Journal of Young Scientist, Volume V, 2017
ISSN 2344 - 1283; ISSN CD-ROM 2344 - 1291; ISSN Online 2344 - 1305; ISSN-L 2344 – 1283

MONITORING OF THE FREEZING DANUBE DELTA BASED ON SENTINEL-1/2 IMAGERY

Giulia-Laura PANTEA, Anca-Simona LACUSTEANU

Scientific Coordinator: Lect. PhD Iulia DANA NEGULA

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăşti Blvd, District 1, 011464, Bucharest, Romania, Phone: +4021.318.25.64, Fax: + 4021.318.25.67, Email:giulia.pantea123@gmail.com; ancaanka27@yahoo.com; iulia.dana@fifim.ro

Corresponding author email: giulia.pantea123@gmail.com

Abstract

In January 2017, extremely low temperatures caused the freezing of the Danube Delta, leading to the complete isolation of some villages for a couple of weeks. The area was monitored from space, based on images acquired by Sentinel-1 and Sentinel-2, two satellite missions launched in the frame of the European Programme Copernicus. Sentinel-1 is equipped with a C-band synthetic aperture radar, while Sentinel-2 has a multi-spectral optical sensor acquiring data in 13 spectral bands. The spatial resolution of the GRD (Ground Range Detected) Sentinel-1 products used in this study is 10 meters, while the spatial resolution of the MSI (Multi-Spectral Instrument) Sentinel-2 products is 10 m, 20 m and 60 m, depending on the spectral band (B2, B3, B4, B8 – highest resolution, B5, B6, B7, B8a, B11, B12 – medium resolution and B1, B9, B10 – lowest resolution). The Sentinel-1/2 satellites collect complementary information that can be used for the frequent monitoring of vast areas, given the fact that each mission is composed of a pair of satellites (Sentinel-1A/B and Sentinel-2A/B). Sentinel-2B was launched on the 7th of March 2017 and it is currently in the commissioning phase. The present study aims at promoting the usefulness and adequacy of satellite data for monitoring the situation on the ground, especially when the area is not accessible by other means.

Key words:*Danube Delta, freezing temperatures,satellite imagery, Sentinel-1/2.*

INTRODUCTION

The Danube River (Figure 1) is considered the most international river on the planet due to the fact that its course runs across or forms a part of the borders of several countries: Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria, Ukraine, and four capitals: Vienna, Bratislava, Budapest and Belgrade (http://romaniatourism.com/danube-delta.html).

Figure 1. Danube River Basin (© WWF 2017)

The Danube Delta (Figure 2) entered the UNESCO World Heritage List in 1991, being classified as a biosphere reserve and as a national park in Romania. The Delta is formed around the three main channels of the Danube, named after their respective ports: Chilia - in the north, Sulina - in the middle, and Sfantu Gheorghe - in the south (http://romaniatourism.com/danube-delta.html).

Figure 2. Danube Delta (UNESCO © Marciela)

According to the UNESCO official description of the Natural Heritage Site, "the waters of the Danube, which flow into the Black Sea, form

the largest and best preserved of Europe's deltas. The Danube delta hosts over 300 species of birds as well as 45 freshwater fish species in its numerous lakes and marshes" (http://whc.unesco.org/en/list/588).

This year, the Danube Delta region experienced one of the harshest winters on record. Temperatures plummeted to -20°C, encasing landscapes in a thick coat of frozen water. Because of the low temperatures the area was completely isolated, and ships could not sail because floes were impenetrable, according to the local media (https://www.agerpres.ro and http://ziaruldetulcea.ro).

According to the historic records, the lowest value was recorded at Constanta in 1929 when the mercury thermometer dropped to -250C, but winters were heavy too in 1954, 1963, 1985 or 2000. In 1929, the Black Sea froze over five kilometres, causing a compact ice blanket. Due to those low temperatures the city of Constanta received the name "Little Siberia".

This year's low temperatures in Dobrogea made the Black Sea to freeze over a distance of 100 metres offshore. Beyond the major ice sheet on the sea, other large pieces of ice were observed. This freezing phenomena has proven that the Black Sea is one of the least salty sea in the world. In the case of the Black Sea, salinity values fall between 10-22‰ compared to 35‰ for the Mediterranean Sea.

The last time Black Sea was covered with a layer of ice was five years ago. According to the meteorologists, in the first decade of January 2017 (the time frame for the present study) the temperatures ranged from -160C to -220C. On the 1st of January, at 8:00 AM, the sea temperature was between -20C and +20C and the air temperature ranged from -140C to -160C, so that the surface layer of the sea water vaporized on the contact with the cold air, giving the impression that the sea "boils". This phenomenon of extreme frost rarely occurs only in areas where depths are relatively small along the coastline. On the other hand, the sudden temperature changes are due to global warming, which caused the reducing of the amount of ice in the Arctic. The blocks of ice appeared to have a considerable thickness for 25 days (http://earth-chronicles.com/anomalies /in-bulgaria-for-the-first-time-in-60-years-frozen-black-sea.html).In the case of the present study, satellite images acquired by Sentinel-1 and Sentinel-2 were selected, downloaded from the Copernicus Open Access HUB (https://scihub.copernicus.eu/) and processed using the open source software SNAP-Sentinel Application Platform.

Sentinel-1 is the first satellite launched in the frame of Copernicus - European Programme for Environmental and Security monitoring.

MATERIALS AND METHODS

Sea ice is a rapidly changing phenomenon. Timely measurements over large areas, at high spatial and temporal resolutions, are fundamental for its surveillance. Thus, the identification of risks and opportunities, such as the opening of shipping lanes, are possible thanks to satellite monitoring of sea ice (http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat/Sea_ice).

For example, since 2015, following the various MyOcean programmes that first started back in 2009, the Copernicus Marine Environment Monitoring Service (CMEMS) has been providing regular and systematic reference information on the physical state, variability and dynamics of the ocean and marine ecosystems, for the world's oceans and Europe's seas. The observations and forecasts produced by the CMEMS service support all marine applications. For instance, the provision of data on currents, winds and sea ice help to improve ship routing services, offshore operations and search and rescue operations, thus contributing to marine safety (http://marine.copernicus.eu/).

From the satellite images, analysts are able to extract how much ice there is over areas of interest and how thick it is, so that ice charts can be used to select the safest routes. Satellites provide the majority of information about the development of ice conditions in the Arctic. Sentinel-1(Figure 3) is equipped with a C-band synthetic aperture radar (SAR) that is capable of monitoring irrespective of cloud cover or light conditions, makes it possible to observe sea ice with higher reliability than optical methods and with better resolution than passive microwave ones. The spatial resolution of the GRD (Ground Range Detected) Sentinel-1 products used in this study is 10 meters. The

Sentinel-1 mission details are provided in Table 1 (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/sentinel-1).

Figure 3. Sentinel-1 on orbit (© ESA 2017)

Table 1. Characteristics of the Sentinel-1 mission

Satellite	Launch date	Orbit type and altitude
Sentinel-1A	03 April 2014	Near-polar, sun-synchronous, 690 km, 98.18° inclination
Sentinel-1B	25 April 2016	

Sentinel-2 is a multispectral operational imaging mission within the Copernicus, former GMES (Global Monitoring for Environment and Security) Programme, jointly implemented by the EC (European Commission) and ESA for global land observation (data on vegetation, soil and water cover for land, inland waterways and coastal areas, and also provide atmospheric absorption and distortion data corrections) at high resolution with high revisit capability to provide enhanced continuity.

The satellite requires excellent pointing accuracy and stability and, therefore, high-end orbit and attitude control sensors and actuators. The multispectral imager is the most advanced of its kind, integrating two large visible near-infrared and shortwave infrared focal planes, each equipped with 12 detectors and integrating 450,000 pixels.

Pixels that may fail in the course of the mission can be replaced by redundant pixels. Two kinds of detectors integrate high-quality filters to isolate the spectral bands perfectly. The instrument's optomechanical stability must be extremely high, which has meant the use of silicon carbide ceramic for its three mirrors and focal plane, and for the telescope structure itself (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/sentinel-2).

Sentinel-2 (Figure 4) has a multi-spectral optical sensor acquiring data in 13 spectral bands. The spatial resolution of the GRD (Ground Range Detected) Sentinel-1 products used in this study is 10 meters, while the spatial resolution of the MSI (Multi-Spectral Instrument) Sentinel-2 products is 10 m, 20 m and 60 m, depending on the spectral band (B2, B3, B4, B8 – highest resolution, B5, B6, B7, B8a, B11, B12 – medium resolution and B1, B9, B10 – lowest resolution). Sentinel-2 mission details are provided in Table 2.

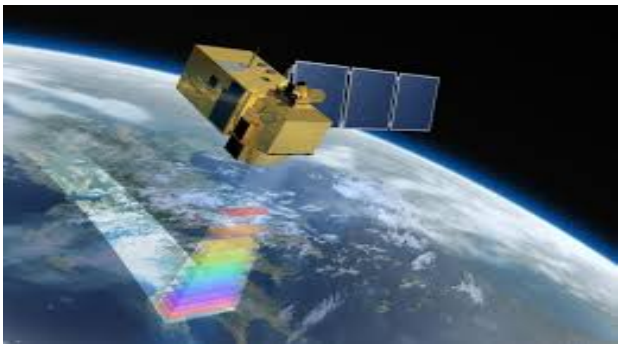

Figure 4. Sentinel-2 on orbit (© ESA 2017)

Table 2. Characteristics of the Sentinel-2 mission

Satellite	Launch date	Orbit type and altitude
Sentinel-2A	23 June 2015	Near-polar, sun-synchronous, 786 km, 98.50° inclination
Sentinel-2B	07 March 2017	

In the present study, two satellite images were downloaded from the Copernicus Open Access HUB. The Sentinel-1 image was acquired on the 9th of January, while the Sentinel-2 image was acquired on the 13th of January. The following processing steps were applied for the processing of the GRD Sentinel-1 image: orbit file application, calibration, speckle filtering and geocoding (based on a DEM). In case of the level-1C Sentinel-2 image, the data contain top-of-atmosphere reflectances in cartographic geometry.

RESULTS AND DISCUSSIONS

The following image windows illustrate some instances of the freezing Danube Delta, both in Sentinel-1 and Sentinel-2 imagery. Figures 5-8 are samples of Sentinel-1 data showing rivers parts unaffected by ice, while figures 9-15 illustrate ice floes, both on Sentinel-1 and 2.

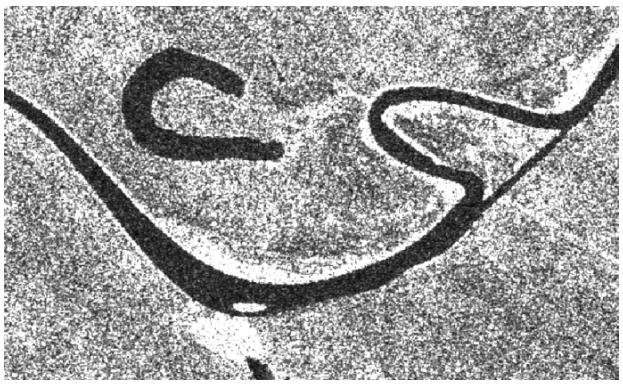

Figure 5. Processed Sentinel-1 image – river area without ice floes (example 1)

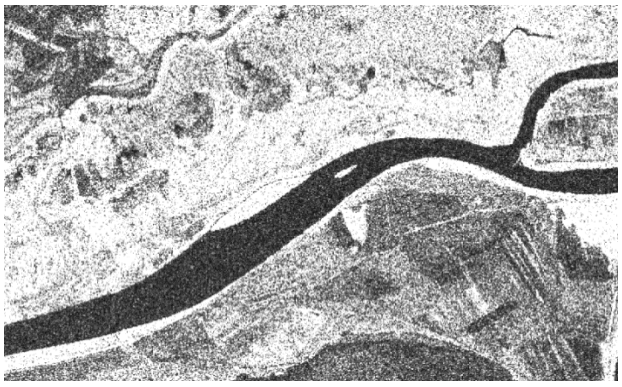

Figure 6. Processed Sentinel-1 image – river area without ice floes (example 2)

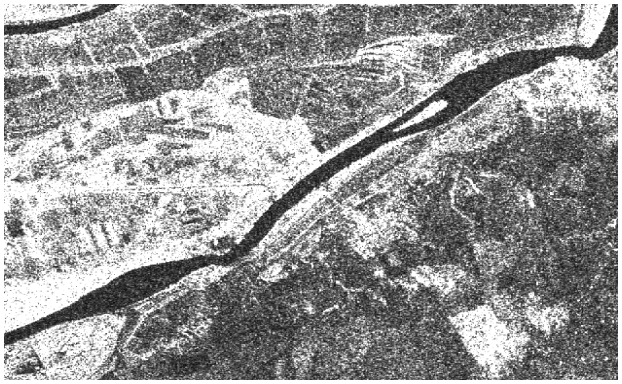

Figure 7. Processed Sentinel-1 image – river area without ice floes (example 3)

Figure 8. Processed Sentinel-1 image – river area without ice floes (example 4)

Figure 9. Processed Sentinel-1 image – river area with ice floes (example 1)

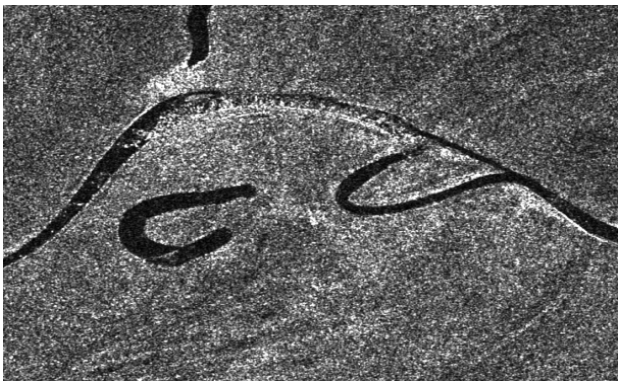

Figure 10. Processed Sentinel-1 image – river area with ice floes (example 2)

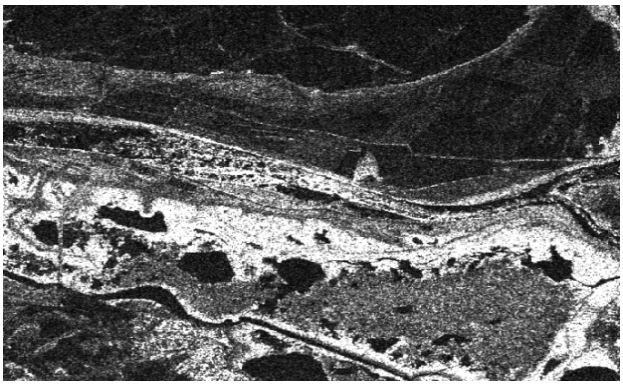

Figure 11. Processed Sentinel-1 image – river area with ice floes (example 3)

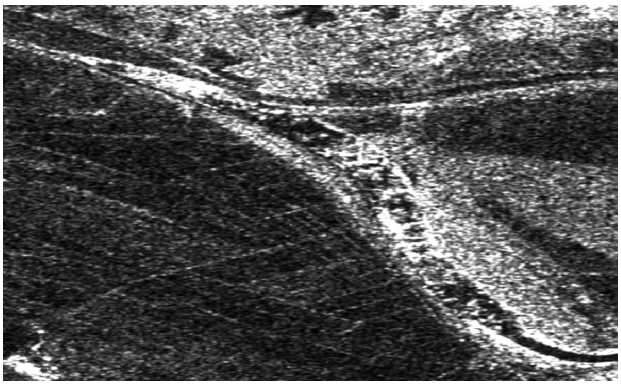

Figure 12. Processed Sentinel-1 image – river area with ice floes (example 4)

Figure 13. Sentinel-2 image (false colour infrared) – river areawith ice floes (example 1)

Figure 14. Sentinel-2 image (false colour infrared) – river area with ice floes (example 2)

Figure 15. Sentinel-2 image (natural colours) – river area with ice floes (example 3)

Figure 16. Sentinel-2 image (false colour infrared) – Razim Lake

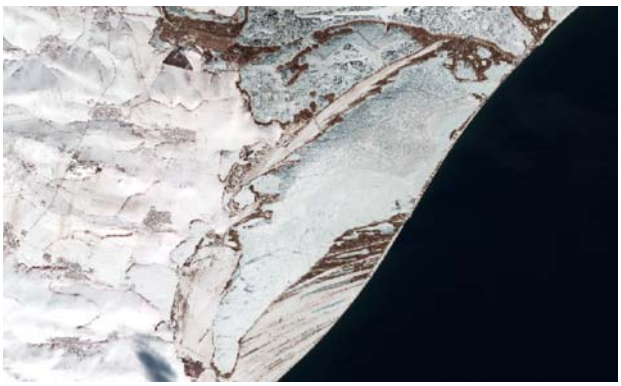

Figure 17. Sentinel-2 image (false colour infrared) – Sinoe Lake

CONCLUSIONS

Satellite data are the optimal solution for monitoring very large areas. The high spatial and spectral resolution of Sentinel enable the detailed monitoring of the different features on the ground, such as large blocks of ice on the navigable channels. With the great advantage of being free and immediately available for the users, Sentinel data can provide critical information for the responsible authorities, just by using visual interpretation without any advanced processing tools. Within the Copernicus Programme, ESA offers free and open access to Sentinel imagery and to data processing tools as well.

Earth Observation data offer necessary information for emergency and disaster management. Satellite remote sensing data and its derived products are essential components in the management of emergency situations. The integration of ancillary data improves the quality and content of the disaster crisis maps offering the guarantee of the in situ collected basic information. The knowledge of the studied area, from the geographical point of view, is vital.

A monitoring service for the Danube River and the Danube Delta can be successfully developed based on Sentinel data, considering the large number of interested parties, i.e. private and public port and marina operators, security, law enforcement and defence agencies, border control, commercial and leisure mariners, harbour responsible authorities, marine insurers, national naval authorities, fishermen organisations and last but not least, scientists from oceanography, riverine and marine environment and ecology.

REFERENCES

AGERPRES: Tulcea – Traficul navelor fluvial pe Dunare, afectat de sloiuri,https://www.agerpres.ro/social/2017/01/08/tulcea-traficul-navelor-fluviale-pe-dunare-afectat-de-sloiuri-13-22-06.

Copernicus Marine Monitoring Service, http://marine.copernicus.eu/, accessed March 2017.

Copernicus Open Access Hub – Open Hub, https://scihub. copernicus.eu/, accessed March 2017.

ESA: Black Sea From Space Workshop http://esa conferencebureau.com/2016-events/16c17---n-black-sea/background, accessed March 2017.

ESA – Earth Online: What is Seninel-1? https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/sentinel, accessed March 2017.

ESA – Earth Online: What is Seninel-2? https://earth.esa.int/web/guest/missions/ esa-operational-eo-missions/sentinel-2, accessed March 2017.

European Space Agency: Observing the Earth - Cryosat http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat/Sea_ice, accessed March 2017.

Romania: Natural and Cultural, The Danube Delta, http://romaniatourism.com/danube-delta.html, accessed March 2017.

The Earth Chronicles of Life – International News. http://earth-chronicles.com/anomalies/in-bulgaria-for-the -first-time-in-60-years-frozen-black-sea.html, accessed March 2017.

UNESCO: World Heritage List, Danube Delta description, http://whc.unesco.org/en/list/588, accessed March 2017.

Ziarul de Tulcea: Apele din Delta Dunării – Oameni aflaţi în situaţii de maximă urgenţă medical rămân captive între apele îngheţate ale Dunării, http://ziaruldetulcea.ro/apel-din-delta-dunarii-oameni-aflati-in-situatii-de-maxima-urgenta-medicala-raman-captivi-intre-apele-inghetate-ale-dunarii/, accessed March 2017.