**USING TERRESTRIAL ANALOGS TO TEST ALLUVIAL FAN FORMATION MECHANISMS ON TITAN.** R. J. Cartwright¹, D. M. Burr¹, N. N. Nagle², ¹Department of Earth and Planetary Sciences, 1412 Circle Drive, University of Tennessee, Knoxville, TN 37916, rcartwi@utk.edu, ²Department of Geography, University of Tennessee.

**Introduction:** Widespread fluvial features have been observed on the Saturnian moon Titan by the Cassini radar instrument ($λ \sim 2.2$ cm), operating in Synthetic Aperture Radar (SAR) mode [e.g., 1-3]. The observed fluvial features display morphologies ranging from large integrated networks [3-5] to hypothesized alluvial fans [6]. On Earth, sediment delivery to alluvial fans occurs in response to catastrophic flow events. Where catchments contain large proportions of fine-grained material, e.g., clays, sediment delivery is dominated by debris flows. Where catchments are clay-poor, delivery is largely by sheetfloods [e.g., 7-8]. Consequently, identification of debris flow and/or sheetflood alluvial fans on Titan would constrain the size of sediments in the catchments and the mechanism by which this sediment is transported to the fan surface.

On Titan, radar-dark, polar fluvial features are interpreted to be mantled with fine-grained sediments [2], and seasonal rainout of condensates at the winter pole [e.g., 9] could enhance this mantling. In contrast, radar-bright, equatorial fluvial features are interpreted to be mantled with coarser sediments [2,10], similar to the cobbles observed at the Huygens landing site [11]. This inferred latitudinal dichotomy in grain sizes suggests that the fraction of fine grained sediments available for transport is larger at the poles than at lower latitudes.

**Hypotheses:** Based on a putative higher proportion of fine-grained sediment at the poles than at the equator, we hypothesize that polar alluvial fans are dominated by debris flows and equatorial alluvial fans are dominated by sheetfloods.

**Data:** To test this hypothesis, we are comparing trends in the normalized radar cross sections ($σ^0$) of 23 putative fans on Titan (some mapped by [6]), spanning $-55^o$ S to $-68^o$ N (Table 1, Figure 1), to the trends in $σ^0$ of terrestrial fans formed by debris flows and sheetfloods. Our terrestrial analog site includes fourteen alluvial fans located in Death Valley, California. A lithological contact between clay-rich sedimentary rocks and clay-poor igneous rocks in the catchments separates these fans into seven debris flow fans and seven sheetflood fans, respectively [7] (Figure 2). These fourteen fans have been imaged extensively by the radar instruments onboard CSA’s Radarsat-1 and JAXA’s ALOS-1 PALSAR satellites ($λ \sim 5.7$ and $\sim 23.6$ cm, respectively).

**Methods:** The planform geometry of each Titan and terrestrial fan includes three components (upfan to downfan): a confined channel, a wedge- or fan-shaped surface, and a terminal fan toe (Figure 1b).

We delineated the planform geometries of these fans (using [7] as a guide for mapping the terrestrial fans) and calculated the mean $σ^0$ for each fan. We also placed seven profile lines across each fan, originating from a common upfan vertex that terminates at the fan toe (Figures 1c and 2b). We then extracted the pixels corresponding to these profile lines, thereby sampling $σ^0$ in the downfan direction for each fan. After normalizing each fan’s seven profile lines by the downfan distance (with 0% distance at the shared vertex and 100% distance at the toe of each fan), we averaged the seven lines together into one mean profile line per fan.

**Results:** Terrestrial: In all of the terrestrial SAR images analyzed in this study, the debris flow fans, as a group, are significantly brighter than the sheetflood fans (in most cases, $>2σ$ difference in $σ^0$). Furthermore, the $σ^0$ profile lines for the debris flow and sheetflood fans display subtle, but apparent, slope differences. To
highlight differences in downfan $\sigma^0$ for the debris flow and sheetflood fans, we averaged the seven debris flow and seven sheetflood fans together, making representative profile lines for both fan types (Figure 3).

**Titan:** The mean $\sigma^0$ of the Titan fans displays significant latitudinal trends, with greater than $2\sigma$ difference in $\sigma^0$ between the brighter low and mid latitudes fans and the darker polar fans. To highlight the latitudinal differences, we averaged three polar fans (T30) and three equatorial fans (T44) together, making representative profile lines for these fans (Figure 3).

**Discussion:** Radar echoes from desiccated terrestrial fan surfaces are likely dominated by diffuse scattering from surface elements, comparable (or larger) in size than the wavelength of the sensing radar (e.g., [12]). Our results demonstrate that clay-rich debris flow fans are brighter than clay-poor sheetflood fans, most likely because of enhanced scattering off large, heterogeneous surface elements like cobbles that are commonly found on debris flows (e.g., [7,8]).

Based on the results from the terrestrial fans, our hypothesis for the Titan fans is not supported. The enhanced backscatter from the equatorial fans suggests a mantling of cobbles, consistent with debris-flow deposits. Conversely, the lower radar brightness of polar fans on Titan, by analogy to the low radar brightness from sheetflood fans on Earth, suggests sediment delivery by sheetfloods. However, seasonal rainout of condensates at the poles [e.g., 9] could form a fine grained mantle that weakens the radar signal [e.g., 13], resulting in the observed low mean $\sigma^0$ for these fans.

Another possibility is that the putative fans on Titan [6] are not analogous to terrestrial fans. Our data show that the slopes of the $\sigma^0$ profile lines of the polar and equatorial fans on Titan do not exactly resemble either debris flow or sheetflood fans on Earth. Two potential explanations for these SAR signature dissimilarities are: (1) fan-shaped fluvial features on Titan are not alluvial fans, and (2) fan formation mechanisms operate somewhat differently on Titan, perhaps due to differences in sediment transport under low gravity and low viscosity [14,15]. Future work will use cross-fan profiles of $\sigma^0$ to further investigate the relative differences between debris flow vs. sheetflood fans on Earth and polar vs equatorial fans on Titan.