MODELLING AEOLIAN – FLUVIAL INTERACTIONS ON TITAN. E. V. Bohacek[1], R. S. Bahia[1], L. Braat[1], S. Boazman[1], E. Sefton-Nash[1], C. Orgel[1], C. Wilson[1] and L. Riu[2], [1]European Space Research and Technology Centre (ESTEC), European Space Agency, Noordwijk, The Netherlands (eleni.bohacek@esa.int), [2]European Space Astronomy Centre (ESAC), European Space Agency, Madrid, Spain

Introduction: The surface of Titan is dynamic, displaying evidence of fluvial and aeolian activity. Titan is the only other planetary body in the solar system aside from Earth to experience rainfall, which results in fluvial landforms (FLs), lakes and seas [1-3]. Unlike Earth, this rainfall is primarily liquid methane [4]. Titan's surface temperature (~94 K) and pressure (1.5 bar) allows for methane and ethane to be in the liquid phase at the surface, allowing it to flow and form rivers, which over time form FLs [2-3]. Although the rainfall is primarily methane, this methane (liquid density ~424 kg/m^3) can be photolyzed to form ethane (liquid density ~544 kg/m^3), resulting in lakes and rivers of ethane [5]. Modelling indicates flowing liquid methane would permeate into the subsurface through Titan's porous, icy crust [5]. This methane would reach subsurface reservoirs of water ice and become trapped to form clathrates. However, preferential enclathration of CH_4 compared to C_2H_6 is at odds with the observed high abundance of methane and corresponding relative deficiency of ethane on Titan [5]. Nonetheless, liquid ethane, with a higher boiling point than methane, is more likely to be fed back into rivers and lakes by springs and play a formative role in the lower reaches of rivers. This contrasts with rivers' upper reaches, which are influenced more by methane dominated rainfall. This change in fluid density from the source (methane) to the terminus (ethane) of Titan's rivers may affect the flow dynamics of the river.

Although rivers are currently active on Titan, the fluid flows are likely episodic. Observations by NASA's Cassini spacecraft, which performed 127 close flybys of Titan over 13 years, and global climate models (GCMs) indicate that global rainfall persisting for 2-100 hours occurs on ~100-1000-year intervals, but at the poles it is more frequent lasting 10-100 hours each Titan year (30 Earth years), with rainfall concentrated in the polar summer [6]. However, northern hemisphere summers (the wet seasons) are likely longer than in the southern hemisphere where wet seasons are more intense but shorter [7]. It is, therefore, apparent that rivers are likely dry for long periods of time.

Titan valleys have been observed to range from five to hundreds of kilometers in length and around a hundred meters to hundreds of kilometers in width [3], however smaller rivers may not be observed due to image resolution limitations. Although precipitation is limited in the mid-latitudes FLs have been observed in several of these regions [3].

Titan is also covered by vast regions of dune fields (~15 % of surface coverage), primarily within the equatorial latitudes, but in some places reaching to ± 30º in latitude [8-10]. Like Earth, most of these dunes are linear in morphology [8]. Linear dunes result from bimodal wind directions or barchan dune elongation [11], and sediment supplies varying from moderate to voluminous [11]. Titan's dunes are generally large: ~0.4 – 3.6 km in width (mean ~1.3 km); ~1.4 – 5.3 km in dune spacing (mean ~2.7); ~100 – 150 m tall; and mean lengths on the order of 50 km [12, 13]. However, due to the difference in wet seasonal lengths, the increased surface moisture in the northern hemisphere generally results in smaller dunes than those in the south [13]. They are composed of hydrocarbon and nitrile sand-sized particles, which form due to photochemical reactions in Titan's atmosphere [14]. Given Titan's gravity (1.35 m/s^2) and thick atmosphere (atmospheric pressure ~ 1.47 bars), and as the estimated saltation threshold for dry sediments is ~1 m/s, if we assume freestream wind speeds are >1 m/s, optimum particle size for saltation has been calculated to be ~0.3 mm [13]. For the short time ESA's Huygen Lander was operational it recorded wind speeds between 0.2 – 0.3 m/s [13], however GCMs indicate that speeds >1 m/s are reached every 14 Earth years (near the Titan equinox) [14], indicating dunes are ephemerally active.

Although observations of Titan are limited, interactions between rivers and dunes have been observed. Although rare, rivers have been seen dissecting dunes [15]. Given that FLs are observed within the mid-latitudes in regions of ephemerally active dune fields, like terrestrial deserts [16, 17], it is likely that fluvial and aeolian processes interact with one another in ways that cannot be easily distinguished without temporally distributed reimaging. Limited data availability means modelling fluvial and aeolian processes is one of the best methods to understand active and previously active processes on Titan.

Here we report the initial study by the Working group on Aeolian-Fluvial Terrain Interactions (WAFTI), based at the European Space Agency, which examines the effects of these processes in synergy under Titan conditions, using a combination of modelling and geomorphological analysis. We hypothesise that these interactions could have implication for the distribution and planforms of Titan FLs, particularly the comparative lack of FLs in the mid-latitudes of Titan and rectangular planform of many channel networks [3].

In this study, we simulate the interactions between migrating dunes and different reaches of an active Titan River channel, to determine the effects on the channel's morphology and geometry. Input parameters for the simulation will be extracted from a combination of literature and newly performed remote sensing analysis.

Datasets and Methods: To simulate the interactions between fluvial and aeolian processes on Titan, we developed the Titan Aeolian-Fluvial Interactions (TAFI) model. This is a landscape evolution model based on a coupled implementation of the Caesar-Lisflood fluvial model, and Discrete ECogeomorphic Aeolian Landscape model (DECAL) dunes model [18]. The Caesar-Lisflood fluvial model routes water over a Digital Elevation Model (DEM) and calculates erosion and deposition from fluvial and slope processes and changes elevations accordingly [19]. It comprises a surface flow model, fluvial erosion and deposition, and slope processes. The DECAL model [20] is based on the Werner slab model of dunes [21], which simulates dune field development through self-organization. The topography is discretized into slabs on the DEM, and slabs are moved across the space according to a set of simple rules.

We test for potential aeolian fluvial interactions on 10 m per pixel DEMs of simplified fluvial geometry: a straight channel with a rectangular cross section, running perpendicular to linear dune transport in an area of 2 x 5 km. Channel widths on Titan have been observed to vary from 20 – 3000 m [22], therefore we model an intermediate order of magnitude 100 m channel width. FLs with dendritic drainage patterns will be the focus of this study, as they make up the majority of the systems [23. The GIS-based database of fluvial features on Titan [3], will be used to identify valleys of interest, particularly those present within the mid-latitudes and adequate DEM coverage. Width measurements will be directly extracted from this database. A variable required to produce the model DEMs is surface slope. To best represent the surface slope of FLs on Titan, we will calculate slope values for main valleys (the lengthiest of the network). Considering valleys have different slopes in different reaches of their profile we will calculate slope within the source, mid and termination. Elevation data will be extracted from RADAR stereo DEMs (~1.4 km per pixel in horizonal resolution). The valleys will be split by length into thirds, representing the three reaches. Changes in fluid composition (methane vs. ethane) shall also be considered when modelling different reaches of the valley. Given the DEMs resolution, slope was only calculated for main valleys of > 20 km in length allowing for adequate data acquisition. Elevation data was extracted at 1.5 km intervals down the segments. Slope (change in elevation divided by change in length) will then be calculated for each 1.5 km interval and averaged for each segment. These values were then averaged to determine the average slope for source, mid-reaches, and termination segments.

Planned Simulations: Several different simulation scenarios shall be modeled; the results of the first shall be presented at LPSC. The initial simulation shall model (1) a continuous methane river, flowing in a straight channel with linear dunes migrating towards the channel parallel to its length. Considering rivers may flow perpendicular to the crest line of the dunes, we simulate (2) a continuous methane river flowing towards a dune field with crest lines perpendicular to the direction of flow. Considering rivers have different slopes in different reaches and on Titan they are composed of both methane and ethane, so we simulate scenario (1), but alter slope to represent the three different reaches of the channel system and simulate for both methane and ethane flows by altering fluid density. Finally, fluvial activity is ephemeral/episodic. We, therefore, simulate scenario (1), with an episodically active river and continually active dunes.

These simulations allow for a greater understanding of the interactions between rivers and the dunes present on Titan. The findings may help with understanding the drainage patterns and distribution of Titan FLs and methane/ethane across the planetary body.

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