MSL Landing Site Analysis for Planetary Protection

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NASA Planetary Protection Subcommittee

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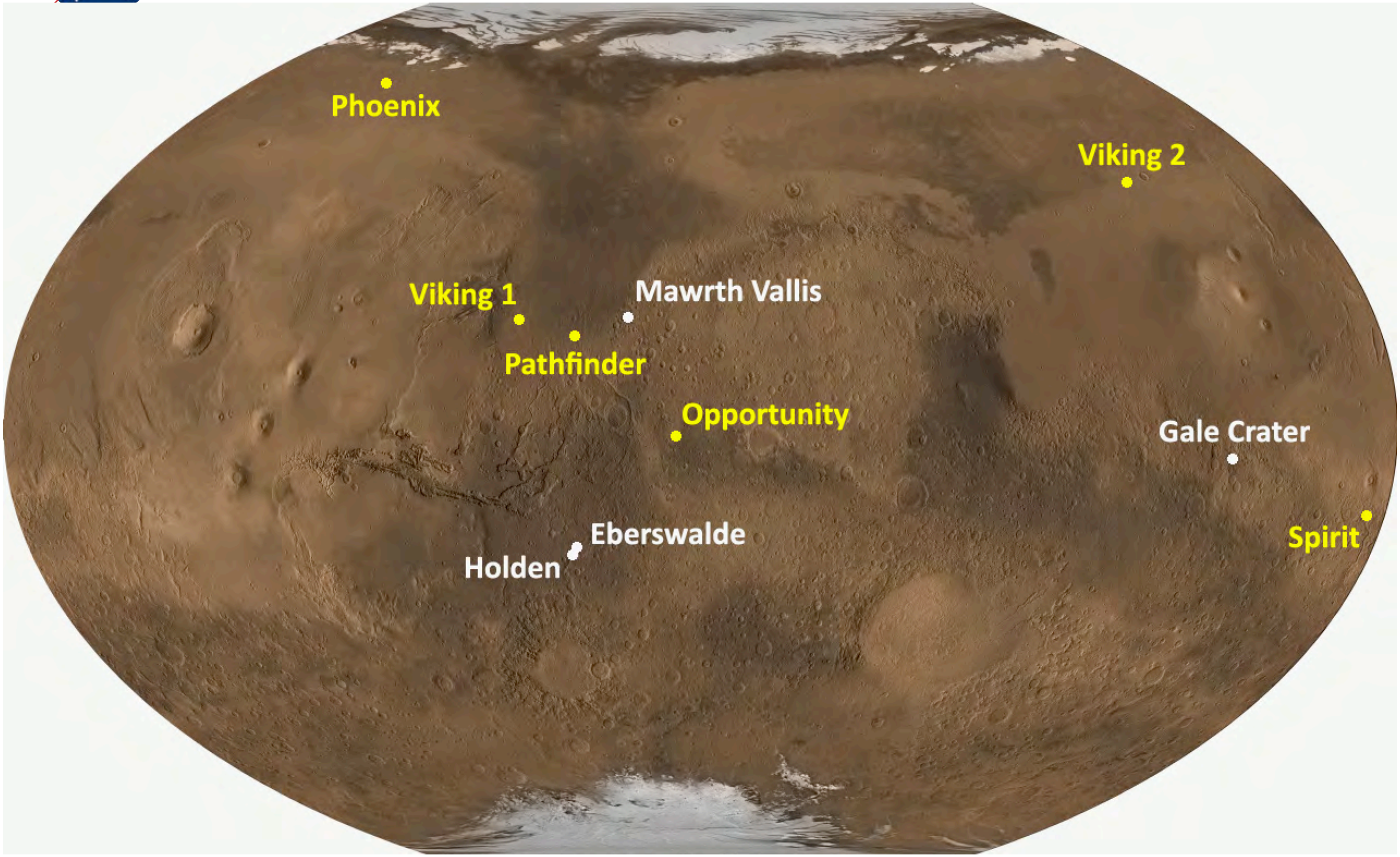
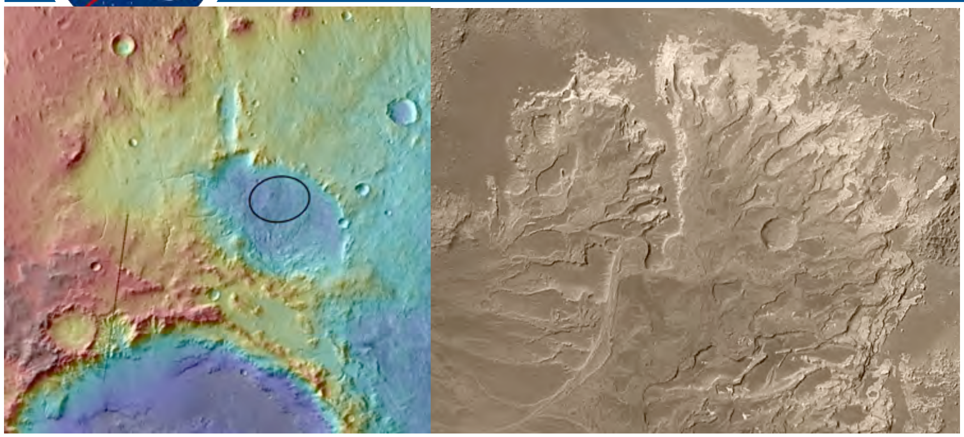
Outline

- Overview of MSL Candidate Landing Sites
- Background on the Planetary Protection Risk
- Definition of Region of Concern
- Direct Detections of Water Ice near the MSL Sites
- Observations Relevant to the Potential for Ground Ice
  - Thermophysical Properties and Temperatures
  - Slopes at 50, 5, and 1-Meter Baselines

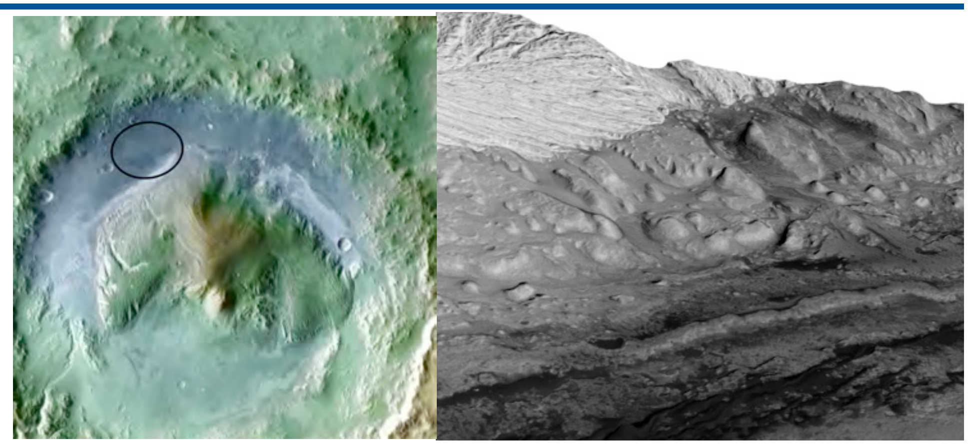
Landing Sites, Past and Future



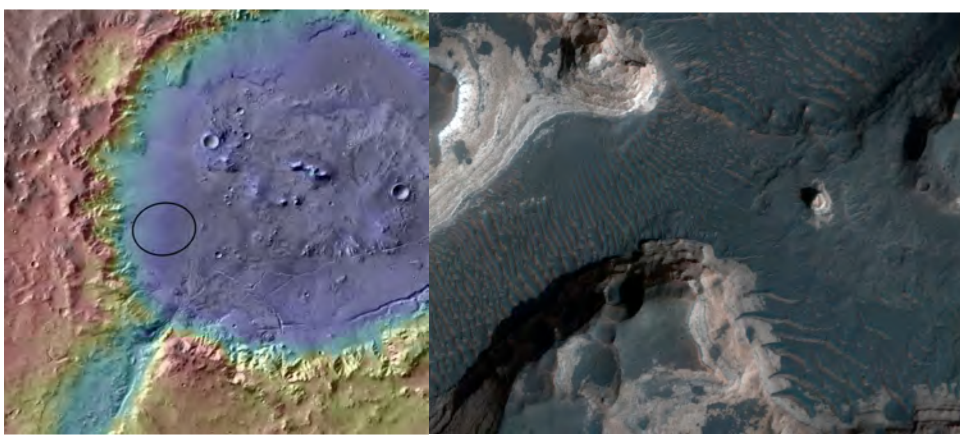
MSL Candidate Landing Sites



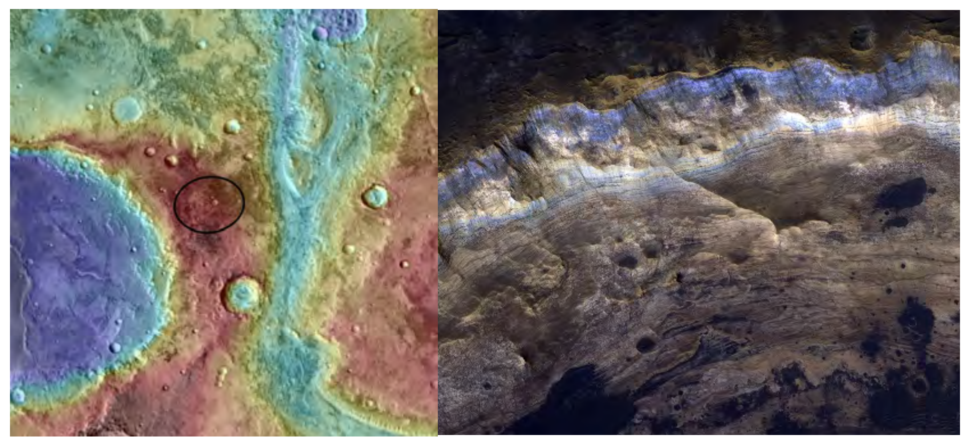
Eberswalde Crater (24°S, 327°E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.



Gale Crater (4.5°S, 137°E, -4.5 km) contains a 5-km sequence of layers that vary from clay-rich materials near the bottom to sulfates at higher elevation.



Holden Crater (26°S, 325°E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.



Mawrth Vallis (24°N, 341°E, -2.2 km) exposes layers within Mars' surface of differing mineralogy, including at least two kinds of clays.

Background

- Early in the MSL Project, it was realized that a failure during EDL would pose a risk to the forward contamination of Mars. Specifically, the power source could become buried along with terrestrial microbes and Martian water or water ice, creating an environment favorable to propagation (i.e., an induced special region as described by the MEPAG SR-SAG, 2006).

- A major effort was made to assess this risk in detail [e.g., Muirhead, 2004; Hecht and Vasavada, 2006]. The PPO used the analysis to define stipulations within the MSL PP categorization.

- The MSL PP Categorization states that landing sites are limited to regions not known to have extant water or water ice within 1 m of the surface.

- The above constraint applies to 1-sigma landing error ellipses that address post-parachute-deploy failure modes.

Additional Questions

For purposes of this request, the area to be considered consists of a 1-sigma landing ellipse including the possibility of failure by any operation that has a <99% probability of being executed successfully prior to parachute opening, and all failures after that event.

1. What is the observed temperature range, diurnal and annual, at each landing site? How would this be affected by local surface features?

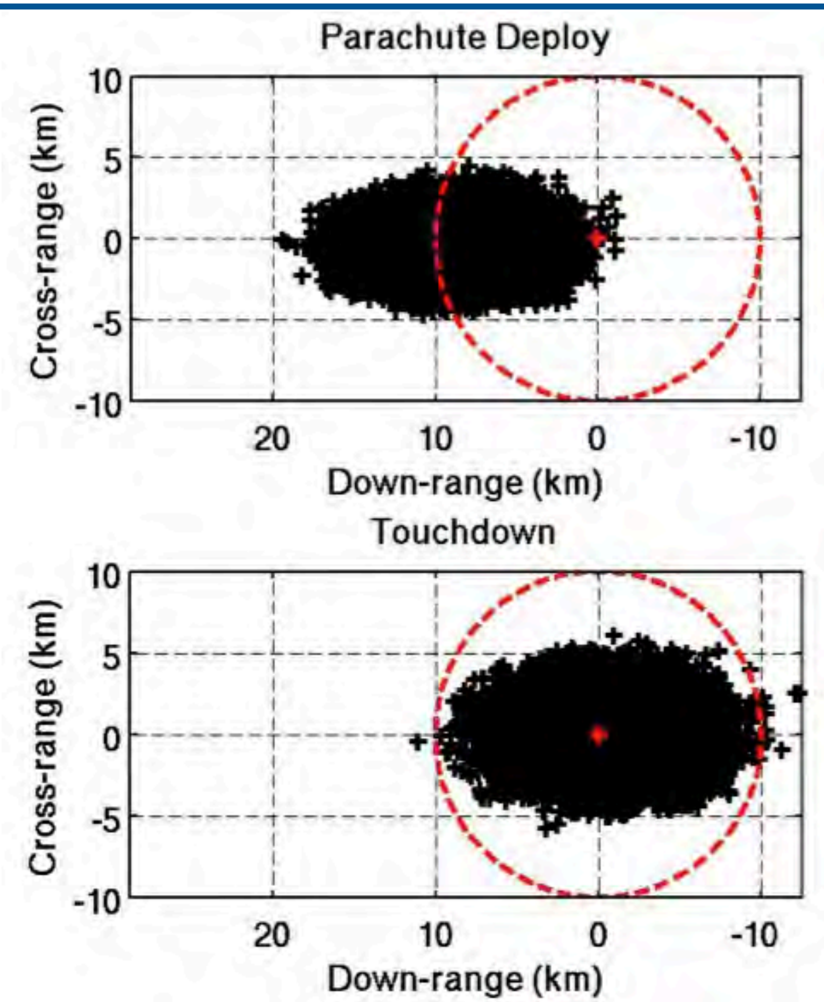
2. What is the observed range of water (hydrogen?) signals over the ellipse? What is the likely complexed state of that water (in minerals, as ice, etc.)? What can be deduced about subsurface water/hydration state? How easy would it be to liberate that water given the temperature regimes observed at each site?

3. What range of density/thermal mass can be estimated for materials at each site, and how might that affect modeling of subsurface temperature or hydration gradients? What potential disequilibrium conditions (dark patches, shadows, etc.) might affect local variability?

4. Given the constraints above, what are the chances that anywhere in the proposed landing ellipse might reach, even transiently, a water activity of 0.5 and a temperature of -25C, should the MSL RTG be introduced? With what duration and periodicity would those conditions exist?

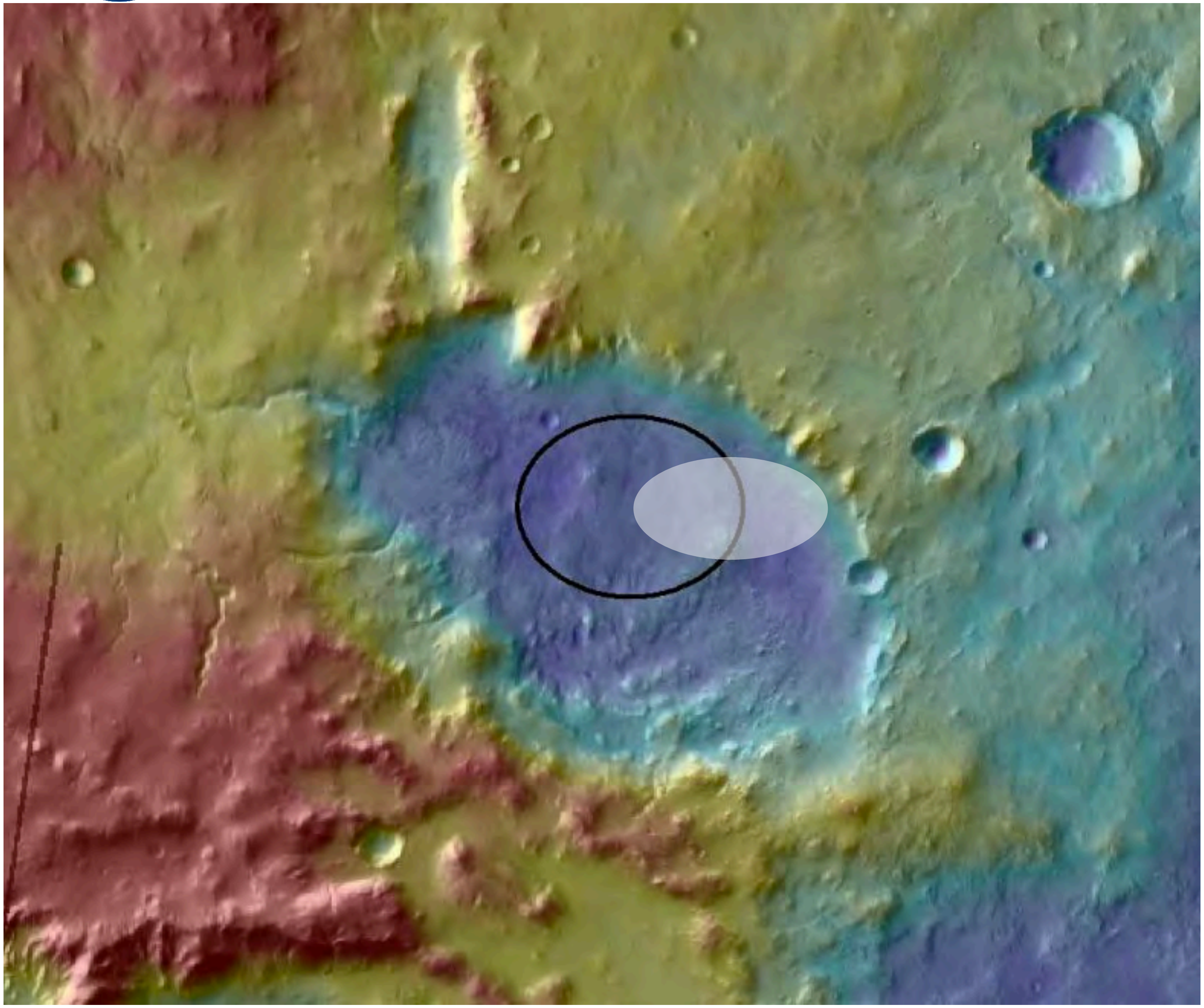
Post-Parachute Failure Ellipses

- The Project has not identified any EDL failure modes prior to parachute deploy with <99% probability of success. So the region of concern for all PP questions becomes the post-parachute-deploy ellipses.
- For a conservative assumption about initial amtude knowledge, parachute deploy occurs ~10 km up range of the center of the ellipse.
- A failure in parachute deployment would result in impact of the vehicle somewhere within a similarly sized cloud of points centered ~9.7 km downrange of the target (computed by MSL EDL Team).



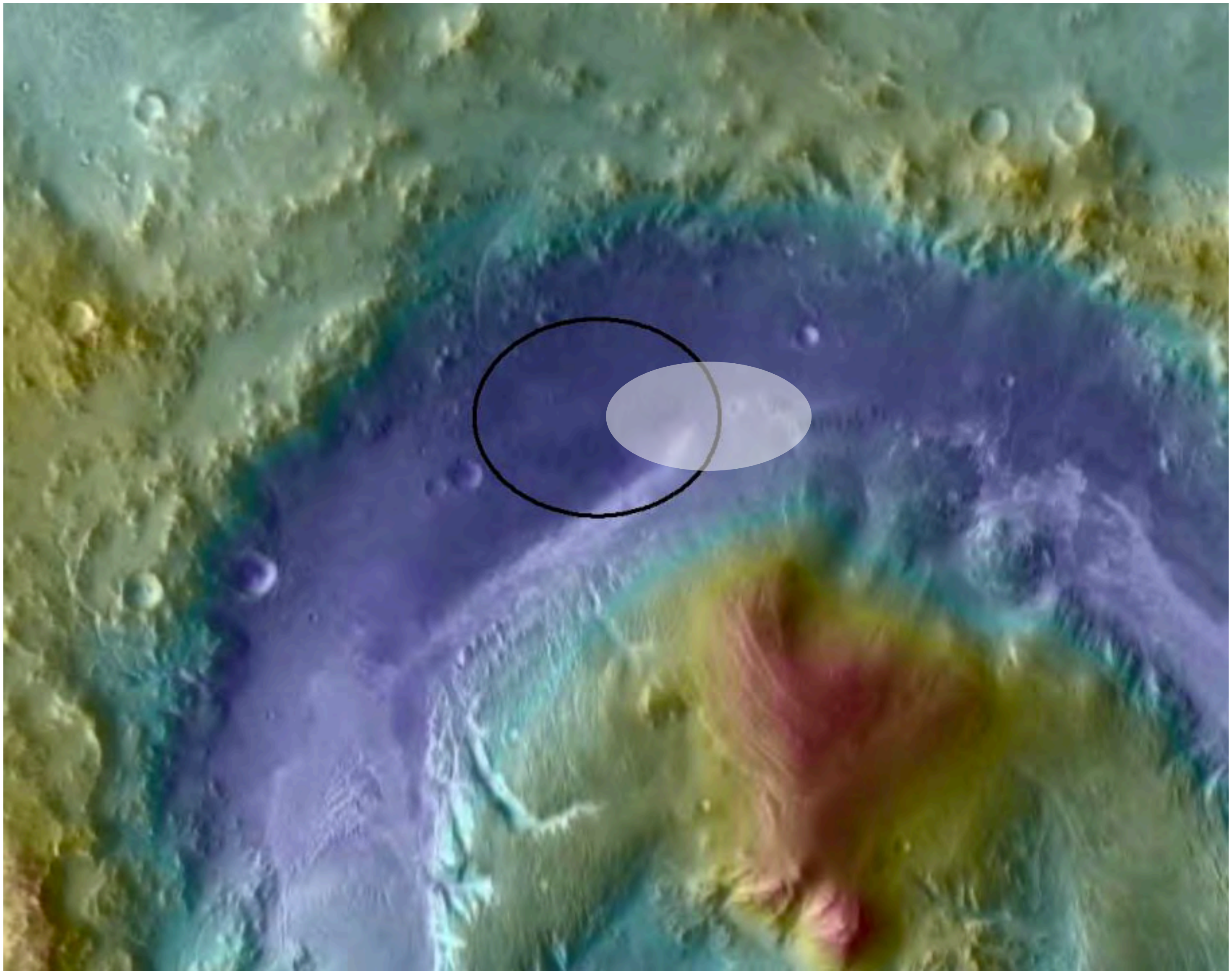
Monte Carlo simulations of parachute deploy and nominal touchdown locations relative to the target (center of the ellipse).

Eberswalde



- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

Gale



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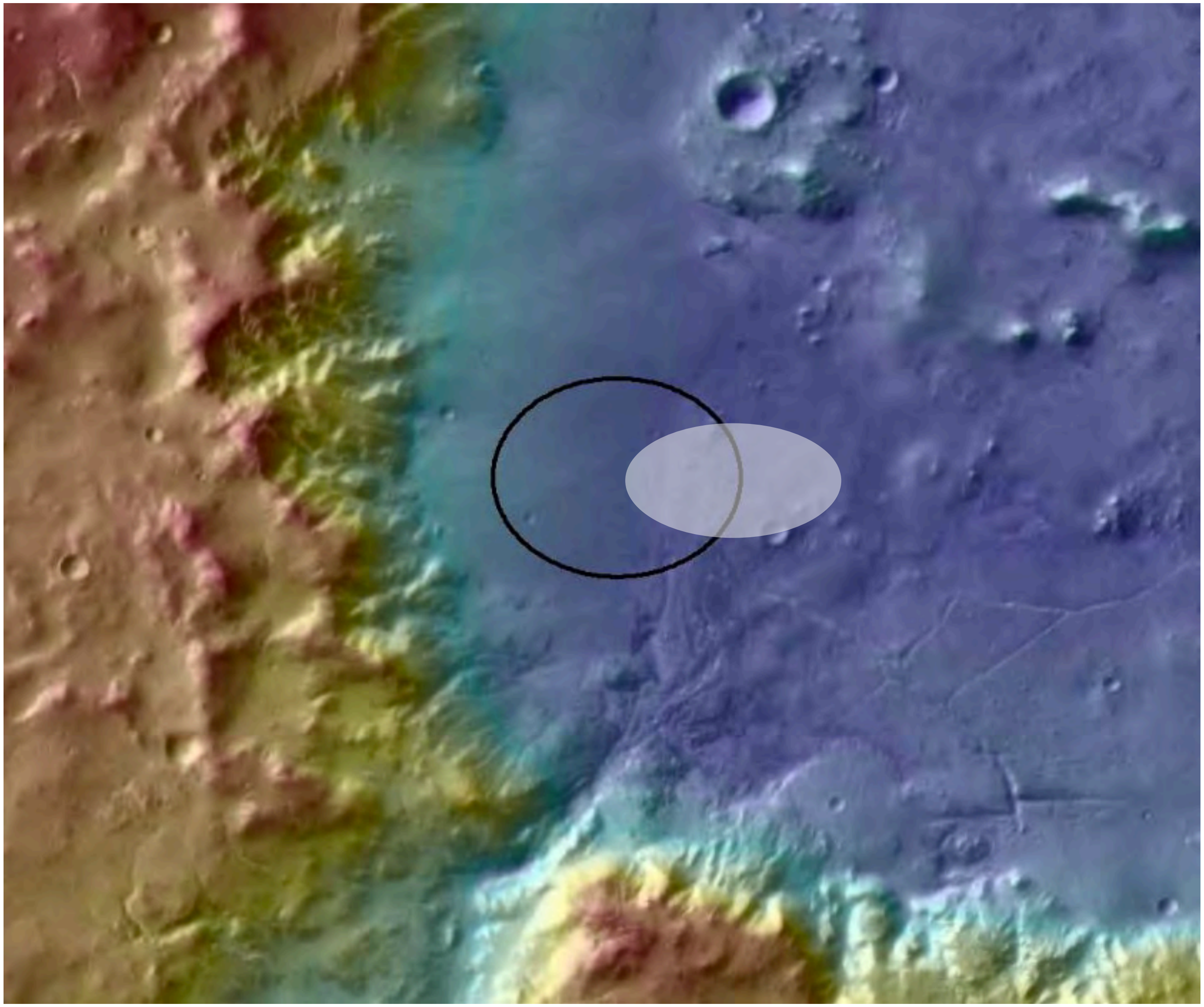
Holden



- Nominal 25×20-km landing error ellipse (solid line).
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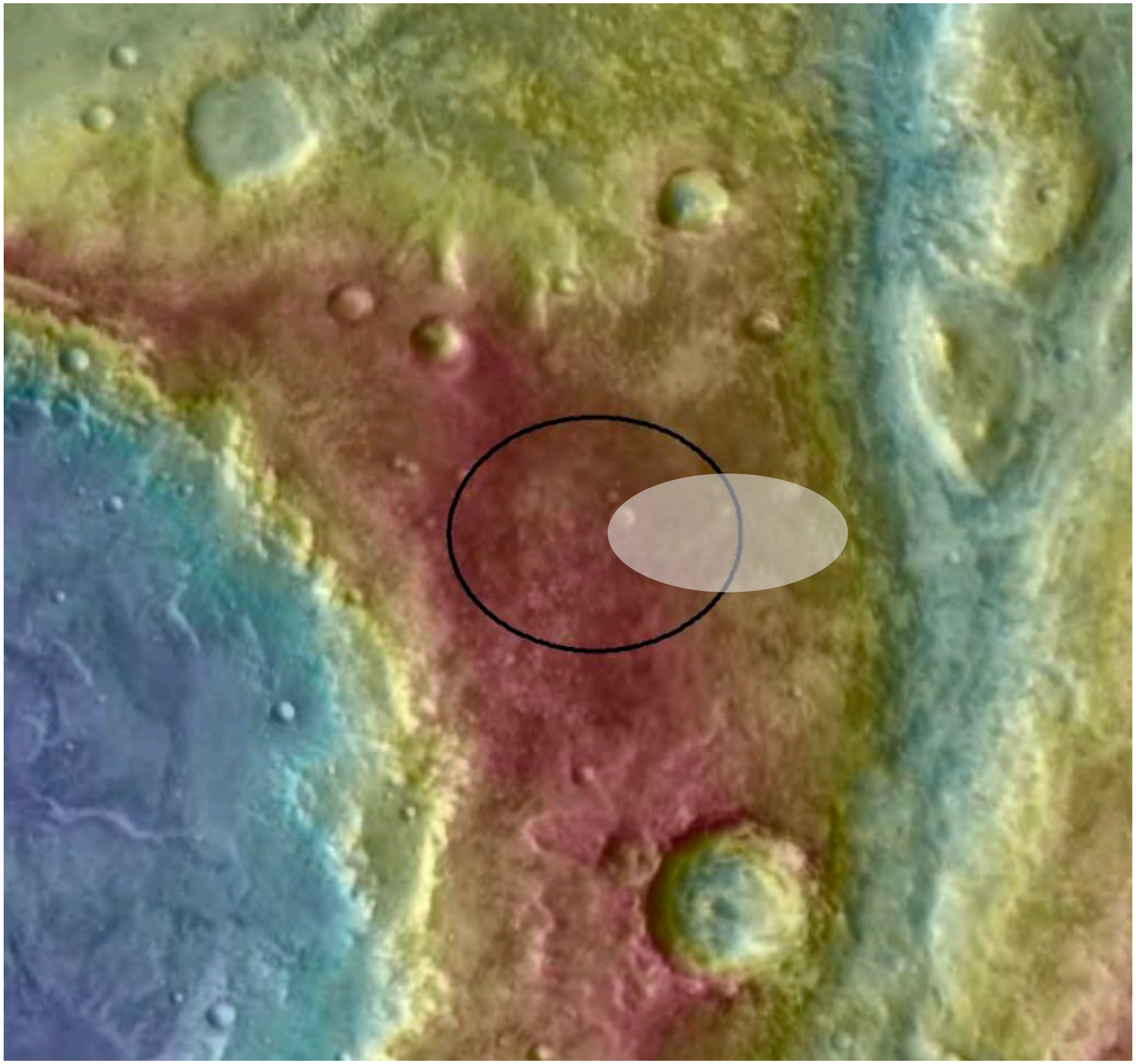
Mawrth



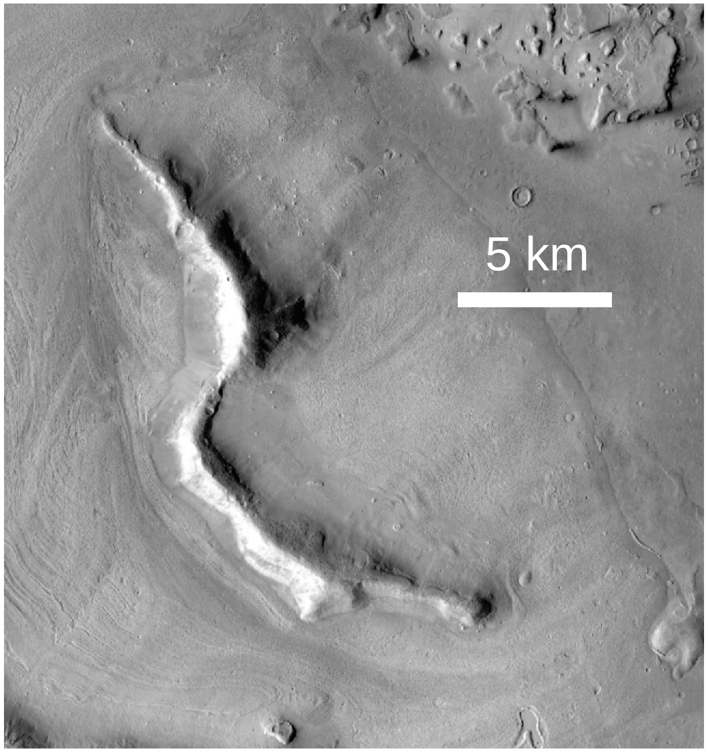
- Nominal 25×20-km landing error ellipse (solid line).
- Region of impact for post chute deploy failure modes (shaded ellipse).

Water and Water Ice

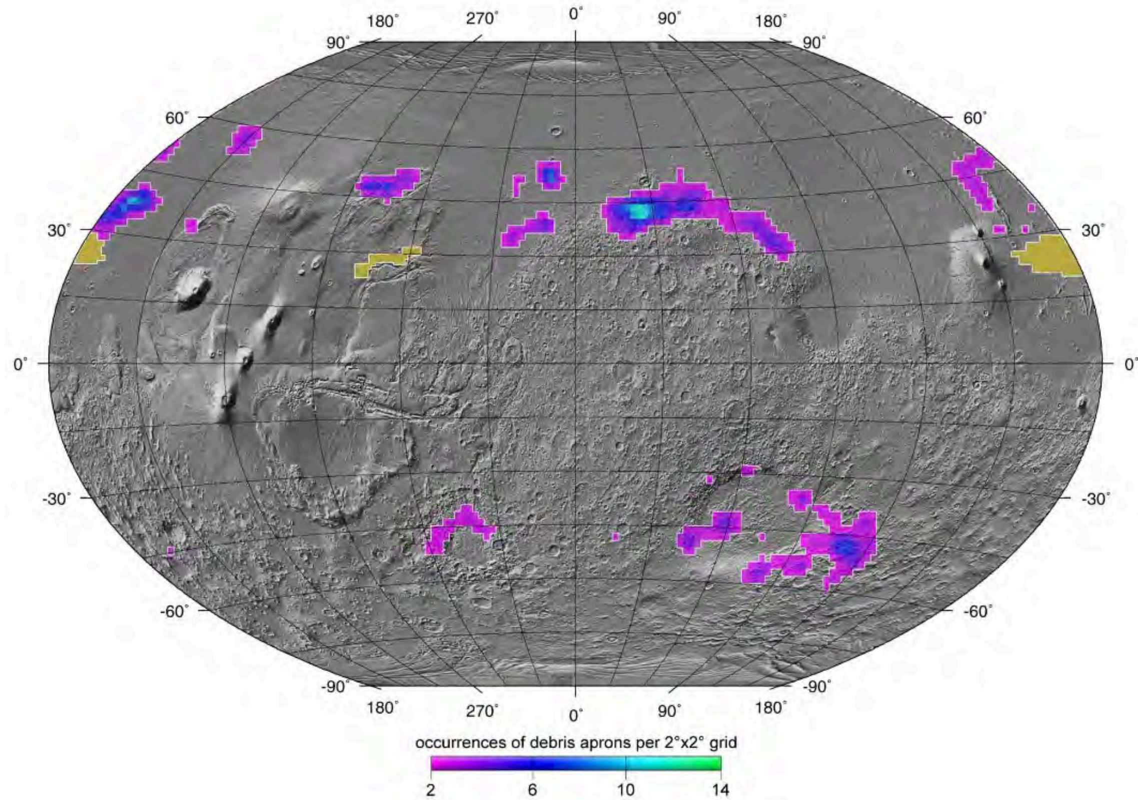
Water/ice near the MSL sites could take any of several forms:

- Seasonal frost: very small %, at surface; not relevant
- Adsorbed water: small %, at surface; not relevant
- Extant liquid water: no gully morphologies observed in the MSL landing site regions
- Exposed perennial ice or icy mantles: none observed at landing site latitudes
- Buried massive ice (i.e., glaciers): no radar signatures or glacial/ lobate morphologies in the MSL landing site regions
- Buried ground ice (i.e., in a permafrost zone): this is investigated further in the following pages
- [Chemically bound water in minerals; questionable relevance]

Lobate Debris Aprons



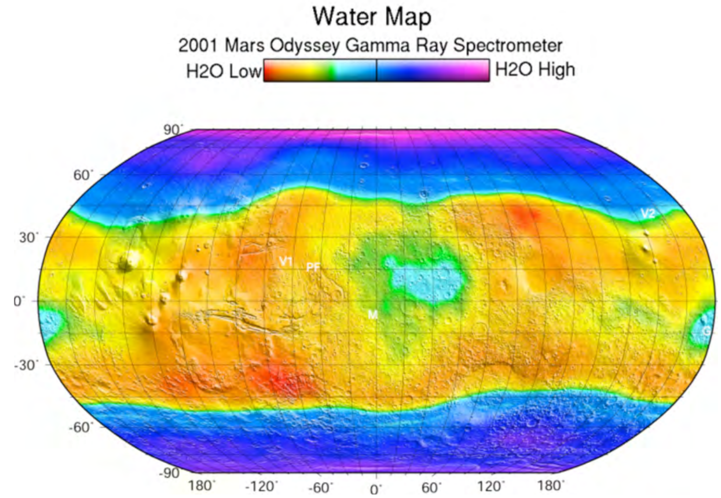
Intact lobate debris apron [CTX/MSSS]



Map of intact (>30° lat) and desiccated (yellow, <30° lat) lobate debris aprons [Hauber *et al*., 2008]

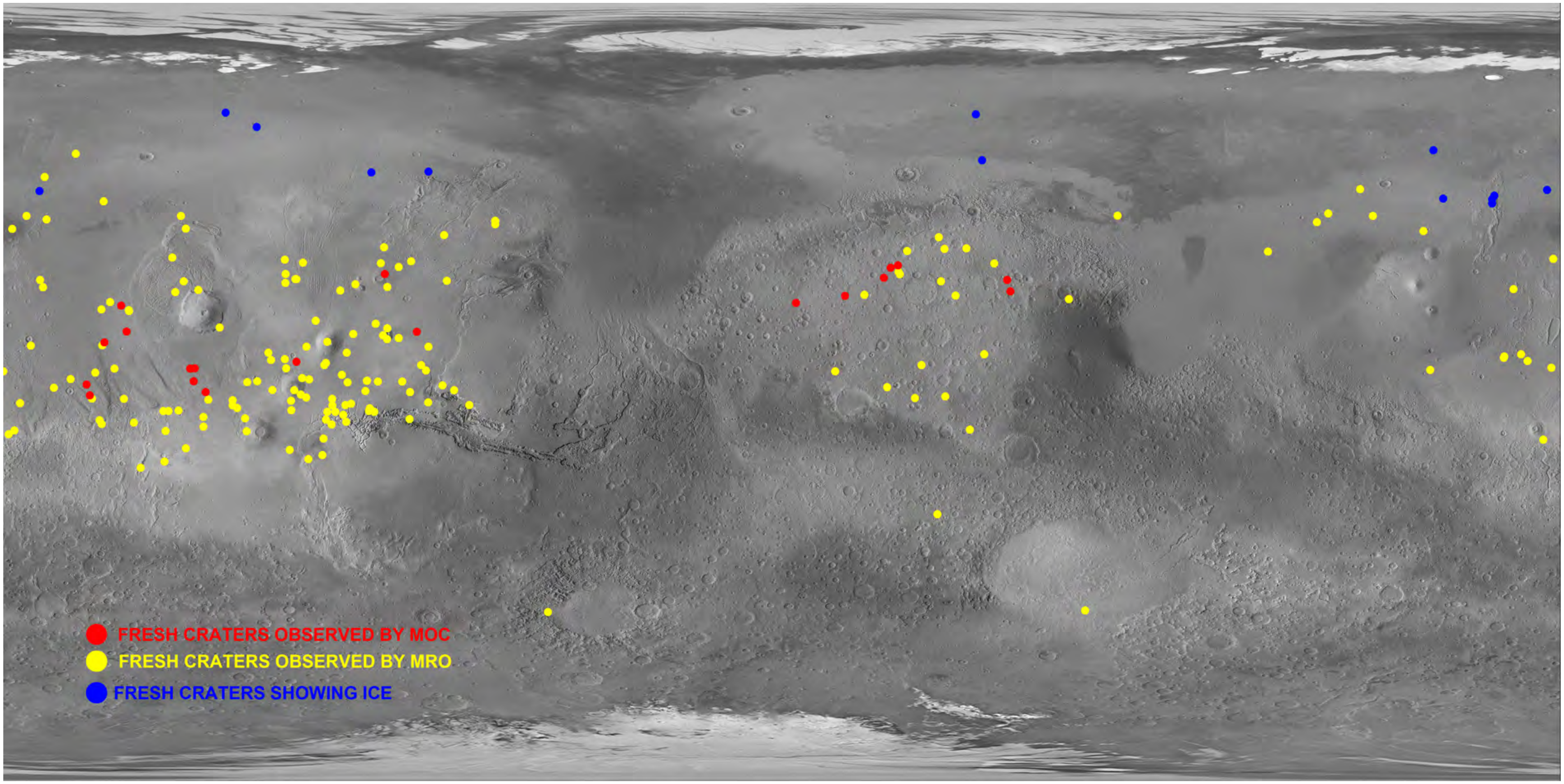
Known Ground Ice

- Stable ground ice is in diffusive and thermal equilibrium with the present atmosphere and climate. Observations by the Mars Odyssey Gamma Ray Spectrometer suite closely match model predictions. Neither indicate ground ice at the MSL sites.
- Recent impacts reveal nearly pure ground ice at mid latitudes, down to 35°. Their more equatorward distribution may indicate deposition under a previous, higher-humidity climate (but likely within 1000s of years of the present).
- Models created to explain the distribution and depth of these relic deposits do not predict ground ice at the MSL landing sites.



HiRISE Color Image
(meter-scale crater)

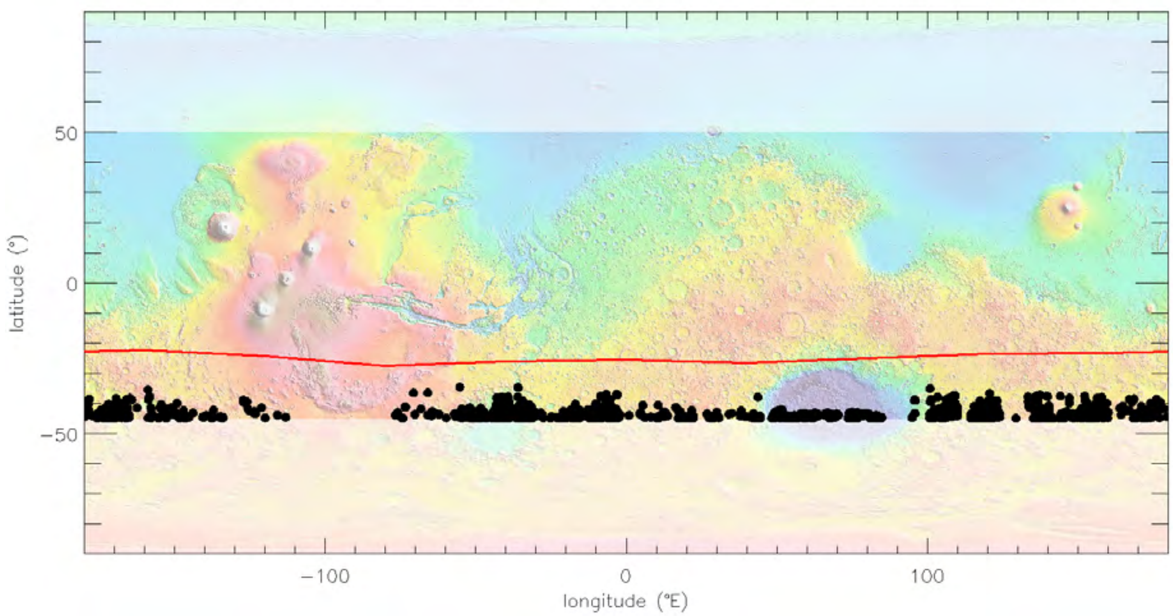
New Impact Craters



About 200 fresh impact sites have been found. MGS-MOC found craters in global maps at 250 m/pxl. MRO-CTX repeat coverage in high albedo areas is about 10% of planet.

Inferred Ground Ice

- A recent set of studies by Vincendon et al. [2010a, 2010b] has inferred ground ice at the latitudes of two MSL sites. They compared spectral detections of seasonal CO2 frost with a modeled distribution. Frost is predicted, but absent, on steep, poleward-facing slopes down to 25°S.
- They explain the mismatch by the presence of high thermal inertia material on these slopes. They argue that ground ice would be locally stable within 0.5 m of such surfaces, and would have the proposed thermal behavior.



Application to MSL Sites

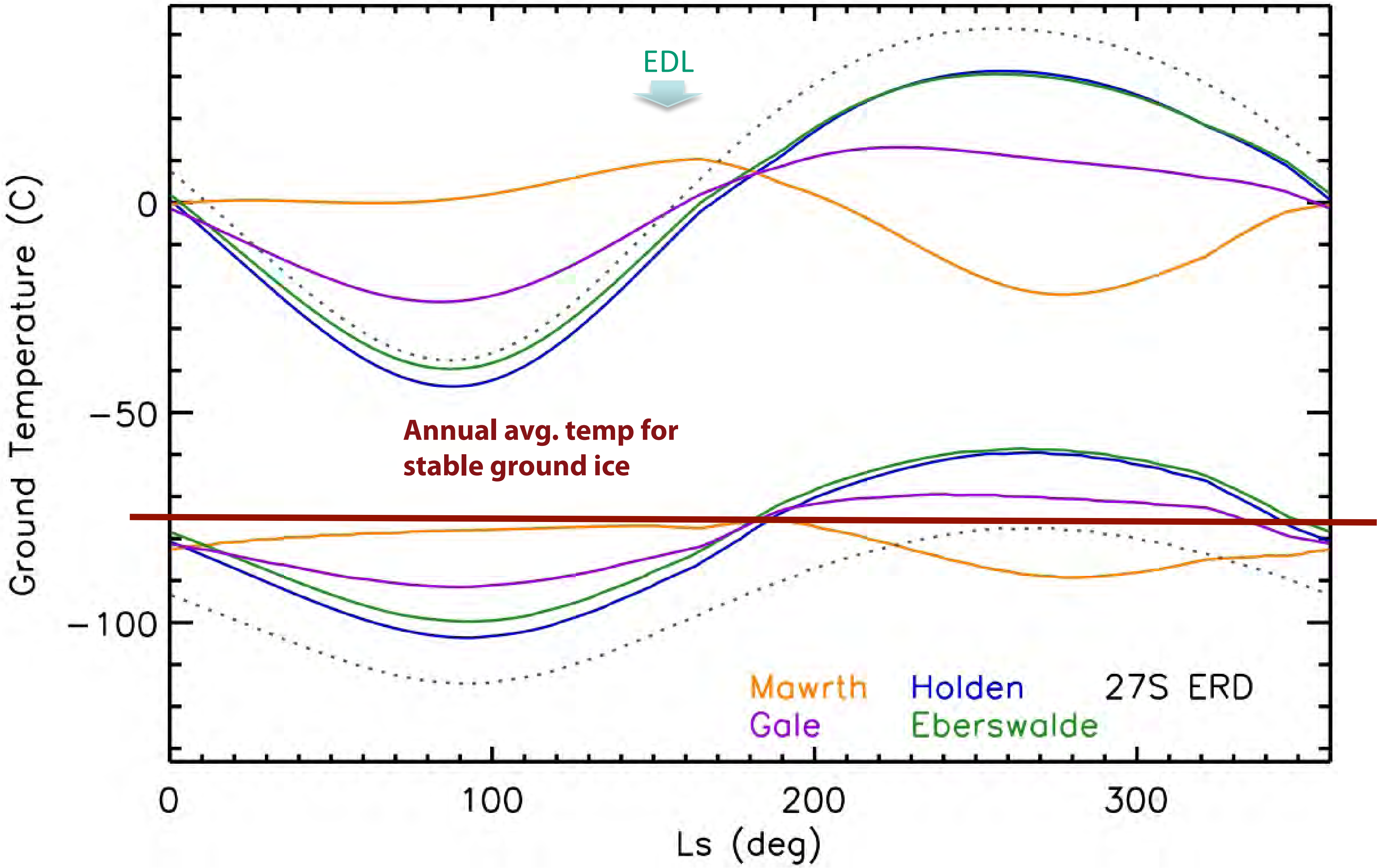
- To address the potential for ground ice including the Vincendon et al. hypothesis, we have compiled temperature and slope data for each of the MSL landing sites.

- Diurnal and annual surface temperatures are predicted by global numerical models and are validated against observations by MGS-TES and ODY-THEMIS.

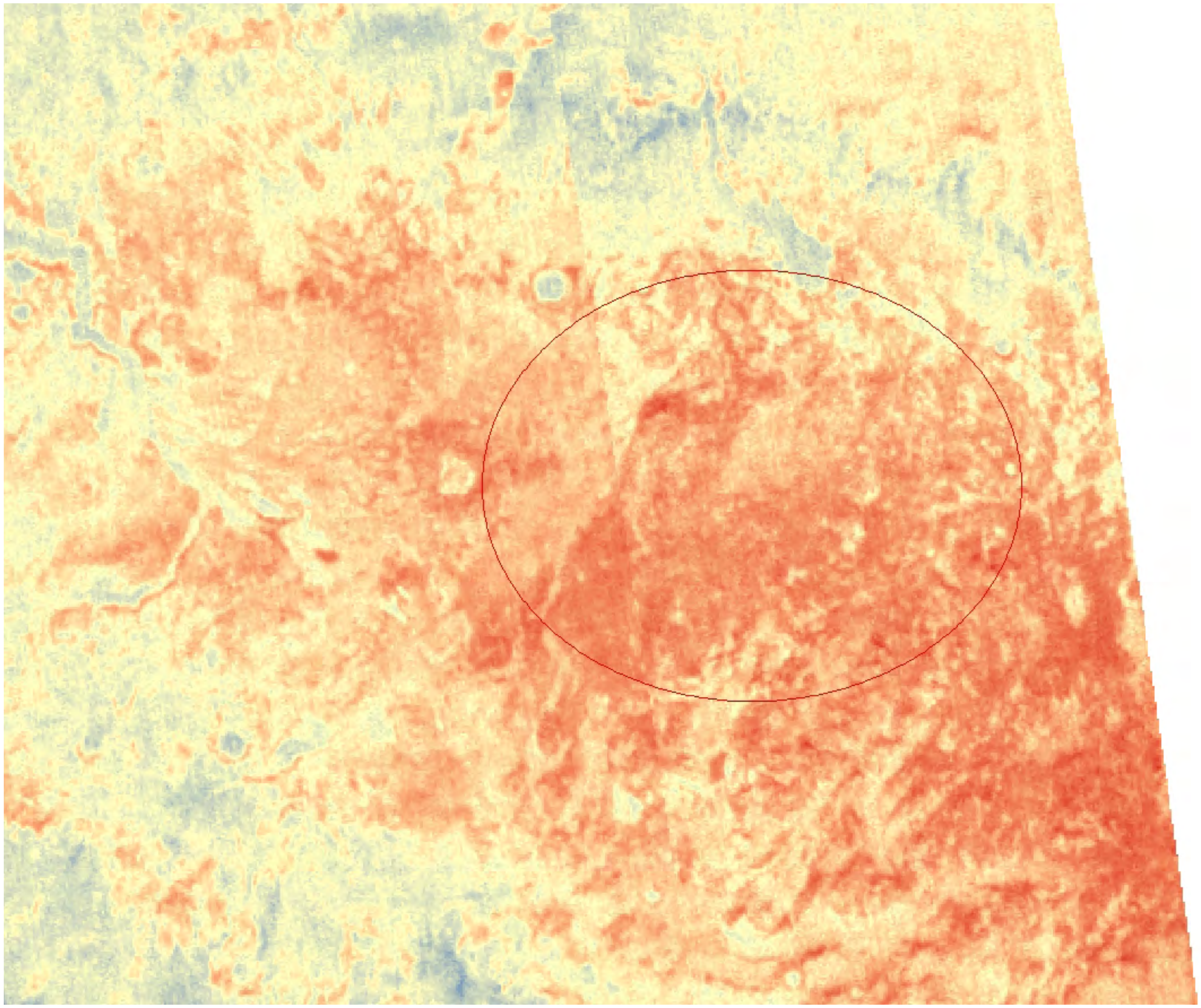
- THEMIS-derived high-resolution temperature maps allow assessment of thermophysical properties and reveal local variability due to thermal inertia, slopes, shadows, etc.

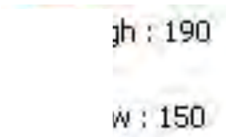
- Slope maps at several baselines relevant to local topography are created from stereo imagery.

Diurnal and Annual Temperatures



Winter/Night - Eberswalde



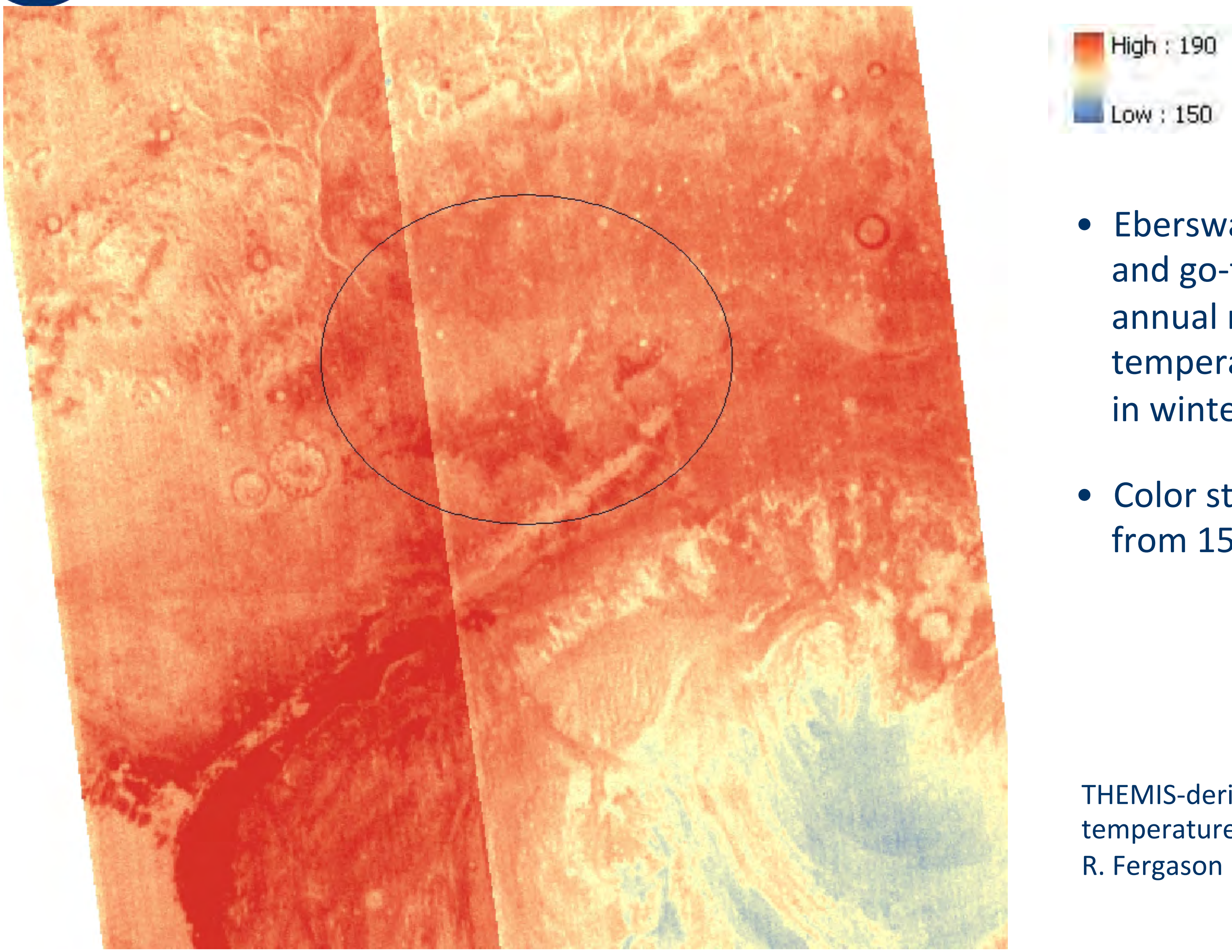


Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=90).

- Color stretch is from 150 to 190K.

THEMIS-derived temperature map. R. Fergason (USGS).

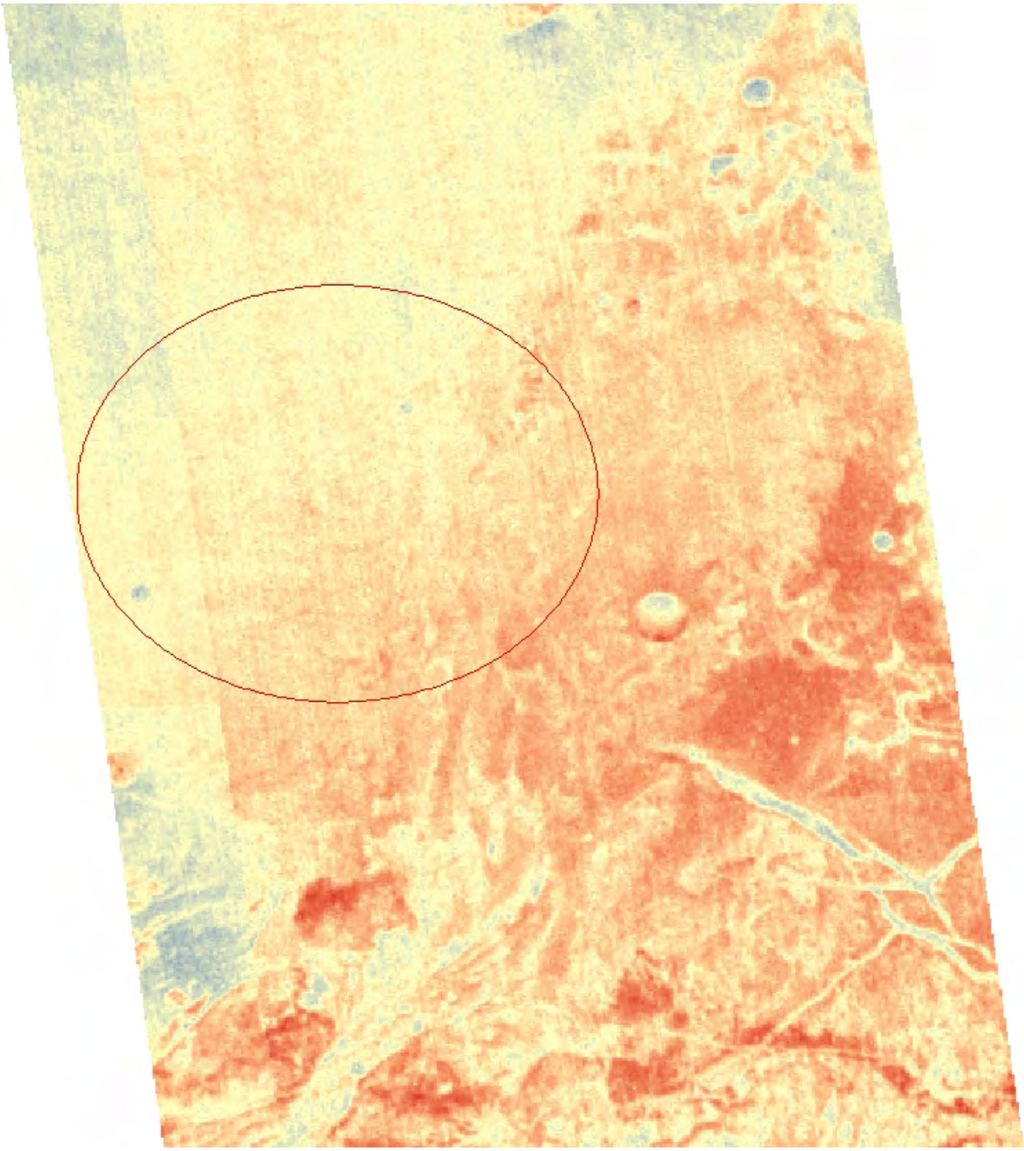
Winter/Night - Gale

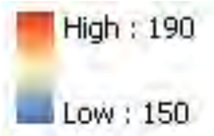


- Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

THEMIS-derived temperature map.
R. Fergason (USGS).

Winter/Night - Holden

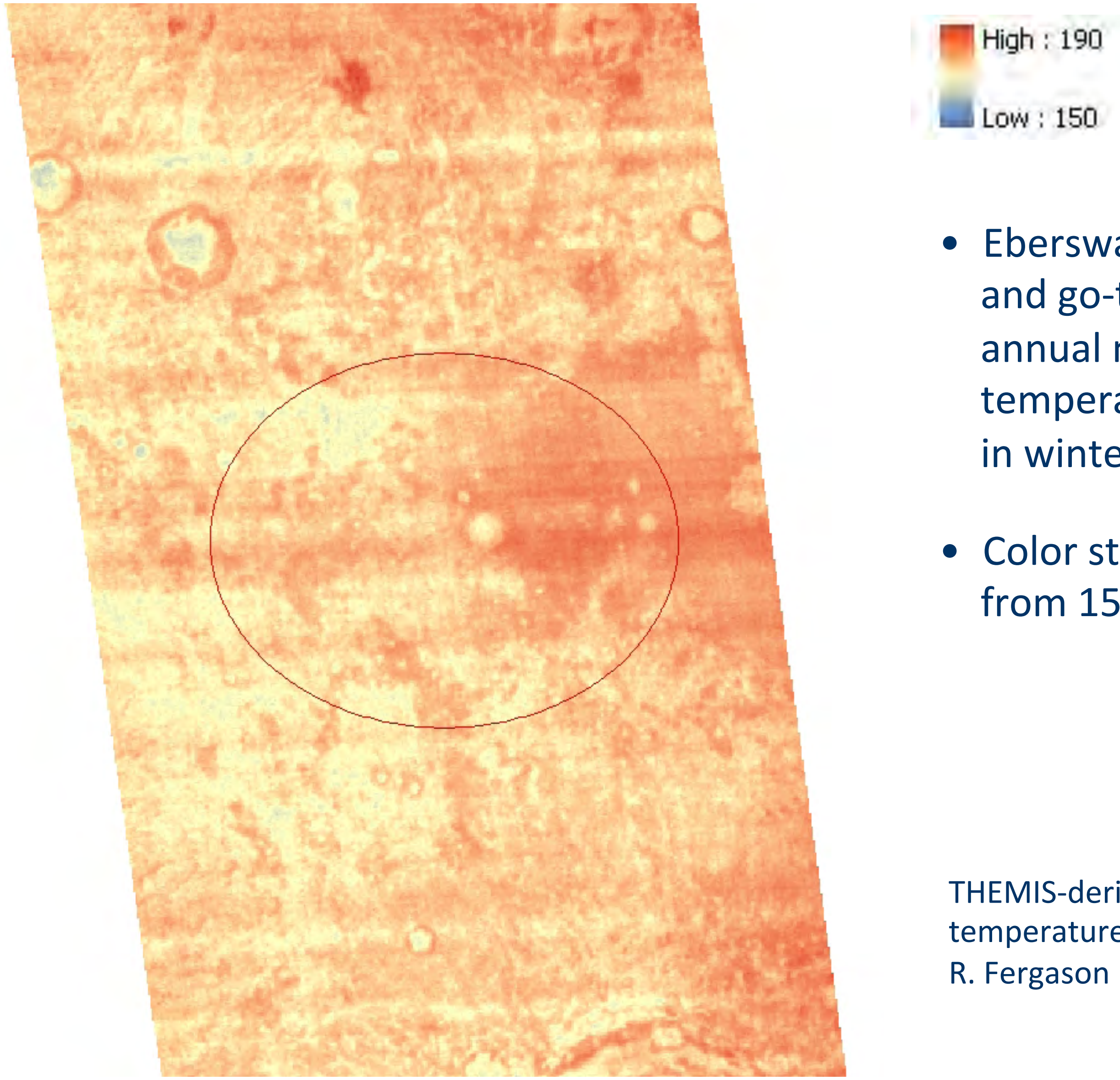




- Holden Crater and go-to region at annual minimum temperature; night in winter (L_s=90).
- Color stretch is from 150 to 190K.

THEMIS-derived temperature map.
R. Fergason (USGS).

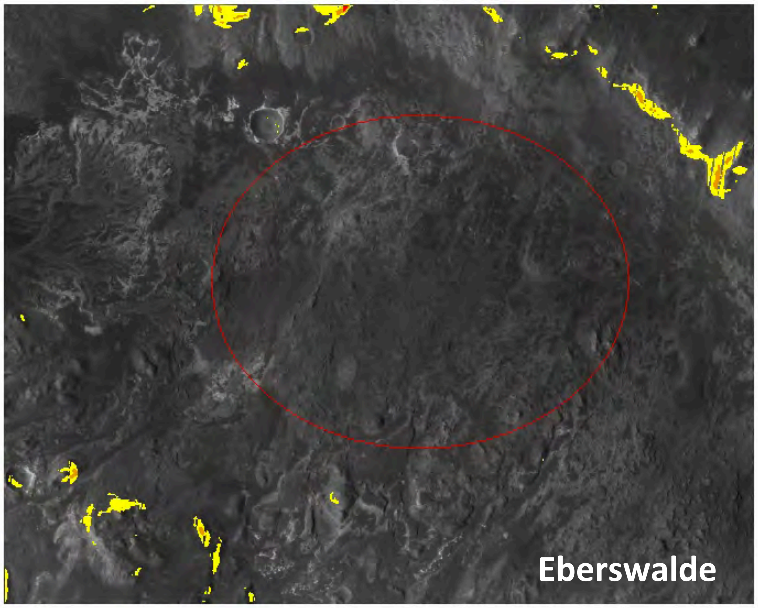
Winter/Night - Mawrth

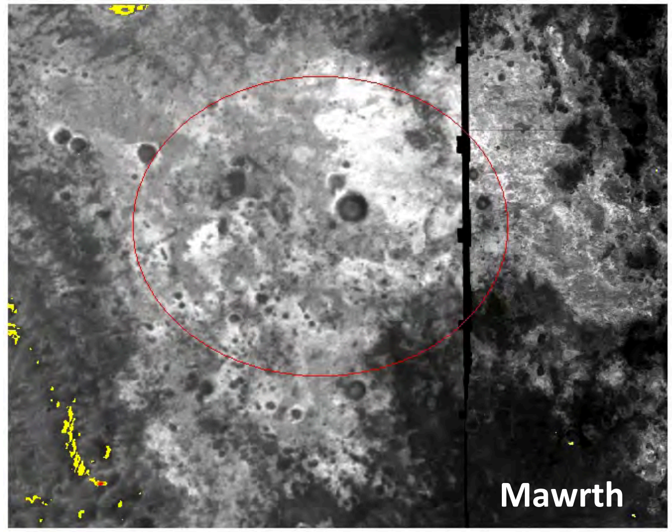


- Eberswalde Crater and go-to region at annual minimum temperature; night in winter (L_s=270).
- Color stretch is from 150 to 190K.

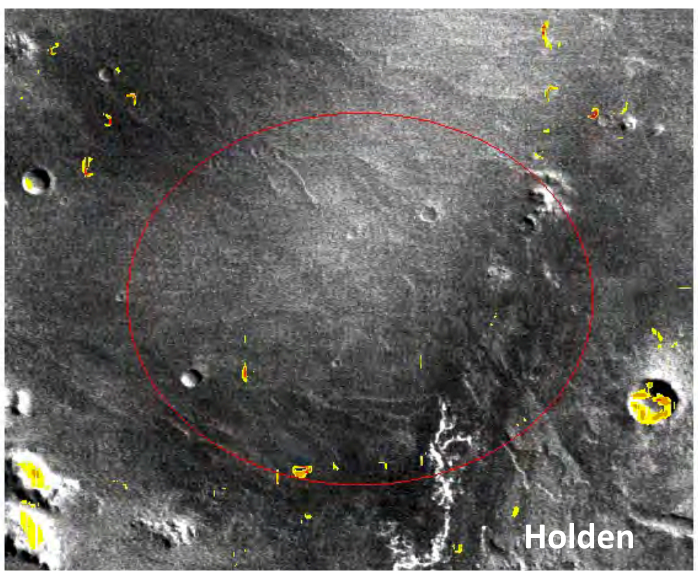
THEMIS-derived temperature map. R. Fergason (USGS).

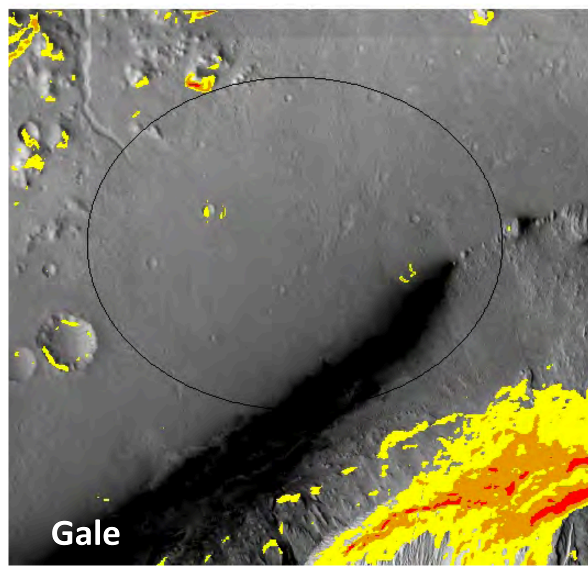
Slopes at 50-m Baseline

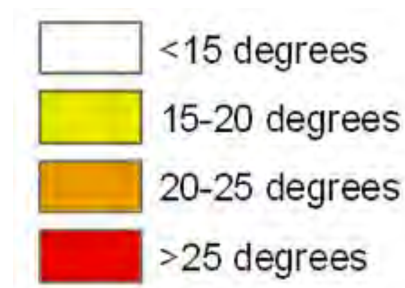




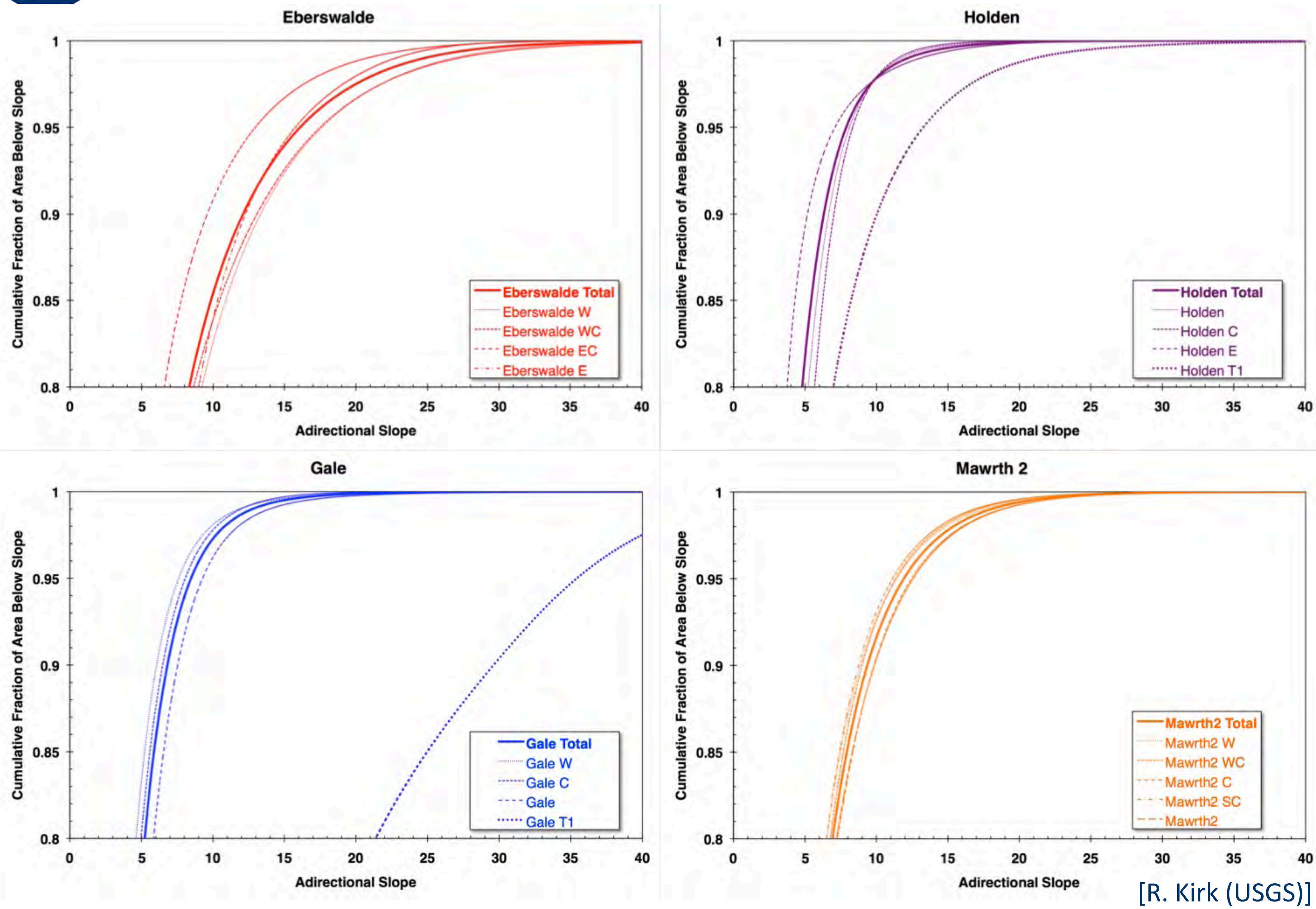
Slopes derived from MEX-HRSC. Digital elevation model of K. Gwinner (DLR-ESA) analyzed by F. Calef (JPL).







5-m Baseline Slope Distributions



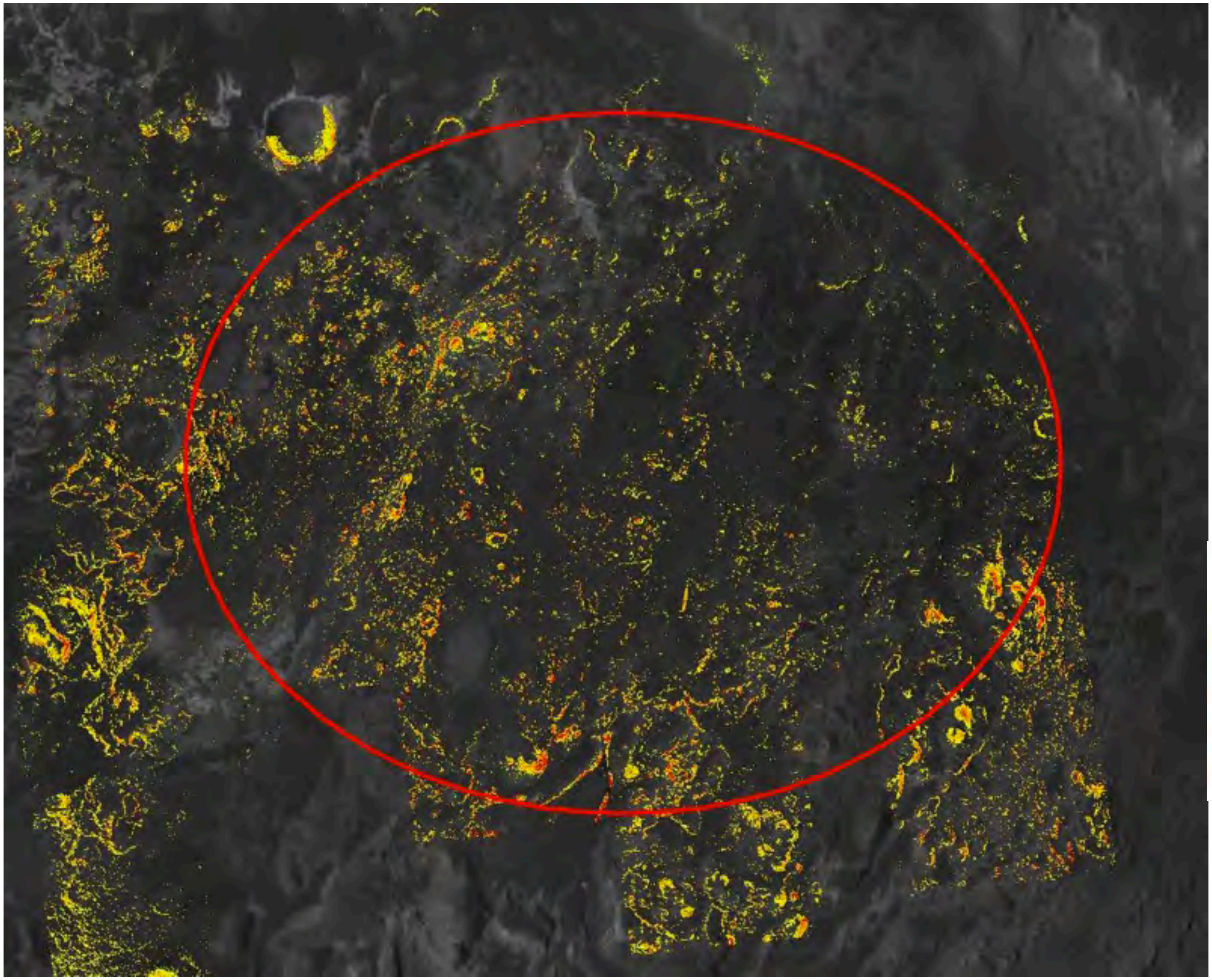
[R. Kirk (USGS)]

5-m Baseline Slope Distributions

Site/DTM	Fraction of Ellipse	RMS Slope	98th %ile Slope	99th %ile Slope	Slopes > 15°	Slopes > 20°	Slopes > 25°
Eberswalde Total	**84%**	**7.03**	**21.3**	**24.9**	**5.93%**	**2.45%**	**0.94%**
Eberswalde W	17%	8.29	23.1	26.9	7.49%	3.31%	1.38%
Eberswalde WC	26%	6.19	23.3	27.3	7.30%	3.28%	1.43%
Eberswalde EC	21%	6.17	17.5	20.9	3.23%	1.15%	0.38%
Eberswalde E	19%	7.75	20.1	22.9	5.69%	1.99%	0.50%
Mawrth 2 Total	**95%**	**6.00**	**15.5**	**18.1**	**2.15%**	**0.57%**	**0.15%**
Mawrth 2 W	16%	5.72	14.9	17.7	1.88%	0.51%	0.13%
Mawrth 2 WC	25%	5.81	14.7	17.1	1.74%	0.42%	0.10%
Mawrth 2 C	22%	6.27	16.1	18.9	2.53%	0.71%	0.20%
Mawrth 2 SC	8%	5.65	14.5	16.9	1.63%	0.40%	0.10%
Mawrth 2	23%	6.25	16.3	18.9	2.60%	0.72%	0.20%
Gale Total	**62%**	**4.46**	**10.9**	**12.9**	**0.48%**	**0.12%**	**0.04%**
Gale W	17%	4.00	9.9	11.9	0.37%	0.06%	0.00%
Gale C	21%	4.21	10.3	12.1	0.29%	0.04%	0.01%
Gale	23%	4.96	11.9	14.1	0.73%	0.22%	0.09%
Gale T1		*17.16*	*41.3*	*44.9*	*33.48%*	*22.15%*	*14.85%*
Holden Total	**50%**	**4.15**	**10.3**	**12.3**	**0.39%**	**0.08%**	**0.02%**
Holden	9%	4.38	10.1	11.9	0.26%	0.05%	0.01%
Holden C	17%	4.63	10.1	11.5	0.17%	0.01%	0.00%
Holden E	25%	3.70	10.5	13.1	0.58%	0.14%	0.03%
Holden T1		*6.45*	*17.7*	*21.1*	*3.41%*	*1.21%*	*0.49%*
Spirit		**3.73**	**10.1**	**12.1**	**0.36%**	**0.05%**	**0.01%**
Opportunity		**3.27**	**8.1**	**9.5**	**0.06%**	**0.00%**	**0.00%**
Phoenix		**1.85**	**4.1**	**4.5**	**0.00%**	**0.00%**	**0.00%**

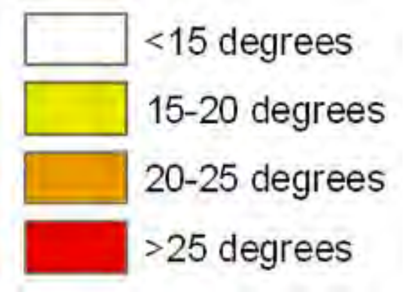
[R. Kirk (USGS); presented at 4th MSL Landing Site Workshop]

Slopes at 1-m Baseline

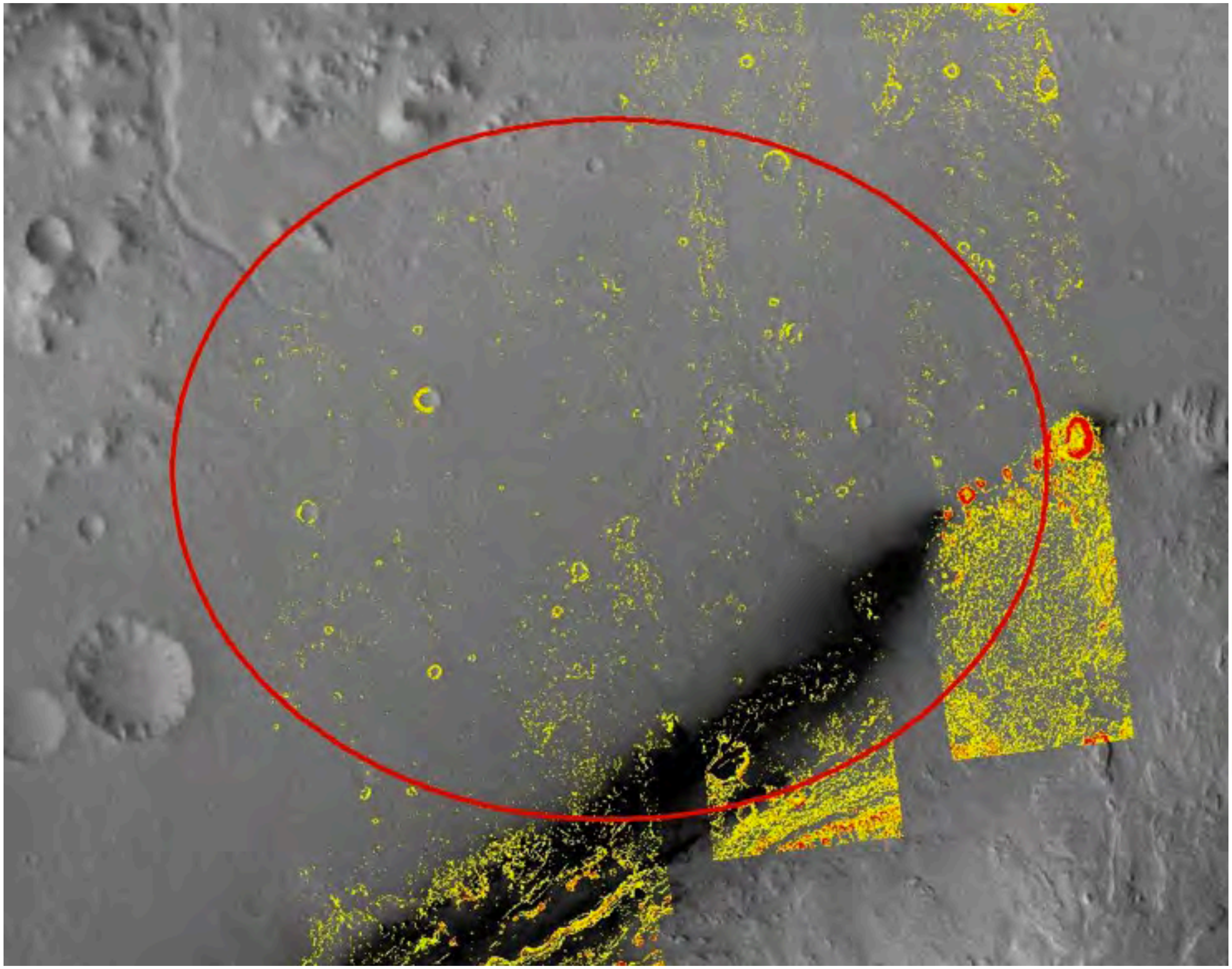


Eberswalde

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).



Slopes at 1-m Baseline



Gale

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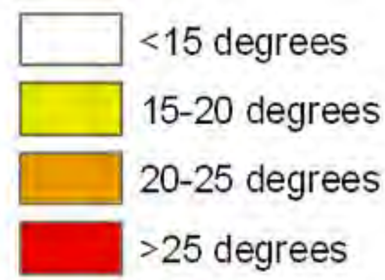
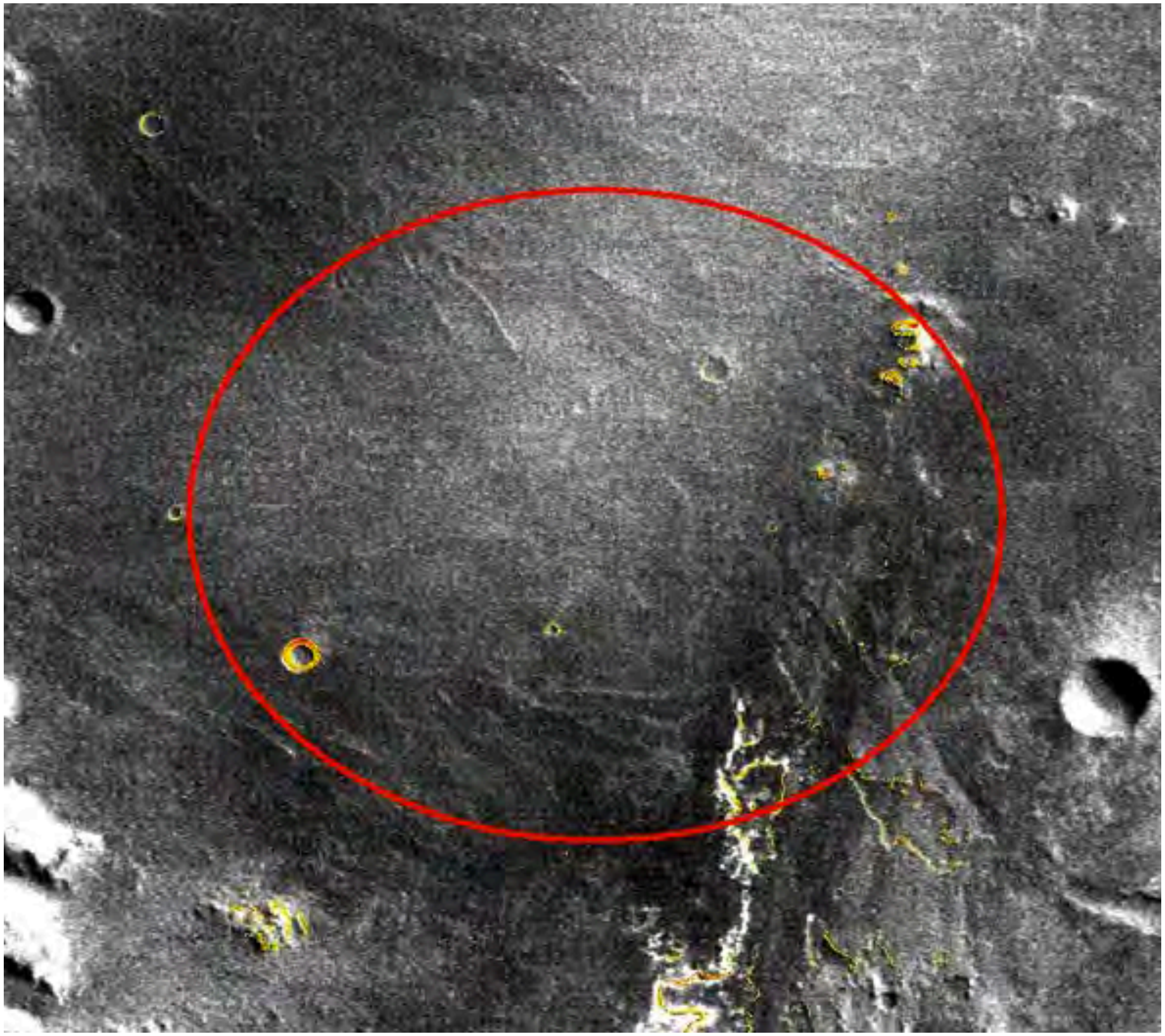


Slopes at 1-m Baseline

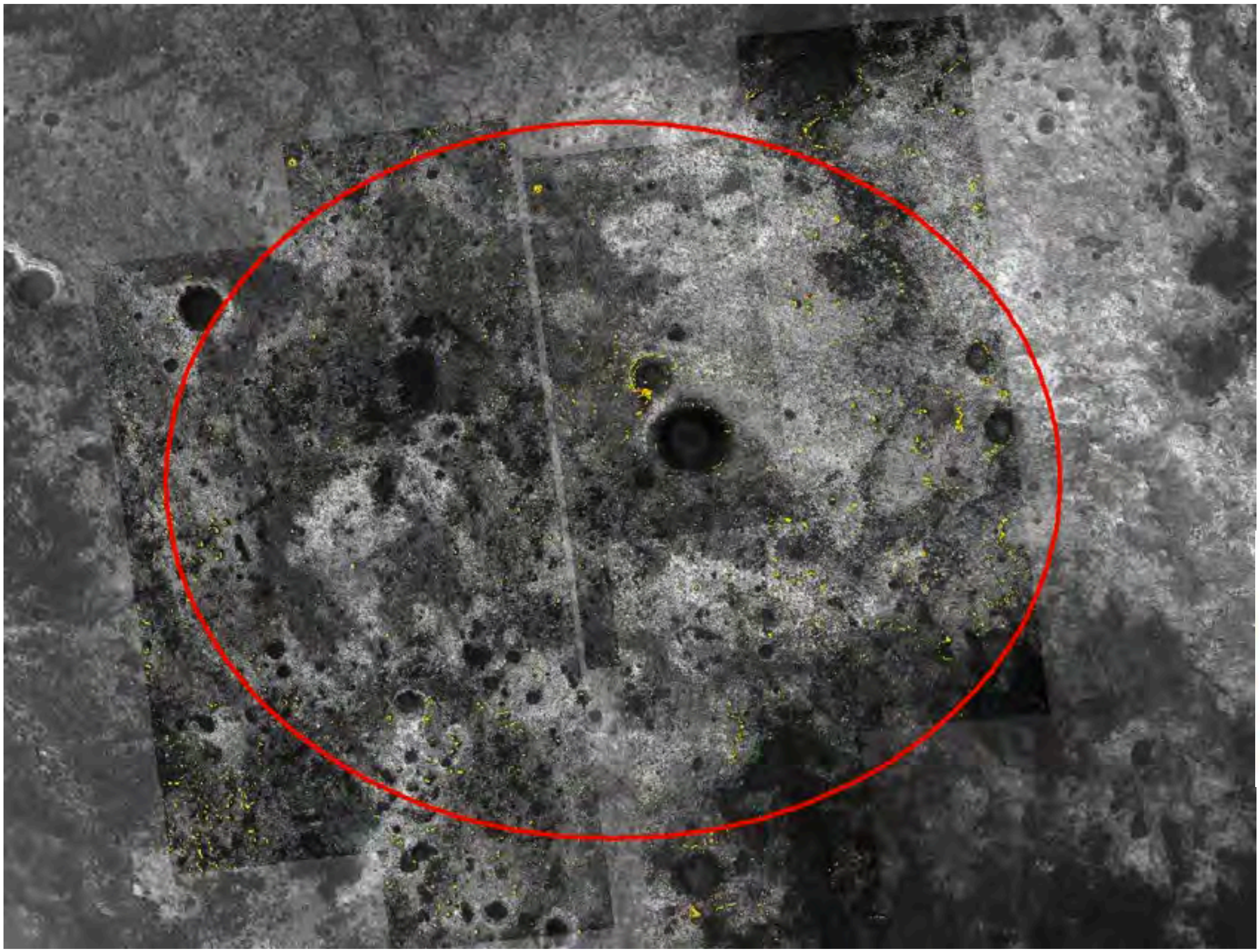


Holden

Slopes derived from HiRISE digital elevation model of R. Kirk (USGS) by F. Calef (JPL).

(white)	<15 degrees
(yellow)	15-20 degrees
(orange)	20-25 degrees
(red)	>25 degrees

Slopes at 1-m Baseline



Mawrth

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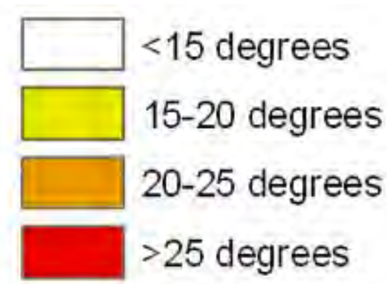

Summary

- No known water or water ice in the region of concern around the MSL candidate landing sites.
- Risk of undetected ground ice is very low due to:
  - Thorough scrutiny of these sites
  - Season and diurnal temperature ranges that preclude the accumulation of subsurface ice from atmospheric water vapor
  - Lack of appreciable area with thermal anomalies such as very low or high thermal inertias, shadowed areas, or poleward-facing high slopes
- Water frost[1], adsorbed water[2], and water bound in minerals[3] are possible; relevance to planetary protection concerns is either negligible (1,2) or questionable (3).