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Climate variations recorded by the North Polar Layered Deposits on Mars

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The Martian polar regions have layered deposits of ice and dust. The stratigraphy of the ice-rich polar layered deposits (PLD) is exposed within scarps and trough walls, and observed from orbit by radar and visual images. The stratigraphy is thought to result from climate variations forced by changes in the orbital parameters of Mars, primarily the obliquity, and their effect on the insolation. The age of the deposits is not well-constrained by geological data, and together with incomplete understanding of the processes controlling ice and dust deposition on long timescales this implies significant challenges in linking the stratigraphic record to the insolation record of Mars and interpreting the climate history from the PLD.

We present a model of PLD formation driven by insolation and show that the model is able to reproduce complex layer sequences observed in the north polar layered deposit (NPLD). The model is based on physical processes that express polar deposition rates of ice and dust in terms of insolation by simplified parameterizations. In this model, layer formation is controlled by the insolation record, and dust-rich layers form by two mechanisms: 1) increased summer sublimation during high obliquity, and 2) variations in polar deposition of dust modulated by obliquity variations. The model is simple, yet physically plausible, and allows for investigations of the climate control of the polar layered deposits.

We compare the model to a stratigraphic column from the north polar layered deposits (NPLD) obtained from a stereo pair of HiRISE images at (87.1°N, 92.6°W) (Fishbaugh et al., 2010, GRL, 37, L07201), and show that the model can be tuned to reproduce complex layer sequences. We identified a set of model parameters that provides a chronology of the NPLD tied to the insolation record and consistently explains layer formation in accordance with observations of NPLD stratigraphy. This model dates the top 500 m of the NPLD back to $\sim$1 million years before present with an average net deposition rate of ice and dust of 0.55 mm/year. This is consistent with a build-up of the NPLD over approximately 5 million years. The model testing was constrained, however, by the length of a reliable insolation record, and the observations cannot uniquely constrain the PLD chronology. We compare the model to radar observations of the internal stratigraphy, and discuss how future work should include more data to provide additional constraints. We discuss the implications of the results for the evolution of the NPLD and the processes controlling ice and dust deposition at the poles.