HARMONIA: strategy of an integrated resilience assessment platform (IRAP) with available tools and geospatial services.

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HARMONIA: strategy of an integrated resilience assessment platform (IRAP) with available tools and geospatial services.

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Abstract.
The huge amount of the available data nowadays has raised some major challenges which are related to the storage, fusion, structure, streaming and processing of these data. In this paper, we present the development of a holistic framework, entitled HARMONIA, that encompasses State-of-The-Art solutions for the emerging issues related to Climate Change, natural and/or man-made hazards and urban/peri-urban risks. The Horizon 2020 HARMONIA project is developing an Integrated Resilience Assessment Platform (IRAP) which plans to provide targeted services for different groups of end-users. In particular, it will actively support urban decision-makers in strategic decisions and planning and citizens in facing daily effects and risks of Climate Change. Additionally, the platform will be a place to interconnect cities which end up facing similar Climate Change effects. HARMONIA IRAP leverages cuttingedge technologies (i.e., explainable Artificial Intelligence, Data Mining, multi-criteria analysis, dynamic programming) and services (ie., Virtual Machines, Containers) in order to provide solutions considering the complexity and diversity of extreme earth and non-earth data. In addition, this platform includes a Decision Support System providing early-warning feedback and recommendations to the end-users. In this way the HARMONIA IRAP design tends to address these challenges by offering the corresponding dynamic, scalable and robust mechanisms with the aim to provide useful integrated tools for the related users. Datacubes architecture, which is a major part of the IRAP, offers the opportunity to investigate more sophisticated correlations among the data and provide a more tangible representation of the extracted information.

1. Introduction
Over the past two decades, we have witnessed a tremendous increase of data production all over the world. This is notably induced by the development of various domains such as Remote Sensing, 3D/4D modelling, Artificial Intelligence (AI), Data Mining and Decision-Making. Nowadays, while Big Data represent an opportunity for various organizations, institutions and small and medium-sized enterprises (SMEs), they ingested in such volume, speed, heterogeneous sources and formats that they exceed the capabilities of traditional management systems for their collection, storage and processing in an efficient manner. This plethora of data remains ambiguous of fuzzy for many researchers, policy makers, urban planners, practitioners and stakeholders.

At the same time, there has been a progressive increase in awareness of the urgency of understanding the climate and environmental changes, taking place on a global scale, in order to be able to appropriately transform human habits and structures to limit the human impact on the acceleration of these transformations and to prepare our societies for future scenarios. Scientific research on the subject has highlighted the key role of cities, as they are at the same time responsible for a majority of climate-altering emissions and also the places where the related threats are likely to have the greatest impact, augmented by urban phenomena such as Urban Heat Island (UHI). From a subject strictly confined to scientific study, the debate has moved to the tables of international politics and then to the streets in a progressive widening of interest and participation. The key importance of these issues has been widely emphasised by the European institutions through a series of strategic documents from the green strategies [1][2] and Climate Change Adaptation Strategy [3] to the Agenda 2030 [4]. Also EU funded research programmes are placing Climate Change (CC) at the very centre of their strategic objectives, emphasising the relevance of the issue for the entire society.

In this framework, HARMONIA project's main objective is to reorganise and integrate the huge amount of data already available and to make the best use of existing monitoring technologies and geospatial services, as recent studies highlighted the usefulness of remote sensing, AI, Geographic Information System (GIS), Machine Learning(ML)/Deep Learning (DL) - based method and modelling for urban hazard assessment and disaster risk management. The final goal is to provide an integrated service to make data and information accessible and usable in a proactive way. In this regard, the clear identification of final users and their requirements has been a crucial step to define the platform architecture. Final users has been divided in three main categories, namely i) researchers; ii) municipalities, local administrators, urban planners and decision-makers; and iii) citizens. The requirements of each category are deeply different as well as the level and type of expertise. For instance, researchers may be interested in getting raw data from the platform and use it as a tool for training and evaluating new ML models. On the other hand, local administrators are at the same time users of the platform and data providers and they would be interested in a Decision Support System (DSS) to guide local politics. Last, citizens have the right to be informed on the risks affecting their cities and need the data to be easily accessible through appropriate visualisations and explanations.

In this paper the HARMONIA IRAP architecture is presented and described, with reference to the overall objectives of the project and guidelines provided by H2020 research programme, as shown in Figure 1. An extensive review of existing instruments and similar platforms allowed to identify the gap and to better define the innovative goal and target of the project, as described in the following paragraphs. Section 4 then explain the proposed approach, detailing the data streaming, data processing and datacubes phases. Last, expected outcomes and preliminary results obtained in the first months of HARMONIA project are discussed in section 5.

2. Related work
Studies on risk management, adaptation to CC and improvement of urban resilience have long been at the heart of European research priorities. The HARMONIA project is therefore part of a domain already rich in contributions, but still in need of research and innovation. Indeed, a review of the main recent projects funded by the European Commission developed to date has highlighted the main limitations of

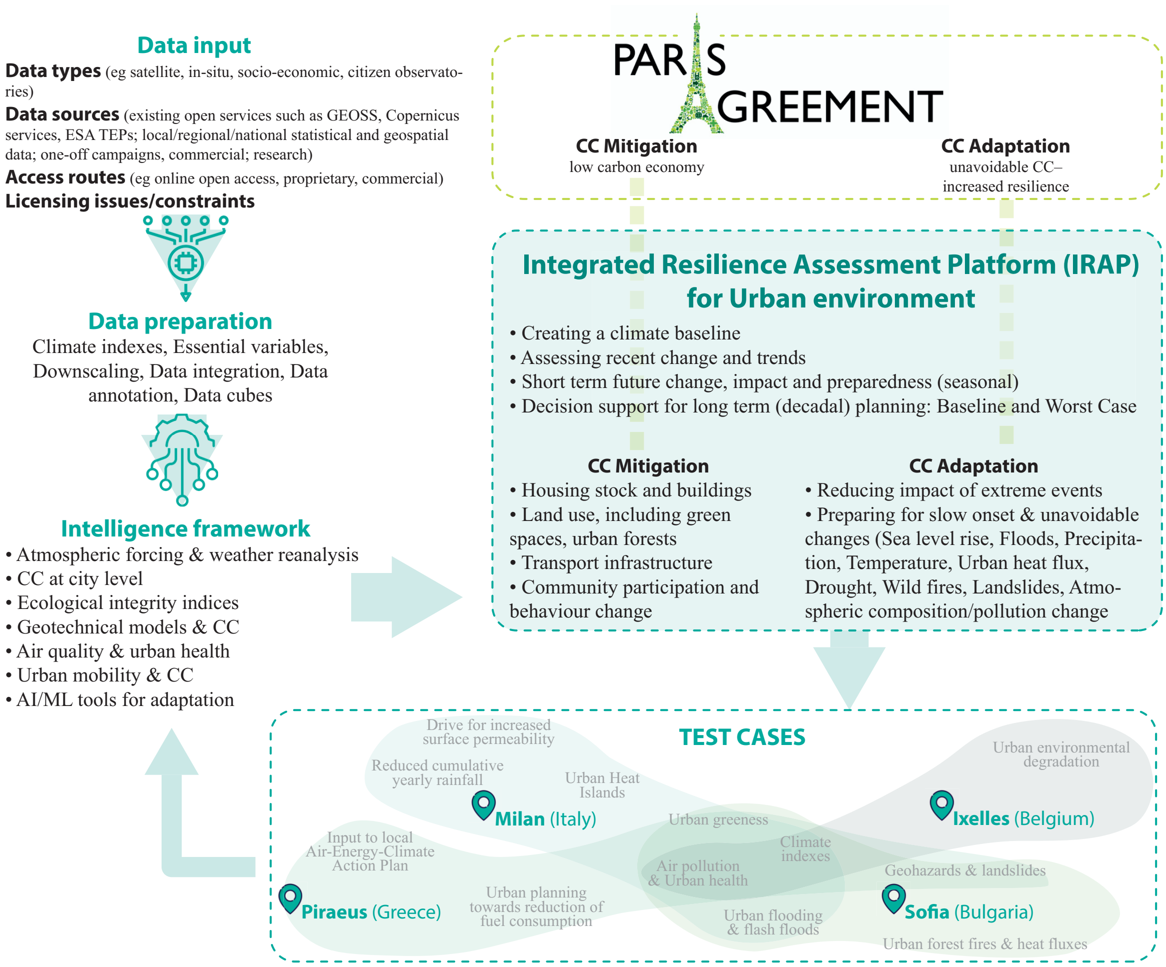

Figure 1. HARMONIA conceptual overview & high-level flow of information.

existing research and allowed to better identify the innovative purpose of HARMONIA. Table 1 shows 12 projects that are close to HARMONIA in terms of topics and objectives. It can be observed that not all of the projects had a risk assessment or decision-making support platform as an output. In particular, the earlier projects in chronological terms had to define a theoretical and methodological framework as a first step. Only in the most recent projects, therefore, there is an attempt to move on to applied research and translate theoretical knowledge into effective tools at the service of the actors involved. Even in these cases, however, looking at the focus of the research, it can be seen that in many cases the methodology of risk assessment concerns very specific causes such as water-related risks in the RESSCUE project or temperature peaks in EXTREMA.

Differently, HARMONIA aims at dealing with the urban scale in an holistic and integrated perspective. From a more technical point of view, in recent years research introduced an integrated framework for the organization and handling of earth observation data using virtualization technology like docker containers [5]. This solution provides scalability, ease of use, reusability and applicability in different use cases. Moreover, even though the idea of datacubes is old and dates back as far as 1992, it has become widely popular in the last few years mostly for its applicability to spatio-temporal and earth observation data, as described in [6] and [7]. In [8], the authors investigate the reliability and the customization of Apache Kafka streaming platform for several applications. It is proved to provide several customization alternatives according to the needs of a potential application. Concluding, we propose an integration of all the aforementioned tools in an effort to build a robust and scalable solution for the needs of the HARMONIA IRAP.

Table 1: Review of existing similar platforms.

NAME	OUTCOME	FOCUS	APPROACH	USERS	DATE	LINK
DRIVER	methodological framework and Portfolio of Solutions	civil society resilience, professional response and evolved learning	systematic assessment and iterative adaptation of research results to operational requirements	expert users, crisis management professionals	2014-2020	[9]
IMPROVER	guidelines and methodological framework	critical infrastructures	Cross sectoral methodology based on risk evaluation techniques and informed by a review of different resilience concepts	expert users	2015- 2018	[10]
RESILENS	Decision Support Platform	critical infrastructures	reference to European Resilience Management Guideline (ERMG); pilot demonstrations and multiple simulated testing events	expert users	2015-2018	[11]
RESOLUTE	guidelines and mobile app for emergency	critical infrastructures / urban transport	systematic review and assessment of the state of the art of the resilience assessment and management concepts	expert users; transport professionals; local administrators	2015-2018	[12]
RESISTAND	guidelines	EU and Member State government level	critical evaluation of standards; pre-standardisation process; feasibility test	institutional actors	2016-2018	[13]
RESIN	guidelines and methodological framework	urban areas	co-creation and knowledge brokerage between cities and researchers	decision-makers	2015-2018	[14]
RAMSES	strategic framework and guidelines for decision-making	urban areas	integrated top-down and bottom-up approach	researchers; policy-makers	2012-2017	[15]
SMR	Resilience Management Guidelines	urban areas	co-creation	local administrators, decision-makers	2015-2018	[16]
GRRASP	Resilience Assessment Platform	critical infrastructures	5x5 resilience matrix	specialized and non-specialized users	2008-2011	[17]
EPICURO	best practices catalogue and toolkits for stakeholders engagement	urban areas	partecipatory activities and professional trainings	civil protection professionals; policy makers; raising citizens	2017-2019	[18]
RESCCUE	Resilience Assessment Framework; RAF-APP mobile app	urban areas, specific focus on water	objective-oriented approach and four resilience dimensions: organisational, spatial, functional, and physical	expert users, urban planners, decision-makers	2016-2020	[19]
EXTREMA	mobile app	urban areas, focus on heat peaks	use of real-time satellite data along with other model and city-specific data to provide alerts	citizens, decision-makers	2018-2019	[20]

3. Contribution and Innovation

One of the main innovative aspects of the HARMONIA IRAP is the widening of the final users considered not only to experts and technicians, but also to external users, stakeholders and municipalities, moving beyond the current concept of “data acquisition”. Currently, the existing methods for data acquisition still present weaknesses in the phases of analysis and detection (lack of completeness, inaccuracies, absence of validation procedures), while HARMONIA will cover in a systematic way: i) data sources (for instance, open services such GEOSS, Copernicus services, ESA TEPs and local regional/national statistical and geospatial data; ii) data types (satellite, in situ, socio economic, citizen observatories). So far, it is essential to organize the several and heterogeneous gaps faced, which are listed and explored in more detail in the following paragraphs. Here the main contribution is the integration of several modules regarding the data fusion, data streaming mechanisms, processing of data, creation of data cubes and visualization tools into a single framework. The idea of using separate docker containers for the streaming and processing modules makes the system more stable in case of any data source gets disconnected. Additionally, the development of data cubes for the organization of the data provide new ways of storage solutions and novel features could be extracted using a variety of learning algorithms. Moreover, the organization of processing layer into containers, makes it easy to add new services in an effort to face a new challenges.

3.1. Limited parameters

Currently, the climatic (mainly referable as air quality) and atmospheric (for instance precipitations and consequently flash flooding) indicators for CC risk scenarios are not directly applicable for impact assessment on urban areas. To overcome this issue HARMONIA has identified an optimal set of quantitative primary parameters, and impact indicators to quantify CC impacts in urban areas, encompassing extreme climate, hydro-geological, soil quality, and structural stress indicators. These will be defined according to a reliability-based approach of durability to identify the most appropriate parameters and their sensitivity. Parameter selection will consider inter alia the probability distributions of mean temperature and diurnal variation, surface hydrometry, CO_2 concentrations as well as pressure inputs for wind. Uncertainties of environmental model inputs and material parameters will be quantified.

3.2. Technical limitations

Firstly, a limit faced in the State-of-The-Art analysis, is about the available numerical modelling which cannot be applied in multi-nested operational applications. The overcoming is meant to be offered with a series of new multi-scale and multi-nesting approaches for the assessment of atmospheric forcing on soil and structures. It will be developed to account the soil temperature and moisture content for different scenarios. Moreover, it will identify the relevant environmental stresses yielded on the selected infrastructures under various climatic conditions, evaluating the efficiency of response actions. A second technical issue is the lack of tools to assess CC threatening urban areas at the city scale. Selection of events will be based on Euro-Cordex climate data, so that extreme events can be simulated and assessed. To get a realistic probability spread the mean climate projections will be combined with seasonal forecast ensembles looking for 7 months ahead. Lastly to include innovative tools in planning risk prevention as part of the current urban and territorial management plans will be assessed. As a third object of interest, the conventional Data Cubes show limited processing capabilities, regarding multi-layered analysis of CC. The implementation is intended to be the application of innovative image analysis and machine learning algorithms to process multi-dimensional image cubes. At the end, it was noticed the limit induced by the management centres devoted to acquire EO and geospatial info manually or semi-automated, involving various software and operations by third parties. This procedure is time-consuming since Big Data must be downloaded and further requires analysis. Therefore, it is proposed the integration of multi-temporal space-ground-airborne geospatial data and operational services towards monitoring hazard and exposure in real-time at several geographical levels, supporting strategies for the decision-makers. Novel technology will be employed and validated for analysing and delivering big EO data and accurate and timely geospatial information.

3.3. User interface

Nowadays, GEOSS data [21][22] are not sufficiently accessible to urban stakeholders to ensure their implementation in CC mitigation planning. The platform will utilize satellite data and auxiliary data available from GEOSS to increase the precision in the analysis, the reliability in the performance and simultaneously achieving the interoperability. This will result into a more reliable and flexible delivery of the GEO data themselves. The project supports integration with other geo-spatial data and socio-economic strategies for pollution and micro-climate.

4. The proposed approach

In Figure 2, the proposed conceptual architecture of the IRAP is presented. It is organized in a 5-layered structure aiming to provide a clear view of the supporting procedures. Mostly for the Streaming and Processing layer, the idea of docker containerization is followed in order to provide modularity to the system, in a sense that each major part of the software is built and executed independently. In this way, the proposed approach provides a scalable, robust and high-performance system that ensures the promised functionality. Additionally, the concept of datacube construction offers the opportunity to investigate the existence of extra features to be extracted from the processed data.

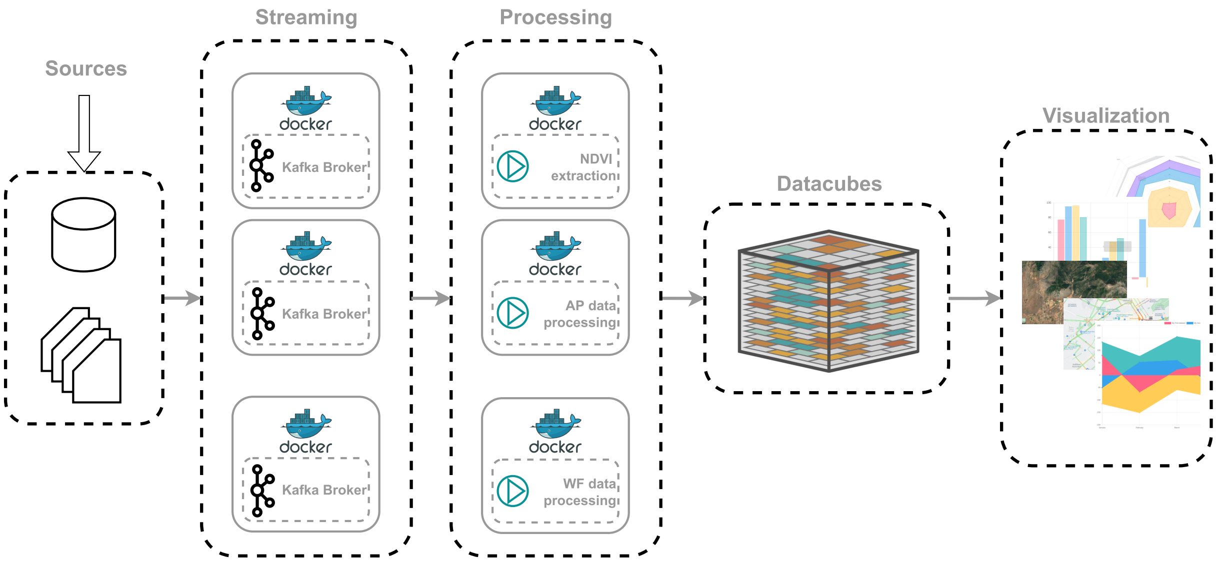

Figure 2. The conceptual architecture of IRAP.

4.1. Data fusion

According to the objective of the HARMONIA project, a huge amount of heterogeneous data will be injected into the IRAP for further processing. In order to handle and organize this data, we introduce the idea of Apache Kafka streaming solution. In this way, it is feasible to create individual streams of data depending on the requested services and organize these streams under docker containers to ensure the robustness of the platform. The basis of the streaming layer consists of some major Kafka brokers that cannot be removed or changed. Apart from them, the administrators of the platform will have the permission to add new streams containing all the data requested by the end-users of the platform (researchers, citizens, etc).

4.2. Processing pipeline

The processing layer is located in a higher level than the sources and the streaming layer, including all the services that will be developed by the researchers/developers and utilized by the end-users of the platform. It receives as input the data streams from the previous layers and produces as output the information occur from the data processing. As shown in Figure 2, an example of a processing layer application could be the extraction of Normalized Difference Vegetation Index (NDVI), using the proper satellite images and any other data needed. Another application could collect air pollution (AP) data and utilize a regression model in order to generate predictions concerning the air quality index of a specific city. All these outcomes will be combined aiming to generate the datacubes of the next layer.

4.3. Data cubes

As it is already mentioned, we propose the use of datacube objects in order to organize the heterogeneous data and investigate the possibility to extract new features that may occur by this new structure. Since the use of datacubes for spatio-temporal data is recommended, it seems to be the ideal solution for the handling of HARMONIA data that are mostly related to Earth Observation, air pollution, weather forecasting, simulation of flash flooding, etc. Furthermore, by adding new services in the processing layer, the generated datacubes are enriched with new information that can accordingly contribute to the outcomes of the platform.

4.4. Visualization

For the visualization purposes, we will utilize a datacube-related open-source toolkit like Xcube [23] in order to exploit as much useful information and features as possible given a datacube object. Furthermore, Google maps [24] features, WebGIS [25] system and other toolkits will be essential for the presentation of information related to satellite and in general earth observation data. For other types of data, like air pollution and weather forecasting, alternative solutions of presentation may be demonstrated. Such solutions could be line, bar, pie or area charts provided by open-source frameworks like Chart.js [26], alert text messages, indicators, etc.

4.5. End-users experience

The final experience is targeted on the different categories of end-users considered since the beginning. Citizens and non-expert users will have access to a basic visualization of information that refer to the pilot cities. Additionally, they will be able to access a service of early-warnings and recommendations about potential risks such as heath peaks or extreme rainfalls. Differently, decision-makers, urban planners and technicians of the municipalities will be able to use the DSS, which would be integrated into the final platform. This system will provide a reliable feedback regarding any spatio-temporal changes and the impact of CC on the environment. From a technical perspective, a series of mechanisms, like recommendation engines, decision support tools and relevance feedback procedures, will be introduced in an effort to enrich the capabilities of the DSS. From a more tangible perspective, the outputs of the DSS along with the existing visualizations of the previous section, will be presented to the end-user as a fully interactive Graphical User Interface (GUI). In this way, the user will have the ability to select the preferred pilot city, extract descriptive information and retrieve the DSS outputs in forms of maps, text, images, charts, etc.

5. Expected outcomes and conclusions

The proposed platform architecture is the main preliminary result obtained in HARMONIA project so far. It is the outcome of a wide overview on available in-situ data and complementary data collection techniques, and of the awareness about the current issues in EO and science-related data. This platform effectively responds to the needs of management for large amount of data and fits the purpose of an integrated and multi-sources assessment of risk scenarios for urban areas. Although it still have to be tested and eventually refined, the current proposal is already valid contribution built above the State-of-the-Art.

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