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Fluvial Erosion on Titan

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1. Introduction

Titan's surface is shaped by a rich abundance of fluvial valleys, which is an indication for the activity of a volatile cycle even in current times (e.g. [1, 2]). In contrast to the water cycle on terrestrial planets such as Earth and Mars, Titan's volatile cycle is based on liquid methane, which is in liquid and gaseous aggregate state within the atmosphere and near the surface, given Titan's environmental conditions (e.g. [3, 4, 5]). This study aims to investigate the entirety of fluvial channels identifiable by the current Cassini-image data inventory.

2. Database and Methods

Titan's channels are investigated based on data obtained by the Synthetic Aperture Radar (SAR) instrument, the Visible and Infrared Mapping Spectrometer (VIMS) onboard the Cassini spacecraft, and by the Descent Imager/Spectral Radiometer (DISR) carried by the Huygens Landing Probe. To gain a deeper understanding of Titan's geology, a database of fluvial features is created based on radar-SAR data to reveal their distribution, morphology, and spectral characteristics on a global scale. This study further explores the ways in which fluvial valleys are spatially related to other geologic landforms and spectral surface units, which are now accessible thanks to Cassini-VIMS data.

3. Results

3.1. Distribution and Types of Channels

Highly developed dendritic networks, with channel lengths of up to 1,200 km and widths of up to 10 km, are concentrated only at a few locations, whereas individual valleys are scattered over all latitudes (see Figure 1). The geometric dimensions of Titan's valleys are comparable to major streams on Earth and Mars. Fluvial valleys are frequently found close to impact craters and in mountainous areas. Large areas at mid-latitudes, such as equatorial dunefields and undifferentiated plains, are almost entirely free of valleys (see Figure 1). Valleys currently filled with liquids are likely at Titan's high northern latitudes where they occur in a high density and connected to the large lakes in this region.

Several distinct morphologic types of fluvial valleys can be discerned based on SAR-images. Extended networks of dendritic valleys occur near the equator as well as close to the north pole. Dendritic valleys clearly indicate an origin from rainfall. The morphology of some valley types, such as putative canyons, cannot uniquely be explained by rainfall but could equally be attributable to volcanic or tectonic action or groundwater sapping. The morphology of many valleys at low and mid-latitudes resembles terrestrial wadis and indicates dry climatic conditions in recent times.

3.2. Spectral Properties of Fluvial Terrain

Regarding their spectral properties, fluvial terrains are often characterized by a high reflectance in each of Titan's atmospheric windows, as most of them are located on Titan's bright 'continents' and 'islands'. Many valleys are spatially associated with a surface unit appearing blue in VIMS false-color RGB composites with R: 1.59/1.27 µm, G: 2.03/1.27 µm, and B: 1.27/1.08 µm, due to its higher reflection at 1.3 µm.

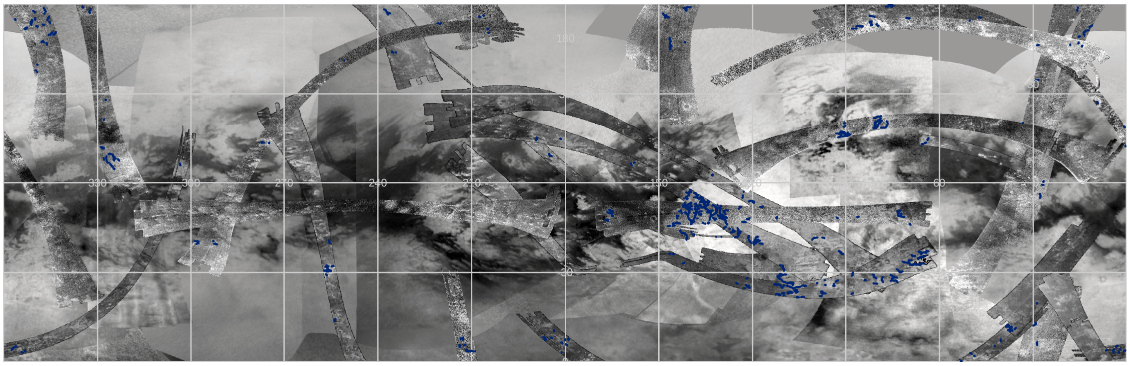

Figure 1: Fluvial valleys (marked in blue) are overlaid on global radar observations and near-infrared ISS map. Simple cylindrical projection of lower and mid-latitudes. Image is centered at 180°W, 0°N.

This observation could have two explanations: either the channels dissect pure bluish surface units, or they are carved into terrain with a mixed spectral signature between bright and bluish surface materials.

4. Discussion and Conclusions

Recent fluvial activity is very likely in the north polar region, which stands in contrast to the more arid conditions at lower and mid-latitudes and at the south pole of Titan. This divergence is a possible indication but not a conclusive proof of seasonal climatic asymmetries between the hemispheres. A general disparity in the distribution of clouds and valleys is observed, since some areas, such as the south polar region, do not possess a high density of active channels despite of their dense cloud coverage (e.g. [6]). This disagreement might be explained by a non-conclusive relation of clouds and channels or by climatic differences at the time when the channels developed. However, traces of previous fluvial activity are scattered over all latitudes of Titan, indicative of previous climatic conditions with at least episodic rainfall. The high prevalence of valleys in mountains point to orographic rainfall shaping these valleys, although this cannot be the single origin of Titan's valleys. The proceeding of Titan's methane cycle is likely to be very slow compared to Earth' water cycle; however, the long-term action of the methane cycle is certain. The global picture of fluvial flows clearly indicates a high significance and a large diversity of liquid-related processes acting near the surface, and provides information about the controlling parameters of fluvial erosion, such as rainfall regimes in space and time, and surface and bedrock types.

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