EPHEMERAL LAKES OR LONG-LIVED SEAS ON TITAN: THE IMPORTANCE OF AQUIFER PROPERTIES AND SEASONAL CLIMATE. D. G. Horvath[1], J. C. Andrews-Hanna[1], C. E. Newman[2], K. L. Mitchell[3], and B. W. Stiles[3], [1]Colorado School of Mines, Golden, CO, dhorvath@mines.edu, jcahanna@mines.edu, [2]Ashima Research, Pasadena, CA, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: The presence of hydrocarbon lakes, fluvial erosion, and cloud formation on Titan suggest an active hydrocarbon-based hydrological cycle similar to Earth's hydrological cycle. Liquid hydrocarbon ponded on the surface is evaporated [1], then atmospherically transported and precipitated [2-3] where it either infiltrates into the subsurface or directly feeds reservoirs as surface runoff [4]. While surface flow explains some of the outflow into these reservoirs, ground-alkane flow in the subsurface may be necessitated by the atmospheric loss rate of methane [5]. Likewise, some lake features on the surface of Titan lack fluvial features feeding these basins [6], indicating these lakes receive liquids either from direct precipitation or flow from a subsurface aquifer. The presence of both fluvial fed lakes and those that lack any observable fluvial activity [7] at similar latitudes are difficult to explain by atmospheric driving forces alone. Although topography has been linked to dense fluvial networks feeding large lakes [8], subsurface processes in Titan's hydrological cycle could be important to the formation of these lakes as well. Observed dry lakebeds in the polar regions imply seasonal lake variations that may be influenced by ground-methane exchange with the surface [7]. Here we examine the importance of aquifer properties and methane exchange between the subsurface and the atmosphere on Titan's hydrological cycle, focusing specifically on seasonal variations and the size distribution of lakes at the polar regions on Titan.

Method: We simulate subsurface flow in an unconfined aquifer with the applied precipitation and evaporation rates from a general circulation model [9]. Ground-liquid flow in the subsurface is modeled using the groundwater flow equation for an unconfined aquifer with a laterally homogeneous permeability varying with depth and an initial liquid table set to follow the surface topography. Due to the large timescales required for the subsurface flow of methane, overland flow is analytically determined using a catchment scale linear reservoir analysis of the basin [10] and incorporated into the subsurface hydrology model. The nature of the topography, the permeability, and the precipitation and evaporation rates affect the rate of inflow to the lakes from overland flow. Because the topography data is too sparse to allow high-resolution catchment scale hydrological modeling, synthetic fractal terrain is generated based on SAR topographic profiles [11]. While this is not a true representation of any specific region on Titan, it does provide a statistical representation of the topographic variance and roughness present at different regions of interest. The distribution of lakes on a fractal landscape for two model runs are shown in Figure 1. Models are run until stability is achieved, as determined by variations in lake area that are repeatable from year to year as shown in Figure 2.

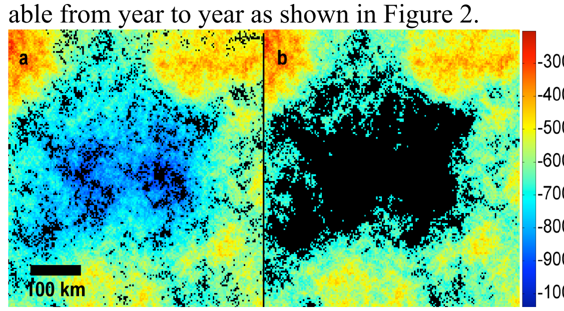

Figure 1. Liquid hydrocarbon ponded on the surface (black) overlain on fractal topography (in meters).

Results: The lake size distribution varies with permeability, with smaller, widely distributed lakes occurring for low permeability (Figure 1a) and fewer but larger reservoirs predicted at high permeability (Figure 1b). As permeability decreases, the lateral flow of liquids in the subsurface becomes hindered by the less permeable aquifer. As precipitation infiltrates into the subsurface, the low rate of lateral ground-liquid flow causes the liquid table to follow the surface terrain, creating ponded methane at local minima. This creates a wide distribution of small lakes similar to ephemeral lakes observed in the South Polar Region [1]. Since lateral subsurface inflow to reservoirs is impeded in this case, evaporation and precipitation dominate the liquid fluxes into and out of the lakes (Figure 2b), respectively, allowing larger changes in lake area (Figure 2a, 3b) and complete evaporation of small ephemeral lakes. When resistance to lateral flow is reduced, as in the case of higher permeability values, subsurface inflow into reservoirs quickly replaces evaporated liquid, decreasing the amount of seasonal change predicted. Larger subsurface fluxes results in a relaxation of the liquid table allowing large, stable lakes to form in larger topographic lows, but no lakes in the smaller local minima. There is some debate as to whether larger lakes, such as Ontario Lacus, have been receeding [1,7] or have remained constant [12] over the Cassini mission lifetime. For high permeabilities, little shoreline recession is predicted for larger lakes.

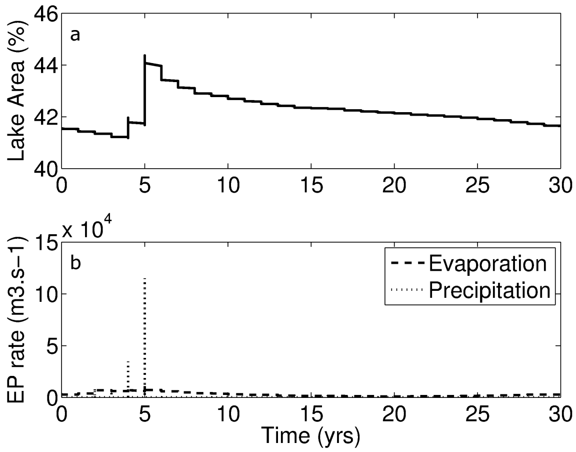

Figure 2. Lake area (top) and atmospheric exchange (bottom) over a Titan year.

For less permeable aquifers, runoff generation would be expected to be higher, creating fluvial networks as observed on the surface. Thus, for given climatic conditions and topography, low permeabilities should lead to enhanced fluvial dissection and larger numbers of smaller lakes, while the opposite is predicted for high permeabilities. The lack of fluvial features associated with ephemeral lakes [7] may indicate low precipitation rates relative to the permeability or low topographic relief and small drainage basins. The extensive fluvial networks feeding larger lakes [4], may imply steeper topographic gradients or higher precipitation rates to generate runoff and channel formation. A high permeability medium for the large lakes observed near the north pole [4] is still possible given higher precipitation rate storm events that may not be captured in the GCM.

Both the predicted total lake area (Figure 3a) and seasonal change in lake area (Figure 3b) vary from pole to equator, as expected based on the observed lake concentration near the poles. At high latitudes where precipitation and evaporation rates are higher, seasonal lake changes become highly dependent on the permeability, with higher permeabilities predicting greater lake seasonality. In contrast, mid and equatorial latitudes show little to no seasonal lake change at all permeability values. Changes in lake area of up to 3% of the total area are predicted near the poles for a permeability of 10^{-6} cm^2, while changes of <1% are predicted for a permeability of 10^{-8} cm^2.

Discussion: The presence of an unconfined aquifer connected to liquid hydrocarbons ponded on Titan's surface affects both the seasonal variations and size distribution of lakes. Permeability is found to have the greatest effect on the distribution of lakes. Higher permeability favors large, stable lakes, while lower permeability favors favors small, ephemeral

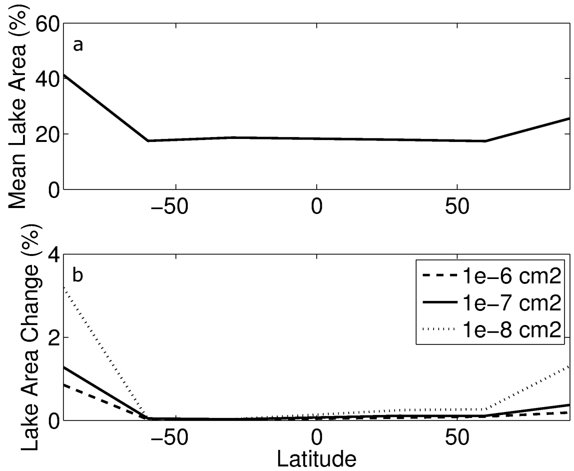

Figure 3. The mean lake area (top) and fractional change in lake area (bottom) as a function of permeability and latitude. The change in lake area is expressed as a percentage of the total area.

lakes similar to specific lake regions found in the South Pole [1]. This could explain the asymmetric lake distribution in the North Polar Region [6], though other processes could also contribute [6-7]. Future work will further examine the competing effects of topography, climate, and aquifer properties in controlling the distribution of lakes on Titan.

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