# SAND SEA AREA ON TITAN FROM CASSINI SAR AND ISS AND A NEW VOLUMETRIC ESTIMATION METHOD FOR TOTAL ORGANIC INVENTORY FROM DUNES

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**Introduction:** Sand seas on Saturn's moon, Titan, confirm similarities with Earth's deserts [1] and cover an estimated 15–20% of the satellite's surface [2]. Nearly all dunes on Titan are linear in form [1,3] and are concentrated within the equatorial region, between +30 and -30 degrees [1,3,4,5]. Dunes are similar in size, radar reflectivity, and morphology to those imaged in Earth's Namib, Saharan, and Saudi Arabian deserts [1,3]. This similarity of morphology suggests that there must be, or has been, sufficient wind, sediment supply, and collection area for the dunes to form.

Similar to Earth, dunes and sand seas on Titan represent the results of major, global atmospheric and surface processes [1,3,4]. Therefore, careful observation of sand sea characteristics, such as dune widths, dune heights, interdune sediment thickness, linear dune profiles, and measurements of dune field extents will help to describe the interaction of wind with Titan's surface [6], unveiling sediment transport pathways and the recent history of Titan's surface.

This project is focused on inferring the mode of sand sea sediment accumulation and transport by quantifying the area and estimating the volume of dune fields across Titan. This is the first detailed study of sand sea areas using images from Cassini's Imaging Science Subsystem (ISS) in conjunction with Cassini Synthetic Aperature RADAR (SAR) images. Unlike SAR images (~50% global coverage)[7], ISS images have 100% coverage of the sand sea latitudes but at lower resolution (~10 km to ~1 km) [8, c].

Precise calculations of the areas of sand seas, along with dune spacing [9], dune heights, interdune sediment thickness, and a realistic dune profile will allow accurate estimates of sand volume by latitude, longitude, and sand sea across Titan. This will help to further refine the global organic inventory in dunes [10,5] and help to identify areas of net sediment gain and loss. Presented here are results from a detailed study of areas of all dunes on Titan from Cassini SAR and ISS and the methods for a new volumetric approach that will be used to understand sediment volume and global transport.

**Area measurements using Cassini SAR and ISS:** First, we map dunefield extents identified within Cassini SAR images. We classify dune material as being SAR dark and linear in morphology and exclude bright mountains and other non-dune, SAR-dark features, similar to [5] (Fig. 1A).

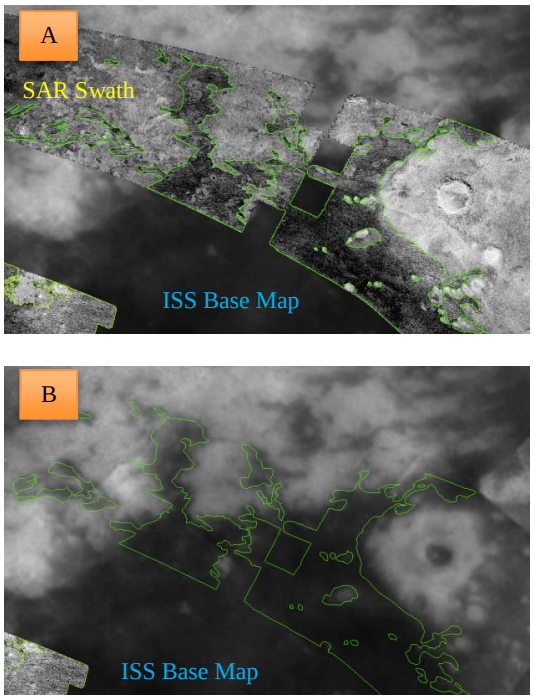


***Fig 1.* (A) *Dune area outlined on a Cassini SAR swath.*** *Dunefields are classified as SAR dark and linear in morphology.* ***(B) Correlation of dune covered areas determined with Cassini SAR to Cassini ISS data shows that dune material is indicated by darker ISS values.*** *Dunefields were mapped on the low resolution Cassini ISS images to estimate total dune volume on Titan (image about 1100 km across).*

Each dune field is outlined in ESRI's ArcMap 10 on Cassini SAR image swaths (Fig 2A). Given the correlation between dunes observed in Cassini SAR images and regions dark to Cassini ISS we can map dune areas in Cassini ISS images with a reasonable degree of accuracy (Fig 1B). The 2013 USGS contolled mosaic is used when mapping Cassini ISS dune material. We found a clear correlation between dune regions identified in Cassini SAR and regions dark to Cassini ISS at 938 nm [11]. Careful correlation of Cassini SAR to ISS data led us to pick ISS data values lower than ~135 to represent dunes (from a range of 0 to 255). This value is the transition from blue to light-green in a custom 20-interval color table from magenta to red (magenta and blue representing low data values). Utilization of the color table facilitated mapping and results in boundaries that are comparatively easily identified (Fig. 2B). Tests of the chosen threshold val-

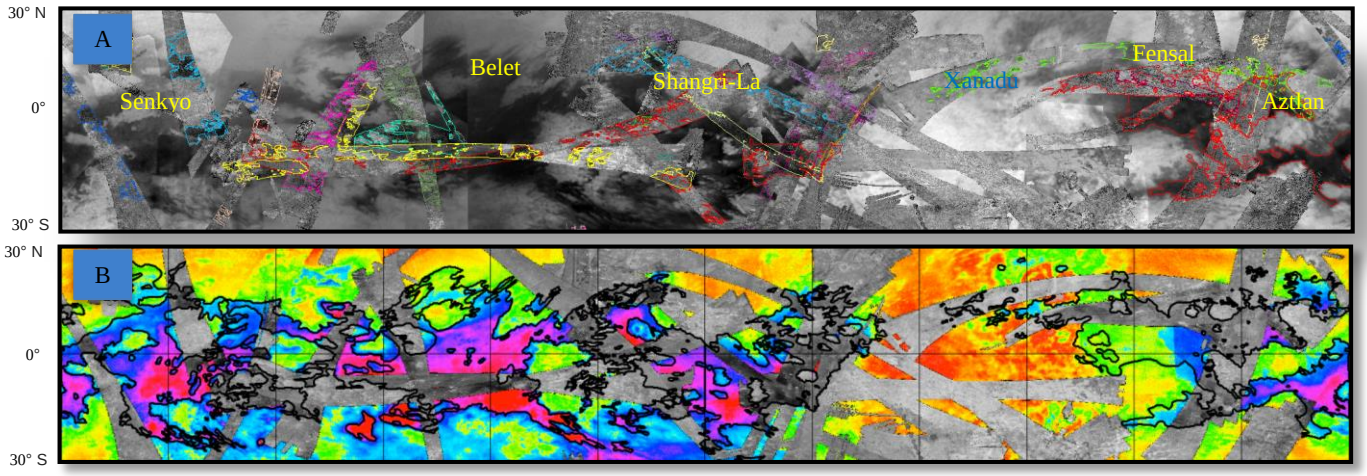


***Fig 2. Dune Fields Mapped on Titan using Cassini SAR, HiSAR and ISS data. (a)*** *Fensal and Aztlan dune fields are to the east outlined in red. The red perimeter indicates estimated dune field extent based on ISS characteristics. All other polygons indicate dune fields mapped using SAR and HiSAR swath data.* ***(b)*** *Cassini ISS data is used to estimate total dune coverage on Titan. Color coded ISS image shows dune covered (dark) areas more clearly.(Cassini ISS and SAR image of Titan's equatorial region between +30˚ and -30˚ latitude)*

ue in different regions yielded a fairly good correlation between dunes seen in Cassini SAR images and those in Cassini ISS images, increasing our confidence in this method.

**Area calculation from Cassini SAR and ISS Data:** To calculate the area of dunes we used a geodesic calculation tool from the USGS Astrogeology Science Center that mathematically takes into account the curvature and size of Titan to accurately represent distances and areas on the surface. In addition, we merged locations where there was overlap of Cassini SAR and ISS area polygons before calculating areas. Dune areas are slightly overestimated in portions of the exposed substrate between the sand seas. It is possible the SAR is penetrating below thin sands observed by Cassini ISS in those regions [1,5,11].

The total area of dunes on Titan measured in Cassini SAR images alone (Oct 2004 to June 2011) is ~12 million km$^2$ or ~14%. The total area of dunes on Titan estimated using Cassini SAR and ISS data (Oct 2004 to June 2013) is also ~12 million km$^2$ or ~14%. This is close to values from [5] of 10 million km$^2$ or 12.5% [see also 12].

**New volumetric technique**: This method involves dividing Titan's dune mapped areas into 100 x 100 km grid cells then using various parameters to calculate volume at each location. Cell volumes will be plotted and a color density map will highlight volume changes and sediment transport pathways through Titan's sand seas. This powerful technique will be the first to indicate volume changes and sediment transport across Titan's surface. All other estimates to date have relied on global assumptions and produced only total global volumes.

This technique includes dune field characteristics, measured over the last decade by several workers [3,4,5,8,9,10,11,13,ect.], such as dune heights, crest to crest spacing, thickness of interdune deposits, and fraction of dune and interdune coverage by location. We will create a map layer for each characteristic and hand contour values based on observed dunefield morphology in Cassini SAR and ISS images. These map layers will be overlaid and dune characteristic values for each specific location will be used rather than global assumptions. The major uncertainty is the thicknesses of sand in interdune areas.

**Conclusions:** We have calculated dunefield coverage in Titan's equatorial region using Cassini SAR and ISS data, ~12 million km$^2$ or ~14% global coverage. Our value is similar to values given by other authors using different methods. Accurately estimating sediment volume will help us to better understand the atmospheric processes that have led to the production of organics on Titan's surface and to understand the controls on sand sea morphology and evolution. We will continue to refine our volume estimating technique as we strive to more accurately estimate Titan's organic inventory from dune material.

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