City lights and urban air

To the Editor — Artificial lights are an essential part of human life at night, necessary for the safety and security of many human activities. However, the illumination of the night sky by artificial lights can adversely affect biological activities such as animal orientation[1], together with human perception of the sky at night[2]. Here we show that city lights can also alter the concentration of nitrate radicals, an important atmospheric oxidant. These alterations have potential — albeit small — consequences for pollution levels the following day.

Nitrate radicals form from the reaction of nitrogen dioxide with ozone. These radicals are highly unstable in sunlight, but they build up during the night, when they function as a key atmospheric oxidant. During this time they react with numerous chemical species, including volatile organic compounds released by plants and human activities, and compounds essential for the production of tropospheric ozone the following day[3,4]. Nitrate radicals also react with nitrogen dioxide, forming dinitrogen pentoxide, a temporary nocturnal reservoir of nitrogen oxides that transforms into nitrogen dioxide when the sun rises. Nitrogen dioxide is another key component of tropospheric ozone production.

Using a research aircraft, we measured light intensities and types during the night over Los Angeles, USA, in May and June 2010 (see Supplementary Information) to determine the rate of nitrate radical loss induced by artificial lights (for calculations see ref. 5). At the same time, we measured the concentration of nitrate, dinitrogen pentoxide and ozone, to determine total nitrate radical loss (see Supplementary Information). Comparison of city-light-induced radical loss with total radical loss suggests that city lights account for up to 2–3% of nitrate radical loss in some regions of Los Angeles (Fig. 1a). The effect is greatest in dry and aged air masses, which have a lower propensity for dinitrogen pentoxide loss and thus a higher propensity to recycle nitrogen oxides the following day[7].

We used one-dimensional model calculations to study the impact of city lights on nitrogen compounds under high and low levels of pollution (see Supplementary Information)[8]. We examined the impact of light levels encountered during our study in Los Angeles, and higher light levels typical of a bright city centre, inferred from satellite data. Because photolysis breaks nitrate radicals down to nitrogen dioxide, light levels analogous to those seen over Los Angeles led to a reduction in nitrate radical levels, and an increase in nitrogen oxide levels, on the order of 1% or less in both the high- and low-pollution scenarios. In the brighter high- and low-pollution scenarios, nitrate radical levels were reduced by up to 4%, and nitrogen oxide levels were increased by up to 3.5%, compared with a control run without lights.

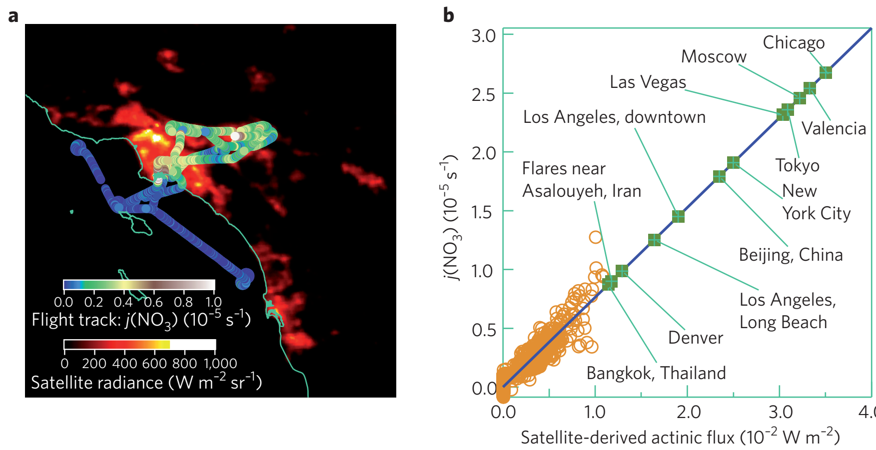

Figure 1 | Light pollution in Los Angeles. **a**, We examined the intensity and quality of artificial lights during the night over Los Angeles in 2010, together with the concentration of trace gases, using a research aircraft. Using this data we calculated the rate of nitrate radical loss as a result of photolysis, $j(NO_3)$, shown by dots. Satellite-derived radiance is shown in the background for reference. We estimate that city lights account for 2–3% of nitrate radical loss during the night. **b**, We extrapolate our findings to other regions of the globe (blue) using satellite-based measurements of light intensity (orange) and show that light intensity probably influences nitrate radical loss elsewhere.

Night-time chemistry is known to influence ozone levels the following day[8]. However, city lights had a minimal effect on next-day ozone levels in our model simulations. The modelled change in ozone levels was generally smaller than the percentage change in nitrogen oxide levels, and varied in sign depending on the concentration of nitrogen oxides and volatile organic compounds. For example, in the high-pollution case the presence of bright city lights resulted in a 0.3% decrease in ozone levels the following day.

The discrepancy in the magnitude of the nitrogen oxide and ozone response can be attributed to the nonlinear dependence of ozone on nitrogen oxides and volatile organic compounds, and the separation of processed layers in the nocturnal troposphere from fresh ground emissions, which reduces the influence of night-time chemistry on these emissions[8]. Furthermore, the model may be overestimating ground-level nitrogen oxide emissions, which also tends to reduce the influence of night-time chemistry on next-day ozone levels (see Supplementary Information).

Finally, we assessed the likelihood that city lights influence nitrogen chemistry in other urban areas around the globe (see Supplementary Information). We converted satellite data on light intensity into nitrate radical loss, using our aircraft measurements, and show that the influence of city lights on nitrate radical loss can be large in regions outside Los Angeles (Fig. 1b). We also find that satellite-derived estimates of light levels tend to correlate positively with independent satellite-derived estimates of nitrogen dioxide (see Supplementary Information)[9,10]. We therefore suggest that city lights are likely to influence nitrogen dynamics in other regions of the globe. ❐

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Additional information

Supplementary information accompanies this paper on www.nature.com/naturegeoscience.

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