SEPARATION OF EFFECTS OF COMPOSITION, ILLUMINATION GEOMETRY, AND CALIBRATION IN VIKING 1 AND 2 MULTISPECTRAL IMAGES.

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Previously, we demonstrated a technique for the separation and identification of the physical causes of spectral variation in a single Viking 1 image (1). The image was modeled as additive mixtures of spectral endmembers of rock, soil, shade, and effects of surface illumination. In this paper, we extend our analysis to include multiple Viking Lander 1 and 2 images.

For all scenes analyzed, two spectral endmembers were found corresponding to the soil and rock. A second soil type is differentiated as being spectrally rock like with a coarse particle size. These results are consistent with (2). Spatial variation in the images over time at both Viking sites was modeled as changes in the proportion of endmembers. For the limited spectral resolution of the Viking multispectral cameras only two consistent surface spectral signatures are present. For the images analyzed, the non-compositional spectral variation observed between the sites is affected in order of significance by shade, illumination geometry, and calibration.

Endmembers for each image were identified independently through interpretation of the endmember concentration images. Spatial patterns were observed to change significantly with subtle changes in endmember selection and recombination, providing a sensitive tool for testing whether the source of spectral variation in the images were caused by instrumental calibration, surface materials, or the illumination geometry. For example, if one has isolated a rock endmember then all rocks with that spectral signature should show high concentrations of that spectral type. Conversely, if an endmember concentration image highlights all or many rocks in an image then its identity is assigned to a spectral rock type.

The number of spectral endmember types neccessary to model spectral variation down to instrumental noise levels (0.5 DN) in the images varied from 4 to 6. In many cases, the less significant spectral endmember types pertained to neither rock, soil, nor shade, but were above error levels associated with that arising from the instrumentation. Spatial patterns of these endmember concentration images highlighted foreground-background differences as well as subtle apparent microtopography of the soil and rocks. It is hypothesized that these spatial patterns are due to effects of illumination geometry (e.g. phase angle or multiple illumination sources). In the Viking 2 images, the spectral endmember of soil was not obtained directly, but rather as two separate spectral endmembers representing extremes of illumination geometry. The two concentration images corresponding to these endmembers, however, when linearly combined produced spatial patterns consistent with the soil concentration images of Viking Lander 1. The variation in the number of spectral endmember types between images is attribruted to treating shade, compostional mixtures, and effects of lighting geometry as linearly separable while in fact the lighting geometry is nonlinear with respect to shade and compositional mixtures. The degree of nonlinearity is dependent upon where the pixels in the image lie on the photometric phase function.

Calibration differences between Landers were determined by a least squares fit of corresponding endmember types between the images to the following equation:

$$G_b \, (DN_{2b} + O_b) = F_n \, (DN_{1b})$$

where the G_b's are the relative differences in gains, O_b's are the relative offset differences, DN_{1b} and DN_{2b} are the image DN's for two Lander images, and the F_n's are the fractional differences between endmembers. The good fit of corresponding image endmembers to this equation suggests the appropriateness of the model (r^2 = .89).

Temporal calibration changes for each Lander were determined by computing the differences between the actual image and that predicted from spectral endmembers derived from a single image area. Changes in the instrument and/or local atmosphere cause these difference images to change in overall brightness. Such differences were observed to be as high as 2 DN's.

References

1. Adams, J. B., M. O. Smith, and P. E. Johnson (1985) Proc. Lunar Planet. Sci. Conf. 16th p5-6.
2. Adams, J. B., M. O. Smith, and P. E. Johnson (1986) J. Geophys. Res., (in press).