Radar Backscatter Properties of the Dragonfly landing site. L. E. Bonnefoy[1], R. D. Lorenz[2], A. G. Hayes[3], A. Lucas[1], D. Lalich[3], V. Poggiali[3], S. Rodriguez[1], A. Le Gall[4], [1]Université de Paris, Institut de physique du globe de Paris, CNRS, Paris, France, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, [3]Department of Astronomy, Cornell University, Ithaca, NY, USA, [4]Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), UVSQ /CNRS/Paris VI, UMR 8190, 78280 Guyancourt, France

Introduction:

The Dragonfly mission, selected as the next New Frontiers mission by NASA, will send a rotorcraft to Titan in the mid-2030s (launching in 2027) approximately one Titan year after the landing of ESA's Huygens probe [1, 2]. The landing site, in the Shangri-la dune field near the geologically young Selk crater (6.5°N, 161.5°E), was chosen [3] to examine possible past interactions between organics and liquid water (impact melt) and for its Earth-facing equatorial position (allowing direct communication with Earth).

The Selk crater region has been observed by several instruments onboard the Cassini spacecraft (in orbit around Saturn from 2004 to 2017), with the Radar in Synthetic Aperture Radar (SAR) mode providing the highest resolution data of up to ~300 m/pixel. These data reveal a complex region, featuring a partially eroded, but geologically young, crater surrounded by reticulated dune fields, radar-bright hummocky and mountainous terrains, and undifferentiated plains that are at least partially composed of crater ejecta [3, 4].

Herein, we investigate the surface properties of various terrain types within the Dragonfly exploration area using overlapping SAR observations to construct backscatter curves, which express the observed normalized radar cross-section (NRCS) at multiple viewing geometries. The NRSC varies with incidence angle in different ways for different terrain units, depending on both the composition (dielectric constant) and the structure (surface roughness, grain size, and diffuse subsurface scattering) of the medium.

Observations and Methods:

Resolved SAR observations of Selk crater have been acquired during six Cassini flybys, with incidence angles that vary between 20° and 70° (Table 1). Unfortunately, no radar altimetry was acquired directly over Selk crater, although nearby altimetry tracks provide both topographic and nadir (0° incidence) information. Within the immediate vicinity of Selk, we mapped three units for this work: dunes (both around the impact crater and within the crater itself), the crater rim, and the undifferentiated plains directly East of the crater. To reduce speckle noise, the NRCS for each SAR swath is averaged within 0.15°×0.15° squares (~150 resolution elements, see Fig.2)

For each of the three units, we apply two standard quasi-specular plus diffuse backscatter models that have previously been used to study Titan's surface [e.g., 5, 6]. For the diffuse component we use an $A\cos^n\theta$ law. For the quasi-specular component, we use either a Hagfors [7] or Gaussian [5, 8] model.

Table 1: SAR data over Selk crater

Date	Swath	Incidence angle (°)	Resolution (km) Azimuth	Resolution (km) Range
2 Oct 2007	T36	42–47	2.6–3.6	2.0–2.6
20 Dec 2007	T39	20–25	0.9–1.7	0.5–1.0
13 Oct 2013	T95	20–29	0.3	0.3–0.4
2 Feb 2014	T98	68–71	0.9–3.6	1.3–1.9
7 June 2016	T120	66–69	0.5–0.9	0.2–0.3
25 July 2016	T121	37–42	3.9–7.2	1.7–2.4

Preliminary Results and Future Work:

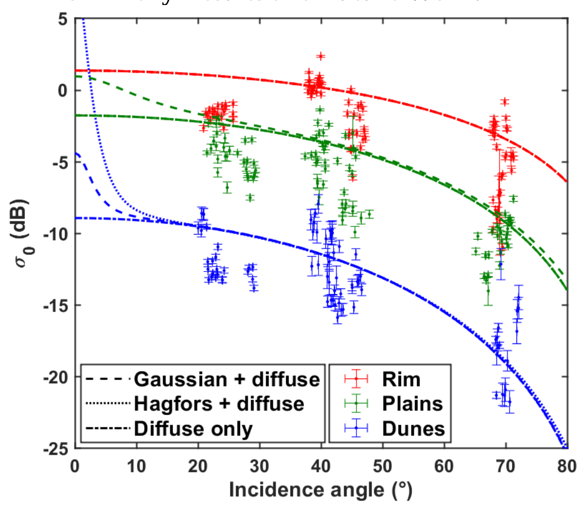

Figure 1: Backscatter curves for the three terrain units, with three different fits for each.

The quasi-specular component is only significant for incidence angles from nadir to up to ~25°. As a result, the scarceness of available data at low incidence means that the surface parameters (rms surface slope, dielectric constant) cannot be well constrained from the examined dataset: i.e., the fit with only a diffuse component is almost as good as fits that include Hagfors or Gaussian quasi-specular components (Fig 1).

The backscatter curve over Selk can be completed with observations from other similar regions of Titan, namely geologically young craters and nearby dunes and plains. In particular, SAR observations of other Titan craters at low incidence angles (down to about 10°) have been identified. Analysis of altimetric tracks located in proximity of (but never directly over) Selk (T41, T64, T83) and other craters is ongoing. Once a larger dataset is assembled, we will fit both the above models and more complex, physical models [e.g., 8, 9] in order to derive surface properties.

Nonetheless, the backscatter curves of the three units near Selk can already be compared both to each other and to other Titan terrains analyzed in previous work. The dunes within the crater are very similar to those around it, indicating likely common ages and compositions. These dunes also have a backscatter curve similar to the one found for dunes in Belet, Shangri-la, and Fensal by [9], consistent with organic, fine-grained sand.

The crater rim is bright, with an NRCS above 1 (linear scale) at a 40° incidence angle, making it brighter than most hummocky terrains and similar to parts of Xanadu, as analyzed by [6]. This high radar backscatter implies either increased surface roughness, or the presence of higher-dielectric and/or radar-transparent material, such as water ice whose high transparency allows for large penetration depths into the subsurface and multiple scattering. This subsurface, or volume, scattering must be caused by organized structures such as cracks, which may have formed during the impact. The crater rim also contains as yet unknown oriented slopes, which change the observed incidence angle. We note, however, that the radar brightness appears roughly consistent across the entire rim, which includes slopes both facing away from and toward the spacecraft. This would suggest that volume scattering, which is less dependent on surface slope, dominates the signal over quasi-specular backscatter. Future work will attempt to extract the surface slopes using radarclinometry assuming uniform properties around a symmetric rim, similar to previous work on Titan's dunes [10, 11]. These slopes would then be compared to those observed over part of the crater in the SARTopo dataset and used to correct the observed incidence angle.

References: [1] Turtle, E. P. et al. (2019), *50th LPSC*, Abstract #2132 [2] Lorenz, R. D. et al. (2018), *John Hopkins APL Technical Digest 34*, pp. 374–387 [3] Lorenz, R. D. et al., *Planetary Science Journal*, in press [4] Malaska, M. J. et al. (2016), *Icarus 270*, pp. 130–161 [5] Wye, L. C. et al. (2007), *Icarus 188*, pp. 367–385 [6] Janssen, M. A. et al. (2011), *Icarus 212*, pp. 321–328 [6] Hagfors, T. (1964), *J. Geophys. Res.* 69, pp. 3779–3784 [7] Beckman, P. and Spizzichino, A. (1987), *Scattering of Electromagnetic Waves from Rough Surfaces* [8] Lucas, A. et al. (2019), *J. Geophys. Res.: Planets 124.11*, pp. 3140–3163 [9] Sultan-Salem, A. K. and Tyler, G. L. (2007), *J. Geophys. Res. 112*, E05012 [10] Lorenz, R. D. et al. (2006), *Science 312*, pp. 724–747 [11] Neish, C. D. et al. (2010), *Icarus 208*, pp. 385–394.

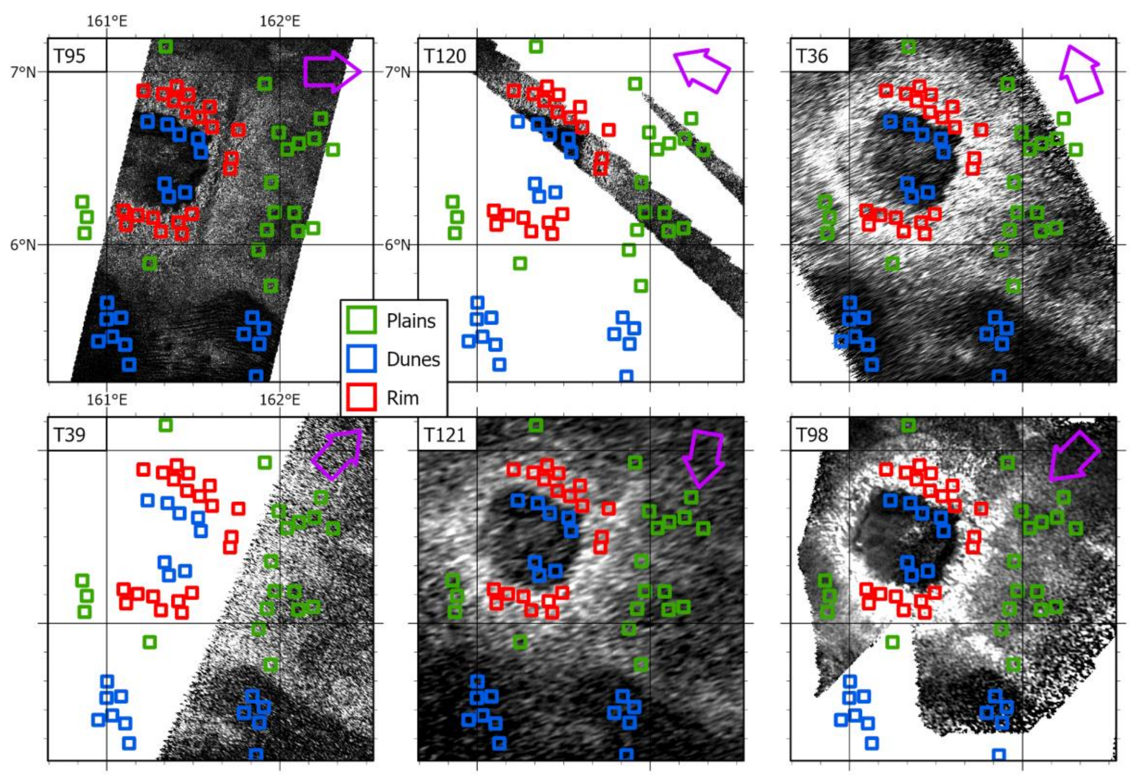

Figure 2: Radar data over Selk crater, corrected for incidence angle effects. The radar illumination direction is indicated by a magenta arrow. The backscatter properties are examined within three different regions: the crater rim, dunes, and plains/ejecta.