Automatic Detection and Characterization of Impact Craters

Tomasz F. Stepinski

May 2010

Detection of Craters

from images

advantages

- Imagery data is most readily available.
- Some imagery data has fine resolution.

disadvantages

- Quality of images varies.
- No high resolution global mosaic.
- Fundamental limitation of 2D data.
- Illumination effects.

from topographic data ✓

advantages

- DEM provides a direct, 3D representation of craters.
- Possibility of calculating more parameters, such as crater depth.
- No problems associated with visibility.
- Global mosaic for Mars.

disadvantages

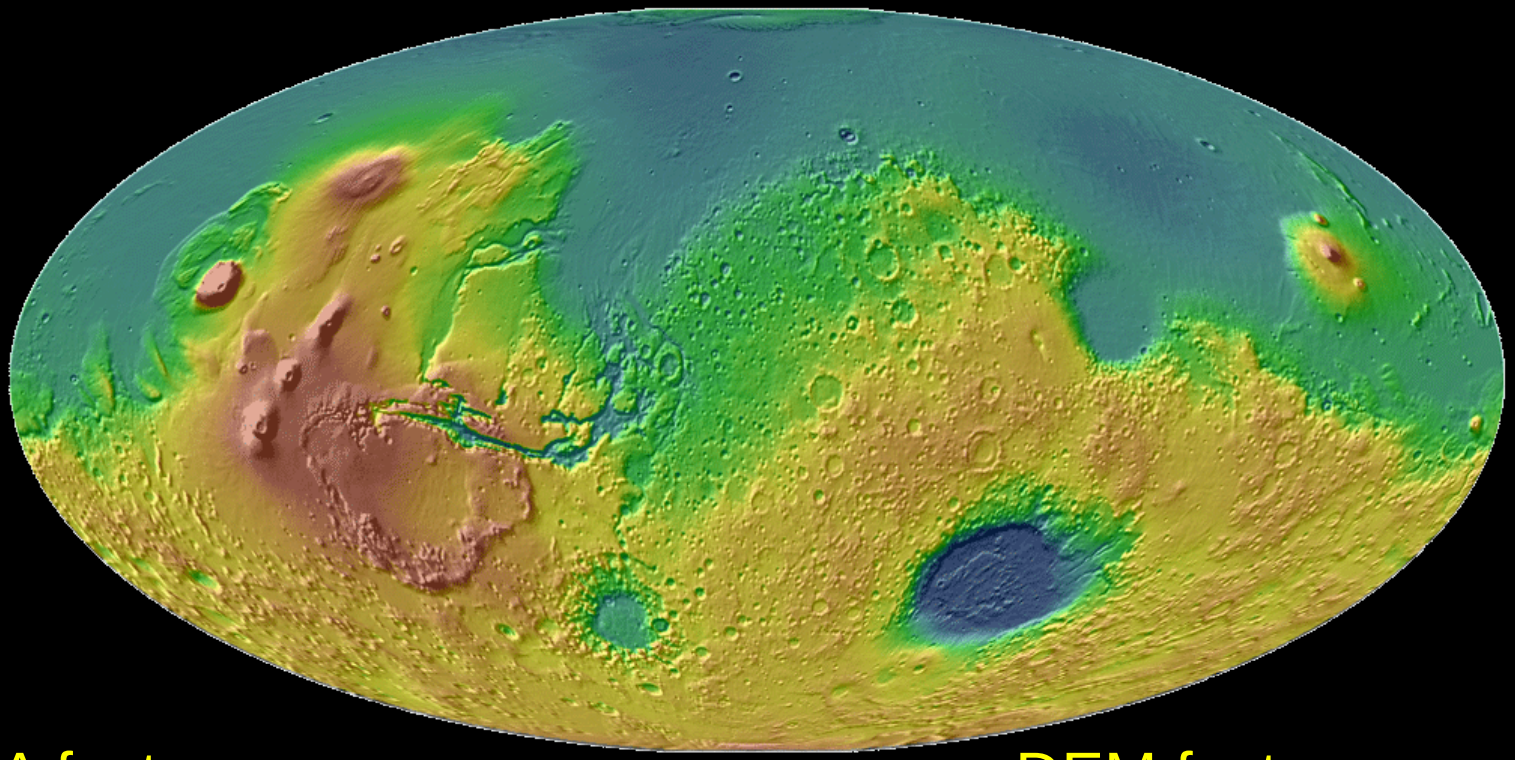
- Low resolution.

Detecting Martian Craters from Topography - Content

- Global auto-detection of craters from MOLA topography
- Comparison to “standard” Barlow global catalog of craters
- Implication for extent of cryosphere
- Where are the deepest craters on Mars?
- Where are the shallowest craters on Mars?

Detection of Martian Craters from Topography

Global dataset



MOLA facts:

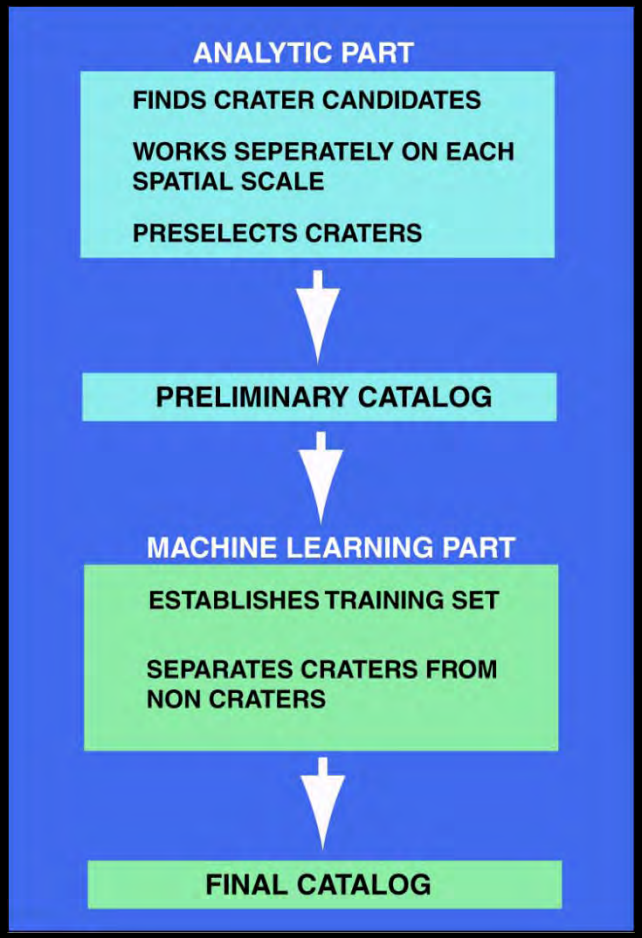
- 640 million measurements
- 300 m along the track
- 1 km between tracks

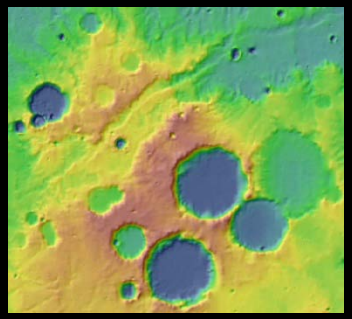
DEM facts:

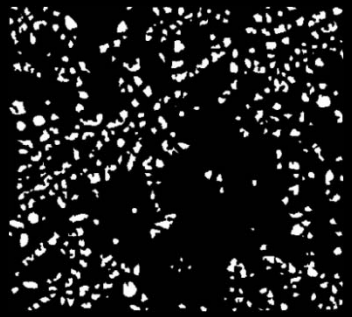
- 46,080 x 22,528 pixels
- 128 pixels/degree
- 40% pixels interpolated

Detection of Craters from Topography

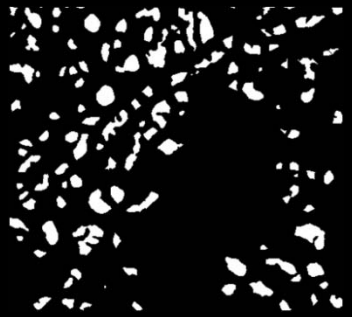
Algorithm for detecting craters from topography



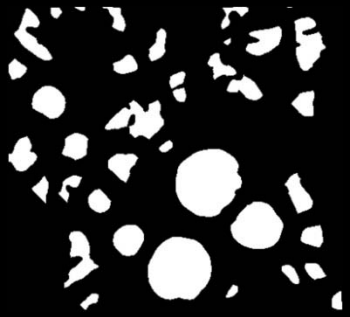




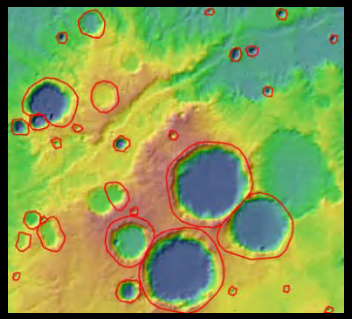
small



medium



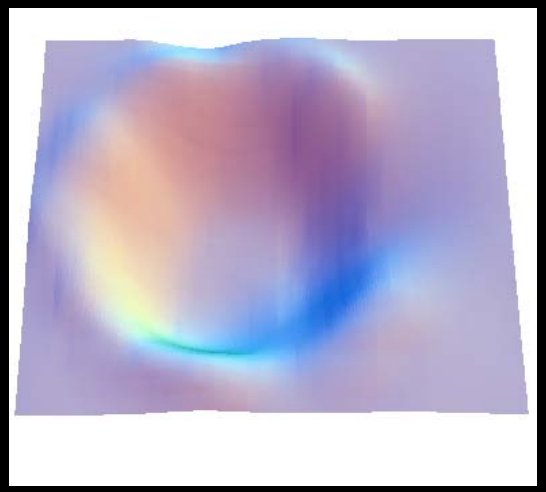
large



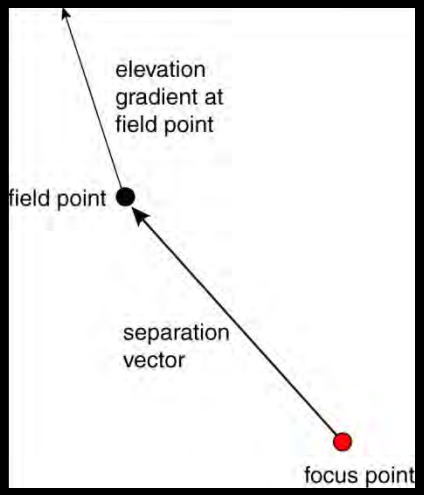
Michael Mendenhall
undergraduate
student

T. F. Stepinski et al., (2009) Machine Cataloging of Impact Craters on Mars. Icarus, 203, p.77-87.

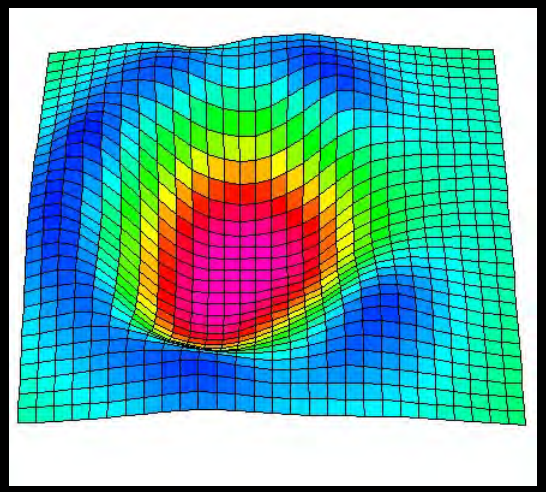
Depressions finding transform



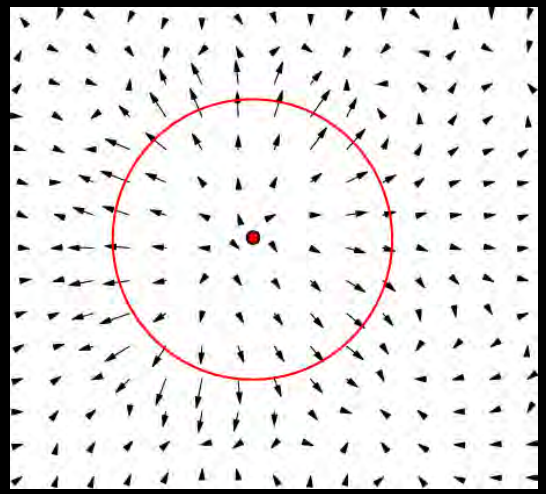
Input: elevation field (DEM)



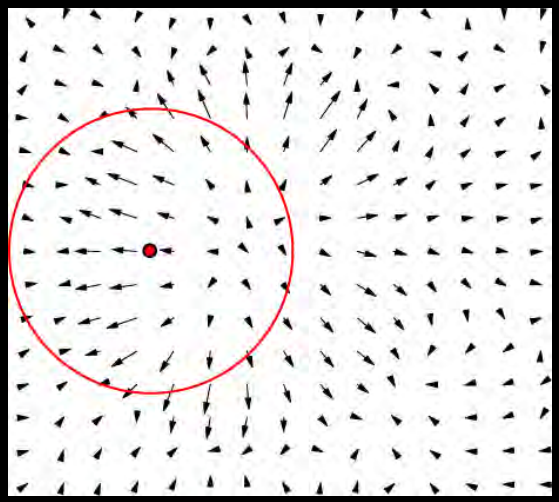
Core idea



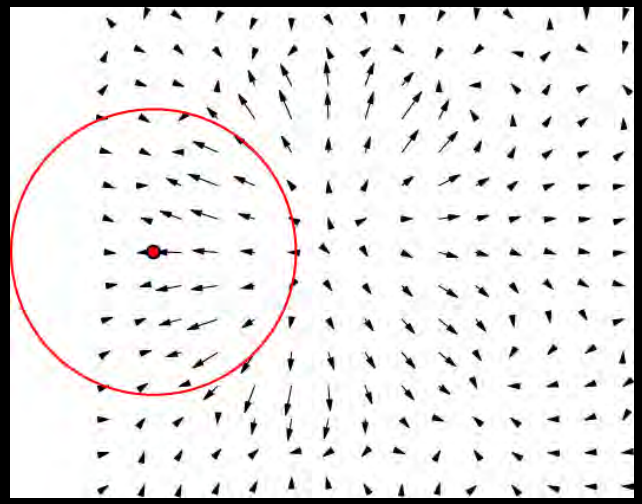
Output: “depressions” field



Focus point in the center of depression (++)

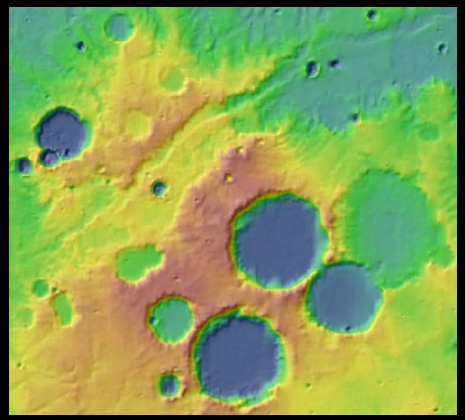


Focus point on the wall of depression (+)

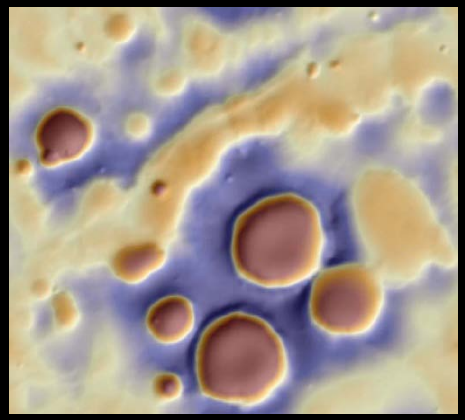


Focus point outside depression (-)

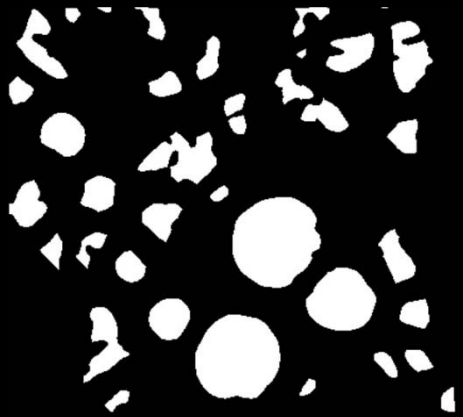
Depressions finding transform: an example



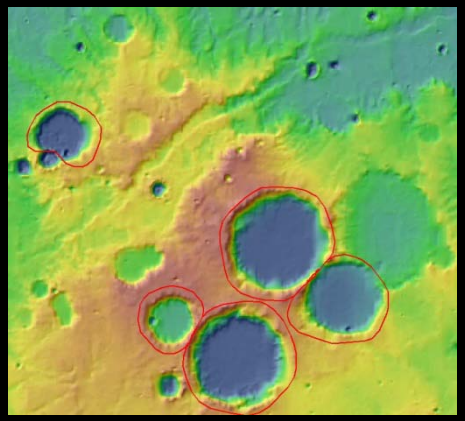
DEM



"depressions" field for r = 20 pixels



individual depressions – crater candidates

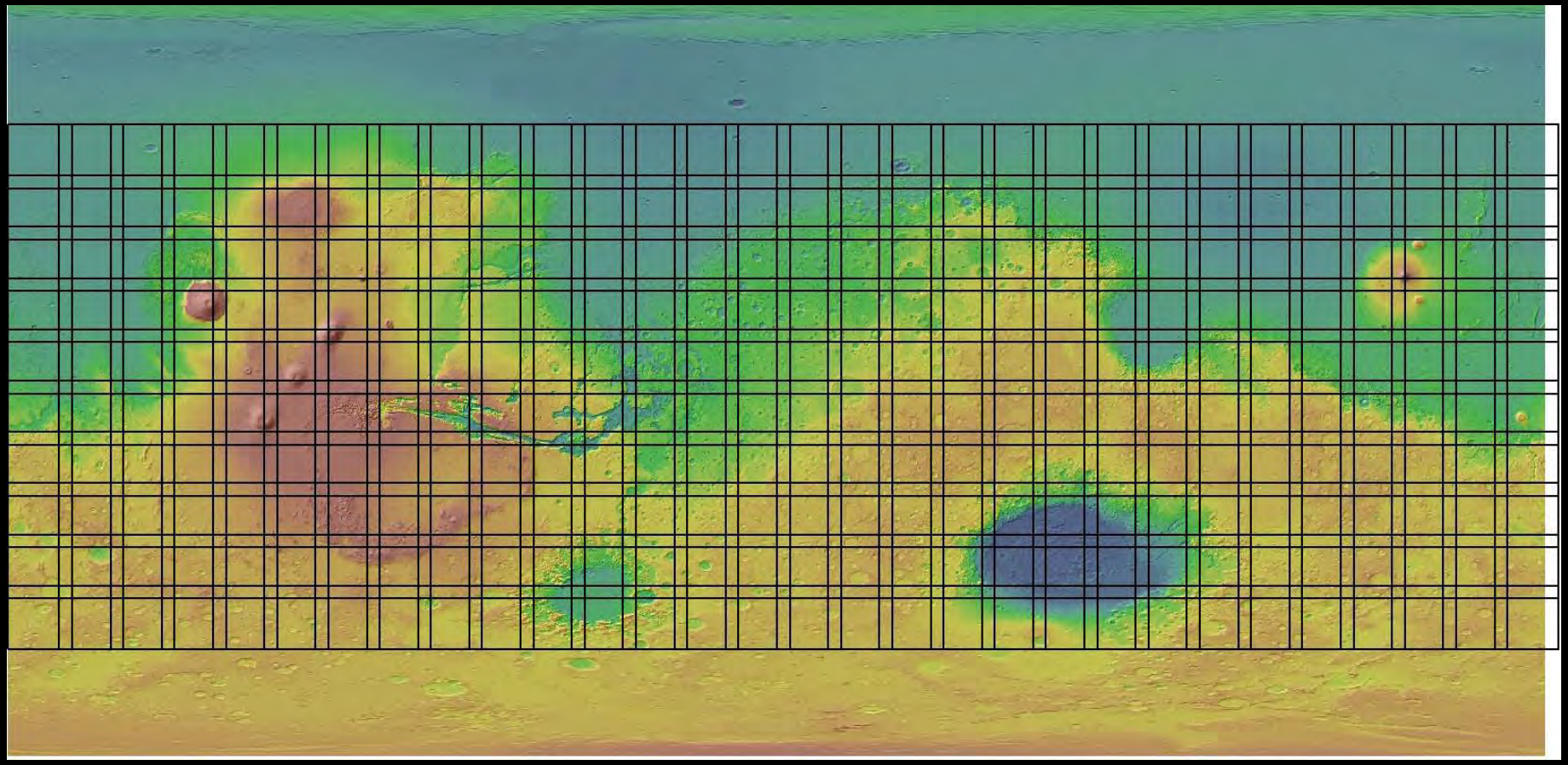


craters selected by Our machine-learning algorithm

- Classifier is constructed using 5 features of each depression: radius, depth, radius/depth ratio, two shape coefficients.
- Initial training set was labeled by human expert. It consists of 4702 samples for small-sized craters, 894 samples medium-sized, and 403 samples for large-sized craters.
- Accuracy of the classifier is 95% for small craters, for larger size craters>85%. Accuracy is determined by averaging over 10 x 10-fold cross-validation.

- CRATERMATC software.
- Fast, written in C++
- Produces catalog of crater candidates.
- Results can be used as an input to the machine learning-based selection algorithm.
- Free!
- Available at cratermatic.sourceforge.net

Global Auto-Survey of Martian Craters from Topography

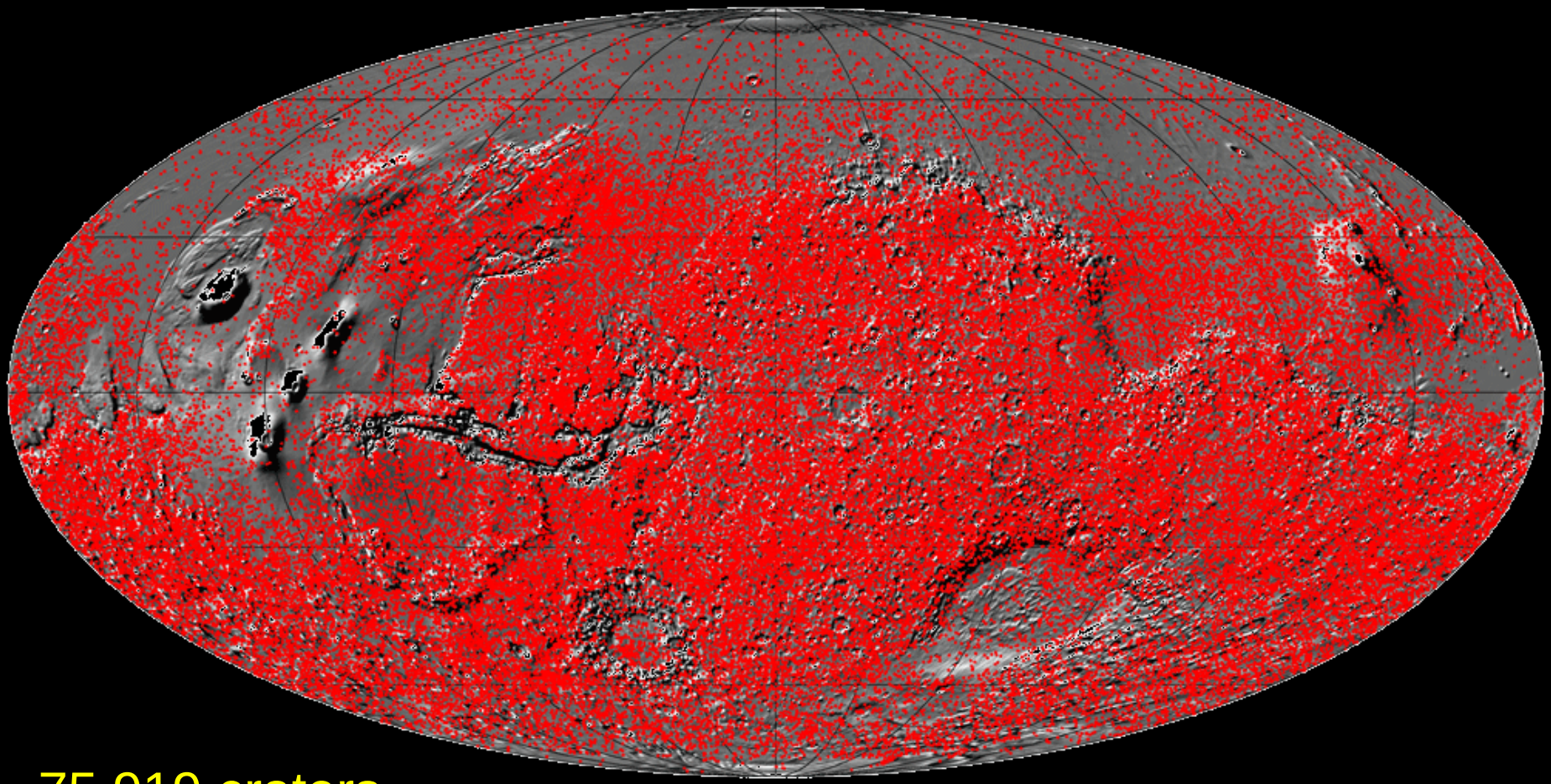


300 overlapping “equatorial tiles

Additional 56 “polar” tiles

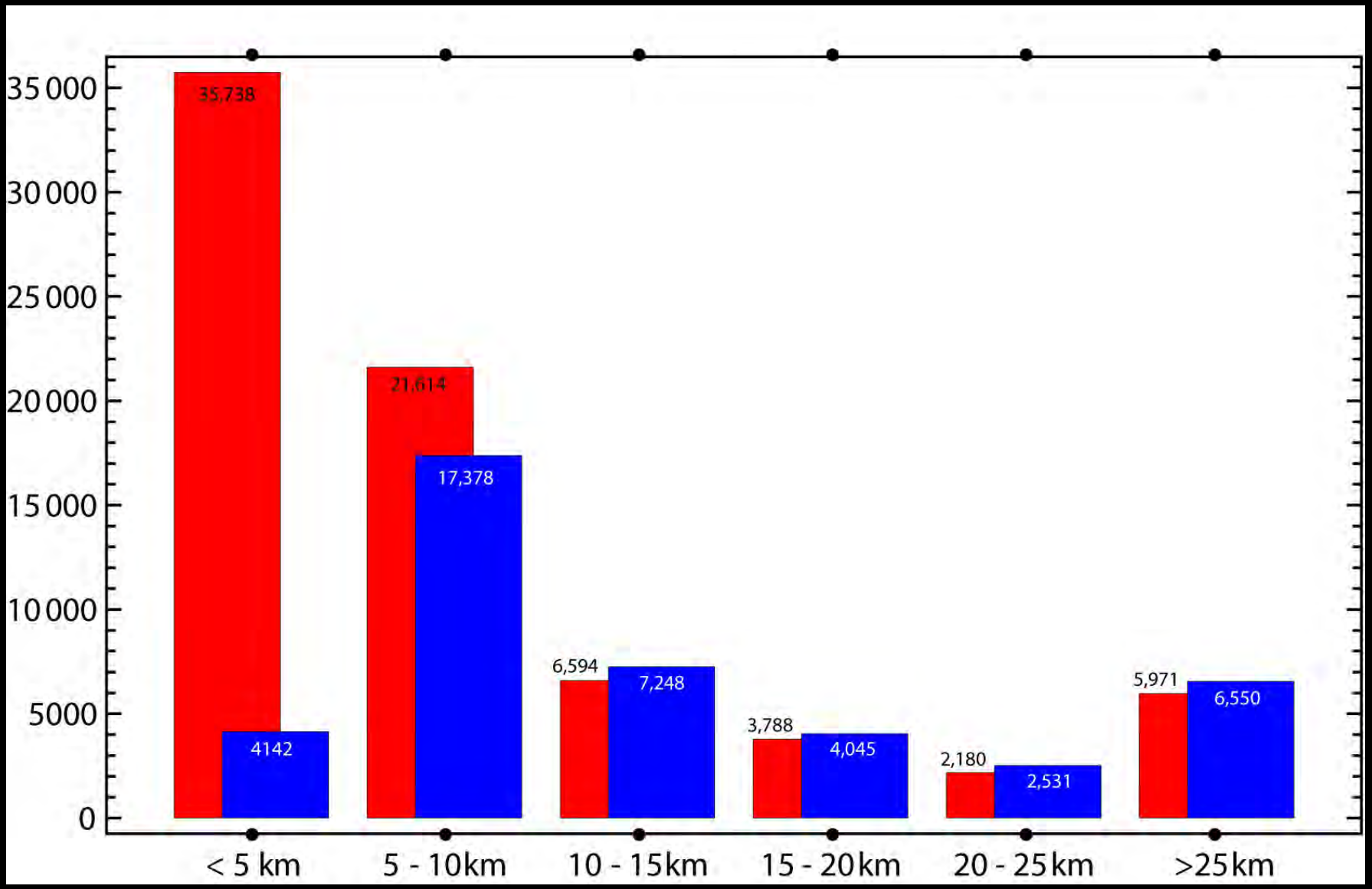
Dr. Erik Urbach
postdoc

Detected craters



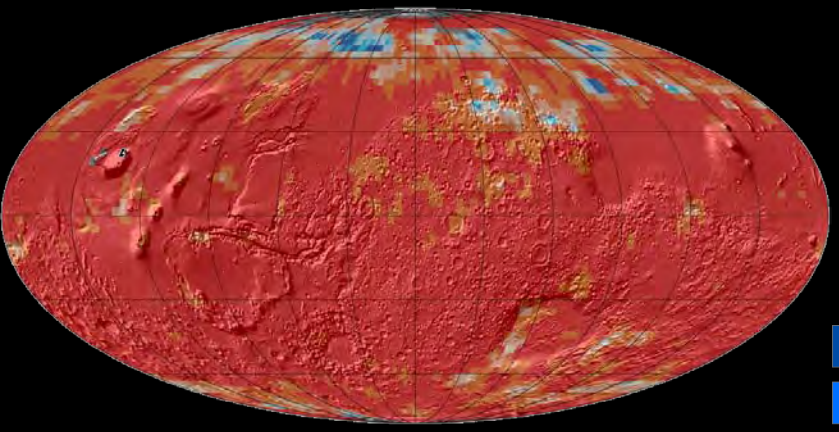
- 75,919 craters
- diameter
- depth

Comparison to Barlow Catalog

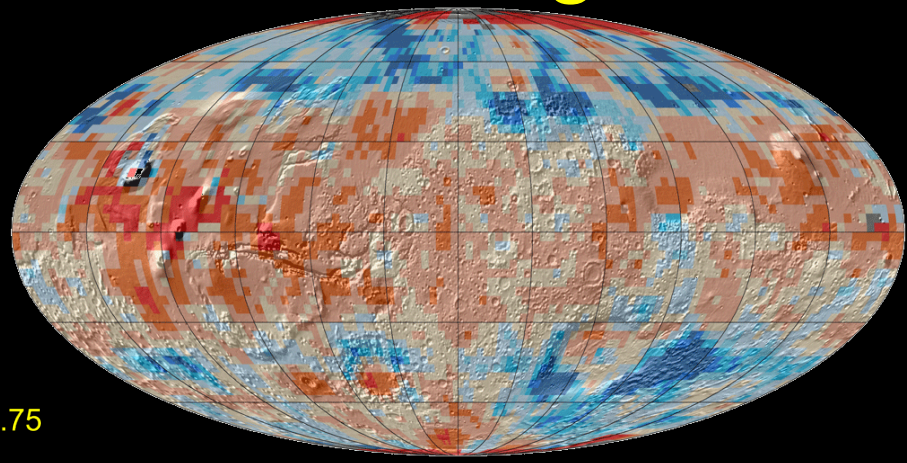


Barlow, N.G., 1988. Crater size-distributions and a revised martian relative chronology. Icarus 75, 285–305.

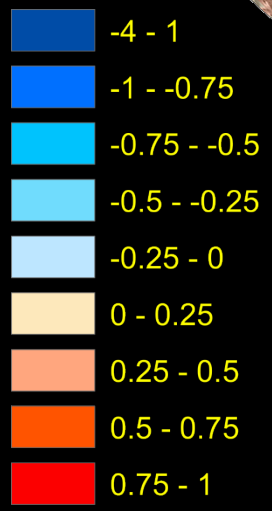
Comparison to Barlow Catalog



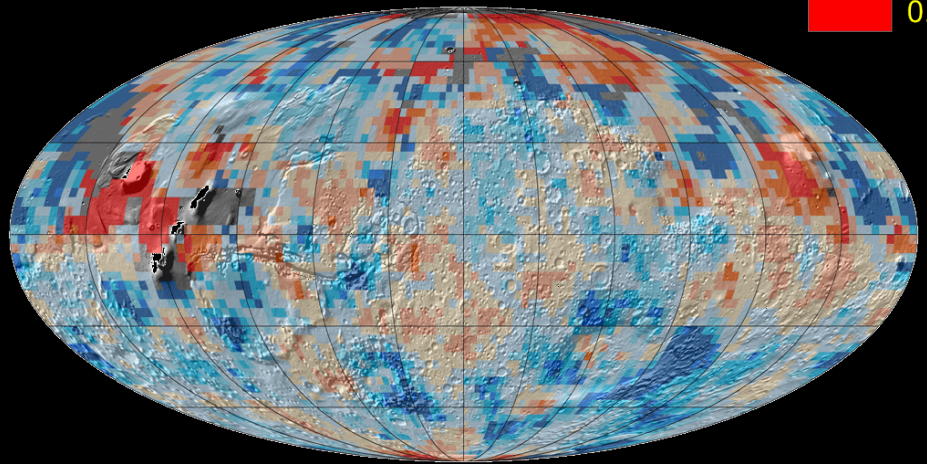
D < 5 km



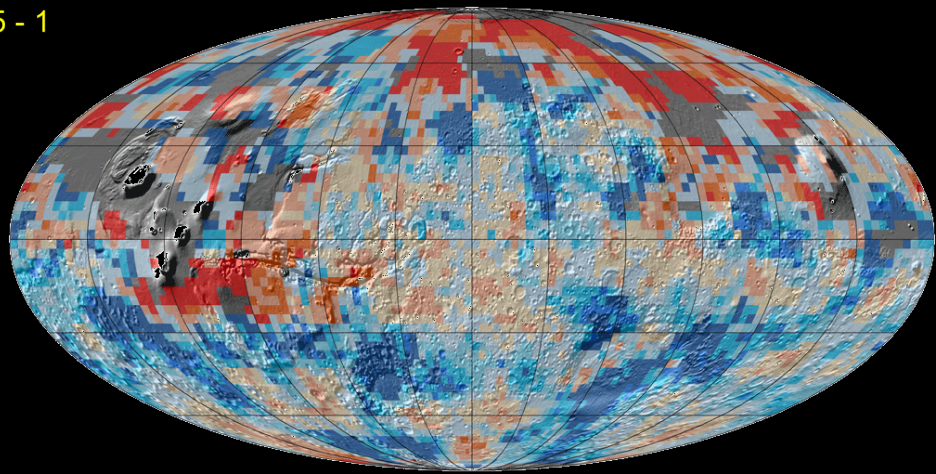
5< D < 10 km



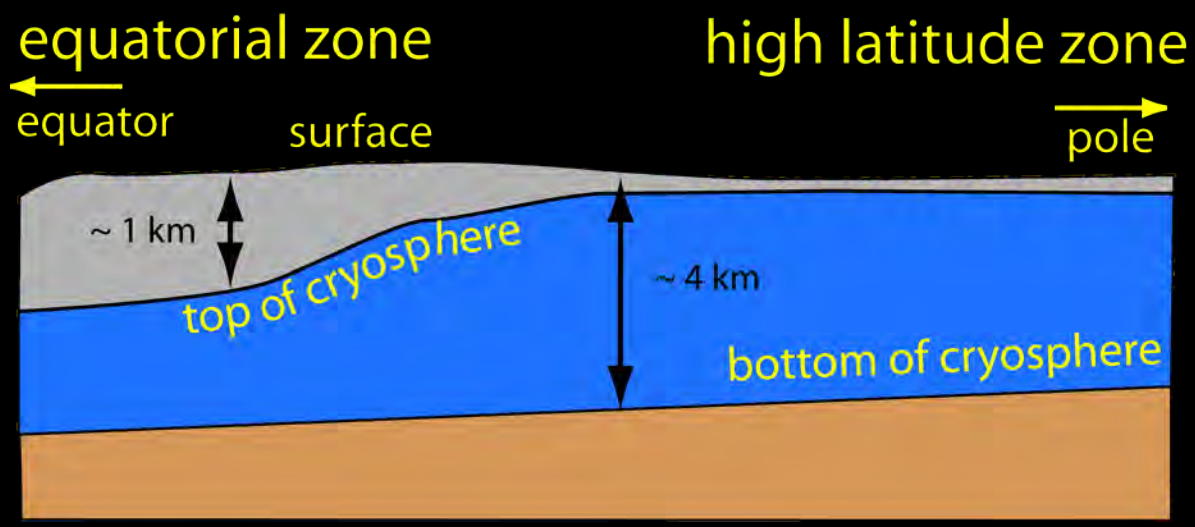
15 < D < 20 km



20< D < 25 km



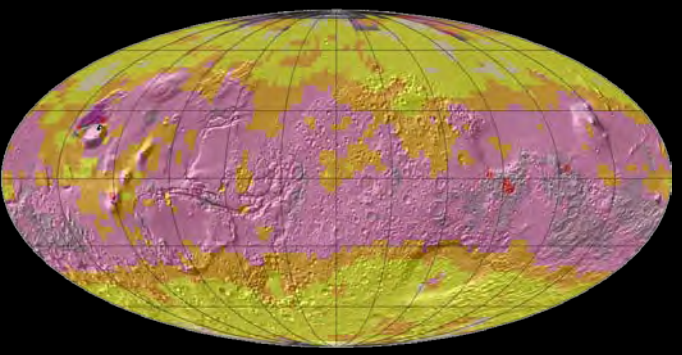
Knowledge Discovery: Martian Cryosphere



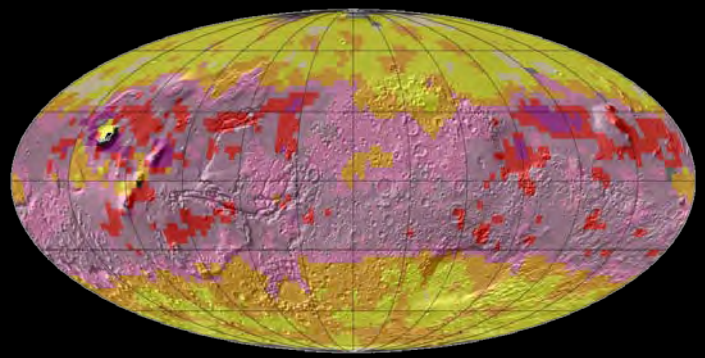
Global distribution of crater “depth/diameter provides “observational” support for existence of cryosphere with varying depth of upper boundary.

How so?

Geographical Distribution of d/D

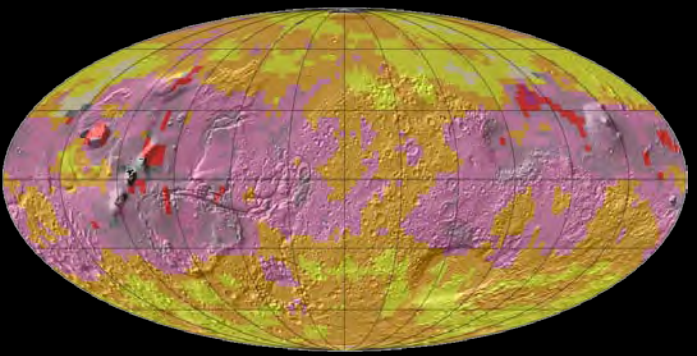


D < 5 km

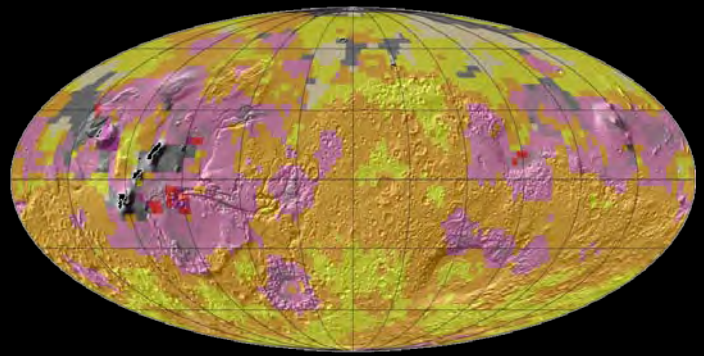


5 < D < 10 km

smaller craters are relatively deeper in equatorial regions !

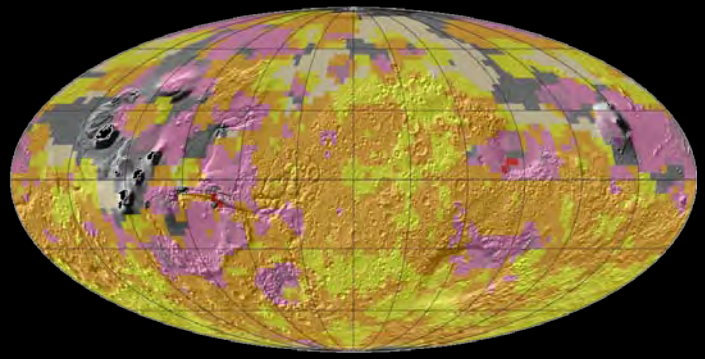


10 < D < 15 km

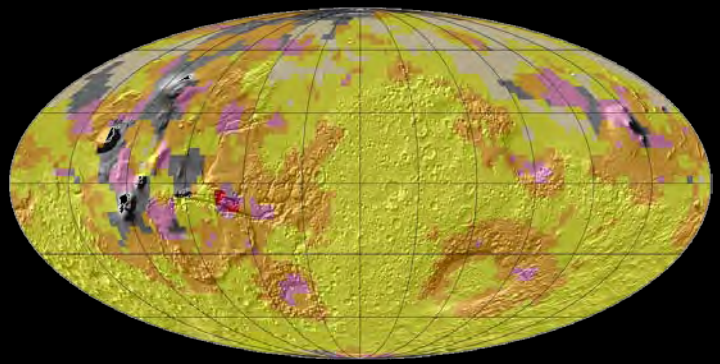


15 < D < 20 km

- 0.00784 - 0.02
- 0.02 - 0.04
- 0.04 - 0.06
- 0.06 - 0.08
- 0.08 - 0.1
- 0.1 - 0.12
- 0.12 - 0.166



20 < D < 25 km

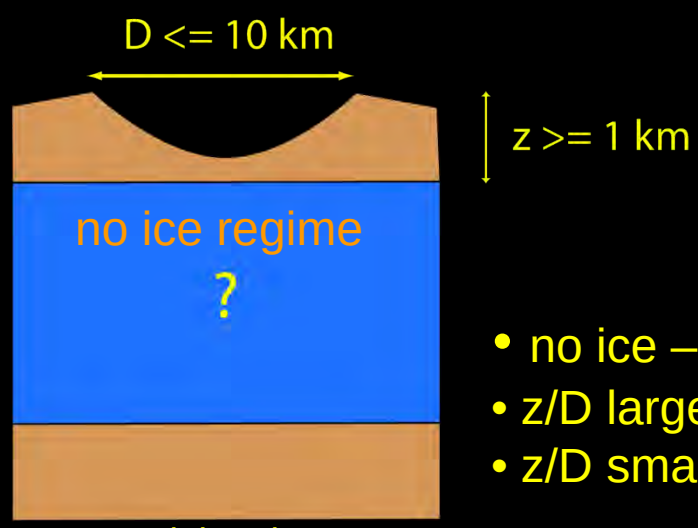


D > 25 km

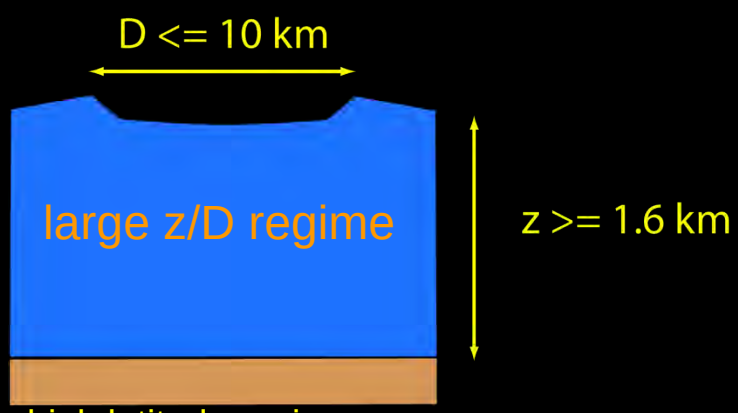
no correlation between Latitude and d/D for large craters !

Explanation in Terms of Viscous Relaxation

small craters



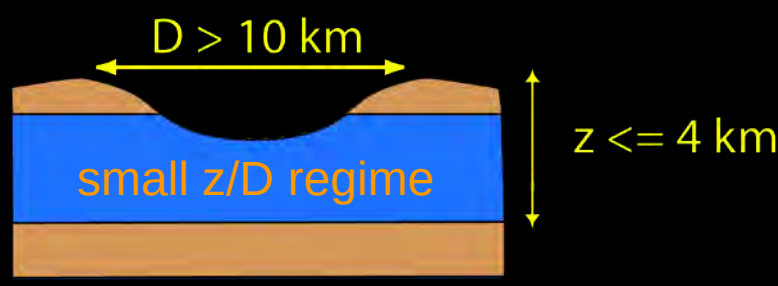
equatorial regions



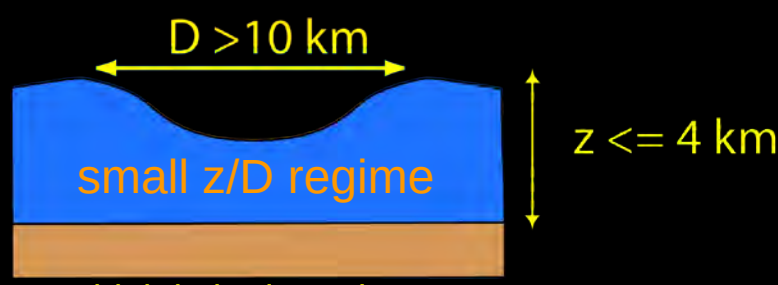
high latitude regions

- no ice – no shallowing
- z/D large – shallowing
- z/D small – no shallowing

larger craters



equatorial regions



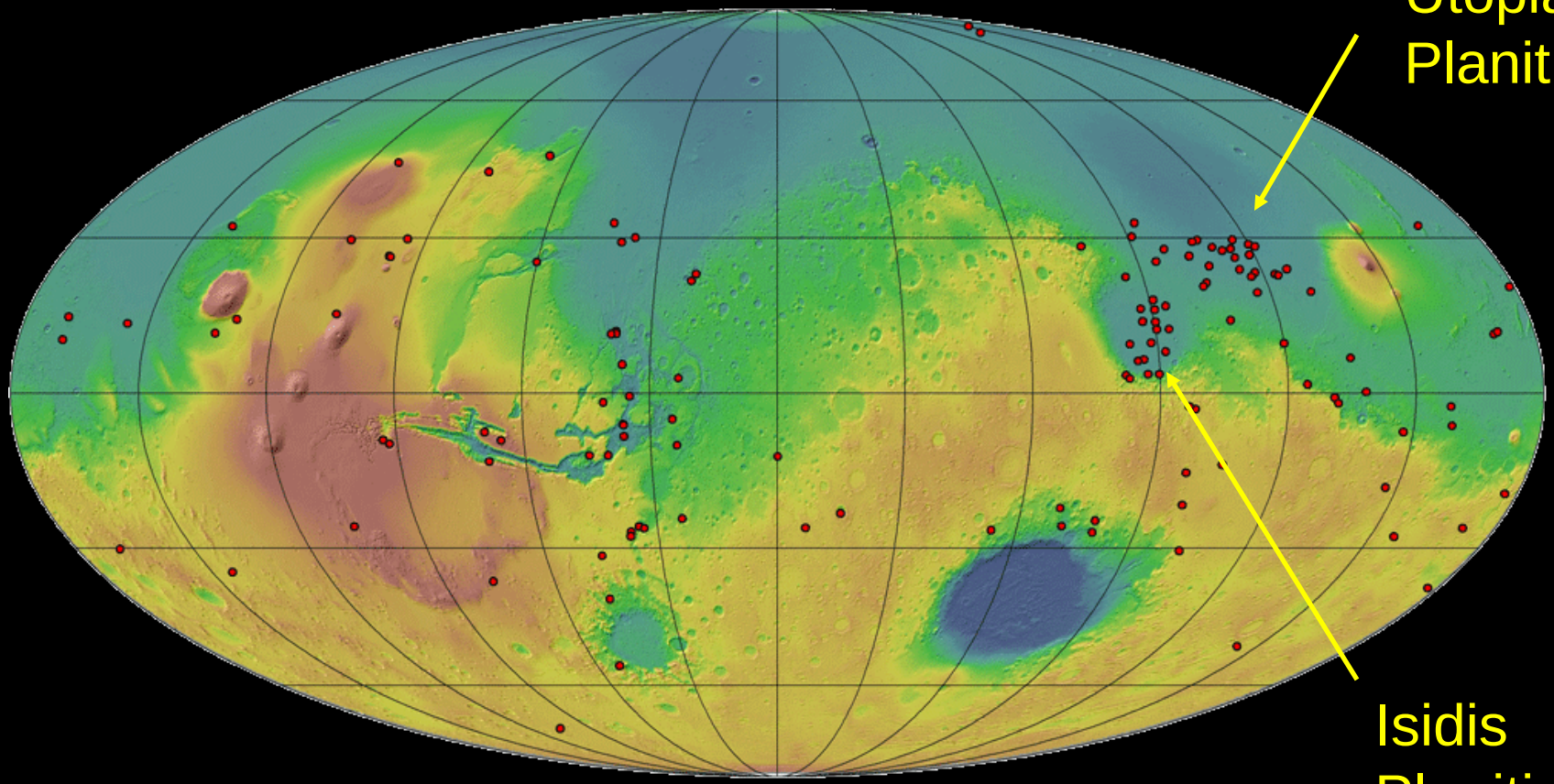
high latitude regions

Parmentier, E. M. and Head, J. W. (1981) Icarus, 47, 100-111.

Jankowski, D. G. and Squyers, S. W. (1993) *Icarus, 106,* 365-379.

Pathare, A. V. et al. (2005) *Icarus 174,* 396-418.

100 Deepest Craters on Mars



133 craters with d/D >= 0.18
Average D = 7 km

J. Boyce et al., (2006), Deep impact craters in the Isidis and southwestern Utopia Planitia regions of Mars: High target material strength as a possible cause, GRL., 33, L06202

Conclusions

- Auto-detection of craters from topography has arrived! New types of analysis are possible for surfaces represented by elevation grids (Mars, Moon, Mercury).

- Geographical distribution of d/D on Mars supports the existence of cryoshpere and provides constraints on its extent.

- Deepest craters on Mars are concentrated in two or three locations. Strong target materials?

Detection of Craters from Images

from images

advantages

- Imagery data is most readily available.
- Some imagery data has fine resolution.

disadvantages

- Quality of images varies.
- No high resolution global mosaic.
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from topographic data

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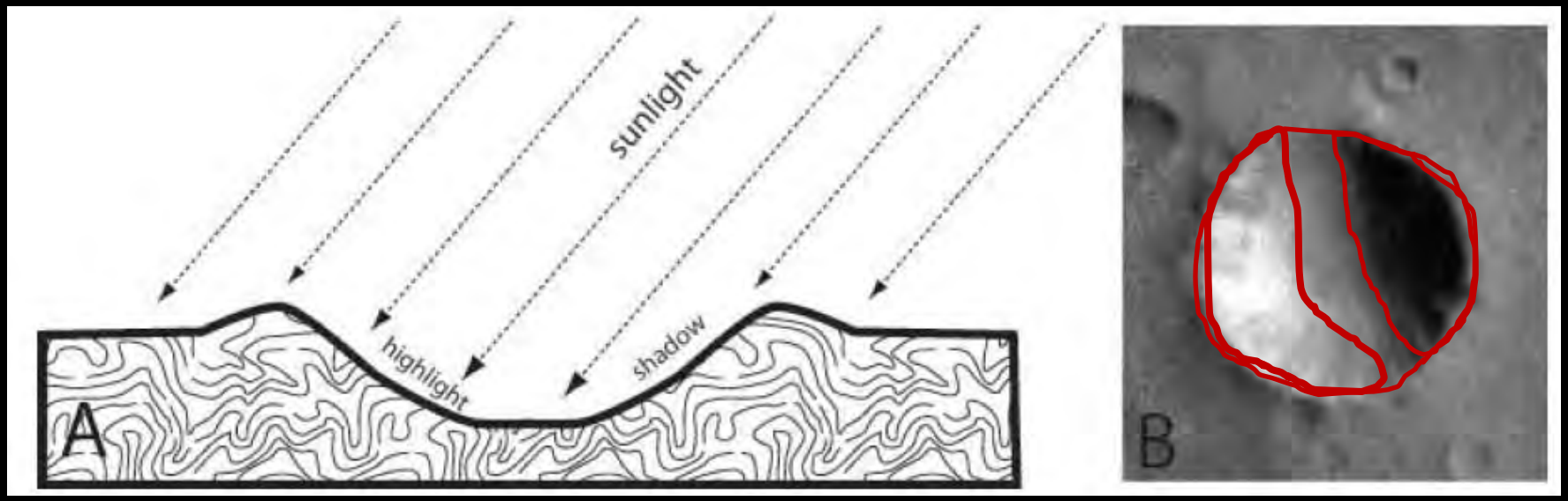
- DEM provides a direct, 3D representation of craters.
- Possibility of calculating more parameters, such as crater depth.
- No problems associated with visibility.
- Global mosaic for Mars.

disadvantages

- Low resolution.

Detection of Craters from Images

Key insight



High resolution images for Mars:

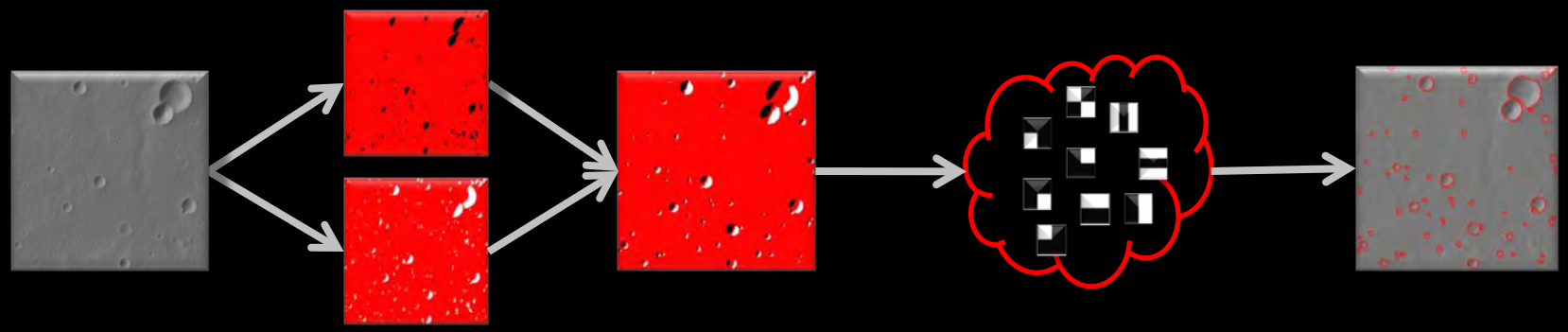
- HRSC (up to 12.5 m/pixel)
- CTX (up to 5m/pixel)
- HIRISE (> 1m/pixel)

Other planets:

- Moon LROC (1m/pixel)
- Mercury Dual Imaging System MDIS, (500m/pixel global)

Detection of Craters from Images

Process pipeline



1. Identifying shadow & highlight regions

2. Combining shadow & highlight pairs

3. Haar-like feature catalogs of smaller construction

4. Crater detection by supervised learning

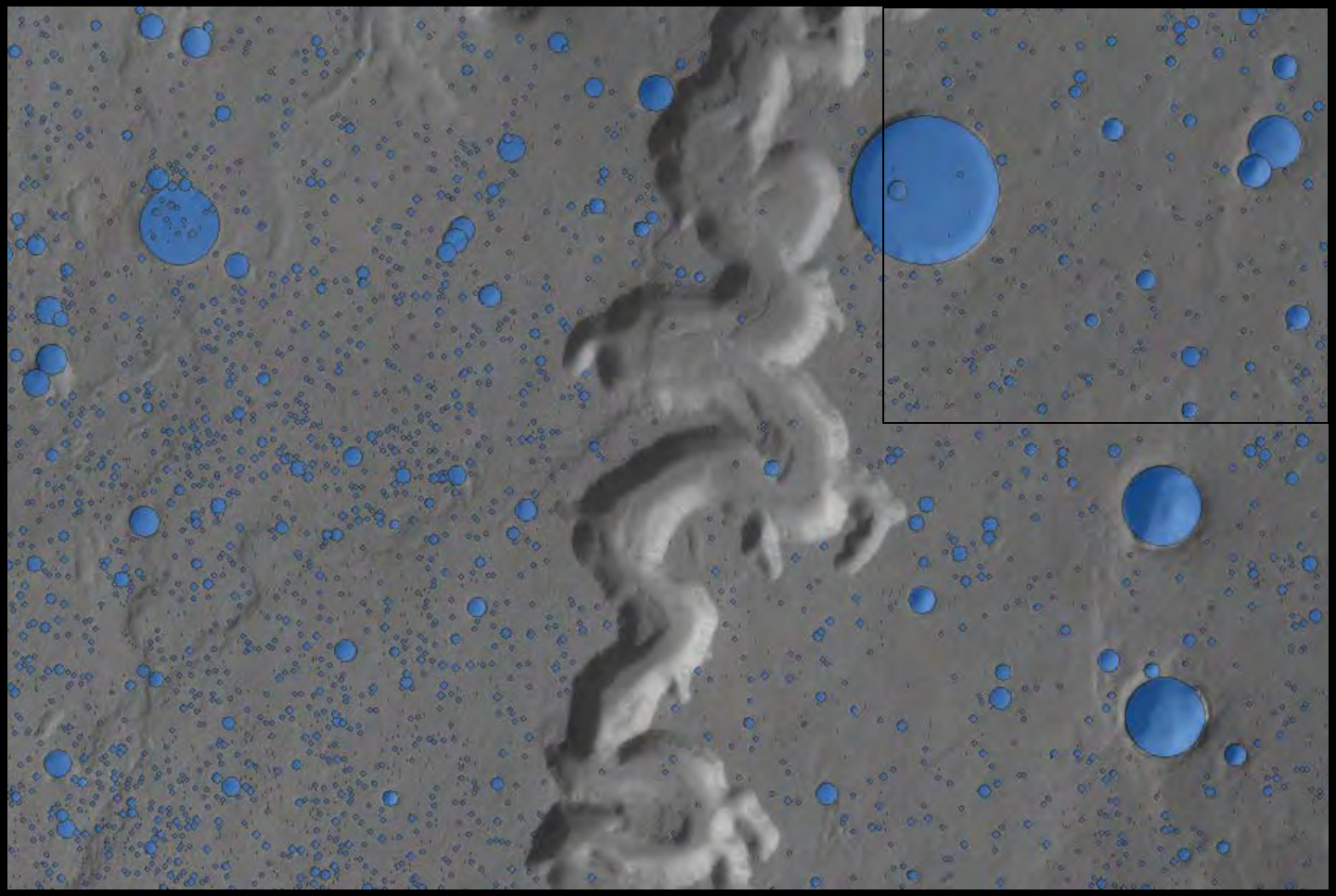
Dr. Wei Ding
collaborator

Dr. Erik Urbach
postdoc

Lourenco Bandeira
graduate student

E. R. Urbach, T. F. Stepinski (2009), Planetary and Space Science, 57(4), p880-887.

Detection of Craters in Nanedi Valles



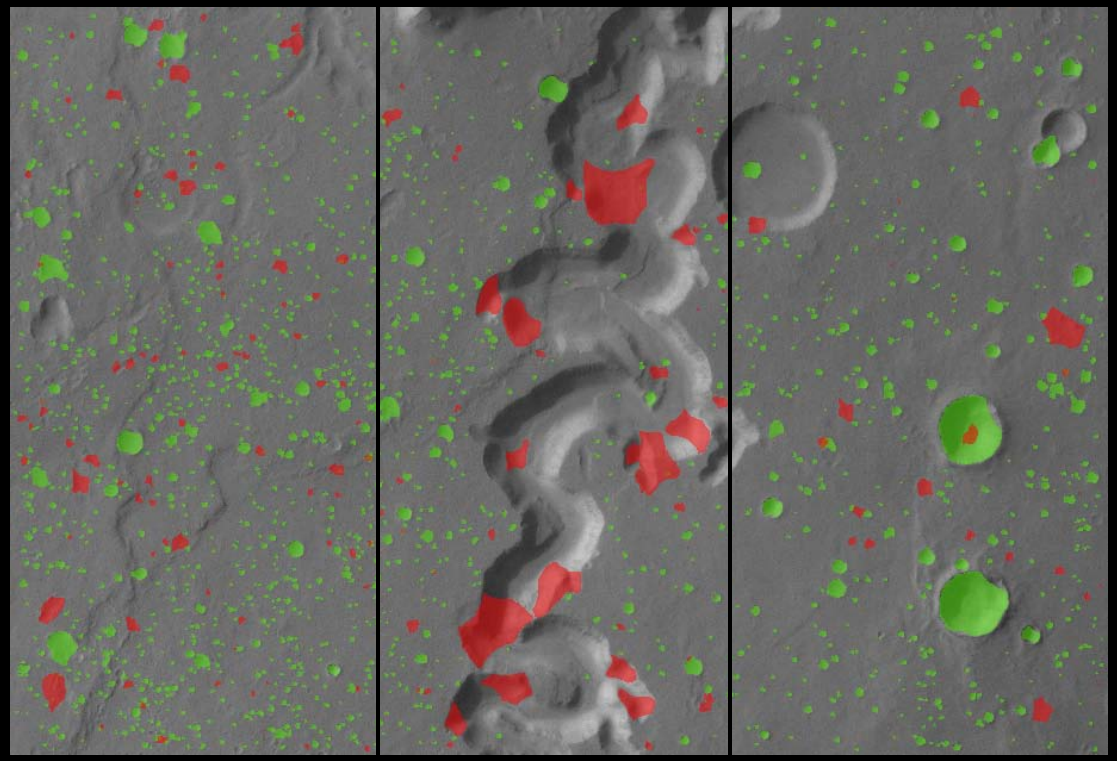
- HRSC image, 37X56 km
- 3050 craters manually identified
- crater size 40m to 6600m

- Training 211 craters + 422 non-craters
- 7% of all craters in the site
- 20% area of the site

Detection of Craters in Nanedi Valles

All regions

	New method	*shape method*
TP	1563	1148
FP	212	285
FN	374	659
D(%)	80.7	63.5
Q(%)	72.7	54.9



west		central		east	
D(%)	79.1	D(%)	78.3	D(%)	86.9
Q(%)	72.5	Q(%)	65.8	Q(%)	80.5

Bandeira, L. et al. 2010, 41st LPSC # 1144

Conclusions

- Auto-detection of craters from images is still a work in progress.

- Shape-based algorithm provides an efficient means of finding crater candidates.

- Recognizing true craters from amongst the candidates on the shapes alone is challenging. Combining shape-based algorithm for fast identification of crater candidates with texture-based algorithm for recognition of true craters may improve the overall quality of detection.