

Copernicus Programme as Challenge for Geodesy and Geoinformatics

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Abstract. European Commission is developing Copernicus program being one of the most ambitious Earth observation programs. It is going to deliver new satellite and in situ data and will present the basis for the development of new products and user oriented services. Copernicus program will provide new business opportunities to develop in many fields and branches like environment protection, management of urban areas, regional and local planning, farming, forestry, fishery, transport, climate changes, tourism and other. Significant influence on geoinformation market can be expected. In situ measurements (terrestrial, air, sea) are going to extend spatial and temporal resolution of satellite data. Principle of combination of satellite and in situ data is going to be strongly developed. Collection of in situ data is a possibility to extend geodetic and geoinformation measurement techniques. Local communities should also have benefits from Copernicus program, as its satellite data can be refined for local areas. New opportunities are open in the development of Local Spatial Data Infrastructures based on satellite and in situ data.

Key words: Copernicus program, geospatial products, in situ, Sentinel, geodesy and geoinformatics

1. Introduction

European Commission (EC), European Space Agency (ESA) and European Environment Agency (EEA) are developing the Copernicus European Earth Observation Program, previously known as Global Monitoring for Environment and Security (GMES) [Aschbacher at all 2010] [URL 1]. Copernicus is one of the fundamental development programs of EU. In the global context, Copernicus is an integral part of the Global Earth Observation System of Systems (GEOSS). One of the main goals for developing the Copernicus program is environmental monitoring and improvement of the overall security of the European Union. Copernicus program also

want to get a long-term continuous services [URL 5]. Basically, it consists of Earth observation satellite system and in situ data.

ESA is responsible for the satellite segment that primarily consists of six families of Sentinel satellite missions [URL 6], whereas EEA is responsible for coordination of in situ data considering environmental policies [URL 7]. Primary Copernicus services will provide necessary information to make decisions about the environment and decisions in case of emergencies such as natural disasters and humanitarian crises.

Copernicus program will cover six thematic areas: land monitoring, marine monitoring, atmosphere monitoring, emergency management, climate changes and security. Copernicus data will have broad spectrum of usage including environment protection, management of urban areas, regional and local planning, farming, forestry, fishery, transport, climate changes, tourism and other. Sentinel satellite data are significantly going to influence the development of spatial data products and services and will have the impact on geoinformation market [Hećimović, Martinić 2015]. In situ measurements (terrestrial, air, sea) are extending spatial and temporal resolution of satellite data and they provide the possibility to develop user focused products and services.

Copernicus will develop global services using satellite data, thus it will greatly contribute to the European sustainable development strategy. The economy and citizens will benefit through innovation and initiative to create new practical applications of products and services [Kovačić, Hećimović 2015a]. Copernicus is so far the most comprehensive program of the Earth observation, thus scientific and socio-economic influence should be significant [SpaceTec 2012] [SpaceTec 2013]. Economic studies of the Copernicus program indicate that by 2030, 2.6 billion of commercial income as well as 83,500 jobs directly and indirectly related to the Copernicus program, will have been achieved. In addition, Copernicus contributes to the European space and technologically highly developed industry and supports numerous scientific institutions, programs and studies [Hoersch, Amans 2015].

Geodesy is facing new challenges. Satellite and in situ data is a concept of spatial products and services that combine small (satellite) and big (in situ) spatial and temporal resolution data.

European Commission focused the financing of Copernicus related projects through Horizon 2020 and through the structural funds. However, public-private partnership is providing quicker advance in development and more financing opportunities. New development concepts of in situ data present a challenge for geodesy the same as for other sciences.

2. Copernicus satellite data

Sentinel satellite data should follow long time continuity of satellite based products and services. For example, Sentinel-1 satellites will collect Synthetic Aperture Radar (SAR), C-Band data. The data are collected by European Remote

Sensing (ERS) satellites, ERS-1 from 1991 to 2000 and ERS-2 from 1995 to 2011 [URL 3]. ESA's successor of ERS satellites was Envisat [URL 4]. It was the largest civilian Earth observation mission with 10 instruments aboard. It was active from 2002 to 2012 when the contact with the satellite was lost. SAR data were also collected by other satellites, as Italian Cosmo-SkyMed (eng. *CO*nstellat*ion of small Sat*ellites for the *Mediterranean basin Observation*), Canadian Radarsat, German TerraSAR-X and TanDEM-X missions and other [Martinić 2015].

Satellite Earth observations are providing data in broad spectrum of sensors, resolutions, wavelengths and other characteristics. The main satellite data of Copernicus interest are [ESA 2015]:

- Optical Medium Resolution (MR) and Low Resolution (LR) (SPOT (VGT), PROBA, Resourcesat),
- Optical Very High Resolution (VHR) and High Resolution (HR) (DMC, Pleiades, Deimos-2, Ikonos-2, IRS-P5-CartoSat, RapidEye, SPOT (HRS), QuickBird-2, WorldView),
- Atmospheric data (MetOp, Meteosat),
- Synthetic Aperture Radar (SAR) (COSMO-Skymed, TerraSAR-X, Tandem-X, Radarsat),
- Altimetry data (Cyrosat, Jason).

Satellite data can provide new products and services. Land surface temperature from obtained from the satellite data is one of the products that can be developed. Figure 2.1 shows land surface temperatures of the city of Zagreb using Landsat 8 TIRS sensor on July 20 and July 29, 2013.

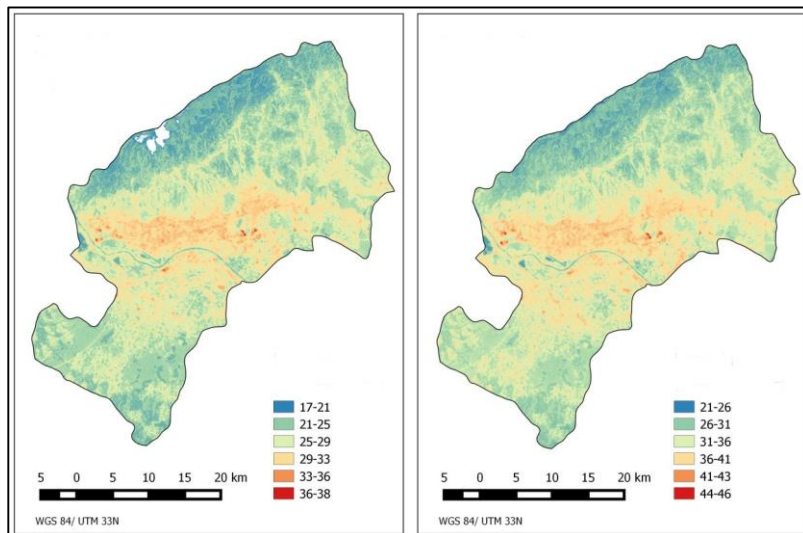


Figure 2.1 Land surface temperatures of the city of Zagreb on July 20 (left fig.) and July 29 (right fig.) 2013 [Kovačić 2015].

Copernicus satellite segment consists of Sentinel and complementary satellites [Copernicus Space Component Mission Management Team 2015] [URL 2]. Sentinels satellites data should be complementary to other satellite data missions [Lukin 2014]. Sentinel satellites will have six families:

- Sentinel-1 mission will provide SAR data for the terrestrial and marine services. Two satellites will provide global data in the temporal resolution of 6 days. The first Sentinel-1A satellite was launched in 2014.
- Sentinel-2 mission is dedicated to land monitoring [Richter et al. 2011]. It will provide vegetation, soil and water data [URL 10].
- Sentinel-3 mission is devoted to marine monitoring. It will measure sea surface topography, sea surface temperature and ocean colour. The mission will provide support for forecasting weather in the oceans.
- Sentinel-4 mission is dedicated to continuous monitoring of the atmosphere that will be part of the Meteosat third generation satellites in geostationary orbit [URL 11].
- Sentinel-5p (predecessor) is a satellite mission devoted to the atmosphere monitoring. It will be launched before regular Sentinel-5 satellites to fill the data gap of lost Envisat.
- Sentinel-5 mission is dedicated to continuous atmosphere monitoring [Levelt et al. 2006].
- Sentinel-6 will carry an altimeter to measure global sea surface height, which will primarily be used for oceanography and climate research.

On March 5, 2016 three Sentinel satellites were active: Sentinel-1A, Sentinel-2A and Sentinel-3A. Figure 2.2 shows their positions.

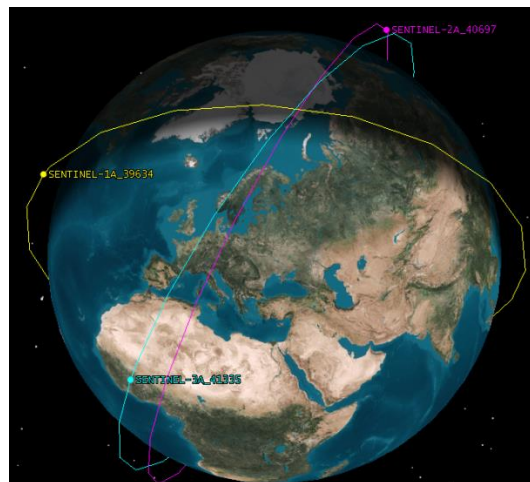


Figure 2.2 Active Sentinel satellites on March 5, 2016 at 10:11 CET.

3. In situ data

Copernicus system relies on satellite and in situ data networks for continuous Earth monitoring [URL 8] [URL 9]. In situ resources include ground, air and marine data. Copernicus services primarily include the network of terrestrial weather stations, ocean buoys, the network for monitoring air quality, and many other.

Data from the Sentinel satellites will be complemented by in situ measurements in order to obtain detailed data for local areas. In the frame of Copernicus program, European Environmental Agency (EEA) is responsible for the development and coordination of in situ measurements at the national level of the EU countries [URL 1]. Using Copernicus service is an integral part of the EEA's strategy for more advanced information about the environment. Copernicus also plays an important role in the implementation of the Shared Environmental Information System (SEIS) and has the potential for efficient use of existing infrastructure in accordance with the INSPIRE Directive.

Collection of in situ data is the opportunity for geodesy to use classical measurements methods and knowledge, moreover, to develop new measurements methods and techniques to produce user focused products and services [Barišić at all 2011]. By the combination of satellites, air, sea and land measurements will become more and more developed (Fig. 3.1).



Figure 3.1 Combination of satellite, plain, ship, land, helicopter measurements [Barišić, Crnković 2009]

In situ measurements can include Unmanned Aerial Vehicle (UAV) measurements using visible spectrum, infrared or thermal sensors, LIDAR, radar, as well as other sensors.

Mobile measurements systems can also be used in situ measurements. They can include different sensors on moving vehicle as GNSS receivers, optical camera, laser scanners, odometer, Inertial Measurement Unit, and alike. They can provide clouds of data to extend the satellite data on local, more detailed level. In situ data the collection can also be made of networks of sensors as thermal sensors, humidity sensors, water

level sensors and many others. The collection of in situ data is very often based on crowdsourcing principles using mobile devices.

Local communities (towns, municipalities) will also benefit from Copernicus program [Hećimović at all 2014]. Development of Local Spatial Data Infrastructures (LSDI) based on satellite and in situ data, beside classical SDI data, is opening new possibilities [Marasović, Hećimović 2014] [Marasović at all 2015]. Big cities already can benefit from Copernicus. Copernicus Land Monitoring Services [URL 12] for Local area can download data from Urban Atlas [URL 13] (Figure 3.2). At this moment detailed land cover and land use information over major EU cities for periods of 2006 and 2012 are available. Copernicus program will significantly influence spatial information products and services as well as geoinformation market, but also everyday life and society [Kovačić, Hećimović 2015b]. To which extent will geodesy and geoinformatics influence and be influenced by Copernicus development is a challenge for the era that has started.

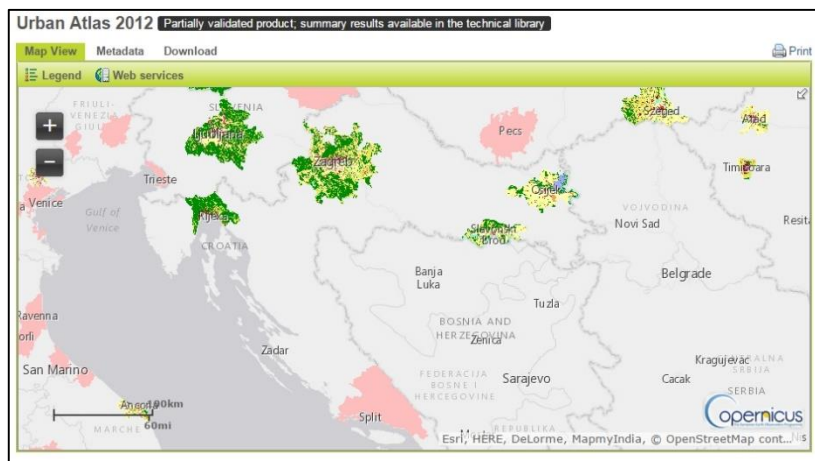


Figure 3.2 Urban Atlas 2012 [URL 13]

4. Copernicus services

Copernicus is intended to provide user oriented services for the protection of the environment, resource management as well as for security and safety. Currently, active Copernicus services base their activities on the recordings obtained by other satellite missions. Copernicus services will cover six major areas: land monitoring, marine monitoring, atmosphere monitoring, emergency management, security and climate change.

Copernicus land monitoring service provides geographic information on land cover. It supports the application in various fields, such as spatial planning, forest

management, water management, agriculture, food security, and other. The service has been operational since 2012.

Copernicus marine monitoring service should give regular and systematic information on the state and dynamics of the oceans and seas for the purpose of their protection and efficient management of the marine environment and its resources. , Giving information on currents, winds and the sea ice to help enhance maritime routes, rescue operations contributing to the safety at sea [URL 1] are some examples of the above said The service also contributes to the protection and sustainable management of living marine resources, especially for fish farming, fisheries research or regional fisheries organizations. The obtained data (e.g. temperature, salinity, sea level, currents, wind, sea ice, etc.) have an important role in weather forecasting and climate changes.

Copernicus atmosphere monitoring service allows the atmosphere monitoring, evaluating and predicting air quality at the continental, regional and local level. Long-term, high-quality observations of the atmosphere are necessary for the continuous monitoring of climate and defining the basis for the control of pollutants [Kaufman and Sendra 1988] [Schläpfer et al. 1998]. Atmosphere monitoring service provides data and information on the composition of the atmosphere. It supports numerous applications in various domains including: health, environmental monitoring, renewable sources of energy, meteorology, climatology and others.

Copernicus emergency management service provides necessary information to all participants involved in the management of natural disasters, human-induced disasters and humanitarian crises. The service uses geospatial information obtained from satellites, combined with in situ data and other available data. The aim of the service is to strengthen the capacity of the EU to respond to the needs of emergencies that could be caused by extreme weather, earthquakes and human-induced crises such as, oil spills, humanitarian crisis and alike. The service started in 2012.

Copernicus security service tends to support related EU policies by the following list of priorities: border control, maritime surveillance and support for EU external actions. In the areas of border control, the main objectives are to reduce the number of illegal immigrants entering the EU and increase the internal security of the EU. In the field of maritime surveillance, the main objective of the European Union is to ensure the safe use of the sea and the safety of maritime borders. The goals of services are often related to the safety of navigation, marine pollution, law enforcement, and to the overall security. EU external actions have the responsibility of promoting stable conditions for human and economic development, human rights, democracy and fundamental freedoms. Copernicus service for security applications is still undergoing the process of development.

Copernicus climate changes service responds to the challenges of environmental and society changes associated with climate changes. The service will allow monitoring

several climate indicators such as temperature rise, sea level rise, melting glaciers, rising temperatures of the ocean and other [Kovačić 2014].

5. Conclusion

Copernicus program is so far the most comprehensive program of observations of the Earth. It is one of the major development programs of the EU. The main thematic areas (land, sea, atmosphere, climate change, management of emergency services and security) define the main directions of Copernicus public sector development. Besides, Copernicus data will have a much wider range of applications. Copernicus will consist of six Sentinel missions that will include one or more satellites. Satellite data will be complemented by in situ data (land, sea and air). The program will supply the whole range of geospatial products and services that will significantly affect the market of geospatial data. Copernicus program will have a significant impact on the development of science, economy and society as a whole. In surveying and geoinformatics Copernicus program will not only improve the existing products and services, but will generate the development of entirely new products and services, as well. New measurements and data collection techniques will be developed. Geodesy and Geoinformatics are confronted with a challenge to participate in Copernicus development. Engineering geodesy can benefit from Copernicus program in collecting in situ data. Development of new engineering geodesy measurement techniques, as well products and services is challenge that in some cases only engineering geodesy can make.

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Kopernik program kao izazov za geodeziju i geoinformatiku

Sažetak. *Kopernik je Europski program motrenja Zemlje koji će davati nove satelitske i lokalne podatke. Oni će biti osnova za razvoj novih geoinformacijskih proizvoda i usluga. Otvorit će nove mogućnosti za razvoj mnogih područja i grana kao što su zaštita okoliša, upravljanje urbanim područjima, regionalna i lokalna planiranja, poljoprivreda, šumarstvo, ribarstvo, promet, klimatske promjene, turizam i druge. Značajno će utjecati na geoinformacijsko tržište. Lokalna mjerenja (kopno, zrak, more) će povećati prostornu i vremensku rezoluciju satelitskih podataka na lokalnom području, a to otvara mogućnosti razvoja novih metoda i tehnika prikupljanja podataka. Kombiniranje satelitskih i lokalnih podataka će biti razvijane. Prikupljanje lokalnih podataka daje mogućnost proširenja geodetskih i geoinformacijskih mjernih tehnika. Lokalne zajednice će imati koristi od Kopernik programa. Globalni, ažurni, javno dostupni satelitski podaci će se moći po potrebi progustiti lokalnim podacima. Otvoraju se nove mogućnosti za razvoj lokalne infrastrukture prostornih podataka na temelju satelitskih i lokalnih podataka.*

Ključne riječi: program Kopernik, geoprostorni proizvodi, Sentinel, geodezija i geoinformatika