

# Planetary Data Services

Astrogeology: what are working on

## Outline

- Quick intro: Astrogeology
- Web Map Services (WMS)
- Tiled WMS (or TMS) services
- STAC/COG
- QGIS

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Feb. 2022

# USGS Astrogeology Science Center

Interdisciplinary science, research and production group

- Partnered with NASA, universities, international space agencies, and primary research institutions since the Apollo era
- Focus on **foundational** data products (geodetic control networks, topography, and orthoimagery) and **framework** data products (compositional maps, nomenclature, and geologic maps)
- Development of planetary imagery processing software (ISIS3), and home to several facilities that represent the broader planetary science community

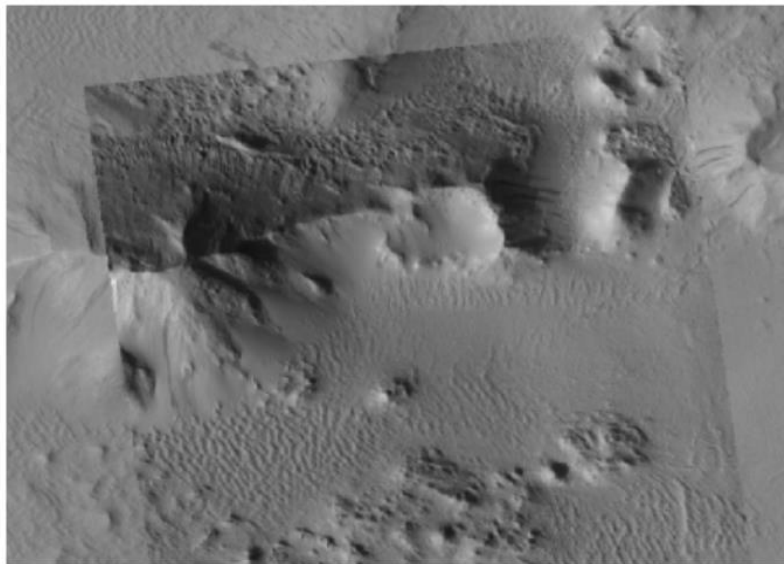


Lobby of the Astrogeology Science Center in Flagstaff, AZ

# MRCTR GIS Lab

## Mapping, Remote-Sensing, Cartography, Technology, and Research

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HiRISE image web service overlying CTX blended mosaic web service

### GIS Tools

- Python Toolboxes and Esri Add-Ins
- Contracted tools
- Python scripts

### Tutorials

- Videos published to YouTube
- Workflows and self-paced exercises

### Technology Tests & Standards

- Tiled imagery web services for global mosaics via MRF with LERC compression
  - Special thanks to Esri's Lucian Plesea
- Representation at OGC and USGS standards WGs

# Our Goals

Develop within a Planetary Spatial Data Infrastructure framework



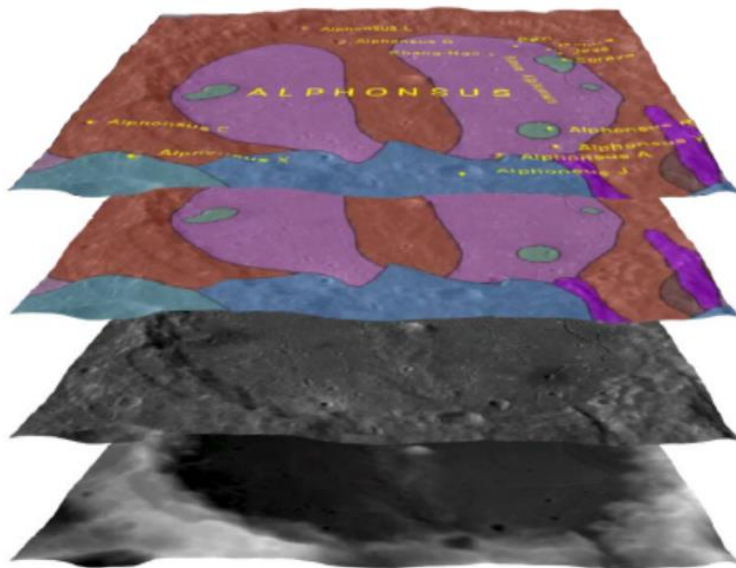
Product-base view of PSDI. Laura, et al. (2017).

Promote discoverability, accessibility and interoperability of spatial data (Naß et al., 2017)

Leverage best practices in terrestrial geoscience mapping (Hare et al., 2018)

# Life-Cycle Approach to Geospatial Data

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Well-controlled foundational data products served in GIS-ready formats

Tools that help to avoid common pitfalls of planetary GIS

Leverage current publication and visualization technologies

Long-term archive and open web services

Community-driven standards to enhance discovery and coordinate advancement



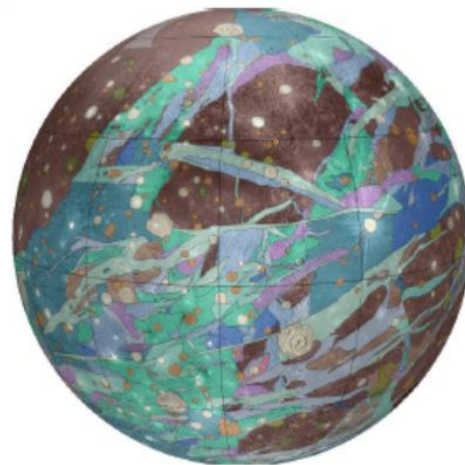
### Aim to meet user expectations that spatial data should ‘just work’

- Develop policies, standards and access needed to connect people and data
- Create tools and training that help geologists think geographically
- Support appropriate use of data mapped at different scales

### Build on existing spatial data standards

- Extend relevant data models for use in planetary domain
- Plug into modern visualization and analysis applications

### Continued advocacy for support of planetary coordinate reference systems in web protocols and visualization tools



Global geologic map of Ganymede

## Groups to help or join

### International Cartography Association

- Members working towards in situ (rover) symbologies

### MAPSIT

- Spatial Data Infrastructure and Planetary Data Ecosystem

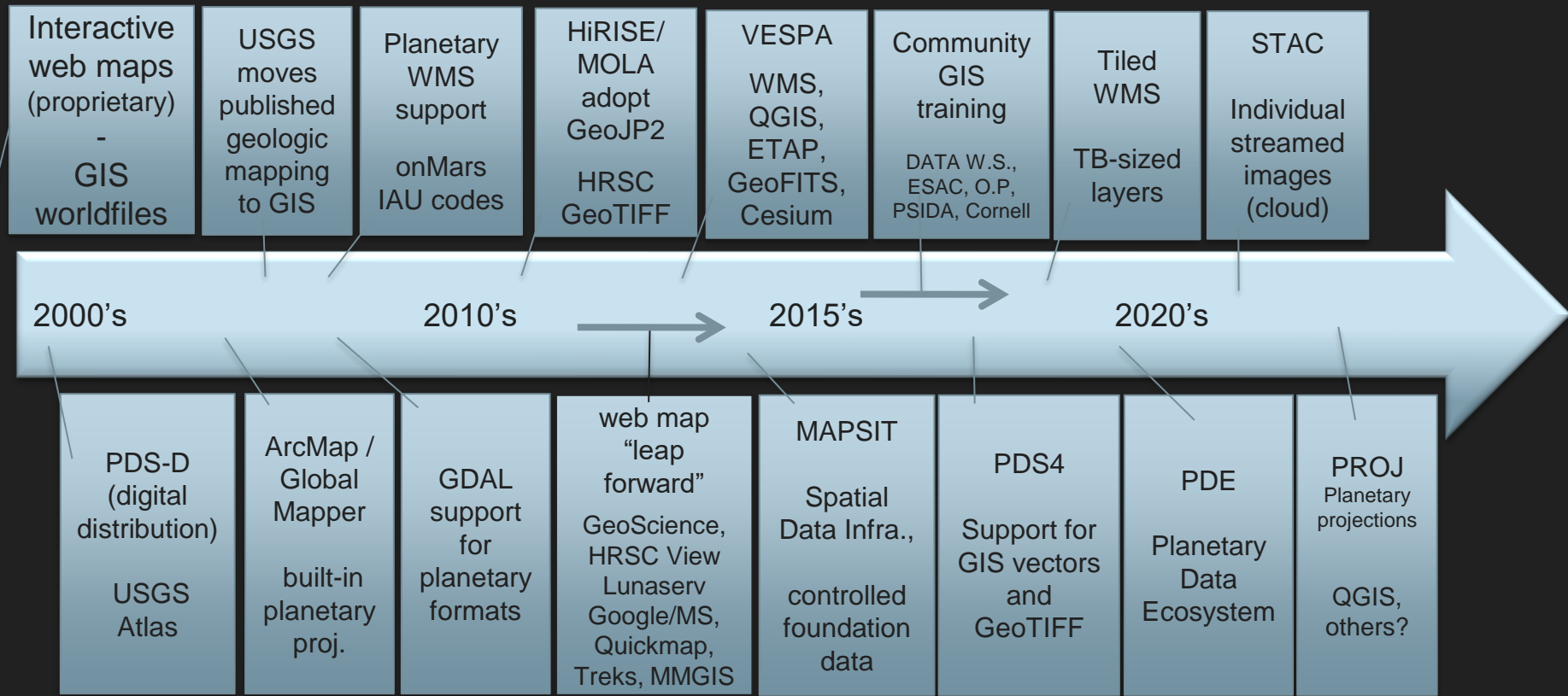
### IAU

- Nomenclature
- Coordinate Systems

### Open Geospatial Consortium

- Planetary Domain Working Group

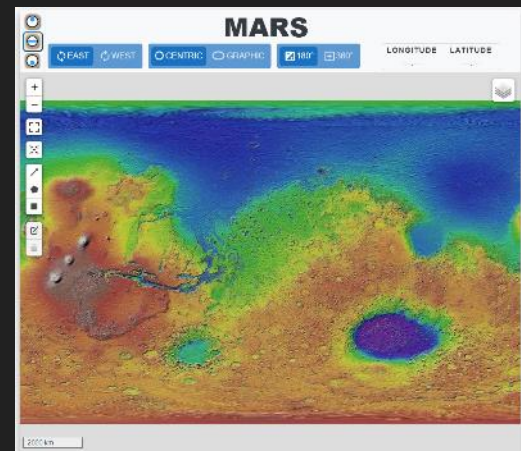
# Evolution of planetary GIS services (my viewpoint)





# What is WMS

Web Map Service Interface Standard (WMS) provides a simple https interface for requesting geo-registered map images. Available since late 90s. Requires map server.



OGC WMTS (Web Map Tile Service, aka TMS): For heavy use and high scalability the OGC has developed the WMTS service standard. It is an area-wide collection of consistently addressable seamless map image tiles organized in a pyramid with fixed scales. Clients request as many tiles as needed to cover the requested area. Available since mid-2000s. Required pre-processing tiles and simple https address (map server optional).

More: <http://planetarygis.blogspot.com/2014/09/tips-to-interact-with-astros-wms-maps.html>

# WMS

## Some Staying Power

- Simple API, thus it can still be useful
- Interfaces can “deal” with earth-centric issues (e.g. web map libraries, QGIS, ArcMap, ...)
- Strive to implement IAU 2015 codes across standard (is it too late?)
- Tiled WMS can support TB-sized mosaics

## Challenges remain

- Based on Earth-centric Open Geospatial Consortium (OGC) standard
- IAU 2000 codes only implemented in retired USGS WMS server, ASU's Lunaserv and Mapserver branch (by Jean-Christophe M.)
- Technology dated (large move toward tiles and streaming formats like COG)

# Astrogeology WMS Layers (in degrees or polar stereographic)

<http://planetarygis.blogspot.com/2014/09/tips-to-interact-with-astros-wms-maps.html>

## Planetary GIS

Discussion and tips for the planetary researcher using GIS.

Thursday, January 6, 2022

### Tips to interact with Astro's WMS maps

update from the original 2014 post:

For years we have supported our live mapping services (called Web Mapping Services, WMS) for use within our own web mapping tools but also for the community to use. For example, these layers are viewable from our Planetary Nomenclature, PILOT, Geologic Mapping sites, etc (example [Aram Chaos on Mars](#)). Thus they are ideal for use in web mapping apps like OpenLayers and Leaflet and also GISs like QGIS, ArcMap, or ENVI. And you can

# Tiled WMS Layers (in degrees or polar stereographic)

[https://bit.ly/HiRISE\\_mosaic](https://bit.ly/HiRISE_mosaic)

## Uncontrolled Global HiRISE Mosaic

### Mars High-Resolution Tiled Web Services

linked from: [http://bit.ly/HiRISE\\_mosaic](http://bit.ly/HiRISE_mosaic)

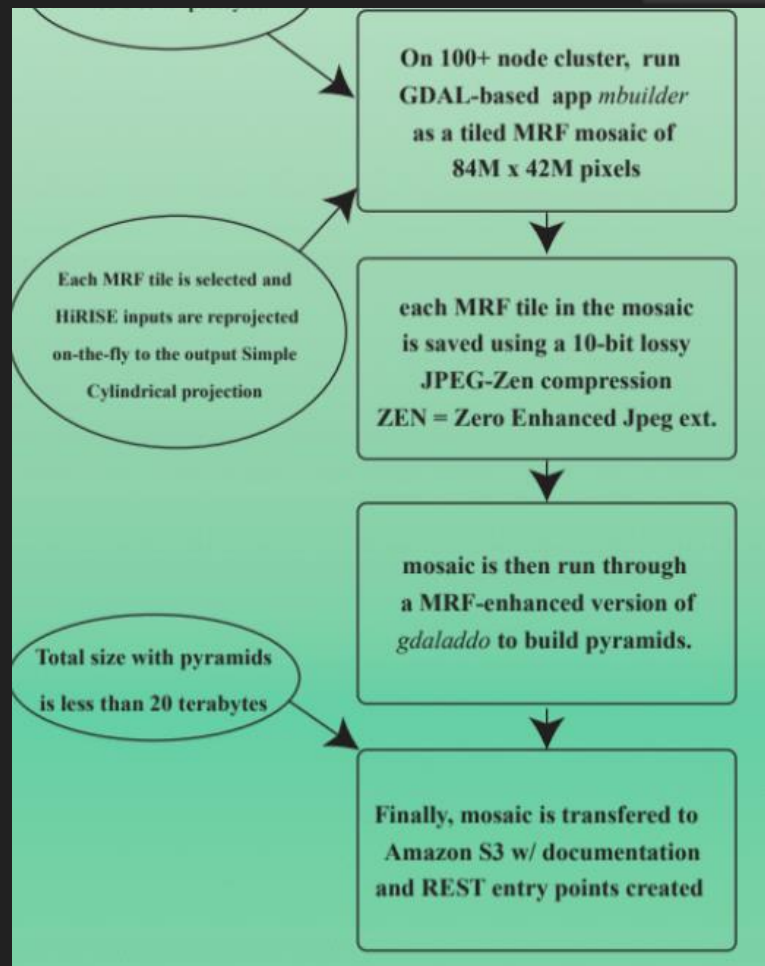
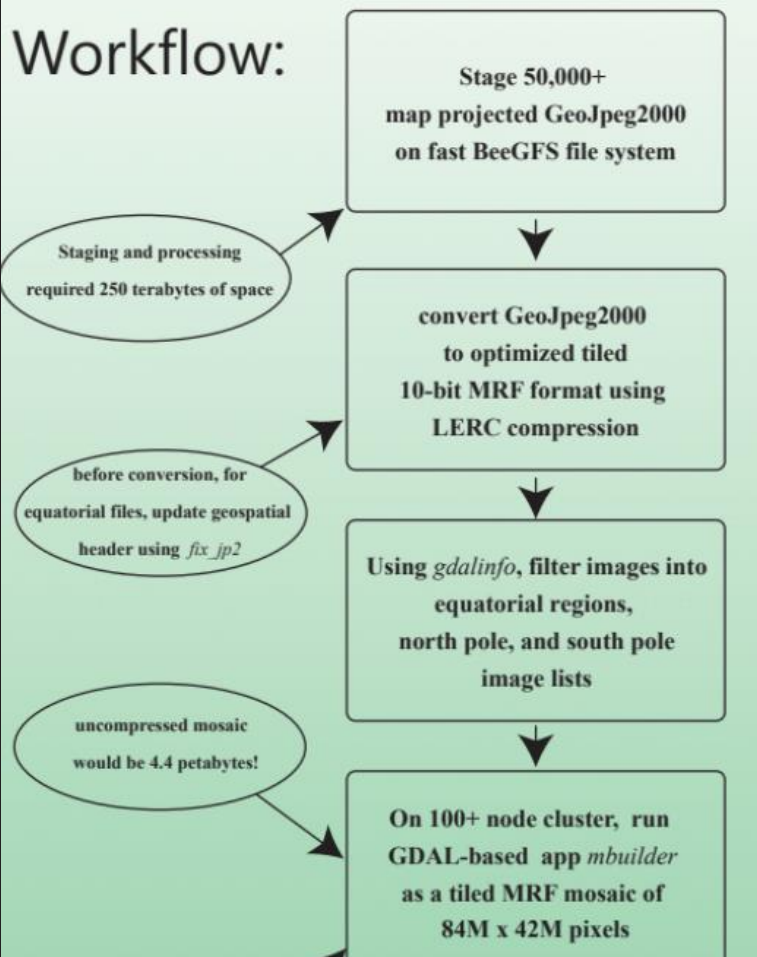
An Esri introduction and Story Map for these layers: <https://www.esri.com/arcgis-blog/products/arcgis-online/imagery/observing-the-red-planet/>

These new Mars service hosted by Esri highlights controlled "foundational" mosaics including Viking MDIM v2.1 [231 m/p], MOLA/HRSC Blended Hillshade [200 m/p], and the USGS-created THEMIS Daytime and Nighttime mosaics [100 m/p]. We have also included the preliminary uncontrolled but high-resolution mosaics created by the Caltech Murray Lab for CTX [5 m/p] and USGS-generated HiRISE PSP/ESP mosaic [0.25 m/p]. Note on disk the

# Tiled WMS Layers (in degrees or polar stereographic)



## Workflow:



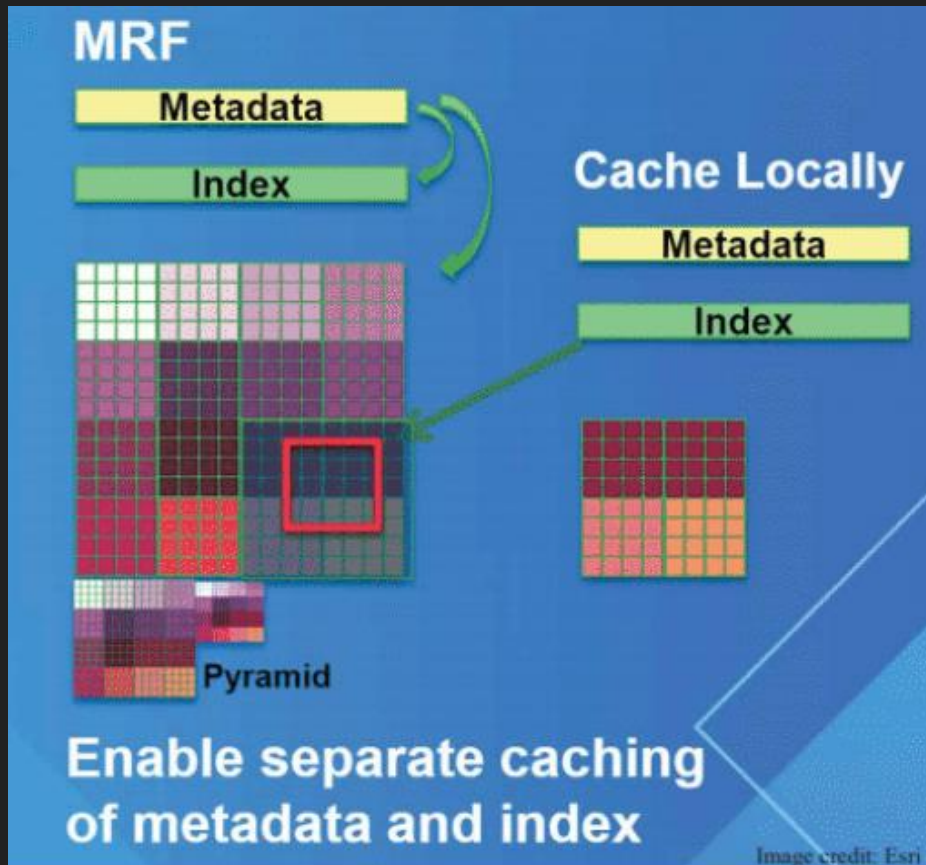
# Tiled WMS Layers (in degrees or polar stereographic)



<https://github.com/nasa-gibs/mrf>

HiRISE helper:

<https://github.com/lucianpls/mbuilder>





# Spatial Temporal Asset Catalog (STAC)

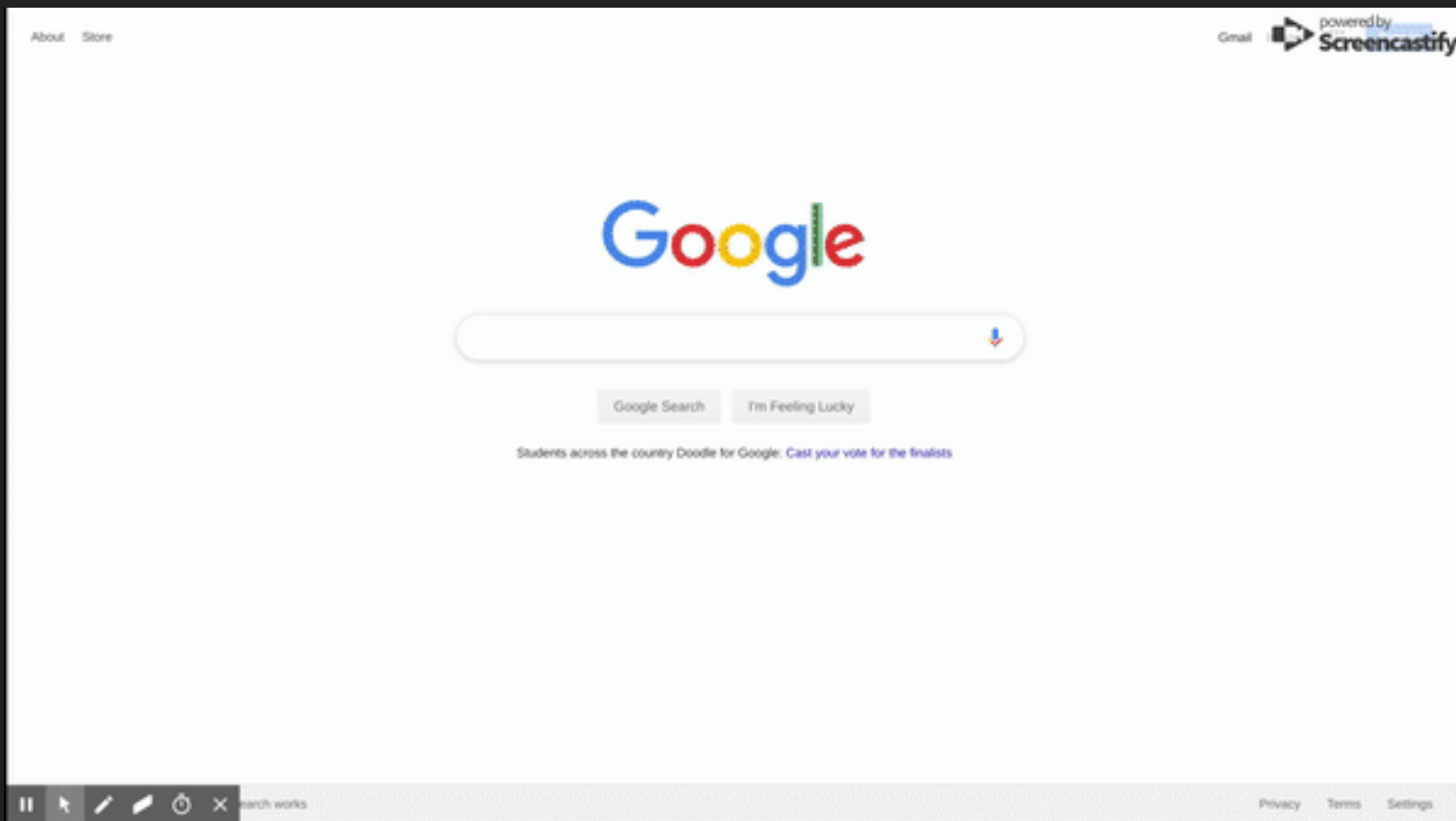
The STAC specification provides a common language to describe a range of geospatial information, so it can more easily be indexed and discovered. A 'spatiotemporal asset' is any file that represents information about the earth captured in a certain space and time.

The goal is for all providers of spatiotemporal assets (Imagery, SAR, Point Clouds, Data Cubes, Full Motion Video, etc) to expose their data as SpatioTemporal Asset Catalogs (STAC), so that new code doesn't need to be written whenever a new data set or API is released.

from: <https://stacspec.org/>

The core JSON pages can be transformed into browsable, interactive HTML pages with tools like [STAC Browser](#). When STAC is used in concert with emerging formats like [Cloud Optimized GeoTIFF](#) or [TileDB arrays](#) the result vastly lowers the barriers for anybody to find and use geospatial assets like satellite imagery:

<https://stacspec.org/overview.html>



# Spatial Temporal Asset Catalog (STAC)

Beta docs: <https://stac.astrogeology.usgs.gov/>

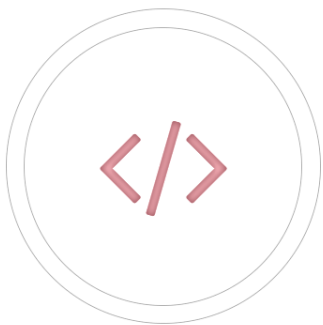
Beta STAC browser: <https://stac.astrogeology.usgs.gov/browser>

STAC help for QGIS: [https://stac.astrogeology.usgs.gov/docs/examples/to\\_qgis](https://stac.astrogeology.usgs.gov/docs/examples/to_qgis)

# What is a Cloud Optimized GeoTIFF (COG)

An imagery format for cloud-native geospatial processing

COG: <https://www.cogeo.org/>



## Efficient Imagery Data Access

COG-aware software can stream just the portion of data that it needs, improving processing times and creating real-time workflows previously not possible



## Reduced Duplication of Data

Accessing COG's with cloud workflows enables diverse software to all access a single file online instead of needing to copy and cache the data

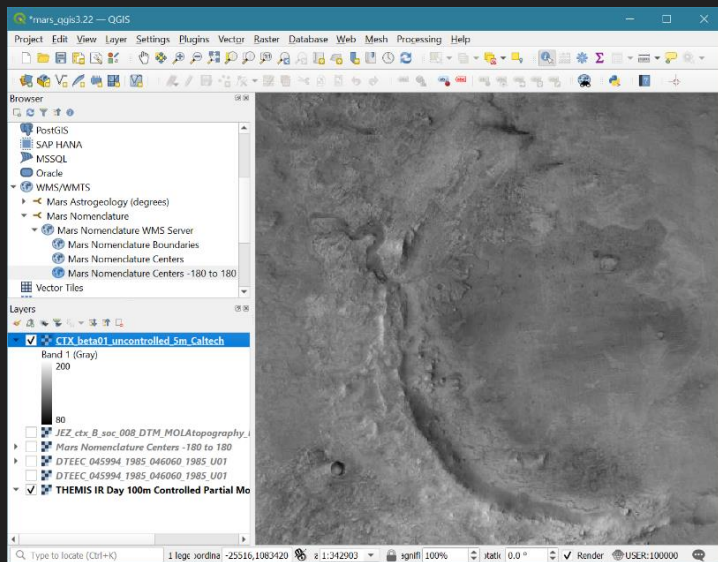


## Legacy Compatibility

Traditional GIS software is able to treat Cloud Optimized GeoTIFF's just like normal GeoTIFF's, so data providers need only produce one format

# QGIS

Current Version: 3.22.3 (Jan. 2022)



Qt version	5.15.2
Python version	3.9.5
<b>GDAL/OGR version</b>	<b>3.4.1</b>
<b>PROJ version</b>	<b>8.2.1</b>
EPSG Registry database	v10.041 (2021-12-03)
GEOS version	3.10.0-CAPI-1.16.0
<b>SQLite version</b>	<b>3.35.2</b>
PDAL version	2.3.0
PostgreSQL client version	13.0
SpatiaLite version	5.0.1

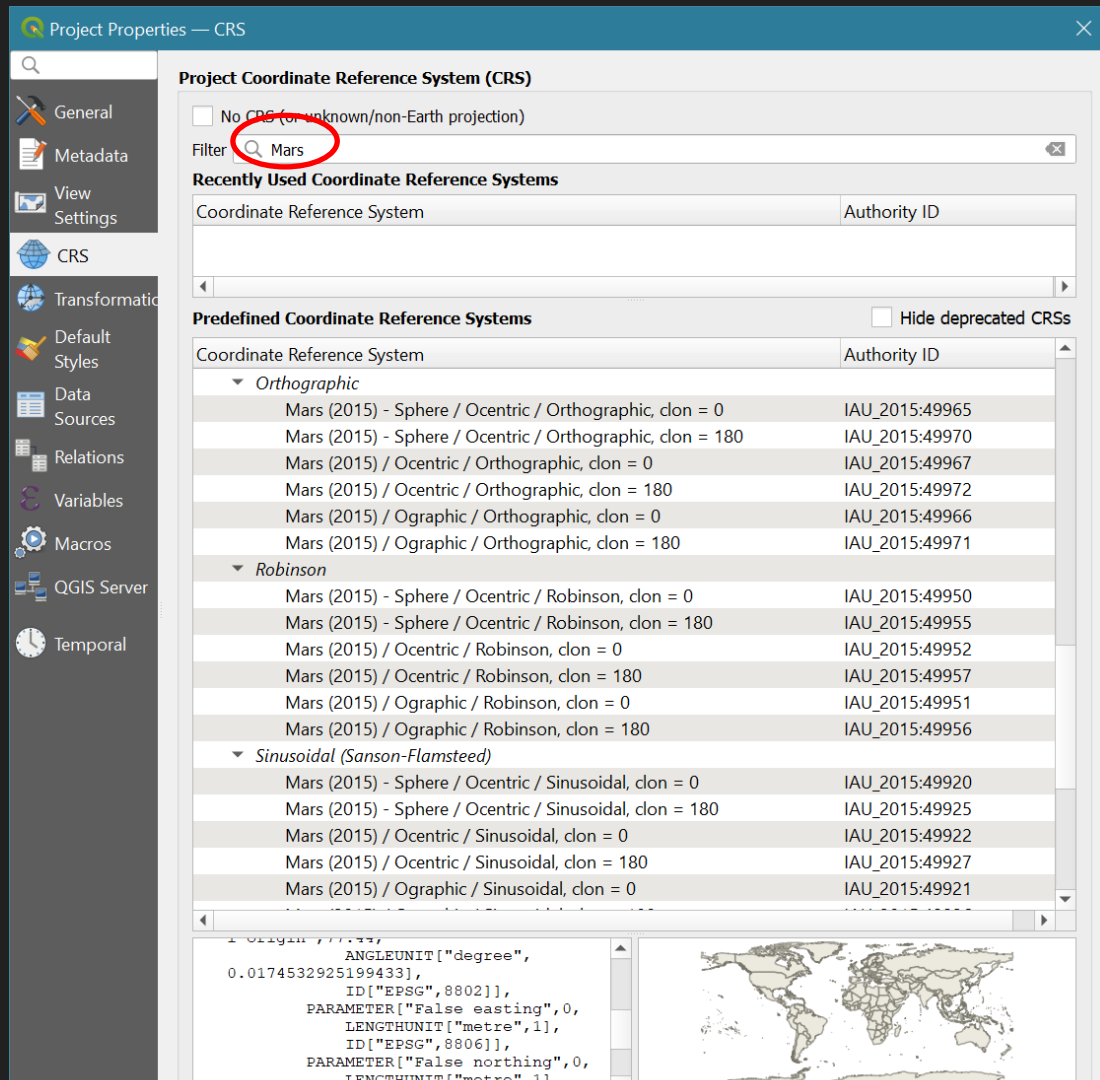
# Planetary Projections now built in

## IAU\_2015:aaabb

## IAU\_2015 report

[doi.org/10.1007/s10569-017-9805-5](https://doi.org/10.1007/s10569-017-9805-5)

aaa = NAIF body code  
bb = projections





# Adding Mars to QGIS 3.22+

[http://planetarymaps.usgs.gov/cgi-bin/mapserv?map=/maps/mars/mars\\_simp\\_cyl.map](http://planetarymaps.usgs.gov/cgi-bin/mapserv?map=/maps/mars/mars_simp_cyl.map)

Data Source Manager | WMS/WMTS

1. WMS/WMTS

2. New

3. Connect

4. Mars Astrogeology (degrees)

ID	Name	Title	Abstract
0	Mars_Simple_Cy...	WMS Mars Server	Planetary WMS service hosted...
1	MOLA_THEMIS_...	MOLA Topogra...	MOLA Colorized DEM blende...
2	THEMIS	THEMIS IR Day ...	Mars Odyssey THEMIS IR Day...
3	THEMIS_controll...	THEMIS IR Day ...	Mars Odyssey THEMIS IR Day...
4	THEMIS_night	THEMIS IR Nigh...	Mars Odyssey THEMIS IR Nig...
5	MDIM21	MDIM 2.1 Glob...	Viking Mars Digital Image Mo...
6	MDIM20	MDIM 2.0 Glob...	Viking Mars Digital Image Mo...

5. THEMIS\_controll...

Image Encoding

☒ PNG ☐ PNG8 ☐ JPEG ☐ GIF ☐ TIFF ☐ SVG

Options

Tile size: [ ] [ ]

Request step size: [ ] [ ]

Maximum number of GetFeatureInfo results: 10

Coordinate Reference System (2 available): EPSG:4326 - WGS 84

☐ Use contextual WMS Legend

Layer name: THEMIS IR Day 100m Controlled Partial Mosaic

1 Layer(s) selected

6. Add

Okay for now...

Create a New WMS/WMTS Connection

Connection Details

Name: Mars Astrogeology (degrees)

3. URL: [http://planetarymaps.usgs.gov/cgi-bin/mapserv?map=/maps/mars/mars\\_simp\\_cyl.map](http://planetarymaps.usgs.gov/cgi-bin/mapserv?map=/maps/mars/mars_simp_cyl.map)

Authentication

Configurations Basic

Choose or create an authentication configuration

No Authentication [ ] [ ] [ ]

Configurations store encrypted credentials in the QGIS authentication database.

HTTP

Referer: [ ]

WMS/WMTS Options

DPI-Mode: all

☐ Ignore GetMap/GetTile/GetLegendGraphic URI reported in capabilities

☐ Ignore GetFeatureInfo URI reported in capabilities

☐ Ignore axis orientation (WMS 1.3/WMTS)

☐ Ignore reported layer extents

☐ Invert axis orientation

☐ Smooth pixmap transform

OK Cancel Help

Now Override  
WMS layer  
(if needed)

The image shows the QGIS interface with the Layer Properties dialog open for the layer 'THEMIS IR Day 100m Controlled Partial Mosaic'. The 'Assigned Coordinate Reference System (CRS)' is set to 'IAU\_2015:49900 - Mars (2015) - Sphere / Ocentric'. A red circle highlights the 'Layer Properties' title bar. A red '1.' points to the CRS dropdown menu.

Changing this option does not modify the original data source or perform any reprojection of the raster layer. Rather, it can be used to override the layer's CRS within this project if it could not be detected or has been incorrectly detected.

The Processing "Warp (reproject)" tool should be used to reproject a raster source and permanently change the data source's CRS.

The 'Coordinate Reference System Selector' dialog is open, showing the 'Filter' set to '49900' (marked with a red '2.'). The 'Recently Used Coordinate Reference Systems' table is empty. The 'Predefined Coordinate Reference Systems' table shows 'Mars (2015) - Sphere / Ocentric' (marked with a red '3.') with authority ID 'IAU\_2015:49900'. The 'OK' button is marked with a red '4.'.

**Layer Properties** — THEMIS IR Day 100m Controlled Partial Mosaic — Source

Layer name: THEMIS IR Day 100m Controlled Partial Mosaic

Assigned Coordinate Reference System (CRS)

IAU\_2015:49900 - Mars (2015) - Sphere / Ocentric

**Coordinate Reference System Selector**

Filter: 49900

Recently Used Coordinate Reference Systems

Coordinate Reference System	Authority ID
-----------------------------	--------------

Predefined Coordinate Reference Systems

Coordinate Reference System	Authority ID
<b>Geographic Coordinate Systems</b>	
Mars (2015) - Sphere / Ocentric	IAU_2015:49900

Mars (2015) - Sphere / Ocentric

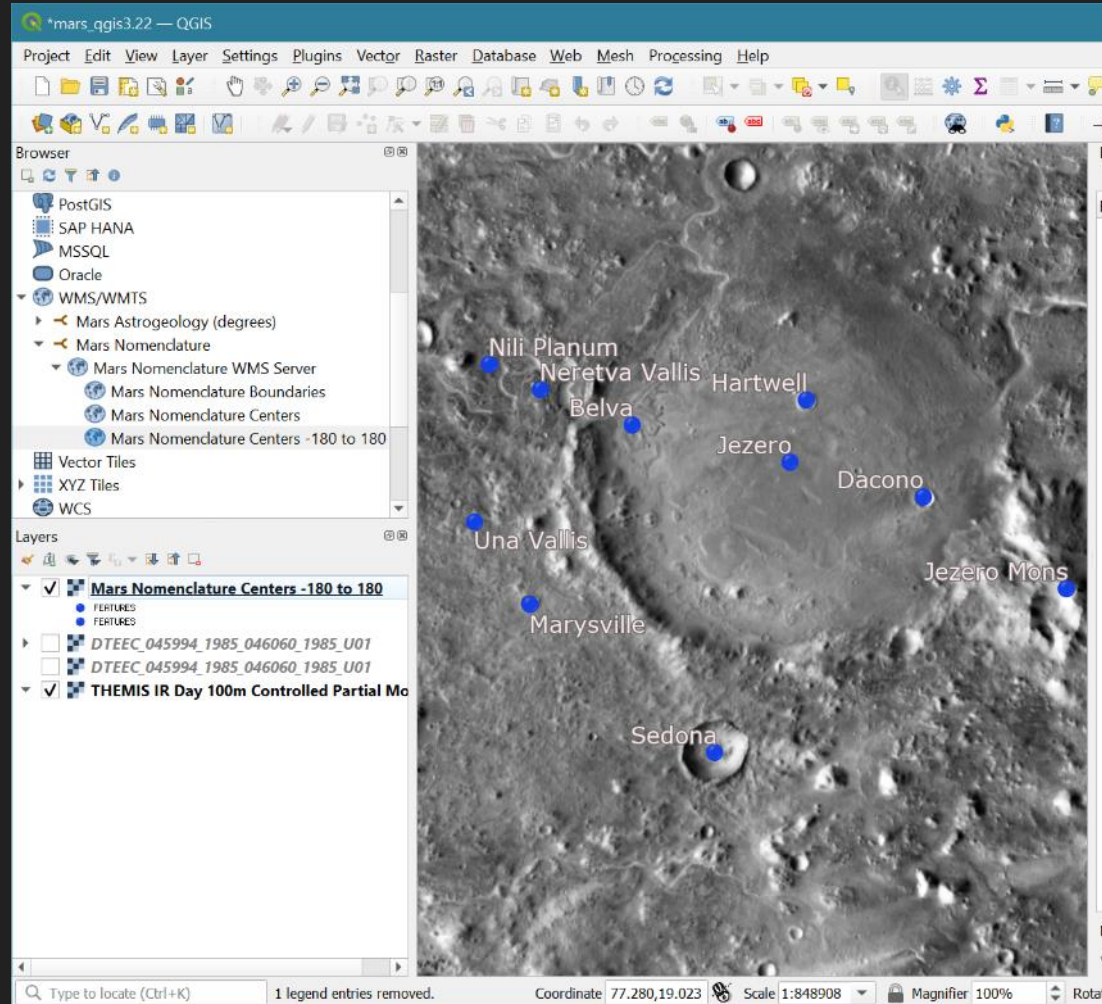
Properties

- Geographic (uses latitude and longitude for coordinates)

OK Cancel Help

Do the same:  
nomenclature WMS  
(simple labels)

[http://wms.wr.usgs.gov/cgi-bin/  
mapserv?map=/maps/mars/  
mars\\_nomen\\_wms.map](http://wms.wr.usgs.gov/cgi-bin/mapserv?map=/maps/mars/mars_nomen_wms.map)



# Custom or local projection

Warning: nomenclature WMS layer may not work

Copy from layer's  
properties and  
create new custom  
projection

Custom Coordinate Reference System Definition

▼ Define

You can define your own custom Coordinate Reference System (CRS) here. The definition must conform to a WKT or Proj string format for specifying a CRS.

Name	Parameters
Jezero Crater...	PROJCRS["EQUIRECTANGULAR MARS",BASEGEOGCRS["GCS_MARS",DATUM["D_M...

2. Name: Jezero Crater Local Equi

Format: WKT (Recommended)

3. Paste here

Parameters:

```
PROJCRS["EQUIRECTANGULAR MARS",  
  BASEGEOGCRS["GCS_MARS",  
    DATUM["D_MARS",  
      ELLIPSOID["MARS_localRadius",3394839.8133163,0,  
        LENGTHUNIT["metre",1,  
          ID["EPSG",9001]]],  
    PRIMEM["Reference_Meridian",0,  
      ANGLEUNIT["degree",0.0174532925199433,  
        ID["EPSG",9122]]],  
    CONVERSION["unnamed",
```

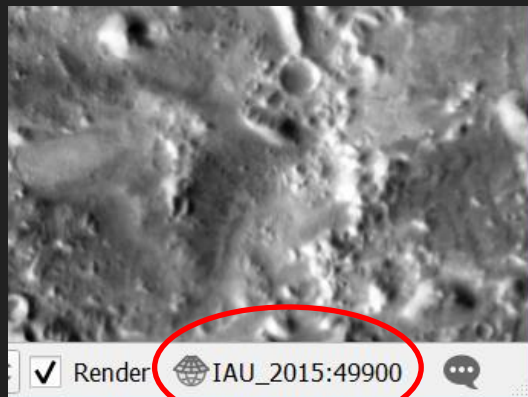
4. Validate

▼ Test

Use the text boxes below to test the CRS definition you are creating. Enter a coordinate where both the lat/long and the transformed result are known (for example by reading off a map). Then press the calculate button to see if the CRS definition you are creating is accurate.

5. OK Cancel Help

# Now set project's CRS to your custom projection



1. Click here

Project Properties — CRS

Project Coordinate Reference System (CRS)

☐ No CRS (or unknown/non-Earth projection)

Filter:  2.

Recently Used Coordinate Reference Systems

Coordinate Reference System	Authority ID
-----------------------------	--------------

Predefined Coordinate Reference Systems ☐ Hide deprecated CRSs

Coordinate Reference System	Authority ID
3.  User Defined Coordinate Systems	
Jezero local projection	USER:100000

Jezero local projection

Properties

- Units: meters
- Static (relies on a datum which is plate-fixed)
- Celestial body: Mars
- Method:

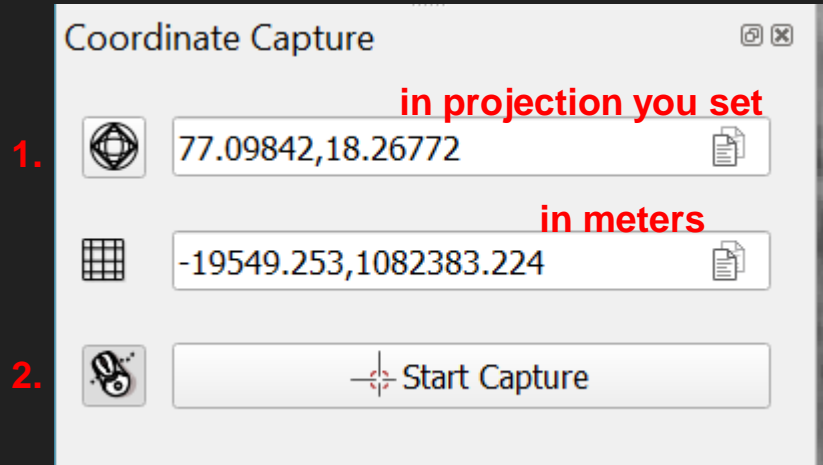
WKT

```
PROJCRS["EQUIRECTANGULAR MARS",  
  BASEGEOGCRS["GCS_MARS",  
    DATUM["D_MARS",  
      ELLIPSOID["MARS_localRadiu  
s", 3394839.8133163, 0,  
        LENGTHUNIT["metre", 1,  
          ID["EPSG",  
8001]]]],  
    PRIMEM["Reference_Meridian", 0,  
      ANGLEUNIT["degree",  
0.0174532925199433,  
        ID["EPSG", 9122]]],  
    ID["EPSG", 9122]]],  
  ID["EPSG", 9122]]]
```



# Coordinate capture plug-in (report/copy degrees)

1. Set to Mars degree (49900)
2. Use stream button or single point “start capture”

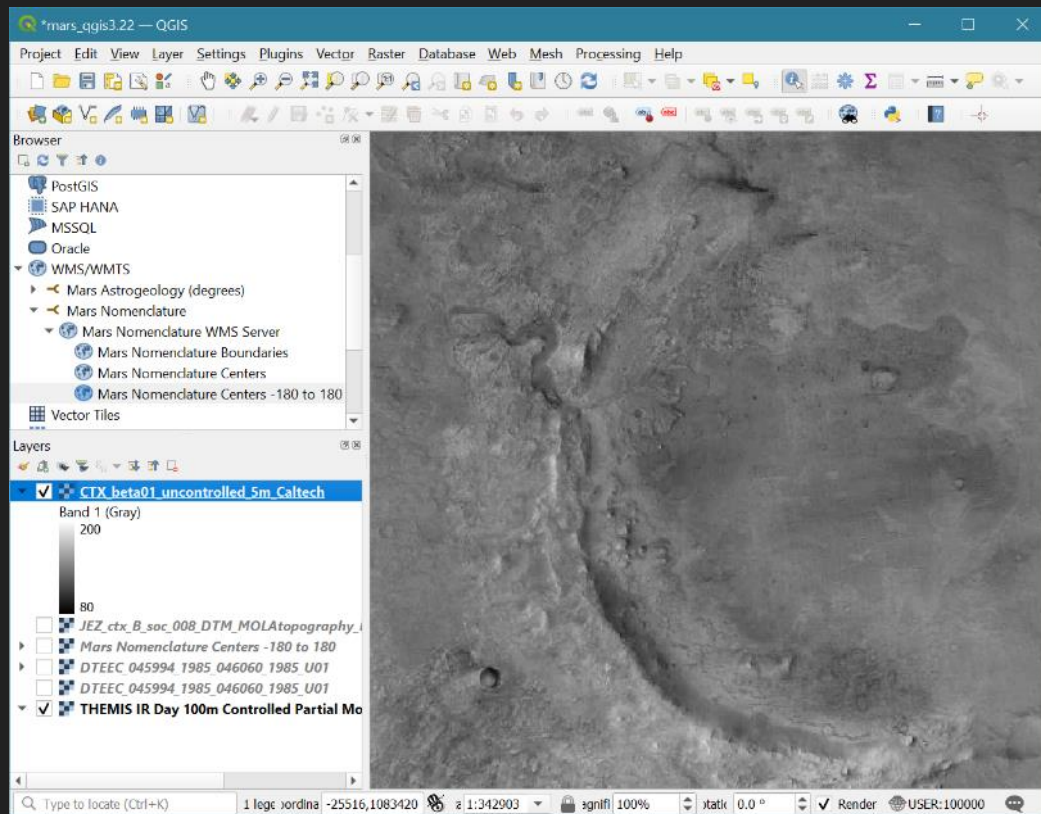


TMS: download zip file ([https://bit.ly/HiRISE\\_mosaic](https://bit.ly/HiRISE_mosaic))

or directly:

[https://www.dropbox.com/s/hhuqj7m9kc127us/OnMars\\_Esri\\_TiledWMS\\_layers\\_04282020.zip?dl=1](https://www.dropbox.com/s/hhuqj7m9kc127us/OnMars_Esri_TiledWMS_layers_04282020.zip?dl=1)

Simply drag \*.til or \*.dem  
into QGIS to load



# What is a \*.til and \*.dem – a simple TMS definition

```
<?xml version="1.0"?>
<GDAL_WMS>
  <Service name="TMS">
    <ServerUrl>http://astro.arcgis.com/arcgis/rest/services/OnMars/CTX/MapServer/tile/{z}/{y}/{x}</ServerUrl>
  </Service>
  <DataWindow>
    <UpperLeftX>-180.0</UpperLeftX>
    <UpperLeftY>90.0</UpperLeftY>
    <LowerRightX>180.0</LowerRightX>
    <LowerRightY>-90.0</LowerRightY>
    <SizeX>4194304</SizeX>
    <SizeY>2097152</SizeY>
    <TileLevel>12</TileLevel>
    <YOrigin>top</YOrigin>
  </DataWindow>
  <Projection>GEOGCS["GCS_Mars_2000_Sphere",DATUM["D_Mars_2000_Sphere",SPHEROID["Mars_2000_Sphere_IAU_IAG",339619
  <BlockSizeX>512</BlockSizeX>
  <BlockSizeY>512</BlockSizeY>
  <BandsCount>1</BandsCount>
  <MaxConnections>5</MaxConnections>
  <DataValues NoData="0"/>
  <ZeroBlockHttpCodes>404,400,503</ZeroBlockHttpCodes>
</GDAL_WMS>
```

# Let's load a COG from a STAC catalog

Beta STAC browser: <https://stac.astrogeology.usgs.gov/browser>

Find an image and copy the link (3N221W)

Direct COG link for DEM: [https://asc-mars.s3.us-west-2.amazonaws.com/ctx\\_dtms/B20\\_017298\\_1830\\_XN\\_03N221W\\_B19\\_017153\\_1825\\_XN\\_02N221W/B20\\_017298\\_1830\\_XN\\_03N221W\\_B19\\_017153\\_1825\\_XN\\_02N221W\\_DEM.tif](https://asc-mars.s3.us-west-2.amazonaws.com/ctx_dtms/B20_017298_1830_XN_03N221W_B19_017153_1825_XN_02N221W/B20_017298_1830_XN_03N221W_B19_017153_1825_XN_02N221W_DEM.tif)

Ortho: [https://asc-mars.s3.us-west-2.amazonaws.com/ctx\\_dtms/B20\\_017298\\_1830\\_XN\\_03N221W\\_B19\\_017153\\_1825\\_XN\\_02N221W/B20\\_017298\\_1830\\_XN\\_03N221W\\_B19\\_017153\\_1825\\_XN\\_02N221W\\_ORTHO.tif](https://asc-mars.s3.us-west-2.amazonaws.com/ctx_dtms/B20_017298_1830_XN_03N221W_B19_017153_1825_XN_02N221W/B20_017298_1830_XN_03N221W_B19_017153_1825_XN_02N221W_ORTHO.tif)

# STAC browser

Trent and Lori's Ho x Mail - Hare, Trent x ARD | Microsoft To x Cloud Optimized C x Ames Stereo Pipeli x Ames Stereo Pipeli x https://asc-mars.s3 x +

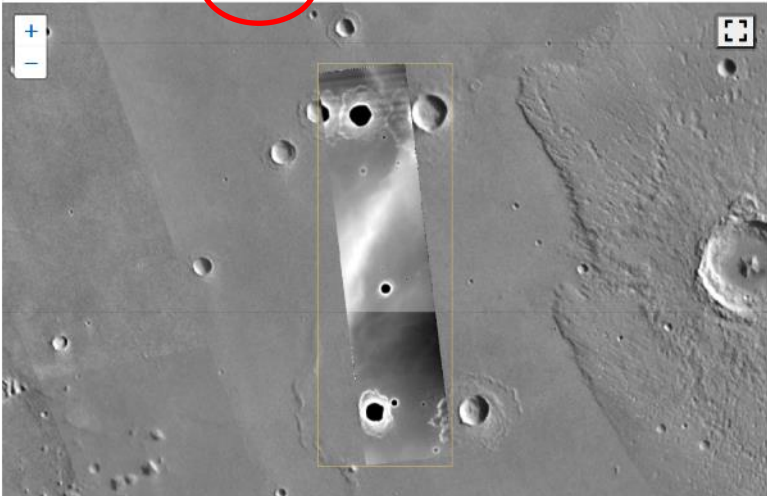
stac.astrogeology.usgs.gov/browser/item/3q52Dkr5nBe3g684y9fzjwTFMjyyQ66QitBuDrNggEBLhzMJFuvkYYXvSppyx71tvjpVWQkxlgEHK/E...

USGS Astrogeology Provided Analysis Ready Data / USGS hosted Mars data. / MRO CTX ASP Generated 20mpp Digital Terrain Models  
/ B20\_017298\_1830\_XN\_03N221W\_\_B19\_017153\_1825\_XN\_02N221W\_DEM

Ames Stereo Pipeline Derived 20mpp Content Camera  
DTM and Ortho Image; Mars;  
B20\_017298\_1830\_XN\_03N221W,  
B19\_017153\_1825\_XN\_02N221W  
(B20\_017298\_1830\_XN\_03N221W\_\_B19\_017153\_1825\_;

[https://asc-mars.s3.us-west-2.amazonaws.com/ctx\\_dtm/B20\\_017298\\_1830\\_XN\\_03N221W\\_\\_B19\\_017153\\_1825\\_XN\\_02N221W/B20\\_017298\\_1830\\_XN\\_03N221W\\_\\_B19\\_017153\\_1825\\_XN\\_02N221W\\_DEM](https://asc-mars.s3.us-west-2.amazonaws.com/ctx_dtm/B20_017298_1830_XN_03N221W__B19_017153_1825_XN_02N221W/B20_017298_1830_XN_03N221W__B19_017153_1825_XN_02N221W_DEM)

Preview Thumbnail **Assets**



METADATA

**Collection** MRO CTX ASP Generated 20mpp Digit

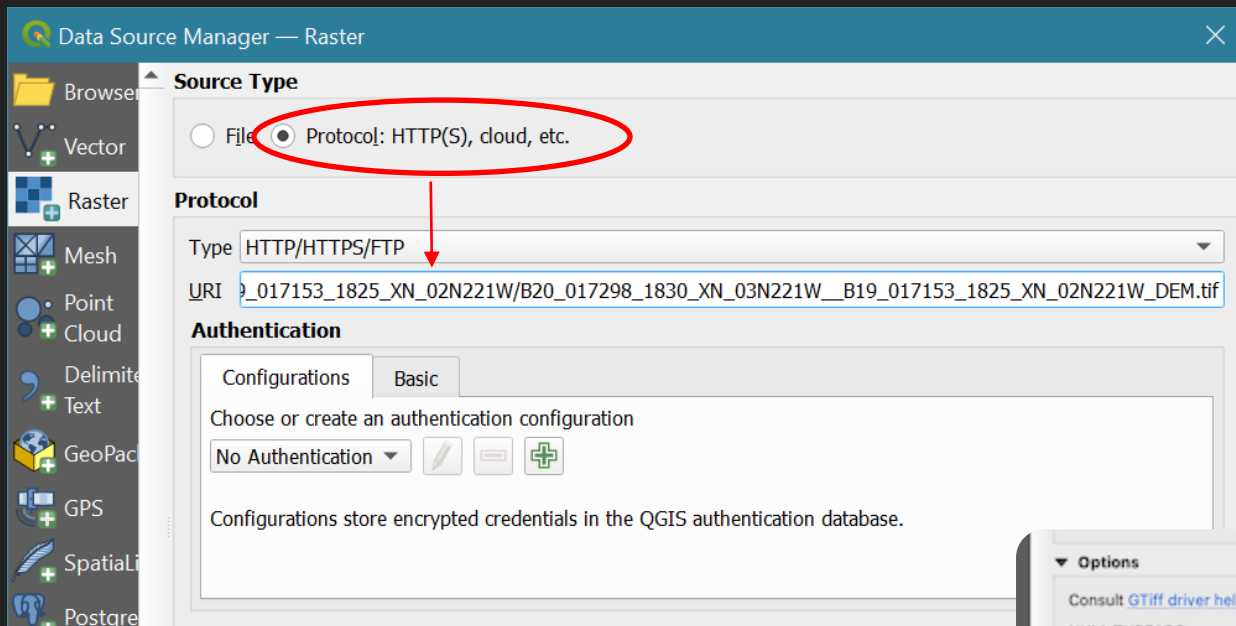
**Title** Ames Stereo Pipeline Derived 20mpp Content Camera (CTX) stereo images from the Reconnaissance Orbiter mission. This is a digital terrain model (DTM) from stereo images acquired at a resolution of 20 meters/pixel. The DTM was generated using the Ames Stereo Pipeline software (https://github.com/NeoGeographyTool/AmesStereoPipeline) using automated methods. This DTM is for general and public use, including scientific purposes. This DTM also serves as a reference for the Ames Stereo Pipeline software.

**Description** This is a digital terrain model (DTM) from stereo images acquired at a resolution of 20 meters/pixel. The DTM was generated using the Ames Stereo Pipeline software (https://github.com/NeoGeographyTool/AmesStereoPipeline) using automated methods. This DTM is for general and public use, including scientific purposes. This DTM also serves as a reference for the Ames Stereo Pipeline software.

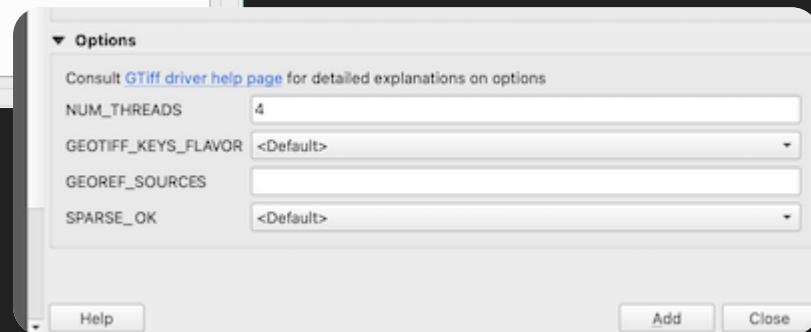
**Missions** Mars Reconnaissance Orbiter

**Instruments** Context Camera (CTX)

# Let's load a COG from a STAC catalog



If available, increase NUM\_THREADS —→





# Loaded COG

