Venus’ Ishtar Terra: Topographic Analysis of Maxwell, Freyja, Akna and Danu Montes

Sara Rastegar: City Colleges of Chicago, Harold Washington College, 30 E. Lake Street, Chicago, IL 60601
Donna Jurdy: Dept. of Earth & Planetary Sciences, Northwestern University, 2145 Sheridan Rd, Evanston, IL 60208

Abstract

Principal component analysis offers an independent and objective mode of comparison of the venusian mountains with terrestrial counterparts with known tectonic origins. Comparison can be made with other topographic features on Venus, such as chasmata. We use topographic profiles to compare the venusian montes of Ishtar Terra using principal component analysis (PCA). Comparing the profiles may help us in understanding the processes involved in the formation of the montes.

Introduction

Western Ishtar Terra consists of a central plateau of smooth plains (Lakshmi Planum) surrounded by four mountain ranges (Akna, Freyja, Maxwell, and Danu Montes [Fig. 1]) and regions of tessera outboard of these mountains. Elevations in Lakshmi Planum range from ~2.5 to 4.0 km above mean planetary radius (6051.9 km)[1]. Critical to the understanding of the tectonic style of Venus is the origin of the major mountain ranges on western Ishtar Terra.

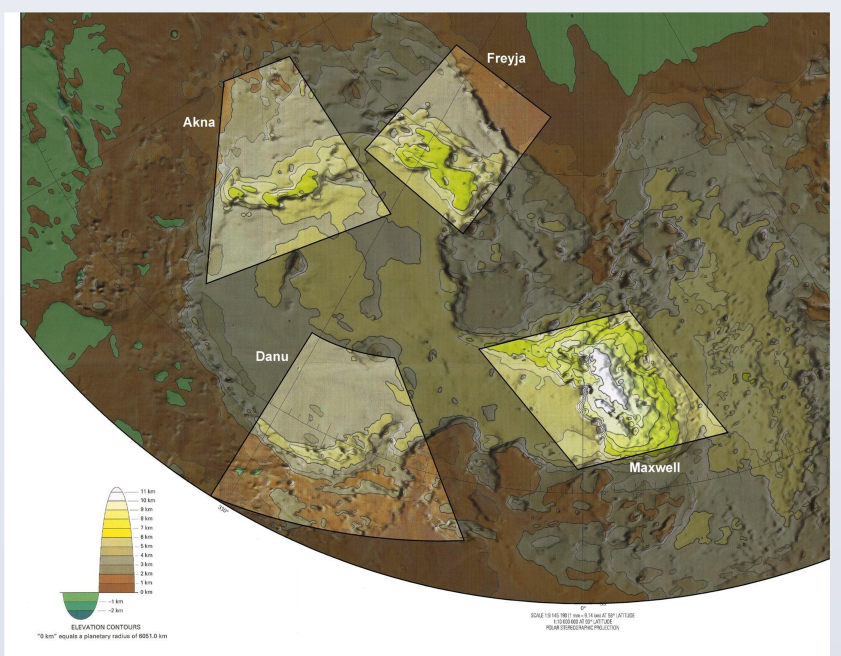


Figure 1: USGS topographic map of the western Ishtar Terra region of Venus, with highlighted study regions.

The highland regions of western Ishtar Terra surround the high plains region of Lakshmi Planum. This roughly axisymmetric configuration has been variously attributed to compression and crustal thickening [2], accompanied by a subsequent cylindrical downwelling [3,4,5] or upwelling [6,7] of the mantle [8]. In these models the montes form approximately synchronously. Other models suggest motion of discreet blocks driven by regional stresses and eventual collisions [9,10], different topographic compensations [11], distinct tectonic fabrics [12] and pulsating continents [13] as alternative scenarios for the formation. The formation of Venus’ mountain chains remains unresolved.

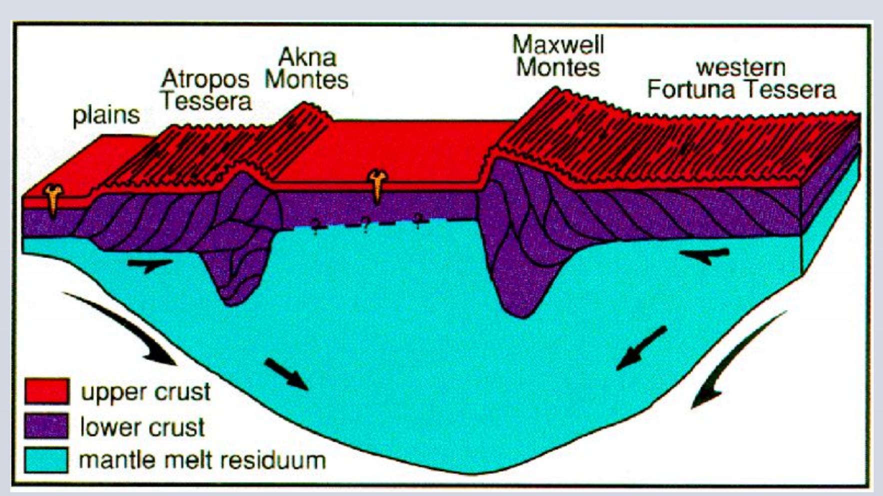


Figure 2: Cartoon of Ishtar Terra formation from surface and gravity constraints; an example of venusian orogeny models [Ref. 12].

In this study, we address this question with the analysis of Magellan topographic data for quantitative comparison of Venus' four mountain chains: Maxwell, Freyja, Akna and Danu. Patterns in topography may provide clues to the dynamics forming these Venusian orogenic belts.

Procedure

We use topographic data from the Magellan mission (1990-1994) to Venus. Using this dataset we extract profiles for the four Montes (Maxwell, Freyja, Akna and Danu) of Ishtar Terra.

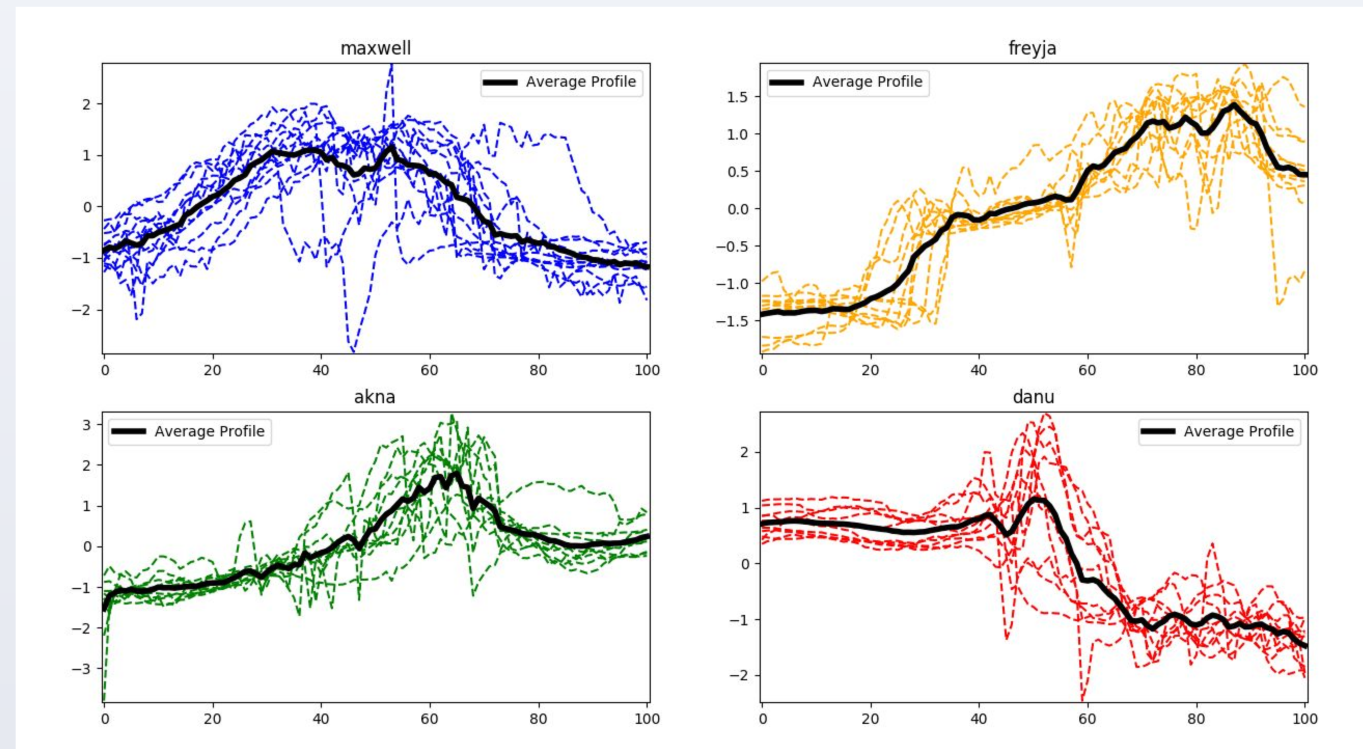


Figure 2: Topographic profiles for Venus' Ishtar Terra Montes, colored lines individual profiles with bold lines averages.

Procedure in PCA:

- Averaging all profiles for each feature
- Cross-correlating the individual profiles with the average profile.
- Shifting the individual profiles to find maximum correlation with average [Fig.2].
- Cross-correlating average profiles and computing correlation percentages [Table 1].

	Maxwell	Freyja	Akna	Danu
Maxwell	1.00	0.99	0.98	0.99
Freyja	0.99	1.00	0.98	0.99
Akna	0.98	0.98	1.00	0.99
Danu	0.99	0.99	0.99	1.00

Table 1: Correlations of average profiles.

- Constructing the covariance matrix from the correlation coefficients.
- Diagonalizing the covariance matrix to find eigenvalues (principal components) [Table 2].

Principal Component	Eigenvalues %	Maxwell	Freyja	Akna	Danu
# 1	65.7%	-0.11	0.69	-0.45	0.55
# 2	28.7%	-0.75	0.003	0.58	0.31
# 3	4%	-0.43	-0.61	-0.64	0.17

Table 2: Principal component synthesis. The first three principal components construct, greater than 98% of each average profiles.

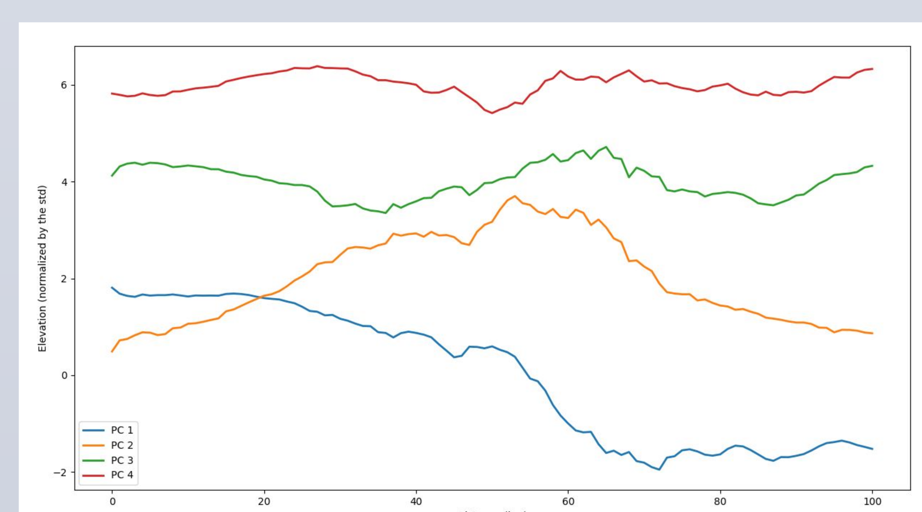


Figure 3: Projection of average profiles on PC-subspace in order of importance (eigenvalues weights decreasing upwards).

The principal components assess the degree of similarity and variability of the shapes of the average profiles [Fig. 3 & 4], offering an independent and objective mode of comparison [14,15].

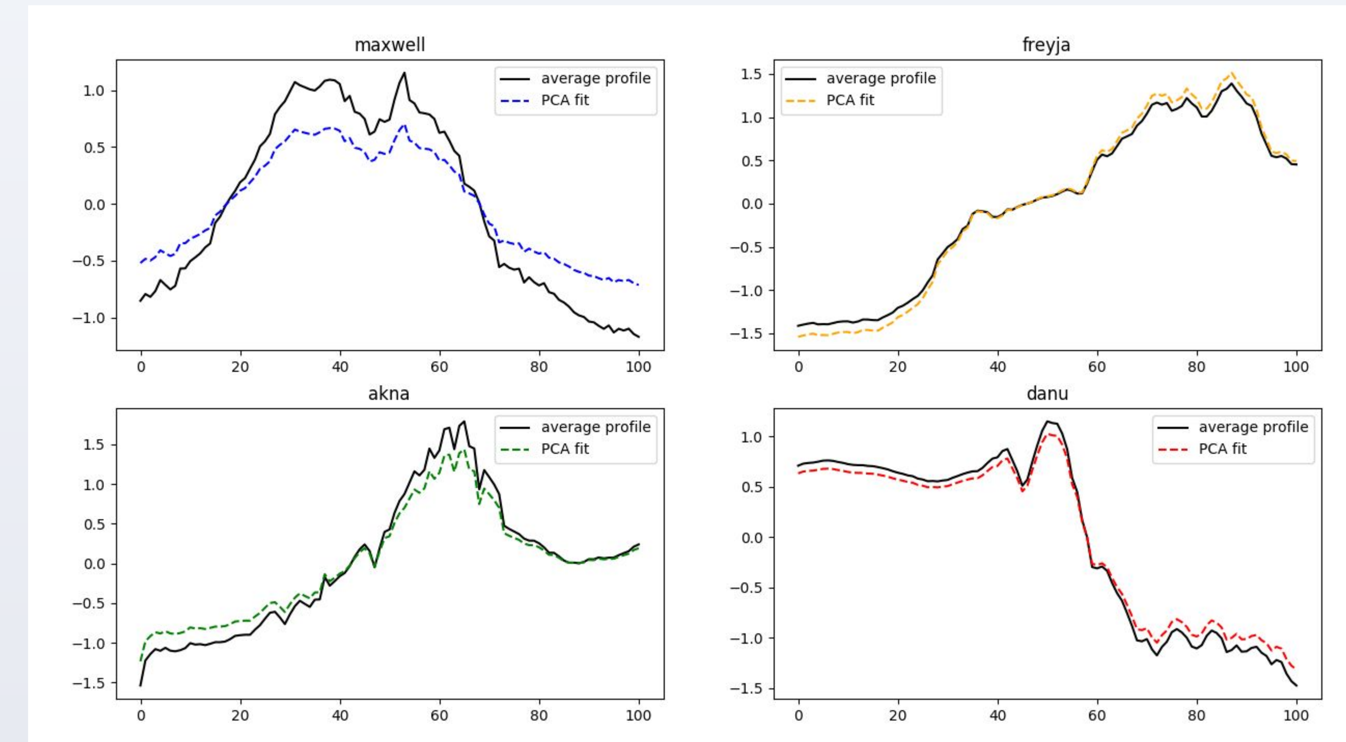
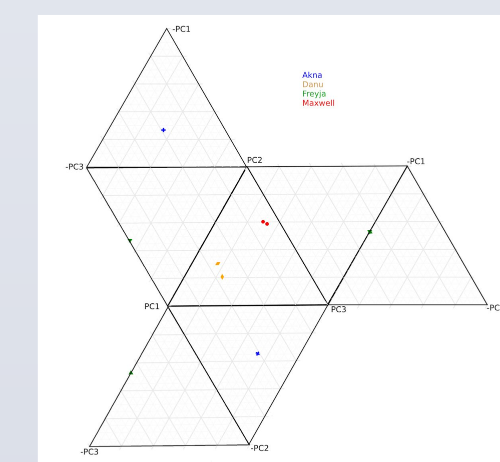


Figure 4: Average profiles vs. synthetic profiles constructed from the first three principal components.

Results

The decomposition of the principal components of the Ishtar Terra montes shows that the first PC is marked by a steep decline and the second PC by a central uplift. These characteristics and the PCA technique provide a quantitative avenue of comparison of the montes. The first component represents a generic or archetypal feature never exactly found. The second and third components describe principal modes of variation.

The ternary diagram to the right gives a visual representation of how similar the montes are to each other. The points corresponding to each feature tend to scatter and do not show any similarity among the montes.



Future Work

The mountains of Venus will be compared with Earth's mountains of known tectonic origin. Some possible analogues:

- Himalayas – Active Continental Collision
- Aleutians – Active Subduction (Oceanic)
- Andes – Active Subduction (Continental)
- Urals – Extinct Continental Collision.

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