SAND VOLUME ESTIMATES ON TITAN FROM CASSINI RADAR AND ISS: FENSAL AND AZTLAN SAND SEAS. K. Arnold[1], J. Radebaugh[1], A. Le Gall[2], E.P. Turtle[3], R.D. Lorenz[3], and the Cassini Radar Team. [1]Brigham Young University, Department of Geological Sciences, Provo, UT 84602, jani.radebaugh@byu.edu. [2]LATMOS-UVSQ, Paris, France, [3]JHU-APL, Laurel, MD 20723, [3]JHU-APL, Laurel, MD 20723.

Introduction: Observations of characteristics of sand seas on Saturn's moon, Titan, confirm similarities with Earth's deserts [1]. A careful study of details of these characteristics, such as sand sea areas, sand volumes, dune and inselberg morphologies, and sediment sources and transport will help to unveil the evolutionary history of Titan's surface. Nearly all dunes on Titan are linear in form [1,2], covering as much as 20% of the body (13% as measured only by Cassini Synthetic Aperture Radar, SAR [4]), and are concentrated within the equatorial region [1,2,3,4]. On Titan, dunes are similar in size, radar reflectivity, and morphology to those imaged in Earth's Namib, Saharan, and Saudi Arabian deserts [1]. This similarity of morphology suggests that there must be, or have been, sufficient wind, sediment supply, and collection area for the dunes to form.

Dunes and sand seas on Titan represent the results of major, global atmospheric and surface processes [1,2,3]. Understanding these regions is key to discovering the evolutionary history of the surface and atmosphere of Titan, and to better understanding similar landforms and processes on Earth.

This project is focused on inferring the mode and time frame of sand sea sediment accumulation by quantifying the area 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 SAR images. Unlike SAR images, ISS images have 100% coverage of the sand sea latitudes but at lower resolution [5]. Precise calculations of the areas of sand seas, along with dune spacing and heights [6], will allow accurate estimates of total sand volume and will help to further refine the organic inventory from dunes, estimated by Le Gall et al. to be ~250,000 km^3, assuming 100 m-high dunes, and an equal areal coverage between dunes and interdunes [4,7]. Area calculations will also help to constrain hypotheses for processes that govern sediment supply, transport, and deposition of grains. Presented here are the preliminary results from a detailed study of areas of Titan's Fensal and Aztlan sand seas.

Methods: In our analysis we focused on areas of the Fensal and Aztlan sand seas east of Xanadu, following the study of Le Gall et al. using SAR images [4]. Fensal is located just north of the equator while Aztlan lies almost directly below, both centered on about 50° W longitude (Fig 1). Both sand seas are identified as dark regions in Cassini's ISS images at 938 nm [5].

Calculating the areas of sand seas is challenging, given the global coverage of moderate-resolution (350 m) SAR images of only ~35%. Within SAR-imaged areas, dune sands and non-dune bedrock are clearly distinguished, so our estimates of areal coverage in SAR-imaged areas is probably good [3]. To outline these dune fields and sand seas in SAR images, we classified dune material as being SAR dark and linear in morphology and excluded bright mountains and other non-dune, SAR-dark features, similar to [4].

Each dune field was outlined in ESRI's ArcMap 10 on Cassini SAR image swaths. When completing this task we found a few slight inconsistences in dune field boundaries where swaths overlapped in coverage. However, given sizes of the dunes and calculated wind speeds, dune migration during the elapsed time between flybys is unlikely. Rather, the inconsistency is attributed to variations in illumination angle and resolution. Image resolution decreases towards swath edges, so we used middle swath imagery where there is overlap. Given the correlation between dunes seen in SAR images and regions dark to ISS, we can map dune areas in ISS images with a reasonable degree of accuracy. This is done by correlating characteristics of dune areas seen in SAR images with those on our ISS base map, where resolution is much poorer (Fig 2).

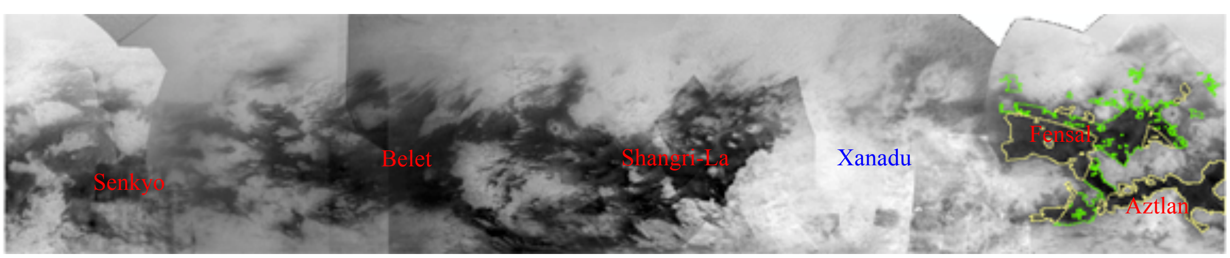
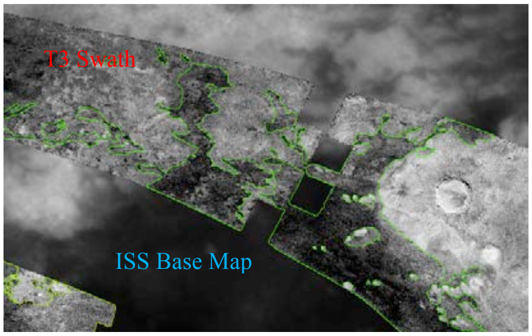


Fig 1. Dune Fields on Titan by Cassini's ISS. *Fensal lies north of Aztlan. Yellow perimeters indicate estimated dune field extent based on ISS characteristics. Green perimeters indicates dune fields mapped using SAR swath data (Cassini ISS, Fensal, 5˚N 50˚W; Aztlan, 10˚S 40˚W).*



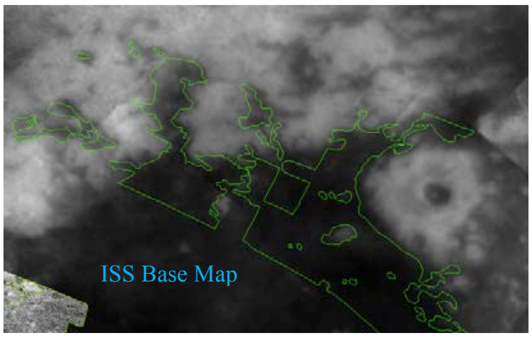


Fig 2. Dune area outlined on SAR and ISS images. *By removing the SAR swath (T3) from the top image we see that dune field areas are charaterized on the lower ISS image by darker values. These fields were mapped on the low resolution ISS base maps to estimate total hydrocarbon grain volume on Titan (image about 1100 km across)*

The ISS mosaic map has been made with an arbitrary grayscale. However, careful correlation of SAR to ISS data led us to pick ISS data values 115 and lower to represent dunes (from a range of 0 to 255). This value is represented where yellow transitions to deep-yellow-orange in a 20-interval color table from yellow to purple (yellow representing low data values). Utilization of the color table facilitated mapping and results in a map product with boundaries that are easily identifiable (Fig. 3). Tests of the chosen threshold value in different regions yielded a fairly good correlation between dunes seen in SAR images and those in ISS images, increasing our confidence in this method. Dune areas are slightly overestimated in ISS images near Sinlap and in portions of the exposed substrate between the sand seas. It is possible the SAR is penetrating below thin sands observed by ISS in those regions [1,4,7].

To calculate the area of dune regions in SAR and in ISS we used a geodesic calculation tool from the USGS Astrogeology division that mathematically takes into account the curvature and size of Titan to accurately represent distances and areas on the surface. We have determined that SAR coverage of the Fensal and Aztlan sand seas is near 45%, relatively more than SAR coverage in other areas on Titan.

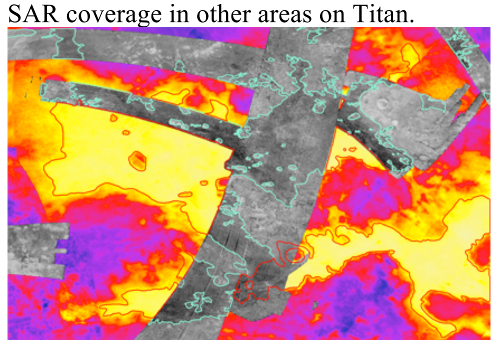


Fig 3. Fensal and Aztlan dune areas outlined on SAR/ISS images. *Dunes mapped on SAR image swaths correlate well with ISS dark regions with only slight deviations (Cassini ISS, Fensal, 5˚N 35˚W; Aztlan, 10˚S 30˚W, about 3,000 x 1,600 km).*

To calculate the volume Fensal/Aztlan, data for dune heights was obtained from Neish et al. [8] and Barnes et al. [9] to be 30 - 180 m, and we assume 100 m for an average. Sand volumes were calculated by taking the average dune height and dividing by 3 to account for non-dune areas and the pyramidal shape of dunes, leaving an average sand depth of ~30 m, slightly over that estimated by Lorenz et al. [7] and Le Gall et al. [4].

Results: Preliminary results for the total area of dunes in Fensal/Aztlan is about 2.3 million km^2, similar to the combined areas of the Libyan and Egyptian sand seas, and about 1/5 the total estimated sand sea area on Titan [4]. The total volume of sand in Fensal/Aztlan from our calculations is ~70,000 km^3, compared with global totals of 200,000-800,000 km^3 from Lorenz et al. [7]. Thus, our preliminary calculations are likely appropriate. Looking forward we plan to refine this calculation by constructing a model to more accurately infer total dune height across Fensal/Aztlan, including accurate dune width and spacing, to help infer dune vs interdune coverage, for the region.

Future work includes similar measurements in other sand seas across Titan, including Belet, Shangri-La, and Senkyo. These volume estimates will help us 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.

References: [1] Radebaugh J. (2010) *Geomorphology* 121, 122-132. [2] Lorenz R. D. et al. (2006) *Science* 312, 724-727. [3] Radebaugh J. et al. (2008) *Icarus* 194, 690-703. [4] Le Gall et al. *Icarus* 213, 608-624. [5] Turtle et al. (2009) *GRL* 37. [6] Savage C. J. (2011) *LPSC* 2261. [7] Lorenz, R.D. et al. (2008) *GRL* 35. [8] Neish et al. (2010), Icarus 208, 385-394.