LABORATORY SIMULATIONS OF PLANETARY SURFACES: INTERPRETING REMOTE SENSING DATA IN TERRESTRIAL CONTEXT. R.M. Nelson¹, M. D. Boryta², B.W. Hapke³, K.S. Manatt⁴, Y.G. Shkuratov⁵, V.A. Psarev⁵, K. Vandervoort⁶, D. Kroner⁵⁷, A. Nebedum², C. Vides⁶⁷, J. Quinones⁸ and Y. Wu⁸; ¹Planetary Science Institute, 775 North Mentor Avenue, Pasadena, CA. rnelson@psi.edu, ²Mt. San Antonio College, Walnut, CA. ³University of Pittsburgh, Pittsburgh, PA, ⁴Jet Propulsion Laboratory, Pasadena CA, ⁵Karazin University, Kharkiv, Ukraine, ⁶California Polytechnic State University at Pomona, Pomona, CA. ⁷University of California at Los Angeles, Los Angeles, ⁸California State University at Los Angeles, Los Angeles, CA. ⁸Key Laboratory of Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, China

Introduction: We present laboratory measurements of the photometric properties of particulate materials of high reflectance. These materials simulate planetary regoliths of the type expected on high albedo atmosphereless solar system bodies (ASSBs). These measurements of the reflectance and polarization phase curves were taken with a goniometric photopolarimeter (GPP) of new and unique design. Our GPP employs the Helmholtz Reciprocity Principle (HRP); i.e., the incident light is linearly polarized and the intensity of the reflected component is measured [1,2]. Instruments of this type are generally classified as a “polarization-sensitive well-collimated radiometers” and the particulate samples are classified as “discrete random media” [3]. We have shown that HRP lab measurements are physically equivalent to remote sensing angular scattering measurements of reflectance and polarization of atmosphereless planets and small bodies [4].

We note that this work suggests an interesting terrestrial application perhaps relevant to geo-engineering efforts to mitigate Earth’s changing climate, particularly to the application of atmospheric aerosols to accomplish solar radiation management (SRM). We stress that in the best of possible circumstances this hypothetical SRM concept would only be a palliative approach while society addresses the imperative of reducing the anthropogenic concentration of greenhouse gasses in the atmosphere.

The Measurements: We used a GPP to measure the reflectance and polarization phase curves of 13 well-sorted particle size fractions of aluminum oxide (Al₂O₃), an industrial optical abrasive, with diameters 0.1 ≤ d ≤ 30 µm. These samples are identical to those studied in our previous experiments where we measured phase curves of the reflectance R(α) and polarization degree P(α) and addressed the amount of multiple scattering in the materials by measuring the phase angle dependence of the circular polarization ratio \[ R(\alpha) = \frac{1}{1 + a_p \exp(b_p \alpha)} \] and \[ P(\alpha) = \frac{1}{1 + a_p \exp(b_p \alpha)} \]. We developed two empirical expressions that are excellent approximations to the wavelength of the incident radiation. This is in qualitative agreement with theoretical predictions [8]. The backscattering effectiveness of any particulate material depends on the area under the phase curve.

The Terrestrial Application: The Al₂O₃ materials that we pioneered for GPP measurements are highly reflective. We independently noted over the years the widespread discussion in the scientific community regarding the emplacement of various aerosols
in the atmosphere for the purpose of SRM. In 2007 we calculated that the amount of Al₂O₃ of appropriate particle size to offset the anthropogenic solar forcing function is surprisingly small. We did not publish the results because of the hazardous nature of such a geo-engineering proposal. (Al₂O₃ has a Mohs hardness of nine, and the prospect of subjecting the population of air-breathing animals to the ravages of silicosis-related diseases is undesirable). We continued a quest for other, more benign materials that might accomplish the same effect.

We were unaware that Al₂O₃ aerosols had previously been suggested, and were surprised when one of our students recently discovered a 1997 proposal by researchers at the Lawrence Livermore Laboratories that advocated the widespread distribution of Al₂O₃ as an aerosol for SRM [9]. (Obviously the LLL team did not share our concern regarding the distribution of high-hardness aerosols and widespread lung disease).

In late 2015 we investigated of the optical properties of highly reflective evaporite salts for possible application to understanding evaporite deposits on other solar system bodies, particularly Ceres (see companion paper by Li et al. at this meeting). We studied the reflectance and polarization properties of Na₂CO₃ and the of lower molecular weight alkali halides, specifically NaCl and KCl. We found NaCl has reflectance properties remarkably superior to Al₂O₃, for the purpose of SRM. It is obviously a candidate deserving of further exploration for SRM application because of its benign effect on air-breathing organisms.

Figure 2 shows the relative reflectance phase curves of three evaporite materials. Al₂O₃ is shown as red dots, Na₂CO₃ as green triangles, and NaCl as blue crosses. All three particulates are of approximately 30 μm particle size. The data are normalized at 10°, where all three materials have a reflectance comparable to Spectralon®. Based on our previous work we anticipate that the phase curve for NaCl will broaden still further as particle size decreases until πD/λ = ~1. We suggest that NaCl particles are of appropriate morphology and of small particle size and in the form of dispersed discrete random media, then they will be highly reflective at ultraviolet, blue and visual (UBV) wavelengths and transparent in the infrared. We suggest that even relatively small quantities of materials (with reflective properties of NaCl) distributed as atmospheric aerosols might reduce insolation at Earth’s surface by several W/m², the amount estimated by the IPCC to be the anthropogenic contribution to greenhouse warming.

Future Work: We suggest investigating the reflectance and polarization of NaCl in particulate form at sizes larger than, approximately equal to, and smaller than λ₀,5ₚₑ to understand these questions further.