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Summary for Scientists

Synthesis of literature and available climate information to support resilience-building following Typhoon Haiyan (Yolanda) in the Philippines

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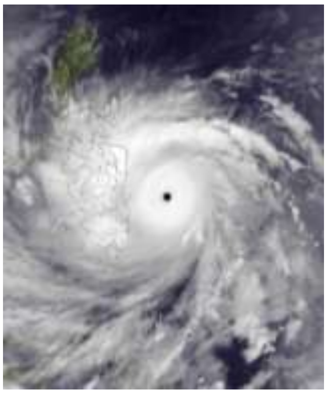
Background Project Information

Typhoon Haiyan (locally named Yolanda) struck the Philippines in November 2013, causing significant damage and loss of life. In response, the UK Department for International Development (DFID) pledged support for the recovery and reconstruction effort. DFID is funding the Met Office, in partnership with the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), to help strengthen PAGASA's technical capabilities as well as provide state-of-the-art information to guide decisions and build resilience to future climate-related risks.

Typhoon Haiyan (Yolanda) was the most severe tropical cyclone to ever make landfall in the Philippines (right - NASA satellite image on November 7th 2013). Maximum wind speeds peaked at 88m/s (197mph) and a storm surge produced wave heights reaching 5-6m above normal in some regions of Leyte. Yolanda caused widespread devastation, killing over 6,300 people and displacing over four million others. Lin et al. (2014) highlight three critical factors that contributed to the intensity and damage of Typhoon Yolanda: warm water accumulation, the fast traveling speed and the rapid increase in sea level over the past two decades. Subsurface ocean warming contributed to the storm's high intensity, and the travelling speed was 9m/s; the long term (1970 to 2011) average is 5m/s.



Scope of the literature review

The review discusses key results from studies examining past and projected future climate extremes in the Philippines, with a focus on tropical cyclones. Information from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), peer-reviewed scientific papers and relevant non peer-reviewed studies is summarised.

The review aims to:

- Assess the availability and reliability of regional climate information to support the reconstruction effort following Typhoon Yolanda
- Summarise information on past and future changes in tropical cyclones and sea level in the Philippines
- Identify the main constraints and opportunities for providing further information on future changes in tropical cyclones using Regional Climate Model experiments

Tropical cyclone activity in the Philippines

A tropical cyclone (TC) is a persistent synoptic-scale low pressure system originating over warm waters, with organised convection and a mean windspeed of at least 17.5m/s (39mph); it is a "typhoon" if the mean windspeed is above 33m/s (74mph). The main development region in the Western North Pacific (WNP) is 5 to 20°N and 135 to 180°E. Activity reaches a maximum between July and October and a minimum between January and April. From 1950 to 2013 over 1,000 TCs entered the Philippine Area of Responsibility (PAR), with an average of 17 TCs (12 typhoons) per year (Met-Office, 2014). About 7 TCs (5 typhoons) make landfall each year, typically towards the end of the main TC season.

Factors influencing tropical cyclones in the region

Sea surface temperatures (SSTs) of at least 27°C are required for TC genesis (Elsner et al., 2008). TC activity is also controlled by the spatial pattern of tropical SSTs as well as the strength of the ocean and atmospheric circulation. TC tracks are influenced by the genesis location, which varies throughout the year (see figure 1). There is also considerable year-to-year and longer term variability in WNP TC activity. These variations are dominated by key modes of ocean-atmosphere variability such as the El Niño Southern Oscillation (ENSO), Madden-Julian Oscillation (MJO) and Pacific Decadal Oscillation (PDO). ENSO and the MJO jointly explain 30-45% of TC activity variance within the instrumental historical record (Frank and Young, 2007). Furthermore, during the low phase of the PDO the number of landfalling TCs in the Philippines decreases significantly in an El Niño year and increases in a La Niña year. Warmer SSTs associated with El Niño events can increase the intensity of TCs but genesis locations move further southeast than usual. TCs therefore usually have longer lifetimes but are more likely to recurve northward avoiding the Philippines. During a La Niña TCs form further northwest than usual resulting in a straighter track increasing the landfall risk in the Philippines (Yonekura and Hall, 2014).

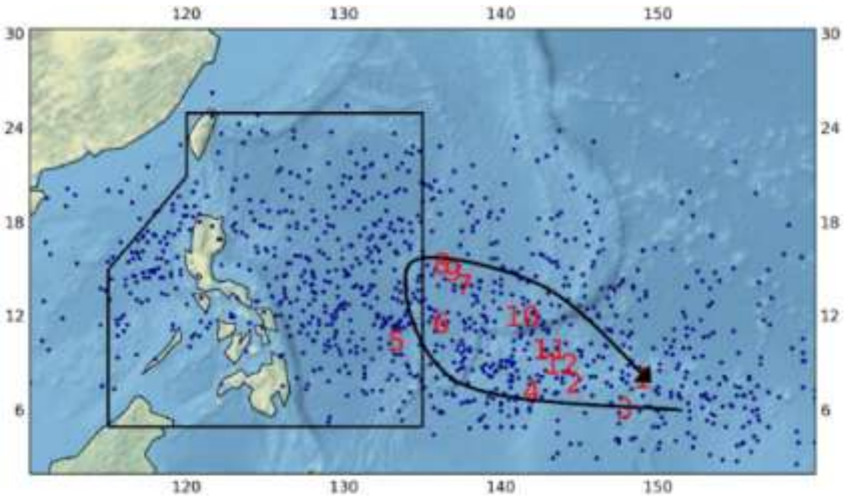


Figure 1: Monthly-mean genesis locations (red values) of tropical storms that pass through the PAR, 1950-2013. A red value of 1, for example, corresponds to the mean genesis location of tropical storms that formed in January. The black line indicates the general direction of tropical storm genesis during the year in a roughly clockwise direction. Blue dots show individual genesis locations of storms. Reproduced from Met Office report (2014).

Historical climate datasets

There are four primary “Best Track” datasets available for the WNP basin with data going back to the 1950s. Some inconsistencies are apparent between these datasets regarding historical trends of TC intensity (Song et al., 2010). In addition, the International Best Track Archive for Climate Stewardship (IBTrACS) is a freely available global dataset that has been used to study TCs in the Philippines.

PAGASA currently operates 59 weather stations in the Philippines and, through the “ICT For the Environment” programme, it will soon be deploying a further 80 automated weather stations and 100 automated rain gauge stations. A number of gridded observed datasets are also available, such as the CRU TS3.10 and APHRODITE datasets. Fifteen radars have been installed by PAGASA, though not all are operational as some are still in construction and one radar (in Guiuan) was damaged by Typhoon Yolanda (ESCAP-WMO Typhoon Committee, 2013).

Data for 25 tide-gauge stations is currently supplied to the Permanent Service for Mean Sea Level (PSMSL) by the Philippine National Mapping and Resource Information Authority (NAMRIA). The tide-gauge in Manila has provided data since 1902. Sea levels are also monitored by satellite-based radar altimeters. The TOPEX/Poseidon, Jason-1 and OSTM/Jason-2 satellite altimeter missions provide global coverage of the world’s oceans (between 66°N and 66°S) every 10 days.

Future climate datasets

The fifth phase of the Coupled Model Intercomparison Project (CMIP5) provides output from approximately 40 state-of-the-art Global Climate Models (GCMs). These data were used in an atlas of regional scale projections in the IPCC AR5 report (e.g. figure 2). Downscaled regional climate projections, using Regional Climate Models (RCMs) or statistical downscaling, provides an additional layer of climate information that aims to account for sub-grid scale processes and finer scale features that are not well represented in GCMs. For example, the SEACLID / CORDEX-SEA programme is downscaling a number of CMIP5 GCMs for the Southeast Asia region using four RCMs: RegCM4, CCAM, PRECIS and WRF.

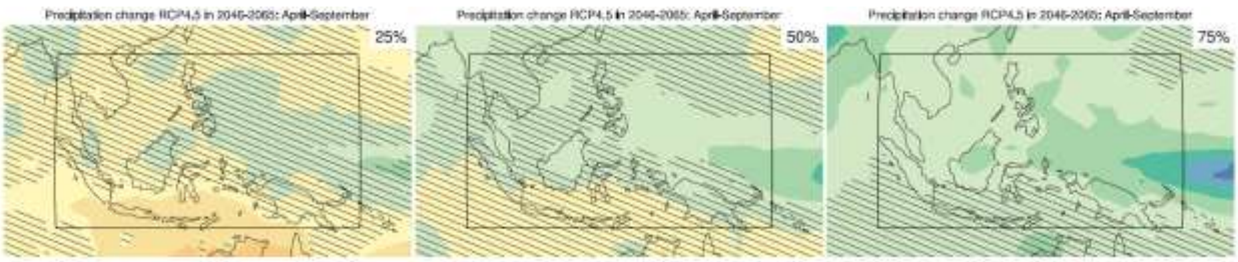


Figure 2: Map of April to September mean annual total precipitation change between 1986-2005 and 2046-2065 under the RCP4.5 scenario. For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown; this includes both natural variability and inter-model spread. Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-year mean differences. Reproduced from van Oldenborgh et al (2013).

Past trends in tropical cyclone activity

Time series analysis of WNP TC datasets show a weak upward trend in TC activity since the 1970s (Hijioka et al., 2013). Kang and Elsner (2012) found that more recently, between 1984 and 2010, there has been a trend towards fewer but more intense TCs in the region. However, Kubota and Chan (2009) found no significant trends in TC activity between 1902 and 2005 west of 150°E over the WNP nor any trends in the number of landfalling TCs in the Philippines.

Key issues in modelling tropical cyclones

The intensity and size of simulated TCs depends crucially on model resolution. Bengtsson et al. (2007) found that the typical size of a TC is reduced by a factor of 2.3 from a T63 resolution (approximately 200km) compared to a T319 resolution (approximately 45km). Strachan et al. (2013) and Rathmann et al. (2014) show that a high resolution is critical for simulating storm intensity but less important for simulating the annual number of TCs and their geographical distribution, finding that GCMs can provide reasonable statistics for these quantities in the present day climate. A key unresolved question is whether GCMs can reliably quantify future changes in the statistics of TC numbers and their geographical distribution.

There are additional issues in simulating TCs other than model resolution. TC activity is influenced by a range of environmental factors, including SSTs, vertical wind shear and tropical atmospheric circulation. Strachan et al. (2013) state that mid-level relative humidity and low-level absolute vorticity are the dominant factors contributing to TC variability in the WNP. Biases in the representation of such factors by climate models affect simulated TC behaviour. Brown et al. (2015) draw attention to significant biases in patterns of tropical Pacific SSTs in the coupled atmosphere-ocean CMIP5 GCMs, which most likely affect patterns of future warming. Also, atmospheric models forced with prescribed SSTs cannot represent the dampening of TC intensity through TC-induced cooling of the underlying sea surface (Rathmann et al. 2014).

Future projections of climate and tropical cyclone activity

According to the IPCC AR5 report, the Philippines is projected to warm by 0.5 to 1.5°C (25th to 75th percentiles of the multi-model distribution) by mid-century. Projected changes to rainfall in the region range from a 10% decrease to a 20% increase by mid-century in Luzon (25th to 75th percentiles of the multi-model distribution) and a 0% to 20% increase by mid-century in the Visayas and Mindanao (25th to 75th percentiles of the multi-model distribution).

Overall confidence in projecting future TC activity is low and different modeling studies disagree on the sign of projected changes. The IPCC AR5 shows a tendency for decreased overall TC numbers and an increase in the number of intense (category 4 and 5) TCs in the WNP; an increase in the frequency of the strongest storms is considered “more likely than not” (IPCC, 2013). Modelling studies that can produce very strong TCs typically project increases in the frequency of the most intense TCs of between 2 and 11% by 2100 in the WNP (Emanuel et al., 2008, Bender et al., 2010, Knutson et al., 2010a,b, Murakami et al., 2012) and increases in the lifetime-maximum wind speeds of the strongest storms have also been projected (Elsner et al., 2008). There is more confidence that precipitation totals associated with TCs will increase. High resolution modeling studies project increases of up to 20% in the precipitation rate within 100 km of the TC centre (IPCC, 2013). The IPCC AR5 does not provide any information on changes to landfalling TCs in the Philippines. There is some evidence that climate change may bring more El Niño like conditions. This could lead to more intense TCs in the region but also favour TC formation further south-east, lowering the risk of TC landfall in the Philippines. Moreover, Typhoon Yolanda and other recent events show that La Niña conditions can also support intensification in the WNP.

Changes to sea level and storm surge risks

The global average sea level is estimated to have risen by approximately 22 cm between 1870 and 2014, primarily due to thermal expansion of the ocean and increased melting of land-based glaciers and ice sheets. Between 1993 and 2012 the sea level in the WNP increased at a rate of 10mm/year, a rate approximately three times the global average of 3mm/year. The difference is due to regional factors, such as the influence of natural modes of ocean variability on regional ocean circulation patterns; there has been an observed increase in the strength of trade winds, raising the sea surface height in the WNP. In Manila the sea level increase has been compounded by human-induced land subsidence (e.g. due to extensive groundwater extraction) of up to 1 metre per decade over the same period.

Globally, the IPCC projects a sea level rise of between 0.52 and 0.98 metres by 2100 and an increase in the rate (presently at 3mm/year) to between 8 and 16 mm/year (Christensen et al., 2013). However, future sea level projections exhibit significant regional variations (Meyssignac and Cazenave, 2012). There are limited studies in the WNP region and there are currently no reliable projections of regional scale sea level rise for the Philippines. The IPCC states, with high confidence, that storm surge risks will increase with sea level rise at the global scale but there is low confidence in region-specific projections. The height of future surges will depend on regional sea level variations, TC intensity changes and the changing nature of coastlines.

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The literature review constitutes an initial phase of the DFID funded project. Building on the information gathered in the review as well as insights gained through further work in developing stakeholder relationships and understanding the needs of decision makers in the Philippines, the project will develop new science to improve understanding of tropical cyclone risks and climate extremes. Ultimately the project aims to inform decisions to increase resilience to climate risks and improve livelihoods in the Philippines.

Further work in the project will:

- Conduct high resolution climate model experiments to improve our understanding of tropical cyclone risks in the Philippines
- Explore the multiple related impacts that affect vulnerability and exposure to climate risks in the region, including sea level rise, extreme winds and intense rainfall
- Enhance the interactions between PAGASA, the Met Office and different stakeholder groups to develop climate products that help address climate risks and improve resilience

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