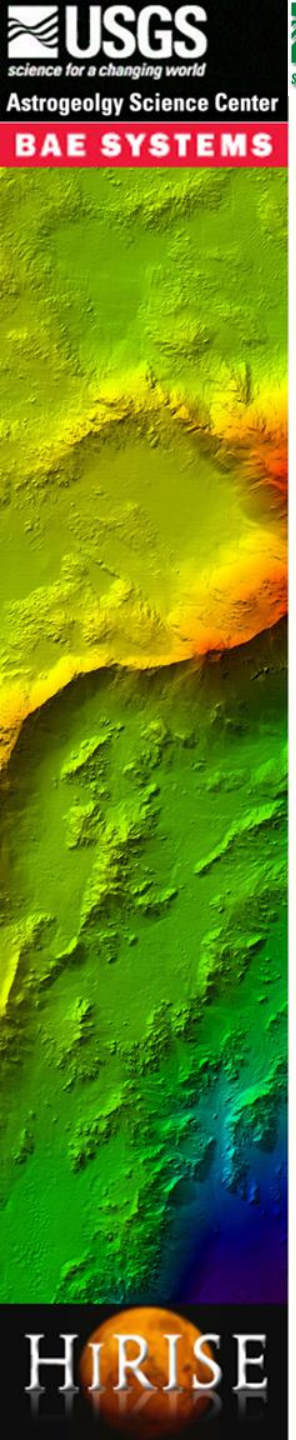


USGS science for a changing world

USGS 50 YEARS ASTROGEOLOGY SCIENCE CENTER 1963 - 2013

USGS Astrogeology Science Center
The Planetary Photogrammetry Guest Facility

Photogrammetric Processing of Planetary Stereo Images Using SOCET SET®

July 27, 28, 29, 2015

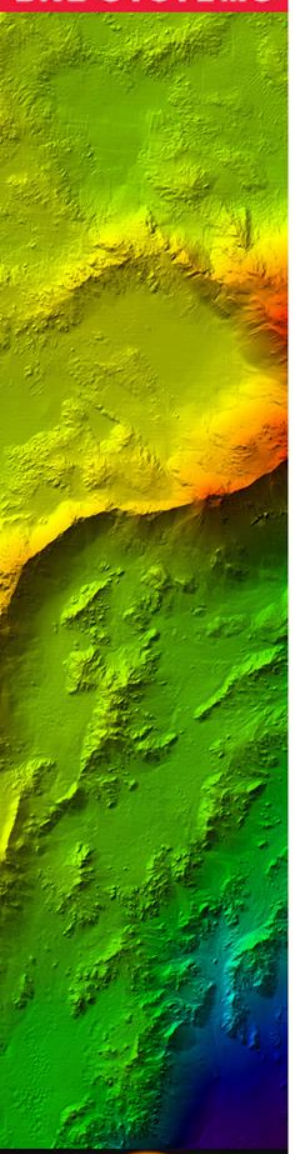


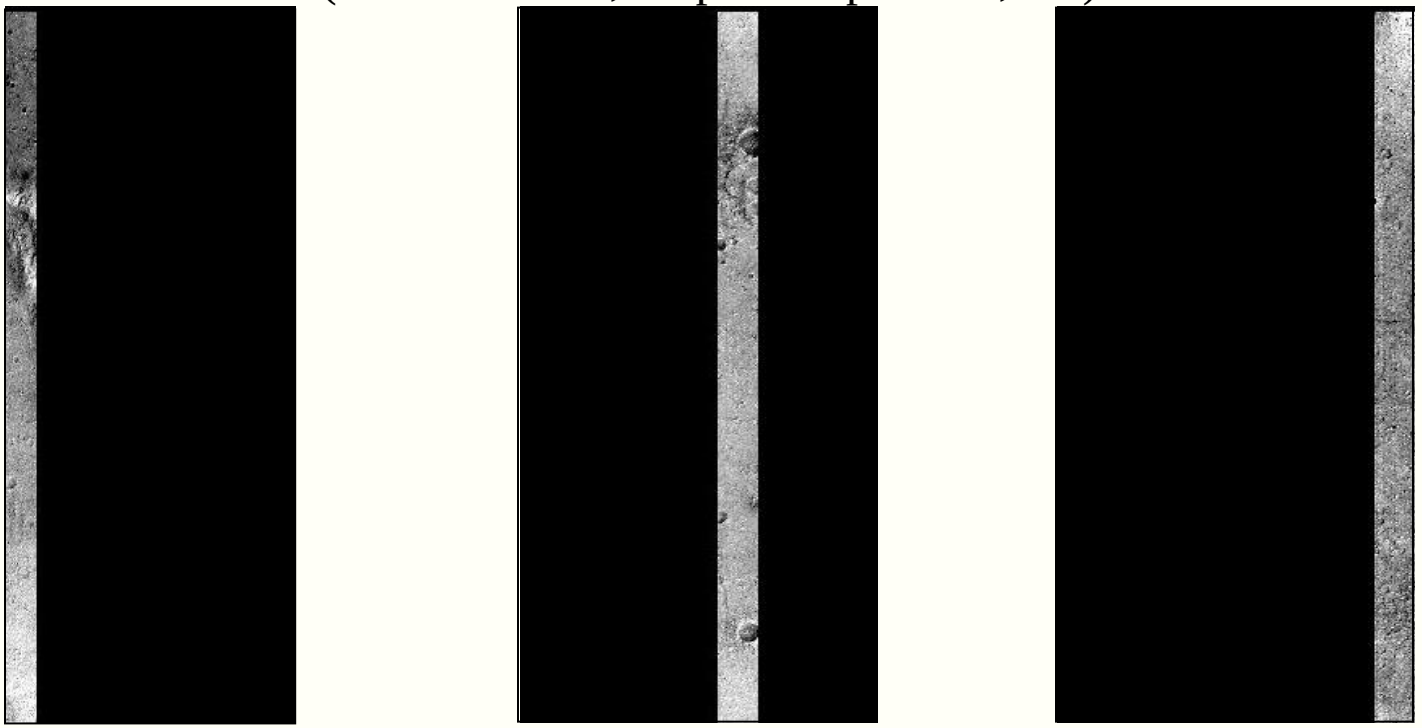
Image preparation for SOCET SET®

The story continues….

Noproj – HiRISE Undistorted ('idealized') Focal Plane

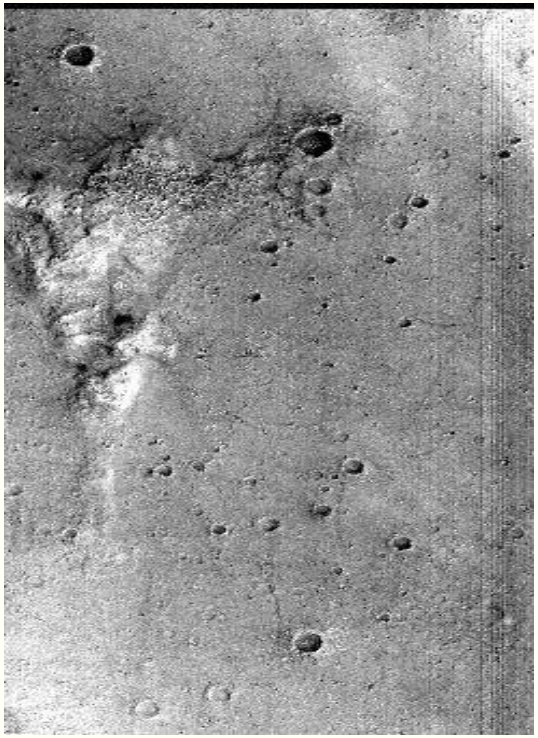
Sample NOPROJ results for PSP_001777_1650

(Summation=1; output samples=20,000)

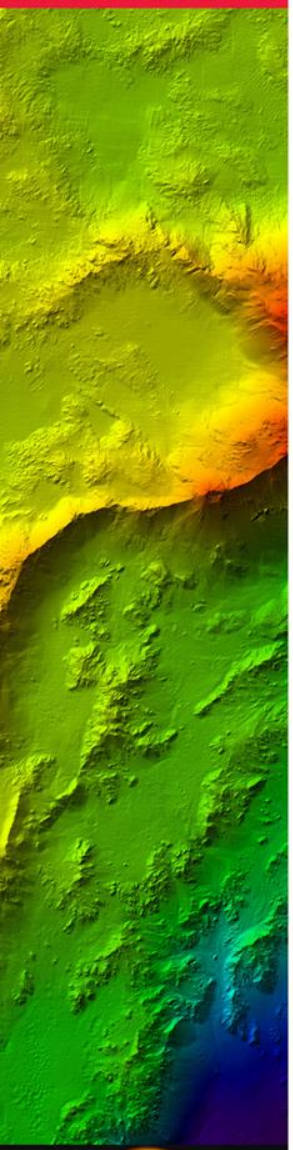


RED0 RED5 RED9

Noproj – HiRISE Undistorted ('idealized') Focal Plane



PSP_001777_1640
Undistorted mosaic

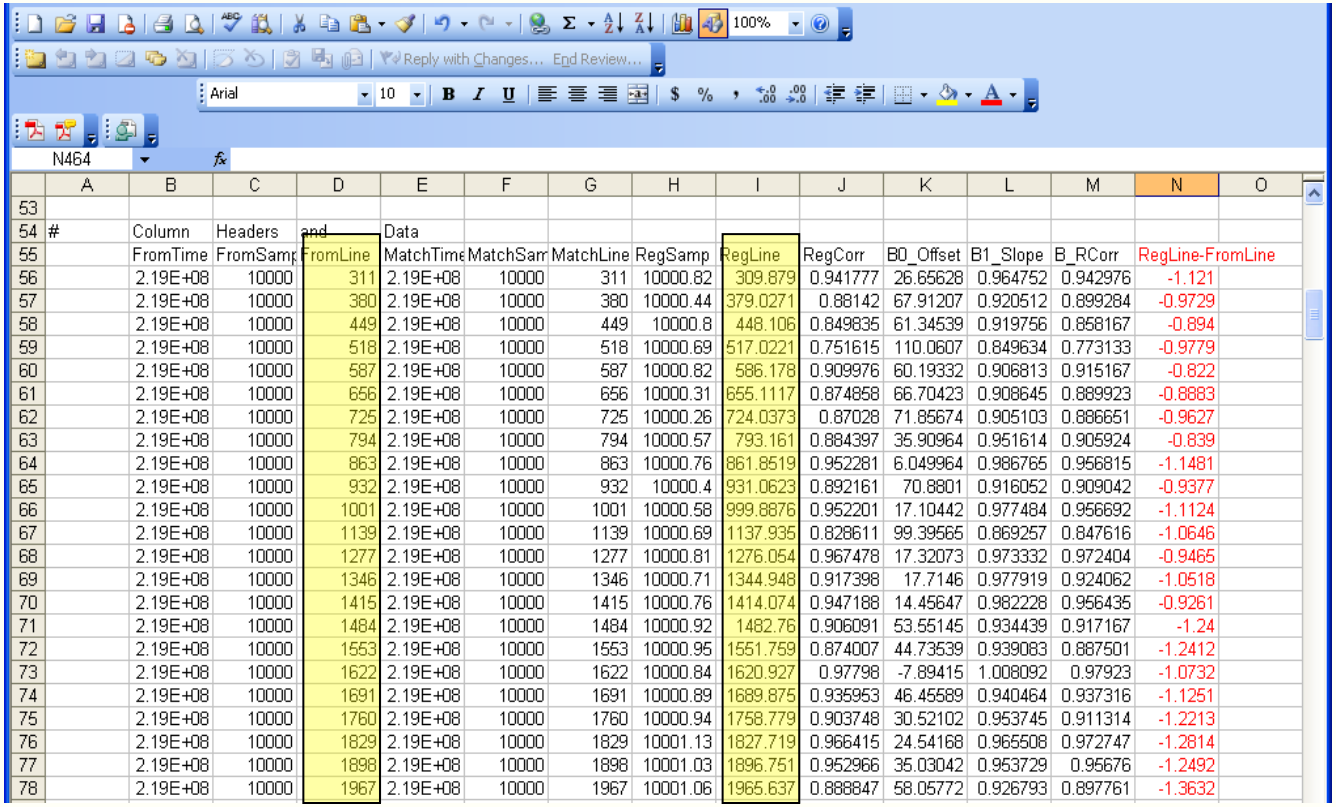


Jitter Evaluation

- *Until correction for spacecraft jitter is part of the HiRISE processing pipeline*, check for extreme spacecraft jitter before processing images for SOCET SET
- Run ISIS3 program hijitreg on the RED4 and RED5 CCDs as follows
  - hijitreg from= <RED4_balanced_cub> match=<RED5_balanced_cub> flatfile=<output_flat_file>

Jitter Evaluation

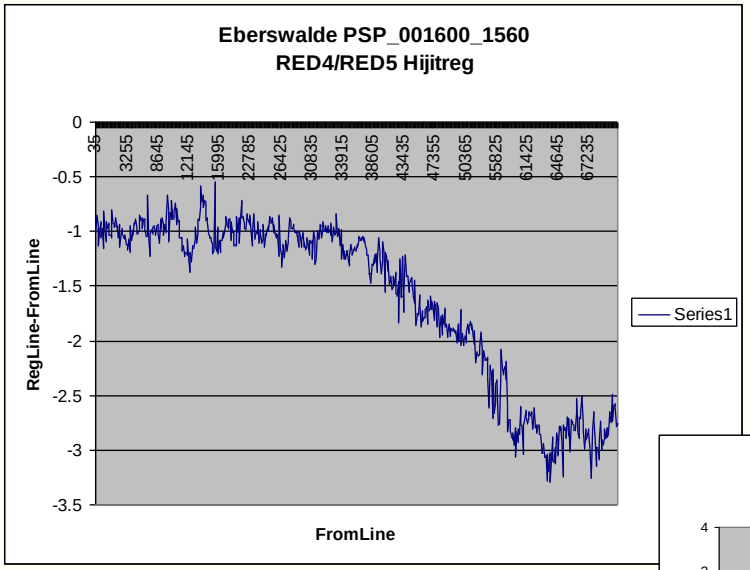
- Bring <output_flat_file> into Excel, calculate the difference of RegLine-FromLine, and plot the differences.
- This difference is an indication of jitter in pixels—look at total range of oscillations to evaluate the severity of jitter problems

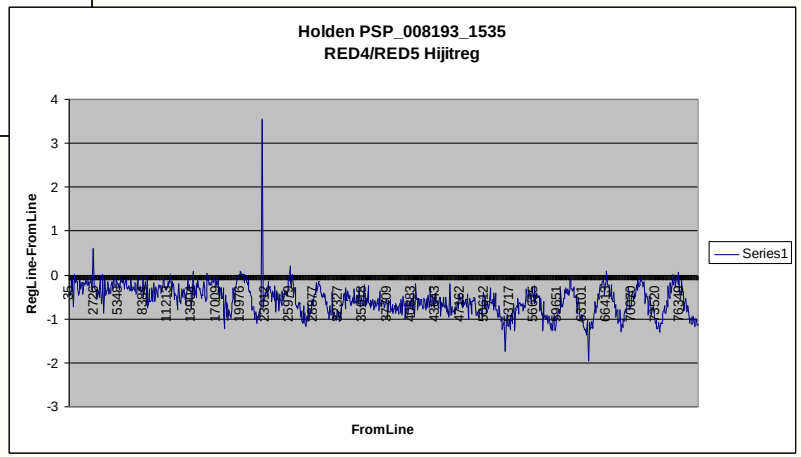


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
53															
54	#	Column	Headers	and	Data										
55		FromTime	FromSamp	FromLine	MatchTime	MatchSam	MatchLine	RegSamp	RegLine	RegCorr	B0_Offset	B1_Slope	B_RCorr	RegLine-FromLine	
56		2.19E+08	10000	311	2.19E+08	10000	311	10000.82	309.879	0.941777	26.65628	0.964752	0.942976	-1.121	
57		2.19E+08	10000	380	2.19E+08	10000	380	10000.44	379.0271	0.88142	67.91207	0.920512	0.899284	-0.9729	
58		2.19E+08	10000	449	2.19E+08	10000	449	10000.8	448.106	0.849835	61.34539	0.919756	0.858167	-0.894	
59		2.19E+08	10000	518	2.19E+08	10000	518	10000.69	517.0221	0.751615	110.0607	0.849634	0.773133	-0.9779	
60		2.19E+08	10000	587	2.19E+08	10000	587	10000.82	586.178	0.909976	60.19332	0.906813	0.915167	-0.822	
61		2.19E+08	10000	656	2.19E+08	10000	656	10000.31	655.1117	0.874858	66.70423	0.908645	0.889923	-0.8883	
62		2.19E+08	10000	725	2.19E+08	10000	725	10000.26	724.0373	0.87028	71.85674	0.905103	0.886651	-0.9627	
63		2.19E+08	10000	794	2.19E+08	10000	794	10000.57	793.161	0.884397	35.90964	0.951614	0.905924	-0.839	
64		2.19E+08	10000	863	2.19E+08	10000	863	10000.76	861.8519	0.952281	6.049964	0.986765	0.956815	-1.1481	
65		2.19E+08	10000	932	2.19E+08	10000	932	10000.4	931.0623	0.892161	70.8801	0.916052	0.909042	-0.9377	
66		2.19E+08	10000	1001	2.19E+08	10000	1001	10000.58	999.8876	0.952201	17.10442	0.977484	0.956692	-1.1124	
67		2.19E+08	10000	1139	2.19E+08	10000	1139	10000.69	1137.935	0.828611	99.39565	0.869257	0.847616	-1.0646	
68		2.19E+08	10000	1277	2.19E+08	10000	1277	10000.81	1276.054	0.967478	17.32073	0.973332	0.972404	-0.9465	
69		2.19E+08	10000	1346	2.19E+08	10000	1346	10000.71	1344.948	0.917398	17.7146	0.977919	0.924062	-1.0518	
70		2.19E+08	10000	1415	2.19E+08	10000	1415	10000.76	1414.074	0.947188	14.45647	0.982228	0.956435	-0.9261	
71		2.19E+08	10000	1484	2.19E+08	10000	1484	10000.92	1482.76	0.906091	53.55145	0.934439	0.917167	-1.24	
72		2.19E+08	10000	1553	2.19E+08	10000	1553	10000.95	1551.759	0.874007	44.73539	0.939083	0.887501	-1.2412	
73		2.19E+08	10000	1622	2.19E+08	10000	1622	10000.84	1620.927	0.97798	-7.89415	1.008092	0.97923	-1.0732	
74		2.19E+08	10000	1691	2.19E+08	10000	1691	10000.89	1689.875	0.935953	46.45589	0.940464	0.937316	-1.1251	
75		2.19E+08	10000	1760	2.19E+08	10000	1760	10000.94	1758.779	0.903748	30.52102	0.953745	0.911314	-1.2213	
76		2.19E+08	10000	1829	2.19E+08	10000	1829	10001.13	1827.719	0.966415	24.54168	0.965508	0.972747	-1.2814	
77		2.19E+08	10000	1898	2.19E+08	10000	1898	10001.03	1896.751	0.952966	35.03042	0.953729	0.95676	-1.2492	
78		2.19E+08	10000	1967	2.19E+08	10000	1967	10001.06	1965.637	0.888847	58.05772	0.926793	0.897761	-1.3632	

Jitter Evaluation

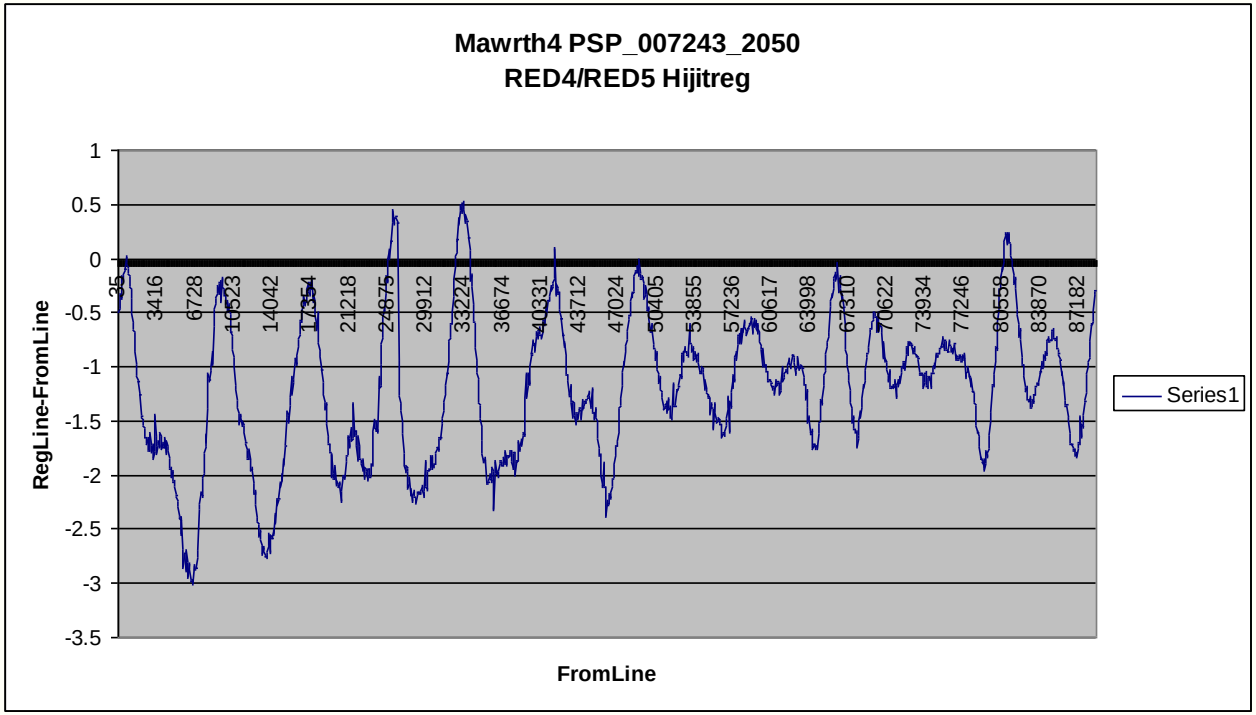
- Jitter less than 2 pixels is acceptable:





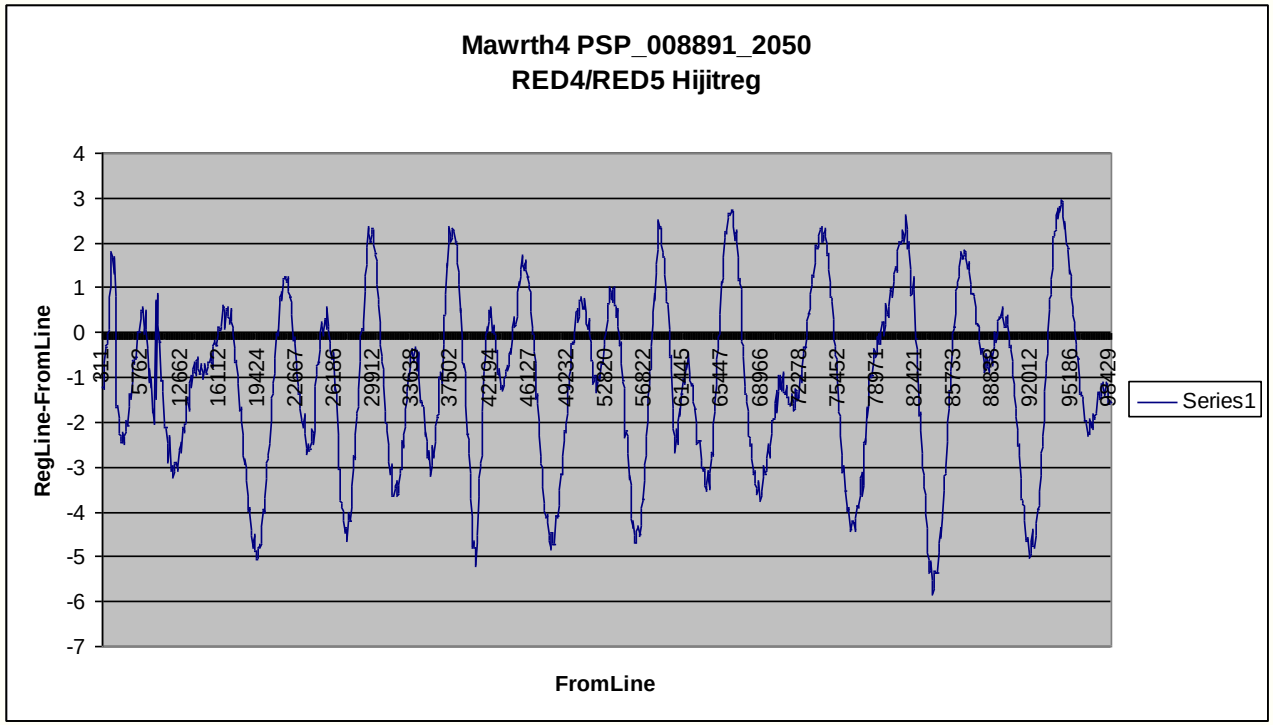
Jitter Evaluation

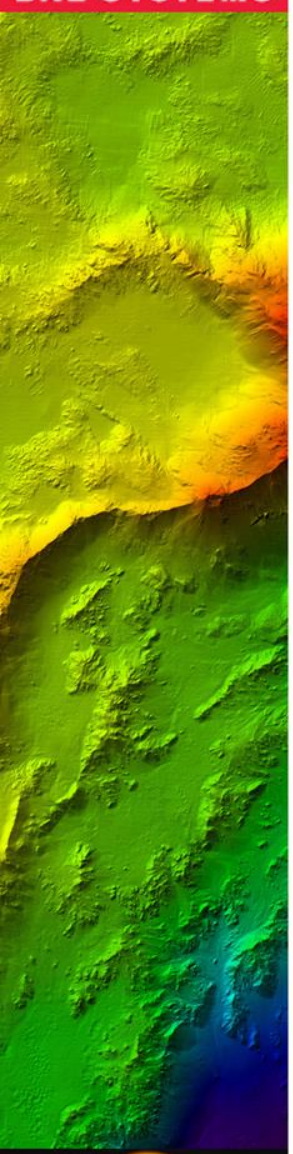
- Jitter between 2 - 3 pixels *may* cause problems



Jitter Evaluation

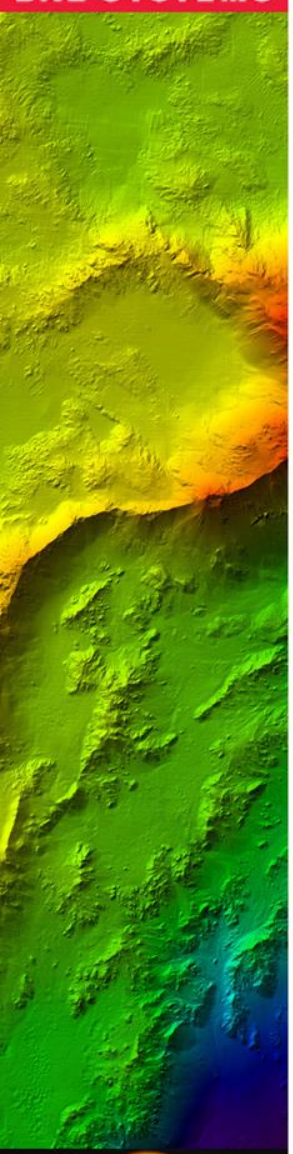
- Jitter >4 pixels is not workable





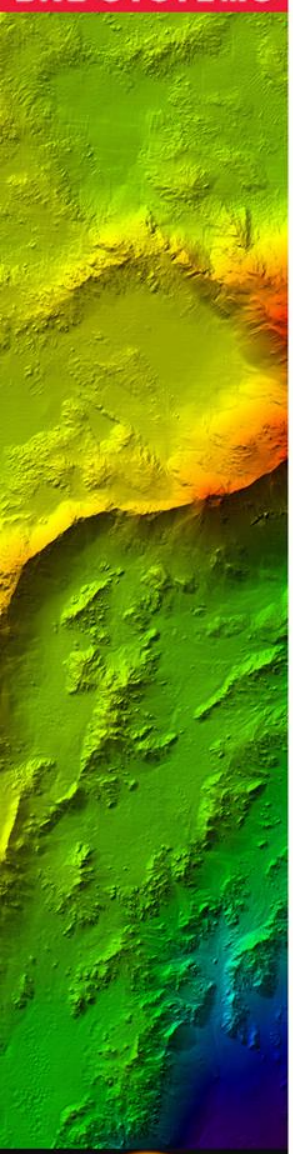
Software Versions

- ISIS 3.4.X
  - http://isis.astrogeology.usgs.gov/
- SOCET SET v5.6
  - Windows workstation
- FTOOLS
  - Source: http://trac.osgeo.org/gdal/wiki/DownloadSource
  - Instructions: http://trac.osgeo.org/gdal/wiki/BuildingOnUnix
  - Solaris Notes: http://trac.osgeo.org/gdal/wiki/SolarisNotes
  - Binaries for Linux: http://fwtools.maptools.org
  - Binaries for Mac: http://www.kyngchaos.com
- GNU C, C++, g77 compilers for FTOOLS and miscellaneous utilities we provide for the ISIS to SOCET Set conversion.



SOCET SET Upgrades from Astrogeology

- **Software to place in <ss_install_dir>\bin**
  - import_pushbroom
  - dem2isis3
  - ortho2isis3
  - calcOrthoBdry
- **Strategy files to place in <ss_install_dir>\internal_dbs\DTM_STRATEGY**
  - ngate_HIRISE.strategy
  - adapt.strat.onepassAfterNGATE
  - filterpass.strat



ISIS/SOCET SET Workflow

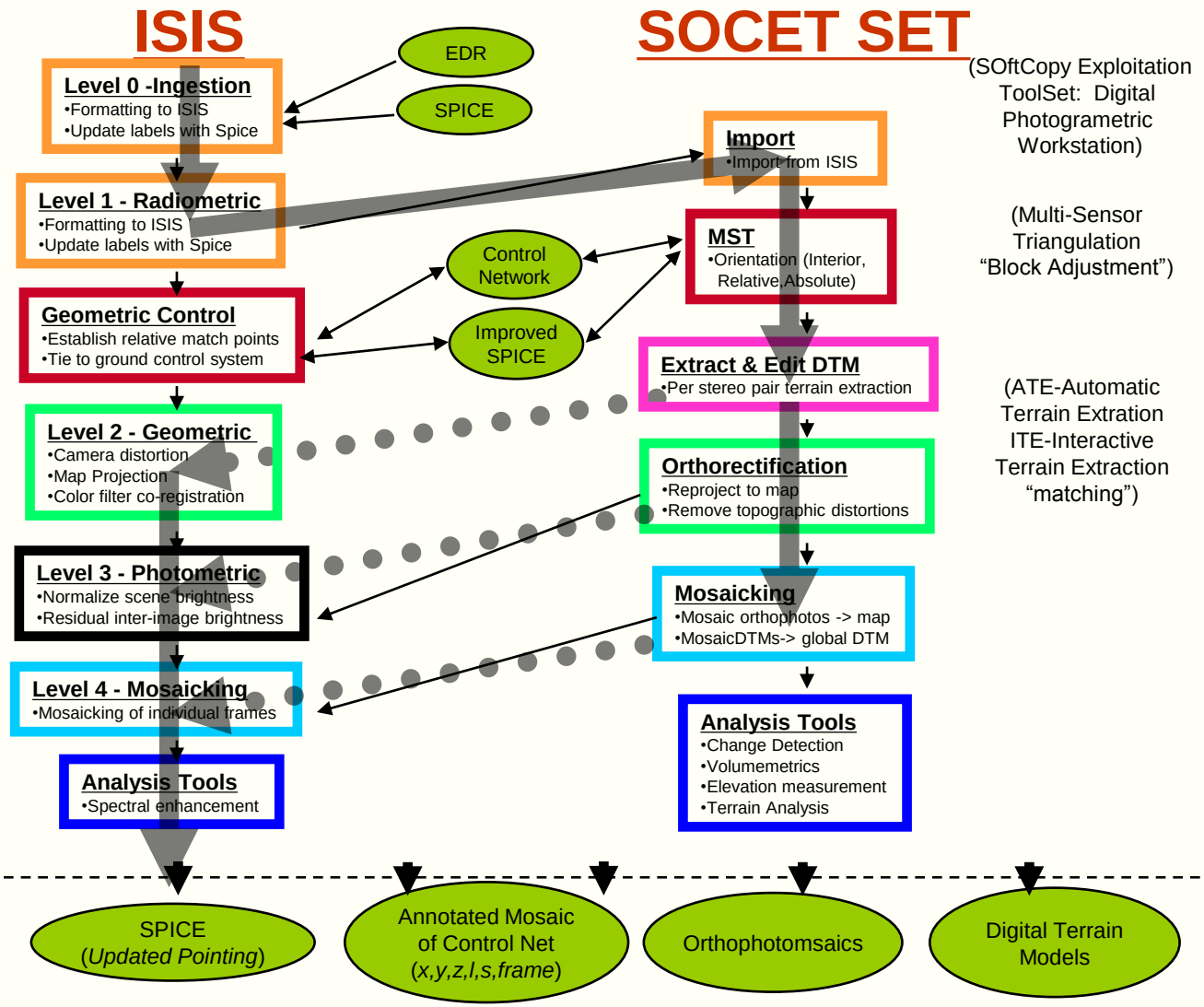
ISIS: Integrated Software for Imagers & Spectrometers

- •USGS in house s/w
- •Strengths:
  - Ingestion/calibration
  - Planimetric mosaicking
  - Quantitative analysis including photoclinometry (shape from shading to estimate topography)
- •Use for calibration, 2D proc.

SOCET SET: SOftCopy Exploitation ToolSET

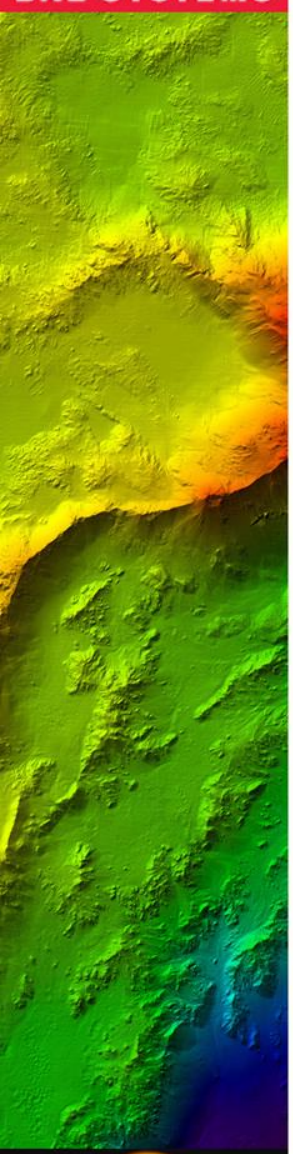
- •BAE Systems commercial s/w
- •Strengths:
  - Stereo display/input
  - Bundle-block adjustment
  - Automatic DTM matching
- •Use for 3D processing
- •Write new sensor models

ISIS/SOCET SET Workflow



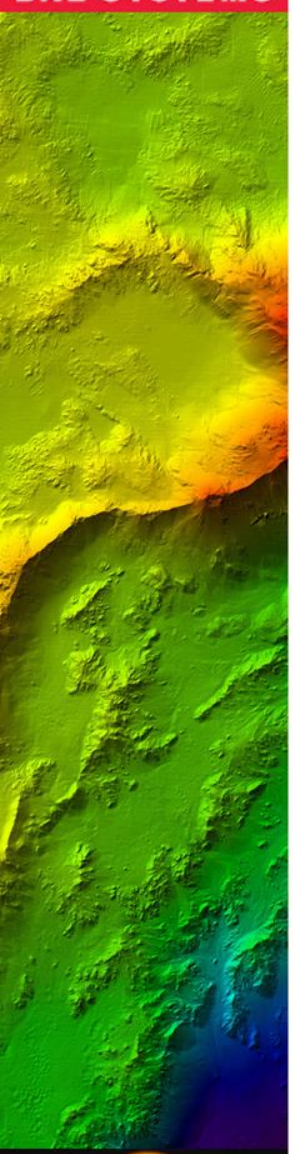
ISIS3 Perl scripts

- Perl scripts not supported by ISIS3 support
  - Email planetaryphotogrammetry@usgs.gov regarding perl script problems/questions
- hinoproj.pl
  - Add SPICE blobs to cube labels (spiceinit)
  - Smooth the Camera Kernel (spicefit)
  - Remove camera distortions from each CCD (noproj)
  - Generate mosaic of undistorted CCDs for import to SOCET SET
    - hijitreg
      - Remove residual misalignment of CCDs
    - Handmos



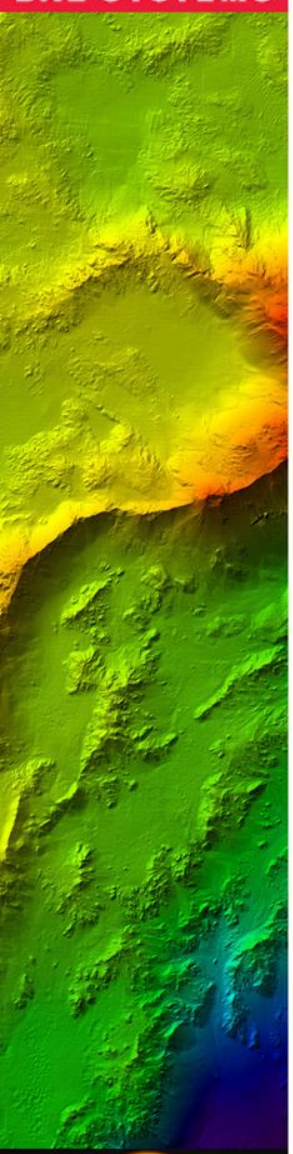
ISIS3 Perl scripts

- hi4socet.pl
  - Wrapper script
  - Start with balanced cubes generated at University of Arizona
  - Runs hinoproj.pl & socetlinescankeywords
  - Outputs images and information needed for SOCET Set import
    - raw 8-bit noproj'ed image mosaic (*.raw)
    - Text file of pushbroom keywords and values (*_keywords.lis)



ISIS3 Perl scripts

- hidata4socet.pl
  - Based on the stereo coverage runs ISIS3 and PEDR programs to:
    - Extract MOLA DTM coverage as an ISIS3 cube and an ascii ARC Grid.
      - <ss_project_name>_mola.cub
      - <ss_project_name>_mola.asc
    - Extract MOLA Track coverage as a Shapefile.
      - <ss_project_name>Z.shp
    - Generate text file listing the geographic reference point coordinate and elevation range of the stereo-overlap area
      - <ss_project_name>_SS_statistics.lis
    - Generate a *campt* listing for each noproj'ed image
      - campt_<noproj_img>.prt.



hi4socet.pl

Command: perl hi4socet.pl fromlist [matchCube]

Where:

fromlist = Ascii file containing a list of input balanced HiRISE ISIS3 cube filenames with extensions.

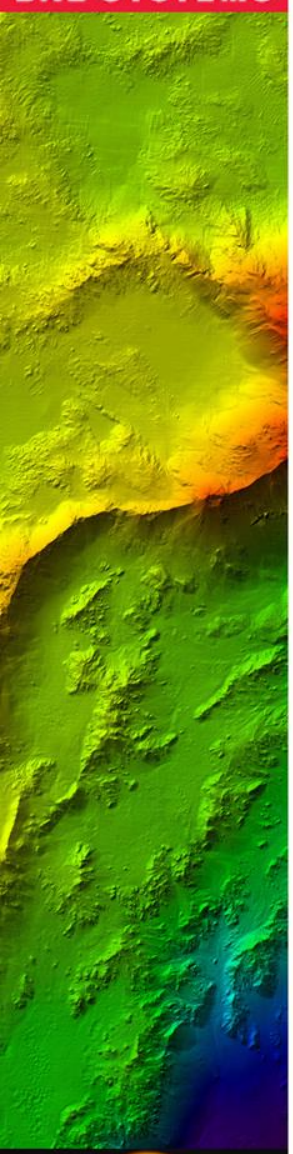
matchCube = Optional user selection of CCD in fromlist to set as the "match cube". This CCD is used as the match cube when running noproj (summation, relative placement on focal plane), and is held in the output noproj mosaic when fine-tuning placement of the noproj'ed CCDs via hijitreg. The default is RED5.

Description:

hi4socet.pl performs ISIS3 processing on HiRISE RED CCDs to create a raw 8-bit noproj'ed mosaic of the CCDs for Socet Set stereprocessing (*.raw), and associated list file of the SOCET SET generic pushbroom sensor model's keywords and values (*_keywords.lis). hi4socet.pl runs hinoproj.pl and socetlinescankeywords.

You will need to bring the *.raw and *_keywords.lis output files to Socet Set and run import_pushbroom to do the import.

Errors encountered in the processing goes to files: "hi4socet.err "hi4socet.err" and "hinoproj.err"



hidata4socet.pl

Command:

hidata4socet.pl <ss_project_name> <imgdir1>/<noproj_img1> <imgdir2>/<noproj_img2>

Where:

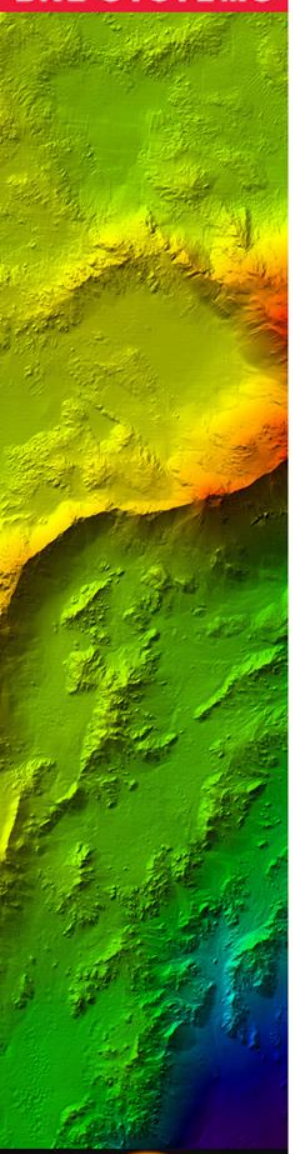
ss_project_name = Name of SS project (e.g. Gullies)
<imgdir1>/<noproj_img1> = First noproj'ed image of a stereo pair
<imgdir1>/<noproj_img2> = Second noproj'ed image of a stereo pair

Description:

Based on the stereo-overlap of the input noproj'ed images, hidata4socet.pl will run ISIS3 and PEDR programs to generate the needed MOLA DTM and MOLA track data, along with a statistics files needed for the creation of <ss_project_name> in SOCET SET.

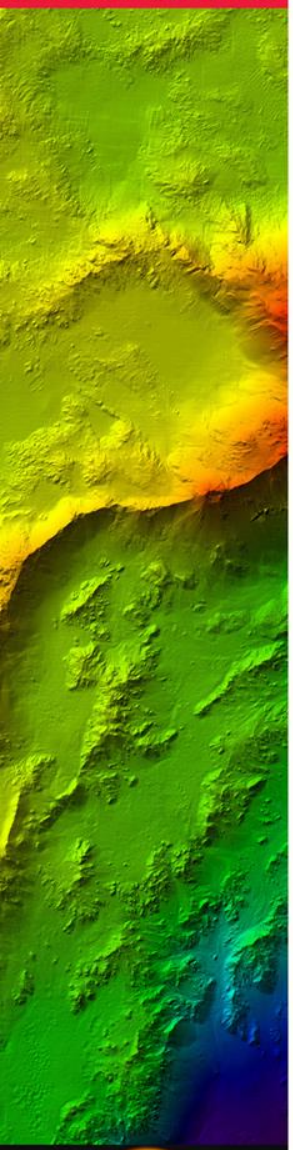
You will need to bring <ss_project_name>_SS_statistics.lis, <ss_project_name>_mola.asc, and MOLA_Tracks directory to Socet Set for project creation and import of MOLA datasets.

Errors encountered in the processing goes to files: "hidata4socet.err"



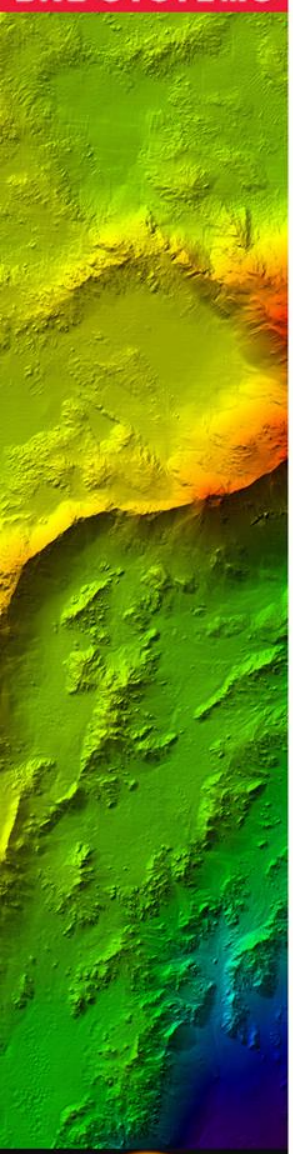
hidata4socet.pl gathers MOLA (*Mars Orbiter Laser Altimeter) data*

- Instrument on Mars Global Surveyor
- Launched in November 1996, collected data through June 2001
- Vertical Accuracy ~ 1 meter
- Profiling resolution (in track spots) on the Martian surface of ~ 300 m
- Reference for controlling HiRISE Images



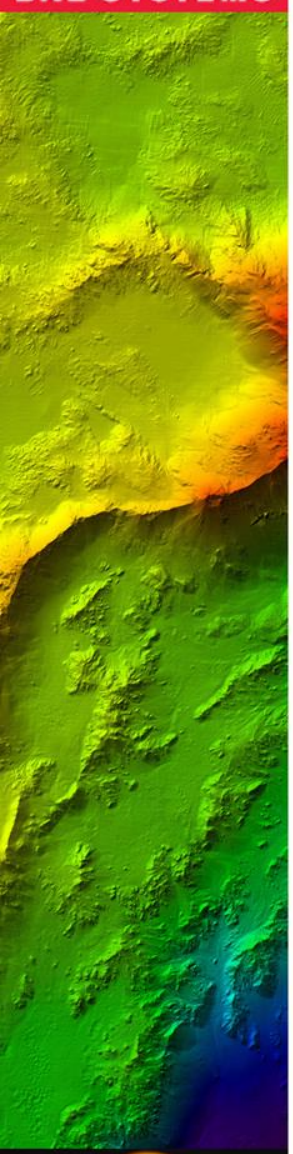
SOCET SET®

The rest of the story….



Key Features of SOCET SET

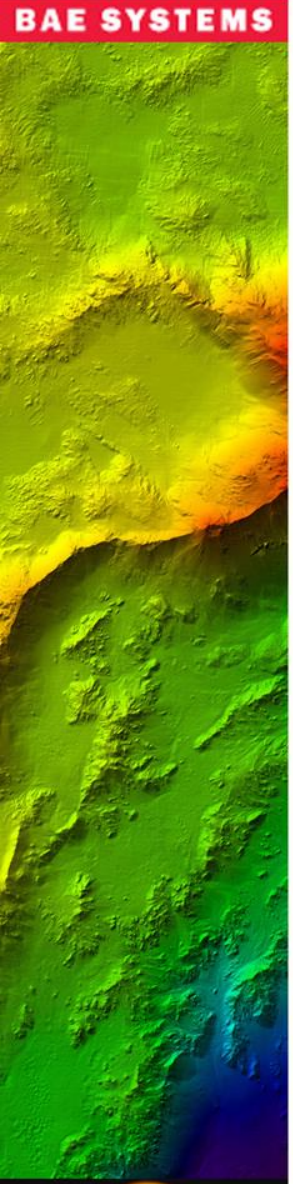
- IPM/APM
  - Interactive and auto point measurement tools
- MST
  Multi-Sensor Triangulation
- ATE/AATE/NGATE
  - Automatic Terrain Extraction options
- ITE
  - Interactive Terrain Edit
- Feature Extraction



SOCET SET Project Creation

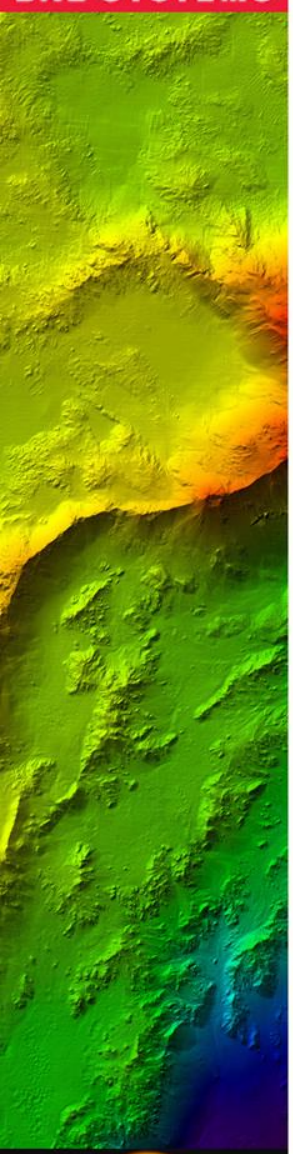
- Create the SOCET SET project
  - Geographic coordinates
  - Set the datum to Mars 2000:

    Positive East lon, ographic lat
  - From <ss_project_name>_SS_statistics.lis,
    - Enter the Reference point
      - The reference point is the clat/clon of the Equirectangular map projection in ISIS
    - Enter the min/max elevation estimate
- Copy *.raw and *_keywords.lis files to the project image directory (generated by hi4socet.pl)
- Copy <ss_project_name>_mola.asc, MOLA_Tracks directory to project's data directory (generated by hidata4socet.pl)



SOCET SET – image import

- **import_pushbroom**
  - SOCET SET Dev-Kit program
  - Imports a raw 8-bit HiRISE noproj'ed image to SOCET in two steps
    1) import the *.raw image output from hi4socet.pl as a framing camera with unknown position/orientation via SS batch import programs
    2) merge what we need from the support file created by the frame import, with the line scanner keywords found in the *_keywords.lis file to create a USGSAstroLineScanner support file.



SOCET SET – image import

Command:

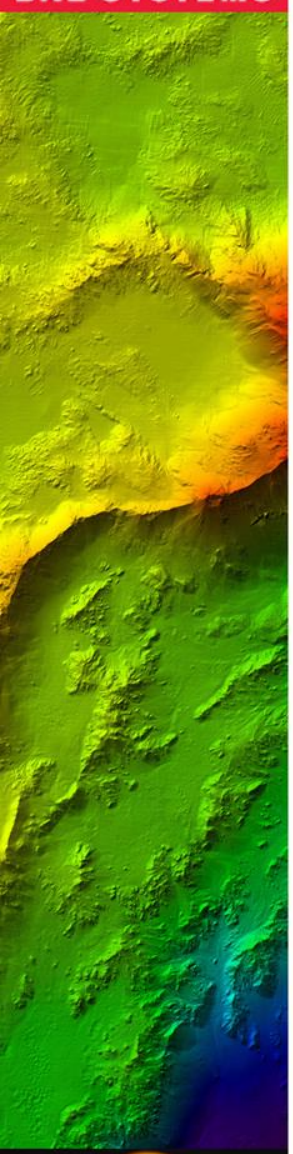
start_socet -single import_pushbroom <project> <fullpath>\<image.raw> <fullpath>\<pushbroom_keywords.lis>

Where:

project = SOCET SET project name to import images under
(path and .prj extension is *not required*)

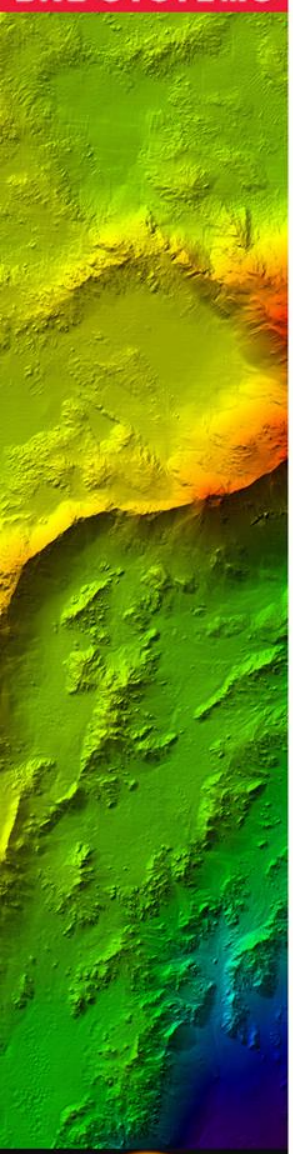
<fullpath>\<image.raw> = *raw* 8-bit linescanner/pushbroom image
(Path to raw image is *required*)

<fullpath>\<pushbroom_keywords>.lis = output file of hi4socet.pl associated with input image.
(Path to keywords file is *required*)



SOCET SET - MST

- **(Dependent) Relative Orientation**
  - Control one image to the other to remove y-parallax
    - Hold nadir-most image and adjust the position and pointing of the second image
  - Manually measure a well distributed set of tie points.
  - Can make height and distance measurements relative to features.
    - Model can be tilted

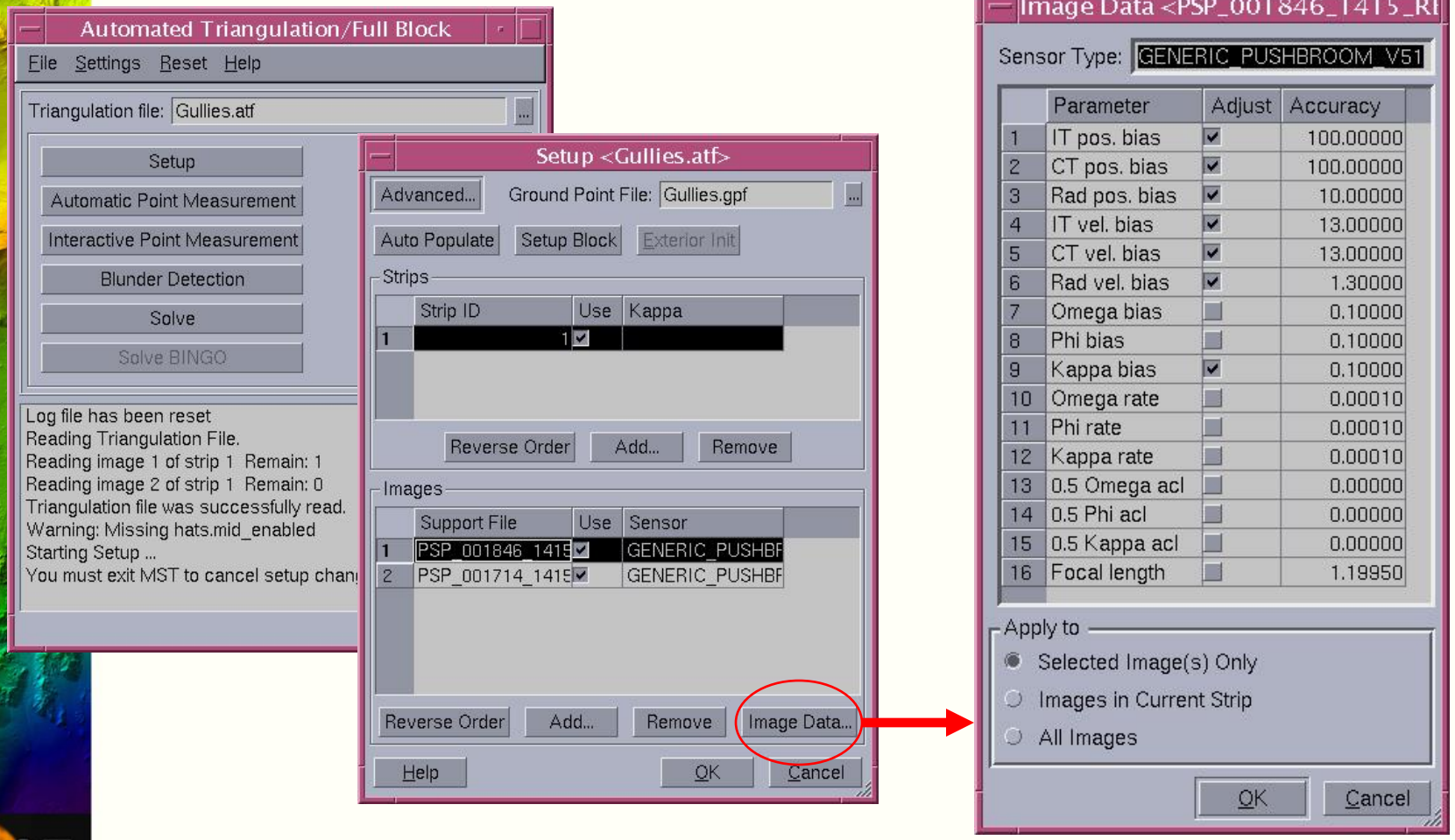


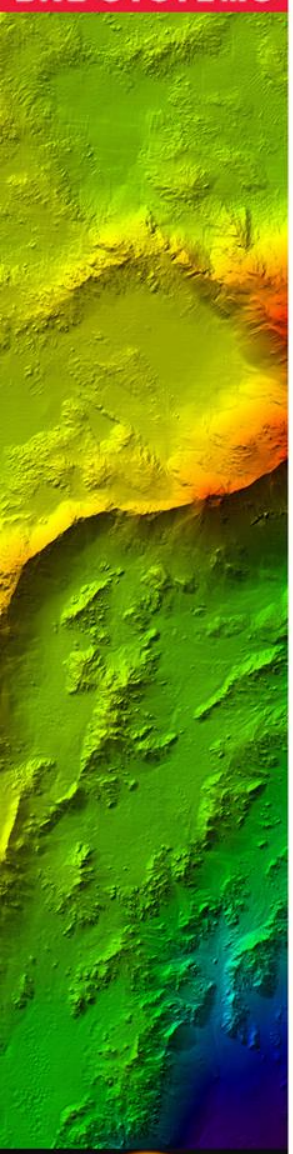
SOCET SET - MST

- **Absolute Orientation (to MOLA)**
  - Uses a combination of XYZ and Z-only ground control points, and tie points
  - Stepwise approach
    - First use heights from MOLA DTM and MOLA tracks for vertical control
    - Then add MOLA track points for horizontal control (if possible)
  - Adjust both images simultaneously
  - Allows use of MOLA DTM as a seed DTM in NGATE / ATE
    - Crucial for DTMs in rough terrain

SOCET SET - MST

- Adjustable Linescanner Parameters





SOCET SET - MST

Recommend Weights (work in progress)

Image Parameters	
Position Bias	
In track	100 m
Cross track	100 m
Radial	10 m
Velocity Bias	
In track	13 m/s
Cross track	13 m/s
Radial	1.3 m/s
Mounting Angle Bias	
Kappa	0.1 degrees
All other image parameters are held	

Ground Point	
Horizontal (XY)	1-5 m
Vertical (Z)	1- 10 m

Weighting Criteria:

Sigma_vel * image_time_in_seconds ~ sigma_bias

Vel_adjust * image_time_in_seconds ~ bias_adjust

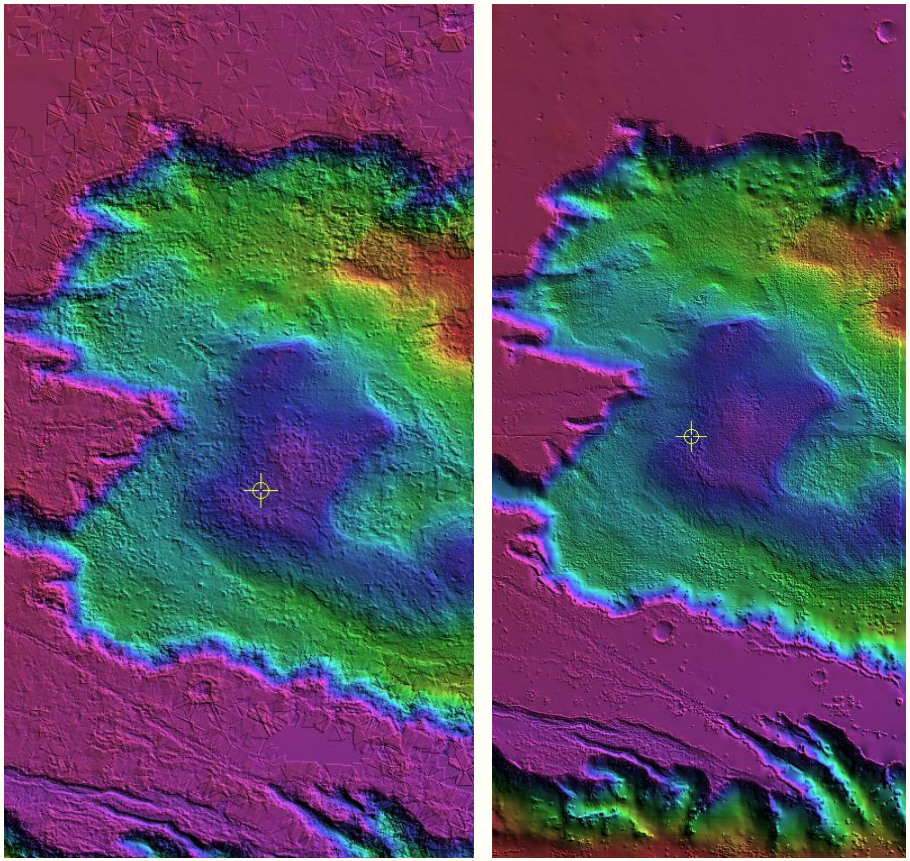
Where ~ means roughly similar, not hugely larger or hugely less

SOCET SET – NGATE & AATE

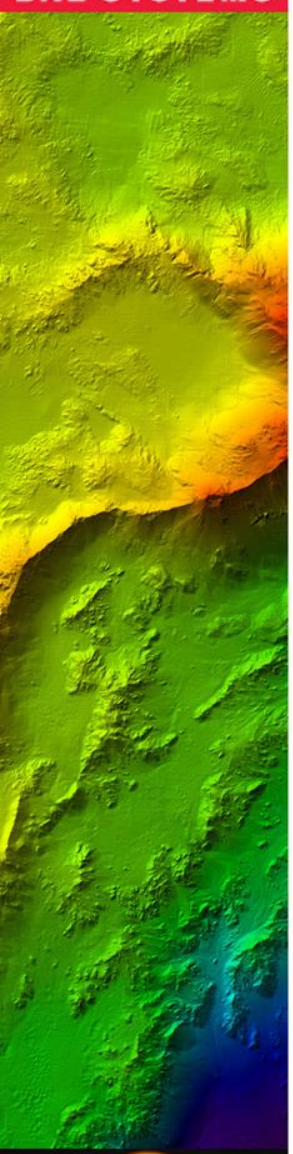
Next Generation ATE

- Area and feature (line) matching
- All image combinations including forward and backward
- Quickly match at every pixel
- Filter all these mutually redundant results for consistency

- Claimed results
  - Faster
  - Higher resolution
  - Fewer errors needing editing



AATE vs. NGATE in Candor Chasma

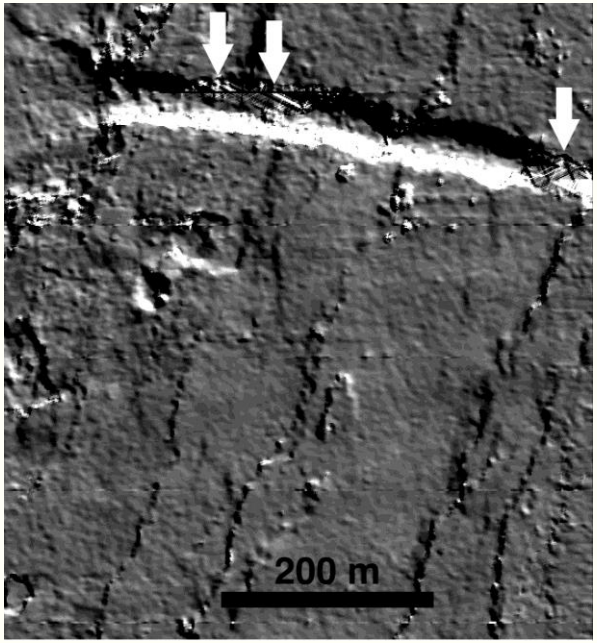


SOCET SET – NGATE & AATE

- ***Must generate epi-polar rectified image pairs***
  - On-the-fly epi-polar rectification does not work for linescanner images in NGATE/AATE
  - Highest resolution image on left
- Recommendations
  - Use NGATE followed by AATE to smooth the NGATE results to generate a 1 m/post DTM.
    - NGATE
      - ngate_HIRISE.strat
      - Seed DTM with MOLA
        - Models with high relief that have been tied to MOLA
        - Not necessary for flat terrain
    - AATE
      - Make a copy of the NGATE DTM
      - Modify keywords the DTM header for AATE
        - *Do not update support files using AATE GUI…elevation values will be reset*
      - Rename adapt.strat.onepassAfterNGATE 'adapt.strat' for AATE
  - DTM polygon boundary that follows terrain

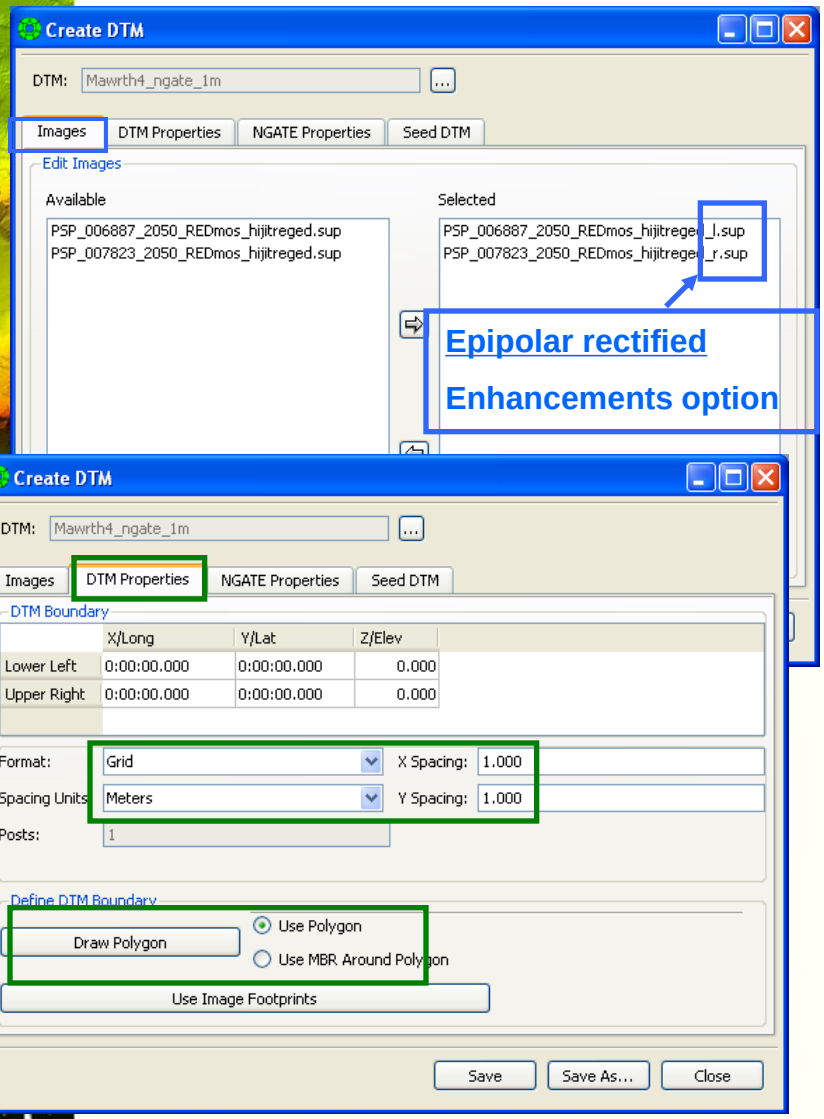
SOCET SET – NGATE & AATE

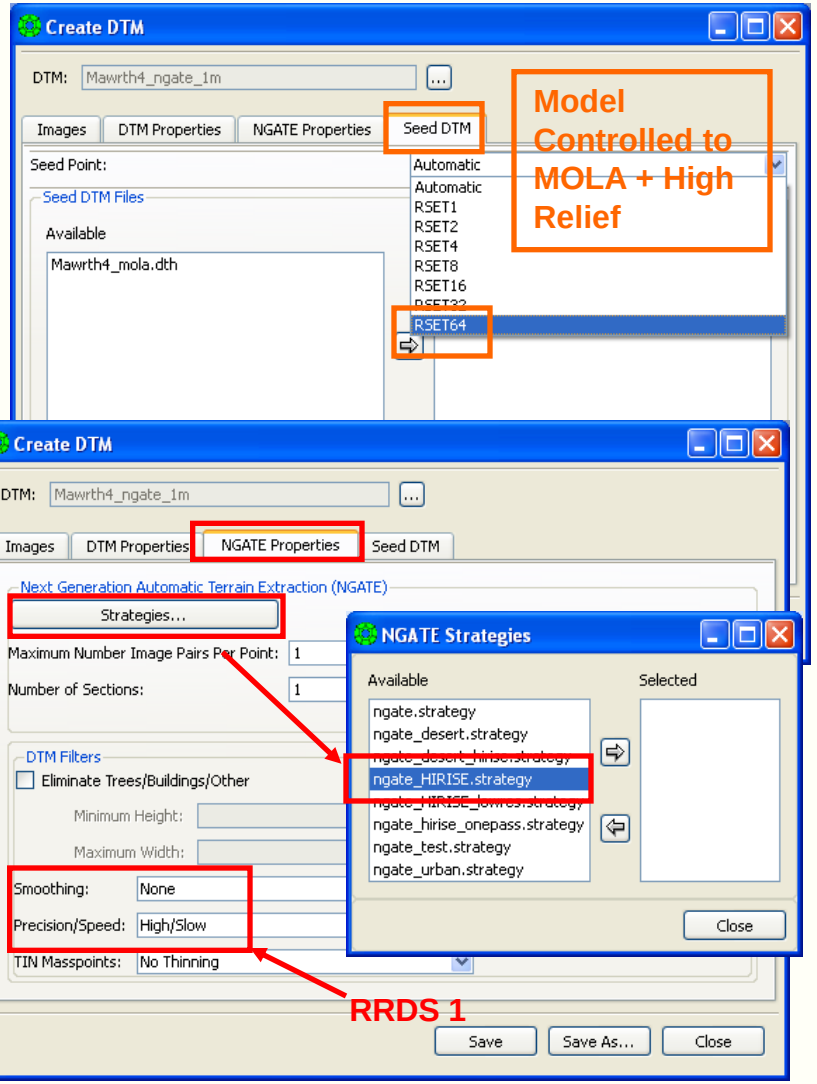
NGATE 'legos' artifacts



AATE DTM results

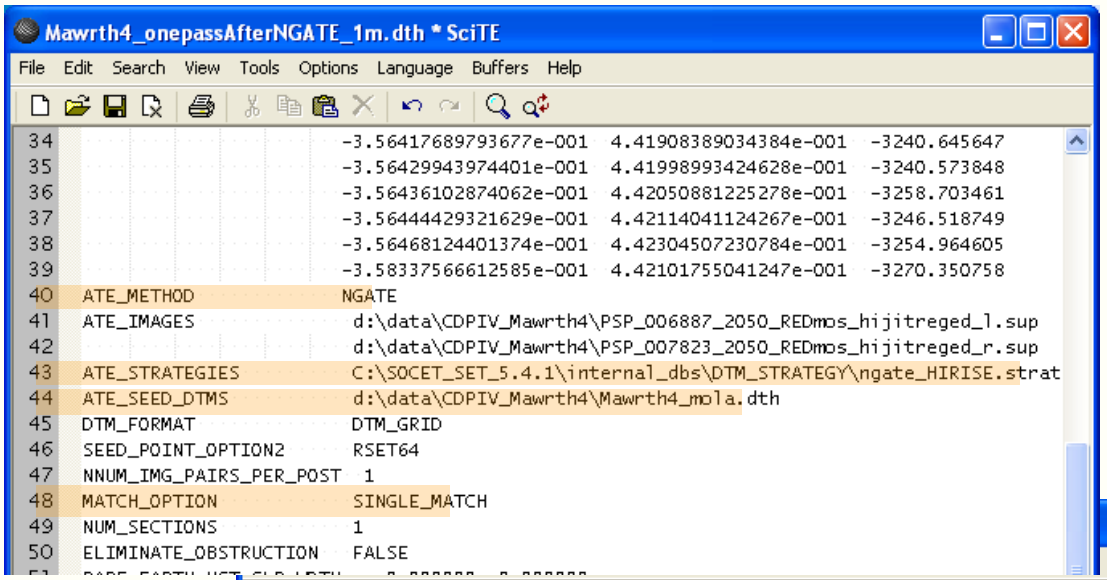
SOCET SET – NGATE & AATE



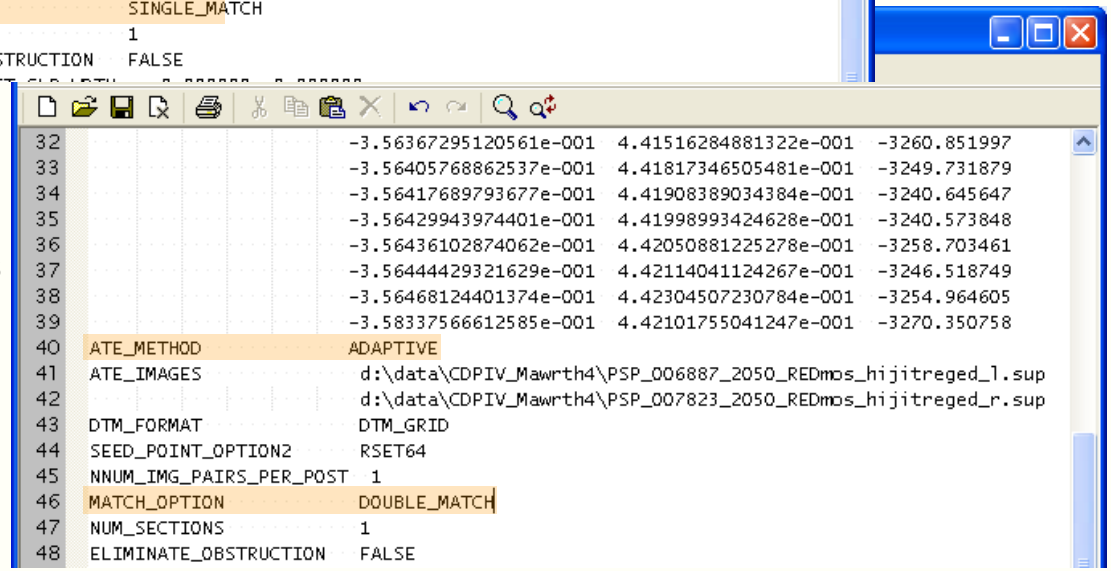


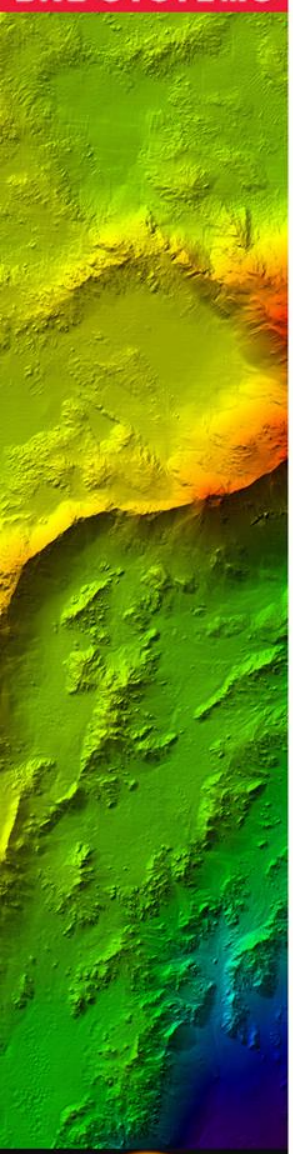
SOCET SET – NGATE & AATE

Keywords to change or delete in NGATE formatted DTM header



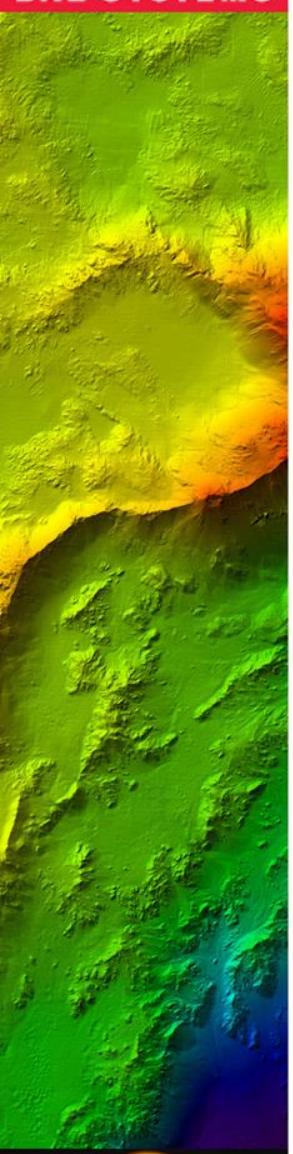
Keywords in AATE formatted DTM header





SOCET SET – NGATE & AATE

- Options
  - Harder image stretch (must be committed to disk)
  - Back matching
  - DTM vs TIN formats
  - Experiment with adding a single pass using filtered or unfiltered images at RRDS 1 after AATE ends.
  - If you want to use nonadaptive ATE in more creative ways, you need to get strategy file training from BAE
    - <ss_install_dir>\internal_dbs\DTM_STRATEGY\README



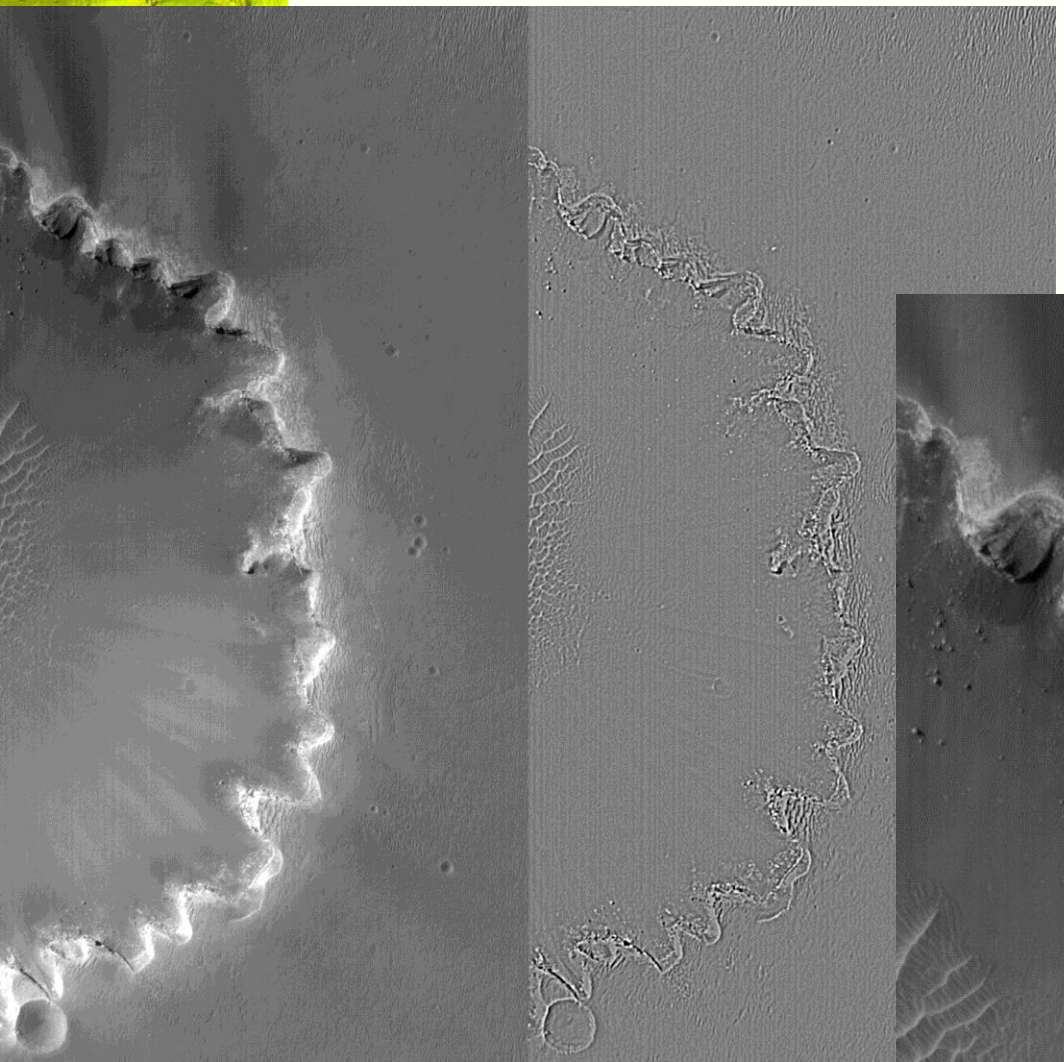
Difference of Gaussians (DoG Filter)

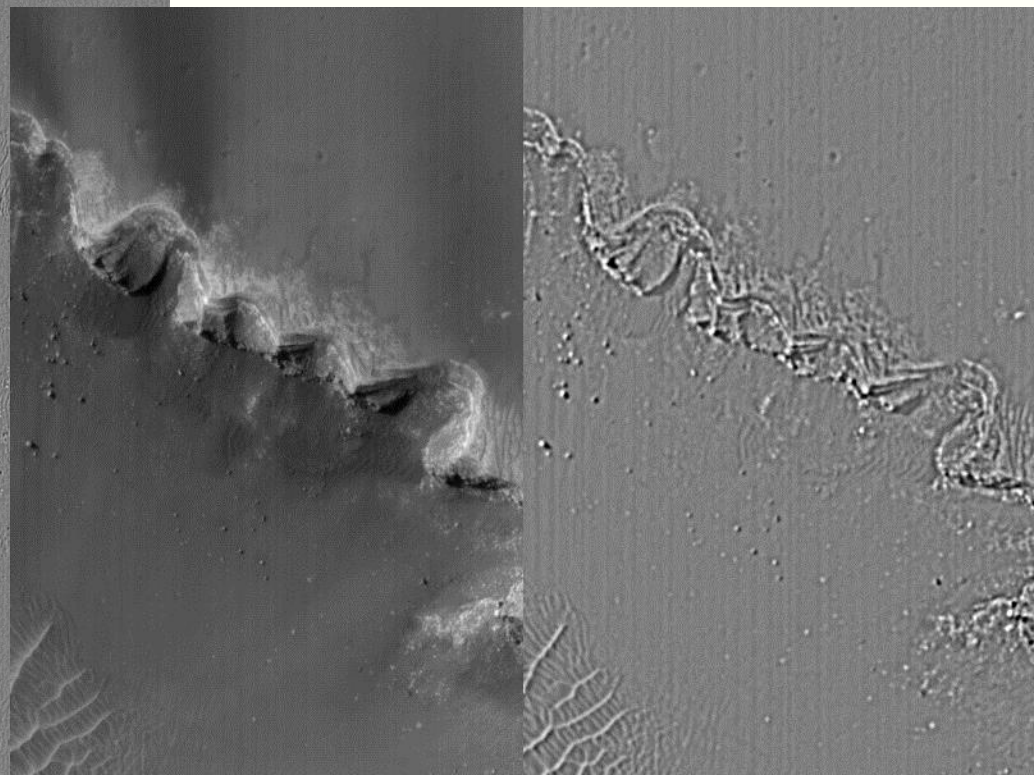
- Technique for very bland, featureless images
  - Opportunity Crater (PSP_001414_1780/PSP_001612_1780)
- ISIS3 commands
  1) gauss FROM=*noproj.cub* to=*gaus1.cub* size=7 stddev=1
  2) gauss FROM=*noproj.cub* to=*gaus2.cub* size=13 stddev=2
  3) algebra from1=*gaus1.cub* from2=*gaus2.cub* to=*DoG.cub* operator=subtract
- Convert DoG.cub to 8-bit raw image
- Import into SS, along with corresponding *_keywords.lis file
- Replace TRI_PARS array of DoG support file with TRI_PARS array of the controlled support file

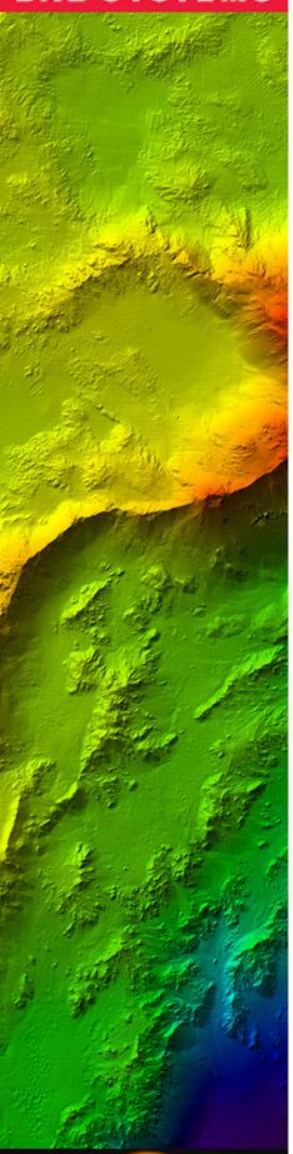
Difference of Gaussians (DoG Filter)

- Run AATE to generate a 2 m/post DTM using original images and default adapt.strat
- (Option) Edit major blunders in 2 m DTM, then resample to 1 m DTM
  - reset FOMS
- Replace <ss_install>\internal_dbs\DTM_STRATEGY\adapt.strat with filterpass.strat
  - One pass strategy file, at RRDS 1
- Edit the 1 m *.dth file to update support files listed to DoG support files
  - *Do not update support files using AATE GUI…elevation values will be reset*
- Run AATE on 1m DTM with DoG filtered images

Difference of Gaussians (DoG Filter)

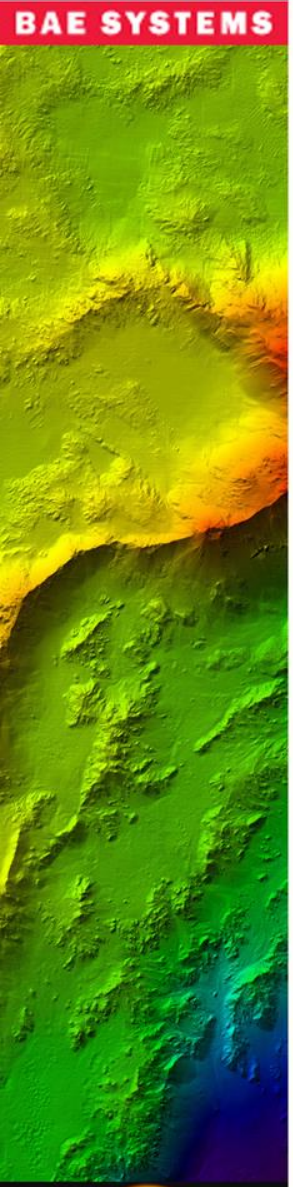


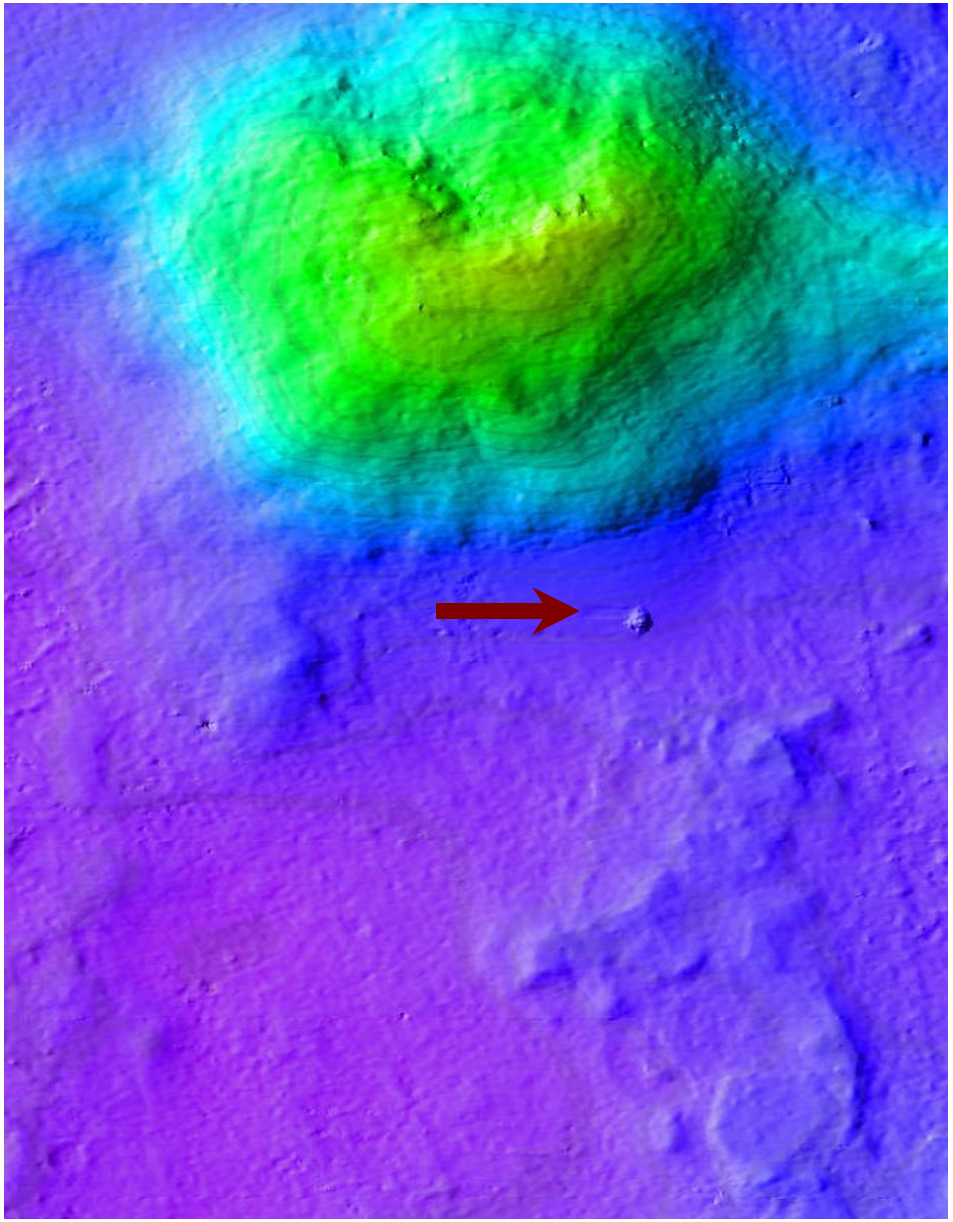




SOCET SET - ITE

- Interactive Terrain Edit (ITE)
  - Editing tools
    - Post
    - Area
    - Geomorphic
    - TIN tools
  - Terrain Shaded Relief (TSR)
  - We concentrate on major blunders
    - can re-evalutate specific areas by request
  - Edit time ranges from 12 hrs to 48 hrs per DTM





Closeup of Columbia Hills DTM

Elevation Range 128 m
Contour Interval 5 m
Rectangle is ~0.6x1.1 km

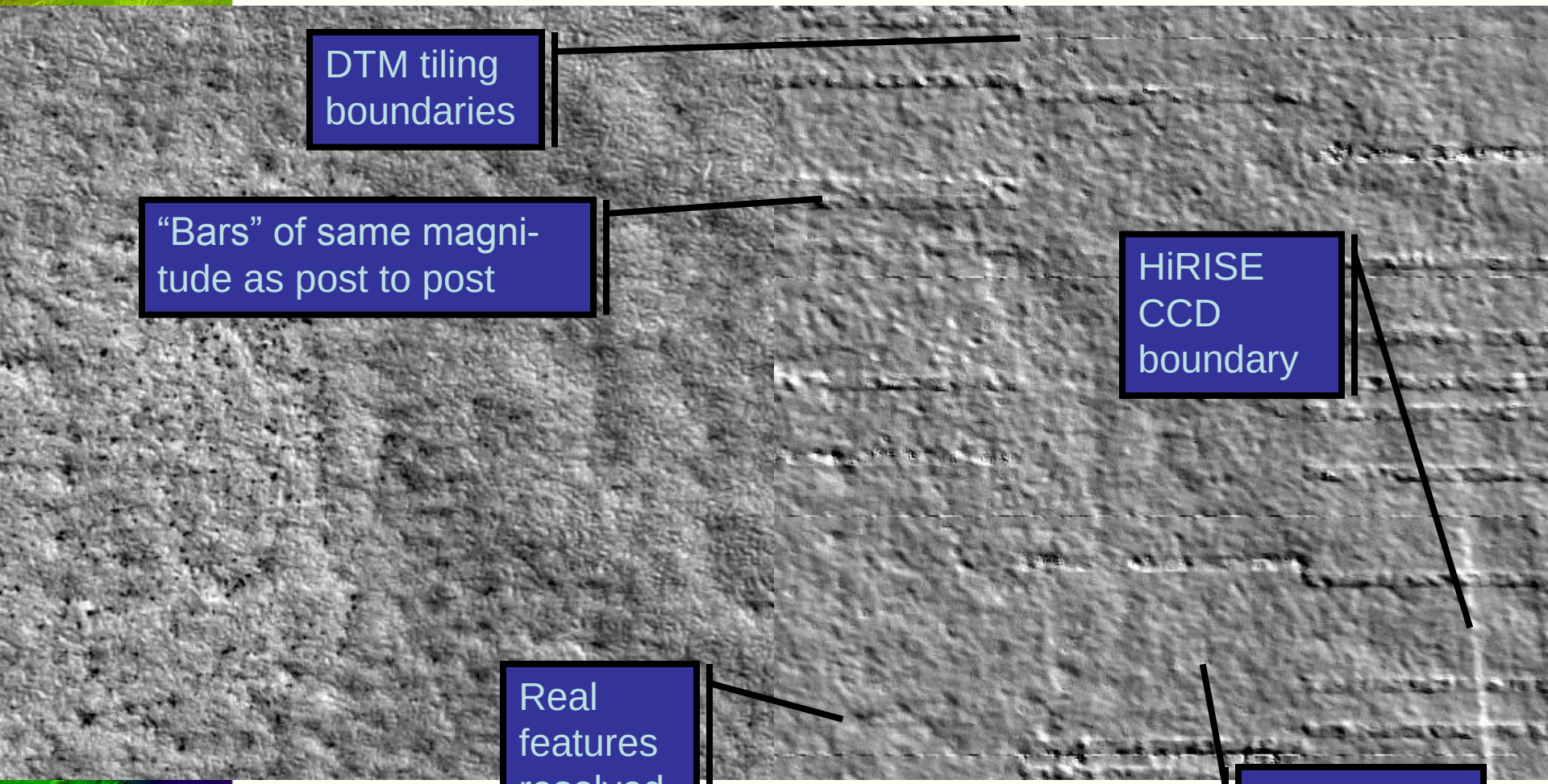
Includes Husband Hill,
Home Plate…
and the worst matching artifact in the entire DTM ("Mound" located in area of very dark, featureless dunes)

Total editing (QC) time: 12 h
= 0.22 h / million posts

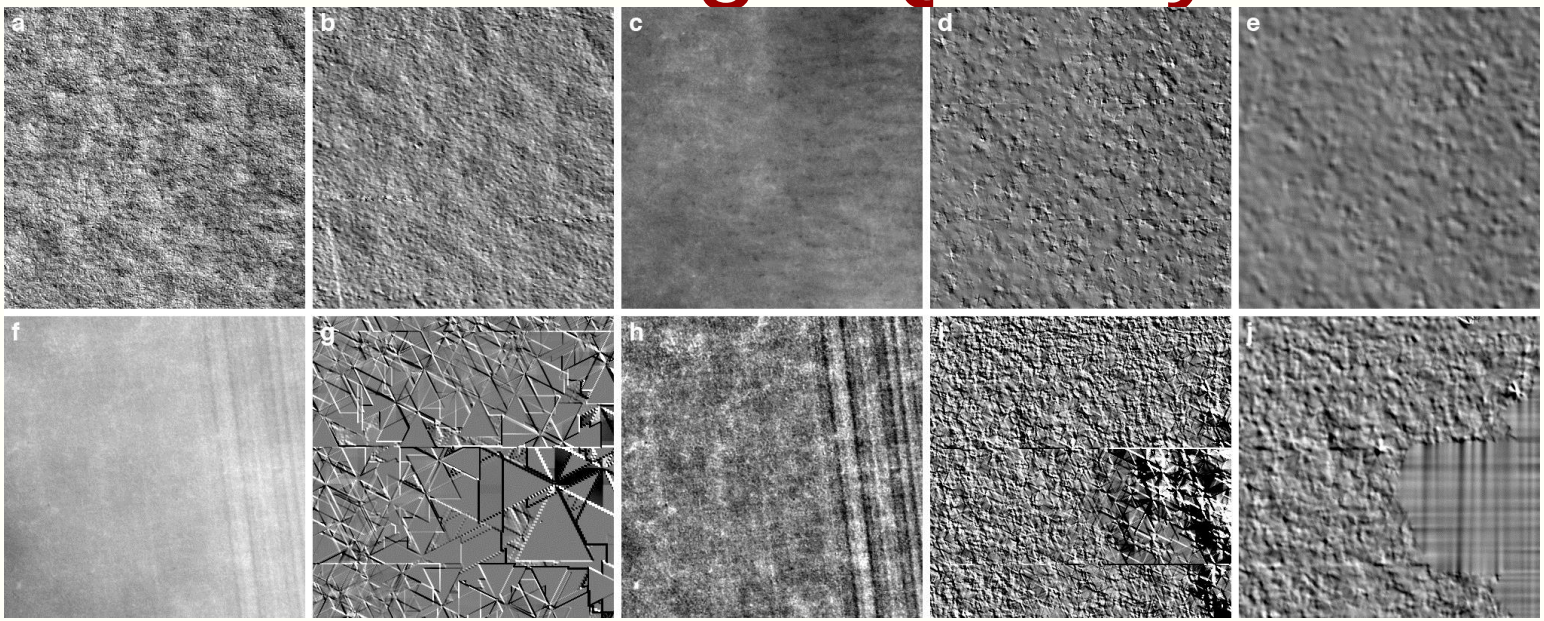
Compare (in same units)
HiRISE pre-mission WAG: 1
Apollo Pan & Metric: 4
Viking, Magellan: 55

"Ordinary" DTM Artifacts

Visible because of low relief of Phoenix landing site



Degradation of DTM with Image Quality



a,b: Decent quality image (Phoenix landing site) and DTM shaded relief

c–e: Cloudy image, DTM shade, DTM shade after smoothing

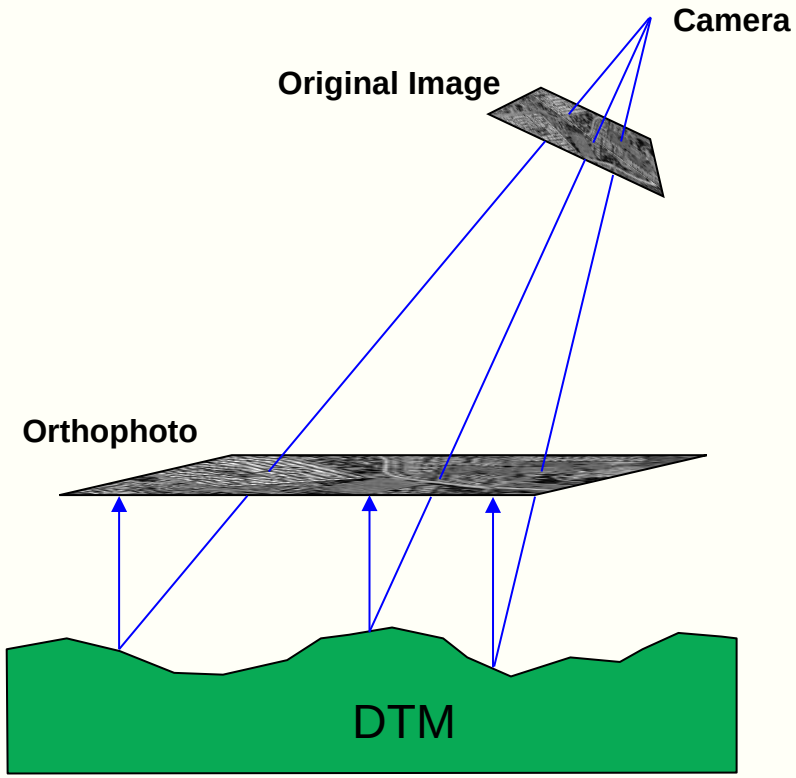
f–g: Very cloudy and noisy image, raw DTM shade with “snow angels” or “crystals”

h–j:DoG filtered image, DTM from filtered image, DTM with area editing and smoothing

Orthorectified Images

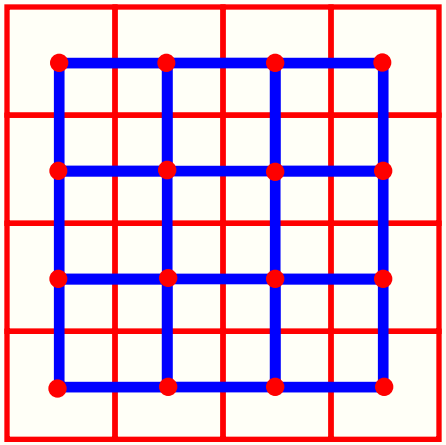
Source: BAE SYSTEMS® Training

- An orthoimage has had all distortion due to camera obliquity, terrain relief, and features removed
- SOCET SET® converts original images into an orthoimage by transforming the pixels to their proper position according to the given sensor, terrain, and feature information
- In the final product all points in the image appear as if the observer were looking down from nadir position



SOCET SET - ORTHOIMAGE

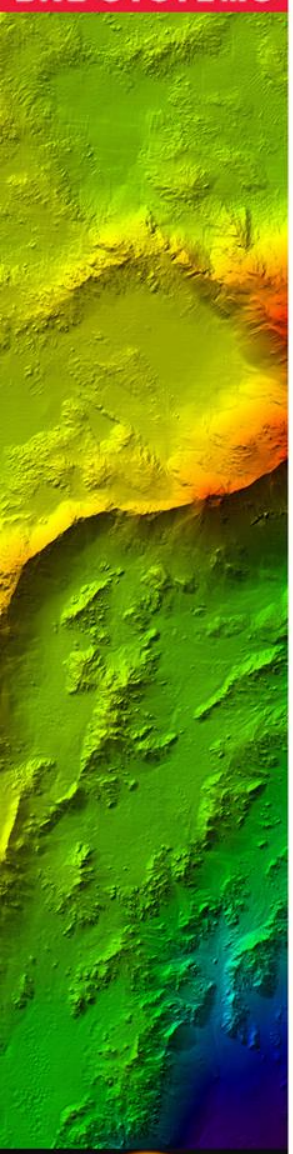
- Orthoimage image production
  - If Orthoimage boundary is set to that of the DTM, the orthoimage will be 1 pixel smaller than the DTM



Red Dots: SS DTM posts

Red Grid: Extent of SS DTM as an image

Blue Grid: Extent of SS orthoimage using the DTM to define the x/y range

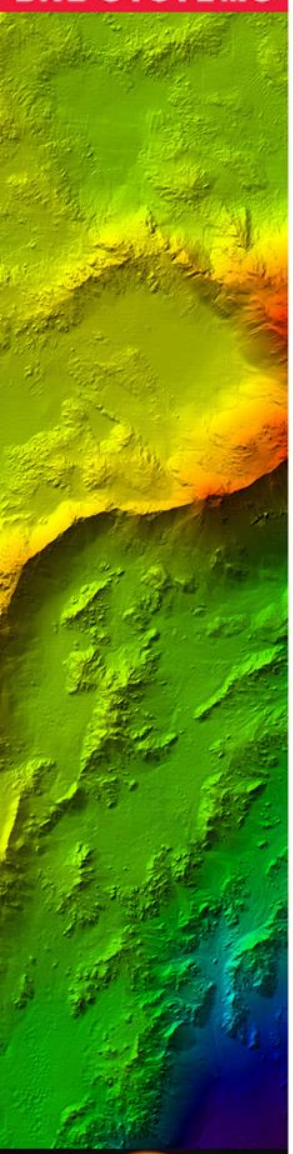


SOCET SET - ORTHOIMAGE

- If need 1:1 pixel correspondence between orthoimage and DTM, enter boundary returned by calcOrthoBdry
  - Values written to screen and <project_data_dir>\calcOrthoBdry.log

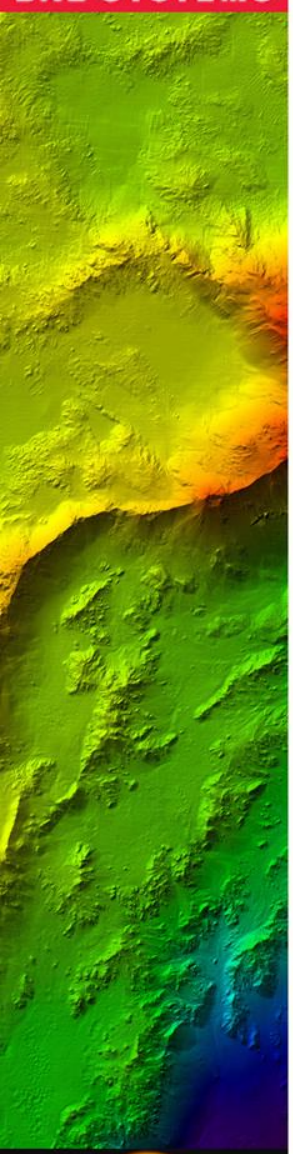
Command

start_socet –single calcOrthoBdry <ss_project> <DTM>



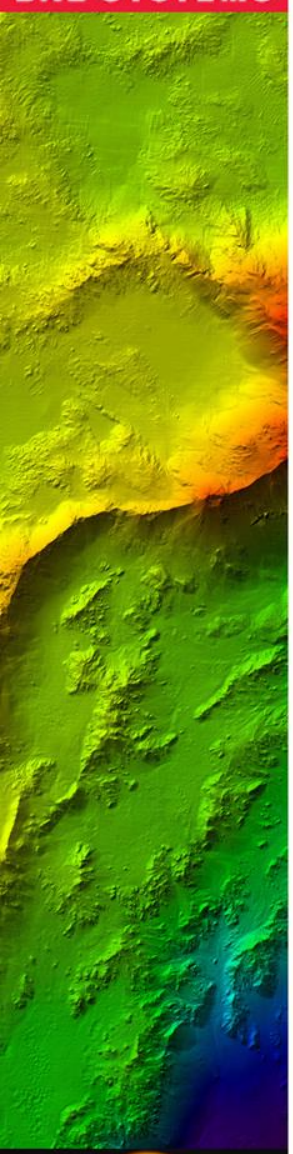
SOCET SET to ISIS3

- USGS standard products
  - DTMs
    - 1 m/post
  - Orthoimages
    - 1 m/pixel and 0.25 m/pixel (nominal)
  - Mars IAU Ocentric lat, +East lon coordinate system
  - -65° lat to +65° lat
    - Simple Cylindrical map projection, clon=180
  - 65° lat to the poles
    - Polar Stereographic map projection



SOCET SET to ISIS3

- *Different scaling radii must be accounted for*
- dem2isis3; ortho2isis3
  - Convert SS DTMs and orthoimages to ISIS3 cubes
  - Outputs
    - Raw format file and corresponding ISIS3 script to generate cubes in:
      - USGS Standard Formats
        - ISIS Scaling radius
      - Socet Set Native Format
        - “SS_” prefix added to output cube name
        - User note: “PIXEL SCALE NOT ISIS COMPATIBLE …”
        - *Adding a SS projection to ISIS so “SS_” cubes can be used directly*

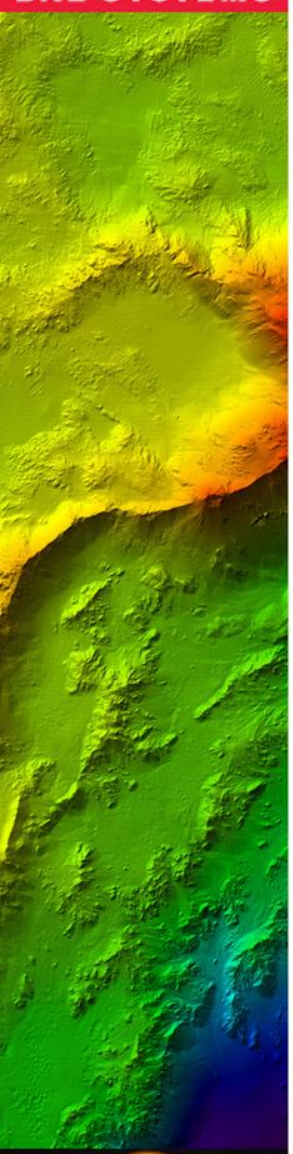


SOCET SET to ISIS3

Commands

start_socet -single dem2isis3 <project>
<socet_DTM> <isis>.cub [layout_flag]

start_socet -single ortho2isis3 <project> <ortho>
<isis>.cub [layout_flag]



Future Work

- Update procedures to work with HiRISE jitter corrected images
  - Waiting for jitter correction to be part of the HiRISE pipeline.
- USGS migration to SOCET SET GXP
  - Framing Sensors need ISIS to GXP translation
  - Non-Framing Sensor Models must be converted to Community Sensor Model (CSM) standards
  - In negotiation with BAE to get USGSAstroLineScanner sensor model that has been converted to CSM standards.
- Systematic development of better matching strategies
- Improve Tutorial
  - Add documentation for working with CTX images.
  - Depending on funding, convert to a web-tutorial.
  - Add other sensors
- WIKI page for download coming…In meantime, download from:
  http://webgis.wr.usgs.gov/pigwad/tutorials/socetset/SocetSet4HiRISE.htm