EVIDENCE OF POSSIBLE GLACIAL FEATURES ON TITAN. L. E. Robshaw[1], J. S. Kargel[2], R. M. C. Lopes[3], K. L. Mitchell[3], L. Wilson[1] and the Cassini RADAR team, [1]Lancaster University, Environmental Sci. Dept., Lancaster, UK, [2]Dept. of Hydrology and Water Resources, University of Arizona, [3]Jet Propulsion Laboratory, Pasadena, CA 91109.

Introduction: It has been suggested previously [e.g. 1] that solid hydrocarbons might condense in Titan's atmosphere, snow down onto the surface and form glacier-like features, but no strong evidence has been obtained. The high northern latitudes imaged in the SAR swath obtained during Cassini's T25 fly-by (figure 1, top), however, exhibit morphological similarities with glacial landscapes on the Earth, particularly the coast of Norway (figure 1, bottom). Several areas exhibit fjord-like valleys, with possible terminal moraine archipelagos, and further inland are dry valleys, reminiscent of glacial scouring. Other noted features may be a ribbon lake and an Arête, both the result of glacial erosion.

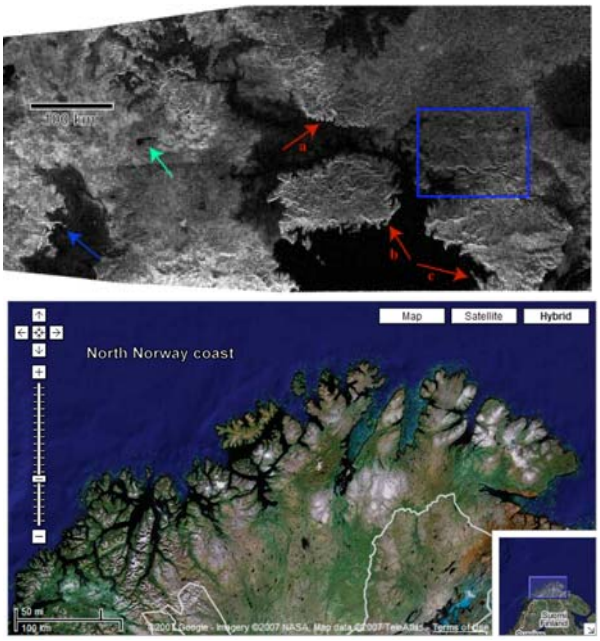

Fig. 1 (top) T25 Cassini RADAR image showing high northern latitude landscape with candidate glacial features. Illumination from below. Red arrows indicate possible glacially-shaped coastline. Green arrow indicates possible ribbon lake. Blue arrow indicates land spur within possible flooded valley. Blue box is region in figure 2, top. (bottom) Coast of northern Norway at similar scale to T25 SAR image. Image credit: Google/NASA.

Morphological Evidence: Fjords are U-shaped valleys scoured by glaciers, with high, steeply sloping sides, usually formed as long inlets from the sea, often terminating in a round-head valley. Typically they have a narrow inlet, steep-sided walls which continue to below sea level, and are often deeper in the upper and middle sections than in the seaward section. Usually they follow the path of a pre-glacial river valley, or in some cases a fault related to tectonic activity. Figure 1 shows coastline that has at least superficial similarities with the coast of Norway and other fjord areas. There are many, roughly parallel, steep-sided valleys, often with rounded heads. Most are approximately the same size as the valleys on the Norwegian off-shore islands.

There also appears to be some similarity between the areas that arrows b & c point to (fig. 1, area shown also in close-up in fig. 2, top) and the islands of the Outer Lands (Fig. 2, bottom), a terminal moraine archipelagic region off the southern coast of New England.

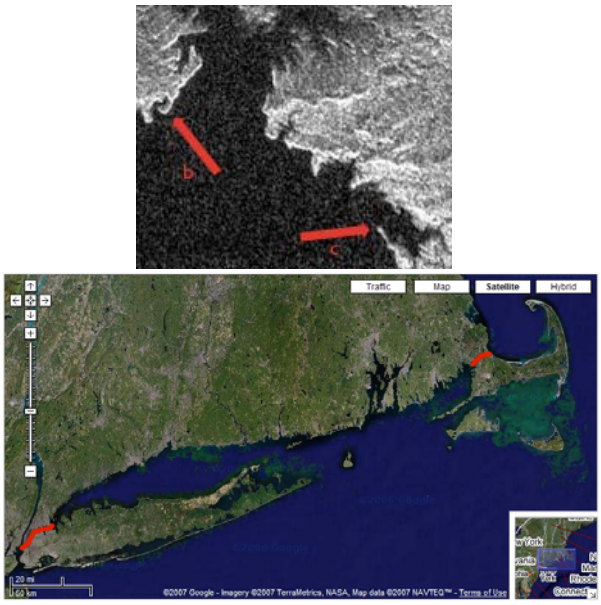

Fig. 2 Possible moraines on Titan (top, T25 Cassini RADAR image, illumination from below) and the Outer Lands, a terminal moraine off the southern coast of New England (bottom). All the land out to sea beyond the red lines, including the small islands, is terminal moraine. Image credit: Google/TerreMetrics/NASA. Scales are approximately equal.

We see further evidence of glaciation as indicated in figure 3; note the right-left running valleys between the red arrows, which are reminiscent of an empty valley carved by a wet-bottomed glacier. (A second set of valleys is towards the top of Fig. 3, but runs along a SAR boundary, so is unclear.)

Between the blue arrows is an east-west feature, which, judging by the width of the nearside bright edge, appears to be a mountain ridge, with a much higher elevation than most of this area. This could possibly be an Arête - a thin ridge of rock formed when

two glaciers erode parallel U-shaped valleys, or when two glacial cirques erode towards one another.

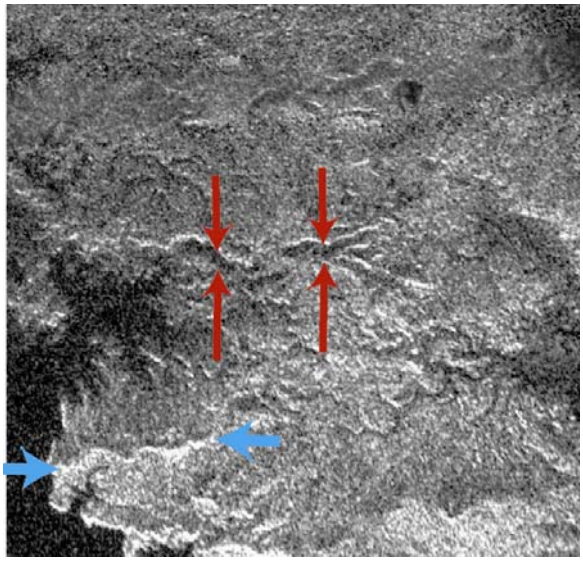

Fig. 3: T25 Cassini RADAR image. Red arrows indicate possible drained glacial valley. Blue arrows indicate possible Arête. Illumination from below.

A small isolated lake (figure 1, indicated by green arrow; also figure 4) appears morphologically similar to ribbon lakes on Earth: long, narrow lakes, formed when a glacier erodes across a softer band of rock, forming a basin. Note that a narrow valley appears to travel into this lake from the west, and leaves as a broader, possibly glacial, valley to the east. Also, the terrain left and right of the lake is brighter than that above and below it, possibly indicating a difference in composition.

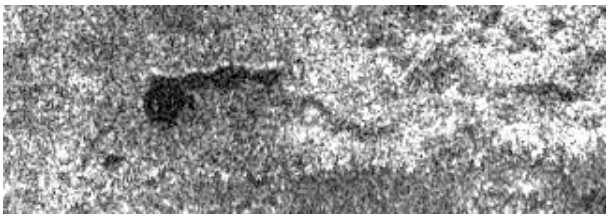

Fig. 4: A small, isolated lake in Cassini RADAR image acquired during T25 fly-by. Illumination from below.

Other features in T25 however (for example, in figure 1, the promontory protruding into the lake at the blue arrow) are more reminiscent of recently-flooded, dammed valleys, such as Elephant Butte Reservoir, New Mexico (Fig. 5). So, whilst glaciation appears to be a strong candidate process for shaping this region, other processes, such as recent flooding, cannot be ruled out as helping to shape parts of Titan's "great lakes".

Fig. 5: Elephant Butte Reservoir, New Mexico. Image credit: Google/NAVTEC/DigitalGlobe

Material and Rheological Considerations: We propose two possible glacial compositions for Titan: (1) frozen methane, the principal liquid on Titan; (2) solid precipitants snowed out from the atmosphere (hydrocarbons, organics, nitriles). The former seems unlikely, as the surface temperature of Titan has not been observed to drop below the liquidus of methane (~91 K), though it is conceivable that local climatic phenomena may reduce the surface temperature sufficiently. In the case of the latter, this would be consistent with interpretations of karst formation in the polar regions [2]. However, solid precipitants pose a problem of how the glaciers could be eroding the valleys, as they are unlikely to be wet-based (i.e. lubricated by their own liquid phase). Instead, their movement may well be more akin to that of cold-based glaciers or highly viscous lava flows. Alternatively, they may be lubricated by a different material - methane and/or ethane - which is plentiful in this area; glacial composition and/or rheology may also be affected.

References: [1] Kargel J. S. et al (2007) *LPS XXXVIII*, Abstract #1992. [2] Mitchell K. L. et al (2008) *LPS XXXIX*, this volume.