QUANTITATIVE CONSTRAINTS ON SURFACE EROSION VIA ADMITTANCE LOCALIZATION FOR ARABIA TERRA, MARS. Alexander J. Evans[1], Jeffrey C. Andrews-Hanna[2], and Maria T. Zuber[1] ([1]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139-4307, xan@mit.edu, [2]Department of Geophysics, Colorado School of Mines, Golden, CO 80401).

Introduction: Arabia Terra, with an area of ~1x10^7 km^2 [1] centered at (25E, 5N), is an anomalous region along the Martian dichotomy. Traditionally considered part of the ancient southern highlands, Arabia Terra is a transitional province between the southern highlands and northern lowlands in both topography [2] (Fig. 1) and crustal thickness [3]. While the geological processes leading to the formation of the region have not been clearly identified [2,3], Arabia Terra contains numerous morphological indicators suggestive of surface erosion, including isolated mesas interpreted as erosional inliers and partially degraded craters [1]. While surface modification has been suggested for the entirety of the highlands [4], the anomalous nature of Arabia and its geomorphology may indicate preferential modification of the region. The amount of erosion may have generated a significant volume of sediment, possibly contributing to the resurfacing of the northern lowlands.

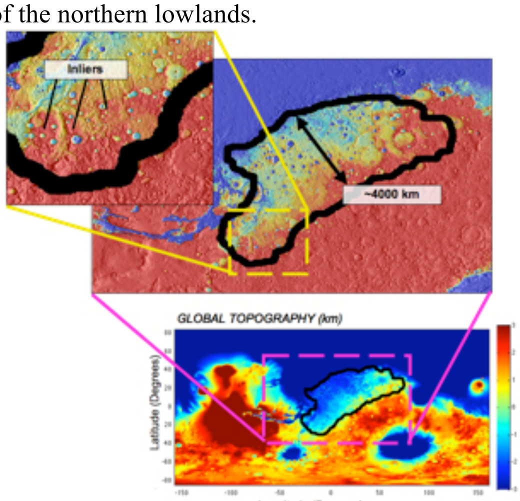

Figure 1: Outline of Arabia Terra in topography (in km). Over a 4000 km span, the elevation decreases by 5 km.

Previous workers have attempted to constrain the amount of erosion for Arabia Terra and the southern highlands, in general. Much of the analysis has been based on crater degradation with anywhere between 200 m to 2300 m of material being eroded [4]. Recent analysis of data from the Mars Exploration Rover Opportunity landing site within Arabia has suggested smaller amounts of erosion have occurred since ~3.0 Ga [5].

Unlike previous analysis, we attempt to constrain the amount of erosion by comparing the expected flexural response and gravitational signature for various erosional amounts to the observational data (Fig. 1-2). Thus, we can quantify an upper limit on the amount of material removed from within Arabia Terra. We employ a lithospheric flexure model to attain the flexural rebound and gravitational signature associated with a given erosional load. Exploiting recent advances in spherical harmonic localization techniques [6,7], we constrain the elastic lithosphere thickness, a crucial parameter in resolving the flexural response to erosion.

Localization Method: We apply the method[1] developed by [6,7] for spatio-spectral localization on a sphere, in which data is localized to the arbitrarily-shaped region of interest by applying a family of orthogonal spherical harmonic tapers.

As a result of the localization, each coefficient of the localized field, l, receives contributions from the data coefficients across the range $l-L_{win} \le l \le l+L_{win}$, where L_{win} is the bandwidth used to define the spherical harmonic representation of the region [7]. This restricts range of the localized field, such that the following inequality holds, $L_{win} \le l \le l_{max}-L_{win}$. Ultimately, we apply this localization technique to Arabia Terra with a bandwidth of 15 and use the free-air admittance relationship to constrain the effective elastic thickness for the region.

Model Admittance Comparison: The free-air admittance, as a function of spherical harmonic degree, is defined as the ratio of the cross-power spectrum of the free-air gravity anomaly and topography to the power spectrum of the topography [9]. In order to place constraints on the elastic thickness at the time Arabia Terra formed, we compute the localized admittance spectrum from the observed gravity and topography of the region, and compare it with a similarly localized admittance from the thin shell model. Subsequently, we identify the best-fit lithosphere thickness by minimizing the misfit between the modeled and observed admittance

The thin shell model is a spherical harmonic transfer function, relating a given load to a final topography and free-air gravity anomaly. Thus, neglecting finite amplitude effects, the model admittance is independent of the applied load.

Our localized admittance analysis (Fig. 3) results in a best-fit of the elastic lithosphere at 15-km Additionally, the associated coherence, the correlation

[1]MATLAB routines made available online by F. J. Simons.

between the surface topography and gravity field, for Arabia Terra is generally high, affirming the validity of the admittance fit.

Erosion Constraints: Using the thin shell model with a 15-km elastic thickness, we can constrain the amount of surface erosion by comparing the relative gravity anomaly (RGA) across the southern highlands boundary and northern lowlands boundary of Arabia Terra, respectively to the observations.

From observational data, we calculate an RGA of 6 and 20 mGal along the southern and northern borders of Arabia, respectively. The RGA for the northern boundary neglects the highly-localized anomaly immediately exterior to northern Arabia, as it could not be produced by an erosional load and may be a result of crustal flow along the dichotomy [10].

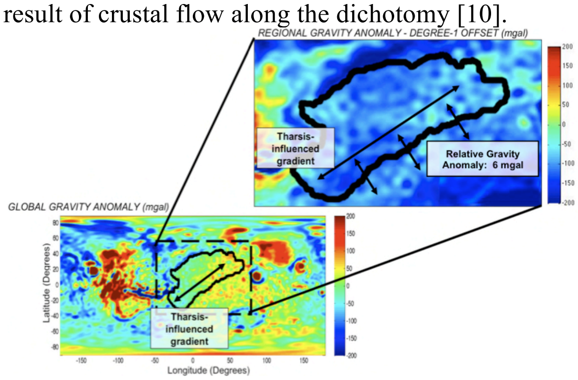

Figure 2: (A) Outline of Arabia Terra in gravity anomaly (mGal) map. (B) Local gravity anomaly (mGal) of Arabia Terra with an offset incorporated into a degree and order 1 term of the spherical harmonics to compensate for the long-wavelength deformation and center-of-mass offset induced by Tharsis.

For a uniform erosional load across Arabia Terra, the 6-mGal RGA on the southern border constrains the maximum allowable erosional load to 2300 m. However, the large RGA difference between the northern and southern boundaries indicates a gradational increase in the amount of erosion from the south to the north may be valid. Allowing for a gradational increase results in an erosional load that increases from 0 to 2600 m from southern to northern Arabia Terra. This maximum allowable erosional load is also limited by the 6-mGal RGA along the southern boundary and can only produce a 9-mGal RGA at the northern boundary. In both cases, the amount of material eroded is ~3x10^7 km^3.

Discussion: Our admittance analysis demonstrates that the present-day topography of Arabia Terra was established in the presence of a 15-km thick elastic lithosphere.

The thin shell model applied here provides constraints on the maximum volume of erosion that reproduces the RGAs comparable to or lower than observed. In addressing erosion from the vantage point of geophysics, we eliminate uncertainty in the interpretation of geological units and employ a model independent of specific fluvial or aeolian processes.

Accordingly, our results indicate no more than ~3x10^7 km^3 of material, or a uniform layer of 2300 m, could have been removed from Arabia Terra in the presence of surface erosion alone. As previous results [11] indicate, the amount of erosion required to form Arabia from the nominal highlands terrain is on the order of ~2x10^8 km^3. Given this amount significantly exceeds the maximum allowable erosional load, it is unlikely that surface erosion represents the primary explanation for the current physiographic expression of Arabia Terra.

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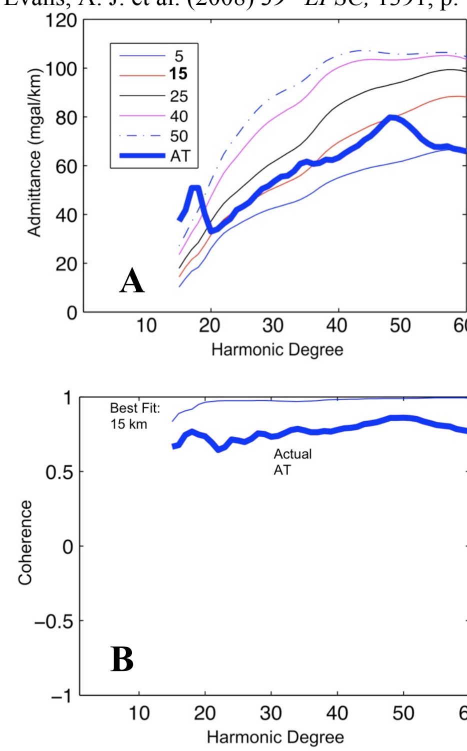

Figure 3: **(A)** Admittance fit for range of model admittances, 5-50 km, to the actual admittance (AT). The best-fit model admittance is at 15-km (B) Model and Observation Coherence. Coherence is high across Arabia Terra indicative that an admittance fit for the elastic thickness is valid.