**SPATIAL AND SPECTRAL FILTERING STRATEGIES FOR CASSINI VIMS SURFACE IMAGES OF TITAN.** S. Le Mouélic[1] , C. Sotin[1], S. Rodriguez[2], G. Tobie[1], L. Le Corre[1], R.H. Brown[3], J.W. Barnes[3], B. Buratti[4], L. Soderblom[5], R. Jaumann[6], K.H. Baines[4], R. Clark[7], P.D. Nicholson[8], [1]Laboratoire de Planétologie et Géodynamique, université de Nantes, France, [2] Laboratoire AIM, CEA, Gif/Yvette, France, [3] Lunar and Planetary Lab and Stewart Observatory, University of Arizona, Tucson, [4] JPL, Pasadena, USA, [5] USGS, Flagstaff, USA, [6] DLR, Berlin, Germany. [7] USGS Denver. [8] Cornell University, USA. [stephane.lemouelic(at)univ-nantes.fr]

**Introduction:** The VIMS imaging spectrometer onbord CASSINI provides hyperspectral images of Titan in 352 spectral channels from 0.3 to 5.1 µm. Infrared channels are particularly useful to map the surface of Titan through narrow atmospheric transmission windows [1,2]. VIMS can be used for geomorphological studies thanks to the imaging capabilities. The spectral dimension is used to investigate the composition of the surface materials. We focus here on the improvement of the S/N ratio both for surface imaging and spectral studies.

**Spatial filtering :** The best images in terms of contrast are acquired in the 2 µm window, where the signal from the surface is still strong and the scattering by the atmosphere (an effect decreasing with increasing wavelength) already low enough (figure 1). When using low exposure time (as low as 13 ms, which is needed when we observe at closest approach), the image quality can be significantly improved by coadding several channels within the methane transmission windows. In order to improve image sharpness and hence to emphasize surface features, we obtained our best results by - 1 coadding several spectral channels (up to 12) in the 7 methane windows, 2- oversampling the actual cube resolution by a factor of four 3- applying a bilinear interpolation to smooth the pixels, 4- applying an unsharp mask procedure. This unsharp mask procedure is similar to the one used for ISS images [3]. It simply consists in substracting ~60% of a low-pass filtered image. Two examples of this processing pipeline are given in figure 1 on T4 (actual resolution 1.5 km/pixel) and T13 (resolution 15 km/pixels) images. Dune fields show up more clearly in the T4 image, so as the Sinlap crater walls in the T13 image. This strategy is useful for geomorhological analyses, but it can not be used prior to spectral analyses as it may modify the spectra (in particular the unsharp mask procedure).

**Spectral filtering:** VIMS acquires images in 352 contiguous spectral channels. The number of spectral channels is much higher than the intrinsic variability of the observed components of a given scene. In order to increase the signal to noise of the spectra, we used the Minimum Noise Fraction (MNF) transform [4]. This algorithm is used to determine the inherent dimensionality of image data, to segregate and equalize the noise in the data. The MNF transform uses two cascaded Principal Components (PC) direct transformations. The first transformation decorrelates and rescales the noise in the data. This results in transformed data in which the noise has unit variance and no band-to-band correlations. The second transform is a standard Principal Components direct transformation of the noise-whitened data. The resulting bands of the MNF transformed data are ranked with the largest amount of variance in the first few bands and decreasing data variance with increasing band number until only noise and no coherent image remains. When applied to the 256 VIMS infrared channels (fom 0.88 to 5.10 µm), it appears that the very first MNF bands correspond to smoothly low pass varying effects. This is illustrated in figure 2, which shows the first 6 bands of the MNF transform of data cubes acquired near closest approach in line mode during the T20 (25 october 2006) flyby. The smooth appearance of the first band is primarily due to the atmospheric variations, which dominates the signal. Surface features can often be found within the next few bands (bands 2, 3 and 4 in our case, but in up to ~10 bands depending on the signal contained in the input data cube). The next bands (5, 6 and higher in our case) contain only noise.

The inherent noise of the hyperspectral cube can then be significantly reduced by using an inverse MNF transform applied on the first MNF bands showing coherent patterns. This is illustrated in figure 3. In this case, the calibration of the raw data (figure 3 left) has also been modified by optimizing the dark frame removal process (subtraction of a the same mean dark frame for each line). This removes the line by line noise effect which can be seen in the raw data (figure 3 middle). Figure 3 (right) shows the same area after noise reduction by inverse MNF. Figure 4 shows the same processing strategy applied to the highest resolution T20 images acquired over equatorial dune fields, with a resolution of ~500 m/pixel. The dunes patterns appear very clearly after this data reduction process, with a frequency similar to the one observed by the radar at T17.

We obtained the sharpest color images by using a false RGB color composite of band ratios (figure 3 and 4 right). In the given example, dark blue areas correspond to surface materials possibly enriched in water ice. Spectral heterogeneities can therefore be easily detected. The MNF filtering can also be useful to increase the signal to noise ratio of the spectra themselves (figure 5). This is of particular interest for data acquired with a short exposure time, in order to investigate small absorption features such as the ones which have been observed in the 5 µm window [5].

**Conclusion and Perspectives :** The imaging capacities of VIMS can be significantly improved by using a series of common image enhancement techniques such as co-adding of channels, ratioing, statistical filtering and/or unsharp mask procedure. This should provide new insights into Titan surface properties when applied on high resolution images, such as the one acquired at T20 during the closest approach.

**Bibliography** : [1] Brown R.H. et al., (2003), *Icarus*, 164, pp. 461-470. [2] Sotin C. et al. (2005) *Nature, 435*, 768–789. [3] Perry J. et al., (2005) *LPSC XXXVI.*, abstract #2312. [4] Green A.A. et al. (1988), *IEEE Trans. Geosci. Remote Sens.*, 26, 64-74. [5] Clark R. N. et al. (2006), AGU fall meeting, abstract #P11A-03

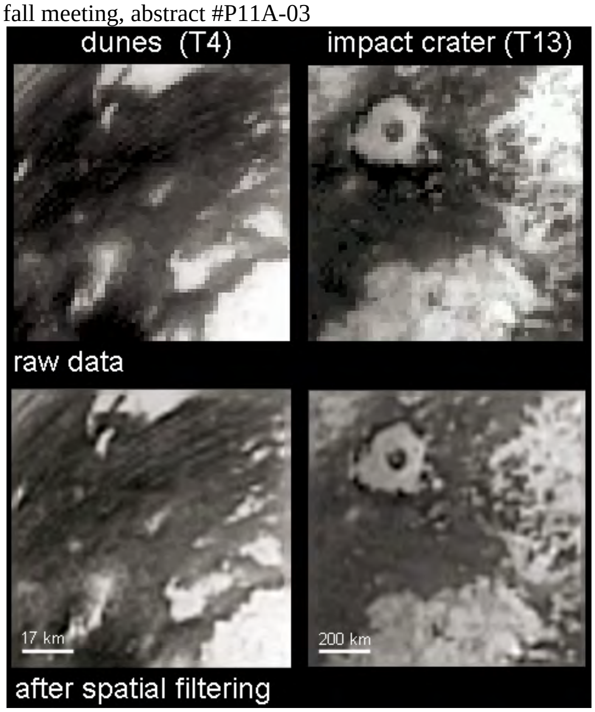


Figure 1 : improvement of single band images (top) by using successively a coaddition of spectral channel, oversampling, bilinear interpolation and unsharp mark procedure (bottom).

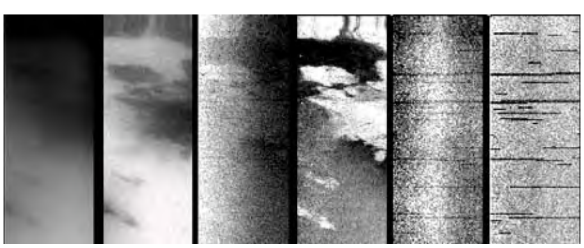

Figure 2 : first six MNF bands of a VIMS hyperspectral cube acquired during T20 flyby (25 October 2006) .

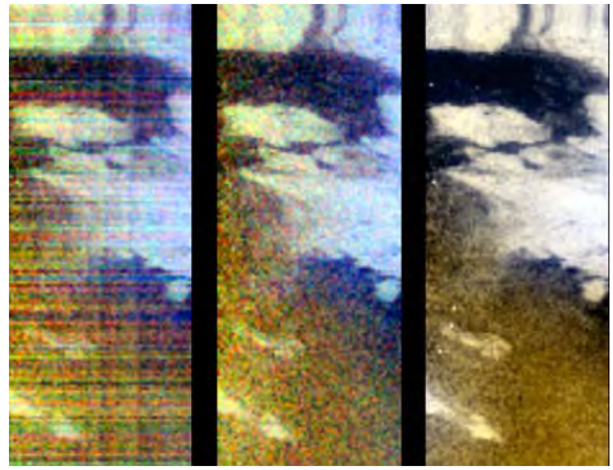

Figure 3 : left : calibrated data. Middle : calibrated data after optimization of the dark frame removal. Right : data after noise reduction by MNF

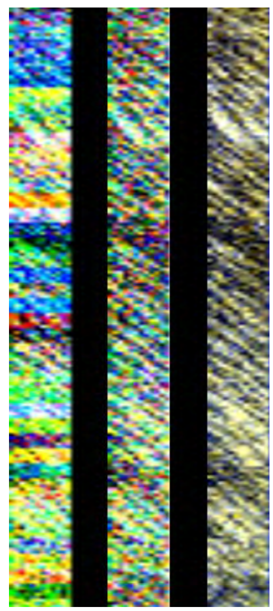

Figure 4 : subset of T20 highest resolution data (RGB composite of 1.59/1.27, 2.03/1.27, and 1.27/1.08 µm band ratios)
Left : calibrated data. Middle : calibrated data after optimization of the dark frame removal. Right : data after noise reduction by MNF

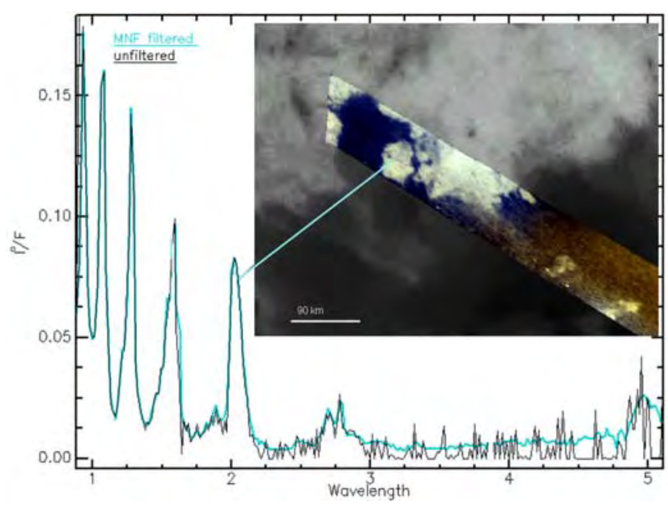


Figure 5 : typical spectrum before (black) and after (blue) filtering by inverse MNF transform.