How do Lakes on Titan form?

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Introduction

- The origin of the depressions that host the lakes on Titan is still debated.
- Proposed origin hypotheses include but aren’t limited to processes that form lakes on Earth.

Major Objectives

To use the Lake’s
- Size distribution,
- Orientation, and
- Outline shape analysis
to narrow down the probable lake formation processes.

What: How do lakes form on Titan?

Why: Understand the surface evolution processes on Titan.

How: By studying the shapes and sizes of lakes.

1 minute take-away

- Size distribution suggests
  - Can’t be Impact craters
  - May be Volcanic Calderas or
  - Collapse karst similar to thermokarst lakes on Earth

Shape distribution analysis in infancy to suggest anything yet!

Lake Shape analysis

Outline shape analysis using Elliptical Fourier Descriptors

Complex shapes can be analyzed using outline shape analysis. The coefficients of mathematical functions like Fourier series are fitted to points sampled along the outline. The Fourier coefficients quantify the outline and are then used to do any statistical analysis like Hierarchical Clustering or Principal component analysis. Increasing the number of harmonics leads to fitting the outline on the leaf’s shape (left) or Oneida Lacus’ shape (left, below leaf) as seen.

Hierarchical Clustering

We started with six lakes on the north pole. The Hierarchical Clustering of Fourier coefficients of 6 lakes gave satisfactory clusters.

Lakes used for the PCA

Titan Lake Principal Components

The north polar lakes (dark features numbered here in red in left) whose outline parameters were used to do the principal component analysis (right). The Principal component analysis of lake shapes indicates that may be the lake formation mechanism is independent of the size of lakes.

Lakes on Earth

- Gracial erosion/deposition
- Impacts
- Volcanic Calderas/Maars
- Tectonic uplift/subsidence
- Interdune lakes
- Dissolution of limestone/Karst
- Thermokarst

Lakes on Titan

- MacKay Lacus (78.32 N, 180 W)
- Muggel Lacus (84.44 N, 203.5 W)
- Neagh Lacus (81.11 N, 32.16 W)
- Myvatn Lacus (78.8 N, 135.1 W)

Lakes on Titan and Earth

- Titan
- Yakutia
- Canada
- Minnesota
- African Rift Valley

Size/Orientation analysis

Size Distribution: Thermokarst lakes on Earth

Thermokarst lake diameters on Earth follow a Lognormal distribution under the assumptions that
- Lake size distribution is small
- Lakes evolved over a small time frame

The paterae (volcanic calderas) on Io do follow Lognormal distribution.

Size Distribution: Paterae on Io

Effective Diameter (km)

Size Distribution: Craters on Titan

The impact craters on Titan do not follow Lognormal distribution.

Size Distribution: Craters on Io

Effective Diameter (km)

Size Distribution: Lakes on Titan

Lake size determination

VIMS north polar composite
R = 5µ, G = 2µ,
B = 1.3µ
RADAR north polar composite
ISS north polar composite
0.93 µ

Orientation

- Wind/Wave activity
- Structural control

Formation Process Possibility Reasons
Impact Craters No Titan impact craters don’t follow lognormal distribution
Weathered Impact Craters Not tested
Volcanic Calderas May be Calderas on Io follow lognormal distribution
Kart/Collaps Kart May be Thermokarst lakes on Earth follow Lognormal Distribution
Tectonic uplift subsidence No No preferred lake orientation

Leaf shape
Red : First harmonic of Fourier Series
Red : Fifth and Tenth harmonics of Fourier Series

¹Bonhomme et al., 2014. Journal of Statistical Software

Lake Shape analysis

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