MAPPING THE TOPOGRAPHY OF MARS

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ABSTRACT

Data from the Mariner and Viking missions of the seventies have been re-analyzed to derive a new model for the fundamental shape of the planet Mars in preparation for the arrival of several spacecraft and landers over the next several years. This model is believed to be a significant improvement at the longer wavelengths over earlier models and is being used to gain new insight into large scale processes in the planets history. Later this year, the US will send the Mars Global Surveyor mission to Mars followed by the Mars Pathfinder lander, that will arrive in the late summer of 1997. The MGS will carry a laser altimeter as part of its complement of instruments which will map the entire planet on horizontal scales of a kilometer and provide a new framework for future high resolution mapping of the planet.

1 INTRODUCTION

The fundamental shape of the planet Mars upon which all maps of the planet have been referenced is based on the analysis of radio occultation measurements of the Mariner 9 and Viking 1 and 2 spacecraft of the nineteen seventies. These observations are a record of the times when the radio signal from the spacecraft was either lost behind the planet or emerged from behind the planet and when the ray path was tangential to the surface on the limb (Kliore et al, 1973; Lindall et al, 1979). The location of the planet and spacecraft at the time of the occultation provide a measure of the radius of the planet at the occultation point. Nearly 400 of these measurements were acquired from these missions and subsequently used to construct a model for the long wavelength shape of Mars (Smith and Zuber, 1966).

Earth-based radar observations have also played a major role in our understanding of the shape of Mars but to a large extent were not included in the early analyses that defined the shape of the planet. The radar data (Downs et al, 1982), along with photographic images (Wu, 1989, 1991), have been the basis of the high resolution models of Mars topography, which were superimposed upon the shape defined largely by occultations. Thus, for many years the size of Mars was in error by several kilometers although relative locations were better known. Atmospheric instrumentation has also been used to infer shape and topography of Mars but these measurements were based on assumptions about the location and shape of the 6.1 mbar surface which was derived from an early low degree model for the gravity field of Mars (Lorel et al, 1973) that we now know to be in error and could not, because of its limitation in resolution, represent even some of the largest geological features of Mars.

2 RESULTS

Recently, these observations have been re-analyzed employing improved ephemerides of the spacecraft and planet and a new model of the long wavelength shape of Mars has been developed. A covariance analysis suggests that the new model has an rms error of $\sim$ 500 meters with a range of 300 meters to 1.2 km. The largest sources of error are the orbital errors of the three spacecraft. The topography is defined as the difference between the shape of the planet and an equipotential surface. Using the most recent models for the gravity field of Mars (Smith et al, 1993; Konopliv et al 1995), which have geoid errors of the order of 100 meters at long wavelengths, a comparison with the DTM suggests errors in the latter of 1 km (rms), with some locations at the 3 km level. A similar comparison with the Consortium topography model indicates errors of many kilometers and a systematic error from the south pole to north pole of about 5 km.

We find no discrete topographic offset between the shapes of the northern and southern hemispheres although prominent impact basins, such as Hellas and Isidis, are clearly seen. On the other hand, the geopotential topography, which corresponds to the planetary radius minus the radius of the Martian geoid or gravitational equipotential, shows the topography has an offset in elevation between the northern and southern hemispheres. A histogram of the geopotential topography exhibits a bimodal distribution of elevations that corresponds to systematic elevation differences between the northern and southern hemispheres.

This re-analysis of the topography has led to a re-examining of the hypotheses for the existence and formation of the hemispheric dichotomy of Mars with the recognition that the topographic low associated with the northern hemisphere is a result of the center of mass/center of figure offset for the planet and not necessarily an impact (s). We also note that the topographic difference between the high southern hemisphere and low northern hemisphere does not generally correspond to the mapped geologic boundary, and it is not as sharp. It appears as a gradual change in elevation consistent with a center of figure displaced from the center of mass along the rotation axis.

3 ALTIMETRY ON MARS GLOBAL SURVEYOR

Early in 1998 the Mars Global Surveyor mission will begin the mapping of Mars. The instrumentation on the spacecraft includes a laser altimeter (Zuber et al, 1992) that will be able to measure the topography of Mars with a vertical resolution of about a meter and horizontal spacing of about 300 meters along track. The resolution across track is determined by the orbit spacing and would be approximately 1 km at the equator at the end of the 1 Mars year of mapping. Allowing for orbital errors it is anticipated that the radial accuracy of the topography will be approximately 10 meters. The altimeter will operate at 10 Hz continuously and will illuminate an area on the surface of the planet approximately 150 meters in diameter. At the end of the 1 Mars year mission it should be possible to develop a topographic map based on a 0.5 degree grid.

The design of the laser and receiver will permit laser returns to be received from the steep slopped (45 degrees) sides of canyon walls and crater rims, over ice, and during both day and night. It is anticipated that the laser will operate continuously for 2 years and successfully measure the distance of the spacecraft from the surface of the planet under most conditions except during dust storm periods. Altimeter returns are also expected from some thick dense fogs or clouds and will provide one of the first measures of the altitudes of these phenomena above the surface.

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