METHODS FOR CRATER PROFILE ROUGHNESS ANALYSIS

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This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 80NSSC21M0309 issued through the NASA Office of STEM Engagement.

Background

Gas-Granular Plume Surface Interactions
Gas-granular plume surface interactions (PSI) occur during spacecraft descent or ascent on regolith-covered surfaces. These interactions span multiple physics regimes, crossing the boundaries between viscous and rarefied flow. Multiple PSI mechanisms, such as viscous erosion and bearing capacity failure, contribute to the surface's response to the impinging plume. New methodology is required to evaluate the experimental and physical evidence of these mechanism and link it to our understanding of PSI physics.

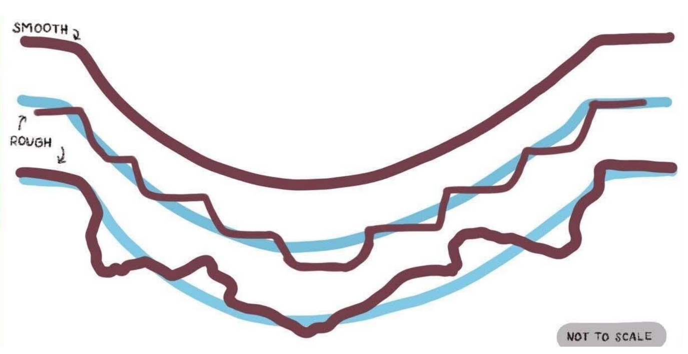

Fig. 1 Examples of smooth and rough variations of the same basic (simple) crater type.

Methods

Defining Crater Profile Roughness
Crater Profile Roughness (Fig. 2) describes small-scale deviations from a smooth or 'ideal' crater shape. Profile roughness is typically on a mm- to cm- scale, whereas landscape roughness and regolith grain roughness are larger (cm- to m-scale) and smaller (nm-scale), respectively.

Quantifying Crater Profile Roughness
We capture the crater profile roughness (CPR) by first fitting the overall crater shape, then using the chosen method to calculate the average size, number, and frequency of deviations from the base crater shape. In method 1 (Simple scale, Fig. 4), this is done by hand. In method 2 (R-squared estimate, Fig. 3), we use NumPy PolyFit to create a model function for each crater, then describe the variance of the data relative to the model function by the R-squared parameter. Method 3 uses Fourier Transform mathematical methods to smooth the 'noisy' crater profile data. By using a high pass filter, we extract the high frequency profile roughness data independently of the low-frequency 'carrier wave' (crater shape). We can then use a Fourier series goodness of fit estimate to calculate a single profile roughness number.

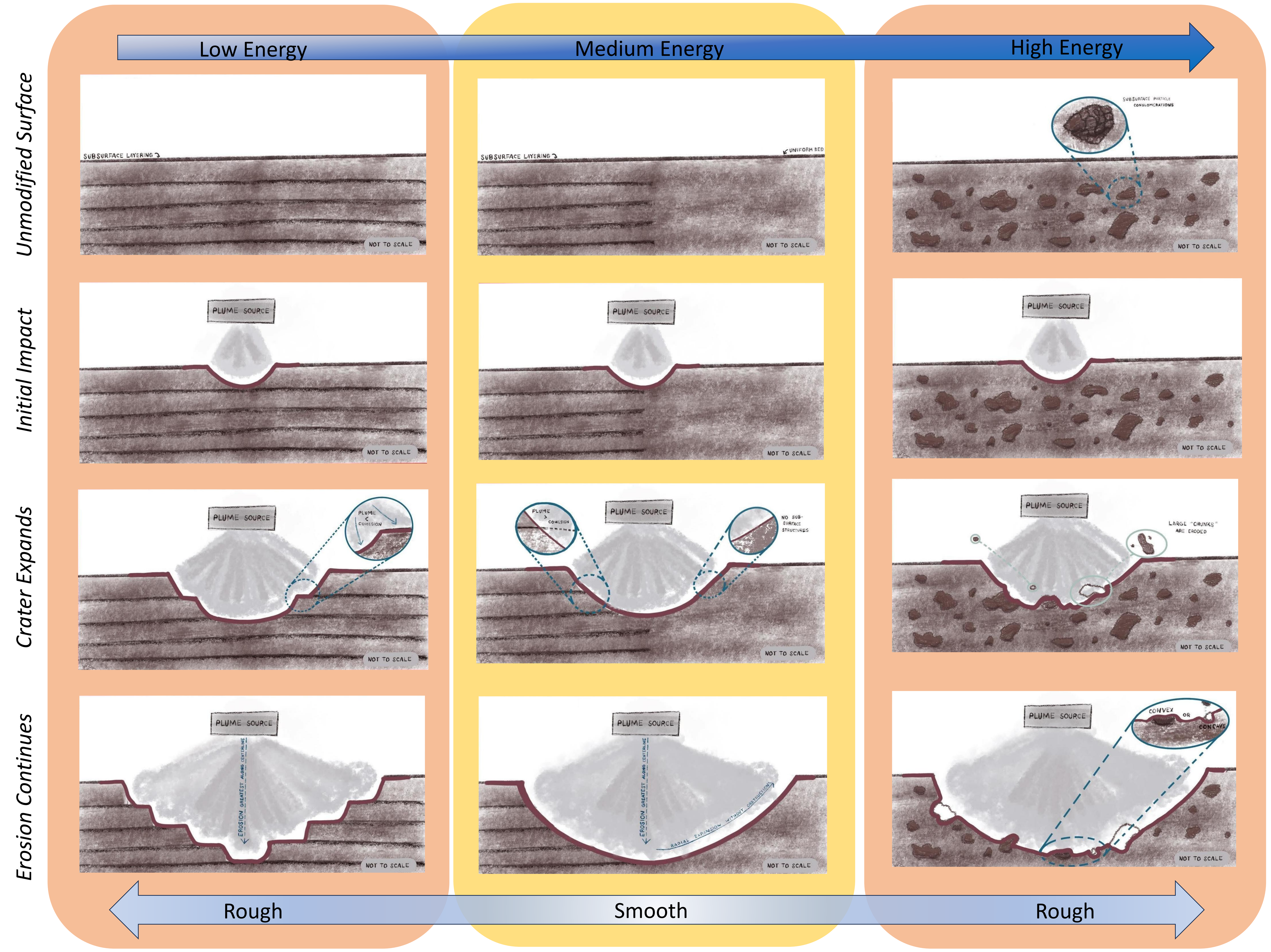

Fig 2. Roughness in the low, medium, and high energy cases. In these examples, profile roughness is expected to vary depending on the balance of cohesive forces versus energy (force) of the incoming plume.

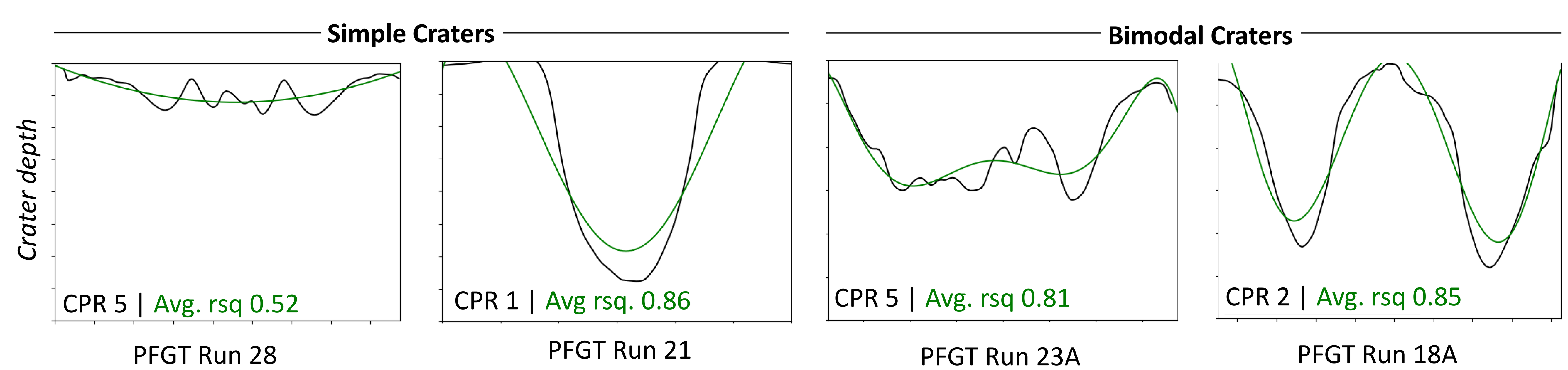

Fig 3. Example of Method 2, polynomial fits with R-squared estimates, compared to the roughness estimates on the sliding scale from 1 (smooth) to 5 (extremely rough). Crater depth is relative to the regolith bin surface.This comparison shows that r-squared is a decent estimate of roughness in the simple crater case but is less accurate as the crater shape becomes more complex (for example, with the bimodal craters).

Results

Method 1: Simple scale
- Relatively easy to produce
- Process is subjective, not very quantifiable

Method 2: R-squared estimate
- Relatively easy to apply
- Accurate for simple craters
- Fitting more complex craters is challenging

Method 3: Fourier Transform estimate
- Independent of crater shape

←------ Less Rough, Smoother ------ Rougher, Less smooth ------→

CPR	1	2	3	4	5
Descriptor	No variance	Some variance	Moderate variance	Significant variance	Extensive variance
	Complex bimodal crater with no variance from a 'perfect' (smooth/model) c bimodal profile once formed. Prime example of this crater profile shape.	Parabolic crater with little deviation from a model parabolic crater profile. Roughness does not impede identification of crater profile shape.	Simple crater with moderate deviation from a model simple profile. Roughness starts to impede ability to define crater profile shape.	Bimodal crater with significant deviation from a model bimodal profile. Roughness significantly impedes ability to define crater profile shape.	Potentially complex bimodal crater with extreme deviation from a model bimodal crater profile. Roughness makes it extremely difficult to define crater profile shape.
Example					

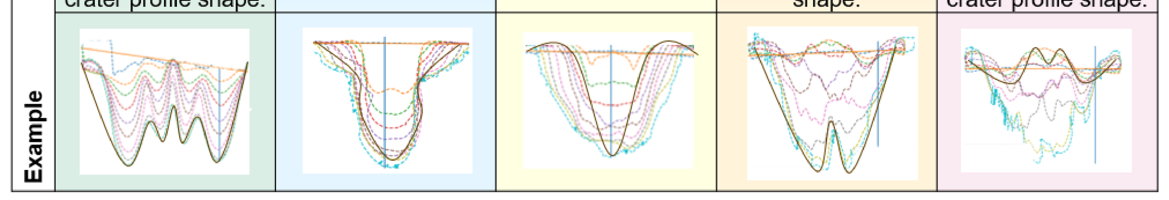

Fig 4. Example of Method 1, scale from 1-5.

Conclusion

Crater profile roughness (CPR) is relevant in efforts to characterize the type(s) of flow along surface structures and craters because it captures the surface roughness in a dynamic environment. Method 3 (in development) is extremely promising.

A good CPR tool is:
(1) Easy to use on large datasets,
(2) Capable of measuring variance *independently* from the overall crater shape, and
(3) Accurate across the expected parameter space

References

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