

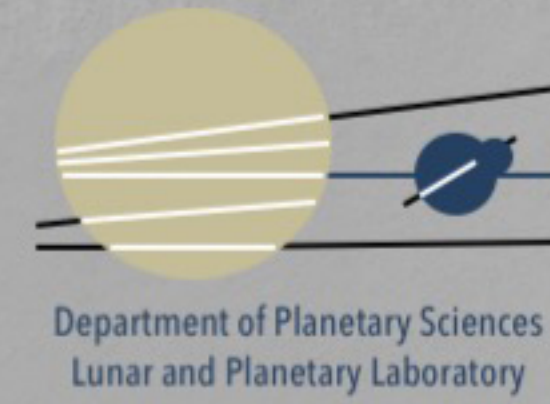
Signals Of Astronomical Climate Forcing In The Exposure Topography Of The North Polar Layered Deposits Of Mars

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Motivation and Key Questions

What chronology, compositional variability, and record of climate change is expressed in the stratigraphy of the Polar Layered Deposits of Mars? [1]

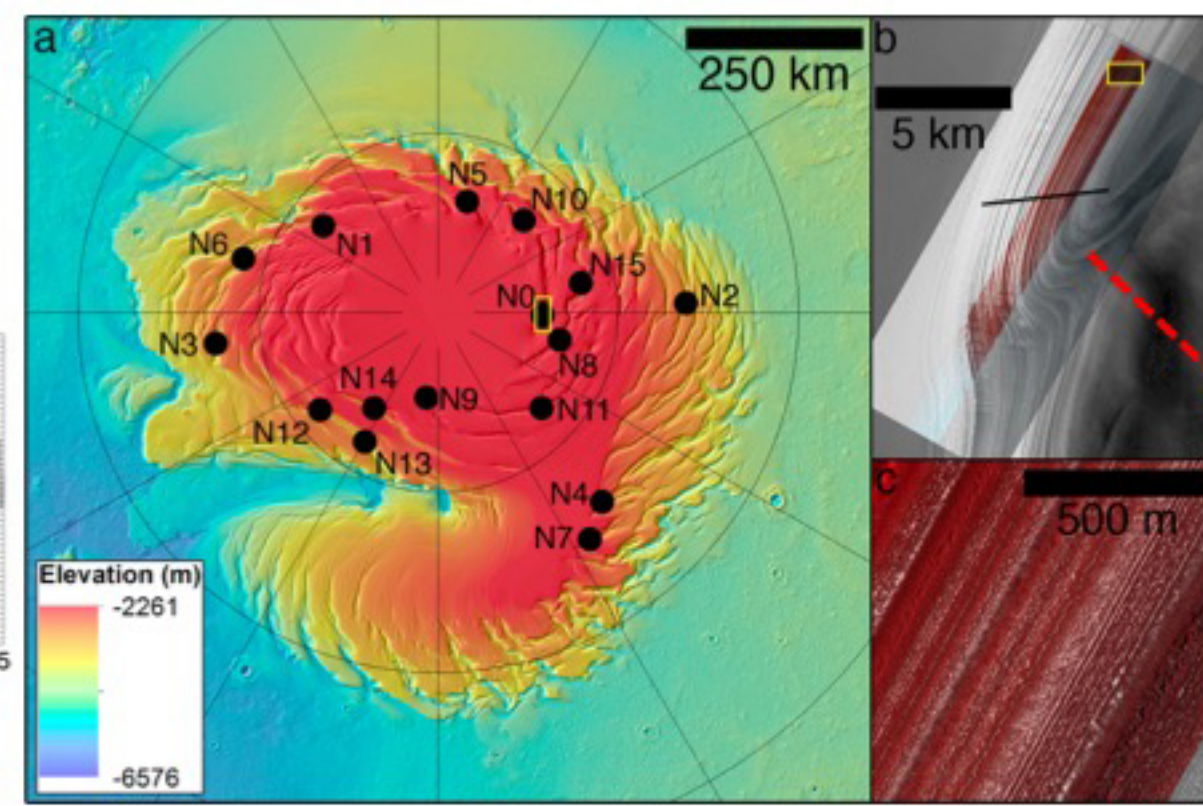
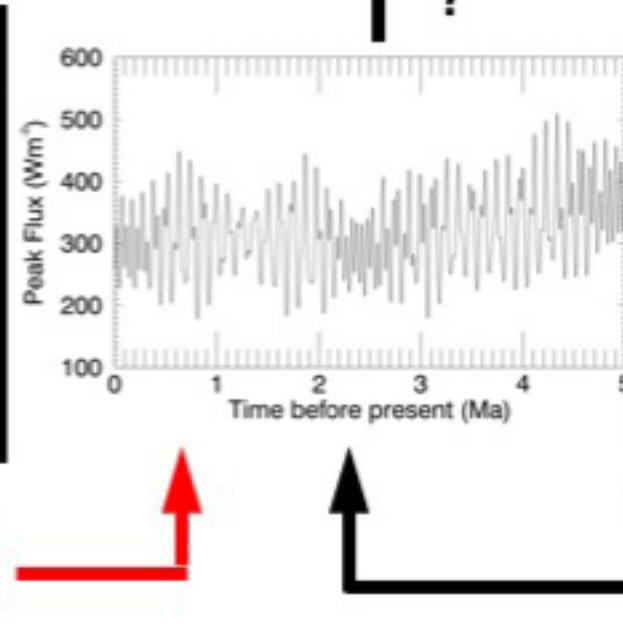
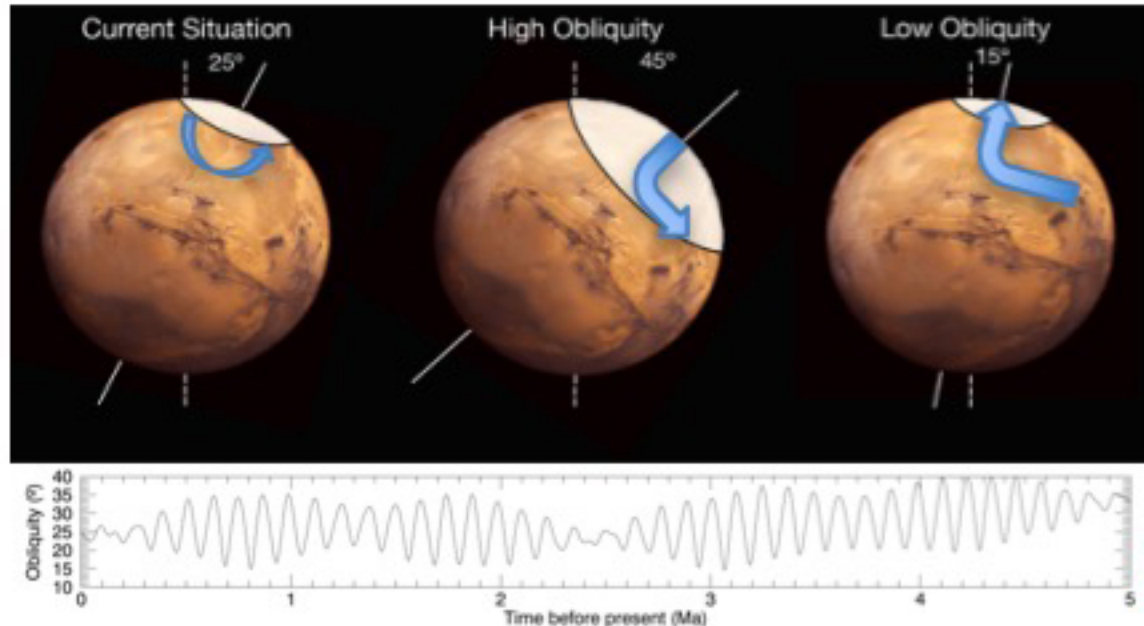
- Is it possible to detect a record of astronomically forced climate in the stratigraphy of the NPLD using the latest available data (DTM) and methods?
- What is the nature of that record, and what does it imply about the history of the NPLD?

Summary

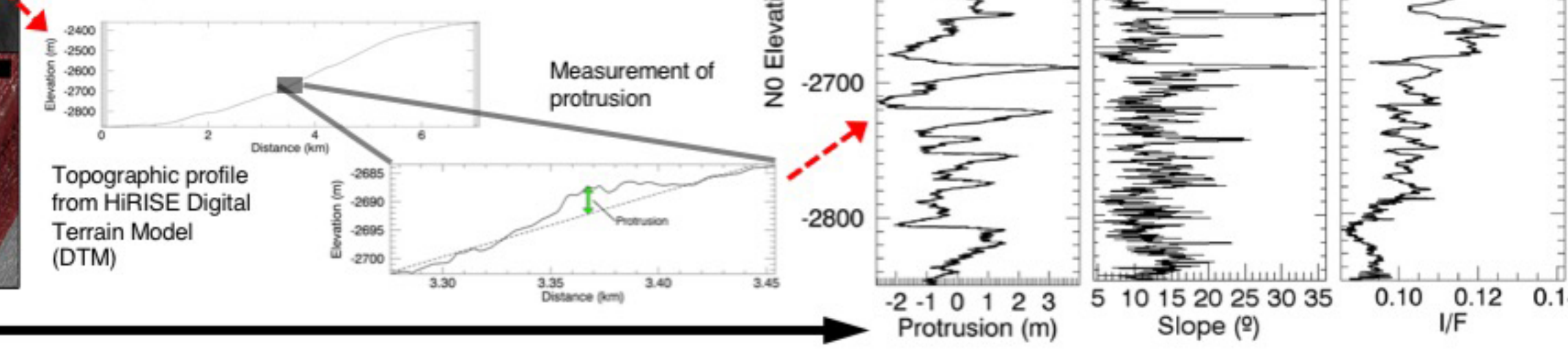
- We use wavelet analysis on stratigraphic profiles of exposed layers from a trough wall to search for periodicities in the stratigraphy and compare them with those in Mars' insolation record
- The ratios of the stratigraphic periodicities are systematically lower than that in the insolation, suggesting a non-linear time-depth relationship and variable deposition
- Simple model of climate-controlled stratigraphic accumulation provides a plausible depositional scenario with variable ice deposition rates

Introduction

Mars' polar deposits are composed of laterally continuous layers [2], and are thought to record recent climatic changes due to temporal variations in the planet's orbital and rotational parameters [3,4]



Becerra et al. [11] showed that the layers' topographic expression, along with brightness, may be a better proxy for e.g. dust/ice ratio, which directly records environmental changes that gave way to varying amounts of ice and dust deposited.

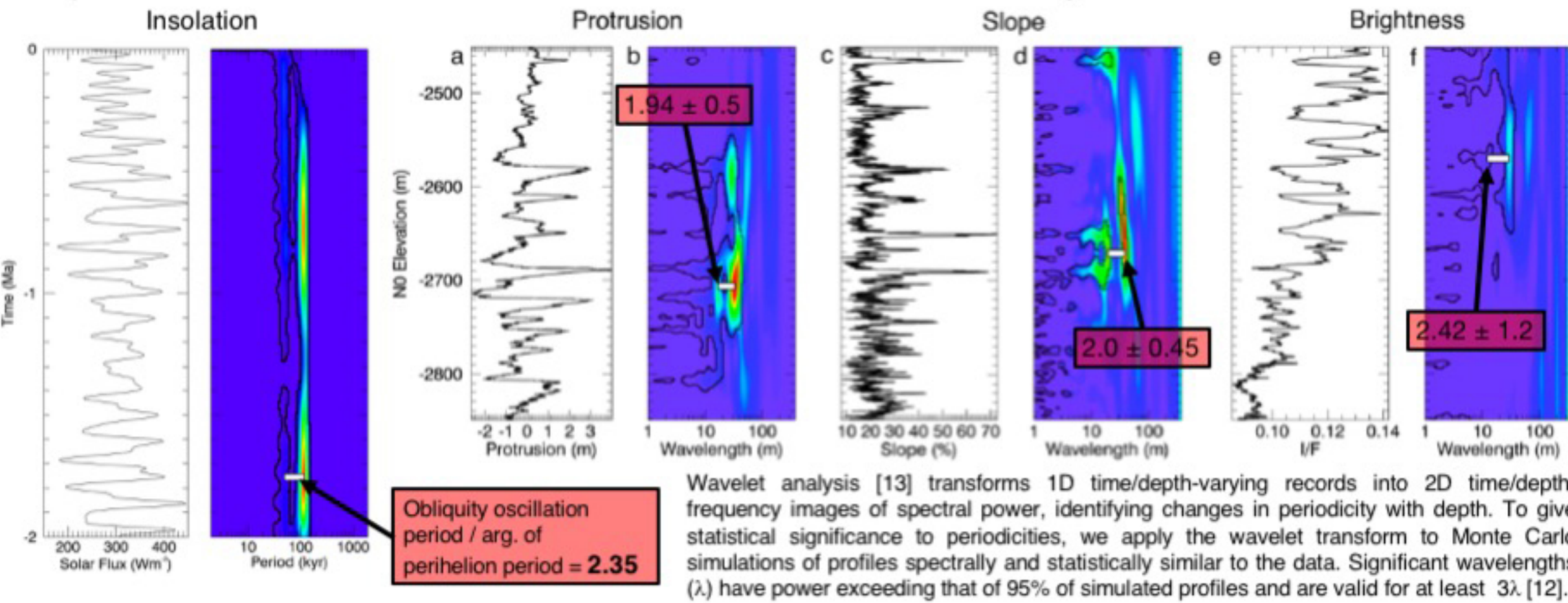


Research into this connection relies on the search for periodicities in virtual "ice cores" that match those of the insolation record [5-9]. Most analyses of the brightness of exposed layers agree that there is a periodic wavelength of 25-30 m in the upper 300-500 m of the NPLD [5-8], but brightness is influenced by a sublimation lag over the exposures [10-12].

We use wavelet analysis to search for periodicities in stratigraphic columns of three different properties of the exposed layers: **Layer protrusion, Local slope, and Brightness**; and we compare these to the periodicities of the historical insolation at the north pole of Mars.

Analysis and Results

There is no absolute chronology of the NPLD, so we search for two periodicities in the stratigraphy to compare to the two main modes of oscillation of the most recent 2 Myrs of insolation.

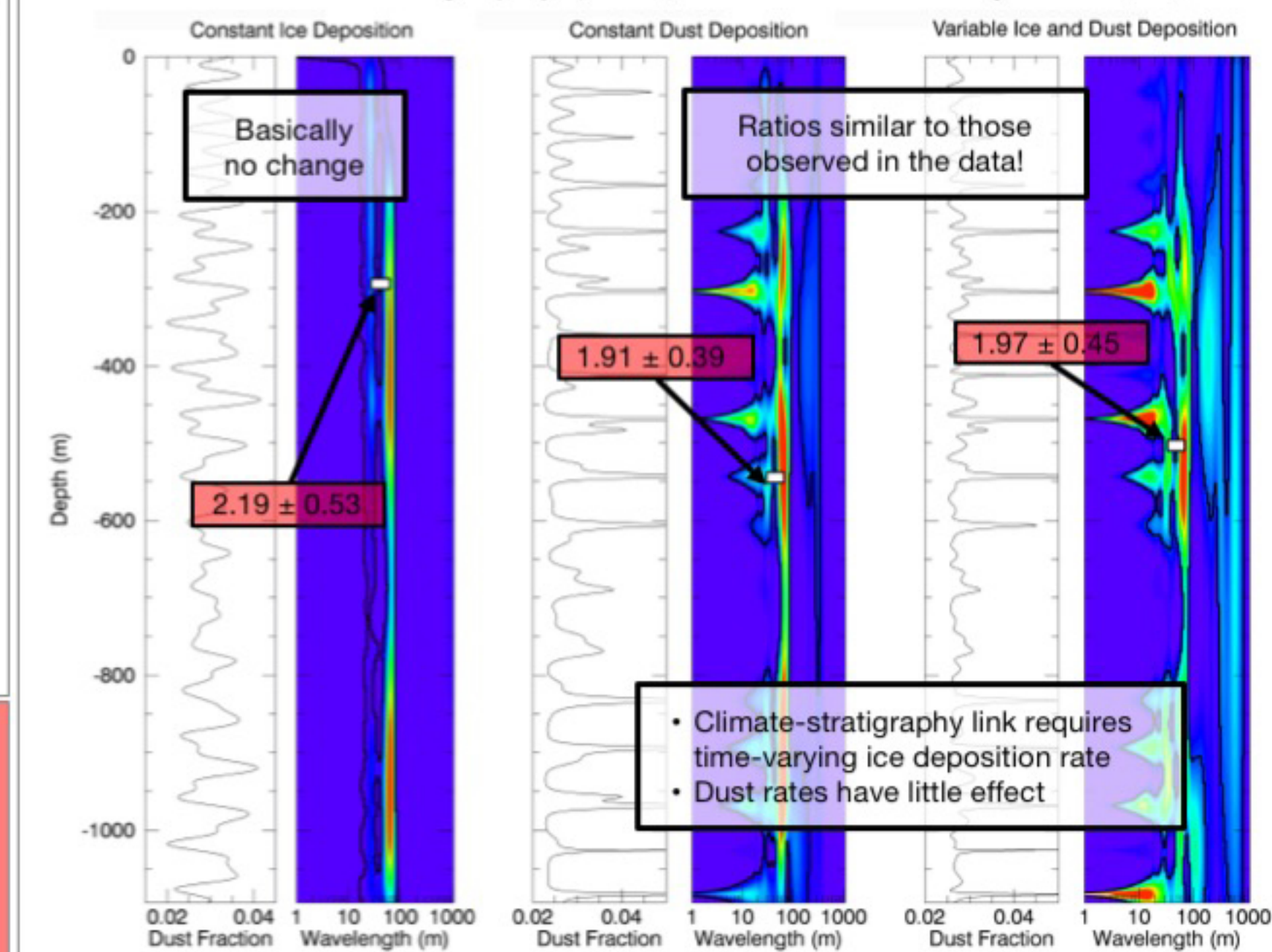


Wavelet Analysis Results	Long λ		Short λ		Ratio of dominant λ		Valid profiles
	λ (m)	σ	λ (m)	σ	Ratio	σ	
Protrusion	40.25	13.26	21.75	7.27	1.87	0.17	8
Slope	17	10.03	9	1.70	1.89	1.17	1
Brightness	24.50	6.36	11.00	1.41	2.21	0.64	2
Insolation	Period (kyr)		Period (kyr)		Ratio		
	120		51		2.35		

- Protrusion exposes periodicities not apparent in brightness
- λ s have a large spread but similar ratio \rightarrow spatial variability up to 4x
- Ratios of stratigraphic periodicities ($\mu = 1.93 \pm 0.2$) systematically lower than ratio of insolation periodicities**

Interpretation: Comparison with accumulation model

Same analysis on synthetic stratigraphic profiles created with the climate-controlled stratigraphy (CCS) model of Hvidberg et al. [14]:



The CCS model simulates accumulation by adding ice and dust deposition rates that depend on surface temperatures, which themselves are dependent on the time-varying insolation function [14].

Conclusions

- Is it possible to detect a record of astronomically forced climate in the stratigraphy of the NPLD? Yes, although systematically lower periodicity ratios in the stratigraphy compared to the insolation forcing signal suggest a non-linear relationship between the cyclic climatic variations and the geologic record.
- What is the nature of that record, and what does it imply about the history of the NPLD? A variable ice accumulation rate is required, but variability of dust accumulation is not. Our data supports the CCS model as a plausible scenario for the accumulation history of the NPLD and its connection to astronomically-forced climate.

References

- [1] Clifford et al. Icarus 225 (2013) [2] Phillips et al. Science 320 (2008) [3] Cutts JGR 78 (1973) [4] Tanaka, et al. Icarus 196 (2008) [5] Laskar et al. Nature 419 (2002) [6] Milkovich and Head, JGR 110 (2005) [7] Fishbaugh et al. GRL 37 (2010) [8] Limaye et al. JGR 117 (2012) [9] Perron and Huybers, Geology 37 (2009) [10] Herkenhoff et al. Science, 317 (2007) [11] Becerra et al. JGR 121 (2016) [12] Becerra et al. GRL 44 (2017) [13] Torrence and Compo, Bull. Am. Met. Soc. 79 (1998) [14] Hvidberg et al. Icarus 221 (2012).

