**Introduction:** The southern residual ice cap (SRC) is composed in-part of high-albedo solid CO₂ [1] that persists throughout the year. It is on the order of a few meters thick [2-3] and has areas at its margins and in its interior where underlying water ice shows through [2-5]. Under current conditions, the SRC exists in a precarious position, where its stability depends critically on its ability to maintain a high albedo [6,7]. This solid reservoir of CO₂ ice currently buffers the seasonal atmospheric pressure cycle although larger buried reservoirs of CO₂ ice have recently been identified [8].

The SRC contains flat-floored, quasi-circular pits (figure 1a) embedded in CO₂ ice slabs that vary in thickness from 2 to 10 meters [9]. The inclined walls of these quasi-circular pits retreat by several meters each year [10-11,3] leading [10] to suggest that the SRC is in the process of disappearing and that the martian climate is changing. Indeed, when one looks at the spatial density of these pits and the rates at which they are expanding, there should be nothing left of the SRC within a century or so. However, a changing climate on Mars is hard to understand as orbital elements of the planet change on timescales much longer than the time needed to ablate all the ice by these expanding features.

Here, we report on model results of icy landscape evolution (incorporating results from analysis of historical and HiRISE imagery) that explain the observed behavior of the SRC without invoking climate change.

**Model Description:** A landscape evolution model was developed to investigate the behavior of the SRC. The elevation of CO₂ ice at each point falls or rises via ablation or condensation due to imbalances in their energy budgets. Several approximations are employed that allow simulations of large landscapes in reasonable times.

In a typical model run (figure 2), we initiate the model with a randomly generated fractal surface with a thin CO₂ ice cover whose surface roughness is low. The surface begins accumulating; however, surface roughness also increases with time. After about 30 years, instabilities begin to occur in the locations with the highest slopes. Pits begin to form and quickly penetrate down to the water ice basement. Over the following decades these pits expand laterally even while the intervening flat surfaces continue to accumulate mass vertically. As the accumulation area (mesas) shrinks, and the ablation areas (pit perimeters) grow, the landscape as a whole passes from a net accumulation to a net ablation regime. The right panel of figure 2 illustrates the behavior of the mean CO₂ thickness (which is a proxy for total volume). We can define a characteristic time for the evolution of the landscape as being when this transition to net ablation takes place. This timescale depends on the initial surface roughness; if one starts with a smoother surface then it will last longer before pits begin to form. Many SRC locations are close to the final state in this model, where only isolated (and shrinking) mesas remain as remnants of the original ice slab (figure 1b). This overall behavior is an inevitable consequence of starting with a surface that is not perfectly flat; CO₂ ice caps can never be stable indefinitely.
Understanding that surface roughness governs the lifespan of the ice cap allows us to answer the original question of how it is that the SRC persists to this day. Extra CO₂ deposition is necessary to re-cover the exposed water ice, but this alone does not reduce surface roughness. However, if we allow this material to drift across the surface, filling in small-scale roughness (treated mathematically as diffusion) then these unusual years of higher deposition can smooth the surface. This behaviour, illustrated in figure 3, where 40cm of loose material, added every 80 MY, allows CO₂ to begin recondensing, forming a new ice cap that may overlap in time with the old one. With each year of unusual deposition, another ice cap may form that is in-turn destroyed by expanding pits. Each cap formed differs in exact appearance, but is identical in behaviour (figure 3).

**Data:** In order to constrain the model behavior we compare it to rates of feature change measured in the HiRISE dataset. Additionally, we compare historical imagery to argue that the winters following global dust storms have higher than usual deposition and that these years correspond to the unusual depositional events in our model.

**Summary and Conclusions:** No climate change is necessary to explain the current erosion of the SRC, expanding pits exist at all phases of its life cycle (figure 3). Interannual variability in the form of unusual depositional events is required to explain a recurring SRC and the fact that different parts of the current SRC are at different stages of the life-cycle. Historical data indicate that winters containing these unusual depositional events are preceded by dust storms.


**Figure 3.** (Top) Evolution of mean and max CO₂ ice thickness when diffusive resurfacing is included. Red lines are spaced every ten martian years and correspond to landscapes shown in the left-hand panels (colors correspond to elevation scale in figure 2).