Measuring and Mapping Light Pollution at a Local Scale

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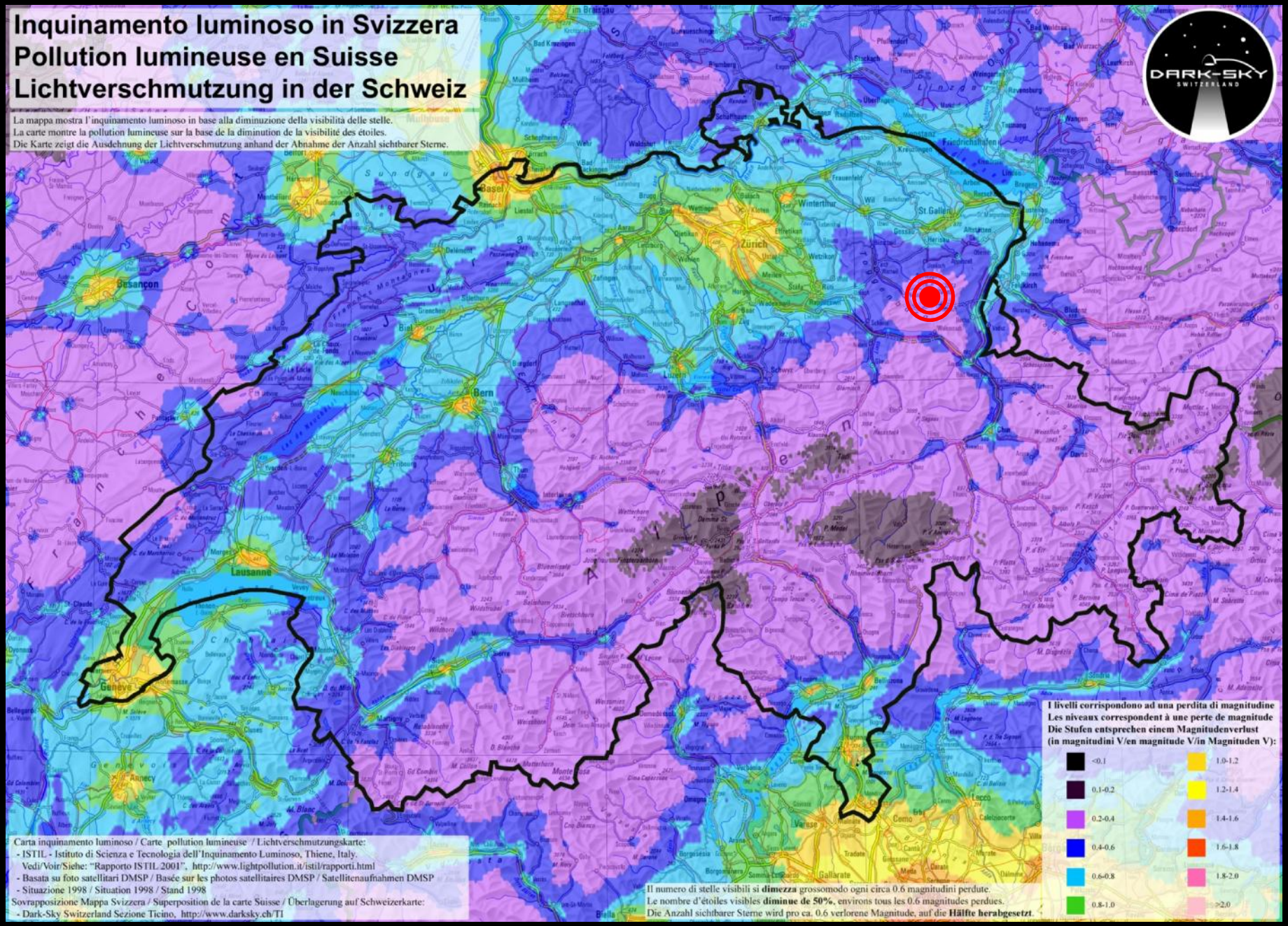
15 to 20 min. presentation followed by questions

1. Introduction

Source: NASA

Inquinamento luminoso in Svizzera
Pollution lumineuse en Suisse
Lichtverschmutzung in der Schweiz

La mappa mostra l'inquinamento luminoso in base alla diminuzione della visibilità delle stelle.
La carte montre la pollution lumineuse sur la base de la diminution de la visibilité des étoiles.
Die Karte zeigt die Ausdehnung der Lichtverschmutzung anhand der Abnahme der Anzahl sichtbarer Sterne.



I livelli corrispondono ad una perdita di magnitudine
Les niveaux correspondent à une perte de magnitude
Die Stufen entsprechen einem Magnitudenverlust
(in magnitudini V/en magnitude V/in Magnituden V):

<0.1	1.0-1.2
0.1-0.2	1.2-1.4
0.2-0.4	1.4-1.6
0.4-0.6	1.6-1.8
0.6-0.8	1.8-2.0
0.8-1.0	>2.0

Il numero di stelle visibili si **dimezza** grossomodo ogni circa 0.6 magnitudini perdute.
Le nombre d'étoiles visibles **diminue de 50%**, environs tous les 0.6 magnitudes perdues.
Die Anzahl sichtbarer Sterne wird pro ca. 0.6 verlorene Magnitude, auf die **Hälfte herabgesetzt**.

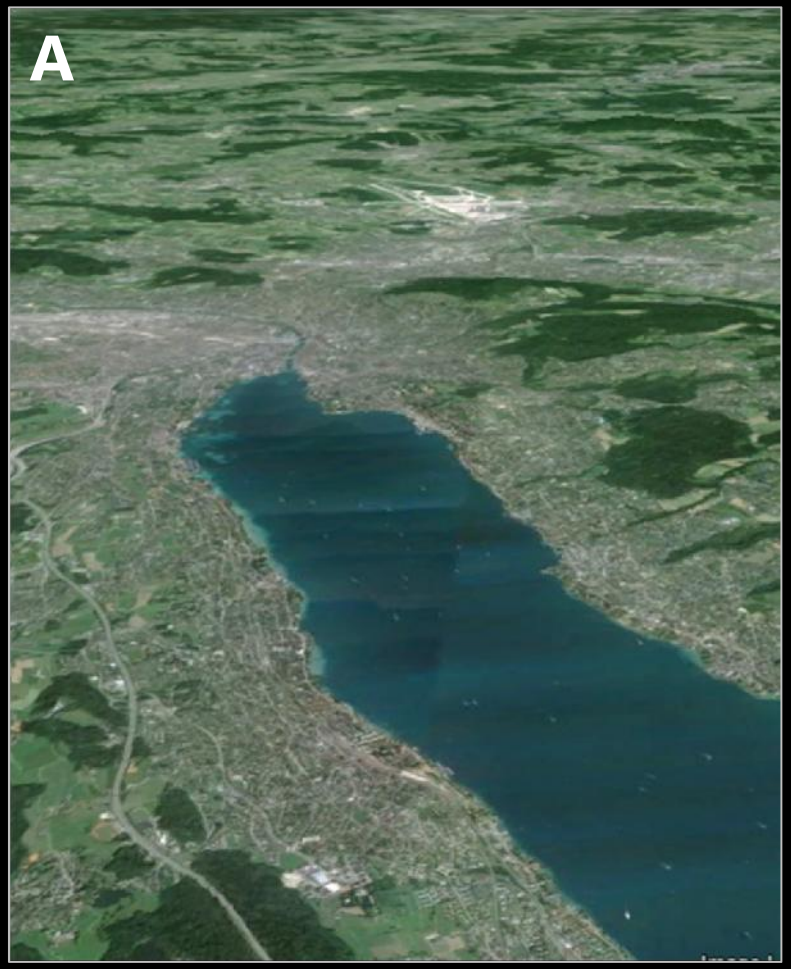
Carta inquinamento luminoso / Carte pollution lumineuse / Lichtverschmutzungskarte:
- ISTIL - Istituto di Scienza e Tecnologia dell'Inquinamento Luminoso, Thiene, Italy.
  Vedi/Voir/Siehe: "Rapporto ISTIL 2001", http://www.lightpollution.it/istil/rapporti.html
- Basata su foto satellitari DMSP / Basée sur les photos satellitaires DMSP / Satellitenaufnahmen DMSP
- Situazione 1998 / Situation 1998 / Stand 1998

Sovrapposizione Mappa Svizzera / Superposition de la carte Suisse / Überlagerung auf Schweizerkarte:
- Dark-Sky Switzerland Sezione Ticino, http://www.darksky.ch/TI

Photo: Stefan M. Bruehlmann

- Light pollution is a local phenomenon
- Available maps are very coarse and generalized
- There are only a few light pollution maps existing at a local (neighborhood) level

Virtual Earth



Source: Google Earth / Landsat

Lake of Zurich from airplane

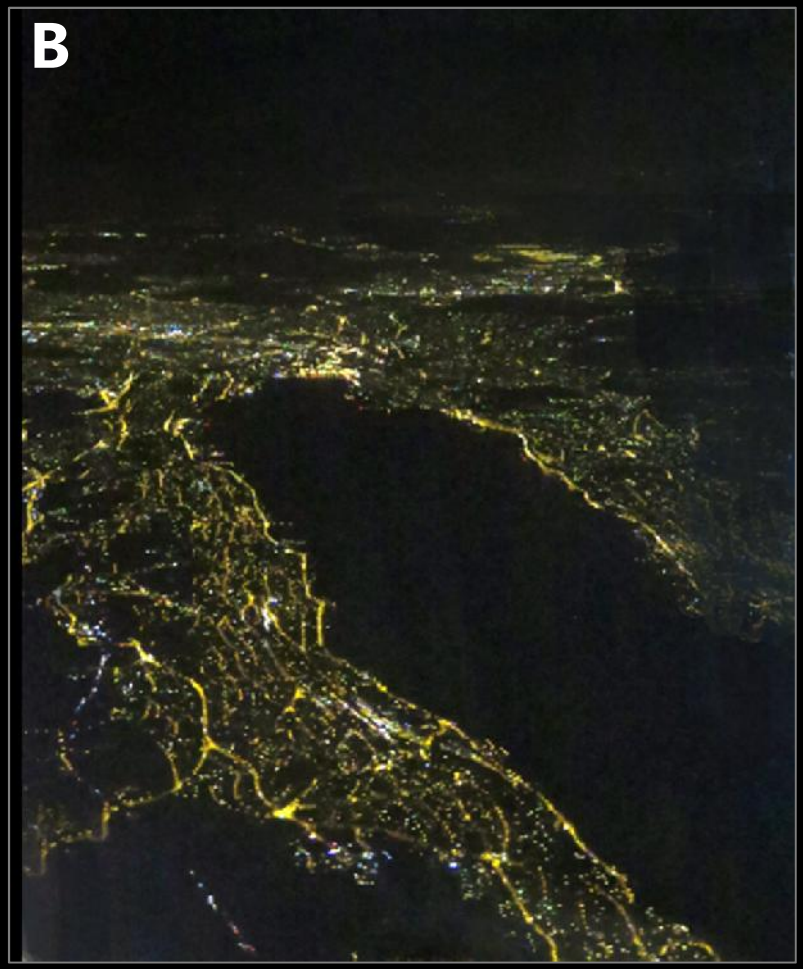
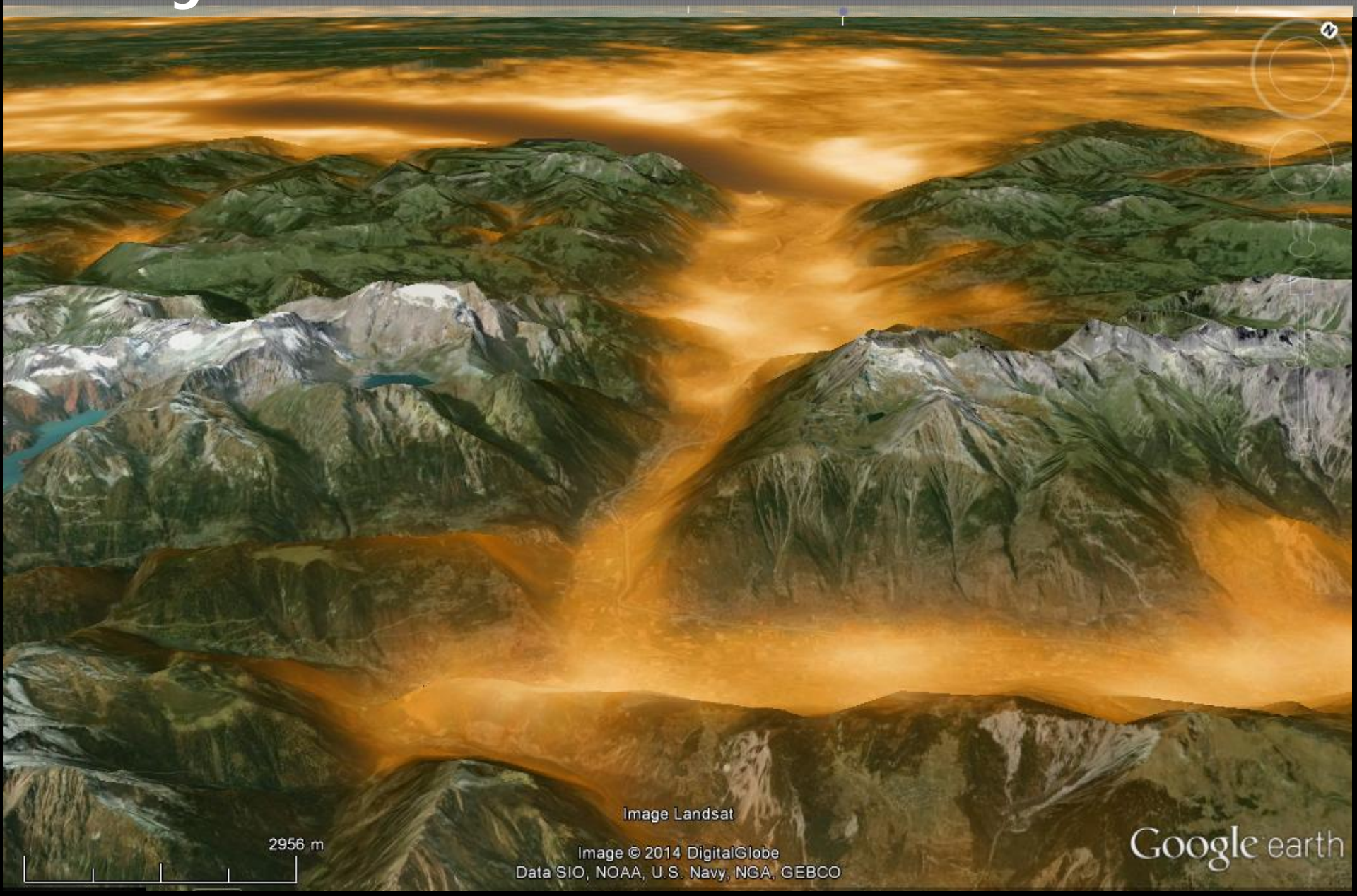


Photo: Stefan M. Bruehlmann

2. Light Pollution



Light Pollution

Definition ¦ Animation

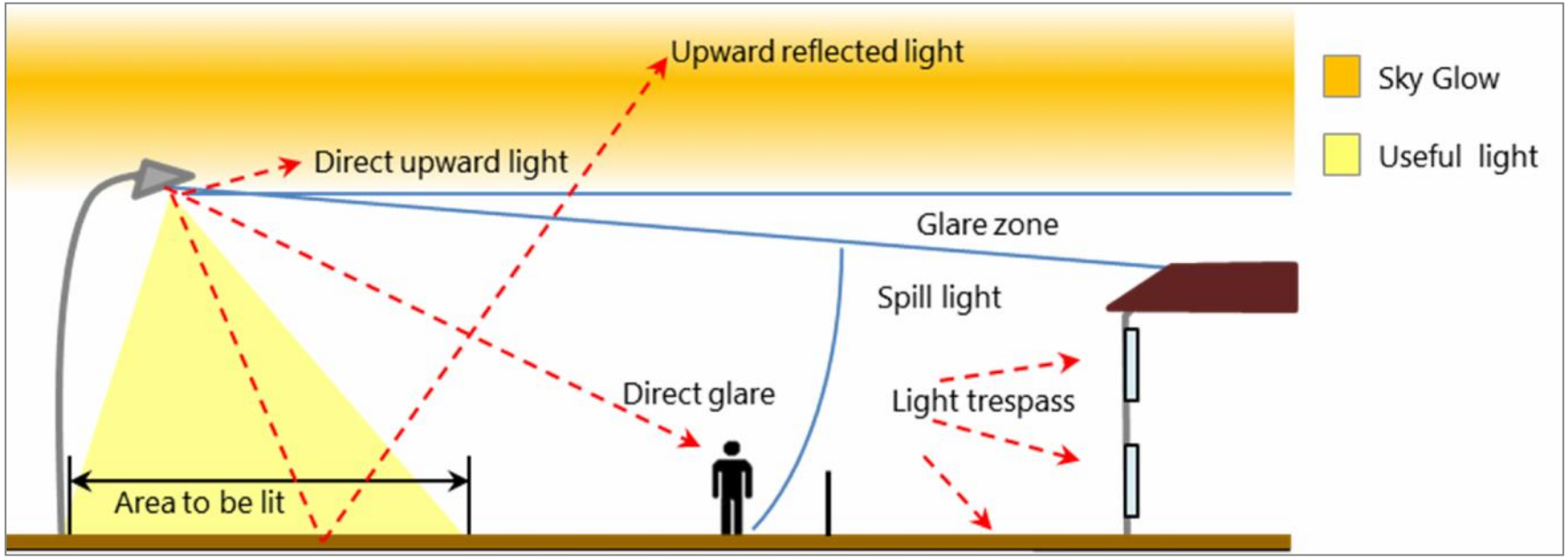


Illustration : Stefan M. Bruehlmann / adapted from Rensselaer Polytechnic Institute, 2007

Definition:

«that part of light that ends up in the sky and is consequently not for functional use»

Detriment effects

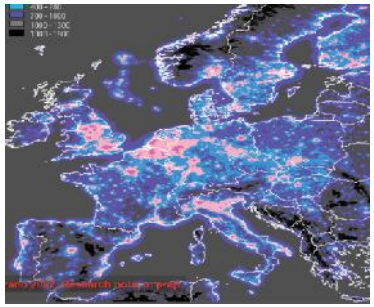
Photo: Jim Richardson

- Health hazards
- Nocturnal insects
- Ecological consequences
- Bird migration

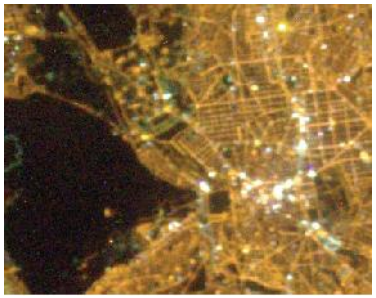
- Consequences for astronomers
- Loss of the night

3. Literature

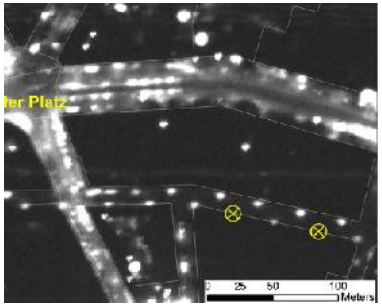
Influencing studies:



Cinzano et al. (Università di Padova, Italy)
- World Atlas of the Night Sky Brightness
- Using satellite data and modelling techniques
- Large scale



Zamorano et al. (2011) (Universidad Complutense de Madrid)
- Field measurements & ISS image analysis
- Quality of ISS image
- Large scale



Kyba et al. (Freie Universität Berlin)
- Aerial photo survey
- Land use analysis
- Large scale

& several regional studies (Geneva, Hongkong, Japan, …)

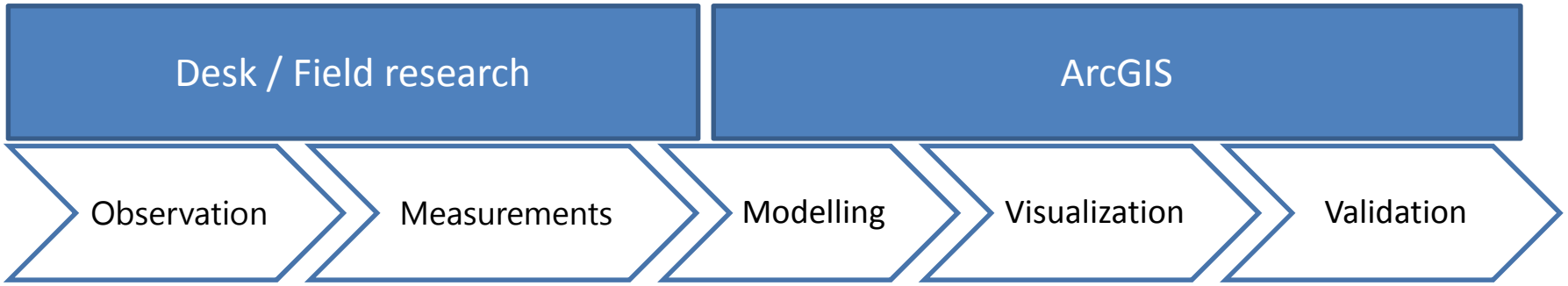
4. Research question

What is a suitable set-up of a **GIS-based model** to produce an upward light emission map at a local scale and what **significance** can the map achieve?

- What are the spatial distribution and the parameters of the light sources?
- What accuracy can the model output reach?
- What are potential advantages and disadvantages of the model?
- What are potential fields of application?

5. Research method

Observation ¦ Measurements ¦ Modelling ¦ Visualization ¦ Validation ¦ Improvement

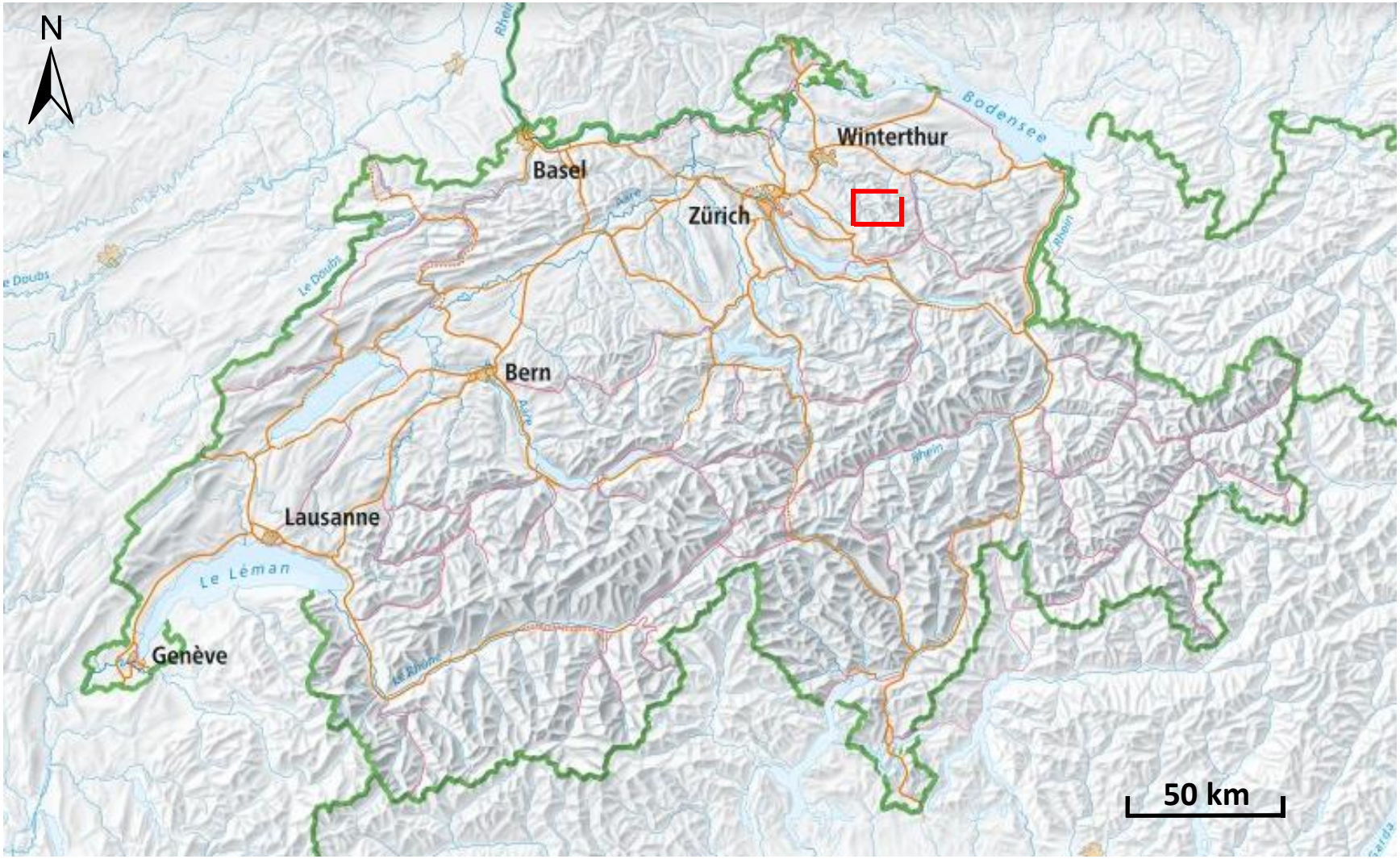


- Understanding light sources
- Propagation of light
  - Measurement equipment
  - Measurement strategy
    - Modelling of relevant features
    - Data quality and data processing
      - Reference image
      - Analysis

Vector Data

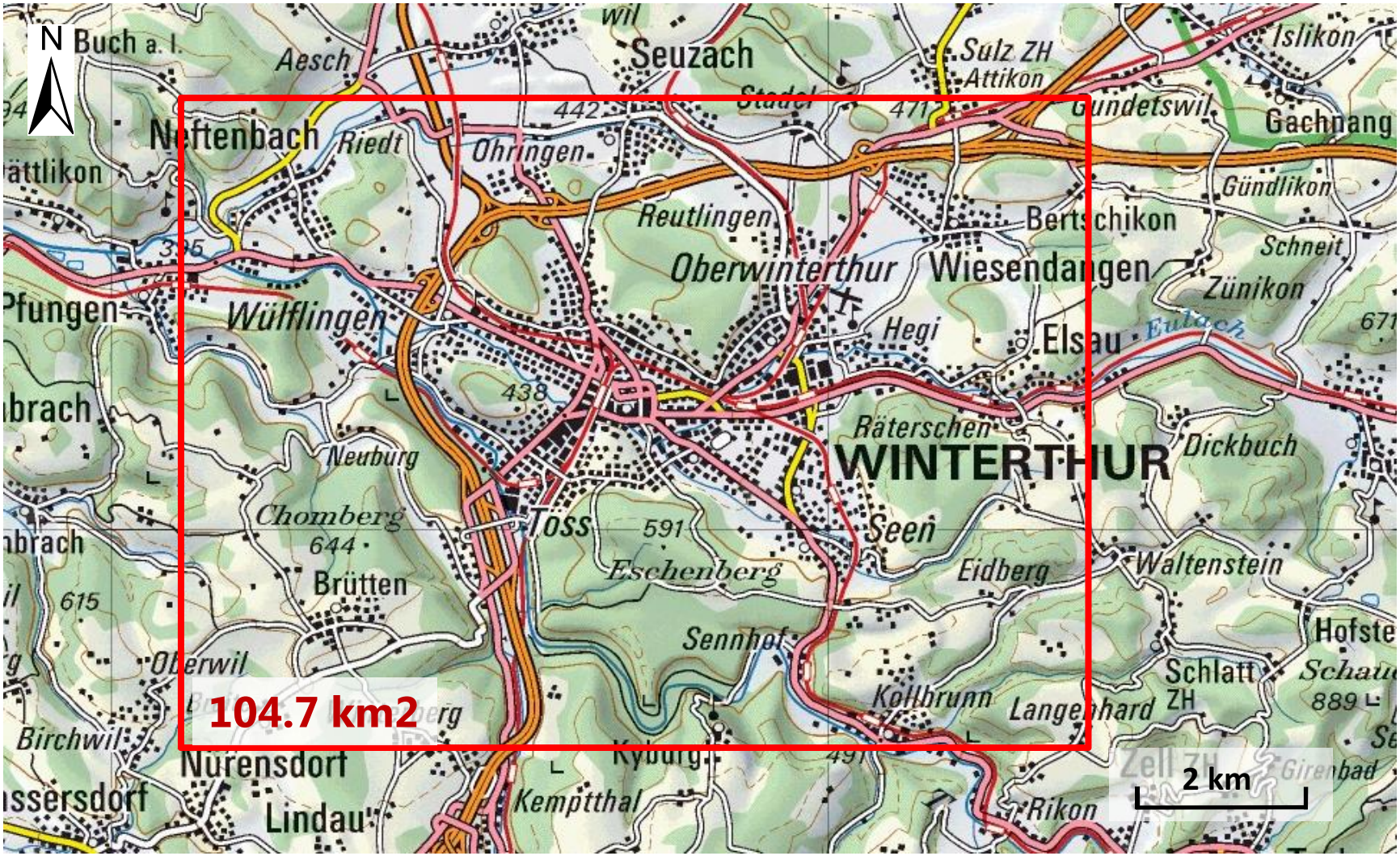
- Swisstopo; OSM, local Geoportals

Research Area



Source: map.geo.admin.ch

Research Area



Source: map.geo.admin.ch

5. Research method

Observation ¦ Measurements ¦ Modelling ¦ Visualization ¦ Validation ¦ Improvement

Motorway

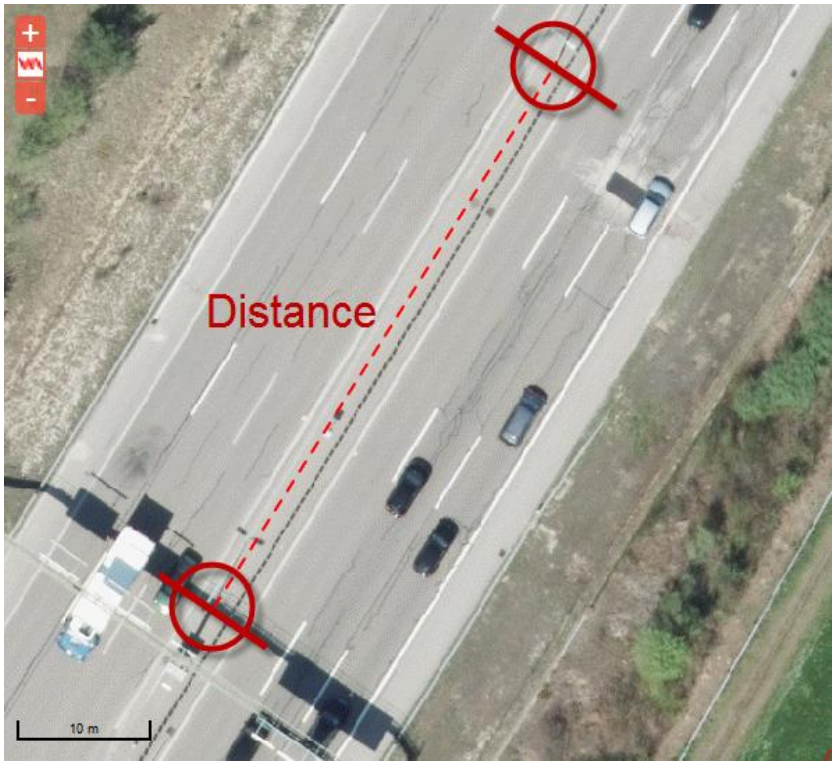
Residential street

Sports fields

Photos: Stefan M. Bruehlmann

5. Research method

Observation ¦ Measurements ¦ Modelling ¦ Visualization ¦ Validation ¦ Improvement



Visual inspection of aerial photos

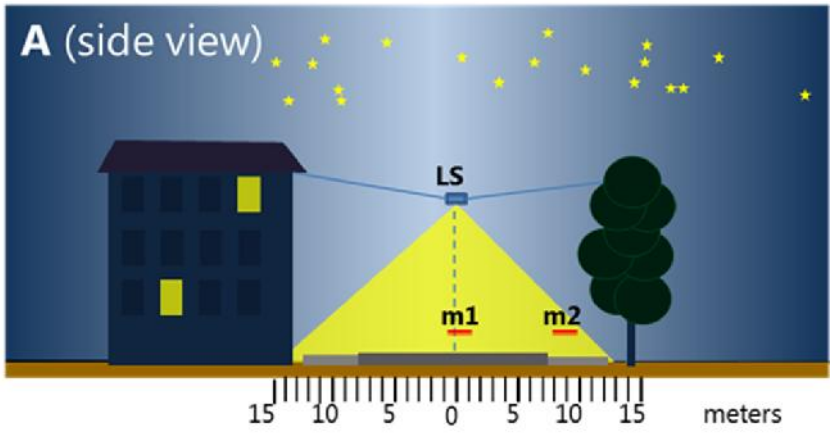
Category	Interval [m]	Intensity
1. Class A Road	50.0	lux
2. Class 1 Road	30.0	lux
3. Class 2 Road	30.0	lux
4. Class Q Road	30.0	lux
5. Residential Buildings	15.0	lux
6. Industrial Buildings	15.0	lux
7. Train station area	30.0	lux
8. Sports pitch	25.0	lux
9. Parking	20.0	lux
10. Old Town	15.0	lux

Data Input for modelling

5. Research method

Observation ¦ **Measurements** ¦ Modelling ¦ Visualization ¦ Validation ¦ Improvement

❶ Measurement procedure in the field



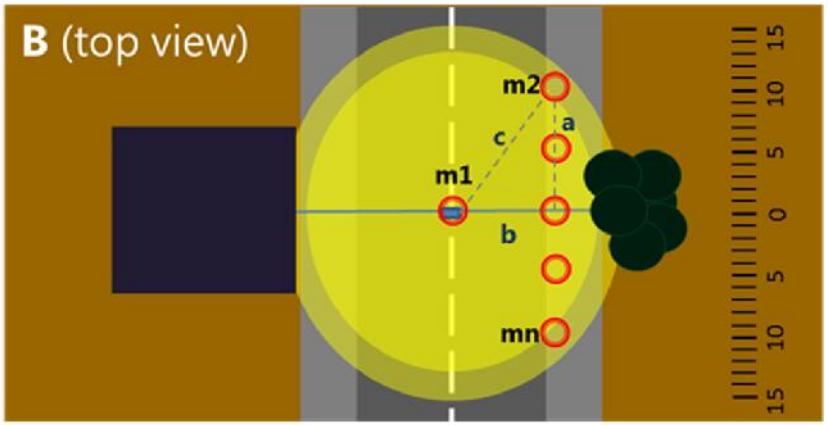
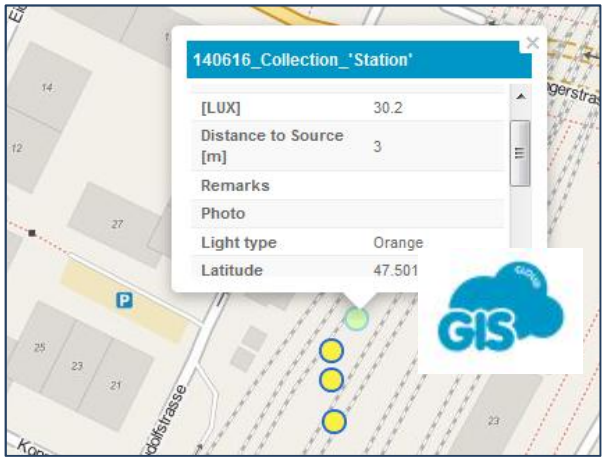
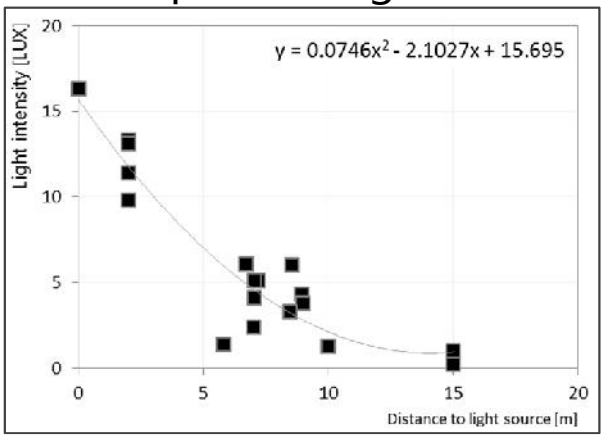


Illustration : Stefan M. Bruehlmann

❷ Data processing



❸ Data processing



Vector Base Data

Observation ¦ Measurements ¦ **Modelling** ¦ Visualization ¦ Validation ¦ Improvement

VECTOR25

VECTOR25 reproduces man-made and natural features in a flexible vector format and is especially suitable for applications in geographic information systems (GIS)

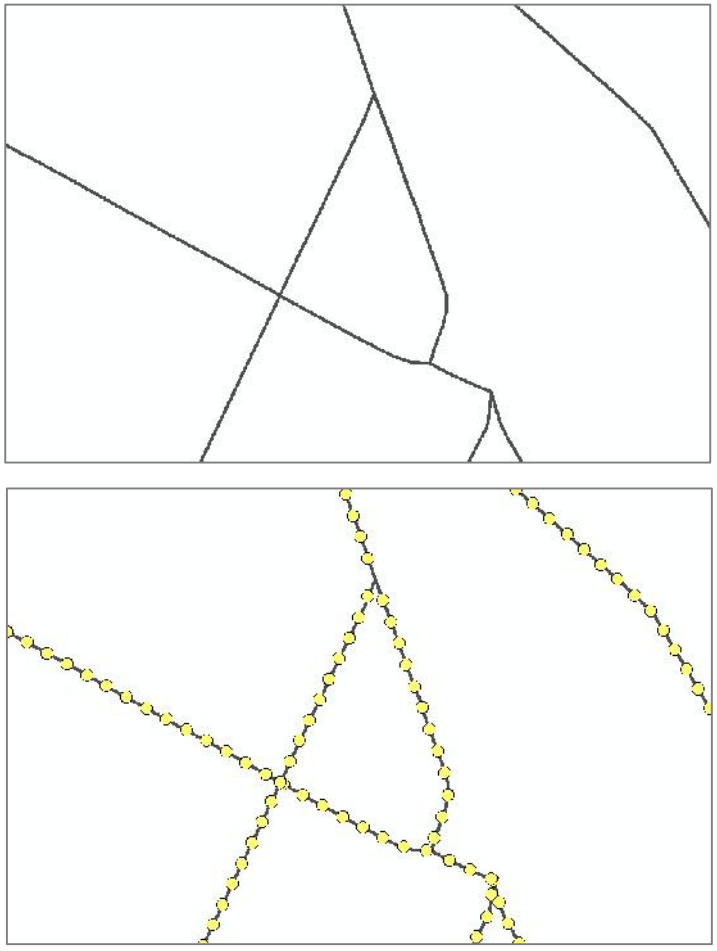
Source: swisstopo

Road network
Other traffic
Primary surfaces
Hedges and trees
Single objects

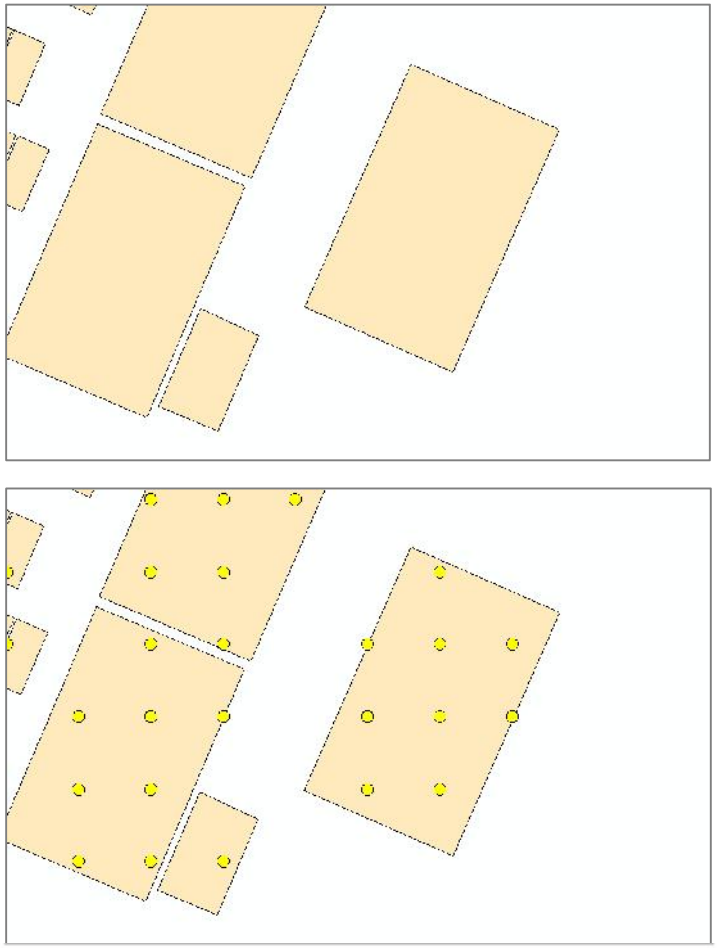
Railway network
Hydrological network
Buildings
Facilities

5. Research method

Observation ¦ Measurements ¦ **Modelling** ¦ Visualization ¦ Validation ¦ Improvement



Polyline: ‘Streets’, ‘Buildings’

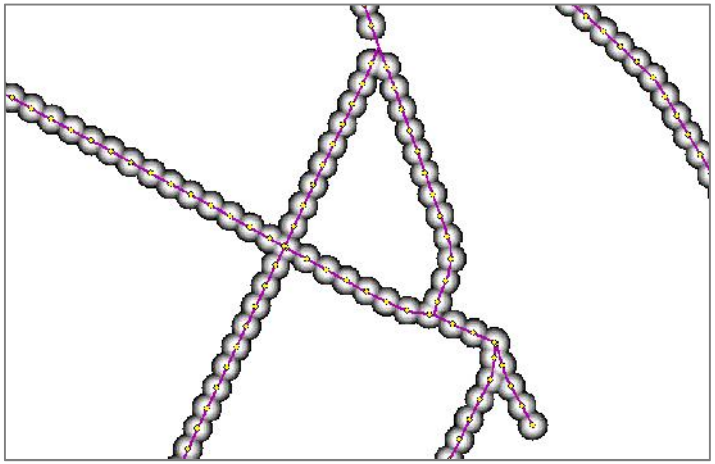


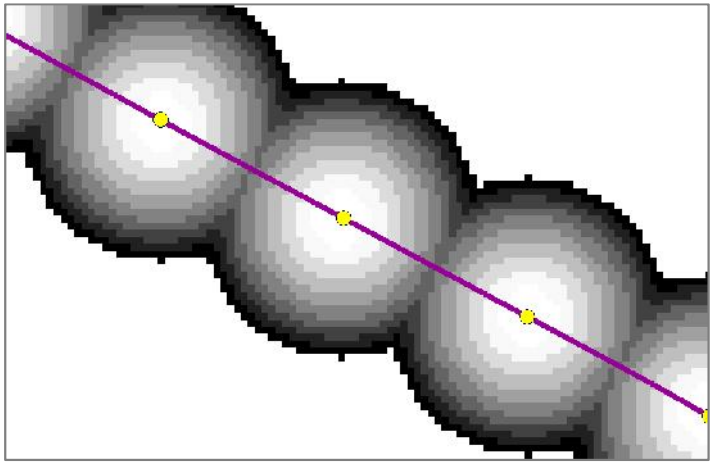
Polygon: ‘Parking’, ‘Sports fields’

5. Research method

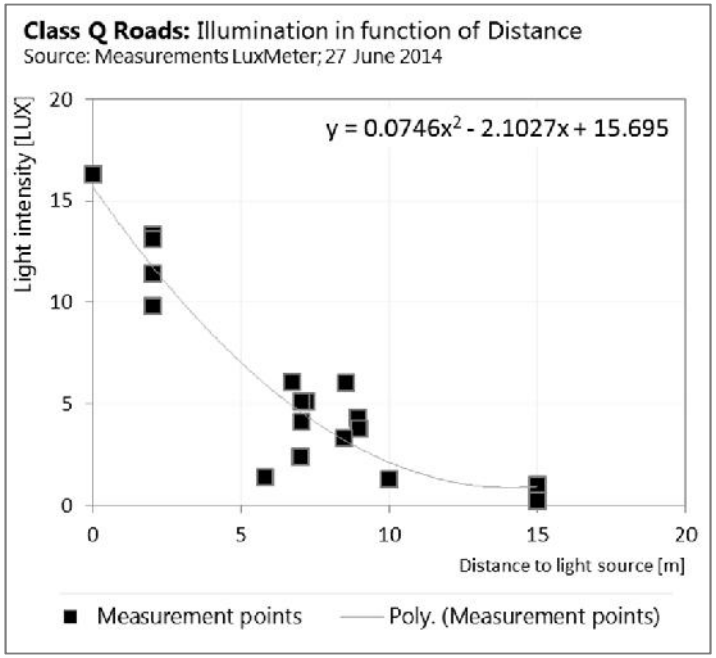
Observation ¦ Measurements ¦ **Modelling** ¦ Visualization ¦ Validation ¦ Improvement

❶ Euclidean Distance



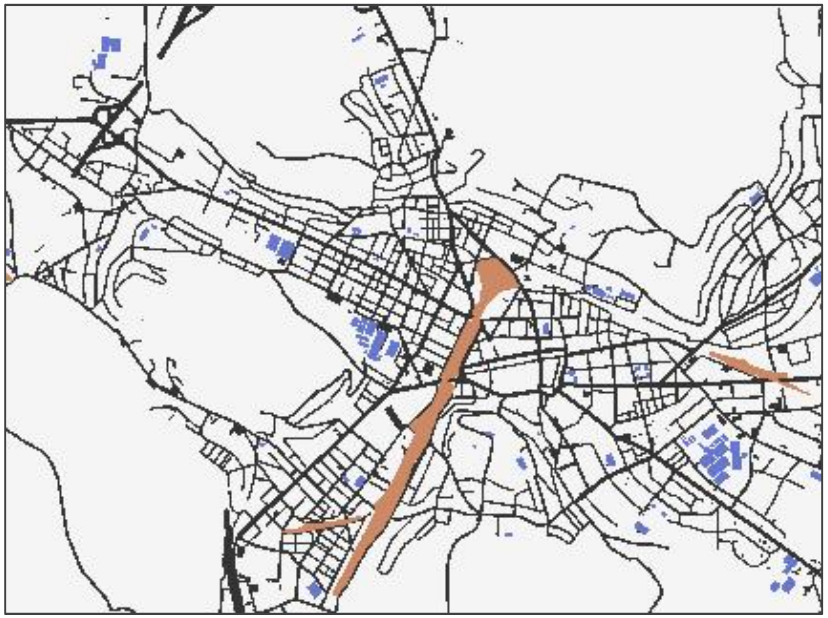


❷ Application of 'lux' and 'spread'



5. Research method

Observation ¦ Measurements ¦ **Modelling** ¦ Visualization ¦ Validation ¦ Improvement

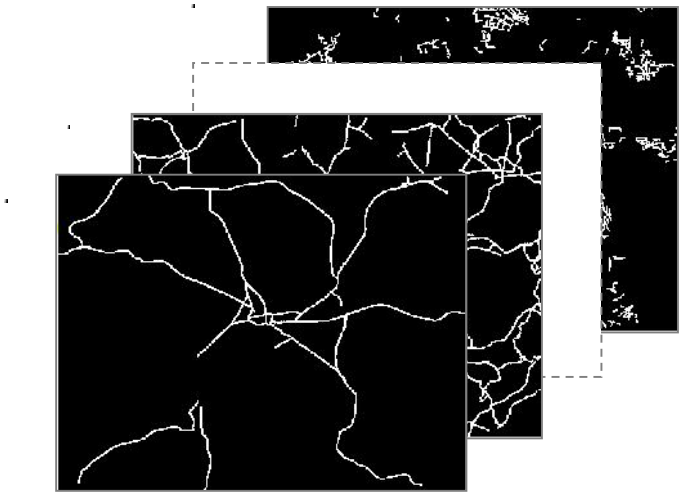


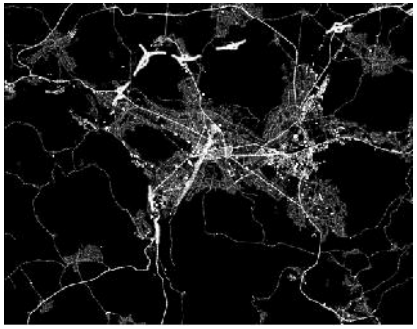
Albedo reflectance

- Asphalt
- Vegetation
- Bare ground

5. Research method

Observation ¦ Measurements ¦ **Modelling** ¦ Visualization ¦ Validation ¦ Improvement





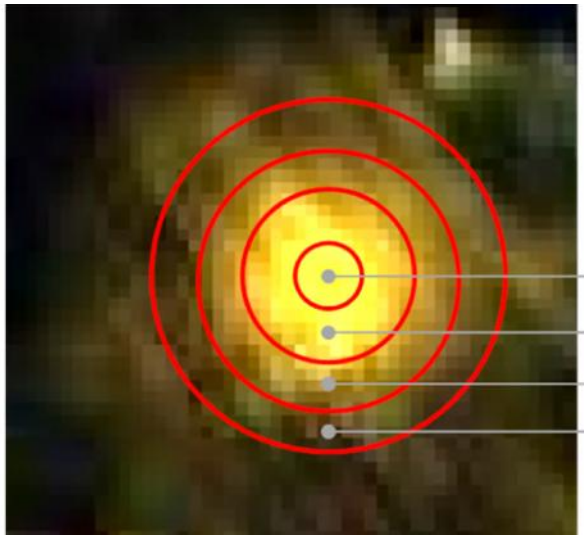
Category	Light points
1. Class A Road	418
2. Class 1 Road	2’097
3. Class 2 Road	6’051
4. Class Q Road	6’518
5. Residential Buildings	67’710
6. Industrial Buildings	2’714
7. Train station area	583
8. Sports pitch	738
9. Parking	601
10. Old Town	1’179
Total	**88’609**

5. Research method

Observation ¦ Measurements ¦ Modelling ¦ **Visualization** ¦ Validation ¦ Improvement

RGB Aerial photo of Geneva

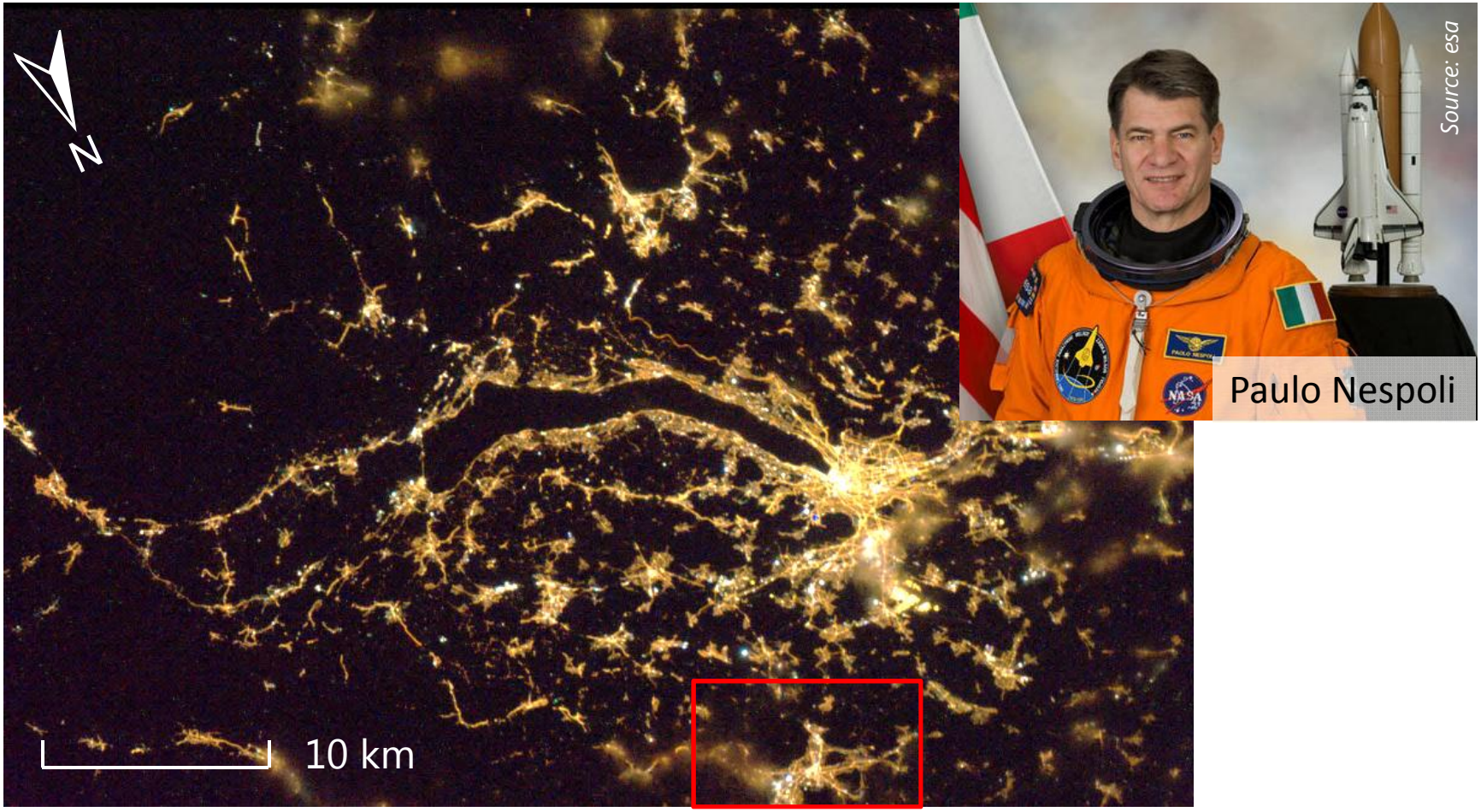
Source : Ville de Genève



R:248 G:246 B:59
R:198 G:151 B:35
R:137 G:106 B:30
R: 67 G: 48 B:15

5. Research method

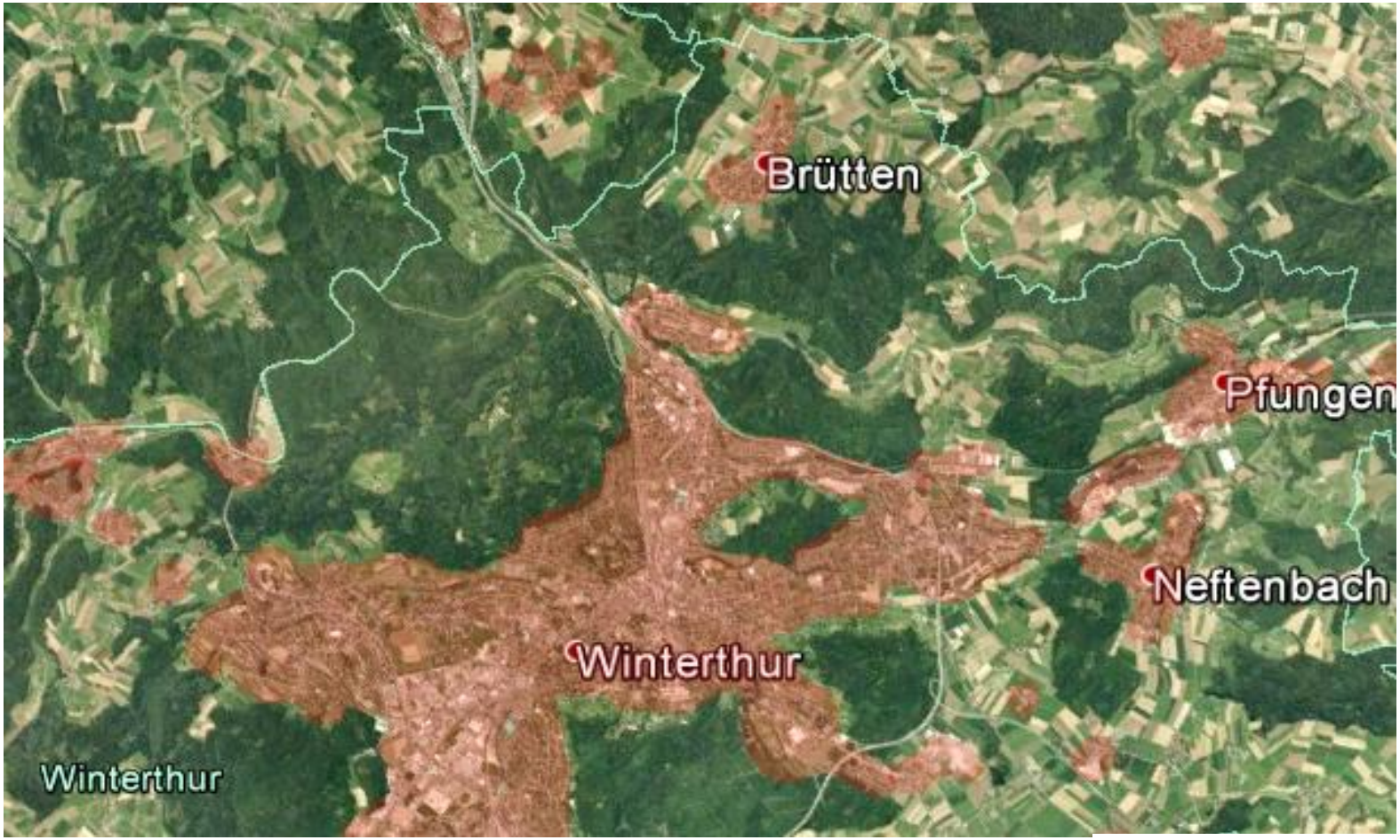
Observation ¦ Measurements ¦ Modelling ¦ Visualization ¦ **Validation** ¦ Improvement



Source: esa
Current ISS position: http://iss.astroviewer.net/index.php

5. Research method

Observation ¦ Measurements ¦ Modelling ¦ Visualization ¦ **Validation** ¦ Improvement



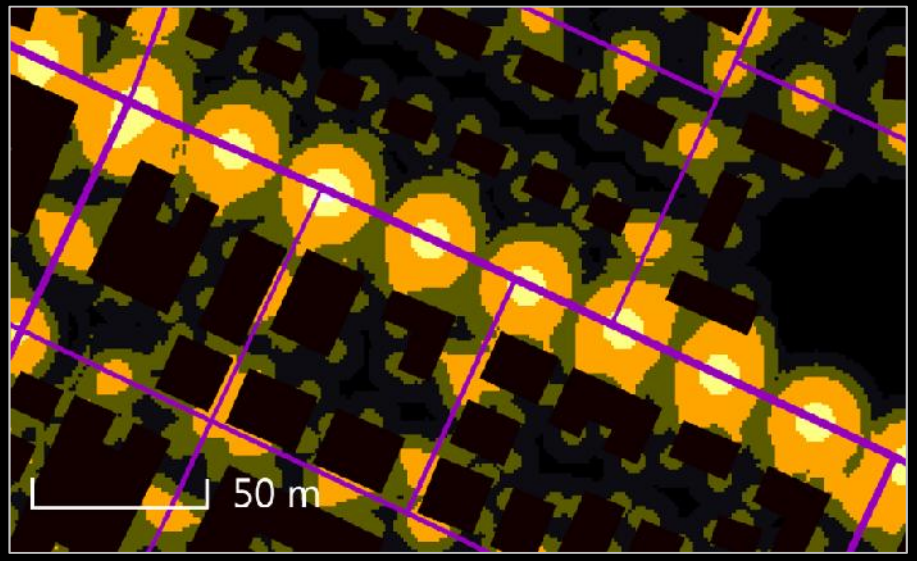
Source: Google Earth

6. Results & Analysis

Source: Light Pollution Model

Source: Light Pollution Model

Modelled:
City of Winterthur



Source: Light Pollution Model

Orthophoto:
City of Winterthur

Source: swissphoto

Modelled:
City of Winterthur

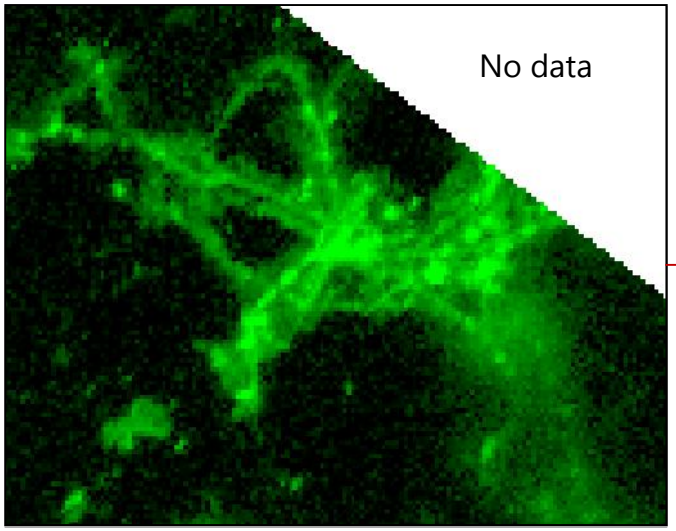
Source: Light Pollution Model

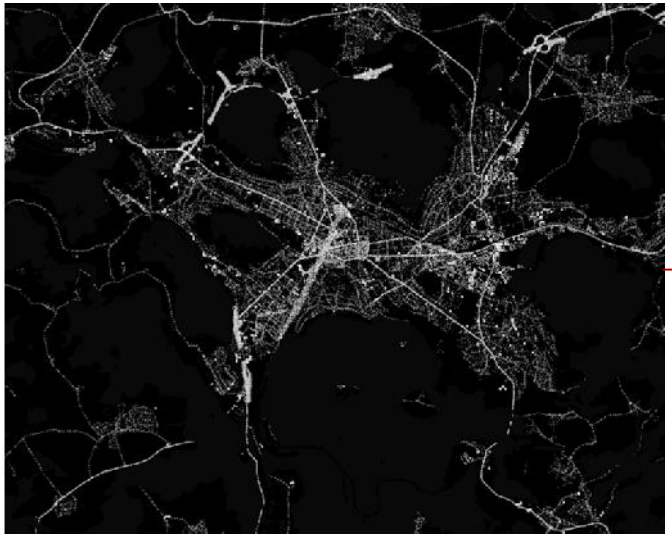
Orthophoto:
City center Geneva

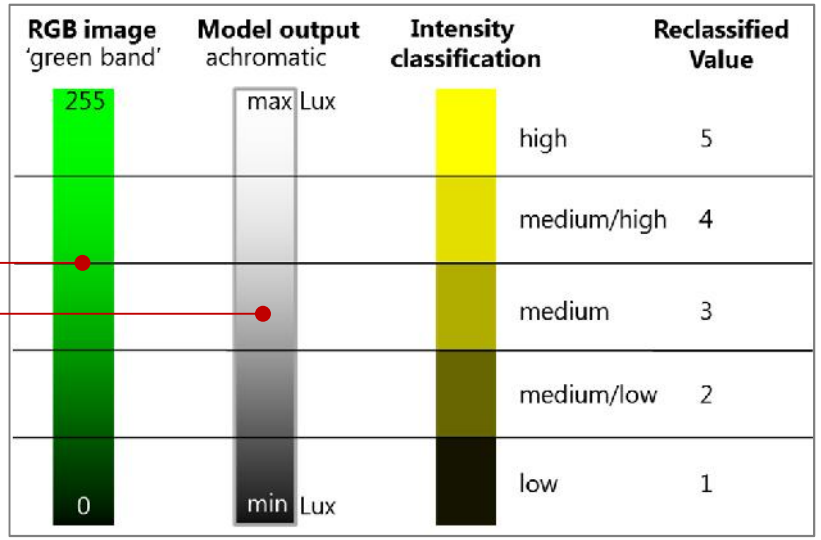
Source: Ville de Genève

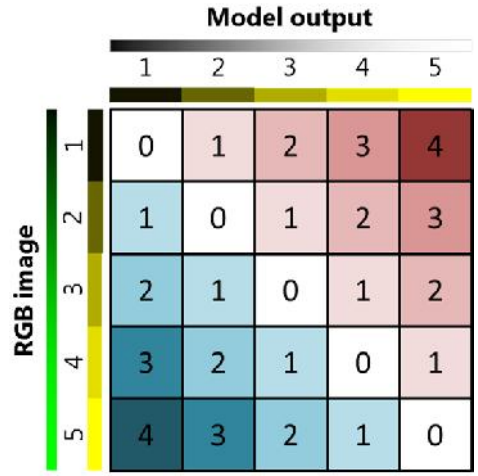
6. Results & Analysis

Comparison ISS ¦ Hotspots



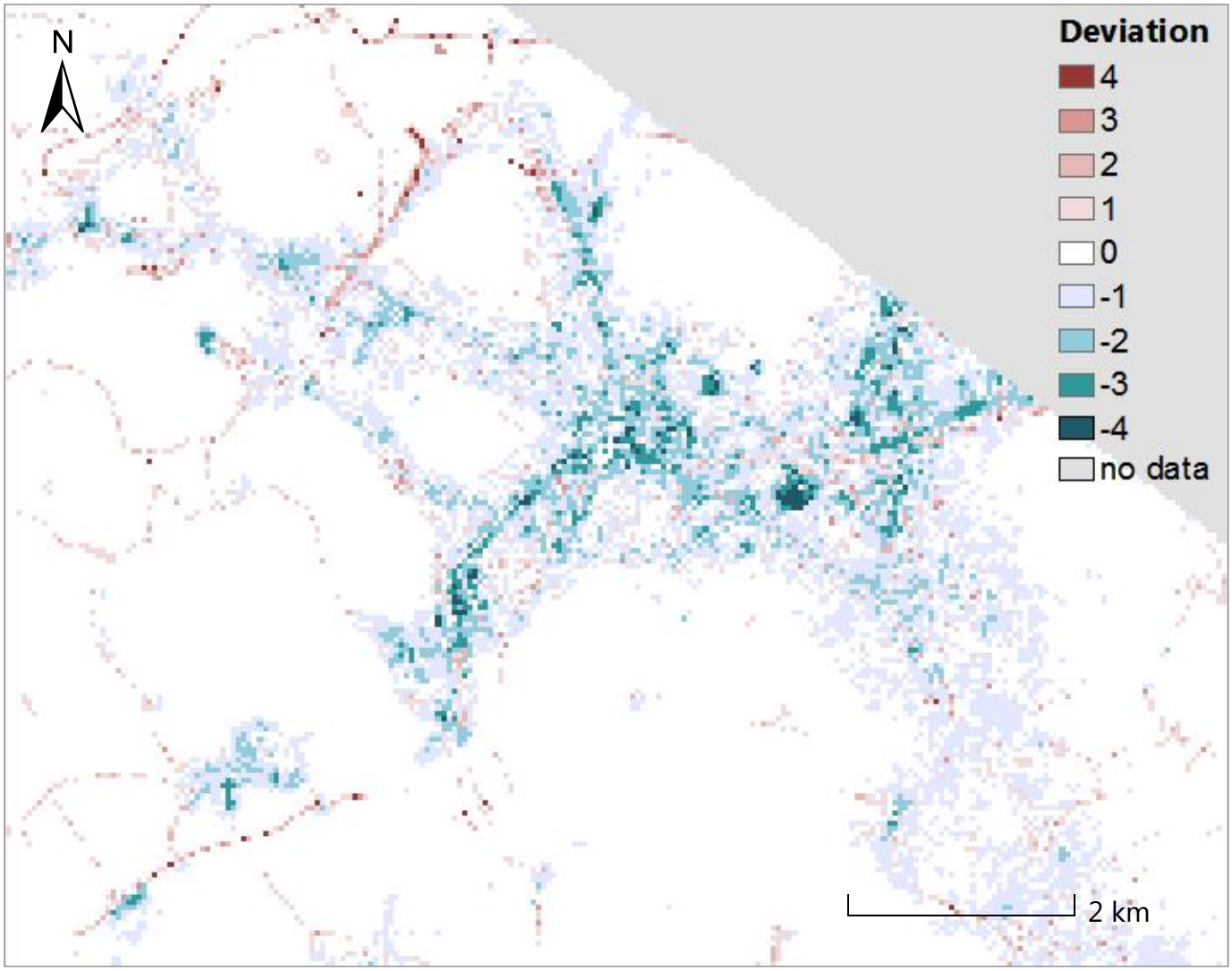






6. Results & Analysis

Comparison ISS ¦ Hotspots



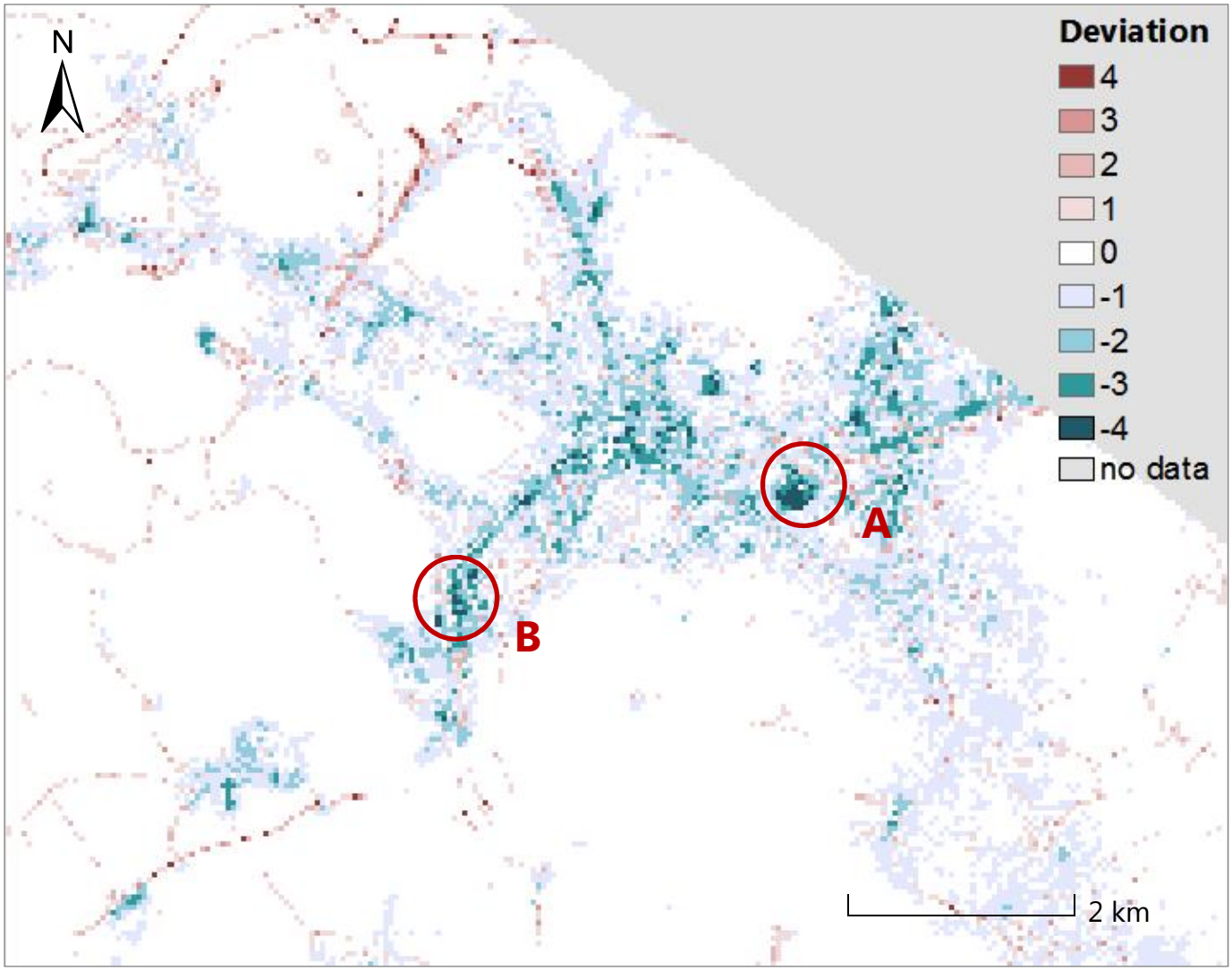
Results & Analysis

Comparison ISS ¦ Hotspots

Deviation Class	Description	Pixel count	Pixel [%] of Total
-4	Very high (ISS image is brighter)	80	0.2
-3	high	391	1.1
-2	moderate	1'417	4.0
-1	small	4'996	14.0
0	**none**	**27'012**	**75.7**
1	small	1'240	3.5
2	moderate	388	1.1
3	high	145	0.4
4	Very high (model output is brighter)	4	0.0
Total	**-**	**35'710**	**100.0**

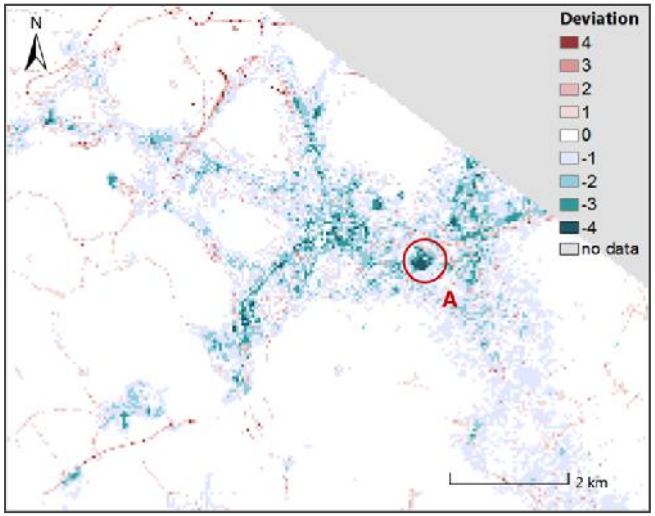
6. Results & Analysis

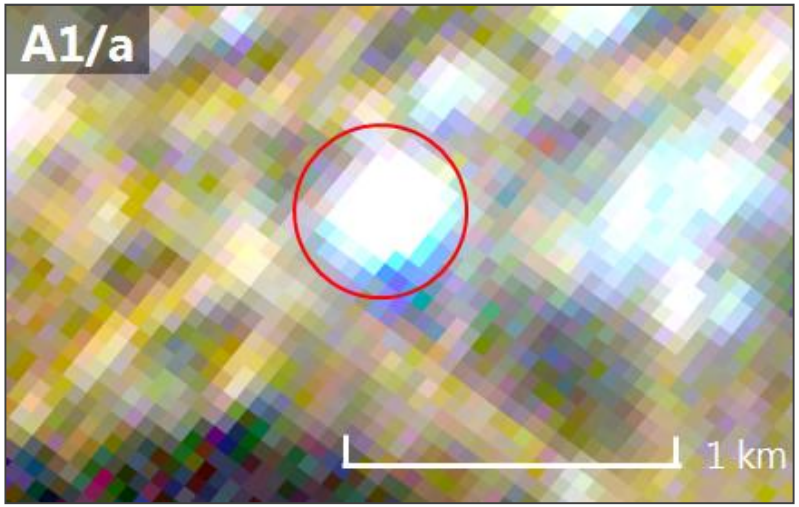
Comparison ISS ¦ Hotspots

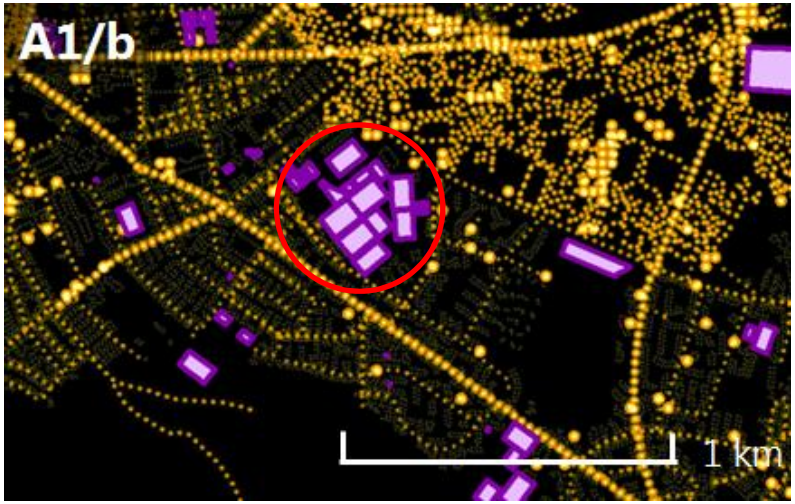


6. Results & Analysis

Comparison ISS ¦ **Hotspots**

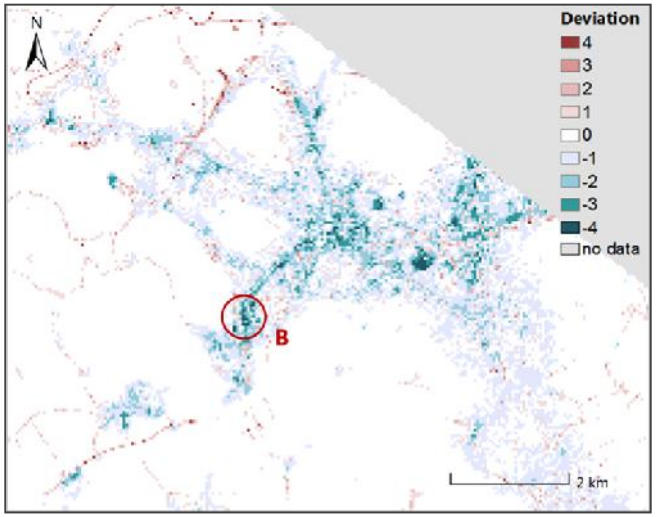


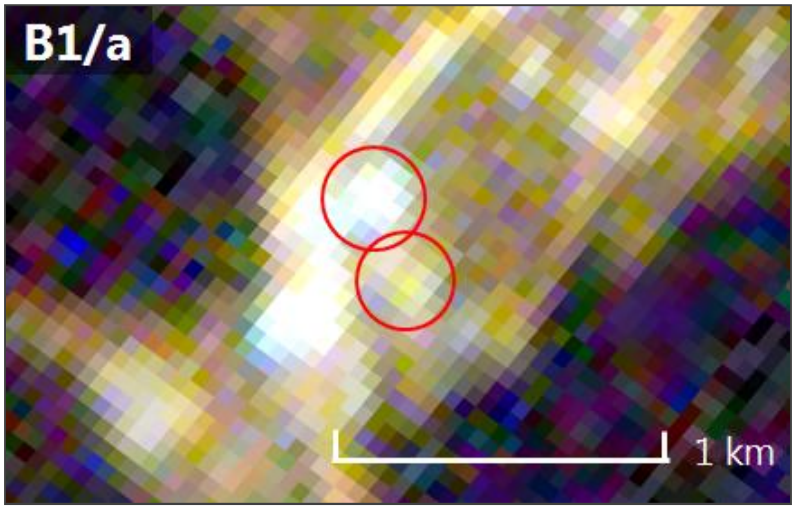


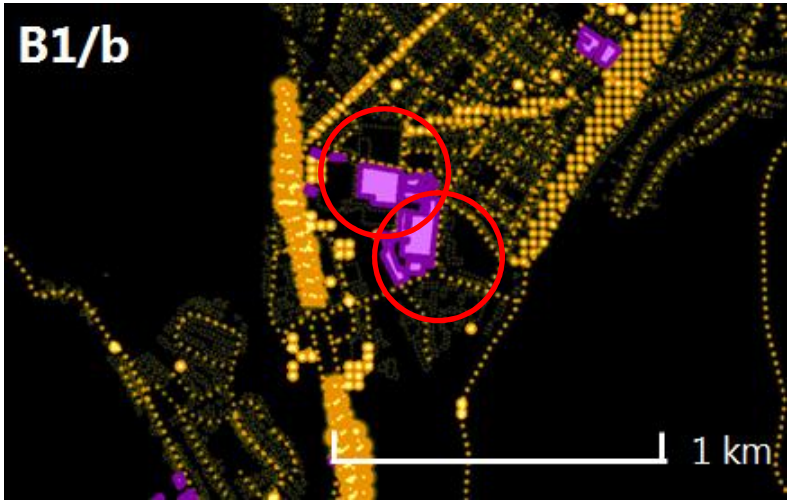


6. Results & Analysis

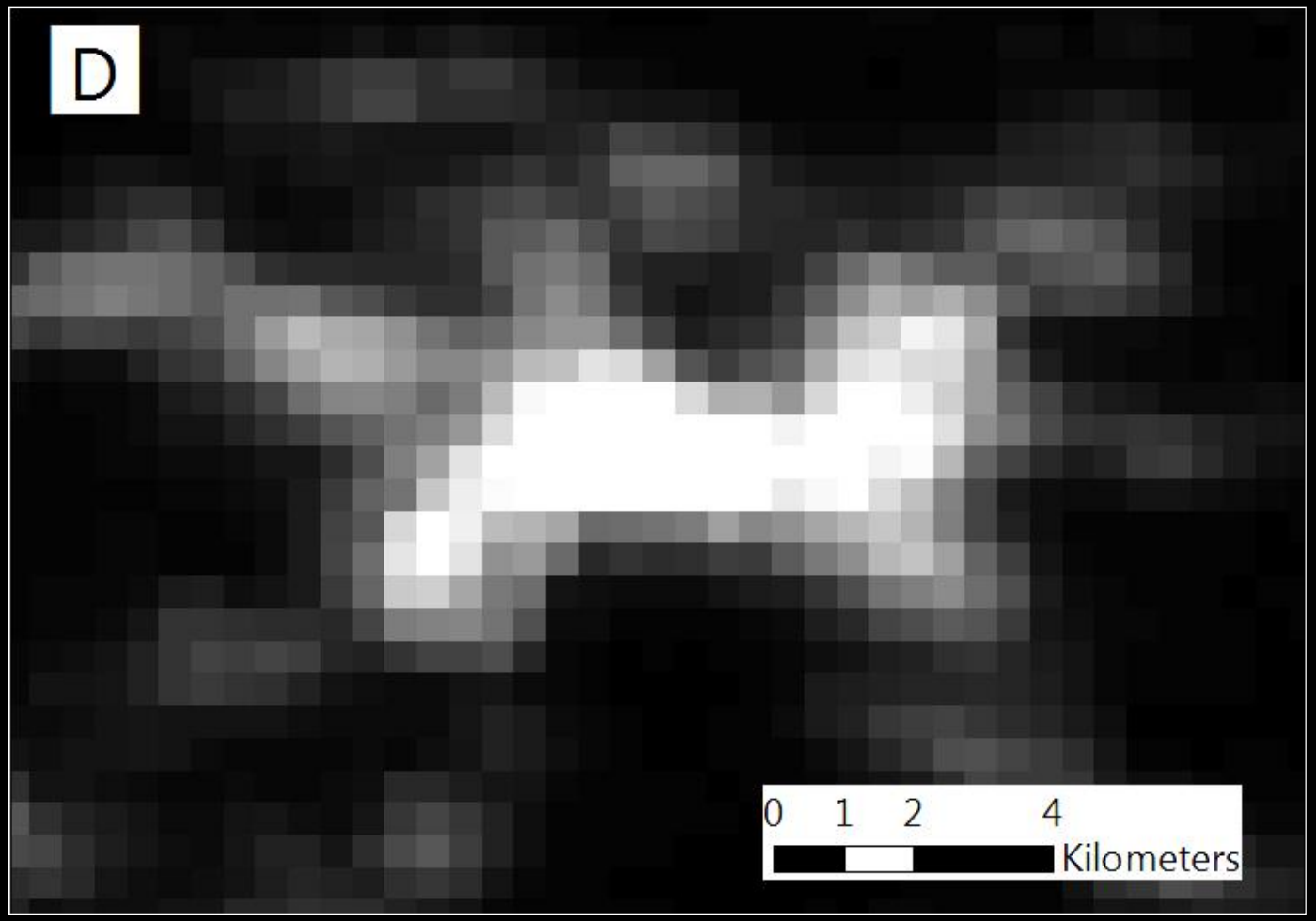
Comparison ISS ¦ **Hotspots**





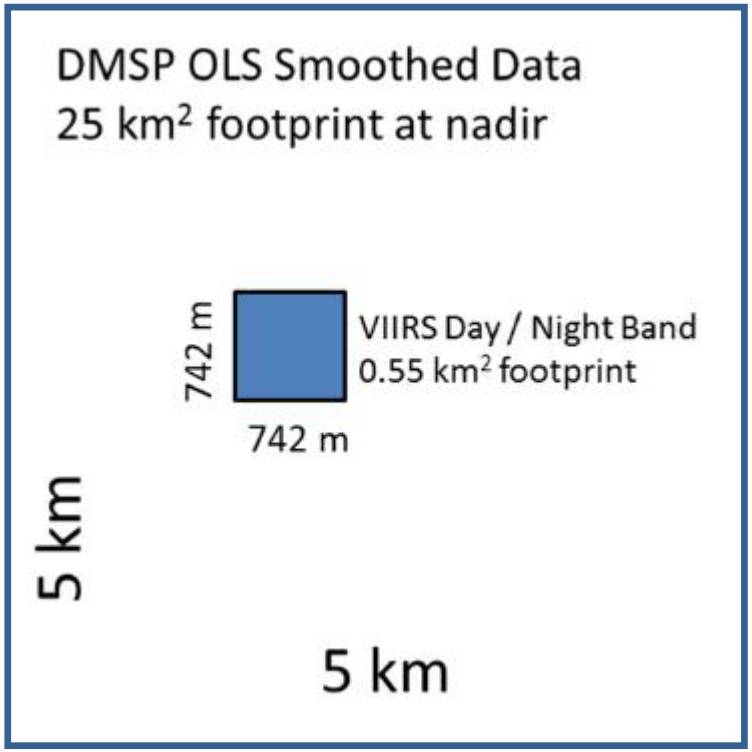


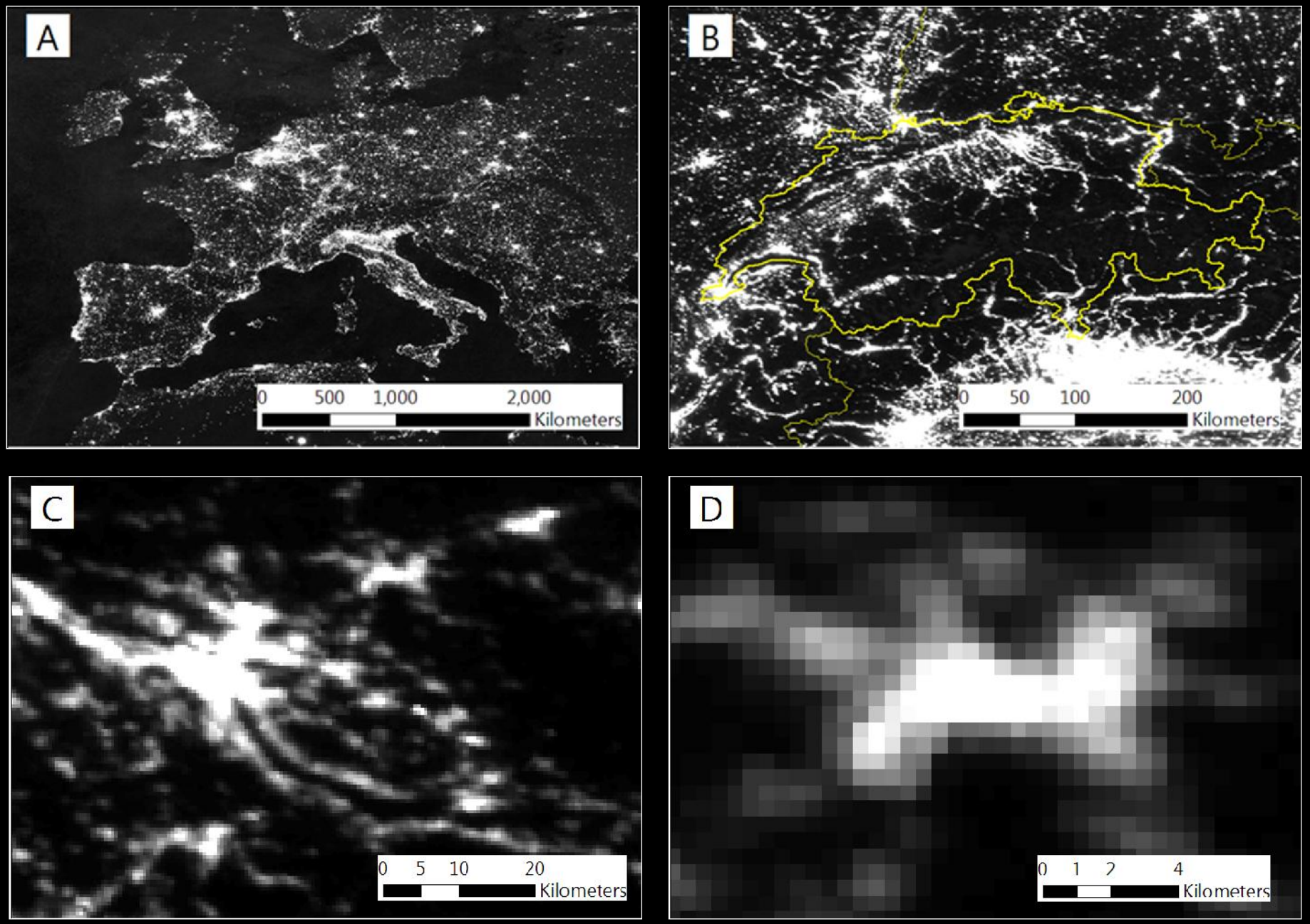
7. Conclusions



7. Conclusions

- Current satellite imagery does not provide a sufficient detail to map light pollution at a local scale.





Source: VIIRS / NASA

7. Conclusions

- Satellite imagery is currently not sufficient for the visualization of light pollution at a local scale.
- A modelled approach proves to be promising.
- Knowledge about the local situation is crucial.
- Dealing with temporal exceptions is an issue.
- Integration of other tools (e.g. Calculux) could be beneficial.

8. Applications

Awareness

Application	Detail
Make the light pollution issue known	Media coverage
Inform the citizens	Layer in Geo-portals

Special interest groups

Application	Detail
Astronomers	Night sky brightness map
Conservationists / Biologists	Input for analysis (example Geneva)

Optimizing light emissions

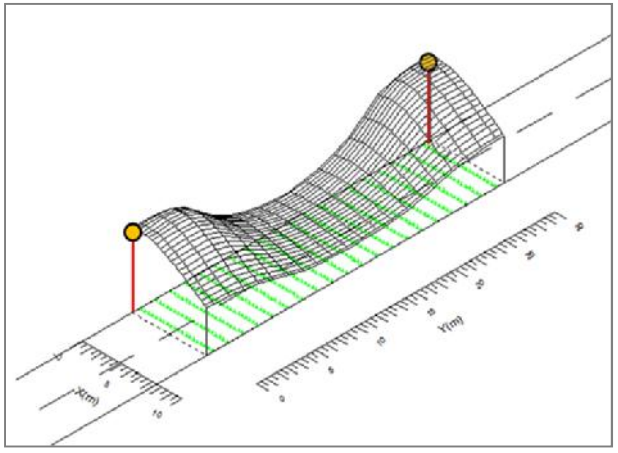
Application	Detail
Lighting scenarios	Visualize different lighting policies (e.g. LED)
Calculation of energy consumption	Optimize energy use

9. Further research

- Acquire further knowledge on characteristics and spatial distribution of light sources.

Photo:
Jim Richardson

- Include a more sophisticated pattern of ‘light spread’ using specfic light planning tools (e.g. Calculux)



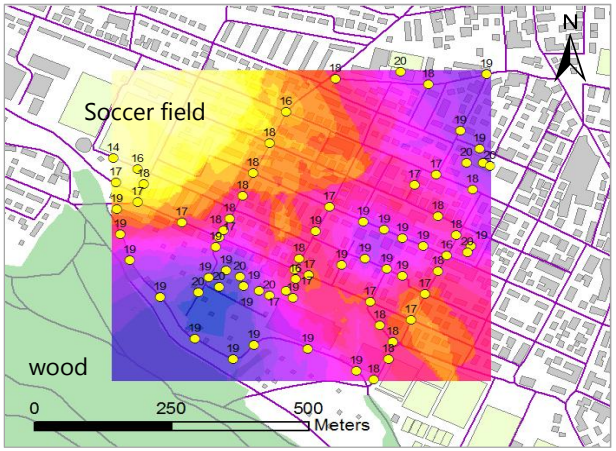
PHILIPS
Calculux V 7.7.01

9. Further research (2)

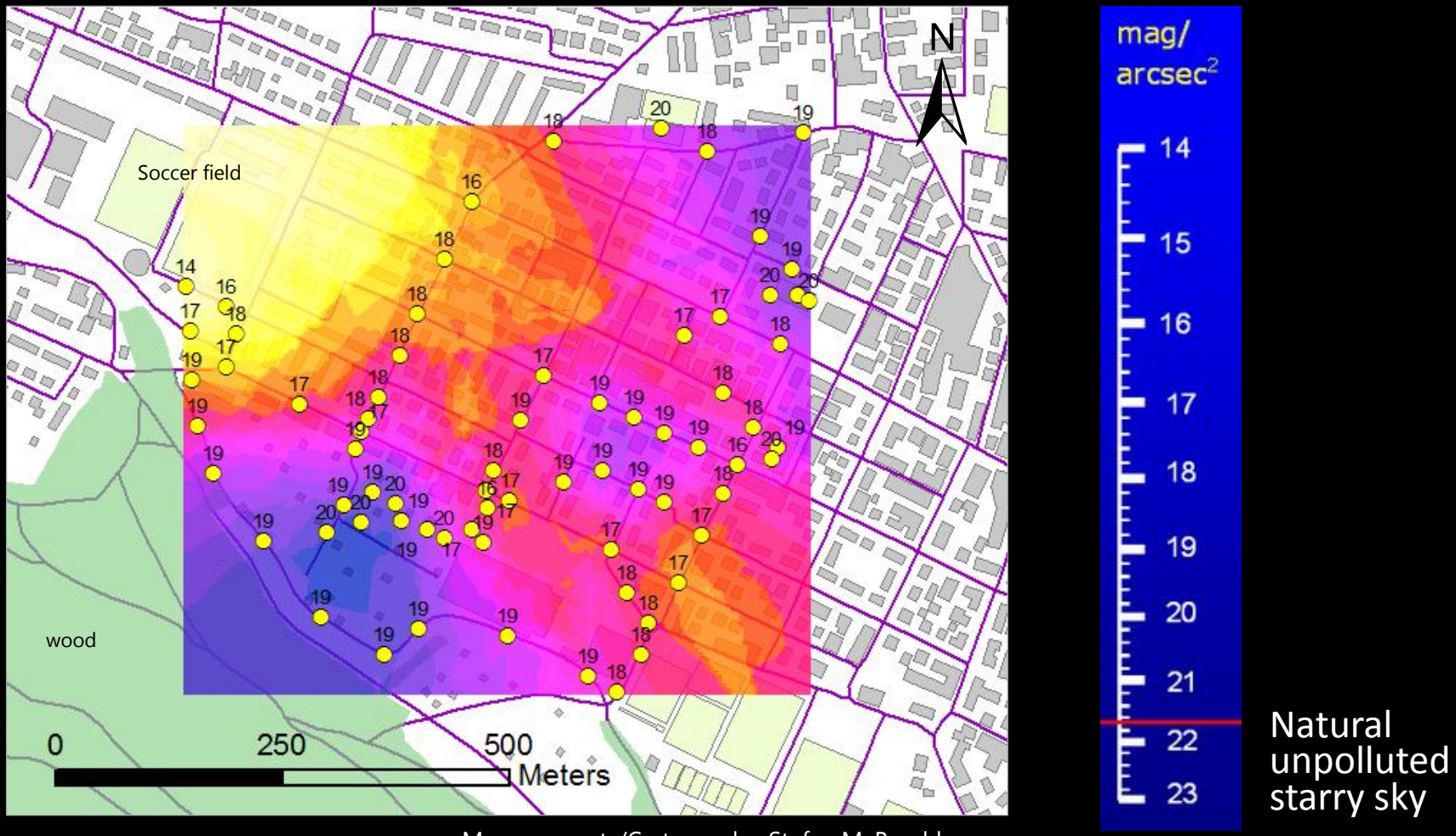
- Enhance model by comparing it to a ‘high quality’ image from the ISS (or orthophoto)

Source: NASA

- Translate the modelled results into a ‘Night Sky Brightness’ map



Night Sky Brightness Map (measured with Sky Quality Meter)



Measurements/Cartography: Stefan M. Bruehlmann