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Open Geospatial Consortium

# OGC DISASTER PILOT: USER READINESS GUIDE

ENGINEERING REPORT

PUBLISHED

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# II ABSTRACT

Disasters are geographic events and therefore, geospatial information, tools and applications have the potential to support the management of, and response to, disaster scenarios.

However, the use of geospatial data varies significantly across disaster and emergency communities. This can often make it difficult to share information between different organizations, and sometimes even within the same organization, involved in disaster response. This could mean that not everyone involved will have the same situational awareness information.

There are many reasons for why geospatial information is fully used and exploited, included a lack of awareness of what geospatial options are available, lack of geospatial technology and skills, lack of funding, etc. The Disaster Pilot User Guide aims to address some of these issues by providing a non-technical showcase of the workflows and tools developed by the Pilot participants demonstrating what opportunities there are for disaster and emergency management communities to use geospatial solutions in practice.

For over 20 years, the Open Geospatial Consortium (OGC) has been working on the challenges of information sharing for emergency and disaster planning, management, and response. In Disaster Pilot 23 (DP23) the aims were to:

- Develop flexible, scalable, timely and resilient information data workflows to support critical disaster management decisions, enabling stakeholder collaboration, and
- Provide applications and visualization tools to promote the wider understanding of how geospatial data can support emergency and disaster communities.

As part of DP23, a trilogy of Guides were developed to improve knowledge and understanding of how geospatial data and tools and could support disaster and emergency communities. Alongside the User Guide is a Provider Guide giving all the detail technical details behind the work, and a companion Operational Capacity Guide describing the steps needed to develop geospatial readiness.

The User Guide contains a summary of the work undertaken in DP23, and Disaster Pilot 21 (DP21), where participants have worked on disaster scenarios relating to:

- Droughts
- Wildland Fires

- Flooding
- Landslides
- Health & Earth Observation Data for Pandemic Response

Case Studies have focused on the hazards of drought in Manitoba, Canada; wildland fires in western United States; flooding in the Red River basin, Canada; landslides and flooding in Peru; and Pandemic response in Louisiana, United States. The participants have developed various data flows, alongside tools to support the collection, discovery, or visualization of data to support disaster management and response.

Annex A describes the tools and applications developed within the Pilots alongside the benefits these can offers. The Guide finishes with details of future possibilities, and where the Disaster Pilot initiative could focus next. Annexes B to E give descriptions of the data flows developed, including the aspects of disaster management or response the data flow relates to; together with the benefits it offers and the type of decisions it can support.

This document is for first responders, emergency managers, decision-makers, and anyone interested in encouraging disaster and emergency communities to realize the value of geospatial data to save lives and limit damage.

1

# INTRODUCTION

# 1 INTRODUCTION

Although there are varying definitions as to what constitutes a disaster event, the general consensus is that the number of these events are increasing. In September 2021, the World Health Organization (WHO) 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). The report summarizes 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. WHO also noted that the number of weather, climate, and water extreme events are increasing and will become more frequent and severe in many parts of the world as a result of climate change.

CRED defines 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.*' In 2022, there were 387 events recorded by CRED, slightly above the average for the 2002-2021 period. These events resulted in 30 704 deaths, impacting the lives of 185 million people, and creating economic losses of at least US $223.8 billion. The most common disaster in 2022 was flooding with 176 events, 5% higher than the twenty-year average, followed by storms, earthquakes, droughts, landslides and wildfires. The geographical spread shows that 53% of disaster events occurred in Europe due to the heatwave last year, with 24% in Asia, 16% in Africa, and 5% in the Americas. Despite the lower geographical spread, the biggest economic losses from disasters were both in America with Hurricane Ian and drought losses accounting for US$100 billion and US$22 billion, respectively.

2023 also saw significant natural disaster events, including storms in the United States, New Zealand & Mozambique; earthquakes in Turkey, Syria & Afghanistan; flooding in Australia and Asia; heat waves in Asia and Europe; and the year saw significant wildfire events across America, Canada and Europe.

## 1.1. Using Geospatial Information For Disaster Planning & Response

Disasters are geographic events that occur in a specific location and impact the people, economy, and society in that, and the surrounding areas — often tens, or even hundreds, of miles away. For this reason, geospatial information has been shown to be effective supporting both the understanding of, and response to, disaster scenarios. The WHO report above also notes 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 including the use of geospatial information.

Geospatial tools and applications have the potential to save lives and limit damage, and the world is becoming better at using these resources. Unfortunately, the ability to share, use, and reuse geospatial information and applications across, and between, organizations within disaster and emergency communities, both governmental and non-governmental, requires the right partnerships, policies, standards, architecture and technologies to be in place before the disaster strikes.

For over 20 years the Open Geospatial Consortium (OGC) has worked on the challenges of information sharing for emergency and disaster planning, management, and response. The Disaster Pilot activities are part of the OGC Collaborative Solutions and Innovation Program (COSI) and aims to address the gaps, and provide support and guidance on how disasters and emergency communities can enhance their sharing and use of geospatial information and applications.

Disaster Pilot 23 (DP23) is the latest in a series of initiatives, focusing on:

- Developing flexible, scalable, timely and resilient information workflows to support critical disaster management decisions, enabling stakeholder collaboration, and
- Providing applications and visualization tools to promote the wider understanding of how geospatial data can support emergency and disaster communities.

This User Guide aims to provide disaster and emergency management decision makers and first responders with a non-technical showcase of the possibilities of the workflows and tools developed by DP23, and previous Pilot, participants with the hope that some of these may be integrated into operational centers and working practices.

Geospatial information offers huge potential resources to enable disaster and emergency communities to enhance their planning, prediction and response to disaster events. It is hoped that the work of the Pilot can contribute towards this, helping save more lives and reducing the impact of disasters on communities.

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**

raw data that have had some initial processing, created in a format that can be immediately integrated with other information and used within a Geographic Information System (GIS)

### 2.1.2. **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

### 2.1.3. **Indicator**

realistic and measurable criteria

## 2.2. Abbreviated terms

| | |
|---|---|
| ACD | Amplitude Change Detection |
| AI | Artificial Intelligence |
| AMSR-E | Advanced Microwave Scanning Radiometer for EOS |
| API | Application Programming Interface |
| AR | Augmented Reality |
| ARD | Analysis Ready Data |
| ASMR-2 | Advanced Microwave Scanning Radiometer 2 |
| CAMS | Copernicus Atmosphere Monitoring Service |
| CDI | Combined Drought Indicator |
| CNES | French Space Agency |
| CONIDA | National Commission for Aerospace Research and Development’s, Peru |
| COSI | OGC Collaborative Solutions & Innovation Program |
| CRED | Centre for Research on the Epidemiology of Disasters |
| CSA | Canadian Space Agency |
| DARSIM | Disaster Augmented Reality Simulation Table |
| DEM | Digital Elevation Model |
| DP21 | Disaster Pilot 21 |
| DP23 | Disaster Pilot 23 |
| DRI | Decision Ready Indicator |
| DT | Digital Twin |
| EGS | Natural Resources Canada’s Emergency Geomatics Service |
| ENSO | El Niño/Southern Oscillation |
| EO | Earth Observation |
| EODMS | Natural Resources Canada’s Earth Observation Data Management Service |

| | |
|---|---|
| ESA | European Space Agency |
| ESIP | Earth Science Information Partners |
| FAIR | Findability, Accessibility, Interoperability, and Reuse of digital asset |
| FME | Feature Manipulation Engine (Safe Software) |
| GDO | Copernicus Global Drought Observatory |
| GEPS | Global Ensemble Predication Service |
| GIS | Geographic Information System |
| GISMO | New York City Geospatial Information System & Mapping Organization |
| ICU | Intensive Care Unit |
| IR | InfraRed |
| JAXA | Japan Aerospace Exploration Agency |
| JSON | JavaScript Object Notation |
| LSTM | Long Short-Term Memory |
| ML | Machine Learning |
| MRLC | Multi-Resolution Land Characteristics |
| MSC | Meteorological Service of Canada |
| MTC | Multi-Temporal and Coherence |
| NASA | National Aeronautics & Space Administration |
| NDVI | Normalized Difference Vegetation Index |
| NLCD | US National Land Cover Database |
| NOAA | US National Oceanic and Atmospheric Administration |
| NRCan | Natural Resources Canada's |
| OGC | Open Geospatial Consortium |
| OSM | OpenStreetMap |
| PHC | Public Health Center |
| PPE | Personal Protective equipment |

| | |
|---|---|
| SAR | Synthetic Aperture Radar |
| SatCen | European Union Satellite Centre |
| SDG | Sustainable Development Goal |
| SEDAC | NASA’s Socioeconomic Data Applications Center |
| SPDI | Standardized Palmer Drought Index |
| SPEI | Standardized Precipitation Evapotranspiration index |
| SPoG | Single Pane of Glass |
| SST | Sea Surface Temperature |
| USGS | US Geological Survey |
| VIIRS | Visible Infrared Imaging Radiometer Suite |
| VR | Virtual Reality |
| WHO | World Health Organisation |
| WMS | Web Mapping Service |
| WUI | Wildland-Urban Interface |
| XR | Extended Reality |

3

# USER GUIDE

# 3 USER GUIDE

The User Guide is one of a trilogy of Guides being developed through Disaster Pilot 2023, alongside the Provider Guide and the Operational Capacity Guide. These three guides are complementary documents, with clear links between them to direct readers to further information, as shown in Figure 1

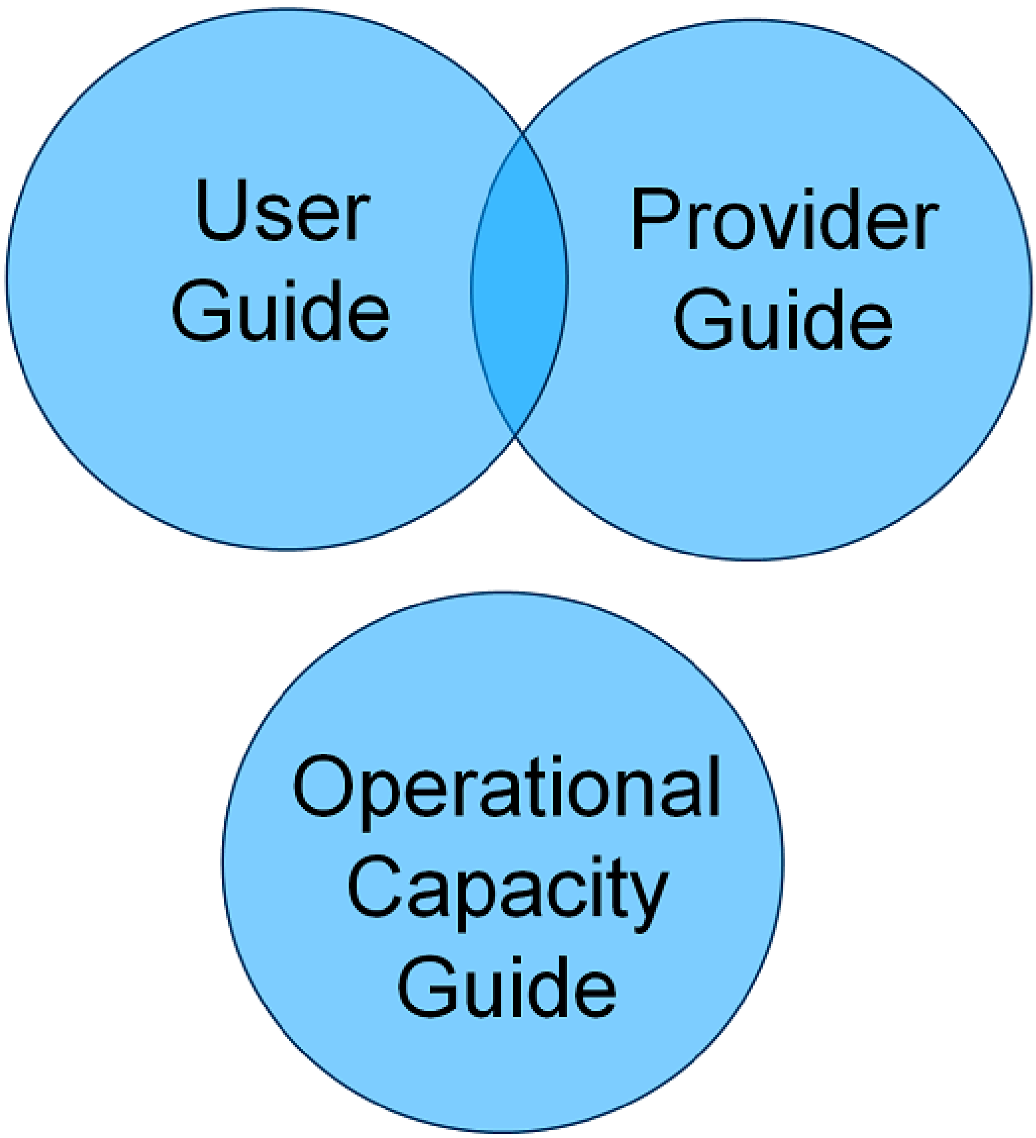


**Figure 1** — Three Guides.

The details of the three guides are:

## 3.1. User Guide

- *Audience:* First responders, emergency managers, decision-makers, and associated people interested in using the geospatial data in their work, or encouraging culture change to realize the potential value of having available geospatial data to support disaster events.
- *Purpose:* Aims to provide a non-technical showcase of the workflows and tools demonstrating what is possible and what opportunities there are for disaster and emergency management communities to use these solutions to support & enhance disaster planning, management, and response.

## 3.2. Operational Capacity Guide

- *Audience*: Disaster and emergency management administrators, operational managers, policy makers, emergency management program funding functions, together with emergency management teams and information technology support functions.
- *Purpose:* Stand-alone document, providing an outline of the strategic actions required for any disaster or emergency management team who wish to establish, enhance or improve their geospatial readiness, delivering a robust and effective geospatial function to respond to disaster events.

## 3.3. Provider Guide

- *Audience:* Existing, and potential, data and technical application providers, data collectors, processors, publishers, emergency management information technology support functions, together with other supporting stakeholders.
- *Purpose:* Describes the detailed technical requirements, data structures, and operational standards providers need to implement to integrate the data flows or tools developed in DP23.

The guides work together with each individual guide focusing on the key information for their audience and providing signposting to further details should it be required. This gives an overall structure for the guides, as shown in Figure 2

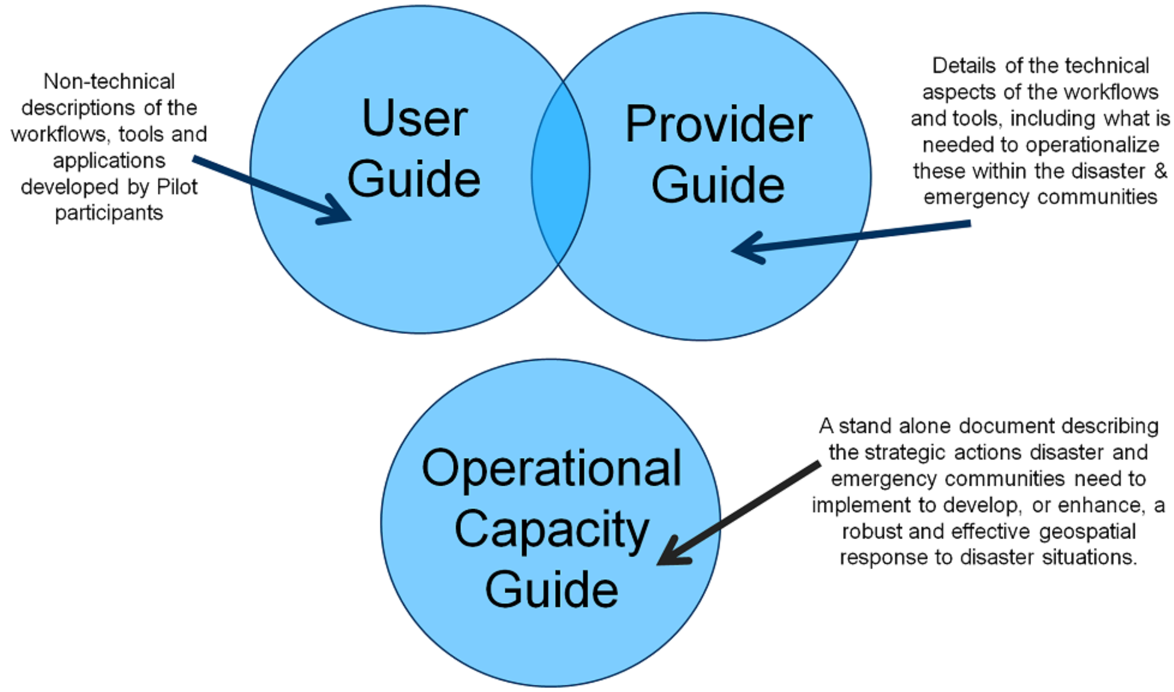


**Figure 2** — Detailed Guide relationship.

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# HOW TO USE THIS GUIDE?

# 4 HOW TO USE THIS GUIDE?

This guide is to showcase the current possibilities offered by using geospatial data more within disaster and emergency communities, by demonstrating the tools and data workflows developed within the Disaster Pilot 2023 (DP23) that could help them better plan, manage, and respond to disasters.

The Guide includes details of each of the tools and data workflows, together with links to persistent demonstrators showing them operating. Using this Guide and the demonstrators, together with the more technical focused Provider Guide, should offer any community the information they need to operationalize any of the tools and workflows.

## 4.1. Prerequisites for Using the Tools and Datasets

To use any of these tools or datasets will require a level of geospatial skills and infrastructure. Within each tool or dataset there will be a description of any specific infrastructure required to operationalize it.

In addition, the Operational Capacity Guide sets out a series of strategic actions that can help disaster and emergency communities to establish, develop, or enhance their geospatial skills and infrastructure. It includes strategic actions for:

- Geospatial Skills
- Technical Infrastructure
- Geospatial Data
- Standards
- Operational Governance
- Testing

## 4.2. Tools to Support Use of Geospatial Data

Within Annex A there is a series of potential tools that can help disaster and emergency communities to gather, find and visualize data for any type of disaster. For each tool there is:

- Description of the tool and what it can offer.

- Details of the benefits the tool offers, how it can support decision making, together with the job roles who would use this tool.
- Details of how to find the online demonstrations for the tool, and any collaborations undertaken as part of DP23.

## 4.3. Data Workflows to Support Disaster Management & Response

A series of data workflows were developed by DP23 participants covering:

- Droughts in Annex B
- Wildfires in Annex C
- Flooding, including landslide and pandemic impacts, in [Flooding]
- Integration of Health & Earth Observation Data for Pandemic Response in Annex D

These data workflows will produce either Analysis Ready Datasets (ARD) or a Decision Ready Indicator (DRI), which are described in more detail below.

For each of the data workflows within the Annexes, there are details of:

- Description of the risk or issue the data workflow aims to support, together with details of the outputs it produces.
- Details of the benefits the workflow offers, the types of decisions it can support, and the job roles that would use the output.
- Details of how to find the online demonstrations the tool, and any collaborations undertaken as part of DP23.

### 4.3.1. Data Set Types

The data workflows take raw data — which could be any form of geospatial data such as geographic data, satellite or airborne data; fixed gauges or instrument; demographic and social data; health data, field observations; or citizen science data, and then undertake some processing to create one of two types of datasets either an ARD or a DRI as shown in Figure 3.

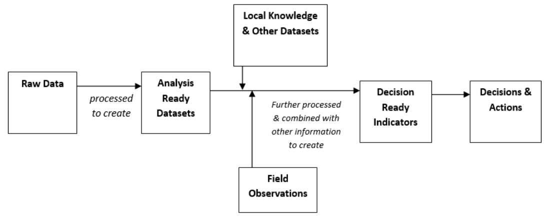



**Figure 3** — A simplified data model from the OGC Disaster Pilot

- **Analysis Ready Datasets (ARD)** — This is raw data to which initial processing was undertaken to create a dataset in a format that can be immediately integrated with other information and used within a Geographic Information System (GIS). This data can be either visualized or further analyzed, interrogated, and/or combined with local knowledge, to create information upon which decisions can be made by Disaster Response Planners and Managers.

  It is most likely to be used by Data Analysts, but it 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 must be made about the disaster.

  This information will be useful for Disaster Response Planners and Managers, Field Responders and the Affected Public, and can be used without any specialist knowledge, skills or software.

A simplified version of the data model can be seen in Figure 3 above, with the more detailed data model available within the Provider Guide.

### 4.3.2. Job Roles Who Will Use the Tools & Data Workflows

DP23 identified four job roles that are considered the most likely to use the geospatial tools and data workflows developed, although it is acknowledged that there could be more potential users. The key job roles are considered to be:

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.

5

# CASE STUDY AREAS AND HAZARDS

# 5 CASE STUDY AREAS AND HAZARDS

In developing their tools and workflows, the Disaster Pilot participants used several case study areas and hazards as the basis for their demonstrators. In Disaster Pilot 23 (DP23), it was Manitoba in Canada and the south western United States, while Disaster Pilot 21 (DP21) focused on the Red River Basin in Canada and the United States, the Rimac and Puira Rivers in Peru, and Louisiana in the United States.

Details of the case study areas and the hazards are:

## 5.1. Manitoba: Drought Hazards

Manitoba in Canada was focused on in DP23 regarding hazards associated with drought. Specifically, the area covered is the provincial boundary of Manitoba, covering the area of latitude from 49 to 52 degrees North.

Canada's Changing Climate Report projected a substantial increase in the number of hot days for the region, highlighting the potential increased risk of droughts that will affect many aspects of Manitoba's landscape. Droughts do not only affect agriculture; water-sensitive areas, such as power generation, fisheries, forestry, drinking water supplies, wildfires, manufacturing, recreation, wildlife, and aquatic ecosystems can be severely affected due to recurring droughts (Manitoba Green Plan, 2020).

For example, in Manitoba, from 1988 to 1990 and 2002 to 2003, drought in the Churchill/Nelson River Basin reduced agricultural production to 60% below average, caused an $80M Canadian dollars loss in reduced hydropower exports, a massive loss of wetland habitat, and an increased incidence of disease (Manitoba Green Plan, 2020). A 2012 drought caused wildfires to break out near the communities of Badger and Vita, leading to the declaration of local states of emergency. Manitoba's recent extreme drought of 2021-22 reduced hydropower exports by $400M Canadian dollars (Manitoba Hydro, 2021) and decreased crop yield by 37%, equivalent to an estimated $100M Canadian dollars in revenue, and caused the loss of an estimated 270 jobs.

## 5.2. South Western United States: Wildfire Hazards

There are three south western states selected as the case study areas for wildland fires:

- **Utah**
  - *Fish Lake with a 50-mile radius.*

Fish Lake is a high alpine lake in south-central Utah, which lies within the Fishlake National Forest. The lake is five miles long and one mile wide, and the surrounding forest covers 1.5 million acres. The forest is home to Pando, a huge cluster of 40,000 aspen trees covering over 100 acres, that all share the same root system. Fishlake National Forest was the site of Utah's largest wildfire of 2023, which began with a lightning strike and burnt almost 8,000 acres during August.

- *Brian Head with a 25-mile radius.*

  Brian Head is a small town in Iron County, Utah, with a population of around 100 people. It sits at 3,000 meters above sea level and is the highest town in Utah. Given its altitude, it has an alpine climate with cold winters and annual snowfall of around 9 meters, while the summer provides frequent thunder storms from the monsoons. It sits within the Dixie National Forest, which covers almost 2 million acres and the vegetation ranges from desert-type plants at lower altitudes, through to pine and juniper, and finally aspen and coniferous trees at the higher altitudes.

- *Parley's Summit with a 25-mile radius.*

  Parley's Summit is a mountain pass at the top of Parley's Canyon, to the east of Salt Lake City in Utah. The summit has an elevation of 2,170 meters and is the highest point of the I-80 highway in the state. In 2021, a wildfire burned almost 550 acres in the Canyon and led to thousands of evacuations.

- **Arizona**

  - *Tucson with a 25-mile radius.*

    Tucson is the second largest city in Arizona and has a population of over a half a million people. It is situated between Saguaro National Park to the east and west, and the Coronado National Forest to north and south; it is surrounded by five minor mountain ranges. It has a hot desert climate, with the summer average daily high temperatures between 98 and 102 °F. The wildland fire risk in Tucson, on the most dangerous fire weather days, is very high and expected to increase with climate change.

  - *Sedona with a 50-mile radius.*

    Sedona is a small city in the north of Arizona, within the Verde Valley region. It sits within the boundaries of the Coconino National Forest and borders four wilderness areas and two state parks. It is surrounded by 1.8 million acres of mostly coniferous woodland and has a semi-arid climate with mild winters and hot summers where the average temperatures approach 100 °F during July. Increasing temperatures coupled with low levels of precipitation mean the forest is ideal fuel for any wildfires. Early in 2023 saw lightning cause the Miller Fire, which covered around 30 acres before being bought under control.

- **California**

  - *South Lake Tahoe with a 25-mile radius.*

South Lake Tahoe is the most populated city in El Dorado County, California, and is based within the Lake Tahoe basin. The city itself covers a total area of 43 square kilometres and lies along the southern edge of Lake Tahoe in the Sierra Nevada mountains surrounded by forest wilderness areas. It has a climate featuring chilly winters, and summers with warm to hot days and cool nights with very low humidity. It can have temperatures reaching up to 90 °F within July and August. The June 2007 Angora Wildfire was the worst forest fire in Lake Tahoe history, which burned more than 3,000 acres destroying more than 250 homes and a large area of forest. Since then, Tahoe Fire and Fuels Team have treated tens of thousands of acres of forest around Lake Tahoe and are using forest management to reduce the threat of catastrophic wildfires. In 2021, the Caldor Fire went around the populated areas due to the treated forest and firefighting effort.

## 5.3. Rimac and Puira Rivers: Landslide & Flooding hazards

Peru's Piura region in the north and the Rimac river basin near Lima are both impacted by the 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 4 shows an index that indicates the El Niño phases in red and La Nina phases in blue.

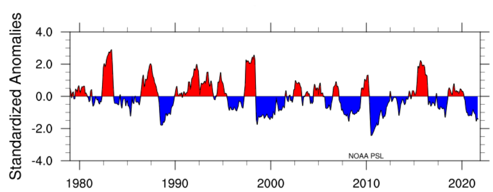



**Figure 4** — ENSO index with red indicating El Niño periods, Multivariate ENSO Index Version 2 courtesy of NOAA, USA

As an example of the relationship between ENSO and flooding, El Niño brought rains 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 and 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 that tore through communities.

## 5.4. Red River Basin: Flooding Hazards

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 increase melting of the snowpack 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 displayed in Figure 5, showing the April 2020/2021 water level comparison for the City of Winnipeg’s main gauge (James Avenue).

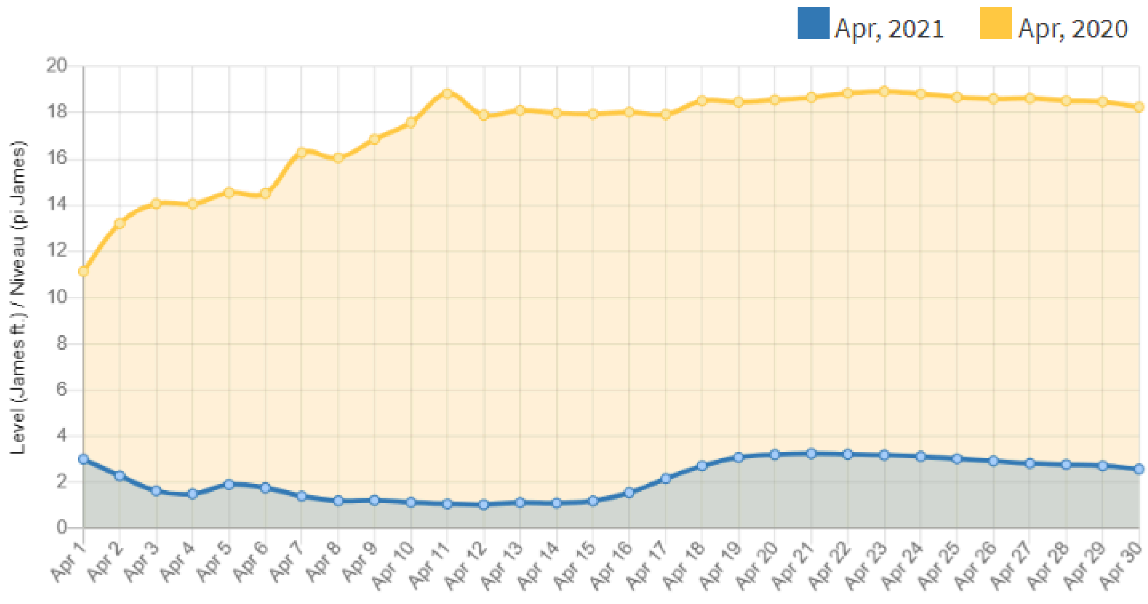



**Figure 5** — Red River water level April 2020/2021 comparison, Winnipeg river levels

Winnipeg has 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. The floodway successfully protected Winnipeg from flooding during the high-water levels of 2020, and it's estimated it resulted in around 930 million m3 of water being diverted around the City of Winnipeg.

Unfortunately, ice jam events impacting the lower reaches of the Red River, between Winnipeg and Lake Winnipeg, increased in both severity and frequency over the last century, a trend that is expected to continue and worsen in the future.

## 5.5. Integration of Health and Earth Observation (EO) Data and Services for Pandemic Response in 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 divided into 64 individual parishes, and was estimated to be home to over 4,600,000 people in 2019. 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 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.

6

# FUTURE DISASTER PILOT POSSIBILITIES

# 6 FUTURE DISASTER PILOT POSSIBILITIES

Disaster Pilot initiatives strive to improve the understanding, accessibility, and demonstration of what's possible with geospatial data for disaster and emergency communities. However, it is acknowledged that there is still a significant way to travel to ensure communities utilize and benefit from geospatial data solutions.

Within this Pilot, the following areas were identified as ways to develop and enhance future Pilots to improve the take-up and use of geospatial data.

## 6.1. User Centric Approach

Pilots need to ensure they focus on addressing the geospatial needs of the disaster and emergency community, particularly for the first responder and emergency manager stakeholders. It would be helpful to give these communities a greater role before a Pilot is established to help define the themes and deliverables to ensure that intended work directly address their needs.

This was identified during talks with first responders, who identified geospatial data flows they would benefit from, and it led to Disaster Pilot 23 (DP23) realizing that these requirements weren't being directly addressed by participants. A similar conclusion was reached in the lessons learnt section of the associated Climate Resilience Initiative.

While Disaster Pilots often focus on the cutting edge of using geospatial data, it should be remembered that many disaster and emergency communities are a long way from that edge. To make a difference to disaster planning and response, the focus must include developments to address the community's current wants and needs. However, this should be done alongside continuing to look to the future and pushing the boundaries on the use of geospatial data.

### 6.1.1. Recommendations

- Increase the involvement of first responder and emergency manager communities before the start of OGC Pilots to help define themes and deliverables, to ensure they meet their wants and needs.
- Ensure Pilots retain work to push the boundaries of the use geospatial data in the areas the users indicate they require help and support.

## 6.2. Artificial Intelligence & Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) are rapidly developing technologies and could offer considerable benefits for the disaster & emergency community. While future Disaster Pilots need to deliver quick wins focused on first responder and emergency manager's needs, as described above, it is still important that innovations and new technology is also part of the work.

AI & ML are changing facets of work across the board, and it is inconceivable that they will not cause an impact for disaster planning and response. For example: historically, Californian firefighters relied on a network of mountain top cameras and spotters to detect wildfires. During 2023, they trained an AI system to do the monitoring. In early results, the AI delivered a faster indication of a fire around 40% of the time improving response times, and identified fires where no 911 calls were ever made. Currently, the programme still requires people to make sure the AI is detecting smoke and not something else. This work began in June 2023, and is expected to be rolled out across all 21 command centers later this year.

This example demonstrates that it is vital for Disaster Pilot initiatives to keep up with this advancing trend, and work should cover areas such as the development of AI/ML solutions using various data from the diverse data sets available, and providing an assessment of the accuracy of different data sets to determine which ones are most useful and beneficial.

### 6.2.1. Recommendation

- Include AI/ML activities as part of future Disaster Pilots, work could include solution development, assessments and comparison of solutions, etc.

## 6.3. Operationalizing Geospatial Data

The use of geospatial data to support decision making is not common place within all disaster and emergencies communities, and in some cases there might be relatively minimal use of geospatial data, tools and applications.

Convincing first responders, emergency managers, and disaster and emergency decision, to implement geospatial solutions, rather than their current tried and tested processes is not going to be easy. To do this there needs to a focus on developing geospatial capacity and quick wins using the benefits of geospatial data. Although, cutting edge geospatial applications, tools and data flows are exciting, the goal of Disaster Pilot initiatives must be the real-life operationalization of the data flows and tools developed, to provide benefit to the disaster and emergency communities.

Another opportunity to demonstrate the benefits of geospatial data would be greater use of real-time sensor data within future Pilots. Producing such indicators would provide a real time view of the current disaster situation, hazards, or risks, and would offer an alternative way of operationalizing the work. This would sit alongside the existing practices used by the first responding community and may highlight the advantages and benefits of geospatial data and information.

Similarly, the Operational Capacity Guide, which received positive feedback from Manitoba Emergency Community who keen to use it to develop and enhance the geospatial readiness of their communities. Further work on specific elements — such as developing example Geospatial Operating Procedures templates, or providing a Geospatial Disaster Guide for Emergency Managers — could also provide a useful and positive step in furthering the use of geospatial data.

### 6.3.1. Recommendations

- Working with first responder and emergency managers stakeholder community to identify quick wins for geospatial data and ensure these form part of the deliverables.
- Encourage implementation of real time data, sensor based indicators, and/or dashboards in future pilots.
- Continue working on specific elements of the Operational Capacity Guide to provide further support to help disaster and emergency communities to improve their geospatial readiness.

## 6.4. Disaster and Climate Resilience

The frequency and severity of disasters are increasing as climate change causes weather and climate variations to become more extreme. Going forward disaster and emergency managers are going to need greater information about what the future scenarios could look like to better understand both possible threats and mitigation options will support improved resilience. Using more climate data to help provide forecasts will be valuable. This data needs to be made more accessible and available, and by getting this information to those directly responsible for managing and mitigating natural hazards should help them better mitigate the issue and find practical solutions at the local level.

Future Disaster Pilots will benefit from have more direct integration between indicators and climate variables and services, and the intention of bringing the Disaster & Climate Pilots will support this.

### 6.4.1. Recommendations

- Ensure climate services are part of future Pilot initiatives, in an accessible format, so that indicators can, where relevant, incorporate a future view of possible scenarios in addition to their representation of current and past impacts.

## 6.5. Standing on the Shoulders of OGC Work

OGC initiatives develop benefits for the geospatial community, and the Disaster Pilot work is no different. Each Disaster Pilot, individually, produces excellent work, and it is demonstrated at the end of each Pilot. However, there is more than could be done by providing a more permanent demonstration of the OGC disaster planning and response ecosystem, providing disaster and emergency communities with a plethora of Analysis Ready Data and datasets (ARD)/Decision Ready Information and indicators (DRI) data flows, applications and tools to support their activities that would have a level of authority, and comply with data sharing and interoperability principles.

This Pilot aimed to deliver persistent demonstrators from each of the participants, as described in the Annexes, which was a positive step. This can go further, with a series of catalogs/registries listing developed data flows; supported by relevant documentation; the data flows themselves should be available and maintained for the long term; and applications and tools should be available (licence and fees dependent). This is not freezing the development of data flows and tools once they are in the ecosystem; if they can be improved within a future Pilot, then they should be. This is about providing a single place for geospatial knowledge and resources to support disaster planning and response, which is available to be used whenever a community is in a position to move forward with their use of geospatial data. This may not be today or even tomorrow, but hopefully it will happen one day. However, it is certain that if the data flows and tools are not easily accessible, they will never be used.

### 6.5.1. Recommendation

- Establish a long term persistent OGC disaster ecosystem where current, past, and future geospatial data flows and tools to support disaster planning and response can be made easily available and accessible to communities and organizations who might want to operationalize them.

A

# ANNEX A (NORMATIVE) TOOLS DEVELOPED

# A ANNEX A (NORMATIVE) TOOLS DEVELOPED

There are many types of emergency disaster events, and the tools described in this Annex can provide support to a range of events. The tools cover:

- **Gathering data** — There are two examples of citizen science projects that use apps on smartphones to gather information for disaster planning, or responding to an event in progress.
- **Finding datasets** — The number of geospatial datasets available can vary; some events have a lot of datasets, others may be more limited. Emergency Managers need quick and straightforward methods of finding what datasets may be able to help them in terms of disaster planning or responding to unfolding events. Below are tools that offer catalogs and registry functions that could help identify available datasets.
- **Visualizing data** — Taking advantage of the developing technology in terms of augmented reality, as shown below, can offer new ways for first responders and emergency managers to look at situations in a different way and can offer new insights.

It should be noted that data generated by a disaster event itself from sensors, observations, etc., exceeds the data generated through normal day-to-day business by a degree of magnitude. Sorting through this massive quantity of data, a significant proportion of which will be from new, or less familiar sources, means that data catalogs and registry services are critical for helping to find and access the right data at the right time.

The tools developed by the Disaster Pilot 23 (DP23) participants are:

- Annex A.1.1 Registry & Catalog Functions developed by Compusult
- Annex A.1.4 Climate Data Catalog, Data Service & Registry Tool developed by Safe Software
- Annex A.1.6 Geospatial Data Registry Services developed by USGS-GeoPathways
- Annex A.2 Emergency Location & Language Application developed by GISMO-Basil Labs
- Annex A.3 FLORA Wildfire Mobile App developed by USGS-GeoPathways
- Annex A.4 Wildfire & Drought Immersive Indicator Visualizations developed by USGS-GeoPathways
- Annex A.5 GeoCollaborate Tool Visualization developed by StormCenter

The detailed technical information about each of these tools can be seen below:

# A.1. Data/Workflow Service Registry and Discovery Tools

## A.1.1. Registry & Catalog Functions Developed by Compusult

### A.1.1.1. Introduction

Compusult enhanced the catalog of its Web Enterprise Suite to offer a registry and catalog function to enable users to discover and have access directed to datasets that the emergency and disaster communities might find helpful.

## A.1.2. Description

Compusult created two services, allowing searching and discovery of Compusult's CSW Catalog and File MetaManager for users.

Compusult also created two services to allow users to publish their own entries into these record services.

### A.1.2.1. Benefits

Compusult's catalog will allow external users to have access to register, search and discover products and services.

This activity improved access and sharing of data and services, and provided an easy-to-use graphical interface to support users to discover and use available data services to support disaster and emergency planning and response.

## A.1.3. Collaborations

Compusult's catalog was made available to all participants to contribute and share data. Content from other participants was harvested into the catalog and an account provided to others to allow them to query for data.

## A.1.4. Climate Data Catalog, Data Service and Registry Tool Developed by Safe Software

### A.1.4.1. Introduction

Safe Software's Climate Data Catalog, Data Service and Registry Tool component is a tool that could help users search, find, and access various climate-related datasets, with a particular focus on Analysis Ready Datasets (ARD) implemented using the FME platform. In addition, the service has the capacity to incorporate base map, Earth Observation (EO), and a wide range of other datasets.

Whatever the type of natural disaster, whether fire, flood, drought, or other hazards, increasingly the severity of natural disasters is exacerbated by the effects of climate change. The challenge of trying to manage and mitigate these changes poses difficulties for geospatial data both in terms of understanding the areas impacted and the timescale. There is a need to translate the outputs of global climate models into specific impacts at the local levels.

The FME platform is a spatial data integration platform, produced by Safe Software, and it can help explore options for bridging this gap given its ability to read datasets produced by climate models and then filter, aggregate, interpolate and transform it as needed. It is configured using no code data transformation models that can bridge the gaps between disparate systems using its support for hundreds of different spatial and nonspatial data formats and services. It can also combine climate data with higher resolution local data, and then output it to whatever format or service is most appropriate for a given application domain or user community.

DP23 had a particular emphasis on incorporating and serving climate model output ARD, which is essential to support disaster management in our changing world. It also explored approaches to support data search and cataloging, to allow users to provide data to the service in a simple way. The component also has a service to support metadata harvesting — in order to supply the information needed to enable the data to be found by other users through searches.

### A.1.4.2. Description

#### A.1.4.2.1. Analysis Ready Data (ARD) Service

The chosen challenge for the ARD service component was to take climate model results and use them to feed forecast and impact models related to the hazards of interest such as drought, fire or flood. The workflow transforms raw data, or data from other sources, into a form of ARD which is more easily integrated in local GIS solutions to enable users to use, analyze, or visualize the data. The underlying goal is to feed the data value chain from raw source data — in this case climate model data cubes, through to ARD in order to feed decision and impact indicator workflows (DRI — Decision Ready Information).

The climate model source data was made available using OGC standards approved processes, which was key to making the data more widely accessible and usable by those likely to be affected by its potential impacts.

For selected climate scenarios, this solution supported the analysis of estimated drought risk impacts over time via simple queries. The primary climate scenario for this work was the drought hazard for the province of Manitoba, Canada. Safe Software provided a projected precipitation time series to fellow DP23 participant, Pixalytics, who used it as an input to their drought severity indicator. More information on this can be found in the Annex B indicator section.

The data service also allows end users to access the climate data using queries and retrieve the environmental variables and statistics for their specific geographic extent and time period of interest. The service itself supports a range of query parameters which can allow users to explore various value ranges and extremes inherent in the climate scenario projections. Multiple environmental variables such as temperature, precipitation and change in precipitation relative to historic are available on the time series points. Users can then ask questions to look for times and places of concern relative to specific natural hazards such as drought, fire, heat or flood.

As example, if the following request was made to the service: "*Find all time step points over the next 40 years for southern Manitoba where projections indicate > 25% dryer and mean monthly temperature > 23C.*" The user would enter the parameters using the following screen

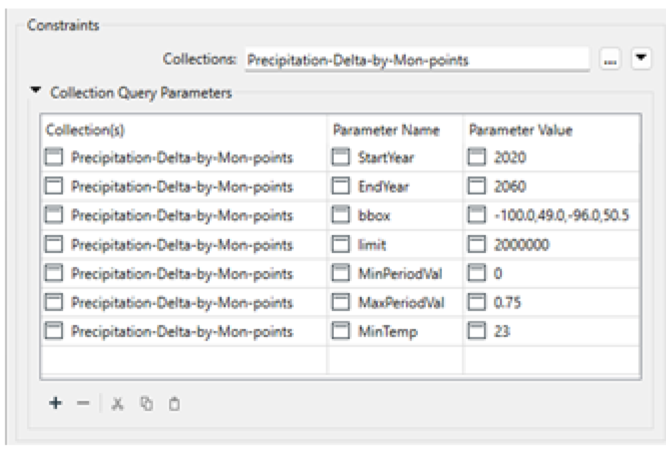



**Figure A.1** — OGC API Features response to above query: 63 temporal points with associated temperature and precipitation values, as shown in FME Data Inspector client.

This would produce the output shown below:

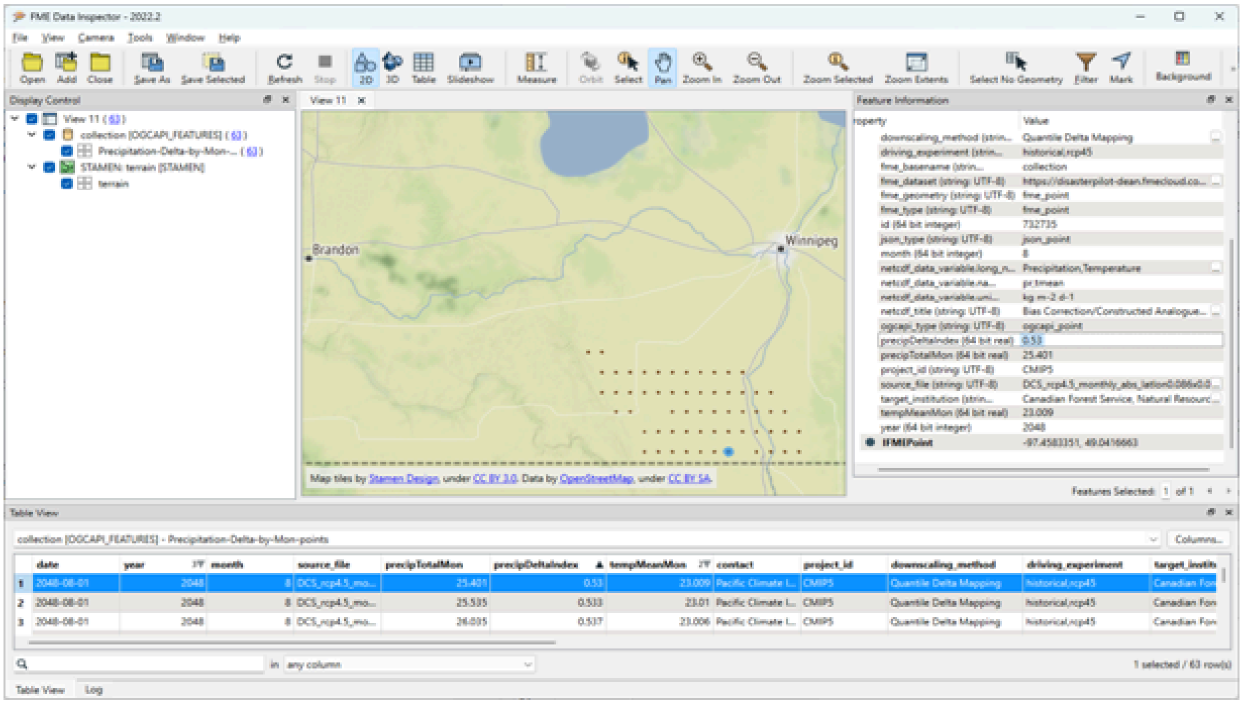



**Figure A.2** — Response to above query: 63 temporal points with associated temperature and precipitation values, as shown in FME Data Inspector client.

This data is displayed in Safe Software's Data Inspector client. This result shows climate model points derived the query above, these points show from August 2048 and 2058 represent the hot and dry areas and times that satisfy the query above and could constitute increased drought and fire risk. The ultimate goal is to make climate model outputs more accessible in a form and structure easy to consume by those used to working with GIS tools.

### A.1.4.2.2. Metadata Harvest & Catalog Service

The Metadata harvest workflow allows users to provide data to the service, and it reads the source data and automatically extracts the key properties and information required to create catalog of the data to enable it to be discovered by other users when searching.

This workflow is a standalone service. In the future, it is hoped that this service could be used to auto-generate a description, which could include the contents contained in the dataset. It could also auto-populate the catalogue entry, and add additional information from the dataset.

Alongside the Metadata Harvest Service, Safe Software also implemented a simply catalog service that could be used to register and make available the data making it easier for other components and users to locate and use response datasets as they become available.

The service is only a basic implementation that allows other components in DP23 to interrogate the catalog service and use the resulting metadata to assess and query other feature data services. It is a read-only catalog service that serves to publish metadata on the datasets and services Safe Software contributed to DP23.

## A.1.5. Benefits

When a disaster occurs, responders need to quickly locate, access, register and share a wide range of datasets. The Metadata Harvesting component can be used to quickly extract metadata from datasets as they come in and register them with the available catalog services. The catalog component can then be used to register and make available item metadata to make it easier for other components and users to locate and use response datasets as they become available.

One such data service for DP23 was the ARD service associated with climate model future projections. Disaster planners can use this service to query for temperature and precipitation anomalies in order to give them a better understanding of environmental extremes that might be expected in the future and test the resilience of their systems to those extremes. The hope is that by testing a range of climate scenarios, planners will be able to explore when and where hazard risks are more pronounced and take steps to mitigate those risks. One key capability is to allow users to directly interact with and interrogate climate projection data, so that they can see what type of environmental variable value ranges they might expect to see in the future, and what trends to be aware of.

Note that the FME Data Inspector tool also supports consumption of more than 500 spatial and non spatial data formats and services including more than 30 OGC standards, other open standards such as Open Street Map, as well as vendor proprietary standards. This can help disaster analysts rapidly review any available data in a rapid response situation and quickly determine which datasets are most useful to support assessment and response efforts

### A.1.5.1. Collaborations

To support future drought risk estimates for Manitoba, Safe Software provided a projected precipitation time series to Pixalytics as an input to their drought analytics and Decision Ready indicators (DRI) component. Their component provides a more sophisticated indicator of drought probability since in addition to precipitation it also takes into account soil moisture and vegetation. The goal was to extract precipitation totals per time step from the climate variable outputs for Manitoba based on model results obtained from Environment Canada. Pixalytics then ran their drought model based on these precipitation estimates in order to assess potential future drought risk in southern Manitoba.

Further information on Safe Software’s contributions to OGC Disaster & Climate Pilots can be found at https://community.safe.com/s/article/OGC-Disaster-and-Climate-Resilience-Pilots

The persistent demonstrators for the services can be found at:

- OGC API Features Service (accessible 9am — 5pm EDT, M-F)
- OGC API Records Service (accessible 9am — 5pm EDT, M-F)

## A.1.6. Geospatial Data Registry Services Developed by USGS-GeoPathways

### A.1.6.1. Introduction

USGS-GeoPathways established a community with resources and data services to enable the public, scientists, and policymakers to boost disaster risk resilience.

### A.1.6.2. Description

The resources available are:

- **Terria Disaster Community Registry (Open Source)** — This uses the web-based TerriaJS application to provide 3D visualizations of disaster-related datasets, for fire, drought, and more, with terrain elevation context.
- **ArcGIS Disaster Risk Resilience Registry (Proprietary)** — This Esri ArcGIS Hubsite includes apps, data catalogs, and external resource links on disaster risk and resilience. This includes:
  - *Knowledge Hub* — This is an experience builder application that allows individuals to input disaster-related information about websites, terms, data, apps, and the metaverse, so the wider public can search for disaster-related information.
  - *Extended Reality Immersive Spatial Market Catalog* — A guide to using 220 of the world's best virtual reality and augmented reality headsets and can be used by anyone interested in metaverse technology to determine which extended reality (XR) headset will work best for their project.
- **Voyager Search Disaster Risk Resilience Registry (Hybrid)** — This web-based application by Voyager Search provides an indexed registry of disaster-related datasets. It facilitates the visualization of data across various map viewer software and enables the integration of AI/ML workflow models with indexed data. Voyager's advanced indexing encompasses millions of datasets from commercial, organizational and government data. Voyager's software includes a powerful search function, exposing API data without complicated API requests. Voyager doesn't store data but reveals endpoints and uses metadata for optimal searchability and data accessibility. Voyagers efficient API connector framework processes entire government and organizational data APIs in minutes for quick data extraction, enrichment, transformation, and deliverability.

  As part of the partnership with Voyager Search, work was undertaken on indexing and testing Esri's Living Atlas and USGS models with workflows that detect, extract, and assess analysis ready data. Workflows are critical to automating repeated tasks that would increase overall efficiency as well as reduce the risk of data errors. Moreover, models operating on indexed data generate fresh data that is automatically integrated into the registry, thereby expanding the volume of data accessible to users.

### A.1.6.3. Benefits

Users will receive updates on technological capabilities, response strategies, breaking news, and relief resources. The dashboard dynamically updates metrics based on selected queries or locations. It links each data record to a geographical location, enhancing analysis of XR hardware and allowing pilot participants to share workflow information.

### A.1.6.4. Collaborations

To develop these resources USGS-GeoPathways worked with USGS, US Forest Service, Federal Geographic Data Committee, NASA, ESRI, AmeriGEOSS, NOAA, GeoPathways Peru, Google, USDA, Microsoft, & Voyager Search.

Further information and demonstrations of this work can be found at:

- Terria Disaster Community Registry
- ArcGIS Disaster Risk Resilience Registry
  - *Knowledge Hub* .
  - *Extended Reality Immersive Spatial Market Catalog*
- Voyager Search Disaster Risk Resilience Registry

# A.2. Emergency Location and Language Application Developed by GISMO-Basil Labs

## A.2.1. Introduction

The Emergency Location and Language Application (Ella) is a mobile crowdsourcing survey & reporting application that aims to give a client the opportunity to design a survey script to collect information directly from individual citizens via a smartphone. The aim is that Ella would act as a supplement to the 9-1-1 system when that system is overwhelmed and important information is being missed.

The Ella application is designed to be user friendly, and easily modifiable by non-technical personnel. Individuals who are comfortable using their smartphone for conversations, texting, and photographing should have no difficulty becoming comfortable with the application. Ella applications should be easy to use by citizens caught within a disaster area, responder teams within a disaster area, and by disaster managers at operations centers, or from vehicles. User-friendly dashboards and analytics can be designed for use both by citizens and by responders, while more technical personnel can be provided with more sophisticated outputs.

### A.2.2. Description

Ella is designed to capture information and use it for various outputs that could be quickly reviewed by the response community, and made available to responders in the field. It can also provide up-to-the-minute status reports of conditions within the disaster zone, and — unlike the way 9-1-1 is utilized — could be modified and redeployed whenever there were changes in the nature of the disaster. Operational capabilities that can be designed into Ella include:

- Rapid survey design using application templates allowing non-programmers to rapidly modify a survey, or quickly create wholly new surveys through the use of simple pull down menus.
- Ability to re-issue surveys as the situation on the ground changes, or when a data refresh is required.
- Collect information and intelligence from people within a disaster zone or other area of interest.
- Support communications between first responders in the field, disaster response managers, and people caught within a disaster zone. Ella can allow response managers to transmit guidance to all those within a disaster area, or to specialized groups, such as those evacuating using vehicles or those identified to be in immediate threat.
- Support communications between different teams of responders dispatched to the same or adjoining areas for improved coordination.

Examples of the visualized outputs available from Ella on survey results are shown below. All responses can be visualized question by question, and are mappable either by exact location from mobile device if given, or general location via IP address.

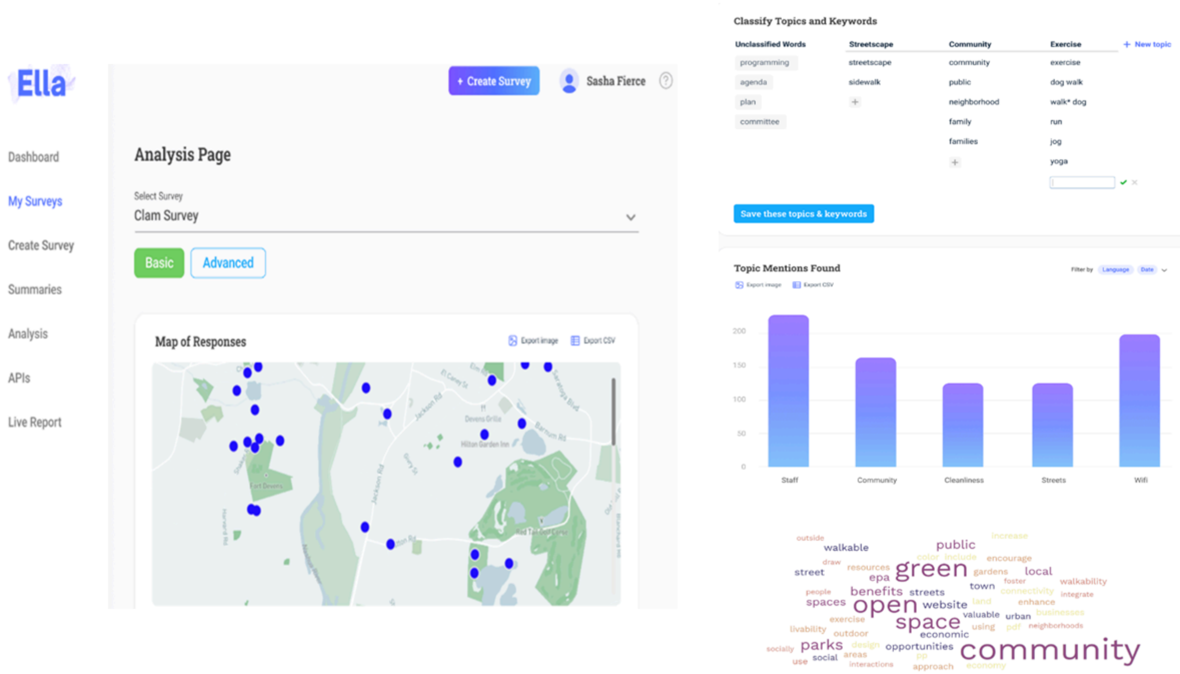



**Figure A.3** — Examples of the type of potential visualized outputs from Ella.

### A.2.2.1. Manitoba Ella (M-Ella) developed within Disaster Pilot 23

M-Ella aimed to capture information about businesses that were affected by drought, with a specific interest in understanding the effects of drought on business revenue and employment. The draft M-Ella Drought survey can be examined in detail here.

The key aspects of the M-Ella survey were:

- For privacy, at the request of Manitoba, respondents were requested to choose their location by one of a list of Forward Sortation Areas instead of using the GPS capabilities of the smartphone.
- Photo(s) were requested of natural areas that were important to the business being surveyed.
- Voice responses were requested relating to:
  - Factors contributing to changes in revenue noted in previous structured questions.
  - Explanation of the importance of natural water to business.
  - Description of business changes due to drought
- Use of voice translation and Artificial Intelligence (AI): Voice responses would be translated into English and converted into text. They would then be analyzed by AI for common

words and themes, which could then be grouped by business type, and by postal location, and other factors.

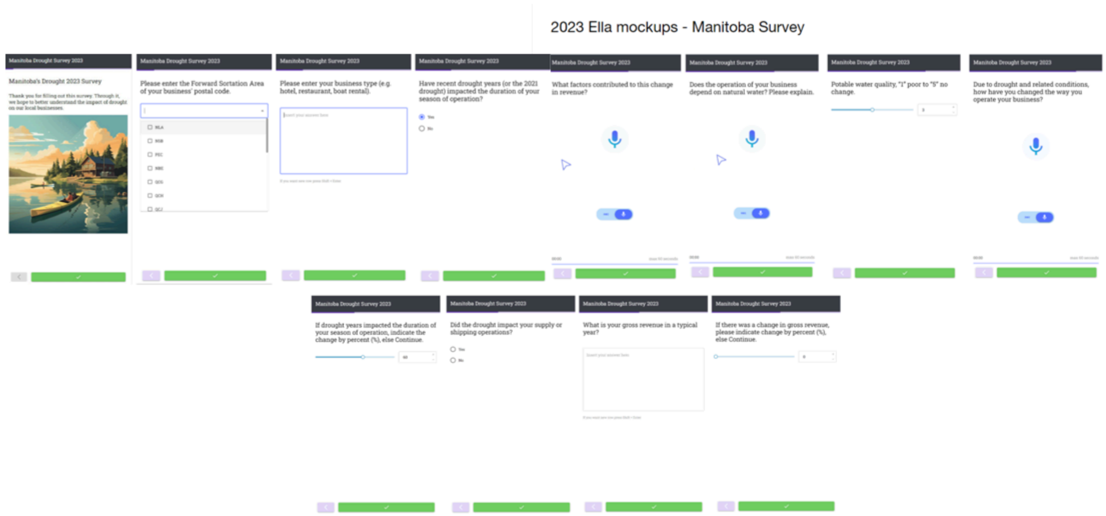



**Figure A.4** — Example mock-ups of the Manitoba-Ella survey

## A.2.3. Benefits

Ella's value is to remove barriers to feedback and extract intelligence from open response surveys to obtain situational awareness about conditions on the ground. There are many ways of using an Ella-type application to track individuals and groups of citizens threatened by a disaster event, and leverage response teams and resources to protect them, whether they remain at home, traveled to a safe place, or are still on the road. Information can be regularly re-calibrated if there is a significant shift in fire direction and speed of spread. Other newly arising conditions impacting on safety can also be included.

All individuals within the disaster zone, responding to the disaster, or managing the disaster, can make use of the information and communications enabled by an Ella-type application. Conducting pre-event exercises will be essential to ensure that Ella can be used with maximum effectiveness. Separate Ella groups can be formed among specialized teams of responders, including medical personnel, fire fighters, and those responsible for coordinating evacuation.

An example scenario for using Ella oriented to wildfire preparedness and response could be:

- Within a community at risk of wildfire citizens would be offered access to the Ella basic application as part of a pre-event exercise or the issuance of a more routine survey of defensible spaces. Basic individual information, including home location, vulnerabilities, number of occupants, mobility, could be pre-installed.

- When conditions favorable to wildfire occurrence exist, emergency responders can issue alerts and request any information about smoke or fire conditions being observed.
- When a wildfire breaks out, its location, directions, speed, and spread of the fire are determined, and those in the threatened areas can be identified and notified. Safe evacuation routes can be identified as can places for shelter, or depending on defensive capabilities, individuals could be advised to shelter in place. Updates about fire movement would be sent regularly.
- First responders would be put into direct communication with individuals needing assistance to evacuate.
- Those able to evacuate by vehicle or by foot would be given updates based on their current location about the safety of their escape routes, and provided with better alternatives if necessary.
- Resources and safety equipment could be sent to areas where people are gathering based on smartphone location tracking.
- Fire suppression and rescue activities could be focused on specific locations and areas where people are directly threatened.
- Citizen reports of health conditions and fire conditions can be reported on at frequent intervals until the crisis is over. Voiced responses can be translated into common text, analyzed, and mapped to provide situational awareness to the responder community.

### A.2.4. Collaborations

The GISMO/Basil Ella Team was in touch with several other DP23 participants, including:

- *USGS GeoPathways Team* To discuss the citizen science solutions they were both developing within DP23.
- *HSR Health Team* To explore the potential of using Ella to support measuring population vulnerabilities to fire and smoke conditions.
- *StormCenter's GeoCollaborate*, Although not a participant in DP23, discussions continued with StormCenter as they offer tools useful for the sorting, combining, analysis, and distribution of data and data products across the entire response community, including citizens caught within the disaster area.

Information about Basil Labs can be obtained from their website. NYC GISMO can be contacted by emailing Alan Leidner at leidnera@nyc.rr.com.

# A.3. FLORA Wildfire Mobile App Developed by USGS-GeoPathways

## A.3.1. Introduction

The FLORA Wildfire Mobile App blends in-situ and EO data via an app, using citizen science to collect field data.

## A.3.2. Description

The FLORA Wildfire Mobile App integrates crowdsourced and EO data to understand wildfire vulnerability. The cross-platform application invites users, like hikers or homeowners, to provide on-the-ground imagery of vegetation. Processing the input imagery data, the app identifies potential wildfire fuel based on the 0-5 scale provided by the National Fire Danger Rating System.

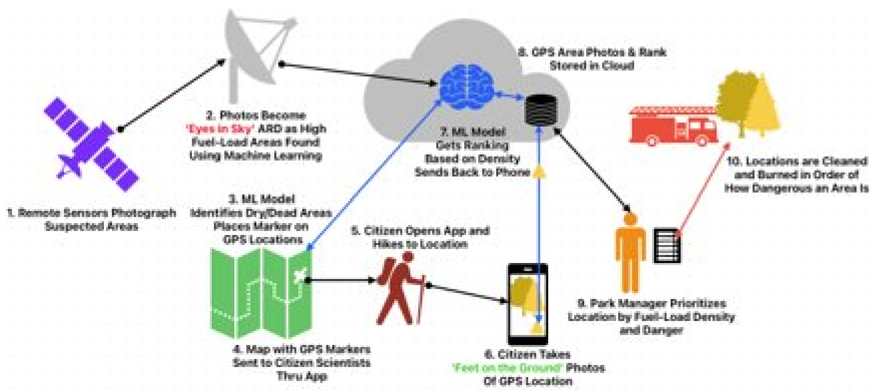



**Figure A.5** — Example of how the Wildfire mobile app operates

How to use the app:

1. Download the ArcGIS QuickCapture mobile app.
2. Enter the ArcGIS QuickCapture app by scanning the QR code below' or enter it directly by using the URL https://arcg.is/HOfnu


**Figure A.6** — QR Code for FLORA Wildfire mobile app

3. Enter an email where the results will be sent to your username.
4. Take 2 pictures, the first at the base of the tree, the second of the whole tree.
5. Edit the picture point on the basemap imagery if necessary.
6. Submit.
7. Results will be sent to the email provided and can also be viewed by clicking on the FLORA map button within the app.

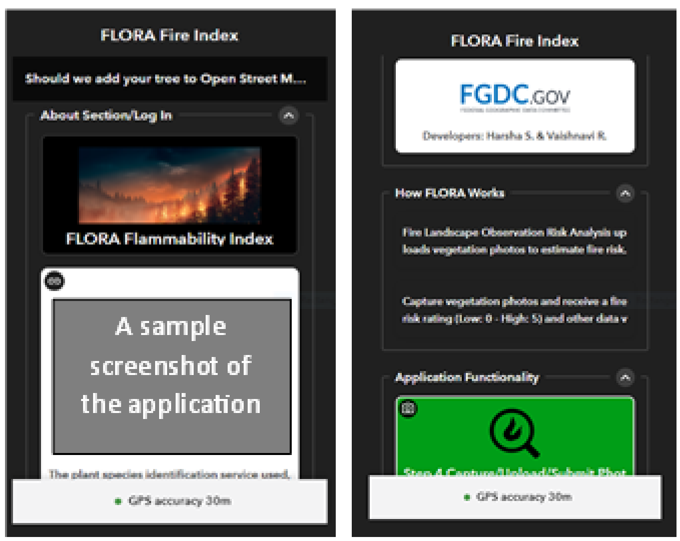



**Figure A.7** — Sample screenshots of front end of the FLORA Wildfire mobile app

**AmeriGEO Mapathon** — Set for late-2023, this event was hosted virtually, and the mapping projects occurred on OpenStreetMap US Task Manager where users could input localized wildfire data. Processed by a Machine Learning (ML) model, the mapping activities aid in evaluating ignition risks. After a successful pilot in varied regions, the app will scale up using cloud resources.

Users navigate to flagged locations, capture photos to assess fire risks. This dual-data approach bolsters decision models. Once verified, the data supports professionals like park managers in refining wildfire strategies.

### A.3.3. Benefits

This approach refines decision models by merging satellite and ground data. Validated data assists professionals in targeted wildfire mitigation during droughts, guiding actions and safe zone identification.

Users navigate to flagged locations, capturing photos to assess fire risks. This dual-data approach bolsters decision models. Once verified, the data supports professionals like park managers in refining wildfire strategies.

### A.3.4. Collaborations

To develop these resources USGS-GeoPathways worked with US Forest Service, Federal Geographic Data Committee, NASA, ESRI, AmeriGEOSS, NOAA, GeoPathways Peru, Google, USDA, Microsoft, Voyager Search, Pl@ntNet, PlantID, & Trefle.io.

The links to the app and event described here are:

- FLORA Wildfire Mobile App
- AmeriGEO Mapathon

## A.4. Wildfire and Drought Immersive Indicator Visualizations Developed by USGS-GeoPathway

*Work on this component is at an early stage and this section outlines what is planned to be delivered.*

### A.4.1. Description

This tool provides ARD and DRI to enhance practitioners' understanding of managing droughts and wildfires across various spatial-temporal scales. It has two elements:

- Disaster Augmented Reality Simulation Table (DARSIM) — An evolution from traditional sand-based simulation tables, DARSIM is a more portable, data-integrated solution designed for wildland firefighter needs.

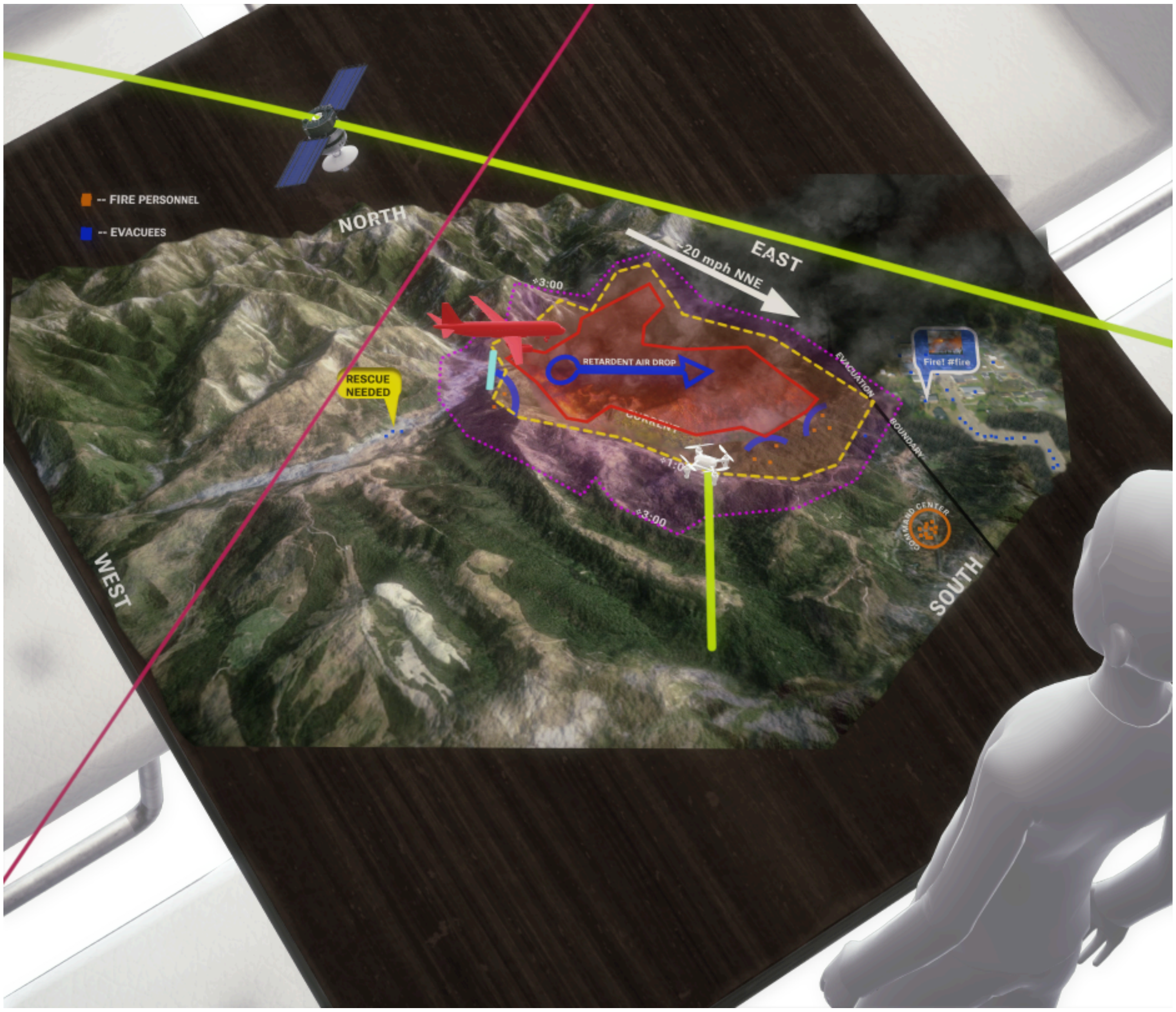



**Figure A.8** — Example of the DARSIM output

- Single Pane of Glass (SPoG) — A comprehensive single-screen tool presenting diverse information sources for decision-making. It combines extended reality, disaster visualizations, geospatial registry data, personal inputs, and other elements. Utilizing DARSIM, the SPoG efficiently dispatches vital ARD and decisions via cloud and local networks.

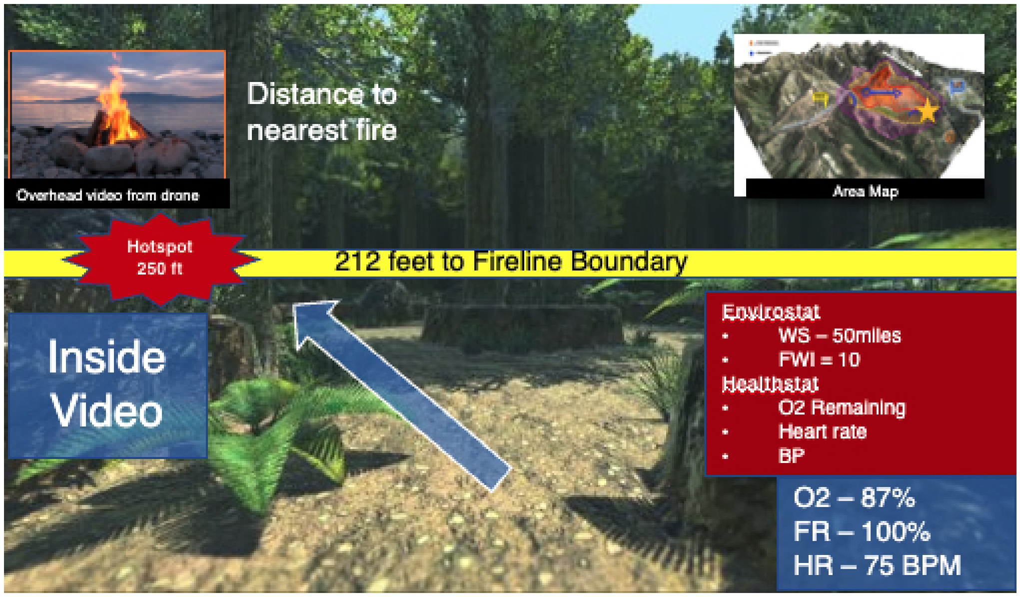



**Figure A.9** — Example of the Single Pane of Glass view

## A.4.2. Benefits

An effective indicator framework is pivotal for robust disaster response. Collaborating with other DP23 Participants, this tool aimed to curate immersive visualizations aligned with developed workflows. Key deliverables included:

- DARSIM (Virtual Sand Table/SIM Table):
  - A 3D digital twin of wildland and wildland urban interface (WUI) areas for data overlay and visualization.
  - Enables swift deployment and assimilation of ARD & DRI, expediting decision-making.
  - Works in a cloud environment, needing just a flat space and augmented reality device to visualize a metaverse environment collectively.
  - Suitable for stakeholders like park managers, forest crews, and fire commanders across augmented reality, virtual reality mobile, and desktop platforms.
- SPoG:
  - Adaptable for various practitioner settings, from field units to command hubs.
  - Aids firefighters by presenting pivotal geospatial data, enhancing their response efficiency.
  - Integrates mixed tech sources, available through augmented reality, virtual reality, and desktops.
  - Example of hardhat with SPoG

### A.4.3. Collaborations

To develop these resources USGS-GeoPathways worked with USGS, US Forest Service, Federal Geographic Data Committee, NASA, ESRI, AmeriGEOSS, NOAA, GeoPathways Peru, Google, USDA, Microsoft, & Voyager Search.

## A.5. GeoCollaborate Tool Visualization developed by StormCenter

### A.5.1. Introduction

GeoCollaborate is a tool to help both the visualizing and disseminating of geospatial data, and this tool was demonstrated during Disaster Pilot 21 (DP21).

### A.5.2. Description

The concept of GeoCollaborate is that there is a lead author of a geospatial map, and other people can follow the map of the leader in real-time, offering an opportunity to provide everyone following the leader to be looking at precisely the same up-to-date information within minutes of a disaster impacting an area.

Figure A.10 shows an example of how visualization and dissemination can occur. 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.

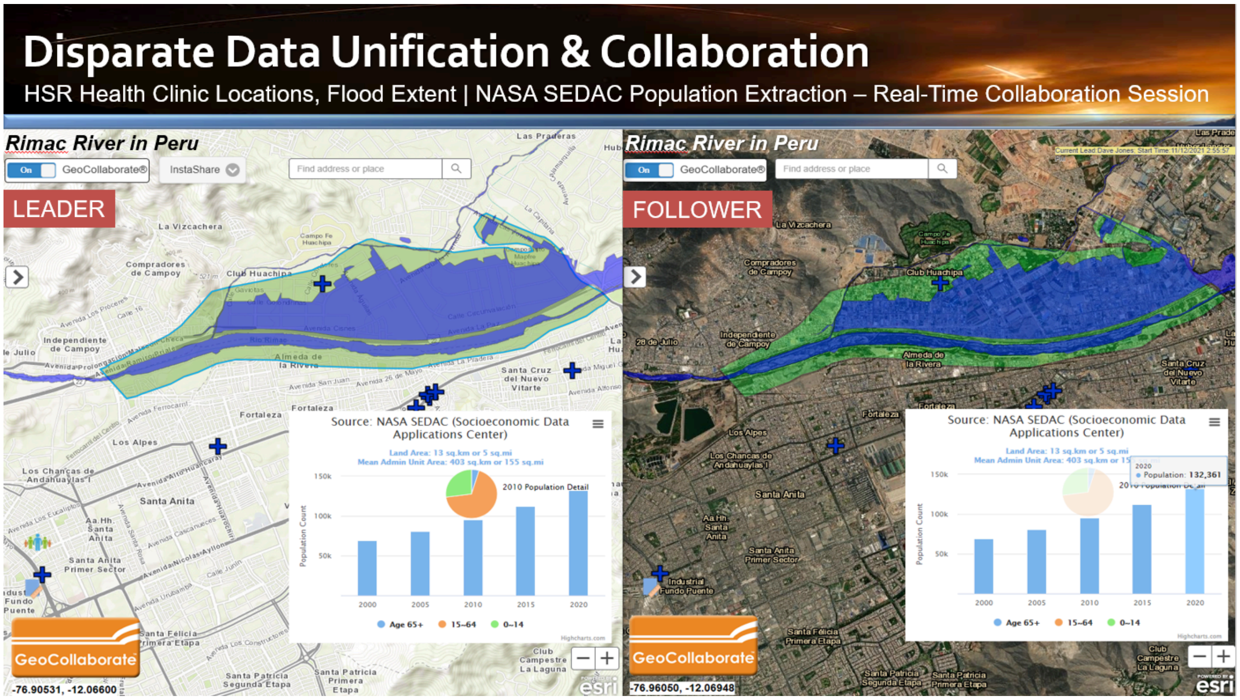



**Figure A.10** — Data for Rimac River in Peru, including flood extent and demographic breakdown of the area, together with clinic locations from HSR.health, visualized via GeoCollaborate

GeoCollaborate 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 and within a large scale disasters there are many different operations going on simultaneously. GeoCollaborate can be configured such that each operational area has it's own leader and own customized operating position, so that the first responders and decisions makers for that location only have information that is relevant to their roles. While Emergency Management leaders could have a combined view of all operations, to have an overall picture of the situation, allowing all the decision makers to be connected and work together in a collaborative environment using the same data and information.

B

# ANNEX B (NORMATIVE) DROUGHT WORKFLOWS/CAPABILITIES DEVELOPED

# B ANNEX B (NORMATIVE) DROUGHT WORKFLOWS/CAPABILITIES DEVELOPED

Drought is a disaster that can impact a wide range of sectors, such as agriculture, health, and, particularly in Manitoba, energy production through hydropower. Both the Manitoba Drought Monitor and the Canadian Drought Monitor can be used to actively track on-going droughts in the region.

Listed below are a series of indicators that look at the overall severity of drought and some of the individual sectors. While these workflows were built as standalone indicators, the Disaster Pilot 2023 (DP23) participants worked together to combine indicators to develop workflows that tell a more complete story of the impact of droughts. For example, the Drought Severity Indicators were used by the Drought Health Risk Impact to help better understand what the impact of a drought occurring in a particular area would be on the health of that population.

These workflows are available to be seen as a demonstration and could provide help and support to communities planning for, and responding to drought scenarios.

The workflows developed by the DP23 participants to provide Emergency and Disaster communities with specific information regarding the impact of, and potential impact of, drought are:

- Annex B.1.1 Drought Severity Indicator Assessment Framework developed by United Nations University
- Annex B.1.3 Drought Severity Workflow developed by Pixalytics Ltd
- Annex B.1.7 Drought Severity Indicator developed by Safe Software
- Annex B.2 Drought Crop Suitability Indicator developed by 52 North
- Annex B.3 Water Supply Indicator developed by RSS Hydro
- Annex B.4 Energy Climate Indicator developed by GECOsistema
- Annex B.5 Drought Health Risk Indicator developed by HSR.health
- Annex B.6 Direct & Indirect Health Impact Indicators of Drought developed by IIT Bombay.

The detailed technical information about each of these workflows can be seen below:

# B.1. Drought Severity Indicators

This series of drought severity workflows aimed to enhance the implementation of interoperability, that is, the ability of data/applications/tools created independently by different individuals and organizations to be understood, integrated, and functionally consistently regardless of user knowledge and technology suites. This helps ensure that diverse information can be quickly brought together to support decision-making in the context of disasters.

## B.1.1. Drought Severity Indicator Assessment Framework Developed by United Nations University

To ensure interoperability of the systems for drought severity and vulnerability analyses, it is essential to bring the right group of people to the table and provide them with adequate data to make fair, efficient, and informed decisions about drought risk and severity. Drought severity workflow knowledge encompasses several aspects of environmental (e.g., precipitation), economic (e.g., income level), and social data (e.g., health and chronic condition data). The summary of steps for an interoperability assessment include:

1. Bringing experts in environmental, economic, and social impacts of drought together. Supply them with adequate data relevant to interoperability capacity.
2. Assessing drought direct and indirect impacts and then ranking impacts.
3. Assessing vulnerability.
4. Developing a “to-do” list and identifying actions.

### B.1.1.1. Description

Figure B.1 shows an example of how to set up a table to prioritize the impacts of drought severity relevant to the Manitoba location.

| Rank | Impact | Cost | Area extent | Trends over time | Public priority? |
|---|---|---|---|---|---|
| 1 | Manitoba Hydro exports | | | | |
| 2 | Farming and crops | | | | |
| 3 | Wildfires fighting | | | | |

**Figure B.1** — Example of how to set up a table to prioritize the impacts of drought severity relevant to the Manitoba location

It also ranks the "current" impacts according to the priority that should be considered. The general public, community advisory committees, and groups of relevant scientists and policymakers can be included in the ranking decisions for informed and equitable impact assessment.

The final step produces a vulnerability assessment output. For example, as the drought impact assessment from the example establishes that mitigating and adaptation strategies for agriculture and crop damages are a priority, Figure B.2 can help identify the underlying conditions. The logic behind vulnerability assessment is finding key entry points and adaptation strategies to mitigate the impact of drought in a region. Many agricultural regions in the world can be impacted adversely by drought, but not all of the impacts are equal. Therefore, finding the root causes of the impacts is a step toward recovering from its assessed severity.

| Impact of drought | Underlying causes | Possible actions | Mitigation (M), Response (R), Accepted Risk (AR) | Feasible ? | Cost | To do? |
|---|---|---|---|---|---|---|
| Crop failure | Variable climate | Weather modification | M | | | |
| | | Weather Monitoring | M | | | |
| | No irrigation | Haul water during a drought | R | | | |
| | | Provide government assistance for irrigation projects | M | | | |
| | Expensive seeds | Subsidize seeds sales | M | | | |
| | Farmers preference to plant specific seeds | Conduct workshops | M | | | |
| | | Conduct research | M | | | |
| | | Enhance communication | M | | | |
| | Government preference to plant specific seeds | Lobby for new incentives | M | | | |
| | No drought warning | Provide weather monitoring | M | | | |
| | High cost of crop insurance | Government Subsidies | R | | | |
| | Lack of research on the efficiency of drought relief efforts | Identify target groups and conflicting relief programs | M | | | |
| | Lack of drought relief program coordination | Streamline relief application on funding | M | | | |

**Figure B.2** — Example vulnerability assessment for crop failure

It is essential to differentiate between the impacts of drought severity versus the underlying reasons (i.e., vulnerability) for drought. The impacts of drought are usually associated with reduced crop yields, livestock losses, and reservoir depletion. Drought impacts can also be traced to social consequences such as the forced sale of household assets or lands or physical and motivational malfunctions. Understanding the underlying drought severity differs from the mentioned direct and indirect drought impacts. It is also essential to evaluate what drought impacts will recur in a region under climate change, as well as population and water demand changes.

Within the DP23 work, the workflow from Pixalytics aimed to look at the impact of drought, while the workflow developed by Safe Software looked at drought vulnerability; in addition, the participants are working together to produce a version of the Pixalytics indicator which combines the two elements.

### B.1.2. Benefits

This workflow highlights how a collaborative drought severity workflow can identify vulnerable populations in drought-affected areas. The benefits of UNU's contribution is a workflow for prioritizing impacts and vulnerabilities relevant to a particular region or activity and supporting scientific researchers, policymakers, and the public.

A drought impact and vulnerability assessment guideline as a prerequisite for enhancing the ability of web services to integrate and exchange spatial data to ensure consistent decision-making results. Having interoperable systems in place becomes especially important during wide-scale emergencies like drought responses and firefighting.

### B.1.3. Drought Severity Workflow Developed by Pixalytics Ltd

### B.1.4. Description

The aim of the Drought Severity Workflow (DSW) was to create a decision-ready Combined Drought Indicator (CDI) to give information about the state of drought in an area. It is a global product that can show how an area moves from drought watch to drought warning to drought alert over a period of time. It describes the type of drought the area is suffering from, whether that is a lack of rain, lack of moisture in the soil, or whether the vegetation is suffering due to lack of water — it will also identify if more than one of these indicators are occurring and so show the progression of drought.

The indicator should help communities understand if a drought is building up in an area, and enable them to take action before the worst impacts of the drought occurs. The workflow would feed into the drought impact and impact assessments described in the work of the United Nations University.

### B.1.5. Benefits

This indicator could be used as a standalone indicator for users such as farmers, who, if they can see their area has a lack of soil moisture, could start irrigation or early crop harvesting; especially when the vegetation indicator is also triggered.

While the individual indicators and CDI will indicate whether drought is occurring, and what the current impact is, they can also be used as an input into wider information systems. This could mean the workflow offers support to decisions in areas with no water, potentially susceptible to flash flooding, or health vulnerabilities of the population through the addition of a temperature indicator. Also, areas suffering from drought or excessive dryness are likely to also be an indicator of potential wildfires.

The aim for this indicator was to support an understanding of whether a location is suffering from drought and what the indication of drought is referring to, i.e. is it a lack of rain, lack of soil moisture, or stressed vegetation. It can also be multiple individual indicators are triggered, and there will be a temporal dependency to this. An example of the multi-parameter inputs to the combined indicator (CDI) is shown in Figure B.3. The top plot shows precipitation (rainfall), middle plot soil moisture and bottom plot shows how much the vegetation is suffering.

The colored (yellow to orange) vertical bars then show the CDI moving from watch to warning when one of the indicators was triggered — when the CDI moves to alert there will be a *reddish* bar with Alert 1 showing two indicators are triggered while Alert 2 is all three individual indicators triggered.

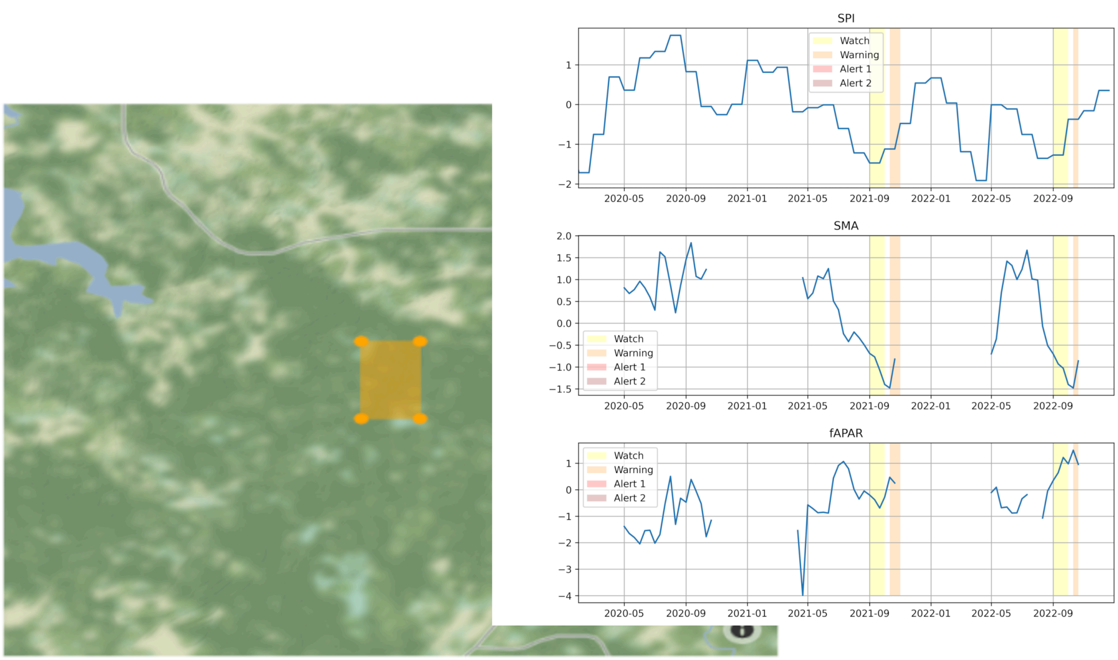



**Figure B.3** — Plot of the CDI for a point location in Canada (Latitude: 55.5 N Longitude: 99.1 W); generated using Copernicus Emergency Management Service information [2023]

The job roles that would use these indicators are a Decision Ready Indicator (DRI) Analyst and DRI Decision Makers within a wider Geographic Information Systems (GIS) solution

## B.1.6. Collaborations

There were collaborations with Safe Software in terms of the input datasets. Also, HSR Health used the DSW to ingest a drought indicator into their Health Impact workflow.

The product runs on a web server owned by Pixalytics, and work was undertaken to transition it to an OGC permanent demonstrator when the cloud computing infrastructure becomes available.

## B.1.7. Drought Severity Indicator Developed by Safe Software

### B.1.7.1. Introduction

The Drought Severity Indicator developed by Safe Software supports the modeling and analysis of drought impacts in southern Manitoba. It takes the climate scenario environmental variable summary ARD (Analysis Ready Data) from the Safe Software Data Service component, and applies the service to drought analysis using appropriate queries to derive preliminary drought risk impacts over time based on selected climate scenarios. This feeds into the drought vulnerability work described in the assessment work of the United Nations University.

Central to this is the identification of key drought risk impact indicators required by decision makers and the business rules and datasets needed to drive them. The workflow includes data aggregation and statistical analysis of precipitation over time, taking into account deviation from historical norms and cumulative impacts over time periods. This should provide a starting point for the assessment of drought risk by region and time. It also represents an important example of how global and regional climate model outputs can be used to support disaster and climate resilience planning at the regional and local scales, by translating scenario model outputs into specific risks and impacts at local levels.

In the DP23, the primary focus has been drought impact in southern Manitoba. This area, historically, has not tended to experience as much drought as other regions of the prairies to the west. However as shown in the Figures below, more recently, with the effects of climate change, this area has shown increasing drought stress which has implications for the need to manage and model drought more closely there.

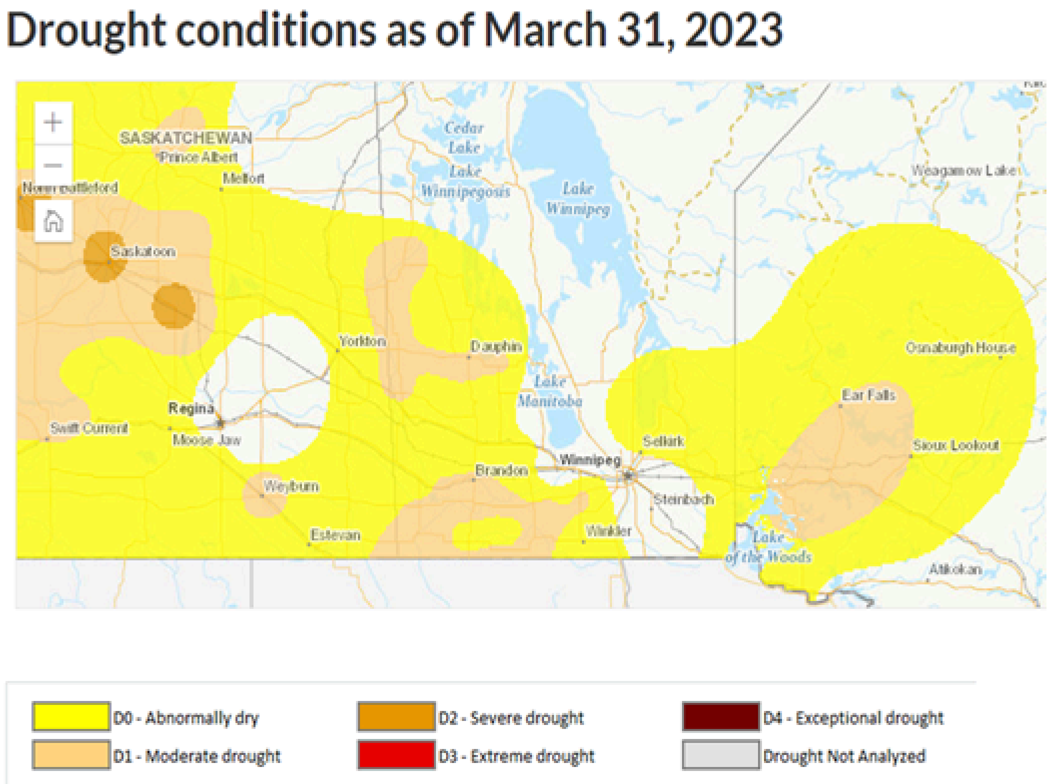



**Figure B.4** — Canadian drought monitor showing areas of the eastern prairies experiencing various degrees of drought as of March 2023 (Agriculture Canada)

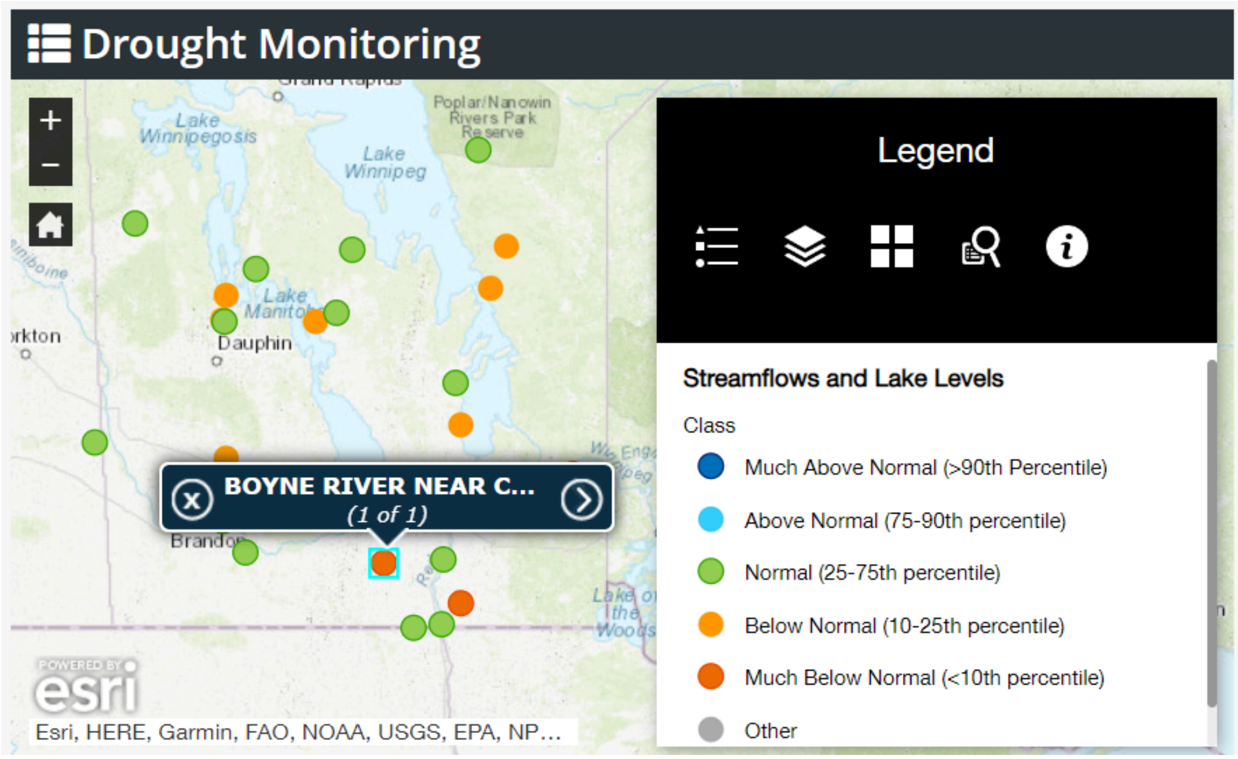



**Figure B.5** — Manitoba drought monitor showing degrees of drought for lakes and rivers in Manitoba, fall 2023 (Manitoba Environment)

Workflows developed for Manitoba drought impact analysis were designed in such a way that they can be readily transposed to other contexts and scenarios, given adequate provision of equivalent source data. The process recipes were implemented using Safe Software's FME platform, which is a no-code, model based, rapid prototyping environment that supports data integration and automation with a special focus on support for all types of spatial data (more than 500 formats supported). With this model driven approach it is relatively easy to rerun or automate the same dataflow based on new inputs. In this way new results can be generated based on different climate scenarios such as those based on low, medium or high emissions.

### B.1.7.2. Description

The indicator analyzes climate model outputs, including environmental variable time series, to derive estimated drought risk impacts over time based on selected climate scenarios for the Manitoba study area.

Drought is driven by multiple environmental and physical factors. As such, the initial goal was to select and provide primary climate variable data that would be useful for deriving drought risks in combination with other inputs. Given that the primary input to drought models is precipitation, or lack thereof, we developed a data flow that extracted total precipitation per month and made this available as data time series points for the province of Manitoba study area. Temperature is also a significant influence on drought given its relation to evaporation rates, water absorption etc, so we provided a temperature time series layer as well.

In order to provide a more broadly usable drought risk estimate, we developed a proxy drought risk indicator, a precipitation index, by looking at the difference between precipitation from the past vs future climate scenarios. The goal for the precipitation index is to provide a value between 0 and 1 where 1 = 100% of the past average precipitation for that month. Naturally this approach can generate values that exceed the range of 1 if the projected precipitation values exceed the historic average. The goal was not so much to predict future absolute precipitation values but rather generate an estimate for precipitation trends, given the influence of climate change. For example, this approach can help answer the question — in 30 years for a given location, compared to historical norms, by what percentage is precipitation expected to increase or decrease?

It is important to underline that this particular indicator is more of an interactive service than one meant to yield one specific result or prediction. As such, it is up to the end user, whether they be drought domain experts or local farmers or administrators, to develop the business rules for drought that they deem most appropriate. This indicator service provides a means of interacting with the relevant environmental variables from the climate model projections, such as precipitation and temperature, to see when and where problems might occur. What is defined as problematic will naturally differ a lot depending on whether the end user is concerned about a specific agricultural crop, water supply for a city or hydroelectric power for the province. This drought indicator service then provides an access point where end users can explore the climate scenario data as it relates to southern Manitoba. The cases shown here are just examples and are only meant to serve as a starting point for further testing and exploration.

In order to better support drought related queries, the indicator component service was enhanced to support multiple environmental variables on each of the time series points. This includes values such as temperature, precipitation and change in precipitation relative to historic mean. Users can ask questions to look for times and places of concern relative to specific natural hazards such as drought, fire, heat or flood.

As example, the following user request was made to the service: “Find all time step points over the next 40 years for southern Manitoba where projections indicate > 25% dryer and mean monthly temperature > 23C.”

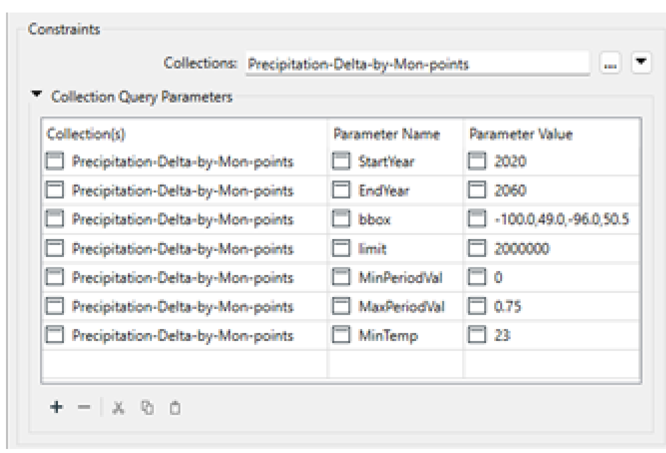



**Figure B.6** — User request was expressed in FME Data Inspector

The request produced the following output:

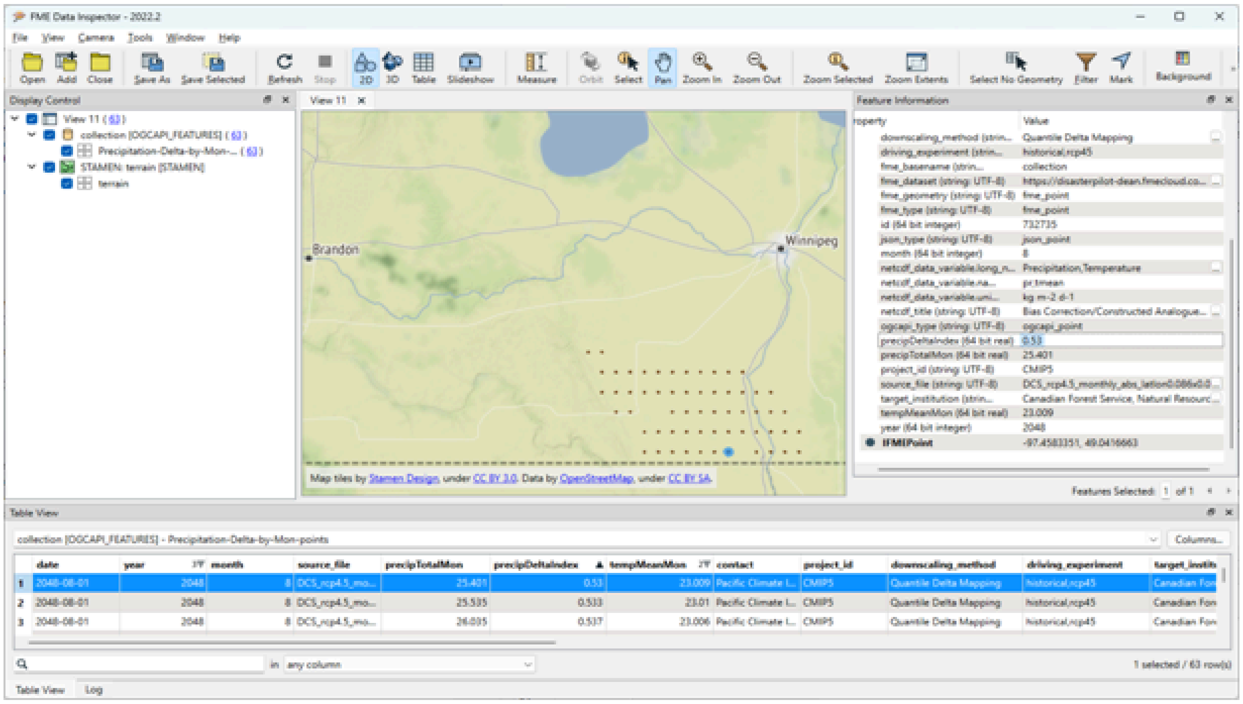



**Figure B.7** — 63 temporal points with associated temperature and precipitation values, as shown in FME Data Inspector client

This result shows climate model points from the query above, they represent the hot and dry areas and times (August 2048 and 2058) that satisfy the query above and could constitute increased drought and fire risk. This illustrates one approach for making climate model outputs more accessible in a form and structure easy to consume by those used to working with GIS tools.

### B.1.7.3. Benefits

The benefits of this workflow can help disaster management and planners evaluate the resilience of their plans against a range of possible future climate scenarios. By making climate model outputs more accessible to common analytics platforms typically used by planners, such as GIS, this indicator component helps shed light on what local trends to expect in the future based on various climate model scenarios. This should help the stakeholders responsible for managing disaster and climate impacts more easily access and interpret the potential risks associated with climate change in their local context.

From a planning perspective, it can be expensive to build comprehensive drought models, either at the local scale or across an entire province. So it may be useful to make basic environmental variable projections available. While it may not be obvious to a non-domain expert how much precipitation is enough, excessive or inadequate, showing changes or trends in key environmental variables is a good first step in looking for regions and times where drought or flood risk may be increasing. For example, knowing where and when precipitation is 20% lower or higher over a given time period might warrant an investigation in the resilience of those areas for drought or flood respectively. Naturally these trends need to be examined in the context of existing drought risk factors and historical drought. Different impact types such as agricultural, drinking water, recreation or hydropower will all have different thresholds of concern. Still, the general trends can at least serve as a first step in terms of locating those of areas and times of interest for closer management and investigation.

In a similar vein, another important benefit of this drought primary indicator is that it can be used to support downstream analysis. More sophisticated drought models such as that developed by Pixalytics can use the precipitation and temperature values as inputs to drive their more refined models. Future forecast scenarios for precipitation and temperature can be combined with localized detailed models that include other drought risk factors. In this way, climate projection data can allow the more sophisticated drought models to make projections about possible future drought risk which neither model or indicator could do on its own. This combination of indicators is crucial to building comprehensive views of disaster and climate risks over time at the regional and local scale. Also, chaining of indicators is also important in that it allows a wider range of indicators to be developed without each indicator recipe having to build the entire analytical workflow on their own.

### B.1.7.4. Collaborations

To support future drought risk estimates for Manitoba, we provided a precipitation forecast time series to Pixalytics as an input to their drought analytics and DRI component described in Annex B.1.3. Their component provides a much more sophisticated indicator of drought probability since in addition to precipitation it also takes into account soil moisture and vegetation. Pixalytics then ran their drought model based on these precipitation estimates in order to assess potential future drought risk in southern Manitoba, as shown below.

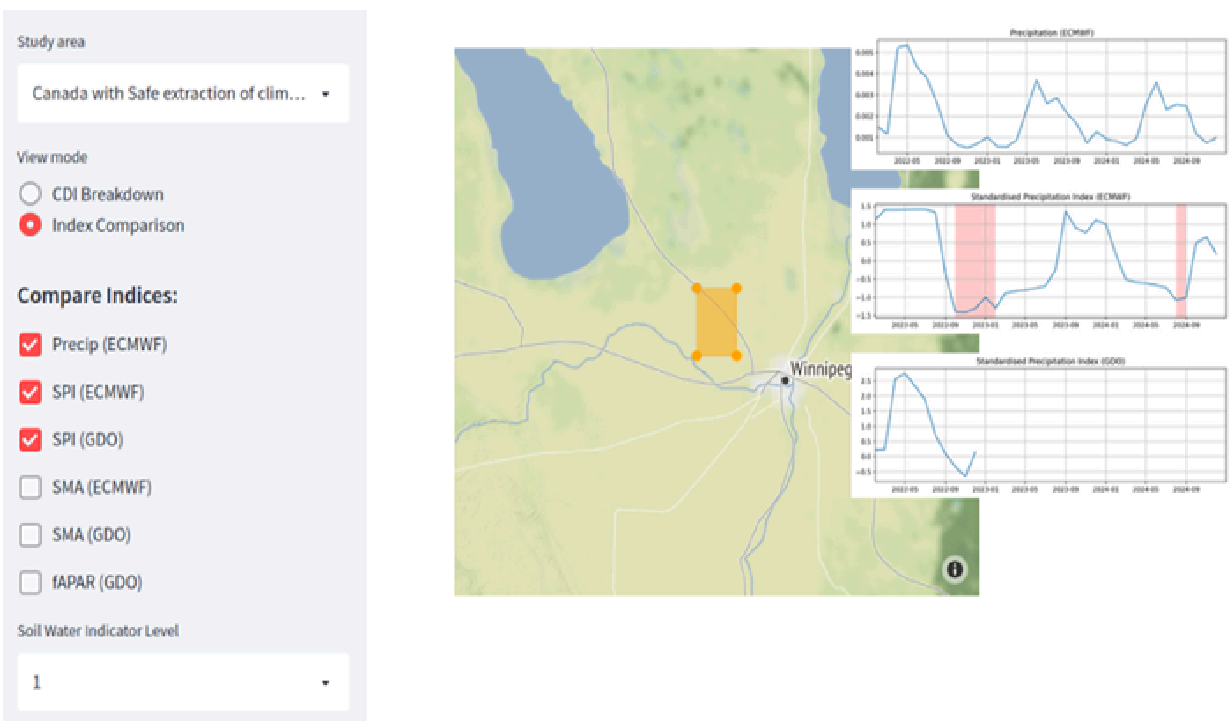



**Figure B.8** — Pixalytics drought DRI component integrates future precipitation projections from Safe Software's drought indicator service with historical and present data (Samantha Lavender)

Further information on Safe Software's contributions to OGC Disaster & Climate Pilots can be found at https://community.safe.com/s/article/OGC-Disaster-and-Climate-Resilience-Pilots

The persistent demonstrators for the services used in this indicator can be found at:

- OGC API Features Service (accessible 9am — 5pm EDT, M-F)
- OGC API Records Service (accessible 9am — 5pm EDT, M-F)

## B.2. Drought Crop Suitability Indicator Developed by 52 North.

### B.2.1. Introduction

The workflow provided crop suitability maps, highlighting the effect of local environmental conditions on crop health/yield.

### B.2.2. Description

The workflow investigated drought impact on crop health with forecasts that extended one month into the future. Users can specify a certain crop species and location for which information is required. Based on the environmental conditions from the forecast and the requirements for the selected crop species, regions will be categorized in five different suitability classes – pessimal, unsuitable, marginal, suitable and optimal. As output, users receive a map that highlights these regions in different colors. This map is provided in a machine-readable format (i.e. GeoJSON) that can easily be integrated into a GIS or visualized using Visualisation Tools like geojson.io.

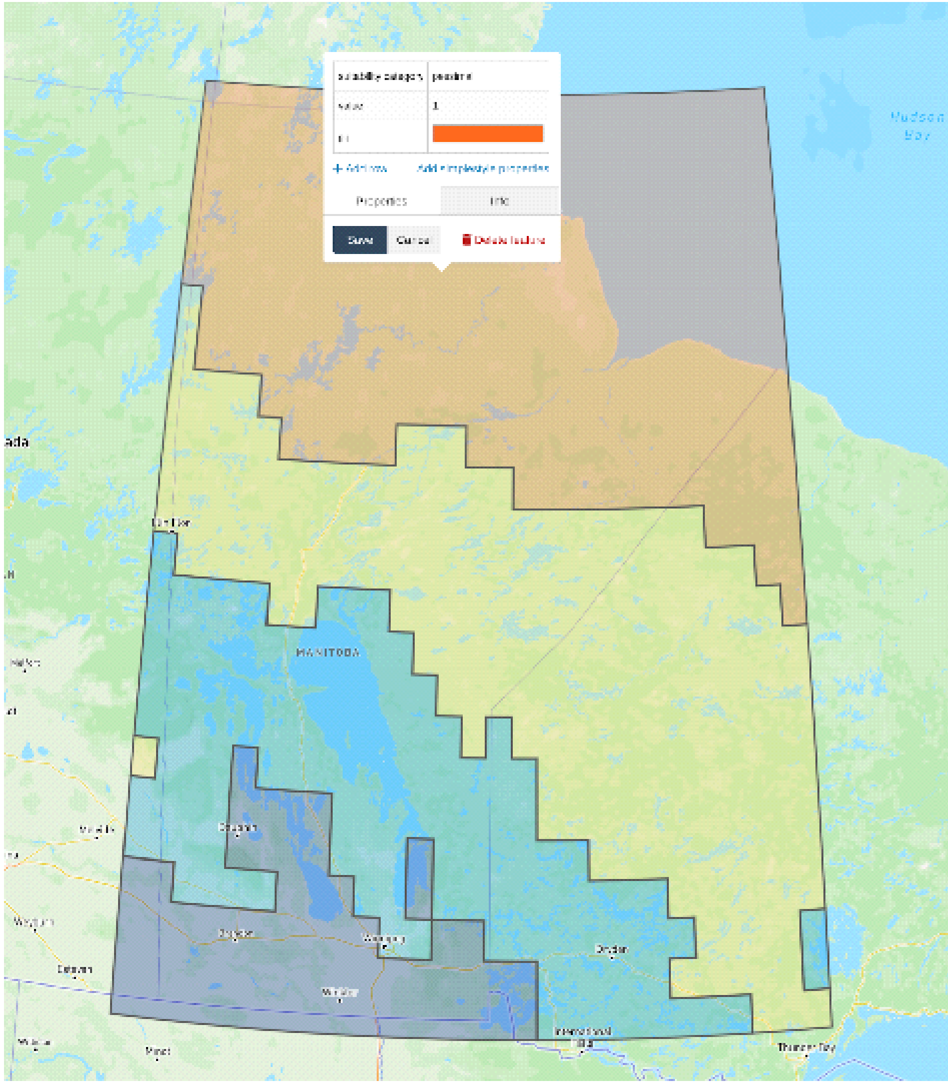



**Figure B.9** — Example of a crop suitability map for the test case of Manitoba. The suitability of the environmental conditions is decreasing from suitable (blue) to pessimal (red). The visualization has been done using geojson.io

## B.2.3. Benefits

Users can adapt to upcoming drought conditions and establish counter measures, e.g. adjustment of irrigation schedules or the choice of crop species that are more suited to challenging environmental conditions.

The main user base of this indicator are farmers. The indicator could also be used to describe the economic implications of climate change in terms of yield loss.

### B.2.4. Collaborations

This indicator was developed as a separate component for DP23. For the future, collaborations in the context of the Wildland Fire Fuel Indicator and Drought Severity Indicators are possible. In case of Wildland Fire Fuel, the crop suitability indicator can be used as a metric of dry biomass while for Drought Severity it can show the resilience/vulnerability of crops.

## B.3. Water Supply Indicator Developed by RSS Hydro.

### B.3.1. Introduction

This workflow produced a global product offering an indicator for the drought impact on freshwater availability.

### B.3.2. Description

Users have access to a satellite-based daily discharge signal and historical time series from 1998 onwards. Daily discharge values are displayed such that users can see if the discharge value is above or below a seasonal low flow threshold, the 1.5-yr flood, the 10-yr flood or the 25-yr flood frequency.

Figure B.10 shows the daily discharge of the last few years for this example station located along the White River, Indiana, USA, at -87.119 Longitude, and 38.969 Latitude. In the figure, the black is the daily discharge, green is the low flow threshold, and the red and purple lines indicate the various flood thresholds that are based on a 25 year daily signal. This example serves as an analog of how well water discharge can be observed utilizing satellite data. Based on ~25 years of daily data, a low flow threshold can be established. We defined the low flow as the 20th percentile discharge derived from the daily data of 2003-2010.

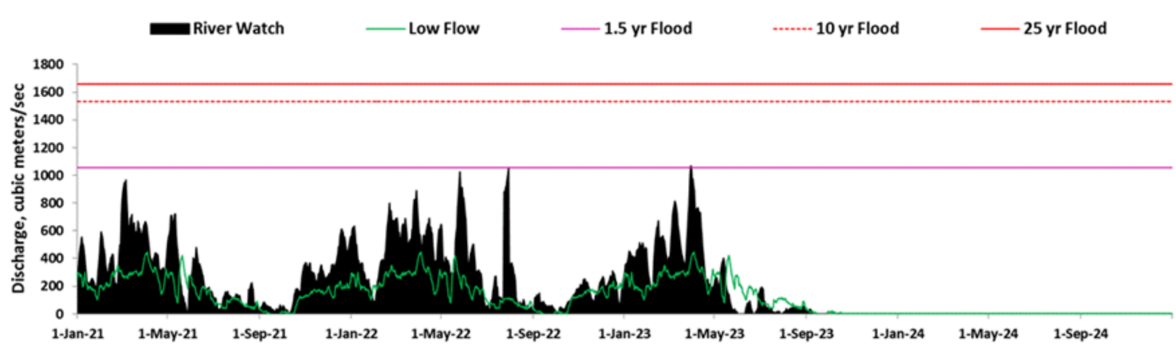



**Figure B.10** — Daily water availability signal (discharge) for station located along the White River, Indiana, USA.

Figure B.11 shows the daily discharge signal for the entire time period starting in 1998 until the summer of 2023 for the same station in the White River. The seasonality of the signal is clearly visible, and how over the last several years the flood intensity somewhat diminished. Also notice in the previous figure that the daily discharge data (black) falls below the low flow line (green). This indicates a drought that is currently developing in the White River basin.

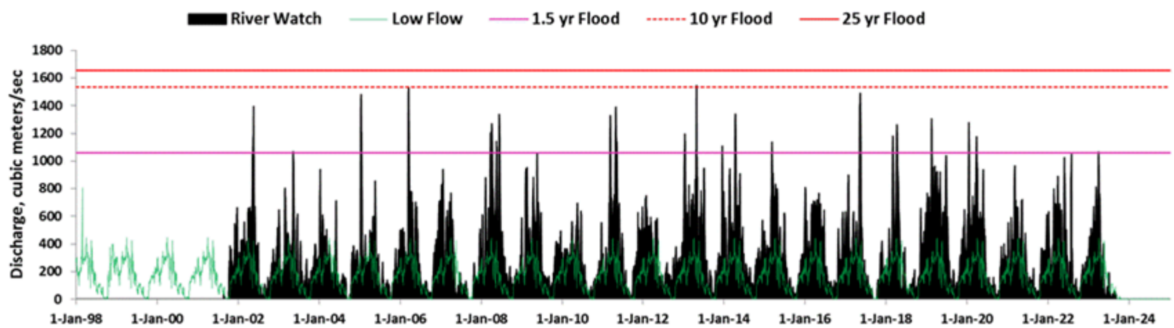



**Figure B.11** — 25 Year time series for daily discharges for station located along the White River, Indiana.

This is a global product. A web portal is used to provide the information. Each virtual station has its own web page.

## B.3.3. Benefits

This benefits disaster relief agencies and local authorities, as they will be able see the magnitude of a drought disaster, to help them determine a response. It also offers benefits to planners as they can see how often floods or droughts occur in an area over the last 30 years approximately.

First responders can use this data to determine when a location became a drought or flood; and if this trend continues or not. First responders can also determine if the disaster happens on a yearly basis, or if it is more rare. While planners can determine if there is sufficient water for agriculture purposes, for drinking water, if a drought or flood is occurring and how significant this disaster is.

## B.3.4. Collaborations

Working with Joint Research Centre in Italy, World Food Programme, Red Cross, and several development banks.

# B.4. Energy Climate Indicator Developed by GECOsistema

## B.4.1. Introduction

The power sector is exposed to weather and climate variability at all timescales, with impacts on both demand and supply. It is well established that global and regional temperatures are increasing and will continue to increase with human-induced climate change, resulting in increasing electricity demand for residential cooling. Recent studies investigating the impact of climate change on demand concur that annual heating-induced demand is likely to reduce, whereas cooling-induced demand is likely to increase.

The purpose of the Energy Climate Indicator was to produce a minimum viable climate service designed to enable the energy industry and the policy makers to assess the impacts of climate variability and climate change on the energy sector in Manitoba (Canada).

The indicator provides a time series forecast of electricity energy demand and supply from hydropower with short-term or long-term monthly, seasonal and climate change outlooks. An improved characterization and prediction of such variability will benefit production and transmission planning, leading to economic and environmental benefits. The energy indicators and associated time series forecasts can be provided both as data files, or as images. There are various ways the data can be shared between individuals and organizations following appropriate standards.

## B.4.2. Description

The climate-based indicator is generated using Long Short-Term Memory (LSTM) and advanced recurrent neural networks ideal for sequence prediction, to forecast energy demand and hydropower river generation.

The indicator uses historical data regarding the country's energy consumption, together with various climate related features such as installed power generation, temperature, precipitation, wind speed, and solar irradiance.

The LSTM model used in DP23 was developed and validated for Italy, but can be easily replicated to any country, or region, in the globe.

The model needs to be trained by feeding it with historical data and adjusting its weighting based on prediction error, and then the model is compared to actual values, with error metrics.

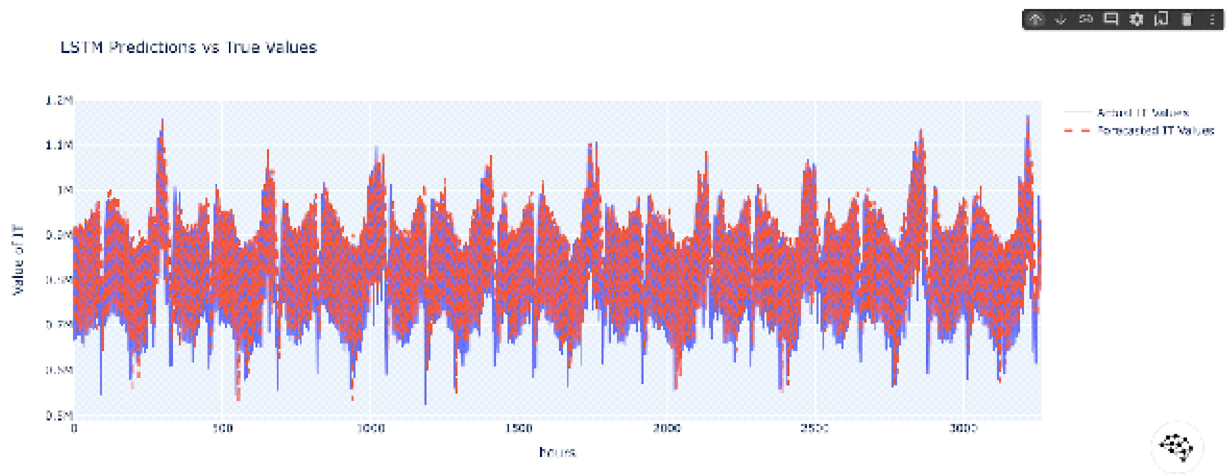



**Figure B.12** — Model's actual vs predicted values

Once the model is correctly trained and validated, it can be used to forecast demand. There are two options:

- Batch Forecasting: If predictions are needed for planning, the model can be run in batches (e.g., once a month for the entire next month).
- Real-time Forecasting: For immediate decisions, set up the model to provide predictions in real-time, processing the most recent data on-demand. The model will return a forecast for energy demand for the future time frame.

#### B.4.2.1. Summary

Incorporating multiple features into the LSTM model enhances its ability to forecast energy demand accurately. Combining energy consumption history with influential factors like weather and power generation offers a holistic view, leading to better predictive performance. Such models can be potent tools for forecasting tasks like country-level energy demand.

### B.4.3. Benefits

The benefits of, and decisions supported by, the Energy Climate Indicators are:

- **Proactive Resource Allocation**: Predictive insights on energy production allow emergency planners to understand potential shortfalls or blackouts during disaster events, enabling them to allocate resources like generators to critical areas in advance.
- **Critical Infrastructure Planning**: Knowing potential energy constraints helps in designing and strengthening critical infrastructure, like hospitals or evacuation centers, to withstand energy shortages during emergencies.

- **Integration with Other Emergency Systems**: Energy forecasts can be integrated into broader emergency response systems to provide comprehensive situational awareness, making it easier to coordinate responses.
- **Assisting Recovery Efforts**: After a disaster event, restoring power is one of the primary recovery efforts. Having accurate forecasts can guide these efforts, prioritizing areas based on their future energy production and needs.
- **Data-Driven Decision Making**: Real-time and forecasted energy data equip decision-makers with actionable insights, enabling them to make informed decisions that can save lives and resources during emergencies.

## B.5. Drought Health Risk Indicator Developed by HSR Health.

### B.5.1. Introduction

Drought affects thousands of people every year in the United States and Canada, it is a longer-term natural disaster compared to wildland fires, hurricanes, or tornadoes. As a result of its long-term nature, there is a broad and multi-faceted impact on the populations suffering from drought. It is important to understand where vulnerable populations are in drought areas to provide ongoing information to governments, local communities, and response personnel that can aid in relief and response efforts.

### B.5.2. Description

HSR.health produced a health risk index that identifies the vulnerable populations by combining population characteristics with health conditions and overlaying vulnerable populations with drought severity indicators. The Drought Health Risk Index was produced for the province of Manitoba, Canada.

The Drought Health Risk Index used data on demographics, health conditions and drought severity to calculate the Drought Health Risk.

Figure B.13 shows the overall workflow used to create and distribute the Drought Health Risk Index, which identified where at-risk populations exist across the drought-affected areas.

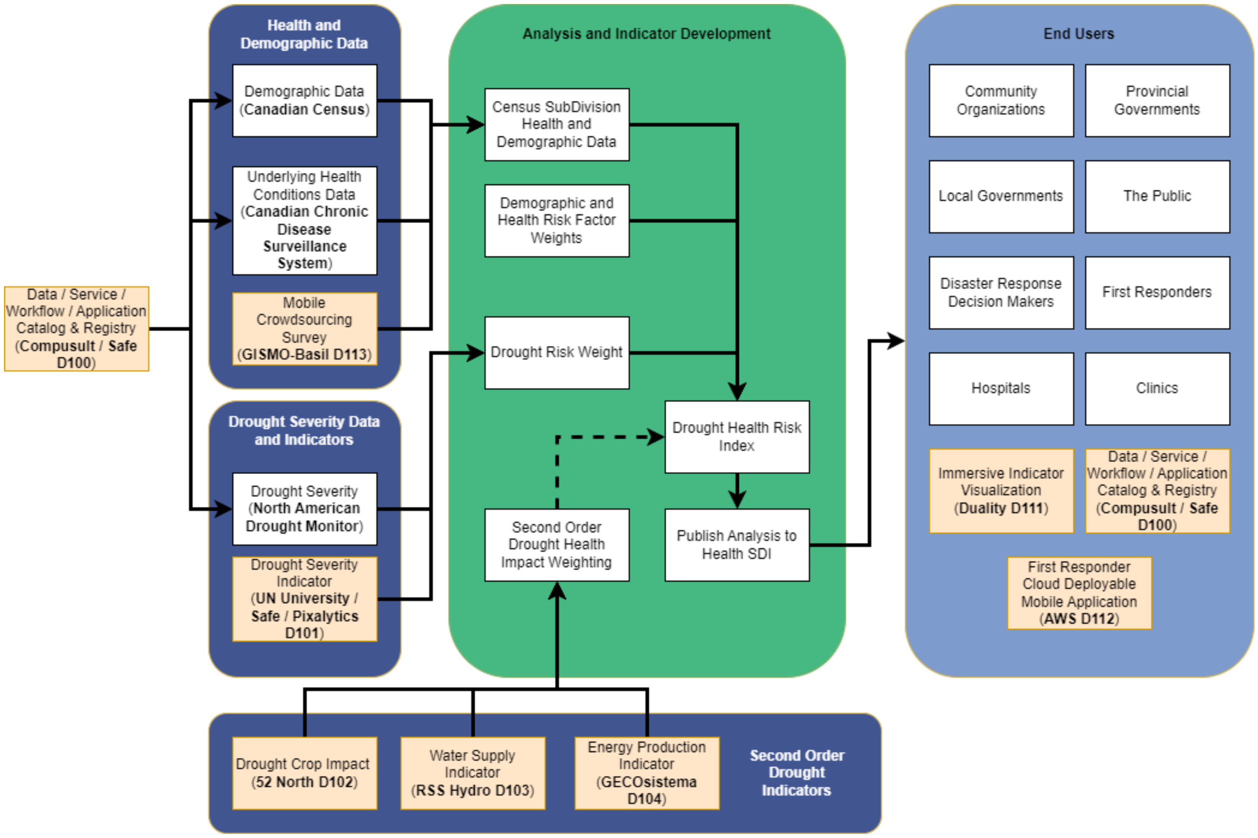



**Figure B.13** — Drought health risk indicator collaborations & workflow

The primary data inputs for the Drought Health Risk Index were demographic data, health condition data, and data on drought severity and risk. The demographic data comes from the Canadian Census Bureau, the health condition data comes from the Canadian Chronic Disease Surveillance System, and the initial drought severity data comes from the North American Drought Monitor. The target granularity for the Risk Index was the census subdivision administrative level for the province of Manitoba, Canada.

The Drought Health Risk Index calculation combined two primary components: the health vulnerability of the underlying population and the drought severity. The population vulnerability risk is a combination of health and demographic factors through a combined risk weighting analysis that provides a priori information on where vulnerable and at-risk populations are. Some of the factors informing the vulnerability risk include: Age, Disability Status, Transportation Access, Fluency, Low Income, Housing Cost Burden, Single Parent Households, Pregnant / Breast Feeding Women, COPD, Cancer, Chronic Kidney Disease, Asthma, and more. The weightings for each factor were determined through input from the public health team, published research, and internal analysis. The population vulnerability risk was combined with the drought risk weight, which was based on drought severity.

An example output of the Drought Health Risk Index Drought Dashboard can be seen in Figure B.14.

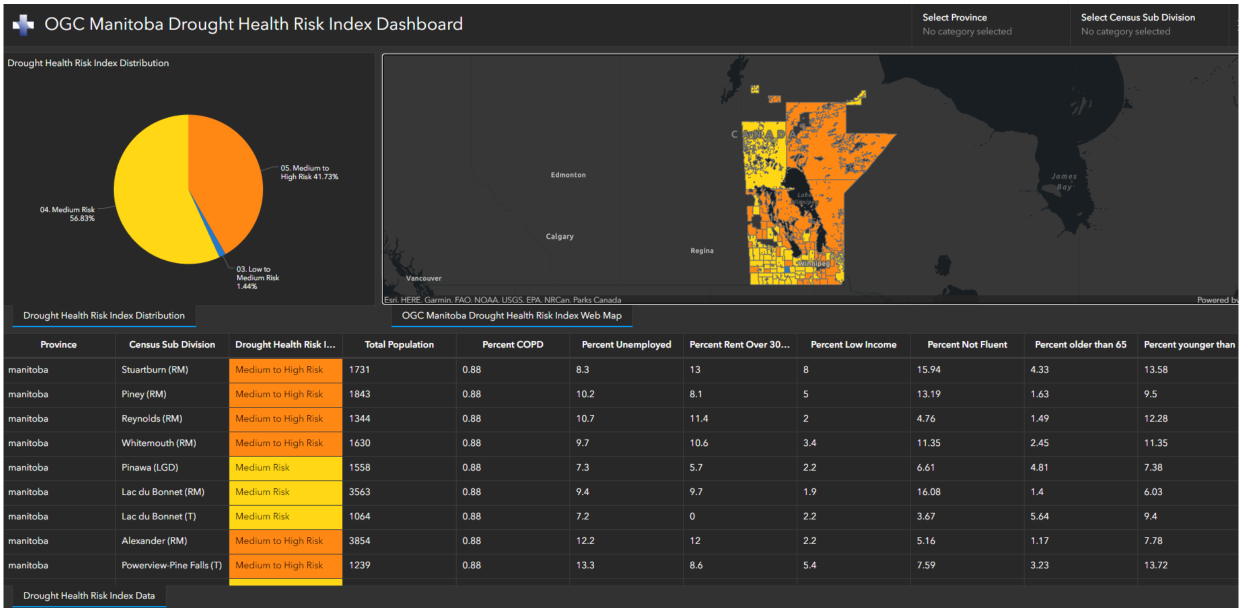



**Figure B.14** — Drought health risk indicator drought dashboard

## B.5.3. Benefits

- **Who does this help?** — The aim is to inform governmental organizations, disaster response personnel and decision makers, Community and Aid Organizations, medical personal, along with local residents and the public of the health and social conditions on the ground to aid in response and relief efforts in drought-affected areas.

  Health-impacts of drought can include, and are not limited, to Food Insecurity, Water Insecurity, Decrease in Air Quality, Heat Stress, Increase in Infectious Disease Risk & Reduced Access to Electricity from Hydro-Power Sources.

- **What decisions are supported by this indicator/tool?** — End Users and stakeholders can utilize the data and analysis presented to understand where vulnerable populations are, and how to create policies and relief plans to alleviate the impact of the drought on these populations.

- **Details of job roles that would use this data?** The job roles that might use this information include a DRI Analyst and a DRI Decision Maker.

## B.5.4. Collaborations

- **Collaborations Undertaken & Potential Combination with other Workflows** — HSR.health collaborated with UN University, Pixalytics, Safe Software, and GISMO-Basil Labs as data inputs for the workflow, and with AWS and Duality, who ingested the output from the risk index. Finally, collaboration with Compusult and Safe Software was to explore and demonstrate interoperability between the data catalog that they are developing for DP23 and the Health SDI.

The Index can be expanded to incorporate second and third-order health impacts from ongoing drought conditions through the inclusion of indicators produced in DP23 by fellow participants including:

- Drought Crop Impact by 52 North
- Water Supply Indicator by RSS Hydro
- Energy Production Indicator by GECOsistema

- **Details of Persistent Demonstrators** — HSR.health's goal of participation DP23 was to provide visibility into and persistent demonstrators of health information in the disaster response ecosystem. The persistent demonstrators are available at: https://opengeomd.hsrhealthanalytics.org/#/

## B.6. Direct and Indirect Health Impact Indicators of Drought Developed by IIT Bombay.

### B.6.1. Introduction

Drought has been documented to be a major disaster around the world and especially in India. While the longer-term aspects of drought naturally overlap with other factors of human society including economic development and institutional support, it has major direct impacts that manifest through Sustainable Development Goal (SDG) indicators as shown in Figure B.15.

| Indicator | Description | Drought Relevance |
|---|---|---|
| 2.1.1 | Prevalence of undernourishment | Food insecurity, Scarcity, Food price rise |
| 2.1.2 | Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES) | |
| 2.2.1 | Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age | |
| 2.2.2 | Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight) | |
| 2.2.3 | Prevalence of anaemia in women aged 15 to 49 years, by pregnancy status (percentage) | |
| 3.1.1 | Maternal mortality ratio | Health, Well-being |
| 3.2.1 | Under-5 mortality rate | |
| 3.2.2 | Neonatal mortality rate | |
| 6.1.1 | Proportion of population using safely managed drinking water services | Availability and sustainable management of water and sanitation (WASH) |
| 6.2.1 | Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water | |
| 6.3.1 | Proportion of domestic and industrial wastewater flows safely treated | |
| 6.3.2 | Proportion of bodies of water with good ambient water quality | |
| 6.4.2 | Level of water stress: freshwater withdrawal as a proportion of available freshwater resources | |
| 6.6.1 | Change in the extent of water-related ecosystems over time | |
| 13.1.1 | Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population | Combat climate change and its impacts |

**Figure B.15** — Drought relevance for SDG indicators

## B.6.2. Description

The indicators of health impact of droughts are reported as two composite indicators of direct and indirect impact along with individual indicators. Figure B.16 shows the overall framework of direct and indirect impact assessment through generalization and aggregation of indicators.

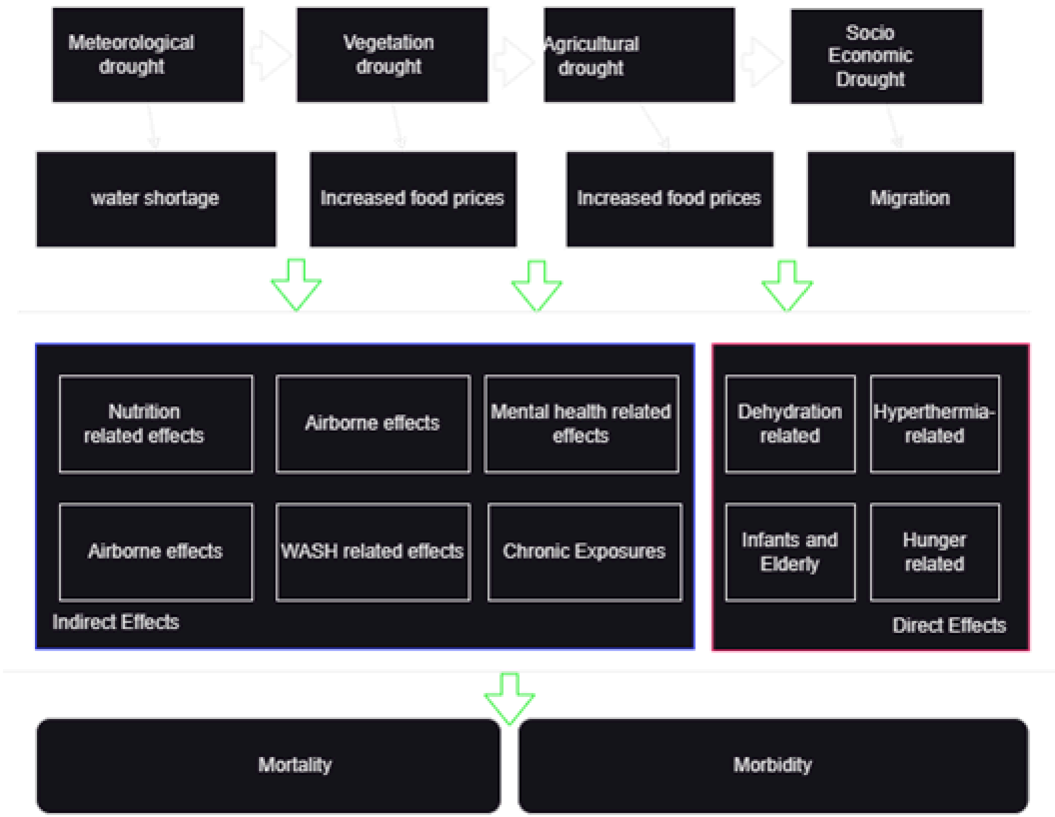



**Figure B.16** — Framework for direct and indirect health impacts of drought indicators

The data inputs for the indicator framework rely on primary datasets coming from National Health Surveys, Census data and registries at Primary Health centers. It leverages direct effects of drought in the context of:

- availability of drinking water
- availability of water for sanitation and hygiene
- availability of food
- environmental factors of drought including hyperthermia
- prenatal and postnatal impacts on pregnancies and childbirth

It also leverages indirect effects related to:

- immigration and long-term individual stress
- mental health impacts
- nutrition imbalance related disorders
- chronic dehydration related conditions such as chronic kidney disease
- loss of immunity and deficient/stunted growth.

The impact of drought has been recorded for many years based on morbidity and mortality, but such indicators are not very useful in understanding the underlying factors that can be addressed to build resilience in communities to droughts. While the health indicators of drought devised in the Drought Dashboard shown in Figure B.17 provide an understanding of the spatio-temporal understanding of the nature of drought impact on health, these are also linked to resilience indicators. Resilience indicators are currently work in progress and only account for financial provisioning.

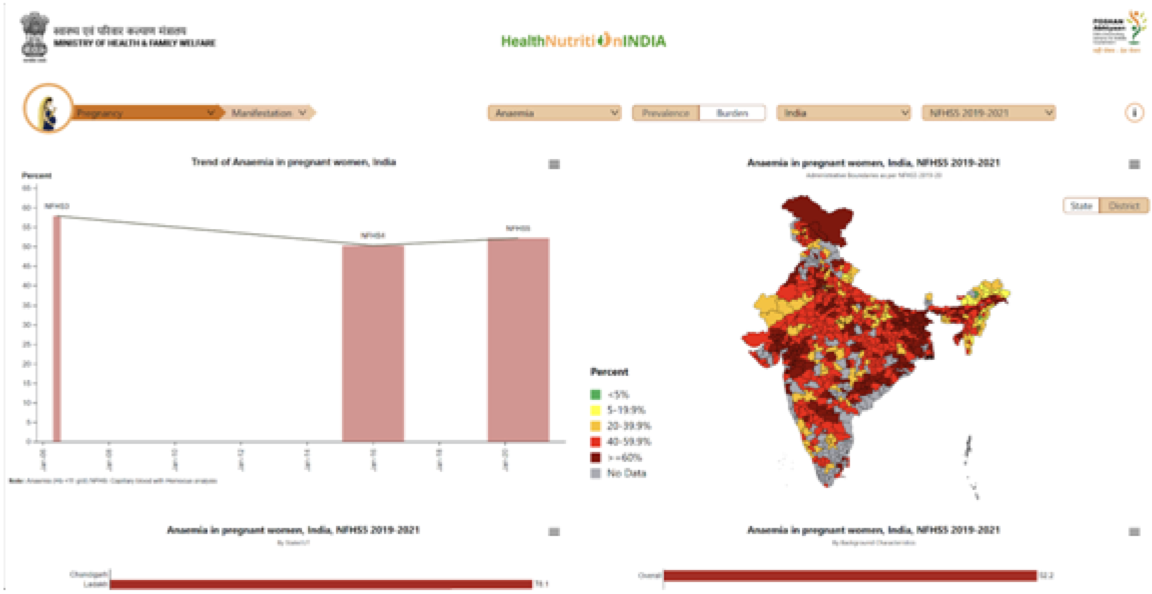



**Figure B.17** — Drought health risk indicator drought dashboard (prenatal health indicator-anemia in pregnant women)

## B.6.3. Benefits

These indicators are important at all levels for public health practitioners. They also help aid agencies aiming to build resilience in communities in different scenarios especially in regions that rely exclusively on local resources of food, water and economic gains. Furthermore, this helps medical practitioners, hospitals and healthcare centers working with communities that face increased vulnerability to droughts in understanding and providing long-term health remedies.

The main objective of these indicators is in the context of understanding evolving health impact scenarios of drought affected communities and supporting decision making on the provisioning of resources for resilience efforts.

Local, state and national agencies engaged in creating climate resilient infrastructures, especially in the context of climate induced disasters will be the main users and thus public health managers and administrators will be the job roles that would use this data.

## B.6.4. Collaborations

Drought health impacts are usually linked to climatic indicators of drought such as Standardized Palmer Drought Index (SPDI), Standardized Precipitation Evapotranspiration Index (SPEI), Palmer

Drought Severity Index (PDSI) and so on, in a complicated chain of lag variables that explain the temporal connection of “meteorological drought” to “socio-economic drought”.

IITB aimed to leverage the possibility of data sharing through open standards to develop spatio-temporal prediction algorithms especially through global drought indicators. In particular, it will leverage the following two activities from DP23.

- Drought Crop Impact by 52 North
- Water Supply Indicator by RSS Hydro

C

# ANNEX C (NORMATIVE) WILDLAND FIRE WORKFLOWS/CAPABILITIES DEVELOPED

# ANNEX C (NORMATIVE) WILDLAND FIRE WORKFLOWS/CAPABILITIES DEVELOPED

Wildland fires are fast-moving disaster situations, and 2023 saw significant wildfires across various states in the USA, Canada & Europe. These fires need fuel, which is often increased through drought where vegetation is bone dry, and when the fires start, rapid evacuations are often necessary.

The National Interagency Fire Center act as a US command hub for mobilization, providing information on fires and relevant Earth Observation-derived products, and according to their figures the extent of area burned by wildfires has been increasing since the 1980s. In the 1980s the figures were around 3 to 5 million hectares burnt each year, while over the last decade, there have been over 10 million hectares burnt in multiple years. In addition, the NASA Fire Information for Resource Management System, provides near-real time fire mapping.

The workflows developed by the Disaster Pilot 2023 (DP23) participants focused on:

- Risk of wildland fires by looking at the fuel and ignition risks
- Safe evacuation routes
- Health impact of wildland fire, which can stretch a long way with the smoke and particulates in the atmosphere.

The workflows developed by DP23 participants to provide Emergency and Disaster communities with specific information regarding the impact of, and potential impact of, wildland fires are:

The workflows developed provide specific information regarding the impact of, and potential impact of, wildland fires are:

- Annex C.1 Wildland Fire Fuel Indicator developed by Ecere
- Annex C.2 Wildland Fire Ignition Risk Indicator developed by Compusult
- Annex C.3 Wildland Fire Evacuation Indicator developed by Skymantics
- Annex C.4 Wildland Fire Health Impact Indicator developed by HSR.health
- Annex C.5 Wildland Fire Immersive Indicator Visualizations developed by Duality

The detailed technical information about each of these workflows can be seen below:

# C.1. Wildland Fire Fuel Indicator Developed by Ecere

## C.1.1. Introduction

As changes in climate can exacerbate the risk of wildfire ignition, understanding the factors that form a catalyst can empower emergency responders and policymakers with knowledge of how to better manage them. Vegetation fuel type is one such predictive factor, on the basis that certain types of vegetation may spread fire more intensely than others. Using imagery and prediction modeling, it is possible to create classified images that illustrate risk and allows policy makers to prepare for it.

## C.1.2. Description

Ecere developed a Wildland Fire Fuel Indicator workflow that generates vegetation fuel type classification, using Machine Learning (ML) training and prediction, which signifies the type of vegetation organized such that each type contributes to the spread and intensity of fire in particular ways.

It takes as an input Sentinel-2 satellite imagery from ESA for the region of interest, and uses a ML model trained on US Fuel Vegetation types to generate a gridded coverage of a vegetation type classification; ten high level vegetation types are used to reduce the complexity of the modeling. In the Figure C.1, the output is shown for Fish lake in Utah.

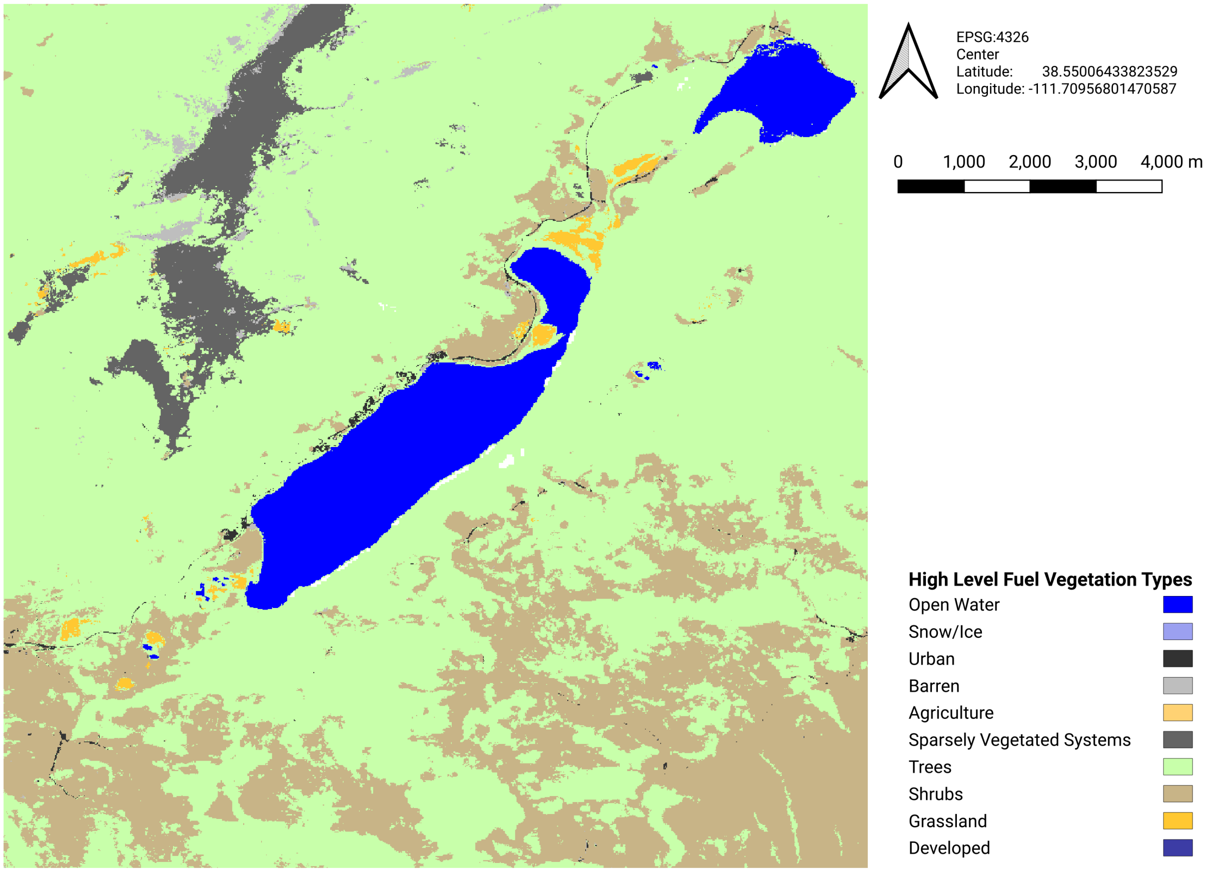



**Figure C.1** — Wildland Fire Fuel Indicator Workflow -
Predicted high level fuel vegetation types (Fish Lake, 2022)

In addition, the high level vegetation types are the mapped to an estimated fuel density. This is specified in the fuel density workflow. Using the Vegetation types identified in Figure C.1, this workflow produces a map of the fuel density for the Fish Lake area as in Figure C.2.

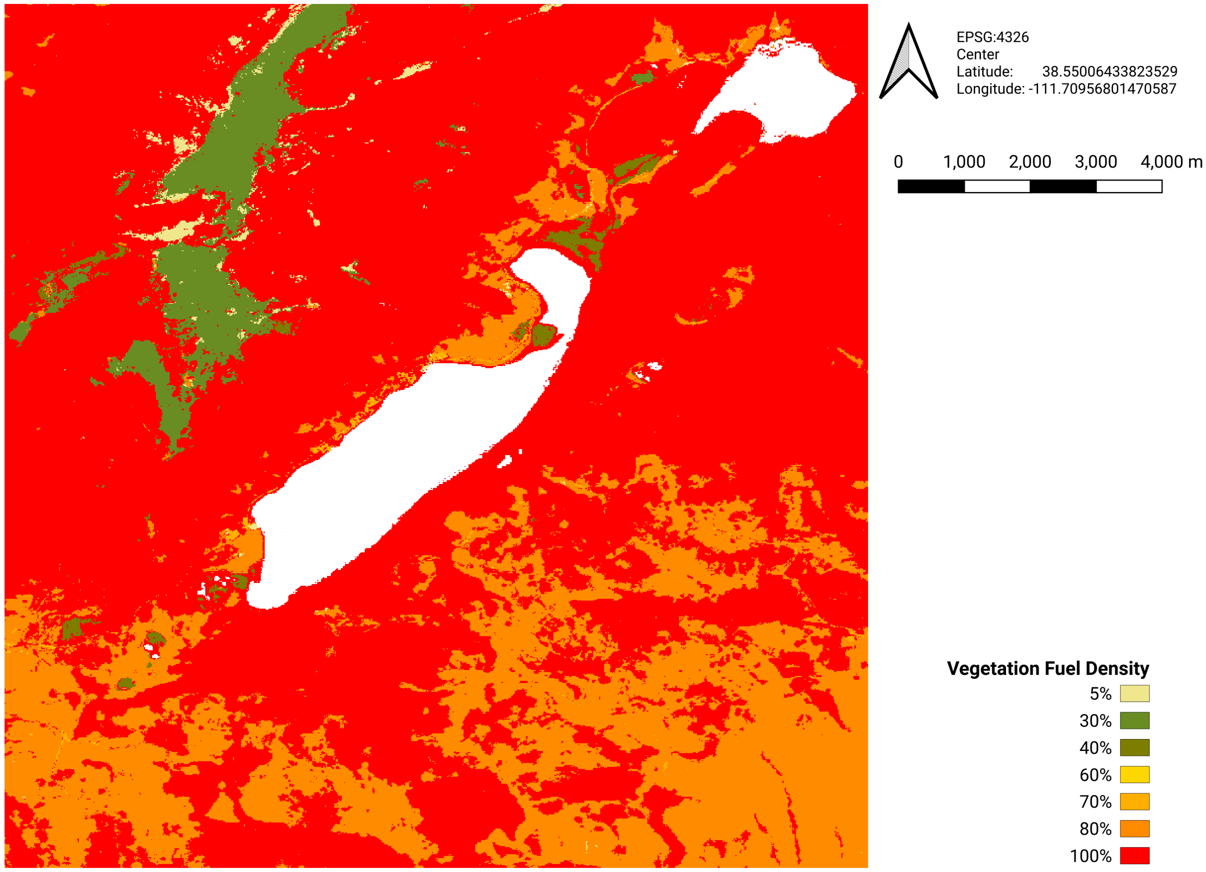



**Figure C.2** — Wildland Fire Fuel Indicator Workflow
- Mapping predicted vegetation types to fuel density

The demonstrator is available at:

- Predicted high level fuel vegetation types
- Secondary Predicted fuel density for vegetation types

The demonstrator is set up to use global products, however, it is likely to be more accurate in the area used for training the modeling around Fish Lake, Utah and Mount Adams, Washington. When using the demonstrator, a specific year and region of interest will need to be selected and the indicator will be calculated. This process will trigger classification modeling using existing training data from vegetation fuel types to generate a classified image.

In addition to this specific indicator, the demonstrator also offers several other datasets relevant to wildfire spread, including climate data such as temperature and precipitation, as well as derived fire danger indices

### C.1.3. Benefits

This Wildland Fire Fuel Indicator will allow users to better ascertain risk of wildfire spread in a given area, allowing them to make informed decisions.

### C.1.4. Collaborations

Ecere collaborated with several other DP23 participants by providing this indicator as a potential input for other workflows, as well as the Sentinel-2 and climate datacubes.

## C.2. Wildland Fire Ignition Risk Indicator Developed by Compusult.

### C.2.1. Introduction

Increased temperatures alone do not necessarily mean that more fires will occur; several other climatic and non-climatic factors are also involved, such as ignition sources, fuel loads, vegetation characteristics, rainfall, humidity, wind, topography and landscape fragmentation.

### C.2.2. Description

Compusult developed a processing service compliant with OGC Standards to identify fire ignition risks in areas specific to the scenarios.

Users provide inputs to the processing service to detail the area of interest and date at which they want the fire risk evaluated. The processes are configurable to allow transparent running of external libraries that will analyze data sources to provide past, present and future output.

The processing service reaches into the data cube and extracts data from the following drivers:

- Normalized Difference Vegetation Index (NDVI)
- soil moisture
- relative humidity
- wind speed
- temperature
- precipitation

## C.2.3. Benefits

Using this data, the risk of fire in the selected area at the given time is determined. This can be seen Figure C.3 showing the fire risk in Western USA on 22 October 2020, where the higher the concentration of red, the higher the fire risk in that area.

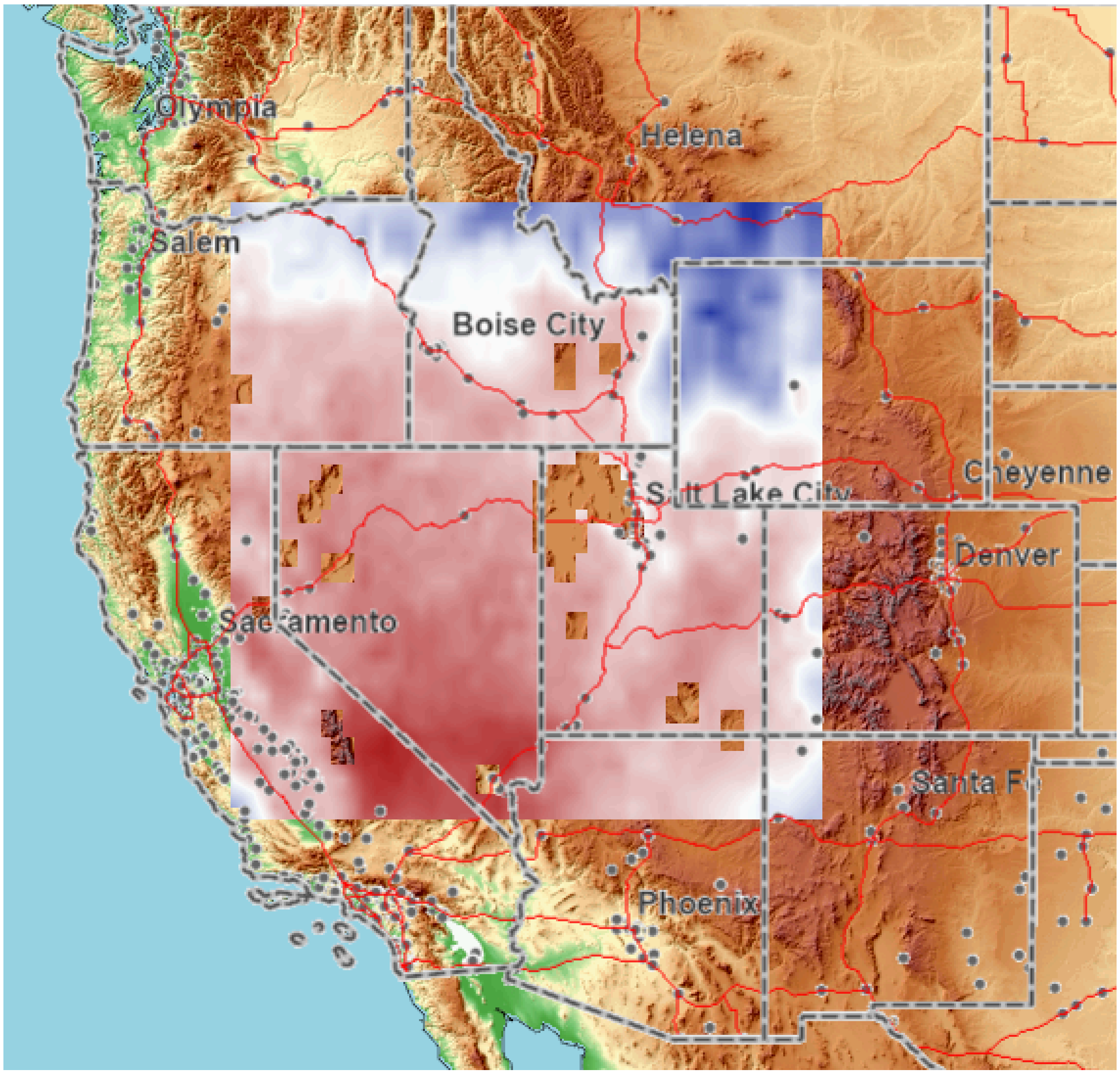



**Figure C.3** — Fire risk for Western USA on October 22, 2020.

Various inputs are required to determine the risk, and these risks can be determined individually, as shown in Figure C.4 for the same date as above. Again, the higher the concentration of red, the higher the fire risk in that area for that element.

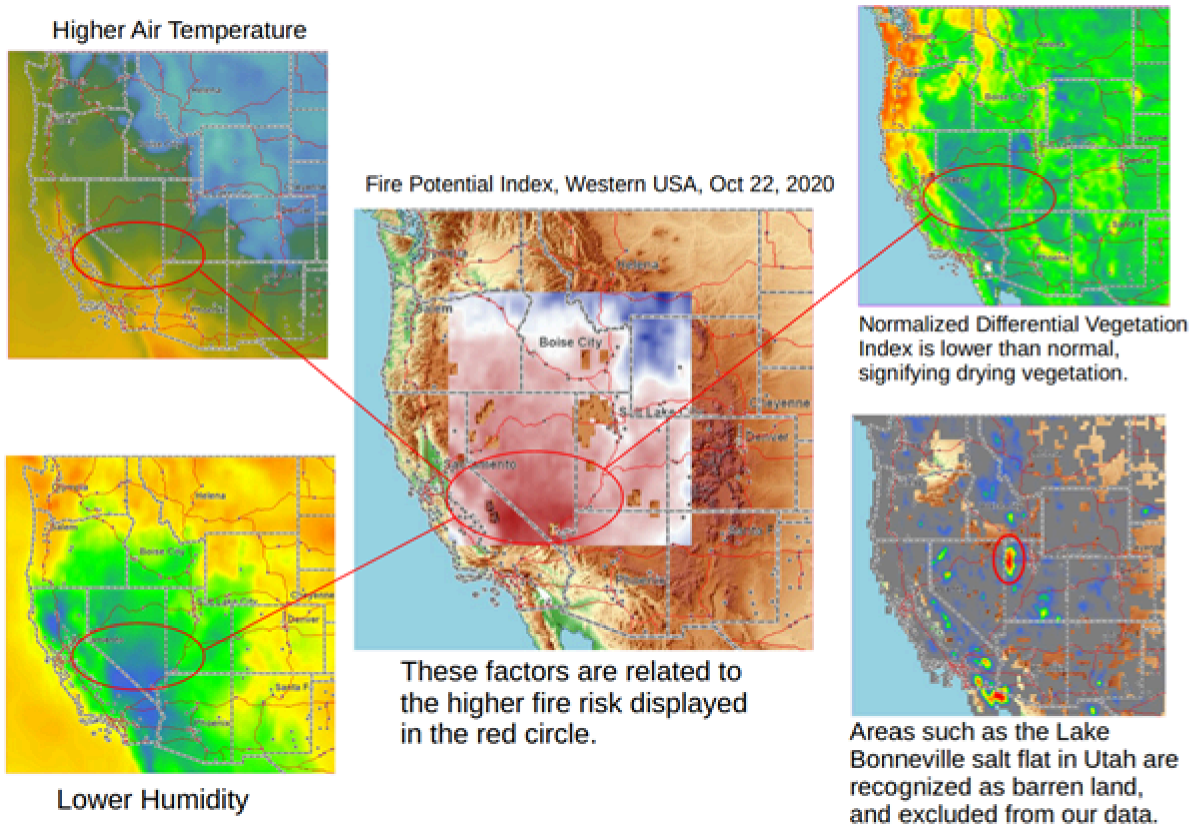



**Figure C.4** — Fire risk for Western USA on October 22, 2020 broken down by specific characteristics.

## C.3. Wildland Fire Evacuation Indicator Developed by Skymantics Europe.

### C.3.1. Introduction

This data workflow allows the emergency manager to organize evacuation plans for populations affected by wildfires. It includes relative priority of neighborhoods to be evacuated, and specific navigation or evacuation instructions.

### C.3.2. Description

The need for an evacuation indicator arises from the fact that populated areas affected by a wildfire are not all equal in terms of vulnerability or time to evacuate to safety. Evacuation agencies require some information about the demographics and geographical distribution of the population area to quantify the impact of a wildfire, assess evacuation challenges, and organize an ordered evacuation that optimizes the use of available roads. This was especially visible during the Maui wildfire in 2023 when evacuation operations failed mostly due to a lack of understanding of the population exposure to wildfire, available capacity in evacuation routes after blockades, and knowledge of population behavior and constraints on the ground.

This workflow computes aggregate evacuation plans of population areas in the vicinity of a wildfire (potential or declared) and indicates evacuation needs and priority based on the vulnerability and geolocation of the population areas (neighborhoods). This workflow supports the assessment of population risks derived from wildfires, taking into account the evacuation route alternatives and the intrinsic health risks of the population.

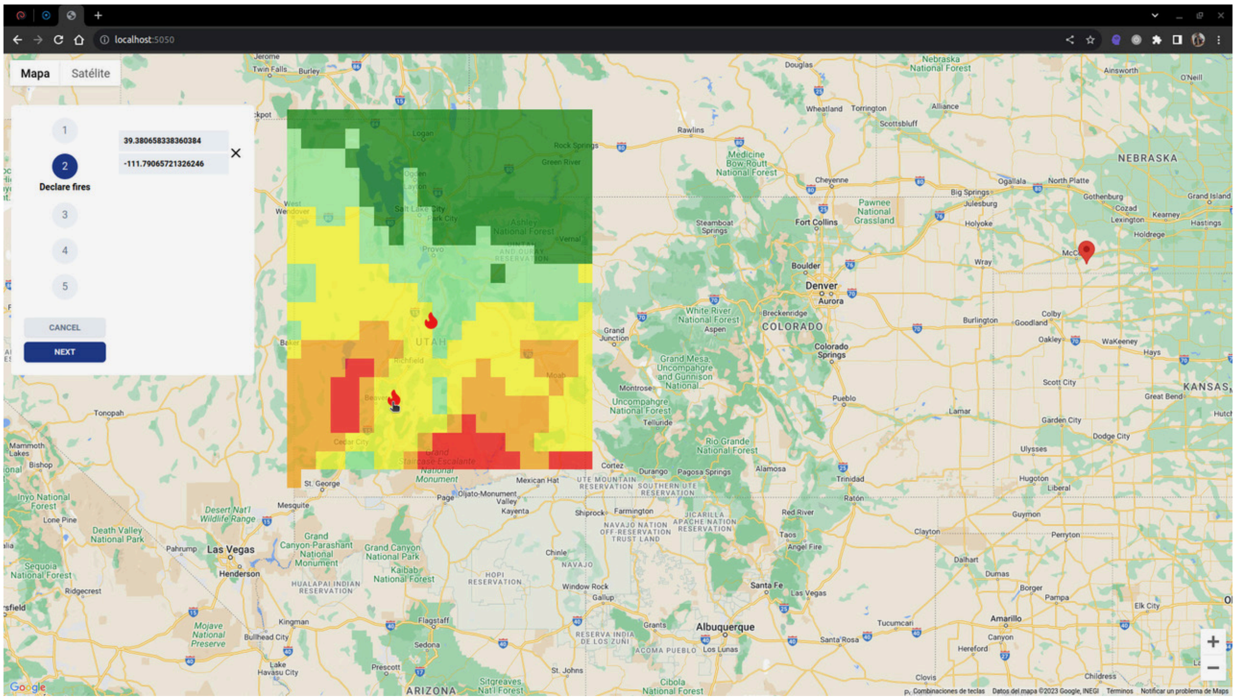



**Figure C.5** — Web client showing fire exposure and vulnerability areas

## C.3.3. Benefits

This workflow can benefit the disaster and emergency response community in three aspects:

- It has a customized level of granularity in the picture of the population to be evacuated from a wildfire. Thanks to synthetic data generation, population areas can be described demographically realistically without the use of personal sensitive information. The scale and level of granularity can be adapted and still maintain statistical accuracy. This allows for emergency agencies to describe demographically affected neighborhoods in their area, as long as demographic survey and statistics data are available. In turn, this localized granularity allows us to take into account differences in population characteristics and vulnerability to wildfires to prioritize and organize an ordered evacuation plan. Note that some emergency agencies are data authorities with full access to personal information of citizens, which allow for disaster preparedness and response based on real data. However, when it comes to collaborating with other emergency stakeholders that are not data authorities (e.g., medical sciences, transportation agencies, citizens) this becomes a barrier as personal records cannot easily be shared. This is where synthetically generated populations are extremely useful to fuel collaborative analysis.

- Organize strategic evacuation plans before wildfires are declared, taking into account probabilities of fire ignition and spread. Then, the same model allows the organization of tactical evacuations once a wildfire is declared in a specific location. This duality allows emergency agents to test how strategic planning works in specific scenarios of actual wildfires.

- Try different evacuation scenarios with varying assumptions. The underlying models to calculate fire exposure, population vulnerability, and evacuation routes allow data exchangeability. For instance, a different dataset defining fire spread rate or demographics can be replaced, which can be used to recalculate the evacuation plan. This allows for searching optimal solutions, such as improving evacuation routes, clearing out vegetation, or relocating population, to minimize vulnerability to wildfires. Scenarios developed this way can build a baseline for tabletop exercises to train coordination and response in a variety of situations among stakeholders

The key information provided to decision-makers is a demographic baseline of population areas affected by wildfires. Therefore, it is possible for emergency managers to assess vulnerability and plan evacuations accordingly. There are two scenarios for emergency managers to establish evacuation plans — Strategic & Tactical:

- **Strategic** — This scenario can inform agencies what areas are most exposed to wildfires generally, for planning purposes. They can consequently act upon the root causes by decreasing wildfire exposure, improving evacuation routes, or proposing changes to the demographic distribution. The strategic scenario has the goal to generate static indicators that do not vary with time evolutions, but are rather scenario-based (i.e. indicators change with varying conditions of the scenario of analysis, such as a newly declared fire, or a change in the road network). There are three types of decisions supported by this workflow:

  - *Decrease wildfire exposure.* Informs emergency agencies of population areas with highest exposure to wildfire, in terms of time to be exposed. This information, together with the spread index and some external indicators (e.g., fuel density indicator) can help identify the forest areas that need action to slow down the spread of potential wildfires.

  - *Improve evacuation routes.* Indicates the time necessary to fully evacuate population areas, considering the mobility profiles of the inhabitants (e.g., vehicle ownership, disabilities) and the number and capacity of the evacuation routes available. This can inform authorities about a potential lack of adequate evacuation options to help build new road segments or improve existing ones.

  - *Inform population demographic shifts.* Directly inform about the intrinsic health vulnerability to wildfires suffered by the inhabitants of each population area, based on their demographic attributes. This information can be useful to plan for potential demographic shifts in the population, or public plans (e.g. building health centers), which may modify the level and type of vulnerability.

- **Tactical** — In this case, there is a declared fire in the vicinity. This scenario supports tactical execution of evacuation plans, in the form of prioritization of population areas to be evacuated, quantification of evacuation time, and special instructions to be applied to certain areas due to specific population vulnerabilities. The tactical scenario is implemented similarly to the strategic scenario, however, it allows for dynamic change of the inputs based on sensing information or user inputs. The update rate of the indicator depends on the change rate of input data, which could be daily, hourly or less (quasi-real time or real-time). Note that due to the higher scale of real-time disaster generated data from sensors and observations, the design of storage and processing capacities, and data cataloging requirements, need to be properly dimensioned. There are two types of tactical decisions supported by this workflow:
  - *Address route capacity constraints*. Emergency managers can identify potential route bottlenecks that require action, e.g., traffic congestion or crossings. By identifying unusually high expected evacuation times for certain population areas, managers can dispatch traffic agents to the field to implement changes in the road configuration (e.g. using all lanes in one direction) or ensure smooth traffic in highly congested segments.
  - *Apply special instructions*. Identifies demographic and vulnerability profiles of inhabitants per area, and can generate special instructions driven by specific attributes observed in the population of the area, e.g., high proportion of the population belonging to a specific cultural background, requiring translation or respect of cultural norms, or high proportion of elderly, disabled or population without a vehicle, requiring dispatch of support vehicles.

### C.3.3.1. Users

In terms of who would use this indicator:

- Emergency managers require access to intermediate data indicators to understand how they combine to produce optimal evacuation plans under varying situations. The three actionable observations (fire exposure, time to safety, and vulnerability) inform the emergency manager about aspects to improve in the environment. It also allows the emergency manager to perform what-if scenario analysis by configuring variations of the environment that have a sensitivity impact on these indicators.
- Responder visualizes the evacuation plan to be executed – be it a firefighter squad to assist in a neighborhood evacuation, or an EMT team to send additional resources to a vulnerable area, or a traffic agent to ensure a change in road traffic directions to maximize capacity. They need information on where the population areas are to be evacuated, their level of urgency and priority, and special instructions, including evacuation routes to be followed. In addition, responder actions have effects on the environment (i.e., a change in traffic capacity, an observed blocked road, or a change in the spread index of wildfire), and thus they can input these changes into the workflow, for recalculation of evacuation plan.

This can be a useful tool during tabletop exercises to account for potential variations of wildfire scenarios and be prepared for special interventions.

- Affected public are informed about the same information as the responder via public dissemination tools. For the public, it is important to know when they need to prepare and leave, and which evacuation route they need to follow to safety.

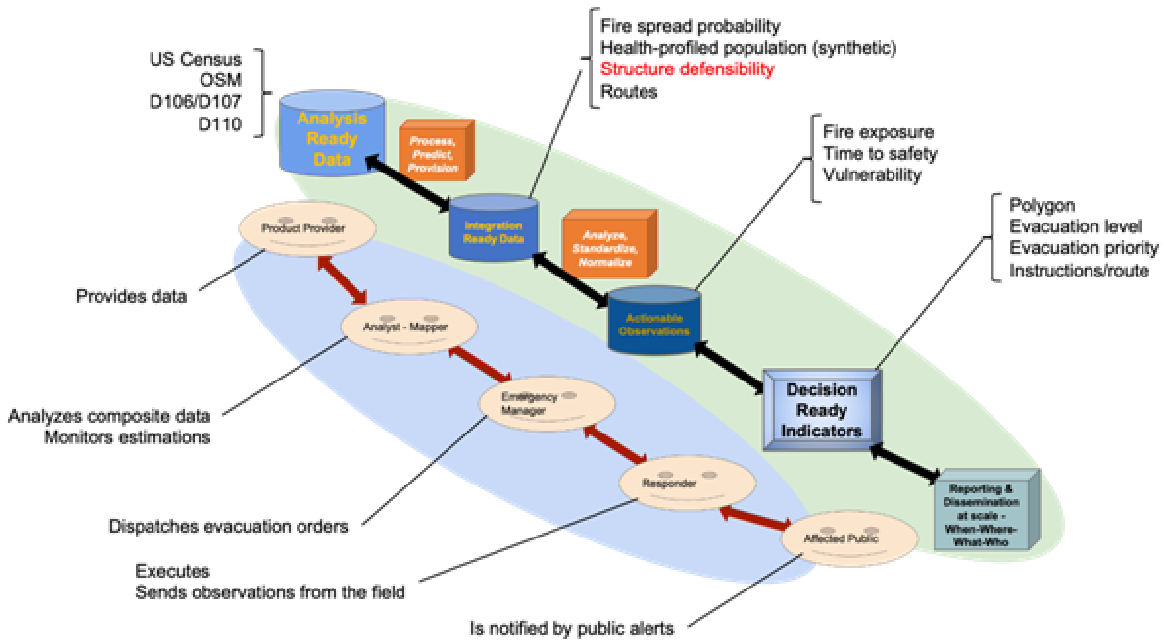



**Figure C.6** — Wildland fire evacuation indicator data & user chain

## C.3.4. Collaborations

In developing this indicator, Skymantics collaborated with several other DP23 participants, namely:

- Wildland Fire Health Impact Indicator Workflow developed by HSR.health, uses the demographic information at neighborhood/block group level to compute the health risk indicators for each area. These indicators then become attributes of the synthetic population representing each of the affected areas.
- Wildland Fire and Drought Immersive Indicator Visualization developed by USGS-GeoPathways can use the Decision Ready Information and indicators (DRIs) as inputs to visualize.

It is hoped that future collaboration can include working with Wildland Fire Ignition Risk Indicator Workflow to develop an indicator that shows the fire ignition risk, but also the severity and spread of the fire edge, in real time. Consuming this in real-time would support tactical evacuation scenarios.

In addition, the Mobile Crowdsourcing Survey/Reporting Applications being developed could in the future evolve into a mobile app that allows first responders in the field to report observations such as blocked roads or new evacuation routes cleared. Consuming this in real-time would support tactical evacuation scenarios.

This is a link to the Wildland Fire Indicator Demonstrator.

# C.4. Wildland Fire Health Impact Indicator Developed by HSR Health.

## C.4.1. Introduction

Wildland fires affect thousands of people every year in the United States. It is important to understand where vulnerable populations are in fire-prone areas and in areas in the direct path of a current wildland fire. HSR.health is producing a Wildland Fire Health Risk index that identifies the vulnerable populations by combining population characteristics with health conditions.

By having this information available a priori to future wildland fires this can help speed the response and evacuation efforts by providing emergency response managers and first responders additional information to help inform their response effort.

## C.4.2. Description

The Drought Health Risk Index used data on demographics, health conditions and wildland fire extents and risk data to calculate the Wildland Fire Health Risk Index.

Figure C.7 shows the overall workflow used to create and distribute the Wildland Fire Health Risk Index, which identified where at-risk populations exist across the drought-affected areas.

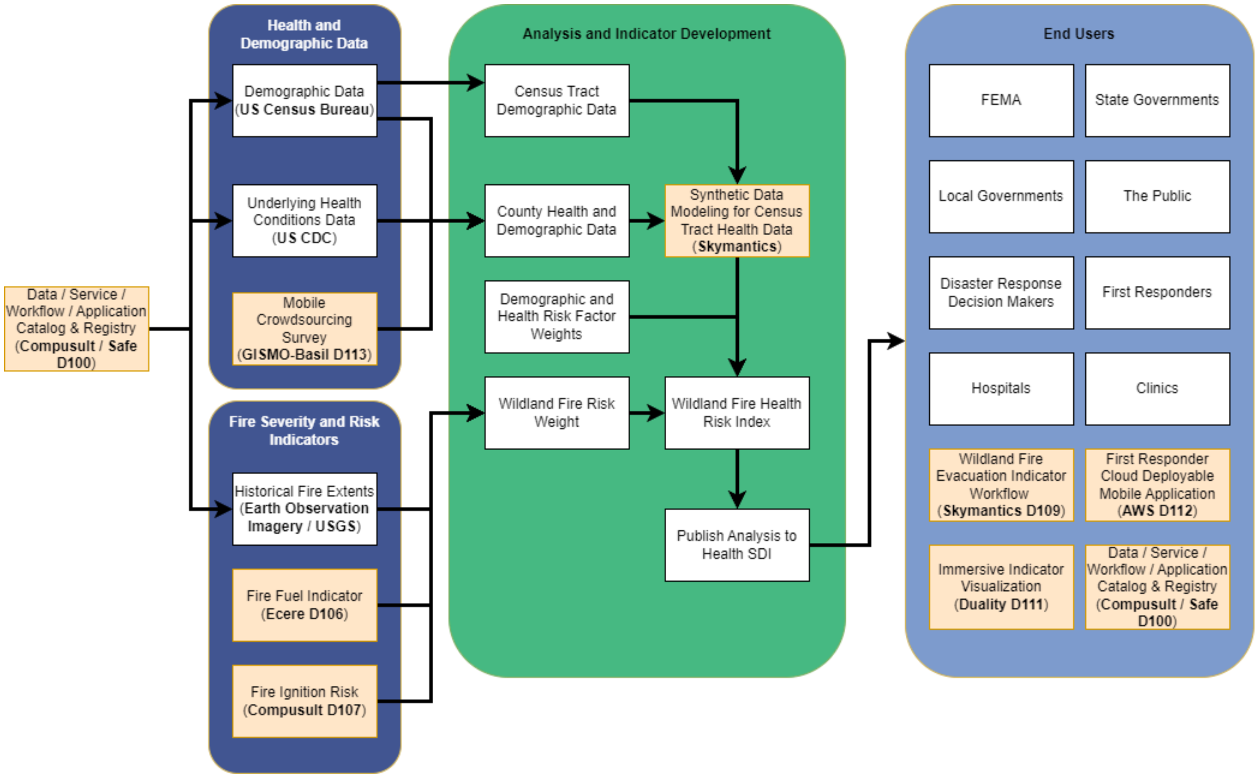



**Figure C.7** — Wildland fire health risk indicator collaborations & workflow

The primary data inputs for the Wildland Fire Health Risk Index were demographic data, health condition data, and data on wildland fire severity and risk. The demographic data comes from the US Census Bureau, the health condition data comes from the US Centers for Disease Control and Prevention, and the initial wildland fire severity and risk data comes from the US Geological Survey. The target granularity for the Risk Index was the Census tract administrative level for the United States. The demographic data was available at the Census tract level however, the health conditions data was not. So, HSR.health working with Skymantics to develop a synthetic data model to estimate the Census tract level prevalence for the underlying health conditions data.

The Wildland Fire Health Risk Index calculation combined two primary components: the vulnerability of the underlying population and the wildland fire risk. The population vulnerability risk was a combination of health and demographic factors through a combined risk weighting analysis that provides a priori information on where vulnerable and at-risk populations are. Some of the factors included in the vulnerability risk include: Age, Disability Status, Transportation Access, Fluency, Low Income, Dialysis Dependent Populations, COPD, Asthma, and more. The weightings for each factor were determined through input from the public health team, published research, and internal analysis. The wildland fire risk weighting component of the index was determined through a combination of historic fire extents. The risk index weight can be augmented with the indicators for Fire Fuel and Fire Ignition Risk from Ecere and Compusult, respectively.

An example output of the Wildland Fire Health Risk Index Drought Dashboard can be seen in Figure C.8.

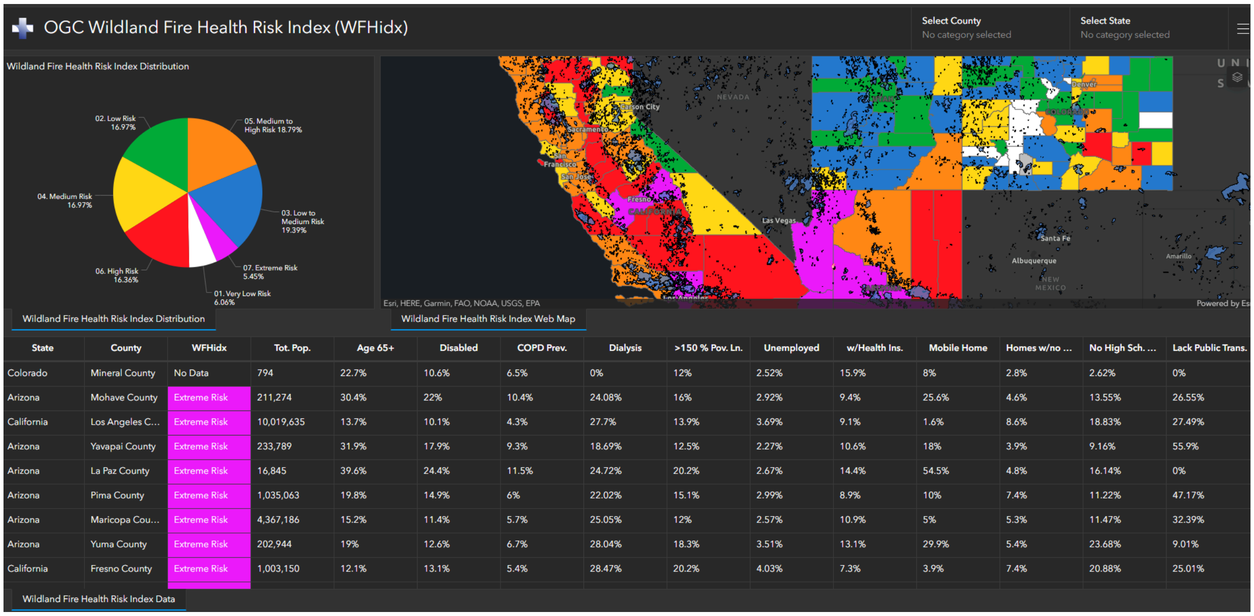



**Figure C.8** — Wildfire health risk indicator drought dashboard

## C.4.3. Collaborations

- **Who does this help?** — HSR.health's goals of participation as related to stakeholders is to create mechanisms to inform the public, local residents, disaster response organizations, and state governments of health and social conditions on the ground a priori to aid in their response to disaster scenarios.

  The aim is to inform governmental organizations, disaster response personnel and decision makers, Community and Aid Organizations, medical personnel, along with local residents and the public of the health and social conditions on the ground to aid in response and relief efforts in wildland fire affected areas.

- **What decisions are supported by this indicator/tool?** — End Users and stakeholders can utilize the data and analysis presented to understand where vulnerable populations are and how to create policies and relief plans to respond to, and alleviate the impact of, wildland fire-affected populations.

- **Details of job roles that would use this data?** — The job roles that might use this information include a DRI Analyst and a DRI Decision Maker.

## C.4.4. Collaborations

HSR.health collaborated with Ecere, Compusult, and GISMO-Basil Labs as data inputs for the workflow, and with Skymantics, AWS, and Duality, who ingested the output from the risk index. Finally, collaboration with Compusult and Safe was to explore and demonstrate interoperability between the data catalog that they are developing for DP23 and the Health SDI.

- **Details of Persistent demonstrators** — HSR.health's goal of participation in DP23 is to provide visibility into and persistent demonstrators of health information in the disaster response ecosystem.

  The persistent demonstrators will be available at: https://opengeomd.hsrhealthanalytics.org/#/

## C.5. Wildland Fire Immersive Indicator Visualizations developed by Duality.

### C.5.1. Introduction

Many federal and state agencies, tribes, local land managers, and other stakeholders work together to manage wildland fires. Training, planning, and managing resources before, during, and after events are critical aspects of the strategies to combat them. The availability of past, real-time, and near-time data, together with their immersive visualization, and the simulation of various possible scenarios can immensely help stakeholders and decision-makers.

The work developed by Duality uses digital twin technology to provide a virtual representation of an area affected, or potentially affected, by wildfires. It allows different physical resource managers and data providers, including government agencies, companies, and research teams, to look at digital representations of the situation. It also allows them to share virtual details of their physical assets and decision-ready indicators (DRIs) in a structured and synchronous way within scenarios of interest.

This gives the stakeholders the ability to look at real-world problems through immersive visualization, collaboration, and training; synthetic data generation; and closed-loop simulation of complex systems and processes such as route planning for disaster evacuation, to enable them to be better prepared to respond to disaster situations. Duality's Falcon has been developed with exactly these kinds of multi-participant workflows in mind.

### C.5.2. Description

While individual scenarios, their functional needs and data objectives can vary widely, a shared digital twin catalog and the Falcon workflow combine these modular and reusable pieces in diverse ways to achieve various goals.

The goal for DP23 was to create a Digital Site Twin of the area of interest (with an area of around 8400 square km) and overlay it with decision-ready indicators (DRIs) generated by our fellow DP23 participants from Skymantics, HSR.health and Compusult. Duality would demonstrate how immersive visualization coupled with an intuitive user interface and navigation can help planners access and act on the data from various sources.

For DP23, Duality have extended Falcon's architecture for building Digital Site Twins to incorporate DRIs. These twins, which are reusable, can then be combined with a library of other digital twins representing terrain, vegetation, energy infrastructure, transportation networks, communication networks, drones, sensors, etc., to have limitless flexibility in defining the scenarios described above and others we have not considered.

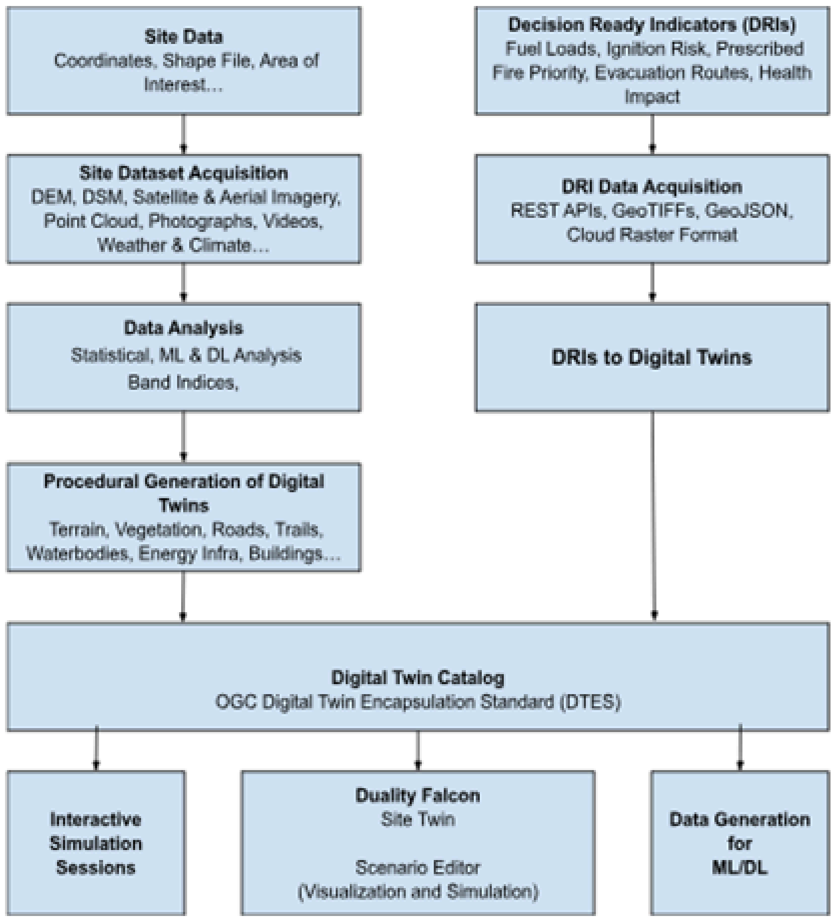



**Figure C.9** — Falcon's enhanced workflow maps showing how DRIs and Digital Twins can be combined to create a wide variety of scenarios for interactive visualization, planning, & validation.

For the DP23 pilot, we selected around 8,400 square km of area near Fish Lake, Utah.

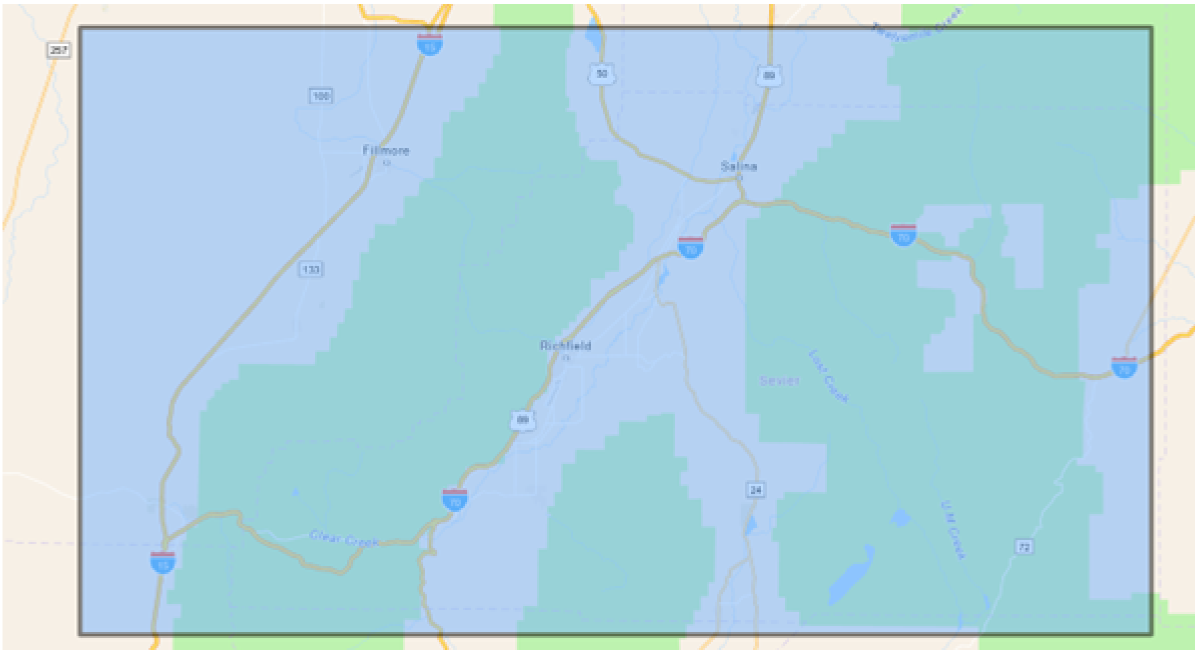



**Figure C.10** — Area of Interest (Fish Lake, Utah).

Falcon's Enhanced User Interface developed for DP23 highlights the use of multiple DRI's with an optional 30-day look. On starting the demonstrator the user is brought to Template screen, click once and it will fade. Click again and the User Interface will appear

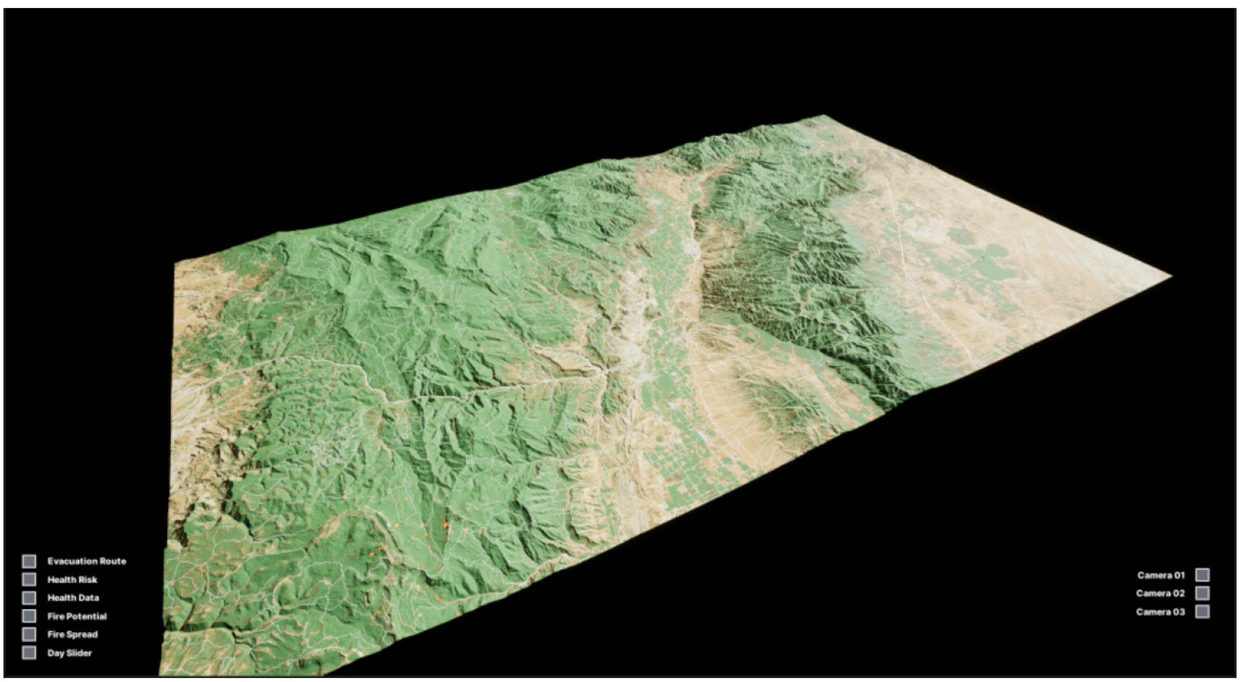



**Figure C.11** — Falcon's Enhanced User Interface with 30-day look and DRIs selection.

To look around the environment, user may use the mouse to orbit (right mouse) and pan (left mouse). While to move around the environment, while holding right mouse, user can use W, A ,S, D, Q, & E keys to move around on cardinal directions.

The DRI options within the demonstrator include:

- Evacuation Route
- Health Risk
- Health Data
- Wild Fire
- Fire Potential
- Day Slider

Examples of these DRI options within the User Interface can be seen below:

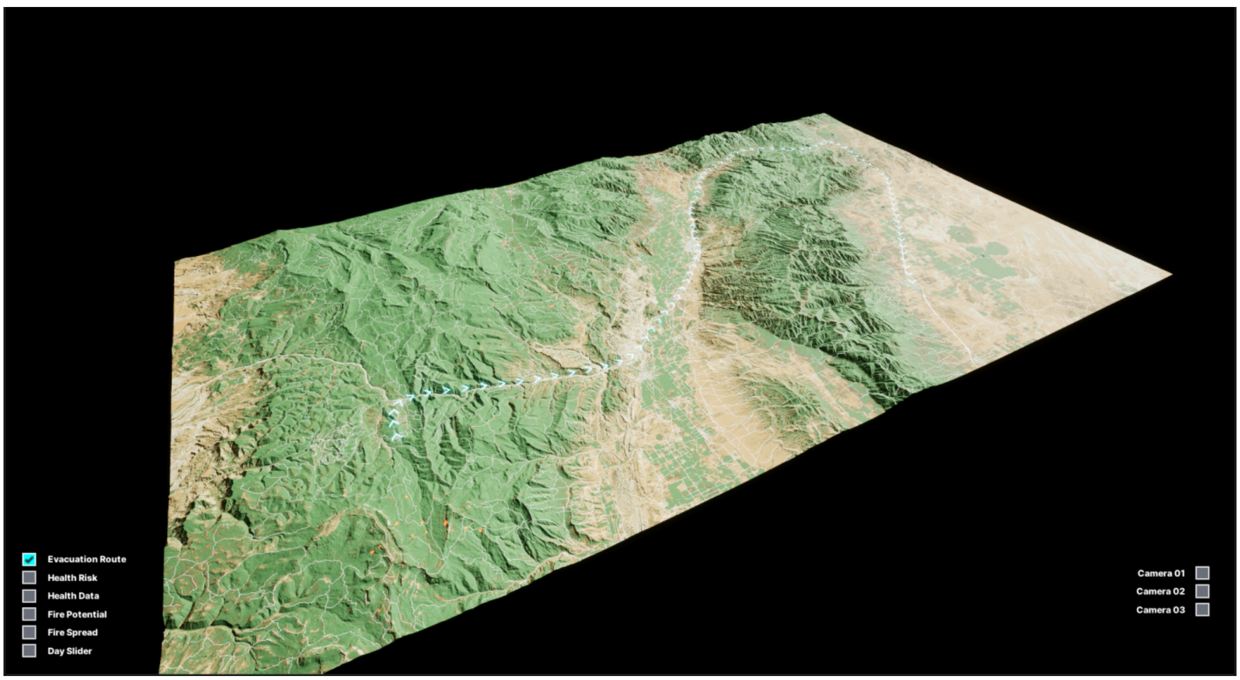



**Figure C.12** — Evacuation Route DRI overlayed on the Digital Site Twin.

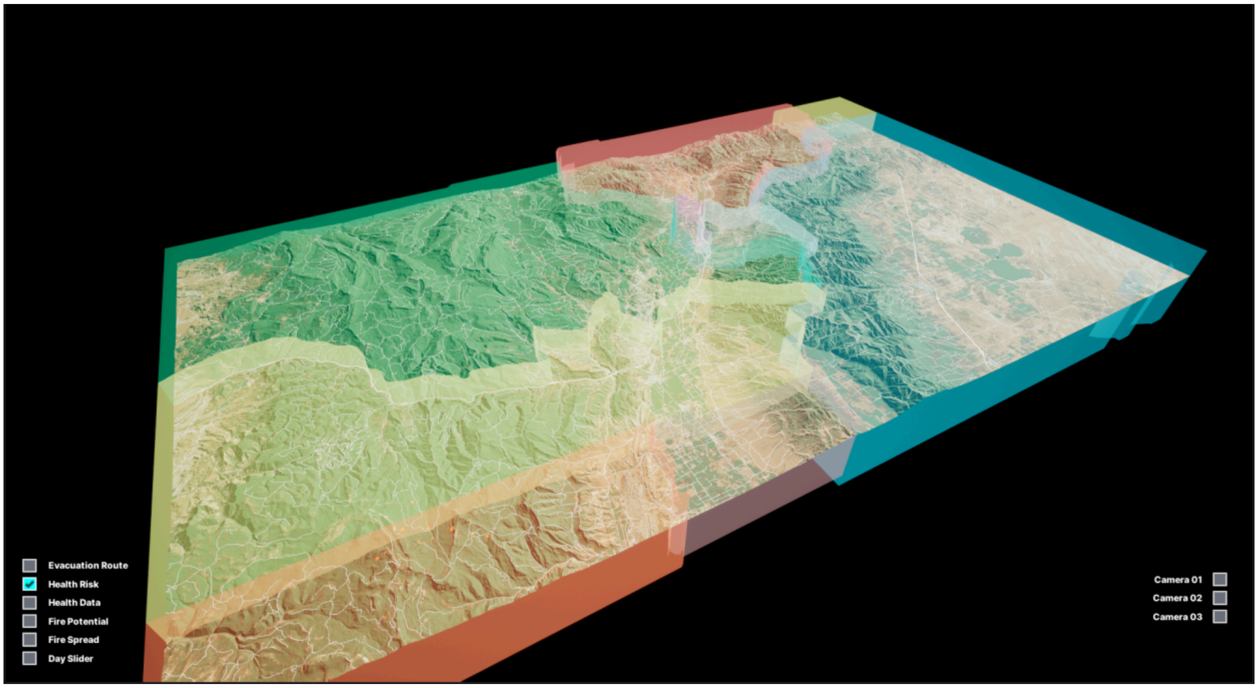



**Figure C.13** — Health Risk DRI per Census Tract. Extrusion height is proportional to the Health Risk Indicator.

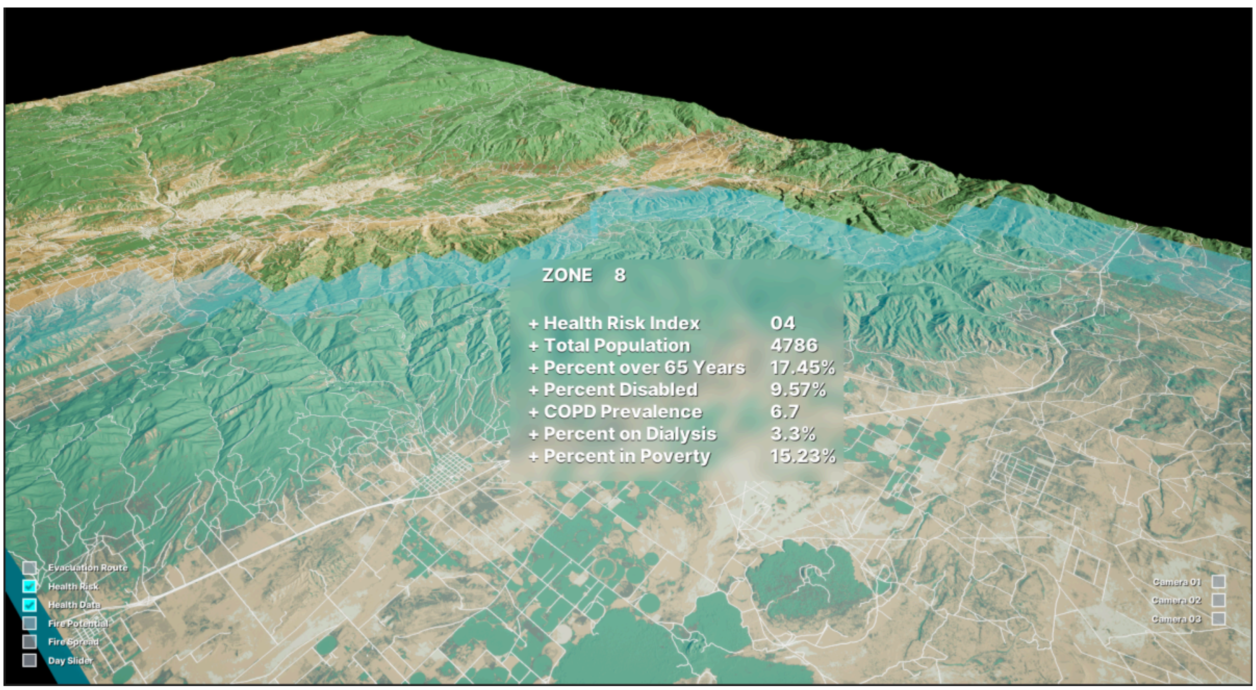



**Figure C.14** — Health Data per Census Tract.

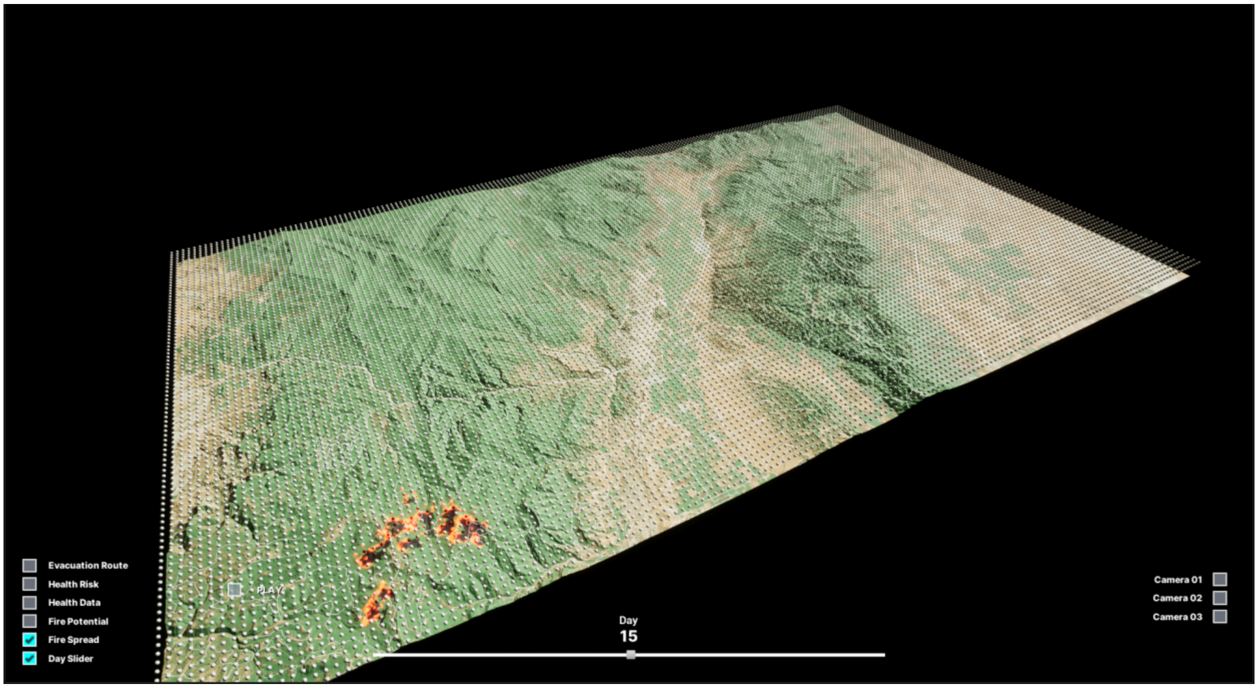



**Figure C.15** — Wildland Fire Visualization over a 30-day period.

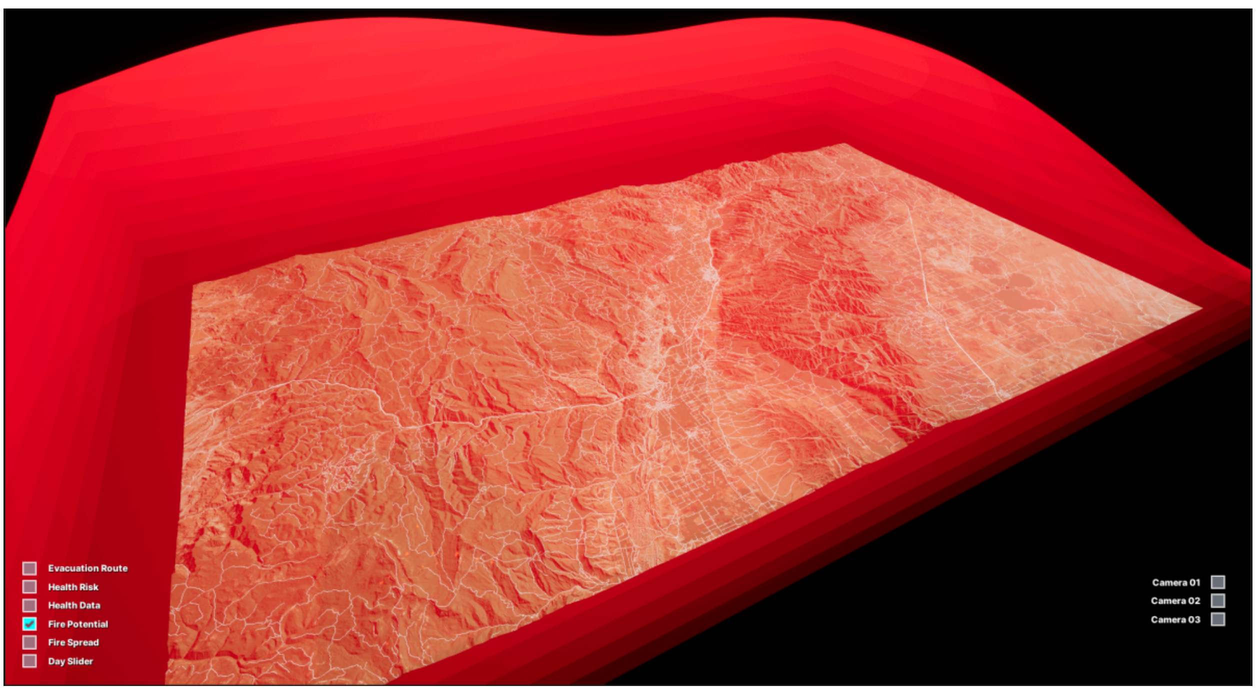



**Figure C.16** — Fire potential DRI overlayed on the Digital Twin Site.

In addition, there are a number of view Options separate from movement:

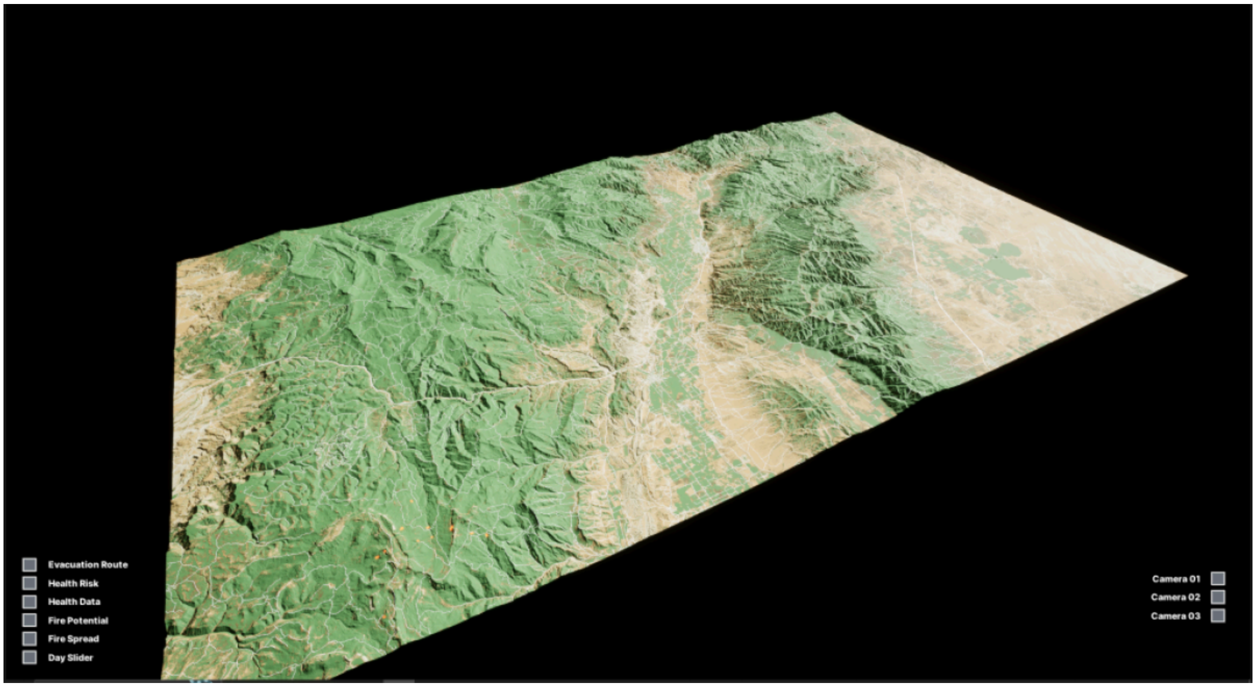



**Figure C.17** — Camera 1 for North looking South view and navigation

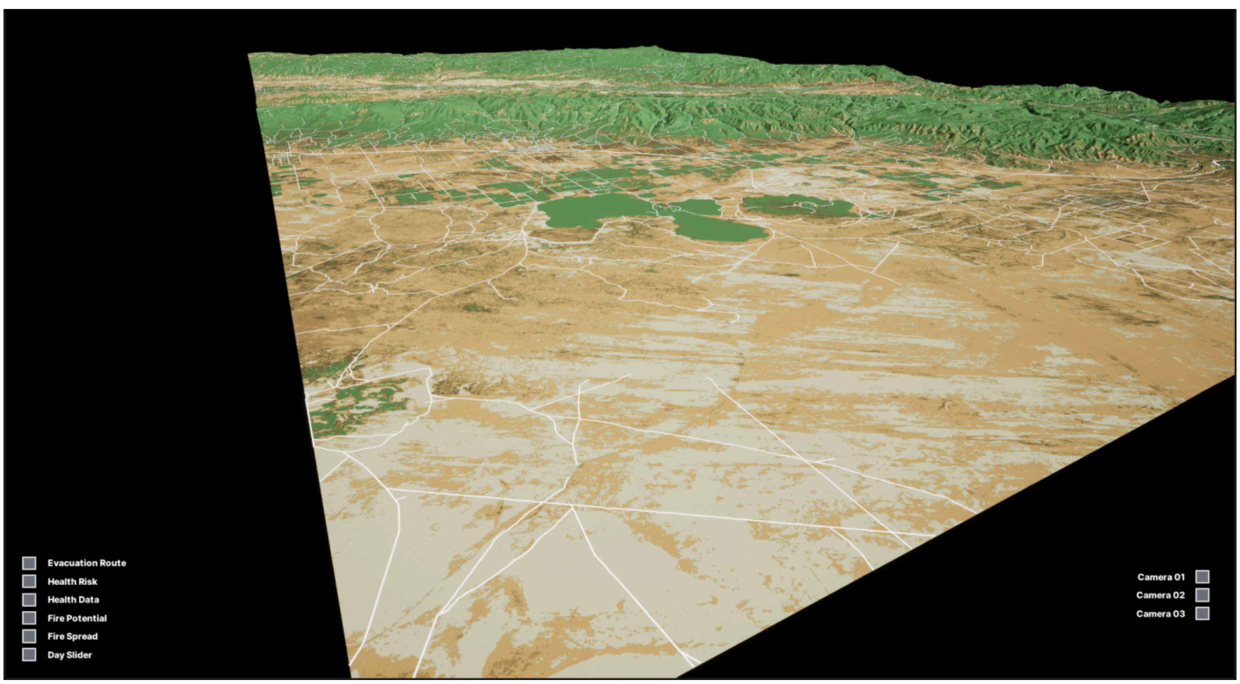



**Figure C.18** — Camera 2 for North West looking South East view and navigation

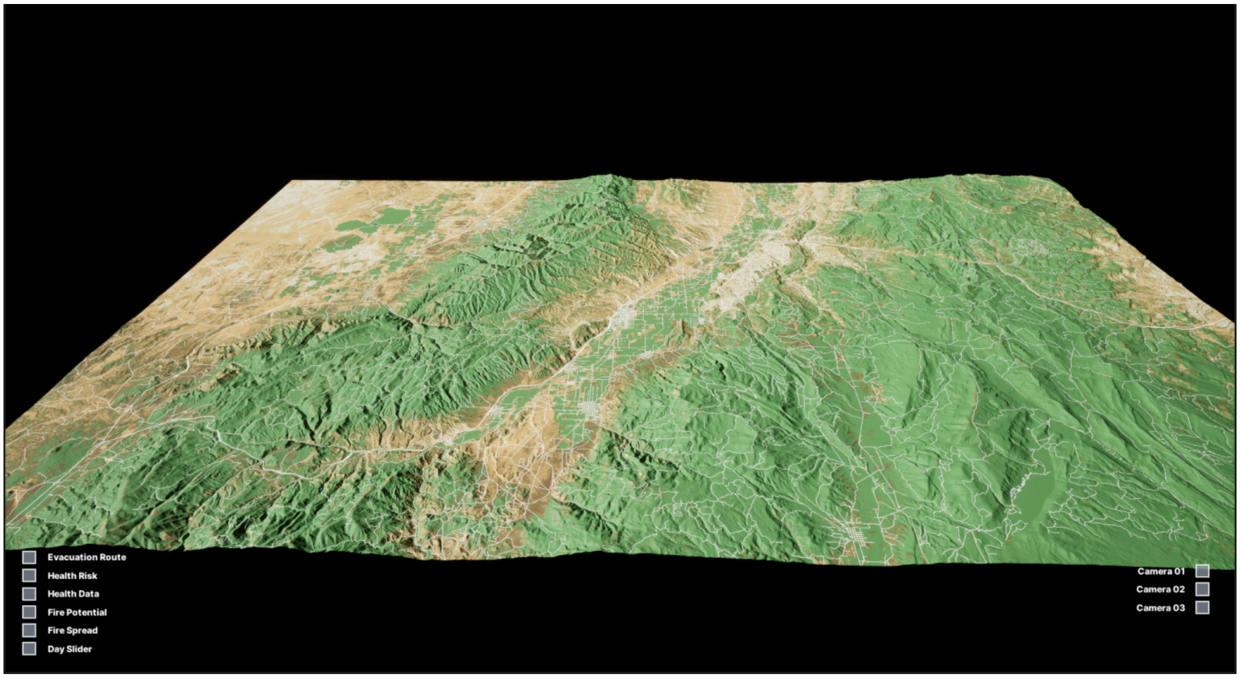



**Figure C.19** — Camera 3 for South looking North view and navigation

## C.5.3. Benefits

A geo-referenced Digital Site Twin of an existing location with immersive visualization, navigation, and ability to simulate various scenarios — opens many opportunities for federal, state & local government organizations, disaster response personnel, decision makers, aid organizations and citizens. Some illustrative examples:

- Immersive visualization for planners and command centers.
- What-if analysis over short and long horizons to evaluate competing strategies.
- Testing end-to-end deployment of workflows and disaster response that combine autonomous, semi-autonomous and human operated systems.
- Synthetic data to train AI-ML models for satellite and aerial infrastructure monitoring.
- Immersively training first responders.
- Educating the community at large by accurately turning data sources into accessible and visceral visual media.

## C.5.4. Collaborations

To overlay DRIs on the 3D Digital Site Twin for immersive visualization, Duality is working with Skymantics, HSR and Compusult. Duality worked with these participants to access the DRI datasets through the respective APIs. These datasets are then converted into the Digital Twins which in turn are managed by Duality's Falcon.

As part of DP23, following DRIs are supported:

- Wildland Fire Evacuation Indicator Developed by Skymantics.
- Wildland Fire Ignition Risk Indicator Developed by Compusult.
- Wildland Fire Health Risk Indicator Developed by HSR. == Flooding Workflows/ Capabilities developed under Disaster Pilot 21

# C.6. Flooding & landslide hazards within the Rimac and Piura river basins in Peru

The data and indicators reviewed, and developed, by the Disaster Pilot 21 (DP21) participants to provide specific information regarding the impact of, and potential impact of, flooding and landslides within the Rimac and Piura river basins in Peru were:

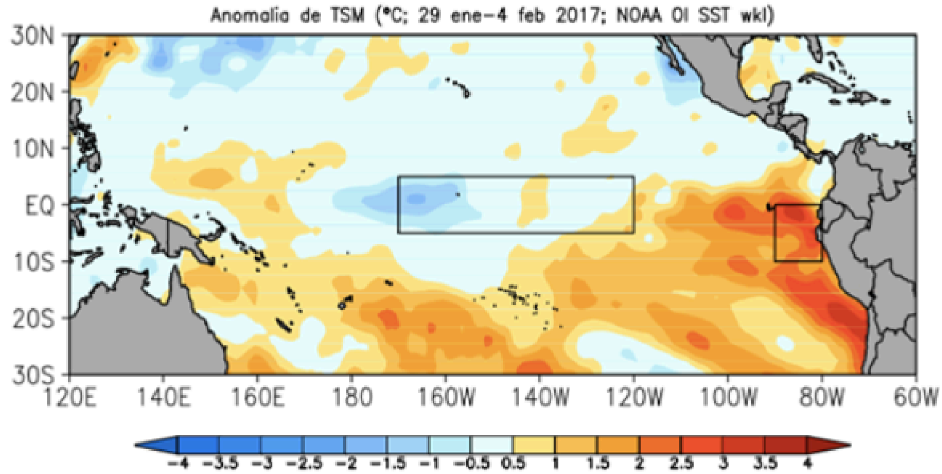
- Annex C.6.1 Flood-focused ARD & DRI to support decision-makers
- Annex C.6.2 Landslide events

## C.6.1. Flood-focused ARD and DRI to Support Decision-Makers

DP21 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 the 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 C.20. 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 have been 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 (1-4 km) and temporal (10-15 min, 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 C.20** — 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 also be 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 C.21 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.

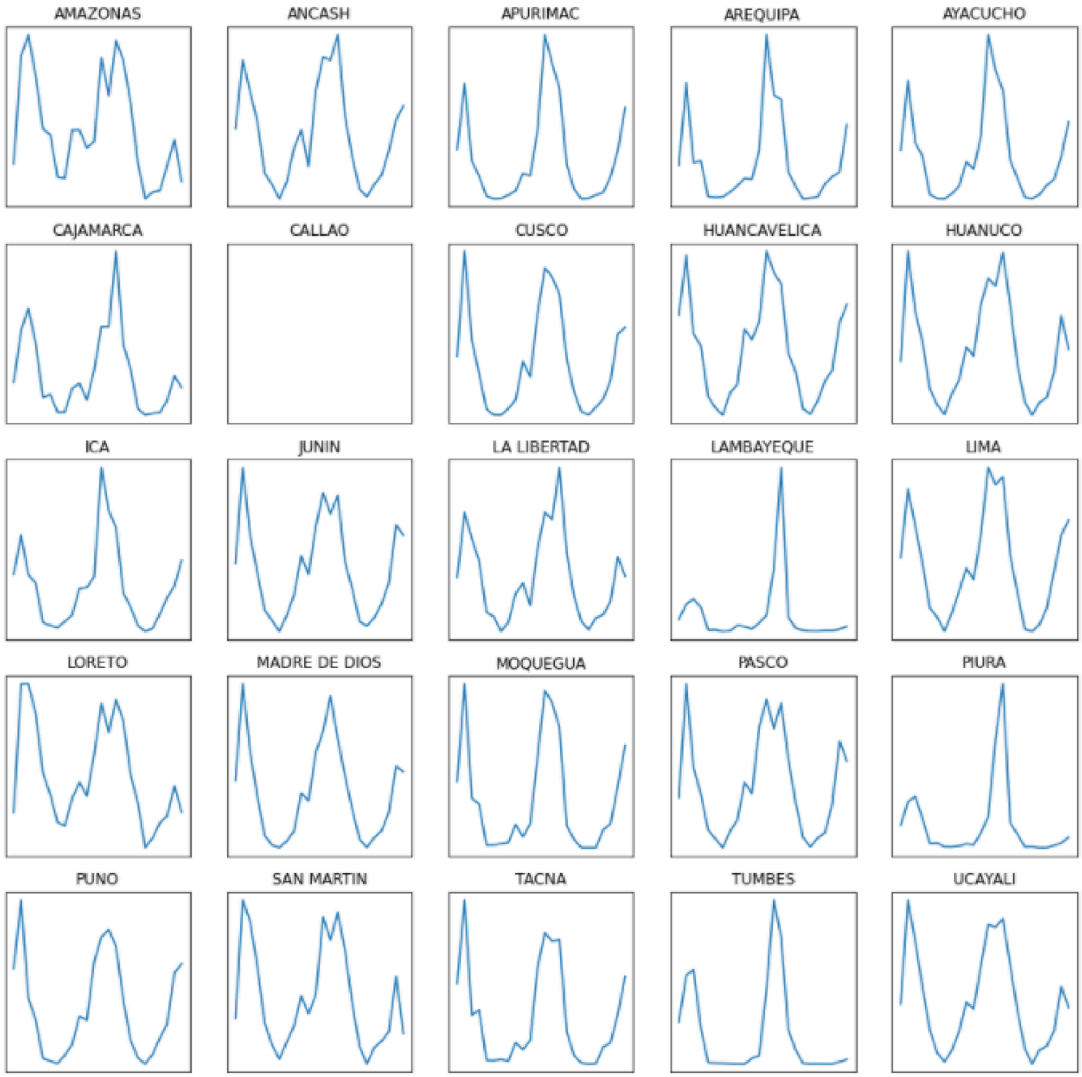



**Figure C.21** — Precipitation in different Peruvian regions 2016-2018; generated by SatCen.

- **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 C.22. However, its adequacy also depends 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 produces 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 bounces;
- In **urban areas**, due to the strong scatterers, it is difficult to detect flooding with SAR.


**Figure C.22** — Sentinel-1 (SAR) processed backscatter during the flood event 2017; generated by SatCen.

- Optical: As seen in some of the examples, Figure C.23, 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.

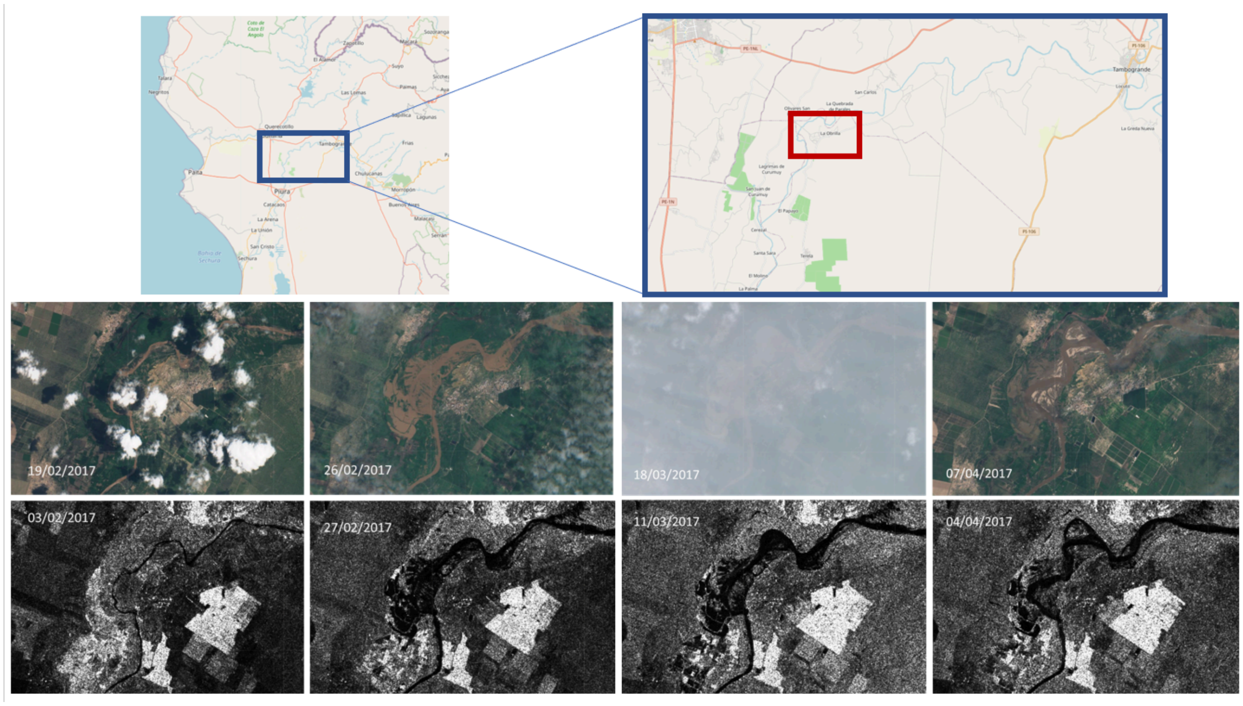



**Figure C.23** — Sentinel-1 (SAR) and Sentinel-2 (optical) during the flood event 2017; generated by SatCen.

- **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 were more greatly impacted by flood events. Several approaches for detecting changes in SAR imagery are proposed:

  - Amplitude Change Detection (ACD), see Figure C.24: An RGB composite of the backscatter of two images before and after the event, which highlights the flooded areas and are visually more straightforward to understand than raw SAR amplitude images.

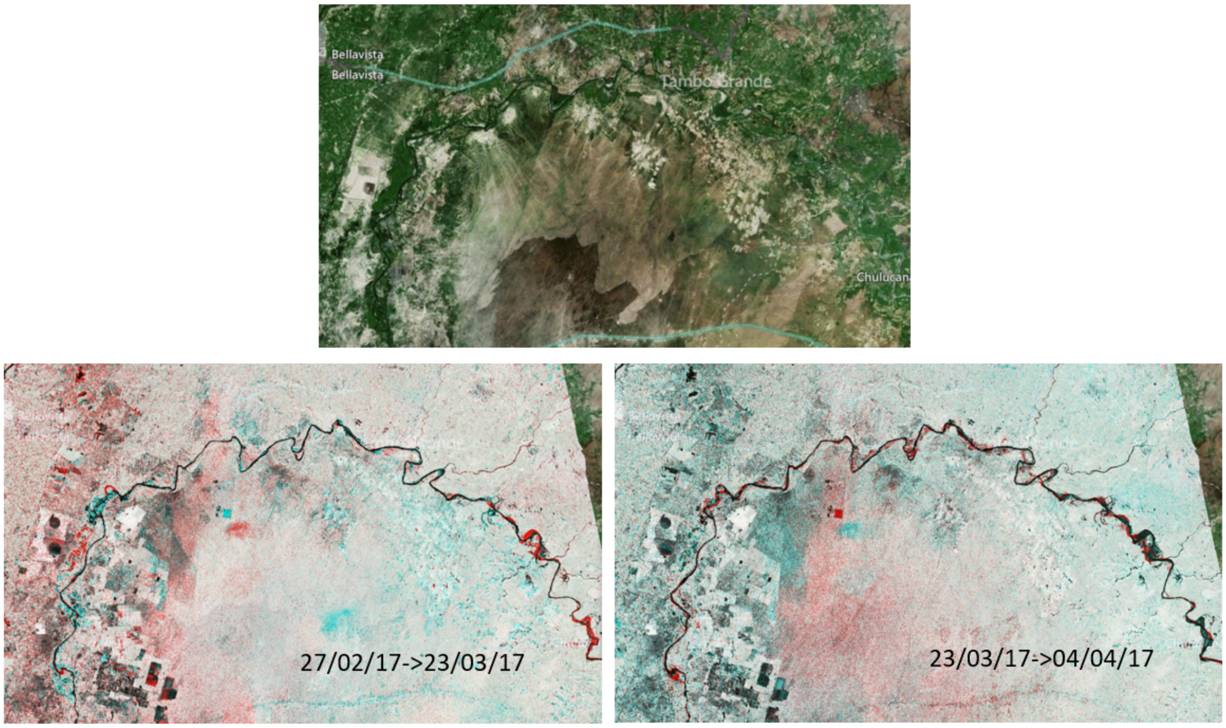



**Figure C.24** — Example of ACD products generated with Sentinel-1. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- Multi-Temporal and Coherence (MTC), see Figure C.25: 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)). 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.

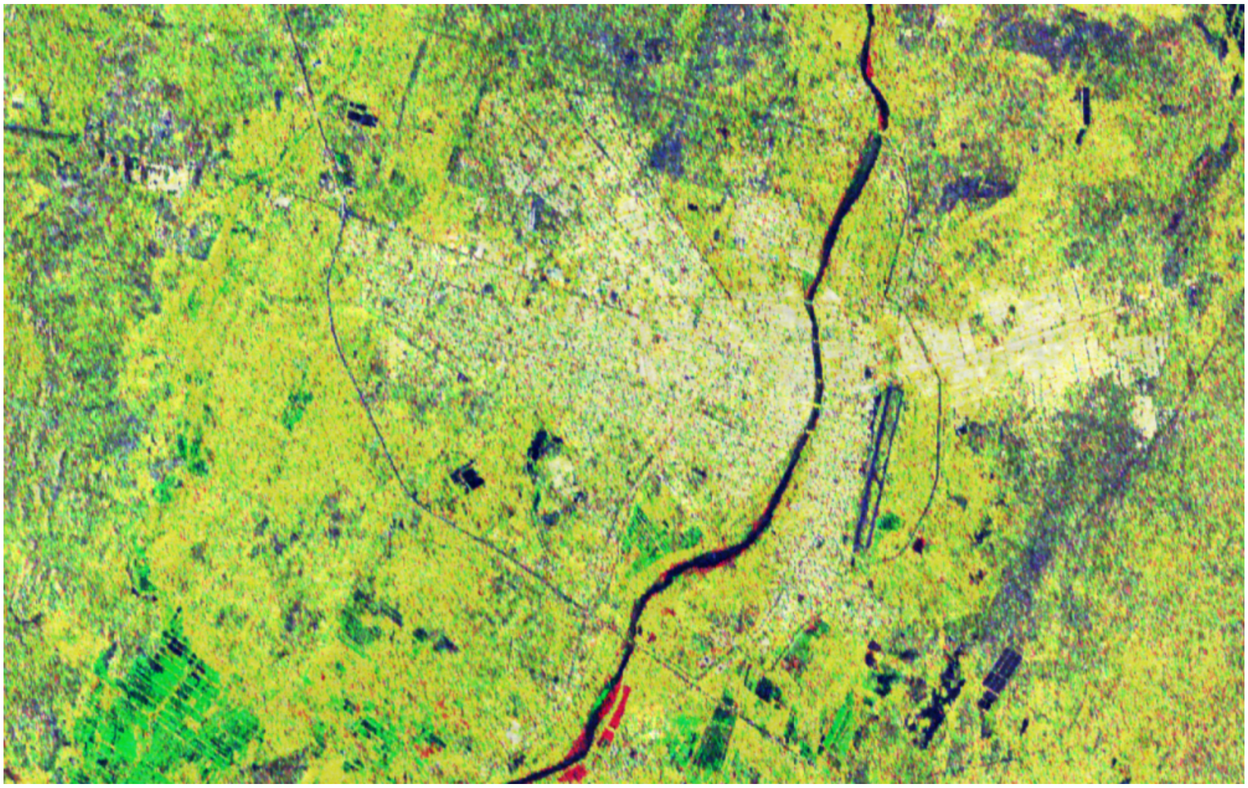


**Figure C.25** — Example of MTC product generated with Sentinel-1 over Piura. Red areas close to the rivers highlight the flooded area during the period; generated by SatCen.

- **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 C.26. 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.

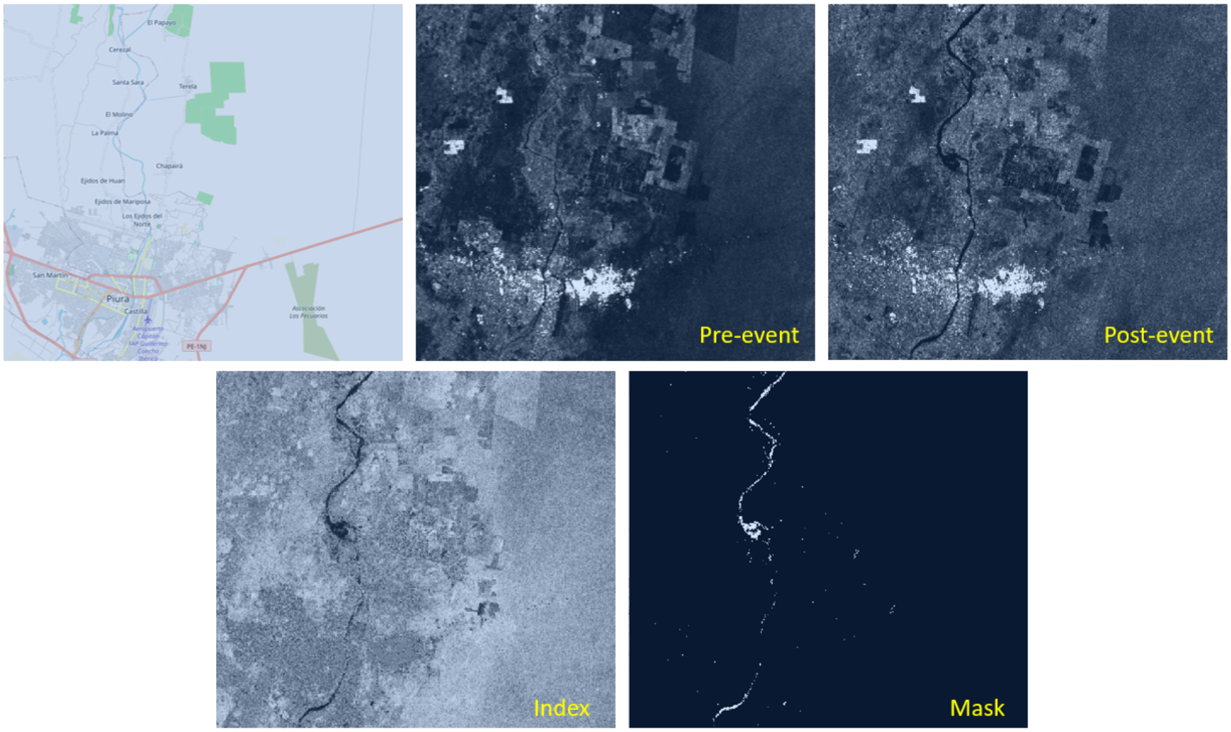



**Figure C.26** — Example of flood mask computed from Sentinel-1 data; generated by SatCen.

## C.6.2. Landslide events

### C.6.2.1. Introduction

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 precipitation, 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, and land cover. Localized landslides are a frequent hazard phenomenon and usually linked to flooding.

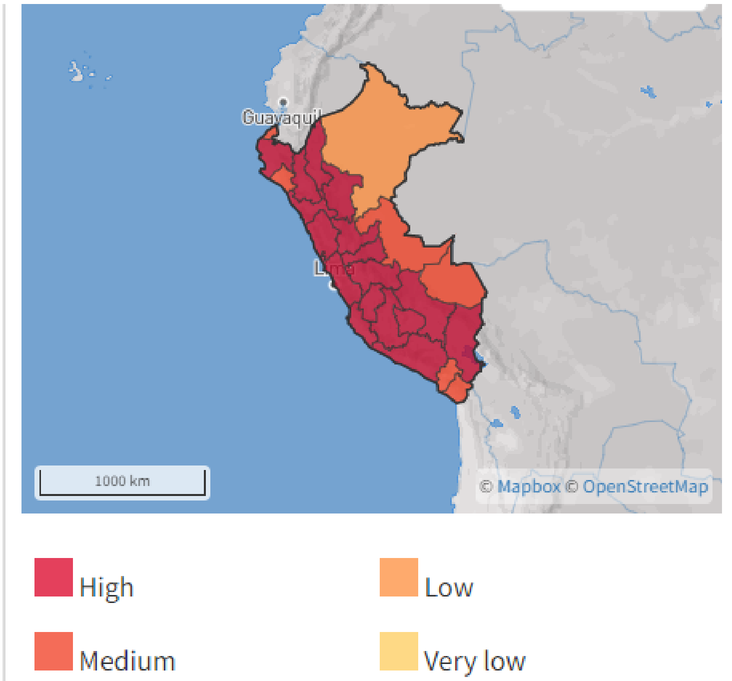



**Figure C.27** — Landslide susceptibility in Peru.

### C.6.2.2. Landslide-focused ARD and DRI to support decision-makers

DP21 explored different ARD and 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 DP21 was the Achoma landslide on 18 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, and is clearly visible using Sentinel-2 data shown in Figure C.28.


**Figure C.28** — 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.

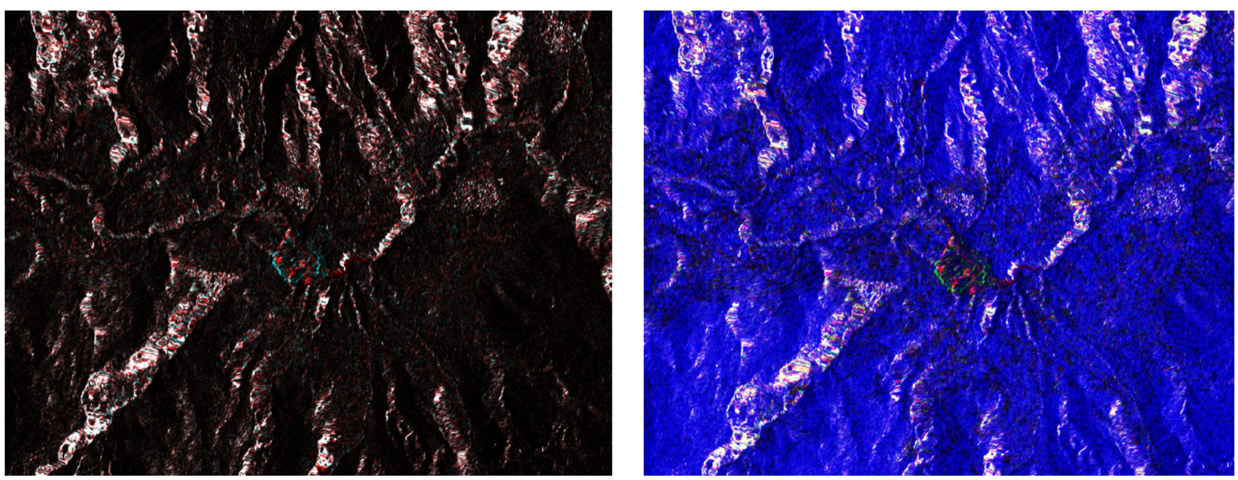


**Figure C.29** — ACD (left) and MTC (right) generated with Sentinel-1 data over Achoma with images before and after the landslide.

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 images (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.

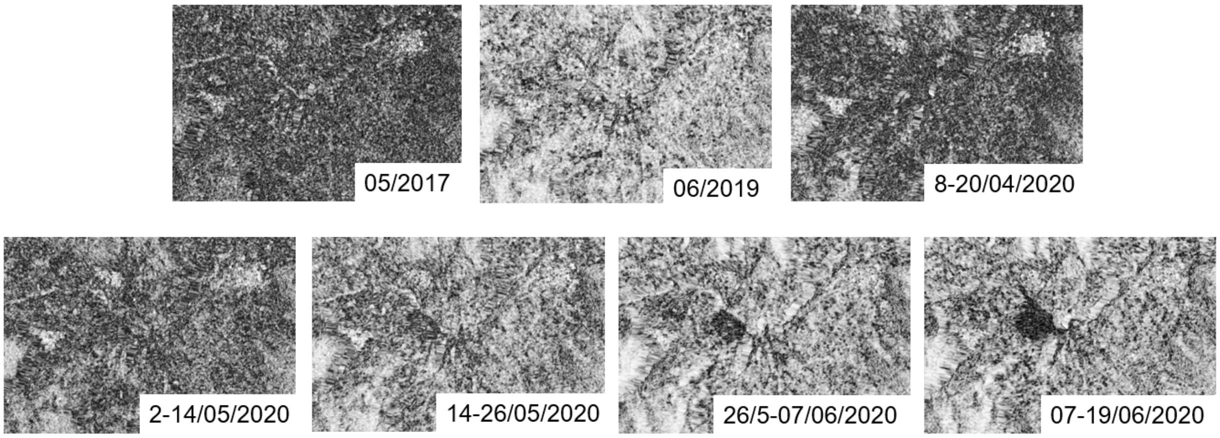



**Figure C.30** — Time series of coherences generated with Sentinel-1 data over Achoma.

In the time series, the coherence in all the areas 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 14 and 26 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.

## C.6.3. Conclusion

The work on Peru’s Rimac and Puira rivers showed it was possible to deliver the value chain to create example ARD and DRI, however, it also identified issues and limitations around automating the process that will need to be addressed.

# C.7. Flooding hazards and pandemic impacts within the Red River Basin in Manitoba, Canada, developed during Disaster Pilot 21.

## C.7.1. What geospatial knowledge is currently used?

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

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

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

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

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

3. **Data Delivery**: Once complete and verified for accuracy, EGS flood products are delivered to disaster response managers for local use e.g., see Figure C.31. Products designed to meet a specific user requirement are provided using data formats and/or web service approaches that meet end-user needs. EGS also makes flood extent products available to the public through the Government of Canada's Open Maps system.

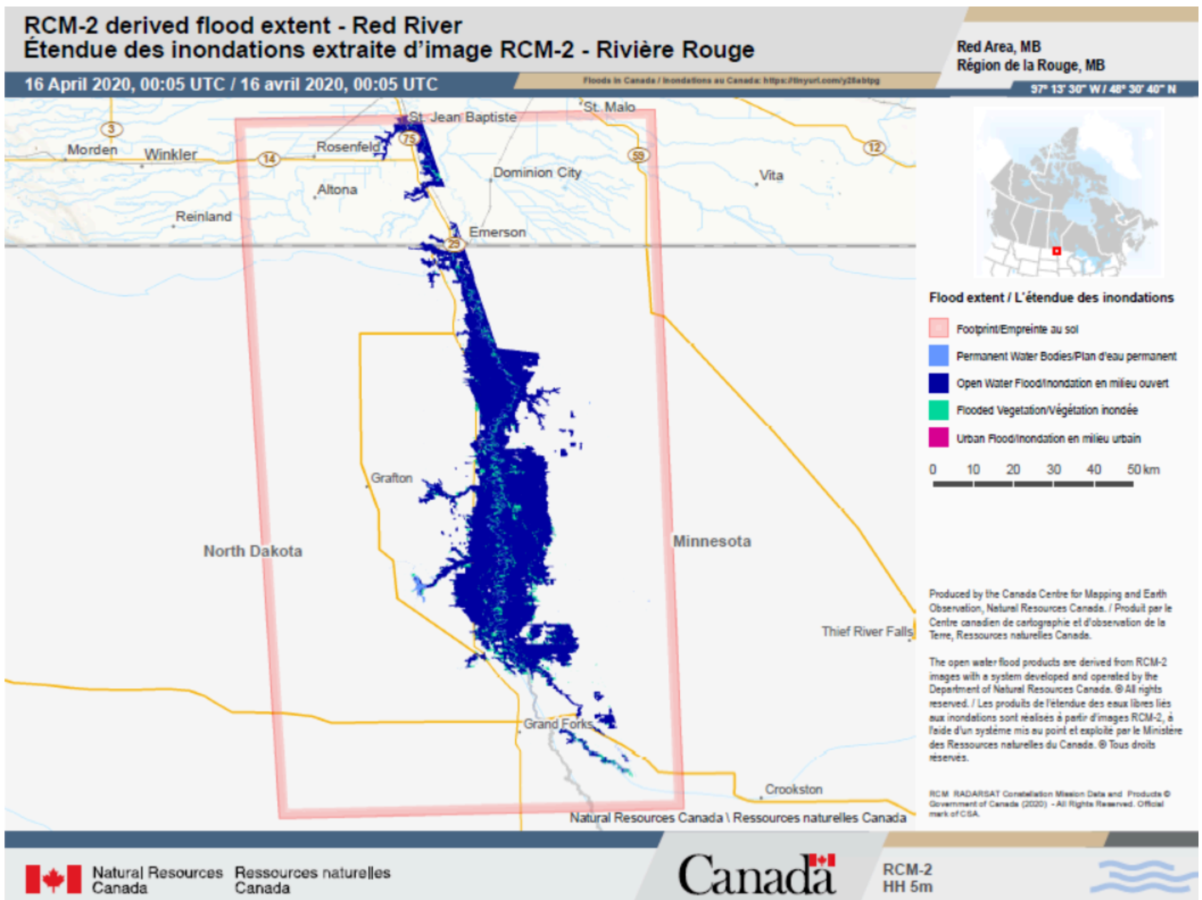



**Figure C.31** — RADARSAT Constellation Mission-2 derived Red River flood extent for April 2020; example courtesy of NRCan.

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

## C.7.2. Description of Flood-focused ARD and DRI to support decision-makers

This activity 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 were 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 used the river gauge measurements, and overlaid these onto a DEM and then a computer model predicts which areas would be expected to be flooded with those river measurements. Figure C.32 shows an output grid for the area of the Red River Basin where the model technique developed by RSS Hydro predicted the flooded area using data from 2011.

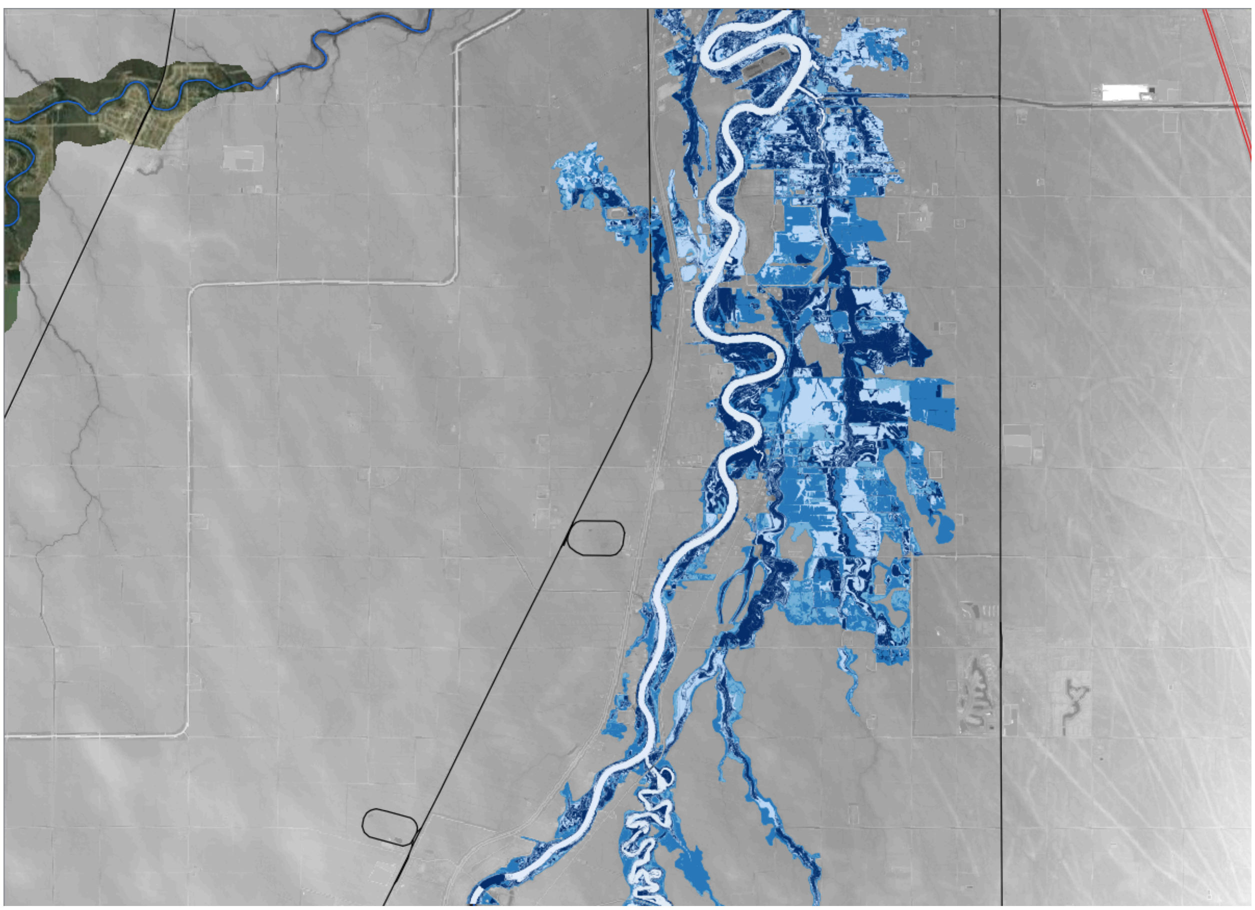


**Figure C.32** — Area of 2011 flooding, colored light to dark blue according to flood day (start to end) overlaid on DEM (shades of gray), with railway line as black lines, and motorway as a red line; flooding area from RSS Hydro.

- **Satellite based ARD** — This technique used both optical and SAR EO satellite data observations as the raw data are combined with mathematical algorithms to identify the areas that have flooded. Figure C.33 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 C.32, but it is for a different time period and a slightly different area of the river.

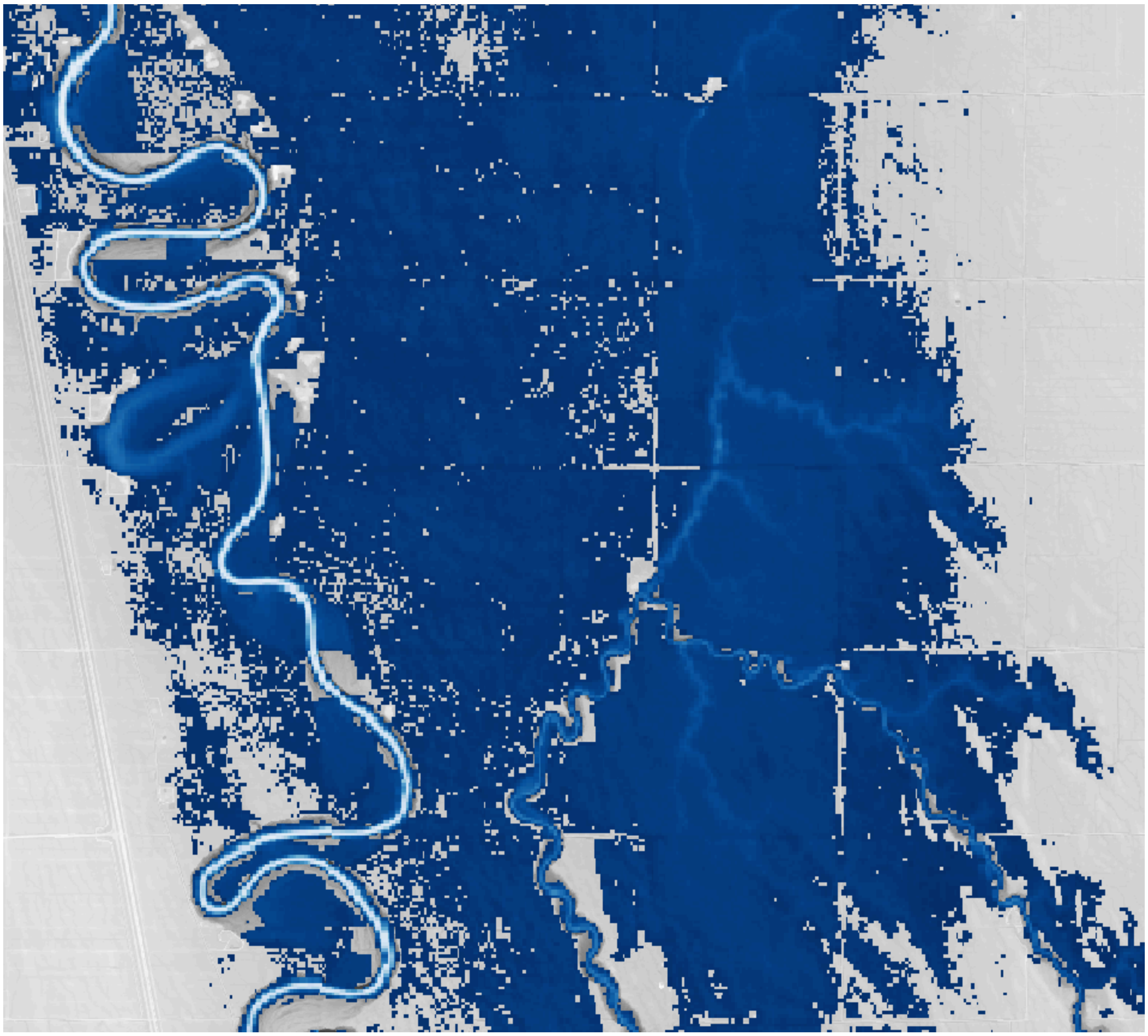


**Figure C.33** — Section of the April 2020 flooding, colored dark to light blue according to occurrence, developed by Wuhan University, overlaid on the DEM.

The above two ARD grids of flooded areas are both based on historic measurements, but they can be useful indicators of how flooding 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 was developed by Safe Software using their FME platform, which is a model based spatial data transformation and integration tool. Taking the input ARDs of modeled flood grids and EO ARDs, these were transformed into flood vector contour IRD, where areas with the same water depth are classified. This step was necessary as the transportation routing DRI, which was the next step in this data value chain, required flood depth estimates to work, not just the area or extents flooded. The flood water was categorized into five depth categories: 0.1 m, 0.3 m, 0.5 m, 1.0 m and above 2.0 m.

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 C.34 shows an example of the workflow used for the FME part of the ARD to IRD / DRI recipe for this flood transportation indicator.

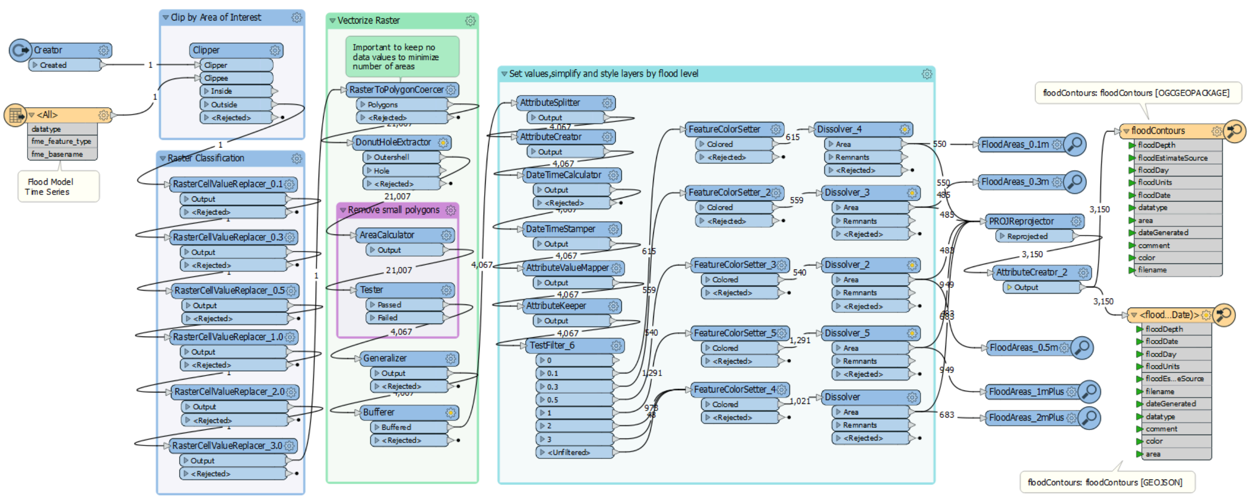



**Figure C.34** — ETL approach for converting flood area grid ARDs to flood contour IRD using FME from Safe Software

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 C.35 shows flood contours in the Red River Valley south of Winnipeg, which was used as the input data for the transportation route DRI.

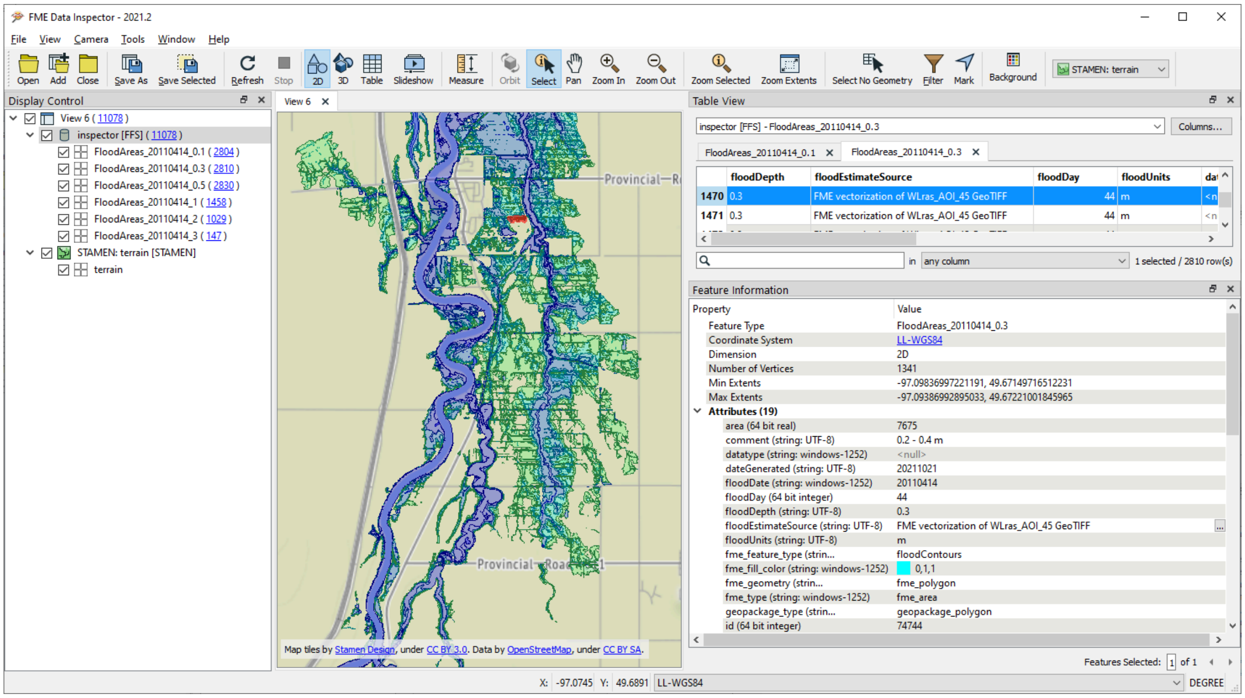



**Figure C.35** — Flood Contour Geopackage showing flooded areas south of Winnipeg by date, as displayed in FME Data Inspector.

To better support online integration, the flood contours were also provided to the HSR.health GeoNode instance, which made this data available to other components via OGC services such as WMS and WFS. Figure C.36 shows an example of the flood contours for the Red River Flood from 07 April 2011.

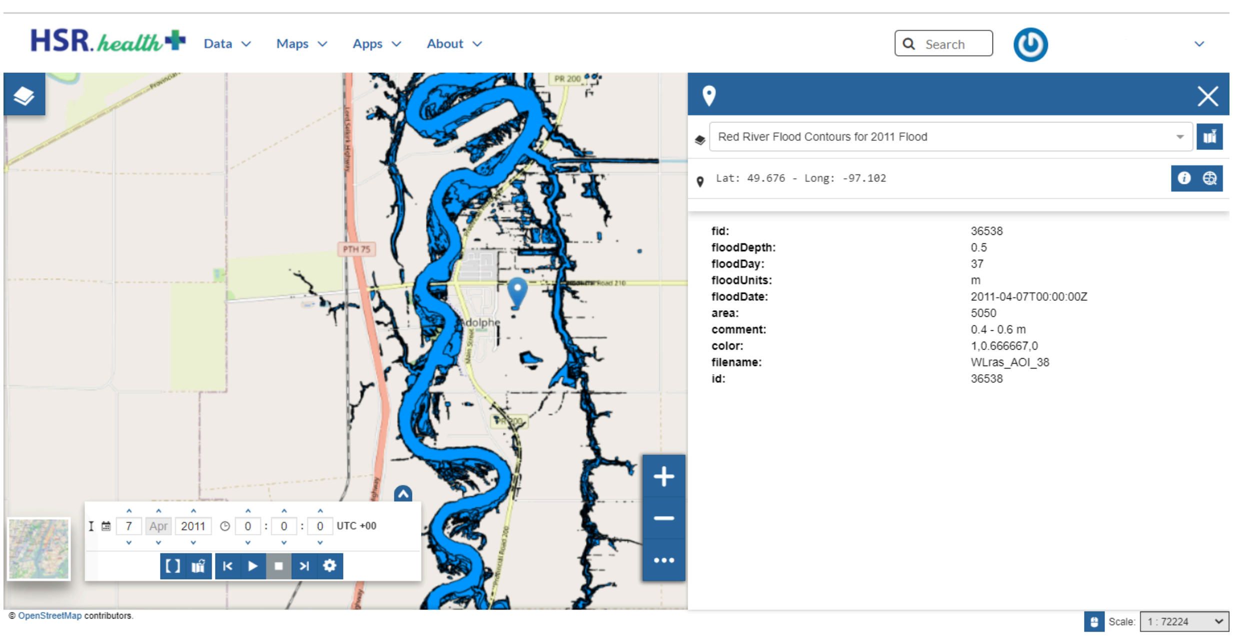



**Figure C.36** — HSR.health GeoNode with Flood Contours for Red River flood from 7th April 2011 loaded from FME workflow outputs.

The approach for calculating the transportation routing DRI implemented by Skymantics and used the flood contours depths to determine the roads impacted by flooding, and how deep the water was. 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 was dynamic software which could be updated as flood water rises or falls to offer the best route at that particular time.

Figure C.37 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.

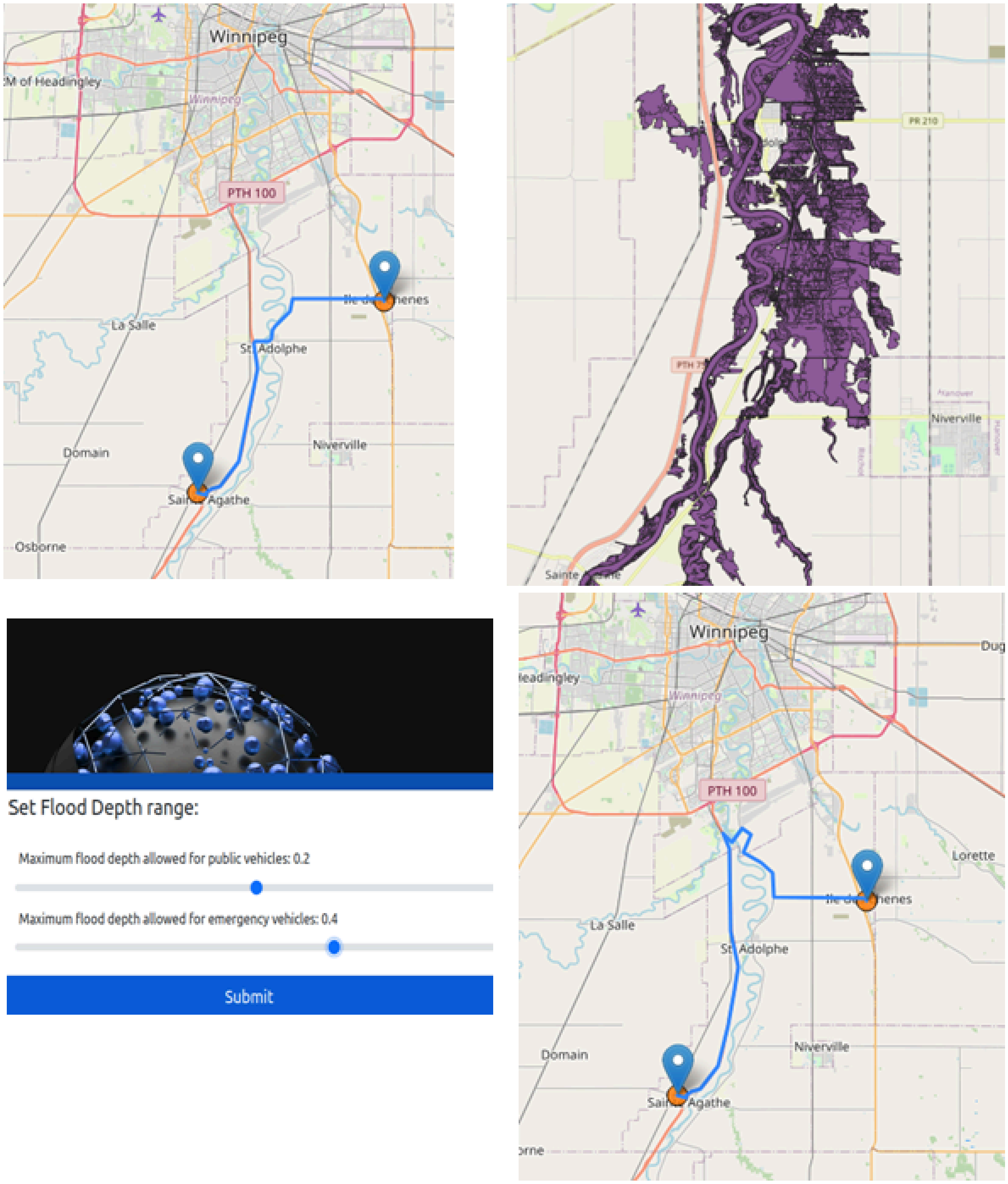



**Figure C.37** — Routing DRI. Showing optimal route, flood contours, user variables and revised route. Produced by Skymantics.

The routing software used 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 used 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.

### C.7.3. Conclusion

The work on Red River Basin showed it was possible to deliver the value chain to create example ARD and DRI, however, it also identified issues and limitations around automating the process which will need to be addressed.

D

# ANNEX D (INFORMATIVE) INTEGRATION OF HEALTH & EARTH OBSERVATION DATA FOR PANDEMIC RESPONSE DEVELOPED UNDER DISASTER PILOT 21.

# D ANNEX D (INFORMATIVE) INTEGRATION OF HEALTH & EARTH OBSERVATION DATA FOR PANDEMIC RESPONSE DEVELOPED UNDER DISASTER PILOT 21.

## D.1. Introduction

In advance of the Disaster Pilot 2021 (DP21), the world became 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.

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 died due to COVID-19.

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

The fact that Hurricane Ida struck Louisiana during the pandemic indicated 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 aim was to demonstrate how integrating health and EO data can add value and provide support and assistance within a pandemic response.

### D.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 included 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, included:

- NASA's EarthData COVID Dashboard was an experimental dashboard looking at 10 areas across the globe and focusing on 7 indicators, demonstrating the changes in the environment that were observed as communities around the world changed their behavior.
- European Space Agency & European Union's Rapid Action on Coronavirus and EO Dashboard demonstrated how EO data could 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 included case and vaccination health data on the diseases, although these are not integrated with the EO data. GeoGlam Crop Monitor (https://cropmonitor.org/) provided 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 gave details on the COVID-19 worldwide spread, plus additional air quality and environmental indicators.

While there were other COVID dashboards across the world, many were focused only on a particular area of the world, specific data indicators or producing reports available to access. Therefore, this review concluded that there were not good examples of integrated health and EO data to support pandemic response. Therefore, DP21 could add value to the current experience.

An example of how EO supports disasters is NOAA's capacity to predict hurricanes, their intensity, path, speed, surge, etc. By anticipating effects days in advance allowing time for evacuation and hardening of infrastructure, many lives are saved. This kind of effectiveness can be extended to other types of disasters.

### D.1.2. What did the Disaster Pilot 21 Do?

Following the data model developed in DP21, the work 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 were developed, describing 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.

### D.1.2.1. Foundation Layers

As highlighted in the Operational Capacity Guide 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 activity 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 — of immense usefulness for many applications, especially emergency and disaster planning and response.
- 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.

All of these data layers need to be collected and presented using agreed standards for data to ensure that they can be easily integrated.

## D.1.3. Pandemic Response

DP21 identified several ARD and DRI which would be potentially beneficial for pandemic response. This section focuses 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.

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.

### D.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 data would support:

  - *Land Cover Overview* – 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* – 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 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 data 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* – Chemicals in the air, such as nuclear radiation, can't be monitored directly, but satellites can provide wind speed measurements and precipitation to support dispersion modeling.

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

  - *Predicted Increases in Illnesses & Populations with Compromised Water Systems* – identification of drinking water or standing water that became 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 was 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 data 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 data 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 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* – 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 data 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* – 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. Also, in combination with stream flow monitors they can identify looming flood conditions, while tidal monitors can detect a building storm/tsunami surge hopefully in time to evacuate the vulnerable. By adding storm sewer capacity and elevation, areas prone to flooding can be identified in advance and safety measures planned.

  The satellites that offer water extent and flooding data would include the optical and SAR missions highlighted above. This data 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.

## D.1.4. Showing How Data Can Be Used

### D.1.4.1. Medical Supply Needs Index developed by HSR.health

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 began with the calculation of the Pandemic Risk Index, which combined a Mortality Risk and Transmission Risk Indicies.

- Mortality Risk Index utilized 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 utilized data on population, case counts, geographical area, and human mobility to identify the risk of the spread of COVID-19.

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

The two indices were 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 was normalized and used 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 calculated the usage level of Personal Protective Equipment (PPE) – in this case, gowns, gloves, and masks — by combining the number of COVID hospitalizations, 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 were combined to produce the supply level which was 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 created a DRI on the difference between current PPE supplies and forecasted need. Figure D.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.

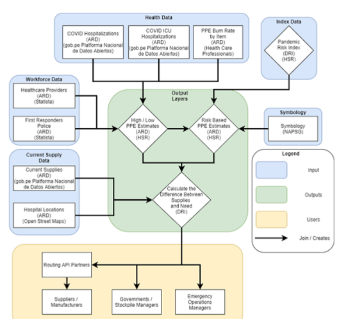



**Figure D.1** — Medical Supply Needs Index Workflow Courtesy of HSR.*health*

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

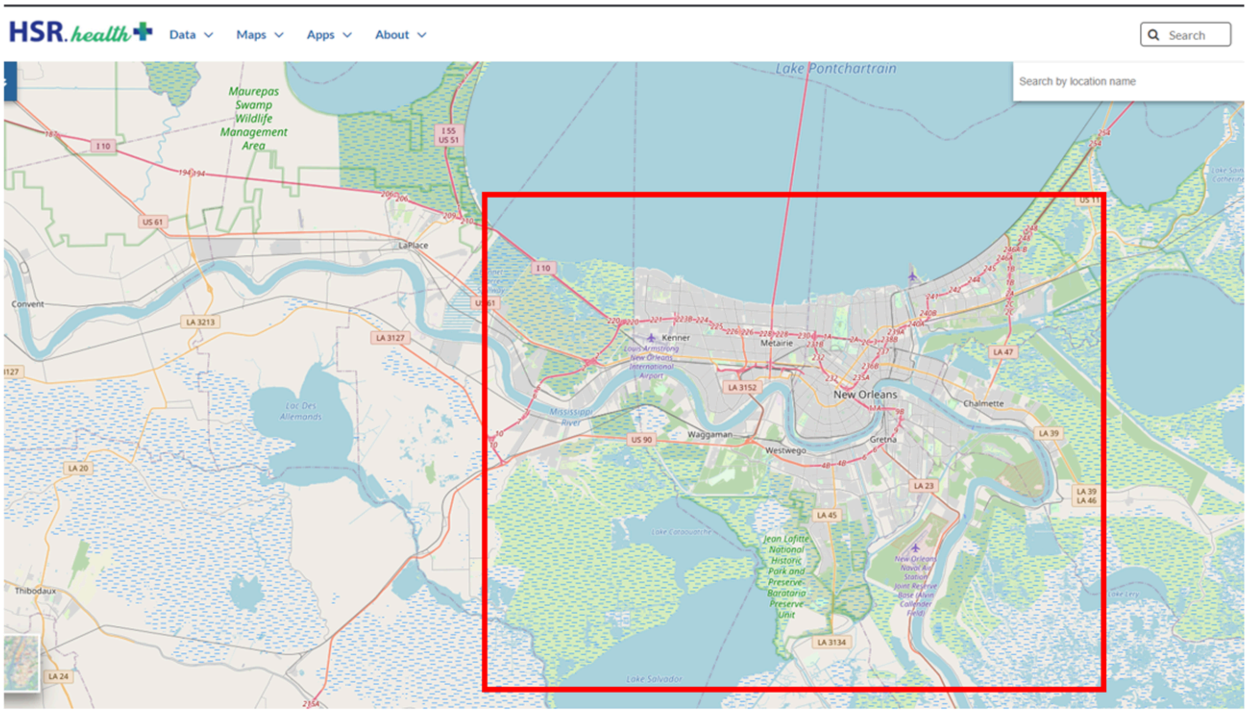



**Figure D.2** — Case Study Area of New Orleans in Louisiana. Courtesy of HSR.*health*

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 D.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.

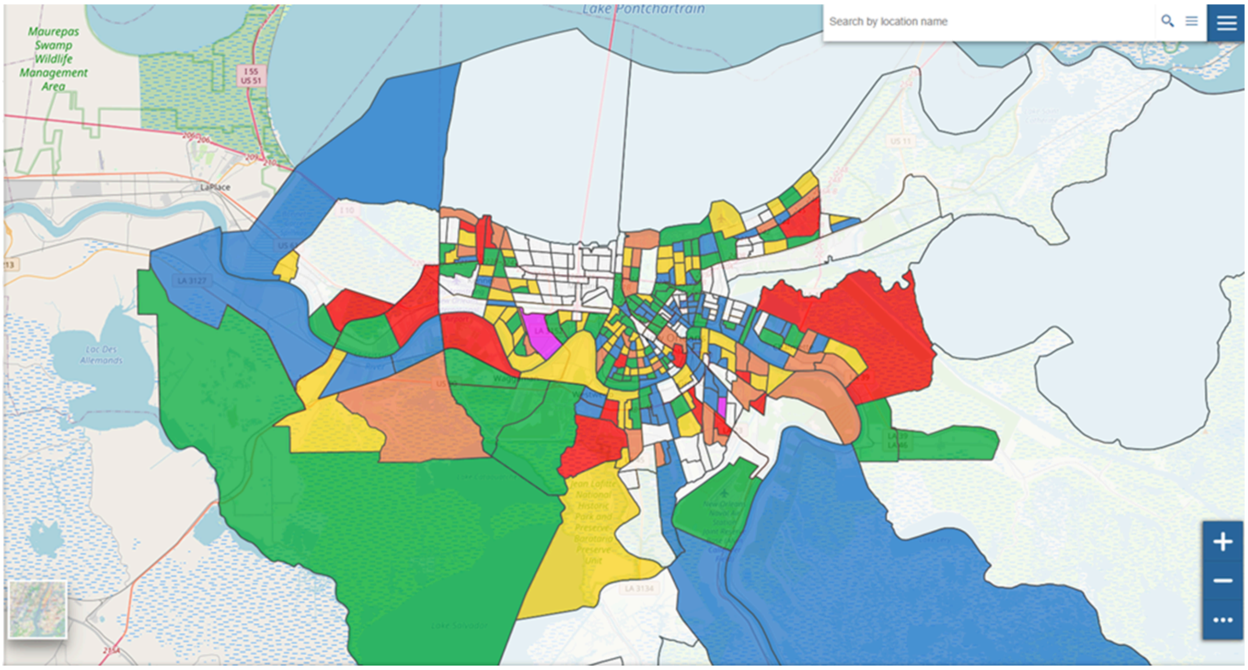



**Figure D.3** — Medical Supply Needs Index for New Orleans at Census Level. Courtesy of HSR.*health*

Figure D.4 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.

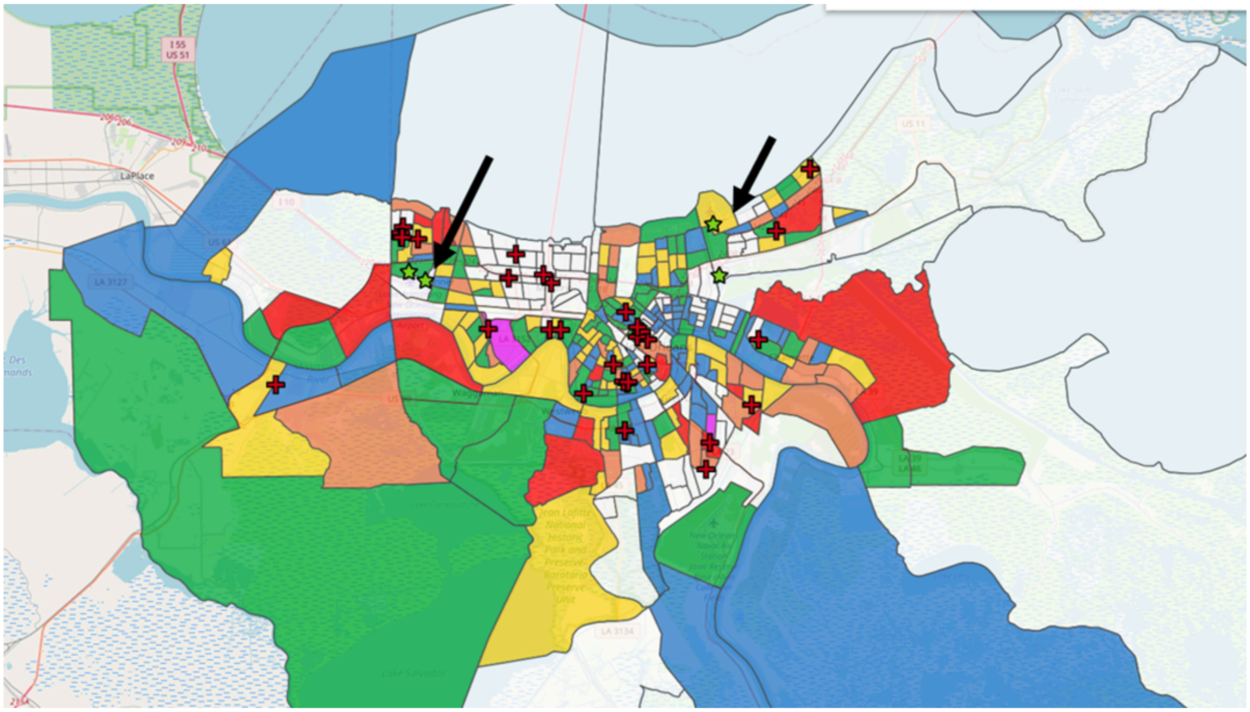


**Figure D.4** — Medical Supply Needs Index with Hospital and Distribution Location. Courtesy of HSR.*health*

### D.1.4.2. Dynamic Routing Solution developed by Skymantics

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 were 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 D.5 shows two examples of the distance to care application for the New Orleans area. The distance to care was 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 became saturated, it is clear that the distance care is increasing for patients in a number of areas.

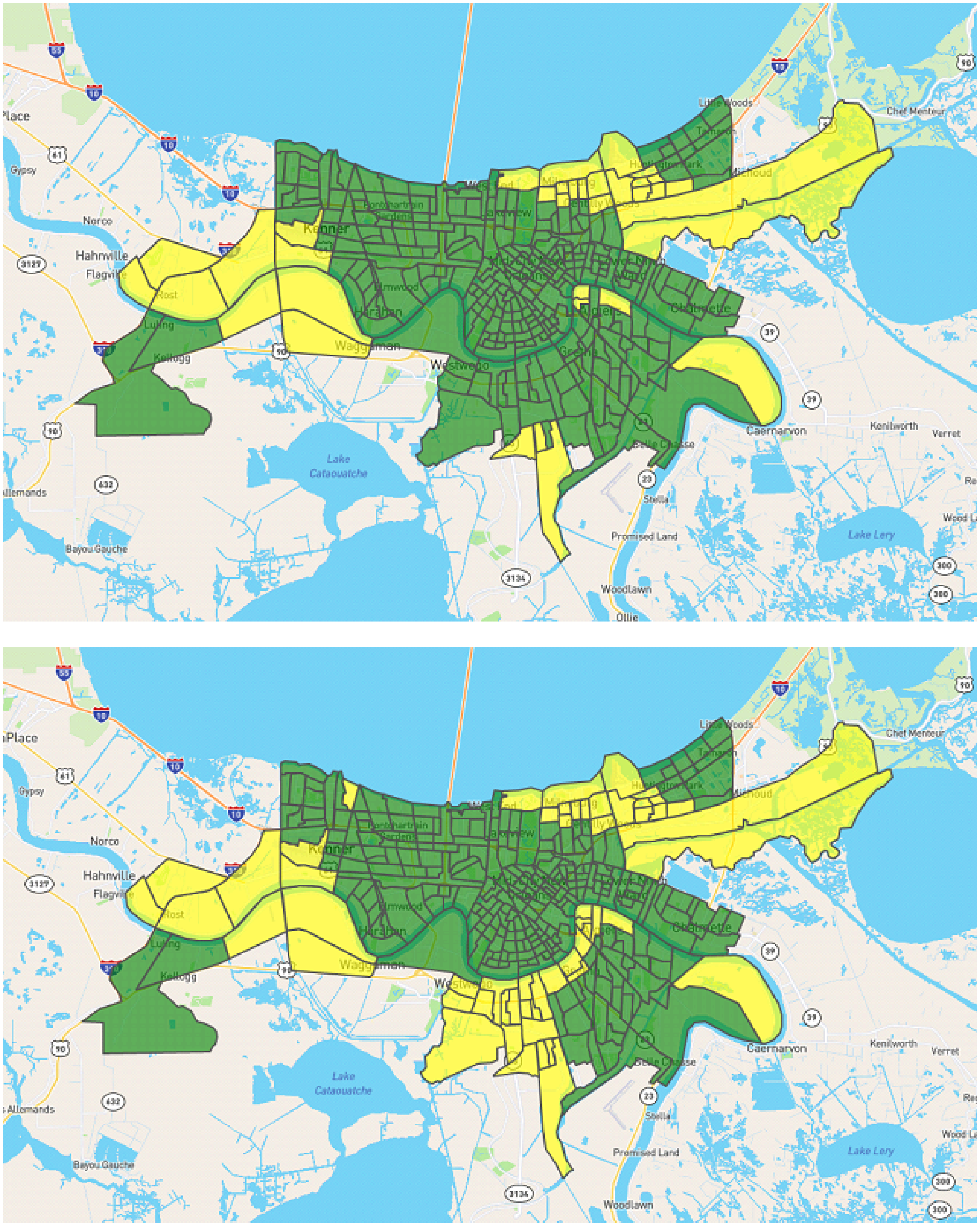



**Figure D.5** — Distance to Care in two scenarios. Normal situation, and where some hospitals are closed to new patients. Courtesy of Skymantics.

### D.1.4.2.1. Earth Observation

A local EO example for Louisiana can be seen in Figure D.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 gray 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.

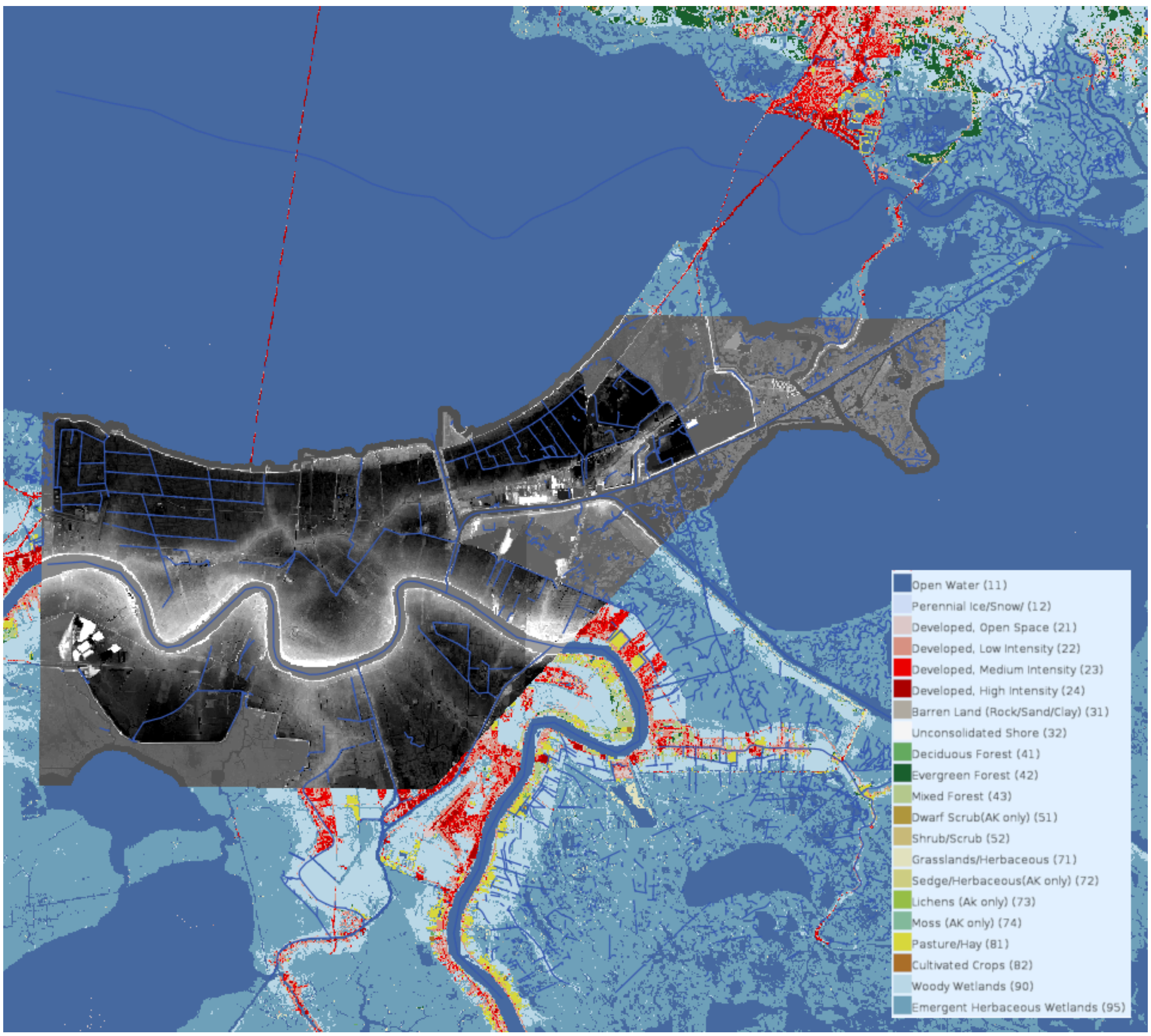



**Figure D.6** — 2017 USGS Lidar DEM overlaid on the US National Land Cover Database layer with OpenStreetMap data for waterways shown as blue lines; for the wider New Orleans area, Louisiana.

For water quality, Figure D.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.

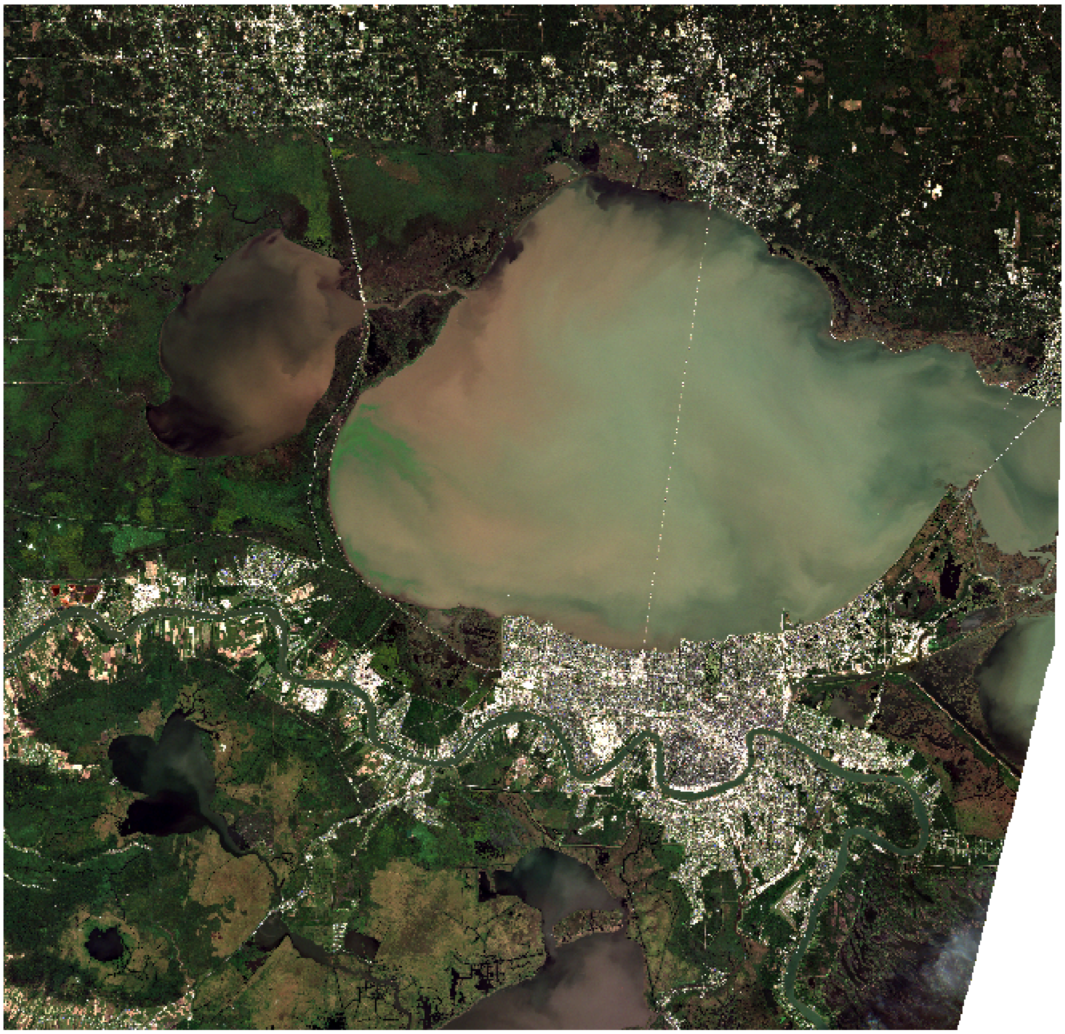


**Figure D.7** — 2017 Sentinel-2 image from 01 November 2021 with a cyanobacteria bloom in the south-western area; for the wider New Orleans area, Louisiana.

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 D.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).

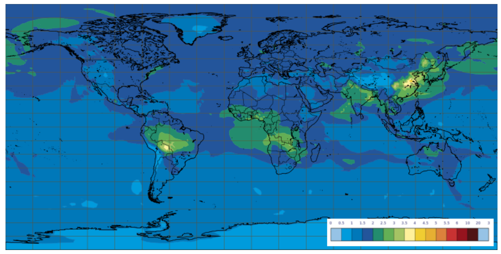


**Figure D.8** — Total column Carbon Monoxide [10^18 molecules / cm2] for the 03 November 2021, provided by CAMS.

## D.1.5. Conclusions

The COVID-19 pandemic conclusively demonstrated that health data, EO data and GIS solutions can play a crucial role in mitigating and managing a healthcare crisis. For DP21, 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 be developed and what ARD or DI might be possible.

By using the outputs and recommendations of DP21, it was 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.

E

# ANNEX E (INFORMATIVE) REVISION HISTORY

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| 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 |
| August 28, 2023 | 0.6 | A. Lavender | all | Revised content and structure linked to Disaster Pilot 2023 work |
| October 28, 2023 | 0.6 | A. Lavender | all | Disaster Pilot 2023 final draft for review by EDM working group |

# BIBLIOGRAPHY

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[1] Joan Masó, Keith Pomakis and Núria Julià: OGC 07-057r7, *OpenGIS Web Map Tile Service Implementation Standard*. Open Geospatial Consortium (2010).

[2] Samantha Lavender, Andrew Lavender: OGC 21-074, *OGC Disaster Pilot: User Readiness Guide*. Open Geospatial Consortium (2022). http://www.opengis.net/doc/PER/DP21-provider-readiness.

[3] Peter Baumann: OGC 17-089r1, *OGC Web Coverage Service (WCS) 2.1 Interface Standard — Core*. Open Geospatial Consortium (2018). http://www.opengis.net/doc/IS/wcs-core/2.1.0.

[4] Panagiotis (Peter) A. Vretanos: OGC 09-025r2, *OGC® Web Feature Service 2.0 Interface Standard — With Corrigendum*. Open Geospatial Consortium (2014). http://www.opengis.net/doc/IS/wfs/2.0.2.

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

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

[7] Knutson, Cody; Hayes, Mike; and Phillips, Tom, How to Reduce Drought Risk (1998). Drought Mitigation Center Faculty Publications. 168.

[8] 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

[9] Sepulcre-Canto, G., Horizon, S., Singleton, A., Carrao, H. and Vogt, J. Development of a Combined Drought Indicator to detect agricultural drought in Europe. Nat. Hazards Earth Syst. Sci., 12, pp. 3519–3531. (2012). doi:10.5194/nhess-12-3519-2012

[10] 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

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

[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] 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

[14] 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

[15] 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

[16] 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/

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