Cassini VIMS observations of the structure of Titan’s atmosphere

Paulo Penteado (penteado@astro.iag.usp.br)

Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo

Introduction

Cassini VIMS observations of Titan at 0.4-5.1 µm probe the atmosphere at varied altitudes, due to the effects of the variable methane and haze optical depths. This has been used to derive the altitudes of observed features, such as methane and ethane clouds, to distinguish between surface and atmospheric phenomena, and to derive methane and haze spatial distributions. However, since the methane and haze vertical distributions determine the altitudes probed at each wavelength, this method is sensitive to the assumptions on the methane and haze vertical profiles, which have been shown to be ambiguous in observations over the surface. To overcome these uncertainties, this work explores the observations over Titan's limb, which directly sample different altitudes in the atmosphere.

Data and calibration

Since Cassini's arrival at Saturn, VIMS has recorded over 10^4 cubes, containing over 10^7 spectra. This still increasing amount of observations precludes direct inspection of all data, either to select the observations, or to identify the occurrence and time variation of specific spectral or spatial features. This work draws its data from titan_browse, a tool developed to deal with these difficulties. Titan_browse comprises both a database of observations, and a visualization tool to inspect them. The database contains every VIMS observation of Titan in the PDS archive, and provides a flexible query system, which can select individual cubes or spatial pixels based on arbitrary functions of the instrumental or photometric data. Once observations are selected, titan_browse can be used to directly inspect them, through mosaics in several map projections, or displaying images of selected bands, or spectra of selected spatial pixels.

The cubes used in the database were processed to contain more geometric information than either the original PDS files or those that are produced by the VIMS pipeline, including the coordinates of the edges of each spatial pixel (necessary to properly determine their extent), and providing the geometry for the entire cubes (not being limited to the pixels that intercept the surface).

The raw data used is publicly available at NASA's Planetary Data System (PDS) Imaging Node (http://pds-imaging.jpl.nasa.gov/index.html).

Since there were still detectable misalignments in the calculated coordinates relative to Titan's disk, a correction was applied to the cubes used here. The center of the disk was determined fitting circles to contour levels of bands where the disk is most uniform. Then the coordinates were offset by a constant amount, to make the disk center coincide with that determined from the images.

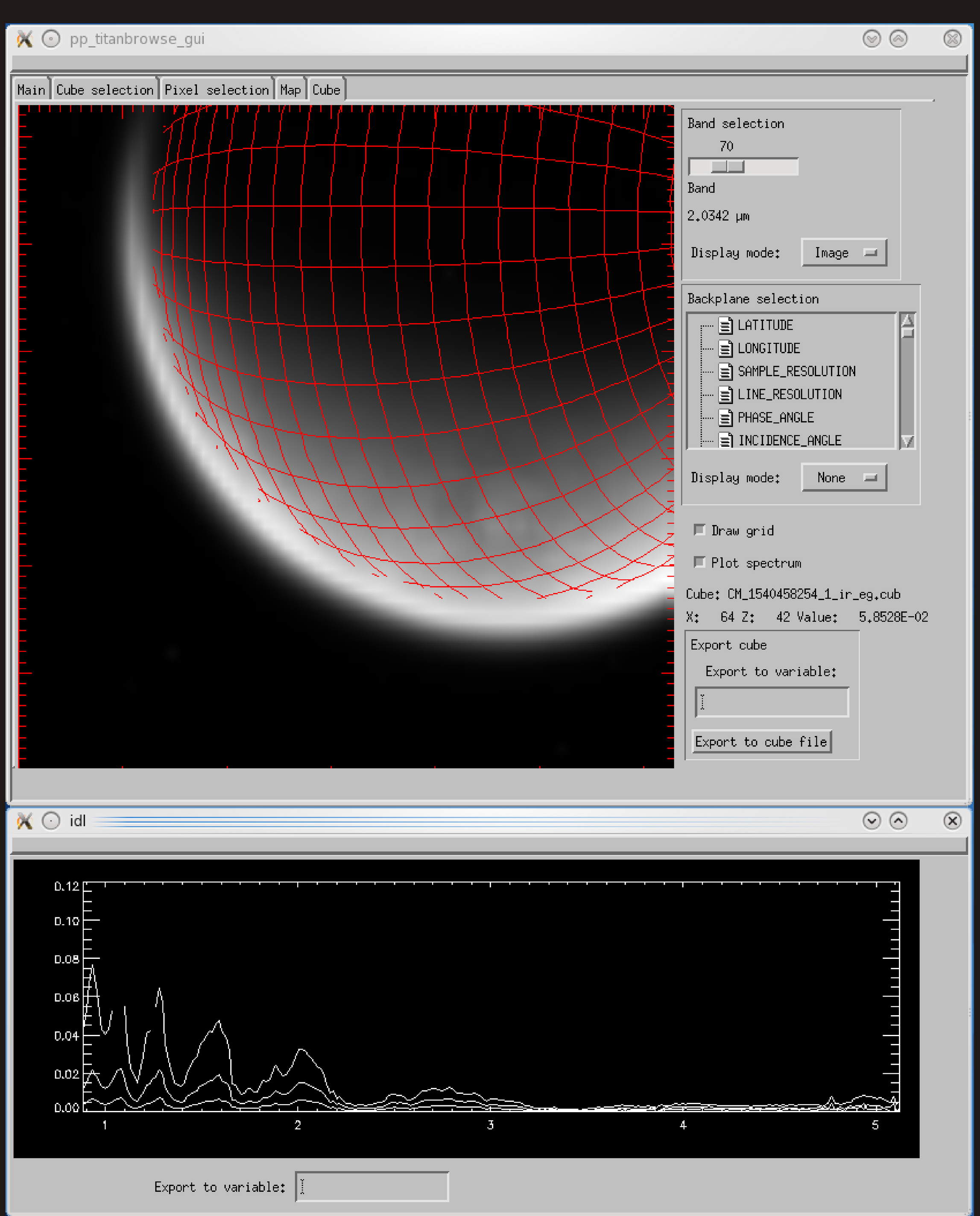

Figure 1. The visualization panel of titan_browse's graphical interface

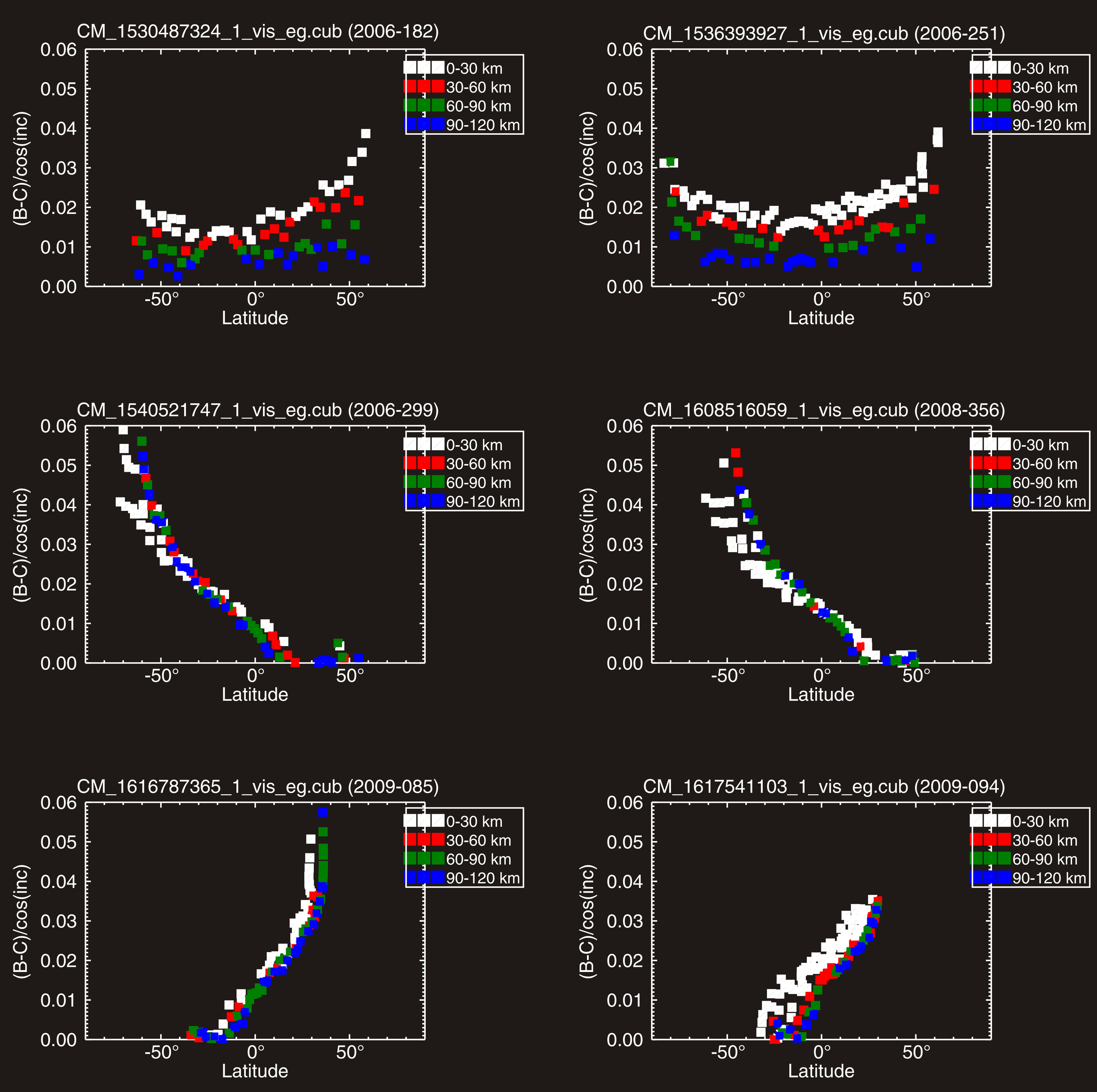

Figure 5. Meridional variation of the spectrum slope at 0.6µm, indicative of the haze variation, normalized by the cosine of the incidence angle, separated in 30 km altitude bins.

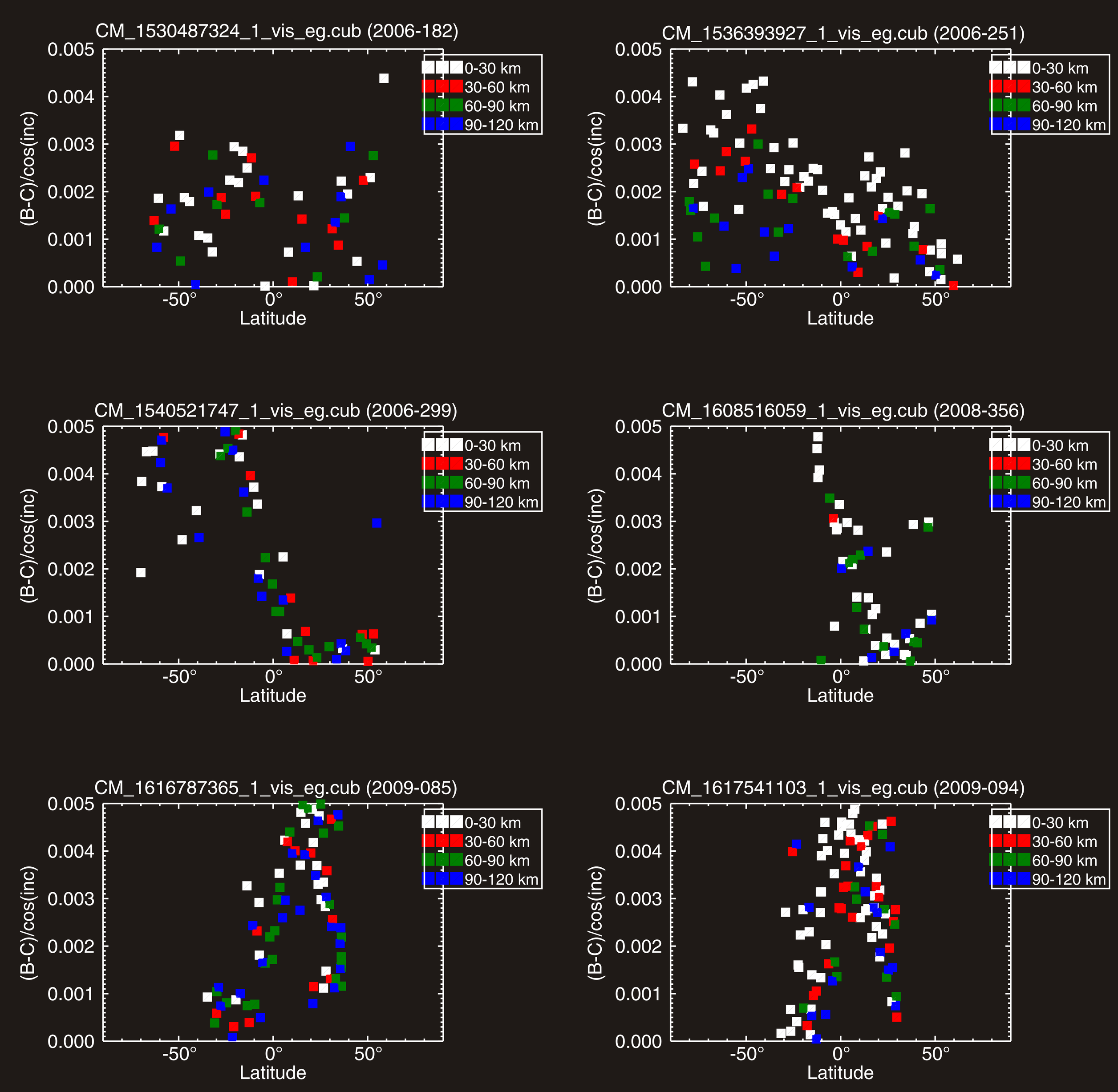

Figure 6. Meridional variation of the methane band depth at 0.64µm, normalized by the cosine of the incidence angle, separated in 30 km altitude bins.

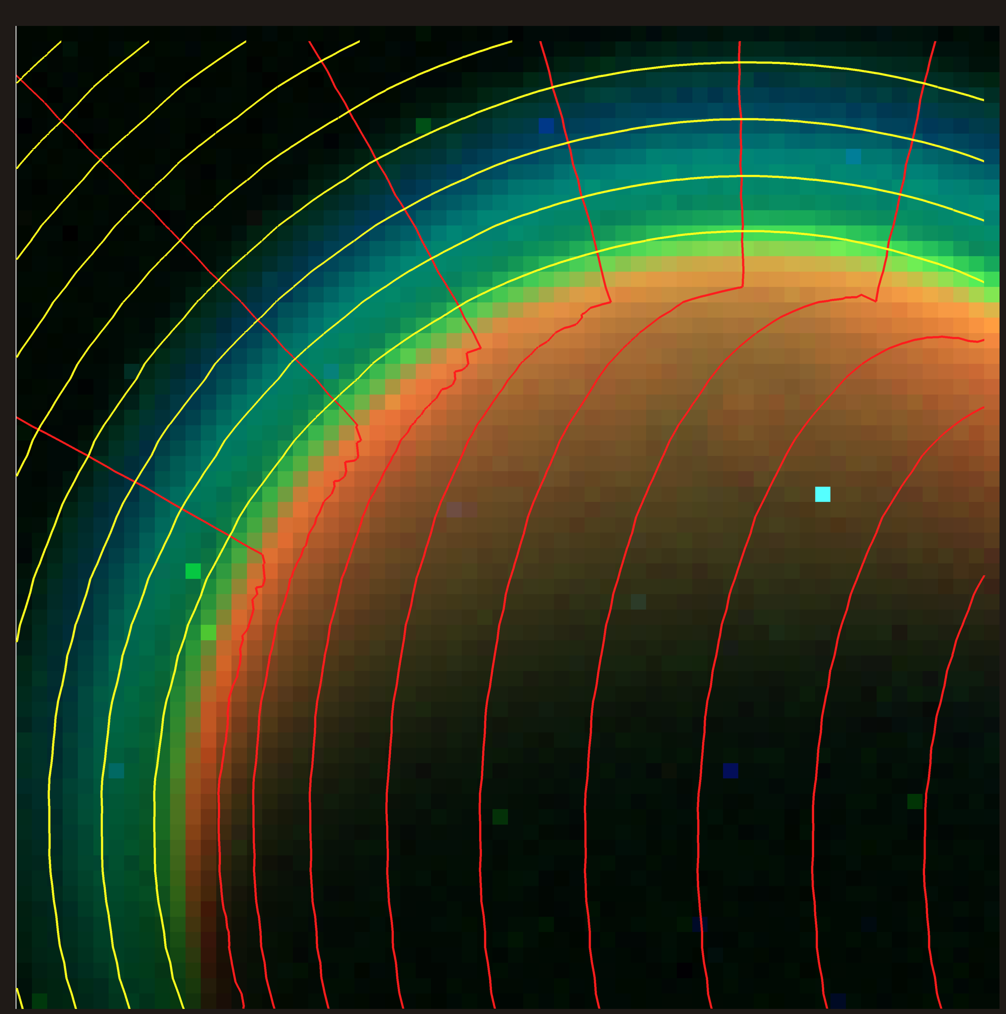

Figure 2. An example of 3 bands of a cube mapped into RGB space, with contours of constant latitude (red) and altitude (yellow) for the pixel centers, to illustrate the geometric data included with the cube, which extends to the pixels that do not intercept the surface, used in this study to measure different altitudes over the limb.

Selected observations

Following the analysis of the 0.64µm methane band of Penteado et al. 2010, that same region was used, due to its sensitivity to the haze the methane at the high troposphere (20-50 km altitude). The same 4 bands were used to map the meridional and vertical variation of the continuum and methane band, shown on the spectrum of Figure 4.

The small sample taken for this preliminary study has 6 cubes, taken between 2006 and 2009. These have vertical resolution of 10-13 km/pix, and cover most of the illuminated limb, at a phase angle of 60°-75°.

Since in this case the spatial pixels are separated by the altitude above the surface, each set has similar emission angles. So the normalization of the band measures B-C and B-A was done dividing these by the cosine of the incidence angle, to account for the varying illumination across the disk.

Figure 5 shows the meridional profiles of the 0.6 µm slope, measured as ((B-A)/cos(inc)), separated on 4 different altitude regions.

Figure 6 shows the meridional profiles of the 0.64 µm methane band depth, measured as ((B-C)/cos(inc)), separated on 4 different altitude regions.

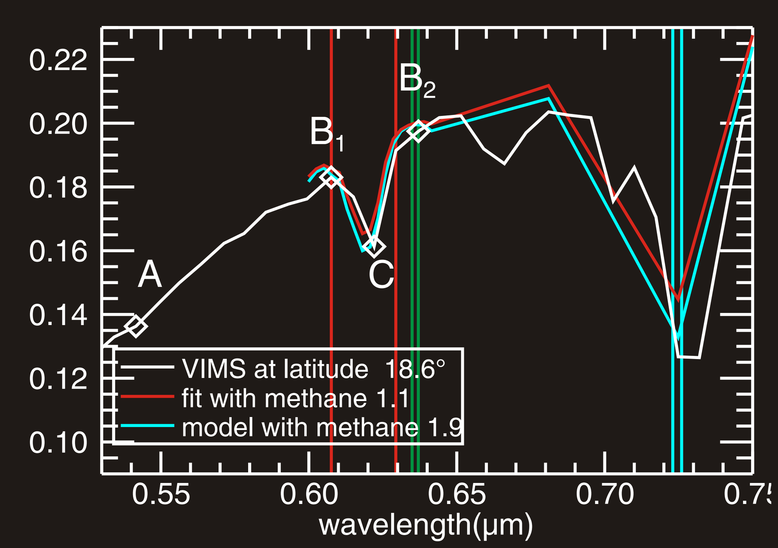

Figure 4. A typical spectrum taken over the disk, showing the 4 bands used in figures 5 and 6 (B is the average of B1 and B2). Figure from Penteado et al. 2010.

Results and future work

The limb observations selected show two transitions in the slope of Titan's spectrum at 0.6µm, at all altitudes, on late 2006 and late 2008. This period immediately precedes the occurrence of the southern fall equinox, in August 2009, during which dynamical models (such as that by Richardson et al., 2007) predict a rapid change in the global circulation, from a single summer to winter cell, to two short-lived equator to pole cells.

In contrast, the depth of the methane band at 0.64µm had no detectable variation in the period, at the altitudes where it can be detected.

Future work will improve on the determination of pointing corrections, to allow the use of larger numbers of observations, for better spatial and temporal coverage.

To determine how these observed variations in the spectra constrain the haze and methane vertical profiles and their temporal and meridional variations, radiative transfer models are being developed to reproduce the spectra. These models are similar to the plane-parallel discrete ordinate models used previously for VIMS observations at low emission angles (Penteado et al., 2010), but incorporate spherical geometry, through the variation in the Sun and observer directions between consecutive plane layers.

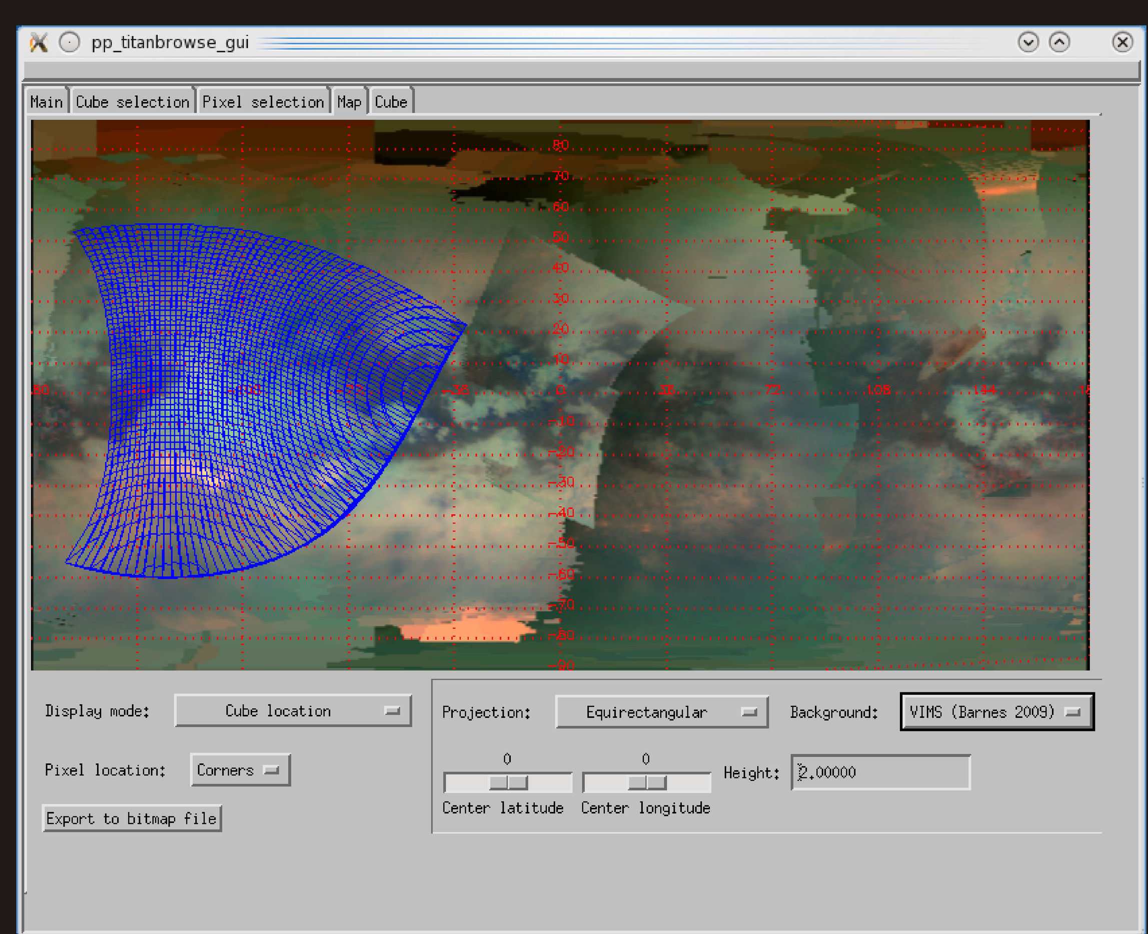

Figure 3. The map panel of titan_browse's graphical interface, showing the shapes of the pixels, from the coordinates of the edges of each pixel.

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