TOPOGRAPHIC MAPPING OF ICY SATELLITES: NEW METHODS AND NEW MAPS. P.M. Schenk, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (schenk@lpi.usra.edu).

Introduction

Topographic mapping of icy satellites is a critical tool for evaluation of geologic problems ranging from the origin of ionian mountains to the thickness of floating ice shells [1,2]. With the lack of on-board altimeters, the primary tools available for areal mapping of icy satellites are stereo image mapping and shape-from-shading (photoclinometry), to produce digital elevation models (DEMs). This report is motivated by several new developments, the most important of which are significant upgrades to our stereo topographic mapping capabilities and the successful application of 2-dimensional photoclinometry techniques to these icy surfaces.

Mapping Innovations – Stereo

The digital stereo mapping technique used here is described in detail elsewhere [3], but in brief is based on scene recognition software. Stereo-based maps are limited by the size of the image patch mapped (typically 5x5 pixels but 3x3 pixel resolution can be achieved in many areas) and by the resolution of the lowest-resolution image in the stereo sequence. Stereo mapping is complicated by several variable factors, principally radiation noise damage, compression artifacts, and variable photometric properties with phase angle. Other difficulties include the blandness of some terrains. The icy satellites tend to be rich in textural detail (except at low resolution), however, and spurious elevation data are thankfully uncommon. To reduce spurious data and fill in gaps where scene recognition failed, I use a Stacked Progressive Cube method of DEM analysis. Briefly this method involves mapping topography at progressively increasing spatial resolutions. The algorithm selects the statistically best DEM elevation value with the best possible resolution for each pixel location. Finally, an anomaly in the original ISIS code that degraded the horizontal resolution of the output DEM has been corrected, thus increasing the spatial resolution of our DEMs.

Mapping Innovations - Photoclinometry

Photoclinometry (PC) potentially allows the rapid mapping of topography over large areas with a single images *at pixel scales* but has not been widely available for planetary use. I have developed a 2-dimensional PC mapping technique that differs from earlier efforts [4] in two major aspects. The first involves the approach to 2-D PC mapping. Here we allow each parallel profile line to integrate free of the influence of its neighbors, adjusting the lines after integration to produce a DEM. Secondly we use low-phase-angle images to model local albedo in our map regions.

Despite these new techniques, PC cannot be considered reliable over distances of hundreds of pixels and we must rely on stereo for regional scale mapping. In some areas, stereo and PC coverage overlap and there I use stereo DEMs to control the long-wavelength aspects of the higher resolution PC DEM.

Finally, the accuracy of topographic mapping tools is dependent on the precision to which we know the location of each image on the surface. It was necessary therefore to update the pointing on all resolved images of the icy satellites from Voyager to Galileo. For the large Galilean satellites, I have updated camera pointing vectors based on over 1000 control points per satellite. Vertical precision of stereo DEMs depends on stereo geometry and is highly variable from site to site. The vertical precision of PC DEMs depends on mean slope and horizontal resolution, which is also hgihly variable. These software are now available for use at LPI. The actual data will be released to the community pending calibration and verification.

Mapping of the Galilean Satellites

Inclusion of PC mapping results and a thorough search of the database for unplanned Galileo and Voyager-Galileo stereo opportunities extends topographic coverage to >25% for the icy Galilean satellites and to >70% for Io. The powerful combination of PC and stereo mapping is best achieved on Europa. Examples include Conamara Chaos and dissected terrain observations, where effective resolutions of 50 m are achieved. . Mapping of Io has been fraught with difficulties due to the complex surface and unusual image properties but these have been largely overcome through the techniques described here. These results are discussed in a companion presentation [5,6]. Most stereo coverage on these satellites is limited to postage stamps <100 km across.

Topographic coverage of Europa has provided a number of unexpected surprises. The limited stereo coverage reveals that there is a total topographic range of 2 km on Europa, much greater than otherwise suggested. Local relief can be up to 1 km along steep scarps or in broad irregular depressions. The Galileo REGMAP observations provide large contiguous topographic coverage of Europa up to ±60° latitude at two longitudes using PC. Topographic provinces of distinctly different character are clearly delineated, despite the limited longitudinal coverage. The only large area on Europa mapped using stereo consisted of overlap between the E1 and E14 Europa global observations. Despite evidence elsewhere for topographiclally distinct provinces, this DEM shows that there are not large scale topographic heterogeneities such as continents in the absolute topography of Europa.

Mapping of Other Icy Satellites

Areal coverage of stereo DEMs is limited by the rapid nature of the *Voyager* flybys and rapid revolution rates of the inner satellites. Rhea (Fig. 1) and Dione have the best stereo coverage, with ~25% of the surface mappable at better than 500 m vertical resolution and better than 5 km horizontal resolution on both. Some stereo coverage was obtained for Tethys, Enceladus, and Mimas, but these satellites all revolve more rapidly than Rhea and Dione and changes in solar illumination during the imaging sequence restrict useful stereo coverage. PC mapping coverage is limited by resolution and by the need for low sun illumination. Most of the areas so covered coincide with stereo coverage, thus effectively increasing the spatial resolution of the stereo DEMs.

The mot obvious features observed on these satellites is impact craters. The largest craters on these satellites all appear to have been relaxed to some degree. Tectonics features dominate on the Uranian satellites Titania, Ariel and Miranda. Topographic mapping of the Saturnian satellites is expected to be complete by summer 2003 and together with updated control networks are available for Cassini planning.

References

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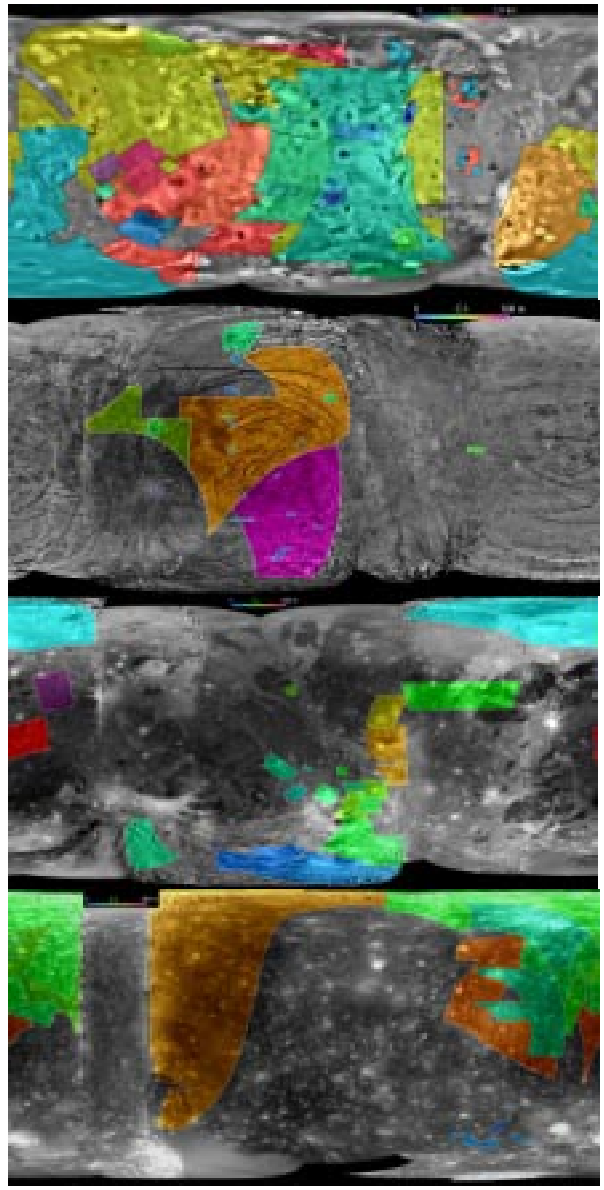

Figure 1. Areal coverage maps for stereo topographic mapping on the Galilean satellites. From top to bottom, the maps show Io, Europa, Ganymede and Callisto. Vertical precision ranges from high (blue) to low (red).