A REMOTE SENSING AND GIS APPROACH FOR CHANGE DETECTION ON TITAN'S LAKES USING CASSINI ORBITER'S SAR DATA. W. D. D. P. Welivitiya[1], F . Wasiak[1], J. A. Tullis[1], D. G. Blackburn[2], V . Chevrier[1], [1]Arkansas Center for Space and Planetary Sciences, 202 FELD, University of Arkansas, Fayetteville, AR 72701 USA, wwelivit@uark.edu. [2]NASA Postdoctoral Fellow, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109,USA

Introduction: The evidence for liquid filled lakes on Titan is abundant, from morphological features similar to terrestrial lakes, to a specular reflection on July 8, 2009 from the large sea known as Kraken Mare [5], to spectra obtained by the Visual and Infrared Mapping Spectrometer (VIMS) instrument identifying ethane as a constituent of Ontario Lactus in Titan's south [1]. As with bodies of water on Earth, Titan's lake levels will be affected by a hydrologic cycle: a combination of precipitation, surface runoff, infiltration into regolith, recharge of methanophers, subsurface flows, and evaporation. There has been much effort to identify changes in these liquid bodies. Although no discernable change has been detected in northern lake shorelines, a possible transient feature within an estuary merits study.

Radar backscatter is influenced by look direction, azimuth, incidence and polarization angles, all of which differ between Titan passes. GIS analysis must consider these effects when searching for change. Deep lakes appear dark in radar, with the incident energy being reflected and absorbed by the liquid, while backscatter from shallow or empty lakes is affected by liquid depth, moisture content, surface roughness, porosity, and composition [2]. SAR swath T25, acquired on February 22, 2007, and swath T28, acquired April 10, 2007, with a temporal resolution of 47 days, overlap the estuary in northeastern Kraken Mare (77N, 280W). While the estuary shows a bright region in T25, a dark appearance (presumably deep) is found in the subsequent T28 swath. Furthermore, the area is morphologically consistent with a deep body of liquid. Since the brightening is limited to a region within the estuary, it is unlikely that the differential backscatter is a function of incidence angle and look direction

Methodology: Titan flyby radar swaths T25 & T28 were processed in two steps. Preliminary processing was carried out using ArcGIS 10, while the subsequent processing was done using IDRISI Taiga image processing tools.

In preliminary processing the radar swath T25 was georeferenced with respect to T28 using carefully selected temporally resistant ground control points (GCP's). A vector polygon mask was created covering the area where the hydrocarbon lakes were located in both images (T25 & T28). Using this vector polygon, both T25 and T28 raster images were clipped in ArcGIS (Fig 1-a,b). Both resulting raster images were then converted to ASCII format for transfer to the IDRISI environment.

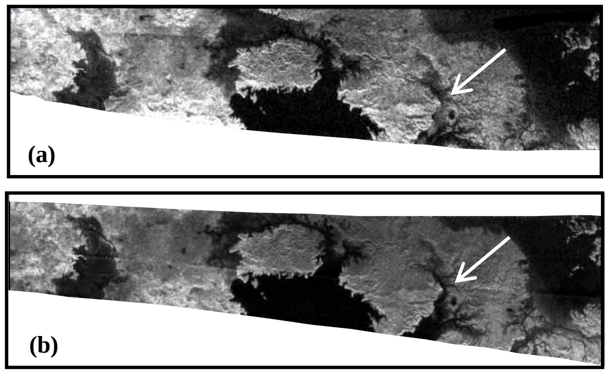

Figure 1. T25(a) & T28(b) after preliminary processing

The remaining processing was performed using the IDRISI Taiga software. First, previously created T25 and T28 ASCII files were imported in to the IDRISI raster file format. A contrast stretch with respect to each image histogram was carried out to normalize the brightness of both images. A 5 × 5 mean convolution filter was applied to the images in order to reduce high frequency noise. Then areas of most prominent changes were identified by visual inspection by comparing T25 and T28 processed images.

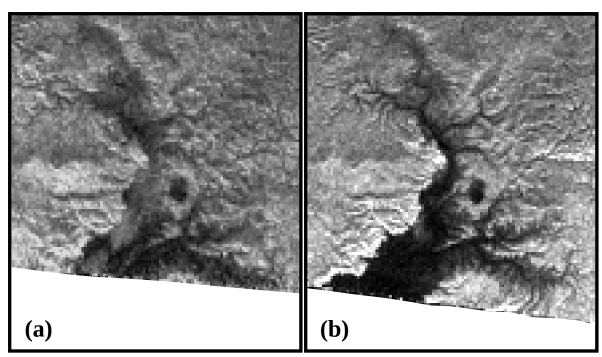

Figure 2. T25(a) & T28(b) Area of prominent change.

Most prominent change was observed in an estuary where a number of drainage patterns converge in the northern region of Kraken Mare. These areas were extracted using another raster clip operation through IDRISI (Fig 2-a,b). In order to derive a difference image of T25 and T28 (i.e. T25 minus T28) for change detection, both images required the same dimensions with respect to number of rows and columns. To rectify this problem T25 was resampled to match the raster parameters of T28. Carefully identified temporally resistant GCP's were also identified during this transformation. The difference map of T25-T28 was developed using the Map Calculator tool and the relevant area was extracted. Some background noise lineament features were observed in the resulting difference map(Fig 4-a). To remove these lineaments a Fourier transform image was produced.

Initially a forward Fourier process was carried out developing a power spectrum image (Fig 3-a), with "Imaginary" and "Real" components [4] of the image in frequency space. Analyzing the power spectrum, a raster filter (Fig 3-b) was created to remove certain parts of frequency space. This filter was applied to the imaginary and real components of the image.

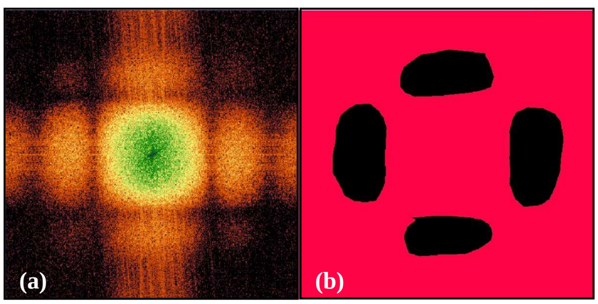

Figure 3. (a) Power Spectrum of the difference image, **(b)** Filtering Mask used for image clarification (Black - 0, Red - 1)

Using filtered real and imaginary components and the original difference image (i.e.T25 minus T28), a reverse Fourier process was performed to develop the enhanced image. A marked improvement was observed when comparing the zoomed in view of the images before and after Fourier processing (Fig 4-a,b).

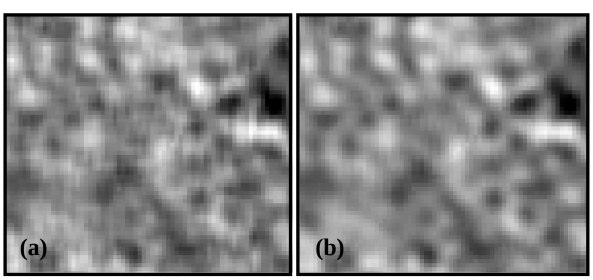

Figure 4. Image enhancement though Fourier transform image processing. Magnified views, (a) before and (b) after Fourier processing.

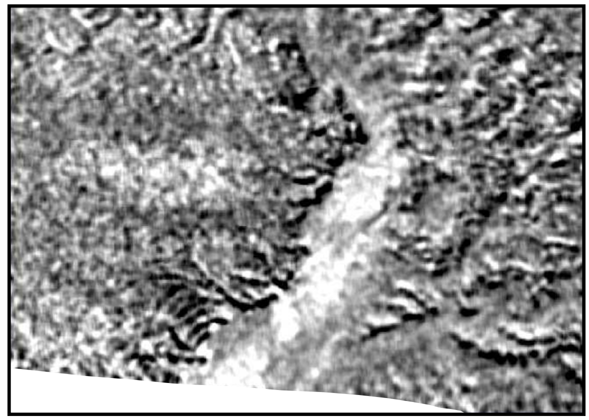

Figure 5. T25 – T28 Difference map in grayscale, bright areas correspond to the most promiment change.

Results & Discussion: The difference image of T25 & T28 (Fig 5) clearly exhibits evidence of temporal change between the two radar swaths[3]. Changes are localized in the estuary-like area where drainage systems enter Kraken Mare. Temporal resolution of the radar swaths are approximately 1.5 months (47 Earth days). It is therefore unlikely that the changes observed are due to seasonal variation on Titan. This suggests these changes are due to short-term dynamic processes. Detected changes can be due to a precipitation event within the time which the two radar swaths were acquired. According to Hayes et al. (2011), who detected this feature utilizing Radar analysis, possible causes are sediment suspension or floating froth in the liquid[3]. Further investigations are needed to positively identify the reason(s) for these short term changes in this liquid body.

Without the benefit of *in-situ* observations, object extraction operations are made through visual interpretation. We continue our analysis and eagerly await future Cassini flybys and PDS data releases, along with the progression of the spring season for both increased temporal spacing and insolation.

References:[1] Brown R. H. et al. (2008) *Nature*, 454, 607. [2] Hayes A.G. et al. (2008) *Geophysical Research Letters*, 35, L09204. [3] Hayes A.G. et al. (2011) *Icarus*, 211, 655-671. [4] Russ J. C. (1995) *CRC Press*, 283-327. [5] Stephan K. et al. (2010) , 37, L07104.