VENUS GRAVITY FIELD MODELING FROM MAGELLAN AND VENUS EXPRESS TRACKING DATA.

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Introduction: The gravitational field of a planet depends on its internal density distribution, and in combination with topography it can provide a powerful method to probe the interior structure of a planet [1]. Models of planetary gravity fields are determined from satellite tracking data. For Venus, data from the Pioneer Venus Orbiter (1978-1980) and Magellan (1990-1994) spacecraft have been used, and the most recent gravity field model is an expansion in spherical harmonics of degree and order 180, called MGNP180U [2]. Due to computational constraints, the potential coefficients of this model were estimated in successive batches, resulting in artificial discontinuities in the solutions and their error estimates (see also Fig. 1). This hampers the application in geophysical analysis of the models over their whole range, but especially at higher resolutions.

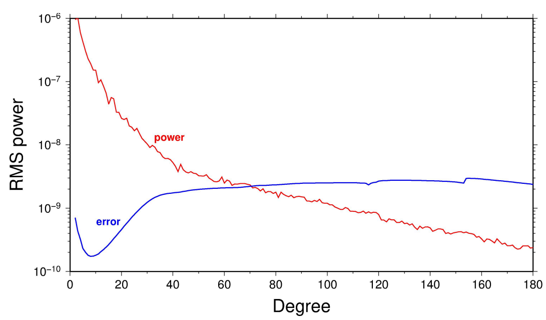

Figure 1 RMS power spectrum of the current Venus model MGNP180U [2], showing clearly the breaks in the error spectrum due to the estimation of the coefficients in batches.

We present results of a reanalysis of the Magellan tracking data. We augment this data set with tracking data from the European Space Agency's Venus Express mission (VEX) [3].

Methods: We use our NASA Goddard Space Flight Center (GSFC) GEODYN II Orbit Determination and Geodetic Parameter Estimation package [4] to process the Venus tracking data. This software package has been used extensively for planetary gravity field determination, using tracking data collected at the Moon [5], Mars [6], and Mercury [7], among others. For our Venus data analysis, we use tracking data from cycles 4, 5 and 6 from Magellan since those were dedicated to radio tracking for the gravity experiment [2]. We also add VEX data.

We process the tracking data in spans of continuous time called arcs. Typically, we divide the tracking data into spans that cover the occurrence of angular momentum desaturation (AMD) events, which are applied regularly to maintain attitude control of the spacecraft. Although generally neutral, these events can impart spurious residual accelerations on the spacecraft, which can be mapped into the gravity field solutions if they are not properly accounted for. We found that especially for Magellan, there are many events not covered by tracking data. We therefore limit our arc lengths to include only AMD events with tracking data coverage, because without data coverage their imparted accelerations cannot be estimated with confidence [8]. We account for the imparted accelerations by estimating a constant acceleration in three directions (in the radial, along, and cross-track component) during the AMD event.

The dense atmosphere of Venus affects the gravity recovery in several ways: through drag acting on the satellite [9], and through (time-varying) atmospheric effects on the gravity field itself. We use a model for the density of Venus' atmosphere [10] in our orbit determination software, and estimate scale factors for the force exerted on the spacecraft by atmospheric drag. In addition we model the atmospheric gravity variations by converting pressure fields derived from Venus General Circulation Models (GCM) into a time series of gravity coefficients expressed in spherical harmonics [11].

Results: Preliminary efforts have focused on the processing of the Magellan data. We use data with a 2 second count interval with the goal to extract high-resolution information from the data. Our efforts will focus on the determination of a gravity model of degree and order 220 at maximum. Despite indications that the remaining dependence of data noise on altitude is related to ionospheric influences rather than unmodeled gravity [2], we aim for a larger expansion because of our use of 2 s data.

We will also leverage the computational tools that we developed for the analysis of the GRAIL gravity data [*e.g.,*5]. In particular, we will focus on calibrating our solutions using variance component estimation

(VCE) [12]. We will divide the data into different sets (the separate cycles for Magellan, and VEX), and determine their relative weight factors with the goal of calibrating the solution by equilibrating the observed weighted residual sum of squares [5].

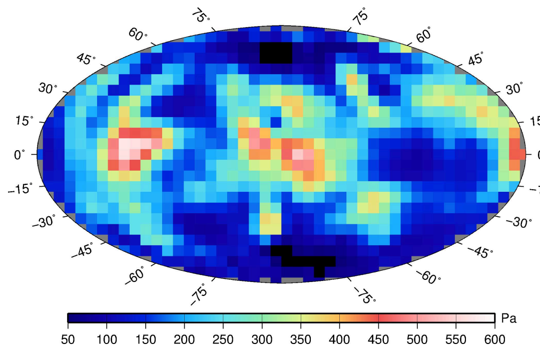

Figure 2 RMS of pressure variations around the mean over two Venusian days. These pressure fields will be converted into gravitational spherical harmonics [10] to account for atmospheric effects on gravity.

Data from VEX will mostly be used to increase resolution in certain areas where VEX collected gravity passes [3], and to extend our temporal baseline for the estimation of time-varying gravity effects such as those described by potential degree 2 Love numbers and the spin-rate secular variations. We use pressure fields from a GCM to model the atmospheric effects. For example, starting from a zonal wind profile close to observations of superrotation [*e.g.,* 13], pressure variations are found to have a distinct east-west pattern, influencing sectorial gravity harmonics. Moreover, similar analysis for Mars [6] has shown that by using the atmospheric effects on gravity, one can decouple the solid tides from atmospheric tides, and directly estimate the solid tidal Love number, which will better constrain models of the interior structure. In addition, we plan to cross-validate our gravity solutions with a different orbitography software, Géodésie par Intégration Numérique Simultanée (GINS), which has been succesfully used for VEX data [9].

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