Characterizing the 2016 Perseid Meteor Shower Outburst

R.C. Blauw1, D.E. Moser2, S. Molau3, C. Schult4, G. Stober4

1All Points Logistics/ACASU ESAX Group/NASA Meteoroid Environment Office (MEO), Huntsville, AL, 35812, USA, rcliffe.r.blaauw@nasa.gov
2Northrop Grumman ESAX Group/NASA MEO Huntsville, AL, 35812, USA, dimoserd.mosern@nasa.gov
3Leibniz Institute of Atmospheric Physics, Bonnich University, Kielbog, Germany
4German Aerospace Center (DLR), Institute for Meteorology and Climate Research, Oberpfaffenhofen, 82230, Germany

Introduction & Predictions

The Perseid meteor shower has been observed for millennia and is known for its visually spectacular meteors and occasional outbursts. Normal activity displays Zenithal Hourly Rates (ZHRs) of ~100. The Perseids were expected to outburst in 2016, primarily due to particles released during the 1862 and 1479 revolutions of parent Comet Swift-Tuttle. NASA/Meteor Environment Office predicted the timing, strength and duration of the outburst for spacecraft risk using the MSFC Meteoroid Stream Model [1]. A double peak was predicted, with an outburst displaying a ZHR of 210 ± 50 at 00:30 UTC Aug 12 (129.5° Solar Longitude), and a traditional peak ~12 hours later with rates still heightened from the outburst [2]. Video, visual, and radar observations taken worldwide by various entities were used to characterize the shower and compare to predictions.

Notable Perseid Outbursts:
1995: ZHR of 239.9°
1995: ZHR of 160-180
2004: ZHR of 187
2009: Triple outburst of ZHR ~ 180-180-220 prior, during, and after traditional peak. See predictions and results below in Figure 3.

Why does this happen?
• Jupiter perturbs the trail of debris left by Comet 109P/Swift-Tuttle.

IMO Video & Visual Observations

Most of North America was in daylight during the outburst peak, thus the International Meteor Organization (IMO) video observations and visual observations were heavily relied upon to characterize the outburst peak.
• The IMO video network had more than 70 cameras in operation in August 2016 with 12,000 effective observing hours and 96,000 detected meteors.
• Detects meteoroids between 0.0001-0.1 grams. These observations are used to calculate fluxes to +6.5 magnitude and ZHRs using a population index of 2.2.
• Visual observations from the 2016 Perseid campaign (See Figure 10). The IMO visual observations resulted in ZHRs, converted to fluxes +6.5 magnitude using a population index of 2.0 [3].
• Results were provided by Sisto Molau. See [8] for full IMO video and visual results.

All Sky Camera Network Results

• NASA’s All Sky Fireball Network consists of 15 cameras, placed in 4 groups around continental USA to detect meteors brighter than the planet Venus (V = 4 magnitude).
• Meteoroids with this brightness correspond to cm-sized meteors, weighing ~7 grams.
• During 2016, clouds were over most of the networks approaching the peak of the Perseids, but cleared off soon after dark on the peak night.
• Being in North America and constrained by daylight, these cameras missed the outburst peak, but detected the period between the outburst peak and the normal peak.
• Rates were heightened in 2016 over 2015.

MAARSY Results

• Middle Atmosphere Alomar Radar System (MAARSY) is an HPLA radar employing an active phased array antenna suitable to monitor the Perseid radiant (6.7°, 116.8°). It was modified to conduct continuous meteor observations and meteor shower studies in 2016 for the Perseid outburst.
• System has a limiting mass of 10^4-10^5 grams.
• In 2015 and 2016, MAARSY detected enough Perseids to produce an activity curve with 3 hour bins.
• Activity is comparable from 2015 to 2016, no notable outburst in this small size range. The population index is low ~1.8 during the peak outburst indicating that the outburst may have been rich in bright particles, not the low-mass particles that MAARSY detects (Figure 11). Additionally, Figure 4 indicates that the most significant new component of particles for the 2016 outburst is in a more massive range.

Conclusions

• NASA’s Meteoroid Environment Office predicted a Perseid Outburst in 2016 with a peak ZHR of 210, 12 hours prior to the traditional peak, and a traditional peak still on schedule.
• The outburst was clearly seen in IMO Video & Visual results, as well as NASA All Sky Fireball Network data. The peak of the outburst was seen to have a ZHR of 280 according to IMO video observations, and 205 as seen in visual observations.
• The outburst was not seen in MAARSY, which has a limiting mass of 10^4-10^5 grams.
• This indicates the outburst was detected primarily in larger particles over smaller ones.
• NASA’s MEO correctly predicted the timing and approximate strength.
• The forecast over-estimated the flux from Perseids approaching and leaving the peak, particularly in large sizes as seen in Figures 6 and 7.

References

Figure 1: MSFC Meteoroid Stream model results for 2016 Perseids. The 2016 peak displayed a ZHR of 210 ± 50 at 139.5° Solar Longitude, and had several peaks with maxima at ~140.0°, with a ZHR of 125, still slightly heightened because of the outburst.

Figure 2: Predictions and results of the 2015 Perseid shower. The large green bar represents the predicted outburst, as seen in International Meteor Organization (IMO) visual observations (red) and NASA All Sky video observations (blue). This indicates the activity in exceeding predictions.

Figure 3: IMO video results of peak Perseid activity. 2016 Perseids (dark) compared with 1994, 1995, 2009, and 2013 Perseids. The forecast overestimated the peak by ~2.0 hours, with a ZHR of 125, still slightly heightened because of the outburst.

Figure 4: Perseids were seen in NASA’s All Sky Fireball Network. Shown here is a time-normalized sky camera result. Sky rates were scaled by the Perseid radiant altitude and normalized by the camera’s sensitivity, and how much additional clear-camera added to rates. 2015 is shown for comparison. The peak in 2016 was followed by a secondary peak at ~277° in 2015. However, when taking into account the camera that was only 13% clear, the peak was significantly lower than expected. The small peak rates in August 2016 as seen in visual observations.

Figure 5: 2016 Perseids as seen in NASA’s All Sky Fireball Network. Shown here is a time-normalized sky camera result. Sky rates were scaled by the Perseid radiant altitude and normalized by the camera’s sensitivity, and how much additional clear-camera added to rates. 2015 is shown for comparison. The peak in 2016 was followed by a secondary peak at ~277° in 2015. However, when taking into account the camera that was only 13% clear, the peak was significantly lower than expected. The small peak rates in August 2016 as seen in visual observations.

Figure 6: 2016 Perseid rate as seen in NASA’s All Sky Fireball Network. Shown here is a time-normalized sky camera result. Sky rates were scaled by the Perseid radiant altitude and normalized by the camera’s sensitivity, and how much additional clear-camera added to rates. 2015 is shown for comparison. The peak in 2016 was followed by a secondary peak at ~277° in 2015. However, when taking into account the camera that was only 13% clear, the peak was significantly lower than expected. The small peak rates in August 2016 as seen in visual observations.

Figure 7: 2016 Perseid activity compared to 2015 Perseid activity. The forecast overestimated the peak by ~2.0 hours.

Figure 8: 2016 Perseids as seen in MAARSY. The 2016 Perseids (dark) compared with 2015 Perseids (light), which were seen as non-outburst years. Between 139° and 140° SL, when both passed the ISS and Alpha Centauri, the rates were clearly higher than average. Solar Longitude 140.7°-145.7° were daylight in Europe in 2016, where most video cameras were located.

Figure 9: Visible activity (dark) is contrasted with the average visual activity (red). Raw corrected activity takes raw activity and scales by radiant altitude as well observation time. Error bars are due to number of visual observers contributed in the 2016 Perseid outburst.

Figure 10: Distribution of visual observers around the world. (IMO)

Figure 11: IMO video results of peak Perseid activity. 2016 Perseids (dark) compared with 1994, 1995, 2009, and 2013 Perseids. The forecast overestimated the peak by ~2.0 hours, with a ZHR of 125, still slightly heightened because of the outburst.

Figure 12: Perseid activity as seen in MAARSY in 2016 and 2015. Corrected activity rates in 2015 are scaled by radiant altitude as well observation time. Error bars are due to number of visual observers. As time rate indices, population indices of 2.0 were detected in 2016, though this is offset by the increased observation time.

Figure 13: MAARSY observation time in 2016 and 2015. For comparison how many hours of observation time occurred in 2016 and 2015.