Modelling of light pollution over Poland using Berry's model with high resolution data

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Objectives

Light pollution, which means brightening of the night sky caused by artificial light scattered in the atmosphere, becomes more and more common. Many models were created in order to estimate the scale of the issue. First models were simple and based on population data. Later those models became more an more advanced and took into account more sophisticated physical condidtions. Another type of models are those based on observations from space (DMSP sattelite).

Nowadays thanks to remote sensing techniques we have an acces to detailed map of human settlements and urbanization. In order to estimate light pollution over Poland we decided to use one of the simplest model, Berry's, and more advanced analysis technique. We used GRASS GIS software and based on the trial version of The Global Human Settlement Layer (GSHL). We obtained map of night sky brightness over Poland in 100-meter resolution. It fits observations very well despite of an extreme simplicity of used model.

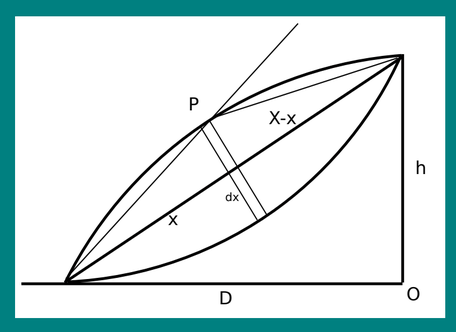
High resolution spatial data

GRASS GIS

MAP

Simple model: Berry's

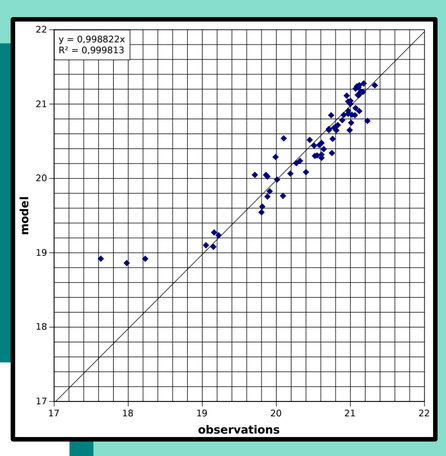
describes brightness (in S 10 units) at the zenith at given distance from the city with a given population

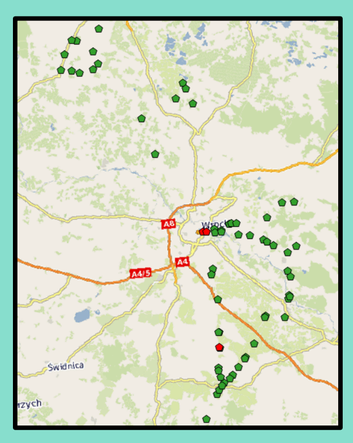


$$B(D) = a\sqrt{P}\left(\frac{U}{D^2+h^2} + \frac{V}{\sqrt{D^2+h^2}}\right)\exp -k\sqrt{D^2+h^2}$$

Data and method

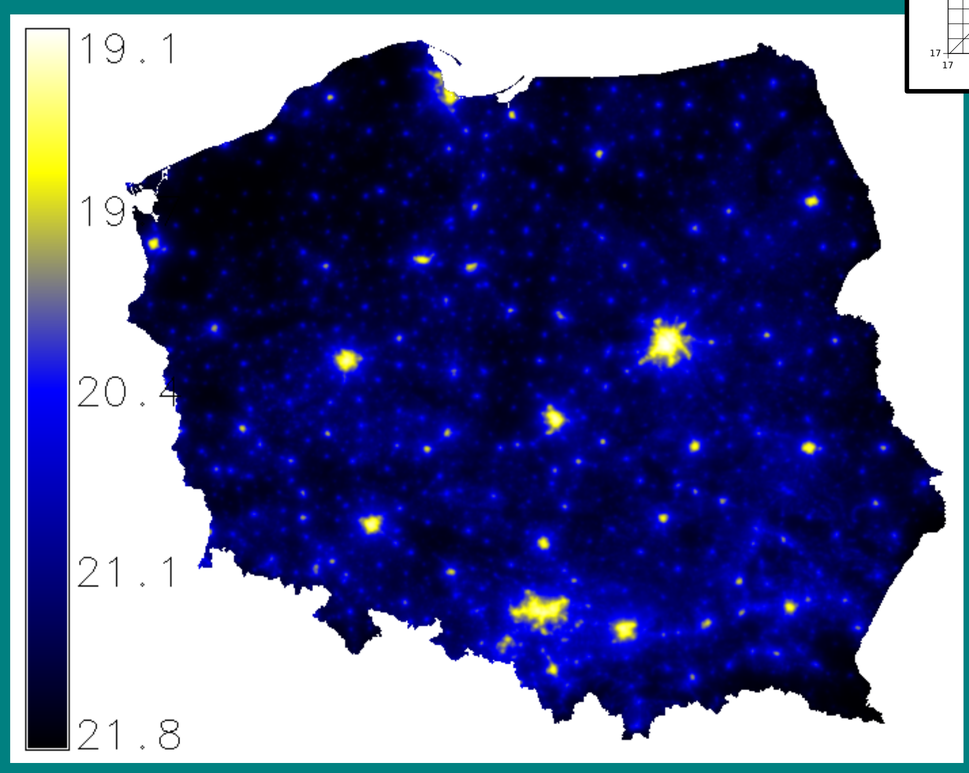
As an input data (instead of cities approximated to points) we used the Global Human Settlement Layer (GSHL). It is a raster map describing percentage of urbanization in 100 meter resolution.
Model was recalibrated (determined constant: a, U, V, h, k) based on observational data. For each datapoint contributions of all cells within a radius of of about 80 km were used to run ~milion models with different constants. Model with the lowest mean squared error was chosen.
Recalibrated model was used in GRASS GIS to create map of Poland.





Calculations:

resolution: 100 meters
number of rows: 7856
number of columns: 9370
number of cells: 73 610 720
Hardware: Dell PowerEdge, 2x Xeon 3.1GHz, 256GB RAM, calculations were perfomed using 14 threads
Time of calculation: 82min 32s
Software: dedicated GRASS module written in C



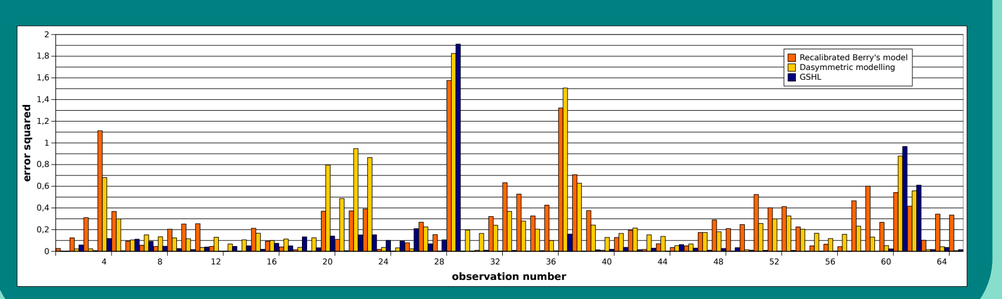
Conclusions

1. Simple model can be used at raster cell level with high resolution data to obtain detailed light pollution map
2. The model can be implemented in GRASS GIS system using standard commands (r.mapcalc, r.mfilter) or as dedicated module (r.skylight)
3. The calculation of light pollution does not need a high computational power
4. GSHL can be used as input data to estimate spatial distribution of light pollution
5. GSHL model can replace original population information in Berry's model

r.skylight input=name output=name [a=value] [U=value] [V=value] [h=value] [k=value] [--overwrite] [--help] [--verbose] [--quiet]

Flags:
--o Allow output files to overwrite existing files
--h Print usage summary
--v Verbose module output
--q Quiet module output

Parameters:
input Name of input raster map
output Name for output raster map
a Parametr a
default: 2.5
U Parametr U
default: 2.55
V Parametr V
default: 0.0
h Parametr h
default: 1.3
k Parametr k
default: 0.031



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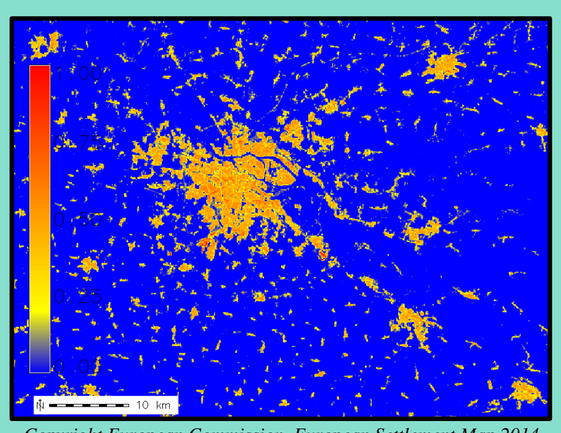

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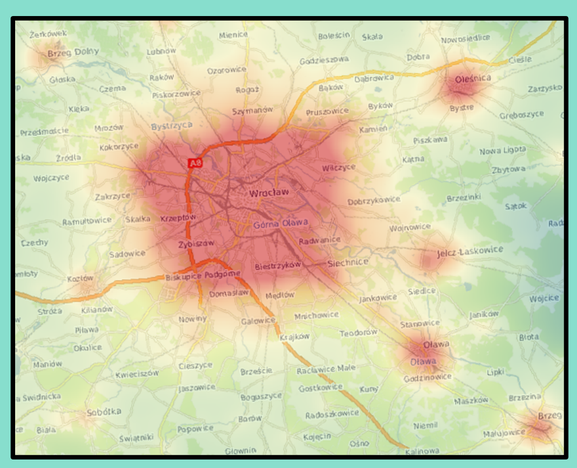
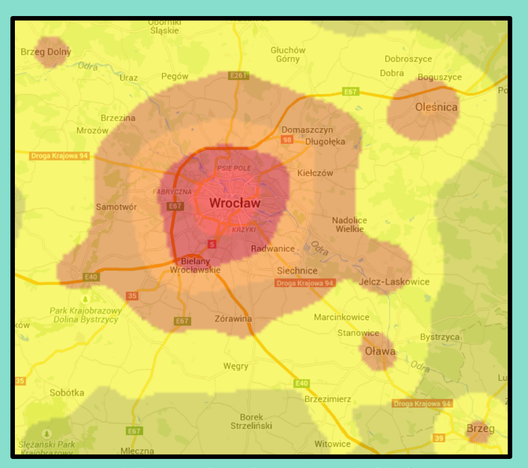
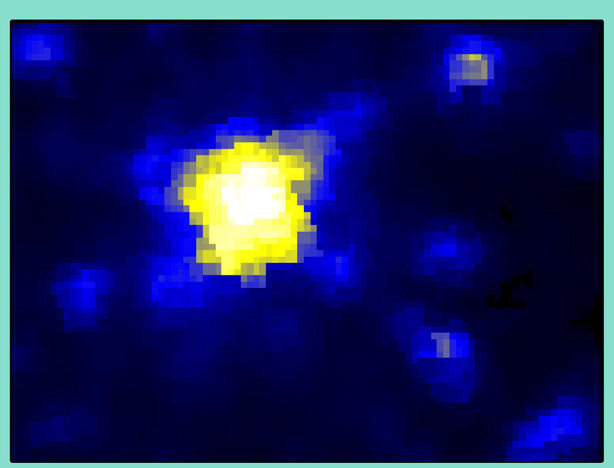




http://djlorenz.github.io/astronomy/lp2006/



http://ngdc.noaa.gov/eog/dmsp/