THE EFFECT OF A HIGH PERMEABILITY POLAR CAP ON THE LATITUDINAL LAKE DISTRIBUTION AT THE NORTH POLAR REGION OF TITAN. D. G. Horvath[1], J. C. Andrews-Hanna[1], C. E. Newman[2], K. L. Mitchell[3], B. W. Stiles[3], [1]Department of Geophysics and Center for Space Resources, Colorado School of Mines, Golden, CO, dhorvath@mines.edu, [2]Ashima Research, Pasadena, CA, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Karst morphology [1] and seepage channels [2] suggest an active subsurface component in Titan's methane-based hydrologic cycle. Karst morphology in particular implies dissolution of material on the surface and in the subsurface. Dissolution of subsurface material leads to an increase in the size and interconnectivity of the pore space and fractures in the subsurface, increasing the permeability of the aquifer. Recent observations of the north polar region with Cassini's Imaging Science Subsystem (ISS) found a bright terrain encompassing the northern lake district with a drop off in albedo at lower latitudes implying a possible change in surface composition that may enable karst formation [3]. Lakes and karst morphology at high polar latitudes associated with a bright albedo unit may be influenced by a higher permeability aquifer compared to the darker albedo lower polar latitudes. This study explores the effects of permeability in general and a high permeability north polar cap on the latitudinal distribution of lakes at the north polar region.

Model: Previous Titan hydrological modeling characterized the behavior of lakes at the catchment scale [4], and used a regional model to explore the effect that long-distance subsurface flow has on the distribution of lakes at the north polar region and hydrologic processes at lakes [5]. These models combined a numerical subsurface flow model with an analytical runoff model, where the total runoff and aquifer recharge were determined using an Earth-based mass balance relationship [6] based on the precipitation and the ratio of the annually averaged potential evaporation to precipitation.

In this study, we continue to investigate the hydrology of the north polar region using large-scale models encompassing a region extending from 90°N to 45°N, varying the climate as a function of the distance from the pole in 5° increments. In contrast to the previous models, the models in this work utilize an annual cycle calculated from an 18-year average of the precipitation and evaporation rates from a general circulation model [7] and a topographic model using SAR topography data [8] where available, in conjunction with a fractal generation algorithm to fill in the gaps.

We first consider two models with uniform permeabilities of 10^{-6} cm^2 (comparable to a fractured aquifer on Earth) and 10^{-8} cm^2 (comparable to an unfractured sandstone aquifer) throughout the model domain. A high permeability organic polar cap is then modeled by imposing a high permeability (10^{-6} cm^2) down to 70°N and a low permeability (10^{-8} cm^2) south of 70°N.

Models are compared to the observed latitudinal distribution of lakes at the north polar region with and without Titan's largest sea Kraken Mare. The extent of this large sea over a broad range of latitudes suggests that Kraken Mare is likely sourced from high latitude precipitation with significant transport within the sea itself. Thus, the lower latitude reaches of Kraken Mare may not be indicative of subsurface flow alone.

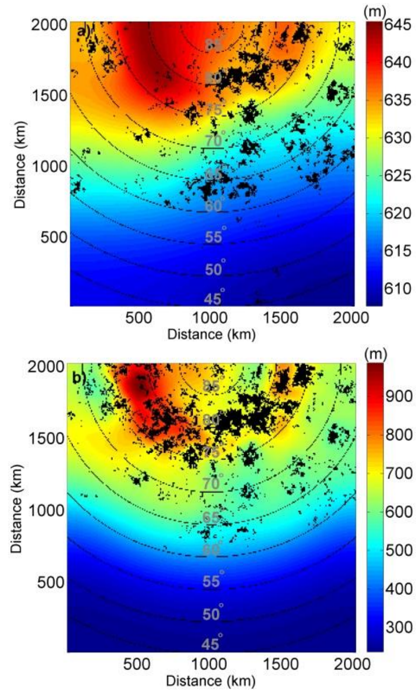

Figure 1. Hydraulic head maps referenced from the minimum regional elevation for **a** the high permeability (10^{-6} cm^2) case and **b** the low permeability (10^{-8} cm^2) case. Predicted lakes are overlain in black.

Results: The effect of different permeability aquifers is first explored. For high permeability aquifers, high recharge at the high polar latitudes (>75°N) results in a precipitation-induced hydraulic head gradient around the pole (Figure 1a). This drives subsurface flow to lower latitudes where lakes are predicted to form as low as 45°N. Compared to the observed latitudinal lake distribution, the lake distribution

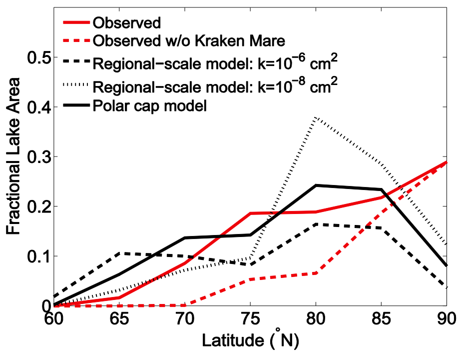

Figure 2. Latitudinal lake area distribution predicted by the models and observed at the north polar region of interest.

predicted by the high permeability model strongly over-predicts lake area below 70°N (Figure 2) as a result of the high rate of subsurface flow to lower latitudes. The model also under-predicts lake area above 85°N, but this is an effect of the poorly constrained topography immediately surrounding the pole.

In contrast, for a lower permeability (10^{-8} cm^2) aquifer, a decrease in subsurface flow to lower latitudes results in a greater lake area at high polar latitudes (Figure 1b). Although most of the surface methane is contained in large seas between 75° and 80°N, subsurface flow to lower latitudes still persists, forming small, low latitude lakes down to 60°N (Figure 2). The fractional lake area predicted by this model strongly over-predicts the lake area between 75° and 85°N, but provides a better match to the lake area below 70°N.

The inhibiting effect of lower permeability aquifers on subsurface flow at low latitudes coupled with a high permeability cap surrounding the north polar region allows high rates of subsurface flow between lakes above 70°N while preventing significant subsurface flow to lower polar latitudes (Figure 3). The low permeability aquifer below 70°N results in more lakes at the high polar latitudes compared to the uniform high permeability model and no significant lake formation below 60°N (Figure 2). The polar cap model provides a better fit to the observed latitudinal lake distribution with Kraken Mare, but over-predicts the observed fractional lake area excluding Kraken Mare. The permeability distribution of the real Titan polar cap is likely more complex than the simple two-permeability model investigated in this study. Large-scale permeability in mature karstic systems is very non-uniform, due to the formation of efficient and directional subsurface conduits. Complex permeability distributions, anisotropic permeability, or different permeability decreases may provide a better fit to the observed lake distribution.

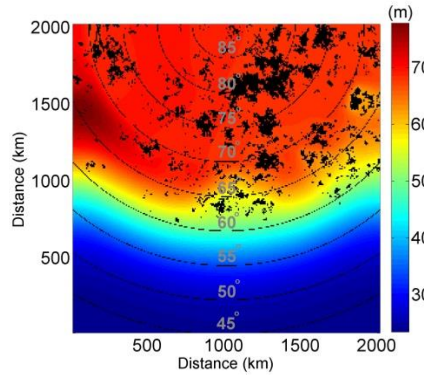

Figure 3. Hydraulic head referenced from the minimum regional elevation for the polar cap model with a permeability distribution of 10^{-6} cm^2 between 90° and 70°N, and 10^{-8} cm^2 below 70°N.

Conclusions: At high permeability values, subsurface flow to lower latitudes is significant, forming low latitude lakes while at lower permeability values, subsurface flow is inhibited resulting in larger lakes at high polar latitudes. All permeability models predict subsurface flow and persistent lakes down to 60°N even when inhibited by a low permeability aquifer. Compared to the observed latitudinal lake distribution, the high permeability model over-predicts the lake area below 70°N while the low permeability model over predicts the lake area above 75°N. Observations of karstic morphologies and a high albedo surface unit surrounding the north polar region [3] suggest the existence of a non-uniform permeability aquifer surrounding the north polar region. A non-uniform permeability distribution with a high permeability aquifer surrounding the pole and a large decrease in permeability at lower polar latitudes allows high rates of subsurface flow in the area around the pole while inhibiting significant flow to lower polar latitudes, providing a better fit to the observed lake distribution. Thus, the observed lake distribution is broadly consistent with predictions for a karstic polar cap.

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