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Open Geospatial Consortium

OGC DISASTER PILOT: PROVIDER READINESS GUIDE

ENGINEERING REPORT

PUBLISHED

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I ABSTRACT

The OGC Disaster Pilot 2021 initiative brought differing technologies together through multiple participants, allowing the future development of a robust solution with no single-point weaknesses. This Guide supports data providers in preparing and coordinating with others to leverage standards-based cloud computing platforms to support disaster management and response efforts. Geospatial data is acquired from multiple sources, including Earth Observation satellites, and converted to Decision Ready Information and indicators (DRI) from Analysis Ready Data and datasets (ARD) alongside recipes.

II EXECUTIVE SUMMARY

When a disaster strikes, disaster relief drives the need to quickly integrate and analyze real-time data streams from multiple sources to plan responses and monitor the evolving situation. Scalable cloud-based systems can bring sizable resources, but components need to be linked through pre-agreed standards. The OGC is at the center of the geospatial marketplace that allows the exploration and testing of state-of-the-art technologies. Therefore, it can uncover market capacities and capabilities and serve as an accelerator for market research activity while at the same time demonstrating the integration potential native to OGC Innovation Program activities.

The web-based publication of “structured data” can link well-known content with up-to-the-minute situation observations, enabling search engines to raise the importance of disaster-relevant information in search results and help the public stay aware of fast-moving events.

Application Programming Interfaces (APIs) and download-and-go GeoPackages can bring Decision Ready Information and indicators (DRI) directly to field workers’ mobile devices even in resource-constrained, low-connectivity areas. The generation of DRIs is supported by data transformation and preparation technologies, geospatial standards, and data sharing arrangements that bring the correct information at the right time to the right people in the right place. The inputs include Analysis Ready Data and datasets (ARD), which is data in a format that can immediately be integrated with other geospatial data, and applied to recipes that convert these diverse sources into actionable and decision ready information necessary to support disaster managers and responders in their demanding and time sensitive roles.

Within the OGC Disaster Pilot 2021 (termed Pilot), differing technologies were brought together through multiple participants, allowing the future development of a robust solution with no single-point weaknesses. These community activities become ever more important as the ability of technology to provide disaster responders with invaluable information improves.

This Provider Guide supports data providers in preparing and coordinating with others to leverage standards-based cloud computing and real-time data sharing & collaboration platforms in support of disaster management and response efforts. It showcases what was developed and tested in the Pilot, alongside describing the standards that have been explored and integrated.

III KEYWORDS

The following are keywords to be used by search engines and document catalogues.

Disasters, Natural Hazards, Landslides, Health, SDI, Analysis Ready Data, ARD, Decision Ready Information, Flood, Indicators, Emergency Response, Health, Pandemic, ogcdoc, OGC document, DP21, ogcdoc, OGC document, Disaster Pilot, Provider Readiness Guide

IV PREFACE

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V SECURITY CONSIDERATIONS

No security considerations have been made for this document.

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1

SCOPE

1 SCOPE

This Provider Guide supports data providers in preparing and coordinating with others to leverage standards-based cloud computing and real-time data sharing & collaboration platforms in support of disaster management and response efforts. It showcases what was developed and tested in the Pilot, alongside describing the standards that have been explored and integrated. The Pilot has also produced a User Readiness Guide [1].

2

TERMS, DEFINITIONS AND ABBREVIATED TERMS

2 TERMS, DEFINITIONS AND ABBREVIATED TERMS

This document uses the terms defined in OGC Policy Directive 49, which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this document and OGC documents do not use the equivalent phrases in the ISO/IEC Directives, Part 2.

This document also uses terms defined in the OGC Standard for Modular specifications (OGC 08-131r3), also known as the ‘ModSpec’. The definitions of terms such as standard, specification, requirement, and conformance test are provided in the ModSpec.

For the purposes of this document, the following additional terms and definitions apply.

2.1. Terms and definitions

2.1.1. ARD

Analysis Ready Data and datasets — This is raw data that have had some initial processing created in a format that can be immediately integrated with other information and used within a Geographical Information System (GIS).

2.1.2. CRS

Coordinate Reference System — coordinate system that is related to the real world by a datum term name (source: ISO 19111)

2.1.3. DRI

Decision Ready Information and indicators — ARDs that have undergone further processing to create information and knowledge in a format that provides specific support for actions and decisions that have to be made about the disaster.

2.1.4. Indicator

Indicator — An indicator is a realistic and measurable criteria.

2.1.5. Lidar

Light detection and ranging — a common method for acquiring point clouds through aerial, terrestrial, and mobile acquisition methods.

2.1.6. GeoNode

GeoNode — a web-based platform for deploying a GIS.

2.1.7. GeoPackage

GeoPackage — an open, standards-based, compact format for transferring geospatial information.

2.1.8. GeoRSS

GeoRSS — designed as a lightweight, community driven way to extend existing RSS feeds with simple geographic information.

2.1.9. GeoServer

GeoServer — a Java-based server that allows users to view and edit geospatial data. Using open standards set forth by the Open Geospatial Consortium (OGC), GeoServer allows for great flexibility in map creation and data sharing.

2.1.10. JSON-LD

JavaScript Object Notation — Linked Data — a lightweight linked data format based on JSON.

2.1.11. Jupyter Notebooks

Jupyter Notebooks — an open-source web application that allows the creation and sharing of documents that contain live code, equations, visualizations and narrative text.

2.1.12. Radar

Radio detection and ranging — a detection system that uses radio waves to determine the distance (range), angle, or velocity of objects.

2.1.13. REST API

REST API — is a Representational State Transfer Application Programming Interface more commonly known as REST API web service. When a RESTful API is called, the server will transfer a representation of the requested resource's state to the client system.

2.1.14. **SAR**

Synthetic Aperture Radar — a type of active data collection where a sensor produces its own energy and then records the amount of that energy reflected back after interacting with the Earth.

2.2. Abbreviated terms

ACD	Amplitude Change Detection
API	Application Programming Interface
COG	Cloud Optimized GeoTIFF
CONIDA	National Commission for Aerospace Research and Development's, Peru
EGS	Emergency Geomatics Service
ENSO	El Niño/Southern Oscillation
EO	Earth Observation
EODMS	Earth Observation Data Management System
ESIP	Earth Science Information Partners
ETL	Extract, Transform and Load
FME	Feature Manipulation Engine (Safe Software)
GIS	Geospatial Information System
GISMO	New York City Geospatial Information System & Mapping Organization
HRD	High Resolution Data
IR	InfraRed
JSON	JavaScript Object Notation
JSON_LD	JavaScript Object Notation — Linked Data
LEO	Low Earth Orbit
MTC	Multi-Temporal and Coherence
NAOMI	New AstroSat Optical Modular Instrument

NIR	Near-InfraRed
NOAA	National Oceanic and Atmospheric Administration, US
NRCan	Natural Resources Canada's
NRT	Near-Real-Time
OLI	Operational Land Imager
ORLs	Operational Readiness Levels
OSM	OpenStreetMap
RCM	RADARSAT Constellation Mission
SDI	Spatial Data Infrastructure
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
STAC	SpatioTemporal Asset Catalog
S3	Amazon Simple Storage Service
TIRS	Thermal Infrared Sensor
VGI	Volunteered Geographic Information
WCS	Web Coverage Service
WFS	Web Feature Service
WKT	Well-Known Text
WMTS	Web Map Tile Service

3

INTRODUCTION

3 INTRODUCTION

The OGC Disaster Pilot 2021 (abbreviated to the “Pilot”) aimed to further improve the ability of key decision-makers and responders to discover, manage, access, qualify, share, and exploit location-based information in support of disaster preparedness and response and multi-hazard risk analysis. Within it, the following key components of a geospatial information flow for disaster management operations were considered:

- **Reduced Time to Discover, Access, and Transform Data:** Near-real-time cloud-based discovery, processing, and access of Analysis Ready Data (ARD) from diverse sources.
- **Analysis and Decision Ready Services:** Analysis, visualization, and collaboration processes enabling generation of situation-appropriate, Decision-Ready Information and indicators (DRI).
- **Decision Support:** On-demand and event-driven dissemination of DRI to responders, decision-makers, and other disasters stakeholders.
- **Mobile Devices:** Usage of offline data containers to work with DRI in the field under connected-disconnected conditions.
- **Work the Web:** Enhancements to data services to optimize discoverability by mainstream search engines and potential of linked data approaches to improve public awareness and sharing.

3.1. Geospatial Data

Geospatial data can be defined as data that describes objects, events, or features using a location on the Earth’s surface, and the simplest form of presenting such information is on a map. Whilst the earliest maps began with the Babalyonians and Greeks in the 6th Century BC; the use of geospatial data in disasters is a bit more recent. Arguably, one of the first uses was in 1854 when Dr. John Snow mapped, by hand, the deaths from a cholera outbreak in London. Earth Observation (EO) started around the same time as Dr. Snow’s map when Gaspard-Felix Tournachon took photographs of Paris from his balloon in 1858. However, it was a century later with the launch of the Explorer VII satellite in 1959 and TIROS 1 weather satellite in 1960 that satellites were used to make observations of the Earth.

The game-changer, which started the industry, was the launch of NASA’s Earth Resources Technology Satellite in 1972: The first real mapping satellite. It was later renamed to Landsat-1 beginning what has developed, to date, into an almost fifty-year archive of satellite observations of the planet. Other space agencies around the world have also launched EO missions including the European Space Agency (ESA) who are involved with the European Union’s Copernicus program, and the Japanese Space Agency (JAXA) that have the National Security Disaster

ALOS-3 optical and ALOS-4 microwave missions, and the Canadian Space Agency (CSA) whose RADARSAT series of satellites support disaster monitoring activities.

Satellite remote sensing in disaster management situations took a step forward with the signing of the International Charter: Space and Major Disasters on 22 October 2000 by ESA, the French Space Agency (CNES), and the Canadian Space Agency. Currently, there are 17 contributing members including the US Geological Survey (USGS) and the National Oceanic & Atmospheric Administration (NOAA). This charter is triggered when a disaster situation occurs and makes satellite data available from different space agencies around the world, providing access to a wide range of data by the teams responding and managing the specific disaster. Since its inception, the Charter has been activated for 692 disasters in 127 countries, and during 2020 it was activated 55 times in 33 countries.

Together, satellites and geospatial technologies such as Geospatial Information System (GIS) offer the potential to provide disaster responders with invaluable information. This information can be used to support both the planning and the implementation of the response, through maps and information, directly to the field responders on the ground, an awareness of the current situation. Therefore, providing access to these technologies allows saving lives and helping people respond to disaster events. Unfortunately, whilst the idea is great in principle, several practical issues can prevent these resources' best use.

4

OVERVIEW

4 OVERVIEW

- Clause 3 introduces the provider guide.
- Clause 5 discusses the use of geospatial information in Disaster Response.
- Clause 6 presents an overview of readiness.
- Clause 7 provides a focus on provider readiness.
- Clause 8 presents the proposed approach for the technical solution.
- Clause 9 presents the technical solution that was developed.
- Clause 10 provides a summary of the pilot outcomes and results.
- Clause 11 discusses the next steps and recommendations.
- Annex A provides the first application: Landslide/flooding hazards and pandemic impacts within Peru’s Rimac and Piura river basins.
- Annex B provides the second application: Flooding hazards and pandemic impacts within the Red River basin in Manitoba, Canada.
- Annex C provides the third application: Integration of Health and EO data and services for pandemic response in a region of the United States.

5

USE OF GEOSPATIAL INFORMATION IN DISASTER RESPONSE

5 USE OF GEOSPATIAL INFORMATION IN DISASTER RESPONSE

5.1. Historic use

The application of satellite remote sensing to disaster management support under an international framework began around 2000 when satellite-based Earth Observations (EO) for rapidly assessing disaster situations globally (namely, response support) were started by the International Charter Space and Major Disasters. After 4 years of operations, user feedback was collated (Ito, 2005) and shortcomings highlighted:

- The average response time was reported as always being better than five days but not seen as being sufficient for real-time monitoring.
- Even with an integrated EO system, users still could not have access to the data when they wanted it; a combination of Charter activation and insufficient EO systems made real-time monitoring of each disaster not a reality.
- The data acquired were not always useful as availability was limited by meteorological and geographical factors.

The Emergency Management Service (EMS) of the Copernicus Program is an operational service; there was a precursor R&D activity and it started operationally in April 2012. As reported by Denis (2016) for activations between June 2011 and March 2015, the time from activation to first delivery was around 9.5 hours for data from an archive and 6.5 hours (55% within 3 hours) for a new acquisition. For the Charter, the paper reported delivery for the first crisis image being 1.3 days in 2014, and so this was a reduction on that previously reported by Ito(2005).

JAXA conducted a user survey (Kaku, 2019) after the 2011 Great East Japan Earthquake, between August 2011 and March 2012, and the conclusions included:

- Numerous general users requested the establishment of a framework to supply satellite images free of charge and quickly in an emergency, which needed to include data providers (space agencies), data analysts (universities, research institutes, etc.), and users (disaster management organizations).
- Users wanted the data to cover the entire disaster management cycle (preparedness, response, and recovery).
- International collaboration was seen as essential for disaster management support, particularly in the case of catastrophic disasters.

- Feedback from users on each disaster event was seen as valuable to data providers; whether it went well or not.

Also, a review from the 2011 US Midwestern Floods (Sivanpillai et al., 2017), supported through the Charter, concluded:

- To increase the chances of obtaining cloud-free or partially clouded multispectral images, the Charter should request its members to task as many satellites as possible for regions prone to high cloud cover.
- It was important to optimize the acquisition plans to meet the data needs specific for that activation, e.g. temporally spread acquisitions from multiple missions where a limited number of acquisitions can occur for each mission.
- The required availability of archived (pre-event) data for interpreting both optical and post-flood Radar imagery. However, it was noted a change in the image can appear different depending on when the pre-flood imagery was acquired, i.e. normal, wet or drought year. Hence, it can be important to use more than one pre-flood image to obtain the average conditions.
- Emergency management agencies fed back that value-added products such as classified (i.e., thematic) images, were useful and integrated quickly into the decision-making process.

5.2. Challenges

In summary, this brief review of the use of primarily EO data for disaster response has identified the following challenges that are still considered relevant at the time of this guide:

- The area impacted by an event, or within which the rescue teams operate, varies considerably from a few square kilometers for local events (landslides, earthquakes, etc.) to thousands of square kilometers for very large area events such as tsunamis, tropical storms, and floods in low-lying areas. Therefore, targeted acquisitions and data availability need to consider the specific disaster event.
- Delivery of the first crisis product within 24 hours remains a challenging objective, due to the characteristics of the satellites, their orbits, and “true operational revisit” that for optical data would include the impact of cloud cover. However, the increasing focus on launching Radar constellations can provide increasing support alongside geostationary missions where there is not persistent cloud cover.
- As more countries gain their own EO capability, commercialization is a common theme. Open-access models for lower spatial resolution data have globally gained support through organizations such as the Group on Earth Observations (GEO). As an example, from the start, Copernicus has provided free-to-access optical and Radar data worldwide, with the number of users increasing exponentially. Also, for disaster response, commercial entities will often supply data for free or at a reduced cost through “special arrangements”.

However, in order to ensure that end-users receive the maximum benefits, and those data providers are able to distribute and control data in a more efficient and effective manner, there is a need for the harmonization of data license standards (Clark, 2017).

6

WHAT IS READINESS?

6 WHAT IS READINESS?

Readiness is the state of being fully prepared, and in this case, it is the state of being fully prepared to take part in the vision of a disaster response ecosystem as defined and demonstrated through the OGC Disaster Pilot 21 (Pilot).

The aim is to improve the amount and speed of data-driven decisions during the disaster response. This means that once activated, the geospatial data providers within this ecosystem will make a large amount of geospatial data available. However, to make it useful and decision-ready these datasets need to be available, processed, analyzed, visualized, and communicated to field responders in a very short amount of time.

This is not something that can be begun when a disaster occurs from either a data provider or user's point of view. There will be too many things to resolve such as data formats, license agreements, geospatial systems used, analysis skills, data aggregation and transformation methods, symbols and colors to be used in the visualization, and so on. By the time these are resolved, the disaster situation will be well underway and responses will be happening without the required geospatial data.

To be part of the envisaged Pilot ecosystem, both data providers and users need to be prepared to take part, and this means making a series of agreements. However, this can't be a set of agreements between individual data providers and users, nor can it be one single solution that everyone has to fit within. Instead, it requires a set of agreed operating approaches and standards such that, for example, the data providers know the format they need to provide the data in and users can immediately integrate that data within the system they are operating. Therefore, these standards will be what will deliver information smoothly and rapidly to enable decisions to be made and actions to be taken. Also, Readiness often means the solution is operational.

Although not developed within this Pilot, one suggestion is to develop a series of Operational Readiness Levels (ORLs), similar to those developed Earth Science Information Partners (ESIP) for making Earth science data more trusted, which will identify the steps and operating standards that both data providers and users will need to take to be able to fully participate.

This next section focuses on provider readiness and the required steps. There is a companion User Guide, which is 'technology-lite' and focuses on the user's perspective.

7

WHAT IS PROVIDER READINESS?

7 WHAT IS PROVIDER READINESS?

This guide is for the providers of the raw data, Analysis Ready Data (ARD) and/or Decision Ready Information and indicators (DRI) to ensure maximum usefulness for the users. This section describes the steps that providers should complete to be in a position to fully participate in the Disaster Response ecosystem envisaged by the OGC Disaster Pilot 2021 (Pilot):

7.1. Step 1: Understand what the users need

This is a two-way conversation as it will be difficult for a user to express their needs if they don't understand what is possible. Also, to have "user confidence" it is likely this communication needs to be an ongoing process of collaboration to seek the best overall disaster ecosystem effectiveness and performance.

One role for the users is to develop, and maintain, the foundation layers of local geospatial information into which the data from the providers can be integrated. This would include elements such as street maps, building footprints, elevation models, satellite imagery, key buildings such as hospitals, electricity substations, land cover, water bodies, etc.

7.2. Step 2: Understand and Implement Standards

To be able to rapidly integrate and transform data into useful DRI, it's necessary to eliminate all the unnecessary challenges of data management. This will include aspects of data formatting, visualization methods, symbols to use on maps, etc. This is critical to cut the time it takes for data to be ready to be used for decisions and actions.

Without standards, the potential for wasted time on data wrangling and preparation is high, and even worse the potential for inefficient, incorrect, or even wrong disaster response decisions the increases.

Within the Pilot, a number of key standards were identified as being important for provider readiness:

- Publishing structured geospatial data to support web-based searching, e.g. JavaScript Object Notation — Linked Data (JSON-LD)
- Transition of imagery to formats that support cloud-native geospatial processing, e.g. Cloud Optimized GeoTIFF (COG)
- Generation of metadata catalogs and self-describing datasets to aid data access and processing, e.g. SpatioTemporal Asset Catalog (STAC) and GeoPackage

- Platforms to serve the geospatial data and visualize it, e.g. GeoServer and GeoNode, with transmission standards such as Web Coverage Service (WCS), Web Feature Service (WFS), and Web Map Tile Service (WMTS)

7.3. Step 3: Develop Recipes to support data flow from source through ARD to DRI

Once the user needs and basic understanding of intended standards support are understood, the core of building an operational disaster support system is to develop recipes to support the data value chain. These recipes describe how to extract data from key sources in ARD and then transform these into information — DRI's — suitable for supporting decision support indicators that responders need to inform their actions and optimize their effectiveness.

A number of tools can be used to implement these recipes in a way that are readily interchangeable and reusable in different contexts. One approach is the use of open-source web-based scripted tools like Jupyter Notebooks, often involving Python and other languages such as Java or R. Another approach explored is to use model-based spatial Extract, Transform and Load (ETL) tools to support data integration and automation. Either approach can support rapid recipe development to generate the data products necessary to support disaster responders, and examples of both approaches were tested in the context of this disaster pilot.

An example of working through the process of understanding what is needed are the discussions within the ARD and DRI working groups, with the OpenStreetMap (OSM) conversion undertaken by Safe Software using FME:

- Areas of interest extents or polygons were shared in GeoJSON format. This allowed everyone to be sure they were talking about the same geographical extent.
- Basemap data was extracted from OSM and shared via a GeoPackage as foundation layers were not available from users at the start of the Pilot. Although this may sound like a trivial exercise, it was not because:
  - There is an interpretation process when extracting information from OSM and 'flattening' it for use in GIS.
  - A further complexity was that the original OSM data uses geodetic coordinates and EPSG:4326 as the defined Coordinate Reference System (CRS), where Latitude is specified before Longitude, while a GeoPackage defines co-ordinates according to the OGC Well-Known Text (WKT) standard of x,y,z,t that will override any CRS axis order.

7.4. Step 4: Determine The Method For Delivering Outputs

Receiving a large amount of data, and then analyzing, processing, and visualizing the data is only the first half of the work. The second half is getting the outputs of that work to the people managing the disaster response, including the field responders on the ground via their mobile phones or similar devices.

There are a variety of solutions for this and the Pilot is not recommending one, nor is it suggesting that the solution would be based around a single technology. Instead by establishing a set of required standards for data sharing, it will enable data to be interoperable and reusable across any platform. Solutions could be provided open source, commercial, or even using existing internal infrastructure.

The key element is that the user organization has a solution where they can upload the decision-ready indicators for users to access.

There is no single answer and the preferred solution will depend on the organization's infrastructure, financial pressures, technical skills, etc. Within the Pilot, several external platforms were tested, including:

- **Geocolloborate** – a platform developed by StormCenter Communications under the U.S. Federal SBIR program, which offers an option for an expert to lead the analysis and sharing of trusted data, with a series of followers receiving the data in real-time on the same screen. This approach offers the potential for a lot of people to interact with the same information at the same time leading to collaborative decision-making with the latest data available, some of which could be updated in real-time.
- **GeoNode Platform** – GeoNode, developed by GeoSolutions, is a web-based application and GIS platform for displaying spatial information. A GeoNode controlled by HSR.health has been used to display various data layers that were then accessible using open standards.

If an external platform is chosen, it is important to ensure that it can comply and adhere to the Standards highlighted in Step 2. In addition, it will be necessary to ensure that:

- Licenses have been agreed with the external provider for the use of the platform, including sufficient licenses are available for everyone who might need access to data during a disaster.
- All possible users have and know any username and passwords required to access the external system. In addition, this could also include additional security to allow only certain users to see specific datasets — this approach was tested through encrypted GeoPackages.
- All possible users have received training in the use of the system for disasters.

It is acknowledged that similar points will be relevant to in-house solutions.

The key element is that the chosen platform itself should support the data standards which will be used by the data providers to ensure that the indicator and data sets will be portable between platforms.

7.5. Step 5: Operationalize The Disaster Response

Simply setting up a disaster response system is not sufficient, as everyone involved needs to understand what sort of decisions will need to be taken. In summary, what information, indicators or triggers the disaster response team will want.

Whilst the data provider can provide a lot of relevant, useful, and helpful information, it will be important to understand the indicators that are most relevant for a disaster. It will also require local knowledge and understanding to interpret the indicators and take decisions and actions. For example, if a flood is occurring, then some of the indicators required might include area impacted, water depth, speed of water rise, potential future areas impacted, land cover, location of hospitals, safe evacuation, and access routes, etc. Within the Case Studies, in the annexes to this Guide, the Pilot showcases three potential disaster scenarios with examples of the type of indicators that might be relevant for those situations.

Users need to consider the indicators and determine whether they are sufficient, or whether important indicators are missing, any key local issues that need to be addressed, etc. Whilst generic indicators will be common across disaster types and regions, it is still possible that specific locations will need additional indicators or data.

Finally, it will be important for the users of the indicators to understand what their impact will be, what specific decision trees will be enacted when an indicator reaches a certain level, for example, in a flood at what point is an evacuation order issued. This will be necessary to give the decision-makers confidence in data-driven decisions and knowing how they should respond.

7.6. Step 6: Test

As with all disaster, resilience, or business continuity plans, preparing and developing the documents is not enough. The approach needs to be tested to practice the process of generating and receiving analysis-ready datasets, using/developing the decision-ready indicators, making decisions, initiating actions, and communicating those actions to people on the ground.

Geospatial data use should be incorporated into large-scale disaster response test events. However, it is acknowledged that large scale test events are complex and occur infrequently, therefore it would also be beneficial to work with some data providers to undertake small tabletop ‘data only’ tests for both providers and users to practice triggering, receiving, analyzing, and visualizing data and indicators.

8

PROPOSED APPROACH & METHODOLOGY

8 PROPOSED APPROACH & METHODOLOGY

The idealized overall solution envisaged by the OGC Disaster Pilot (Pilot) is that when a disaster event occurs, the user will log onto the Disaster Portal via either a computer or mobile, and search for the information that they want or need from the latest datasets that are available.

This best available data of the type requested will be provided to the user in the most useful or selected, format. This might be:

- Map with the key points or issues highlighted.
- Map showing different colored areas each indicating a different value.
- Table with the most critical or urgent points at the top.
- Graph showing the change over a variable over time. These outputs will enable the user to integrate the data with local knowledge they have or act on the information directly.

Whilst this is the idealized solution, practically there is a long way to go to have this solution available to everyone across the world.

Therefore, the Pilot is starting the process of developing an operational prototype to demonstrate how this might work with three hazards in selected areas, to better understand what is possible, where the challenges are and how to take this forward.

8.1. Users & Data

8.1.1. Types of users

The Pilot has identified four user groups:

1. Data Analysts working for the responding organizations providing insights and information for the disaster planners or field responders. These may include data analysts, GIS analysts, and logisticians.
2. Disaster Response Planners or Managers who lead the disaster readiness and response activities for the responding organizations.
3. Field Responders who are on the ground responding to the disaster and reporting to the responding organizations.
4. Affected public and communities who want direction and guidance on what they should do.

Each of these user groups requires different types of data or information, at different levels and presented in different ways.

8.1.2. ARD vs DRI data

The Pilot envisages two main types of data/information being produced and supplied to the users:

- **Analysis Ready Data (ARD):** This data is observations about what is happening in a format that can be immediately integrated with other geoinformation and used within a Geospatial Information System (GIS). These datasets can be interrogated by people with the right skills to gain greater insight, having already undergone some processing to remove errors, get the data in the right format, etc. It includes satellite data, together with in-situ data and data from other sources, and would be supplied as a dataset. It is most likely to be used by the Data Analysts but could also be used by Disaster Response Planners and Managers.
- **Decision Ready Information/Indicators (DRI)** – These are ARDs that have undergone further processing to create information and knowledge in a format that provides specific support for actions and decisions to be made in relation to the disaster. This information will be useful for Disaster Response Planners and Managers, Field Responders and Affected Public, and will be able to be used without any specialist knowledge, skills or software. DRI datasets may also be useful to Data Analysts in order to build composite or multi-stage indicators.

Note that although these are the two main types of data envisioned here, throughout the course of the pilot there were discussions around what stages of data might exist between ARD and DRI. For example, some datasets may be considered to be actionable observations: more refined and richer than basic ARD, but without the clearly defined rules or parameters as to what action should be taken, that would be necessary to consider them DRI. In support, a diagram was developed to show the relationship between ARD to DRI; see Figure 1.

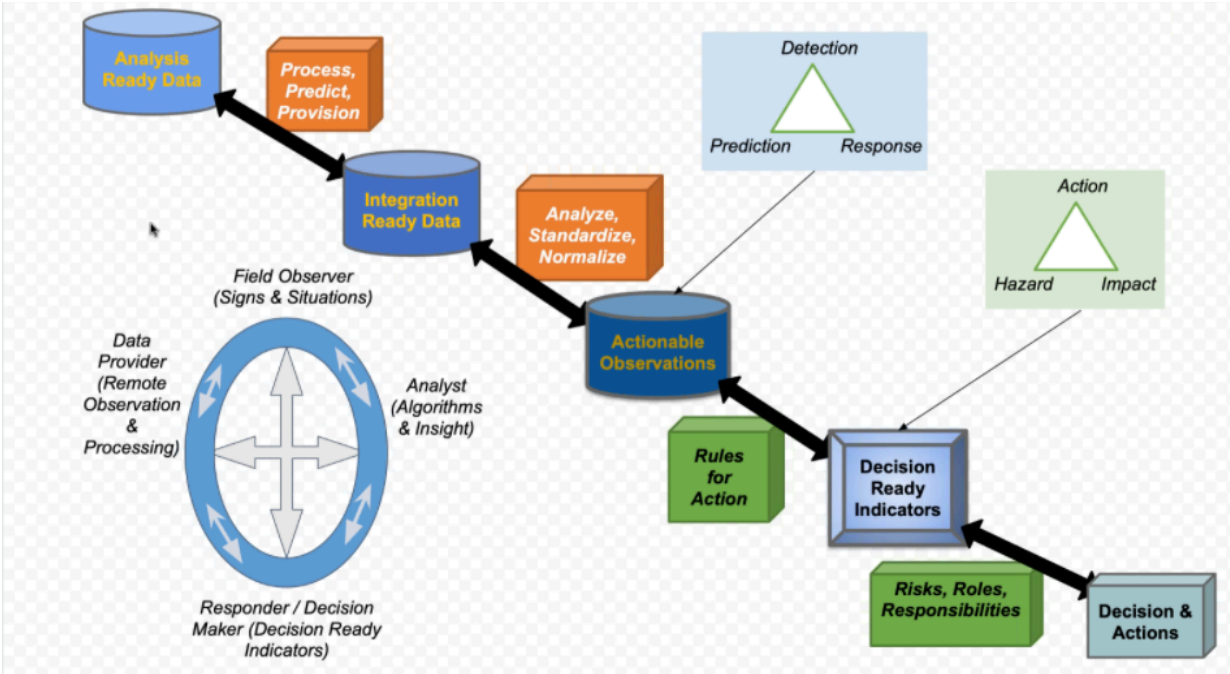


Figure 1 — Relationship between ARD to DRI, courtesy of Josh Lieberman.

8.1.3. Recipes and Indicators

Although recipes and indicators vary from disaster to disaster, they can be set up within a structure that includes their applicability timescale (short-term predictions and impacts to medium and long-term predictions) and type/geospatial extent of the disaster.

Example recipes include those related to:

- **Predicting future flooding**: Using Earth Observation (EO) and modeled data to provide the current ocean state and weather conditions in support of predicting the onset of flooding due to heavy rainfall; see Annex A for further details.
- **The blockage of roads by floodwater:** EO and modeling data is used to extract/predict the floodwater extent, and then used to determine which and to what depth roads are affected, which is then used to influence the routing of traffic; see Annex B for further details.
- **Availability of health supplies:** Use of geospatial health data to predict a Pandemic Mortality Risk Index and Medical Supply Needs Index; see Annex C for further details.

9

TECHNICAL SOLUTION

9 TECHNICAL SOLUTION

9.1. Proposed technical solution – data, cloud, processing, registry, visualization and serving to users

The OGC Disaster Pilot (Pilot) technical solution aimed to bring together multiple providers into an ecosystem that transforms input data into actionable information by developing prototypical components and services. These components should utilize modern cloud architectures and next-generation technologies to optimize collaborative workflows and scale solutions rapidly. An overview of the architecture envisioned for the Pilot is shown in Figure 2.

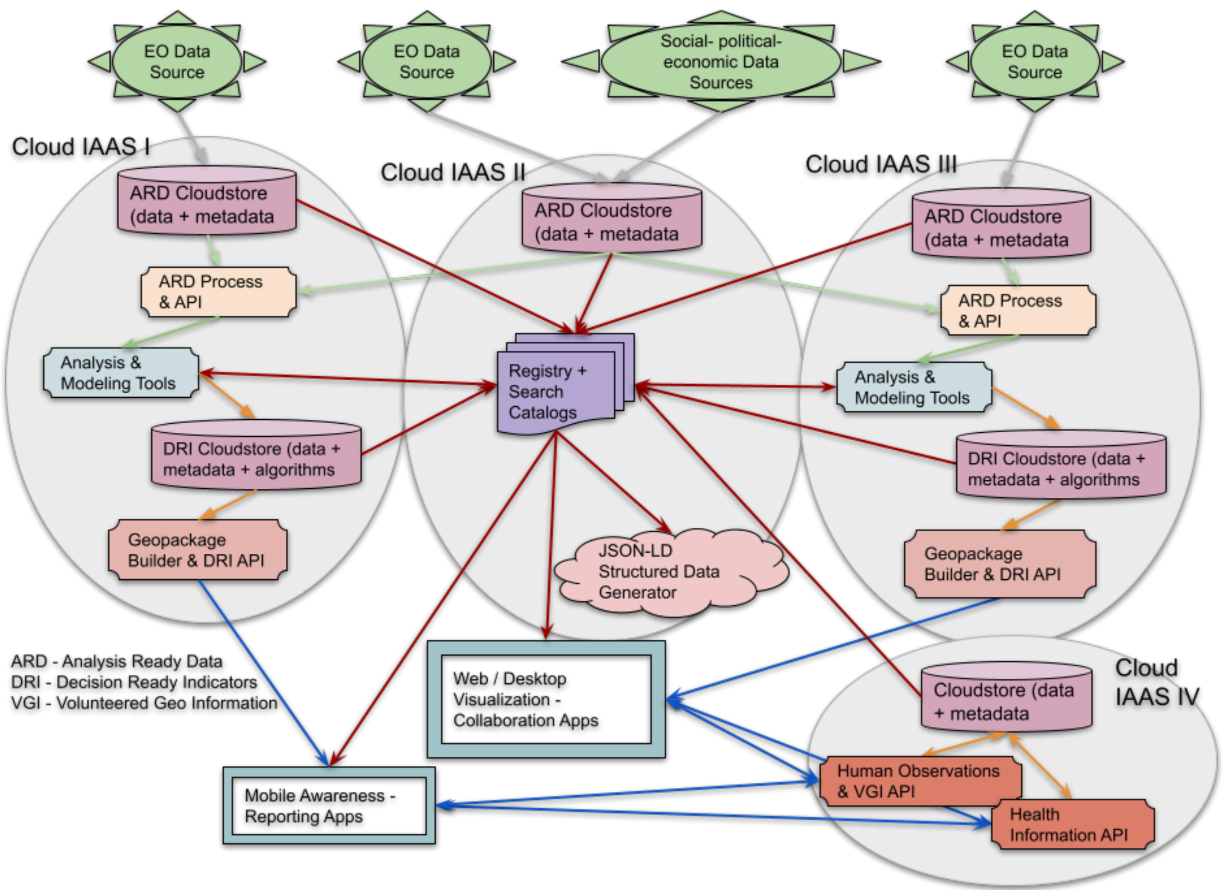


Figure 2 — Pilot Architecture Overview

At the top of Figure 2 are the data sources, which include Earth Observation (EO) and social-political-economic data alongside ancillary geospatial sources. The sources of data were seen as both being free-to-access and paid-for, and the availability could be restricted depending on the source and sensitivity of the data.

Sources consider or used within the Pilot include:

- **Satellite Earth Observation**:
  - *Copernicus Sentinel Missions:* Operated by the European Union, with data acquired by constellations of global missions focused on specific technologies. For example, Copernicus Sentinel-1 are two Radar missions (A&B) that operate at the C-band frequency.
  - *Landsat-8:* A high resolution (30 m spatial resolution) mission that carries the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments. Landsat 9 is the most recently launched Landsat satellite, but was not launched in time for the Pilot.
  - *NewSat:* Satellogic constellation currently consists of 17 commercial NewSat satellites in sun-synchronous Low Earth Orbit (LEO).
  - *PeruSat-1:* National Commission for Aerospace Research and Development's (CONIDA) small (~ 430 kg) satellite launched in September 2016, which carries NAOMI (New AstroSat Optical Modular Instrument) that has a panchromatic and four multispectral wavebands: Blue, green red, and Near-InfraRed (NIR). The panchromatic band has a spatial resolution of 0.7 at nadir, while the multispectral bands have a spatial resolution of 2.5 m at nadir.
  - *RADARSAT:* The three RCM (RADARSAT Constellation Mission) satellites operate at the C-band frequency, with a spatial resolution from 1 to 100 m depending on the acquisition mode.

- **Health data**:
  - *Tracking*:
    - Locations of interest e.g., specific and black markets.
    - Large gatherings
    - People and items going into and out of any facility to access disease spread risk.
    - Land Use Change e.g., change in air quality, coastline, the water table, access to water, deforestation, animal, insect, human habitats, and many others.
    - Migration of Animals and Insects
  - *Measuring*:
    - Point-in-time population density
  - *Monitoring and monitoring*:
    - Evacuation routes, and development of alternate evac routes
    - Health resource utilization within a medical facility
    - Volume of traffic at discrete points in transportation infrastructure, e.g. bridges, key intersections, train/light rail stations, etc.
  - Assess distance, travel time between population centers & medical facilities (based on traffic, land cover, storm, etc.)
- **Social-political-economic**:
  - Administrative boundaries
- **Ancillary geospatial**:
  - *OpenStreetMap (OSM):* Buildings and road network.
  - *Meteorological Data:* For example, storm tracking alongside information on weather conditions such as precipitation and wind speed.
  - *Digital Elevation Model (DEM):* Shuttle Radar Topography Mission (SRTM) @ 30 m spatial resolution provides global coverage, and several enhanced DEM versions thereof (e.g. http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_Hydro/), while airborne Lidar data can provide sub-meter resolution locally.
  - Other *in situ* observations such as stream gauge data.

The input data, ideally in an Analysis Ready Data (ARD) format, is ingested into cloud-based storage areas from where it can be transformed into Decision-Ready Information and indicators (DRI).

Users interact through Mobile and Web/Desktop Applications (Apps), shown in the boxes at the bottom, which are interacting with the DRI through a Registry & Search Catalog and GeoPackages. In addition, users provide Volunteered Geographic Information (VGI) into the overall ecosystem to support real-time insights into what is happening.

9.2. Principles/Standards

The principles/standards for each of the elements from discovery to visualization included:

- **Discovery**: Service(s) and associated application(s) supporting near-real-time registration, search, and discovery of ARD sources and DRI products, alongside contextual social-political-health datasets and local observations within impacted areas. This element includes implementations of OGC API Standards that provide such information with JavaScript Object Notation — Linked Data (JSON-LD).
- **Data Storage and Processing in the Cloud:** Cloud-based storage, processing, and service elements to support the loading, preparation, and access to individual satellite-based datasets alongside complementary geospatial datasets. Then, further application elements are deployed near to source datasets and support agile, rapid, and scalable generation of decision-ready (e.g. indicator) information products.
    - *Registry and Search Catalog generation* has utilized SpatioTemporal Asset Catalog (STAC);
    - *Processing* has utilized Jupyter Notebooks;
    - *Storage formats* included Cloud Optimized GeoTIFF (COG) and GeoPackage.
    - *Storage locations* such as Amazon Simple Storage Service (S3).
- **Visualization:**
    - *Mobile client applications* able to discover, request, and download DRI products as GeoPackages in support of disaster response field personnel, operations, and decision making during connected-disconnected operations.
    - *Web/desktop client applications* able to interact with cloud-based server components to access both ARD and DRI products for analysis and visualization by analysts and decision-makers.
    - *Delivery standards* for these clients include GeoRSS, Web Coverage Service (WCS), Web Feature Service (WFS), and Web Map Tile Service (WMTS).

Having these pre-agreed and understood in advance can ensure consistency and an efficient processing/delivery of the needed disaster-related information.

10

OUTCOME AND RESULTS

10 OUTCOME AND RESULTS

The OGC Disaster Pilot (Pilot) focused on bringing scenarios together through multiple participants working together rather than a single participant providing the whole solution. Therefore, a significant amount of time was spent discussing different approaches and collaboratively working on the scenarios. Also, there have been difficulties in quickly bringing on-board the required cloud resources and hence making the underlying cloud infrastructure available to all participants.

The example scenarios highlighted in the annex located case studies showcase how multiple participants, and technologies, contributed to an initial assessment of:

- Landslide/flooding hazards within the Rimac and Piura river basins in Peru: Annex A;
- Flooding associated with the Red River in Manitoba, Canada: Annex B;
- Integration of Health and Earth Observation (EO) data: Annex C.

These Case Studies start by providing the context and then describe what the Pilot has achieved.

10.1. Provider Success and Achievements

The successes at this relatively early stage of development include:

- Recipes developed to go from Analysis Ready Data (ARD) to Decision Ready Information and indicators (DRI) for:
  - prediction of El Niño related flooding (Annex A);
  - analysis of flooding scenarios based on historic, real time or forecast stream gauge data (Annex B)
  - traffic routing around flooding (Annex B);
  - health supplies availability (Annex C).
- Supply of user gathered survey results via an RSS feed using GeoRSS (Annex A);
- Integration of ARD and DRI outputs into a Medical Supply Needs Index that's hosted within a GeoNode platform (Annex C);

11

NEXT STEPS RECOMMENDATIONS

11 NEXT STEPS RECOMMENDATIONS

11.1. What needs to be done to make this available in real-time for disaster support?

At present, the Pilot has started the process of bringing providers together. The Case Studies focused on historical data rather than real-time support, which meant more data and information was available. Therefore, further work needs to be taken to improve the technical setup, e.g., APIs or other computer-to-computer interfaces need to be set up rather than manually transferring data from one provider to another. This approach was being accomplished towards the end of the Pilot and further work for the ecosystem of providers to function smoothly and handle near-real-time data.

Then, as discussed in Clause 7 large scale disaster response test events need to be conducted to stress-test the setup and see where the points of weakness are.

11.2. Technical requirements

In terms of an extension of the Pilot:

- Having the required cloud-computing infrastructure and input datasets available at the start, or within a short period of time, so this element does not slow down the collaborative activities.
- Agreeing a minimum viable product that the end-users wish to see so that the minimum specifications or any component can then be formulated.
- Agreeing on metadata to consistently describe the datasets and recipes.

More broadly:

- Communities work to establish clear indicators to ensure the responsive data, products and services are mobilized in advance of an event. The landslide community has established ISO standards to support this. The flood, health, fire etc. should consider doing the same.
- Data sharing agreements are in place in advance to support user readiness.
- Governments support the FAIR principles to improve user readiness

- Additional investments be made by governments in capacity development activities that support knowledge and technical transfer to improve user readiness
- Community work together to develop ARD standards that support interoperability and bring together in-situ and remote sensing data.

11.3. Going beyond the applications to an international approach

- The developed recipes need testing for a large range of examples, and further recipes need development.
- Consider how observations and predictions can be brought together to form time consistent datasets.
- Preparing for Readiness:
  - Establishing data sharing agreements between the Providers and Users, including the concept of any liability, onward sharing, and use. This is a critical issue and proved a difficulty even within the Pilot.
  - Establishing a set of Operational Readiness Levels for both Providers and Users, so that they can demonstrate to each other that they are ready to participate in the disaster response ecosystem.
  - Refining the roles required both on the Provider and User side, together with the skill set those people require.
  - Practice! A disaster scenario should not be the first time data is shared. Provider data handlers need to practice responding quickly to receiving data requests to find the correct data, process and supply it. User data handlers need to practice receiving datasets integrating, visualizing, and disseminating it.
  - Improved engagement with the disaster response decision-makers and field responders, which is something the Pilot struggled with, to understand the information they believe they want and need.

A

ANNEX A (INFORMATIVE) CASE STUDY 1: RIMAC AND PIURA RIVERS

ANNEX A
(INFORMATIVE)
CASE STUDY 1: RIMAC AND PIURA RIVERS

A.1. Landslide/flooding hazards and pandemic impacts within the Rimac and Piura river basins in Peru

A.1.1. Rimac and Piura river basin flooding hazards, including the 2021 flood

Peru's Piura region in the north and the Rimac river basin near Lima are both impacted by difficult to predict El Niño related flooding. The El Niño/Southern Oscillation (ENSO) is a naturally occurring phenomenon in the tropical Pacific coupled ocean-atmosphere system that alternates between warm and cold phases called El Nino and La Nina, respectively.

The Piura climate is arid but can experience very heavy rainfall associated with the high nearby Sea Surface Temperature (SST) during El Niño phases. When heavy rain occurs it can cause severe floods, which in turn can cause mudslides called *huaycos*.

Figure A.1 shows an index that indicates the El Niño phases in red and La Nina phases in blue.

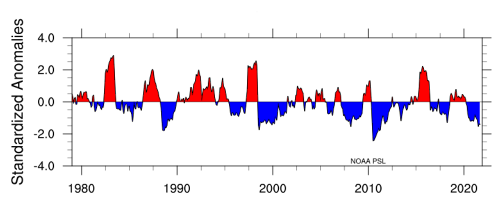


Figure A.1 — ENSO index with red indicating El Niño periods, Multivariate ENSO Index Version 2 courtesy of NOAA, USA

As an example of the relationship between ENSO and flooding, El Niño brought rains that caused severe flooding in 1982-1983 and again in 1998 but then, for several years, droughts and extreme heat were the main worries for these communities. Then the flooding returned again in 2002-2003, 2017-2019. In 2017, ten times the usual amount of rain fell on Peru's coast, swelling rivers which caused widespread flooding, and triggering huge landslides which tore through communities [6].

El Niño has two different variants: The global, with consequences at global scale, and the local (e.g. the event in 2017), also known as El Niño Costero, which affects the coasts of Peru and Ecuador. While the global changes can be predicted some months before happening (more studied, bigger area, slower process), the Niño Costero is a shorter and more abrupt event.

There has been recent flooding, February and April 2021, but Figure A.1 and the WMO ENSO September 2021 Update indicated that it was likely to still be La Niña conditions. Further clarifications from NOAA in October 2021 confirmed that it was a double-dip La Nina, that is expected to last through the early spring of 2022. Therefore, instead of heavy rainfall caused by the El Niño phase, the spring 2021 flooding could be linked to an overall regional vulnerability to heavy rainfall, with climate change increasing the occurrence. In addition, as the Piura River does not have the infrastructure for flow regulation, the impacts of deforestation and unplanned urban development have increased its vulnerability.

In early February, the Civil defense authorities in Peru reported that flooding had affected over 90,000 people in the northern region of Piura since heavy rain began to fall on 30 January. As many as 2,545 people were displaced, with over 500 homes destroyed and almost 19,000 flooded. Then on 02 March 2021 it was reported that as a result of intense rainfall, there was damage to roads, homes, and public buildings with damage spreading by 04 March. In total, 182 homes and three health facility buildings were reported damaged and five homes destroyed.

Figure A.2 shows a pair of Sentinel-2 pseudo-true color images of the Poechos Reservoir and surrounding land on 18 February and 20 March 2021. The rainfall has resulted in a greening of the surrounding land alongside an increase in the area covered by the reservoir and turbidity of the water (from blue/green to brown).

Figure A.2 — Poechos Reservoir as seen using Sentinel-2 on 18 February (left) and 20 March 2021 (right); generated by Pixalytics; generated by Pixalytics.

The transfer of the heavy rainfall from the rivers to the sea is also shown in terms of the plume of sediment seen extending from the Rimac river on 26 March compared to 01 March 2021 image; see Figure A.3.

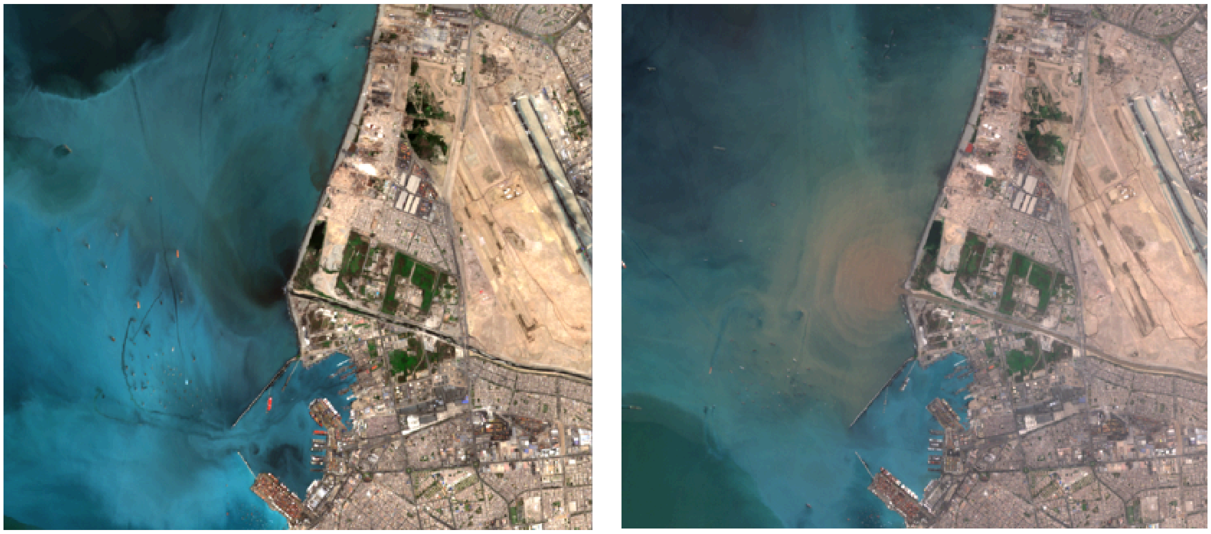


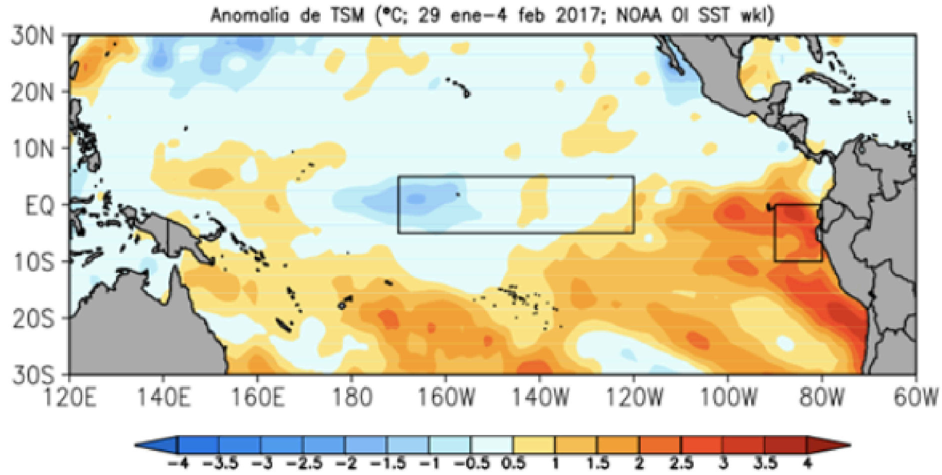
Figure A.3 — Transfer of water extending from the Rimac river as seen using Sentinel-2 on 01 (left) and 26 March 2021 (right); generated by Pixalytics.

A.2. What has the Pilot done?

A.2.1. Flood-focused ARD and DRI to support decision-makers

The Pilot has explored different Analysis Ready Data (ARD) and Decision Ready Information and indicators (DRI) that can be considered by decision-makers during the whole event, starting from indicators that can serve to support prediction of the event and an assessment of the consequences.

- **Sea Surface Temperature (SST)**: Historically, scientists estimate the intensity of El Niño based on SST anomalies in a certain region of the equatorial Pacific. For El Niño Costero, the increase of the SST is produced closer to the coast; see Figure A.4. Multiple historical datasets are available to observe the trends and standard values (e.g. NOAA Extended Reconstructed Sea Surface Temperature). Being able to monitor these values, especially in El Niño Costero, would be very useful when trying to predict, anticipate and be better prepared for such events earlier in advance. Satellite SST is a mature application of ocean remote sensing. Passive observations are made with InfraRed (IR) sensors onboard multiple polar-orbiting and geostationary platforms, and microwave sensors onboard polar platforms. The IR sensors have higher spatial (1-4km) and temporal (10-15min, onboard geostationary satellites) resolution, and superior radiometric performance. Also, satellites like Sentinel-3 with a daily revisit can be used if higher spatial resolution is needed.



El cuadro negro de la derecha a la altura de la costa norte del Perú ubica el calentamiento inusual. Fuente: NOAA/IGP/ENFEN.

Figure A.4 — SST anomaly in El Niño Costero 2017. Unusual heating is shown by the right-most black square; generated by the the European Union Satellite Centre (SatCen).

- **Wind**: Wind could be also considered an important parameter to monitor. In the case of El Niño Costero (2017), rain caused a decrease in the wind speed that prevented the reduction of SST, generating a virtuous cycle.

- **Precipitation**: Prediction and monitoring of precipitation are crucial since it is the cause of the flooding. As an example, during El Niño Costero (2017), Figure A.5 shows it can be clearly distinguished which were the most affected departments according to the significant increase of precipitation with respect to the previous and following years. The bigger deviations with respect to the previous (2016) and following (2018) year can be observed in the regions more greatly affected by the effects of El Niño Costero during 2017 e.g., Lambayeque and Piura.

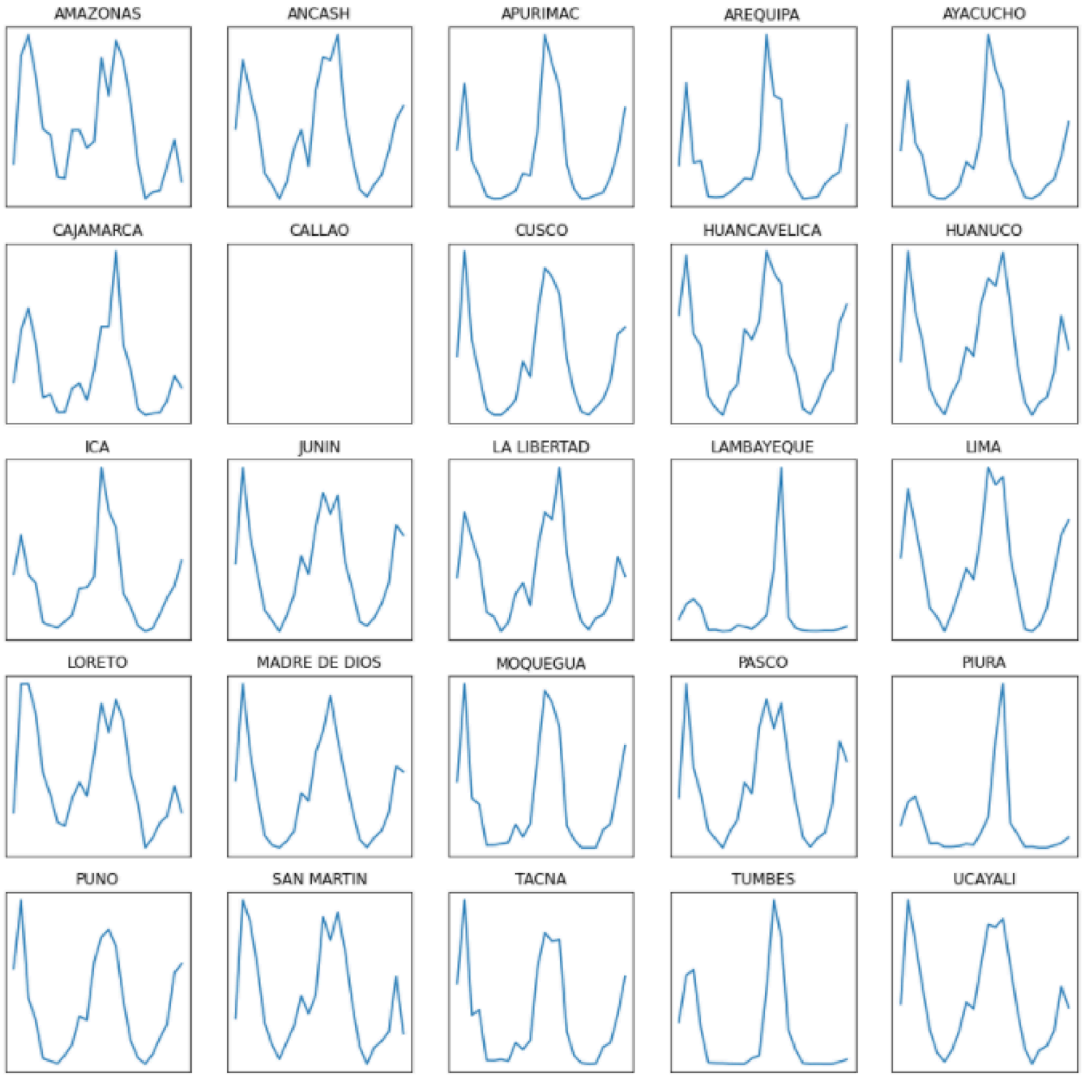


Figure A.5 — Precipitation in different Peruvian regions 2016-2018; generated by SatCen.

- **Earth Observation data**: Remote sensing data from space may be used for the characterization and monitoring of large-scale phenomena such as floods, as it allows users to obtain data over large areas at a scale difficult to reach using field-based instruments and methods. In addition, the availability of open data with a high temporal resolution, such as the one provided by the Copernicus Program, makes it very well suited for the scenario under analysis. In particular, two main sensors are considered in the analysis:
  - Synthetic Aperture Radar (SAR): SAR is very useful for mapping flood extent since it can acquire images in all weather conditions; see Figure A.6. However, its adequacy would also depend on the characteristics of the area under analysis. In this sense, different strategies have to be applied depending on the characteristics of the terrain.
    - In **open areas**, water surfaces are smooth and the specular reflection produce low backscatter (black pixels in the image);

- In **forested areas**, if the SAR penetrates the canopy, the backscatter is higher than the reference image in flooded areas due to double bouncing;
- In **urban areas**, due to the strong scatterers, it is difficult to detect flooding with SAR.

Figure A.6 — Sentinel-1 (SAR) processed backscatter during the flood event 2017; generated by SatCen.

- Optical: As seen in some of the examples, Figure A.7, optical sensors can also be used for mapping flood extent. The changes are easily detected visually and algorithms like Change Vector Analysis can be applied to automate the task. The main disadvantage of optical data sources is their dependency on weather conditions since if there are clouds, no information is available.

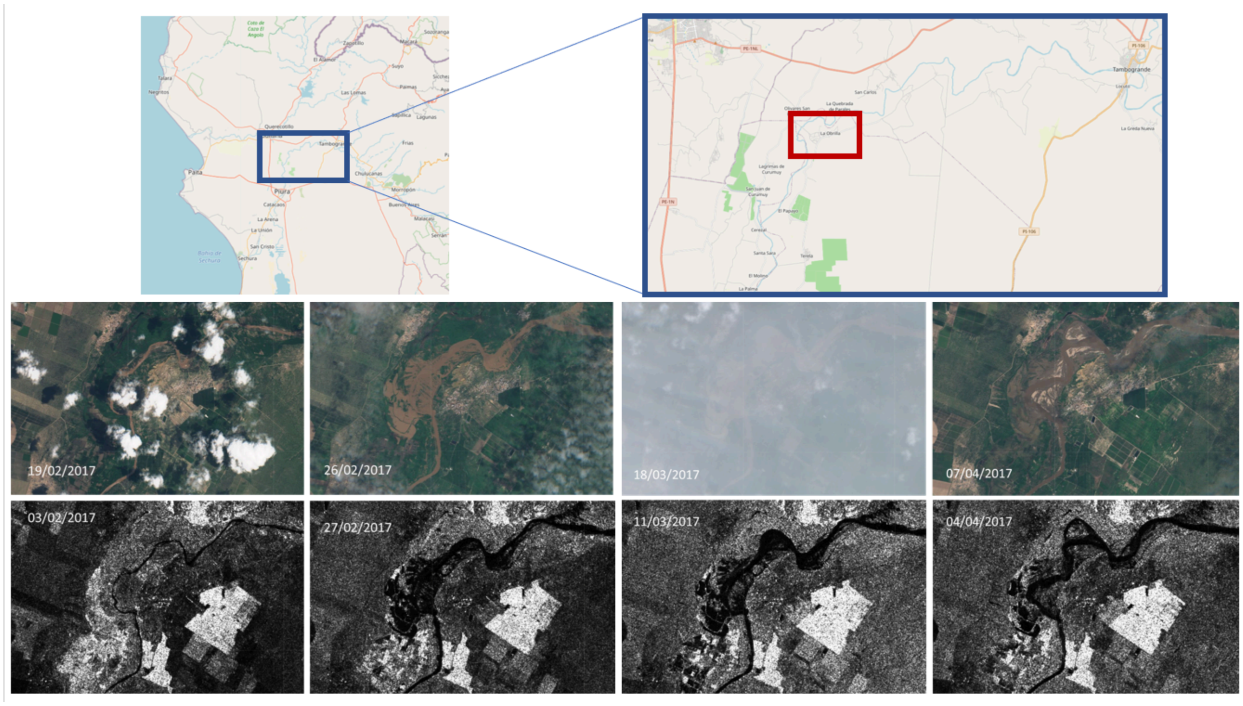


Figure A.7 — Sentinel-1 (SAR) and Sentinel-2 (optical) during the flood event 2017; generated by SatCen.

- **Change detection algorithms and products**: The automatic detection of changes in the remotely sensed imagery can be an important asset in the detection of flooded areas, as it serves to automate the analysis and provide information to decision-makers that can be directly used for example to prepare contingency plans, or to understand the areas that have been more greatly impacted by flood events. Several approaches for detecting changes in SAR imagery are proposed:
  - Amplitude Change Detection (ACD), see Figure A.8: An RGB composite of the backscatter of two images before and after the event, which highlights the flooded areas and which are visually more straightforward to understand than raw SAR amplitude images.

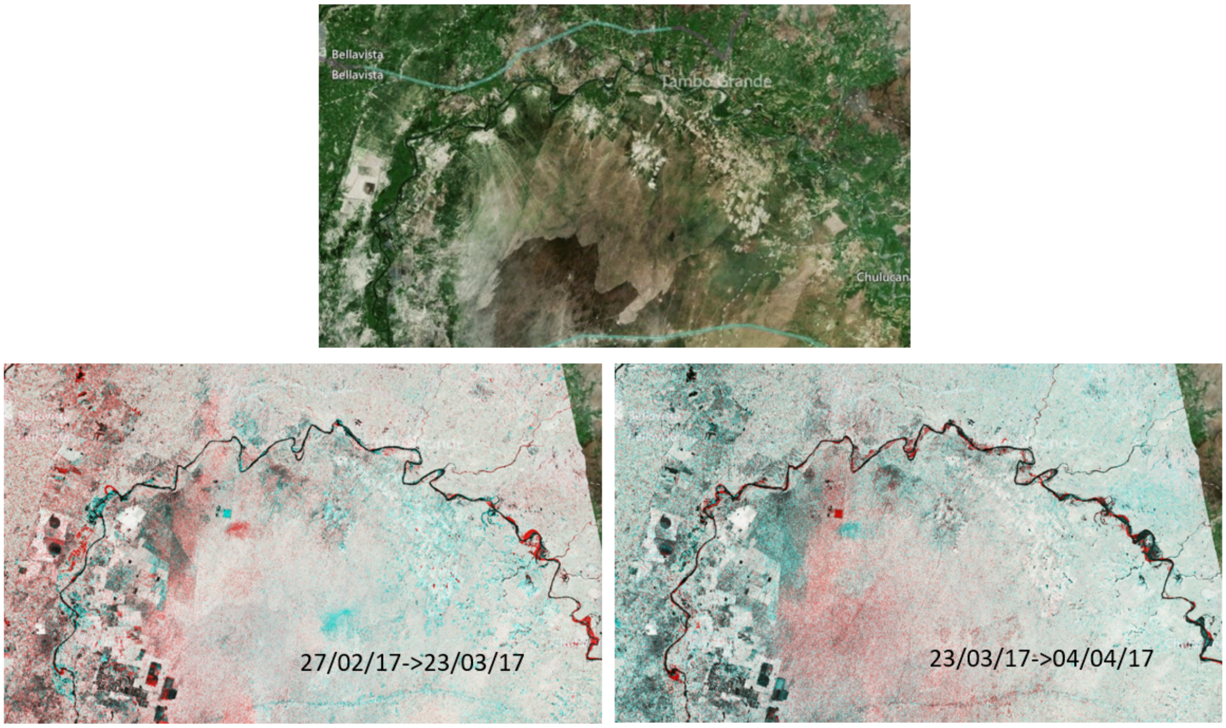


Figure A.8 — Example of ACD products generated with Sentinel-1. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- Multi-Temporal and Coherence (MTC), see Figure A.9: An RGB composite of the backscatter of two images before and after the event and the coherence (which represents the amplitude of the correlation between the images). As the coherence between two interferometric acquisitions is a measure of the degree of correlation between the phase of the signal in the two acquisitions, it is a very good and reliable method for detecting changes in pairs of SAR images. In the cities, the predominant color is white (high values in R and G channels because of high backscatter, and high value in B channel because of high coherence (no changes)), but if there are changes, they will be highlighted in red, green or yellow depending on their origin. This could be useful to detect possible infrastructure affected by flooding or landslides for example.

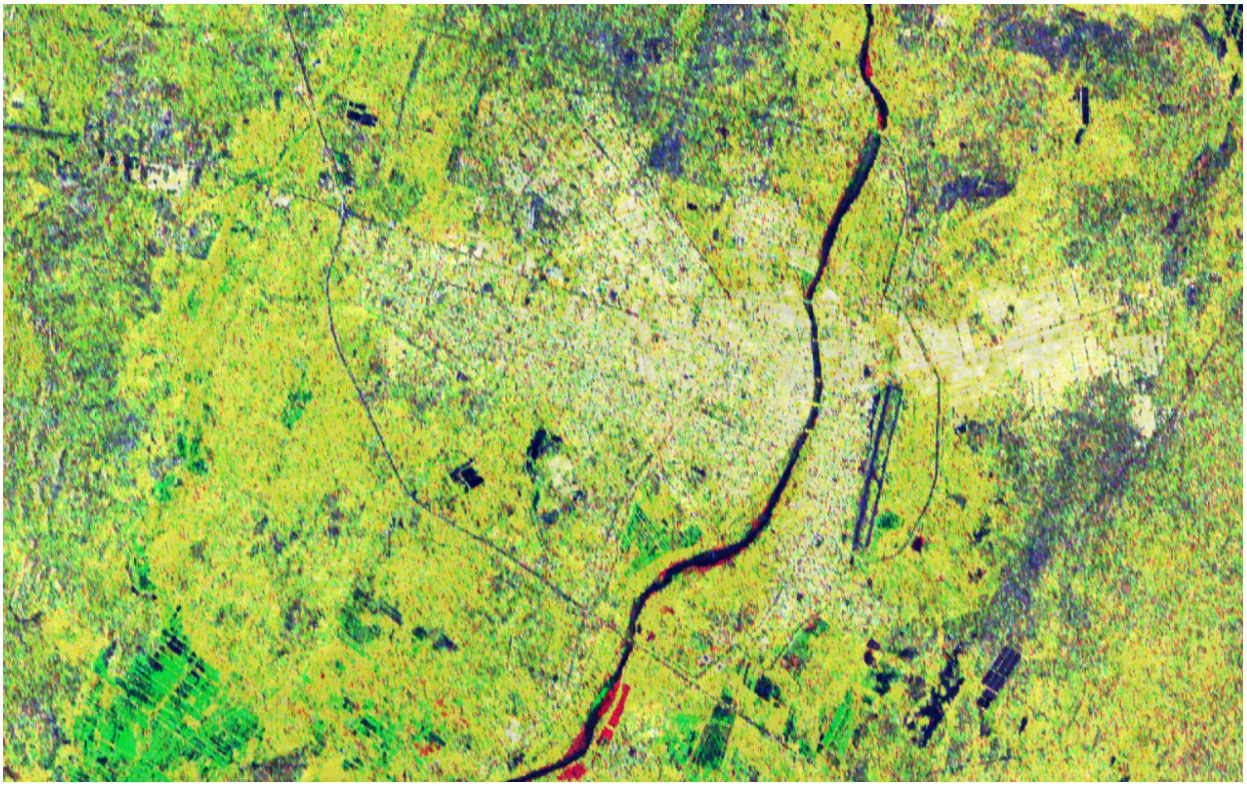


Figure A.9 — Example of MTC product generated with Sentinel-1 over Piura. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- **Flood monitoring**: Based on the above-mentioned Change Detection products, it is then possible to extract the flood mask through, for example, image segmentation techniques such as simple thresholding; see Figure A.10. The flood mask can be consequently used to monitor the extension of the areas affected, as well as to overlay it with reference maps (e.g. as obtainable from OpenStreetMap) to identify possible affected critical infrastructure.

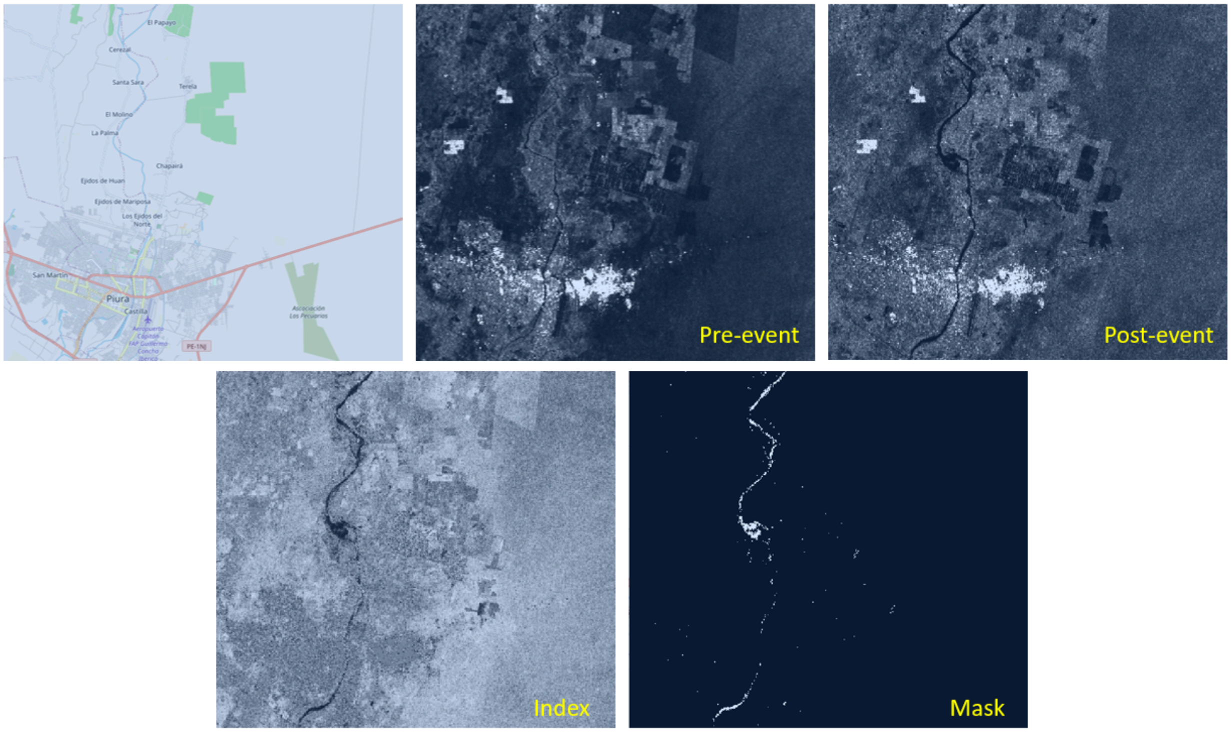


Figure A.10 — Example of flood mask computed from Sentinel-1 data; generated by SatCen.

A.2.2. Collecting voice-activated survey data

The New York City Geospatial Information System & Mapping Organization (GISMO) developed a voice-activated survey to allow people to record a series of responses to set questions. The system is multi-lingual and supplies both the original language and a translation into English.

An example GeoRSS URL output, with artificial survey data, is shown in Figure A.11

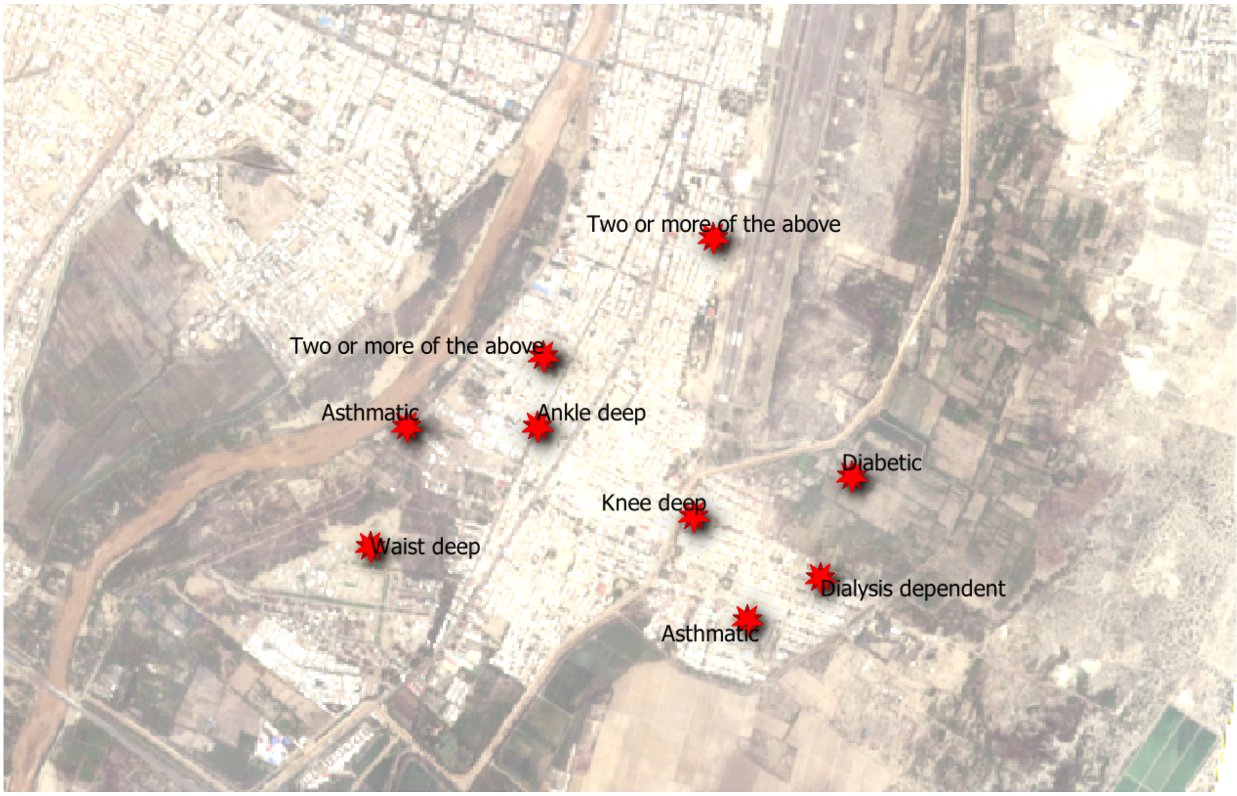


Figure A.11 — Example of GISMO GeoRSS URL output, overlaid on a Sentinel-2 pseudo-true color composite from the 20 March 2021.

A.2.3. Visualization

Figure A.12 shows an example of how visualization and dissemination can occur using the GeoCollaborate tool developed by StormCenter. The screenshot shows the leader's screen on the left and the followers' screen on the right. A flooded area is overlaid with a geospatial service provided by the NASA SEDAC (Socioeconomic Data Applications Center) at Columbia University, giving details of the demographic breakdown of the people in that area that can support both responders and decision-makers. The leader controls the screen, and everyone else follows, so all of the people involved are getting the same information simultaneously. As this approach only requires an internet-connected device, the lead can operate the solution with minimal bandwidth. The data is pulled into the tool via a REST API using standards such as WFS (Web Feature Service) and WMTS (Web Map Tile Service).

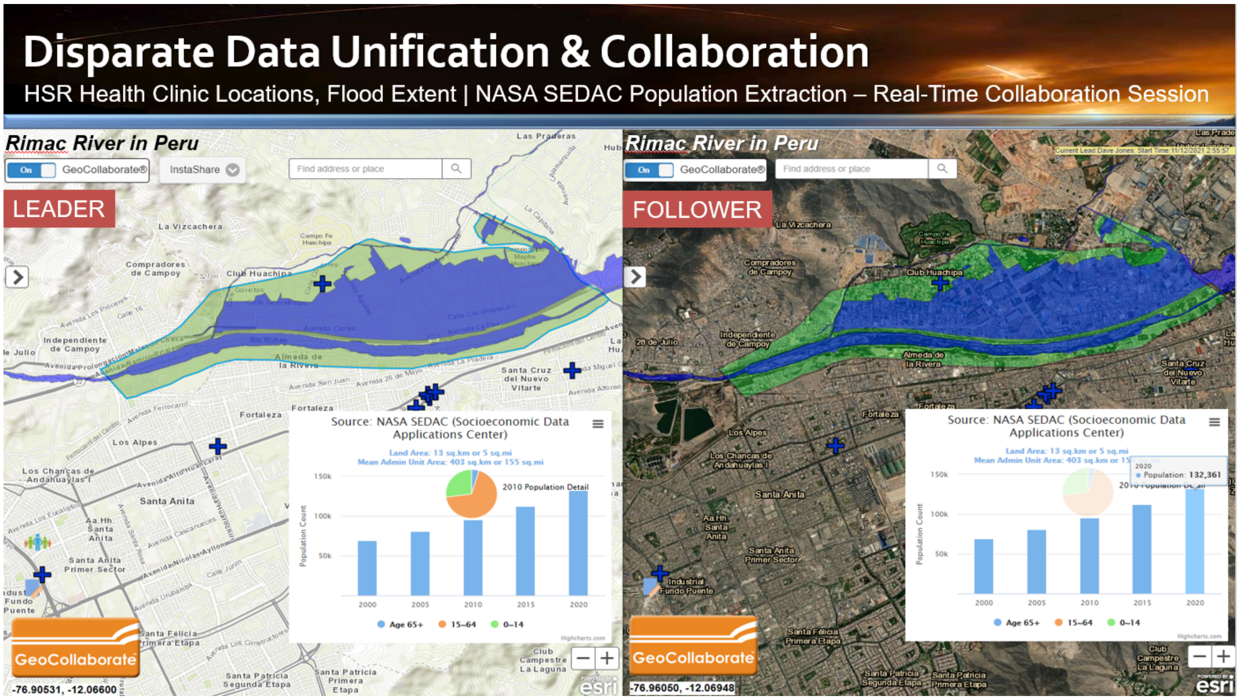


Figure A.12 — Data for Rimac River in Peru including flood extent and demographic breakdown of the area, together with clinic locations from HSR.Health, visualized via GeoCollaborate

A.3. Conclusion

Satellite source of EO data can support the prediction and detection of disaster events, including floods and associated landslides. For Peru, this Case Study has focused on events associated with ENSO.

The envisioned sources of satellite EO data were not available to support an assessment of the most recent, spring 2021, flooding. Sentinel-1 and -2 have been used to show the increased river flow and the associated increase in suspended solids but did not capture the flood events themselves; a known limitation of EO is the ability to capture short-timescale extent flooding, but this is improving with greater availability of missions that are providing more frequent temporal coverage. Access to PeruSat-1 is being negotiated but has not been available for use in the current analysis.

Therefore, the Disaster Pilot ARD to DRI focused on analyzing the 2017 flooding captured by a range of EO data sources, showing how recipes can use EO to support both the prediction and capture of flooding. The calculations were carried out in Jupyter Notebooks — these are increasingly being used for Python code development as they contain the code, visualizations, and narrative text. They can also be used in automated workflows by running them from within Python scripts, or they can be used for development before the operationalization of the approach.

The Case Study also highlights the work undertaken by GISMO on field observations, where user data is collected using a voice-activated survey. Then the results can be pulled into a visualization platform using GeoRSS. Then, an example showcased in the GeoCollaborate tool demonstrates how the ARD and DRI can be shown to end-users.

B

ANNEX B (INFORMATIVE) CASE STUDY 2: RED RIVER BASIN

B

ANNEX B (INFORMATIVE) CASE STUDY 2: RED RIVER BASIN

B.1. Flooding hazards and pandemic impacts within the Red River basin in Manitoba, Canada

B.1.1. Introduction to the Red River flooding hazards, including the 2020 flood

One of the most common types of flooding is river flooding, where the river (or rivers) overflow due to high rainfall or rapid melt upstream that causes the river to expand beyond its banks. The Red River flows north from Northeast South Dakota and West Central Minnesota into Manitoba Canada and eventually out into Hudson Bay. The relatively flat slope of the Red River valley means that the river flow is slow, allowing runoff to backfill into tributaries, particularly when the downstream river channel remains frozen. In addition, localized ice jams may impede the water flow, resulting in higher river levels.

Therefore, conditions that determine the magnitude of a spring flood include (Anatomy of a Red River Spring Flood):

1. The freeze/melt cycle
2. Early spring rains increase melting of the snowpack or late spring snowstorms adding to the existing snow pack
3. The actual snowpack depth and water equivalency
4. Frost depth
5. Ground soil moisture content
6. River ice conditions

A typical spring thaw occurs from the middle of March across southern portions of the basin and mid or late April across the north.

An unusually wet fall and winter, combined with spring melting, drove the water levels up in April 2020; as shown in the April 2020/2021 water level comparison for the City of Winnipeg's main gauge (James Avenue) in Figure B.1.

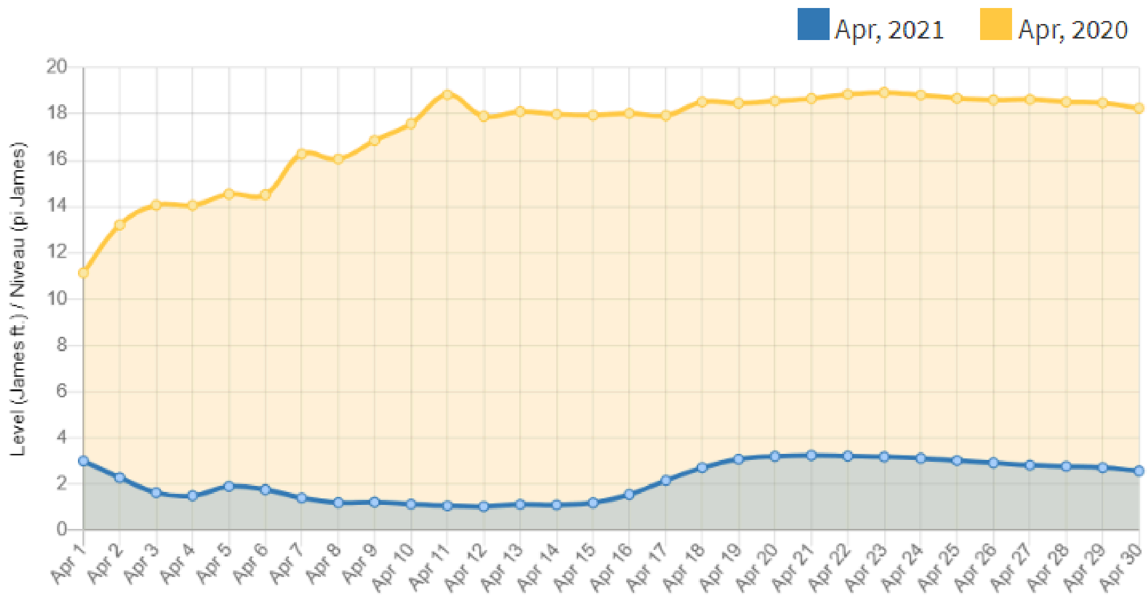


Figure B.1 — Red River Water level April 2020/2021 Comparison, [Winnipeg river levels]

On 17 April, a separate stream gauge at Drayton, North Dakota, recorded water levels of 43 feet (13 meters), just high enough to be classified as major flooding [10]. The flooding continued into May when, as shown by the James Street gauge in Figure B.2, it declined.

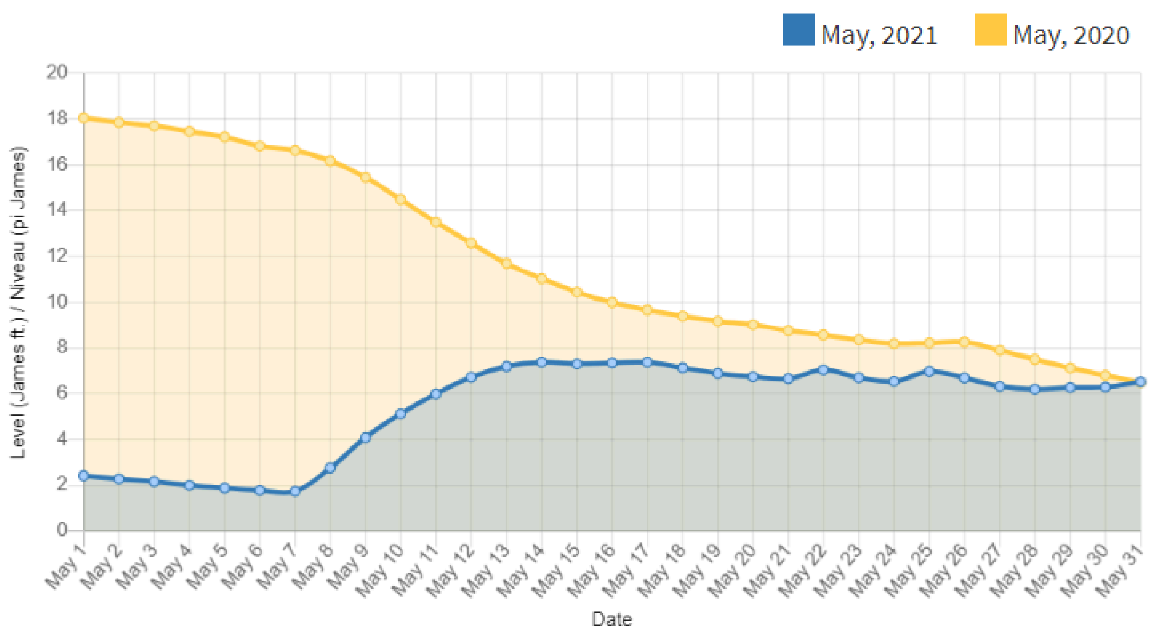


Figure B.2 — Red River Water level May 2020/2021 Comparison, [Winnipeg river levels]

There is a floodway (48 km long excavated channel) to reduce flooding within the City of Winnipeg, but it can only be opened when there are no ice jams. Water started naturally flowing into the floodway on 07 April, and it was put into full operation on the evening of the 10 April resulting in around 930 million m3 of water being diverted around the City of Winnipeg [7].

The lower reaches of the Red River, between Winnipeg and Lake Winnipeg, are affected by ice jam events that have increased in both severity and frequency [8]. Severe jams can cause extensive property damage, economic loss, and sometimes loss of life.

There have been previous events, like 2011, which have had similar impacts and generating processes and so was used for the modelling activity of the Pilot.

B.1.2. What geospatial knowledge is currently used?

Earth Observation (EO) data is a key source of geospatial information that supports Red River flood response activities. Natural Resources Canada's (NRCan) Emergency Geomatics Service (EGS) uses satellite-derived EO imagery to monitor active Red River floods, as well as indicators that may predict a flood event (e.g. spring ice break up). EGS's activities fall into three categories, each of which leverages geospatial standards:

1. Imagery Acquisition and Access — Satellites are tasked to capture imagery for the Red River region. Acquired data is transmitted to NRCan's ground-receiving stations, where initial data processing is undertaken to transform the satellite data into information that can be read by computers (i.e. "raw" data). This data is then uploaded into a secure file system at the Canadian Space Agency, where it can be directly accessed by EGS scientists in near-real time. The data is also stored within NRCan's Earth Observation Data Management System (EODMS) for long-term archiving and access by other users.

Different types of standards enable each of these steps. Standards related to satellite sensor design and calibration support the data acquisition. Data models allow for the reception of imagery by ground-receiving stations, and for the automated application of processing to generate raw data. Web service standards support the flow of data from ground-receiving stations to the EODMS archive, and then to scientists for use. Metadata standards allow both humans and machines to understand the characteristics of a given dataset, allowing it to be used appropriately.

2. Processing and Analysis — Once imagery is received, EGS scientists apply several types of processing to prepare the imagery for analysis. These steps are specific to the type of imagery used, which for the Red River is typically Synthetic Aperture Radar (SAR) data. SAR imagery has a significant advantage for monitoring floods due to its ability to monitor conditions through clouds or at night. SAR can also identify flooded vegetation, providing insight into the amount of terrain that is experiencing flooding. Comparisons over time allow for the monitoring of flood progression, with a limitation that the satellite return frequency can be several days.

The resulting Analysis Ready Data (ARD) is used by EGS scientists to create flood products for the Red River. This is achieved through a combination of automated and manual processes. For example, the application of an automated water identification algorithm to the ARD allows the geographic extent of the river to be determined. Comparisons with imagery acquired under non-flood conditions, as well as with geospatial products capturing permanent, non-flood waters (e.g. Canada's National Hydrographic Network), allow the flooded area to be mapped. Manual visual analysis is used to verify results and correct any problems. Similar approaches can be applied for different types of conditions (e.g. mapping ice jams). Scientists use the results of their analysis to create products that support decision-making by local disaster response managers (e.g. maps of flood extents and associated interpretations).

3. Data Delivery — Once complete and verified for accuracy, EGS flood products are delivered to disaster response managers for local use e.g., see Figure B.3. Products designed to meet a specific user requirement are provided using data formats and/or web service approaches that meet end-user needs. EGS also makes flood extent products available to the public through the Government of Canada's Open Maps system.

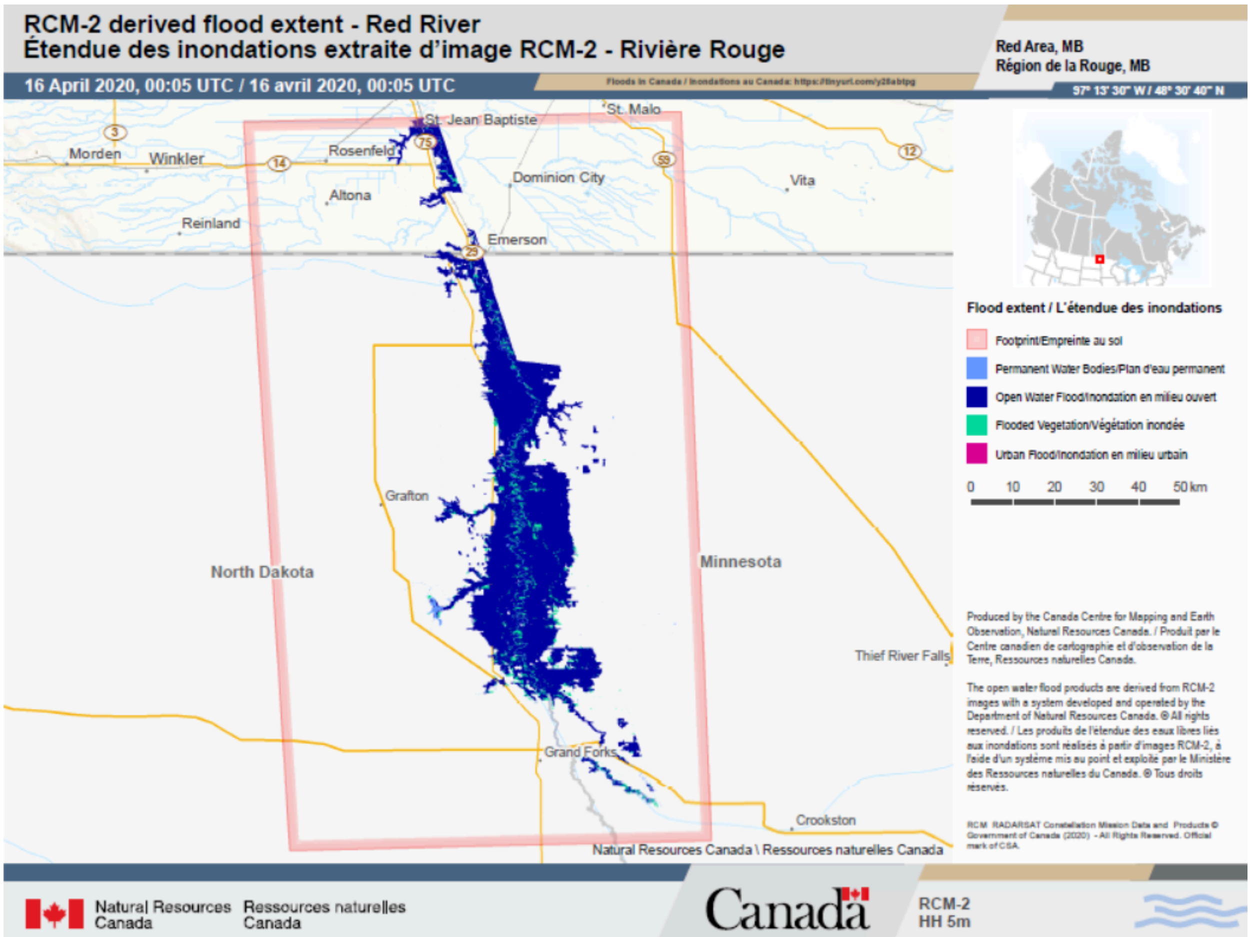


Figure B.3 — RADARSAT Constellation Mission-2 derived Red River flood extent for April 2020; example courtesy of NRCan.

Standards are critical for the effective delivery of EGS flood products as they enable consistent use and understanding. For example, flood extent products delivered as web services allow this geospatial information to be used by a wide variety of technologies seamlessly. The use of web services also ensures end-users are always using the most up-to-date information without requiring regular manual data downloading.

B.2. What has the Pilot done?

The Pilot has undertaken the following steps in going from flood extent to traffic control:

- Calculation of ARD flood extent from:
  - Digital Elevation Model (DEM), e.g. from 5 m Lidar, and Near-Real-Time (NRT) river gauge data to predict flooded areas, e.g. Figure B.4 that shows the output for the 2011 flooding as suitable 2020 gauge data was not accessible. This is the so-called “bathtub” approach, where the flood surface is projected onto the DEM by assuming a horizontal plane of predetermined height or elevation.
  - Optical or radar satellite data combined with algorithms used to detect flooding. Figure B.4 shows flooding occurrence for April 2020 determined using Sentinel-1, Sentinel-2, and Landsat-8 data by Wuhan University. This is overlaid on the same DEM as used for Figure B.5 but is for an area further north that overlaps with the modeled flood extent.

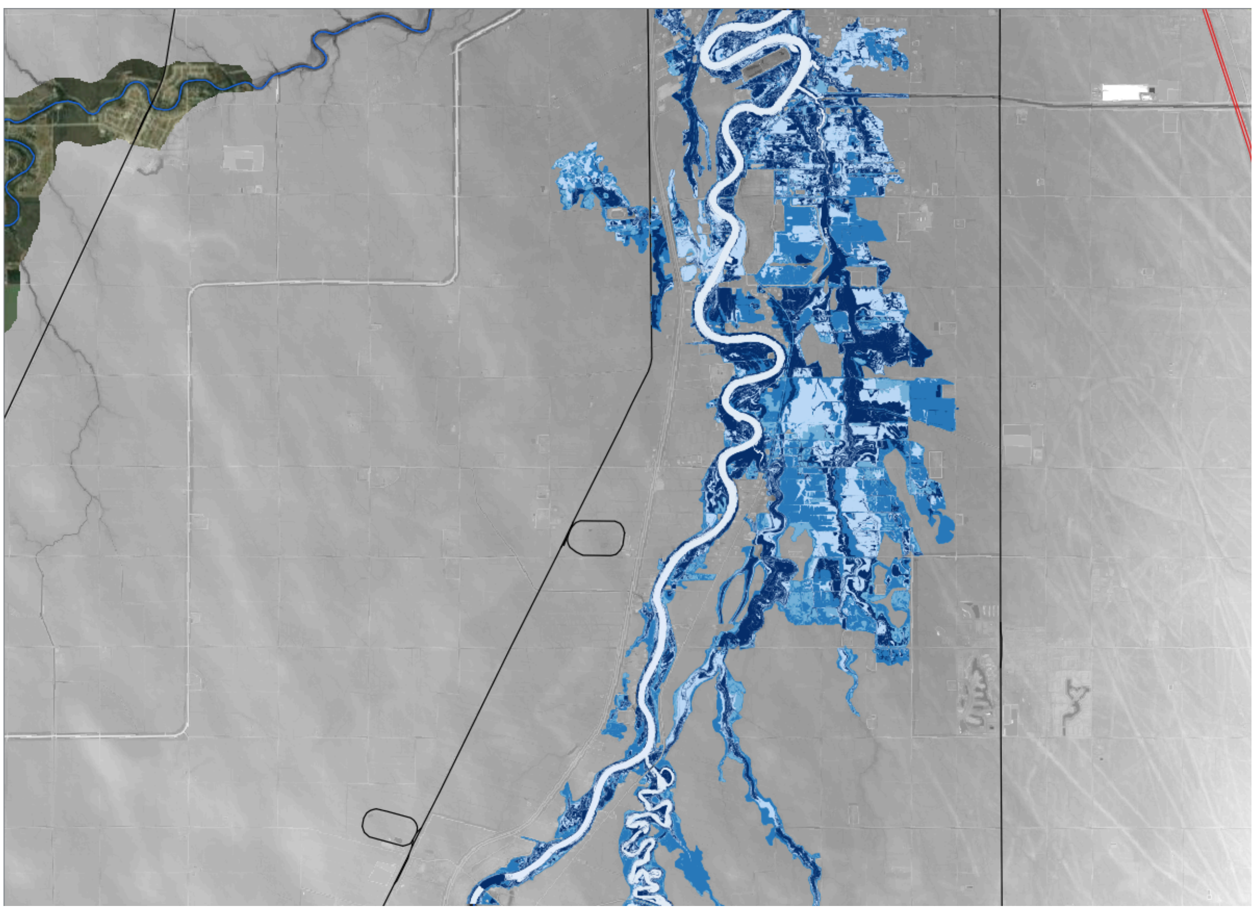


Figure B.4 — Area of 2011 flooding, colored light to dark blue according to flood day (start to end) overlaid on Lidar DEM (shades of grey), with railway line as black lines, and motorway as a red line; flooding area from RSS Hydro using the “bathtub” approach.

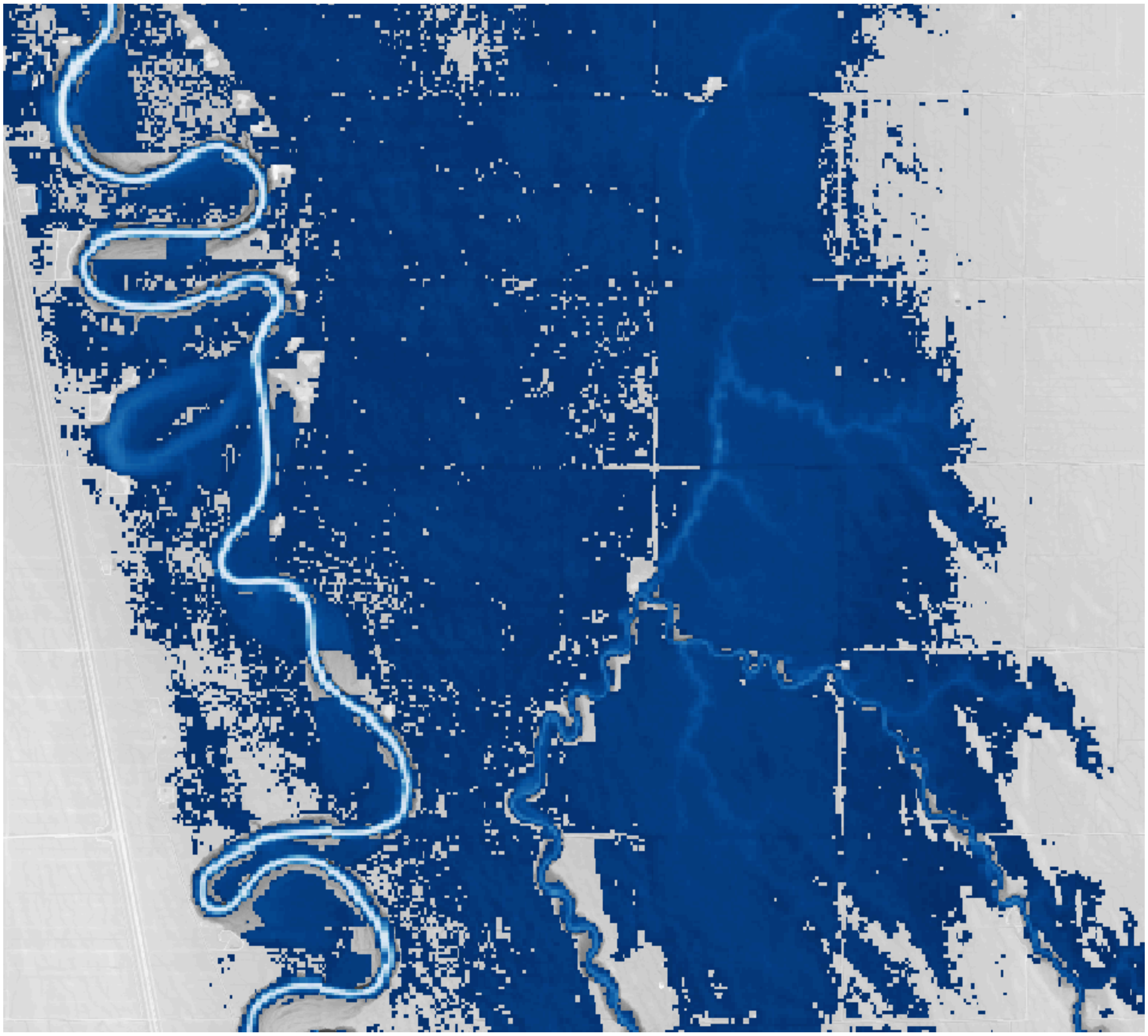


Figure B.5 — Section of the April 2020 flooding, colored dark to light blue according to the occurrence, developed by Wuhan University, overlaid on the Lidar DEM.

- ARD raster area grid flood predictions converted to ARD flood contours, e.g. following an approach implemented by Safe Software using their FME platform (model based spatial ETL data transformation and integration tool); as shown in Figure B.6.
- Given the sensor and computational tools used, both EO and flood model output datasets tend to generate grid based observations or time series. However, many decision support tools are based on GIS approaches that are best adapted to work with vector datasets. This is why the ARD to DRI approach for flood impact analysis was designed to convert raster flood depth grids to vector flood contour polygons. Flood contours were used instead of flood extents because the rules associated with the transportation impact DRIs required flood depth estimates and not just flood state.
- In this example, a raster to vector conversion is performed, followed by the removal of the smallest polygons, generalization to reduce detail (e.g. by smoothing lines), classification

into five depth categories (0.1, 0.3, 0.5, 1.0 and 2.0+ m), and finally dissolving (aggregate touching features to further reduce complexity).

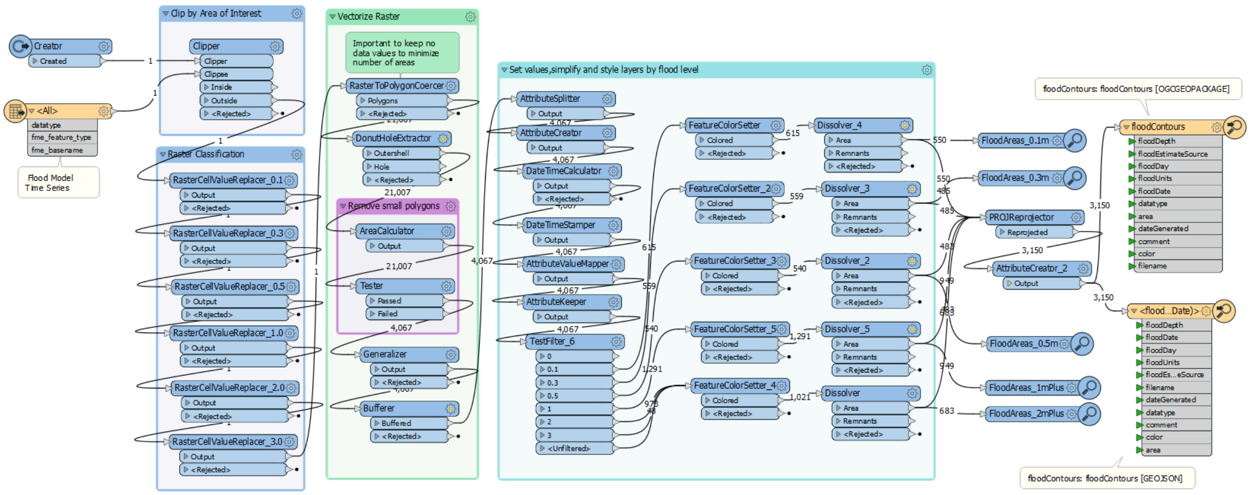


Figure B.6 — ETL approach for converting flooding areas to contours, using FME from Safe Software

- The result is saved as an OGC GeoPackage, which makes it easy to share with other components as well as to use offline. To better support online integration, the vector flood contour time series is also provided to the HSR.Health GeoNode instance, which makes this data available to other components via OGC services such as WMS and WFS. The data is also made available directly to users with web browsers via the GeoNode web map interface; see Figure B.7. The data is published with the flood date field used as a time series index so that the time slider can be used to explore the propagation of the flood over time.

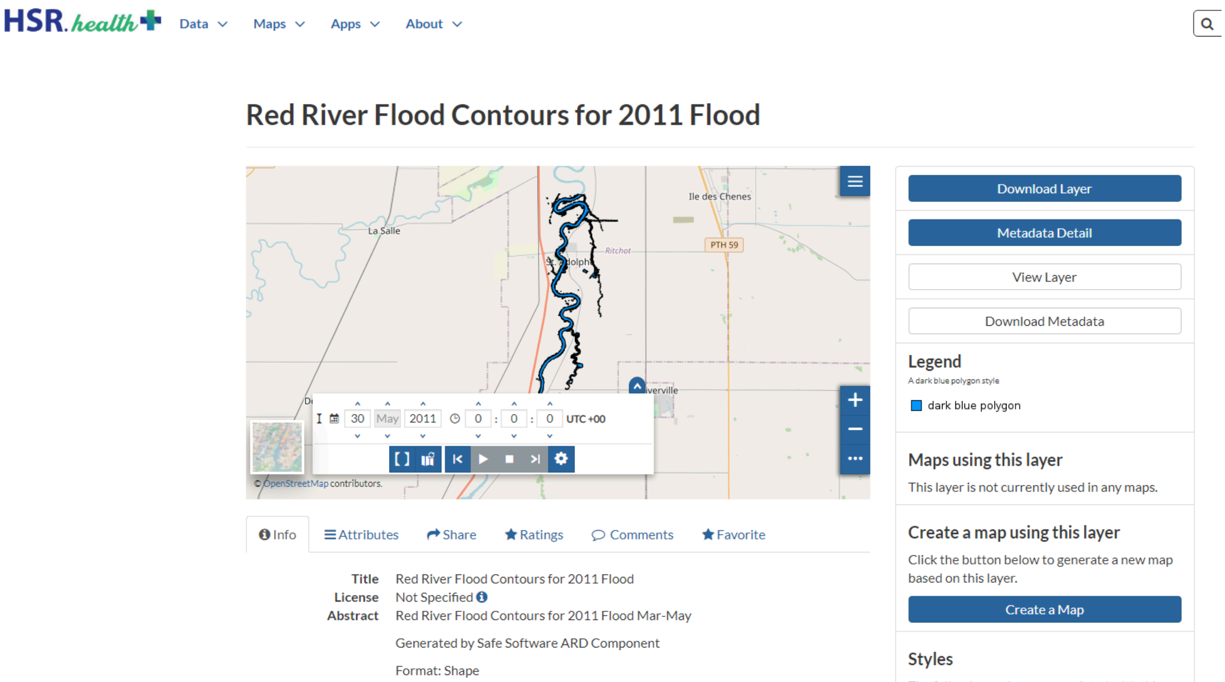


Figure B.7 — HSR.Health GeoNode with Flood Contours for Red River flood from April 7 2011 loaded from FME workflow output.

- Flood contours are used to generate Decision Ready Information and indicators (DRI) routing information, e.g. following the approach outlined in Figure B.8 as designed by Skymantics.

Figure B.8 — Converting the flooding ARD inputs to DRI to support the management of flooded rivers, Skymantics

- The flood contours are used to determine the roads affected by flooding, and the depth, plus the user has specified what depth of flooding is passable. Then, the routing determines the best route between two locations; see Figure B.9 that shows (from top to bottom) the route without flooding, routing parameters, and route with flooding. A full list of recipes and resulting DRIs is given in the Appendix.

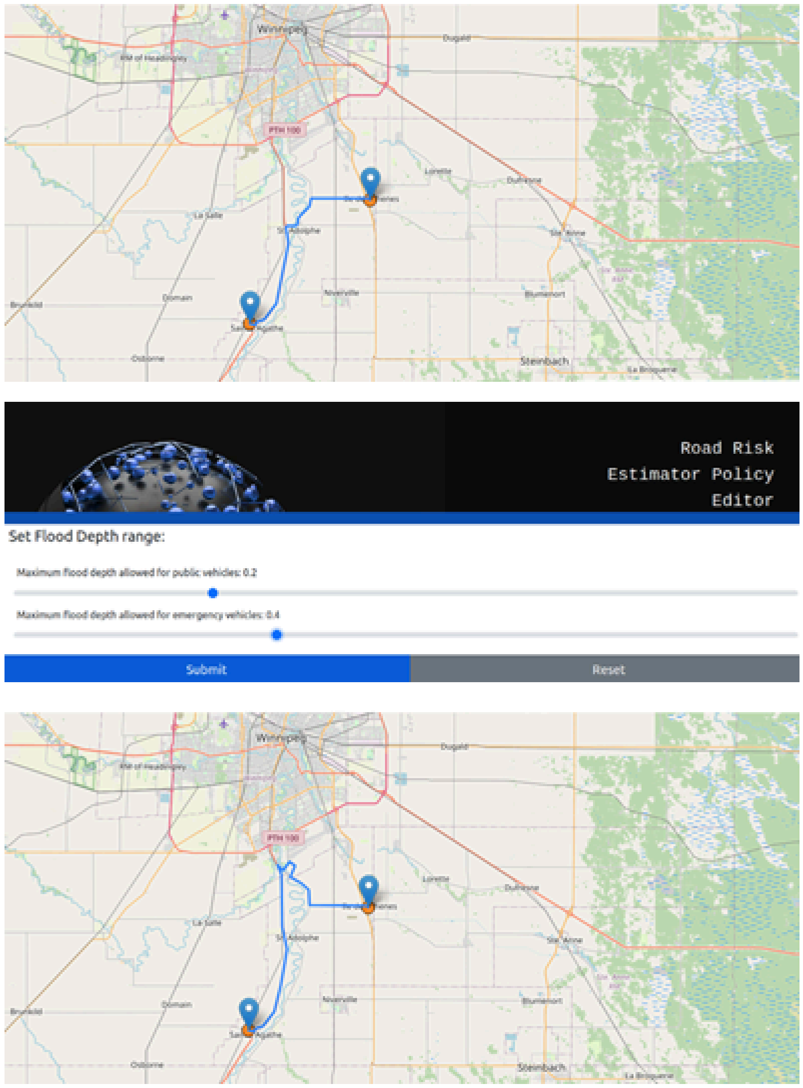


Figure B.9 — Route determination without (top) and with (bottom) flooding overlaid on OSM, and the routing parameters (middle); Skymantics

B.3. Conclusion

This Case Study has focused on flooding within the Red River basin, Canada. The Pilot generated ARD data and then converted it to DRI following a recipe that focused on the routing of emergency vehicles. The ARD data includes numerical modeling and EO sources (Sentinel-1, Sentinel-2, and Landsat-8) that are first generated as raster (image) products and then converted to vector (point, line, polygon) products to better support downstream impact analysis components.

The transfer of data between the different players was primarily through manual transfer in a GeoPackage with the addition of web service support once the flood contours were published to GeoNode. The flooding figures were generated using QGIS but could have used another visualization package that supports geospatial information.

During the Pilot, some of the core datasets were published to GeoNode, and it was recognized there was a need to deal with the encountered size and scaling limitations. Therefore, further work is needed to bring all components together via cloud computing, so that manual data transfer is removed wherever possible.

Also, when data is provided as a service with a REST endpoint, technologies such as GeoCollaborate can access and share those data products in a real-time collaborative environment, connecting all decision-makers immediately and enabling interactivity across the collaborative participants. Therefore, a reasonable goal for data providers is to offer their data as a service to put it to work more rapidly.

B.4. References

- Lindenschmidt et al. 2010
- Manitoba, 2020, Red River Floodway Operation Report Spring 2020
- NASA, 2020, Another Flood on the Red River

B.5. Appendix: Flooding DRI Recipes

Routing recipes for a flood scenario

Table B.1

RECIPE DESCRIPTI	INPUT ARD	PROCESS	OUTPUT DRI	THRESH	EXPLANAT	SUGGES ACTION
Sentinel-1 Change Detection Algorithm	Sentinel-1 GRD	Satellite algorithm	Change detection map (Geo TiFF); Change detection mask			

RECIPE DESCRIPTI	INPUT ARD	PROCESS	OUTPUT DRI	THRESH	EXPLANAT	SUGGES ACTION
			(Geo JSON); Flood mask / extension, change maps			
Update road estimated speeds due to precipitatio	Current precipitatio area and intensity; Roads dataset	Find roads affected by precipitatio	Light rain occurring in road X; Heavy rain occurring in road X	0.25–6.4 mm/h; >6.4 mm/h	Common thresholds and impacts in observation studies. Considerabl regional variations	Reduce estimated road speed by 10%; Reduce estimated road speed by 25%
Update estimated speeds from traffic cameras	Real-time traffic cameras live-stream	Find jammed roads	Road X average speed	<50% speed limit	Successfully tested in OGC SCIRA pilot	Mark road as jammed and notify it; Reduce estimated road speed
Manage flooded roads	Extension & depth of current flooding; Terrain topography (road elevation); River and flood gauges (water level); Inputs from public and first	Find roads affected by flooding	Road X flooded but passable; Road X flooded and only passable by special vehicles; Road X flooded and impassab	<150mm flood depth; 150-300 mm flood depth; >300 mm flood depth	With 150 mm depth, water can enter a small car's exhaust pipe. With 300 mm depth, cars can start floating. Several articles point to a traffic speed reduction	Reduce estimated road speed to 70-20 km/h; Reduce estimated road speed to 20-2 km/h; Block road for

RECIPE DESCRIPTI	INPUT ARD	PROCESS	OUTPUT DRI	THRESH	EXPLANAT	SUGGES ACTION
	responders (water level); Roads dataset				based on depth.	public; Notify traffic apps; Block road for all transit
Forecast flooded roads during night time	Extension & depth of future flooding (during night time); Terrain topography (road elevation); Roads dataset	Find roads affected by future flooding during night time	Road X flooded and only passable by special vehicles; Road X flooded and impassable	150-300 mm flood depth; >300 mm flood depth	Roads that are expected to get flooded during the night should be closed in advance. Somerset road closure gates are an example.	Block the road for the public. Notify traffic apps; Block road for all transit

C

ANNEX C (INFORMATIVE) CASE STUDY 3: INTEGRATION OF HEALTH AND EO DATA

C

ANNEX C (INFORMATIVE) CASE STUDY 3: INTEGRATION OF HEALTH AND EO DATA

C.1. Integration of Health and EO data and services for pandemic response in a region of the United States

Over the last eighteen months, the world has become very familiar with the word 'pandemic', but it is important to understand what it means. When a known or unknown disease affects a large number of people within a community or population it is classed as an epidemic. It becomes a pandemic when the disease spreads to multiple countries, whereas an epidemic is an unexpected increase in the number of disease cases in a specific geographical area. The reference to geography in both definitions is a useful indication of why geographic information and Earth Observation (EO) data can offer help when integrated with health data to support the response to pandemic situations.

Over the last two years, the world has been suffering from the COVID-19 pandemic. COVID-19 is an infectious disease caused by a coronavirus named SARS-CoV-2. Most people infected experience mild to moderate respiratory illness and recover without requiring special treatment. Some experience no symptoms at all. However, older people and those with some underlying medical conditions are more likely to develop serious illness and may require medical attention, and sadly, many people have died due to COVID-19.

This case study focuses on how health and EO data can be integrated to improve pandemic response within Louisiana in the United States.

The State of Louisiana is located on the coast of the Gulf of Mexico, between Texas and Mississippi. It covers a geographical area of just over 43,000 square miles and is divided into 64 individual parishes, and overall it was estimated to be home to over four million six hundred thousand people in 2019 [9]. Almost 16% of the population are over the age of 65, and just over 23% of the population are under the age of 18. Like the rest of the planet, Louisiana has suffered from COVID-19. By the middle of October 2021, over three-quarters of a million cases of COVID-19 had been confirmed in the State, with over fourteen-thousand deaths reported to date. The climate within Louisiana is considered to be subtropical and the physical geography of the area includes the Mississippi floodplain; coastal marshes; Red River Valley; terraces; and hills. It is prone to flooding and hurricanes with its largest city, New Orleans, lying five feet below sea levels protected by natural levees. During the pandemic, the area was hit by its second-most damaging and intense hurricane, Ida, the most damaging being Hurricane Katrina in 2005 that flooded 80% of New Orleans.

The fact that Hurricane Ida struck Louisiana during the pandemic indicates the need to be able to monitor and respond to other disaster events that might occur at the same time as a pandemic. Therefore, the case study aims to demonstrate how integrating health and EO data can add value and provide support and assistance within a pandemic response.

C.1.1. What's there now?

Before the COVID-19 pandemic, there was no integration of health and EO data for a pandemic response within Louisiana. Once the pandemic began, datasets began being produced to look at the disease spread and its impact. These datasets tended to be produced in isolation, rather than integrated, as described below.

For health, together with the data already collected by the State, various analyses looked at the spread of the disease. For example, the Louisiana Coronavirus Data Dashboard includes a Parish risk index displayed in a Geographic Information System (GIS).

For EO, existing datasets were applied to the pandemic situation, however, most of the analysis focused on the impact of the pandemic rather than the health issues. For example, there was a lot of work looking at the reduction in Carbon Dioxide emissions due to the large-scale reductions in the number of planes flying, or looking at a reduction in thermal energy and light pollution in urban centers as factories and offices were not operating due to government directions that people should stay at home.

Some examples, although not all, of the use of EO data to look at the pandemic, include:

- NASA's EarthData COVID Dashboard is an experimental dashboard looking at 10 areas across the globe and focusing on 7 indicators, demonstrating the changes in the environment that have been observed as communities around the world have changed their behavior.
- European Space Agency & European Union's Rapid Action on Coronavirus and EO Dashboard demonstrating how EO data can support the monitoring of societal and economic changes due to the pandemic using data from the Copernicus Sentinel satellites and other Copernicus Contributing Missions. It also includes case and vaccination health data on the diseases, although these are not integrated with the EO data. GeoGlam Crop Monitor (https://cropmonitor.org/) provides information on global agriculture conditions and crop conditions, and how COVID-19 might impact food markets, and the knock-on effects of this on food insecurity.
- GIS COVID-19 Dashboard from the BEYOND Centre of Earth Observation Research and Satellite Remote Sensing, National Observatory of Athens gives details on the COVID-19 worldwide spread, plus additional air quality and environmental indicators.

Whilst there are other dashboards across the world, many are focused only on a particular area of the world, focusing on specific data indicators or producing reports available to access. This review concludes that there is currently not a good example of the integration of health and

EO data to support the pandemic response, which is why this Pilot can add value to the current experience.

C.1.2. What has the Pilot Done?

Following the data model developed in the Pilot, the work on this Case Study has focused on developing a set of potential Analysis Ready Datasets (ARD) and Decision Ready Indicators (DRI) that can be used to support a pandemic response and identify those health indicators which could be supported by EO data.

Examples of how this might work have been developed, and the Case Study will show how health data can be used within GIS to support pandemic response through a Medical Supplies Index and routing map developed by HSR.health and Skymantics, together with EO examples images that could be integrated to create, develop, or improve the ARD or DRI.

C.1.2.1. Foundation Layers

As highlighted in Step 1 of Clause 7, it is recognized that a number of foundation data layers of local geospatial information need to be established and developed into which health and EO data can be integrated.

This Case Study has identified the following Foundation Layers for pandemic response, most of which can be achieved from national or local information:

- Habitation Layer (villages, homes, farms) including building footprints.
- Health infrastructure including hospitals, clinics, medical offices, health centers, pharmacies, labs, dental clinics, nursing homes, long-term care centers, diagnostic testing centers, emergency dispatch centers, health supply manufacturers and warehouses, drug manufacturing plants, etc.
- Critical infrastructure including power, telecommunications including wireless network, water, sanitation, etc.
- Transport network including road network, freight train route, helicopter, and aircraft landing zones.
- Address database and geocoding application.
- Critical Supply Chain facilities and routes for key medical, food, etc.

The EO specific Foundation Layers would include:

- Satellite Imagery of the area the disaster response team is responsible for, with coordinates or addresses.
- Land Use and Land Cover maps identifying how the land is being used, e.g. urban centers, agriculture, woodland, lakes, and rivers, etc.

- Digital Elevation Models to understand the height of land.
- Potential Hazard and Vulnerability (High Risk) Areas for natural hazards such as flood risks, tornado risk, etc., based on models and developed using EO data.

As highlighted in Step 2 of the User Readiness, all of these data layers need to be collected and presented using agreed standards for data to ensure that they can be easily integrated.

C.1.3. Pandemic Response

The Pilot identified a number of ARD and DRI which would be potentially beneficial for pandemic response. This section will focus on how EO data could potentially be used to support the development of those ARD and DRI datasets by integration with health data. Although the focus is on the pandemic, the summary listed below is equally applicable to other disaster response scenarios.

The full list of the identified health and pandemic-related ARD and DRI can be found in Appendix A of this Case Study.

Below is a listing of EO datasets with a description of their potential use, for example, current satellites or missions to find the data together with the relevant ARD or DRI indicators that they might support. Some of these datasets are simply downloadable from the relevant satellite data provider, others may require some pre-processing by a data provider to turn the raw satellite data into the datasets listed here. Of course, all satellite datasets will need processing to turn them into integration-ready datasets with relevant data standards applied.

C.1.3.1. Analysis Ready Datasets (ARD)

- **Optical & Synthetic Aperture Radar (SAR) Satellite Imagery –** Both of these types of imagery are used for observing, giving a snapshot of what was happening at the time the image was acquired. They can be useful for detecting how things change over time. Images normally take at least a couple of hours from acquisition to delivery, and so this will always be a near past viewpoint. Several satellites can provide similar data: Example satellites that offer optical imagery include NASA's Landsat missions, European Space Agency's (ESA) Copernicus Sentinel-2 satellites, PeruSAT, Planet's constellations & Satellogic's Newsat constellation. Examples offering SAR imagery include Canada's RADARSAT, ESA's Sentinel-1, Japan Aerospace Exploration Agency's (JAXA) ALOS PALSAR, and commercial missions such as the ICEYE constellation. These would support:
    - *Land Cover Overview* – Gives an overview of a wide area in a disaster situation, which can be useful to compare to the foundation layers to identify any changes as a result of the disaster scenario.
    - *Pandemic tracking worldwide* – Using the imagery to identify the frequency of transportation, where there are ship movements, lorries on roads, cars in car parks, etc. All of which will give an indication of economic activity where vehicle and construction

activity has slowed during COVID-19, and when it increases as countries resume. This can give a useful insight into how the pandemic might be spreading.

- *Crushing Trauma* – If damage is significant enough or using very high-resolution satellite imagery, the images can be used to pinpoint the location of building damage which would give an indicator of potential crush injuries.

- *Incidents of Panic Buying and Looting* - If using very high-resolution satellite imagery, it would be possible to see crowds or damage from looting.

- *Deaths Above Normal* – Tracking increased activity in graveyards and cemeteries through high-resolution imagery can also be a measure of mortality about normal due to the pandemic.

- **Air Quality –** Measuring the concentration of pollutants in the air such as Nitrogen Dioxide and Carbon Dioxide, both of which reduced significantly across the globe due to the COVID-19 pandemic due to a reduced burning of fossil fuels. Example satellites offering this type of data include the Copernicus Sentinel-5P & the commercial GHGSat satellites. This would support:

  - *Pre-existing conditions* – air pollution such as smoke, particulates, ash, etc., could cause people who have existing respiratory, cardiovascular, and other conditions to have their symptoms worsen.

  - *Population in Area of Dangerous Air Pollution* – risk models of pollution movement in the air can be developed or enhanced, alongside actual pollution levels can be monitored.

  - *Respiratory Illnesses* – air pollution such as smoke, particulates, ash, etc., could cause an increase in respiratory symptoms amongst sufferers, or increase the number of people suffering from respiratory issues.

  - *Dangerous Chemicals in the Air* – Some chemicals in the air, such as nuclear radiation, can't be monitored directly, but satellites can provide wind speed measurements and precipitation to support dispersion modeling.

- **Water Quality –** Satellites can measure several elements of water quality, such as temperature, phytoplankton levels (microscopic algae) & turbidity, which individually, and combined, can offer an indication of water quality. Example satellites that offer this data include Copernicus Sentinel-3, NASA's MODIS, and JAXA's GCOM-C. This would support:

  - *Predicted Increases in Illnesses* – identification of drinking water or standing water that has become contaminated, which can lead to an increase in gastric illnesses which can cause dehydration.

  - *Pathogen Identification In Water* – some indicators of pathogens in water can be indirectly identified by satellites, for example, high turbidity can be linked to sewage in the water, or cholera has been predicted by increases in phytoplankton during dry seasons as the aquatic animals that carry cholera feed on phytoplankton. (https://earthobservatory.nasa.gov/features/disease-vector)

- *Dangerous Chemicals in Water* – some chemicals in water can be indirectly identified by satellites, for example, mine waste in water shows up as brightly colored.
- *Population with Compromised Water Systems* – identification of drinking water that has become contaminated, which can lead to an increase in gastric illnesses which can cause dehydration.

- **Thermal Imagery –** This measures the amount of heat being generated by a location, and can measure everything from the temperature of the ground through heat loss from buildings to wildfires. Example satellites that offer this type of data include NASA's Landsat-8, -9 & MODIS; Copernicus Sentinel-3 and JAXA's GCOM-C. This would support:
    - *Population of Power Outage Area* – Drop-in thermal activity in urban centers can indicate a loss of power.
    - *Pandemic response tracking worldwide* – Drop in thermal activity across countries due to offices and factories having fewer lights on and less machinery and heating operating. Whilst not a direct indicator of the pandemics spread, it could be an indicator of the spread of quarantine measures across countries and how populations are abiding by quarantine measures
    - *Deaths Above Normal* – For cultures that use funeral pyres or similar burial rituals, the increase in small fires would indicate the increase in deaths above normal.
    - *Exposure (Cold, Heat)* – for any communities living outside, or forced to be outside from a disaster scenario this will measure the temperatures they are facing and will indicate the additional support they might need.

- **Air Temperature & Relative Humidity –** Whilst these two elements are not measured directly by satellites, water vapor can be determined by the delay in the return of satellite signals passing through the atmosphere, or by assimilating satellite data into numerical weather forecasting models. Air temperature is the temperature 2 meters above the ground, and relative humidity is the concentration of the water vapor present in the air. The signals from positioning satellites can be used to support these datasets, alongside data from the commercial SPIRE satellites. These would support:
    - *Exposure (Cold, Heat)* – for any communities living outside, or forced to be outside from a disaster scenario this will measure the temperatures faced and the support they might need.
    - *Pandemic Spread* – Scientific research has indicated that humidity may be a useful supporting indicator of COVID-19 transmission – although this needs more research as it was not uniform across the different States in the US study.
    - *Weather Forecasts* – give indications of future temperature and humidity and how this might impact both the disaster response efforts and those vulnerable people suffering from the disaster.

- **Light Pollution –** Monitoring the lights of the world can give indications of what is happening in the terms of economic activity and transportation. Light pollution measurements can only be acquired at night. Example satellites that offer these datasets include the NASA/NOAA Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS), and JPSS-1/NOAA-20. It would support:

- *Population of Power Outage Area* – Reduction of light pollution in urban centers can indicate a loss of power.
- *Pandemic tracking worldwide* – A drop in light pollution in urban areas across the world can indicate a slowdown of economic activity as factories and offices reduce their working hours.

- **Precipitation –** This is the measurement of the amount of water falling from the sky in all forms, including rain, hail, snow, or other particles. Example satellites with these datasets include EUMETSAT's Meteosat & SEVERI, JAXA's GCOM-C, NOAA's AVHRR, and NASA's GPM. This would support:
  - *Vector (Disease Carrying Mosquitoes) & Pathogen Identification in Vectors (e.g. Mosquitoes)* – Mosquitoes breeding favors standing water that can be caused by heavy rainfall.
  - *Water Extent & Floods* – Heavy precipitation fall can be an indicator of flooding, whether this is flash flooding, rivers bursting banks from rainfall upstream, potential snowmelt, or additional water falling onto the already sodden ground.
  - *Weather Forecasts* – gives an indication of current and future precipitation and how this might impact both the disaster response efforts and those vulnerable people suffering from the disaster.

- **Water Extent & Flood Modelling –** Measurements of water extent are useful to map water bodies, particularly flooding. Combined with elevation models they can also be useful to understand depths of water and be used to predict floods. The satellites that offer this type of data would include the optical and SAR missions highlighted above. This would support:
  - *Vector (Disease Carrying Mosquitoes) & Pathogen Identification in Vectors (e.g. Mosquitoes)* – Mosquitoes breeding favors standing water that can be caused by heavy rainfall.
  - *Drownings/Suffocation* – Dramatic increases in water extents or depths would also give an indication of potential drownings.
  - *Transportation* – Flooding and changes in water extents or depths impacts the transport network in terms of understanding the open medical supply routes, flooded areas to avoid, distance to medical care, safe routes to the care, and safe evacuation routes

C.1.3.2. Decision Ready Indicators (DRI)

EO data can also contribute directly to the Hazard and Vulnerability Areas (High Risk) DRI through the various risk modeling tools, such as Flood Risk Modelling, Flood Forecasting, Hurricane/Tornado Forecasting.

These will utilize various datasets identified above to contribute towards the model. More details on the flood risk model can be found in Case Study 2.

C.1.4. Showing How Data Can Be Used

The Medical Supply Needs Index, developed by HSR.health, gives an estimate of the number of medical supplies a medical facility may need to deal with, considering the anticipated patient load during the current pandemic and/or disaster situation.

In this case study, the calculation of the Medical Supply Needs Index for the COVID-19 pandemic begins with the calculation of the Pandemic Risk Index, which combines both Mortality Risk and Transmission Risk Indices.

- Mortality Risk Index utilizes data on population demographics and the prevalence of comorbidities to identify the risk to the underlying population of severe illness or mortality due to the COVID-19 pandemic.
- Transmission Risk Index utilizes data on population, case counts, geographical area, and human mobility to identify the risk of the spread of COVID-19.

Both of these indices are normalized so that the output falls between 0 and 100, where 100 is high. The current generalized recommendations from those indices are that 0-25 is low risk, 25-75 is moderate risk, and 75-100 is high risk.

The two indices are combined to create the Pandemic Risk Index, which represents both the spread of the pandemic and the health risk that the pandemic poses. Similar to the indices which make it up, the Pandemic Risk Index is normalized and uses the same generalized recommendations such that 0-25 is low risk 25-75 is moderate risk and 75-100 is high risk creating an ARD.

The Medical Supply Needs Index calculates the usage level of Personal Protective Equipment (PPE) – in this case, gowns, gloves, and masks — by combining the number of COVID hospitalizations, the number of those hospitalizations in the Intensive Care Unit (ICU), numbers of healthcare workers, first responders, and other users of PPE and the current PPE usage rates. This gives a second ARD of the high and low estimates of current PPE needs.

These two ARD's are combined to produce the supply level which is based on the spread of the pandemic and the health risk to the underlying population. Once compared to the current supplies of PPE by hospital location, this creates a DRI on the difference between current PPE supplies and forecasted need. Figure C.1 shows the workflow for the Medical Supply Needs Index.

Stockpile Managers, Emergency Operation Managers, Supplier Chains, and Government agencies can use the DRI generated by the Medical Supply Needs Index to determine when and how much PPE supply needs to be delivered to ensure the location has sufficient PPE to continue to operate effectively.

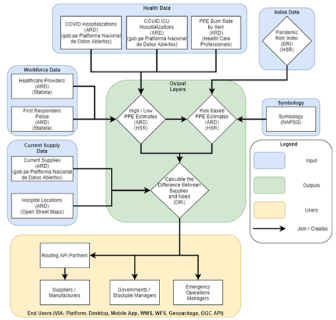


Figure C.1 — Medical Supply Needs Index Workflow Courtesy of HSR.health

Figure C.2 below shows the Medical Supply Needs at a small census district level, with each color indicating a different level of Medical Supply Needs; purple as the highest, followed by red, orange, yellow, green, blue, and the white areas have the lowest level of need. Overlaid are the first hospital locations shown by the red crosses, and distribution locals for the medical supplies with green stars. This allows users to easily identify the areas that need supplies and the closest distribution depots.

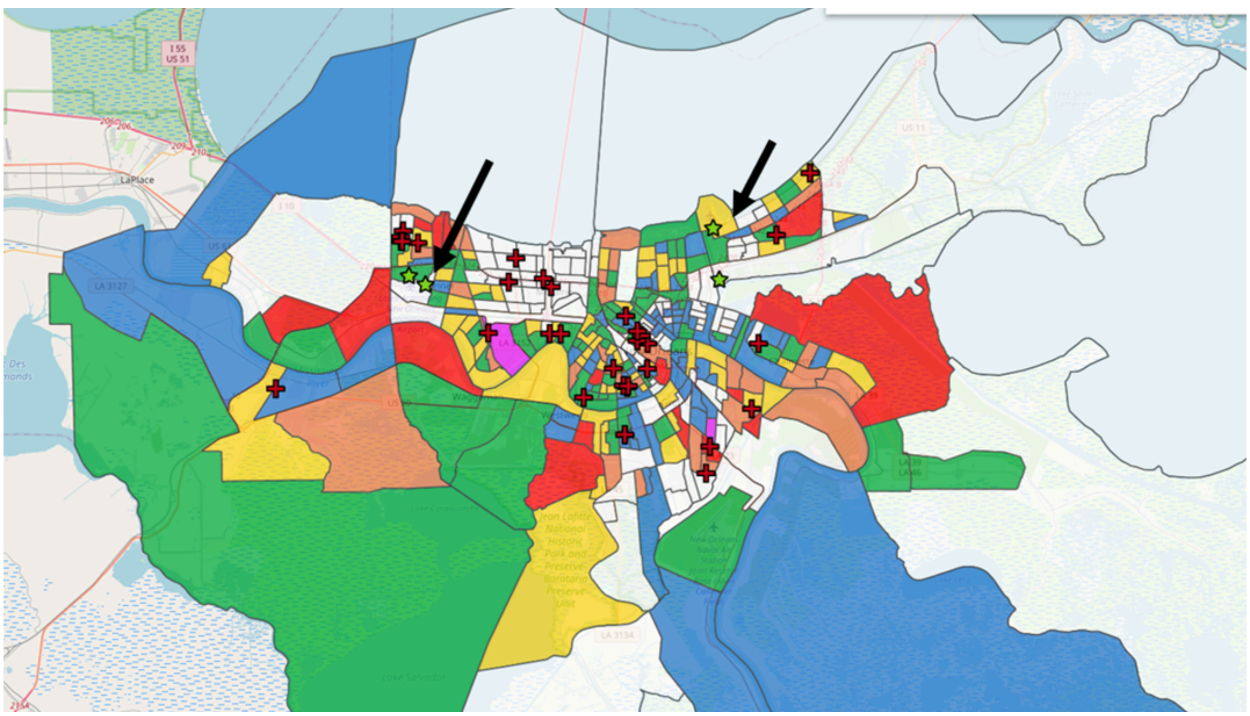


Figure C.2 — Medical Supply Needs Index with Hospital and Distribution Location. Courtesy of HSR.*health*

As a part of the Pilot, Skymantics has developed a dynamic routing solution that can be utilized to identify the quickest or best route to transfer the supplies from the distribution centers (such as warehouses, airports, or ports) to the hospitals and clinics. This will include dealing with any road closures for any reason. This solution will enable decision-makers to improve their ordering for Medical Supplies taking into account changing utilization, delays in delivery, etc.

Figure C.3 shows an example of distance to the closest hospital calculated for all districts in New Orleans; districts colored according to their time to care: less than 5 minutes are green and less than 30 minutes are yellow.

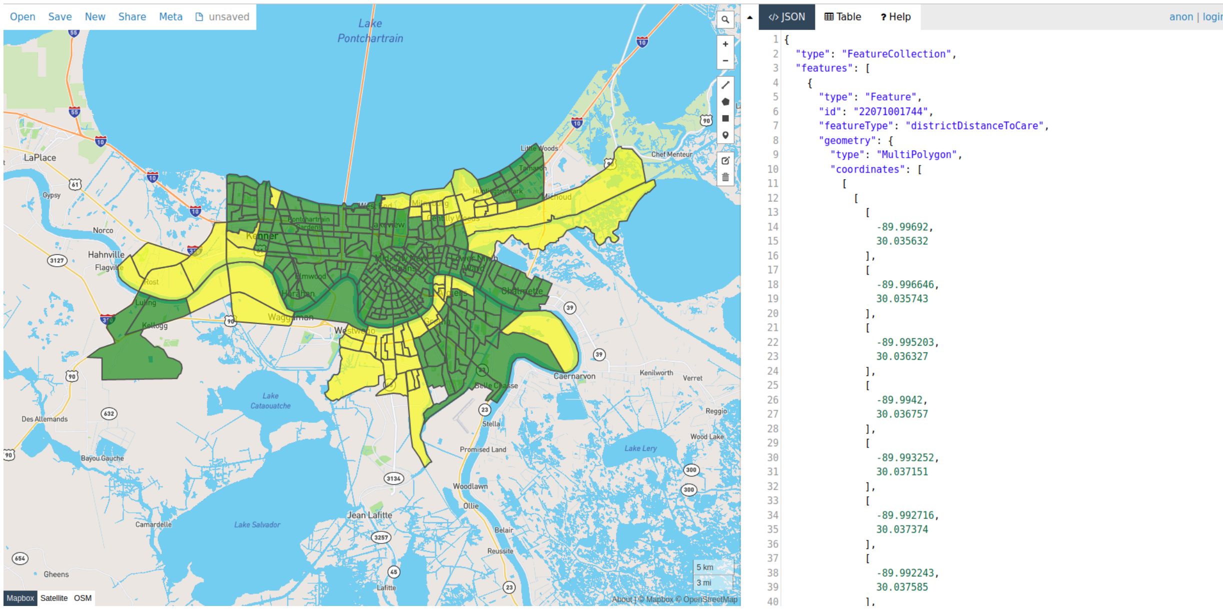


Figure C.3 — Distance to the closest hospital calculated for all districts in New Orleans, colored according to time to care. Visualization courtesy of Skymantics.

C.1.4.1. Earth Observation

A local EO example for Louisiana can be seen in Figure C.4, which includes the 2017 USGS Lidar DEM overlaid on the 2019 US National Land Cover Database (NLCD) layer with OpenStreetMap (OSM) data for waterways shown as blue lines. As the NLCD is a large dataset, for the whole of the US, then rather than downloading it was pulled from the Multi-Resolution Land Characteristics (MRLC) consortium, a group of US federal agencies, using their Web Map Service (WMS). The DEM was developed based on a horizontal projection/datum of NAD83 (2011) — Universal Transverse Mercator (zone 15 N) with a vertical datum of NAVD88 (GEOID12B). Heights are shown in meters above/below this datum, and parts of New Orleans are below this datum that would be confusing to users. So, when fully used the dataset needs to be converted to a meaningful height.

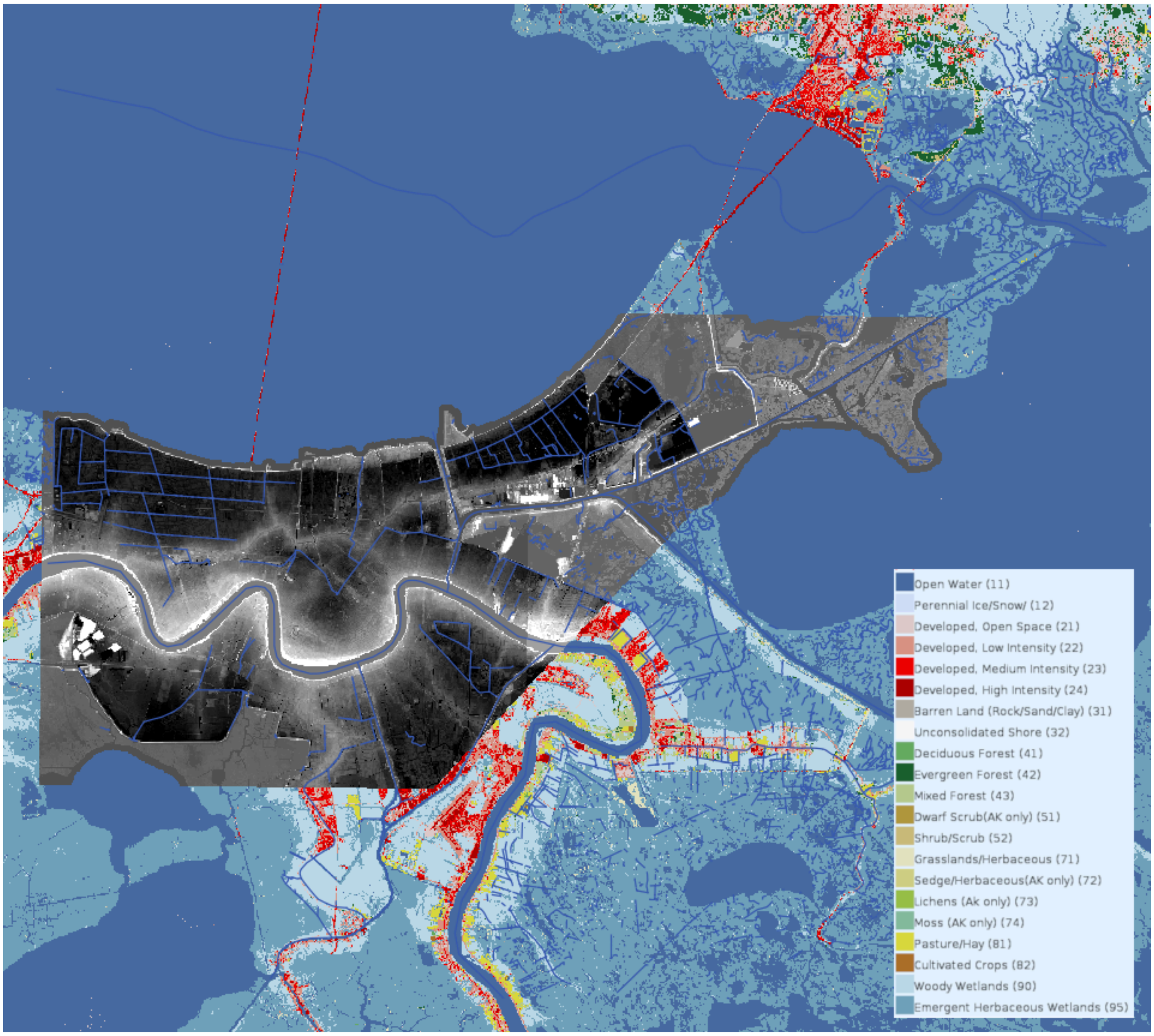


Figure C.4 — 2017 USGS Lidar DEM overlaid on the US National Land Cover Database layer with Open Street Map data for waterways shown as blue lines; for the wider New Orleans area, Louisiana.

For water quality, Figure C.5 shows an example Copernicus Sentinel-2 image as a pseudo-color composite. Lake Pontchartrain is turbid with the mixing of different water masses shown by the different colors. On the southwestern area of the lake, there appears to be an algal bloom as the water is green in color. From analyses by the NOAA Harmful Algal Bloom Monitoring System, using Copernicus Sentinel-3 imagery, it is cyanobacteria that form a surface floating accumulation. Cyanobacteria blooms can grow rapidly and produce toxins that cause harm to animal life and humans.

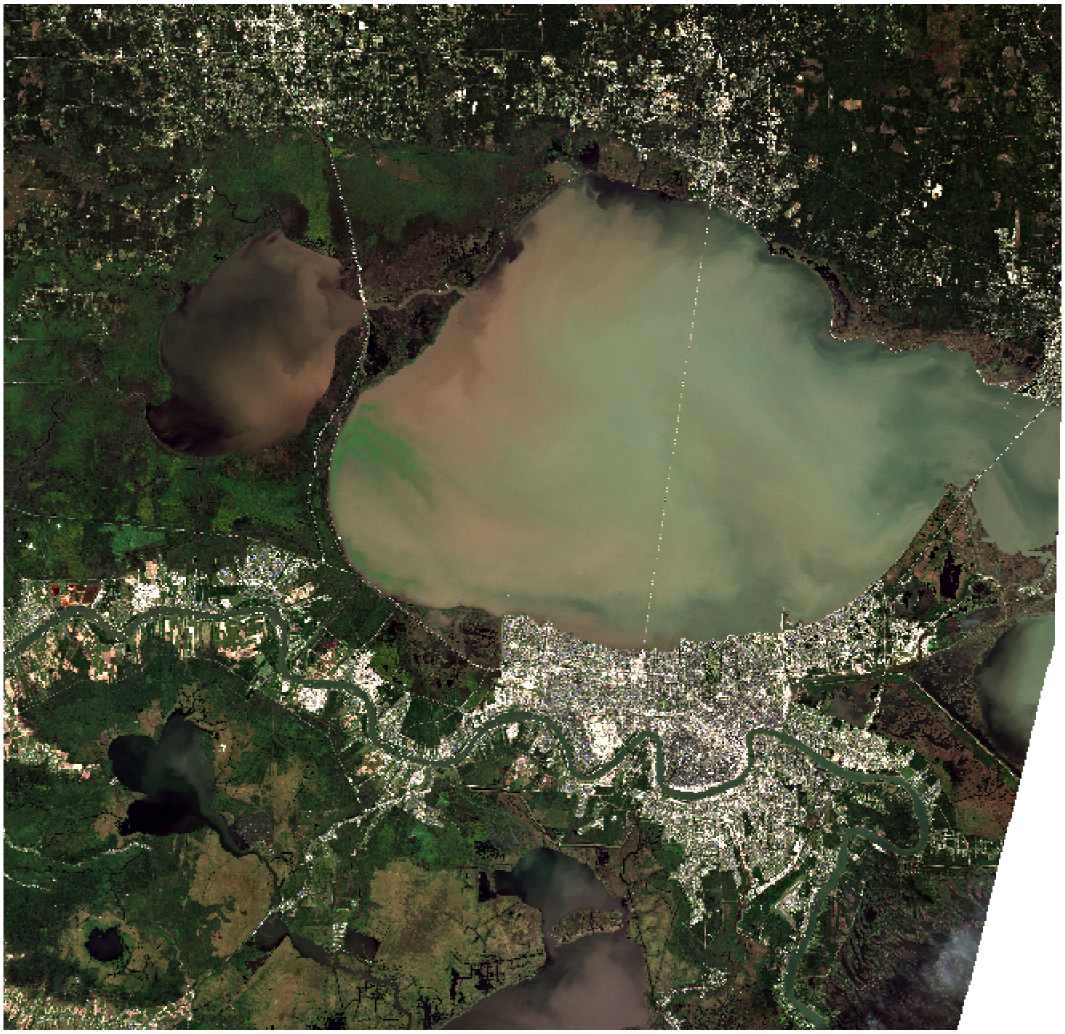


Figure C.5 — 2017 Sentinel-2 from 01 November 2021 shown as a pseudo-true color composite with a cyanobacteria bloom in the south-western area; for the wider New Orleans area, Louisiana.

The World Health Organization (WHO) reports on six major air pollutants, namely particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. The Copernicus Atmosphere Monitoring Service (CAMS) provides both global and European focused air quality parameters as both reanalysis and predicted data. Figure C.6 shows an example predicted for 03 November 2021 as the total column Carbon Monoxide (CO), further real-time parameters can be seen on the CAMS website. CO is a colorless, odorless, gas that can be harmful when inhaled in large amounts and is released when something is burned liked gasoline or forest fires. New Orleans has a higher than the background value but is not one of the hotspots (green to yellow colors).

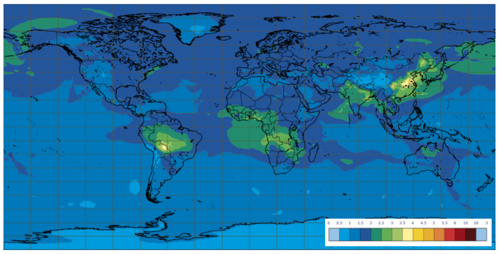


Figure C.6 — Total column (total amount in a column of air extending from the surface of the Earth to the top of the atmosphere) Carbon Monoxide [10^18 molecules / cm2] for the 03 November 2021, provided by CAMS.

C.1.5. Conclusions

The COVID-19 pandemic has conclusively demonstrated that health data, EO data, and GIS solutions can play a crucial role in mitigating and managing a healthcare crisis. For this Pilot, a lot of the work was spent developing the approach from a standing start. Using the outputs and recommendations of this Pilot, it will be possible to create a better opening position that will help respond to similar disasters and pandemics in the future.

The Medical Supply Needs Index, developed by HSR.health, gives an estimate of the number of medical supplies a medical facility may need to deal with the anticipated patient load during the current pandemic and/or disaster situation. Its combination with EO could be applied in a flooding scenario where the EO data is converted to flood maps that support routing; see Annex B for further details.

A range of EO data visualizations were generated by Pixalytics that showcase potential EO-derived products.

- Within Annex B, a Lidar DEM was used to support the modeling of floodwater height, and for New Orleans, a detailed (1-meter spatial resolution) DEM was available to download in GeoTIFF format. This data was visualized in QGIS alongside the Land Cover that was accessed using a WMS feed.
- The Sentinel-2 image of Lake Pontchartrain shows the presence of a Cyanobacteria bloom — a species of phytoplankton that can be associated with health issues in animals and humans. The data was downloaded from the Copernicus Open Access Hub and can be visualized using ESA's SNAP Toolbox.
- The Sentinel-5P visualization was accessed from the CAMS website, with the data also accessible for download and access via Application Programming Interfaces (APIs).

Future work will investigate bringing EO and Health data together with the EO data manipulated within a cloud-computing environment and provided to the Health (GeoNode) platform web services.

C.1.6. Appendix A: Full List of Health Analysis Ready Datasets And Decision Ready Indicators Identified From The Case Study

- Analysis Ready Datasets (ARD)
  - Vaccination Prevalence
  - Pre-Existing Conditions
  - Measure of mobile phone access
  - Pandemic tracking worldwide
  - Syndromic Surveillance, e.g. Drug sales, Health supply sales
  - Internet Linked Thermometers, e.g. Kinsa.
  - Structured Voice & Written Messages
  - Wastewater Testing for Pathogen
  - Hotspot and Micro-Cluster Identification
  - Testing and Diagnosis at First Contact with Health System
  - Diagnosis at Triage and After Hospitalization
  - RO Measurements in Micro Areas
  - Predicted Increases in Illnesses
  - Inventory levels of medical supplies, e.g. test kits, lab chemicals, syringes, sanitizers, alcohol swabs, cotton swabs, test tubes, masks, gowns, beds, oxygen, etc.
  - Supply levels of Other Essential Supplies, e.g. food, water, sanitary products, etc.
  - Deaths Above Normal
  - Population of Power Outage Area
  - Population with Compromised Water Systems
  - Population in Area of Dangerous Air Pollution
  - Population in Area Lacking Communications
  - Incidents of Panic Buying and Looting
  - Exposure (Cold, Heat)
  - Vector (Disease Carrying Mosquitoes)
  - Pandemic Spread

- Respiratory Illnesses
- Digestive Illnesses
- Crushing Trauma
- Drownings/Suffocation
- Mental Health
- Criminal Victimization
- Pathogen Identification In Water
- Pathogen Identification in Vectors (e.g. Mosquitoes)
- Dangerous Chemicals in Water and Air
- Weather Forecasts

- Decision Ready Indicators (DRI)
  - Hazard and Vulnerability Areas (High Risk)
  - Vaccination Prevalence
  - Pre-Existing Conditions
  - Resistance to Modifying Behavior
  - Resistance to Vaccines (Vaccine Hesitancy)
  - Infected Responders
  - Hotspot and Micro-Cluster Identification
  - Diagnosis at Triage and After Hospitalization
  - RO Measurements in Micro Areas
  - Predicted Increases in Illnesses
  - Inventory levels of medical supplies, e.g. test kits, lab chemicals, syringes, sanitizers, alcohol swabs, cotton swabs, test tubes, masks, gowns, beds, oxygen, etc.
  - Supply levels of Other Essential Supplies, e.g. food, water, sanitary products, etc.
  - Deaths Above Normal

D

ANNEX D (INFORMATIVE) REVISION HISTORY

D

ANNEX D (INFORMATIVE) REVISION HISTORY

DATE	RELEASE	AUTHOR	PRIMARY CLAUSES MODIFIED	DESCRIPTION
October 29, 2021	0.1	S. Lavender	all	Initial version for comment
November 18, 2021	0.2	S. Lavender	all	Improved version integrating comments for submission to the OGC member meeting
January 17, 2022	0.3	S. Lavender	all	General review and update of the new setup, including consistent approach to figure referencing
March 14, 2022	0.4	S. Lavender	all	Inputs received via the website in parallel with the public presentation

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