GALE WIND SPEED WEIBULL DISTRIBUTION BASED ON THE FIRST TWO YEARS OF REMS WIND DATA

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Introduction:

The probability of wind speed exceeding a given value is important for many engineering and geophysical applications, instead of the more standardized use of the diurnal variation in wind speed [1]. Thus, the characterization of the Martian wind at different locations can increase our knowledge of Mars and assist in this application for future unmanned and manned missions.

Weibull distributions are widely used for characterizing wind speed probability distributions on Earth [2-5], as for example in renewable energy applications to identify optimal locations for wind farms. In addition, the Weibull distribution has also been used for estimating wind speed probability distributions in Martian atmospheric models [6-10].

However, there are few datasets that can be used to characterize the Weibull parameters for Mars. The MER rovers did not carry meteorological instruments, and calibrated wind speeds are not available for the Mars Pathfinder wind sensor. The Phoenix wind sensor provided data for only a small portion of the Mars year, and the same is true for reliable Viking Lander 1 wind data. Previous detailed studies were performed in [1] based on the Viking Lander 1 and 2 datasets for the particular landing sites of these spacecraft.

NASA's Mars Science Laboratory (MSL) mission has been measuring wind speeds and directions since the Curiosity rover landed at Gale Crater in 2012. The instrument acquiring these measurements is the Rover Environmental Monitoring Station (REMS) [11], developed at the *Centro de Astrobiología* (Spain). This paper presents a new Weibull model parameters based on the REMS data, and compares this with previous Viking results.

Weibull Distribution:

This probability distribution can be described by two parameters, the scale parameter c and the dimensionless shape parameter k [1-2,6,12]. The distribution gives a probability density function:

$$f(v) = (k/c)(v/c)^{k-1}e^{-(v/c)^k} \tag{1}$$

and a cumulative probability function:

$$P(< v) = 1 - e^{-(v/c)^k} \tag{2}$$

where the scale parameter c describes how much the distribution is stretched along the horizontal axis, and it therefore it relates to the wind speed while the shape parameter k controls the form of the distribution [6]. These parameters can be obtained by some different methods [2,4], as maximum likelihood estimation or least squares.

Thus, the applicability of a Weibull distribution lies in the asymmetry of this function [1], because wind speed distributions typically are asymmetric, and therefore other probability functions such as Gaussian distributions offer poor model fits due to their symmetry.

REMS Wind Data:

The REMS wind sensor (WS) [11] follows the Viking design [1] and uses thermal anemometry to record wind speed. Hot wire anemometry is based on recording either the amount of power required to heat a wire so that it maintains a constant temperature difference with the ambient (CTA) or to record the temperature of the wire when supplied with a constant amount of power (CPA). The convective power is then calculated, which in turn is used to obtain the wind speed. The REMS wind sensors use a thin film instead of a wire: titanium thin film resistors patterned on the surface of a silicon chip. The WS incorporates two booms [11] angled at 120° to each other and mounted on the large circumference remote sensing mast (RSM). Each boom has three sensor boards angled differently to the incoming wind direction. An algorithm combining the data from all 6 boards determines the true wind speed and direction.

As described in [11], REMS wind data are strongly influenced by the MSL rover body and some of its appendages. Unfortunately, an additional complexity derives from sensor damage sustained by flying debris during the MSL landing which makes it difficult to obtain complete wind data. In short, the side/rear-pointing boom cannot be used, leaving only the front-pointing boom, which sits in the wake of flow coming from behind the RSM. This means that wind speeds cannot be retrieved for winds coming from the hemisphere behind the rover (for a given rover heading).

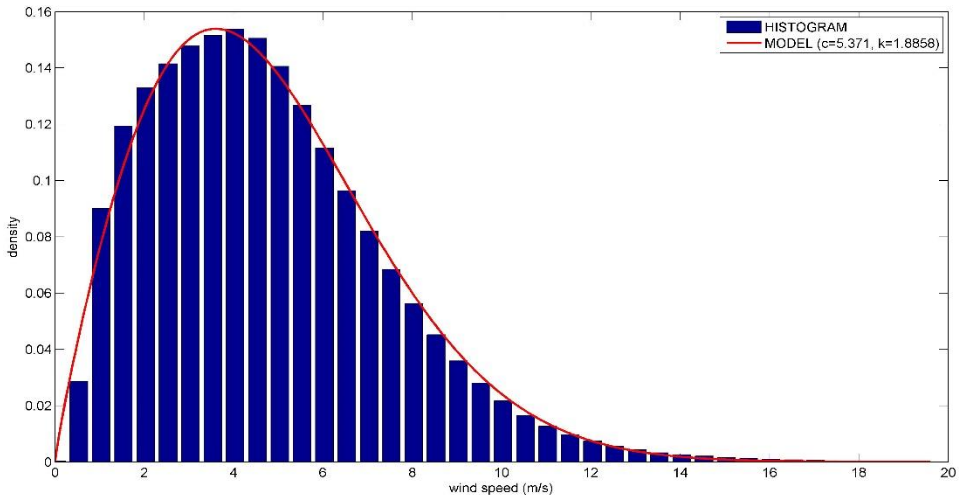

Figure 1: Weibull probability density function and comparison with empirical data

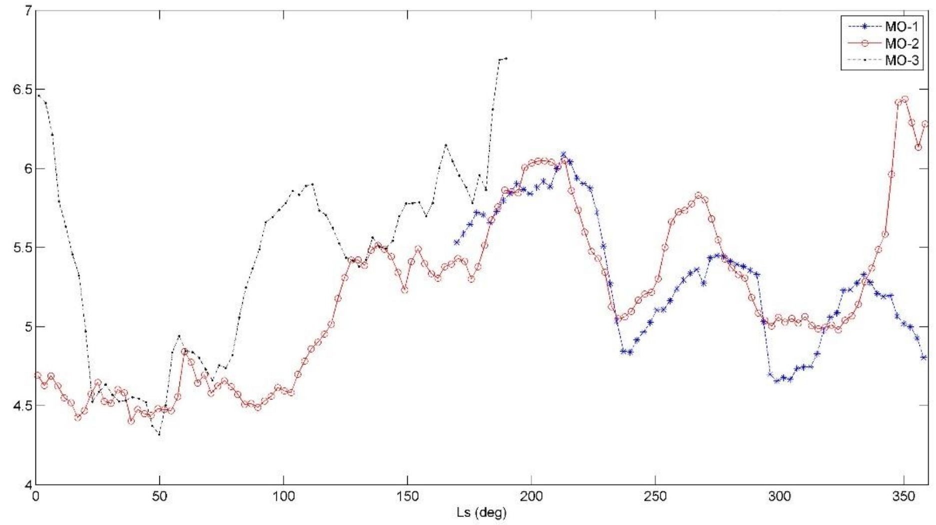

Figure 2: Seasonal effect on Weibull parameter c (m/s)

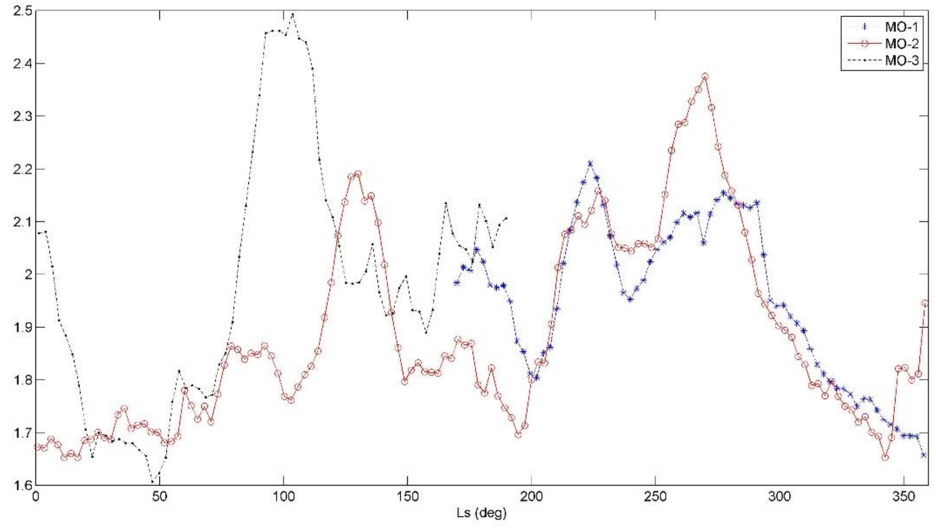

Figure 3: Seasonal effect on Weibull parameter k

Due to memory restrictions, REMS operates in 5 minute sessions per hour, measuring specific full hours each day, based on a cadence table and daily scientific decisions. Thus, global measurements are not uniform from a daily point of view. Therefore, data has been size uniformed in order to uncouple the effect of the measurement times within a day.

For this study, segments of data for sols (Martian days of the MSL mission) 9 to 1474, in a Local Mean Solar Time (LMST) periods between 10:00 and 18:00 were utilized to generate a wind speed distribution using 0.5 m/s wide bins, where $0 < v < 20$ m/s. Data with calm periods are removed based on the procedure described in [1] for the Viking data, and the other values rescaled accordingly.

Weibull model results:

Figure 1 shows the global Weibull probability density function (red line) and the comparison with the REMS empirical data (blue histogram), taking into account everysol. As can be seen, the model fits the empirical data well if the scale parameter $c = 5.3710$ m/s and shape parameter $k = 1.8878$.

Figure 2 and Figure 3 show the variability in Weibull parameters (c and k respectively) with the aforementioned areocentric solar longitudes (Ls) for the data that have been received until now, taking into account 40 sols for each model centered in the Ls values. For the scale parameter c (4.3 m/s < c < 6.6 m/s), there is a linear dependency with the average wind speed. As average wind speed varies, the c parameter varies in the same way, achieving maximum values in the 180 deg < Ls < 220 deg range, next to the southern spring equinox. There is another maximum in the 330 deg < Ls < 10 deg range for the MO-2, next to the southern autumn equinox, which is not performed in the MO-1. For the shape parameter k (1.60 < k < 2.5), it achieves maximum values in two different Ls ranges: 80 deg < Ls < 120 deg and 250 deg < Ls < 290 deg, and minimum values in three different Ls ranges: 20 deg < Ls < 60 deg, 180 deg < Ls < 220 and 310 deg < Ls < 350 deg. In these ranges, wind distributions are more symmetric. In addition, except for the autumn equinox, there is a good interannual correlation in winds, especially for the southern spring and summer. However, more Martian years of data should provide a more accurate characterization of the seasonal and interannual effects.

REMS results are similar to those obtained for the two Viking spacecraft [1], where scale parameter ranges between 2.55 and 7.90 m/s, and shape parameter ranges between 1.06 and 1.68. Differences could be mainly explained by the parameter dependence on the spacecraft landing site locations, surface morphologies, the LMST dependence and the meteorological conditions in the mission lifetime.

Typical terrestrial values for the shape parameter are close to 2, while the scale parameter has a strong time and spatial dependency, whose values are between 2 and 7 for most of places [1-5].

Future wind sensors headed to Mars as part of NASA missions include TWINS for Insight and MEDA for Mars 2020, both developed at the *Centro de Astrobiología* (Spain). These will increase our knowledge of Martian winds by enabling this and other wind studies at further locations.

Conclusions:

This study presents the first results of a Weibull wind distribution model applied to the MSL REMS data, which shows similar results to those obtained for the Viking spacecraft. Further research will be focused on increasing the model domain to the remaining timeslots in order to achieve a complete diurnal characterization. Thus, the characterization of the Martian wind speed at different locations can increase our knowledge of Mars and assist for future unmanned and manned missions, since probability of wind speed exceeding a given value is often required for engineering and geophysical (e.g. aeolian studies) applications.

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