西日本に関する ASTER G-DEM と SRTM-3 の比較

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Comparison of ASTER G-DEM and SRTM-3 for West Japan

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Abstract

A new global elevation dataset known as G-DEM, based on the ASTER satellite imagery, will be released in late 2008. This paper assesses the quality of G-DEM in comparison with 3-arc-second SRTM DEM, the best current global elevation dataset, using a pre-release version of G-DEM and SRTM DEM for western Japan.

Keywords

DEM, quality, geomorphometry

1. Introduction

The ASTER Global Digital Elevation Model (G-DEM) is a new global DEM (digital elevation model) set with a resolution of 1 arc second for the whole world, which will be released in December 2008. This dataset, from a joint endeavor of the Ministry of Economy, Trade and Industry of Japan (METI) and NASA, is based on satellite imagery from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor. The officially announced vertical accuracy of the G-DEM is 7 m, less than half that of the SRTM-3 (Shuttle Radar Topographic Mission 3 arc second, 90-m DEM), formerly the best global DEM with horizontal and vertical accuracies of about 20 m and 16 m, respectively. However, because of noise related to insufficient contrast in some parts of radar imagery, SRTM-3 tends to give overly high average slope gradient in flat areas and overly low gradient in high-relief areas. The G-DEM is expected to be a better source of global topographic information for various scientific applications, and it is necessary to evaluate whether its quality other than resolution and vertical accuracy is superior to

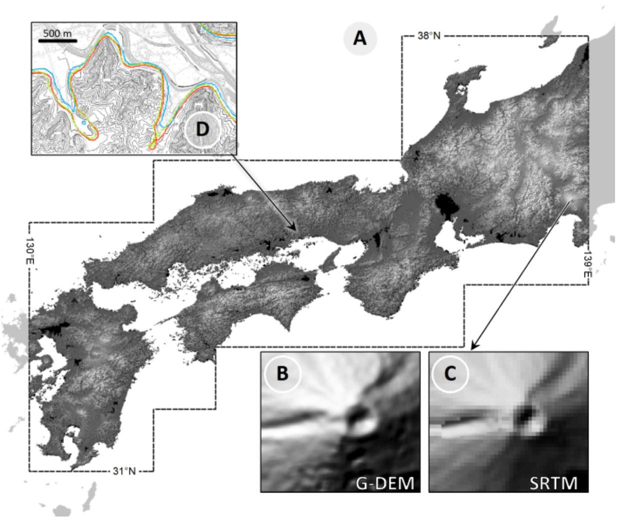

Fig. 1. Study area. (A) A hillshade image from G-DEM for western Japan. (B, C) Hillshade images by G-DEM and SRTM. (D) Contours at 50 m elevation from G-DEM, Contracted G-DEM, SRTM and 1:25000 topo map.

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that of the SRTM data. In particular, the accuracy of DEM-derivatives such as slope gradient and curvature should be determined. Here we compare topographic representations based on a pre-release version of the G-DEM with those from SRTM-3.

2. Data and Methods

We analyzed the pre-release G-DEM for western Japan (Fig. 1), which was distributed temporarily by ERSDAC, Japan. We also analyzed the SRTM-3 DTED Level 1 for the same area, the latest (finished) version of SRTM products. A DEM set with resolution 3 arc seconds was also derived from the G-DEM by reading the elevation every three columns and rows (referred to as Contracted G-DEM), to allow comparison with the SRTM-3 at the same resolution. Sea surfaces included in the DEMs were excluded using the 1:25,000-scale coastline vector data provided by the Geographical Survey of Japan.

We first checked the frequency and spatial distribution of missing data in both DEMs due generally to incorrect radar reflection for the SRTM-3 and cloud cover for the G-DEM. A cell for which the elevation record is missing in either the G-DEM or SRTM-3 is excluded from following analysis. The slope and curvature were then derived from the DEMs as basic geomorphometric parameters. Grid cells of 2-minute resolution (ca. 4×4 km) were also used to summarize statistic values of the elevation, slope and curvature.

3. Results and Discussion

3.1. Missing data

The area of cells missing in the G-DEM for the study area is 1,614 km^2 (0.77% of the whole area), and for SRTM-3 is 3,418 km^2 (1.63%), where 509 km^2 areas are missing in both datasets. Missing data in SRTM-3 are particularly frequent in regions higher than 1900 m or steeper than 25°, as well as in flat lowlands (<100 m elevation or <10° slope). Missing data in G-DEM are mostly in flat lowlands (<100 m elevation or <6° slope) (Fig. 2).

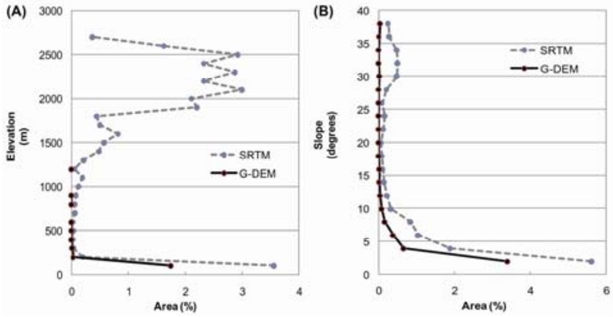

Fig. 2. Missing data area versus (A) elevation and (B) slope.

The smaller extent of missing data in G-DEM than in SRTM-3 is an advantage for the former. This is particularly true in high mountainous areas with steep slopes, where SRTM-3 typically has many missing data. Although G-DEM includes a relatively large amount of missing data in lowlands, below an elevation of 100 m, it is still only about one-half that of the SRTM-3. Moreover, the amount of data missing in G-DEM should decrease because the acquisition of new ASTER images is continuing.

3.2. Elevation, slope and curvature

The mean G-DEM elevation for the entire study area (455.6 m) is lower than that from SRTM (460.7 m) (Fig. 3). DEM cells having <50 m elevation in the G-DEM but >=50 m in the SRTM-3 are often found along valley floors in low-relief hilly regions. Comparisons between DEM elevations and 1:25,000 topographic maps show that the elevation of the floors of some small valleys in low-altitude hilly regions is overestimated in SRTM-3 (Fig. 1D), whereas the elevation of some adjacent ridges is underestimated in G-DEM. Japanese low-altitude hilly regions are usually characterized by a high density of small valleys, due to heavy dissection of unconsolidated bedrock including Quaternary fluvial and marine deposits and tephras. SRTM-3 does not accurately represent the details of such complex topography. In high altitude regions, areas with lower G-DEM elevation tend to occur in valley bottoms within mountains, whereas areas with higher G-DEM elevations are frequent along mountain ridges. Comparison with 1:25,000 topographic maps shows that G-DEM better reflects the actual height of mountain ridges and valleys than SRTM-3.

The slope from the Contracted G-DEM is systematically gentler than that from the original G-DEM, reflecting the scale effect by which lower-resolution DEMs generally indicate smaller gradients. However, this does not account in full for the differences between slopes from G-DEM and SRTM-3, because gentle (0–12°) and steep (33°–) slopes are more common in G-DEM whereas intermediate slopes (12°–33°) are more common in SRTM-3. This frequency distribution of slope angles also indicates the lack of detail in the SRTM-3 topographic representation. The better representation of valleys by the G-DEM, with clear contrast of steep side slopes and gentle valley floors, partly account for the differing slope frequencies. In high mountainous areas, G-DEM shows the steep topography of ridges and V-shaped valleys better, accounting for the higher frequency of steep slopes from the DEM.

Curvature based on SRTM-3, with a mean value of 32.4 and a standard deviation of 4.7×10^4, tends to be larger and more variable than that from G-DEM, which gives an average of -1.4 and a standard deviation of 4.1×10^4. The curvature for the

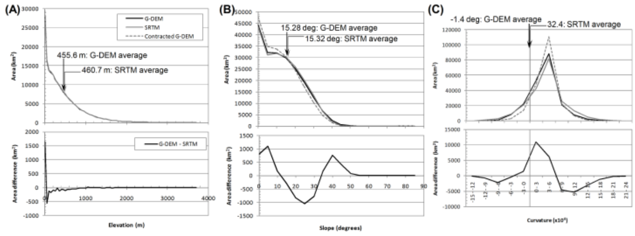

Fig. 3. Frequency and its differences (G-DEM - SRTM-3) of (a) elevation, (b) slope and (c) curvature from G-DEM, SRTM-3 and Contracted G-DEM.

entire study area according to G-DEM is more concentrated at medium values (close to zero) than for SRTM-3. This difference also stems from differences in the representation of valley topography. In Japanese hilly regions, box-shaped valleys are dominant, with the steep side slopes and flat valley floors clearly distinguished. G-DEM accurately represents such topography, and tends to show slopes having near-zero curvature except at the boundary of the two types of slope. The less detailed representation of valleys in SRTM-3 shows as concave slopes near the valley floor, and convex slopes near ridges. Similar considerations apply to the V-shaped valleys common in mountainous regions in Japan.

3.3 Change of slope and curvature with altitude

The mean and standard deviation of the slope were computed for each 50-m elevation bin (Fig. 4). Elevation bins higher than ca. 3100 m are omitted because they occupy only a very small area (<1 km^2). Steeper mean slope angles are generally found in higher areas. The slope according to G-DEM is larger than that from SRTM-3 in areas higher than 500 m; the difference is clear (ca. 1°) if the elevation exceeds 1400 m. The mean slope angle from the Contracted G-DEM is consistently smaller than that from the original G-DEM by ca. 1° due to the scale effect. The mean slope angles from the Contracted G-DEM and from the SRTM-3 are similar in areas higher than 2000 m. The standard deviation of the slope angle from the SRTM-3 is always smaller than that from the G-DEM, and is smaller than that from the Contracted G-DEM in regions higher than 1400 m.

Changes of the mean curvature with altitude from the G-DEM and Contracted G-DEM are fairly similar. The curvature from SRTM-3 is, however, clearly smaller in regions below 300 m, but larger in areas of altitude 300–2300 m. The standard deviation of the curvature from the SRTM-3 is consistently larger than that from the G-DEM for elevations between 50 and 2000 m, but is smaller and fluctuates less in areas higher than 2000 m; it is also smaller in the lowermost areas (<50 m).

The greater noise in the SRTM-3 height distribution may account for the differing frequency distributions of the curvature. Since curvature is a measure of variation in slope, the greater standard deviation of slope and lower curvature in G-DEM, for elevations between 300 and 2,300 m (Fig. 4B,C), may appear contradictory. However, this combination is possible if the SRTM includes frequent but relatively minor changes in slope within a small area, giving rise to more local curvature. Topographic representation by SRTM correspondingly includes more local noise, such as spikes and holes, particularly in lowlands. The noise can lead to the reduced area of terrain with small slope angles in SRTM-3 mapping, and an overall decrease in less curved surfaces.

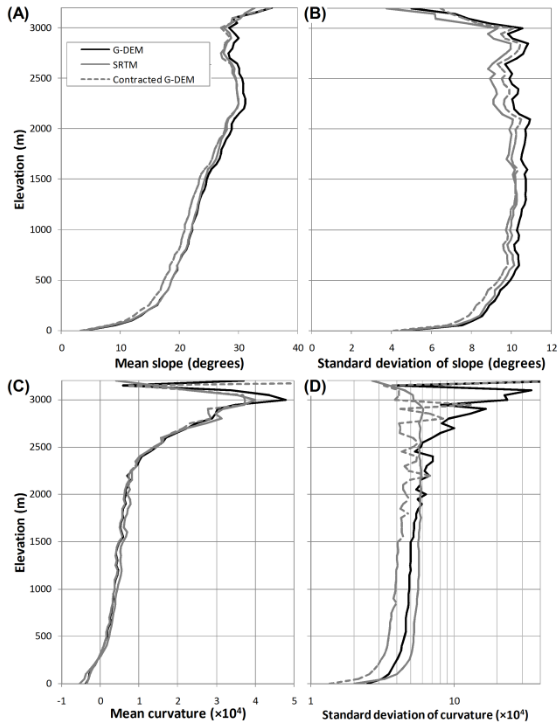

Fig. 4. Changes with altitude of (A) mean slope angle, (B) standard deviation of slope angle, (C) mean curvature and (D) standard deviation of curvature, computed for each 50-m elevation bin.

4. Conclusions

Terrain representation by G-DEM seems superior to that by SRTM-3 for most landform elements, including hilly lowlands and steep mountains. More realistic representation of valleys and mountain ridges, as well as reduced local noise, constitute major improvements in G-DEM, along with higher spatial resolution and less missing data. We used the pre-release version of G-DEM, and further improvement in quality is expected in the final product. In areas where only the 3-arc-second SRTM-3 is currently available, G-DEM will be the best digital elevation data that are frequently used for geoscientific and environmental applications. Because landforms in western Japan include both gentle and steep terrains, we believe that the present results have wide applicability. This assertion should, however, be verified using data for other regions, after the official release of the G-DEM for the entire globe.