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Titan's surface properties inferred from the seasonal brightness variation at 2-cm wavelength

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Abstract

A comprehensive calibration and mapping of the thermal microwave emission from Titan's surface at 2.2-cm wavelength has been completed by the passive radiometer included in the Cassini RADAR instrument. A seasonal brightness temperature variation has been determined that is comparable to but slightly smaller than that obtained by Cassini's Composite Infrared Spectrometer (CIRS). This difference has implications for the composition and structure of Titan's surface; namely, that most of Titan's surface is covered by the deposition and possible redistribution of tholin-like atmospheric photochemical products to a depth of at least a meter.

1. Introduction

Brightness temperature data including polarization were accumulated by the RADAR radiometer over the period from Saturn Orbit Insertion in 2005 to the present, and were used to construct global mosaics of effective dielectric constant and emissivity. The mapping approach is described in [1]. Because the observations now span a time interval of nearly one-half a Saturn season, the seasonal brightness temperature variation had to be accounted for. The difference between this variation, originating at some depth to be determined, and that obtained by CIRS at the surface, can be expected to place constraints on the thermophysical properties of Titan's surface layer.

2. The 2.2-cm seasonal variation

Using a massive least-squares approach [1], the accumulated brightness data were used to solve for Titan's surface intrinsic microwave properties of emissivity and effective dielectric constant along with time-dependent Titan and instrumental properties such as the seasonal brightness variation, antenna sidelobes and gain drift. The inter-dependence of the data allowed a robust solution for all important parameters along with excellent determinations of systematic errors and statistical uncertainties. For the seasonal variation with time and latitude compared with the average, we used a model for that variation obtained by CIRS as a basis [2,3] for comparison with our results. Specifically we determined the amplitude of our observed 2.2-cm variation as a fraction F_{2cm} of that of the CIRS model. Using 2-cm data from all latitudes, we obtained a global result $F_{2cm} = 0.87 \pm 0.05$, where the uncertainty was determined by a Monte-Carlo technique in conjunction with the least-squares approach. In order to test dependence on latitude and terrain, we used subsets of points specific to these parameters and repeated the determination of F_{2cm} and its uncertainty for those subsets, where we found that essentially every subset gave the same result within statistical uncertainty.

3. The 2-cm penetration depth

We used the one-dimensional thermal diffusion equation

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} \quad (1)$$

to compute the seasonal variation of temperature as a function of depth for likely values of the thermal diffusion coefficient α [4]. We assumed the variation of the thermal diffusivity to be driven by the range of thermal conductivity values for wet and dry organic sands, finding that the seasonal amplitude of the temperature variation is reduced by a factor of 0.87 at depths ranging from 40 to 100 cm.

4. Interpretation

Most organic materials that may be considered candidates for Titan's surface that have been measured in the laboratory under Titan conditions have penetration depths greater than 1 m [5]. The laboratory data are limited; nevertheless, laboratory-produced tholins have been reported as having penetration depths as small as 22 cm when the material is compacted. While the relationship between tholins produced in the laboratory and that produced by photochemistry in Titan's atmosphere may be debated [6], this is at least an existence proof that the complex organics made by such processes can have constituents with sufficient microwave absorption to accommodate the present results, and provides another connection between atmospheric and surface processes.

5. Summary and Conclusions

The amplitude of the seasonal microwave thermal wave was found to be barely smaller than that at the surface as determined from the CIRS observations. Analysis showed that this relationship holds for the majority of Titan's surface, including most likely all of the radar-dark (high emissivity) terrains, which consist primarily of dunefields and plains. Using Titan-relevant thermophysical properties for the thermal conductivity of the subsurface based on their organic composition, we estimated a mean depth < 1m for the emission in these terrains. Laboratory-produced tholins demonstrate microwave absorption sufficient to explain this opacity. We infer that photochemical products from Titan's atmosphere with similar properties are a plausible source of the opacity and a potential tracer in understanding the evolution of Titan's surface.

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References

[1] Janssen, M.A., R.D. Lorenz, R. West, F. Paganelli, R. M. Lopes, R.L. Kirk, C. Elachi, S.D. Wall, W.T.K. Johnson, Y. Anderson, R.A. Boehmer, P. Callahan, Y. Gim, G.A. Hamilton, K.D. Kelleher, L. Roth, B. Stiles, A. Le Gall, and the Cassini Radar Team, 2009. Titan's surface at 2.2-cm wavelength imaged by the Cassini RADAR radiometer: calibration and first results, Icarus 200, 222-239.

[2] Cottini, V., C.A. Nixon, D.E. Jennings, R. de Kok, N.A. Teanby, P.G.J. Irwin, and F.M. Flasar, 2012. Spatial and temporal variations in Titan's surface temperatures from Cassini CIRS observations, Planet. Space Sci. 60, 62-71.

[3] Jennings, D.E., private communication, 2014.

[4] Carslaw, H.S. and Jaeger, J.C., 1959. Conduction of heat in solids, Oxford: Clarendon Press.

[5] Paillou, P., J. Lunine, G. Ruffié, P. Encrenaz, S. Wall, R. Lorenz, M. Janssen, 2008. Microwave dielectric constant of Titan-relevant materials. Geophysical Research Letters 35, L18202, doi:10.1029/2008GL035216.

[6] Cable, M.L., S.M. Horst, R. Hodyss, P.M. Beauchamp, M.A. Smith, P.A. Willis, 2012. Titan tholins: Simulating Titan organic chemistry in the Cassini-Huygens era, Chem. Rev. 112, 1882-1909.