atmosphere

MDPI

Perspective

What Does It Mean to Be El Niño Ready?

Michael H. Glantz [1,*], Lino Naranjo [1], Marie-Ange Baudoin [2] and Ivan J. Ramírez [1,3]

1 Consortium for Capacity Building, Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309, USA; blino2011@outlook.com (L.N.); ivan.cxa@gmail.com (I.J.R.)
2 Senior Climate Change Consultant, C4EcoSolutions, Capetown 7945, South Africa; marieange007@gmail.com
3 Department of Anthropology, Colorado State University, Fort Collins, CO 80523, USA
* Correspondence: mickeyglantz@hotmail.com; Tel.: +1-303-579-4034

Received: 3 January 2018; Accepted: 5 March 2018; Published: 7 March 2018

Abstract: Once an El Niño event has been forecast, government warnings and news headlines highlight the need for society to get ready for the potential impacts of the event, whether drought, flood, heatwave, disease outbreak, or water shortage. The notion of readiness for a climate-, water- or weather-related hazard or disaster is a fuzzy term, subject to a wide range of conflicting perceptions. Not every government sees El Niño as a direct threat to the wellbeing of its citizens. In this paper, we conceptualize readiness and identify reasons that some governments do not as well as cannot prepare for El Niño's foreseeable consequences. Central among those reasons are its characteristics: quasi-periodicity, event variability, difficulties with onset forecasting, and the fact that El Niño and its "teleconnections" are influenced by numerous other oceanic and atmospheric oscillations. As a result, there is no universally accepted approach to or reliable measure of readiness. The concept is often discussed qualitatively in terms of "shades of readiness", such as hardly ready, somewhat ready, almost ready, and absolutely ready. Although El Niño is still difficult to forecast, the existing knowledge about it can provide usable information for decision makers to choose whether to pursue strategic or tactical disaster risk reduction policies.

Keywords: El Niño; disaster risk reduction; readiness; teleconnections; lessons; disasters; satisfice; hurricane; NMHS

1. Introduction

This paper, written from a social science perspective as part of a larger multiyear study to develop the concept of "El Niño Ready Nations" (ENRNs), is meant to examine the notion of readiness, especially with regard to El Niño events and government responses. Inspired by a number of country-based lessons identified in previous lessons-learned research as well as from our recently published study of societal responses in 16 countries to the 2015–16 El Niño [1], the following six themes related to the notion of "readiness" for El Niño events were raised: what does it mean to be "El Niño Ready"; readiness as a fuzzy concept; limits to readiness; who has to be ready, by when, and to what degree; strategic and tactical social responses; and using El Niño history and science in readiness decision-making.

Although El Niño has been a field of academic and applied study since at least the beginning of the 1890s [2–4], the body of knowledge represented by each of the above themes has especially grown over the past few decades. While scientific understanding of El Niño events specifically, and El Niño-Southern Oscillation (ENSO) in general, has advanced considerably since the 1972–73 event, enhanced understanding has seemingly slowed down in the past two decades with regards to step-like improvements in forecasting its onset [5]. As an example, L'Heureux [6] observed that "El Niño prediction is not 'solved'. It wasn't at the beginning of 2014 and it isn't now. There are still big challenges we face and it will take a lot of time and effort to analyze the data to better understand ENSO and informed by that new knowledge, predict it with greater accuracy".

El Niño was first a concern in the eastern tropical Pacific Ocean and allegedly given its name by Peruvian fishermen in the late 1800s. Since then, it has increasingly been recognized as a naturally occurring air–sea interaction with adverse impacts on societies around the globe. It has also increasingly become a political concern because decades of physical and social science studies have uncovered its reach in distant locations worldwide referred to as El Niño's teleconnections. Improved knowledge of El Niño's influences at all socio-economic levels and across many aspects of society has value to ENSO-related decision making for disaster risk reduction (DRR) [7].

Pigeon and Rebotier state the generally acknowledged DRR paradox: "although more time and resources are increasingly dedicated to understanding disaster and mitigating their impacts, the number of disasters and the magnitude of their associated damage are increasing, at least in some statistically significant categories" [8] (p. 3). They underscored how the rise in the number of hydro-meteorological (hydromet) disasters has been the result of natural and of social conditions, which unwittingly pave the way for known hazards to bring about catastrophe.

El Niño, similar to the seasons, is not generally considered a natural hazard. However, all can agree that El Niño events are at the very least a generator of extreme—and most often now foreseeable—hydromet anomalies (e.g., droughts and floods), not to mention secondary effects such as food insecurity and disease outbreaks in teleconnected areas the world over [9–12]. The hydromet anomalies associated with El Niño provide additional lead time for society to prepare for the likely foreseeable adverse conditions and potential benefits that might occur. In addition, acknowledging El Niño's known uncertainties, that is, what we know that we do not know, can be applied to DRR efforts.

El Niño is a key phase of an irregular multi-year, three-phase cycle called ENSO (Figure 1). The "EN" represents warm extremes in sea surface temperatures in the central and eastern tropical Pacific Ocean. The "SO" represents the Southern Oscillation, which brings about seesaw-like changes in sea level surface pressure across the tropical Pacific between Darwin, Australia and Tahiti.

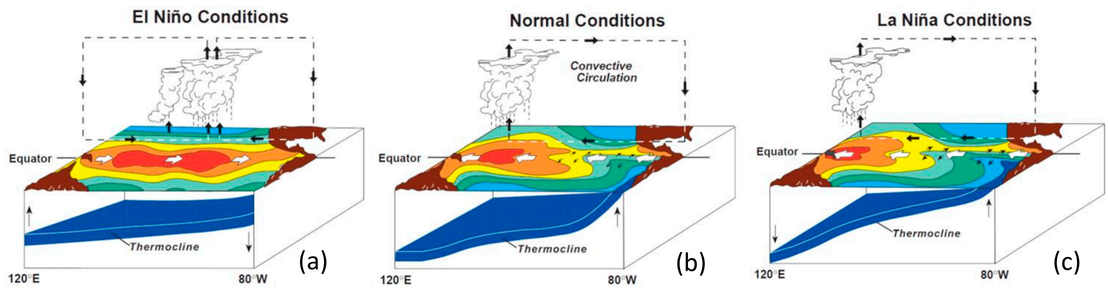

Figure 1. Red depicts anomalously warm Sea Surface Temperatures. ENSO's three phases: (**a**) El Niño; (**b**) Normal (Neutral); and (**c**) La Niña Source: Pacific Marine Environmental Laboratory [13].

Trenberth [14] estimated that El Niño (ENSO's warm extreme) and La Niña (ENSO's cold extreme) phases, taken together, occur about 50% of the time. The Neutral phase, encompassing the remaining time, is perceived by the general public as their normal, e.g., expected, climate. Each of the ENSO phases has different expected influences on seasonal and sub-seasonal weather, as in the case with tropical hurricanes (Figure 2). For example, in El Niño years, there is a tendency for the number of hurricanes to decrease in the Atlantic Ocean, in part due to the enhancement of the jet stream which increases vertical shear over the Atlantic. Conversely, in La Niña years, the number of hurricanes tends to increase, due to the decrease of vertical shear over the Atlantic. It should be noted however that this relationship is asymmetrical and one should not assume that societies are safe from hurricanes during El Niños [15]. For example, Pielke Jr. and Landsea [16] showed that: (a) the La Niña link was stronger (e.g., more hurricanes and losses); and (b) even though there are fewer hurricanes during El Nino years, one event can still incur catastrophic damage. Advances made in forewarnings about ENSO's extremes provide added foreseeability to governments of El Niño- or La Niña-related teleconnected weather anomalies and societal consequences.

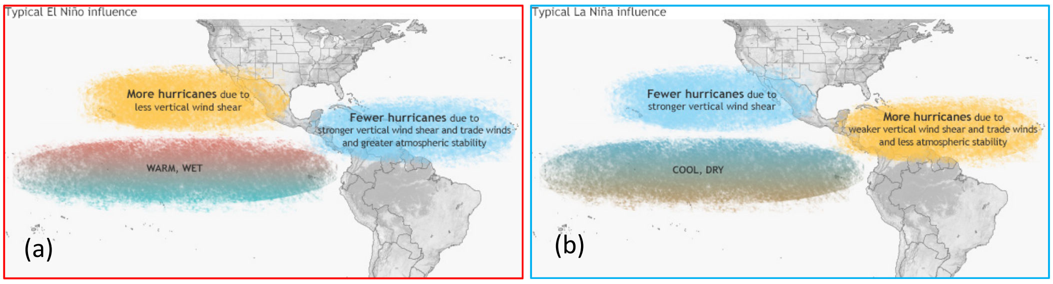

Figure 2. Relative frequency of tropical Atlantic hurricanes during (**a**) an El Niño and (**b**) a La Niña episode. Source: NOAA [17].

Better awareness and understanding of a nation's current level of readiness in the context of El Niño contribute toward disaster risk reduction and toward disaster risk avoidance defined as "the elimination of hazards, activities and exposures .... Whereas risk management aims to control the damages and financial consequences of threatening events, risk avoidance seeks to avoid compromising events entirely" [11].

2. What Does It Mean to Be El Niño Ready?

However readiness is defined, as a "state of preparedness" or as "based on a thoroughness of planning", different observers would likely agree on what it means to be perfectly ready to manage El Niño's impacts in an ideal circumstance. Yet, those same observers would be less likely to agree on what would be acceptable as less-than-perfect readiness in less-than-ideal circumstances. This lack of agreement would reflect the varied, real-world interests, concerns, and priorities of those various observers. Perceptions of what it means to be ready are influenced by existing as well as historic trends having to do with socio-economic systems, cultural expectations, religious beliefs, political structures, and other important factors, which of course vary from country to country let alone from people to people.

The point is that there can be no universally agreed upon definition of what it means to be ready—either proactively or reactively—for an El Niño event and its various global teleconnections. In the same way, there is also likely no universally acceptable way to classify or measure levels of readiness, especially not to meet the decision-making objectives or specific needs of all nations, cities, socio-economic sectors, or even national meteorological and hydrological services (NMHSs).

Interestingly, the UN's International Strategy for Disaster Risk Reduction (ISDR) [18] glossary of disaster-related terms does not include a formal definition of readiness; however, its annotation for the definition of preparedness mentions "readiness", suggesting that it is approached reactively (tactically) rather than proactively (strategically). The current UNISDR definition and accompanying annotation for Preparedness is as follows:

> "The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.
>
> Annotation: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery.
>
> Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, the stockpiling of

equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term 'readiness' describes the ability to quickly and appropriately respond when required".

Preparedness and readiness are often used interchangeably, suggesting that for all practical purposes they are synonyms.

There are several reasons why a nation, industrialized or developing, might have difficulty becoming fully prepared for the adverse impacts of recurring hydromet hazards, even known ones. Some of those reasons relate directly to the scientific uncertainties that surround forecasting El Niño's physical components. These scientific uncertainties are not trivial inconveniences; they can have notable influence on a nation's readiness capabilities. Currently, for instance, forecasting the timing of the actual onset of the next El Niño cannot yet be reliably done well enough in advance, which is an important uncertainty to decision makers. Another uncertainty results from the combined influences at any given time of other air–sea oscillations (Figure 3) on a specific El Niño's impacts and its worldwide teleconnections, e.g., the Indian Ocean Dipole [19,20] or the Pacific Decadal Oscillation [21,22]. Such oscillations at any given time can amplify or dampen the intensities of El Niño and of its impacts. The precise mechanisms of the interconnectedness of the oscillations remain of interest to researchers. Breakthroughs in El Niño science continue to be hemmed by uncertainties that make enhanced reliability of prediction challenging [5,23]. The science of El Niño is still on a learning curve. El Niño-related surprises must be expected as had been the case for the 1982–83 "El Niño of the Century" and most recently the unanticipated "Niño Costero" off the coast of Peru and Ecuador in early 2017 [24].

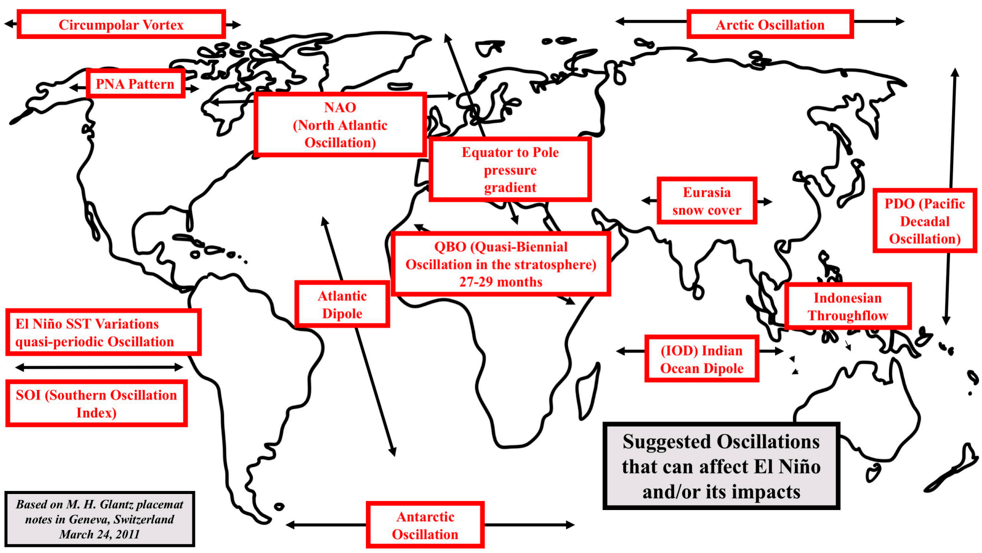

Figure 3. Diagram of various oscillations in the ocean and atmosphere and their interactions that can influence the behavior of El Niño and the intensity and location of its teleconnections.

Societal uncertainties also exist. For example, there is uncertainty generated by the way El Niño forecasts are worded and then how they are communicated as early warnings to civil society. Societal constraints such as socio-political, psychological, cultural and economic factors can hinder achieving desired levels of readiness. Weak events might be perceived by decision makers as of relatively little concern, even though the societal and ecological impacts of a decaying El Niño could be major. Another major human factor affecting readiness is that El Niño occurs every 4.5 years on average. How can or should policy makers from nation to community prepare for a hazard that can return any time within

2–7 years? How can the interest and DRR action of policy and other decision makers be sustained between El Niño events?

Decision makers are under constant pressure to deal with various emerging as well as chronic crises. They tend to shift their attention from El Niño to other concerns. Once forecasters have announced that an El Niño's strength has peaked, policymakers tend to shift focus and resources, thereby discounting dire warnings of yesterday in favor of dire threats of today. However, history shows that even a weakened El Niño well beyond its peak intensity can continue to disrupt economies, commodity prices in the marketplace and the social order during societal coping and recovery phases.

3. Readiness as a "Fuzzy" Concept

"How important is it to be exactly right when a rough answer will do?" [25]. That question merits attention, when discussing levels of readiness. It also raises the question, when is "enough" information enough to make an informed decision? As René Dubos once noted, "Sometimes the more measurable drives out the most important" (as quoted in [26]). Fuzzy Logic provides a useful approach to concerns about precision vs. significance of information in any given situation. It "imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO" and between zero and one [27].

Fuzzy logic can be used to identify as well as communicate about levels of readiness for coping with possible hydromet hazards and disasters. We propose that such levels can best be understood by the general public as qualitative, verbal expressions as suggested in Figure 4. We also recognize that a quantitative ranking may be more accurate and useful for the ranking of nations in terms of their actual readiness in face of a foreseeable El Niño. Qualitative and quantitative expressions of readiness are complementary.

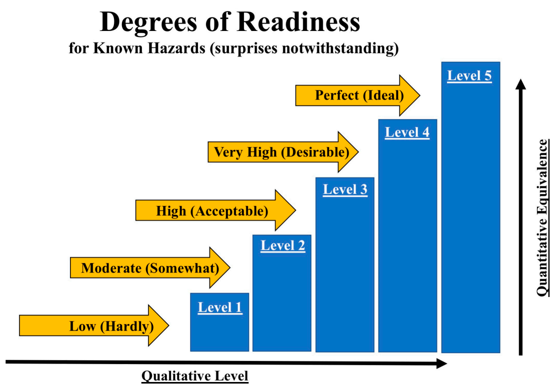

Figure 4. Levels of fuzzy readiness. Source: CCB.

Related to fuzzy logic is the concept of satisficing [28]. To satisfice is to "decide on and pursue a course of action that will satisfy the minimum requirements to achieve a goal" [29]. Glantz and Baudoin [30] (p. 112) described satisficing as a new notion from the mid-twentieth century that has ethical as well as economic implications:

> "'Satisficers', those who are satisfied to meet minimal requirements to achieve their goals through their actions, are usually viewed in opposition to 'maximizers', who seek the greatest outcome possible from their actions in order to achieve their goals.... Perhaps the notion of 'satisfice' has a useful role to play in disaster preparedness, response & recovery.... In fact one could argue that the adage "Do not let the perfect become the enemy of the good" could serve as a reminder to agencies that 'satisficing' is an option for development activities".

Changes over time in a qualitative readiness ranking for country or community serve to remind the public of "what is" its level of readiness. Qualitative levels could generate proactive interest in improving that country's or community's overall security with the enticement offered by the prospect of moving from "hardly ready" to a higher level. Once the people in a country or a community are so prompted to pay attention to the hydromet risks they face, they can then be trained to "self-identify" what to do to reduce their personal risk by striving for a higher level of readiness. They would be encouraged to rely on their own experience, resources, expertise and ingenuity.

4. Limits to El Niño Readiness

There are, of course, limits to being El Niño ready for hydromet hazards. Awareness of limits is important because it underscores the necessity of a shared responsibility between governments and civil society to respond, when a hydromet hazard threatens a society.

The spate of devastating hurricanes that plagued Caribbean countries and the US in 2017 again exposed that even industrialized societies cannot "climate proof" themselves, despite desires and even attempts to do so [31]. However, they engage in long-range planning, often based on plausible scenarios about the future. Given uncertainties about the future, not all plans work out as expected. As an instructive example of such a scenario, about 250 people from US government and local to federal agencies, under the auspices of the US Federal Emergency Management Agency (FEMA), spent 2 weeks discussing a hypothetical Hurricane Pam scenario in July 2004. It was a realistic scenario about a fictitious US Category 3 hurricane making landfall at New Orleans [32–34]. The Hurricane Pam exercise was, in retrospect, an appropriate, timely attempt at hydromet DRR.

After the Hurricane Pam exercise ended, FEMA issued a press release, which provided an illustrative list of plans identified by conference attendees responding to this hypothetical scenario: debris removal, the need for shelters, search and rescue protocols for stranded residents, plans for support of hospitals, the relocation of refugees from inundated coastal areas, and so forth [35]. FEMA's regional director noted, "We made great progress in our preparedness efforts".

Thirteen months later, the usefulness of the hypothetical Hurricane Pam activity was tested, when in late August 2005 Katrina, a Category 3 hurricane, made landfall along the US Gulf Coast and headed inland. In fact, a near-perfect forecast had been issued by NOAA about 44 hours in advance of Katrina's landfall. Hurricane Pam was a realistic "perfect-scenario" of an extreme event that was foreseeable. Despite the best planning efforts, however, when Hurricane Katrina made landfall, death, destruction and misery followed. One of the many take-away lessons from Pam is that scenarios are excellent learning devices but are relatively limited as guides to action [33].

Another limit is an El Niño surprise. Between 2014 and 2016, the quasi-periodic El Niño-Southern Oscillation (ENSO) cycle has been accompanied by several surprises with respect to El Niño knowledge which had been considered fairly reliable. For example, in 2014, the ocean warmed to El Niño levels BUT the atmosphere did not react to that warming, hence no El Niño occurred in 2014; the forecast for that El Niño had been given a probability of occurrence at the 90% level. It did not happen [5]. An unusual unexpected warm water (i.e., "the Blob") off the NW coast of the US had not been witnessed before, causing unusual impacts that disrupted the otherwise expectable impacts during the onset and growth phases of the 2015 El Niño [36]. For example, Jacox et al. [37] found that "the Blob" overshadowed El Nino's influence in California resulting in a weaker teleconnection on marine fisheries. However, given our knowledge of the ENSO phenomenon, which has been gathered over more than a century, why are researchers still being surprised by El Niño's behavior? The reality is there is a lot about the science and impacts that researchers have yet to discover.

"The 1982–83 El Niño, by many measures the strongest thus far this century, was not predicted and not even recognized by scientists during its early stages" [38]. Fifteen years later, the 1997–98 El Niño, also not predicted well in advance [23], was accompanied by several surprises: it was not forecast several months in advance, it emerged faster than expected, and it decayed more rapidly than expected. Researchers suggested that no two El Niño events are alike in their characteristics, or their consequences for ecosystems and societies. Then came the difficult to quantify notion of "flavors of El Niño". Most recently, Capotondi et al. [39] referred to El Nino "diversity" in order to understand the different types of ENSO.

The truth of the matter is that each El Niño has been accompanied by surprises: surprising in its timing, behavior, in its characteristics such as intensity or duration or in its societal and environmental consequences. The positive aspect of surprises, however, has shown that they are usually followed by research to improve scientific and societal understanding of the phenomenon.

5. Who Has to Be Ready, by When, and to What Degree?

A nation is expected to protect its citizens from harm, and that harm includes naturally occurring climate, water and weather-related hazards. In the real world, many governments do not have the resources necessary to protect everyone within their borders. They do, however, have a moral obligation to warn everyone of impending hazards. Even with a perfect forecast, it can be difficult to warn in a timely way all people and communities at-risk. The problem is that a forecast cannot be judged as having been reliable until an event occurs. El Niño forecasts as early warnings for hydromet hazards are not perfect, but they can provide governments with some months of lead time to prepare for foreseeable impacts (see Figure 5 for a map of teleconnections).

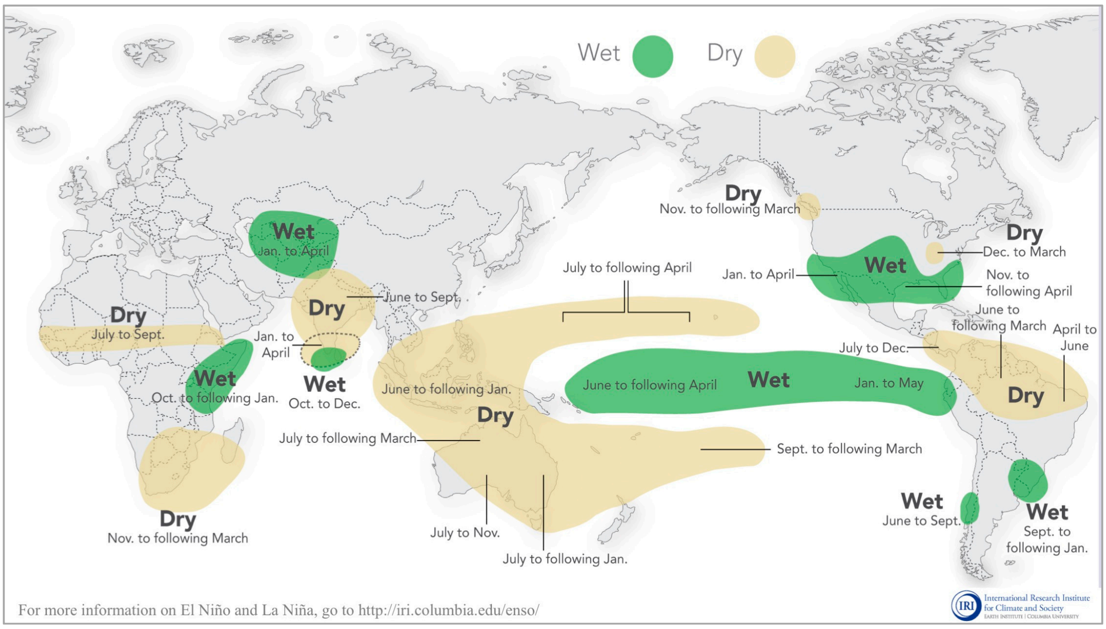

Figure 5. El Niño and Rainfall. El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map above. Source: IRI [40].

Whenever a major international forecasting center such as NOAA in the USA, the Hadley Center in the UK, or the Japan Meteorological Agency (JMA) issues an El Niño forecast, other national and regional centers also issue forecasts to their societies. Ideally, an NMHS director first informs political authorities that an El Niño is likely, warning them about teleconnected impacts in their country. Government agencies for their part make decisions on whether or how to respond to hydromet impacts within their administrative jurisdictions. This initial El Niño forecast has the potential to spark a cascade of societal responses and of forecasts about possible socio-economic impacts.

Following the initial onset forecast, which is in essence an early warning of potential extreme impacts in a country, other official forecasts are released to the public as the event progresses: a forecast of El Niño's intensity, another when El Niño locks-in (i.e., the point after which the El Niño can be expected to continue), and yet another of its potential regional impacts worldwide. As the lifecycle of the event progresses, the next important forecast relates to the belief that the El Niño has peaked and months later a forecast noting that the anomalous tropical sea surface temperatures have return to average. Even though the physical event has ended, its teleconnected socio-economic impacts on an economy can last for some years.

Each of these forecasts serves to alert various decision makers from local to national about potential adverse impacts on different climate-sensitive socio-economic sectors. However, each forecast is surrounded by its own degree of uncertainty which can affect how they choose to utilize the forecast information. For example, in 2015 L'Heureux [6] noted "Clearly, the model forecasts made during the Northern Hemisphere spring of 2014 (March, April, May) were not as skillful as the rest of the year".

What must be understood is that, even in a perfect world with a perfect forecast, potentially affected groups will not respond at the same time or in the same way, when first informed about an El Niño forming in the tropical Pacific. Some affected groups may not respond at all, even when the forecasted regional consequences of an event begin to appear. Before other groups take El Niño seriously, they may still wait for successive early warning updates for follow-ups that provide more detail on the expected intensity or spatial scale of the event. Figure 6 is El Niño's life cycle, which presents a generalized view of the various stages of strong and very strong events from 1950 to 2016. The timing of the stages is only illustrative and do not represent the timing of all such events, e.g., El Niño Costero's occurrence in the early months of 2017 was a surprise to the El Niño forecast community [24].

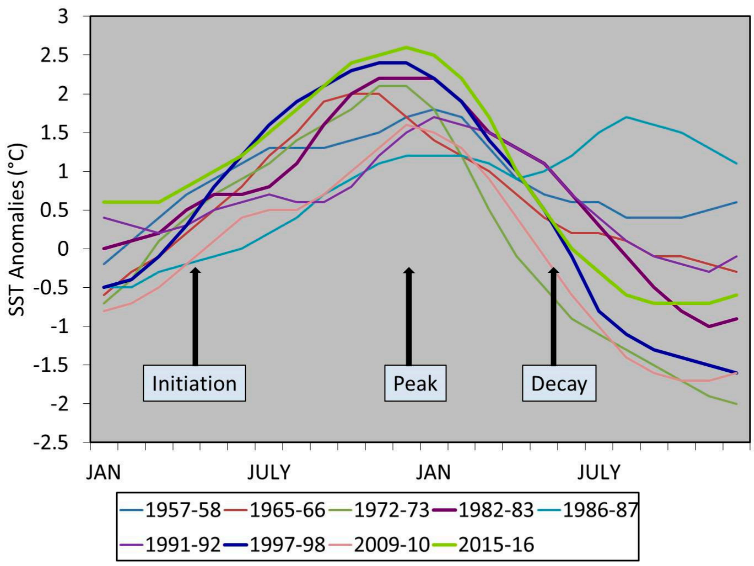

Figure 6. Generalization of El Niño's life cycle based on Oceanic Niño Index (ONI) (Niño 3.4 SST Anomaly). The reference is a "multiple centered period" that is updated for successive five-year periods. Strong events from 1950 to 2016 are highlighted. Data source: NOAA [41].

A government could benefit from establishing a standing committee for El Niño (even more so, for ENSO). It could be composed of representatives from El Niño-concerned government agencies, institutes, and groups drawn from society at large. Some governments already do this, like In the Philippines, its Civil Defense; military; ministries of Agriculture, of Water, of Public Safety; and various NGOs collaborate on the various problems that can be influenced by an El Niño event [42,43]. Another government example is Peru; its Civil Defense and the Navy along with Peru's NMHS, ocean and geophysical institutes, and ministry of health respond to various hydromet disasters, including those associated with El Niño. In other words, a societal group, agency or institute—aside from a traditional (20th century) NMHS—must have the responsibility to continue thinking about, preparing for, and responding to an El Niño's negative and even positive impacts, as the event evolves into a neutral phase.

A new generation of non-traditional NMHSs is emerging according to various and new initiatives to modernize NMHSs worldwide [44–46]. This would require that they need to actively engage to a greater extent in a broader range of societal activities and have more involvement in hazard response, by, for example, working directly with emergency managers about understanding how to use the forecast. The new type of NMHS could establish working relationships with forecast recipients to assure that the information the former provides is better understood. To be such a multidisciplinary focal point, however, would require political and financial support from the national government to enable its traditional NMHS to effectively "refunction" in order to become the more broadly defined 21st century NMHS envisioned here.

6. Societal Responses: Strategic and Tactical

Governments, communities, groups and individuals can choose to respond strategically (long-term) or tactically (short-term) to El Niño (see Figure 7). At the minimum, they need timely, credible and reliable forecasts based on experience, foresight and an appropriate level of sustained funding. Such foresight provided by researchers and forecasters is a necessary condition for DRR, but is not sufficient by itself. To be sure, truly adequate preparation for coping with hazards is necessary and will come with financial costs that a society will have to bear.

Figure 7. Relationship between strategic, operational and tactical planning based on FEMA Comprehensive Preparedness Guide 101, Version 2.0., 2010. Source: FEMA [47].

To prepare for an El Niño adequately and effectively requires long-term (strategic) thinking that is often well-beyond any individual policymaker's tenure in office. Strategic thinking about El Niño DRR will be a precursor for goals of planning for sustainable development and for post-disaster response and recovery (drr, with lower-case letters). Therefore, DRR and drr activities must be undertaken with the prospects of longer-term, sustainable development in mind.

Reasons for governments to delay or to shelve their El Niño-related strategic responses may be the scientific uncertainty that continues to surround ENSO or may be because the impacts of the previous event were perceived as not major. Still other governments might lack the funds to engage in DRR activities and have to deal with El Niños as separate episodes. They do not have the resources to deal with future ones. Basically, a government's "willingness" to pursue strategic as opposed to tactical planning may exist but the necessary funding is not available. It is important to note that governments that have developed strategic DRR plans for El Niño may choose to wait for a first reliable forecast of its onset before energizing preparation for its potential impacts.

As noted earlier, El Niño characteristics as well as forecasting them entail enough scientific uncertainty to enable decision makers to opt for tactical over strategic responses. For example, El Niño's intensities can range from weak to very strong. A government might wait to see if a strong El Niño actually develops. Forecasting El Niño is still not perfect. Its history shows that several onset forecasts were inaccurate (i.e., 1974, 1990, 1997, and 2014) while others failed to capture in a timely way events that did occur (i.e., 1982–83). Similar issues relate as well to the intensity of the impacts of the regional teleconnections.

Speculating aloud, the relatively short history of scientific monitoring of El Niño [48] hints that very strong basin-wide events might recur on the order of every 10–20 years (i.e., suggested by differences in the number of years between onsets of major events during 1957–58, 1972–73, 1982–83, 1997–98 and 2015–16), and may suggest to policymakers that there is little need to direct resources to a problem that will likely not appear for many years after the last major event. Less intense El Niños can be handled in the normal scheme of coping with seasonal anomalies. For example, a weak borderline event may show little difference when compared to the societal consequences of an increasingly warmer neutral phase as it transitions toward the El Niño phase.

Given the availability of funding, expertise and a government's inclination, El Niño readiness levels can be "self-identified", in qualitative terms, by a country's various administrative jurisdictions. One thing sub-national jurisdictions have in common is their reliance, if not complete dependence, on early warnings and the country's NMHS forecasts. The activities of an NMHS must be understood as being essential for an effective pursuit of readiness at any administrative level.

7. Using El Niño History and Science for Readiness Decision Making

It is now an accepted scientific fact that El Niño has been linked to foreseeable direct and indirect hydromet anomalies worldwide. At a bare minimum, decision makers need to know about the history of El Niño as it relates to their specific country. In this regard, El Niño history, like forecasts, provides a "heads up" to decision makers about hazards and possible disasters. Receiving an El Niño forecast causes decision makers in their respective administrative jurisdictions to deal with whether, and if so how, to take into account impacts of and responses to previous events. Societies—their researchers and their leaders, especially—tend to have in the front of their minds the impacts of the last major El Niño. For example, in 1982–83, researchers looked back to the 1972–73 event; in 1997–98, they looked back to the 1982–83 event; and, in the 2015–16 event, a new generation of researchers looked back to 1997–98 for insights on what teleconnected hydromet hazards they might reasonably expect and what responses they might have to pursue [5].

The recent 2015–16 El Niño highlighted the confusion about which previous El Niño event to rely on as an analogue. Media and scientists tended to favor the last major event, 1997–98. Preparing for and coping with the consequences of only the 1997–98-like event, however, does not provide accurate information about the range of potential impacts that a country might face. Therefore, previous events, not just the most recent memorable one, must be taken into account to provide a clearer picture of what to expect. For example, during the 1997–98 event, it was anticipated that drought would affect the south central Andes based on the 1972–73 and 1982–83 events; however, drought did not come [49]. Using El Niño history requires care to capture at least a glimpse of foreseeable impacts of future events.

No two El Niños have played out exactly alike. The same can be said of their impacts. However, a specific event and its potential impacts (e.g., a drought, flood, disease outbreak, etc.) are foreseeable for several geographic locations. Social change must also be considered when a previous El Niño is being used for comparative purposes, as societies are constantly changing in ways that can make them either more or less vulnerable or resilient in the face of future hydromet hazards.

A contribution to the DRR and El Niño research and application communities would be to develop guidelines about how best to use existing El Niño knowledge for enhancing DRR, drr and CCA (climate change adaptation). These guidelines would identify "best practices for the use of El Niño history" in both strategic and tactical decision making.

"History does not repeat, but it does instruct.... History can familiarize, and it can warn".
Timothy Snyder, On Tyranny [50] (prologue)

8. Concluding Thoughts

The authors set out to explore the concept of readiness in the context of El Niño. The concept is often discussed in qualitative terms and can be seen as "shades of readiness", such as hardly ready, somewhat ready, almost ready, and absolutely ready. They are on a continuum anchored by extremes of not-at-all ready and perfectly prepared. Shades of readiness could be useful to both providers and end users of hydro-meteorological products. Readiness is a fuzzy concept, similar to others commonly used by the DRR community (e.g., vulnerability, resilience, mitigation, adaptation and sustainability). Readiness plans at the national level may not be directly down scalable to lower-level political jurisdictions and local communities within them.

Clearly, uncertainty continues to surround various aspects of the ENSO cycle. It also surrounds the characteristics of the El Niño phenomenon itself. However, we can still identify ways that decision makers can add value to their deliberations about coping with El Niño's hydromet teleconnections by using what we already know and what we know that we do not know.

Early warnings are an integral part of readiness. Central to national and community readiness is a country's NMHS, which is responsible for the collection of relevant data, for producing and disseminating forecasts, and for informing the government, the media and civil society about hydromet hazards. Today's NMHS is no longer the traditional NMHS of previous decades. It has been given new responsibilities, while still expected to perform its older ones. Many organizations at one time or another internally re-structure. They do not often re-function. NMHSs are in the process of informally "re-functioning" but also required is re-budgeting to account for their new activities such as interacting with civil society. Re-function enables them to take full advantage of the opportunities provided by their expanded responsibility.

Acknowledgments: This study was made possible through the support provided by the Office of U.S. Foreign Disaster Assistance, Bureau for Democracy, Conflict and Humanitarian Assistance, U.S. Agency for International Development. The opinions expressed in this publication are those of the authors and do not necessarily reflect views of the U.S. Agency for International Development.

Author Contributions: M.H.G. and L.N. conceived the idea; M.H.G., L.N., M.-A.B., and I.J.R. wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Glantz, M.H. *El Niño Ready Nations and Disaster Risk Reduction (DRR): Executive Summary*; Consortium for Capacity Building: Boulder, CO, USA, 2017. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/Crop-REVISED-FINAL-Xmas-Master-CrossCutting-QUICK-Qian-12-23A.pdf (accessed on 24 December 2017).
2. Carrillo, C. Disertacion sobre las Corrientes Oceanicas y Estudios de la Corriente Peruana de Humboldt (Investigation of Ocean Currents and the Peruvian Humboldt Current). *Boletines del la Sociedad Geografica de Lima* **1892**, *11*, 84. (In Spanish)
3. Eguiguren, D.V. Las Lluvias de Piura. *Bolétin de la Sociedad Geografica de Lima* **1894**, *241*, 258. (In Spanish)
4. Glantz, M.H. *Currents of Change: Impacts of El Niño and La Niña on Climate and Society*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2001.
5. Glantz, M.H. Shades of chaos: Lessons learned about lessons learned about forecasting El Niño and its impacts. *Int. J. Disaster Risk Sci.* **2015**, *6*, 94–103. [CrossRef]
6. L'Heureux, M. Were Model Predictions of El Nino a Big Bust? 2015. Available online: https://www.climate.gov/news-features/blogs/enso/were-model-predictions-el-ni~no-big-bust (accessed on 4 February 2018).
7. Staupe-Delgado, R.; Glantz, M.H. Identifying commonalities between individual El Niño events. In *Safety and Reliability of Complex Engineered Systems, Proceedings of the 27th European Safety and Reliability Conference*

(ESREL), Portoroz, Slovenia, 18–22 June 2017; Cepin, M., Bris, R., Eds.; Taylor & Francis Group: London, UK, 2017; pp. 1567–1575.

8. Pigeon, P.; Rebotier, J. *Disaster Prevention Policies: A Challenging and Critical Outlook*; ISTE Press Ltd.: London, UK, 2016.
9. Glantz, M.H. Usable Science: Food Security, Early Warning and El Niño. Usable Science Workshop, Budapest, Hungary (25–28 October 1993). 1994. Available online: www.ilankelman.org/glantz/Glantz1993UseableScience1.pdf (accessed on 23 December 2017).
10. Glantz, M.H. El Niño: Spawner of Hazards. Presentation at the Open Meeting of Global Environmental Change Research Community (PowerPoint). 2001. Available online: http://www.ccb-boulder.org/1997-98-el-Ni~no-impacts-el-Ni~no-spawner-of-hazards/ (accessed on 13 June 2017).
11. Glantz, M.H. *Once Burned, Twice Shy? Lessons Learned from the 1997–98 El Niño*; United Nations University Press: Tokyo, Japan, 2001.
12. Ramírez, I.J. Cholera resurgence in Piura, Peru: Examining climate associations during the 1997–98 El Niño. *GeoJournal* **2015**, *80*, 129–143. [CrossRef]
13. Pacific Marine Environmental Laboratory. El Nino Theme Page. Available online: https://www.pmel.noaa.gov/elnino/schematic-diagrams (accessed on 2 March 2018).
14. Trenberth, K.E. The definition of El Nino. *Bull. Am. Meteorol. Soc.* **1997**, *78*, 2771–2777. [CrossRef]
15. Pritchard, E. Behind the 2015 Atlantic Hurricane Season: Wind Shear and Tropical Cyclones. NOAA, 2015. Available online: http://www.aoml.noaa.gov/keynotes/keynotes_0715_windshear.html (accessed on 12 February 2018).
16. Pielke, R.A., Jr.; Landsea, C.W. La Nina, El Nino, and the Atlantic Hurricane Damages in the United States. *Bull. Am. Meteorol. Soc.* **1999**, *80*, 2027–2033. [CrossRef]
17. NOAA. El Niño and La Niña: Frequently Asked Questions. Available online: Https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions (accessed on 12 February 2018).
18. UNISDR. Terminology on DRR. 2 February 2017. Available online: https://www.unisdr.org/we/inform/terminology#letter-r (accessed on 30 December 2017).
19. Saji, N.H.; Goswami, B.N.; Vinayachandran, P.N.; Yamagata, T. A dipole mode in the tropical Indian Ocean. *Nature* **1999**, *401*, 360–363. [CrossRef] [PubMed]
20. Li, Y.; Wang, Y.; Mu, L.; Wang, Q.; Song, J.; Wang, G. Impact of preceding El Niño and the Indian Ocean Dipole on the southern China precipitation in early summer. *Adv. Meteorol.* **2014**, *2014*, 12. [CrossRef]
21. Mantua, N.J.; Hare, S.R.; Zhang, Y.; Wallace, J.M.; Francis, R.C. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bull. Am. Meteorol. Soc.* **1997**, *78*, 1069–1079. [CrossRef]
22. Fan, Y.; Fan, K. Pacific decadal oscillation and the decadal change in the intensity of the interannual variability of the South China Sea summer monsoon. *Atmos. Ocean Sci. Lett.* **2017**, *10*, 162–167. [CrossRef]
23. Barnston, A.G.; Glantz, M.H.; He, Y. Predictive skill of statistical and dynamical climate models in SST forecasts during the 1997–98 El Niño episode and the 1998 La Nina onset. *Bull. Am. Meteorol. Soc.* **1999**, *80*, 217–243. [CrossRef]
24. Ramírez, I.J.; Briones, F. Understanding the El Niño costero of 2017: The definition problem and challenges of climate forecasting and disaster responses. *Int. J. Disaster Risk Sci.* **2017**, *8*, 489–492. [CrossRef]
25. Mathworks.com. What Is Fuzzy Logic? Available online: https://www.mathworks.com/help/fuzzy/what-is-fuzzy-logic.html?requestedDomain=www.mathworks.com (accessed on 5 June 2017).
26. What Is Fuzzy Logic? Available online: https://edoras.sdsu.edu/doc/matlab/toolbox/fuzzy/fuzzyint.html (accessed on 12 February 2018).
27. TutorialsPoint. Artificial Intelligence—Fuzzy Logic Systems. 2014. Available online: http://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_fuzzy_logic_systems.htm (accessed on 26 June 2017).
28. Simon, H.A. Rational Choice and the Structure of the Environment. *Psychol. Rev.* **1956**, *63*, 129–138. [CrossRef] [PubMed]
29. Oxford Dictionary. Satisfice. Available online: https://en.oxforddictionaries.com/definition/satisfice (accessed on 30 December 2017).
30. Glantz, M.H.; Baudoin, M.-A. *Working with a Changing Climate, Not Against It: Hydro-Meteorological Disaster Risk Reduction; A Survey of Lessons Learned for Resilient Adaptation to a Changing Climate*; Consortium for

Capacity Building: Boulder, CO, USA, 2014. Available online: http://www.ccb-boulder.org/wp-content/uploads/2012/11/Lex_Sum_03-17a-14_150p.pdf (accessed on 30 December 2017).
31. Glucksman, E. Climate-Proofing The Netherlands. EGU Blogs, 2014. Available online: https://blogs.egu.eu/geolog/2014/05/28/climate-proofing-the-netherlands/ (accessed on 23 December 2017).
32. McQuaid, J. 'Hurricane Pam' Exercise Offered Glimpse of Katrina Misery. The Times-Picayune, 9 September 2005. Available online: www.nola.com/katrina/index.ssf/2005/09/hurricane_pam_exercise_offered_glimpse_of_katrina_misery.html (accessed on 23 December 2017).
33. Glantz, M.H. Hurricane Katrina as a "teachable moment". *Adv. Geosci.* **2008**, *14*, 287–294. [CrossRef]
34. Glantz, M.H. The Perfect "Storm Scenario": The Hurricane Pam Exercise. Fragile Ecologies 1 www.fragilecologies.com (1 February 2006). Available online: http://fragilecologies.com/?p=601 (accessed on 23 December 2017).
35. FEMA. Hurricane Pam Exercise Concludes. 2004. Available online: Https://www.fema.gov/news-release/2004/07/23/hurricane-pam-exercise-concludes (accessed on 23 December 2017).
36. Milstein, M. 'The Blob' Overshadows El Niño. GeoSpace. AGU Blogosphere, 6 July 2016. Available online: https://blogs.agu.org/geospace/2016/07/06/blob-overshadows-el-nino (accessed on 23 December 2017).
37. Jacox, M.G.; Hazen, E.L.; Zaba, K.D.; Rudnick, D.L.; Edwards, C.A.; Moore, A.M.; Bograd, S.J. Impacts of the 2015–16 El Nino on the California Current System: Early assessment and comparison to past events. *Geophys. Res. Lett.* **2016**, *43*, 7072–7080. [CrossRef]
38. Reports to the Nation: El Niño and Climate Prediction. September 1997. Available online: https://atmos.washington.edu/gcg/RTN/rtnt.html (accessed on 23 December 2017).
39. Capotondi, A.; Wittenberg, A.T.; Newman, M.; Di Lorenzo, E.; Yu, J.-Y.; Braconnot, P.; Cole, J.; Dewitte, B.; Giese, B.; Guilyardi, E.; et al. Understanding ENSO Diversity. *Bull. Am. Meteorol. Soc.* **2015**. [CrossRef]
40. International Research Institute for Climate and Society. El Nino and Rainfall Map. Available online: https://iridl.ldeo.columbia.edu/maproom/IFRC/FIC/ElNinoandRainfall.png (accessed on 12 February 2012).
41. NOAA. Cold and Warm Episodes by Season. Available online: http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php (accessed on 12 February 2018).
42. ChannelNEAsia. Philippines Braces for Worst El Niño Phenomenon. 2015. Available online: www.channelnewsasia.com/news/asiapacific/philippines-braces-for-worst-el-Ni~no-phenomenon-8228352 (accessed on 17 June 2017).
43. CRDC. Citizens' Disaster Response Center Participates in El Niño Readiness Policy Workshop. 2016. Available online: http://www.cdrc-phil.com/cdrc-participates-in-el-Ni~no-readiness-policy-workshop (accessed on 8 June 2017).
44. Rogers, D.P.; Tsirkunov, V.V. *Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. Directions in Development—Environment and Sustainable Development*; World Bank: Washington, DC, USA, 2013. Available online: https://openknowledge.worldbank.org/handle/10986/15932 (accessed on 12 February 2018).
45. WMO. Global Framework for Climate Services. WMO Bulletin 61. 2012. Available online: https://library.wmo.int/opac/index.php?lvl=bulletin_display&id=2301#.WoJ0ZXxG2Uk (accessed on 12 February 2018).
46. Lengoasa, J. The Global Framework for Climate Services. PowerPoint. Available online: https://www.wcrp-climate.org/JSC33/presentations/GFCS.pdf (accessed on 12 February 2018).
47. FEMA. Developing and Maintaining Emergency Operations Plans: Comprehensive Preparedness Guide (CPG) 101 Version 2.0. 2010. Available online: Https://www.fema.gov/media-library-data/20130726-1828-25045-0014/cpg_101_comprehensive_preparedness_guide_developing_and_maintaining_emergency_operations_plans_2010.pdf (accessed on 12 February 2018).
48. Santoso, A.; McpHaden, M.J.; Cai, W. The Defining Characteristics of ENSO Extremes and the Strong 2015/2016 El Niño. *Rev. Geophys.* **2017**, *55*, 1079–1129. [CrossRef]
49. Velasco-Zapata, G.A.; Broad, K. Peru Chapter. In *Once Burned, Twice Shy? Lessons Learned from the 1997–98 El Niño*; Glantz, M.H., Ed.; United Nations University Press: Tokyo, Japan, 2001; p. 191, ISBN 92-808-1063-4.
50. Snyder, T. *On Tyranny: Twenty Lessons from the Twentieth Century*; Crown Publishing: New York, NY, USA, 2017.