REGIONAL RESOLUTION ANALYSES OF MEGELLAN GRAVITY DATA

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Summary

Many geophysical investigations of Venus are concerned with establishing the mechanism(s) by which topography is supported. Distinguishing between local, flexural, or dynamic compensation requires gravity observations over a wide range of wavelengths. Table 1 demonstrates that identifying support of topography by static flexure of a strong lithosphere ideally uses gravity observations down to wavelengths as short as 300 – 800 km, for elastic thicknesses of 20 – 70 km respectively (the range currently estimated for Venus, [1,2,3,4,5,6,7]). The spatial resolution of the Magellan gravity data depends primarily on the spacecraft altitude. Table 2 shows spacecraft altitudes for cycles 4 – 6 of the Magellan mission, during which time gravity data was acquired. Resolution analyses of some cycle 5 data suggest a maximum resolution of about 400 – 450 km [8], equivalent to approximately 2 – 2.5 times the spacecraft altitude. Thus, using a combination of all of the available data, we might expect minimum resolvable wavelengths of less than 400 km in a few regions, given a good signal-to-noise ratio. These predictions are consistent with the power spectra of spherical harmonic models for the Venus gravity field. At present, spherical harmonic models are available to degree and order 75, corresponding to a wavelength of 500 km. The power spectrum for model MGN75ISAAP, shows anomalously high power at degrees 74 and 75 [9], indicative of shorter wavelength signal in the gravity field, which is unresolved in current spherical harmonic models. In this study, resolution analyses of cycles 4 – 6 gravity data over several regions of geophysical interest are presented. Both single-taper and multi-taper spectral coherence methods are applied to the line-of-site (LOS) doppler velocity residuals at each region studied. The effects of spacecraft altitude, viewing geometry and noise due to solar effects are examined. The inference of elastic lithospheric thickness from the gravity data (on a regional basis) is discussed in the light of the resolution analysis results.

Method

Initial analyses have been performed using LOS doppler velocity residuals within a 25° latitude band of periapsis. This allows arcs of data to be analyzed, over which the spacecraft altitude is almost constant. The doppler residuals are relative to a degree and order 40 spherical harmonic model (MGN40E). Since the LOS accelerations are a linear function of the LOS velocity residuals, computing the spatial resolution of the velocity residuals is equivalent to computing the resolution of the accelerations. Two approaches are used to calculate the minimum resolvable wavelength in the data.

A conventional single-taper spectral coherence approach requires several (at least 6) sequential orbit tracks over a given study area, to obtain statistically significant results. The sampling interval for cycles 5 and 6 LOS data is typically 2 seconds. Gaps in several (N) adjacent profiles are filled by linear interpolation, and the profiles padded or truncated to the same length. The resulting profiles are stacked end-to-end to produce two time series: the first contains profiles 1 to N-1, the second contains profiles 2 to N. A joint spectral analysis of these extended series provides an estimate of the power spectra, coherence and phase. Resolvable wavelengths are defined as those for which the coherence is greater than 0.5 and the phase is close to zero, or smoothly varying from zero. Examination of the power spectra confirms that in most cases the resolvable signal contains substantially more power than the ambient noise level.

An alternative approach is a multi-taper spectral analysis. Joint spectral analysis can be performed between single pairs of orbits, allowing the resolution of the gravity data to be established in regions where only a few tracks are available. The maximum along-track resolution can also be investigated as a function of cross-track distance. Two orbits across a given region are taken, and the gaps again filled by linear interpolation. Each time series is then multiplied by a series of orthogonal tapers and the discrete fourier transform calculated for each tapered series, providing several spectral estimates for each orbit. These estimates are combined to produce a single smooth spectra for each orbit and the coherence and phase computed.

Regional Analyses and Implications for Elastic Plate Models

To date, our resolution analyses have primarily used near-periapsis cycle 5 data. The completion of the processing and verification of cycle 6 LOS data allows this study to be extended, to include these new data, the remaining cycle 5 data and the small percentage of near-periapsis cycle 4 data with reasonable viewing geometry.

Near-periapsis cycle 5 data from the Beta-Atla-Themis region indicates a minimum resolvable wavelength of about 400 km. So far we have examined only data from the very eastern edge of Atla, and from W. Beta and N. Themis. A more detailed study of Beta Regio is possible; unfortunately the same is not true of Atla and Themis Regiones, as no cycle 5 and 6 data are available for these areas. Minimum estimates of elastic lithospheric thickness from altimetry data over the rift zones at Beta Regio are in the range 20 – 40 km [7]. Hence the gravity data over this region is of sufficient resolution to investigate flexural compensation of topography.

LOS data from cycles 4, 5 and 6 are available for Eistla Regio, and for cycles 5 and 6 the viewing geometry is also good. However, the near-periapsis cycle 5 data is extremely noisy, as a result of solar conjunction which ocurred just prior to the collection of data over Eistla. A detailed resolution analysis in this region is worthwhile, as estimates of elastic thickness beneath Sif and Gula Mons are in the range 30 – 70 km. A recent study using regional inversions of the LOS data suggests that the minimum resolvable wavelength in this area may be as low as 220 km [10].

Cycles 5 and 6 LOS data are also available over Ishtar Terra and Alpha Regio. Establishing the resolution of the gravity data over Ishtar Terra is more challenging due to variations in spacecraft altitude.

Finally, results from the resolution analyses presented here can be used to design filters in the frequency domain to calculate LOS accelerations from the LOS velocity residuals. This provides an improvement over the current LOS accelerations which are derived from spline fits to the velocity residuals, resulting in a loss of resolution in the data [8]. Forward modeling of the LOS accelarations at spacecraft altitudes is then an alternative method for investigating the validity of elastic plate models.

References: [1] D. T. Sandwell & G. Schubert, *JGR, 97*, 16069, 1992; [2] C. L. Johnson & D. T. Sandwell, *GJI, 119*, 627, 1994; [3] W. Moore et al., in *Inter. Colloq. on Venus*, p. 789, LPI, 72, 1992; [4] S. A. Evans et al., in *Inter. Colloq. on Venus*, p. 30, LPI, 1992; [5] S. C. Solomon et al., *LPSC XXV*, 1317, 1994; [6] S. E. Smrekar, *in press, Icarus*, 1994; [7] D. A. Senske, *submitted, JGR*, 1994; [8] C. L. Johnson, *PhD. Thesis*, 1994; [9] A. S. Konopliv & W. L. Sjogren, *in press, Icarus*, 1994; [10] W. M. Kaula, *1994 Fall Meeting Program, AGU*, p. 265, 1994

Table 1

Elastic Thickness (km)	*Flexural Wavelength (km)*
10	192
20	322
30	437
40	542
50	641
60	734
70	824
80	912

Table 2

Cycle	*Periapsis Altitude (km)*	*Apoapsis Altitude (km)*
4	165 – 185	8458 – 8503
5	154 – 220	384 – 591
6	165 – 207	361 – 431