FLOW ROUTING IN A CRATERED LANDSCAPE: 2. MODEL CALIBRATION FOR PLEISTOCENE AND MODERN LAKES AND RIVERS OF THE U.S. GREAT BASIN. Y. Matsubara[1] and, A. D. Howard[1] [1]Department of Environmental Sciences, University of Virginia, P.O. Box 400123, Charlottesville, VA 22904-4123, ym9z@virginia.edu.

Introduction: Geomorphic features such as valley networks, fans, and deltas indicate that there were fluvial processes acting on Martian surface some time in the past [*1-6*]. While geomorphic and mineralogical evidence for an early "wet Mars" has strengthened with recent Mars missions, the question remains as to the magnitude and duration of environmental conditions that could support surface liquid required to create observed channels and other fluvial features.

The Great Basin as an analog of Martian terrain: Many terrestrial geomorphic processes have been seen as analogs for former Martian conditions. The Great Basin (GB) province in the southwestern U.S. (including the Basin and Range and Mojave regions) has many similarities with Mars, thus was chosen as the study site to validate and calibrate our flow routing and lake simulation model [*7*].

Like Mars, the GB consists of many enclosed basins and lakes. At present it supports an extremely dry environment with an evidence of wetter conditions in the past. Moreover, the GB has been strongly shaped by fluvial erosion and paleolacustrine deposits and shorelines indicate that the climate has fluctuated greatly during the late Quaternary [*8-10*]. Application of the model to this region has several benefits: 1) it allows testing of model water balance and routing, 2) it demonstrates sensitivity of lake levels and drainage network integration to variation in climatic parameters, 3) it can be incorporated into the General Circulation Models (GCMs) to model the lake-atmosphere interactions, and 4) though GB Pleistocene climate has been studied extensively, work on spatially explicit flow routing is limited. Furthermore, the GB has modest vegetation so that its influence on hydrological cycle is minimal.

Data sources: Producing a hydrological model requires spatially explicit estimates of runoff and evaporation, which are in turn functions of precipitation, temperature, latitude, and elevation. Model validation in turn requires comparative data on the spatial distribution of modern and paleolakes. Relevant data were collected for California, Idaho, Nevada, Oregon, Utah, and Wyoming and reduced to the GB region (34-44° N, 109-122° W).

Modern environment. Many of the data used for this study were available via websites. The digital elevation data and mean annual precipitation data were obtained from the Shuttle Radar Topography Mission (SRTM) and National Resources Conservation Services (NRCS), respectively. Both data files were converted to ASCII surfer grid format with reduced resolution of 1000 m per pixel.

The National Climatic Data Center (NCDC) provides mean annual temperature (MAT) data along with the deviation form the historical average for each year for 318 stations that are within the GB. For each station, the MAT, geographic coordinates, and elevation were recorded. Microsoft Excel was used to conduct a multiple regression analysis between the MAT and latitude (lat), longitude (lon), and elevation (elev) in meters, which had resulted in a following relationship with regression R^2 of 0.87:

$$MAT = 137.721 - 1.556 lat - 0.00263 elev + 0.117 lon .$$

Lake evaporation rate is hard to estimate owing to difficultness of accurately measuring its controlling parameters like wind speed, atmospheric moisture content, and cloud cover [*11*]. A simpler method for estimating evaporation rate was suggested by [*12*], using a graph of evaporation against elevation for two different latitudes for Nevada. Using this graph as a basis, we estimated the mean annual evaporation rate, E, as a function of latitude and elevation:

$$E = 4.976 - 0.0744 lat - 0.00062 elev .$$

Similarly, mean annual runoff (Q) was expressed as a function of mean annual precipitation (P: in m yr^{-1}) and MAT (F), using another graph provided by [*12*]:

$$Q = 27222 P^{2.48} MAT^{-2.91} \quad (R^2 = 0.99) .$$

Aside from these climate data, maps of lakes in the GB for both the present time and for the maximum extent of Pleistocene lakes were obtained from the W.M. Keck Earth Sciences and Mining Research Information Center. This file was converted to ASCII surfer grid file from its original ESRI® arcGIS shapefile format to see how the model results compare to the actual lake distributions.

Estimates of Pleistocene conditions. Many researchers have estimated climatic conditions that had caused the formation of mega-lakes at the GB during the Pleistocene time. Radiocarbon dating of ostracodes [*13*] and plant fossils from fossil middens [*14*] and computer modeling such as GCMs [*15*], water balance model[*16*, *17*], and energy balance model [*18*] are a few of the methods commonly utilized for studying the paleoclimate. The numerous studies are far from agreement about the plaeoclimatic conditions of the late Quaternary. Estimated Pleistocene conditions range from 10 to 50 % reduction in evaporation rate, 5 to 27 °F decrease in MAT, and -20 % to +100% change in precipitation [*10, 12-16, 18, 19*]. For our study, we have used the median values of 60% increase in precipitation, 30% decrease in evaporation, and 13°F decrease in MAT as reference conditions, and changed one factor at a time over the extreme range of suggested values to determine their relative effects on lake sizes and distributions.

Results: *Predicted lake distribution under modern conditions.* The result shows that the spatial distribution and the extent of the lakes compare reasonably well with those of actual lakes under the present conditions (Fig. 1a). Most of the basin lacks lakes as expected, and two of the larger lakes, Lake Tahoe and the Great Salt Lake, are well predicted, although the simulated Great Salt Lake is smaller than actual size. This could be because of the high salinity of the Great Salt Lake. Saline water has lower evaporation rate, and depending on the type of brine, it could be as low as 10% of that of fresh water [*10*]. Currently, our model does not take into account the effect of salinity on evaporation rate. Additionally, our model always generates a small lake in every enclosed depression to balance the runoff. In an arid system, many enclosed basins have ephemeral lakes balancing the episodic precipitation. A "playa" sub-model for predicting which lakes are ephemeral is being implemented [*7*].

Predicted Pleistocene lake distributions. The lake distribution under the proposed Pleistocene conditions is consistent with the mapped Pleistocene paleoshorelines (Fig. 1b). Predicted Lake Lahontan and Lake Bonneville are almost at their known maximum extent. Conversely, Lake Manly and Panamint Lake at southern GB were not predicted. This is probably due to the median values we have used as our Pleistocene conditions, since full size Panamint Lake and Lake Manly, though smaller, were predicted when the precipitation was increased to 100% of the present value (result not shown). Further trials are required to find the climatic conditions that would result in best fitted lake distributions. However, the overall good match between predicted and actual late Pleistocene lake distribution suggests that the consensus values of Pleistocene hydrologic conditions are reasonable. The simulations also suggest that modest changes in environmental conditions on early Mars could have had dramatic effects on the presence and size of lakes and drainage integration.

References: [1] Irwin, R. P., III *et al.* (2002) *Science, 296*, 2209. [2] Malin, M. C., Edgett, K. S. (2003) *Science*, *302*, 1931. [3] Moore, J. M. *et al.* (2003) *GRL 30*, 2292. [4] Wilson, L. *et al.* (2004) *JGR 109*, doi:10.1029/ 2004JE002281. [5] Moore, J. M., Howard, A. D. (2005) *JGR 110*, doi:10.1029/ 2004JE002352. [6] Howard, A. D. *et al.* (2005) *JGR 110*, doi:10.1029/ 2005JE002459. [7] Howard, A. D., Matsubara, Y. (2006) *LPSC XXXVII*, Abstract. [8] Benson, L. V. *et al.* (1990) *PPP*# *78*, 241. [9] Oviatt, C. G. *et al.* (1992) *PPP. 99*, 225. [10] Smith, G. I., Street-Perrott, F. A., in *The Late Pleistocene* Porter, S. C., Ed. (U. Minn. Press, 1983), 1, 190-212. [11] Shevenell, L. (1999) *Hydrol. Processes 13*, 577. [12] Mifflin, M. D., Wheat, M. M., *Tech. Rpt.94* (Nev. Bur. Mines. Geol., 1979). [13] Quade, J. *et al.*, *Geol. Soc. Am. Spec. Paper 368* (2003) 165-88. [14] Madsen, D. B. *et al.* (2001) *PPP 167*, 243. [15] Hostetler, S. W., Benson, L. V. (1990) *Climate Dyn. 4*, 207. [16] Menking, K. M. *et al.* (2004) *Quat. Res. 62*, 280. [17] Wells, S. G. *et al.*, *Geol. Soc. Am. Spec. Paper 368*,(2003) 79 - 114. [18] Benson, L. V. (1981) *Quat. Res. 16*, 390. [19] Galloway, R. W. (1970) *Ann. Assoc. Am. Geogr. 60*, 245.

#*Paleogeogr., Paleoclimatol., Paleoecol.*

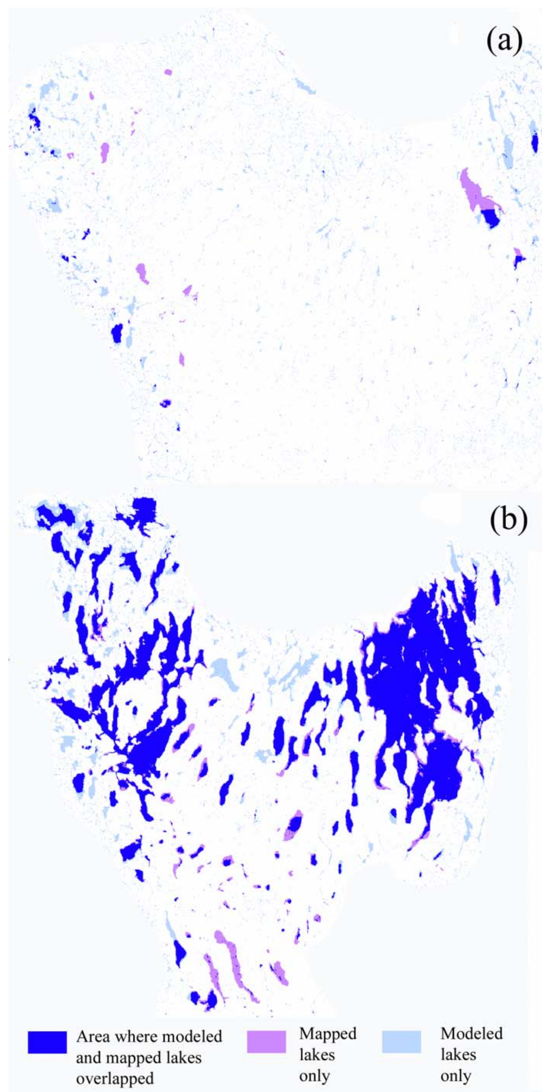

Fig. 1. Lake distribution map of the Great Basin for present time (a) and Pleistocene period (b).