THE HYDROLOGY OF THE SOUTH POLAR REGION OF TITAN. D. G. Horvath[1], J. C. Andrews-Hanna[1], C. E. Newman[2], [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ. [2]Aeolis Research, Chandler, AZ. (dhorvath@lpl.arizona.edu)

Saturn's moon Titan is unique in the Solar System as the only body besides Earth with an active hydrological system. In the case of Titan, liquid methane precipitates on the surface [1], fluvially dissects the landscape [e.g., 2, 3], ponds as lakes and seas in the north and (to a lesser extent) south polar regions [4, 5], and evaporates [1]. Ground-methane appears to be an important component to this hydrological cycle [6], with some atmospheric models requiring a subsurface source to explain the observed distribution of clouds, surface liquid distribution and precipitation patterns [7, 8]. Possible dry paleo-seas in the south polar region [9] and the lake area asymmetry may indicate a long-term change in lake stability potentially due to long time period oscillations in the orbital parameters of the Saturnian system [10].

The lake area distribution at the north polar region have been reproduced by modeling the large-scale subsurface and surface hydrology of Titan coupled with a general circulation model of the present-day climate [11]. That work showed that subsurface flow contributes substantially to the fluid budget of lakes, but that a locally lower permeability around the pole and suppression of evaporation over the seas, due to either lake cooling effects or less volatile hydrocarbons in the large north polar seas, is required to explain the distribution of north polar lakes. However, there has been no comparable hydrological investigation of the south polar region, which is characterized by one large sea, smaller lakes, and large paleo-basins. Moreover, the hypothesis that Saturn's orbital evolution exerts a dominant effect on the lake distribution has not been tested with a detailed hydrological and climatic modeling. In this study, we use results from a Titan general circulation model [12] and a hydrological model [11] to investigate the formation of lakes at Titan's south polar region, comparing to the present lake distribution.

Methodology: The hydrological modeling was performed with a well benchmarked finite-difference model of unconfined saturated flow that incorporates an analytical solution to the overland flow equation [11]. Recharge and surface runoff are determined using an Earth-based empirical relationship dependent on the annual potential evaporation and precipitation rates at the south polar region based on a Titan general circulation model (TitanWRF [12]). Similar to previous work [11], the lake area distribution as a function of latitude was compared to the observed lake distribution at the south polar region [5].

Though long-wavelength topographic models have been generated for Titan [13], we use the method outlined in [11], in which synthetic topography is generated based on the statistical properties of the Synthetic Aperture Radar (SAR) topography. This produces a fractal model of the topography at Titan's poles but includes SAR topography data where present. For this work, we first test the relative importance of climate, running models using the south polar climate with the north polar topography from previous work [11], which can be compared to models using north polar topography and the north polar climate. Next, to test the relative importance of topography, we run models using the south polar topography and the south polar climate. Finally, we test the importance of permeability, running models using the north polar topography, the south polar climate, and a higher aquifer permeability. This setup allows us to explore the climatic, hydrologic, and topographic influence on the north and south polar lake distribution.

Results: We first investigate the difference between north and south lake area from a purely climate perspective. Comparing the fractional lake area as a function of latitude at intermediate permeability (10^{-12} m^2) for the same north polar topography forced by the north and south polar climates, we find only a slight difference between the two (Fig. 1a, d). The somewhat more arid south polar climate results in a slightly smaller total lake area, but this difference cannot explain the large north-south lake asymmetry. We also investigated the influence of topography on lake area using a synthetic topographic model for the south polar region. The distribution of basins and topographic lows has a significant influence on the distribution of lakes at the south polar region (Fig. 1b), predicting an average fractional lake area decrease of 13% above 75°N (Fig. 1d) compared with the model using north polar topography. This difference is driven by the distribution of depressions in the south polar region compared to the north polar region. A larger number of deep depressions at lower latitudes in the south polar region facilitates the transport of methane away from the polar-lakes and toward the arid low latitudes. In contrast, a larger number of deep lake- and sea-filled basins are concentrated at higher latitudes in the north polar topography where methane is more stable.

However, the predicted lake area for the south polar region substantially exceeds the observed lake area in the models above. Large seas in the wetter polar regions are predicted at permeability values of 10^{-12} m^2

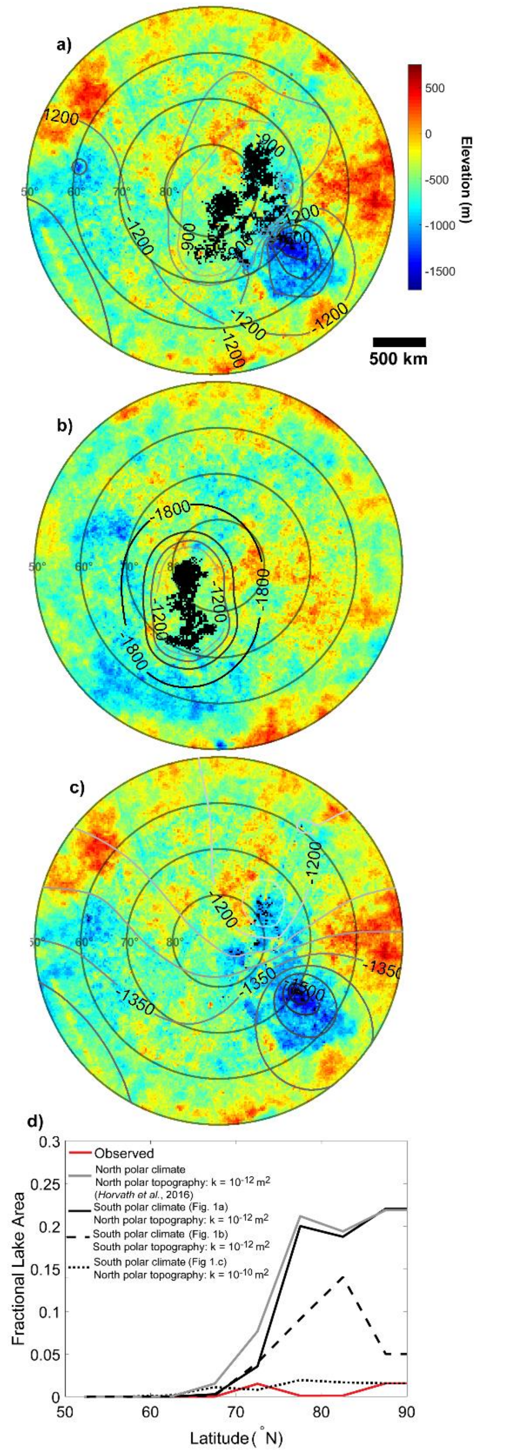

Fig. 1. Modeled lake distribution (black) overlain on synthetic topography under the current south polar climate for an ***a)*** *an intermediate permeability on north polar topography,* ***b)*** *an intermediate permeability on south polar topography, and* ***c)*** *a higher permeability on north polar topography.* ***d)*** *The latitudinal distribution of lakes is compared to the observed lake distribution at the south polar region and the distribution for the north polar region [10].*

as large basins at high polar latitudes allow methane to accumulate and the intermediate permeability prevents this methane from draining to the more arid lower latitude regions (Fig. 1a). As the permeability is increased, lake area decreases because methane is transported to the arid low latitudes, and only small scattered lakes are predicted at high latitudes (Fig. 1c). Comparison of these results to the observed distribution of lakes at the south polar region suggests that increased permeability may be responsible for the observed lake distribution (Fig. 1d). Though a permeability difference between the north and south polar regions is not expected geologically, evidence for a possible polar deposit [14] and karstic features [15] suggests that the permeability structure at both poles may be complex. This is also consistent with local hydrological models at Ontario Lacus (not shown), which predict a seasonal lake area change of ~ 1.5 m for higher permeabilities ($>10^{-11}$ m^2), compatible with an annual average lake level change of ~ 2 m/yr inferred at Ontario Lacus [16].

Conclusions: Though the south polar region is expected to be more arid than the north, we show that permeability and, to a lesser extent, topography can significantly influence the distribution of lakes and total lake area. While the south polar region may have similar-sized paleo-basins as the north polar region [9], the distribution and extent of these basin exerts a large control on where subsurface methane flows and ponds at the surface. Future work will investigate the topographic influence on lake formation by using the mapped paleo-lakes to drive synthetic topography generation, as well as investigate additional hydrological parameters such as recharge and runoff, and the influence of evaporation suppression over large seas.

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