SHEAR Science for Humanitarian Emergencies & Resilience

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Applied Earth observations for the disaster management sector

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Earth observations can support crucial humanitarian activities such as disaster management and disaster risk assessment. This knowledge product explores examples of how Earth observations have been used within the disaster management and disaster risk reduction contexts alongside a discussion of the current uses, ethics, and the future of Earth observation data.

Earth observations for disaster risk management

The use of Earth observations for disaster risk management is already expansive, including:

- Tracking and forecasting weather hazards for use in early warning systems, including near-real time hazard detection and monitoring of recovery processes.
- Observation and forecasting of vegetation health and climate-related crop damage, and land-use tracking of deforestation.
- Index-based insurance.
- Validating and reinforcing *in situ* observations. and complementing stakeholder surveys.
- Vulnerability and exposure population mapping.

Introduction

Earth observations derived from satellites and other remote-sensing tools are **increasingly available and used by the humanitarian sector and disaster management communities**. However, because of the ever-lower barrier of entry in the production and dissemination of Earth observation data and derived tools, users of these tools need to understand the **opportunities, challenges, and responsibilities** involved (Percivall et al. 2013, Le Cozannet et al. 2020).

Earth observations support or complement land-based measurements and can **answer questions** where *in situ* (such as rain gauges or weather stations) measurements are unavailable. With many applications, Earth observations can be incredibly powerful, but like most scientific tools, **without careful consideration, will continue to perpetuate socio-economic, racial, and cultural divides**.

These tools are becoming **more accessible and prevalent**. Therefore, being deliberate in our use of Earth observations, at every step of the process from idea development to impact assessment, and from cost and consequences to benefit evaluation is essential. The field must migrate from the perception that any integration of Earth observations into disaster risk management processes will yield positive, or at least non-negative, results. By **creating a space for accountability,** a more appropriate estimate of cost can begin - to the benefit of all Earth observations.

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Data Use, Collection, and Analysis

While Earth observation includes any systems or tools used to measure the Earth, for the purposes of this knowledge product, the focus will be on **satellite and remote-sensing-derived data**. This also aligns with the definition of Earth observations from the scientists and researchers interviewed. Globally, **the decision-making processes of many individuals already rely on Earth observation data and analysis**. For example, it is likely that the publicly available temperature and rainfall probability forecasts, are in some part driven by Earth observation data. Even if the data isn't directly derived from Earth observations, the calibration and skill assessment of the products (which can also lead to further improvement of the product) are often done with satellites.

The use of Earth observations can be broken into two categories: indirect and direct (Rayner, 2001). **Direct Earth observation** products pull data directly from satellites or other remote-sensing tools. **Indirect Earth observation** products, like weather forecasts, incorporate Earth observations during development, but do not rely strictly on satellite data for regular output (Makapela et al., 2015; Rayner, 2001).

Behind SHEAR, and other disaster-related projects, are many different Earth observations sensors, missions and derived data, such as:

- **CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data):** This dataset combines satellite-measured rainfall with rainfall data from rain gauges, to create a uniform dataset. CHIRPS is used widely, often for monitoring drought, calculating seasonal anomalies and validating different forecast products.

- **Landsat:** Landsat is a jointly run program between NASA and the United States Geological Survey. This mission features some of the longest time series (since 1972) Earth observation data, and longest moderate resolution land remote sensing, which allows for broad spatial and temporal analyses.

- **SAR (Synthetic Aperture Radar):** SAR is a type of radar sensor that provides capability to monitor the Earth at night, independent from weather conditions. SAR is particularly useful in regions that are frequently covered by clouds, such as the tropics, and can be used to monitor disasters during when other sensors and optical images are obscured by clouds, smoke, and ash.

These products (and many of the products used in disaster management and risk) are unique among hundreds of indirect and direct uses of Earth observations, as the imagery and data from these systems are **freely available** for researchers across the globe to access and analyse. The Landsat free and open data policy has provided extensive scientific and economic benefits not captured prior to the 2008 open data policy change (Zhu et al., 2019).

SHEAR, earth observations, and data

PICSEA
Earth observations are not a stand-alone tool. When used alongside other data sources, Earth observations can improve, verify, or complement traditional data collection.

For example, the PICSEA project uses Earth observation data to assess tropical cyclone forecast systems and their effects on southeast Africa.The team compared satellites rainfall data with hurricane forecast models to assess skill. This project aims to assist users in determining what cyclone impact forecast information they can, and cannot, trust.

ForPAc
Forecasting a hazard or assessing impacts alone cannot mitigate damage or prevent further impacts.

However, when Earth observations are used to develop Forecast-based Preparedness Action, like the ForPAc project, it can protect property and save lives.

ForPAc uses CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) and TAMSAT (Tropical Applications of Meteorology using SATellite data and ground-based observations) to validate experimental sub-seasonal forecast models to identify in which seasons we can potentially predict floods, on a lead-time that is 'actionable' for disaster risk reduction practitioners.

SHEAR and the value of open data

SatWIN-Alert & TAMSAT-Alert
Programmes like SatWIN-Alert and TAMSAT-Alert built their products on ARC (African Rainfall Climatology) and CHIRPS, two publicly available high resolution satellite-based datasets with more than 30 years of historic data.
With this robust and freely-available data,

TAMSAT-Alert can assess and anticipate the risk of meteorological hazards, like drought or flooding, to agriculture (Asfaw et al., 2018) and SatWIN-Alert can support operational drought insurance design.

SHEAR bridging social and physical science.

LANDSLIP
LANDSLIP combines the expertise of social scientists and practitioners with physical scientists in order to improve multi-hazard landslide risk assessments and landslide early warning.

The India Meteorological Department shares rainfall data, which is calibrated using data from seven satellite products, to adjust the models of the UK team.

This project is an example of the stakeholders and intended users contributing to the methods of the project, which will lead to an improved benefit on early action (Neal et al., 2019).

Ethical Considerations

Space agencies design most satellites for general purpose missions and widespread data use (Harris, 2013). This one-size-fits-all model, while beneficial in some cases - like pushing for **open and freely available data** - is also hindered by the virtual monopoly on Earth observation systems by well-established space agencies. With the increase in data availability, **discussions around responsibility have increased**, however **policies holding disseminators accountable are few**. In 2018, the **Humanitarian Data Science and Ethics Group** formed to address ethical considerations around artificial intelligence and touched on considerations of Earth observation data; Earth observation data is used in various artificial intelligence methodologies. Recent outputs related to this working group reference the Alan Turing Institute in regards to data developed and disseminated with the intent to intervene in not-for-profit and humanitarian contexts. The group notes that project owners "owe **stricter legal and ethical obligations** towards those affected by their data science tool" (Dodgson et al., 2020).

However, the concept of satellite remote sensing, especially 'value added' activities - such as data derivations and interpretations - from remote sensing, has long been identified as a set of activities for which **professionals need heightened awareness of the potential detrimental effects** (Wasowski, 1991). Recent work expands these activities to include **unconscious user bias** that may be present in both initial data acquisition and subsequent processing and/or development of remote sensing data driven algorithms (including, but not limited to, artificial intelligence) (Bermen et al., 2018).

The Future

Earth observation science and research still has far to grow technologically, but some of the most exciting areas for growth are in **expanding the use and application of Earth observation data for disaster risk management** including: in anticipatory action to reduce risk of impact from a potential disaster, preparedness when impact from a disaster is imminent, response to a disaster, and long term recovery and risk assessment (Le Cozannet, 2020).

The future integration of Earth observation into disaster risk management should be driven primarily by discussions around the **cost and benefit of potential intervention** into any decision making process. While there will be many opportunities to benefit disaster management decision making, prioritization of an ex-ante analysis of impact of potential interventions will be a significant step forward towards **understanding accountability, privilege and power dynamics** that inevitably are associated with dissemination of data, particularly those of vulnerable people.

SHEAR looking towards the future.

WeAct
Recent advances in Earth observation technology and modelling has opened doors to exciting spaces where previously data-limited analyses are now possible.

WeACT uses Earth observation and high-performance dam-break flood modeling on a natural flood hazard assessment and forecasting system. The goal is to improve preparedness in Nepal, though the products will be likely transferable to other mountainous regions.

NFLICS
Earth observations can shorten warning lead times; NFLICS uses historical and satellite data to detect land surface drivers of extreme Mesoscale Convective Systems and develop probabilistic nowcasts of likely urban flood damage.

Additionally, from a technical perspective, **new opportunities** arise with the **increased spatial and temporal resolution** of new sensors onboard new satellites and within various constellations. For example, the TROPICS mission from NASA is a constellation of smaller satellites which aims to produce three-dimensional profiles of temperature and humidity in all weather conditions, including the difficult to measure and analyze conditions in and around the world's strongest tropical cyclones. By better understanding the composition of these dangerous hazards, forecasts can improve and disaster managers will likely have increased lead time to support prioritization activities (Blackwell et al., 2018). Further, the Indian Space Agency (ISRO), in collaboration with NASA, is launching a new mission featuring the first dual frequency radar imagery. The data from this mission will be available with relatively low latency, with some data being available just one day after acquisition, which is likely to be useful for disaster applications (Rosen and Kumar, 2019).

However, while improvements in spatial and temporal resolution would be welcomed by most scientists and researchers, **technological developments alone will not answer all - or even most - of the problems faced by disaster risk management.** To respond to such problems, the remote sensing community must ask: who needs to not only be part of this discussion, but also have the decision making power? Asking, answering, and acting on this question helps to ensure the right questions are being asked and the **most vulnerable populations are identified**. It also allows for the development of the necessary **governance structures** with the roles and responsibilities filled by the people most able to answer these questions.

The use and development of Earth observations must be re-incentivized such that scientists, researchers, and funding organizations will **allocate resources to develop integrated approaches** that include not just talking to impacted and relevant communities, but also thinking about **how the data extracted from those communities will be returned with added value**.

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