MRD 155- Global Thermal Inertia Map

Data Product Overview

Executive Description

The global thermal inertia product will be a map of thermal inertia of the surface of Bennu at an appropriate spatial resolution from each observing point in the Detailed Survey mission phase.

Overview

Global thermal inertias will be produced and stored as a map of thermal inertia. The format of the map will conform to the mapping format established by the mission. The file will include input parameters (e.g., info on the asteroid shape and albedo) as well as derived intermediate products.

The product measures the average thermal inertia at a spatial scale comparable to the OTES spot size during Detailed Survey. Thermal inertia is a measure of the response of the surface to changes in temperature.

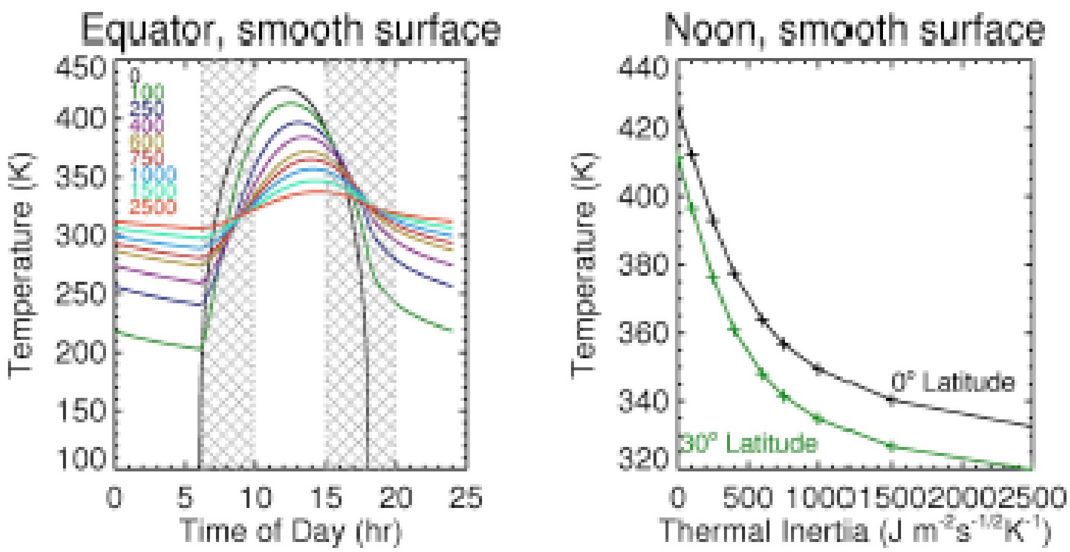
Global thermal inertia maps will be derived from temperature maps derived from OTES measurements during Detailed Survey. The primary observations required are OTES thermal flux observations at several times of day of the surface of Bennu. These observations are currently scheduled in the DRM during Detailed Survey, when the spacecraft observes Bennu for an entire rotation from each of 7 stations: 9pm, 6pm, 3pm, 12:30pm, 10am, 6am, 3am. Basic information on spacecraft and asteroid position is also required.

Supplemental information includes updates to the shape, spin-state, or albedo of Bennu from approach and preliminary mapping observations.

Global thermal inertias are used as inputs to temperature predictions for subsequent mission phases and for sample site selection and science value.

Note: Determination of Thermal Inertia requires OTES observations at specific times at the surface of Bennu.

Thermal Inertia Determination as a Function of Time of Day: Constraints on Observations



Constraints on Observations: The plot on the left above shows temperature curves at the equator for a smooth, spherical 101955 Bennu at perihelion for different values of thermal inertia (TI). The thermal inertia values are listed in colors of the corresponding curve. Times of day where the temperature difference between any two thermal inertia curves is less than 2K are hatched out. Acceptable observing periods are: midnight to 6am, 10am - 3pm, and 8pm to midnight. Note that for the Detailed Survey Phase, the 8 different time-of-day measurements will enable a very robust estimate of thermal inertia. In that phase, observations in the hatched regions can distinguish between some thermal inertias and are still required, as they will be part of the fit to the entire temperature curve. For Reconnaissance (or TAG Rehearsal) observations when we intend to derive thermal inertia from a single time-of-day temperature measurement, the hatched times in the left-hand figure above would be poor times for the observations because of the temperature degeneracy. In other words, it would likely not be possible to meet the ± 50 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$ requirement during the Reconnaissance phase for observations at the hatched-out times of day.

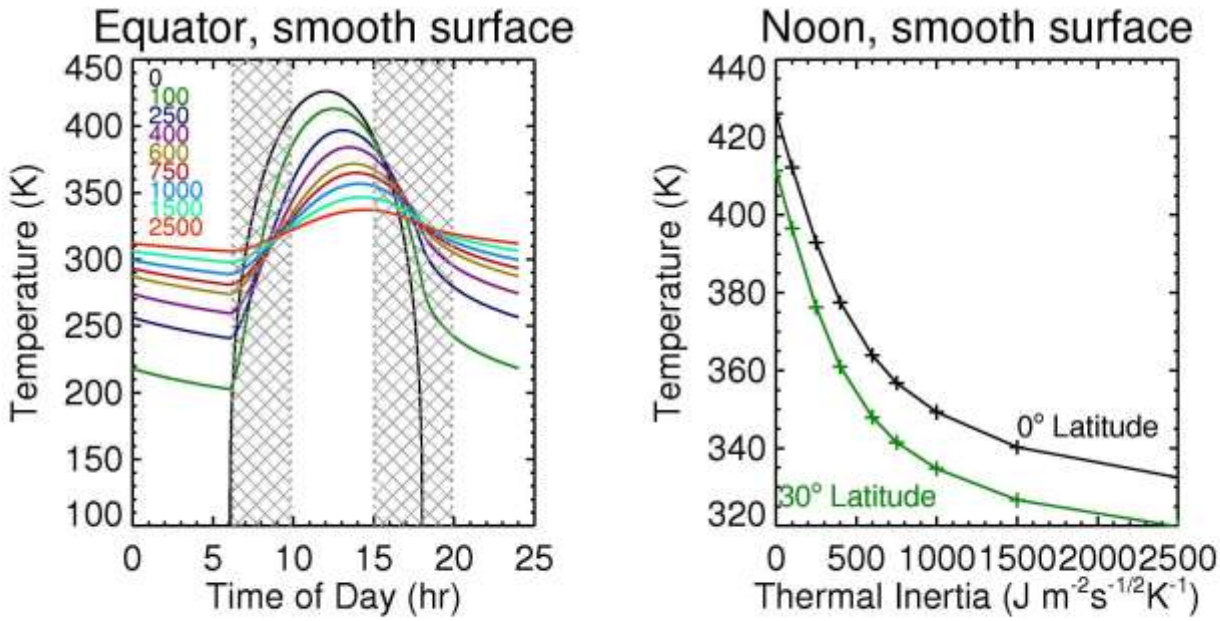
The plot on the right above shows the temperatures at noon as a function of thermal inertia at the equator and 30° latitude. This plot illustrates that different thermal inertias can be distinguished by a single temperature measurement, given the OTES temperature retrieval accuracy of +/- 2K at these warm temperatures.

Contributors: Josh Emery, Vicky Hamilton, Ben Clark, Beth Ellen Clark, Lucy Lim, 7 June 2012

Thermal Inertia Determination as a Function of Time of Day: Constraints on Observations

Rationale: Sample site selection will benefit from having thermal inertia data for evaluating surface properties. For example, surfaces with relatively low thermal inertia in Approach and Detailed Survey phase data may be inferred to have promising surface regolith properties for sampling, such as small particle sizes and non-indurated textures. Thermal inertia information can be used to select up to 12 areas for further investigation. Without this information, evaluation of suitability for sampling will be severely hampered at this point in the mission. During Reconnaissance, the PolyCam is expected to identify material in the sample-able size range (< 2 cm) but cannot assure that the material is not indurated. For this reason, thermal inertia observations are also needed from OTES data collected during Reconnaissance phase flyovers. At present, there is no requirement to produce thermal inertia data products from Approach and Reconnaissance phase data, and the global thermal inertia map to be produced from Detailed Survey phase data is presently linked to a descope-able science requirement for Yarkovsky science. Addition of these products to MRD-183 ensures that they will be produced in support of sample site selection, independent of science that is subject to descope.

Supporting information: The fidelity requirement of ±50 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$ is designed to ensure that OTES does not acquire data for thermal inertia at a time of day where there is insufficient temperature separation between thermal inertia curves. This is primarily relevant to the Reconnaissance phase, as Approach phase data are disk-integrated and Detailed Survey phase data are acquired at many times of day and all will be used in a final, integrated thermal inertia model. This fidelity also is related to (the parent for) the OTES L-3 requirement for temperature accuracy (±2 K for 220 K and 350 K sources and ±5 K for a 70 K source).



Constraints on Observations: The plot on the left above shows temperature curves at the equator for a smooth, spherical 1999 RQ36 at perihelion for different values of thermal inertia (TI). The thermal inertia values are listed in colors of the corresponding curve. Times of day where the temperature difference between any two thermal inertia curves is less than 2K are hatched out. Acceptable observing periods are: midnight to 6am, 10am – 3pm, and 8pm to midnight. Note that for the Detailed Survey Phase, the 8 different time-of-day measurements will enable a very robust estimate of thermal inertia. In that phase, observations in the hatched regions can distinguish between some thermal inertias and are still required, as they will be part of the fit to the entire temperature curve. For Reconnaissance (or TAG Rehearsal) observations when we intend to derive thermal inertia from a single time-of-day temperature measurement, the hatched times in the left-hand figure above would be poor times for the observations because of the temperature degeneracy. In other words, it would likely not be possible to meet the $\pm 50\ J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$ requirement during the Reconnaissance phase for observations at the hatched-out times of day.

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7 June 2012

Note: Information in this document was copied from "MRD_Change_Request_TI_Maps_V5", written in June 2012

Data Product Structure and Organization

Global thermal inertias (and associated uncertainties) will be stored as floating point arrays. These will likely be 2-D (longitude and latitude), but could also be mapped to surface facets of a shape model of appropriate spatial resolution. There will be a single file, as this product only applies to the Detailed Survey OTES observations.

Data Format Descriptions

Header data (metadata) to be included:

- Number of x and y bins in the array
- Start longitude, latitude of the array
- Longitude/latitude bin size
- Start/end time of OTES observations
- Version/calibration set of OTES observations
- Bennu position relative to the Sun (distance, ecliptic longitude and latitude)
- Bennu position relative to the spacecraft (distance, ecliptic longitude and latitude)
- Bennu rotational state (ecliptic coordinats of spin-pole, rotation period)
- Name/location of shape file used in model
- Name/version of thermal model used
- Average bolometric Bond albedo used for model, or name/location of bolometric Bond albedo map
- Bolometric emissivity used for model
- User inputs for the constraints used to create the map. These include, but are not limited to: data quality, incidence angle, emission angle, surface temperature, albedo, surface tilt, latitude, longitude.
- Log file name (a file of all inputs used to create this data product)

Detailed Description of Data Format:

- Data type – floating point array (likely 2-D)
- Field 1: Thermal inertia (0 to 2500), floating point, precision of 0.1
- Field 2: Thermal inertia uncertainties, floating point precision of 0.1

Data Product Generation

Global thermal inertias are generated from OTES temperature maps using a thermal model. Basically, thermal inertia is varied in the model to match the diurnal temperature curve for each map position.

Required inputs and formats are:

- Temperature maps created from OTES spot measurements
    - 7 floating point values, one for each time of day/Detailed survey station

- Time of each OTES temperature measurement
    - 7 floating point values
- Location of each OTES temperature on the shape model
    - Latitude, Longitude, Radius, or some other mission-agreed-upon specification of location on the surface
- Shape of Bennu
    - vector-facet format of shape model
- Spin state of Bennu
    - 3 floating point values: rotation period and ecliptic coords of spin pole
- Bennu position relative to Sun
    - 3 floating point values: distance, ecliptic longitude and latitude relative to the Sun
- Bennu position relative to spacecraft
    - 3 floating point values: distance, ecliptic longitude and latitude relative to the Sun
- Average albedo or albedo map
    - single floating point value, or file of bolometric Bond albedo for each facet in the shape mode

Co-I Emery has been assigned to this product

Multiple versions of the product may be produced. New versions would be produced if changes occurred in: 1) the OTES calibration or Temperature/ Emissivity algorithms; 2) the shape model used to determine the longitude, latitude and local time of each Spot Temperature observation; 3) changes in Bennu longitude/latitude reference system; 4) changes in the knowledge of spacecraft or Bennu locations as contained in the SPICE kernels.

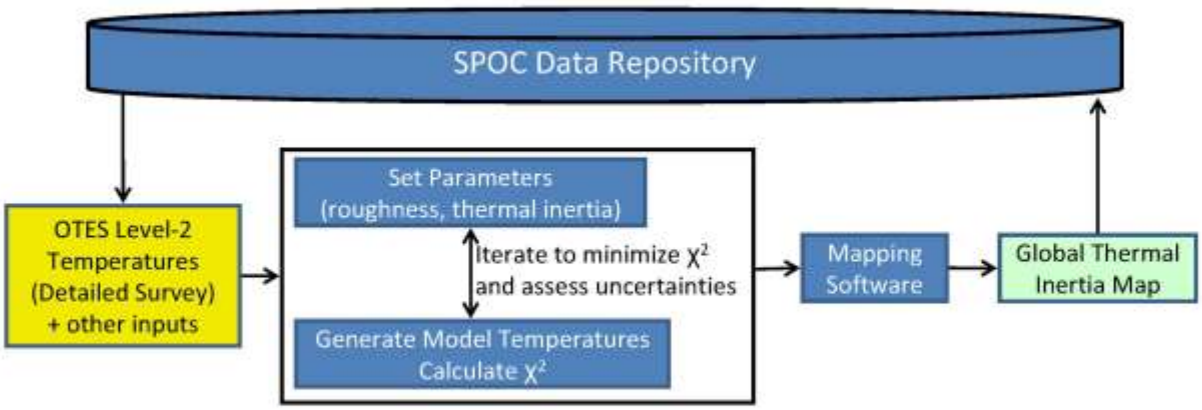
The current expectation is that it will take approximately 1 week to produce and validate the global thermal inertia map, once all of the required inputs are available. This timeline will be re-evaluated as the thermal model itself is developed and tested. Maintaining this timescale is a primary factor in thermal model development.

Data Product Validation

Validation of the thermal inertia maps will assume that the individual OTES Spot Temperature data used as inputs to the maps have already been validated. The map contents will be validated by inspection for erroneous data values or obvious positioning errors indicated by non-physical thermal inertia variations. If the maps are valid, then the thermal inertias should be a smoothly varying function of latitude and longitude. The maps will also be examined by inspection to observe any data gores, which could indicate missing data or unexpected exclusion of data through incorrect or overly limiting constraints. The Detailed Survey maps will also be compared with Rotationally Resolved thermal inertias produced from Approach phase observations.

Data Flow

Input data, including OTES temperatures, will be read from the SPOC database. The thermal model will be run at each location to find the thermal inertia that best-fits the diurnal temperature curve at that location. The model will also determine confidence limits in order to establish uncertainties in the derived parameters. The mission mapping software will be used to bin and average the derived thermal inertia into appropriate format for the maps.



Standards Used to Generate Data Product

- All time will be in UTC.
- Ecliptic coordinate system will be used for specifying Bennu's position relative to the Sun and spacecraft and for the orientation of the spin pole.
- Distance of Bennu from the Sun will be in Astronomical Units (AU).
- Distance of Bennu from the spacecraft will be in km.
- Map format will conform to the OSIRIS-REx Project standard.

Final product will be stored as floating point arrays.

Data Product Storage

If the maps were produced that the nominal OTES resolution, then the global maps would have a resolution of 40 m, resulting in an approximately 50x50 pixel map of floating point data and a data volume of approximately 20 Kbytes per map.