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Evaluation of TanDEM-X DEMs on selected Brazilian sites: Comparison with SRTM, ASTER GDEM and ALOS AW3D30

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ABSTRACT

A first assessment of the TanDEM-X DEMs over Brazilian territory is presented through a comparison with SRTM, ASTER GDEM and ALOS AW3D30 DEMs in seven study areas with distinct geomorphological contexts, vegetation coverage, and land use. Visual analysis and elevation histograms point to a finer effective spatial (i.e., horizontal) resolution of TanDEM-X compared to SRTM and ASTER GDEM. In areas of open vegetation, TanDEM-X lower elevations indicate a deeper penetration of the radar signal. DEMs of differences (DoDs) allowed the identification of issues inherent to the production methods of the analyzed DEMs, such as mast oscillations in SRTM data and mismatch between adjacent scenes in ASTER GDEM and ALOS AW3D30. A systematic difference in elevations between TanDEM-X 12 m, TanDEM-X 30 m, and SRTM was observed in the steep slopes of the coastal ranges, related to the moving-window process used to resample the 12 m data to a 30 m pixel size. It is strongly recommended to produce a DoD with SRTM before using ASTER GDEM or ALOS AW3D30 in any analysis, to evaluate if the area of interest is affected by these problems. The DoDs also highlighted changes in land use in the time span between the acquisition of SRTM (2000) and TanDEM-X (2013) data, whether by natural causes or by human interference in the environment. The results show a high level of detail and consistency for TanDEM-X data, indicate that the effective horizontal resolution of SRTM is coarser than the nominal 30 m, and highlight the errors in ASTER GDEM and ALOS AW3D30 due to mismatch between adjacent scenes in the photogrammetric process.

1. Introduction

Global Digital Elevation Models (DEMs) have become essential data for research in areas such as geomorphology, climatology, oceanography and biodiversity, with applications as diverse as the development of geopotential global models (Arabelos, 2000), evaluation of glacier volume change (Berthier et al., 2006), climatic modeling (Moore et al., 1991; Thomas et al., 2004), vegetation mapping (Kellndorfer et al., 2004; O'Loughlin et al., 2016) or navigation systems for commercial aviation (Fox et al., 2008).

Global or quasi-global DEMs currently available include SRTM (Farr et al., 2007), ASTER GDEM (Tachikawa et al., 2011a) and ALOS AW3D DEM (Tadono et al., 2015). SRTM is likely the most successful and widely used DEM to date, despite limitations such as presence of voids caused by radar shadowing and lack of coverage at high latitudes. ASTER GDEM and ALOS AW3D are built based on photogrammetric processing of optical satellite imagery, thus containing artifacts and voids due to cloud cover in the original images.

TanDEM-X DEM is a new dataset produced by the German Aerospace Center (DLR) with global coverage, spatial (i.e., horizontal) resolution of 12 m, and is expected to represent a new standard in global DEMs regarding geometric resolution, accuracy and ability to depict complex topography (Krieger et al., 2007; Zink et al., 2014; Rizzoli et al., 2017).

Early and intermediate products of the TanDEM-X mission have been evaluated for their height accuracy by Gruber et al. (2012), Wessel et al. (2014), Wecklich et al. (2015), Baade and Schmullius (2016) and Wecklich et al. (2017), while Erasmi et al. (2014) assessed its applications in archeology, and Pandey and Venkataraman (2013) conducted a comparison with SRTM in the Himalayas.

In this paper, a first assessment of the final TanDEM-X DEMs over Brazilian territory is presented through a comparison with SRTM, ASTER GDEM and ALOS AW3D30 DEMs in seven study areas with distinct geomorphological contexts, vegetation coverage and land use. The results show a high level of detail and consistency for TanDEM-X data, indicate that the effective spatial resolution of SRTM is coarser than the nominal 30 m, and highlight the errors in ASTER GDEM and ALOS AW3D30 due to mismatch between adjacent scenes in the

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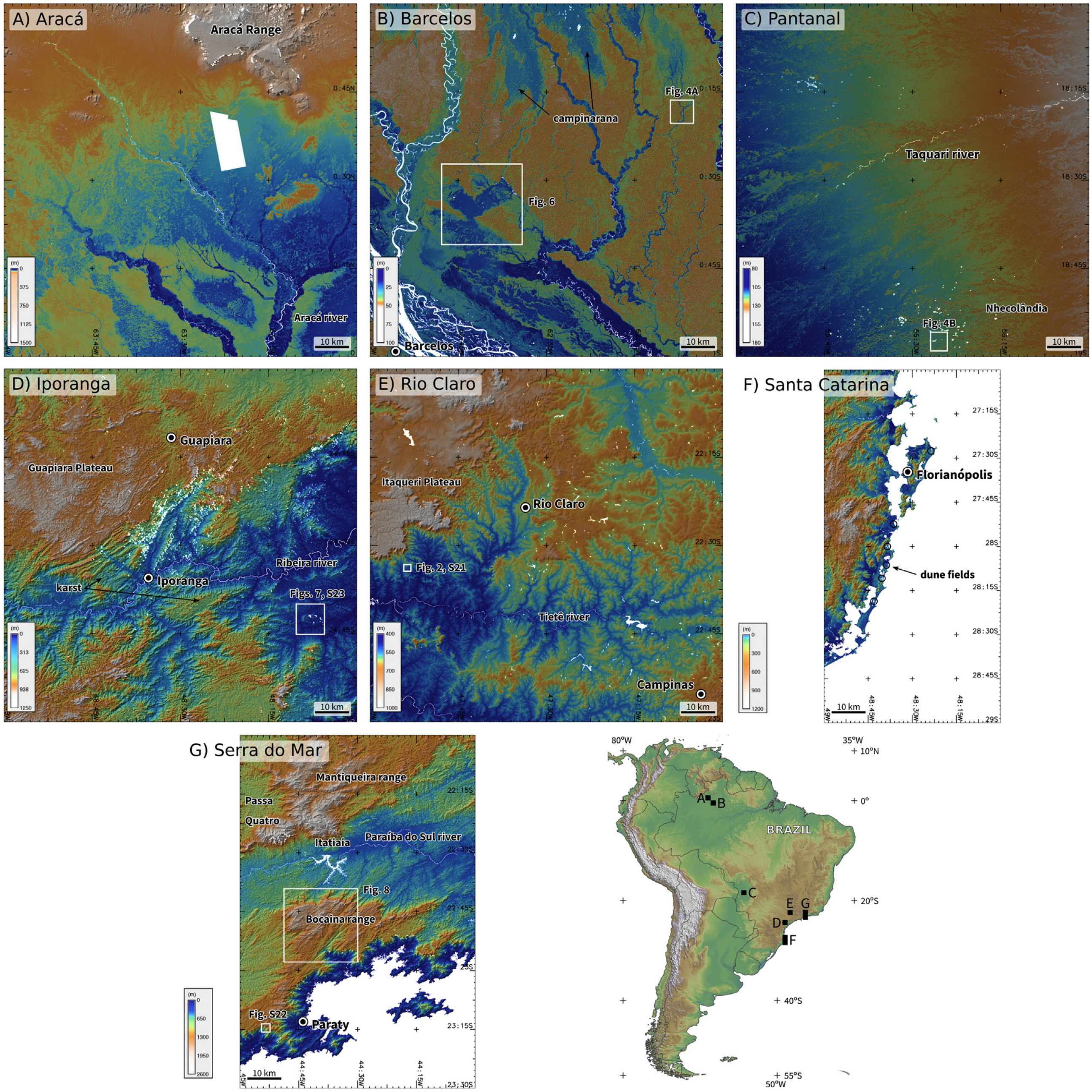

Fig. 1. Shaded relief maps of studied areas with indication of places or landscape features referred in the text (TanDEM-X 30 m data, shaded relief illumination from 315°N, 20° above horizon).

photogrammetric process. Additionally, DEMs of differences proved to be a simple and effective tool to perform a preliminary evaluation of a DEM, and are recommended prior to any analysis which intents to use ASTER GDEM or ALOS AW3D DEMs.

1.1. Study areas

Seven areas were selected for analysis, in order to represent a wide range of geomorphological contexts, vegetation coverage and land use. Each area is defined by one or two 1° × 1° tiles of the analyzed DEMs. Fig. 1 shows shaded relief images of TanDEM-X (30 m resolution) for all areas; satellite imagery is presented in Supplemental Fig. S1. In this paper, areas are referred to after geomorphological features, cities or location; labels in Fig. 1 are provided as guides to the reader and do not represent an exhaustive description of all landscape elements.

Shaded relief images for all DEMs and areas are shown in the Supplemental Figs. S2–S8; it is possible to observe the large area of voids (no data) in ALOS AW3D30 data, likely due to cloud coverage, notably in the Aracá, Barcelos and Iporanga areas. Voids in TanDEM-X DEMs are not present in the original data, and result from a filtering process based on the Water Indication Mask (WAM — Wendleder et al., 2013) supplementary information layer (see Section 2.2). An inset of the Rio Claro area (Fig. 2) highlights the level of detail resolved by TanDEM-X data. Located in the outskirts of the small town of São Pedro, it shows suburban and rural lands with a large linear erosional feature in its central zone. At resolution of 30 m, the erosion is barely seen in SRTM and ASTER GDEM, while it can be identified in ALOS AW3D30 and TanDEM-X 30 m. With 12 m resolution, it is possible to delineate not only the erosion gully, but also streets, roads and agricultural areas.

Two areas are located within the Amazon Forest in northern Brazil: the Aracá range area (tile N00W064 — Fig. 1A) and the Barcelos City and Negro River floodplain area (tile S01W063 — Fig. 1B). These two