EPSC Abstracts
Vol. 9, EPSC2014-647, 2014
European Planetary Science Congress 2014

Martian Polar Stratigraphy from Stereo Topography

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Abstract

We present a new approach to the stratigraphic analysis of the Polar Layered Deposits of Mars. We use 1 m/pixel Digital Terrain Models (DTMs) in order to construct stratigraphic columns of quantities that are representative of the morphology of the individual layers, and attempt to extract periodic signals from the stratigraphy using wavelet analysis.

1. Introduction

The North and South Polar Layered Deposits (NPLD and SPLD) of Mars are broad sheets of water ice and dust that make up the bulk of the martian polar caps. Erosional features, such as canyons, allow a view of their internal stratigraphy (fig. 1), which is composed of many depositional layers of varying thicknesses that are thought to represent a record of recent climate change on Mars [1].

Several researchers have attempted to extract a periodic climate signal from stratigraphic sequences constructed from images of the PLD scarps [1-7]. They created virtual ice cores of the NPLD by plotting layer albedo from Mars Orbiter Camera (MOC) versus depth from Mars Orbiter Laser Altimeter (MOLA) [3,4,6]. These studies generally agree that there is a dominant stratigraphic wavelength of 25 – 30 m in the upper 300 m of the NPLD. Wavelet analysis by [6] found little evidence for this signal, but found a possible dominant wavelength at 1.6 m.

Exact co-registration of the MOC and MOLA data and the limited resolution of both datasets (especially MOLA) are issues that may be circumvented by using HiRISE stereo topography and orthorectifying the input images. Using HiRISE stereo, Limaye et al. [7] performed Fourier analysis on varying brightness and slope with depth. They confirmed a 1.6 m signal for the NPLD and found no periodicity in the SPLD.

The major weakness of the previously mentioned studies is the use of albedo as the mapped layer property. The brightness of exposed PLD layers is a complicated product of slopes, frost retention, albedo and surface texture. In addition, it is now known that a sublimation lag deposit mantles these exposures (fig. 1, right) [8]. So it is not clear how brightness relates to the properties of the layers themselves.

In this study we seek to expand upon the work done by [2] and [7], examining depth-varying properties that are characteristic of the morphology of the layers, and using more advanced spectral analysis, as well creating new HiRISE DTMs and orthoimages to examine a widespread area of both PLDs. We use a measure of how the protrusion of layers from the scarp face varies with depth (extracted from DTMs), which can be taken as a proxy for a layer's resistance to erosion [9].

2. Data and Analysis

Using 1 m/pixel HiRISE DTMs [10,11], we can create linear profiles of layer protrusion to be examined with spectral analysis methods [9]. An example DTM profile, along with a schematic of the method to extract layer protrusion is shown in fig. 2.

A profile is extracted from the DTM in the downhill direction. The small-scale structure is quantified with a "sliding window" along the profile in which the best-fit linear trend is evaluated. The protrusion is then computed from the difference between the actual topography and the window centre.

We identified 11 sites on the NPLD and 4 sites on the SPLD with completed DTMs. In addition, we plan to create more DTM's from available HiRISE stereo pairs, as well as acquire new targets in order to achieve as much geographical coverage as possible. Our approach is to calculate five protrusion profiles from different areas of one DTM, which can be compared to each other in order to identify individual layers from different sections of one scarp. This will help the construction of more accurate stratigraphic columns from each DTM, and will make it easier to identify and correlate these layers in other DTMs taken from different regions of the PLD. Three of the protrusion profiles calculated from the DTM from fig. 2 are shown in fig. 4 (these have not yet been adjusted to line up in elevation).

Byrne et al. [9] performed wavelet analysis on protrusion profiles of NPLD exposures at five locations, and found a common dominant wavelength in the stratigraphy of ~40-45 m, as well as multiple secondary signals. The wavelet power spectrum of one of the protrusion profiles from the left panel of fig. 4 is plotted as a function of elevation and wavelength on the right panel of fig. 4. The advantage of wavelet analysis is that it can quantify signals that change in periodicity with depth [12]. We will use this method to examine all of selected sites from both polar caps.

3. Discussion and Future Work

There are many complications in deducing the relationship between the stratigraphy of the PLDs and Martian climate. The cratering record of the SPLD indicates that it is much older than the NPLD [13,14], meaning they might contain records of two different periods in Martian climate. Although the variations of orbital elements that could force climate change are well known for the past 10-20 Myrs, the polar accumulation and erosion rates are not. In addition, unconformities that break the record make the detection of a periodic signal much more complicated.

Hvidberg et al. [15] made progress with a model of polar deposition rates of ice and dust in terms of insolation, and comparing it to the stratigraphic column constructed by [2]. Their results date the top 500 m of the NPLD at 1 Myr with an average net deposition rate of ice and dust of 0.55 mm/yr.

Our primary objective is to analyze new DTMs with more advanced methods, focusing on the SPLD. Ultimately, we wish to develop a model following the work of [15], with which we can create synthetic layers to be compared with our observations and evaluate the relationship between PLD stratigraphy and climate.

4. Figures

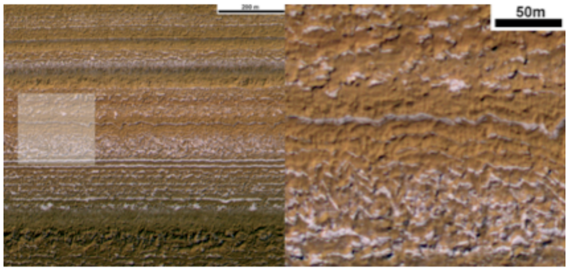

Figure 1: HiRISE PSP_001738_2670. Left: Layer exposures on a scarp on the NPLD. Right: Blow-up of highlighted area showing slumping lag deposits.

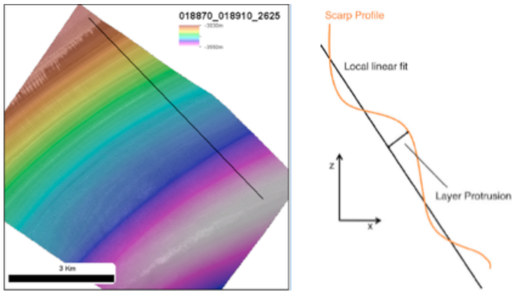

Figure 2: Left: HiRISE DTM displaying NPLD layers at 82N 34 E. Right: Schematic of the calculation of layer protrusion from the local (~ 100 m) scarp-face.

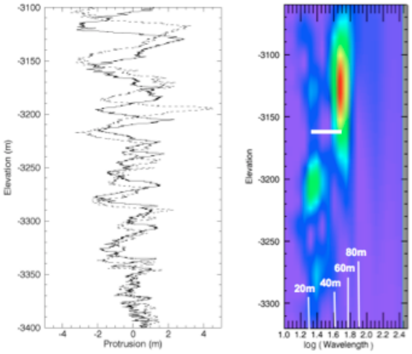

Figure 4: Left: 3 protrusion profiles taken from the DTM shown in fig. 2 (NPLD 1). Right: Wavelet power spectrum (using a Morlet basis) of the solid profile form the left, as a function of wavelength and position.

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