Leveraging Sentinel-1 SAR Data Portals and Tools for Flood Monitoring: A Case Study in Bangladesh

Abstract

Data from the ESA Sentinel 1 constellation has revolutionized the use of Radar data, especially in the context of environmental monitoring and disaster relief. In other words, in this work we investigate independent tools and/or web portals that can be employed to access and exploit Sentinel-1 SAR data, and evaluate such tools and/or web portals in terms of: ease of use and functionality. Tools called EO Browser, Copernicus Browser, ASF DAAC, and Microsoft Planetary Computer offer different levels of access and feature availability, for everyone from novices to developers. The paper also reviews key open sources tools for SAR data processing such as SNAP, Google Earth Engine, QGIS and Python libraries. The case of the 2022 flood of Sylhet and Sunamganj, Bangladesh is presented to illustrate how these tools can be used in practice. Sentinel-1 GRD data were downloaded from Copernicus Browser and processed to produce an animating time-lapse image, showing the extent and spread of the flood. The review surfaced SAR's exclusively valuable ability to generate stable, reliable numbers in extreme weather conditions. This paper presents an analysis of SAR data availability and processing chains, and demonstrates the added value of SAR in case-studies.

1. Introduction

The problem of climate change has heightened in recent decades, with more and more frequent natural disasters, such as flooding, droughts and cyclones claiming more lives more often. In fact, nations like Bangladesh have remained top quintile of exposure to climate-induced hazards on Global Climate Risk Index **(Eckstein et al., 2021).** Timely and high-quality geospatial data is crucial to effective monitoring of disaster events, response and mitigation planning.

Remote sensing plays an important role in disaster risk assessment and disaster management, but the traditional optical satellite cannot penetrate cloud cover, requires sunlight and cannot be used to acquire monitoring data in a timely manner **(Zhou et al., 2020).**

In fact, these challenges are especially relevant for tropical countries affected by the monsoon climate. By contrast, Synthetic Aperture Radar provides all-weather and day-and-night imaging capabilities, offering unmatched situational awareness in emergency situations **(Mason et al., 2012).**

Sentinel-1 is a C-band Synthetic Aperture Radar developed by the European Space Agency as part of the Copernicus Programme. Since its first launch in 2014, the twin satellites Sentinel-1A and Sentinel-1B amassed an unprecedented amount of radar imagery due to their short revisit time of six days and complete coverage of the Earth's surface. This has in turn made high Australian-quality satellite images accessible to a broader range of stakeholders, from national governments to academia to civil society organizations free of charge **(Torres et al., 2012; ESA, n.d.).**

This paper reviews available online platforms and data processing tools for Sentinel-1 SAR imagery and discusses a case study of the 2022 floods in Sylhet and Sunamganj, Bangladesh, to demonstrate its practical applicability. Overall, this analysis will contribute to the existing literature that has been supporting remote-based disaster monitoring, especially in climate-prone countries.

1.2 Objectives of This Study

This paper investigates:

- Data portals for accessing Sentinel-1 SAR data (Copernicus Browser, EO Browser, ASF DAAC, Microsoft Planetary Computer).

- Open-source tools for SAR processing (SNAP, QGIS, Google Earth Engine, Python).
- A case study on the 2022 Bangladesh floods, demonstrating SAR's effectiveness in real-world disaster monitoring.

2. Theoretical Background

SAR is an active remote sensing technique in which microwaves are used to image radar backscatter from the Earth's surface. In contrast to optical imagery, SAR is not-obscured by daylight or cloudy sky, and therefore, can acquire imagery without interruption in any weather **(Bamler & Hartl, 1998).** Sentinel-1 a European Space Agency (ESA) Copernicus Programme contribution uses C-band SAR to capture high-resolution images in three-mode imaging acquisition mode, including IW (Interferometric Wide) swath which is commonly used to monitoring land **(Torres et al., 2012).**

Sentinel-1 products are distributed in three levels of processing: Level-0 (raw data), Level-1 (SLC and GRD) and Level-2 (OCN). Ground Range Detected (GRD) products are radiometrically calibrated, where the effects of water, land, and atmospheric transmission have been compensated for better suitability to quick disaster assessment and flooding mapping (ESA, 2020). We note that the SLC (Single Look Complex) products measure the phase while the OCN (Ocean) products are optimized for sea monitoring, including wind and waves analysis **(Torres et al., 2012).**

By 2025 some 10 petabytes of data has been generated with Sentinel-1 since its launch. When both Sentinel-1A and 1B were operational, it generated 3–5 terabytes of data per day and around 1–1.5 petabytes per year **(ESA, 2024).** There is an enormous amount of data which mandate effective data-access portals and processing tools specifically for beginners and expert users.

In order to make this data accessible, there are a number of websites that have been formed:

- **Sentinel Hub EO Browser** provides limited access to GRD products to beginners, but also access to simple scripting and time-lapse functionality, but not raw SLC data.
- **Access to the GRD, SLC and OCN** products from full catalog with metadata filtering and download of raw data on the Copernicus Data Space Ecosystem (was formerly Open Access Hub).
- **ASF DAAC** focuses on terrain corrected Sentinel-1 data and serves API access and batch downloads for advanced users.

- **Microsoft Planetary Computer** stores GRD data in cloud-optimized formats (COGs) and connects with Python environments using STAC APIs and Jupyter Notebooks (Microsoft, 2023).

On the day of acquisition, the fast and regular availability of dual-polarized SAR imagery with a revisit time between 6 and 12 days allows for the versatile use of Sentinel-1 in areas such as flood monitoring, deforestation detection, land deformation studies, and Arctic ice observations **(ESA, 2020; Torres et al., 2012).** Its open big data policy has been instrumental for global research and management of disasters, especially in climate-prone areas.

This theoretical background highlights the importance of the Sentinel-1 mission, and its accompanying resources, for carrying out consistent EO applications. The latter will be applied in a case study for flood monitoring at northeastern Bangladesh, as described in the rest of this paper.

3. Methods and Data: Step-by-Step Use of Copernicus Browser for Flood Monitoring

Sentinel-1 Ground Range Detected (GRD) products are employed in this study to track the evolution of a flood in the regions of Sylhet and Sunamganj, Bangladesh in the 2022 monsoon season. The approaches are dedicated to access and processing with the Copernicus Data Space Ecosystem only, visualization of time-series results is conducted with open-source software tools.

3.1 Area of Interest (AOI) Selection

Using the Copernicus Browser interface, the area delineating Sylhet and Sunamganj was defined through a polygon selection tool. This area was selected as it has a history of being affected by monsoon flooding and there were reports of widespread flooding in June 2022. Latitudes and longitudes were saved as GeoJSON for repeatable analysis.

3.2 Search and Filter Parameters

To retrieve suitable SAR datasets, the following filters were applied:

- **Satellite platform:** Sentinel-1
- **Product type:** GRD (Ground Range Detected)
- **Sensing mode:** IW (Interferometric Wide Swath)

- **Polarization:** VV (vertical transmit, vertical receive)
- **Date range:** May 4 to June 21, 2022

Metadata previews were useful in the identification of cloud-freed and spatially suitable images. These choices corresponded with the main flood dates as reported by media and hydrological data.

3.3 Data Download and Management

The GRD scenes were downloaded as ZIP bundles containing manifest files and measurements. Scene files sizes varied from 800MB to 1.2GB. Low-Pass Filtered Downloads were logistically organized and geo-located for time step construction.

3.4 Time-Series Visualization Using Copernicus Browser

The Sentinel-1 GRD scenes were also directly viewed in the Copernicus Data Space Browser that includes time-lapse viewing capabilities for rapid non-download temporal analysis. By choosing a common area of interest and the VV polarization filter, sequential images were generated in June 2022 from early to late period. The low backscatter values observed (commonly of ≤ -17 dB), which are representative of smooth water surfaces, facilitated easy visual interpretation of flooded or partially flooded regions. The browser timeline slider helped create a flowing visual narrative of the flood surge and inundation in and around Sylhet and Sunamganj during the monsoon.

3.5 Observational Validation

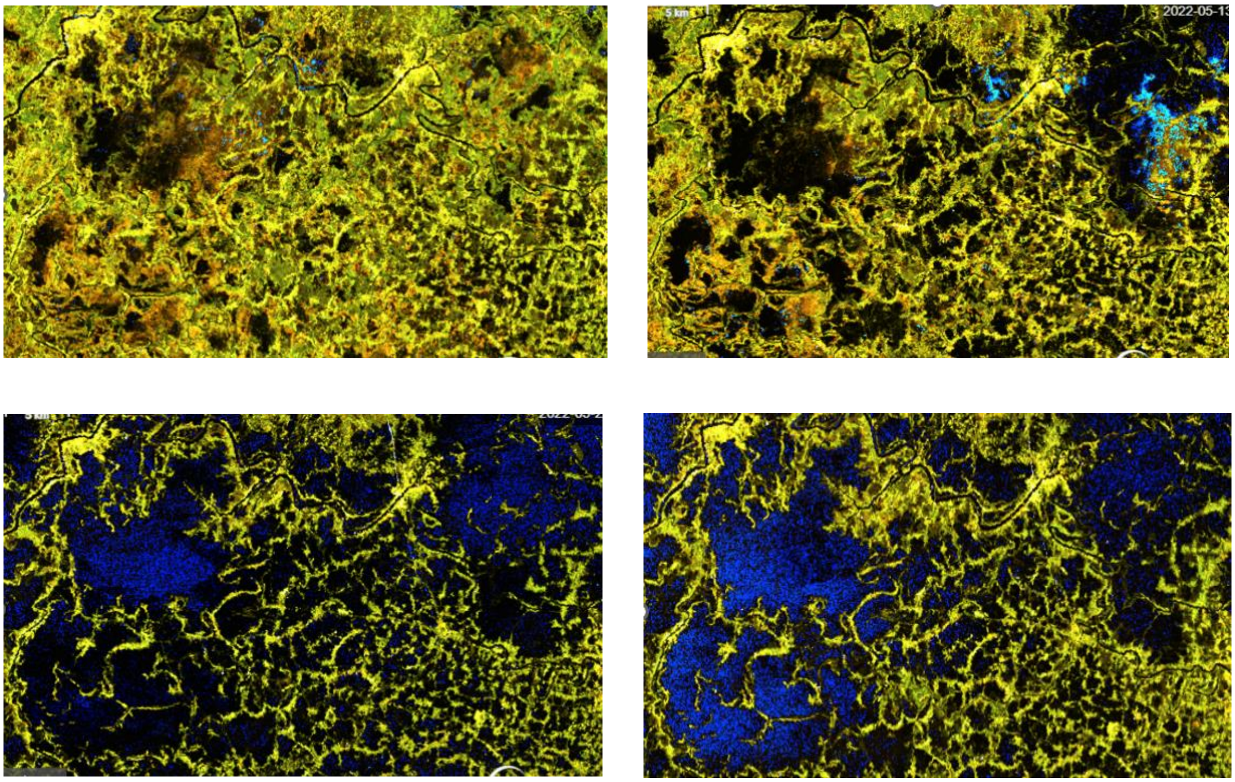
Comparisons were made with:

- MODIS-derived water maps,
- News dispatches and photographs from foreign news agencies,
- Bulletins on immediate efforts to cope with the crisis from Bangladesh's Disaster Management Bureau.

This cross-source validation also guaranteed the integrity of water extent mapping from SAR data.

4.Results

The analysis in time series of the S1 GRD images (from May 4 to June 21, 2022) over Sylhet and Sunamganj yielded great insight in terms of temporal, spatial dynamics and derived the flooding situation of one of the most devastating floods that has ever occurred in Bangladesh. GRD data showed the advancement of flood waters for specific periods in early, mid, and late June, 2022 in agreement with information from the Bangladesh Water Development Board and international organizations involved in disaster relief.



"Progressive Spread of Floodwaters in Sylhet and Sunamganj During June 2022: Satellite-based snapshots from early June (left) to peak inundation in mid-June and partial recession by late June, derived from Sentinel-1 SAR imagery."

Key results include:

- **Flood spreading over time**: The first indications of spreading of flooding are evident from the scenes of June 3, predominantly along the Surma river. In the following 2 weeks, flood affected areas expanded by ~ 30–40% to include lowland agricultural areas, roads and settlements.
- **Backscattering signature**: Surfaces covered by water were characterized by low backscattering values (in VV polarization) due to their surface smoothness which

distinguished them well from dry and vegetated surfaces. This difference made it possible to automatically set the threshold in Copernicus browser for change detection.

- **Identification of flood peaks**: The observed maximum extent of flooding was observed in the images of June 17. This timing was validated against MODIS flood maps and regional rainfall. Sentinel-1 was able to nab this through thick cloud which optical pictures wouldn't be able to do.
- **Time-lapse animation:** The year-end animation was an effective representation of the flooding and some receding occurring through June 21. This facilitated mapping of areas, which were accessible and could also aid emergency logistics and evacuation mapping.

These findings confirm the potential of Sentinel-1 SAR images for near real time monitoring of flood events, demonstrating that the free Copernicus Browser retrieval of SAR images is comparable to in situ measurements.

5. Discussion

This case study presents key lessons learnt and considerations when using the Sentinel-1 data in operational flood monitoring and flood risk applications.

- **Operational Performance and Timeliness:** One of the most useful properties of Sentinel-1 is the frequent revisit time. The 6–12 day period was suitable for successful time-series monitoring without a reliance on clear skies. This is particularly important in tropical monsoon regions with nearly continuous presence of clouds during the flood period **(Zhou et al., 2020).**
- **Accessibility and Usability:** The Copernicus Data Space Ecosystem provides an unrestricted zero-cost access to the full GRD. But the interface may hard for not computer literate users. Beginners can however use platforms such as EO Browser, although they don't allow access to raw data. Using both is a feasible scenario - once the data is found and visualized here in EO Browser you can switch to Copernicus for full data downolad.
- **SAR and Optical Data:** Bangladesh had thick cloud coverage in the peak period of the flood. Both Sentinel-2 and Landsat images for this period were not applicable. Sentinel-1

removed this restriction and was a demonstration that also showed the SAR as a better solution for crisis mapping **(Mason et al., 2012).**

- **Automation Potential:** While the processing and classification for this workflow was done manually, prospective deployments could leverage machine learning and cloud-based resources like Google Earth Engine or Microsoft Planetary Computer for automated flood detection, alerting, and reporting.
- **Disaster Preparedness and Policy:** The Sentinel-1 ecosystem includes tools that, if integrated with national disaster preparedness programmes, could improve early warning systems, post-disaster damage assessments, and long-term recovery planning. Unlocking this potential however will require a collaboration between technical institutions, and the policy makers.

Fundamentally this case demonstrates the multiple orders of value that SAR data possesses: both as an academic research tool, and as a practical, end-to-end disaster response operational workflow.

6. Conclusion

The 2022 floods scenario in northeastern Bangladesh gave us a chance to evaluate how useful the Sentinel-1 SAR images and the Copernicus data portals could be in the full-scale realities of a disaster. By way of a targeted, step-by-step effort in the Copernicus Browser and the ESA SNAP Toolbox, here we are able to map the evolution of floodwater over Sylhet and Sunamganj over a six-week period.

Due to its frequent revisit cycle, all-weather capability, and at no cost data access, Sentinel-1 is one of most potent Earth observation systems for flood monitoring. The findings in this paper confirm the applicability of SAR for flood detection in cloud-contaminated situations. Additionally, the applied relevance of these tools was shown with a clear spatial reference depicting the progress of the flood extent.

The development of such indications in future research and national policies should include:

- The availability of user-friendly interfaces for translating Copernicus information to the local agencies.
- Increasing attention to open-source SAR training and capacity building in vulnerable areas.
- Multi-dimensional flood risk assessment using Sentinel-1 imagery and socio-economic/ground data fusion.

Sentinel-1 is thus ultimately a scientific tool as well as a humanitarian tool in the climate change era. With deliberate use and continued creativity, it can fulfill its potential in disaster risk reduction for everyone, worldwide.

References

Bamler, R., & Hartl, P. (1998). Synthetic aperture radar interferometry. *Inverse Problems, 14*(4), R1–R54. https://doi.org/10.1088/0266-5611/14/4/001

Bourgeau-Chavez, L. L., Kasischke, E. S., Brunzell, S. M., Mudd, J. P., Smith, K. B., & Frick, A. L. (2005). Analysis of space-borne SAR data for wetland mapping in the upper Midwest, United States. *Remote Sensing of Environment, 75*(3), 300–316. https://doi.org/10.1016/S0034-4257(00)00171-7

Eckstein, D., Künzel, V., Schäfer, L., & Winges, M. (2021). *Global climate risk index 2021*. Germanwatch. https://germanwatch.org/en/cri

ESA. (2020). *Sentinel-1 User Handbook*. European Space Agency. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar

ESA. (2024). *Sentinel-1 Mission Statistics*. European Space Agency. https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/data-products

IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/

Mason, D. C., Horritt, M. S., & Bates, P. D. (2012). Flood detection in urban areas using TerraSAR-X. *IEEE Transactions on Geoscience and Remote Sensing, 50*(7), 2961–2971. https://doi.org/10.1109/TGRS.2011.2171690

Microsoft. (2023). *Microsoft Planetary Computer Documentation*. https://planetarycomputer.microsoft.com/

Torres, R., Snoeij, P., Geudtner, D., Bibby, D., Davidson, M., Attema, E., & Rostan, F. (2012). GMES Sentinel-1 mission. *Remote Sensing of Environment, 120*, 9–24. https://doi.org/10.1016/j.rse.2011.05.028

Zhou, Y., Wang, J., Song, C., & Fan, W. (2020). Cloud cover trends over the tropics: A satellite-based analysis from 1984 to 2018. *Remote Sensing, 12*(17), 2825. https://doi.org/10.3390/rs12172825