1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Identification and variability of anthropogenic light emission sources in Poland using remote sensing methods

1.1. Project goals

Artificial light pollution of the night sky has become a common phenomenon accompanying man and a significant problem of contemporary urbanized areas of all sizes.

The aim of the project is to determine the sources and time variability of light emission of anthropogenic origin over the territory of Poland. This will be done based on the processing of available satellite imagery (DMSP98, SUOMI-NPP99 or Luojia 1-01 CubeSat) and images from the International Space Station (ISS), and the result of the processing and analysis will be developed in the form of a static atlas and a variability model forecast.

Analysis of satellite measurements of radiance will allow to determine how much light is emitted from a given area to the environment. Higher emissions translate to higher levels of light pollution. This level also depends on the state of the atmosphere at the time of recording and therefore all elements affecting the observed phenomenon should be taken into account.

1.2. Outline

The phenomenon of light pollution of the sky is global today. Statistically, over 99% of the European population and 80% of the world's population live in areas polluted by artificial light. This phenomenon systematically spreads spatially along with the advancing development of civilization and the emergence of new housing estates, as well as the ill-considered expansion of road, utility and advertising lighting infrastructure.

Light pollution is caused by excessive point and surface emission of incorrectly designed or mounted lighting that has been improperly directed. These causes cause many negative consequences for the health and life of plants, animals and humans. Light pollution additionally increases during the occurrence of unfavorable weather conditions, such as fog or cloud cover, and the increased presence of anthropogenic dust in the troposphere.

There are several different methods for measuring the phenomenon of light pollution, both very complex and simple, available to amateurs. The most common are measurements with a specialized photometer. Another frequently used method is to take images of the night sky with all-sky lenses and post-process them. An alternative to terrestrial research is the increasingly popular remote sensing methods that allow to observe excessive light emission with the use of satellite imagery and aerial photographs. This makes it possible to simultaneously explore a larger area of interest and periodically repeat these acquisitions.

When using the satellite method, the amount of artificial light emission in the geographical environment is then determined by measuring radiance (light energy of radiation emitted from a given area). An important advantage of satellite radiance measurements is the free access to the obtained data provided by observation satellites, e.g. DMSP98, SUOMI-NPP99 or Luojia 1-01 CubeSat (6U)100. The next generation of satellites will be characterized by increasingly higher spatial and temporal resolution, which will allow for an increase in the scale of observation and identification of light sources.

1.3. Work plan

The project will be realize within four years. The following main stages can be distinguished:

- literature study on artificial light pollution of the night sky,
- analysis of available spatial data sets on light pollution
- selection and acquisition of remote sensing data for Poland,
- remote sensing data processing to determine the quantitative amount of artificial light emission in the natural environment,
- time analyzes (seasonal and long-term) for Poland,
- preparation of a report and an atlas presenting the variability in time and space of artificial light emission over Poland.

1.4. Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

Cinzano, P., Falchi, F., Elvidge, C.D., & Baugh, K.E. (2000). The artificial night sky brightness mapped from DMSP satellite Operational Linescan System measurements. *Monthly Notices of the Royal Astronomical Society (318)*, 641–657.

Elvidge, C.D., Baugh, K.E., Zhizhin, M., & Hsu, F.-C. (2013). Why VIIRS data are superior to DMSP for mapping nighttime lights. *Proceedings of the Asia-Pacific Advanced Network (35)*, p. 62.

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C.C.M., Elvidge, C.D., Baugh, K., Portnov, B.A., & Rybnikova, N.A., Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science advances, 2(6)*, e1600377.

Hänel A., Posch, T., Ribas, S.J., Aubé, M., Duriscoe, D., Jechow, A., Kollath, Z., Lolkema, D.E., Moore, C., Schmidt, N., Spoelstra, H., Wuchterl, G., & Kyba, C.C.M. (2017). Measuring night sky brightness: Methods and challenges. *Journal of Quantitative Spectroscopy and Radiative Transfer 205*, 278–290. DOI 10.1016/j.jqsrt.2017.09.008.

Karpińska, D., & Kunz, M. (2023). Vertical variability of night sky brightness in urbanised areas. *Quaestiones Geographicae 42(1)*: 5–14.

Levin, N., Kyba, C.C.M., Zhang, Q., Sánchez de Miguel, A., Román, M.O., Li, X., Portnov, B.A., Molthan, A.L., Jechow, A., Miller, S.D., Wang, Z., Shrestha, R.M., & Elvidge, C.D. (2020). Remote sensing of night lights: A review and an outlook for the future. *Remote Sensing of Environment, Volume 237*, 111443, https://doi.org/10.1016/j.rse.2019.111443.

Linares, H., Masana, E., Ribas, S.J., Aubé, M., Simoneau, A., & Bará, S. (2020). Night sky brightness simulation over Montsec protected area. *Journal of Quantitative Spectroscopy and Radiative Transfer 249*. DOI 10.1016/j.jqsrt.2020.106990.

Mander, S., Alam, F., Lovreglio, R., & Ooi, M. (2023). How to measure light pollution – A systematic review of methods and applications, *Sustainable Cities and Society, Volume 92,* 104465, https://doi.org/10.1016/j.scs.2023.104465.

Ribas, S., Torra, J., Figueras, F., Paricio, S., & Canal-Domingo, R. (2016). How clouds are amplifying (or not) the effects of ALAN. *International Journal of Sustainable Lighting 18*. DOI 10.26607/ijsl.v18i0.19.

Zhang, C., Pei, Y., Li, J., Qin, Q., & Yue, J. (2019). Application of Luojia 1-01 Nighttime Images for Detecting the Light Changes for the 2019 Spring Festival in Western Cities, *Remote Sensing (12)*, p. 1416.

1.5. Required initial knowledge and skills of the PhD candidate

- practical skills in remote sensing data processing,

- practical knowledge of using GIS software (ArcView, QGIS and others),
- programming skills,
- interests related to the subject of the project,
- analytical thinking ability,
- independence and creativity in solving scientific problems,
- research passion and enthusiasm,
- distance to reality,
- teamwork skills are not required.

1.6. Expected development of the PhD candidate's knowledge and skills

The candidate for doctoral studies should develop in the effective use of image data processing tools and remote sensing data sets to analyze changes in the extent of light pollution. It is assumed that the doctoral student will develop knowledge in the field of satellite data processing, performing multi-time spatial analyzes and comparative analyses. The PhD student should also develop his skills in the practical use of GIS in environmental research. The envisaged development should prepare for conducting independent scientific research at the intersection of geography, environmental protection and astronomy and physics of atmosphere.