OSIRIS

Optical, Spectroscopic, and Infrared Remote Imaging System

OSIRIS Georeferenced Data Products

RO-RIS-MPAE-TN-089

Issue: 1

Revision: c

17 December 2021

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Approval Sheet

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Document Change Record

Iss./Rev.	Date / Author	Pages affected	Description
D / -	8 Mar 2018 C. Güttler	all	First draft
1 / -	25 Apr 2018 C. Güttler	1, 2, 4	Several clarifications: - level counting (internal vs. CODMAC) - emission / incidence / phase angle unit -.fts and .log files - shape model filename
1 / a	22 Nov 2018 C. Güttler	Sect. 2.2 & 3	- added explanation of dataset completeness - .SUM files and shape model now in Cheops frame
1 / b	09 Jul 2020 C. Güttler	all	- added Level 4S (CODMAC L5) - changed approx. number of images per level
1 / c	17 Dec 2021 C. Güttler	Sects. 2.1 & 3	- updated Figure 1 & Figure 2 - clarify level 4 (CODMAC L5) layer shift

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1 General aspects

1.1 Scope

This document describes the OSIRIS georeferenced Level 4[1] (CODMAC L5) data products and their creation.

1.2 Introduction

OSIRIS Level 4 (CODMAC L5) data products are .IMG files with nine layers. The first layer repeats the Level 3 (CODMAC L4) calibrated image data, while the other layers contain pixel-precise information on distance, emission angle, incidence angle, phase angle, (shape model) facet index, and *x*/*y*/*z* coordinates. These images are a subset of Level 3 (CODMAC L4) since not all images can be georeferenced.

Level 4 (CODMAC L5) is provided in two flavours: One where the geometry is provided by SUM files, a by-product from SPC shape model generation (Level 4 / CODMAC L5), the other where the geometry is computed by the SPICE toolkit (Level 4S / CODMAC L5). Apart from the geometry information, the simulated layers are produced by two different pipelines.

Section 2 describes the products on a user level while Sect. 3 and 4 provide the technical details of the product generation.

1.3 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	Software Interface Specification for OSIRIS Science Products	RO-RIS-MPAE-ID-023 OSIRIS_SIS_V??
RD2	OSIRIS calibration pipeline OsiCalliope	RO-RIS-MPAE-MA-007 OSIRIS_CAL_PIPELINE_V??
RD3	Rosetta-OSIRIS To Planetary Science Archive Interface Control Document	RO-RIS-MPAE-ID-015 OSIRIS_EAICD_V??
RD4	OSIRIS Archive Completeness Report	RO-RIS-MPAE-RP-352

1.4 Acronyms and Abbreviations

CODMAC	Committee on Data Management and Computation
MPS	Max Planck Institute for Solar System Research
NAC	(OSIRIS) Narrow Angle Camera
OSIRIS	Optical, Spectroscopic, and Infrared Remote Imaging System
PSA	Planetary Data System
SPC	Stereo-Photo-Clinometry (shape reconstruction method)
SPG	Stereo-Photo-Grammetry (shape reconstruction method)
WAC	(OSIRIS) Wide Angle Camera

[1] Note that OSIRIS levels and CODMAC levels are shifted by one [RD3]. OSIRIS levels are used internally and converted to CODMAC levels for public data delivery to PSA.

2 Product Description

2.1 Data Structure and Content

The OSIRIS Level 4 and 4S (CODMAC L5) data products are derived data products that include pixel-precise georeferencing information. The data are organised in nine layers with their PDS OBJECT names and content listed in Table 1. Note that incidence-, emission-, and phase angle are provided in radians and not degrees.

Table 1: Image layers of OSIRIS Level 4 and 4S (CODMAC L5) data product.

PDS OBJECT Name	Unit	Description
IMAGE	W m^{-2} sr^{-1} nm^{-1}	Copy of the OSIRIS Level 3 (CODMAC L4) radiometric calibrated and geometric distortion corrected and boresight corrected image layer.
DISTANCE_IMAGE	km	The distance per pixel from the camera to the target surface.
EMISSION_IMAGE	rad	The emission angle per pixel.
INCIDENCE_IMAGE	rad	The incidence angle per pixel.
PHASE_IMAGE	rad	The phase angle per pixel.
FACET_IMAGE	integer	The facet ID per pixel, related to the shape model used for the product generation.
X_IMAGE	km	The x coordinate per pixel in the target body fixed frame.
Y_IMAGE	km	The y coordinate per pixel in the target body fixed frame.
Z_IMAGE	km	The z coordinate per pixel in the target body fixed frame.

Visual examples of the nine layers of an OSIRIS Level 4 or 4S (CODMAC L5) product are presented in Figure 1 (image) and Figure 2 (georeferencing layers).

The georeferencing data are generated through raytracing, based on a 3D digital terrain model. The accuracy of the data are thus limited by (a) the precision of the relative spacecraft-comet orientation, depending on the method described below and (b) the resolution of the utilized shape model.

The HISTORY section of the .IMG attached headers contain the necessary information to reproduce the data, in particular the name of the shape model with the PDS tag SHAPE_MODEL. The specified filename is in most cases not the same as the publicly delivered shape model filename but contains the model name (e.g., SHAP5, SHAP7, …) and number of facets such that it can be related. The shape model that was used when writing this document is *cg-dlr_spg-shap7-v1.0_4Mfacets.ver*, which is the 4 million facet SPG model from the SHAP7 data set in version 1.0. Moreover, it provides traceability of shifting the simulated layers for Level 4S (CODMAC

L5) to optimise the match between image and simulated layers (see Sect. 4.1 for details on this shift). The PDS OBJECT names of the layers are defined in the OSIRIS SIS [RD2].

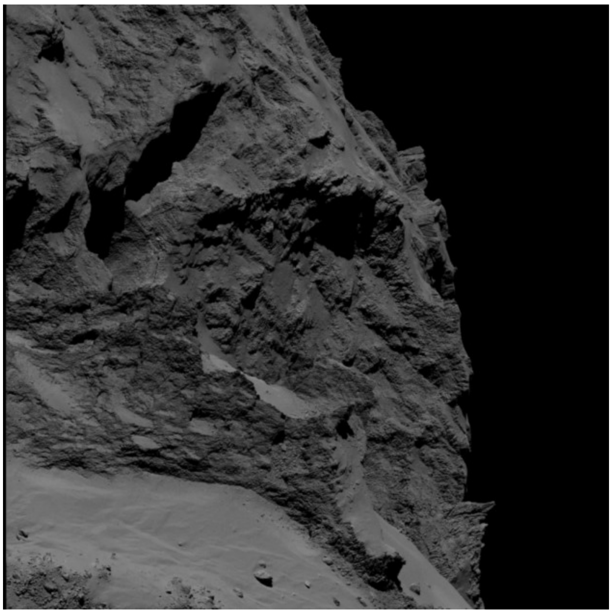

Figure 1: Image layer of the sample product NAC_2016-06-08T14.06.26.742Z_ID40_1397549100_F22 (displayed in Rosetta standard orientation, see [RD2]).

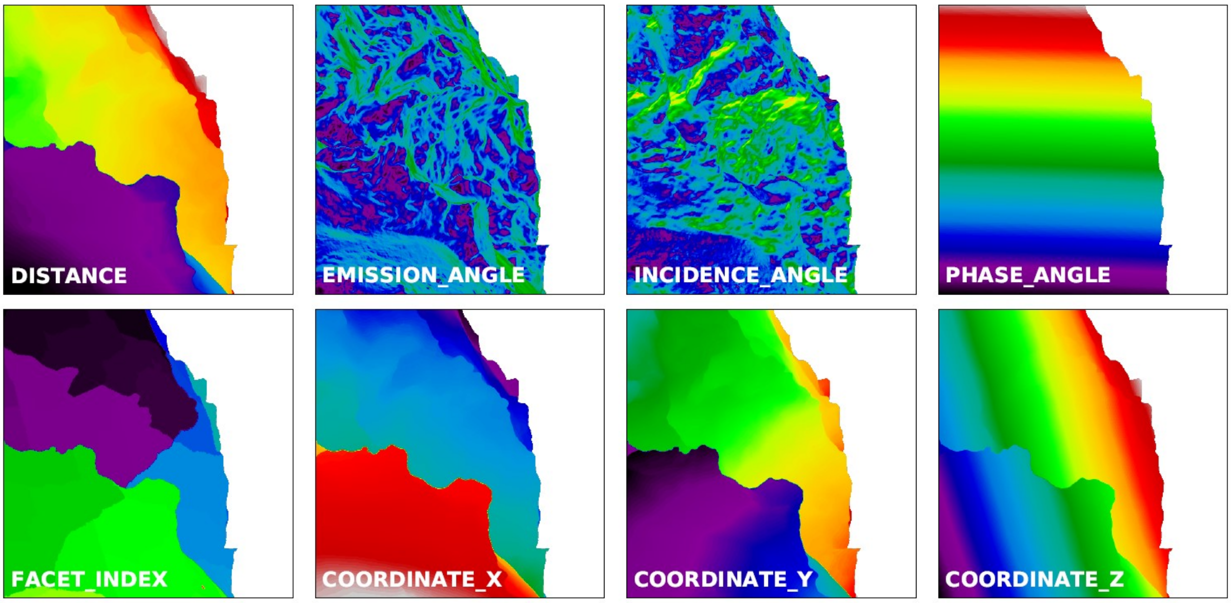

Figure 2: Eight geometry layers for the sample product NAC_2016-06-08T14.06.26.742Z_ID40_1397549100_F22.

2.2 Completeness of the Dataset

The dataset of OSIRIS Level 4 (CODMAC L5) products is created for a subset of lower level images. Out of the approx. 77,000 OSIRIS Level 3 (CODMAC L4) images[2], approx. 27,000 could

[2] The numbers are approximate and intended for illustrative purpose. Exact numbers are maintained in [RD4].

be georeferenced and produced as OSIRIS Level 4 (CODMAC L5). The procedure for generating these products – as described below – relies on the availability of .SUM files provided by the Planetary Science Institute (PSI). The initial set of .SUM files covered images that were used for SPC shape reconstruction of comet 67P. This implies that no OSIRIS Level 4 (CODMAC L5) data are available for the pre-comet phase of the Rosetta mission.

After the usefulness of these files was recognized in the team, .SUM files were also produced from additional images, which were not initially used for shape model generation. These are preferentially non-saturated images, showing a large fraction of the comet nucleus in the field of view. However, since this data cannot be generated in an automated pipeline, the dataset is not and will not be complete in these terms.

The set of OSIRIS Level 4S (CODMAC L5) images is larger. As these rely only on SPICE geometry information, the geometry layers can be computed for all images. They are selected to be produced only for images with TARGET_NAME = 67P/Churyumov-Gerasimenko and in which the comet nucleus is in the field of view. Thus the majority of nucleus images is available in OSIRIS Level 4S (CODMAC L5).

3 Product Generation from SUM Files

The data are generated using the sumxgeo.exe from June 2016, provided by the Laboratoire d'Astrophysique de Marseille (LAM). The software is based on the following input:

- Set of SUM files, provided by the Planetary Science Institute (PSI) during shape model reconstruction:
    - One .SUM file per image in a non-OSIRIS naming scheme.
    - The file make_sumfiles.in, providing the list of .SUM files and the translation to their internal OSIRIS filename [RD1].
    - The file PICTLIST.TXT, providing a list of bad .SUM files, which are to be ignored.
- Shape model in the same coordinate system as the SUM files. Early SUM files are in the SPC coordinate system, such that an SPG shape model in the Cheops frame had to be converted into the SPC frame. SUM files since May 2019 are in the Cheops frame (as are SPC and SPG shape models).

The software is run on a Linux system, through the Python script sumxgeo.py. The script is parsing the required input files above to run and monitor sumxgeo.exe per image file. The output is one .log file per image with metadata and runtime data and – in the case of success[3] – eight .fts files with the 32-bit georeferenced data. These are copied into the .\ancillary\geo\ subfolder per observation activity on the OSIRIS internal data server.

The filenames are:

- Logfile: .[level_1_image_filename].log
- Distance: [level_1_image_filename]-d.fts
- Emission angle: [level_1_image_filename]-e.fts
- Incidence angle: [level_1_image_filename]-i.fts
- Phase angle: [level_1_image_filename]-p.fts
- Facet index: [level_1_image_filename]-t.fts
- X coordinate: [level_1_image_filename]-x.fts
- Y coordinate: [level_1_image_filename]-y.fts
- Z coordinate: [level_1_image_filename]-z.fts

The .fts and .log files in the .\ ancillary\geo\ folder are used by the OSIRIS calibration pipeline OsiCalliope [RD2] to create PDS compliant .IMG files with 9 layers as described above in Sect. 2. Since .fts and .log files are intermediate products and all information is covered in the resulting .IMG files, these are not delivered to PSA.

SUM files are based on OSIRIS images that are not filter and temperature boresight corrected, i.e., from an earlier version of the calibration. To maintain the match between the image layer and the geometry layers also after the boresight correction of the image layer, the geometry layers are shifted by an integer value along with the image (documented in the HISTORY section of the header). This results in a few black lines and/or columns on the side opposite to the shift direction.

[3] At the time of writing this document, 84 out of 27160 images produce errors in the sumxgeo.exe run. The status is followed on the OSIRIS CVS server, under .\Archiving\Comleteness\geoStatus.txt.

4 Product Generation using Spice Geometry

Georeferencing products using SPICE data are produced by the OSIRIS tool GhostCrawler. This tool produces .fts and .log files that are compatible with those provided by sumxgeo. As input data for geometry computation, GhostCrawler uses SPICE kernels instead of SUM files. The size of the shape model is limited to 2 million facets in the current version of GhostCrawler, so the shape model is different for these compared to the SUM file pipeline.

The geometry information per pixel is computed as the geometry of that shape model facet inside the pixel, which is closest to the camera. Data for cropped images is computed as full frame and cropped in the same shape factor as the image in the first layer. Binned images are first computed as un-binned images and binned by OsiCalliope following the same scheme of using the value from the pixel that is closest to the camera.

Data are generated for the following conditions:

- The TARGET_NAME is "67P/CHURYUMOV-GERASIMENKO 1 (1969 R1)"
- The OSIRIS Level 1 (CODMAC L2) image file contains an IMAGE object
- The comet nucleus is in the field of view
- The image is from the comet phase (START_TIME > 2014-03-19)

Output data are stored in the .\ ancillary\GSO_SPICE\ subfolder per observation activity on the internal OSIRIS archive.

The GhostCrawler output data in fits format is integrated into OSIRIS Level 4S (CODMAC 5) PDS format files with 9 layers by the OSIRIS calibration tool OsiCalliope. To improve the match between the image layer (layer 1; see Table 1) and the simulated layers (layers 2-9; see Table 1), the residual offset between the geometry from SPICE and the image are computed wherever possible and the simulated layers are shifted to match the image layer. The computation of the shift is explained in Sect 4.1.

OSIRIS Level 4S (CODMAC L5) products are provided as normal and enlarged frames (file mask ID and EF), see [RD1] for further details on this.

4.1 Shift of Simulated Layers

To compute the shift, GhostCrawler produces an extra file ([level_1_image_filename]-s.fts) representing the simulated image. The geometry is based on SPICE and the intensity based on a photometric model.

The shift between the OSIRIS Level 3 (CODMAC L4) image (example in Figure 3 left) and the simulated image (example in Figure 3 centre) is then computed from a 2D correlation of the numerical derivative of the two arrays (example in Figure 3 right). For this, the simulated image is cropped by typically 20 pixels in all directions to compute a shift of up to ±20 pixels in both axes. The shift in the example of Figure 3 is 4 pixels to the right and 3 pixels down, which is computed as the highest value of the array in Figure 3 right.

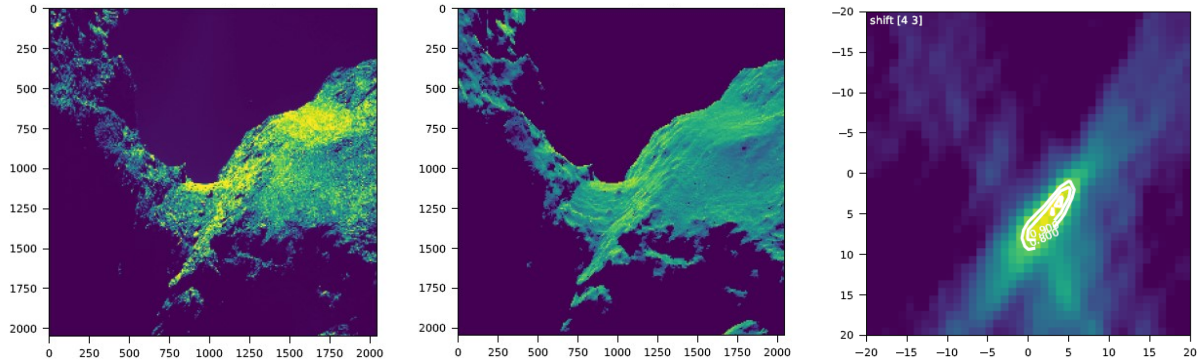

Figure 3: Example for shift computation. OSIRIS Level 3 image (left), simulated image (centre) and 2D correlation result (right).

The result of the 2D correlation (a 2D array, 41x41 pixels if the crop above is 20 pixels; example in Figure 3 right) is processed by a goodness assessment algorithm that binarises the 2D peak in the correlation result and analyses the resulting binary patch on the following conditions.

- The patch must not exceed a threshold area (default value is 50).
- The maximum extension of the patch must not exceed a threshold size (default value is 10).
- The patch must not touch the edge of the array.

If any of these criteria fails, the goodness assessment is negative and a shift is not provided. The method works preferentially for images where the comet is not frame filling and a large fraction of the limb is in the image.

The average shift is 0 with a standard deviation in the order of 5 pixels for the NAC as visualised in Figure 4 (top). The shift for WAC (Figure 4, bottom) is smaller due to the wider field of view.

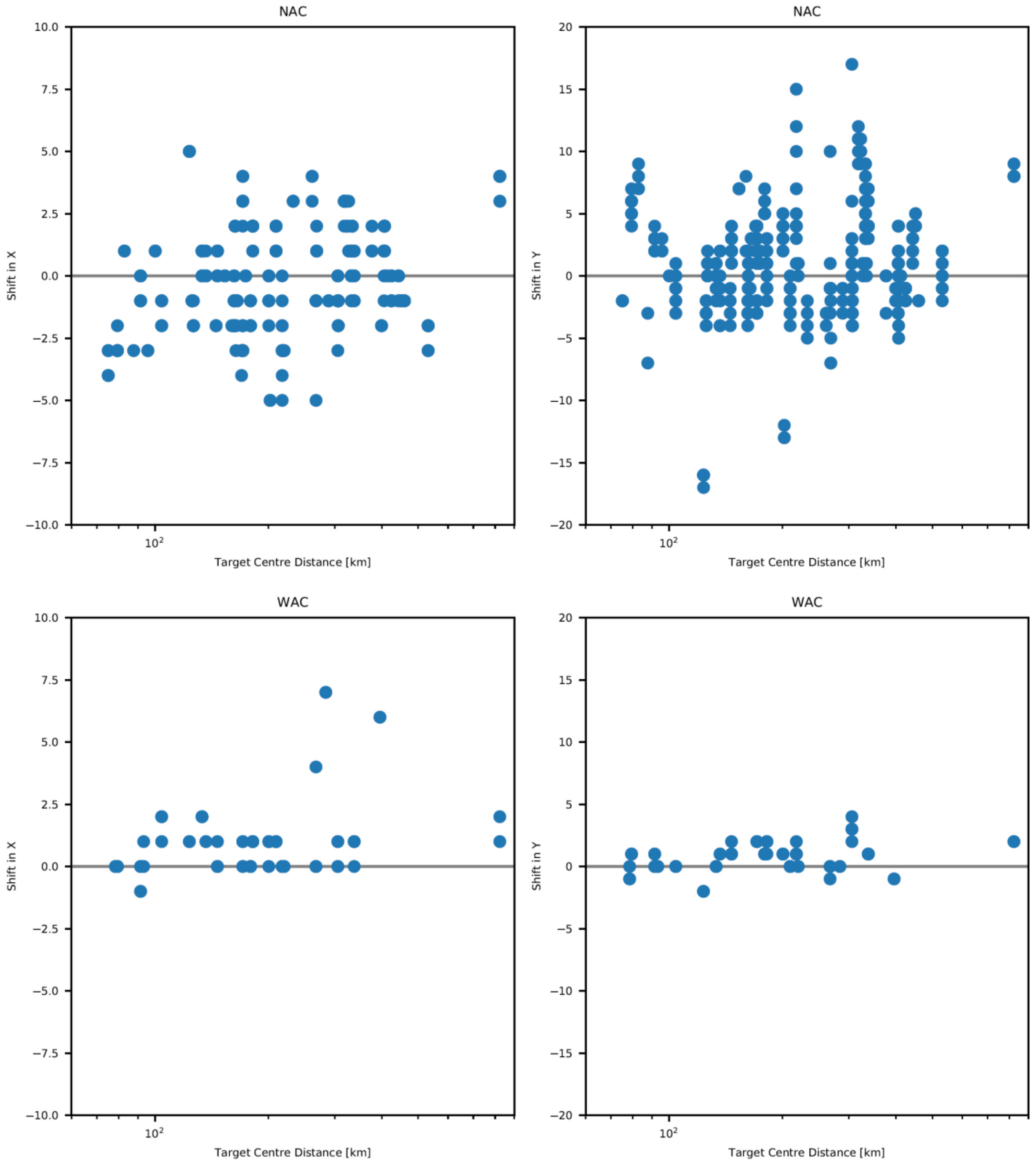

Figure 4: Shift between image and simulated image for NAC (top) and WAC (bottom).

The output of the shift computation for each image is provided in an OsiCalliope calibration file ./Geo/ GEO_SPICE_SHIFT_V01.TXT. This file is read by OsiCalliope to apply the shift when combining the layers (see [RD1]).

5 Calibration files used by OsiCalliope

The calibration file used by OsiCalliope to calibrate OSIRIS images is:

- GEO_SPICE_SHIFT_V01.TXT

The file is included in each public delivery of OSIRIS data to PSA. The location is specified in the OSIRIS EAICD [RD3].