Investing in Hydro-meteorological Infrastructure to Address Inequality of Impacts from Climate Variability and Change

Julio Enrique Herrera Estrada, PhD Candidate in Environmental Engineering and Water Resources, Princeton University*

Inequality of Weather and Climate Impacts

The World Meteorological Organization estimated that weather and climate disasters that occurred between 1970 and 2012 caused 1.94 million deaths and US$ 2.4 trillion (2012 prices) in economic losses worldwide (WMO, 2014). While these hazards affect developed and developing countries alike, the latter suffer from higher climate risks due to higher exposure and vulnerability. In the case of Africa, for example, droughts account for only 20% of the disasters in the continent, but for more than 80% of the population affected by a natural hazard (UN/ISDR, 2007).

More resilient individuals and nations have better access to financial resources (e.g. income, subsidies, and insurance) that allow them to mitigate the impacts of these extreme events, such as loss of crops and cattle, or having to rebuild flooded structures. Wealthier regions have the ability to replace lost hydropower capacity during a drought with more expensive alternatives, including fossil fuels in the short run, or building capacity of renewable energy in the long run. They also have the means to build stronger levees and barriers to prevent their rivers from overflowing. However, many or all of these options are not available for poor individuals, regions, or nations.

In addition, losses from weather and climate disasters can further entrench regions into poverty. The loss of crops and cattle reduces the livelihoods of farmers, and decreasing population due to migration or loss of lives reduces the workforce and productivity within a poor country, leading it to continuous low-economic output. Furthermore, a recent study by the World Bank found that the impacts of climate change threaten current development achievements and future development goals, since they might push more than 100 million people into poverty by 2030, particularly in Sub-Saharan Africa and South Asia (Hallegatte et al., 2015).

Hydro-meteorological Monitoring and Forecasting

One of the most important assets we have to mitigate the impacts of weather and climate extremes in current and future climates is information. The earlier we can predict a drought or a flood, the more prepared communities can be, helping them reduce some of their economic and material losses. Several regional monitoring systems for the water cycle have been developed, including Princeton University's Flood and Drought Monitors in Africa and Latin America (Sheffield et al., 2014), the U.S. Drought Monitor, and the European Drought Observatory. These systems use a combination of data from satellites, observations from hydro-meteorological stations (e.g. precipitation, river flows, etc.), and data from regional and global computer models (Chaney et al., 2014). They bring together decades of efforts from the scientific community around the world that have focused on extending our data gathering tools, and our understanding of the Earth system.

The satellite missions launched by space agencies around the world have allowed us to obtain a global understanding of our climate, and more specifically, the water cycle. They have made it possible to develop these regional early warning systems for droughts and floods by filling in the gaps of hydro-meteorological stations on the ground (Famiglietti et al., 2015). Nevertheless, data from satellites alone is not enough. Studies have shown that simulations that also assimilate station data and run them through computer climate models represent climate variability more accurately compared to satellite data alone (e.g. Peña-Arrancibia et al., 2013). Thus, hydro-meteorological stations are not made obsolete by satellites, for they are in fact, complementary. Satellites provide a global coverage, but stations provide more accurate data wherever available.

The number of satellite missions has increased since the late 1970s providing larger amounts of global data, but the number of reporting hydro-meteorological stations has dramatically decreased throughout the past century. This has crippled our local and regional understanding and predictability of weather and climate events (Fekete et al., 2015). These decreases in availability of station data has predominately taken place in developing regions, such as Sub-Saharan Africa, the Middle East, South and Southeast Asia, and some regions of Central and South America. Figure 1 shows the case of decreasing information availability of river-discharge around the world. Similar maps could be drawn for stations monitoring rainfall and other important hydrological variables. Without station data in these regions, satellite data cannot be validated appropriately, increasing the uncertainty of the computer simulations used to drive drought and flood monitors and forecasts at sub-seasonally and seasonal timescales. Furthermore, climate models used to understand climate change throughout the 21st century also rely heavily on station data throughout the world for calibration. Thus, not incorporating station data lead climate change projections in these regions to have higher uncertainties. This decreasing availability of station data in developing countries is very troubling, because the poorest regions of the world where impacts from climate extremes and climate change will be felt the most, have the most deficient infrastructure for gathering data needed to monitor and predict them.

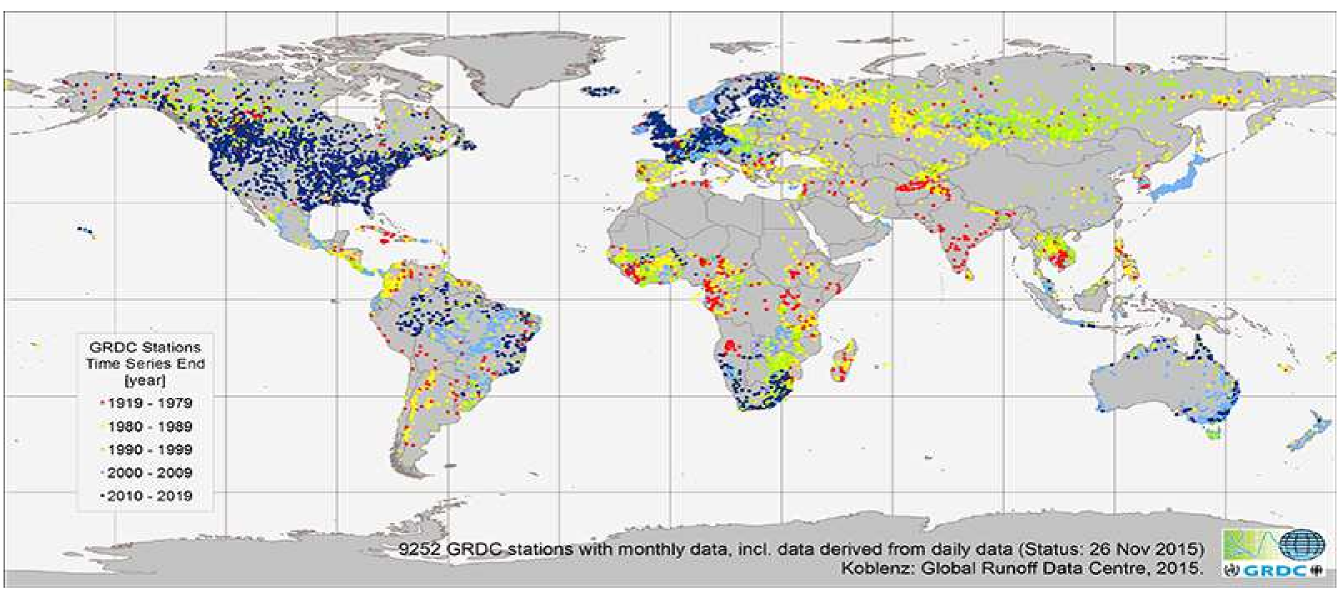

Figure 1. Last year of data reported by river-discharge stations belonging to the Global Runoff Data Centre (GRDC). All but dark blue dots represent stations that are no longer reporting data. Source: GRDC.

Recommendations

In order to protect developing communities from weather and climate shocks, such as droughts and floods, their countries need to invest on local infrastructure for data gathering. The World Bank recently estimated that US$ 1.5-2 billion will be needed to modernize the hydro-meteorological monitoring infrastructure in developing countries, and an additional US$ 400-500 million will be needed annually for maintenance (Rogers and Tsirkunov, 2013). In comparison, a different World Bank study estimated that the benefits of improving hydro-meteorological services in developing countries to standards used in developed ones would lead to an increase of US$ 30 billion per year in economic productivity and a decrease of up to US$ 2 billion per year from reducing asset losses (Hallegatte, 2012). Similarly, a literature review of economic assessments of hydro-meteorological services reports benefit-costs ratios greater than one (WMO, 2015), making strong cases for government investments in this area.

The cost of deploying new monitoring stations and maintaining them can also be reduced in multiple ways, including the following:

1) *Leverage cellphone networks for continuous automatic reporting.* Regions that are hard to access due to lack of well-built roads and highways, for example, can still host hydro-meteorological stations that make use of nearby cellphone towers for data transmission. Several low-cost sensors that make use of existing telecommunications infrastructure have already been developed (e.g. Siegfried et al., 2013).
2) *Involve communities and stakeholders in their maintenance.* Outsourcing the maintenance of monitoring stations to local stakeholders who benefit from their existence can bring down the costs for the governments. For example, farmers have an incentive to have working stations around their fields that can help monitor weather conditions and predict future droughts. In exchange for maintaining a station, farmers can be delivered free monitoring and forecasting services using their station data. Upkeep of stations can also become educational activities in schools and universities, acting as laboratories that can help students around the world learn math, earth sciences, and engineering. An example of this is The GLOBE Program, cosponsored by NASA and NSF.
3) *Add new sensors and stations to existing global networks*. To speed up transference of information from the stations' sites to scientists, stakeholders, and decision makers who need it around the world, new stations should be encouraged to report directly to existing global monitoring networks, such as those coordinated by the WMO (e.g. the Global Climate Observing System).
4) *Encourage data digitization and sharing*. Governments oversee many existing stations, but their data may not be readily available because it is either not captured digitally, or it is not shared with regional or global monitoring networks. Thus, governments should be encouraged to share their hydro-meteorological data, citing the multiple benefits that they would receive by doing so, including improved climate risk assessment and management (WMO, 2015).

Conclusion

Climate variability and change affect the poorest nations the most. Paradoxically, these nations also have the most limited capabilities of gathering hydro-meteorological data, which is critical for monitoring and predicting extreme events, and to study climate change in their region. Investing in robust monitoring networks of hydro-meteorological stations is a sound decision within a cost-benefit framework that would advance development efforts by contributing towards achieving multiple Sustainable Development Goals (SDGs). The data that these networks would provide is necessary for risk assessment and mitigation, in particular regarding agriculture (SDG #2), infectious diseases (SDG #3), and availability of water resources (SDG #6). Furthermore, these networks are important for the study of climate change impacts (SDG #13), and the science diplomacy involved in data sharing amongst countries would contribute to building regional cooperation and collaborations (SDGs #16 and #17).

Moreover, not all the burden of maintaining these new stations has to fall on governments' shoulders. New low-cost sensors that report automatically using existing cellphone networks dramatically reduce reporting time and related costs. Maintenance of some stations can also be outsourced to stakeholders such as farmers in exchange for hydro-climatic services, and to schools, which can also use them for educational purposes.

References

Chaney, N. W., J. Sheffield, G. Villarini, and E. F. Wood (2014), Development of a High Resolution Gridded Daily Meteorological Data Set over Sub-Saharan Africa: Spatial Analysis of Trends in Climate Extremes. J. Climate, 27, 5815-5835.

Famiglietti, J. S., Cazenave, A., Eicker, A., Reager, J. T., Rodell, M., and I. Velicogna (2015), Satellites provide the big picture, Science, 349, 684-685.

Fekete, B., Robarts, R. D., Kumagai, Mi., Nachtnebel, H.-P., Odada, E. and A. V. Zhulidov (2015), Time for in situ renaissance, Science, 349, 685-686.

Hallegatte, S. (2012), A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning and Evacuation. World Bank policy research paper No. 6058. The World Bank, Washington, DC.

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., and A. Vogt-Schilb (2016), Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development. The World Bank, Washington, DC.

Peña-Arrancibia, J. L., van Dijk, A. I. J. M., Renzullo, L. J., and M. Mulligan (2013), Evaluation of Precipitation Estimation Accuracy in Reanalyses, Satellite Products, and an Ensemble Method for Regions in Australia and South and East Asia, J. Hydrometeorology, 14, 1323-1333.

Rogers D. and V. Tsirkunov (2013), Weather and Climate Resilience: Effective Preparedness Through National Meterological and Hydrologica Services, The World Bank, Washington DC.

Sheffield, J., E. F. Wood, N. Chaney, K. Guan, S. Sadri, X. Yuan, L. Olang, A. Amani, A. Ali, and S. Demuth (2014), A Drought Monitoring and Forecasting System for Sub-Sahara African Water Resources and Food Security. Bull. Am. Met. Soc., 95, 861-882.

Siegfried, B. Wolf, A., Caylor, K.K., Sheffield, J., Wood, E.F., Gosset, M., and F. Cazanave (2013). Development and field deployment of real-time precipitation sensors using cell-phone communications. 11th International Precipitation Conference, Wageningen University, Netherlands.

UN-ISDR (2007), Drought risk reduction framework and practices: Contributing to the implementation of the Hyogo Framework for Action, United Nations Secretariat of the International Strategy for Disaster Reduction, Geneva, Switzerland.

WMO (2014), Atlas of Mortality and Economic Losses from Weather, Climate, and Water Extremes (1970-2012).

WMO (2015), Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services, WMO-No. 1153.