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In Search of Cold Traps on Rhea

Georgina Miles[1], Carly Howett[2], John Spencer[2] and Paul Schenk[3]
(1) Affiliated to Southwest Research Institute, Riehen, Switzerland, (2) Southwest Research Institute, Colorado, USA, (3) Lunar and Planetary Institute, Texas, USA, (georgina.miles@gmail.com)

Abstract

We use a 1-D surface thermal model to explore the existence and potential properties of cold traps at Rhea's poles, and compare its simulated temperatures to those observed by the Cassini Composite Infrared Spectrometer (CIRS). We identify suitable candidate observations of very cold scenes (<40 K) that have good spatial resolution (~70km radii) and differing spectral slopes between scenes, suggestive of strong local temperature contrasts within the fields of view. The model is able to recreate these very cold surface temperatures. It will be combined with high resolution ancillary information to improve understanding of the observed scenes and their potential to harbor cold traps.

1. Introduction

A tenuous, seasonal exosphere consisting of oxygen and carbon dioxide was identified around Saturn's moon Rhea by Cassini's Ion Neutral Mass Spectrometer (INMS) [4], but its exact origins have been subject to some debate. Observations from the Cassini's Composite Infrared Spectrometer (CIRS) instrument have revealed the poles of Saturn's moon Rhea can be amongst the coldest places in the solar system [2]. Furthermore, it likely that Rhea's poles have a deep unconsolidated surface layer [2], providing an ideal environment for the trapping of volatiles. As such, we search for evidence of cold traps in CIRS data. By building a model capable of emulating the observed thermal properties of the CIRS scenes, we can build a consistent picture of whether the environment is supportive of cold traps.

1.1 CIRS data

CIRS had a number of encounters with Rhea's polar regions. The first of its three focal planes (FP1, 10-600 cm^{-1}) is the only one sensitive to the very cold temperatures found there (as low as circa 25 K [2]). It comprises a single circular detector with course spatial resolution (3.9 mrad/pixel) [1], which (when combined with Cassini's orbital tour) limits the number of scenes that can be used for high-spatial resolution studies. The best-fitting blackbody temperature for each CIRS FP1 observation is found by fitting a curve to the spectra and an estimate of uncertainty from Monte Carlo error determination [2]. Here we discuss observations made during an encounter on 20th December 2012 in Cassini orbit (or rev) 177, shown in Fig. 1.

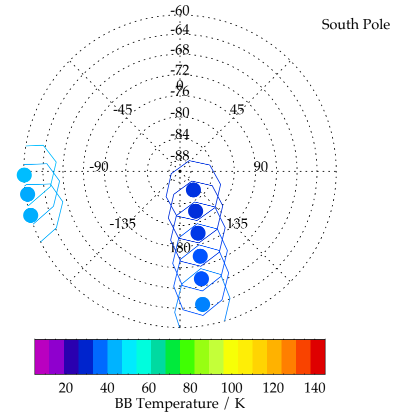

Figure 1: Blackbody temperatures derived from CIRS FP1 footprints at Rhea's Southern Pole. The FP1 Field of view (FoV) is circular but the projected ellipse is approximated here by an octagon. The centre of the FoV is given by a filled circle for clarity.

1.2 Spectral slope

The spectral slope of an observation describes how the brightness temperature of a scene varies with wavenumber. It is influenced by variations in emissivity and local temperature within a scene. Assuming a generally flat emissivity [2], the latter is likely to cause the variations we observe in Fig. 2. Very cold scenes with local temperature inhomogeneity are supportive of the presence of cold traps.

1.3 Thermal model

A 1-D thermal model *thermprojrs* is used to evaluate thermophysical properties of the surface, as described in (and using input values from) [3, 2], including thermal inertia, albedo, emissivity to generate an effective emitting temperature on a rotating body with time.

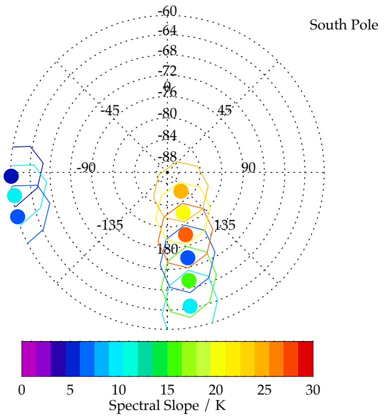

Figure 2: Spectral slope of CIRS FP1 observations, showing large variations between scenes.

We account for inhomogeneity in surface topography in the scene using a crater model after [3], neglecting the reflection term here due to the coarseness of the observations.

2. Results

These specimen observations represent very cold scenes with strongly contrasting spectral slopes. The model results in Fig. 3 show the spread of predicted temperatures for a set of 41 tiles within a crater of given steepness angle, to represent the range of potential surface temperatures within the CIRS scenes. The model broadly fits to within the observation error. The model tends to slightly underestimate the observed temperature. This will be further explored through the many degrees of freedom offered within the model, considering that at these very low temperatures the error on the measurement is considerably larger than the observation-model difference. There is scope to further improve the sophistication of the model.

3. Further development

Topographical maps of Rhea have been developed by Schenk, from which more information about surface properties can be inferred. This future work will improve the fidelity of the observation-model comparisons by the improvement of scene modeling.

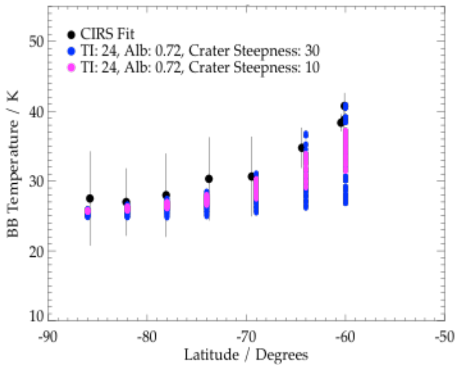

Figure 3: A comparison of the observations and modeled blackbody (BB) temperatures. Black represents CIRS BB temperature with associated uncertainty (described in text). Colored dots represent modelled surface temperature (matched to observation) of each tile representing a theoretical crater. Thermal Inertia in MKS units (J m^{-2} K^{-1} $s^{-1/2}$) and overall crater angle in degrees.

4. Summary and Conclusions

We have compared observations of Rhea's polar temperatures to a model that emulates the thermophysical properties of Rhea's surface to explore whether they are consistent with the hypothesis that cold traps of volatiles form a reservoir for the observed exosphere. We find that it is possible to simulate the observed temperatures at Rhea's poles at typical surface geometries, the validity of which will be further explored using ancillary information of higher spatial resolution.

Acknowledgements

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References

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