Introduction: Several datasets indicate the presence of water in permanently shadowed regions (PSRs) near the lunar poles (see [1] for a recent review), but the abundance, distribution, and physical form of polar water remain uncertain. Ground-based and orbital observations of the Moon at radar wavelengths have played an important role in the search for water ice (e.g., [2,3]), but can also be challenging to interpret. In this work, we reconsider the expected radar signature of icy regolith, in light of recent analyses of the radar scattering properties of PSRs on Mercury [4] and the Moon [5,6].

The presence of water ice has often been associated with high radar reflectivity and circular polarization ratio (CPR), defined as the ratio of same-sense (SC) to opposite-sense (OC) returns of incident circularly polarized waves. However, recent work illustrates that even for Mercury’s relatively pure water ice deposits [7], CPR alone cannot be used to infer the presence or absence of ice [4]. Meanwhile, on the Moon, there do not appear to be significant differences in SC and OC albedo between polar and non-polar craters [5], and some south polar craters where subsurface ice has been detected or suggested appear to have anomalously low CPRs [6]. What do these observations tell us about the state of subsurface ice and how it may be identified? We investigate this question by modeling the radar response of simulated rocky/icy regoliths.

Numerical Method: We use an electric field Monte Carlo approach (based on [8]) to model multiple scattering, including coherent backscatter, from subsurface scatterers embedded in an otherwise homogeneous medium. The Monte Carlo approach is based on tracing the propagation of a large number of representative “energy bundles” through the medium. This approach allows us to model different angles of incidence as well as different bistatic (phase) angles between the transmitted and received signal. Each energy bundle is associated with an electric field vector that defines the polarization characteristics of the transported energy.

During each scattering event, the electric field vector is modified by multiplication with a scattering amplitude matrix. The terms of the scattering matrix depend on the dielectric properties (refractive index) of the scatterers and surrounding medium, as well as the size of scatterers relative to the wavelength of interest. Here, we consider a distribution (based on [9]) of spherical scatterers ranging in size from 1.5–13.5 cm, and a wavelength of 12.6 cm (S-band). We model four different scenarios: (i) void space in ice; (ii) rocky scatterers embedded in ice; (iii) rocky scatterers embedded in regolith; and (iv) icy scatterers embedded in regolith. Refractive indices used are: 1.58+0.0042i for regolith [10], 2.54+0.0100i for rock, and 1.78+0.0011i for ice [11].

Results: Initial results for the cases described above are shown in Figure 1. We find that relatively pure ice with embedded scatterers (void space or ‘rocks’) exhibits a CPR vs. phase response similar to that of rocky regolith, although the intensity of both SC and OC returns (not shown in Figure 1) from the icy substrates is higher than from rocky or icy regolith. Modeled CPR values for ice dispersed in regolith are notably low, even when the concentration of icy scatterers is increased. These results reaffirm that icy deposits are difficult to identify based on CPR alone [4], and suggest that the anomalously low CPRs observed at some south polar craters [6] may be consistent with – or even an indicator of – the presence of dispersed ice. We will explore this scenario, and other possibilities, in more detail.

![Figure 1. CPR vs. phase angle for four different cases, at normal incidence. The ‘ice in regolith’ case is repeated with five and ten times as many icy scatterers.](image)