Summary of the Fiftieth ASTER Science Team Meeting

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Introduction

The fiftieth Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting [ASTM] was held June 10-12, 2019, at the Japan Space Systems (JSS) offices in Tokyo, Japan. The year 2019 also marks the twentieth anniversary of the launch of ASTER on the Terra platform (December 1999), so the meeting had twice the cause for celebration. Altogether, there were 41 people, from both Japan and the U.S. that participated in the meeting. U.S. participants were from NASA/Jet Propulsion Laboratory (JPL), NASA's Goddard Space Flight Center (GSFC), U.S. Geological Survey (USGS), University of Hawaii (UH), and University of Pittsburgh (UP). From Japan, participants were from JSS, Ibaraki University (IU), Nagoya University (NU), University of Tokyo (UT), National Institute of Advanced Industrial Science and Technology (AIST), National Institute for Environmental Studies (NIES), Geological Survey of Japan (GSJ), Remote Sensing Technology Center of Japan (RESTEC), and University of Tsukuba (UTs). The goals of the meeting were to:

- review the pending release of the Global Digital Elevation Model (GDEM) Version 3;
- review the status of the data acquisition programs; and
- discuss the need for future updates to the radiometric calibration coefficients, based on field campaigns and onboard calibration sources.

After beginning with a brief history of the development of ASTER and the activities of the ASTM, this article summarizes the fiftieth ASTM meeting. Interested readers can contact the author to gain access to the agenda and full versions of the presentations summarized here.

Brief History of ASTER

ASTER has its roots in several moderate-resolution imaging sensors. The Landsat instruments (Multispectral Scanner and Thematic Mapper) had developed a large and devoted user community comfortable with analyzing multispectral data.[1] The second most used data were provided by the French Satellite Pour l'Observation de la Terre (SPOT) instruments.[2] Between 1992 and 1998 the Japanese Ministry of International Trade and Industry's (MITI) Japan Earth Resources Satellite–1 (JERS-1) Optical Sensor (OPS) instrument acquired three bands of VNIR data, four bands of shortwave infrared (SWIR) data, and along-track stereo data.

The Earth Observing System's (EOS) ASTER program began as two instruments proposed separately by the U.S. and Japan in the 1980s. The U.S. proposed the Thermal Infrared Ground Emission Radiometer

[1] To learn more about Landsat's instruments, see "The Living Legacy of Landsat 7: Still Going Strong After 20 Years in Orbit" in the July–August 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 4**, pp. 4-15—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Jul_Aug_2019_final_color_508_0.pdf#page=4*].
[2] SPOT has 10–20 m (~33–66 ft) visible-and-near-infrared (VNIR) wavelength data, and cross-track stereo observing capabilities.

Participants of the fiftieth ASTER Science Team Meeting. The ASTER quilt displayed in front was made by Yasushi Yamaguchi's [NU—*Japanese ASTER Science Team Leader*] wife, Mrs. Yamaguchi, in 1992, on the occasion of the fourth ASTM held in Tsukuba, Japan. **Photo credit**: Tetsui Tachikawa [JSS]

(TIGER), a fourteen-channel imager plus a profiling spectrometer.[3] At the same time, Japan's MITI was designing and proposed the Intermediate Thermal Infrared Radiometer (ITIR) with five shortwave infrared (SWIR) bands and four thermal infrared (TIR) bands as a follow-on to JERS-1. Starting in 1988 a joint U.S. and Japanese ITIR/TIGER Science Team worked to develop a compromise design for a VNIR-SWIR-TIR instrument to go on NASA's EOS AM-1[4] platform (renamed Terra after launch). The number of TIR bands was increased to five; the number of SWIR bands was increased to six; spatial resolution was decided; VNIR band 3 was selected for the along-track stereo; and bandpasses of all the channels were determined. Following six ITIR/TIGER Science Team Meetings in the late 1980s, the newly designed instrument was named the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and the first ASTER Science Team Meeting was held in November 1990, in Pasadena, CA.

For the next fourteen years, two ASTMs were held each year, alternating between Japan and the U.S. Starting in 2013 the next eight meetings were held in Tokyo at the request of the Japanese team. Until the 1999 launch of Terra, the AST was primarily concerned with the instrument design, creating the data-processing algorithms and software, creating the data acquisition scheduler, helping design the data processing system with interfaces between Japan and the U.S., and promoting potential uses of the data, once they became available. After the launch of the instrument, however, new working groups were formed, centering on science and applications, data calibration and validation, verification of the production algorithms, and outreach to the general science community. The fiftieth ASTM maintained this structure, with working groups reporting on the previous years' status and accomplishments.

Opening Plenary Session

Yasushi Yamaguchi [NU—*Japanese ASTER Science Team Leader*] and **Michael Abrams** [JPL—*U.S. ASTER Science Team Leader*] opened the meeting and welcomed participants. To highlight the fiftieth meeting, Yamaguchi presented a historical archive of pictures from many previous meetings. The Team then observed a moment of silence to remember several team members who passed away since the beginning of the project, 30 years ago. Abrams highlighted ASTER science presentations and posters from various professional meetings over the past year. ASTER's presence at the 2018 Fall American Geophysical Union (AGU) meeting held in Washington, DC, was particularly noteworthy, with 35 contributions using ASTER data. Of particular interest to all participants was the status of the Diplomatic Note, which formally extended the ASTER mission for an additional seven years after October 2019, when the previous agreement was due to expire. The previous note, signed by the U.S. State Department, and the Japan Ministry of Foreign Affairs, confirms the terms of the 1999 Memorandum of Understanding, detailing the roles and responsibilities of NASA and the Ministry of Economy, Trade and Industry (METI) to jointly operate the ASTER project. It is expected that the new Diplomatic Note will be executed before October 2019. In the U.S., the next Earth Science Senior Review[5] proposal will be submitted to NASA in March 2020 for an additional three years of extended mission funding. The Terra project has scheduled a science meeting in September 2019 to discuss and coordinate Terra's Senior Review proposal submission.

Sticker commemorating 100,000 orbits of Terra. **Photo credit**: Sticker designed by Tassia Owen [GSFC]; photo of sticker taken by Michael Abrams

Jason Hendrickson [GSFC] reviewed the status of the Terra platform. All systems are functioning nominally. Terra had to execute four collision-avoidance maneuvers over the past 12 months—about an average annual number. The spacecraft has sufficient fuel to maintain its current orbital Equatorial crossing time until late 2022. On October 6, 2018, Terra achieved a milestone of orbit number 100,000. To mark the milestone, Terra was featured in an article on the NASA Homepage. The team also produced commemorative stickers—shown above.[6]

[3] In the late 1970s JPL operated an airborne Thermal Infrared Multispectral Scanner (TIMS). In 1981, TIMS was one of the "strawman" instruments proposed to be part of *System Z**, which envisioned several large polar-orbiting Earth Science platforms maintained by the Space Shuttle in a manner similar to the Hubble Space Telescope. As the Earth Observing System (EOS) concept evolved in the late 1980s, however, the instrument design was refined and became known as TIGER.
*To learn about *System Z*, read "The Early Beginnings of EOS: 'System Z' Lays the Groundwork for a Mission to Planet Earth" in the September–October 2008 issue of *The Earth Observer* [**Volume 20**, **Issue 5**, pp. 4-7—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Sep_Oct08.pdf#page=4*].

[4] The original nomenclature, AM-1, indicated that this was the first in the series of platforms with a morning (AM) local Equator crossing time, as opposed to the afternoon (PM) series, which later became known as Aqua. The original concept to achieve the long-term continuity needed for climate studies was to launch the exact same instrument complement on three platforms, launching five years apart. The later development of constellation flying techniques rendered this approach obsolete.

[5] The Earth Science Senior Review is NASA's once-every-two-years process when all Earth Science instruments, operating beyond their original funded mission, submit proposals requesting funding for extended mission lifetimes.

[6] To read the feature article, visit *https://www.nasa.gov/feature/goddard/2018/nasa-s-terra-satellite-celebrates-100000-orbits*.

Hitomi Inada [JSS] discussed the status of the ASTER instrument. All telemetries for aliveness check and electrical performance trends are currently stable. Most of the life items (like VNIR pointing) have exceeded their planned life in orbit; however, their operational reliability and performance continue without anomalies and are expected to last the lifetime of the mission.

Kurt Thome [GSFC—*Terra Project Scientist*] presented certificates from their NASA Group Achievement Award to several Science Team Members. The recipients were being recognized for the 2017 Terra Lunar Deep Space Calibration maneuver, that involved a 360° pitch-over of Terra to observe the Moon. He also announced that he had just received notification that the Terra project was the recipient of the 2019 William Pecora Team Award, to be presented at the Pecora conference in Baltimore, MD on October 6, 2019. The AST is proud to be part of the Terra project—the longest operating satellite in NASA's Earth Observing System.

Applications Working Group

The Applications working group session featured presentations of science research projects. A summary is shown in **Table 1** on page 24.

Operations and Mission Planning Working Group

The Operations and Mission Planning working group oversees and reviews the acquisition programs executed by the ASTER scheduler. Because ASTER data acquisitions have to be scheduled every day (due to ASTER's average 8% duty cycle),[7] an automatic program was developed to select ~600 daily scenes from the possible 3000+ in the request archive. **Masaru Fujita** [JSS] discussed the status of acquisition scheduling. Urgent observations have the highest priority, and can be scheduled close to acquisition time. About 70 scenes are programmed per month, with over 95% acquisition success. Global Mapping data acquisitions are the lowest priority, and fill in the scenes for the daily quota. ASTER's goal is to acquire at least one cloud-free image each season for every place on Earth. Due to persistent cloud cover, success is typically ~85% after several years, at which time the program is restarted. The next restart is planned for summer 2019. Currently the effort has achieved about 45% success, so the program will continue, and will be reviewed again during the next team meeting. The thermal group submits areal requirements to acquire global nighttime coverage with the thermal bands. Several smaller acquisition programs focus on islands, volcanoes, glaciers, and cloudy areas. These programs are ongoing, and will be reviewed again next year to determine when to restart them. **Tetsui Tachikawa** [JSS] reviewed the status of the cloud avoidance algorithm. The scheduler incorporates cloud prediction values to eliminate possibly cloud-contaminated acquisitions. Application of the program continues to result in an ~10% increase in efficiency acquiring cloud-free or less-cloudy images.

Data Products and Digital Elevation Model (DEM) Working Group

There is now an improved version of the Level-2 processing algorithms in place. For higher-level products (e.g., surface reflectance) a user can request that the input data be the terrain-corrected product (Level-1T) and that atmospheric correction be implemented using simultaneously acquired MODIS data products (e.g., water vapor profile). The next version of the software will implement a more accurate water vapor correction for the TIR data.

Most of the DEM discussion focused on the coming release of the Global Digital Elevation Model Version 3 (GDEM3) and the ASTER Water Body Dataset (ASTWBD). **Michael Abrams** showed the improvements resulting from Robert Crippen's [JPL] editing of the over 22,000 DEM tiles using his custom software. Almost all of the artifacts have been removed, including remnant cloud artifacts and those caused by use of low-quality USGS GMTED2010 data to fill

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[7] This rate is due to ASTER's allocation of 8 minutes of data acquisition per 99-minute orbit.

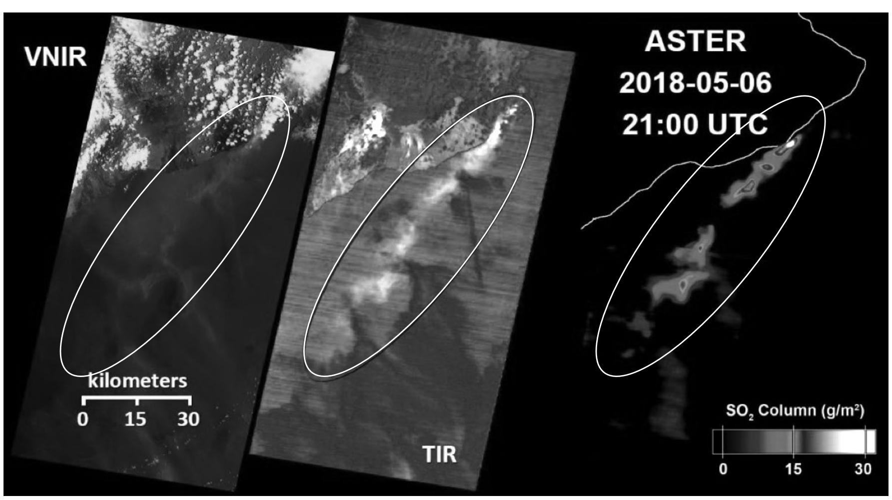

Figure 1. Sulfur dioxide (SO_2) retrieval [*right*] from ASTER TIR data obtained on May 6, 2018 over the Kilauea East Rift Zone eruption in Hawaii [*center*]. The VNIR image [*left*] is shown for comparison; notice that at VNIR wavelengths, the SO_2 plume, seen clearly in the TIR image, is indistinguishable from clouds. **Image credit:** Vincent Realmuto [JPL]

Table 1. Speakers, presentation topics, and summaries from the Applications working group.

Name [Affiliation]	**Topic**	**Summary**
Yasushi Yamaguchi [NU]	Characterizing urban sprawl	Described a *sprawl elasticity index*, derived from remote sensing data and population data, to characterize urban sprawl.
Michael Abrams [JPL]	Meeting presentations	Presented highlights from posters presented at the European Space Agency's Living Planet meeting, and at the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) Science Team meeting.*
Michael Ramsey [UP]	ASTER Urgent Request Program (URP)	Explained how the URP now uses the Middle InfraRed Observation of Volcanic Activity (MIROVA) algorithm, which is more sensitive than that which is used by the Moderate Resolution Imaging Spectroradiometer (MODIS), to trigger ASTER data acquisitions over volcanic hotspots.
Dave Pieri [JPL]	ASTER Volcano Archive (AVA)	Stated that the AVA is being ported to Amazon Web Services, with a more sophisticated graphical user interface. New sulfur dioxide (SO_2) and thermal anomaly detections will be available.
Truong Van Thinh [UT]	Forest mapping	Explained that using PALSAR-2** data, accuracy annual forest cover maps have been produced to help the government manage Vietnam's resources.
Vincent Realmuto [JPL]	Sulfur dioxide (SO_2) detection and mapping	Showed how SO_2 retrievals from ASTER, MODIS, and Visible Infrared Imaging Radiometer Suite (VIIRS) data were compared for the 2018 Hawaii eruption. Results were similar, despite large resolution differences—see **Figure 1**.
Michael Ramsey [UP]	ASTER volcanic ash library	Showed how laboratory TIR spectra of volcanic ash were applied to ASTER image data. Particle size distribution within plumes could be extracted from the ASTER TIR data.
Hiroyuki Miyazaki [UTs]	Building mapping	Explained how detailed building maps were produced for Sri Lanka, Rwanda, parts of Kenya, and Laos using ~0.5-m data from Google Earth.
Tomoaki Miura [UH]	Land surface dynamics	Described how using Himawari geostationary data, high-temporal-resolution data were combined with more traditional (e.g., MODIS) data to study land surface dynamics.
Yoshiee Ishii [IU]	Land cover classification	Showed how grade-added rough set classification method was applied to land cover classification. An improvement was found compared with traditional methods.
Hiroki Misuochi [AIST]	Deforestation mapping	Described the development of an automated deforestation mapping system using ASTER, Landsat, and Palsar-2 data.
Toru Kouyama [AIST]	Finding solar panels	Explained how deep learning algorithms have been used to find solar panels on rooftops and in fields using Landsat 8 images, and monitoring thermal anomalies with ASTER data.

* The ESA Living Planet meeting was held May 13-17, 2019, in Milan, Italy. The ECOSTRESS Science Team Meeting took place March 19-20, 2019, in Pasadena, CA; a related ECOSTRESS Workshop, held March 21, is summarized in the July–August 2019 issue of *The Earth Observer* [**Volume 31**, **Issue 4**, pp. 15-18—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Jul_Aug_2019_final_color_508_0.pdf#page=15*].

** PALSAR 2 stands for Phased Array type L-band Synthetic Aperture Radar; it flies on Japan's Advanced Land Observing Satellite-2, or DAIACHI-2, which launched in 2014.

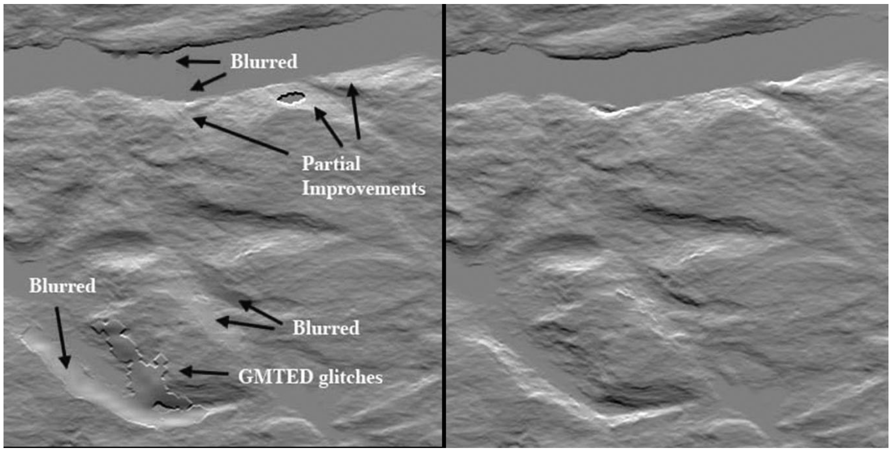

Figure 2. ASTER GDEM3 before [*left*] and after [*right*] editing to remove artifacts. **Image credit**: Robert Crippen [JPL]

voids—see **Figure 2**. The ASTWBD is a raster dataset, identifying ocean, lakes, and rivers, and also providing elevation values for the three different water bodies. This is a unique, global dataset that will be welcomed by the hydrology community. Both the Land Products Distributed Active Archive Center (LP DAAC) and JSS are ingesting the datasets into their distribution systems. A simultaneous release of GDEM3 and ASTWBD is planned for late July.

Chris Torbert [USGS] reviewed the status of the geometric performance of ASTER. Using the Landsat assessment system, thousands of ASTER scenes have been examined and compared with a library of ground control points. The geometric accuracy of the ASTER scenes continues to fall within mission requirements, indicating there are no problems either with the processing system, spacecraft, or instrument performance.

Temperature-Emissivity Working Group

The Temperature-Emissivity working group is concerned with ASTER's kinetic temperature and emissivity products. They discussed applications of these products, and reviewed the status of the nighttime TIR global map program. Based on **Masaru Fujita's** [JSS] assessment of the map's progress, the working group recommended restarting the program, as the one currently running has achieved 85% success.

A summary of presentations delivered at the working group is shown in **Table 2**.

Table 2. Speakers, presentation topics, and summaries from the Temperature-Emissivity Working Group.

Speaker [Affiliation]	**Topic**	**Summary**
Yudai Mizoguchi [IU]	Classification of Lakes	Showed that by using the satellite-based lake and reservoir temperature database in Japan, 228 of 1003 water bodies were classified—see **Figure 3**.
Michael Ramsey [UP]	Status of the Miniature Multispectral Thermal (MMT) TIR camera	Showed how UP has developed a portable multispectral TIR camera. It is calibrated for low and high temperature sources.
Yuji Yoike [IU]	Ice thickness estimation	Explained how MODIS data were used to estimate ice thickness of Lake Saroma, Japan; validation was measured with ice cores.
James Thompson [UP]	Evaluation of TES code	Discussed development of a scaling factor to minimize effect on low contrast spectra when determining emissivity from ASTER data.
Yuta Oguri [IU]	Emitted power of industrial zone	Showed measurements of the intensity of radiant energy for Kashima Coastal Industrial Zone, Japan, from 30 ASTER night TIR scenes.
Jigjidsuren Batbaatar [UW]	Mapping the zero curtain duration	Showed how using a time series of MODIS land surface temperature data, it was possible to distinguish between seasonal ground ice and permafrost.
Hideyuki Tonooka [IU]	Status of cloud assessment and nighttime TIR map	Explained that based on detailed analysis of cloud cover of the entire archive of nighttime TIR scenes, 89% of scenes have been observed at least once.

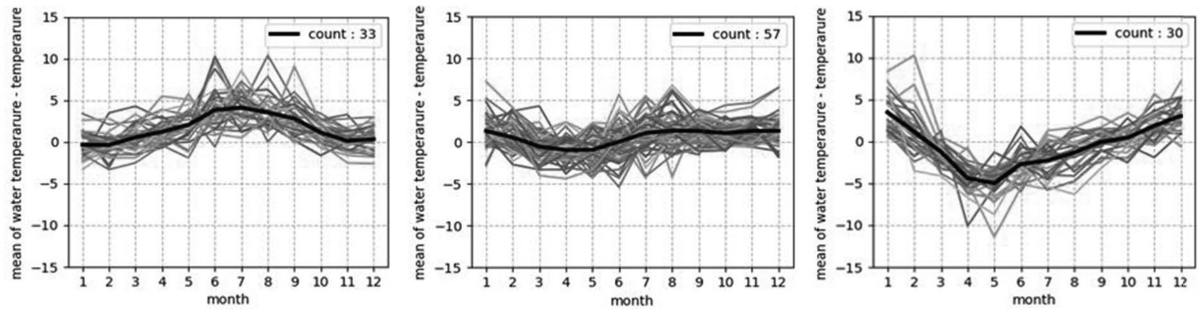

Figure 3. Classification of 120 Japanese lakes based on differences in seasonal change of water temperature minus air temperature. The three graphs show data for lakes with: shallow depth, low elevation, abundant inflow, high summer water temperature [*left*]; shallow depth, middle elevation, weak snowmelt, almost uniform temperature difference all year [*center*]; and deep depth, high elevation, large snow runoff, water warmer than air in winter [*right*]. The back curve is average of individual lake curves, shown in shades of gray. **Image credit:** Yudai Mizoguchi [IU]

Calibration/Validation Working Group

The Calibration/Validation working group is responsible for monitoring the radiometric performance of ASTER's VNIR and TIR instruments. For the VNIR, calibration and validation are performed by analysis of onboard calibration lamps and measurements of pseudo-invariant ground targets during field campaigns. Since the last ASTM, **Satoru Yamamoto** [JSS] reported that seven VNIR onboard calibrations were performed. There have been no significant changes in any of the data trends, including dark current response, lamp calibration data, output and temperature of the photodiodes, and signal-to-noise values. For the TIR, an onboard blackbody provides several measured temperatures to evaluate instrument response. Seven TIR calibrations were performed. There was no significant change for all measured data trends. Calibration accuracy is within the mission specifications of 0.5% for ground temperatures between 300 K and 320 K, and within 1% for temperatures greater than 340 K.

There were six reports on calibration/validation field campaigns: two for the VNIR and three for the TIR; and one VNIR calibration report using the Lunar Calibration experiment. **Satoshi Tsuchida** [AIST] and his team went to Railroad Valley, NV, four times in 2018. Weather conditions were marginal, so the results of the campaign were of questionable value. Seven more measurement campaigns are planned for 2019. **Hirokazu Yamamoto** [AIST] matched up ASTER data over the Committee on Earth Observation from Space (CEOS) Radiometric Calibration Network (RadCalNet) sites in the U.S., France, China, and Namibia. Larger errors were found for the ASTER acquisitions when the instrument pointed 8.5° off-nadir. **Toru Kouyama** [AIST] summarized the radiometric results from the August 2017 Terra Deep Space Lunar Calibration Maneuver, and compared them with a similar maneuver from 2003—see **Figure 4.** The results provide strong support for constraining ASTER VNIR degradation curves and establishing and updating the calibration coefficients. **Satoshi Tsuchida** [AIST] led a discussion of possible methods for the next update of the radiometric calibration coefficients. The favored method is to combine the results from the Lunar Calibration Maneuver and vicarious results from field campaigns. After three months the committee will report the results of exercising this option.

There were three reports on TIR field campaigns. A team led by **Soushi Kato** [RESTEC] visited three sites in Nevada. The brightness temperature difference between vicarious top-of-atmosphere values and ASTER standard product values was within 1 °C for Band 14. Other field campaigns found that Band 14

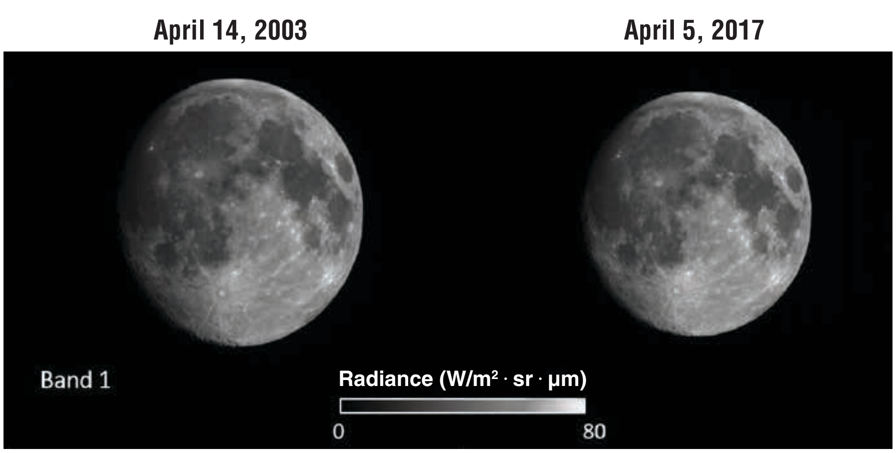

Figure 4. Comparison of ASTER Band 1 images of the Moon obtained during the two Terra Deep Space Lunar Calibration Maneuvers on August 14, 2003 [*left*] and August 5, 2017 [*right*]. Comparison of data between the two maneuvers has allowed for more accurate calibration of ASTER data. **Image credit**: Toru Kouyama [AIST]

met specifications. **Hideyuki Tonooka** [IU] occupied three sites in Nevada and two sites in Japan to conduct his validation activities. While four of the experiments were successful, clouds contaminated the other campaigns. He made measurements both during the day and at night. Results indicate that the onboard calibration is keeping the design accuracy of 1 K. **Michael Abrams** reported on the past year's vicarious calibration measurements at the instrumented buoys on Lake Tahoe and Salton Sea, CA. Comparison between the buoy measurements and ASTER data products indicated that there has been no noticeable change in the TIR instrument performance the past twelve months.

Closing Plenary Session: Meeting Summary

The chairpersons of each of the working groups presented summaries of presentations and discussions of their sessions. The overall consensus of participants was that ASTER continues to perform nominally, with no change since the 2018 meeting. Updates of the calibration coefficients will take place in 2020, incorporating results from onboard calibration sources, the 2017 Terra Deep Space Lunar Calibration Maneuver, and field-based validation measurements. The GDEM Version 3 and the new ASTWBD will be released in July 2019. The AST anticipates that NASA and METI will sign the Diplomatic Note extending joint operation of the ASTER project for an additional seven years starting October, 2019. The next meeting will be held June 1-3, 2020, at the same venue in Tokyo.

Acknowledgment

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