QUANTIFYING NET ANNUAL POLAR DEPOSITION RATES OF WATER ICE AND DUST ON MARS AT VARIOUS OBLIQUITIES WITH THE NASA/AMES LEGACY MARS GLOBAL CLIMATE MODEL.

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Introduction: The polar layered deposits (PLD) are ~3 km-thick surface deposits in Mars' North and South polar regions comprised of layers of water ice and dust in various mixtures, which are thought to record astronomically-forced climate variations over the past 1's–10's of Myrs [3]. Understanding the formation mechanisms of layers is critical to the interpretation of this climate record.

Methods: *Models.* We utilize the NASA/Ames Legacy Mars Global Climate Model (MGCM) [2] to investigate the sensitivity of annual rates of water ice and dust surface deposition in the polar regions to various obliquity parameters and surface water ice distributions plausibly characteristic of the past ~5 Myrs (the inferred age of the NPLD) [3]. The MGCM utilizes fully interactive dust lifting schemes [2], infinite global sourcing of dust, and infinite sourcing of water where surface water ice reservoirs are specified. The radiative effects of water vapor and suspended dust are considered, but are currently neglected for water ice.

MGCM-derived polar deposition rates produced under specified obliquity and water source locations are then ingested into a time-marching integration model to simulate layer formation during a recent low-eccentricity epoch spanning ~1.7-1 Myrs ago [3].

MGCM Simulations. Paleoclimate simulations employ obliquities ranging from 15^o-35^o and initial surface water ice source locations consisting of various combinations of polar ice caps and middle latitude surface water ice reservoirs (glaciers). We here focus upon two surface water ice source prescriptions: Simultaneous north and south ice caps poleward of 77.5^o N/S (representing a post-low-obliquity epoch characterized by polar accumulation [5]), and surface water ice between 37.5-42.5 N and S (representing a post-moderate obliquity epoch characterized by middle latitude glaciation [5]).

To investigate polar processes under present-day climate conditions, a simulation utilizing present orbit parameters and a source distribution defined by the morphology of the present-day NRC was analyzed.

Results: *Paleoclimate Simulations.* Zero eccentricity simulations that employ simultaneous north and south polar ice caps generally predict an annual north-to-south exchange of water ice. Annual loss/gain in the north/south results from polar summertime surface

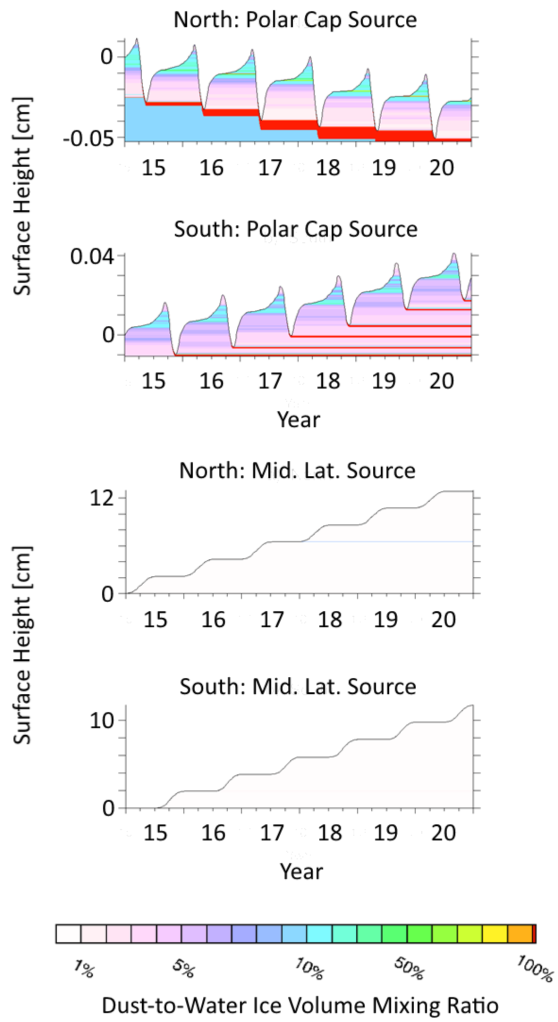

Figure 1: Five-year evolution of the polar water ice and dust deposits under 25^o obliq., zero eccen., polar cap source and middle latitude source conditions.

pressure-temperature conditions favoring greater sublimation in the north. The 15^o and 30^o obliquity scenarios exhibit a south-to-north exchange. At 15^o, this is due to the presence of perennial CO_2 ice caps and the relatively late recession of the north's CO_2 cap edge (late exposure of water ice). At 30^o, this is due to a southern summer dust event that enhances total downward radiative flux upon the south cap in that season. The magnitude of the annual cap-to-cap water ice exchange increases with increased obliquity from ~1e-5 cm/yr (15^o) to ~0.1 cm/yr (35^o). The polar surfaces accumulate dust at all obliquities, primarily as dust cores nucleated by snow particles. Polar dust deposition increases with increased obliquity from ~1e-4 cm/yr (15°) to ~1e-2 cm/yr (35°) due to increased wind stress lifting (increased temp. gradient) along the more latitudinally-extensive seasonal CO_2 cap edges.

Zero eccentricity simulations that employ simultaneous north and south middle latitude glacial deposits predict rapid annual polar water ice accumulation at the expense of the middle latitude ice. Polar accumulation (and middle latitude loss) of water ice increases with increased obliquity from ~1 cm/yr (15°) to ~3 cm/yr (35°). The polar surfaces accumulate dust at all obliquities, primarily as dust cores. Polar dust deposition rates decrease from ~3e-3 cm/yr (15°) to ~1e-3 cm/yr (35°) as increasing overlap between the extensive seasonal CO_2 caps and the middle latitude surface water ice deposits reduces cap-edge wind stress lifting.

Present-Day Simulation. The present-day simulation predicts an annual migration of water ice from the periphery of the modern north residual water ice cap towards the cap interior (poleward of 77.5° N) at ~0.01 cm/yr but no annual water ice accumulation in the south. Both polar regions accumulate dust at 0.001 cm/yr, resulting in ~15% dust northward of 77.5° N.

A Model of PLD Growth and Layer Formation at Low-Eccentricity. Over the period spanning 1.7-1 Myrs ago, a subset of integration model simulations are capable of accumulating a northern surface deposit at a time-averaged rate close to that estimated for the NPLD's recent and long-term accumulation history (~0.5 mm/yr) [4]. Such integration model simulations:

- Are characterized by persistent north and south polar caps, and exhibit a long-term transfer of water from the south cap to the north cap.
- Like [1], accumulate two types of dust-rich layers per obliquity cycle in the north:

1) A ~30 m-thick layer containing ~20% dust forms at high obliquity when both NPLD water ice deposition and dust deposition are high.
2) A 2 cm-thick dust lag deposit forms at low obliquity when water ice is annually removed from the NPLD (and transferred to the SPLD).

Discussion: Integration model results suggest that a south cap-to-north cap exchange of water could sustain NPLD accumulation at ~0.5 mm/yr under low-eccentricity conditions, and produce ~30 m layers reminiscent of observed NPLD stratigraphy [3].

The inability of these zero eccentricity GCM models to form or retain middle latitude glacial deposits at any obliquity suggests, like [4], that excursions to low-eccentricity epochs may act as interglacial periods.

This work predicts instability of the SPLD under present-day conditions but has identified plausible paleoclimate scenarios conducive to annual accumulation of SPLD water ice, providing possible insight into its estimated >10 Myr age.

The polar deposition of dust primarily in the form of snow nuclei suggests that the microphysical coupling of water ice and dust may have a considerable impact on PLD formation processes and composition.

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References: [1] Hvidberg, C.S. et al. (2012) *Icarus* 221(1). [2] Kahre M.A. et al. (2006) *JGR* 111(6). [3] Laskar J. B. et al. (2007) *Nature*, 419. 375-77
[4] Madeleine J.B. et al. (2009) *Icarus* 203(2). 390-405
[5] Mischna M.A. et al. (2003) *JGR* 108(6). 405-19

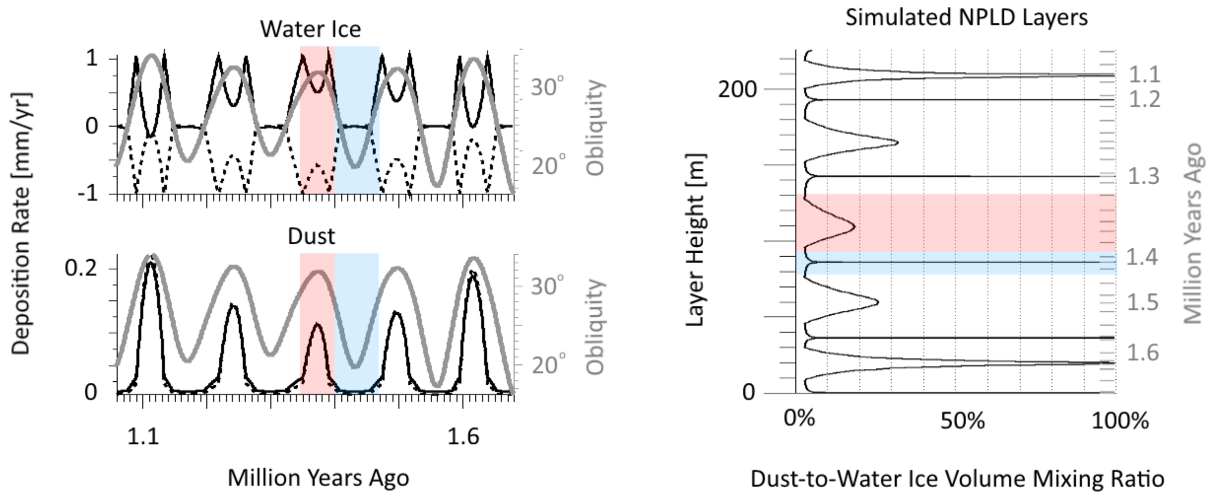

Figure 2: Results of an integration model simulation initialized with 1.5 km-thick north and south polar ice caps yielding a time averaged simulated NPLD accumulation rate of 0.35 mm/yr **(left)** Simulated net water ice and dust deposition rates vs time (solid = NPLD, dashed = SPLD) with superimposed obliquity history (gray). **(right)** Resulting simulated NPLD stratigraphy. Pink/Blue strips highlight the two described layer types.