LACK OF SOUTH POLAR METHANE LAKES ON TITAN. J. I. Lunine[1] G. Mitri[2], C. Elachi[2], E. Stofan[3], R. Lorenz[4], R.L. Kirk[5], K. Mitchell[2], R. Lopes[2], C.A. Wood[6], J. Radebaugh[7], S.D. Wall[2], L.A. Soderblom[5], Ph. Paillou[8], T. Farr[2] B. Stiles[2], P. Callahan[2], and the RADAR Science Team, [1]Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85721-0092 jlunine@lpl.arizona.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109; [3]Proxemy Research, PO Box 338 Rectortown VA 20140; [4]Applied Physics Laboratory, [5]US Geological Survey, Flagstaff, AZ 86001; [6]Planetary Science Institute, Tucson, AZ 85701 & Wheeling Jesuit University, Wheeling, WV 26003. [7]Department of Geological Sciences, Brigham Young University, Provo, UT 84602, [8]Observatoire Aquitain des Sciences de l'Univers, UMR 5804, Floirac, France
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Introduction: The T39 pass by the Cassini spacecraft on December 20, 2007 included the first radar imaging of the South Pole of Titan [1]. Although only a single radar swath, it appears evident that the region lacks the extensive dark features that have been identified as methane or methane-ethane lakes [2]. Only two features in the swath are sufficiently dark to be considered as potential lakes (figure 1). Also missing, however, are the extensive lake-shaped but bright basins present in the north, in their place, areas between heavily eroded terrains might or might not be capable of holding liquid but appear to be empty (figure 2). There are multiple possibilities as to why the South Pole is devoid of lakes. These include (a) depletion by seasonal evaporation of methane from the southern to northern hemisphere; (b) elevation differences between the two poles leading to a lack of retention of surface liquids in the south; (c) differences in surface properties or geology favoring subsurface retention in the south versus surface retention in the north; (d) the northern lakes are themselves not filled with liquid.

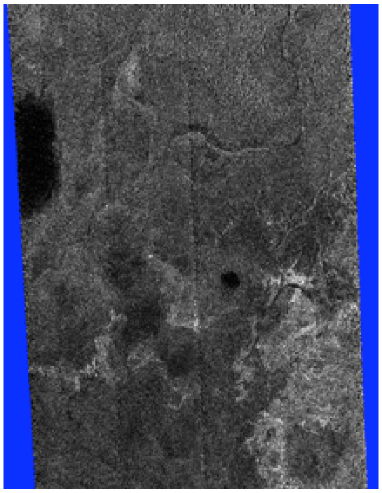

Fig. 1. Portion of T39 swath obtained by the Cassini spacecraft on its recent pass by Titan's south pole. This SAR image is centered near 86S, 201 W and covers an area of 220 by 170 km. The two very dark circular features are the only features interpretable as methane lakes in the swath.

(a) Depletion by seasonal evaporation: The seasonality of Titan's climate, whereby volatile materials might be transported from pole to pole [3], is highly dependent on latitudinal temperature gradients and atmospheric circulation. Here we use the bulk aerodynamic method [4] to determine the evaporation rate E in kg m^{-2} s^{-1} of liquid methane and a mixture of methane-ethane, from a lake with a surface exposed to the wind. The method assumes that the evaporation rate is proportional to the difference between the saturation vapor pressure (100% relative humidity) and the actual atmospheric partial pressure; this roughly holds for terrestrial experience. The evaporation rate is given by $E=\rho_{air}K\Delta qu$, where ρ_{air} is the air density, K the transport coefficient calculated in [4] for the Titan near-surface environment to be 0.0013, Δq the difference between the saturation relative humidity and the actual relative humidity of methane over the lake, and u the horizontal wind speed.

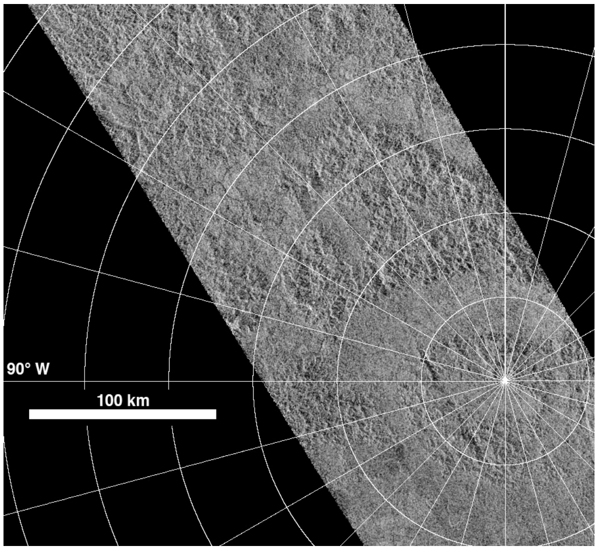

Fig. 2. Portion of T39 swath showing areas at and near the South Pole that might be basins surrounded by higher but heavily eroded terrain. Latitude lines are in one degree increments from 90°S.

The absence of evident waves in the larger northern hemisphere seas (now called “mare” by the IAU) suggests that surface wind speeds are less than ~ 1 meter per second. Figure 3 plots the resulting amount of liquid evaporated from a lake over a Titan season as a function of the temperature and the ethane-methane mole fraction. The saturation pressure of methane over a mixed ethane-methane lake is the pure methane saturation vapor pressure multiplied b the methane mole fraction in the lake. We neglect the effect of dissolved nitrogen, which will decrease the numbers given in the figure by about 5% (pure ethane) to 20% (pure methane). The density of the liquid itself, needed to convert from *E* to equivalent depth, is assumed to be 500 kg m^{-3}; strictly this is not constant with ethane abundance but the error is ~ 20%.

Since it is the end of summer in the southern hemisphere, we assume that methane has evaporated from the southern polar region and been transported to the north. In order to dry out the lakes in the southern hemisphere, their depth cannot have been greater than ~100 meters for pure methane at 93K. Smaller lake depths are possible for ethane-methane mixtures, but since the ethane left behind as a (still) lake would be as dark as the liquid methane, a self-consistent result requires the lakes be nearly pure methane. The 100-meter depth limit scales at a given temperature as *u*, where *u* is the wind speed in meters per second. Lake depths of tens of meters agree with estimates from the radar loss tangent measured in liquid methane (5).

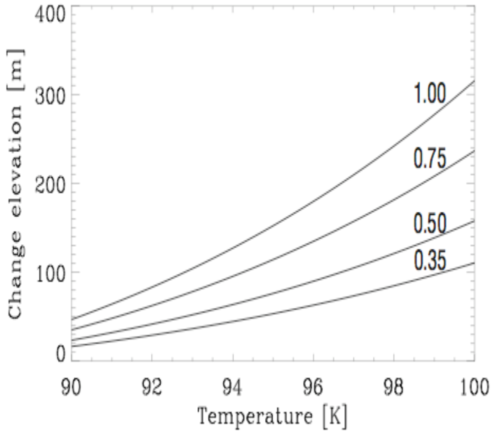

Fig. 3. Plot of evaporation over a Titan season (7 years) in equivalent lake depth decrease, versus temperature and methane mole fraction, for a wind speed of 1 m s^{-1}.

(b) Elevation differences between the north and south poles This hypothesis cannot be evaluated given the absence of relevant topographic and Titan figure data. Differences in polar crustal properties, including elevation and surface composition, are seen for the Earth (one pole oceanic, the other continental), and for Mars. It is certainly possible, but at this point somewhat arbitrary, to invoke a Titan shape that excludes the retention of liquids at the south pole or leads to a contrasting precipitation regime.

(c) Differences in surface properties or geology favoring subsurface retention in the south versus surface retention in the north: Dry lake basins with the characteristics seen near the north pole are absent from the T39 swath. It is possible that the nature of the crust in the two hemisphere is different, with the southern polar region perhaps more porous and hence capable of storing larger amounts of methane or methane-ethane liquid beneath the surface. Testing of this hypothesis will require analysis of radiometry data for the southern hemisphere and comparison with the northern hemisphere radiometry; it is work in progress.

(d) The northern hemisphere lakes are not filled with liquid: If in fact the dark northern hemisphere “lakes” and mare are not filled with liquid, but are extremely dark for a different reason, then the rationale for assuming evaporative transport from one pole to the other disappears. The absence of very dark patches in the south could be a compositional or crustal geological difference. However, we can think of no hypothesis as compelling as that of methane liquid to explain the various properties of the lakes and mare in the northern hemisphere, not only their very low radar albedo but also their shapes, presence in some cases of drainage channels, and radiometric properties [2].

We consider the evaporation hypothesis at present the most compelling. Under this hypothesis, typical lake depths in the south were tens of meters and the lakes there pure methane prior to their nearly complete evaporation. If it is correct, then evaporation at the high northern latitudes should begin in the late northern hemisphere spring, some 7 years from now. While the Cassini orbiter may not be operating at that time, ground-based adaptive optics studies might look for bright clouds that, as in the south until a few years ago [6], might signal vertical moist convection associated with the evaporation of polar methane and its recondensation in the colder upper troposphere.

References: [1] Stofan, E.R. et al., *LPSC* 39, submitted. [2] Stofan E.R. et al. (2007) *Nature* 445, 61-64. [3] Stevenson, D.J. and Potter, B.E. (1986) *GRL* 13, 93-96 (1986) [4] Mitri, G et al. (2007) *Icarus* 185, 386-394. [5] Pallou, P. et al, *GRL*, subm.; Lorenz, R.L. et al., *GRL*, in press [6] Schaller, E.L. et al.(2005) DPS *37, abstr.* 51.08.