

Coregistration of CTX images to HRSC Global Datasets

HIGHLIGHTS

- Precise coregistration of various planetary remote sensing data sets is fundamental for researchers to analyse data combinations with the desired properties
- HRSC products play a unique role as an intermediary geometric reference data set linking MOLA to other data sets with higher ground resolution such as CTX, HiRISE and CaSSIS.
- To achieve change detection visualisation functionality for planetary application, we want to be able to display all images available from a certain spot on the surface in their full spatial resolution, and to show them together animated as time series.

INTRODUCTION

- CTX coverage converges to full coverage of Mars [1].
- Individual images show offsets of tens to hundreds of pixels from their real ground position leading to a large-scale processing requirement including definition and application of geodetic control for the images.
- Lack of ground control points requires use of globally available reference dataset for ground control.
- Current efforts for ortho-rectification and lateral control use MOLA data (e.g., [2]).
- Major challenge at equator due to spatial resolution differences of data sets (6 m/px for CTX, 463 m/px for MOLA).
- Automatic point matching of image to DTM pixels not reliable
- Hence, usually CTX pixels matched to datasets that are themselves controlled to MOLA, such as THEMIS IR [3].
- This is sensitive to error propagation from unequal (and potentially unknown) quality of tie points between different instrument's datasets.

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HRSC TO THE RESCUE

- The global topography and mosaicking campaign of the High-Resolution Stereo Camera (HRSC) team expects to finalise the creation of HRSC global mosaics by end of 2023.
- They consist of bundle-block-adjusted DTMs and pixel-aligned image mosaics based on HRSC Mars Chart 30 (HMC30) quadrangle scheme [4].
- HMC30 products are available at <http://hrscteam.dlr.de/HMC30> and under <https://maps.planet.fu-berlin.de> as a map-based interface.
- HMC30 DTMs provide an internal photogrammetric precision better than the used grid size of 50 m.
- Deviations from MOLA profile heights are less than 50 m due to the control to the MOLA dataset as a global geodetic reference during the processing [5].
- The corresponding image mosaics provide precise pixel-by-pixel alignment to respective DTM with 12.5 m/px resolution, matching seamlessly with neighbouring tiles [6].
- Here we show a first approach for use of HMC30 products as the global combined (image and DTM) reference dataset for Mars, by creating complete CTX quadrangle mosaics with absolute geodetic control to HRSC (and therefore also to MOLA).

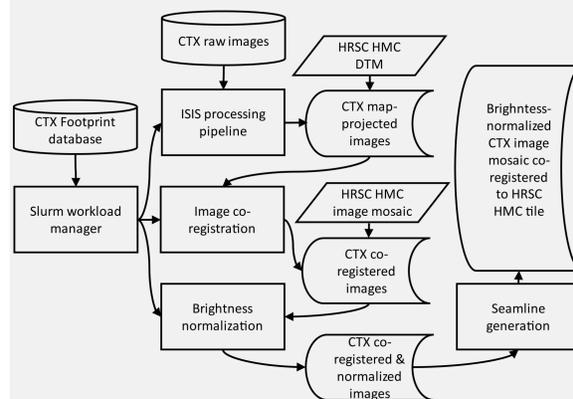


Figure 1: Flow chart of the proposed CTX processing workflow from single images to a complete mosaic.

SCIENCE CASES

Seasonal/interannual changes at the south polar cap

- Comparison of images from within same Martian year but different L_s allows studies of **seasonal** variability (Fig. 2).
- Comparing images from same range of L_s but from different Martian years allows studies of **interannual** variations (Fig. 3).

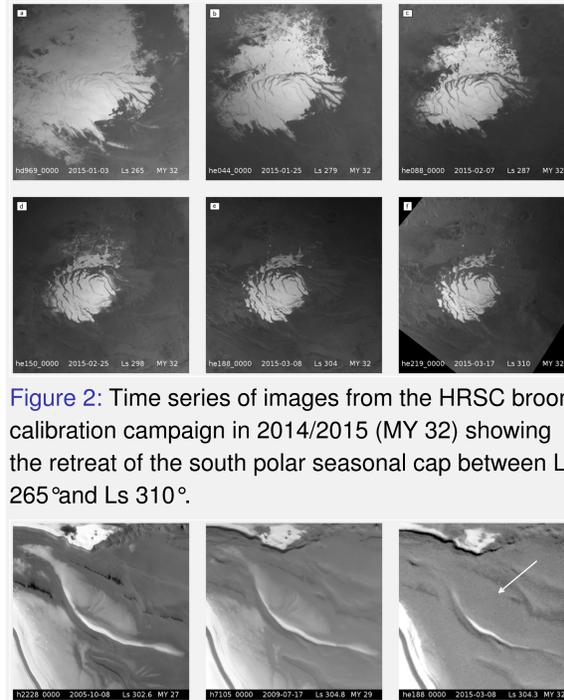


Figure 2: Time series of images from the HRSC broom calibration campaign in 2014/2015 (MY 32) showing the retreat of the south polar seasonal cap between L_s 265° and L_s 310°.

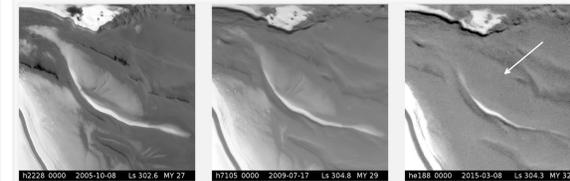


Figure 3: Last retreat of seasonal frost/ice at around L_s 304° for each of three MYs. From left to right MY 27 (2005), MY 29 (2009), and MY 32 (2015). While still present in MYs 27 and 29, the bright deposits have been sublimated in MY 32 (arrow).

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METHODS

Tasks of our workflow:

- Ortho-rectify CTX images towards HRSC DTM instead of the MOLA DTM.
- Use HRSC image mosaic as reference for automatic point matching and co-registration of ortho-rectified CTX images.
- Apply well-established brightness correction as used for HRSC [6].
- Combine multitude of images from quadrangle into seamless mosaic, export as single image.

The general workflow of our processing pipeline is shown in Fig. 1.

Some general facts about our workflow:

- Due to large CTX dataset per HMC30 tile, we use a database management system (DBMS) for storage and retrieval of the CTX data catalogue.
- In the spatially-enabled DBMS we perform geometric queries by intersection of the HMC30 boundary with the CTX footprints.
- The map-projection and coregistration of the data is slow - processing time can be significantly decreased by high-performance computing (HPC).
- The current HPC cluster maintained by Freie Universitaet Berlin provides 5,440 cores for simultaneous processing [7].
- Aspects we are currently implementing:
 - The ISIS [8] processing pipeline performs image ortho-rectification using the HMC30 DTM, which itself has been re-projected to the IAU sphere beforehand.

- The resulting nominally ortho-rectified CTX images show a significant offset to HRSC based on inaccurate spacecraft attitude control (see Fig. 4 top).

- For correction, we introduce a subsequent co-registration based on a phase correlation approach [9].
- The consecutive brightness correction uses the same HRSC image mosaic as a radiometric reference – the software has been re-implemented for the cluster-based pipeline setup and adapted to CTX properties.
- A final step for seamline creation and image export is performed outside of the cluster on a high-performance compute server running Desktop GIS software.

METHODS II

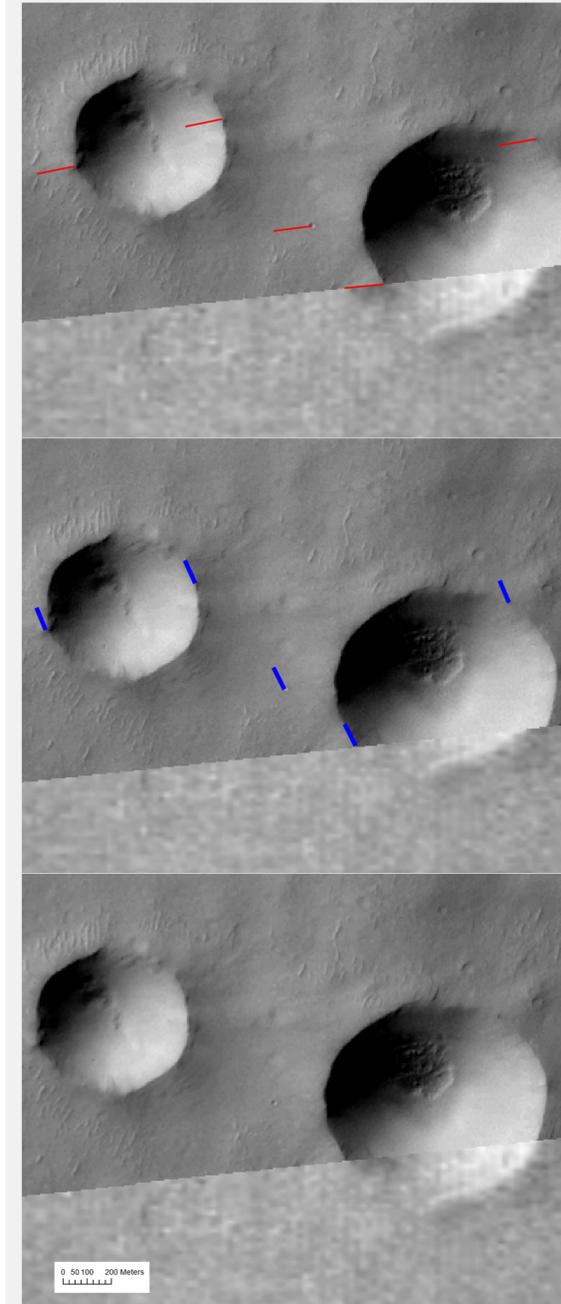


Figure 4: Image offsets between CTX image D02_027799_1580 (6.25 m/px) and HRSC HMC30_20W (12.5 m/px); top: CTX with nominal pointing after ISIS standard processing, offsets to HRSC in red; middle: CTX co-registered to HRSC by global x/y shift, remaining offsets marked in blue; bottom: CTX co-registered by warping to dense network of tie points, with no visible offsets