A PRELIMINARY INVESTIGATION OF INTERLAKE GROUNDMETHANE TRANSPORT ON TITAN.

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Introduction: The discovery of lakes on Titan (especially those with no discernible source channels), and the likelihood of atmospheric methane replenishment from an interior source, have prompted some workers to consider the viability of a Titanian methane aquifer [1, 2].

Repeated flybys of Titan by the Cassini spacecraft have allowed the idea of groundmethane flow to be further explored using topographic elevations derived from radar data. Topography is essential for any planetary study of subsurface liquid flows, since topographic gradients likely provide the driving force for these flows or, alternatively, modify flows that are driven by other forces. Of particular use in Titan studies are SARTopo data, which provide strips of topographic elevations along the several thousand km length of individual radar strips [3].

One of the shortest spatial scales likely for groundmethane flows on Titan is from one lake to another. Here, I use SARTopo data to obtain estimates for steady state, topographically driven interlake groundmethane flow rates and lake fill times. These estimates provide insight into the possible nature of subsurface communication between lakes and whether it might offset losses due to evaporation.

Methods: *Lake shore elevations:* With the aid of ISIS software, I produced a polar stereographic projection of the highest resolution Radar data, and overlaid all available SARTopo tracks ([4], Fig. 1). Since topographic variations on Titan are relatively gentle, care must be taken when interpreting the likely direction of gravity-driven flows. Toward this end, I subtracted from the topographic data the most recent available geoid [5].

In order to compare lake elevation differences, two problems had to be overcome: the first was that the projected SARTopo data exhibit a small but significant degree of spatial scatter about the ground track of the instrument. This makes it difficult to compute reasonable lateral displacements between data points for use in 2-D topographic profiles. The second problem lies in the likely high uncertainties resulting from assigning lake shore elevation on the basis of individual SARTopo data points: a more stable aggregate of multiple data close to the shoreline is preferred.

To address the scatter problem, I used a moving average of SARTopo points in order to select those that lay on the imaginary line passing through the center of the data strip. Specifically, I calculated for each datum the mean location of all data in the neighborhood of that point and, if the mean location fell on an existing data point, I included that point in the final dataset. Put differently, I only selected those data that coincided with the average location of their neighbors.

Once this selection was complete, I computed the great circle displacement between successive SARTopo points, which I used to produce 2-D topographic profiles of the kind shown in Fig. 2.

To address the problem of lake shore elevation estimation, I selected the ten points that lay closest to each lake boundary, performed a linear regression on these points, and used the best fit line to estimate the topographic elevation at the lake boundary (Fig. 2). Lake surface elevation was taken as the average of the two shoreline measurements for each lake.

Groundmethane flow estimates: To quantify the flow of groundmethane between lakes, I selected each lake pair from the shoreline elevation analysis whose intervening terrain did not contain other lakes, i.e. those which were most likely to be straighforwardly connected by groundmethane flow.

I used the steady state form of Darcy's Law to compute the time needed for the topographically lower lake in each pair to be completely filled (from empty) by groundmethane flow from the upper lake. This involved several assumptions. First, the volume of the "methanofer" connecting the two lakes was assumed to have a depth approximately equivalent to the depth of the lakes themselves. The advantage of this assumption is that it caused depth to be eliminated from the fill time calculations. Second, I assumed that the permeability of the methanofer was 10^{-10} m^2, at the upper end of the terrestrial range. Estimates of Titanian permeability [6] suggest that even higher values may be reasonable. Using a gravitational acceleration of 1.35 m.s^{-2}, and methane density and viscosity of 450 kg.m^{-3} and 1.84×10^{-4} Pa.s, I obtained a hydraulic conductivity of 3.3×10^{-4} m.s^{-1}, similar to Martian aquifers of the same permeability [7].

Results: Lake inundation times for the 13 lake pairs in the study are on the order of 100s to 1000s yr (Table 1). This equates to only a few tens of Titan's 29 yr seasonal cycle, suggesting that groundmethane flow at these spatial scales may have an important influence on lake levels. Inter-lake distances range from 5 to 60 km (which correspond to the two extreme filling times of 130 and 3900 yr). These distances are gener-

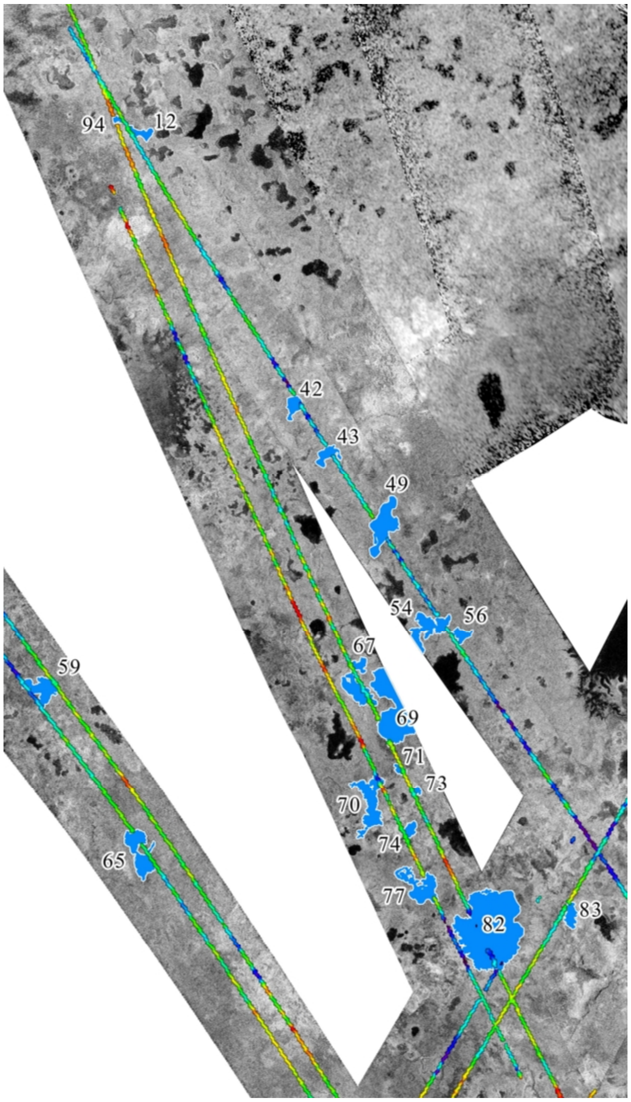

Figure 1. SARTopo data (colored lines) and the lakes they intersect (blue regions). Numbers indicate unique identifiers assigned to each lake. Each SARTopo strip is colored independently in order to emphasize local, rather than regional topographic variations Image width is approximately 950 km.

ally greater than more typical separations of small lakes elsewhere in the northern lakes region for which topographic coverage is not yet available. The smaller volumes and separations of the latter lakes imply much shorter fill times than those obtained in the present analysis. Finally, I considered steady state filling rates, which required an estimate of lake depth. Using the broad estimate of 200 m from [6], I obtained fill rates (Table 1) in the range 0.05 to 1.6 m/yr. These overlap with the lake level changes of 0.3 to 10 m/yr estimated to occur due to evaporation [8].

Conclusions: Preliminary estimates of the hydraulic connectivity of Titanian lakes suggest that, especially for smaller lakes, groundmethane has the potential to strongly influence lake levels. Some lakes' entire volume may, in principle, be provided by groundmethane discharge over only a few seasonal cycles. It also appears that groundmethane discharge may, in some cases, be sufficiently strong to compensate for evaporative losses.

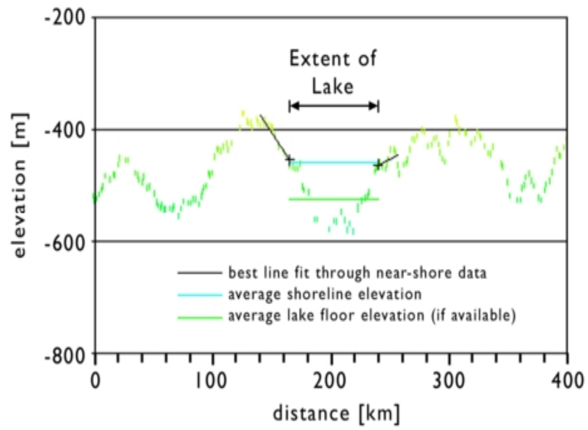

Figure 2. SARTopo elevation data (colored symbols) passing through lake 59 (Fig. 1). Two black lines indicate average topographic slope near the lake boundaries. The ends of these lines ("+") are used to approximate lake shore elevation (blue line). Where data from lake floor scattering is available (as in this case), the floor elevation is also estimated (green line).

Table 1. Time taken for the upper lake in each pair to fill the lower lake. Lake IDs correspond to numbers in Fig. 1.

Lower lake	Upper lake	Lake fill time [yr]			Fill rate [m/yr]
		lower bound	mean	upper bound	
12	94	130	**170**	220	1.2
43	42	680	**1700**	none	0.12
43	49	2600	**4900**	44000	0.041
54	56	340	**690**	none	0.29
67	69	100	**130**	190	1.5
71	69	250	**490**	8100	0.41
70	71	770	**1100**	1700	0.19
73	71	100	**140**	210	1.5
73	74	100	**130**	180	1.6
70	74	630	**820**	1200	0.24
74	77	320	**490**	1000	0.41
82	77	2900	**3300**	3700	0.061
82	83	3200	**3900**	4800	0.052

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