

# Supporting Information for “Limits on runoff episode duration for early Mars: integrating climate models and lake hydrology”

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## Introduction

This Supporting Information (SI) document contains 5 Supplementary Texts, 5 Supplementary Figures, and 5 Supplementary Tables. Here we include additional information on assumptions made during mapping of open- and closed-basin lakes (Text S1). This document also describes the effects of sedimentary infill on our results (Text S2) as well as the (limited) role of groundwater (Text S3). Then, it provides a full derivation of the volumetric and timescale functions presented in equations (2) – (4) in the main text (Text S4). It also discusses the assumptions and implications for precipitation rate uniformity (Text S5). Further, the SI contains a schematic overview of the early Mars climate and the relevant parameters used in this study (Figure S1), maps of the coupled lake systems (Figure S2), as well as modified results from Figure 4 assuming a climate regime with no evaporation (Figure S3) and modified results if we reduce the population of coupled systems following Text S1 (Figures S4 and S5). Finally, the SI provides five tables (Tables S1-S5): Table S1 lists additional information for studies shown in Figure 1, Table S2 presents our full database of coupled lake systems and their morphometric parameters, Table S3 summarizes the climate model scenarios used for Figure 4 (and Figures S3,S5), Table S4 lists the relative breaching times (as shown in Figure 2e,f), and Table S5 exhaustively lists all individual values for breaching and maximum episode duration values for all models, scenarios, and systems (used to generate histograms in Figures 4, S3, and S5).

**Text S1. Identification of open- vs. closed-basin lakes**

Open- and closed- basin lakes were classified based on whether or not they contained an outlet canyon. Although it is possible some overflow may have occurred without visible outlet canyon erosion, we interpret the lack of geologic evidence for overflow as an indication that the lake system was closed (Supplementary Figure S2). However, because the craters we interpret as closed basins may have been modified by later processes, the lack of an observed outlet is not definitive proof that one never formed. Based on contextual evidence, however, the odds that more than 1-2 of the basins we interpret as closed overflowed is low. Further, the observation that closed-basin lakes always allow greater water inputs (smaller areas, larger basins) than their coupled open-basin lake counterparts is in line with the assumption that they were not breached.

Stucky de Quay et al. (2020) showed that removal of closed-basin lakes with depressions on their rims (potential outflows that did not form defined canyons) did not affect distributions of hydrologic reconstructions. Here we apply a similar modification to our results and remove two systems from our analyses that could arguably be of reduced confidence: Basin IDs 47/13 and 231/216 (see Supplementary Table S2; Figure S2). Recalculation of results using the 5 remaining coupled systems (as shown originally in Figures 2e,f and 4 in the main text) are shown in Supplementary Figures S4 and S5. These results show that the removed basins lie within the range of our original population, and thus do not affect our overarching quantitative findings: the range of  $T_{max}/T_B$  values in Figures 2e,f ( $1.6 - 63$ ) or the range of episode runoff durations in Figure 4 ( $10^2 - 10^5$  yr).

## Text S2. Basin infill and sedimentary volume considerations

Here we consider various infilling scenarios—depending on when they occur—and how they may (or may not) affect our results.

First, although the morphology of basins indicates they have been significantly infilled (e.g., flat crater floors in Figure 2a and Figures S2a-f), the majority of this infill would have occurred prior to the valley network era (i.e., during the Noachian period; Malin & Edgett, 2000; Craddock et al., 2002). As such, this infill occurred before our valley network-fed runoff events and do not affect our results. Subsequently, during the valley network period, sediment may also have been eroded from the valley network watersheds (from both open- and closed-basin lakes) and deposited into the basins for any episode preceding the breaching runoff episode (e.g., any of the episodes before breaching episode in Figure S1a indicated by (i)). This sediment volume would not affect our results because it was deposited prior to the breaching episode, and our measured lake volumes exclude this sediment volume.

Second, sediment may be added to the basins during the breaching runoff episode (breaching episode in Figure S1a, (ii)). This sediment could be derived from either inlet incision (from both open- and/or closed basin lake watersheds) and/or outlet canyon incision (deposited in the downstream closed-basin lake). In both cases, this sedimentary infill will not affect our results because we are only concerned with basin water volumes at the end of runoff episode. In other words, any sediment volume that is eroded, transported, and deposited in the basin at any point within the breaching runoff episode *remains* in the basin up to the present—thus, when we measure lake volumes using present-day topography, the sediment volumes are not incorporated in our lake volumes. In this

way, our lake volumes consider only the water volume and are not affected by synfluvial sedimentation during the breaching episode.

Third, infill may occur after the breaching runoff episode. This could either be due to (a) subsequent runoff episodes (i.e., if there are many more runoff episodes after the breaching episode; Figure S1a, (iii)), or (b) postfluvial processes such as aeolian deposition. Although these would have an impact on our results, they are unlikely to significantly modify our volume estimates, as we explain below. To assess the maximum value of the first contribution, let us make the assumption that the breaching episode is the very first runoff episode to occur in a series of episodes (e.g., the breaching episode is the first peak in Figure S1a). This would mean that approximately the entire eroded watershed volume (measured from the inlets) would be deposited into the basin after our breaching event, resulting in our measured lake volumes being an underestimate. For Jezero crater, the eroded volume from the watershed is  $\sim 58 \text{ km}^3$  (Fassett and Head, 2005). The basin volume is  $\sim 424 \text{ km}^3$  (see Open Basin ID 45 from Stucky de Quay et al., 2020). This would mean the basin volume before sediment deposition from inlets would have been  $482 \text{ km}^3$ , i.e., only 14% greater. For the second contribution, aeolian deposits are likely to be a few tens of meters (e.g., dust mantle thickness of  $\sim 20 \text{ m}$  from Mangold et al., 2009) and would only infill  $\sim 10\%$  of the basins, which are on average  $\sim 200 \text{ m}$  deep (Stucky de Quay et al., 2020). As such, even if we sum up both liberal contributions, paleolake volumes could only have been up to  $\sim 24\%$  larger, which would change episode duration values by the same proportion, and thus not significantly alter our results.

In summary, sediment deposition into the basins occurring before or during the breaching runoff episode does not affect our lake volume calculations, and sediment deposition

occurring after the breaching runoff episode (whether through fluvial or aeolian processes) is not significant relative to the size of the basin.

### Text S3. Groundwater considerations

In this section we explore how groundwater contributions might affect our runoff episode durations. Although we do not explicitly include net groundwater losses,  $G_{out}$ , or gains,  $G_{in}$ , in this study, Stucky de Quay et al. (2020) explore the implications for possible losses due to infiltration both from the watershed and the lake. Adding large infiltration losses of 50% (where half of the available runoff is lost to groundwater, as observed for rubbly basalts in Idaho; Stephenson & Zuzel, 1981) does not result in significant changes in the hydrology for a semi-arid system, since evaporation is the dominant water loss mechanism. Further, the minimum aridity index used,  $AI \sim 0.26$ , was estimated by taking the ratio of maximum water loss permitted relative to the water gains that open-basin lakes need to overflow (see Stucky de Quay et al., 2020); these losses need not be evaporative only, but could also include groundwater losses. Thus any lake losses due to infiltration can be considered as already accounted for in the AI term (although it is likely that  $E \gg G_{out}$ , as explained above).

We can also quantitatively explore how groundwater losses, or any other losses, in the watershed could affect our results. One way to assess fractional losses in the watershed is to include a term,  $R$ , which describes the fraction of watershed precipitation that ends up as runoff and contributes to the lake volume. This results in a variation of equation (1) in the main text, which can be expressed as  $V = (RPA_W + XA_L)T$ . In the main text we assume the simplest case of  $R = 1$ , but a value of  $R < 1$  could occur due to any combination of (i) evaporation from the watershed directly from any standing water, overland flow, or bedrock rivers, (ii) ablation (e.g. sublimation) off accumulated snow volumes (if precipitation is nival in origin), and (iii) interbasin infiltration (where



groundwater does not flow back into the associated lake basin). However, the value of  $X$  (where  $X = \frac{1}{At} - 1$ ) that we use also depends on  $R$ , since it is given as  $X = R \frac{A_{W,O,182}}{A_{L,O,182}}$  for the most humid open-basin lake in our database (Basin ID 182; Stucky de Quay et al., 2020). As such, the value of  $T_B$  and  $T_{max}$  is simply inversely proportional to  $R$  (i.e.,  $T \propto \frac{1}{R}$ ). This would mean that a value of  $R = 0.5$ , where only 50% of precipitation contributes to runoff, would result in a doubling of runoff episode duration values. Note that a loss of 90% ( $R = 0.1$ ) would need to occur in order to change our results by an order of magnitude, which is more than is observed for similar hydrologic regimes in the Great Basin Range (Matsubara and Howard, 2009; Stucky de Quay et al., 2020). As such, groundwater losses, either in the lake or the watershed, are unlikely to significantly alter the results shown in Figures 2e,f and Figure 4.

#### Text S4. Full derivation of lake hydrology and timescale expressions

**Open-basin lake.** In an embedded lake system, where an open-basin lake is located within the watershed of a closed-basin lake, the changes in lake volume over time can be calculated using a simple model. The following derivation of this expression builds on the standard hydrological balance in equation (1) in the main text to derive the final expression for lake volumes in equations (2) and (3).

For an open-basin lake ( $O$ ), the volume of water,  $v_O$  within its basin as a function of time,  $t$ , before breaching (and excluding any losses; discussed further later) can be expressed as

$$v_O[t \leq T_B] = (A_{L,O} + A_{W,O})P \times t, \quad (6)$$

assuming a steady precipitation rate,  $P$ , across the lake area,  $A_{L,O}$  and watershed area  $A_{W,O}$ . When the volume of water within open-basin lake reaches the maximum volume held by the basin, i.e.,  $v_O = V_{L,O}$ , then the lake breaches. When this event occurs at a time  $t = T_B$ , the lake overflows and causes catastrophic canyon erosion (Fassett & Head, 2008; Goudge et al., 2019). Due to the lowered outlet canyon floor, some water drains from the open-basin lake into the downstream closed basin lake. The remaining volume of water in the basin contained after breaching is given by  $V_R$ . Since the open- and closed-basin lakes are now hydrologically connected—and the open-basin lake volume remains steady at  $V_R$ —any additional water input to this volume is not topographically contained and would be transferred downstream. We can now express these two time-dependent states as a piece-wise function:

$$v_O = \begin{cases} (A_{L,O} + A_{W,O})Pt & \text{if } t \leq T_B; \\ V_R & \text{if } t > T_B; \end{cases} \quad (7)$$

This function describes how the lake volume changes as a function of  $t$ , given the measured morphometric parameters  $A_{L,O}$ ,  $A_{W,O}$ , and  $V_R$ , and a known  $P$ . Below we derive a similar, expression for the closed-basin lake.

**Closed-basin lake.** For a closed-basin lake (C) in an embedded coupled system, the changes in lake volume can also be broken down into before and after open-basin lake breaching. Before the breach at  $T_B$ , the closed-basin lake is not connected to the upstream open-basin lake, and so the volume of water that accumulates in the basin, again excluding losses, is simply proportional to the combined watershed and lake areas, analogous to equation (6):

$$v_C[t \leq T_B] = (A_{L,C} + A_{W,C})P \times t. \quad (8)$$

However, after the open-basin lake breach two key events occur. First, the drained volume in the upstream open-basin lake is transferred to the closed-basin lake; we assume this to be instantaneous following a catastrophic erosion event (Goudge et al., 2019). Second, the closed-basin system has now captured the watershed of the upstream open-basin lake, such that the contributing watershed now consists of both watersheds. This means that the volume of a closed-basin after  $T_B$  consists of three terms: (i) the total volume accumulated from equation (8) up to the breach,  $(A_{L,C} + A_{W,C})PT_B$ , (ii) the transferred water volume from upstream lake overflow and outlet canyon erosion,  $V_{L,O} - V_R$ , and (iii) the new rate of volume accumulation from the combined watersheds after breaching,  $(A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})P(t - T_B)$ . We can thus express the post-breach volume of a closed-basin lake as the total sum of these terms, such that

$$v_C[t > T_B] = (A_CPT_B) + (V_{L,O} - V_R) + (A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})P(t - T_B). \quad (9)$$

By expanding the third term and canceling out repeated terms, equation (9) can be written as

$$v_C[t > T_B] = V_{L,O} - V_R + (A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})Pt - (A_{L,O} + A_{W,O})PT_B. \quad (10)$$

In order to simplify this, we substitute the term for the open-basin lake volume at  $T_B$ . The open-basin lake volume  $v_O$  is equal to  $V_{L,O}$  when  $t = T_B$ . Hence, we can rewrite equation (6) as

$$V_{L,O} = (A_{L,O} + A_{W,O})PT_B. \quad (11)$$

Since this is equivalent to the final term in equation (10), we substitute equation (11) into equation (10), which, after simplifying, results in

$$v_C[t > T_B] = (A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})Pt - V_R. \quad (12)$$

Similarly to equation (7), we express the volume of a closed-basin lake as a function of time, using piece-wise functions built from equation (8) and (12):

$$v_C = \begin{cases} (A_{L,C} + A_{W,C})Pt & \text{if } t \leq T_B; \\ (A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})Pt - V_R & \text{if } t > T_B; \end{cases} \quad (13)$$

As a result, we now have two sets of equations, (7) and (13), which describe open- and closed-basin lake volumes, respectively, as a function of time, both before and after open-basin lake breaching. However, both of these expressions require knowledge of a precipitation rate,  $P$ . Since both open- and closed-basin lakes are spatially coincident, and thus it is safe to assume they experience the same precipitation rate, we can remove the precipitation term by normalizing both expressions, obtaining lake volume expressions as a function of relative time (see below).

**Normalization.** In order to solve for lake volumes as a function of relative time, we remove the  $P$  dependency from equations (7) and (13). To do this, we can take equation (11), which defines the open-basin lake volume at the time of breach, and rearrange it so that we instead obtain a definition for  $P$ :

$$P = \frac{V_{L,O}}{(A_{L,O} + A_{W,O})T_B}. \quad (14)$$

Since the precipitation rate is assumed to be the same for both open- and closed-basin lakes, we substitute equation (14) into the precipitation term in equations (7) and (13). This means that  $Pt$  can now be expressed as  $\frac{V_{L,O}}{A_{L,O} + A_{W,O}} \left( \frac{t}{T_B} \right)$ ; this allows the volume expressions to be a function of time relative to breaching, i.e.,  $v = f\left(\frac{t}{T_B}\right)$ . This substitution results in the following expressions:

$$v_O = \begin{cases} V_{L,O} \left( \frac{t}{T_B} \right) & \text{if } t \leq T_B; \\ V_R & \text{if } t > T_B; \end{cases} \quad (15)$$

$$v_C = \begin{cases} (A_{L,C} + A_{W,C}) \frac{V_{L,O}}{A_{L,O} + A_{W,O}} \left( \frac{t}{T_B} \right) & \text{if } t \leq T_B; \\ (A_{W,O} + A_{L,O} + A_{L,C} + A_{W,C}) \frac{V_{L,O}}{A_{L,O} + A_{W,O}} \left( \frac{t}{T_B} \right) - V_R & \text{if } t > T_B. \end{cases} \quad (16)$$

Note that the volume expressions are essentially normalized to the morphology of the open-basin lake. Equations (15) and (16) are similar to equations (2) and (3) in the main text, but do not take into account losses due to evaporation, for which our approach is described below.

**Evaporation losses.** Thus far, equations (6)-(16) do not consider the effects of evaporation on lake volumes. Equation (1) in the main text shows that evaporation is assumed

to occur over the lake area. Note that we assume here all precipitation from the watershed ends up in the lake, whether through surface runoff or infiltration and subsequent re-emergence into the valleys or the lake. Stucky de Quay et al. (2020) investigated how losses from the watershed affected the water balance, showing that even a 50% fractional loss (where half of the precipitation incident on the watershed is lost) results in limited changes to the overall hydrological reconstruction of the lake system. As such, the only lake loss explicitly considered in this study is evaporation from the lake surface (see Supplementary Text S3 above for further discussion on groundwater).

In order to take into account losses due to lake evaporation, we can express evaporation as a fraction of the precipitation. One way to do this is using the aridity index, AI, which is simply the ratio of precipitation to evaporation ( $AI = P/E$ ). Another, related term, is the X ratio defined in Howard (2007), which is given as  $X = (E - P)/P$ , if we assume that all the precipitation ends up in the lake as described above. Note that both values are interchangeable, as  $X = 1/AI - 1$ . The aridity index benefits from being a common parameter that can be easily compared to terrestrial values; however, the X ratio results in a more simplified balance expression. For instance, when using the aridity index as a substitute for the evaporative term, equation (1) becomes

$$V_L = ((A_W + A_L)P - (A_L)\frac{P}{AI})T, \quad (17)$$

whereas the same equation expressed using the X ratio would take the form

$$V_L = (A_W - XA_L)PT. \quad (18)$$

Due to the simplicity of equation (18) relative to equation (17), we favor the X ratio for display purposes. In a system with no evaporation, the aridity index is infinite, and the

X ratio is -1. For this study we use a semiarid scenario as proposed in Stucky de Quay et al. (2020), where open-basin lakes need a minimum global aridity index  $AI \simeq 0.26$  to overflow (consistent with the semiarid hydrological regime required by Matsubara et al., 2011). This value is the most arid scenario that allows all open-basin lakes on Mars to exist. Timescale results in Figure 2e,f, Figure 4, and Figure S3 consider two end-member scenarios: no evaporation and  $AI = 0.26$ . Adding the evaporative terms in equation (18) to equations (15) and (16) results in the final equations (2) and (3) in the main text. Finally, to calculate the values plotted in Figures 2e,f, we normalize equations (2) and (3) by the volume of the closed-basin lake, i.e., both sides of both equations are divided by  $V_{L,C}$ . This allows all the plots to have maximum permitted normalized volumes  $< 1$  for better comparison.

**Embedded vs. Adjacent systems.** The expressions derived thus far are only applicable to embedded coupled systems, i.e., systems wherein some lake overflow volume from the open-basin lake is transferred directly (and instantaneously) to the closed-basin lake, and where the closed-basin lake captures the watershed of the open-basin lake. However, one out of our seven mapped coupled systems is not embedded (Table S2; Figure S2), and is instead classified as an adjacent coupled system. These systems share significant drainage divides and are also assumed to be formed synchronously, with the main difference to embedded systems being that the outlet canyon does not flow into the closed-basin lake. For the case of our one adjacent system,  $v_O = f(t/T_B)$  remains the same, but equation (3) takes the simpler, modified form:

$$v_C = (A_{W,C} - X A_{L,C}) \frac{V_{L,O}}{A_{W,O} - X A_{L,O}} \left( \frac{t}{T_B} \right), \quad (19)$$

for all values of  $\frac{t}{T_B}$  (i.e., independent of breaching), and where  $v_C < V_{L,C}$ . For our unique coupled system (Basin ID 171/140; Table S2), we use equation (19) instead of (3). Note that Figure 3b,c only includes the 6 embedded systems, and not the adjacent system, since it does not follow the schematic behavior presented in Figure 3a. Relative timescale results are summarized in Supplementary Table S4.

**Timescales.** In addition to investigating lake volume changes with respect to relative timescales, we also derive expressions to solve for the absolute runoff episode duration lengths permitted. By rearranging equation (14), we can obtain an expression for  $T_B$ , such that

$$T_B = \frac{V_{L,O}}{(A_{L,O} + A_{W,O})P}. \quad (20)$$

Since the breaching timescale is the minimum timescale permitted to allow for the open-basin lake to breach,  $T_B$ , we combine this with the evaporation loss term in equation (18) to obtain the equation (4) presented in the main text. Conversely, for the maximum timescale for an embedded couple system, we take equation (12) and find the maximum volume permitted,  $v_C = V_{L,C}$ , and set  $t = T_{max}$ , such that

$$V_{L,C} = (A_{L,O} + A_{W,O} + A_{L,C} + A_{W,C})PT_{max} - V_R. \quad (21)$$

We then use the same evaporation expression from equation (18), and rearrange to solve for  $T_{max}$ , resulting in equation (5) in the main text. For our adjacent coupled system, equation (21) takes the simpler form:

$$V_{L,C} = (A_{L,C} + A_{W,C})PT_{max}, \quad (22)$$



as it has no dependency on the open-basin lake morphology. Accounting for evaporative losses, this results in the following expression for  $T_{max}$  as recorded by adjacent coupled systems:

$$T_{max} = \frac{V_{L,C}}{(A_{W,C} - X A_{L,C})P}, \quad (23)$$

analogous to equation (5) in the main text.

**Text S5. Non-uniform precipitation and aridity in space and time**

Here we discuss the requirements and assumptions related to precipitation rate,  $P$ , both spatially and temporally, as well as the aridity (see below). For our simplified hydrologic balance in equation (1), the true precipitation rate does not need to be uniform in space or time, and is allowed to vary in these dimensions. However, the single value of  $P$  used for this equation is a time-averaged value for the duration of  $T$  and also space-averaged across the total lake system area ( $A_W + A_L$ ).

For equations (2) and (3), used to calculate lake volumes over time, it is assumed that (i) the precipitation rate is steady over the duration of  $T$ , and that (ii) it is equal for both the open- and the closed-basin lake. If the precipitation rate is not steady in time, then the resulting  $v(t)$  curves in Figure 2e,f would not be straight lines as currently depicted, but would display some shorter-scale variability. However, the values for the limits  $T_{max}/T_B$  would remain largely unchanged as long as the average  $P$  for the entire duration was considered, and that the time-averaged  $P$  before and after breaching were broadly equivalent. For the second assumption, we note that it is indeed very likely that local orographic effects existed (e.g. Scanlon et al., 2013), perhaps resulting in slightly greater  $P$  values for open-basin lakes, since they are generally further upstream (especially in embedded systems) and thus at a higher elevation. Below we consider how this discrepancy in precipitation values between open- and closed-basin lakes may affect relative timescales. Building on equations (4) and (5) from the main body,  $T_{max}/T_B$  may be expressed as

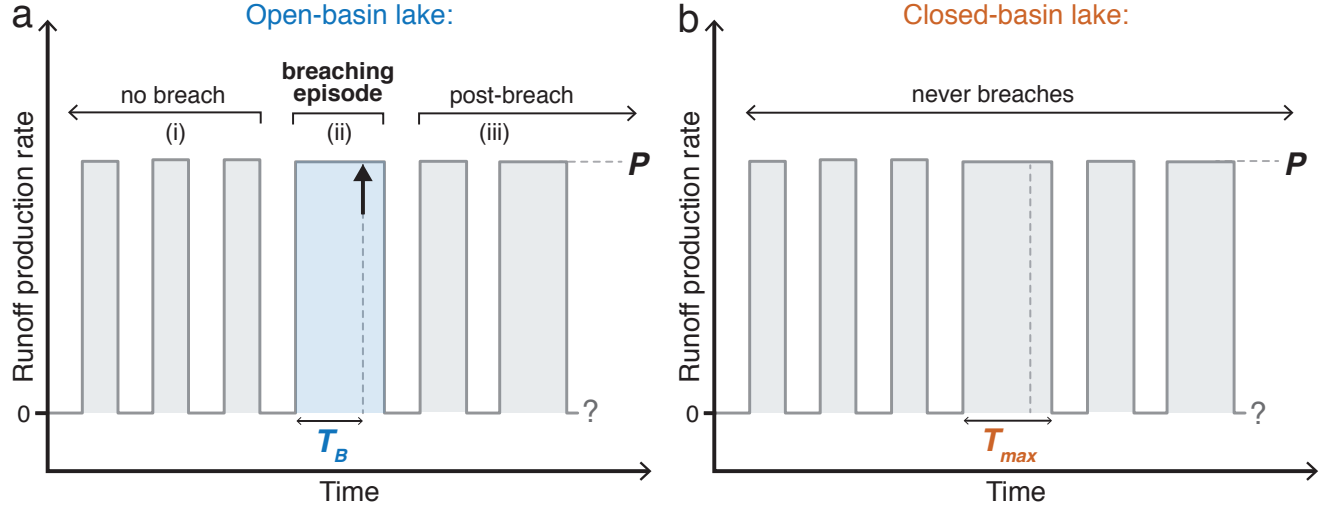
$$\frac{T_{max}}{T_B} = \frac{P_O}{P_{C+O}} \times \frac{(V_{L,C} + V_R)(A_{W,O} - XA_{L,O})}{V_{L,O}(A_{W,O} + A_{W,C} - XA_{L,O} - XA_{L,C})}, \quad (24)$$

where  $\frac{P_O}{P_{C+O}}$  is the ratio of average precipitation rate incident on the total open-basin lake area ( $A_{L,O}$  and  $A_{W,O}$ ) and the average precipitation rate incident on the combined, total area of the coupled system ( $A_{L,O}$ ,  $A_{W,O}$ ,  $A_{L,C}$ , and  $A_{W,C}$ ). Note that this expression is for embedded systems, and a similar variation using equation (23) may be applied to adjacent systems. To calculate the  $\frac{T_{max}}{T_B}$  results shown in Figure 2e,f and Table S4, we assume that  $\frac{P_O}{P_{C+O}} = 1$ , i.e., the average precipitation rate of the open-basin lake is the same as that of the closed-basin lake. However, as implied by equation (24), if these are not the same, then  $\frac{T_{max}}{T_B} \propto \frac{P_O}{P_{C+O}}$ . Thus, if the precipitation were twice as large in the open-basin lake, then  $\frac{T_{max}}{T_B}$  would be doubled. Because the climate models used here have a coarse resolution, such that datapoints are often separated by a few degrees, it is not possible to fully assess whether local orographic effects are reflected in precipitation outputs at the scale of our watersheds. Further identification and study of more coupled systems, with open- and closed-basin lakes at variable elevations (particularly adjacent coupled systems, for which the open-basin lake does not need to be upstream), would provide valuable insights into this short wavelength altitude dependency. Alternatively, future work towards developing meso-scale climate models in regions with lake systems, potentially reproducing orographic effects at topographic scales relevant to basin geometries, would also shed further light into the importance of this process during early Mars.

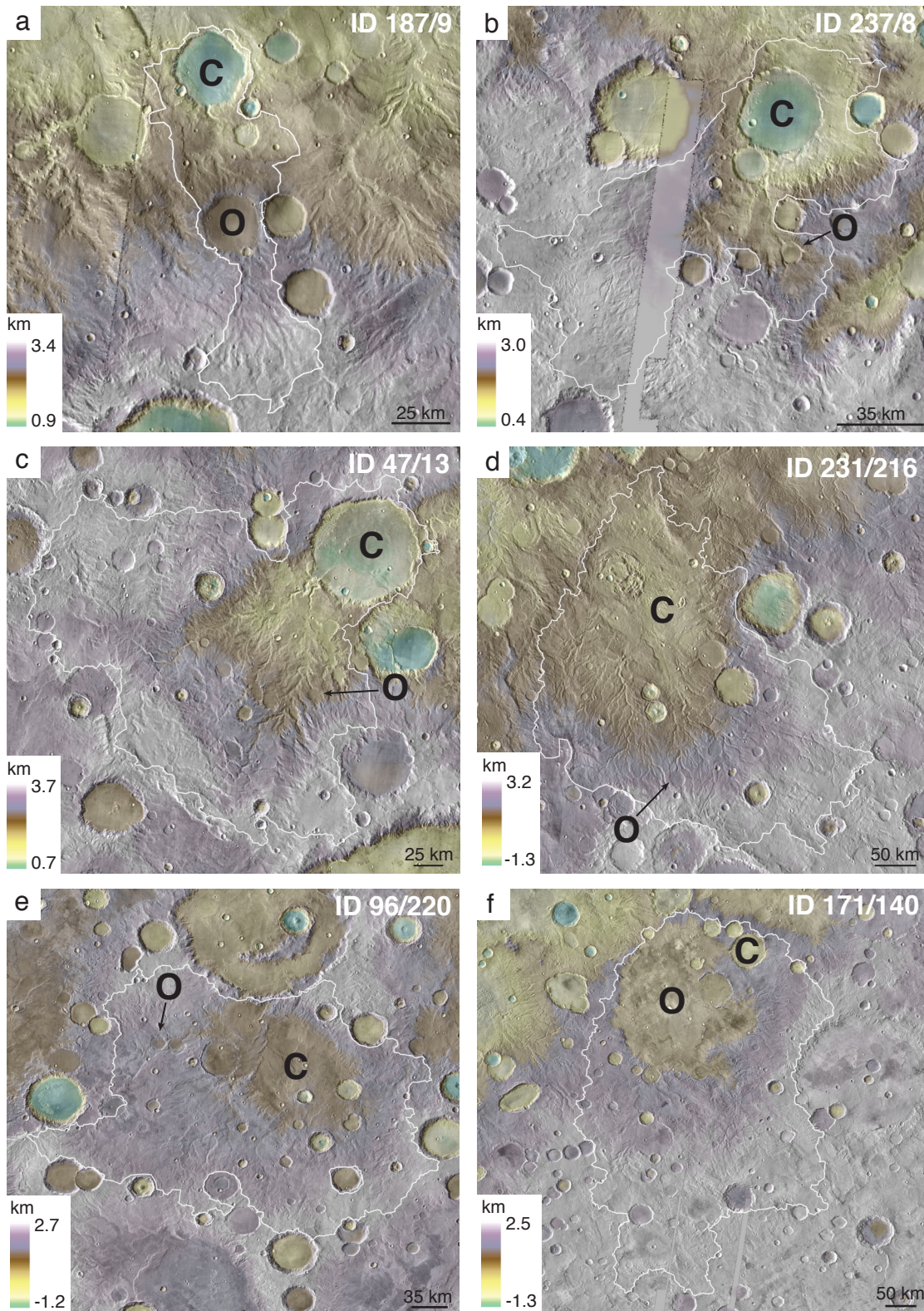
Although the spatial heterogeneity of  $P$  between basins has an effect on  $\frac{T_{max}}{T_B}$ , the absolute values for  $T_{max}$  do not rely on any assumption on the relative precipitation between both lakes. As long as the time-averaged precipitation across the entire runoff episode can be assumed to be well-represented by the local  $P$  value extracted for each

watershed from each climate model scenario, then spatial and temporal variations of  $P$  are not critically important.

In our hydrological reconstruction, one key assumption we make is that the relationship between the evaporation rate,  $E$ , and  $P$  is spatially and temporally constant and defined by the aridity index,  $AI \simeq 0.26$ , which is an estimate of the most arid scenario that allowed for open-basin lakes to exist on early Mars (Stucky de Quay et al., 2020). In our calculations we also consider a scenario with no evaporation, which is an end-member overestimate on how humid the Mars regime was. Together, these two aridity regimes are likely to bound regionally averaged real values. However, we cannot solve for episode durations if there are two unknowns ( $E$  and  $P$ ) and so this constant value of  $AI$  is used for all systems, across the coupled lake areas. If both the precipitation and evaporation rates are spatially variable and uncorrelated, within a single coupled system, then  $T_{max}$  is unsolvable (since there is no single  $AI$  for the system). Future work that includes spatially variable aridity (evaporation rates) from global climate models, in addition to precipitation rates, into our hydrological reconstruction could provide critical insight into the validity of this assumption and the accuracy of our results.

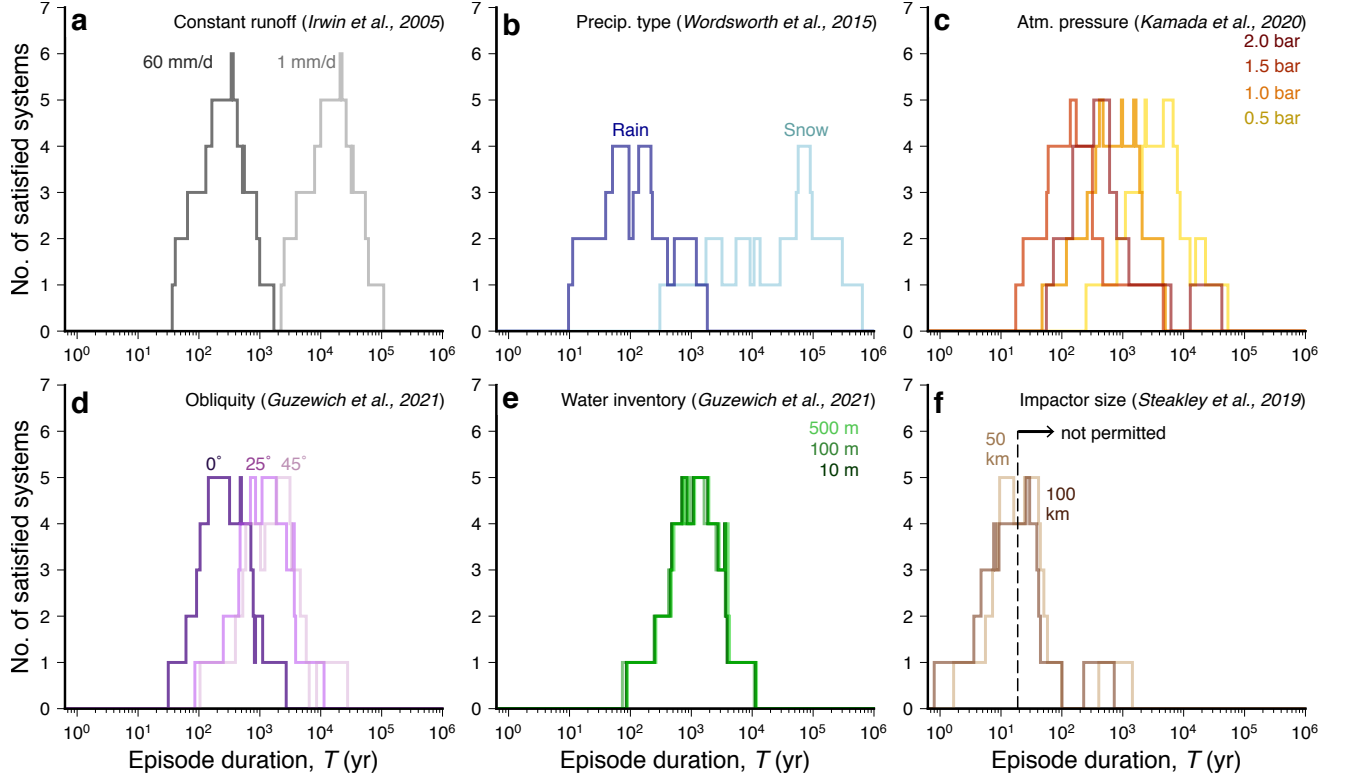


**Figure S1:** Schematic oscillating climate for late Noachian / early Hesperian Mars ( $>3.7$  Ga), with variable runoff production rate over time (modified from Figure S1 in Stucky de Quay et al., 2020). Note that episodic runoff may be sourced from rainfall or snowmelt (e.g., Kite et al., 2013; Kite, 2019). In a coupled lake system, the (a) open-basin lake breaches (= black arrow) if a given runoff episode is sufficiently continuous, i.e., the duration exceeds  $T_B$ , and enough liquid water is supplied (where  $P$  is the time-averaged runoff rate). We term this episode the ‘breaching runoff episode’ (= light blue shaded box; (ii)). However, within the same coupled system, the (b) closed-basin lake never breaches. Thus, we can estimate maximum runoff episode duration,  $T_{max}$ , for a given runoff rate,  $P$ , from climate model outputs. In this work we quantify  $T_B$  and  $T_{max}$  for the breaching runoff episode of each coupled system. Importantly, episode durations before the breaching episode (see (i)) must always be less than  $T_B$ , but can be longer or shorter after the breaching episode (see (iii)). No episode duration can ever be greater than  $T_{max}$  (as this would cause the closed-basin lake to breach). Note that to erode the deep valley networks which feed these coupled systems, water volumes greatly exceeding lake volumes are required, suggesting multiple runoff events likely occurred (see Discussion section in the main text).

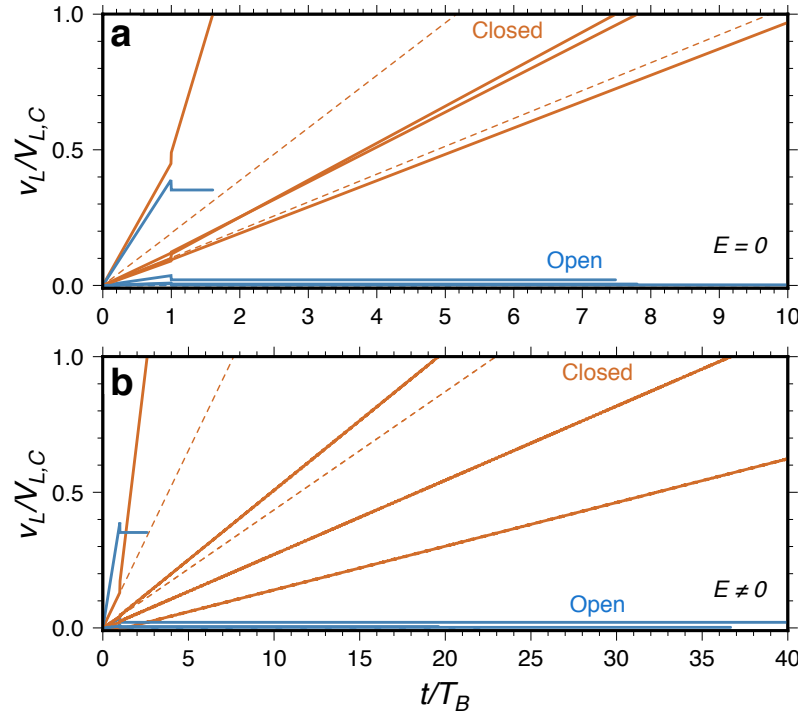


**Figure S2:** Coupled lake systems identified on Mars (excluding ID 185/89 in Figure 2a). O = open-basin lake; C = closed basin lake; white polygon = combined watershed and lake areas of each coupled system (Table S2). Elevation and images from MOLA and THEMIS, respectively.



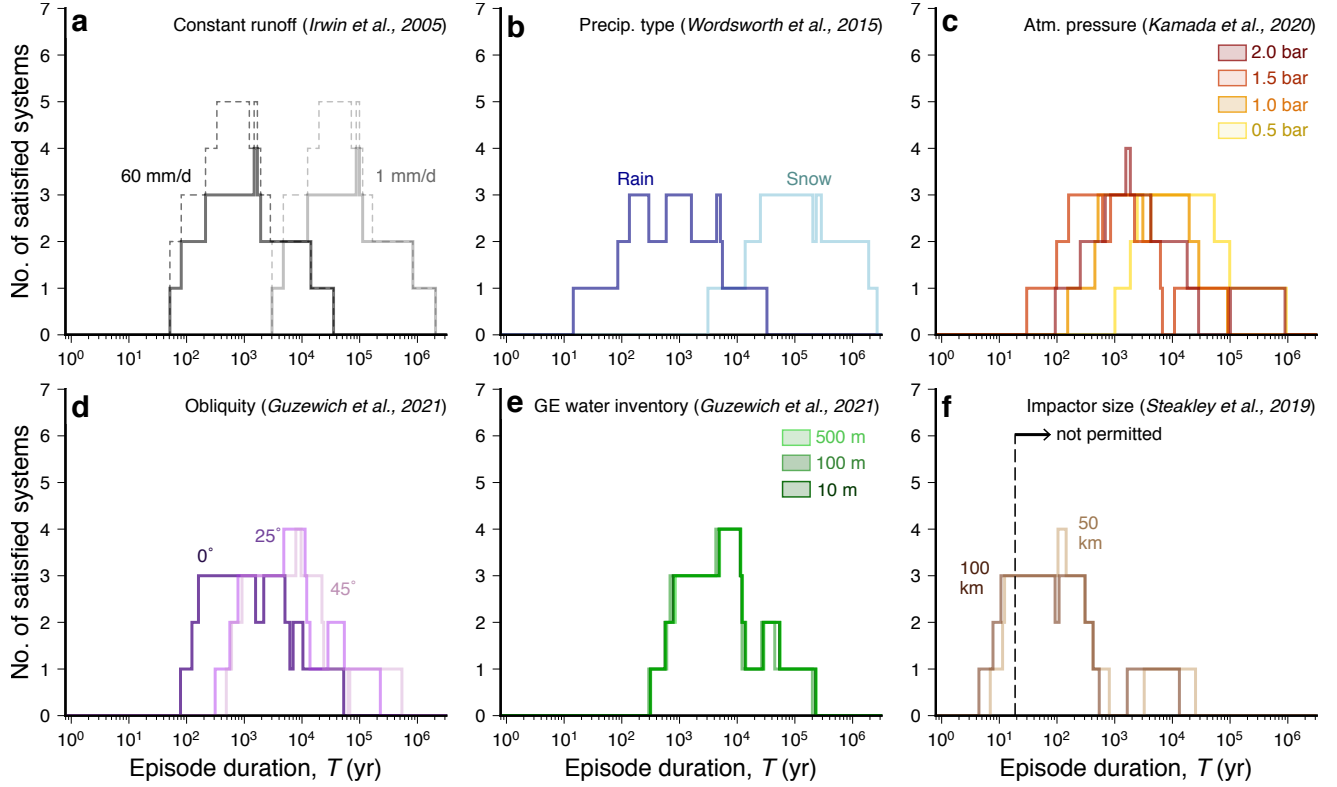


**Figure S3:** Distribution of runoff episode durations (assuming no evaporation;  $E=0$ ) that satisfy the 7 studied coupled systems using different runoff constraints. See Figure 4 in main text for comparison and further details (where aridity index,  $AI = 0.26$ ).



**Figure S4:** Lake volume changes over time (analogous to Figure 2e,f), but excluding two systems: Basin IDs 47/13 and 231/216 (shown in dashed lines; see Supplementary Text S1 for discussion; Table S2; Figure S2). Note that the total range of  $T_{max}/T_B$  remains unchanged. See Figures 2e,f for additional details.





**Figure S5:** Distribution of runoff episode durations that satisfy 5 of the studied coupled systems using different runoff constraints. Here we exclude two systems: Basin IDs 47/13 and 231/216 (see Supplementary Text S1 for discussion; Table S2; Figure S2). Note that the new maximum is now 5. Dashed distributions in (a) show original distributions from Figure 4 for comparison. See Figure 4 in main text for further details (where all 7 coupled systems are considered). Note that location of peaks is similar to Figure 4.

**Table S1:** Water availability rates and their data sources. Minimum and/or maximum values are shown below in the format they were published in (before converted to an order of magnitude estimate in mm per Earth year for Figure 1 in the main text). Rates/studies are listed in the same order as Figure 1. When min/max results were not explicitly stated or tabulated, these were estimated from scale bar ranges provided in figures. The specific location of data in the original publication is indicated in the final column. Studies marked with an asterisk (\*) indicate datasets that were made available to the authors and were used to derive timescales (e.g., Table S5; Figure 4). For rates given in ‘years’, if the study does not explicitly state Earth or Mars years (written as Eyr or Myr below), we assume Mars years for model studies and Earth years for geomorphic studies. For rates given in ‘days’ or ‘hours’, we assume Earth time units (unless explicitly stated otherwise; e.g., for Ramirez et al., 2020; ‘Mars day’). Mars/Earth year conversions (factor of 1.88) have negligible effects on our order of magnitude estimates in Figure 1.

Rate	Study	Data location
8 – 3000 m in $10^6$ Eyr	Fastook & Head (2015)	Table 1; Figs. 7-12(b, f, j)
–2 – 0.5 $\log_{10}(\text{kg/m}^2/\text{avg.})$ in 5 Myr	Wordsworth et al. (2015)*	Fig. 5a
0.001 – 5 cm in a Mars winter	Mischna et al. (2003)	Figs. 6, 8, 10
0.009 – 1.26 cm/Myr	Urata & Toon (2013)	Table 4
< 33 $\text{kg/m}^2$ in 40 Myr	Wordsworth et al. (2013)	Figs. 4, 6, 7, 10
0 – 3 $\log_{10}(\text{mm/Myr})$	Kamada et al. (2020)*	Fig. 8
0.001 – 1 mm/day	Von Paris et al. (2015)	Abstract; Fig. 8
< 20 mm/yr	Palumbo et al. (2018)	Section 3.3.2; Fig. 11
< $10^{-2}$ mm/hr	Scanlon et al. (2013)	Section 3.1; Fig. 1
–1 – 0.5 $\log_{10}(\text{m/Myr}/\text{avg.})$	Wordsworth et al. (2015)*	Fig. 4b
30 mm–2.4 m/Myr	Ramirez et al. 2020	Figs. 11, 12
< 100 mm/Myr	Guzewich et al. (2021)*	Fig. 2
0.23 – 5.84 m/Myr	Steakley et al. (2019)*	Abstract
< 100 cm/yr	Soto et al. (2010)	Fig. 1B
0.7 – 9.69 mm/Mday	Ramirez et al. (2020)	Table 1
1.5 – 10.6 mm/day	Von Paris et al. (2015)	Table 1; Section 2.2.3
0.1 – 6 cm/day	Irwin et al. (2005)*	Table 1
4 – 11 m in a Mars summer	Fastook & Head (2015)	Conclusions (Section 5.9)
0.4 – 63 cm/day	Hoke et al. (2011)	Table 3
< 2 – 3 mm/hr	Kite et al. (2013)	Section 8.5
< 0.15 m/day	Scanlon et al. (2016)	Section 3.1

**Table S2:** List of 7 coupled lake systems on Mars used for this study (originally identified in Stucky de Quay et al., 2020). Each row corresponds to a single coupled system, providing details on both the open- and closed-basin lake morphological parameters. The system type indicates whether it as an embedded (Em) or adjacent (Ad) system (see main text for description).

Open-basin lakes (O)							Closed-basin lakes (C)							Type
Basin	Lat.	Long.	Lake Area, $A_{L,O}$ (m <sup>2</sup> )	Lake Volume, $V_{L,O}$ (m <sup>3</sup> )	Watershed Area, $A_{W,O}$ (m <sup>2</sup> )	Remaining Lake Volume, $V_R$ (m <sup>3</sup> )	Basin	Lat.	Long.	Lake Area, $A_{L,C}$ (m <sup>2</sup> )	Lake Volume, $V_{L,C}$ (m <sup>3</sup> )	Watershed Area, $A_{W,C}$ (m <sup>2</sup> )		
ID	(°)	(°)					ID	(°)	(°)					
187	-7.2	43	6.73E+08	7.08E+10	2.69E+09	6.38E+10	9	-5.8	42.8	9.37E+08	1.81E+11	2.95E+09	Em	
<sup>a</sup> 231	7.8	47.8	7.13E+07	2.21E+09	9.23E+08	1.21E+09	216	11.2	47.3	1.64E+10	2.00E+12	7.48E+10	Em	
185	2.2	45.5	1.53E+08	1.21E+10	1.35E+09	6.88E+09	89	3	45.5	1.20E+09	3.32E+11	2.93E+09	Em	
237	-4.4	88.4	4.22E+07	3.53E+09	8.36E+08	2.05E+09	8	-3.3	88.3	2.16E+09	3.94E+11	9.59E+09	Em	
<sup>a</sup> 47	-10.4	128	8.41E+07	6.33E+09	5.43E+08	5.56E+08	13	-8.3	128.7	1.05E+10	3.16E+12	4.95E+10	Em	
96	-29.8	147.2	2.01E+08	1.19E+10	4.50E+09	4.38E+09	220	-30.1	149.7	1.37E+10	1.83E+12	5.20E+10	Em	
171	-21.3	-5.3	5.15E+10	7.55E+12	1.77E+11	1.04E+12	140	-19.9	-2.9	3.44E+09	1.46E+12	1.06E+10	Ad	

<sup>a</sup> Coupled systems removed from consideration for Figures S4 and S5. See Supplementary Text S1 for more information.

**Table S3:** Summary of all model outputs used in this work, with a total of 16 scenarios from four climate model studies. Note only 13 scenarios are used in Figure 4.

Study/Model	Scenario	Location in Figure 4
Wordsworth et al. (2015)	Rainfall (1 bar, solar flux= $764.5 \text{ W m}^{-2}$ )	b (rain)
	Snowfall (0.4 bar, solar flux= $441.1 \text{ W m}^{-2}$ )	b (snow)
Kamada et al. (2020)	0.5 bar	c (0.5 bar)
	1.0 bar	c (1.0 bar)
	1.5 bar	c (1.5 bar)
	2.0 bar	c (2.0 bar)
Guzewich et al. (2021)	10 m GEL <sup>a</sup> , obliquity= $25^\circ$	d ( $25^\circ$ ) & e (10 m GEL)
	10 m GEL, obliquity= $45^\circ$	d ( $45^\circ$ )
	10 m GEL, obliquity= $0^\circ$	d ( $0^\circ$ )
	100 m GEL, obliquity= $25^\circ$	e (100 m GEL)
	100 m GEL, obliquity= $0^\circ$	-
	500 m GEL, obliquity= $25^\circ$	e (500 m GEL)
Steakley et al. (2019)	1 bar, 50 km-impactor, RAC <sup>b</sup>	f (50 km)
	1 bar, 50 km-impactor, RIC <sup>b</sup>	-
	1 bar, 100 km-impactor, RAC	f (100 km)
	150 mbar, 100 km-impactor, RIC	-

<sup>a</sup>GEL = global equivalent layer; <sup>b</sup>RAC/RIC = radiatively active/inert clouds.

**Table S4:** Results for the ratio between the maximum episode duration,  $T_{max}$ , and the (minimum) open-basin lake breaching duration,  $T_B$ , for all embedded coupled systems as shown in Figure 2e,f, as well as the adjacent coupled system (Basin ID 171/140). These values are a maximum bound on how long runoff production could have occurred after upstream breaching. We include results with and without evaporation (where AI = aridity index and  $E$  = evaporation).

Basin ID	$T_{max}/T_B$	
	AI $\sim 0.26$	$E = 0$
47/13	7.64	5.17
171/140	7.44	3.15
231/216	23.0	9.74
96/220	36.7	10.3
237/8	19.6	7.80
185/89	63.4	7.49
187/9	2.59	1.61

**Table S5:** Extracted precipitation,  $P$ , from each model/study (listed in Table S3) for each individual coupled system (listed in Table S2) and the derived timescale values (lake-breaching runoff duration,  $T_B$ , and maximum runoff duration,  $T_{max}$ ) used to generate histograms in Figure 4 (and Figures S3, S5). We include results with and without evaporation (where AI = aridity index and  $E$  = evaporation). Time units are calculated in Earth years.

Study/Scenario	Basin ID	$P$ (mm/yr)	AI $\sim$ 0.26		$E = 0$	
			$T_B$ (yr)	$T_{max}$ (yr)	$T_B$ (yr)	$T_{max}$ (yr)
<i>Irwin et al. (2005):</i>						
1 mm/yr	47/13	1.00E+00	2.10E+04	1.61E+05	1.01E+04	5.22E+04
	171/140	1.00E+00	2.61E+05	1.94E+06	3.31E+04	1.04E+05
	231/216	1.00E+00	3.09E+03	7.07E+04	2.23E+03	2.17E+04
	96/220	1.00E+00	3.03E+03	1.11E+05	2.53E+03	2.61E+04
	237/8	1.00E+00	4.94E+03	9.66E+04	4.02E+03	3.14E+04
	185/89	1.00E+00	1.33E+04	8.31E+05	8.03E+03	6.01E+04
	187/9	1.00E+00	9.29E+04	2.40E+05	2.10E+04	3.38E+04
60 mm/yr	47/13	6.00E+01	3.51E+02	2.68E+03	1.68E+02	8.69E+02
	171/140	6.00E+01	4.35E+03	3.24E+04	5.51E+02	1.74E+03
	231/216	6.00E+01	5.14E+01	1.18E+03	3.71E+01	3.62E+02
	96/220	6.00E+01	5.05E+01	1.85E+03	4.21E+01	4.35E+02
	237/8	6.00E+01	8.23E+01	1.61E+03	6.70E+01	5.23E+02
	185/89	6.00E+01	2.21E+02	1.39E+04	1.34E+02	1.00E+03
	187/9	6.00E+01	1.55E+03	4.00E+03	3.50E+02	5.63E+02
<i>Wordsworth et al. (2015):</i>						
Rainfall	47/13	2.48E+02	8.48E+01	6.48E+02	4.07E+01	2.10E+02
	171/140	5.89E+01	4.44E+03	3.30E+04	5.62E+02	1.77E+03
	231/216	2.27E+02	1.36E+01	3.11E+02	9.80E+00	9.55E+01
	96/220	2.18E+01	1.39E+02	5.08E+03	1.16E+02	1.20E+03
	237/8	3.40E+02	1.45E+01	2.84E+02	1.18E+01	9.23E+01
	185/89	1.52E+02	8.71E+01	5.46E+03	5.27E+01	3.95E+02
	187/9	1.50E+02	6.21E+02	1.60E+03	1.41E+02	2.26E+02
Snow	47/13	1.77E-01	1.19E+05	9.07E+05	5.70E+04	2.95E+05
	171/140	1.11E+00	2.36E+05	1.76E+06	2.99E+04	9.41E+04
	231/216	7.14E+00	4.32E+02	9.90E+03	3.12E+02	3.04E+03
	96/220	4.26E-02	7.11E+04	2.60E+06	5.93E+04	6.12E+05
	237/8	3.62E-01	1.36E+04	2.67E+05	1.11E+04	8.66E+04
	185/89	4.37E+00	3.03E+03	1.90E+05	1.84E+03	1.37E+04
	187/9	3.65E+00	2.55E+04	6.58E+04	5.77E+03	9.26E+03
<i>Kamada et al. (2020):</i>						
0.5 bar	47/13	4.36E+00	4.82E+03	3.68E+04	2.32E+03	1.20E+04
	171/140	2.10E+00	1.24E+05	9.26E+05	1.58E+04	4.96E+04
	231/216	9.12E+00	3.38E+02	7.75E+03	2.44E+02	2.38E+03
	96/220	1.18E+00	2.57E+03	9.38E+04	2.14E+03	2.21E+04
	237/8	4.97E+00	9.93E+02	1.94E+04	8.08E+02	6.31E+03
	185/89	7.17E+00	1.85E+03	1.16E+05	1.12E+03	8.39E+03

**Table S5 continued from previous page**

Study/Scenario	Basin ID	$P$ (mm/yr)	AI $\sim$ 0.26		$E = 0$	
			$T_B$ (yr)	$T_{max}$ (yr)	$T_B$ (yr)	$T_{max}$ (yr)
1.0 bar	187/9	4.61E+00	2.02E+04	5.21E+04	4.56E+03	7.33E+03
	47/13	2.77E+01	7.60E+02	5.80E+03	3.65E+02	1.89E+03
	171/140	2.15E+01	1.21E+04	9.03E+04	1.54E+03	4.84E+03
	231/216	4.65E+01	6.63E+01	1.52E+03	4.79E+01	4.66E+02
	96/220	5.87E+00	5.16E+02	1.89E+04	4.30E+02	4.44E+03
	237/8	3.22E+01	1.53E+02	3.00E+03	1.25E+02	9.74E+02
	185/89	2.92E+01	4.54E+02	2.85E+04	2.75E+02	2.06E+03
1.5 bar	187/9	2.10E+01	4.42E+03	1.14E+04	1.00E+03	1.61E+03
	47/13	1.68E+02	1.25E+02	9.54E+02	6.00E+01	3.10E+02
	171/140	2.23E+01	1.17E+04	8.71E+04	1.48E+03	4.66E+03
	231/216	1.27E+02	2.44E+01	5.59E+02	1.76E+01	1.71E+02
	96/220	1.81E+01	1.67E+02	6.12E+03	1.40E+02	1.44E+03
	237/8	1.64E+02	3.02E+01	5.90E+02	2.45E+01	1.92E+02
	185/89	1.29E+02	1.03E+02	6.45E+03	6.23E+01	4.67E+02
2.0 bar	187/9	1.08E+02	8.63E+02	2.23E+03	1.95E+02	3.14E+02
	47/13	6.47E+01	3.25E+02	2.48E+03	1.56E+02	8.06E+02
	171/140	2.38E+00	1.10E+05	8.18E+05	1.39E+04	4.38E+04
	231/216	3.88E+01	7.95E+01	1.82E+03	5.74E+01	5.59E+02
	96/220	4.25E+00	7.13E+02	2.61E+04	5.95E+02	6.14E+03
	237/8	5.29E+01	9.34E+01	1.83E+03	7.60E+01	5.93E+02
	185/89	4.85E+01	2.74E+02	1.72E+04	1.66E+02	1.24E+03
<i>Guzewich et al. (2021):</i> 10 m GEL, obliquity=25°	187/9	5.74E+01	1.62E+03	4.18E+03	3.66E+02	5.88E+02
	47/13	1.40E+01	1.51E+03	1.15E+04	7.23E+02	3.73E+03
	171/140	9.14E+00	2.86E+04	2.13E+05	3.62E+03	1.14E+04
	231/216	2.59E+01	1.19E+02	2.73E+03	8.61E+01	8.38E+02
	96/220	9.73E+00	3.11E+02	1.14E+04	2.60E+02	2.68E+03
	237/8	8.62E+00	5.73E+02	1.12E+04	4.66E+02	3.64E+03
	185/89	1.63E+01	8.15E+02	5.11E+04	4.93E+02	3.69E+03
10 m GEL, obliquity=45°	187/9	1.84E+01	5.06E+03	1.31E+04	1.15E+03	1.84E+03
	47/13	8.09E+00	2.60E+03	1.99E+04	1.25E+03	6.45E+03
	171/140	3.73E+00	6.99E+04	5.21E+05	8.86E+03	2.79E+04
	231/216	2.12E+01	1.46E+02	3.34E+03	1.05E+02	1.02E+03
	96/220	4.66E+00	6.50E+02	2.38E+04	5.43E+02	5.60E+03
	237/8	9.80E+00	5.04E+02	9.86E+03	4.10E+02	3.20E+03
	185/89	1.32E+01	1.00E+03	6.29E+04	6.07E+02	4.55E+03
10 m GEL, obliquity=0°	187/9	1.09E+01	8.49E+03	2.19E+04	1.92E+03	3.08E+03
	47/13	6.65E+01	3.16E+02	2.42E+03	1.52E+02	7.85E+02
	171/140	3.77E+01	6.94E+03	5.16E+04	8.78E+02	2.76E+03
	231/216	6.98E+01	4.42E+01	1.01E+03	3.19E+01	3.11E+02
	96/220	2.35E+01	1.29E+02	4.71E+03	1.08E+02	1.11E+03
	237/8	6.45E+01	7.66E+01	1.50E+03	6.23E+01	4.87E+02

Table S5 continued from previous page

Study/Scenario	Basin ID	$P$ (mm/yr)	AI $\sim$ 0.26		$E = 0$	
			$T_B$ (yr)	$T_{max}$ (yr)	$T_B$ (yr)	$T_{max}$ (yr)
100 m GEL, obliquity=25°	185/89	8.43E+01	1.57E+02	9.86E+03	9.53E+01	7.13E+02
	187/9	4.23E+01	2.19E+03	5.67E+03	4.97E+02	7.98E+02
	47/13	1.48E+01	1.42E+03	1.09E+04	6.83E+02	3.53E+03
	171/140	9.82E+00	2.66E+04	1.98E+05	3.37E+03	1.06E+04
	231/216	3.07E+01	1.00E+02	2.30E+03	7.25E+01	7.06E+02
	96/220	1.05E+01	2.89E+02	1.06E+04	2.41E+02	2.49E+03
	237/8	8.30E+00	5.95E+02	1.16E+04	4.84E+02	3.78E+03
100 m GEL, obliquity=0°	185/89	1.89E+01	7.02E+02	4.40E+04	4.25E+02	3.18E+03
	187/9	2.12E+01	4.37E+03	1.13E+04	9.90E+02	1.59E+03
	47/13	7.54E+01	2.79E+02	2.13E+03	1.34E+02	6.91E+02
	171/140	4.38E+01	5.96E+03	4.44E+04	7.55E+02	2.38E+03
	231/216	8.65E+01	3.57E+01	8.17E+02	2.58E+01	2.51E+02
	96/220	2.66E+01	1.14E+02	4.16E+03	9.50E+01	9.80E+02
	237/8	7.73E+01	6.39E+01	1.25E+03	5.20E+01	4.06E+02
500 m GEL, obliquity=25°	185/89	1.23E+02	1.08E+02	6.77E+03	6.54E+01	4.89E+02
	187/9	5.78E+01	1.61E+03	4.15E+03	3.64E+02	5.84E+02
	47/13	1.26E+01	1.66E+03	1.27E+04	7.99E+02	4.13E+03
	171/140	8.76E+00	2.98E+04	2.22E+05	3.78E+03	1.19E+04
	231/216	2.47E+01	1.25E+02	2.86E+03	9.01E+01	8.78E+02
	96/220	9.49E+00	3.19E+02	1.17E+04	2.66E+02	2.75E+03
	237/8	8.10E+00	6.10E+02	1.19E+04	4.96E+02	3.87E+03
<i>Steakley et al. (2019):</i> 1 bar, 50 km-impactor, RAC	185/89	1.53E+01	8.69E+02	5.45E+04	5.26E+02	3.94E+03
	187/9	1.79E+01	5.19E+03	1.34E+04	1.17E+03	1.89E+03
	47/13	1.06E+03	1.98E+01	1.51E+02	9.51E+00	4.91E+01
	171/140	7.55E+01	3.46E+03	2.58E+04	4.38E+02	1.38E+03
	231/216	1.31E+03	2.36E+00	5.41E+01	1.70E+00	1.66E+01
	96/220	2.59E+02	1.17E+01	4.28E+02	9.76E+00	1.01E+02
	237/8	6.92E+02	7.14E+00	1.40E+02	5.81E+00	4.54E+01
1 bar, 50 km-impactor, RIC	185/89	1.02E+03	1.30E+01	8.15E+02	7.87E+00	5.89E+01
	187/9	8.39E+02	1.11E+02	2.86E+02	2.50E+01	4.02E+01
	47/13	8.33E+02	2.52E+01	1.93E+02	1.21E+01	6.26E+01
	171/140	3.45E+02	7.57E+02	5.64E+03	9.59E+01	3.02E+02
	231/216	8.66E+02	3.56E+00	8.17E+01	2.57E+00	2.51E+01
	96/220	1.82E+02	1.66E+01	6.09E+02	1.39E+01	1.43E+02
	237/8	1.04E+03	4.75E+00	9.30E+01	3.87E+00	3.02E+01
1 bar, 100 km-impactor, RAC	185/89	7.02E+02	1.89E+01	1.18E+03	1.14E+01	8.56E+01
	187/9	4.07E+02	2.28E+02	5.89E+02	5.16E+01	8.29E+01
	47/13	1.33E+03	1.58E+01	1.21E+02	7.60E+00	3.93E+01
	171/140	1.47E+02	1.77E+03	1.32E+04	2.24E+02	7.06E+02
	231/216	2.85E+03	1.08E+00	2.48E+01	7.80E-01	7.60E+00
	96/220	2.78E+02	1.09E+01	3.98E+02	9.08E+00	9.37E+01

**Table S5 continued from previous page**

Study/Scenario	Basin ID	$P$ (mm/yr)	AI $\sim 0.26$		$E = 0$	
			$T_B$ (yr)	$T_{max}$ (yr)	$T_B$ (yr)	$T_{max}$ (yr)
150 mbar, 100 km-impactor, RIC	237/8	1.11E+03	4.43E+00	8.67E+01	3.61E+00	2.82E+01
	185/89	1.66E+03	8.01E+00	5.02E+02	4.85E+00	3.63E+01
	187/9	7.98E+02	1.16E+02	3.00E+02	2.63E+01	4.23E+01
	47/13	1.48E+02	1.42E+02	1.09E+03	6.83E+01	3.53E+02
	171/140	1.89E+02	1.39E+03	1.03E+04	1.75E+02	5.52E+02
	231/216	9.28E+02	3.32E+00	7.61E+01	2.40E+00	2.34E+01
	96/220	2.39E+02	1.27E+01	4.64E+02	1.06E+01	1.09E+02
	237/8	1.30E+02	3.81E+01	7.46E+02	3.10E+01	2.42E+02
	185/89	4.20E+02	3.16E+01	1.98E+03	1.91E+01	1.43E+02
	187/9	1.55E+02	5.98E+02	1.54E+03	1.35E+02	2.17E+02