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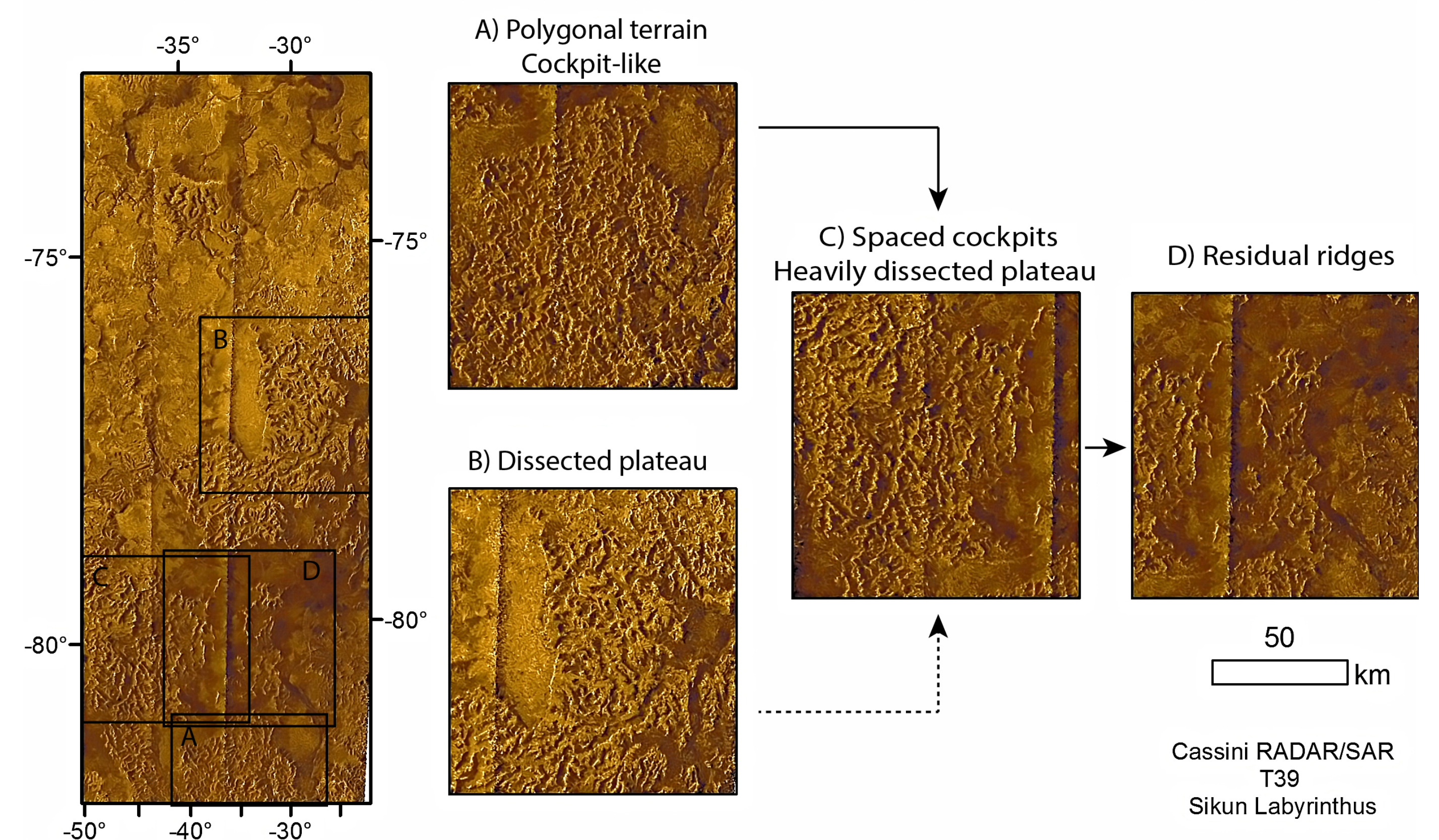
# Evolution of Titan's labyrinths through chemical erosion and hillslope transport

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## Introduction

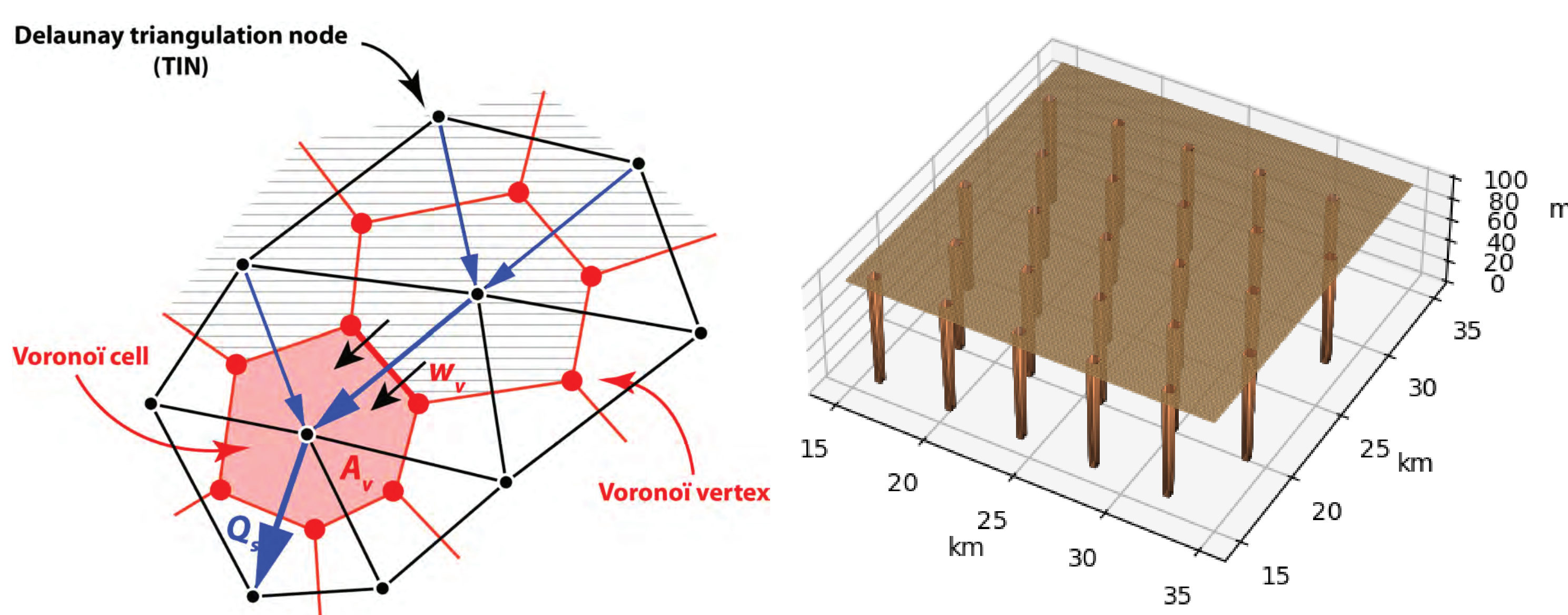
- First detected in the Cassini RADAR Synthetic Aperture Radar (SAR) T39 data of the Sikun-Tupile-Ecaz Labyrinths area acquired in 2007 (Figure 1).
- Labyrinth terrain on Titan are dissected terrain formed by complex valleys networks ranging from polygonal to linear features [1], and are high altitude / high latitude areas [2].
- Titan's labyrinths present morphological similarities with terrestrial karst landforms [1], where the chemical erosion (dissolution) of fractured carbonates drives the landscape evolution [3].
- Theoretical predictions of the dissolution rates of some of Titan's expected solid organics in liquid methane are high, comparable to carbonates in water [4].
- In this work, using a Landscape Evolution Model (LEM), we study the influence of two main geomorphological processes on the development of eroded landscapes on Titan: a dissolution-driven erosion, and the hillslope transport.
- Using the simulated landscapes, we produce artificial radar SAR images that can be compared to the Titan Cassini Radar SAR data.



**Figure 1:** The Sikun (B) - Ecaz (A) -Tupile (D) labyrinth area seen at the high southern latitudes on Titan. Cassini Radar NLDSAR data [5].

## Methods: Landscape simulation

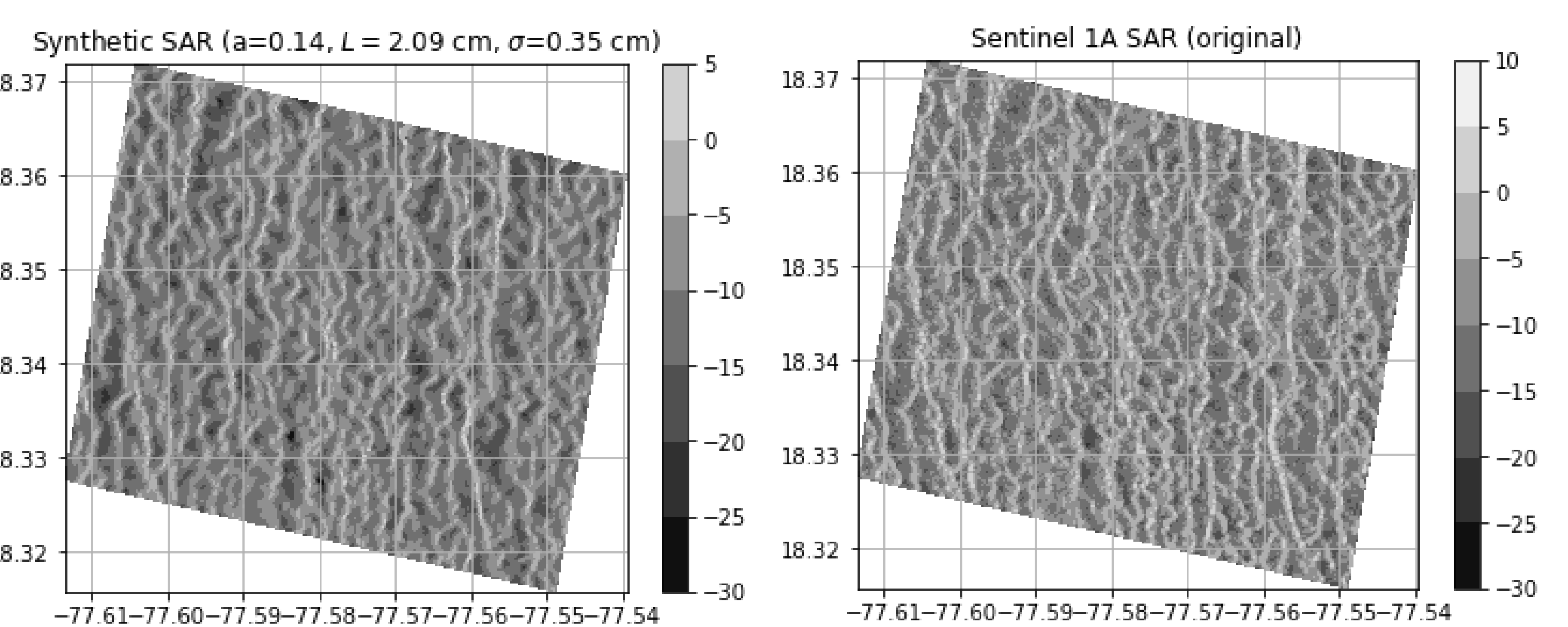
- We use the Channel-Hillslope Integrated Landscape Development (CHILD) model [6], modified to include the rock dissolution process (epikarst zone theory) to model the Jamaican cockpit karst of Cockpit Country [7].
- We study the influence of the erosion via bulk dissolution (insoluble to soluble substrate), hillslope transport (linear diffusion), and fracturation (variable number of "sinks" as proxy for crossing fracture planes).
- Initial CHILD mesh setup (Figure 2):
  - 40 x 40 km regular hexagonal mesh, with a 100 m horizontal resolution.
  - Flat ( $\Delta h = 10$  cm) or gently sloped surface, with an initial elevation  $h_{ini}$  (100m, 200m).
  - Titan climate net precipitation at relevant latitude taken from [8].
  - Run over 10 millions of Titan years.



**Figure 2:** Initial CHILD mesh for a flat surface, and concept to track elevation changes. Changes in elevation and discharge ( $Q_s$ ) are tracked from one node to the next downslope, each node being associated to a Voronoi cell with a given collecting area ( $A_v$ ).

## Methods: SAR images simulation

- Cassini observed Titan with the Radar in SAR mode in Ku-band ( $f=13.7$  GHz,  $\lambda=2.17$  cm).
- The measured microwave backscattering ( $\sigma^0$ ) is primarily a combination of surface and sub-surface (volume) contributions depending on topography, roughness (via the correlation length  $L$  and RMS surface height  $\sigma$ ), and composition (albedo  $a$ , dielectric constant  $\epsilon$ ) [9].
- We use surface and volume scattering models [9] to generate artificial SAR images from simulated topography.
- We validate the approach on the Cockpit Country area in Jamaica, test area of the CHILD modified model [7], using Sentinel 1A data (Figure 3). We adapt the radar and substrate properties to this terrestrial case to successfully reproduce radar SAR images of the area.



**Figure 3:** Radar SAR image of the Cockpit Country (Jamaica) reconstructed using the characteristics of real Sentinel 1A SAR data (C-band, look angle, altitude), SRTM topography, and limestone dielectric properties. Roughness parameters ( $\sigma$ ,  $L$ ) and albedo ( $a$ ) inferred by fitting the backscatter distribution of the original S1A image. Colour scale in dB.

## Results

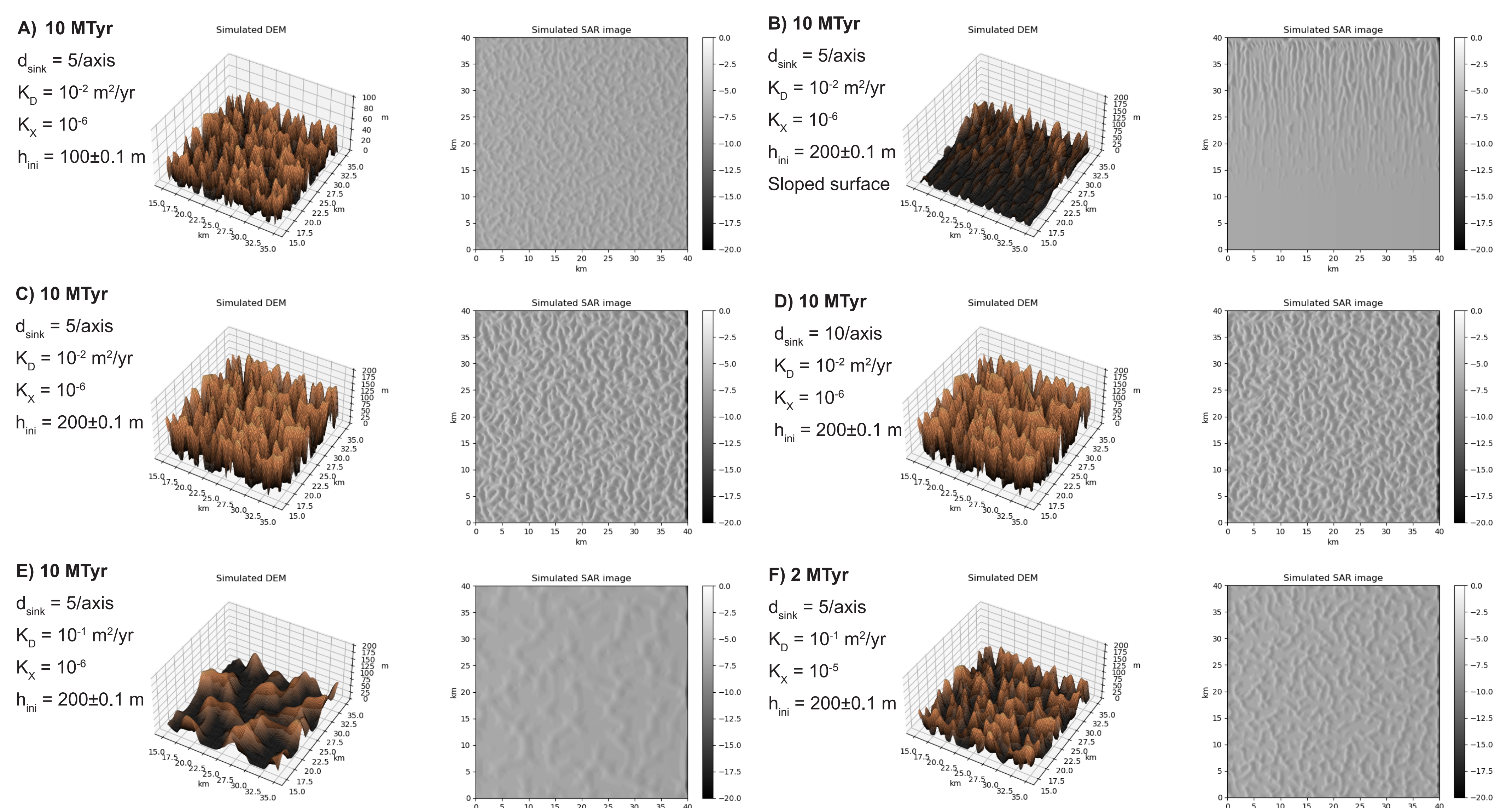
Comparison of landscapes in Figure 4 shows:

- (A/C) Higher initial elevation favours the development higher residual hills.
- (A/B) Contrary to flat surfaces, slopes lead to the development of linear ridges.
- (C/D) For a set of geomorphological parameters ( $h_{ini}$ ,  $K_D$ , and  $K_X$ ), the number of sinks ( $\sim$  degree of fracturation) has little influence on the final landscapes.
- (C/E) Higher hillslope transport diffusion coefficients lead to the spread/smoothing of the topography, when coupled with another erosion mechanism (here dissolution).
- (E/F) Higher erosion rates (bulk dissolution) drastically increase the denudation speed of the landscape.

## Future work

Future work will complete this parameters space study by expanding the range of values tested.

Quantitative comparisons with Titan labyrinths Cassini SAR images will be performed.



**Figure 4:** Contribution of the erosion rate via bulk dissolution ( $K_X$ ), hillslope transport ( $K_D$ ), fracturation ( $d_{sink}$ ), initial elevation ( $h_{ini}$ ), and slope on the resulting topography and simulated Titan SAR images (colourbar in dB).