NEW PROSPECTS OF TITAN’S RIVER ANALYSIS FROM A REFINED TOPOGRAPHIC MAP OF THE HUYGENS LANDING SITE. C. Daudon1, J.T. Perron2, J.M. Soderblom2, S. Rodriguez3, A. Lucas1, S. Jacquemoud1. 1Université de Paris, Institut de physique du globe de Paris, CNRS, Paris, France (daudon@ipgp.fr), 2Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, USA.

Introduction: After 13 years of observations by the Cassini-Huygens probe, Titan, Saturn’s largest moon, has been found to be unique in the Solar System. Singularly similar to the Earth, its surface displays morphologies familiar to us: drainage basins and river systems [1,2], lakes and seas [3,4], dune fields [5,6], and incised mountains [7,8].

Titan’s methane cycle plays a major role in its climate and geology, driving a wide range of processes that shape the landscape, such as fluvial erosion [9]. Similar to erosion by water on Earth, liquid methane carves into Titan’s surface, forming river valleys. These river networks are particularly discernible in images acquired near the equator by the Huygens probe. To improve understanding of the processes at work, one needs a detailed and accurate digital terrain model (DTM) of this region.

Previous studies investigated the river networks near the Huygens landing site [10,11] but they based their analysis on a DTM [12,13] that has some limitations that could significantly bias the interpretation of the morphology and the geology of the area. Taking advantage of significant improvements in the quality of Huygens navigation information and of the DISR images, we built a new DTM of the landing site offering a higher spatial sampling and a more reliable topography.

Since we focus our study on the river networks, we hydrologically conditioned our DTM, as is commonly done for terrestrial studies (i.e., HydroSHEDS, MERIT Hydro) [14]. Then we used this DTM, which offers the best available resolution of hillslopes and river valleys on Titan, to perform an accurate morphometrical analysis of the terrain.

DTM improvements: We based the analysis of the DTM on morphological information and river routing. Routing is a common technique used in hydrology to determine the natural route taken by a liquid over a given topography. Ideally, a liquid flowing on the DTM should choose the same path as the one followed by the rivers seen in the images.

However, even if it works properly overall, routing does not always follow the observed rivers. Assuming that the flow path remains unchanged (no uplift), it should follow the exact same path as the rivers. This discrepancy is common even in terrestrial studies and is caused by inaccuracies and noise in the elevation data.

The DTM is subject to uncertainties that we estimated by computing the expected vertical precision (EP) for each stereo pair [15]. EP that only depends on the geometry of acquisition and the image resolution gives an estimate of the best achievable accuracy:

\[ \text{EP} = \rho \times \text{GSD}/(p/h) \]

Where

- \( \rho \) is the accuracy, expressed in pixels, with which features can be matched between the images (i.e., the RMS stereo matching error).
- \( \text{GSD} \) is the ground sample distance.
- \( p/h \) is the parallax-to-height ratio describing the convergence geometry of the stereo pair. It can be computed as \( p/h = | \tan(e_1) - \tan(e_2) | \)
  where \( e_1 \) and \( e_2 \) are the emission angles of the two images of each stereopair. The sign is positive if the target is viewed from opposite sides and the negative if it is viewed from the same side.

In our case, \( \rho \) (accounting for calibration residual) is provided by MicMac [16], the software used to compute the DTM (\( \rho = 0.6 \)) and the average GSD of our images is 20 m, according to the image pairs. This formula provides an EP value for each pixel of the DTM since it depends on the emission angle computed for each pixel.

Thus, we can modify the elevations of the DTM when routing does not match the location of the rivers, as long as the changes are smaller or equal to the EP values. This modified DTM, which best matches the river profiles, can be then used to analyze the rivers and the hillslopes (Figure 1).

River profile analysis: A \( \chi \) plot [17] is a typical tool for bedrock river profiles analysis when the topographic data are noisy, as is our DTM. It is based on the integration of a stream power equation at steady state and serves as a metric for the elevation of a channel at a given location along the river. If the river is at steady state and if it incises based on the stream power model, the data plot is a straight line with a slope proportional to the ratio of the uplift rate to the erodibility. Non-linear relationships could provide clues about the maturity of the landscape or could be an indication that the channel does not completely obey the stream power incision model.

In cases where limited information about the uplift rate is available, \( \chi \) plots can also be used in a comparative sense in order to extract information about the local dynamics of the landscape formation.

A preliminary analysis was carried out on the \( \chi \) plot of the major river (Figure 2) using the modified DTM.
It is noteworthy that the plot is slightly concave down, which could mean that the channel is slightly out of equilibrium or that the mechanics of river incision are not fully included in the stream power law. This analysis needs to be further investigated.

**Future work:** Next steps will include further analysis of the $\chi$ plot and interpretation of information it contains. This could bring new insights on the tectonics and climate history of the study area.

Additional work will be to plot a map of the $\chi$ values across separate drainage basins. This could tell us if the basins are in equilibrium and or if the landscape is still actively evolving.

![Figure 1](image1.png)

**Figure 1:** 3D views of the DTM with routing superimposed (white line) on each DTM. The top panel shows the DTM built with MicMac and the bottom panel shows the hydrologically conditioned DTM used for the $\chi$ plot. A blue frame delineates the major river network in the bottom panel.

![Figure 2](image2.png)

**Figure 2:** $\chi$ plot of the major river and tributaries (top) and the 2D shape of this river (bottom).

**References:**