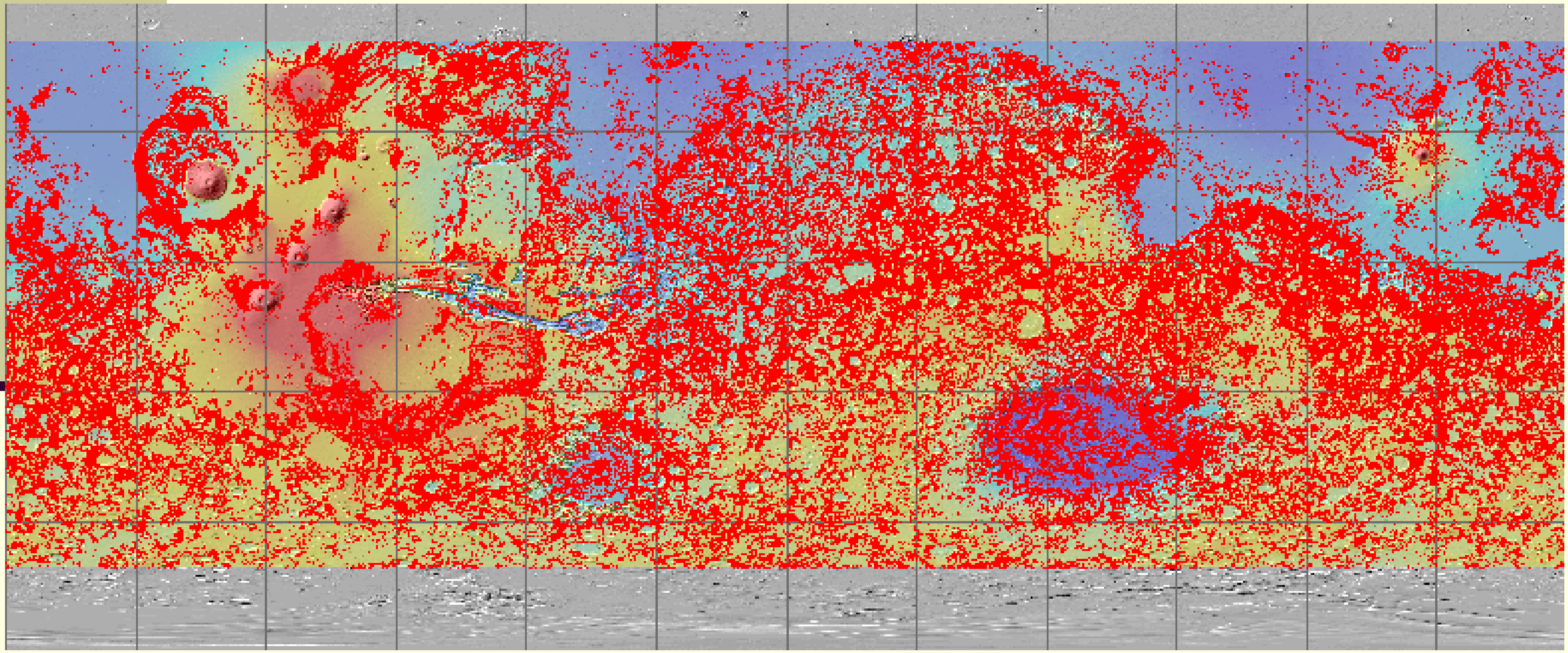
Global Patterns of Dissection on Mars and the Northern Ocean Hypothesis

Tomasz Stepinski, Lunar and Planetary Institute

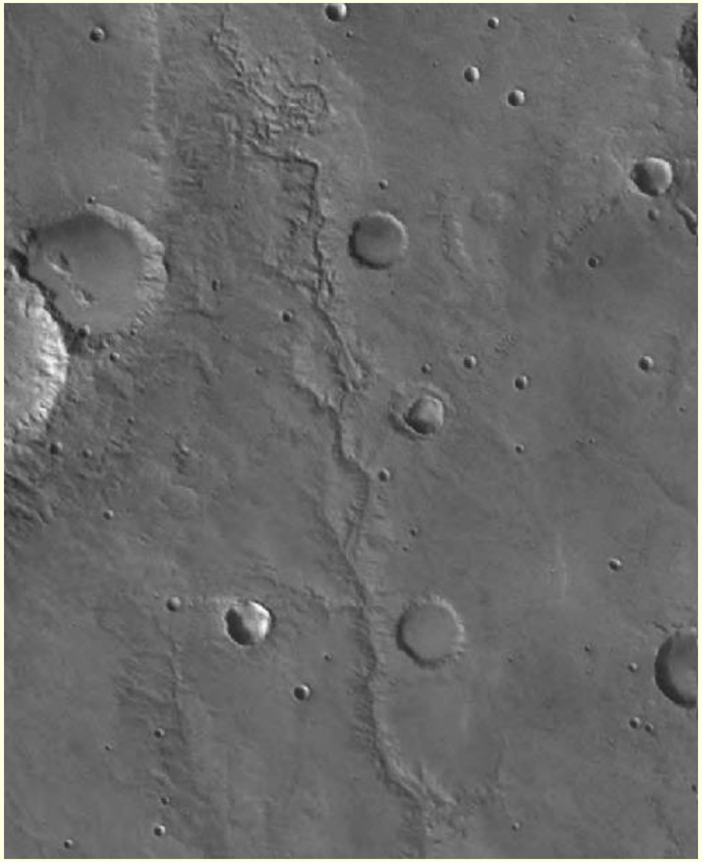


University of Houston Clear Lake, April 26, 2010

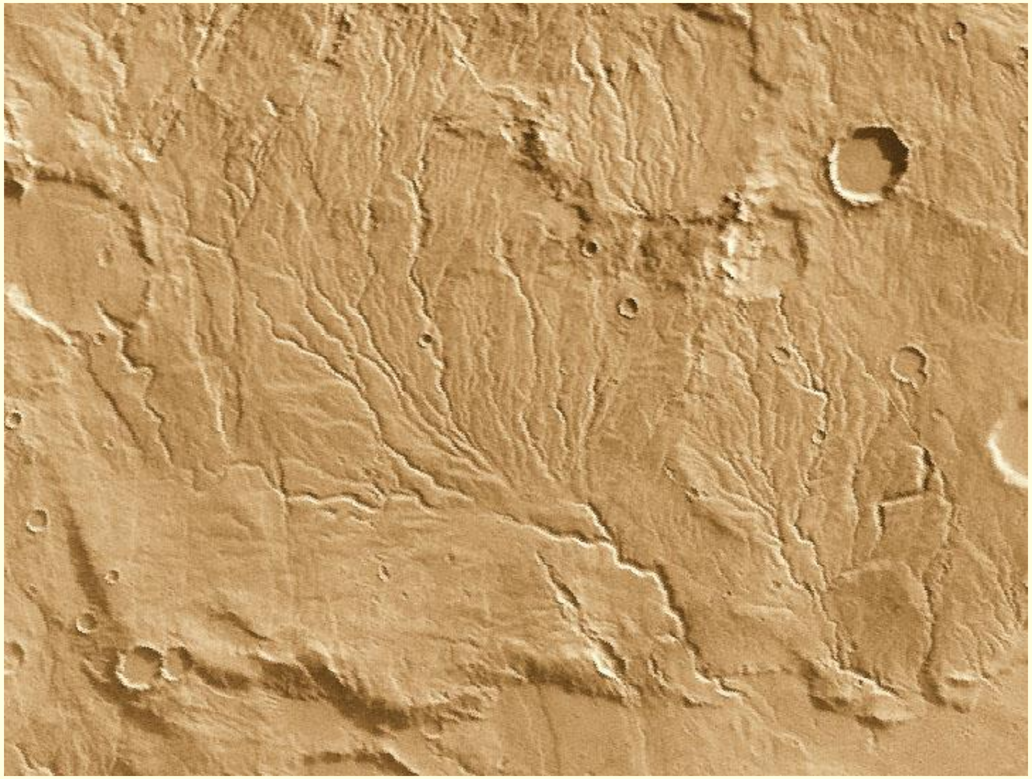
Outline

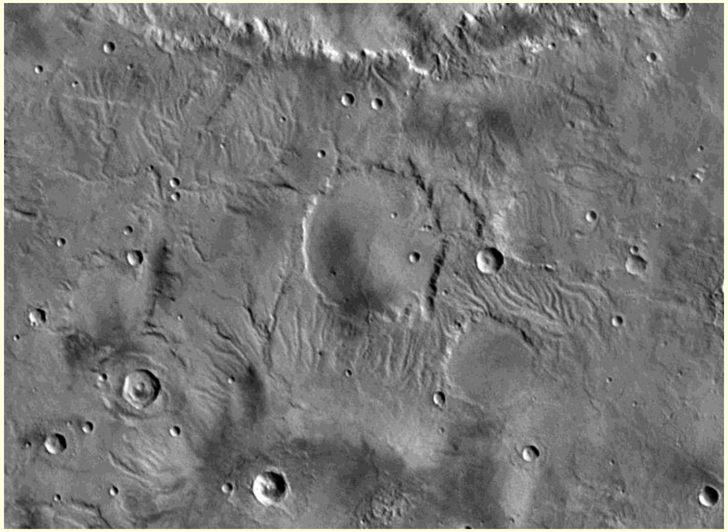
- Valley networks on Mars – what are they?
- Valley networks – the search for their origin.
- Existing global maps of valley networks and their shortcomings.
- Mapping valley networks by computer – review and critique of off-the-shelf techniques.
- Mapping valley networks by computer – a method that works.
- Constraints on the origin of valley networks from the global distribution of dissection – global ocean hypothesis.

What are valley networks?

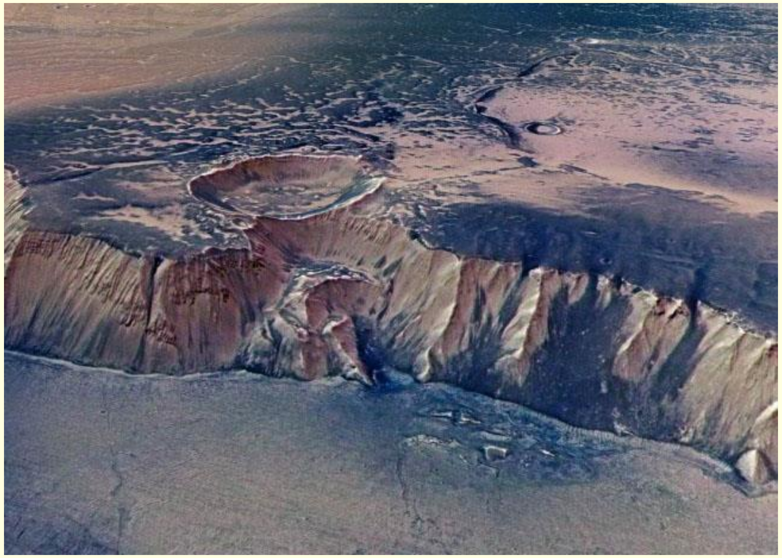


What are valley networks?



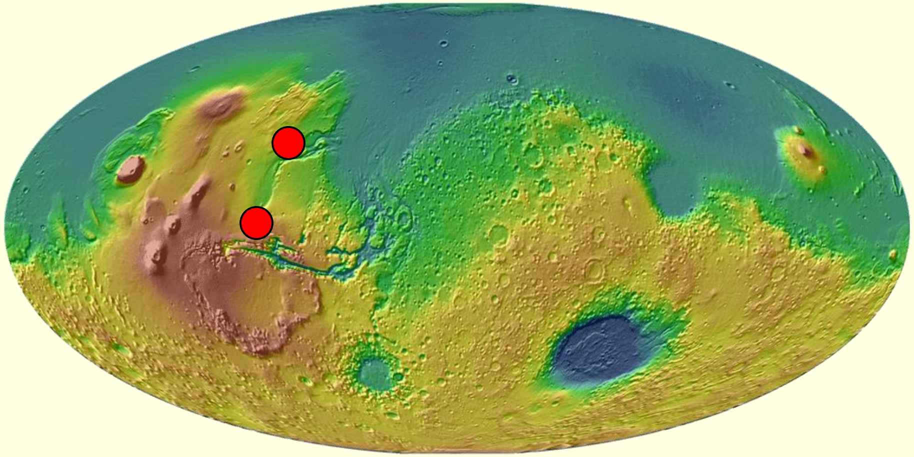


Valleys close-ups



Echus Chasma

Kasei Valles

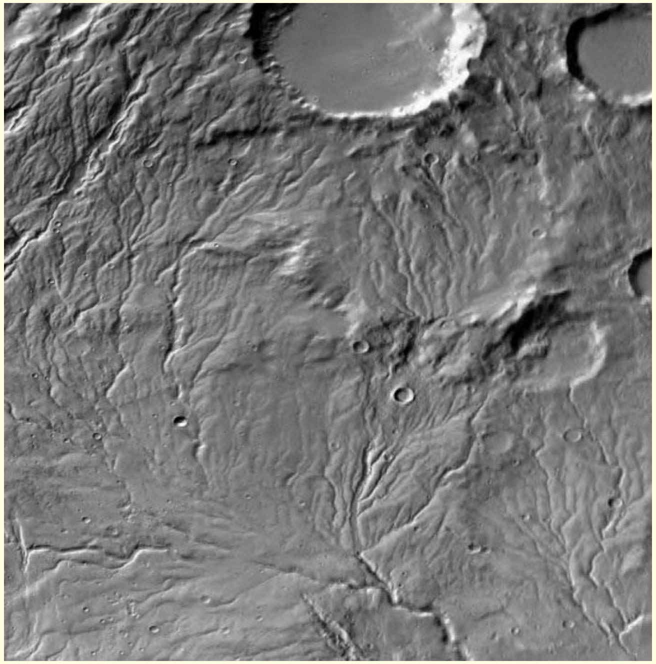


What is the origin of valley networks?

Runoff erosion vs. groundwater sapping

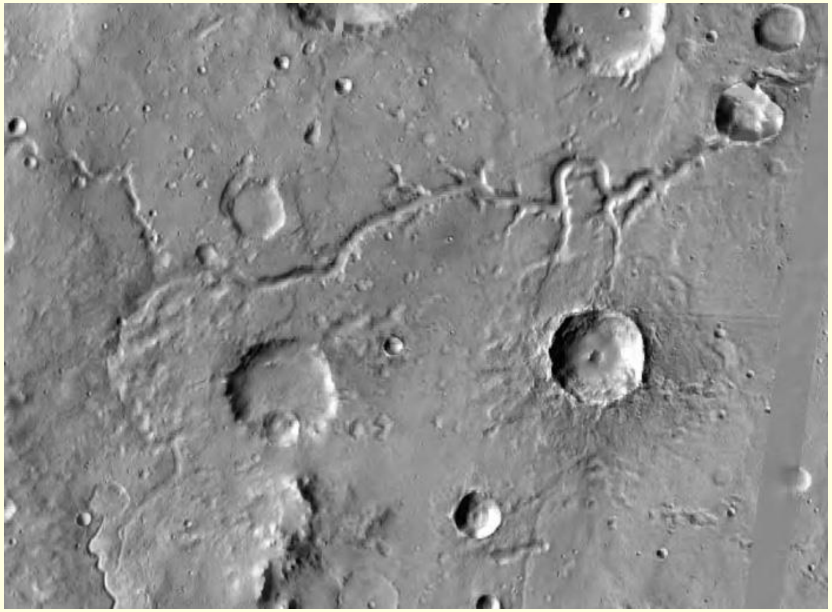
Runoff

- Dendritic patterns
- Origin near watershed boundaries.
- Overall significant erosion.



Sapping

- Widely spaced tributaries with alcove-like terminations
- Short, stubby tributaries
- Flat longitudinal profiles
- U-shaped cross sections



Runoff origin of valley networks?

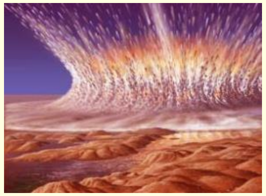
Challenge: To come up with a viable hypothesis of valley network origin

Proposed scenarios

- episodic melting of snow accumulated during high obliquity epochs

- High intensity rare storms

- episodic, multi-year intense rainfall events due to basin-scale impacts or intense volcanic eruptions



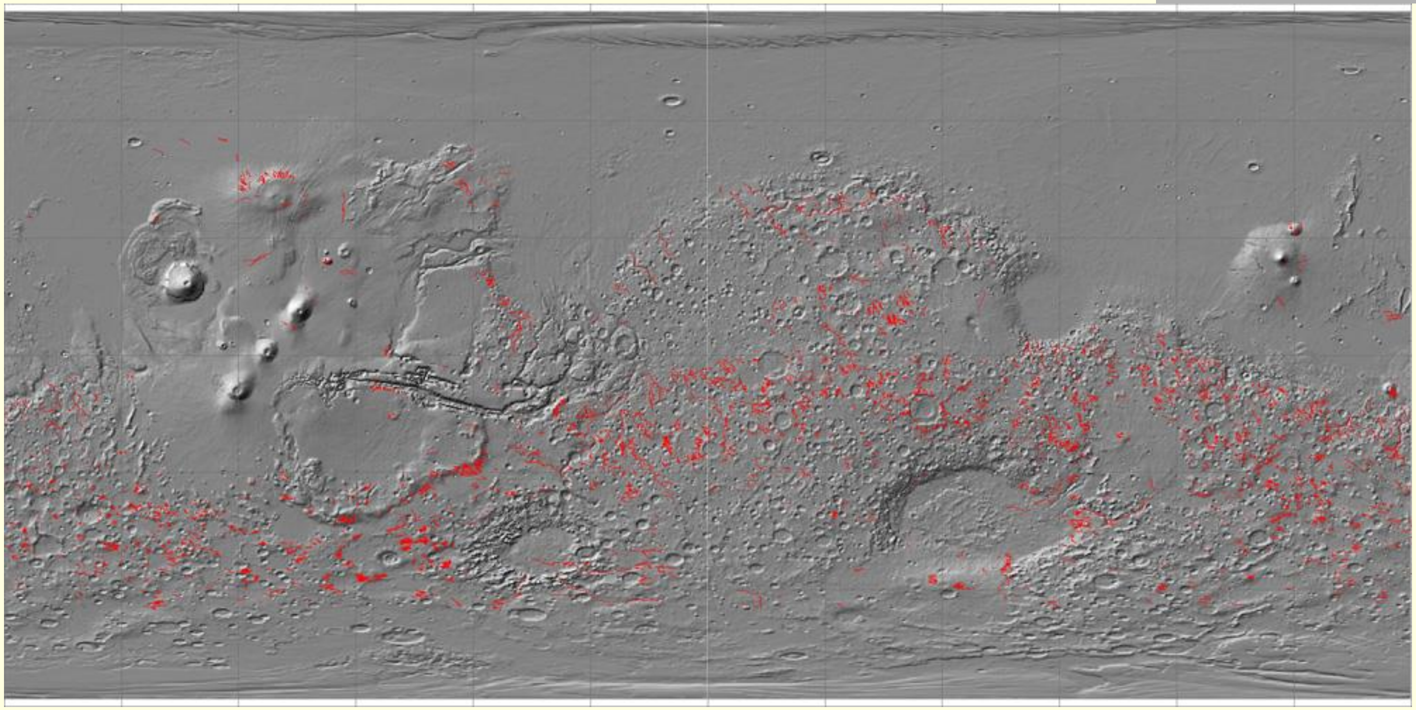
Common factor

Hypothesis are evaluated on the basis of local geomorphic features.

Our contribution

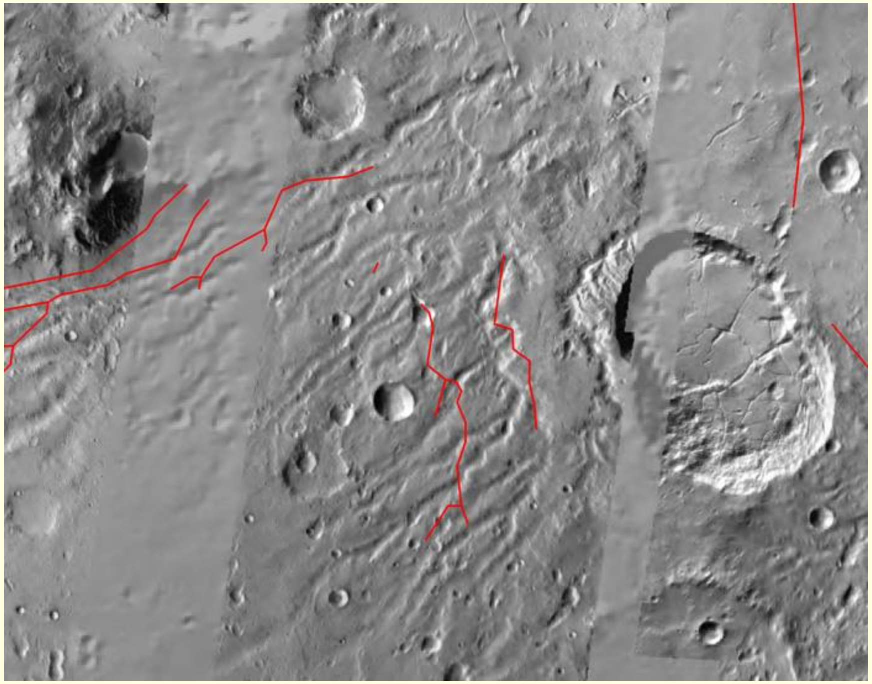
To evaluate origin of valley Networks on the basis of global distribution of dissection pattern.

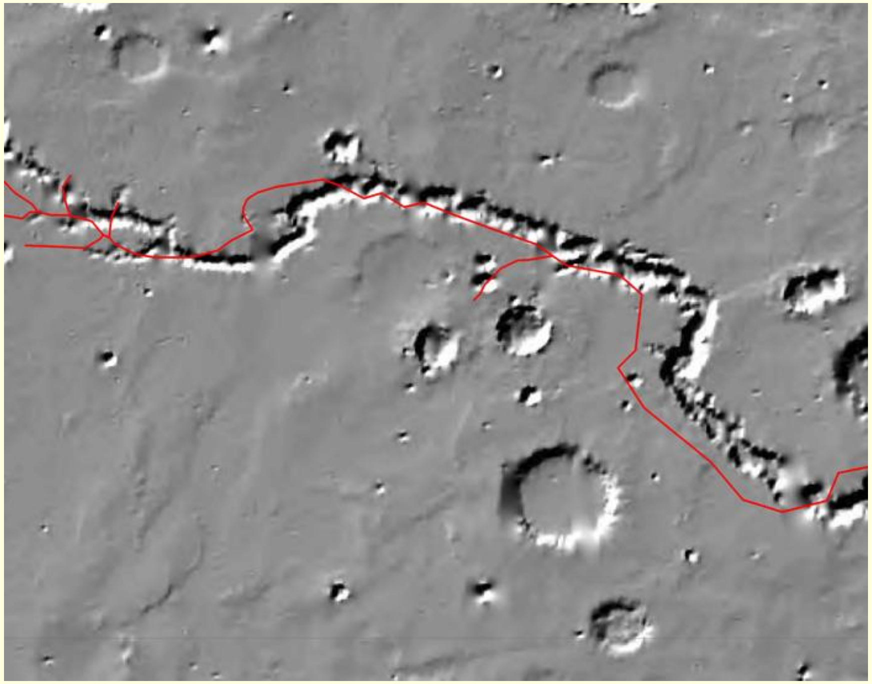
Existing Maps: Carr 1995, 1997



- Covers surface of Mars between ±65^{o} latitude
- 11,336 segments, ~800 networks
- Mapped from Viking images
- Depicts immature drainage
- VN located mostly in southern highlands

Shortcomings of Carr's map

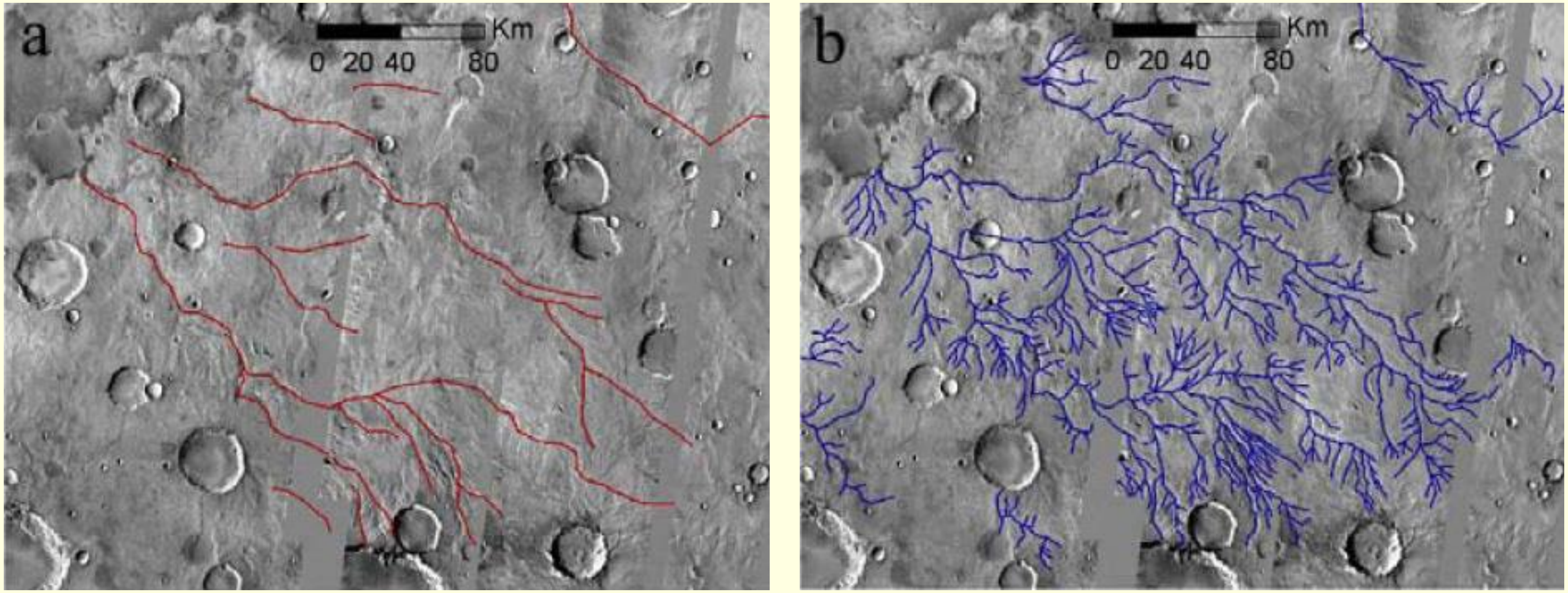




- Incompleteness. Update is desirable.
- Not aligned with actual VN. This problem is not fixable.

Updating Carr's map:

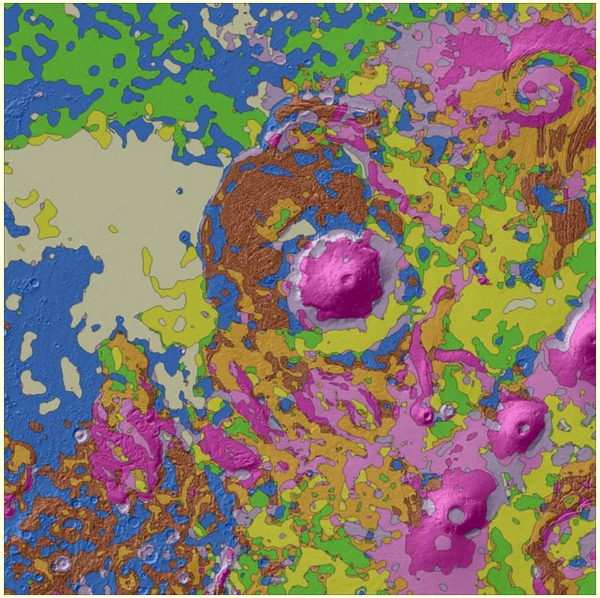
Brian Hynek campaign



- First presented at 39th LPSC.
- Mapped manually from THEMIS images.
- Factor of 4 increase in drainage density.

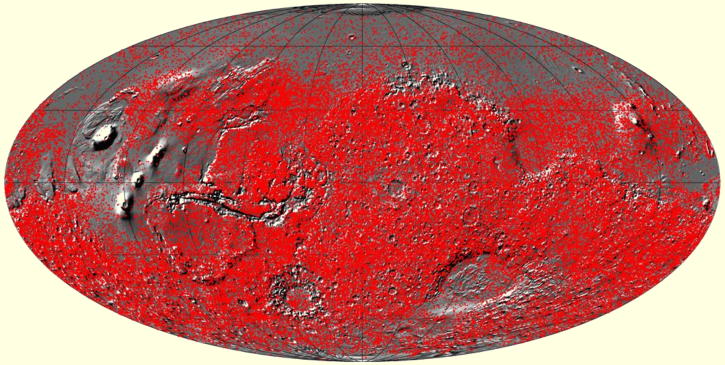
Updating Carr's map using a computer algorithm:


Stepinski and Luo campaign (1)



Immediate goals

- To develop mapping algorithm.
- To test the algorithm.
- To map VN on global scale.
- The emphasis is on global scale.
- The emphasis is on statistics.



Long term goals

- To advance the science of planetary geocomputation.
- To automate the process of surveying and mapping.

graduate student

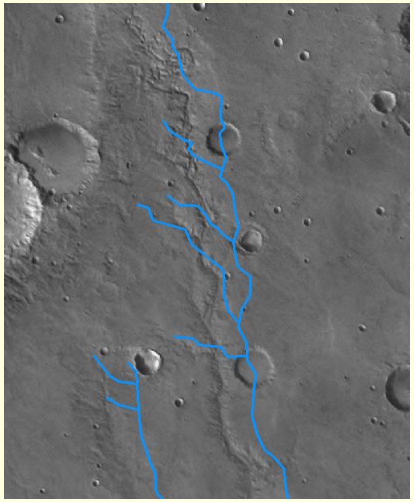
computer algorithm

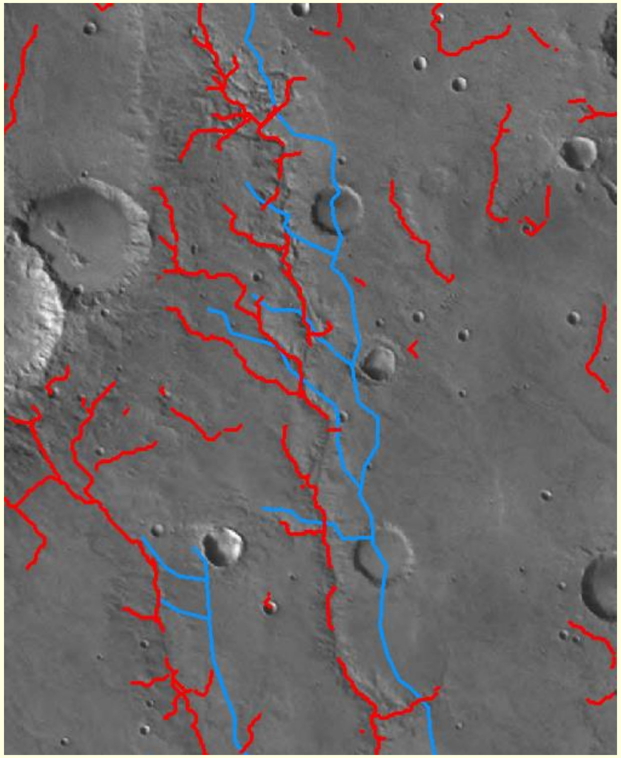
Updating Carr's map using a computer algorithm:

Stepinski and Luo campaign (2)

The good,

- Computer can do it!
- Low cost of map acquisition.
- Consistent results.
- Properly registered.
- Scalability.





the bad,

- Requires topographic data.
- Accuracy issues, false positives
- Heavily segmented map

and the ugly.

- Additional work is required to improve accuracy of computer mapping:
- (a) manual inspection,
- (b) machine learning.

Do’s and don’ts of computer mapping of valley networks

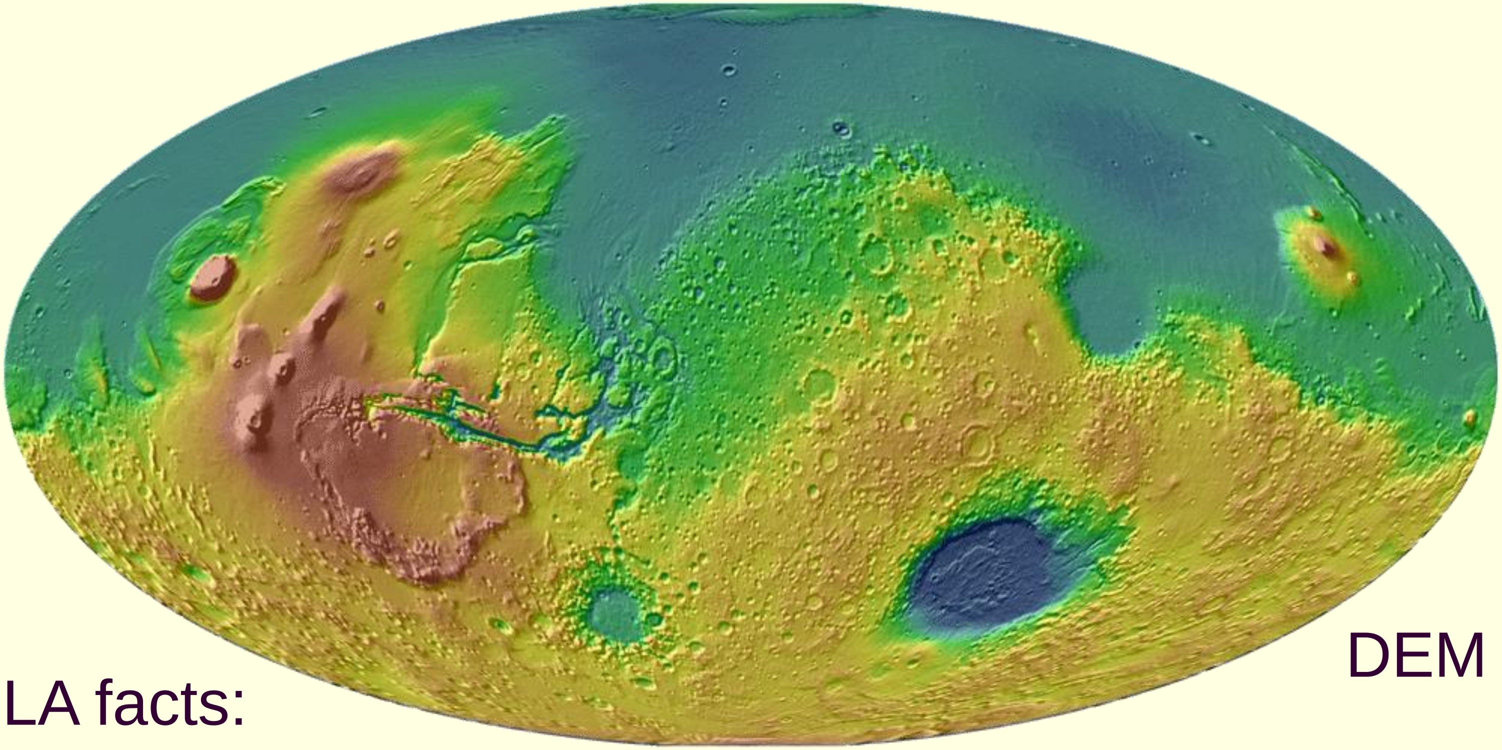
Don’ts

- Don’t use easily available commercial software as it is optimized for terrestrial applications – you will get an overwhelming number of false positives.
- Don’t use any algorithm that extracts valleys by thresholding the D8 network.
- Don’t assume it’s easy.
- Don’t assume you are going to get a perfect result.

Do’s

- Use an algorithm that marks valleys directly from terrain morphology – this minimizes false positives.
- Expect false positives, eliminate them using either visual inspection or an another algorithm.
- Expect some false negatives, learn to live with them.
- Hope for high resolution, high quality global topographic map of Mars to materialize in the future.

Data: global Martian topographic grid



MOLA facts:

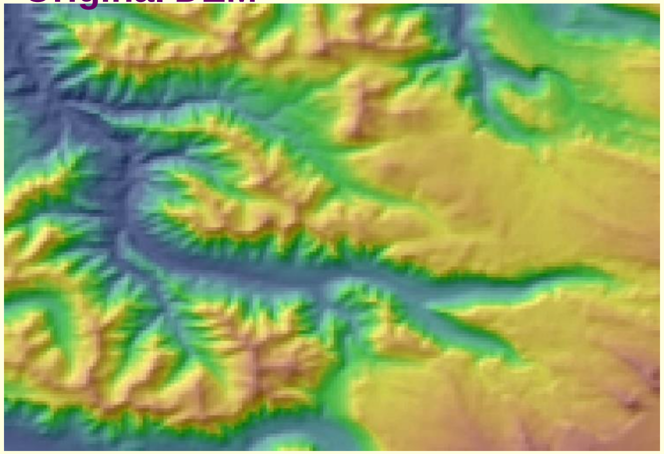
- 640 million measurements
- 300 m along the track
- 1 km between tracks

DEM facts:

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

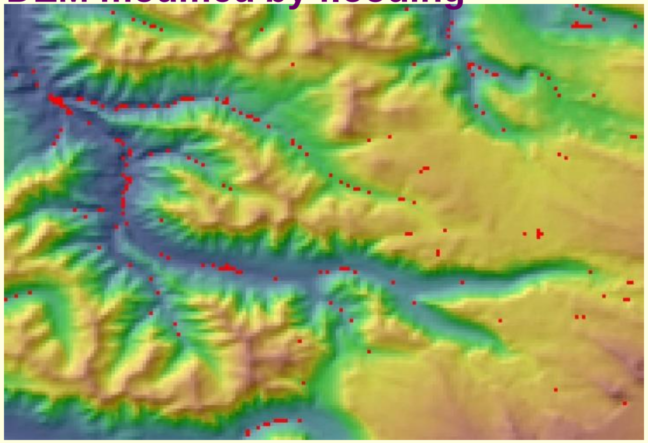
Available stream extraction method: D8

Original DEM



128 x 187 = 23,936 pixels

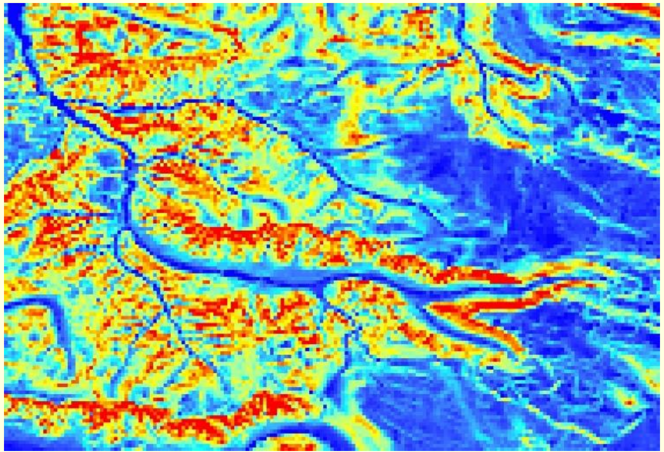
DEM modified by flooding



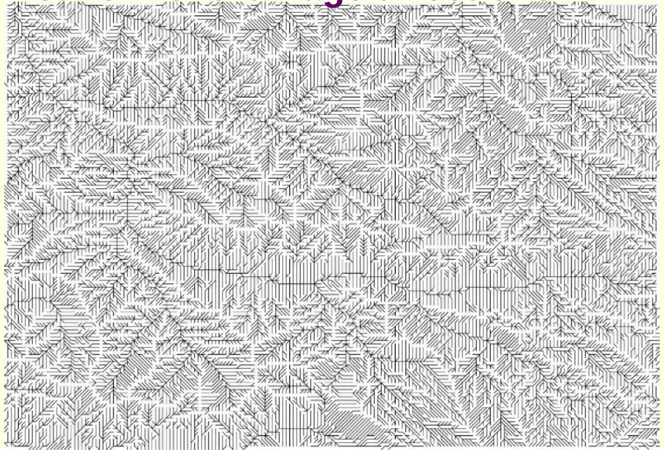
216 (0.9%) pixels are modified by flooding

Mean flood < 1 meter Max. flood 30 meters

Slope

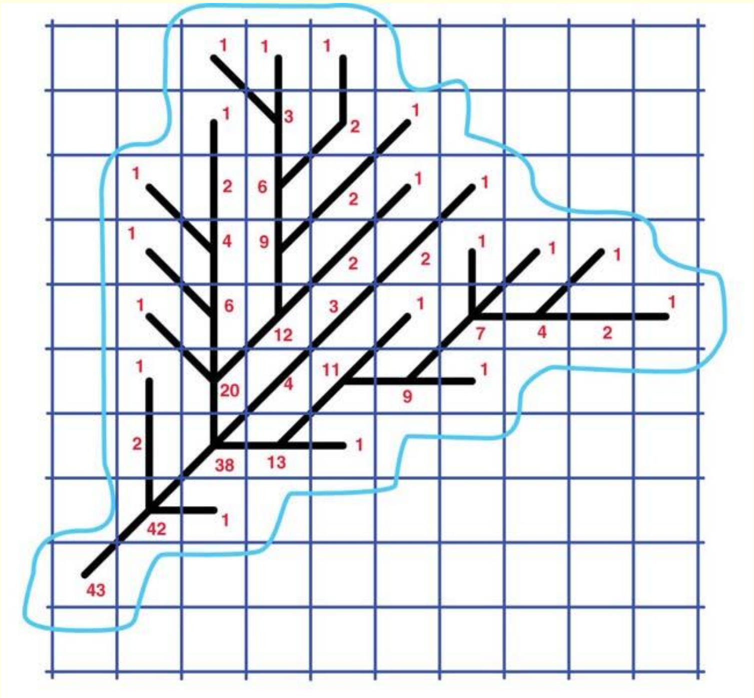


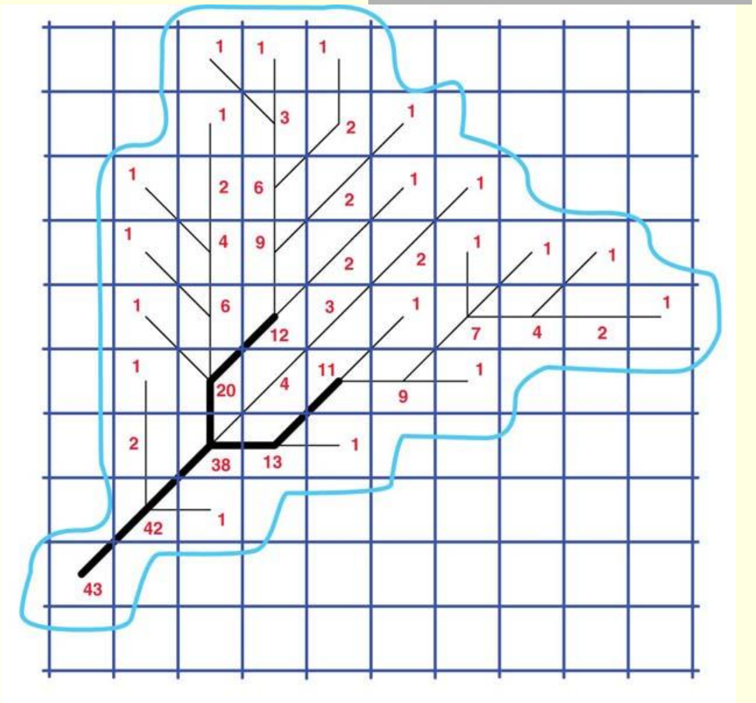
Network of drainage directions



From D8 network to streams

Contributing area





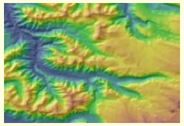
A – drainage (contributing) area

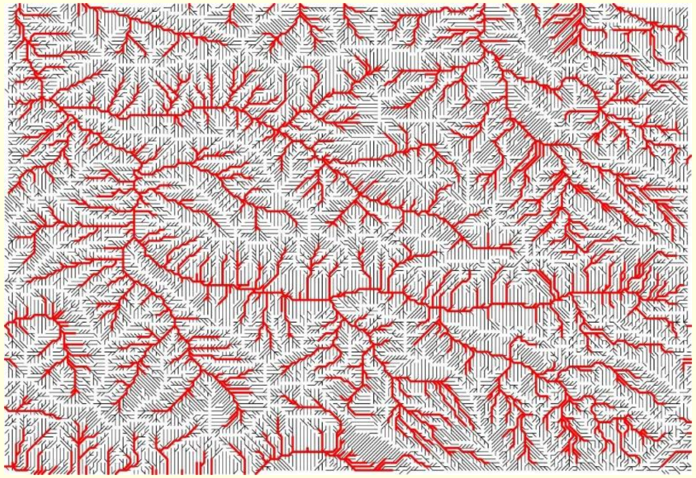
Threshold = 10 pixels

Q – mean annual discharge

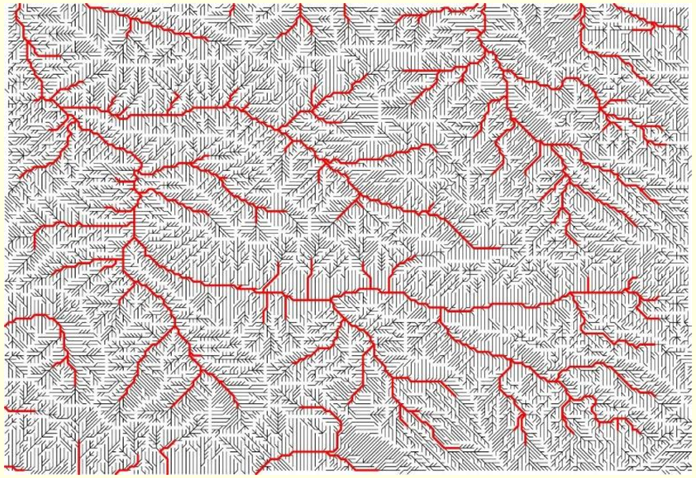
Q ~ A

Thresholding the D8 network:





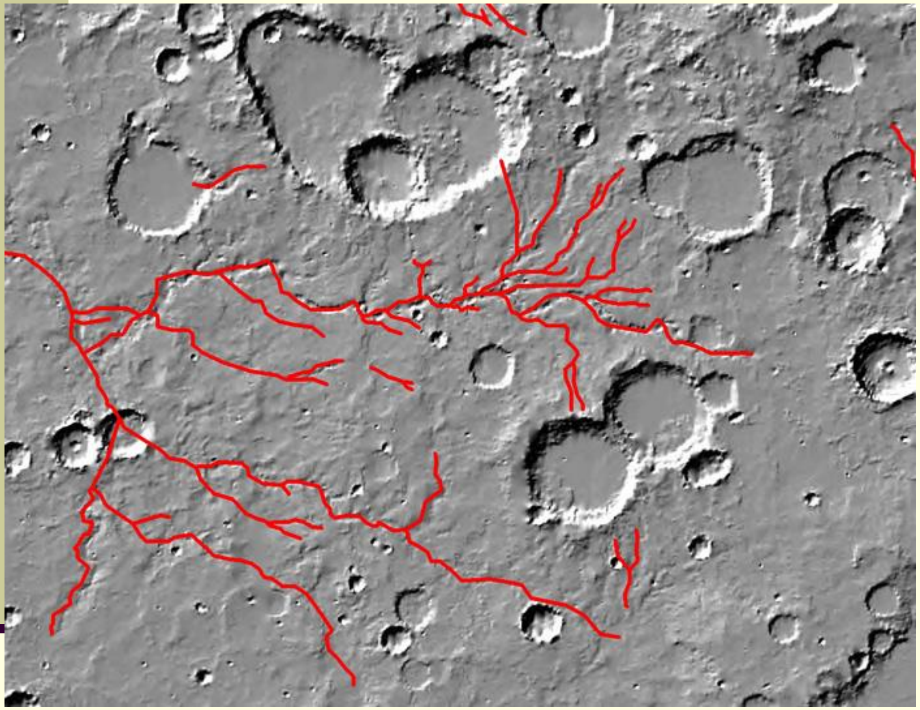
Threshold = 10 pixels

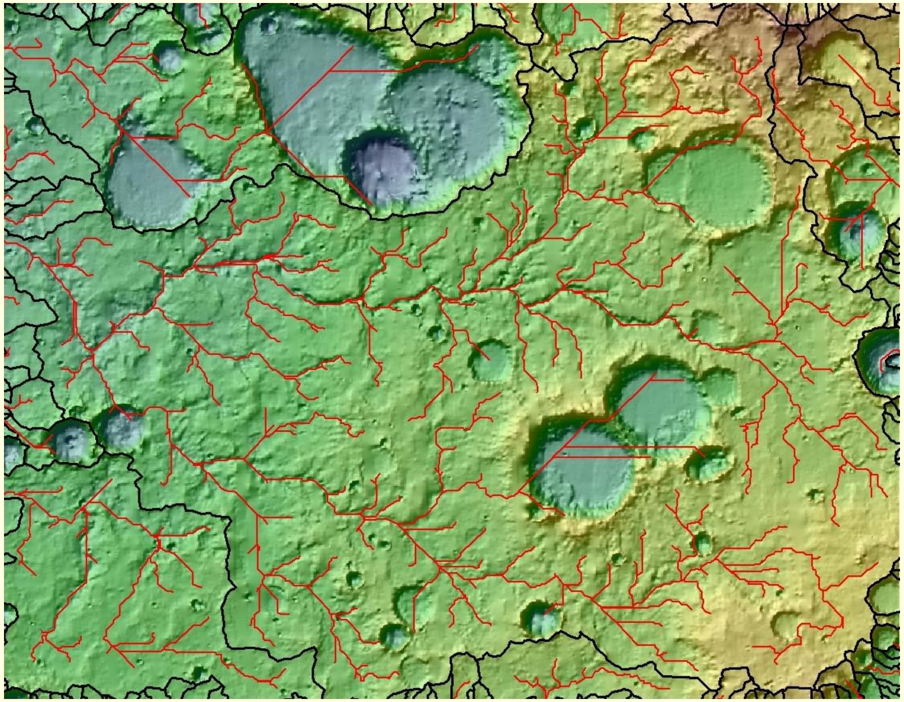


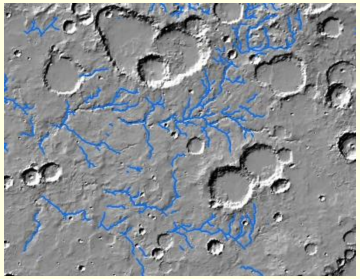
Threshold = 50 pixels

- Drainage network depends on arbitrary threshold.
- Network is always spatially uniform.
- Surface with non-uniform dissection will always be mapped incorrectly.

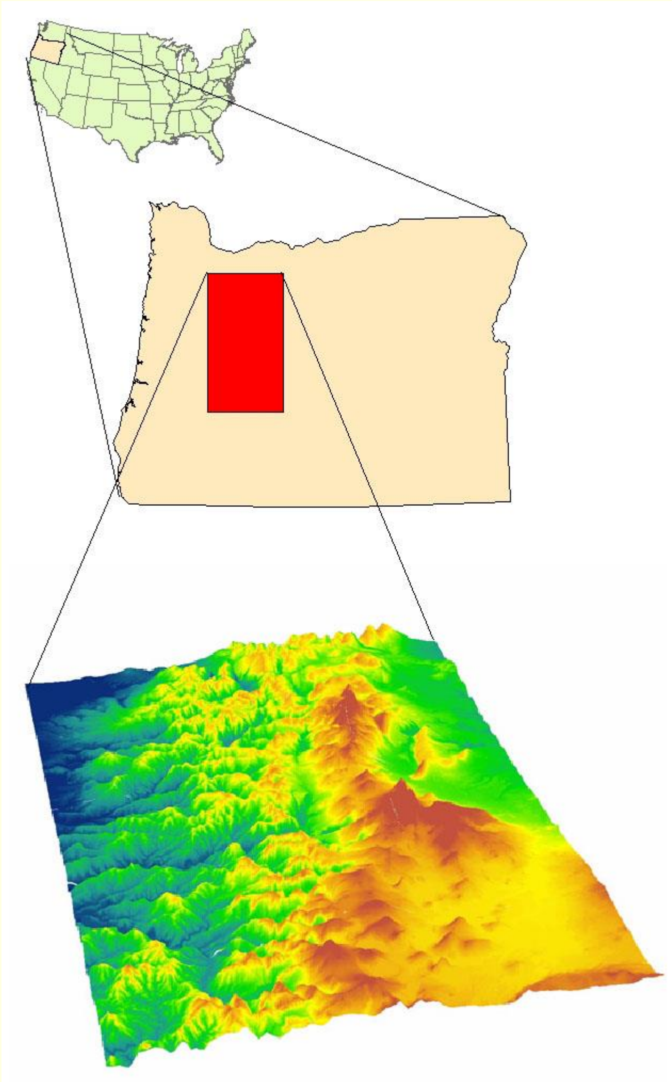
Thresholding the D8 network: Mars

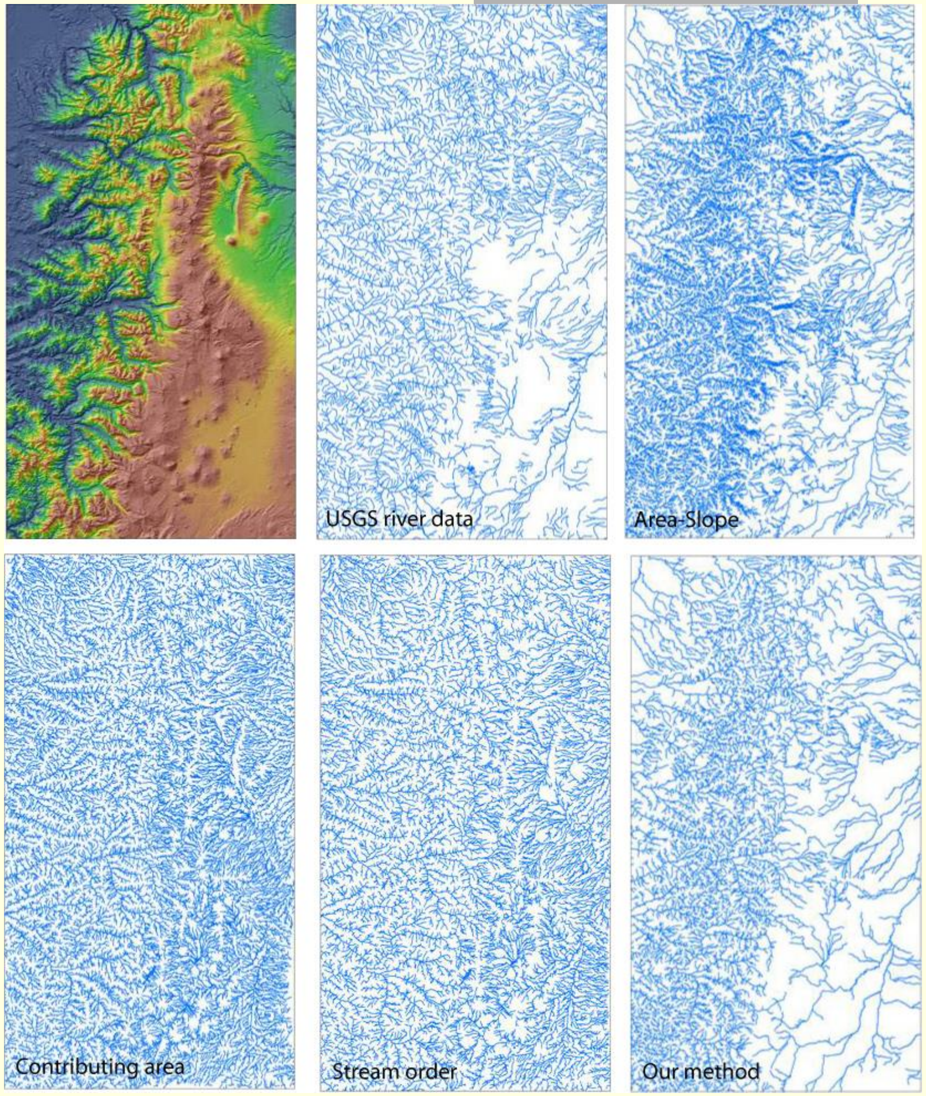






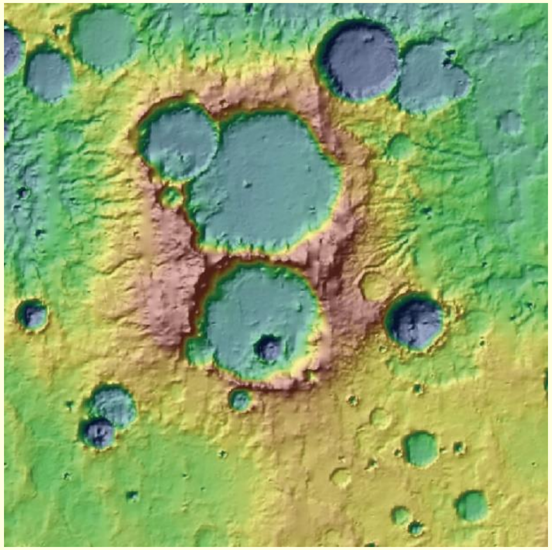
Comparing mapping of drainage network:
Luo and Stepinski, Geomorphology 99, pp 90-98, 2008

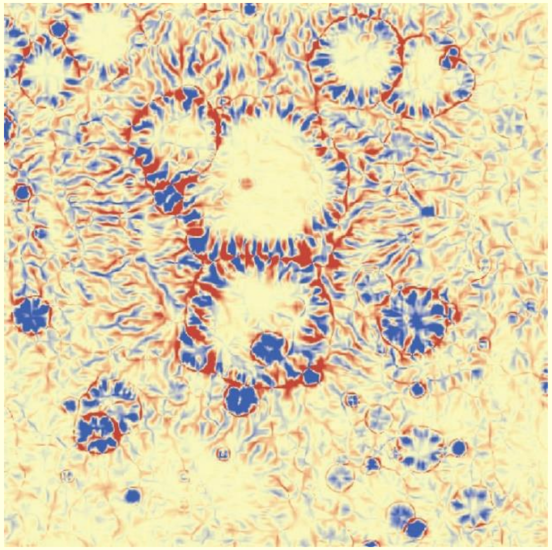


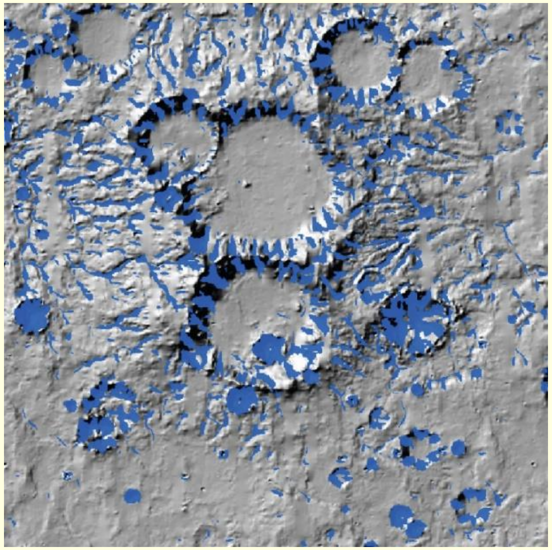


Our approach to mapping valley networks:

Morphology-based algorithm



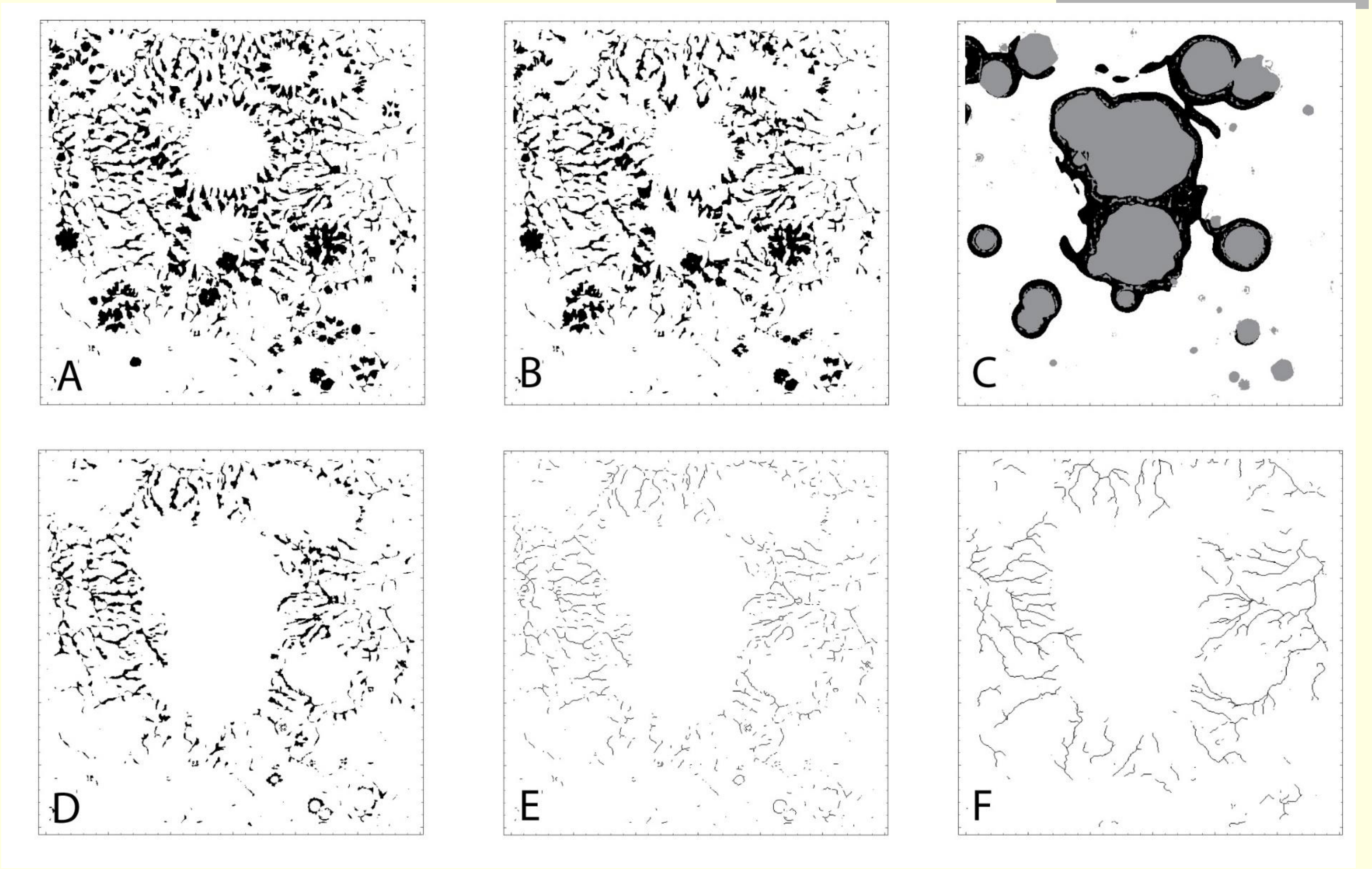




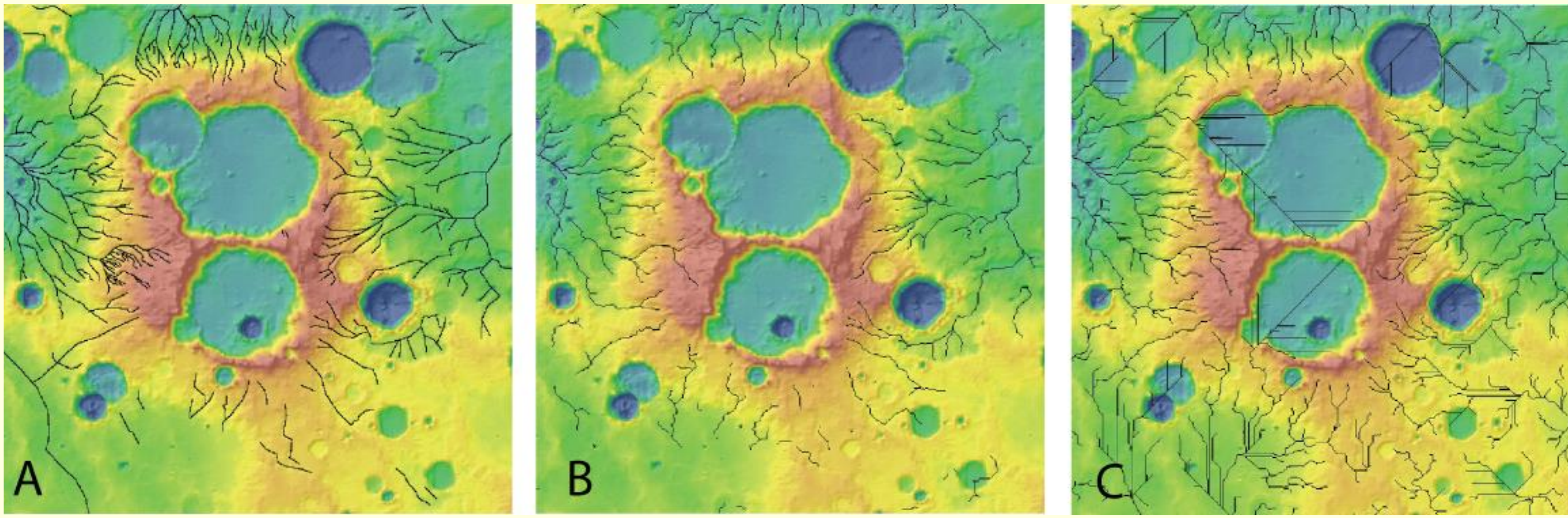
Blue: positive curvature (convergent)
Red: negative curvature (divergent)

Only pixels with curvature > threshold are shown in blue

Mapping VN using terrain morphology



Mapping VN using terrain morphology

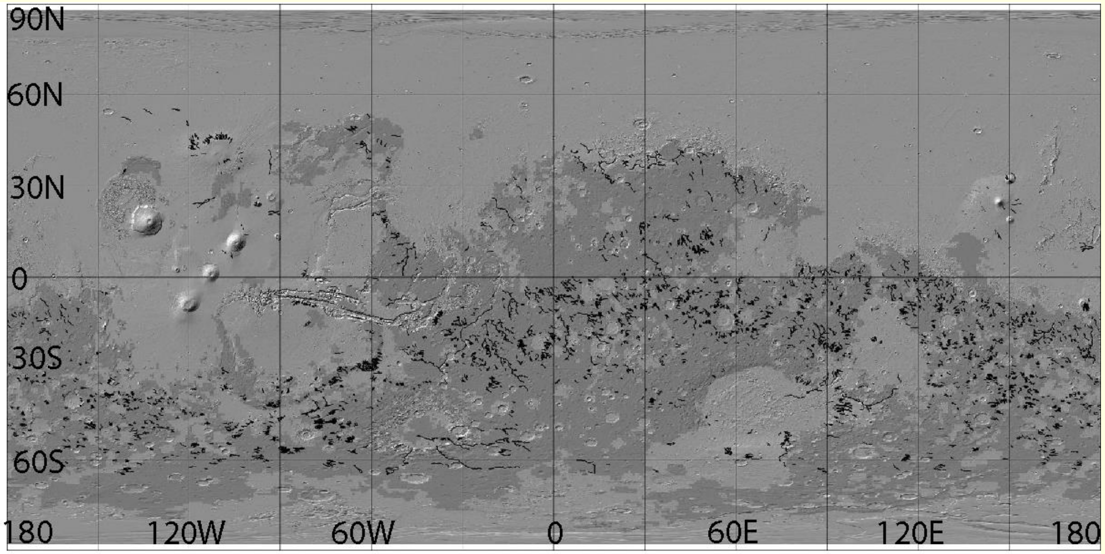


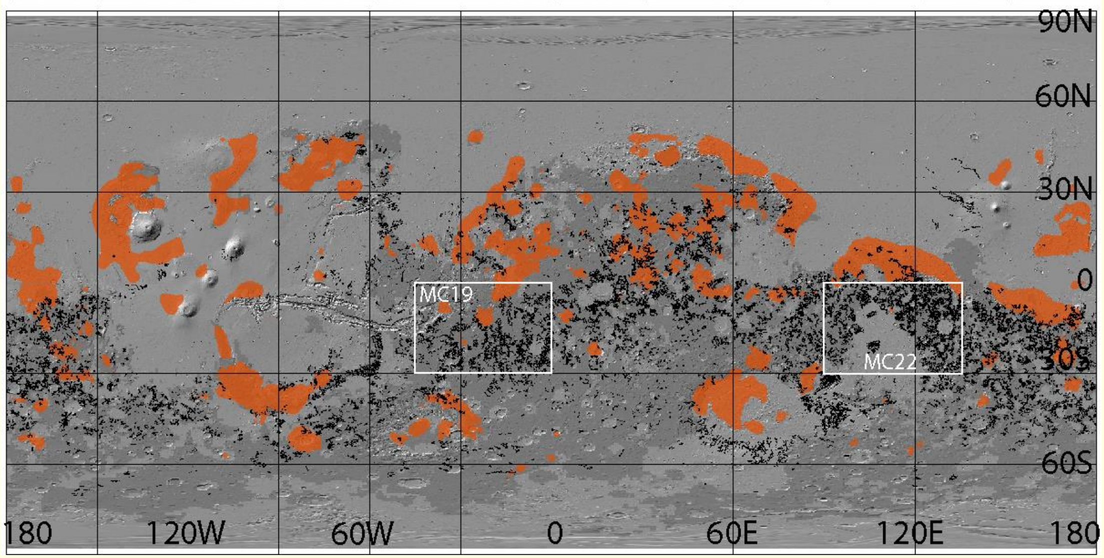
Manually mapped

Map of VN derived using our algorithm

Map of VN derived using our D8 Algorithm with A>=200 pixels threshold

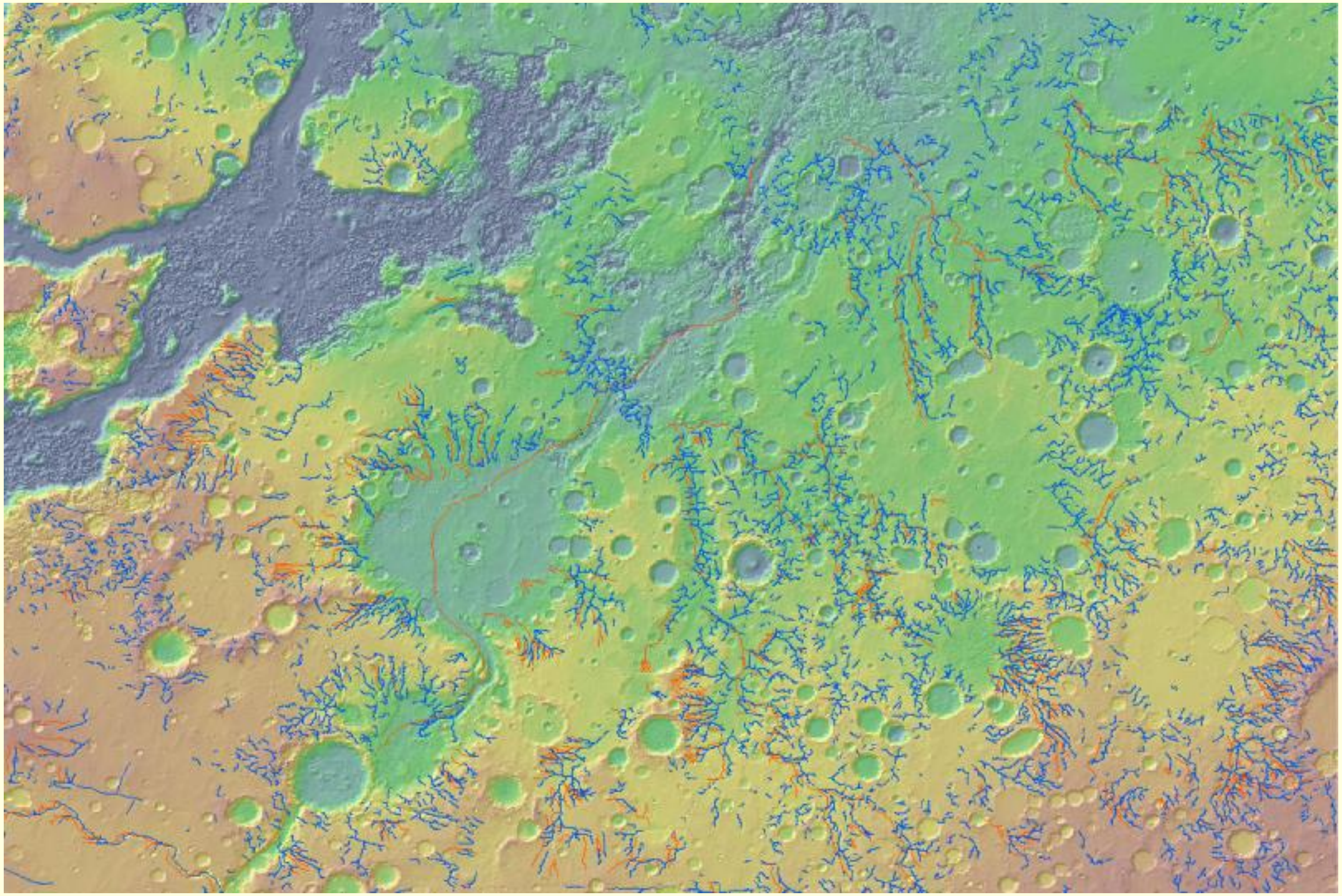
Global map





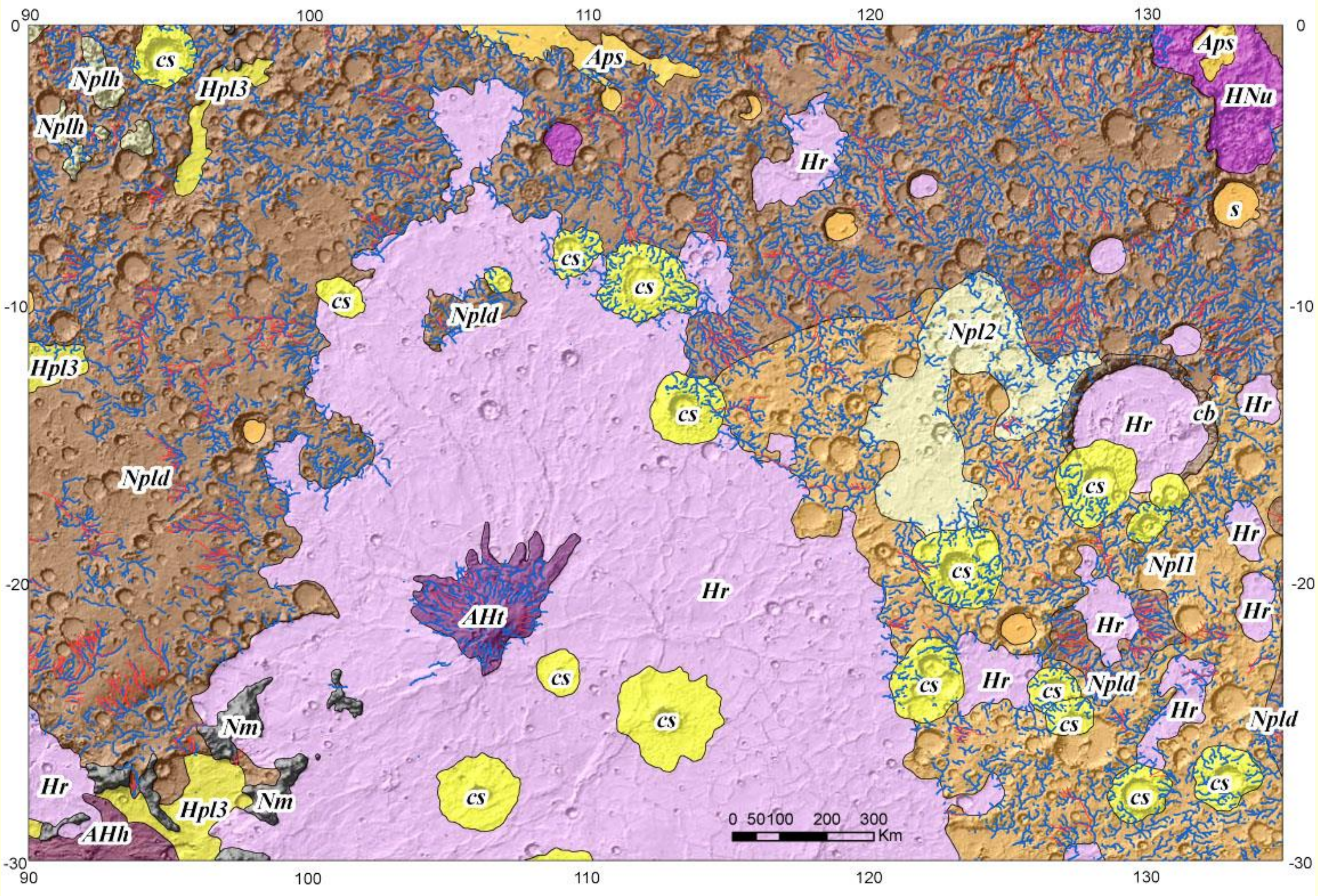
807,000 km of valleys ~ 2.3 times more than on the Carr map.

MC-19 quadrangle

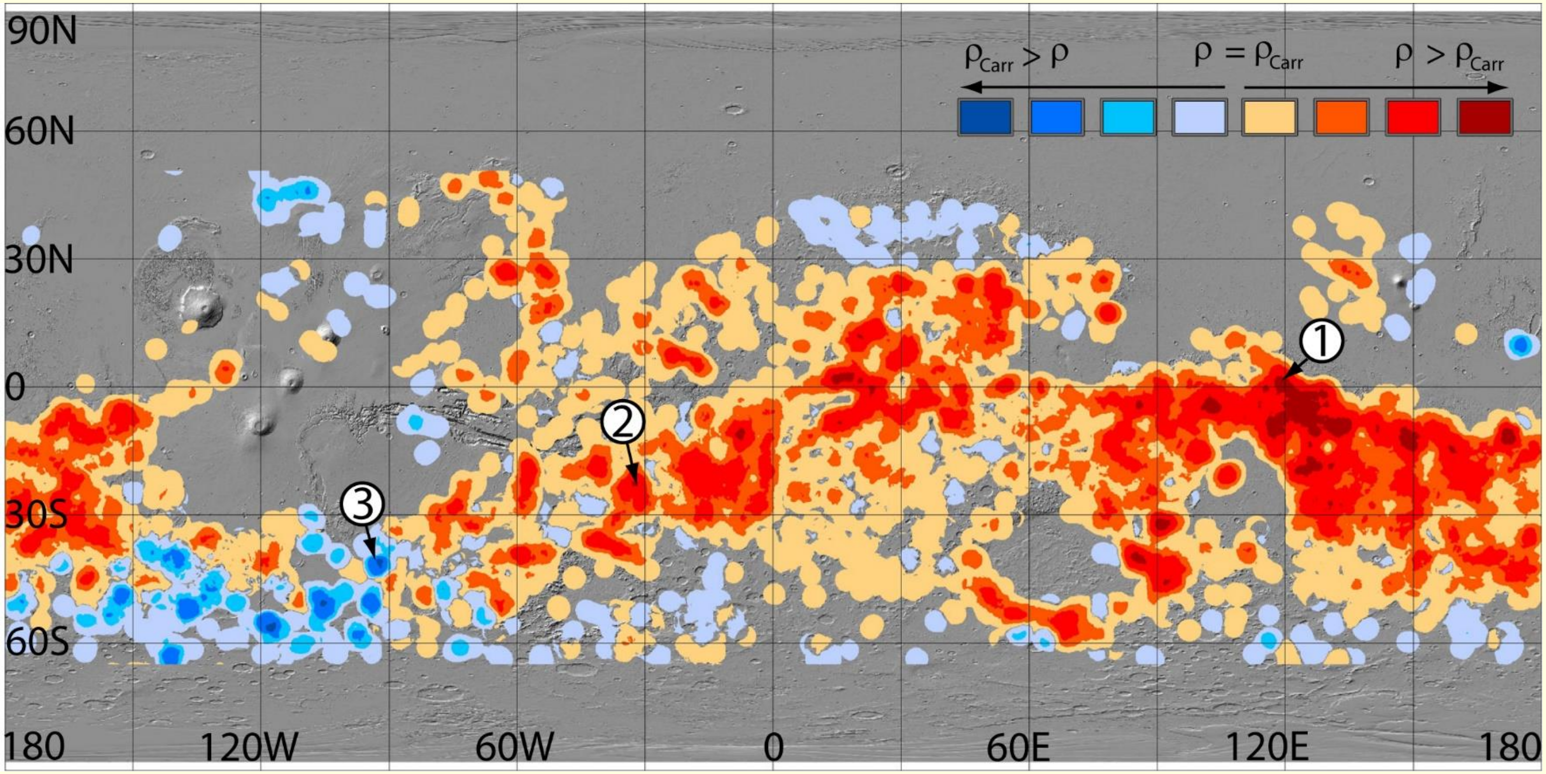


~ 3.4 times more valleys than on the Carr map.

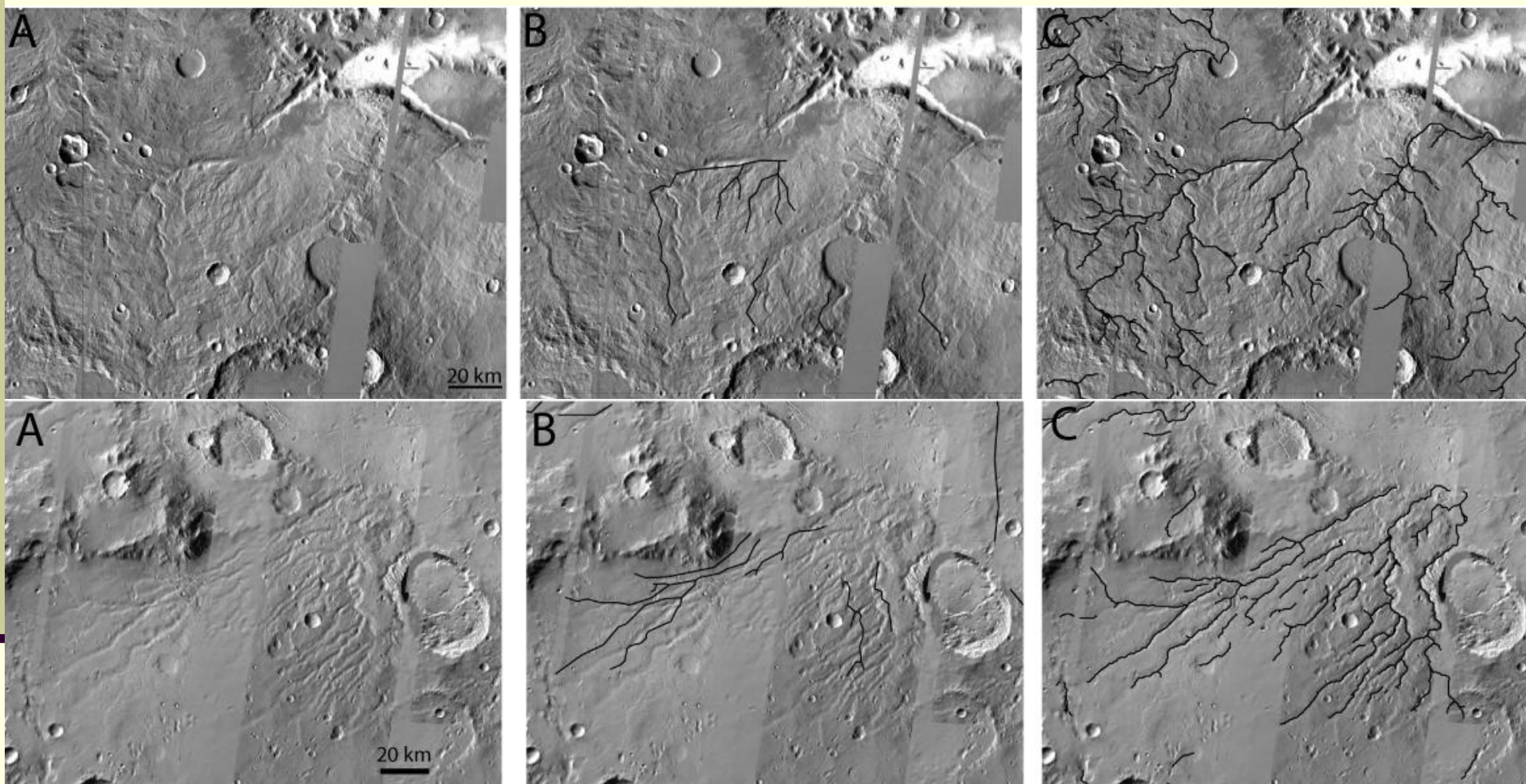
MC-22 quadrangle

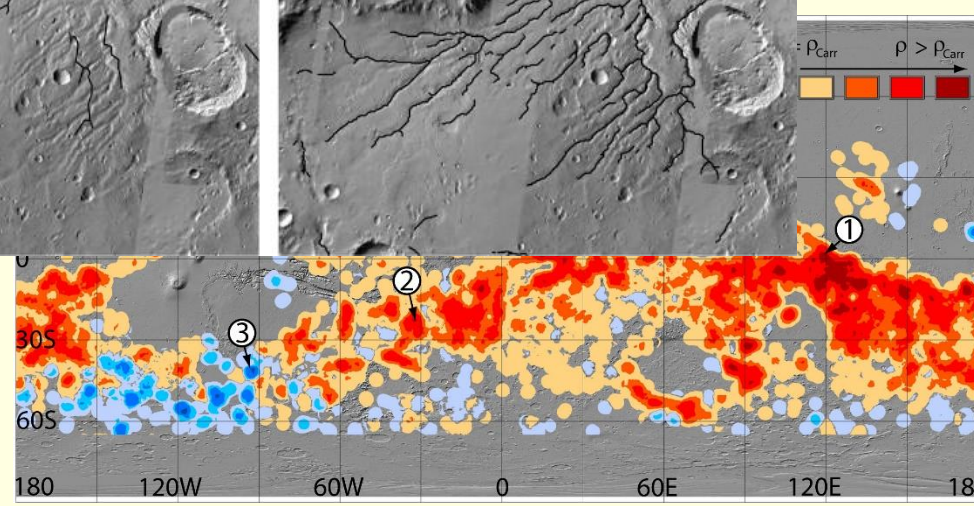


Map comparison using valley density

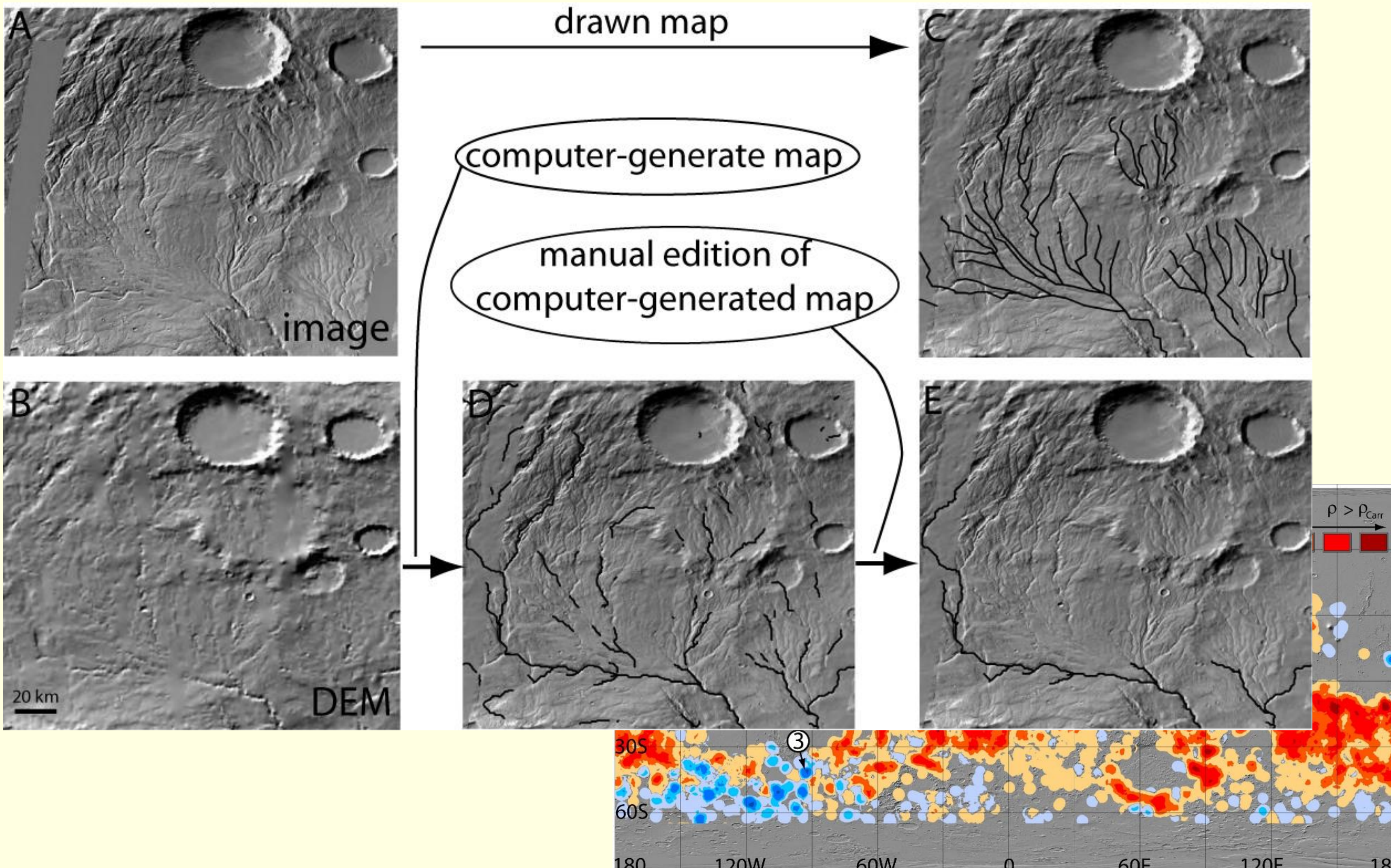


Comparison of elected sites

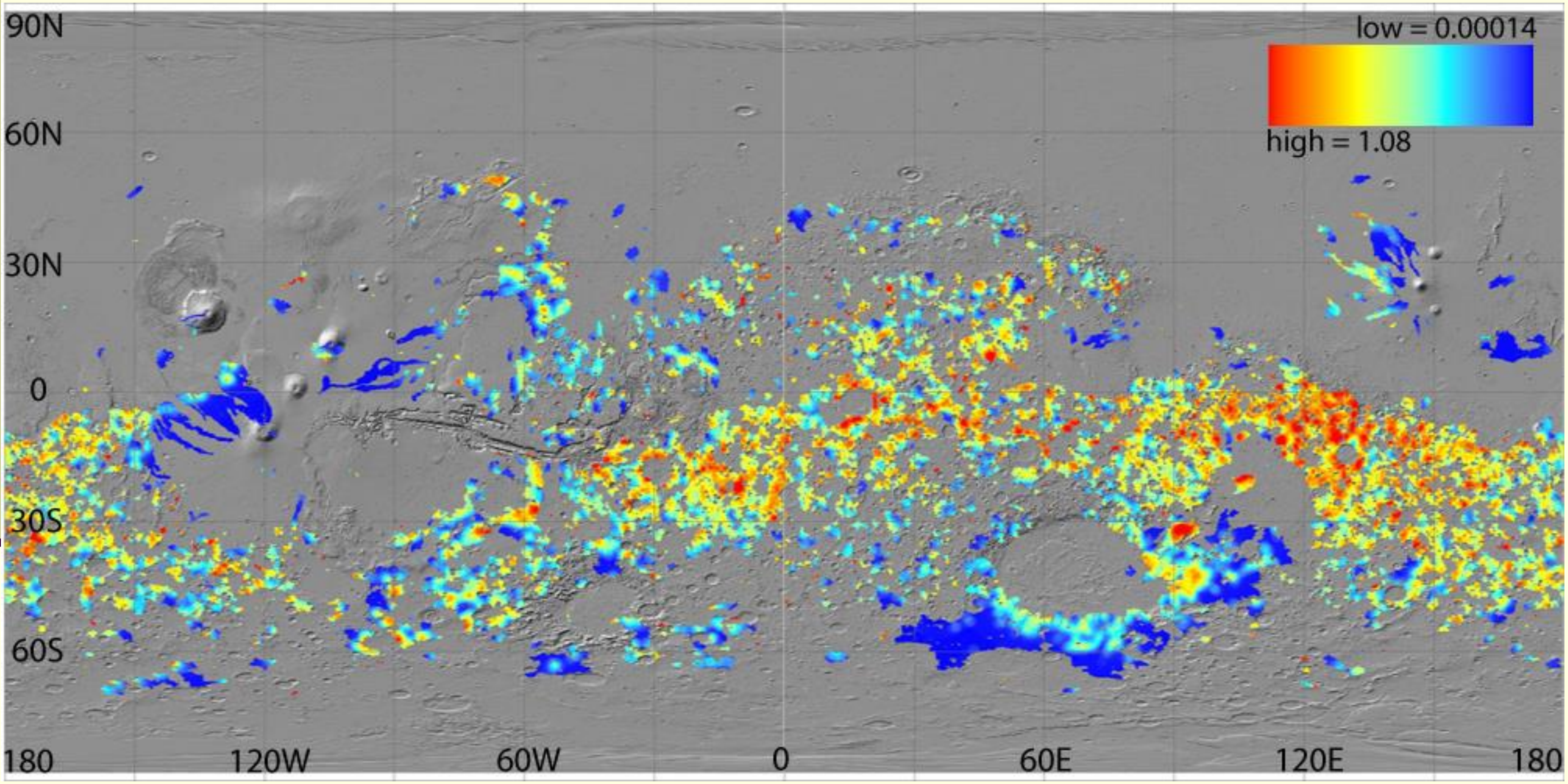




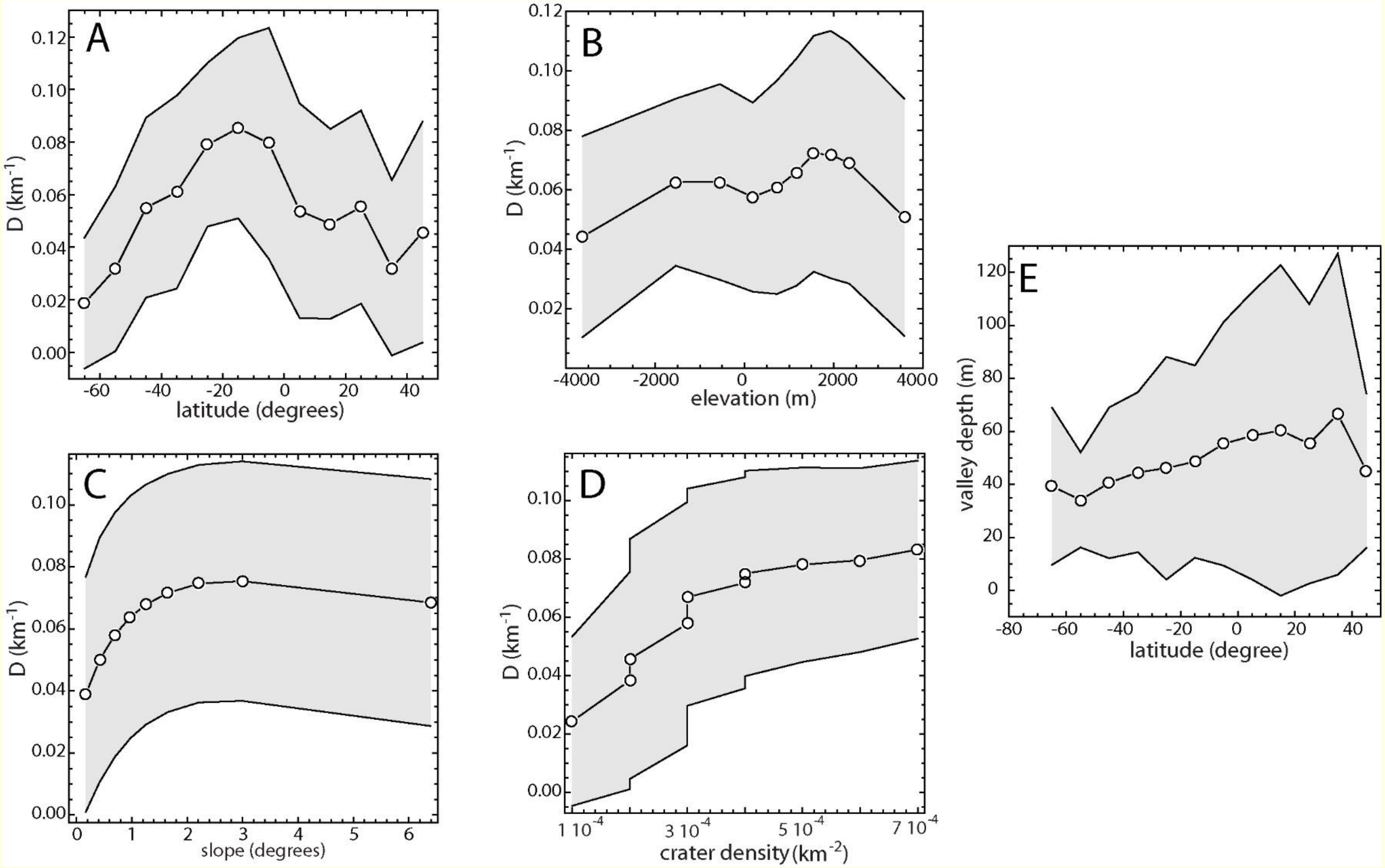
Comparison of elected sites



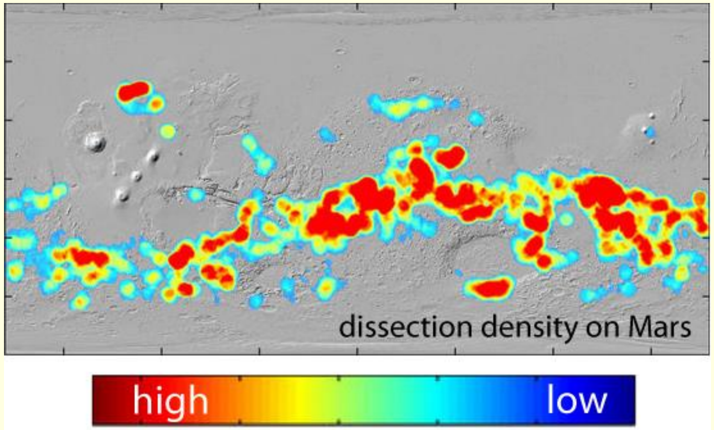
Global map of dissection density

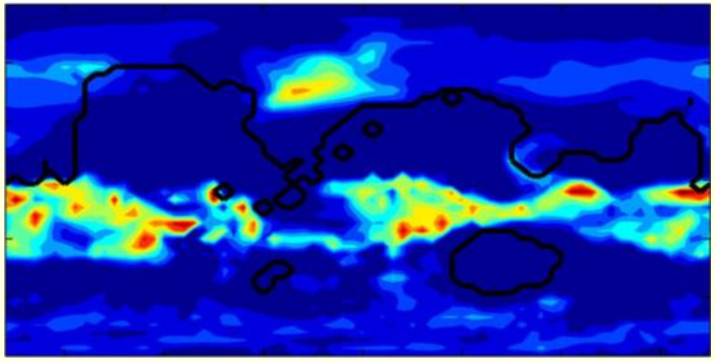


Zonal statistics of dissection density

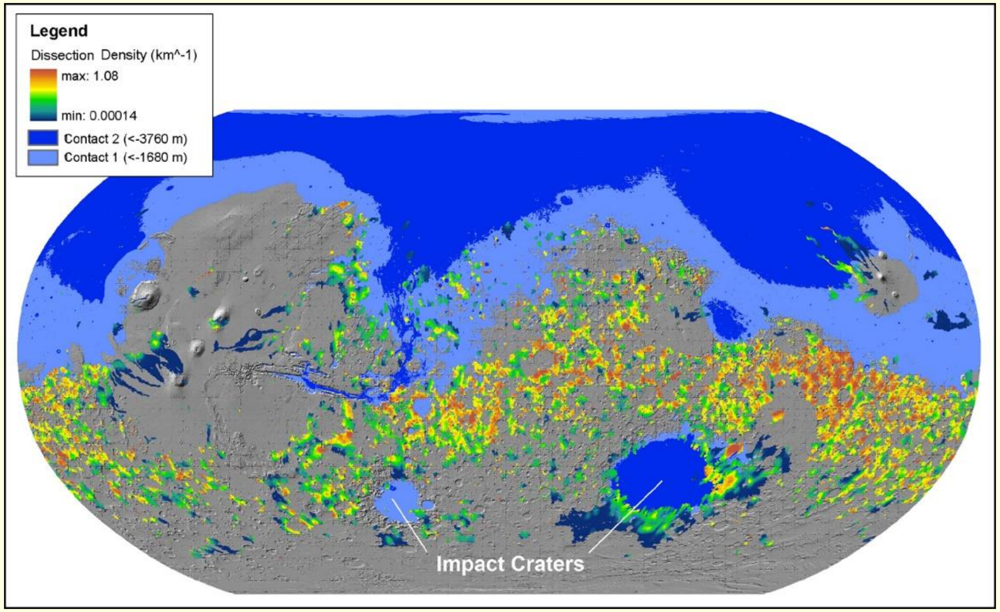


Global map of drainage density





Soto et al., 41st LPSC, #2397, 2010



Global distribution of VN on Mars supports existence of the Northern Ocean. In turn, existence of the Northern Ocean supports runoff origin of VN.

Conclusions

- VN tell the story of the ancient climate on Mars.
- Global map of VN is needed to infer their origin.
- Computer mapping of VN from topography is viable but off-the-shelf algorithms cannot be used.
- Our algorithm maps VN globally but the result must be reviewed to eliminate false negatives.
- The global map of VN favors runoff origin and warmer, wetter ancient climate on Mars.
- The global pattern of VN is in agreement with a global pattern of precipitation as derived from computer simulations, but only if the northern ocean was present.