THERMAL GRADIENTS AND KIRCHHOFF'S LAW; J. W. Salisbury, A. E. Wald, and D. M. D'Aria, Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218

Kirchhoff's Law (ε=1-R) strictly applies when the radiating material is isothermal. Laboratory experiments have indicated that steep thermal gradients exist in particulate surface materials on airless bodies like the Moon, or on planets with thin atmospheres, such as Mars [1,2]. These gradients significantly increased the spectral contrast compared to that measured for more isothermal samples, showing that Kirchhoff's Law did not apply. Henderson and Jakosky [3] have modeled heat transfer in a particulate medium under different atmospheric pressure conditions to determine the magnitude of near-surface gradients and their effect on emission spectra. Their model indicates gradients steep enough to cause significant spectral effects on bodies like Mars and the Moon, in agreement with the earlier laboratory experiments. These gradients occur because near-surface heat transport is dominated by radiation to cold space on airless, or near-airless, bodies. On bodies with thick atmospheres like the Earth, however, their model shows that heat transport by interstitial gas dominates heat transport between grains, and tends to mitigate near-surface thermal gradients. We have made the first quantitative laboratory measurements of emissivity and directional hemispherical reflectance under terrestrial atmospheric conditions, to test the applicability of Kirchhoff's Law. We find that most materials obey the Law, despite the occurrence of weak thermal gradients. Fine materials that form underdense structures at the surface (the "fairy castle structures" of Hapke [4]), however, may develop a thermal gradient that significantly distorts the spectrum.

This result can be illustrated by comparison of spectra predicted from directional hemispherical reflectance measurements with actual emittance spectra. Figure 1 shows this comparison for a solid sample of fused silica heated from below (the condition of the Henderson and Jakosky model), which should minimize thermal gradients. Predicted and measured emissivity agree within experimental error. Figure 2 shows the same comparison for a soil sample, which has a similar agreement, despite the occurrence of a weak gradient. Figure 3 shows this comparison for a fine quartz powder having fairy castle structures on its surface, which displays a significant difference between predicted and measured emissivity. This difference in spectral contrast indicates that a significant thermal gradient has formed within the fairy castle layer, suggesting that some improvement is needed in the Henderson and Jakosky thermal model. Specifically, they need to incorporate a decreasing density in the fairy castle layer, which appears to be the factor that causes samples with fairy castle surfaces to display significant thermal gradients.

References:

[1] Logan, L. M., and G. R. Hunt, *Journal of Geophysical Research*, 75, 6539-6548, 1970.

[2] Logan, L. M., G. R Hunt, J. W. Salisbury, and S. R. Balsamo, *Journal of Geophysical Research*, 78, 4983–5003, 1973.

[3] Henderson, B. G., and B. M. Jakosky, Lunar and Planetary Science Conference XXIV, 639-640, 1993.

[4] Hapke, B., *Icarus*, 67, 264-280, 1986.

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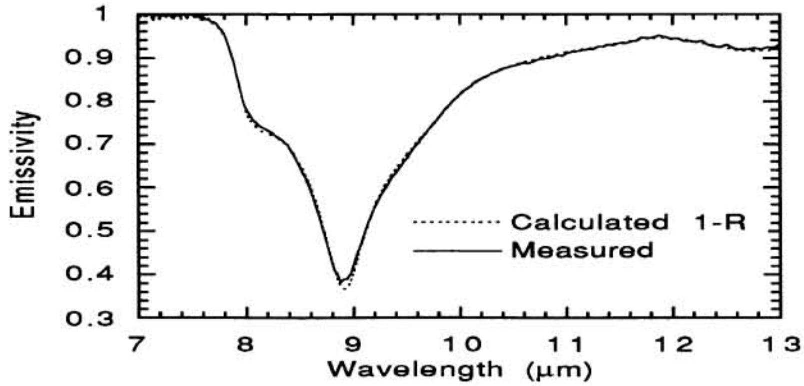
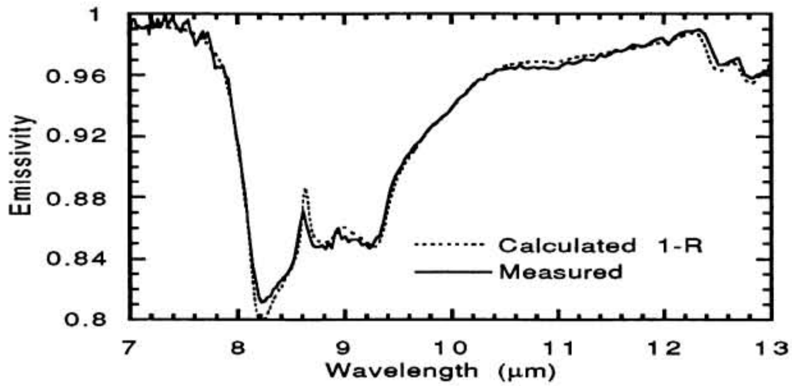
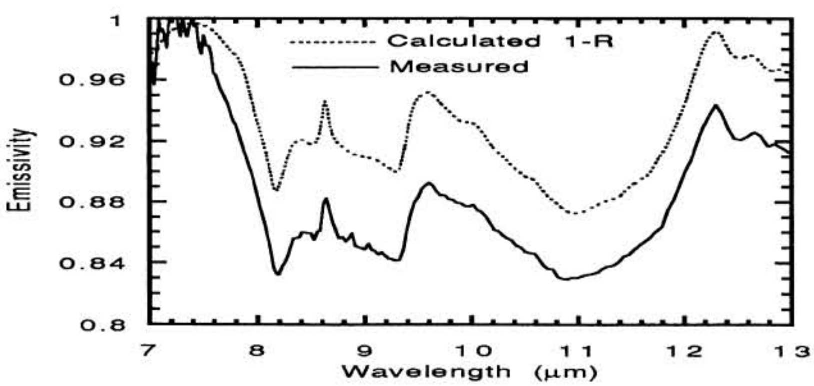


1. Comparison of measured spectral emissivity with emissivity calculated from directional hemispherical reflectance of a solid sample of fused silica.



2. Comparison of measured spectral emissivity with emissivity calculated from directional hemispherical reflectance of soil 0133.



3. Comparison of measured spectral emissivity with emissivity calculated from directional hemispherical reflectance of a sifted, 0-75 µm, quartz powder.