Mars Seismic Catalogue, InSight Mission; V1 2/1/2020.

Overview

This catalogue includes Martian seismic events as recorded by InSight up to September 30, 2019 / Sol 299 for the InSight mission. Actual files are available at IPGP and IRIS.

The citation for the catalogue is:
InSight Marsquake Service (2020). Mars Seismic Catalogue, InSight Mission; V1 2/1/2020. ETHZ, IPGP, JPL, ICL, ISAE-Supaero, MPS, Univ. Bristol. https://doi.org/10.12686/a6

The catalogue is provided in 2 files. Both are in QuakeMl format. One is in standard BED format and validates against the QuakeML 1.2 schema. The second includes a Mars-specific extension that includes basic information for single station locations and Mars catalogue management that is not available in the BED format. These include:

- Distance
- Back Azimuth
- Mars Event Types
- Mars Event Quality

The XML schema and documentation of the Mars-specific extension will be provided in a subsequent release.
A pre-landing description of the MQS is at Clinton et al, 2018. More detailed descriptions of the catalogue, key event presentations, and MQS procedures, will be provided in forthcoming InSight team publications that are currently under preparation and review.

The InSight seismic event catalogue is subject to revision, as new events are collected and analysed, the velocity models are improved, and our understanding of the seismicity increases and MQS procedures evolve. We expect to release revised catalogues alongside new waveform data releases, major publications, and revised planetary models.

MQS conventions

MQS assigns an event type and quality to seismic signals. The event type reflects the frequency content. The event quality is assigned based on the signal strength and ability to identify and interpret the phase arrivals.

MQS Event Type

Events Types dominated by long period signals	
Low frequency (LF)	energy in 3 components all below 2.4Hz
Broadband (BB)	energy in 3 components predominantly below 2.4Hz though also includes excitement at possibly above 2.4Hz.
Events Types dominated by high frequency signals	
High Frequency (HF)	energy in 3 components predominantly at 2.4Hz and above. 'Predominantly' indicates some leakage of energy below 2.4Hz is possible
2.4Hz	energy in 3 components centered around 2.4Hz resonance, with very limited excitation above of below. (It is likely these are small amplitude HF events.)
Very High Frequency (VF)	Special case of high frequency events that show clear differences in energy between vertical and horizontal components. Horizontal energy is significantly larger the vertical energy at higher frequencies. Events tend to have shorter durations than HF events.

MQS Event Quality

Label	**Quality summary**	**Key features**
A	High	Multiple clear and identifiable phases / clear polarisation (implies possibility of distance and BAZ => location)

B	Medium	Multiple clear and identifiable phases but no polarisation (implies possibility of distance but no location)
C	Low	Signal is clearly observed but phase picking is challenging: - no clear phases can be identified OR - only a single phase is clearly identifiable OR - multiple phases are identifiable, but no clear picks can be attributed to P and S phases
D	Suspicious	Signal only weakly observed OR Signal is likely not attributable to a seismic event

MQS Event Names
Events are labelled following the convention S[xxxx][z]; where [xxxx] indicates the InSight mission sol the event begins on (starting from sol 0, the sol InSight landed on Mars), and [z] is a letter that ensures unique names if multiple events occur on a single Sol.

MQS Phase Picks
When possible, MQS selects the first arrival times for distinct energy packets. Pick time uncertainties are on the order of seconds if made on the waveform in the time domain; and on the order of 10's of seconds if these are based on a distinctively new signal visible on a spectrogram. Typically, only 1 or 2 energy packets are identified, if any, and are labelled P and S for HF/BB event types, and Pg and Sg for HF,VH and 2.4Hz event types.

For each event, MQS also includes 'picks' for event start and end and start and end of noise windows with similar noise as observed during the event. Since there are numerous glitches in many events, when possible, we also include 'clean' P and S coda windows. Depending on the event type, the time at which peak amplitudes occur with bandpassed signals are also indicated. MQS is tracking all significant glitches within the event start and end window, but these are not currently available.

Pick uncertainties are assigned for P/S/Pg/Sg, but not for any other pick type.

Distances, Back Azimuth and Location
BB/LF events: If multiple picks are assigned as P and S phases and used to provide preliminary distance estimates using a priori Martian velocity models. The back-azimuth can be estimated using first phase arrivals if they are assumed to be P-waves and polarization is present. A single station location estimate can be made by combining both. This approach is outlined in Clinton et al, 2018 and Böse et al, 2017. Distance / Location / Back Azimuth uncertainties are included in the catalogue.

HF,VH and 2.4Hz events: If multiple picks are assigned as Pg and Sg phases a preliminary distance estimate is made using a simple crustal velocity model with Vp=2km/s, Vp=3.46km/s. There are no back-azimuth estimates for any of these events. Location uncertainty is provided as +/-(0.75xDistance).

Only a handful of events in the catalogue include a computed latitude/longitude location. A location is required for a valid QuakeML origin, so by default all other events are assigned the location of the lander, at lat=4.5024, long=135.6234.

Depth
Depths are currently not included in the catalogue.

Magnitude
Magnitude scales for Martian events are developed in Böse et al, 2018 and have been revised since landing. These are described in Giardini et al (in review). Magnitude scales using P and S ($m_{\mathrm{b}}^{\mathrm{Ma}}$ and $m_{\mathrm{b}S}^{\mathrm{Ma}}$) body phase amplitudes, 2.4Hz resonance ($M_{2.4\mathrm{Hz}}^{\mathrm{Ma}}$) amplitudes, and spectral fitting ($M_{\mathrm{FB}}^{\mathrm{Ma}}$) are included, when possible. The preferred magnitude is $M_{\mathrm{FB}}^{\mathrm{Ma}}$ when available.

Magnitude uncertainty is currently not populated.

Catalogue Overview

	Total	A	B	C	D
Total	174	2	36	71	65
LF	15	1	2	5	7
BB	9	1	3	2	3
HF	13	-	8	4	-
VF	6	-	4	3	-
2.4Hz	131	-	19	57	55

References

Böse, M. et al. A probabilistic framework for single-station location of seismicity on Earth and Mars. Phys. Earth Planet. Inter. 262, 48–65 (2017).

Böse, M. et al. Magnitude Scales for Marsquakes. Bull. Seismol. Soc. Am. 108, 2764–2777 (2018).

Clinton, J. et al. The Marsquake Service: Securing Daily Analysis of SEIS Data and Building the Martian Seismicity Catalogue for InSight. Space Science Reviews vol. 214 (2018).