How Earth Observation Can Enable Anticipatory Action in Humanitarian Crises

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Interviewees

The authors would like to extend our deepest gratitude to the individuals who took the time to meet with us, answer our questions, and share stories, guidance and wisdom around the realm of utilizing Earth observation data in anticipatory action. Having conversations about the ways in which the humanitarian community is working across geographies and across sectors was both inspiring and eye opening. As this report is based predominantly on the experiences of the interviewees, it would not be possible without them.

This paper does not represent the views of the interviewees unless explicitly stated. The authors have drafted the paper based on a combination of literature review and interviews.

Name	Title	Organization
Alexander Kjærum	Senior Analyst	Danish Refugee Council
Ben Webster	Head of Secretariat	Risk-informed Early Action Partnership
Cheila Cullen	Assistant Professor, Earth and Environmental Science	The Avalon Lab, City University of New York
Daniel Pfister	Humanitarian Affairs Officer, Humanitarian Financing Strategist	UNOCHA
Daniela Cuellar Vargas	Humanitarian Affairs Officer	UNOCHA
David Hodgson	Consultant	
Einar Bjørgo	Director	UNOSAT
Emily Black	Professor, Senior Research Fellow	University of Reading
Igor Oliviera	Consultant	UNEP
Imra Hodzic	Programme Officer	UNOSAT
Jesse Mason	Global Coordinator Forecast-based Financing, Humanitarian Financing Strategist	WFP

Name	Title	Organization
Leonardo Milano	Predictive Analytics Lead	UNOCHA | The Centre for Humanitarian Data
Luca dell'Oro	Chief, Disaster Risk Management and Climate Resilience	UNOSAT
Nicki McGoh	Director	Caribou Space
Samir Belabbes	Programme Officer	UNOSAT
Sandor Frigyik	Programme Management Officer	UNEP
Tinka Valentijn	Data Scientist	UNOCHA | The Centre for Humanitarian Data
Veronica Bell	Co-lead Earth Observation for Anticipatory Action Working Group	Australian Red Cross, Anticipation Hub

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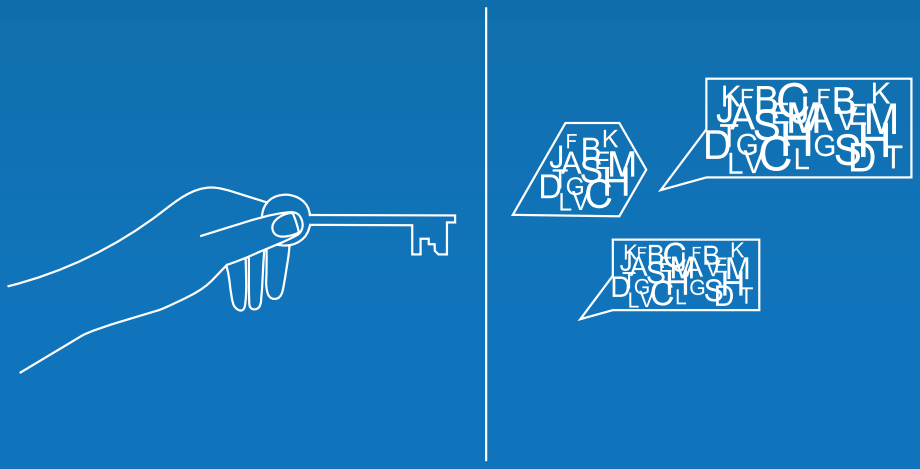
Key messages

- Earth observation data can fill the gaps in data prevalence and access in remote areas with limited local meteorological, hydrological and/or geological data collection, thereby enabling locally informed anticipatory action
- Earth observation data provides a historical dataset on such a grand temporal and spatial scale that it is hard to replicate through other data streams.
- To ensure successful interpretation and dissemination of forecasts based on Earth observation, continued collaboration and effective communication will become increasingly important as more actors enter the anticipatory action space.
- No one can do everything, but everyone can do something. Earth observation is one piece in the value chain, so actors should remain focused on their specialties to enable others.
- The human impact of climate disasters is multifaceted and dependent on risk, exposure and vulnerability. In each stage of the anticipatory action framework, the pathways of impact need to be understood from a local level. From there, Earth observation data can complement local understanding.
- Earth observation data allows aid to be targeted and tailored to specific geographic locations when used in conjunction with other data, such as population modelling.
- Perfection is the enemy of the good. We need to continuously build off the knowledge gained from pilot projects.



Introduction

Climate change is spurring the increased frequency, severity and variability of climate disasters.[1] The number of populations affected by humanitarian crises is projected to continue growing.[2] Being proactive in the face of a looming disaster saves more lives, is a more dignified approach[3] and is cheaper[4] than acting responsively. With such realities in mind, the ability to foresee climate-induced humanitarian crises is imperative.

Over the past decade, the institutional capacity and willingness to act in anticipation of crises has gained momentum, with a plethora of pilot projects undertaken or supported by Governments; various UN agencies; humanitarian aid organizations, such as the International Federation of Red Cross and Red Crescent Societies (IFRC); non-governmental organizations; the private sector; and academia. The prevalence of anticipatory action is exemplified in its prominence at the 2022 Humanitarian Networks and Partnerships Weeks, where it was one of nine focuses.[5]

The anticipatory action framework is defined by a trigger. When that trigger's threshold is reached, pre-arranged funding is released and pre-agreed action begins in order to get ahead of a predicted crisis.[6] In reality, each stage of the execution of this framework is highly context dependent and involves multilateral cooperation and engagement. Much literature exists on the anticipatory action framework and its variations across implementation, with most projects utilizing predictive analytics for trigger activation.

For the past five decades, satellites have been a crucial tool for Earth observation, allowing for greater understanding of Earth system processes and continuing to inform scientists on climate evolution.[7] Utilizing this vast dataset as a resource in trigger development is already prevalent across numerous

1 IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001.

2 "Global Humanitarian Overview 2022." Global Humanitarian Overview, gho.unocha.org/.

3 Interview with Alexander Kjærum, 31 May 2022.

4 Aly, Heba. "The Push to Anticipate Crises Gains Steam." The New Humanitarian, 14 September 2021, www.thenewhumanitarian.org/the-wrap/2021/9/13/the-push-to-anticipate-crises-gains-steam.

5 "Climate and Anticipatory Action among Nine Focuses at Humanitarian Partnership Weeks." Red Cross Red Crescent Climate Centre Climate and Anticipatory Action among Nine Focuses at Humanitarian Partnership Weeks Comments, www.climatecentre.org/8453/climate-and-anticipatory-action-among-nine-priorities-at-humanitarian-networks-and-partnerships-weeks-2022/.

6 "What Are the First Steps?" Anticipatory Action Toolkit, anticipatory-action-toolkit.unocha.org/first-steps/.

7 "Climate Change: The Evidence from Space." ESA Climate Office, climate.esa.int/en/evidence/observations-change/.

anticipatory action programmes. [8,9,10,11,12] Therefore, **the specific purpose of this report is to examine the role of remote-sensing satellite technologies in enabling anticipatory action in climate-induced humanitarian crises.** In the context of the framework, this involves understanding the technologies' possible contributions to trigger development and, on a grander scale, their impacts on the efficacy of anticipatory action programmes.

We explore the unique contributions of Earth observation data to anticipatory action, the development-humanitarian spectrum, the various challenges of the data's incorporation (and corresponding solutions, where they exist), and a collection of guidance and best practices from experts.

The report concludes with a look at systems modelling to help practitioners understand the impacts of intervention spurred through anticipatory action.

8 United Nations Office for the Coordination of Humanitarian Affairs, The Centre for Humanitarian Data, centre.humdata.org/anticipatory-action/.

9 World Food Programme Innovation, PRISM, innovation.wfp.org/project/prism.

10 Food and Agriculture Organization of the United Nations, Office of Emergencies and Resilience, Pilot Programmatic Partnership Increasing Capacities and Scale for Anticipatory Action Including through Social Protection Systems, www.fao.org/3/cb9372en/cb9372en.pdf.

11 Red Cross Red Crescent Climate Centre, www.climatecentre.org/priority_areas/fbf-ibf/.

12 Start Fund at the Start Network, startnetwork.org/start-fund.

The Time is Now

Gaining Momentum

> *"Anticipatory action seems to be the new shiny thing, but these forecasts are not new. Now, there is a willingness from donors and CERF [the Central Emergency Response Fund] to take the risk [with anticipatory action]; now, we have more capacity to trust these models."*
>
> — Leonardo Milano

Earth observation data enables practitioners to holistically embrace the sentiment of "Leave No One Behind"[13] through its ubiquitous nature, across both time and space. The passivity of observation and the inherent historical nature mean such a set of time-series data grows only richer as collection continues. The vantage point of orbit allows for observational coverage of large geographies and remote areas that otherwise would be difficult to access and assess,[14] filling data gaps[15] for areas that do not have the human resources or physical infrastructure for such an undertaking. This scale of data collection is inherently hard to replicate, with no other practical solutions existing in some cases, especially in those where historical data is imperative for forecasting.[16]

In a way, technological progression has spurred a self-fulfilling prophecy in that a kind of mutual recognition emerges between what we see on the ground and what is reflected in the data.[17] Hence, it becomes easier to gain confidence in the technology, which may lead to more attention and funding, bolstering it even further. This progression can be partly credited to the accessibility of cloud computing, which has enabled the utilization of high-performance computing without hands-on access to a

13 Interview with Einar Bjørgo, 25 May 2022.
14 Interview with David Hodgson, 23 May 2022.
15 Interview with Leonardo Milano, 24 May 2022.
16 Interview with David Hodgson, 23 May 2022.
17 Interview with Igor Oliviera, 7 June 2022.

supercomputer, which was historically necessary.[18] In addition, the integration of many data streams in conjunction with Earth observation data has allowed for increased reliability and trust, ensuring more holistic assessments and inspiring action.[19]

Data Streams

> *Every year there's cyclone season, which will undermine the resilience gains, the development projects … anticipatory approaches and good responses can protect [that].*"
>
> — Ben Webster

Climate events are inevitable. Climate-induced humanitarian crises don't have to be. The climate events that spur humanitarian crises are generally of two varieties: sudden onset (flood, cyclone, hurricane, landslide, earthquake, etc.) or gradual onset (drought, sea-level rise). Many of these events are cyclical in nature, but simply knowing approximately when they will come is not enough. The context in which the event occurs is crucial in understanding the human impact and approaching the situation subjectively.

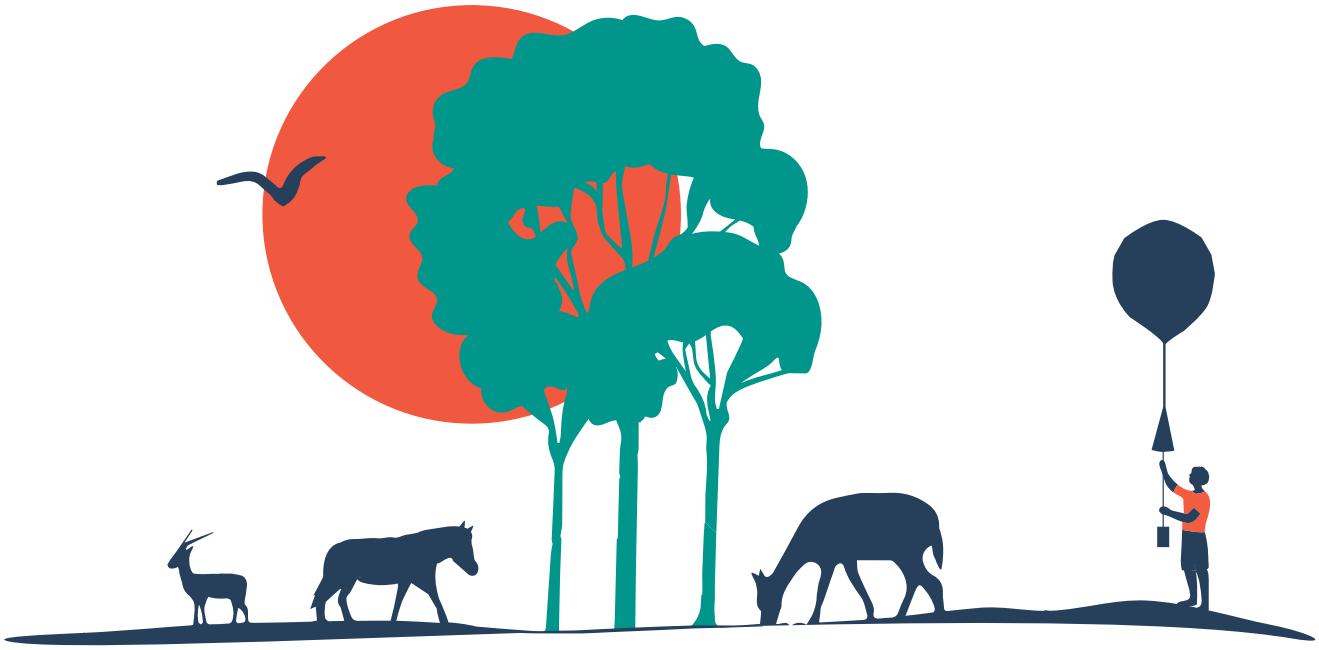
To ascertain the severity of such an event on an affected population, it is crucial to understand not only the risk and exposure but the vulnerability of the population.[20] In addition, mapping the temporal and sectoral impact pathways is vital in understanding the chain of events that lead to interconnected and often *compounding* impacts.[21] Identifying these impact pathways first allows practitioners to identify data requirements and develop appropriate thresholds. It is here that the incorporation of Earth observation data is considered.

A brief overview of three relevant categories of Earth observation data follows, along with an unpacking of their unique value in the anticipatory action space.

18 Interview with Cheila Cullen, 24 May 2022.
19 Interview with Einar Bjørgo, 25 May 2022.
20 Interview with Daniela Cuellar Vargas, 25 May 2022.
21 Ibid.

> *We are not necessarily anticipating the actual shock, but we are trying to anticipate the humanitarian needs arising from a shock.*

— Leonardo Milano



> *EO [Earth observation] isn't observing humanitarian needs. You're estimating [those] by other factors.*

— Daniel Pfister

Land Imagery

Land imagery, acquired predominantly by satellites but also by drones, gives practitioners a spatial awareness of the area forecasted to be affected, including topographical details such as infrastructure (roads, bridges, rivers), buildings and waterways (coastal areas, rivers, streams). This type of data can aid practitioners in **identifying exposure** and **understanding vulnerability**.[22] In conjunction with meteorological and hydrological forecasting, land imagery can provide insight on the regions most acutely affected from a humanitarian perspective. For example, building identification, both quantitative and qualitative, can indicate population density and resilience, respectively. When overlaid with the forecasted mapping of the climate event, this can indicate to practitioners what resources to pre-position and where.[23] Infrastructure mapping can inform the planning of evacuation corridors for affected populations; complementing this is near-real-time observational imagery of how such infrastructure is affected upon event onset. These types of schematics allow practitioners to take the most suitable set of pre-agreed actions upon trigger activation.[24] In this case, anticipatory action complements response and vice versa; this overlap is when near-real-time observation complements the work of anticipatory action notably well.[25] It is here that "forecasts become less important, and [near-real-time] Earth observation [imagery] becomes more important."[26]

Meteorological and Hydrological Forecasts

For the past five decades, satellites have continuously observed oceanic and atmospheric conditions, informing the development of meteorological and hydrological forecasts, all while building a vast data repository across time and (geographic) space.[27] Generally, meteorological forecasts are "weather" forecasts; in the context of this report, meteorological forecasts mainly inform the characteristics of sudden-onset events, such as floods, cyclones and hurricanes. Hydrological forecasts are those pertaining specifically to water resources, and they mainly inform the characteristics of flooding and drought. These forecasts are both interrelated and complementary.

Acting in accordance with the certainty (or lack thereof) of such forecasts is critical in utilizing forecasting data. The probabilistic nature of forecasting allows practitioners to **develop thresholds for trigger activation**, with the varying levels of certainty **informing pathways of action.** For example, an anticipatory action framework with a relatively low activation threshold (action activated with a less certain forecast) may employ "low-regret" actions that ultimately benefit the community and bolster resilience regardless of the forecast coming to fruition.[28]

22 Tang, Tao, et al. "Classification of Building Structures on High Spatial Resolution Satellite Image for Mapping the Readiness to Hurricane Hazards, Cancun and Chetumal, Mexico." 2013 21st International Conference on Geoinformatics, 2013, doi.org/10.1109/geoinformatics.2013.6626086.

23 Ibid.

24 Interview with Daniela Cuellar Vargas, 25 May 2022.

25 Interview with Jesse Mason, 30 May 2022.

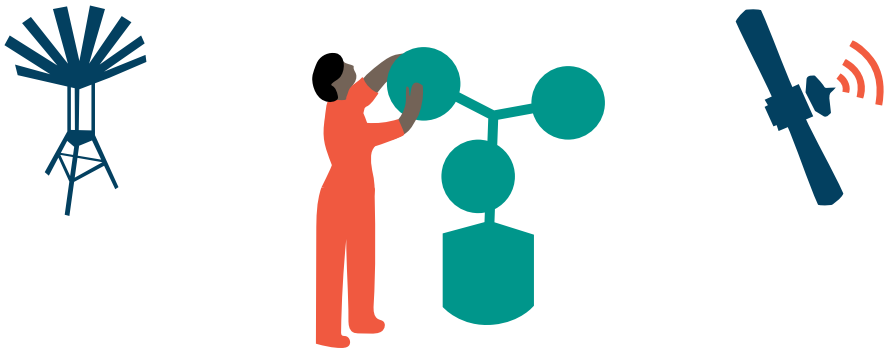
26 Ibid.

27 "Climate Change: The Evidence from Space." ESA Climate Office, climate.esa.int/en/evidence/observations-change/.

28 Interview with Emily Black, 31 May 2022.

Incorporating low-regret actions (where applicable) lowers the (financial) stakes when forecasts go amiss while providing benefits that ultimately build resilience in a community that will likely (if not inevitably) face a similar climate event in the future.

> *If you're a scientist, you have to sit there and say, '[The data] wasn't good enough. It didn't provide what we thought.' Owning that is really important and ultimately builds trust, rather than the opposite."*
>
> **— Emily Black**



> *We can offset that risk that people perceive in financing something that might not happen by actually providing assistance."*
>
> **— Daniel Pfister**

Soil, Vegetation and Biomass

> *Vegetation is a proxy of a proxy [for food (in)security].”*
>
> **— Daniela Cuellar Vargas**

The various transformations and interpretations of Earth observation data can be viewed as forming a value chain: “regular” **imagery** taken in the visible spectra[29] provides a bird’s-eye view of Earth; amalgamating and analysing observations across time and (geographic) space informs climate **forecasting**; and multispectral observation (across the electromagnetic spectrum) allows for the determination of moisture, vegetation and biomass levels.

Each type of multispectral observation is often expressed as an index. Together, these indices can be used as a proxy of a proxy for food (in)security, ultimately informing the human impact of drought.[30]

> *Soil moisture is directly relevant to agricultural drought, a major precursor of food insecurity.”*[31]

29 The visible spectra of the electromagnetic spectrum is composed of blue, green and red wavelengths.

30 Interview with Daniela Cuellar Vargas, 25 May 2022.

31 Boult, Victoria L., et al. “Evaluation and Validation of TAMSAT Soil Moisture and WRSI for Use in Drought Anticipatory Action.” Meteorological Applications, vol. 27, no. 5, 2020, doi.org/10.1002/met.1959.

The Water Requirement Satisfaction Index (WRSI) quantifies the degree to which vegetation is able to grow without experiencing water stress.[32] In conjunction with soil moisture estimates, this articulates a picture of drought development and ultimately contributes to drought forecasting when viewed from a time-series perspective.[33, 34] WRSI and soil moisture estimates are based on rainfall data and meteorological forecasts, highlighting the dependency of these indices on other streams of Earth observation data.[35]

It is widely understood that the reflectance of light spectra varies between plant species and can be used to determine water content.[36] To form a holistic picture, multispectral imaging techniques are employed, ultimately providing practitioners with a mapping of plant species and their corresponding stress levels. One of the most utilized indices based on this multispectral observation is known as the Normalized Difference Vegetation Index, which is predominantly used to characterize canopy and leaf growth.[37]

In a way, soil, vegetation and biomass indicators form their own value chain. Not only do these indices derive meaning from other forms of Earth observation data to deliver more granular insights, but they rely partially on each other to paint a holistic picture of impact. These indices enable practitioners to **develop thresholds for trigger activation** and **understand vulnerability**.

The Value Chain

> *"Let the rainfall experts debate about rainfall and the action experts debate about action. There's a little bit of translation needed, but you don't need to create new experts. We need to bring the pieces together."*
>
> **— Daniel Pfister**

32 Ibid.

33 Ibid.

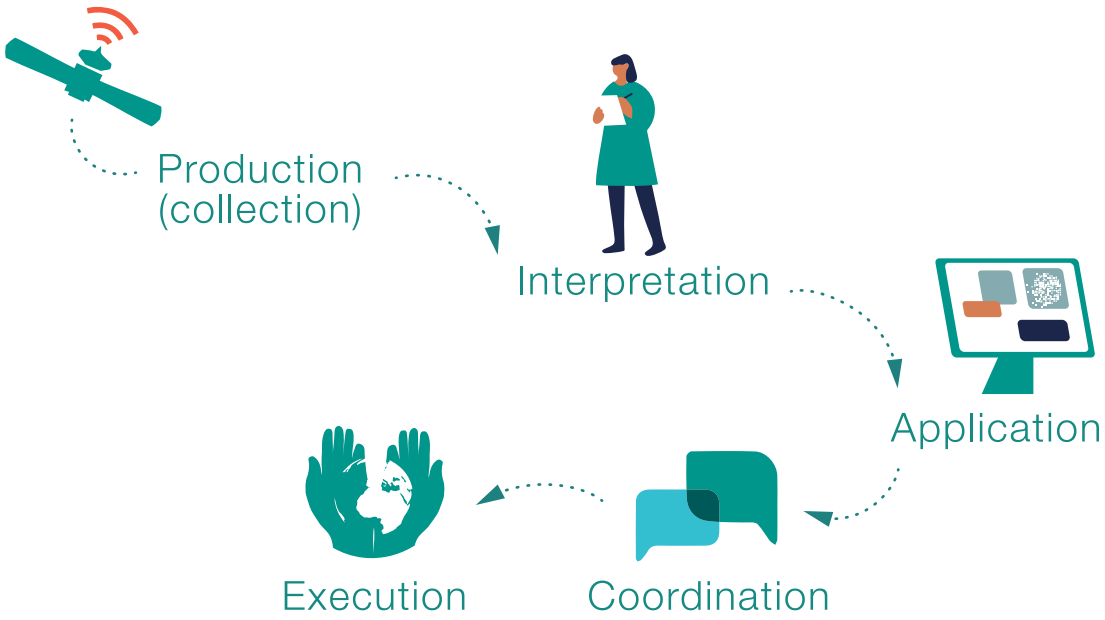
34 Interview with Emily Black, 31 May 2022.

35 Boult, Victoria L., et al. "Evaluation and Validation of TAMSAT Soil Moisture and WRSI for Use in Drought Anticipatory Action." Meteorological Applications, vol. 27, no. 5, 2020, doi.org/10.1002/met.1959.

36 Xue, Jinru, and Baofeng Su. "Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications." Journal of Sensors, vol. 2017, 2017, pp. 1–17., doi.org/10.1155/2017/1353691.

37 Ibid.

The EO Data Value Chain



Designing such triggers and action pathways requires an intersection of practitioners, each with their own domain expertise. Though the domains outlined above may seem suited for scientists and engineers, in reality it is only the collection of such Earth observation data that is "limited" to them, and only in the technical sense. **Beyond collection and production comes interpretation, application, coordination and delivery, necessitating cross-sectoral collaboration.** It is in this way that Earth observation data is transformed to meet specific needs. It is vital that each group of practitioners and experts find their place in this value chain and remain cognizant of those working adjacent to them.[38] The **Risk-informed Early Action Partnership (REAP)** fosters such practical connections across the value chain and across the spectrum of impact.[39]

38 Interview with Ben Webster, 9 June 2022.

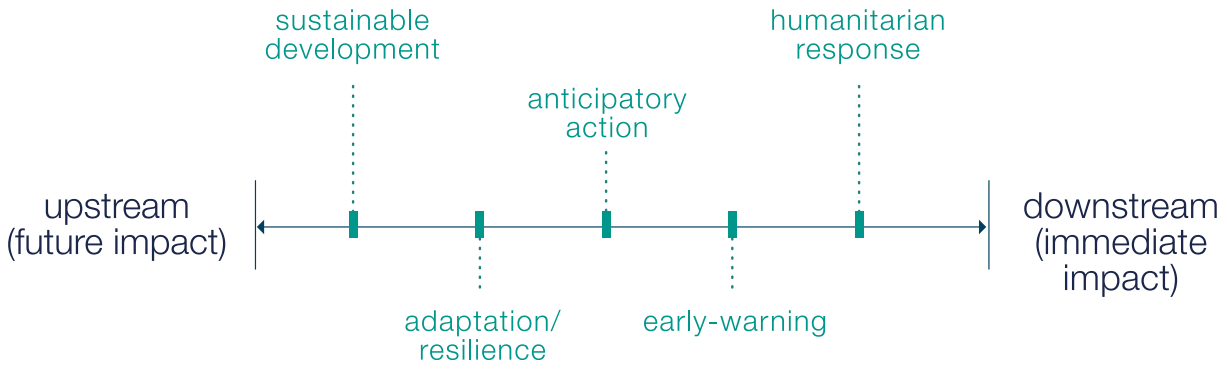
39 Ibid.

Spectrum of Impact

> *We [in anticipatory action] are responding to alleviating a crisis we can see coming. Resiliency people are responding to lessening people's exposure to crises."*
>
> **— Alexander Kjærum**

Earth observation data delivers impact across the continuous spectrum between development and humanitarian aid. For the sake of logistics and linguistics, it is easy to bring a clear-cut separation between development and humanitarian work. However, they "are not separate or distinct worlds"[40] but rather symbiotic, and they act in complementary ways towards net risk reduction.[41, 42]

Spectrum of Impact



40 Interview with Veronica Bell, 15 June 2022.

41 Interview with Ben Webster, 9 June 2022.

42 Interview with Daniela Cuellar Vargas, 25 May 2022.

> *In my mind, we want to constantly push everything further upstream..*"
>
> — Ben Webster

When is impact most genuine? There are two streams of impact to consider, both revolving around collaboration. The first is collaboration between providers; the second is collaboration between providers and the affected community.

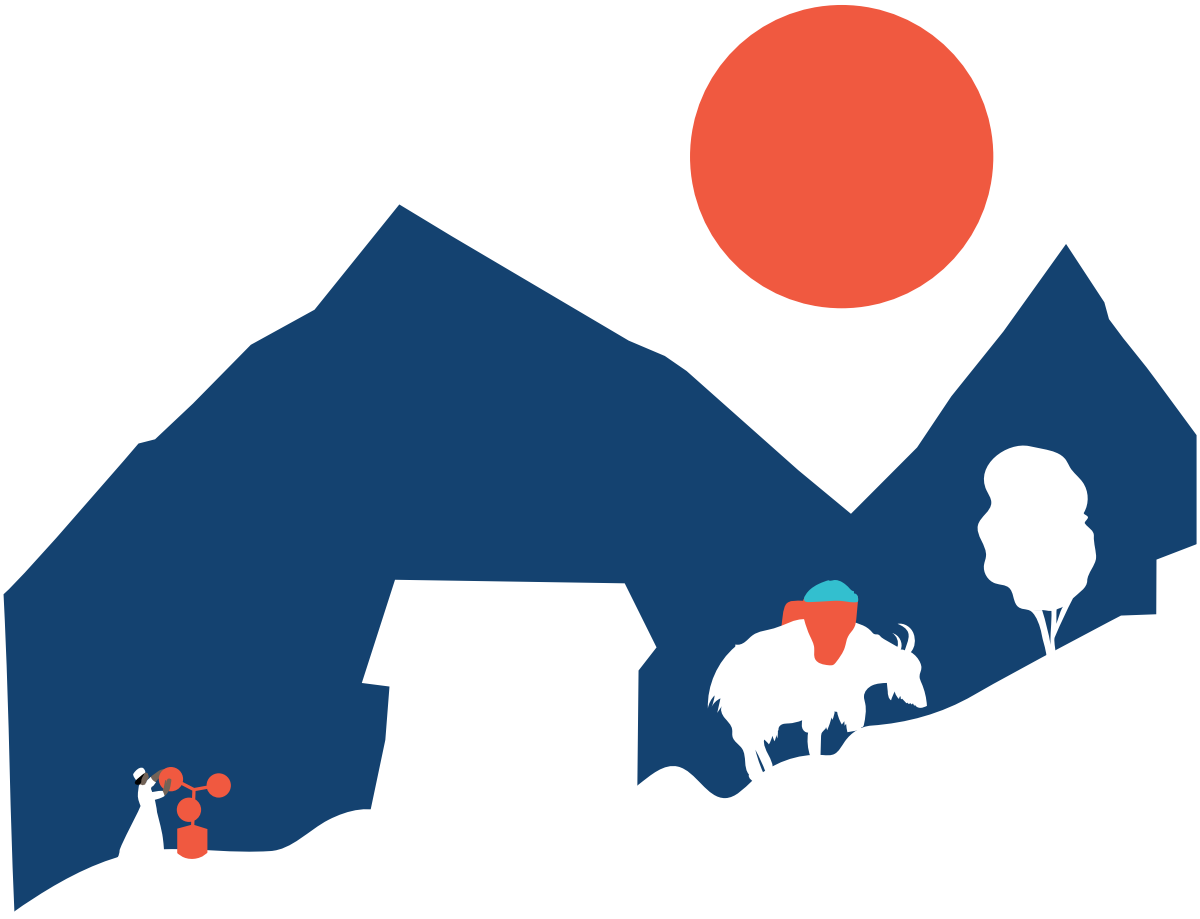
Regarding the former, it is imperative that the organizations involved in delivering service come together, independent of terminology, while recognizing ways in which they may contribute to and benefit from compounding effects.[43] For example, Daniela Cuellar Vargas spoke of a UNOCHA anticipatory action pilot in Malawi, where the "integration with local communities was relatively easier because people were already exposed to knowledge from [previous] experiences" with UNDP, IFRC and WFP.[44] This prior knowledge can jump-start and even alter the types of actions planned.

Regarding the latter, it is paramount that collaborating *with* rather than providing *to* stakeholders occurs. Here, the ultimate stakeholders are the affected communities.[45] As Veronica Bell elucidates, "it's about exposing and consulting as opposed to imposing."[46] This sentiment is acutely relevant when organizational objectives (and the sometimes grandeur promises of data) present themselves in contrast with, rather than complementary to, Indigenous expertise. For example, a pilot project in Papua New Guinea set out to implement a course of anticipatory action using Earth observation data that would quell the effects of flash flooding.[47] The local means of anticipatory action capitalized on the fact that flash flooding was spurred when a river, located at a higher altitude, breached its banks.[48] The community at this higher altitude would ring their church bell to alert the community at the next lower altitude, and so on, ensuring that those nearer the bottom would have sufficient time for preparatory actions and relocation.[49] Ultimately, the pilot project vied for a technology-based solution reliant on forecasting where one was neither requested nor more ideal than the communities' solution.[50]

43 Ibid.
44 Ibid.
45 Interview with Einar Bjørgo, 25 May 2022.
46 Interview with Veronica Bell, 15 June 2022.
47 Interview with Emily Black, 31 May 2022.
48 Ibid.
49 Ibid.
50 Ibid.

In such cases, "recognizing when to step back is also important."[51] It is an act of humility to understand that sometimes "there [is] nothing we [can] do better than what they [the affected populations] do.[52]

> *We'll never be successful in isolation."*
>
> **— Veronica Bell**



51 Ibid.

52 Ibid.

Anticipatory Action in Action

Challenges and Risks

> *Earth observation data strengthens systems – but they need to be good systems in the first place. We need to make sure we're utilizing data for the right things, for the right questions. [Data] is not a silver bullet, but it can strengthen practice.*"
>
> — **Veronica Bell**

The popularity and commotion in the anticipatory action space, mixed with a general tendency towards technological solutionism, makes it ever more crucial to spend at least as much time assessing the challenges and risks of anticipatory action as understanding what it can, ideally, provide.

To that end, let us examine some of the most pertinent challenges and risks present in the anticipatory action space, ranging from general management of expectations to the possibility of engendering inaction.

Managing Expectations

With over 20 years' experience working to utilize Earth observation technologies for practical, human-oriented benefit, Einar Bjørgo, Director of the UN Satellite Centre, has had a panoramic view of the Earth observation and anticipatory action landscape.

He believes that movement in the anticipatory action space has picked up over the past decade not because something new is being offered, but rather because stakeholders' expectations and understanding have shifted.[53] This echoes the sentiments of Leonardo Milano, Predictive Analytics Lead at The Centre for Humanitarian Data, who highlights that a mindset shift is occurring alongside shifting politics and increased willingness to act early.[54]

53 Interview with Einar Bjørgo, 25 May 2022.

54 Interview with Leonardo Milano, 24 May 2022.

A shift towards willingness implies a shift away from unwillingness, but where could this unwillingness have originated? In theory, utilizing Earth observation data that is at our disposal for anticipatory action *just makes sense*. But overselling and overpromising have historically increased scepticism towards the technology and diluted its appeal, which left decision makers resistant to the approach.[55] With this hindsight, every actor along the spectrum of impact should be aware that managing expectations is a challenge that becomes ever more important when anticipatory action projects scale.

Moving Beyond Demonstration

Pilot projects carry an implication of testing the waters: can this technology, that of utilizing Earth observation data for anticipatory action, deliver? This kind of technology demonstration doesn't necessarily produce sustainable, scalable solutions,[56] but the lessons learned and the progress achieved do contribute to building more robust, sustainable and scalable implementations upon this foundation. So the real challenge to be highlighted here is committing to moving beyond the pilot stage. However, achieving this may only be genuinely achieved with foresight and through collaboration.

> *"Thinking about data … we have guidelines [for that]; that is regulated. When it comes to analytics, it's the wild west. Everyone is doing what they want."*
>
> **— Leonardo Milano**

Foresight comes into play when acknowledging the need for **regulation and evaluation** in the anticipatory action framework. To this end, The Centre for Humanitarian Data has developed a peer-review framework for predictive analytics models used in anticipatory action. The framework is developed in light of three realities: there is no common standard for documenting predictive models and their intended use; there is no common standard for assessing these models; and their development is often led by experts who focus more heavily on technical implementation than on possible ethical concerns.[57]

Such a tool may be viewed primarily as one to be used post-development for external review purposes, but it can also be a **guiding framework** to be consulted during development. To evaluate a model's reliability, robustness and usability, it is critical to understand how it formulates projections, and how these projections and their consequences are altered with respect to the quality, quantity and combination

55 Interview with Einar Bjørgo, 25 May 2022.

56 Interview with David Hodgson, 23 May 2022.

57 UNOCHA, The Centre for Humanitarian Data, Peer Review Framework for Predictive Analytics in Humanitarian Response, centre.humdata.org/wp-content/uploads/2020/03/peer-review-framework-2020.pdf.

of input data, including Earth observation data.[58] In this way, guidance and regulation are synonymous, because being cognizant of regulatory processes and frameworks may induce reflection during design.

> *"Evaluation is often tacked on at the end as an afterthought; it needs to be embedded into the design phase so we have measurement throughout the course of an implementation."*
>
> **— Ben Webster**

To keep the momentum going, wider monitoring and evaluation (M&E) is critical:[59] what works and what doesn't? What do we perceive as success, and how does this differ from what the affected community perceives as success? In what ways do insights from Earth observation data truly contribute to the objectives of an anticipatory action project, and what may just be solutionism?

If questions like these are not evaluated at each stage of implementation, the value of the data generated may become lost or misconstrued.[60] This is especially relevant when considering that interests and priorities differ between stakeholders, and therefore the kind of evidence they want or need will also differ. Generally, evidence generated and disseminated tends to focus on an audience of donor Governments and international agencies, which is useful in its own right for "proving" why funding should continue (or increase).[61] But the evidence needed by local governments and members of parliament is likely to be different and may be more action-informing. Therefore, it is critical to understand the target audience of M&E and work with them to ensure the data generated is genuinely useful.

Climate Change

> *"Perceptions of the past are not as reliable now [because of climate change]."*
>
> **— Daniel Pfister**

58 Ibid.
59 Interview with Emily Black, 31 May 2022.
60 Ibid.
61 Interview with Ben Webster, 9 June 2022.

While climate change induces crises that anticipatory action aims to ameliorate, the use of Earth observation data to this end does not come without inherent complications. The historical nature of Earth observation data is a selling feature (for prediction) that also introduces a predicament: With climate change, the characteristics of climate events are changing, with intensity and variability fluctuating.[62] So while the process of trigger derivation relies heavily on historical analysis, looking at past events is not sufficient because *the events themselves will inevitably evolve over time*.[63] Though this may seem obvious, the occurrence of climate events also alters the environment, which introduces further complications from a humanitarian perspective. For example, crops that have adapted to high-stress conditions such as drought may present altered warning signs of crop failure; alternatively, what may be perceived as normal crop progression may no longer be.[64]

Adopting a more holistic approach to anticipation can mitigate the risks that flow from depending too heavily on historical analysis. Understanding the meteorological and hydrological processes underpinning climate events allows for more robust trigger derivation and evaluation than relying predominantly on observation data.[65] Being cognizant of these "fundamentals at the process level are paramount, and Earth observation complements this understanding of the logistics of [such climate] processes."[66]

Inaction

> *"Despite red flags [raised by early warning systems], we see a huge humanitarian crisis [in Somalia] – we have those systems already, that did warn us, but we didn't do enough. This is worse than just not knowing; we knew and still didn't do anything."*
>
> **— Alexander Kjærum**

62 Interview with Daniela Cuellar Vargas, 25 May 2022.
63 Ibid.
64 Ibid.
65 Interview with Emily Black, 31 May 2022.
66 Ibid.

The risk of inaction is not necessarily inherent to incorporating data into decision-making, but it seems to be a kind of scapegoat to inaction. There are myriad reasons why inaction may occur, including because the data "isn't perfect yet" or the model could be further refined and polished.[67] Ultimately, these feelings are precursors to not really genuinely reaching the (soon-to-be) affected population.[68] But data is not a silver bullet; it can ideally strengthen practice if utilized for the right things and to answer the right questions.[69] A common mistake (which persists as a risk to future projects) is that those who procure and interpret Earth observation data and forecasting, i.e. those who are relatively upstream on the value chain, are hesitant to provide their data until they're absolutely sure of its validity.[70] In some cases, this precludes the data from being used and valued accordingly; practitioners get to the end of their project lifecycle and the data still hasn't been used.[71]

We collectively "need to push a lot faster to allow people in the humanitarian sector to use the data as they will in operational programmes."[72] This incorporation, inherently, should be taken with a grain of salt: It is critical to manage expectations and generally understand that Earth observation data should not be the sole informant of action.

> *"Don't go EO [Earth observation] alone. It has to be combined with other information."*
>
> **— Einar Bjørgo**

67 Interviews with Alexander Kjærum (31 May 2022), Igor Oliviera (7 June 2022), Emily Black (31 May 2022), Veronica Bell (15 June 2022).

68 Interview with Igor Oliviera, 7 June 2022.

69 Interview with Veronica Bell, 15 June 2022.

70 Interview with Emily Black, 31 May 2022.

71 Ibid.

72 Ibid.

Nuggets of Wisdom: Complementing Earth Observation with the Subjective Human Experience

> *If there's no human impact, we don't care. It's all about anticipating human impact."*
>
> — Daniela Cuellar Vargas

The promise of data objectivity is largely elusive as long as the context in which we are using data is humanistic. Subjectivity through bias may be introduced at various stages of the Earth observation data value chain: (geographic) decisions regarding collection and production of datasets; the subjectivity of labelling and interpretation in knowledge production (what, numerically, constitutes a crisis, and for whom?); the application of this knowledge in the context of what the practitioner(s) are familiar with; and so on.

Letting go of the ideal of objectivity and recognizing the presence of subjectivity, and even the value of some level of subjectivity, in the value chain allows us to embrace the human element of anticipatory action. Asking questions that elucidate the subjective, human experience of a crisis can inform the development of triggers, complementing the "cold" observational data. Questions like **"What's a flood for you?"**[73] and **"What was a bad drought year for you?"**[74] include the lived experiences of the people who know best the processes that are meant to serve them.

The objective complements the subjective in holistically informing the development of an anticipatory action framework. But the future impacts of such actions also need to be top of mind.

73 Interview with Jesse Mason, 30 May 2022.

74 Interview with Daniel Pfister, 30 May 2022.

Informing Future Action

> *Not taking a holistic view means we don't understand the value of some of these potential interventions."*
>
> — Emily Black

The metrics of a successful anticipatory action scheme shouldn't be only how well the affected communities survive a bad year, but whether or not their livelihoods improve in the good years to come.[75] Ideally, action taken across the spectrum of impact should compound to enable communities to consistently have better years. But understanding which interventions work best, where (geographically) and when (timeline of intervention) depends on a host of factors that cannot be gleaned solely through Earth observation data. By discerning the structure of the systems in which interventions are applied, practitioners can design better trigger mechanisms that are not informed only by the past but by the present and future.

Systems Modelling

Systems modelling is a structure-based approach used to model the cause and effect across a number of correlated variables, allowing for the simulation of the potential impact of intervention.[76] This approach differs from what most anticipatory action projects currently utilize; in contrast to relying on historical datasets for predictive analytics, systems modelling is guided by regional experts to determine the strength of causal relationships between almost any factor, whether or not they may be related at first glance.[77] These factors include gender equality, fishery protection and restoration, agriculture, health-service provision, housing, and social stabilization and mediation.

75 Interview with Emily Black, 31 May 2022.
76 Interview with Igor Oliviera, 7 June 2022.
77 Ibid.

While this report highlights the ways in which Earth observation data–when viewed as a historical informant–can inform acting early to mitigate climate-induced humanitarian crises, integrating the complexity of the system is critical.[78] This integration leads to looking at areas outside of what may be the most proximate realm (e.g. UNEP practitioners looking outside of the environmental realm).[79] To explore an example of work being done in systems modelling to this end, see the **UNEP Strata platform.**

The lessons learned from an anticipatory action pilot undertaken in Malawi, predominantly by UNOCHA and The Centre for Humanitarian Data, highlight the need for more precise linkages between climate shock and humanitarian impact.[80] They demonstrate that without understanding the nuance of these relationships, it becomes much harder to design adequate triggers.[81] This is an exemplary case in which systems modelling can complement predictive analytics.

> *"It's a great moment to unite these two ways of thinking [predictive analytics and systems modelling]."*
>
> **— Igor Oliviera**

Citizen Engagement

A paradigm shift on what the phrase "Earth observation" entails can highlight the ways in which people can be observers of their environment, essentially collecting their own Earth observations. This perspective moves "observation" from something we rely on satellites for to an extremely tangible and accessible tool that citizens in all locales already possess. Here we introduce two modes of human-based Earth observation, namely human sensors and citizen science, to highlight a path forward for Earth observation that embraces citizens as a resource.

78 Interview with Sandor Frigyik, 7 June 2022.

79 Ibid.

80 UNOCHA, The Centre for Humanitarian Data, 2021, Detecting Dry Spells in Malawi, Learnings from Developing an Anticipatory Action Trigger, https://drive.google.com/file/d/1jTMXCryxghJB7OlzORhmfrXmNqJFcq4c/view.

81 Ibid.

Human Sensors

> *It could be a way to overcome some of the data gaps we have … because people talk about [their issues], right? People talk about drought. People talk about crop failure. People talk about lack of fish, where they used to fish.*"
>
> — Igor Oliviera

The idea of human sensors entails utilizing social listening tools across social networks, including social media and news media, to get a sense of what issues are on citizens' metaphorical radar.[82] Ideally, implementing social listening tools to utilize humans as sensors or observers of their own environment would fill gaps where human capital is scarce,[83] for instance, where information and communication technologies adoption is notable but institutional capacity is lacking.

> *It comes down to a combination of Earth observation [from satellites] as a data source, a literally top-down data source, and social listening and human sensors as a bottom-up data source, ideally.*"
>
> — Igor Oliviera

Practitioners keen to explore this mode of Earth observation to glean what a community or population deems noteworthy in their daily life should be cognizant of the bias involved in the (in)accessibility of publishing such observations on the Internet.

82 Interview with Igor Oliviera, 7 June 2022.

83 Ibid.

Citizen Science

The idea of human sensors is mainly passive; the citizens involved are likely not publishing their observations with the intention of having them impact anticipatory action schemes, response or policy. Therefore, we turn to a more active role of Earth observation, in which citizens engage with observation for the purpose of informing practitioners or projects.

Smartphone adoption allows citizens to document their observations instantaneously and ubiquitously with photograph and video capture. This on-the-ground, in-the-moment observation can inform the roll-out of anticipatory actions during the response phase. **UN-ASIGN**, a tool developed by UNITAR and UNOSAT, allows just that: the uploading of geo-tagged photos, messages and other relevant data to a live map, which can be used in the roll-out of anticipatory action schemes.

On the opposite end of the spectrum is a variety of citizen science which is relatively low tech: the manual measurement of environmental factors that can inform local anticipatory action schemes. Tools such as **volunteer rain-gauge networks**[84] are fantastic for regional weather monitoring to inform farmers and regional meteorologists who may not have data to make informed forecasts because of insufficient funding or lack of institutional capacity.[85]

Seeing the reality of climate events on the ground, "with your own eyes", and reporting on them is empowering to local citizens, and in a way it "proves" what the more high-tech forms of observation through satellite imagery deliver. When more high-tech forms of Earth observation are integrated with something more traditionally trusted, willingness to act increases, trust grows and understanding improves.[86, 87]

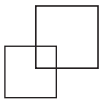
84 Interview with Emily Black, 31 May 2022.

85 Wambi, Michael. "Rain Gauge Shortages Impact Rain Information Service." Uganda Radionetwork, 31 January 2017, ugandaradionetwork.net/story/rain-gauge-shortages-impact-rain-information-collection.

86 Interview with Einar Bjørgo, 25 May 2022.

87 Interview with Emily Black, 31 May 2022.

Conclusion



As is the nature of anticipatory action, **predictions may come to fruition but ideally the humanitarian impact will not**, because the anticipatory action mitigated the worst effects. In this way, the non-observation of an event is an event itself.[88] Utilizing the vast sets of Earth observation data that span time and (geographic) space enables those in the humanitarian community to act early in anticipation of climate crises that pose significant humanitarian harm.

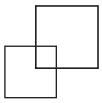
While **Earth observation data is continuously transformed** through processing and interpretation through what we term "the value chain," its utility spans sectors across what we term the "spectrum of impact," ranging from more upstream sustainable development and resiliency efforts to more downstream anticipatory action, early warning and response efforts.

Earth observation data takes on many forms, ranging from the **highly technical** (satellite imagery, meteorological and hydrological forecasting, and soil, vegetation and biomass indices) to the more **personal** citizen engagement forms of observation. Therefore, practitioners must remain cognizant of the challenges and risks associated with using such data in anticipatory action schemes. As many anticipatory action schemes learn from the past by utilizing predictive analytics from historical datasets, **practitioners themselves can learn from the experiences of other practitioners, cumulated in this report.**

Continuously recentring the objectives of anticipatory action schemes that utilize Earth observation data around the populations they serve builds norms around including subjectivity and lived experience in project development, especially surrounding developing triggers for action. **We ultimately want technology to complement human understanding and fill human needs. Where Earth observation can do this, it should.**

88 Interview with Samir Belabbes, 31 May 2022.

Resources



CommonSensing

European Centre for Medium-Range Weather Forecasts

GEO Sahel

GlobalFloods.eu | Medium-Range Flood Forecasts (GloFAS)

Lessons from Malawi, UNOCHA, The Centre for Humanitarian Data

Measuring Vegetation (NDVI & EVI), NASA Earth Observatory

Peer Review Framework for Predictive Analytics in Humanitarian Response

Risk-informed Early Action Partnership (REAP)

TAMSAT-AgriculturaL EaRly warning sysTem (TAMSAT-ALERT)

Tropical Applications of Meteorology using SATellite data and ground-based observations (TAMSAT)

Towards drought impact-based forecasting in a multi-hazard context

UN-ASIGN

UNEP Strata

DH Network
Digital Humanitarian Network