GLOBAL MAPPING OF TITAN WITH VIMS HYPERSPECTRAL IMAGES : A STATUS AT THE END OF THE CASSINI MISSION

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Introduction: The Visual and Infrared Mapping Spectrometer (VIMS) onboard Cassini acquires up to 64x64 pixels images in 352 spectral channels from 0.35 to 5.12 µm [1]. Between 2004 and 2017, spectral observations have been gathered during 127 targeted Titan close encounters, in addition to more distant surveys. Our objective is to produce a global hyperspectral mosaic of the complete VIMS data set of Titan between T0 (July 2004) and the end of the Cassini mission in September 2017, in order to emphasize spectral heterogeneities linked to surface compositional and/or physical state variations.

Methodology: All the data cubes have been calibrated in I/F following the VIMS pipeline described in [2], and further refined using a time-dependent radiometric calibration aimed at correcting a small wavelength shift that has been identified during the last years of the mission [3]. The VIMS wavelengths shift is less than 0.1 channel per year, resulting in a total of ~10 nm of shift when comparing data taken in 2004 and data taken in 2017. Despite this effect being very small, it has to be taken into account to avoid unwanted seams in the global maps of Titan, considering the fact that the surface methane windows are very narrow.

Quicklook images have been produced to identify and remove spurious cubes. Data have been sorted by increasing spatial resolution, with the high resolution images on top of the mosaic and the low resolution images used as background. We filtered out the observing geometry in order to remove the pixels acquired in too extreme illuminating and viewing conditions, which produce strong seams due to atmospheric and photometric effects. We used thresholds of 80° both on the incidence and emission angles, 110° on the phase angle, and 7 on the airmass (defined by 1/ cos i + 1/cos e). These thresholds correspond to a trade-off between surface coverage (in particular in polar areas) and data quality.

Fig 1a shows the resulting mosaic at 2 µm, with no correction for geometry nor the atmosphere. Many seams appear between individual images. They are mainly caused by the varying viewing angles (incidence, emission, phase) between data acquired during the different flybys, which induce strong atmospheric and surface photometric effects. Other discrepancies might be present due to surface and atmospheric temporal variations, and residual calibrations artifacts.

Several surface photometric corrections have been tested. Whereas a pure lambertian function was used to perform a first order correction in the first versions of the maps [4], we realized that a supplementary correction of the emergence and phase angles was needed to account for the extreme diversity of the viewing conditions. We finally ended up with a Lunar Lambert function [5], with a lunar-like weighting factor A=0.241, which was computed to minimize the seams at 5 µm in a test region on homogeneously bright terrains observed with strongly varying geometry. The corrected map at 5 µm is shown in Fig. 1b. Very bright terrains in this map corresponds to possible evaporites, specular reflexions or unfiltered clouds. Although the 5 µm window is almost free of atmospheric scattering, this is not the case for shorter wavelengths, which contain an additive scattering contribution of the atmosphere. To mitigate this effect, we use the wings of the atmospheric windows as a proxy to correct for the amount of additive scattering present in the center of these windows, where the surface is seen by VIMS [4]. The resulting map at 2 µm, corrected from scattering and photometry, is shown in Fig 1c. The level of residual seams has been significantly decreased.

To investigate spectral heterogeneities, we computed RGB composites of various wavelengths, and also investigated several band ratios. An RGB global color map with the red, green and blue controlled by the 5, 2 and 1.27 µm images empirically corrected from scattering and photometry with the method exposed above is presented in Fig 1d. For Titan, using band ratios is still quite challenging, as they are generally much more sensitive to residual calibration artifacts and atmospheric residuals than RGB composites of single bands. We obtained our best results by using an empirical correction of the airmass dependence computed on each ratio, prior to the scattering correction.

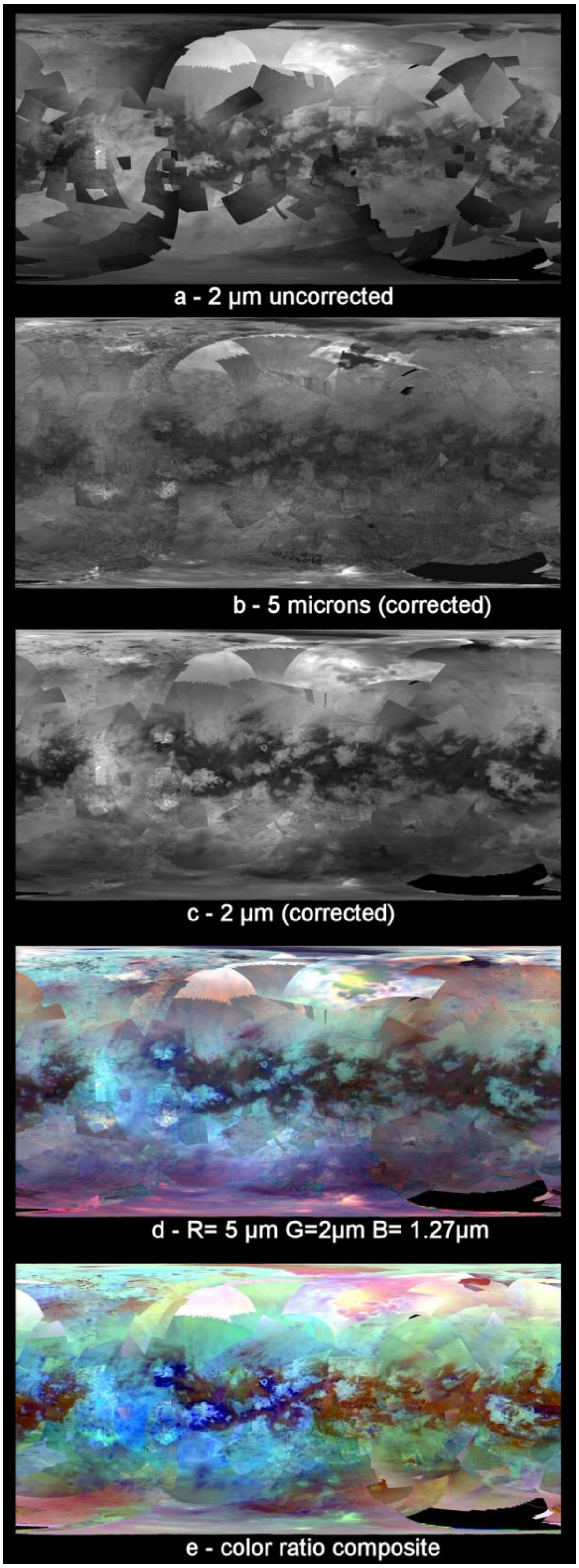

Fig.1 : Global maps of Titan computed with all data from T0 to T126.

The result is displayed in Fig. 1e, which corresponds to a RGB composite of the 1.59/1.27 µm, 2.03/1.27 µm and 1.27/1.08 µm ratios empirically corrected from the airmass dependence. Whereas this map still contains some dependence with pure albedo variations, subtle color differences are strongly emphasized due to the use of the ratios, which cancels out multiplicative terms. The strongly diffusing atmosphere still hampers the study of the polar areas (appearing in pink), but the ratios easily reveal the extent of equatorial dune fields appearing in brownish tones. A zoom on the Huygens landing site area is given in Fig. 2 for example.

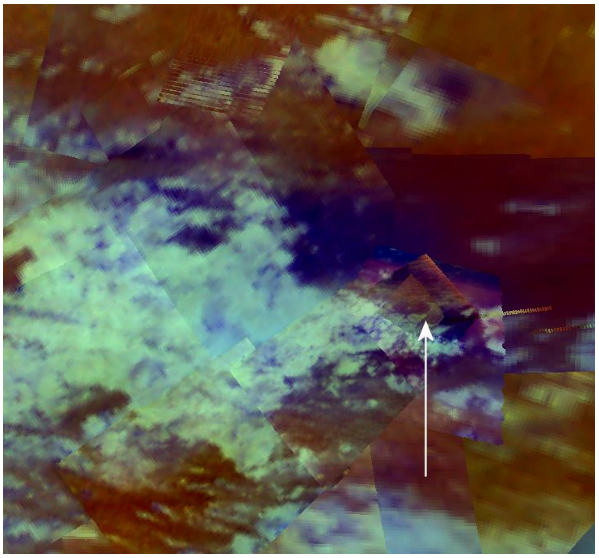

Fig.2 : Zoom of the color ratio color composite on the Huygens landing site area (Arrow).

Conclusion and perspectives : The residual discrepancies in the maps are due to several factors such as temporal variations at the surface and in the atmosphere (haze and clouds), specular reflections (mostly around Kraken and Ligea Mare). The surface photometric behavior can also be improved using a more complex photometric function with wavelength-dependent parameters. More inputs derived from a complete radiative transfer analysis [6] could also provide another way to improve the homogeneity of the maps in future works.

References: [1] Brown R.H. et al. (2004) *Space Sci. Rev.*, 115, 111-168. [2] Barnes et al. (2007) *Icarus*, 186, 242-258. [3] Clark et al. (2016), *Nasa Planetary Data system*. [4] Le Mouélic S. et al. (2012), *Planet. Space Science*, 73, 178–190. [5] Cornet et al. *(2012)*, *Icarus*, 218, 2, 788-806, . [6] Cornet et al., *48th LPSC*, abstract#1847, 2017