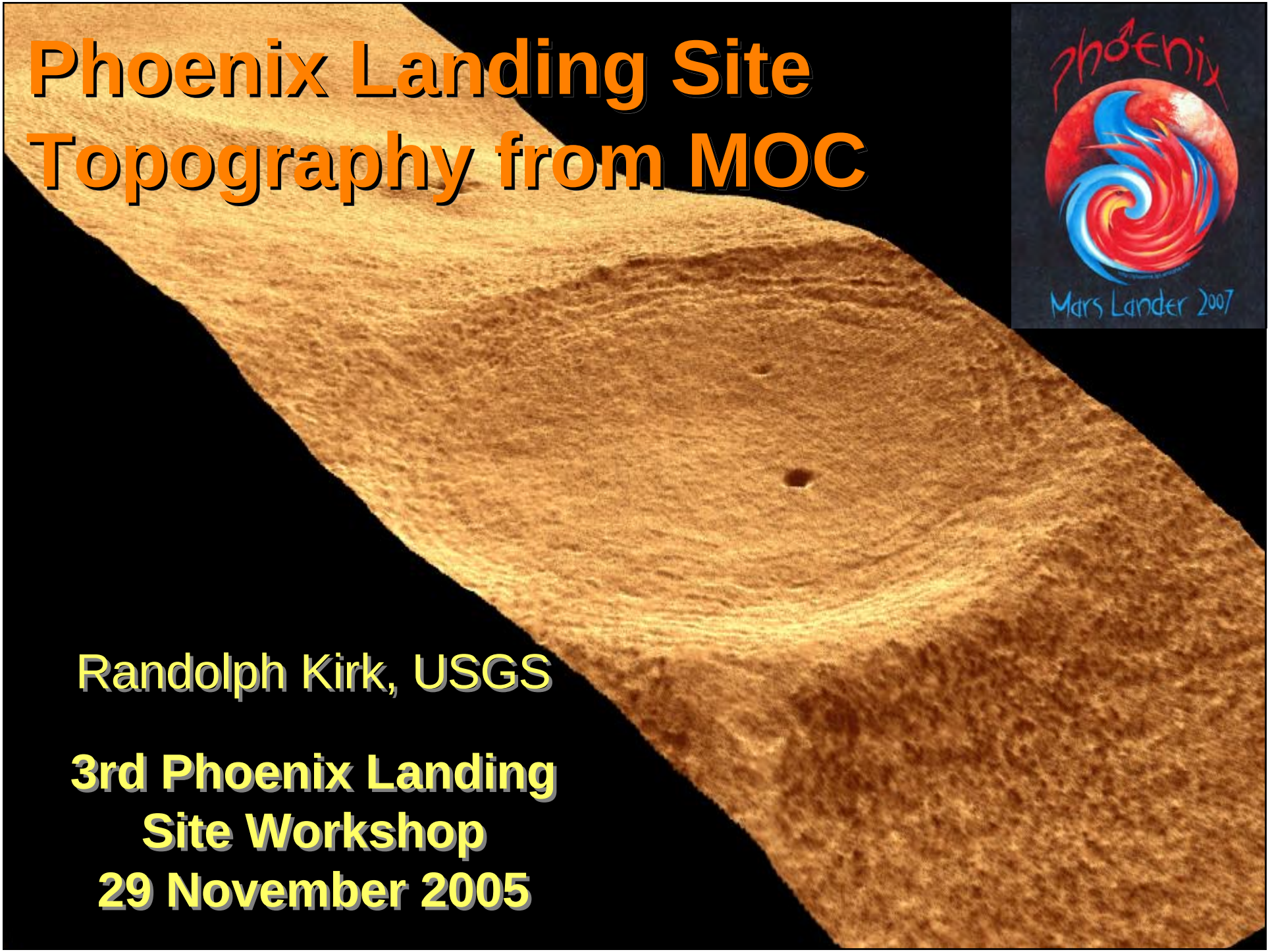
Phoenix Landing Site Topography from MOC



Randolph Kirk, USGS

3rd Phoenix Landing Site Workshop
29 November 2005

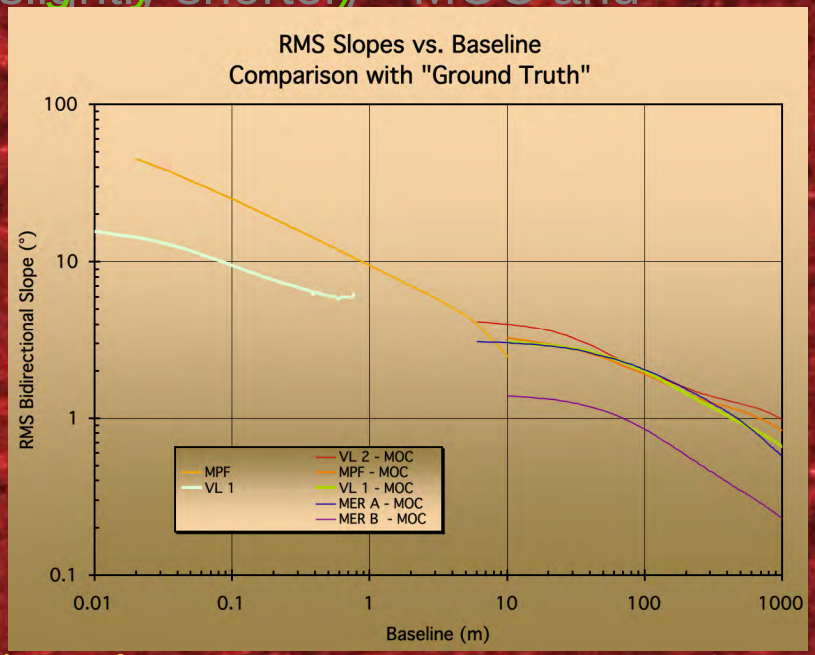
Objectives

Contribute to assessment of safety of candidate PHX sites for landing

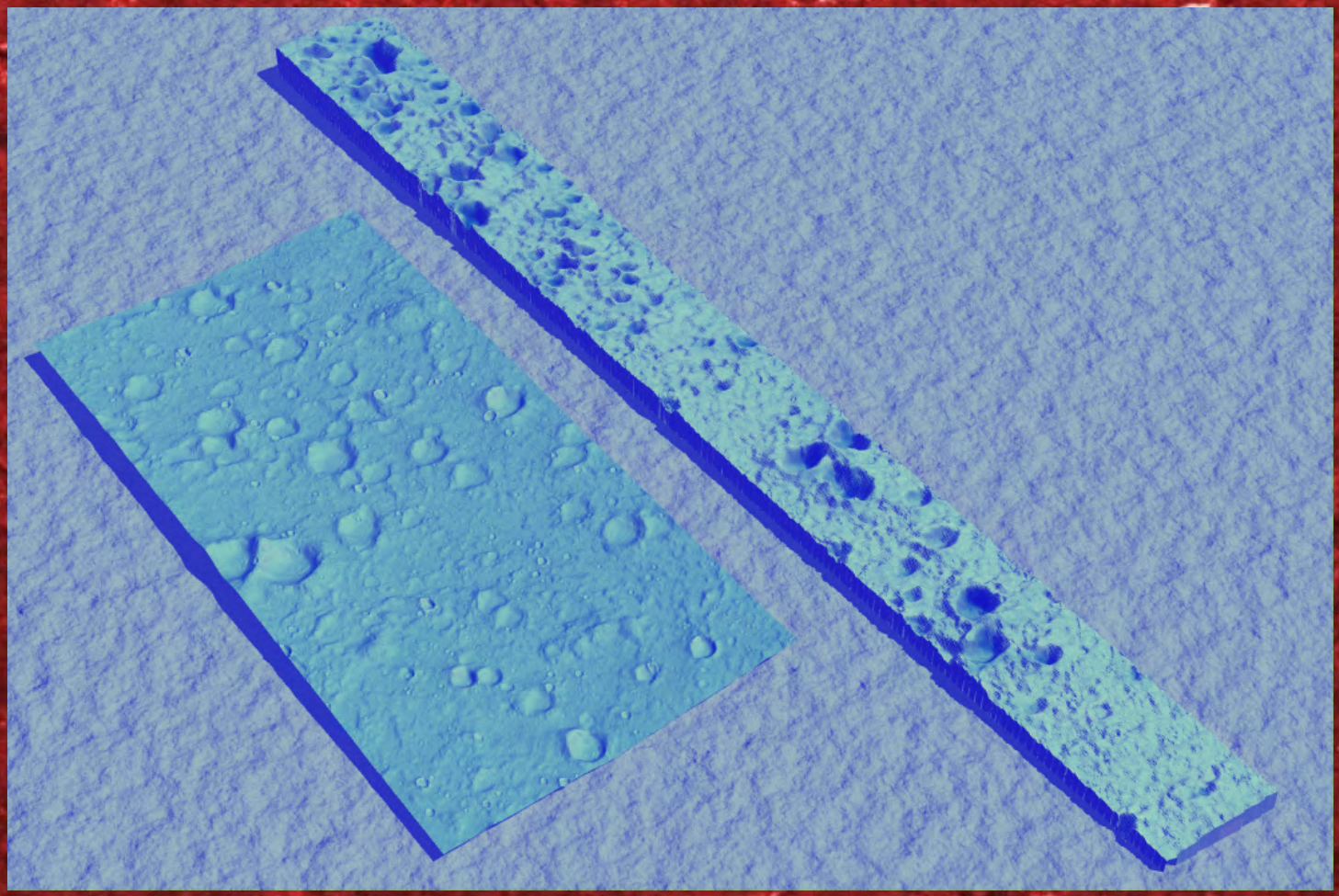
- Supported by Mars Critical Data Products Initiative (CRUDPIE)
- Builds on similar work done for MER (Kirk et al., 2003. *JGR* 108(E12), 8088, doi:10.1029/2003JE002131)
  - Assess "roughness" at highest resolution (MOLA, THEMIS, HRSC provide information on longer baselines)
  - Use MOC-NA images (3-6 m/pixel typ.)
  - Make DTMs by stereo and photoclinometry
  - Report slope statistics, supply DTMs for simulations
  - Start by sampling all candidate areas, work to sample all terrain types in areas…will never achieve 100% area coverage
- Differences
  - Detailed safety criteria will be different for tripod lander
  - Initial image and stereo coverage is even sparser (but will grow)
  - HRSC-SRC may become important (paired with MOC-NA)
  - HiRISE will be important when available
  - Less geomorphologic diversity?
  - More problems with image data?

Topographic Scales Affecting Safety and Relevant Datasets

- ≥300 m baselines—MOLA point-to-point
- ≤150 m baselines—MOLA pulsewidth
- ~100 m baselines—THEMIS photoclin., HRSC stereo
- 3–20 m baselines (and extrapolation to slightly shorter)—MOC and MOC+SRC stereo and photoclinometry
- <3 m baselines (rocks)—requires modeling…or HiRISE



Photoclinometry & Stereo



Methodologies Compared

Photoclinometry

- Single image
- Horizontal res 1 pixel
- Measure, ∫ *slopes*
  - Neighbor hts to << 1 pix
  - Errors grow w/baseline
- Radiometric
  - Artifacts if albedo varies
  - Scale error if haze not calib. to stereo/MOLA
  - No absolute heights
- CPU & labor intensive

Stereo

- Two convergent images
- Horizontal res ≥3 pixels
- Vert res 0.2 pix / (b/h)
  - ~1 pix for MOC
  - Independent of baseline
- Geometric
  - Ignores albedo
  - Ignores atmosphere
  - Absolute heights require control (e.g. to MOLA)
- CPU & labor intensive

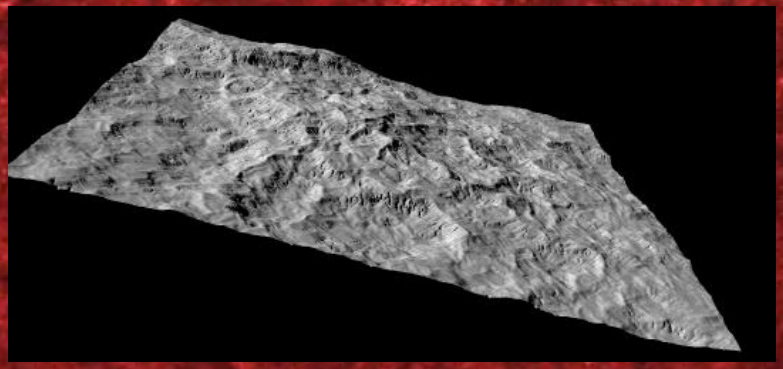
Effect of Haze and Albedo

Sun is from upper left in all examples

Correct Haze and Albedo

Too much Haze subtracted

Albedo underestimated

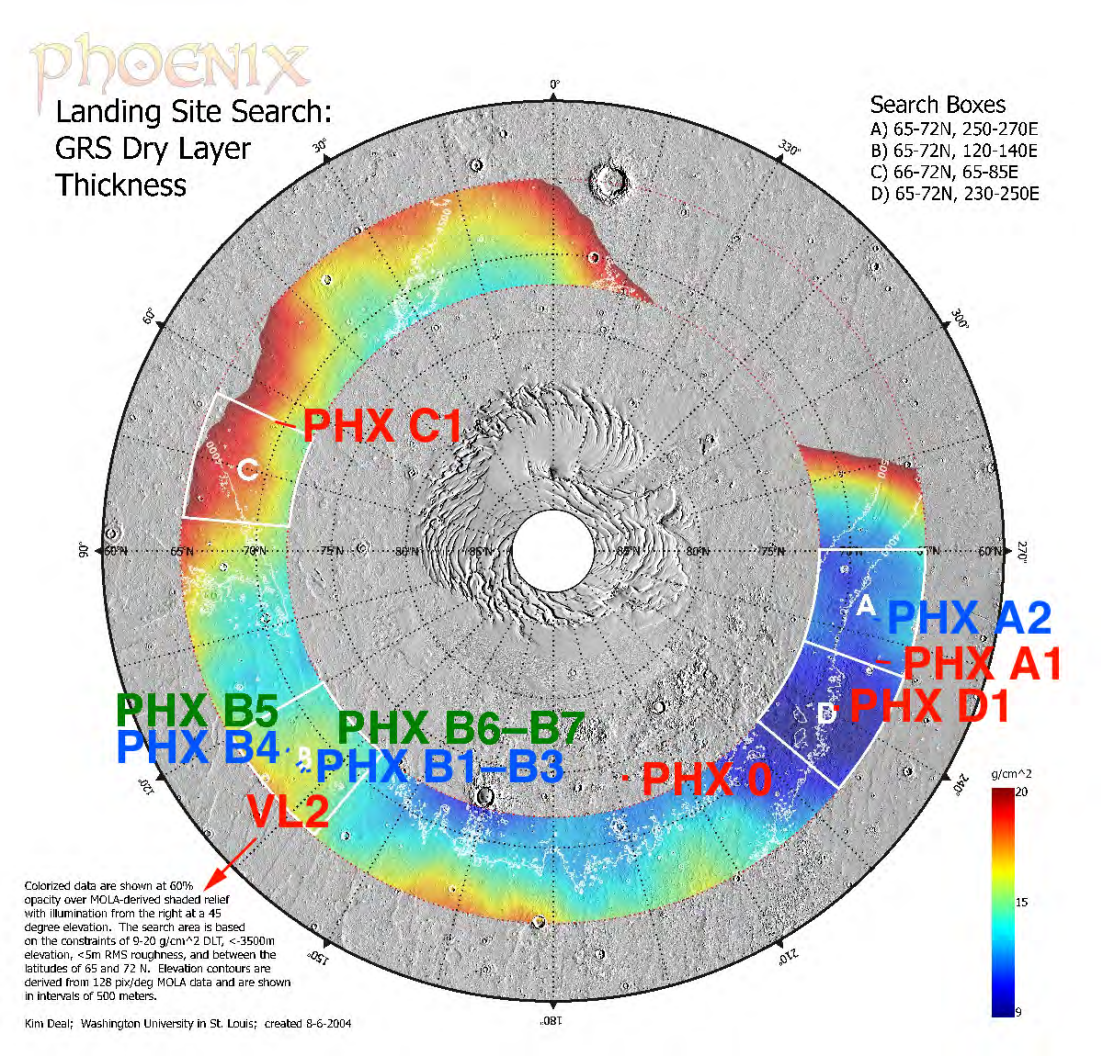


Albedo overestimated

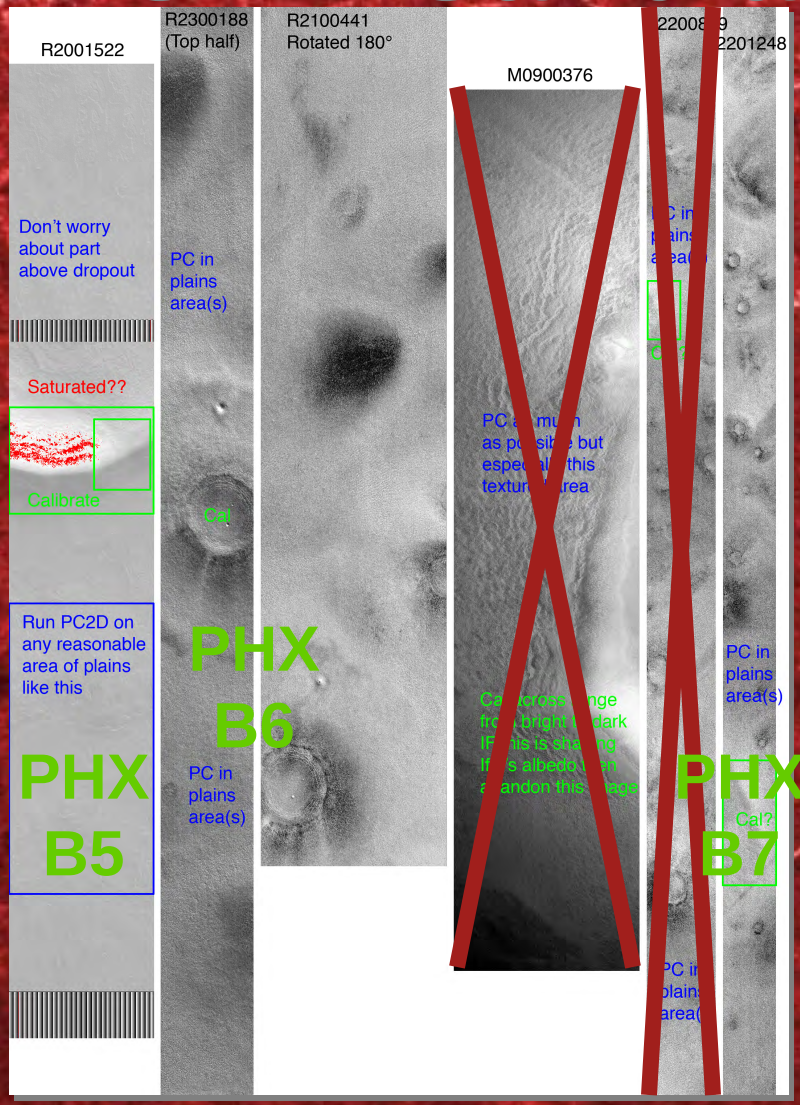
Evolving Strategies

- Workshops 1 and 2
  - Map available MOC stereopairs (and request others)
    - Slopes at ≥10m baselines (does not resolve basketball texture)
  - Try to calibrate PC against stereo DTMs
    - Largely thwarted by lack of clear topo at ST scales, variable albedo
    - Success at one site (A1) gives consistent slopes down to 3m
- Workshop 3
  - Identify single MOC images overlapping “prominent” (typ <100m high) relief features in MOLA
  - Perform PC with calibration against MOLA

Study Locations



MOLA-Calibrated PC Candidates



9 candidates ID'd by Tim Parker

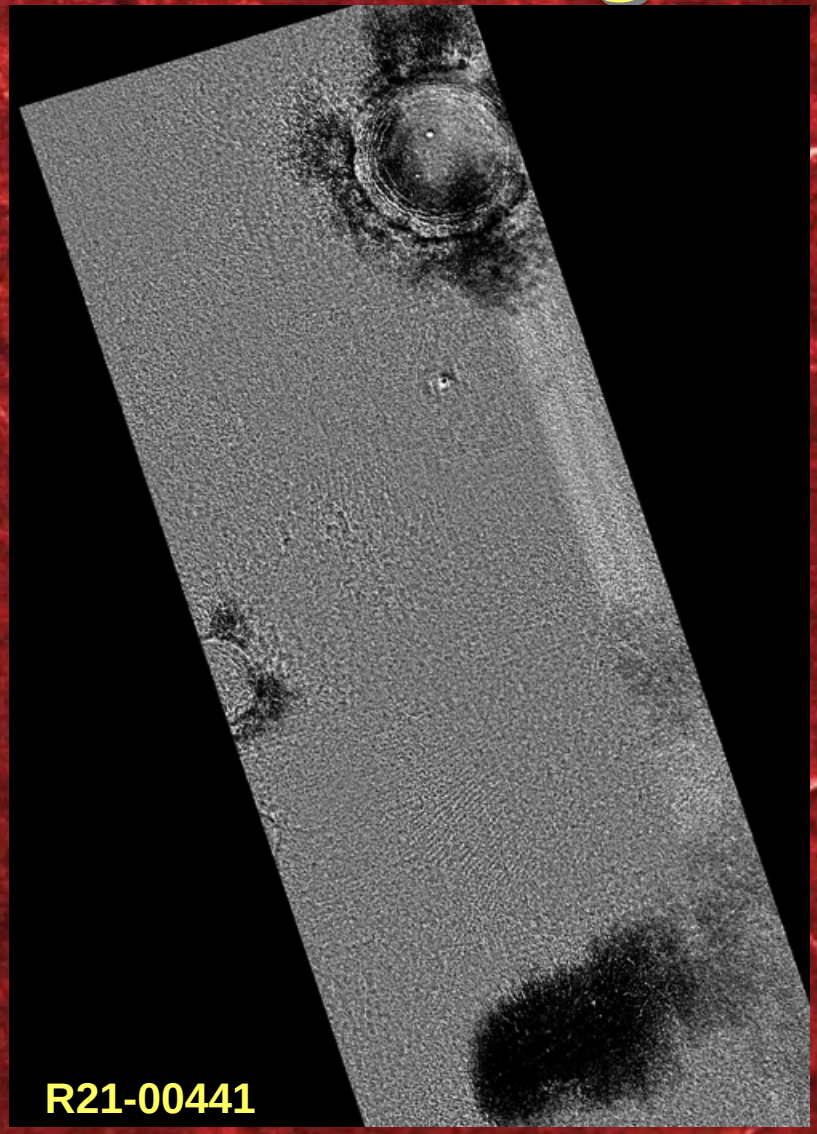
3 eliminated: no sign of MOLA topo in image

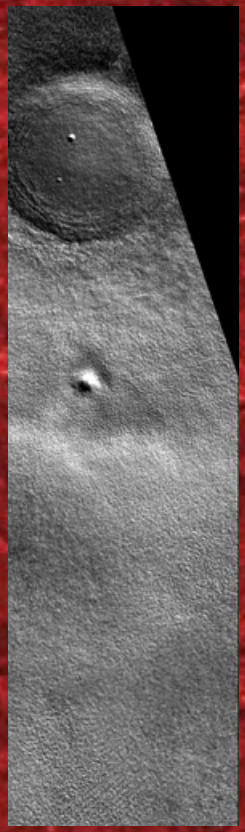
2 eliminated: albedo too variable

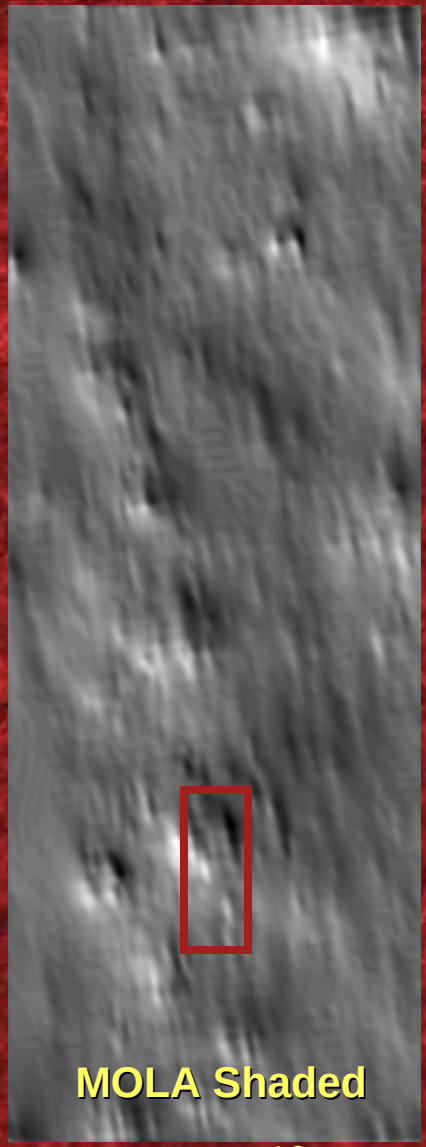
1 eliminated: mostly in shadow

3 sites studied, 1 using pair of images to suppress albedo var

PHX B6 “Magic Airbrush”



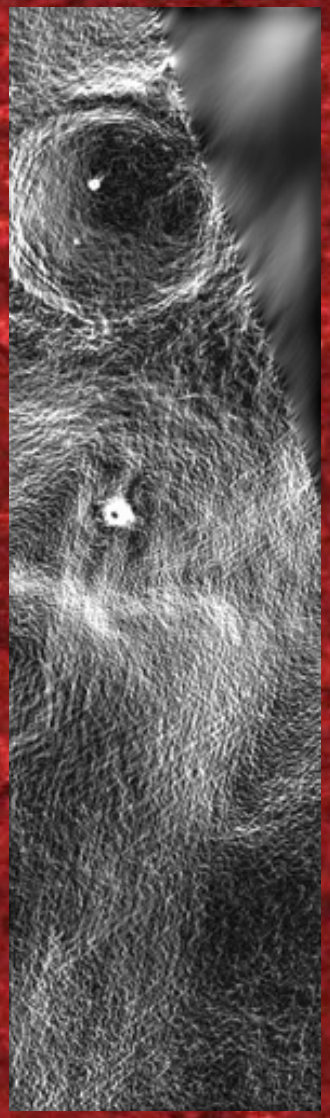




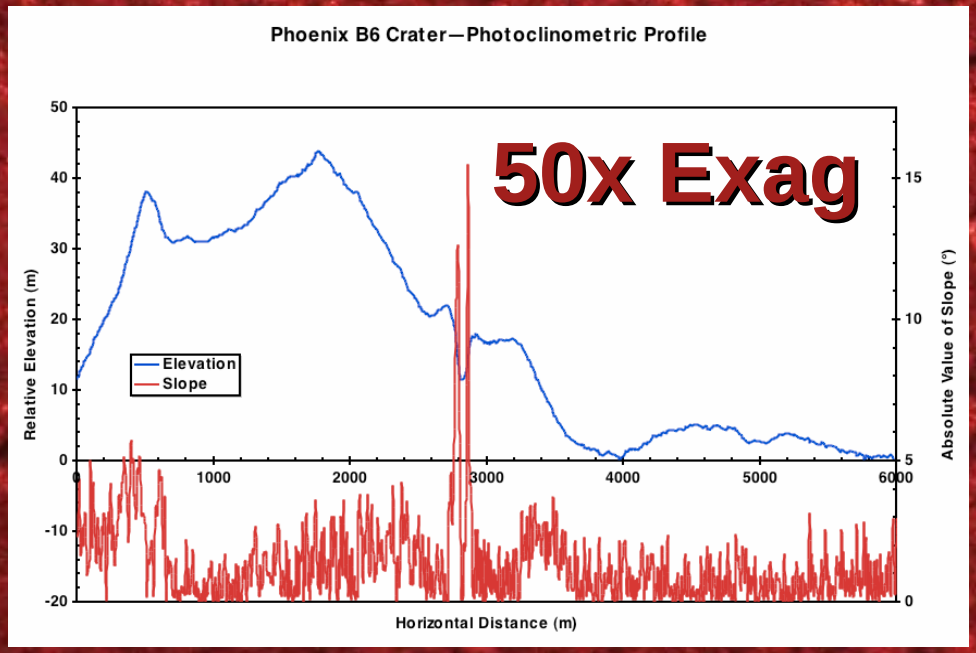
PHX B6 PC and MOLA Compared

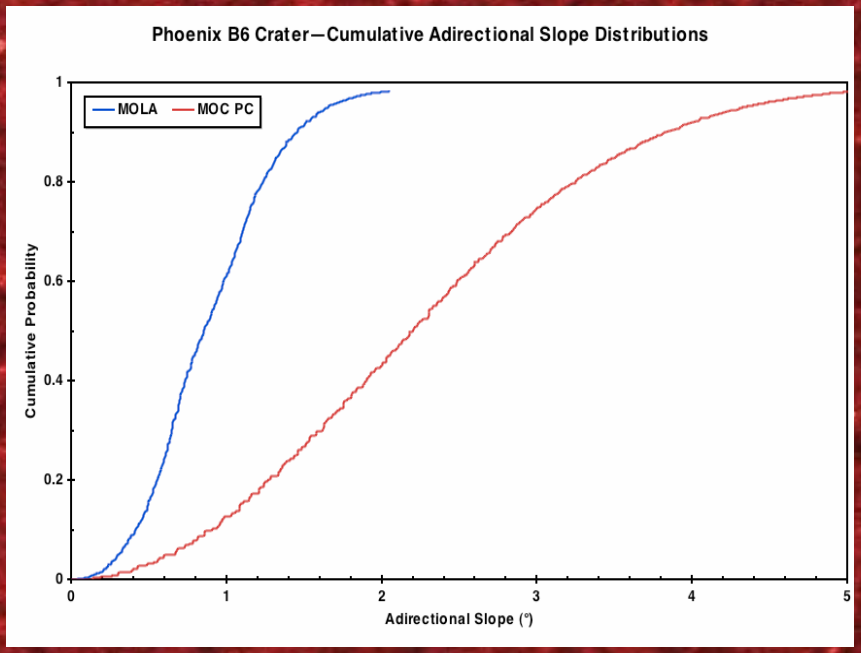
Rel Elevations (0–80m)

Adirectional Slope (0–5°)

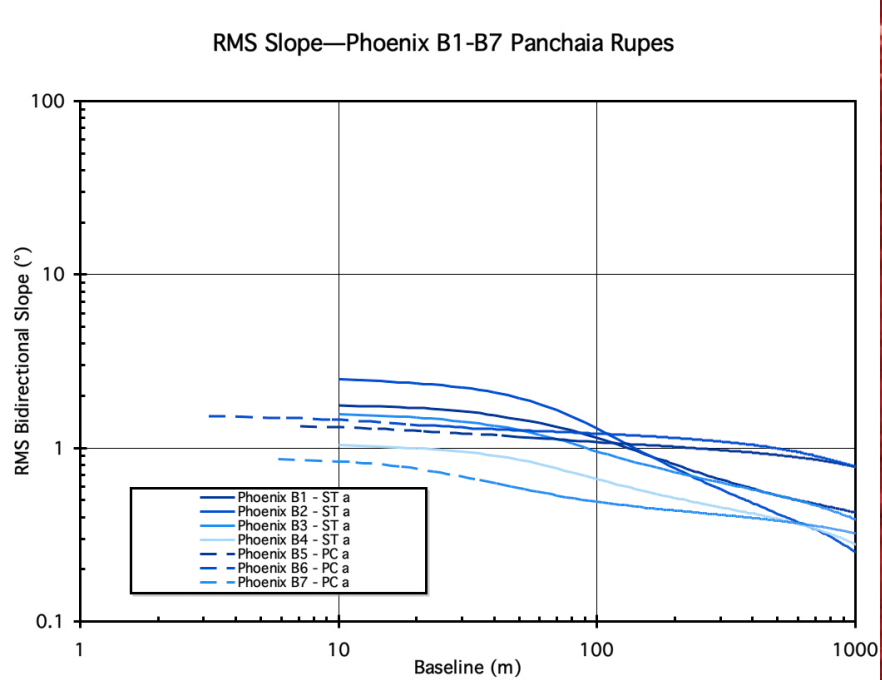


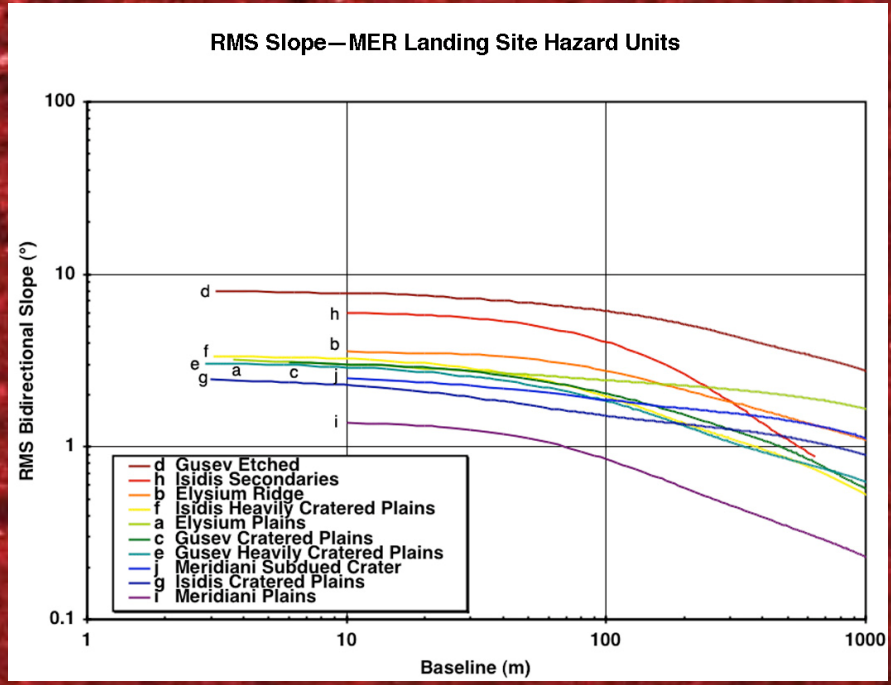
PHX B6 Crater Slopes



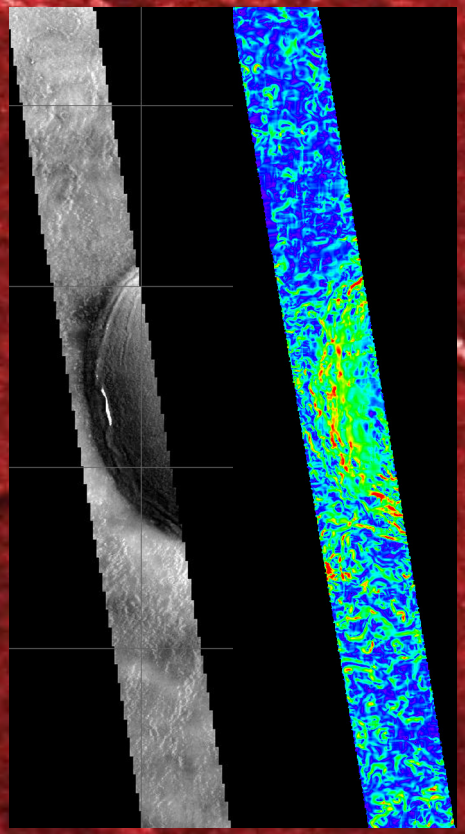


Slope vs. Baseline
Phoenix B1-7 and MER Compared

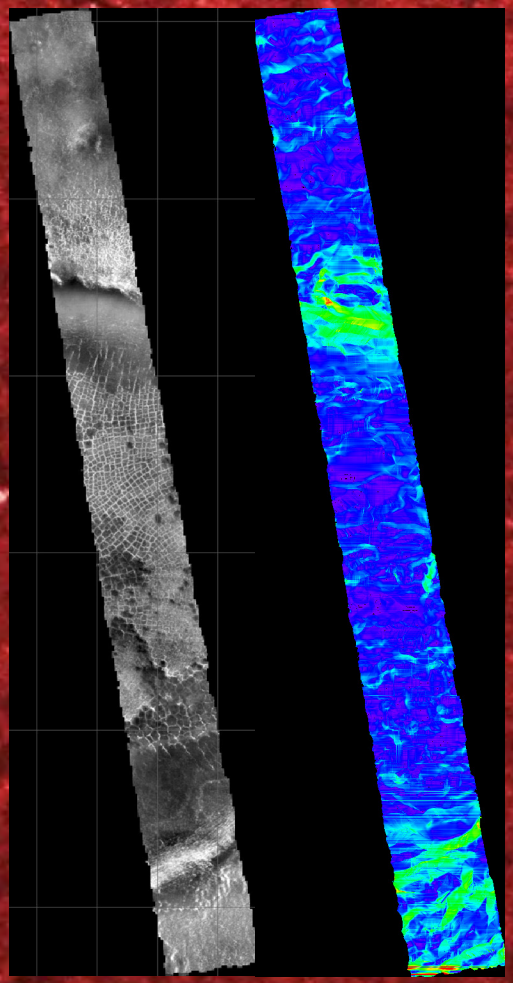




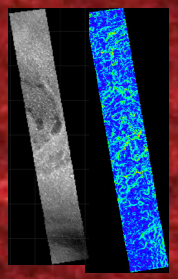
Crater Slopes from Stereo



PHX A1



PHX C1



PHX D1
(degraded)

Slopes at 18 m base-line from stereo DTMs collected at 6-21 m/post

Conclusions

- Reliable slope estimates have been obtained despite difficulties with sparse coverage, albedo variations and lack of clear topo features for PC haze calibration
- Stereo resolves hills and craters; PC resolves "basketball" nubs and pits
- Slopes on fresh craters, pits exceed 10° *in small areas*
- Slopes on pedestal & degraded craters, hills are ≤5°
- Slopes on "basketball" nubs are <<5°
- Overall, roughness compares to MER A/B sites

Spare Slides

Potential Problems

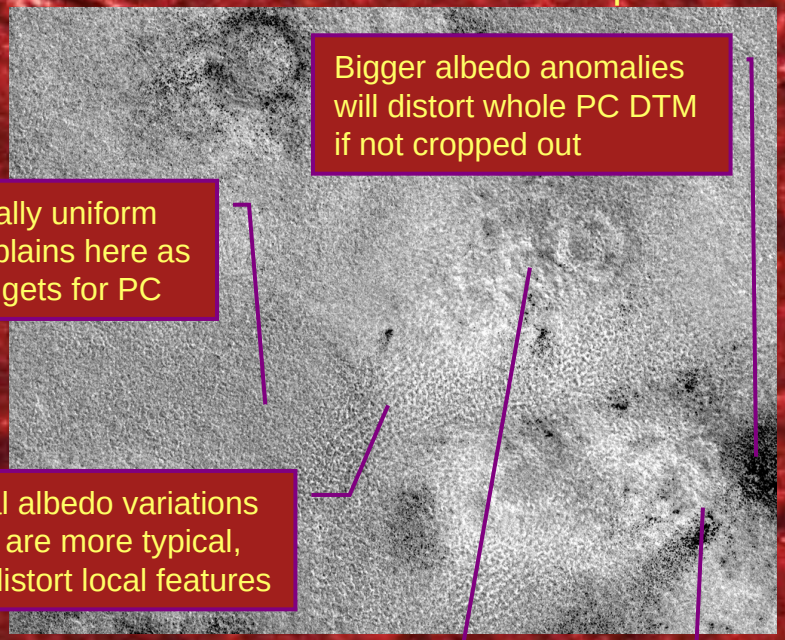
- For stereoanalysis
  - Scarcity of image pairs
  - Poor image quality, lack of texture, surface changes, etc.
  - Imaging modes not yet usable (cPROTO)
  - "Jitter": high-frequency motion of s/c during imaging
    - Along stereobase —> "washboard" topography
    - Around boresight —> "lasagna" topography
    - Across stereobase —> difficulty steresmatching ("beer goggles")
- For photoclinometry
  - Must be "calibrated" for contrast-reduction due to haze; requires presence of suitable features
    - Big enough to be resolved in stereo DTM
    - Small enough that photoclinometry is relatively accurate
    - Steep enough to modulate brightness appreciably
    - Not too much albedo variation
  - Variations in albedo introduce artifacts in DTM

Why Roughness Hazard Assessment for Phoenix is Hard

- Geomorphology of landing zone is relatively uniform and large features are subdued/benign
- *Identity, roughness of small features crucial*
  - A few huge boulders (fully shadowed) among the "basketball" bumps, or
  - A continuum of bumps with slope-related shading more or less visible through their low albedo?
- *Can only make quantitative discrimination by photoclinometry*; features are only a few pixels so stereo does not resolve them
  - Requires good haze calibration (from stereo)
  - Equivalent question in qualitative terms: What do the features look like w/atmospheric haze stripped away? Better yet, with albedo stripped away?
    - High contrast (boulders/steep slopes/shadows), or
    - Low contrast (bumps/gentle slopes/shading)?
- *Low relief and strong albedo variations on features seen in stereo make them almost useless for calibration purposes*
- **HiRISE images/DTMs will be incredibly valuable**

Example: A favorable case (!) for photoclinometry calibration

PHX B3 S01-00601 3.36 m/pixel



Bigger albedo anomalies will distort whole PC DTM if not cropped out

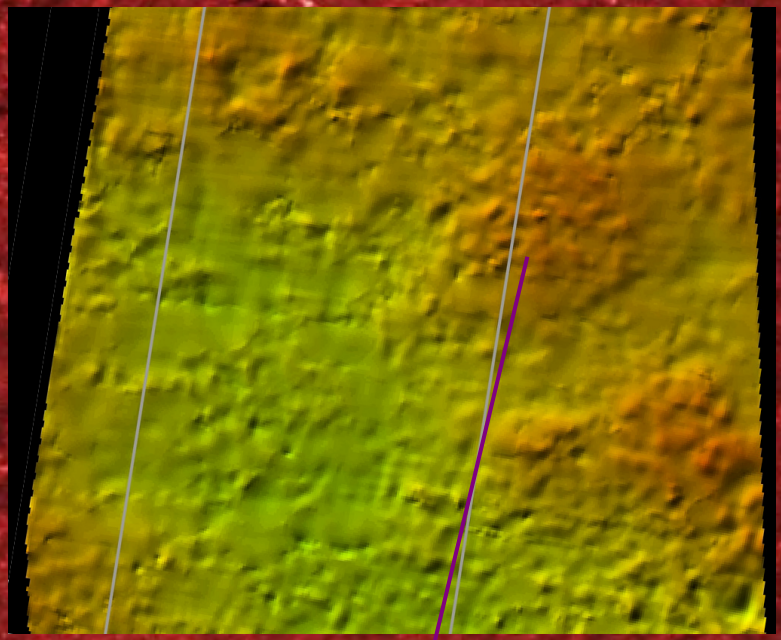
Exceptionally uniform albedo in plains here as good as it gets for PC

Local albedo variations here are more typical, will distort local features

This hill is as good as it gets for calibration… but close examination shows "shading" is mostly variation in density of bright cracks

Total I/F range 0.12-0.14 (15%) *Mostly albedo*

Portion of stereo DTM



"Calibration hill" is only 10 m high

Previously Reported Models

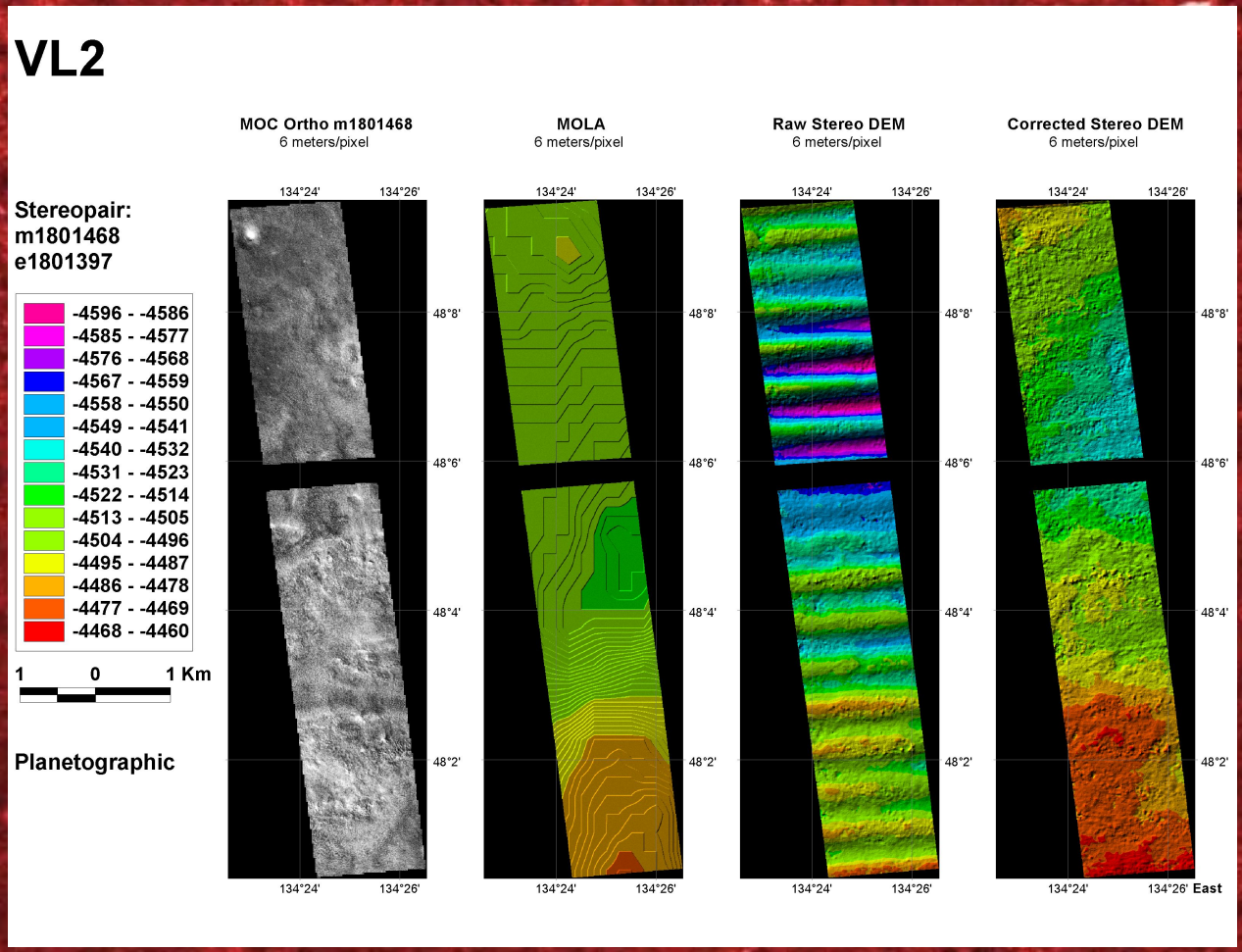
Workshop 1 Sites

- Viking Lander 2
  (PHX analog S of zone)
  - 134°E 48°N
  - M18-01468/E18-01379
  - PC calibration difficult
- Phoenix 0
  (analog N of zone)
  - 196.5°E 73.5°N
  - E02-01891/R01-01314
  - Stereo hopeless
  - PC calibration difficult
- Phoenix A1
  - 251.6°E 66.8°N
  - M23-02019/E23-00945
  - Crater useful for calibration; assess roughness outside
- Phoenix C1
  - 64.6°E 70.2°N
  - M19-01733/E19-00409
  - Crater, bright polyg. cracks
  - Calibration poss but albedo variations make PC imposs
- Phoenix D1
  - 241.1°E 68.4°N
  - M00-00483/R19-02207
  - Very subdued crater
  - Albedo variations, low relief for cal make PC impossible

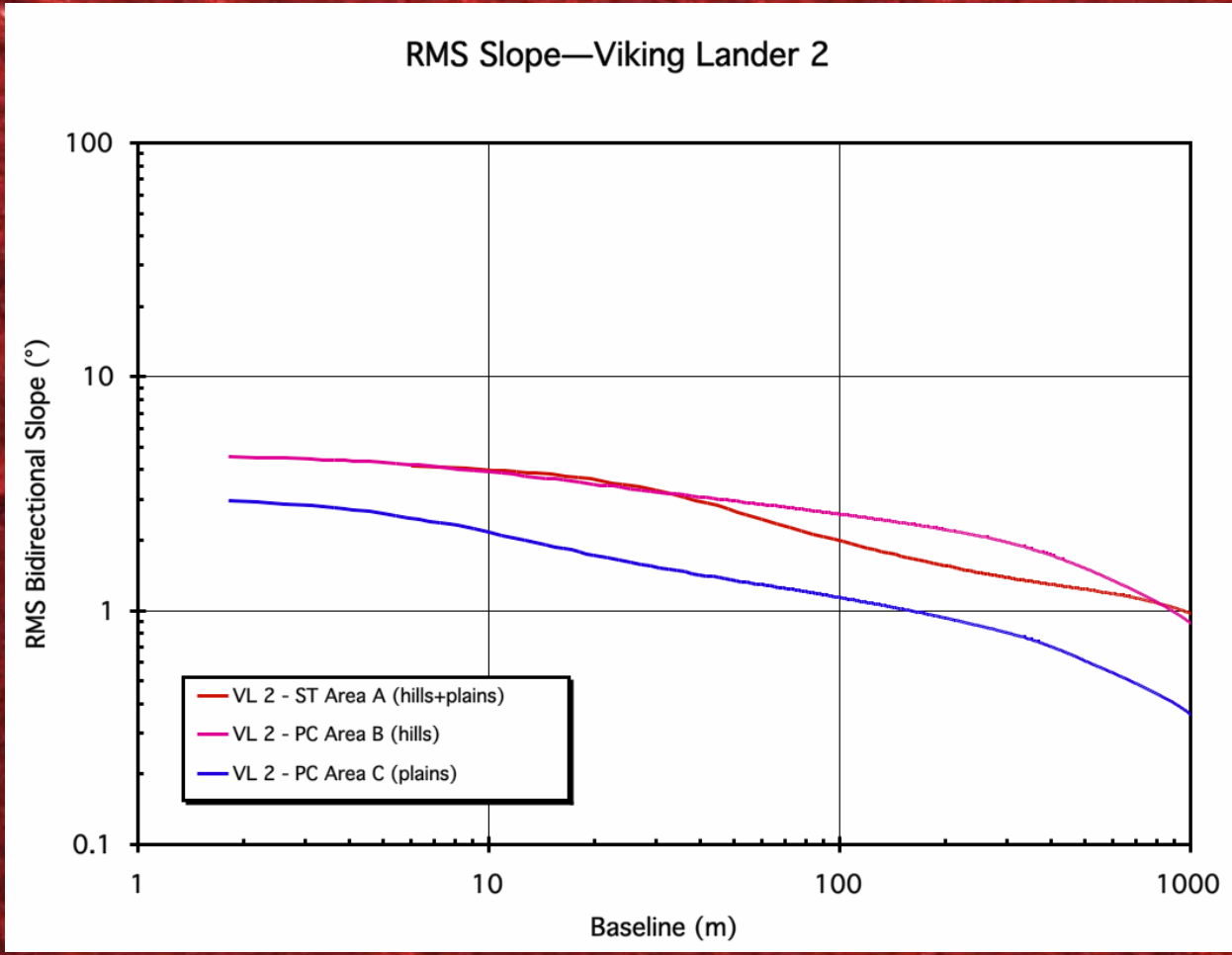
Workshop 2 Sites

- Phoenix B1
  - 130.4°E 67.8°N
  - R22-00168/S01-00644
  - Subdued crater marginally resolved; PC cal impossible
- Phoenix B2
  - 131.6°E 67.6°N
  - R23-00231/R22-00846
  - No resolved features, albedo variable; PC calibration impossible
- Phoenix B3
  - 131.4°E 67.2°N
  - S02-00705/S01-00601
  - Some resolved hills; PC calibration maybe possible
- Phoenix B4
  - 126.6°E 67.1°N
  - S02-00736/S01-00875
  - Crater w/ polygons on floor
  - Low hill with dark albedo; PC calibration impossible
- Phoenix A2
  - 259°E 69°N
  - R22-01155/R23-00908
  - No resolved features; PC calibration impossible

Viking Lander 2 – Utopia



Slope vs. Baseline at VL2: Modest slopes w/ conservative PC haze level

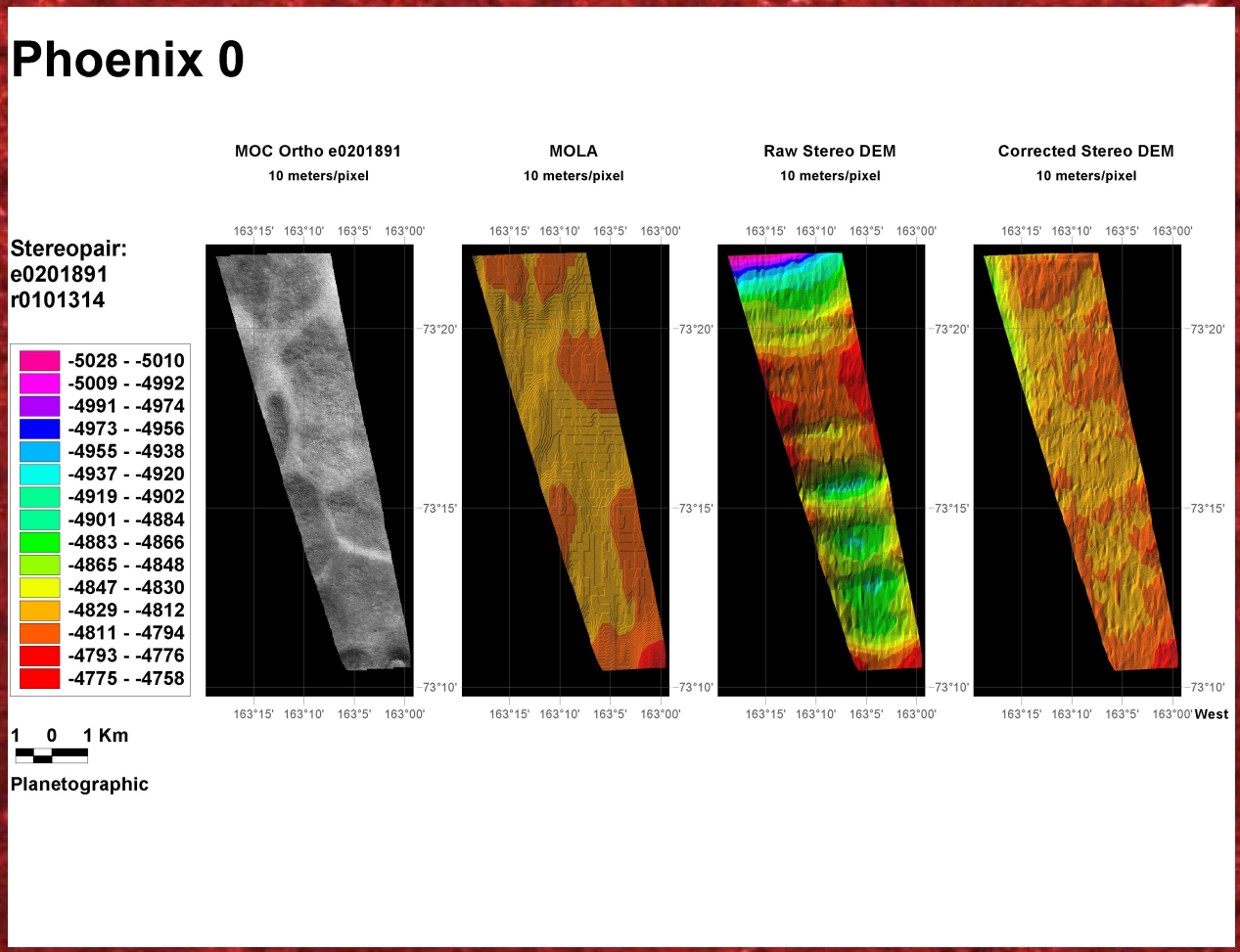


One stereopair analyzed, ~20 km NNE of landing pt

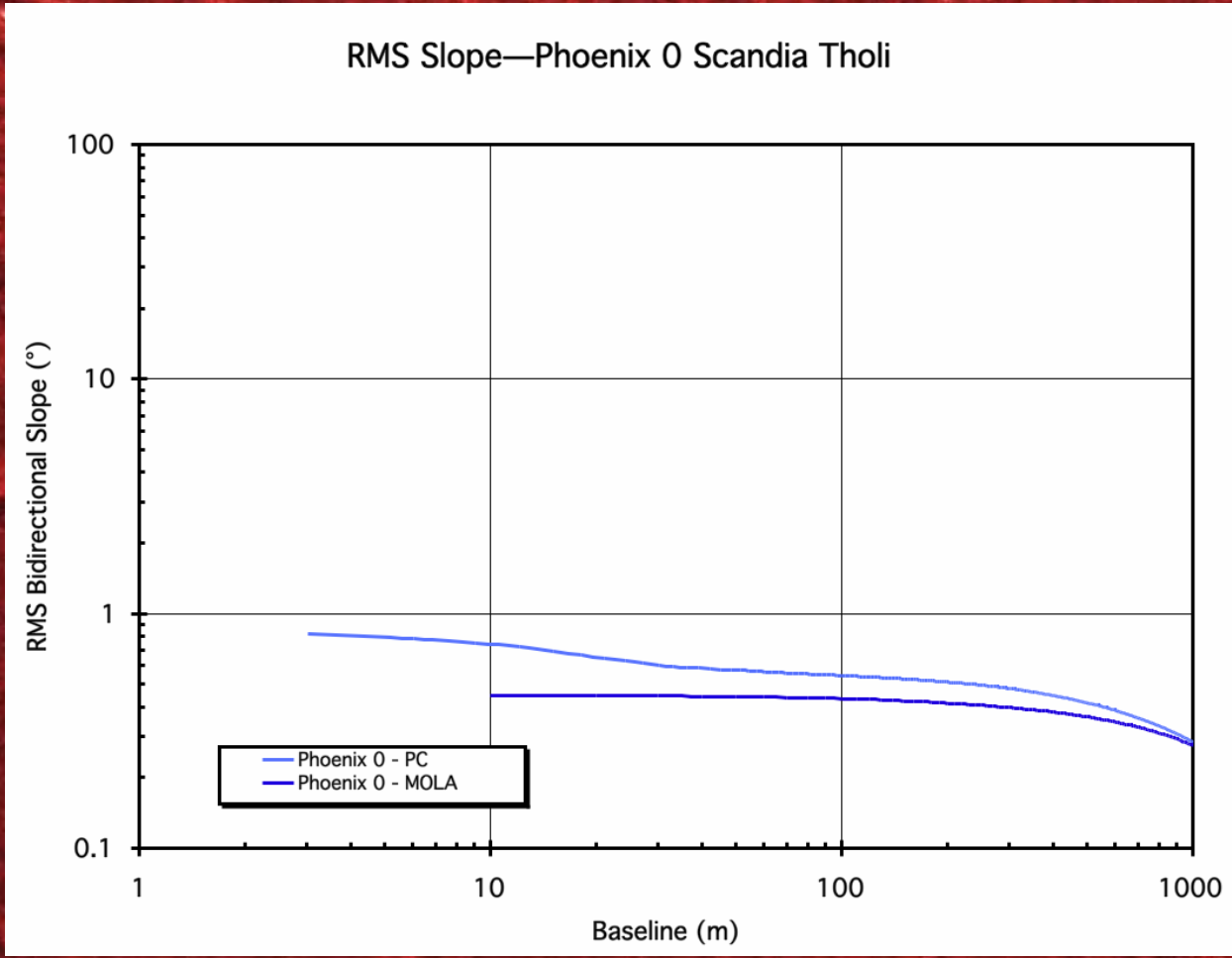
Stereo DTM not useful for calibration of image haze—using darkest pixel gives good agreement with stereo slopes: 4.5° RMS at 1.8 m

Flat area with bumpy texture has 2.9° RMS

Phoenix 0 – Scandia Tholi

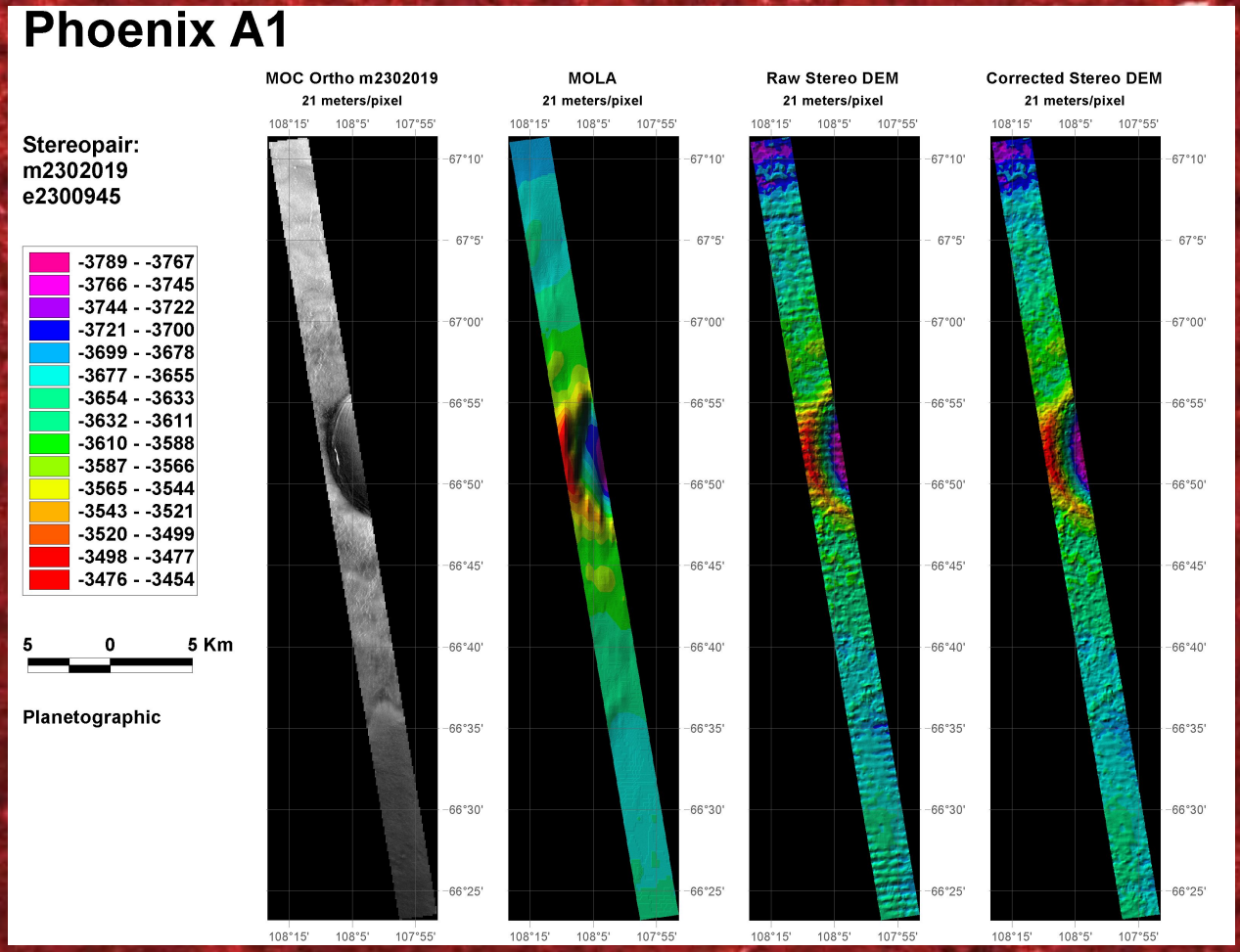


Slope vs. Baseline at Phoenix 0: Very low slopes from MOLA and PC

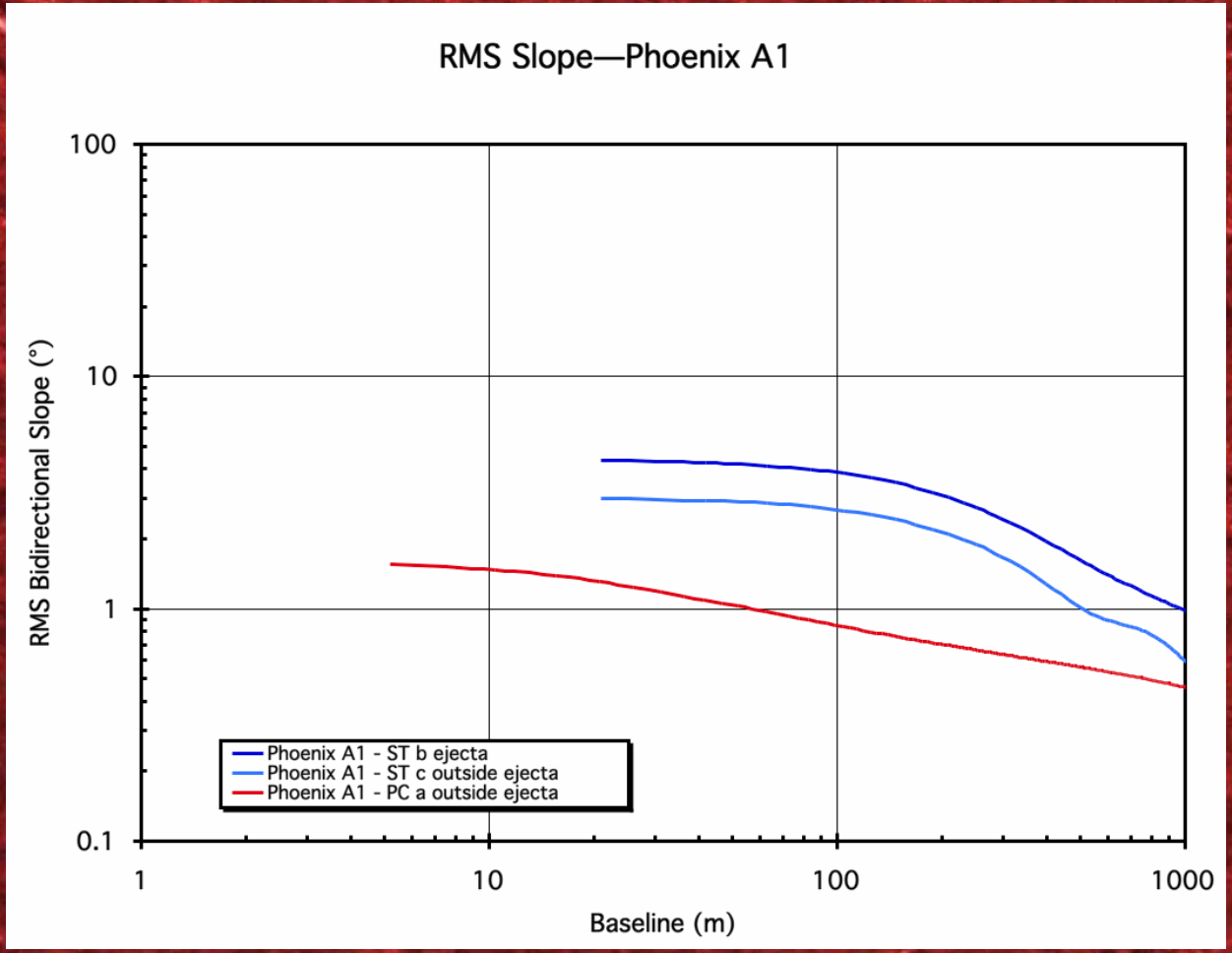


- First stereopair (after VL2) in Phoenix analog knobby terrain has severe jitter problems; stereo DTM useless
- MOLA resolves km polygons, cal gives haze = 0
- PC gives RMS slope 0.8° at 3 m with bumps well resolved
- Max possible haze would give RMS slope 3.4°

Phoenix A1


Phoenix A1
Stereopair:
m2302019
e2300945
-3789 - -3767
-3766 - -3745
-3744 - -3722
-3721 - -3700
-3699 - -3678
-3677 - -3655
-3654 - -3633
-3632 - -3611
-3610 - -3588
-3587 - -3566
-3565 - -3544
-3543 - -3521
-3520 - -3499
-3498 - -3477
-3476 - -3454
5 0 5 Km
Planetographic
MOC Ortho m2302019
21 meters/pixel
MOLA
21 meters/pixel
Raw Stereo DEM
21 meters/pixel
Corrected Stereo DEM
21 meters/pixel
108°15'
108°5'
107°55'
67°10'
67°5'
67°00'
66°55'
66°50'
66°45'
66°40'
66°35'
66°30'
66°25'

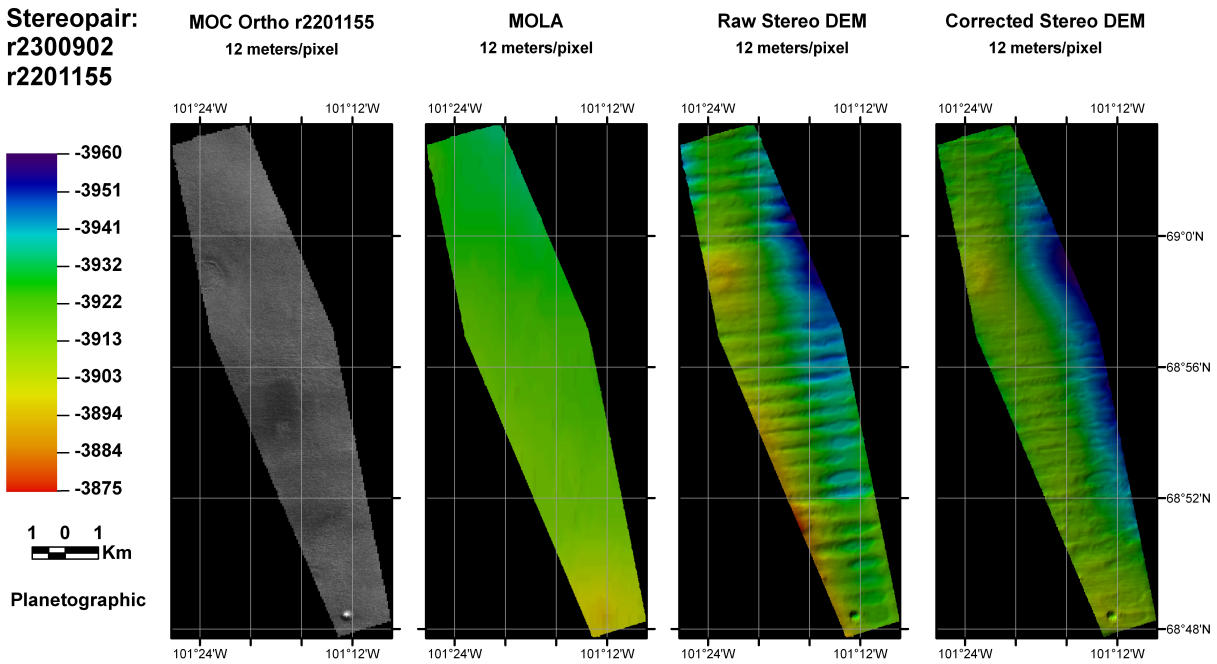
Slope vs. Baseline at Phoenix A1: Low slopes outside crater



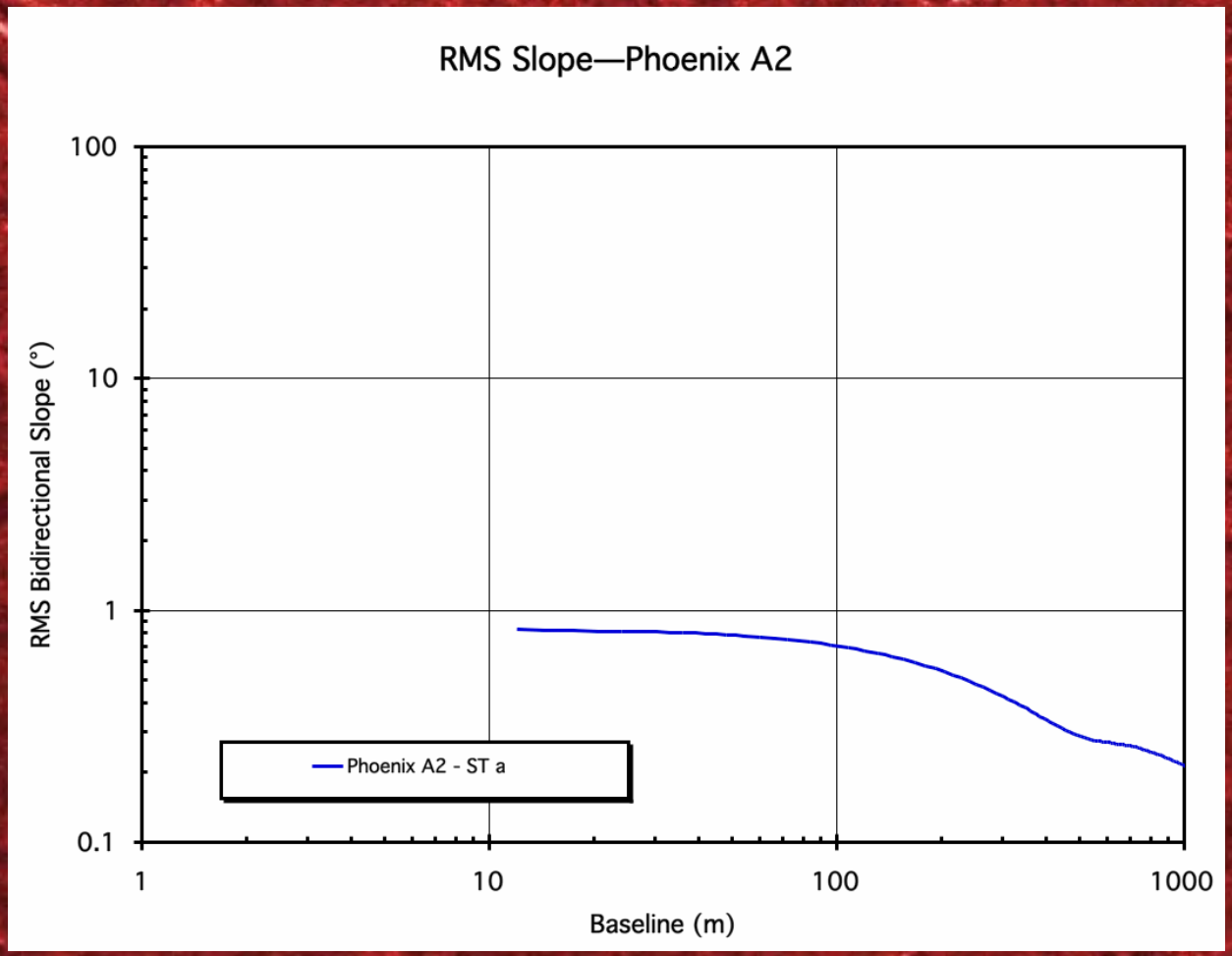
- First stereopair in Phoenix Zone, on edge of Box A
- Stereo DTM of crater rim gives excellent haze cal
- ST gives RMS slope 3.7° outside ejecta —dominated by residual jitter effects
- PC gives RMS slope 1.5° at S end of image (bumpy terrain farthest from ejecta blanket)
- ST slopes inside crater rim ~10° to locally 20°

Phoenix A2

Phoenix A2



Slope vs. Baseline at Phoenix A2

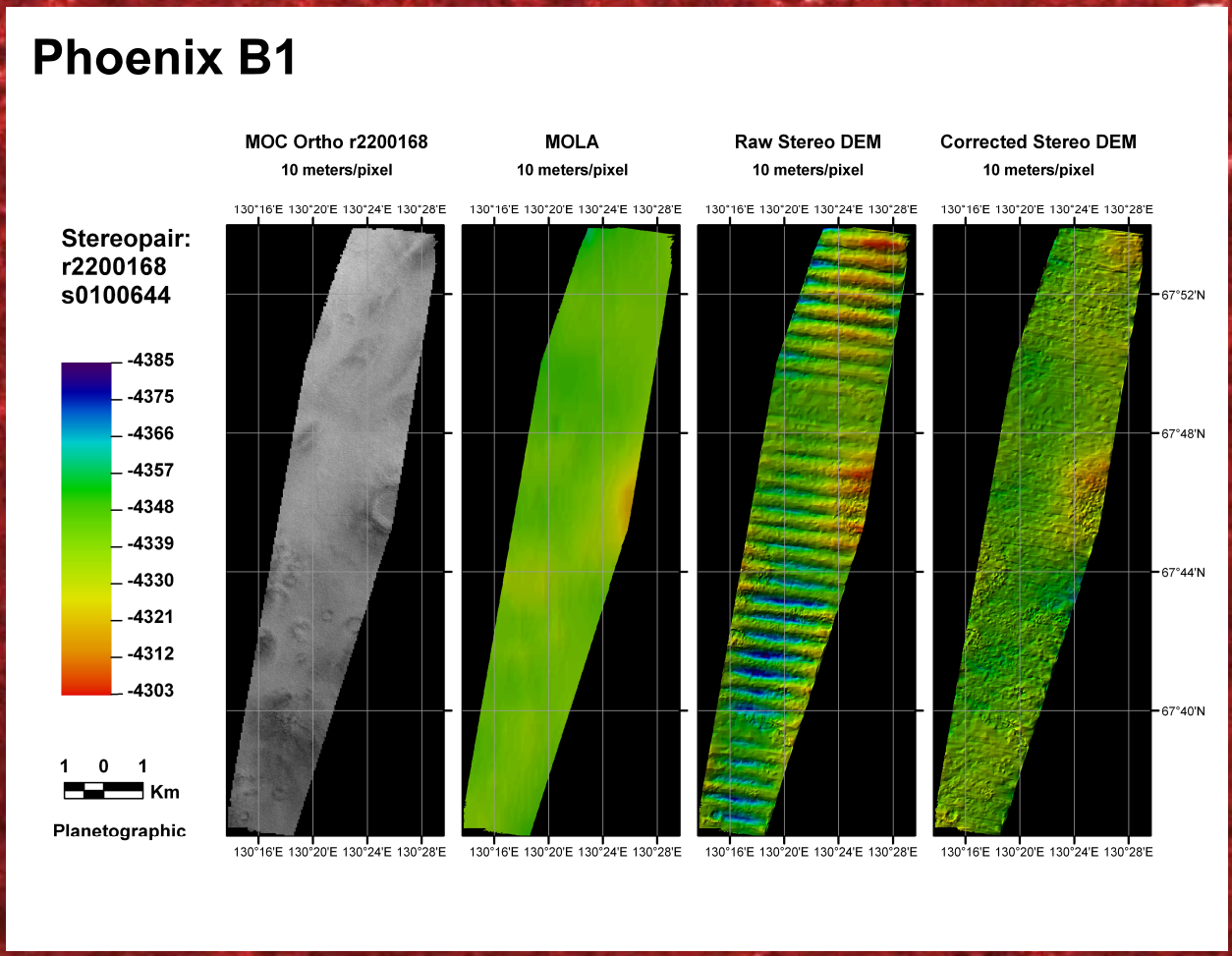


Second pair in Box A

ST Slope 0.8° RMS in N-S direction despite residual jitter "washboard"; almost no real features seen

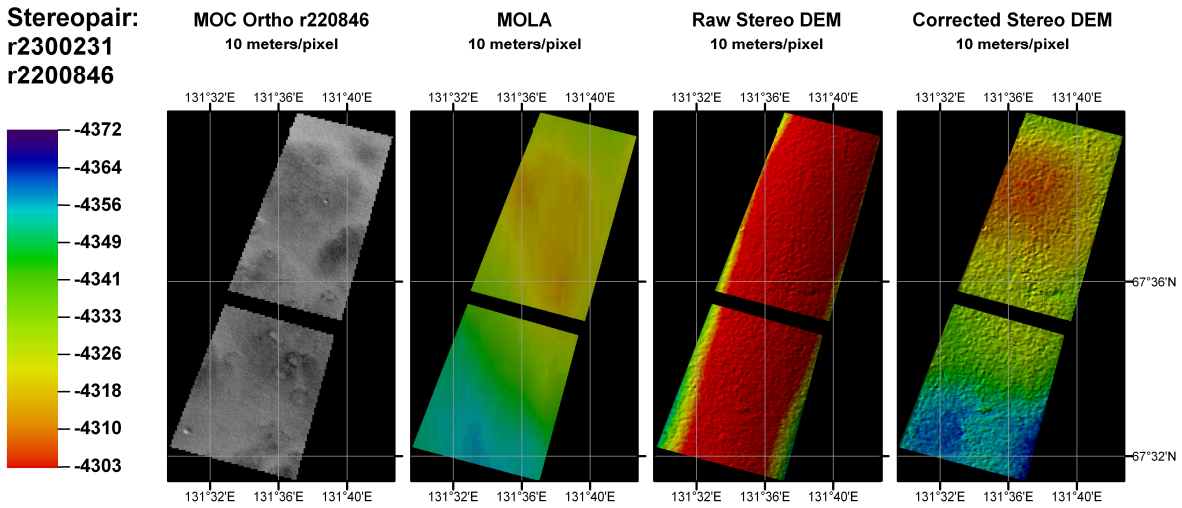
PC calibration impossible without features in ST

Phoenix B1

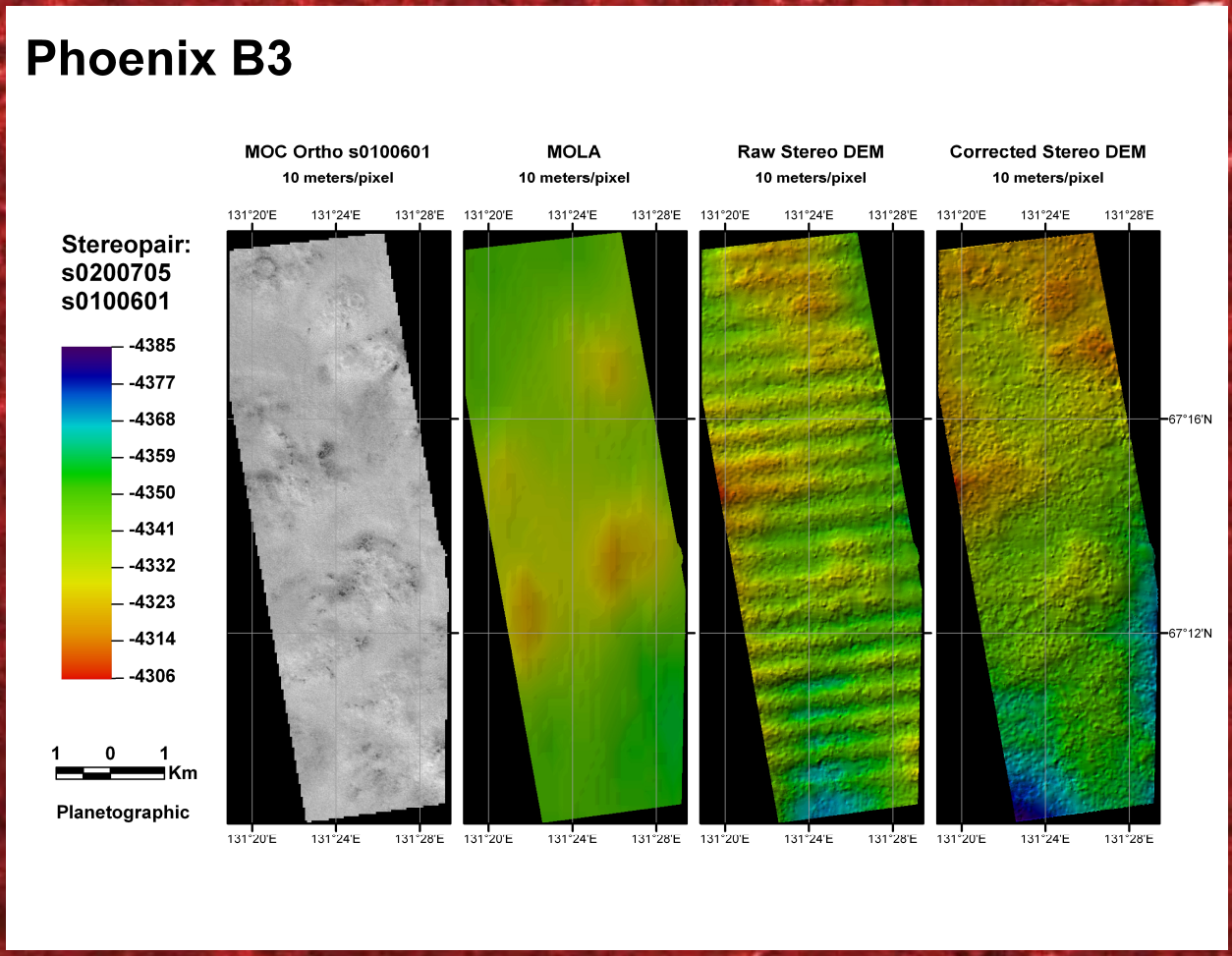

Phoenix B1
MOC Ortho r2200168
10 meters/pixel
MOLA
10 meters/pixel
Raw Stereo DEM
10 meters/pixel
Corrected Stereo DEM
10 meters/pixel
130°16'E 130°20'E 130°24'E 130°28'E
67°52'N
67°48'N
67°44'N
67°40'N
Stereopair:
r2200168
s0100644
-4385
-4375
-4366
-4357
-4348
-4339
-4330
-4321
-4312
-4303
1 0 1
Km
Planetographic

Phoenix B2

Phoenix B2

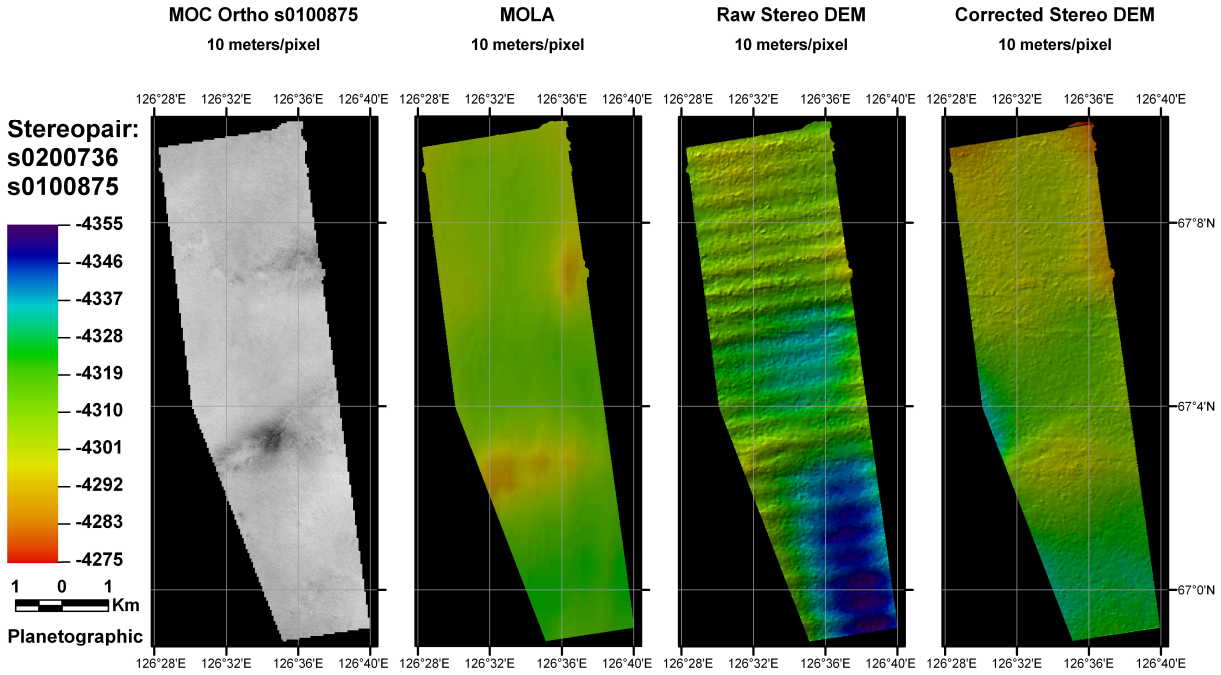


Phoenix B3

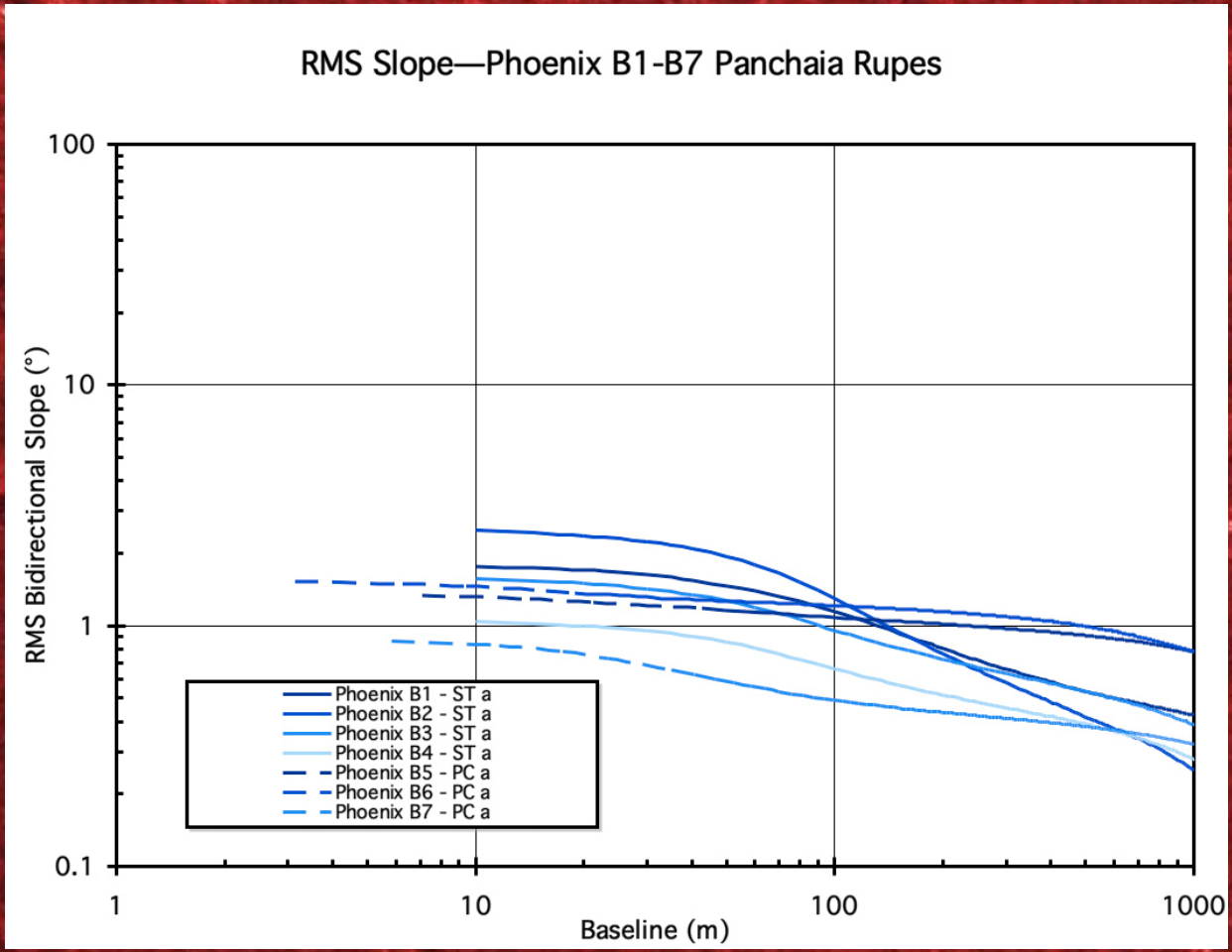

Phoenix B3
MOC Ortho s0100601
10 meters/pixel
MOLA
10 meters/pixel
Raw Stereo DEM
10 meters/pixel
Corrected Stereo DEM
10 meters/pixel
Stereopair:
s0200705
s0100601
-4385
-4377
-4368
-4359
-4350
-4341
-4332
-4323
-4314
-4306
1 0 1
Km
Planetographic
131°20'E
131°24'E
131°28'E
67°16'N
67°12'N

Phoenix B4

Phoenix B4

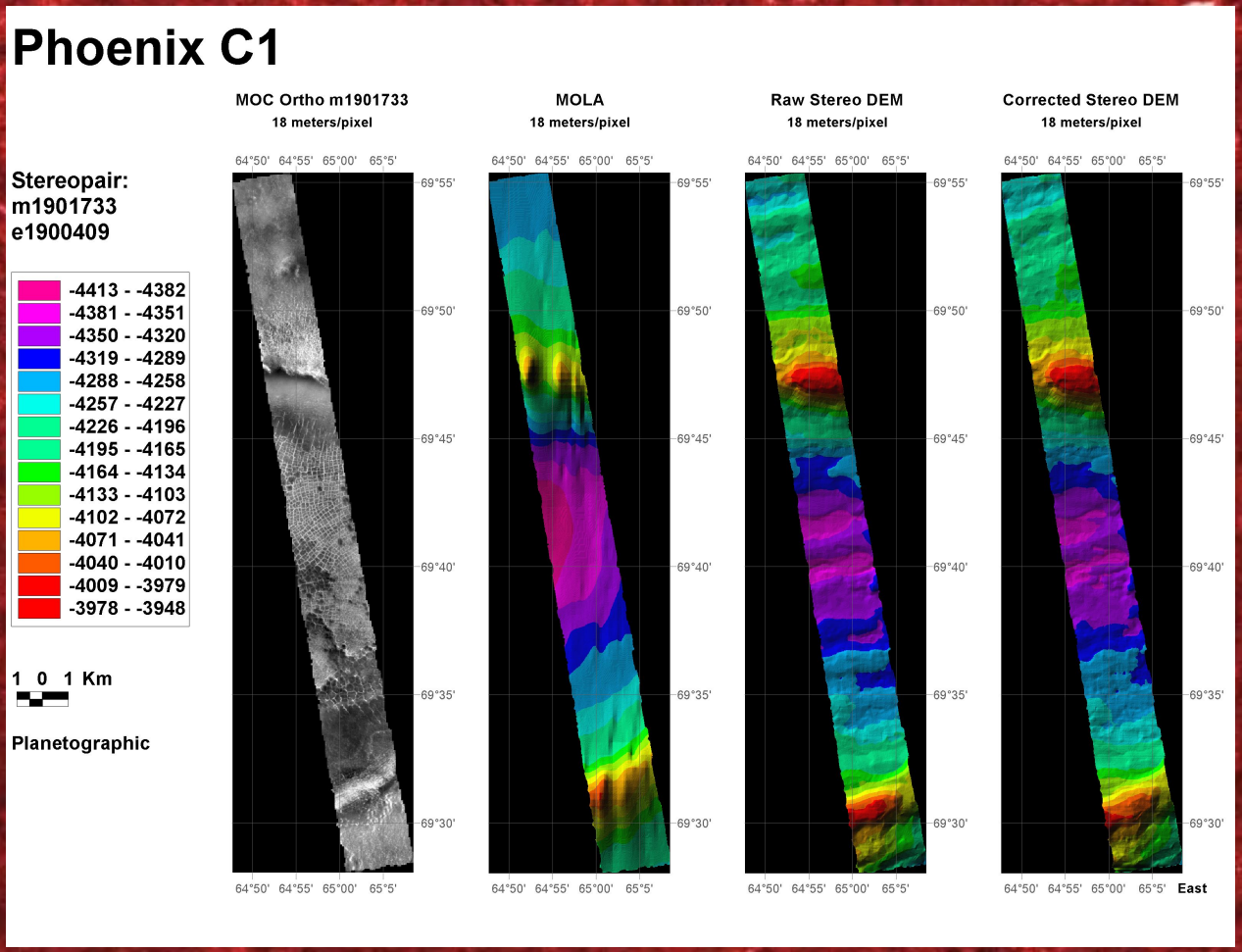


Slope vs. Baseline at Phoenix B1-7

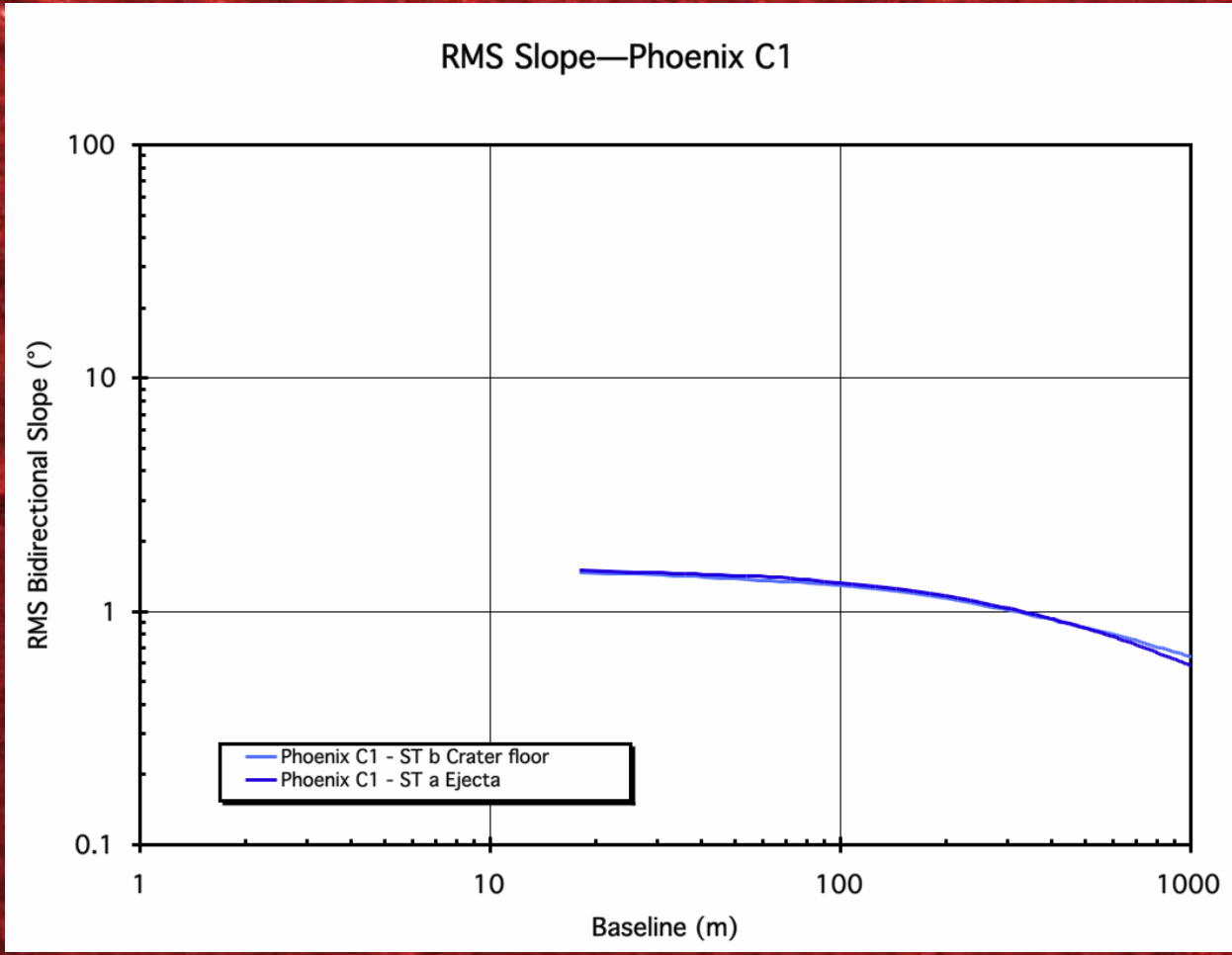


- Four stereopairs analyzed
- ST slopes range from 1.0°-2.5° RMS
- Three images cal to MOLA for PC
- PC slopes range from 0.8°–1.6° RMS

Phoenix C1

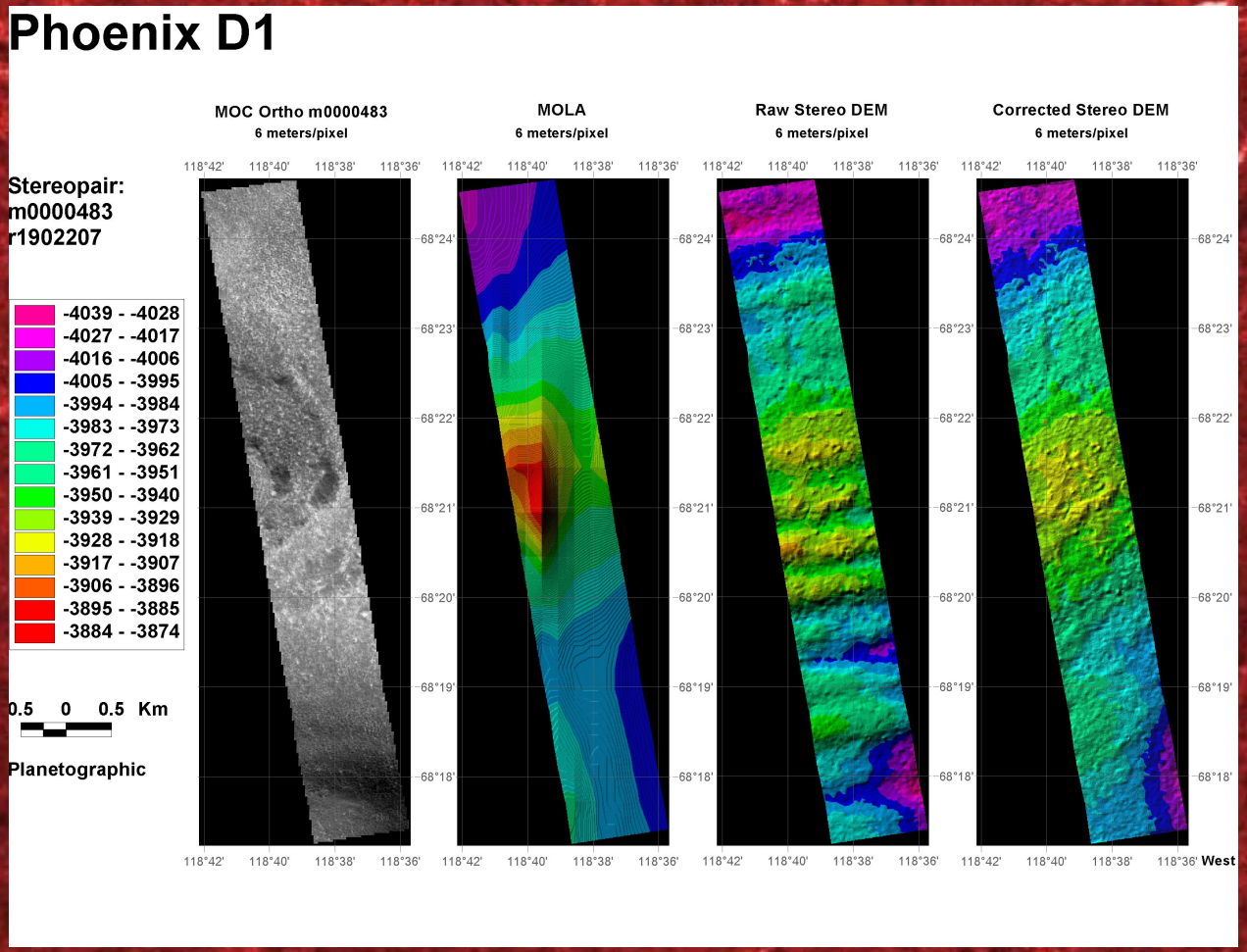

Phoenix C1
MOC Ortho m1901733
18 meters/pixel
MOLA
18 meters/pixel
Raw Stereo DEM
18 meters/pixel
Corrected Stereo DEM
18 meters/pixel
Stereopair:
m1901733
e1900409
-4413 - -4382
-4381 - -4351
-4350 - -4320
-4319 - -4289
-4288 - -4258
-4257 - -4227
-4226 - -4196
-4195 - -4165
-4164 - -4134
-4133 - -4103
-4102 - -4072
-4071 - -4041
-4040 - -4010
-4009 - -3979
-3978 - -3948
1 0 1 Km
Planetographic
64°50' 64°55' 65°00' 65°5'
69°55'
69°50'
69°45'
69°40'
69°35'
69°30'
East

Slope vs. Baseline at Phoenix C1: Stereo gives low slopes outside crater

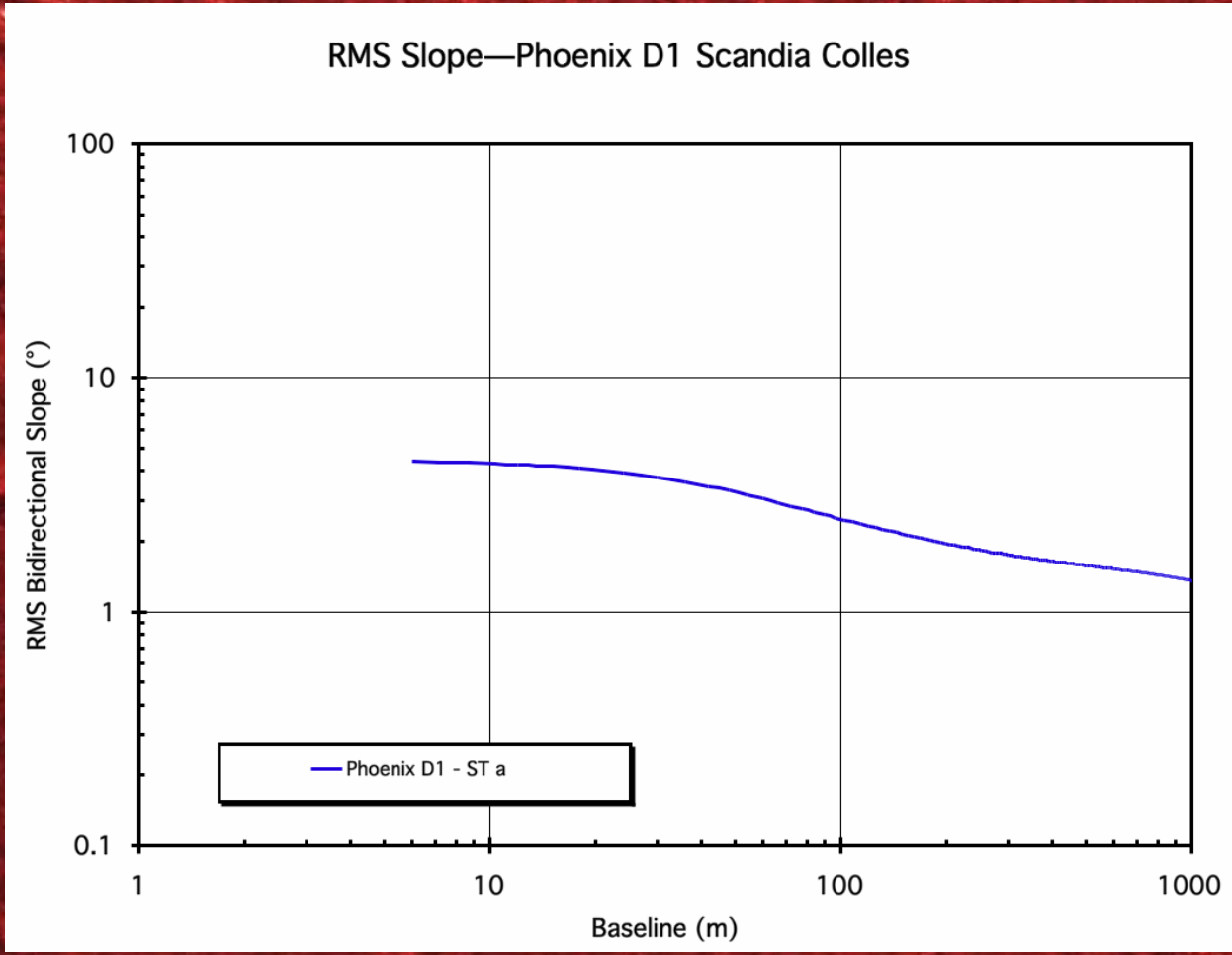


- First pair in box C (W edge) is crater with polygons on floor
- Stereo gives RMS slope 1.5° inside and out
- Good topo (crater rim) for calibrating haze but terrain consists of bright fractures on dark background; PC impossible
- Slopes on crater rim ~8° to locally 15°

Phoenix D1 – Scandia Colles



Slope vs. Baseline at Phoenix D1: Stereo gives moderate slopes



- First pair in box D is bumpy with degraded crater
- Stereo gives RMS slope 4.4°
- PC unlikely to give reliable results because of albedo variations; calibration difficult because of absence of well defined relief features