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Co-developing Earth observations-driven solutions for disaster risk reduction: a case study and where we could go from here

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- Basics - Disaster Management cycle, Earth observations, Risk
- Anticipatory Action
- Stakeholder Mapping
- Case study - 2009 El Salvador tropical cyclone, floods & landslides
- Looking back, looking forward
- Takeaways

EO can inform decisions throughout the DM cycle

mitigation - all actions designed to reduce the impact of future disasters (planning)

- structural (engineering)
- nonstructural (land-use planning, insurance, legislation, evacuation planning)

preparedness - actions taken to reduce the impact of disasters when they are forecast or imminent (execution)

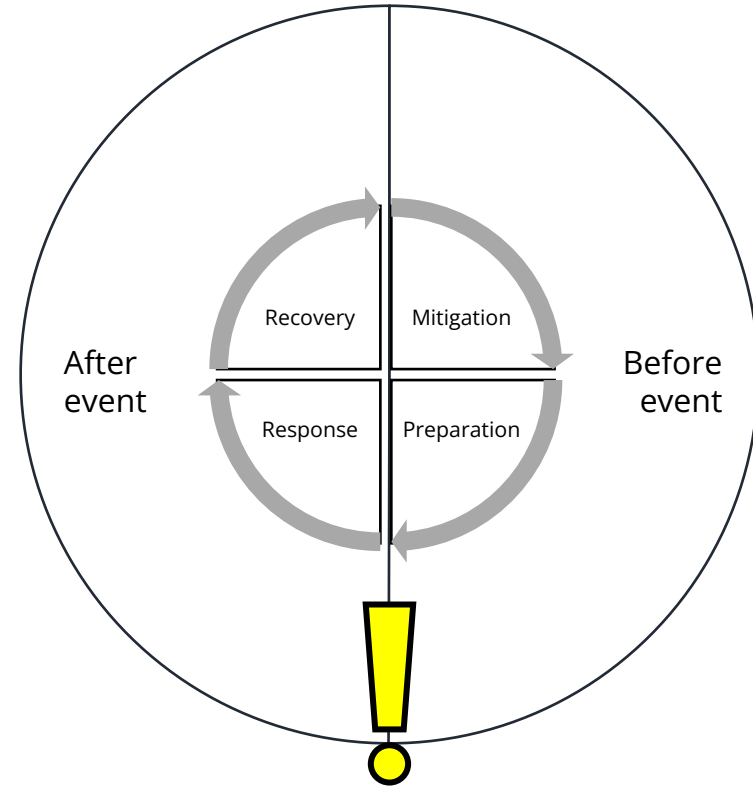
- includes security, such as evacuation, sandbagging river levees

response - actions taken during the impact and short-term aftermath of a disaster

- principal emphasis on saving lives and safeguarding lives

recovery - repairing damages, restoring services and reconstructing facilities after a disaster has struck

- major catastrophes may mean that recover takes as long as 25 years



(adapted from Alexander 2002)

Scope of Earth observations (for this talk)

Information derived from...

Satellite-based measurements

- Historical
- Near real-time

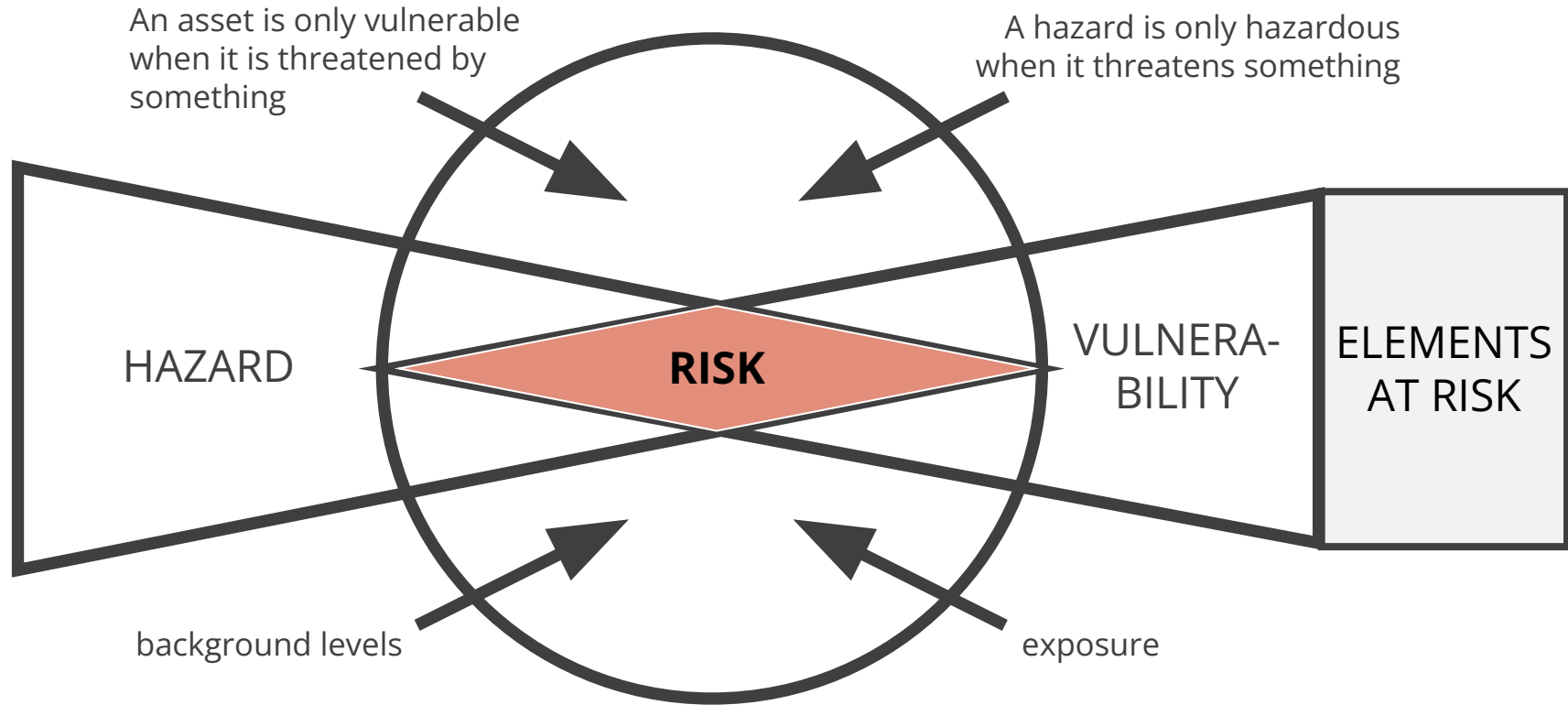
Models that include satellite measurements

- Historical
- Near real-time / Nowcast
- Forecast

Models that include a blend of satellite and in situ measurements

- Historical
- Near real-time / Nowcast
- Forecast

Risk is where hazard and vulnerability intersect



(adapted from Alexander 2002)

Calculating disaster risk, and attention to scale

$$R(DI) = P(H) \times P(S|H) \times P(T|S) \times V(L|T)$$

$R(DI)$ is risk (annual probability of loss of life to individual, **DI = death of individual**)

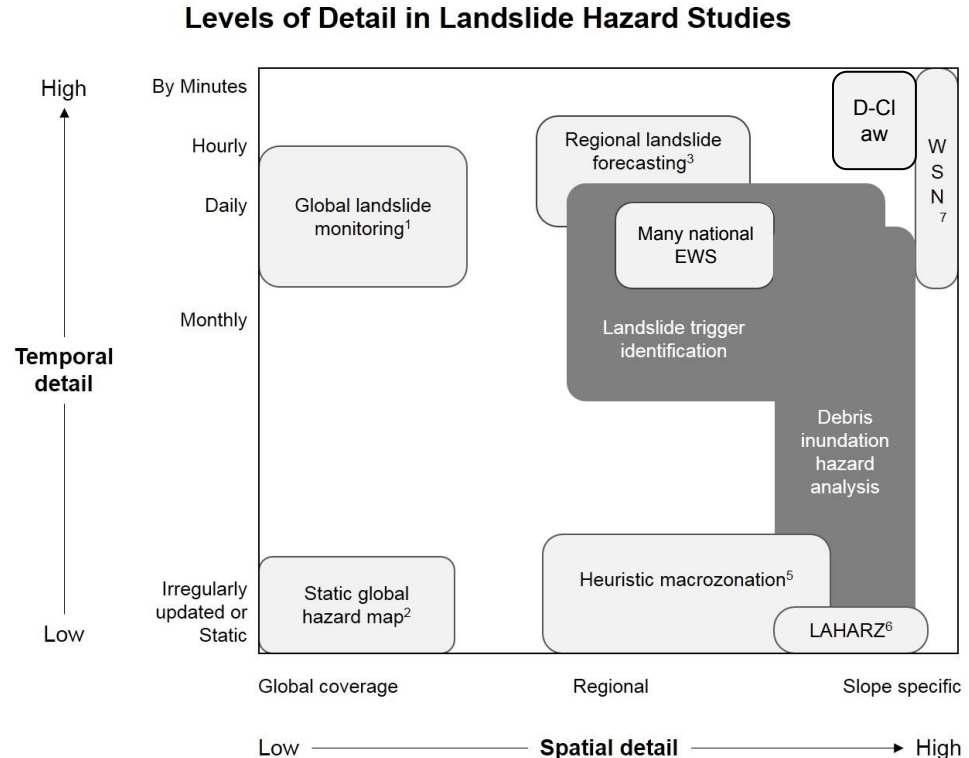
$P(H)$ is annual probability of the landslide event (**H = hazard**)

$P(S|H)$ is probability of **spatial** impact given the event

$P(T|S)$ is probability of **temporal** impact given the spatial impact

$V(L|T)$ is **vulnerability** of individual (probability of loss of life of individual given impact)

Modified from Dai, et al 2002



(modified from Anderson 2013)

Anticipatory action a.k.a. forecast-based financing (FbF), forecast-based early action (FbA) (1)

- An approach to shift disaster response towards anticipation in order to mitigate impacts to at-risk communities;
- Builds on early warning / early action
- *Timely and accurate information is needed in the development of impact-based triggers and thresholds for action.*
- “Early action protocols” define the data inputs, actors, and early actions
- Movement to define impact-based triggers
 - Hazard, exposure, vulnerability

(1) <https://www.anticipation-hub.org/learn>

Anticipatory action a.k.a. forecast-based financing (FbF), forecast-based early action (FbA) (1)

Table of FbA outcome scenarios (2,3)

	Extreme event	No extreme event
Action	Worthy action (true positive)	Action in vain (false positive)
No Action	Fail to act (false negative)	Worthy inaction (true negative)

- Considerations
 - Forecast skill (accuracy, uncertainty, lead time)
 - Economic valuation of observations and forecasts
 - Reputational risks
 - Not all “actions in vain” are bad

(1) <https://www.anticipation-hub.org/learn>

(2) Nauman et al., 2021, JARS. <https://doi.org/10.1117/1.JRS.15.032002>

(3) A. Lopez, “Bridging forecast verification and humanitarian decisions: a valuation approach for setting up action-oriented early warnings,” Weather Clim. Extremes 27, 100167 (2020).

Anticipatory action a.k.a. forecast-based financing (FbF), forecast-based early action (FbA) (1)

A few examples of flood early actions and lead times (2)

Early action	Lead time
Work with communities to reduce risk through concrete actions (e.g., reforestation and reinforcement of houses)	General preparedness years in advance
Conduct vulnerability and capacity assessments	General preparedness at season's beginning
Build shelters; build latrines	Three months
Support storage of seeds and food items; bag vulnerable items and move storage facilities to higher ground	Three months to one week
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Dig trenches around homes to divert water	One week
Evacuate	Days to hours

(1) <https://www.anticipation-hub.org/learn>

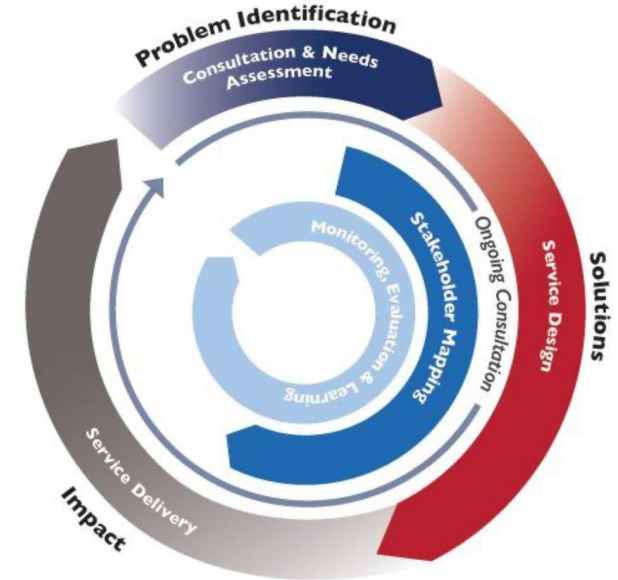
(2) Nauman et al., 2021, JARS. <https://doi.org/10.1117/1.JRS.15.032002>

Before, during, and after Implementation... Design and Evaluation matter

Fundamental reorientation of the SERVIR program

Service Planning Approach

- Consultation & Needs Assessment
- Stakeholder Mapping
- Service Design
 - Co-development
- Monitoring, Evaluation & Learning
 - Theory of Change

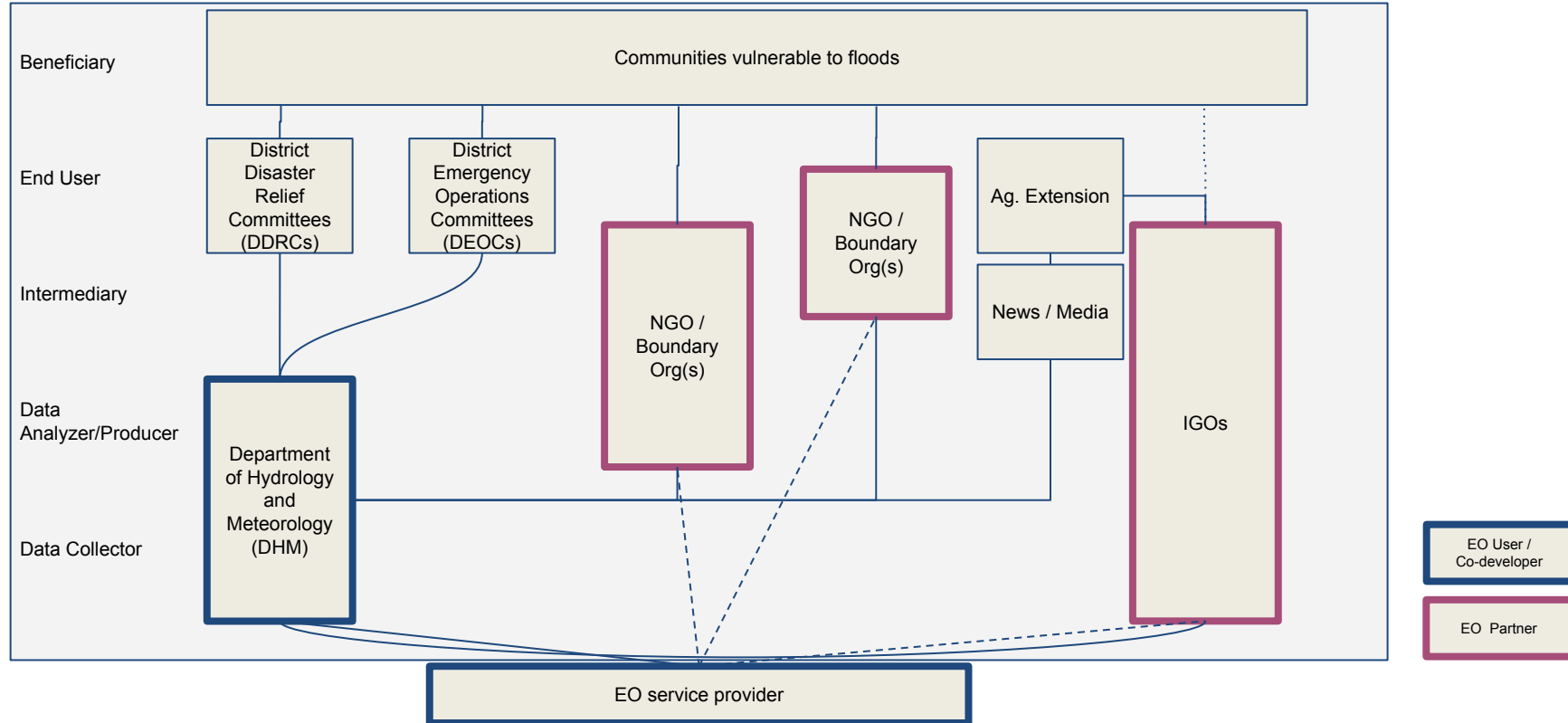


SERVIR Service Planning Toolkit, 2021. <https://www.servirglobal.net/about-Servir>

Before, during, and after Implementation...

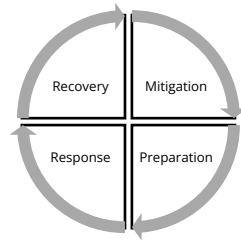
Design and Evaluation matter

Stakeholder mapping – simplified **information flow** for a service designed to build capacity in using EO in a flood early warning system



2009 El Salvador floods & landslides (1,2)

- Convergence of Tropical Storm Ida and Low Pressure System 96E over Central America,
- 355 mm (14 in) of rainfall in a period of 24 hours,
- maximum intensity of 81 mm (3.2 in) per hour
- extensive flooding and landslides throughout the central region of El Salvador
- 130 persons lost their lives,
- 60 were reported missing,
- 10,400 had to take refuge in public shelters.
- Widespread ramifications; estimated 122,000 people affected directly or indirectly
- Economic losses estimated at US 314.8 million dollars



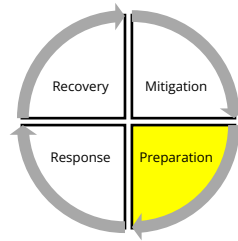
(1) Anderson, E. R., Irwin, D., Delgado, F., Diaz, M., Molina, G., & Cherrington, E. (2012). Evaluation of space-based support through SERVIR during and after the 2009 floods and landslides in El Salvador.

(2) CEPAL, 2010. "El Salvador: Impacto Socioeconómico, Ambiental y de Riesgo por la Baja Presión Asociada a la Tormenta Tropical Ida en Noviembre de 2009." Economic Commission for Latin America, Mexico Sub-regional Headquarters, Mexico City.

2009 El Salvador floods & landslides

Preparation

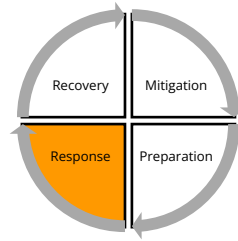
- Static maps of flood and landslide hazards developed by local authorities
- Flood and landslide early warning systems (EWS) in place, operated by local authorities
- Constant monitoring of weather conditions with geostationary satellites by local authorities, leveraging global satellite resources (e.g., GOES)



2009 El Salvador floods & landslides

Response

- National emergency declared
- International Charter activation
- 15+ value added products created
 - before/after scenes identifying extent of flood and landslide damage
 - volcanic lahars
 - Affected bridges and roads



2009 El Salvador floods & landslides

Recovery to Mitigation



- Reassessment of flood and landslide hazard zones
 - And subsequent structural and nonstructural plans to reduce future risk (e.g., zoning)
- Strengthening of *observadores locales* network
 - Enhancement to early warning systems
- Better understanding of risk (underlying vulnerability of populations, buildings, etc.)



(L) Informational kiosk on disaster risk in the Central Park of Verapaz.

(R) Preliminary map of a reconstruction and restoration guide for Verapaz, developed by DGOA/MARN in 2009, showing dredging, suggested location for wall or dike, zones appropriate and not appropriate for restoration, and suggested areas for development.

Imagining new ways to link EO and disaster risk reduction



Anticipatory Action

Early Action Protocols

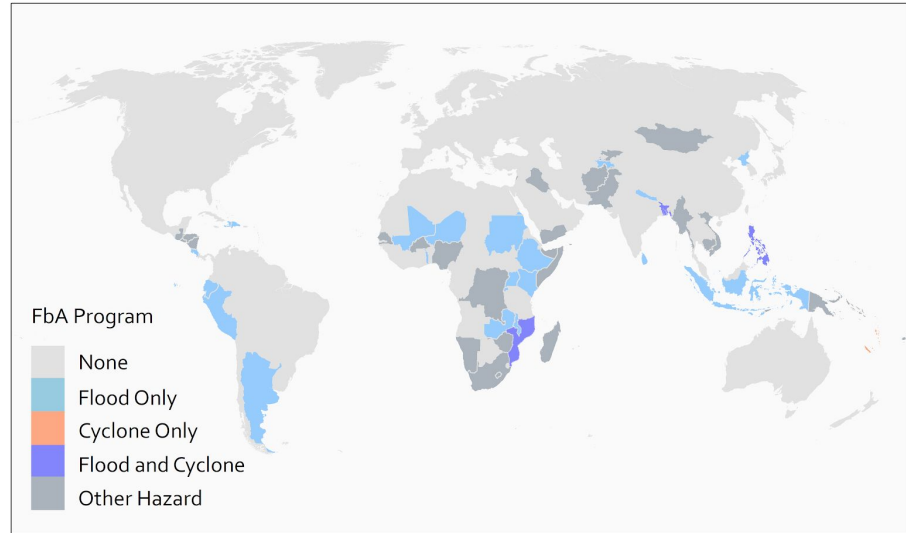
Impact-based Triggers

Building Trust

Perspectives on flood forecast-based early action and opportunities for EO (Nauman et al. 2021, *JARS*)

Collaboration between SERVIR, Red Cross Red Crescent Climate Centre, and NASA Risk Reduction & Resilience

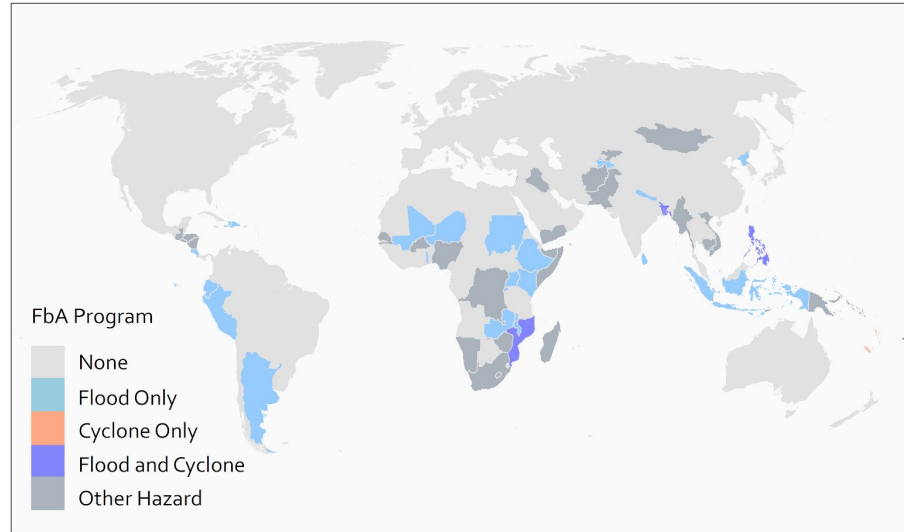
- Identify opportunities to integrate Earth observations (EO) into **flood forecast-based early action**
- Propose **future directions** for research and collaboration between EO and humanitarian communities.
- Underscore the role of “**translators**” and “**boundary organizations**”



Perspectives on flood forecast-based early action and opportunities for EO (Nauman et al. 2021, *JARS*)

Givens

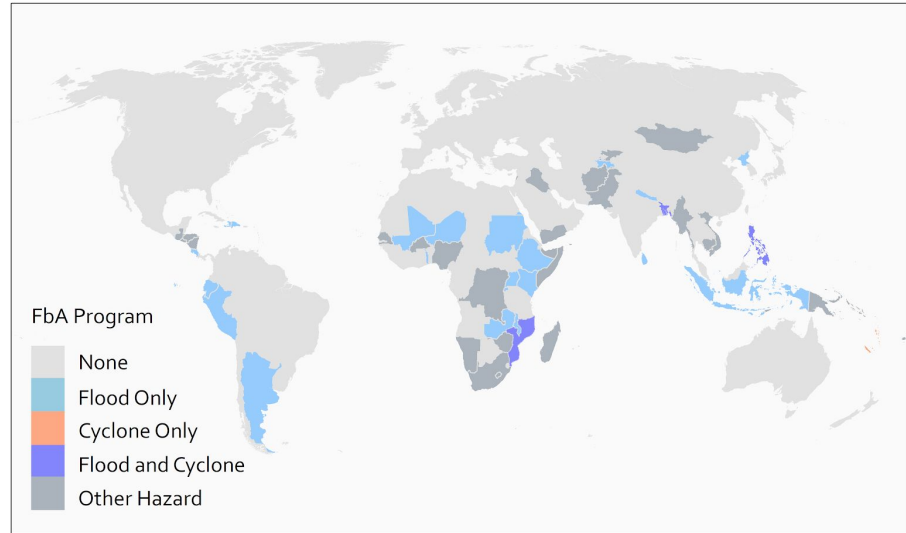
- Flood **forecasts** can be generated from
 - hydrologic and/or hydraulic models
 - with data from in situ, **remotely sensed**, and **modeled** inputs
 - inputs can be static (e.g., **elevation**, **land cover**, and river channel morphology)
 - inputs can be dynamic (e.g., **precipitation**, **evapotranspiration**, **soil moisture**, **snow cover**, and **snow water equivalent**).
- Flood **monitoring** with **EO** often refers to historical or near real-time observation of flood extent
 - **includes both active and passive sensors.**
- To measure or forecast flood **exposure**, **vulnerability**, and **impact**, requires more than EO data
 - dynamic socioeconomic data
 - multidisciplinary perspectives



Perspectives on flood forecast-based early action and opportunities for EO (Nauman et al. 2021, *JARS*)

Current Examples of EO in the Operational Phase of FbA Programs

- Main Triggers: river height and streamflow
- EO-based precipitation observations and numerical weather prediction (NWP) products are often used as inputs to hydrologic models that provide streamflow or river height-based triggers
 - e.g., Bangladesh, Zambia, Peru
- Global forecasts often provide longer outlooks to trigger a first phase of initial preparedness actions
 - e.g., Global Flood Awareness System (GloFAS)
- National forecasts often provide shorter outlooks that can trigger a second phase of actions like evacuation and cash assistance
 - e.g., Bangladesh Flood Forecasting and Warning Center



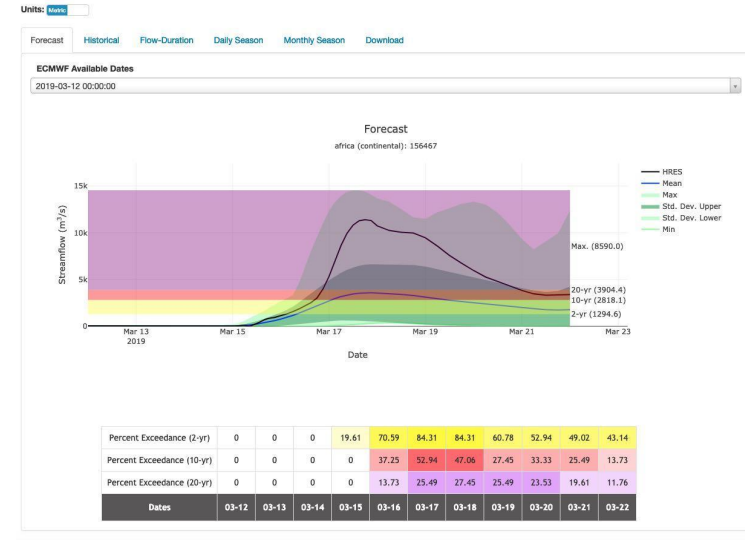
Types of flood early actions and lead times (2)

Early action	Lead time
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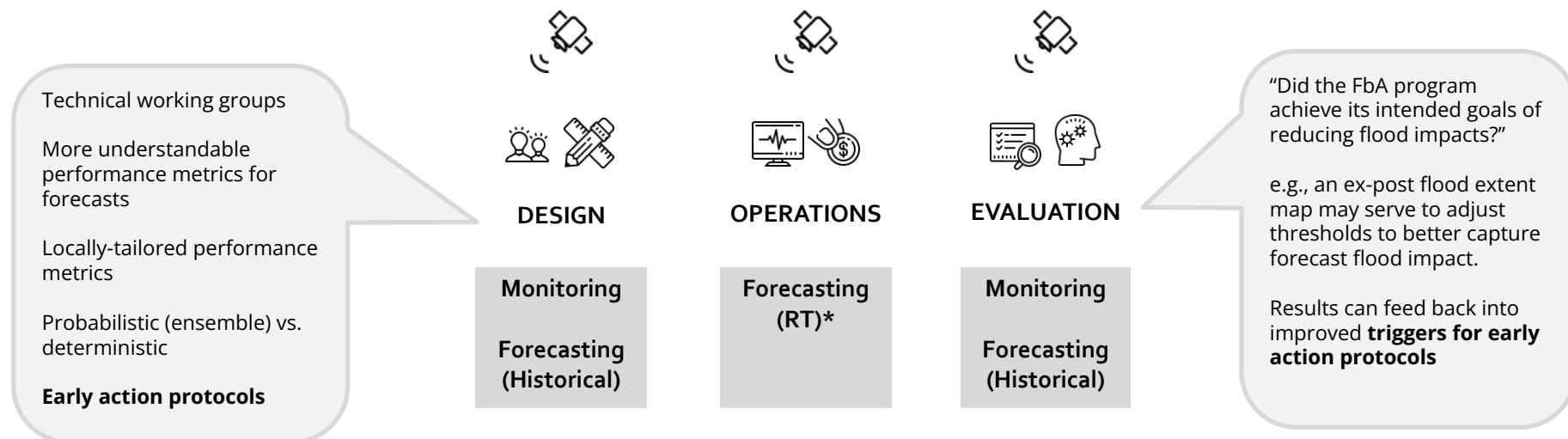
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The most significant opportunities for EO to inform Anticipatory Action efforts lie in the design and evaluation phases

Recall the importance of Stakeholder Mapping

EO can aid in the development of **impact**-based triggers.

Phases of forecast-based early action



*Generally, only forecast variables have roles in the operations phase, unless a monitoring variable that characterizes antecedent conditions is determined to add value to predicting flood impact during the design phase.

Perspectives on flood forecast-based early action and opportunities for EO (Nauman et al. 2021, JARS)

The **readiness** of a wide range of EO inputs for flood monitoring and forecasting in the design and evaluation phases of FbA.

Symbol	Readiness of EO in FbA phase (ARL range) ¹	Interpreting EO for FbA Readiness as "Calls to action"
*	Low (1-2)	More multidisciplinary, fundamental and applied research must be funded, ideally by multiple agencies
**	Medium (3-5)	Some fundamental research and significant applied research are required
***	High (6-7)	Some applied research remains; EO scientists and humanitarian organizations should be poised to co-develop better solutions
****	Very high (8-9)	Connections may already exist; if not, these should be ready to incorporate into early action protocols

FbA phase	Flood-related phenomena	EO inputs ²	Readiness
DESIGN <i>Development of impact-based trigger</i>	Precipitation	Satellite Precipitation Products (SPPs), Quantitative Precipitation Forecast (QPF)	****
	Soil Moisture	all all above inputs + typical variables in a Land Surface Model (LSM)	**
	River Height	all above inputs + potentially including altimetry and reservoir operations into hydrologic model	***
	Streamflow	all above inputs	****
	Flood Extent	all above inputs + optical and radar satellite imagery	***
	Flood Depth	all above inputs + Digital Elevation Model (DEM)	***
	Exposure	all above inputs + nighttime lights, populated areas/density, agricultural areas / crop type, building footprints, infrastructure	***
	Vulnerability	all above inputs + additional socioeconomic analysis	*
	Impact	all above inputs + additional socioeconomic and cost analysis	*
EVALUA-TION <i>Program monitoring, evaluation & learning</i>	Precipitation, Soil Moisture, River Height, Streamflow		n/a
	Flood Extent	Optical and radar satellite imagery	****
	Flood Depth	all above inputs + DEM	***
	Exposure	all above inputs + nighttime lights, populated areas/density, agricultural areas / crop type, building footprints, infrastructure	***
	Vulnerability	all above inputs + additional socioeconomic analysis	*
	Impact	all above inputs + additional socioeconomic and cost analysis	*

Perspectives on flood forecast-based early action and opportunities for EO (Nauman et al. 2021, *JARS*)

The roles of “**translators**” and “**boundary organizations**”

- facilitate communication, translation, and mediation across the current EO-FbA divide, e.g.,
 - Each early action should seed conversations about the readiness of EO to enhance existing inputs to reduce flood impacts.
 - Discuss forecast lead time and uncertainty, the need or ability to design spatially disaggregated triggers, how each trigger for these actions is tied to impact, and more

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The roles of “**translators**” and “**boundary organizations**”

- Tailoring forecasts to humanitarian needs, e.g.,
 - local rainfall intensity-duration thresholds,
 - relating historical streamflow with historical flood impacts
 - new ways of assessing and communicating model performance, judged by effectiveness of informing an early action (rather than by a geophysical parameter)
- Articulate new challenges and questions to justify further research & analysis (e.g., and downstream applications of future NISAR and SWOT missions)
- Empathy and understanding of others’ unique challenges, opportunities, goals, and metrics



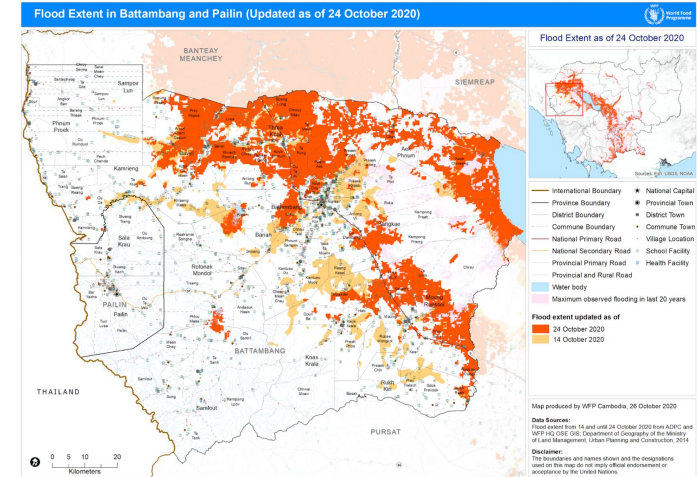
Preventing or reducing impacts of “cascading disasters” (1)

- Actions taken *before* the hazard turns into a disaster. Can be...
 - Triggered by a forecast
 - Triggered by an observation
- Actions taken during one disaster's impact but *before* that process **cascades** into other disasters and impacts. Can be...
 - Triggered by a forecast
 - Triggered by an observation

(1) Pescaroli, G., and Alexander, D. (2016). Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Nat. Hazards* 82, 175–192. doi: 10.1007/s11069-016-2186-3

SERVIR Flood Mapping Service Brings Speed to Cambodia Disaster Management

- Cambodia experienced some of the worst floods in decades in October 2020.
- HYDRAFloods (1) provides daily flood maps using available optical & radar satellite products
- Streamed directly into WFP's PRISM (3) to trigger relief actions
- WFP, their humanitarian partners, and the Cambodian government could better understand the geographic extent of the floods over time
 - Vulnerability layers, such as household-level poverty data are used for visualization and analysis
- To stem impacts of cascading disasters, this can help
 - Target emergency assistance
 - Manage recovery management
 - Re-evaluate future response plans



<https://www.climatelinks.org/blog/servir-flood-mapping-service-brings-speed-cambodia-disaster-management>

- (1) [Markert et al., 2020.](https://doi.org/10.3390/rs12152469)
- (2) <https://github.com/Servir-Mekong/hydra-floods>
- (3) <https://innovation.wfp.org/project/prism>

Mitigating disasters altogether

Extend anticipatory action to nature-based solutions (i.e., ecosystem-based disaster risk reduction)

Windows of opportunity:

- Disaster recovery phase (e.g., “build back better”)
- Climate change adaptation programming
- “No-regrets” climate risk management strategies

Social inclusion, environmental justice

- Partly a data problem (e.g., gender-disaggregated spatial data)
- Partly an inclusion problem - who has a seat at the table to design an intervention?
- Partly a mindset problem (e.g., how we design and resource applied EO projects)



1. EO is advancing our understanding of **individual hazards** and **cascading disasters**.
2. To reduce impacts, identify specific **anticipatory actions** that EO interventions can inform. Work backwards from there. How can advances in science inform newer and better early actions?
 - Don't forget "no regrets" actions or ecosystem-based DRR that can take place in many phases of DM cycle and can also build climate resilience.
3. EO data and EO people have a home in more than just the operations phase for any risk financing / anticipatory action program. There's also program **design** and **evaluation**.

Thank you

