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A framework and pilot study for assessing usability of flood data portals for interdisciplinary research

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Data Availability Statement: The flood data portals described in this paper all make their data products freely and publicly accessible on their websites: https://worldview.earthdata.nasa.gov/ (NASA Worldview); https://global-surface-water.appspot.com/ (Global Surface Water Explorer); https://www.globalfloods.eu/ (Global Flood Awareness System); http://flood.umd.edu/ (Global Flood Monitoring System); https://floodobservatory.colorado.edu/ (Dartmouth Flood Observatory).

Abstract

There is a lack of datasets to study the climate and human outcomes nexus. There are many flood data portals due to recent improvements in flood identification using satellites, providing opportunities to study the human impacts. The development of these portals is rapid and there is currently no standard for evaluating their usability for interdisciplinary research. This paper addresses this important data gap. We put forth a usability framework that includes data availability, approaches to flood identification, alignment, velocity, variety, and user feasibility aspects. We piloted it through an in-depth review and user survey of NASA Worldview (NW), Global Flood Awareness System (GloFAS), Global Flood Monitoring System (GFMS), Global Surface Water Explorer (GSWE), and Dartmouth Flood Observatory (DFO) GSWE and GloFAS were rated most favorably. Respondents had discrepancies in their opinions on the clarity of the goals and platform accessibility for GFMS, DFO, and NW, and in data and visualization quality for all portals. Historical data and measures of flood recurrence and other characteristics are needed. Flood data products should be provided in multiple formats, aggregated by sub-national boundaries, with mechanisms that delineate incomplete or unreliable data. Flood data portals should include interdisciplinary research as part of their mission. Their longevity and maintenance should be secured to preserve these important data sources for future research. This framework can be adapted and used to enable interdisciplinary spatial and survey data linkages.

Introduction

The frequency and duration of flood events is increasing globally, presenting threats to public health and nutrition through vector borne diseases, water contamination, and agricultural losses [1–10]. Flooding due to river overflow, coastal seawater intrusion, or flash floods are all impacted by climate factors such as extreme precipitation and sea level rise [11–13]. Other factors such as urbanization, land use, mitigation infrastructures, and socioeconomic conditions also impact flood risk [14, 15]. With a growing global population exposed, floods are among

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the most impactful environmental hazards [6, 16, 17]. The destructive nature of floods warrants data for situational awareness and disaster planning efforts, and research of the human impacts.

Currently, datasets to study the impacts of environmental changes on food security, nutrition, and health outcomes are lacking. Spatial and survey data linkages–the process of assembling information from these different data sources into one dataset–are needed. Remotely sensed imagery from optical and synthetic-aperture radar sensors are instrumental for this purpose [13, 18, 19]. After decades of Earth observing satellite missions, abundant data are now available to the public for flood identification, monitoring, forecasting, and assessment of long-term environmental changes. These data present an opportunity for researchers to study the human impacts of disasters and environmental changes. The challenge, however, is integrating geospatial and population data that traditionally do not speak to each other. There is a heavy user burden for researchers outside the earth sciences to process geospatial data products into formats that can be linked to population surveys (e.g., extracting raster values into polygon attributes and aggregating data by administrative boundaries). With many flood data portals and products available, it is unclear which ones are best suited for use with population datasets.

To address this data gap, we propose a usability framework applied to flood data portals and pilot it among interdisciplinary graduate students with backgrounds predominantly in public health and nutrition who are potential end-users of these portals. We derived the framework from metrics defined in a prior paper for assessing modern dashboards using principles of evidence, efficiency, emphasis, and ethics. An important component of this framework is the end-user, or external perspective [20]. Other papers have evaluated data usability within public health and disaster relief, but interdisciplinary perspectives are lacking [21–23]. Findings from this pilot study may be of interest to developers of these portals to improve their data products. This framework can be adapted and may be useful for researchers interested in spatial and survey data linkages. We hope to raise awareness of these data sources to facilitate this critical interdisciplinary research.

Overview of remote sensing and flood mapping

Thirty meter resolution imaging (once considered high resolution, but currently considered moderate resolution) provided by optical sensors aboard Landsat satellites has been valuable to monitor seasonality and long-term changes in surface water over four decades [24]. With the launch of NASA's Terra (1999) and Aqua (2002) satellites, daily tracking of wide areas (250 m resolution) of the Earth's surface water has been made possible by the optical sensor MODIS (moderate-resolution imaging spectroradiometer) [6, 25–27]. Synthetic aperture radar sensors (SAR) such as those aboard Sentinel-1 satellites, operated by the Copernicus program, have the advantage of penetrating cloud cover [19, 27, 28]. Multi-satellite precipitation data products from NASA's Global Precipitation Measurement Mission are used in flood detection models [29].

Identifications and monitoring of floods and long-term changes remains challenging, despite availability of data provided by satellites [24]. Landsat imagery is limited by a wide temporal coverage (8 days), however, this has been recently resolved by a new product that combines Landsat and Sentinel-2 images to derive daily surface water extent maps with global coverage [24, 28]. While MODIS sensors can monitor large floods daily, it cannot detect floods where there is persistent cloud cover, complex terrain such as urban environments, or smaller flash floods [6]. Sentinel-1's SAR sensors are limited in flood detection capability in the presence of wind or vegetation as the contrast between flooded and non-flooded areas is reduced

[19, 30, 31]. Due to the temporal cycle of Sentinel-1 satellites (2 to 3 days at best), SAR flood detection is more accurate for longer duration events rather than flash floods [19, 30, 31]. Several indices derived from satellite imagery, such as NDWI (Normalized Difference Water Index), WI (Water Index), RSWIR (Red and Short Wave Infra-Red), or GSWIR (Green and Short Wave Infra-Red), have been used for flood mapping, but each have limitations (e.g. tendency to classify cloud shadow as water) [32, 33]. NDWI, for example, tends to underestimate inundated areas while GSWIR, in contrast, tends to overestimate [32].

In recent years many websites and data archives containing geospatial flood data products (i.e. flood data portals) have come into existence, each with their own mission and purpose [6, 24, 29, 34–38]. These portals use various sources of information from satellite imagery, government, or media sources to provide information or generate usable products about floods. Some portals such as USDA's Global Agricultural & Disaster Assessment System are interactive web map viewers that allow users to visualize floods without any special software [24, 38–40]. Some offer data products in different formats [25, 29, 37, 38, 41, 42]. The Dartmouth Flood Observatory, for example, provides a downloadable database of flood events [6, 25, 40]. Others, such as the Global Surface Water Explorer, provide high resolution map products of surface water changes [24].

Interdisciplinary example: Quantifying flood in studies examining the impact on nutrition and food security

Measurement of flood varies widely within the literature on nutrition and food security. One challenge is measuring flood at the community or household level. Another measurement challenge is distinguishing the type of flood–e.g. river, pluvial, coastal, or multiform floods–which can have different impacts [43, 44]. Many studies that have examined nutrition and food security impacts of floods have focused on single flood disasters, comparing pre/post or flooded and non-flood areas [45–56]. Some studies have measured flood through self-report using surveys, having the unique advantage of directly identifying flood-affected households but raising the risk of bias due to potential overreporting of flood exposure [46, 57, 58]. Others have used direct measures from satellite or other spatial data, aggregated at various levels [10, 59–61]. These studies typically do not differentiate the type of flood or main cause. Few studies in this body of literature have linked spatial data to household surveys. One recent study examined the effect of flooding on food security across broad regional, country, and all-continent scales in Africa and found both positive and negative impacts of floods and their related meteorological conditions. This study highlighted the important data gaps for assessment of flooding and food security outcomes across different spatial and temporal aggregations [44].

Linking spatial and survey data is challenging due to usability aspects. While flood data portals classify whether an area is flooded, with varying approaches, the differing spatial and temporal attributes make it difficult to link this information to surveys which include community, sub-district, or district level boundaries. In contexts where flooding is recurrent and commonplace, such a measure could deepen understanding of the impacts and how to respond. The heterogeneity in the literature makes it difficult to compare studies across contexts to determine, broadly, the human impacts of floods. But also, this heterogeneity makes it difficult to compare across studies within the same context. Currently there is no universal definition or classification system of flood for use in disaster relief efforts or research.

Goals of this paper

We share a usability framework for flood data portals for research on human outcomes that incorporates the end user perspective. To showcase this framework, we conducted a pilot study using NASA Worldview (NW), Global Surface Water Explorer (GSWE), Global Flood Awareness System (GloFAS), Global Flood Monitoring System (GFMS), and Dartmouth Flood Observatory (DFO). This framework can be adapted and aids researchers wanting to link spatial and survey data to study how natural disasters and environmental changes are impacting human outcomes, e.g., health, economics, migration, food security, or nutrition.

Flood data portals included in this pilot study

All flood data portals included in this review are publicly accessible. This is not an exhaustive list or systematic review of all flood monitoring or flood data portals in existence, of which there are many. We selected five commonly used flood data portals that had global coverage based on a literature review and exploratory search for data in consultation with an expert in the application of Remote Sensing and Geographic Information Systems. Our criteria were that the data were freely and publicly available. We included:

- **NASA Worldview (NW)**: NW is a large satellite data archive with both an interactive, dynamic (spatiotemporal) map viewer and data repository offering download of multiple spatial data layers. A few of the many data products it offers are related to floods or surface water extent [37]. Hosted by the United States government's National Aeronautics and Space Administration (NASA) and built by the Earth Science Data and Information System Project, NW includes satellite derived data from all aspects of the earth system and aims to support monitoring of natural hazards by providing access to current, daily satellite imagery data [37].
- **Global Surface Water Explorer (GSWE):** GSWE is an interactive, dynamic map viewer allowing visualization of long-term changes in the Earth's surface water over 37 years [24, 42]. GSWE displays datasets comprising the Global Surface Water collection (since 1984) produced using Landsat satellite imagery. While these data are continuously being updated with no end date, the data products are made available periodically. Currently, the 1984–2021 dataset is available. Data are accessible via several download options provided through a separate data access page. The European Commission's Joint Research Centre developed this portal and corresponding datasets under the Copernicus Program to support a range of applications such as water resource management, conservation, and food security [42]. While not specific to flood events, this portal provides information on the extent and change of surface water including development of new permanent water bodies, e.g. from seasonal to permanent inundated areas.
- **Global Flood Awareness System (GloFAS):** GloFAS provides an interactive map viewer to visualize current flood forecasts and detailed information about how to access the underlying data [35, 41]. Data are derived from satellite imagery and are accessible through the Copernicus Climate Data Store and can also be downloaded through the map viewer by creating an account. Implemented by the European Commission and Copernicus Program, the Global Flood Awareness System aims to support flood disaster preparedness efforts through global flood monitoring and forecasting of large river basins [41]. This is a component of the Copernicus Emergency Management Service.
- **Global Flood Monitoring System (GFMS):** GFMS is an experimental, quasi-global flood monitoring system using real-time, multi-satellite precipitation data to create a gridded flood model that users can view on 1/8th degree resolution maps [29, 62]. GFMS uses TRMM (Tropical Rainfall Measuring Mission) multi-satellite precipitation analysis and global precipitation measurement (GPM) integrated multi-satellite retrievals for GPM

(IMERG) to create the flood model which is based on land surface and river tracing routing models [29]. The maps allow users to change the different parameters and view time series of regional areas. The portal provides several variables that can be viewed, but the only data available for download is flood intensity (in depth) above threshold. This portal is developed and managed by the University of Maryland and funded by NASA.

- **Dartmouth Flood Observatory (DFO):** DFO is a resource of information about large flood events worldwide, provided through a range of dynamic maps and visualizations and a downloadable historical archive developed from media reports and other sources [25]. DFO originated at Dartmouth College in 1993 and then transferred to the University of Colorado in 2010 where it is hosted currently. DFO is often the first to map major flood events. Its mission is to support research and other humanitarian and water management applications.

Methods

Ethics statement

Ethical approval for the external user survey was obtained from the Tufts Social, Behavioral & Educational Research Institutional Review Board. The study met criteria for exempt status. All participants were informed of the study by reviewing a consent script on the first page of the webform and selecting "I consent to participate" to begin the survey.

Usability framework

Our framework incorporated data usability aspects as well as user feasibility. The data usability component included an in-depth review of the portals for data accessibility and availability, approaches to flood identification through the data sources and flood detection methods, and data quality through alignment, velocity, and variety (**Table 1**).

The user feasibility component included a survey of graduate students reviewing and rating each of the portals for several criteria. The survey captured participants' opinions about the portals' goals and scope, data and visualization quality, and platform accessibility from an external user perspective. We developed the survey using metrics adapted from a previous study which were based on principles of evidence, efficiency, emphasis, and ethics (**Table 2**)

Table 1. Usability characteristics for flood data portals.

Aim	Characteristic	Description
Data availability	Accessibility	Refers to the aim and mission of the portal and the ease of access of their data products
	Availability	Refers to availability of data products and type of information about floods
Approach to flood identification	Data sources	The sources of data used to create products
	Algorithms/ models	Refers to how flood is identified and classified from the raw data
Data quality	Alignment	Refers to how the data products are structured with respect to time and space, the time span, levels of spatial and temporal aggregation, and how well the data allow linkages to other datasets
	Velocity	Refers to how the data are collected and processed, and the frequency at which data products are updated, collected, reported, and made available
	Variety	Refers to the types of data products, formats available for download, and variable types

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Table 2. Assessment metrics for external user survey of flood data portals derived from principles of evidence, efficiency, emphasis, and ethics[1].

Principle	Indicator	Sub-indicator	Metric
Evidence	Goals & Scope		Overall goals are clearly stated.
			The available data products are clearly listed with a sufficient description.
			Overall, it was quick and easy to understand what data products are offered.
	Data Quality	Integrity	The data sources and metadata are clearly described.
		Standardization	The level of available geospatial aggregations is clear: e.g. flood extent, postal code, village/city/town, state/province/region, and country.
			The level of available temporal aggregations is clear: e.g. day, week, month, quarter, year, etc.
			Historical data are provided (1980s to present).
		Granularity	The data can be classified into sub-national administrative boundaries (e.g. province, district, or village).
			The data can be classified into sub-yearly temporal units (e.g. month, week, or day).
		Definition of flood	A definition of flood or classification of how a flooded area was identified is clearly listed.
			A definition or classification of flood exposure is provided (e.g. how a person, household, or community could be classified as being exposed to flood across space and time).
			The available data classifies type of flood (e.g. river, tidal, or flash flood).
			The available data classifies or provides a measure of flood recurrence for a given spatio-temporal aggregation.
			The available data includes other information about flood (such as duration, depth, damages)
		Completeness	If data is not available for a given variable, reasons are clearly stated.
Efficiency	Visualization Quality	Readability	The portal provides adequate and effective visualizations to demonstrate the data distribution, time trend, quality, quantity and relationship of the data.
			The visualizations clearly communicate the data.
Emphasis	Platform Accessibility		The portal is user-friendly and allows users to easily navigate and explore data and visualizations.
			The portal includes a tutorial or user guide (e.g., informative pop-ups, a tutorial video).
			The data are easily accessible.
			Multiple data formats are available to facilitate a range of uses in different programs (statistical packages and spatial).
			Links are updated and provide updated information.
	Contacts & Communication		The portal includes contact information for questions, suggestions and feedback.
Ethics	Conflicts of Interest		The host organization and purpose of providing the data is clearly stated.
			Funding sources and roles of funders are clearly stated.

[1] Adapted from B. Zhou et al., "Food and Nutrition Systems Dashboards: A Systematic Review," Adv. Nutr., vol. 10, no. Supplement_4, pp. S308–S319, 2019, doi: 10.1093/ADVANCES/NMAC022.

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[20]. Under the evidence principle are metrics assessing the quality of a portal's data products and whether the data is presented in line with the goals and objectives. Under the efficiency principle are metrics assessing the content organization and visual properties of a portal. Under the emphasis principle are metrics assessing a portal's "user-friendliness" and ability to recognize the needs of a target audience and tailor the content to their perceptions, abilities, and interests. Finally, the ethics principle seeks to evaluate whether best practices are applied.

From the above principles, Zhou et al. designed metrics to assess functionality and operation features of nutrition dashboards, which communicate nutrition data through interactive visualizations (**Table 2**) [20]. While these metrics were designed mainly for the evaluation of visualization dashboards, they can be applied more broadly to other types of data platforms. The functionality and operation aspects aligned with our purposes related to the practicality of flood data portals and provided the opportunity and structure to develop a survey instrument to capture end-users' opinions in a quantifiable way, which is critical for making recommendations to improve the portals. We developed the survey by reviewing the criteria from Zhou et al. and tailoring it to the application of flood data portals.

Pilot study

From February to March 2022, we explored the flood data portals in depth and completed a structured form containing the usability characteristics defined in Table 1 (see Appendix for data gathering form). The forms were completed with as much detail as possible that could be obtained from the websites and associated articles. We summarized the information in a table.

From May to September 2022, we recruited graduate students from Tufts University and Boston University to review each portal and complete a webform survey (see Appendix). For each portal, participants were asked to spend no more than 20 minutes exploring the portal and rating the assessment metrics using 5-point Likert responses. The survey was created and conducted using the Kobo Toolbox platform.

We used Stata 17 (StataCorp LLC, College Station, TX) for analysis of the external user assessment survey. Survey responses were recorded using a 5-point Likert scale defined as: Strongly Disagree, Disagree, Agree, Strongly Agree, Not clear/ Difficult to assess. For each of the 25 metrics in the survey, we calculated percent agreement (i.e. rated either 'Strongly Agree' or 'Agree') for each portal. Then, we assessed interrater agreement using a generalization of weighted Kappa allowing for the situation of more than 2 raters, more than 2 ratings, and an incomplete design. We calculated the Kappa statistic for each flood data portal and interpreted the level of agreement as 0 to .20 = slight, .21 to .40 = fair, .41 to .60 = moderate, .61 to .80 = substantial, and .81 to 1 = perfect. Survey respondents were also asked to leave notes about each of the portals they reviewed. We summarized common themes from these notes inductively.

Results

Usability characteristics

Table 3 shows the suite of flood-related data products offered by the flood data portals. A comparative summary of the usability characteristics across the flood data portals is presented in Table 4.

Data accessibility and availability

All five portals in this review are in the public domain and free to users. All are currently maintained but it was unclear whether they receive long-term funding. The aims and missions varied and included flood monitoring (NW, GloFAS), flood forecasting (GloFAS), disaster preparedness (GloFAS), humanitarian (DFO), water-management decision-making and applications (DFO, GSWE). Only DFO specified a research purpose. The GFMS is an experimental system and did not specify an aim or mission.

All portals make their data products accessible directly from the site but NW and GloFAS require login. The portals offer 18 different flood-related data products (Table 3). Most provide information about flood occurrences from satellite imagery. For example, the MODIS NRT Global Flood Product from NW is a daily global map of flooding derived from Terra and Aqua satellite imagery. The collection of Global Surface Water datasets from GSWE capture changes in surface water occurrence at 30m resolution (previously considered high, but currently considered moderate resolution) from Landsat imagery since 1984. While not specifically measuring flood events, GSWE datasets can be used to identify flooded areas. GloFAS data products measure ongoing and upcoming river floods from Sentinel-1 imagery. While the other portals offer multiple data products, GFMS offers only 1, flood intensity (in depth),

Table 3. Summary of flood-related data products provided by the portals in this pilot study.

Portal	Data Product	Timespan	Temporal aggregation	Spatial aggregation	Format	Description of variables
NW	MODIS NRT Global Flood Product	2022-present	Daily[1]	Global, ~232-m pixel res.	HDF-EOS or GeoTIFF[2]	Flood occurrence
	Flood Hazard: Frequency and Distribution	1985–2003	Total timespan	Global 2.5-minute grid	ASCII	Frequency of floods
	Flood Hazard: Mortality Risk	1985–2003	Total timespan	Global 2.5-minute grid	ASCII	Mortality loss
	Flood Hazard: Economic Risk	1985–2003	Total timespan	Global 2.5-minute grid	ASCII	Economic loss as proportion of Gross Domestic Product
GSWE	Water Occurrence	1984–2021	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Frequency with which surface water was present
	Change Intensity	1984–2021	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Change in surface water occurrence as increase, decrease or no change
	Water Seasonality	2020	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Intra-annual behavior of surface water
	Water Recurrence	1984–2021	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Frequency with which water returns from year to year
	Water Transitions	1984–2021	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Change in seasonality between the first and last years
	Maximum Water Extent	1984–2021	Total timespan	Global, 30-m pixel res.	GeoTIFF[2]	Flag indicating if water was ever detected or not
GloFAS[3]	Forecasts	2011-present	Daily	Global 20-m pixel res.	Grib or NetCDF	River discharge
	Seasonal forecasts	2017-present	Monthly	Global 20-m pixel res.	Grib or NetCDF	River discharge
	Global Flood Monitoring[4]	2021-present	Near Real Time	Global 20-m pixel res.	GeoTIFF or shapefile	Flood extent, number of people affected, affected land use
GFMS	Flood Detection / Intensity (in depth)	2001–2022	Daily	Quasi-global (50˚S to 50˚N) 1/8th degree res.	Binary files	Depth above threshold
DFO	Global Active Archive of large flood events	1985-present	Date of flood	Global, flood extent	Excel or shapefile	Flood location, river names, duration, #dead, #displaced, damages in USD, main cause, severity
	River and Reservoir Watch Version 4.5	1998—present	Daily	Global	Tabular	Present status and rate of change using River Discharge & Reservoir Area measurements, flood magnitude
	Master Index of Rapid Response Inundation Maps[5]	2000–2008	Date of flood	Global, flood extent	Tabular	Glide number, flood locations, river names, duration

[1] The Global Flood Product is based on Near Real Time satellite imagery and is provided daily for 2 compositing periods (2-day and 3-day).

[2] Downloaded as 10x10 degree tiles.

[3] GloFAS does not provide information on flash flood risk, coastal flooding, or inundated areas. Only focuses on rivers.

[4] The Global Flood Monitoring product provides 11 different output layers accessible via the GloFAS map viewer. [5] Not currently being updated (last update was 2008).

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derived from multi-satellite precipitation data. DFO data provide information on occurrence of large flood events, compiled mostly from media sources.

In addition to data on flood occurrence, NW and GSWE capture recurrence and NW, GloFAS, GFMS, and DFO provide data on other characteristics of floods (Table 3). The Flood Hazard: Frequency and Distribution gridded data from NW measures frequency of floods between 1985–2003 using DFO data. The Recurrence dataset from GSWE measures inter-annual frequency of surface water between 1984 to present time, capturing areas that were episodically flooded. NW offers Mortality Risk and Economic Risk Flood Hazard layers, providing information on mortality and economic losses. Both are derived from the International Emergency Events Database (EM-DAT). GloFAS flood monitoring has data layers of the affected population and affected land use. GFMS provides data on flood depth. DFO provides

Table 4. Usability characteristics of flood-monitoring data portals in this pilot study.

		DFO	GSWE	GloFAS	NW	GFMS
Accessibility	**Host organization**	**University of Colorado[1]**	**European Commission's Joint Research Centre, Copernicus Programme**	**European Commission's Joint Research Centre, Copernicus Emergency Management Service**	**NASA**	**University of Maryland**
	Intended for research	✓				
	Intended for flood monitoring, forecasting, or humanitarian efforts	✓		✓		✓
	Any other purpose		✓[2]		✓	
	Data can be downloaded directly from portal	✓	✓	✓	✓	✓
	Data access requires user login			✓	✓	
	Has a user guide or tutorial		✓	✓	✓	✓
	Portal is currently being maintained	✓	✓	✓	✓	✓
Availability	Number of flood related data products	3	6	3	4	1
	Spatial data product in vector format	✓		✓		
	Spatial data product in raster format		✓	✓	✓	
	Spatial data in other format (ASCII, HDF-EOS, binary)				✓	✓
	Commonly used dataset format (e.g. Excel, Stata, SAS, R)	✓				
	Requires further processing for use with statistical software		✓	✓	✓	✓
Data sources	Satellite imagery	✓	✓	✓	✓	✓[3]
	Non-satellite sources (media, government, other)	✓			✓[5]	
Alignment	Provides a dataset structured by flood event	✓				
	Provides a spatiotemporal dataset		✓	✓	✓	✓
	Provides historical data (1980s to current)	✓	✓		✓	
	Provides detailed locations (towns, rivers, etc.)	✓				
Variety	Classifies type of flood		N/A			
	Includes river floods	✓	N/A	✓		✓
	Includes coastal/tidal floods	✓	N/A			
	Classifies main cause of flood	✓	N/A			
	Classifies flood severity	✓	N/A			
	Classifies or measures flood frequency/recurrence		✓		✓	
	Other flood information (e.g. duration, depth, damages, etc.)	✓	N/A	✓	✓	✓
Volume	Number of variables	15	6	3	2	1
	Size/extent	Global	Global	Global	Global	Quasi-global
Velocity	Data products are updated regularly	✓	✓	✓	✓	✓

(*Continued*)

Table 4. (Continued)

		DFO	GSWE	GloFAS	NW	GFMS
Accessibility	**Host organization**	**University of Colorado**[1]	**European Commission's Joint Research Centre, Copernicus Programme**	**European Commission's Joint Research Centre, Copernicus Emergency Management Service**	**NASA**	**University of Maryland**
Completeness	Documents incomplete or missing data			✓	✓	
	Gaps between time points of collected data	✓[6]			✓[7]	
Visualizations	Has dynamic / timelapse maps	✓	✓		✓	✓
	Has interactive web-map viewer/tool		✓	✓	✓	✓

[1] Dartmouth Flood Observatory originated at Dartmouth College in New Hampshire, USA, in 1993 and moved to University of Colorado in 2010.

[2] Purpose is to quantify changes in global surface water over time to support water management decision making.

[3] Uses multi-satellite precipitation data.

[4] The Flood Hazard: Frequency and Distribution data product is derived from Dartmouth Flood Observatory data. The Flood Hazard: Mortality Risk and Flood Hazard: Economic Risk are derived from the Emergency Events Database (EM-DAT).

[5] Derived from media reports and include hand drawn areas of where the media reported flooding.

[6] Poor or missing data in the early/mid 1990s.

[7] Does not provide data between 2003–2022.

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the most information about floods in its Global Archive of flood events including main cause, area affected, detailed locations, names of rivers, duration, known number of deaths and displaced, and damages in USD. None of the portals' data products distinguish or classify the type of flood, but DFO does provide the main cause and a measure of flood severity. GloFAS data only includes river floods.

Most of the data products are geospatial, provided in raster or vector data formats. Only DFO provides a non-geospatial format–an Excel sheet of flood events.

Approaches to flood identification and their potential errors

The portals had different approaches to flood identification and minimizing type 1 (false positive) or type 2 (false negative) errors by: compositing (NW), ensemble of different flood detection algorithms (GloFAS), classification over an extended time (GSWE), or combining land surface and river runoff models (GFMS).

NW classifies floods via the MODIS Near Real Time Global Flood Product and the Flood Hazard: Frequency and Distribution layer. The Global Flood Product is derived from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor datasets from both Terra and Aqua satellites. Flood identification is based on time compositing water detections over 3 periods (1, 2, and 3-day) and differentiating them from surface water using a reference mask [63]. If a water detection does not match the reference layer, it is classified as flood. The compositing approach minimizes false flood detections by combining multiple observations, thus reducing error from clouds. For each period, all observed water detections are combined, and pixels are classified as water if they exceed thresholds of 1, 2, or 3 observations based on the periods, respectively. While this approach minimizes error, the Global Flood Product still has limitations and false detections cannot be entirely removed, especially if cloud cover is persistent over multiple observations [63]. False-negative detections may result from obscuration from buildings, canopy, or clouds, while false-positives may still result from cloud or terrain shadow or dark rock or soil. Users are encouraged to compare flood maps to reflectance imagery to determine potential sources of false-positives or false-negatives [63]. Another potential source of error is the reference mask used to differentiate surface water from floods, which is outdated and planned for improvement [63].

The Flood Hazard: Frequency and Distribution layer from NW is derived from DFO data (discussed further below).

GSWE uses high resolution Landsat satellite imagery to classify changes in surface water from 1984–2021 [24]. This portal differs from the others in its goal to detect and classify surface water, not flood events, over multiple decades. Challenges include variations in measurement across the Landsat sensors (TM, ETM+, OLI) and in the conditions in which they're observed [24]. False water detection may be caused by shadows (e.g. from buildings, terrain, or cloud), or lava flow. GSWE applies a combination of expert systems, visual analytics, and evidential reasoning techniques to classify pixels and prevent water classification errors [24]. This is followed by manual visual inspection and cleaning of the maps to remove false detections, and further validation to handle remaining errors [24]. An important feature of GSWE data is its classification over an extended period. Because classifications are made over time, the temporal behavior of the pixels is also used in determining their likelihood of being water, thus strengthening the accuracy of the classification.

GloFAS captures river flooding using Sentinel-1 SAR satellite data and a combination of 3 separate flood detection algorithms [64]. A final ensemble algorithm generates the final flood product based on a consensus of the 3 flood detection algorithms [64]. Like NW, a reference water mask is used to differentiate flooding from permanent surface water [64]. The ensemble approach helps prevent flood classification errors attributed to any one of the flood detection algorithms. However, classification errors are possible due to limitations inherent with SAR data. False positives can occur from land characteristics such as very dry soil, frozen ground, wet snow, or impervious surfaces or from radar shadowing [64]. False negatives can occur from urbanization or dense vegetation or strong, heavy winds and rainfall [64]. To address these classification challenges, GloFAS produces exclusion mask (for effects due to ground surface characteristics) and advisory flag (for effects due to weather conditions) layers along with their flood product layers [64]. Users can apply these layers to determine which pixels to disregard.

GFMS uses a real-time multi-satellite precipitation data product from NASA's Global Precipitation Measurement Mission to identify floods using a dual land surface with river runoff model–the Dominant River Tracing-Routing Integrated with Variable Infiltration Capacity Environment (DRIVE) model [29]. Flood is defined when the routed runoff is greater than the flood threshold of that grid cell. Precipitation biases and the size and duration of flood events can impact GFMS flood detection capability [29]. False positives can occur in areas with dams or related to winter surface features in higher latitudes. False negatives can occur due to underestimation of orographic rainfall (due to hills or mountains). Generally, GFMS has improved flood detection performance with longer, larger floods.

Unlike the other portals, the DFO historical archive is based mainly on media sources (news reports, governmental and international relief agency websites). DFO captures large flood events spanning large geographic extents which are mostly hand drawn based on where the media reported flooding. In some instances, the archive might also have satellite observations to determine the flood extents. While it is a good source for identifying where large flood events occur globally, it is not useful for identifying which specific locations or communities are affected, making it prone to type 1 error. The differences in news coverage by country and region may impact the accuracy of information about a particular flood event.

Alignment, velocity, variety

We assessed data quality through *alignment*, *velocity*, and *variety* (**Table 2**). All portals provide data products structured by spatiotemporal attributes, but only DFO provides a dataset of flood events. All provide daily or Near Real Time data except for GSWE which classifies the whole timespan. DFO is the most important source of historical data about flood events from the 1980s. NW and GSWE also provide historical data products from the 1980s, but the products available through NW are derived from DFO data and EM-DAT. While GSWE has historical data, it captures changes over time and is not specific to flood events. GSWE and GloFAS provide the highest resolution data products, but only DFO provides detailed locations including names of rivers and towns.

All portals update their data products regularly. GFMS, NW, GloFAS, GFMS, and DFO (River and Reservoir Watch), provide daily updates. DFO may have some poor or missing data in the 1990s. The flood data products provided by NW cover the 1985–2003 and January 2022-present timespans, but there is a gap between 2003 to January 2022.

External user feasibility assessment

We present an exploratory descriptive and qualitative assessment of graduate student raters from the external user assessment survey. Eight raters participated in the survey, with 6 completing ratings for all 5 portals. Fig 1 shows the percent agreement. According to raters' opinions, GSWE and GloFAS were ranked most favorably for their usability on average (73% average agreement), while DFO and NW were ranked least favorably (39% and 37%, respectively) and GFMS was in the middle (58%). Fig 1 shows the breakdown by the assessment metrics and areas where the portals can improve their usability. For goals and scope, raters agreed for GSWE, GloFAS, and GFMS, but did not seem to agree for DFO and NW. Ratings for data and visualization quality were mixed across the portals, with raters agreeing on different aspects for each portal. For platform accessibility, raters agreed for GSWE, but less so for the other portals. For contacts, communication, and conflicts of interest, raters agreed for GFMS, GloFAS, and GSWE and did not seem to agree for DFO and NW. Inter-rater reliability for each of the portals ranged from slight to fair. When examined across all 5 rating categories and across 2 rating categories (either agree or disagree), respectively, Kappa coefficients were 0.06 and 0.40 for GSWE, 0.03 and 0.16 for GloFAS, 0.25 and 0.40 for GFMS, 0.05 and 0.08 for DFO, and 0.08 and 0.11 for NW.

Notes provided useful feedback about the portals. For DFO, comments indicated the difficulty of navigating the website. E.g.,

> "*The website is not intuitive and difficult to navigate.*"
>
> "*There is a wealth of useful data on this portal, however, the site is not user-friendly.*"

For GFMS, the ease of navigating the portal was commonly described. E.g.,

> "*This website was easy to navigate.*"
>
> "*This portal is well organized and provides easy to-use instructions.*"

But improvements could be made to the visualization tools, e.g.:

> "*The visual presentation and design leaves somewhat to be desired—there are missing spaces and grammatical errors, and the formatting changes throughout the webpage.*"

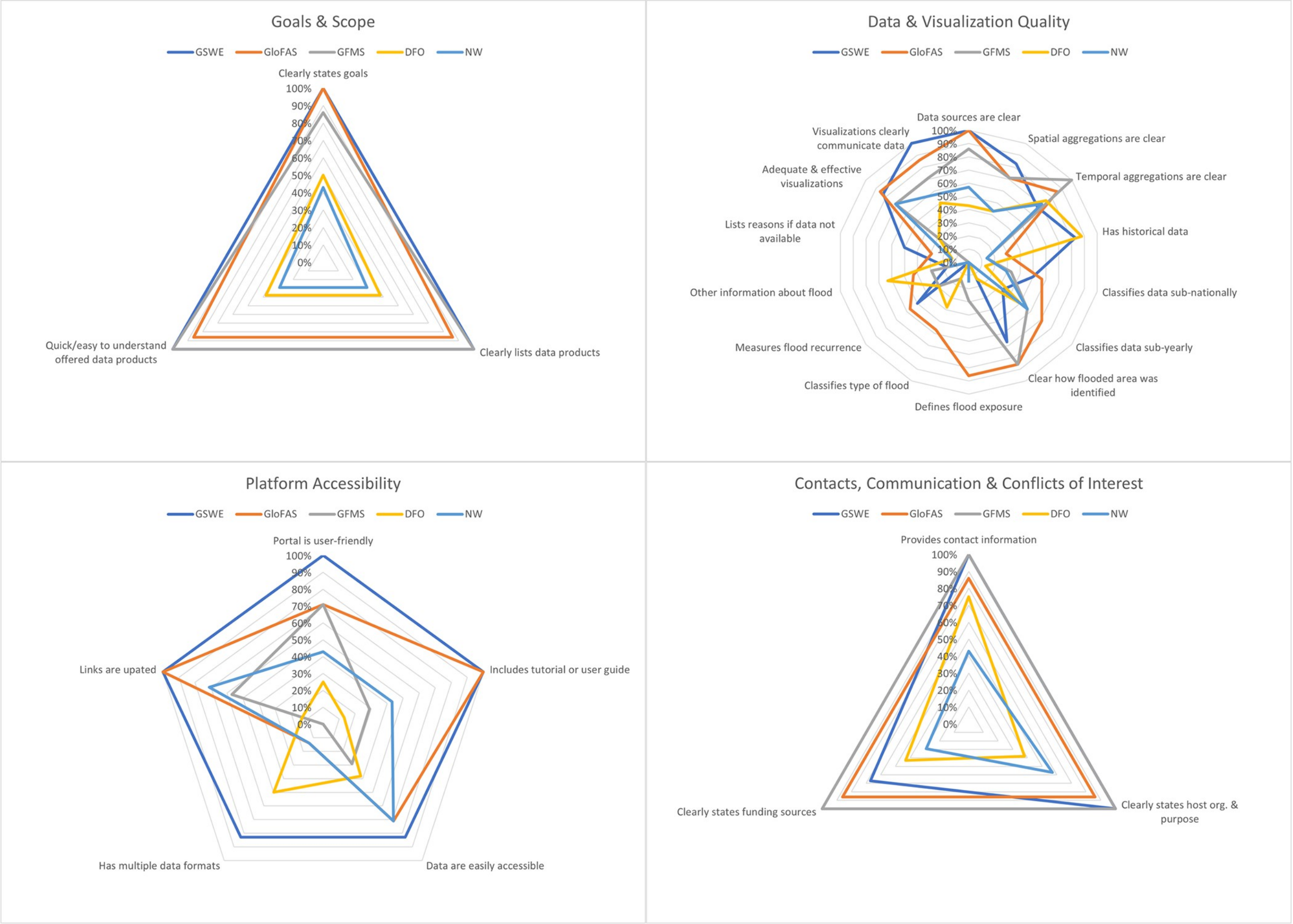

Fig 1. Percent agreement among raters of external user assessment of flood portals in this pilot study.

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> *"Some data links were dead, and some visualization options resulted in blank white areas without any stated reason as to why data could not be produced."*

Comments about GloFAS were positive and indicated that it was clear and user-friendly, e.g.:

> *"This website is the most clearly laid out and the outputs are all described well."*

Comments about GSWE were mixed. Comments indicated the site was well-designed. One rater felt the data download process was difficult, while another commented on the difficulty of the graphs:

> *"You are able to explore the data but downloading it is a bit more complicated. The website is well designed though and easy to use!"*
>
> *"The tool to explore global surface water was impressive. . . however, either I was not able to properly understand the graphs, or the graphs weren't working properly."*

Finally, comments about NW were focused on difficulty of accessing and downloading flood-specific data, e.g.:

> "*While this tool is visually impressive, I couldn't even find a way to view flooding or surface water after several minutes of exploration.*"

Discussion

We addressed an important data gap in interdisciplinary research of how climate events are impacting human outcomes. We provided a usability framework for flood data portals, which previously did not exist. We piloted this framework using 5 flood data portals, which resulted in a detailed comparison that is useful to researchers and host organizations seeking to improve these important and valuable data products. Our framework can be adapted to other climate data products. We did not evaluate the correctness of the flood detection algorithms in our framework, as it depends largely on the intended use and our focus was on the end-users of these data products. We found considerable heterogeneity in the data products and information provided, and identified areas where these portals could improve. Overall, these portals should include research within their scope and provide products that facilitate interdisciplinary research.

There are several case examples of how data from these portals have been used in prior research (Table 5). DFO and GloFAS have been used more frequently than the other portals. DFO has had a broader range of applications in the literature including spatiotemporal variability of floods, impacts on mortality, displacement, and economy, while GloFAS has been used mainly for early warning systems [65–73]. Several studies have linked DFO to other datasets [70, 72, 74]. It appears GFMS, NW, and GSWE have been used less frequently for research. Few studies seem to use GSWE, and these have focused on changes in delta morphology and coastal morphology over time due to human activity [75, 76]. We are not aware of any studies using GSWE variables to measure flooding. These case examples point to the need for improvements to usability so these important data products can be used more efficiently in longitudinal studies to examine human impacts of flooding.

Historical data products that span several decades are needed for longitudinal studies examining impacts of flooding on health, nutrition, or other population outcomes. A few of the portals provided historical data products, with DFO providing an important historical archive of floods since the 1980s. Historical data from NW was derived from DFO data and from EM-DAT but is not ongoing. GSWE also provided important historical data taken from satellite imagery, but it captured the overall change over time. Data products that capture flood events over a long period of time are valuable for population studies, though deriving such products retrospectively is difficult due to quality of data from earlier decades.

Most data captures flood occurrences, but measures of flood recurrence are needed. Only GSWE and NW provided this type of information. GSWE provides a 'recurrence' layer, which captures information about the inter-annual behavior showing areas that are inundated regularly versus those that are flooded episodically [42]. NW captures flood recurrence through its 'Flood Hazard: Frequency and Distribution' layer, providing information about flood frequency using data from the DFO historical archive [37]. Additionally, a planned future improvement to the NW Global Flood Product is to include a 'recurring flood' layer to identify regularly flooded areas [63]. Incorporating other information about floods is also important, such as size, duration, depth, or damages. Only DFO and NW provided other information about floods, including the human and economic impacts. Other classifications of flood exist that incorporate potential damages [13, 25, 77]. For example, the US National Weather Service uses a 3-level classification system based on the level of damage caused [13]. If flood data portals can extend beyond flood monitoring, to incorporating these other elements, the usability of their products will improve greatly.

Table 5. Uses of flood portals in prior studies.

Flood Portal	Use cases	Linked to other datasets
Dartmouth Flood Observatory	Flood severity and magnitude[2]	✓
	Spatiotemporal variability of floods[3]	
	Flood occurrence and human impacts[4]	
	Validation of flood warning system[5]	
	Human determinants of floods[6]	
Global Surface Water Explorer[1]	Changes in delta morphology and coastal morphology over time due to human activity[7]	
	Context to stakeholders' opinions regarding river conservation[8]	
Global Flood Awareness System	Early warning of flood events[9]	
Global Flood Monitoring System	Accuracy of flood monitoring systems[10]	
	Flood prediction and identification of risk zones[11]	
NASA Worldview	Impact of palm oil expansion and wildfires on land use[12]	
	Forest fire risk and subsequent flooding[13]	

[1] This portal does not classify flood events. Its purpose is to quantify changes in global surface water over time. While not specifically measuring flood events, GSWE datasets can be used to identify flooded areas.

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[4] Chen A, Giese M, Chen D. Flood impact on Mainland Southeast Asia between 1985 and 2018—The role of tropical cyclones. J Flood Risk Manag. 2020 Jun 1;13(2): e12598.; Cunado J, Ferreira S. The Macroeconomic Impacts of Natural Disasters: The Case of Floods. Land Econ. 2014 Feb 1;90(1):149–68.; Hu P, Zhang Q, Shi P, Chen B, Fang J. Flood-induced mortality across the globe: Spatiotemporal pattern and influencing factors. Sci Total Environ. 2018 Dec 1;643:171–82.

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[6] Ferreira S, Ghimire R. Forest cover, socioeconomics, and reported flood frequency in developing countries. Water Resour Res. 2012 Aug 1;48(8):8529.

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[10] Kumar N, Kumar M, Sherring A, Suryavanshi S, Ahmad A, Lal D. Applicability of HEC-RAS 2D and GFMS for flood extent mapping: a case study of Sangam area, Prayagraj, India. Model Earth Syst Environ. 2020 Mar 1;6(1):397–405.

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[12] Pittman A, Carlson K, Curran L, Ponette-González A. NASA Satellite Data Used to Study the Impact of Oil Palm Expansion Across Indonesian Borneo. Earth Obs. 2013;25(5):12–6.; Sherbatov A, Hsiang E, Kilburn C, Ortiz J, Koppe B. Case Study of Camp Fire Employing Novel Metric for Time Series Analysis of Vegetation Recovery. ESS Open Arch. 2021 Oct

[13] Peters B V., Bagwell RE, Wong MM. Flood Analysis of the Thomas Flood in California Using NASA Data in a GIS. 2018.

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Spatial and survey data linkages are challenging and not intuitive for researchers in public health and nutrition related fields. All the data products in this review require extra steps to be linked to surveys. None provide aggregations by administrative boundaries, which could facilitate this process. Having multiple data formats available that are accessible to a broad range of researchers could also facilitate this process. High resolution data products are important for data linkages, as aggregating up to community, sub-district, or district levels is more advantageous than downscaling coarse data. A deeper exploration of data integration methods is needed, including their challenges, benefits, and disadvantages. This is a future direction.

Survey respondents highlighted areas where the portals could improve or provide better clarification. DFO and NW could improve the clarity of their goals and scope. All portals could improve with respect to classifying flood types, providing more information about floods, and measuring recurrence. Sub-national and sub-yearly classifications are also needed to facilitate data linkages. GSWE was the most accessible platform, with raters agreeing on some aspects for GloFAS and improvements to user-friendliness, outdated links, tutorials, and data accessibility and formats could be made to the other portals. Taken together, this external user review can help these portals determine where they could improve either in terms of their products or the clarity of their websites. It has wider application to other types of data portals or environmental hazards. Addressing scalability is another future direction.

The low inter-rater agreement could reflect either the variability of the raters or of the portals themselves. The raters in this review were graduate students who were familiar with spatial and survey data, although some had more expertise than others. The low agreement was more likely due to the variability of the portals, indicating a need for common standards to improve their usability. Some criteria may have been easier to judge than others. Regardless, the percent agreement still provides valid and important information. A larger sample size would yield more precision.

We did not conduct an extensive review of all flood or disaster data portals in existence, of which there are many. We highlighted major aspects of 5 common flood data portals that we identified. However, it is possible that other flood data portals not included in this review have different usability aspects. While not specific to other flood data portals, our findings may provide general guidance on how to improve these important data sources. The portals included in this review–NW, GloFAS, GFMS, GSWE, DFO–may take specific recommendations from these findings.

Flood data portals should include research as part of their purpose and mission and should incorporate the interdisciplinary user perspective. Usability of the data products could be improved by providing sub-national aggregations, different data formats such as statistical datasets in Stata or R format, and mechanisms that clearly indicate where data may be incomplete or unreliable. Historical data products that span decades can provide an opportunity for longitudinal research of the human impacts of climate changes and extreme events. Measures of flood recurrence, not just occurrence, are needed. Data on other characteristics of flooding such as type of flood, depth, duration, and damages are also needed. Finally, the longevity and maintenance of these data portals should be secured through long-term funding for future generations and research.

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