

MÚ AV květen 2022

Paleooceán na Marsu

**Mars – new findings with gravity and magnetic data
using gravity aspects**

Rukopis do Planetary and Space Sciences
v druhem recenznim kole 5/2022
obrazky vesmes Jan. Kostecky

Highlights

Northern Martian Paleo-ocean

Isidis – volcano rather than a basin or mascon

**Impact of Hellas likely stopped the Mars
differentiation process**

**Gravity aspects confirmed asymmetry related
to magnetic anomaly distribution**

Gravitační a magnetické pole Marsu z družicových měření

Detailní globální topografie povrchu Marsu z laserového výškoměru

Metoda gravitačních aspektů poprvé aplikována na Mars

Význačný přínos jednoho z gravitačních aspektů – úhlů napětí pro indikaci hypotetického severního paleooceánu

Abstrakt:

S novými daty a novou metodou nové výsledky o gravitačním a magnetickém poli Marsu. Mezi nimi indikace pro severní paleooceán na Marsu: rozsáhlá nížina, tlustá vrstva sedimentů, delty někdejších řek a fretted terén na přechodu mezi vysočinou na jihu a nížinou na severu, relativně klidné gravitační aspekty, velkoplošně učesané úhly napětí (analogie se Zemí pro místa paleojezer, říčních kaňonů, podzemní vody, nalezišť uhlovodíků, lemů impaktních kráterů...)

Gravitational aspects (descriptors)

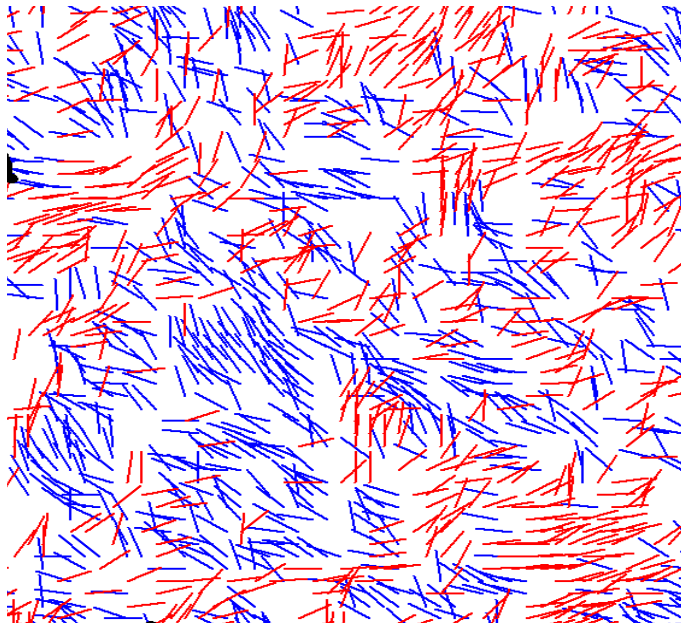
Gravity aspect	Explanation
T	Disturbing static gravitational potential
Δg	Gravity anomaly or perturbation (various versions)
Γ	Marussi tensor (just 5 independent second derivatives of T)
T_{zz}	Element of the Marussi tensor (second derivative of T in the radial direction), usually most important
I_j	3 gravity invariants of the Γ (I_0, I_1, I_2); preserved under any coordinate rotation
I	a ratio of I_1, I_2; when $I \sim 0$, the causative body is $\sim 2D$; when $I \rightarrow 1$, causative body is $3D$
θ	Strike angle is the main direction of Γ, under certain conditions
vd	Virtual deformation based on horizontal derivatives of T in latitudinal and longitudinal directions, expressing dilatation and pure shear (compression)

The gravity disturbances (anomalies) are in milligals [$mGal$], the second order derivatives in Eötvös [E]. Negative values are in blue colour, positive in red. Recall that $1mGal = 10^{-5} ms^{-2}$, $1E \equiv 1 \text{ Eötvös} = 10^{-9} s^{-2}$ and that the invariants have units $I1 [s^{-4}]$ and $I2 [s^{-6}]$. The strike angles are in degrees and vd are dimensionless.

We count azimuths from North to East (=90 deg E), South, West, and back to North (=360 deg E). We count longitudes from the main meridian (defined by astronomers) to East from 0 to 360 degrees (this differs from astronomers).

The strike angle θ [deg, 0] is expressed with respect to the local meridian; its red colour means its direction to the north and blue to the south of the east.

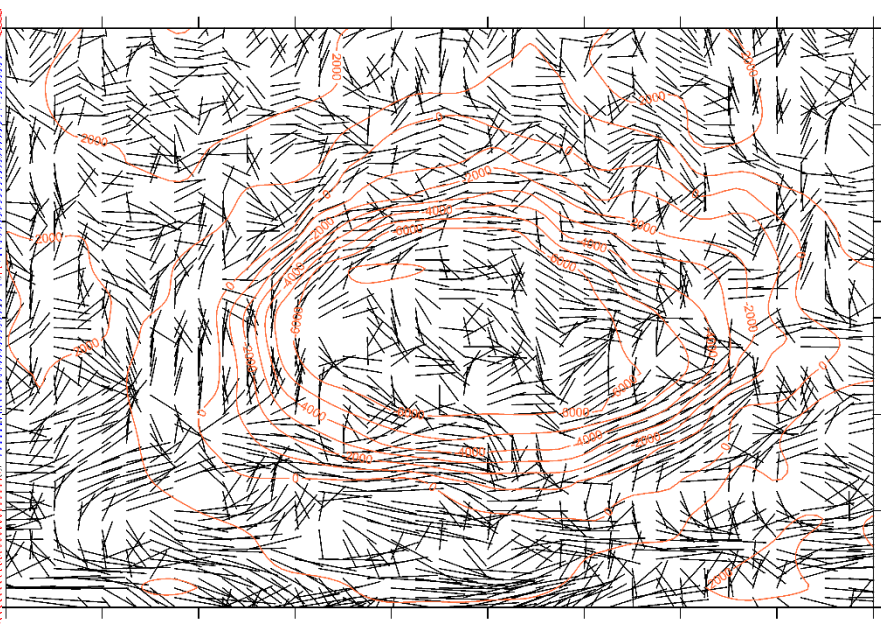
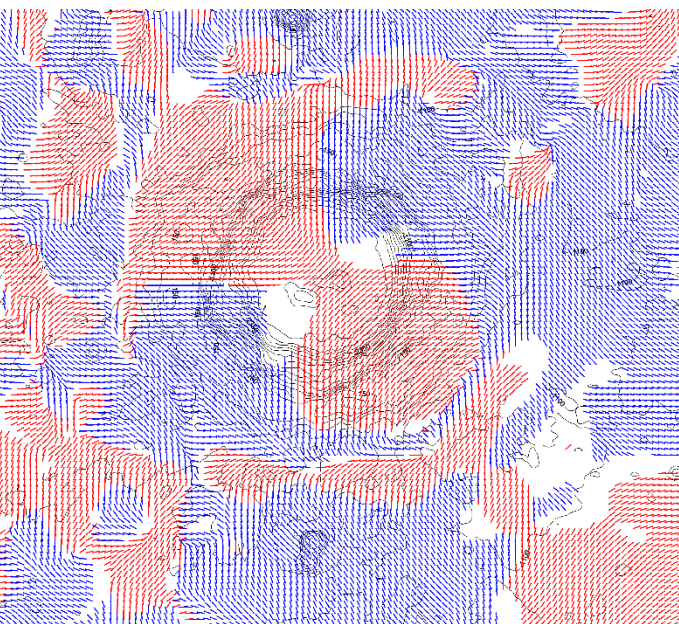
The strike angles are angles, not vectors. We plot them as short abscissae of the same length everywhere, in a regular network (5x5 arcmin). It does not mean that in the real world something like a regular net of tensions exist: geological and geophysical lineaments are never of a constant or identical length, and neither are they separated by uniform distances.



Comments:

Left
highly combed,
linearly

Right
dishevelled



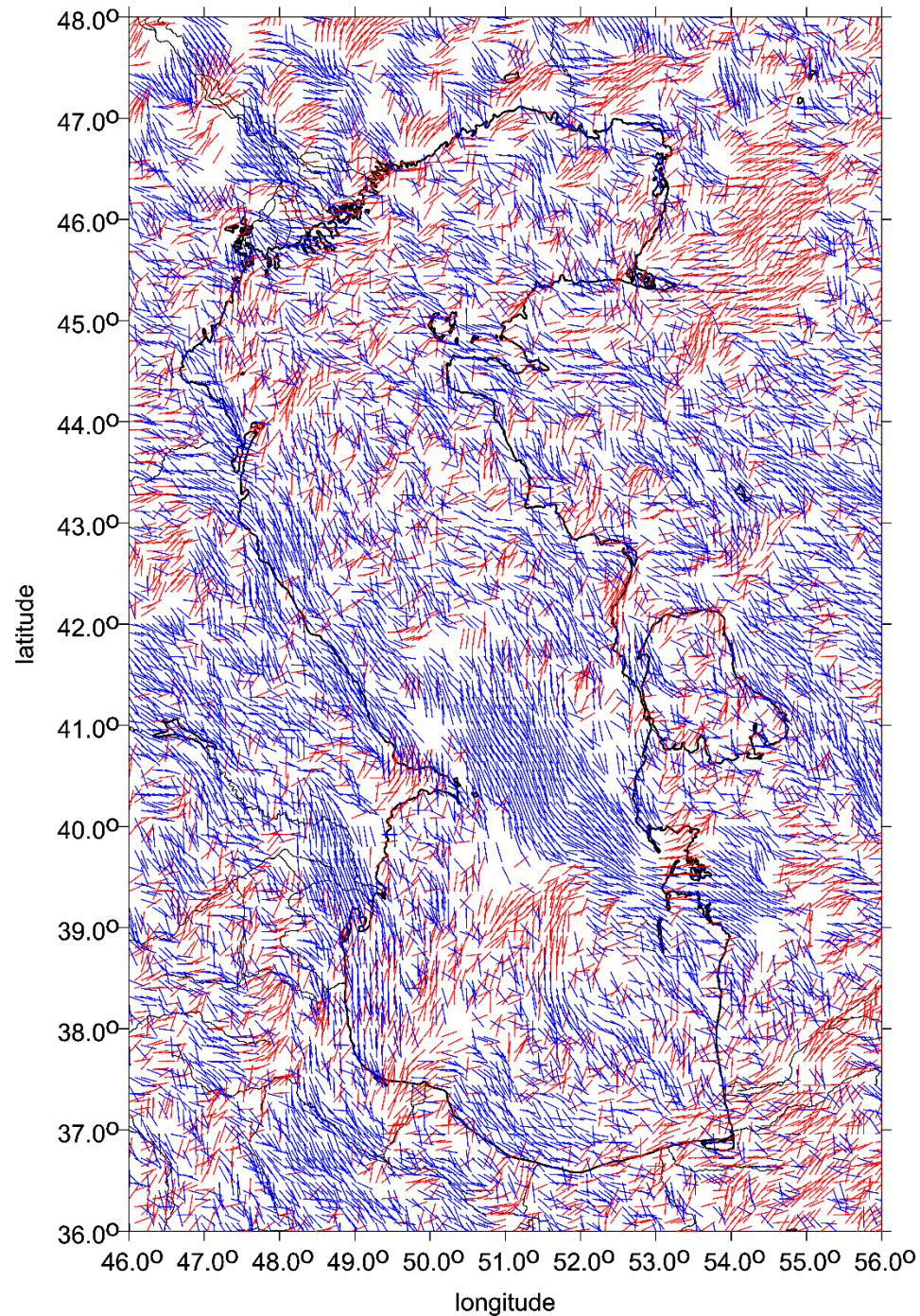
Left
combed,
creating a halo
around the crater
segments
in color

Right
halo
in black&white

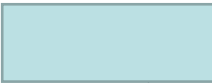
the Moon/Copernicus

Hellas basin on Mars

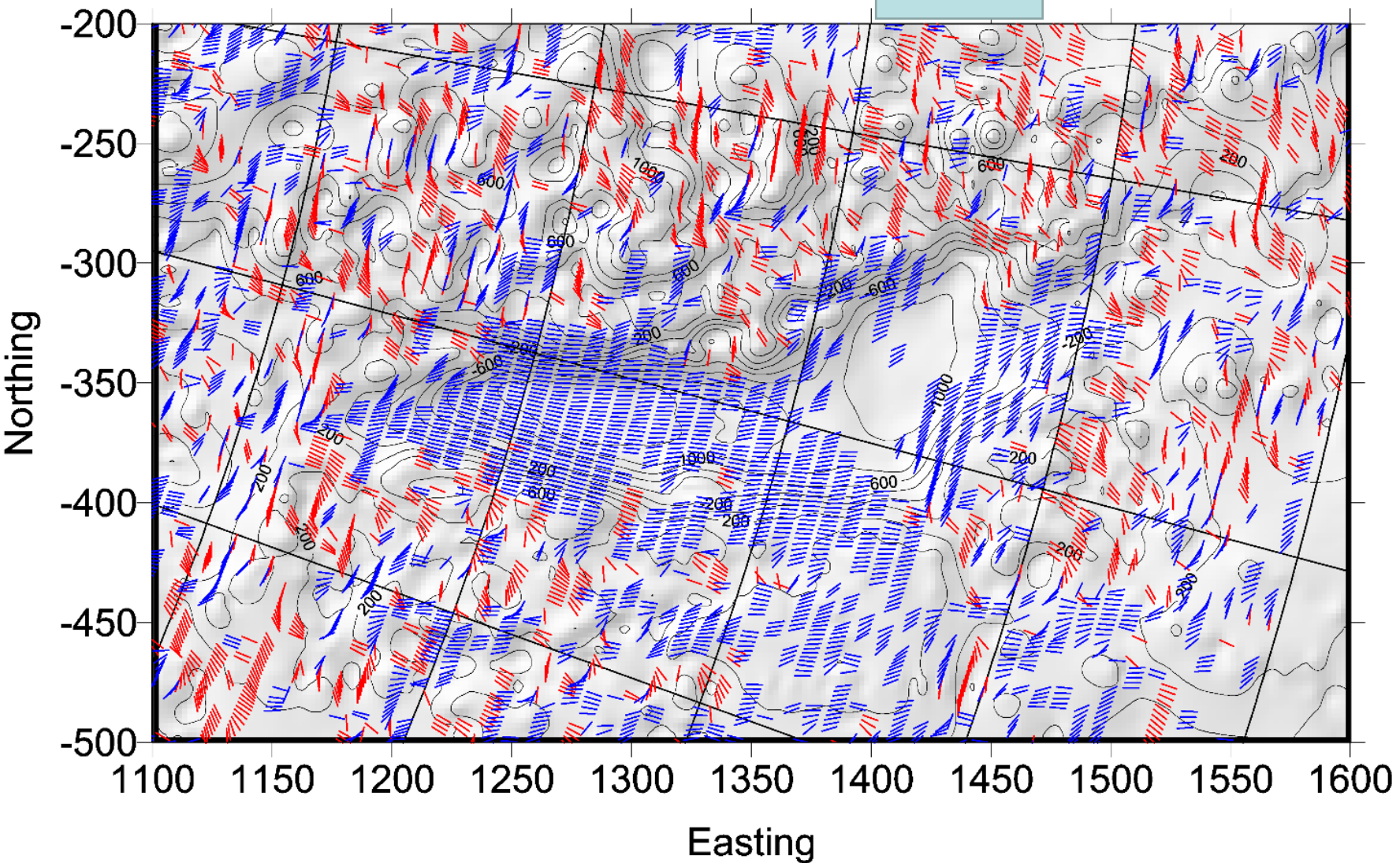
Eigen 6C4 - 01 Caspian - Theta for RI < 0.5

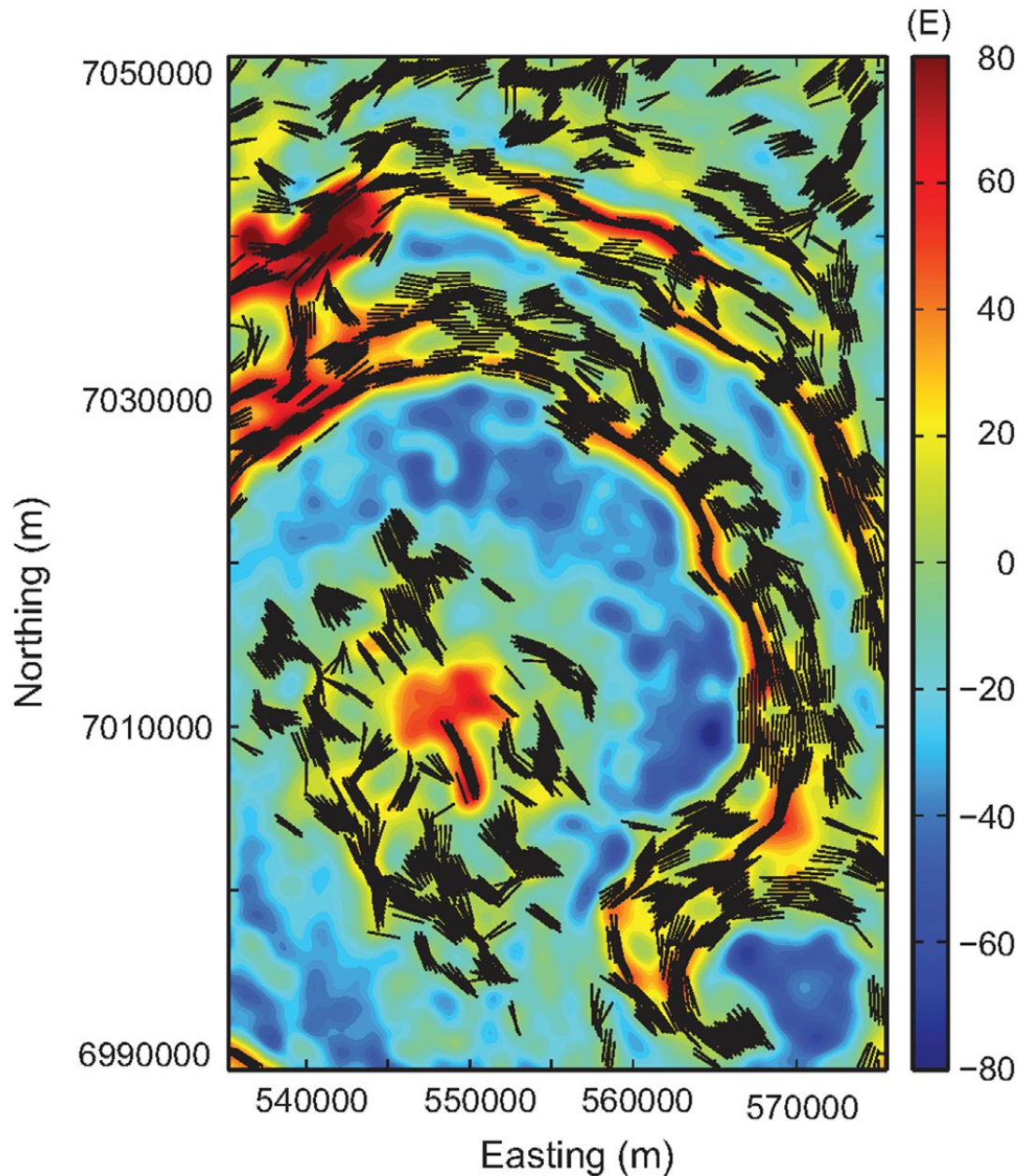


RET-2014-Vostok-Theta-



sever vpravo



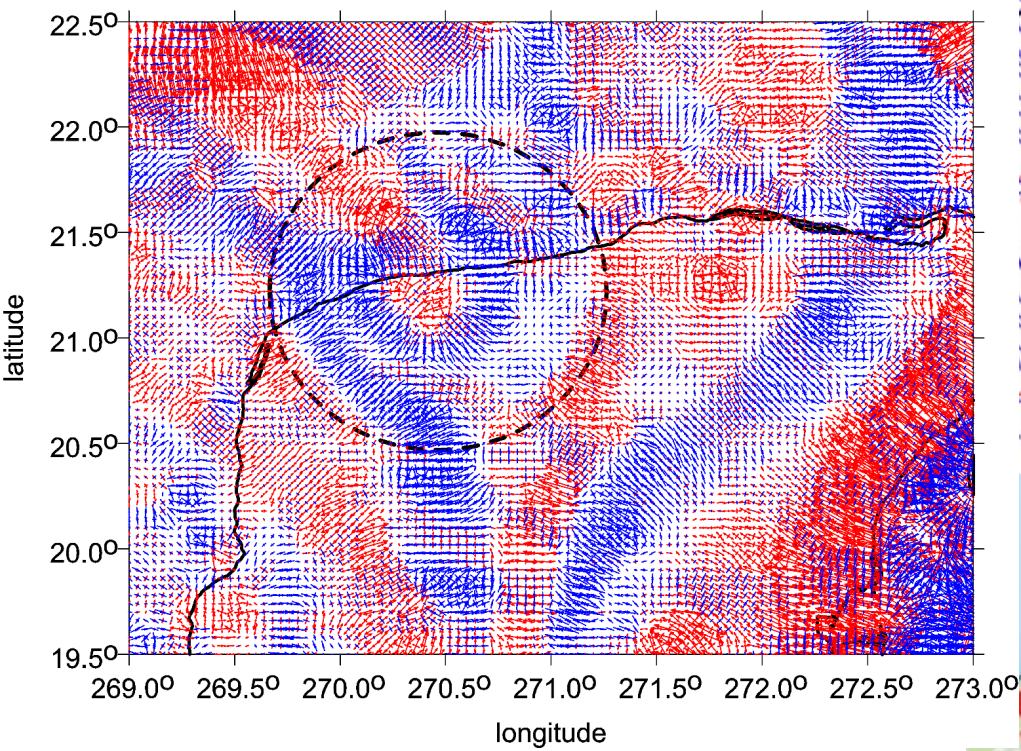


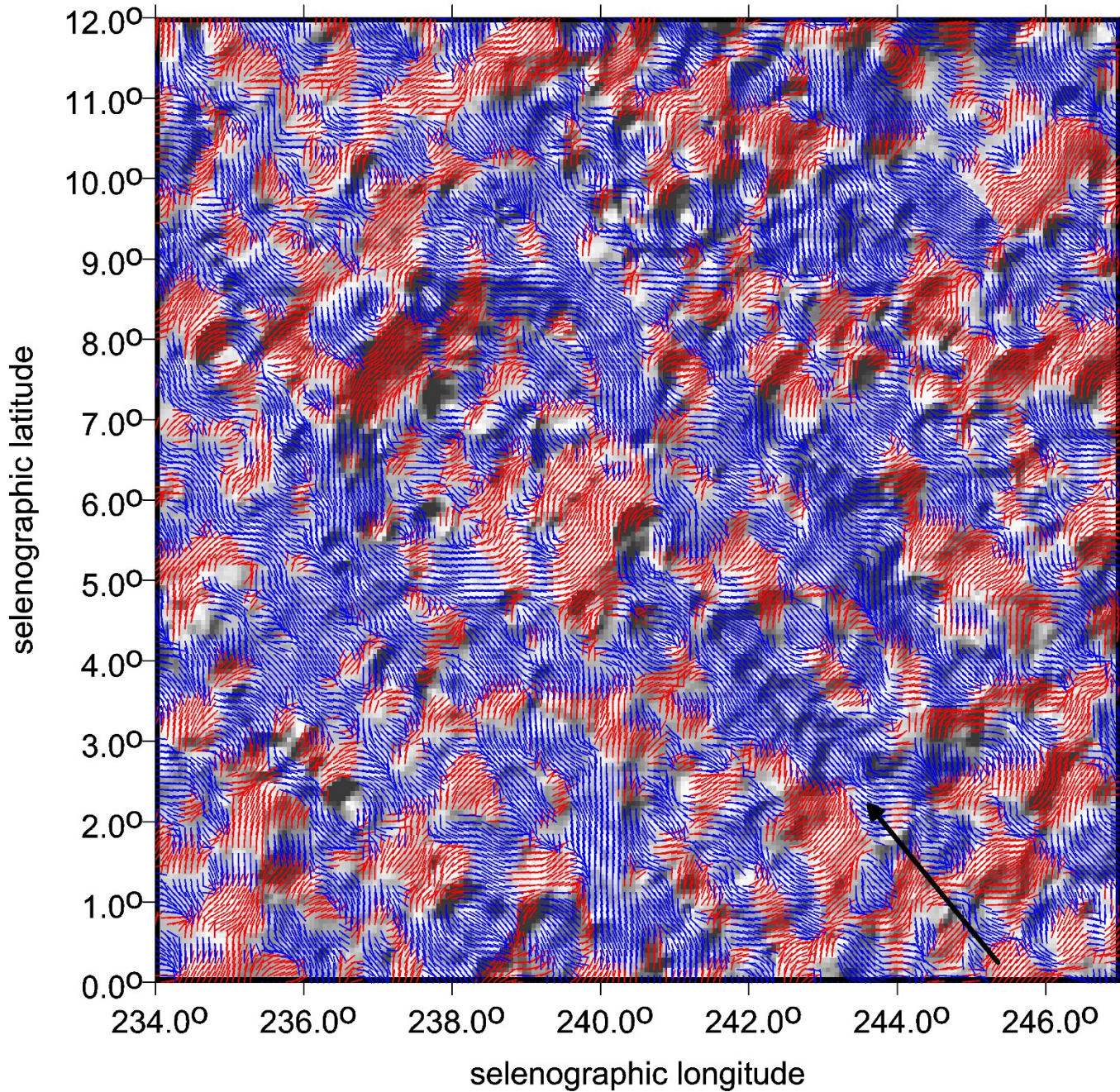
impact crater
Vredefort, South Africa

The strike angles follow rings of the impact structure Vredefort, South Africa. In the central part of the crater they are combed not around the crater but in one prevailing direction.

To draw this, **Beiki and Pedersen (2010)** used the detailed local airborne gradiometry data, which we have not available and the resolution of our data source (EIGEN 6C4) is not sufficient for this purpose.

Eigen-6C4-Chicxulub - virtual deformation





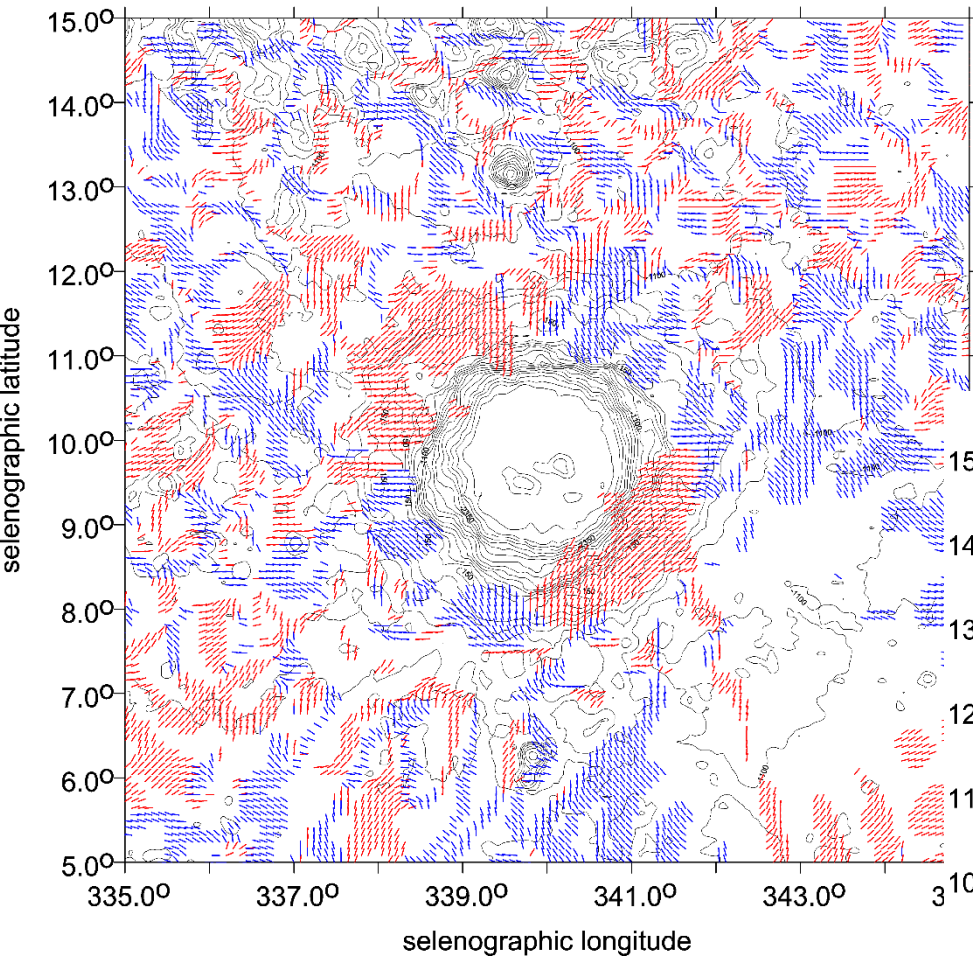
Michelson

crater and catena

Fig. Supp. 65
for Michelson

θ [deg]

Moon - Copernicus - 600 - Topography + Theta for RI < 0.3



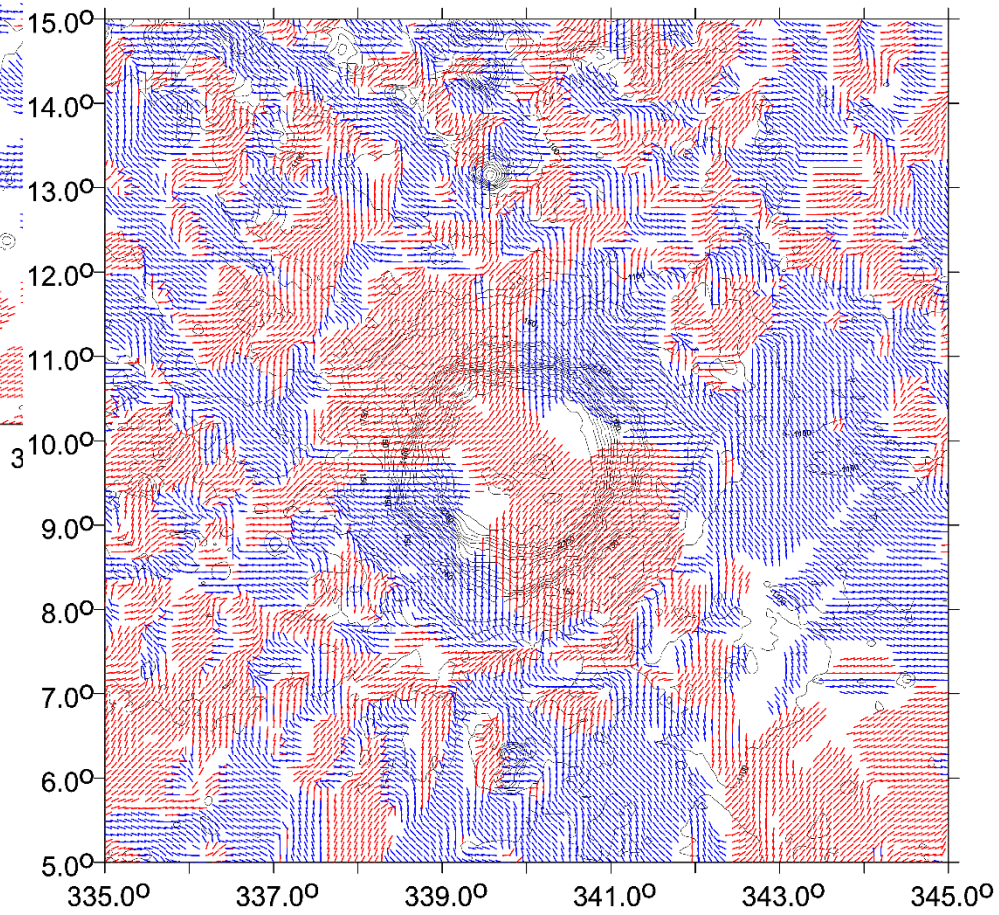
the Moon/ Copernicus

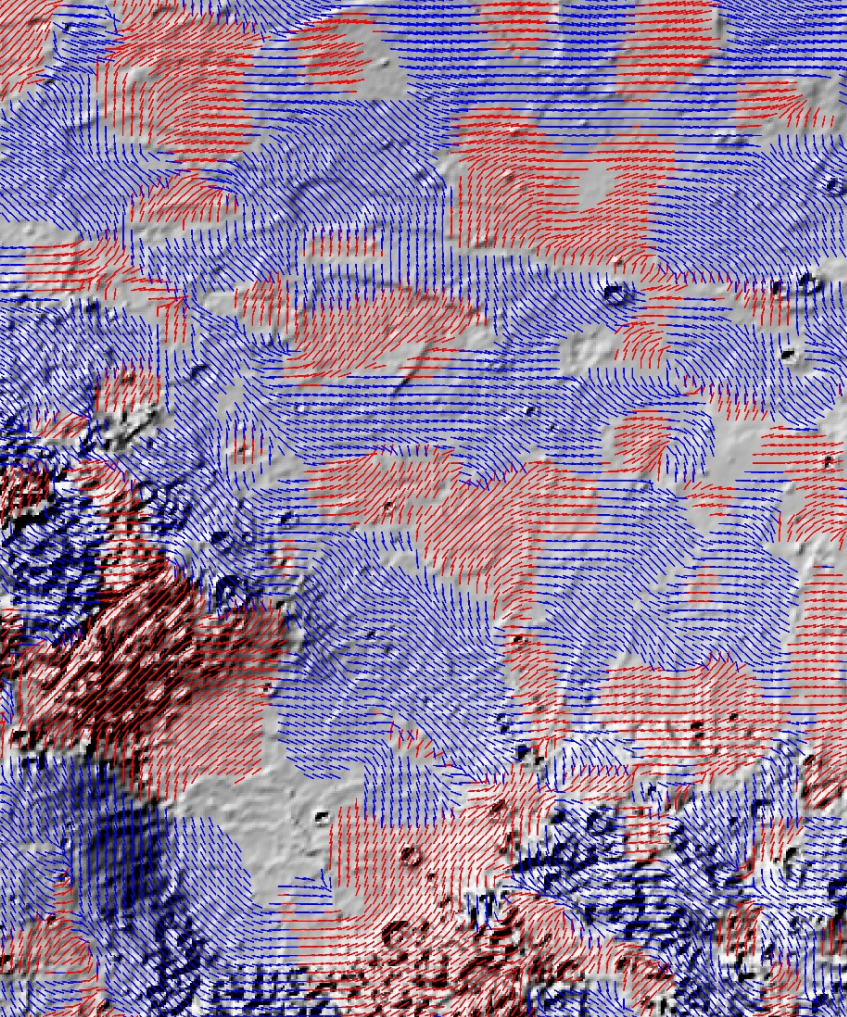
Strike angles for

$I < 0.3$ (left) and

$I < 0.9$ (right down)

Moon - Copernicus - 600 - Topography + Theta for RI < 0.9





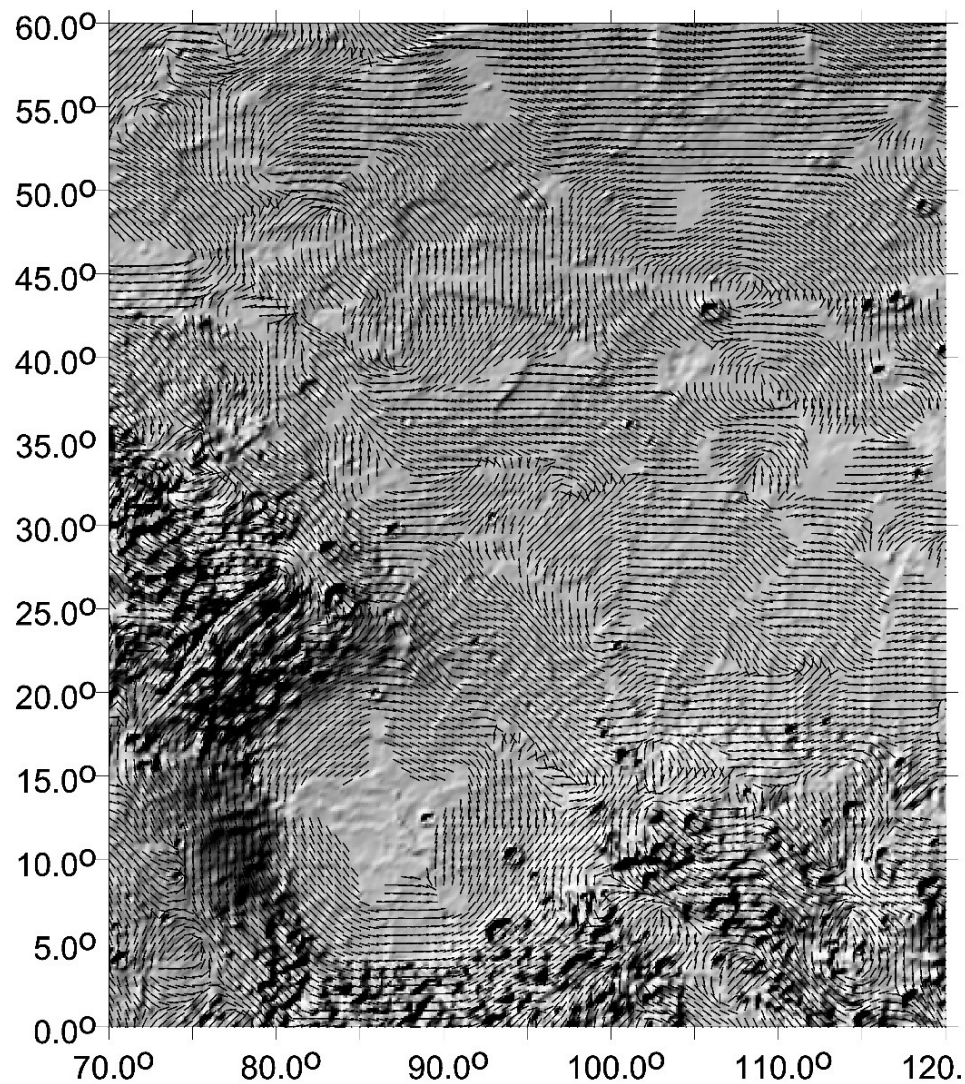
Comments:

Left

combed in plates

**Mars
Isidis**

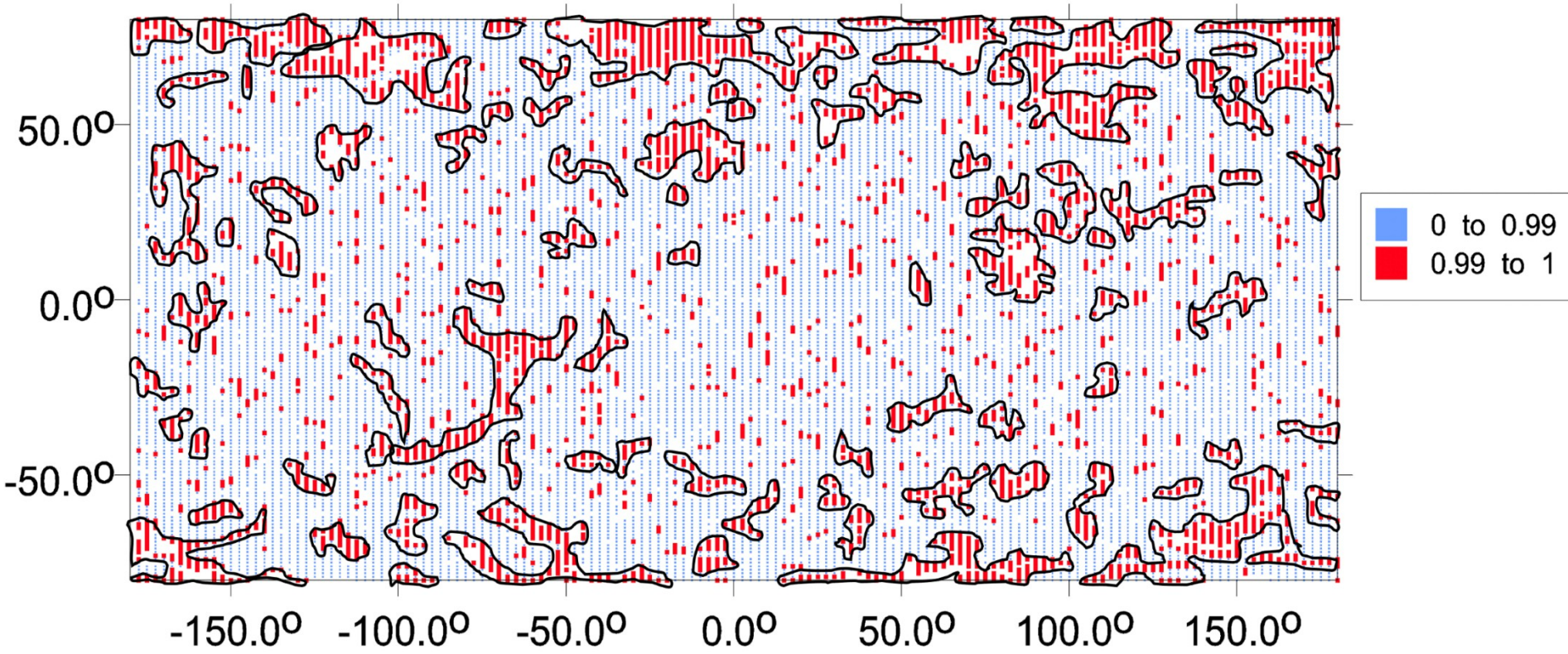
Right
combed in plates
b&w version



Example of the strike angles plotted as a color comb scale (not dashes)

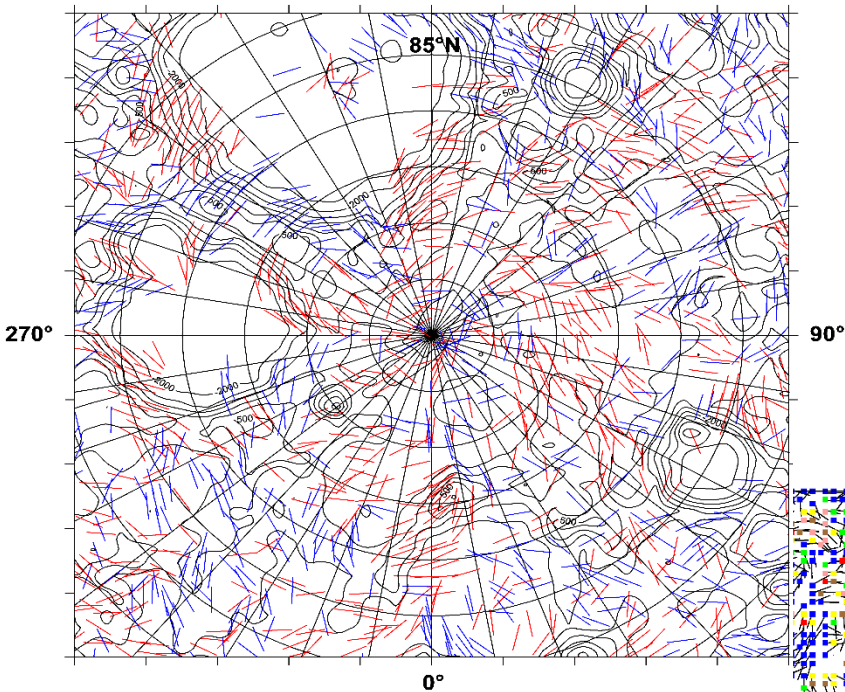
Strike angles with the comb factor to emphasize highly combed areas

Mars, Northern paleocean - potential water more probably for red areas



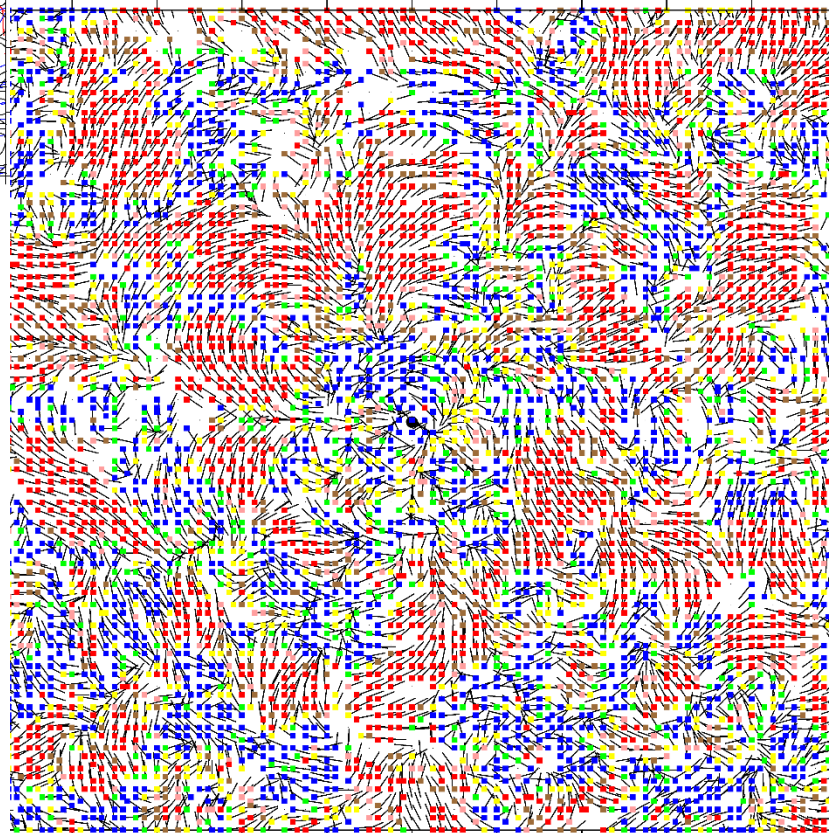
Moon - north pole - Topo + Theta for RI < 0.3

180°

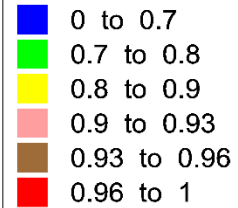


Example of the strike angles plotted as a color comb scale (not lines)

Moon - north pole - Theta for RI < 0.9



comb



Strike angles with the comb factor scaled

to quantify a degree of strike angle alignment

the polar zone of the Moon

Ground Resolution

A usual simple estimate of the smallest representable feature of the gravity field or the **shortest half-wavelength L_{half} (as a distance on a sphere) that can be resolved with all C_{lm} , S_{lm} to L_{max} , is**

$$L_{half} = \pi R / L_{max}$$

or equivalently, taking the circumference $2\pi R = 40\,050$ km for the Earth:

$$L_{half} = 2\pi R / (2 L_{max}) = 40\,050 / (2 L_{max}).$$

This L_{half} is what we call the “ground resolution”. For $L_{max} = 300$ and 2190 , we have $L_{half} = 67$ and 9 km, respectively. The former limit roughly corresponds to the resolution of the GOCE data alone, and the latter belongs to the combined models, EGM 2008, EIGEN 6C4 or SatGavRET2014 (in the case of the Earth).

Body	R [km] rounded	max d/o of model used	resolution [km]
Earth	6380	2190	9
Moon	1740	600	9
Mars	3400	80-120	130-90
Venus	6050	120	160

The gravity field of Mars

used here

Konopliv et al 2020

Name: JPL-MARS-MRO120F (d/o =120) “Mars - gravitační pole JGMRO”

Ground resolution: ~ 100 km

Geophysical Research Letters

47, e2020GL090568 13 October 2020

Detection of the Chandler Wobble of Mars From Orbiting Spacecraft

Alex S. Konopliv , Ryan S. Park , Attilio Rivoldini , Rose-Marie Baland Sebastien Le Maistre Tim Van Hoolst Marie Yseboodt, Veronique Dehant

<https://doi.org/10.1029/2020GL090568>

For the first time for any planetary body other than the Earth, the free wobble of the pole called the Chandler wobble has been detected for Mars with a period of 206.9 ± 0.5 days and amplitude of 10 cm from radio tracking observations of Mars Odyssey, Mars Reconnaissance Orbiter (MRO), and Mars Global Surveyor (MGS), in order of decreasing sensitivity. The motion of the rotation pole location on the surface of Mars, or polar motion, is observed using two different approaches: (1) joint global estimates of Mars' orientation and its gravity field and (2) time series solutions of $C21$ and $S21$. For Mars interior models, the Chandler wobble period is combined with other measurements including the moments of inertia from our estimated precession rate $\dot{\psi} = -7603.9 \pm 1.3$ mas/year and tidal Love number $k_2 = 0.169 \pm 0.006$. The Chandler wobble period constrains the rheology of the Martian mantle and in particular its long-term frequency dependence.

The gravity field model of Mars JPL-MARS-MRO120F (to max. d/o =120) used here (Konopliv et al 2020) superseded the older solutions (e.g. GGM 3 by Genova et al 2016). The model is based on data from Mars orbiters: the Mars Reconnaissance Orbiter (MRO), the Mars Global Surveyor (MGS) and Mars Odyssey. The data spanned 18 years (and still coming) was considered to be precise enough even to measure the Chandler wobble of Mars. The model has the ground resolution about 100 km; its nominal precision is 10 mGals.

As many times before in the gravity field modelling for the Earth, the Moon, Venus and Mars, Kaula rule has been used to stabilize least squares adjustment for the harmonic geopotential coefficients. For JPL-MARS-MRO120F, it was applied above d/o=80. Thus, this d/o limit indicates to which maximum d/o the model should actually be used. This is supported by our truncation error tests for various gravity aspects and the d/o limits 80, 100, and 120, showing an increasing graining as a typical first symptom of incoming artefacts in the gravity signal when the user asks for too much details from the model which are not due to the data imperfections of various types contained in.

References:

Alex S. Konopliv , Ryan S. Park , Attilio Rivoldini , Rose-Marie Baland Sebastien Le Maistre Tim Van Hoolst Marie Yseboodt, Veronique Dehant 2020. Detection of the Chandler Wobble of Mars from Orbiting Spacecraft , *Geophys Res Letts* 47, e2020GL090568, <https://doi.org/10.1029/2020GL090568>.

Genova, A., Goossens, S., Lemoine, F. G., Mazarico, E., Neumann, G. A., Smith, D. E., & Zuber, M. T. 2016. Seasonal and static gravity field of Mars from MGS, Mars Odyssey and MRO radio science. *Icarus*, 272, 228-245. doi:10.1016/2016.02.050

Geoidemartien[19]	G Balmino, B Moynot and N Vales	1982	18[19] [~600 km]	Tracking data of Mariner 9, Viking 1 and 2 spacecraft[19]
GMM-1[20]				
Mars50c[21]				
GMM-2B[14]	FG Lemoine, DE Smith, DD Rowlands, MT Zuber, GA Neumann, DS Chinn, and DE Pavlis	2001	80[14]	Tracking data of Mars Global Surveyor (MGS), and MOLA-derived topography data [14]
GGM1041C[22]				
MGS95J[23]				
MGM08A[7]	JC Marty, G Balmino, J Duron, P Rosenblatt, S Le Maistre, A Rivoldini, V Dehant, T. Van Hoolst	2009	95[7] [~112 km]	Tracking data of Mars Global Surveyor (MGS) and Mars Odyssey, and MOLA-derived topography data [7]
MRO110B2[24]				
MGM2011[1]				
GMM-3[13]	A Genova, S Goossens, FG Lemoine, E Mazarico, GA Neumann, DE Smith, MT Zuber	2016	120[13] [115 km]	Mars Global Surveyor (MGS), Mars Odyssey and Mars Reconnaissance Orbiter (MRO)[13] <ul style="list-style-type: none"> • MGS (SPO-1, SPO-2, GCO, MAP)[13]

SURFACE TOPOGRAPHY OF MARS used here

Topography of Mars in resolution 0,25°:

http://www.asu.cas.cz/~bezdek/JK&JK/Mars/topografie_MOLA/

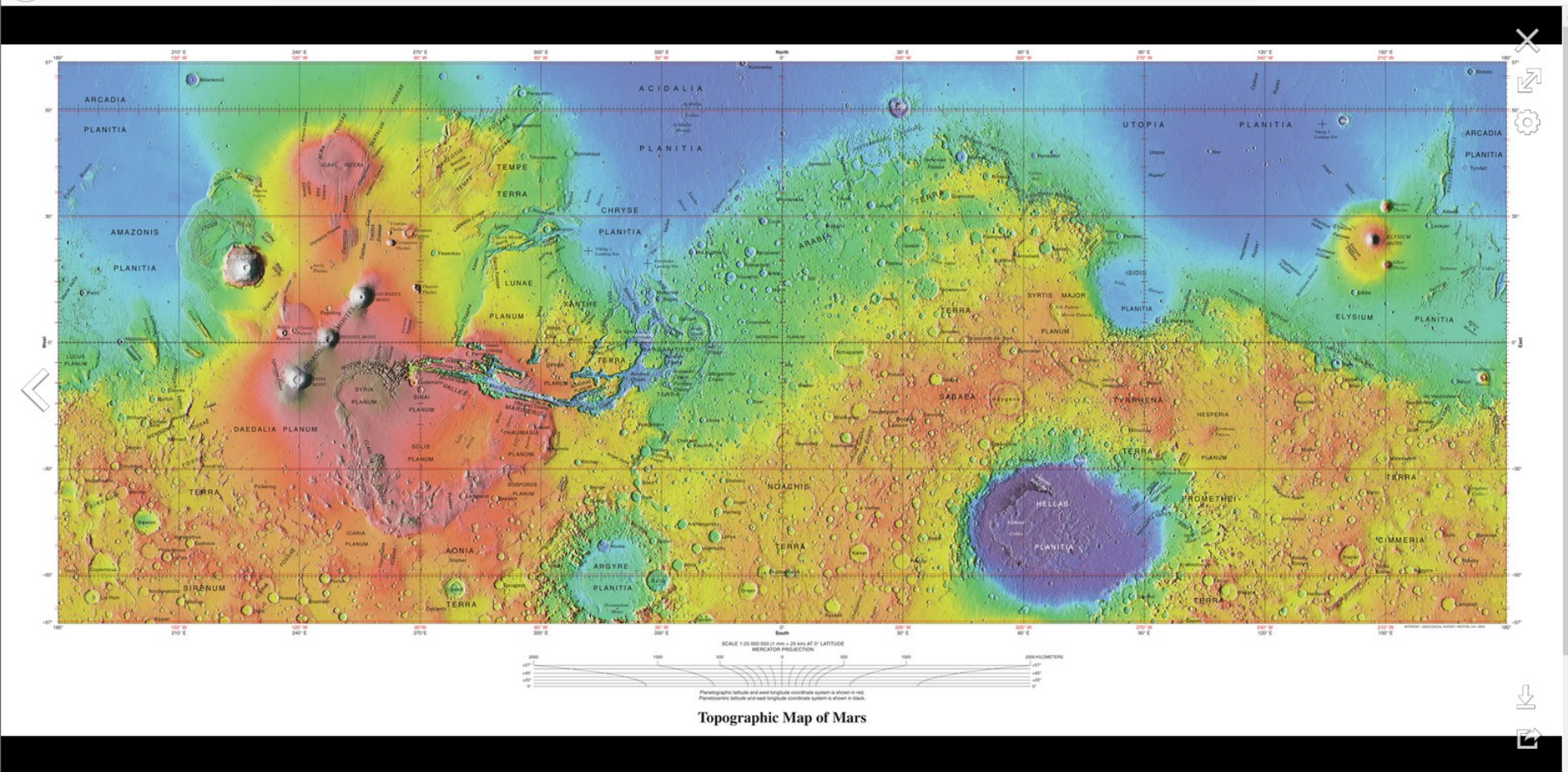
topography of Mars from the MOLA experiment:

<https://pgda.gsfc.nasa.gov/products/62>

Smith, D. E., M. T. Zuber, H. V. Frey, J. B. Garvin, J. W. Head, D. O. Muhleman, et al. (2001), Mars Orbiter Laser Altimeter: Experiment summary after the first year of global mapping of Mars, *J. Geophys. Res.*, 106, 23689–23722, DOI: 10.1029/2000JE001364.
http://www.asu.cas.cz/~bezdek/JK&JK/Mars/topografie_MOLA/ref/

The Mars Orbiter Laser Altimeter (MOLA), an instrument on the Mars Global Surveyor spacecraft as measured the topography, surface roughness and 1.064- μ m reflectivity of Mars and the heights of volatile and dust clouds.

Radial precision 1 meter with respect o the planet's center of mass.



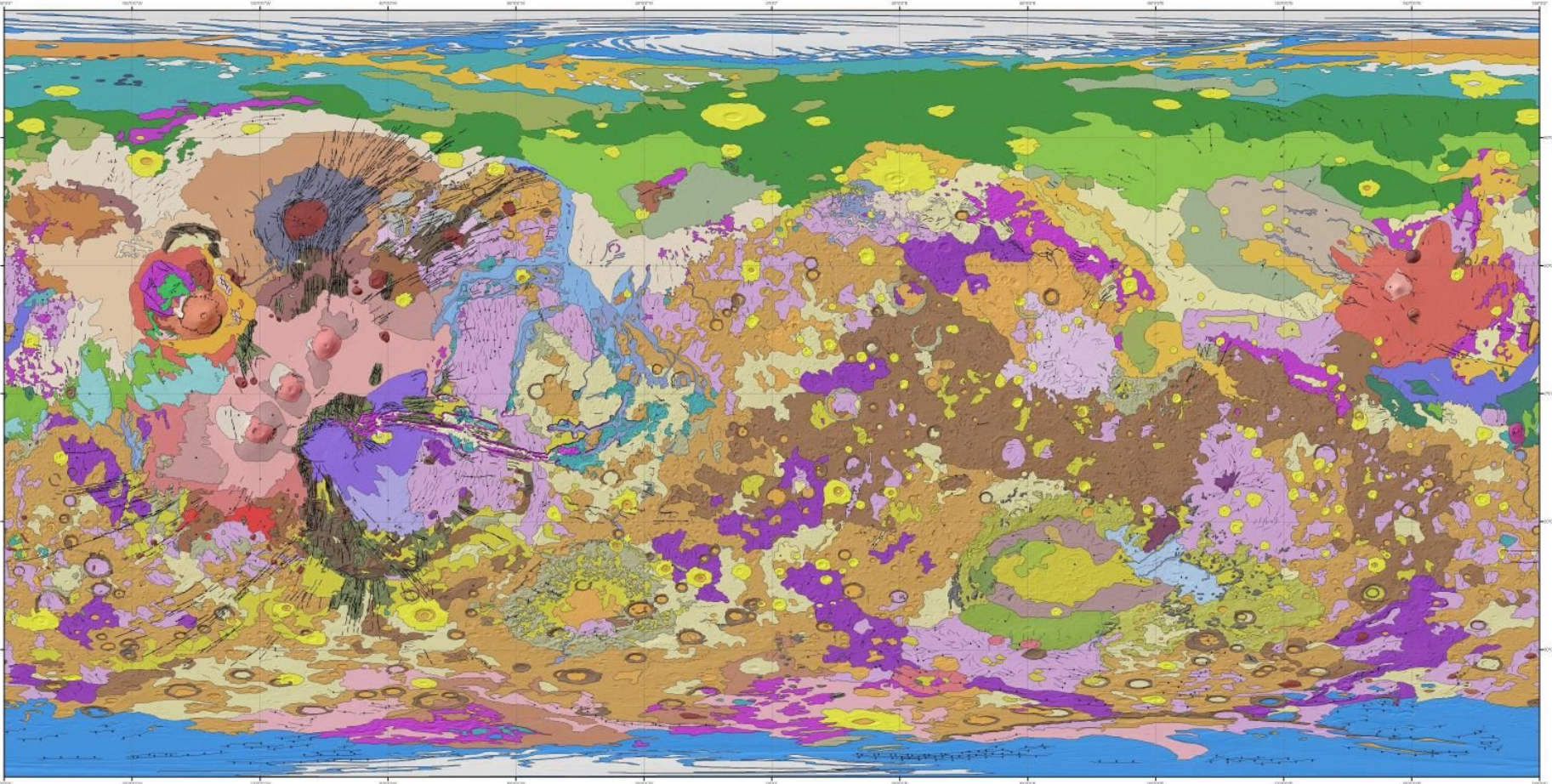
Topographic Map of Mars

[More details](#)

Planet Mars - Topographical Map (USGS; 2005)

U.S. Geological Survey - <https://pubs.usgs.gov/imap/i2782/>; https://pubs.usgs.gov/imap/i2782/i2782_sh1.pdf

Public Domain



1:28,267,459



Mars Global Geologic Map 1802ABC

Legend

- APPROX
- CERTAIN

geo_structure_EquidistCyl

- <-all other values>

StrucType

- Large scarp, symbol points downslope
- Crater rim
- Caldera
- Crest of basal scarp on Olympus Mons, exposed
- Crest of basal scarp on Olympus Mons, buried
- Depression
- Fault with differentiated offset
- Fault with undifferentiated and (or) unmapped offset
- Mare-type structural ridge, symbol on crest
- Channel

AH1a	Ad	Aop	Hdu	Hm
AH1b	Ad1	Aos	Hf	Hv
AH1c	Ae	Api	Hh2	Nb
AH1d	Ae1	Apk	Hh3	Nf
AH1e	Ae2	Apk	Hh3	Nf
AH1f	Ae3	Apk	Hh3	Nf
AH1g	Ae4	Apk	Hh3	Nf
AH1h	Ae5	Apk	Hh3	Nf
AH1i	Ae6	Apk	Hh3	Nf
AH1j	Ae7	Apk	Hh3	Nf
AH1k	Ae8	Apk	Hh3	Nf
AH1l	Ae9	Apk	Hh3	Nf
AH1m	Ae10	Apk	Hh3	Nf
AH1n	Ae11	Apk	Hh3	Nf
AH1o	Ae12	Apk	Hh3	Nf
AH1p	Ae13	Apk	Hh3	Nf
AH1q	Ae14	Apk	Hh3	Nf
AH1r	Ae15	Apk	Hh3	Nf
AH1s	Ae16	Apk	Hh3	Nf
AH1t	Ae17	Apk	Hh3	Nf
AH1u	Ae18	Apk	Hh3	Nf
AH1v	Ae19	Apk	Hh3	Nf
AH1w	Ae20	Apk	Hh3	Nf
AH1x	Ae21	Apk	Hh3	Nf
AH1y	Ae22	Apk	Hh3	Nf
AH1z	Ae23	Apk	Hh3	Nf
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AH120	Aa473	Aa474	Aa475	Aa476
AH121	Aa477	Aa478	Aa479	Aa480
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AH123	Aa485	Aa486	Aa487	Aa488
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AH127	Aa501	Aa502	Aa503	Aa504
AH128	Aa505	Aa506	Aa507	Aa508
AH129	Aa509	Aa510	Aa511	Aa512
AH130	Aa513	Aa514	Aa515	Aa516
AH131	Aa517	Aa518	Aa519	Aa520
AH132	Aa521	Aa522	Aa523	Aa524
AH133	Aa525	Aa526	Aa527	Aa528
AH134	Aa529	Aa530	Aa531	Aa532
AH135	Aa533	Aa534	Aa535	Aa536
AH136	Aa537	Aa538	Aa539	Aa540
AH137	Aa541	Aa542	Aa543	Aa544
AH138	Aa545	Aa546	Aa547	Aa548
AH139	Aa549	Aa550	Aa551	Aa552
AH140	Aa553	Aa554	Aa555	Aa556
AH141	Aa557	Aa558	Aa559	Aa560
AH142	Aa561	Aa562	Aa563	Aa564
AH143	Aa565	Aa566	Aa567	Aa568
AH144	Aa569	Aa570	Aa571	Aa572
AH145	Aa573	Aa574	Aa575	Aa576
AH146	Aa577	Aa578	Aa579	Aa580
AH147	Aa581	Aa582	Aa583	Aa584
AH148	Aa585	Aa586	Aa587	Aa588
AH149	Aa589	Aa590	Aa591	Aa592
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AH151	Aa597	Aa598	Aa599	Aa600
AH152	Aa601	Aa602	Aa603	Aa604
AH153	Aa605	Aa606	Aa607	Aa608
AH154	Aa609	Aa610	Aa611	Aa612
AH155	Aa613	Aa614	Aa615	Aa616
AH156	Aa617	Aa618	Aa619	Aa620
AH157	Aa621	Aa622	Aa623	Aa624
AH158	Aa625	Aa626	Aa627	Aa628
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AH166	Aa657	Aa658	Aa659	Aa660
AH167	Aa661	Aa662	Aa663	Aa664
AH168	Aa665	Aa666	Aa667	Aa668
AH169	Aa669	Aa670	Aa671	Aa672
AH170	Aa673	Aa674	Aa675	Aa676
AH171	Aa677	Aa678	Aa679	Aa680
AH172	Aa681	Aa682	Aa683	Aa684
AH173	Aa685	Aa686	Aa687	Aa688
AH174	Aa689	Aa690	Aa691	Aa692
AH175	Aa693	Aa694	Aa695	Aa696
AH176	Aa697	Aa698	Aa699	Aa700
AH177	Aa701	Aa702	Aa703	Aa704
AH178	Aa705	Aa706	Aa707	Aa708
AH179	Aa709	Aa710	Aa711	Aa712
AH180	Aa713	Aa714	Aa715	Aa716
AH181	Aa717	Aa718	Aa719	Aa720
AH182	Aa721	Aa722	Aa723	Aa724
AH183	Aa725	Aa726	Aa727	Aa728
AH184	Aa729	Aa730	Aa731	Aa732
AH185	Aa733	Aa734	Aa735	Aa736
AH186	Aa737	Aa738	Aa739	Aa740
AH187	Aa741	Aa742	Aa743	Aa744
AH188	Aa745	Aa746	Aa747	Aa748
AH189	Aa749	Aa750	Aa751	Aa752
AH190	Aa753	Aa754	Aa755</	

Legend











--- APPROX

— CERTAIN

geo_structure_EquidistCyl

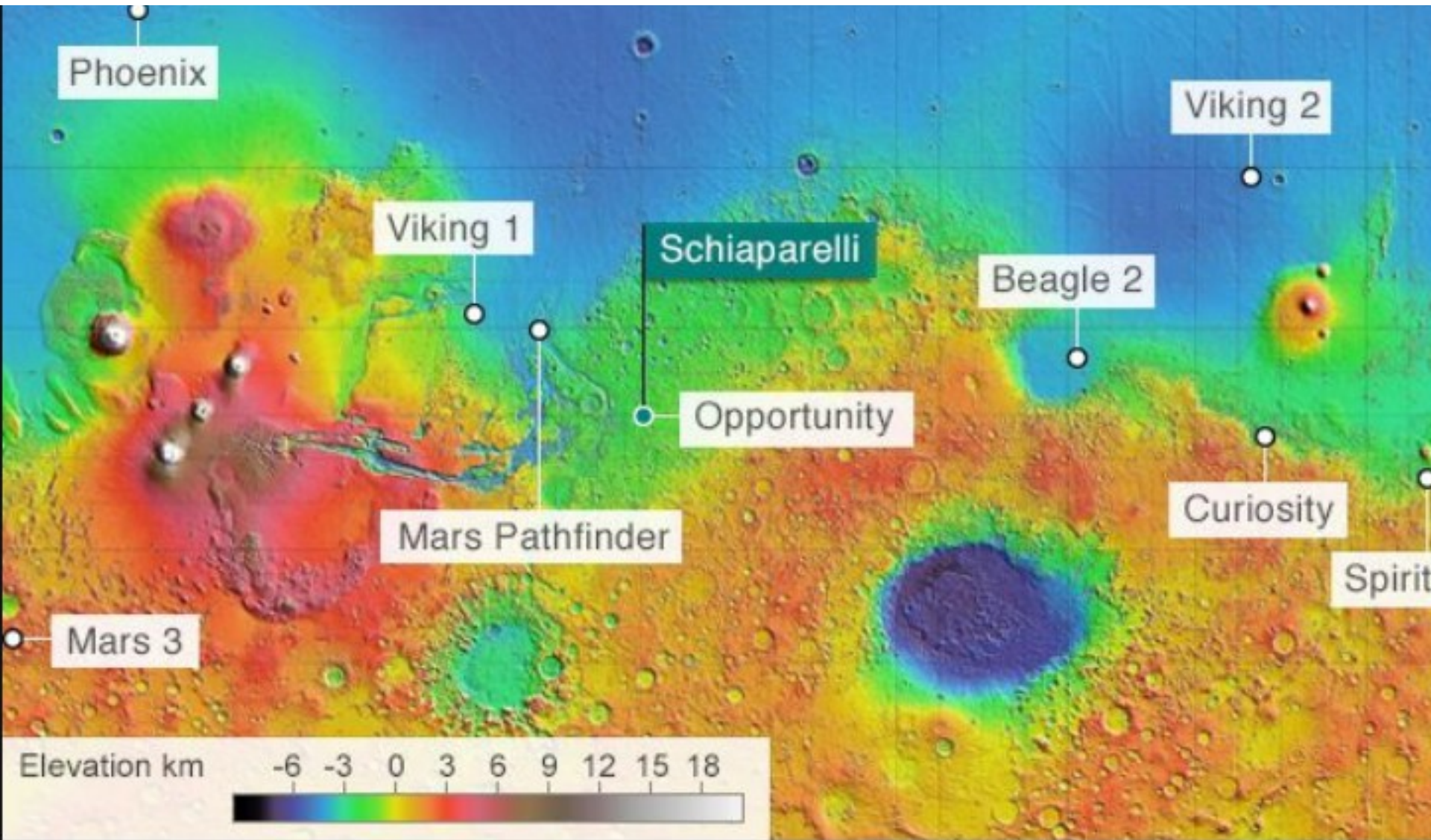
— <all other values>

StrucType

-  Large scarp, symbol points downslope
-  Crater rim
-  Caldera,
-  Crest of basal scarp on Olympus Mons, exposed.
-  Crest of basal scarp on Olympus Mons, buried.
-  Depression.
-  Fault with differentiated offset.
-  Fault with undifferentiated and (or) unmapped offset.
-  Mare-type structural ridge; symbol on crest.
-  Channel

 Aha	 Adl	 Aop	 Hdu	 Hvm
 AHat	 Ae	 Aos	 Hf	 Hvr
 AHcf	 Aol1	 Api	 Hh2	 Nlb
 AHh	 Aol2	 Apk	 Hh3	 Nf
 AHpe	 Aol3	 Apl	 Hhet	 Nh1
 Aht	 Aol4	 Aps	 Hpl3	 Nm
 AHt3	 Aol4	 As	 Hplm	 Npl1
 Aa1	 Aol5	 At4	 Hr	 Npl2
 Aa2	 Aol6	 At5	 Hs	 Npld
 Aa3	 Aol7	 At6	 Hsl	 Nple
 Aa4	 Aol8	 Avf	 Hsu	 Nplh
 Aa5	 Am	 HNu	 HT1	 Nplr
 Aam	 Am1	 Had	 HT2	 b
 Aau	 Amm	 Hal	 HTl	 cb
 Ach	 Amu	 Hap	 Htm	 cs
 Achv	 Aoa1	 Hch	 Htu	 d
 Achp	 Aoa2	 Hchp	 Hvg	 m
 Ad	 Aoa3	 Hcht	 Hvk	 s
 Adc	 Aoa4	 Hdl	 Hvl	 v

General info



Perseverance

is a near clone of Curiosity with better equipment designed to answer difficult question:
Could there have been Martians living on Mars long ago?

Crater named Jezero Crater, an ancient Martian lake roughly the size of Lake Tahoe has been chosen as the target landing area.

Not surprisnly it is in our hypothetical NMPO. We did not know about it.

TARGET LANDING AREA 1/2 mile

By Jonathan Corum | Image by NASA, Jet Propulsion Laboratory, European Space Agency, German Aerospace Center, Freie Universität Berlin and Justin Cowart. Inset image by NASA and J.P.L.

Sdílet pristani

<https://youtu.be/4czjS9h4Fpg>

Jezero Crater's ancient lake-delta system offers many promising sampling targets. Parts of Jezero may be especially rich in carbonates, minerals that, on Earth, can preserve fossilized signs of ancient life and can be associated with biological processes. And new landing technologies will allow Perseverance to touch down even closer to the most promising locations than any Mars mission before it.



Martian polar ice caps

From Wikipedia, the free encyclopedia

The planet Mars has two permanent polar ice caps. During a pole's winter, it lies in continuous darkness, chilling the surface and causing the deposition of 25–30% of the atmosphere into slabs of CO₂ ice (dry ice).^[1] When the poles are again exposed to sunlight, the frozen CO₂ sublimes.^[2] These seasonal actions transport large amounts of dust and water vapor, giving rise to Earth-like frost and large cirrus clouds.

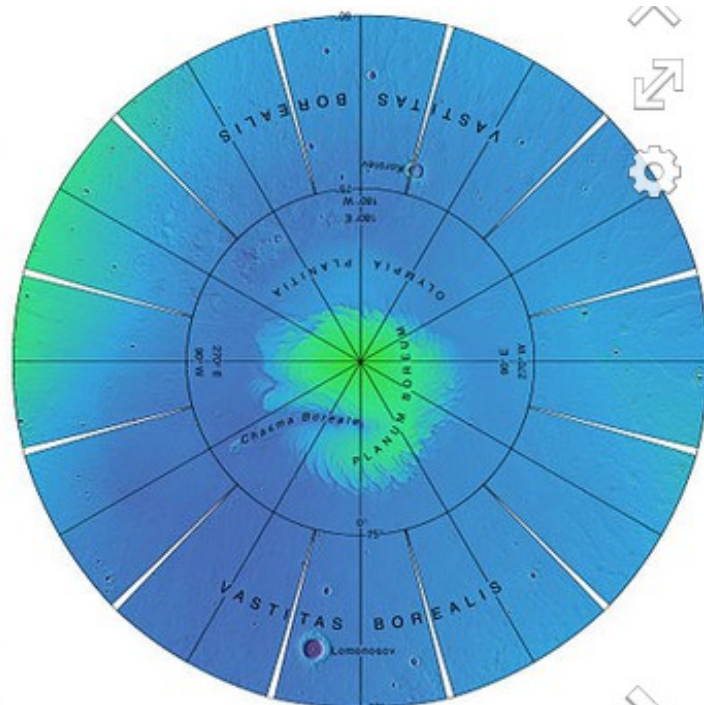
The caps at both poles consist **primarily of water ice**. Frozen carbon dioxide accumulates as a comparatively thin layer about one metre thick on the north cap in the northern winter, while the south cap has a permanent dry ice cover about 8 m thick.^[3]

The northern polar cap has a diameter of about 1000 km during the northern Mars summer,^[4] and contains about 1.6 million cubic km of ice, which if spread evenly on the cap would be 2 km thick.^[5] (This compares to a volume of 2.85 million cubic km (km³) for the Greenland ice sheet.)

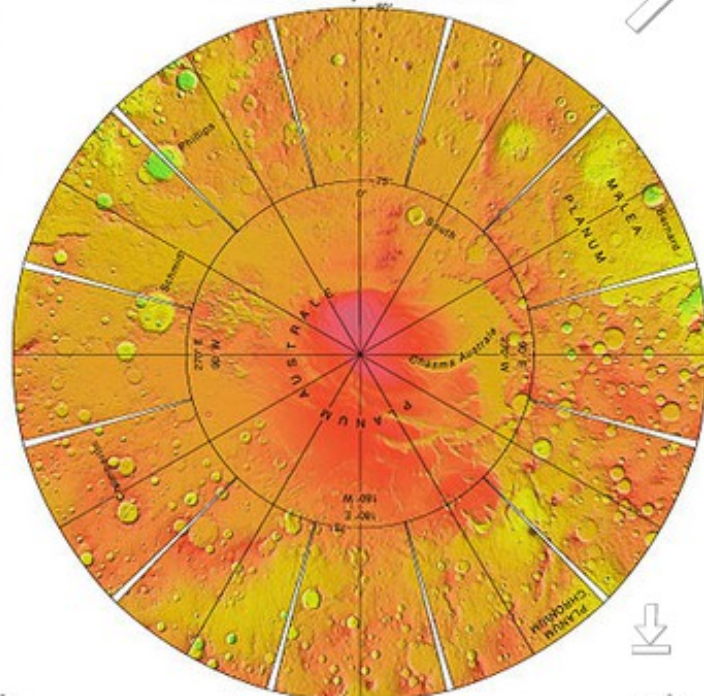
The southern polar cap has a diameter of 350 km and a thickness of 3 km.^[6] The total volume of ice in the south polar cap plus the adjacent layered deposits has also been estimated at 1.6 million cubic km.

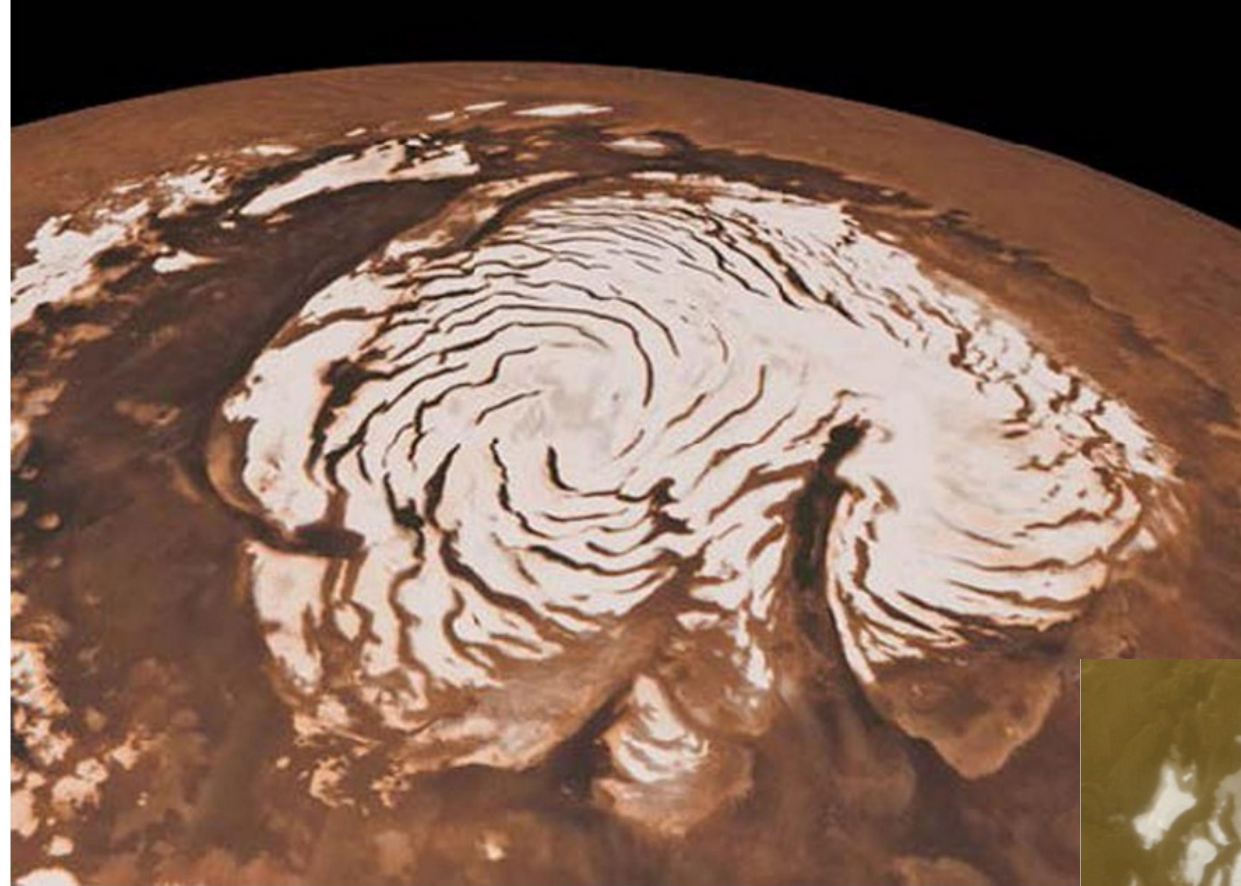
Unlike the northern polar cap, the southern ice cap stands on heavily cratered ground in the southern highlands. It is elevated about 6 km (4 mi) higher than Martian "sea level," which is the average radius of Mars. The southern also covers part of the ancient Prometheus impact basin.

The polar cap has a thickness similar to the northern one — about 3,000 m (10,000 ft) — but it spreads only about 400 km (250 mi) wide. The cap's highest point lies at −87° latitude and 0° longitude, not the actual pole (−90°) but about 180 km (112 mi) away from it. Polar materials also extend hundreds of kilometers toward the equator in a direction centered on 150° east longitude.

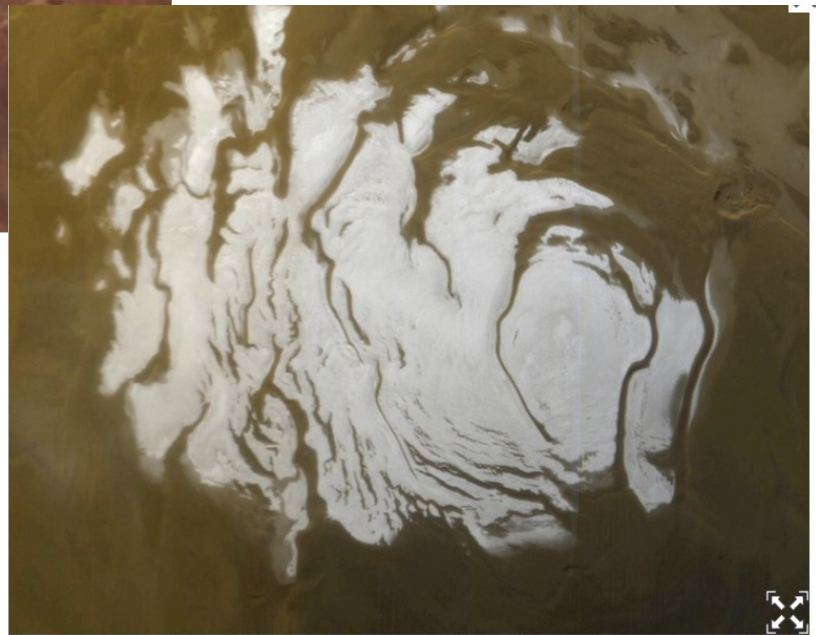


0° E or W, 60° N or S





northern



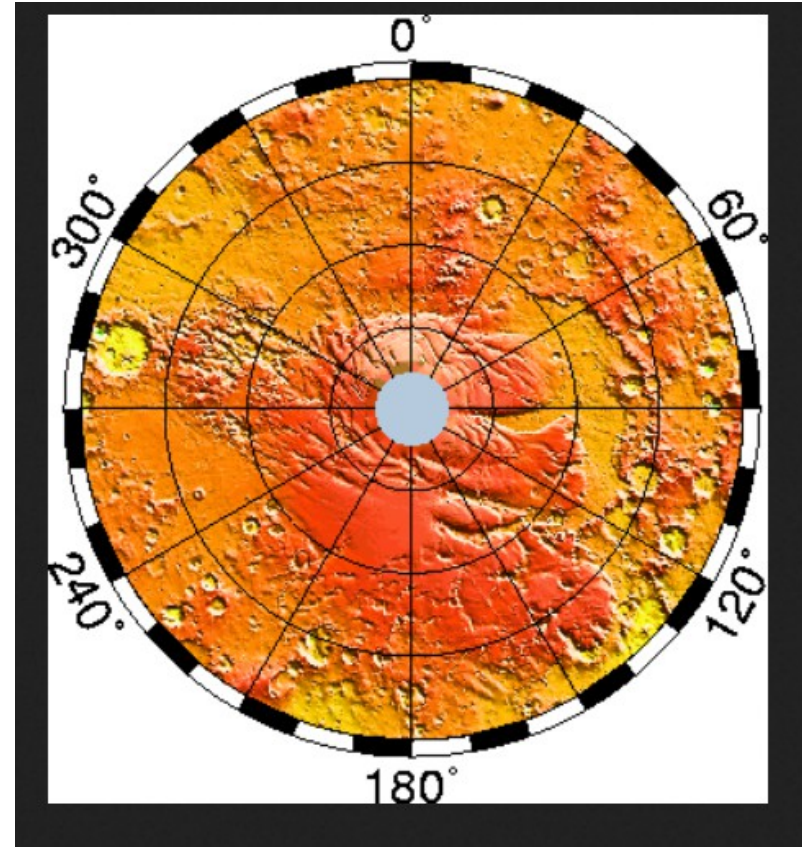
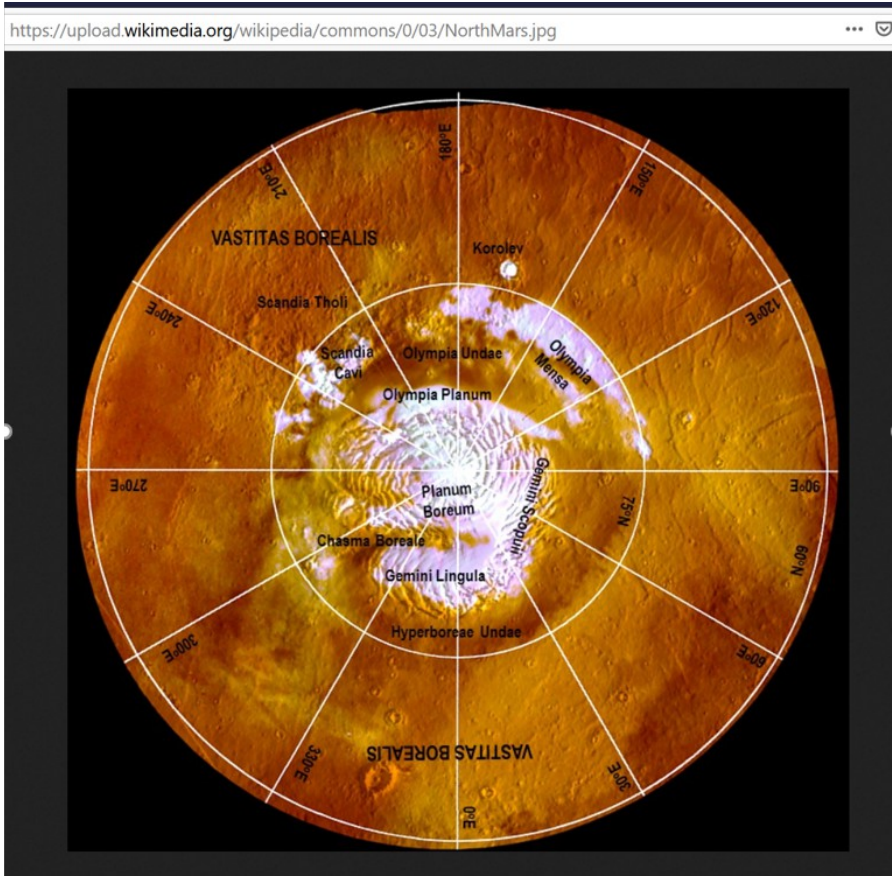
southern

The south polar cap spreads about 420 kilometers (260 miles) wide. This image was made in summer and shows the ice at its smallest extent. In winter and early spring this entire scene would be covered by frost. Like the northern ice cap, the southern one is cut into by troughs. (NASA/JPL-Caltech/Malin Space Science Systems)

[Download Image](#)

Northern cap

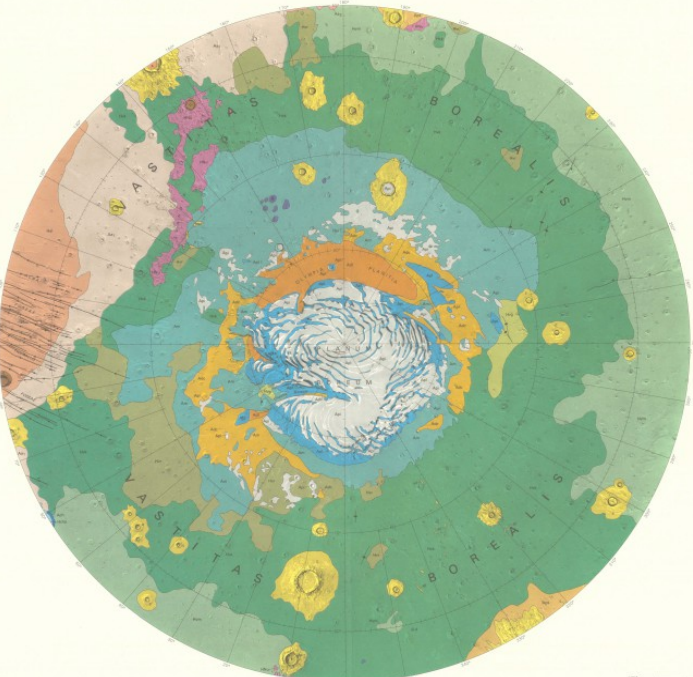
Southern cap



Assymetry around poles, different size and thickness (southern smaller), effect of Coriolis force, see also strike angles for more study

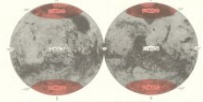
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

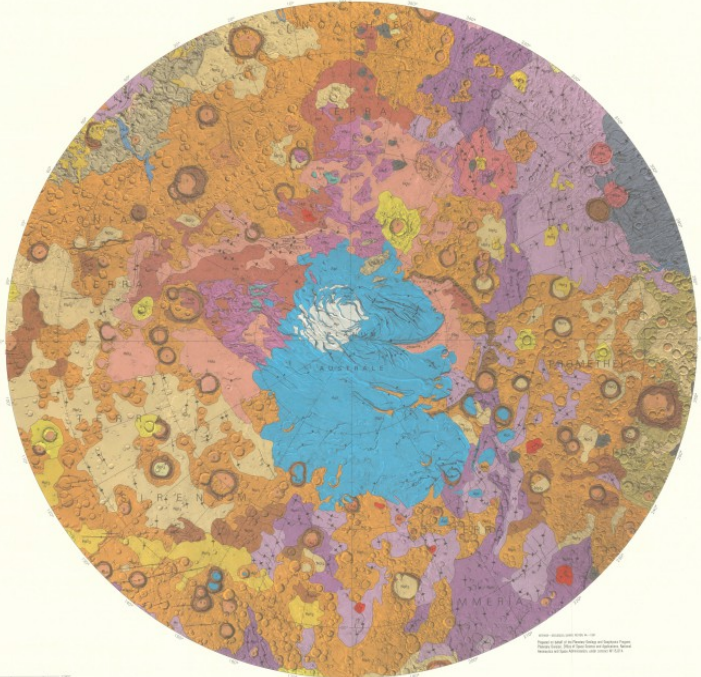


NORTH POLAR REGION

NOTES ON MAP
This map was compiled from the most recent data available from the Mars Global Surveyor (MGS) and Mars Reconnaissance Orbiter (MRO) missions. It is based on the Mars Geologic Map of the North Polar Region (MGS-1) and the Mars Geologic Map of the South Polar Region (MGS-2). The map shows the geologic units and features of the North Polar region of Mars, including the North Polar ice cap, the North Polar desert, and the North Polar plateau. The map is based on the Mars Geologic Map of the North Polar Region (MGS-1) and the Mars Geologic Map of the South Polar Region (MGS-2). The map shows the geologic units and features of the North Polar region of Mars, including the North Polar ice cap, the North Polar desert, and the North Polar plateau.



TOP OF THE 1:500,000-SCALE MAPS



SOUTH POLAR REGION

ACKNOWLEDGMENTS
The Mars Geologic Map of the North Polar Region (MGS-1) and the Mars Geologic Map of the South Polar Region (MGS-2) were prepared by the U.S. Geological Survey, Reston, Virginia, in cooperation with the National Aeronautics and Space Administration, Washington, D.C. The map is based on the Mars Geologic Map of the North Polar Region (MGS-1) and the Mars Geologic Map of the South Polar Region (MGS-2). The map shows the geologic units and features of the North Polar region of Mars, including the North Polar ice cap, the North Polar desert, and the North Polar plateau.

REFERENCES CITED
Baker, V.R., and Scott, D.B., 1989, Mars: A geologic and geomorphologic synthesis, *Journal of Geophysical Research*, v. 94, p. 15,101-15,120.
Baker, V.R., and Scott, D.B., 1990, Mars: A geologic and geomorphologic synthesis, *Journal of Geophysical Research*, v. 95, p. 15,101-15,120.
Baker, V.R., and Scott, D.B., 1991, Mars: A geologic and geomorphologic synthesis, *Journal of Geophysical Research*, v. 96, p. 15,101-15,120.

CORRELATION OF MAP UNITS, GEOLOGIC EVENTS, AND CRATER DENSITIES IN THE POLAR REGIONS OF MARS

MAP UNIT	CRATER DENSITY	RELATIVE AGE
UNIT 1	High	Old
UNIT 2	Medium	Intermediate
UNIT 3	Low	Young

MAP UNIT DESCRIPTIONS
UNIT 1: This unit is the oldest and is characterized by a high density of craters. It is composed of various geological units, including the North Polar ice cap, the North Polar desert, and the North Polar plateau. The unit is characterized by a high density of craters, which are generally small and simple in shape. The unit is composed of various geological units, including the North Polar ice cap, the North Polar desert, and the North Polar plateau.

CRATER DENSITY
The crater density of the map units is a key indicator of their relative age. The units with the highest crater density are the oldest, while the units with the lowest crater density are the youngest. The crater density is measured as the number of craters per square kilometer of a given size range. The units with the highest crater density are the oldest, while the units with the lowest crater density are the youngest.

RELATIVE AGE
The relative age of the map units is determined by their position in the geologic column. The units that are higher in the geologic column are younger than the units that are lower. The units with the highest crater density are the oldest, while the units with the lowest crater density are the youngest.

CRATER DENSITY
The crater density of the map units is a key indicator of their relative age. The units with the highest crater density are the oldest, while the units with the lowest crater density are the youngest. The crater density is measured as the number of craters per square kilometer of a given size range. The units with the highest crater density are the oldest, while the units with the lowest crater density are the youngest.

ATLAS OF MARS
1:500,000-SCALE GEOLGIC MAPS
POLAR REGIONS
US GPO 1992 1:880
1:880 C

Map of Mars, the red planet, showing the North and South Polar regions. The map is based on the Mars Geologic Map of the North Polar Region (MGS-1) and the Mars Geologic Map of the South Polar Region (MGS-2). The map shows the geologic units and features of the North Polar region of Mars, including the North Polar ice cap, the North Polar desert, and the North Polar plateau.

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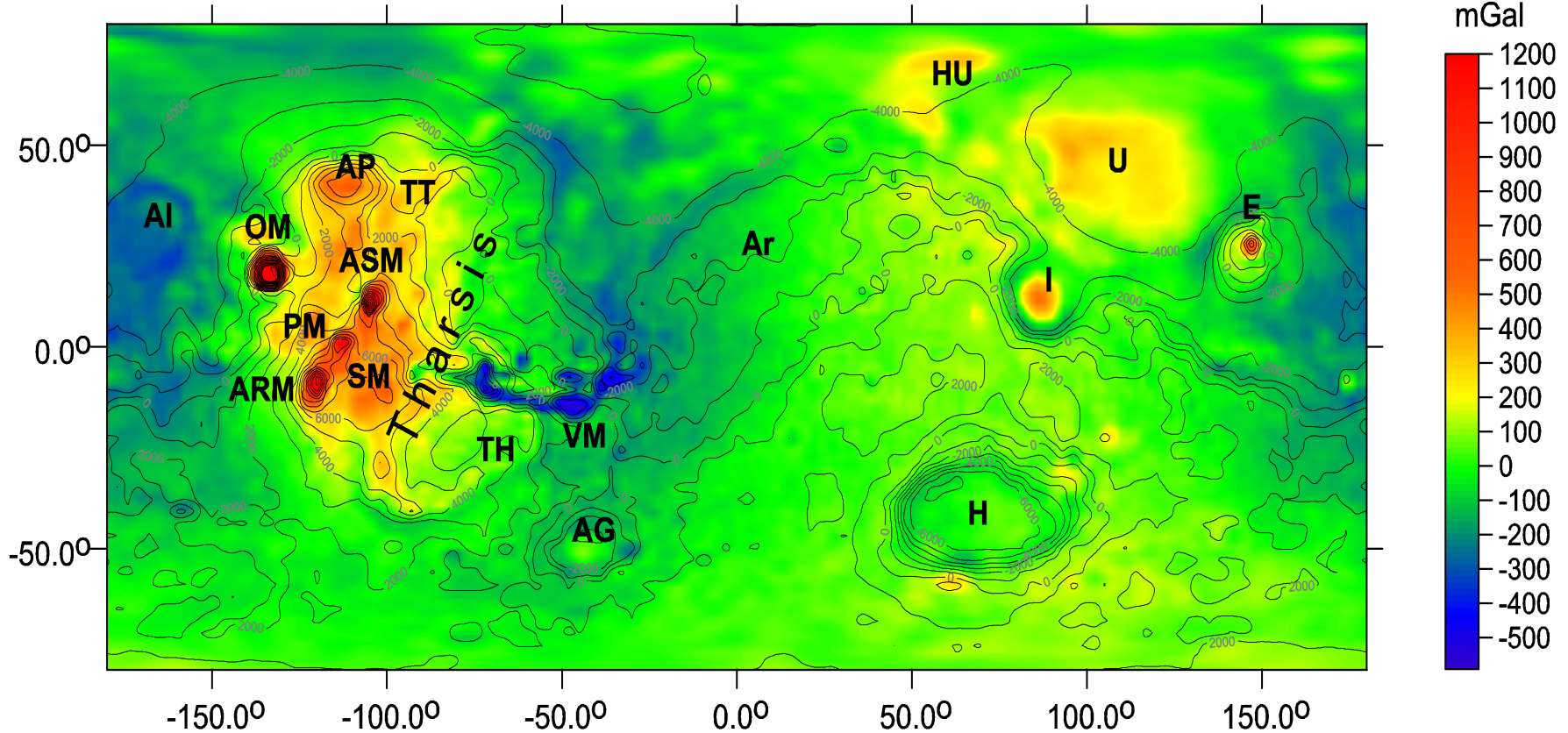
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Our main results

global

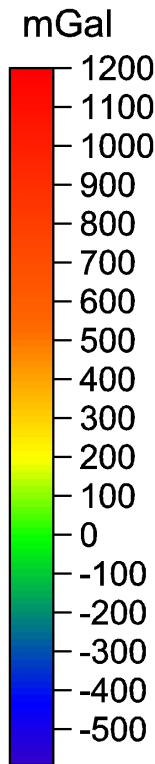
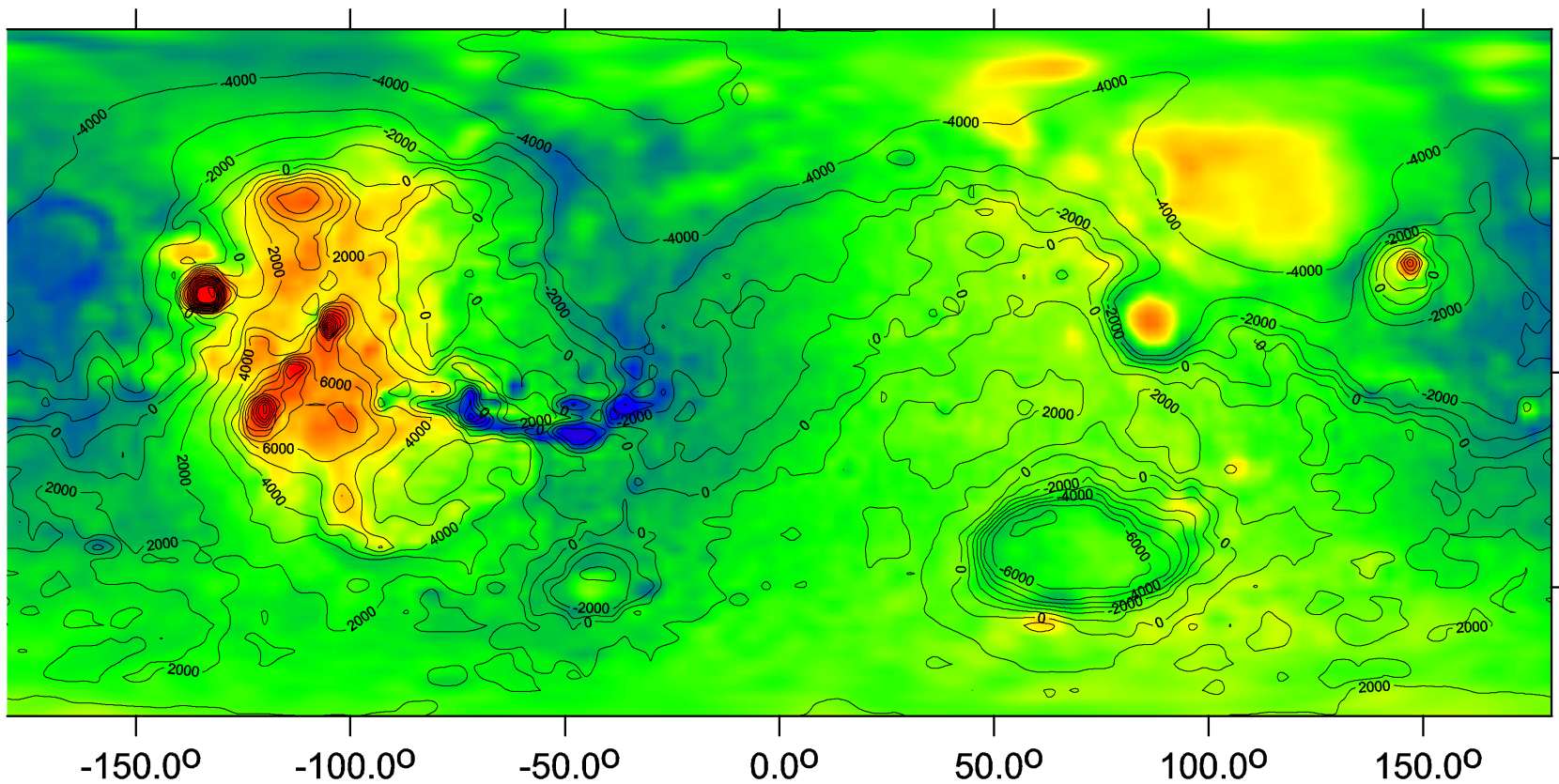


Gravity disturbances Δg [mGal] on Mars

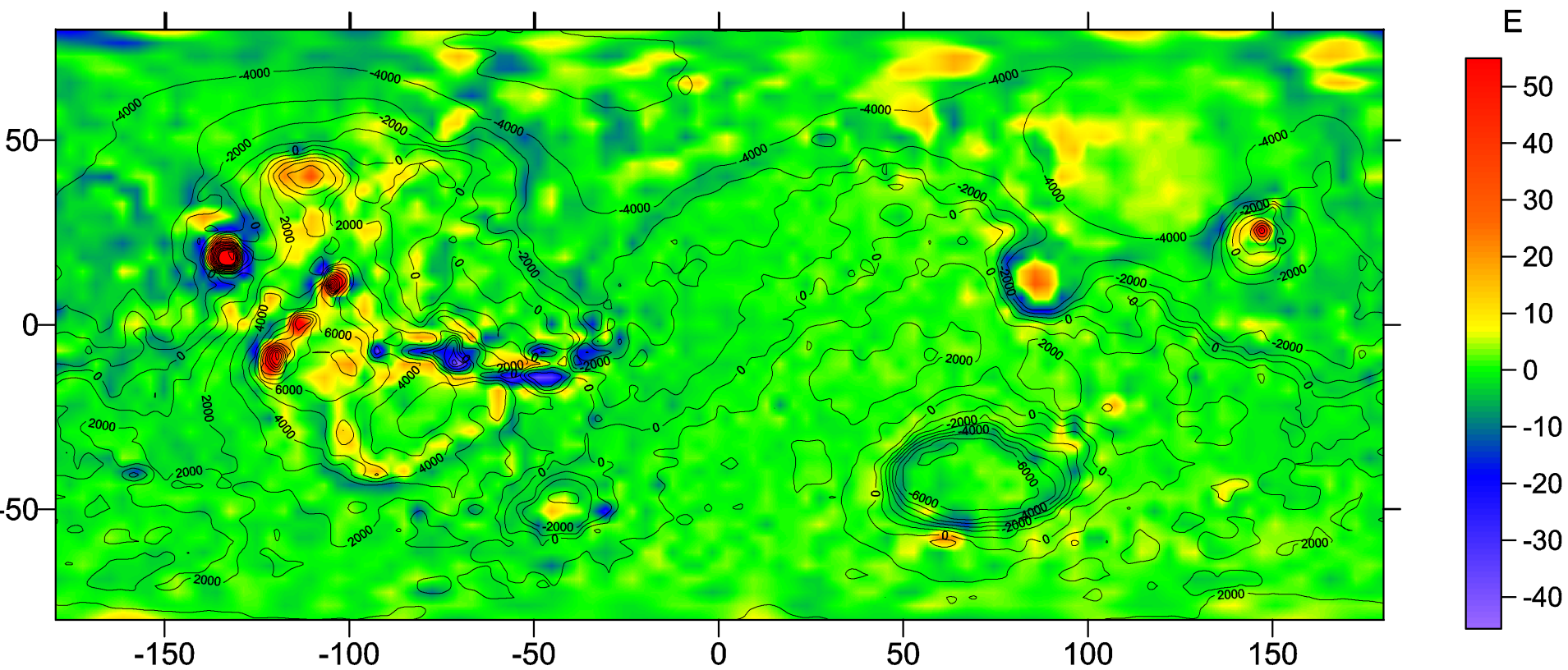
according to the gravity field model JGMRO_120 F (Konopliv et al. 2020), used here everywhere to plot the gravity aspects, cut always at maximum degree and order $d/o = 80$, as recommended by the authors of the model, together with contour lines derived from the MOLA topography [m] (metres above the reference ellipsoid).

Valles Marineris (VM). Hellas (H), area at the Crater Lake (Syrtis Major/Isidis) I, Utopia (U), Hustak (HU), Elysium (E), Tharsis area (T), Olympus Mt (OM) and other volcanoes in T, Ascraeus Mons (ASM), Pavonis and Arsia Mons (PM and ARM), Alba Patera and Syria Mons (AP and SM), Tempe Terra (TT), Thaumasia Highlands (TH), one of ancient structures (AI).

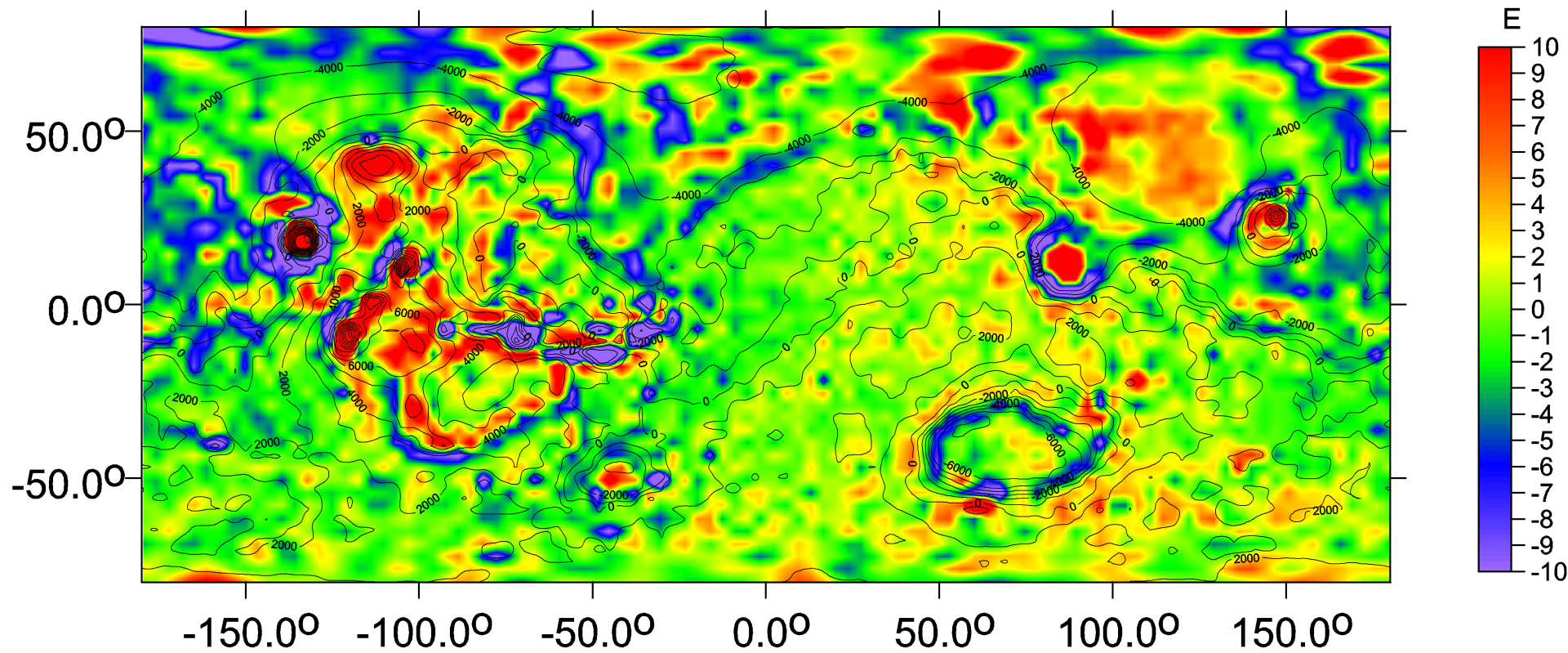
Mars - Topo + delta g



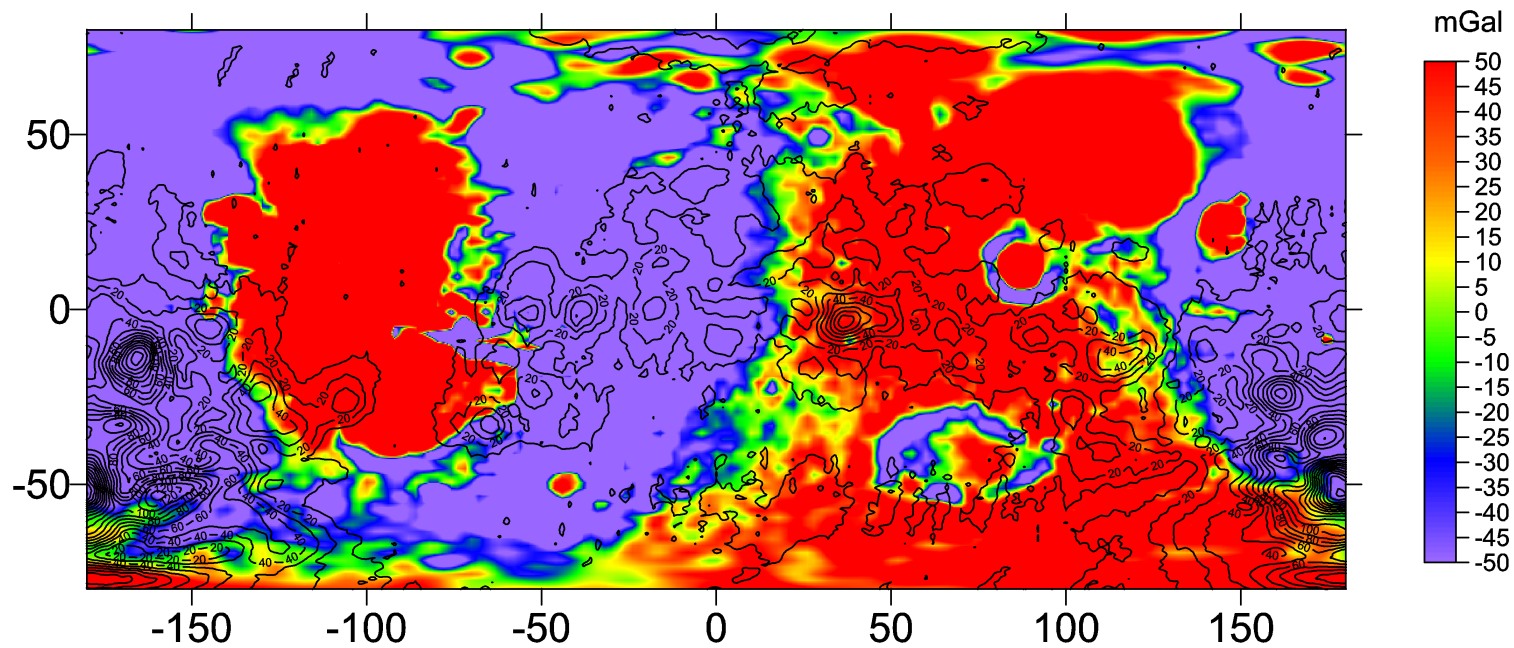
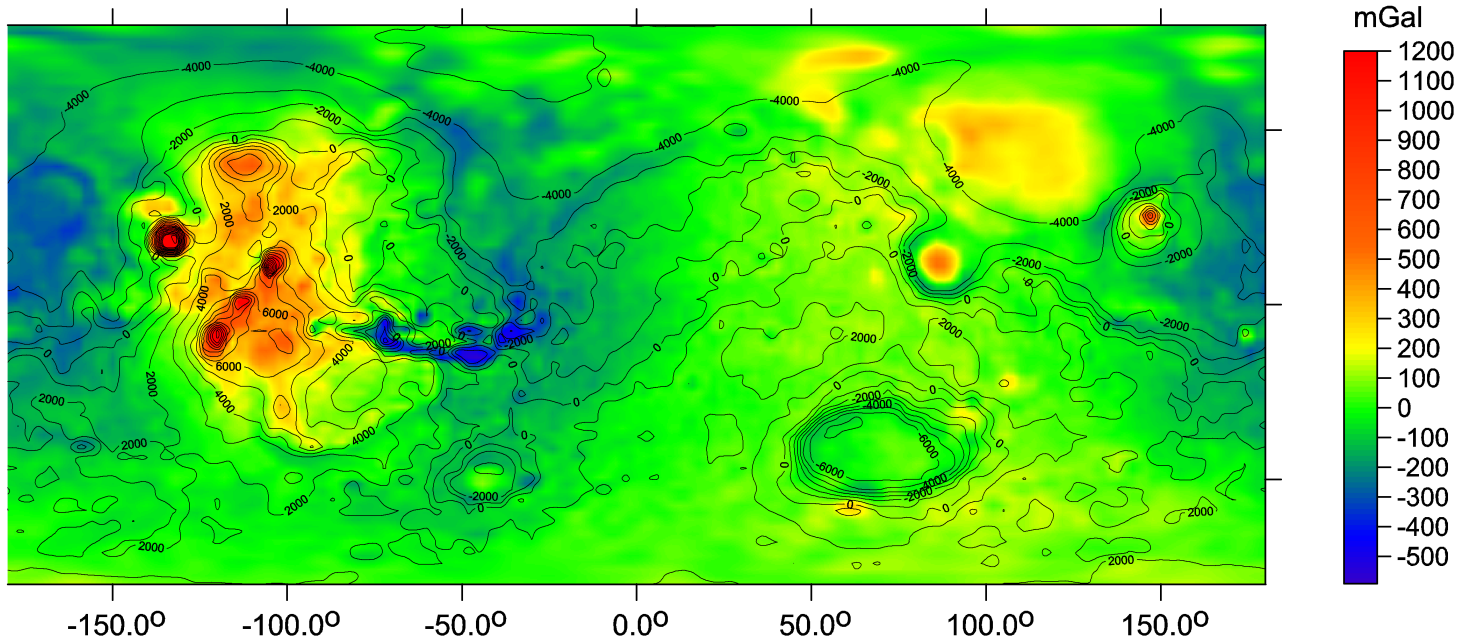
Mars - Topo + Tzz



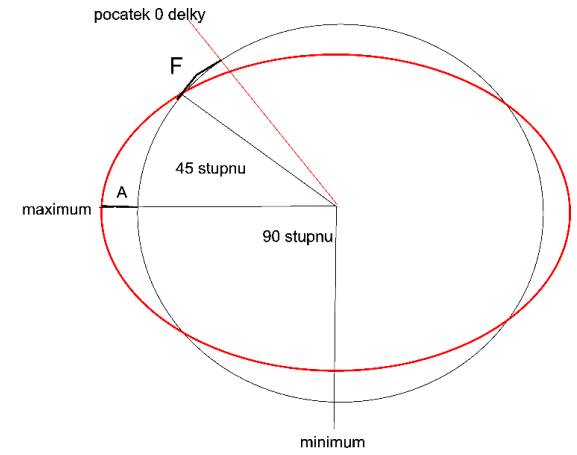
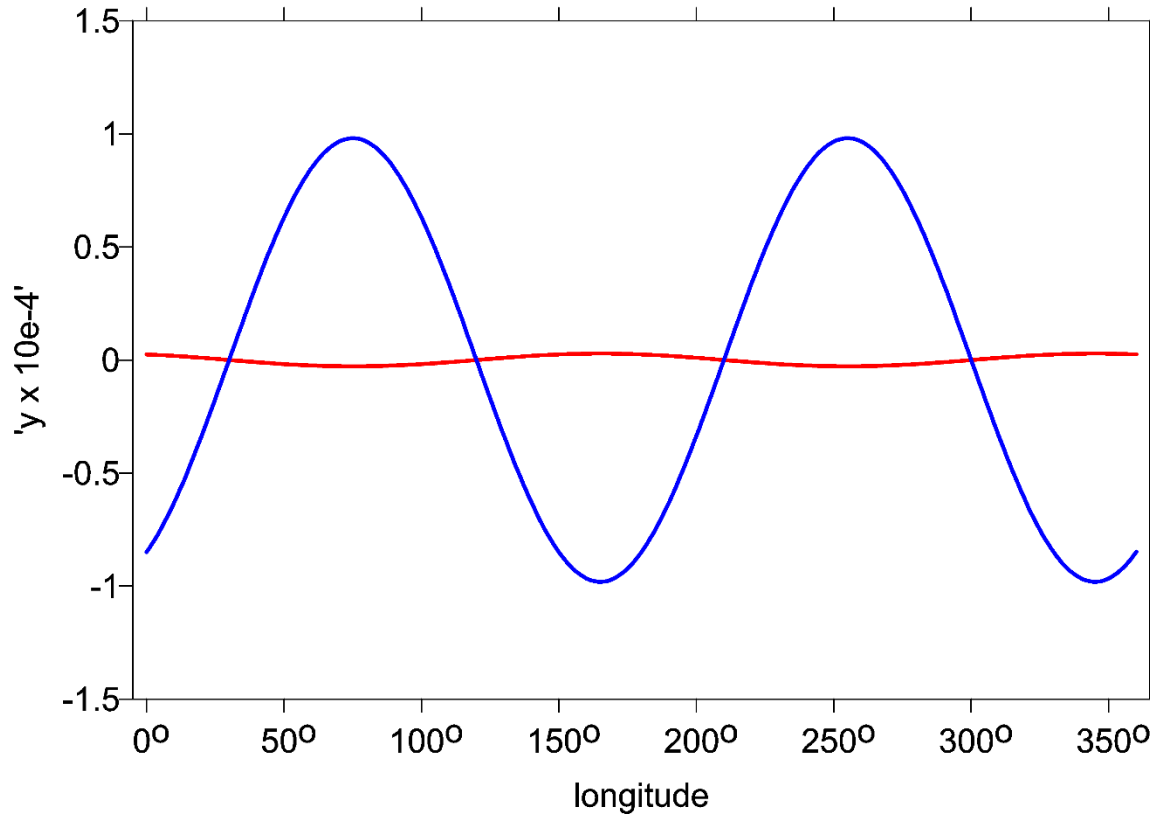
Mars - Topo + Tzz



Mars - Topo + delta g



Equatorial flattening [C22 * cos(2 * lambda) + S22 * sin(2 * lambda)]
 Earth (red), Mars (blue)



Mars (gravity model JGMRO_120 F):

GM (C00) = 0.4282837×10^{14} [m³ s⁻²]

C20 = $-0.88 \cdot 10^{-3}$

C30 = $-0.12 \cdot 10^{-4}$

C50 = $-0.17 \cdot 10^{-5}$

C22 = $-0.85 \cdot 10^{-4}$, S22 = $0.49 \cdot 10^{-4}$

J22 = $0.98 \cdot 10^{-4}$, $\lambda_{22\text{stable}} = 165.30^\circ \text{ E}$,

$\lambda_{22\text{unstab}} = 75.20^\circ \text{ E}$

The Earth (gravity model EIGEN 6C4):

GM (C00) = $3.986004419 \times 10^{14}$ [m³ s⁻²]

C20 = $-0.48 \cdot 10^{-3}$

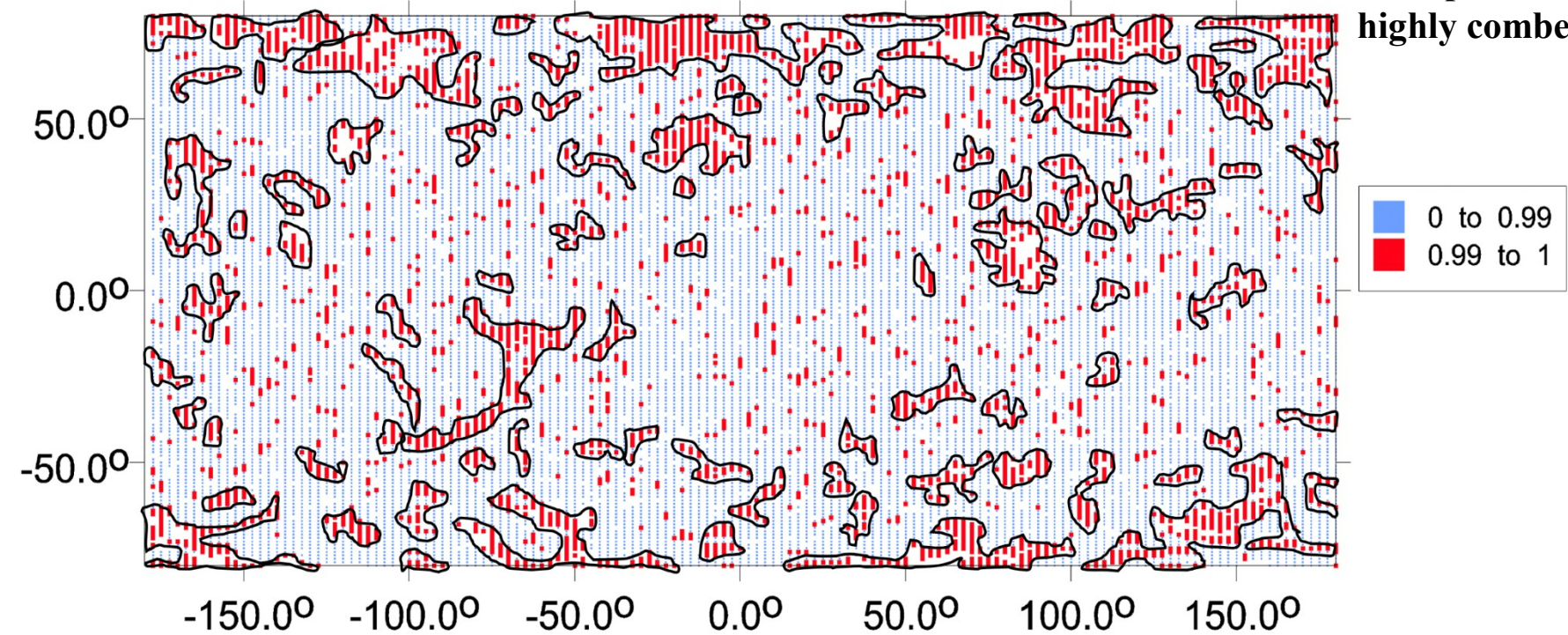
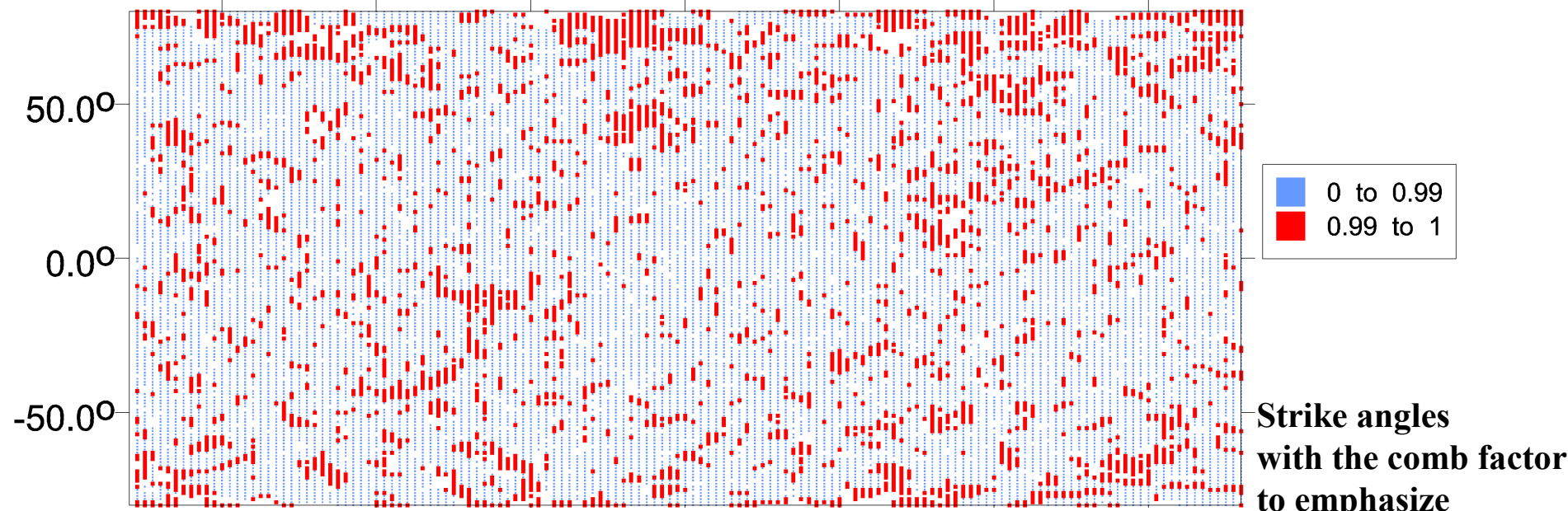
C30 = $+0.01 \cdot 10^{-4}$

C50 = $+0.69 \cdot 10^{-7}$

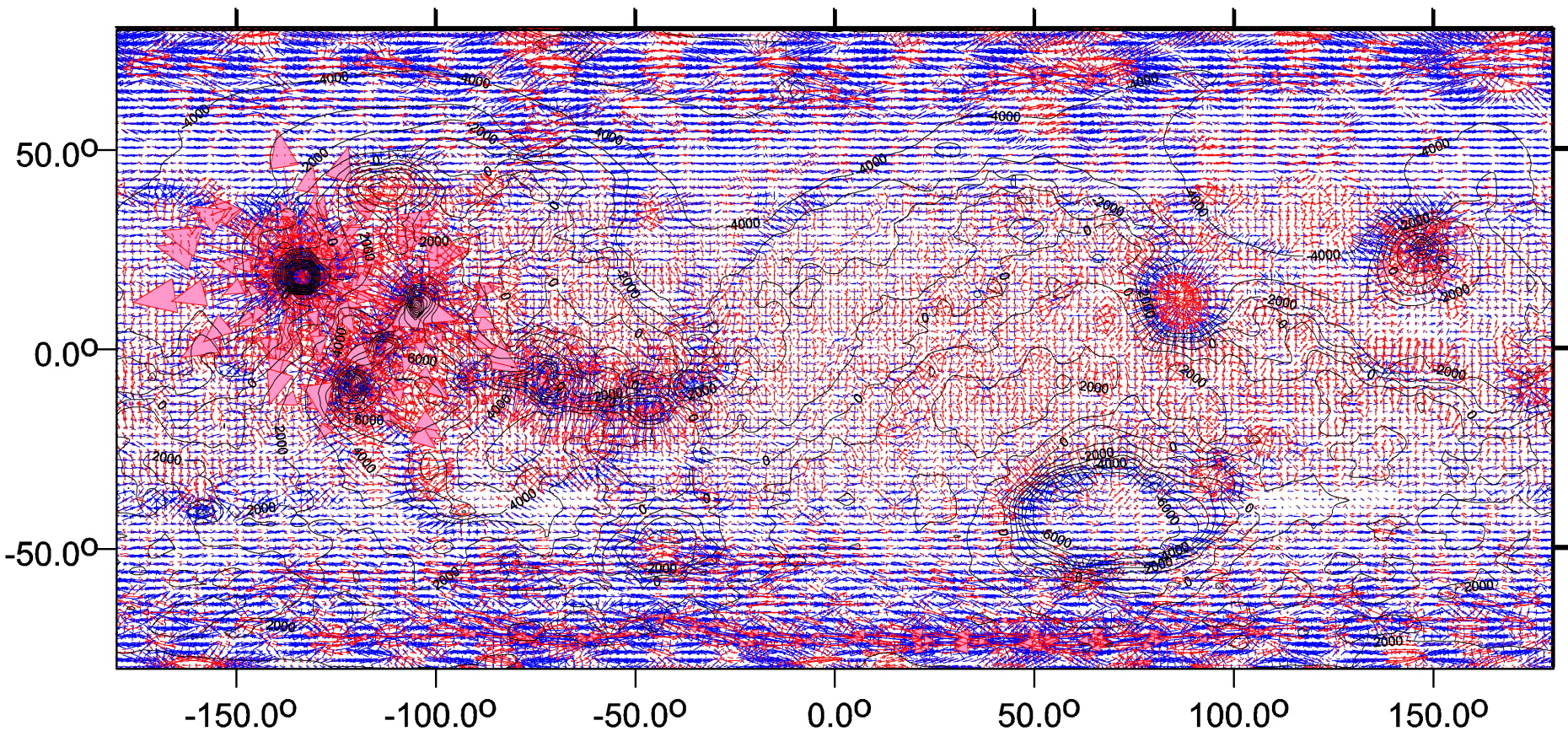
C22 = $2.44 \cdot 10^{-6}$, S22 = $-1.40 \cdot 10^{-6}$;

J22 = $2.81 \cdot 10^{-6}$ = $0.03 \cdot 10^{-4}$, $\lambda_{22\text{stable}} = 75.20^\circ \text{ E}$,

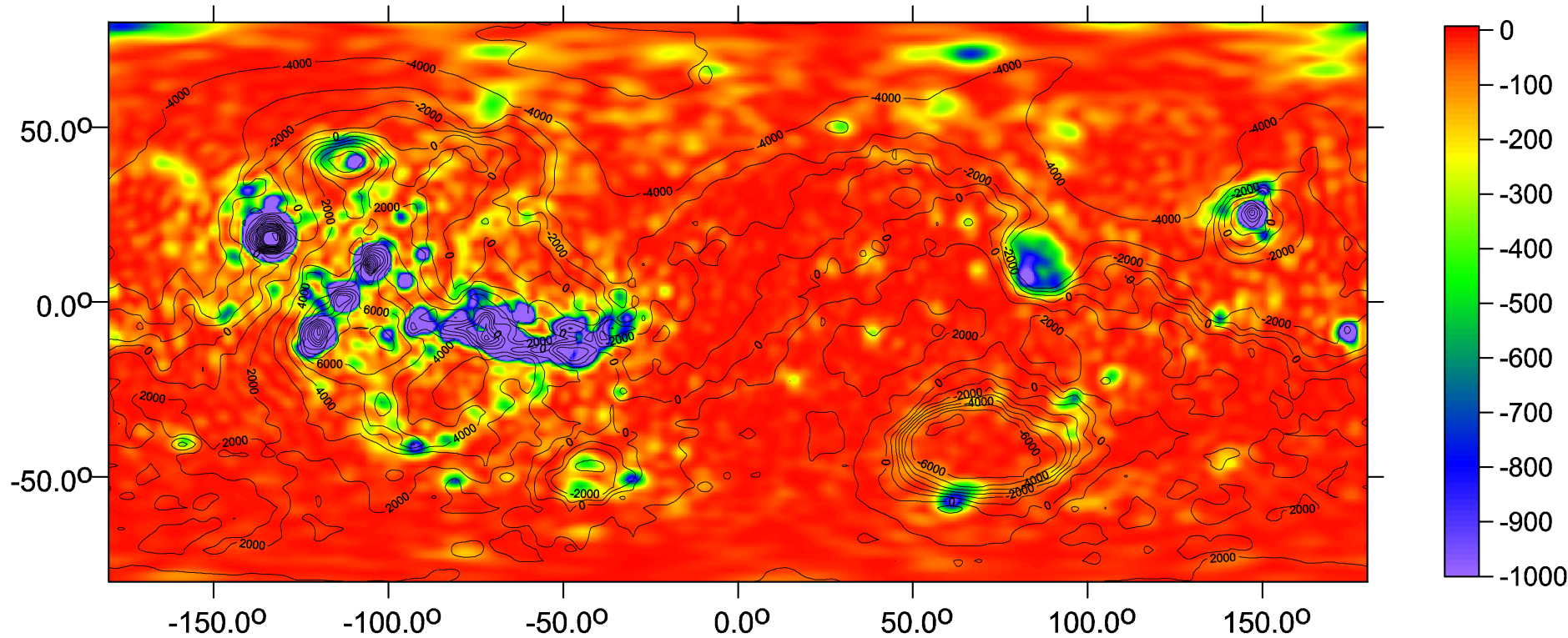
$\lambda_{22\text{unstab}} = 165.30^\circ \text{ E}$



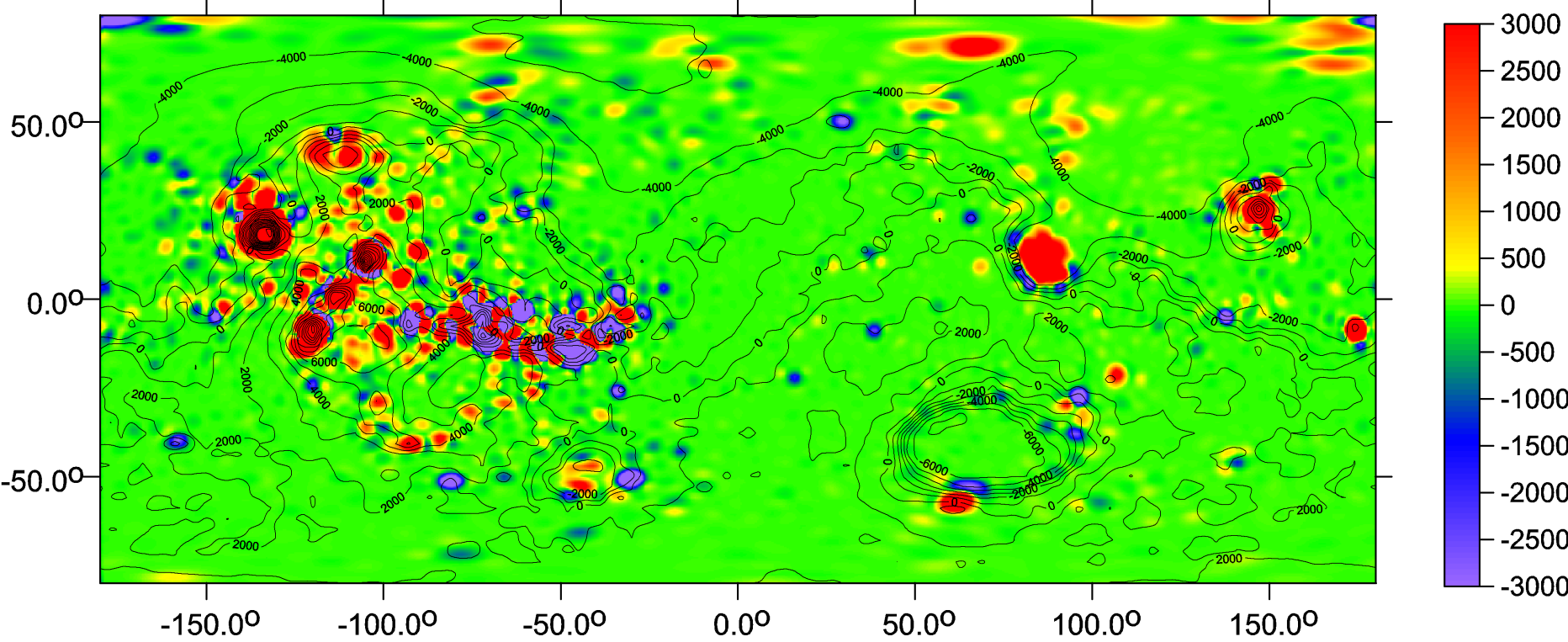
Mars - Topo + vd



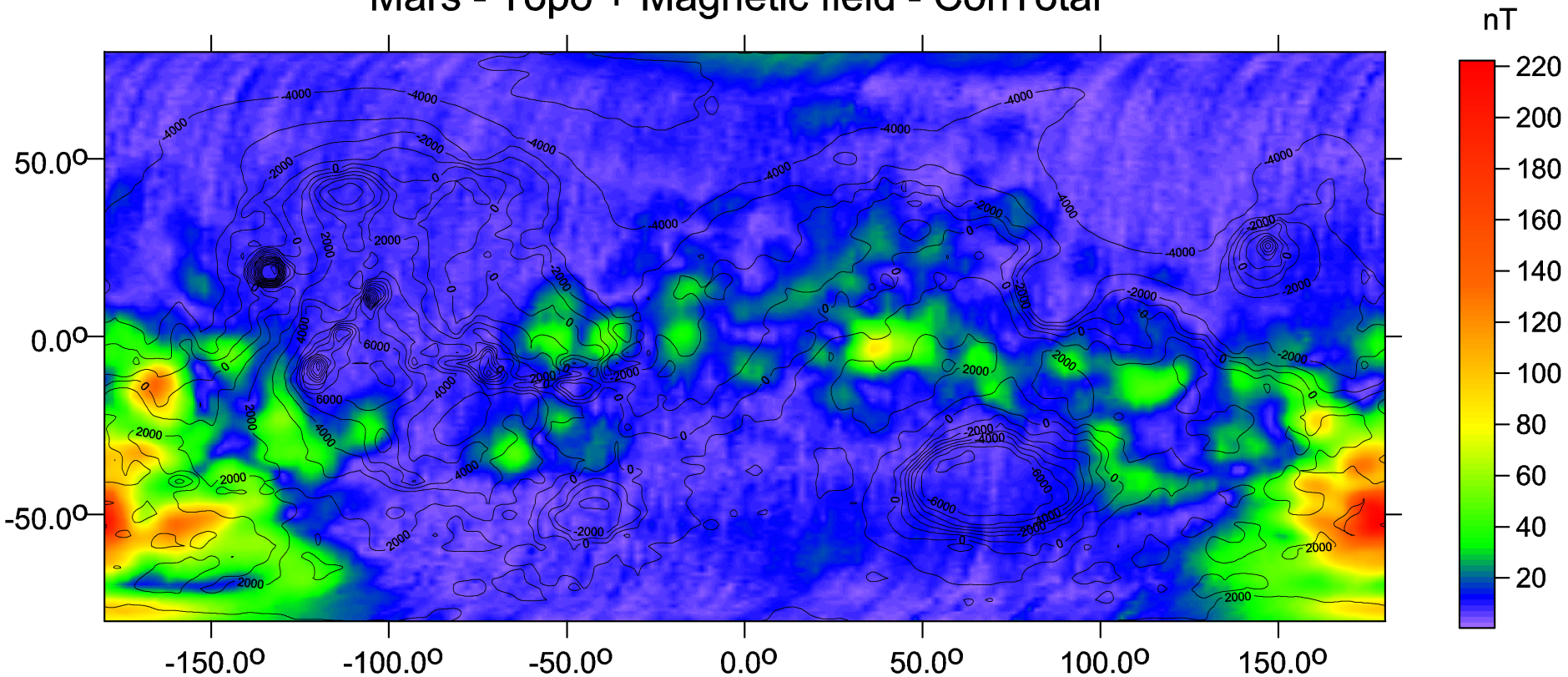
Mars - Topo + RI2



Mars - Topo + RI3



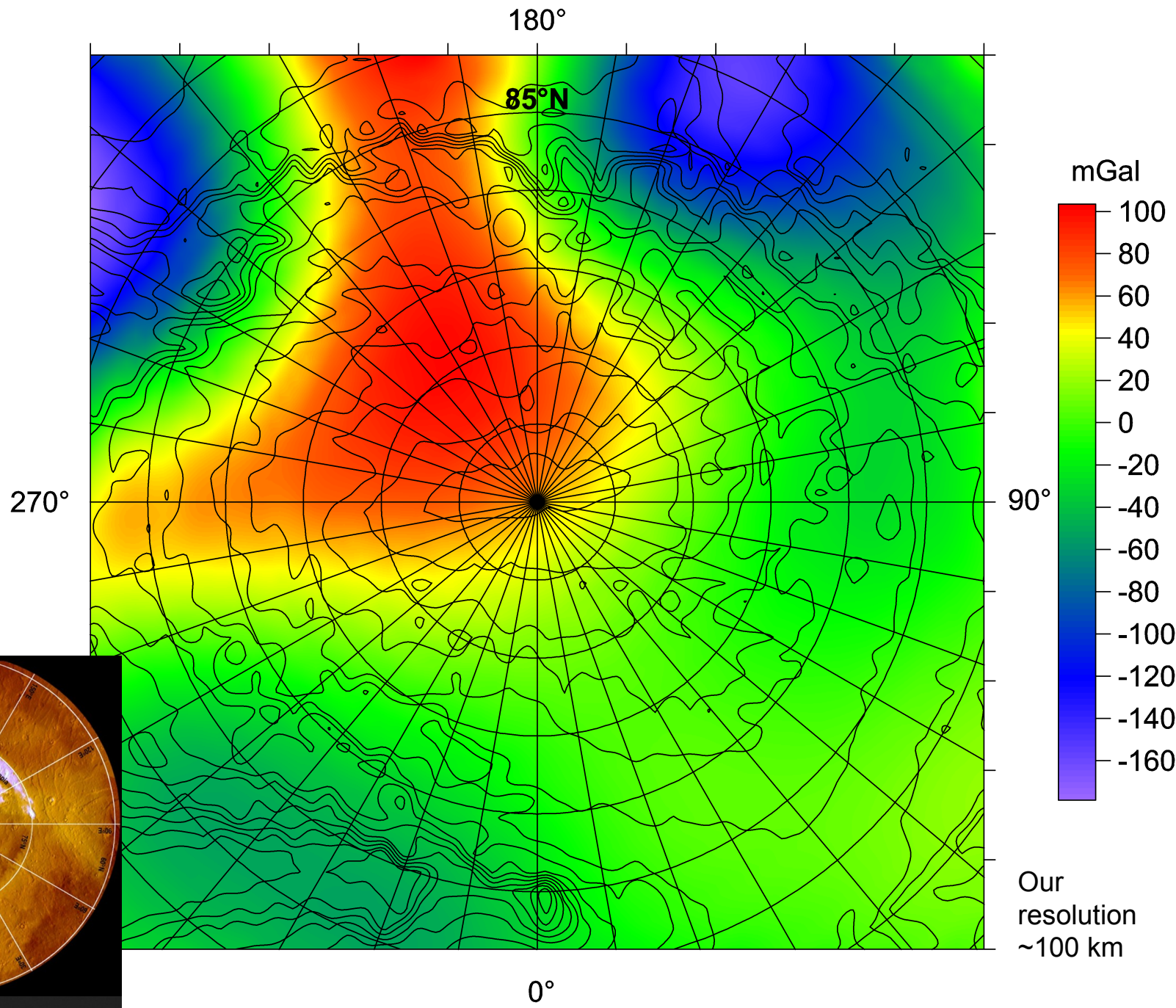
Mars - Topo + Magnetic field - ConTotal



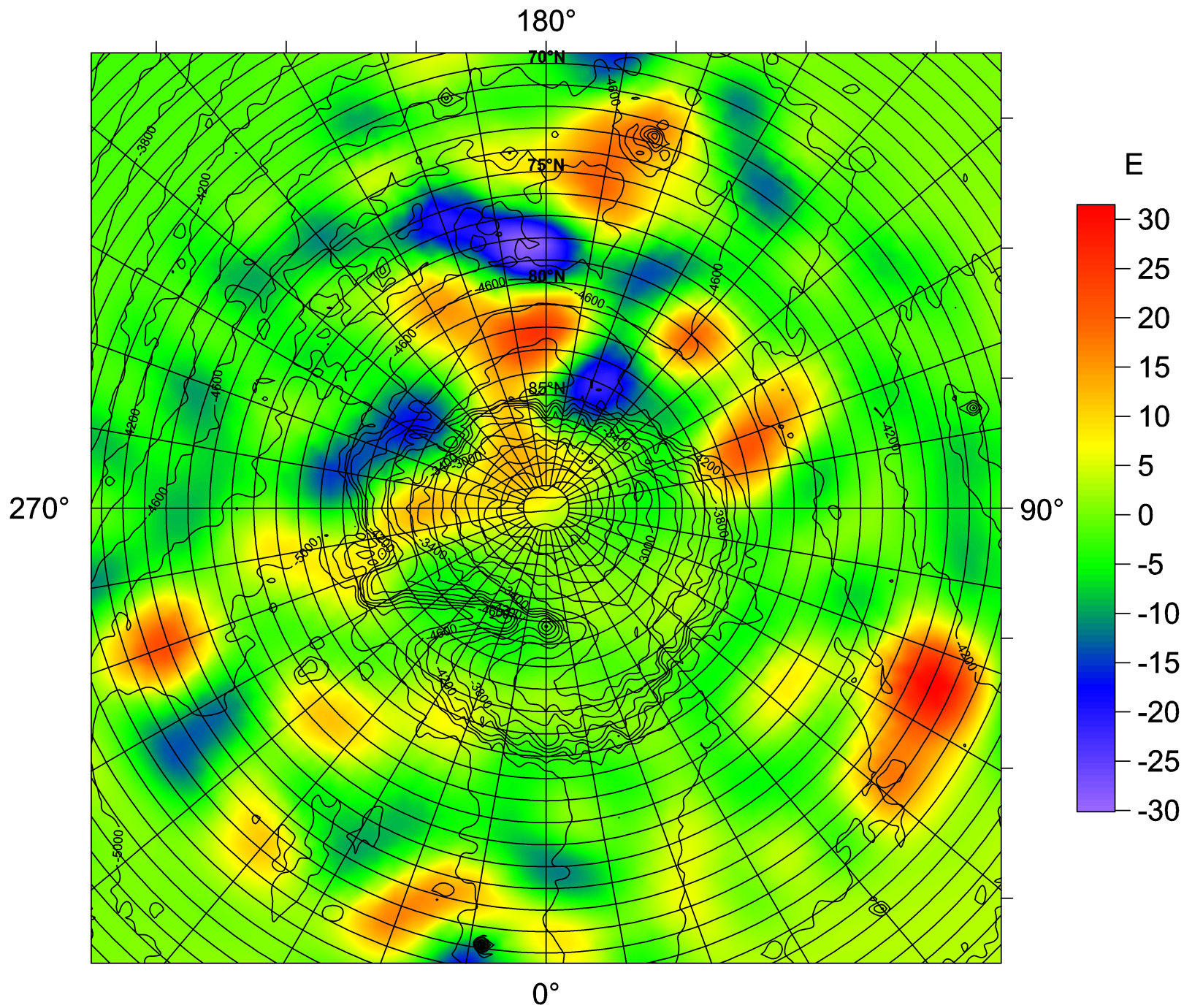
Our main results

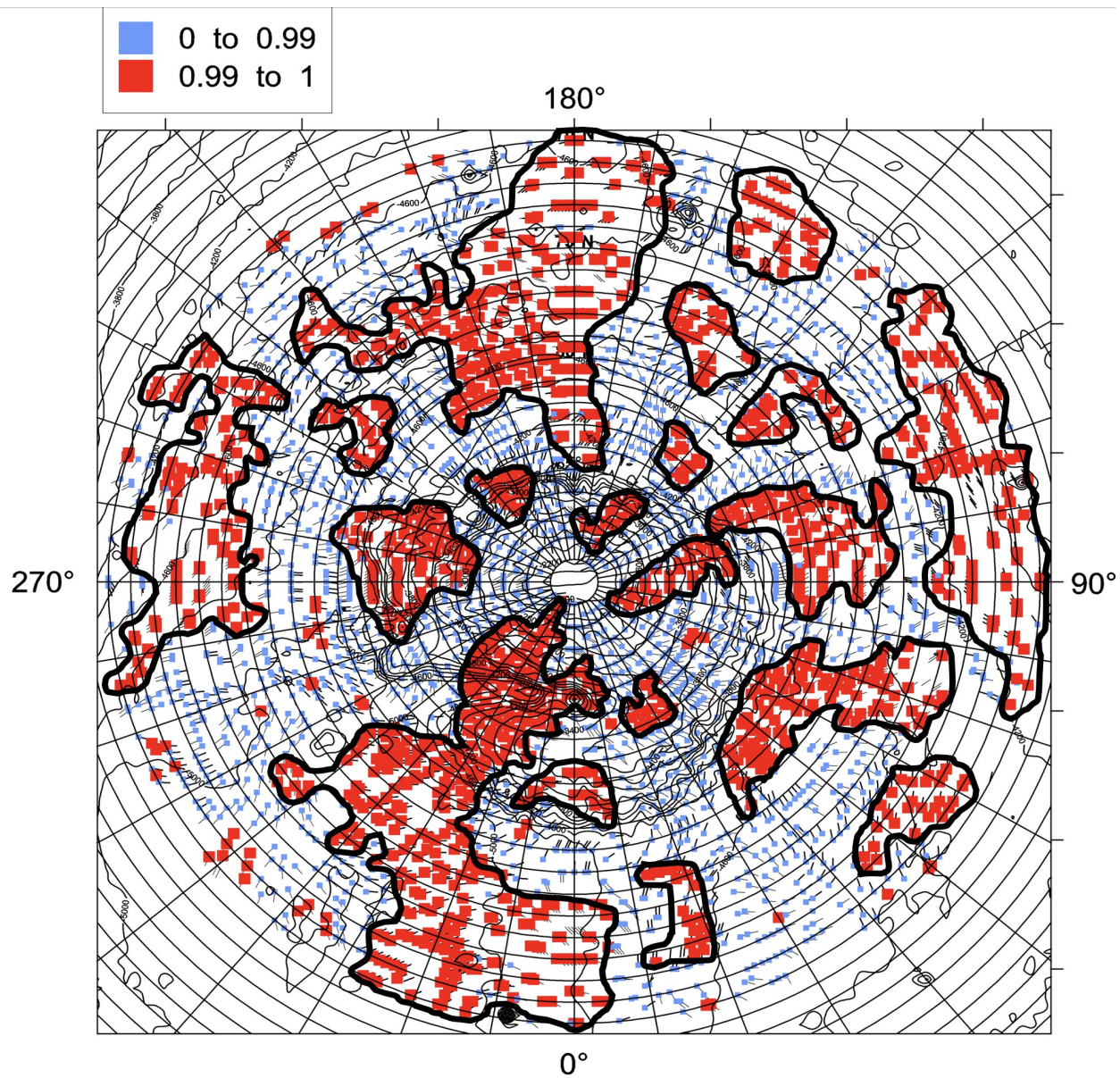
polar

Mars - north pole - Topography + delta g



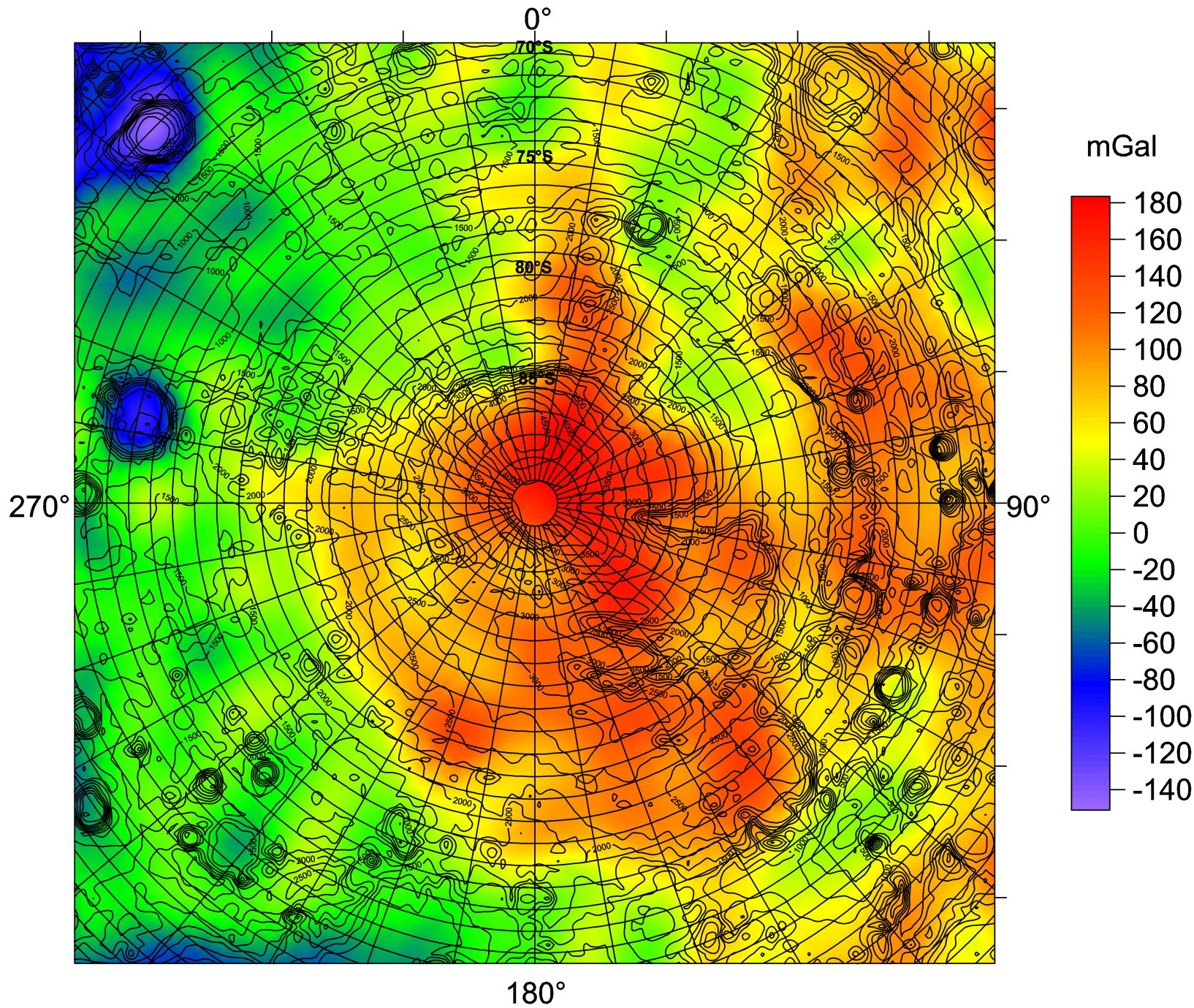
Mars - north pole - Topography + Tzz





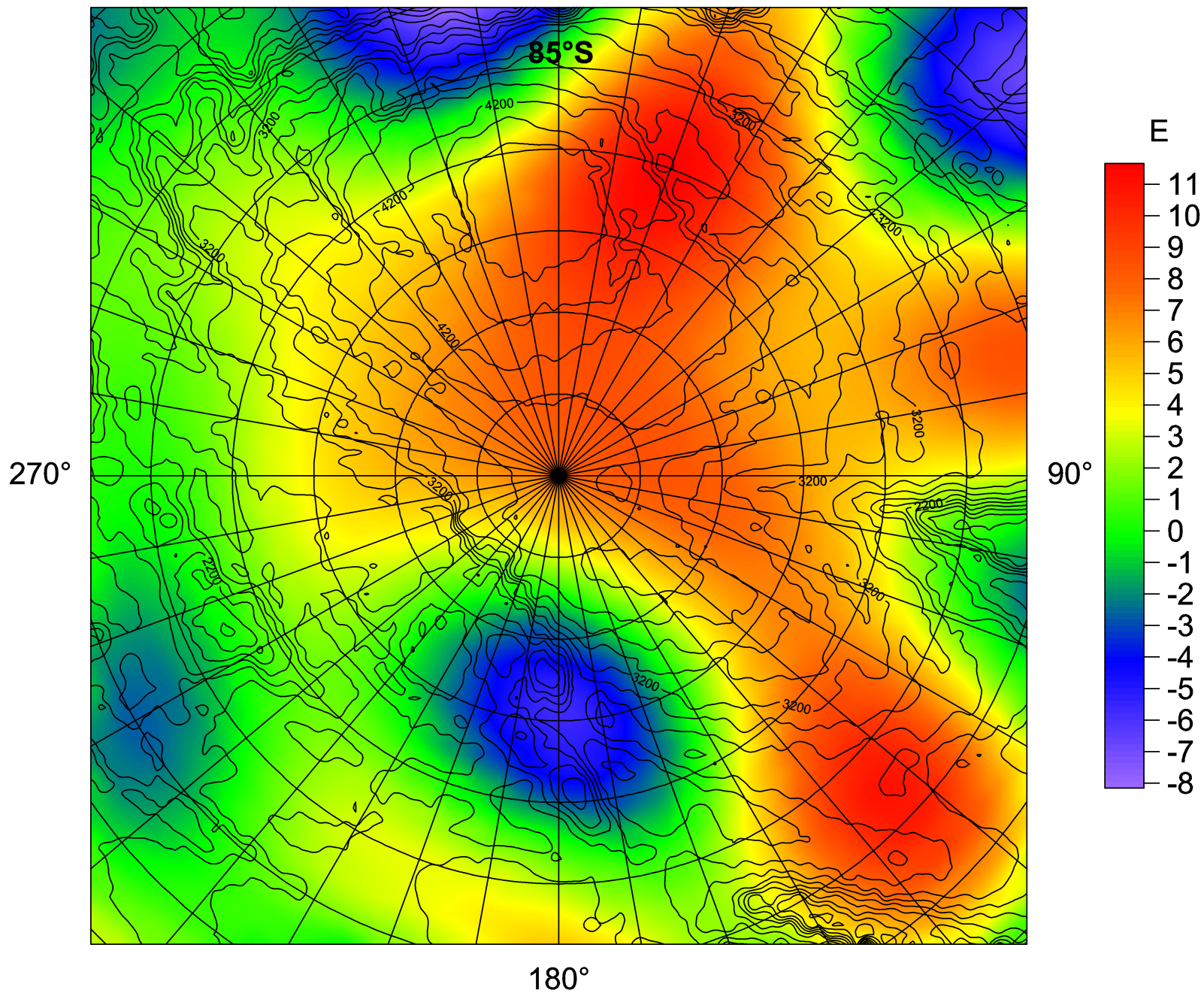
The strike angles θ [deg] (with the *comb* statistics) for the northern polar area.

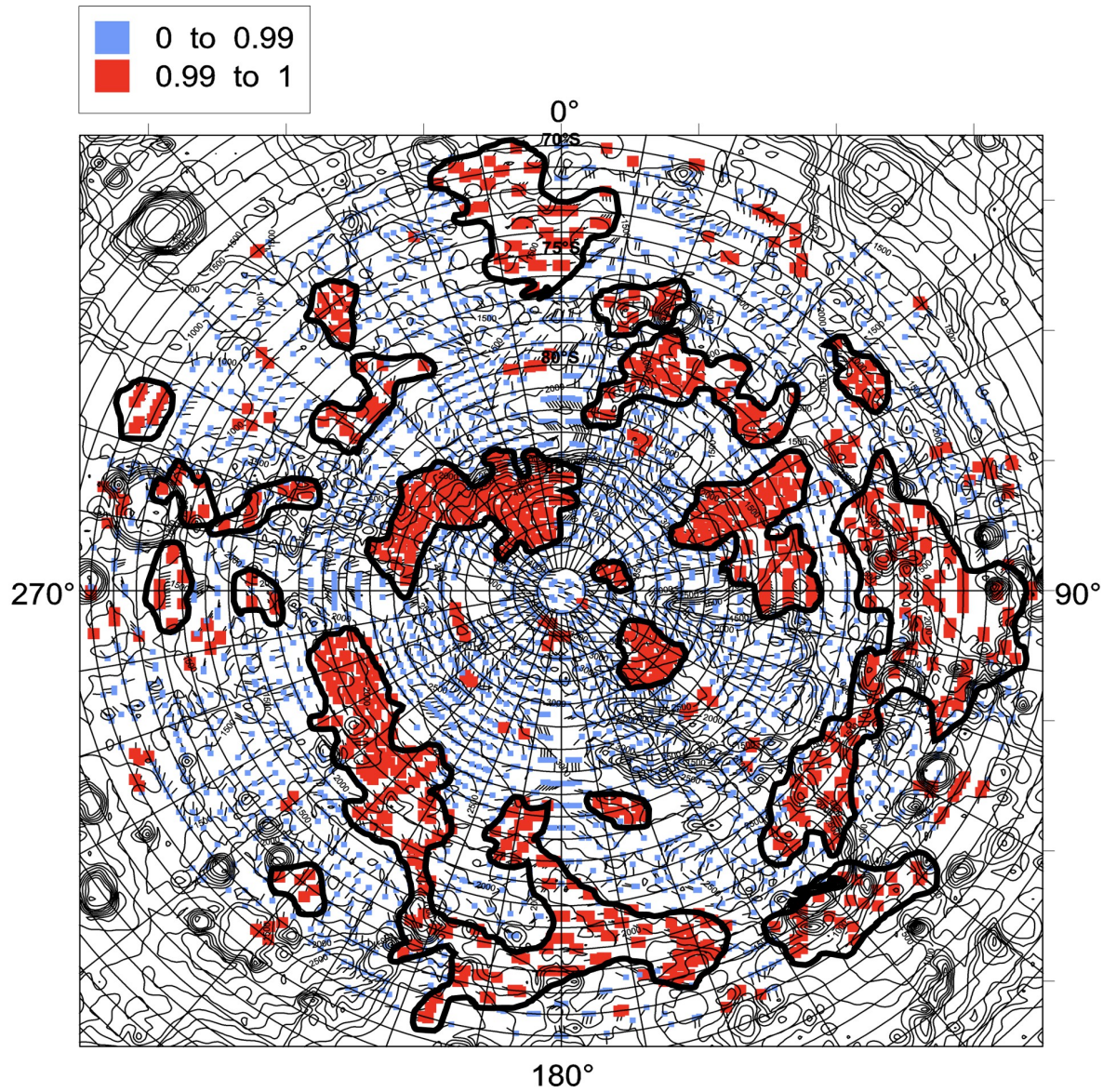
Mars - south pole - Topography + delta g



Mars - south pole - Topography + Tzz

0°





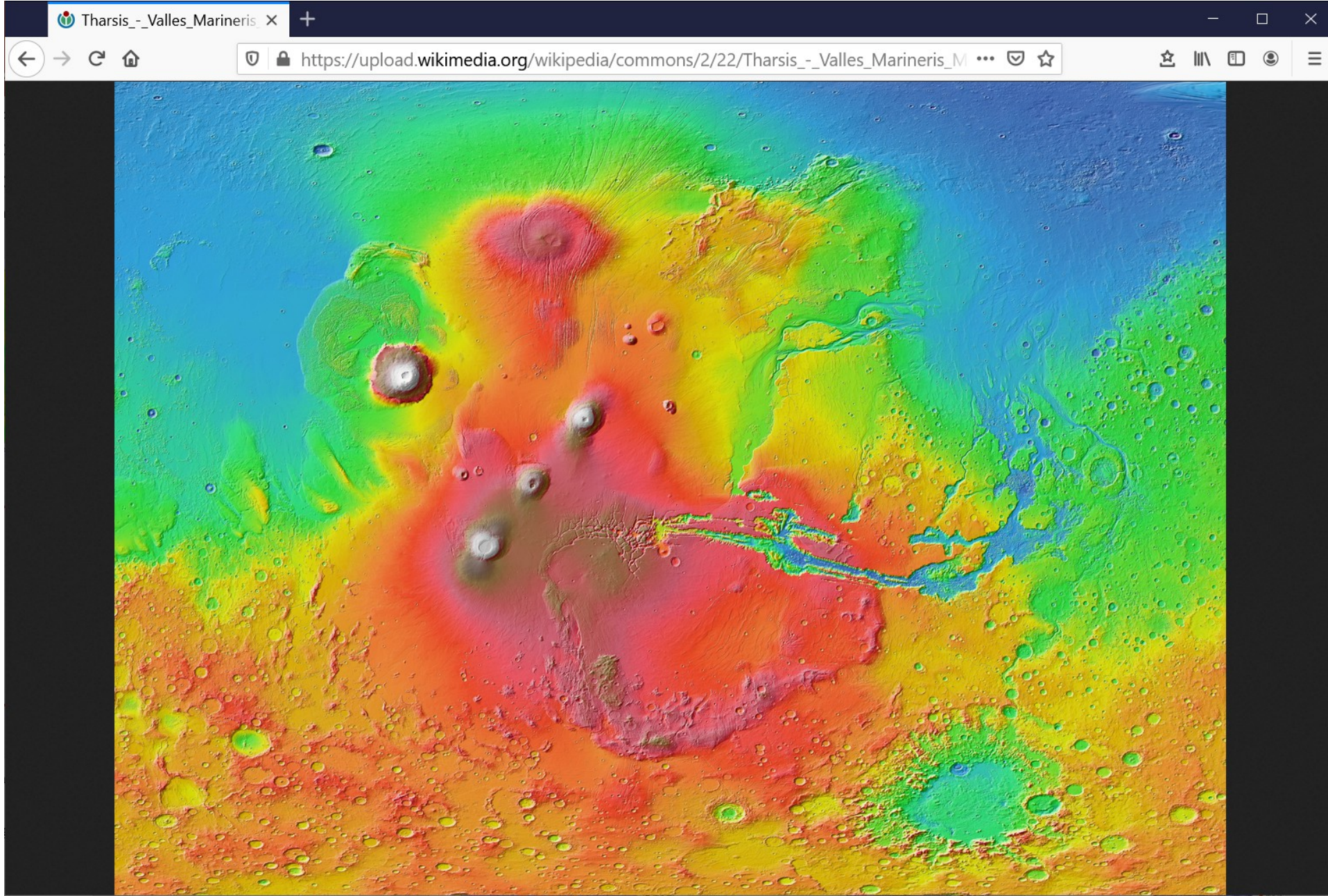
The strike angles θ [deg] (with the *comb* statistics) for the southern polar area.

Our main results

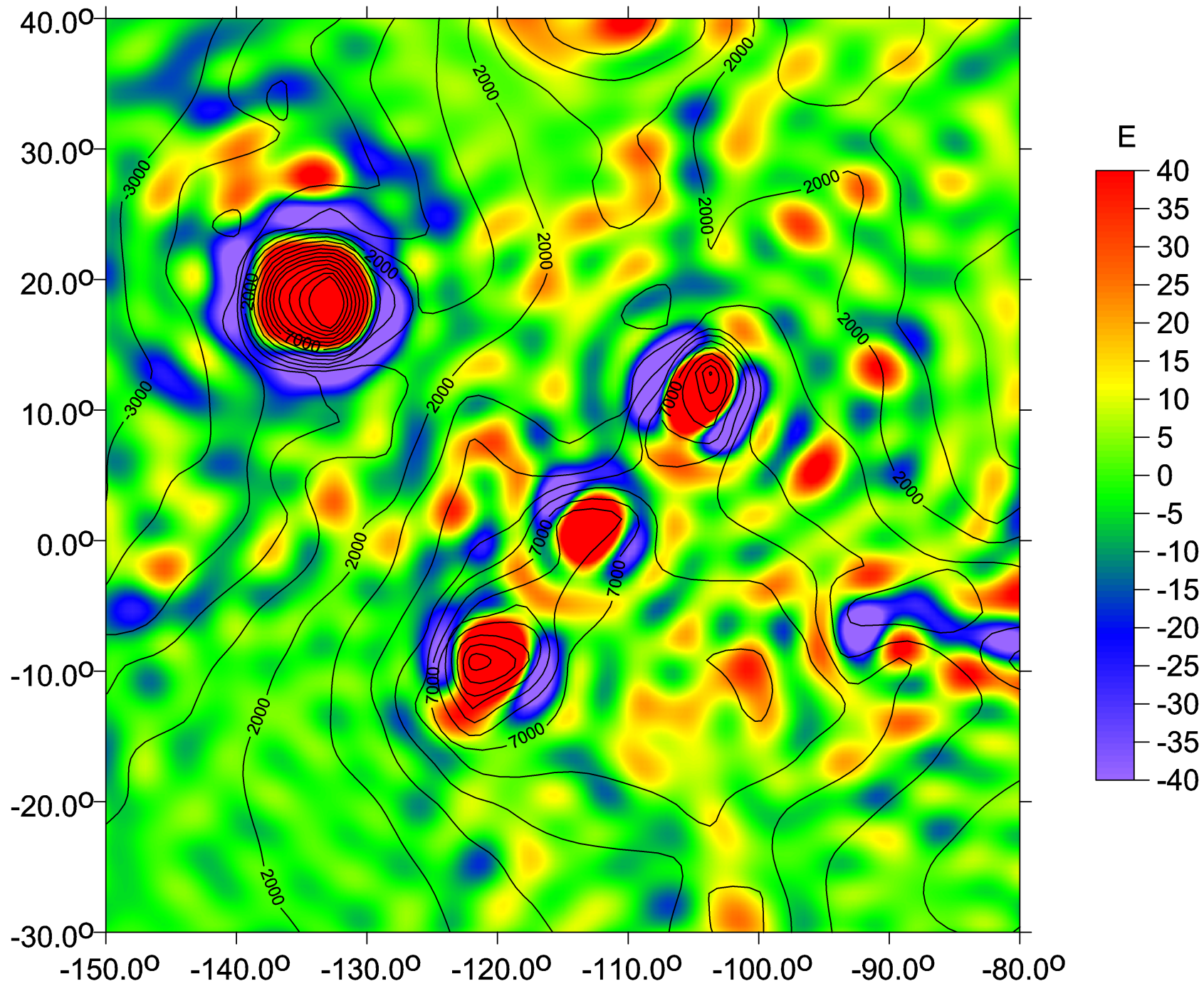
selected regions

Tharsis volcanoes

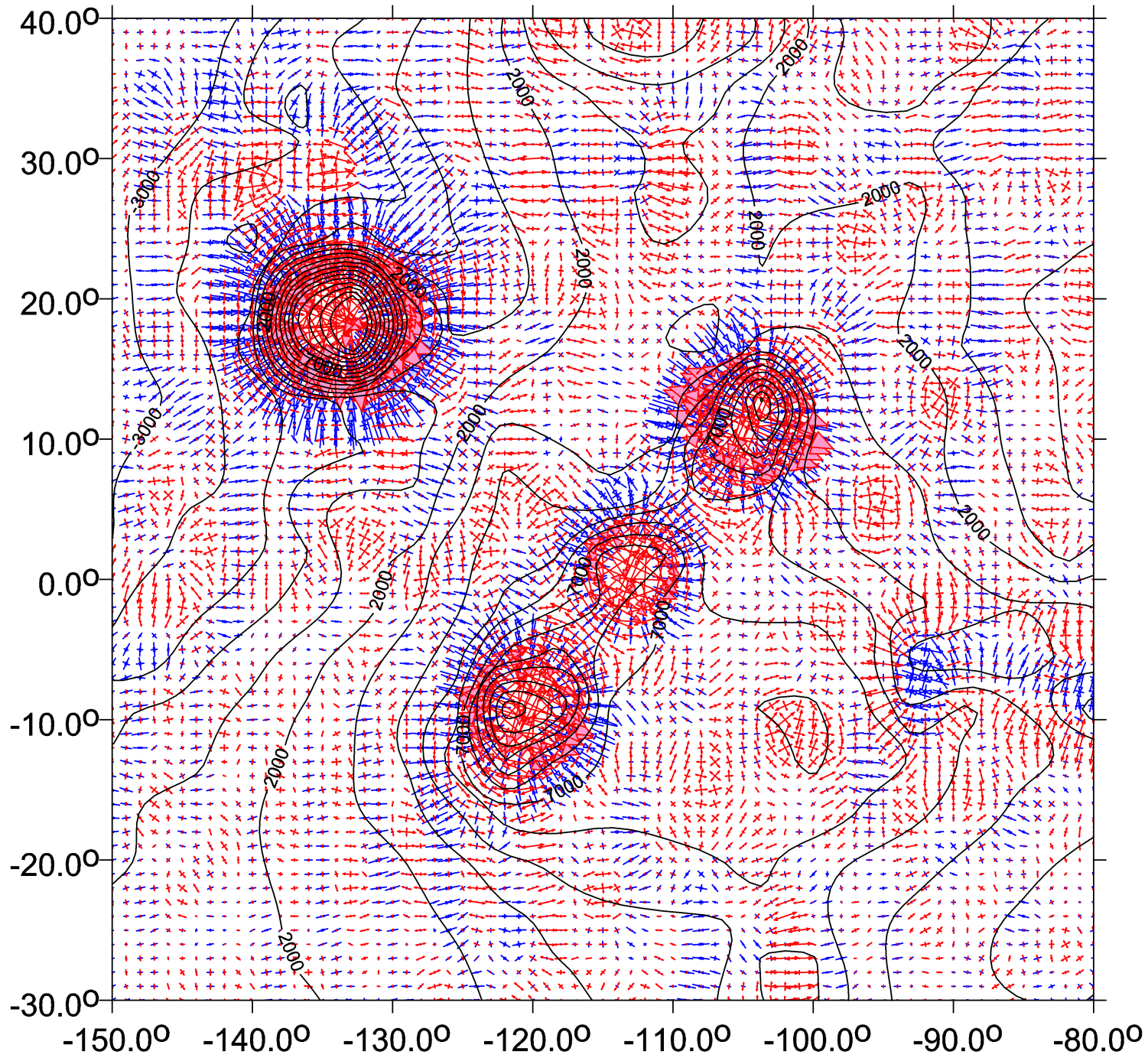
MOLA topo



Mars - Tharsis - topo + Tzz

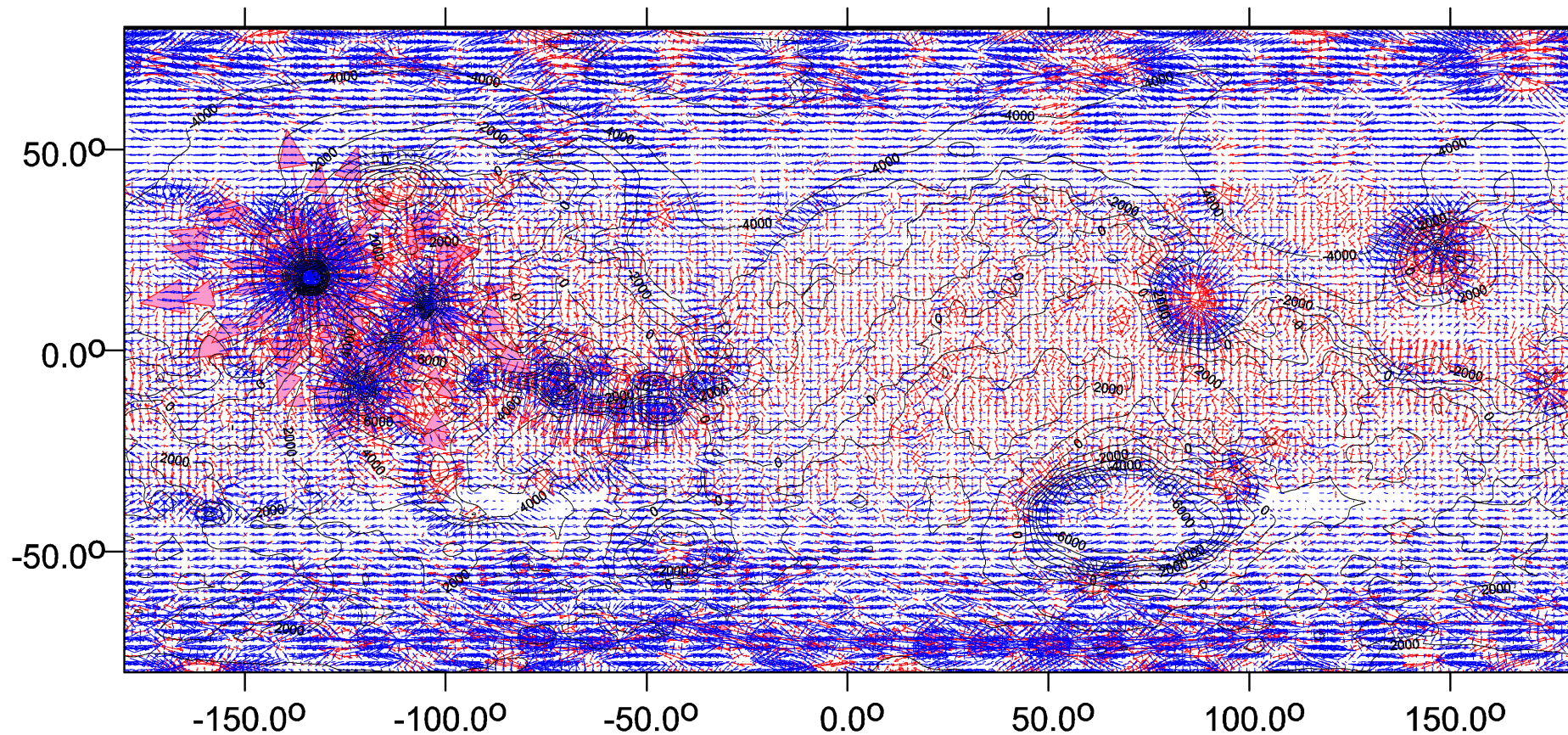


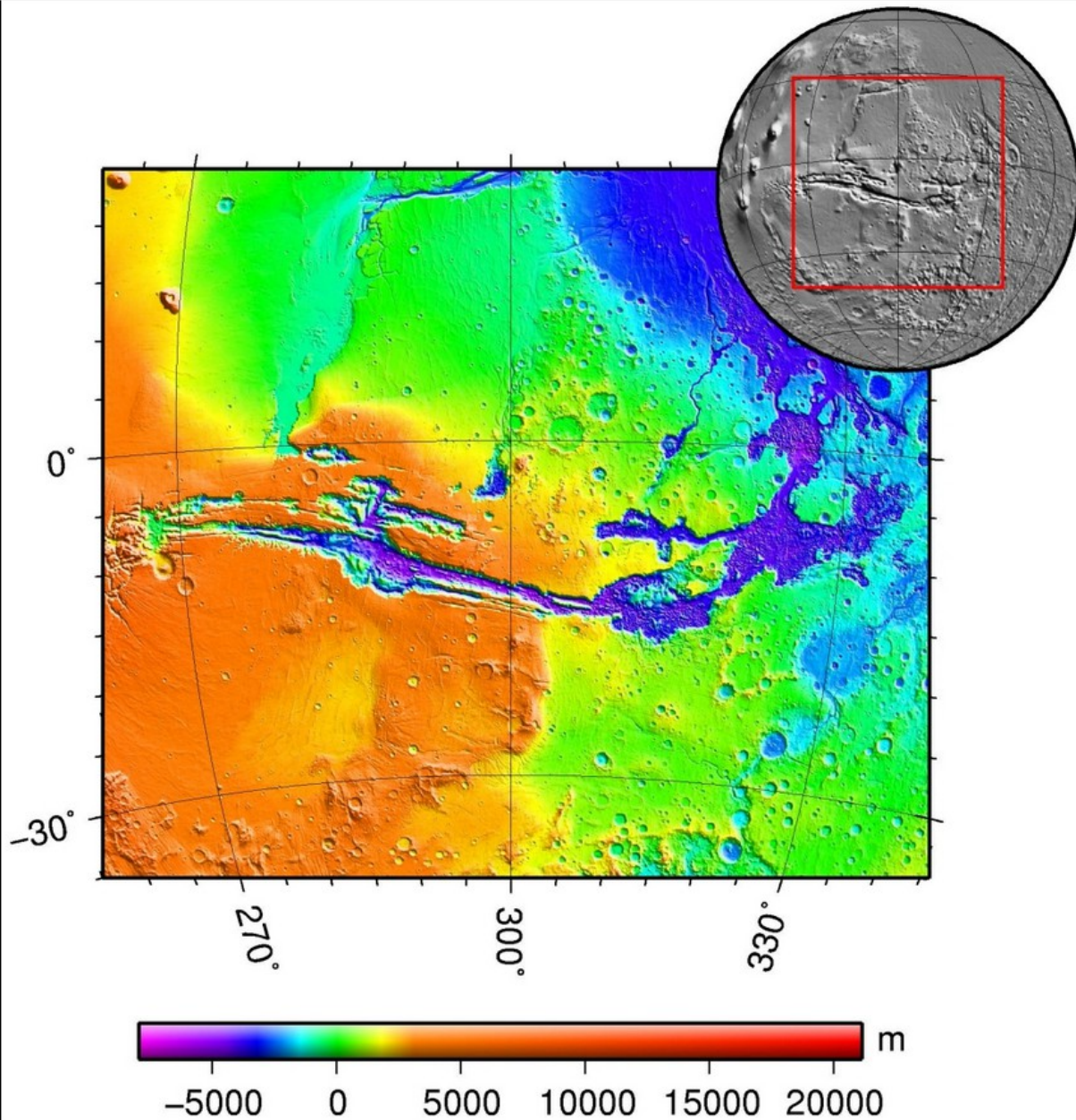
Mars - Tharsis - topo + virtual deformations



Hellas

Mars - Topo + vd

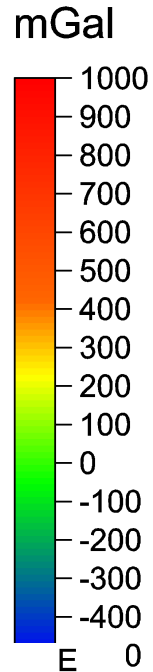
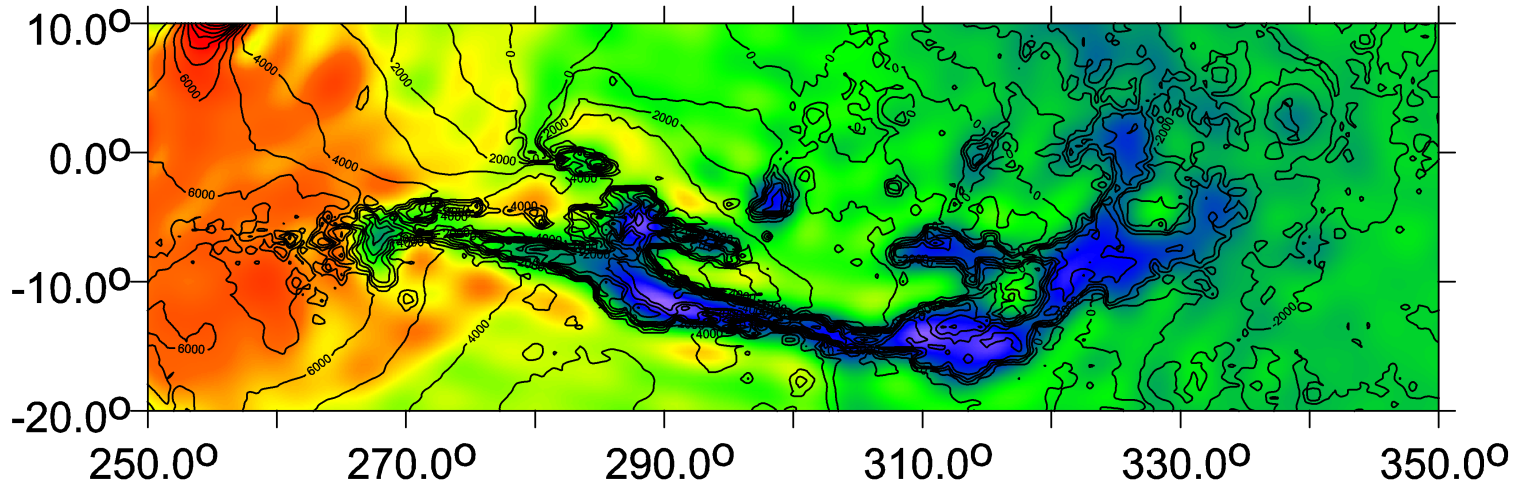




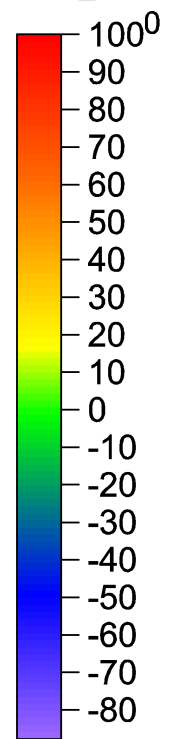
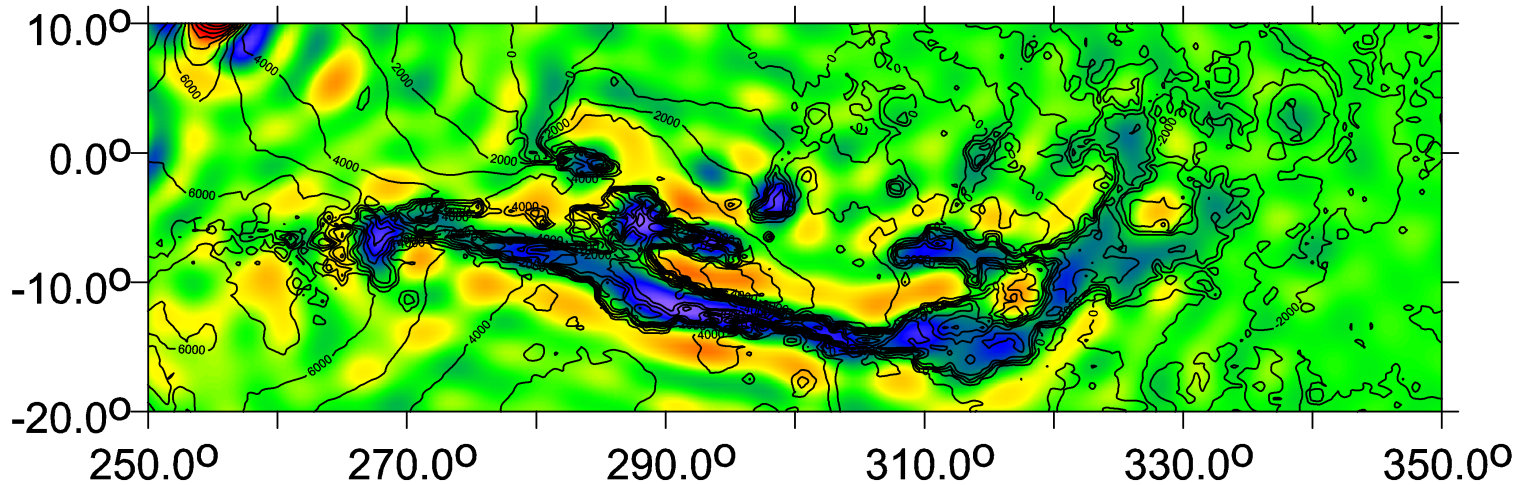
Valles Marineris topo

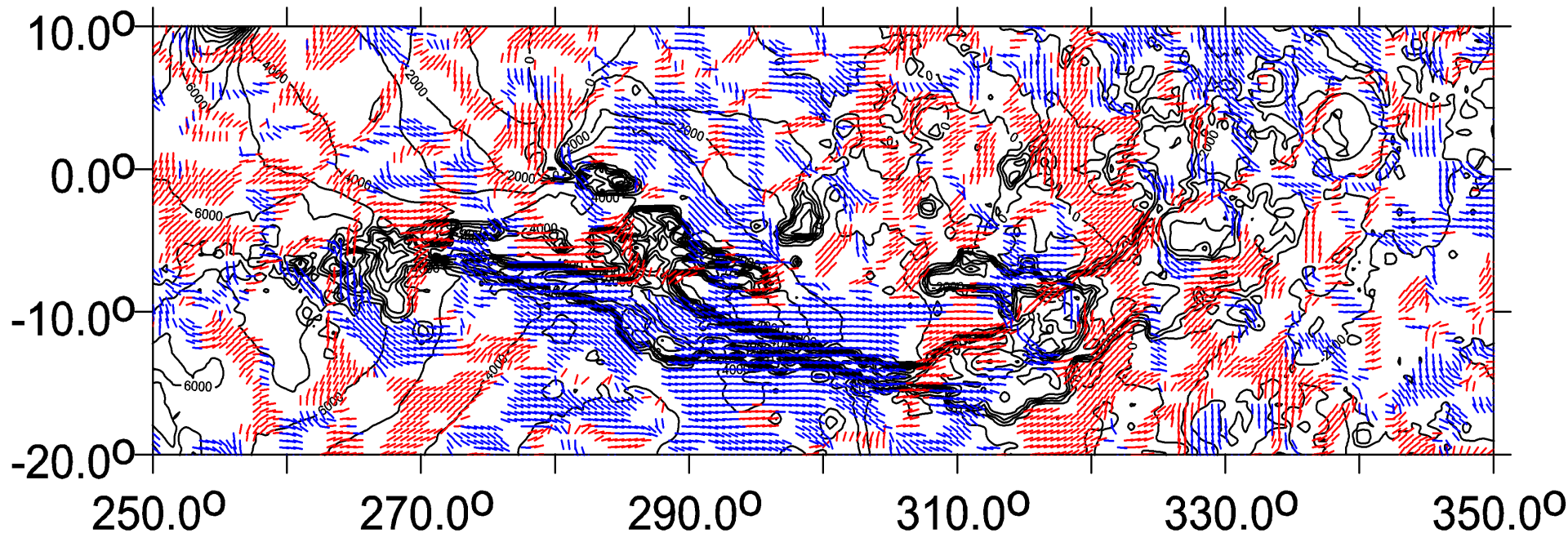
Valles Marineris

Mars - Topo + delta g



Mars - Topo + Tzz

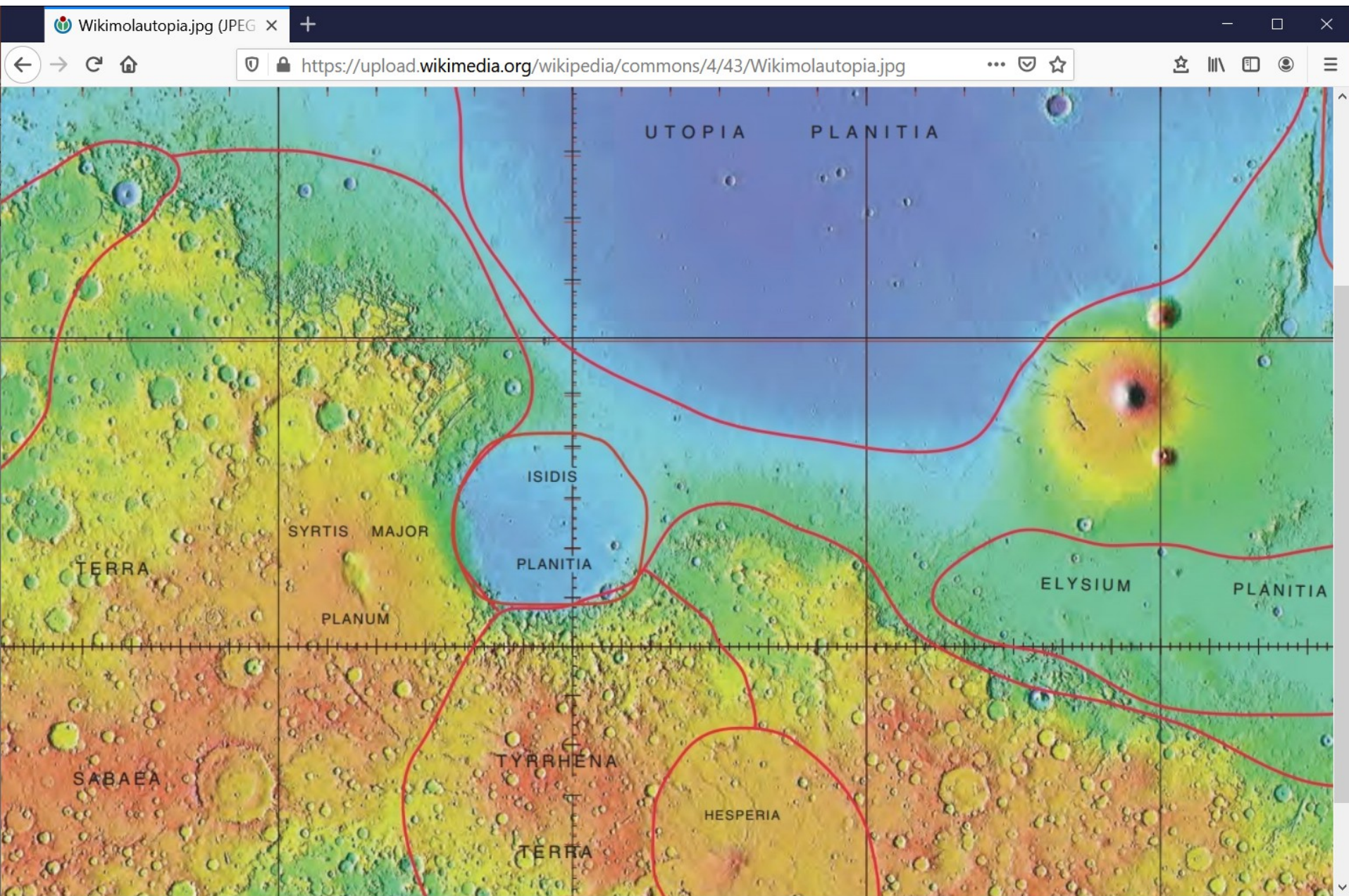


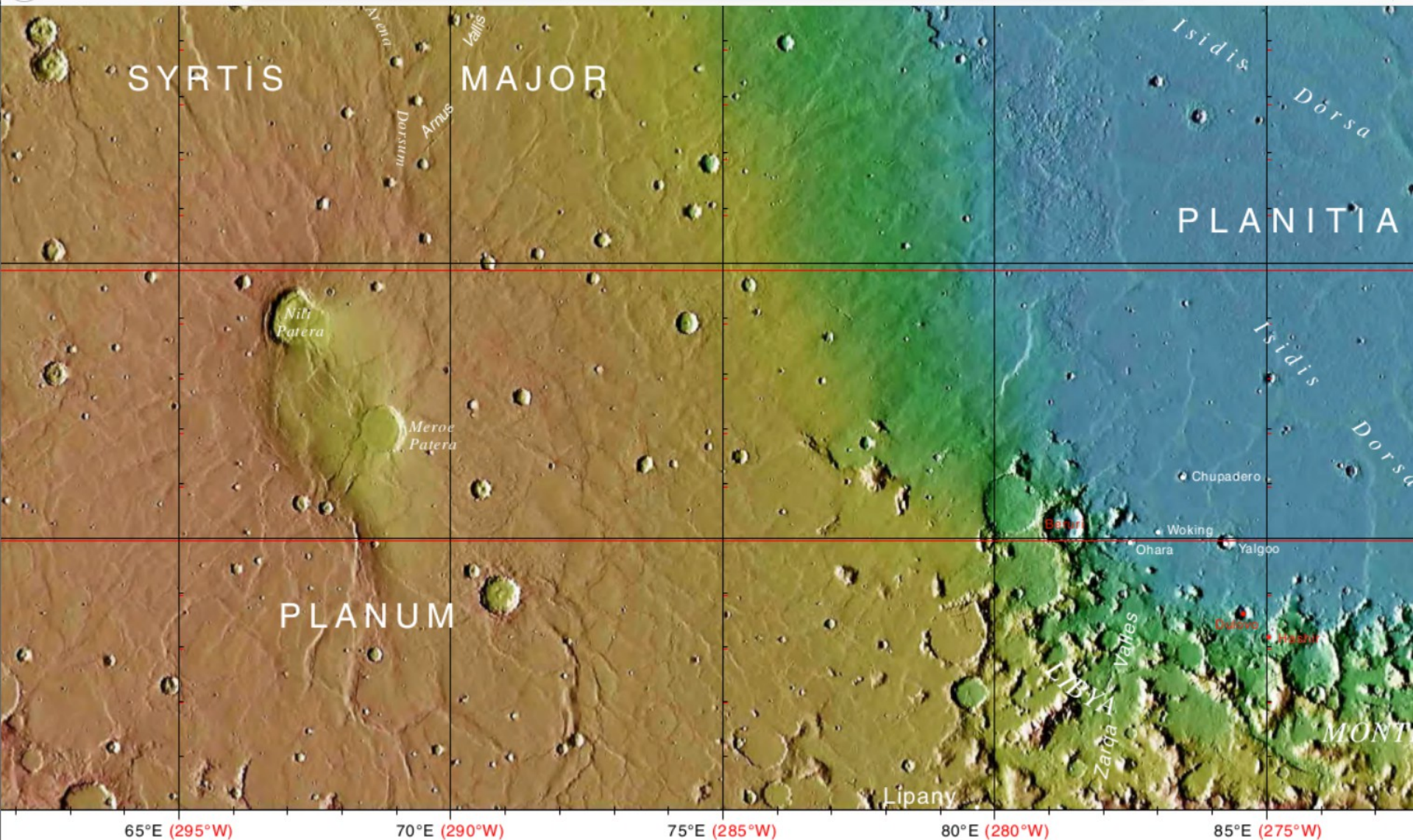


Isidis Planitia (8.4N, 69.5E)

MOLA topo

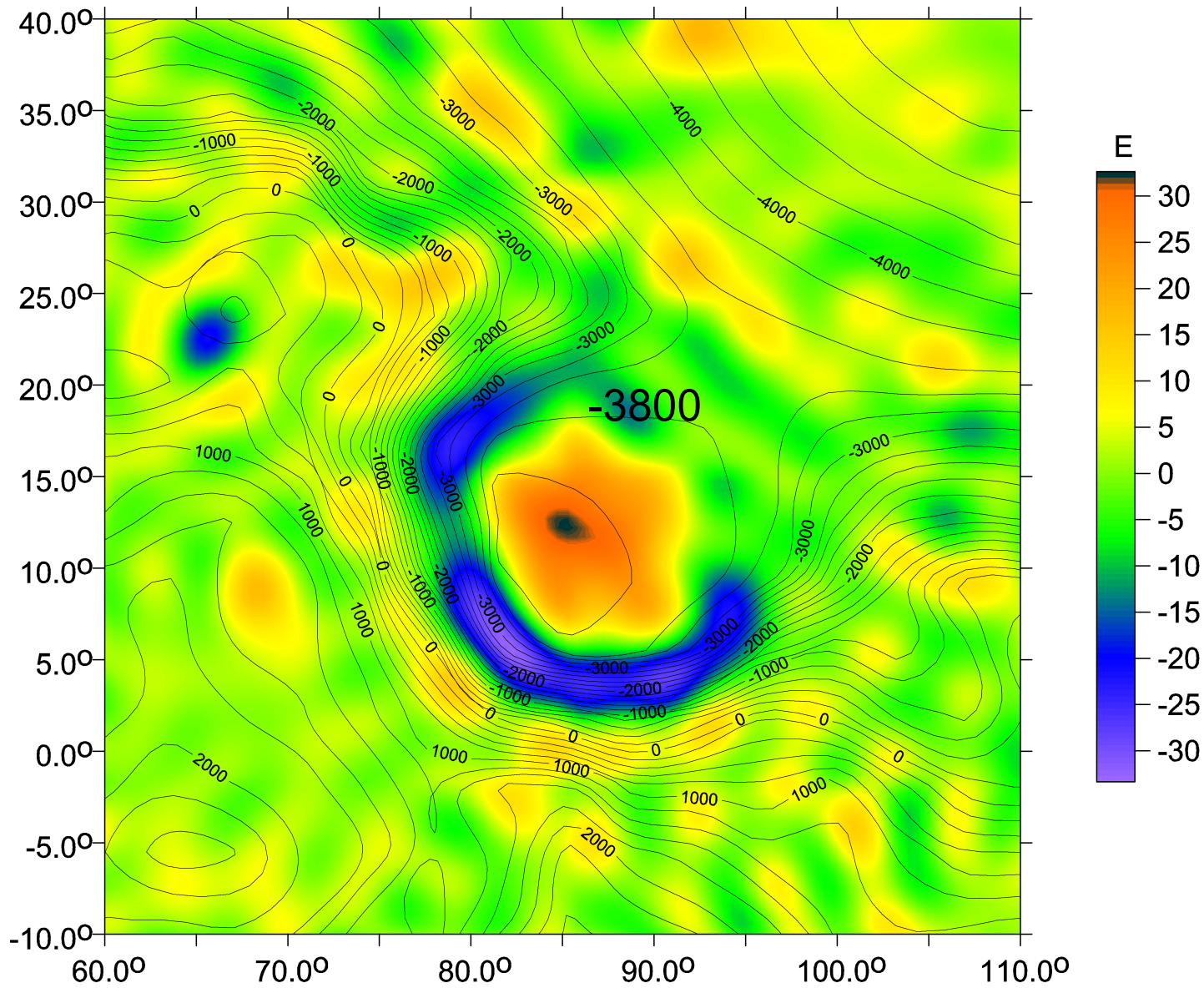
& Syrtis Major (SM) Planum (black spot) shield volcano



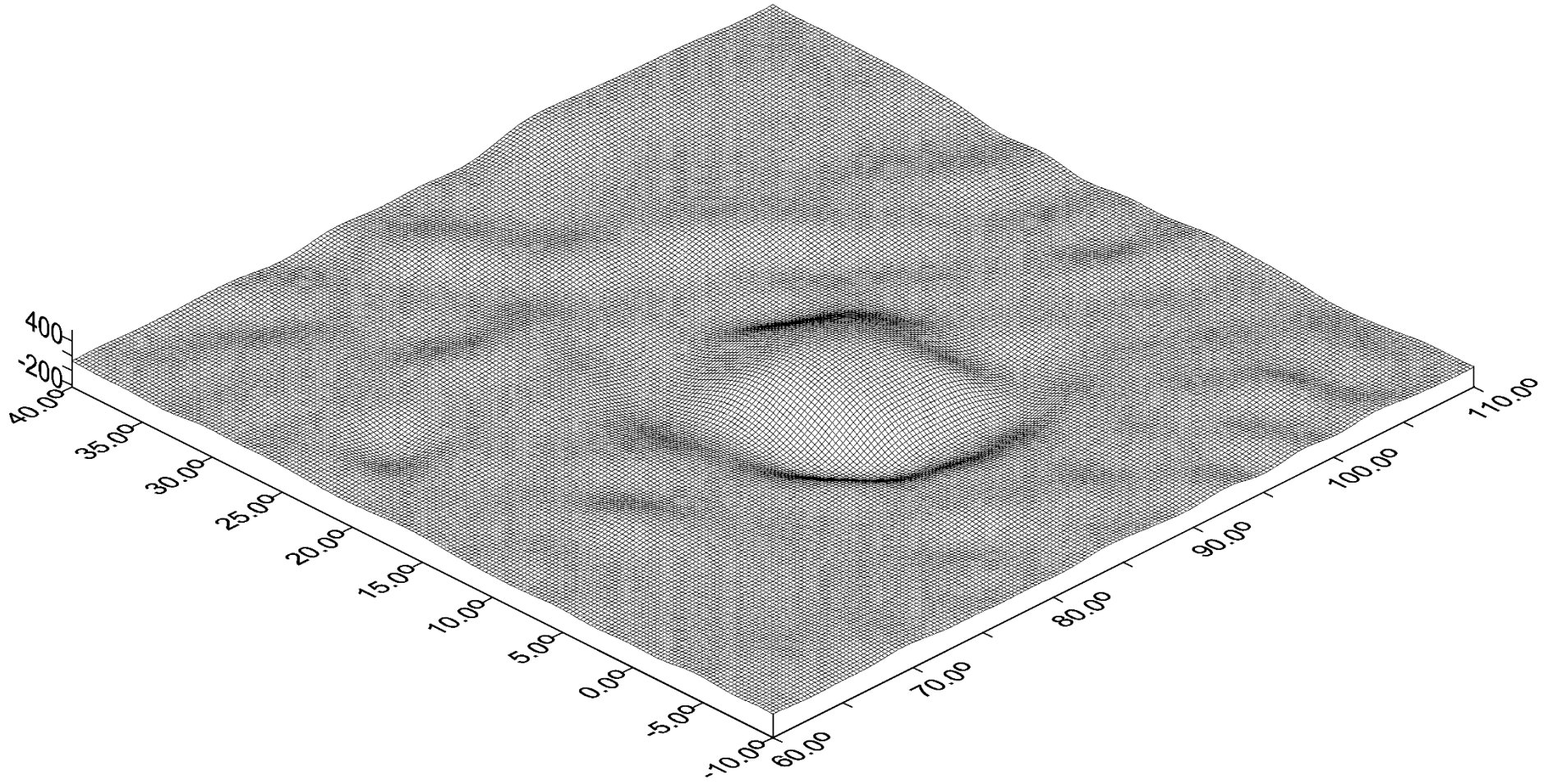


ISIDIS = volcano, nothing else

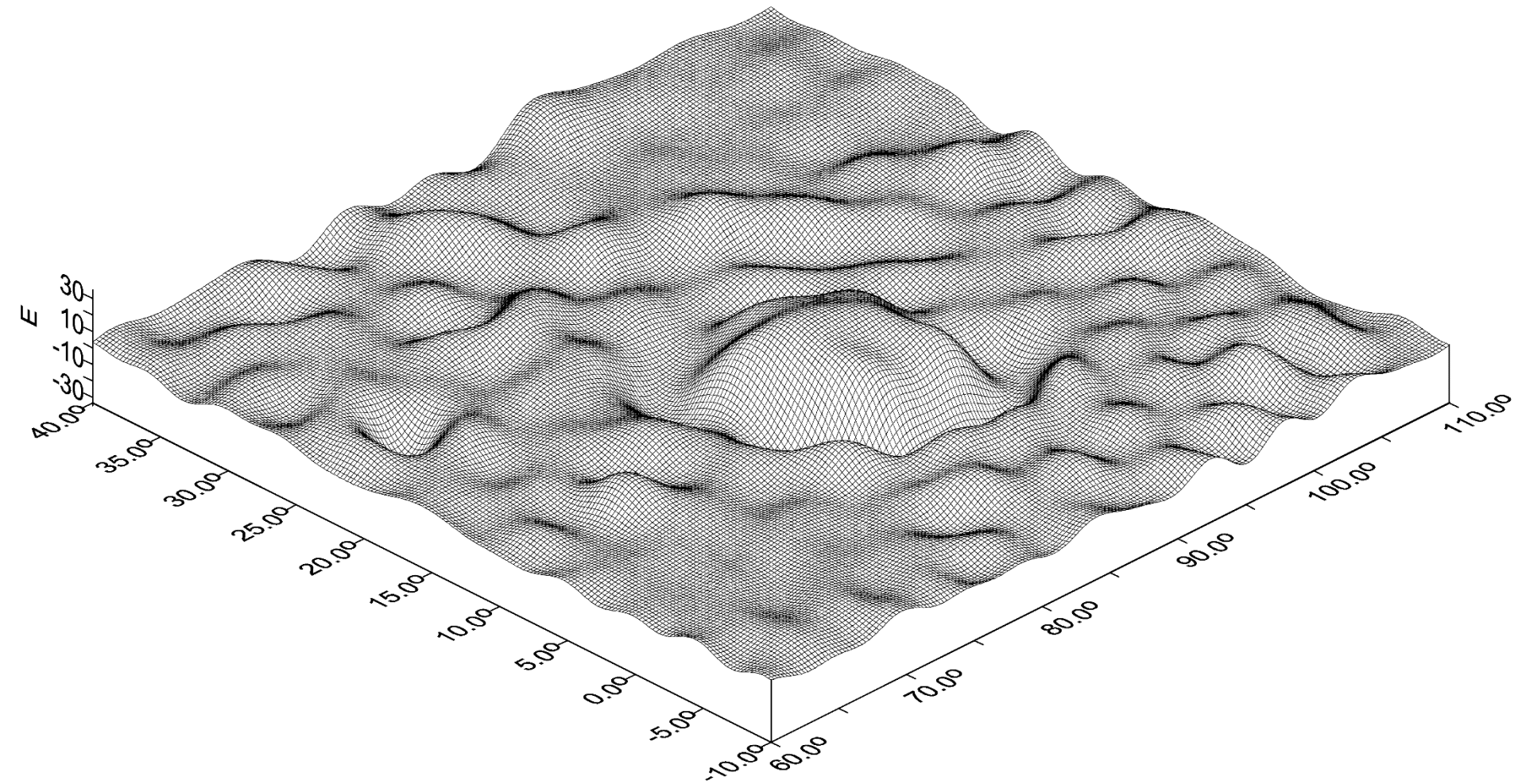
Mars - Isidis - topo + Tzz

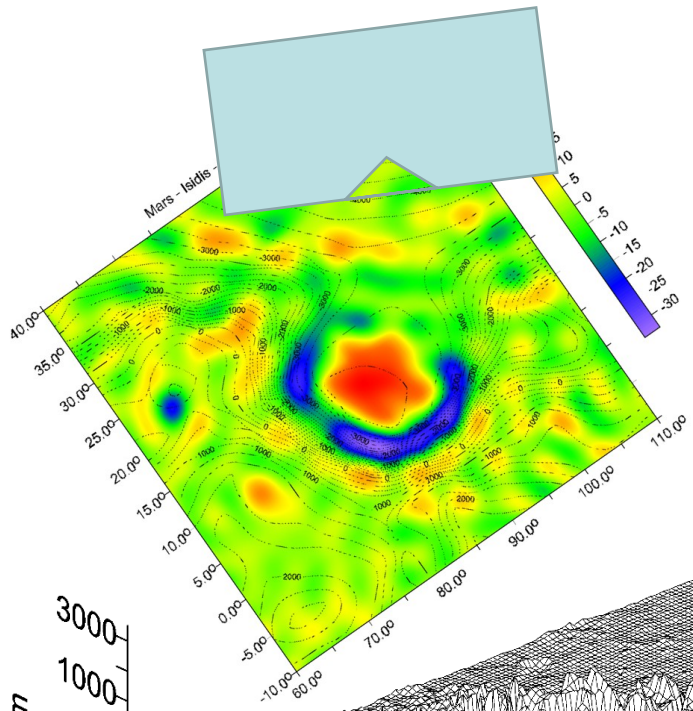


Mars - Isidis - delta g

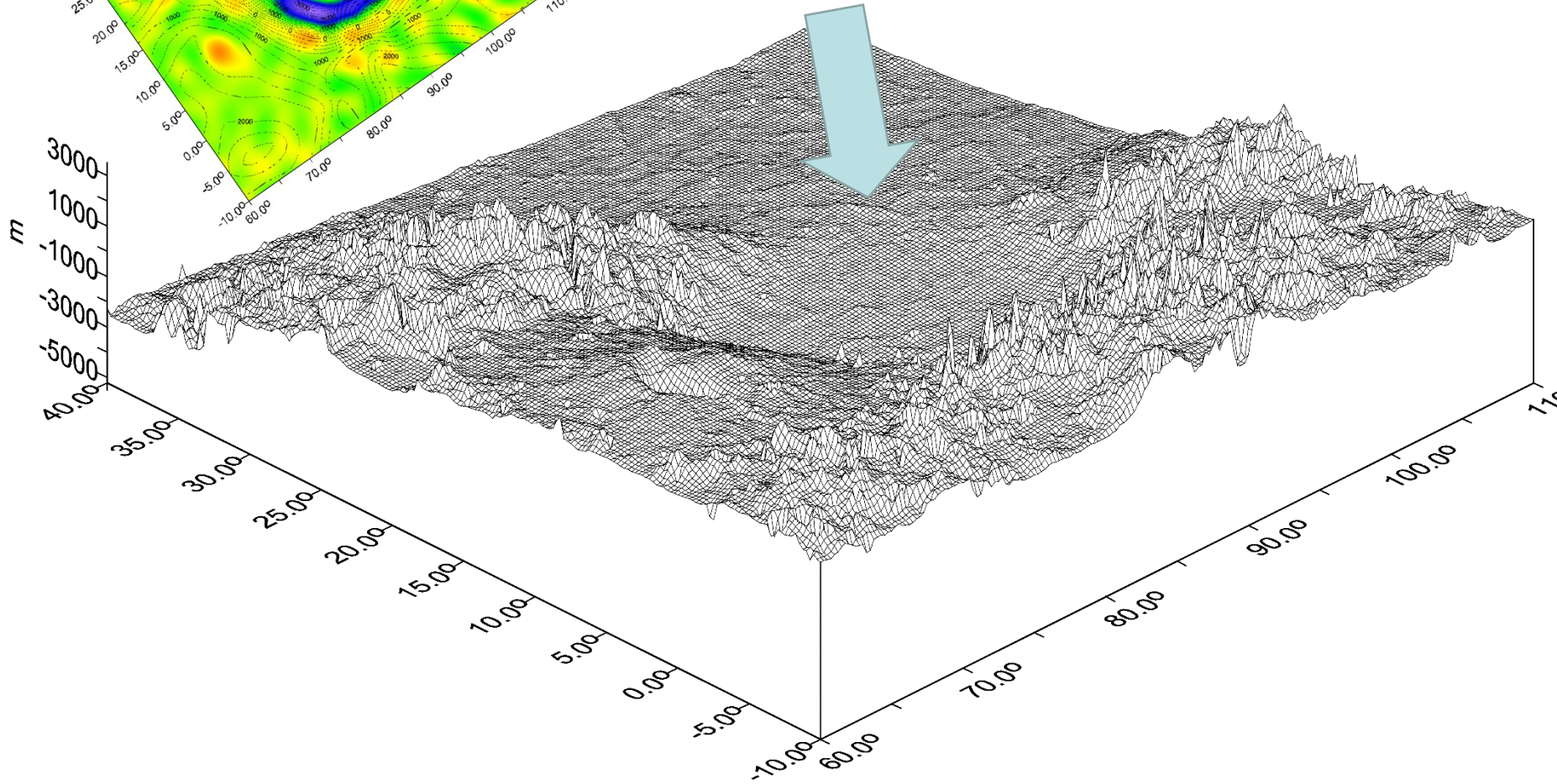


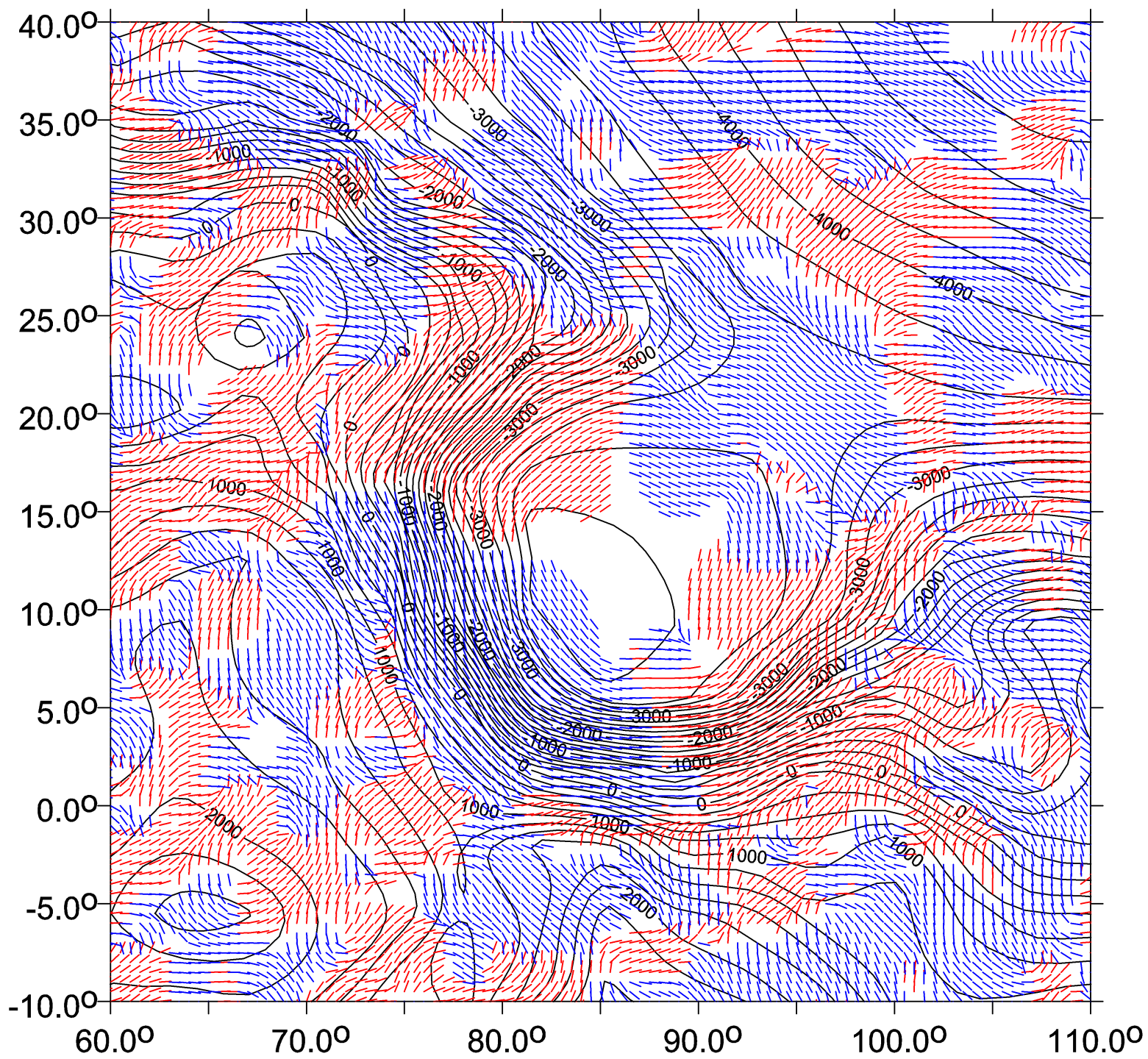
Mars - Isidis - Tzz



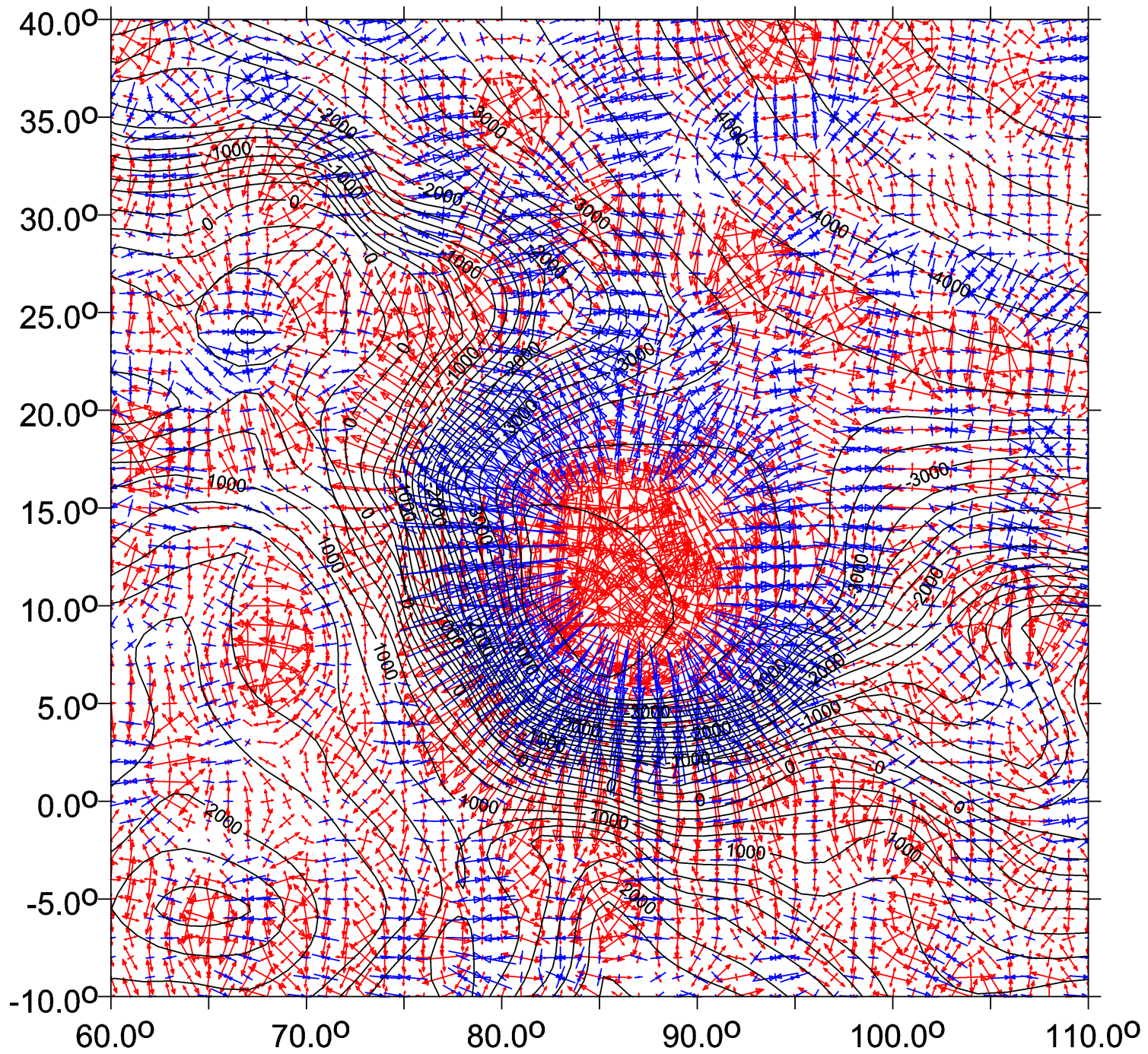


Mars - Isidis - topo

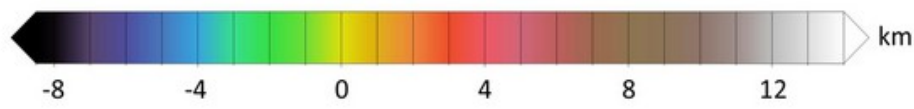
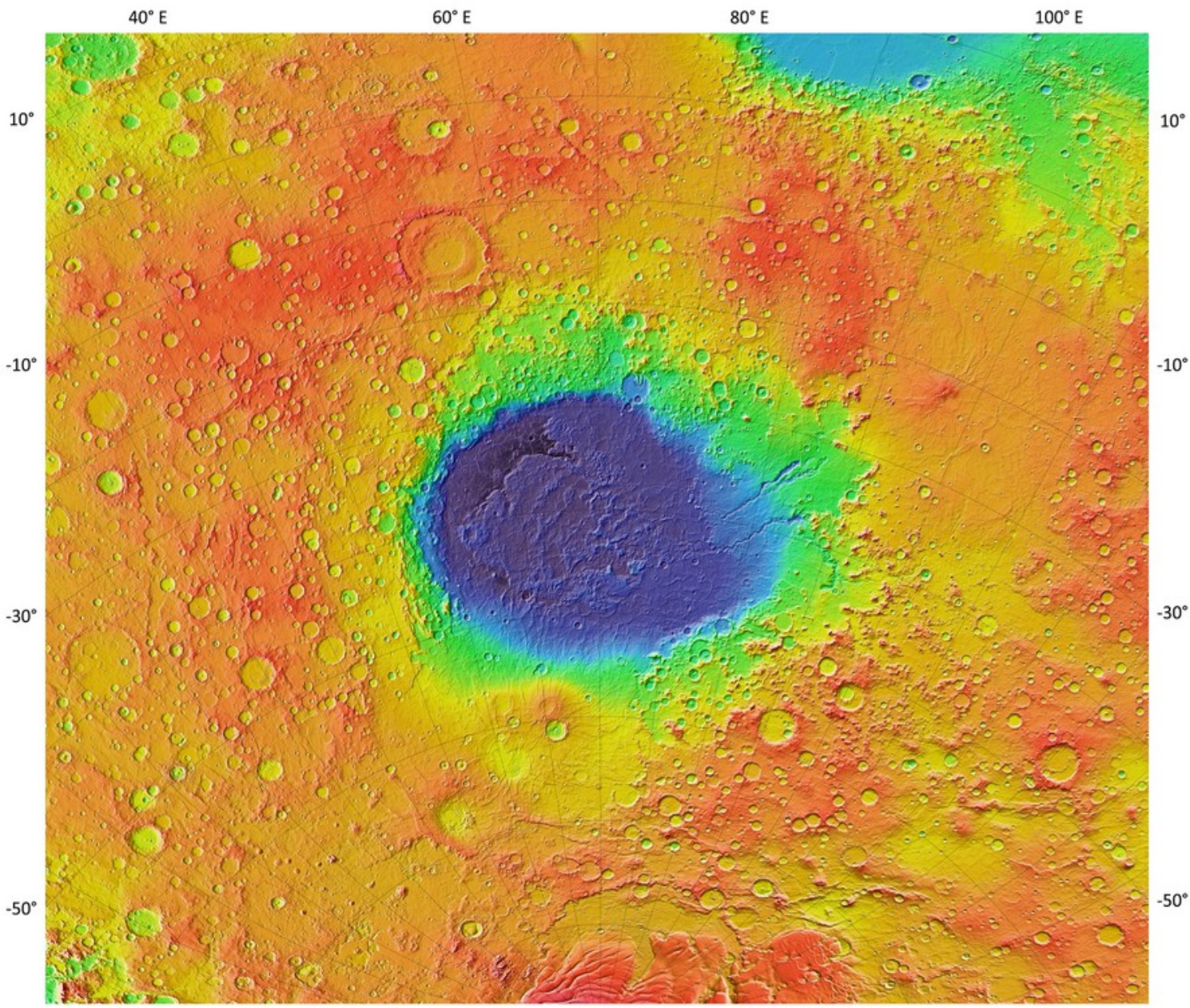


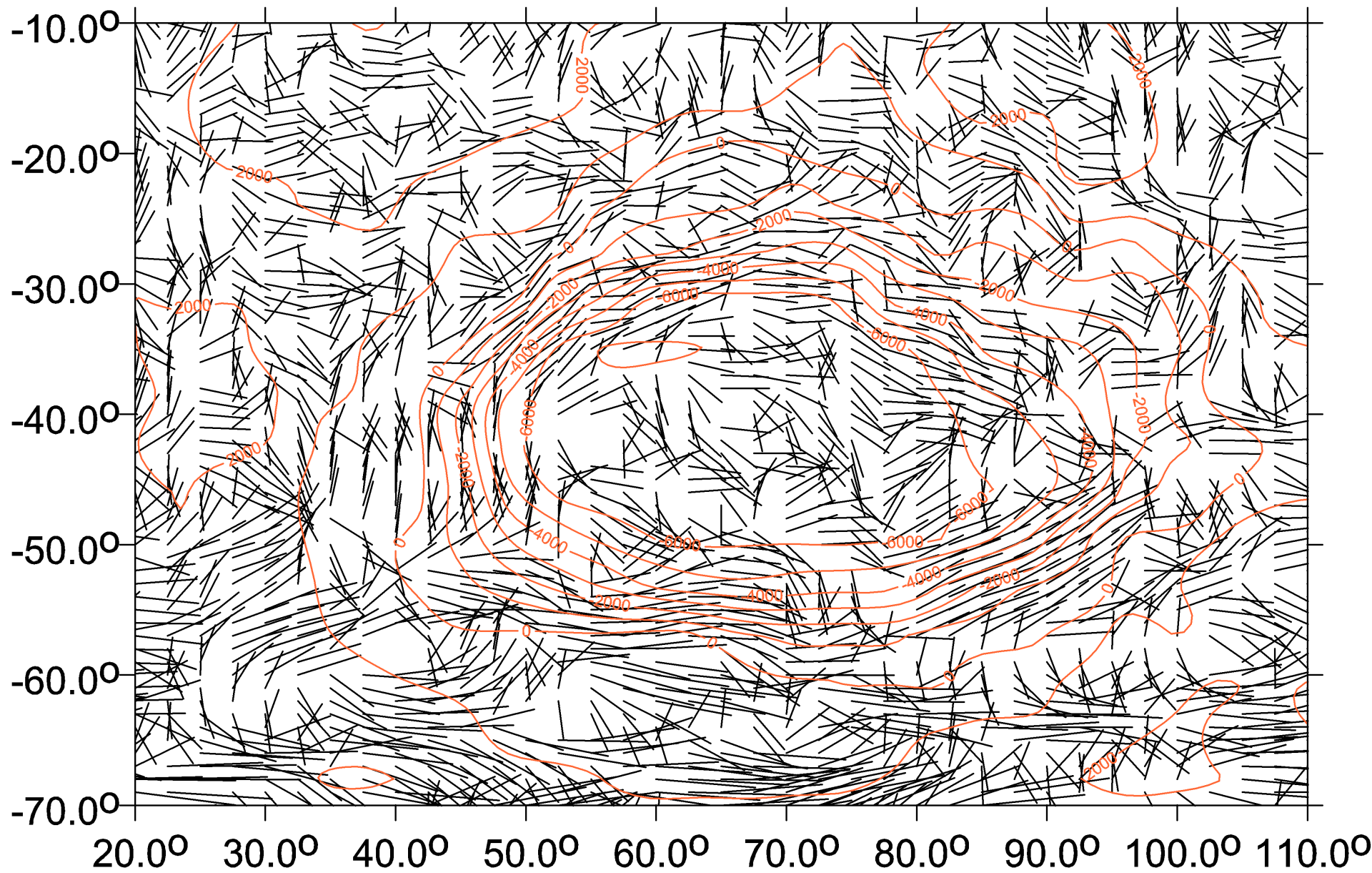


Mars - Isidis - topo + virtual deformations



Hellas Planitia *topo*





dichotomy

Mars dichotomy

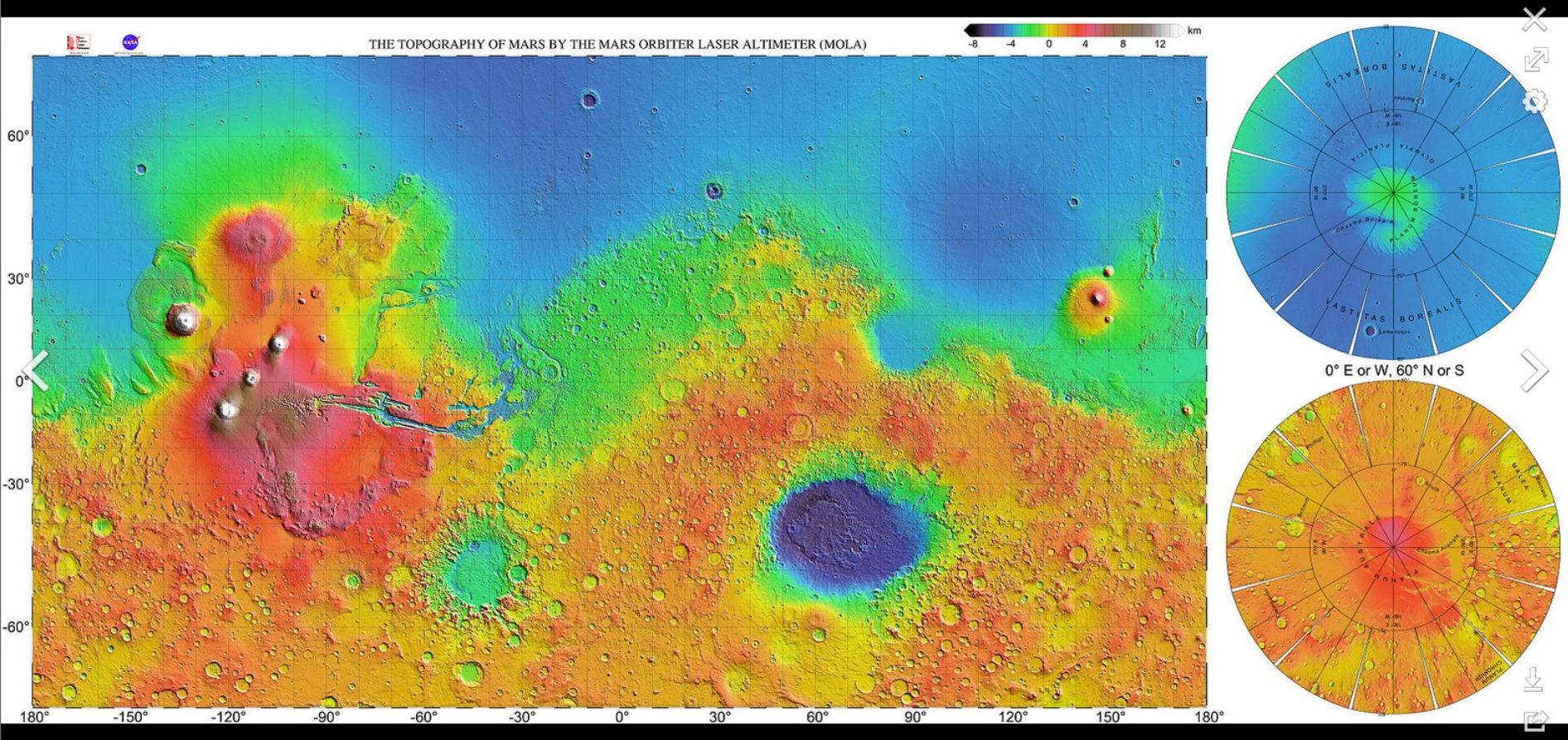
The crustal dichotomy of Mars describes the topographic division between the plains in the northern hemisphere and the terrain in the southern hemisphere.

The two hemispheres' geography differ in elevation by 1 to 3 km. The average thickness of the Martian crust is 45 km, with 32 km in the northern lowlands region, and 58 km in the southern highlands.

The boundary between the two regions is quite complex in places. One distinctive type of topography is called **fretted terrain**. It contains mesas, knobs, and flat-floored valleys having walls about a mile high. The Martian dichotomy boundary includes the regions called Deuteronilus Mensae, Protonilus Mensae, and Nilosyrtis Mensae. All three regions have been studied extensively because they contain landforms believed to have been produced by the movement of ice[12][13] or paleoshorelines questioned as formed by volcanic erosion.[14]

The **northern lowlands comprise about one-third of the surface of Mars and are relatively flat**, with as many impact craters as the southern hemisphere.[15] The other two-thirds of the Martian surface are the highlands of the southern hemisphere. The difference in elevation between the hemispheres is dramatic.

Three major hypotheses have been proposed for the origin of the crustal dichotomy: **endogenic (by mantle processes), single impact, or multiple impact**. Both impact-related hypotheses involve processes that could have occurred before the end of the primordial bombardment, implying that the crustal dichotomy has its origins early in the history of Mars.



THE TOPOGRAPHY OF MARS BY THE MARS ORBITER LASER ALTIMETER (MOLA)

-8 -4 0 4 8 12 km

0° E or W, 60° N or S

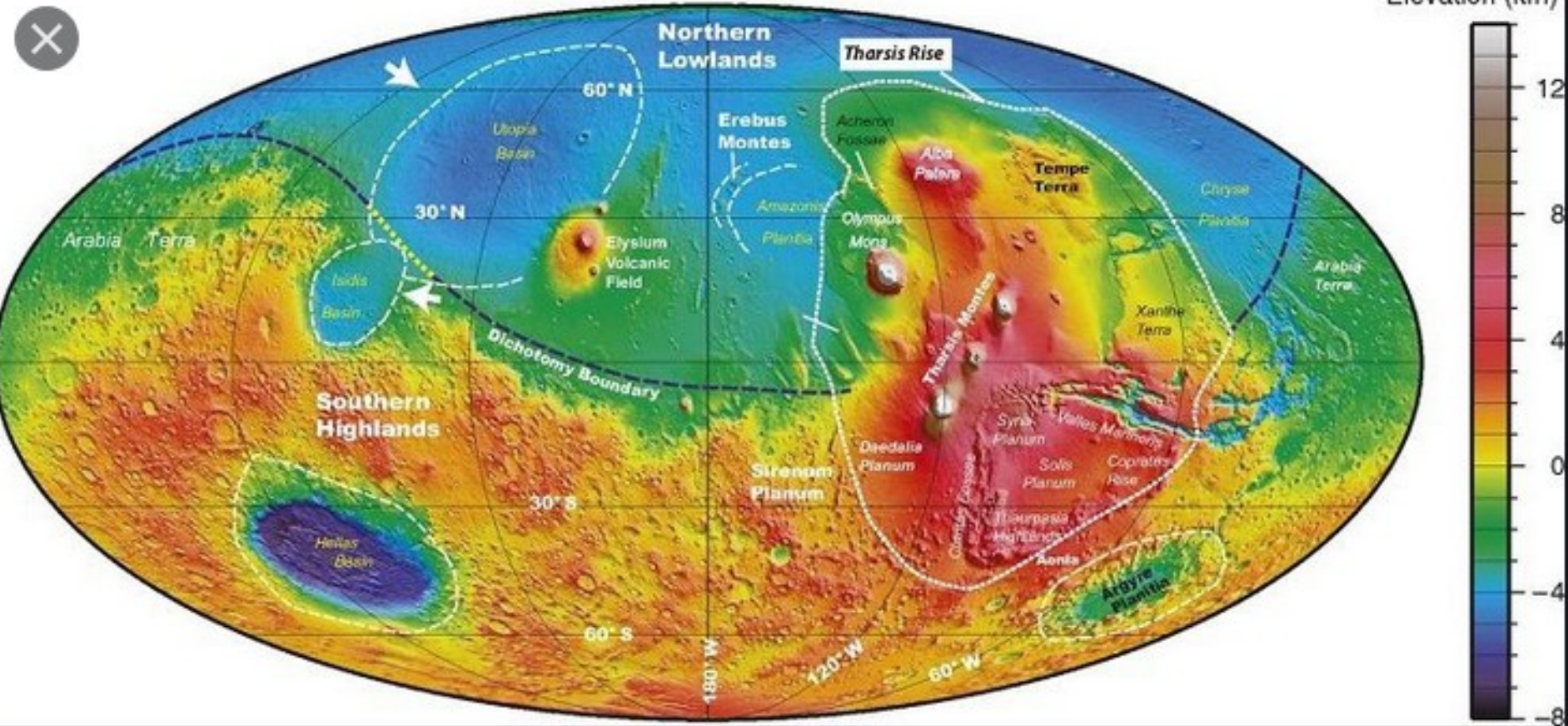
High resolution topographic map of Mars based on the *Mars Global Surveyor* laser altimeter research led by [Maria Zuber](#) and [David Smith](#). North is at the top. Notable features include the [Tharsis volcanoes](#) in the west (including [Olympus Mons](#)), [Valles Marineris](#) to the east of Tharsis, and [Hellas basin](#) in the southern ...

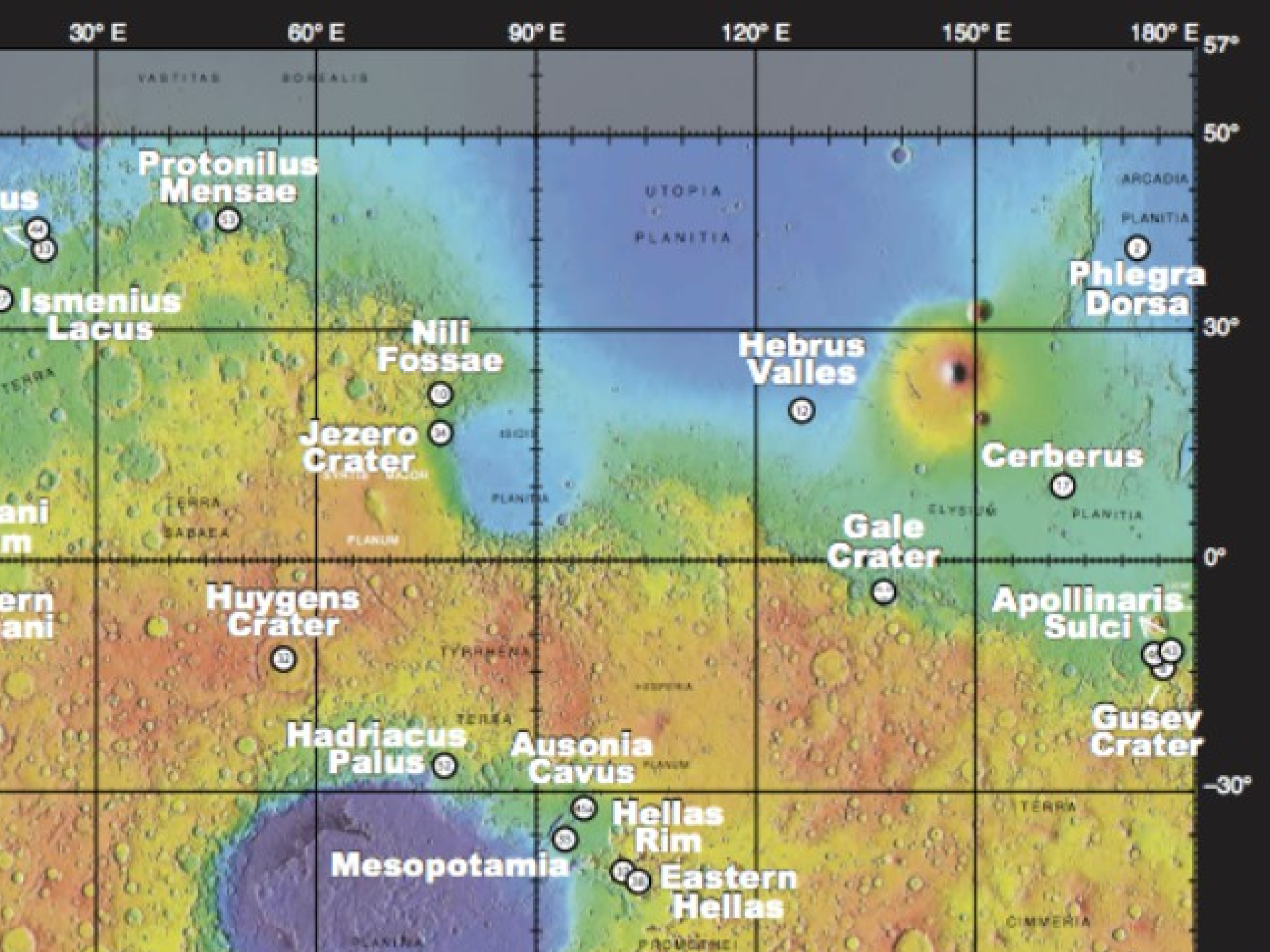
[More details](#)

NASA / JPL / USGS - <https://attic.gsfc.nasa.gov/mola/images.html> and <http://photojournal.jpl.nasa.gov/catalog/PIA02993>

Public Domain

Elevation (km)





30° E

60° E

90° E

120° E

150° E

180° E

57°

50°

30°

0°

-30°

VASTITAS BOREALIS

UTOPIA
PLANITIA

ARCADIA
PLANITIA

Protonilus
Mensae

Phlegra
Dorsa

us
Ismenius
Lacus

Nili
Fossae

Hebrus
Valles

Jezero
Crater

Cerberus

ani
m
ern
ani

Huygens
Crater

Gale
Crater

Apollinaris
Sulci

Hadriacus
Palus

Ausonia
Cavus

Gusev
Crater

Mesopotamia

Hellas
Rim
Eastern
Hellas

TERRA
CIMMERIA

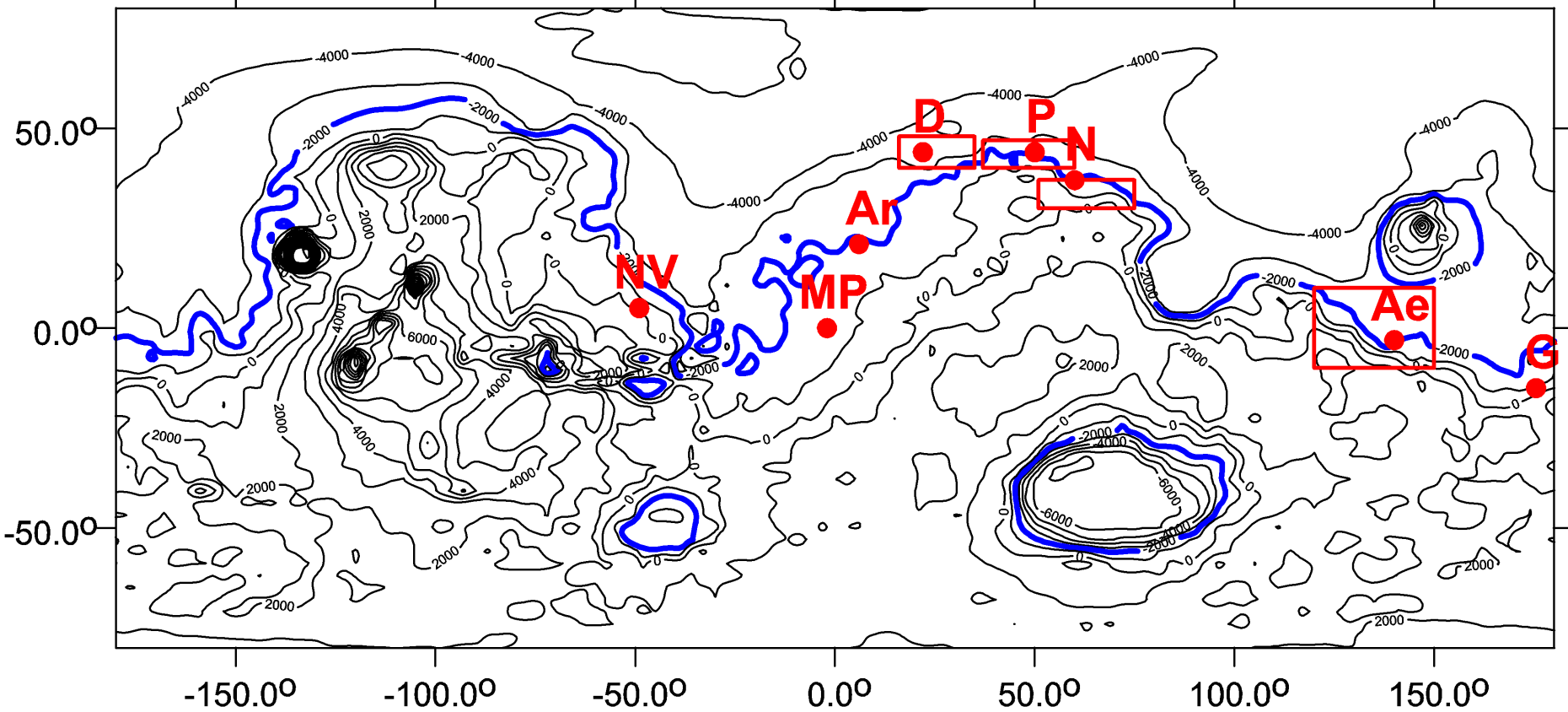
Fretted terrain Mars

prechodova zona mezi severnimi lowlands a jiznimi highlands

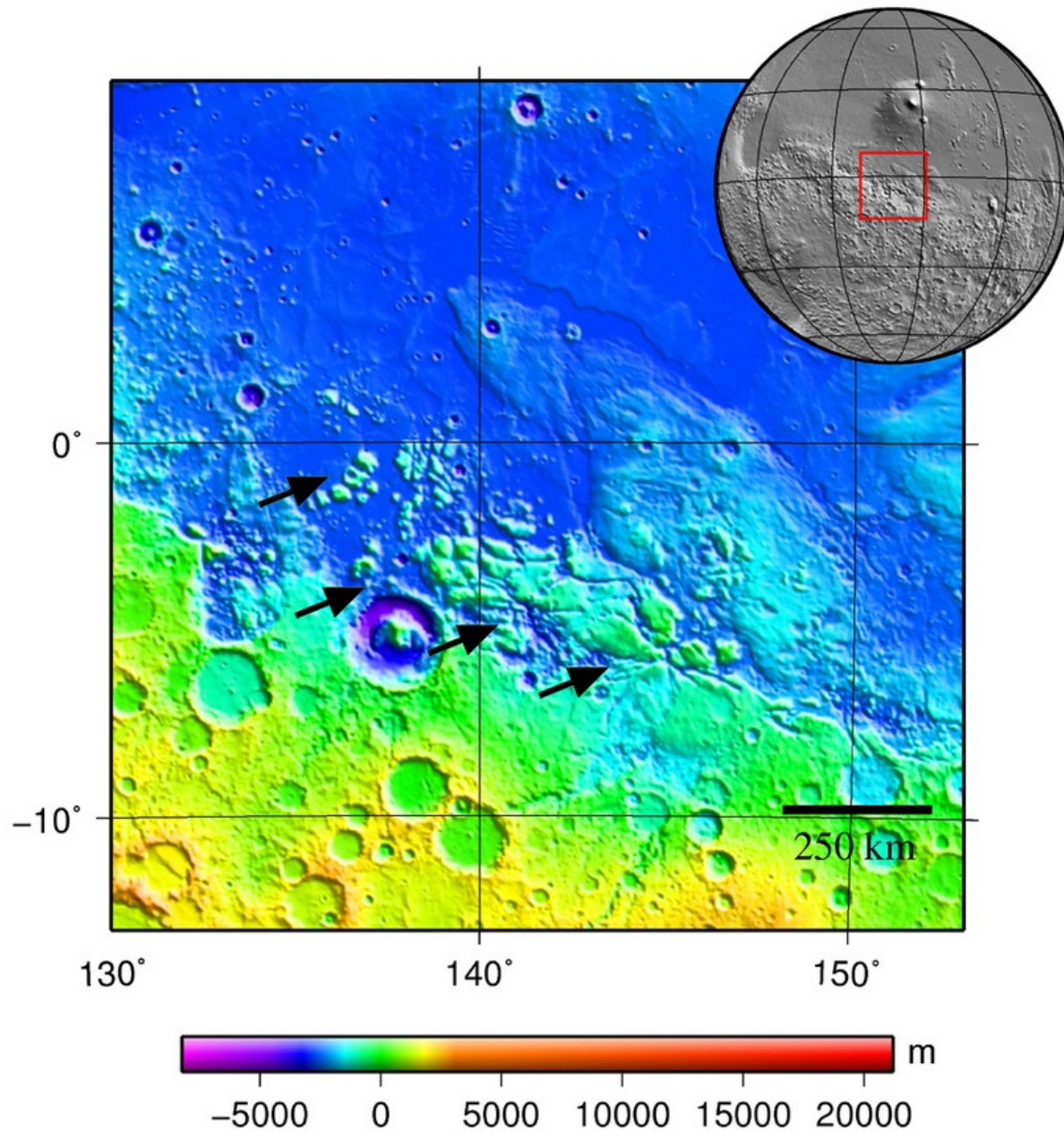
This terrain contains a complicated mix of cliffs, mesas, buttes, and straight-walled and sinuous canyons. It contains smooth, flat lowlands along with steep cliffs. The scarps or cliffs are usually 1 to 2 km high. Channels in the area have wide, flat floors and steep walls. Fretted terrain shows up in northern Arabia, between latitudes 30°N and 50°N and longitudes 270°W and 360°W, and in Aeolis Mensae, between 10 N and 10 S latitude and 240 W and 210 W longitude. Two good examples of fretted terrain are Deuteronilus Mensae and Protonilus Mensae.

Name	centered at latitude longitude E		range latitudes longitudes	
Arabia Terra Ar	21N	6	large area	
Aeolis Mensae Ae	3S	140	10N-10S	210-240W
Deuteronilus Mensae D	44N	22	40N-48N	325-344W
Protonilus Mensae P	44N	50	40N-47N	37-60E
Nilosyrtis Mensae N	37N	68	30N-37N	51-75E
Nanedi Vallis (Lunae Palus) NV	5N	311		
Meridiani Planus MP	0N	358		
Gusev crater G	15S	175		

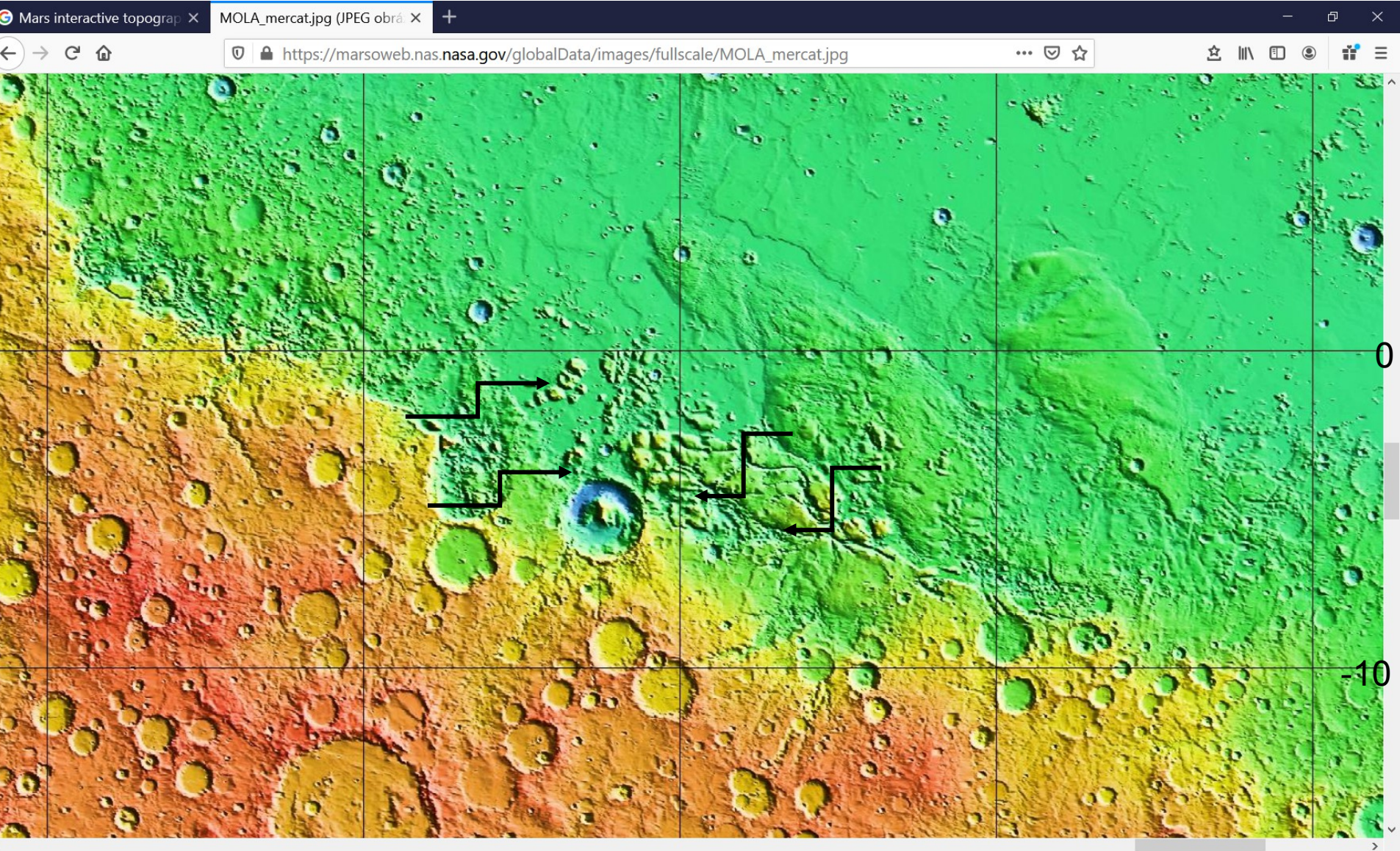
Mars - Topo + oblasti



Aeolis Mensae



Aeolis Mensae 3S 220W



220W

Nilosyrtis Mensae is an area of Mars in the Casius quadrangle. It is centered on the coordinates of 36.87° N and 67.9° E. Its western and eastern longitudes are 51.1° E and 74.4° E. North and south latitudes are 36.87° N and 29.61° N.[2] Nilosyrtis Mensae is just to the east of Protonilus Mensae and both lie along the Martian dichotomy boundary

36.87° N 67.9° E
Coordinates of centre



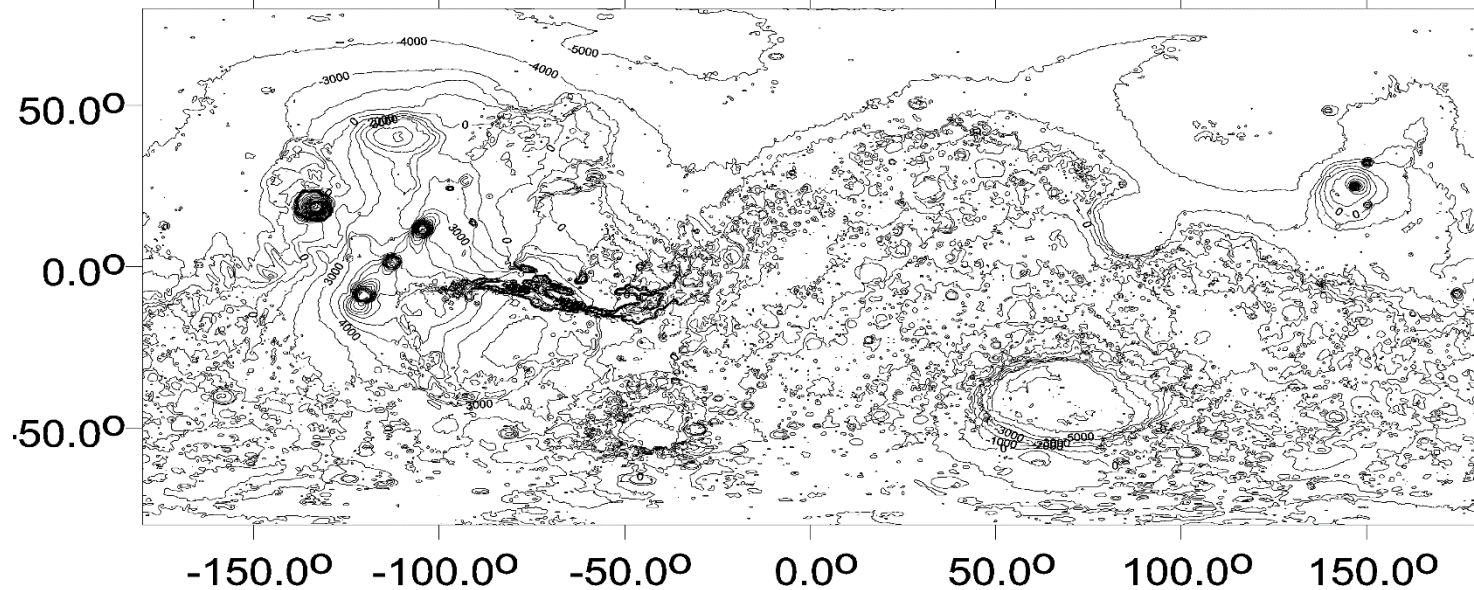
Perseverance landing site (18N, 70E), Lake Crater, wet and dry zone

The image is a screenshot of a web browser displaying the NASA Mars 2020 Landing Site Selection page. The browser's address bar shows the URL: <https://mars.nasa.gov/mars2020/timeline/prelaunch/landing-site-selection/>. The page header includes the NASA Science logo and the text "MARS 2020 MISSION PERSEVERANCE ROVER". Navigation links for "Mission", "Timeline", "Spacecraft", "News", "Multimedia", "Participate", and "All Mars" are visible. A search icon is also present. Below the header, a navigation bar highlights "Landing Site Selection" among other options: "Mission Timeline", "Pre-Launch", "Summary", and "Science Definition and Instrument Selection". The main content area features a large, detailed topographic map of the Perseverance landing site. The map uses a color scale to represent elevation, with purple and blue indicating lower elevations and green and yellow indicating higher elevations. A prominent feature is a large, circular crater with a central peak, surrounded by a network of ridges and valleys. The map is overlaid on a grayscale satellite image of the same area. On the left side of the page, there is a vertical sidebar with social media sharing icons for Facebook, Twitter, and YouTube, along with an email icon and a plus sign for additional sharing options. Below these icons, it indicates "16 SHARES".

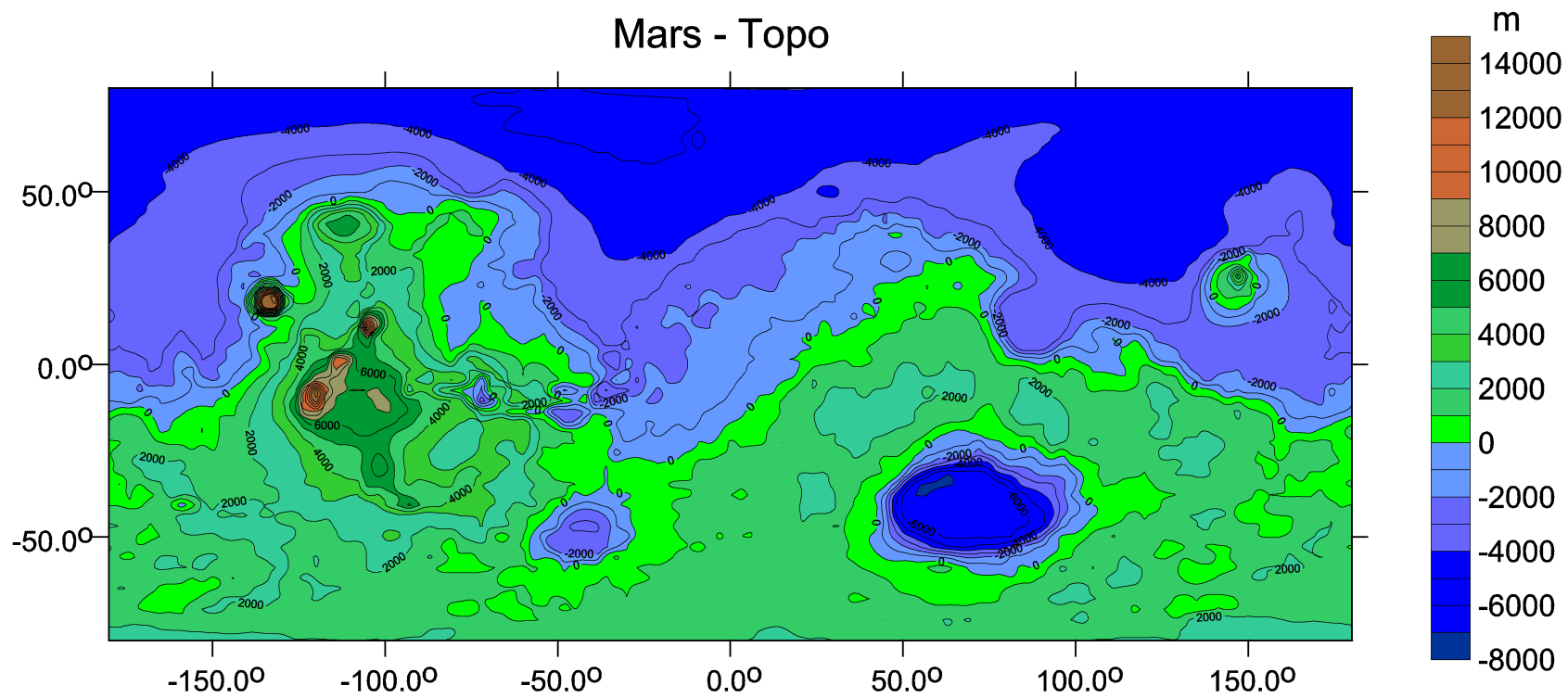
Our main results

Northern paleocean

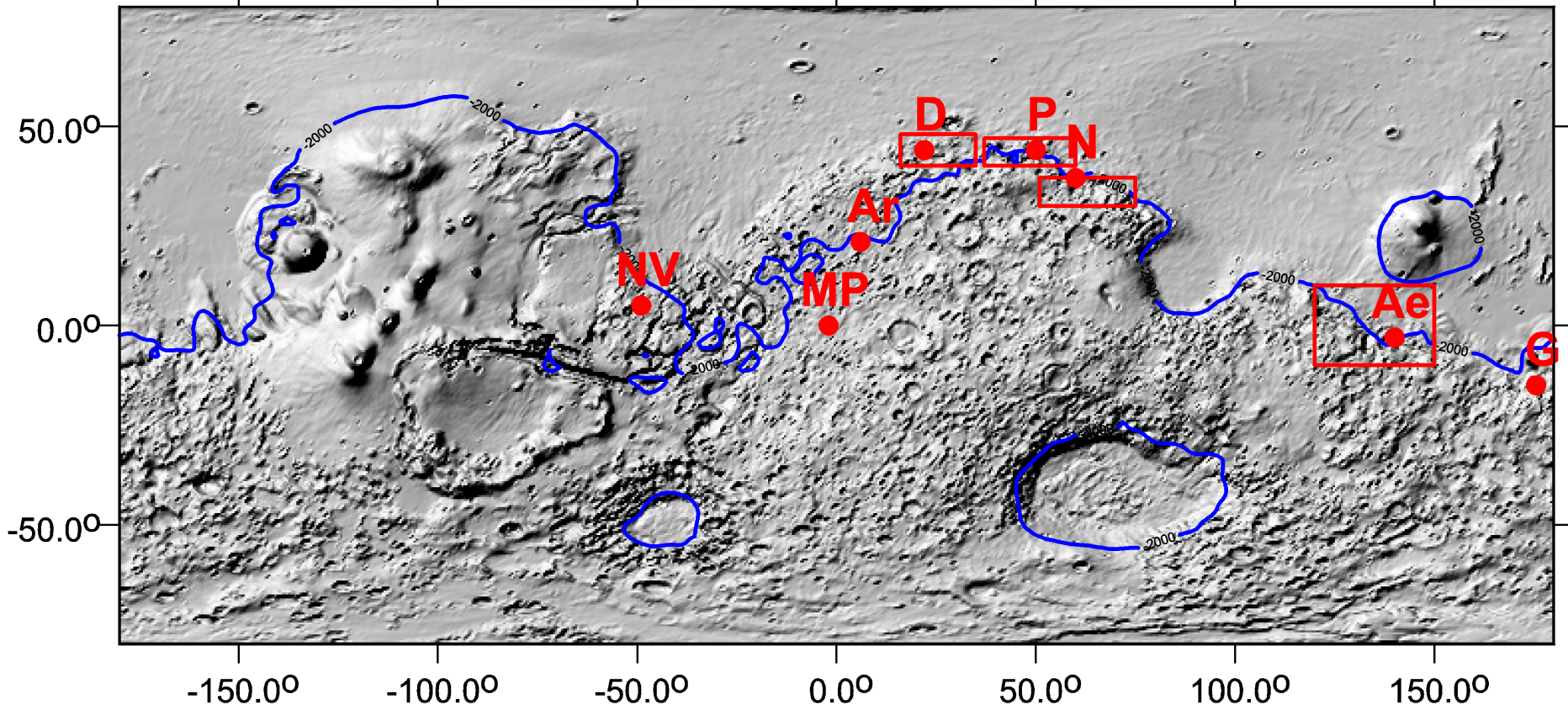
Mars - topo - interval isolines 1000 m - grid 0.5 deg



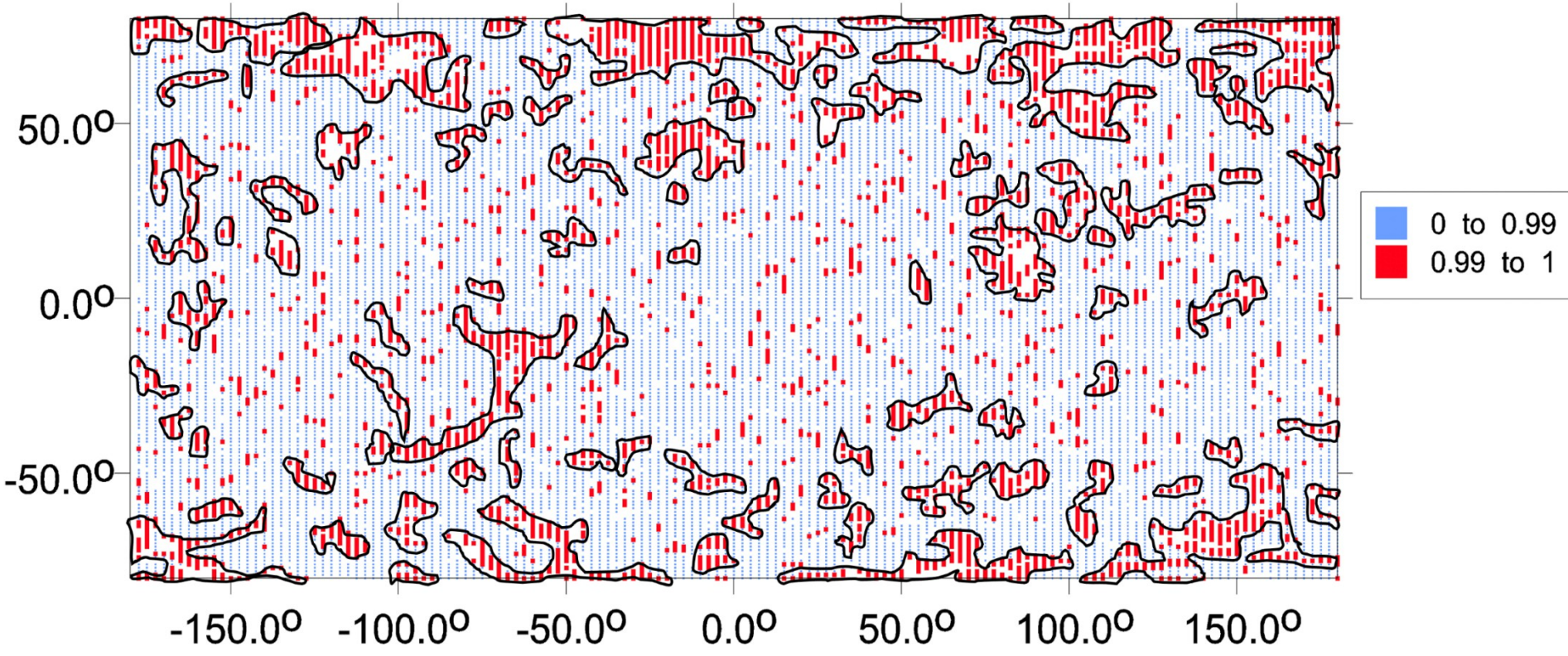
Mars - Topo

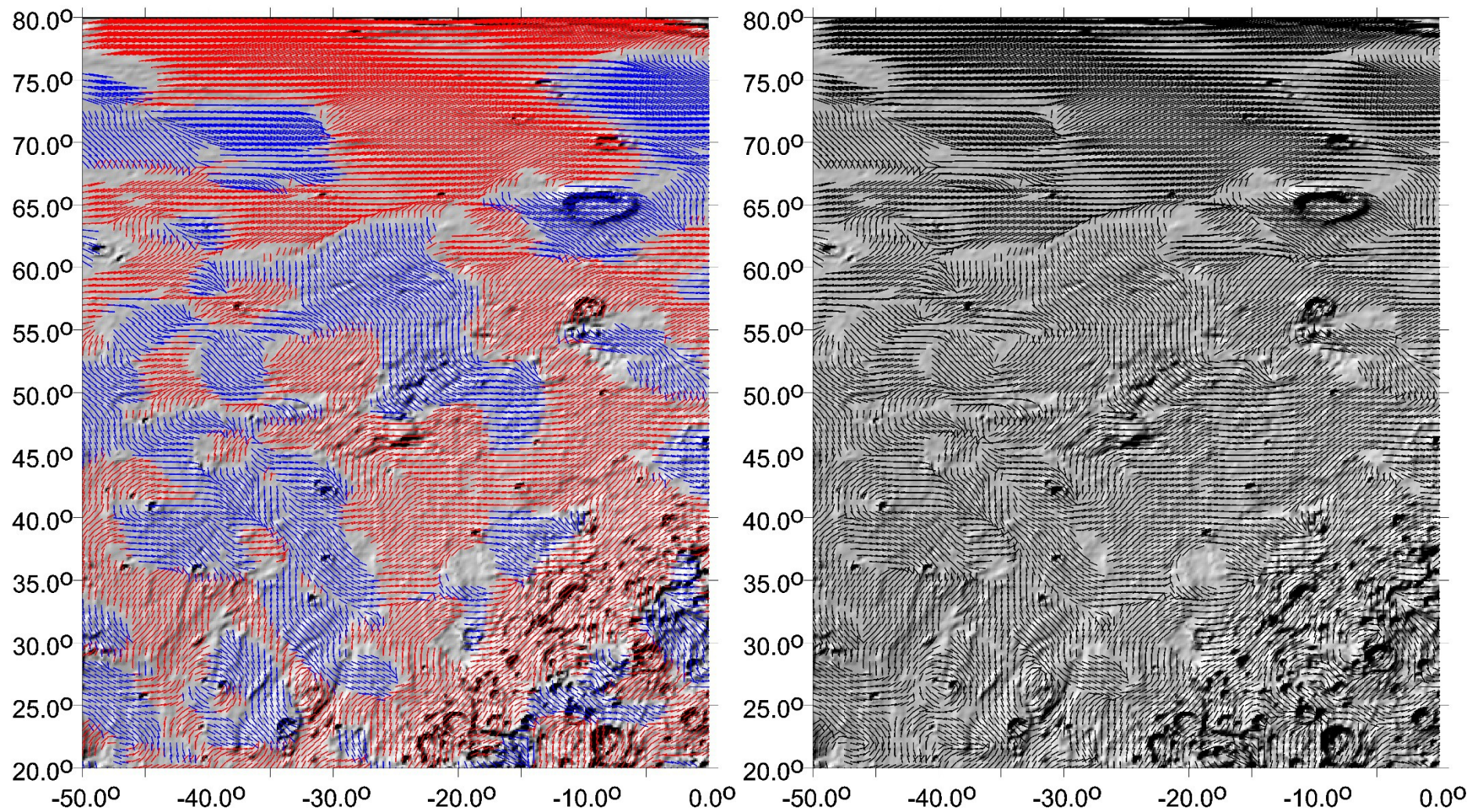


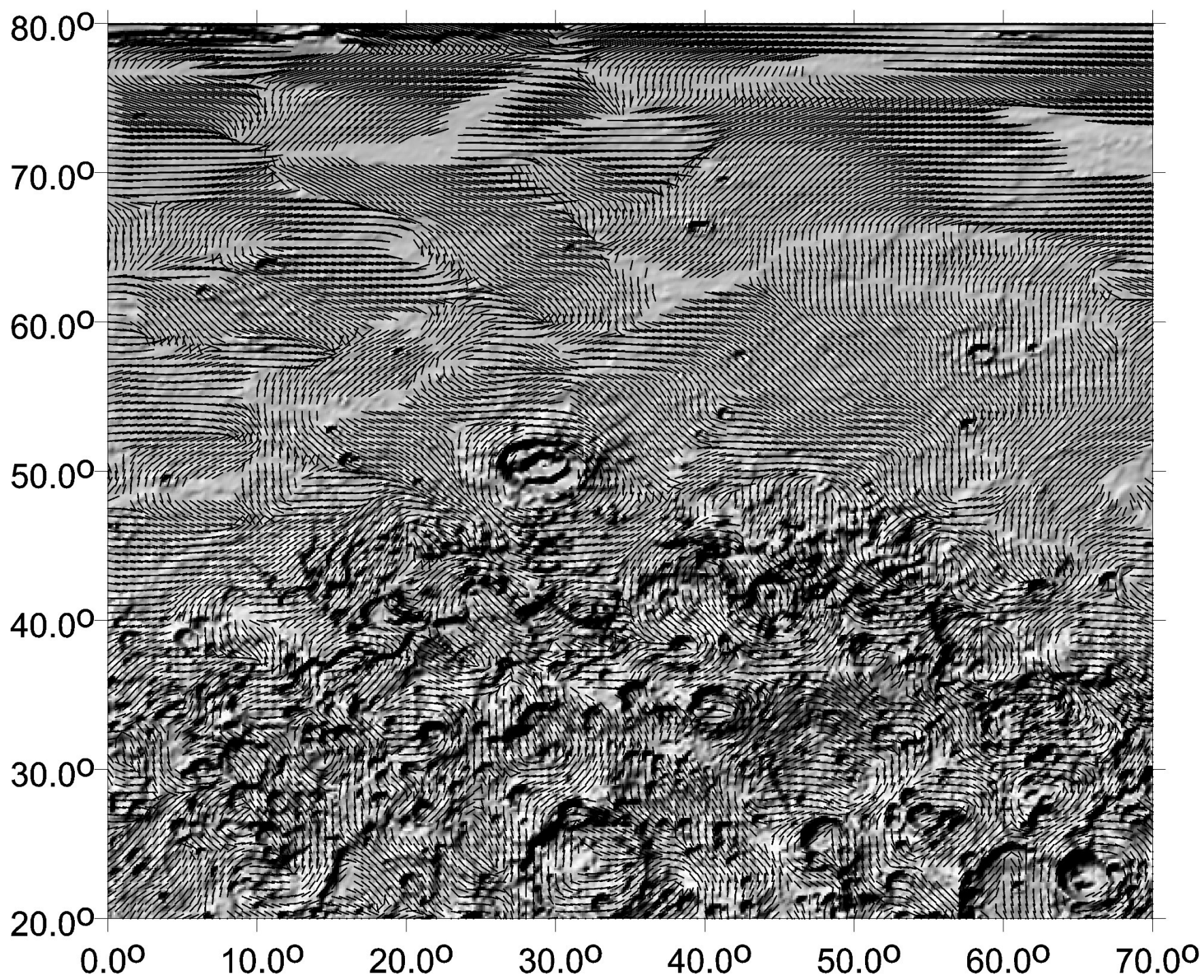
Mars - Topo + oblasti

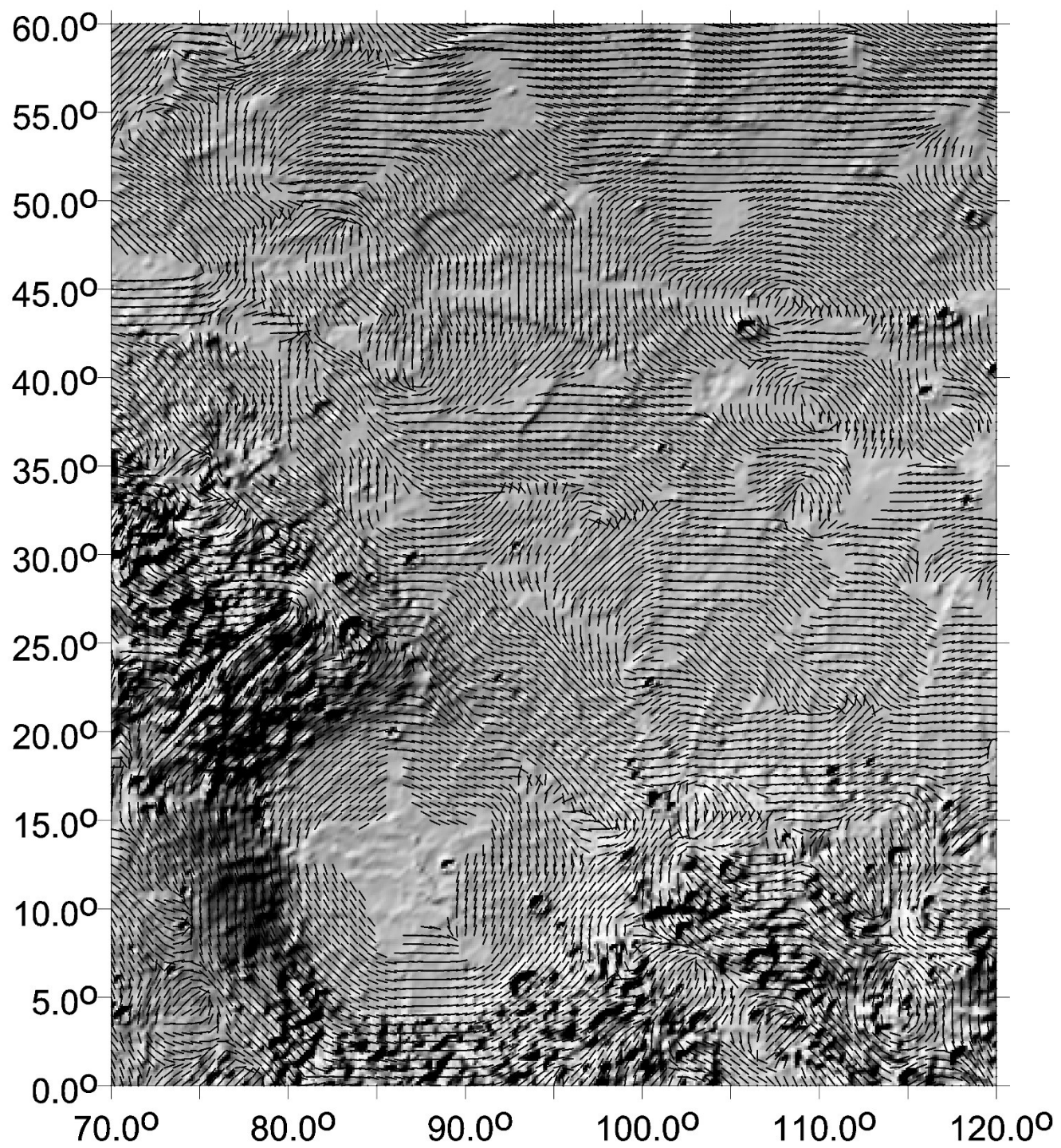


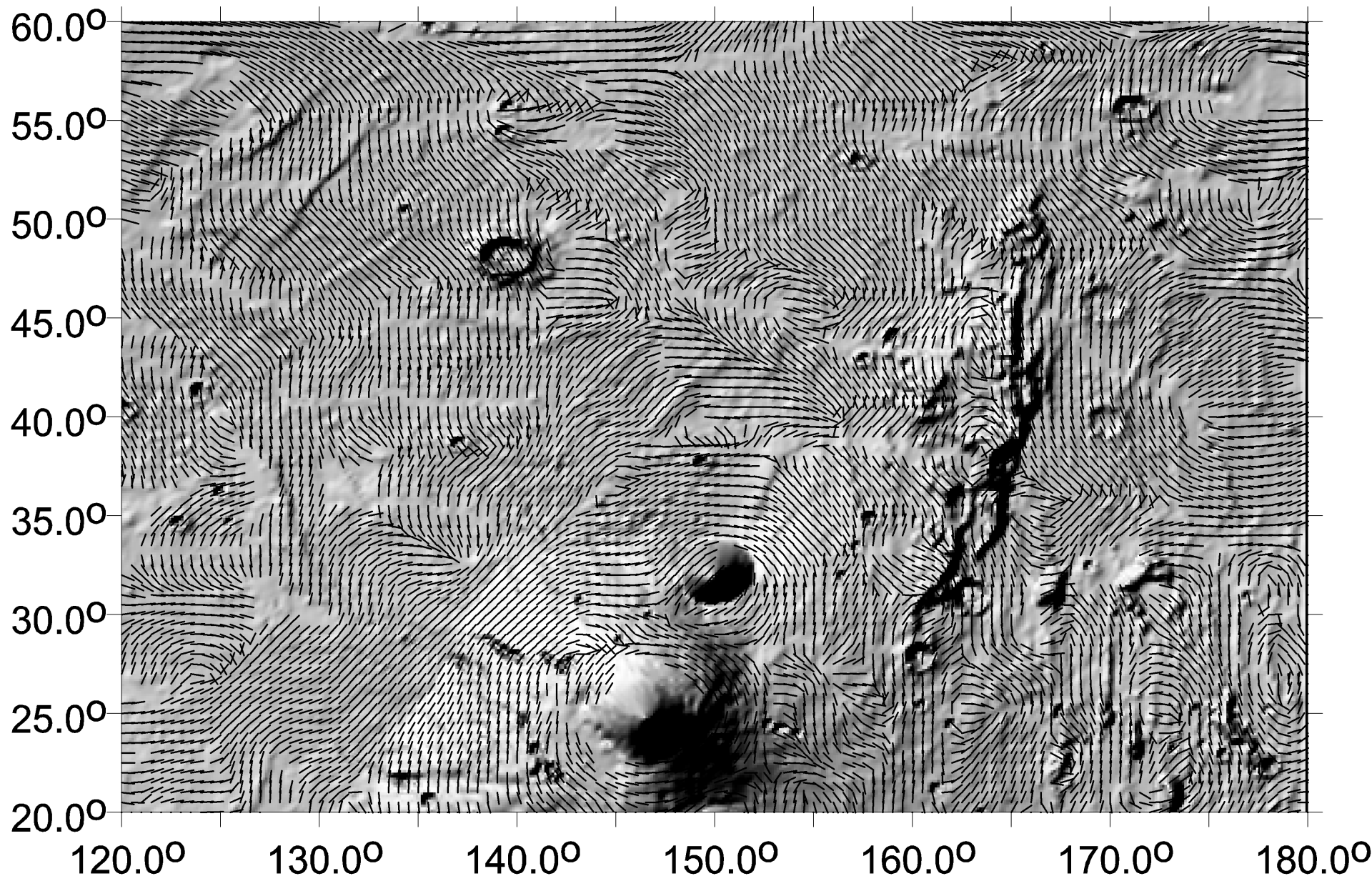
Strike angles with the comb factor to emphasize highly combed areas / potential water



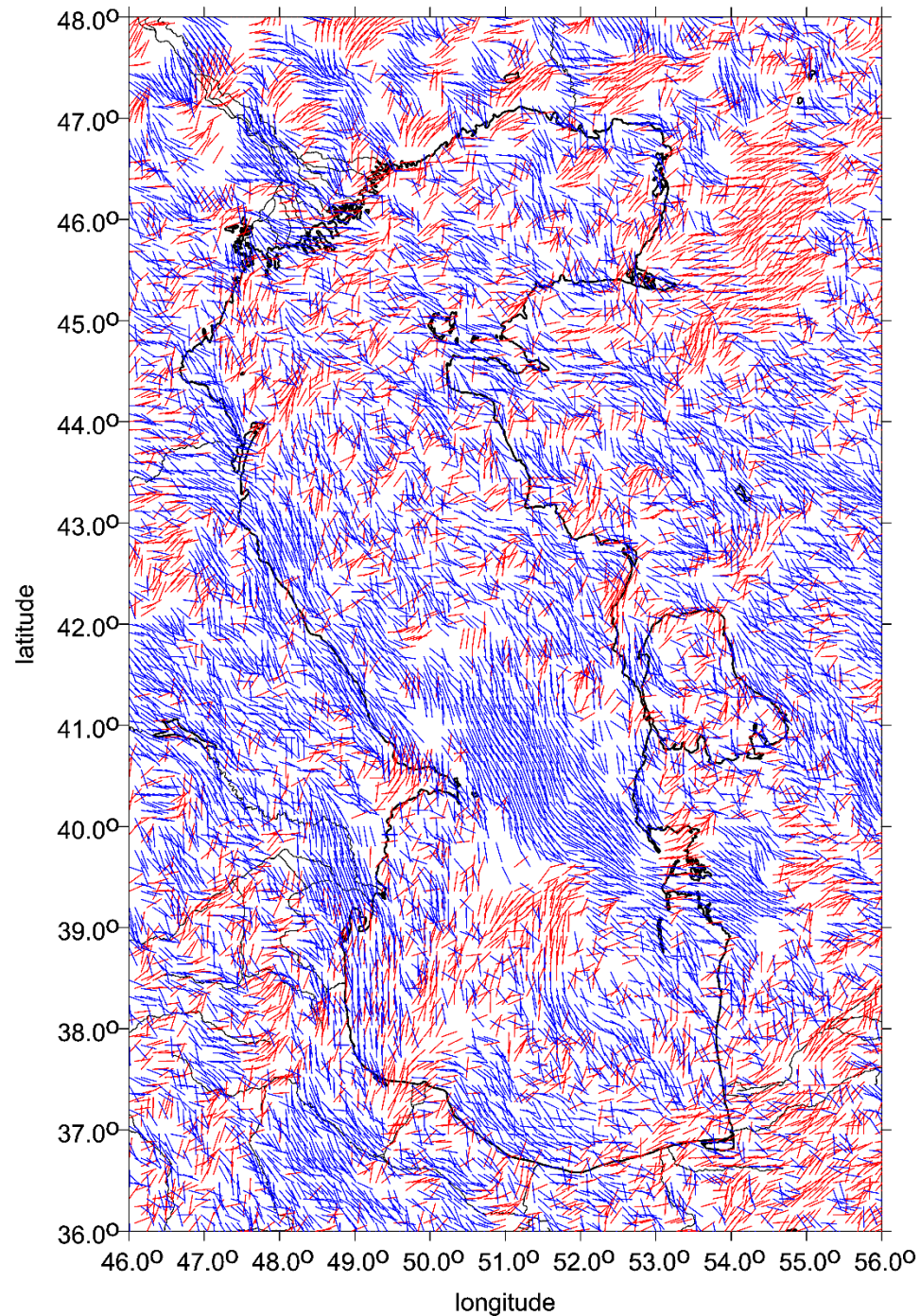




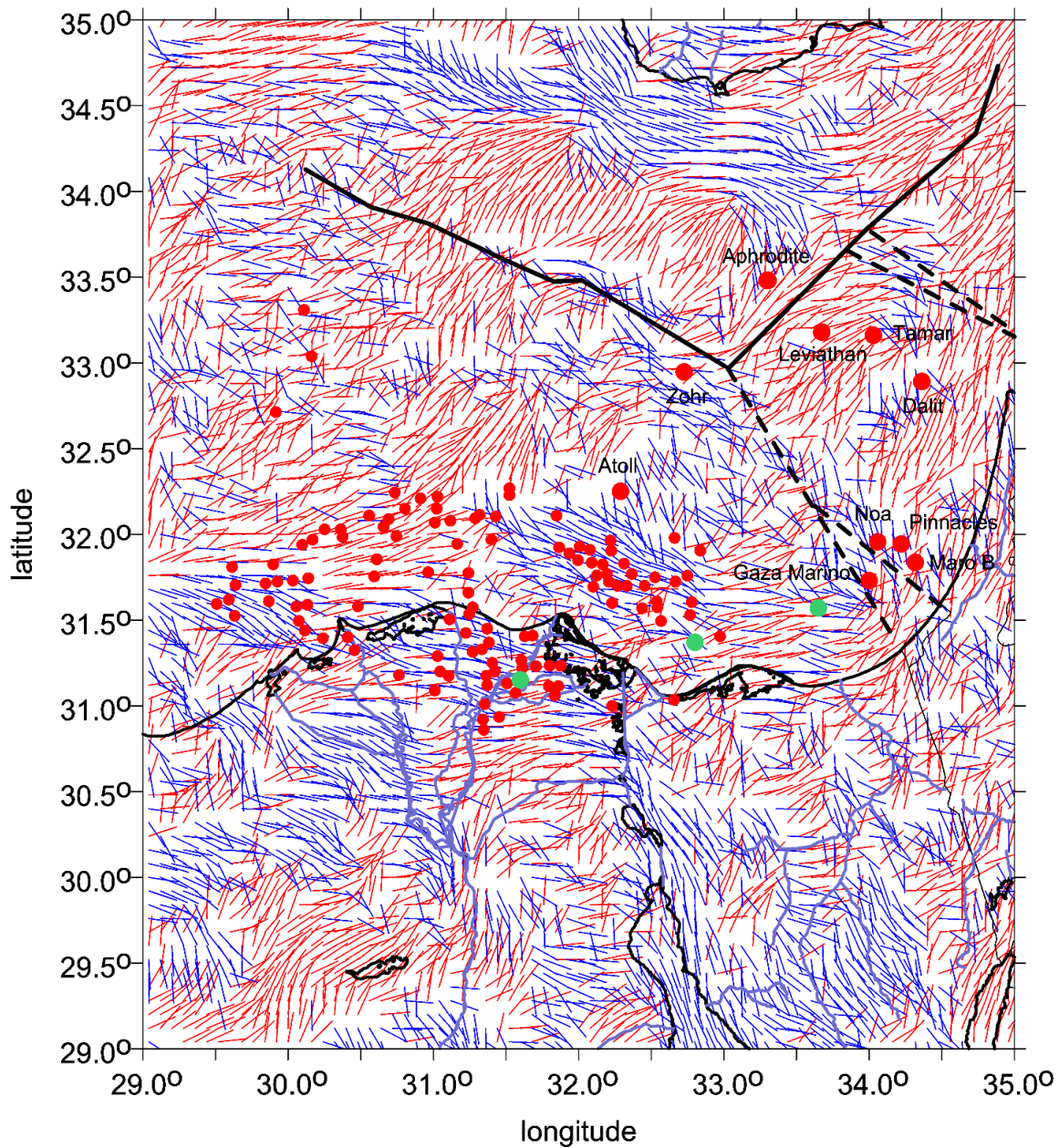




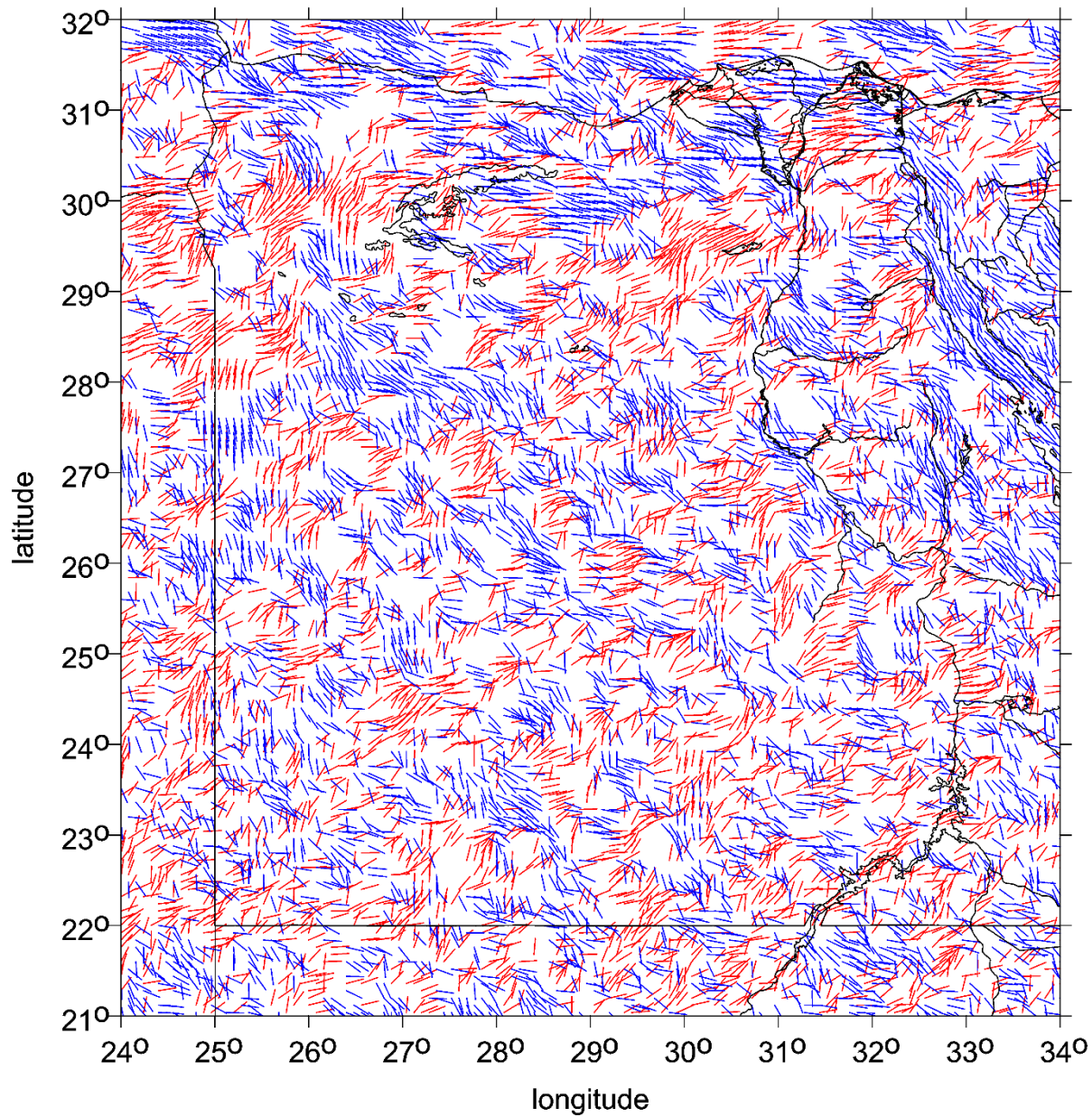
Eigen 6C4 - 01 Caspian - Theta for RI < 0.5

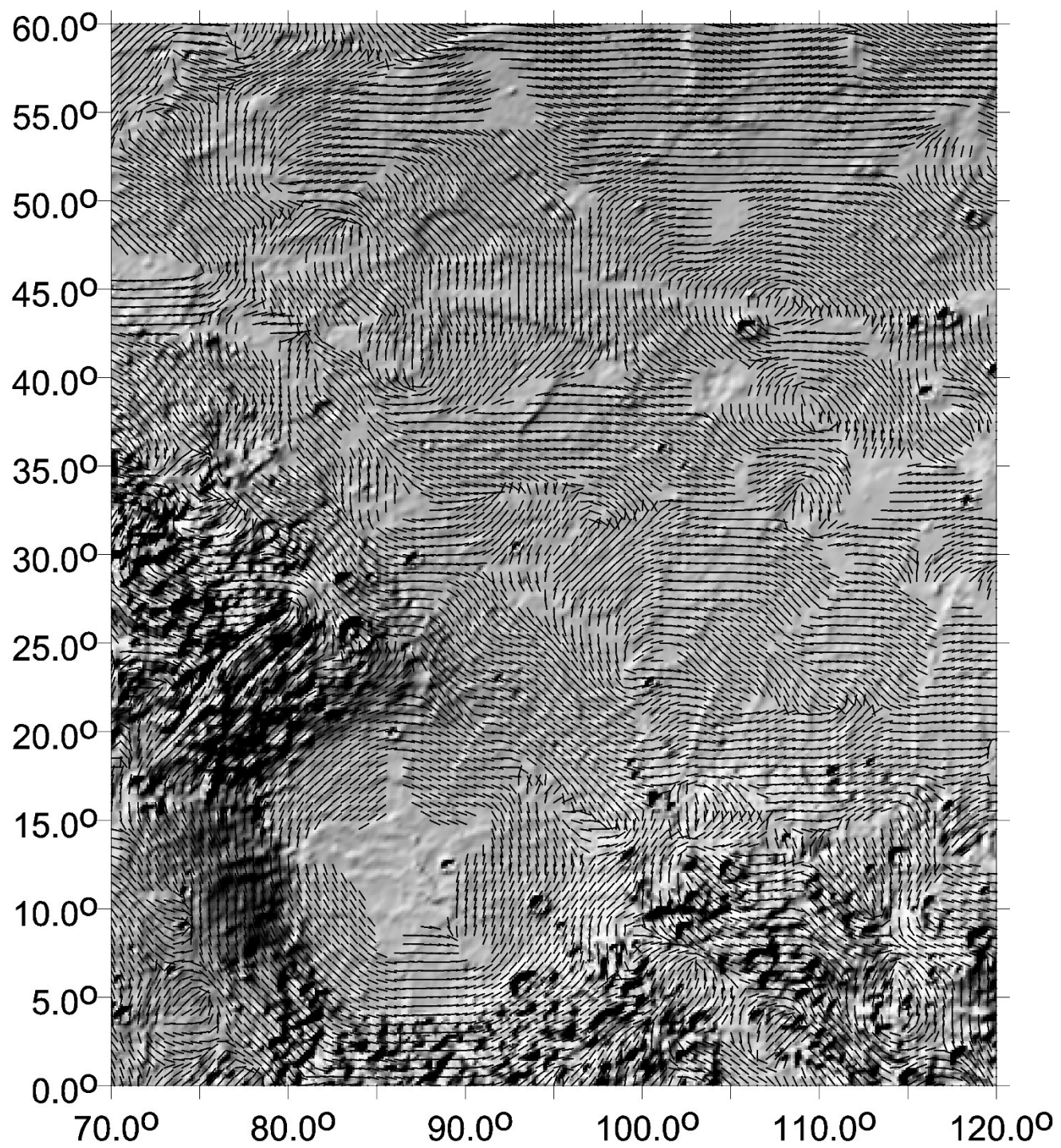


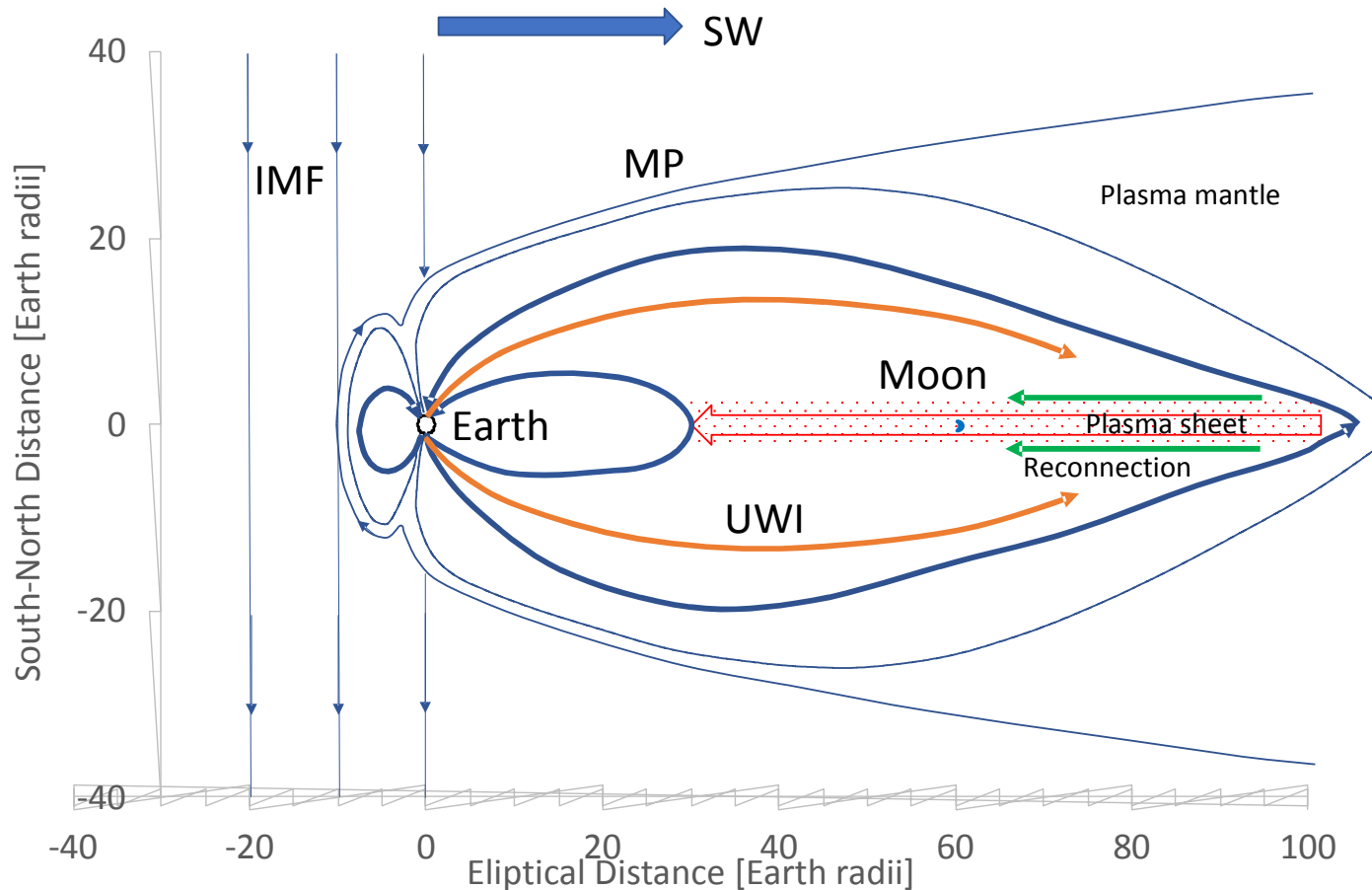
Eigen 6C4 - Egypt - Theta for RI < 0.9 - opr
and sources of GAS ● and Oil ●



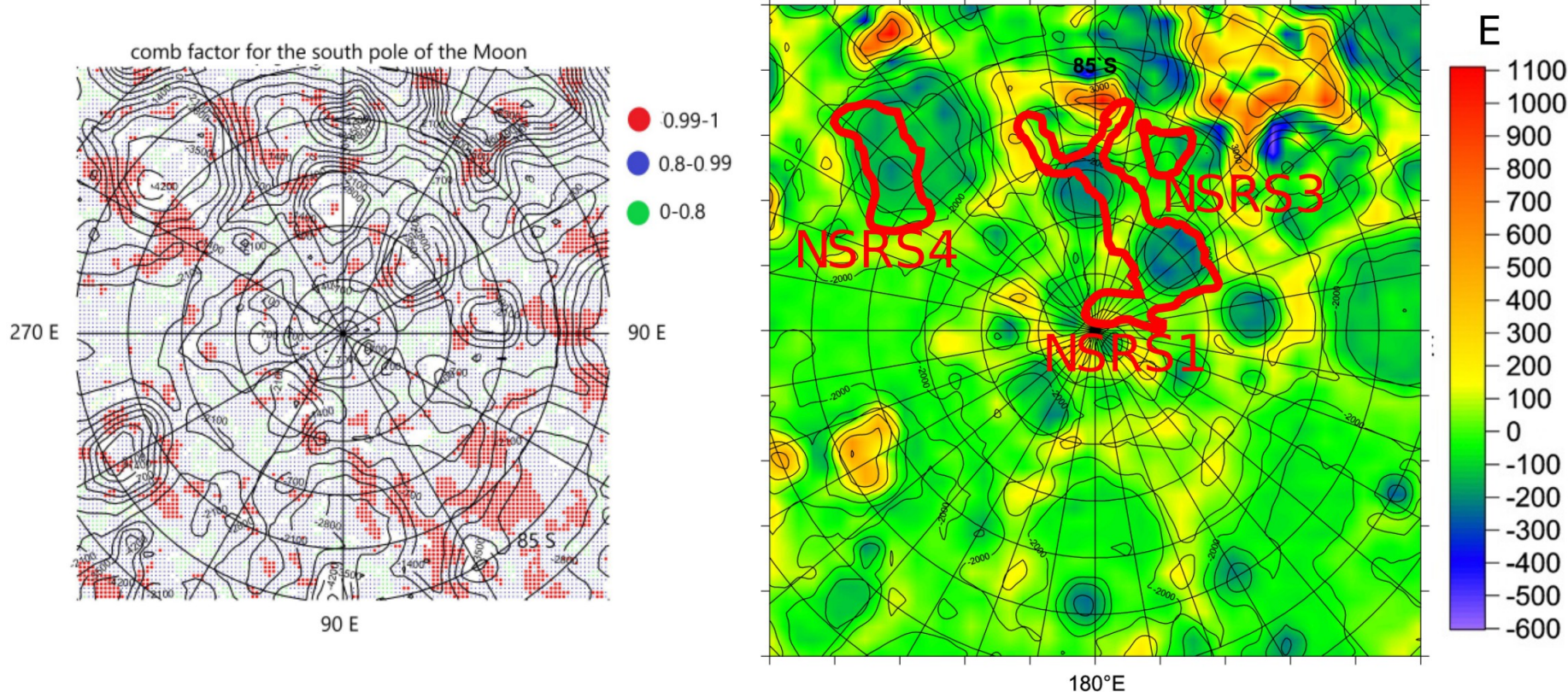
Eigen-6C4 - Egypt - Theta for RI < 0.3 - opr







Tvar zemské magnetosféry. Rovina oběžné dráhy Měsíce kolem Země je skoro totožná s rovinou oběžné dráhy Země kolem Slunce. Magnetosféra Země směrem od Země sahá daleko za oběžnou dráhu Měsíce kolem Země. Měsíc prolétá zemskou magnetosférou každý měsíc kolem úplňku po dobu asi pěti dnů. Z ionosféry se ionty dostávají do magnetosféry a pohybují se podél oranžových šipek. Zelené šipky ukazují na pohyb iontů díky tzv. “rekonekci“ (přepojení siločar magnetického pole, což způsobí urychlení iontů v magnetosféře směrem k Zemi). IMF meziplanetární magnetické pole se slunečním větrem SW, MP magnetopauza, UWI ionty ze Země, které se mohou dostat na Měsíc.



Oblast kolem jižního pólu Měsíce, vlevo úhly napětí (největší učesanost červeně), vpravo druhé radiální derivace poruchového potenciálu (v jednotkách Eötvös) z nejnovějšího modelu gravitačního pole Měsíce z měsíčních družic (lunárních orbiterů), spolu s topografií měsíčního povrchu z laserového altimetru LOLA (vrstevnice). Tři oblasti označené červeně NSR S1, NSR S3 a NSR S4 s potenciálně na vodu bohatým permafrostem (regolitem) z nezávislých měření. Obrázky J. Kostelecký, G. Kletetschka, K. Karimi z [1].

Citace [1] Kletetschka G, Klokočník J, Hasson N, Kostelecký J, Bezděk A, Karimi K. 2022, Distribution of water phase near the poles of the Moon from gravity aspects . *Scientific Reports* (Springer-Nature), Mar 16;12(1): 4501; doi: 10.1038/s41598-022-08305-x.

Více info o našich procesech tohoto typu na www.cas.cz/en/ild/leban



Astronomický
ústav
AV ČR



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Institute
of the Czech Academy
of Sciences