Modelling light pollution over Poland using high resolution data

Henryka Netzel\textsuperscript{1} \quad dr Paweł Netzel\textsuperscript{2}

\textsuperscript{1}Institute of Astronomy
University of Wrocław, Poland

\textsuperscript{2}Space Informatics Lab
University of Cincinnati, USA

Light Pollution: Theory, Modelling, and Measurements, 2015
Light pollution as a problem

Figure: Pictures of night sky at different distances from Wroclaw taken with a camera SBIG AllSky 340C (http://www.izera-darksy.eu/sky/allsky-test.html)
Existing models

Simple models

\[ B(D) = a\sqrt{PQ(D)} \]

Advanced models

\[
\begin{align*}
 b &= \pi N_m \sigma \exp(-cH) \int \frac{dx dy}{\pi R^2} \int_0^\infty du \\
 &\times I_{up} s^{-2} (EF)_X (EF)_Q (DS) \\
 &\times \{ \exp(-ch)3(1 + \cos^2(\theta + \phi))/16\pi \\
 &+ \exp(-ah)11.11 Kf(\theta + \phi) \} .
\end{align*}
\]
Our solution

High resolution spatial data

GRASS GIS

Simple model
Berry's

\[ B(D) = a \sqrt{PQ(D)} \]

MAP

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GRASS GIS

- Geographic Resources Analysis Support System
- GNU public licence
- modular architecture
- data management
- image processing
- spatial modelling
Berry’s model

\[ B(D) = a\sqrt{P} \left( \frac{U}{D^2 + h^2} + \frac{V}{\sqrt{D^2 + h^2}} \right) \exp(-k\sqrt{D^2 + h^2}) \]
Berry’s model

\[ B(D) = a \sqrt{P} \left( \frac{U}{D^2 + h^2} + \frac{V}{\sqrt{D^2 + h^2}} \right) \exp\left( -k \sqrt{D^2 + h^2} \right) \]

**Figure:** Physical situation described by Berry’s model.
Berry’s model

\[ B(D) = a\sqrt{P} \left( \frac{U}{D^2 + h^2} + \frac{V}{\sqrt{D^2 + h^2}} \right) \exp(-k\sqrt{D^2 + h^2}) \]

**Figure:** Physical situation described by Berry’s model.

**Figure:** (Berry, 1976)
The Global Human Settlement Layer (GHSL)

Percentage of built-up area coverage per spatial unit.

Figure: Copyright European Commission, European Settlement Map 2014

- resolution: 100m
- ranges: 0 - 1
- No data: -1
- Water: -2
- EPSG 3035
Wrocław

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Model recalibration

\[ B(D) = a \sqrt{P} \left( \frac{U}{D^2 + h^2} + \frac{V}{\sqrt{D^2 + h^2}} \right) \exp\left( -k \sqrt{D^2 + h^2} \right) \]
Model, comparison with observations

Mean squared error: 0.0788

\[ y = 0.998822x \]

\[ R^2 = 0.999813 \]
Model, comparison with observations
Night sky brightness over Poland

resolution: 100 meters
cells: 73,610,720

Hardware: Dell PowerEdge, 2x Xeon 3.1GHz, 256GB RAM, calculations were performed using 14 threads

Time of calculation: 82min 32s

Software: dedicated GRASS module written in C
Poland, comparison with other results

http://djilorenz.github.io/astronomy/lp2006/

http://earthobservatory.nasa.gov, VIIRS observations

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Wrocław, comparison with other results

http://dijonre.github.io/lowseremey/g2005/
Summary and conclusions

1. We used very simple model and high resolution data and obtained detailed map of night sky brightness in a reasonable time of calculations.

2. The model can be implemented in GRASS GIS system using standard commands (r.mapcalc, r.mfilter) or as dedicated module (r.skylight).

3. GSHL can be used as input data to estimate spatial distribution of light pollution instead of population data.

Future work:

1. Finish and publish new GRASS module.
2. Shadowing effect (Dark Sky Park).
3. Change of atmospheric extinction.