Several volatiles implanted into the lunar regolith by the solar wind are potentially important lunar resources. Lunar $^3$He might be mined as a fuel for terrestrial nuclear fusion reactors [1]. Several other elements commonly implanted by the solar wind (H, C, and N), could be important for life support and for propellant production for lunar bases. Here, we consider the possible importance of solar wind fluence variations on elemental distributions.

We have used a simple model to predict relative solar wind fluences at various lunar locations. We have then generated maps of estimated volatile contents, assuming that saturation is not important. Finally, we have begun a test of the importance of saturation effects.

The solar wind fluence received by lunar locations varies with both longitude and latitude as a result of two geometric effects. First the fluence is lower at higher latitudes (by a factor of the cosine of the latitude) because of the shallower angle of incidence. Second, the fluence is lower at the central near side because the Moon is in the Earth's magnetotail once each lunation at opposition. Fig. 1 shows the variations in solar wind fluence at various lunar locations, assuming the Moon is fully exposed to the solar wind 75% of the time and fully shielded the rest of the time. Under these conditions, the subearth point will receive less than 30% as much solar wind as its antipode, and only about 35% as much as the equatorial limbs. Fig. 1 is also a map of relative element abundances, if 1) variations in impact history are only locally important, 2) not all grain surfaces are saturated, and 3) soil chemistry is not important (C, N, heavy noble gases).

The abundance of $^3$He also depends on Ti content, since ilmenite ($\text{FeTiO}_3$) retains He much better than other major lunar minerals. We assume that $^3$He abundance can be represented as a product of (a) the amount of $^3$He received, and (b) the fraction of the received amount retained. This seems to be the case for Apollo samples [2], where $^4$He content correlates with the product of Ti content and $\text{I}_2/\text{FeO}$ (the ratio of fine-grained reduced iron to oxidized iron, a widely-used measure of amount of exposure [3]). On a global scale, we suspect the dominant factor in variations in the amount received may be the fluence rather than the impact history. In Fig. 2, we have produced maps of...
estimated $^3$He abundance based on this assumption, multiplying each point in our fluence map (Fig. 1) by an estimated TiO$_2$ abundance and scaling the results to the $^3$He abundance at the Apollo 11 landing site in Mare Tranquillitatis. The near-side mare TiO$_2$ abundance (top) comes from spectral imaging [4], the equatorial data (bottom) from γ-ray spectroscopy [5].

How important is saturation? The maps in Fig. 2 assume that most grain surfaces are not saturated with solar wind. It is not certain how prevalent saturation effects are on the lunar surface [cf. 6, 7], although it seems likely that He is saturated on some surfaces. Heavier species are less likely to be saturated [7]. One way to test for saturation is to see whether samples which have received different solar wind fluences have systematically different volatile contents. The Apollo samples all come from a limited geographic range on the central near side. However, the Soviet Luna samples, which come from the Mare Crisium area, closer to the eastern limb of the nearside, would be expected to have received about twice the solar wind fluence of the average Apollo sample. In fact, Luna 24 samples have remarkably high noble gas contents, given their $I_x/FeO$ values [8]. We have measured $I_x/FeO$ on four Luna soils (Table 1, FeO from [9]), the first such measurements on soils from either Luna 16 or Luna 20, and plan to perform noble gas analyses on these soils. Existing noble gas data on other Luna 16 and 20 soils (tabulated in [10]) suggest a situation similar to that at Luna 24 for heavy noble gases, although the He data is more ambiguous because of the spread in available measurements.

From a lunar resource standpoint, the most favorable areas for C and N are probably the equatorial regions near or beyond the limbs. As expected, the high-Ti areas in Mare Tranquillitatis appear high in $^3$He, but several areas in Oceanus Procellarum and in northeastern Mare Fecunditatis on the near side, and Mare Smythii on the far side, also look promising. Although saturation may mitigate fluence effects, we suspect that fluence will prove to be important at some level.

Fig. 2: Estimated lunar $^3$He abundance, based on product of Ti abundance and solar wind fluence. Ti abundance from [4] (top) and [5] (bottom).

Table 1: $I_x/FeO$ in Luna soils

<table>
<thead>
<tr>
<th>Mission</th>
<th>$I_x/FeO$</th>
</tr>
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<tbody>
<tr>
<td>Luna 16</td>
<td>89</td>
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<tr>
<td>Luna 20</td>
<td>62</td>
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