A Bump in the Night : Wind Statistics point to Viking 2 Sol 80 Seismometer Event as a real Marsquake

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Introduction: The Viking Lander 2 seismometer operated successfully for over 500 Sols. An event on Sol 80 was identified [1] as a likely candidate Marsquake. However, there was no contemporaneous wind measurement with which to eliminate a wind gust as a cause (since the instrument was mounted on the lander deck, which was above the ground on partly compliant landing legs, it was susceptible to wind noise during the day.) Further, since the Viking 1 instrument to uncage after landing, there was no independent measurement of ground motion (Viking 1 would likely have been too far away to detect such a small event in any case). Here we examine the wind measurements that do exist, and assess quantitatively the probability that there was an unobserved gust large enough to produce the observed event

Viking Seismometer: The Viking seismometer was a 3-axis velocity sensing instrument (essentialy similar to a magnet-coil geophone with an appropriate spring arrangement to give a resonant frequency of about 3 Hz). The 2.2kg, 3.5W instrument included variable gains and filters and (for the time) elaborate data handling.

The instrument operated for over 500 Sols before failure of a Lander memory unit prevented further data acquisition. Although some high rate data were acquired, most measurements (including the Sol 80 detection) were in 'Event' mode, which records the envelope in each axis at 1.01Hz, as well as the number of zero crossings (thus a measure of frequency) in the same interval.

Raw seismometer data are stored at the National Space Science Data Center (NSSDC), although in a somewhat inconvenient form. Somewhat ordered data ('VUSA' tapes retained by one of us (YN) are available at https://darts.jaxa.jp/planet/seismology/viking/index.html. A reduced dataset, together with wind data refined by JM, is being prepared by RL for delivery to the PDS under MFRP funding.

Sol 80 Event: Measurements were made regularly in this season during the night, when wind noise was expected to be a minimum. On Sol 80, at 0300 hrs, an event was captured (Figure 1) with unusual frequency characteristics which suggested its origin as a 'true' seismic event.

The signal has been compared [1] slightly stronger with events captured at distances of 65-69km from an identical instrument at Caltech, namely a Magnitude 3.0 aftershock and a Magnitude 2.5 mining explosion (102 tons). Assuming magnitude-duration relationships, i.e. scattering and attenuation characteristics for the Martian crust similar to Southern California, a distance of 110km was estimated [1] for the event and a magnitude of 2.7.

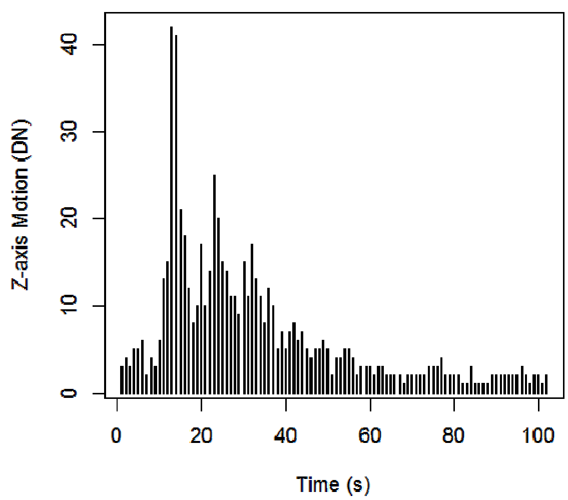

Figure 1. Z-axis seismic record of the Sol 80 event. The record shows the envelope amplitude of motions in a WSW-ENE direction.

Although the event's occurrence during the normally quiet night was noted, the possibility of wind gusts was noted, but not until now quantified.

Correlations of wind speed with seismometer output [1,2] suggest an amplitude A=0.15V^2 (see also [3]) and so the peak of 40 DN implies that a wind of ~16 m/s was required to generate the lander motion shown in Figure 1.

Meteorology Data : Although meteorology data were not acquired continuously, such that the winds would be known at the instant of the recorded seismic event, measurements were made regularly. The measurements adjacent in time to the 0300 event (assuming the time-tagging of records to be correct – there is some uncertainty in thei reconstruction) were at 0240 and 0345, of 2.6 and 3.6 m/s.

The surface winds at the Viking sites generally had a very consistent diurnal cycle (see Fig. 2), with windspeeds being lowest in the early hours – which is indeed why the seismometer was operating at that time. Thus we can use the winds in adjacent nights to estimate the probability that a wind gust strong enough to cause the Sol 80 seismic event would occur.

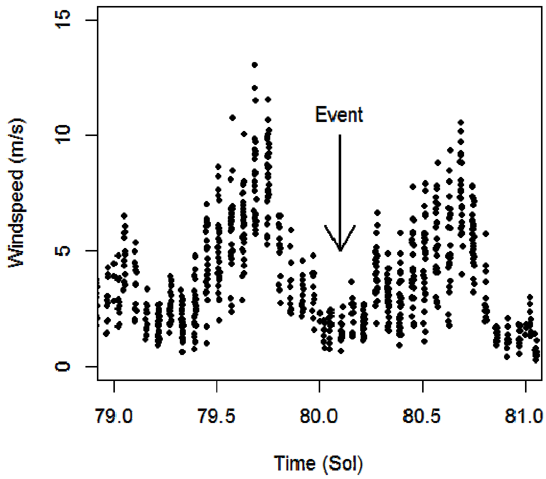

Figure 2. Wind data for the two days around the Sol 80 event. Data were acquired in bursts at roughly hourly intervals.

Figure 3 shows the probability distribution of wind measurements made between midnight and 0600 in the 20 day period around Sol 80. Those measurements can be described by a Weibull distribution (as indeed can other subsets or the entirity of the Viking wind record). A representative fit by eye is also shown in Figure 3, with a cumulative probability distribution

P(>v)=exp(-(v/c)^k)

where P(>v) is the probability of exceeding windspeed v, c is a scale speed, and k is a shape parameter. For c=2.4 m/s, k=1.4 as shown, the probability of a 16 m/s datapoint is ~6E-7, or roughly one in a million. Even so, the largest actual measurement out of the 1348 datapoints is 9.44 m/s so the probability of a gust with the strength needed is certainly small.

Meteorological time series exhibit properties of persistence. Thus it may be that a more elaborate conditional probability (e.g. Markov chain) exercise could be performed to refine the probability that a gust of sufficient strength and duration to cause the observed ~30s event AND that no other gusts (say) 50% as large occurred during the seismic observation period.

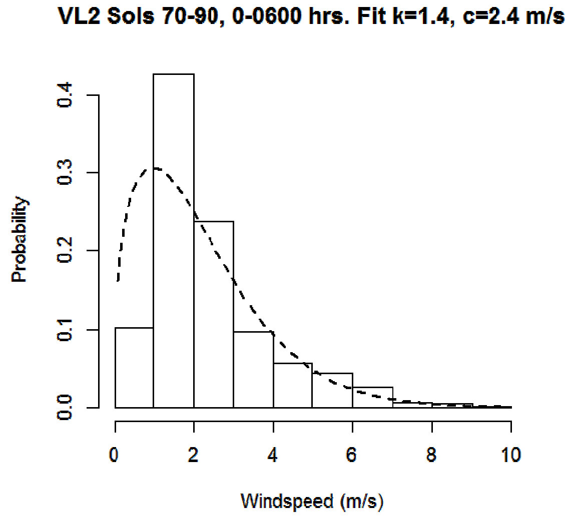

Figure 3. Histogram and Weibull fit for early morning data in a 20-sol period. Less than 5% of speeds measured were above 6 m/s.

Conclusion : Simple point statistics of night-time winds show that the overwhelming probability is that the Sol 80 event was a marsquake. We are examining other events in both seismic and wind data.

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References: [1] Anderson, D. L. et al., Seismology on Mars, Journal of Geophysical Research, 82, 4524-4546, 1977 [2] Nakamura, Y. and D. L. Anderson, Martian Wind Activity Detected by a Seismometer at Viking Lander 2 Site, Geophysical Research Letters, 6, 499-502, 1979 [3] Lorenz, R. D., Planetary Seismology - Expectations for Lander and Wind Noise with Application to Venus, Planetary and Space Science, 62, 86–96, 2012 [4] Lorenz, R. D., Martian Surface Windspeeds described by the Weibull distribution, Journal of Spacecraft and Rockets, 33,754-756, 1996
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