OGC Disasters Resilience Pilot User Guide

Flood - Emergency Response and Impact Assessment

by RSGIS, Wuhan University

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Chapter 1. Introduction

Floods are far and away the most common natural disaster worldwide and account for the most deaths. The deadliest disaster of the 20th century was the China floods of 1931, which resulted in more than a million deaths (1931 China floods, https://en.wikipedia.org/wiki/1931_China_floods). The Chinese administrative jurisdictions are spending increasing time and resources to assist communities and citizens to prepare, respond and recover from flood disasters.

The goal of the Disaster Resilience pilot is to develop and demonstrate user guides to build reliable and powerful data infrastructures that make all data required for decision making, analysis, and response in a flooding, hurricane, or wildfire situation available in a cost-effective way. The initiative will bring data and infrastructure experts together to exercise specific scenarios. Focus is on disaster resilience but exercised together with additional scenarios that have similar interoperability challenges.

This user guide provides guidance for using a series of data services and geoprocessing services based on OGC standards to build the capabilities of flood emergency response and impact assessment, thus help the head, officers and researchers of Ministry of Emergency Management, and China National Commission for Disaster Reduction (NCDR) to understand the disaster situation, help them make decisions.

Data Interoperability and open standards are core to SDIs for disasters and other similar contexts, as they enable the exchange of geospatial data and efficient use of data in the processing, visualization and representation services in distributed systems. A recent OGC Disasters Interoperability Concept Development Study proposed an initiative architecture, which utilizes a set of standardized service interfaces that allow well-defined access to data, following the OGC standards baseline. The geospatial vendors in China are also developing SDI infrastructure and services for disaster responses.

This user guide provides guidance for using the remote sensing imagery data sources provided by Hainan Earth Observation Institute, Chinese Academy of Sciences and elsewhere (Sentinel-1, Sentinel-2, etc.), as well as USGS land use/cover data, etc., to contribute to the successful implementation of Scenario 1. Flood. We focus on the scenario of flood, where massive remote sensing data is collected and computed to obtain inundated area for further use, such as damage evaluation and disaster relief.

The user guide addresses the proposed disaster emergency service platform, which enables sharing and accessing large-scale disaster data, especially remote sensing data. The platform provides stable and powerful database backend, which manages large volume of data with multiple data types. To support data interoperability, data access services such as WFS and WCS, as well as WPS and workflow services are published on the platform. In addition, a web-based visualization tool is also developed for interactive analysis.

1.1. Flood Scenario: Typhoon Mangkhut &Dianmu

This user guide presents the flood scenario based on 2 use cases: Typhoon Mangkhut hit South China in September 2019, and Typhoon Dianmu hit Hainan province in August 2018. The goal is to demonstrate how multi-source geospatial datasets can be used generate the right information to the right person at the right time. The section below briefly outlines the use cases and demonstrate what capabilities could provide to the target end users, why these information are important to them.

1.2. Use Cases

The first use case demonstrates the scenario of Typhoon Mangkhut and Flooding at Guangdong Province, China in 2018. The platform generates the typhoon track and impact area according to the information/message from National Meteorological Center, China Meteorological Administration (CMA) and uses population destiny to calculate the time-series impact population and the resident activity distribution. It also provides path allocation service for the emergency rescuer and relief supplies.

The second use case shows the scenario of Hurricane Dianmu & Flooding at Hainan, China in 2016. The platform provides flood extraction data products and the inundation area calculation. In addition, it also provides the impact transportation facilities (road, bridge, railway) data products, the impact public infrastructures (villages, school, hospitals) data products and the statistical analysis.

1.3. User Guide Organization

Chapter 2 introduces the simple architecture in terms of data and formats, data providers and data users.

Chapter 3 describes the general use cases by user activity, includes details on the use case and end users.

Chapter 4 briefly outlines how the right data are passed to the right person.

Chapter 5 presents the detailed description of the scenario and the description of the tools used in the demonstration.

The final Chapter 6 lists any issues encountered and makes future recommendations.

Chapter 2. Simple Architecture

This section provides an architectural overview, that includes the main architecture (see Figure 1) and data storage framework (see Figure 2). The main architecture demonstrates the workflow of how we use massive multi-source data and scientific models to provide effective services for the flood disaster assessment and decision making. The data storage framework demonstrates our data management logics and structures by using some cutting-edge technologies. The section also provides the overview of the Data providers, Catalogs and Data users for the disasters pilot scenario.

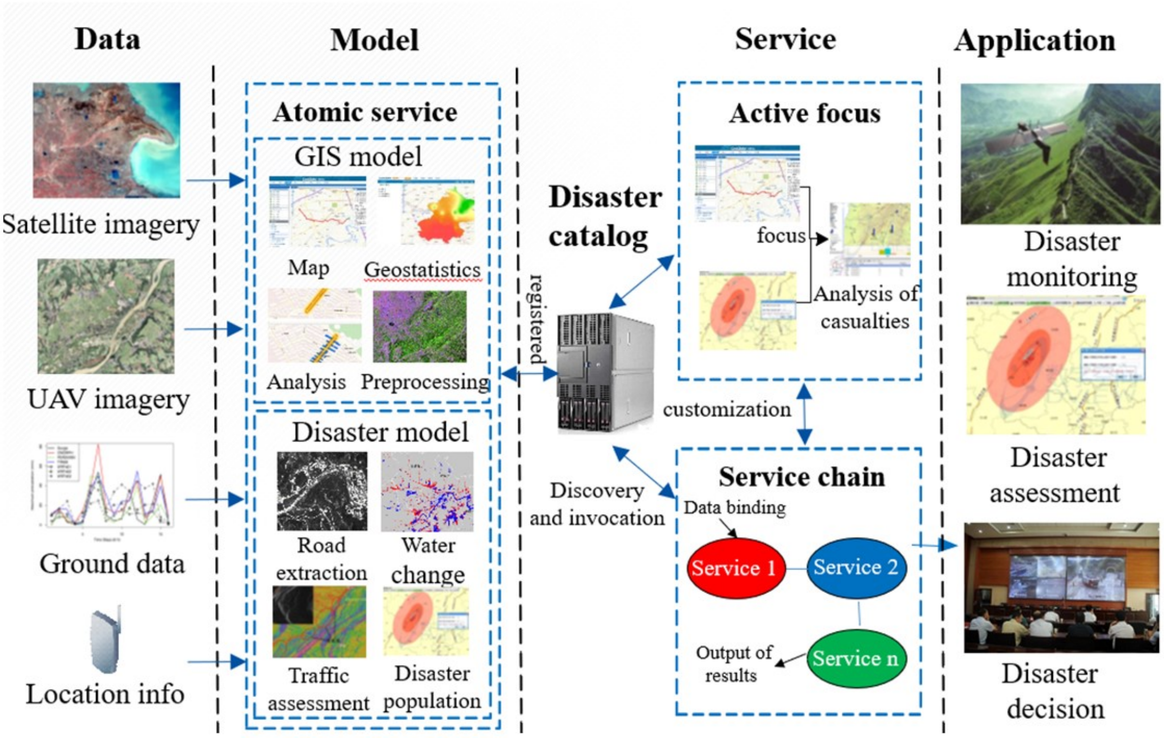
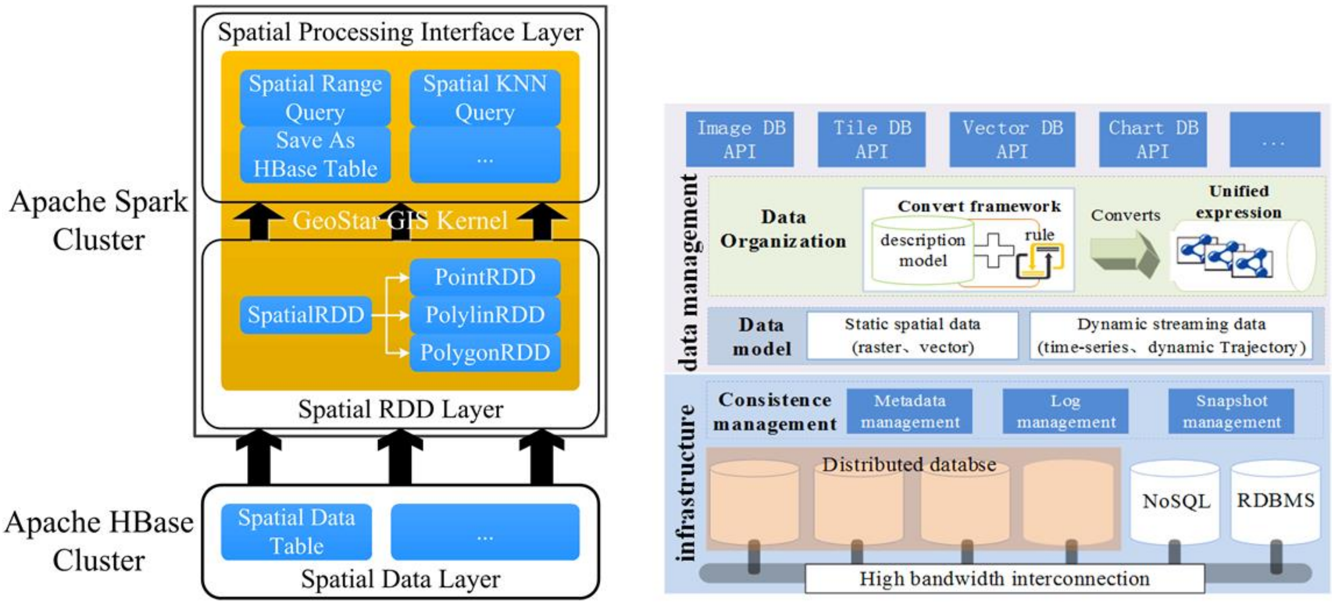


Figure 1. Main Architecture



Distributed data storage

Spark processing for Vector Data

Figure 2. Data Storage Framework

2.1. Data Provider

Major data providers are as follows:

- Hainan Earth Observation Institute, Chinese Academy of Sciences (http://gfdc.hainan.gov.cn/)
- National Meteorological Center (http://www.nmc.cn/)
- Department of Emergency Management of Hainan Province (http://lbs.tianditu.gov.cn/server/MapService.html)
- Map World (http://lbs.tianditu.gov.cn/server/MapService.html)
- Worldpop (https://www.worldpop.org/geodata/summary?id=131)
- GPM (https://pmm.nasa.gov/data-access/downloads/gpm)
- OpenStreetMap (https://www.openstreetmap.org/)

2.2. Catalog Providers

Major catalogs used in this Pilot are as follows:

- Sentinel high resolution satellite data was obtained from Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus/#/home
- GaoFen-1 high resolution satellite data was obtained from China Centre for Resources Satellite Data and Application data hub: http://218.247.138.119:7777/DSSPlatform/index.html
- Chinese Administrative division and Annotation data was obtained from MapWord data hub: http://lbs.tianditu.gov.cn/server/MapService.html
- Chinese population density data was obtained from the University of Southampton portal:

https://www.worldpop.org/

2.3. Data Consumers

Flood data products are used by a wide variety of governmental agencies, research institutes and industrial organizations. The following data consumers are considered in this flood scenario:

- Ministry of Emergency Management (governmental agency & first responder)
- China National Commission for Disaster Reduction (governmental agency)

Chapter 3. General Use Cases by User Activity

This section provides details on the use case and end user.

3.1. Publication of data

- Flood inundation map derived from GaoFen-1 satellite image: A workflow using GaoFen-1 remote sensing image to extract flood inundation area is set up to be run event by event where the data from GaoFen-1 constellation become available. Data are published as OGC WMTS and WFS services.
- Flood inundation map derived from Sentinel-1 (A/B) satellite image: A workflow using remote sensing image to extract flood inundation area is set up to be run event by event where the data from Sentinel-1 constellation become available. Data are published as OGC open standards for easy access using WMTS and WFS services. Impact assessment for facilities and infrastructures: The impacted road, railway, bridges, hospitals, schools, villages and population data are published as OGC WMTS and WFS services.
- Path allocation: By using path allocation geographic model based on real-time Baidu traffic data, path allocation service is published as OGC WPS services

3.2. Registration of data

- Flood inundation maps derived from GaoFen-1 satellite image are registered in GeoPlatform and the platform of Department of Emergency Management of Hainan Province.
- Flood inundation maps derived from Sentinel-1(A/B) satellite image are registered in GeoPlatform and the platform of Department of Emergency Management of Hainan Province.
- The impact assessment for facilities and infrastructures services are registered in GeoPW (Geospatial Processing Web, https://geos.whu.edu.cn/) platform and shared through a disaster pilot group.
- Path allocation service is registered in GeoPW platform and shared through a disaster pilot group.

3.3. Discovering of data

The data sets used during flood disasters are numerous. In the presented scenario, datasets are used that would typically be made available during disaster, the data and use cases presented here can be repeated for any other flood disaster. The following catalogs are consulted to find the impact assessment data and services:

- Accessing the official website of Department of Emergency Management of Hainan Province
- GeoPW
- GEOSS Registry

3.4. Downloading of data

The following data and service interfaces are primarily used in downloading products.

- OGC Web Map Tile Service (WMTS) & Web Map Service (WMS) for rendering and Web-based visualization
- OGC Web Coverage Service (WCS) for coverage data access
- OGC Web Feature Service (WFS) for vector data access
- OGC Web Processing Service (WPS) for geoprocessing service access

3.5. Data Integration

Integration of data with social data sources to analyze the disaster impacts - road, railway, bridges, hospitals, schools, villages and population.

3.6. Republication of data

The Flood inundation maps and integrated results of impact assessment will be republished based on OGC standard services (WMS, WMTS, and WFS) and registered into catalogs.

3.7. Displaying of the data with proper symbology

All WMS data sources used have proper symbology and comply with OGC standards.

3.8. References

- China Centre for Resources satellite data and application, URL: http://218.247.138.119:7777/DSSPlatform/index.html
- Department of Emergency Management of Hainan Province, URL: http://gfdc.hainan.gov.cn/, http://zh.hainan.gov.cn/portal/index.html
- National Meteorological Center, URL: http://www.nmc.cn/
- Windy, Wind map and weather forecast, URL: https://www.windy.com/
- USGS, GeoPlatform, URL: https://geoplatform.gov
- USGS, AmeriGEOSS Data Hub, URL: https://data.amerigeoss.org/
- GeoPW, URL: http://geos.whu.edu.cn/

Chapter 4. Special Topics

This section provides a description of any or all of the following special topics. It includes the following sections

4.1. Right data for the right user

This scenario aims on providing near real-time data and services to help the first responder such as Ministry & Department of Emergency Management to save time and resources when assisting communities and citizens to prepare, respond and recover from flood disasters.

A series of remote sensing-based thematic analysis maps can be generated and served through the story line of flooding event, such as the flood inundation map, the impacted road, railway, bridges, hospitals, schools, villages and population. These data products and services are republished as OGC WMTS, WMS, WFS and WPS, provide on-line impact assessment to the user and help them with the decision making.

The Event time Steps are as follows:

- First hour: Disaster platform construction and simulation (preparation of platform deployment and test).
- The next 18 hours: EO data acquisition and pre-processing (Acquisition of satellite remote sensing data after the disaster□geometric calibration□radiation correction□atmospheric correction).
- The next 2 hours: Flood inundation extraction (NDWI calculation of both pre-disaster and post-disaster images, Image binarization after NDWI, Extracting water body boundary vector, Analysis of inundation area after the disaster).
- The next 2 hours: Comprehensive assessment of disaster based on multi-source data (Impact population, Impact transportation facilities (road, bridge, railway), Impact public infrastructures (villages, school, hospitals, buildings)).
- The final 8 hours: Disaster emergency decision-making results report (Formulation of decision-making plans for post-disaster disaster relief and rescue assistance).
- Repeat the above steps at make the impact assessments 48hours & 72hours after the disaster.

Chapter 5. Scenarios and Tools Demonstration

This section provides a detailed description of the scenario(s) and the description of the tools used in the demonstration.

5.1. Flood

Floods are far and away the most common natural disaster worldwide and account for the most deaths. The deadliest disaster of the 20th century was the China floods of 1931, which resulted in more than a million deaths(https://en.wikipedia.org/wiki/1931_China_floods). The Chinese administrative jurisdictions are spending increasing time and resources to assist communities and citizens to prepare, respond and recover from flood disasters.

5.2. Audience

- Ministry and Department of Emergency Management (governmental agency & first responder)
    - Head - the decision-maker of disaster emergency rescue and relief supplies allocation
    - Officers - the responsible people that need to make the plan of disaster event time steps and produce the impact assessment maps
- China National Commission for Disaster Reduction (governmental agency)

5.3. Capabilities and advances for the end users

- Flood data products and the inundation area calculation
- Impact transportation facilities (road, bridge, railway) data products and the length statistics
- Impact public infrastructures (villages, school, hospitals) data products and the statistical analysis based on administrative division.
- Path allocation service for the emergency rescuer and relief supplies.

5.4. Typhoon Mangkhut & Flooding (2018)

End User: Officers and researchers of Chinese National Disaster Reduction Committee (NCDR)

Target area: Guangdong (China)

Description: The Typhoon Mangkhut was an extremely powerful tropical cyclone that caused widespread damage in South China, resulted in a direct economic loss of $5.2 billion, over 3 million people were impacted, 1.6 million people were evacuated. During the flooding events, the NCDR need to provide real-time impact assessment and make plans for resource allocation.

Application service & capabilities proposed to provide:

According to the information/message from the National Meteorological Center, generate the typhoon track and influence field. Use the population destiny data from the sponsors to calculate the time-series affected area and population. Path allocation for emergency rescuer and relief supplies.

First, according to the information from the National Meteorological Center, we can generate and visualize the typhoon track and impact area (see Figure 3). Second, we use the population density data to calculate the time-series impact population and the resident activity distribution (see Figure 4). Finally, based on the real-time traffic, we provide the path allocation service for the emergency rescuer and relief supplies (see Figure 5).

These capabilities could help NCDR with the rapid decision makings. The data and processing services are published based on OGC WMTS, WMS, WFS, and WPS standards, that could be easily accessed online.

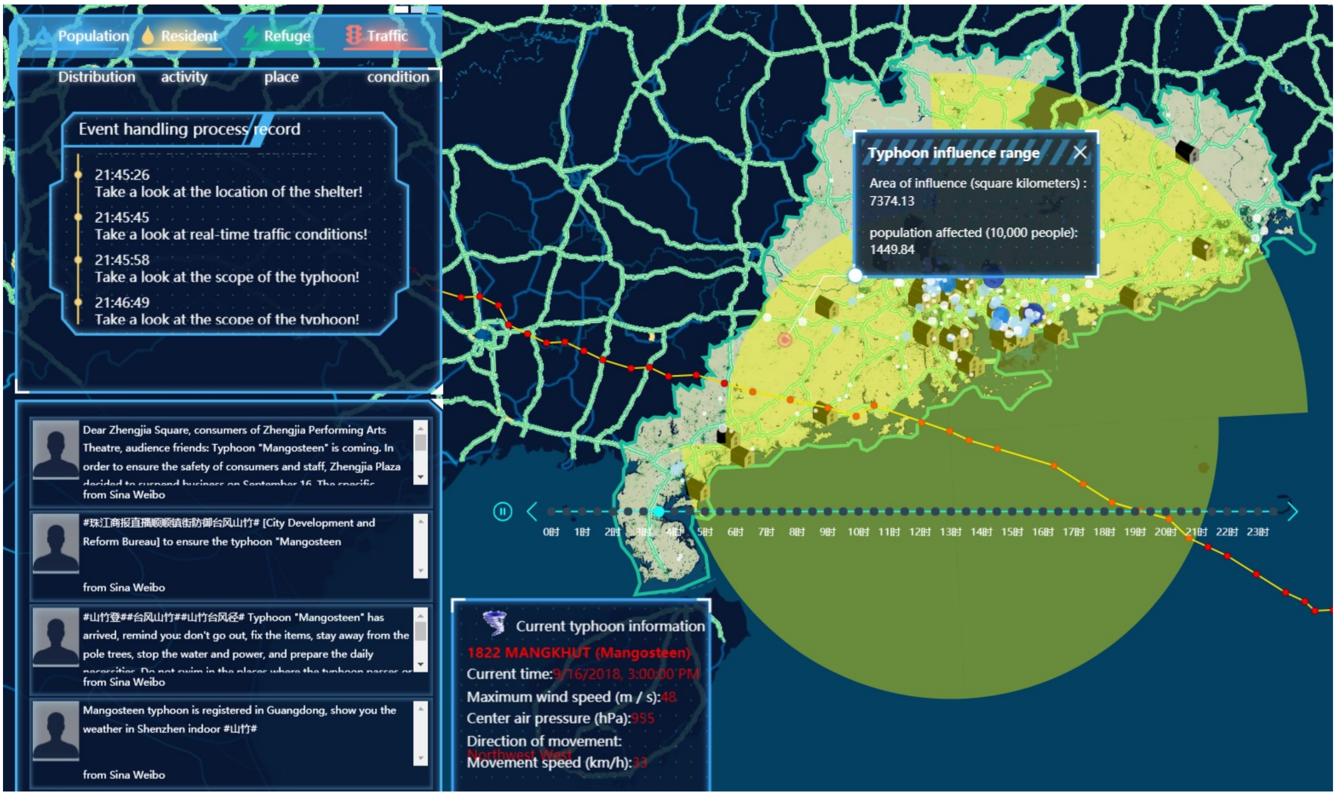


Figure 3. Typhoon track, impact area and impact population

Figure 4. Time-series resident activity distribution

Figure 5. Path allocation service for the emergency rescuer and relief supplies based on the real-time traffic

5.5. Hurricane Dianmu & Flooding (2016)

End User: Head and officers of Ministry of Emergency Management (governmental agency & first responder)

Target area: Hainan (China)

Description: Hurricane Dianmu was a tropical cyclone that struck South China and Northern Vietnam. It brought heavy rain to the western part of Hainan Island, resulted in flood disasters in a lot of cities. Over five hundred thousand people were evacuated, many transportation facilities were impacted, the water level of Nandu River reached a ten-year high of 14 meters. The Ministry of Emergency Management need the rapid damage assessment to make further decisions.

Application service & capabilities proposed to provide:

With the use of remote sensing Image, we can extract the water body of both pre and post-disaster, and generate the flood inundation data products (see Figure 6). Furthermore, we can analyze the impact transportation facilities such as road, bridge, railway and calculate the length (see Figure 7). We can also analyze the impact building facilities such as villages, schools, hospitals (see Figure 8).

All these data products, statistical results, and reports could help the Ministry of Emergency Management make rapid decisions. The data and processing services are published based on OGC WMTS, WMS, WFS, and WPS standards, that could be easily accessed online.

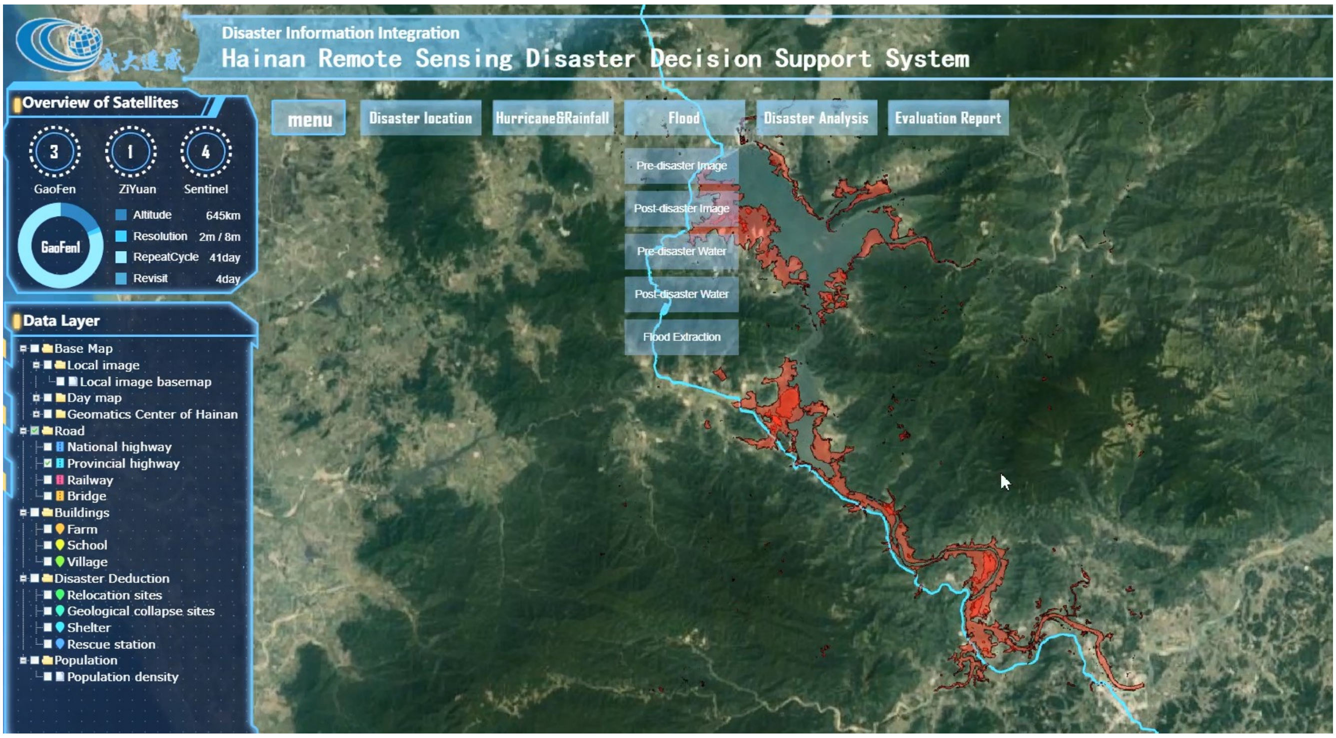


Figure 6. Flood inundation area

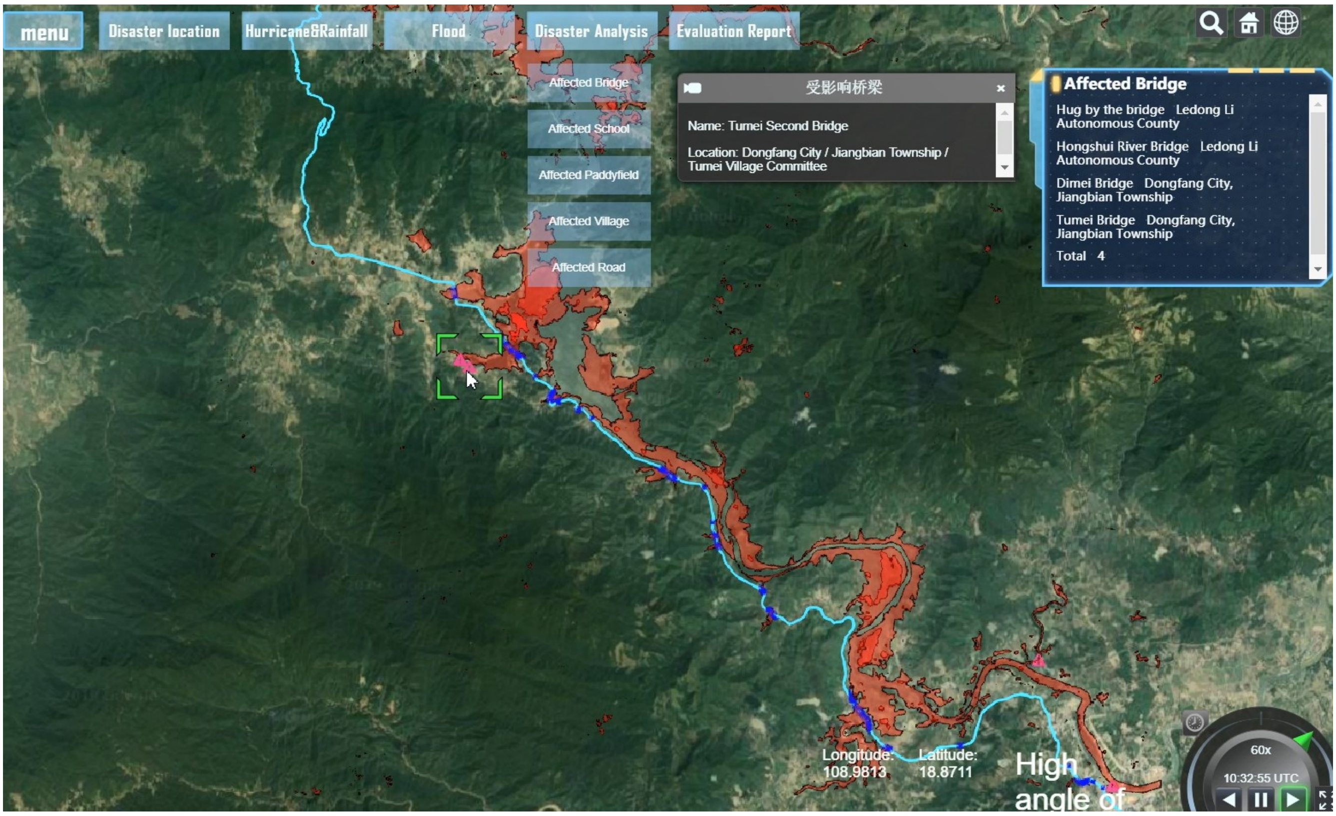


Figure 7. Impact transportation facilities (bridges)

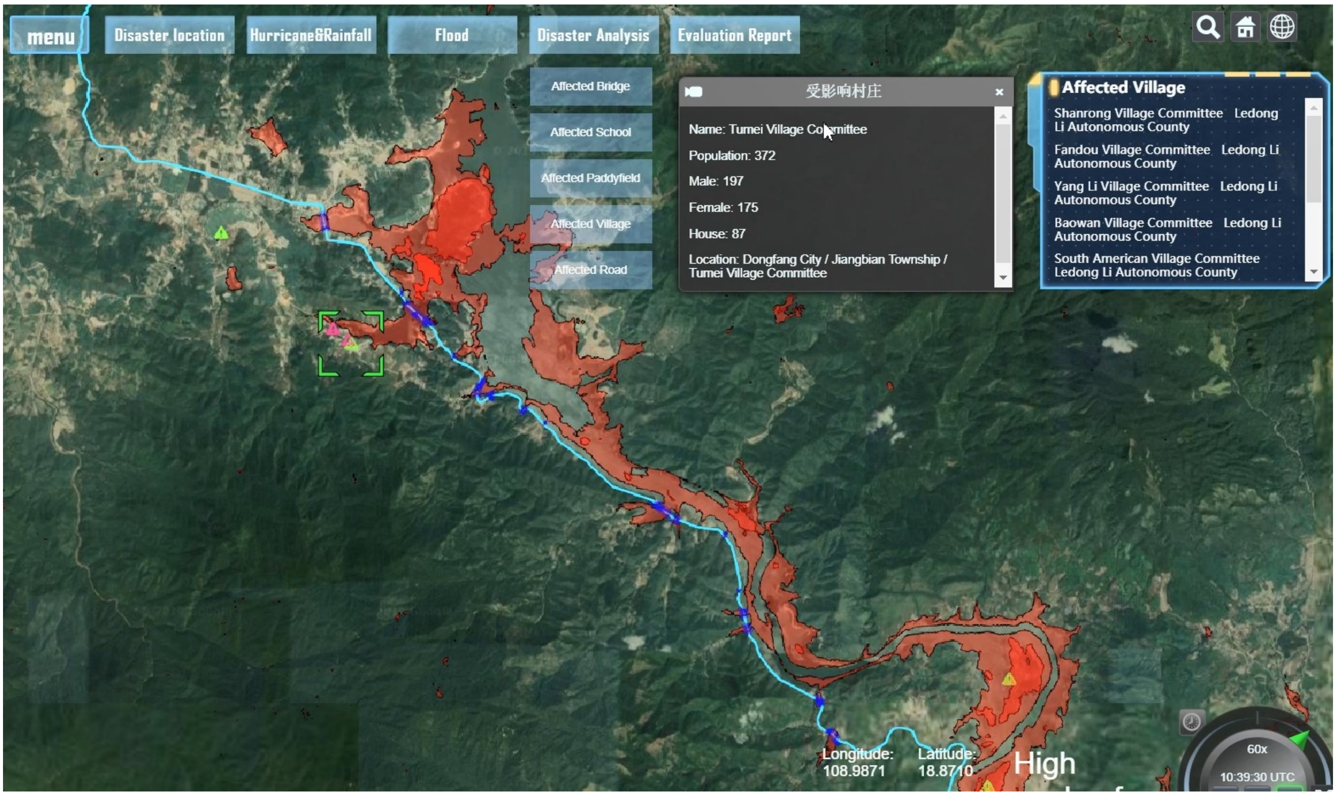


Figure 8. Impact building facilities (villages)

5.6. List of data layers in the scenario:

EO data

(1) GaoFen-1, GaoFen-2. Data source: http://www.cresda.com/CN/, Hainan Earth Observation Institute, Chinese Academy of Sciences http://gfdc.hainan.gov.cn/ (Pre and Post-disaster)

(2) Sentinel-1, Sentinel-2. Data source: https://sentinels.copernicus.eu/web/sentinel (Pre and Post-disaster)

Background

(1) Base Map. Data source: OpenStreetMap, https://www.openstreetmap.org/

(2) Road Map. Data source: OpenStreetMap，https://www.openstreetmap.org/, Map World, http://lbs.tianditu.gov.cn/server/MapService.html

(3) Administrative division. Data source: Map World, http://lbs.tianditu.gov.cn/server/MapService.html, Department of Emergency Management of Hainan Province

Meteorological Data

(1) Typhoon Track. Data source: National Meteorological Center, http://www.nmc.cn/

(2) Precipitation. Data source: GPM, https://pmm.nasa.gov/data-access/downloads/gpm

Thematic analysis

(1) Land cover/Land use. Data source: USGS, http://download.geofabrik.de/asia/china.html, http://download.geofabrik.de/africa/mozambique.html, https://earthexplorer.usgs.gov/

(2) Population density. Data source: Worldpop, https://www.worldpop.org/geodata/summary?id=131, https://www.worldpop.org/geodata/summary?id=139

(3) Main Road, Railway. Data source: Map World, http://lbs.tianditu.gov.cn/server/MapService.html, Department of Emergency Management of Hainan Province

(4) Rescue station, Shelter, Relocation sites, Geological collapse sites. Data source: Department of Emergency Management of Hainan Province

(5) School, Hospital. Data source: Department of Emergency Management of Hainan Province

(6) Village, Farm. Data source: Department of Emergency Management of Hainan Province

Chapter 6. Conclusion and Way Forward

During this pilot, we developed a disaster emergency service platform for sharing and accessing flood related data through Spatial Data Infrastructures (SDIs). The main work we have done is summarized as follows:

- Disaster platform construction and simulation.
- EO data acquisition and pre-processing (Acquisition of satellite remote sensing data after the disaster□geometric calibration□radiation correction□atmospheric correction).
- Flood inundation extraction (NDWI calculation of both pre-disaster and post-disaster images, Image binarization after NDWI, Extracting water body boundary vector, Analysis of inundation area after the disaster).
- Comprehensive assessment of disaster based on multi-source data (Impact population, Impact transportation facilities (road, bridge, railway), Impact public infrastructures (villages, school, hospitals, buildings)).
- Disaster emergency decision-making report (Formulation of decision-making plans for post-disaster disaster relief and rescue assistance).

6.1. Overview of lessons learned during the Disasters Resilience Pilot:

- OGC Disaster Pilot 2019 provides a great opportunity to demonstrate the “right information to the right person at the right time”. Making an objective decision on resources dissemination is only possible when the right data is ready for the right decision-maker to use. With using the powerful online platform such as GeoPlatform, data and services are able to communicate and generate meaningful data for decision-maker at the right time. In this way, it helps administrative jurisdiction save time and resources to assist communities and citizens to prepare, respond and recover from disasters.
- It would be important to locate the end users, figure out what information is important to them and how we using multiple data sources and scientific models to provide the information, these ideas are always running through the system functionalities we designed.
- The scenario and use cases of flood have been demonstrated by leveraging the geospatial Web technologies and OGC open geospatial standards. The pilot applications showed improvements and extended accessibility and interoperability through open geospatial standards.
- It would be important to build reliable and powerful data infrastructures that make all data required for decision making, analysis, and response in a cost-effective way during the flood disaster.
- In this pilot, we use Typhoon “Mangkhut” and “Dianmu” as case studies, which is a way to simulate disasters that have happened in the past. However, the user guide of how we provide impact assessment data products and the event time steps for emergency response would be still applicable for the future disaster.

Appendix A: Abbreviations

- CMA: China Meteorological Administration
- GEO: Group on Earth Observations
- GPM: Global Precipitation Measurement
- NASA: National Aeronautics and Space Administration
- NCDR: China National Commission for Disaster Reduction
- NOAA: National Oceanic and Atmospheric Administration
- URL: Uniform Resource Locator
- WCS: Web Coverage Service
- WFS: Web Feature Service
- WPS: Web Processing Service
- WMS: Web Map Service
- WMTS: Web Map Tile Service