3-D MOONS: THE VOYAGER STEREO ATLAS OF THE OUTER SOLAR SYSTEM; P. Schenk, Lunar and Planetary Institute, Houston, TX; J. M. Moore, NASA Ames, Moffett Field, CA

Comprehension and analysis of geologic features on any planet is enhanced manyfold by a clear perception between albedo and topography. On many of the icy satellites significant albedo contrasts due to mixtures of dark rocky and bright icy materials can be associated with topographic features. Subtle topographic features can be masked by albedo variation and under high solar illumination albedo and topography can be difficult to separate. To this end we are compiling an atlas of stereo image pairs of the outer solar system based on Voyager imaging for the investigation of various geologic problems and for general use.

For the icy satellites, general perceptions of topography are usually gleaned from shape-from-shading information in the images processed by the human brain (i.e., visual inspection). With few exceptions, actual topography has been measured on a spot-by-spot basis using shadow heights or photoclinometry [1-3], or along limb profiles (where geographic context may be unavailable) [4]. Shadow heights are limited to regions within ~10° of the terminator and images with resolutions better than ~ 1 km/pixel. Photoclinometric scans can be used more widely but are subject to a variety of errors, primarily uncertain assumptions of uniform scene albedo or poorly understood photometry. Stereoscopic analysis, where available, has the potential for greatly expanding topographic perception.

Stereo imaging of selected icy satellites has already been used on occasion to some advantage. Examples include Miranda, Ariel [5, 6], Triton [7] and even Europa [8]. Quality stereo coverage exists for portions of eight icy satellites, including Miranda, Ganymede, Iapetus, Dione, and others, as well as Io. Up to 30% of the surface areas of some of these bodies can be viewed stereoscopically. Limited coverage may exist for at least six other icy satellites and perhaps several of the irregular satellites. The satellites with the best stereo coverage and resolution are Rhea, Miranda, Ariel, and Io; all satellites with especially prominent topography.

Format and Problems

No one map projection is ideal for stereo images that cover large fractions of curved surfaces. Stereo pairs are being constructed of images reprojected to a common orthographic map projection in order to minimize aspect-ratio distortion. For primary targets, such as Miranda, global-scale scenes covering nearly an entire hemisphere, as well as smaller-scale scenes providing optimum viewing of selected targets, have been constructed. Other map projections are being evaluated. Selected stereo pairs of varying targets, viewing geometries and resolutions will be on display via LPI's Tektronix stereo monitor for viewing and evaluation.

The Voyager mission plan did not specifically include targeted stereo coverage. As a result, the quality of stereo coverage is uneven. As viewing geometry changed, resulting in stereo capabilities, imaging resolution often changed significantly, as did local sun angle. These effects varied with encounter geometry and satellite characteristics, primarily orbital period. (In contrast, lighting geometry did not change at all between the two Mercury Mariner 10 encounters,

eliminating this problem.) Also, changes in phase angle often resulted in changes in overall brightness of the scene, necessitating cosmetic corrections to produce similar brightness levels in both pair elements. This was achieved using a 301x301 pixel high-pass filter. Inherent topographic relief also affects stereo discriminability. On Callisto and Ganymede, for example, relief rarely exceeds 1.5 km [2]. Therefore, wider stereo divergence was required for relief to be detectable than on satellites such as Miranda were relief sometimes exceeded 5 km [4]. As a result of these factors, selection criteria for most stereo pairs included a minimum 15° angular convergence, and a maximum factor of 2 difference in the resolution between images.

Stereo Height Determination

Methodology to determine local height variations is similar to that employed for terrestrial air photos. Because the scale of satellite topography is significantly less than the flyby distances for Voyager (factoring in angular separation), the formal errors associated with height determinations can be greater than 50%, and in many cases renders the resulting values meaningless. Prominent exceptions include Miranda, Ariel, Rhea, etc., where formal errors (depending on scene location) can be as low as a few percent.

Work in progress

Craters: Many satellites are heavily cratered. Preliminary analysis of stereo pairs has already confirmed earlier measurements of crater depths and peak heights on Rhea, as well as general conclusions that extensive terracing is absent on most of these satellites [1]. Stereoscopic study also confirms the existence of prominently raised rims on icy satellites, which was difficult to demonstrate using photoclinometry [2]. Stereo is also being employed to map the structure detail of large impact features on Ganymede, including several penepalimpsests (e.g., Nidaba), and the multi-ring structures Gilgamesh and Valhalla and the W. Equatorial Basin. Using the extensive stereo coverage of Rhea, we are also mapping the putative multi-ring structures reported on that satellite [9].

Tectonics and volcanism: On many of the satellites, volcanism and tectonism has deformed the surface. Stereo is being used to map and investigate the topography of graben and other geologic structures. It has already been useful in mapping Miranda's coronae [6]. Stereo is also being used to investigate the geology and structure of volcanic vents on Io, both active (circa 1979) and inactive. Because of complex albedo patterns, stereo is the only means of mapping local topographic relationships on Io (although coverage is spotty). Haemus Mons and other prominent Ionian mountains are also stereo candidates. Stereo mapping of the outer solar system will open new avenues of investigation and enhance our understanding of geologic processes in these diverse, complex bodies.

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