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Comparison of Observed Surface Temperatures of 4 Vesta to the KRC Thermal Model and Possible Implications for GRaND Observations.

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Abstract

Comparisons of surface temperatures, derived from Dawn VIR observations, to thermal models suggest that Vesta generally has a low thermal inertia surface, consistent with a thick layer of fine grain material. Estimates of the annual mean surface temperatures range from 176 K – 188 K for flat zenith-facing equatorial surfaces but these temperatures can drop as low as 112 K for polar-facing slopes at mid-latitudes.

1. Introduction

In this work, we will compare observed temperatures of the surface of Vesta (using data acquired by Dawn [4] Visible and Infrared Mapping Spectrometer (VIR-MS) [2] during the approach phase) to model results from the KRC thermal model.

1.1 Thermal Inertia

Thermal inertia (I) is a measure of how quickly a material's temperature responds to changes in heat flux and is defined as $I = \sqrt{k \rho c}$, where k is the thermal conductivity, ρ is the bulk density, and c is the specific heat capacity. SI units for I are J m^{-2} s$^{-1/2}$ K^{-1} which henceforth will be referred to as ''TIU'' (thermal inertia unit). High thermal inertia materials, such as bedrock, resist changes in temperature while temperatures of low thermal inertia material, such as dust, respond quickly to changes in solar insolation. The surface of Vesta is expected to have low-to-medium thermal inertia values, with the most common value being extremely low at 30±5 TIU [1]. There are several parameters that affect observed temperatures in addition to thermal inertia: bond albedo, slope, and surface roughness.

1.2 KRC Thermal Model

We employ a multi-layered thermal-diffusion model called 'KRC' [3], which has been used extensively in the study of Martian thermophysical properties. This thermal model is easily modified for use with Vesta by replacing the Martian ephemeris input with the Vesta ephemeris and disabling the atmosphere. This model calculates surface temperatures throughout an entire Vesta year for specific sets of slope, azimuth, latitude and elevation, and a range of albedo and thermal-inertia values. The ranges of albedo and thermal inertia values create temperature indices that are closely matched to the dates and times observed by VIR. After this interpolation, our working index contains modelled temperatures for all times of observation for thermal inertias between 7 and 42 TIU. Higher values of TIU can be included if necessary.

1.3 Roughness Effects

Because KRC is a 1-D model, the effects of roughness are approximated by combining a suite of KRC model results with a range of slopes and slope azimuths. While this approach captures many of the effects of surface roughness, it does not correct for the secondary effects of radiative coupling between facing surfaces of varying temperatures. A secondary effect of surface roughness is to lower the effective emissivity.

2. Dawn VIR Data

The Dawn spacecraft [4] acquired approach observations on June 30, 2011. These data provide full-disk view of Vesta, at a range of local times.

2.1. Vesta Temperature Data

Temperatures were calculated using a Bayesian approach to nonlinear inversion as described by Tosi et al. [5]. In order to compare observed temperatures of Vesta to model calculations, several geometric and photometric parameters must be known or estimated. These include local mean solar time, latitude, local slope, bond bolometric albedo, and the effective emissivity at 5µm. Local time, latitude, and local slope are calculated using the USGS ISIS software system. The bolometric bond albedo is estimated from the observed surface, percent of surface assumed flat (zenith-facing), and effective thermal inertia. While the slopes used in the best-fit algorithm varied from 10° to 40°, all results used slopes of 40°.

3. Results

Table 1 shows the estimated bond albedo used as a function of latitude zone. This table also shows the best-fit modeled effective emissivity.

Table 1: Zonal Temperature Fits to KRC Models for approach observations.

Lat. Zone	Estimated Albedo	Effective Emissivity	Flat%	Thermal Inertia
30 N	0.22	0.65	0	30±6
10 N	0.24	0.50	40	42±8
10 S	0.24	0.60	60	11±2
30 S	0.26	0.55	0	42±8
50 S	0.24	0.65	0	11±2

Table 2 shows the estimated annual mean surface temperatures for flat surfaces and north/south facing slopes. Estimates of the annual mean surface temperatures range from 176 K – 188 K for flat zenith-facing equatorial surfaces, but these temperatures can drop as low as 112 K for polar-facing slopes at mid-latitudes.

Table 2: Estimated Zonal Annual Mean Temperatures.

Lat.	Flat	North Slope	South Slope
30 N	180	147	191
10 N	200	189	201
10 S	176	177	166
30 S	188	201	151
50 S	156	176	112

4. Future Work

Comparisons of thermal inertia, annual mean temperatures and implications for the Gamma Ray and Neutron Detector (GRaND) will be presented.

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