Reconstructing the paleo Lake Bonneville in Utah/Idaho

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Background

Approximately 15,000 years ago, lakes in the Great Basin of the western United States achieved their maximum late Pleistocene extents. Three of those lake systems stand out in terms of surface area: Lake Lahontan with a surface area of 22,300 km^2, Lake Bonneville with a surface area of 51,300 km^2, and Lake Missoula with 7,770 km^2. These gigantic freshwater bodies, which had surface areas approximately 10 times their reconstructed mean-historical values, have been the subject of intensive scientific research since Russell's seminal study of Lake Lahontan (Russell, 1885) and Gilbert's seminal study of Lake Bonneville (Gilbert, 1890).

Three main questions have occupied the minds of present-day paleoclimatologists working in these basins: (1) what caused the lakes to grow so large, (2) what was the record of lake-level change in each basin during the last glacial period, and (3) were lake-size changes linked to abrupt changes in the climate of the North Atlantic signaled by Dansgaard-Oeschgerand Heinrich events (see, e.g., Bond et al., 1993; Dansgaard et al.,1993). It is assumed that the ice shield covering North America during that period placed ground moraine dams on the lakes, which led them to grow in area and depth. It is assumed that melting of the ice sheets "pulled the plug" and rapidly lowered water levels. Bonneville reached its highstand level at 18.6 ka; it fluctuated near that level until 17.5 ka, at which time it incised its threshold at Red Rock Pass, Idaho, reaching the spillover level named "Red Rock Pass level" at 17.4 ka.

Multiple research groups dated paleo-shorelines of Lake Bonneville and corroborated dates of lake levels using sediment cores (e.g., Benson et al. 2011). For this project proposes to explore the potential to use publicly Digital Elevation Models (DEMs) to calculate the water volumes in the Lake Bonneville system at different times during the last glacial. Specifically, this project seeks to answer whether spillover points and outflow locations can be detected using satellite imagery.

Objectives

a. What was the volume and area of glacial paleo-Lake Bonneville during different time intervals and how does it compare to the modern Great Salt Lake?
b. How much of a difference in volume is represent by different shoreline levels?
c. Where were the spillover points/dams for ancestral Lake Bonneville for shoreline levels at various heights?

Digital Elevation Models will be readily available from U.S. agencies. However, I expect that no "paleo-DEMs" will be available, since paleo-cartography includes a lot of uncertainty. It has to be assumed that the geomorphology did not change dramatically since the last glacial maximum, which will be an error factoring into the model. Further, locations of dams/spillover points will need to be extracted from the literature and modeled.

Data Sources

I will mainly use government-published GIS data for this project, which is a data source most reliable and best-documented. First, shapefiles for the maximum extent of Lake Bonneville provided by the The Utah

Automated Geographic Reference Center (AGRC) https://gis.utah.gov/data/water/historic-lake-bonneville/. Second, 1-arc second (30 m) DEMs provided by the USGS The National Map via the Utah ARGC https://raster.utah.gov/. Optionally, the USGS also provides 10 m DEMs but at a much larger size of the dataset, which would make processing unwieldy (time and memory). Third, multiple shapefiles for the various water levels of the modern Great Salt Lake also provided by the Utah State government on ARGC.

Planned Methods

The different ages and lake levels will have to be gathered from the literature. Only the highest lake level is typically referenced in most publications – multiple lower levels were recognized from the sediment record. For each published elevation, the DEM can be clipped in order to obtain the extension of each paleo lake level.

Using ArcScene's capabilities, 3D views will be created showing choke points and valley inundation. The tool "3D Analyst - Surface Volume" will be used to set a hypothetical plane representing lake level and calculate the volume enclosed between DEM and plane (lake surface), which will be saved to a table. These methods will be repeated for each lake level published in the literature and the modern Great Salt Lake for comparison. Using these volume and area data, fluxes as a time series can be calculated.

Expected Results

First, I expect that finding paleo DEMs will not be possible largely because it would involve speculation that is difficult to put in numbers without an uncertainty measure. This means that the dam and spillover point will not be represented properly. Second, neither shapefiles of Lake Bonneville other than the most publicized highest water level. Instead it is necessary for this project to iterate and model the paleo conditions of the last glacial as GIS features. However, it is to be expected that much of the geomorphology present today will be reasonably similar and spillover points reliably determined by empirical modeling in GIS. Once complete, differential volumes and fluxes into the lake per year can be calculated and compared with literature, if available.

References

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