

Long-term trends of light pollution assessed from SQM measurements and an empirical atmospheric model[†]

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ABSTRACT

We present long-term (4–10 yr) trends of light pollution observed at 26 locations, covering rural, intermediate, and urban sites, including the three major European metropolitan areas of Stockholm, Berlin, and Vienna. Our analysis is based on (i) night sky brightness (NSB) measurements obtained with sky quality metres (SQMs) and (ii) a rich set of atmospheric data products. We describe the SQM data reduction routine in which we filter for moon- and clear-sky data and correct for the SQM ‘aging’ effect using an updated version of the twilight method of Paschnig et al. (2021). Our clear-sky, aging-corrected data reveal short- and long-term (seasonal) variations due to atmospheric changes. To assess long-term anthropogenic NSB trends, we establish an empirical atmospheric model via multivariate penalized linear regression. Our modelling approach allows to quantitatively investigate the importance of different atmospheric parameters, revealing that surface albedo and vegetation have by far the largest impact on zenithal NSB. Additionally, the NSB is sensitive to black carbon and organic matter aerosols at urban and rural sites, respectively. Snow depth was found to be important for some sites, while the total column of ozone leaves impact on some rural places. The average increase in light pollution at our 11 rural sites is 1.7 per cent per year. At our nine urban sites, we measure an increase of 1.8 per cent per year and for the remaining six intermediate sites we find an average increase of 3.7 per cent per year. These numbers correspond to doubling times of 41, 39, and 19 yr. We estimate that our method is capable of detecting trend slopes shallower/steeper than ± 1.5 per cent per year.

Key words: atmospheric effects – instrumentation: photometers – light pollution – methods: data analysis – techniques: photometric.

1 INTRODUCTION

During the last decade, an ever increasing number of studies found evidence that artificial light at night (ALAN) leads to negative consequences – not only for astronomy but also for ecosystems (e.g. Longcore & Rich 2004; Perkin et al. 2011), biodiversity (e.g. Höller, Wöller & Perkin 2010), animals (e.g. Eisenbeis 2006; Perkin, Höller & Tockner 2014; Matthews et al. 2015; Owens et al. 2020; Parkinson, Lawson & Tiegs 2020), and human beings (e.g. Chępciniak 2009; Haim & Portnov 2013; Cho et al. 2015; García-Saenz et al. 2018; Khodasevich et al. 2020; Méndez-Velázquez, Morales & García-Delgado 2022). Therefore, monitoring night sky brightness (NSB) was soon recognized as being an inevitable effort in order to keep track of light pollution. Various organizations and individuals around the globe started to continuously measure the NSB using different methods and devices (Häsel et al. 2018).

One of the probably most widely used devices is the so-called sky quality meter (SQM). Operational SQM networks are found e.g. in Austria (Posch, Binder & Paschnig 2018; Paschnig, Wallner & Posch 2020), Spain (Zamorano et al. 2015; Bará, Lima & Zamorano 2019), Italy (Bertero et al. 2019), and the Netherlands (Schmidt & Spoelstra 2020). Furthermore, several individuals have mounted SQMs at various sites on Earth (e.g. Paschnig, Posch & Uttenhaler 2014a; Paschnig et al. 2014b; Andreić 2018). Kyba et al. (2015) have compiled many of these heterogeneous data sets to study the change of light pollution on a global scale.

Early light pollution studies based on SQM data revealed the strong impact of clouds (Kyba et al. 2011; Paschnig et al. 2014a; Jechow, Höller & Kyba 2019; Ściężor 2020) on the NSB. And more recently, the impact of several atmospheric parameters, in particular aerosol optical depth (AOD) and particulate matter (PM) were observed to show correlations with NSB (Ściężor & Kubala 2014; Posch et al. 2018; Ściężor & Czaplícka 2020; Kocijaj & Barentine 2021). Also, other seasonal parameters such as e.g. surface albedo or vegetation (Wallner & Kocijaj 2019; Paschnig et al. 2020) were previously discussed in the literature as potential factor causing changes in NSB.

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[†]Generated using Copernicus Climate Change Service (C3S) Information and Atmosphere Monitoring Service (IAMS) Information, 2019.

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