

## EO BASED URBAN SERVICES FOR SMART CITIES AND SUSTAINABLE URBANIZATION

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### List of Principal Investigators (PIs)

Topic Nr.	PIs	Title
32248_1	Prof. Paolo Gamba, Prof. Peijun Du	<b>Mapping and Monitoring Urban Agglomeration and Urban Capacity in China for Smart and Sustainable Cities</b>
32248_2	Prof. Andrea Monti-Guarnieri, Dr. Mi Jiang	<b>Land Cover Mapping Over Textural Urban Area in East China by Combining Multi-Source Datasets and Accurate InSAR Parameters Estimation Methods</b>
32248_3	Prof. Constantinos Cartalis, Prof. Huili Gong	<b>Assessment of the impact of urbanization to urban climate in support of the development of smart tools for sustainable urbanism</b>

### EXECUTIVE SUMMARY

More than half of the world population now lives in cities, and 2.5 billion more people are expected to move into cities by 2050. 90% of the increase will concentrate in Asia and Africa, with China, India and Nigeria expected to account for 37% of the projected growth of the world's urban population. Although only a small percentage of global land cover, urban areas significantly alter climate, biogeochemistry, and hydrology at local, regional, and global scales. Thus, timely and accurate information on urban land cover and their changing patterns as well as sound assessment of environmental/climate impact are needed to support smart cities and sustainable urbanization. With the recent launches of Sentinel-1A/-2A and planned launch of Sentinel-3A, high resolution SAR and optical data with global coverage and operational reliability become routinely available. Together with Chinese EO data, ESA TPM data and historical EO data, they provide excellent opportunity to develop EO-based urban services to support smart and sustainable planning. The overall objective of this research is to develop EO-based urban information services to support smart cities and sustainable urbanization. The specific objectives are: 1) to develop urban information better characterization of urban agglomeration patterns and assessment of urban capacity, i.e., how much the environment is able to sustain new settlements without reaching a no-return point. 2) to exemplify the smart city approach through the use of Earth Observation, in conjunction with GIS and urban models, in order to address two fundamental pillars of urban climate and environment: (a) urban thermal environment, with emphasis to surface energy balance and the urban heat island, the presence and spatial distribution of thermal hot spots and energy efficiency at the district level (b) urban hydrology, with emphasis to urban flooding and subsidence. The methodologies to be developed are all aimed at the fusion of data from different satellite sensors and from ancillary data. For mapping and monitoring urban agglomeration and urban capacity, novel methods will be developed for i). extraction of impervious surfaces, urban extent and urban land cover using multispectral, hyperspectral and SAR data. ii). extraction of patterns of human settlements and their changes with respect to their spatial structure in association with socioeconomic data and night-time imagery. Iii). urban capacity characterization by using land use/cover classification maps and biophysical parameters derived from EO data, spatio-temporal models, ground observations and statistical data. For urban thermal environment, downscale techniques and data fusion methods will be developed and used for the best exploitation of earth observation data, whereas in urban hydrology, models will be developed for urban rain floods and geohazards. In both, smart tools will be developed in support of the theme Urbanization and smart cities. The project is expected to contribute to i). development of novel and robust methods for improved EO-based urban services to support smart and sustainable urban development; ii). the goals and activities of GEO SB-04 Global Urban Observation and Information Task and the UN post-2015 sustainable development goals. The project will be partially funded by the projects that the team partners have been secured, including the EO4Urban project funded by ESA involving KTH and UNIPV, the Swedish National Space Board grant to KTH for Sentinel-based urban services (2016-2019), the EU funded project MASS and the state funded project on adaptation planning for urban climate (Univ. of Athens), funding from the SEB project (U. Twente), Natural Science Foundation of China and provincial funding (Chinese partners).

**ABSTRACT 32248\_1: “Mapping and Monitoring Urban Agglomeration and Urban Capacity in China for Smart and Sustainable Cities”**

***European Principal Investigator***

Prof. Paolo Gamba  
 (University of Pavia, Italy)

***Chinese Principal Investigator***

Prof. Peijun Du  
 (Nanjing University, CHINA)

The project objectives are related to the need of a better characterization of spatio-temporal patterns of urbanization and the interaction between human settlement and the surrounding natural environments. Because of this need, it is of primary importance to obtain an accurate map of the urban-rural fringe, and especially how this boundary changes in time. At the same time, the concept of urban capacity has arisen as a way to obtain how much the environment is able to sustain new settlements without reaching a no-return point. Finally, within urban areas, urban villages and areas where low income people tend to cluster are also very important focal points to understand the socio-economical dynamics of urban areas, especially in mainland China, where the urban internal structure are often too old and existing cities are subject to sudden changes, and new built-up areas are quickly realized instead of less appealing village structures.

The methodologies to be developed are all aimed at the fusion of data coming from different satellite sensors and possibly from ancillary data collected on the ground or from other sources, such as GIS from municipalities and local government, census data and economic information about the regions and provinces that are considered as test areas for the project. Specifically, it must be noted that we focus on three urban agglomeration regions and two cities because of their rapid urbanization trend and the availability of the ground truth data set, either from past analysis or from current connections by the members of the team. Since one of the important output of this project are maps, and we often find that maps of urban areas in wide geographical regions are not enough validated, we will put a significant part of the project effort in collecting the validation data sets and in designing a procedure for validation of multitemporal urban data to be used in different areas and provinces and eventually applied to other areas of interest in the whole mainland China.

The methods used in the project, more detailed in the relevant section, are:

- a) extraction of impervious surfaces at the subpixel levels using non-linear unmixing techniques for multi/hyperspectral data sets;
- b) built-up area extent extraction from SAR data at multi-resolution by using textural features at multiple scales to ensure that the previously mentioned extractions are relevant to human settlements;
- c) urban capacity characterization by using land use/cover classification maps and biophysical parameters derived from Chinese and ESA remote sensing images, GIS supported urban capacity analysis models and coupling of remote sensing derived information, spatio-temporal models, ground observations and statistical data.
- d) multi-temporal high-resolution data automatic land cover classification by means of semantic indexes;
- e) land use characterization according to the feature histograms (including area, aspect ratio, orientation, etc.);
- f) extraction of patterns of human settlements and their changes with respect to their spatial structure using spatially explicit partitioning and clustering techniques and generalized additive models in association with socioeconomic data and night-time multitemporal brightness imagery.

The project will be partially funded by the projects that the team partners have been secured. Specifically, the EO4Urban project funded by ESA and involving KTH and UNIPV will be instrumental to fund the researches from the European side. KTH recently received a substantial grant (2016-2019) from the Swedish National Space Board for evaluation of Sentinel-1A/-2A data for supporting sustainable urban planning that includes study areas in China. Additionally, UNIPV and KTH will make available own funds from past and current projects, which will be recognized in the forthcoming publications. The Chinese partners will apply for the funding from Natural Science Foundation of China and related provinces to support this project.

**ABSTRACT 32248\_2: "LAND COVER MAPPING OVER TEXTURAL URBAN AREA IN EAST CHINA BY COMBINING MULTI-SOURCE DATASETS AND ACCURATE INSAR PARAMETERS ESTIMATION METHODS"**

**European Principal Investigator**

Prof. Andrea Monti-Guarnieri  
 (Politecnico di Milano, ITALY)

**Chinese Principal Investigator**

Dr. Mi Jiang  
 (Hoai University, CHINA)

**Abstract:**

The global view of urban areas makes satellite missions a valid instrument for updating urban maps and carrying out the analysis of settlement dynamics. Optical remote sensing is a well-established tool for land cover mapping, but it suffers from atmospheric limitations, especially when unpredictable abnormally long periods of cloud cover affect usually clear-sky regions. The use of synthetic aperture radar (SAR) might become suitable when a systematic and timely survey is required. Unlike optical systems which provide spectral information of the Earth's surface, SAR systems generate structural and electromagnetic information (e.g., slope, shape, and surface roughness). Therefore, integrating both optical and SAR data provides opportunities for a more comprehensive understanding of land cover mapping. However, as yet relatively few studies have developed analyses that have fused both data types over urban areas. One of the main difficulty is that the shapes of the structures in SAR image cannot be represented in detail and mixed pixels are likely to occur when conventional SAR parameter estimation method has been used. For example, de-speckling procedure reduces the speckle effect and simultaneously attenuates the resolution of the image, especially over rich texture areas. Moreover, the InSAR coherence cannot be estimated accurately and the features cannot be discriminated due to the observations are highly biased over the fast decorrelation areas. In this context, one objective of this study is to determine the effectiveness of advanced InSAR parameter estimation for land cover mapping in textural areas.

Based on optimized InSAR layers (Intensity, coherence), the study on the combination of high resolution optical image, mutli-temporal and multi-wavelength SAR dataset (X- and L- band) for land cover mapping have been further explored over the urban area in East China. Different classifications are first carried out using Random Forest and SVM classifiers at the SAR datasets estimated by different parameter estimation methods. The results show that accurate InSAR parameter estimation is able to generate higher classification accuracies when mapping land cover including linear features, infrastructures, and point targets. Moreover, the combination of mutli-source data and advanced InSAR parameter estimation method can provided the best information to map complex textures. The methods and analyses suggested in this paper extend previous research into remote monitoring of urban environment and illustrate the opportunities for mapping areas with rich textures afforded through combinations of multi-source high resolution data and accurate InSAR parameter estimation.

**2. Objective:**

This project will focus on the applications of Multi-source and Multi-temporal datasets for land surface classification and change detection in East China (mainly including Shandong province and Jiangsu province ) based on advanced InSAR and Optical image processing techniques. More specifically, the project will study: (1) MT-InSAR covariance matrix estimation over urban areas with rich textures; (2) Land cover mapping by combining optical remote sensing and Multi-source SAR datasets; (3) A long-term scheme aimed at observing the urban changes with Multi-temporal SAR data at year scales;

**3. Availability of funding:**

1. "The Study of Multitemporal InSAR Coherence Estimation" is supported by National Natural Science Foundation of China (NSFC, No. 41404009) to investigate the approach of applying MT-InSAR technique for coherence estimation and its applications to Earth observations.

(Amount of the project: CNY ¥250,000; principle investigator: Mi JIANG; Date: 2015.1– 2017.12)

2. "Multi-Temporal InSAR Techniques for Bridge Health Monitoring" is supported by National Natural Science Foundation of Jiangsu Province for Youth (NSFJ, No. BK20140625) to investigate the reliability of bridge using advanced MT-InSAR technique.

(Amount of the project: CNY ¥200,000; principle investigator: Xin TIAN; Date: 2014.7.1-2017.6.30)

**ABSTRACT 32248\_3: “Assessment of the impact of urbanization to urban climate in support of the development of smart tools for sustainable urbanism”**

**European Principal Investigator**

Prof. Constantinos Cartalis  
 (Univ. of Athens, Greece)

**Chinese Principal Investigator**

Prof. Huili Gong  
 (CNU, CHINA)

Approximately 50% of world’s population live in urban areas, a number which is expected to increase to nearly 60% by 2030. High levels of urbanisation are even more evident in Europe where today over 70% of Europeans live in urban areas, with projections that this will increase to nearly 80% by 2030. Urbanization in the People's Republic of China increased in speed during the last two decades; by the end of 2014, 54.7% of the total population lived in urban areas, a rate that rose from 26% in 1990.

(Source: UN Habitat report, Cities and Climate Change: Global Report on Human Settlements. United Nations Human Settlement Programme, 2014).

Urbanization and its associated socio-economic and environmental impacts is one of the key drivers of change that challenges the sustainability and resilience of urban environments globally, placing significant pressure to citizens and reducing urban security (Cartalis C., Towards Resilient Cities – A review of definitions, challenges and prospects, Advances in Building Research, 2015). In particular urbanization influences negatively urban climate and environment, with most prominent challenges being the increased urban density and the associated higher heat emissions from anthropogenic sources, the presence and intensity of urban heat island, the modification of energy fluxes between the surface and the lower atmosphere, the changes in the wind patterns within the urban web and the increase in urban floods as related to extreme weather events. A strong necessity thus arises, namely the public authorities to respond to urbanization by mitigating and adapting to these challenges. Recently, smart cities have been gaining a lot of attention from academia, scientific and ICT, government, practitioners and planning experts. Due to vibrant set of smart applications and tools, these cities can support the recognition and continuous monitoring of pressures to the urban climate and environment due to urbanization, thus contributing to sustainable urban planning, development and governance.

Smart cities applications rely heavily on new ICT methodologies, processes, tools, technologies (e.g. sensors, cloud computing, IoTs). Space/satellite downstream services (earth observation data) can be used to facilitate a top-down data collection approach. This top-down approach is then used for the development of smart tools for a variety of urban applications.

In this research activity, the smart city approach is exemplified through the use of Earth Observation, in conjunction with geographic information systems and urban models, in order to address two fundamental pillars of urban climate and environment: (a) urban thermal environment, with emphasis to surface energy balance and the urban heat island, the presence and spatial distribution of thermal hot spots and energy efficiency at the district level (b) urban hydrology, with emphasis to urban flooding and subsidence. In (a) downscale techniques and data fusion methods will be developed and used for the best exploitation of earth observation data, whereas in (b) models will be developed for urban rain floods and geohazards. In both (a) and (b), smart tools will be developed in support of the theme “Urbanization and smart cities”.

The research activity reflects a 4-year cooperation period, whereas it will be implemented by a thematically balanced consortium of experienced in urban studies, research teams from Universities in Europe and China. Furthermore the consortium includes teams with experience in the ESA-MOST Dragon Program as well as new entries, i.e. teams with the potential to enhance the strength of the consortium. The consortium by also consisting of members which have established collaboration within the Dragon Program, guarantees the successful implementation of the project. The areas of study will reflect cities of varying sizes and urbanization rates, in both Europe and China.

The project will be partially funded by the projects that the team partners have secured or by means of own funding for the staff members involved. Specifically, Univ. of Athens will link the project to the EU funded project MASS and the state funded project on adaptation planning for urban climate; U. Twente will combine funding from the SEB project. The Chinese partners will apply for funding from Natural Science Foundation of China and related provinces. A multitude of active and passive Earth Observation data (Sentinel series, Envisat, China HJ-1 and FY, Landsat, Aqua/Terra and others) will be used for this research project. In addition, a major element of the project is to provide professional training to young scientists so as enhance their research, teaching, and communication skills. Finally, the research activity will be also supported by well established international platforms, such as the UNESCO Chair in Hydroinformatics for Ecohydrology and the UNESCO Beijing Water Security Demo Site in the Capital Normal University of China.