El Niño: Potential Asia Pacific Impacts

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Executive Summary

Weather shocks represent a major threat to global security. Climate stress increases risk of conflict, particularly among agriculturally dependent economies.[1] The U.S. Department of Defense's 2014 Quadrennial Defense Review (QDR) declared climate-induced stressors as threat multipliers among the world's fragile regions.[2] An empirical relationship between higher temperatures and sub-state violence has been demonstrated in a number of studies.[3] The stability of modern societies – not just in ancient times – relates strongly to global climate.

Building on these earlier works, our white paper specifically looks at various scenarios that could happen during a strong El Niño year. Using the latest findings in meteorology and social science, this study is organized into two major parts: (1) the fundamental science and prediction of the El Niño phenomenon, and (2) ten potential security scenarios that may be induced or exacerbated by El Niño.

Droughts pose the most pervasive threat in the Asia Pacific. Water shortage in rainfall-sensitive economies could trigger destabilizing conditions such as energy crisis, human and animal migration, food shortage, and wildfires – leading to conflict and regional vulnerability.

The figure below summarizes some of the major environmental patterns of El Niño and their corresponding security impacts.

Summary of El Niño Impacts on Asia Pacific

	South Asia	Southeast Asia	Northeast Asia	Oceania
Environmental Impacts	• warmer • drier • suppressed summer monsoon • delayed onset and magnitude of Somali Jet	• warmer • drier • fewer but potentially more intense tropical cyclones	• warmer • drier or wetter depending on location relative to Mei-Yu Front • more frequent tropical cyclones	• dry and warm in western Pacific • dry in Australia and subtropical Pacific islands • warm, wet, and more hurricanes in central Pacific
Primary Security Impacts	• economic loss from drought ↑ • agricultural productivity ↓ • food security ↓ • rice riots ↑ • disease ↑ • human migration ↑ • maritime piracy ↑	• fish stock ↓ • agricultural productivity ↓ • water supply ↓ • energy crisis ↑ • social unrest ↑ • disease ↑ • human migration ↑ • wildfires ↑ • South China Sea conflicts ↑	• water supply ↓ • energy crisis ↑ • fish stock ↓ • political reform and instability ↑ • infrastructure and economic damage from tropical cyclones ↑	• fish stock ↓ • fish migrations ↑ • disease ↑ • wildfires ↑ • economic loss from drought ↑ • infrastructure and economic damage from tropical cyclones ↑

Introduction

El Niño is a recurrent global environmental phenomenon that causes shifts in global weather patterns every 2 to 7 years.[4] The resulting weather extremes change the pattern of floods, droughts, tropical cyclones, and fish stock in the Asia Pacific.[5] According to some studies, agriculturally dependent economies suffer from these extremes, and the likelihood of organized political violence in the tropics doubles during El Niño.[6]

In this paper, the authors briefly describe the oceanic and atmospheric effects of El Niño and highlight environmental shifts that could impact regional security in the Asia Pacific. There are indications that an El Niño will occur in 2014, with less certainty on the magnitude of the potential event.

Regardless of the 2014 event, the considerations and scenarios discussed in this paper can and should be applied to more effectively plan for future El Niño events that are certain to occur in the coming years.

El Niño Overview

El Niño is characterized by the periodic warming of the sea surface in the central and eastern Pacific Ocean, most pronounced during northern hemisphere winter months. The name of "El Niño" was derived from the Spanish term for "Christ Child," because the phenomenon was first discovered off of the coast of Peru around Christmas.[7] El Niño is part of a broader oceanic and atmospheric cycle called the El Niño Southern Oscillation (ENSO).

There are warm, neutral, and cool phases of ENSO. El Niño is the warm phase, and La Niña is the cool phase. Occurring every 2 to 7 years,[8] each El Niño event is associated with weather and environmental impacts that extend well beyond the immediate region of warmest sea surface temperature (SST) anomalies in the Pacific. Prior to, during, and following these ENSO events, the spatial variability in SSTs drives atmospheric circulation patterns and subsequent precipitation anomalies around the world.

Under "normal" prevailing conditions (non-El Niño periods), northeasterly and southeasterly trade winds just north and south of the equator collectively push the warm layer of water near the surface of the ocean from east to west. This leads to a higher sea level and deeper thermocline (the layer of ocean with a steep temperature gradient that separates warmer water above from cooler water below) in the western Pacific (Figure 1a), with an average sea level differential of 1.5 ft (46 cm).[9] The depth of the warm ocean water near the surface typically decreases toward the eastern Pacific.

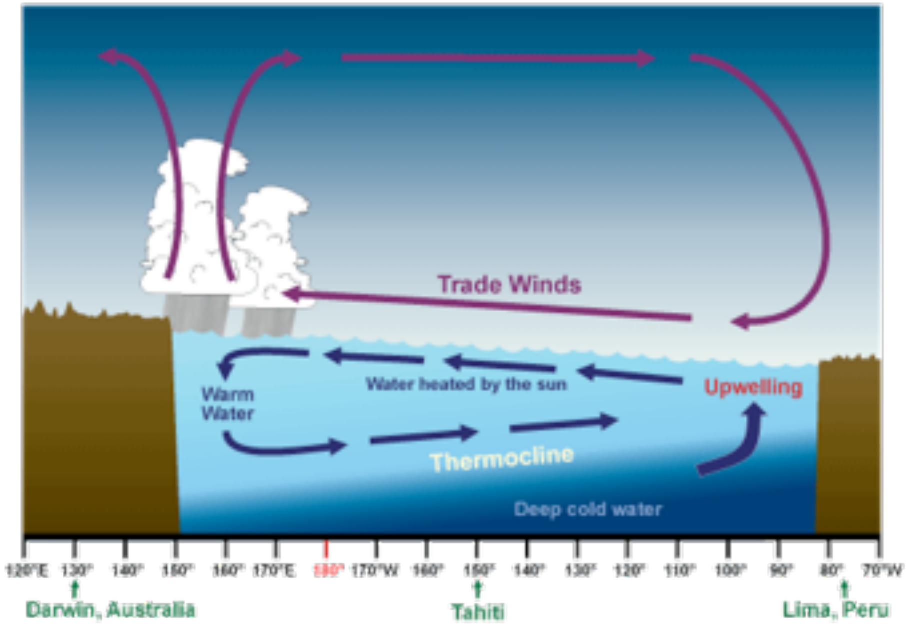


Figure 1a – *During normal, non-El Niño conditions, prevailing northeasterly and southeasterly trade winds blow across the Pacific Ocean, pushing warmer waters toward the western Pacific, resulting in higher sea levels. In the eastern Pacific, cooler water from the deep ocean rises to fill the void in a process called upwelling. [Figure from NOAA.]*

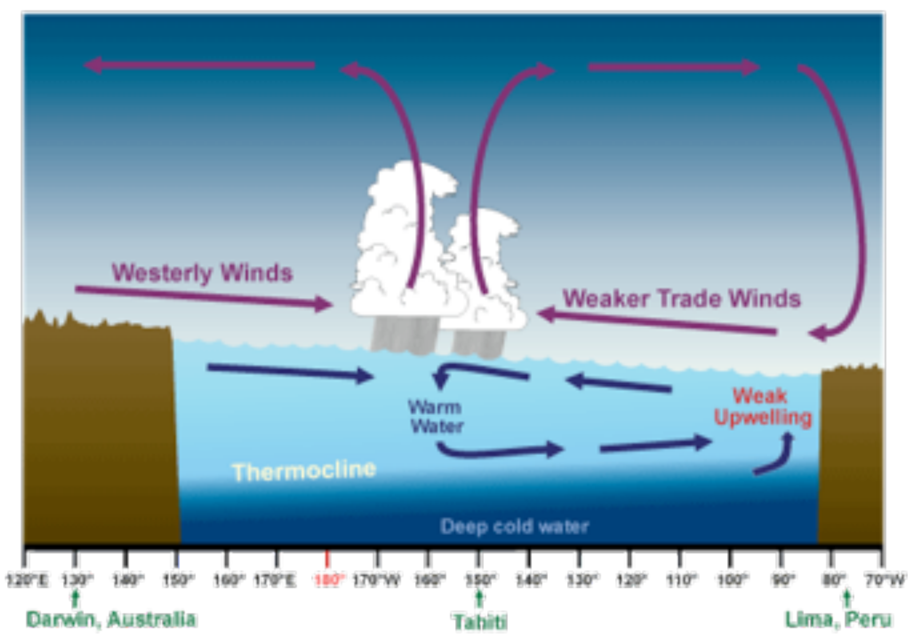


Figure 1b – *During El Niño conditions, prevailing northeasterly and southeasterly trade winds weaken, allowing westerly winds and oceanic Kelvin Waves[10] to move the warm water from the western Pacific back toward the east. The east-west sea level gradient decreases, and upwelling in the eastern Pacific decreases. [Figure from NOAA.]*

At the easternmost boundary (west coast of the Americas), cool interstitial waters are pulled to the surface in a phenomenon called upwelling. These cooler subliminal ocean layers are nutrient rich and provide the building blocks for primary productivity.[11] This is the reason that fisheries are so rich during the neutral and cool phases of ENSO (i.e., La Niña). Nutrients from the deep ocean that reach the surface, when combined with abundant sunlight, allow phytoplankton (plant microorganisms) to bloom. This phytoplankton is an abundant food source for zooplankton (animal microorganisms), which are consumed by small fish like the anchovy, which form the basis for a productive oceanic food chain. Additionally, the predominance of warm waters in the western Pacific and cooler SSTs in eastern Pacific provides the energy that drives the east-west atmospheric circulation called the "Walker Circulation" (Figures 1 and 2).

During El Niño episodes, the strong trade winds subside, often giving rise to light surface wind conditions or westerly wind bursts that drive the warmer surface waters eastward, creating a more uniform thermocline depth across the equatorial Pacific (Figure 1b). Upwelling in the eastern Pacific ceases, and the primary productivity pyramid collapses for the duration of the El Niño episode.[12] Sea level decreases in the western Pacific and rises in the eastern Pacific. The induced atmospheric circulation response to the changes in size and location of the warm sea surface temperature areas drives anomalous precipitation patterns across the Pacific and globally. In the Pacific, the higher precipitation region shifts eastward, resulting in a generally warmer and drier western Pacific (Figure 2).

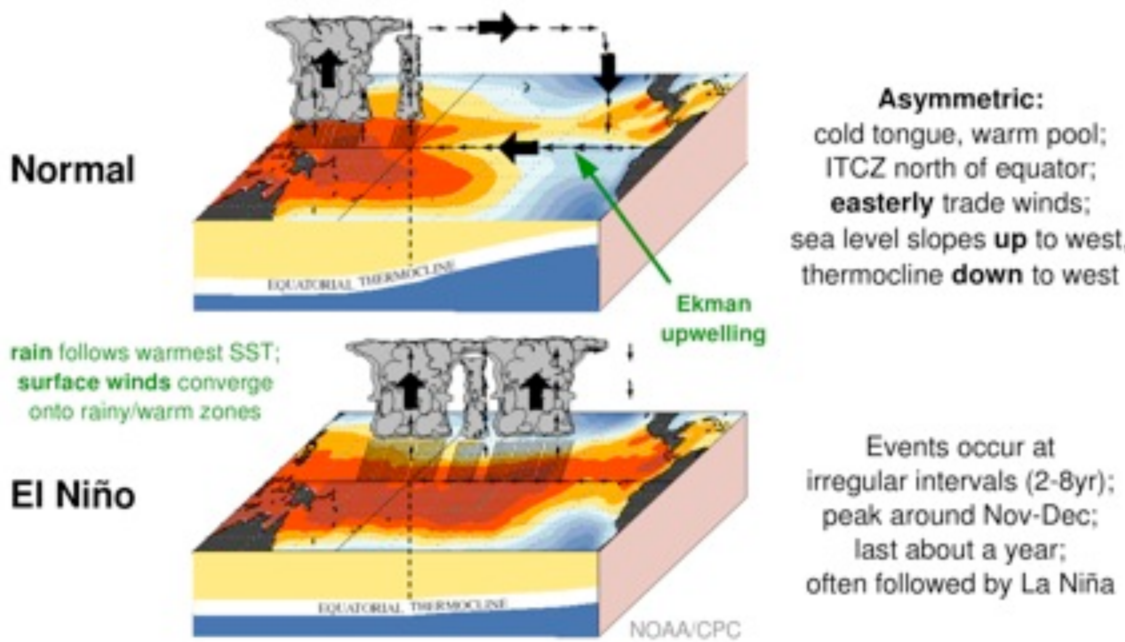


Figure 2 – *During El Niño, changes in the east-west Walker Circulation (black arrows) move precipitation eastward, leading to drier, drought-inducing conditions in the western Pacific. The western Pacific tropical cyclone formation region also tends to shift eastward. The mixed surface layer becomes more uniform across the Pacific and upwelling along the west coast of the Americas breaks down or becomes non-existent, resulting in a sharp decrease in productivity.*

During the 1997-1998 El Niño, the productivity was so diminished that sea lions and sea birds starved to death in the Galapagos and surrounding areas. [Figure from NOAA.]

El Niño Prediction

A very strong El Niño developed in 1982 with impacts extending well into 1983. Events prior to that often caught scientists by surprise, which inspired researchers to better understand and predict El Niño occurrences. These improvements required environmental systems to provide regular observations, which led to the development of the Tropical Atmosphere Ocean (TAO) array observing system that spans a large portion of the Asia Pacific (Figure 3).[13] The TAO buoy array, in conjunction with observations from satellite, drifting buoys, underwater gliders, aircraft, ships, and other instrument platforms, provide the data necessary to model environmental systems. Today, numerical environmental predictive models are run multiple times daily on large clusters of supercomputers, where data are used to estimate the initial and future states of the atmosphere-ocean system. These serve as guidance to forecast the timing and magnitude of ENSO events.[14]

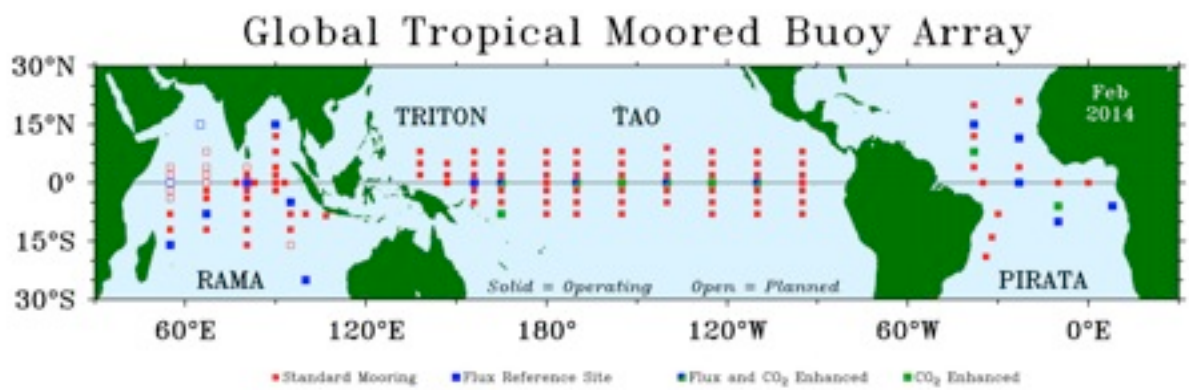


Figure 3 – *The Tropical Atmosphere Ocean buoy array consists of TAO, TRITON, RAMA and PIRATA fixed moored buoys. These buoys support a host of instruments, including anemometers to measure wind speed and direction, barometers to measure the barometric pressure, current meters to measure ocean currents at various levels directly, thermometers to measure both air and sea surface temperatures, and Acoustic Doppler Current Profilers (ADCP) to measure currents remotely at various levels throughout the water column. These data are transmitted to satellite and are available in near real-time on the Global Telecommunications System (GTS) for use in numerical weather, ocean, and climate models run by the National Weather Service, European Centre for Medium-Range Weather Forecasts, Canadian Meteorological Service, U.S. Department of Defense, and others. [Figure from NOAA.]*

The official forecast authority for ENSO within the U.S. Government is the Climate Prediction Center (CPC), which is part of the National Centers for Environmental Prediction (NCEP) within the National Weather Service (NWS). Numerical predictions on climate timescales (from two weeks to several months lead time) are challenging, with less skill the farther the prediction is made ahead of the actual event.

Given the uncertainties, a deterministic view is impractical, so techniques such as ensemble modeling can provide better predictive capability. Hence, ***all climate-scale forecasts are probabilistic, so decision makers should keep in mind that there is always a chance that a forecast event will not occur this year but may still develop in the future.***

The CPC provides probabilistic forecasts of ENSO, with the most recent forecast in June 2014 calling for an 80% chance of an El Niño occurring during the northern hemisphere fall and winter. Current forecasts updated regularly are available from the CPC website,[15] in conjunction with the International Research Institute for Climate and Society (IRI).[16]

In 2014, early indications were extreme[17] and comparable to the most severe El Niño ever recorded (1997-1998).[18] The scientific community was concerned that the latter part of 2014 could bring a significant El Niño. However, as the spring progressed, some of the indicators subsided, and the likelihood of an El Niño of a similar magnitude to the 1997-1998 event have become a much less likely possibility.

As of late June 2014, it appears that the most likely scenario is for a weak-to-moderate El Niño to develop by later in 2014, keeping in mind that significant impacts can still be associated with a weaker El Niño.

Regional Environmental Impacts

While there are variations in the timing of the onset and severity of each El Niño event, some patterns of impacts have been identified through the study of past episodes (Figure 4).

Precipitation

The most obvious effect of El Niño is the eastward shift of the areas of highest precipitation from the western Pacific toward the central Pacific. In general, there is deficient rainfall for Hawaii in the winter and spring months during an El Niño and the following year.

Additionally, the risk of drought tends to increase over the Philippines, Indonesia, Papua New Guinea, and Australia (e.g., Ash Wednesday bushfires of 1982 in Victoria and South Australia[19]).

India and surrounding countries are also susceptible to changes in the flow of the Asian monsoon and the potential exists for drought conditions (although this relationship depends on other factors[20]) that exacerbate a fragile balance in food supply for the largest population centers on the globe.

Tropical Cyclones

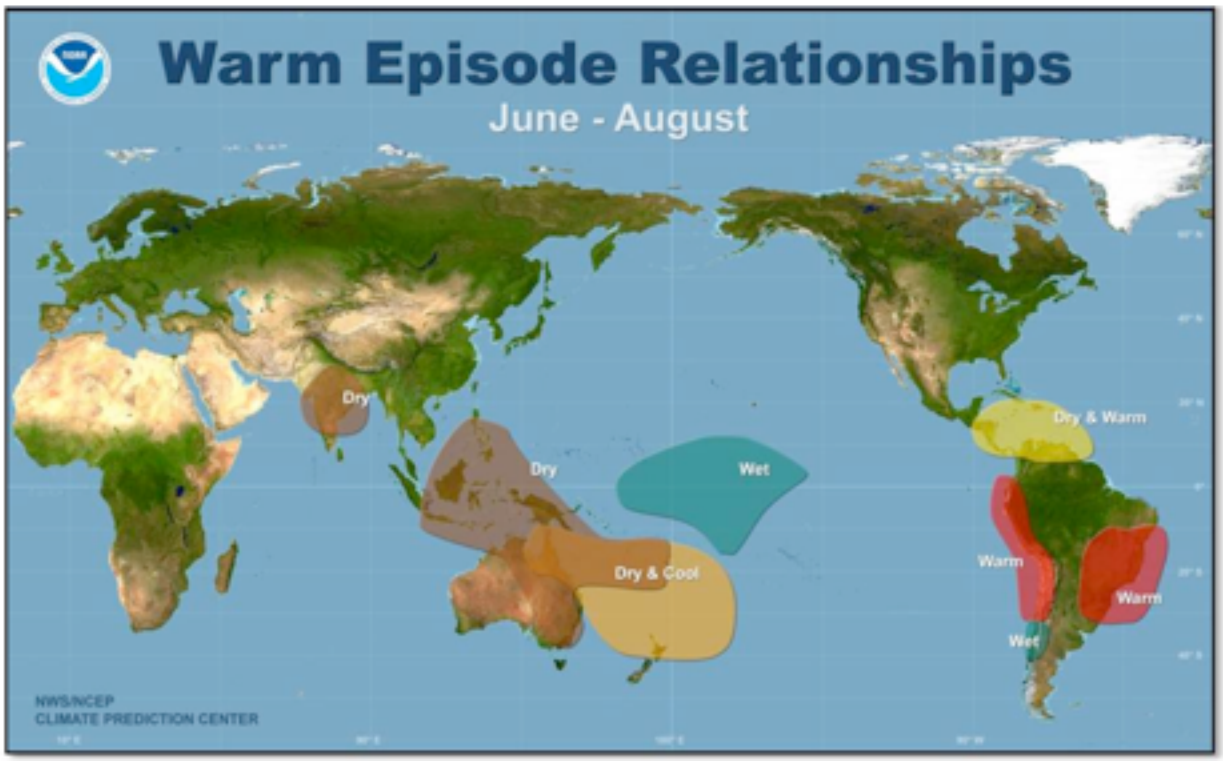
The eastward shift in warmer SSTs in the Pacific results in an eastward shift in the generation region of western North Pacific (WPAC) tropical cyclones (TCs), which are the most violent and destructive type of tropical weather system that affects vast regions of the Asia Pacific each year. Approximately 89% of the world's TC activity[21] occurs within the Pacific and Indian Ocean regions and shifts in TC formation could have strong implications for disaster response, humanitarian assistance, and overall regional stability.
There is a decrease in the number of Atlantic and Gulf of Mexico TCs during El Niño and slight increase in the eastern Pacific. Although there is no evidence for an increase in the frequency of TCs during El Niño in the WPAC, there is evidence for an eastward shift in WPAC TC formation region.[22] This allows the TCs that do form to spend more time over warm ocean waters away from land, which can have the indirect effect of increasing their average intensity during El Niño years.

Furthermore, WPAC TCs have a greater opportunity to "re-curve" toward the north more frequently, thus threatening East Asian regions such as Japan. TC frequency may decrease for Southeast Asia, thereby exacerbating drought concerns.

In the central Pacific, relaxation of the trade winds and warmer SSTs result in a heightened threat of TCs for Hawaii during El Niño years.[23] Hurricane Iwa (1983) and Iniki (1992) both impacted Hawaii during El Niño years.

FISHERIES

The spatial distribution of warm water throughout the Pacific also impacts highly migratory fish species of which Pacific Tunas (Skipjack, Yellowfin and Bigeye) are the most valuable ($1 billion annually[24]) and sought by most nations particularly in the South China Sea (SCS). The SCS is one of the major fishing grounds for tunas but also the center of controversy for Asian geopolitics. Changes in the fish migration pattern during El Niño increases the risk of conflict as fishermen venture further away from their territorial waters.


Warm Episode Relationships
June - August
Dry
Dry
Wet
Dry & Cool
Dry & Warm
Warm
Warm
Wet
NWS/NCEP
CLIMATE PREDICTION CENTER

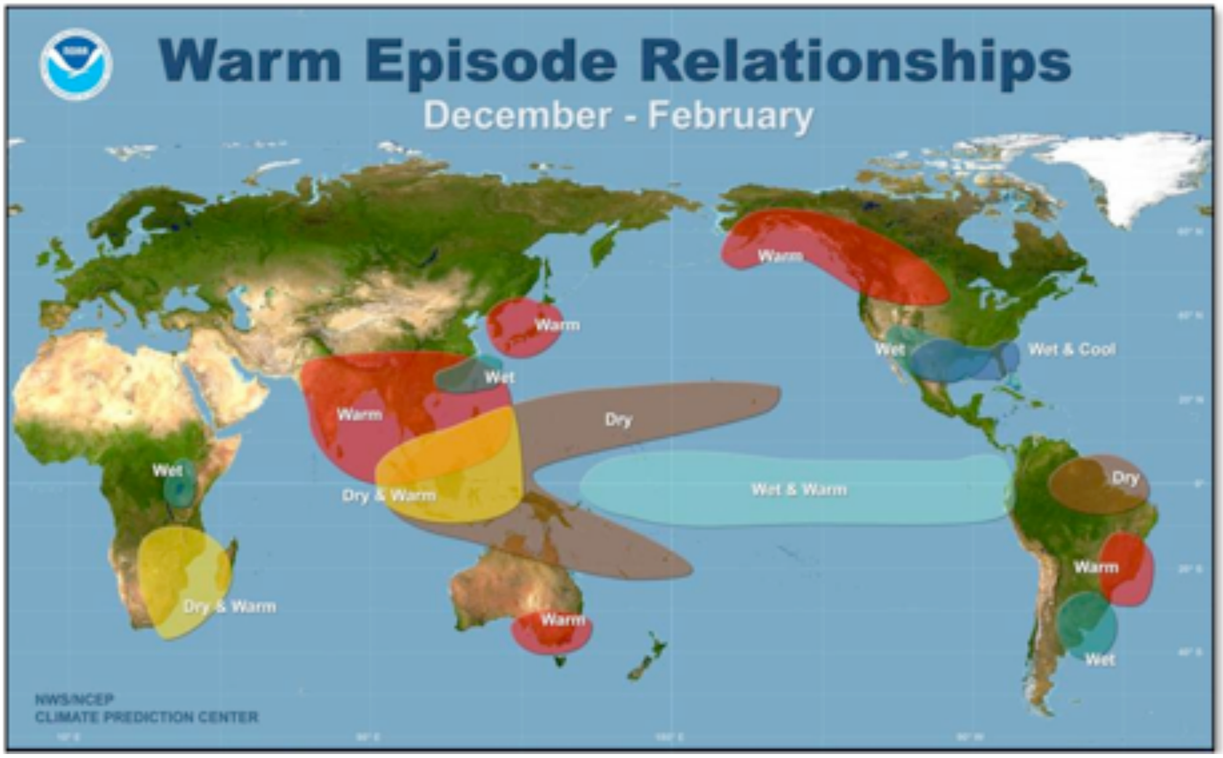


Figure 4 – *El Niño (warm episode of ENSO) affects temperature and precipitation patterns globally, differing depending on season. Vigilance and awareness of these impacts is critical given the distribution of anomalies across Asia and the Pacific islands. [Figure from NOAA.]*

Regional Security Impacts

The following ten projected scenarios illustrate the potential societal effects of a strong and exceptional El Niño on the Asia Pacific region. ***No two El Niño events are exactly alike, so while these scenarios are all possible, they can potentially vary in magnitude and extent.***

SCENARIO 1: WIND SPEEDS AND WAVE HEIGHTS MODULATE MARITIME PIRACY

Monsoons predict skiff piracy. Summer monsoons usher in high winds off of the coast of Somalia (Somali Jet) resulting in decreased maritime piracy. If the surface wind is less than 15.6 knots (8 m s^{-1}), pirate attacks are more likely to occur.[25] Once wind speeds exceeded 17.5 knots (9 m s^{-1}), pirates rarely attack or succeed.[26] The majority (94%) of pirate attacks happened when the wave heights were below 8.2 ft (2.5 m). El Niño could potentially increase pirate activity by causing delays in the onset of the Somali Jet as well as weakening it,[27] resulting in more favorable wind and sea states for maritime piracy.

SCENARIO 2: EL NIÑO PRECIPITATES ENERGY CRISIS

Coal mining operations throughout Northeast and Southeast Asia heavily depend upon a steady supply of water. Coal remains the second greatest energy source worldwide. Although warmer weather might result in lower demand for coal that is used for heating, a prolonged drought could completely shut down coal mining operations and transport, particularly those that use barges to move coal through the rivers. [28]

Scenario 3: Climate-Induced Food Insecurity Sparks Social Unrest

The last El Niño in 2009 caused the worst drought in nearly four decades in India, the world's second largest rice producer, cutting global rice output by 10 million tons.[29] Rice requires a large amount of water to grow. Water shortage leads to decrease in rice and other food supply which, without intervention, generally result in increase in food prices that could precipitate conditions for civil unrest. Certain studies show that when the United Nations Food and Agriculture Organization (FAO) Food Price Index, which tracks the monthly change of international prices of a basket of food (cereals, dairy, meat, sugar, and oils/fats), exceeds 201, riots are likely to occur.[30]

Scenario 4: Warmer Ocean Fuels South China Sea Conflicts

El Niño raises the sea surface temperature (SST) of the South China Sea (SCS) the following summer after its occurrence.[31] With hot and dry conditions throughout Asia potentially triggering a series of destabilizing events, an increased dependence on fishing stocks could push fishermen to venture further away from their respective territorial waters, thereby increasing the likelihood of potential friction in the SCS.[32]

Numerous skirmishes have already occurred in the contested waters of the SCS resulting from fishing disputes. Economic pressures could be further aggravated by the physio-psychological effects of heat. Studies show that higher temperatures induce aggressive behaviors and increase people's propensity to fight.[33]

Scenario 5: Heavy Rainfall and Warmer Weather Cause Disease Emergence

Extreme weather and the subsequent outbreaks of diseases have been well studied particularly when epidemics spread rapidly after disasters due to the displacement of populations and the destruction of health infrastructures.[34] The 1918 flu epidemic[35] and the SARS transmission in 2003[36] have been linked to ENSO.

While the link between El Niño and the transmission of vector-borne diseases remains tenuous, studies show that weather conditions favor the spread of serious epidemics particularly when a population lacks protective immunity.

In 1998, the World Health Organization reported that many Southeast Asian countries suffered unusually high level of dengue and dengue hemorrhagic fever due to ENSO-related extreme weather.[37] Malaria may resurge following an El Niño. Areas normally too dry for malaria transmission run the risk of an epidemic as a result of excessive rainfall after a drought.[38]

Scenario 6: Abnormal Winter Weather Plagues North Korea

El Niño can lead to warmer and drier winters on the Korean Peninsula.[39] While chronic food shortage and famine have plagued North Korea in the past, grain shortage could be particularly acute during El Niño.[40] There is also evidence that certain types of El Niño events called El Niño "Modoki," which is characterized by broader anomalous SST warming in the central Pacific rather than in the eastern Pacific, can lead to ice storms, heavier winter precipitation, and rainfall increases in the Korean peninsula.[41] Snow could deter North Korea's launching of its ballistic missile tests particularly with extreme freezing temperatures, strong wind, and heavy rainfall.[42]

Scenario 7: Typhoons in Asia Increase Security Risks

During El Niño, less frequent but more intense typhoons could hit Southeast Asia and Taiwan,[43] while more frequent typhoons could affect Northeast Asia, especially Japan. The frequency of typhoon impacts could also increase for the Mariana Islands, including Guam, during strong El Niño years.[44] Strong typhoons in Asia have weakened state capacity for governance particularly among vulnerable areas, which has implications to national and regional stability.

Scenario 8: China's Rainfall Extremes Destabilize Region

El Niño events have been linked to major floods in China, particularly the Yangtze River.[45] This spatial redistribution of precipitation, depending on changes in the summer monsoon circulation and the migration of the seasonal Mei-Yu Front, can simultaneously cause drought to the north, exacerbating China's water security issues.

The growing demand for safe drinking water, irrigation for agriculture, and energy production for rapid economic development expose the underlying need to allocate water supply over competing demands from the municipal, food, and industrial sectors.[46] A strong El Niño that causes chronic and prolonged drought in China could impact its internal stability.

Scenario 9: Severe Drought Aggravates Wildfires in Southeast Asia & Oceania

Water shortage due to El Niño droughts has caused massive forest fires. This was particularly evident in 1997-98 when large areas of tropical rainforests worldwide burned down.[47] The entire Southeast Asian region suffered from the tremendous haze emanating from Indonesian forest fires. Australia followed in 1982-83, when very hot temperatures led to a devastating bushfire disaster (Ash Wednesday bushfires).[48]

Guam and other Micronesian islands also suffered drought and grass fires in the 1983 El Niño, but it was the 1998 El Niño where it suffered the most.[49] However, forest fires and water security threats could also provide a platform for greater regional cooperation that transcends organizational and even national boundaries.

Scenario 10: Tropical Cyclone Hits Hawaii, Guam, and Okinawa

A tropical cyclone hitting Hawaii, Guam, and Okinawa around the same time, while unlikely, is a possibility that increases during El Niño conditions. All three locations are islands vulnerable to tropical cyclones.

During El Niño, warmer waters in the central and eastern Pacific compounded by reduced wind shear over Hawaii could increase the likelihood of a hurricane. Hurricane Iniki (1992), which formed during an El Niño year, devastated the south shore of Kauai. There is no scientific reason why hurricanes would prefer Kauai over Oahu, given the proximity of the two islands.

With the understanding that central Pacific hurricanes often approach Hawaii from the east or the south as they re-curve to the mid-latitudes, the south shore of Oahu is particularly vulnerable to a direct impact by a hurricane. Honolulu International Airport and Honolulu Harbor are both located along the south shore of Oahu within inundation zones. They can be easily incapacitated by a hurricane storm surge from the south.

Conclusion

Understanding the basic science, timing, scope, and severity of potential El Niño impacts could save lives. Regardless of the uncertainties associated with long-term climate change, inter-annual climate variability such as El Niño has been and will continue to be a phenomenon that could contribute to extreme natural and human events. Our ability to translate scientific knowledge into operationally relevant action items could enhance the readiness of responders. This white paper takes the first step by demonstrating how science could help inform planners and responders who confront a shared global challenge. As with most weather and climate phenomena, the impacts of El Niño cut across national boundaries. Thus, climate shocks affecting large geographic regions have the potential to inspire greater collaboration and goodwill around the world.

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