VENUS TOPOGRAPHY AND POTENTIAL k_2 MODELING USING PLANET-WIDE DIFFERENCED ALTIMETER MEASUREMENTS. Kun Shang[1], C.K. Shum[1], Hoksum Fok[1], Junyi Guo[1], Koji Matsumoto[2], Yuchan Yi[1]. [1]Division of Geodetic Science, School of Earth Sciences, Ohio State University, Columbus, Ohio, USA (shang.34@osu.edu), [2]National Astronomical Observatory of Japan, Mizusawa, Japan.

Introduction: The topography of a planetary body, its gravity and rotation are the fundamental quantities to provide insights into the internal structure and thermal history. Venus is the second planet from the Sun and considered to be a virtual twin to Earth in size and composition. However, Venus has a small obliquity or axial tilt of 177.3^0, with respect to its orbital plane around the Sun, thus practically has no seasons. Venus' slow rotation (in resonance with the Earth due to its tidal perturbation), its super-rotating and thick carbon/sulphur dioxide atmosphere, and its extremely high surface temperature and pressure mark its drastic difference from the Earth. The US Pioneer Venus Orbiter (PVO), the former Soviet Union Venera missions during the late 1970's and early 1980's, US's Mariner 10 with a flyby mission, and the US Magellan mission have provided significant information on the geophysical structure of Venus, including topography, gravity and magnetic fields, and the atmosphere. The Pioneer Venus Orbiter, which as launched on May 20, 1978, with an elliptical orbit (105^0 inclination) around Venus, included the Orbiter Radar Mapper (ORAD) instrument. The Magellan mission was launched in May 1989 and was in an elliptical near-polar orbit around Venus. Accurate estimate of the 2nd degree Love number (k_2) reveals internal structures of the planet including its core composition and size. The contemporary determination of the Venusian k_2 using the PVO and Megellan tracking data is reported as 0.295±0.066 [5]. Availability of radar altimetry from PVO and Magellan provides an opportunity to improve the topography modeling and potentially improve the estimates of k_2, in addition to the use of orbital tracking data.

Methodology: We used Magellan's radar altimetry (MRA) data, and Pioneer Venus Orbiter's surface radar mapper (PSRM) data, to improve Venus topography and potentially the Venusian k_2 using a technique which uses planet-wide differenced altimeter measurements [1][2], as opposed to the traditional crossover measurements [3][4]. The difficulty in the use of planetary crossovers from polar orbiters, e.g., for orbit adjustment, is due primarily to the pointing errors of the orbiters, or geo-location errors, geometry of the crossover locations with high-inclination orbiters, and to the slow rotation of the planets, making the crossover computation inaccurate and predominantly available in polar regions (e.g., for lunar or Mars altimetry) [4]. MRA or PSRM are not multi-beam lasers, therefore it is more difficult to mitigate geo-location error [4]. Here we use a new method, which emulates crossover measurements not necessarily at the crossover locations, but over gridded topography of the planets [1][2]. The crossover or planet-wide altimeter measurements, when filtered or smoothed appropriately, *potentially* reveal signals from gravity field perturbations on orbits [3], including gravity perturbations due to thermal tides due to dense atmosphere in the case of Venus and body tides related to k_2 [5], and other orbit errors and orientation (due to poorly known libration) errors.

Magellan orbit error analysis and topography modeling: Fig. 1 shows the Magellan differenced altimetry residual time series (and as functions of longitude and latitude) of the PDS Magellan radar altimetry data after removing the referenced topography model [7], using the method described above, except that no topographic gradient correction is applied, or smoothing of the altimeter measurement to be commensurate with the orbital sensitivity to gravity field perturbation [3]. Fig. 2 shows the corresponding periodigram computed from the differenced altimeter residual time series (Fig. 1, top). Long period signals at 84 and 120 days represent errors (or signals) of the Venusian resonant gravity coefficients sensitive to the differenced altimeter residuals. In addition, the once, twice, three-times, etc. per orbital revolution signals are present, largely agreeing with Kaula-type analytical predictions. This indicates that the differenced altimetry residuals, properly filtered, can be used to remove long-period orbit errors in the altimetry measurement, leading to an improved topography over the current Magellan determined topography model [7] (Fig. 3). PVO orbit can be improved using the planet-wide differenced altimeter measurements with PVO altimetry derived topography differenced with respect to the Magellan topography model to conduct an orbit and bias adjustment. This is equivalent to the use of dual-satellite crossovers, which employs the Magellan direct altimeter data to improve the PVO orbit, which in turn improves the altimeter accuracy and thus an improved topography model.

Simulation study: In order to assess the feasibility of using differenced altimetry measurements to potentially improved the estimate of k_2, we conduct a numerical simulation using the Magellan orbit (near circular orbit in 1994, orbiting Venus) to compute the altimetry residual time series, $\Delta h(t)$, assuming k_2 = 0.3 for Venus [5], while keeping the respective gravity field models fixed or with no error: Venusian gravity model values used in the study are from [6]. We then use the simulated $\Delta h(t)$, assuming the case with no data noise, to estimate k_2. Fig. 4 shows the spectra of the orbit error due to the mis-modeling include the once, twice, etc. per orbital revolution and long-period signals 120-day and 250-day periodicities, with the latter associated with the Venusian rotation rate of 247 days. k_2 is estimated using the perturbation method, and is completely recovered for the this (noise-free) case. The experiment (noise-free case) indicates the feasibility of potentially using the differenced altimeter measurements to estimate k_2. Future work includes more realistic simulations and an attempt to use the real data to conduct the study.

References: [1] Shum, C. et al. (2011) *The 5th KAGUYA (SELENE) Science Working Team Meeting*. [2] Fok, H. et al. (2011) *EPS, 63*, 15–23. [3] Shum, C. et al. (1995) *GJI, 121*, 321–336. [4] Neumann, G.A. et al. (2001) *JGR, 106(E10)*, 23753–23768. [5] Konopliv, A.S. and Yoder C.F. (1996) *GRL, 23(14)*, 1857–1860. [6] Konopliv, A.S. et al. (1999) *Icarus, 139*, 3-18. [7] Ford, P.G., and Pettengill G.H. (1992) *JGR, 97(E8)*, 13103–13114,

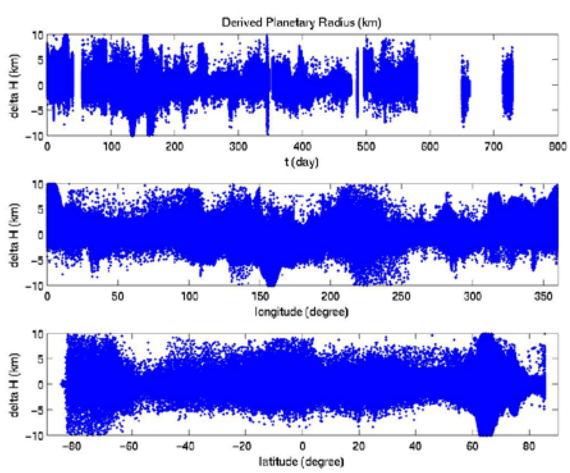

Figure 1. Magellan dervied planet-wide *differenced radar altimeter residual measurement* time series, computed using the Magellan altimetry data subtracting the Venusian topography model [7]. (Top) as a time series, (middle) as a function of longtidue, and (bottom) as a function of latitude.

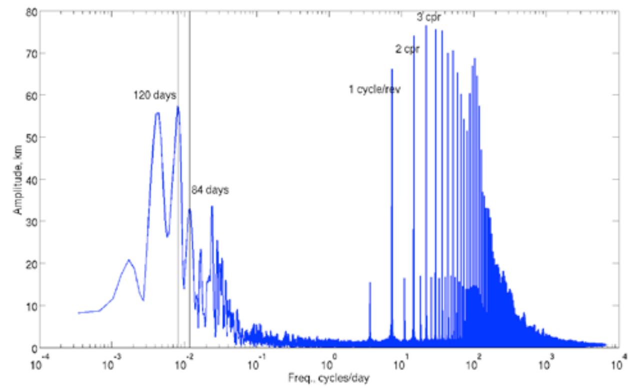

Figure 2. Periodogram computed for the *differenced radar altimeter measurement residual* time series (Fig. 4, top). 84-day, 120-day, and the once/rev, twice/rev, three times/rev, etc. signals present in the time series.

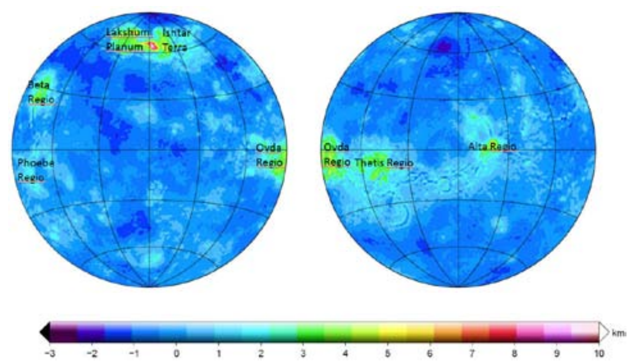

Figure 3. Venusian topography determined by Magellan altimetry [7].

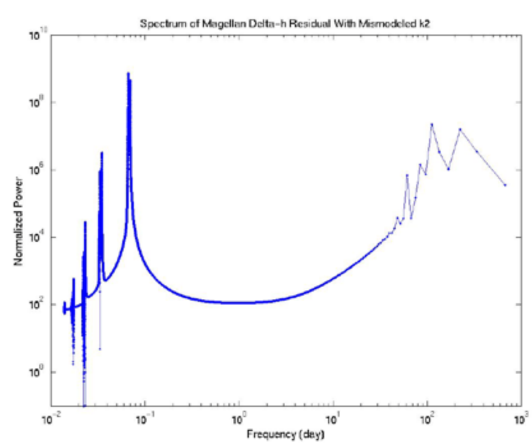

Figure 4. Spectrum of the Magellan (Venus) simulated *differenced radar altimeter measurement* residual over 700 days (600 day time series used to generate the spectrum plot) with mismodeled k_2 and noise-free case.