*Exomars Atmospheric Science and Missions Workshop, Saariselkä, Finland, 26.-30.3.2017*

# *How Windy is Mars ?*

# *(and, are Martian dust devils really bigger than Earth's?)*

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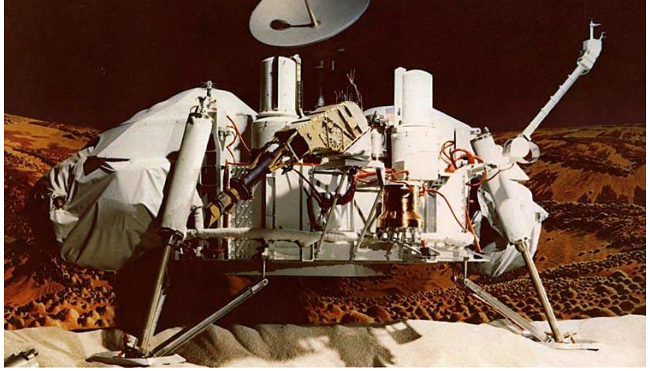
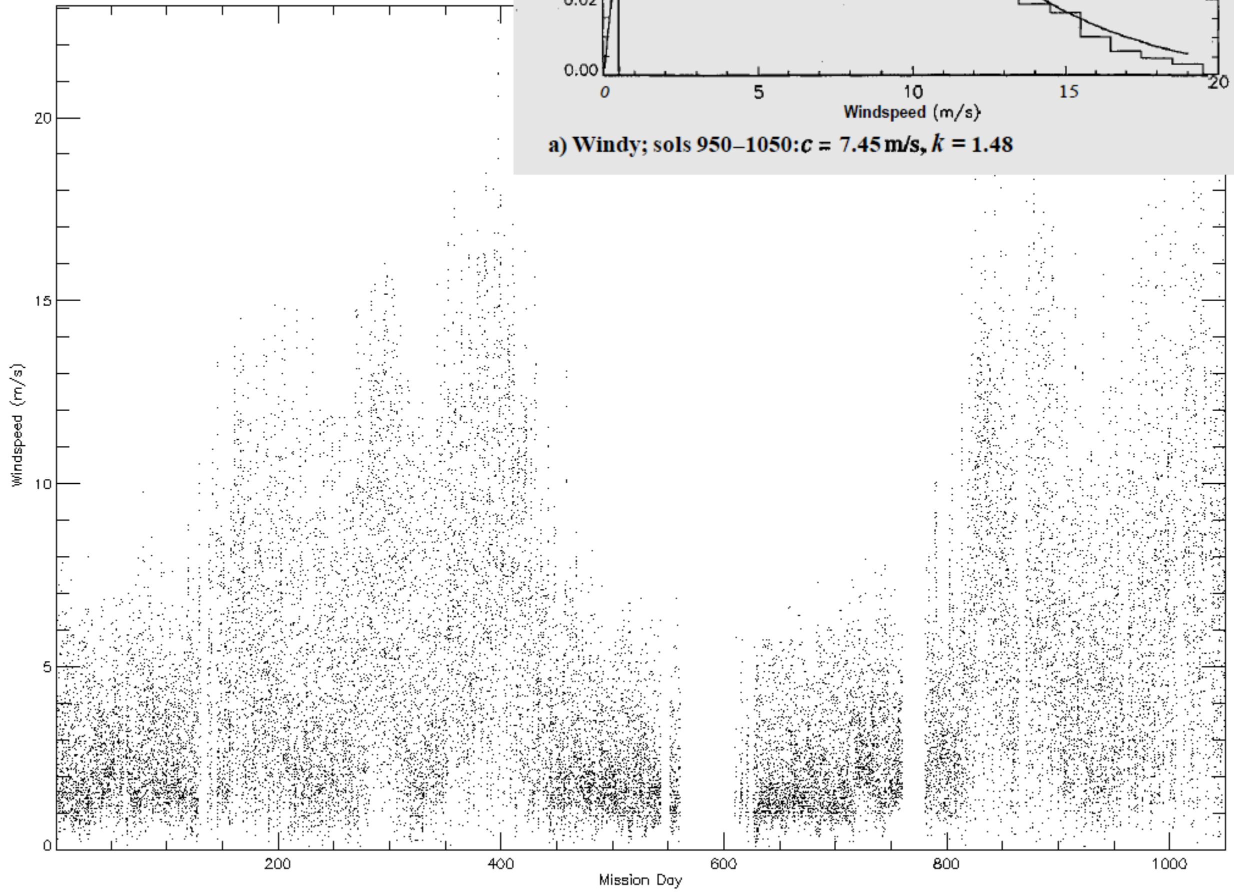
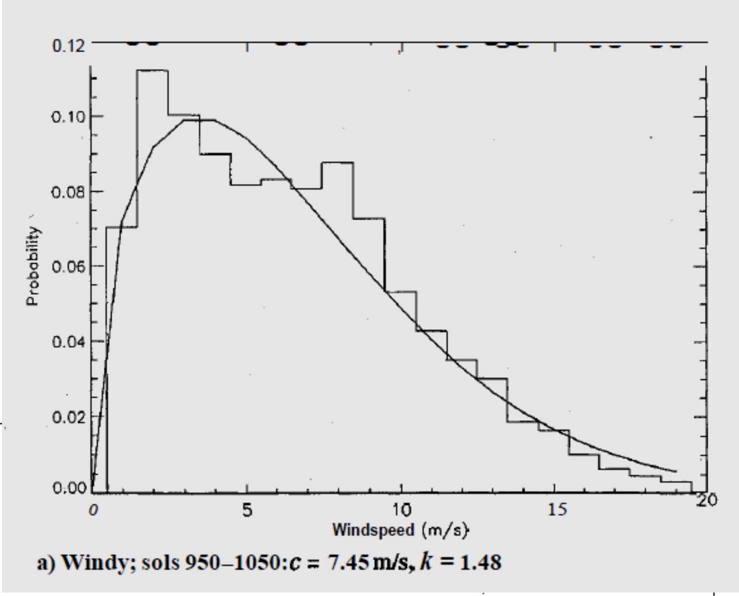
View from balcony 04.05hrs this morning

| Mission | Remarks |
|---|---|
| Viking 1 | Hot wire anemometer. Operated for ~40 sols. Hourly averages archived |
| Viking 2 | Hot wire anemometer. Operated for 1050 sols. Hourly averages archived. |
| Pathfinder ASI/MET | Hot film anemometer.  Operated  for 83 sols (650,000 measurements)  Power constrained – superheat inadequate during strong turbulent convection – calibrated dataset not released. |
| Pathfinder Windsock | 3 windsocks on mast, imaged by camera to estimate aerodynamic roughness.  A handful of measurements only. |
| Phoenix | Telltale indicator, imaged by camera.  >7000 measurements over 150 sols  (not evenly sampled) |
| MSL/ Curiosity | 2 Hot film anemometers. One damaged by debris on landing.  Other failed after a few years |

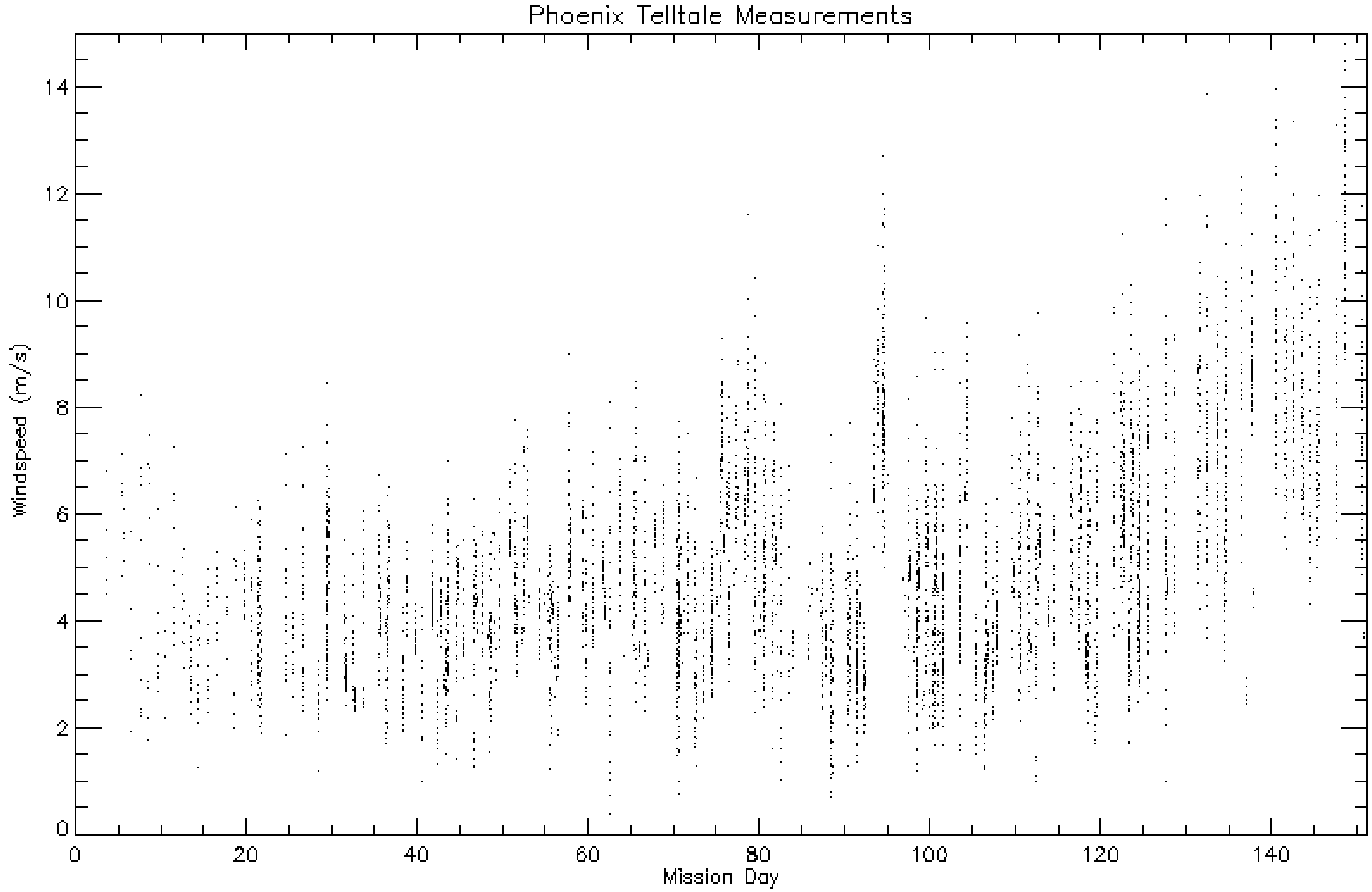
Mars Polar Lander, Beagle 2 had wind sensors, but were lost.  Mars Exploration Rovers Spirit & Opportunity have no meteorological instrumentation



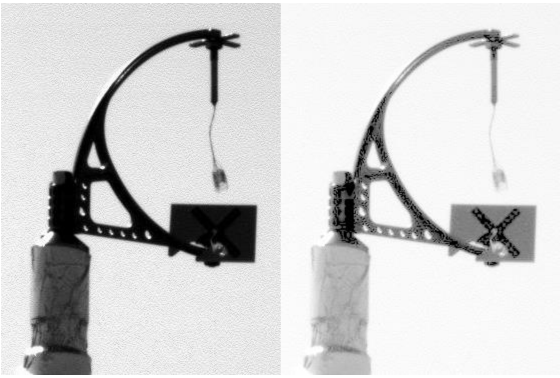


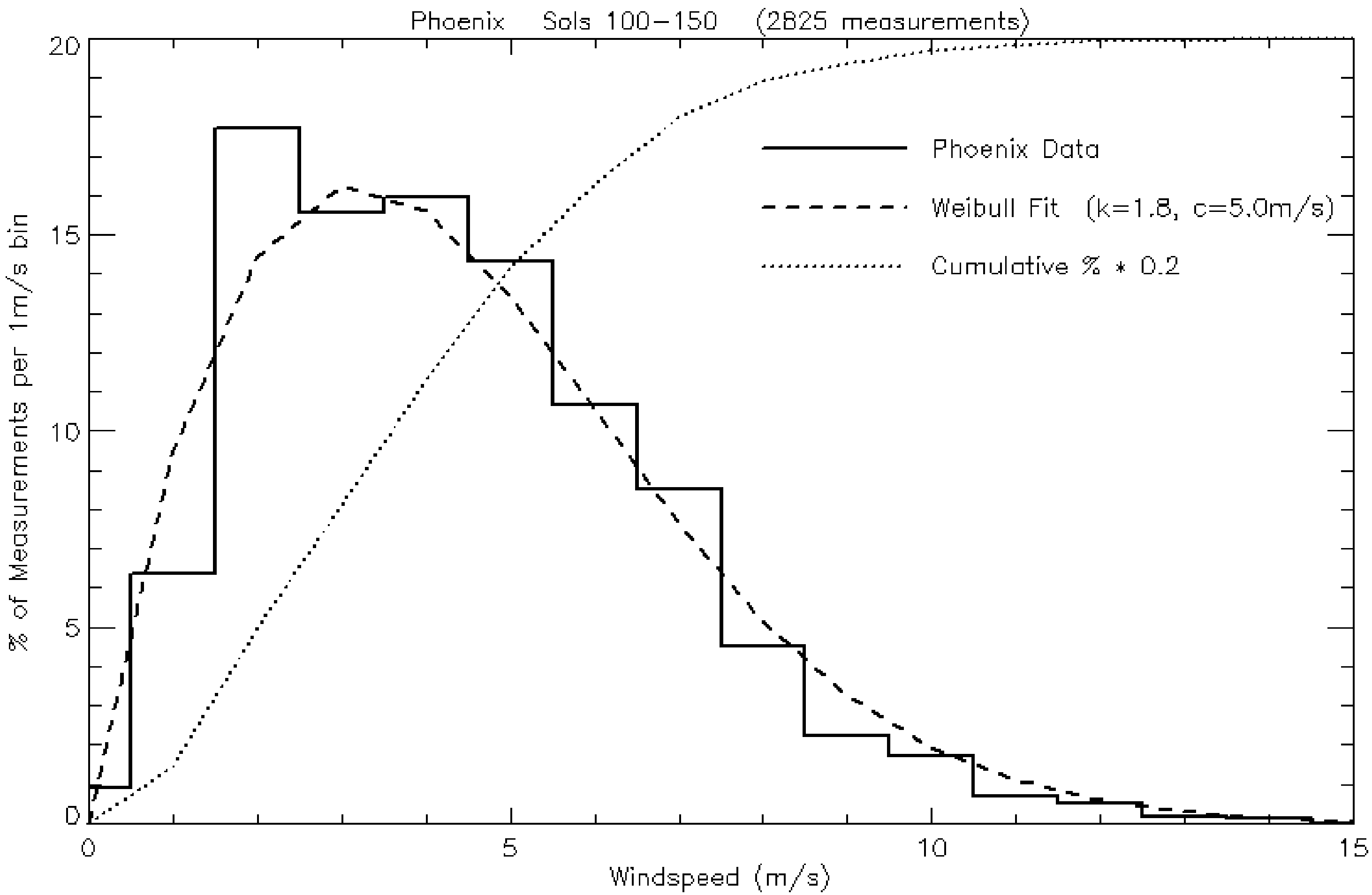




The Viking 2 met package at the Smithsonian Air and Space Museum
Weibull fit to speed data, R. Lorenz, J. Spacecraft and Rockets, 1996




Telltale ‘better than nothing’. Somewhat inefficient data-wise, and labor-intensive to reduce, but in fact a worthwhile archive was generated of some >7000 measurements, allowing turbulent fluctuations, diurnal cycle and seasonal trends to be identified.

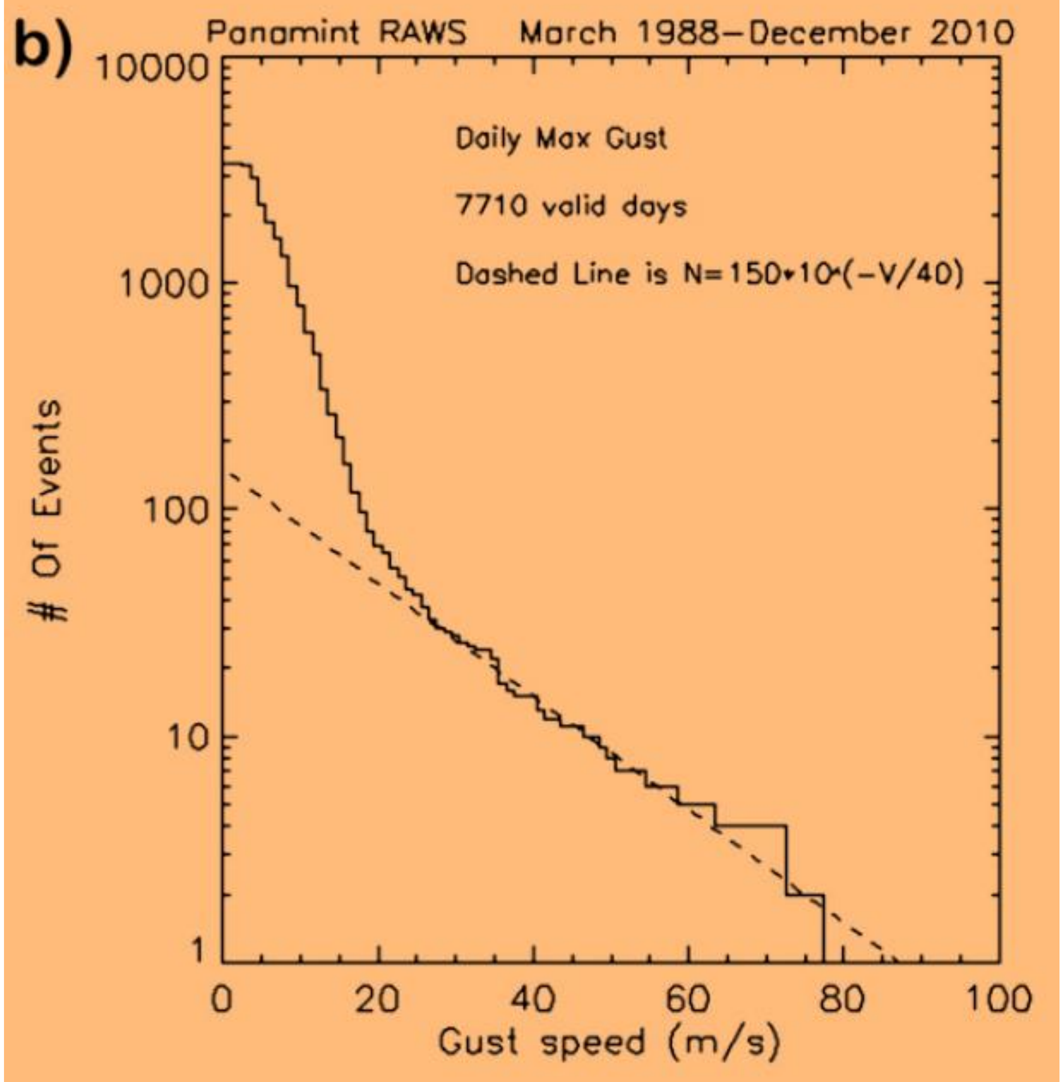


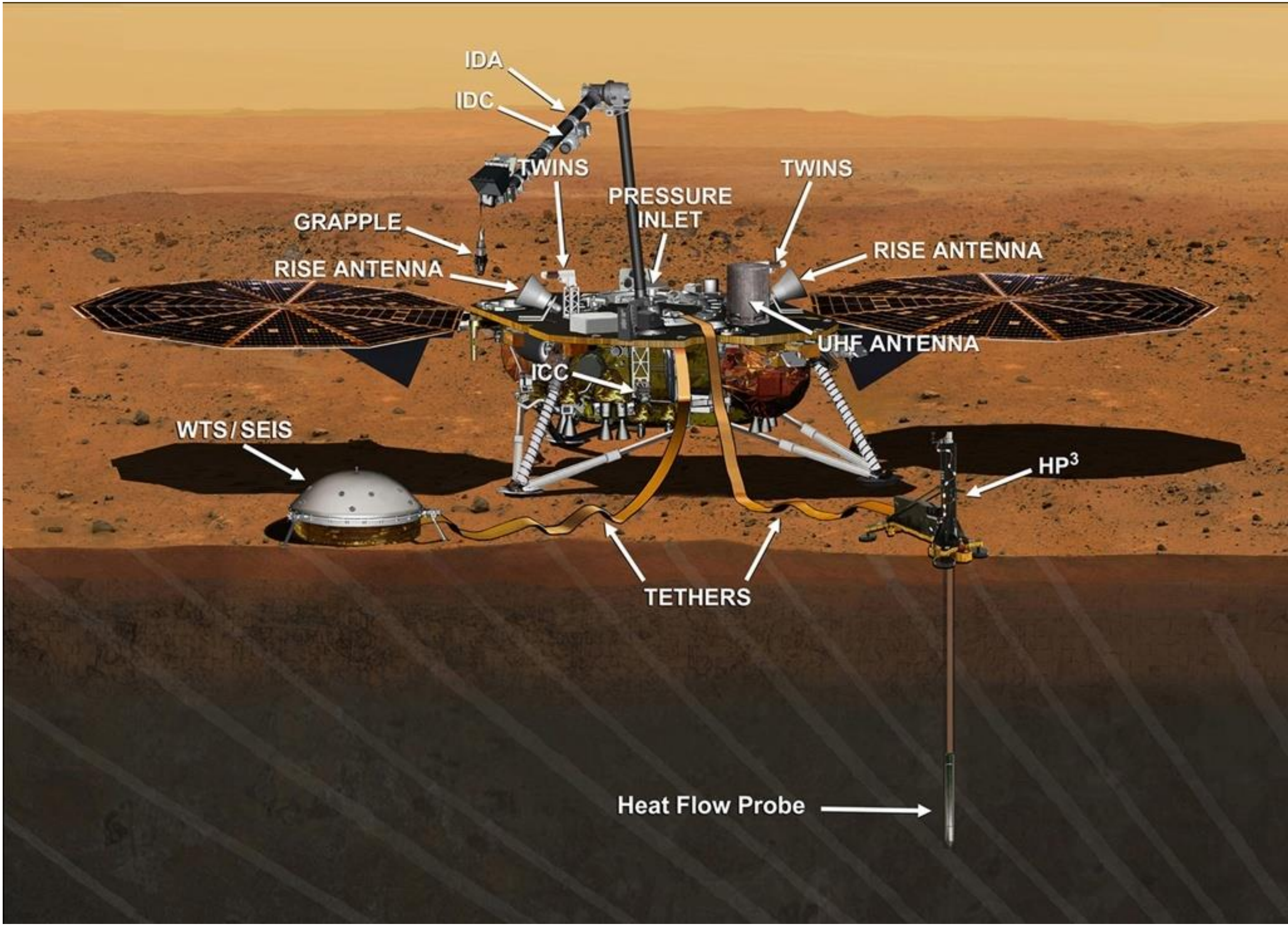



Mars windspeed probabilities are well-described by the 2-parameter Weibull distribution (used in terrestrial wind-energy projects), as noted by Lorenz (Journal of Spacecraft and Rockets, 1996).

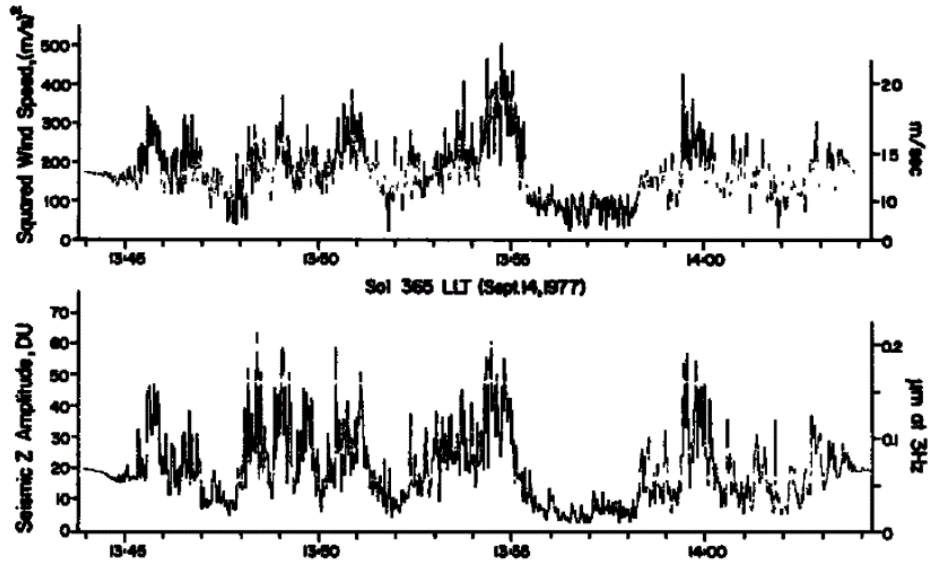
# Meteorological Conditions at Racetrack Playa, Death Valley National Park: Implications for Rock Production and Transport

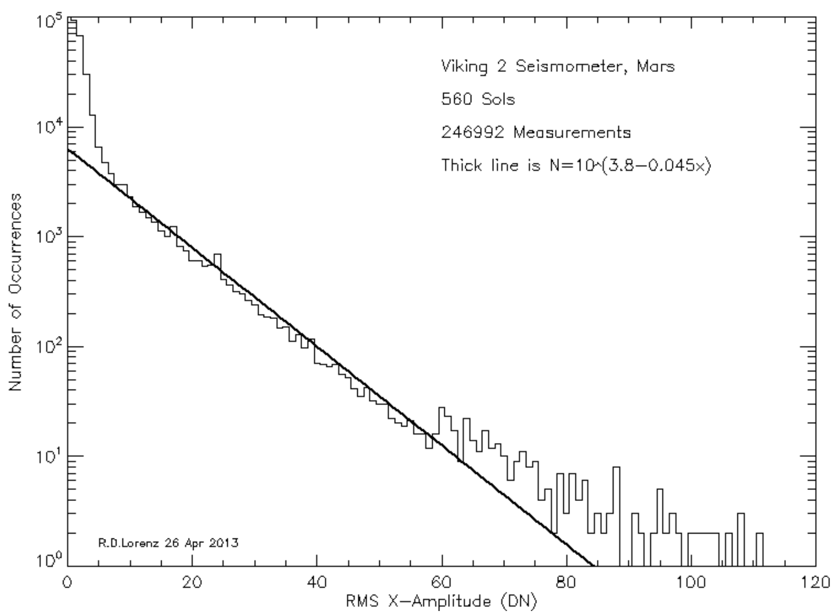
RALPH D. LORENZ,* BRIAN K. JACKSON,+ JASON W. BARNES,# JOSEPH N. SPITALE,@ JANI RADEBAUGH,& AND KEVIN H. BAINES**

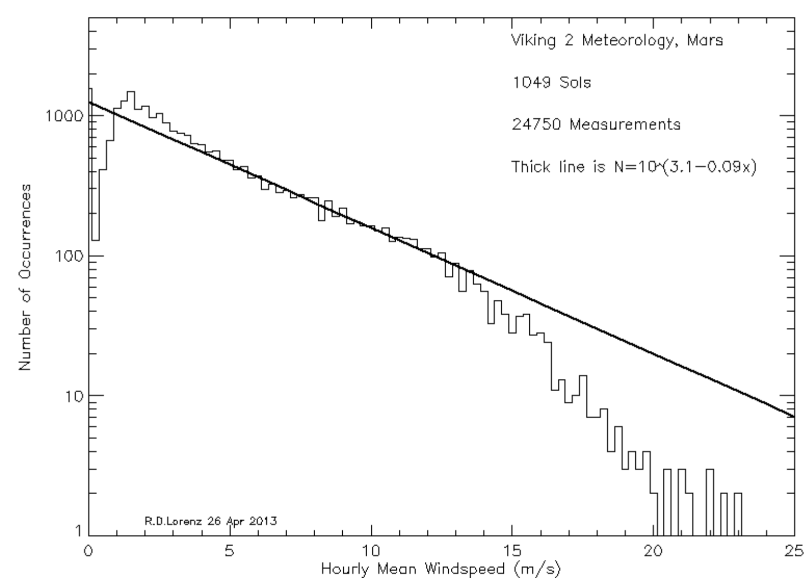


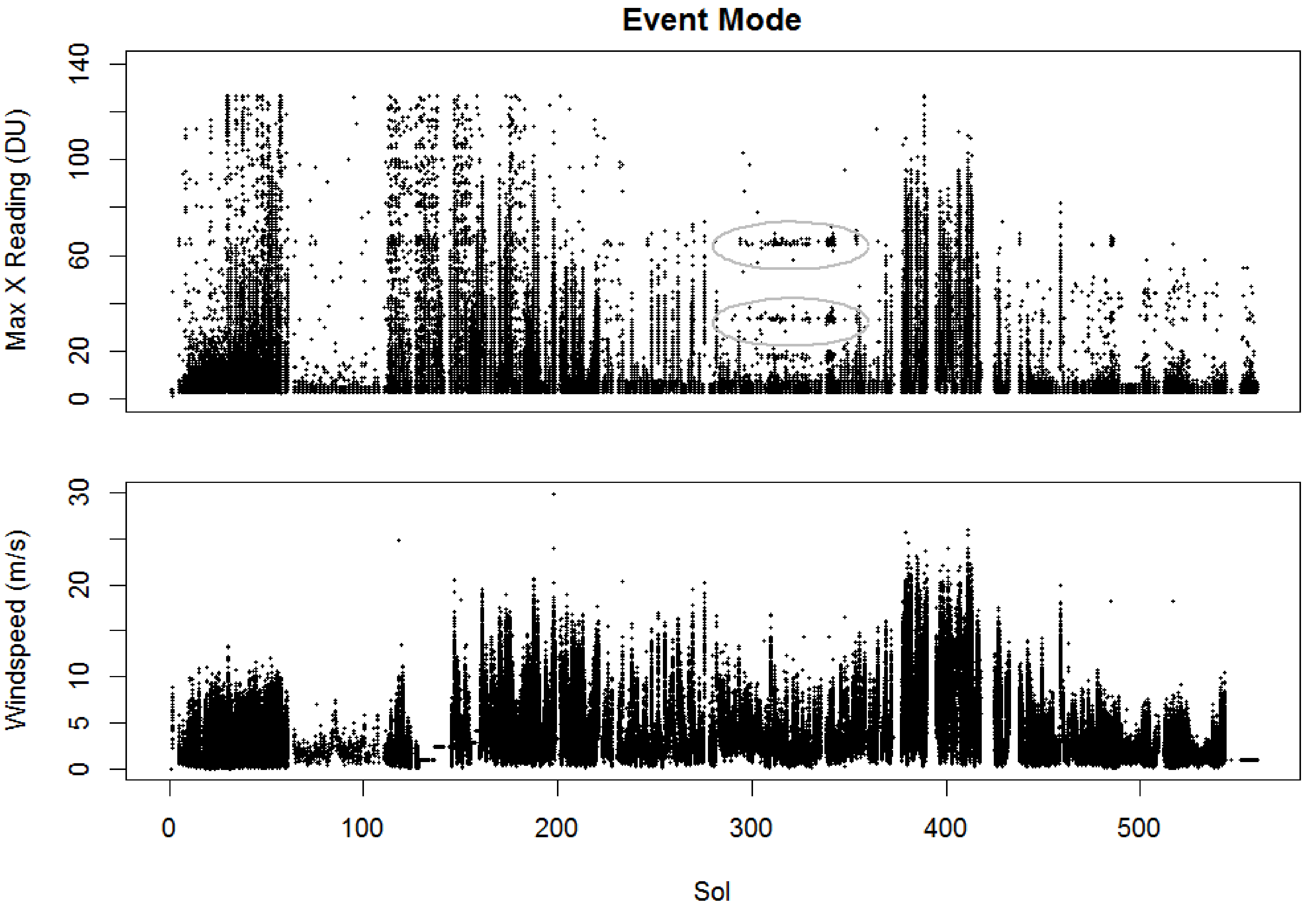

IDA
IDC
TWINS
TWINS
PRESSURE INLET
GRAPPLE
RISE ANTENNA
RISE ANTENNA
UHF ANTENNA
ICC
WTS / SEIS
HP3
TETHERS
Heat Flow Probe

A new source of wind data ? The Viking 2 seismometer is widely dismissed as being contaminated by wind noise. In fact it was sampled much more often than the anemometers themselves, so may (presently being explored with NASA MFRP funding, along with a data restoration/archiving effort) provide some new insights.

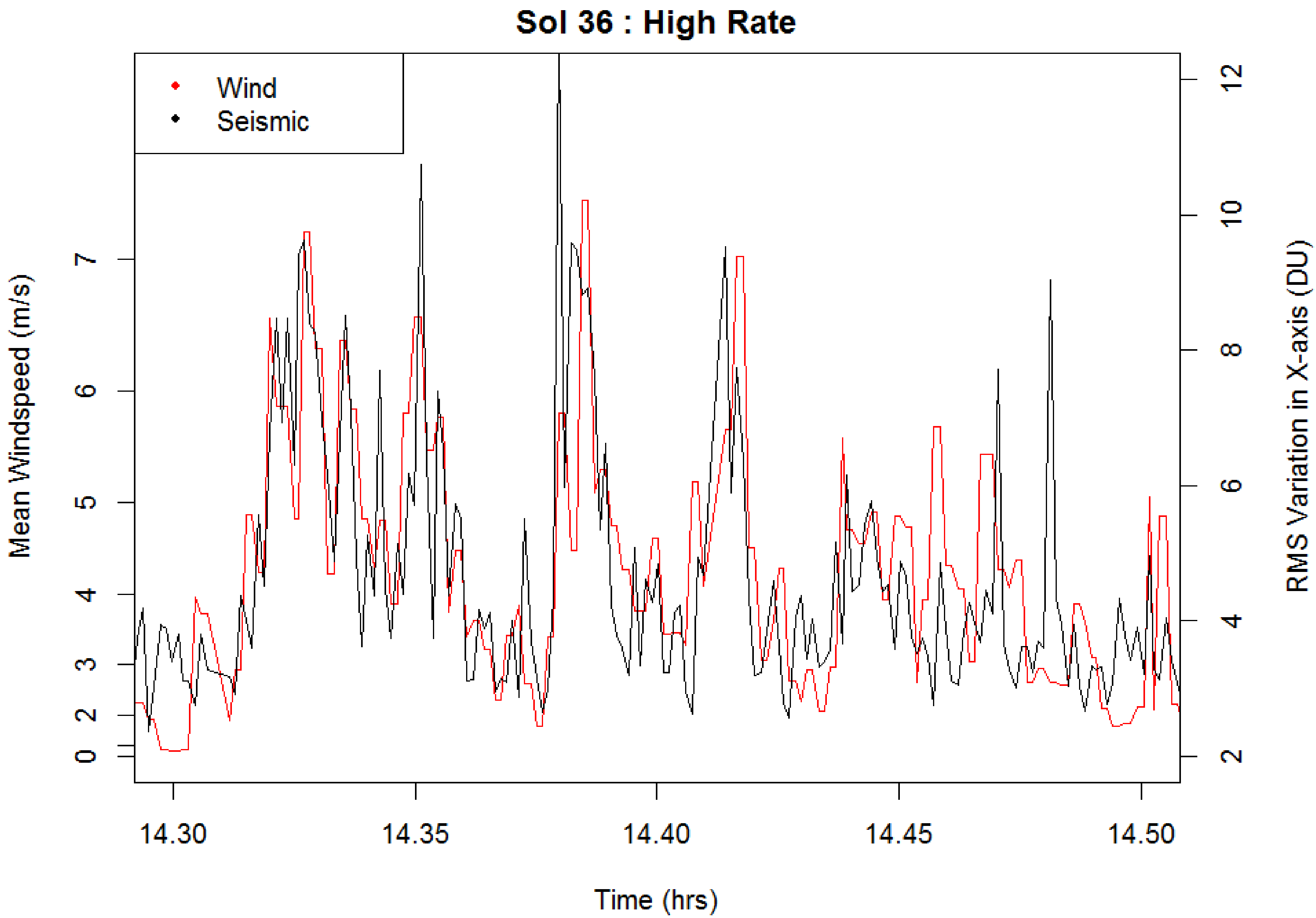


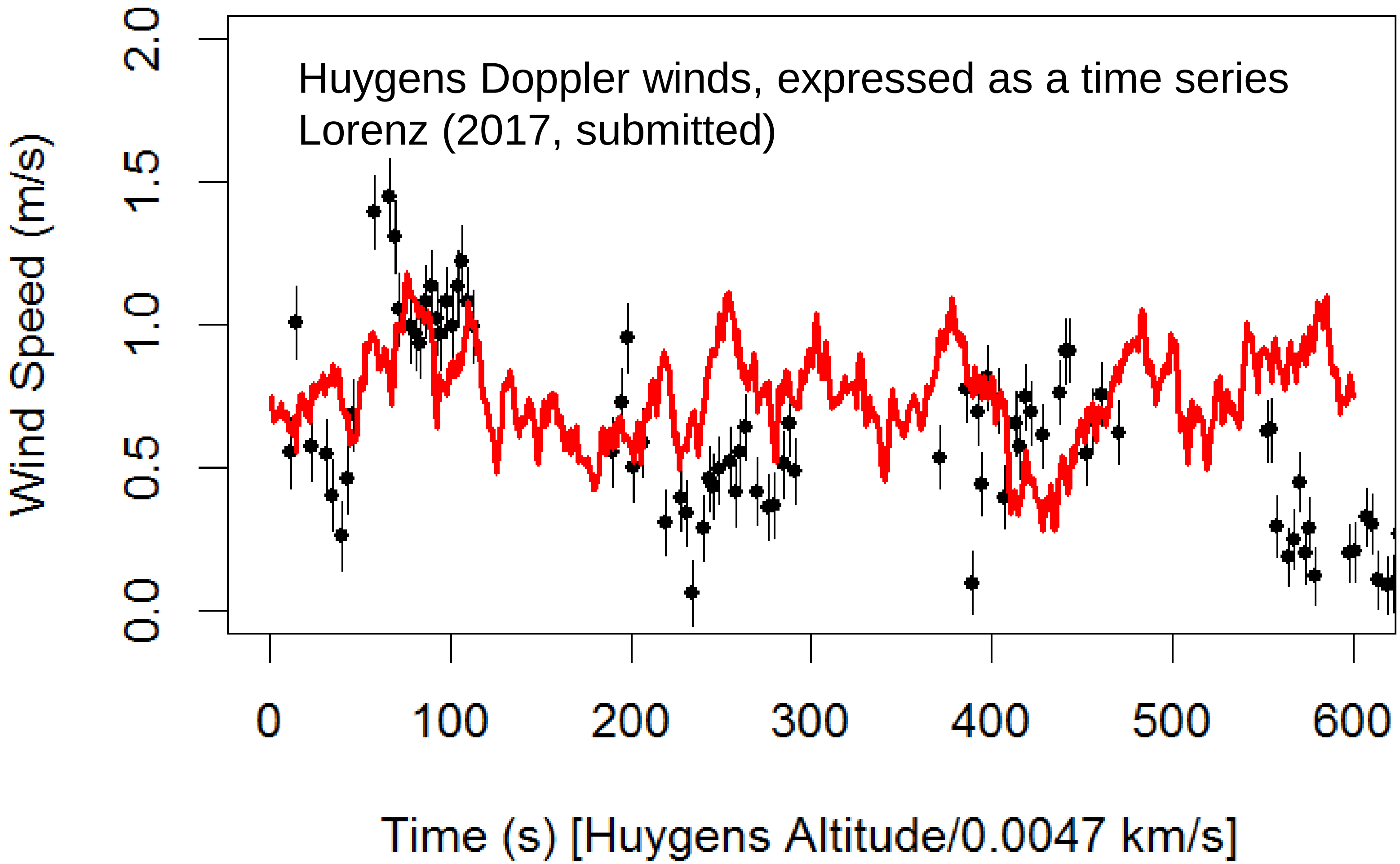



Viking Seismometer record  VL2-M-SEIS-5-RDR-V1.0“  recently archived on PDS (Geosciences Node).  Includes summary product with nearest-neighbor meteorology readings




Generally ~1s amplitude/frequency measurements in 51s strings. Some 20Hz High rate data with ~1s summary/meteorology data

Persistence is evident in the record




Character of wind time series on short timescales is well-captured by AR(1) random-walk model. Von Karman turbulence model used in aeronautics is similarly-generated (low- or band-pass filtered white noise).

Can introduce longer-term correlation, and known periodic variations

# APPLICATION OF MARKOV CHAIN THEORY TO ASTP NATURAL ENVIRONMENT LAUNCH CRITERIA AT KENNEDY SPACE CENTER

By M. E. Graves and M. Perlmutter

NASA CR-129044

Table 2-1. EMPIRICAL PROBABILITIES AND CALCULATED PROBABILITIES OF FAVORABLE CONDITIONS FOR ASTP LAUNCH

| | EMPIRICAL VALUE | CALCULATED VALUE | CALCULATED FROM |
|---|---|---|---|
| $P(F_1)$ | $0.694 \pm 0.026$* | | |
| $P(U_1)$ | | $0.306 \pm 0.026$* | $P(F)$ |
| $P(F_1 \mid F_0)$ | $0.788 \pm 0.028$ | $0.787 \pm 0.022$* | $P(F_1 \mid U_0)$ |
| $P(F_1 \mid U_0)$ | $0.483 \pm 0.051$* | $0.481 \pm 0.064$ | $P(F_1 \mid F_0)$ |
| $P(F_1 \mid F_0 F_{-1})$ | $0.823 \pm 0.028$ | $0.807 \pm 0.020$* | $P(F_1 \mid F_0 U_{-1})$ |
| $P(F_1 \mid F_0 U_{-1})$ | $0.714 \pm 0.070$* | $0.654 \pm 0.103$ | $P(F_1 \mid F_0 F_{-1})$ |
| $P(F_1 \mid U_0 U_{-1})$ | $0.493 \pm 0.069$* | $0.492 \pm 0.072$ | $P(F_1 \mid U_0 F_{-1})$ |
| $P(F_1 \mid U_0 F_{-1})$ | $0.473 \pm 0.077$ | $0.472 \pm 0.074$* | $P(F_1 \mid U_0 U_{-1})$ |

***** *The subscripts indicate the order of days for a favorable (F) or unfavorable (U) case. The asterisks indicate the values used in subsequent calculations.*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Design, assembly, testing (instruments and flight systems)
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Flight operations
Science Planning
Huygens descent and Cassini results
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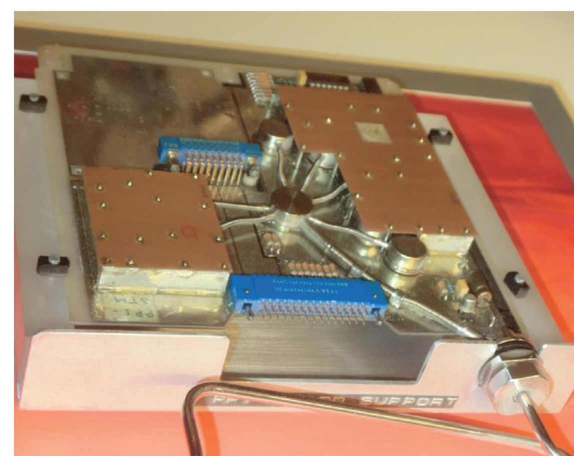
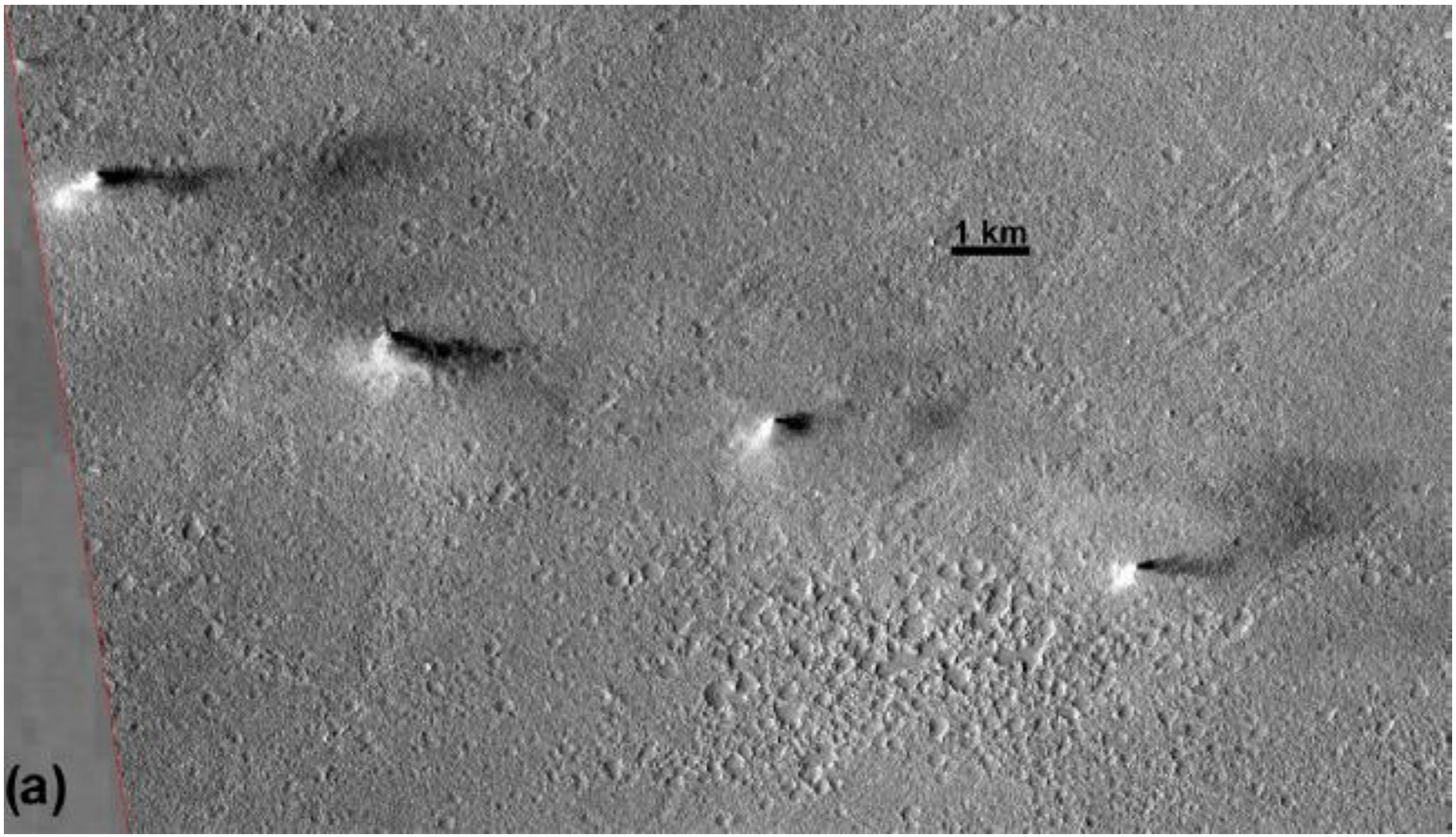
US release May 2017

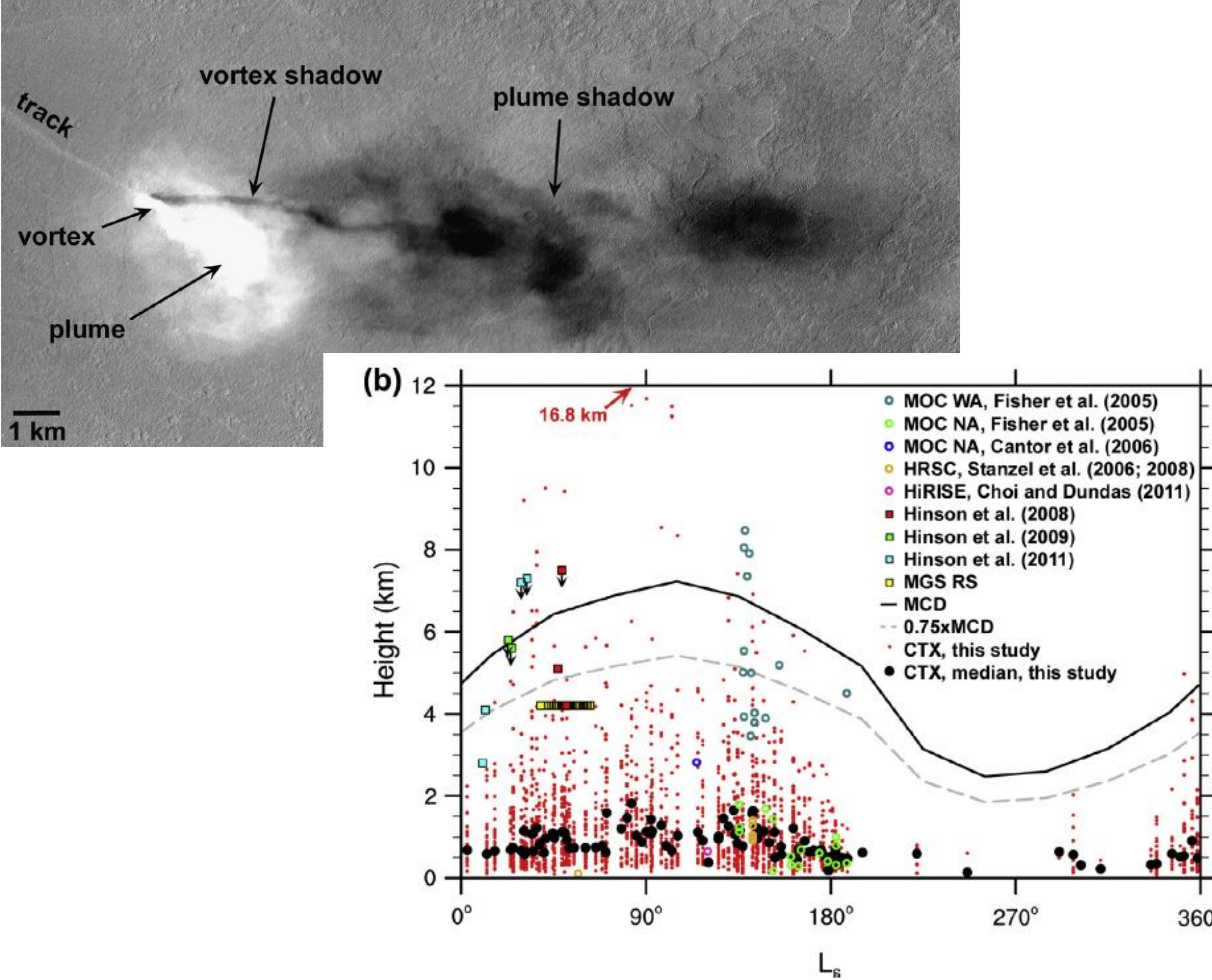


Icarus 260 (2015) 246–262

# Dust devil height and spacing with relation to the martian planetary boundary layer thickness

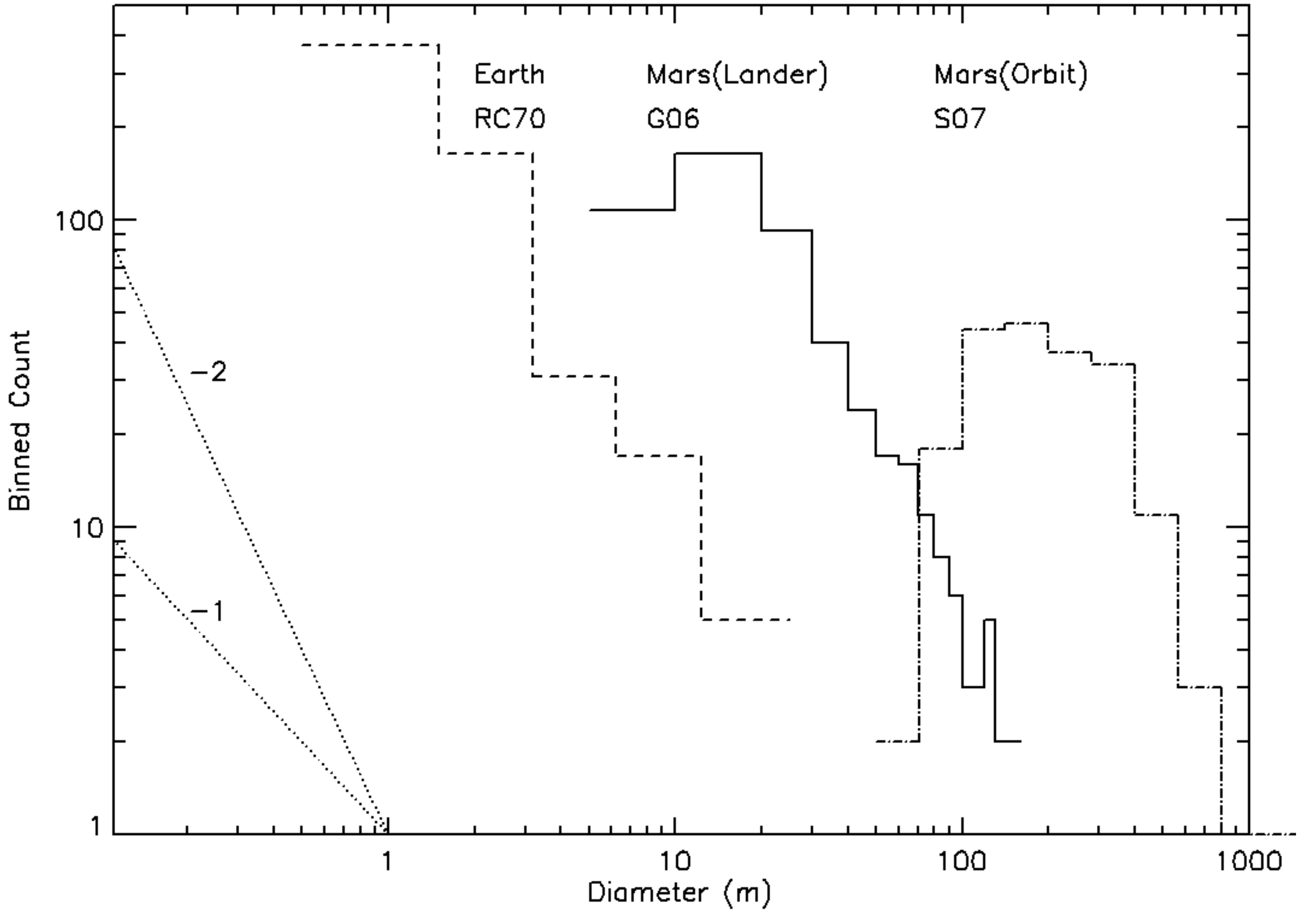
Lori K. Fenton [a,*], Ralph Lorenz [b]



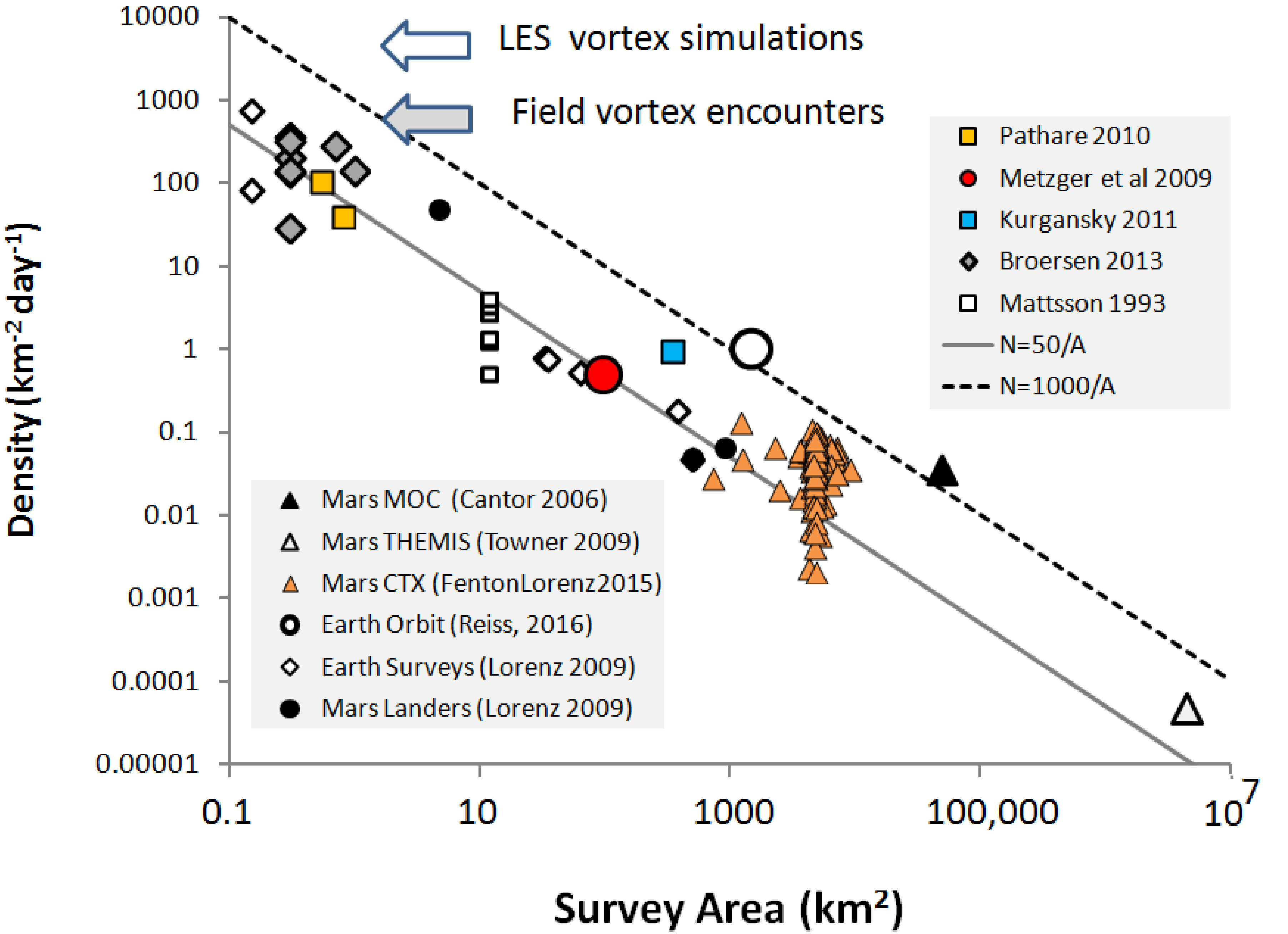


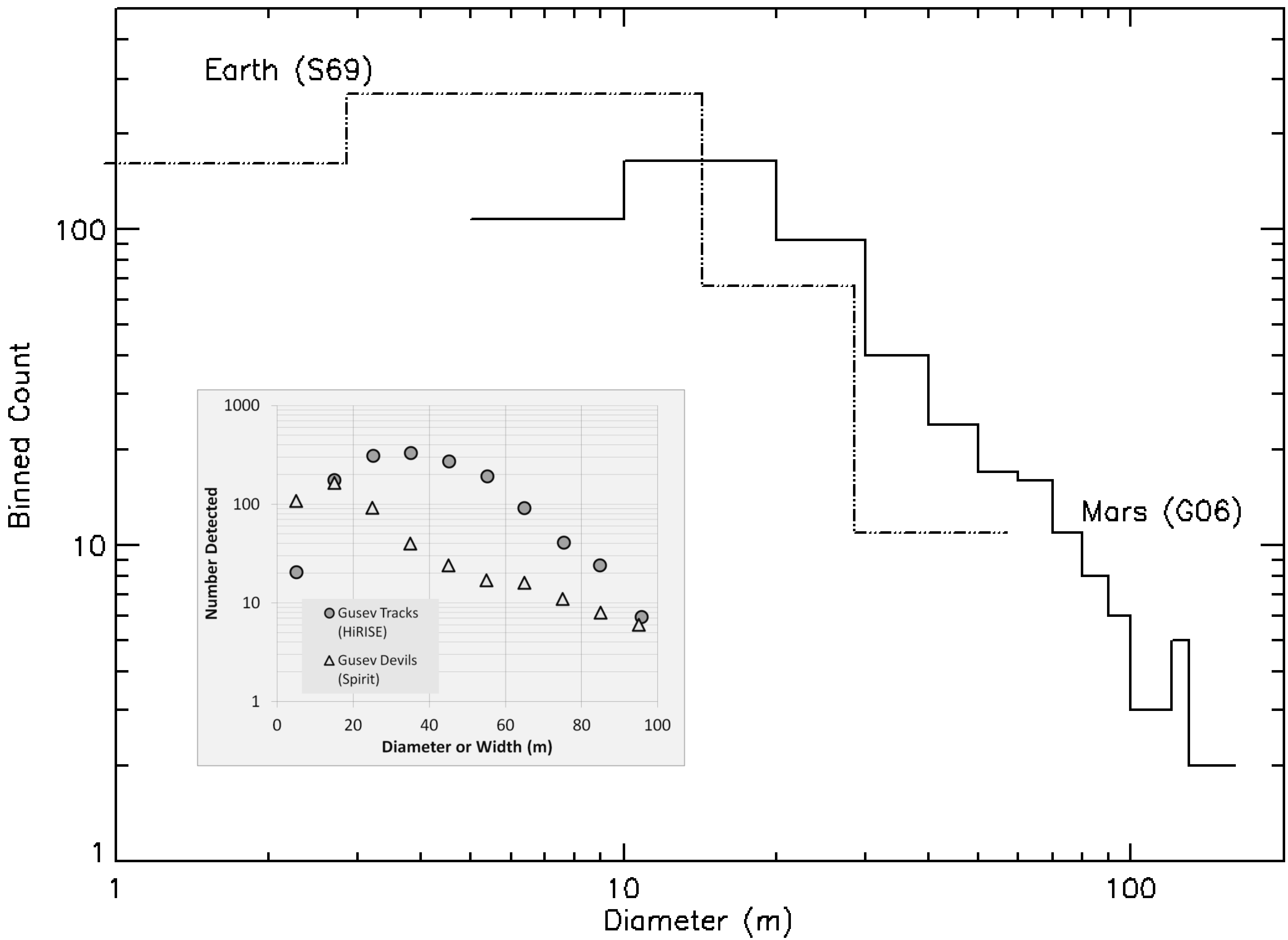
track
vortex shadow
plume shadow
vortex
plume
1 km
(b)
16.8 km
MOC WA, Fisher et al. (2005)
MOC NA, Fisher et al. (2005)
MOC NA, Cantor et al. (2006)
HRSC, Stanzel et al. (2006; 2008)
HiRISE, Choi and Dundas (2011)
Hinson et al. (2008)
Hinson et al. (2009)
Hinson et al. (2011)
MGS RS
MCD
0.75xMCD
CTX, this study
CTX, median, this study
Height (km)
0
2
4
6
8
10
12
0°
90°
180°
270°
360°
$L_s$

Lorenz and Jackson, Dust Devil Populations and Statistics, Space Science Reviews, in press (ISSI volume)




Plotted are the binned counts of dust devils on Earth (Ryan and Carroll, 1970), and on Mars from the Spirit rover (Greeley et al, 2006) and from Mars Express (Stanzel et al., 2007). Differential power law slopes of -1 and -2 are shown at right.


LES vortex simulations
Field vortex encounters
Pathare 2010
Metzger et al 2009
Kurgansky 2011
Broersen 2013
Mattsson 1993
N=50/A
N=1000/A
Mars MOC (Cantor 2006)
Mars THEMIS (Towner 2009)
Mars CTX (FentonLorenz2015)
Earth Orbit (Reiss, 2016)
Earth Surveys (Lorenz 2009)
Mars Landers (Lorenz 2009)
Density (km-2 day-1)
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
0.1
10
1000
100,000
10^7
Survey Area (km²)

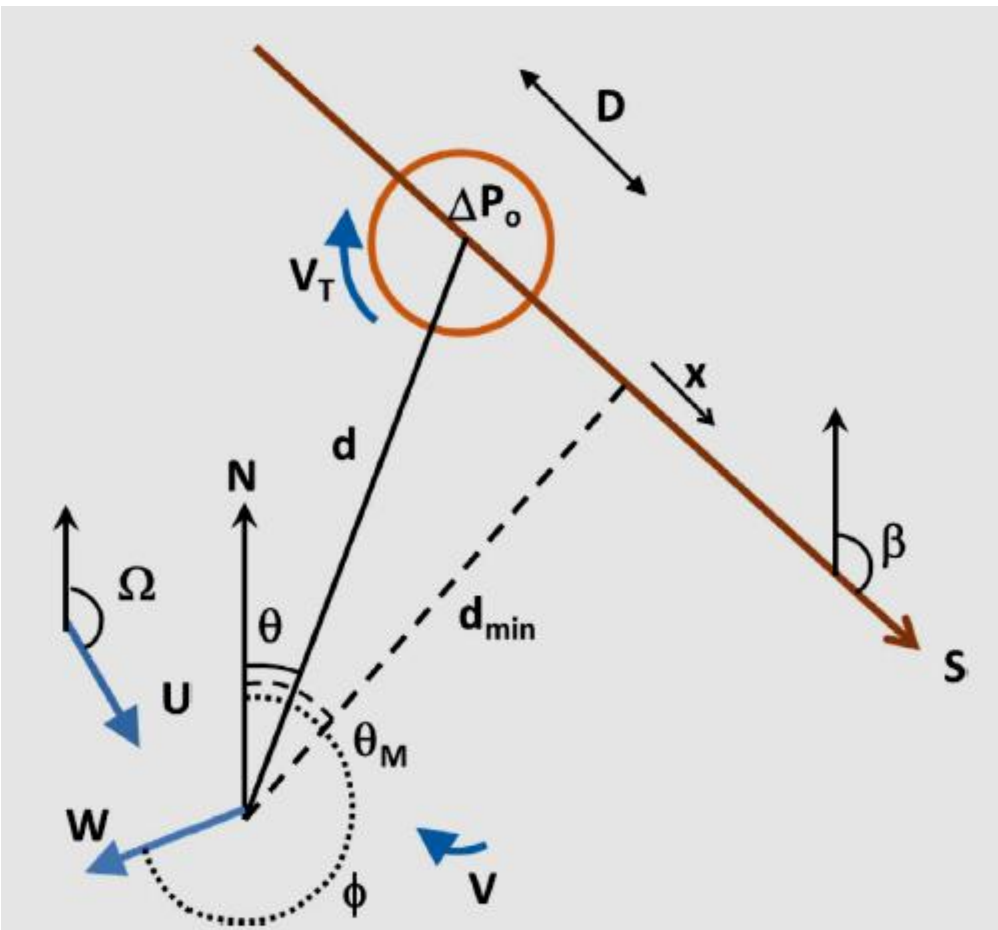


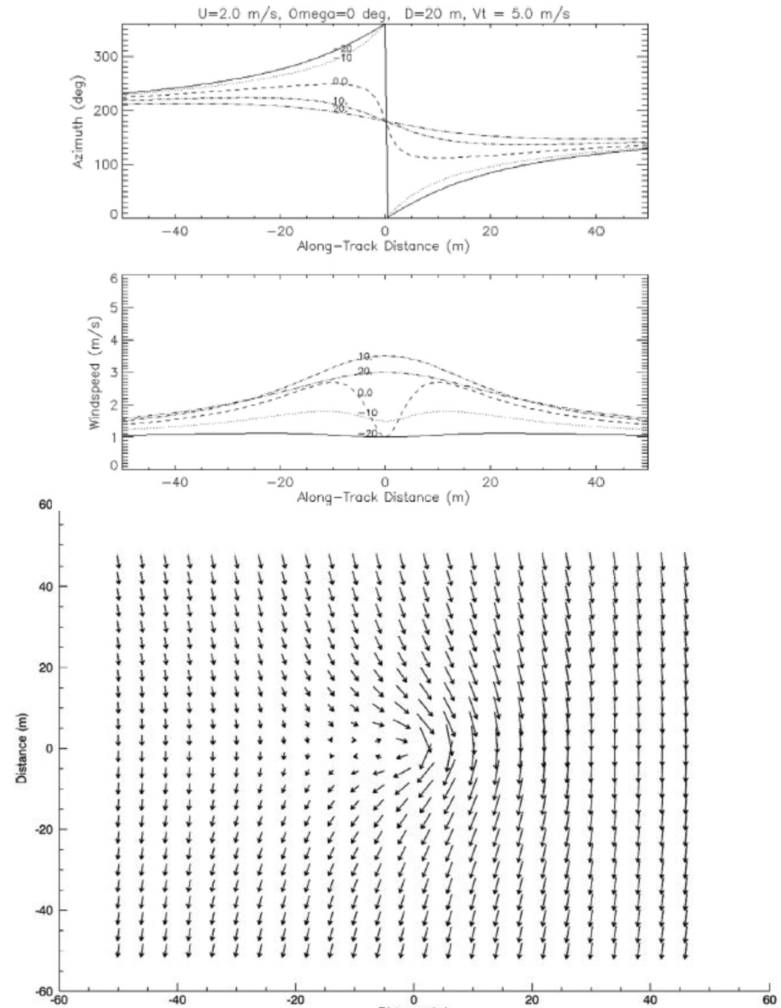
Earth (S69)
Mars (G06)
Binned Count
Diameter (m)
100
10
1
1
10
100
1000
100
10
1
0
20
40
60
80
100
Number Detected
Diameter or Width (m)
Gusev Tracks (HiRISE)
Gusev Devils (Spirit)

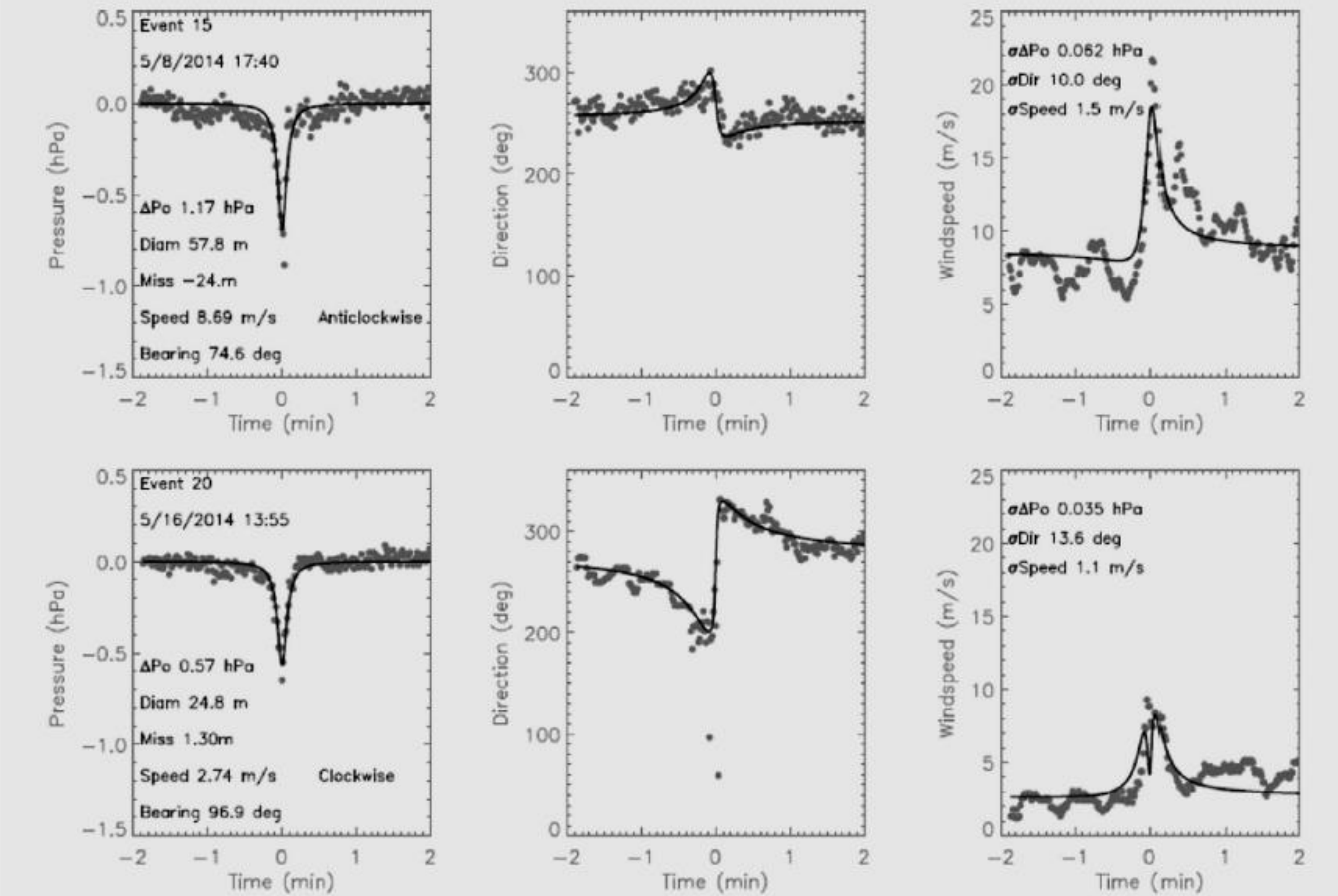
# Heuristic estimation of dust devil vortex parameters and trajectories from single-station meteorological observations: Application to InSight at Mars

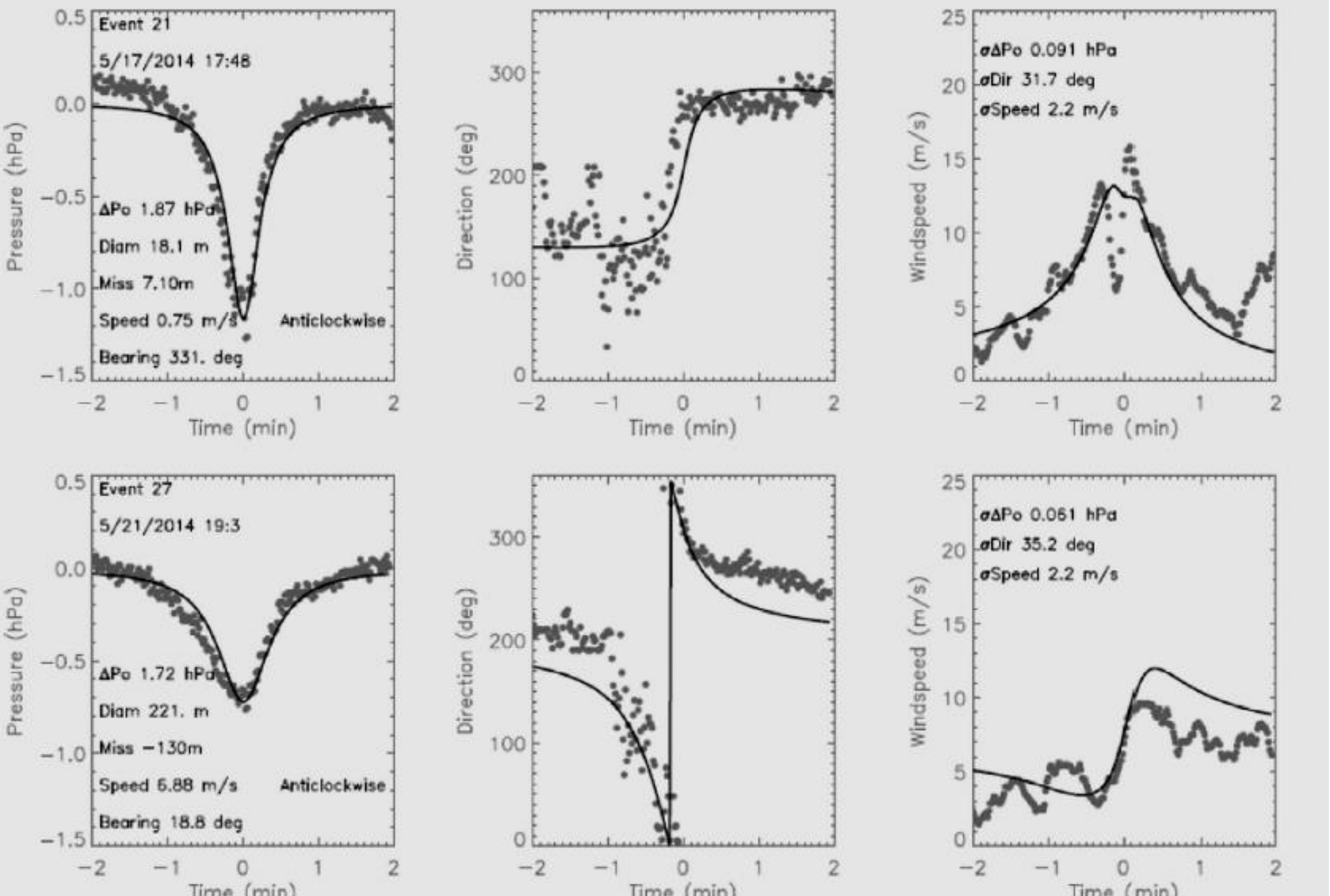
Icarus 271 (2016) 326–337

Ralph D. Lorenz*




Event 15
5/8/2014 17:40
ΔPo 1.17 hPa
Diam 57.8 m
Miss −24.m
Speed 8.69 m/s
Anticlockwise
Bearing 74.6 deg
σΔPo 0.062 hPa
σDir 10.0 deg
σSpeed 1.5 m/s
Event 20
5/16/2014 13:55
ΔPo 0.57 hPa
Diam 24.8 m
Miss 1.30m
Speed 2.74 m/s
Clockwise
Bearing 96.9 deg
σΔPo 0.035 hPa
σDir 13.6 deg
σSpeed 1.1 m/s
Pressure (hPa)
Direction (deg)
Windspeed (m/s)
Time (min)



Event 21
5/17/2014 17:48
ΔPo 1.87 hPa
Diam 18.1 m
Miss 7.10m
Speed 0.75 m/s
Anticlockwise
Bearing 331. deg
Pressure (hPa)
Time (min)
Direction (deg)
Windspeed (m/s)
σΔPo 0.091 hPa
σDir 31.7 deg
σSpeed 2.2 m/s
Event 27
5/21/2014 19:3
ΔPo 1.72 hPa
Diam 221. m
Miss −130m
Speed 6.88 m/s
Anticlockwise
Bearing 18.8 deg
σΔPo 0.061 hPa
σDir 35.2 deg
σSpeed 2.2 m/s

## Conclusions

Landed wind measurements still sorely needed.

Viking Seismometer dataset may be of interest meteorologically

Average wind values are not very meaningful – the geological record, and hazards, are typically driven by the long tail of the distribution.

A variety of distributions can be used to describe wind speed statistics: Weibull is popular, but is not the only one, and may (like any other 2-parameter distribution) fail to capture rare but distinct conditions.

Useful comparisons can be made with GCMs, mesoscale models. Merit of Markov (and hidden Markov) models not yet explored.

Dust devils really are bigger on Mars, but maybe only by a factor of 3…

RL acknowledges the support of Europlanet to attend, and the NASA Mars Fundamental Research and Mars Data Analysis Programs.