MULTISPECTRAL MAPPING OF THE MARTIAN POLAR ICE CAPS. A. W. Nolin[1] and W. H. Farrand[2], Cooperative Institute for Research in Environmental Sciences, National Snow and Ice Data Center, Campus Box 449, University of Colorado, Boulder, CO 80309-0449, nolin@spectra.colorado.edu, [2]Farr View Consulting, 300 W. 123rd Ave., #2816, Westminster, CO 80234, farrand@rmi.net.

Introduction. The Martian polar caps contain temporally and spatially varying amounts of water, CO_2, and dust but the concentrations of these components are not well constrained. Improved estimates of the surface composition of the polar caps are needed for water, CO_2, and dust budgets. Furthermore, accurate mapping of the layered terrains of the polar regions is also required for interpretation of geologic history. This new investigation, funded under the Mars Data Analysis Program (MDAP) will map the polar regions with a focus on providing better constraints on water ice, CO_2 ice, and surface dust abundances.

Multispectral Remote Sensing of Snow and Ice. The spectral differences between ice, frost and dust in the polar regions of Mars point to the need for a multispectral sensor. Ideally, we would choose to have a sensor that has numerous spectral bands located in the wavelengths that would allow us to best distinguish between surface cover types. Spectral uniqueness and detectability are both functions of the components that are present on the surface and the spectral resolution of the sensor. In this case, we are limited to current sensor technology, that lacks full multispectral capability.

Creating a "virtual sensor": ORBSS. The need for multispectral data requires an innovative approach in combining existing data sets. In this new investigation we are creating a virtual multispectral sensor by combining the blue and red image data from the Mars Orbiter Camera (MOC) with the shortwave infrared (SWIR) footprints of the Mars Orbiter Laser Altimeter (MOLA). We call this virtual sensor the Optical Red Blue SWIR Sensor (ORBSS). The wide-angle camera of MOC collects image data in the blue and red channels providing the basis for the multispectral data. The Mars Orbiter Laser Altimeter (MOLA) instrument is a Nd:YAG laser with a wavelength at 1064 nm. During the Mapping Mission, MOLA's 160-m spot size will correspond relatively closely in size to the nadir view 280-m pixels of MOC in its wide angle, intermediate resolution regional targeting mode. In addition to collecting elevation data, MOLA will be measuring the 1064 reflectivity for each footprint. It is these data that will be combined to create the ORBSS (see Figure 1). Fusion of information from different sensors is not an new idea but use of spectral data from a combination of instruments on the same platform for multispectral analysis is original. It is hoped that the concurrent nature of the MOC and MOLA data will allow multispectral analysis of temporally transient features such as frosts, dust and clouds.

The data will be combined as follows: The center row of pixels from a MOC wide angle camera image will be used as the initial building block of the sensor. Using an interpolation scheme, each MOLA footprint will be expanded to match the closest MOC pixel. With 12.7 revolutions per day, this narrow swath will create a pinwheel of data over the polar caps. While spatial coverage will be reduced by using only the center line of pixels of the MOC data it has the advantage of having a nadir view, like that of MOLA. What will differ are the illumination angles (and sources of illumination) for the two instruments. MOLA will always have both nadir illumination and viewing angles while MOC, using solar illumination, will have a varying illumination angle depending on time of year. However, for each multispectral image, the relationship between the two sensors will be constant for the newly created multispectral image. To characterize the surface composition of the polar ice caps, the abundances of the constituent materials need to be mapped. Given that multiple materials are to be expected to occur within each 280 m pixel of the ORBSS, it will be appropriate to apply a technique that can resolve this “mixed pixel” problem, namely spectral mixture analysis [3, 4].

Hierarchical Data Analysis. The fraction images derived from spectral mixture analysis of the ORBSS data will also be combined with ancillary data sets as part of a hierarchical mixing analysis. Hierarchical data analysis was first introduced by Adams et al. [5]. As those authors describe the concept, “any physical attribute that can be measured pixel-by-pixel such as net radiation, radiant temperature, ..., precipitation, and elevation also can be used in the mixing-model framework to define fractions of end members. The approach requires only that there is pixel-to-pixel variation in the measured properties, and that the endmembers have significance to an observer in the field.” We propose to apply the hierarchical mixing analysis (HMA) approach to the residual ice fields and to the layered terrains to better constrain the results from the initial SMA. In particular we propose to register the ORBSS data against the elevation data derived from MOLA as well as the brightness temperature and albedo data products to be produced as standard data products for the PDS by the TES team

[6]. These data products will be at a more coarse resolution than the ice and dust fractions derived from spectral unmixing of the ORBSS data. Thus, we will look at aggregate regions of approximately 3 km by 3 km. ORBSS data will be aggregated to that resolution and then co-registered to the TES data. Each of the endmembers used in the SMA will have a distinct brightness temperature and a distinct albedo. The expected brightness temperature for each pixel, based on the fractions of ice, dust and other components, can be calculated (call this T_B') and subtracted from the brightness temperature (T_B) map in order to provide a residual image. Likewise, a model albedo (A') image can be generated from the fraction images and compared against the observed albedo (A). The amount of the offset between T_B and T_B' and between A and A' will provide information on whether appropriate endmembers were chosen, whether the estimated thermal inertia and albedo of the endmembers was physically realistic, and consequently will better constrain the physical identity of the endmembers. As a result of the analysis of these residual images, we might adjust the values for T_B and A for one or more of the endmembers based on a refined understanding of their physical character and recalculate T_B' and A' to see if the residuals decrease. Elevation (and possibly slope) data will come into play in a similar fashion as described for brightness temperature and albedo. Regions with particular ice characteristics may also have similar elevation and slope properties. By relating these variables in this organized manner, we expect to understand more about the overall characteristics of the polar regions. Scenarios for different ice-mineral mixtures include combinations of the following parameters: Grain size (fine, coarse, mixture), red dust, dark dust, water ice, CO_2 ice. These components can be combined in a variety of ways including: layered ice and dust, separate spheres of ice and dust in an intimate mixture, ice coated dust spheres, and dust coated ice spheres. These combinations are those for which we can apply radiative transfer models to model surface reflectance. The hierarchical mixture analysis should provide some additional data for use in constraining us to certain scenarios. We will consider a wide range of possible mixture scenarios and base our ice/dust concentration estimates on those scenarios. Thus, the outcome of this research is not a single estimate for ice/dust concentrations, but a range of estimates based on differing assumptions. Finally, these polar region images will be combined into multiday composites to extend spatial coverage. Because we will only be using the central portion of the MOC data, rather than the entire swath, complete spatial coverage will not be possible. However, we will to maximize coverage within the 7-day repeat cycle by compositing the imagery. The number of orbits to be included in the composited product will depend on the nature of the mapping data; we will balance tradeoffs between temporal integrity (where transient features are most important) with spatial coverage. The flowchart in Figure 1 shows the steps from development of the ORBSS to the fractional mapping and hierarchical analysis.

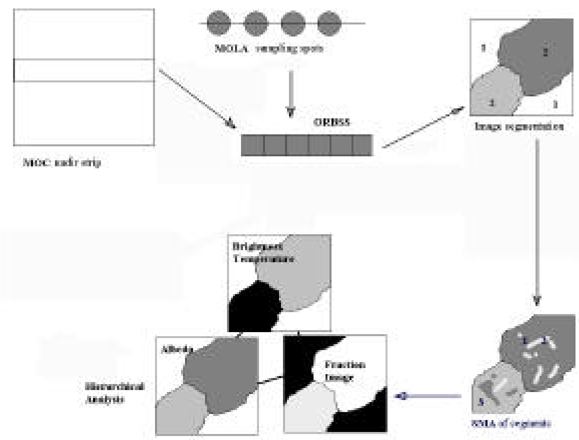

Figure 1. Flowchart showing the steps involved in combining the data for the ORBSS, performing spectral mixture analysis and hierarchical analysis.

In this presentation we will present results from algorithm tests using data from SPO-2 and will discuss plans for use of the Mapping Mission data that will become available in Fall, 1999.

References:

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