Photometry of rock-rich surfaces on the Moon

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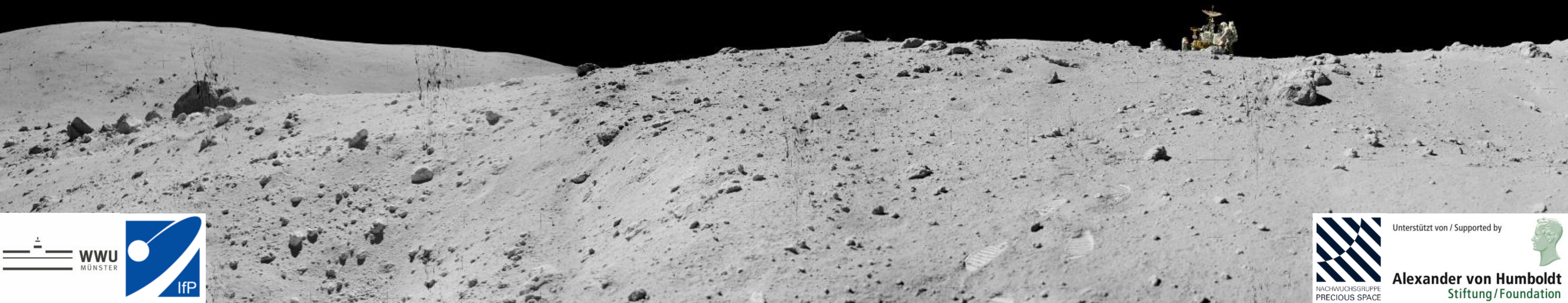

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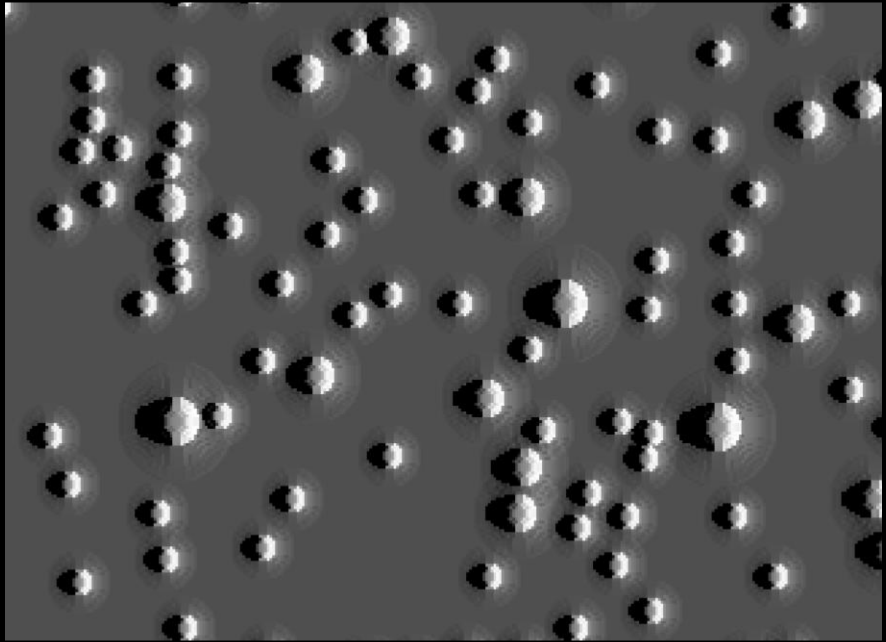
Introduction

- Aim: Characterise the **roughness** exhibited by rock fields on the lunar surface
- Little is known of the photometric behavior of rock fields despite their ubiquity on airless bodies
- Why study photometric properties of rock fields ? - Interested in characterizing the regolith at a **local scale** by looking at the regolith formation process i.e., **rock degradation**
- General consensus : rocky surfaces are “photometrically rougher” in comparison to a field that does not host rocks
- In this study we employ **phase ratio technique** to study the photometric properties of resolved boulder fields (Kaydash et al., 2012, Shkuratov et al., 2011)
- What are the effects of **rock morphology, abundance and size frequency distribution (SFD), scattering properties** etc. on photometric roughness ?

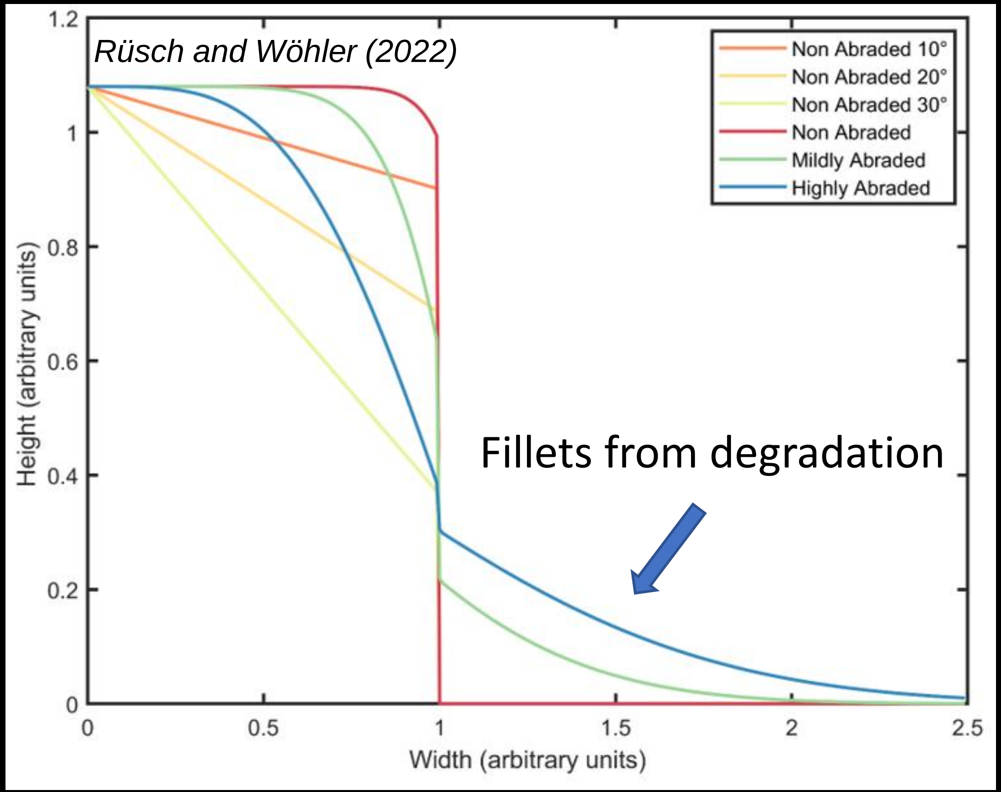
Methods – Model Based

- Create model DTMs – using various rock morphologies
- Convert DTM to reflectance image



- Calculate **Normalized Log Phase Ratio Difference** i.e. proxy for **roughness** for the image pairs :

$$NLPRD = \frac{log10\left(\frac{F_{P2}}{F_{P1}}\right) - log10\left(\frac{B_{P2}}{B_{P1}}\right)}{P2 - P1}$$

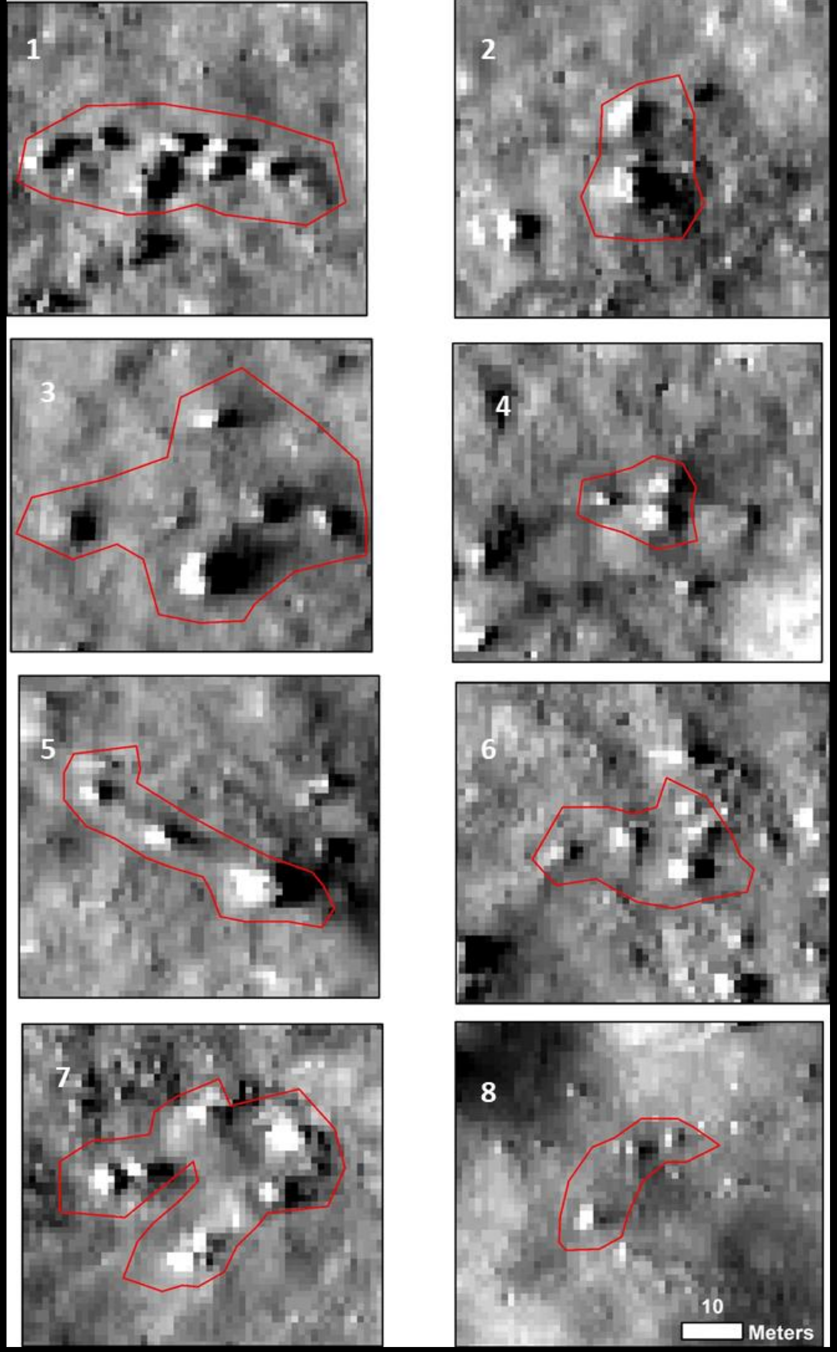


Where P1, P2 are incidence angles/phase angles and F and B are rock free and rock rich surfaces respectively

Methods – LROC NAC

- Select image pairs with **suitable viewing geometry**
  - **Equal incidence angle and varying emission angle**
  - Varying incidence angle and nadir emission angle
- Digitize polygons around boulder fields
- Extract mean reflectance of boulder fields **($\boldsymbol{B_{P1}}$, $\boldsymbol{B_{P2}}$)**
- Digitize reference rock free surfaces
- Extract mean reflectance of rock free surface **($\boldsymbol{F_{P1}}$, $\boldsymbol{F_{P2}}$)**
- Calculate **NLPRD** i.e., “how fast does B darken compared to F across given phase angles“?

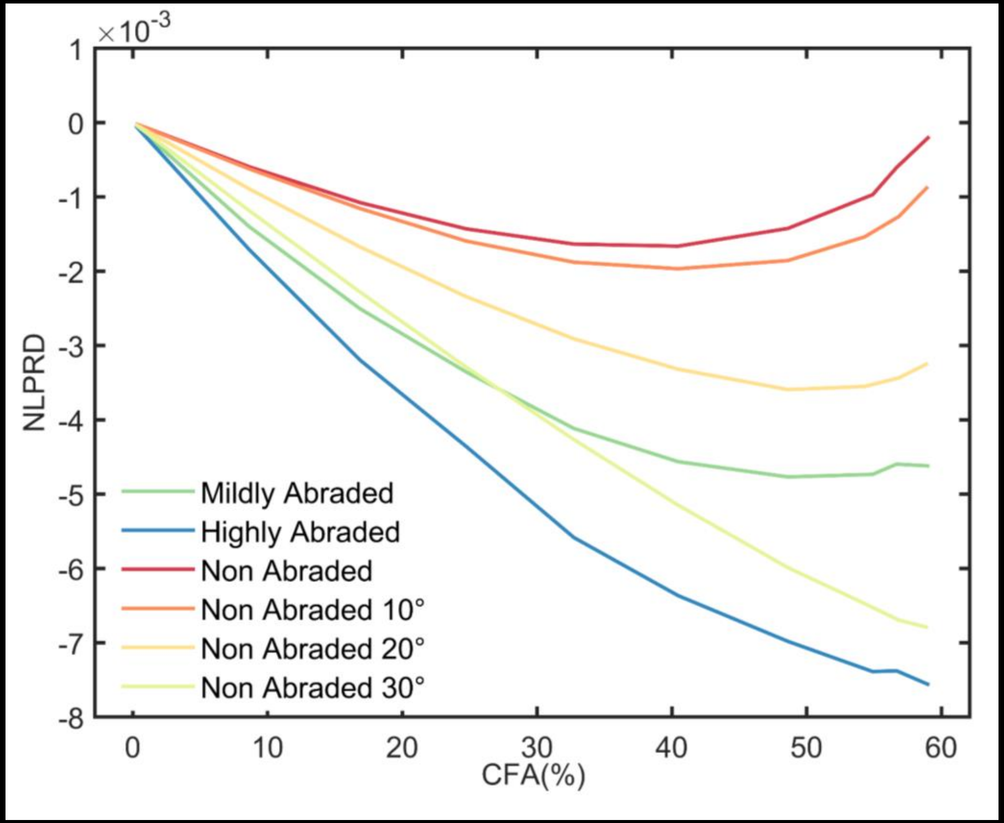
$$NLPRD = \frac{log10\left(\frac{F_{P2}}{F_{P1}}\right) - log10\left(\frac{B_{P2}}{B_{P1}}\right)}{P2 - P1}$$



Resolved rock fields in LROC NAC data.
Location: Young crater on the inner flank of Hertzsprung S crater

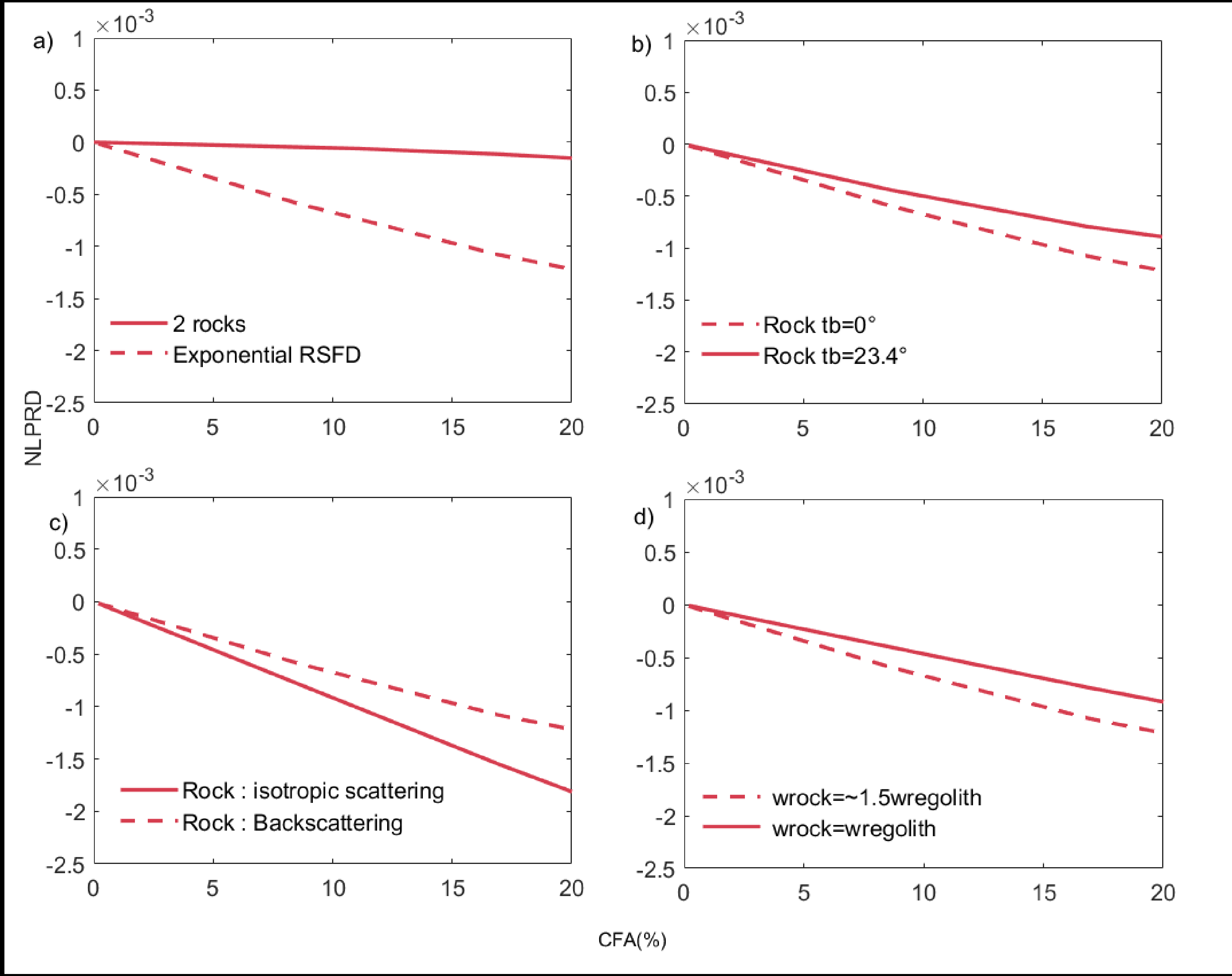
Model Based Results : NLPRD as a function of rock abundance

- Rocks **do not exhibit uniform photometric behavior** in both configurations.
- The **abundance** and **morphology** of rocks contribute strongly to how rough it appears in reference to a rock free surface.
- Rocks with tilted top faces darken much slower in comparison to a rock-free field.
- Role of **fillets** is **minor** in characterizing rock field roughness



NLPRD as a function of rock abundance for model topographies with increasing rock abundance in the "emission ratio configuration 1" where i1=54°, e1=2° and i2= 55° e2= 16°

Model Based Results : Effects of variables on model based NLPRD

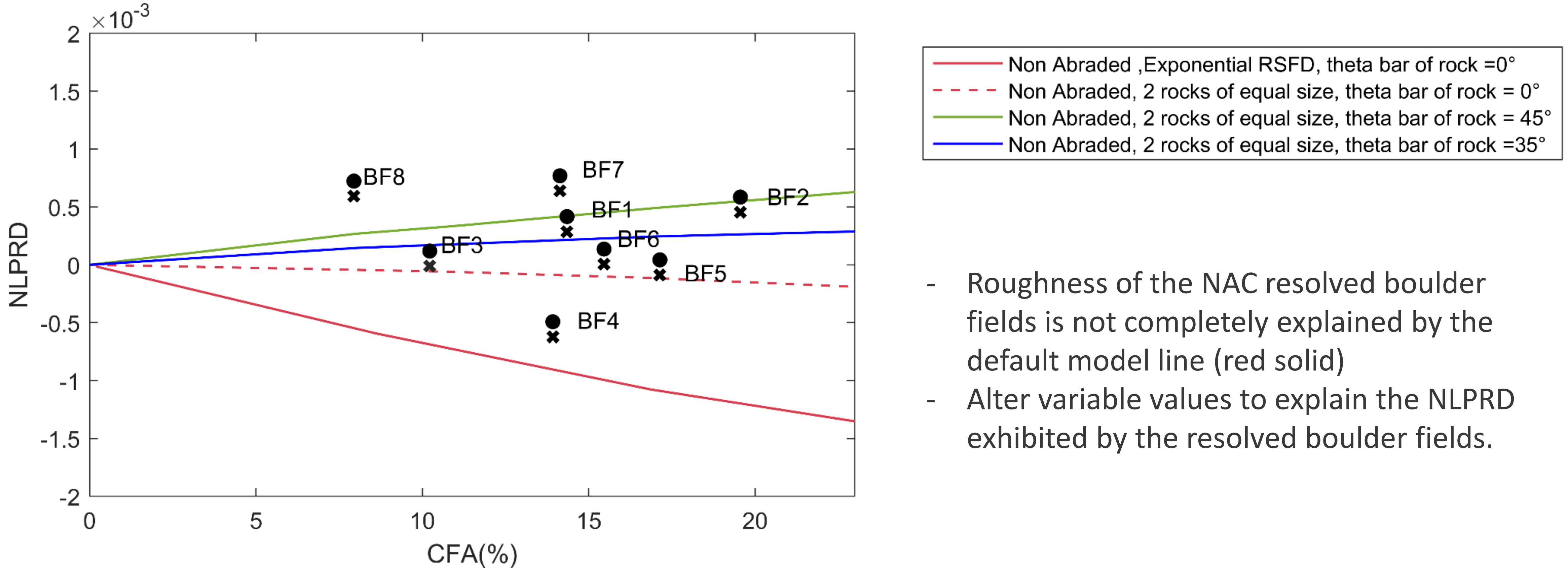


- Default parameter combination (dotted line):
  - (i) Morphology: **Non Abraded**
  - (ii) Scattering : **Backscattering**
  - (iii) RSFD : **Exponential**
  - (iv) Albedo values : w_{rock} **=0.65** $w_{regolith}$ **=0.48**

  (De Angelis et al. 2017; Watkins et al. 2019)

- **RSFD** has the **largest effect** on the NLPRD.
- Introduction of additional sub-mm scale roughness and decreasing the albedo of rocks have similar effects on the modelled NLPRD

How do we explain the data ?



- Roughness of the NAC resolved boulder fields is not completely explained by the default model line (red solid)
- Alter variable values to explain the NLPRD exhibited by the resolved boulder fields.

Summary

- **Rock morphology** creates different optical roughness
- **Visually and photo-geologically indistinguishable** rock fields have different roughness characteristics in image ratios
- **Rock morphology** and **RSFD** have the largest effects on the computed NLPRD**.**
- Roughness of actual fields can be greater or less than expected from the model implying effects of sub-mm scale roughness (**θ**b) and/or single scattering albedo values.

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