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In-flight geometrical calibration of OMEGA detectors and implication for mapping

N. Manaud (1,2), F. Poulet (2), J.P Bibring (2), B. Gonget (2), Y. Langevin (2)
(1) European Space Astronomy Centre, Madrid, Spain, nmanaud@sciops.esa.int, (2) Institut d'Astrophysique Spatiale, Orsay, France

1 Introduction

Since orbit insertion in January 2004, the OMEGA experiment on board the Mars Express spacecraft, is mapping the surface composition of Mars at a 0.3- to 5-kilometre resolution by means of visible-near-infrared (IR) hyperspectral reflectance imagery operating from 0.35 to 5.1 μm.

The OMEGA data sets, archived in the ESA's Planetary Science Archive, currently contain uncalibrated observational data along with calibration routines, and geometry data associated to each observation.

Geometry data provide key information for the mapping and photometric analysis of the observational data, and for cross-instrument data analysis. Although these data are very useful to obtain a first estimate of the regions mapped by OMEGA observations, the remaining registration errors ($\sim$2.5 pixels) prevent the controlled production of composite maps without degrading spatial resolution.

We will first present the approach currently used to reconstruct the geometry of observations, then we will introduce a new method being developed to refine the OMEGA detectors geometry model so as to achieve sub-pixel georeferencing accuracy. The detectors geometry model includes both interior and exterior orientation data.

2 Current reconstruction of observations geometry

A SPICE-based geometry processing software, *GEOMEG*, is used to reconstruct the observations geometry. The process for each observation can be simplified as follows:

1. Compute pointing vectors of each pixel of each of the three OMEGA detectors.
2. Compute the intersection of the pointing vectors with the target of the body surface.
3. Compute viewing and illumination angles at each intersection point.

Pixel pointing vectors are computed using the detector geometry model parameters available from the ground calibration data [1]: detectors frame alignment with respect to the spacecraft frame, IR scanning mirror position calibration function, optical distortion data for the visible line detector.

The position and orientation of the Mars Express spacecraft and solar system bodies are modeled using SPICE data kernels [2], compliant to IAU 2000 cartographic standards. A specific algorithm has been developed to intersect spacecraft viewing vectors with a digital elevation model using MGS MOLA Mission Experiment Gridded Data Records.

Limb observations constitute a special case that is also handled by GEOMEG.

An important limitation of this software and methodology is that it does not estimate not accommodate potential model errors. Spacecraft position and orientation data accuracy, alignment and optical properties of the detectors can all change over time [3]. Given these remaining uncertainties, the georeferencing error is estimated as 3 mrad ($\sim$2.5 pixels) or better for most observations.

3 On going methodology to refine detectors geometry model

This method is based on the fact that georeferencing errors can be estimated by analyzing the similarities between actual and reconstructed observables in the image coordinate space. We can for example use existing correlations between the 2 μm CO_2 absorption band and topography, and the albedo at wavelength lower than 3.5 μm (no thermal contribution) and cosine of local incidence angle.

Assuming a transformation function between the reconstructed and actual observable image coordinates, the identification of tie points between the two images allows the calculation of the transformation coefficients. This transformation function is then applied to the intersection points coordinate images (X, Y, Z) to provide an estimation of the ground control points coordinates associated to each pixel of the detector image. Given the position and orientation of the spacecraft at the time of data acquisition, and the ground control points coordinates, it is possible to calculate the corresponding pixel pointing coordinates with respect to the spacecraft reference frame. From these pixel pointing coordinates, the detector frame orientation and scanning mirror position calibration function are derived for a given observation, assuming there are no spacecraft orientation errors.

As pixel pointing vectors are assumed to be coplanar, it is also possible to estimate the spacecraft positioning error along its orbit. The pixel pointing coordinates are computed for different times around data acquisition time. The time offset is then estimated as the interpolation of the solution that best matches the coplanar condition.

In order to estimate both the spacecraft pointing errors and the detector frame orientation, the process described above must be repeated for a large number of observations. The statistical analysis of the derived geometry model parameters therefore allows the distinction between, and correction of systematic and non-systematic errors.

4 Example of improvement

We present here an example of the improvement that has been achieved by manually registering a selection of 61 observations of Mawrth Vallis, which only represents a subset of available observational modes. We have been able to re-estimate the scanning mirror position calibration function. Figure 1-a shows that the angular variation (red curve) between the currently modeled and the new estimated pixel pointing vectors significantly differs for high scanning mirror amplitude.

We then reconstructed the observations geometry using the new calibration function. Figure 1-b shows a subset of the reconstructed topography as currently available for a 128-pixel swath observation, and figure 1-c shows this same subset after applying the new calibration function. We mostly see the georeferencing improvement near the top edge of the images as the IR detector field of view is smaller than previously modelled.

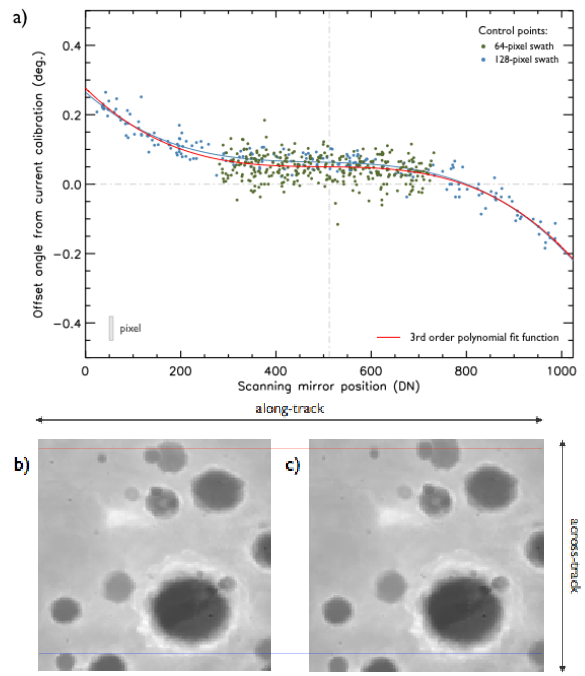

Figure 1: Refinement and effect of new IR scanning mirror position calibration function

5 Conclusion

We are developing a method to improve the accuracy of the OMEGA hyperspectral images mapping. Preliminary results are encouraging. As a next step, we will develop an automatic registration method in order to perform a systematic analysis and refinement of the detectors geometry model valid for all observational modes.

References

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[3] Jouglet et al. *OMEGA long wavelength channel: Data reduction during non-nominal stages*, Planetary and Space Science (2009)