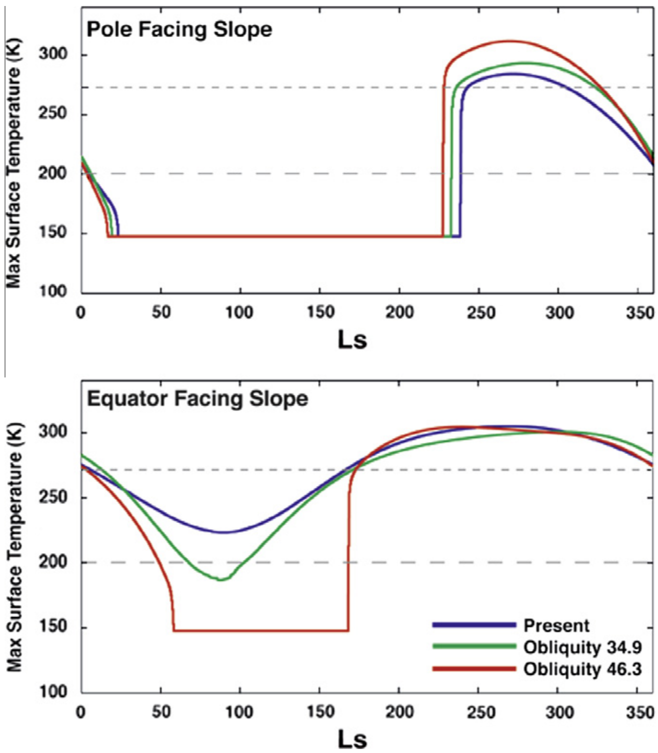


**Fig. 8.** Maximum daily surface temperatures (K) over a year at 46°S for a 25° polar facing slope and a 25° equator-facing slope under present conditions, and under the conditions dictated by the orbital parameters (obliquity, eccentricity and longitude of perihelion) predicted by Laskar et al. (2004) for 868 ka (obliquity 34.9°) and for 9.1 Ma (obliquity 46.3°).

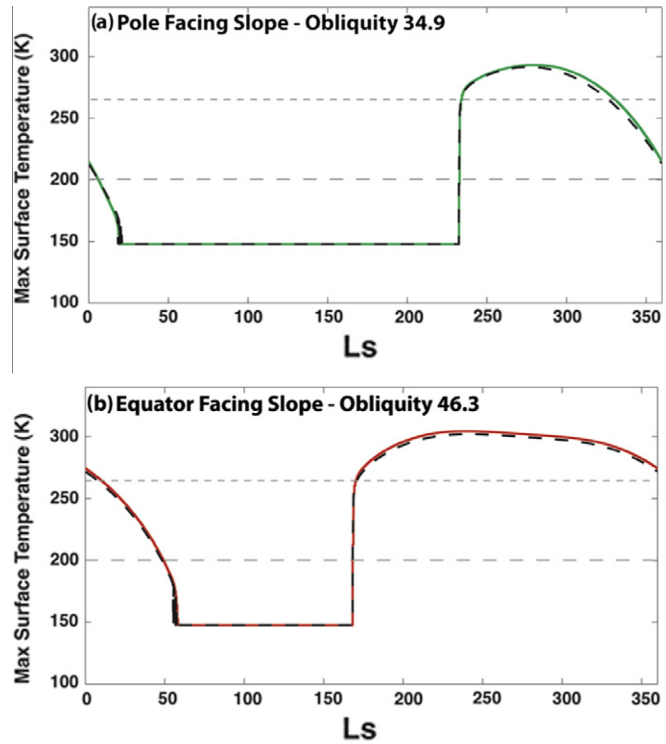


**Fig. 9.** Maximum daily surface and subsurface (~1 cm depth) temperatures (K) over a year at 46°S for: a 25° polar facing slope under the conditions dictated by the orbital parameters for 868 ka (obliquity 34.9°) and a 25° equator-facing slope under the conditions dictated by the orbital parameters for 9.1 Ma (obliquity 46.3°). Both the surface and subsurface maximum daily temperatures exceed the melting point of water during the late spring. The subsurface temperature profile was calculated based on thermal properties for a windblown martian snowpack (heat capacity = 2200 J $K^{-1}$, conductivity = 0.11 W $m^{-1}$ $K^{-1}$, thermal inertia = 313 J $m^{-2}$ $s^{-1/2}$ $K^{-1}$, snow density = 400 kg $m^{-3}$).

three parameters. Through this method we can pin point specific points in Mars history of interest. We used the 1D model to compare the maximum daily surface temperatures at the study site under three different scenarios: (1) present insolation conditions, (2) maximum insolation conditions during the most recent period of ~ 35° peak obliquity values (868 ka), and (3) maximum insolation conditions during the most recent period of ~ 45° peak obliquity values (9.11 Ma). We assessed the results in terms of conditions that might permit the accumulation, and subsequent melting, of snow and ice (Figs. 8 and 9).

The input parameters chosen for the model are provided in Table 1. In regards to surface temperatures the values of thermal inertia and surface albedo are of the most significance. In the regions where snow accumulation was assessed to be possible, we assumed that the surface of the slopes were covered in a thin layer (~1 cm) of snow, and our model parameters were chosen accordingly. In response to our Antarctic observations (Fig. 2) and the modeling results of Williams et al. (2009), which both describe the formation of a surficial lag of dust on ablating snowpacks, an albedo of 0.15 was chosen. With regards to thermal inertia, a value of 313 SI was chosen to reflect that of terrestrial measurements of wind-hardened snow.

### 4.1. Pole-facing gullies

Our simulations demonstrate that for the majority of the year the PF slope temperatures at all obliquities are constrained by the frost point of $CO_2$ (as was highlighted by Costard et al., 2002) and thus remains at ~150 K (Fig. 8). As this temperature is below the frost point of $H_2O$, the PF slopes will also be favorable environments for the accumulation of snow and ice, provided that there is a source of snow. Under current conditions snowfall is unlikely to occur, although seasonal ice accumulations have been reported in

**Table 1**
Model parameters used in the study.

| Parameter | | | Value |
|---|---|---|---|
| $H_2O$ snow albedo | | | 0.15 |
| $H_2O$ snow thermal inertia | | | 313 SI |
| $H_2O$ snow emissivity | | | 0.95 |
| $CO_2$ albedo (when present) | | | 0.5 |
| $CO_2$ emissivity | | | 0.9 |
| Time at which models were run | Present | 868 ka | 9.112 Ma |
| Obliquity | 25.2 | 34.94 | 46.27 |
| Eccentricity | 0.0934 | 0.0558 | 0.0844 |
| Longitude of perihelion | 251 | 289.2 | 245.6 |

this latitude range (Schorghofer and Edgett, 2006; Head et al., 2008). During periods of higher obliquity, greater amounts of snow and ice may have been deposited as a result of the increased sublimation of the residual summer cap (e.g., Mischna et al., 2003; Madeleine et al., 2009). Snow and ice deposits could have been built up on the PF slopes through the winter by the redistribution of snow by the winds in a similar manner to that observed in gullies in the Antarctic Dry Valleys (Figs. 1 and 2) (e.g. Morgan et al., 2008). During the martian spring, the rapid removal of the $CO_2$ frost cover permits enhanced heating of the surface. The exposure of any $H_2O$ snow deposits accumulated during the winter would prevent this temperature increase from immediately reaching the $H_2O$ melt point due to the relatively high albedo of snow (0.4, for slightly dusty snow: Williams et al., 2008). However, modeling by Williams et al. (2009) and our Antarctic fieldwork (Fig. 2) has