TOWARDS IMPROVED REGIONAL AND GLOBAL GRAVITY FIELDS ON MARS BY MEANS OF LOCALIZED HARMONIC ANALYSIS S.-C. Han[1,2], E. Mazarico[1], F. G. Lemoine[1] [1]Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD; shin-chan.han@nasa.gov, [2]Goddard Earth Science and Technology Center, University of Maryland Baltimore County.

Introduction: We present the ongoing progress towards improved Mars gravity fields to understand the density structure of the Martian crust and polar layered deposits by optimally resolving the geopotential from radio tracking data. We use the lumped harmonic representation which yields regionally-concentrated orthogonal basis functions such as spherical Slepian functions [1] and spherical radial basis (or spherical wavelet) functions, instead of representing the gravity fields as non-localized spherical harmonic functions. These new representations have been successfully used for regional gravity analysis on the Earth with improved resolution and accuracy (for example, the GRACE data [2]) and also for improved regional gravity fields on the Moon from Lunar Prospector [3,4]. The Mars global gravity field will be constructed with the optimal spectral constraint by exploiting low altitude data and densely covered data over the polar region. The optimal constraint would stabilize the global solutions without affecting the peak gravity signals stemming from the Tharsis province for example.

Global gravity fields and the power law constraint: The difference between the unconstrained and constrained gravity solutions shows the effect of the power law constraint. The RMS of the radial gravity difference was computed over all longitudes at each latitude since the satellite altitude (i.e., sensitivity) varies primarily with latitude. The difference at low degrees (l, m ≤ 50) is not so pronounced (less than 1 mGal). In general, the difference gradually increases from south to north. It is mostly due to the altitude change of MRO (the gravity solutions are heavily constrained by the MRO data). The southern hemisphere is more sensitive to higher degree harmonics due to the low altitude orbit (~250 km) as shown in Figure 1(b). The rule-of-thumb sensitivity is about degree 90. The northern hemisphere is less sensitive due to higher altitude (300 – 325 km) with the rule-of-thumb sensitivity of degree 70. The power law constraint, applied to stabilize the global spherical harmonic solution to degree and order 95 with the data at variable altitudes, affects the gravity solutions to 10 mGal (RMS) for the southern hemisphere and to 100 mGal (RMS) for northern hemisphere. The gravity field over the southern hemisphere may be deteriorated by the arbitrary power law constraint, which is not required to get stable gravity solutions for the southern hemisphere (low altitude region) to degree and order 90 or so. A better way is to apply the constraint that minimally affects the gravity around the southern hemisphere and is only effective for the northern hemisphere (high altitude region).

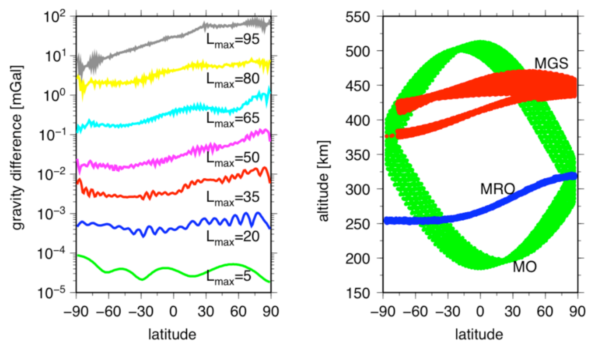

Figure 1. (a) RMS of radial gravity difference at a reference sphere (radius of 3396 km) between the constrained and unconstrained gravity models over latitude and over various truncation degrees. (b) Altitudes of the three satellite missions (MRO, MGS SPO, and ODY transition).

Tharsis province and polar cap regions: The Olympus Mons and Tharsis Montes are the largest constructional features in the solar system reaching ~30 km in height with a base several hundreds of kilometers wide, which yield ~3000 mGal in gravity anomaly. These exceptional topographic features generate the dominant gravitational signal in the Mars gravity field. The spectral constraint, which assumes a random process, tends to attenuate the peak magnitude of these distinct features. The degree RMS, cross correlation, and admittance of the localized coefficients around Tharsis and its complementary region were computed and are shown in Figures 2(a), (b), and (c), respectively. The gravity anomalies around the Tharsis province play a major role in the band of ($20 \leq l \leq 50$) yielding roughly the two third of total gravity in magnitude. Two peak degree RMS at degree 27 and 38 found in both the global power spectrum and the localized power spectrum strongly suggest that they stem from the anomalies in the Tharsis province. The correlation for the localized anomaly around Tharsis is greater than 0.9 up to degree 70. It also indicates that the exceptionally large global correlation with topography (greatest correlation observed among the terrestrial planets) is mostly due to the anomalies in the Tharsis province.

The global gravity-topography admittance of Mars approaches to a maximum of 100 – 125 mGal/km, a value larger than for other planets (for example, <100 mGal/km for the Moon; <50 mGal/km for Venus; ~60 mGal/km for the Earth). But not all the areas on Mars produce such level of admittance. As shown in Fig. 2(c), the signals solely over the Tharsis region yields exceptionally large admittance ~140 mGal/km. However, the admittance over the complementary region merely reaches ~90 mGal/km, like the Moon.

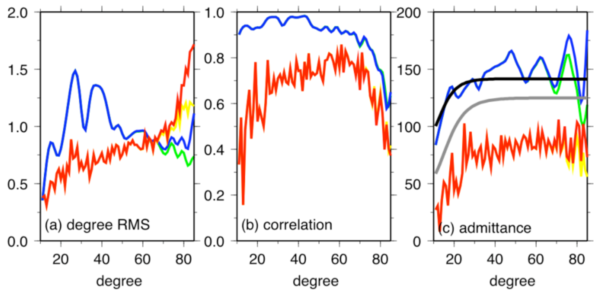

Figure 2. (a) Degree RMS of the gravity gradient signal in Eötvös (E = 10^{-9} s^{-2}) from the localized coefficients of the unconstrained solution (blue) and constrained solution (green) around the Tharsis region and from the localized coefficient of unconstrained (red) and constrained (yellow) solutions around the complementary of the Tharsis; (b) cross correlation between gravity and topography after localization around Tharsis (blue and green) and around its complementary (red and yellow); (c) gravity-topography admittance in mGal/km from the localized coefficients around Tharsis (blue and green) of the two gravity solutions and from the localized coefficients around the complementary region (red and yellow). The model admittance with the crustal density of 2960 kg/m^3 (gray) and 3350 kg/m^3 (black) are also shown.

The antithesis between gravity and topography over the polar regions [5] can be also seen when computing localized degree RMS (Figure 3). The gravity variability (blue and green) is greater than the topography-induced gravity (yellow and red for uncompensated and compensated, respectively) over the northern polar cap (Fig. 3a). The opposite occurs over the southern polar cap (Fig. 3b). Another feature of interest is the fact that the gravity in the northern polar region is of lesser quality than the one in the southern region, which is readily evident from the increased power existing in the degree RMS for the northern polar cap. The satellite tracking data from MRO (and other missions) are not uniform in the sense that (1) the average altitude and corresponding sensitivity to the gravity change and (2) the polar orbit yields higher tracking data density toward the polar regions due to orbit convergence, e.g., the polar regions are visited more frequently than any region near the equator. We will exploit the richness of the tracking data over the polar regions to estimate the regional gravity fields over the polar cap areas. We also propose to analyze MGS data particularly during the Science Phasing Orbit (SPO) period when the periapsis altitude was about 170 km near the north pole. MGS SPO data are sometimes noisier (transmitted by the low-gain antenna) but there is a potential for improved regional estimation by virtue of low altitude and dense spatial coverage around the north pole region. The improved regional solution for the north polar region is of particular interest since the presumed gravity signatures from the terrains are poorly resolved in the current Mars gravity models.

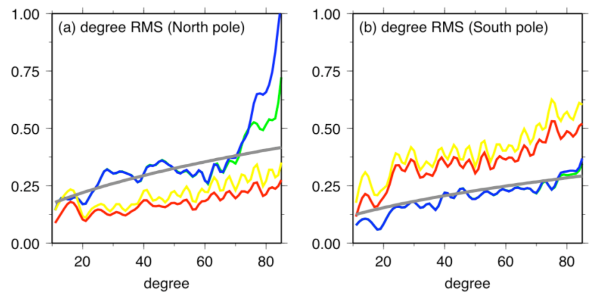

Figure 3. (a) Degree RMS of the gravity gradient signal in Eötvös (E = 10^{-9} s^{-2}) from the localized coefficients of the unconstrained solution (blue) and constrained solution (green) around North polar cap with radius of 30° and (b) around South polar cap. Degree RMS of the gravity gradient predicted from the uncompensated (yellow) and compensated (red) topography was also depicted after localizing global topography field. The Kaula power law (in gravity gradient) was depicted in gray after applying a scale factor to follow the gravity power spectrum.

Remarks: The gravity fields in several regions on Mars need to be better analyzed with a special processing method. Global harmonic solutions cannot accommodate such characteristics in a dedicated manner, whereas regional solutions are proposed to be able to articulate the intense regional signals and exploit extensive data coverage. We will present various localized constraint algorithms with the normal equations for the global geopotential coefficients accumulating MO, MGS, and MRO tracking data separately and together, for the optimally constrained global solutions. A maximum degree and order of 95 will be used for the accumulation. We will also show the on-going analysis of the LOS residual acceleration data for regional refinement of the gravity fields over Tharsis province and the polar regions.

References: [1] Simons, F. J. and F. A. Dahlen (2006) *GJI*, 166, 1039-1061. [2] Han S.-C. et al. (2008) *JGR*, 113, B11413. [3] Han S.-C. (2008) *JGR*, 113, E11012. [4] Han S.-C. et al. (2009) *GRL*, 36, L11203. [5] Smith D. E. et al. (1999) *Science*, 286, 94–97.