Modelling light pollution over Poland using high resolution data

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Light Pollution: Theory, Modelling, and Measurements, 2015

Light pollution as a problem

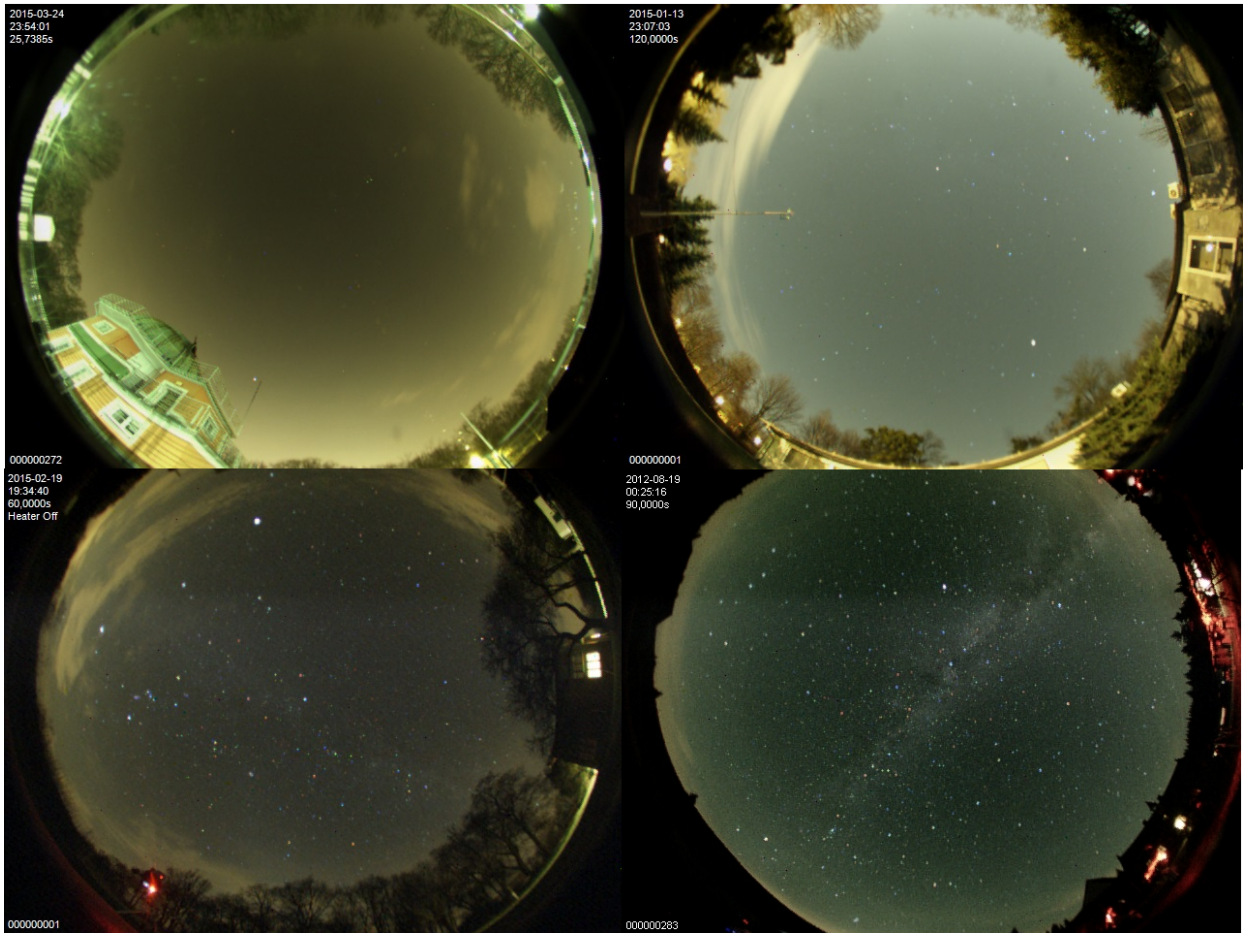


Figure: Pictures of night sky at different distances from Wroclaw taken with a camera SBIG AllSky 340C (*http://www.izera-darksky.eu/sky/allsky-test.html*)

Existing models

Simple models

$$B(D) = a\sqrt{P}Q(D)$$

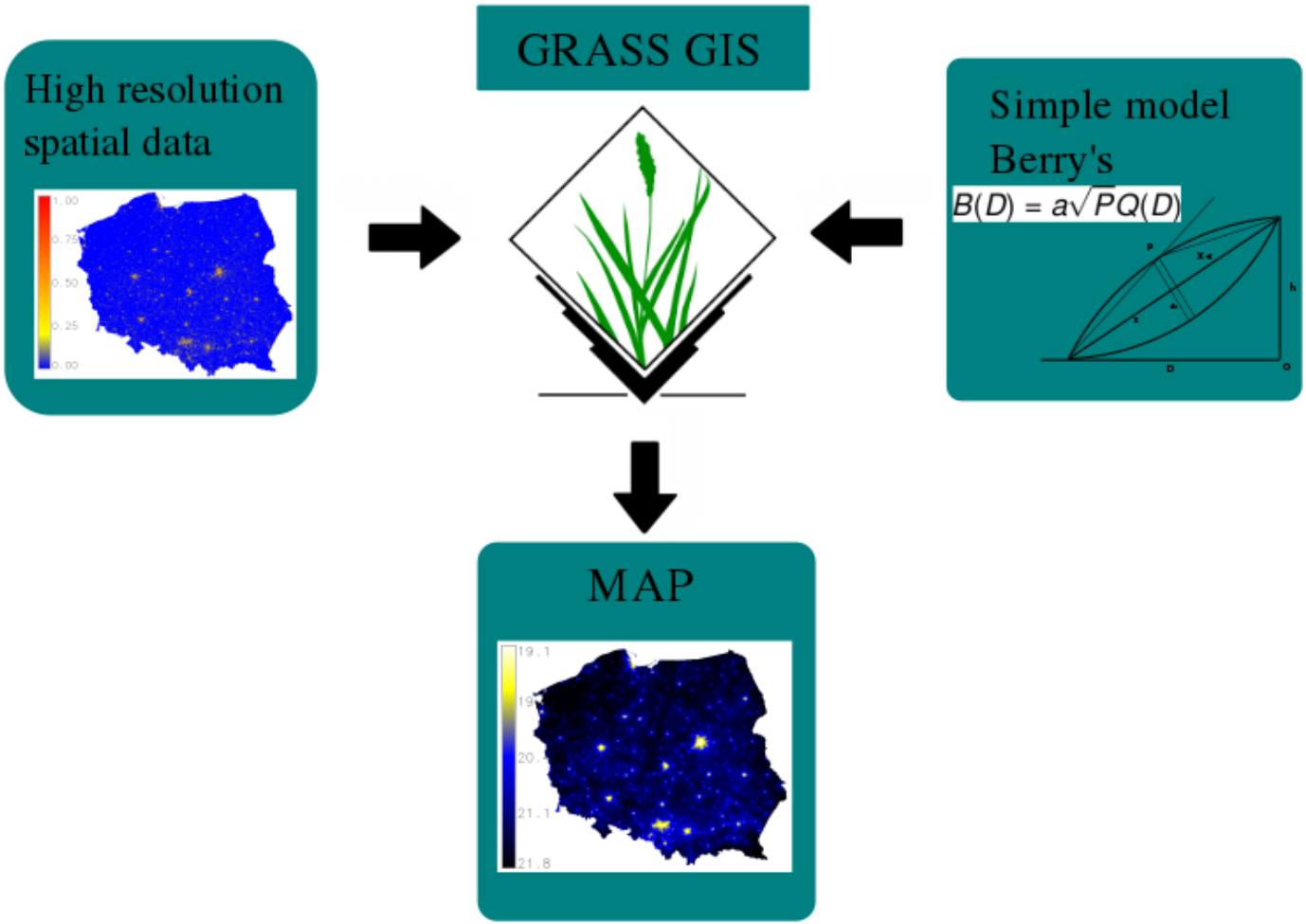
MODELS

Advanced models

$$b = \pi N_m \sigma_R \exp(-cH) \iint (dxdy/\pi R^2) \int_0^\infty du$$
$$\times I_{up}\, s^{-2}\, (\mathrm{EF})_{XQ}\, (\mathrm{EF})_{QO}\, (\mathrm{DS})$$
$$\times \{\exp(-ch)3(1 + \cos^2[\theta + \phi])/(16\pi)$$
$$+ \exp(-ah)\, 11.11\, Kf(\theta + \phi)\} \ .$$

Satellite data

Our solution



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

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

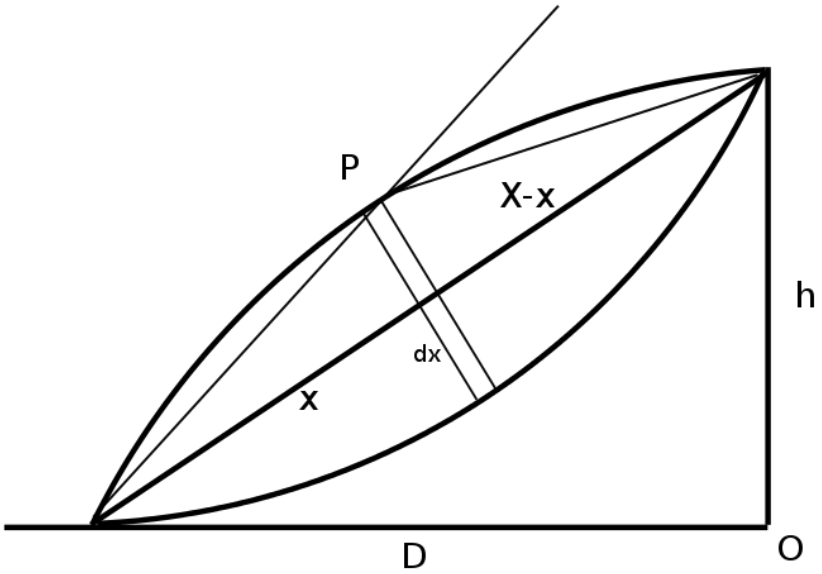


Figure: Physical situation described by Berry's model.

Berry's model

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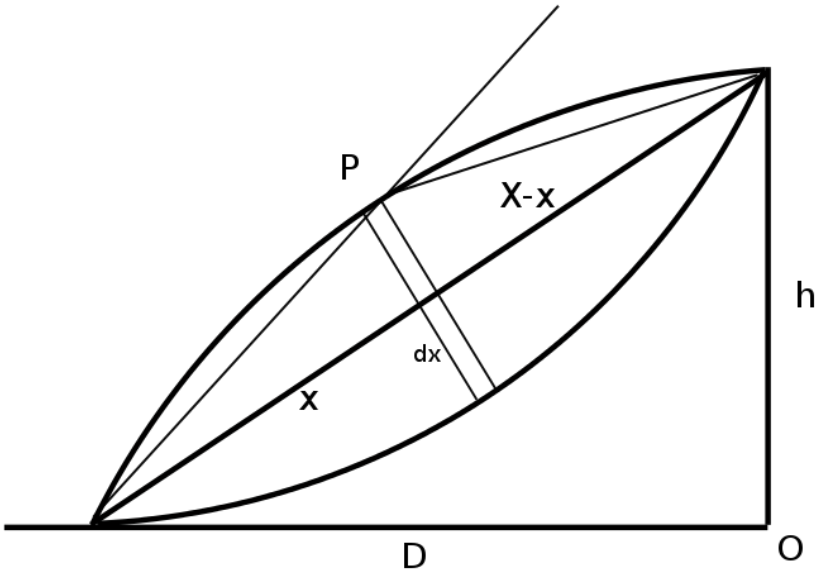


Figure: Physical situation described by Berry's model.

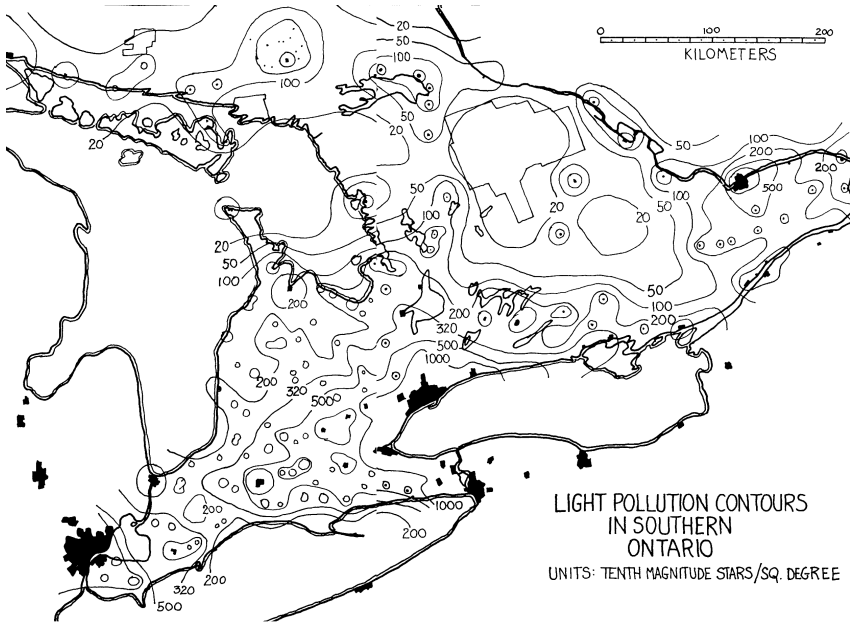
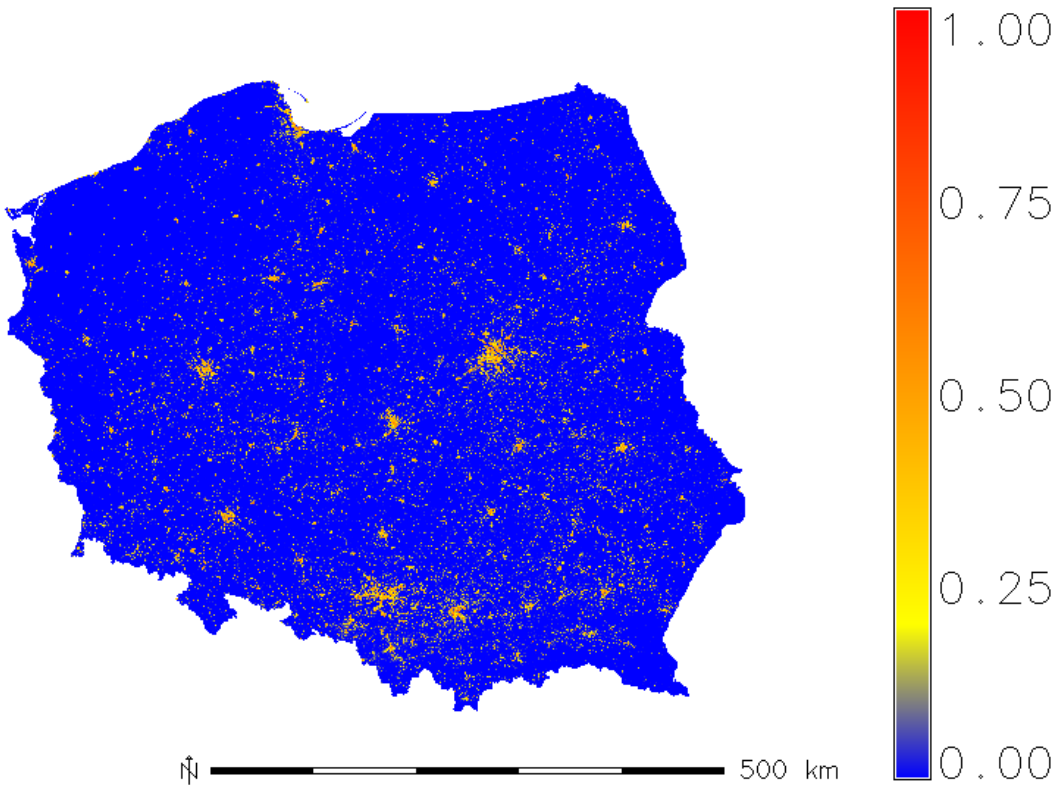


Figure: (Berry, 1976)

The Global Human Settlement Layer (GHSL)

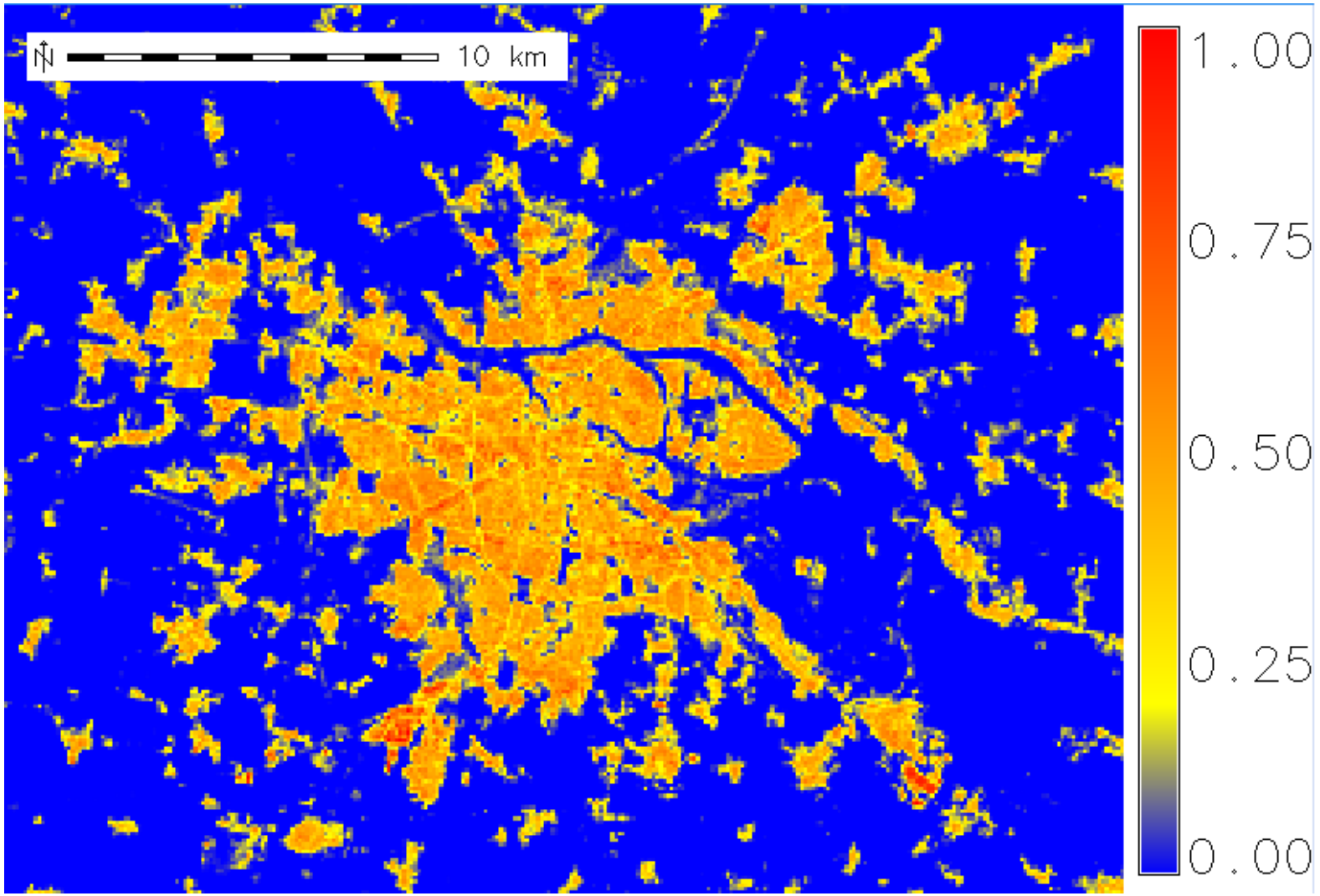
Percentage of built-up area coverage per spatial unit.



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

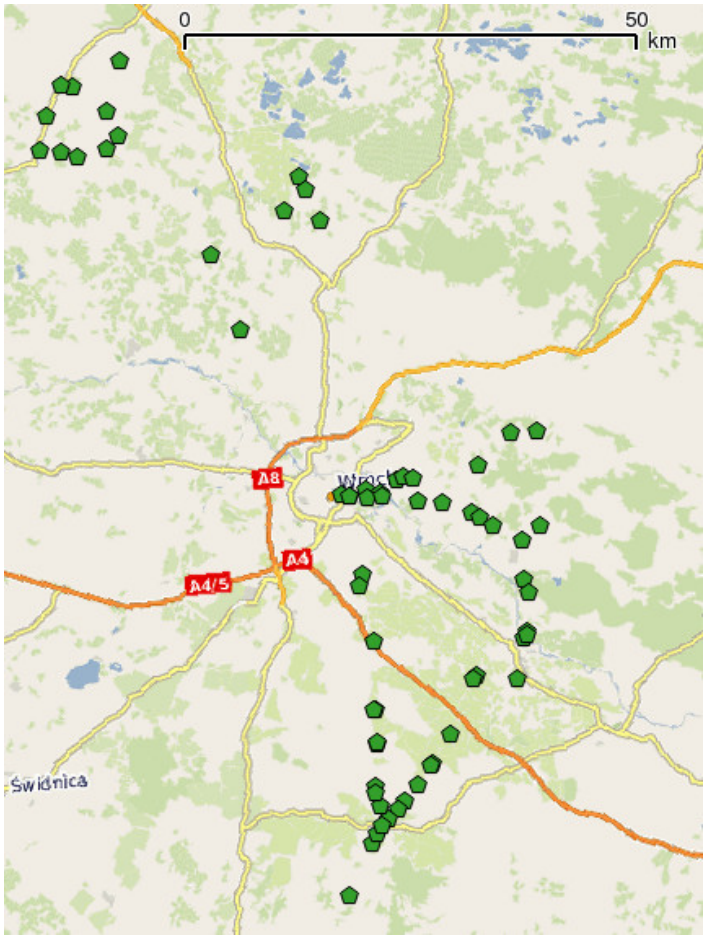
Figure: Copyright European Commission, European Settlement Map 2014

Wrocław



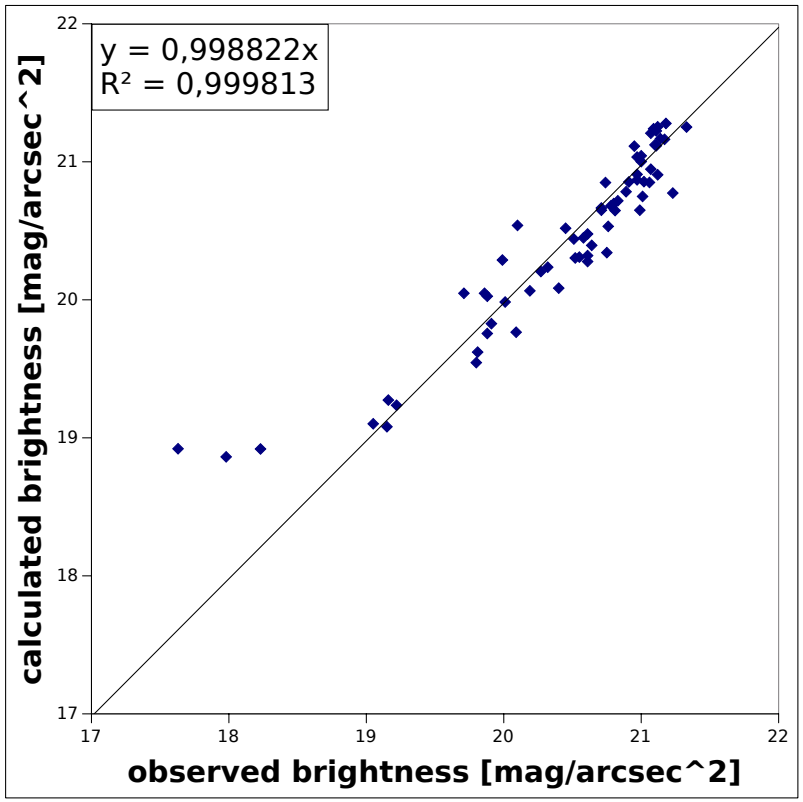
Model recalibration

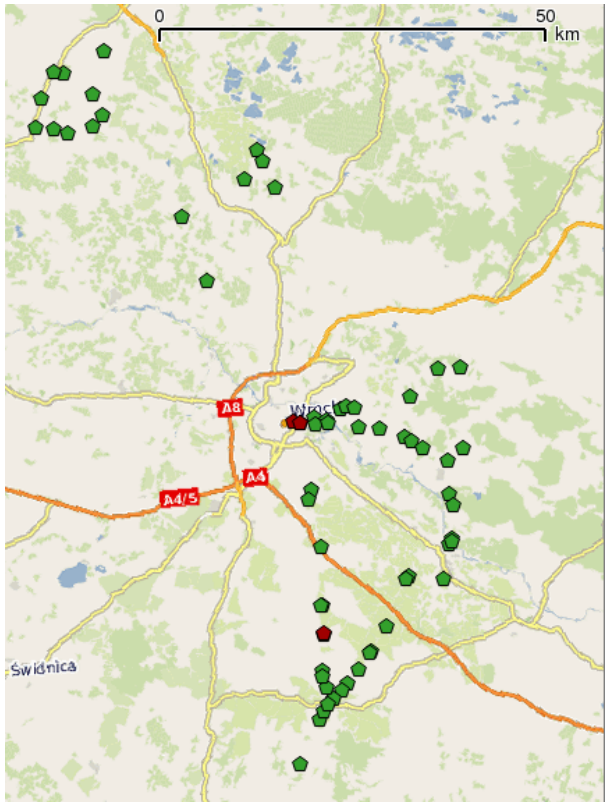
$$B(D) = a\sqrt{P}\left(\frac{U}{D^2+h^2} + \frac{V}{\sqrt{D^2+h^2}}\right)\exp(-k\sqrt{D^2+h^2})$$



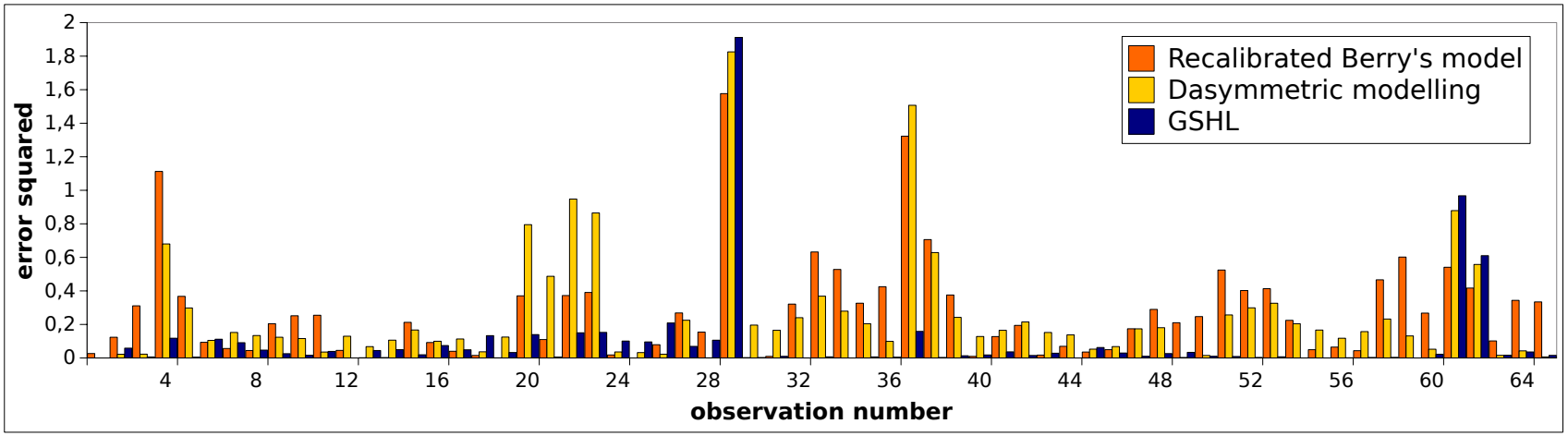
Model, comparison with observations

Mean squared error: 0.0788

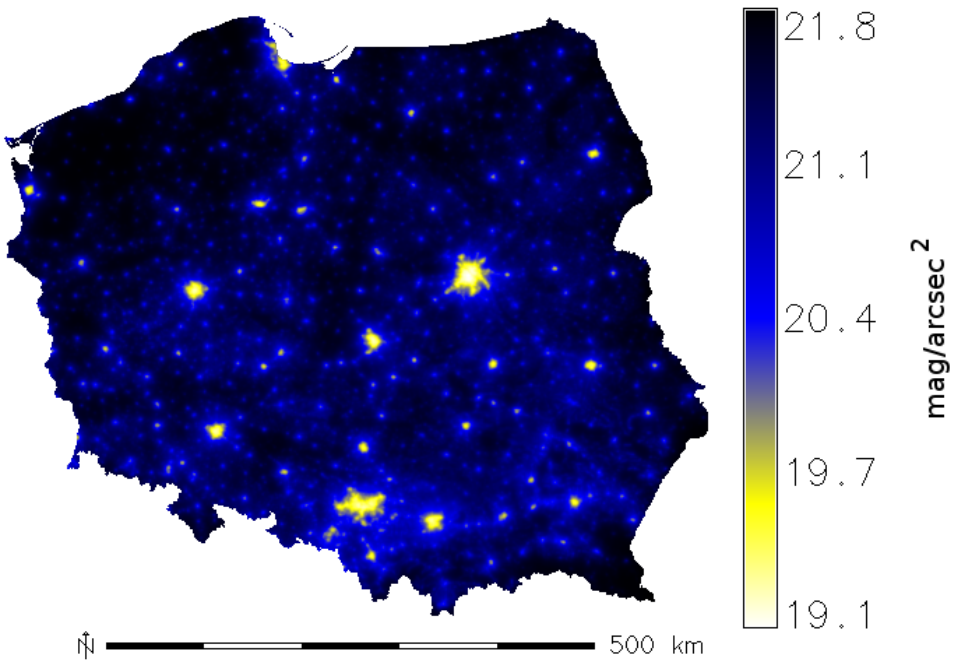




Model, comparison with observations

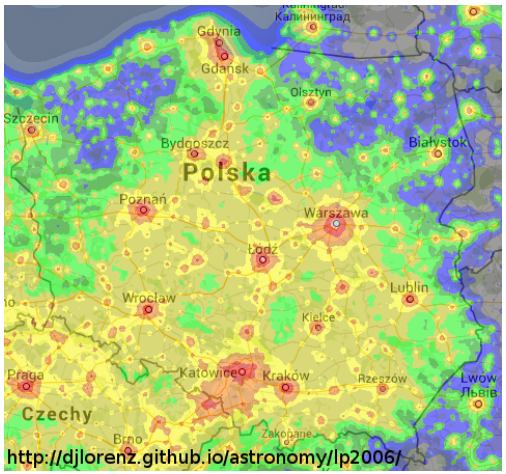


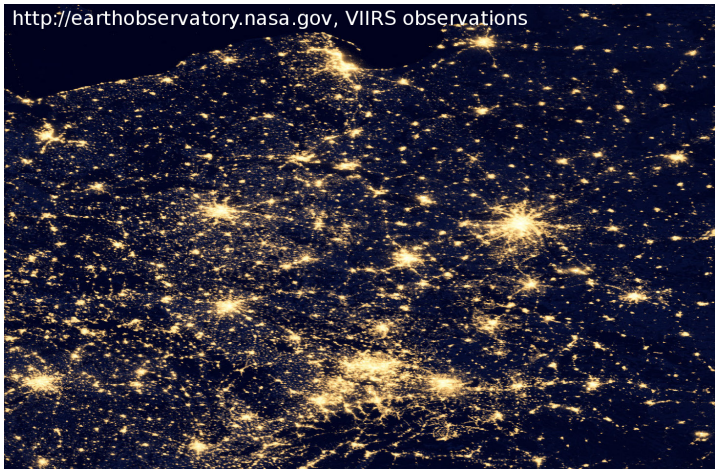
Night sky brightness over Poland

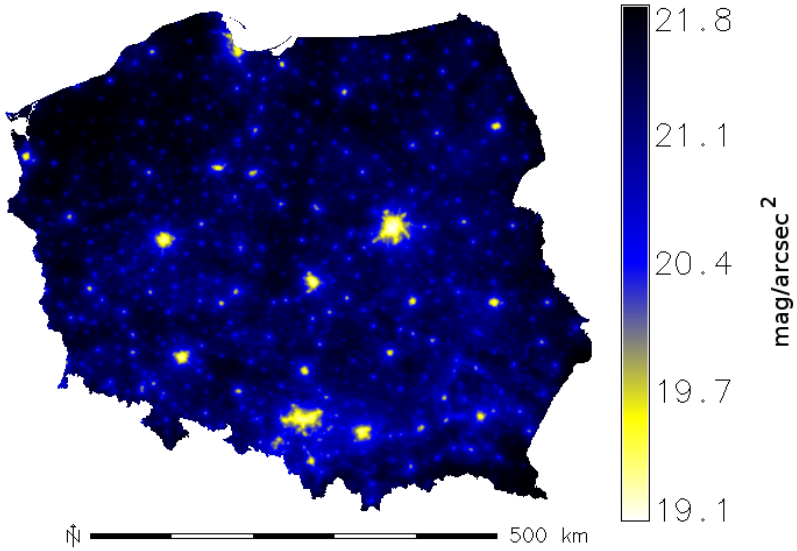


resolution: 100 meters
cells: 73 610 720
Hardware: Dell PowerEdge, 2x Xeon 3.1GHz, 256GB RAM, calculations were perfomed using 14 threads
Time of calculation: 82min 32s
Software: dedicated GRASS module written in C

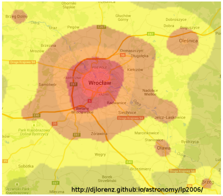
Poland, comparison with other results

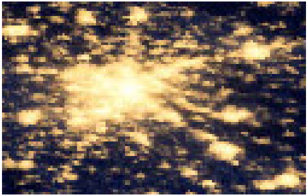






Wrocław, comparison with other results





Summary and conclusions

1. We used very simple model and high resolution data and obtained detailed map of night sky brighntess 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 atmosferic extinction