OGC® DOCUMENT: 21-075

External identifier of this OGC® document: http://www.opengis.net/doc/PER/DP21-UserReadinessGuide

Open Geospatial Consortium

OGC DISASTER PILOT: USER READINESS GUIDE

ENGINEERING REPORT

PUBLISHED

Submission Date: 2021-11-18
Approval Date: 2021-12-10
Publication Date: 2022-05-06

Editor: Andrew Lavender, Dr Samantha Lavender

Note

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

CONTENTS

LIST OF FIGURES

I ABSTRACT

Improving the ability of key disaster decision makers and responders to discover, manage, access, transform, share, and exploit location-based and Earth Observation data will enhance decision making and, hopefully, save lives. The OGC Disaster Pilot 2021 has developed a number of prototype capabilities to demonstrate solutions for providing consistent, and reliable information to enable real-time actions to be taken using multiple technologies working together through pre-agreed standards.

This User Guide describes how the solution works, how users can be part of it, and showcases what can be achieved if everyone is willing to work together and share data and knowledge to improve the information available to those responding to a disaster.

II EXECUTIVE SUMMARY

Improving the ability of key disaster decision makers and responders to discover, manage, access, transform, share, and exploit location-based and Earth Observation (EO) information will enhance decision making and save lives. The full ambition of the OGC Disaster Pilot 2021 (termed Pilot) is to have such data available within the 'golden hour' of the disaster – the first sixty minutes — which is the key time for affecting the future outcomes of the overall response.

To deliver on such an ambition requires the use of multiple technologies underpinned by pre-agreed standards that would establish a robust solution with no single point of weakness, and enable a rapid deployment when a disaster occurs.

The Pilot has focused on developing a number of prototypes to demonstrate how a solution could be established to help users find disaster-relevant data with a particular focus on EO data, process it to develop analysis ready datasets that are easily sharable, use these datasets to create decision ready indicators to improve the amount and speed of data-driven decisions, and to provide tools to visualize, communicate and collaborate with everyone involved in the disaster response.

The Pilot has used three Case Studies to demonstrate what is possible, each with a different disaster focus, these are:

- Landslide, flooding and pandemic impacts within the Rimac and Piura river basins in Peru.
- Flooding hazards and pandemic impacts within the Red River basin in Manitoba, Canada.
- Integration of Health and Earth Observation data and services for pandemic response in Louisiana in the United States.

This User Guide sets out the history of using location-based geospatial data in disaster response and the future vision for how a solution would work. It also highlights the importance of being ready to participate in such a solution, it defines what readiness means, sets out the steps users need to undertake to achieve readiness and defines the pre-agreed standards that need to be implemented. Finally, it showcases the capabilities that the Pilot has achieved and the future recommendations and next steps to take this forward.

This Pilot is just the start and there is so much more that can be achieved if everyone is willing to work together and share data and knowledge to improve the information available to those responding to a disaster.

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, User Readiness Guide

IV PREFACE

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

V SECURITY CONSIDERATIONS

No security considerations have been made for this document.

VI SUBMITTING ORGANIZATIONS

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

- Pixalytics Ltd

VII SUBMITTERS

All questions regarding this document should be directed to the editor or the contributors:

NAME	ORGANIZATION	ROLE
Andrew Lavender	Pixalytics Ltd	Editor
Dr Samantha Lavender	Pixalytics Ltd	Editor
Antonio San José	Satellogic	Editor
Ryan Ahola	Natural Resources Canada	Contributor
Omar Barrilero	European Union Satellite Centre	Contributor
Dave Borges	NASA	Contributor
Paul Churchyard	HSR.health	Contributor
Ignacio Nacho Correas	Skymantics	Contributor
Theo Goetemann	GISMO	Contributor
Ajay K Gupta	HSR.health	Contributor
Dean Hintz	Safe Software	Contributor
Amy Jeu	GISMO	Contributor
Dave Jones	StormCenter Communications	Contributor

NAME	ORGANIZATION	ROLE
Albert Kettner	Consultant	Contributor
Alan Leidner	Consultant	Contributor
Adrian Luna	European Union Satellite Centre	Contributor
Niall McCarthy	Crust Tech	Contributor
Carl Reed	Carl Reed and Associates	Contributor
Guy Schumann	RSS-Hydro	Contributor
Marie-Françoise Voidrot	Open Geospatial Consortium	Contributor
Jiin Wenburns	GISMO	Contributor
Peng Yue	Wuhan University	Contributor

1

SCOPE

1 SCOPE

This User Guide describes how the solution works, how users can be part of it, and showcases what can be achieved if everyone is willing to work together and share data and knowledge to improve the information available to those responding to a disaster.

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. GeoServer

GeoServer — GeoServer is 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..

2.1.9. JSON-LD

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

2.1.10. Radar

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

2.1.11. 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

CAMS	Copernicus Atmosphere Monitoring Service
CEOS	Committee on Earth Observation Satellites
CNES	French Space Agency
COG	Cloud Optimized GeoTIFF
CONIDA	National Commission for Aerospace Research and Development's, Peru
CRED	Centre for Research on the Epidemiology of Disasters
CSA	Canadian Space Agency
DEM	Digital Elevation Model
EGS	Natural Resources Canada's Emergency Geomatics Service
EMS	Copernicus Emergency Management Service

EO	Earth Observation
EODMS	Natural Resources Canada’s Earth Observation Data Management System
ESA	European Space Agency
ESIP	Earth Science Information Partners
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
GISMO	New York City Geospatial Information Systems & Mapping Organization
HRD	High Resolution Data
INSPIRE	Infrastructure for Spatial Information in the European Community
IRD	Integration Ready Data
JAXA	Japan Aerospace Exploration Agency
JSON_LD	JavaScript Object Notation — Linked Data
NASA	National Aeronautics and Space Administration, US
NCEI	National Centers for Environmental Information, US
NOAA	National Oceanic & Atmospheric Administration, US
NRCan	Natural Resources Canada
NRT	Near Real-Time
OGC	Open Geospatial Consortium
ORL	Operational Readiness Levels
SAR	Synthetic Aperture Radar
SDI	Spatial Data Infrastructure
SEDAC	Socioeconomic Data Applications Center
SST	Sea Surface Temperature
STAC	SpatioTemporal Asset Catalog
USGS	US Geological Survey
WCS	Web Coverage Service
WFS	Web Feature Service

WHO	World Health Organization
WMO	World Meteorological Organization
WMTS	Web Map Tile Service

3

INTRODUCTION

3 INTRODUCTION

For over 20 years the Open Geospatial Consortium (OGC) has been working on the challenges of information sharing for emergency and disaster management, including response. The goal of the OGC Disaster Pilot 2021 (Pilot) was to look at fast moving scenarios where the rapid sharing of interoperable data requiring minimum preparation to use can provide disaster response teams with geospatial information that makes a real difference to the response activities.

The Pilot tested prototyping for the use of geospatial data in disaster response. To demonstrate the potential, the Pilot team focused on implementing data sharing for a small number of scenarios in a handful of regions. These were:

- Landslide, flooding and pandemic impacts within the Rimac and Piura river basins in Peru.
- Flooding hazards and pandemic impacts within the Red River Basin in Manitoba, Canada.
- Integration of Health and Earth Observation data and services for pandemic response in Louisiana in the United States.

This User Readiness Guide aims to provide potential users with an introduction for rapidly using geospatial information in a disaster situation. This goal is accomplished by providing a future framework for how data providers will provide data enabled by standards to allow users to more quickly analyze, integrate and visualize such data to help make decisions and take actions. This report is a non-technical description of the work undertaken in the project. The report details a case study for each of the three chosen scenarios. The report concludes with a discussion of next steps to implement this framework more fully. A more detailed technical description can be found in the accompanying Provider Readiness Guide (OGC 21-074) [1].

3.1. Disasters

Although there are varying definitions as to what constitutes a disaster event, the general consensus is that the number of these disaster events are increasing over time. In September 2021, the World Meteorological Organization (WMO) released 'The Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)' calculated using data from the Centre for Research on the Epidemiology of Disasters (CRED) [7]. The report describes that over the last 50 years, 50% of all recorded disasters, 45% of related deaths and 74% of related economic losses were due to weather, climate and water related events, translating to 2.06 million deaths, and US$ 3.6 trillion in economic losses [8]. In addition to CRED, the World Health Organization (WHO), Public Health England, and the United Nations Office for Disaster Risk Reduction (UNDRR) also contributed to the report.

The report also indicates that the number of disasters has increased by a factor of five over the 50 year period, although they acknowledge that this is partly due to improved reporting. However, the WMO also noted that the number of weather, climate, and water extremes are increasing and will become more frequent and severe in many parts of the world as a result of climate change.

Looking specifically at 2020, excluding the COVID-19 pandemic, there were 389 disaster events recorded by CRED. These events resulted in 15,080 deaths, impacting 98.4 million people, and creating economic losses of at least US$ 171.3 billion. During the same period, the COVID-19 pandemic resulted in almost two million deaths, 90 million confirmed cases and impacted many more, creating trillions of dollars of economic losses.

CRED, who have maintained a database of these disaster events for over 30 years, and define a disaster as '*a situation or event that overwhelms local capacity, necessitating a request at national or international level for external assistance; an unforeseen event that causes great damage, destruction and human suffering.*' The figures for 2020 were higher than the average number for the previous decade, which was 368, although slightly lower than the 396 recorded in 2019. For comparison, reports from a global insurance and reinsurance company showed 2020 losses from natural hazards increased by 25% from 2019 [9].

According to CRED the most common type of disaster in 2020 was flooding with 201 events, 23% higher than the average for the previous decade, followed by storms, landscapes and earthquakes. The geographical spread shows that 41% of disaster events occurred in Asia, with 23% in the Americas, 21% in Africa, 10% in Europe and 5% in Oceania. During 2020, flooding resulted in the deaths of 6,171 people, impacted 32.2 million people and created economic losses of US$ 51.3 billion; storms resulted in the deaths of 1,742 people impacted 45.5 million people and created economic losses of US$ 92.7 billion; landslides resulted in the deaths of 512 people, impacted 200,000 people and caused economic losses of US$100 million.

2021 has also seen significant disaster events with wildfires in various parts of the world, the heat dome over North America, flooding in China and Europe, Hurricane Ida impacting Louisiana in the USA, and the earthquake in Haiti to name a few. For information, by the start of 08 October 2020, there had already been 18 weather/climate disaster events reported by the US National Centers for Environmental Information (NCEI) with losses exceeding $1 billion each, to impact the United States in 2021 [10]. These events included 1 drought event, 2 flooding events, 9 severe storms, 4 tropical cyclones, 1 wildfire, and 1 winter storm. These have resulted in 538 deaths and had significant economic impact on the communities impacted. For comparison, the 1980–2020 annual average is 7.1 events and for the last five years the average is 16.2 events.

The last two years have been challenging for the world, and while these simple numbers give an outline of what has happened in terms of disasters, the pandemic will have also influenced the information in terms of potential underreporting, difficulties in determining the causality of losses, and the multiplying effect of having a disaster during a pandemic, which is likely to exacerbate all types of impact and losses.

While the number of disaster events continues to rise, the WMO report does have an element of hope: That the death toll from the weather, climate and water extremes have fallen significantly over the last 50 years due to the introduction of early warning systems. From 50,000 deaths a year in the 1970s, to 20,000 a year in the 2010s, the world has become better at reducing the number of lives lost to disaster events.

There is still more that can be done and it is important that all types of industries come together and do whatever they can to support the people and communities affected by disasters. This

Pilot aims to add value and demonstrate benefits to the continuing effort to save more lives and reduce the impact of disaster events.

4

USE OF GEOSPATIAL INFORMATION IN DISASTER RESPONSE

4 USE OF GEOSPATIAL INFORMATION IN DISASTER RESPONSE

Geospatial data can be defined as data that describes objects, events or features using a location on the Earth's surface. The simplest form of presenting such information is on a map. While the earliest known maps began with the Greeks and Babylonians in the 6th Century BC, the use of geospatial data in disasters is more recent. Arguably, one of the first known uses was in 1854 when Dr. John Snow mapped, by hand, the deaths from a cholera outbreak in London. His map allowed him to see a pattern others had not noticed. When combined with local knowledge and other statistical analysis this map enabled him to determine the source of the outbreak. This work, emphasizing the need for a multidisciplinary approach, was credited with contributing significantly to the containment of the outbreak, saving many lives, and changed the way geospatial data could be used in disasters by joining the pattern of a disease to a location.

Earth Observation (EO) began 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 that satellites were used to make observations of the Earth. In 1959 the Explorer VII satellite launched and the heat reflected by the Earth could be measured, and in 1960 the TIROS 1 weather satellite began producing daily cloud formations. The game changer that started the EO industry was the launch of NASA's Earth Resources Technology Satellite in 1972, the first real mapping satellite. This satellite was later renamed to Landsat-1 beginning what has developed, to date, into an almost fifty-year archive of satellite observations of the Earth. 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 and ALOS-4 missions, and the Canadian Space Agency (CSA) whose RADARSAT series of satellites support disaster monitoring activities.

As summarized by Pixalytics, as of the end of 2021, in their review of the Union of Concerned Scientists (UCS) satellite database. In total, just over a quarter of the world's countries have control over at least one EO satellite. The USA & China manage two-thirds of the EO satellites; see Figure 1. There are just under 20 countries that only have access to one satellite. Over the last four years, the number of EO satellites orbiting the planet has grown 70%, and the number of countries controlling such satellites has grown by 39%. In addition, a number of multinational missions offer data access to other countries; for example, the Landsat and Copernicus programs offer global data freely available to anyone, making EO data more accessible. The increasing role of private companies with commercial EO satellites has increased significantly since the first one launched in 2000, and many of these also offer data services which can again broaden access at a cost. Geospatial data can also be provided from aircraft and increasingly from remotely piloted drones.

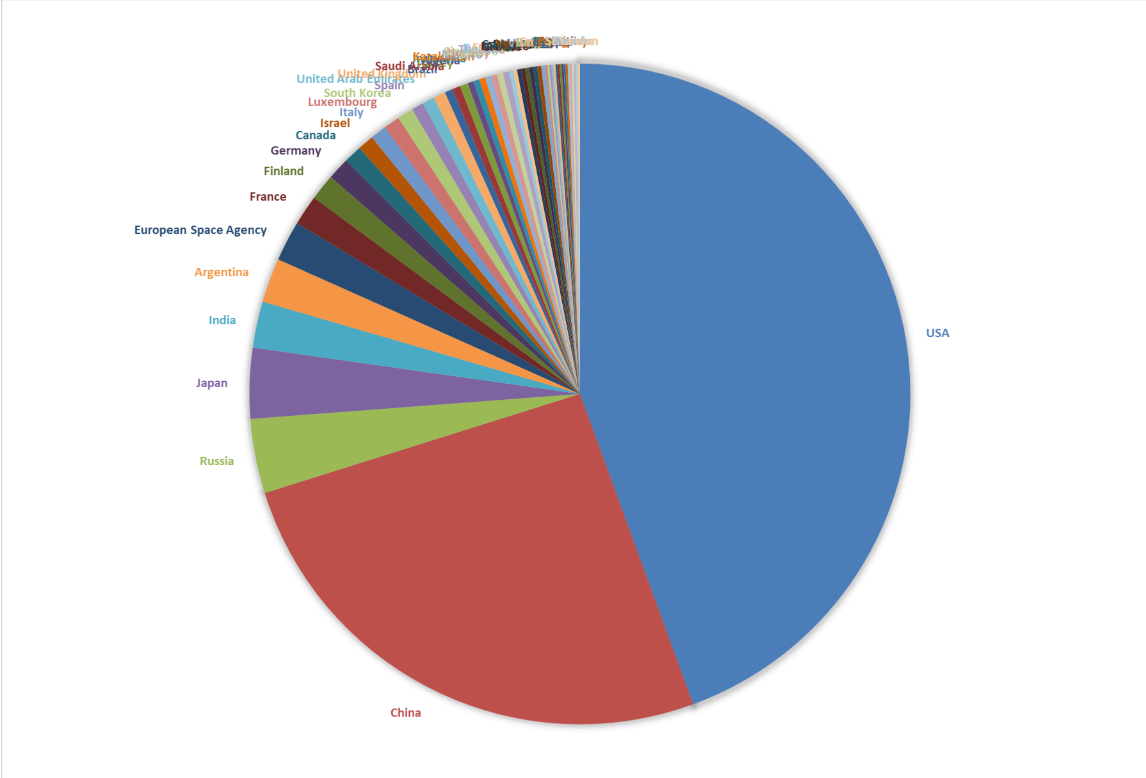


Figure 1 — Number of EO satellites as of the end of 2021,
extracted from the Union of Concerned Scientists satellite database

Around the same time as satellites were first launched, the second big development in geospatial data was the advent of computers, and the introduction of Geographic Information Systems (GIS). GIS made it much easier to map, combine, analyze and visualize geospatial information, although initially the hardware and software were expensive. Despite these developments, it was not until the early 1980s that the potential for using GIS in disaster situations was recognized. After Hurricane Andrew caused devastation to Florida in 1992 the Federal Emergency Management Agency (FEMA) committed to setting up a GIS for mapping damage and analyzing community demographics (Dash (1997)). This program soon developed into supporting areas such as Public Assistance and Hazard Mitigation.

The use of satellite remote sensing in disaster management situations took a step forward with the signing of the International Charter: Space and Major Disasters on the 22nd October 2000 by ESA, the French Space Agency (CNES) and the CSA. 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 to 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.

In addition, the European Union Copernicus Program has an operational service called the Emergency Management Service (EMS) which provides on-demand information for selected emergency situations including floods and droughts across the globe; as well as for wildfires in European, North Africa and the Middle East.

All of these developments mean that geospatial data can be made available to help with preparing for, responding to, and mitigating impacts of disasters, as well as supporting post event recovery. Some examples of the type of data that might be made available are:

- Satellite imagery showing the level of flooding across an area, or showing how quickly the level of flooding is increasing.
- Maps, based on computer models, predicting what areas could flood in a storm.
- Population maps showing densities and locations.
- Disease maps, like the original one for Dr Snow, showing the locations of specific disease incidences.
- Maps showing roads that are impassable or a map of local medical facilities.

Satellite, other geospatial and sensor data combined in a GIS offers the potential to provide disaster responders with invaluable information to support decision making and directly help field responders on the ground with the implementation of the response. This enhances the possibility of saving more lives and helping more people in disaster scenarios. Unfortunately, while the idea is great in principle, there are a number of practical issues which currently prevent the best use of these resources.

4.1. Gaps With Using Geospatial Data

There are a number of challenges with using geospatial data within a disaster response situation, and most relate to the need to have rapid access to the right information:

- **Formats**
    - Geospatial datasets often come in a variety of formats, and to integrate this variety often requires some, or all, of the datasets being converted to a format that can be managed within the GIS.

- **Time and Spatial Resolution limitations**
    - Optical satellite sensors, which operate like cameras or your eyes, cannot see through clouds. This makes it more difficult to get accurate information about what is happening on the ground during floods or storms. Although microwave data can see through the clouds, this is more complicated data to use.
    - Satellite images are often only acquired over an area every few days as the satellite orbits the Earth. Some constellations can capture an image every day. However, this is still only a snapshot each day and not real-time information. For example, a satellite might completely miss a flash flooding event as the water can rise and drop between when the satellite images acquisitions.

    - Satellite images are observations of what has happened. Depending on when the imagery was acquired the actual situation on the ground may be different to what the image shows. This is called data latency.

    - Spatial resolution of satellite images is limited. While some satellites can see items on the ground which are less than a meter in size, others can only see things that are bigger than 15 or 30 meters. This may mean the images may not be able to detect the level of detail on the ground that the disaster responders require.

- **Infrastructure Availability**

    - Some satellite images such as those from Landsat or Copernicus are free for anyone to use, while others, such as those from commercial sources, are not free or have restrictions placed on their use. Unless there is an agreement in place prior to an event, securing funding and purchasing such images in a disaster is difficult. So some data may not be available. Although there are various Disaster Charters within the industry whereby certain operators may make their data freely available when a disaster occurs, it can still be challenging to get permission to have access to the data.

    - Similarly, the cost of GIS software and licenses may also limit the number of people who can access the data. Available free GIS software can help mitigate this limitation.

- **Synthesizing large volumes of data**

    - Satellite images and maps are large data files and in disaster situations field responders are likely to be working with poor internet and phone signals. They simply may not be able to download the information they need. Processing the data into smaller files is helpful to overcome this issue.

- Extracting useful information from satellite images is not straightforward and requires a level of subject matter knowledge and expertise.

- Equally interpreting data from satellites or models can take knowledge and experience. For example, models predict what might happen based on the information they have. This may be very different to what actually happens. It's important that this element of uncertainty in what models are predicting is understood and communicated.

Put together, all of these issues mean that often 80% of time spent is on accessing and preparing geospatial data for disaster management and response, rather than using it! This includes getting permission to use it, getting it into the right format, correcting errors, getting the computing resources to process it, etc.

Therefore to address these issues, the aim of the Pilot is to provide Analysis Ready Data (ARD) for people who have the skills to use it, together with Decision Ready Indicators (DRI) from which decisions can be made and actions taken. The aim is to provide the right information to the right people at the right time in an easy-to-understand format to enable informed decisions on disaster management and response activities to be made.

5

FUTURE VISION OF USING GEOSPATIAL DATA TO SUPPORT DISASTER RESPONSE

5 FUTURE VISION OF USING GEOSPATIAL DATA TO SUPPORT DISASTER RESPONSE

The full ambition of the OGC Disaster Pilot (Pilot) is to have data ready and available within the 'golden hour' of the disaster – the first sixty minutes. This is the key time for saving lives and response actions taken within this period will profoundly affect the future outcomes of the overall response. However, it is challenging to provide data within the golden hour as the overall system needs to be smooth and fast!

The vision is that when a disaster occurs there will be a trigger to activate the response process. At that time the organization/individual responsible for coordinating the disaster response will be able to log onto a website and confirm the disaster they have, and this system will then highlight a series of relevant indicators, data products, and co-operating data providers. These providers will be tasked with supplying the relevant geospatial data in relation to those indicators, or the indicators themselves. The data will be transferred to either the responding organization's Disaster Portal (a Geographical Information System (GIS) or similar) or to a selected externally provided system, where the data can be visualized and decision-driven data made available.

Users will then be able to log into a Disaster Portal via either a computer or mobile device, and search for the information that they want or need, from the indicators and datasets available within the portal. The 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 of a variable over time.

These outputs will enable users to rapidly integrate the data with the local knowledge they have, and/or act on the information directly to make decisions on how to respond to the unfolding disaster scenario.

The data available will be continually updated and improved as new datasets become available or as first responders provide ground-level observations, aiming always to provide disaster responders with the most up to date and accurate information available. When data is provided as a standards-based service, it is immediately available and updated within any GIS mapping environment that supports the standard.

This is the future vision the Pilot was focused on. However, it is acknowledged that to be able to use this solution both the potential users and data providers need to be ready to participate.

6

WHAT IS READINESS?

6 WHAT IS READINESS?

Readiness is the state of being fully prepared. In this case of disaster response, 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). As described in Clause 5, the objective is to improve the number 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 able to be accessed, processed, analyzed, visualized, and communicated to field responders in a very short amount of time.

This process is not something that can begin when a disaster occurs from either a data provider or a data user point of view. There will be too many things to resolve such as data formats, license agreements, geospatial systems, analysis skills, 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 geospatial data input.

To be part of the future Pilot framework, both data providers and data users need to be prepared to take part, and this means making a series of agreements. However, this cannot 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 data, thereby enabling users to immediately integrate that data within the system they are operating. These standards will enable the smooth and rapid delivery of information to enhance decision support.

Although not developed within this Pilot, one suggestion is to set out a series of Operational Readiness Levels (ORLs), similar to those developed by Earth Science Information Partners (ESIP) for making Earth science data more trusted (https://www.esipfed.org/orl), particularly by non-technical decision makers. This would identify the steps and operating standards that both data providers and users will need to take to be able to fully participate.

The next section of this report focuses on user readiness and will be 'technology-lite' with minimal jargon and technical language. The intent is to demonstrate how this might work and what it can deliver. However, it is acknowledged that some parties might be both data users and data providers. Therefore, the companion Provider Guide will offer a more technical description of the proposed solution and requirements.

7

WHAT IS USER READINESS?

7 WHAT IS USER READINESS?

This guide is for users — practitioners, decision-makers, and responders who want to both make use of Analysis Ready Datasets (ARD) and Decision Ready Indicators (DRI), and influence how they are developed for maximum usefulness in action. This section describes a series of steps that users should undertake 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: Preparation of Foundation Layers

Users need 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.

These foundation layers are critical as they form the framework for the ARD and DRI to be displayed, and without these layers, it will be a struggle to analyze, interpret and transform the additional data into decisions and actions. For example, if the indicators show an area of a city is going to be flooded, the response will be very different if that area is a park, a residential area or a hospital.

Care and attention must also be given to the currency, accuracy and intended use of the data acquired. For example, applications such as landslide or flood modelling and impact analysis require high resolution elevation models which may be difficult to acquire depending on the spatial data infrastructure available for a given region.

The Pilot has not specified a particular standard for the Foundation Layers, as there are a number of worldwide standards already available. While they are all different, there is considerable crossover within these standards and many of the layers are very similar. Current example foundation layer standards include:

- *United Nations Global Geospatial Information Management Fundamental Geospatial Data Themes* which has 14 themes.
- *Infrastructure for Spatial Information in the European Community (INSPIRE) Implementing Rules on Interoperability of Spatial Datasets & Services* which has 34 data themes in 3 groupings.
- *USA National Geospatial Data Assets/Framework Themes* which has 18 themes.

In addition, although not a standard, the *OGC's Health Domain Working Group* has produced a Health Spatial Data Infrastructure Concept Development Study Engineering Report looking specifically at what Foundation would be useful in a health emergency. This report identified 8 spatial datasets, 12 local government datasets & 7 national datasets which would be useful to have as foundation and background layers.

Using any of these standards as the basis for identifying foundation layers would be a beneficial step, high resolution data (HRD) to improve accuracy. The selection of a preferred standard may be helpful in the future.

One aspect of data preparation that should not be underestimated is the amount of work involved to acquire the source data for a given disaster response effort. A typical response involves a wide range of datasets that must be researched, accessed, filtered to the area of interest, and transformed into a form suitable for the user's application environment. This process is sometimes called ETL (extract transform and load), and can involve significant effort in terms of data wrangling. Ideally this effort is supported by spatial data infrastructure based on open standards, data services via open Application Programming Interfaces (APIs) and domain specific conventions. More commonly, the reality is more of a mix, so often significant time and effort is required to procure the required datasets and render them into a form that is usable within the user's disaster response application. The importance of these standards in the context of disaster response is discussed in the next section.

Typically there are a range of tools available to support this data extraction, integration and conversion process. These include both specialized data integration platforms or middleware, and custom applications developed with open source tools and libraries such as GDAL and OGR. For this pilot, the FME spatial data integration platform from Safe Software was used to perform many data extraction and transformation tasks. This included workflows where proprietary source files were read and written to open standards formats such as OGC GeoPackage and GeoJSON [4] for use by other components (see Figure 2). FME was also used to load datasets onto the pilot geoportal: GeoNode, which in turn hosted these datasets for download or delivery via OGC-conformant interfaces such as those implementing the Web Feature Service (WFS) standard (using GeoServer).

Besides basic format conversion, key aspects of any data integration platform is the ability to perform geometry and schema transformation. The native OSM schemas are complex and nested, so FME was used to flatten this into a more relational or GIS friendly structure. Time series raster datasets were converted to vector features and loaded into GeoPackage tables to make them easier to integrate with other GIS workflows within downstream tools. Finally coordinate transformation is usually required to bring the application datasets into a common reference frame.

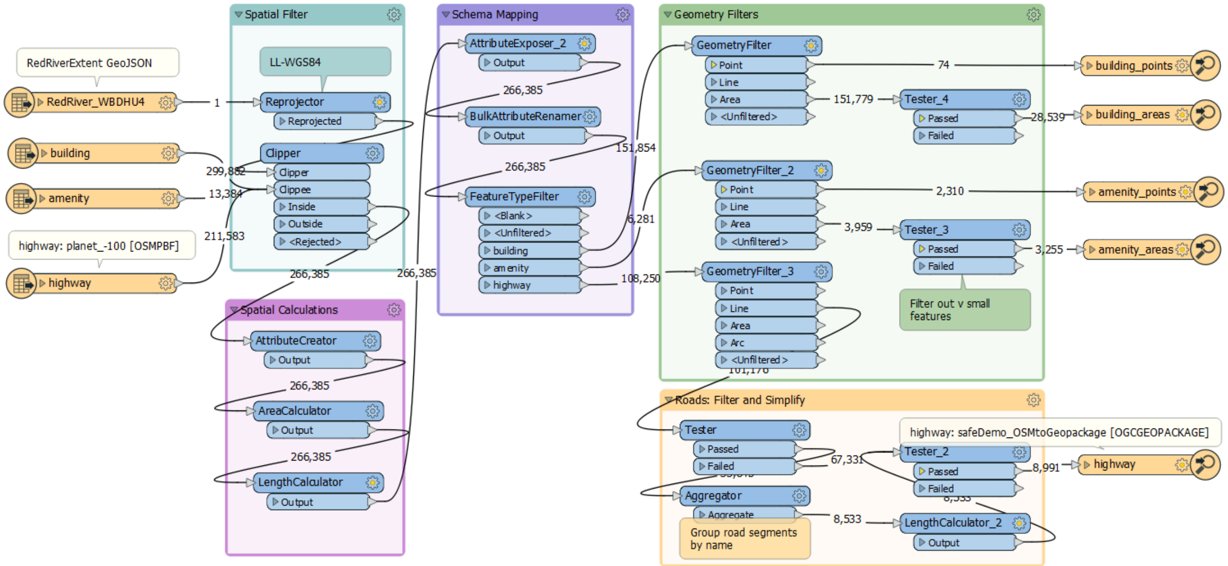


Figure 2 — FME data integration platform - OSM and GeoJSON to GeoPackage foundation data loader

7.2. Step 2: Understand and Implement Standards

To be able to rapidly integrate and transform data into useful decision-ready information, 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. The use of standards will enable these processes to happen effectively and efficiently.

Without such 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 increases. The standards will also help non-technical decision makers, who require trusted data to be used to drive decision making, but cannot find what they need, due to the varied and complex semantics of hazards and disasters.

Within the Pilot, a number of key standards were identified as being important for user readiness. These are described below with technical examples of such standards.

- Ensure that data and imagery use formats that can be easily used, integrated and visualized by any GIS, such as Cloud Optimized GeoTIFF (COG).
- Ensure that when publishing geospatial data, it is done in a structured way to best support web-based searching. For example, using JavaScript Object Notation — Linked Data (JSON-LD).

- Generation of catalogs and self-describing data sets which will help users find and understand the accessing and processing of data, for example, GeoPackage and SpatioTemporal Asset Catalog (STAC) [5].
- Platforms which visualize and communicate information should do so using standard formats such as Web Coverage Service (WCS)[6], Web Feature Service (WFS)[2] and Web Map Tile Service (WMTS)[3]. These standards also make the data much more shareable across platforms

7.3. Step 3: Utilize and Implement Indicators and Supporting Indicator Recipes

Once the required foundation data layers are assembled, the next step is to determine what decision ready indicators are required to support disaster managers and responders in the field. As described above, DRI are built on a foundation of ARD, and enriched by the context of foundation data described in Step 1 above. There can also be Integration Ready Data (IRD), which is an intermediate step between ARD and DRI, that could include flood extents and disease density.

While data providers may publish a set of primary ARD, IRD or DRI, often there is the need for the disaster response users to take this primary information and develop secondary indicators more closely calibrated to day to day needs of their disaster response mission.

For example, the data provider may publish disaster extents (flood or fire extent) plus areas for evacuation or submerged roads. The disaster response user with some GIS skills may need to take this information and develop more precise information as to what areas to evacuate first (hospitals and high density residential), what areas to protect (critical infrastructure) or what routes may be passable for specific types of emergency vehicles. Also disaster managers often benefit from composite indicators and dashboards that combine a range of indicators and IRD to build a more comprehensive operational picture of the overall disaster and corresponding response efforts.

The Provider Guide describes in more detail the data value chain that was developed in the context of this pilot to take source datasets, process them into ARD, IRD and ultimately DRI to drive the outputs described below. Recipes describe the specific procedure for combining source foundation layers, dynamic observations related to the disaster context and analyzing this to produce ARD, IRD and DRI. However, even from a user perspective, the datasets published by data providers can often be seen just as a starting point.

For this pilot, several key indicators and associated recipes were developed related to flood severity, landslide risk and pandemic impacts. For example, for the flood scenario, flood model grid outputs from RSS Hydro were processed into vector flood contours using FME and stored in GeoPackage IRD. Skymantics was then able to take this IRD and compute indicators about transportation routes taking into account flood depth not just extents. In addition, users could utilize this same flood depth data to generate other related indicators, such as areas to prioritize for evacuation.

Key to this is the understanding that often one indicator may be used to support other indicators downstream. Also, the development of effective indicators and supporting IRD often require frequent feedback from users, and responsiveness from data providers, to ensure that the data and information being provided is suitable and tuned to the needs of the end users. Finally, any recipe implementation should use approaches that promote reuse and automation to the extent possible. In this way rapidly evolving disasters can be met with timely indicator updates and associated response actions. A model based, reuse and automation orientation also makes it more practical for tools and recipes to be applied to new contexts. In this way, the disaster response community as a whole can benefit from the development of these indicator-based tools and systems. Note that ARD, IRD and DRI in the context of this pilot are described in more detail in the Clause 8, and in the adjoining annexes.

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 is getting the outputs of that work to the people managing the disaster response and 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 to this question 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:

- **GeoCollaborate** – This platform, developed by StormCenter Communications offers an option for a cross-platform real-time collaborative environment led by a subject matter expert, engaging with a series of followers who are actually receiving the data on any platform or device. This offers the potential for many people to interact with the same shared information at the same time leading to faster situational awareness and decision making accordingly. The solution can connect any device with an internet connection and a browser, allowing the user to see and interact with the information in real time while also enabling leaders to hand-off control so additional datasets can be shared or turned off. Since the data is not downloaded and saved on everyone’s device it can be used by people on the on-ground with limited bandwidth. GeoCollaborate is not screen sharing but delivers actual cross platform geospatial interoperability to any number of participants wherever they are located. GeoCollaborate can access data from any portal, hub, geoplatform, server or share uploaded data across all follower's web maps.

Figure 3 shows a screenshot from a GeoCollaborate instance with the leader's screen on the left, and the follower's on the right. The image itself is sharing data for Rimac River in Peru, and includes a flood extent and clinic location datasets produced by HSR.*health* via their geoplatform in real-time.

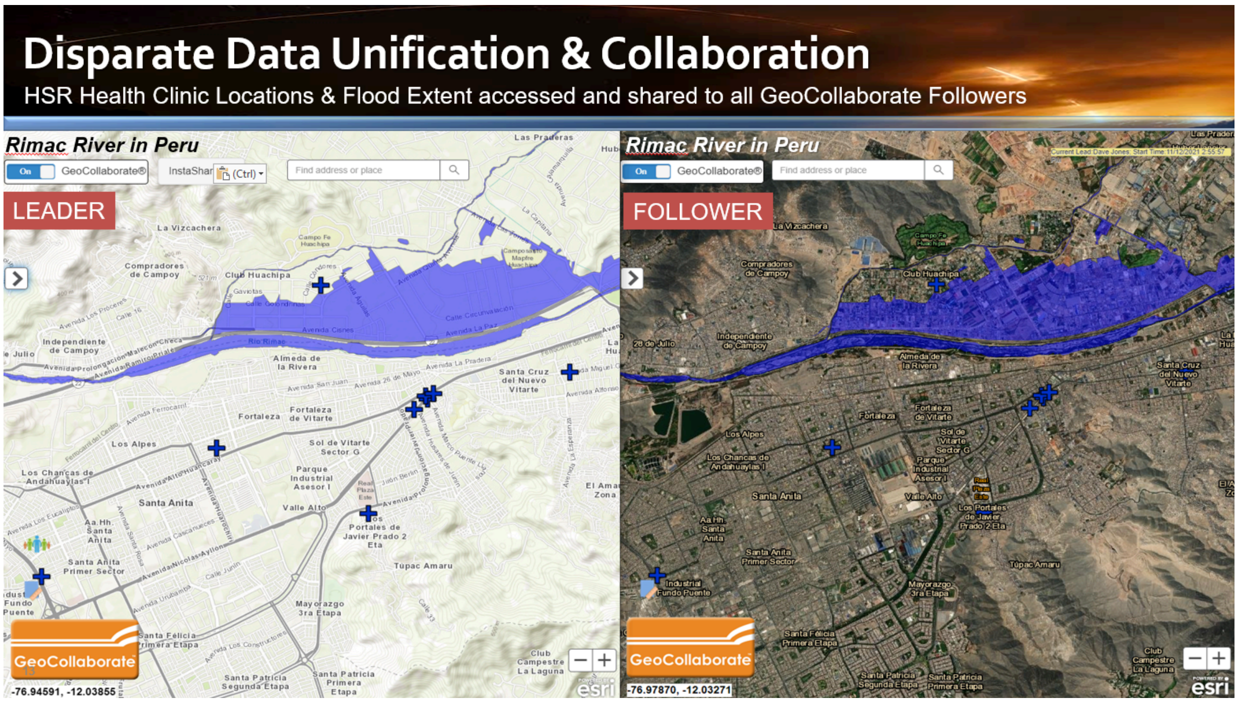


Figure 3 — Data for Rimac River in Peru including flood extent and clinic locations produced by HSR.Health, visualized via GeoCollaborate

- **GeoNode Platform** – The second approach is to use GeoNode developed by GeoSolutions which is a web-based application and GIS platform for displaying spatial information. In this case, the GeoNode instance supplied by GeoSolutions is controlled by HSR.*health* who can use it to display various data layers which have been accessed using open standards, and similarly it can equally export data to other platforms. Figure 4 is an example from this platform.

Rimac Medical Supply Needs Index Supply Routes with and without a flooding event

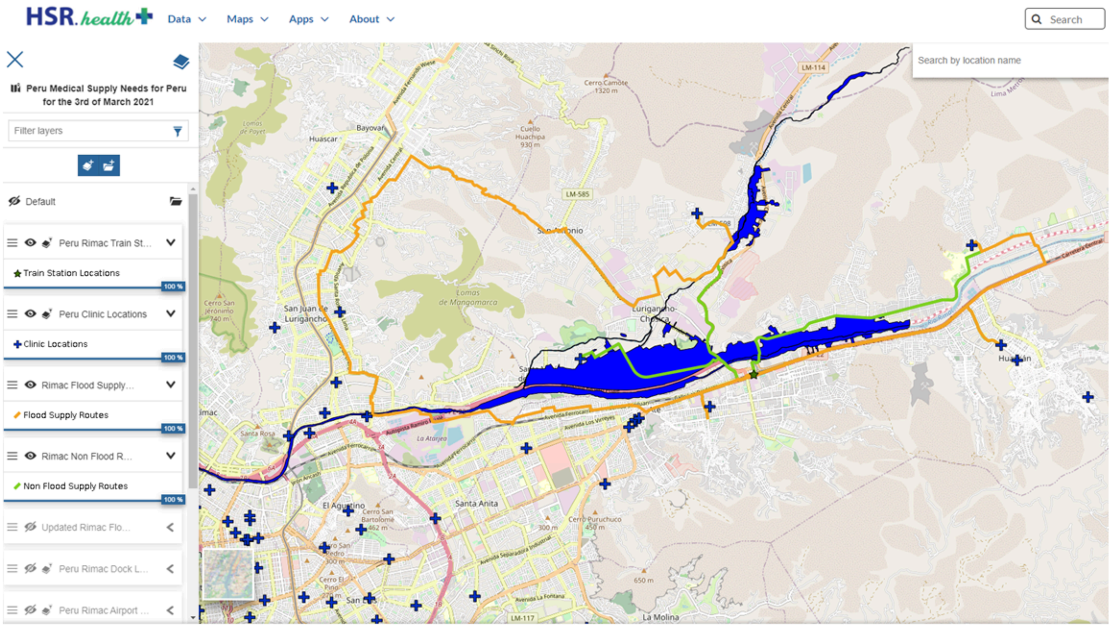


Figure 4 — Example Medical Supply Needs Index Supply Routes with and without a flood event during 2017.

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 ensuring 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 or similar, required to access the external system.
- All possible users have had 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, everyone involved needs to understand what sort of decisions will need to be taken for a disaster, and therefore what information, indicators or triggers the disaster response team will want. Readiness means that the solution is operational.

While the data provider can provide a lot of relevant, useful and helpful information, it will be important to understand which indicators are most relevant for a disaster. It will also require local knowledge and understanding to interpret the indicators, to 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 annex to this Guide, the Pilot has selected three potential disaster scenarios and has given examples of the type of indicators that might be relevant to that situation.

Users will need to consider the indicators available to them and determine whether they are sufficient, whether important indicators are missing, any key local issues that need to be addressed, etc. While some generic indicators will be common across geographical areas, it is possible that specific locations will need additional indicators or data. Any gaps will need to be discussed with the data providers to find a solution to provide the information needed.

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 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, 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

WHAT HAS THE DISASTER PILOT ACHIEVED?

8 WHAT HAS THE DISASTER PILOT ACHIEVED?

The OGC Disaster Pilot 21 (Pilot) focused on developing prototype examples, including three Case Studies, to demonstrate how the Future Vision might work, together with identifying the issues, challenges, and next steps required to make the solution a reality. The three Case Studies are:

- Landslide, flooding and pandemic impacts within the Rimac and Piura river basins in Peru.
- Flooding hazards and pandemic impacts within the Red River Basin in Manitoba, Canada.
- Integration of Health and Earth Observation (EO) data and services for pandemic response in Louisiana in the United States.

The Pilot has identified four user groups that will be considered for the operational prototype. It is acknowledged that there could be more potential user groups, but for the Pilot the groups are:

1. **Data Analysts** working for the responding organizations providing insights and information for the disaster planners or field responders.
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 will require different types of data or information, at different levels and presented in different ways. It is also accepted that organizations will have different systems in place to receive, process, visualize and communicate data and information.

The operational prototype examples will focus on delivering information in an interoperable manner using specific standards to demonstrate how such an approach allows organizations using different systems to work together rapidly and effectively within a disaster scenario extemporaneously.

The data model envisaged by the Pilot involved a series of raw data sources being brought together to create Analysis Ready Datasets, and then Decision Ready Indicators:

- **Analysis Ready Datasets (ARD)** — 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). These datasets can be interrogated by people with the right skills to gain greater insight, having already undergone some processing to remove errors, transform the dataset into a standard format, etc. It includes satellite data, together with in-situ data and data from other sources that would be supplied as a dataset. It is most likely to be used by Data Analysts, but could also be used by Disaster Response Planners and Managers.

- **Decision Ready 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 that have to be made about 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.

A simplified version of this data model can be seen below in Figure 5, with the more detailed data model available within the Provider Guide.

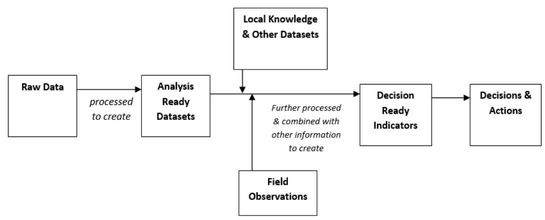


Figure 5 — A simplified data model from the OGC Disaster Pilot 21

To support the transition of data flowing from raw data through to ARD and DRI, a series of recipes have been developed within the project. Essentially, these are a series of steps that describe how to extract the data from key sources, apply the relevant processes to turn the raw data into an ARD, and additional processes required for the final transformation into a DRI. This will ensure a consistent and reliable approach is taken to the development of the ARD and DRI.

Example recipes include those related to:

- **The blockage of roads by floodwater:** Earth Observation (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.

While there will be commonality on the ARD that will benefit every disaster scenario, there will also be specific ARD that will be useful for each disaster type. Whereas, for the DRI the commonality between disasters will likely be smaller and it is more likely that there will be different DRIs for every disaster. DRIs will be influenced by the disaster event type, its size, impact, and other events happening at the same time.

8.1. Raw Data

This section summarizes the key raw data sources that have been used within the Pilot.

8.1.1. Earth Observation (EO) Data

The EO data used in the Pilot is provided from satellites orbiting the planet. There are different types of satellite data, which are listed below, but two important aspects of all satellite data are their spatial and temporal resolution.

- **Spatial Resolution** can be used to both describe the size of the smallest object that can be seen in an image and the distance on the ground each pixel on an image represents — a 15-meter spatial resolution means that each pixel represents 15-meters on the ground and, in general, objects smaller than 15-meters cannot be seen. For a disaster scenario, a 15-meter resolution might be acceptable to investigate how far flooding has spread across a broad region, but not for determining if a specific road has been flooded.
- **Temporal resolution** is the frequency of the data collection over a specific point on the Earth. Most satellites orbit the Earth and so can only see a part of the Earth at any one time, and can take hours or days to come back to the same point on the planet. This is a challenge with a fast-changing disaster situation. To resolve this issue, some geostationary satellites stay over the same point on the Earth at all times – although data from this type of satellite was not used within the Pilot. Alternatively, some providers use multiple satellites operating as a constellation which mean different satellites image the same area more frequently. Finally, it is possible to use datasets from different satellites to increase the frequency of monitoring; using this approach reinforces the need to have implemented data standards to ensure that the use, integration and comparison of different datasets are simple.

There are a number of different types of data provided by satellites and the most common are:

- **Multispectral Optical Data** is an image of the Earth taken by a sensor onboard a satellite, and the imagery is similar to how the human eye sees the world. The biggest challenge with optical data is that they can't see through the clouds. Example satellites that offer optical imagery include USGS/NASA Landsat missions, European Space Agency's (ESA) Copernicus Sentinel-2 satellites, Japan Aerospace Exploration Agency's (JAXA) ALOS-3, National Commission for Aerospace Research and Development's (CONIDA) PeruSAT-1, Planet's constellations & Satellogic's Newsat constellation.
- **Hyperspectral Optical Data** is collected across a wider part of the electromagnetic spectrum from the visible to shortwave infrared, and these sensors collect lots of individual measurements each of which is a potential dataset. This allows this data to identify and specify features in the land and the atmosphere. It could be used to identify potential pollutants in the air for disasters, although it has not been used specifically within this Pilot. Examples offering this type of data include ESA's CHRIS-PROBA for the land and the TROPMI instrument on Sentinel-5P for the atmosphere.

- **Microwave Data** is the companion to optical data and is captured from the microwave part of the electromagnetic spectrum. The most common type of microwave data is Synthetic Aperture Radar (SAR) data, and this has the advantage over optical data in that it can see through clouds and acquire data at night. Examples offering SAR imagery include Canada's RADARSAT, ESA's Sentinel-1, JAXA's ALOS PALSAR and commercial missions such as the ICEYE constellation.

It is acknowledged that EO data is not only available from satellites as it can also be supplied from both airborne missions and drones; however, the Pilot only used satellite EO. Aircraft are commonly flown in disaster scenarios, although poor weather or no-fly zones can restrict their use. Remotely piloted drones are potentially a really useful development for data collection, however, currently, they are still relatively new technology. While some government agencies have drones, there are also a lot of volunteer/amateur drone pilots available. These are not currently fully utilized, and solutions need to be sought to marshal such resources such that they complement and don't hinder official drones and agreeing on processes for making the data available.

In addition, EO satellite technology is constantly developing with more satellites being launched offering more data more frequently, together with new technology such as video based EO. As such, the capabilities of what EO can offer will continue to develop in the coming years.

8.1.2. Demographic and Social Data

Several demographic and social datasets have been utilized by the Pilot. These are standard datasets available from various government or international bodies such as the US Census Bureau and Peru's Instituto Nacional de Estadística e Informática. Examples of the types of raw data used within the Pilot include:

- Demographic data
- Population data
- Mobility data

8.1.3. Geographic Data

Geographic data is a key foundation layer on which to overlay other datasets to improve an understanding of what is happening within a disaster situation. The data itself is made up of large-scale freely available data sources such as OpenStreetMap, local datasets held by local government agencies/disaster response teams/voluntary organizations and EO data.

Examples of this type of data that have been used within the Pilot include:

- Geographical Boundaries
- Street maps

- Key locations highlighted, such as medical facilities, power facilities, etc.

8.1.4. Health Data

The Pilot has investigated the need to integrate health and EO data to support disaster response, with a specific focus on the COVID-19 pandemic. This data has been provided from government or health sources, together with example data from specific locations. The types of health data that have been used include:

- COVID cases data describing the number of COVID cases within an area.
- COVID hospitalization data gives details of the number of people being admitted to hospital with COVID and also identifies the number of those patients who were in Intensive Care Units.
- Co-morbidity data describes where patients have multiple diseases or medical conditions present.
- Use of Personal Protection Equipment in Medical Facilities.
- Health care and first responder workforce data.

8.1.5. Field Observations

- *Voice Activated Survey* – Developed by the New York City Geospatial Information System & Mapping Organization (GISMO). This allows people to record a series of responses to set questions. This system does not replace 911, but is an additional offering and requires users – both general public and first responders – to register first, and then they can provide voice responses to the solution. The system is multi-lingual and supplies both the original language and a translation into English. An example survey developed for the Pilot focused on flooding, and had 11 questions focusing on three themes:
  - Safety Questions: What is your zip code/postal code? Do you need to be rescued? How high is the water (Options: Ankle, Knee Waist deep)? How fast is water flowing (Options: Not moving, Things floating by, Rushing)? Tell us the street condition?
  - Health: Do you suffer from diabetes, asthma, dialysis-dependent, or all three? Do you have medication for the next 3 days? If you are injured, tell us how?
  - Supply: Do you have power? Do you have water? What supplies do you need?

8.2. Analysis Ready Datasets (ARD)

As described earlier, the raw data is processed by providers to create ARD's, which can be interrogated and integrated with other datasets, and visualized within a GIS. This processing will achieve a variety of aspects including removing errors and applying corrections for accuracy; compiling, classifying and combining information into a better dataset; transforming the data by applying mathematical formulas to the data to develop a derived dataset, and implementing standards on the data to improve its ability to be integrated, etc.

As highlighted earlier, some of the ARD's will be specific to the type of disaster involved, and the three Case Studies in the appendix to this guide will give details of the specific ARD's used in those cases. Some examples of the ARD's used within the Pilot include:

- Land Use and Land Cover maps identify how the land is being used.
- Water maps from EO showing where floodwater is.
- Flood risk models indicate what areas have flooded in the past or could be flooded in the future.
- Pandemic Transmission Risk Index that identifies the current risk of the spread of COVID-19.
- Leveraging the responses to the voice-activated surveys using Artificial Intelligence to pull together the common themes and information to help prioritize the needs from the public or first responders, and categorize what to send and where to send it.

8.3. Decision Ready Indicators (DRI)

DRI are created using a set recipe which pulls together one, or more, ARDs to create an indicator of action and/or decision in relation to a disaster situation. The use of a recipe is to ensure that consistency is achieved for the DRI, to give confidence to the people using them to make decisions that the information can be relied upon.

The recipes will combine one or more specific datasets and have various rules for action applied to resulting output, and some decisions will also have a risk assessment or similar element attached.

Although recipes and indicators may vary from disaster to disaster, by establishing them within a consistent framework that includes their applicability timescale (short-term predictions and impacts to medium and long-term predictions) and type/geospatial extent of the disaster, there will be a commonality.

Some example DRIs include:

- Flooding over roads can determine the roads to restrict access to or close, or can help decide safe routes for evacuation or medical supply delivery routes.
- Flooding around buildings can help decide which buildings need to be evacuated.
- Medical Supply Needs Index shows the need for medical supplies based upon the spread of a pandemic and the number of healthcare workers, supply utilization and burn rate.

Further details on DRIs can be found in the individual Case Studies, which specify the individual indicators developed within the Pilot.

9

CAPABILITIES DEVELOPED DURING THE PILOT

9 CAPABILITIES DEVELOPED DURING THE PILOT

The Pilot participants have been working on developing a number of prototype capabilities across the proposed solution as outlined in Clause 5 to demonstrate what can be offered to support disaster response. These capabilities represent the work of the Pilot participants; however, the proposed solution does not have a single technology approach, but is focused on standards. Using standards can support data sharing and aim at making data findable, accessible, interoperable and reusable across any platforms.

The capabilities developed in the Pilot have been:

Discovery & Registration Capabilities — Participants have been working on the critical starting point of the solution, providing the tools and solutions to help users find disaster-relevant information when a disaster occurs, to ensure that such data is put at the top of web search engine results.

Data Platforms Capabilities — Participants have been developing cloud-based solutions that can be scalable when a disaster occurs to support the exploitation of Earth Observation and other data in relation to the disaster.

Analysis Ready Data & Analytical Processing Capabilities — These participants have been taking the raw data described in section 10.1 and turning it into ARD through processing, which can be shared with other participants using a standard output format which can then be integrated or displayed within a GIS. The focus of this work is on the three Case Study scenarios.

Human Observations & Volunteered Geo Information Capabilities — A participant has developed an ARD from real-time human observations to demonstrate how this can add value to the DRI recipe development.

Decision Ready Indicators Capabilities — Participants have developed a series of recipes for DRI based around the three Case Studies, and used the ARDs to develop example output DRIs to demonstrate how they would support decision making in a disaster. The Participants have also been using standards-based formats for transferring geospatial information, such as GeoPackage, together with encrypted versions.

Visualization & Communication Capabilities — Participants have developed online tools to support both the visualization of ARD and DRI, enabling users involved in the disaster response to collaborate, share information and allow field responders to take the information into the field without needing an internet connection. This aims to ensure that everyone working on the disaster has the right information at the right time.

These capabilities, which are described in more technical detail in the Provider Guide, are currently only prototypes, but it is a paradigm for what could be achieved if everyone within the ecosystem is willing to work together and share data and knowledge to improve the knowledge and information available to those responding to a disaster.

10

NEXT STEPS & RECOMMENDATIONS

10 NEXT STEPS & RECOMMENDATIONS

This Pilot has taken further steps towards developing a solution to rapidly deliver geospatial and Earth Observation (EO) data in a readily accessible format to inform and enable better decision making to support disaster preparedness and response.

The prototypes developed by participants have successfully demonstrated the data value chain by taking raw satellite data converting it into Analysis Ready Datasets (ARD) and then combining with other geospatial datasets to transform the information into Decision Ready Indicators (DRI). Also, having all of this information easily shareable across multiple platforms using agreed standards to enable users to visualize and disseminate the information to everyone involved in a disaster scenario.

The Pilot hopes to have showcased what is possible and shown the ways by which the geospatial and EO communities can work together to make a real difference to disaster responses around the world. In the longer term it is hoped that this leads to improved outcomes and saved lives.

However, this is only one activity focusing on three specific disaster scenarios; therefore, there is more work to do to expand these prototypes and turn them into a robust, reliable and operational processes that are available to any disaster preparedness and response team throughout the world.

The Pilot has suggested a number of further steps that are required going forward under the following categories of Standards, Data, Technical, and Readiness.

10.1. Standards

To deliver the envisaged solution both Providers and Users need to implement and use agreed-upon technical standards to allow the rapid sharing, processing, integration and visualization of data. Standards have been used within the Pilot, but a number of areas where further agreements may be required have been identified:

- Agreeing to minimum content within the Foundation Layer framework.
- Agreeing to standard symbols, colors and consistent identification of features on imagery and maps.
- Agreeing to a process to identify what can be trusted data within the solution, including what is good enough.
- Communities work together to develop ARD standards that support interoperability and bring together in-situ and remote sensing data.
- 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 (International Organization for Standardization) standards to support this. The flood, health, fire etc. should consider doing the same.

10.2. Data, Analysis Ready Datasets & Decision Ready Indicators

The Pilot focused on three disaster scenarios and has developed some ARD and DRI for those scenarios. This work needs to be expanded in terms of both individual disaster types and the interaction between disasters and other events. In addition, a number of ideas were not fully tested or completed and would benefit from further investigation. Therefore, suggested next steps are:

- Looking at more disaster scenarios such as hurricanes, wildfires, drought, and food security.
- The ARD and DRI solutions developed within the Pilot need to be tested beyond the three Case Study areas to understand whether they are applicable worldwide or whether adjustments need to be made to enable them to operate internationally.
- Looking at the interaction between disasters and other events:
  - Impact that climate change is going to have on the future of disaster scenarios.
  - Human impact on disaster scenarios, for example, the different responses for varying depths of flood water.
  - Interplay between disasters and the immediate, subsequent and long-term impact on the health of the affected population.
  - Potential for zoonotic crossover where pathogens move from animals to humans.
- Creation of a Health-Disaster Vulnerability Index that conveys the situation on the ground.
- Further investigation on the integration of EO and Health data. While initial concept modelling was undertaken during the Pilot, integrating the data was not fully achieved.
- Developing a better catalogue of satellite EO data and understanding the data that is available, including both temporal and spatial resolutions.
- The Pilot used EO data which are *observations* together with models that are *predictions*. The next stage would be to consider moving into *forecasting*.
- Consider engagement with the Insurance industry on an open standards approach to bring their data into the overall solution.

10.3. Technical

The Participants successfully delivered prototypes and achieved many successes. However, there is still a lot of technical progress that needs to be made. The suggested next steps include:

- The value and importance of Spatial Data Infrastructure (SDI) and establishing National SDI's to support disaster readiness.
- Agreeing to an approach on the front-end visualization and/or data sharing tools in terms of preferred or required capabilities, using either open source, commercial or existing options, etc. This is not about defining a single technology solution for users, but ensuring that the minimum requirements are set out to enable them to receive, process, visualize and share information effectively.
- Go beyond the Pilot and search out other technologies that may already exist to enable environments like real-time data sharing and collaboration across platforms, and give users the opportunity to leverage these within any future vision.

10.4. Preparing for Readiness

The Pilot has been clear that in order for data to flow efficiently between providers and users extemporaneously everyone involved needs to be ready to participate before any disaster scenario strikes, and this requires a number of procedures, processes and agreements to be established for users. The following are suggested as useful next steps in moving towards 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.
- Governments support the FAIR principles to improve user readiness
- 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 integrating, visualizing, and disseminating datasets.

- 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.
- Training for decision makers such that they can understand what the data is telling them, so that they know what questions to ask before making decisions and to be confident about making decisions based on the information they receive.
- Additional investments be made by governments in capacity development activities that support knowledge and technical transfer to improve user readiness.

Finally, on readiness, the Pilot identified a number of procedural suggestions for local or national Governments that could be beneficial when responding to a disaster. While these are not fully within the mandate of OGC to develop, it would be worth engaging officials in discussions to progress aspects such as:

- Establish an after-action review process for any geospatial data used within a disaster scenario, to highlight what specific datasets were used to improve understanding of what key elements of information are needed for decision making.
- Looking at how best to use the expanding population of remotely piloted drones. Satellite EO data has limitations that could be supplemented by drones, but there needs to be a clear plan so that drone operators don’t fly into restricted airspace or interfere with official efforts. Instead, they should be officially approved and registered as remotely piloted drones who could then provide valuable data.

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.

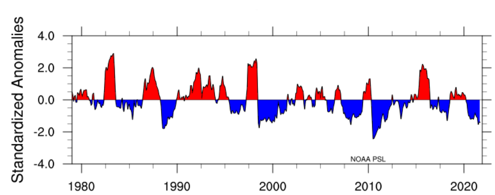


Figure A.1 — ENSO index with red indicating El Niño periods, Multivariate ENSO Index Version 2 courtesy of NOAA, USA

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 [11].

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.

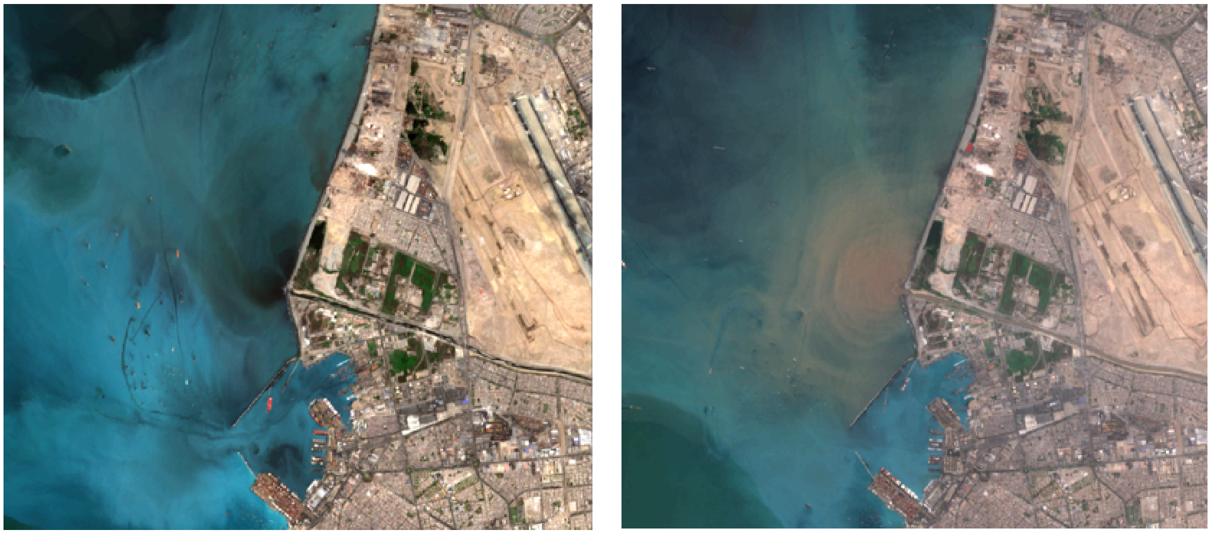


Figure A.3 — Transfer of water extending from the Rimac river as seen using Sentinel-2 on 01 (left) and 26 March 2021 (right); generated by Pixalytics.

A.1.2. Landslide events

Landslide is a general term used to describe the downslope movement of soil, rock, and organic materials under the effects of gravity and also the landform that results from such movement. The landslides can be of different types according to the material involved and the movement (fall, topple, slide, spread or flow). The triggers for a landslide are diverse, including intense rainfall, rapid snowmelt, prolonged precipitations, flooding, earthquake, volcanic eruption… and they can be aggravated by natural (weak materials, erosion…) and human (excavations, deforestation…) causes. Peru is classified as a high susceptibility area for landslides because of its rainfall patterns, terrain slope, geology, soil, land cover. Localized landslide is then a frequent hazard phenomenon and usually linked to flooding.

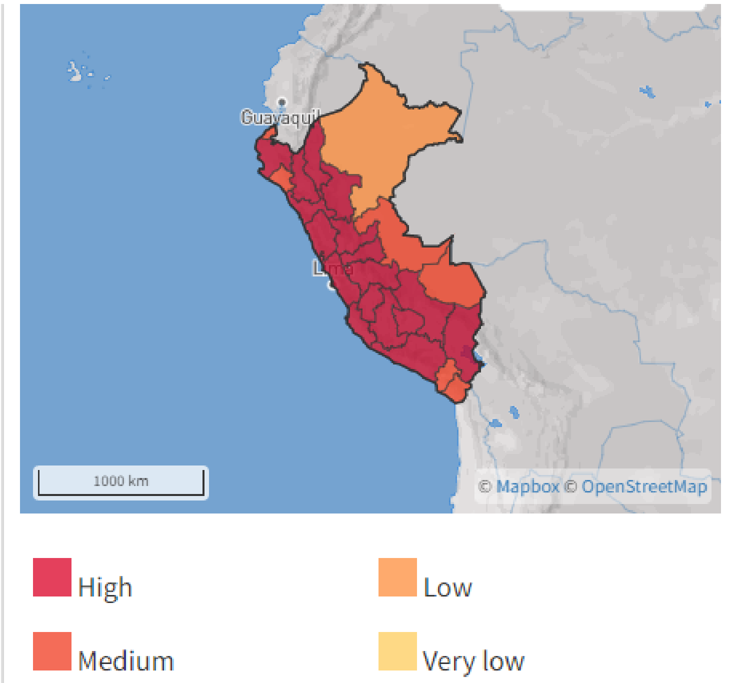


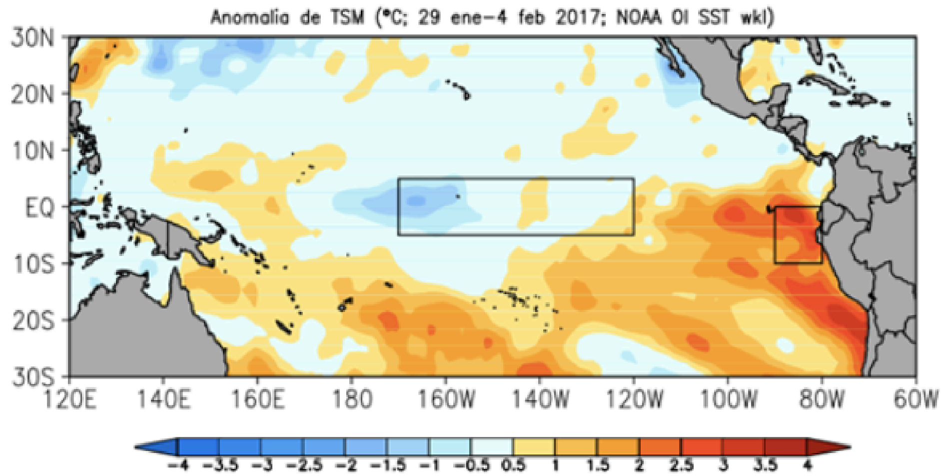
Figure A.4 — Landslide susceptibility in Peru.

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.5. 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.5 — SST anomaly in El Niño Costero 2017. Unusual heating is shown by the right-most black square; generated by 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.6 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.

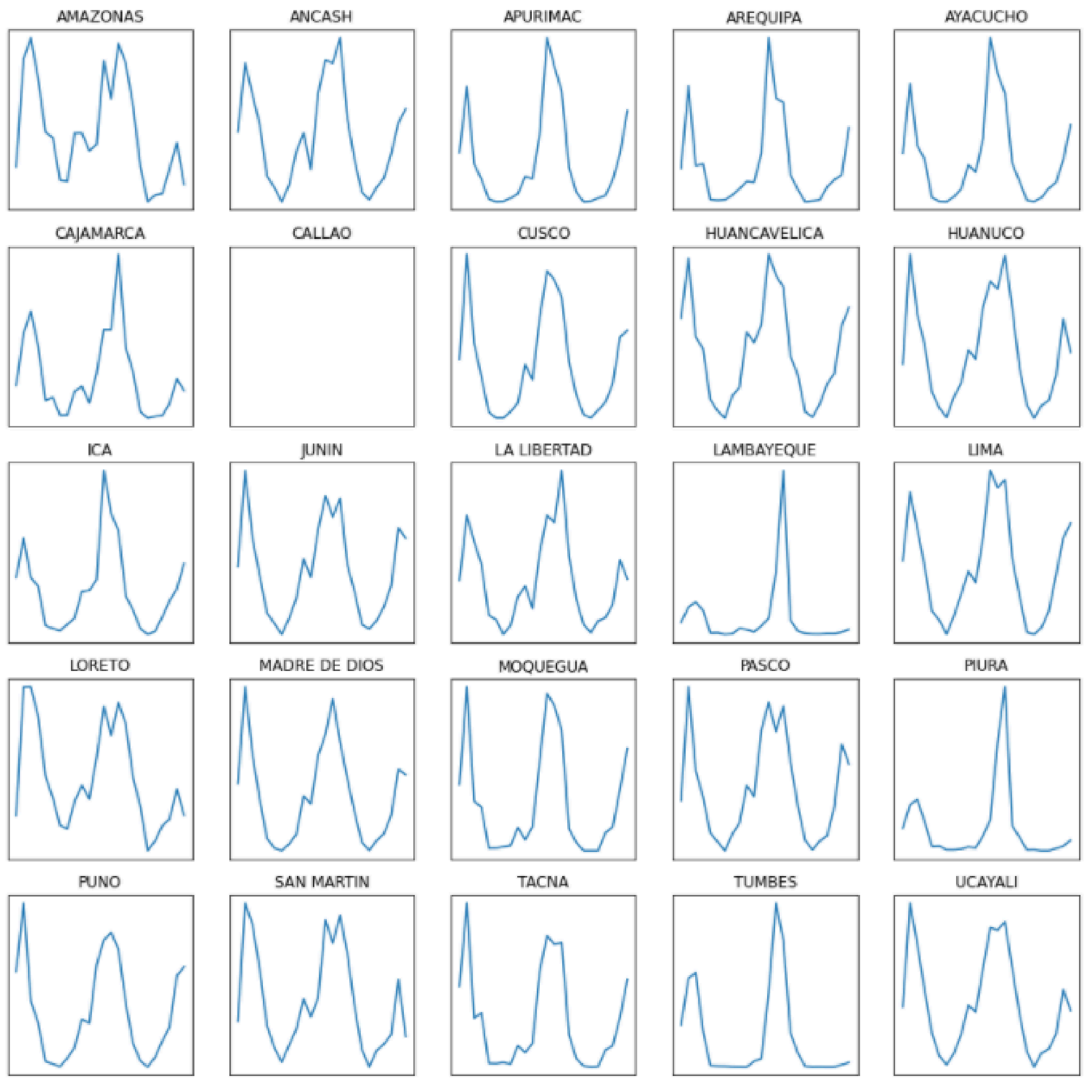


Figure A.6 — Precipitation in different Peruvian regions 2016-2018; generated by SatCen.

- **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.7. 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.7 — Sentinel-1 (SAR) processed backscatter during the flood event 2017; generated by SatCen.

- Optical: As seen in some of the examples, Figure A.8, 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.

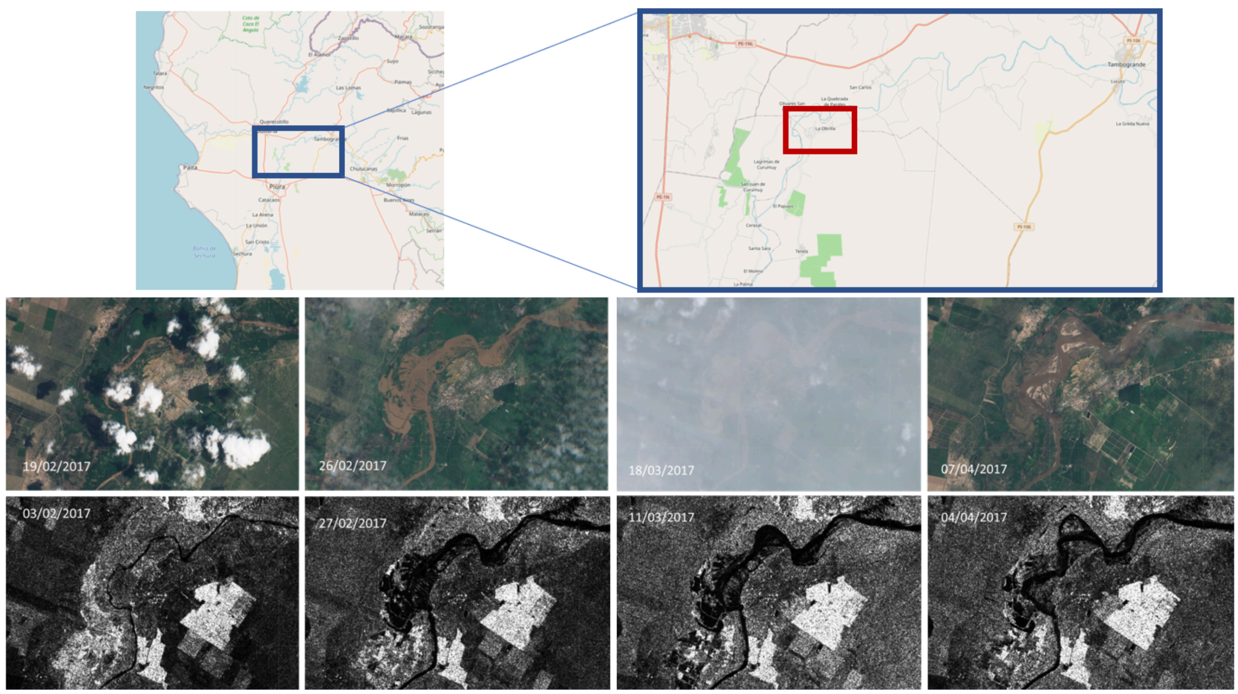


Figure A.8 — Sentinel-1 (SAR) and Sentinel-2 (optical) during the flood event 2017; generated by SatCen.

- **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.9: 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.

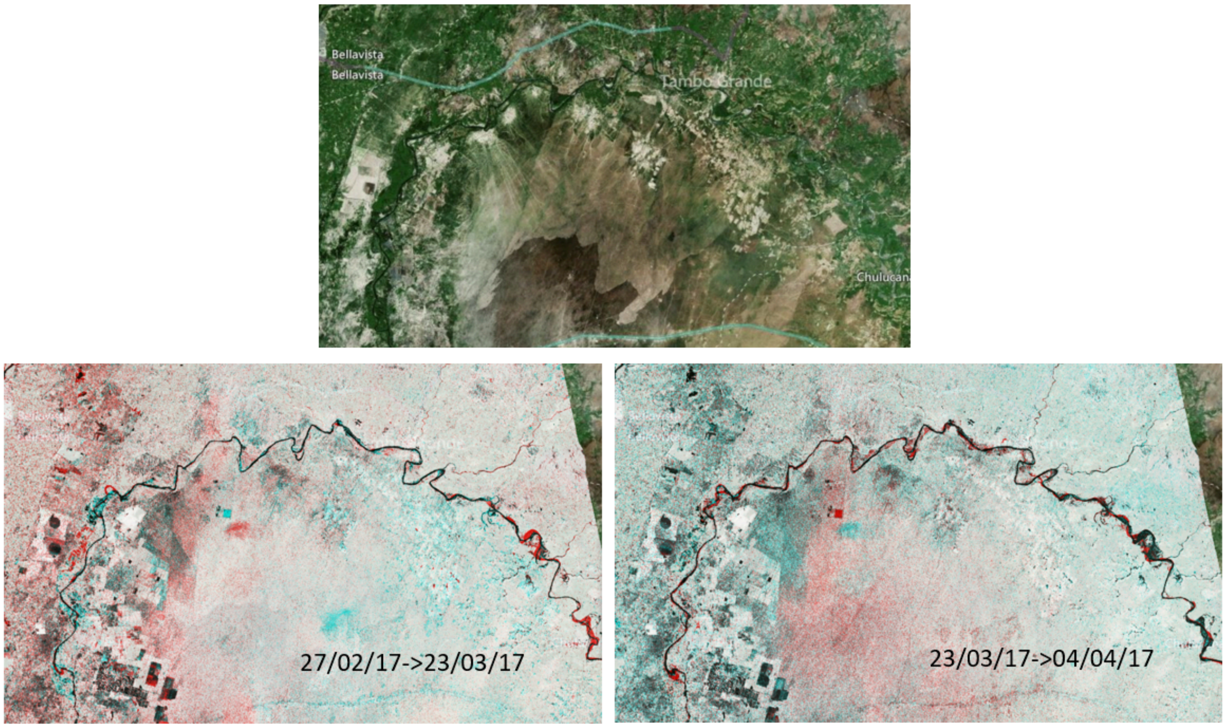


Figure A.9 — Example of ACD products generated with Sentinel-1. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- Multi-Temporal and Coherence (MTC), see Figure A.10: 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.

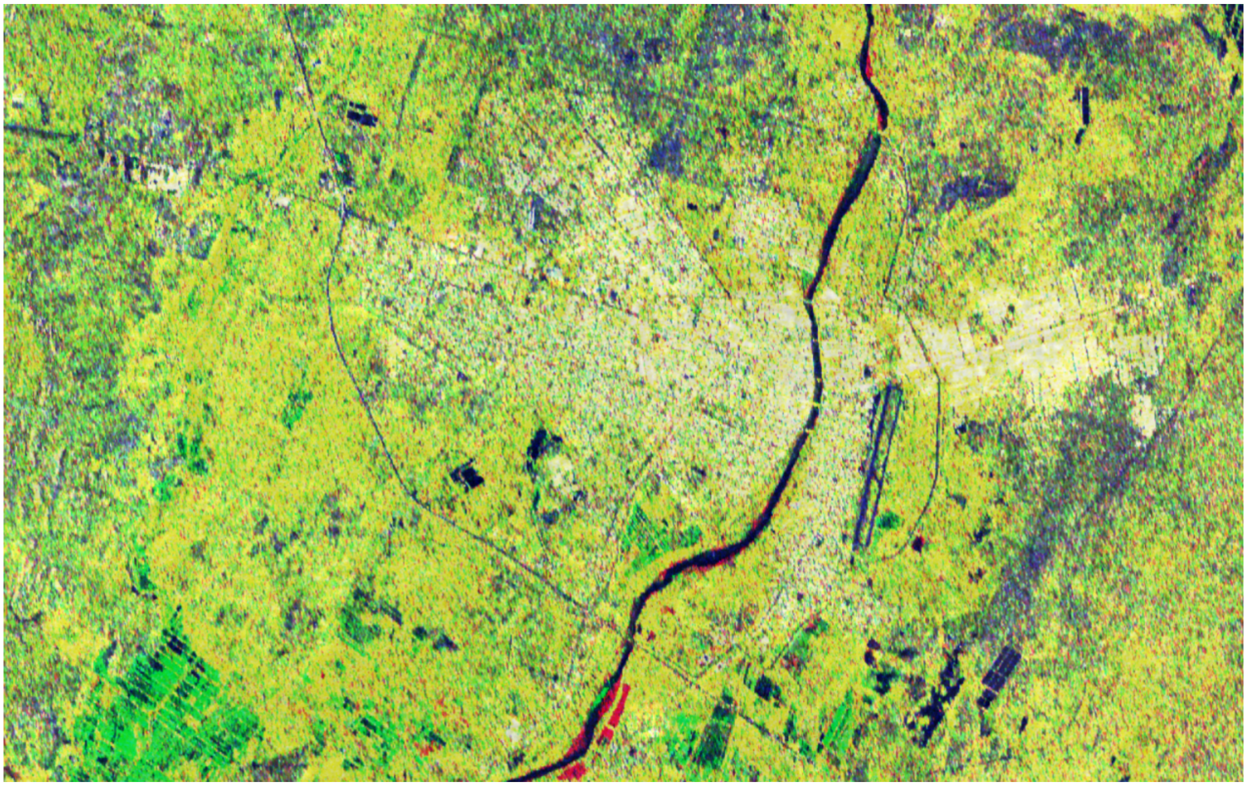


Figure A.10 — Example of MTC product generated with Sentinel-1 over Piura. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- **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.11. 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.

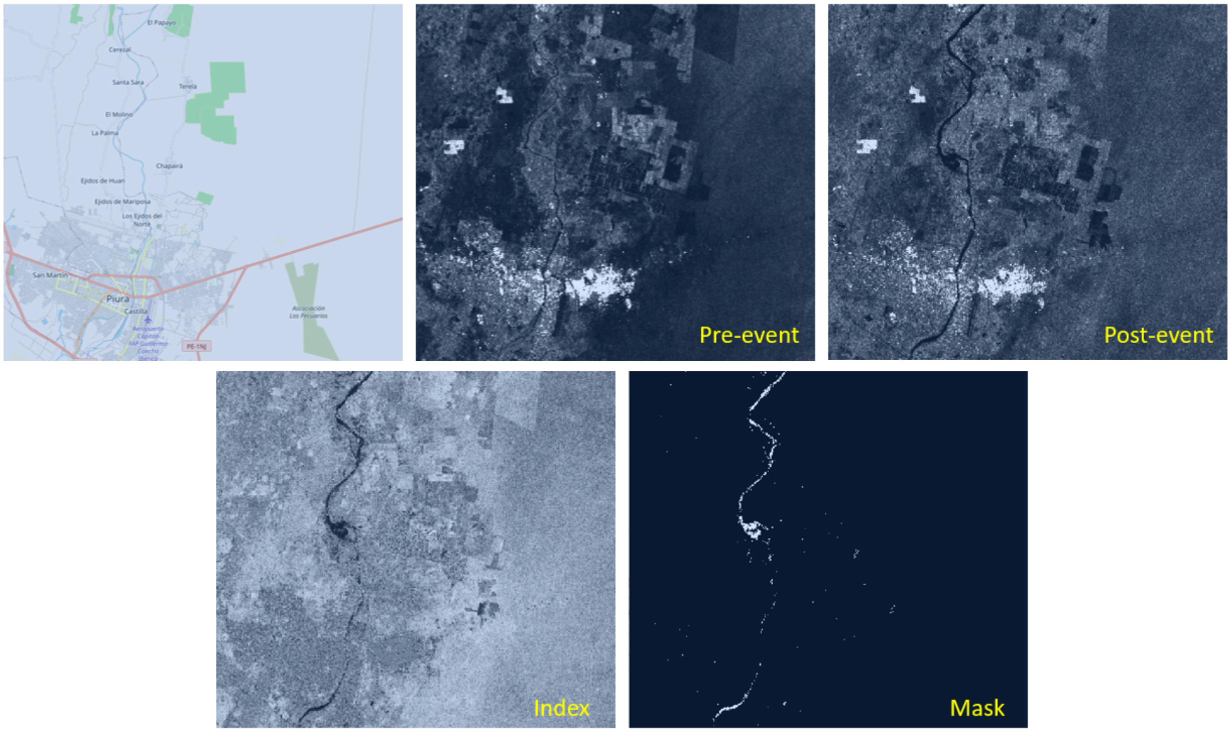


Figure A.11 — Example of flood mask computed from Sentinel-1 data; generated by SatCen.

A.2.2. Landslide-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. Some of these data are the same considered in flooding scenarios.

The main event studied during the pilot is the Achoma landslide on 18th June 2020. In this event, soil and rock on a hillside slipped loose and created a landslide affecting more than 40 hectares. The landslide generated a dam in the Colca river, which caused flooding.

The event is clearly visible using Sentinel-2 data as shown in the image below.

Figure A.12 — Sentinel-2 images over Achoma landslide.

Similar analysis to the flooding was carried out with Sentinel-1 (SAR) to detect changes. The preliminary products for visual assessment were the ACD and MTC.

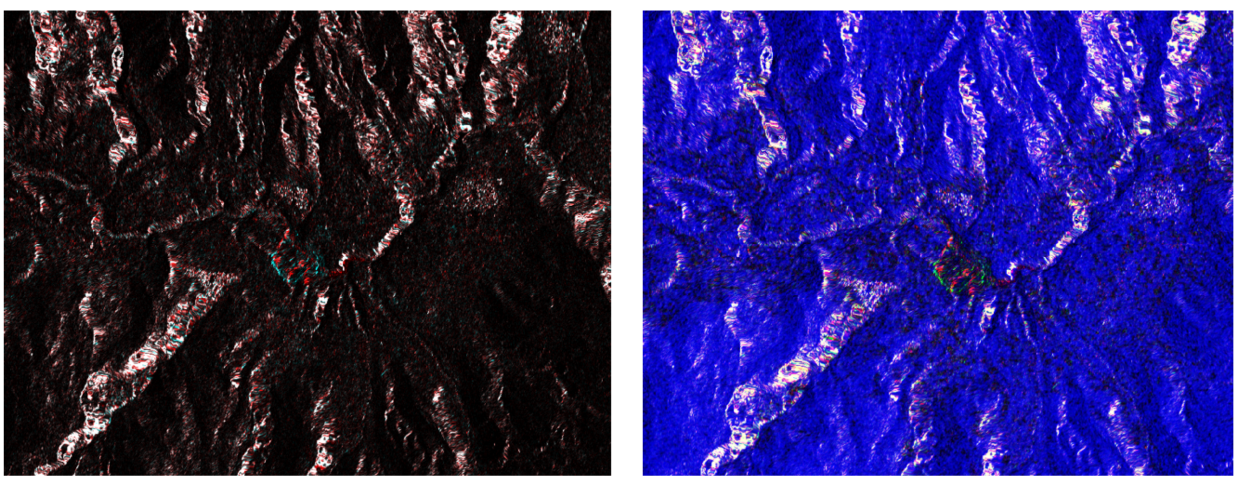


Figure A.13 — ACD (left) and MTC (right) generated with Sentinel-1 data over Achoma with images before and after the landslide.

The change in the terrain is visible in the ACD at the center of the image. The changes are highlighted in red and cyan (depending on the slope, the landslide increases or decreases the backscatter amplitude). But in the MTC, the change can be distinguished more precisely due to the loss of coherence. In the MTC composite, the blue band corresponds to the coherence. In the image above, the coherence is high in all the image (blue and white color) except in the area affected by the landslide.

In particular, for this event, a time series of the coherence was computed using the S1 SLC products.

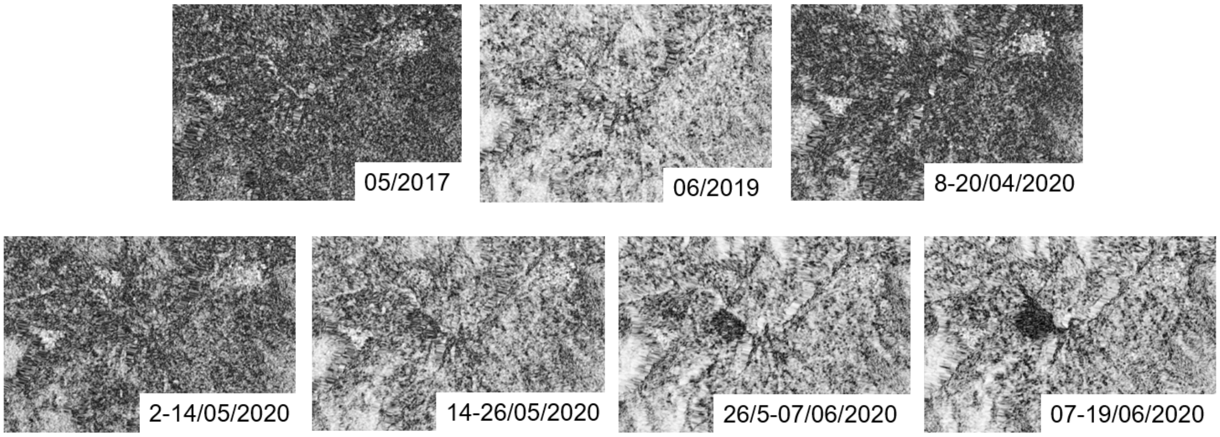


Figure A.14 — Time series of coherences generated with Sentinel-1 data over Achoma.

In the time series, the coherence in all the area seems uniform. It is higher or lower depending on the specific pair of images (probably to soil moisture), but always homogeneous. After the pair from 14th and 26th May 2020, the area where the landslide will happen can be distinguished because of the loss of coherence. The loss of coherence is maximum in the last image (computed with a pair of images just before and after the landslide), and the contour of the affected terrain can be delineated easily.

But the coherence in this example is not only useful to identify the affected area, since it seems possible to use it to predict the event some days before it happens.

A.2.3. 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.15 with the output locations shown as red stars overlaid on a Sentinel-2 pseudo-true color composite from 20 March 2021.

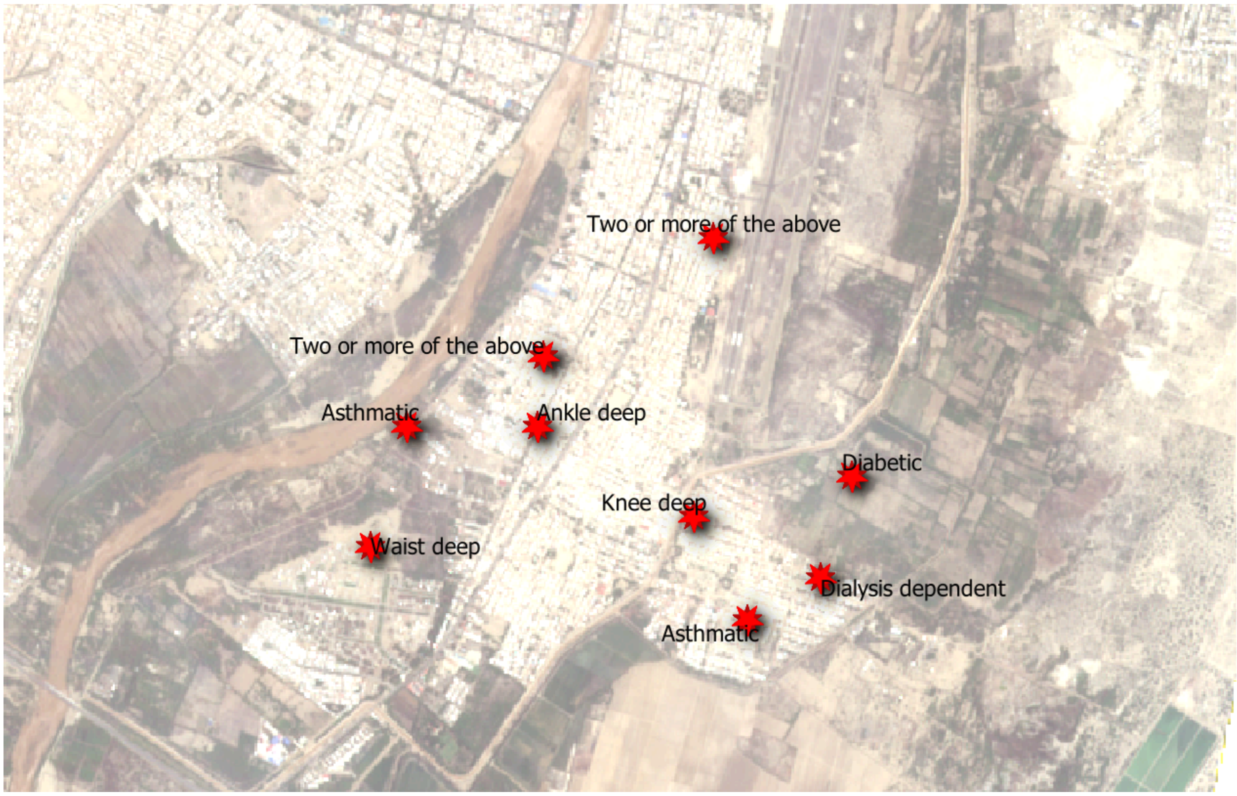


Figure A.15 — Example of GISMO GeoRSS URL output, overlaid on a Sentinel-2 pseudo-true color composite from the 20 March 2021.

A.2.4. Visualization

Figure A.16 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 web service interface that implements standards such as WFS (Web Feature Service) and WMTS (Web Map Tile Service).

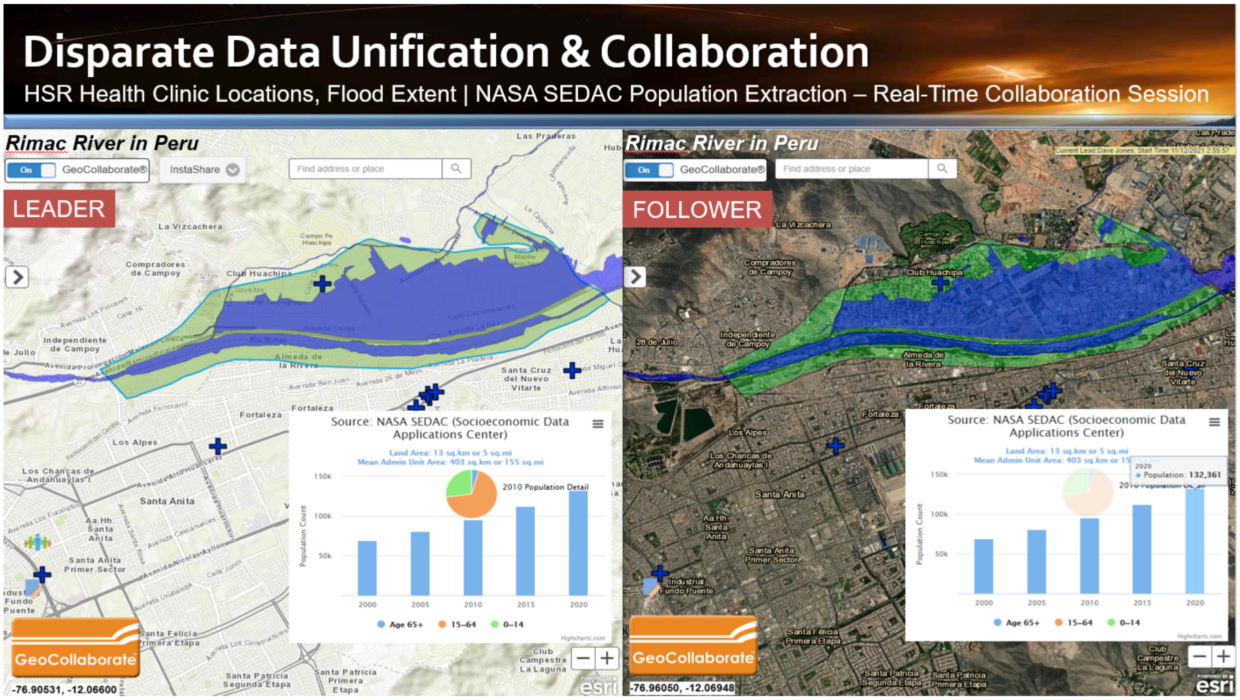


Figure A.16 — Data for Rimac River in Peru including flood extent and demographic breakdown of the area, together with clinic locations from HSR.Health, visualized via GeoCollaborate

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 & 2011 floods

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 water runoff from the land 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 which increase melting of the snow pack or late spring snow storms adding to the existing snow pack
3. The actual snow pack 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 City of Winnipeg's main gauge (James Avenue).

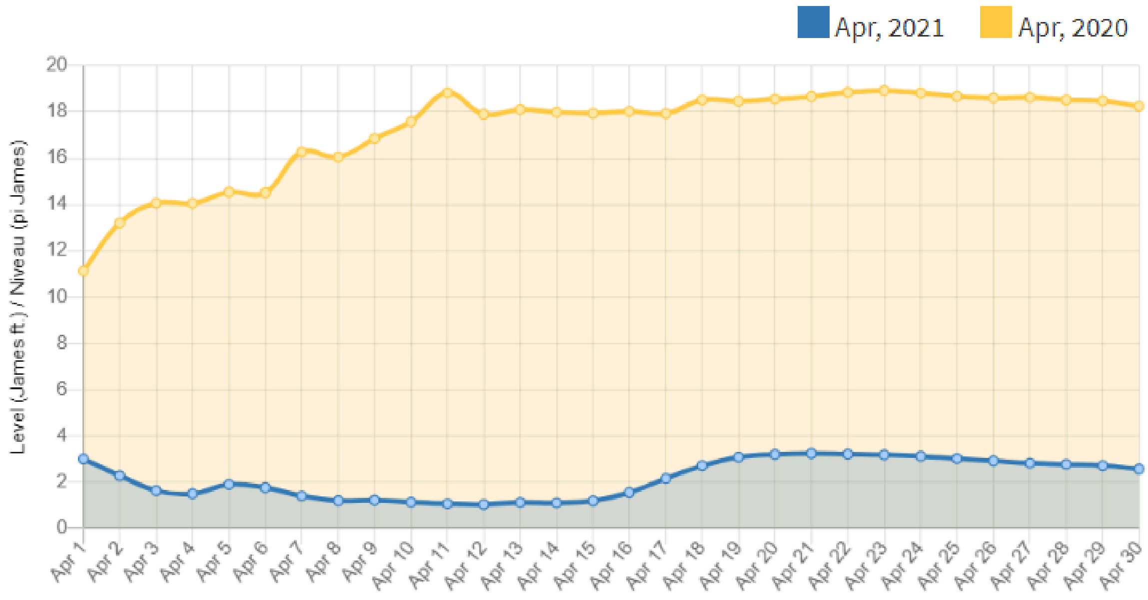


Figure B.1 — Red River Water level April 2020/2021 Comparison, Winnipeg river levels

Winnipeg does have a 48 km floodway (long excavated channel) to reduce flooding within the city, but it can only be opened when there are no ice jams. Water started flowing naturally into the floodway on the 07 April, and it was put into full operation on the evening of the 10 April. The impact of the floodway is seen in 71 as the flooding peaks at around 19 meters on 11 April and is held approximately steady for the rest of the month.

Figure B.2 shows the May 2021/21 water levels for the same river gauge. The water level started to drop at the beginning of the month, and fell steadily until at the end of May the levels were the same as the previous year. It is estimated that the floodway resulted in around 930 million m3 of water being diverted around the City of Winnipeg [12].

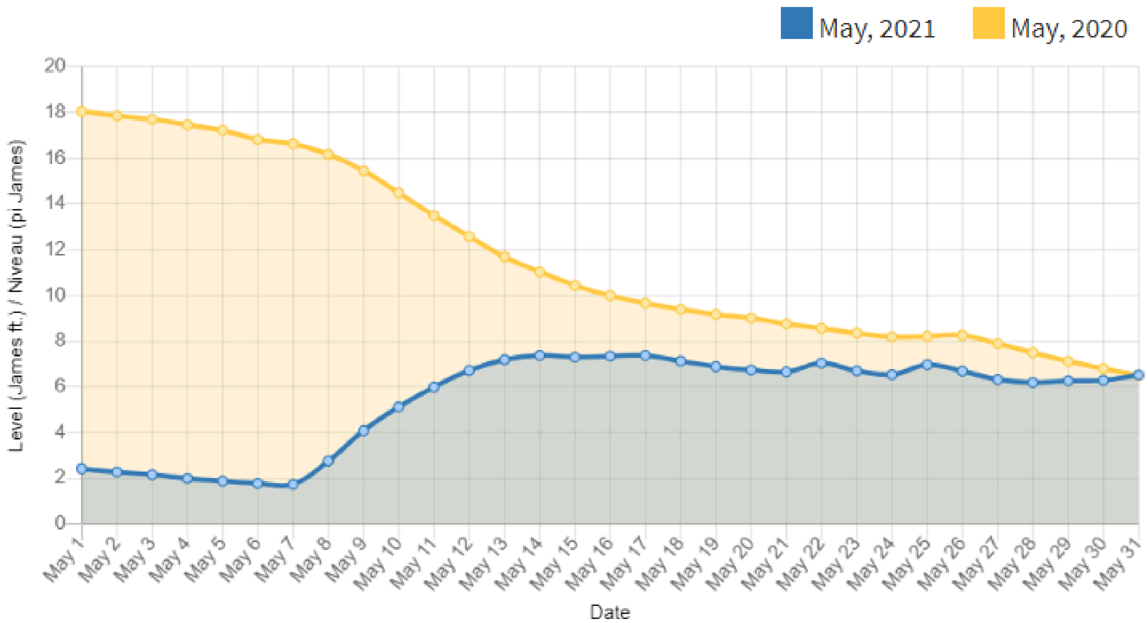


Figure B.2 — Red River Water level May 2020/2021 Comparison, Winnipeg river levels

The floodway successfully protected Winnipeg from flooding during the high-water levels of 2020. As noted above, it can only be operated when there are no ice jams. Unfortunately, ice jams events impacting the lower reaches of the Red River, between Winnipeg and Lake Winnipeg, have increased in both severity and frequency over the last century, a trend which is expected to continue and worsen in the future [13].

Water level rises similar to the 2020 ones described above have occurred before, such as 2011, which have had similar impacts. It is the 2011 event which has been used in the Pilot for the modelling activity, although the processes undertaken to generate the datasets would be the same whichever year was selected.

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 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 leverage geospatial standards:

1. Imagery Acquisition and Access — Satellites capture imagery for the Red River region and this 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 uploaded into a secure system at the Canadian Space Agency, where it can be 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. Metadata standards allow both humans and machines to understand the characteristics of a given dataset, allowing it to be used appropriately.

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.

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 monitoring of flood progression with the limitations that the satellite return frequency is 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, 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 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. 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.

Standards are critical for 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. 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?

This Case Study has focused on creating recipes for an idealized data value chain ending with DRIs for the best transportation routes to avoid flood water.

The value chain starts with observations of flooding using both river gauge measurements and satellite EO observations. These datasets are combined with mathematical algorithms and a Digital Elevation Model (DEM) which describes the height of the land, to produce two different approaches for the creation of a flooded area ARD.

- **Model based ARD** — This first approach uses the river gauge measurements, and overlays these onto a DEM and then a computer model predicts which areas would be expected to be flooded with those river measurements. Figure B.3 shows an output grid for the area of the Red River Basin where the model technique developed by RSS Hydro has predicted the flooded area using data from 2011.

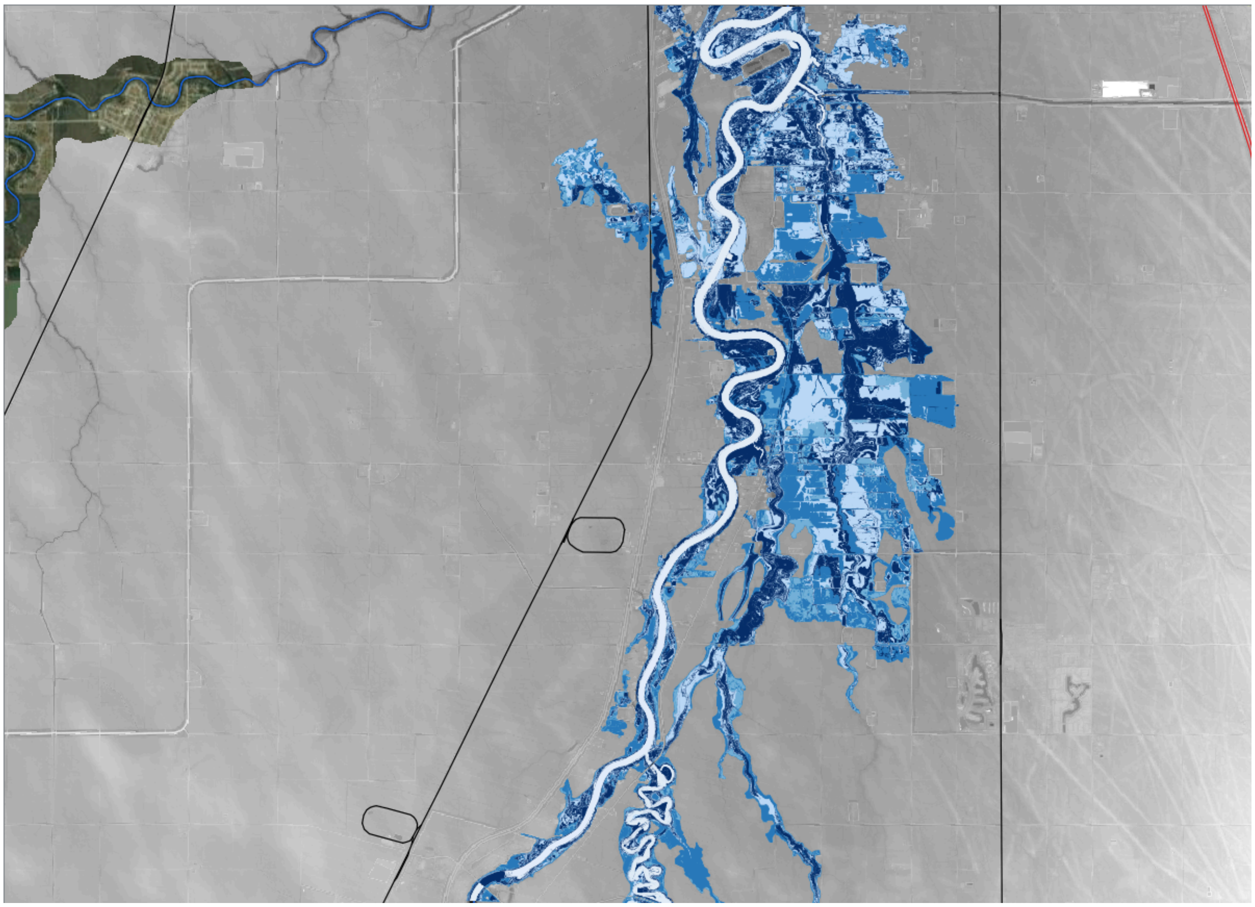


Figure B.3 — Area of 2011 flooding, colored light to dark blue according to flood day (start to end) overlaid on DEM (shades of grey), with railway line as black lines, and motorway as a red line; flooding area from RSS Hydro.

- **Satellite based ARD** — This technique uses both optical and SAR EO satellite data observations as the raw data which are combined with mathematical algorithms to identify the areas that have flooded. Figure B.4 shows flooding in the area for April 2020 determined using Sentinel-1, Sentinel-2 and Landsat-8 data produced by Wuhan University. This is overlaid onto the same DEM as used for Figure B.3, but it is for a different time period and a slightly different area of the river.

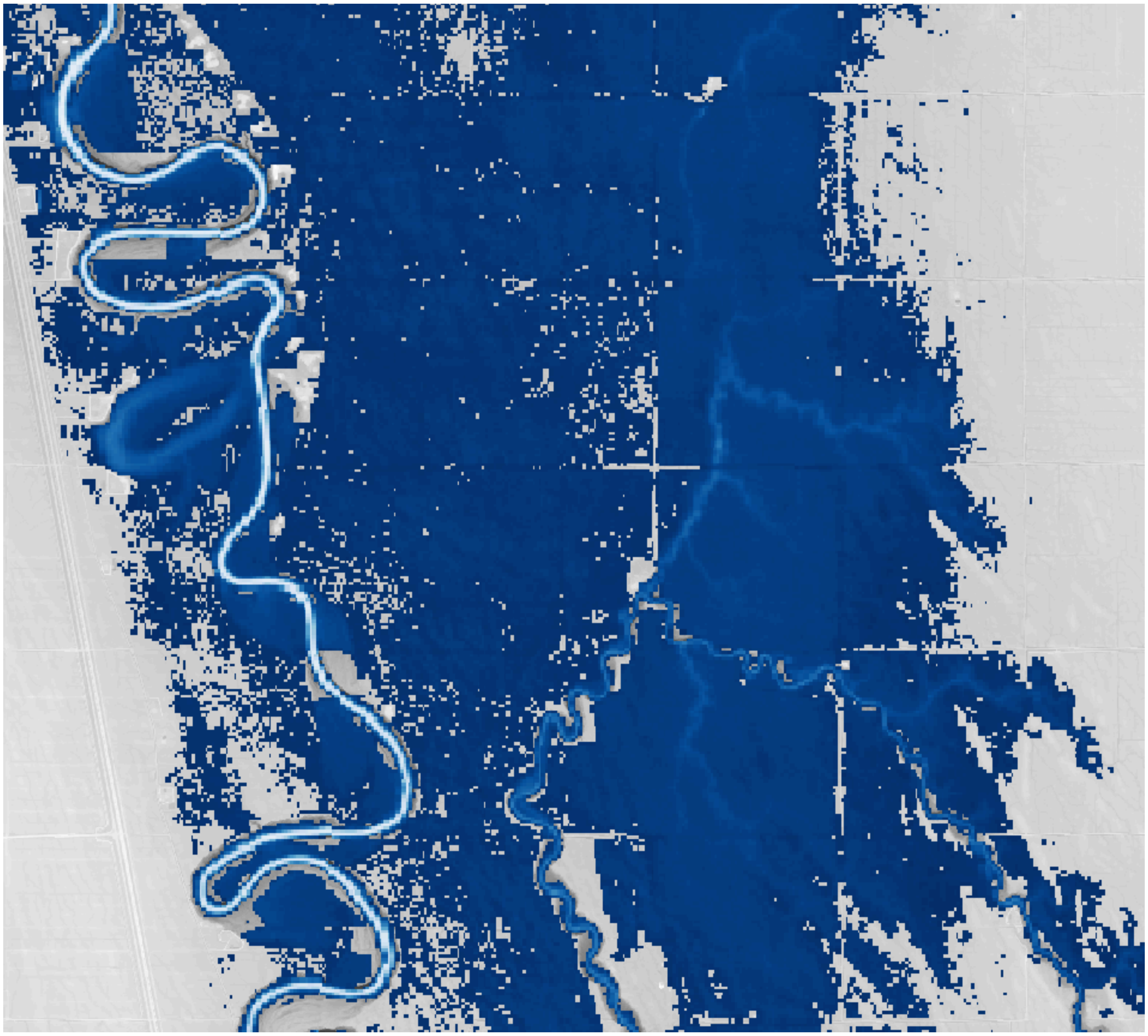


Figure B.4 — Section of the April 2020 flooding, colored dark to light blue according to occurrence, developed by Wuhan University, overlaid on the DEM.

The above two ARD grids of flooded areas are both based on historic measurements, but they can be useful indicators of how flooding has occurred in the past, and what the disaster teams can expect if similar water levels or rainfall are experienced again in the future, enabling them to get on the front foot in any response.

- **Flood Contours IRD** — As well as being used directly, the flooded area ARDs move along the data value chain and are used as input data for the next stage which transforms the data into Flood Contour IRD — integration ready data.

This approach has been developed by Safe Software using their FME platform which is a model based spatial data transformation and integration tool. Taking the input ARDs of modelled flood grids and EO ARDs, these are transformed into flood vector contour IRD, where areas with the same water depth are classified. This step is necessary as the transportation routing DRI, which is the next step in this data value chain, requires flood depth estimates to work, not just the area or extents flooded. The flood water is categorized into five depth categories: 0.1 meters, 0.3 meters, 0.5 meters, 1.0 meter and above 2.0 meters.

Given the sensor and computational tools used, both EO and flood model output datasets tend to generate grid observations or time series. However, many analytic and GIS tools more readily work with vector datasets. This is why the ARD to IRD approach for flood impact analysis was designed to convert raster flood depth grids to vector flood contour polygons to better support downstream integration required for the IRD. Figure B.5 shows an example of the workflow used for the FME part of the ARD to IRD / DRI recipe for this flood transportation indicator.

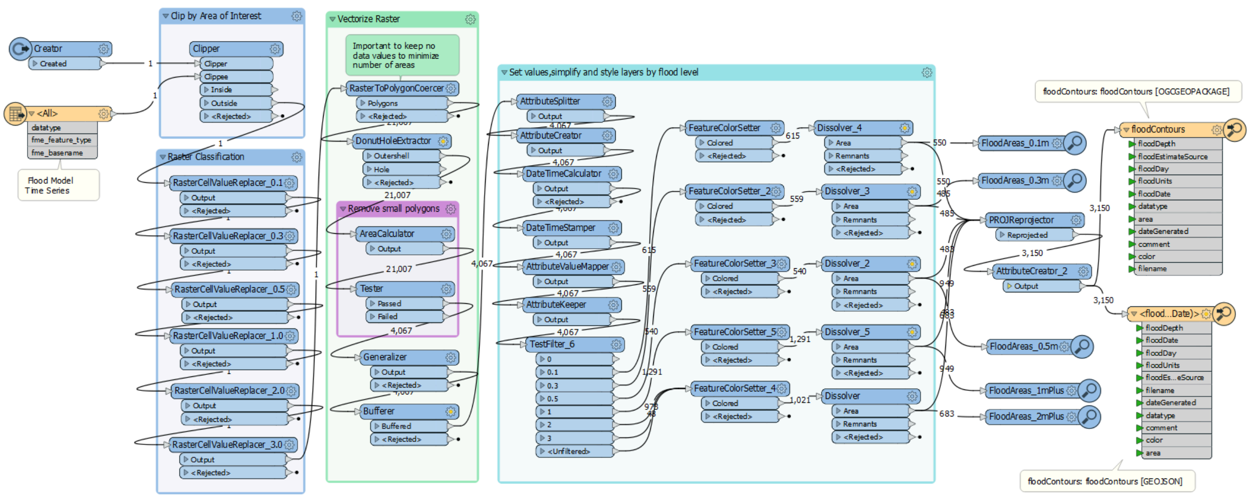


Figure B.5 — ETL approach for converting flood area grid ARDs to flood contour IRD using FME from Safe Software

To improve accessibility, the result was saved as an OGC GeoPackage, which makes it easy to share with other components as well as to use offline. The IRD Flood Contours were then used as input data for the creation of the transportation routing DRI. Figure B.6 shows flood contours in the Red River Valley south of Winnipeg which was used as the input data for the transportation route DRI.

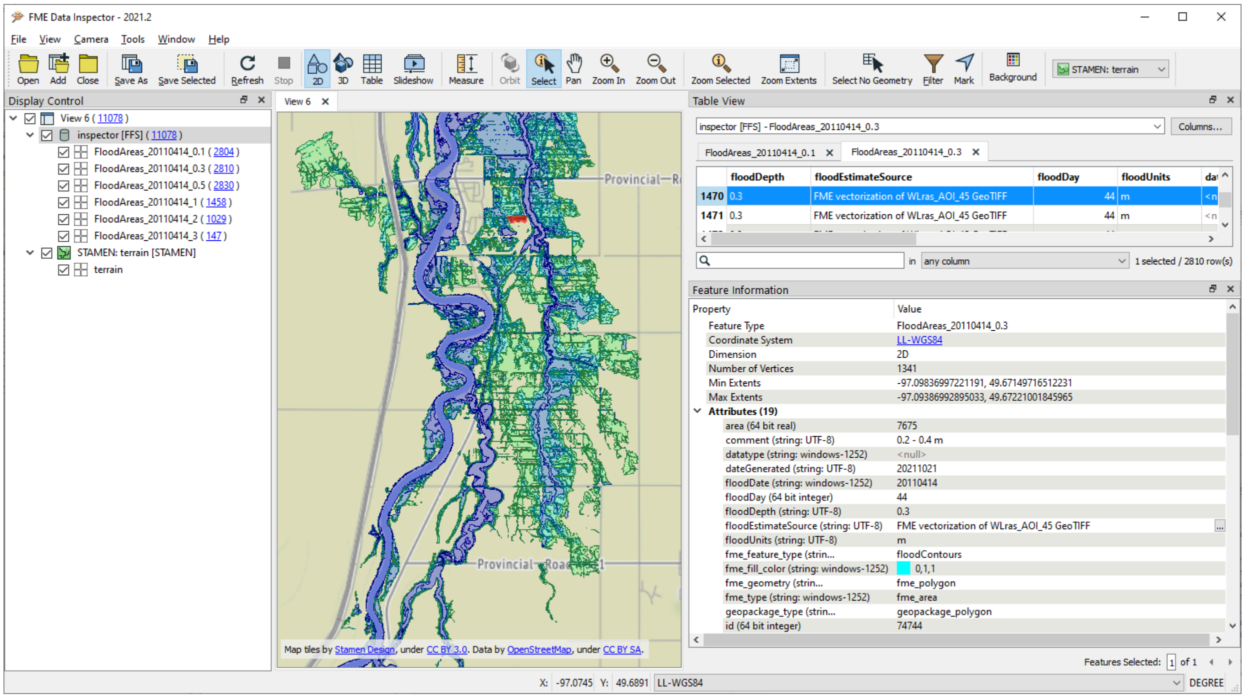


Figure B.6 — Flood Contour Geopackage showing flooded areas south of Winnipeg by date, as displayed in FME Data Inspector.

To better support online integration, the flood contours were also provided to the HSR.Health GeoNode instance, which makes this data available to other components via OGC services such as WMS and WFS. Figure B.7 shows an example of the flood contours for the Red River Flood from 7th April 2011.

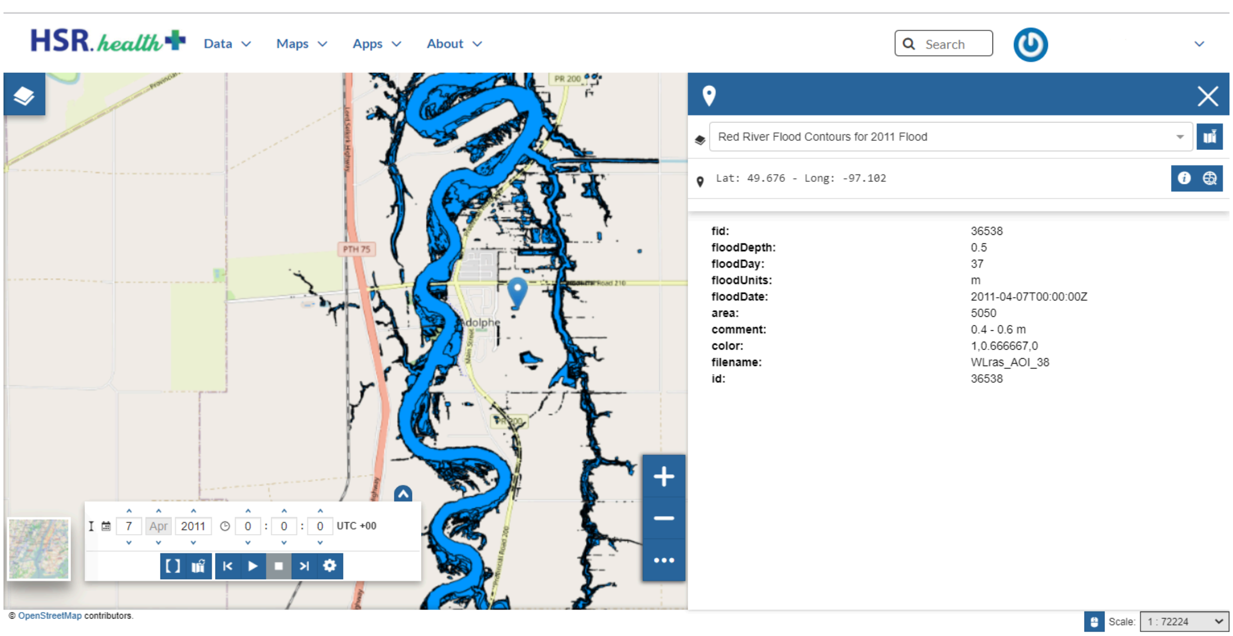


Figure B.7 — HSR Health Geonode with Flood Contours for Red River flood from 7th April 2011 loaded from FME workflow outputs.

The approach for calculating the transportation routing DRI implemented by Skymantics and it uses the flood contours depths to determine what roads are impacted by the flooding, and how deep the water is. The user has the potential to specify what depth of flooding is passable which is important for different vehicles that could be involved; for example, a large lorry or 4X4 would likely be able to handle deeper water than a motorbike or small car. The user enters the starting position and the intended destination, and the routing software works out the best route to take to avoid the flooded routes. This is dynamic software which can be updated as flood water rises or falls to offer the best route at that particular time.

Figure B.8 demonstrates the process. Top left shows the optimal route between Ste. Agathe and Ile des Chênes, two places in Manitoba that are approximately 30 km apart. Top right shows the flood contours produced in the process above for Winnipeg and surrounding areas. Bottom left is the user specified elements, which in this case allows a maximum flood depth of 0.2 m for public vehicles and 0.4 m for emergency vehicles. Finally, in the bottom right is the new optimized route taking account of the flooding and user requirements.

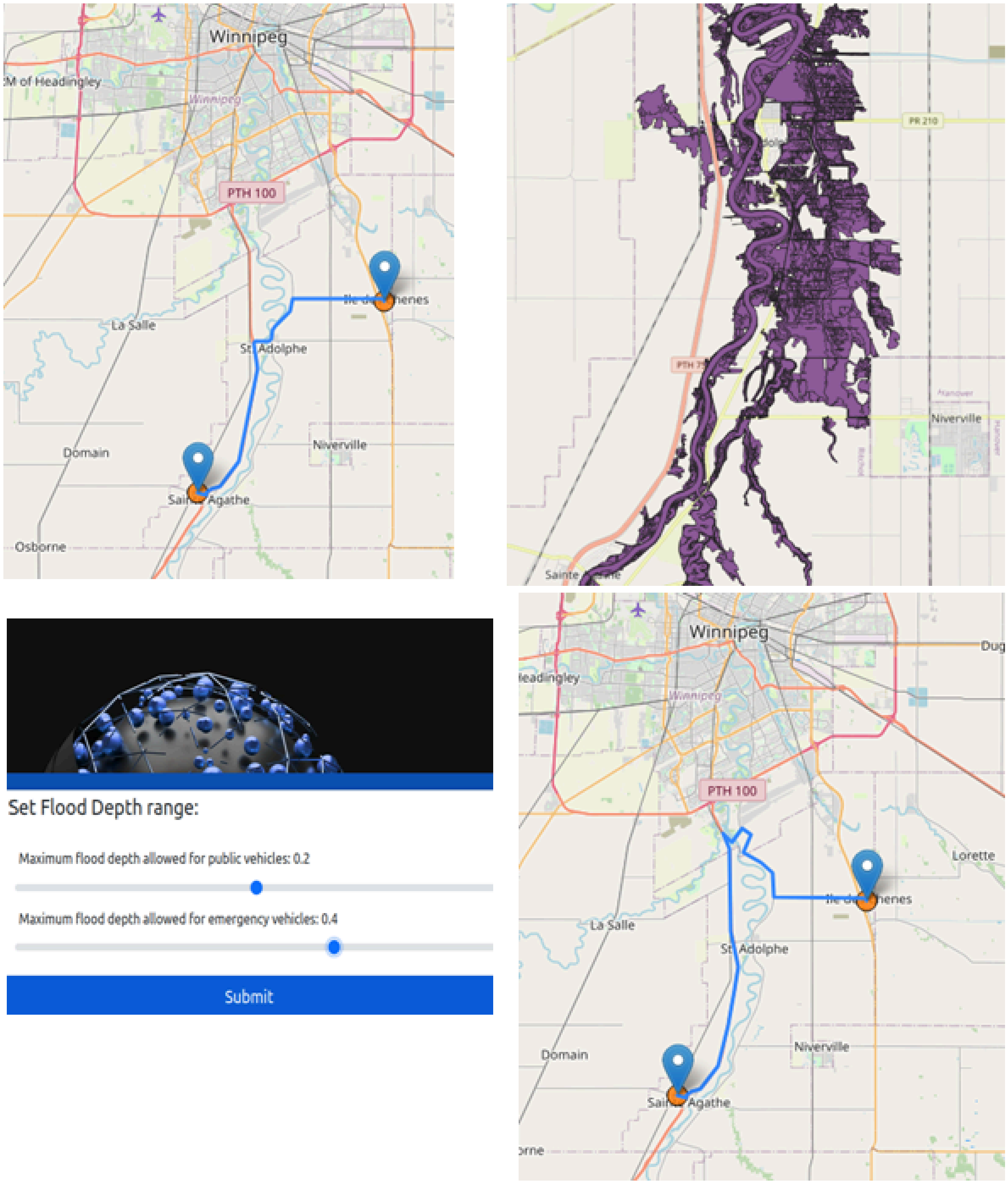


Figure B.8 — Routing DRI. Showing optimal route, flood contours, user variables and revised route. Produced by Skymantics.

The routing software uses the flood contours, topography of the area and a road dataset to find the roads that would be impacted by the flood, and then determines where the road is passable, passable only by emergency vehicles or impassable. It uses these determinations to create a revised route between the two locations.

This application is important for response teams trying to get to situations, evacuation routes or the delivery of supplies. In addition, it is possible to identify roads that should be closed so that teams can go and close the road and update navigation apps, which should prevent more people using the road and getting stuck in their car in the flood water.

As highlighted in the Case Study 1, web-based solutions such as GeoCollaborate or GeoNode, can offer a way of communicating and collaborating on the information available to help speed up situational awareness and decision making. GeoCollaborate offers an approach to access and share the datasets across multiple followers or users from its dashboard including any datasets or layers that have been provided, giving a way of connecting decision makers together in a collaborative environment. Whilst GeoNode offers an online web GIS where datasets or layers can be visualized and shared with anyone involved in the disaster response. Both solutions offer an opportunity to provide up-to-date information within minutes of a disaster impacting an area.

B.3. Conclusion

This Case Study has focused on flooding within the Red River Basin, Canada. The Pilot generated several ARD datasets using model predictions, satellite observations and flood contours and then developed a series of DRI recipes. The details of the recipes are included in the Appendix to Case Study 2 in the Provider Guide (i.e. Annex B.5 of OGC 21-074).

The Pilot used the recipes created to produce a data value chain focused on the routing of emergency vehicles.

This Case Study has shown that it is possible to deliver the value chain to create the example DRI, however it has also identified some issues and limitations around automating the process. The next steps will be to develop this workflow further to move it closer to real time which would be required within a disaster scenario to allow decision makers and field responders to work together.

C

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

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 continents, 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 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 was estimated to be home to over 4,600,000 people in 2019 [14]. 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 with COVID-19. By the middle of October 2021, over 750,000 cases of COVID-19 had been confirmed in the State, with over 14,000 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 2005's Hurricane Katrina 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 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. Examples, although not all, of these EO datasets, 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.

While there are other dashboards across the world, many are focused only on a particular area of the world, specific data indicators or producing reports available to access. This review concludes that there are currently not good examples of integrated health and EO data to support pandemic response. 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 describe the Medical Supplies Index and routing map developed by HSR.health and Skymantics, together with example EO 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 the User Readiness section, 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 a pandemic response, including both health and spatial data, based on the work undertaken on the OGC Health OGC's Health Spatial Data Infrastructure Group's Concept Development Study Draft Report:

- Street maps and names, together with address databases.
- Census area boundaries and maps, including population and health information
- Habitation Layer (villages, homes, farms) including building footprints.
- Transport network including road network, freight train route, helicopter and aircraft landing zones.
- 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.
- Critical Supply Chain facilities and routes for key medical, food, etc.
- Telecommunication infrastructure.
- Community facilities such as schools, colleges and libraries, etc., together with commercial establishments such as supermarkets, gyms, sports venues, 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 disasters 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 will need processing to apply the relevant data standards to allow the datasets to be rapidly shared, integrated and visualized.

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 that 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 by 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 above normal.

- **Air Quality –** Measuring the amount of pollutants in the air such as Nitrogen Dioxide and Carbon Dioxide, both of which reduced significantly across the globe during 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., can 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.

  - *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 modelling.

- **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 & Populations with Compromised Water Systems* – identification of drinking water or standing water that has become contaminated, which can lead to an increase in gastric illnesses and can lead to 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 is brightly colored on an image.

- **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. While not a direct indicator of pandemic 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 measuring the temperatures they are facing will indicate any additional support they might need.

- **Air Temperature & Relative Humidity –** While 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 measuring the temperatures they are facing will indicate any additional 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. While not a direct indicator of pandemic spread, it could be an indicator of the spread of quarantine measures across countries and how populations are abiding by them.

- **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 snow melt, 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 DRIs relating to various risk modeling tools, such as Flood Risk Modeling, Flood Forecasting, or Hurricane/Tornado Forecasting. All of which will help identify the high-risk areas most vulnerable to a potential disaster.

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

C.1.4.1. Health Data

The Medical Supply Needs Index was developed by HSR.*health* to give 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.

The calculation of the Medical Supply Needs Index for the COVID-19 pandemic begins with the calculation of the Pandemic Risk Index, which combines a 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, representing both the spread of the pandemic and the health risk that the pandemic poses. Similarly 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 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 ARDs 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.

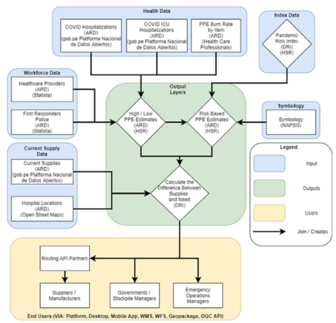


Figure C.1 — Medical Supply Needs Index Workflow Courtesy of HSR.*health*

The work on this case study was focused around New Orleans in Louisiana, and Figure C.2 shows the area city that was used for the Medical Supply Needs Index.

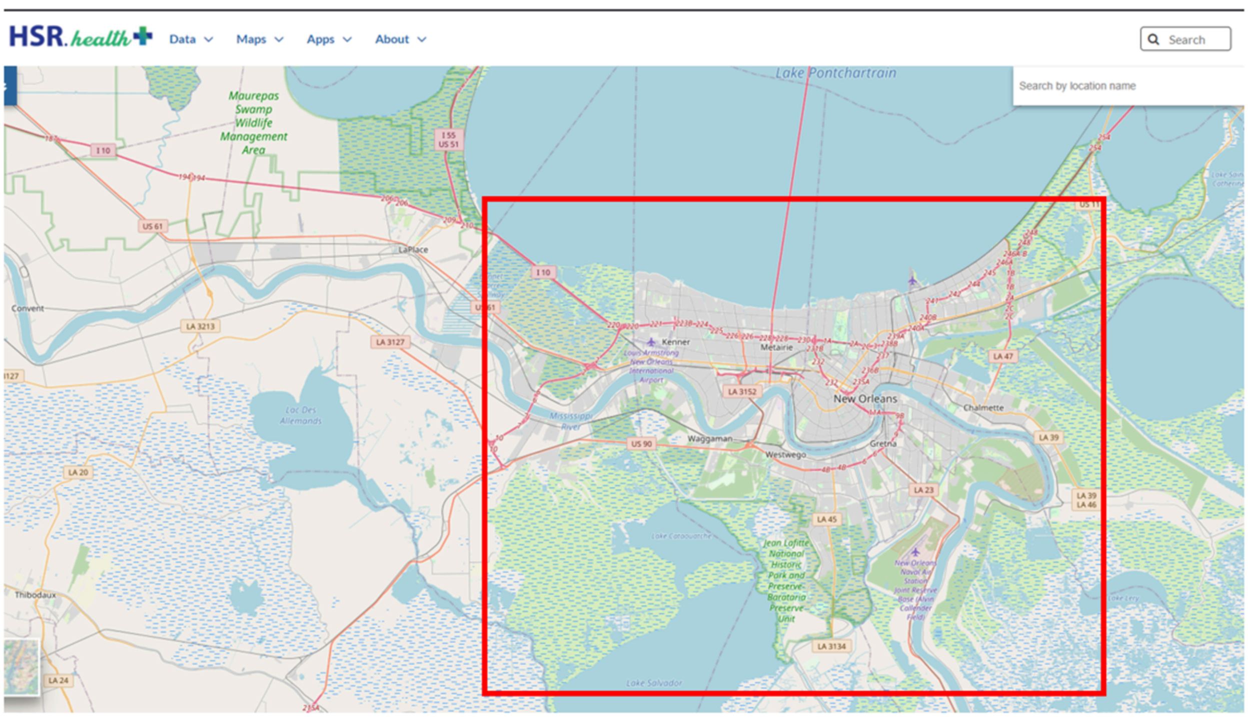


Figure C.2 — Case Study Area of New Orleans in Louisiana. Courtesy of HSR.*health*

The following three figures show the output of the Medical Supply Needs Index, and how the data can be developed and enhanced layer by layer. Figure C.3 shows the Medical Supply Needs at a small census district level, with each different color indicating a different level of Medical

Supply Needs with purple showing the highest level of need, followed by red, orange, yellow, green, blue, and the white areas have the lowest level of need.

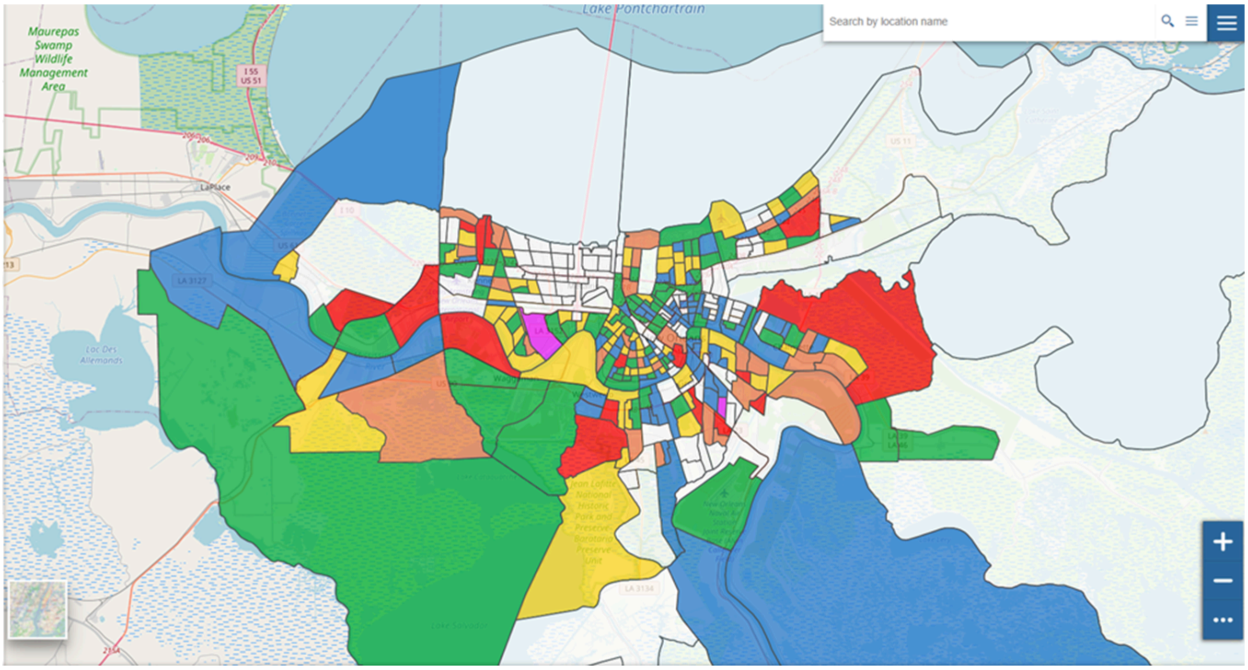


Figure C.3 — Medical Supply Needs Index for New Orleans at Census Level. Courtesy of HSR.*health*

Figure C.4 below shows that by overlaying first the hospital locations shown by the red crosses, and secondly with distribution locals for the medical supplies which are the green stars, it is easy to identify the areas that need supplies, the closest distribution depots and the distances that need to be covered to deliver them.

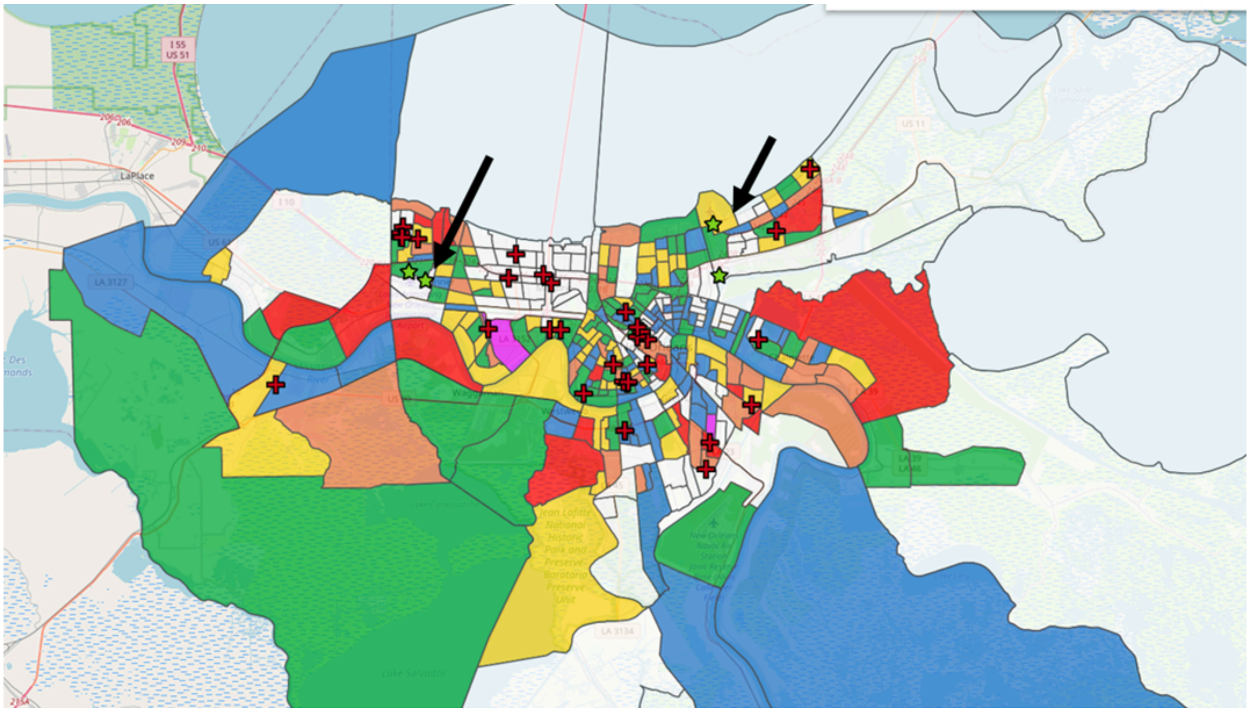


Figure C.4 — Medical Supply Needs Index with Hospital and Distribution Location. Courtesy of HSR.*health*

A further demonstration of the developing data value chain in this Case Study was developed by Skymantics, who ingested health data from HSR.*health* together with flood extend example for Louisiana to create a dynamic routing solution.

This solution can be utilized to identify the quickest or best route to hospitals/clinics either for patients or to transfer the supplies from the distribution centers (such as warehouses, airports, or ports). This will include dealing with both medical facilities or roads that have been closed for any reason.

For decision makers within medical facilities the solution will help them improve their ordering for Medical Supplies taking into account changing utilization, delays in delivery, etc. For the general public it will also give useful information if they need to attend a hospital/clinic, by providing an indication of the time it will take to get to care facilities.

Figure C.5 shows two examples of the distance to care application for the New Orleans area. The distance to care has been calculated for two scenarios, the top image is a normal situation, whilst the bottom image is where around one third of hospitals are saturated with patients and cannot deal with any new attendees. In both cases, the distance to care is 5 minutes for the green areas, and 10 minutes for the yellow areas. As some hospitals have become saturated, it is clear that the distance care is increasing for patients in a number of areas.

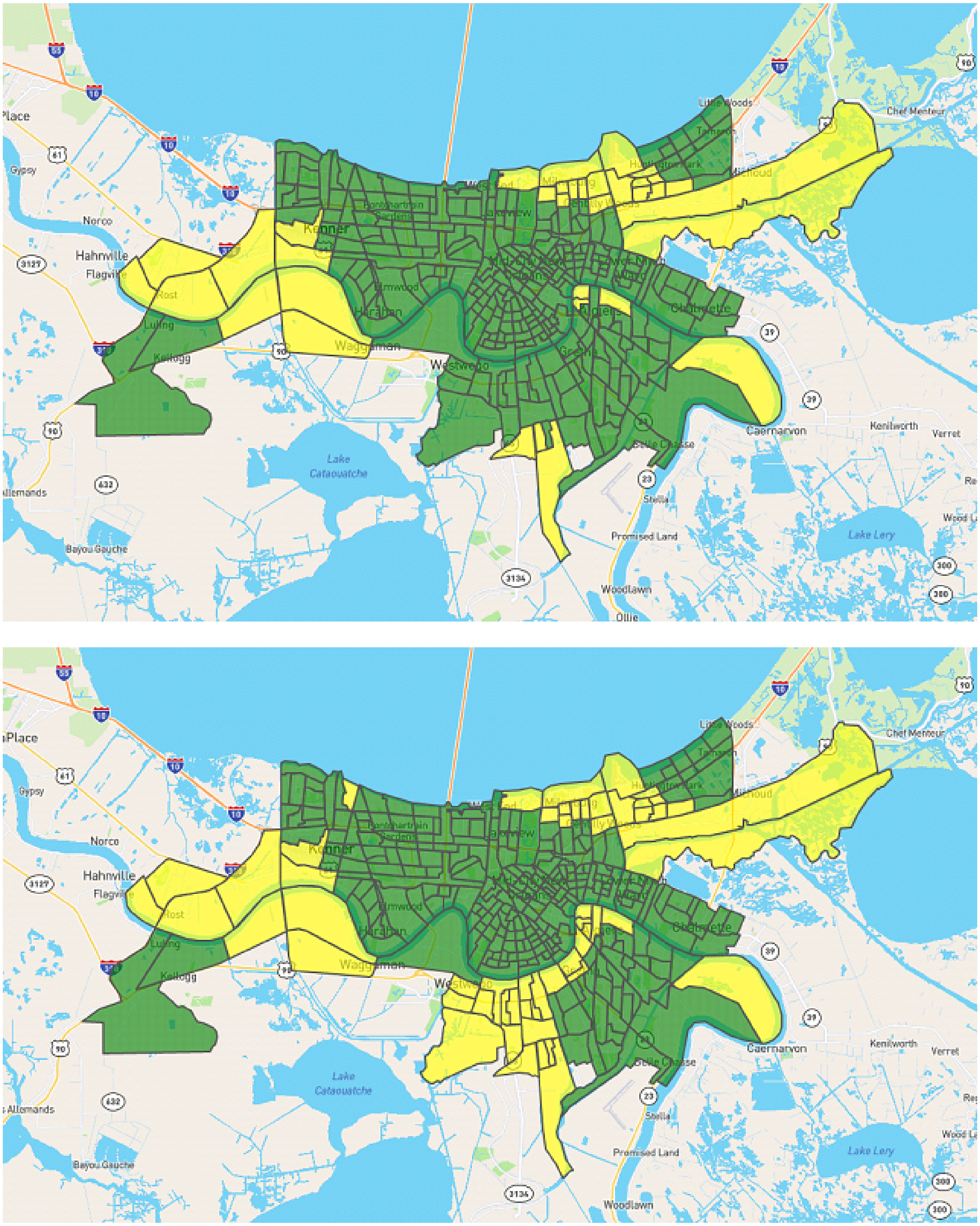


Figure C.5 — Distance to Care in two scenarios. Normal situation, and where some hospitals are closed to new patients. Courtesy of Skymantics.

C.1.4.1.1. Earth Observation

A local EO example for Louisiana can be seen in Figure C.6, which includes the 2017 USGS Lidar Digital Elevation Model (DEM) that shows the height of the land above a relative point. The shades of grey indicate the height with lighter colors indicating higher elevations. This DEM is overlaid on the 2019 US National Land Cover Database (NLCD) layer with OpenStreetMap (OSM) data which was obtained from the Multi-Resolution Land Characteristics (MRLC) consortium, a group of US federal agencies using the OGC Web mapping Service (WMS). The Mississippi River runs through the center of New Orleans, and in blue the canals and levees of the city's waterways can be clearly seen. The other colors on the image represent different land cover types as shown on the legend.

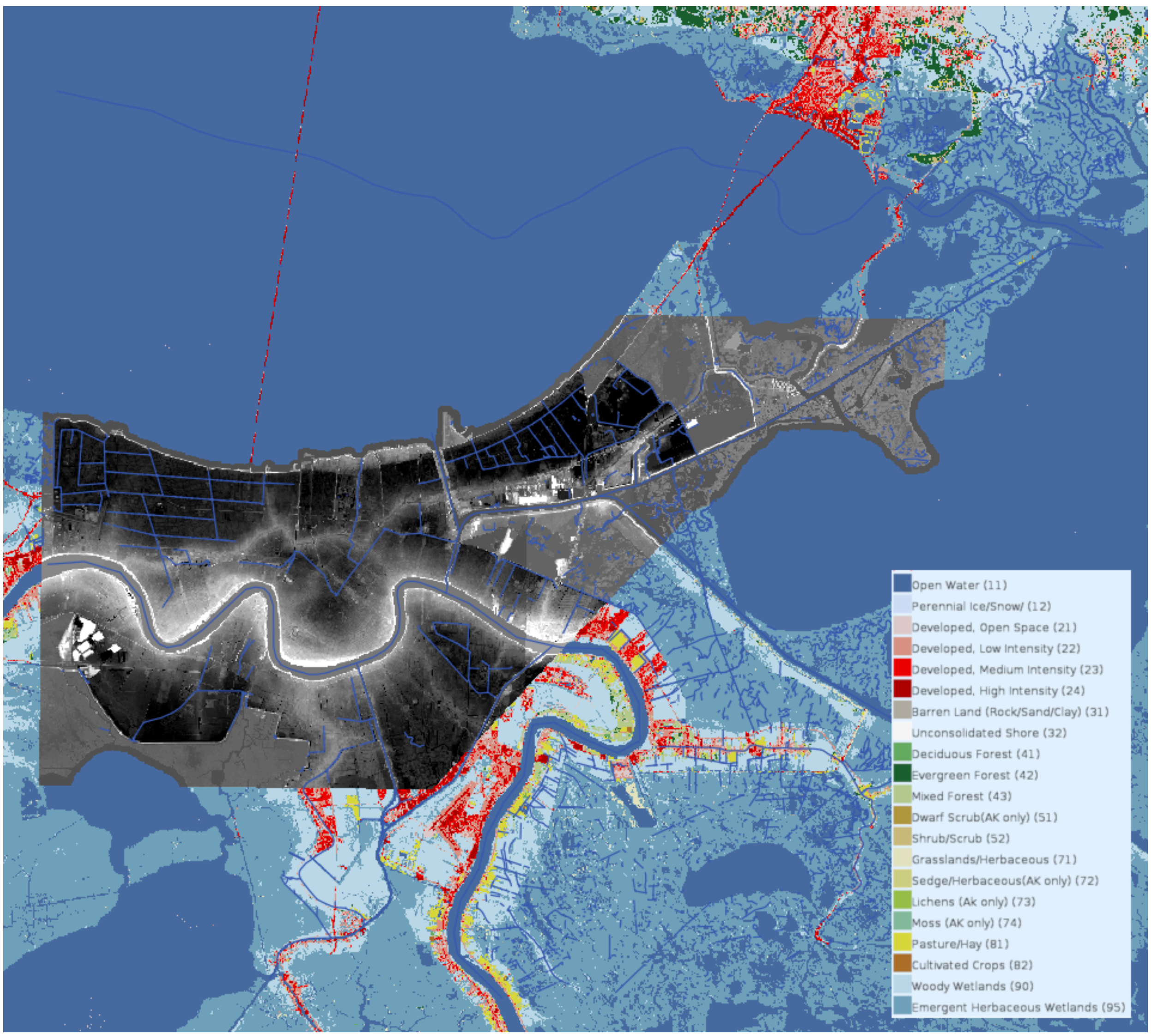


Figure C.6 — 2017 USGS Lidar DEM overlaid on the US National Land Cover Database layer with OpenStreetMap data for waterways shown as blue lines; for the wider New Orleans area, Louisiana.

For water quality, Figure C.7 shows an example Copernicus Sentinel-2 image shown as a pseudo-color composite. Lake Pontchartrain is turbid with the mixing of different water masses shown by the different colors. The majority of the lake is a mixture of browns which show the different types of sediment in the water. While in the south-western area of the lake along the edge 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 if consumed, and in turn to humans through the food chain.

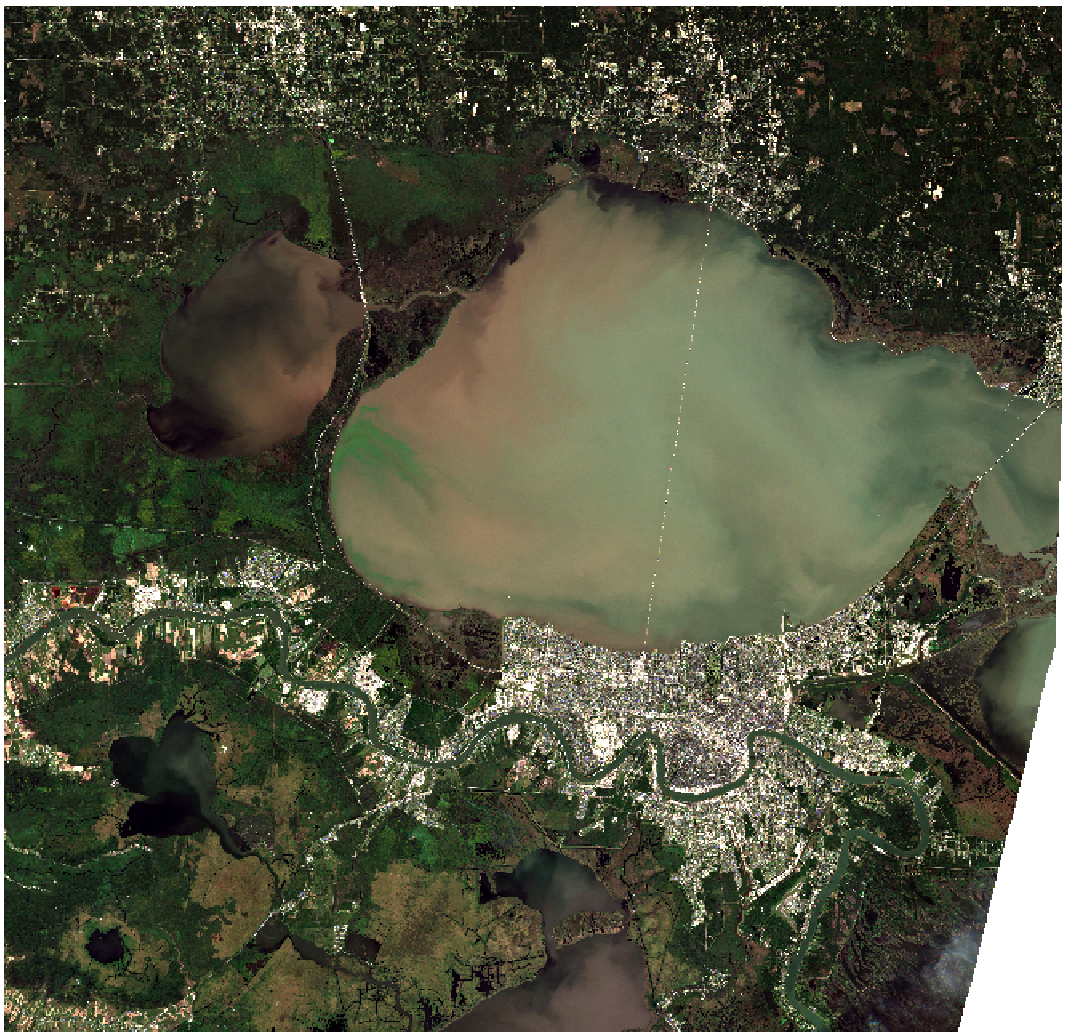


Figure C.7 — 2017 Sentinel-2 image from 01 November 2021 with a cyanobacteria bloom in the south-western area; for the wider New Orleans area, Louisiana.

For air quality, the Copernicus Atmosphere Monitoring Service (CAMS) provides both global and European focused air quality parameters as both reanalysis and predicted data. Figure C.8 shows an example predicted for the 03 November 2021 as the total column Carbon Monoxide, 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 like gasoline or forest fires. New Orleans has a higher than the background value as it is dark blue, but is not one of the hot spots (green to yellow colors).

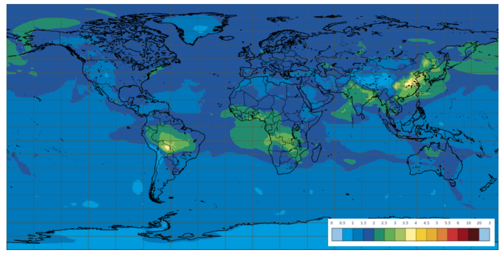


Figure C.8 — Total column Carbon Monoxide [10^18 molecules / cm2] for the 03 November 2021, provided by CAMS.

C.1.4.2. Disseminating & Communicating Information

As highlighted in the Case Study 1, web-based solutions such as GeoCollaborate or the GeoNode, can offer a way of communicating and collaborating on the information available to help speed up situational awareness and decision making. Some of the figures in this Case Study were produced using the GeoNode solution instance controlled by HSR.*health*, who have used it to display various data layers which have been accessed using open standards. Similarly, as a collaboration and dissemination environment, GeoCollaborate can access and share critical COVID-19 pandemic related datasets across any number of decision-making environments to speed up the use of geospatial data produced by the pilot participants.

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. Further work should investigate both developing ARDs and DRIs for health using EO data, but also to fully integrate datasets from health and EO to understand what insights can to developed and what ARD or DI might be possible.

By using the outputs and recommendations of this Pilot it will be possible to develop a better opening position and further ARDs and DRIs that will help to respond to similar disasters and pandemics in the future.

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 (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 (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	A. Lavender	all	Initial draft version for comment
November 18, 2021	0.2	A. Lavender	all	Improved version integrating comments for submission to the OGC member meeting
December 15, 2021	0.3	S. Lavender	Annex A	Pulled in Satcen inputs for landslides, deleted empty section for Peru stakeholder inputs, adjusted figure numbering and annex conclusion
January 17, 2022	0.4	S. Lavender	all	Inputs from Safe Software in Sections 8 and Annex A plus a general review and update of the new setup, including consistent approach to figure referencing
March 14, 2022	0.5	S. Lavender	all	Inputs received via the website in parallel with the public presentation

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Lavender, S., Lavender, A.: OGC Disaster Pilot: Provider Readiness Guide. OGC 21-074, Open Geospatial Consortium (2022). http://www.opengis.net/doc/PER/DP21-provider-readiness

2. Panagiotis (Peter) A. Vretanos: OGC 09-025r2, *OGC® Web Feature Service 2.0 Interface Standard — With Corrigendum*. Open Geospatial Consortium (2014). http://docs.opengeospatial.org/is/09-025r2/09-025r2.html.

3. Joan Masó, Keith Pomakis and Núria Julià: OGC 07-057r7, *OpenGIS Web Map Tile Service Implementation Standard*. Open Geospatial Consortium (2010). https://portal.ogc.org/files/?artifact id=35326.

4. H. Butler, M. Daly, A. Doyle, S. Gillies, S. Hagen, T. Schaub: IETF RFC 7946, *The GeoJSON Format*. (2016). https://www.rfc-editor.org/info/rfc7946.

5. STAC Community: The SpatioTemporal Asset Catalog (STAC) specification. Radiant Earth Foundation (2022). https://stacspec.org

6. Peter Baumann: OGC 17-089r1, *OGC Web Coverage Service (WCS) 2.1 Interface Standard — Core*. Open Geospatial Consortium (2018). http://docs.opengeospatial.org/is/17-089r1/17-089r1.html.

7. WMO: 'The Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)'. World Meteorological Organization (2021). https://un-spider.org/index.php/news-and-events/news/wmo-releases-atlas-impacts-weather-climate-and-water-extremes-1970%E2%80%932019

8. Centre for Research on the Epidemiology of Disasters: CRED recorded disaster events, https://www.cred.be/publications

9. Swiss Re Institute: Swiss Re Institute estimates USD 83 billion global insured catastrophe losses in 2020, Swiss Re Group (2020). https://www.swissre.com/media/news-releases/nr-20201215-sigma-full-year-2020-preliminary-natcat-loss-estimates.html

10. NOAA National Centers for Environmental Information: U.S. Billion-Dollar Weather and Climate Disasters. National Oceanic and Atmospheric Administration (2022). https://www.ncdc.noaa.gov/billions/

11. Collyns, D.: How can Peru prepare to withstand more devastating floods and landslides?. The Guardian (2017). https://www.theguardian.com/global-development-professionals-network/2017/apr/13/peru-prevent-floods-landslides-climate-change

12. Manitoba Government: 2020 Red River Floodway Operation Report Spring (2020). https://web40.gov.mb.ca/mit/wms/wm/pdf/reports/red_river_floodway_operation_report_spring_2020.pdf

13. Lindenschmidt, K., Syrenne, G., Harrison, R.: Measuring Ice Thicknesses along the Red River in Canada Using RADARSAT-2 Satellite Imagery. Journal of Water Resource and Protection, 2(11), pp. 923-933. (2010). http://dx.doi.org/10.4236/jwarp.2010.211110

14. US Census Bureau: QuickFacts — Louisiana, https://www.census.gov/quickfacts/fact/table/LA/PST045219

15. NASA: Another Flood on the Red River. National Aeronautics and Space Administration (2020). https://earthobservatory.nasa.gov/images/146616/another-flood-on-the-red-river