A Dynamic Spatial Data Infrastructure for Mars based on Data from the High Resolution Stereo Camera

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Introduction: Over the years, the map-based data dissemination system focused on the the High Resolution Stereo Camera (HRSC), developed at the planetary sciences group of Freie Universität Berlin, has evolved in multiple ways. Starting as a footprint-centered querying tool [1, 2] of HRSC imagery in the context of other Mars-Express datasets, it has grown to a mosaic-enriched data system with GIS-ready product download capabilities [3] into a complex research and analysis system allowing spatio-temporal data queries combined with dynamic single-image visualization options. Its latest instance is focused on planetary surface change analysis including novel tools for simultaneous visualization of time series images in their original sequence [4]. All the named demonstrators are still fully-functional in production and have in common to be based on open standards and solely on open source software – innovations developed in the framework of the funding projects are fed back into the open source community. Here we present the current state of our system available online at http://maps.planet.fu-berlin.de (Fig. 1) and propose to integrate such dynamic visualization capabilities into other future Planetary Spatial Data Infrastructure (PSDI) systems.

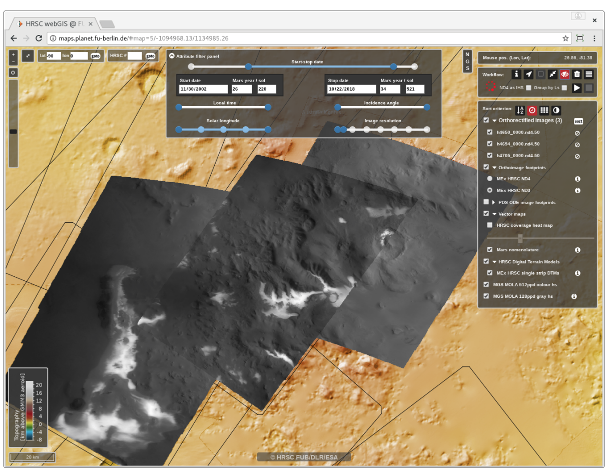

Figure 1: Browser view of the HRSC PSDI at the Australe Montes region, south pole; three HRSC single images are loaded as dynamic layers.

Overall system design: The system comprises a browser-server infrastructure which loads dynamic code from a website and connects to web services of a server-based backend. The web services stream pre-processed data from connected databases and storage subsystems according to the standards of the Open Geospatial Consortium (OGC), adapted to the HRSC-based planetary reference system ($sphere; radius = 3396.0\,km$). The web content is retrieved from a server, gets executed in the browser and dynamically streams the topography, image and vector data from various server backends, namely a map cache, a map server and a database engine (Fig. 2). The frontend consists of the map canvas with user interface components including attribute filter masks and data layer selection tools. The selected data layers are requested directly from the map cache instance via concurrent OGC-based Web Map Service (WMS) and Web Feature Service (WFS) calls.

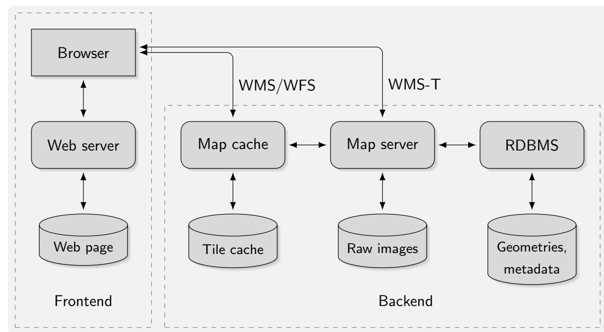

Figure 2: System design of the HRSC PSDI outlining frontend (client) and backend (server) components. The stored web page on the server logically belongs to the frontend of the system, as it is interpreted on-the-fly and launched on the client. WMS-T = WMS with time support.

HRSC Data and geodetic control: We provide different available standard processing levels of the HRSC data products. As "level 3" we provide the available grayscale nadir single images orthorectified to MOLA. The "level 4" products are DTMs from single image stereo-photogrammetry and bundle adjustment (along-track between the five different panchromatic channels) and the respective image products orthorectified to these DTMs. Individual level 4 products (DTMs and images) are shown embedded in the map and are available for download – images either as grayscale or pan-sharpened color-composites – all in GIS-ready formats. As a result of a delay in the release process, we currently provide new level 4 products still not available in the PDS. As "level 5", we provide the multi-orbit DTMs produced using additional cross-track bundle block adjustment techniques and respective orthoimage mosaics based on the "MC-30" Mars quadrangle scheme [5]. Since the data products (level 4 and higher) are tied to the global MOLA reference system, HRSC plays a unique role as an intermediary geometric reference dataset for Mars, linking MOLA to other stereo datasets. Within the iMars project, DTM and image data from CTX, MOC and HiRISE have been successfully co-registered to HRSC [4].

Frontend/user interface: Since the previous release we have added polar views of the planet in Polar Stereographic Projection. To adequately query the polar data with its special requirements for seasonal and interannual surface change visualization, we have added filter elements for local time, incidence angle, solar longitude and image resolution (Fig. 1).

Dynamic time series and external access: To achieve change detection visualization functionality for planetary application, we have implemented a dynamic way to serve all single images available from a certain spot on the surface in their full spatial resolution – and to show them together animated as time series [for details, see 4]. For external data queries and access to the backend, we have successfully extended the dynamic WMS services and implemented the Europlanet Data Model Table Access Protocol (EPN-TAP) [6] to provide Virtual Observatory (VO) access to the single HRSC "granules" via WMS. Currently, all level 3 images have been made available in Equidistant Cylindrical projection and can be queried by attribute keywords or spatial selection criteria.

Science cases and visualization examples: By use of the dynamic image visualization functions of our system, we were able to find and visualize new surface changes in aeolian deposits of a crater near Mawrth Vallis, located at 21.6°N, 16.6°W. The first visual impression may be tempting to claim that the dark material in the crater has been transported (see Fig. 3), a scenario often found in the surrounding craters of the Arabia Terra region. Still, a closer look on the available imagery data

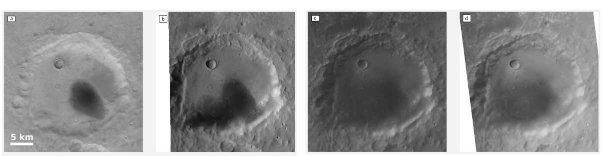

Figure 3: Low albedo unit in a crater south of Mawrth Vallis. Series of four subsets of images from different acquisition times in chronological order (HRSC sequences H2229_1, H5163_9, HC423_0, CTX image F01_036094).

reveals dark ejecta around a young crater with white deposits on top of it (see white arrow in Fig. 4 a) . Also, bright dust fillings with transversal dunes are visible inside dark craters (Fig. 4 b). This leads to the conclusion that the bright (young) dust has been deposited on top of the dark cratered (older) unit, and then the dust has been periodically removed by aeolian processes.

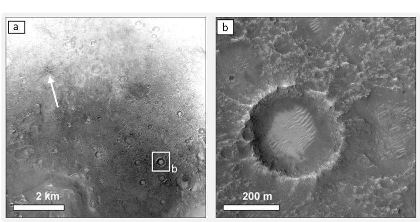

Figure 4: Details of the low-albedo crater floor of Fig. 3. (a) CTX image F01_036094_1999_XI; (b) HiRISE image ESP_037017_2015.

A broom calibration campaign between 12/2014 and 5/2015 resulted in a data series of 13 HRSC images showing the seasonal retreat of the south polar cap between Ls 260°and Ls 343°of Martian Year (MY) 32 in great spatial and temporal detail (Fig. 5). After Ls 310°the point of the largest retreat has been hit and the remainder of the images show darkening as the terminator is reaching the polar area in southern winter.

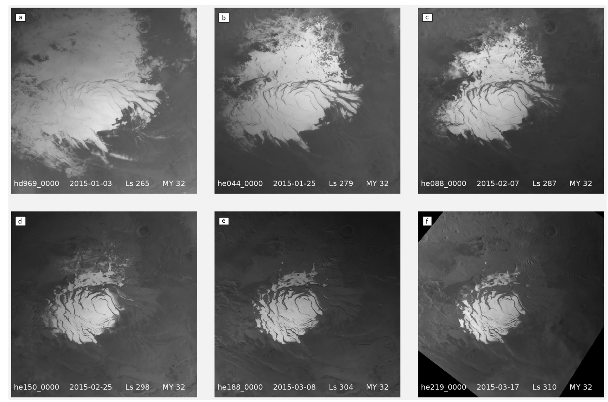

Figure 5: (a–f) Time series of images from the HRSC broom calibration campaign in 2014/2015 (MY 32).

A comparison between three interannual images between MY 27 and MY 32 at around Ls 304°reveals a significant faster retreat of the seasonal frost in MY 32.

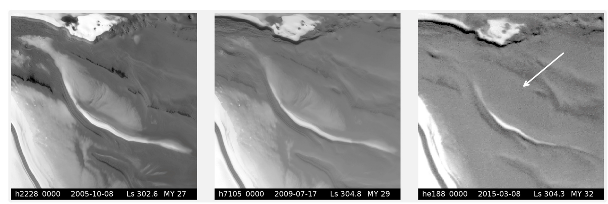

Figure 6: Last retreat of seasonal frost/ice for three MYs (27, 29, 32). While still present in MYs 27 and 29, the bright deposits have been sublimated in MY 32 (arrow).

Summary: The examples demonstrate that for the detailed analysis of morphologic features it is necessary to interactively work with the available images simultaneously in their different levels of resolution and detail. Having available preprocessed and coregistered images within the HRSC PDSI enables immediate analysis of the data without any further manual processing required by the users.

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References: [1] S.H.G. Walter et al., EPSC, 2006, #508. [2] S.H.G. Walter et al., LPSC, 40, 2009, #1609. [3] S.H.G. Walter et al., LPSC, 45, 2014, #1088. [4] S.H.G. Walter et al., *E&SS* 5.7 (2018), 308–323, DOI: 10.1029/2018EA000389. [5] K. Gwinner et al., *P&SS* 126 (2016), 93–138, DOI: 10.1016/j.pss.2016.02.014. [6] S. Erard et al., *P&SS* 150 (2018), 65–85, DOI: 10.1016/j.pss.2017.05.013.