GUIDE 03: MAPPING PRODUCTS AND SHORELINE ANALYSIS

Sébastien Delbour, Vera Gastal (Collecte Localisation Satellites, France); Josep Pardo Pascual, Jesús Palomar Vázquez, Carlos Cabezas Rabadán (Universitat Politècnica de València, Spain); Clara Armaroli (University of Bologna and IUSS Pavia, Italy)

1. ECFAS aims

The main aims of the ECFAS project concerning the Mapping components were to (i) improve the efficiency and performance of Copernicus Emergency Management Service (CEMS) On-Demand Mapping component through the provision of forecasted flood extent and impact layers in support of image analysis; (ii) implement new coast-targeted product such as the observation of shoreline displacements (beach erosion impact) in the aftermath of a storm event and beach recovery analysis.

2. ECFAS glossary

Shoreline: alongshore position defining the boundary between land and sea.
SDS, Satellite-Derived Shoreline: shoreline position obtained from satellite images.
SAET, Shoreline Analysis and Extraction Tool: algorithm for the identification of the shoreline position from satellite images.
Ground-truth data: information accurately defining the position of the water/land boundary with an accuracy level higher than the one associated with the use mid- and high-resolution satellite images (i.e., ground-truth data are derived from sources of information with a higher spatial resolution).

3. Methods

The Copernicus EMS On-Demand Mapping component addresses a wide range of emergency situations resulting from natural or manmade disasters. The service is provided in two modules:

- Rapid Mapping (RM) service consists in delivering satellite-derived data and maps within hours or days, immediately following a catastrophic event.
- Risk & Recovery Mapping (RRM) service consists in delivering satellite-derived data and maps within weeks or months, in support of activities dealing with preparedness, disaster risk reduction and recovery phases. Thematic information is provided for different hazards on the exposure, vulnerability and resilience of people and infrastructures.

CEMS On-Demand Mapping component provides geospatial information layers and ready-to-print maps related to pre- and post-event situations. Outputs are derived from optical or SAR satellite image analysis performed by means of semi-automatic classification techniques (e.g., calculation of spectral indices and thresholding) and visual interpretation. Any other kind of reference or in-situ data (e.g., high resolution Digital Elevation Model) can be used, if available, to support the analysis.

Mapping products:

One of the main limitations of CEMS Rapid Mapping is the time between the activation of the service and the image availability to conduct the impact analysis of the event (current target is 24h). ECFAS aims to support the immediate response phase of coastal flooding in a relevant way. Thus, the early warning system would not only provide the opportunity to request image acquisition in advance, but also layers of information giving a first estimate of the impact and help in the analysis of satellite images by CEMS Rapid Mapping. Methods used for generating forecasted flood extent and impact

This project has received funding from the European Union's Horizon 2020 programme under Grant Agreement No 101004211

as well as the results are described in the dedicated guide (refer to *Guide 02: flood and impact maps*).

Satellite-based mapping of flood extent and impact on assets has also been produced over more than a dozen of sites which were severely affected by remarkable historical storms from the last decade. The same image analysis methods have been implemented as for CEMS On-Demand Mapping component and the results were used for LISFLOOD-FP model calibration (see *Guide 02: flood and impact maps*).

Shoreline analysis:

ECFAS purpose is to provide tools that will add value to the existing methodologies of CEMS. The innovative shoreline extraction methodology would also contribute significantly to CEMS Risk & Recovery Mapping. Pre-event shoreline position and its evolution in the aftermath of a storm event is indeed a crucial information especially for assessing erosion risk and monitoring beach recovery.

The capacity of the shoreline extraction tools currently available in the literature as CoastSat (Vos et al., 2019 a, b) and SHOREX (Sánchez-García et al., 2020; Cabezas-Rabadán et al., 2021) to detect the shoreline position and to implement a new semi-automatic mapping methodology was assessed. A new algorithm was developed and tested on sixteen sites across Europe, considering different morpho-sedimentary and oceanographic conditions. The new solution is named SAET (Shoreline Extraction and Analysis Tool; Palomar-Vázquez et al., 2022, in review) that analyses and extracts the shoreline position on mid- to high-resolution optical satellite images (Sentinel 2 or Landsat 8, 9). Satellite Derived Shoreline (SDS) extracted using CoastSat, SHOREX and SAET were compared to ground-truth data derived from coastal video-monitoring systems and from very high-resolution images (VHR1 and VHR2 available through the Data Warehouse mechanism of ESA) in order to evaluate their accuracy.

4. Results

In order to demonstrate the value of the geospatial information generated by ECFAS, the results obtained on a selection of case studies are presented in the web platform:

- XYNTHIA storm (February 2010), La-Faute-sur-Mer site (France)
- GLORIA storm (January 2020), three sites on the Mediterranean coast of Spain (Girona, the Ebro delta and Castellon)
- EUNICE storm (February 2022), The Hague site (Netherlands)

These are the events for which the impacts observed by satellite image analysis were the most significant.

ECFAS model-based vs. satellite-based mapping products

Users of the platform are free to visually compare the results derived from the analysis of satellite images with the impact information provided prior to events by the models developed, tested and integrated in ECFAS (Figure 1). This would be a timely and reliable source of data in particular for the CEMS Rapid Mapping service providers to support and facilitate satellite image analysis and increase performance during activations.

Shoreline displacement and recovery

Regular mapping of the coastline position based on available satellite images before and after a storm also allows monitoring and understanding whether coastal erosion is taking place, and which is the magnitude of beach recovery through time. This information could feed into a new specific map product as part of the CEMS Risk & Recovery Mapping service.

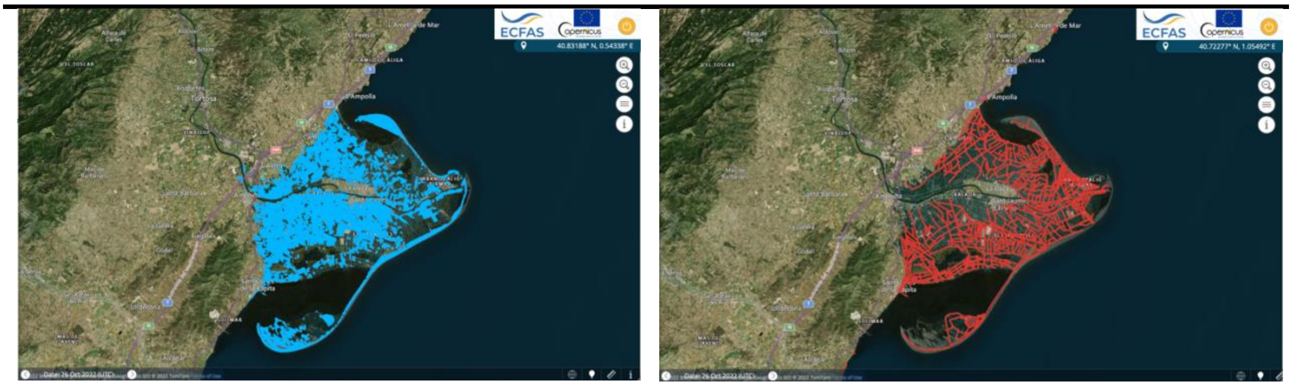

Figure 1: ECFAS web platform view showing the flooded area extent (satellite-based product) on the left and ECFAS impact layers on roads on the right. Ebro delta, Spain. Gloria storm (January 2020).

The assessment of the SDSs obtained with SAET shows that the tool is a robust solution, with good accuracy levels even for meso-tidal and exposed coasts. The algorithm shows some limitations in beaches with saturated sand and puddles in the intertidal zone that may cause landward bias of the shoreline position and reduce the accuracy of the SDS. Nevertheless, in general the resulting SDS are highly accurate, offering errors of the same magnitude as the other available solutions in the literature (i.e., CoastSat and SHOREX). Mapping shorelines through the analysis of satellite images before and after storm events enables the identification of beach changes (Figure 2), as well as the quantification of shoreline retreat and the possible beach recovery through time. Ready-to-print maps showing these results with relevant statistics are finally available for download for each of the events and sites selected as demonstration cases.

Figure 2: ECFAS web platform view showing shoreline analysis after the Gloria storm (January 2020), Ebro delta, Spain: purple line is the 11 January 2020 pre-event shoreline; violet line is the 10 February 2020 post-event shoreline (both analysed with SAET on L8 satellite images).

5. References

Cabezas-Rabadán, C., Pardo-Pascual, J. E., & Palomar-Vázquez, J. (2021). Characterizing the Relationship between the Sediment Grain Size and the Shoreline Variability Defined from Sentinel-2 Derived Shorelines. Remote Sensing, 13(14), 2829. https://doi.org/10.3390/rs13142829

Sánchez-García, E., Palomar-Vázquez, J. M., Pardo Pascual, J. E., Almonacid-Caballer, J., Cabezas-Rabadán, C., & Gómez-Pujol, L. (2020). An efficient protocol for accurate and massive shoreline definition from mid-resolution satellite imagery. Coastal Engineering, 103732. doi: 10.1016/j.coastaleng.2020.103732

Palomar-Vázquez, J., Cabezas-Rabadán, C., Almonacid-Caballer, J., Fernández-Sarría, A., & Pardo-Pascual, J.E. (2022). Shoreline Analysis and Extraction Tool (SAET): una nueva herramienta para monitorizar los cambios en la línea de costa. In XI Jornadas de Geomorfología Litoral. Galicia 2022, pp. 217-221. DOI https://dx.doi.org/10.15304/9788417595487

Palomar-Vázquez, J., Pardo-Pascual, J.E. Almonacid-Caballer, J., Cabezas-Rabadán, C. (in review). Shoreline Analysis and Extraction Tool (SAET): a new tool for the automatic extraction of satellite-derived shorelines with subpixel accuracy. Coastal Engineering, SI ECFAS.

Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. L. (2019a). CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. Environmental Modelling & Software, 122, 104528.104528. https://doi.org/10.1016/j.envsoft.2019.104528

Vos, K., Harley, M. D., Splinter, K. D., Simmons, J. A., & Turner, I. L. (2019b). Sub-annual to multidecadal shoreline variability from publicly available satellite imagery. Coastal Engineering, 150, 160-174. https://doi.org/10.1016/j.coastaleng.2019.04.004

How to cite this document: Sébastien Delbour, Vera Gastal, Josep Pardo Pascual, Jesús Palomar Vázquez, Carlos Cabezas Rabadán, Clara Armaroli (2022). Guide 02: mapping products and shoreline analysis. H2020 ECFAS project (GA 101004211), www.ecfas.eu

Find out more about the datasets and how to cite them here and refer to Deliverable 3.1 – Deliverable 3.2 - Deliverable 5.5