The ASTER along-track stereo experiment - a potential source of global DEM data in the late 1990's

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ABSTRACT

In addition to acquiring multispectral data, the Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) will also acquire along-track stereo data. ASTER is capable of acquiring 771 digital stereo pairs per day, each covering 60 X 60 km on the ground, at 15 m resolution with a base/height ratio of 0,6. According to present plans, approximately 30 digital elevation models (DEMs), with 7-50 m accuracy (RMSExyz) will be produced daily. During the 5 year mission on the EOS AM1 platform, ASTER has the potential to provide a coherent digital stereo dataset covering the Earth's land surface. At minimum, DEMs derived from these data will augment topographic data from other sources. These fundamental geophysical measurements will be a major contribution to interdisciplinary studies of the Earth as a planet.

KEYWORDS: ASTER, EOS, Along-Track Stereo, Topography, DEMs

1. IN'1'ROI)UCTION

The Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) is a multispectral imaging system scheduled to fly in Earth orbit in June, 1998, on the first NASA Earth Observation System platform (EOS AM]). An overview of the ASTER system is provided by Kahle et al.[1] Detailed documentation of the ASTER stereo experiment is provided by I ang and Welch.z

Important specifications of the stereo subsystem that govern digital elevation model (DEM) generation capabilities include nadir- and aft-viewing (27.-/ off-nadir) telescopes that provide a base/hcig,ht ratio of 0.6, a platform altitude of 705 km, and an IFOV of 15 m in the 0.76-0.86pm 3N (nadir) and 3R (aft) stereo channels, Nine seconds arc required to acquire a 60 X 60 km ASTER scene, and approximately 60 seconds for a stereo pair. With its 24 degree pointing capability, tbc stereo subsystem provides global coverage between 85°N and 85°S. Based on its 8% duty cycle, ASTER is capable of acquiring a maximum of771 digital stereopairs per day.

During the planned 5 year mission, ASTER will be capable of acquiring the 45,000 cloud-free, digital stereopairs required for coverage of the land area of the Earth. This is based on our mission simulations and experience with Landsat.[2] Thus, ASTER incorporates capabilities that were proposed, but never implemented, for the Stereosat[3] and Mapsat[4] mission concepts of the late 1970s.

2. DEM PRODUCT GENERATION

2.1 Overview

Development of an approach for generating ASTER DEM products benefited substantially from efforts to generate DEMs from Landsat[5], SPOT[6] and the Japanese Earth Resources Satellite (JERS- 1) OPS system[7]. A digital stereocorrelation approach will be used to calculate parallax differences and derive DEMs from ASTER stereopairs.

Two types of DEM products will be created with compatible formats and elevation postings every 30 m. *Standard Data Product DEMs will be* produced at the rate of 1 scene per day at the Land Processes Distributed Active Archive Center (LP DAAC) at EDC in the U.S. *Special Data Product DEMs will be* produced at the rate of 30 scenes per day at the Product Generation System (PGS) facility in Japan. The LP DAAC will use commercial off-the-shelf software, which will be acquired through a request for proposals to be released in August, 1996. The PGS facility is now testing software that is being developed in-house. The LP DAAC will use space oblique mercator projected Level 1B data (calibrated, registered radiance at sensor) for input; the PGS facility will use Level 1 A (decommutated instrument data) for input, *Standard Data Product DEM* production will emphasize generation of absolute DEMs; *Special Product DEM* production will emphasize generation of relative DEMs with geographic emphasis on 20,000 scenes covering Fast Asia.

2.2 Procedures

The digital stereocorrelation approach requires that the digital band 3N and the band 3R full scene images must be "matched" to establish parallax difference values. To accomplish this, a correlation window of specified size (e.g., 11 x 11 pixels), defined prior to initiating the correlation procedure is automatically centered over a 15 m pixel in the band 3N image. The area on the band 3R image within which the conjugate pixel is located is defined by a search window sized to account for the maximum possible image displacement due to terrain relief, The correlation window is then moved, pixel by pixel, across the. search window and the correlation coefficient computed at every pixel location. The pixel location at wihich the correlation coefficient reaches a maximum is considered to be the match point, The difference in pixel location in the conjugate images, parallel to the direction of satellite motion is the parallax difference value, and is proportional to the terrain elevation relative to the vertical datum. This procedure is systematically repeated across the entire band 3N image.

Although it is not necessary to determine parallax values for every pixel, the matching process must be operated on a per pixel basis. This optimizes the reliability of the correlation process and accounts for high frequency terrain variations. Subpixel parallax values can be obtained by interpolation, Our simulations, using commercial software on a single workstation, show that approximately 22 minutes to 5.5 hours of computation time will be required to generate a DEM with 30 m spacing from an ASTER stereopair.

The DEM generation process will require an editing step using batch and interactive processes. With standard image processing routines, the DEM can be filtered to correct for spikes and outliers.

After editing (if required), the pixels for the. nadir image and the derived DEM can be geodetically rectified to a standard coordinate. system, such as Universal Transverse Mercator (UTM), and "fitted" to the surface of the. Earth. This requires ground control points (GCPs) which will be provided by users who request "absolute" DEMs. All GCPs will be recorded in the UTM coordinate system. For areas within the United States and Canada, GCPs will be referenced to the North American Datum of 1983 (NAD83); and for other areas, to the World Geodetic System of 1984 (WGS 84).

3. ACCURACY

Based on present understanding of platform stability and pointing knowledge, experience with other stereo satellite. systems, and our work using simulated ASTER data sets for DEM generation, ASTER DEMs should have $RMSE_{xyz}$ accuracy values of approximately 7 m to 50 m.[2] Accuracy will be strongly dependent on such factors as: 1) availability, number and quality of GCPs (expected GCP accuracy range, ±5- 10 m); correlation errors (expected range, ± 0.5- 1.0 pixels); and 3) planimetric errors (expected range, ±0.75 pixels).

Based on these values, slope measurement accuracies of 5° should be obtainable using ASTER DEMs over measurement distances exceeding 100m-500m. We estimate conservatively that ASTER DEMs will meet accuracy standards for mapping scales in the 1: 100,000 to 1:250,000 range. In some cases, ASTER DEMs will be of sufficient quality for 1:50,000 scale mapping.

4. CONCLUSION

During a planned 5 year mission, starting in mid-1998, ASTER has the capability of aquiring cloud-free digital stereo coverage of the land area of the Earth, between *85"N* and 85°S. Using digital stereocorrelation procedures, that are now available in commercial off-the-shelf software, these data can be used to generate DEMs that meet accuracy standards for 1:50,000 to 1:250,000 cartography. Present plans call for production of ASTER DEMs as both Standard (1 scene/day) and Special (30 scenes/day) EOS data products.

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