SURFACE EROSION OF TITAN. Ralf Jaumann1,2*, Robert H. Brown3, Katrin Stephan1, Larry A. Soderblom4, Christophe Sotin5, Stephane Le Mouélic6, S. Rodríguez7, Roger N. Clark8, Jason Barnes3, Bonnie J. Buratti7, Tom B. McCord9, Kevin H. Baines10, Dale P. Cruikshank11, Caitlin A. Griffith3, Phil D. Nicholson12, and Roland Wagner1, 2 DLR, Institute of Planetary Research. Rutherfordstrasse 2, 12489 Berlin, Germany; 3 Dept. of Earth Sciences, Inst. of Geosciences, Freie Universität Berlin, Germany; 4 Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721, USA; 5 U.S. Geological Survey, Flagstaff, AZ 86011, USA; 6 University of Nantes, 44072 Nantes Cedex 3, France; 7 U.S. Geological Survey, Denver Federal Center, Denver CO 80225, USA; 8 Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, USA; 9 Planetary Science Institute, 22 Fiddler’s Rd., Winthrop WA 98862-0067, USA; 10 NASA Ames Research Center, 245-6, Moffett Field, CA 94035-1000, USA; 10 Department of Astronomy, Cornell University, Ithaca, NY 14853, USA; * Corresponding author (Fax: +493067055 402; Email address: ralf.jaumann@dlr.de).

Introduction: The surface of Titan has been revealed globally by the Cassini observations in the infrared and radar wavelength ranges as well as locally by the Huygens instruments. Sand seas, recently discovered lakes, distinct landscapes and dendritic erosion pattern indicate dynamic surface processes. During Cassini’s T20 flyby the Visible and Infrared Mapping Spectrometer (VIMS) [1] observed an extremely eroded area at 30° W, 7° S with resolution better than 350 m. Analyses of the drainage dynamics and comparison with the drainage systems at the Huygens landing site yield high discharge values of the associated channel systems and extreme runoff production rates of 10 to 50 cm/day. In addition, large sandur-like alluvial fans covering ten thousands of square kilometres are discovered at the boundary between high-standing bright and low-laying dark regions. To account for the estimated runoff production and widespread alluvial fan deposits of fine-grained material both frequent recurrence intervals and sudden release of area-dependent large fluid volumes are required. Frequent equatorial storms with heavy rainfall of methane and large accumulations of sand in alluvial fans that is picked up by winds to form Titan’s vast dune fields. Weathering and erosion are suggested to be responsible for transforming the state of surface materials. However the related geologic processes are not completely understood so far.

Erosional processes: Surface conditions on Titan are different from that on Earth. However discharge of fluids are also driven by the gravity and to a first order estimate we can model flows and discharges on Titan based on Earth-analogues for surface runoff. Liquid methane (CH$_4$) is suggested to be the main fluid on Titan. Its viscosity at surface temperature (95° K) is 1.8 $10^{-4}$ Pa s which is approximately five times smaller than water at 298° K (1.8 $10^{-4}$ Pa s) [4,5]. Thus, liquid methane will produce turbulent flows on Titan’s surface that have significant erosive power. On Earth an empirical function relates channel width $W$ to discharge $Q$ in a first order approach, for alluvial confined channels with sand or silt banks that have comparable mechanical properties of terrestrial gravel and river sands. In order to scale the empirical discharge equation to Titan’s grav-

$$Q = 1.9 W^{1.22}$$ (1)

Although the conditions on Titan are different of that on Earth the equatorial vast sand seas and dunes [7] requires enormous production and sedimentation of small particles that have comparable mechanical properties of terrestrial gravel and river sands. In order to scale the empirical discharge equation to Titan’s grav-
ity, we have to adopt depth, width, and velocity of 1.39, 1.61 and 0.46 times that of unconfined erosional channels on Earth, respectively.

According to the measured channel widths in the backyard of Bohai Sinus, discharges should be in the order of 2000 m$^3$/s to 22500 m$^3$/s with a mean value of 8600 m$^3$/s, which are comparable to discharges in large river systems on Earth and Mars. If we assume a drainage area that directly feeds Bohai Sinus with a maximum radius of 50 km behind the bay, the production rates ($P = Q/\text{area}$) will range between 2.2 cm/day and 24 cm/day with a mean of 9.3 cm/day. The much better resolved drainage pattern at the Huygens landing site [8] yield first order channel widths of about 250 m that result, according to the above model, in discharges of about 900 m$^3$/s. However, due to the much smaller drainage areas at the landing site [8] of about 7 km radius the runoff production rates reach 50 cm/day. Runoff production rates on Titan seem to be one to two magnitudes higher than those typically for river systems on Earth [9]. Such runoff production rates will induce high erosion power to Titan’s high standing bright areas causing intense mechanical weathering and production of fine-clastic debris that is rapidly transported along the local gradient.

To account for the estimated high runoff production rates and observed widespread alluvial fan deposition of fine-grained material both frequent recurrence intervals and sudden release of area dependent large fluid volumes are required.


Fig. 1: High resolution VIMS observations during orbit T20 including the Bohai Sinus Region (top) including the Pacman Bay (bottom).

Fig. 2: VIMS color composite using ratios at 1.59/1.27 μm (red), 2.03/1.27 μm (green), and 1.29/1.08 μm (blue).