DFID – GFDRR Challenge Fund

PHASE II FINAL REPORT

I. Project

Title project: PHASE II: Development of Web Map Services to improve access, query and visualization of near real time and historical global flood data
Target countries: World
Funding amount: $150,000 USD
Time frame grant: March 1st, 2017 to March 15th, 2018**.**

II. Product description

Introduction

Flooding occurs on all continents and impacts over half a billion people every year worldwide. This is more than any other natural hazard, and may increase to two billion by 2050. Occurring both in developed, as well as less developed countries, flooding is ***the most common*** hazard worldwide. Over the last decade of the 20th century, floods caused circa 100,000 fatalities with an additional 1.4 billion people directly affected and contributes to a global-average annual loss of US$104 billion. While some events are more seasonal – so easier to anticipate for, large floods tend to be more episodic which makes flooding difficult to predict. Although flooding can be very impactful for communities and countries, there hasn't been an effort to identify and determine global flood risk areas.

This project is the first initiative to establish globally a flood risk database that scales from a global overview to local hotspots and is based on measured observations.

Developed product

To identify flood risk areas as well as provide open access to information of flooding during an actual event, we developed an 'interactive online flood portal' that provides 24/7 access to historical flood information as well as to Near Real Time (NRT) flood data (http://floodobservatory.colorado.edu/WebMapServerDataLinks.html; Figure 1). The flood information products are mainly derived from data of various satellites using state of the art, often newly developed and implemented algorithms, and include for some continents, model simulated flood extents as well. These products are hosted on the server of the Dartmouth Flood Observatory (DFO), the University of Colorado. Each dataset is provided as a Web Map Service (WMS) which are than grouped per continent in the interactive flood portal.

Additional to the web interface to access flood data (so the only requirement is to be online, no need to download and install software), users have the opportunity to ingest each individual dataset into their local GIS system like QGIS or ArcMap by utilizing the various WMS layers. This enables clients to overlay current or historical flood data with their local datasets, a necessity for planners and decision makers to identify flood hazardous areas! An additional advantage of using WMS is that clients have access to the most up to date flood information data. As soon as

Figure 1. Flood portal, providing access to flood data per continent

we update datasets (like some of our daily updated, NRT layers), so will it directly update on the client's site through the WMS, that is, as long as the client is online.

The following flood related data products have been developed for this project and are provided per continent to reduce the time it takes to read in a layer:

1. ***Current daily water extent data***. (250-meter horizontal resolution). A fully automated, daily updated product that shows flooding based on 6 MODIS optical images, 3 from Aqua and 3 from the Terra satellite. A pixel is classified as water as 4 or more pixels are marked as water. Floods will not show when it is cloudy.
2. ***2-week accumulated flooded area***. (250-meter horizontal resolution). This fully automated, daily updated MODIS derived product shows the maximum flood extent over a moving 2-week period. So even when it gets clouded for several days (so detection of water is hampered), flooded area is still indicated.
3. ***January till current flooded area***. (250-meter horizontal resolution). The January till current flood extent layer is derived from MODIS and updated monthly, at the first of the month. The layer has been useful for for example insurance companies who are interested in areas that have been flooded in the past few months.
4. ***Annual flood inundation area extent***. (250-meter horizontal resolution). The annual maximum flood extent layers are created utilizing MODIS data. This is a partly manual derived product, that is available from 2013 onwards.
5. ***Flood hazard (frequency) map*** (Figure 2.). (250-meter horizontal resolution). This layer shows as a percentage, how often in the last five years an area has been flooded on an annual base.
6. ***Flood heat map***. (250-meter horizontal resolution). The heat map shows how often an area has been flooded on an annual base, with the following classification: less than

one week, between 1 and 2 weeks, between 2 weeks to a month, and more than a month. These layers are provided per year and indicate how long an area has been flooded.

7. ***Regular water layer***. (250-meter horizontal resolution). The regular water layer shows areas that contain at least 3 out of 4 years water. Therefore, this layer can be used as a mask, to remove permanent water bodies like large rivers, lakes, reservoirs and the coastal zone that always show as 'flooded' (or water).
8. ***Flood event layers***. (30-meter horizontal resolution). The flood event layers are manually derived using ESA's free available Sentinel-1 Synthetic Aperture Radar (SAR) data. The advantage of using SAR data is that: a) flooding can be detected through clouds, and b) data is of much higher horizontal resolution, 30m instead of 250m. However, the recurrence interval of getting satellite data of the same area is significant less, several days. So short lasting flood events might not be fully captured.
9. ***Satellite River Discharge Measurements***. DFO has developed a technique to measure water discharge at an area of interest. We can place a 'satellite-based station' where requested and generate daily discharge from 1998 onwards. The available locations for which we do have satellite-based discharge data have been included as WMS in the 'flood portal'. Information of the stations is updated on a daily base and color indicates if the river is in: low or normal flow, or in moderate or major flooding.
10. ***Integration VIIRS satellite derived water product to guarantee product sustainability.*** Currently used MODIS data to detect flooding has only a limited lifetime left. Therefore, an algorithm has been developed and successfully tested to classify water using data of the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi NPP satellite. Suomi NPP is flying in a polar orbit, circling the Earth over both poles about 14 times a day. This is sufficient to get one imagery of an area of interest per day. The horizontal resolution is very similar as the used MODIS data, ~325m, making it possible to easily detect large persistent flood events in non-urban areas. Similar as MODIS data is currently processed to remove cloud shadows false positives, daily processed data will be binned in 3-day water products, where each daily pixel classified as water has to at least 2 out of 3 times be classified as water. This greatly reduces the number of cloud shadows that would otherwise show up as water (false positive). Scripts have been developed to automatically download and process the VIIRS data tiles daily by implementing the developed water classification algorithm. The data tiles cover each an area of ~10x10km. Only land area is processed. Produced geotiff files are converted to shapefiles, imported as PostGIS, a Spatial and Geographic Object for PostgreSQL database and integrated in the currently available 3-day MODIS product.

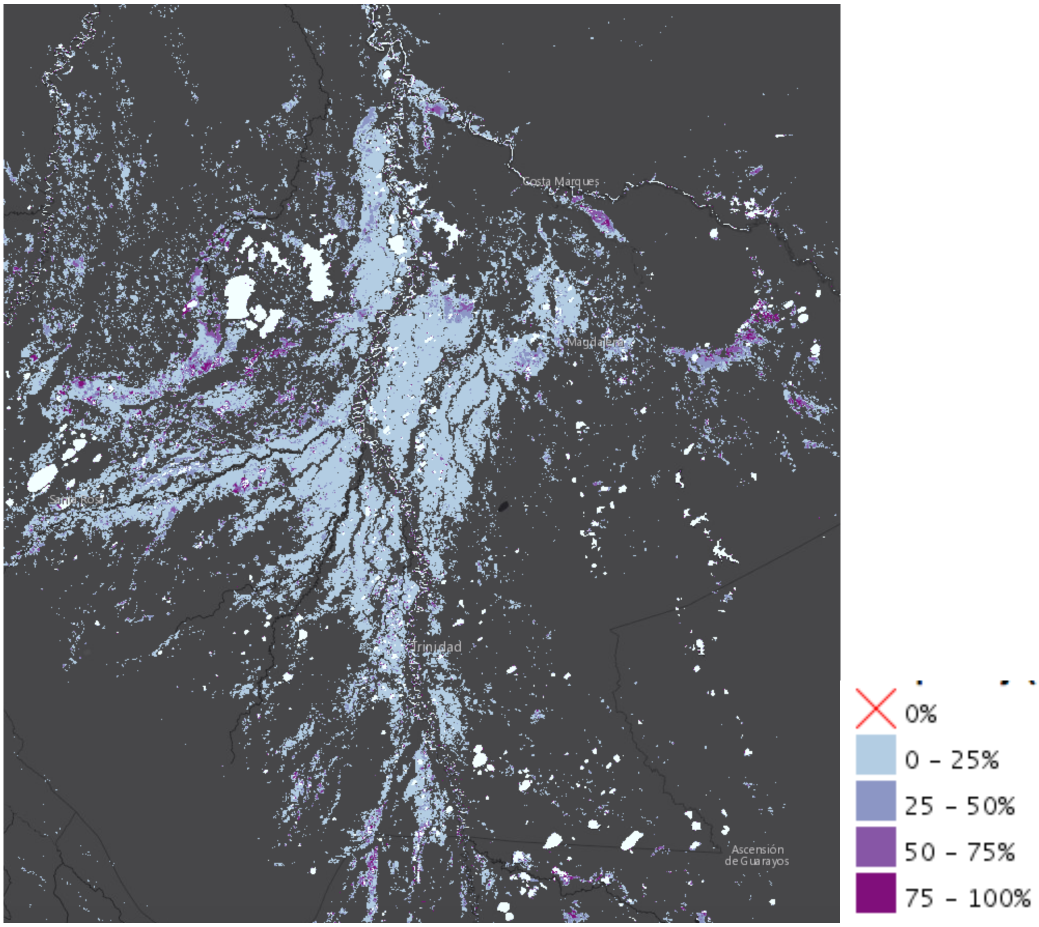

Figure 2. Flood hazard map of part of Bolivia, where flooded areas show up as dark purple if they can flooded multiple years or more towards light blue when flooded only 1 or 2 out of 5 years. The white-to-light blue areas are areas that experience regular or permanent water throughout the year (so lakes and larger streams).

Approach

Our approach was to develop a 'one stop shop' for flood information for the world. There are no other initiatives that fully implemented this. Some regional efforts have been made and are successful but historical context is often missing and these initiatives are limited to a specific area of interest. We developed a ‘one stop shop’ for floods by implementing WMS capability for the newly developed flood data layers as well as setting up the interactive web-based flood portal is demand driven by a wide variety of clients who like to use data of the Dartmouth Flood Observatory (DFO). DFO receives many data requests, especially during or after a flood event. These data requests vary from for example news agencies who help create flood hazard awareness; disaster relief agencies like the Federal Emergency Management Agency (FEMA), World Food Program (WFP) and the Red Cross who among others provide first-aid; to government agencies and development bank funded projects that have the intention to increase data availability for often less developed region in the world (e.g. GeoSUR project, South America).

For our approach we requested feedback from beneficiaries by sending out an anonymous survey to ~300 potential DFO product users we have identified over the years and asked them specifically if satellite derived products are useful, if a 'one stop shop' for flood information is useful and if people are familiar with WMS technology (in case people would like to directly ingest the data into their local GIS system). We received feedback from 26 people, that represent researchers (42%), product developers (12%), field level emergency responders (12%), decision makers (4%), insurance companies (8%), development aid (12%) and 10% didn't reveal their main profession. Of those that replied, over 73% uses satellite derived flood products for their work, by far the highest category compared to e.g. field observations (50%), news media (38%), verbal information (19%) or computer models (65%), and almost half of them are familiar with WMS. Therefore, we are confident that the interactive flood portal as well as the underlying WMS for each layer is beneficial for the user community.

III. Partnerships

Over the course of this project (phase I and II), DFO has actively worked together and strengthening partnership with several organizations. We have especially been working together with the WFP, and organized a 3-day meeting in Boulder, Colorado to discuss among others the need and potential use of the to developed flood products. Of the WFP, Amy Chong and Ruangdech Poungprom (WFP Bangkok office) as well as Lara Prades, Sarah Muir, and Andrea Amparore (WFP Rome headquarters), attended this meeting. DFO works together with NASA to generate in NRT raw water products from MODIS so therefore Dan Slayback (NASA) attended as well. On several occasions after the workshop, attendees reached out for specific satellite derived flood products. For example, last September the WFP reached out to obtain information of three flood affected regions of Niger: Dosso, Niamey, Tillabéri. Within 2-days we had flood extent data provided as WMS and made this also available through the interactive portal (Figure 3).

During this project we have also worked intensively with founders of the GeoSUR project. The GeoSUR project is a Latin American initiative led by spatial data producers to implement a regional geospatial framework and to help establish a spatial data infrastructure for the region. GeoSUR supports the development of free access geographic services useful to find, view and analyze spatial information through maps, satellite images, and geographic data. Our mains contact are Jesus Suniaga (project lead) and Miguel Blanco (GIS expert), both from CAF - Development Bank of Latin America. Several of products described above are implemented in the GeoSUR geospatial portal as well, simply by ingesting the DFO flood data as WMS. We are currently trying to strengthen our partnership by seeking support for additional products for the GeoSUR portal.

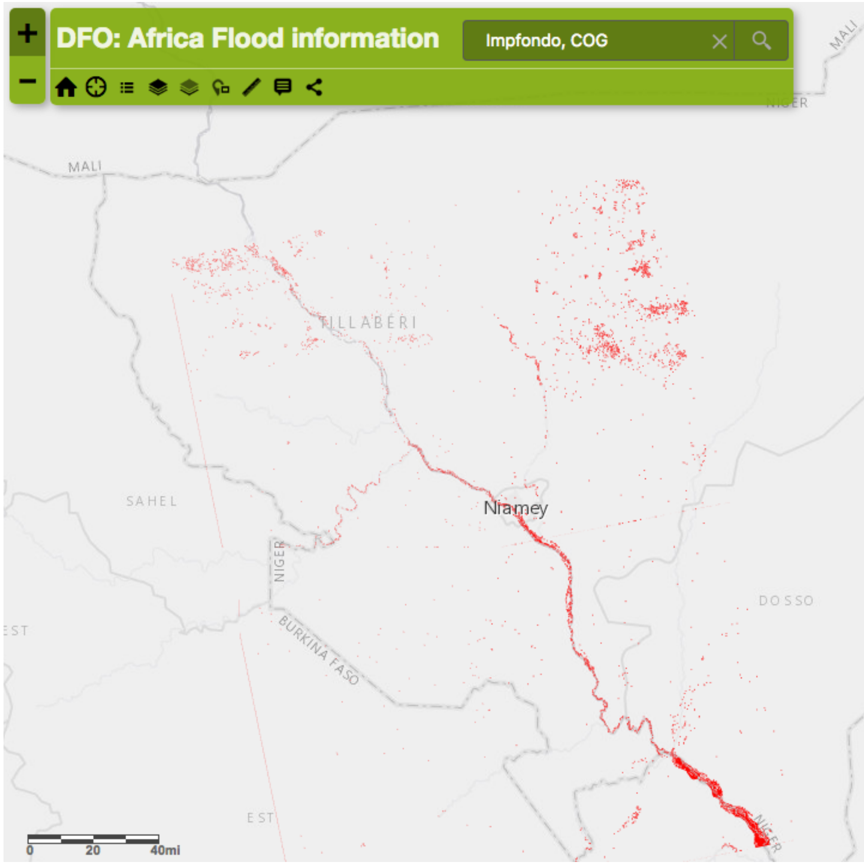

Figure 3. Flood event 4519; flooding at Niger, in the regions Dosso, Niamey, Tillabéri. Areas in red illustrate where water was detected using SAR data.

IV. Capacity building with local stakeholders

For promoting uptake and receiving constructive feedback on the products we have developed over the course of this project, we have successfully sought support from additional funding agencies. Due to logistical reasons we have scheduled an USAID supported, two-day training workshop featuring the products of this project at the end of this project, March 21st - 22nd. The workshop is titled: "Applied tools to monitor water discharge and flooding for South American Rivers" and will be hosted at EAFIT University, Medellin, Colombia for just over 25 participants (table 1). The main goal of this meeting is to introduce participants to near-real-time satellite-derived estimations of river discharge and flood extent and to evaluate flood magnitudes frequencies and variability along South American Rivers by using DFO data and the interactive flood portal. Through the several scheduled discussion sessions we anticipate receiving feedback on how to make the data and the portal more useful.

Table 1. Participants of the 2-day workshop at EAFIT, Medellin, Colombia

Name	Country	Institution
Naziano Pantoja Filizola Júnior	**Brasil**	Federal University of the Amazon
Miguel Angel Blanco Calderón	**Nicaragua**	Andean Bank, CAF
Héctor Andrés Angarita Corredor	**Colombia**	The Nature Conservancy, Colombia
Juan Carlos Bazo Zambrano	**Perú**	
Juan D. Restrepo	**Colombia**	EAFIT University
Andrea Gianni Cristoforo NARDINI	**Italia**	ONG-Urban Flooding, Colombia
Andrew C. Wilcox	**USA**	University of Montana
Johan Manuel Redondo	**Colombia**	Humboldt Institute, Colombia
Jesús Suniaga	**Venezuela**	Andean Bank, CAF
Consuelo Del Rosario Castilla Marrugo	**Colombia**	Cormagdalena, Colombia
Claudia Martínez Correa	**Colombia**	Cormagdalena, Colombia
Luz Fernanda Jiménez	**Colombia**	Antioquia University
10 Geological Sciences undergrads.	**Colombia**	EAFIT University
7 faculty and researchers	**Colombia**	EAFIT University

During phase I of this project we had already successfully obtained additional resources to hold a meeting with the World Food Program (WFP) and demonstrated the then available products that had an African focus (see section III).

V. Private and public-sector leverage

Same as for phase I, this project leveraged by making use of existing computer hardware, a web server and software which was funded by NASA and a project of the Latin American Development bank. The leverage allowed development of the WMS services without additional infrastructural costs. Estimated leverage: $12K USD.

The project also leveraged from a 24-hour hardware contract for replacements in the event of a hardware failure. Data backup support (24/7) to minimize data loss is made available through a 5-year supported NSF project. Estimated leverage: $4K USD.

Through a University of Colorado contract, employees can use GIS software for free. Most of the software used for this project is open source accept for the online portal. Estimated leverage: $33K USD.

DFO has the capacity to manually produce high resolution flood maps, based on Sentinel-1 SAR data. This is supported by a larger NASA grant. These products are made available through the WMS as well as the flood portal. Estimated leverage: $40K.

Furthermore, phase II received additional leverage from NASA by providing numerical flood extent simulations from the LISFLOOD-FP model for several continents. Estimated leverage: $700K USD.

The project will also benefit from a USAID supported two-day workshop at EAFIT University, Medellin Colombia. During the workshop the various products developed over the course of this project will be demonstrated to potential users to gain feedback. Estimated leverage: $23K.

VI. Gender aspects of the project

We envisioned that freely available, easy-to-use products support end-users irrespective of gender, but realize that there is inequality in information access as for example access to computational resources might be gender biased. We have made a concerted effort to involve a diverse group of end-users and formally solicit product feedback from them. For this project, gender is addressed in two ways:

- First and foremost, we aim to make flood disaster information freely and widely available. Women are disproportionately represented over men in fatalities after large-scale disasters due to social and cultural situations. One reason is that women tend to have less access to or control over assets, including the resources necessary to cope with hazardous events, such as information (Bradshaw and Fordham, 2013). Khondker (1996) indicated that in Bangladesh, floods often destroy the household resources, undermining the economic well-being of rural women. However, women are rarely involved in the disaster response decision-making process. The data we provide will be available not only for water management agencies, but also for NGO's and other end-users with active programs addressing women's resilience. We sought collaboration with one such international organization that has a local office in Boulder (Institute for Social and Environmental Transition-International; ISET). The flood maps are meant to identify hazard areas (flood plain detection through data of model simulations as well as flood extent archive) and thus help to early inform the various planning and disaster response groups of the severity of a flood, and allow analysis of vulnerable households by these users. Although collaboration with ISET, who have specialists in gender and social inclusion, and very much embed and embrace this in their projects, hasn't result in a joined project yet, we have developed a flyer to strengthen seeking support for joint gender applied opportunities (see appendix I).

- Through this project, it has been our intent to work with as many women end-users as possible to specifically get their feedback of what products work best and what needs to change to better support women. We have explicitly engaged with gender experts for this. During phase 1 of the project, wherein our focus is on Africa, 33% of our end-users were female and it is our goal to increase the participation of women during phase 2 of the project. We have extended our female points of contact within the World Food Program to 60%.
- Recent collaboration with a female scientist, Xiujuan Liu at the China University of Geosciences, Wuhan has led to joined manuscript that describes the impact of three flood events that occurred for the Yangtze River in 2011, 2012 and 2016. In the last century alone, the Yangtze River basin has undergone frequent catchment wide flood disasters, showing an increasing trend in frequency of occurrence, and causing significant economic and social losses to the local population. Given the events that are currently classified for flooding we are able to provide her with flooding data regarding maximum extent and flood duration (Figure 4).

Figure 4. Water extent (river flow and flooding) observed by MODIS of the middle reach of the Yangtze River at Wuhan city, of the June 2011 flooding.

VII. Scalability opportunities

Several new flood data products as well as an interactive web-based geospatial flood portal has been developed and are made more robust during phase I and II of this project. The coverage was extended from a focus of Africa during phase I, to a worldwide focus for phase II, and now we provide at no cost access to new derived flood data while an event occurs, and at the same time preserve and keep providing access to historical data as well. The last is challenging as historical data encompasses terabytes worth of data that we try to make available through the web in a meaningful and most efficient way. Despite significant progress in creating a 'one stop shop' for flood related products, we have identified four main areas in which the, for this project developed, products can improve:

1. ***Uptake of the products.*** The flood related data and the interactive flood portal are free of costs available 24/7. Although the obtained survey shows that DFO is known for it satellites derived flood products, I think the portal and data that is made available through the WMS is relatively unknown as we have not marketed the products extensively. So it can be expected that the uptake will significantly increase when we market this more. Something we will keep doing, also to receive more feedback such that we can improve the current products and develop new once if there is a need.
2. ***Extending accessibility of historical flood data***. Current shortcoming, we identified is the accessibility of historical data. Five years of historical flood data derived from MODIS imagery is available as WMS through the web-based flood portal. However, there is an additional 12-years of daily MODIS data available that could be back processed. Getting better insights in flood history will help identify flood risk areas and so support decision makers. Therefore, we see this as a very important task but currently we are lacking the needed support to do so.
3. ***Integrate flood supporting information***. With support of GFDRR we have developed a platform through which users can access current as well as historical satellite derived flood information. For some continents we also provide model simulated flood extents over a 50-year period, to help decision-makers identify areas that are likely to be in a flood hazard zone. What is missing is a full integration framework that incorporates other water related data such as an early flood warning system (flood forecast system), or data from ground-based river gauging stations so people can better relate the maximum flood extent with its associated peak discharge. This will help for example decision-makers as they can for example set restrictions on developing certain flood zones. This data is made available for some of the more developed countries by organizations like FEMA. These 100-year or 500-year flood zones determined by FEMA is based on a combination of detailed field studies and numerical models, and are very expensive to develop. But potentially could be made available at a lower cost by mapping flood extent and link this to a measured peak discharge.
4. ***Extend platform and allow integration of social media***. In a next phase we propose to extend the current data framework to a mobile app through which users can view historical data as well as current flood data. Users can download flood data of an area of interest such that there is no need to be continuously online, especially useful for disaster responders over the course of a flood event. When back online, maps get automatically updated such that the responder has the latest information. We propose to integrate data of social media as well. Satellite based flood data has at best a delay of 1 day but often it takes several days to identify the areal impact of a flood. Those directly involved however often warn friends and family through social media. This data can be used to roughly determine the affected

area. Additional we can ask users of the flood app to upload images of the flood, so a better understanding of the impact can be obtained.

VIII. Lessons learned

There are two main learning points from this project, a) Focusing more on identifying flood risk areas by providing access to historical information, and b) better marketing of the available data and tools such that there is a broader uptake and therefore more feedback.

DFO is working closely with relief agencies and these are mostly interested in flood events that are either happening or just happened. However, historical flood data is more important if you want to identify flood risk areas for, for example flood mitigation projects, or for planning agencies that can restrict development in flood zones. DFO has always valued historical data but it becomes clearer that we need to seek support to process back more than a decade of daily satellite data as this will be very valuable to map areas with potential high flood risk.

Feedback on the usefulness of data products and developed tools is of utmost important to optimize products, making them of more value for users. Getting feedback can be achieved by providing workshops and demonstrations. No workshops have been proposed for this grant. Fortunately, additional support has become available to support a workshop in Colombia. And although the GFDRR support is by then ended, we still think it is very valuable to get feedback on the products and tools we developed and are intended to seek ways to improve the products we have developed under this grant based on the Colombia workshop feedback.

IX. Monitoring statistics for product uptake

Monitoring

For this project a web-based interactive flood portal is developed that provides 24/7 open access to spatial flood information for the world. This is not a tool to download but a portal that can be visited online. The underlying data is provided as Web Map Services (WMS) such that the various flood map layers also can be ingested for free in most local GIS systems, as long as these systems are connected to the internet.

The web portal is a map of the continents through which each continent users can access flood information, see also: http://floodobservatory.colorado.edu/WebMapServerDataLinks.html. During phase I the web portal as currently provided wasn't available yet, but the underlying data was viewed as of March 7th, 2018 1,560 times since November 29th, 2016. Table 2 provides an overview of how often flood data has been viewed per continental as of March 7th, 2018. The web portal itself (URL above) has been visited 4,406 times from 104 different countries of which the top 5 visiting countries are: the USA (51.3%), the UK (5.9%), India (3.9%), Canada (2.7%), and Germany (2.7%).

No detailed usage of the flood data can be monitored, nor do we have an insight in how the data has changed local policy. Given the survey however, this is not a tool only used by academia. A wide variety of users, including policy makers and first responders indicated to use the data.

For the project, 1,040 different WMS flood layers are at no cost available, and maintained in GeoServer. GeoServer is open source free available software to host spatial data. GeoServer doesn't come standard with a product monitoring tool. Available plugins to do so are available but limited in their usability and therefore not installed.

Table 2. Number of flood data views per continent.

Continent	**Start date monitoring**	**Number of views**
Africa	11/29/2016	1,560
Europe	3/26/2017	336
Asia	3/26/2017	1,310
Australia	3/26/2017	357
North America	3/26/2017	2,815
South America	3/26/2017	458

What becomes directly clear is that for regions where there is a relative limited availability of flood related data, like Africa and Asia, the provided products are significantly more used. This with exception of North America, that shows the highest number of users but one can argue that this is due to the 2017 hurricane season which include three hurricanes of category 4 (Harvey, Irma, and Maria) that produced significant flooding for an extensive period.

Exit strategy project

The Dartmouth Flood Observatory (DFO) is a not-for-profit entity. It is part of the University of Colorado, USA, and has been operating since 1995. DFO moved to the University of Colorado, Boulder in 2010. It is DFO's mission is to: 1) Conduct global remote sensing-based freshwater measurement and mapping in "near real time" and record such information into a permanent archive. 2) Collaborate with humanitarian and water organizations in partnerships for enabling the maximum utility of such information. 3) Perform hydrological research in the area of surface water variability, using both remote sensing and modeling, and continue to develop new methods of measuring the Earth's water cycle.

DFO is funded over the years on a project bases by: NASA, the U.S. Geological Survey, the World Bank, the Development Bank of Latin America, the UN-ISDR, GFDRR and from the European Commission's Global Disaster Alert and Coordination System (GDACS) at the Joint

Research Centre. The Observatory has no baseline support but instead relies on a variety of grants and contracts and the infrastructure provided by its not-for-profit university home. To maintain operational the Flood Observatory actively seeks new projects that are compatible with its mission and capabilities.

Through an active NASA-GEO grant, partial funds are available for maintenance of the WMS available datasets and for the interactive online flood portal for the coming 3 years. Additionally a NASA Small Business Innovation Research (SBIR) grant is awarded and will supply additional support to extend the number of available datasets and research the best strategy for better marketing of the portal in the coming 2 years.

X. Detailed budget and how it was spent

	GFDRR Funding	*In kind Funding*	*Other Funding*	**Total Funding**
CONSULTING SERVICES				
TASK TEAM SUPERVISION **(List key personnel and their related expenditure)**	Kettner $99,265 Brakenridge $21,870	Supervision of total project will be in kind and includes weekly meetings. Estimated: ~$15K	Hardware $12K Software $33K Backup $4K LISFLOOD-FP simulations $700K SAR processing ~$40K	$885,135
DISSEMINATION				
LOGISTICS		2-day training workshop Colombia. Estimated: ~$23K		$23,000
GOODS AND WORKS	$1,535			$1,535

OTHER (please specify): Indirect Cost	System & project admin: $7,305 Indirect cost: Phase I: 53.5% of MTDC: $17,427 Phase II: 54% of MTDC: $52,597 Total: $70,024			$77,329
TOTAL				***$1M***

IX. Appendix

ISET – 1-page flyer of what DFO is about

The Dartmouth Flood Observatory (DFO) mission is to 1) produce and deliver global surface water information that is useful to plan for, prevent, and respond to water-related disasters, 2) provide an ongoing and freely available global record of satellite-based water measurements, 3) collaborate with humanitarian and development organizations to apply this information effectively (for example for risk reduction or disaster response) and, 4) conduct hydrological research, and establish forecasting capabilities.

DFO provides a database of historical and near real time measurements and mapping of global water that can help inform global flood disaster risk reduction efforts. This as the historical database provides information on previous inundated areas and how often flooding occurs. Water extent (area) and water discharge (volume) measurements are derived through a combination of satellite imaging and microwave radiometer data. These daily (or twice daily) measurements, can help us understand and reduce flood risk when compared with historical data. To better determine potential risks, DFO uses averages and extremes from this growing dataset as a context to evaluate current surface water extents and predict future ones by determining flood extents for near future simulated discharges. Unlike ground based gauging stations, satellite derived water discharge gauges will not be damaged or destroyed during large flows. As a result, satellites are consistently able to capture peak flows, and determine their size relative to previous measurements.

Unconstrained by borders, bureaucratic obstacles or barriers to access, DFO's data and data services are freely available and can be applied globally to 1) map the 25-year floodplain, 2) provide discharge data for infrastructure, irrigation and urban planning risk assessment, and 3) provide information important to flood disaster response. For example, during or following a flood, flood extent mapping determines if roads are accessible, and locates safe areas to support emergency response teams and expedite their relief efforts. During major events, DFO collaborates with relief agencies and emergency managers; they also maintain collaborations with water organizations worldwide for data sharing and to further develop technical capabilities. Local disaster resilience can be supported by incorporating the observed history of floods and surface water extent into development and infrastructure planning. Through “on the ground” feedback from end users, the specific data and data service outputs can also be further improved. Improved forecasting efforts are also underway by a joined effort with NCAR and soon most likely also with the GLOFAS group at JRC, to provide early warnings for those in the floodway.

The Dartmouth Flood Observatory is an independent not-for-profit international organization located within the University of Colorado’s Institute of Arctic and Alpine Research (INSTAAR). Its name reflects its origin at Dartmouth College in 1993 and sustained work there prior to its move to the University of Colorado in 2010.