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High-resolution Ceres High Altitude Mapping Orbit atlas derived from Dawn Framing Camera images

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ABSTRACT

The Dawn spacecraft Framing Camera (FC) acquired over 2400 clear filter images of Ceres with a resolution of about 140 m/pixel during the six cycles in the High Altitude Mapping Orbit (HAMO) phase between August 18 and October 21, 2015. We ortho-rectified the images from the first cycle and produced a global, high-resolution, controlled photomosaic of Ceres. This global mosaic is the basis for a high-resolution Ceres atlas that consists of 15 tiles mapped at a scale of 1:750,000. The nomenclature used in this atlas was proposed by the Dawn team and was approved by the International Astronomical Union (IAU). The full atlas is available to the public through the Dawn Geographical Information System (GIS) web page [http://dawngis.dlr.de/atlas] and will become available through the NASA Planetary Data System (PDS) (http://pdssbn.astro.umd.edu/).

1. Introduction

The Dawn mission has mapped Ceres during the High Altitude Mapping Orbit (HAMO) phase from an altitude of 1475 km (Russell and Raymond, 2011) in six different cycles. The Dawn spacecraft is equipped with a framing camera (FC) (Sierks et al., 2011) which has one clear filter and seven band pass filters. About 2490 clear filter images were taken during the HAMO, which resulted in a multiple global coverage. By selecting all 386 images from the first HAMO cycle and filling minor gaps with images from the second cycle, we produced a global photomosaic of Ceres with a mean resolution of 140 m per pixel (m/px), together with a 15-tile atlas at a scale of 1:750,000. Here we describe the different processing steps involved in the production of the Ceres HAMO atlas, including the image processing steps (Section 2), and the cartographic processing procedure (Section 3). We also show as example three map tiles from the atlas.

2. Data processing

The image data returned from the spacecraft are distributed inside the Dawn team in NASA Planetary Data System (PDS) format. The first step of the image processing pipeline was the conversion to Video Image Communication and Retrieval (VICAR) format followed by the radiometric calibration of the images (Schröder et al., 2013, 2014).

The next step in generating these cartographic products was to ortho-rectify the images to the appropriate scale and map projection. This process required detailed information of the Dawn spacecraft's orbit and attitude data as well as of the topography of Ceres. Both improved orientation and a high resolution shape model were provided by stereo processing (bundle block adjustment) of the HAMO stereo image dataset (Preusker et al., 2016). Ceres' shape model was then used for the calculation of the ray intersection points, while the map projection itself was placed onto a reference sphere of Ceres with a mean radius of 470 km.

The phase angle in these continuant images changed from about 10° near the equator to 90° at the poles (Fig. 1). We derived the mean brightness for every phase angle and used these values to calculate a phase angle dependent brightness function. We applied this function to all images to minimize the brightness changes between images at different latitudes. The final step was the mosaicking of all images to produce a global “base map”

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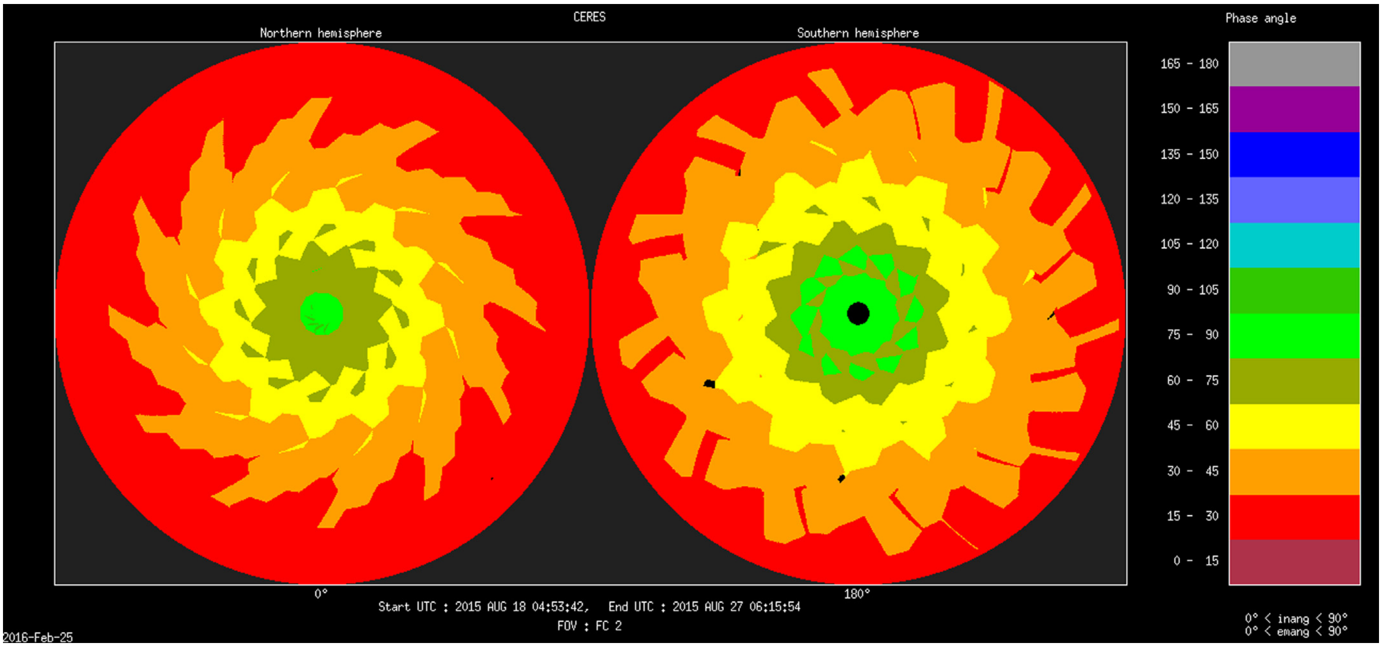

Fig. 1. Phase angle distribution over the northern and southern hemisphere.

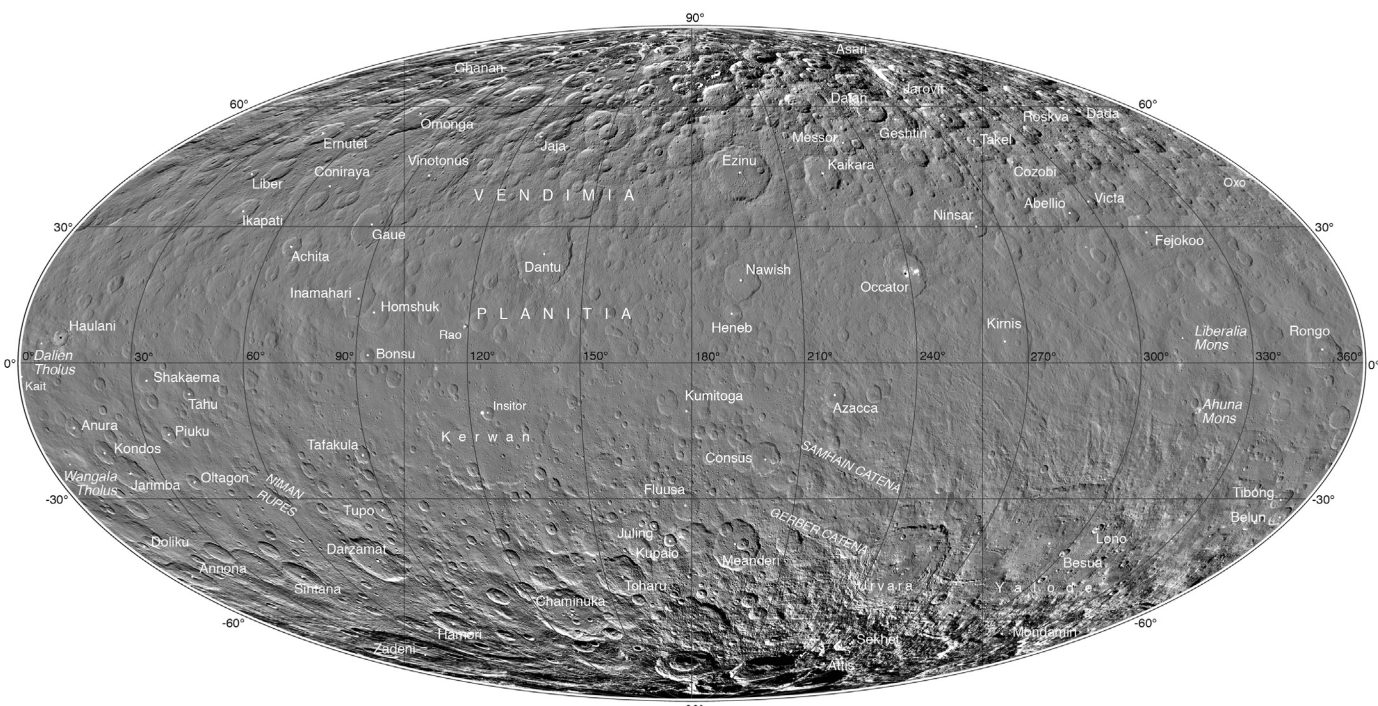

Fig. 2. Global HAMO mosaic with nomenclature in Mollweide projection.

mosaic of Ceres (at 140 m/px).

The longitude system of Ceres is defined by the tiny crater Kait (400 m diameter) (Roatsch et al., 2016), the pole axis and rotation rate of the body were calculated during the bundle block adjustment process (Preusker et al., 2016).

The Dawn team proposed 82 names for geological features. Following international agreement, craters were named after gods and goddesses of agriculture and vegetation from world mythology, whereas other geological features were named after agricultural festivals of the world. The nomenclature proposed by the Dawn team was approved by the IAU [http://planetarynames.wr.usgs.gov/] and is shown in Fig. 2.

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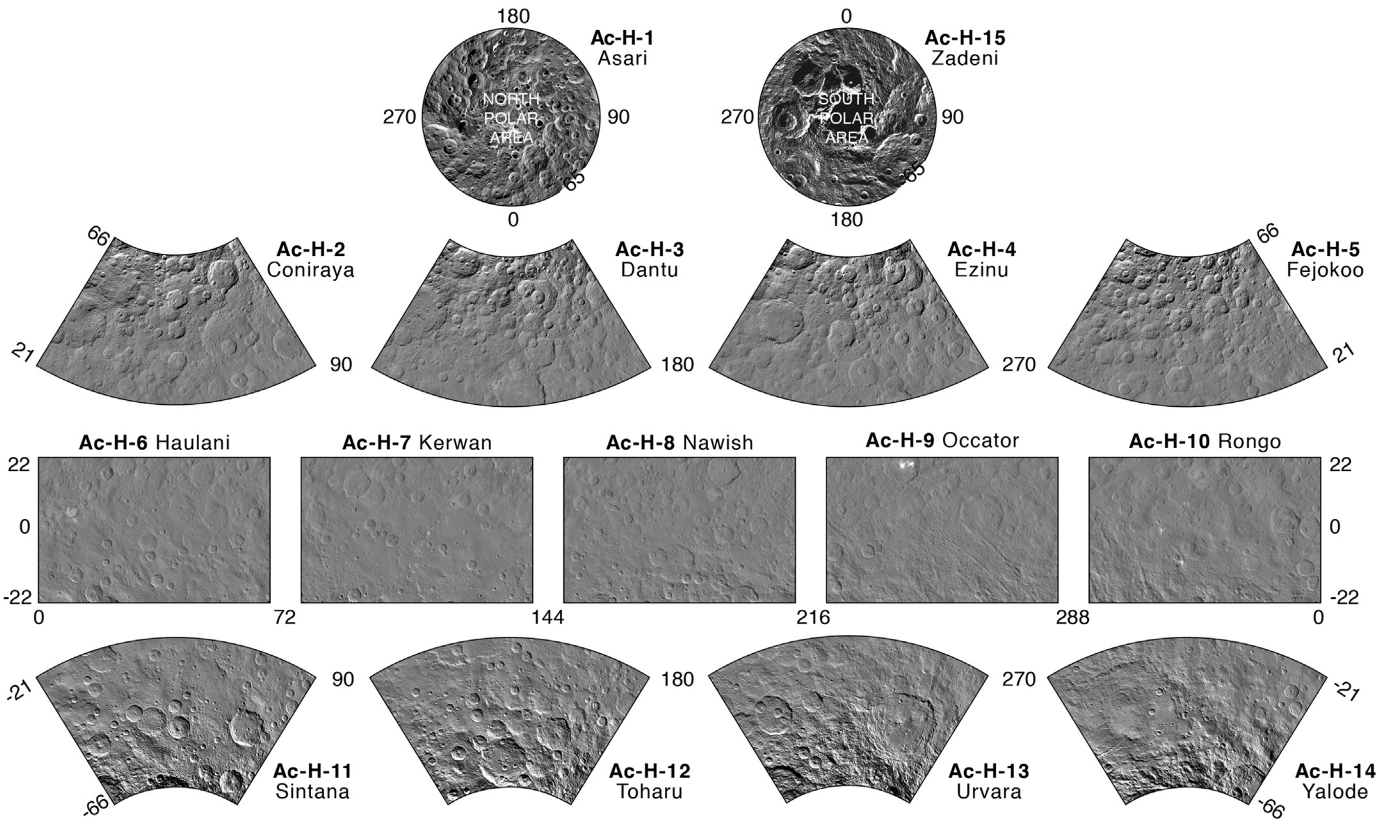

Fig. 3. HAMO atlas schema.

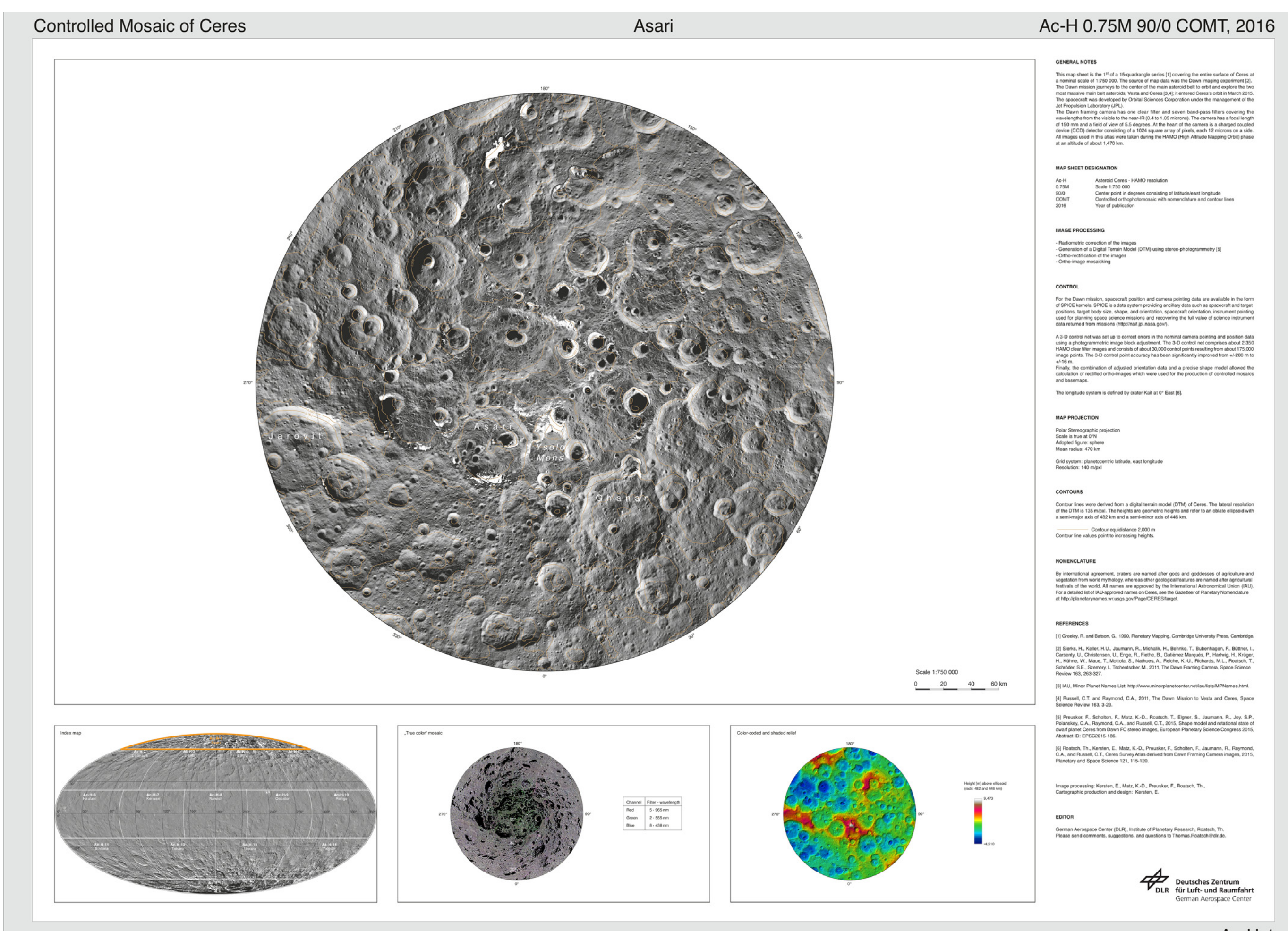

Fig. 4. HAMO atlas map 1 (Ac-H-1-Asari).

3. Ceres map tiles

The Ceres Survey atlas created after the earlier Dawn spacecraft Survey mission phase consists of three tiles with a resolution of 1:2,000,000 (Roatsch et al., 2016) whereas this new HAMO Ceres atlas consists of 15 map tiles (Fig. 3) with a resolution of 1:750,000. The tiling scheme conforms to that proposed by Greeley and Batson (1990) for medium-sized planetary bodies and high-resolution imaging and has been used elsewhere e.g., for mapping the asteroid Vesta at a scale of 1:500,000 (Roatsch et al., 2012). A map scale of 1:750,000 guarantees a map product at the highest available Dawn FC HAMO resolution and results in an acceptable printing scale for the hardcopy map of 5 px/mm. The individual tiles were extracted from the global mosaic and re-projected, coordinate grids were superposed as graphic vectors and the resulting composites were converted to the widespread portable document format (PDF). The portion of the atlas covering Ceres' equatorial region (i.e. 22°S–22°N) has a Mercator projection onto a secant cylinder using standard parallels at 13°S and 13°N latitude. The maps between the equatorial region and the poles (i.e. 66–21°S and 21–66°N) have a Lambert Conic Conformal projection with two standard parallels at 30°S and 58°S (or 30°N and 58°N, respectively). The polar portions of the atlas have a Stereographic projection (90–65°S latitude and 65–90°N latitude). Individual tiles overlap in the north–south direction by one degree, although no overlapping region is present in the east–west direction (see Fig. 3). The map tiles have a true scale of 1:750,000 at the standard parallels and have the same scaling factors in the overlapping regions at the matching parallels (±21.34° and ±65.19° latitude) of 1.0461 and 1.0484, respectively (Snyder, 1987). The longitudinal extension of the map tiles are 72°, 90°, and 360° for those with a Mercator projection, Lambert Conic Conformal projection, and a Stereographic projection, respectively. Using this tiling scheme for Ceres with a high-resolution mosaic, the printed map tiles have a final width of 125 cm and a height of 90 cm. Contour lines were derived from a digital terrain model (DTM) of Ceres (Preusker et al., 2016), which features a lateral resolution of 135 m/px and a vertical control point accuracy of ±16 m. The depicted elevations are geometric heights and refer to an oblate ellipsoid with a semi-major axis of 482 km and a semi-minor axis of 446 km. Topographic maps showing the terrain with color-coded elevations and true color mosaic maps from HAMO data were added to every individual tile. Three examples of the atlas map tiles in different map projections are shown in Figs. 4–6.

The entire Ceres HAMO atlas is available publicly through the Dawn geographical information system (GIS) web page at http://dawngis.dlr.de/atlas and will become available through the Planetary Data System (http://pdssbn.astro.umd.edu/).

4. Outlook

The Dawn spacecraft entered the Low Altitude Mapping Orbit (LAMO) since December 2015 in which it acquires images with a

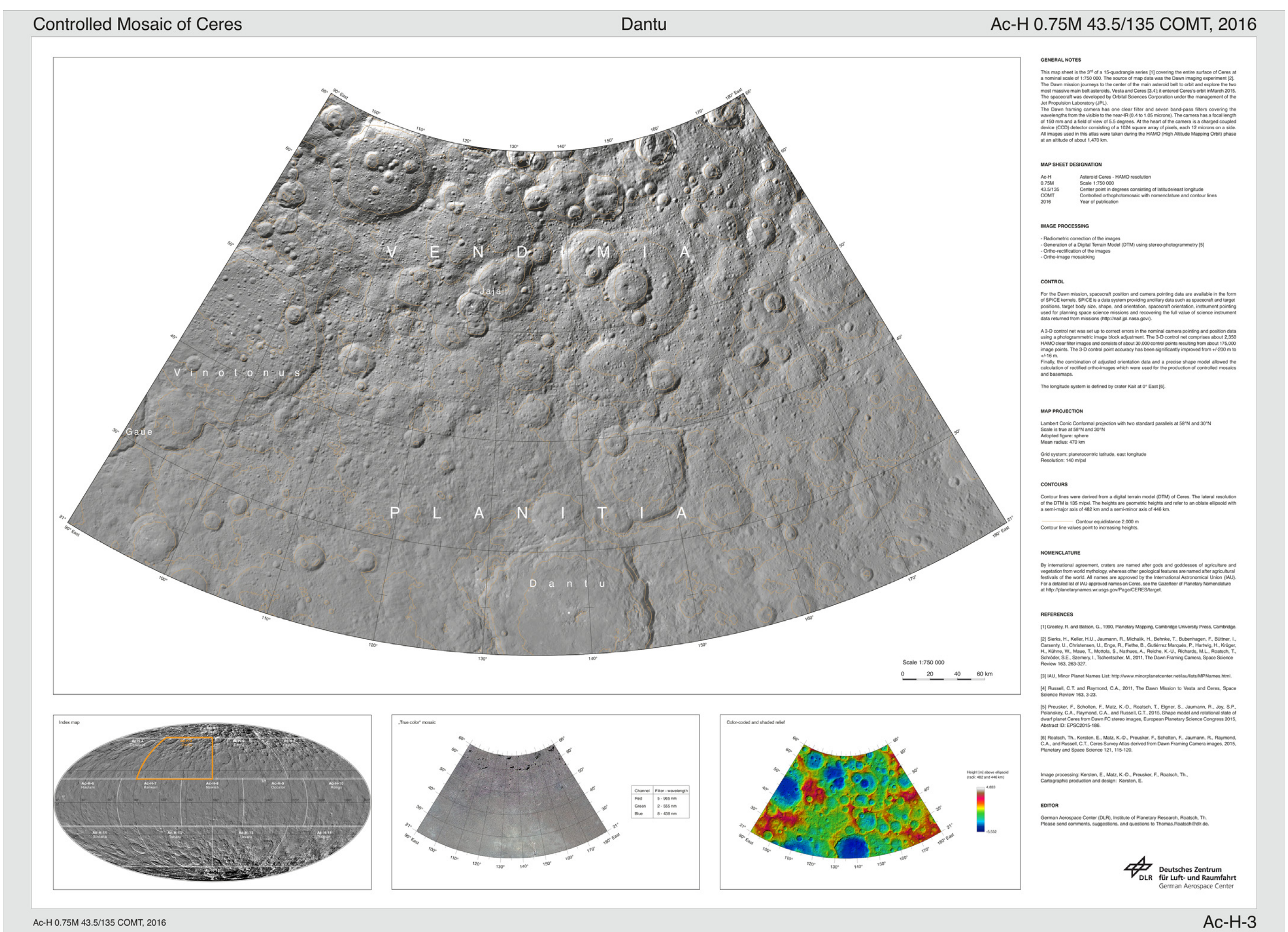

Fig. 5. HAMO atlas map 3 (Ac-H-3-Dantu).

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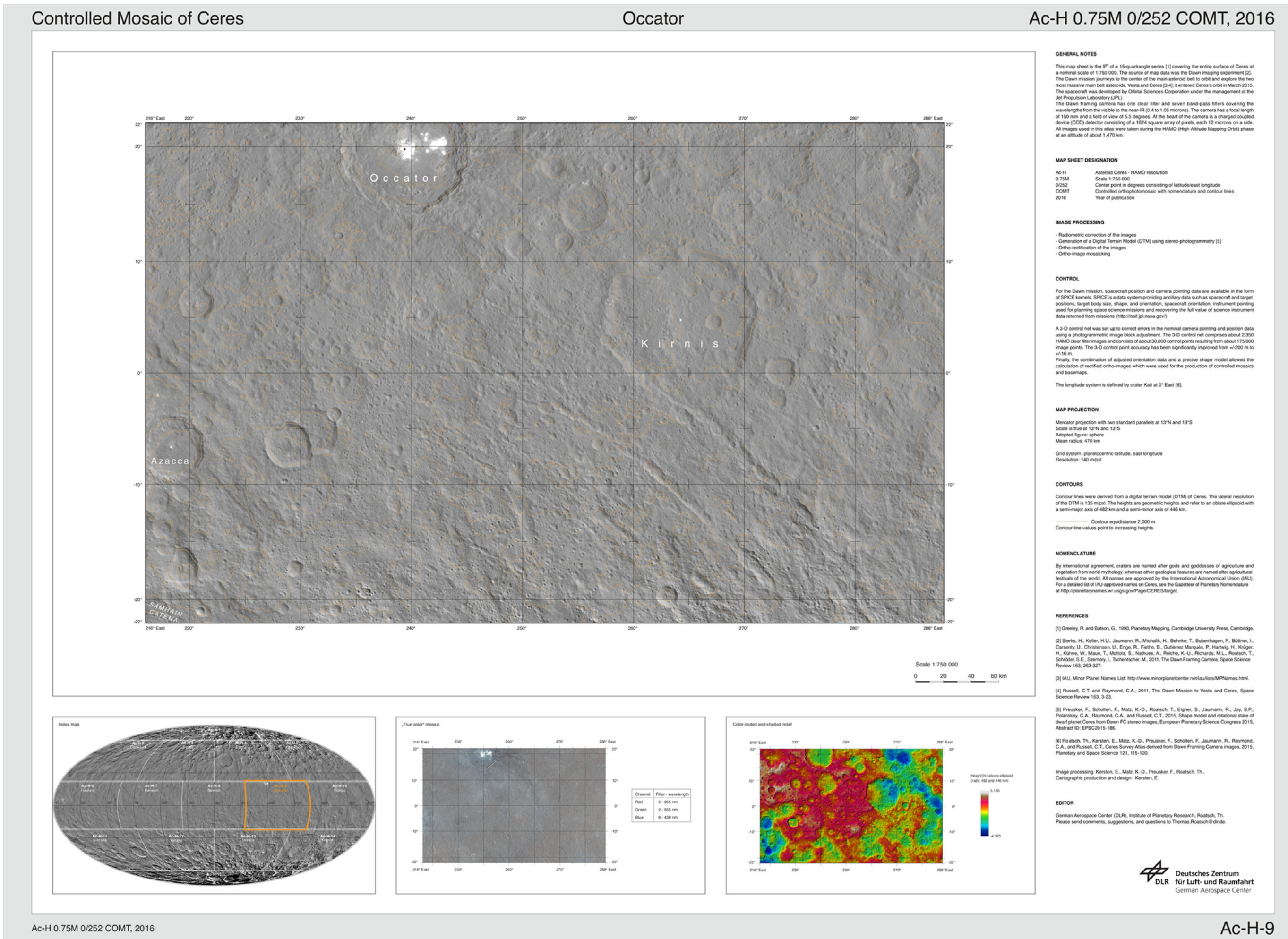

Fig. 6. HAMO atlas map 9 (Ac-H-9-Occator).

resolution of about 35 m/px. Global coverage will give us the opportunity to generate a higher resolution atlas of Ceres, similar to the LAMO atlas of Vesta (Roatsch et al., 2013).

Acknowledgments

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