INFLUENCE OF EXTERNAL LOADS ON INTERPRETATIONS OF LITHOSPHERIC FLEXURE AND TECTONICS AT ISIDIS PLANITIA, MARS.

J. Andreas Ritzer and Steven A. Hauck, II, Case Western Reserve University, Department of Geological Sciences, Cleveland, OH 44106-7216 USA (andreas.ritzer@case.edu)

Introduction: Isidis Planitia is a relatively unique impact basin on Mars as it has a clear, large gravity anomaly, reminiscent of lunar mascons, and circumferential tectonic features consistent with lithospheric flexure [e.g., 1, 2]. Curiously, the tectonic signature is limited to a portion of the basin's periphery at Nili and Amenthus Fossae, zones of circumferential extensional faulting, to the NW and SE, respectively, of Isidis. Moreover, the basin is bounded to the west by the Syrtis Major volcanic province and to the E-NE by Utopia Planitia, each capable of imposing their influence on the deformation and state of stress in the lithosphere in the vicinity of the basin. Previously, we have estimated lithospheric flexure and stresses in the vicinity of the impact basin using a global dataset that implicitly includes the impact of loads external to the basin [3]. However, a more common practice in the study of flexure in the vicinity of mascon basins, including Isidis, utilizes axisymmetric or localized approaches that instead yield predictions of faulting over the entire circumference of the basin's periphery [e.g., 1, 2, 4] rather than in concentrated zones as observed.

Here we seek to address the importance of external loads on lithospheric flexure in the vicinity of the Isidis impact structure and on inferences of lithospheric structure made using the location(s) of faulting as constraints on models of such flexure. Our basic approach to this problem is to compare the flexural response of the lithosphere in the vicinity of Isidis using an inverse thin shell deformation model constrained by global gravity and topography [e.g., 3, 5, 6] against an equivalent forward solution that models the response only due to loads within the impact basin.

The inverse model uses a global data set of topography and gravity obtained by the Mars Global Surveyor [7, 8]. These data are represented in spherical harmonics up to degree and order 90, but are truncated at degree 75, due to limits on the accuracy of the gravity data at shorter wavelengths [8]. The forward model uses a localized set of loads focused within the impact basin. The comparison of these two models allows us to investigate the effects of exterior loads.

Flexural Models: Two approaches to modeling lithospheric flexure are employed to understand the effects of external loads on tectonic features related to Isidis. The first model, (hereafter, the "inverse" or "global" model) calculates an estimate of the density structure and deformation of the lithosphere using the present topography and geoid heights as constraints [3, 5, 6]. The second model, (hereafter, the "forward" or "local") model, uses a reasonable representation of the loading structure on a spherical surface to calculate the deformation pattern and estimates of topographic and geoid relief that can be compared with observations.

Both models use a modified version of the thin elastic shell flexural model of [5] with re-derived loading equations that include an additional density interface to account for the differences between crustal and basin fill densities. The loading equations in both models are identical and include the effects of bending and membrane stresses, horizontal loads, multiple density interfaces and the vertical variation in gravity between them [3].

Localization Approach: The importance of loads external to the basin is investigated by isolating estimates of the lithospheric loads within Isidis from a global loading model in spherical harmonics using an appropriate localization window. The localization approach used in this study was developed by [9] and was selected for its optimally concentrated data tapers.

The band-limited and space-concentrated tapers used here minimize the spectral leakage commonly associated with windows represented in spherical harmonics. Each of these tapers concentrates the power of the data inside the window to reduce signal loss. An even energy density distribution throughout our circular data tapers was achieved with a weighted multi-taper averaging technique [9]. A weighted average between four different tapers was taken with weights calculated to minimize the variance between the power of the global data and the expectation of the power of the localized model [9].

The ideal window configuration is a perfect spherical cap which has a value of one within the radius of the cap, and zero outside of this radius. Although this ideal window is technically unfeasible, the multi-taper window method of [9] is an optimal spectral representation of the ideal window.

Method: In order to minimize the effects of comparing models with differing load shapes and magnitudes between the global and local models we extract the inferred loads from the global, inverse models and apply them to the local, forward models. First, for a given lithospheric thickness, crustal thickness and density, and density of the basin filling material we use the inverse model to determine a set of loading conditions, which are constrained to the observed geoid and topography of Mars. Next, we extract the loads on the lithosphere at Isidis by localizing the results for the size and shape of the basin, its fill material, and compensating relief along the crust-mantle interface from the global, inverse model using the optimally concentrated multi-tapers. Finally, we use the local, forward model, with identical loading and flexure equations, to determine the amount of deformation and lithospheric stress within and peripheral to the load that result from the mascon loading, and compare to the results of the global model.

Preliminary Results: In order to generate the best possible comparison between the global and local loading models it is necessary that the loading conditions be as similar as possible. The optimally concentrated multi-tapers used here result in localized loads with a maximum difference of less than 10% with the global models. Indeed, at the center of the window (i.e. basin), where the load magnitudes are the greatest and will generate the most deformation, the localized loads are identical to loads from the global model. The forward models based on these localized loads generally produce comparable topographic relief and deflections with the global model, providing some confidence in our approach.

The most readily apparent differences between the models are the azimuthal variations of the stresses. The global model predicts circumferential extensional stresses concentrated near the locations of graben observed on the surface, Nili and Amenthus Fossae. The localized model, however, does not produce any azimuthal variations. Therefore, variations in loading internal to the basin do not contribute to the azimuthal variations seen in the global model nor observed tectonics. The variations of stresses radially from the center of the load are used to compare our models to observed conditions on the surface. The style of faulting predicted by our models is quantified by the use of Simpson's shape parameter [10], a continuous, robust extension of Anderson's faulting criteria. The average radius from the center of Isidis to the inner bound of Nili Fossae is ~620 km [2]. We use the shape parameter at that distance along a NW profile (Fig. 1) to estimates bounds on the thickness of the elastic lithosphere by using the observed style of faulting as a constraint on allowable models. Both the local and global models employ the same crustal thickness (60 km), Young's Modulus (1.25e11 Pa), crustal density (2900 kg/m^3), fill density (3100 kg/m^3), and Poisson's ratio (0.25); lithospheric thickness was varied over a range of 60-220 km. Assuming that the original basin was fully compensated before loading, the lower bound on the lithospheric thickness inferred from our model is 88 km thick in the local model, while the global model predicts 75 km. The upper bound on lithsopheric thickness is the same value for both models at 126 km (Fig. 1). The variation due to localization of the model is quite small, far less than the difference between the upper and lower bounds themselves.

Discussion: The difference between the results of the localized and global models presented here is small. This may be due to the large magnitude of the load in Isidis, which may overwhelm most external signatures. Our preliminary results suggest that the greatest difference between the two models is in the azimuthal structure of the stresses. This result suggests that the concentrations of stresses which produced Nili and Amenthus Fossae were due to external effects rather than internal loading variations, though differences in the inferred lithospheric structure were limited. An axisymmetric or localized model may effectively simulate the load of Isidis Planitia, but analysis can only be carried out near the load and in the radial sense. Smaller mascons or other types of loads might be more significantly affected by exterior loads and the discrepancy increases with distance from the load.

References: [1] Comer R. P. and Solomon S. C. (1979) *LPS X*, 2441. [2] Comer R. P. et al. (1985) *Rev. of Geophys.*, 23, *No. 1*, 61. [3] Ritzer J. A. and Hauck S. A. (2005), *Eos Trans. AGU, 86(52), Fall Meet. Suppl.*, Abstract P51B0923. [4] Janes D. M. and Melosh H. J. (1990) *JGR, 95*, 21345. [5] Banerdt W. B. (1986) *JGR, 91*, 403. [6] Searls M. L. and Phillips R. J. (2006) *JGR, 111, E8*, 8005. [7] Smith et al. (1999) *Science, 284, 5419*, 1495. [8] Konopliv A. S. et al. (2006) *Icarus, 182*, 23. [9] Wieczorek M. A. and Simons F. J. (2005) *GJI., 162*, 655. [10] Simpson R. W. (1997) *JGR, 102, B8*, 17909. [11] Freed A. M. (2001) JGR, *106*, *E9*, 20603.

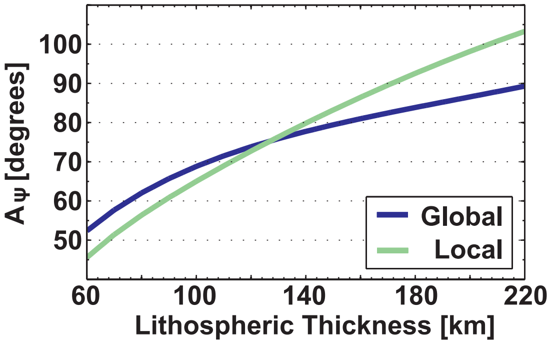

Figure 1. Simpson's shape parameter at a radius of 620 km along a NW profile centered in Isidis Planitia as a function of lithospheric thicknesses. Simpson's shape parameter quantifies the predicted style of faulting for a given stress state. $A_\Psi < 60°$ predicts extensional faulting, $75° < A_\Psi < 105°$ strike-slip, and $A_\Psi < 105°$ compressional faulting [12].