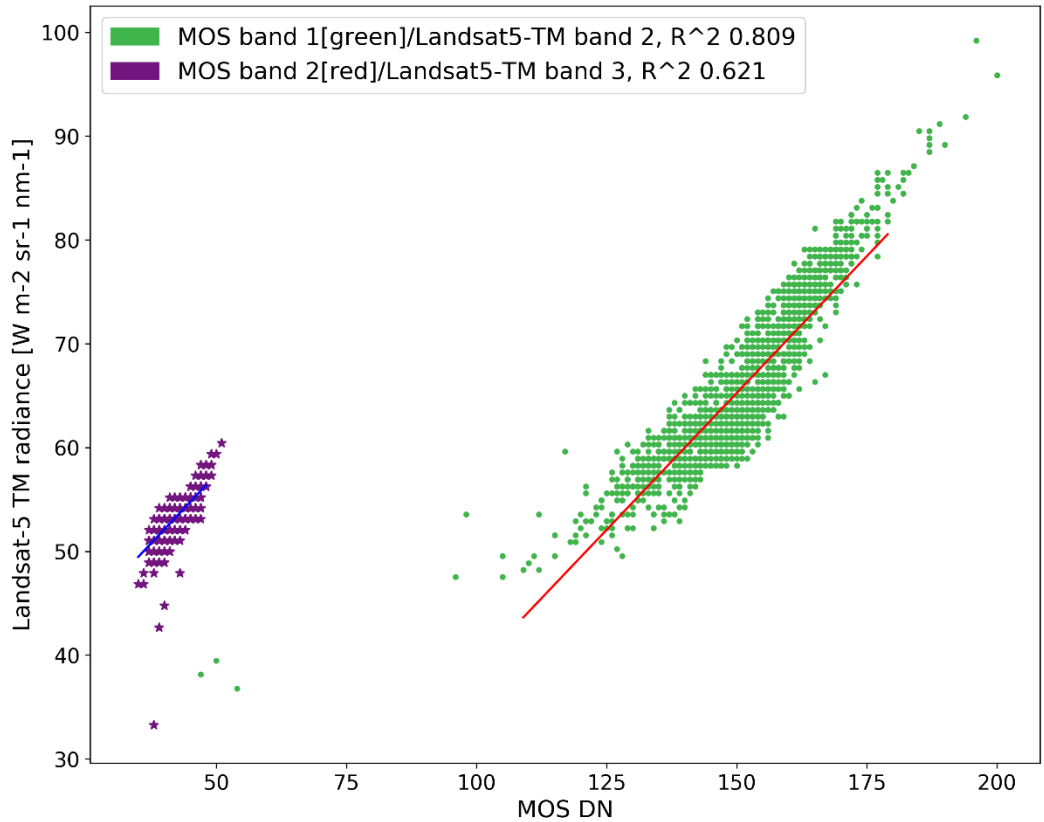

Figure 3-5: Regression between the MOS (MESSR) digital numbers and Landsat-5 TM radiance data for band 1/2 and 2/3 combinations.

4. CONCLUSIONS

The conclusions from this preliminary assessment are:

- The literature survey revealed that previously developed processing systems converted both the MESSR and VTIR data to radiometric units, with VTIR then converted to SST when acquired over the ocean.

- For both sensors, a combination of pre-flight and post-flight inputs were combined with a cross-sensor calibration.

- VTIR has an onboard calibration source while MESSR does not.

- The processing of the full MOS-1/1b MESSR dataset is ongoing. So, when that parallel Quality Control activity finds orbits covering the desert area of interest, they will be added to this assessment if the geometric accuracy is sufficient.

- As the current version of the IPF does not extract the VTIR band gain information, conducting a radiometric comparison will be complicated and has not been tried for this preliminary assessment. The ability to extract this gain information needs to be explored with the IPF developer.

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