ROBUST, AUTOMATED STEREOGRAMMETRY OF VENUS MAGELLAN SAR IMAGERY AND PRELIMINARY TESSERA RESULTS

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Introduction: The Magellan Radar mapping experiment included a dedicated left-side stereo imaging campaign (Cycle 3) that covered ~20% of the surface. These data were only partially processed in the mission aftermath due to computing and funding limitations, and more recent independent efforts all have limitations, either incomplete data or processing shortcomings. Our fully-automated approach differs from those other efforts due to a combination of (i) the extensive coverage made possible by full automation, (ii) the use of updated Magellan ephemeris, significantly reducing error, (iii) the use of original F-BIDR data, bypassing the F-MAP product which introduces seam errors, and (iv) the formal error calculation attached to elevation values. Taken together, these enable the most rigorous approach based on currently available data, which can be achieved within a realistic timeframe.

We report here on progress towards robust automated matching of SAR image pairs relative to our previous reports [1, 2, 3].

Automated image selection and seeding: The processing chain we have implemented, at a high level, consists of different sequential steps: 1) overlap determination, (2) reprojection, (3) initial offset determination, (4) formal offset determination, (5) stereo processing and elevation calculation, and (6) mosaicking. The processing chain steps are now integrated and fully automated, allowing multiple regions to be processed in parallel. Magellan F-BIDR "noodles" are divided by latitude into 8° blocks and an organizational file management structure was chosen so that each regional block is initially contained in its own directory. One of the biggest improvements since our last report is that that we have fully automated the initial offset estimation in step (3), which seeds the formal offset determination in step (4). The approach consists of running the matching tool first with broad parameters, and then performing a cluster analysis on the data and feeding the result into the full run of the matching software. We are currently conducting a verification of the seeding by comparing with our previous results for Xi Wang-Mu tessera that used manual determination of initial offset.

Preliminary stereo results and comparison: Tesserae consist of terrain that is rich in tectonic features of scales ranging 100 m to 100 km, and they represent good radargrammetric targets to test our matching algorithm and DEM pipeline due to their richness in features. Of specific interest to this test are small-scale "ribbon" grabens [4] because they permeate vast tracts of tesserae, their morphology relative timing may elucidate the formation history of tesserae, and ribbon topography cannot be resolved in Magellan GTDR data.

Fig. 1 shows a comparison of our stereo-derived DEM with Magellan GTDR altimetry and the stereo-derived DEM of [5] for a cross-section elevation profile of tessera folds at Xi Wang-Mu tessera inlier. These folds are on the order of 10's of kilometers across, as determined from SAR imagery, and arguments based on backscatter intensity in SAR images and long-wavelength topographic elevation [e.g., 6, 7] concluded the amplitude of these folds to be on the order of a few hundred meters to ~ 1 km in height. Our results show that fold amplitude ranges from 300 m to 1 km and proves predictions to be correct. An average ~200 m offset in elevation exists of between our results and GTDR data, and GTDR fails to capture even some of the mid-wavelength (~20 km) features. The DEM from [5] does not properly resolve all folds or their amplitudes.

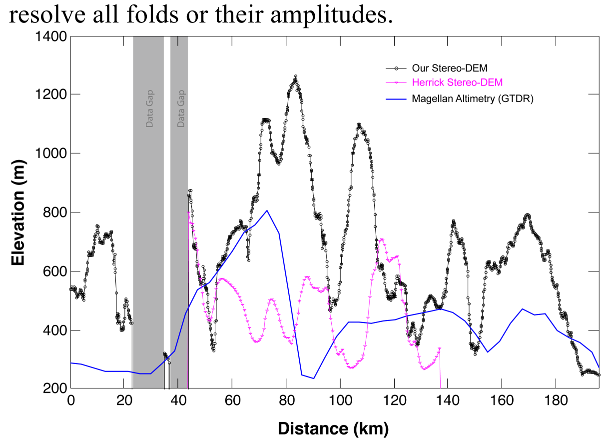

Fig. 1 – *Profiles through Xi Wang-Mu tessera inlier along fold strikes (60.5°E, 31.5°S).*

Fig. 2 shows a profile at the same location as in Fig. 1, but now across the strike of ribbon grabens. Based on the same type of backscatter, cross-cutting and fold amplitude arguments, depths of grabens have been estimated to be < 1 km, and likely less than 0.75 km [e.g., 7, 8]. We have found that our DEM resolves grabens and that, at this location, graben depths are variable and range between 50 to 300 m. The stereo-derived DEM of [5] only partly resolves some of the grabens and severely underestimate their depths.

While our measurements of width and depth validate predictions, the variability of ribbon graben depth is somewhat surprising. Consistent wavelength of grabens, on the order of a few km, had been thought to indicate a shallow depth of the brittle-to-ductile transition (BDT) at the time of graben formation [4,7,8]. This large variation in graben depth (nearly one order of magnitude) in this very compact of an area is hard to reconcile with a uniform BDT, and may call into question the formation mechanism proposed by [4,7,8]. As we expand our processing to the entirety of C3 stereo coverage, it is to be seen whether ribbon grabens are as variable in depth at other tesserae.

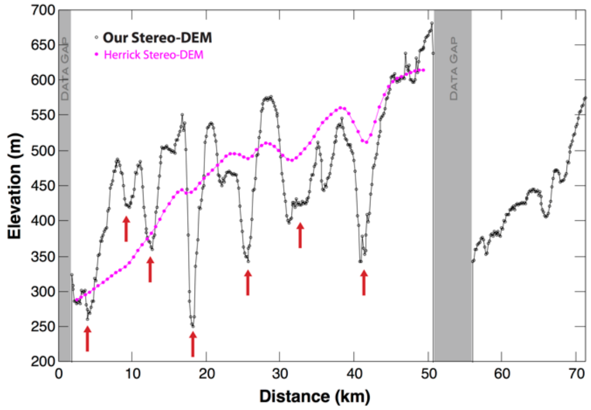

Fig. 2 – *Profiles through Xi Wang-Mu tessera inlier across graben strikes. Graben floors marked by red arrows.*

Delivery to the community: Complete automated production of C1-C3 stereo pairs is anticipated to require substantial amounts of non-stop computation, and so care is being taken to perform careful assessment and optimization before this commences. Products, including stereo match and intersection ASCII files as well as derived raster DTMs sorted by quadrangle, will be delivered to the community in PDS4 format, together with a dedicated editor/viewer which will allow manual matching and tweaking of previous stereo matches.

The Magellan Stereo Tool (Fig. 3) is a desktop stereo-viewing application that allows users to view and edit feature points generated by our matching processes. The viewer works with a variety of display hardware, from basic monitors utilizing red/blue anaglyphs to high-end stereo monitors linked with special stereo-viewing glasses. Currently, the tool supports loading a pair of image products and displaying those image pairs in adjacent or stereo panes, loading associated match-point files and displaying match-points across levels, panning and zooming, and match-point information display. We will be adding image stretch, manual adding/editing of match points, and writing out updated match point files.

References: **[1]** Mitchell K. L. et al. (2012) LPSC XLIII, #2744. **[2]** Nunes D.C. et al. (2013) AGU Fall Mtg., #P41-1961. **[3]** Hensley, S., et al. (2016), EUSAR 2016. **[4]** Hansen V.L. and Willis J.J. (1996), *Icarus 123*, 296-312. **[5]** Herrick R.R. et al. (2012), *Eos 93*, 125-126. **[6]** Gilmore M.S. et al. (1998), *JGR 103*, 16813-16840. **[7]** Ghent R. and Hansen V. (1999), *Icarus 139*, 116-136. **[8]** Hansen V.L. and Willis J.J. (1998), *Icarus 132*, 321-343.

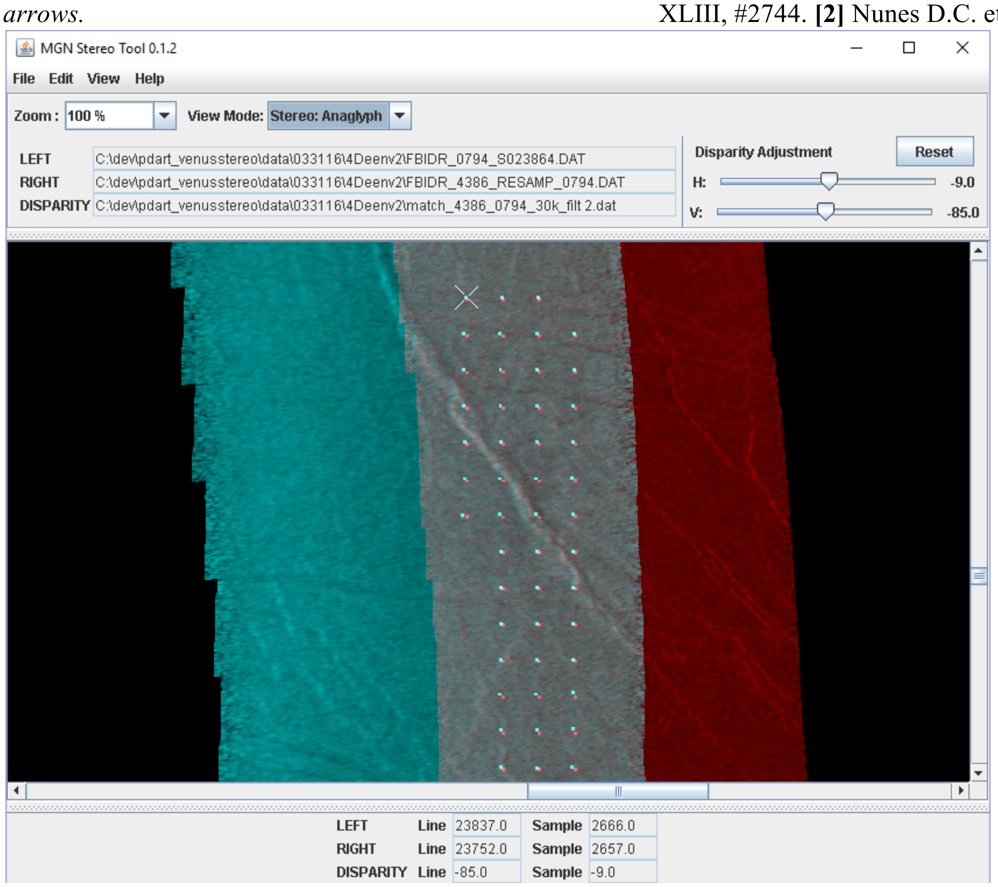

Fig. 3 – *Screen-shot view of the current version of the Magellan Stereo Tool, showing Cycle 1 (left, red) and Cycle 3 (right, blue), as well as match points with offsets.*