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GEOPHYSICAL INTERPRETATION OF VENUS GRAVITY DATA

Grant NAGW-409

Semiannual Status Report No. 4 and 5

For the period 1 July 1984 to 30 June 1985

Principal Investigator

Robert D. Reasenberg

July 1985

Prepared for
National Aeronautics and Space Administration
Washington, DC 20546

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory
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Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Dr. Joseph M. Boyce, Code EL-4, Solar System Exploration Division, NASA Headquarters, Washington, DC 20546

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I. SUMMARY OF RESULTS

Our principal scientific objective remains the investigation of the subsurface mass distribution of Venus through the analysis of the data from Pioneer Venus Orbiter (PVO). In particular, we use the Doppler tracking data to map the gravitational potential, which we compare to the topographic data from the PVO radar (ORAD). In order to obtain an unbiased comparison, we filter the topography obtained from the PVO-ORAD to introduce distortions which are the same as those of our gravity models. During the reporting period, we made use of the last major software package that was required in order to determine the spectral admittance $Z(\lambda)$. This package solves the "forward problem": given the topography and its density, and assuming no compensation, find the resulting spacecraft acceleration along a given nominal trajectory. The filtered topography is obtained by processing these accelerations in the same way (i.e., with the same "geophysical inverter") as the Doppler-rate data that we use to estimate the gravity maps. A more thorough discussion of our analysis technique is given in Goldberg and Reasenberg [1985].

The work performed with NASA funding during the reporting period yielded the following scientific results:

- The extension of the mapped portion of the Venus gravity field from 6 to 8 "inversion regions" with 1 more remaining to complete the planet.
- The re-mapping of one region using an entirely new set with Doppler data.
- The development of software and procedures for producing color contour maps of gravity and filtered topography.
- The discovery of a relationship between the size of topographic features on Venus and their effective depth of compensation.

- The identification of a relatively small region of the planet which is thus far unique in its consistency with a simple (Airy) model of compensation.

These, along with related work, formed the basis for the two papers listed in Section V. The above topics are discussed in more detail in the next three sections of this report.

II. EXTENSION OF MAPPED AREA

Prior to the beginning of the reporting period, we had completed the mapping of six "inversion regions" in two separate spans: one includes the eastern third of Aphrodite Terra (130°E) and extends through Beta Regio to the eastern edge of Guinevere Planitia (≈350°E); the other, just west of Aphrodite Terra, contains the eastern portion of Eisila Regio. These together cover 270 degrees in longitude and are based on Kalman filter residuals taken from 184 spacecraft orbits.

Since then, we have completed the mapping of two additional regions, which has brought the total extent of our coverage to 335 degrees in longitude, now in a single unbroken span from the eastern two-thirds of Aphrodite Terra through Eisila Regio. This new coverage made use of residuals from 55 newly processed orbits, along with 19 previously used orbits. It was necessary to postpone the processing of the 16 orbits required for the one remaining inversion when we discovered that our data set was incomplete. While waiting for the additional data to arrive from JPL, we completed the orbit determination for yet another new set of data, so that we might perform an independent inversion for a previously-mapped region to test the consistency of our results. These 42 orbits, together with 11 as yet unused orbits, brings to 287 the number of orbits for which Kalman filter residuals had been obtained by the end of the reporting period.

In order to create combined maps that were based on a uniform process, it was also necessary to remap one of the original regions using the most recent refinements in our inversion technique.

III. DEVELOPMENT OF COLOR GRAPHICS CAPABILITY

With the increase over the past year in the extent of the mapped region of Venus, we found a need to produce maps that contain more information than can be displayed with our customary black-and-white contour maps. The CfA image processing system, which we used to produce color contour maps, and which is used principally to display and manipulate astronomical photographs and CCD images, required some effort on our part before it was suited to the Venus data. The resulting color images make it much easier to discern patterns, such as the similarities and differences between gravity and topography, that may be relevant to geophysical interpretation.

We prepared a composite color figure (containing gravity and topography maps) for a paper to be submitted soon to PEPI. In order to make our results available to those working on closely related studies, Z.M. Goldberg recently distributed a descriptive "Dear Colleague letter" and a slide of the figure. Copies of the memorandum and the figure comprise section VI.

IV. GEOPHYSICAL IMPLICATIONS

The first region of Venus analyzed with our current technique -- a 4000 km square region west of Beta Regio -- turned out, rather fortuitously, to exhibit a spectral admittance consistent with the Airy model of isostatic compensation (with a depth of compensation of about 50 km). When we extended our analysis to the remainder of the currently mapped portion of the planet, however, we could find no other region that even came close to fitting such a straightforward model.

Instead, we found that if we calculated the depth of compensation separately for each wavelength (i.e., lateral topographic extent) in a given region, to a surprising degree of accuracy the results obeyed a simple power law of the form $d=k\cdot\lambda^{a}$, where d is the depth of compensation and λ is the wavelength. Moreover, although the power-law parameters changed from one region to another, they all tended to pivot around a point (in the d-λ plane) corresponding to a depth of $\approx$70 km and a wavelength of $\approx$1100 km. While we have yet to understand the geophysical significance of the power law, it appears that we have identified an important measure of the near-surface structure of Venus. These results were presented at DPS Meeting #16 and are being prepared for submission to PEPI (see below).

V. PUBLICATIONS

R. D. Reasenberg and Z. M. Goldberg, "Spectral Admittance of Venus," BAAS, 16, 693, 1984. Presented at the AAS/DPS Meeting #16, Kona, Hawaii, 8-12 October 1984.

Z. M. Goldberg and R. D. Reasenberg, "Venus Gravity West of Beta Regio," Icarus, 62, 129-142, 1985.

An additional paper is in preparation for Physics of Earth and Planetary Interiors. This paper will be submitted in response to an invitation that was extended by the editor, Prof. S. K. Runcorn, after he heard the paper at the DPS Meeting in Kona.

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18 July 1985

Dear Colleague:

Enclosed is a slide showing color maps of the gravity and topography of a portion of Venus, produced by means of techniques that Bob Reasenberg and I have developed over the past few years. Also enclosed, for your convenience, is a preprint (of Goldberg and Reasenberg, Icarus 62, 129, 1985) in which we describe these techniques in some detail.

Since the slide lacks numeric (or other) labels, some explanation is required. The two color-scale bars should appear above their respective maps, with the purple squares to the left, and the white to the right. Then, the gravity map is seen correctly at the top, and the topography at the bottom. The maps are rectangular projections, with grids marking intervals of 15°, from 120°E (at the left) to 360°E, and from 30°S (at the bottom) to 60°N. (A slight distortion of ostensibly straight lines can be seen, which is due to the curvature of the CRT monitor from which the slide was taken.)

The (anomalous) external gravitational potential is displayed as the equivalent height of matter one-half the mean density of Venus. For the gravity, each color marks an interval of 0.15 km, with the deepest purple representing -1.20 to -1.05 km, and the white +1.80 to +1.95 km. For the topography, each color marks an interval of 0.30 km, with the deepest purple representing -1.2 to -0.9 km, and the white +4.8 to +5.1 km, with respect to the nominal radius of 6051.2 km.

Because of the latitude-dependent resolution of the gravity data, along with other considerations, it is difficult to quantify the errors of our results in any straightforward way. However, for at least one indication of accuracy, we call your attention to a comparison of figures 2 and 3 in the preprint. (Captions are on page 30, related discussion on page 19.)

We would be grateful for any comments you might care to make, concerning either the production or the interpretation of these maps, and will be more than happy to try to answer your questions or to supply any other information that might make the maps more useful to you.

Thank you for your interest.

Sincerely,

Zachary M. Goldberg

Zachary M. Goldberg
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Encls.

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ZMG:nm