(None) = RL-2005

The Radiobrightness Measurement of Apparent Thermal Inertia

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Abstract

Thermal inertia is a measure of a material's resistance to change in temperature. If a material's thermal conductivity, K, and its volumetric heat capacity, ρc, are independent of temperature, then its thermal inertia, P, is $(K\rho c)^{1/2}$. Thermal inertia, as a geologic mapping tool, has been estimated from the differences in pre-dawn and afternoon thermal infrared (TIR) brightnesses. Materials that have high thermal inertias exhibit low day-night, TIR brightness differences. Discrimination among geologic materials based upon thermal inertia has been demonstrated both by aircraft experiments, and by the Heat Capacity Mapping Mission (HCMM) satellite experiment.

In principle, thermal inertia can as easily be estimated from day-night differences in microwave radiobrightness temperatures. The advent of the Special Sensor Microwave/Imager (SSM/I) class of satellite instruments, with their 6:00 am and 6:00 pm daily coverage over most of the Earth, invites thermal inertia mapping. However, the spatial scales of appropriate microwave targets are very different from the spatial scales of HCMM targets. HCMM had a spatial resolution of 600 m, and SSM/I resolutions vary from 15 km at 85.5 GHz to 69 km at 19.35 GHz.

For the coarse resolutions of the SSM/I instrument, appropriate thermal inertia targets would have to be regionally extensive such as soil moisture or snow wetness. To test thermal inertia's sensitivity to soil moisture, thermal models of diurnally heated, prairie soils containing 10%, 15% and 20% by weight moisture were developed for a typical September through December period near Bismarck, North Dakota. Thermal profiles from these models were incorporated in radiobrightness models for each of the SSM/I frequencies to produce expected diurnal radiobrightnesses and spectral gradients for the study period. This combination of models has also been used to explain the day-night shift in the spectral gradient of radiobrightness that is observed in Scanning Multichannel Microwave Radiometer (SMMR) data, and to guide development of an algorithm for classifying frozen soils.

Prior to the onset of night-time freezing, the day-night radiobrightness differences show only weak sensitivity to moisture content. However, once diurnal freezing and thawing begins, the latent heat of fusion of moisture in soil greatly enhances the soil's apparent thermal inertia, and this enhancement is strongly dependent upon the quantity of available moisture. This enhanced sensitivity of apparent thermal inertia to moisture content is most evident in the October and November profiles. The full effects of freezing and thawing are not realized during September because soils are only partially frozen during a clear, September night, nor are they realized in December because soil surfaces are only partially thawed during a typical December day. Furthermore, the models assume a snow-free surface and, thus, are less appropriate for late fall in North Dakota.