Research Assessment Exercise 2020
Impact Case Study

University: The Chinese University of Hong Kong
Unit of Assessment (UoA): 26 geography
Title of case study: *Urban and environmental monitoring and modeling with advanced spatiotemporal analytics*

(1) Summary of the impact

The innovative models of spatiotemporal analytics (**STA**) developed by the UoA have improved the quality of urban and environmental monitoring. **STA**'s professional data products and analytical models for business agencies (e.g., PIESAT and D-e Tech) had benefitted many stakeholders in cities/regions worldwide, assisting governmental and intergovernmental organizations (e.g., Hong Kong and Nansha's planning departments and UNESCAP) in urban management and planning. In addition, the crowd-sourced air-quality App TouchAir developed from the research had facilitated ubiquitous monitoring of air pollution for the public. This research will continue to contribute to sustainable urban management worldwide.

(2) Underpinning research

Situated within the larger field of urban and environmental sustainability, HUANG Bo and FUNG Tung's research used geospatial technologies to monitor and model urban and environmental phenomena such as land use, urban heat islands and air pollution, particularly their changes over space and time. Their research integrates geographic information science with statistics and artificial intelligence into a unified framework of **spatiotemporal analytics (STA)**, which provides a solid scientific foundation for a wide spectrum of urban and environmental applications.

The value of **STA** lies in providing an integrated framework for change detection, analysis, and prediction. At the core of their **STA** framework is a combination of **Unified Satellite Image Fusion (USIF)** and **Geographically and Temporally Weighted Regression (GTWR)**. To elaborate, USIF applies spatiotemporal contextual fusion to generate time-series images with a high "Spatial-Temporal-Spectral-Angular" resolution to capture complex structures and changes in dynamic circumstances. USIF sensibly blends remote sensing images from multiple satellite sensors into data-rich "piped image cubes" **[R1]**. These image cubes can facilitate the monitoring of urban and environmental changes, such as urban heat islands **[R3]** and urban sprawl **[R4; R5]**, in a more detailed and continuous manner. As a distinctive scientific contribution, USIF, grounded in compressed sensing theory and spatial un-mixing, enables the achievement of two conflicting but desirable properties of satellite imagery: (a) greater spatial detail and (b) greater "timeliness". GTWR is another focal **STA** technique that produces reliable and accurate results from local spatial and temporal volatility in the prediction of a dynamic distribution, e.g., air pollution concentrations **[R6]**. It is a refined statistical tool for both spatial and temporal non-stationarity modeling **[R2]**.

STA capitalize on the abundance of geospatial data in the digital age to enable remote sensing from a few meters to hundreds of kilometers above the Earth, as well as in situ observations at and below the surface and in the atmosphere. Specifically, the use of multiple sensors to obtain geo-observations has led to exponential increase of geospatial data at multiple spatial and temporal resolutions available for urban and environmental change monitoring, obsoleting traditional data fusion and knowledge extraction approaches. By breaking new grounds in (a) spatiotemporal data fusion and (b) spatiotemporal data modeling and prediction, STA allows researchers **to answer questions about how spatial change evolves over time**, and **how such change varies geographically** - thereby **advancing understanding of urban and environmental problems**.

These breakthroughs in advanced quantitative analysis and their applications in using geographic data for urban and environmental change monitoring were documented in recent publications **[R5; R6]**. The **STA** framework is globally recognized in academia and widely adopted in geo-scientific analysis, including remote sensing and in situ observations. Simultaneously, HUANG and FUNG had communicated their findings to various business audiences via prestigious geospatial forums such as the World Geospatial Developers Conference **[C1]** and OFweek 2018 **[C2]**. These efforts have led to the adoption of the USIF and GTWR models by large businesses, such as GEOWAY Ltd. **[C3]** and Huawei Technology Co., Ltd. **[C4]**. The STA framework is also used in the management processes of some government agencies **[C6; C7]**.

(3) References to the research

[R1] Spatiotemporal Reflectance Fusion via Sparse Representation
B Huang, H Song
IEEE Transactions on Geoscience and Remote Sensing 50(10), 3707-3716, 2012

[R2] Geographically and temporally weighted regression for modeling spatio-temporal variation in house prices (ESI highly cited paper)
B Huang, B Wu, M Barry
International Journal of Geographical Information Science 24(3), 383-401, 2010

[R3] Generating high spatiotemporal resolution land surface temperature for urban heat island monitoring
B Huang, J Wang, H Song, D Fu, KK Wong
IEEE Geoscience and Remote Sensing Letters 10(5), 1011-1015, 2013

[R4] Projection of Land Use Change Patterns using Kernel Logistic Regression
B Wu, B Huang, T Fung
Photogrammetric Engineering & Remote Sensing, 75(8), 971-979, 2009

[R5] A robust adaptive spatial and temporal image fusion model for complex land surface changes
Y Zhao, B Huang, H Song
Remote sensing of environment, 208, 42-62, 2018

[R6] Satellite-based mapping of daily high-resolution ground PM2.5 in China via space-time regression modeling (ESI highly cited paper)
Q He, B Huang
Remote Sensing of Environment, 206, 72-83, 2018

(4) Details of the impact

Aside from being a pioneering theoretical and data analytic framework, **STA has been used to develop products and practical tools that had many impactful applications**. As such, its non-academic impact has been both deep and far-reaching. Between 2013 and 2019, many organizations and individuals had benefited from the products developed from **STA** research. In this section, we use a few examples to illustrate the research and significance of **STA** for business agencies, governmental and inter-governmental institutions, and the public.

1. Business agencies

Geospatial data used optimally can offer innovative geomantic solutions. For example, precise, accurate and high-resolution digital terrain or surface maps can be produced to help navigation. **GEOWAY Ltd.**, a leading provider of geomantic solutions in China, used USIF to construct data-enriched imagery to maximize the use of historical and newly received remote sensing imagery from multiple satellite platforms. GEOWAY had incorporated USIF into its flagship product ImageStation, a software specially designed to turn large volume of raw spatial data into actionable or exploitable formats for government, commercial photogrammetry and mapping agencies. According to GEOWAY Ltd., the use of USIF algorithm in ImageStation was instrumental to achieving "*a substantial increase in ImageStation's satellite image fusion accuracy for spectral reflectance*" **[C3]**.

By 2018, the number of ImageStation active users had grown to 1,000; they used the USIF toolkit regularly. These subscribers of the software and the end consumers of the various ImageStation-supported products and services had directly benefited from ImageStation's enhanced performance. In addition, GEOWAY's financial gain from the USIF-enabled ImageStation software was more than RMB 1 million annually **[C3]**.

Changes in land use and waste heat generated by energy usage in an urban or metropolitan area can lead to significantly higher temperature in the urban region than its surrounding suburban areas, creating a heat island. Heat islands may in turn contribute to global warming. The need to monitor weekly heat waves is useful for government to formulate land use, energy and other pertinent policies. **D-e Tech Corporation (Japan)** is a company that produced weekly heat wave monitoring reports at a fine scale for the local government. This company was able to provide this service because it had incorporated **STA** techniques into its urban heat island monitoring business. According to the Company's CEO, "*Using the technology provided by Prof. HUANG, we can monitor our city at both a dense temporal resolution (each week) and a high spatial resolution (15 m)*". This level of precision was not attainable using other remote sensing technologies. The Company anticipated that the government would continue to seek D-e Tech's services, supported by the USIF technology, for monitoring urban heat islands **[C5]**. The Company is planning to provide its services to other cities in Japan.

2. <u>Governmental and inter-governmental institutions</u>

Real Estate Assessment Center (REAC), Shenzhen. **STA** had also been used by the Shenzhen Government in the assessment of real estate prices. REAC used GTWR in its regular property price assessment efforts to track and estimate the prices of Shenzhen apartments. The Company had assessed 1.67 million apartments in 2016 using GTWR. The use of GTWR in property price assessment had increased the precision of the assessment, and hence allowed assessment prices to fall into a narrower and more reliable range **[C7]**. HUANG's research had enhanced REAC's ability to track spatially and temporally sensitive house prices by identifying hot spots. The Government could then consider this information when formulating guidelines on the management of an overheated market. The Urban Benchmark House Price Tracking System is now in full operation in REAC. In 2016, this project won a national prize called "The Chinese Construction Science and Technology Award".

The Planning Department of Nansha New District, Guangzhou. In 2015, to create a comprehensive land use plan of Nansha that prioritized ecological conservation and resilience to typhoon-induced flooding, the Urban Plan-Making Center in the District Planning Department adopted **STA** techniques to generate high-quality time-series geoscientific assimilation data and develop a scientific method of evaluating resilience planning. By taking heed of local resilience to typhoon disasters in urban land use planning, this **STA**-informed suggestions of the resilience plan had reduced the damage cost of typhoons by RMB 500 million since 2017 **[C8]**.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). UNESCAP's Space Applications Section (SAS) has been working with HUANG since 2013. USIF and GTWR were used to formulate space (satellite imagery fusion) and geospatial (spatial pattern analysis) solutions to promote the Sustainable Development Goals initiative in ESCAP's member states, particularly undeveloped countries and small islands **[C9]**. Representative outcomes of this long-term cooperation include the Drought Observation System in Mongolia, the Multi-hazard Early Warning System in Tonga and the Solomon Islands, and the Urban Resilience Assessment System in DKI Jakarta, Indonesia.

3. <u>General public</u>

Air pollution is a major economic and health hazard in China. The annual economic costs of air pollution in China was estimated to be RMB 267 billion (US$38 billion) in the form of early deaths and lost food production, according to a CUHK study published in *Environmental Research Letters* in 2018. To protect their health, Chinese citizens need readily available information to know how to reduce their exposure to pollutants in their daily activities. HUANG's research on GTWR inspired the creation of a smartphone App, **TouchAir**, which enabled real-time air pollution monitoring in any location in China and Southeast Asia. This App did not require the construction of many monitoring stations in a region. In recognition of its significant and far-reaching social impact, the App won the Smart People Award at the Hong Kong ICT Awards 2018. According to the IOS App Store and Google Play, this innovative App (first released on Nov. 7, 2016) is now regularly used by more than 10,000 people in their daily life **[C10]**. According to Keran Wang, Chief of SAS, UNESCAP: "*The functions of TouchAir have helped me reduce my exposure to air pollution in my daily life and while traveling. I use it every day to check air pollution levels to avoid significantly polluted routes when driving to my workplace.*" **[C9]**

In summary, **STA** and the products and services it supported had profoundly influenced urban management practices in different regions around the world and delivered both economic, health and environmental benefits to a large and growing user community.

(5) Sources to corroborate the impact

Reviews by popular business media:

[C1] The 3sNews review - "Improve the Application Value of Remote Sensing Technology" http://www.3snews.net/wxdsj/335000046186.html [Also *Appended*]

[C2] The OFweek review - "Spatiotemporal Data Fusion from the Perspective of Smart City" https://ai.ofweek.com/news/2018-11/ART-201713-9050-30282186.html [Also *Appended*]

Business agencies:

[C3] Corroborating letter from GEOWAY Ltd. c*onfirms the use and impact of the USIF research.* [*Appended*]

[C4] R&D contract with Huawei Co., Ltd. *confirms the use and impact of the GTWR research.* [*Appended*]

[C5] Corroborating letter from D-e Tech Co. *confirms the use and impact of the STA research.* [*Appended*]

Governmental and intergovernmental institutions:

[C6] Corroborating letter from the Planning Department of Hong Kong *provides details of the land use change detection system developed by Fung Tung and Huang Bo.* [*Appended*]

[C7] Corroborating letter from Shenzhen Real Estate Assessment Center *provides details of the use of the Urban Benchmark House Price Tracking System in Shenzhen.* [*Appended*]

[C8] Corroborating letter from the Planning Department of Nansha New District, Guangzhou *provides details of its use and applications of the USIF and GTWR technologies.* [*Appended*]

[C9] Corroborating letter from Keran Wang (Section Chief, SAS, UNESCAP) *provides details of collaboration projects between UNESCAP and Huang Bo.* [*Appended*]

General public:

[C10] Supporting documents for TouchAir *provides details of TouchAir's application.* [*Appended*]