NASA METEOROID ENVIRONMENT OFFICE

The 2024 meteor shower activity forecast for low Earth orbit

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The purpose of this document is to provide a forecast of major meteor shower activity in low Earth orbit (LEO). Most annual showers are expected to display typical activity, but the eta Aquariids (ETA) are once again expected to exhibit more than double their typical activity level.

1 Overview

The only significant shower outburst we expect next year is that of the eta Aquariids. This shower, which normally has a zenithal hourly rate (ZHR) of 60, is forecasted to reach a peak ZHR of approximately 160 in 2024 [1]. This makes it the strongest shower of the year in terms of ZHR, as the eta Aquariids are disproportionately large and bright due to their high speed. In terms of flux, however, they are expected to produce an enhancement that is a fraction of that of the Geminids (GEM).

We revised our parameters for a number of other showers this year based on the current state of knowledge. We refined the timing of five showers: the Daytime Arietids (ARI), alpha Capricornids (CAP), Daytime Sextantids (DSX), Orionids (ORI) and Ursids (URS). We also reduced the peak ZHR of three showers: the Quadrantids (QUA), alpha Capricornids, and Ursids. The Daytime Arietids, Orionids, Quadrantids, and Ursids were updated to have steeper mass distributions (that is, proportionally more small particles) than we have assumed in recent years. The kappa Cygnids (KCG) and beta Taurids (BTA) have been removed entirely, as they do not contribute significantly to the meteoroid flux in a typical year. These changes are based on an analysis of a combination of data from the Canadian Meteor Orbit Radar [2], Global Meteor Network [3], and the International Meteor Organization Video Meteor Network [4] and Visual Meteor Database [5].

This document is designed to supplement spacecraft risk assessments that incorporate an annual averaged meteor shower flux (as is the case with all NASA meteoroid models). Results are presented relative to this baseline and are weighted to a constant kinetic energy. One shower – the Geminids – attains a flux level exceeding that of the baseline meteoroid environment for 105-J (0.1-cm-equivalent) meteoroids. This size is a rough threshold for structural damage. The Geminids, along with the Daytime Arietids, Quadrantids, and eta Aquariids, match or exceed the baseline flux for 2.83-kJ (0.3-cm-equivalent) particles, which is near the limit for pressure vessel penetration.

Meteor shower fluxes drop dramatically with increasing particle size. Thus, a PNP (probability of no penetration) risk assessment should use the flux and flux enhancements corresponding to the smallest particle capable of penetrating a component because this size will be the dominant contributor to the risk.

2 Details

Our forecasting algorithm is presented in detail in ref. [6] and has not changed in the past year. Figure 1 gives the expected visual meteor rates (ZHR) for ground observers during calendar year 2024. The visual rate is dominated by the Quadrantids in early January, the eta Aquariids in May, the Geminids in mid-December, and, to a lesser extent, the Perseids (PER) in mid-August. Although meteor astronomers record and predict showers in terms of visual rates, ZHR does not directly correspond to meteoroid flux. The conversion from ZHR to flux must take into account the biases of the typical human observer, the speeds of the shower meteors, and the mass distributions of meteoroids belonging to these showers. The result is a flux profile that looks significantly different from the ZHR profile and in which high flux does not necessarily correspond to a visually spectacular meteor shower.

Showers typically contain proportionally more large particles than the sporadic background does; for this reason, showers are more significant at larger particle sizes, masses, or energies. Figure 2 gives the flux profiles for four limiting kinetic energy values, listed in Table 1. These are the same limiting kinetic energies for which we have been reporting fluxes, 7-hour fluences, and enhancement factors for many years; starting with the 2020 annual forecast, we began labeling these plots with the energy itself rather than with the diameter when such a particle has a speed of 20 km s^{-1} and a density of 1 g cm^{-3}. Equivalent masses and diameters are provided in Table 1.

Figure 2 also includes an estimate of the sporadic meteoroid flux for each of these limiting kinetic energies (horizontal lines). Note that for small particle sizes (low kinetic energies), shower fluxes are less significant when compared to the sporadic flux. Figure 2 also indicates that, depending on the energy threshold considered, a handful of showers produce the highest fluxes. The basic characteristics of six major or outbursting showers, including radiant position at the time of the shower's peak, are listed in Table 2 (the full list of included showers is provided at the end of this document in Table 3). For a spacecraft, the apparent directionality of a meteor shower (i.e., the aberrated radiant) will be shifted by the spacecraft's geocentric velocity.

In order to facilitate risk assessments, including Bumper PNP calculations, we provide flux enhancement factors for all of 2024 in 1-hour intervals (Figure 3). The larger flux enhancement factors in Figure 3 correspond to a kinetic energy of 105 J (0.1-cm-equivalent particles), which have lower absolute fluxes.

The fluxes and enhancement factors presented in this memo may or may not apply to individual spacecraft. For instance, we have not presented crater-limited fluxes; meteoroids incident on a surface at right angles penetrate deeper for many ballistic limit equations, and, for a surface directly facing the shower, this can further boost the significance of a shower relative to the background by another factor of approximately 2. Conversely, a surface tilted away from a shower radiant will encounter a less significant flux enhancement, and it is possible for the Earth to shield the spacecraft from all or part of a shower at a particular point in time. This forecast is designed for spacecraft in LEO; it does not, for instance, cover spacecraft orbiting the Moon or near the Sun-Earth Lagrange points.

kinetic energy	equivalent mass at 20 km s^{-1}	equivalent diameter at 1 g cm^{-3}
6.7 J	3.35×10^{-5} g	0.04 cm
105 J	5.24×10^{-4} g	0.1 cm
2.83 kJ	1.41×10^{-2} g	0.3 cm
105 kJ	5.24×10^{-1} g	1.0 cm

Table 1: The limiting kinetic energies (and their equivalent masses and diameters at 20 km s^{-1} and 1 g cm^{-3}) to which we report fluxes, fluences, and enhancement factors.

shower name	radiant		speed	date of maximum
	RA (°)	dec (°)	(km s^{-1})	(UT)
Quadrantids	230	+49	41	2024-01-04 06:32
eta Aquariids	338	-1	66	2024-05-05 13:53
Daytime Arietids	42	+24	39	2024-06-09 22:39
Southern delta Aquariids	342	-16	42	2024-07-27 20:08
Perseids	47	+58	61	2024-08-12 14:59
Geminids	113	+32	35	2024-12-14 02:10

Table 2: Highly active (in terms of flux) meteor showers in 2024. The radiant is the geocentric, unaberrated radiant and speed is that at an altitude of 100 km.

3 Contact information

The Meteoroid Environment Office will update this forecast as necessary. Those with questions or special needs in the near future are encouraged to contact:

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References

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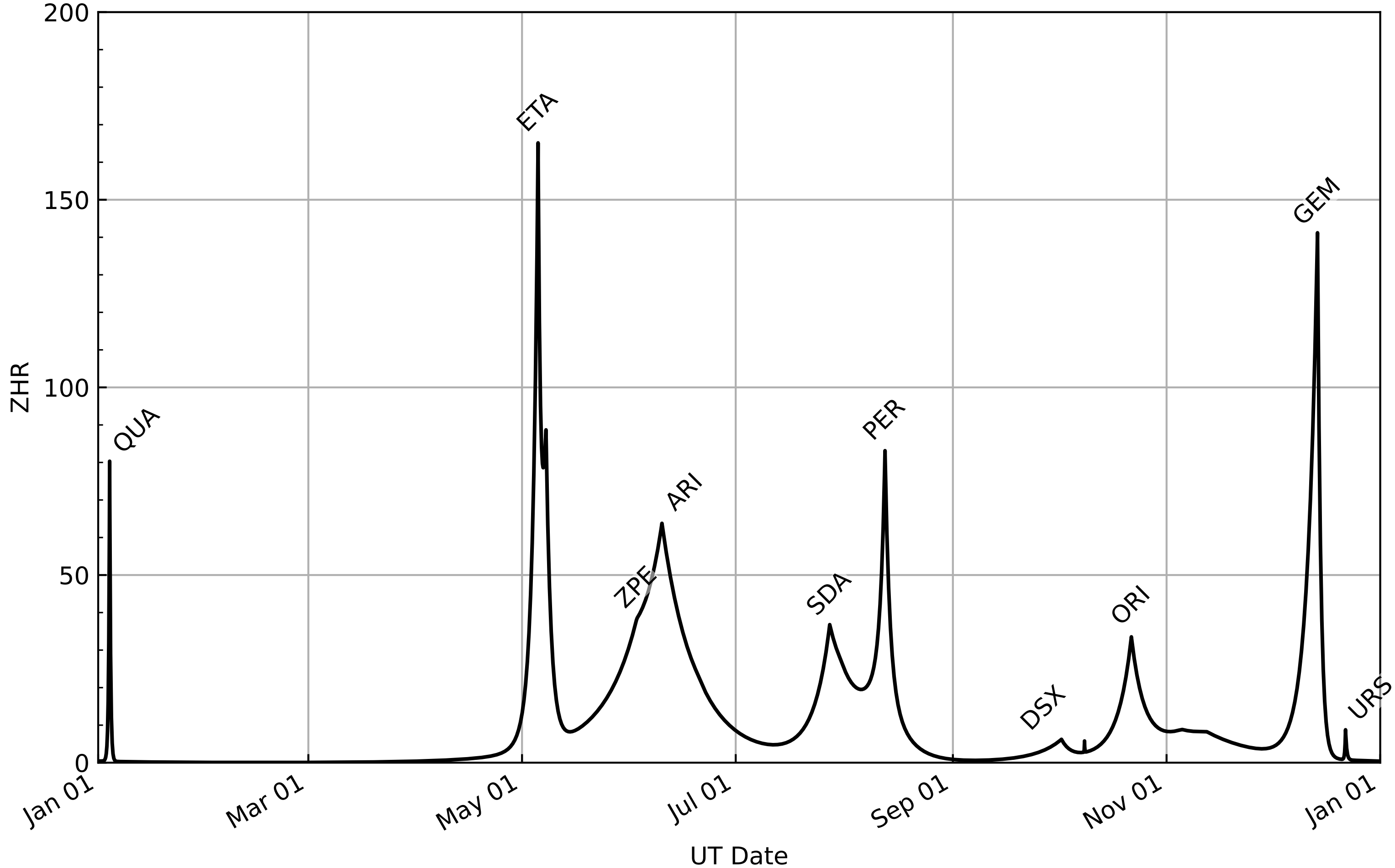

Figure 1: Meteor shower visual rates (zenithal hourly rate, or ZHR) over the course of 2024. Note how showers overlap; a large, broad shower such as the Daytime Arietids (ARI) can boost the cumulative shower ZHR and flux at the peak of an adjacent shower such as the Daytime zeta Perseids (ZPE).

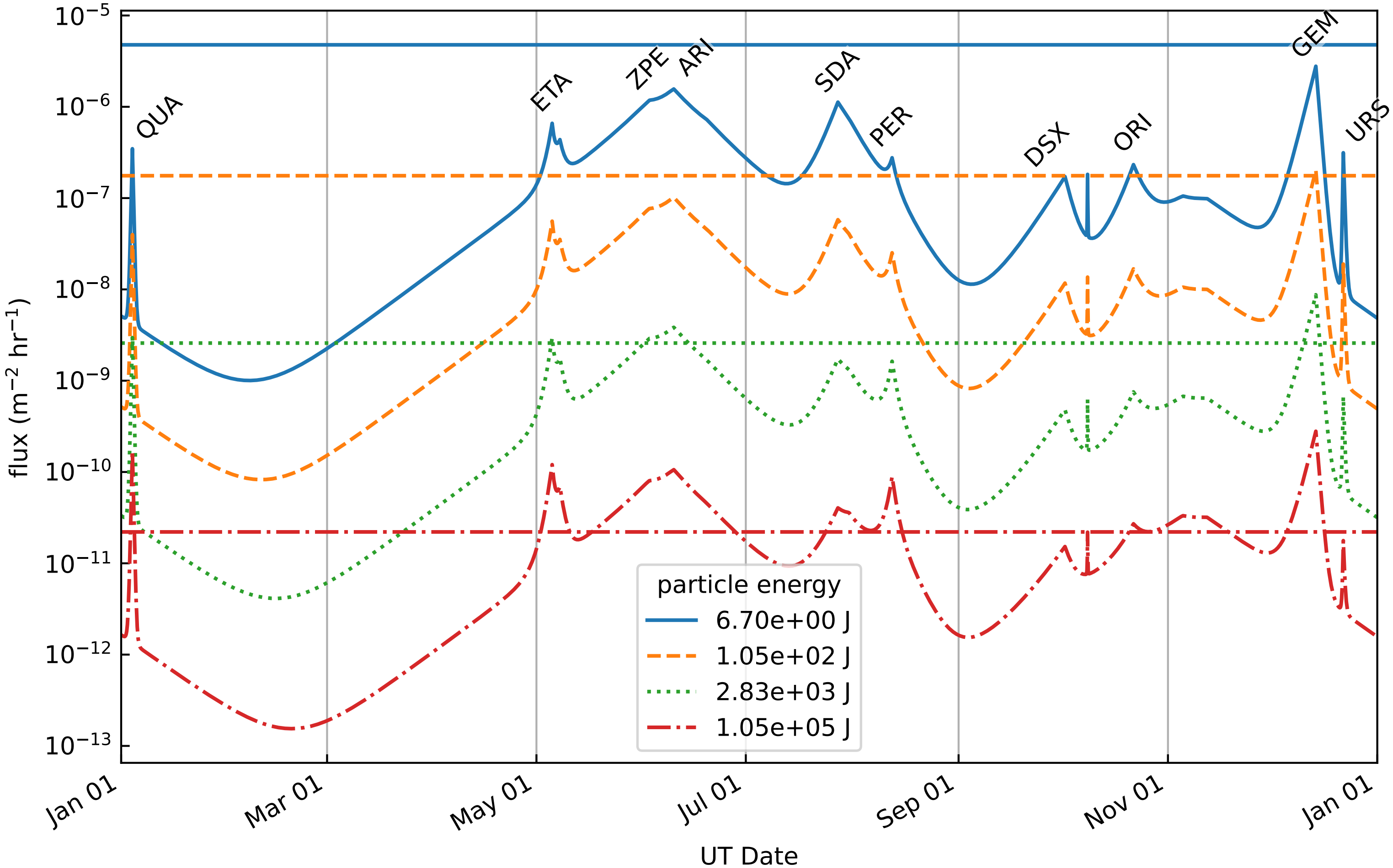

Figure 2: Meteor shower flux (variable lines) and sporadic meteoroid flux (horizontal lines) over the course of 2024. Fluxes have been weighted to a constant limiting kinetic energy. Fluxes are quoted for four particle kinetic energies; these kinetic energies correspond to particles with diameters of 0.04 cm, 0.1 cm, 0.3 cm, and 1 cm, assuming a density of 1 g cm^{-3} and a speed of 20 km s^{-1}. Some showers, such as the Perseids (PER) and Quadrantids (QUA), are more heavily weighted toward large particles and thus play a more significant role for 1-cm-equivalent particles than for 0.04-cm-equivalent particles.

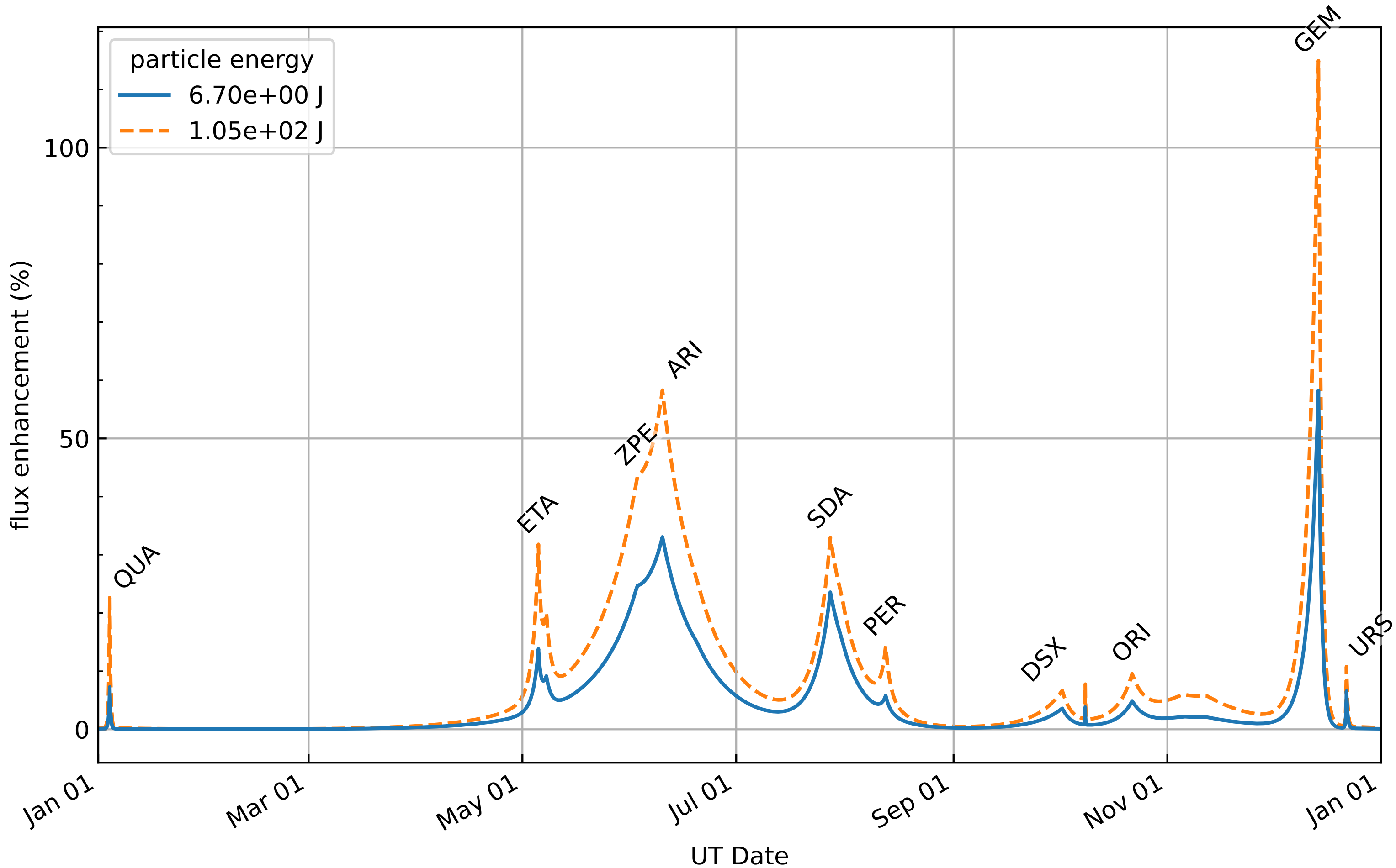

Figure 3: Meteor shower flux enhancement relative to the sporadic meteoroid flux over the course of 2024. These factors can be used in conjunction with a meteoroid model such as the Meteoroid Engineering Model (MEM) [7], to compute the flux at a particular time of year on a plate facing the unobscured shower radiant.

shower name	**ID**	**date of maximum** (UT)	**max ZHR**
Quadrantids	QUA	2024-01-04 06:32	80
eta Aquariids	ETA	2024-05-05 13:53	161
Daytime zeta Perseids	ZPE	2024-06-02 18:25	20
Daytime Arietids	ARI	2024-06-09 22:39	50
Southern mu Sagittariids	SSG	2024-06-19 15:34	2
Southern delta Aquariids	SDA	2024-07-27 20:08	30
alpha Capricornids	CAP	2024-07-31 00:41	3
Perseids	PER	2024-08-12 14:59	80
Daytime Sextantids	DSX	2024-10-01 23:58	5
October Draconids	DRA	2024-10-08 13:55	3
Orionids	ORI	2024-10-21 22:52	30
Southern Taurids	STA	2024-11-05 06:39	5
Northern Taurids	NTA	2024-11-12 05:56	5
Geminids	GEM	2024-12-14 02:10	140
Ursids	URS	2024-12-22 02:10	8

Table 3: Meteor showers in 2024. Column 2 provides the 3-letter code for each shower, column 3 lists the date and time of maximum activity, and column 4 provides the shower's ZHR at the time of maximum activity.