1. Executive Summary

Full title of the Community Activity: Night-time light remote sensing for sustainable development goals

Short title or acronym: GEO Night Light

Proposed or existing category: Community Activity

Overview

The United Nations 2030 Agenda for Sustainable Development Goals (SDGs) provides the world a bright path for a more sustainable future. The SDGs aim to solve a number of key issues, such as extreme poverty, income inequality, and disaster risk reduction etc. Evaluating the implementation progress of the SDGs is critically important since the international community can focus on the unsolved issues far behind the 2030 Agenda. Night-time light (NTL) remote sensing images have been widely applied in socioeconomic researches, and have shown great potential for monitoring some indicators of SDGs. Although a number of international organizations have noticed the great value of NTL for SDGs, their shortage of skills and knowledge on NTL has limited use of it.

This project aims to produce high quality NTL products, and derive a variety of NTL-based thematic products including poverty maps, electrification maps, regional inequality maps and regional growth maps as well as disaster evaluation maps for monitoring several targets of SDGs (e.g. targets 1.1, 7.1, 7.b, 8.1, 9.a, 10.2, 11.5 and 16.1). These products will map the implementation progress of SDGs from both spatial and temporal perspectives. In addition, several application cases for monitoring SDGs at regional scales (e.g. disaster-affected and war-torn regions) will also be carried out based on the products. The data products and application reports will be delivered to international users, including inter-governmental organizations, aid groups and investment agencies, to fill the gap between NTL remote sensing community and the users who are likely to use the NTL product for SDGs.

Planned activities

We will produce high quality night-time light products for human settlement, and derive a set of thematic products (e.g. poverty maps, regional inequality maps and regional growth maps) for several SDG targets based on the NTL products. Based on the products, a number of application case analyses such as humanitarian situation in disaster-affected regions will be carried out. Additionally, the lighting technology upgrade will also be evaluated by NTL remote sensing approaches. All the products and research reports will be freely shared and delivered to stakeholders and users including NGOs and intergovernmental organizations under GEO framework and policy.

Points of Contact

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2. Purpose

Rationale for the Community Activity

Night-time light remote sensing, observing visible lights at night, provides a unique perspective on the human activities and socioeconomic dynamics. It has shown powerful capabilities in analyzing a number of issues in sustainable development. A number of night-time light (NTL) remote sensing satellites are now available. Since the 1970s, night-time light images acquired by DMSP/OLS have been applied to monitoring oil field combustion, estimating socioeconomic parameters and light pollution. In 2011, the Suomi NPP/VIIRS was launched with significantly improved performances compared with DMSP/OLS, ushering in a new era to the NTL remote sensing community. In addition, China's Wuhan University launched Luojia-1 satellite in June 2018, providing freely available global night-time light images at 130 m resolution. High quality night-time light remote sensing data is critical to retrieve detailed information on the geographical distribution of human population and their properties for sustainable development.

Although night-time light remote sensing has been applied to different issues of SDG, there is a significant gap between the scientists in NTL remote sensing and users who are seeking high quality NTL remote sensing data for SDGs. Therefore, a systematic project of night-time light remote sensing for global collaboration and applications is urgently needed.

Planned outputs of the Community Activity and their geographical scope.

- Develop a high resolution night-time light products at global scale
- Develop NTL-derived thematic products for sustainable development, the standard products are at a global scale and special products for hotspot are at a regional scale.
- Monitor light technology upgrade in selected cities
- Carry out SDG application cases using the products at regional scales

Intended users of the outputs

Users/stakeholders include the United Nations organizations, aid groups (e.g. Care International) and investment agencies (e.g. Asian Development Bank)

3. Background and Previous Achievements

The project leaders and co-leaders have solid research experience and international collaboration on NTL data processing and application with typical cases as followings:

- **Night-time light remote sensing for global peace**. On March 2015, collaborating with a global coalition of 130 NGOs, Prof. Xi Li and Prof. Deren Li have released their work of night-time light remote sensing of Syrian Civil War (e.g. 83% of the city light in Syria has disappeared due to the war), to global media during a telebriefing which was also attended by Madeleine Albright, the former U.S. Secretary of the State. The satellite analysis results have been cited by about 600 global media and organizations including CNN, BBC, Al Jazeera, Reuters, New York Times, Los Angeles Times, The Guardians, La Figaro and Save the Children, as well as the 7418th meeting of the United Nations Security Council (started at 5:45 of the U.N. video from the link). The release of the result has played an important role for the 4th anniversary of the Syrian Civil War.

  On April 3, 2018, the United Nations, Sweden Government and Swiss Government held 2018 Yemen High-Level Pledging Event in Geneva. Collaborating with Care International, Switzerland, Prof. Xi Li and Prof. Deren Li, have supported this event by releasing remote sensing analysis result for Yemen Crisis, finding out that 21 provinces in Yemen have lost more than 70% of the lights due to the war, cited by a U.N. media.

- **The Luojia-1 satellite**. In June 2018, the research group led by Prof. Deren Li at Wuhan University, launched Luojia-1 satellite, which is the first space-borne satellite acquiring night-time light images globally at near 100 m resolution. The research group has provided free data service of Luojia-1 images for more than 3000 global users and has supported the U.N. work for Syrian refugees.
- **Collaboration between Wuhan University and the United Nations for SDGs**. Prof. Xi Li led a delegate to visit United Nations for Training and Research (UNITAR) in August, 2018, and introduced the night-time light remote sensing work by Prof. Deren Li's research group. Due to this event, in July 2019, UNITAR and Wuhan University signed a Memorandum of Understanding (MoU) for achieving U.N 2030 Sustainable Development Goals by using geospatial techniques.
- **NTL remote sensing and Asian Development Bank**. From 2017 to 2018, Prof. Xi Li worked as an international consultant for Asian Development Bank under project "TA-8591 REG: Macroeconomic Modeling for Improved Economic Assessment: Nightlights Data and Nowcasting (47146-001)". The project aims to estimate the GDP growth rate by using VIIRS night-time light data, especially for the countries lacking of statistical data. The project has been finished on June 2019, but the collaboration between Asian Development Bank and Prof. Xi Li continues.
- **Generating high resolution night-time light imagery**. The research group at Sun Yat-Sen University led by professor Qingling Zhang is collaborating with the Google Earth Engine team at the Alphabet Incoporation (parent company of Google) to successfully generate cloud-free NDVI mosaics from Landsat and then combined with DMSP/OLS imagery to produce 30 m resolution night-time light products worldwide, and this work has been published in "*Zhang, Q., et al. (2015). Building a Better Urban Picture: Combining Day and Night Remote Sensing Imagery. Remote Sensing, 7, 11887*" and has been applied to measure the Hurricane Maria effect on Puerto Rico in the paper "*Román, M.O., et al. (2019). Satellite-based assessment of electricity restoration efforts in Puerto Rico after Hurricane Maria. PloS one, 14, e0218883*"
- **Night-time observation techniques**. The research group at the Department of Geography, The Hebrew University of Jerusalem, led by Prof. Noam Levin, has substantial experience in the remote sensing of night lights, using both satellite observations, UAV imagery, and ground based sensors such as the SQM and hemispherical images analyzed with the Sky Quality Camera software.

4. Key Activities

- **Develop high quality night-time light products for human settlement**. The existing coarse resolution night-time light remote sensing imagery (e.g. DMSP/OLS and VIIRS images at different temporal resolution) can help monitor human settlements at large scales but cannot provide sufficient spatial details at the neighborhood level. Finer resolution images are very useful in mapping human settlements details but their application to large scales is often limited. We aim to highlight human settlements by fusing 30 m resolution Landsat and the coarse resolution night-time light remote sensing data (e.g. DMSP/OLS and VIIRS). Very high resolution night-time light images, acquired from China's Jilin-1 satellites, will be used as a reference dataset supporting the

data fusion process. Considering that both Landsat and night-time light remote sensing have long historical archives, the new generated NTL dataset at 30 m resolution will also enable tracking human settlements dynamics over time.

- **Develop NTL-derived thematic products for SDGs**. Using the produced high resolution night-time light products, population density products (e.g. Landscan), as well as socioeconomic statistical data, we will produce a series of NTL-derived thematic products including poverty maps, electrification maps, regional inequality maps and regional growth maps for sustainable development. Develop special night-time light products, such as humanitarian disaster NTL maps for conflict and natural disaster regions. Luojia-1 satellite imagery, at original 130 m spatial resolution, will be used as a reference dataset to support producing the above datasets.
- **Carry out SDG application cases using the products**. A number of case analyses will be carried out based on the NTL-derived products. We will evaluate the aid project impacts on the regional development based on the produced high resolution night-time light images as well as the poverty maps and regional inequality maps. We will evaluate humanitarian conditions in several disaster and conflict-affected zones (e.g. Syria, Iraq, Yemen and etc.) and to support humanitarian relief work. We will also evaluate the implementation progress of poverty reduction in different countries and compare it to the statistical data and official reports.
- **Monitor lighting technology upgrade**. The revolution of LED lighting, is leading many municipalities and countries to change their street lighting from HPS/LPS lighting to LED street lights, in order to reduce energy consumptions. Here we aim to evaluate to what degree are such transitions detectable from current spaceborne sensors (e.g. China's Jilin-1 satellites and photos from International Space Station), and whether this transition also reduces skyglow and light pollution.
- **Sharing data**. Freely share the data products in this project in a cloud platform, make the downloading process as easy as possible, and advertise the platform to potential users.
- **Collaborate with regional and global organizations.** Provide the night-time light products to the United Nations, aid groups and investment agencies. Help these organizations to analyze the issues of sustainable development by use of the night-time light products.

5. Relationship to GEO Engagement Priorities and to other Work Programme Activities

The project will help to support SDG targets using the NTL products and analysis as listed:

SDG Targets	Related NTL products and analysis
Target 1.1: By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day	Product: Poverty map
Target 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services	Product: Electrification map
Target 7.b: By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy	Analysis: Monitor lighting technology upgrade

services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support	
Target 8.1: Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Product: Regional growth maps
Target 9.a: Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States	Analysis: Evaluate the aid project impacts on the regional development
Target 10.2: By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	Product: Regional inequality maps
Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	Product: Humanitarian disaster NTL maps Analysis: Evaluate humanitarian conditions in several natural disaster-affected zones
Target: 16.1 Significantly reduce all forms of violence and related death rates everywhere	Product: Humanitarian disaster NTL maps Analysis: Evaluate humanitarian conditions in several conflict-affected zones

6. Governance

The leader of this project is Prof. Deren Li, who is responsible to lead the entire project. The co-leaders, Prof. Qingling Zhang, Prof. Xi Li and Prof. Noam Levin will be responsible for their technical tasks. Prof. Xi Li will be responsible to coordinate all the individual participants and contributing organizations. Prof. Qingling Zhang and Prof. Xi Li will be responsible for contacting all the external users. Dr. Einar Bjorgo will be the advisor.

7. Data Policy

- All the NTL products from this project will be shared and managed fully satisfying the GEOSS Data Sharing Principles and GEOSS Data Management Principles.
- All the data products, metadata as well guideline files will be shared in the cloud storage platform with permanent links, and will be delivered to participant organizations as well as the user network without any charge.
- All the data format will be widely recognized formats (e.g. Geotiff and shapefile)

- All the data products will have at least one copy of backup.

Annexes

Acronyms and abbreviations

Acronyms and abbreviations	Full term
SDG	Sustainable Development Goal
NTL	Night-time light
Suomi NPP	Suomi National Polar-orbiting Partnership
VIIRS	Visible Infrared Imaging Radiometer Suite
DMSP	Defense Meteorological Satellite Program
OLS	Operational Linescan System

Brief CV of Project Leaders

About Deren Li

Prof. Deren Li is a scientist in photogrammetry and remote sensing from Wuhan University, China. He enjoys dual memberships of both Chinese Academy of Sciences and Chinese Academy of Engineering. He is also the member of International Eurasia Academy of Sciences and International Academy of Astronautics. He received doctor degree from University of Stuttgart in 1985 and honorary doctorate from ETH Zürich in 2008. In 2012, International Society for Photogrammetry and Remote Sensing (ISPRS) awarded him Honorary Member, the number of which ISPRS limits to a maximum of ten at any time as the highest honor.

About Qingling Zhang

Qingling Zhang is currently a professor at the School of Aeronautics and Astronautics, Sun Yat-sen University. He served as a research scientist at Yale University. Dr. Zhang is conducting or has completed a number of research projects funded by NASA and the Chinese government as PI or co-PI. He is an expert in nighttime light remote sensing and its application, with more than 10 years research experience. He has published more than 15 academic monographs and SCI articles (total impact factor 42.779), with a total of more than 400 citations. He proposed a multi-source remote sensing image assimilation and fusion algorithm, and established the VANUI urban index and NDUI urban index, which successfully reduce overglowing effects in nighttime light imagery. The NASA nighttime light researh group has applied the NDUI method to produce high-resolution black marble products for monitoring natural disaster relief processes.

About Xi Li

Xi Li is an associate professor at Wuhan University, and he also serves as an editorial member of *International Journal of Remote Sensing*. As a first author or correponding author, he has published 15 peer-reviewed international journal papers on night-time light remote sensing. One of his papers ,"Can night-time light images play a role in evaluating the Syrian

Crisis? " had made siginicant impact on global peace petition of Syrian Civil War in March 2015. Since then, he has built strong collaboration with global NGOs, media and inter-governmental organizatoins including United Nations. He also served as an international consultant for Asian Development Bank.

About Noam Levin

Noam Levin is a professor and Head of the Remote Sensing Lab in Hebrew University of Jerusalem. So far Dr. Levin has published more than 90 peer-reviewed papers, and has published more than 10 papers on remote sensing of night lights, working on case studies ranging from local to global, and using both satellite imagery and field measurements. Six of these papers were published in the leading journal of *Remote Sensing of Environment*. Dr. Levin plans to continue this line of research, using light intensity to examine the impact of military conflicts on society, as well to explore the impacts of light pollution on natural ecosystems and biodiversity, and to examine the implications of the LED lighting revolution on light pollution.