30th ASTER Science Team Meeting

Elsa Abbott, Jet Propulsion Lab, elsa.a.abbott@jpl.nasa.gov

The 30th U.S./Japan Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team meeting was held in Pasadena, CA, December 4-7, 2006. **M. Abrams** [Jet Propulsion Lab (JPL)—*U.S. ASTER Science Team Leader*] and **H. Tsu** [Earth Remote Sensing Data Analysis Center (ERSDAC)—*Japan ASTER Science Team Leader*] welcomed sixty-some U.S., Japanese, and other team members and allied guests.

Plenary Session

Abrams and **W. Turner** [NASA Headquarters] discussed the current funding situation for both Terra as a whole and ASTER in particular. Currently, per the 2003 Earth Observing System (EOS) proposal, the team leader budget decreases 5% per year, plus decreases due to salary increases. A senior review at NASA for Terra and the instruments on it will occur in early 2007.[1] This will determine the future of the U.S. ASTER team funding. In the previous senior review held in 2005, Terra was ranked second of 18 missions. The selection of new U.S. ASTER Science Team members will be announced starting in Spring 2007. It seems the available funds for the science team will be between one-half to two-thirds of the previous funding levels.

Abrams gave a report on the recent test of the ASTER direct downlink which was designed as a fallback in case of failure of the solid state recorder on Terra, and secondarily to allow for acquisition of more ASTER data over the U.S. with minimal impact in case Landsat 5 and Landsat 7 should fail. The receiving station is at Earth Resources Observations and Science (EROS) Data Center in Sioux Falls, SD, near the center of the continental U.S. The acquisitions took place July 17, and August 2, 4, and 9 during which some decoding problems were encountered. The test will be re-scheduled when the software is working. Abrams also discussed the Mid-Decadal Global Land Survey. This project is a partnership between the U.S. Geological Survey (USGS) and NASA to characterize trends in land cover and land use, in particular changes that have taken place since the publicly available GEOCOVER-2000 30-m-orthorectified Landsat dataset. Landsat 7, which has global coverage, now has data gaps and Landsat 5 is not global and is now 20 years old, so backup plans are needed and a plan to use ASTER to augment the Landsat coverage has been submitted. Landsat 5 coverage excludes parts of central and northern South America, northwest and central Africa, and parts of central Asia to Siberia, all of which might be covered by foreign stations. However, there is no possibility of coverage over parts of the Middle East, Iran, Iraq, Pakistan, and Kamchatka, making ASTER an attractive instrument for this task.

T. Sato [Japan Resources Observation System and Space Utilization Organization (JAROS)] gave a presentation on the instrument's health, particularly on the rise in temperature of ASTER's shortwave infrared (SWIR) detector. He began with a synopsis of the history of the temperature rise and measures that have been taken to understand and attempt to solve the problem to date. As the temperature of the detector rises the SWIR offset digital numbers (DNs) increase and are corrected by the radiometric calibration, but the dynamic range decreases, meaning the detectable maximum radiance decreases and more pixels will be saturated. There are two possible ways to fix this problem. The *set point* of the heat transport system can be lowered, which will decrease the dewar temperature and then the detector temperature. This is a safe operation but only a short-term solution as it will only buy about a month. The cooler capability can also be enhanced by increasing the *piston stroke,* which may work for as much as half-a-year, after which the detector temperature will again rise. Risks to this second approach are: 1) a small increase in the power consumption, which may not be acceptable to the Terra Project; 2) the possibility of cooler failure; and/or 3) the possibility of complete SWIR subsystem failure. The project could do nothing and continue to use Band 4 (which is not very affected by the temperature problem) for cloud assessment. Sato requests that the ASTER Team make a decision as to what to do before the detector reaches 83 K, which will happen soon.[2]

B. Bailey [U.S. Geological Survey Land Processes Distributed Active Archive Center (USGS LPDAAC)] gave an update on current activities and concerns at the DAAC. Since the decision was made to make all Level-1B and higher products on demand and not archived (implemented in May 2006) an average of more than 3300 Level-1B and 1000 digital elevation models (DEMs) per month have been produced. The production of DEMs continues to be monitored and improved upon based on user comments and findings at the DAAC. An orthorectified image product was made available in early March 2007. The number of ASTER products distributed by the DAAC continues to be impressive with more than 140,000 granules

[1] The Senior Review of Terra took place April 26 at NASA HQ; results were still pending when this issue went to press.

[2] The piston stroke was in fact increased in May 2007. While the temperature reduction was not as great as hoped, the rate of increase has slowed and the SWIR is now collecting good science data. At present, it appears that the procedure gained about 6 months of operating time.

distributed last year. The distribution by data type and by recipient type was shown in addition to trends in requesters and data type. *GloVis* and the Data Pool are two popular ways for users to select ASTER products. *GloVis* is now fully populated with up-to-date Level-1A browse images and higher level products. The Data Pool, which is a free dataset covering the U.S., is populated with a 2-year "rolling archive" of Level-1B data. Cross talk within the SWIR continues to pose a problem for users, but two new products, *AST_07XT* and *AST_09XT*, are now available through the DAAC to help mitigate the problem, while uncorrected products are still available to users who prefer them. The DAAC will begin to offer media distribution for ASTER products in 2007, available both via EROS Data Center and *GloVis*. For users requesting ASTER data takes, there is a new data acquisition request (DAR) tool available. The old tool will remain available until May of 2007.

M. Hato [ERSDAC] reported that the Japanese Ground Data System (GDS) is running smoothly with very few problems. At the end of November 2006, more than 1.26 million scenes had been acquired and Hato presented a breakdown of types of higher level products produced and demographics of their customers. The ASTER Level-1B on demand processing has gone so well that they will no longer be sending that product to the U.S. after the end of January 2007. The one item of concern to all is the rise in temperature of the SWIR detector (as mentioned above); the problem has been addressed in the last GDS Interface Meeting. Hato followed with a discussion of the status of the late change operation, which is an opportunity to make changes in the scheduler primarily to include weather updates. There was a five-month hiatus in this operation whereby updates had to be done in a very labor-intensive manner starting May 3, 2006, due to a security breach at several NASA centers including Goddard. This operation was re-started October 5, 2006, and is now in place, with updates made during ordinary weekday hours. Network access from GDS to the EOS Operation Center (EOC) is one hour per day for the normal one-day schedule and for late changes. GDS also is re-engineering the scheduling tool to improve its functionality.

K. Okada [ERSDAC] showed graphically the locations of all ASTER scenes, and showed them broken down by year of acquisition, cloud cover and time of acquisition—i.e., day or night. He then showed priority areas for the third round of global mapping, and scenes acquired with these priorities. Of the high priority scenes, observations of Japan and North and South America are being achieved but the Middle East, India, and Australia are not well represented. By the end of November 2006, 33% of the high priority scenes had been acquired. For the medium priority scenes, the same trend is found with the additional trend that North Africa is not well represented. Antarctica should be covered starting December 2006. By the end of November, 2006, 36% of the medium priority sites and 29% of the low priority sites were achieved, with only Siberia poorly represented. Okada also showed a map of the nighttime thermal scenes acquired over prioritized areas. It seems that a band through central Europe and Africa is difficult to acquire partially due to problems in the daily scheduler. Areas of high daytime priority adversely affect acquisition of nighttime scenes on the same orbit. Okada then showed an assessment of the causes of failure to collect data for urgent and ground campaign requests. Causes included product generation failure, conflict with other data sets, and late submission. Some of these situations can be fairly easily solved but others are intrinsically more difficult to correct. There is some concern that since ASTER has now well-exceeded its nominal lifetime, the resources for pointing the telescopes are being used up. Okada asks that the working groups consider whether and how to restrict the number of pointings. The system may be robust enough to outlast the nominal lifetime expectation but perhaps the team may suggest restricting the number of pointings.

Y. Yamaguchi [Nagoya University] put forth some questions that should be discussed in the splinter working groups for recommendation to the whole ASTER team. They include:

- how to proceed with the third round of global mapping and nighttime TIR mapping;
- what to do about the consumption of pointing resources;
- what to advise as guidelines for the Landsat mid-decadal Geocover gap filler; and
- what to do about the rise in temperature of the SWIR detector.

Additional items on the agenda are timely updates of the coefficients for each telescope [Visible-Near Infrared (VNIR), Shortwave Infrared (SWIR) and Thermal Infrared (TIR)] and plans for vicarious calibration exercises. Yamaguchi also provided more details on the effects of the SWIR detector temperature rise discussed previously and potential effects of the proposed measures to alleviate the problem. Each working group was asked to decide how to advise the project on this matter since if the *piston stroke* is to be increased it should take place soon.

Working Group Reports

Atmospheric Calibration Working Group

K. Thome [University of Arizona] gave a summary of the historical background of atmospheric correction and reviewed the decisions and reasons for the approach used by ASTER. He also summarized the effects of atmosphere on Band 3B and mentioned that radiative transfer calculations are accurately handling these effects.

Surface Bidirectional Reflection Distribution Function (BRDF)/roughness effects are dominant in this backward looking band.

B. Eng [JPL] gave a status report on the atmospheric correction software. The current version, running on a Linux platform, is *Version 3.1-3* and it includes crosstalk correction. *Version 3.2* is to be delivered to the DAAC in the spring of 2007 and will include a new ozone source from the Total Ozone Mapping Spectrometer (TOMS) satellite and will also be able to do interpolation to smooth artifacts in VNIR and SWIR corrected products. There is also a plan to implement Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol information.

H. Yamamoto [National Institute of Advanced Industrial Science and Technology (AIST)] reported on the Global Earth Observation (GEO) Grid, which is an ambitious infrastructure for archiving and processing satellite imagery and geographic information system (GIS) geographical datasets using ASTER data are at its core. Its atmospherically corrected products are based on ASTER Level-3A01 data with the ability to use ASTER DEMs for atmospheric correction and orthorectified ASTER radiance data. It has the capacity to be easily compared with MODIS products and to be used to conduct quality checks using ground measurement data. It is a sophisticated and complicated system integrating many types of data with which they aim to address many global problems.

Ecosystem/Oceanography Working Group

G. Geller [JPL] and **T. Matsunaga** [National Institute for Environmental Studies] reviewed the action items and reported that the Ecosystems and Oceanography Working Group has decided as a whole that all of the SWIR bands are important and that the *piston stroke* of the detector should be increased when the detector temperature reaches 83 K.

Geller and **Abrams** requested that someone from the United Nations Educational, Scientific and Cultural Organization (UNESCO) be invited to future ASTER meetings, and that they be requested to provide a report on the experience that World Heritage Site Park Managers have in using ASTER images.

The group also heard a number of reports on research done by team members and their affiliates:

- **Matsunaga** reported on the threat of sea level rise.
- Matsunaga gave a report on behalf of **T. Ishiyama** [Chiba University] discussing efforts to assess the degradation of oases surrounding the Taklimakan Desert by studying land cover change.
- **S. Scheidt** [University of Pittsburgh] discussed data fusion of ASTER VNIR, SWIR and TIR measurements to aid classification of desert coastal ecosystems and assessment of damage from the 1991 oil spill in the Persian Gulf.
- **Scheidt** also reported on the research to study the composition of potential dust sources in the Sahara Desert using ASTER TIR.
- **Yamaguchi** introduced a method to estimate carbon and heat fluxes by a combination of models and satellite data and showed validation results.
- Matsunaga presented on behalf of **Y. Sakuno** [Hiroshima University] about using satellite thermal imagery to study anoxic water distribution in Hiroshima Bay.
- Matsunaga presented on behalf of **H. Yamano** [National Institute for Environmental Studies] about a waterline method of extraction of satellite data over coral reefs using a case study in Australia.
- **A. French** [U.S. Department of Agriculture] discussed monitoring landcover change with ASTER emissivities over the Jornada New Mexico test site, and observing small but consistent decreases in emissivity.
- **Geller** gave an update on *TerraLook*, which was to have gone operational at EROS in January at which time Version 1.0 of the free viewer/toolkit should have been available.

Operations and Mission Planning Working Group/Science Scheduling Support Group

Abrams and **Yamaguchi** reviewed the action items from the last team meeting. **Okada** and **L. Maldonado** [JPL] gave a report on the operation status including the status of global mapping third round, SWIR pointing resource status and the search for causes of data acquisition failures. **K. Duda** [EROS Data Center], Abrams, and Okada discussed direct downlink issues. Okada also reported on his activities at the Ground Data System (GDS) during scheduling testing. There was some discussion on how to process data if SWIR ceases to function. Japan Resources Observation System Organization (JAROS) will investigate what happens to signal if the SWIR power is turned off and GDS will look into processing data without SWIR. The team recommends that the *piston stroke* be increased at 83 K. Okada also reported that some ecology users of ASTER data are not happy with the frequency that they can get ASTER data. He said that he would look at the Global Land Ice Monitoring from Space (GLIMS) project, the coral reef project, and the Amazon (LBA) project to assess success of data acquisitions in these areas. He also reported on a survey that found 97 published ASTER articles in just five journals.

Radiometric Calibration Working Group

Representatives of the companies that designed each of the four telescopes on ASTER (**Mitsubishi** for SWIR, **Fujitsu** for TIR, and **NEC/Toshiba** for VNIR) gave presentations on onboard calibration trends.

- *SWIR.* The Mitsubishi representative showed the latest onboard calibration datasets for SWIR that show the same tendencies as the previous set. Based on these findings, the Radiometric Calibration Coefficients (RCCs) will not be revised. The offset levels have been rising since September 2004, but the offset can be eliminated by the RCC offset correction using the detector temperature as a parameter.

- *TIR.* The Fujitsu representative showed the TIR onboard calibration trends including calculated temperature change by date for each band at four different DNs followed by a chart showing the fitting function description, date and version of each implementation. The representative also compared two fitting functions, one developed by Fujitsu and one developed by **F. Sakuma** [AIST], and showed that the one by Sakuma produced better results. Sakuma then reported on an action item to find the cause of the difference in the TIR error estimation between the two methods. He described both methods and showed why the Sakuma method will be adopted. In *Version 3.03* the error is within the threshold.

- *VNIR.* The NEC/Toshiba representative showed VNIR onboard calibration trends including optical calibration and dark pixel output by date for each band and dark pixel by gain state, as well as a series of other plots showing calibration trends with particular emphasis on the last two years.

The group also heard several other presentations about various calibration efforts related to ASTER.

S. Hook [JPL] discussed the inflight validation of ASTER and Terra MODIS TIR bands using the Lake Tahoe California/Nevada automated validation site. He described the site and the data reduction methods. The site was established in 1999 and since then many scenes have been validated with a broad range (3–18 C) of temperature. Ninety nine total clear ASTER scenes have been validated, 22 in 2005 and 16 in 2006. Hook then showed results for both Terra MODIS and ASTER. Corrected MODIS scenes show no evidence of bias throughout the mission. Validation of ASTER indicated a problem with the application of the radiation calibration coefficients that has been resolved. There remains a small bias which is under investigation.

K. Thome [University of Arizona] reported on continued ground-reference calibration results for Landsat data. He compared the similar Terra and Aqua sensors of ASTER, MODIS, Multiangle Imaging Spectro-Radiometer (MISR), and Enhanced Thematic Mapper Plus (ETM+) by computing the reflectance-based results using the same area of Railroad Valley Playa, NV. Thome showed graphs of the average percent differences of sensor bands versus wavelength in various combinations of common date, VNIR only, and morning versus afternoon sensors.

H. Tonooka [Ibariki University] reported on field campaign activities for the thermal infrared. He showed pictures of the field sites and experiments in progress and the vicarious calibration results.

J. Buchanan [University of Arizona] described vicarious calibrations over the lifetime of ASTER, showing the methodology and the test sites. Seventy-seven clear ASTER scenes at five different test sites were used, Level-1A imagery, one person evaluation, and MODTRAN radiative transfer code. The MODTRAN results were shown and were compared with results using the Gauss-Siedel radiative transfer code with very similar results. ASTER and Landsat 7 calibration using two sets of similar bands (Landsat 7 being ~30 minutes later) were then compared using MODTRAN code for both. Results were consistent with the standard deviation for all bands between 0.03 and 0.04, showing the reliability of the vicarious calibration method.

A. Kamei [AIST] described the field campaigns for vicarious calibration of the VNIR for the Japanese team using Railroad Valley, NV and Ivanpah Playa, NV. This team evaluated many radiative transfer codes for adoption in *GEOGrid* : G6, MODTRAN, Gauss-Seidel, Doubling/Adding and others, and decided on G6. Future work includes doing aerosol characterization trends for each site, collecting BRDF data and vicarious calibration with the National Space Organization's FORMOSAT-2 satellite data to be obtained in summer of 2007.

S. Tsuchida [AIST] presented information on a scheme to be offered in *GEOGrid* to determine the radiometric calibration coefficient of ASTER's VNIR 3B band, which has no onboard calibrator. The theoretical scheme for cross-calibration is quite complex with a need to assume many parameters and the currently used cross-calibration using the Earth and lunar surfaces as targets has uncertainties. They propose to estimate the degradation curve using the ratio of Band 3B to Band 3N, which has almost the same spectral characteristics.

Eng gratefully accepted the Japanese Level-1B SWIR crosstalk correction software on behalf of the U.S. It

was implemented as two new products in the ordering system (*AST_09XT* and *AST_07XT*) that use default parameters to be consistent with Japan.

Temperature/Emissivity Working Group

A. Gillespie [University of Washington] reviewed the action items from the previous meeting and gave a report on the Recent Advances in Quantitative Remote Sensing II (RAQRS II) Meeting held at the University of Valencia, Spain in September 2006. There was a strong emphasis on the Thermal Infrared (TIR) and the performance of ASTER Temperature/Emissivity Separation (TES) at the meeting. There were seven TES presentations made at RAQRS II. Gillespie felt that it was useful to present discussions on the problems and solutions since European users were beginning to notice problems with TES. He feels RAQRS III in 2010 will be a good venue for TIR presentations.

Okada reviewed the TIR nighttime data acquisition and he and **Matsunaga** both discussed the nighttime acquisition of TIR data, noting that acquisition of the Sahara and South Africa data, may impinge on daytime collections in Japan and Australia. Collections in South America should not impinge on any other collection sites but there seem to be several scheduling problems causing the lack of data. They suggest requests be submitted for South America and Africa and the effect on other regions watched, and then followed up with other nighttime requests.

Tonooka reported on the nighttime cloud assessment problem and offered a cloud mask based on a MODIS product that can be applied to Level-1A scenes and is available through the web. He also reported on a study on the impact of band-to-band misregistration on emissivity products. Emissivity scenes, especially those resampled by the nearest neighbor, have stripe noise due to resampling in the Level-1 processing, equivalent to 5–10% in emissivity and most likely caused by slope effects where one side is in shadow and one side warmed by the sun. If, in the processing, a single Ground Control Point (GCP) table is used for all bands rather than the standard one GCP table for each band, the results are better although some cross-track adjustment is still necessary for better quality. Tonooka also evaluated 102 emissivity scenes, nearly evenly divided in day and night, for temporal stability using vegetation free surfaces from three differenet sites: Big Island, HI; Death Valley, CA; and the Sahara Desert in Chad. The results indicated that the standard products are generally stable for dry areas but not so for humid areas due to errors in the atmospheric correction. The deviation of retrieved emissivity is roughly 0.01 per 1 cm of precipitable water vapor (PWV). The study continues.

B. Gustafson [University of Washington] made a presentation suggesting some changes to the Temperature/Emissivity Separation (TES) algorithm to address local unpredictable step discontinuities in emissivity and temperature images. They are visually disruptive and the temperature errors are particularly troubling because many users are interested in water and canopy temperatures. Local variability of water in the atmosphere is probably the cause of most of the error. Gustafsan tested the atmospheric compensation with a series of cloud free images looking at water at five different elevations from -69 m at the Salton Sea to 3193 m at Koko Nur, and checked the number of pixels in error in the downwelling radiance in Band 10. This test lead to a recommendation to change the Minimum/Maximum Difference (MMD) threshold from 0.03 to 0 and to eliminate the irradiance correction. He also suggests that temperature users check the emissivity values of their scenes. He suggests that the MODIS assist for atmospheric correction will be helpful, but also plans to do an in-scene atmospheric correction and use a classification of VNIR bands to assist daytime temperature/emissivity separation.

A. Mushkin [University of Washington] described a method of using subpixel roughness estimates from ASTER stereo images to compensate for roughness effects in the thermal infrared. He used lidar measurements and a two-look approach using an ASTER Band 3B / Band 3N ratio as a proxy for relative surface roughness. This approach has the advantage of being independent of albedo and most atmospheric conditions.

Geology Working Group

F. Kruse [Horizon GeoImaging, LLC] and **M. Urai** [Geological Survey of Japan] lead the discussion as the Geology Working Group discussed what to recommend about the SWIR detector temperature rise. The group agreed that in this group mineral mapping efforts and volcano temperature change detection and mapping will be most affected by loss or degredation of SWIR. The group unanimously recommended first to increase the *piston stroke*, followed by adjustment of the gains at a later date as required. The group also heard 17 presentations on a variety of geologic problems: three on geothermal topics and earthquake applications; three on glaciers; four on geological and mineral mapping; six on volcanoes; and one on DEM generation.

Level-1/DEM Working Group

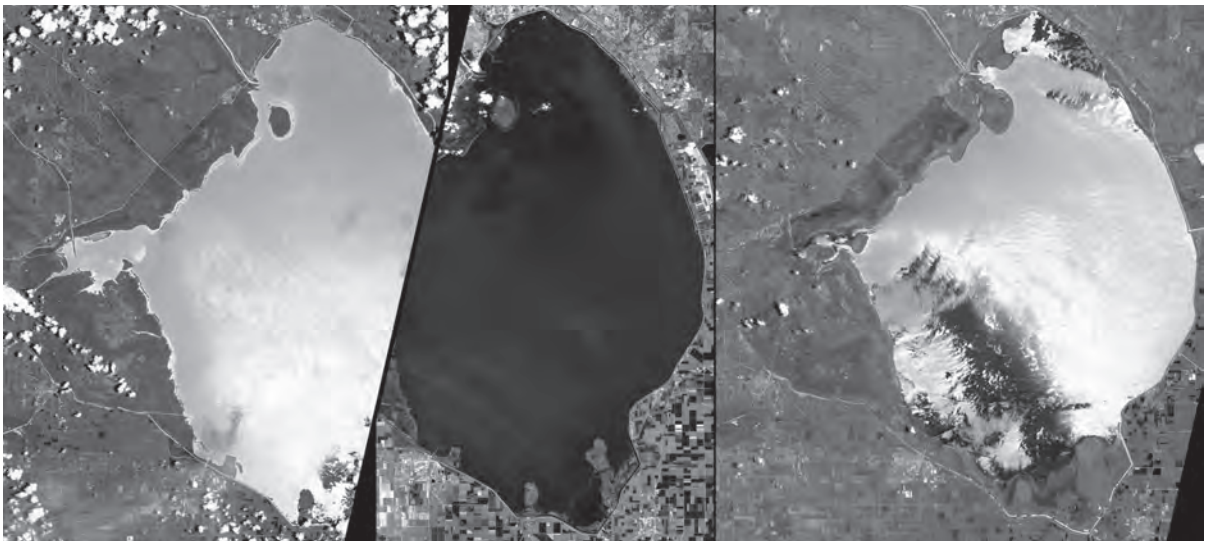
B. Bailey [USGS LPDAAC] reported on the status of the LPDAAC DEM and orthorectified image products. They began routine batch-mode production of the new ASTER DEM product on May 24, 2006. They pro-

duce relative DEMs only, at 30-m postings referenced to the Earth's geoid delivered in *GeoTIFF* format via *FtpPull* from the EOS Data Gateway. Production is running smoothly and they continue to monitor the data quality. Problems have been reported for several scenes at high altitude especially where there is abundant shadowing. The problem seems to be traced to *"water detection=on"* so the DAAC is adding an option for *"water detection=on or off"*. He showed a number of examples. Unlike Japan's ASTER Ground Data Center (GDC), the LPDAAC had not previously offered an orthorectified product, due to development complications and lack of approval from NASA HQ. Production was approved in July 2006 and should be running in January 2007. The new orthorectified product will be available to users via EROS Data Gateway and *GloVis* early in 2007 as zip files via *FtpPull* separately or with a DEM for $80 without or $160 with DEM, the same as other products. He then gave the status of several other items. The new billing and accounting product codes had been provided, the new Linux hardware had been delivered but not installed, which will take additional time after instillation for system integration, testing and product validation, and product documentation was in review.

H. Fujisada [Sensor Information Laboratory Corp. (SILC)] talked about ASTER Level-1, DEMs, and orthorectified products produced in Japan. Fujisada first discussed the Level-1 algorithms and software improvements (Fujitsu Ltd.). All the radiometric coefficients were updated to *Version 3.03* and were working well. The Level-1 geometric performance has no appreciable problems. Tests were done with band-to-band registration and geolocation accuracy day and night. He then discussed the SWIR parallax correction status (Mitsubishi Space Software Co., Ltd.). They measured cloud free scenes scattered over the world, Band 6 vs. Band 7, matching images in the along track and across track directions and found no problems in either direction and no problems in the error distributions, meaning the parallax correction is working properly. The inter-telescope registration correction tests (Hitachi, Ltd.) done both across track and along track showed that the registration had not changed since June 2006, and the relationship between inter-telescope offsets and pointing angles had not changed since November 2003. The DEM ortho-validation results (Central Computer Services, Co., Ltd.) using several validation sites in Japan and Australia show no problems. Fujusada also gave the values for the calculated offsets for SWIR at 83 K for the Level-1A data.

R. Nakamura [AIST] presented a paper describing the accuracy estimate of ASTER DEMs from the GEOGrid and described the methods used. Data transmission from ERSDAC to AIST started November 1, 2006, and data transfer from tape archive should be finished in 5-6 months. The GEOGrid portal is open to special users at *www.geogrid.org* and currently users can order DEMs and orthorectified products. The geometric accuracy is validated using the ERSDAC Level-3A data, Ground Control Points (GCPs), and lidar from the west coast of California, including the San Andreas fault zone. In summary, the GEOGrid product has similar geolocation accuracy as the ERSDAC product and the elevation accuracy may be better. Nakamura welcomed the ASTER team as *beta* testers.

Abrams and **Tsu** closed the meeting and declared it a success, with a promise to meet again in late spring in Japan. ■



Lake Okeechobee is located in south-central Florida and is the second-largest freshwater lake wholly within the continental United States, second only to Lake Michigan. The massive lake is 1913 km^2 (730 mi^2), with an average depth of 2.7 m (9 ft). Due to drought and usage of water for agriculture and residential purposes, the current water level is about 1 m (3 ft) below its historical average for this time of year. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on the Terra satellite acquired the left image on June 19, 2000, the middle image, January 19, 2003, and the right image, June 23, 2007. Shrinking is particularly evident on the west and the southeast parts of the lake. **Credit:** NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.