Geomorphometric and Geospatial Patterns in Differences Between ALOS and COPDEM

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Abstract—**We proposed three new criteria to use in addition to those presented in the DEMIX wine contest for evaluating 1 arc second global DEMs. We use the criteria to compare the COPDEM and ALOS DEMs. These criteria use a pairwise, pixel by pixel comparison of the candidate DEM to a reference DEM for elevation, slope, and roughness. With two candidate DEMs and a tolerance for differences not considered significant, we can score each pixel as a tie or win for COPDEM or ALOS. The method allows us to map the differences, and shows that the terrain has a major impact on the errors in these DEMs.**

I. Introduction

DEMs represent a fundamental building block for work in science, engineering, social science, government, and the military. DEMs at 1 arc second (~30 m) provide the best resolution freely available globally. The DEMIX group is working to compare and rank those DEMs [1]. We use their database [2] to show the geomorphometric and geospatial patterns of the differences. While we performed this analysis for 6 DEMs, space restricts us to concentrate only on COPDEM and ALOS which are demonstrably much better than SRTM, NASADEM, and ASTER [3]. We also limit consideration of FABDEM, which attempts to approximate a DTM but only improves on COPDEM for some landscapes, so that we can look at the simpler case of only two DEMs.

II. Methods

The wine contest [1] uses geomorphometric criteria to rank DEMs. The criteria must allow numerical ranking, which means the evaluations must be unsigned, and the method requires at least 3 DEMs for the statistical significance to be valid. While the criteria must be unsigned, the signed parameters like the mean and median differences provide important auxiliary information.

We use ½ arc sec grids (Fig. 1), so that COPDEM and ALOS are equally affected by interpolation. We create the reference DTM and DSM where available by aggregation from high resolution source data. For ALOS and COPDEM the points in the original DEM are in their positions within the ½ sec grid, and they are surrounded by points from bilinear interpolation. This allows direct difference maps between COPDEM and ALOS, and shows the geometric pattern of the differences, without introducing variable interpolation effects between the DEMs. We consider elevation, slope, and roughness defined as the standard deviation of slope in a 5x5 window [3]. We make pixel by pixel comparisons for approximately 520,000 pixels in each DEMIX tile which covers approximately 100 km². The difference grids allow us to map the differences. We must set tolerances for what we consider significant differences before creating some grids, because the grids classify the map area into categories using the tolerances (Fig. 2).

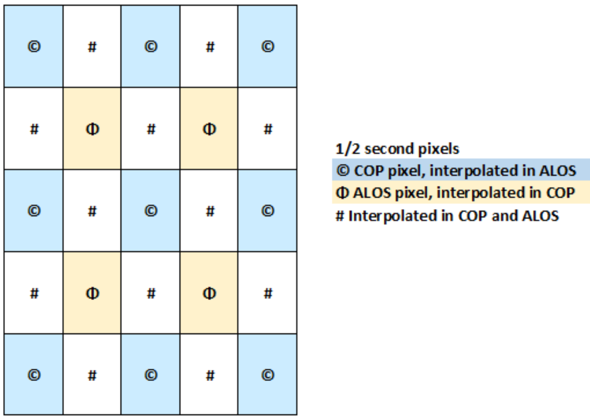

Figure 1. ½ second resampling for arc second DEMs with rectangular pixels.

We will show two representations of the results (Figures 2 and 3), and the summary statistics for 20 test areas with over 200 100 km² tiles (Figure 4 and Table 1). Figure 3 considers the pixel a tie if both COPDEM and ALOS are within the tolerance of the reference DTM; otherwise the DEM closer in absolute value to the reference DTM is the best.

III. Results

Figure 2 shows the largest differences from the reference DEM occur in steeper terrain. The computation has nine categories (each test DEM can be high, equal within tolerance, or low). The complex category lumps 6 categories.

The elevation bias in this tile is not representative of all tiles; the lack of bias for the slope and roughness are representative. The very small standard deviations are characteristic of COPDEM and FABDEM, as is the greater dispersion for ALOS, and the large dispersion for the other DEMs with a poorly defined mode.

Despite the negative overall bias for slope difference, the distribution skews toward less steep slopes. This results from

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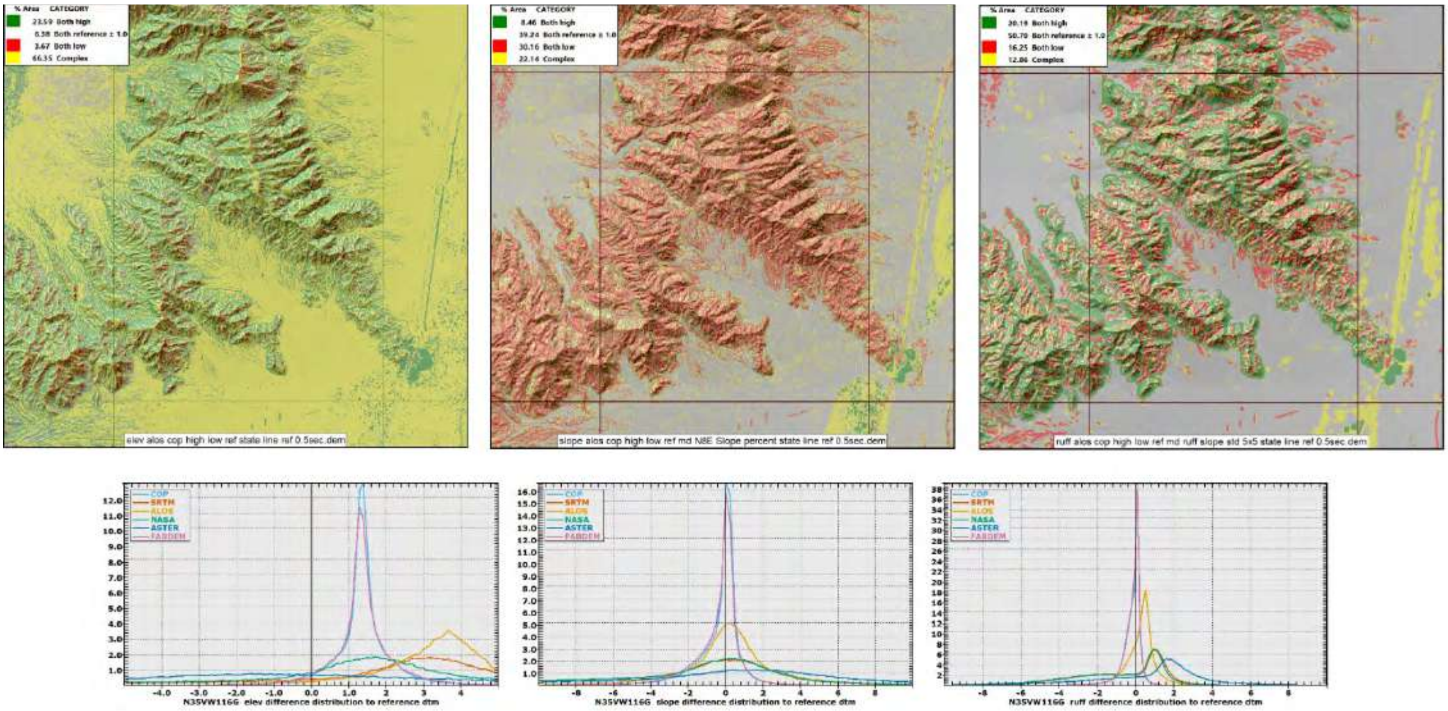

Figure 2. Comparison of COPDEM and ALOS to the reference half second DTM for DEMIX tile N35VW116G in the center of the map. Difference maps above and difference histograms below. Instate 15 on the right side of the map shows up difference appearance in the three DEMs.

comparting the ½ second reference DEM with an interpolated test DEM which has lower average slopes.

Figure 5 shows roughness differences for a tile in the Canary Islands. The volcanic cones show the effect of trying to compare a pixel-is-area DEM and a pixel-is-point. The half pixel offset means that peaks, ridge crests, and valley bottoms in ALOS and COPDEM occur at different locations, and each is "better" compared to the reference DEM about half the time and the map pattern closely mimics the topography.

IV. Discussion and Conclusions

The wine contest criteria used in by DEMIX [1] use 5 metrics for the unsigned difference distribution. For each parameter (elevation slope, roughness), the 5 metrics are highly correlated and do not provide greatly different results. The 5 metrics progressively get larger as they factor in increasingly extreme values in the tails of the distribution, but the global DEMs generally follow the same ranking. Beyond the evaluation numbers and rankings the criteria do not provide a simple, visual and intuitive way to assess the results.

Our three new criteria for elevation, slope, and roughness take the percentage of points in the DEM where each DEM is closest to the reference DEM, and ranks the DEMs. As designed these criteria have less influence from the tails of the difference distribution. With only two DEMs in our test, we can create maps showing the spatial patterns, and relate them to the characteristics of the region and see how slope, roughness, and aspect affect where ALOS and COPDEM diverge from the reference DEM.

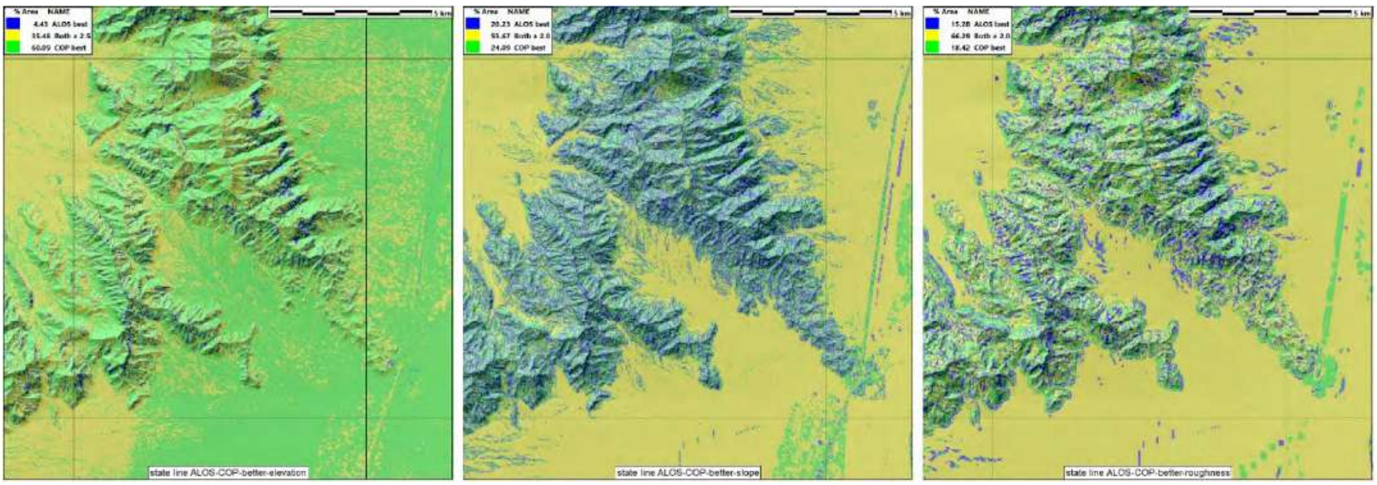

Figure 3. Comparison of COPDEM and ALOS to the reference half second DTM for DEMIX tile N35VW116G. Difference maps above and difference histograms below.

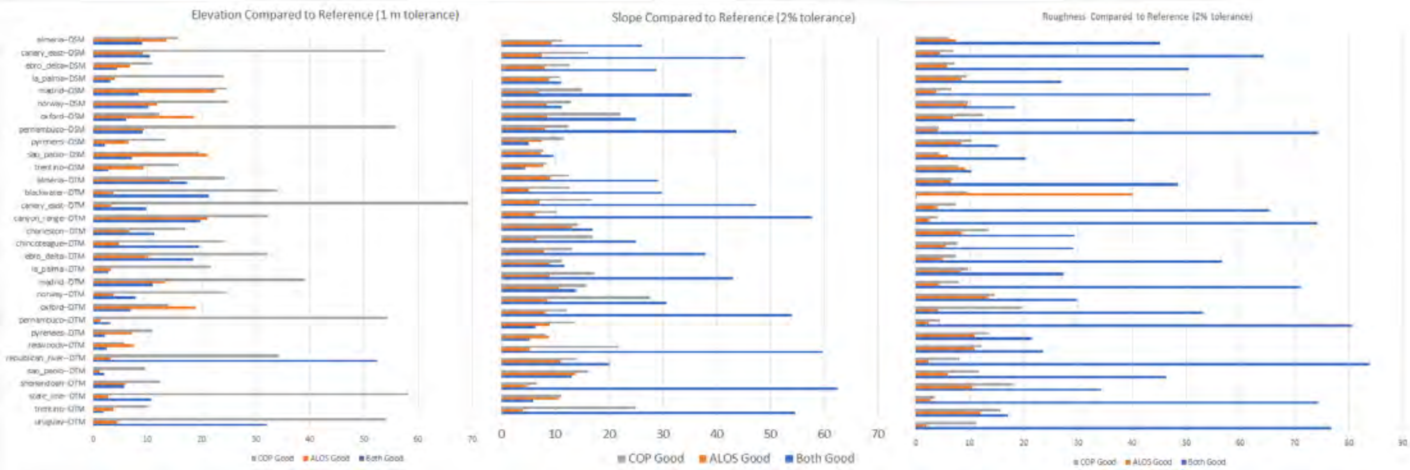

Figure 4. COPDEM and ALOS comparisons to the reference half second DTM and DSM where available for 20 test areas.

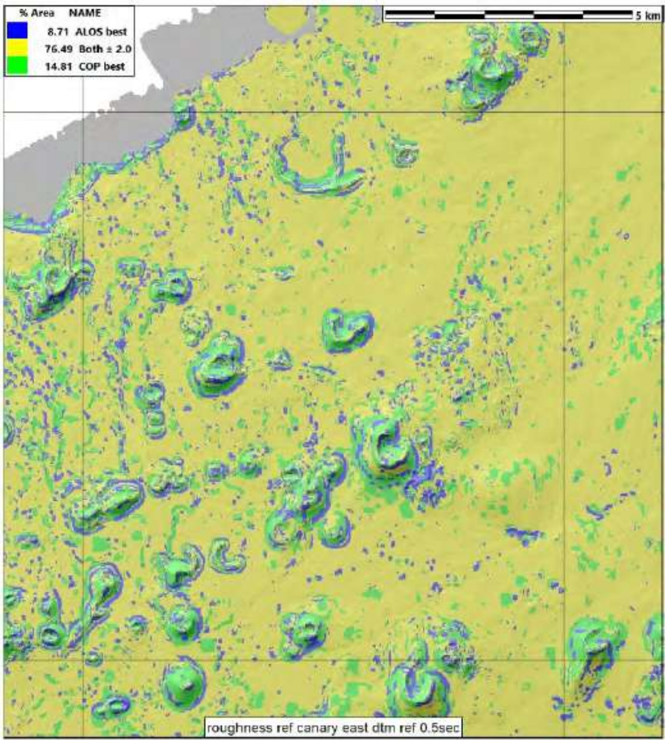

Figure 5. Roughness differences between COPDEM and ALOS from a reference DTM for DEMIX tiles N29MW014D. Supplementary figure 2 shows maps for elevation and slope, and both the DTM and DSM.

TABLE I. BEST DEM BY AREA

	DTM		DSM	
	ALOS	COPDEM	ALOS	COPDEM
Elevation	2	18	2	8
Slope	1	19	0	10
Roughness	1	19	3	7

The maps allow a subjective assessment of DEM quality that adds to the quantitative results; as one example, we have noted that ALOS frequently has small anomalies tacking the satellite's orbit path where different images where merged, something we did not observe with COPDEM.

We assume that the reference DEM is the closest to a true value of what the elevation should be for a 1 arc second pixel. Aggregating the high resolution DEM to 1 arc second necessarily loses detail, and the largest differences to the global DEMs occur in steep terrain. In these pixels there is a large variation in elevation, and picking a single value to represent the pixel presents a challenge. We must consider the possibility that the choice for the elevations in the reference DEM has much more uncertainty in steep areas than in flat areas.

These comparisons (Table I) show that COPDEM is clearly better than ALOS, but the differences are generally small. COPDEM is better in the most heavily forested areas, reinforcing the suggestion that the radar sensor has greater penetration in the canopy compared to an optical sensor as suggested in evaluating the positions of the global DEMs in lidar point clouds [7].

Using ½ grids allows direct comparison of ALOS and COPDEM, but does affect the slope differences and clearly shows the ½ pixel difference between the two DEMs.

V. ACKNOWLEDGMENTS

All work done in the open source MICRODEM [5], which has source code and a 64 bit Windows executable. Larger figures and Supplementary figures available on zenodo. We thank our collaborators on the DEMIX group for stimulating discussions.

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