

**Enhancing Resilience to Extreme Climate
Events:
Lessons from the 2015-2016 El Niño Event in
Asia and the Pacific**



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FOREWORD

Stronger regional collaboration to prevent El Niño episodes from becoming disasters in the Asia-Pacific region.

The 2015/2016 El Niño episode severely affected more than 60 million people around the world. In Asia and the Pacific, the event destroyed crops, killed livestock, dried up water-sources in some areas, caused severe flooding in others, led to malnutrition and food insecurity, increased disease outbreaks, and drove migration to other areas. The long-term impacts of the 2015-2016 event has yet to be fully assessed and its effects are lasting well into 2017. While the impacts were substantial, the slow-onset nature of El Niño provides us with opportunities to put in place measures for mitigation aimed at protecting lives and minimizing impacts such as provision of early warning services and generation of accurate risk information to support decision making and early action. Turning early warning into early action, managing risks to protect people and assets, and climate proofing development can support countries to better prepare for and respond to ENSO events while making progress toward achievement of the SDGs and the 2030 Agenda for Sustainable Development.

Our motivation for this report is hence to learn the lessons from the 2015-2016 El Niño event, put these lessons into practice to reduce the impacts of future extreme climate events, and to help enhance the resilience of people across the Asia-Pacific Region. At the time of writing the report, during April and May 2017, The Republic of the Marshall Islands declared a state of emergency and several countries (Papua New Guinea, Viet Nam, Mongolia, Sri Lanka, and East Timor) requested support from UNDP to prepare for the incoming El Niño event. While some aspects of the 2015-2016 event were unique in nature and may not be good predictor of future El Niño events, we must make every effort to learn how we can reduce the potential impacts of future events and how we can strengthen the resilience of countries likely to be affected.

Under the Regional Cooperation Mechanism and the Thematic Working Group on disaster risk reduction and resilience (D3R), the United Nations is committed to providing a coherent and coordinated support for disaster risk reduction and resilience in the region and to develop regional analyses and knowledge products that could be used for risk-informed policy and advocacy work at the global, regional and country levels. Thus, this report represents a one UN approach with collaborations between United Nations Development Programme (UNDP) Bangkok Regional Hub (BRH), United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), and United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), and the APEC Climate Center (APCC). In addition, the Stockholm Environment Institute has been instrumental in collating information from all the involved agencies and preparing the final report. The agencies collectively set themselves the task to produce an informative document that presents key actionable insights on how climate-induced hazards can be better addressed based on the lessons learned from previous El Niño events. In addition, the agencies jointly propose a multi-agency offer of service for countries at risk that describes what support they can collectively provide to address these risks. This will ensure that the lessons learned from previous experience can guide strategic preparedness and future response plans at both the regional and the national level.

The report highlights key achievements in science and technology for understanding and addressing El Niño related risks through climate modelling, vulnerability assessment, and disaster impact modelling, as well as describes remaining gaps and challenges and sets priorities for early action. It further stresses the importance of regional coordination and collaboration so that UN agencies, international humanitarian and development organizations, and countries and other stakeholders in

the region can plan for and respond to climate risks arising from extreme events such as the El Niño in a timely, coordinated and effective manner.

Armed with this toolkit and a coordinated “One-UN” approach, we feel confident that countries across Asia and the Pacific will be equipped to weather the next ENSO related event.

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EXECUTIVE SUMMARY

The El Niño Southern Oscillation (ENSO) is one of Earth's most important climatic phenomena. ENSO, which refers to interactions between the ocean and atmosphere in the Equatorial Pacific Ocean, influences global temperatures and precipitation, and can therefore significantly impact human societies and ecosystems. El Niño and La Niña are the opposite extremes of the ENSO cycle conditions; La Niña is known as the cold phase and El Niño as the warm phase of the ENSO. Most typically, El Niño conditions occur every 2-7 years when sea surface temperatures in the Equatorial Pacific Ocean become warmer and the easterly trade winds blow weaker than normal. El Niño events, which can last a year or more, have a variety of climatological impacts across parts of Africa, North and South America, Australia, Asia, and the Pacific, the most typical of which are increased temperatures, reduced precipitation leading to drought, and changes to tropical cyclone areas of formation and tracking. These changes have historically had large-scale social and economic impacts on millions of people across the affected regions.

The 2015-2016 El Niño event was one of the strongest and most significant on record. Pacific Ocean sea surface temperatures were higher than the temperature for all previously recorded events, in part due to the unusually warm conditions recorded throughout the previous year when an El Niño event was anticipated but did not form. Furthermore, both the Central and Eastern Pacific regions experienced extreme warming, when typically only one of the two regions experiences warming, creating an extreme 'mixed-type' event. The 2015–2016 El Niño event resulted in unusually warm conditions for many of the tropical and sub-tropical countries, and the global average surface air temperature for 2015 and 2016 marked two of the warmest years on record. Large parts of Asia and the Pacific experienced hot spring and summer seasons, as well as many extreme weather events such as drought, flood, and tropical cyclone. It is possible that global climate change combined with the ENSO phenomenon drove these extreme conditions in Asia and the Pacific- arguably the most at-risk region in the world with regard to disasters, climate change, and El Niño impacts.

The 2015–2016 El Niño affected the lives and livelihoods of more than 60 million people across the globe with the full socio-economic cost still being estimated. Many of the socio-economic impacts of El Niño events relate to food security by affecting agriculture inputs (e.g. water – availability and quality), agricultural productivity, food availability, food prices, food quality, and nutritional value. As with all of the major El Niño events over the past several decades, the 2015-16 event undoubtedly took its heaviest toll on these aspects. In Asia and the Pacific, the event has destroyed crops and killed livestock, in some cases dried up water-sources and in others, caused massive flooding, driven up malnutrition rates, increased disease outbreaks, and driven migration. Long after the weakening of the event was declared, the long-term impacts have yet to be fully assessed and its effects will last well into 2017. What we do know with some certainty is that impacts of El Niño-related disasters are typically felt most by the rural poor in middle- and lower-income countries in Southeast Asia, South Asia, and the Pacific.

Measures aimed at protecting lives and minimizing impacts include the generation of risk information and the provision of early warning services. A range of sophisticated models are available for seasonal climate prediction. Generally, there are two different approaches for generating operational seasonal forecasts: (1) statistical (empirical) prediction and (2) dynamical prediction. The statistical prediction utilizes previously observed relationships between El Niño and the local climate, as well as past experiences during El Niño and La Niña years. While statistical prediction has been successful in some regions and years, dynamical prediction, which utilizes global climate models, has improved in many ways and demonstrates better promise for future operational use. Some techniques, e.g., multi-model ensemble (MME), have also been developed to improve the prediction skills of dynamical seasonal

prediction. Although there are still issues like the spring predictability barrier (a forecast issued before boreal spring is generally less reliable than the one issued after spring season), current seasonal predictions utilizing the dynamical MME provide reliable seasonal forecasts for El Niño several months ahead of the event's actualization.

Solutions for integrating the available science and information on socio-economic vulnerabilities into Information Technology (IT) enabled platforms that enable easy access and sharing of information and coordinating response include the creation of an El Niño Regional Dashboard and the Specialized Expert System for Agro-Meteorological Early Warning (SESAME) developed by RIMES. The Dashboard could be hosted by the Pulse Lab Jakarta as an expansion of existing tools and services, such as the Vulnerability Analysis Monitoring Platform for the Impact of Regional Events (VAMPIRE). This tool can be used to understand the evolving nature of slow, onset phenomena like El Niño in near real-time to better target assistance from governments and international organizations to vulnerable populations. The Dashboard could be extended to provide a range of other services that could benefit El Niño affected countries. SESAME generates advisories for preparing contingency plans in agriculture based on seasonal and sub-seasonal climate outlooks that integrate forecasts, location specific hazard thresholds, and risk patterns. The climate forecast helps to analyze the risk and understand the vulnerability based on climate risk profiles so that action plans can be prepared and implemented. Similar sophisticated expert systems could be developed for generating location-specific advisories for other sectors.

We conclude the report by providing a proposal for a 6-step approach aimed at strengthening regional coordination and collaboration between agencies and national governments across the Asia-Pacific Region to prepare for and respond to extreme climate events. Our streamlined offer-of-service will provide countries at risk from El Niño with a coordinated step-by-step plan that can be activated and implemented at the appropriate time as the event is unfolding. The different steps in the provision of services and products will be triggered by critical changes in seasonal rainfall during the monsoon cycle. The approach consists of the following six steps: 1) Provision of Regional Climate Outlooks; 2) Provision of National Climate Outlooks; 3) Assessment of risk management options; 4) Delivery of humanitarian support; 5) Critical support during time of crisis; and 6) Post-event recovery.

Abbreviations & acronyms

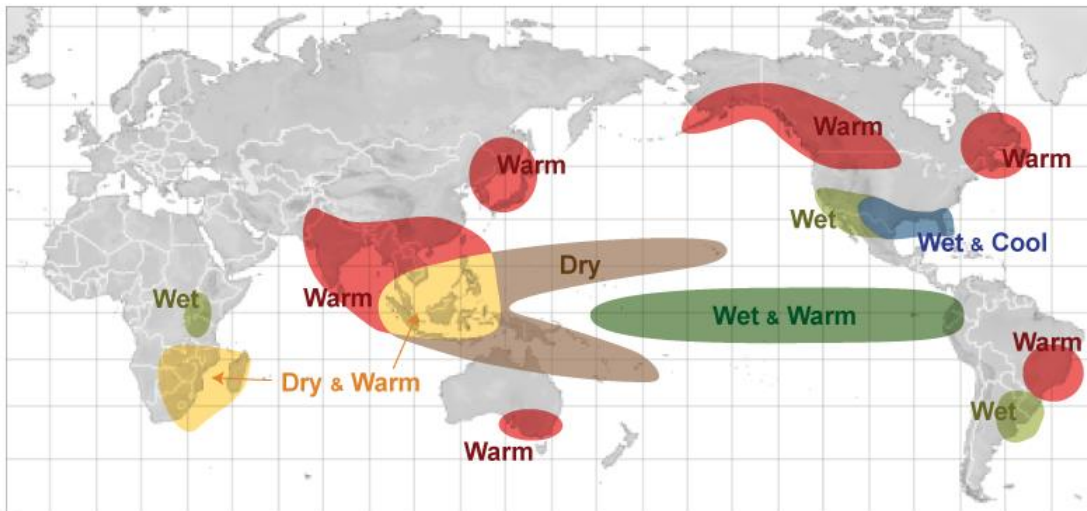
AAL	Annual Average Loss
APCC	APEC Climate Center
APEC	Asia-Pacific Economic Cooperation
Bappenas	Indonesian Ministry of National Development and Planning
BoM	Australian Bureau of Meteorology
BRH	Bangkok Regional Hub
CCA	Climate change adaptation
CERF	Central Humanitarian Response Fund
CIDA	Canada International Development Agency
CLIK-P	Climate Information Toolkit for the Pacific
COF	Climate Outlook Forum
CP El Niño	Central Pacific El Niño
CRED	Centre for Research on the Epidemiology of Disasters
DRR	Disaster risk reduction
ECMWF	European Centre for Medium-Range Weather Forecasts
EM-DAT	Emergency Database
EMI	El Niño Modoki index
ENSO	El Niño Southern Oscillation
EP El Niño	Eastern Pacific El Niño
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EV	Expected value
FAO	Food and Agriculture Organization
GDP	Gross domestic product
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
JMA	Japan Meteorological Agency
KMA	Korea Meteorological Agency
K	Kelvin (degrees)
MME	Multi-model ensemble
NMHS	National Meteorological and Hydrological Services
NOAA	US National Oceanic and Atmospheric Administration
NWSCPC	National Weather Service Climate Prediction Center
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PEAC	Pacific ENSO Applications Climate Center
PIC	Pacific Island Countries
PICASO	Pacific Island Countries Advanced Seasonal Outlook
PNA pattern	Pacific-North America pattern
PNG	Papua New Guinea
RBAP	Regional Bureau of the Asia and the Pacific (RBAP)
RCOF	Regional Climate Outlook Forum
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
SASCOF	South Asian Climate Outlook Forum
SEI	Stockholm Environment Institute
SESAME	Specialized Expert System for Agro-Meteorological Early Warning
SIDS	Small Island Developing States

SPREP	Secretariat of the Pacific Regional Environment Programme
SST	Sea surface temperature
UKMO	United Kingdom Meteorological Office
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children Fund
US\$	US dollars
USA	United States of America
VAMPIRE	Vulnerability Analysis Monitoring Platform for the Impact of Regional Events
WASH	Water, sanitation and hygiene
WFP	World Food Programme
WMO	World Meteorological Organization

1. Introduction

The El Niño Southern Oscillation (ENSO) is one of Earth's most important climatic phenomena. The US National Oceanic and Atmospheric Administration (NOAA) describes El Niño and La Niña, the opposite phases of ENSO, as complex weather patterns that result from variations in ocean temperatures in the Equatorial Pacific Ocean. The ENSO cycle describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific Ocean. La Niña is known as the *cold phase* and El Niño as the *warm phase* of ENSO. These temperature variations can have large-scale impacts not only on ocean processes, but also on global weather and climate. The typical climatological impacts of El Niño events on different regions of the globe, and during different seasons (i.e. boreal winter and boreal summer) are shown in Figure 1.1. As shown in the two maps, the Asia and Pacific regions are at high risk of multiple climatological shifts related to precipitation, temperature, and tropical cyclone activity.

El Niño impacts during boreal winter (December – February)



El Niño impacts during boreal summer (June – August)

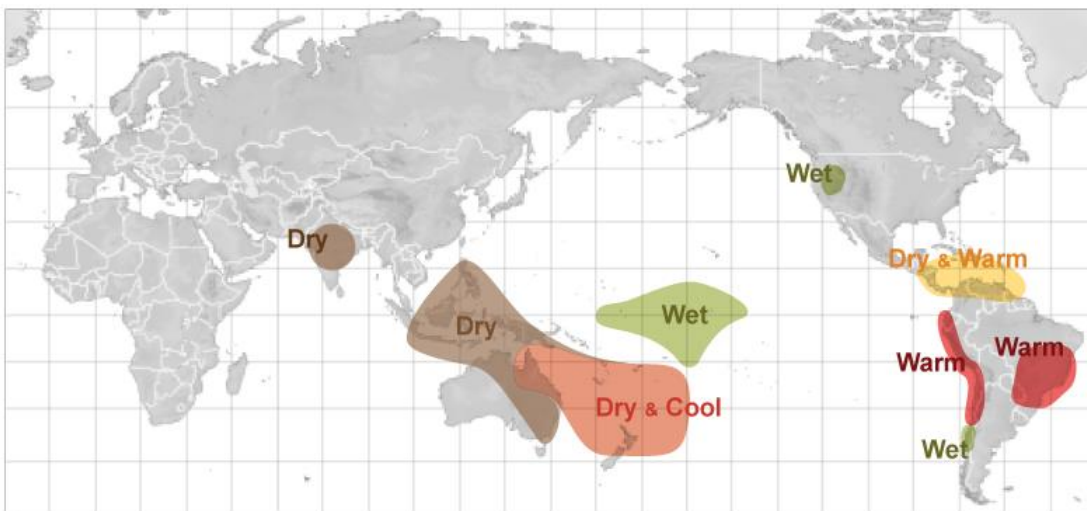


Figure 1.1 Differential impacts of El Niño on different seasons (adopted from NOAA)

Differential impact of El Niño during boreal winter and summer (adopted from NOAA). Shaded areas indicate geographic locations for which seasonal precipitation and/or temperature exhibit significant coincidence rates with El Niño. The upper map shows the boreal winter (Dec-Jan-Feb) and the lower map shows the boreal summer (Jun-Jul-Aug) impacts.

The name “El Niño” dates to the 1800s and originates from the fishermen off the coast of South America who noticed the appearance of unusually warm water in the Pacific Ocean around Christmas time and named the phenomenon “the boy”, or *El Niño* in Spanish. During normal and *La Niña* (or “the girl” in Spanish) years, a stream of cold water, known as Humbolt current, flows along the Pacific coast of South America, bringing with it rich nutrients that increase fish catch numbers. During El Niño years, however, the current weakens and the Eastern Pacific warms, resulting in an overall catch decline. The El Niño and La Niña events, which occur on average every two to seven years, typically last nine to twelve months, but some prolonged events may last for multiple years. The 2015-16 event was one such extreme El Niño event, the impacts of which persisted over two years.

Purpose of the report

This report, *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific*, is the result of a multi-agency study on the lessons learned from the 2015-2016 El Niño event and its impacts in Asia and the Pacific, and is written for the purpose of improving readiness for future El Niño events. Under the Regional Cooperation Mechanism and the Thematic Working Group on disaster risk reduction and resilience (D3R), it represents the collaboration between United Nations Development Programme (UNDP) Bangkok Regional Hub (BRH), United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), and the APEC Climate Center (APCC), as agencies of the El Niño ad hoc Regional Task Team formed during the 2015-2016 event to monitor and respond to events in an collaborative and coordinated manner. For example, in 2016, UNDP and ESCAP partnered with RIMES to develop a socio-economic assessment methodology and train government officials from El Niño-affected countries in the region.

Following the introduction, this report contains the following sections:

- El Niño events and meteorological impacts
- Risk information, early warning, and preparedness
- Socio-economic impacts of the 2015-2016 El Niño event
- Platforms for accessing and sharing information and for coordinating response
- Improving future impact assessment and planning

It is imperative that agencies, including UNDP and its partners, undertake measures to ensure that the lessons learned from the 2015-2016 El Niño event guide future approaches to building resilience to extreme climate events. UNDP’s approach to resilience development encompasses broader support in recovery, systematic improvements to livelihoods, and environmental management, while working with governments to strengthen their climate risk management and investment in risk informed development.

For countries with critical vulnerabilities such as Cambodia, Myanmar, and Sri Lanka, ESCAP, with RIMES, has put in place strengthened monsoon forums (national climate outlooks) to communicate disaster risk information through downscaled climate outlooks, seasonal forecast, and *in-season* drought monitoring using earth observation satellites. These monsoon forums, owned and adapted by the respective countries, are multi-stakeholder risk communication platforms through which scientific knowledge is applied in disaster preparedness and resilience practice. Synthesizing the downscaled information on the coarse scale global climate model, ESCAP’s Impact Outlooks for El Niño also analyze and assess the localized and sector impacts of El Niño. These policy notes have been used to interpret the global El Niño phenomenon at regional, sub-regional and national levels with sector-specific implications. The strengthened monsoon forums and the policy notes were critical to

countries in the region for implementing risk-sensitive strategies to achieve the development goals laid out in the 2030 Agenda for Sustainable Development and the Sendai Framework for Disaster Risk Reduction 2015-2030.

The recommendations of this report will help to improve the ad hoc Regional Task Team and identify appropriate services and products to be developed to address current gaps.

onset is delayed and termination occurs earlier than usual. Similarly, approximately half of the total precipitation variability over Eastern Indonesia is associated with the developing phase of El Niño, and Indonesia therefore experiences a relatively longer dry season during El Niño years. Northeastern Australia may also experience drought, but the temperature response differs throughout the seasons. On the other hand, the equatorial Central Pacific countries suffer extreme rainfall and hot temperatures, while Northern South America may undergo hot and dry conditions during the peak of the El Niño event. The regional meteorological impacts of El Niño are summarized in Figure 2.2 (precipitation variability) and Figure 2.3 (temperature response).

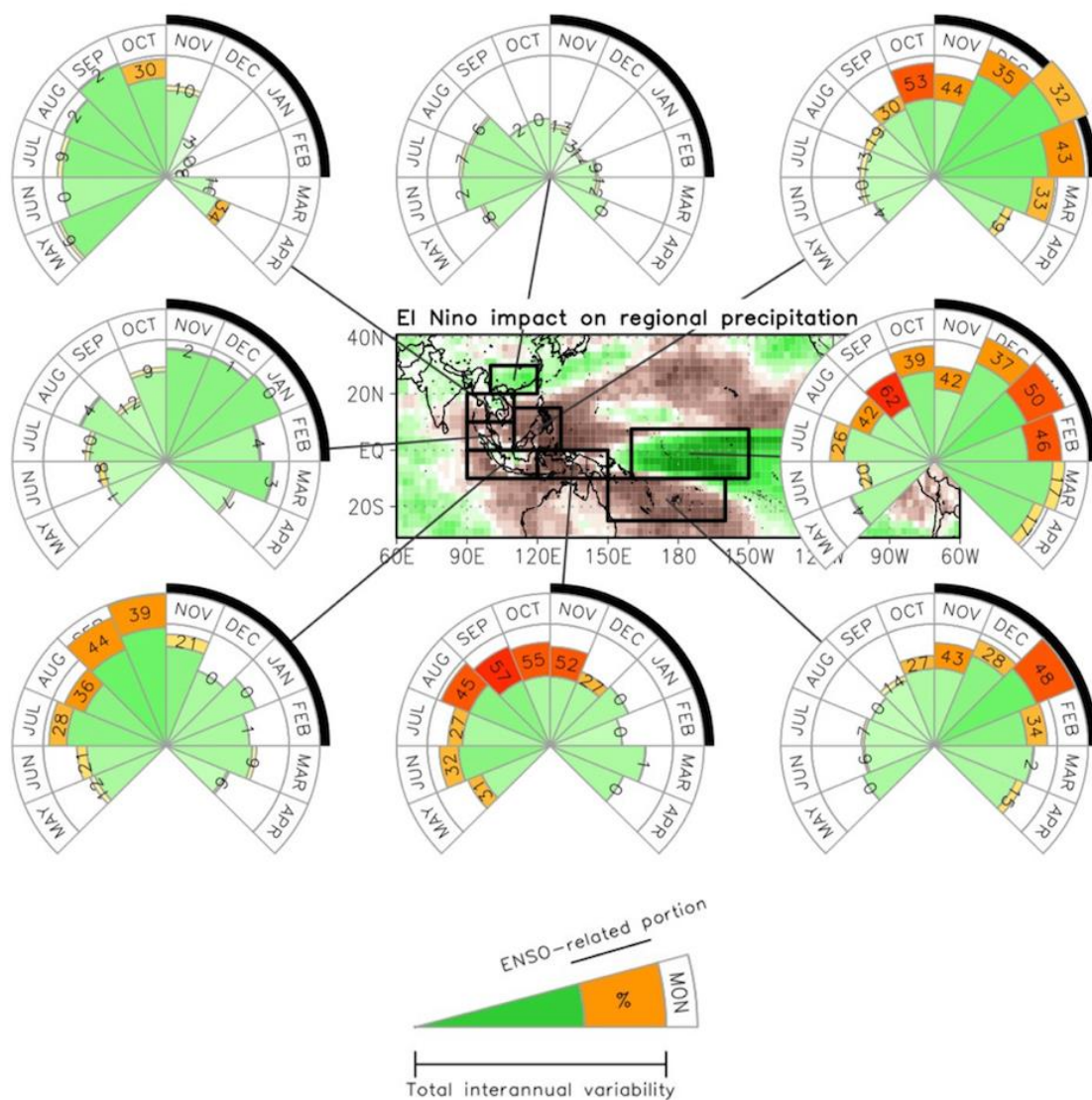


Figure 2.2 Precipitation variability and regional impacts of El Niño

Green (wetter-than-normal) and brown (drier-than-normal) colors in the map (center) shows general precipitation tendency during the El Niño peak seasons. The rose plot reads clock-wise from El Niño developing in May to decaying in April, and the El Niño peak seasons are indicated with black strips. The height of each rose plot indicates the magnitude of inter-annual rainfall variability, and the reddish portion and its corresponding number indicate the fraction of rainfall variability related to El Niño impact. The higher the bar, the stronger the inter-annual rainfall fluctuation, while the larger the percentage value, the more severe the El Niño impact on total inter-annual variability.

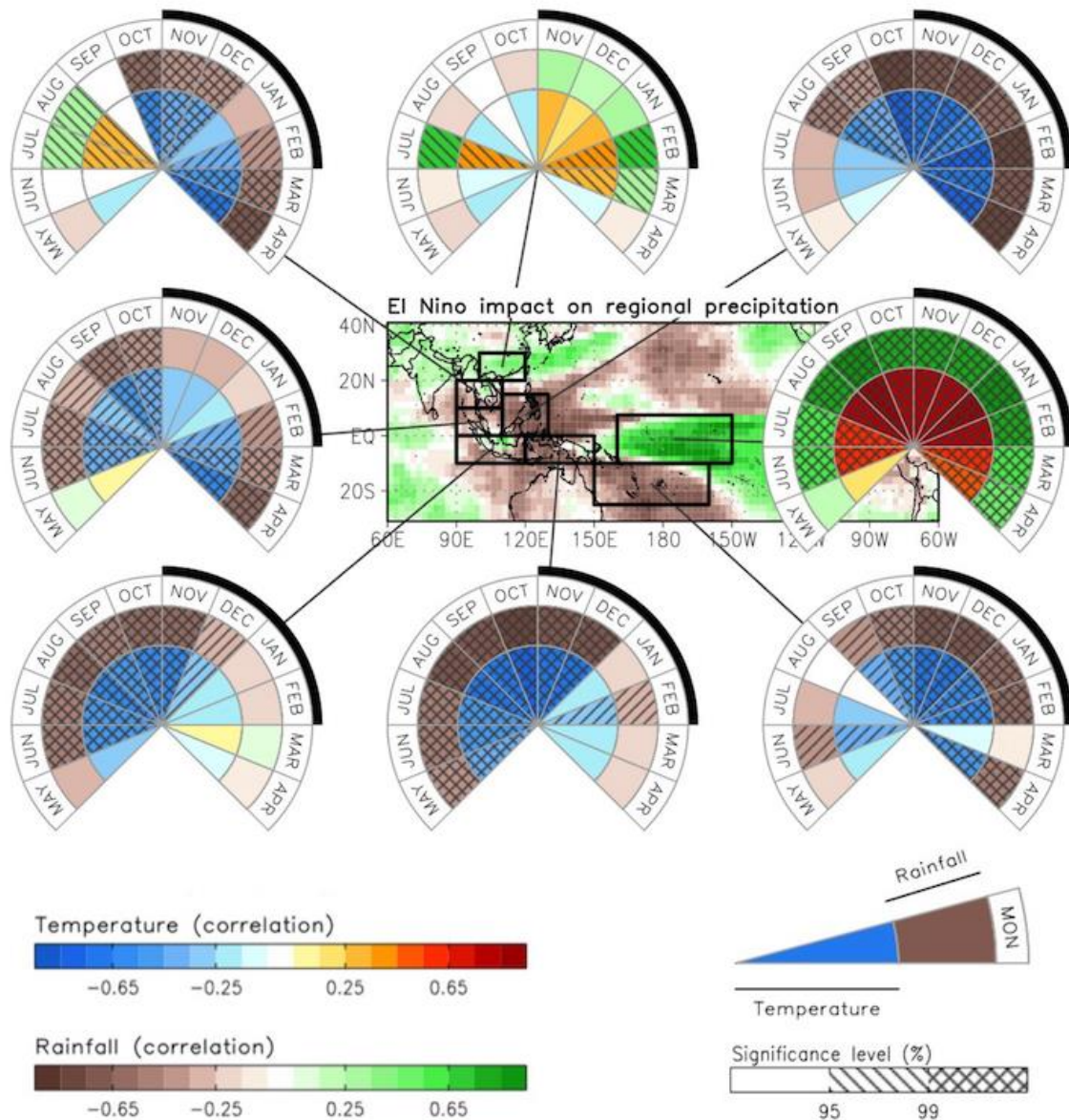


Figure 2.3 Temperature responses and regional impacts of El Niño

The inner circles indicate the temperature responses (red for hotter-than-normal and blue for colder-than-normal, yellow for insignificant and the outer circles indicate the precipitation responses (green for wetter-than-normal and brown for drier-than-normal). Significant impact of El Niño at 90 per cent confidence levels are indicated by the diagonal lines, and 95 per cent confidence levels are indicated by the hatch pattern.

The climatological impacts of El Niño spread globally through a process of teleconnection, which refers to the relationship between climate anomalies at large distances (i.e. thousands of miles). The atmosphere tries to balance with the anomalous atmospheric mass and momentum disturbances associated with El Niño, and thus creates the global teleconnection pattern. El Niño is known to be partially responsible for the Pacific-North America (PNA) pattern (Hoerling et al., 1997), which causes a warmer north-east and a colder south-west, and wetter conditions over the southern part of North America. Conversely, the eastern coast of Australia may experience dry conditions, together with the tropical Maritime continental regions (Dai, 2000). Although the seasonal variation is large and subject to long-term modulation (Oldenborgh and Burgers, 2005), South China and Western Europe frequently experience wetter winter and spring seasons. On the contrary, Southern Africa generally encounters warm and dry Austral summer.

Tropical cyclone activities can also be influenced by El Niño. During the El Niño years, generation of tropical cyclones in the Pacific basin can expand to the Central Pacific, and the number of storms increases in the eastern half of the Pacific, while decreasing in the western half of the Pacific. The South Pacific also tends to experience increased cyclone activity. However, in the North Atlantic region, storm frequency and intensity typically decreases slightly.

2.2 Variables in El Niño events

While El Niño is the dominant mode of equatorial Pacific SST variability, its realization is never identical. Some El Niño events are stronger than others, and some have action centers over the Eastern Pacific while others have action centers over the Central Pacific. With the variation of El Niño formation comes a diversity of impacts due to type, amplitude, and pre-existing climatic conditions.

2.2.1 El Niño types

Although each El Niño is climatologically unique, the type of El Niño event with its action center over the Central Pacific, rather than over the Eastern Pacific, is becoming more frequent. The impact of this type of El Niño is different from the impact of the conventional El Niño.

The historical inter-annual SST fluctuation associated with El Niño is concentrated over the equatorial Eastern Pacific. The conventional Eastern Pacific El Niño (EP El Niño) is characterized as the warm SST anomaly occurring at the equatorial Eastern Pacific, mostly as a result of the weaker up-welling of cold abyssal water from below. As the equatorial Eastern Pacific is not a convectively active region, the climate impact is usually caused by the weakening of the trade wind and the corresponding extratropical responses. Since the 1990s however, more El Niño events accompanied the SST fluctuation centered at the equatorial Central Pacific. This different type of El Niño (Ashok et al., 2012; Kao and Yu, 2009; Kug et al., 2009; Lee and McPhaden, 2010) is called the Central Pacific El Niño (CP El Niño) (also known as Warm Pool El Niño, date-line El Niño, or El Niño Modoki) in contrast to the conventional EP El Niño. This CP type of El Niño owes its dynamics relatively to the advection of warm water from the west rather than the shut-down of the up-welling (Kug et al. 2009). When the warm SST anomaly center occurs over the Central Pacific as in this different type of El Niño, the convectively active rainy areas can easily move from the Western Pacific to the Central Pacific. For the purpose of this report, we will refer to the new Central Pacific El Niño as CP El Niño, and refer to the conventional Eastern Pacific El Niño as EP El Niño.

As the center of action moves to the west compared to the conventional EP El Niño, CP El Niño exerts a quite different climatic response in some regions (Ashok et al., 2012; Gu and Adler, 2016; Murphy et al., 2013). Specifically, the probability of drought increases over the maritime continental region during the conventional EP El Niño. However, the precipitation variability differs substantially in many of the Pacific Islands according to the type of El Niño event. For example, Nauru is likely to receive more rainfall during the CP El Niño, while Kiribati experiences a higher chance of a wet season during the EP El Niño event. On the other hand, Tonga, Solomon Islands, South-Eastern to Southern Cook Islands, Palau, Federated States of Micronesia, and Marshall Islands face drier than normal conditions during EP El Niño episodes. The climatic impacts on much of East Asia are considered to be more sensitive to the CP El Niño than to the EP El Niño. Therefore, timely forecast relating to the different possible types of El Niño, and the subsequent temperature and precipitation forecasts, is crucial to the reliable prediction of conditions for climate centers and meteorological offices.

2.2.2 El Niño amplitudes

Typically, the amplitude of the El Niño event shows a strong positive correlation to the strength of its climatological impacts. However, in the event of an extremely strong El Niño, the response pattern can dramatically shift. Such was the case for the 2015–2016 El Niño.

During the extremely strong El Niño events that occurred during the 1982–1983 and 1997–1998 boreal winters, the world’s warmest oceanic water gathered in the tropical Western Pacific to the Central and Eastern Pacific, which resulted in the severe reduction of rainfall in the South Pacific while dramatically increasing precipitation over the equatorial Central Pacific (Cai and et al., 2012). The Southeastern part of North America received heavy rainfall, and warmer and drier conditions dominated over the Maritime Continents. The remote responses however, were substantially different between the above extreme events. While East and Southern Africa frequently suffer from drought during El Niño events, these regions actually experienced heavy rainfall during the 1997–1998 event. Eastern Australia suffered extreme droughts during the 1982–1983 El Niño episode, but the impact was relatively moderate during the 1997–1998 and 2015–2016 El Niño events. There is still uncertainty regarding the future of El Niño amplitudes and types due to climate change, but the extreme atmospheric response that controls local temperature and precipitation impacts is expected to increase in the future (Cai et al. 2014).

2.2.3 Pre-existing conditions and the stages of evolution

Usually, cold SST follows an El Niño event and a La Niña state develops through the phase-transition mechanisms (Battisti 1988; Jin 1997; Suarez and Schopf 1988; Wang and Picaut 2004). However, some El Niño events (*e.g.*, the 1986–1987 El Niño) have been followed immediately by another El Niño event. The 2015–2016 El Niño event was unique in that it occurred after anomalously warm SST conditions (*i.e.* semi-El Niño conditions) in 2014. This may have resulted in more severe impacts due to the pre-existing El Niño-like conditions.

Early in 2014, many of the operational climate prediction centers, as well as the related scientific community, anticipated a strong El Niño to take place during the 2014–2015 boreal winter as the observed ocean conditions and SST indicated its impending arrival. However, the atmospheric interruption during the boreal summer disrupted the manifestation of El Niño, leaving the SST conditions warmer than normal for the next 2015–2016 El Niño event (Hu and Fedorov, 2017). As a result, many of the affected countries were pre-conditioned for more than a year before the actual El Niño impact. For example, Southern Africa suffered two consecutive droughts during 2014–2015 and 2015–2016, while East Asia experienced heavy summer rainfall and cold winter temperatures. Some Central Pacific countries were affected by excessive rainfall in 2016 directly following strong hurricane activity during 2015.

2.3 The 2015–2016 El Niño event

2.3.1 Event classification

The 2015–2016 El Niño was one of the strongest events in the past 100 years. Both the equatorial Central Pacific and Eastern Pacific SST anomalies exceeded +2 Kelvin (K). Moreover, the 2015–2016 El Niño occurred immediately following the pre-existing warm conditions of 2014, making the impact potentially even more severe (Hu and Fedorov, 2017).

The 2015–2016 El Niño event can be classified as an extreme El Niño by any measure (Huang and et al., 2016). An El Niño event is declared when the 3-month averaged equatorial Pacific SST anomaly exceeds +0.5 K for 5 consecutive months (*e.g.*, NOAA). The usual magnitude of the moderately strong El Niño SST anomaly fluctuates between +1.0 and +2.0 K, and rarely exceeds +2.0 K. Only the 1982–1983, the 1997–1998, and the recent 2015–2016 events exceeded the +2.0 K threshold during the last 60 years. Moreover, the SST anomaly, as shown in Figure 2.4, confirms that the 2015–2016 El Niño was an extreme warming event both in the Central and the Eastern Pacific, which can be potentially classified as a mixed-type (*i.e.*, mixed CP and EP El Niño type) El Niño. The equatorial Eastern Pacific SST anomaly reached up to +3.0 K, which is largely comparable to historical extreme El Niño events, and the Central Pacific SST anomaly marked the warmest event since modern observation. Additionally, a prolonged warm SST existed from the year prior, as the expected 2014–2015 El Niño had not materialized. As a result, the recent 2015–2016 El Niño event can be classified as an extreme El Niño in terms of the magnitude and a (potentially) mixed-type El Niño in terms of type and flavor. Also, the 2015–2016 event was preconditioned by the existing El Niño-like oceanic conditions, but the phase transition to La Niña was not as obvious as other extreme El Niño events.

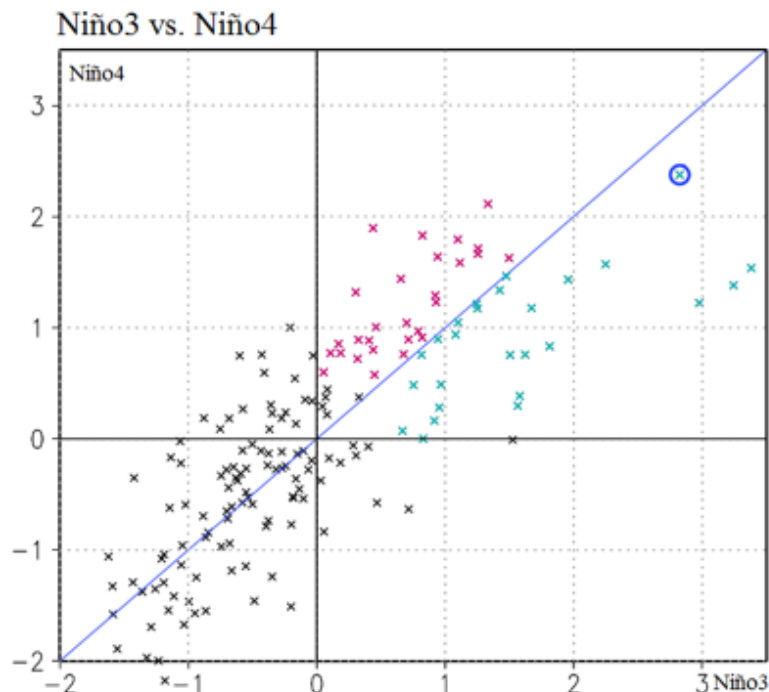


Figure 2.4 Observed SST anomalies in Niño3 and Niño4 watch regions

Relatively higher value in Niño3 (Niño4) indicates that the event is more EP (CP) type. The 2015–2016 event is indicated with a blue circle. Niño3 is equatorial Eastern Pacific; 150°W–90°W, 5°S–5°N and Niño4 is equatorial Central Pacific; 160°E–150°W, 5°S–5°N.

2.3.2 Climatological impacts

In 2015, the Maritime Continents received less-than-normal rainfall and many European countries experienced dry conditions. Southeastern USA, Northeastern Argentina, and Paraguay experienced much wetter conditions. Similarly, in 2016, many East Asian countries had normal rainfall, but the dry conditions continued in the Maritime continents and tropical Pacific countries. The global warming signals were also superimposed onto the existing warm SST anomaly in the equatorial Pacific.

The 2015–2016 El Niño event resulted in record-breaking warm conditions for many of the tropical and sub-tropical countries, and the global average surface air temperature for 2015 and 2016 marked

two of the warmest years on record. Large parts of Asia and the Pacific experienced hot spring and summer seasons, and many extreme weather events were observed. For example, in August 2015, three major hurricanes (named Kilo, Ignacio, and Jimena) successively hit the North Eastern Pacific region; in May 2016, a destructive wildfire devastated Western Canada; and throughout 2015 and 2016, severe droughts affected India, the Lower Mekong countries, and many of the Pacific islands. As we know, 2015 and 2016 were designated as El Niño years, and in fact, the event developed into one of the strongest El Niño events on record (Huang and et al., 2016), giving it the nickname “Godzilla El Niño” (e.g. Schiermeier, 2015).

3. Risk information, early warning and preparedness

Section 3 summarizes the current state-of-the-art seasonal prediction skills for El Niño, and explores the potential predictability of dynamical forecasts that support measures to protect lives and minimize impacts.

3.1 Predictability of El Niño in seasonal prediction system

3.1.1 Model performance and prediction skill for El Niño in general

Skillful prediction of El Niño events allows us to provide useful, global/seasonal climate prediction of variables such as precipitation and surface temperature (Kim et al., 2012; Peng et al., 2011). The successful prediction of these global climate variables with long lead times allows decision makers to utilize this information to reduce potential socioeconomic and environmental impacts.

When predicting an El Niño occurrence a few seasons ahead, scientists rely on two types of prediction models: (1) statistical models and (2) dynamical climate models. The statistical models predict how current climate conditions may possibly change based on historical experiences, and do not use physical equations of the ocean and atmosphere. The dynamical climate models predict various oceanic, atmospheric, and land variables by solving a set of dynamical and physical equations which govern the processes in the ocean, atmosphere, and land surface. The dynamical models use current weather observations from observation systems as inputs and calculate the possible future as outputs. There has been noticeable progress in predicting El Niño events using dynamical climate models due to improved observation systems, improved physical representation in models, higher resolution of models, and a better understanding of the tropical Pacific oceanic and atmospheric processes related to El Niño development (Barnston et al., 2012; Guilyardi et al., 2009). As a result, the dynamical forecast model has performed better than the statistical model in the recent decade, although the dynamical model requires much more computing resources than the statistical model¹.

In addition to the progress of the dynamical model itself, many methods have been proposed to achieve the most reliable El Niño prediction with dynamical models. One method is the multi-model ensemble (MME) forecast method (Jin and et al., 2008). The MME forecast combines the prediction outputs from a number of climate models. This method is known to be efficient in reducing model errors and integrating spread information of El Niño prediction from various dynamical models. Some operational centers including IRI², NOAA/NWS CPC³, ECMWF⁴, APCC⁵, etc., are utilizing MME forecasts. For example, as indicated in Figure 3.1, the El Niño forecasts from the APCC MME system have better skill when predicting El Niño events than those of any of the individual climate models. Here, to quantitatively measure the skill of climate models for El Niño prediction, we use the temporal

¹ Statistical models can be run on a small computer (e.g., desktop computer) but the dynamical models have to be run on high-performance supercomputers.

² International Research Institute for Climate and Society, USA (<http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/>)

³ National Oceanic and Atmospheric Administration/National Weather Service Climate Prediction Center, USA (<http://www.cpc.ncep.noaa.gov/products/NMME/>)

⁴ European Centre for Medium-Range Weather Forecasts (<http://www.ecmwf.int/en/forecasts/documentation-and-support/long-range/seasonal-forecast-documentation/eurosip-user-guide/multi-model>)

⁵ The APEC Climate Center (APCC), Busan, Korea (www.apcc21.org)

correlation skill score. A correlation score that is close to 1.0 indicates that the climate model provides a perfect prediction for El Niño events. The MME forecast system is able to provide reliable El Niño prediction at the 6-month lead time shown by the persistence of a skill score greater than 0.8 throughout the period. For example, the MME forecast system successfully predicted that the extreme 2015/16 El Niño event would occur during the upcoming winter season when the 6-month forecasts were issued in the August 2015 (Figure 3.2).

However, there is still room to improve dynamical models through a better understanding of model errors when predicting El Niño events. For example, dynamical climate models tend to have a harder time making accurate predictions of El Niño when the models start from the spring season. This is called the “spring predictability barrier problem” (McPhaden, 2003; Yang and Webster, 1999). During 2015 early spring, the MME models were not able to predict the El Niño related extreme SST (i.e., Niño 3.4 index) increases as was the case in the 1997/98 event. Moreover, many other climate centers were also unable to predict this pending El Niño related extreme SST increase (McPhaden, 2015). Numerous research and model development is currently in progress to better understand the reason for errors in El Niño forecasts, and will be helpful in improving the El Niño representation and prediction by dynamical climate models (Duan and Wei, 2013; Kim et al., 2014; Magnusson et al., 2013; Vannièrè et al., 2014).

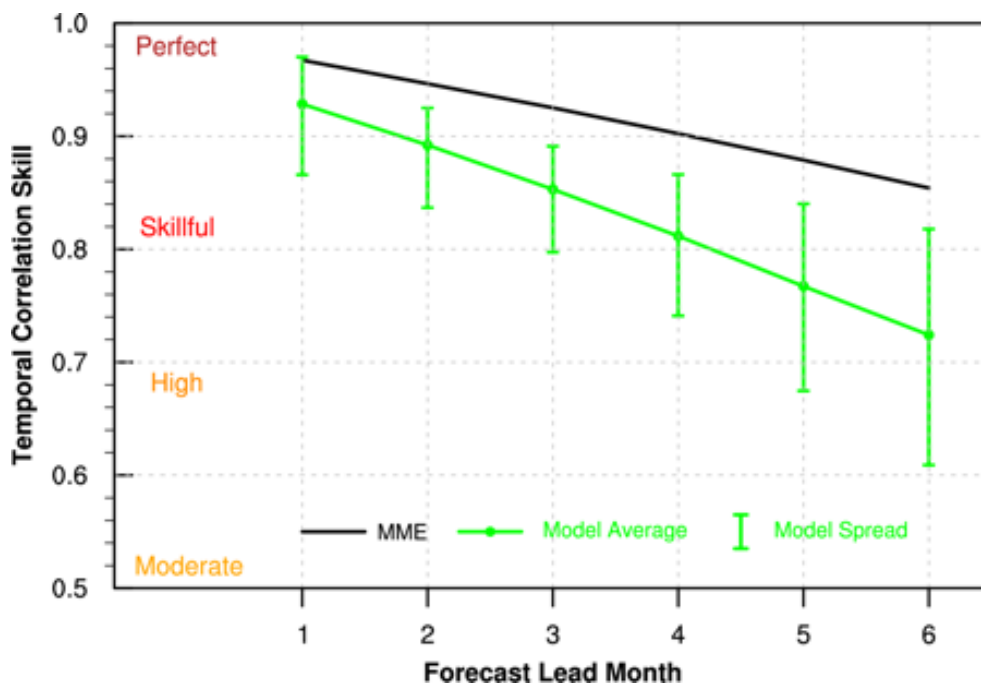


Figure 3.1 Change in prediction skill score (temporal correlation skill) of the APCC MME system for El Niño events from 1- to 6-month forecast lead times

The black line denotes the MME forecast and the green line shows the inter-model differences for El Niño prediction. The temporal correlation skill score ranges from 1.0, indicating a perfect forecasting capability of dynamical models for El Niño events, to 0, indicating no forecasting capability. Generally, a skill score of 0.8 is considered to be “skillful”, 0.7 is considered to be “high skill”, and 0.5 is considered to be “moderate skill”. Generally, when releasing forecast information, a score of 0.5 to 0.6 is considered to be acceptably reliable.

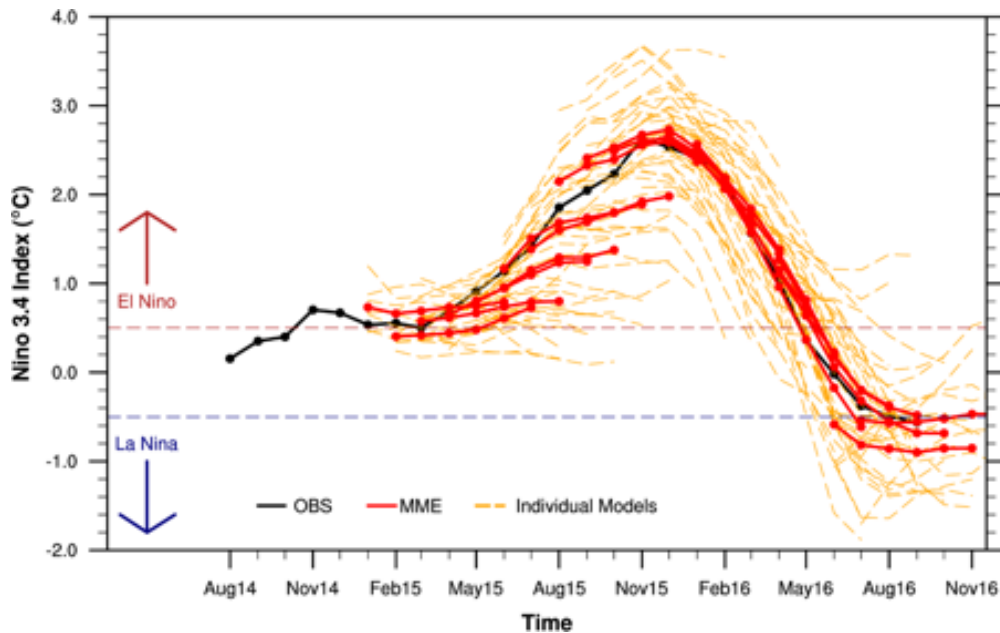


Figure 3.2 2015/16 El Niño event prediction with the APCC MME system

Dynamical forecast models were run for 6 months, using the observed conditions from December 2014 to June 2016 as inputs. The red lines denote MME forecasts and the yellow dashed lines denote the individual model forecasts. The black line shows the temporal evolution of the observed Niño 3.4 index. In general, El Niño (La Niña) condition is defined when Niño 3.4 index is above + 0.5 C (-0.5C) which is indicated with brown (blue) dashed horizontal line.

3.1.2 Model-simulation of the diversity of El Niño events in terms of types/amplitudes

The climate impacts of EP and CP El Niño types are different from one another. The amplitude of El Niño-driven SST change also dominates the local and remote regions' climate on an inter-annual time scale. Therefore, it is essential to monitor the types and amplitudes of El Niño in seasonal forecasting and early warning systems in a timely manner so that policy makers and stakeholders can facilitate better mitigation measures. Due to their significance, the El Niño phenomenon and global SST changes are constantly monitored by most operational climate centers. In addition, APCC is developing a probabilistic prediction system for better prediction of the El Niño amplitude.

In order to predict and verify the diverse El Niño behaviors in terms of types and amplitudes through dynamical predictions, we often use an index-based approach (e.g., Niño 3 and Niño 4 indices and their linear combination, the El Niño Modoki index (EMI), etc. (Yu and et al., 2012).

The predictabilities of the EP and CP El Niño types in dynamical seasonal forecasting are quite dependent on which index is used in defining the El Niño type. For instance, Kim et al. (2009) concluded that when using a dynamical prediction system, the CP El Niño based on the Niño 4 index is more predictable than the EP El Niño based on the Niño 3 index due to seasonality of prediction skill and the spring predictability barrier. On the other hand, Hendon et al. (2009) showed that the EP El Niño based on the Niño 3 index is more predictable than the CP El Niño based on the EMI index. Additionally, when considering El Niño-driven SST changes, the ability to predict the CP El Niño type is limited and has a shorter lead time compared to the EP type (Imada et al., 2015).

Similar to the general skills of El Niño events, the MME can predict the amplitudes of both eastern and central Pacific El Niño events and discern the important differences in the patterns of tropical Pacific SST anomaly for those different types of El Niño events during boreal winter. However, the prediction of the central Pacific El Niño has limitations in capturing its relevant regional impacts. For example, EP

and CP El Niño types have different large-scale SST-driven wind patterns and shifts in rainfall patterns in the main convergence zones. However, climate models do not accurately capture the variations of impacts on Pacific rainfall due to the difference in El Niño types and amplitudes (Murphy et al., 2015). However, Pacific Island countries consistently experience different impacts due to the varying El Niño types and amplitudes (Murphy and Power, 2014).

When predicting the amplitude of El Niño, we usually consider the Niño 3.4 index, which is different from the methods used to predict El Niño type. During strong high amplitude El Niño events, models were able to successfully predict SST changes. On the other hand, coupled models had difficulties in capturing the SST pattern during weak low amplitude El Niño events. This is because the amplitude of El Niño is closely associated with the type of El Niño (Sohn et al., 2016). Most strong high amplitude El Niño events were the EP type of El Niño, whereas all weak low amplitude El Niño events were found to be the CP type of El Niño. Given the variations of prediction skills and predictability based on different El Niño types and amplitudes, it is critical to not only consider the amplitude of El Niño, but also the type of El Niño event (EP and CP El Niño types) when conducting dynamical prediction in order to have the most reliable El Niño predictions.

3.1.3 Practical advice for decision makers

Therefore, it is recommended for decision makers to utilize El Niño predictions from dynamical MME systems as they provide the most reliable prediction and level of uncertainty, amongst currently operational prediction systems. MME is currently the best and most efficient way to remove model errors and overcome the inter-model spread of El Niño prediction. Furthermore, the dynamical MME system is able to produce predictions regarding local precipitation and air temperature by combining the effects of El Niño with other factors. A combination of the El Niño prediction information, the local prediction, and air temperature predictions from the MME system can be useful to mitigate the disasters caused by extreme climate variability like El Niño.

3.2 Availability of ENSO predictions at global, regional, and local levels and the challenges in their utilization

ENSO forecasts are available from various global and regional centers (Table 3.1). These forecast products are available as texts (summaries and outlooks) and graphics (graphs and maps). The technical agencies provide the multi-model ensembles of ENSO predictions along with the confidence level and its diagnostics interpretation. Most of these centers also post updates on the oceanic and atmospheric conditions that describes the ENSO conditions over the Pacific Ocean. Depending on their needs and specific region of interest, both technical and non-technical users can find information at global and regional levels on El Niño/La Niña or neutral conditions.

El Niño/La Niña impacts vary considerably over different areas within a region, as well as the timing with respect to the main rainfall season. The National Meteorological and Hydrological Services (NMHSs) who are most aware of the country's climate context are best placed to interpret the influence of ENSO on climate and weather at national or sub-national level.

Table 3.1 Summary of El Niño–Southern Oscillation (ENSO) forecasts made available by technical agencies.

Agencies/ Institutes	Frequency of the product released	ENSO Forecast Format	Type of Forecast		Forecast Information	
			Dynamical or Statistical	Single-Model or MME	ENSO	Others
APEC Climate Center (APCC)	Monthly	Graphical products, outlook	Dynamical	MME (multi agency ⁶)	http://www.apcc21.org/ser/enso.do?lang=en	http://www.apcc21.org/ser/outlook.do?lang=en <ul style="list-style-type: none"> • Air temperature • Precipitation • 500hPa Geopotential Height • SST
International Research Institute for Climate And Society (IRI)	Monthly	Graphical products, interpretation	Dynamical & statistical	MME (multi agency ⁷)	http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/	http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/ <ul style="list-style-type: none"> • Air temperature • Precipitation
World Meteorological Organization (WMO)	Regular seasonal	Bulletins issued with press briefing	Expert opinion based on assessment of all important global sources (from about 28 climate centers) of ENSO predictions		http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html	

⁶ Climate forecasting information from 16 climate centers

⁷ Climate forecasting information from 22 climate centers

Climate Prediction Center (CPC)/National Centers for Environmental Prediction (NCEP)/National Weather Service (NWS)	Monthly	Graphical products, diagnostic discussions	Dynamical & statistical	MME (multi agency ⁸)	http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/	http://www.cpc.ncep.noaa.gov/products/NMME/seasanom.shtml <ul style="list-style-type: none"> • Air temperature • Precipitation • SST
European Centre for Medium Range Weather Forecasting (ECMWF)	Monthly	Graphical products	Dynamical	Single-model (SEAS2011 Cycle 36r4)	http://www.ecmwf.int/en/forecasts/charts/seasonal/NipercenF10-plumes-public-charts-long-range-forecast	
Met office, UK (UKMO)	Monthly	Graphical products, interpretation	Dynamical	Single-model (GloSea5)	http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/el-Niño-la-Niña	
Australia Bureau of Meteorology (BOM)	15 days	Graphical products, interpretation	Dynamical	Single-model (POAMA) + multi-agency survey ⁹	http://www.bom.gov.au/climate/enso/	http://www.bom.gov.au/climate/model-summary/#tabs=Indian-Ocean <ul style="list-style-type: none"> • Indian Ocean Dipole

⁸ The official outlook is produced jointly with IRI

⁹ Climate forecasting information from 8 climate centers

Japan Meteorological Agency (JMA)	Monthly	Graphical products, outlooks	Dynamical	Single-model (JMA/MRI-CGCM2)	http://ds.data.jma.go.jp/tcc/tcc/products/elNiño/outlook.htm	http://ds.data.jma.go.jp/tcc/tcc/products/model/index.html <ul style="list-style-type: none"> • Air temperature • Precipitation • 500hPa geopotential height • Sea level pressure • 200hPa & 850hPa Stream function • Velocity potential • SST
Korea Meteorological Administration (KMA)	Monthly	Graphical products	Dynamical	Single-model (Glosea5)	https://web.kma.go.kr/eng/weather/forecast/ella_forecast.jsp	
Beijing Climate Center	Monthly	Graphical products	Dynamical	Single-model (BCC-CGCM)	http://cmdp.ncc.cma.gov.cn/Monitoring/en_enso.php	http://cmdp.ncc.cma.gov.cn/pred/en_cs.php <ul style="list-style-type: none"> • Air temperature • Precipitation • 500hPa geopotential height • 200hPa & 850hPa winds • SST
India Meteorological Department	Monthly	Graphical products in bulletin	Dynamical	Single-model (CFS V2 from NCEP)	http://www.imdpune.gov.in/Clim_RCC_LRF/Products.html	<ul style="list-style-type: none"> • Indian Ocean Dipole
Pacific ENSO Applications Climate Center (PEAC)	Quarterly, with supplemental updates as required	Graphical products in bulletin (Pacific ENSO update for the Pacific region)	Climate model information is not provided.		https://www.weather.gov/peac/update	<ul style="list-style-type: none"> • Precipitation • Tropical Cyclone Activity • Sea level

3.2.1 Readiness of countries to interpret global products within their respective contexts

The national agencies face challenges while interpreting the global ENSO prediction outlooks to their national and local contexts due to insufficient understanding about the ENSO condition and its influence on regional and local weather patterns. Even the characterization of ENSO conditions has lot of complexities. The impacts of El Niño/La Niña conditions could vary based on onset, magnitude, duration, spatial extent of warming/cooling in the Pacific, antecedent warming/cooling conditions, and so on. Furthermore, the manifestation of these El Niño/La Niña conditions at different stages has differential impacts on global weather patterns; especially on temperature, precipitation, and cyclone frequencies. The impact of El Niño/La Niña is also not consistent all the time over a region, and it exhibits variations over space and time. Interactions of ENSO conditions with the local climate drivers produce different weather scenarios in a region. A classic example is normal summer monsoon rainfall over Indian subcontinent during the 1997 El Niño episode.

3.2.2 Identify gaps in understanding and use of available science information

The following limitations/gaps persist within national agencies in making use of climate information in their preparations to minimize the negative impacts and maximize the opportunities. Especially while interpreting ENSO predictions and preparing impact outlook for the various sectoral agencies, which limits the preparedness.

- Understanding on how the ENSO conditions could alter the normal weather patterns at national and local level. Ongoing efforts are trying to build capacities of NMHSs to provide better national climate outlooks.
- Interpreting the impacts with respect to hazard profile and climatological zone of a region. As space-time variations exist in distribution of weather parameters even during the normal season because of climatological zones, region-wise and season-wise contextualization become important for assessing the impacts of El Niño.
- Translating how these changes in weather patterns due to ENSO conditions could affect various sectors as there is existing established closer coordination between provider and sector and knowledge on the sensitivity of sectoral behavior to climate variability and hazards.
- Lacking effective risk communication processes that play a key role in making the stakeholders understand the risk of El Niño for making appropriate informed decisions to minimize the negative impacts and consequences.

3.2.3 Document existing institutional set up at regional and national levels to deliver information, support decision making and garnering feedback for sustained and innovative development.

Having appropriate institutional mechanism in place would help deliver risk information to sectoral agencies for decision-making. Feedback mechanisms would help improve this system over the years. Effective risk communication is vital for disaster risk reduction (DRR). For instance, though a consensus outlook was released well ahead of time on above normal rainfall conditions over Tamil Nadu (India), Sri Lanka, and Maldives, jointly by WMO, IMD/Government of India, RIMES, and CIDA during the 2015 El Niño year, the Tamil Nadu state experienced high damage and losses from flood disasters due to heavy downpours during the North East monsoon season, which highlights the existence of gaps in communicating the risk. These gaps could be addressed through incorporating monsoon forums (Box 3.1) or climate outlook briefing forums that connects the information provider and the users.

Box 3.1

Impacts of climate variability, extremes, and change on societies may be exacerbated by development decisions that are not guided by climate information. Application of climate information to anticipate events and guide decision-making is not optimum due to gaps that exist in the end-to-end information generation and application system. These gaps include limited user understanding of forecast products, mismatch between users' needs and available climate products and services, and limited institutional mechanisms to facilitate efficient and effective translation and communication of information to and receive feedback from users.

The Seasonal Forum is a platform for regular dialogue between the National Meteorological and Hydrological Service (NMHS) and multi sectoral forecast users, aimed to address these gaps. The Seasonal Forum is a cyclical process of forecast provision by the NMHS; forecast users' analysis of potential impacts on their sectors based on the forecast, identification of impact management options, providing feedback at the end of the season on actions taken during the course of the season, and identification of recommendations for improving forecast product generation and provision, as well as application; and NMHS improvement of products and provision of services to meet user demands.

The main objectives of this forum are to

- Ensure that forecast products, including their limitations and uncertainties, are communicated to and understood by users.
- Encourage forecast applications for optimizing resource management and mitigating risks in climate sensitive sectors.
- Receive user feedback for improving usability of forecast products.
- Provide a platform for inter-agency coordination of policies, sectoral plans, and programs for managing potential impacts.
- Provide a platform for long-term process of understanding climate opportunities/risks.

Source: (RIMES, n.d.)

Box 3.1 Monsoon Forum – Connecting science, institutions and society (RIMES, n.d.)

3.3 Climate outlooks for 2015 and 2016 Monsoon seasons over South Asia

The ENSO Impact Outlooks (UNESCAP and RIMES, 2014a; 2014b; 2015) focus on assessing and communicating risks from slow onset disasters and El Niño among Pacific Island Countries (PICs) and Small Island Developing States (SIDS) in order to facilitate timely and risk-sensitive interventions by countries.

During the 2015-2016 event, the outlooks provided regularly updated information on El Niño conditions across Asia and the Pacific, presented risk scenarios at regional, sub-regional and national levels, identified the countries most at risk, and provided sector-specific risk profiles. They also analyzed the potential impacts of El Niño on weather patterns such as rainfall and cyclone frequency, on sea level, and on climate-sensitive socio-economic sectors such as agriculture, freshwater resources, fisheries, reef ecosystems, public health, and infrastructure, and introduced the AAL methodology to estimate potential economic losses.

Furthermore, the outlooks made a number of policy recommendations targeted at national governments and at international and regional organizations. These focused on the need to develop

climate resilient policies that specifically address El Niño sensitive sectors; to enhance understanding of how El Niño interacts with socio-economic factors in order to better target and link climate change adaptation (CCA) and DRR measures; to enhance public education and community awareness; to improve the sharing of risk information among stakeholders; and to strengthen regional collaboration.

Strategies for building climate resilience in the agricultural sector proposed in the outlooks included early warning and monitoring strategies; pre-or in-season mitigation, adaptation and response strategies; and long-term or seasonal adaptation strategies.

The outlooks recommended that early warning and monitoring strategies could be enhanced by strengthening seasonal drought forecasts; improving knowledge networks for transferring information and alerts from government agencies to farmers; enhancing education of community and farmers; and by developing El Niño government contingency plans.

Recommendations for pre-or in-season mitigation, adaptation and response strategies focused on diversifying employment or income; livestock management through migration of stock or destocking; stockpiling through seedbanks, feedstocks and water at the household level; diversification of crops; changing to alternative crops needing less water or varieties that are drought-resistant; changing agricultural practices (e.g. no tillage); and improving water conservation and storage systems.

Long-term or seasonal adaptation strategies recommended in the outlooks included the improvement of planning and zoning to restrict agricultural practices in high risk areas; encouragement of farming systems or crops more suitable for the climate; rehabilitation of degraded land; improvement of education of community and farmers for long-term management and adaptation; improvement of information for land management and drought planning; establishment of financial risk management strategies during good seasons to support households during El Niño drought events; and utilization of intergovernmental platforms such as the WMO/ESCAP Panel on Tropical Cyclones and the ESCAP/WMO Typhoon Committee to undertake research and pilot projects to improve the understanding of tropical cyclones, related hazards and bringing about closer regional cooperation in early warning.

To support planning for drought in the agricultural sector, the outlooks highlighted the application of Agricultural Drought Monitoring. ENSO forecasts can help countries at risk of El Niño induced drought to guide farmers in adapting their farming practices before the main growing season in order to mitigate the risk of drought and its impacts.

Recommendations to governments included the strengthening of monitoring and early warning systems, including institutions such as Monsoon Forums, to ensure that timely information reaches all key stakeholders and groups at risk; the use of critical early warning and risk information for decision-making; building on best practice; mainstreaming DRR and CCA into national development plans in order to create a culture of resilience; promoting contingency planning and preparedness actions, especially in agriculture and other most vulnerable sectors; strengthening institutions such as Monsoon forums; conducting thorough, multi-sector risk and impact assessments; and engaging in regional cooperation to share information and take collective action.

Recommendations targeted at international and regional institutions included supporting countries in ensuring adequate policy, institutional and technical responses to El Niño and providing platforms for sharing of information, knowledge and solutions. Development partners and financial institutions were asked to provide financing for preparedness actions in the context of El Niño, and consider this as an investment that will save costs due to reduction of potential impacts associated with climate variability.

Examples of national efforts to mitigate the effects of El Niño highlighted in the outlooks included strategies for addressing the impacts of El Niño, such as lower food production, higher prices, and lower farm incomes; activities to help farmers cope with drought, such as cloud seeding, seed distribution, crop diversification and rotation, and water saving; the allocation of funds for drought response and livelihoods support; water conservation and distribution of emergency water supplies and water desalination services; and flood and landslide alerts for communities at risk.

Table 3.2 Climate outlooks and realized climate conditions for 2015-2016 El Niño

(based on South Asian Climate Outlook Forum reports available from Regional Climate Centre, India Meteorological Department (IMD), Pune website (http://www.imdpune.gov.in/Clim_RCC_LRF/Products.html) WFP, 2017, Sri Lanka – Initial Rapid Assessment on Drought 2016/17, World Food Program (WFP) & Ministry of Disaster Management, Government of Sri Lanka, 15 Jan 2017. pp 18.)

	Climate Outlook	Realized climate conditions
<u>Summer 2015</u> SASCOF 6 Summer Monsoon outlook issued in April 2015	Below normal rainfall is most likely during the 2015 southwest monsoon season (June – September) over South Asia as a whole. The weak El Niño conditions are established over the Pacific Ocean with the possibility of its continuation during the southwest monsoon season being the main factors that lead to this consensus opinion. Region-wise, the forecast had indicated below-normal rainfall over broad areas of western, central and southwestern parts of South Asia.	The observed rainfall for the 2015 southwest monsoon season was below - normal over most parts of South Asia except over some northeastern parts of the region. India Meteorological Department (IMD) reported that June 1 to September 30, the country got 760.6 mm of rainfall, as against a normal average of 887.5 mm. Year 2015 was the first back-to-back drought for India in three decades, and only the fourth in more than a century. Similarly, Sri Lanka got low rainfall during June-September months.
<u>Winter 2015</u> SASCOF 7 Northeast Monsoon season outlook issued in Oct 2015	Consensus forecast indicated Normal to above normal rainfall as likely during the 2015 Northeast monsoon season (October - December) over southern parts of South Asia including southeast peninsular India, Sri Lanka and Maldives. This consensus climate outlook for the South Asian region considered the strong El Niño conditions that prevailed in the Pacific Ocean and predictions that such El Niño conditions will continue during the northeast or winter monsoon season.	Observed rainfall in the region was above normal rainfall over southern part and northern most parts of the region. Many parts of Tamil Nadu in southern India and Sri Lanka experienced heavy rainfall spells with some locations getting flooded during this season.
<u>Summer 2016</u> SASCOF 8 Outlook for the summer monsoon season issued in April 2016	Above normal rainfall was predicted as most likely during the 2016 southwest monsoon season (June-September) over most areas of central and western south Asia. Below normal rains were likely over eastern parts of the region and southeastern peninsula like Tamil Nadu, India and Sri Lanka. Normal rains were predicted for the rest of the region.	Below normal rainfall was experienced over southern, north and northeastern parts of the region. Many parts of Sri Lanka experienced below normal rainfall. Above normal rainfall occurred over some central and western areas of the region, while most parts of the region received normal rainfall during the season.
<u>Winter 2016</u> SASCOF9 Seasonal climate outlook for the 2016 Northeast Monsoon (October – December) over South Asia	Normal rainfall was expected over most parts of south Asia during the 2016 Northeast monsoon season (October – December). However, below normal rainfall was likely over some areas of southeast peninsular India, Sri Lanka and Maldives. Below normal rainfall is also likely over some areas of north and eastern parts of the region. Above normal rainfall is likely over Western and northwestern parts of Pakistan and some northeastern parts of the region.	The NorthEast Monsoon rainfall over most of the southern peninsular states of India was deficient (-20per cent to 59per cent below their normal). Sri Lanka also experienced deficient rainfall season during Oct-Dec, 2016 with about -23per cent decrease from the normal that has now prolonged into a drought situation (WFP, 2017)

4. Socio-economic impacts of the 2015-2016 El Niño event

Earlier, Section 2 detailed the various climatological and hydro-meteorological impacts of the 2015-16 El Niño event. Large parts of Asia and the Pacific, a region at high risk during El Niño events, has experienced extreme precipitation, temperatures, drought, and tropical cyclones likely influenced and intensified by the El Niño event. Scientific advances are increasing our understanding of the El Niño phenomenon and its impacts on weather and climate. However, capturing, quantifying, and attributing social and economic impact data of El Niño events and associated extreme events remains a significant challenge. Here, Section 4 presents summaries of the available bio-physical and socio-economic impact data and the potential causes of these impacts, including pre-existing vulnerabilities, in affected countries at national and sub-regional scales in Asia and the Pacific.

4.1 The 2015-2016 El Niño event in Asia and the Pacific

The 2015–2016 El Niño phenomenon has been one of the strongest since 1950, having affected the lives and livelihoods of more than 60 million people across the globe, with the full socio-economic cost still being counted. In Asia and the Pacific, the event has destroyed crops and killed livestock, in some cases dried up water-sources and in others caused massive flooding, driven up malnutrition rates, increased disease outbreaks, and driven migration. While scientists declared the weakening of this event in May 2015, the long-term impacts of the 2015-2016 El Niño have yet to be fully assessed, and its effects may last well into 2017. It is also difficult to isolate and attribute socio-economic impacts exclusively to El Niño events. What we do know with some certainty is that impacts of El Niño-related disasters are typically felt most by the rural poor in middle- and lower-income countries.

UNESCAP et al. (2017) classify socio-economic impacts under several categories: food security and nutrition, inflation, unemployment, income, migration, conflict, poverty, and economy, as per the *Assessment of El Niño-associated risks* report. Based on this classification, impact summaries per sub-region are provided here. Table 4.1 shows the concerned sub-regions and countries, alongside an indication of the severity of impacts associated with hazards likely intensified by the El Niño event.

Table 4.1 Indicative hazard types associated with El Niño and their potential enhanced impacts severities in Southeast Asia, South Asia and the Pacific for 2015-2016

Impact classification is per El Niño-related hazard type (flood and landslide, drought, and tropical cyclone). Red: High impact, Yellow: Low to Medium impact, White: No impact/no data. Impact assessed on number of deaths, number of people affected, and total economic damage (data from CRED, 2016).

Sub-region	Nation	El Niño-associated hazard type and their potential enhanced impact severity (2015-2016 data)		
		Flood & Landslide	Drought	Tropical Cyclone
Southeast Asia	Cambodia			
	Indonesia			
	Lao PDR			
	Malaysia			
	Myanmar			
	Philippines			
	Thailand			
	Viet Nam			

South Asia	Afghanistan			
	Bangladesh			
	Bhutan			
	India			
	Nepal			
	Pakistan			
	Sri Lanka			
North Pacific	Marshall Islands			
	Micronesia			
	Palau			
Central Pacific	Kiribati			
	Niue			
	Samoa			
	Tonga			
	Tuvalu			
South Pacific	Fiji			
	New Caledonia			
	Papua New Guinea			
	Solomon Islands			
	Vanuatu			

Many of the socio-economic impacts of El Niño events relate to the many aspects of food security¹⁰, including agriculture inputs (e.g. water – availability and quality), agricultural productivity, food availability, food prices, food quality, and nutritional value. As with all the major El Niño events over the past several decades, the 2015-16 event undoubtedly took its heaviest social and economic toll on these aspects. In large parts of the region, it is the rural poor, with a high reliance on agriculture for income and subsistence that have suffered the greatest and most prolonged impact in terms of food security. The following sub-sections address the major socio-economic impacts per Asia-Pacific sub-region. Although these impacts cannot be exclusively attributed to the 2015-16 El Niño event, they can be interpreted as an “enhancement factor” due to the extreme El Niño event.

4.2 Southeast Asia

In Southeast Asia, drought has affected large parts of the Mekong river basin region over the past two years. Viet Nam has suffered severe drought in South Central and Central Highlands regions and extended saltwater intrusion in the Mekong Delta. Between 400,000 and 600,000 hectares (ha), or up to 60 per cent, of crops in Central Viet Nam and the Delta are thought to have been very severely to extremely damaged or lost. Over 6,000 livestock perished as a result of the drought and 70,000 ha of aquaculture areas, mostly in the Delta, were damaged. As of late 2016, over 1 million people were still food insecure and 1.75 million people had lost some or all of their livelihood and income across 52 (out of 64) provinces in Viet Nam (FAO, 2016). In 2015, Viet Nam experienced negative agricultural growth for the first time since records began (UNOCHA, 2016). In the most severely affected 18

¹⁰ *Food security* is a flexible concept with many definitions. For the purposes of this report we use perhaps the most commonly cited definition; based on the 1996 Declaration on World Food Security (World Food Summit, 1996) (that refers to the importance of nutrition), with the addition of ‘social’ access (Committee on World Food Security, 2009) – “All people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and health life”.

provinces, two million people have been affected, including approximately half a million children facing higher risk of malnutrition due to limited access to water (UNICEF, 2016a) Moreover, water shortage and the use of unsafe water have increased the likelihood of outbreaks of water-related diseases; up to 400,000 people may have been affected (UNESCAP et al., 2016). The total economic impact in Viet Nam has been estimated at USD \$674 million, or 0.35 per cent of national GDP (UNOCHA, 2016).

Elsewhere in the region, other countries have faced similar impacts. In Cambodia, an estimated 2.5 million people have been affected by drought, many severely so, that led to potable and irrigation water shortages, land degradation, loss of livestock, and reduced agricultural productivity. In 2015, however, large parts of Cambodia were also impacted by flooding and storms, which caused damage to homes and infrastructure in both rural and urban areas (*ibid*). Regions of Myanmar have also faced similar risks (severe drought coupled with flooding) and impacts on agriculture and livelihoods (water shortages, crop losses, and damage to land, properties, and other assets).

The Philippines is one of the most disaster-prone countries in the world. The typical indicators of El Niño in the Philippines are shorter and weaker monsoon rains leading to drought conditions and weaker tropical cyclone (typhoon) activity (i.e. fewer and less intense). During 2015-16, the country still experienced 18 typhoons that affected a total of 6 million people and caused US\$ 2 billion worth of economic damage. However, this could be described as 'typical' as it is in line with the trend of slightly reduced cyclone activity. The most notable impact of El Niño in the Philippines then, is drought. 85 per cent of provinces were affected in terms of water availability and loss of crops, with Mindanao and the Visayas regions being the worst affected. Mindanao supplies close to half of the nation's food. The Department of Agriculture estimated close to 200,000 farmers, largely rice and corn farmers have been affected. Nationally, an 11 per cent drop in production compared with 2014 was recorded. Similarly, a 20 per cent decline in fish catch due to warmer waters was reported, affecting at least 100,000 fishermen and women. The severe economic impact and perceived lack of government action led to protests in some areas. Total losses may have been as high as US\$ 11 billion (UNESCAP 2016).

4.3 South Asia

The primary meteorological impact of El Niño on Southeast Asia, particularly the Indian sub-continent, is a weakening of monsoon rains. Throughout 2015 and into 2016, large parts of India suffered a severe and prolonged drought. The government estimated that around 330 million people were affected. The full social economic costs are still being counted, but early figures suggest at least \$US 3 billion worth of losses (CRED, 2016). The rural poor were particularly impacted in terms of water and food security, livelihoods, health, education, and social protection of the vulnerable (i.e. women, children, and the elderly) (UNICEF, 2016b). For instance, most states had to rely on India's Public Distribution System for staple food grains; huge crop losses and land degradation meant, farming became a non-viable option for many small and marginal farmers across India. Many households had to forego vegetables and other foods that were rising in price as the drought persisted, causing widespread reduced protein consumption (*ibid.*). Decreasing purchasing power and increasing household debt are major secondary consequences of droughts across rural areas. For example, in the southern state of Marathwada, it was documented that over 600 farmers committed suicide in 2015 due to their inability to pay back loans taken out to support crop cultivation (Oxfam, 2015). These issues frequently occur in semi-arid areas of India, but are exacerbated during El Niño events.

UNICEF (2016b) reported a whole host of social and economic impacts across many states that they conducted surveys in – reduced access to safe drinking water, increase in open defecation and worsening water, sanitation, and hygiene (WASH) facilities and personal hygiene due to water shortages, high prevalence of malnourished and stunted children and malnourished pregnant women, reduced employment in the agriculture and forestry sectors, incidences of migration, increase in school dropouts, absenteeism and subsequently child labour, and finally cases of child trafficking were recorded in the state of Odisha.

Large parts of South Asia are also exposed to changing tropical storm (or cyclone) frequency, intensity, and tracking associated with El Niño events. In May 2016, Cyclone Roanu causes severe flooding in Sri Lanka and Bangladesh. In Sri Lanka, around 200 people died and upwards of 100,000 people were displaced. Estimates of the total economic damage range from US\$ 1.2 – 2 billion. In Bangladesh, the storm affected electricity supply, damaged infrastructure, and damaged crops. Food in storage was spoiled by the storm surge inundation, and livestock, fish, and shrimp farms were swept away. In total, around 40,000 homes and businesses were damaged and approximately 1.2 million Bangladeshis were affected. But since tropical cyclones are hazards that occur regularly in Sri Lanka and Bangladesh, it is difficult to attribute these impacts to El Niño.

4.4 The Pacific

A high economic dependence on subsistence agriculture of staple crops and local fisheries makes the Pacific Islands one of the most vulnerable regions to the effects of El Niño conditions. Across the islands, here sub-categorized into North (Marshall Islands, Federated States of Micronesia, and Palau), Central (Kiribati, Niue, Samoa, Tonga, and Tuvalu) and South (Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu) Pacific, a range of El Niño-related impacts occurred during the 2015-16 event. As shown in Figure 4.1, at the height of conditions, as many as 4.7 million people across the Pacific (of which 2.4 million were in PNG) were thought to be at risk from the effects of drought (OCHA, 2015).

Figure 4.1 also shows that Central and Southern Pacific Islands face elevated tropical storm (or cyclone) risk under El Niño conditions due to a shift in the tracking of storms in the Pacific Ocean. Previous El Niño years have seen some of the most severe cyclones in the Pacific, such as Cyclone Heta in 2004 that impacted Tonga, Niue, and Samoa. Figure 4.2 shows the impacts of the 2015-16 El Niño on the agriculture, infrastructure, and fisheries sectors of Pacific Island nations.

El Niño conditions can also shift fish populations and migration patterns throughout the Pacific, which increases the uncertainty risk to national economies with high dependence on revenue from fish exports (UNESCAP and RIMES, 2014). Coral reefs, which provide livelihood and extra income from tourism are also impacted by more extreme weather patterns. As SST rapidly rises and falls, coral becomes more at risk from bleaching, which also has a compounding effect on the wider ecosystem.

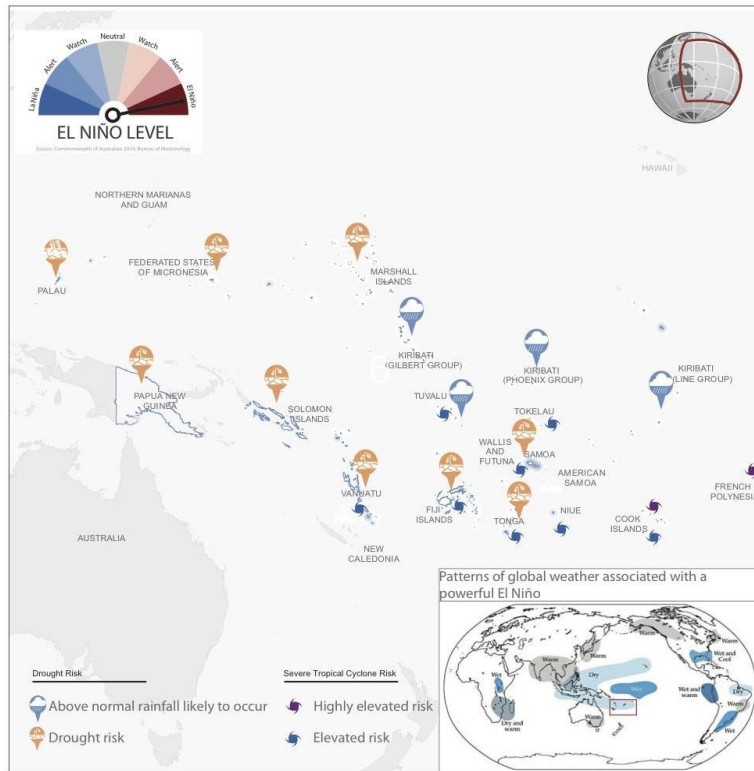
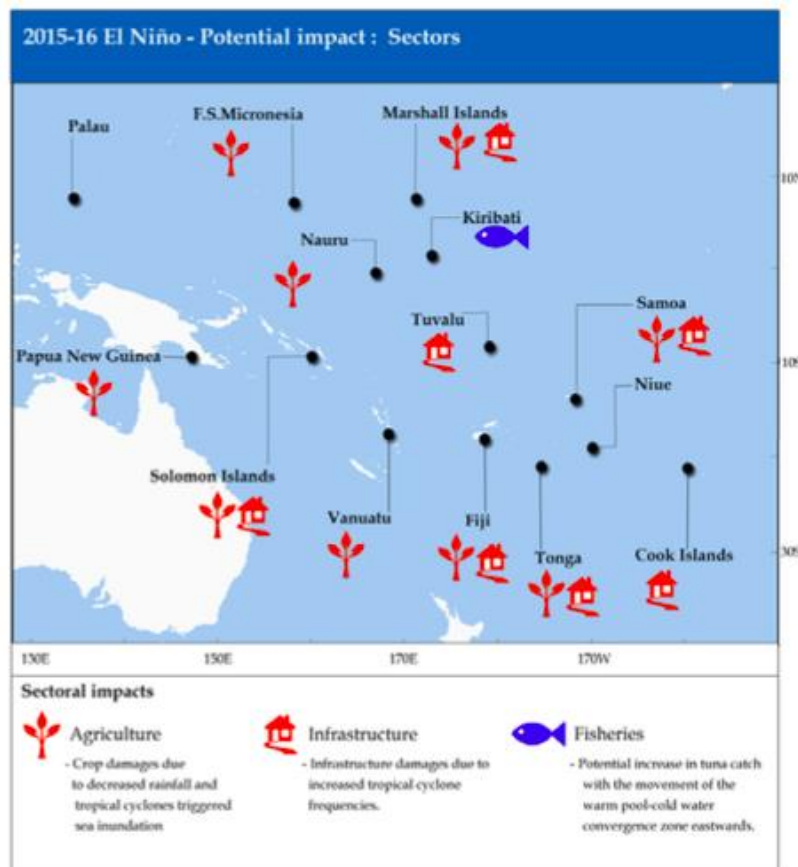


Figure 4.1 The 2015-2016 El Niño in the Pacific (OCHA, 2015)



Source: Regional Integrated Multi-Hazard Early Warning System for Africa and Asia, 2015.

Figure 4.2 Potential 2015/2016 El Niño impacts on different sectors (RIMES, 2015)

4.4.1 North Pacific

Drought is the primary El Niño associated risk for the islands of the North Pacific. Worsening conditions in early 2016 led to the Marshall Islands and Micronesia declaring states of emergency, where at least 20,000 and 100,000 people were reported to have been affected, respectively. In Palau, some states were on an emergency water-rationing schedule and farm irrigation was suspended for a time due to low water levels in the Ngerimel Dam and the Ngerikiil River, which caused significant agricultural losses in both crops and livestock. In total, approximately 80 per cent of Palau experienced a decrease in water supply with 10 of 16 states categorized as highly affected (FAO, 2016).

4.4.2 Central Pacific

Drought conditions for the Central Pacific islands were most pronounced in 2015, but have persisted in parts of Kiribati and Tuvalu into early 2017. Tonga faced extremely dry conditions for nearly a year, affecting crop yields including a trial project that planted different varieties of maize intended to encourage the expansion of small holder farming. Tuvalu was also struck by Cyclone Pam in 2015, with the outermost islands hardest hit in terms of agriculture and infrastructure losses. Water supplies were contaminated by seawater. Tuvalu estimated nearly half of the nation's population were temporarily displaced and the damage amounted to close to US\$ 100 million.

4.4.3 South Pacific

As noted above, El Niño can affect the occurrence and strength of tropical cyclones, broadly increasing risk and the chance of an increase in cyclone frequency by up to 50 per cent. In March 2015, Cyclone Pam barreled through the South Pacific, most severely impacting Vanuatu, where at least 11 people were killed, nearly 200,000 were affected, and damage totaled approximately US\$ 500 million (CRED, 2016). Cyclone Pam produced heavy rains and high winds that damaged infrastructure on the remote Solomon Islands of Anuta and Tikopia, where around 1500 homes were damaged and up to 90 per cent of crops and fruit trees were destroyed. Water sources were contaminated, telecommunications infrastructure destroyed, and Anuta was isolated for at least a week after the cyclone had passed. In Fiji, a reported 100 tonnes of sugarcane were destroyed by the strong winds. New Caledonia faced light damage such as temporary power outages and small-scale yam crop loss within subsistence farming communities on Mare and Lifou.

In February 2016, Cyclone Winston struck Fiji, killing 46 people, severely affecting 350,000 (up to 40 per cent of the total population), and causing an estimated US\$ 1.4 billion in total damages. 40,000 homes and 229 schools were damaged or destroyed. Around US\$ 61 million of economic losses were accounted for by damages to crops and livestock. The inundation of seawater due to storm surge is likely to have rendered large swathes of land indefinitely infertile, creating a long-term agricultural and food security impact that stretches beyond the official El Niño time period (FAO, 2016; UNESCAP and RIMES, 2014a).

In PNG, an estimated 2.7 million people were affected by a persistent drought, frost (in highland areas), and forest fires, with severe impacts on crop production and water availability deepening food insecurity in much of the country and impacting export revenues, and thus national GDP growth. Furthermore, torrential rains that followed the drought caused floods and landslides damaging households, food gardens, potable water sources, and physical infrastructure most severely in Highland and Momase region provinces. Reduced food availability has resulted in significant and rapid increases in food prices, further exacerbating food insecurity in PNG. The country's lucrative fishing industry was also hit by changes in sea temperatures affecting fish stocks and migration.

4.5 Average Annual Loss

The evidence presented here contributes to considerations of the amplification effect El Niño events have on socio-economic losses and damages. While the socioeconomic impacts of El Niño can often be difficult to fully ascertain due to the interconnectedness to a variety of sectors and industries, calculations like Annual Average Loss (AAL) and amplification factors can allow scientists and economists alike to more accurately predict how much of an impact its effects will have on many parts of a nation's economy. The concept of cascading impacts becomes important to this weather phenomenon as the reliance of various systems creates vulnerabilities in almost every part of the chain. In looking at the impacts described in this section, the 2015-16 El Niño event has had significant socio-economic impacts such as extending losses in agricultural and fisheries production, revenue, and GDP far beyond its active years. This is particularly the case when looking at examples of mass unemployment and even instances where primary education was halted, showing its generational impacts which will eventually translate to economic losses for both individuals and countries. These calculations can be used to provide a very rough estimate allowing officials to better prepare for losses in the immediate future, especially in order to secure funding and resources for periods when the effects of El Niño are most present and harmful. As an example, Figure 4.3 below shows calculated AAL and the El Niño amplification factor for cyclones in the Pacific. See Annex for more detailed information on how the AAL and El Niño amplification are calculated.

Country	Annual average losses due to cyclones ^a (million USD)	El Niño Amplification factor ^b	Potential losses due to El Niño 2015/2015-associated cyclones (million USD)
<i>Northern islands</i>			
Federated States of Micronesia	9.8	-	-
Marshall Islands	3.7	2.73 ^c	10.1
Palau	2.8	-	-
<i>Central islands</i>			
Kiribati	0	-	0
Nauru	0	-	0
Papua New Guinea	27.9	1	27.9
Solomon Islands	7.1	1	7.1
Tuvalu	0.1	1.43	0.14
<i>Southern islands</i>			
Cook Islands	6	1.46	8.76
Fiji	94.1	1.04	97.86
Niue	1.1	1.33	1.46
Samoa	8.5	1.41	11.99
Tonga	11.7	1.14	13.34
Vanuatu	44.3	1	44.3

Figure 4.3 Potential losses due to El Niño 2014/2015-associated cyclones in Pacific nations (UNESCAP and RIMES, 2014)

a. Figures for annual average losses associated with cyclones were calculated using the Pacific Risk Assessment Methodology developed by the World Bank et al., (2011). The methodology incorporates exposure information, hazard assessment (i.e. experience of 2,400 cyclones in 15 PICS over a 60-year period), intensity calculation, damage estimation and casualty and loss calculation.

b. An El Niño event is expected to increase the magnitude of risk associated with tropical cyclone activity. The El Niño Amplification Factors for the 2014-2015 cyclone season were sourced from Cyclone Outlook 2014-2015 (NIWA, 2014). These factors were developed based on historical El Niño events that exhibited similar atmospheric and oceanic conditions to the 2014/2015 El Niño.

c. The El Niño Amplification Factor for the Marshall Islands was sourced from a study conducted by Wright (2006), which uses the same methodology as NIWA (2014)

5. Platforms for accessing and sharing information and for coordinating response

Section 5 presents two possible solutions for integrating available science and information on socio-economic vulnerabilities into Information Technology (IT) enabled platforms that enable easy access and sharing of information and coordinating response.

El Niño Regional Dashboard

During the stakeholder meeting of Asia-Pacific countries, which was part of the regional consultative workshop held in Bangkok, Thailand from 7-9 June 2016, and organized by ESCAP and UNDP, an El Niño Regional Dashboard was proposed with the aim to integrate science and vulnerability information into IT enabled platforms (UNESCAP et al., 2017). The dashboard could be hosted by the Pulse Lab Jakarta, which was established in 2012 by partnership between the United Nations and the Government of Indonesia, and through UN Global Pulse and the Indonesian Ministry of National Development and Planning (Bappenas). The first innovation lab of its kind in Asia, Pulse Lab Jakarta brings together experts from United Nations agencies, the Indonesian government, non-governmental organisations, and the private sector to conduct research and facilitate the adoption of new approaches for applying new digital data sources, as well as real-time analysis techniques to social development. The Indonesian cross-government partners include the Ministry of National Development and Planning, the Ministry of Health, and the Ministry of Communication and Information.

One of the tools developed in response to the 2015 start of El Niño by the World Food Programme (WFP), the Food and Agricultural Organization (FAO), and UN Global Pulse is the Vulnerability Analysis Monitoring Platform for the Impact of Regional Events (VAMPIRE). The tool can be used to understand the evolving nature of slow onset phenomena like El Niño in near real-time to better target assistance from government and international organizations to vulnerable populations. It is embedded in the situation room of the Office of the President of the Republic of Indonesia. The platform provides integrated map-based visualizations that shows not only static information, such as a distribution of population by different socioeconomic levels and disaster history profiles in Indonesia, but also dynamic information, such as the extent of drought affected areas and the impacts on markets.

The tool is a multi-tier system that fuses several databases. First, it visualizes the national socioeconomic survey and WFP's ad-hoc household food security surveys. This data provides information on the percentage and distribution of poor, agriculture-dependent populations, as well as food insecure communities. Second, it analyzes daily satellite imagery data to show rainfall anomalies and the Indonesian Vegetation Health Index. Rainfall anomaly is a measure of the amount of rainfall in a period compared to the long-term average for that time of year while the vegetation index is a proxy for drought. Based on the measure of economic vulnerability and exposure to drought, the tool can identify priority areas where people may require assistance.

While collecting data on rainfall anomalies and food security is not a new or unique activity for governments, the platform adds value by dramatically reducing the time required to bring this information together and visualize it in high-resolution and in near real-time. The system allows to integrate additional data sources and features, such as passively monitored big data and operational data from designated government organisations. For example, mobile phone data could be used to provide information on the movement of people affected by climate events. Text message alerts could be incorporated to notify affected populations, such as farmers, of climate related threats.

VAMPIRE could be deployed to address food security issues in other countries throughout Asia and the Pacific. For example, The Government of Sri Lanka has recently expressed interest in applying the

tool in Sri Lanka, and The Government of Cambodia is in the process of developing a similar system for their country in close collaborations with WFP. Each country will have different needs and priorities, so it will be important to tailor the tool to the particular situation and to provide localized solutions.

In addition to VAMPIRE, the El Niño Regional Dashboard could be extended to provide a range of other services that could benefit El Niño affected countries. During the 2015-2016 event, a number of ideas for an El Niño Regional Dashboard were discussed. These include the visualization of data through risk and seasonal forecasting lenses at the regional level; the use of satellite images to assess long-term impacts, such as the location and extent of coral bleaching and to monitor indicators such as sea surface chlorophyll in coastal regions and signs of developing drought; the mining of social media and news data on El Niño through hash tags and other information sources; and the geotagging of images reflective of climate change impacts for understanding the micro-climatic picture.

Replicating the monitoring services offered by the platform to other countries and upscaling them to the regional level will require enhanced coordination and collaboration between national governments, UN agencies and international organisations. UN agencies will need to take a lead role in coordinating regional efforts, particularly in providing information, data, and financing. Countries will need to buy into the value of the platform and commit to support the integration and localization of the tools and services into their national frameworks.

SESAME

RIMES has developed an expert System called Specialized Expert System for Agro-Meteorological Early Warning (SESAME) for generating agro advisories, being tested in Myanmar, which integrates forecast, location specific hazard thresholds, risk patterns for preparing contingency plan in agriculture based on seasonal and sub-seasonal climate forecast/outlook (RIMES, 2015). The climate forecast helps to analyze the risk and understand the vulnerability based on climate risk profile, so that actions plans can be prepared and implemented. This system is an example for managing agricultural risks. Similarly, a sophisticated expert system could be developed for generating location specific advisories for multiple sectors.

6. Improving future impact assessment and planning

Section 6 provides a proposal for a 6-step approach for strengthening regional coordination and collaboration between the agencies and the national governments across the Asia-Pacific Region in preparing for and responding to extreme climate events.

The aim of the agencies engaged in writing this report is to ensure that the lessons learned from the 2015-2016 El Niño event will guide future approaches toward building resilience to extreme climate events across Asia and the Pacific. The agencies seek to improve the activities of the ad hoc Regional Task Team and to identify and develop appropriate services and products that address current gaps in climate risk management at the regional, sub-regional, and national levels.

Responding to requests made by several countries in the region, the agencies would like to develop an offer of service, which will provide countries at risk from El Niño with a coordinated step-by-step preparedness and response plan that can be activated and implemented at any time.

Figure 6.1 shows the sequence of steps that would be taken in such an approach using selected locations in Viet Nam, the Philippines, and PNG as illustrative examples. The different steps in the provision of services and products will be triggered by critical changes in seasonal rainfall during the monsoon cycle, which vary between countries depending on their geographical location and climate.

Step 1 – Provision of Regional Climate Outlooks. The first step is the provision of information provided by the Regional Climate Outlook Forums (RCOFs) at the onset of the monsoon season. As shown in Figure 6.1, this is in May in Viet Nam and the Philippines and in January in PNG. The RCOFs produce consensus-based, user-relevant climate outlook products in real time on a regional scale with the aim to reduce climate-related risks and to support sustainable development for the coming season in sectors of critical socio-economic significance for the particular region. The outlooks generally include probabilistic predictions of seasonal mean rainfall, surface air temperature, and other weather parameters, as well as the likely evolution of key drivers of seasonal climate variability relevant to the region such as the El Niño/Southern Oscillation (ENSO).

The Pacific Island Countries Advanced Seasonal Outlook (PICASO, developed by APCC and SPREP through the Republic of Korea-Pacific Islands Climate Prediction Services, or ROK-PI CliPS, Project) is a PC-based seasonal prediction tool tailored for the Pacific Island countries, and will be launched at the end of 2017. The PICASO produces probabilistic forecast of the seasonal mean rainfall of the given weather stations by customizing the data from the many climate models in the world (from the APCC dynamical seasonal prediction multi-model ensemble, MME). This downscaled hybrid dynamical-statistical prediction system offers better opportunity for reliable seasonal forecast, where conventional empirical methods showed poor prediction skill, while also taking the prediction uncertainty into account. Through a series of capacity building activities, PICASO is anticipated to be operated by NHMSs of Pacific Island countries together with SPREP, which operates the regional data and computation server (CLIK-P) for the PICASO. It is possible to develop this type of downscaled prediction system to increase the reliability of forecasts in various countries or regions in a longer time-frame (roughly three years).

Step 2 – Provision of National Climate Outlooks. National Monsoon Forums or Climate Outlook Forums (COFs) communicate climate and hydrological outlooks for the incoming season in May-June in Viet Nam and the Philippines and in January-March in PNG. The COFs produce applications for mitigating risks in climate-sensitive sectors and provide a platform for inter-agency coordination of policies, sectoral plans, and programs for addressing the impacts of hydro-meteorological hazards.

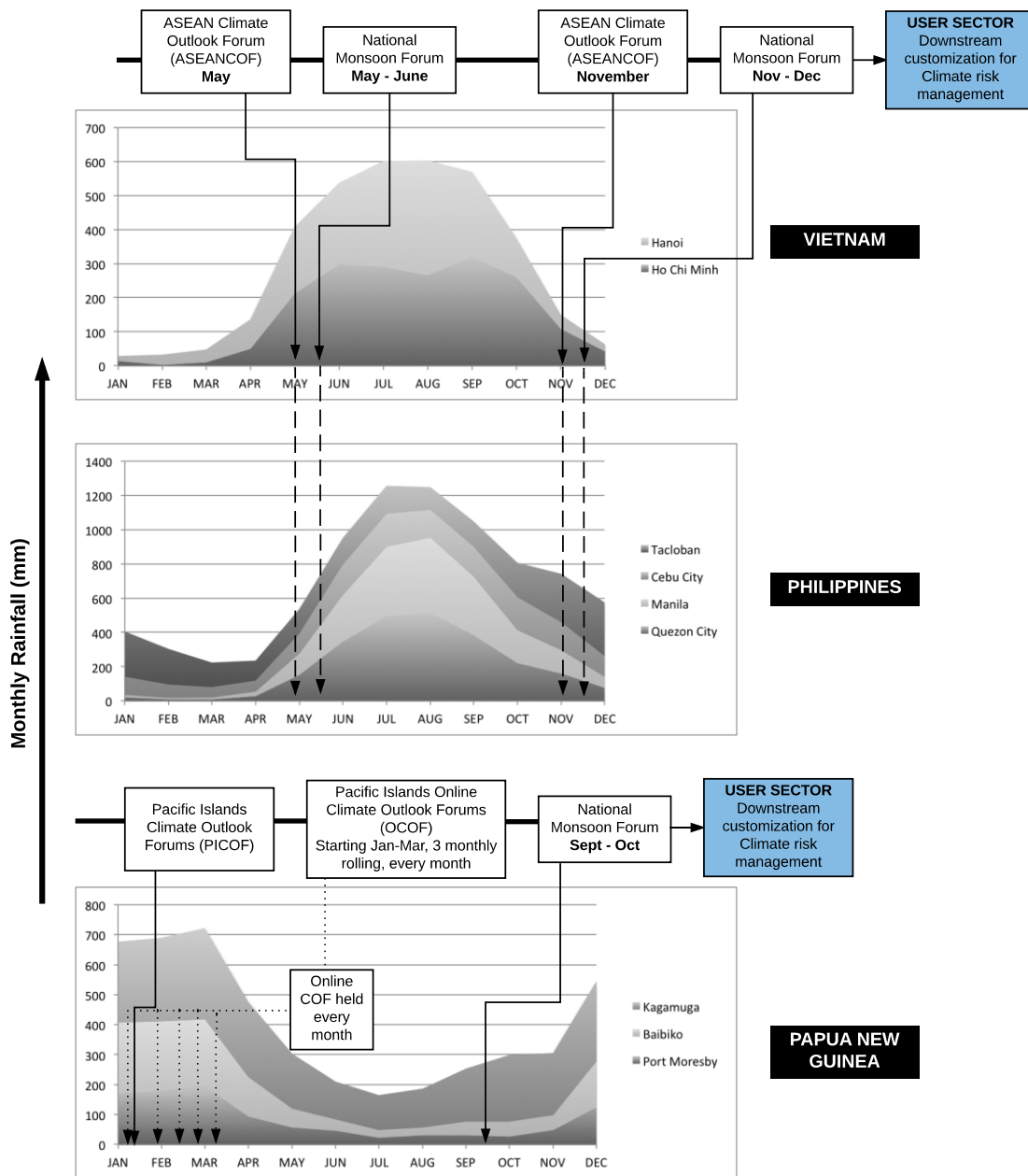


Figure 6.1 Sequence of steps to prepare for and respond to El Niño-related climate risks

Illustrates the sequence of steps that begin with the Regional Climate Outlook Forums (RCOFs) and link to the National Forums that ultimately share seasonal climate outlooks, including El Niño status with user sectors for downstream customization and use in Climate Risk Management.

Step 3 – Assessment of risk management options. Risk management is the concept and practice to avoid, lessen or transfer the adverse effects of hazards and the potential impacts of disasters through activities and measures for prevention, mitigation and preparedness. It is a systematic process of using administrative directives, organizations and operational skills and capacities to implement strategies, policies and improving coping capacities.

Risk management is an important step in our offer of service. It identifies what management strategies can be used to minimize risks; examines which sectoral and institutional services are important for managing and mitigating risks; and determines how risk management strategies can be implemented and financed.

Examples of drought risk management include a wide range of strategies from promoting appropriate technologies and practices in land and water management such as switching to drought resistant crops, the efficient use of natural resources and sustainable agriculture methods; to developing alternative livelihoods options for people at risk; to developing disaster prevention plans; to building the capacity of communities to adapt to climate-related hazards.

Risk management strategies can be promoted through public outreach, awareness and education activities; good planning and coordination at all governance levels; mobilization of funding sources; engaging in new partnerships with the private sector; and the application of innovative methods and tools. Methods for improving risk management include the Training of Trainers; the documenting and sharing of good practice, success stories and lesson learnt; and the development of new skills.

Step 4 – Delivery of humanitarian support to countries expecting impacts. At this stage, an estimation of the humanitarian and development intervention is made for countries at risk. Based on the hazard forecasting information provided by the RCOFs and COFs, combined with an assessment of vulnerability and exposure, ESCAP provides impact based forecasting services, which support risk-informed early warning and help to identify response scenarios and mitigation strategies.

Step 5 – Critical support during time of crisis. Extreme climate occurrences such as El Niño may last for many months, so a number of efforts are needed to support countries throughout an event. These include the establishment of institutional mechanisms that ensure authority and accountability of actions, the provision of actionable information, as well as measures that support sectoral planning, identify and implement no regret interventions, and provide safety nets.

Step 6 – Post-event recovery. Towards the end of the monsoon season there is another RCOF in November in Viet Nam and the Philippines followed by another National Monsoon Forum in November-December in Viet Nam and the Philippines and in August-September in PNG. These forums continue to monitor the ongoing climate conditions and guide humanitarian recovery efforts in affected countries through the Central Humanitarian Response Fund (CERF) of the United Nations.

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8. Annexes

8.1 Quantifying future risk: Annual Average Loss and the El Niño amplification factor

Annex 8.1 describes how El Niño related macroeconomic impacts can be calculated using a hazard multiplication factor in the Annual Average Loss (AAL) method. Such calculations can be used to quantify future risk with the aim to guide long-term risk-informed economic development.

AAL refers to the long-term expected losses per year, averaged over many years. It captures long-term expected losses, as a yearly average, over a given period of time. It is the weighted average of expected loss from every disaster event, given their probability of occurrence. AAL includes measurements of both direct damage and indirect losses, and takes into account exposure and vulnerability data, plus past disaster occurrences and their impacts (UNESCAP et al., 2017).

Unlike historical estimates, AAL is inherently forward-looking. It considers the possibilities of all disaster occurrences through incorporating small frequency, high damage disaster risks that have not been experienced as yet. As a result, the analysis will not be biased towards disasters that occurred in the past, but contain a more comprehensive picture of what can be expected given current climate dynamics and socio-economic developments.

The general procedure of calculating AAL consists of an individual evaluation of losses for each hazard scenario, and a subsequent probabilistic integration of these results, using the frequency of occurrence of each scenario as a weighting factor.

The AAL utilizes data from hazard (frequency and severity of events at a specific geographical location), exposure (infrastructure or population components that can be affected by a specific event), and vulnerability (determined by relating the level of damage with the intensity of the phenomenon) to determine a specific scenario's forward-looking risk. The risk for a given area estimate is based on combining probabilistic hazard models and vulnerability functions for exposed assets.

The result of this combination is a Loss Exceedance Curve (Figure 8.1). The Loss Exceedance Curve depicts the relationship between estimated loss and risk of occurrence. It illustrates the relationship between frequency and severity. Different disaster scenarios will have different Loss Exceedance Curves. For example, infrequent but high impact events, like earthquakes, will have lower and flatter curves.

The economic losses during El Niño years can be calculated by multiplying the AAL and an El Niño amplification factor. The annual average losses caused by climate related hazards during the normal years are assumed to be amplified during El Niño years. An example of estimating potential economic losses in the Pacific Island during an El Niño year is presented in Table 8.1.

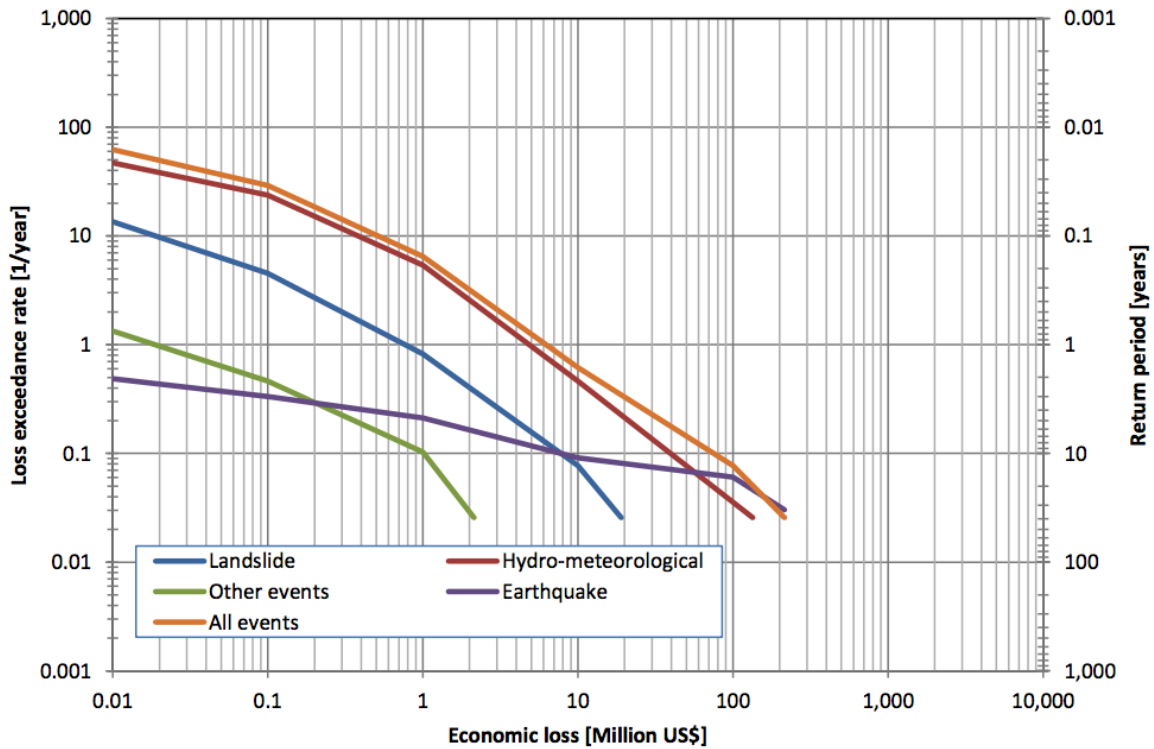


Figure 8.1 Example of a Loss Exceedance Curve for different types of disasters (UNISDR, 2011)

Table 8.1 El Niño amplification factor and AAL in the Pacific Islands (UNESCAP et al 2017)

Country	AAL (Million USD)	El Nino associated amplification factor	Potential losses (Million USD)
Marshall Islands	3.7	2.7	10.1
Papua New Guinea	27.9	1	27.9
Tuvalu	0.1	1.43	0.14
Cook Islands	6	1.46	8.76
Fiji	94.1	1.04	97.86
Niue	1.1	1.33	1.46
Samoa	8.5	1.41	11.99
Tonga	11.7	1.14	13.34
Vanuatu	44.3	1	44.3

Of the many indicators of probabilistic risk, AAL is considered as one of the most robust (CIMNE-INGENIAR, 2014). It takes into account both historical experiences and futuristic projections. An AAL calculation involves three components: (1) Hazard modelling; (2) Exposure and Vulnerabilities; and (3) Risk estimations.

Hazard modelling of different disasters are made through a stochastically generated set of events that has a possibility of occurring. Each hazard event is associated with a frequency of occurrence to

represent its relative probability of occurrence at a given region. From this a hazard curve can be constructed, which plots the intensity value to the probability of exceeding that intensity. With modeled hazard information, the analysis can move on to study disaster impacts. This involves looking at **exposure and vulnerability functions**, which identifies different types of exposed physical elements in the region and the potential impact disasters can deal.

Hazard models and vulnerability functions are combined to produce a **risk model**, which gives the probability distribution of loss for each hazard scenario. For all possible scenarios, potential losses are mapped to their respective exceedance probabilities. The 2015 Global Assessment Report on DRR (GAR) (UNISDR, 2015) used the risk model of (Ordaz, 2000), which provides the probability distribution from the following model:

$$f(p_j | E_i) = \int_0^{\infty} f(p_j | s) f(s | E_i) ds$$

The function $f(p_j | E_i)$ describes the probability distribution of disaster losses in exposed element j , conditional on the occurrence of event i (E_i). This is defined as the integral of the “vulnerability” measurement $f(p_j | s)$, which is a probability distribution of the loss p_j given disaster intensity s ; and “hazard” measurement $f(s | E_i)$, the probability density of the intensity, given occurrence of event i . This is graphically depicted in Figure 8.2. For every value of losses in the horizontal axis, the area under the probability curve represents the probability that losses exceed the amount.

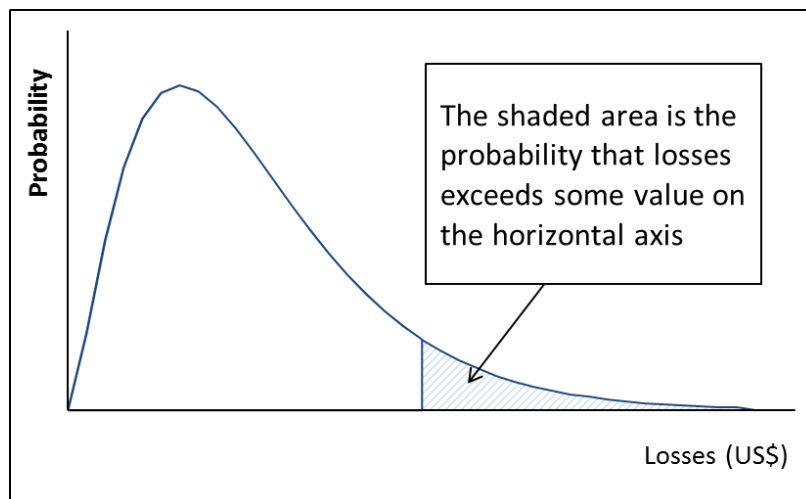


Figure 8.2 Probability distribution of event i on exposed element j .

The summation of the probability distribution of losses of individual events gives the loss exceedance curve. This is the aggregate probability distribution of losses for the whole region concerned. The loss exceedance curve is a key output for a probabilistic risk model. It can be obtained as follows:

$$v(p) = \sum_{i=1}^N Pr(P > p | E_i) \cdot F_A(E_i)$$

$v(p)$ is the loss exceedance rate of loss p , there are N disaster events from $i=1$ to $i=N$. $F_A(E_i)$ describes the frequency of occurrence of scenario i , $Pr(P > p | E_i)$ is the probability loss p is exceeded, conditional to disaster i occurring. The graphical mapping of $v(p)$ for all possible losses (p) would give us the loss exceedance curve (Figure 8.3). In this model there is no distinction between events of different natural hazards. Therefore, it reflects multiple disaster risks.

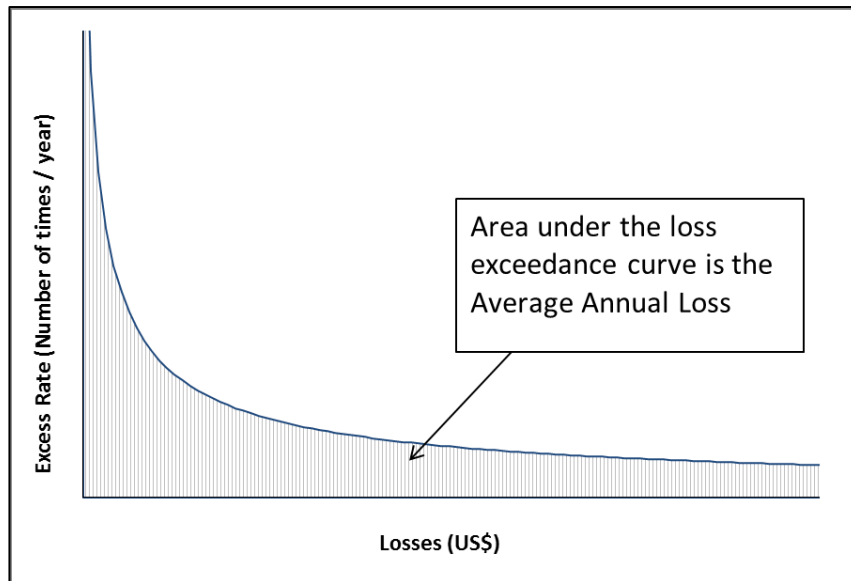


Figure 8.3 The loss exceedance curve.

The AAL is obtained by calculating the area under the loss exceedance curve. This can be done by finding the integral of the loss exceedance curve, which is the same as the weighted sum of all individual expected losses from all events:

$$AAL = \int_0^{\infty} v(p)dp$$

AAL is the expected value (EV) of annual loss. It estimates the amount needed to compensate future losses of natural disasters over the long-run by finding, a single number, the impact of multiple disaster events on exposure assets. It is the combination of all potential losses that can happen every year, weighted by their relative likelihoods. It is, simply put, the average loss expected by a region every year.

In summary, the AAL can be used to calculate the amplified socio-economic losses resulting from El Niño impacts. The methodology is presented in the El Niño Risk Assessment - Step-wise process (UNESCAP et al., 2017). AAL is a long term annualized loss estimate that indicates the trend of risk at the macro-level and in specific economic sectors. It's an important tool for planning and financing risk sensitive development. Because it is a sector-based risk assessment, it supports sector-level risk sensitive development planning. For example, climate scenarios can be used for resilient agriculture policy planning. One of the challenges for applying the method at the national level is the availability of disaggregated disaster damage data. However, because AAL is a probabilistic method it overcomes data gaps to some extent.

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The Stockholm Environment Institute (SEI) is an international non-profit research organization that has worked with environment and development issues from local to global policy levels for a quarter of a century. SEI works to shift policy and practice towards sustainability. SEI's mission is to support decision-making and induce change towards sustainable development around the world by providing integrative knowledge that bridges science and policy in the field of environment and development. SEI has been providing scientific knowledge and solutions to policy-makers for over 25 years. SEI's overarching objectives for 2015-2019 are: (i) to enhance the quality and impact of our problem- and solution-driven scientific research, (ii) to provide effective decision support and engage in key policy arenas, and (iii) to strengthen the capacity of individuals, organizations and institutions to make decisions that promote sustainable development. In 2016, SEI was ranked as the world's most influential environmental policy think tank in the University of Pennsylvania's 2016 Global Go To Think Tanks Index.

GLOSSARY

All definitions from UNGA (2016) unless otherwise stated.

Climate change

Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. (IPCC, 2007)

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Contingency planning

A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses.

Critical infrastructure

The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society.

Disaster

A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Disaster management

The organization, planning and application of measures preparing for, responding to and recovering from disasters.

Disaster risk

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Disaster risk assessment

A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

Disaster risk management

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

Disaster risk reduction

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Early warning system

An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.

Economic loss

Total economic impact that consists of direct economic loss and indirect economic loss.

- *Direct economic loss*: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage.
- *Indirect economic loss*: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts.

El Niño and La Niña

El Niño and La Niña are opposite phases of what is known as the *El Niño-Southern Oscillation* (ENSO) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific (approximately between the International Date Line and 120 degrees West).

La Niña is sometimes referred to as the *cold phase* of ENSO and El Niño as the *warm phase* of ENSO. These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate (NOAA).

Exposure

The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Food security

All people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and health life (Committee on World Food Security, 2009).

Hazard

A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Hydrometeorological hazards are of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges. Hydrometeorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and in the transport and dispersal of toxic substances and volcanic eruption material.

Mitigation

The lessening or minimizing of the adverse impacts of a hazardous event.

Preparedness

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.

Prevention

Activities and measures to avoid existing and new disaster risks.

Reconstruction

The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and “build back better”, to avoid or reduce future disaster risk.

Recovery

The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster- affected community or society, aligning with the principles of sustainable development and “build back better”, to avoid or reduce future disaster risk.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Response

Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Structural and non-structural measures

Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non-structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Underlying disaster risk drivers

Processes or conditions, often development-related, that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity.

Vulnerability

The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.