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The Titan Wind Tunnel: a resource in the NASA Ames Planetary Aeolian Laboratory

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Abstract

The Titan Wind Tunnel in the NASA Ames Research Center is now available to simulate the kinematic viscosity and wind speeds of the Titan near-surface atmosphere. Early results indicate that threshold wind speeds may differ from previous (terrestrial) models.

1. Introduction

Aeolian processes are common on bodies with an atmosphere and particulate materials [1], as most recently evidence by Titan [2,3]. Wind tunnel simulation of planetary atmospheric surface layer flows has been used for decades to better understand wind-driven particle motion [1,4]. The aeolian dunes on Titan can provide information on multiple processes. To exploit this opportunity, the Venus Wind Tunnel (VWT) at the NASA Ames Research Center's Planetary Aeolian Laboratory (PAL) has been refurbished to enable analog Titan work. This abstract reports the availability of the wind tunnel for use and initial results regarding threshold wind speed.

2. Titan Wind Tunnel

The Titan Wind Tunnel (TWT) [Figure 1] is a closed-circuit, high-pressure, boundary layer tunnel measuring 6 x 2.3 meters with a fan to move the air at freestream wind speeds (u_{inf}) of up to ~5 m/s. The test section [Figure 1] is 122 cm in length and 18 cm in interior diameter (ID) and moves laterally on rails into or out of its position within the wind tunnel. Floor plates (for either calibration or experimental data collection) are inserted into the test section and rest against the inside walls. The test section has observing ports for viewing the test bed during the experiments and providing illumination.

The TWT currently operates with line air desiccated to dew point at -40 degrees and supplied at 150-165 psig to the wind tunnel, where a booster pump may be used to augment the pressure up to 300 psig. Total pressurization time is ~5 minutes. Gases can also be supplied from cylinders. Static gas pressure is monitored using a calibrated gauge attached to the front of the tunnel instrument panel.

3. Wind Tunnel Calibration

To convert the measured threshold freestream wind speeds ($u_*(\rho,d)$) into the desired threshold friction wind speeds ($u_{*t}(\rho,d)$) requires knowledge of the boundary layer profile, specifically, of the roughness height (z_0). A series of calibration runs was accomplished to describe the boundary layer profiles at different wind speeds. A stepping motor raised the pitot tube by logarithmically increasing steps above the plate to the approximate the vertical center of the flow region. Boundary layer data for different wind speeds were taken with the traverse pitot show that the freestream boundary layer begins at ~2 cm, so the pitot tube reached well into the freestream. At each step, the differential pressure from the pitot tube was read over a 10 second interval by the transducer and recorded on laptop computer. After collection, these data were converted to differential pressures using the correlation curve provided by the transducer manufacturer (Tavis Corporation). These pressures were in turn converted to wind speeds according to the expression $\sqrt{(2\ P/\rho)}$, where P is the differential pressure and ρ is the density of the gas (air).

During experimental runs, the traverse pitot tube is removed in order to prevent it from becoming clogged with sediment or affecting the wind regime within the test section, and wind speeds were collected using the fixed pitot tube. A correlation curve to convert the freestream wind speeds collected with the fixed pitot tube with those collected with the traverse pitot tube was constructed of six calibration runs at fan motor speeds of 20% increments up to

105% of maximum rated speed. Voltage data from the transducer were collected independently from the traverse pitot tube and from the fixed pitot tube for the same series of fan motor speeds, and those data were then converted into velocities as described above. The correlation between wind speeds at the traverse and fixed pitot locations was derived using the freestream wind speed for the traverse pitot.

4. Experimental procedure

We have used the TWT to conduct experiments into the threshold wind speeds required to move sediment on Titan. Sediment analogue material was selected to provide a range of densities from which we could interpolate to Titan weights. Data collection entailed slowly increasing fan motor speed while making visual observations of each stage of grain movement, namely: (i) first motion, (ii) flurries, (iii) patches, (iv) 50% of bed in motion, and (v) 100% of bed in motion. For our definition of threshold velocity, we use 50% of the bed in motion. When during data collection a particular grain movement stage was observed, the time was recorded for later correlation to the transducer voltage, and the fan motor speed was also noted. Observations were made by two independent observers at both the upwind and downwind viewing ports; the data from the downwind port are considered the threshold data of record because the fetch allows for development of the turbulent boundary layer and for any effects from the test plate edge to be damped out. Data of grain movement stages were collected during three successive runs from the same bed. Transducer voltage at each observed stage was converted to differential pressure using the manufacture's calibration curves for the transducer and then a correlation curve between the fixed and traverse pitot. These differential pressures were then converted into freestream wind speeds. Lastly, a conversion factor is applied to account for the differences between gravity and atmospheric density on Earth and Titan.

5. Results

Our initial results are shown in Figure 2, overplotted with the model of Greeley and Iversen [1]. This empirically derived model is based on experiments at terrestrial conditions. Our results suggest that the low atmospheric pressure and low weight of organic or icy sand particles on Titan would produce lower threshold wind speeds than are accounted for in this model. The difference of our experimental results from the model appears to increase for decreasing grain sizes, suggesting the influence of interparticle forces for these low mass (weight) particles.

References

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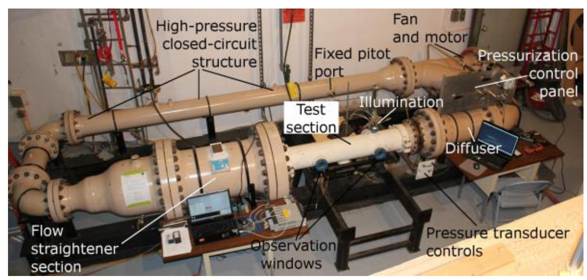

Figure 1: The Titan Wind Tunnel in the Planetary Aeolian Laboratory, NASA Ames Research Center

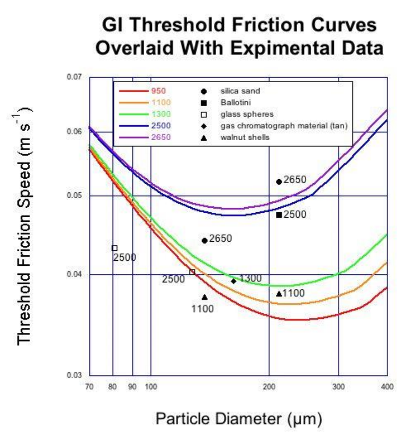

Figure 2: Experimental results overplotted with empirically derived models by Greeley and Iversen [1].