**LANDSCAPE FORMATION THROUGH DISSOLUTION ON TITAN: A 3D LANDSCAPE EVOLUTION MODEL.**
T. Cornet[1], C. Fleurant[2], B. Seignovert[3], D. Cordier[3], O. Bourgeois[4], S. Le Mouélic[4], S. Rodriguez[1,5], A. Lucas[5]. Laboratoire AIM, CEA Saclay, Gif sur Yvette, France. [2]LETG, Université d'Angers, Angers, France. [3]Laboratoire GSMA, Université de Reims, Reims, France. [4]LPG Nantes, Université de Nantes, Nantes, France. [5]IPGP, Université Paris-Diderot, Paris, France. (thomas.f.cornet@gmail.com)

**Introduction:** Titan is an Earth-like world in many aspects: a $N_2$-rich atmosphere is present ontop the surface, lacustrine depressions, lakes and seas exist at polar latitudes [1], they are sometimes connected to liquid-filled/dried fluvial valleys and channels at polar to tropical latitudes [2], and deserts made of longitudinal dunes are the dominant geological features close to the equator [3]. Despite many similarities between the landscapes seen in the Cassini/RADAR and VIMS images of Titan and the Earth, the chemistry implied in the geological processes, however, is strikingly different. Titan's cold environment (T = 90 - 94 K) only allows water to exist under the form of an icy "bedrock". The presence of methane as the second major atmospheric constituent in these cold conditions, as well as an active photochemistry, allows methane and ethane to drive a hydrocarbon cycle similar to the terrestrial hydrological cycle. Finally, a plethora of organic solids, more or less soluble in liquid hydrocarbons [4], are produced in the atmosphere and fall down onto the surface over geological timescales.

Based on comparisons with terrestrial analogues, dissolution and crystallization have been suggested in various instances to take part in the landscape development on Titan [5-8]. Dissolution has been invoked, for instance, for the development of the so-called "labyrinthic terrain", located at high latitudes and resembling terrestrial cockpit or polygonal karst terrain [7] (Figure 1). Here we aim at testing this hypothesis by comparing the natural landscapes visible in the Cassini RADAR SAR images, with the results of a 3D Landscape Evolution Model (LEM) that includes dissolution as the major geological process [9].

**Methods:** We make use of the Channel-Hillslope Integrated Landscape Development (CHILD) Landscape Evolution Model (LEM) developed by Tucker et al. [10] and modified by Fleurant et al. [9] to include dissolution in the landscape formation. Tectonics and mechanical erosion are disabled and only dissolution and solute transport along the steepest gradient alter the intial mesh, set as a planar surface covered by a 100.0 ±0.1 m organic layer with a 50 m spatial resolution over a 25×25 km area. Three factors are tested: the dissolution rate, the diffusion rate for solute transport, and an initial "sink spatial density" designed to simulate pre-existing fracturation of the basement. Using this LEM, we are able to follow the terrain elevation over millions of years.

Cassini/RADAR SAR images are the only high resolution imagery data available, where cockpit-like landforms can be distinguished (Figure 1). To compare these SAR images of Titan's surface with the model results, we compute synthetic SAR images from the Digital Elevation Models generated with the landscape evolution model. The step is ensured following the procedure described in [11], which takes into account surface reflections of microwaves but do not include volume scattering effects. Since we are concerned with large scale patterns dominated by topographic effects at the scale of several tens of meters in the SAR images (typically triangular or sharp facets, and their spacing), and not the absolute $\sigma^0$ values, this assumption does not alter the results.

**Results:** Figure 2 shows the output of the elevation time evolution (from 200 kyr to 8 Myr), and the SAR images that have been derived from the modelled to-

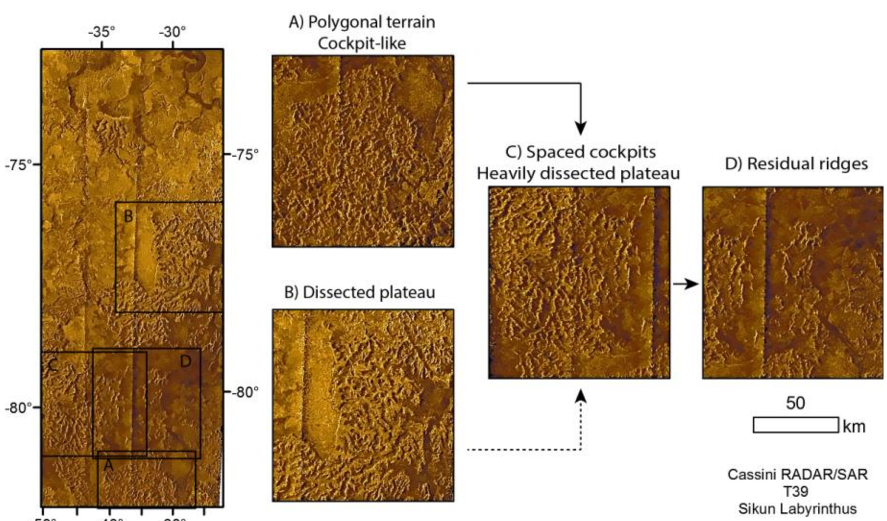


**Figure 1:** The Sikun Labyrinthus area on Titan seen at T39. The area display set of ridges and valleys that seem to widen from polygonal terrains to isolated ridges/hills toward the south pole, where GCMs predict high precipitation rates [13].

pography. The dissolution rate we take into account in Figure 2 is that of a surface organic layer whose bulk composition is given by the relative abundance of organic solids produced by photochemistry in the atmosphere [12] and accumulated at the surface, as computed in Cornet et al. [4]. These deposits are exposed to methane precipitation rates given by Schneider et al. [13] at high latitudes ($P$ ~ 8 m/Tyr), which leads to a dissolution rate on the order of $DR = 10^{-4}$ m/Tyr [4], adimensioned into $DR/P \sim 10^{-5}$. The incidence angle for the SAR image simulation is that of the T39 SAR swath where Sikun Labyrinthus has been observed. The dielectric constant of the ground corresponds to tholin materials [14].

Despite a lack of preferred orientation of radar reflectors in our SAR simulated images, sometimes seen in Cassini images, striking similarities can be seen between the synthetic and actual SAR images in the areas of the polygonal terrain to residual hills (Figure 1), especially if the landscape has been exposed to several millions of years of chemical erosion (> 5 Myr in our simulations). This allows the facets to be spaced by a few kilometres, such as for the polygonal and isolated ridges on Figure 1. Besides, the simulations indicate that residual hills of only a few tens of meters in height are able to generate radar patterns similar to what is observed on Sikun Labyrinthus. This is consistent with the idea that the surface organic layer, if present, undergoing dissolution is perhaps not thicker than a few tens of meters in some areas on Titan.

**Conclusions:** We are able to produce digital elevation models of landscapes formed by dissolution under Titan's surface conditions. These DEMs are used to produce synthetic SAR images of the surface in order to compare the modelled landscapes with the actual Cassini/RADAR SAR images of Titan. Striking similarities are seen between simulated and real SAR images, which suggests that the landscapes generated could explain the patterns observed in Cassini data. Further work will include the statistical analysis of the modelled landscapes in order to infer possible quantitative information about Titan's high latitude terrain.

**References:** [1] Stofan E. et al (2006), Nature. [2] Langhans M. et al. (2013), Icarus. [3] Lucas A. et al. (2016), GRL. [4] Cornet T. et al. (2015), JGR. [5] Lorenz R. et al. (2009), PSS. [6] Cornet T. et al. (2012), Icarus. [7] Malaska M. et al. (2010), LPSC. [8] Barnes J.W. et al. (2011), Icarus. [9] Fleurant C. et al. (2008), Geomorph., Rel., Proc., Envir. [10] Tucker G. et al. (2001), Computers Geosciences. [11] Paillou Ph. et al. (2016), Icarus. [12] Krasnopolsky V. (2009), Icarus. [13] Schneider T. et al. (2012), Nature. [14] Rodriguez S. et al. (2003), Icarus.

**Additional Information:** TC is funded by the Centre National d'Etudes Spatiales (CNES) Research Fellowship programme. The authors also acknowledge financial support by the LabEx UnivEarthS.

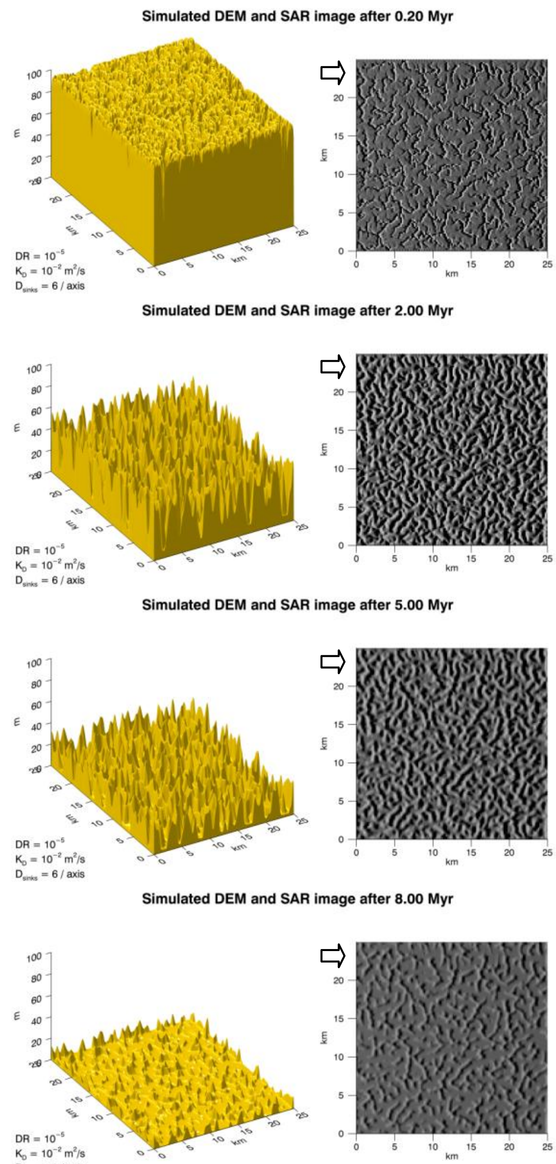


**Figure 2:** Snapshots of landscape evolution by dissolution and solute transport taken after 200 kyr, 2 Myr, 5 Myr and 8 Myr (from top to bottom) with a dissolution rate of $10^{-5}$ and a diffusion coefficient of $10^{-2}$ $m^2/s$. Left: Digital Elevation Models (DEMs) of the topographic surface generated by the LEM under Titan conditions. Right: synthetic SAR images generated from the DEMs on the left, the arrows indicate the look direction.