

# Titan’s global map combining VIMS and ISS mosaics

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## 1. Introduction

Titan, Saturn’s largest moon, is the only ocean world, besides Earth, with a dense atmosphere. This outstanding feature is also a challenge since it was believed before the launch of the Cassini mission that optical cameras (visible and infrared) could not see the surface and that only radar instruments could map Titan’s surface. However, the Visual and Infrared Mapping Spectrometer (VIMS) and the Imaging Science Subsystem (ISS) onboard the Cassini spacecraft demonstrated that Titan’s surface can be observed in several infrared atmospheric windows. These windows are located at (1.08, 1.27, 1.59, 2.03, 2.69, 2.78 and 5  $\mu\text{m}$ ) for VIMS [1, 2] and 938 nm (CB3 filter) for ISS [3]. Between 2004 and 2017, Cassini performed 127 targeted Titan flybys and recorded about 60 000 VIMS hyperspectral cubes [4] and 20 000 ISS images [5].

Both datasets were acquired with a variety of observing geometries (incidence, emission, and phase angles) and different atmospheric characteristics. Light scattered by aerosols complicates the radiative transfer model to infer surface albedo. The VIMS observations are small hyperspectral images of 64 pixels  $\times$  64 pixels spanning a large range in pixel size from 500 m to 30 km. 90 % of Titan’s surface is covered by VIMS images at better than 25 km/pixel and only 5 % at better than 5 km/pixel [4] (Fig. 1a). The ISS images are 1024 pixels  $\times$  1024 pixels with typically a few kilometers pixel scale, and provide a more homogeneous global coverage (Fig. 1b). Semi-empirical techniques have been used to remove boundaries between individual data cubes and images with varied degrees of success [6, 7].

This study combines the VIMS color mosaics at different wavelengths [4] and the global ISS mosaic [5] to provide a seam-free color map of Titan revealing the diversity of geological structures.

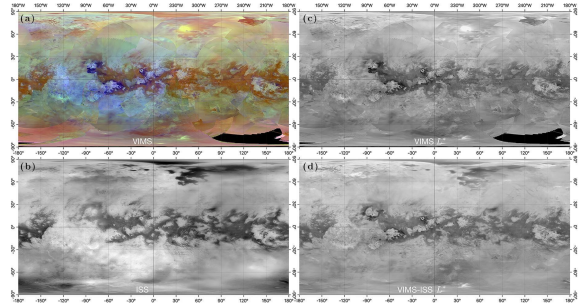


Figure 1: (a) VIMS RGB global map at 1.59/1.27, 2.03/1.27 and 1.27/1.08  $\mu\text{m}$  empirically corrected for airmass effects [4]. (b) ISS grayscale global map at 938 nm [5]. (c) Original  $L^*$  lightness component of VIMS map. (d) Combined VIMS  $L^*$  component with filtered ISS map. On the original VIMS map, the equatorial dunes fields appear in brownish tones, and several occurrences of bluish tones are localized in areas such as Sinlap, Menrva and Selk craters. However, some regions are not covered (80°S, 120°E) or are affected by extreme observation geometries. The saturated yellow area at (70°N, 40°E) is due to a specular reflection on Kraken Mare.

## 2. Method

We selected the VIMS map in band ratio at 1.59/1.27 (Red), 2.03/1.27 (Green) and 1.27/1.08  $\mu\text{m}$  (Blue) from [4]. To keep the spectral information from VIMS, we decompose the representative RGB map into three channels: Lightness ( $L^*$ ), the Green-Red ( $a^*$ ) and Blue-Yellow ( $b^*$ ) color components (CIELAB decomposition [8]). With this band ratio choice, VIMS ( $L^*$ ) component looks similar to the albedo map retrieved by ISS (Figs. 1b and c).

In order to better emphasize the north-polar lakes and seas and the equatorial features from ISS, we added the ISS albedo map to  $L^*$  with a darkening luminosity filter of 50 % to extract the details from the

darkest areas of the ISS map. Additionally, we use the VIMS resolution map (Fig. 1 from [4]) – smoothed with a Gaussian filter of 15 pixels radius to remove the seams between the different cubes – as a secondary filter to preserve the high resolution area covered by VIMS (Fig. 1d). Where VIMS data don't exist, the value of  $a^*$  and  $b^*$  components are filled with the mean value of the adjacent pixels and the remaining seams are manually removed. Finally, the new lightness layer is recombined with the filled  $a^*$  and  $b^*$  layers to compose a new color map (Fig. 2).

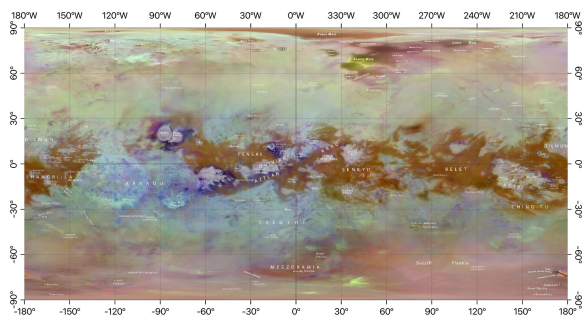


Figure 2: Merged VIMS-ISS global map after CIELAB recomposition. The final map is available at this doi: [10.22002/D1.1173](https://doi.org/10.22002/D1.1173)

### 3. Discussion

The overall correlation matches the two global maps with an accuracy of a few kilometers. Locally, some advanced refinements could be required but the overall correlation matches the expected resolution provided by the instruments.

The enhanced map shows more pronounced contours in the northern maria and lakes as compared to the original VIMS map improving the identification of individual features. The specular reflection over Kraken Mare (70°N, 40°E) is partly compensated by the ISS data. In the equatorial region, the high resolution VIMS data over the craters Sinlap (10°N, 15°W), Menrva (20°N, 85°W) and Selk (5°N, 160°E) are preserved and the sharpness of the brownish dune fields is increased (25°S, 45°E). The light blue feature centered at (10°S, 120°W) within Xanadu was already present in the original VIMS map [9]. Finally, at the South Pole, the hole at (80°S, 120°E) is now covered but its spectral interpretation is unknown due to the absence of VIMS data (Fig. 3). The western part of Ontario Lacus is also completed by the ISS map.

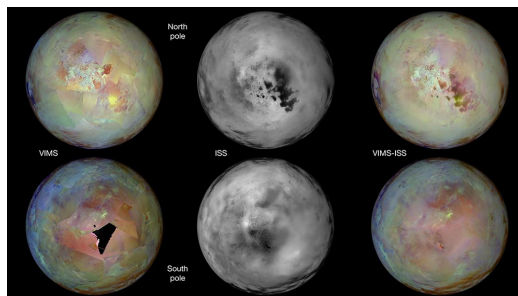


Figure 3: Orthographic projection of Titan's poles from VIMS, ISS and VIMS-ISS global maps. The northern lakes are more pronounced and the South Pole hole is filled.

### 4. Conclusion

This combined VIMS-ISS map provides an overview of Titan's known geological features. The differences in color reflect differences in geomorphology and composition (e.g. the equatorial dune field [10] appears in brownish tones whereas the dark blue areas are interpreted as local enrichment in water ice [11]). This map could be used as a basemap for local studies but feature identification is best conducted using the original VIMS [4] and ISS [5] maps.

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