Urban Meteor Map: a map-based forecast of hourly rates for visual observers

de Vet, S.J.

Publication date
2024

Document Version
Final published version

Published in
Proceedings of the IMC, Redu, 2023

Citation (APA)
de Vet, S. J. (2024). Urban Meteor Map: a map-based forecast of hourly rates for visual observers. In U. Pajer, & C. Verbeeck (Eds.), *Proceedings of the IMC, Redu, 2023* (pp. 177-180). International Meteor Organization .

ISBN 978-2-87355-036-3

Proceedings of the International Meteor Conference

Redu, Belgium, 2023
August 31 – September 3

Published by the International Meteor Organization

Edited by Urška Pajer and Cis Verbeeck

Proceedings of the International Meteor Conference
Redu, Belgium, August 31 – September 3, 2023
International Meteor Organization
ISBN 978-2-87355-036-3

Editing and printing:

Front cover picture: Group picture of the IMC 2023, by Peter Slansky
Publisher: The International Meteor Organization
Printed: The International Meteor Organization
Editors: Urška Pajer and Cis Verbeeck
Bibliographic records: all papers are listed with the SAO/NASA Astrophysics Data System (ADS)
http://adsabs.harvard.edu with publication code 2024pimo.conf

Distribution:

Further copies of this publication may be ordered from the International Meteor Organization, through the IMO website (http://www.imo.net).
Legal address: International Meteor Organization, Mattheessensstraat 60, 2540 Hove, Belgium.

Urban Meteor Map: a map-based forecast of hourly rates for visual observers

Sebastiaan J. de Vet[1,2,3]

[1] **Delft University of Technology, Aerospace Engineering, section Planetary Exploration**
[2] **Meteor Section, Royal Netherlands Association for Meteorology and Astronomy (KNVWS)**
[3] **Naturalis Biodiversity Centre, Leiden**
s.j.devet@tudelft.nl

The visible rate of meteors is dependent on various local viewing condition during shower peak nights. The interrelationship of the visible fraction of the night sky, radiant elevation and effects of the light pollution on sky brightness confounds outreach efforts to manage realistic expectations for visual meteor observations by the public. The Urban Meteor Map offers a map-based forecast of hourly rates to help make the effects of local viewing conditions more insightful. The project generates maps based on raster data for parameters in the Zenithal Hourly Rate formula. A Digital Surface Model (DSM) covering the Netherlands was used to generate maps of the visible percentage of the sky. At 5 m resolution this DSM offers insights into obstruction by buildings, vegetation and topography. To incorporate effects of light pollution, a national sky brightness map for cloudless nights was converted into Naked Eye Limiting Magnitudes (NELM). Combined with known shower parameters such as population index and radiant height, maps were generated with hourly rates forecasts at local and national scales. Ultimately, observing conditions will remain dependent on the individual observers, their night adaptation and local light interference. The Urban Meteor Map aims to helps raise awareness for the effects of light pollution, and thus promotes exploration of local living environment to seek the best viewing spots for meteor showers.

1 Introduction

The visible rates observed during meteor showers are dependent on both stream parameters and local observing condition during shower peak nights (Rendtel, 2022a). For this reason *Zenithal Hourly Rates* (ZHR) of meteor showers can be determined using the observed meteors and viewing conditions reported by an experienced visual observer. However, the normalised ZHR values are frequently mistaken by media and others and reported as the best-case scenario, risking meteors shower to underwhelm the ill-informed casual observer. We can partly mitigate this challenge and forecast the anticipated hourly rate if meteor shower parameters are known and some crude assumptions are made for the observing conditions. However, such prognoses are valid for specific conditions and may in practise offer little predictive power for observers across the broad range of observations settings along the gradient of urban, peri-urban and rural environments. The faceted interrelationships of the visible fraction of the night sky, radiant elevation and the effects of light pollution on sky brightness thus confounds outreach efforts to manage realistic expectations for visual meteor observations by the public. Therefore we studied if a map-based meteor forecast could be created to spatially resolve the combined effects of various viewing parameters. This approach, dubbed the *Urban Meteor Map*, could potentially help guide novice visual observers in exploring their local living environment to seek the best observing spots for unspoiled views of the main meteor showers across the year.

2 From the ground up: using a raster-based approach

The *Urban Meteor Map* aims to create a representative map-based forecast of hourly rates to help make the effects of local viewing conditions more insightful. The underlying approach is to make use of spatial data sets for relevant parameters in the Zenithal Hourly Rate formula. Rather than one single value, these data are raster data sets where pixels contain the variation of the parameter for a given spatial extent. Processing of these data sets is possible using a Geographic Information System (GIS) and allows mathematical relations to be applied to raster data: i.e., we can perform calculations using spatially resolved heterogeneous data.

3 Data sources and map production

The processing pipeline to perform the raster calculations was implemented in ESRI ArcGIS Pro (version 2.9.3) based on parameters in the formula for the Hourly Rate (*HR*):

$$HR = ZHR \cdot sin(h)/(100/VS)r^{(6.5-Lm)}$$

Here, the *ZHR* and population index r were obtained from shower data for the Perseids published in the IMO 2023 meteor shower calendar (Rendtel, 2022b). A radiant elevation h was taken for a pre-dawn observer at 02:00 UT (04:00 LT). The radiant height h across The Netherlands will vary little over 3.5 degrees in latitude

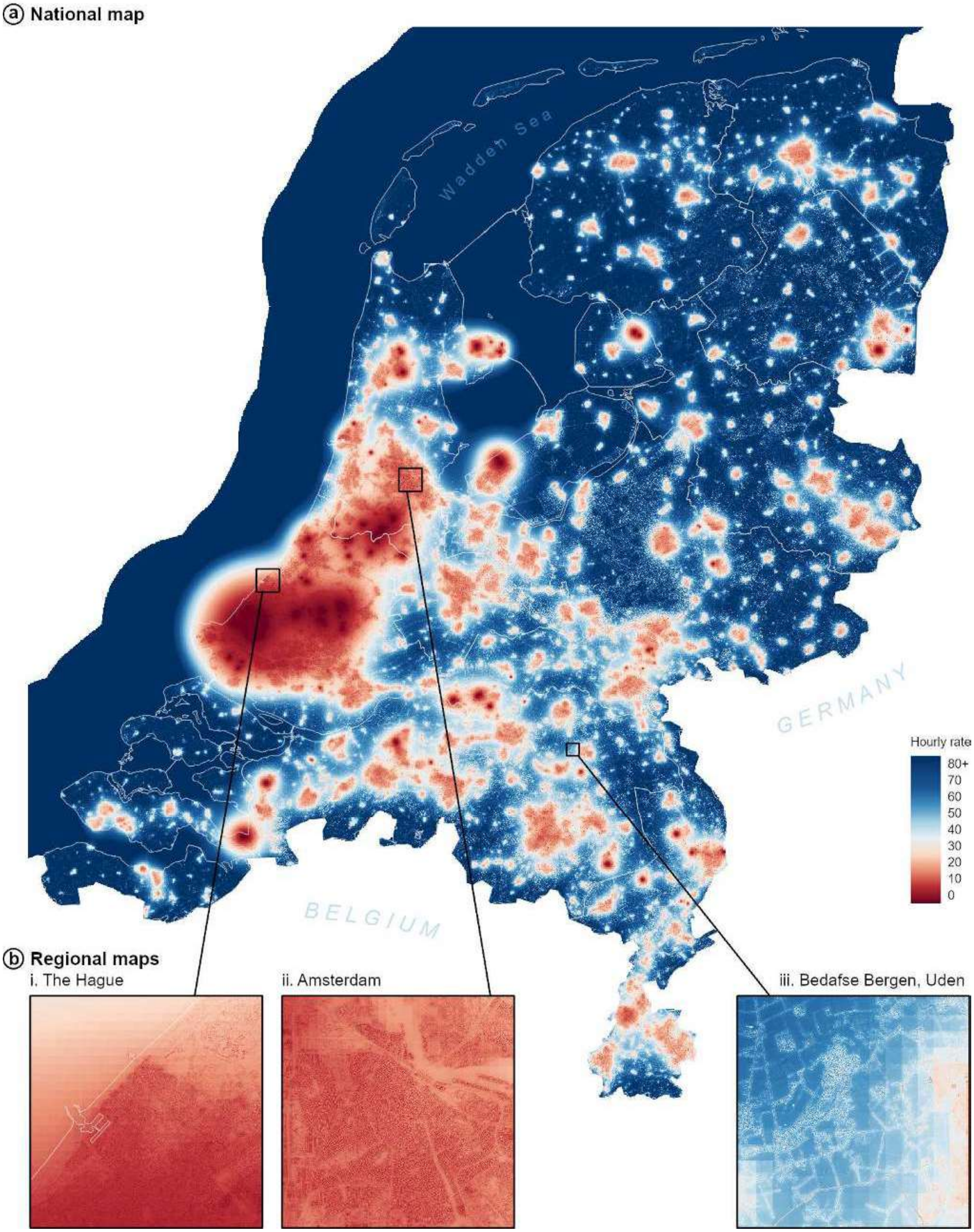

Figure 1 – Forecast map of Hourly Rates for the 2023 Perseids meteor shower. (a) The main map is valid for the near moonless night of August 13 at 04:00 UT (06:00 LT), assuming a radiant elevation of h=65°, r=2.2, ZHR=100. (b) Local maps of Hourly Rates for (i.) The Hague, with HR=16 at the beach with the lowest sky brightness and best unobstructed view; (ii.) Amsterdam, with HR=18 at the Vondel Park; and (iii.) Bedafse Bergen near Uden

and will have a small influence on the absolute hourly rates. For this reason this parameter was simplified by using a constant integer value. The visual sky percentage (VS) and the limiting magnitude (Lm) for a visual observer will spatially vary, so we used raster data for these parameters to generate a spatially resolved map.

The visual sky percentage (VS) was calculated using the AHN3 Digital Surface Model (DSM). A DSM is an elevation model that includes all landscape elements, including buildings and vegetation (forests etc.), this is contrasted by a Digital Terrain Model (DTM) where such objects have been removed. For this project, the DSM thus offered the appropriate data product for further processing. The AHN3 model is made available at various ground sampling distances, of which the 5m resolution version was considered here as it contains sufficient detail for this mapping project. After downloading 1371 individual panels, the rasters were stitched together to create one single raster file covering the Netherlands. This new data set was used for further processing in the software SAGA GIS (version 9.1.1) to obtain the visible sky percentage resulting from the obstruction by buildings, terrain and other objects. The function 'Sky View Factor' was used with maximum search radius set to 500 map units, across 8 directions.

The Dutch Institute for Public Health (RIVM) has published several sky brightness maps with national coverage, including one for cloudless, moonless nights, via its platform 'Environmental Health Atlas' (*Atlas Leefomgeving'*). The map details the luminance (light intensity per surface unit) in the imaginary point in the sky when you look straight up (the so-called 'zenith'). The source data of the map for cloudless, moonless nights was downloaded as a raster file for subsequent raster calculations in ArcGIS Pro. The sky brightness (B) was converted into magnitude per square arc second (MPSAS, see Unihedron, 2023b) using:

$$MPSAS = Log_{10}(B/108,000)/-0.4,$$

which was then converted into the Naked Eye Limiting Magnitude (NELM, see Unihedron, 2023a) using:

$$NELM = 7.93 - 5Log(10^{4.316-(BMPAS/5)}) + 1.$$

The new raster data for Lm was limited to the visual magnitude +6.5, meaning that cells with lower magnitudes were reassigned the value +6.5.

After completing these preparatory steps, all raster data sets were imported into ArcGIS Pro. In the final step of the processing pipeline the *Raster Calculator* of the *Spatial Analyst* toolbox was used to generate a new raster containing the spatial variation in observable hourly rates. The meteor forecast was then visualised at various scales such as a national map (Figure 1a) and at local scales (Figure 1b) to illustrate the local, regional and national variations.

4 First order validation

As sky brightness will strongly control the visible rate, a first order validation of the source data was performed by comparing the sky brightness map with actual measurements that are made by the light pollution network *WasHetDonker.nl*. The network obtains daily point measurement at 33 locations in the Netherlands using a Unihedron SQM-L sensor. Data from May 16-20, 2023, close to the new moon, featuring some nights with clouds, shows reasonable agreement between the sensor measurements and the corresponding pixel value for the stations in the sky brightness map (Figure 2). Here, the physical difference between the single pixel value on the map and the sensor footprint on the night sky, as well as the twilight conditions in May can explain the observed differences. Future iterations of the map will involve an assessment of how instrument data can help calibrate the map result, as well as validating the map output based on visual observations by experienced visual meteor observers.

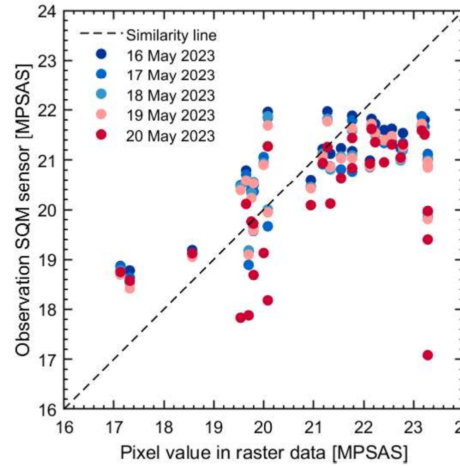

Figure 2 – Sensor measurements of maximum sky brightness by the 'Washetdonker.nl' network on nights leading up to new moon on May 20, 2023 are compared to values based on the national sky brightness map from the RIVM.

5 Results

5.1 Gradients

Is observing meteors from light-polluted cities promising enough to promote? Many meteor observers will agree that it is possible, but for the casual observer is might sometimes be difficult to grasp all observing factors for a realistic meteor count. For example, based on the model we expect that an urban observer will see roughly as many meteors on the South Beach (Zuiderstrand) of Scheveningen, behind the dunes at the sea front, as on a reasonably open spot in the Vondel Park in the nation capital Amsterdam. Variations in observing conditions were found along gradients from urban to peri-urban and rural area that can help casual observers find a suitable spot or better viewing spot.

5.2 Online engagement

The finalised *Urban Meteor Map* was shared online via an ArcGIS StoryMap. This platform allows map data to be presented in an interactive story-based format. The scrollable and responsive web environment combines maps with text and multimedia content, and allowed us to includ basic observing tips, map usage tips and meteor shower background in native language, before the user arrived at the actual map. On this map several pins with larger-scale sections of the Urban Meteor Map were shared to illustrate combined effects, and suggestions were made where to go for a better viewing spot. An small *ad hoc* social media campaign was carried out on August 12 and 13 to direct users to the ArcGIS StoryMap. To gauge the engagement with the map, we monitored the interactions and comments placed under social media outings on Twitter, Facebook and LinkedIn, which accumulated >13k views and >1k specific interactions in a matter of two days.

6 Discussion

The *Urban Meteor Map* aims to forecast a plausible scenario for the amount of visible meteors on a moonless observing night before the onset of twilight conditions. It principally relies on the raster data made available by the National Institute for Public Health and the Environment (RIVM), based on a model that includes Dutch sources in the calculation. Due to the nature of this modelling approach, a small darkening gradient in sky brightness is also visible towards the Dutch borders. Sources from abroad are not included and as a result the calculated sky brightness near the border is probably an underestimation of the actual sky brightness. However, these have little effect on the overall map.

Future iterations of the map will focus on forecasts using near-real time flux estimates, for example based on observational data from the GMN network[1]. Furthermore, we anticipate that the next release will be a tiled model that allows users to zoom and pan to their living area. Some observing parameters will remain dependent on the individual observer: their night sight adaptation; alertness and attention in their visual field; and local light interference, which will influence the observed rates. However, rather than aiming to constrain all parameters, a key point of a map-based approach lies in its ability to make the spatial variation insightful. Especially the regional differences were found to be pronounced. Light pollution generated by the greenhouse horticulture in the Westland area notably reduces visible meteors near The Hague: the forecast for hourly rates at the beach are better than inside the city, but lower than those for observers in the Vondel Park in Amsterdam's city center. So, not all light-polluted areas are equally 'poor' for observing, yet some areas may be more favourable as this mapping approach illustrates. The best approach to using the map and the level of detail it offers, is to direct users to finding a better viewing spot within several minutes of cycling from their home. For example, rather than observing from the Kijkduin or Scheveningen beaches, a darker area could be found in the dunes and on the beaches just north of The Hague, towards Wassenaar. As expected, rural areas with higher flux estimates are more common in the north-east and east of the country, while the darkest viewing spots can be found in the Veluwe National Park and the Wadden Islands.

[1] https://globalmeteornetwork.org/flux/

7 Conclusions

Hourly rates of meteor showers are dependent on local observing conditions, but their limiting effects are not intuitive to assess. A map-based approach to meteor forecasting has offered a first spatially resolved framework to make these effect comprehensible for the whole of the Netherlands at a resolution of 5 m. Pronounced, small scale variations were found across the gradient of urban, peri-urban and rural areas, whilst illustrating noteworthy variations within city boundaries. Light pollution is often and rightfully used as an argument to motivate observers to seek better observing spots. However, this narrative does not tell the entire story. The *Urban Meteor Map* helps raise awareness for the combined effects of light pollution and obstructing infrastructure when observing astronomical events. Most importantly it can promote the exploration of our local living environment to seek the best viewing spots to enjoy the splendor of the year's main meteor showers.

Acknowledgements

This projects used open-source data: the AHN3 is published via PDOK, courtesy of the Dutch government. The author wishes to thank Martin Søndergaard for supporting Python coding to automate retrieval of the extensive AHN3 data set via PDOK. The light pollution map was obtained via the Environmental Health Atlas (*Atlas Leefomgeving*), courtesy of the National Institute for Public Health and the Environment (RIVM, 2015). Sky brightness validation data were obtained via *Washetdonker.nl*, an observation network coordinated by Theo Jurriens (Groningen University, Faculty of Science and Engineering, Kapteyn Institute and ScienceLinX).

References

Rendtel J., editor (2022a). *Handbook for Meteor Observers*. IMO.

Rendtel J. (2022b). "Imo meteor shower calendar for 2023". *WGN, Journal of the International Meteor Organization*, **50:2**, 35.

Unihedron (2023a). "Conversion calculator - nelm (v) to mpsas (b) systems". `http://www.unihedron.com/projects/darksky/NELM2BCalc.html` . Viewed 28 August 2023.

Unihedron (2023b). "Magnitudes/arcsecond^2 to cd/m^2 converter". `http://unihedron.com/projects/darksky/magconv.php` . Viewed 28 August 2023.