TITAN'S NORTH POLAR LAKES AS OBSERVED BY CASSINI RADAR: AN UPDATE. K. L. Mitchell[1], S. D. Wall[1], E. R. Stofan[2], R. M. C. Lopes[1], M. Janssen[1], B. Stiles[1], P. Paillou[3], G. Mitri[1], J. Lunine[4], S. J. Ostro[1], R. D. Lorenz[5], T. G. Farr[1], R. L. Kirk[6], J. Radebaugh[7] and the Cassini Radar Science Team. [1]Jet Propulsion Laboratory, Mail Stop 183-601, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, USA <Karl.L.Mitchell@jpl.nasa.gov>. [2]Proxemy Research Inc., Laytonsville, MD. [3]OASU, UMR 5804, 33270 Floirac, France. [4]Lunar and Planetary Lab, Univ. Arizona, Tucson, AZ. [5]Space Dept., Johns Hopkins Univ. Applied Physics Lab, Laurel, MD. [6]USGS Flagstaff, Flagstaff, AZ. [7]Brigham Young University, Dept. of Geological Sci., Provo, UT.

Introduction: The north-polar lakes of Titan [1] are among the most spectacular discoveries by Cassini to date. Their anomalously radar-dark appearance is consistent with expectations for radar backscatter properties of lossy liquid hydrocarbons (methane and/or ethane, possibly with nitrogen), the presence of which was predicted by previous workers [2]. Furthermore, their areal coverage and location are consistent suggestions [3] that 0.2 – 2% high-latitude lake coverage would be sufficient to buffer atmospheric methane against photolysis, negating the need for continuous resupply by e.g. volcanism. Here we describe SAR observations over 7 north polar fly-bys, and discuss our attempts to understand the current state of the lakes, especially the meaning of coherent radar backscatter variations both within and between lakes.

Morphology and distribution: About 70% of the region polewards of 65 N has been imaged with a total of 7 SAR and 2 Hi-SAR scenes (Fig. 1). Of this, we map ~15% as lakes. On the assumption that the distribution is homogeneous, and similar in the southern hemisphere, we expect the final lake coverage of Titan to be within the 0.2 – 2% range. The first three fly-bys (T16, T18 & T19) revealed lakes exhibiting a range of morphologies, some in steep-sided depressions similar in appearance to volcanic crater lakes, glacial lakes or massive dolines (sinkholes), and others consistent with dammed lakes (e.g. Lake Powell) or submergent coastlines (rias), and the interpretation of these different morphologies has been a matter of some debate (e.g. [4,5]). The most recent data (T25, T28, T29 and T30) revealed even more variety, most strikingly the massive "great lakes", with surface areas of 10,000s of km^2 comparable with those of North America, and greater in terms of fractional coverage of the planet. The largest of these are greater in extent than any terrestrial lakes, leading to our informal use of the word "sea".

On-going mapping efforts have revealed that lakes of a given morphological class often appear in clusters, with steep-sided small lakes more often appearing at the lower latitudes. Many lakes are seen to be fed by channels, some short and stubby, indicating intersection with subsurface liquid methane reservoirs (equivalent to aquifer or water table), others long and sinuous, probably indicating that they are fed pluvially or via artesian springs. This plethora of landforms suggests a dynamic system of liquid hydrocarbons, equivalent to terrestrial hydrologic system (informally we use the expression "methanologic"), underlain by variable surface materials [1,6,7].

Fig. 1: Polar stereographic projection (65 – 90 N) of Cassini SAR imagery, consisting of imagery obtained during T16, 18, 19, 25, 28, 29 and 30 fly-bys. Longitude given in non-standard degrees E.

Present-day state: While the interpretation of the extremely radar-dark patches as currently active (liquid) lakes remains the favored hypothesis, it has not been possible to completely rule out that we are merely seeing residues or some sort: muds, evaporites, or similar. We have argued previously [6] against the non-liquid interpretation for some, if not most, of the observed lakes. Besides the consistency with predictions based on present-day methane humidity [3], there is a broad range of observations and measurements consistent with models of lossy liquid hydrocarbons over a solid substrate, and although solids could not be completely ruled out, the characteristic properties would be extremely constrained, although not necessarily impossible. Furthermore, observations of some features, appearing morphologically similar to the small, steep-sided lakes, but in terms of backscatter properties similar to their surrounds, are best explained as drained lakes containing little-to-no radar dark residues, which seems at odds with a radar-dark-residue hypothesis.

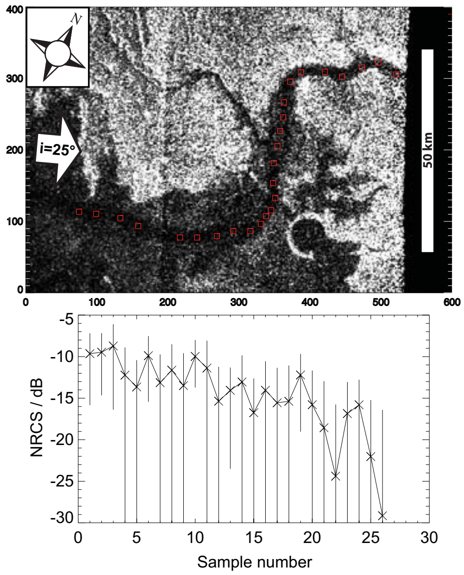

Fig. 2: Channel extending into the body of a lake (T29 fly-by). (top) Noise-subtracted SAR image, centred on 82.9N, 242W, with sampling sites (box sizes not representative of sampling areas). (bottom) Results of sampling 5x5 pixels, given in dB, numbers are from 1 (upstream, right of image) to 26 (downstream, left of image). Error is limited by the noise floor in some cases.

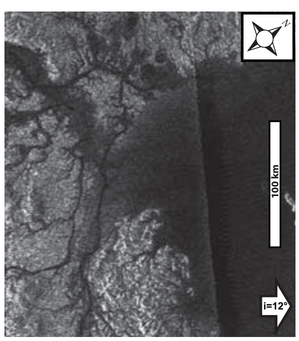

Fig. 3: Methanologically-complex region on the southern shore of "the Black Sea", centred on 75.7N, 260W, including east-to-west narrow rivers, and an approximately perpendicular north-south broad channel.

However, this light-dark dichotomy is not clear-cut for all the lakes. In many cases, there are variations in brightness both within and between lakes that are clearly not the result of noise or incidence-angle effects. This was expected; If methane is has a small loss tangent, the radar backscatter should decrease with increasing depth of liquid. Unfortunately, the loss tangent of the candidate liquids is poorly constrained. We might expect to be able to see through a few to many tens of metres before reaching the RADAR noise floor, but we cannot say more precisely than this at present, even if we assume no wind effects or "floaters". What we perhaps did not expect to observe was that some of the lakes contained features consistent with "methanologic" structures; what appears to be intra-lake channels, usually continuations of other channel systems (e.g. fig. 2 top). The appearance is somewhat reminiscent of tidal flats, leading to renewed suggestions that we might be looking at some sort of dry or wet radar-dark solid residues; perhaps hydrocarbons or nitriles. More intriguing still are intra-lake channels that appear to cross each other (fig. 3).

Intra-lake channel analysis: In order to test the idea that some of the lakes might contain, or even be, something akin to tidal or mud-flats, we predicted that, if a channel extending into a lake body became progressively more radar-dark, this is consistent with a subaqueous system in which we were seeing an old channel through progressively greater depths of liquid. If instead the backscatter remained more-or-less constant, then this is more consistent with a channel incised into a present-day solid surface. The results of our test on only one channel (most are too small or noisy to present reliable statistics) are presented (fig. 2 bottom). Note that the incidence angle decreases slightly from right-to-left, meaning that we would expect, all things being equal, for channel materials to become systematically brighter downstream. Instead, the opposite is observed, clearly supporting the present-day-liquid hypothesis.

Discussion: So, what are we to make of the case in which the channels seem to cross one another? One explanation could be that, when the lake level reaches a critical threshold, it overflows into another, outside of the imaged area. The narrower channels are deeply incised rivers that are only active when local liquid levels are low. As liquid levels increase, these channels become submerged. As they increase further, the lake overflows into an adjacent regions, resulting in the broader of the channels which would therefore be more consistent with catastrophic flood plains, such as in the Channeled Scablands, USA. Clearly this is an untested model, but it is at least a coherent explanation as to how perpendicular channels might be established.

Although no single observation is completely unambiguous, the body of evidence supporting the present-day-liquid hypothesis is now overwhelming. In future work, we will refine our understanding of the dielectric properties of candidate lake materials in the laboratory, and use these to attempt to quantify lake depths based on multi-incidence angle SAR images.

References: [1] Stofan E. R. et al. (2007) *Nature, 445,* 61. [2] Lunine J. I. et al. (1983) *Science, 222,* 1229. [3] Mitri G. et al. (2007) *Icarus, 186,* 385. [4] Wood C. et al. (2007) *LPS XXXVIII,* Abstract #1454. [5] Mitchell K. L. et al. (2007a) *LPS XXXVIII,* Abstract #2064. [6] Mitchell K. L. et al. (2007b) *LPS XXXVIII,* Abstract #2081. [7] Mitchell K. L. et al. (in prep.).