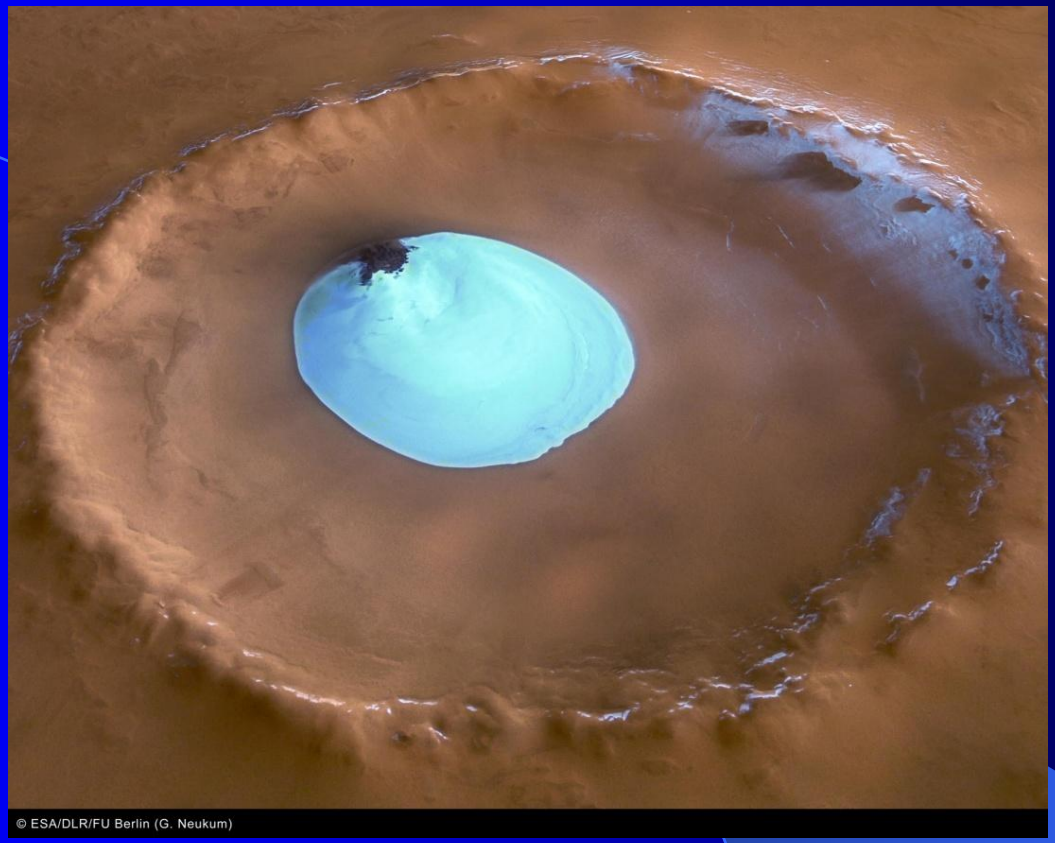
ENIGMA OF THE MARTIAN ATMOSPHERE: Higher than Advertised Air Pressure?



Presented by David A. Roffman,
Embry-Riddle Aeronautical University,

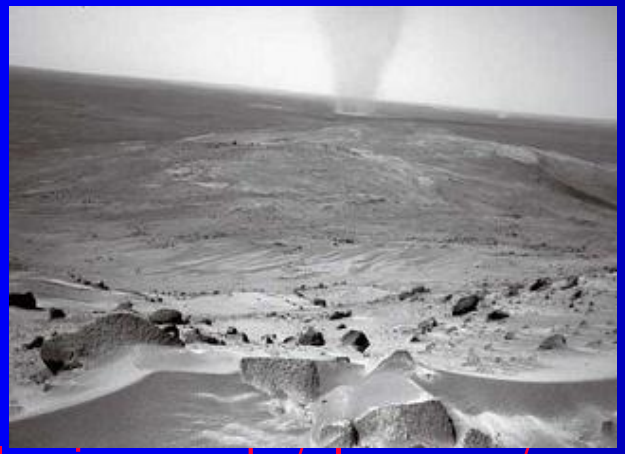
At the Thirteenth Annual International Mars Society Convention, Dayton, Ohio, 5 August 2010

Accepted Average Pressure 6.1 Mbar at Mars Areoid

- **Areoid is Mars equivalent of Sea Level.**
- **Average Pressure on Earth at sea level: 1013.25 Mbar.**
- **6.1 Mbar is nearly a vacuum.**

Why Question Accepted Pressure?

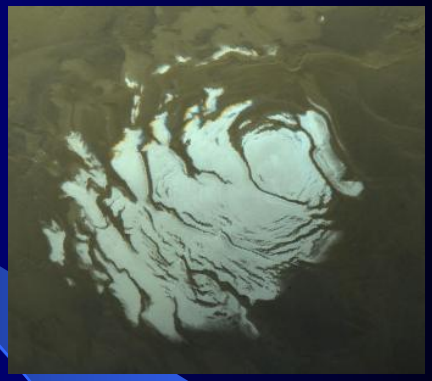
- Initial stimulus - similarities in Martian & Terrestrial dust devils.



http://www.lpl.arizona.edu/~lemmon/mer_dd/dd_enhanced_587a.gif

- Scope of Research: 1 yr. study, special topics course at ERAU, literature & NASA Ames Archives review, interviews of pressure transducer designers

Why Question Accepted Pressure?



- Not enough CO_2 at the South Pole to account for annual pressure fluctuations at Viking landers (Byrne and Ingersol, 2003).

- NASA Ames inability to replicate dust devils in tests at 10 mbar without using winds too high.

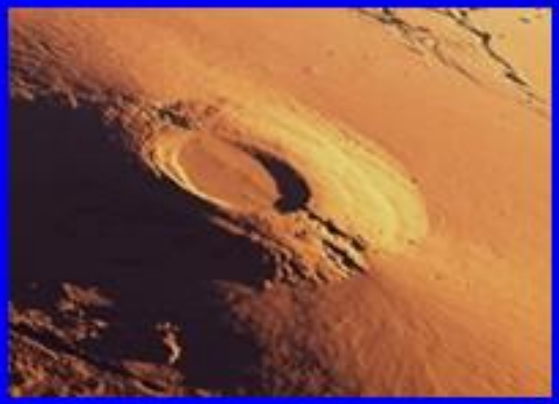
NASA AMES Experiment

Mars dust devils typically have speeds of 6m/s (~13 MPH), but during an Ames experiment at 10 mbar, a wind speed of 70 m/s (~156 MPH) was needed to form a dust devil.

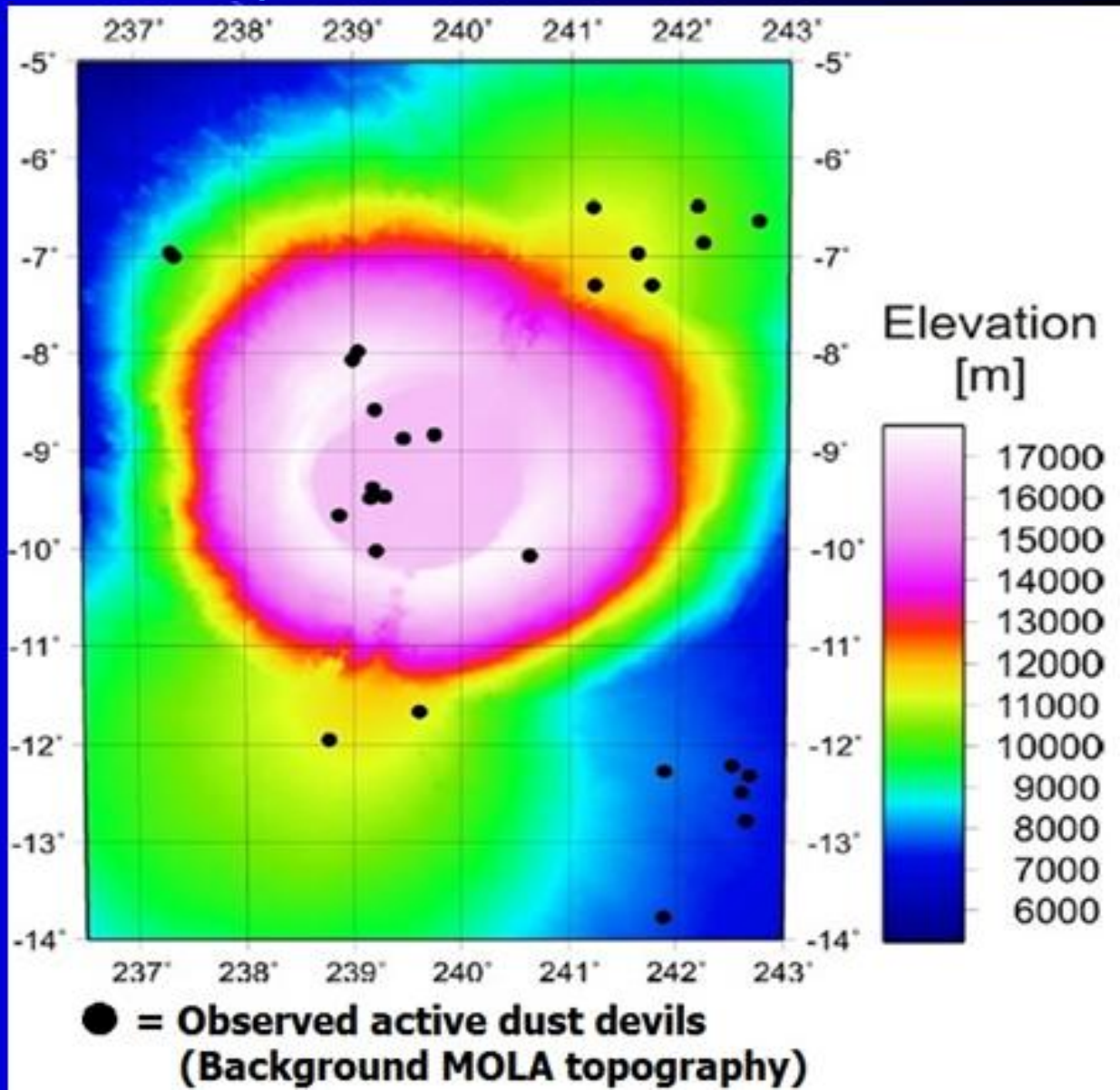
http://www.nasa.gov/centers/ames/research/exploringtheuniverse/vacumchamber_prt.htm.

Why Question Accepted Pressure?

Dust devils on Mars even form at 17 km on Arsia Mons.

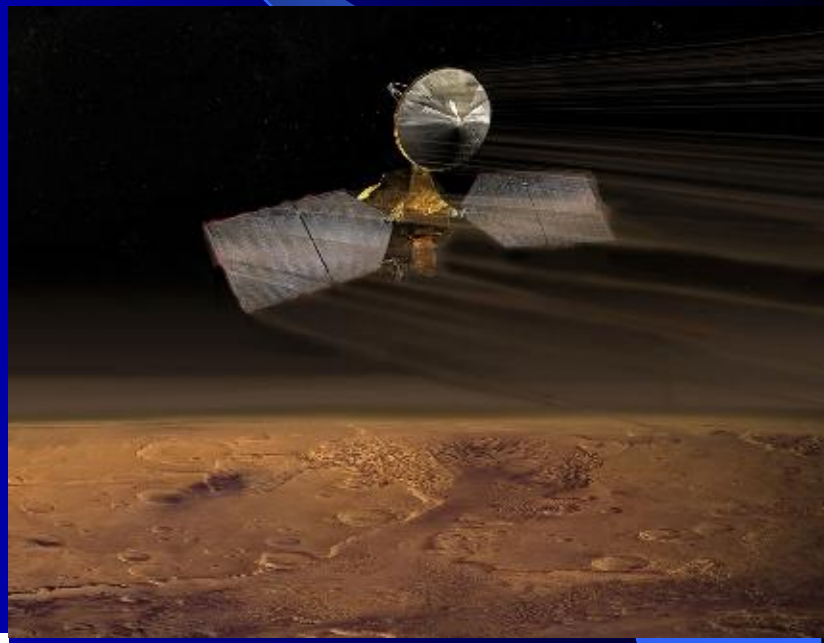


Pressure there should be only about 1 mbar!



Why Question Accepted Pressure?

- Dust storms increase dynamic pressures at 121 km (75 miles) by a factor of 5.6.



- Unexpectedly high deceleration during MRO & MGS aerobraking operations. Up to 350% error at South Pole.

Why Question Accepted Pressure?

- No way to change small dust filters on Vikings, Pathfinder, or Phoenix! Rapid clogging likely.

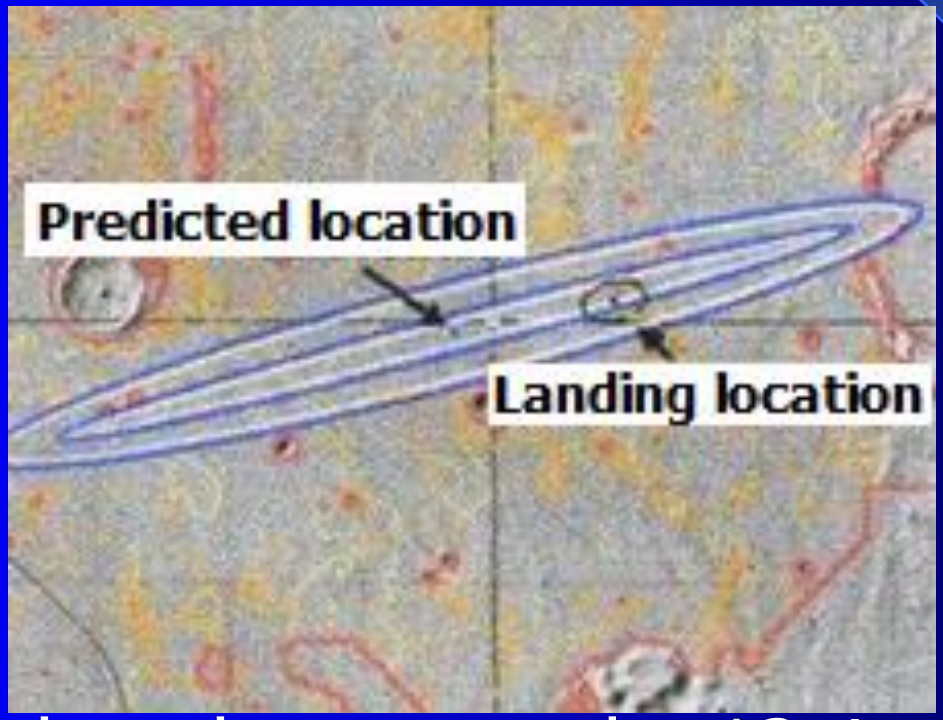
DIME SURFACE AREA = ~251.9 mm^2

TAVIS DUST FILTER FOR VIKING & PATHFINDER= ~40 mm^2

VAISALA DUST FILTER FOR PHOENIX = ~10 mm^2

Why Question Accepted Pressure?

- Disagreements between radio occultation and scale height calculations.



- Last 4 landers downrange by 13.4 - 27 km (request for help from NASA's Prasun Desai, 2008)

Why Question Accepted Pressure?

- Pathfinder anemometer could ***not*** be calibrated (due to misunderstanding pressure?)

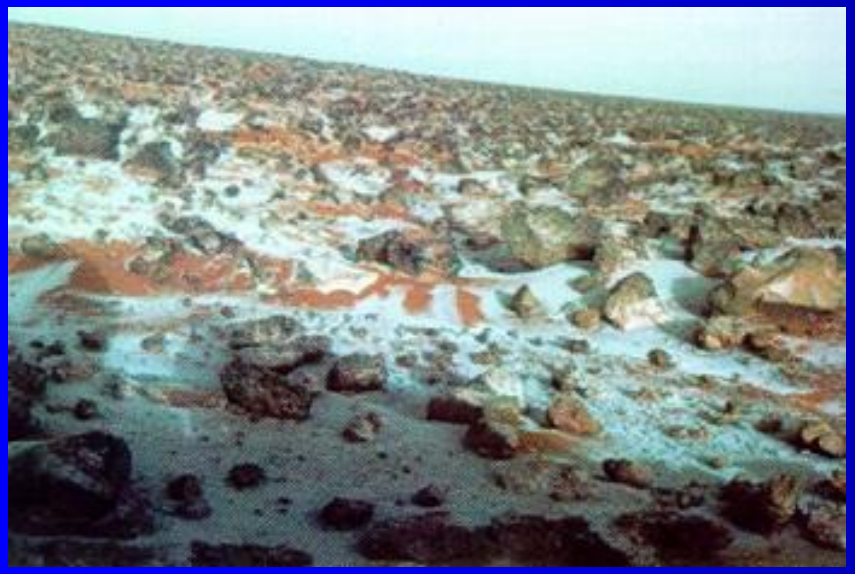
- No anemometer on Phoenix.
  Telltale could not measure speeds >10 m/s and only had 20 - 40% accuracy for winds <10m/s.

http://www.nasa.gov/mission_pages/phoenix/images/press/16613-animated.html

Why Question Accepted Pressure?

- Snow. Ice particles in clouds an order of magnitude too small for GCMs – 2 μm vs. 20 to 30 μm

(Richardson, et al., 2002)

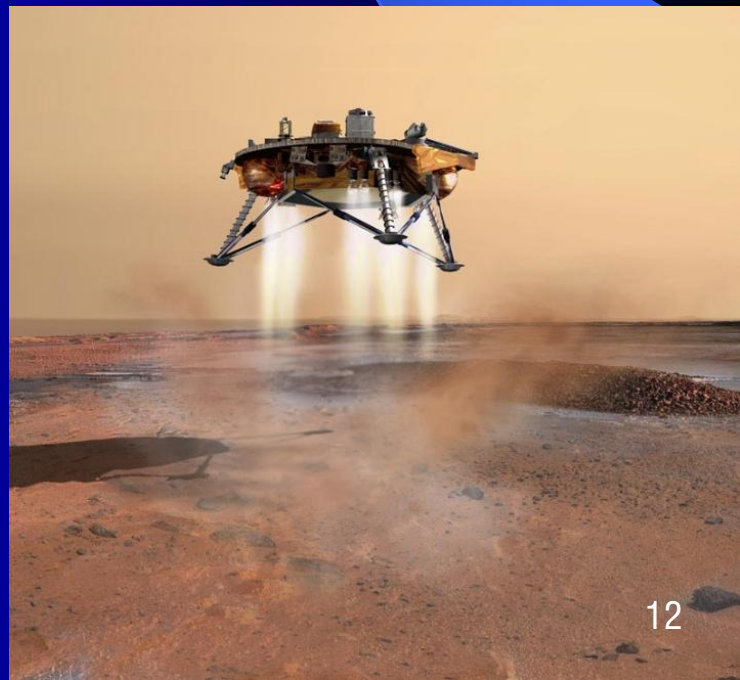


  - Small ice particles would sublimate too fast to fall as snow.

DUST DEVILS ARE THE MOST OBVIOUS WEATHER ANOMALY

- Dust devils are driven by pressure differentials. If there is so little air on Mars, how can there be enough Δp to generate them at all?

- Over 30 dust devils hit the Phoenix lander in just 150 days. MPF detected ~79 in 86 days.



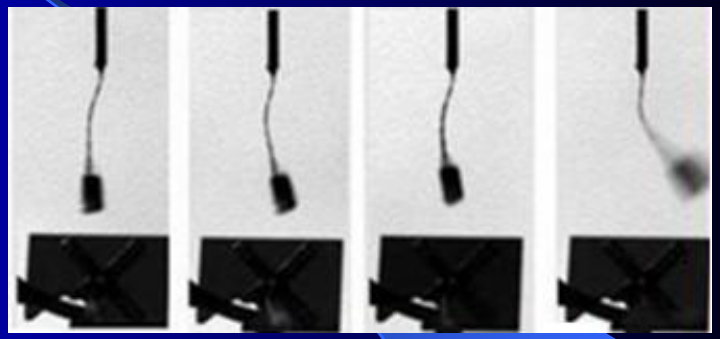
Similarities between Terrestrial and Martian Dust Devils

- Latitudes most often seen (30º and 65º N & S)
- Seasons (regional summer)
- Electrical properties

- Shape & often size (but can be 50 x wider and 10 x higher on Mars)
- Daily formation times (around noon)

Similarities between Terrestrial and Martian Dust Devils

- wind speed (6 m/s typical)

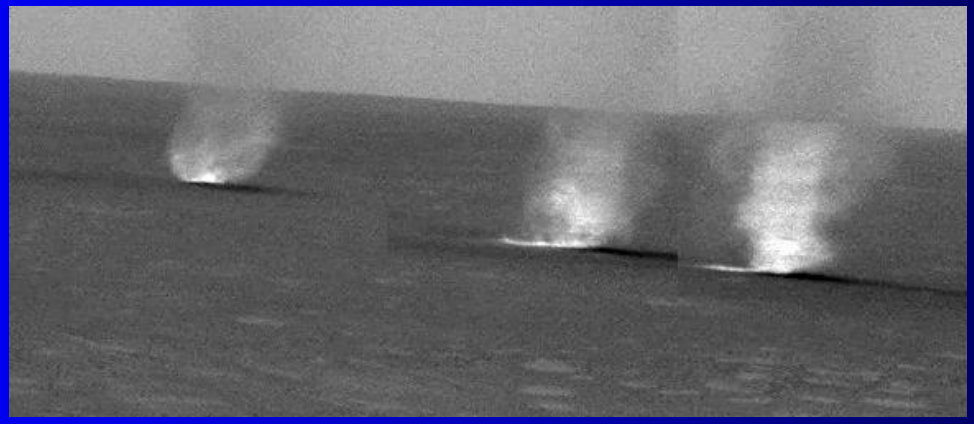


- core temperature increase (up to 10 K)

- dust particle size (1 μm typical). But with low 6.1 mbar pressure, 500 m/s (1,118 mph) wind required to lift 1 μm dust. (Read & Lewis, 2004)

Differences between Terrestrial and Martian Dust Devils – mainly Absolute and Relative Pressure Excursions

- Maximum pressure drop for a Mars d.d. at Phoenix was ~0.003 mbar.



- Pressure drop for a terrestrial d.d. (Utah): 1.354 mbar - 451 times > Mars event.

RELATIVE PRESSURE DROPS ARE OFTEN LESS IN MARTIAN DUST DEVILS TOO

- Utah relative pressure drop from 26.98” Hg to 26.94” Hg = 0.148%.
- Pressure drop at Phoenix 8.425 mbar to 8.422 mbar (0.036%)
- 75 Pressure drops at Pathfinder between 0.075 and 0.75% (Balme and Greeley, 2006).

SCALE HEIGHT

- The pressure acquired by a parcel of air moved up or down a certain height at a constant temperature.

$p = p_0 e^{-(h/h0)}$ **where**

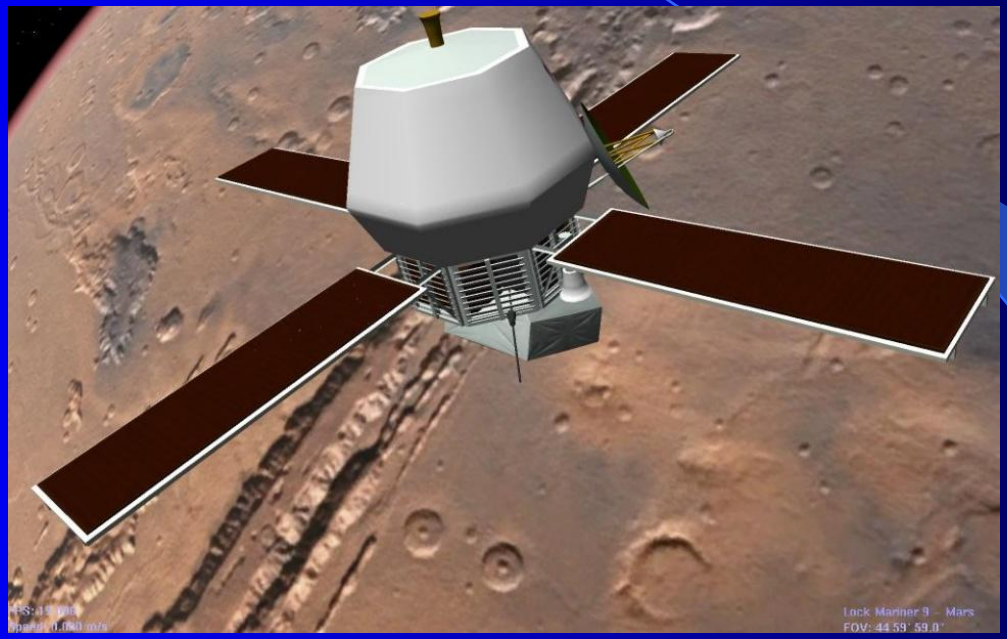
p **= atmospheric pressure,**
h **= height (altitude),**
P_0 **= pressure at height**
h **= 0 (surface pressure),**
and H_0 **= scale height.**

- By scale height math, pressure on Arsia Mons where dust devils occur at 17 km should be about 1.17 mbar. Again, Ames couldn't produce a dust devil @ 10 mbar.

SCALE HEIGHTS FOR MARTIAN MOUNTAINS AND VALLEYS

	A	B	C	D	E	F	G	H	I
1	MARS SITE	ENTERING ARGUMENTS SCALE HEIGHT 10.8 KM AND AVERAGE MARTIAN PRESSURE 6.1 MBAR							
2		KILOMETERS	10.8 KM	RATIO B/C	=-EXP(D VALUE)	1/E value	-F VALUE =	PERCENT	PRESSURE
3			SCALE				PRESSURE	OF	IN
4			HEIGHT				MULTIPLE	PRESSURE	MILLIBARS
5							OF 6.1	AT MEAN	
6							MBAR MEAN	AREOID	
7	MARS AREOID	0	10.8	0	-1	-1	1	100	6.1
8									
9	MOUNTAINS:								
10	OLYMPUS MONS	21.171	10.8	1.960277778	-7.101299374	-0.140819299	0.140819299	14.0819299	0.858997724
11	ASCRAEUS MONS	18.209	10.8	1.686018519	-5.397946041	-0.18525565	0.18525565	18.52556495	1.130059462
12	ARSIA MONS	17.779	10.8	1.646203704	-5.187250063	-0.192780373	0.192780373	19.27803726	1.17596027
13	PAVONIS MONS	14.037	10.8	1.299722222	-3.66827756	-0.272607507	0.272607507	27.26075068	1.662905792
14	SYRTIS MAJOR	2.3	10.8	0.212962963	-1.237338823	-0.808186069	0.808186069	80.81860695	4.929935024
15									
16	VALLEYS:								
17	HELLAS BASIN	-7.825	10.8	-0.724537037	-0.484548845	-2.063775427	2.063775427	206.3775427	12.58903011
18	VALLES MARINERIS	-5.31	10.8	-0.491666667	-0.611606201	-1.635039015	1.635039015	163.5039015	9.973737994
19									
20	LANDERS:								
21	VIKING 2	-4.495	10.8	-0.416203704	-0.659545905	-1.516194692	1.516194692	151.6194692	9.248787621
22	PHOENIX	-4.126	10.8	-0.382037037	-0.682469776	-1.465266353	1.465266353	146.5266353	8.938124755
23	PATHFINDER	-3.682	10.8	-0.340925926	-0.711111581	-1.40624907	1.40624907	140.624907	8.578119329
24	VIKING 1	-3.637	10.8	-0.336759259	-0.714080728	-1.400401889	1.400401889	140.0401889	8.542451525
25	SOURCE FOR SCALE HEIGHT: THE MARTIAN CLIMATE REVISITED PAGE 2.								

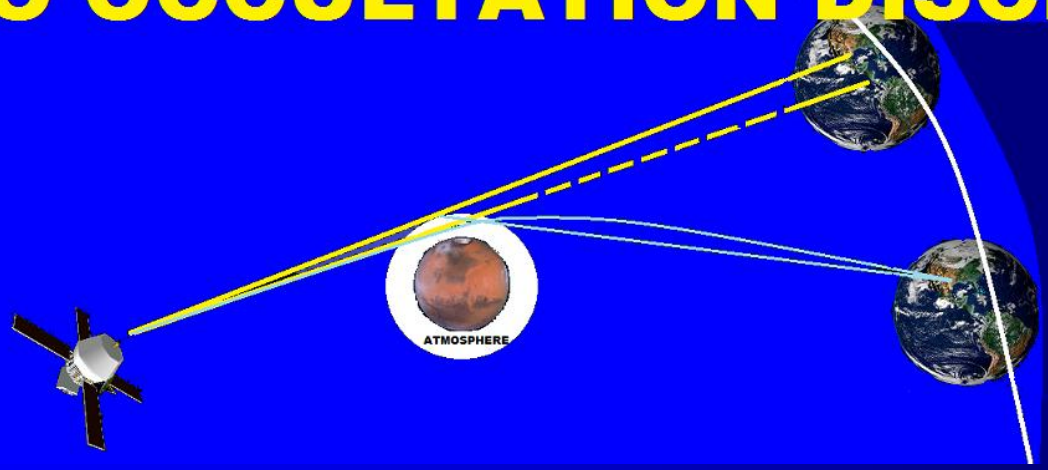
SCALE HEIGHT, MARINERS, AND MARTIAN MOUNTAINS



http://homepage.eircom.net/~jackhiggins/celestia/images/mariner9-3.jpg

Scale height math seemed to predict pressures at the landers, but **raise questions about how Mariners could miss pressures on large mountains.**

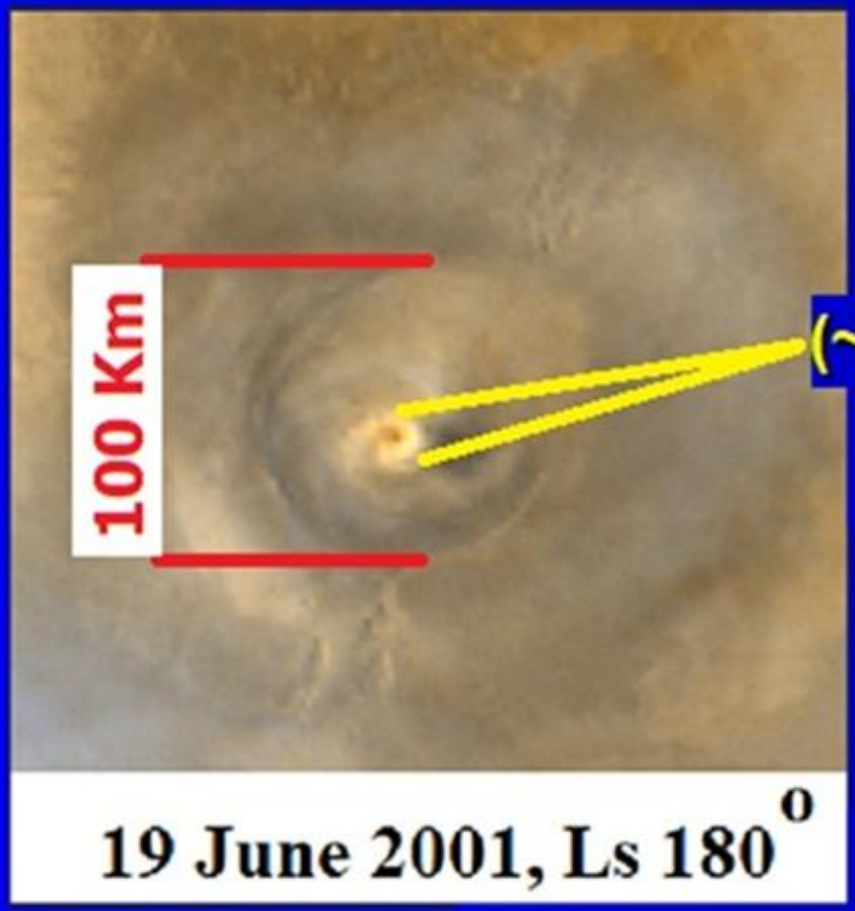
RADIO OCCULTATION DISCREPANCIES



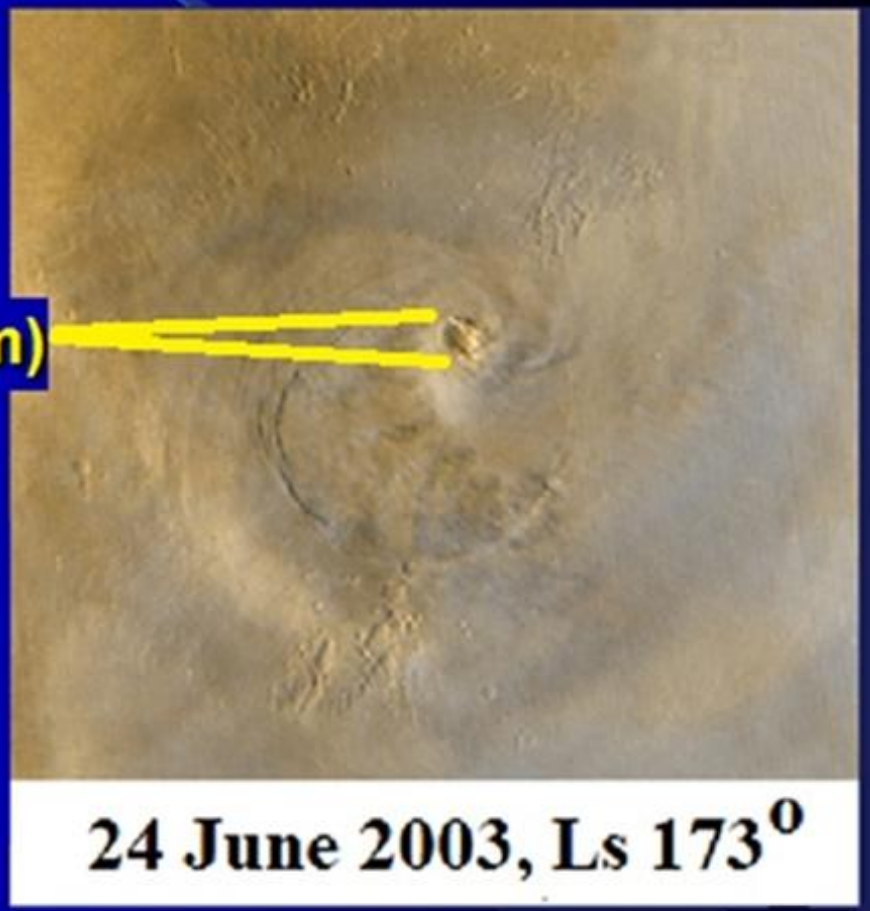
- Minimum Pressures Seen by Mariners:
  - **Mariner 9 (Orbit): 2.8 mbar**
  - Mariners 4, 6, & 7: 3.8 to 4.1 mbar

- Scale Height Predicted Mountain Pressures:
  - **Olympus Mons: 0.86 mbar**
  - **Arsia Mons: 1.17 mbar**

Spiral Clouds on Arsia Mons (only) Look like Hurricane Eye Walls. 1.17 mbar?



(~10 km)

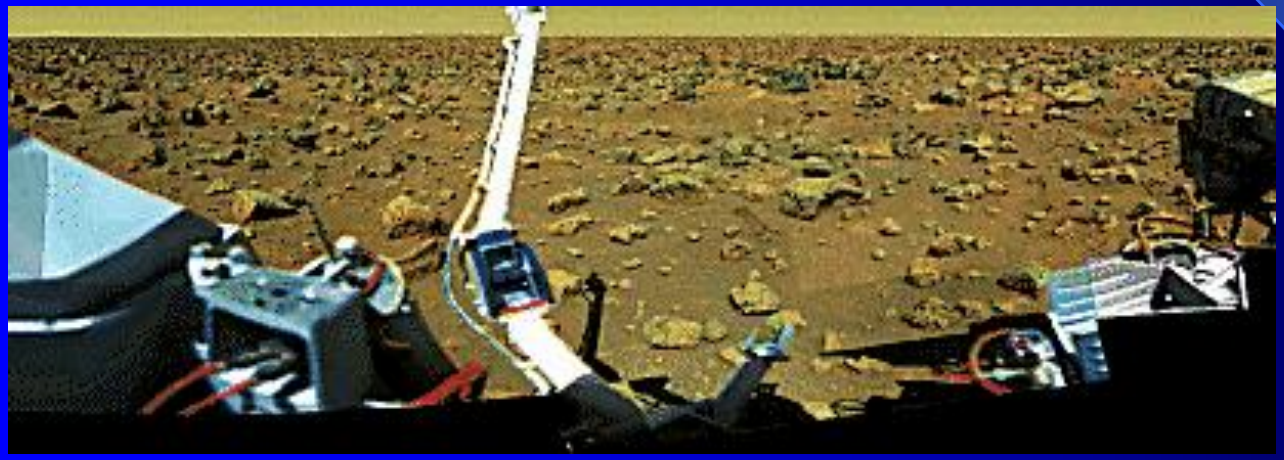


Mars Lander Pressure Sensors

- Only 4 landers could measure pressure.
- None could measure above 18 mbar (and 2 were limited to 12 mbar).
- Limited pressure ranges based on previous radio occultation measurements.

Viking & Pathfinder Pressure Sensitivity Ranges

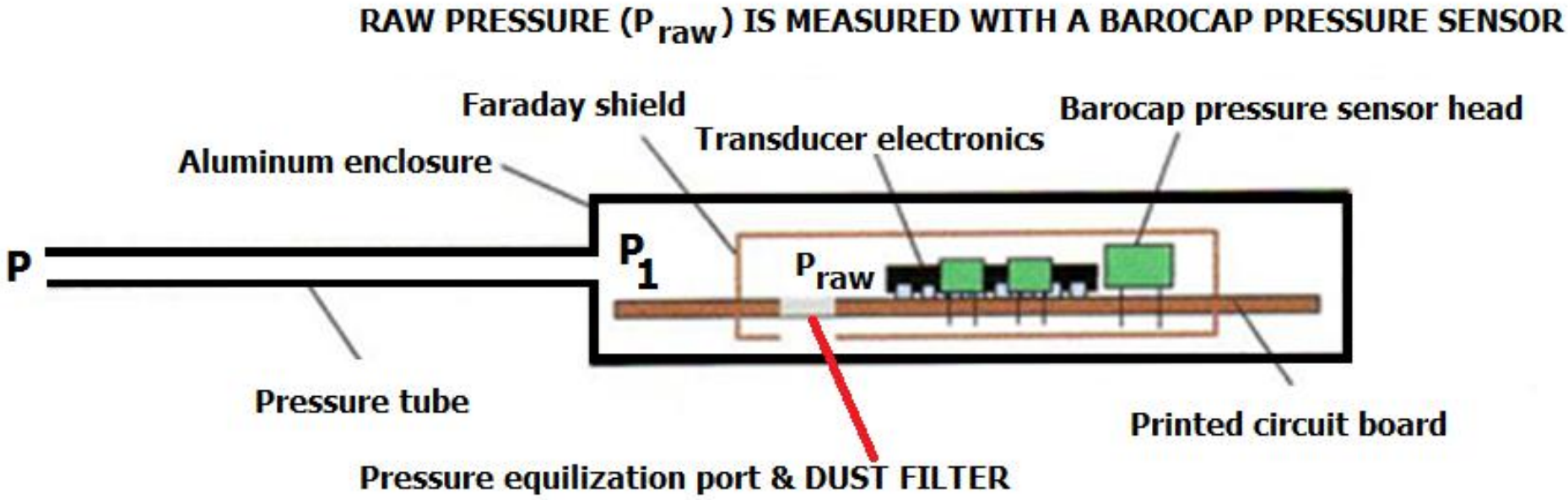
- 3 Tavis pressure sensors sent by NASA:
  Viking 1 & 2 Range: **0 to 18 mbar**



- **Pathfinder: Only 0 to 12 mbar**

  A 1,034 mbar sensor was also ordered (Tavis CAD 10484 - 1), but Tavis rep says it remained on Earth.

5 to12 Mbar Range Phoenix Dust Filter



A Finnish Meteorological Institute report (2009) States that, *"We should find out how the pressure tube is mounted in the spacecraft and if there are additional filters etc."* FMI designed the sensor.

International Traffic in Arms Regulations (ITAR)

- *"After Phoenix landed it appeared that the actual thermal environment was worse than the expected worse case…* ***Information on re-location of the heat source had not been provided initially due to ITAR restrictions."****

* Taylor, P.A., et al, 2009, On Pressure Measurement and Seasonal Pressure Variations at the Phoenix landing site, Submitted to *J. Geophys. Res. (Planets).*

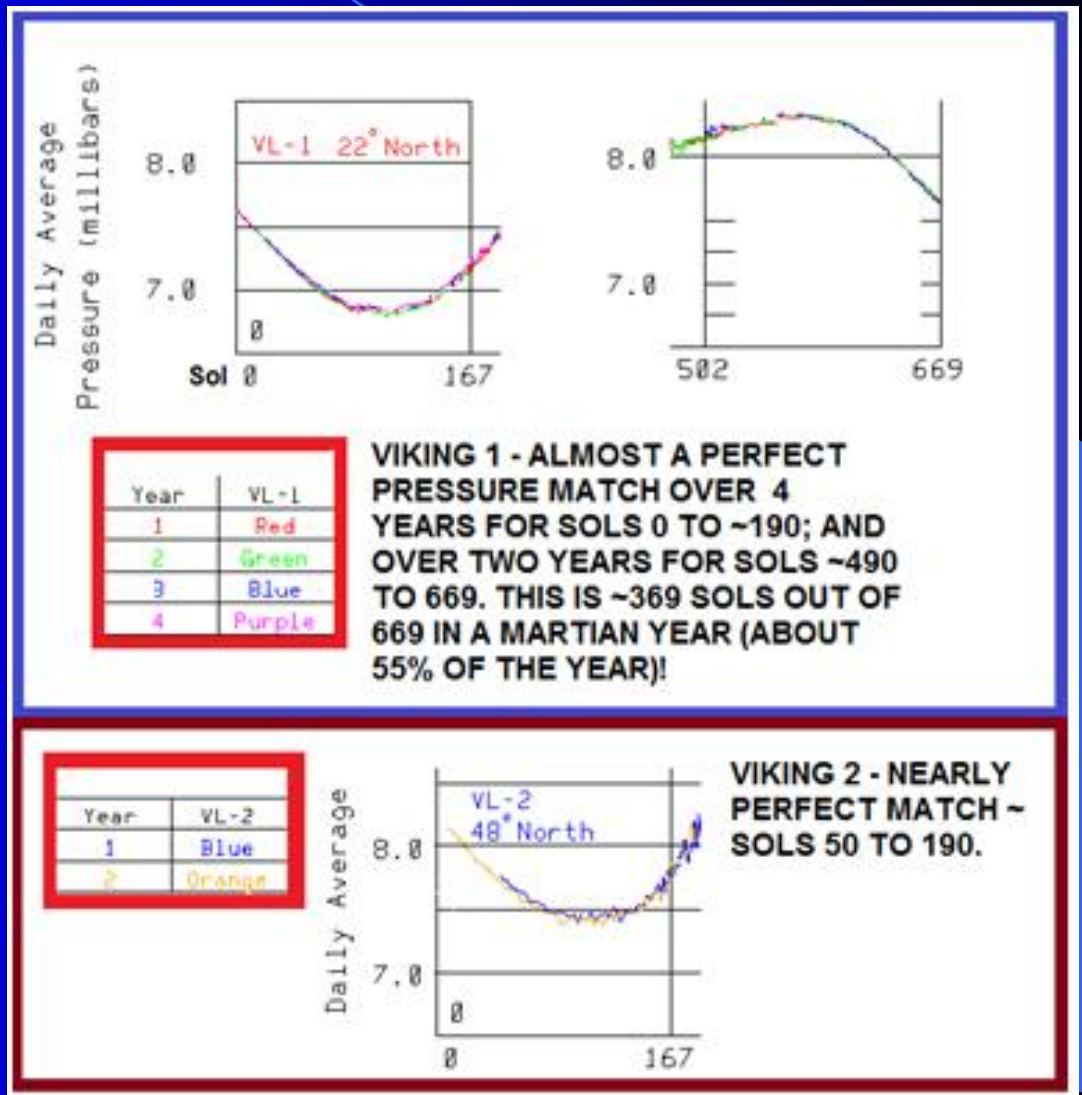
International Traffic in Arms Regulations (ITAR)

"That we at FMI did not know how our sensor was mounted in the spacecraft and how many filters there were shows that the exchange of information between NASA and the foreign subcontractors did not work optimally in this mission!"

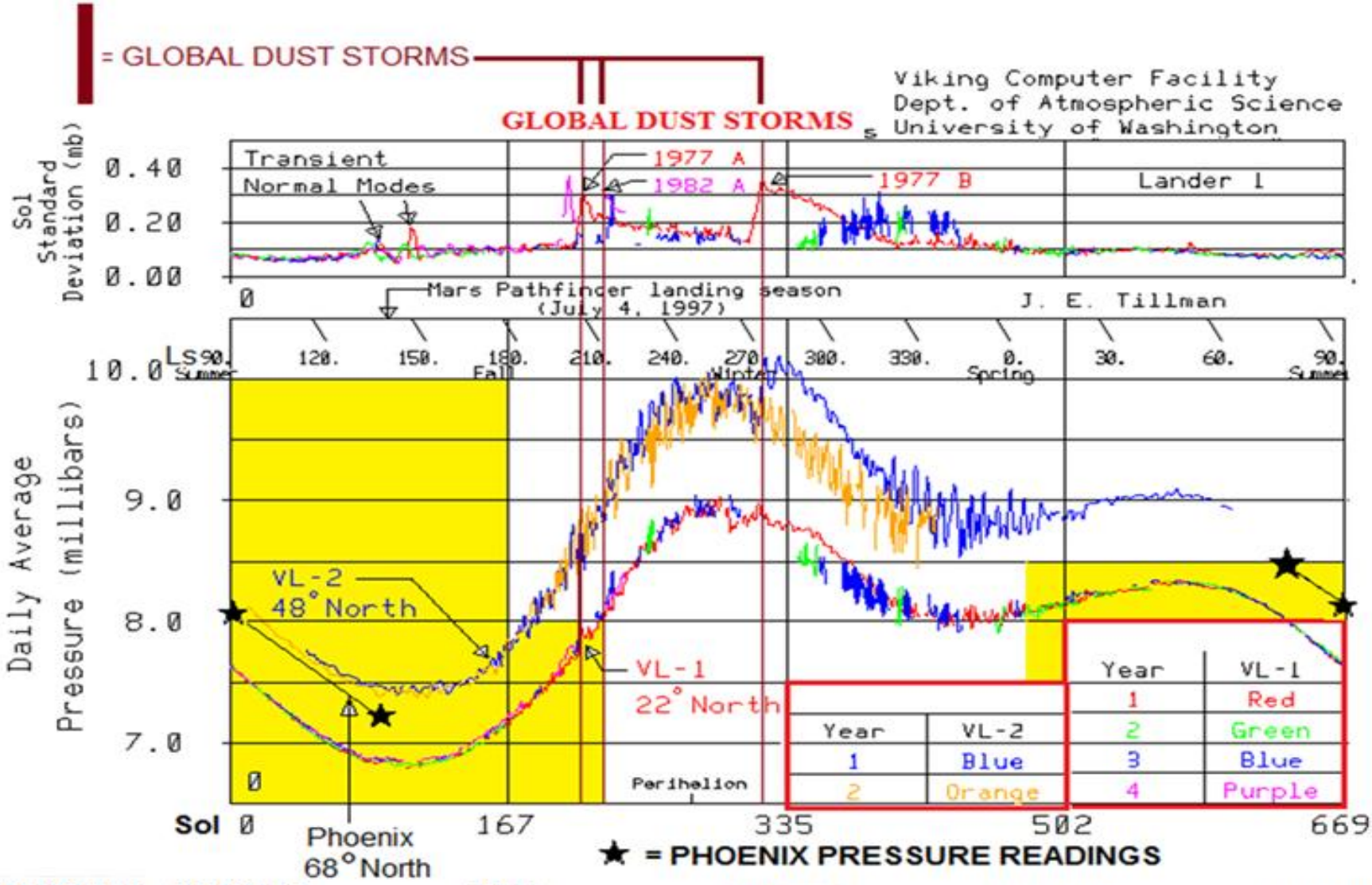
(Kahanpää [FMI]
Personal communication,
December 15, 2009)

Viking Pressure Problems
1. Data Too Similar Year to Year?

55% percent of same days each year for 4 years straight the **pressure was identical.** A Martian year is 669 days (sols).



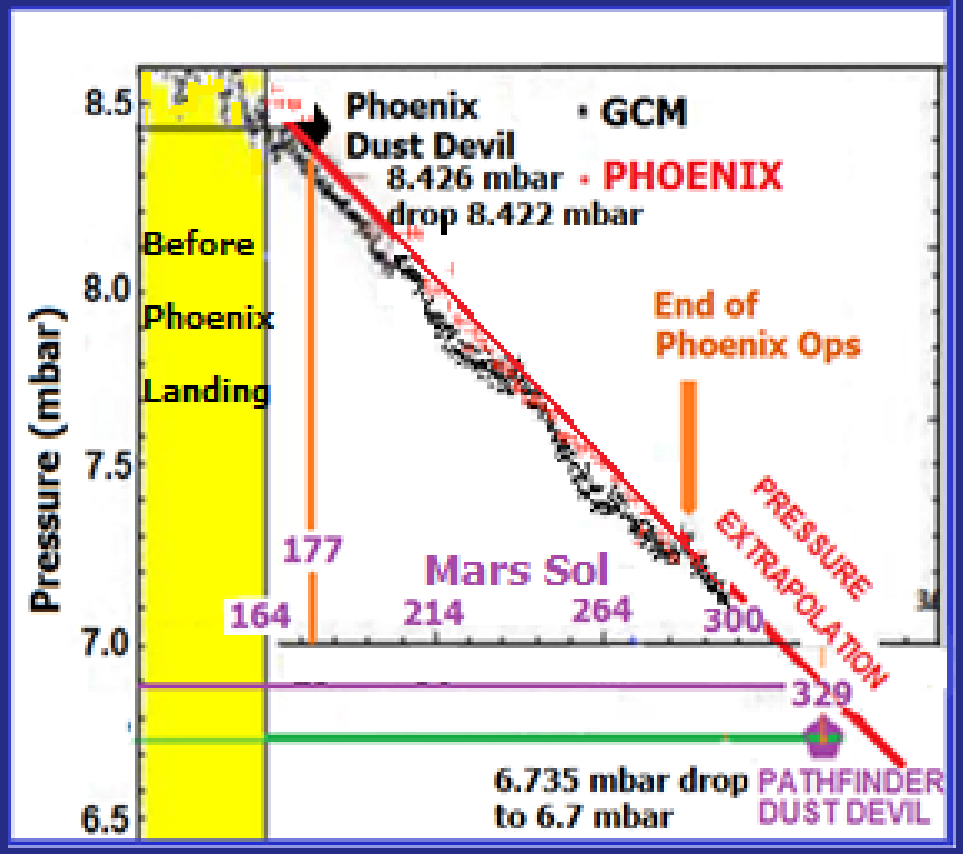
Repeatable Data – Yellow Shading



Atmospheric Pressure at the Surface of Mars (all years)

2. Pressure projections for dust devils

Is 98.694% too accurate?



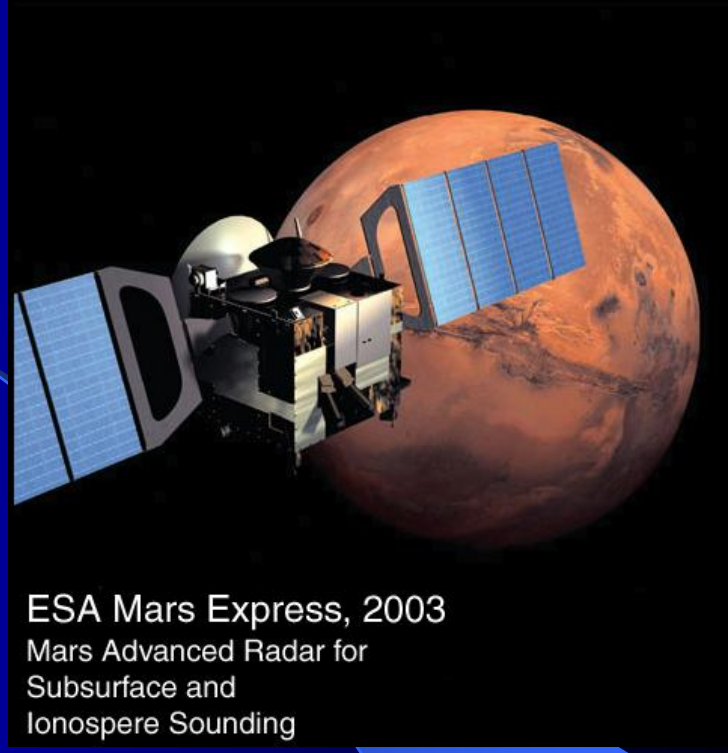
Martian Calendar

Month	Sol
1	0-61
2	61-127
3	127-193
4	193-258
5	258-318
6	318-372
7	372-422
8	422-468
9	468-515
10	515-562
11	562-613
12	613-669

3. Problems at the Martian South Pole

- Byrne and Ingersoll (2003) state, "a CO_2 residual ice cap with an area of 88,000 km^2, would contribute only 0.36 mbar of additional **atmospheric pressure if it completely sublimed."**
- Annual pressure swings at Vikings: 2.1 – 2.6 mbar.
- Classical explanation for annual pressure fluctuations (CO_2 sublimation) appears wrong.

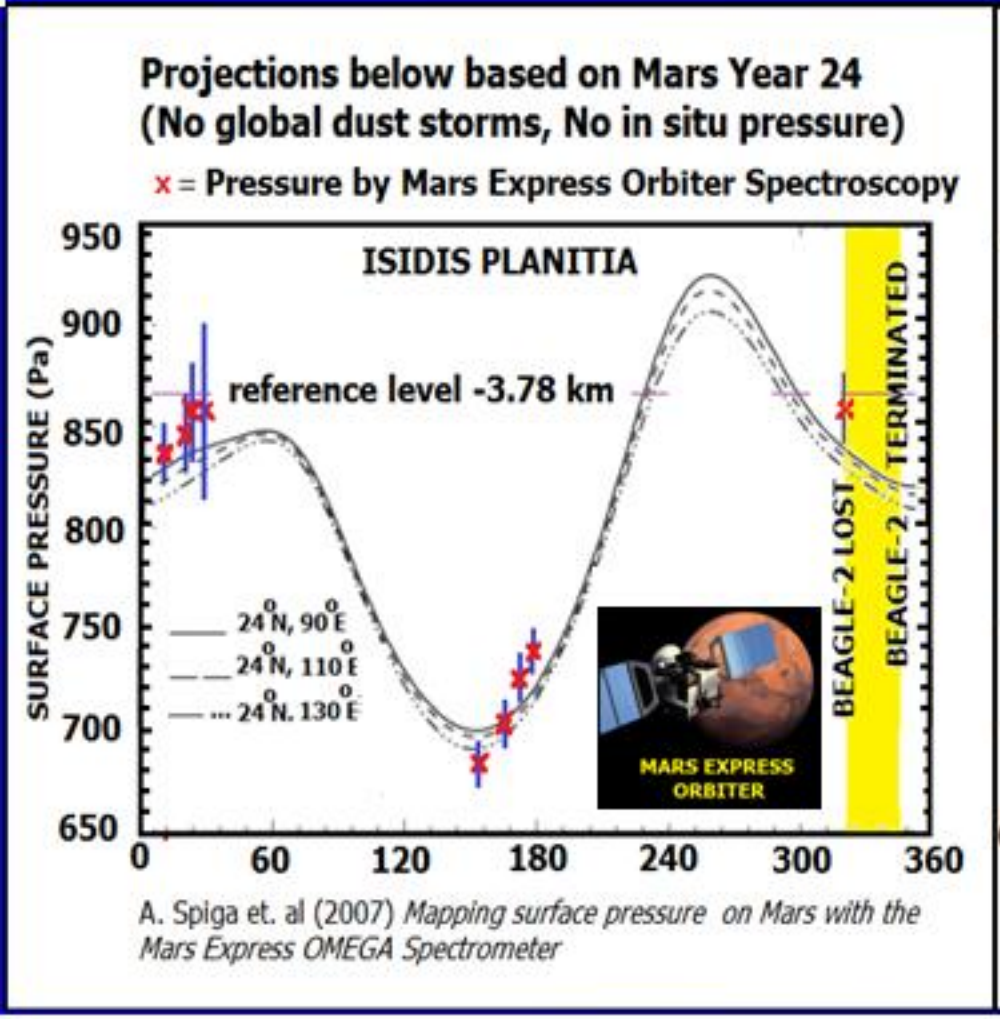
PRESSURES DERIVED BY SPECTROMETER

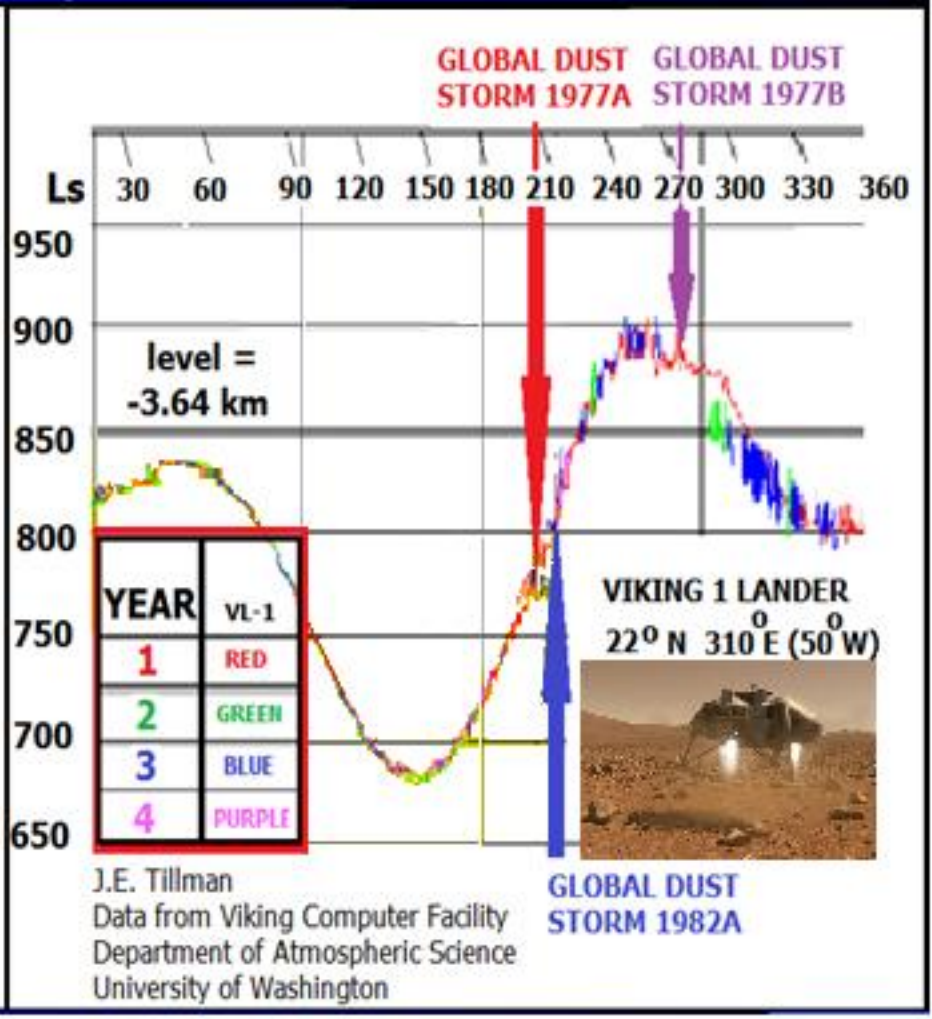


Similar to VL-1; agree with traditional Leighton & Murray polar CO_2 sublimation ideas from 1966, but

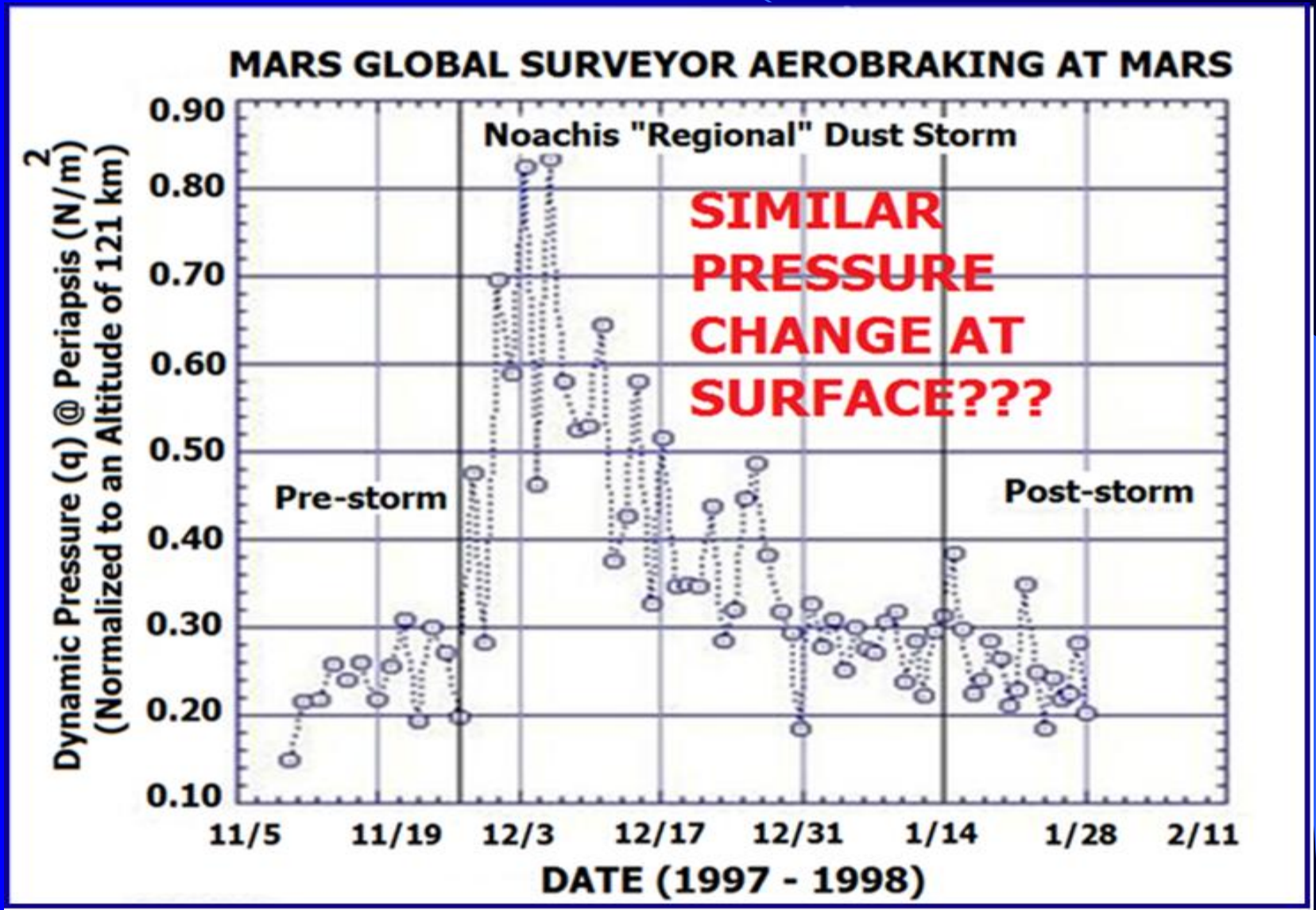
- **Don't work with ice clouds and frost (at poles)** (Spiga et al., 2007).
- **Ignore max pressure change of 0.36 mbar possible due to sublimation of CO_2 at poles.** (Byrne and Ingersol, 2003)

COMPARISON OF MARS EXPRESS SPECTROSCOPY AND VIKING 1 PRESSURES



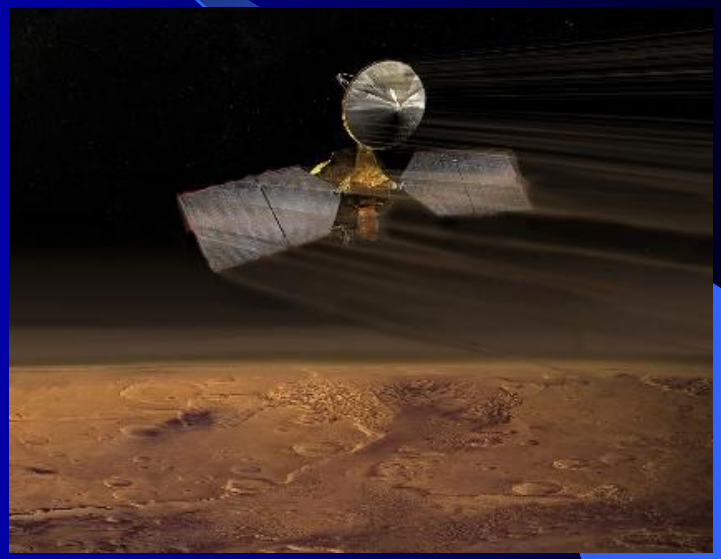


MGS Dynamic Pressure Spike Due to Dust Storms. Pressure Doubles in 48 Hours, Up 5.6 Fold in 4 Weeks.



MRO AEROBRAKING

"*At some points in the atmosphere, we saw a difference in the atmospheric density by a factor of 1.3, which means it was 30% higher than the model...*



but ***around the south pole we saw an even larger scale factor of up to 4.5, so that means it was 350% off of the Mars GRAM model.***"

Han You, Navigation Team Chief for MRO.

http://www.universetoday.com/2006/09/21/aerobraking-mars-orbiter-surprised-scientists/

Occam's Razor

- "Entities must not be multiplied beyond necessity and the conclusion thereof, that the simplest solution is usually the correct one."
- **The Razor suggests repeatable Viking pressure data should be believed.** Some reasons for this conclusion are that:
  - Radio occultation pressure results from Mariners are similar to lander pressures recorded.
  - Consistent Viking-Pathfinder-Phoenix pressures.
  - **Extraordinary reason to fake data required.**

Humor? Occam and Buzz Aldrin

I need an EXTRAORDINARY reason to suspect disinformation. Did Buzz let the cat out of the bag?

=

?

Aldrin on C-SPAN 7/22/2009: "Visit the moon of Mars, there's a Monolith there, a very unusual structure…When people find about that they'll say who put that there?" http://www.youtube.com/watch?v=bDIXvpjnRws

Seriously, Why Trash Occam?

- Weather doesn't match low pressure values
  - Dust Devils
  - Dust Storms
  - Eye walls on huge storms over Arsia Mons
  - Frontal systems & fog seen from orbit
  - Even snow seen falling at Phoenix
- Mariners saw higher minimum pressures than scale height-calculated mountain pressures

Seriously, Why Trash Occam?

- CO_2 at poles doesn't explain Viking pressure swings.
- No way to change Viking, MPF and Phoenix dust filters that could clog.
- Viking data suspicious due to exact repeat over 4 yrs.
- Diurnal pressure max of Viking & MPF (midnight & 1000) do *not* agree with Phoenix (0830 & 1530).
- Phoenix transducer design problems. ITAR at fault.

Seriously, Why Trash Occam?

- MRO Aerobraking effects 350% above Mars GRAM.
- MGS experienced pressure spike at 121 km that was 5.6 times higher than pre-dust storm levels.
- Pathfinder & Phoenix wind data missing.
- No pressure sensors could measure > 18 mbar
- NASA failed to simulate dust devils at 10 mbar with appropriate winds.

What else is in the full Mars Enigma Report? See:

- http://davidaroffman.com/Roffman%20Report%20Enigma%20of%20the%20Martian%20Atmosphere%20Higher%20Than%20Advertised%20Air%20Pressure%20July%2028%202010.pdf

- Discussions about
  - Methane found on Mars
  - Caves on Arsia Mons
  - Viking Labeled Release Experiment for life detection
  - Potential pressure on Mars
  - Recommendations

CONTACT INFO

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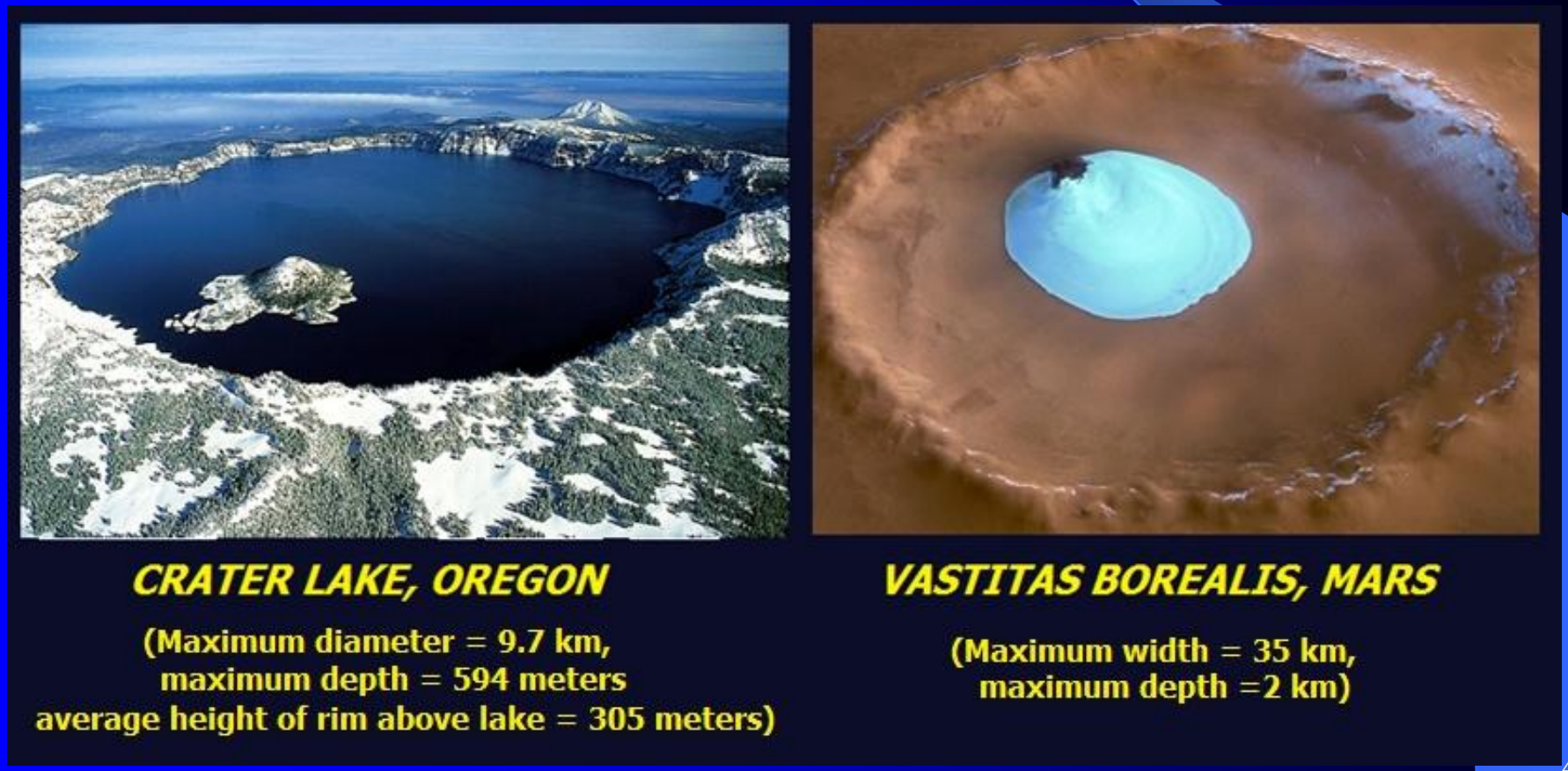
- Website: http://DavidARoffman.com



CRATER LAKE, OREGON

**(Maximum diameter = 9.7 km,
maximum depth = 594 meters
average height of rim above lake = 305 meters)**

VASTITAS BOREALIS, MARS

**(Maximum width = 35 km,
maximum depth =2 km)**

Slide References

- Slide 1: http://www.nytimes.com/imagepages/2008/05/19/science/20mars.2.ready.html
- Slide 2: 6.1 mbar from: Sherman, S.C. Wu (1977), Mars synthetic topographic mapping, United States Geological Survey, Branch of Astrogeologic Studies, Flagstaff, Arizona 86001, USA
- Slide 3:

http://www.lpl.arizona.edu/~lemmon/mer_dd/dd_enhanced_587a.gif

- Slide 4:
- Byrne, S., Ingersoll, A. A Sublimation Model for Martian South Polar Ice Features , Science, Vol 299, 14 February 2003.
- NASA, (2005). *NASA simulates small Martian 'dust devils' and wind in vacuum tower*. Retrieved from http://www.nasa.gov/centers/ames/research/exploringtheuniverse/vaccumchamber_prt.htm

Slide References

- Slide 5: http://www.nasa.gov/centers/ames/research/exploringtheuniverse/vacchamber_prt.htm.
- Atkinson, Nancy (2006), Aerobraking Mars Orbiter Surprised Scientists http://www.universetoday.com/2006/09/21/aerobraking-mars-orbiter-surprised-scientists/
- Johnston, M.D., Esposito, P. B., Alwar, V., Demcak, S. W., Graat, E. J., & Mase, R. A. of the Jet Propulsion Laboratory, California Institute of Technology, *Mars Global Surveyor Aerobraking at Mars*, 1998.
- Slide 6: Reis, D., Lüsebrink, D., Hiesinger, H., Kel-ling, T., Wurm, G., and Teiser, J. (2009). High altitude dust devils on Arsia Mons, Mars: Testing the greenhouse and thermophoresis hypothesis of dust lifting. *Lunar Planetary Science.* [CD-ROM], *XXXII*, Abstract 2157. Retrieved from http://www.lpi.usra.edu/meetings/lpsc2009/pdf/1961.pdf
- Slide 7: Atkinson, Nancy (2006), Aerobraking Mars Orbiter Surprised Scientists http://www.universetoday.com/2006/09/21/aerobraking-mars-orbiter-surprised-scientists/

Slide References

- Slide 7: Johnston, M.D., Esposito, P. B., Alwar, V., Demcak, S. W., Graat, E. J., & Mase, R. A. of the Jet Propulsion Laboratory, California Institute of Technology, *Mars Global Surveyor Aerobraking at Mars*, 1998.
- Slide 8: http://www.stevenhobbsphoto.com.au

  Slide 9: Desai, P.N., (2008) All Recent Mars Landers Have Landed Downrange - Are Mars Atmosphere Models Mis-predicting Density? Third International Workshop on The Mars Atmosphere: Modeling and Observations, held November 10-13, 2008 in Williamsburg, Virginia. LPI Contribution No. 1447, p.9103. http://www.lpi.usra.edu/meetings/modeling2008/pdf/9103.pdf
- Slide 10:
- Schofield, J.T. et al, (1997). The Mars Pathfinder atmospheric structure investigation meteorology (ASI/MET experiment, *Science*, *278*, 1752-1758
- Taylor, P. A., Catling, D. C., Daly, M., Dickinson, C. S.,. Gunnlaugsson, H. P, Harri, A.M., and Lange C. F., (2008). Temperature, pressure, and wind instrumentation in the Phoenix meteorological package, Journal of Geophysical Research,113, E00A10.
- http://www.nasa.gov/mission_pages/phoenix/images/press/16613-animated.html

Slide References

- Slides 11: Richardson, M., Wilson, R. J., and Rodin, A. V. Water ice clouds in the Martian atmosphere: General circulation model experiments with a simple cloud scheme, J. Geophys. Res., 107(E9), 5064, doi:10.1029/2001JE0011804, 2002.
- Slide 12: Balme, M., Greeley R. (2006), Dust devils on Earth and Mars, *Review Geophysics.*, 44, RG3003,doi:10.1029/2005RG000188.
- Slide 13:
- Balme, M., Greeley R. (2006), Dust devils on Earth and Mars, *Review Geophysics.*, 44, RG3003,doi:10.1029/2005RG000188.
- Slide 14: Balme, M., Greeley R. (2006), Dust devils on Earth and Mars, *Review Geophysics.*, 44, RG3003,doi:10.1029/2005RG000188.
- Read, P. L., & Lewis, S. R. (2004). *The Martian Climate Revisited, Atmosphere and Environment of a Desert Planet*, Chichester, UK: Praxis.

  Slide 15: Balme, M., Greeley R. (2006), Dust devils on Earth and Mars, *Review Geophysics.*, 44, RG3003,doi:10.1029/2005RG000188.
- Wyatt, R. E. (1954), Pressure Drop on a Dust Devil, Monthly Weather Review, Jan. 1954, pp. 7-8. Retrieved from
- http://docs.lib.noaa.gov/rescue/mwr/082/mwr-082-01-0007.pdf

Slide References

Slide 16: Balme, M., Greeley R. (2006), Dust devils on Earth and Mars, *Review Geophysics.*, 44, RG3003,doi:10.1029/2005RG000188.

- Wyatt, R. E. (1954), Pressure Drop on a Dust Devil, Monthly Weather Review, Jan. 1954, pp. 7-8. Retrieved from
- Slide 17: Photo from http://www.space4case.inhetweb.nl/mmw/media/mars2005/tharsismontes9000_20051126_10_1024.jpg
- Slide 18: Calculations by David A Roffman
- Slide 19: http://homepage.eircom.net/~jackhiggins/celestia/images/mariner9-3.jpg
- Slide 20: http://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html
- Slide 21: NASA/JPL/MSSS, (2005). *PIA04294: Repeated Clouds over Arsia Mons*. Retrieved from http://photojournal.jpl.nasa.gov/catalog/PIA04294
- Slide 22: Personal communications with Dr. Tillman who worked for the Viking Computer Facility and Tavis rep.
- Slide 23: Personal communications and with a Tavis rep.

Slide References

- Slide 24: Kahanpaa, H., Polkko J., 2009-02-26. The Time Response of the PHOENIX Pressure Sensor, Finnish Meteorological Institute. Doc. No. FMI_S-PHX-BAR-TN-002-FM-99.
- Slide 25: Taylor, P.A., Weng, W., Kahanpää, H., Akingunola, A., Cook, C., Daly, M., Dickinson, C., Harri, A., Hill, D., Hipkin, V., Polkko J., and Whiteway, J. (2009). On Pressure Measurement and Seasonal Pressure Variations at the Phoenix landing site, Submited to *Journal of Geophysical Research (Planets).*
- Slide 26: Personal communication with H. Kahanpää, FMI
- Slide 27: J. E. Tillman, University of Washington, Dept. Atmospheric Sciences
- Slide 28: J. E. Tillman, University of Washington, Dept. Atmospheric Sciences
- Slide 29: Nelli, S.M., Renno, N. O., Feldman, W. C., Murphy, J. R., & Kahre, M. A. Reproducing Meteorological Observations at the Mars Phoenix Lander Site.

Slide References

- Slide 30:
- J. E. Tillman, University of Washington, Dept. Atmospheric Sciences
- Byrne, S., Ingersoll, A. A Sublimation Model for Martian South Polar Ice Features , Science, Vol 299, 14 February 2003.
- Slide 31:
- Byrne, S., Ingersoll, A. A Sublimation Model for Martian South Polar Ice Features , Science, Vol 299, 14 February 2003.
- Remote sensing of surface pressure on Mars with the Mars Express/OMEGA spectrometer: 1. Retrieval method
  A. Spiga, Forget, F., B. Dolla, S. Vinatier, R. Melchiorri, P. Drossart, A. Gendrin, J.-P. Bibring, Y. Langevin, and B. Gondet (2007)
  Journal of Geophysical Research, 112, E08S15
- Slide 32: Remote sensing of surface pressure on Mars with the Mars Express/OMEGA spectrometer: 1. Retrieval method
  Forget, F., A. Spiga, B. Dolla, S. Vinatier, R. Melchiorri, P. Drossart, A. Gendrin, J.-P. Bibring, Y. Langevin, and B. Gondet (2007)
  Journal of Geophysical Research, 112, E08S15
- J. E. Tillman, University of Washington, Dept. Atmospheric Sciences

Slide References

- Slide 33: Johnston, M.D., Esposito, P. B., Alwar, V., Demcak, S. W., Graat, E. J., & Mase, R. A. of the Jet Propulsion Laboratory, California Institute of Technology, *Mars Global Surveyor Aerobraking at Mars*, 1998.
- Slide 34: http://www.universetoday.com/2006/09/21/aerobraking-mars-orbiter-surprised-scientists/
- Slide 36: Buzz Aldrin C-SPAN remarks from http://www.youtube.com/watch?v=bDIXvpjnRws
- **Slide 38:** Diurnal pressure times from Taylor, P.A., Weng, W., Kahanpää, H., Akingunola, A., Cook, C., Daly, M., Dickinson, C., Harri, A., Hill, D., Hipkin, V., Polkko J., and Whiteway, J. (2009). On Pressure Measurement and Seasonal Pressure Variations at the Phoenix landing site, Submitted to *Journal of Geophysical Research (Planets).*
- Levin, G.V. (1997) The Viking Labeled Release Experiment and Life on Mars, *Proceedings of Spie-The International Society for Optical Engineering, "Instruments, Methods, and Missions for the Investigation of Extraterrestrial Microorganisms.* 29 July-1August 1997, San Diego, California.
- Read, P. L., & Lewis, S. R. (2004). *The Martian Climate Revisited, Atmosphere and Environment of a Desert Planet*, Chichester, UK: Praxis.

Slide References

- Slide 40: Krasnopolsky, V., Maillard, J., Owen, T. (2004). Detection of methane in the Martian atmosphere: evidence for life? ICARUS, 172. doi: 10.1016/j.icarus.2004.07.004
- Cushing, G. E., Titus, T. N., Wynne, J. J. Christensen, P. R. (2007). Themis Observes Possible Cave Skylights on Mars, *Lunar Planetary. Science. XXXVIII*, Abstract, Lunar Planet. Sci., 1371.pdf http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1371.pdf
- Slide 41: http://oregonexplorer.info/craterlake/facts.html

  and Water ice in Vastitas Borealis Crater (Credit: European Space Agency / ESA/DLR/FU Berlin (G. Neukum))