AUTOMATED STEREOGRAMMETRY OF VENUS.

K. L. Mitchell[1], S. Hensley[1], D. C. Nunes[1], S. J. Shaffer[1], R. Deen[1] and A. Ansar[1], [1]Jet Propulsion Laboratory, Mail Stop 183-601, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, United States, Karl.L.Mitchell@jpl.nasa.gov.

Introduction: Only a small fraction of potential Magellan stereo coverage has been exploited to date. The dedicated stereo campaign (C1-C3) covers <20% of the surface (Fig. 1), but is only partially processed due to computing and funding limitations in the mission aftermath. Opposite-look C1-C2 stereo, which has the capability to increase coverage to ~50% of the surface, has barely been explored due to on-going technical difficulties in matching opposite-look radar.

Since the 1990s, computing power has improved massively and machine vision techniques have been refined. In the light of these advancements, and improvements to our understanding of the Venus Magellan ephemerides, we are automating F-BIDR stereo processing to obtain the most precise and extensive terrain database possible, including formal uncertainty calculation, offering better than order-of-magnitude improvement in horizontal resolution over altimetry at comparable vertical precisions. This will permit accurate measurements of absolute height and comparative studies across different geological provinces.

Stereo matching: Our preliminary results, using the *ampcor* stereo matcher [1], show great promise. Using a fully automated hierarchical approach, we were able to produce compelling results down to 8×8/~600 m sampling (Fig. 2), comparable with previous semi-automatic and manual results [e.g. 2]. Some blunders and holes are present, largely due to a lack of tuning the algorithm, but on-going refinements to the matcher are in development, including mapping of similarity patches to non-square targets, allowing sub-pixel accuracy and improving quality where slopes are variable.

Additional strategies are being investigated for more challenging C1L-C2R data, as this will increase coverage substantially and, in theory, permit greater vertical precisions. The *Optimal Gradient* method [3] will be used to refine the *ampcor* processing chain, removing directionality from the data. Another approach is the *Mutual Information* matcher [4], which has demonstrated success matching very different datasets with moderate match density. Preliminary results suggest that these techniques have different strengths, and are capable of producing a good match density in many areas. Efforts are on-going to validate them and, if successful, they have the potential to massively improve geographic coverage in our efforts.

Geometric processing: An iterative calculation incorporating the least-square methods allows the best solution from all information, after [1]. We calculate the Range and Doppler covariance from updated spacecraft ephemerides [5], and correct for refractive distortions due to Venus' thick atmosphere using Snell's Law. The approach reduces radial error to <90 m, along- and across-track error to 200 m and 50 m respectively, facilitating order-of-magnitude improvements in absolute precision.

The formal estimate of height measurement error, based on both updated ephemerides and calculation of covariance [6], is an improvement over previous studies which incorporated only one of these or neither. Re-derivation of F-BIDRs is un-necessary, as our method [1] takes into account differences between the old and new ephemerides to reconstruct the height information.

Applications: These new data lend themselves to a variety of studies. They are not only directly useful, but also provide a base-DEM from which to refine and measure further using manual methods, which utilize an open-source viewer/editor [7] that works with a variety of display hardware, from regular monitors (side-by-side or analglyph) to specialist stereo systems. We currently focus on: (1) tesserae studies, obtaining the best estimate of deformation in order to better understand their evolution, and (2) lava-flow measurements, obtaining DTMs using opposite-look techniques in order to improve vertical resolution to 10s of metres, sufficient for rheological studies that will help to distinguish between different eruptive chemistries.

Deliverables: DTM precisions as fine as ~600 m horizontal and ~100 m vertical are achievable over much of C1L-C3L stereo coverage, at pixel-scale sampling. C1L-C2R may improve vertical precision, but is a major technical challenge due to illumination of different features under opposite viewing. Terrain models will be released in the form of raw match data, including geographic position, provided with the open-source viewer. Hence, the user will be able to measure features directly, generate image-referenced on-the-fly DTMs, refined manually if required.

References: [1] Hensley, S., Shaffer, S., 1994. *Geosci. Remote Sens. Symp. 3*, pp. 1470-1472. [2] Howington-Kraus, E., *et al.*, 2006. In: *Euro. Planet. Sci. Conf.*, Berlin, Germany, p. 490. [3] Paillou, P., Gelautz, M., 1999. *IEEE Trans. Geosci. Remote Sens. 37(4)*, 2099-2107. [4] Ansar, A., Matthies, L., 2009. *IEEE/RSJ Conf. on Intelligent Robots and Systems*, St. Louis, 3349-3354. [5] Rappaport, N. J., *et al.*, 1999. *Icarus 139*, 19-31. [6] Hensley, S., 2009. *Proc. Radarcon 2009*, Pasadena CA. [7] Pariser, O., Deen, R. G.,

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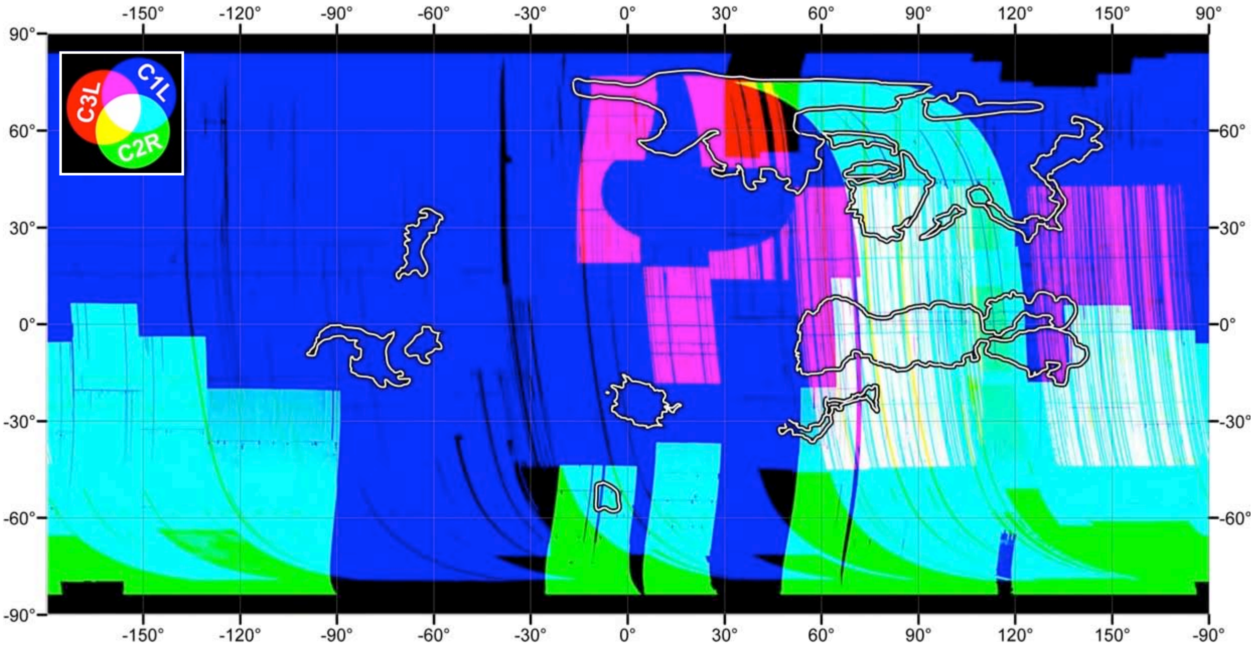

Figure 1: Map denotes the SAR coverage of the three Magellan mapping cycles (C1L: left-look Cycle 1; C2R: right-look Cycle 2; C3L: left-look Cycle 3). RGB colors are added to show multiple cycle coverage. Outlines correspond to all tessera plateaus and some of the major tessera inliers.

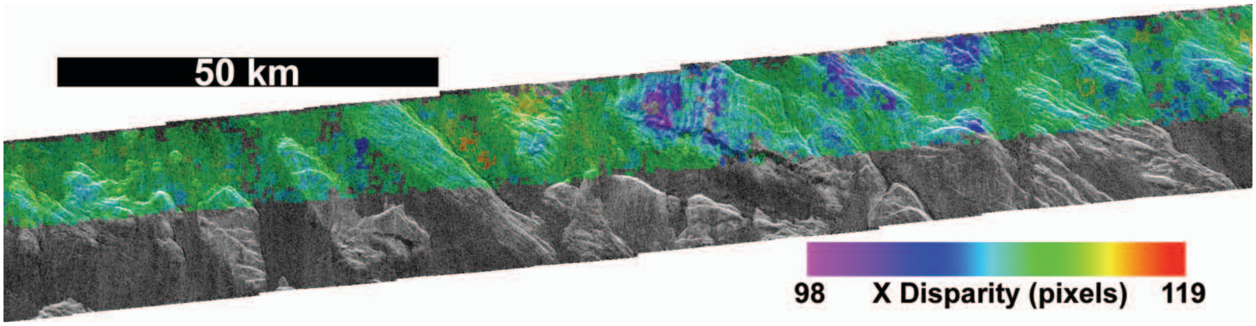

Figure 2: Tessera terrain in F-BIDR 0849 at 75 m resolution, with a disparity map (generally indicative of vertical relief) showing ampcor matching results with F-BIDR 4436 overlain in pseudocolor. The matches are achieved at an 8x8 grid spacing using 8x8 patches, representing a surface resolution of 600 m. Vertical resolution is variable, and <<300 m.