Philippines Catastrophe Risk Assessment and Modeling: Component 3

Responses to Peer Review Comments from Geoscience Australia

February 26, 2014

AIR WORLDWIDE

adpc

Copyright

Trademarks

Confidentiality

Contact Information

If you have any questions regarding this document, contact:

AIR Worldwide Corporation
388 Market Street, Suite 750
San Francisco, CA 94111
USA
Tel: (415) 912-3111
Fax: (415) 912-3112

Peer Review by Geoscience Australia and AIR Responses

The Terms of Reference (ToR) for the Philippines Catastrophe Risk Assessment and Modeling study being conducted by AIR Worldwide Corporation (AIR) for the World Bank on behalf of the Government of Philippines require under Component 3 a peer review of the work being conducted by AIR. The World Bank has retained Geoscience Australia (GA) for the peer review. As part of the peer review process, AIR provided GA with technical documentation on the underlying AIR catastrophe risk models and comprehensive presentations on the work being carried on the project by AIR. This report addresses peer review comments from GA, received October 30th, 2013 and December 17th, 2013 in the following areas:

- Industry Exposure Database
- Government Asset Database
- Earthquake Hazard
- Earthquake Vulnerability
- Typhoon/TC (Wind and Rainfall) Model for the Philippines
- Wind Damage Functions
- Flood Damage Functions

The comments from GA are included below without any edits to the same. AIR's responses to the specific comments are provided immediately following each comment, in red text, to facilitate a read of this report. For reference, a copy of the presentation that AIR/ADPC delivered to GA is included as an Appendix to this document.

PEER REVIEW OF PHILIPPINES CATASTROPHE RISK ASSESSMENT PROJECT

EXPOSURE DATA DEVELOPMENT

SCOPE OF REVIEW

Based on the information provided to Geoscience Australia by the World Bank and AIR Worldwide, the scope of this review is limited to a high level review and comment based on presentation material on:

- Overall methodology for exposure data development;
- Opportunities for data development from accessible input datasets;
- Comparisons with existing exposure information development in the Philippines.

OVERALL COMMENTS

The development of the Industry Exposure Database and Government Asset database for the Philippines is understandably challenging, given the limited public data and difficulties in obtaining suitable data from agencies and custodians. From the material presented, the approach seems sensible, and aspects of it align very well with Geoscience Australia's exposure information development methodologies. From the material presented, there seems to be some underestimation of the highly vulnerable informal settlement areas, which can significantly contribute to the building stock in some parts of the Philippines. This is detailed in the sections below. There are also some unanswered questions about the data development and distribution, which would be useful to consider for data maintenance and enhancement in the future.

INDUSTRY EXPOSURE DATABASE

Occupancy Class of buildings

Information on buildings is current grouped into four main occupancy classes:

- Residential dwellings;
- Commercial establishments;
- Industrial establishments;
- Government (public) establishments.

This schema for grouping building occupancy types provides a good, generalised method of categorising building types. It may be possible to improve the clustering of the occupancy types into more distinct land use classifications. These classifications could group specific land uses together, such as for Education, Health and Welfare, Government, Waste Management, Flood Control, Road Transport, Air Transport and others.

AIR Response: In regards to the Industry Exposure Database (IED), AIR obtained data from the Philippines National Statistics Office, which contains establishment count splits by the following industries: wholesale and retail trade; accommodation and food; information and communications; financial and insurance activities, real estate activities; technical activities; administrative and support services; education; human health and social work; arts, entertainment and recreation; other services; mining and quarrying; manufacturing; electricity, gas steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; and transportation and storage. Sufficiently detailed land use data was not available to explicitly split out the classifications as listed, so they were grouped into the general commercial and general industrial occupancies.

In regards to the National Government Asset Database, assets are grouped into the following types and are explicitly indexed as such in the database: Road, Light Rail, Bridge, Airport, Prison, Public Administration Building, Public School, Port, Public University, Power Plant, Rail, Government Hospital, Government Medical Facility, and Residual Institutions. Furthermore, certain asset types are further identified with more detailed subtypes, such as “Secondary” and “Elementary” School.

There is no mention of informal settlers in the Occupancy Classes for the Exposure Database. In some areas of the Philippines, and particularly in the urban centres, informal settlements contribute significantly to the residential building stock. It may be appropriate to distinguish between the formal and informal residential dwelling types.

AIR Response: Informal settlement assets are not classified as a separate occupancy, but rather included in a separate construction category, which is referred to as "non-engineered" construction. These do indeed contribute significantly to the dwelling count as indexed by the IED, but not significantly to the overall replacement cost, mainly due to their low replacement value.

Buildable Land estimation

The estimation of buildable locations through the Buildable Land algorithm seems to be a very good approach to constraining the data disaggregation, especially for large scale for estimating land areas capable of carrying development.

It is not possible to comment on specifics of the technique without more detailed descriptions of each layer's development. The accuracy of the result of this method may be dependent on the resulting masks for:

Elevation

An elevation mask may not be required for the Philippines case, as its topography and climate is unlikely to restrict human settlement.

AIR Response: In the Philippines, no grid cells reached the threshold typically used to mask out areas due to elevation (5,000 meters).

Land Use/Land Cover (LULC)

The accuracy of the land cover classification would be driven by:

- The spatial resolution of the input imagery;
- The selection of training sites for supervised classification;
- the accuracy of the spectral analysis for the supervised classification.

It is assumed that this mask eliminates areas that cannot carry development. However, there may be some differences between areas of 'hard' constraint (such as protected areas, where development is not permitted) and areas of 'soft' constraint (where there are restrictions on the type and quantity of development, due to zoning regulations or land use opportunities). The inclusion of 'hard' and 'soft' constraints might result in a more realistic spatial and statistical distribution of buildings. This would be of particular importance in rural areas, where the building stock is likely to be widely distributed over large areas, some of which would have limited development opportunity.

AIR Response: For land use, the primary dataset is NASA's 500 meter resolution 2012 MODIS Global Land Cover dataset. AIR uses this dataset in other models and has found it to be one of the most accurate sources of global land cover data available. In addition, the MODIS data was augmented with other data sources such as water body data provided by GFK Marketing. An algorithm has been developed which uses the geo-spatial data to distribute exposure. The exposure masks (which are not always complete masks) are developed with different levels of constraints based on this algorithm. Thus, both "hard" and "soft" constraints are somewhat imbedded into the exposure distribution algorithm.

<u>Risk Location Probabilities</u>

<u>Impervious Surface Data</u>

We understand the Impervious Surface Data is derived from analysis of night light data over the Philippines. Where urban areas, are well lit, this can be a useful indicator of impervious surfaces. It is not clear whether this data would identify the informally settled areas, which may not exhibit the same brightness as formally settled areas. It is possible that this technique may therefore underestimate the spatial extent of impervious surfaces.

AIR Response: The National Geophysical Data Center uses supplementary data, such as population data, in addition to night time lights to create the ISA, which typically accounts for densely settled areas that lack bright night time lights. Spot checks were performed on some large informal settlements, such as the BASECO area in Manila, and significant biases were not observed. Additionally, residential data was disaggregated at the Municipality Level (over 1,600 divisions for the

Philippines), which is the highest resolution readily available from the Census data. Thus, the residential exposure distribution is deemed precise, at minimum, at the Municipality Level.

STRUCTURAL TYPES

One common building type that is absent from the structural types is the Half Wood – Half Concrete buildings. These are typically 2 storey buildings constructed with reinforced concrete blocks on the ground floor and wooden walls on the upper floor. There are also variants with unreinforced masonry/blocks for the ground floor.

AIR Response: Prior to defining structural categories, AIR performed a thorough review of the engineering and construction literature in the Philippines. Reports such as “Development of Vulnerability Curves of Key Building Types in the Philippines” from the UPD Institute of Civil Engineering indicate that half-wood/half-concrete buildings are generally of low quality and high vulnerability. In order to best represent the vulnerability of these structural types for catastrophe risk modeling purposes, AIR typically classified them as Unreinforced Masonry.

In the Construction Distribution by Replacement Cost comparisons for Legazpi City, the comparison shows Unreinforced Masonry buildings are significantly underestimated. As these buildings have the potential to be highly vulnerable, this underestimate could have implications for economic loss computations.

AIR Response: In general, AIR found that the IED compares favorably overall to the Legazpi study. There are a few possible reasons for the perceived difference noted in the unreinforced masonry category. First, the survey was conducted some years back, and AIR believes that more reinforced masonry and concrete buildings have been built since then. Second, the plot presented compares the IED construction distribution for the entire city of Legazpi to the small survey area that appears to contain a significant amount of lower quality housing. Consequently, the construction distribution found in the survey area could differ substantially from the construction distribution of Legazpi City as a whole. On a side note, in the comparison made to Iloilo City, AIR found that IED had a greater concentration of unreinforced masonry than the study indicated. Consequently, it is AIR’s view that the IED does not significantly underestimate the prevalence of unreinforced masonry in general.

There is no mention of the method for spatially distributing the non-engineered structures found in informal settlers. The informal settlements in urban areas such as Metro Manila are not evenly distributed across the urban footprint.

AIR Response: The non-engineered structures were first classified at the Municipality Level using wall type, roof type, and year built information from the Census, along with information from reports such as Geoscience Australia's "Strengthening Natural Hazard Risk Assessment Capacity in the Philippines". In addition to AIR's algorithm for distributing exposure, some informal settlements (such as those in Metro Manila) were disaggregated to the ≈1km^2 resolution using geo-referenced polygons that were manually delineated with satellite imagery.

GOVERNMENT ASSET DATABASE

Public Roads

The inclusion of Primary and Secondary Roads was a feature of the Roads data, but there is no indication of whether local roads (such as for local access to suburban residential areas) was included. It may be possible to capture local road centreline data in different urban and rural settings and calculating a mean length of road per unit area for different settings. These values will clearly be highest in dense urban areas and lowest in remote rural areas. The mean values for different land use types can then be used to estimate of local road length in all areas of the country.

AIR Response: Since the scope of the government asset database was to focus on nationally-owned assets, only paved "national primary" and "national secondary" roads were included in the final database (about 30,673 km of paved roads). These road types are defined by the Department of Public Works, from which AIR and ADPC obtained the raw data. AIR noted that many kilometers of local and rural roads do exist in the Philippines (most of which are not paved - see table below), but these were considered outside of the project scope.

Total Road Lengths and Paved Road Ratio, by Classification (Adapted from Cabral, 2009)

Classification	Reported Paved Length (km)	Reported Unpaved Length (km)
National Arterial	12,292	3,267
National Secondary	8,286	5,524
Provincial Roads	7,821	23,463
City Roads	5,430	1,622
Municipal Roads	5,373	10,430
Barangay Roads	8,539	113,450
TOTAL	47,741	157,756

Other Assets

The Philippines Geoportal is now publically available and is displaying numerous spatial data layers that can be interrogated. Was the Philippines Geoportal considered for locations/types of assets?

AIR Response: AIR noted that the Philippines Geoportal became publically available towards the end of the database development. As such, a systematic processing of the Geoportal data was not performed.

However, the Geoportal was used to some extent to cross-reference and validate some of the asset types considered in the AIR database.

Referencing data from other studies

It is noted that data from MMEIRS was used to supplement Department of Health data. Some MMEIRS datasets are quite old now, and known to be incomplete and erroneous, so reliance on that data could introduce errors.

AIR Response: The MMEIRS data was mainly used for cross-validation of the other datasets. In fact, only about 100 of the 46,600 schools included in the final AIR database use MMEIRS as the primary data source. For hospital, no entries used MMEIRS as the primary data source.

OTHER POTENTIAL SOURCES OF DATA

No mention is made of the data and information available through community contributed mapping in Open Street Map, and other sites such as Wikimapia. While the completeness and consistency of community mapping can be variable, the mapping may provide locations of facilities where government data is insufficient. For example, in the case of missing schools in the DepEd datasets, Open Street Map shows the location of many public and private elementary, secondary and tertiary facilities.

AIR Response: Open Street Map, Wikimapia, and several other public data sources (including GeoNames) were fully reviewed and considered during the database development. Although these were not used systematically, typically due to the lack of completeness and consistency, they were leveraged to cross-reference and help improve some of the other data sources used.

ADDITIONAL QUESTIONS FOR THE EXPOSURE DATABASE DEVELOPERS:

1. Is the scale of the final scale of the exposure database sufficient for analysing risk from flood, landslide, tsunami and other hazards with specific extents?

   AIR Response: The industry exposure was developed at a resolution appropriate for only the perils and the level of detail agreed upon for this study. The 1-km grid is sufficient for the earthquake shaking and typhoon wind perils. For the non-tropical cyclone precipitation, it was agreed that the hazard would be developed at a very coarse resolution because time constraints of the study would not allow for a full riverine flood model to be developed. It is recognized that this may pose limitations for analyzing any flood-related perils as well as using this exposure for other perils outside the scope of this study (e.g. tsunami, landslide, etc.). This limitation can be addressed in future studies.

   The government asset database typically includes the location at the site level (when available), especially for high value assets. Only some datasets, namely roads and rail, were aggregated to the ≈1km^2 for modeling purposes. When accurate location data was not available, government assets were aggregated to settlement locations or approximate population centroids of given administrative boundaries. Thus, with the available data, the resolution is deemed appropriate for portfolio loss analysis. For single location analysis, the accuracy may result in higher modeling uncertainty for some perils. However, the government database explicitly indicates the level accuracy of the location data for each entry.

2. How has the team dealt with mismatches between the land use data from global datasets and the actual settlement patterns (given that informal settlements often develop in areas that are most vulnerable and also very opportunistic)?

   AIR Response: AIR considered several land use datasets that were available for the Philippines, and concluded that the 2012 MODIS dataset was the most accurate and appropriate for model development. Overall, this dataset was found to match settlement patterns reasonably well based on spot checks with satellite imagery. AIR did not find any major areas that were significantly inaccurate that required manual adjustment to the MODIS data.

3. Does the residential category distinguish between, or allow for, formal/informal settlements to reflect difference in building/population densities, or is only the vertical density considered?

   AIR Response: The IED contains a construction category called "non-engineered" that includes informal settlement buildings. To disaggregate residential buildings, AIR used high resolution (Municipality Level) housing counts, and disaggregated them to the ≈1km^2 grid using a combination of land use, slope, and Impervious Surface Area (ISA) data. The final density of risks will vary based on these data sets.

4. Did the team experience discrepancies and mismatches with LGU/Barangay geographies between datasets, and how did you resolve these?

   AIR Response: AIR used different vintages of Municipality Level data, and some discrepancies were noted between the boundary geographies. For example, the vintage of the main GIS administrative boundary data used is from 2006 to 2008, while the underlying exposure data vintage is generally from 2000 to 2010. Since 2008, the political boundaries in the Philippines have changed, most notably the now defunct Shariff Kabunsuan Province. AIR Worldwide and ADPC considered these changes and carefully mapped data to the GIS defined boundary layer. Some assumptions, such as aggregation and distribution by population density, were made for certain regions.

5. What inputs are used to estimate the high rise areas, and how does the team rate the accuracy of these estimates?

   AIR Response: Publically available data (e.g., from emporis.com and skyscraperpage.com) were used to identify cities that were likely to have large high-rises, and high resolution satellite imagery was used to manually locate major high-rise buildings in these areas. In addition, other data/literature was used when available (such as MMEIRS and a 2003 Vibrametrics Survey), which contained information about the height distribution of buildings.

After combining these datasets, AIR felt that the final distribution of high-rise buildings was reasonably accurate for modeling purposes.

6. What are the sources of data used to derive the numbers of buildings with the Commercial, Industrial and Government (Public) occupancy types?

   AIR Response: Commercial and industrial risks were derived from the National Statistics Office's Annual Survey of Philippine Business and Industry as establishment counts by industry. The government asset data sources vary by asset type, and are described in detail for each asset type in the Component 2 Report.

7. Is the data for Gross Capital Stock available at the sub-national or local level? If so, can this be used as a form of data validation?

   AIR Response: Gross Capital Stock data was available nationally. This data was used as an independent validation of the IED valuation for the entire country.

8. Did the exposure information for roads include any actual or estimated data on local roads (i.e. those roads not maintained by DPWH but found in suburban areas, subdivisions etc.)?

   AIR Response: Explicit road data in polyline form was obtained from the DPWH and is defined as "national primary" and "national secondary" roads by the DPWH.

9. Was any attempt made to develop spatial data reflecting the construction date of buildings, or the proportions of buildings constructed within certain time periods?

   AIR Response: When available, construction date data was included in the government asset database (for example, the DepEd data for schools includes some age-built information). When age information is not available, assets are assigned "unknown year", which, for the purposes of vulnerability, is modeled as a weighted average of the year-built for a given class. For the IED, year built was not included in the database, and every asset is assigned "unknown year". However, research was done to estimate construction year statistics for buildings in different parts of the Philippines. These statistics are used in the vulnerability module, which assigns assets with "unknown age" a weighted average damage function based on the construction year statistics.

10. What is the finest scale at which the exposure data is managed? Is there a level of accuracy or variability assigned at the 1km grid scale to recognise the variability with in the grid? Are results going to be reported at Barangay level or Local Government Unit (LGU) level?

    AIR Response: The IED resolution is built on a uniform 1/120 decimal degree (≈1km^2) grid. The government asset database resolution is at the exact site location, when data was available, or aggregated to other resolutions as the data permitted (refer Component 2 report for more detail). Results will not be reported finer than the Municipality Level (e.g., they will not be reported at the Barangay level or Local Government Unit (LGU) level).

11. Did the exposure team approach agencies such as the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the Philippines Atmospheric, Geophysical and Atmospheric Services Agency (PAGASA), the National Mapping and Resource Information Authority (NAMRIA) and the National Statistics Office (NSO) for data, information and/or advice on data products?

    AIR Response: AIR and ADPC reached out to most of the main pertinent official agencies in the Philippines, including those mentioned above. In general, the response from such agencies was minimal.

12. Will the Government of the Philippines and/or the public have access to the Industry Exposure Database and/or the Government Asset database at the completion of the project?

    AIR Response: The IED will not be distributed as it is proprietary to AIR, although certain information from the IED has been provided to the World Bank for the purposes of responding to Haiyan. The government asset database has been released to the World Bank, and they would be able to distribute it to any stakeholders they are willing to release it to.

EARTHQUAKE HAZARD

The report summarizes the procedures followed to compile several databases that can be used to estimate the level of seismic hazard/risk in Philippines. All the compiled databases are based on existing information, and are developed by either merging data from different sources (e.g. historical earthquake catalogue) or from just a single available database (e.g. Vs30 database). Overall it is a well written overview of the compiled databases, but based on the information provided in the presentation it is not feasible to provide a detailed technical review and assess the quality of the outcomes of this study.

AIR Response: Note that for Component 1, the main objective was to collect and process existing public data. The project uses, in part, an existing earthquake model for the region. Thus, the data described in Component 1 was not necessarily the direct inputs into the EQ hazard module. Rather, this data was used to validate the stochastic catalog and update various components of the hazard module. More information on the EQ hazard, primarily regarding the stochastic catalogue, can be found in the AIR Southeast Asia Earthquake Model Documentation.

Here are some general comments:

1- As indicated in sections 5.5 and 5.6, models for seismic sources are from Torregosa et al. (2001 & 2002). If data from Torregosa et al. are used to develop PSH map of Philippines, then what is the use of compiled earthquake catalogue (section 3.1)?

   AIR Response: The data from Torregosa et al. (2001 & 2002) is included to illustrate existing publically available data on seismic source zones. The PSH maps are developed primarily from the stochastic catalog, which uses a combination of seismicity modeling techniques, including historical seismicity data, seismic source zone data, fault data, and kinematic modeling. Refer to the AIR Southeast Asia Earthquake Model Documentation for more information on the development of the stochastic catalog.

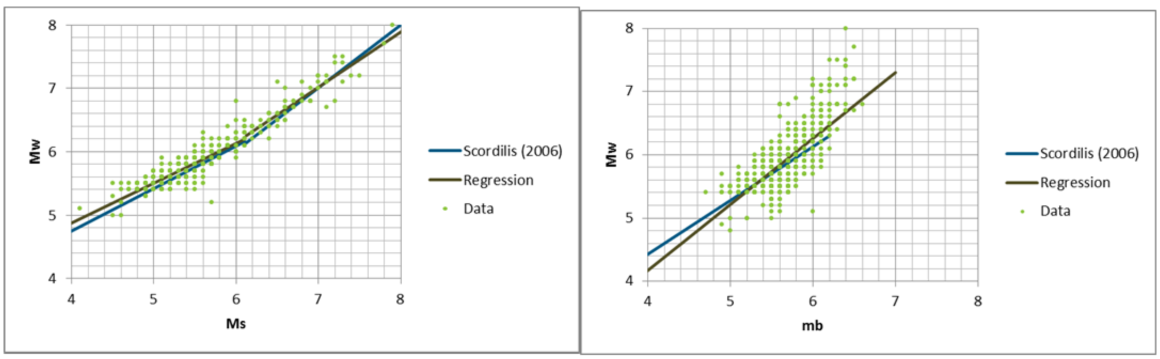
2- It is not quite clear how the catalogue is processed, for example:

   a. How the spatial variation of the magnitude of completeness is taken into account?

AIR Response: Overall completeness of the entire historical catalog is estimated and discussed in the Component 1 Report. However, completeness time in the catalog varies for different regions. The spatial variation of the magnitude of completeness is taken into account in the development of the stochastic catalog.

b. Are the developed conversion equations significantly different from those developed by Scordilis (2006)

AIR Response: The difference between the conversion equations developed for Component 1 and those developed by Scordilis (2006) are shown in Figure 2 in the Component 1 Report (and also shown below for convenience).



Regression-Based Magnitude Relationships Developed from USGS PAGER-CAT Data in the Philippine Region along with Previously Published Relationships (e.g., Scordilis, 2006)

c. Is focal mechanism information also included in the final catalogue?

AIR Response: Focal mechanism information is not included in the final historical catalog. However, focal mechanism information was considered and explicitly modeled in the stochastic catalog.

3- Regarding the compiled data-base for earthquake losses, is the loss information disaggregated based on the responsible sources (ground-shaking, landslide, Tsunami, etc.)

AIR Response: Due to the general lack of explicit disaggregation of sub-peril damage in the literature, the consequence database does not systematically disaggregate the losses by sub-peril. However, a tsunami/landslide flag is given for each event in the database. Events that have a report of a tsunami or landslide are flagged. Also, events with reported destruction from a tsunami or landslide (e.g., those that caused reported deaths, injuries, and/or damage) are flagged. In addition, the raw source data is provided for each event, and the disaggregation can be easily investigated per event. For example, some raw datasets, such as the NGDC/WDS and PAGER-CAT data, occasionally indicate the estimated consequence of the effect of ground shaking only (and tsunami only) for some events.

4- In the presentation:

a. Which GMPE(s) is used for subduction interface and intra-slab tectonic regimes? All listed GMPEs in the presentation are for active shallow crust.

AIR Response: For deep subduction events, a combination of the attenuation relationships of Youngs et al. (1997), Atkinson and Boore (2003), and Zhao et al. (2006) was used with appropriate weighting factors. For deep intra-slab events, a combination of the relationships of Youngs et al. (1997) and Atkinson and Boore (2003) was used. These GMPEs were not listed in the presentation but were used in the analysis and will be provided in the final report.

b. How the epistemic and aleatory uncertainties are captured?

AIR Response: Aleatory uncertainty of the hazard is accounted for by the stochastic catalog and by propagating ground motion uncertainty (both inter- and intra-event) using Monte Carlo simulation. Epistemic uncertainty (i.e. modeling uncertainty) is not currently being accounted for explicitly due to lack of comprehensive and reliable uncertainty parameters.

c. How the GMPEs are selected and modified?

AIR Response: As there is no currently published standard GMPEs for the Philippines, multiple GMPEs were reviewed as candidates for computing intensities generated by crustal earthquakes. Several Japanese GMPEs – specifically, equations developed by Fukushima and Tanaka (1990) and Torregosa et al. (2001) – have been proposed for use in the Philippines because they are based on regional ground motion recordings. Modern U.S. GMPEs (e.g. the Pacific Earthquake Engineering Research Center's Next Generation Attenuation - PEER NGA - equations) have also been used by previous researchers to assess local hazard within the Philippines due to certain tectonic similarities between the Philippines and the western US.

Ultimately, the PEER NGA GMPEs [Abrahamson & Silva (2008); Boore & Atkinson (2008); Campbell & Bozorgnia (2008); Chiou & Youngs (2008)] were selected to calculate earthquake intensity of ground shaking for crustal events. Although the Japanese GMPEs are considered regional, they are still not based on Philippine specific recordings. The PEER NGA equations were developed more recently than the other candidate equations and are derived from a much larger database of ground motion recordings. Further, the NGA GMPEs use the average shear wave velocity in the upper 30 meters of sediments, VS30, as a parameter for characterizing the effects of sediment stiffness on ground motions. Using VS30 in place of generic soil and rock categories differentiates shaking intensities between stiff and softer soils. Lastly, the PEER NGA equations can output spectral accelerations at different fundamental periods, whereas, the Japanese equations only compute peak ground acceleration (PGA). Converting PGA to spectral accelerations at different periods is a highly uncertain process.

VULNERABILITY

The damage functions for Philippine buildings are analytically developed and validated with empirical data. The base damage functions are developed for post 1992 built low-rise masonry and concrete buildings in Philippines. The damage functions for other building classes are further developed by assessing their vulnerabilities relative to the base models. The methodology seems appropriate given the fact that there is not much of data available at the moment.

Item specific comments are presented below:

Building vulnerability classification (slide #101):

1. In the building classifications there seems to be no construction class for makeshift buildings which are abundant in informal settlement area in Metro Manila. The vulnerability of makeshift buildings is believed to be higher than that of wood buildings.

   AIR Response: The referenced slide (#101) was incomplete. Makeshift structures are accounted for by the model. A weighted average of other construction types was used to quantify damage of these types of structures in the Philippines because these makeshift structures are often made of a combination of different materials. Engineering judgment was used to determine the weights.

Estimation of building response (slide #102)

- The pushover curves from EQTAP project are derived from experts' judgments. How do they compare with HAZUS capacity curves? As per NSCP 1992, majority of the Philippines should be designed as per UBC Zone 4, which corresponds to HAZUS High-Code. However the vulnerability of base building types is found to be similar to that of buildings in NW Pacific region of US, which corresponds to UBC Zone 3 and HAZUS Moderate-Code. The comparison of the capacity curves may give some insight on why the vulnerability of buildings in Philippines is found to be similar to that of buildings in NW Pacific region.

  AIR Response: In general, EQTAP capacity curves have higher strength (i.e. higher ultimate point values) when compared to HAZUS for the same building type. However, EQTAP capacity curves have capacity points that demonstrate lower displacements compared to HAZUS. This suggests that although Philippine construction is designed to high seismic loads they may not be as ductile as those in the U.S., which would make them more vulnerable to earthquake shaking.

- The pushover curves for two base building types (Masonry and Concrete) are available for other built-year categories. Did you use them to develop damage functions for other built-year categories?

  AIR Response: EQTAP capacity curves were used only to develop damage functions for buildings built post-1992. This is primarily because of the concern that EQTAP capacity curves are based on a survey conducted around 2003 and hence the information regarding old buildings may not be reliable. Relative vulnerability factors derived from AIR's database of damage functions were used to develop damage functions for other year-built categories.

Computation of mean damage ratio (Slide #104)

- Can you provide values of damage ratio for each damage state as well as reference for each of the base building types?

AIR Response: The damage ratios are as follows:

Damage State	Mean Damage Ratio
Slight	0.02
Moderate	0.10
Extensive	0.50
Collapse	1.00

The base building types are as follows:

Construction Class	Year Built	Height Classification
Concrete	Post 1992	Low-Rise
Masonry	Post 1992	Low-Rise

Relative vulnerability of buildings (Slide #106)

- The damage functions for other building types are developed by assessing their vulnerabilities with respect to the developed base damage functions. It is not clear how damage functions are developed for other built-year categories.

AIR Response: The damage functions for other built-year categories are developed in a similar fashion as the functions for other building types by estimating relative vulnerably factors using post-1992 construction as the base-case. The factors were computed by selecting functions from U.S. built-year categories that best represented the Philippine built-year categories based primarily on equivalent code provisions. For instance, functions for buildings built in the Philippines prior to 1972, when no seismic provisions were implemented, were mapped to U.S. damage functions that are used for buildings that have not been subjected to any significant seismic design.

- Details of uncertainty in damage functions need to be provided.

AIR Response: The uncertainty in the damage and loss estimation is quantified by assuming a peril-specific probabilistic distribution that AIR has derived from claims data taken from previous earthquake events. A probability distribution is fitted to represent the scatter observed in the available earthquake claims data that is based on the level of ground motion intensity and level of damage sustained. Monte Carlo simulation is then used to combine this dispersion with other sources of uncertainty that have been propagated from the hazard to obtain the overall uncertainty from all modules in the methodology.

- It is not clear whether contents damage is factored in damage function development.

AIR Response: Building contents (i.e. coverage C) is not explicitly included in the reported loss estimates for this study.

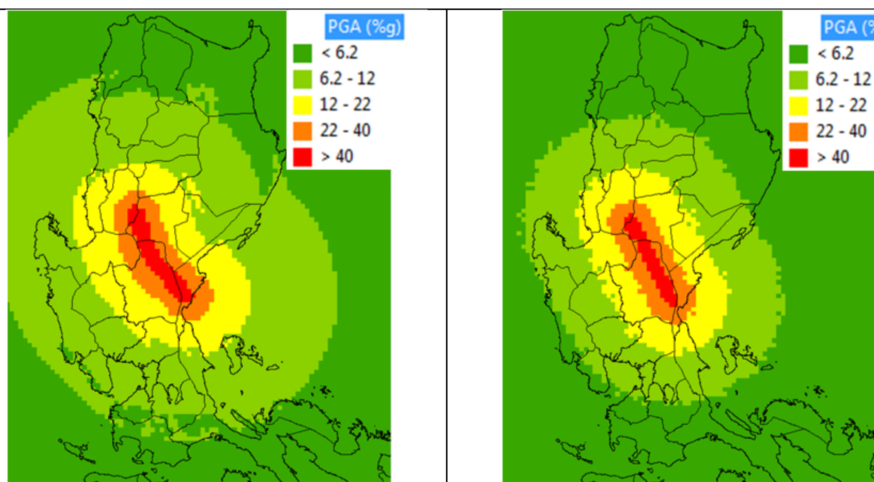
Validation (Slide #107~#108)

- The shake table test results are used to validate the damage function for masonry building. How did you estimate mean damage ratio of each of physical damage states of the test model? Is the estimate consistent with the relationship that you used in developing damage functions (slide #104)?

AIR Response: Slide #104 aims to provide a high-level qualitative comparison between the final damage function and experimentally observed damage. For each test, the peak ground acceleration was used to look up what corresponding mean damage ratio was computed using our resulting damage functions. The mean damage ratio was then compared to the damage states observed from the descriptions of the tested buildings to see if the damage function was predicting similar levels of damage. For instance, when the building built to prevailing construction practices was subjected to a PGA of 0.85g, the building collapsed. This was consistent with what AIR's derived damage function, which was computing a mean damage ratio close to 1.0.

- 1990 Luzon earthquake is simulated to validate damage estimates using the developed damage functions. The simulated damage estimates are in good agreement with the historical damage data. How does simulated ground motion compare with observed one? Is the assumed damage ratio for each of damage ratios (e.g., less than 2% for no damage) consistent with the relationship that you used in developing damage functions (slide #104)? Do you see the same level of agreement if you make comparisons by province?

AIR Response: Unfortunately, there is virtually no ground motion recording data close to epicenter available from the 1990 Luzon earthquake. One available point of comparison is the Shakemap computed by USGS. The figure below shows the comparison of the mean PGA values for Luzon 1990 earthquake provided by USGS Shakemap and simulated by AIR's model.



USGS Shakemap Atlas | AIR Simulated Mean

Although there may be some discrepancies in the fault segment rupture assumptions, in general, there is good level of agreement between AIR-derived and the USGS-derived ground motion intensities. Furthermore, macroseimic (human-felt) observations are available (e.g., Wakamatsu et al., 1992) and compare favorably to AIR's simulated ground motions.

The Cambridge Earthquake Impact Database provides data for three damage states for the 1990 Luzon earthquake: undamaged, partially damaged, and collapse. These damage states are broader than the damage states used to develop the base damage functions; however, they are generally consistent. The table below shows the used damage ratio based classification of reported damaged states, which is similar to the classifications used for the base damage functions:

Damage State	Assumed Damage Ratio	Corresponding Damage States used for Base Damage Function Development
Undamaged	Less than 2%	No Damage
Partially damaged	2% to 70%	Slight, Moderate, and Extensive Damage
Collapse	Greater than 70%	Extensive Damage and Collapse

It is recognized that mapping the assumed central damage ratio can introduce some level of subjectivity; however, an effort was made to formulate an unbiased validation using this data and the assumed damage ratios are deemed consistent with those used for damage states from the base damage functions.

Comments on the Typhoon/TC (wind and rainfall) model for the Philippines

Summary:

The nation-wide estimation of damages from TC's and non-TC rainfall for the Philippines is a challenging task. The general approach of this study appears to be reasonable, appropriate and robust for a nation-wide study of this nature, given the available data and the time-frame. Good use is made of available databases, including remotely sensed rainfall information, to get an idea of the spatial distribution of events, wind speed, rainfall and losses. However, few detailed descriptions of methodology and validation are provided, which prevents us from properly understanding and being able to assess the quality of the results.

The limited model validation that we have seen suggests that the modelled rainfall losses cannot be expected to be very accurate. This means that the uncertainties should be carefully considered when translating the study results into policy or business decisions. It is not clear to what extent these uncertainties have been quantified.

MODEL DEVELOPMENT-CALIBRATION:

AIR first develop a database of significant tropical cyclone and flood events from 1905-2013. It is based on reports from a range of databases / online information sources. About 520 events are included. For each event, it includes information on Deaths, Injuries, People Affected, Buildings Damaged, Buildings Destroyed, and other economic damages. This database is used to calibrate and validate hazard and loss models. This seems to be a good approach to support the modelling in this study.

The TC hazard / loss model is based on an updated version of the AIR TC model for Southeast Asia. Statistics of spatially distributed TC properties are estimated from the International Best-Track Archive for Climate Stewardship database, which is a widely used database for this purpose. 10000 years of TC's are then simulated from these statistics. The TC model includes the effects of both wind and rain.

Winds take account of friction/gust factors, which are derived at the CRESTA level (we understand?). This would appear to be a very low resolution for the purpose of determining effective hazard at location/building level. If this was not already done, we would suggest that the CRESTA friction/gust factors should at least be based on an exposure-weighted aggregation of higher-resolution factors.

Along the same lines, the wind speed is derived for the CRESTA centroid (we understand?). If this was not already done, we would suggest that it would be better to derive a CRESTA hazard value that is weighted by the location of exposure. For example, if most exposure in a large, forested, hilly CRESTA is located on the coast, the CRESTA centroid windspeed could significantly underestimate the windspeeds experienced by the exposure. The impact of this would vary with the distribution/concentration of a particular portfolio.

Precipitation damages are related to an 'effective water depth' parameter, computed from total event rainfall at the CRESTA REGION centroid above a threshold value. This is not the 'real water depth', but is basically an index used to estimate flood event intensity. The damage functions in this model are apparently calibrated/validated using a range of data sources described in slide 30, but we are not provided with enough information to tell how well they perform.

The non-TC rainfall from 2000-2008 is then estimated using TRMM data, separating out the TC rainfall. This is a nice use of remote sensing data. The record is quite short, and it would be nice to see it extended to also use more recent data if available. The statistics from this data are used to simulate rainfall statistics at points in each CRESTA REGION, using the GiST model to account for the correlations between and within stations. The results are validated by comparing the daily and monthly rainfall statistics from the data and the simulations, suggesting that the GiST model is reasonably reproducing key features of the data.

Flood events are defined using the 7-5 days clause. When applied to the 2000-2008 TRMM data, there is some relation between the relative frequencies of TRMM flood events and the frequencies estimated from the damages database [slide 57], which to some extent 'validates' the approach. It would be better to see this figure as a scatterplot with a 1:1 line, and to avoid normalisation [or to explain why it should be done, e.g. to correct for bias in one or other dataset].

Losses are estimated by first extracting the damage relationships in the TC model, separating the damages between precipitation and the exposure. The details of this process are opaque, especially as the losses are not presented separately for the perils. Next, the non-TC rainfall is somehow used to estimate the non-TC damages from the TC rainfall damages. Again, insufficient details are provided for us to assess this step.

One limitation of the approach is that (as with TC wind and flooding), the non-TC flooding in each CRESTA region is related to rainfall at a single point, so does not account for the spatial variation in rainfall, topographic effects, etc. The impact of this on loss estimation would vary based on the distribution of a particular exposure portfolio.

MODEL VALIDATION

Validation of the wind hazard is predominantly done based on frequency, although local wind intensities are also provided for low return periods. Most of the presented statistics look reasonable to very good. Fig. 51 in the report suggests good validation of observed against simulated landfall frequencies. It is not so easy to assess what the tail looks like, however. It would be worth showing the observed vs. simulated frequency above 12 separately. Furthermore, given the size of the Philippines, it would also be good to see this figure broken down for different 'gates' or regions across the archipelago.

Fig. 55 in the report suggests that the frequency of Cat 1 storms is over-estimated, versus an underestimate in TS. This appears to be a consistent bias for all countries. On the basis of an average of nine landfalls a year, this could conceivably be expected to lead to a (positive) bias in the resulting hazard and losses for the Philippines at the low RP. Is this borne out by the results?

Based on Fig 46/Fig 47 in the report, there appear to be more simulated than observed storms transitioning at extremely low latitudes (between 0 and 30N), particularly in January to May. The figure is a little hard to read, so it is not clear at what 'expense' that shift in frequency occurs (see next point). However, it could reasonably be expected to affect the TC rainfall losses for the Philippines.

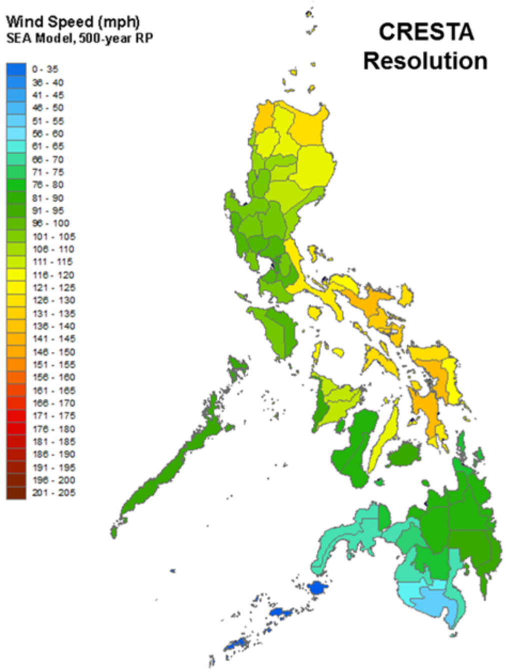
Table 10 vs. Fig. 57/Fig. 47: It would be valuable to see the modelled vs. observed Central pressure, Rmax and Forward speed for latitude 'bins', or on a similar grid as Figure 57. Among other things, it would help understand what the impact of the transitioning is on the storm intensity and behaviour.

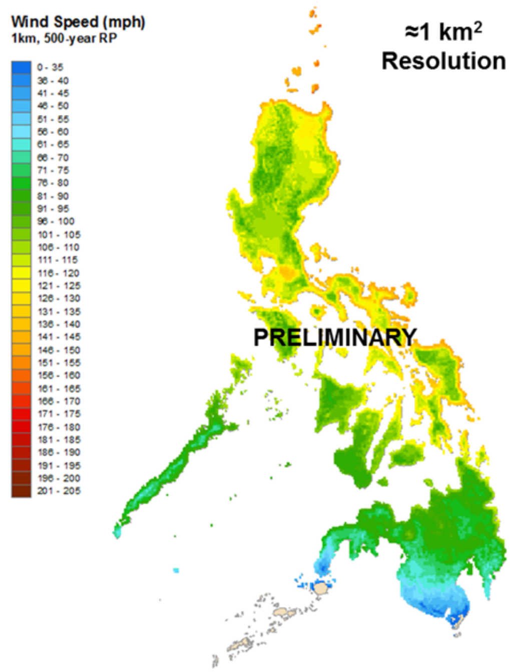
The modelled TC losses are validated against historic losses in slide 32. This figure suggests a variable relationship between the modelled losses from historic events, and the corresponding losses estimated from other sources. There does not appear to be a consistent bias in the modelled losses, which is encouraging. The apparent fit is improved by an extreme event, ie TC Joan; if this were removed from this scatterplot on slide 32, the relationship between observed and modelled events would be significantly weaker. The absence of a strong relation in itself is not very surprising given the difficulties associated with modelling historical events, and the fact that both the reliability of historical loss data and the trending of the historical loss data raises further complexities.

The modelled EP curve for TC losses is validated against exceedance probabilities from observed losses (presumably normalised) in Figures 91 to 93 in the report. The exercise would benefit from a bit more discussion of the outcomes, as well as including more historical events. For the Philippines, only TC Joan and TC Angela are shown. The figures do not have a vertical scale, which makes it hard to asses the fit. Assuming the arrows are meaningful indicators for the insured loss value of the historical events, the observed losses from TCs Joan and Angela fit well with the modelled EP curve.

Unfortunately, we do not see the details of the calibration / validation for non-TC rainfall losses.

AIR Response: The reviewers are correct in identifying that the wind hazard and precipitation hazard is resolved at a coarse CRESTA level only. This is an area of improvement in the model which is currently being implemented by AIR (the resolution is being modified to be on a 1km x 1km grid). However, the scope of work associated with the ToR and the timeline for the project did not permit incorporation of the higher resolution hazard into the analysis. This can be carried out in future analyses. The damage functions are calibrated considering that the hazard is at the coarse CRESTA level. While, uncertainty will certainly be higher in the province to province results, the overall results are expected to be well calibrated. A preliminary comparison amongst the 1km x 1km wind hazard was carried out against the CRESTA level hazard (see figure below for comparison of coarse resolution wind hazard with higher resolution preliminary wind hazard), and the differences observed do not suggest any bias in the results nor a significant over or under prediction in the loss estimates at the province level.





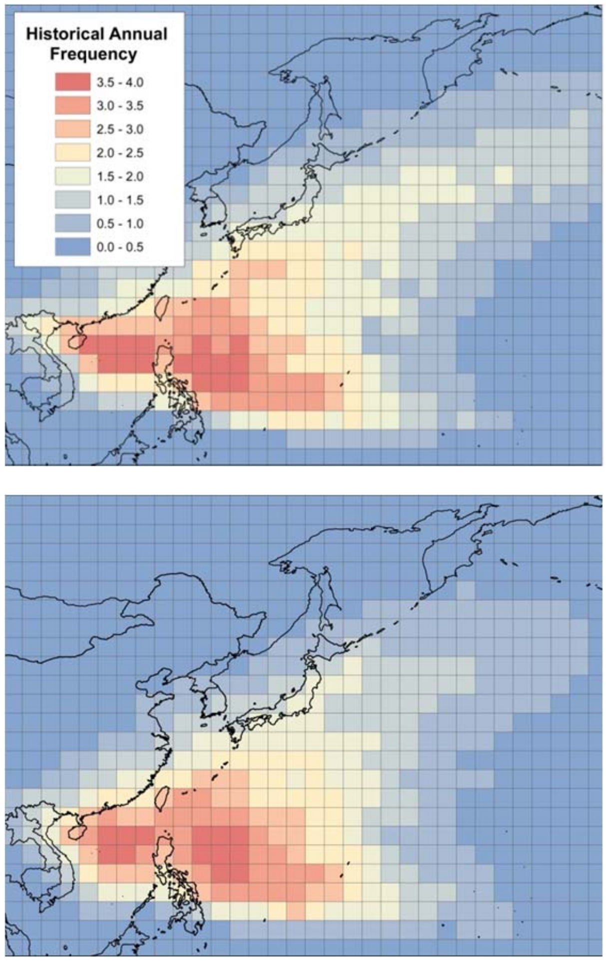
QUESTIONS FOR AIR

- How does the model parameterise the relationship between the individual storm characteristics, e.g. central pressure, Rmax, location etc, and the rainfall characteristics?

  AIR Response: The parameters used to define rainfall are peak rainfall intensity and rainfall radius. The peak rainfall intensity is the maximum hourly precipitation rate at or near the radius of maximum winds. The rainfall radius is the mean distance from the storm center, averaged over all directions, across the extent of the precipitation from the event. These parameters are calculated using empirical relationships between the storm size (Rmax), storm position, forward speed, storm intensity (Cp), and other topographic factors. The stochastic distributions for peak rainfall intensity and rainfall radius are developed using data from the Tropical Rainfall Measuring Mission (TRMM) between 1998 and 2007.

- Does Fig 57 include transitioned storms for the higher latitudes in either observed/historical track frequency?

AIR Response: Figure 57 includes all storms generated in the stochastic catalog and contained within the historical catalog, thus transitioned storms are also represented in this figure (shown below for convenience).



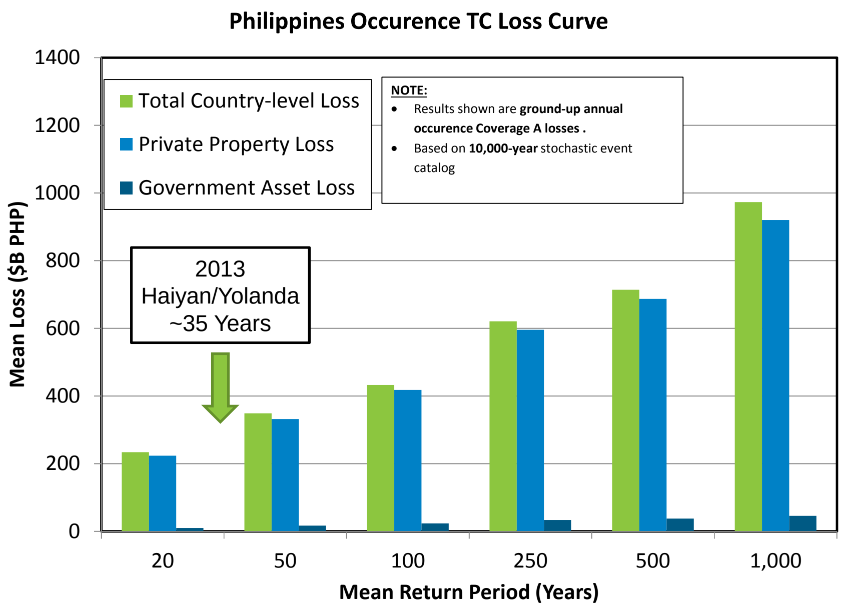
Annual Storm Track Density based on Historical (Top Panel) and Simulated Events (Bottom Panel)

- Can you explain the transitioning model in a bit more detail?

AIR Response: The frequency of extratropical transition (ET) is modelled temporally and spatially using a Weibull distribution that has been calibrated using JMA weather records. For each month of the year, a Weibull distribution is derived to provide a transition probability given latitude. In summer months (e.g., August), the probability of ET from latitudes 0-20° N is close to zero, while in winter months (e.g., January) the probability is much higher. While each month has an independent distribution, the model is calibrated to have smooth inter-month transitions that are not strictly aligned with the non-uniform fluctuations exhibited in the historical record. The Weibull ET parameters are developed by computing a best fit of the historical ET data and are not intended to precisely match the historical record for all latitudes and months. It should be noted that, because of the relatively low-latitude location of the Philippines, it is rare for an ET to have occurred before a storm has impacted the country, thus loss estimates in the Philippines remain driven by TC and are not expected to be biased by ET.

- This goes beyond the presented material or manual, but it would be very useful to discussion TC Haiyan/Yolanda in the context of the model. For example where does the projected loss sit in Figure 92? How close is the match of a Haiyan/Yolanda 'like' event in the event set in terms of hazard and/or projected loss?

  AIR Response: Real time loss analysis obtained through the AIR Alert process estimated the ground-up losses resulting from Haiyan to be similar in magnitude to those from Joan in 1970. While TC Haiyan was larger in scale and intensity than Joan, the affected area was comparatively less populated than that affected by Joan and therefore a smaller percentage of the Philippine's exposure experienced damage from the event. Analysis of TC Haiyan has been shared with the World Bank, but detailed results are independent of the commissioned report and are not included herein. The figure below shows how AIR's central loss estimate for Haiyan lines up with the occurrence loss EP Curve of the Philippines.



- Can you describe in more detail of the calibration/validation of the loss functions associated with TC and non-TC rainfall, and provide more detail on the development of the non-TC rainfall loss functions?

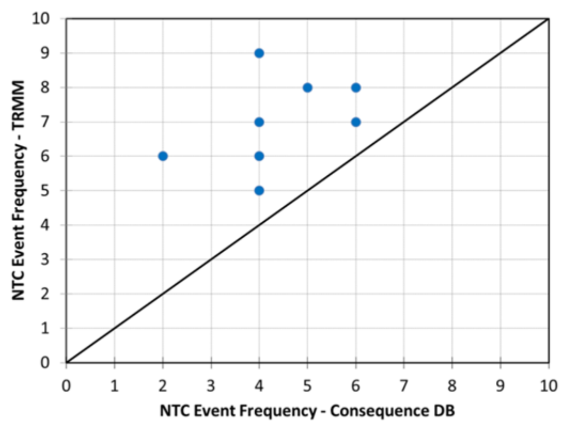
AIR Response: Please refer below regarding the discussion on the vulnerability functions.

- Why did you use the TRMM data only for 2000-2008?

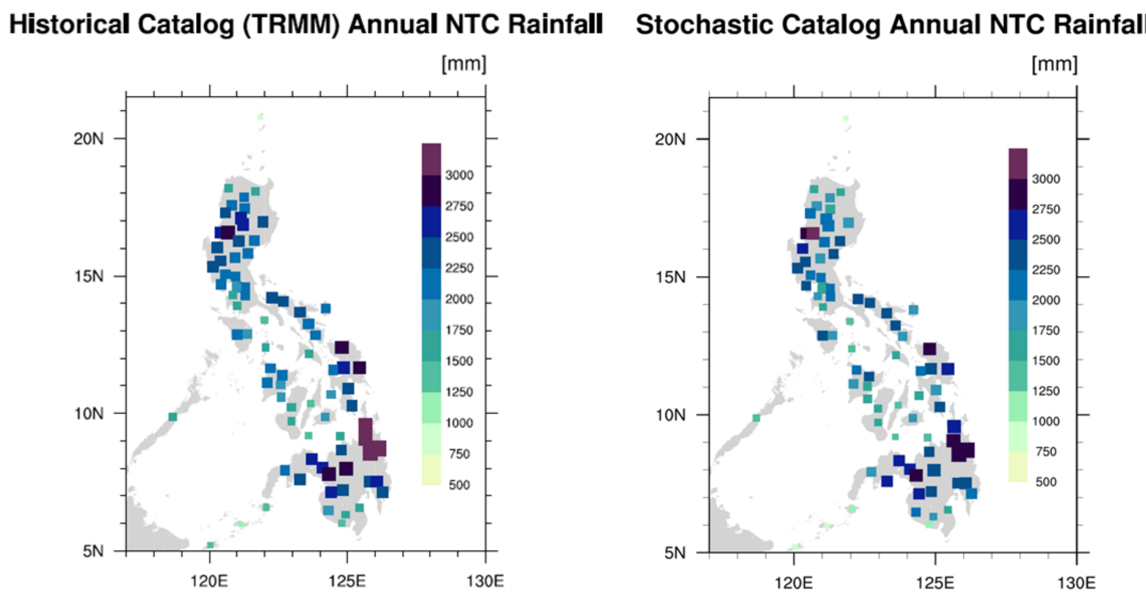
AIR Response: The TRMM data from 2000 to 2008 represent the most of amount of available data AIR could reliably post-process and verify its quality given the project time constraints. There are data quality issues with the TRMM data before the 2000 period and it was decided not to use these years. Given the scope and timeline of the project, there was insufficient time to retrieve and process the TRMM data post 2008.

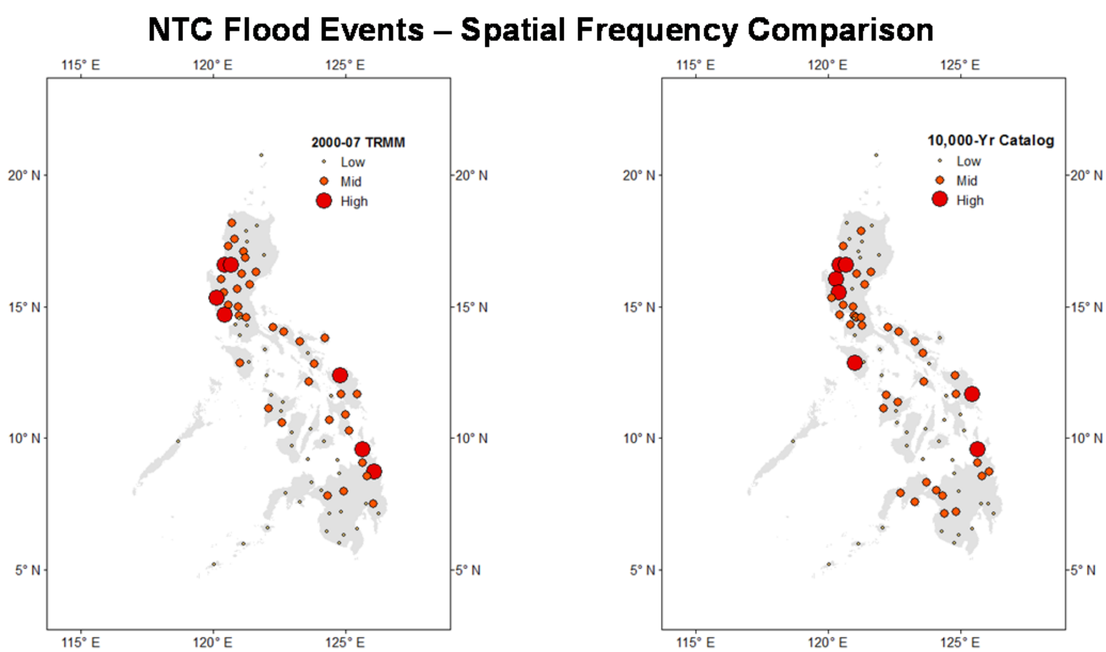
- For the comparison of the TRMM flood event relative frequencies with the database [slide 57], can you report it as a scatterplot on the un-normalised results -- or explain why this should not be done?

AIR Response: See below for a figure illustrating the comparison between the annual event frequency derived from the TRMM data and that indicated from the consequence database (it is more valuable to illustrate the inter-annual variation, rather than the exact count). The figure shows that the number of events derived from the TRMM data is slightly more than reported events. This is because the events typically reported in the historical record are those that have caused significant damage and casualties. From a hazard perspective, events that occur without severe consequences typically are not recorded and, therefore, we would expect that a representative model should estimate a higher number of events than what is reflected in the consequence database.



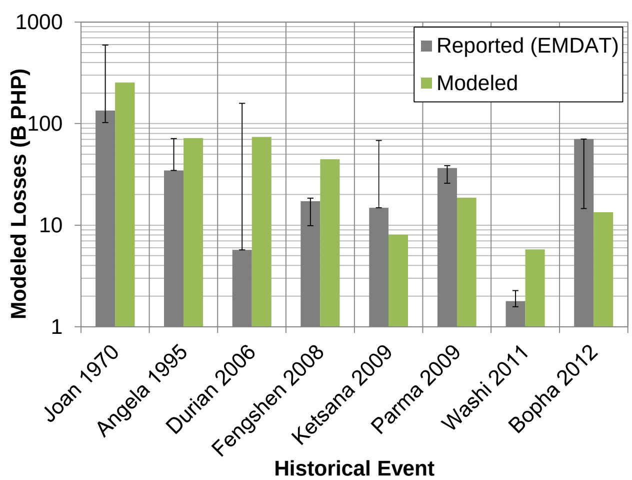
Additional validation was conducted by comparing the historical TRMM data and the resulting stochastic output for: (1) the annual NTC rainfall across the Philippines (2) the spatial frequency of NTC events throughout the country (see respective figures below).


Historical Catalog (TRMM) Annual NTC Rainfall
Stochastic Catalog Annual NTC Rainfall
[mm]
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
20N
15N
10N
5N
120E
125E
130E


NTC Flood Events – Spatial Frequency Comparison
2000-07 TRMM
10,000-Yr Catalog
Low
Mid
High
115° E
120° E
125° E
20° N
15° N
10° N
5° N

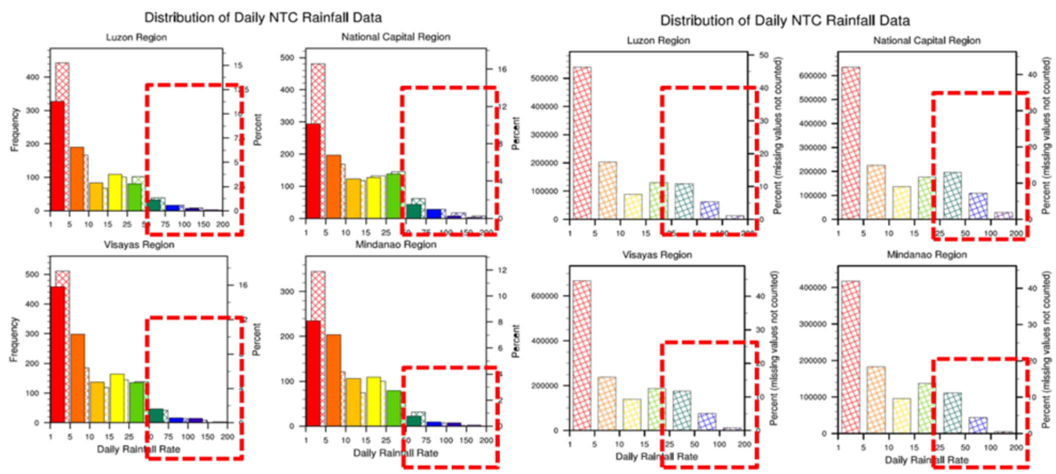
- How much overlap is there between the calibration and validation data? Did you perform any 'validations' which do not involve the use of data from calibration?

  AIR Response: The AIR Typhoon Model for Southeast Asia is a part of the 2010 release of the AIR Northwest Pacific Basinwide Typhoon Model where the hazard module is calibrated with over 1600 historical tropical cyclones that took place in the Northwest Pacific Ocean between the years 1951 and 2008. Loss validation is done for a number of pre-2008 events, as well as for notable storms that occurred after 2008 including 2013 Typhoon Haiyan. Refer to the figure below for loss validation results (error bars represent the range of reported loss estimates from SwissRe, MunichRe, AXCO, ROHK, GuyCarp, and NDRRMC; losses are trended to 2012).



- The EP for non TC-loss appears to be very 'flat', especially for government exposure. What do the extreme events look like – is there a tendency for the methodology to represent observed events, and underestimate the likelihood of extremes? (Especially given the observational record is relatively short). Can you discuss how this compares against observed losses?

  AIR Response: In regards to the shape of the EP curve, below is a histogram showing the distribution of rainfall for four distinct climate regions in the country. The plots on the left show the TRMM (solid) and the GiST (hatched) for the 8 years of TRMM data and 8 random years of GiST data. On the right, the same is shown for all 10,000 years of the GiST (stochastic) catalog. As shown, the model appears to be able to adequately represent the extreme tail events, and in general, tends to overestimate those compared to the observed. However, as the reviewers noted, the observational record is relatively short, and it is difficult verify how well the model represents extremely rare events which have not been documented in the historical record.



- Are quantitative estimates of the uncertainty in the loss calculations provided? What sources of uncertainty are accounted for? Can you estimate 'ballpark' uncertainties in the EP curves, considering the plausible biases in the model?? The latter could perhaps could be constrained from the scatter for individual events that we see in e.g. slide 32??

  AIR Response: Percentiles and other statistical measures for characterizing the loss ranges can be computed, but are not included in the scope of the current investigation. Please refer to the following section on "Wind Damage Function" for an explanation on how uncertainty is quantified.

Wind damage functions

The wind damage functions for Philippine buildings are developed leveraging previously developed damage functions for US and Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI). Both US and PCRAFI damage functions are developed based on engineering analyses and validated against available claims data and/or loss data from past events. The damage functions for Houston, TX were selected for Philippine buildings reflecting the difference of building characteristics, level of code enforcement, and construction practices between US and Philippines. For residential construction PCRAFI damage functions were leveraged because residential buildings constructions in 15 Pacific Island Countries is more similar to Philippines than US. The wind damage functions for Philippine buildings are developed using a combination of the two damage functions. Overall the methodology seems appropriate given the fact that there is not much of building damage data available at the moment.

Item specific comments are presented below:

- The current building schema does not take into account year of construction even though it was noted that design wind speeds changed from NSCP 1992 to NSCP 2001. In the UPD-ICE building classification certain building types were subdivided into before-1992 and after-1992 to take into account the regulatory change on roof system.

  AIR Response: Data on when buildings were constructed was not available to reliably categorize the building exposure into age bands that would differentiate structural wind performance. Therefore, it was decided to implement damage functions that were representative of all building vintages. The review of the code changes over time was conducted such that if exposure data improves, damage functions can be developed to capture the effect of when buildings were built at a later time.

- It is not clear whether damage functions are developed to account for three wind zones in the Philippine building design codes.

AIR Response: A single set of damage functions is used for the entire Philippines. The different wind zones were analyzed obtain a mapping to U.S. damage functions; however, there was not sufficient data to suggest that building code compliance was at a high enough level to differentiate vulnerability between the different zones.

- Damage functions were indirectly validated by comparing simulated losses with reported losses from several historical typhoons.

  AIR Response: This statement is correct. In addition to comparing regional hazard and code similarities, modeled losses were validated against reported historical values.

- Details of uncertainty in damage functions need to be provided.

  AIR Response: The uncertainty in the damage and loss estimation is quantified using probability distributions that AIR has derived based on claims data from previous tropical cyclone events. A probability distribution is fitted to represent the scatter observed in the available tropical cyclone claims data that is based on the level of wind speed intensity and level of damage sustained. Monte Carlo simulation is then used to combine this dispersion with other sources of uncertainty that have been propagated from the hazard to obtain the overall uncertainty from all modules in the methodology.

- It is not clear whether building damage due to windborne debris is factored in damage function development.

  AIR Response: Airborne debris is not explicitly included in the wind damage functions for the Philippines; however, the damage associated with airborne debris is implicitly included within the claims data and post-disaster assessments used for vulnerability calibration.

Flood damage functions

The flood damage functions for Philippine buildings are developed by using insurance claim data and latest research. The developed functions provide a relation between damage and effective water depth. These functions have been broadly classified based on building usage. The validation of these damage functions have been based on engineering research, damage data from past events and post-disaster surveys. A few points of interest seeking clarification are mentioned below:

AIR Response: In general, a full riverine flood model should be developed to compute the hazard at a high resolution and draw out differences in vulnerability across various construction/occupancy combinations, similar to what AIR has done for its flood models in the U.K., Germany, South East Europe, and soon to be released the U.S. Those developments take multiple years, which could not be incorporated within the scope of work and timeline for this ToR. AIR is independently developing the detail riverine flood model for the South East Asia region, including the Philippines, which will address most, if not all, of the reviewers comments. The intent in this study, given the various constraints, was to get an idea of the loss potentials associated with the non-TC precipitation. It is acknowledged that the estimates are associated with high uncertainty, but can be significantly improved in future analyses.

- Slide 28 (Precipitation Vulnerability Modelling), how the threshold value is calculated to assess effective water depth. Is the threshold value constant for each building/usage type? Is the threshold value catchment specific or applied uniformly throughout the country? The precipitation losses strongly depend upon the ground floor height, how the ground floor height for different building types is estimated. Is it linked to the hazard threshold value?

  AIR Response: The threshold value reflects the degree of sophistication and efficiency of the flood defense systems of the entire country (e.g., based on completed flood control, drainage system rehabilitation, and river improvement projects) and is applied uniformly. Therefore, it the value is constant for every building and usage. The height of building ground floors and usage type is implicitly accounted for in the damage functions through the validation against reported losses.

- Slide 29, how do you define 'flood index'? It is stated that precipitation damage is a function of the occupancy type. Is it not also a function of building type/material (wood, masonry, concrete, steel etc.)? The graph presents few functions according to the building use/occupancy; the difference in MDR seems to be quite small among these functions which is contrary to our experience. Does this graph show a real trend or it is just a schematic diagram? The slope of the curves seems to be very flat generally and especially for Single Family type (e.g., wooden structures) where at low depth (a meter or less) all the foundation, floor covering, lower wall panels, electrical wiring, vanities and kitchen cupboards etc. would have been damaged and would result in significant repair cost and MDR.

  AIR Response: The flood index is defined as the total amount of precipitation at a regional station less the threshold value. The precipitation damage functions only depend on occupancy. This is because occupancy class was more reliably documented than construction material and building height in the available south eastern Asian claims data used to develop the damage relationships. The provided graph is a schematic diagram, but does reflect the relative shape and scale of the flood damage functions for each occupancy class.

- Do you develop separate functions for each number of storey as for a given inundation depth and building type the MDR would be quite different for a single storey structure to a double/multiple storeys building (as the replacement cost which is a denominator for MDR calculation depends upon the number of storeys).

  AIR Response: Separate precipitation damage functions for buildings of different number of stories could be not developed based on the available data. Please refer to the response to the previous question.

- Slide 67, in the Aggregate Non-TC Precipitation Loss Curve, the difference in Mean Losses between 20 and 1000 years mean return period does not seem to be significant. What is the reason behind? How the hazard changes for 20 to 1000 years return periods? Why there is a less change is Government Asset Loss compared to Private property Loss from 20 to 1000 years?

AIR Response: The relative difference between the 20 and 1,000 year changes in losses in the government assets (50% increase) versus the private assets (70% increase) are similar to each other and are considered significant given the peril. Differences between the losses for the two asset types are primarily due to the vulnerability, as government assets are generally less vulnerable than private property assets and thus less susceptible to losses due to flood damage.

Refer to the discussion above regarding the shape of the EP curve and the associated hazard.

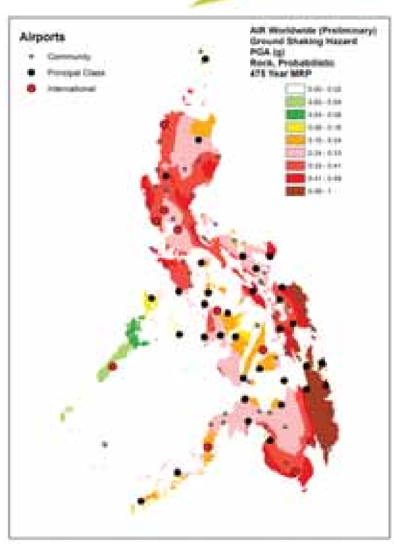
Appendix: AIR/ADPC Slides from Peer Review Presentation to Geosciences Australia

Philippines Catastrophe Risk Assessment Project

Peer Review Presentation
San Francisco
September 19, 2013

Meeting Agenda

- Overview
  - AIR Worldwide and ADPC
  - Project Components 1 – 4
- Exposure Data
  - Industry Exposure
  - Government Asset Database
- Earthquake Hazard
- Earthquake Vulnerability
- Preliminary Loss Results



Overview of AIR Worldwide and Asian Disaster Preparedness Center

About AIR Worldwide

- Founded 1987 as 1st provider of probabilistic catastrophe risk models
- Models cover natural and man-made hazards in over **95 countries**
  - Earthquake; Tsunami; Tropical and Extra-Tropical Cyclone; Severe Thunderstorm; Wildfires Floods; Terrorism; among others
- Helps clients **quantify, manage, and mitigate** their catastrophe risk
  - Over 400 re/insurer, broker, corporations, and government entity clients
- Offices in Boston, San Francisco, London, Munich, Hyderabad, Beijing, Singapore, Tokyo
- Consulting services (CRE) provide **engineering-based** model development and site-specific risk assessment and mitigation planning
  - Industrial Clients: Dow Chemical, Walt Disney, International Power, Timex, Abbott Labs, Devon Energy, GIC Real Estate, among others
  - **Asian Development Bank**: Risk Profiling & Disaster Risk Financing Projs.
  - **World Bank**: Model Development and Disaster Risk Financing Projects

About Asian Disaster Preparedness Center (ADPC)

- Founded in 1986 by UNDP, UNOCHA, and WMO, as a regional resource center
- Became an intergovernmental agency in 2005, with 9 member countries
- Serves countries in Asia and the Pacific region through providing high quality advisory and practical technical solutions in Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA)
- Headquartered in Thailand, with offices in Bangladesh, Myanmar, Loa PDR, and Cambodia
- Maintain strong connection with technical institutions, national & local government agencies, regional bodies, private firms, and international development agencies
- Have worked particularly on risk assessment works in Bangladesh, Myanmar, Lao PDR, Nepal, Timor-Leste, and Thailand

Project Overview

Philippines Catastrophe Risk Assessment Project

- Part of Technical Assistance supported by the Global Facility for Disaster Reduction and Recovery (GFDRR) to support the Government of Philippines in **formulation of a risk finance strategy**
- Provide information assisting in **reduction of the fiscal burden** to natural disaster impacts to the Government of Philippines
- Implement a **quantitative (monetary basis) catastrophe risk assessment** for typhoon, precipitation, and seismic hazards for entire country that would inform design and implementation of a **financial risk mitigation strategy** in terms of catastrophe liquidity facility addressing the higher layers of risk (different from physical risk mitigation and emergency response plans)

Major Project Tasks

- The project is developed over five distinct components

Component	Description
1	Hazard Data and Loss Data Collection and Management
2	Exposure Data Collection and Management and Vulnerability Assessment
3	Country Catastrophic Risk Profile
4	Design of Parametric Indices for Financial Transactions
5	Ongoing Support During Placement of Parametric Risk Transfer Product (conditional on DRF placement)

Overview of Project Plan

Existing AIR Catastrophe Models for the Philippines
1. Earthquake Ground Shaking and TC (Wind and Precip)
2. Province level aggregated exposure database

Expand Existing Models
1. Add non-TC Induced Precipitation Hazard
2. Add National Government Assets and Contingent Liabilities

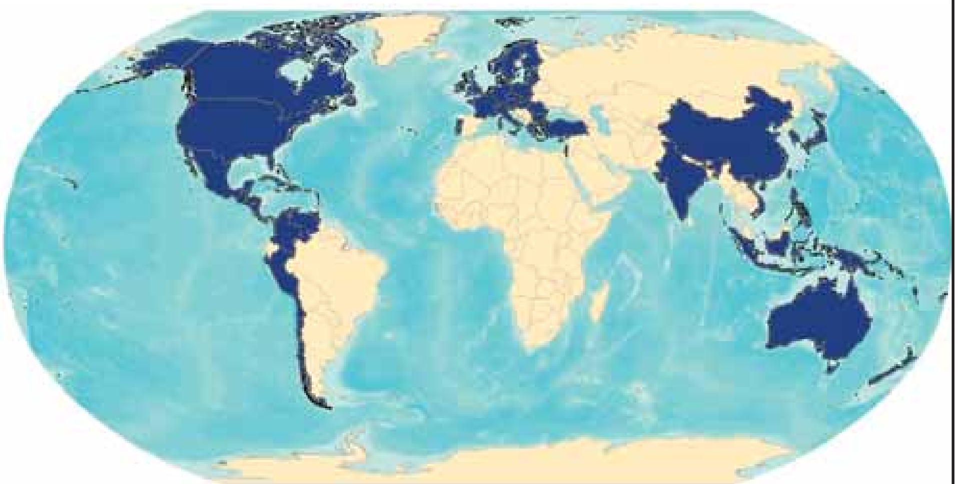
Enhance Existing Models
1. Improve Country-wide Exposure Data
2. Update Representation of Seismic Risk in the Model

Develop Catastrophe Loss Metrics
1. Monetary physical damage loss metrics
2. Including Emergency Losses and input towards Financial Risk Statement

AIR Industry Exposure Database (IED) for Philippines

AIR

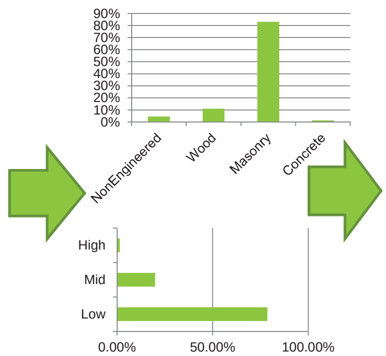
AIR Currently Has Industry Exposure Databases (IEDs) for More Than 90 Modeled Countries



The Importance of Robust Industry Exposure Databases

- AIR's industry exposure databases are critical for
  - Developing and validating models
  - Providing confidence in industry loss distributions
  - Estimating industry losses for real-time events
  - Validating losses for individual companies
  - Assessing exposure data quality for individual companies

AIR Developed a Comprehensive Database of Industry Exposures for Philippines in 2013

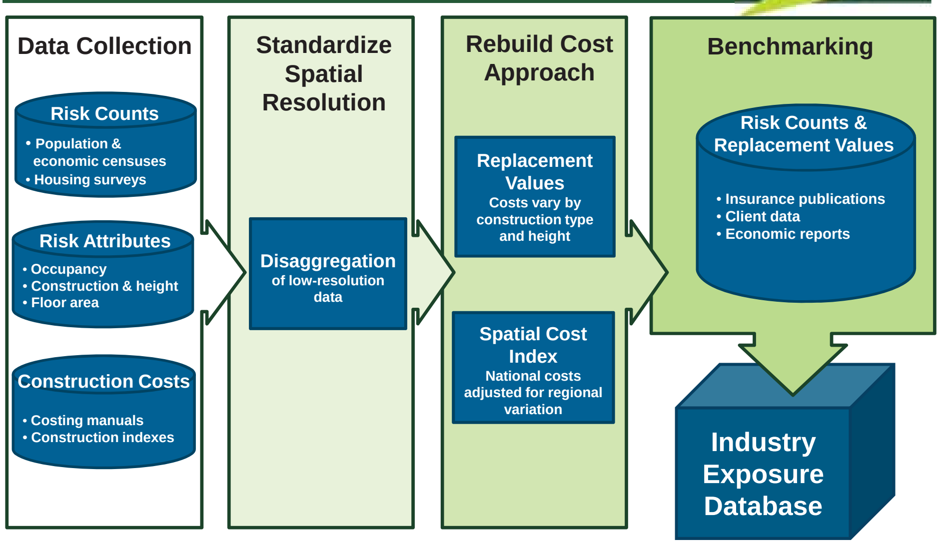


Risk counts by occupancy

Distributions of risks by construction and height

Replacement Values

AIR Employs a Robust Approach for Building Industry Exposure Databases



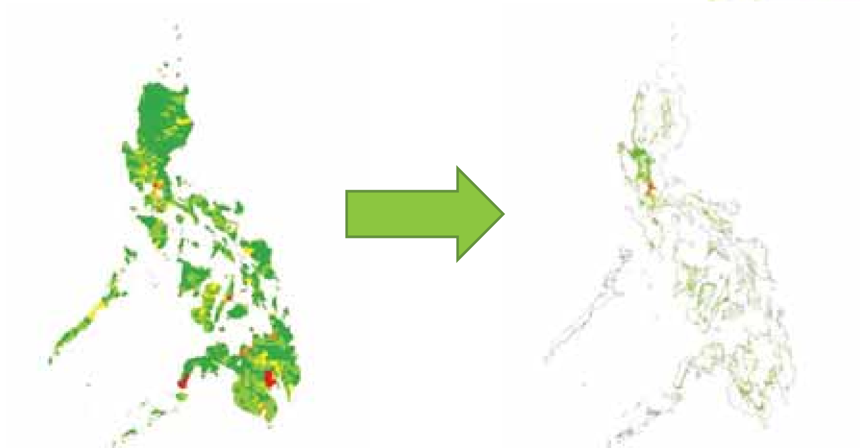
Primary Data Sources Used to Develop Risk Counts

Variable	Vintage	Nationwide	Region (17)	Province (82)	Municipality (1,621)
Census of Population and Housing	2010			X	X
	2007				X
	2000				X
Annual Survey of Philippine Business and Industry	2012	X			
	2010		X		
	2000				X

Detailed Occupancies Included in the Exposure Database

- Residential dwellings
  - Single family; duplex; and apartment
- Commercial establishments
  - Wholesale and retail trade; accommodation and food; information and communications; financial and insurance activities, real estate activities; technical activities; administrative and support services; education; human health and social work; arts, entertainment and recreation; other services
- Industrial establishments
  - Mining and quarrying; manufacturing; electricity, gas steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; transportation and storage
- Government (Public) assets
  - Roads, residual institutions, bridges, power plants, public schools, airports, public universities, ports, light rail, government hospitals, public administration buildings, government medical facilities, rails, prisons

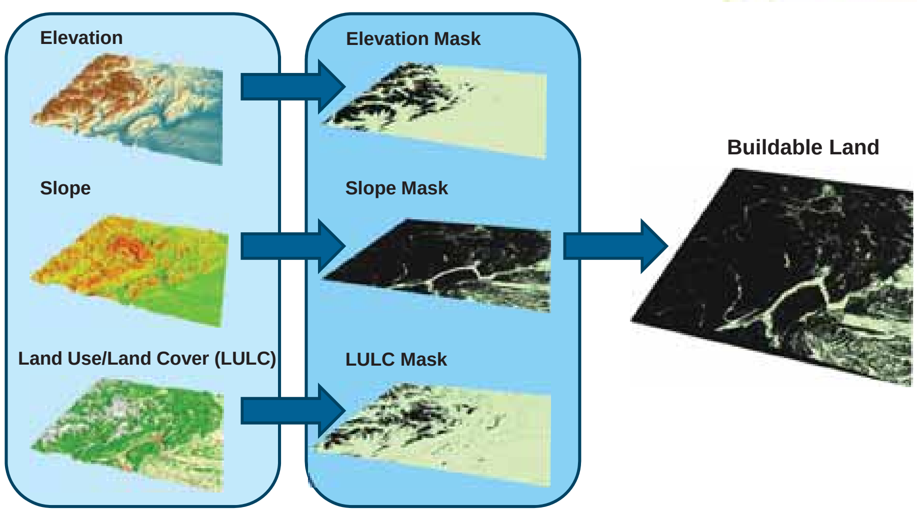
Data Disaggregation Improves Spatial Accuracy of Exposures



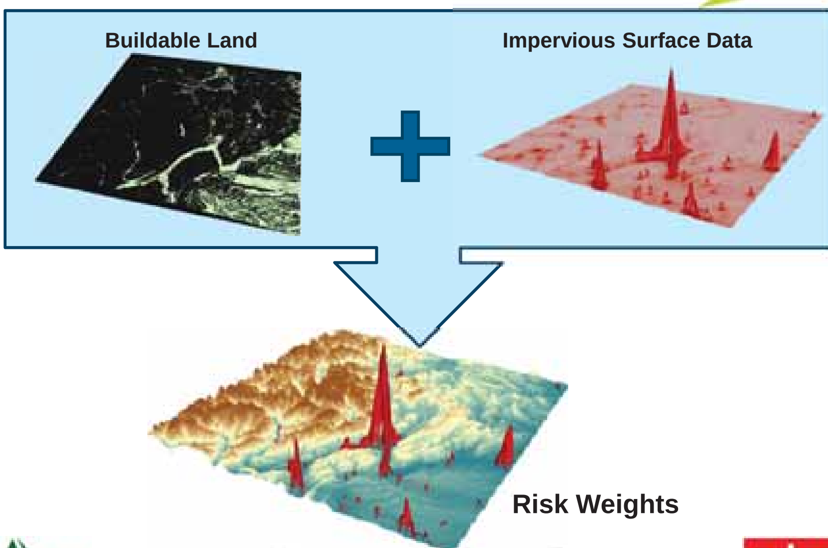
Data typically available at low geographic resolution

Actual risk distributions reflect human settlement patterns

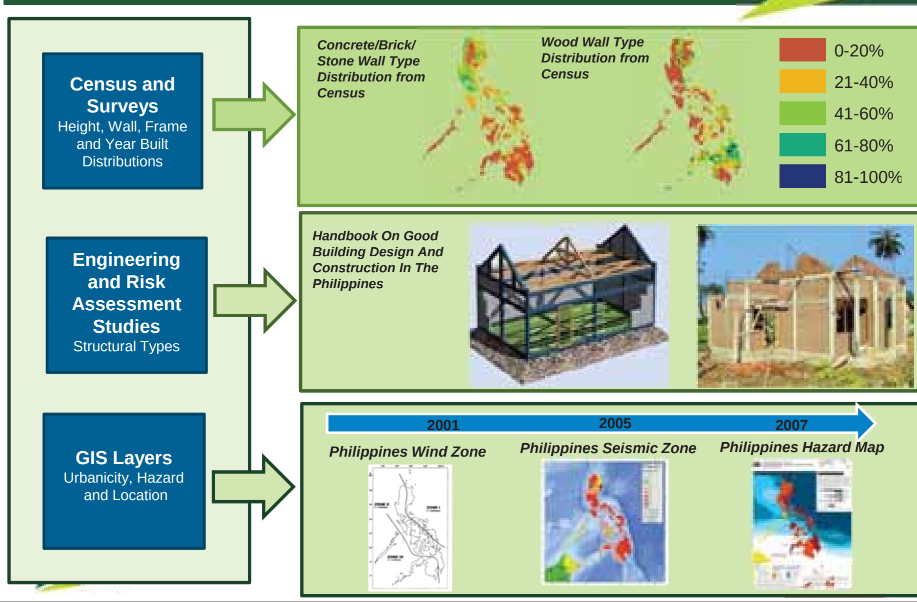
Buildable Locations Are Determined through Sophisticated Spatial Algorithms



Risk Location Probabilities Are Calculated Using Buildable Land and Impervious Surface Data



Various Types of Data Used to Develop Construction Distributions



Structural Types Included in the Industry Exposure Database

Non-engineered & Wood
- Non-engineered
- Wood Frame

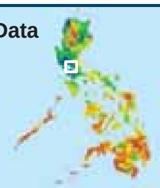
Masonry
- Unreinforced
- Reinforced

Concrete
- Reinforced Concrete Shear Wall(With MRF)
- Reinforced Concrete Shear Wall(Without MRF)
- Reinforced Concrete MRF

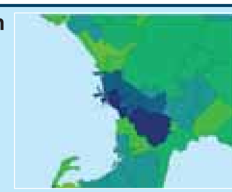
Steel
- Light Metal
- Steel MRF

Construction Distributions are Developed by Occupancy and Applied at High Resolution

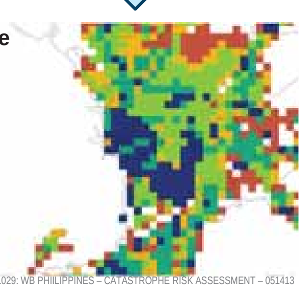
Census Data



Construction Distribution

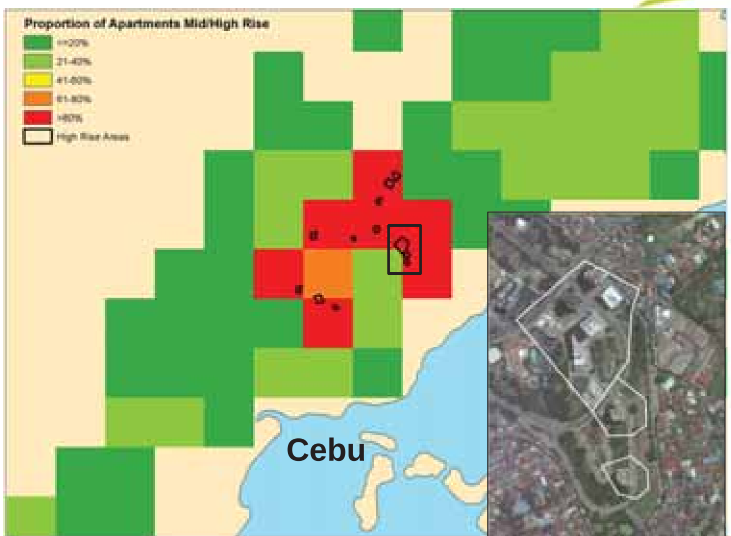


Proportion Concrete Apartments

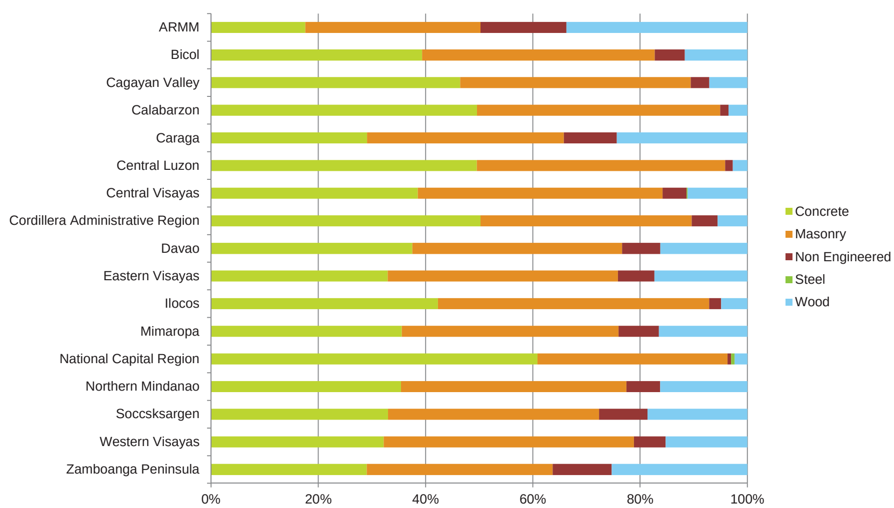


- 0% - 20%
- 21% - 40%
- 41% - 60%
- 61% - 80%
- 81% - 100%

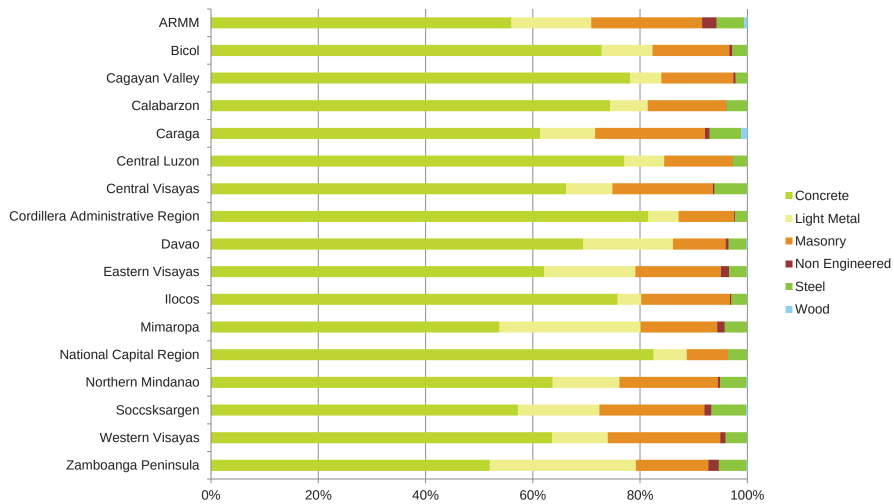
Multiple High Resolution Inputs Used to Identify Areas of High Rise Buildings



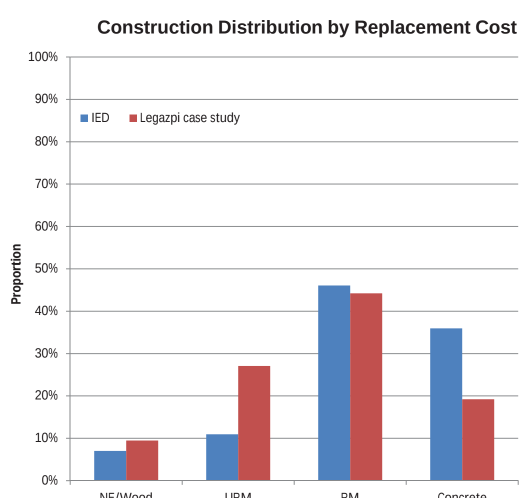
Residential Construction Distributions Vary by Region



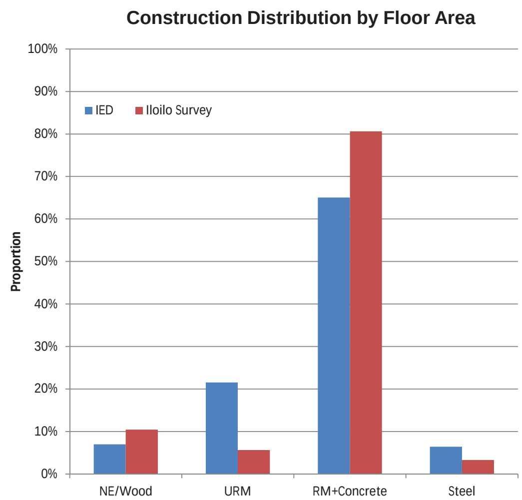
Commercial/Industrial Construction Distributions Vary by Region



Construction Distributions in Legazpi are Consistent with Independent Surveys

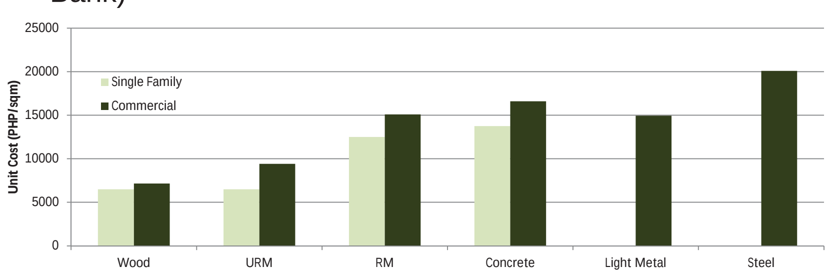


Independent Surveys from Iloilo City Compare Favorably with AIR's Construction Distribution



Sources of Data Used to Derive Replacement Values

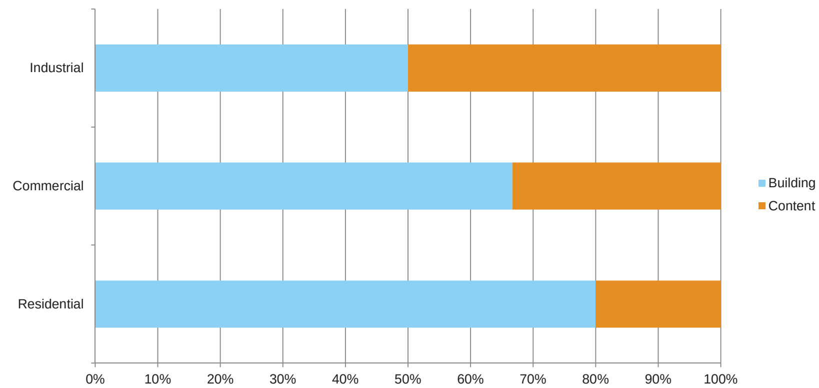
- Spon's Asia-Pacific Construction Handbook (Davis Langdon & Seah International)
- Philippines Report, Rider Levett Bucknall
- International Report, Rider Levett Bucknall
- Construction Statistics from Approved Building Permits (Philippines National Statistics Office)
- Strengthening Natural Hazard Risk in the Philippines (World Bank)



Low Rise National Rebuild Cost Estimates

Dwelling and Establishment Contents Value is Included in the Industry Exposure Database

- Residential contents covers personal belongings
- Commercial and Industrial includes equipment and inventory

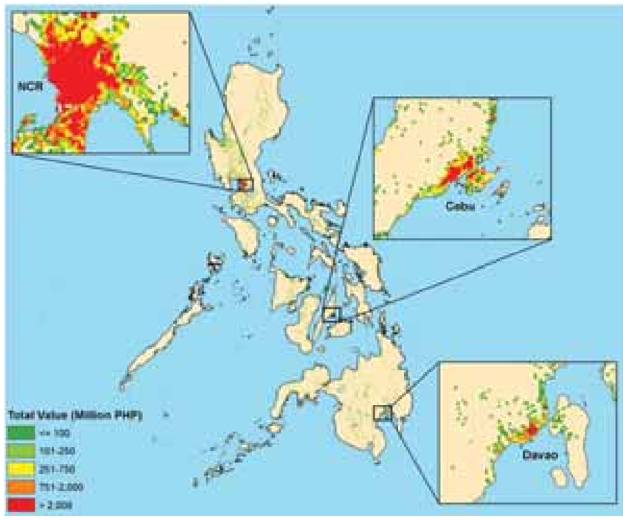


Summary of Exposure Values by Region

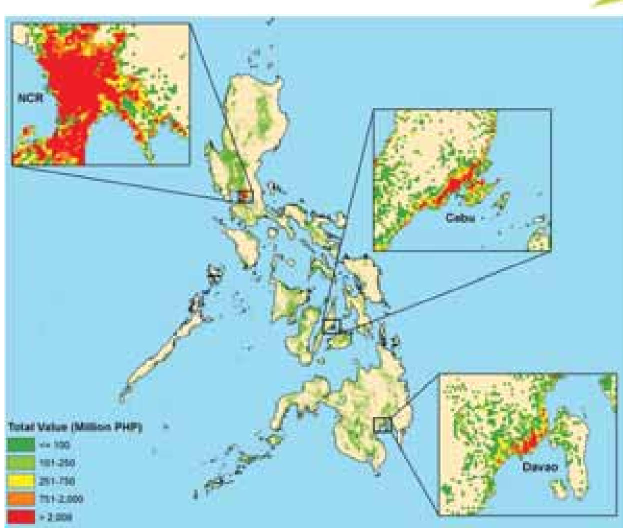
Region	Commercial*	Industrial*	Residential*	Total*
ARMM	23,187	32,671	229,350	285,207
Bicol	123,441	129,191	679,340	931,972
Cagayan Valley	97,868	63,446	538,284	699,597
Calabarzon	681,770	1,156,533	2,812,159	4,650,462
Caraga	50,956	66,211	247,129	364,296
Central Luzon	515,735	544,242	1,989,159	3,049,136
Central Visayas	496,072	444,315	1,206,439	2,146,826
Cordillera Administrative Region	95,486	63,212	269,489	428,187
Davao	177,087	144,901	609,419	931,407
Eastern Visayas	52,510	69,889	527,618	650,017
Ilocos	198,107	134,463	897,366	1,229,936
Mimaropa	64,555	105,986	326,247	496,788
National Capital Region	4,205,976	2,121,562	5,016,953	11,344,491
Northern Mindanao	197,956	312,011	623,058	1,133,025
Soccsksargen	100,668	189,349	451,754	741,771
Western Visayas	226,195	202,721	1,003,100	1,432,017
Zamboanga Peninsula	62,453	128,086	345,185	535,724
Total	7,370,024	5,908,787	17,772,049	31,050,859

***Values in million PHP**

Commercial Exposures are Concentrated in Urban Areas

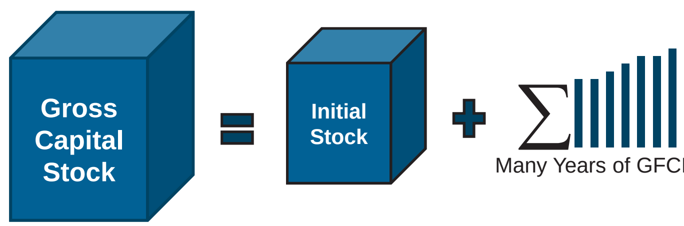


Residential Exposures Reflect Population Centers



Industry Exposure Database Validation Using Government Datasets

- The Gross Capital Stock (GCS) represents the value of the national productive assets
  - A subset of the GCS is directly comparable to residential, commercial, and public buildings
  - Starts with an initial value from a fixed point in time, for example1970
  - New buildings are created and old ones may be removed, this is known as Gross Fixed Capital Investment (GFCI)



Comparison with Modeled Capital Stock

Occupancy	GCS Value (Million PHP)	IED Value (Million PHP)
Residential	13,903,870	14,217,639
Commercial	10,010,787	9,381,036*

*Includes public buildings

Limitations of Available Data

- Current high geographic resolution census data was unavailable
  - Commercial establishment and dwelling counts by type were only available at municipality from 2000
- Limited data available on residential vacancy rates
  - Adjustments made to occupied housing counts
- Building counts were unavailable for all occupancies
  - Dwellings per building ratios were used to develop building counts
- Poor quality spatial data available in rural areas
  - Land use data available from global datasets did not match settlement patterns

Government Asset Database

AIR

Government Asset Database

- Massive data collection effort by AIR Worldwide and ADPC
- Objectives:
  - Develop a GIS-based exposure database of national government assets including state-owned enterprises and specific infrastructure assets
  - Liaise and collect data from local national agencies
  - Condition raw data to be used with catastrophic risk models

Balangbalang Elementary School, Agusan Del Norte

Data Collection Challenges

- Data was incomplete and inaccurate in general
- Same data from two sources was sometimes contradicting
- Data often was not in a format for use with CAT models
- Data sometimes came as a hard copy requiring significant effort to turn them into a usable electronic database
- Frequent disorganized internal communication within the agencies lead to delayed responses
- Some departments were not fully cooperative in providing data
- **While it was perceived that a lot of data was available and easily accessible in the Philippines, the data in general was difficult to obtain, incomplete, and not at the level that can be used for an exposure database**

Local Agencies Contacted

Abbreviation	Agency
BOC	Bureau of Corrections
CAAP	Civil Aviation Authority of the Philippines
CHED	Commission of Higher Education
DepEd	Department of Education
DILG	Department of Interior and Local Government
DOH	Department of Health
DPWH	Department of Public Works and Highways
GSIS	Government Service Insurance System
LRTA	Light Rail Transit Authority
NPC	National Power Corporation
NSO	National Statistics Office
PNR	Philippine National Railway
PPA	Philippine Ports Authority
TransCo	National Transmission Corporation

Raw Data Collected from Local Agencies

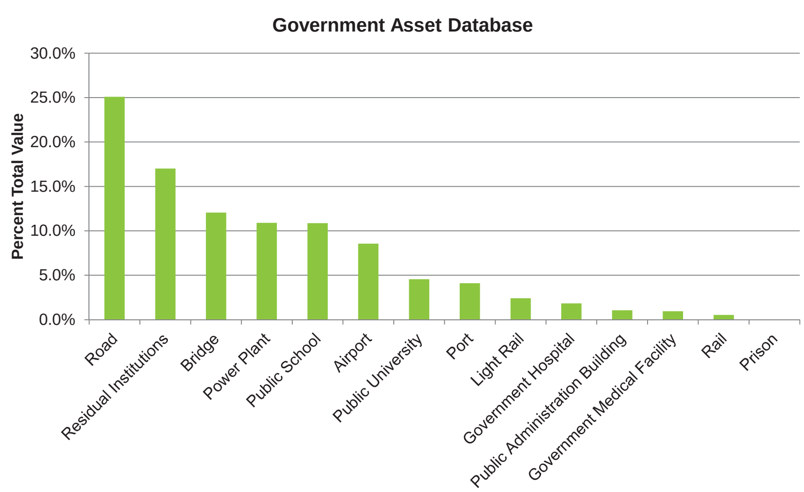
Dataset	Agency	Raw Data Quality		
		Location	Attributes	Replacement Values
Roads	DPWH	Good	Good	Good
Bridges	DPWH	Good	Good	Good
Prisons	BOC	Good	Good	Good
Light Rail	LRTA	Good	None	None
Airports	CAAP	Good	None	None
Schools	DepEd	Poor	OK	OK
Public Administration Buildings	DPWH	Poor	OK	OK
Hospitals	DOH	Poor	None	None
Seaports	GSIS	Poor	None	OK
Flood Control & Drainage	DPWH	Poor	Poor	Poor

Final Government Asset Database Scope

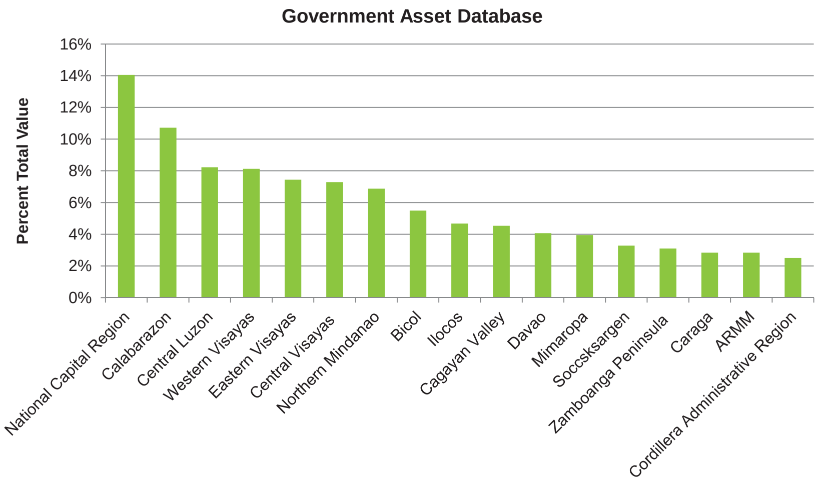
Asset Type	Number	Estimated Replacement Value (PHP)	Percent Value
Road	30,673 km	680,566,613,326	25.1%
Residual Institutions	n/a	461,674,455,000	17.0%
Bridge	7,860	326,790,678,987	12.0%
Power Plant	24	295,667,261,120	10.9%
Public School	46,606	294,944,436,274	10.9%
Airport	85	232,017,926,000	8.6%
Public University	113	123,874,249,854	4.6%
Port	190	111,280,700,659	4.1%
Light Rail	49 km of track & 45 stations	65,470,607,012	2.4%
Government Hospital	774	49,986,422,951	1.8%
Public Administration Building	4,417	28,750,872,283	1.1%
Government Medical Facility	17,969	25,867,915,868	1.0%
Rail	479 km of track & 32 stations	14,829,614,040	0.5%
Prison	122 buildings in 7 prisons	509,850,000	0.0%
Total	-	**2,712,231,603,374 (62 billion USD – 25% of GDP)**	-

Assets in red required substantial additional work from AIR

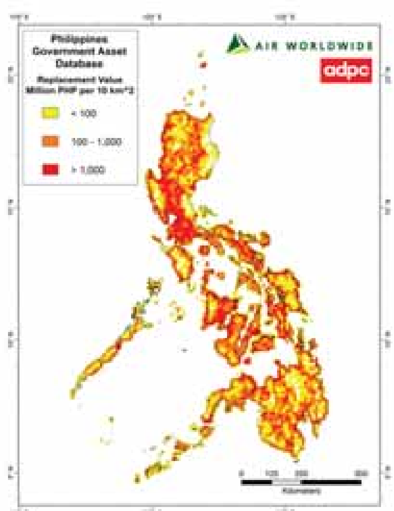
Final Government Asset Database Statistics



Final Government Asset Database Statistics



Final Government Asset Database Cost Map



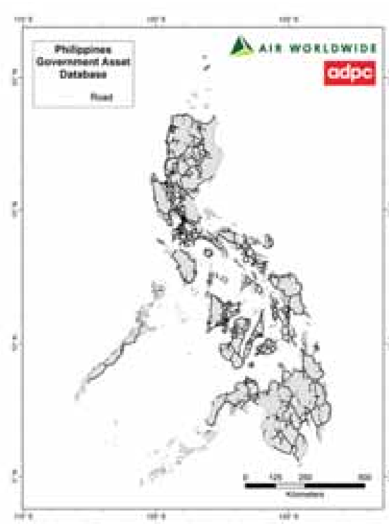
Example of Database

ID	Name	Note	Y	X	Estimated Value (PHP)	Construction	Occupancy	Height	Type	Municipality
91667	Philippine Heart Center	DOH Hospital Level 4	14.644	121.047	1,518,595,041	131	316	4	Government Hospital	Quezon City
39243	Zamboanga International Airport	Runway	6.919	122.062	1,486,555,000	206	353	1	Airport	Zamboanga City
90765	Negros State College of Agriculture	.	9.851	122.889	1,433,671,735	131	345	1	Public University	Kabankalan City
90598	Cagayan De Oro Port	PMO: Cagayan De Oro	8.494	124.663	1,407,678,481	100	354	1	Port	Cagayan de Oro City
38534	Narciso Ramos Bridge	.	15.993	120.686	1,353,873,084	203	300	1	Bridge	Asingan

Good Quality Data: Roads

- Very good quality raw GIS (polyline) data obtained from the DPWH
- Raw data total: 31,341 km of national primary and secondary roads
- Validation: 31,597 km of national primary and secondary roads from DPWH aggregate data (October 2012)
- Raw data attributes include road length, surface type (asphalt, concrete, gravel, earth), and condition (good, fair, bad, poor)
- Replacement costs:
  - Unit cost estimated from data acquired by the DPWH
  - RC a function of road length, road type, and condition
- Aggregated to 1-KM grid for modeling purposes

Paved National Primary and Secondary Roads



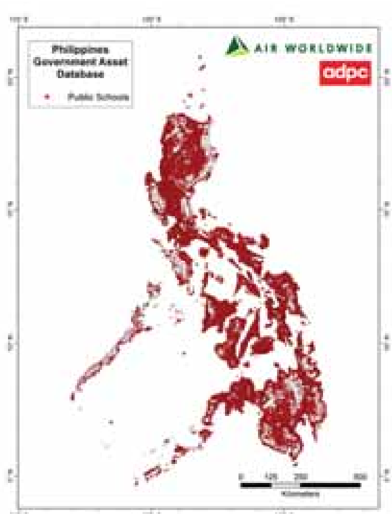
Moderate Quality Raw Data: Public Schools

- Moderate quality raw SQL data obtained from DepEd
  - 43,647 schools; 177,325 buildings aggregated at 34,296 schools
  - Given locations of schools are not correct in general. Based on spot checks of satellite imagery, many schools are “located” away from populated area (e.g., the middle of a forest)
  - Not all public schools are represented. Some municipalities are completely missing schools (e.g., in Manila)
- Building attribute data includes School ID, building type (97 categories such as Bagong Lipunan, Marcos Type, etc.), year of construction, number of stories, building length, and building width
  - The attribute data from DepEd is incomplete and had several errors (e.g., the given length of the buildings vary from 0m to 11km)
    - Obvious errors were corrected based on “good” data
- Replacement cost:
  - Unit cost estimated from DepEd data
  - RC is a function of total floor area and region

Moderate Quality Raw Data: Public Schools

- Data from the MMEIRS Study and tables downloaded from the DepEd website were used to supplement the DepEd SQL data.
- The locations (lat/long) of over 75% of the schools were not given in the raw data. Schools with unknown lat/long were aggregated to the centroids and population centroids of Municipalities, Barangays, or settlements based on given data
- Final Database Total:
  - 46,606 public elementary and secondary schools
    - 43,646 from DepEd SQL data
    - 103 from MMEIRS data
    - 2,857 from DepEd table data
- Validation:
  - 45,973 public elementary and secondary schools in 2011-2012 from DepEd website aggregate table

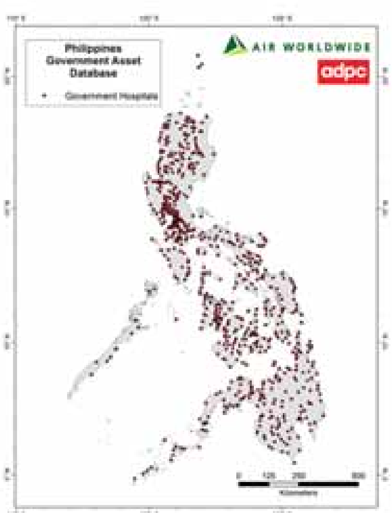
46,606 Public Elementary and Secondary Schools

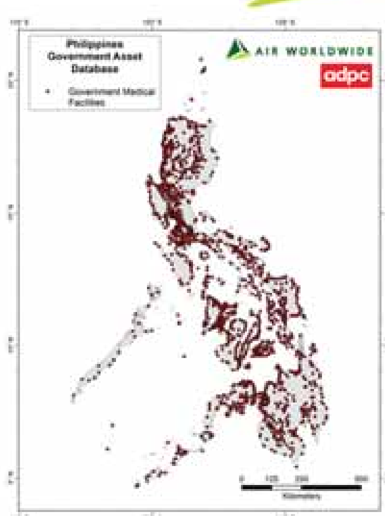


Poor Quality Raw Data: Hospitals

- Poor quality raw GIS data obtained directly from the DOH Agencies
  - 679 hospitals; 2,390 regional health units, 172 Barangay heath station
  - Given locations of buildings are not correct in general. Based on spot checks of satellite imagery, many buildings are “located” away from populated area (e.g., the middle of a forest, in the ocean). Seemed to be issues with scrambled lat/longs.
  - Not all buildings are represented. For example, Barangay heath stations are included in only in a few Barangays
- Very limited building attribute data from the DOH GIS data
  - Name and (old) Unit ID
- Data from the MMEIRS Study, DOH website, the National Health Facility Registry, and other public sources, were used to supplement the raw DOH GIS data
- All government hospital locations were manually validated and corrected via satellite imagery
- No replacement cost information obtained from DOH
  - Replacement cost data was inferred from industry reports and public sources
  - RC was simulated using several metrics including building footprint area, facility type, and number of beds
- An additional 17,969 government health facilities were included based on data from the National Health Facility Registry
  - The location (lat/long) of assets were aggregated to the centroid of municipalities based on given data

774 Government Hospitals and 17,969 Government Medical Facilities

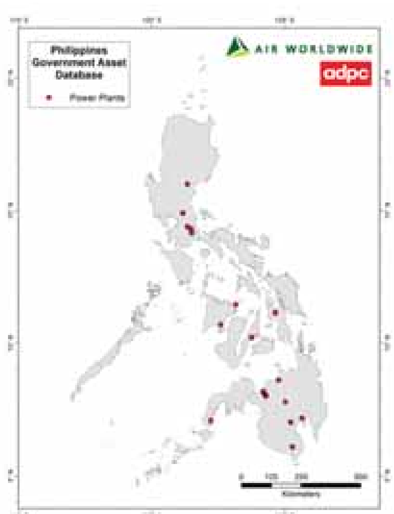




No Raw Data: Power Plants

- No useful data obtained from the local agencies
  - Agencies had originally promised good data
- Data obtained from public sources including DOE aggregate tables, CARMA, industry reports, and the literature
- Only large NPC (National Power Corporation) and NPC/IPP (joint NPC and independent power producer) facilities considered
- Locations of plants validated via satellite imagery
- Attributes collected include construction year, type (coal, gas, geothermal, etc.), power capacity, etc.
- Replacement costs estimated from industry data, construction data, publically available reports, etc.
  - For facilities without direct costing data, RC is simulated from several metrics including plant type, size, and total power capacity

24 NPC and NPC/IPP Power Plants



Bridges

- Very good quality GIS data obtained from DPWH
- Database Total: 7,860 bridges maintained by the National Government under the Bridge Management System (2011)
- Validation: 7,949 bridges from DPWH aggregate Data (Jan 2012)
- Raw data attributes include bridge length, bridge type (arch, box, girder, etc.) and bridge material (bailey, concrete, steel, timber)
- Replacement costs:
  - Unit costs estimated from data obtained from the DPWH
  - RC a function of bridge length and bridge type/material

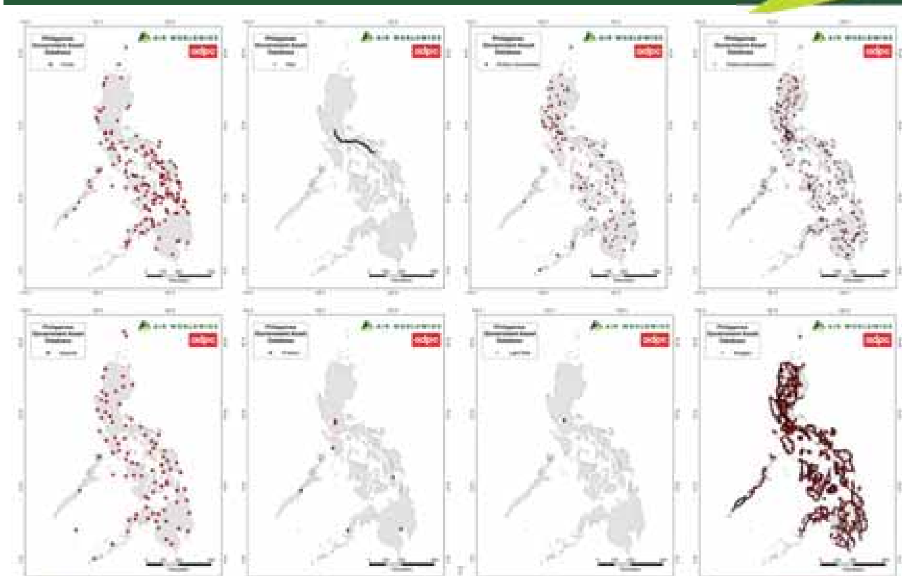
Airports

- OK quality GIS data obtained from CAAP
- AIR Database Total: All 85 CAAP Airports
- Validation: CAAP aggregate data and other public sources
- Limited attribute data provided by CAAP
  - Location, name, and airport type
  - AIR collected supplementary information such as runway length, runway material, approximate footprint size, number of passengers, and number of aircraft movements
- Replacement costs estimated from public data, construction reports, news articles, and global industry data
  - For airports with no replacement value data, the value is simulated considering the collected attribute data (including size, type, runway length, aircraft movements, etc.)

Seaports

- OK aggregate GIS data obtained from PPA
  - 24 base ports with aggregate replacement costs
- 190 government ports located from satellite imagery and supplementary information
- Validation: Summary tables on PPA website
- No attribute data given
- Aggregate replacement costs given for each PMO (port management office) jurisdiction
  - RC data is disaggregated to every port within a PMO region through metrics including shipping calls, cargo traffic, passengers, and port size based on satellite imagery

Other Assets

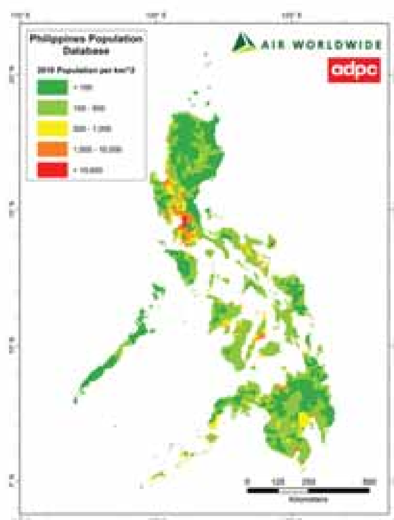


Residual Institutions

- Residual institutions represent government assets for which direct data was not obtained
  - These include fire stations, police stations, city halls, other public buildings, etc.
- The value was determined from official construction statistics and census data, with reference to the modeled IED and government assets explicitly accounted for in the database
- Assets were simulated on 1-km grid based on population data

Population Database

- Population data collected from the 2010 National Census
- 1,646 municipality-level data in GIS form
- ≈42,000 barangay-level data in table form
- Used to inform model development

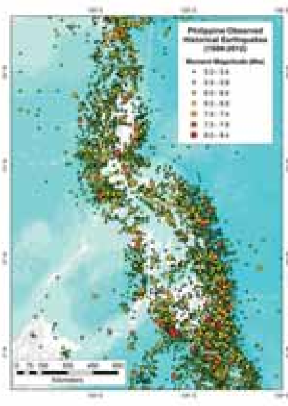


Earthquake Hazard

Historical Database: Earthquake

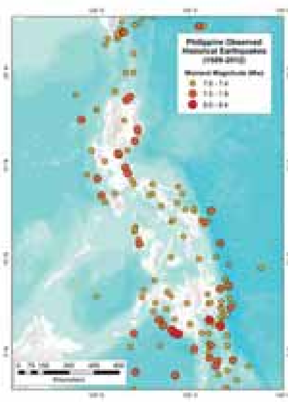
- Data Sources:
  - The ISC-GEM Global Instrumental Earthquake Catalogue
  - The USGS PAGER-CAT catalog
  - The Philippine historical earthquake catalog from Bautista & Oike (2000)
  - The International Seismological Centre (ISC) Bulletin
  - Abe's Catalog of Major Earthquakes of the World
- Harmonized (uniform M_w) earthquake catalog covering the period from 1589 to 2012 (over 21,000 earthquake events)
- Scope: magnitude M_w 4.5 or greater and epicenters within latitude 3 to 23 and longitude 115.5 to 130
- Not de-clustered (done later for stochastic catalog validation)

Historical Database: Earthquake



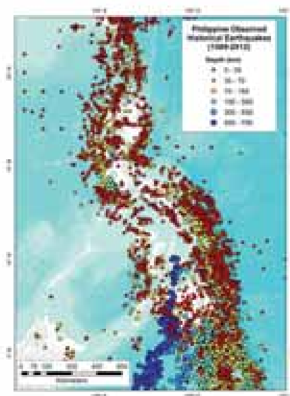
$M_W \geq 5.0$

7,980 Events



$M_W \geq 7.0$

142 Events



Event Depth

Earthquake Historical Database: 1976 Moro Gulf Earthquake and Tsunami

- The historical database for earthquake events contains parametric information about the events

Images source: en.wikipedia.org/wiki/1976_Moro_Gulf_earthquake

Hist_ID	Year	Month	Day	Hour	Minute	Lat	Long	Depth_KM	Depth_Fix	Raw_Magnitude	Raw_Unit	Catalog	ISC_Mag_Author	Mw_Converted
3220	1976	8	16	16	11	6.175	124.047	20		7.96	Mw	GEM	.	8

Historical ID

Chronological information

Location

Magnitude and data source

Converted magnitude

Data sources vary (Bautista & Oike 2000; ABE Catalog, revised May 15, 2000; USGS PAGER-CAT Earthquake Catalog; GEM; ISC).

Consequence Database: Earthquake

- Data Sources: Over 20 databases and other sources, including:
  - National Geophysical Data Center / World Data Service (NGDC/WDS) Significant Earthquake Database
  - USGS PAGER-CAT earthquake catalog
  - Emergency Events Database (EMDAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED)
  - Philippine Institute of Volcanology and Seismology (PHIVOLCS)
  - Catalogue of Violent and Destructive Earthquakes in the Philippines (Maso, 1910)
  - Catalogue of Destructive Earthquakes in the Philippines (Garcia et al., 1985)
- ~300 significant earthquake events dating from 1599 to 2012
- Primary Data Fields: Tsunami Flag, Landslide Flag, Buildings Damaged, Buildings Destroyed, People Injured, Life Loss, Economic Loss

Earthquake Consequence Database: Summary

Time period	Number of Events	Number of Catastrophic Events	Estimated Economic Damage (Current Million USD)	Estimated Economic Damage (Trended Million 2012 USD)	Estimated Life Loss	Estimated Life Loss (Trended 2012 Value)
16th Century	24	15	190	n/a	1,274	n/a
17th Century	15	7	105	n/a	1,124	n/a
18th Century	100	20	298	n/a	2,815	n/a
1900s	14	6	60	n/a	408	n/a
1910s	14	3	39	n/a	109	n/a
1920s	17	7	62	n/a	871	n/a
1930s	5	1	12	n/a	1	n/a
1940s	5	2	5	n/a	90	n/a
1950s	5	2	6	n/a	487	n/a
1960s	2	2	9	302	274	792
1970s	19	2	146	2,348	7,115	16,328
1980s	22	8	14	98	42	75
1990s	30	2	469	2,658	1,721	2,681
2000s	16	1	6	16	11	13
2010 – 2012	10	1	21	21	114	114

Earthquake Consequence Database: 1976 Moro Gulf Earthquake and Tsunami

- The earthquake event is uniquely identified, and the human and economic losses are enumerated.

Preferred Consq_ID	Preferred Hist_ID	Preferred Year	Preferred Month	Preferred Day	Preferred Hour	Preferred Minute	Preferred Lat	Preferred Long	Preferred Depth_KM	Preferred Depth_Fix	Preferred Raw_Magnitude	Preferred Raw_Unit	Preferred Catalog
214	3220	1976	8	16	16	11	6.175	124.047	20	.	7.96	Mw	GEM

Consequence ID and Historical ID

Chronological information

Location

Magnitude and data source

Significant fields are labeled Minimum, Maximum, or Preferred with a data source for each field. For this example, reliable sources of available data vary.

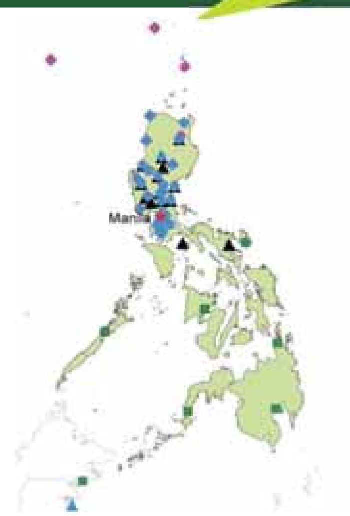
Preferred People Affected Min	Preferred People Affected Min Source	Preferred People Affected Max	Preferred People Affected Max Source	Preferred People Affected Preferred	Preferred People Affected Preferred Source
90000	NGDC_Notes	181348	EMDAT	181348	EMDAT

- Buildings Damaged Preferred = 10,000 (EERI)
- Buildings Destroyed Preferred = (no data)
- People Affected Preferred = 181,348 (EMDAT)

- People Injured Preferred = 9,928 (PAGER)
- Life Loss Preferred = 7,079 (PAGER)
- Damage Preferred = 134 million USD (NGDC)

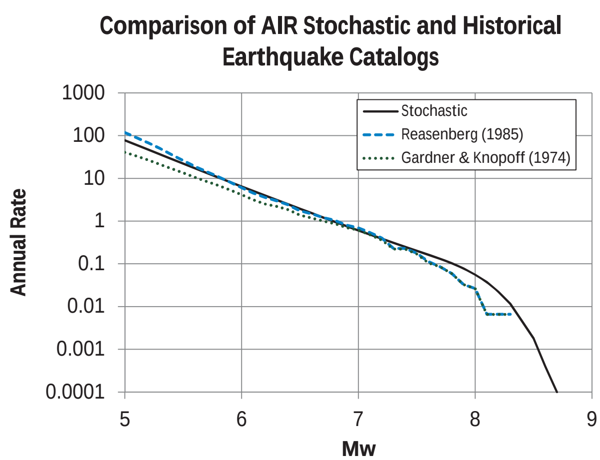
AIR Stochastic Earthquake Catalog for SE Asia

- AIR's seismicity model is based on geodetic data, geological fault data, paleoseismic data, plate tectonics, and historical earthquake catalogs
- Model domain is divided into multiple depth layers based on the depth distribution of historical events
- Modeled region is divided into seismic source zones
- Kinematic model is based on published GPS data and fault slip rates to obtain the seismic moment rate for each seismic source zone



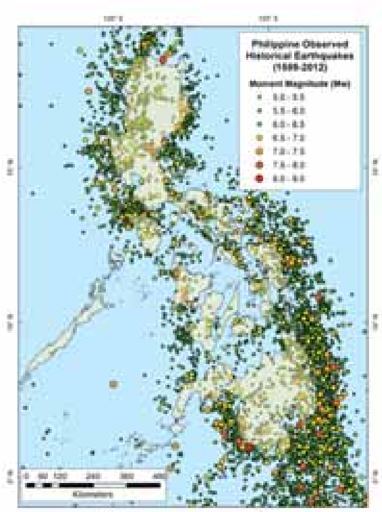
Distribution of GPS stations in the Philippines
(some stations abroad are not shown)

Stochastic Catalog Rate Validation

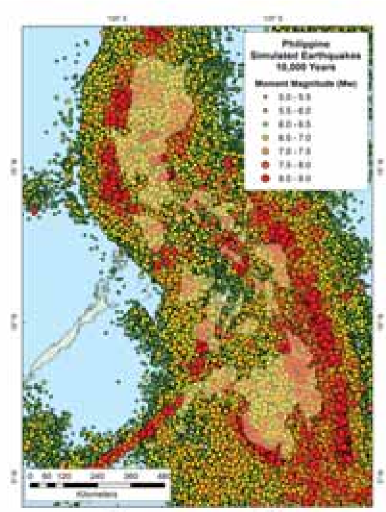


Historical Versus Simulated Earthquakes ($M_w \geq 5.0$)

Historical (423 years)

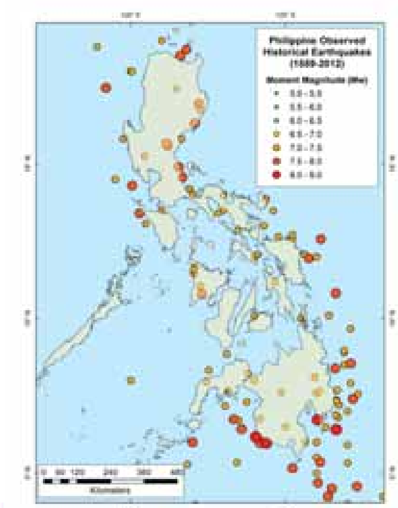


Stochastic 10,000 Years

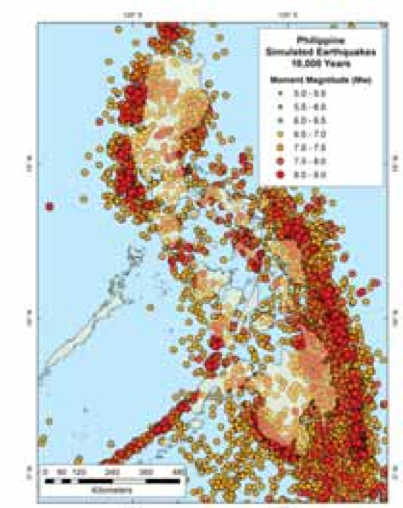


Historical Versus Simulated Earthquakes ($M_w \geq 7.0$)

Historical (423 years)



Stochastic (10,000 Years)

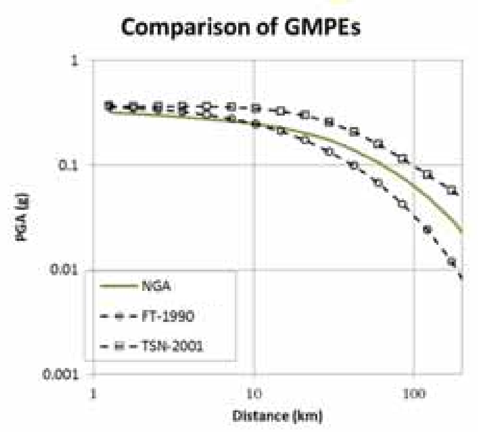


Local Intensity Computation: Ground Motion Prediction Equations

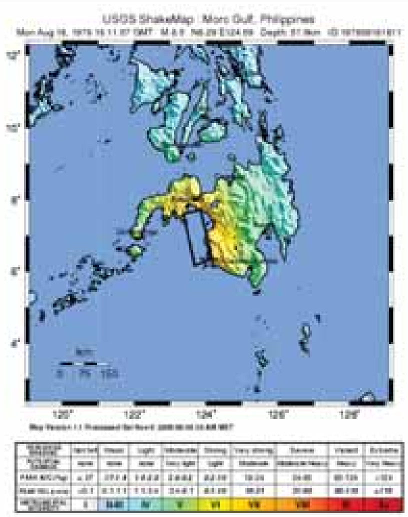
- No published standard GMPE developed specifically for the Philippines
- Existing GMPEs which have been used to assess local hazard
- Japanese GMPEs
  - Fukushima and Tanaka (1990)
  - Torregosa et al. (2001)
- PEER NGA GMPEs
  - Abrahamson & Silva (2008)
  - Boore & Atkinson (2008)
  - Campbell & Bozorgnia (2008)
  - Chiou & Youngs (2008)
- Empirical validation to historical ground motions in the Philippines has not been performed

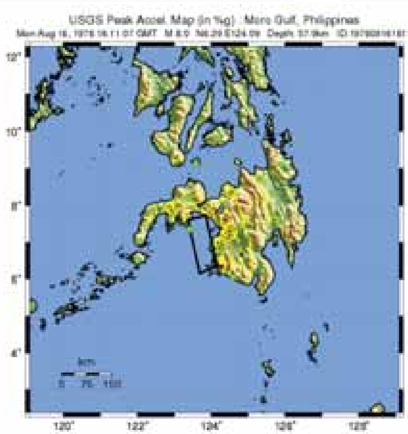
Comparison of GMPE models

- Moment magnitude M_w 7.0
- Depth of 30 km (NGA models)
- Shown for a strike-slip earthquake (NGA models)
- V_{s30} = 760 m/s (rock)
- NGA equations used with equal weighting



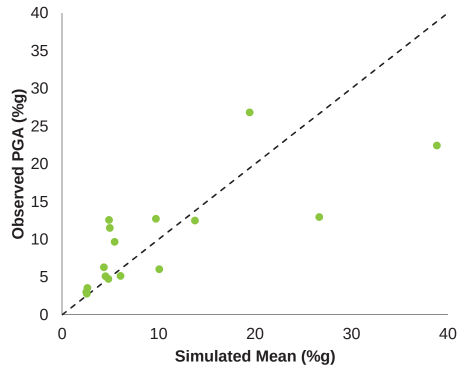
Validating Local Intensity: M8.0 Moro Gulf Earthquake





Macroseismic Observations from Acharya, 1978

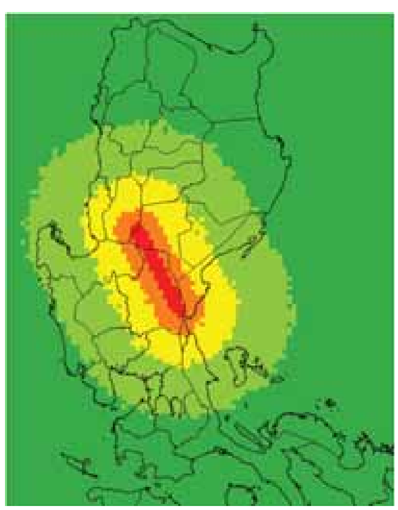
1976 M8.0 Moro Gulf Earthquake – Model comparison with observations



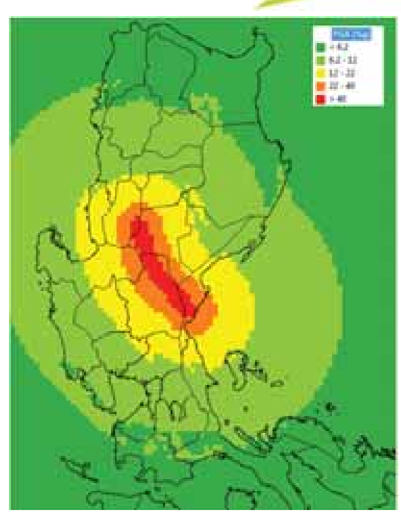
Average simulated / observed = 0.98

COV = 0.48

Validating Local Intensity: 1990 M7.7 Luzon Earthquake

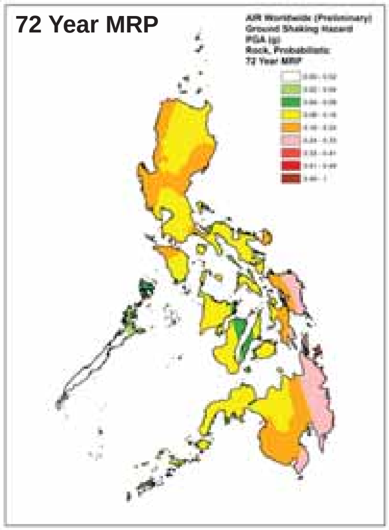


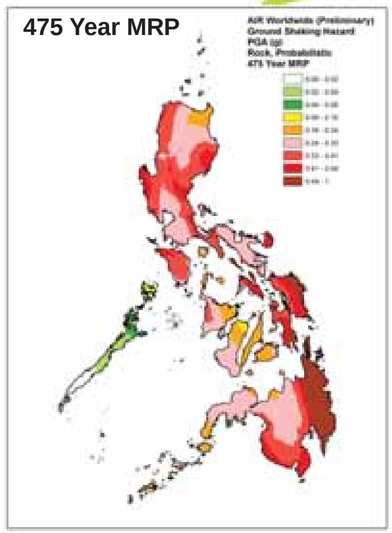
Simulated Mean



USGS Shakemap Atlas

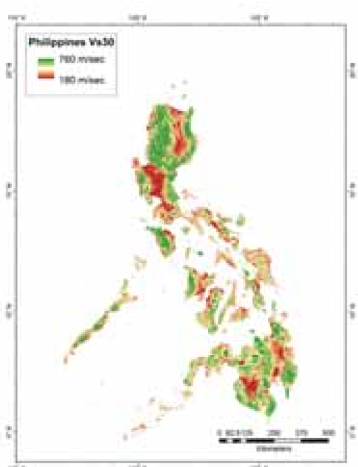
Fully Probabilistic Ground Shaking Hazard Maps



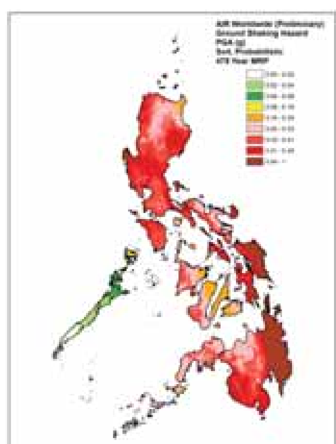


Use of Selected Ancillary Data

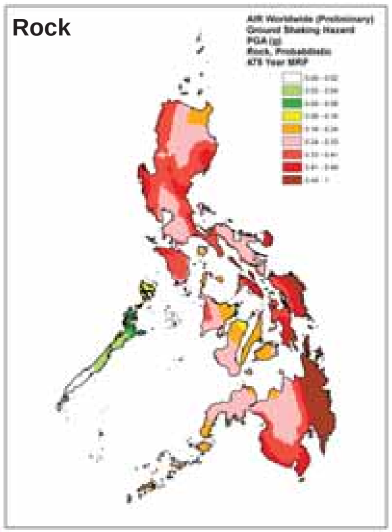
USGS Vs30 (Soil) Map

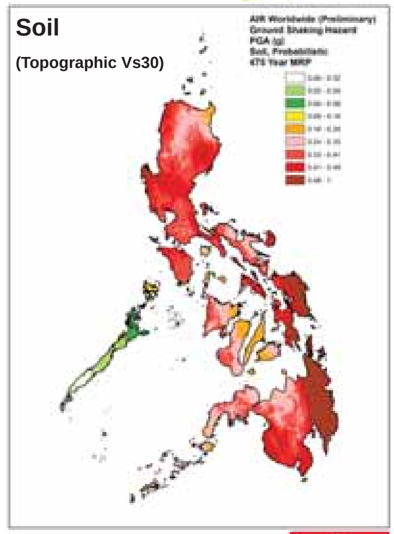


Soil-Based Hazard Map

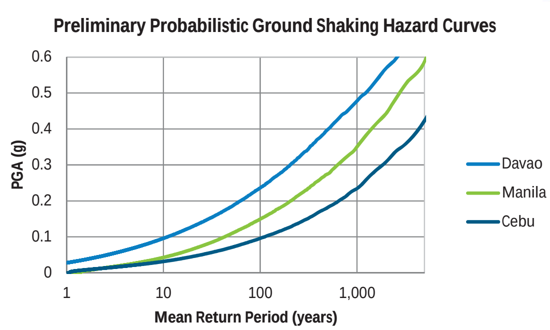


Fully Probabilistic Ground Shaking Hazard Maps





Probabilistic Hazard Result Comparisons



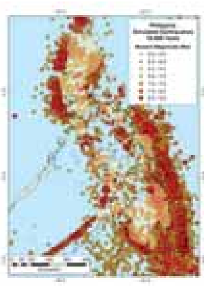
475-year, Rock-Based, Probabilistic PGA (g)		
City	GSHAP/Others[1]	AIR (preliminary)
Davao	0.38	0.38
Cebu	0.25	0.18
Cotabato	0.32	0.37
Central Manila	0.17 – 0.40	0.27

[1]Bautista/PHIVOLCS (2001);Thenhaus et al. (1994); Torregosa et al. (2001); GSHAP (1999); Koo et al. (2009)

Earthquake Vulnerability

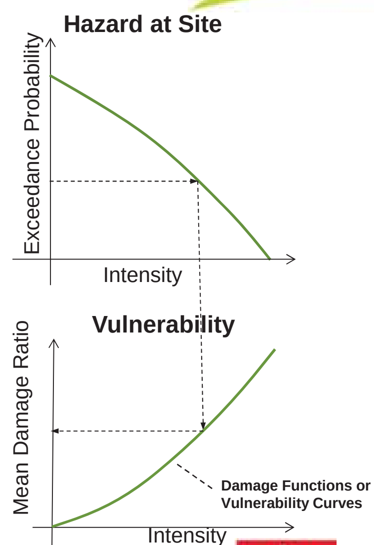
AIR

Key Components of Probabilistic Loss Estimation



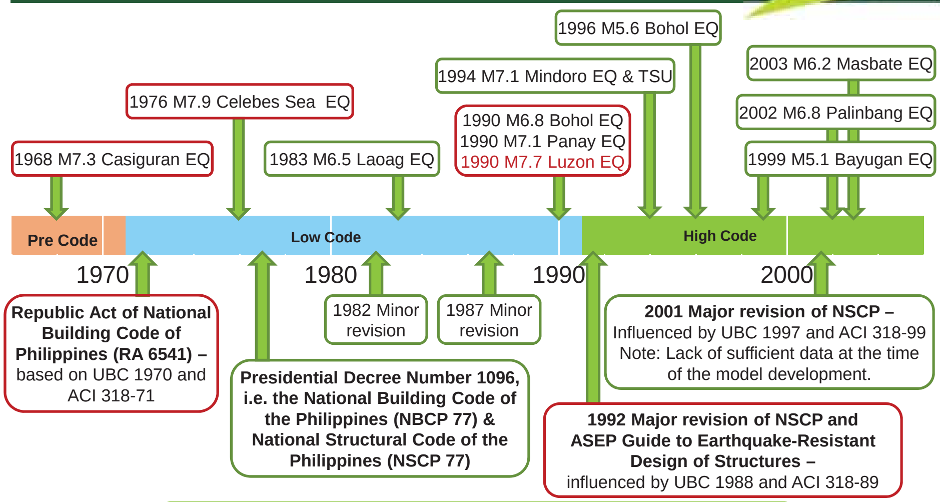
Stochastic Event
Generation at Source

Ground Motion Attenuation →



Mean Loss = Replacement Value x   Mean Damage Ratio ←

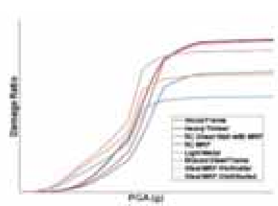
Understanding the Characteristics of Philippine Buildings: The Evolution of Building Codes

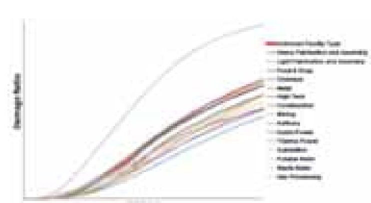


Philippine building codes have been traditionally based on US codes

Overview of AIR's US Damage Functions

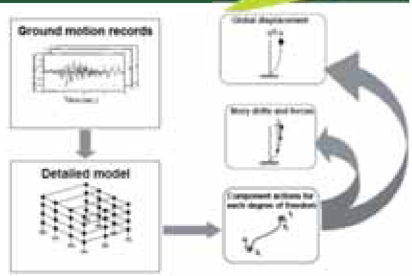
- US earthquake model is one of AIR's flagship models
- The building damage functions are derived using nonlinear dynamic analysis of detailed 3D frame models
- The damage mechanisms are explicitly modeled
- Covers a wide range of residential, commercial and industrial building types

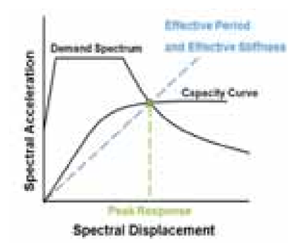




Commonly Adopted Methodologies to Develop Seismic Vulnerability Curves for Buildings

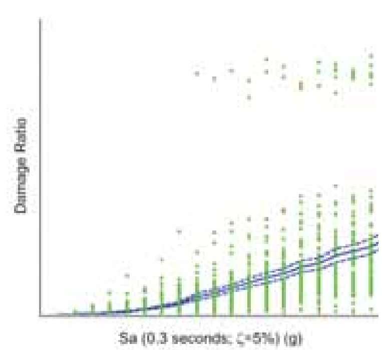
- **Analytical Methods**: Primarily based on computer modeling of buildings. The major steps are:
  – Representing seismic hazard
    - Response spectra
    - Ground motions
  – Structural modeling and prediction of engineering demand parameter (EDP)
    - Equivalent Static Load Analysis: *Capacity Spectrum Method* (CSM)
    - Dynamic Load Analysis: *Incremental Dynamic Analysis (IDA) with SDOF and MDOF systems*
  – Developing the damage and EDP relationship
  – Developing damage functions and fragility curves





Common Methodologies to Develop Seismic Vulnerability Curves for Buildings

- **Empirical Methods**: Primarily based on damage data. The major steps are
  – Developing damage probability matrix (DPM)
    - Damage data from past earthquakes
    - Expert opinion
  – Developing fragility curves and damage functions
- **Hybrid Methods**: Combination of Analytical and Empirical methods.



Overview of AIR's US Damage Functions

Construction and Occupancy Classes Supported

Categories of Construction Classes	Categories of Occupancy Classes
Wood	Residential
Masonry	Commercial
Concrete	Industrial
Steel	Religion and Nonprofit
Special	Government
Mobile Homes	Education
Bridges	Transportation
Pavements	Utilities
Dams	
Tunnels	
Storage Tanks	
Pipelines	
Chimneys	
Towers	
Equipment	

Seismic design levels supported

Seismic Design Levels	UBC Zone
California	4
Pacific Northwest	3
Rest of US	1, 2

Age bands supported

Region	Construction Classes	Age Bands
California	Wood (101, 102, 104)	Pre-1941 1941–1960 1961–1975 1976–1995 Post-1995
	Masonry (112–115, 119)	Pre-1951 1951–2000 Post-2000
	Steel-Light Metal (152)	Pre-1961 1961–1975 1976–2000 Post-2000
	Other Classes (103, 111, 116–118, 121–151, 153–155)	Pre-1951 1951–1975 1976–2000 Post-2000
	Mobile Homes (191–194)	Pre-1971 1971–1995 Post-1995
Oregon and Washington	Steel-Light Metal (152)	Pre-1961 1961–1975 1976–2000 Post-2000
	Masonry (112–115, 119)	Pre-1951 1951–2000 Post-2000
	Other Classes (101–104, 111, 116–118, 131–135, 137, 151, 153–155)	Pre-1951 1951–1975 1976–2000 Post-2000
All States except California, Oregon, and Washington	Steel-Light Metal (152)	Pre-1961 1961–2000 Post-2000
	Other Classes (101–151)	Pre-1951 1951–2000 Post-2000

Understanding the Characteristics of Philippine Buildings: Seismic Design

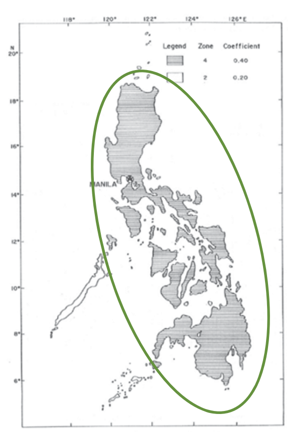
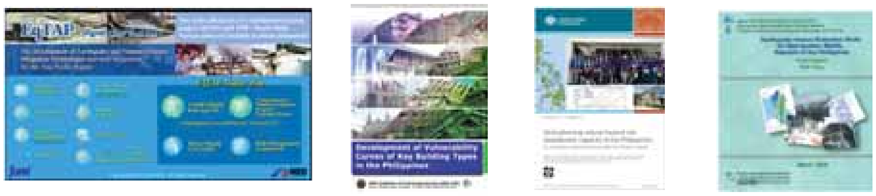


Figure 2.2-B. Seismic Zone Map of the Philippines

- As per NSCP 1992, majority of the Philippines should be designed as per UBC Zone 4 seismic loads

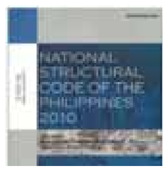
Literature Review was Conducted to Understand Seismic Performance of Philippine Construction

Major studies on seismic vulnerability of buildings in the Philippines



Other Major Sources of Literature

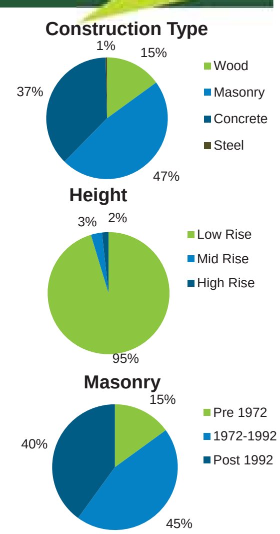
FEMA USGS



ASEP PHIVOLCS

Overview of the Adopted Methodology to Assess Vulnerability

- Buildings are classified based on construction class, occupancy class and year built.
- **Base** damage functions are developed for post 1992 built, **low-rise concrete** and **masonry** buildings in Philippines using a combination of analytical and empirical approach.
- The base damage functions are validated using observed damage data and existing literature.
- The damage functions for other building classifications are developed by assessing their vulnerabilities relative to the base model base types.

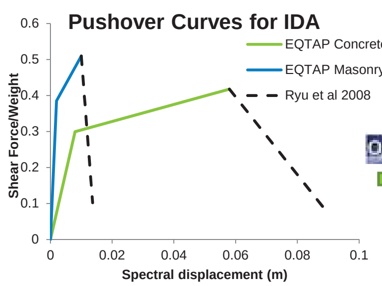


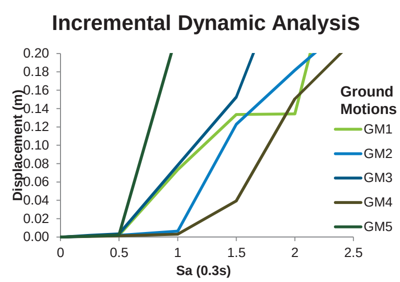
Modeled Building Classifications

Construction Class	Occupancy Class	Height	Year Built
Wood frame (modern)	General residential	Low Rise	Built Pre 1972
Masonry	Permanent dwelling: single-family	Mid Rise	Built between 1972 and 1992
Unreinforced masonry bearing wall	Permanent dwelling: multi-family	High Rise	Built Post 1992
Reinforced masonry	Apartment/Condo		
Reinforced concrete	General commercial		
Reinforced concrete shear wall with MRF	Health care services		
Reinforced concrete shear wall without MRF	General industrial		
Reinforced concrete MRF —ductile	General services		
Pre-cast concrete	Emergency services		
Reinforced concrete MRF	Universities, colleges and technical schools		
Reinforced concrete MRF w/ URM	Agriculture		
Steel	Hydro-Electric Power Systems – General		
Light metal	Thermo-Electric Power Systems – General		
Braced steel frame			
Steel MRF—perimeter			
Steel MRF			

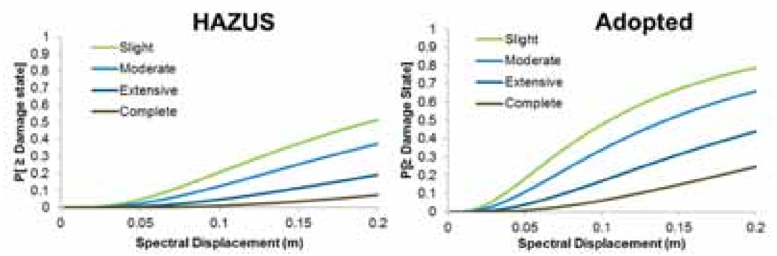
Development of the Base Damage Functions: Incremental Dynamic Analysis (IDA)

- SDOF systems with tri-linear pushover curves are developed in OpenSees
- The pushover curves are developed using the capacity curves available from EQTAP project
- Standard hysteretic and damping properties are used for modeling
- Benchmark ground motions from SAC are scaled and used for IDA



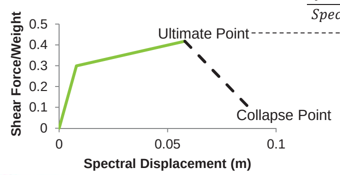


Development of the Base Damage Functions: Fragility Functions

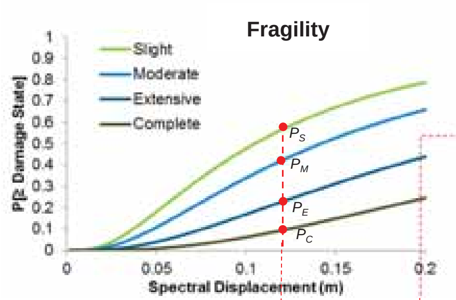


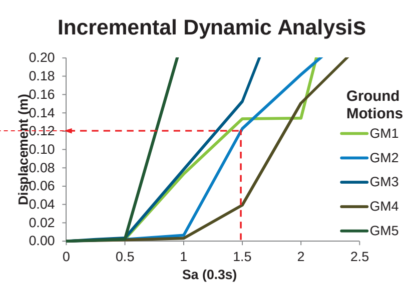
The X axis is transformed using :

$$\frac{Spectral\ Displacement\ (Adopted)}{Spectral\ Displacement\ (HAZUS)} = \frac{Ultimate\ Displacement(EQTAP)}{Ultimate\ Displacement(HAZUS)}$$

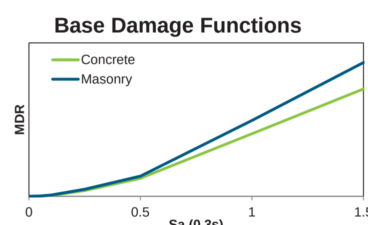


Development of Base Damage Functions: Computation of MDR



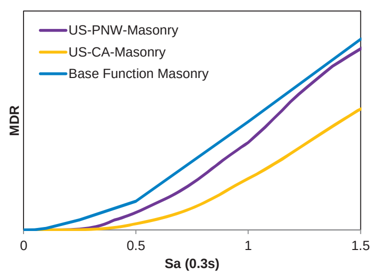


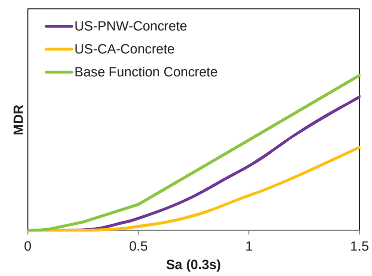
DR = $(P_S - P_M)$ x DR_S + $(P_M - P_E)$ x DR_M + $(P_E - P_C)$ x DR_E + P_C x DR_C



Comparison between US and Philippine Base Damage Functions

- The seismic vulnerability of low rise masonry and concrete buildings is found to be similar to that of buildings in NW Pacific region of US
- Therefore, NW Pacific damage functions are used to estimate the relative vulnerabilities for Philippine buildings

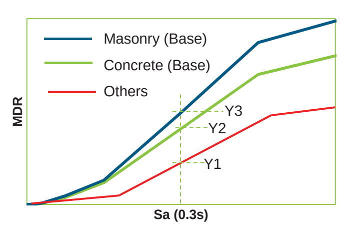




Although NSCP 1992 recommends UBC Zone 4 for seismic design, the vulnerability of the existing buildings may be higher due to prevailing construction practices

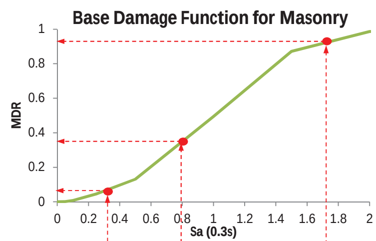
Computation of Relative Vulnerabilities

- The damage functions for all construction types are developed by assessing their relative vulnerabilities with respect to the developed base damage functions
- The relative vulnerabilities are estimated using AIR's pre-existing damage functions for US buildings



Relative vulnerability at Sa = 1.0 g :
w.r.t Concrete = Y2 / Y1
w.r.t Masonry = Y3 / Y1

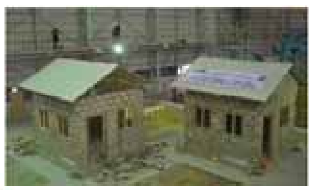
Validation of Damage Estimates: Shake Table Test



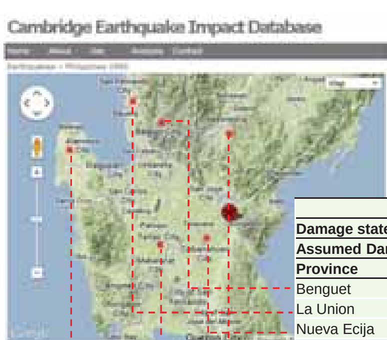
- Imai et al (2012) performed shake table tests for two full scale models of masonry buildings – one built as per NSCP 2010 and the other built as per locally prevailing practices

Shake table test of full scale masonry buildings buildings in the Philippines (Imai et al 2012)

PGA (g)	As per NSCP 2010	Locally Prevailing Practices
0.17	No damage	No damage
0.4	No damage	Moderate damage
0.85	Heavy Damage	Collapse



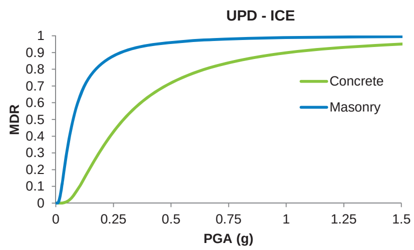
Validation of Damage Estimates: 1990 Luzon Earthquake

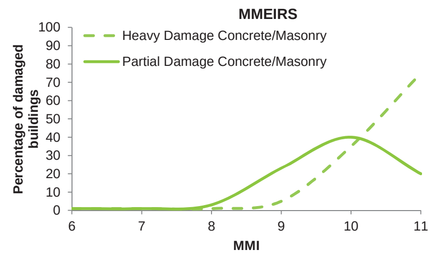


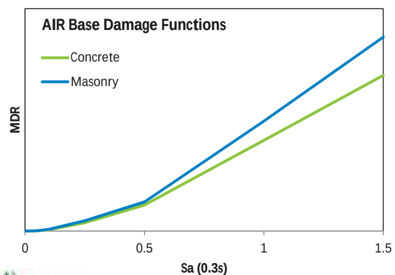
- The resulting damage functions were used to simulate the 1990 Luzon EQ.
- The percentage of buildings in particular damage states were compared to historical damage data.

Luzon 1990 Earthquake Damage			
Damage state	**No damage**	**Partial damage**	**Complete damage**
Assumed Damage Ratio	**Less than 2%**	**2% to 70%**	**Greater than 70%**
Province	**Cambridge EQ Impact Database (number of buildings)**		
Benguet	72293	14618	7970
La Union	82722	16066	3583
Nueva Ecija	223839	14339	1679
Nueva Vizcaya	50250	5352	2620
Pangasinan	360692	16764	3044
Tarlac	147582	10736	3396
Total	**937378**	**77875**	**22292**
Percentage	**90.35%**	**7.51%**	**2.15%**
Model Predictions	**91.91%**	**7.75%**	**0.34%**

Comparison of Damage Functions







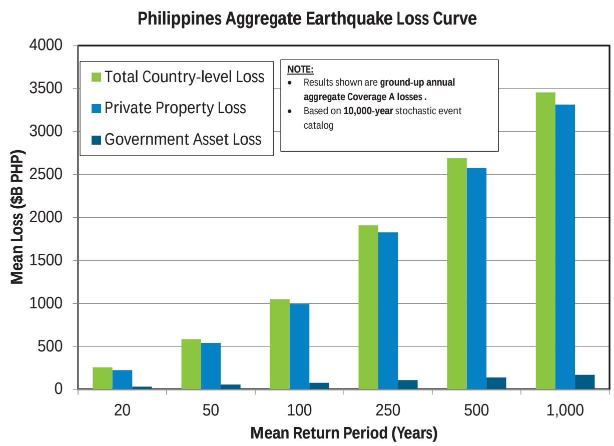
Luzon 1990 Earthquake Damage			
Damage state	No Damage	Partial Damage	Complete Damage
Cambridge EQ Impact Database	90.35%	7.51%	2.15%
Model Predictions using developed DFs	91.91%	7.75%	0.34%
Model Predictions using UPD-ICE DFs	57.22%	41.56 %	1.23%

AIR SF12-1029: WB PHILIPPINES – CATASTROPHE RISK ASSESSMENT – 051413 CONFIDENTIAL adpc

Preliminary Loss Results

AIR

Earthquake Loss: EP Curve



MRP (Years)	Aggregate Loss ($B PHP)		
	Government Asset Loss	Private Property Loss	Total Country-level Loss
20	32	223	256
50	55	539	582
100	76	993	1047
250	108	1826	1908
500	137	2575	2689
1,000	169	3313	3456

Replacement Values (Coverage A):
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

Questions

AIR

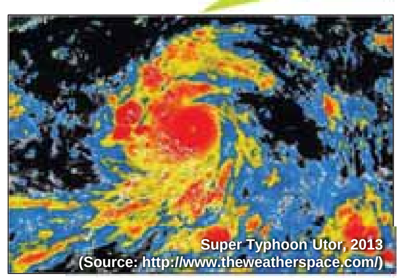
Philippines Catastrophe Risk Assessment Project

Tropical Cyclone Induced Wind and Precipitation and Non-Tropical Cyclone Induced Precipitation

Peer Review Presentation
San Francisco
November 7, 2013

Presentation Agenda

- Project Overview
- Tropical Cyclone Induced Wind and Precipitation
- Non-tropical Cyclone Induced Precipitation
- Summary Loss Results


Super Typhoon Utor, 2013
(Source: http://www.theweatherspace.com/)


Monsoonal Flooding in Laguna Province, 2013
(Source: http://ca.news.yahoo.com/)

Project Overview

AIR

Major Project Tasks

- The project is developed over five distinct components

Component	Description
1	Hazard and Loss Data Collection and Management
2	Exposure Data Collection and Management and Vulnerability Assessment
3	Country Catastrophe Risk Profile
4	Design of Parametric Indices for Financial Transactions
5	Ongoing Support During Placement of Parametric Risk Transfer Product (conditional on DRF placement)

Overview of Project Plan

Existing AIR Catastrophe Models for the Philippines
1. Earthquake Ground Shaking and TC (Wind and Precip)
2. Province level aggregated exposure database

↓

Expand Existing Models
1. Add non-TC Induced Precipitation Hazard
2. Add National Government Assets

↓

Enhance Existing Models
1. Improve Country-wide Exposure Data
2. Update Representation of Seismic Risk in the Model

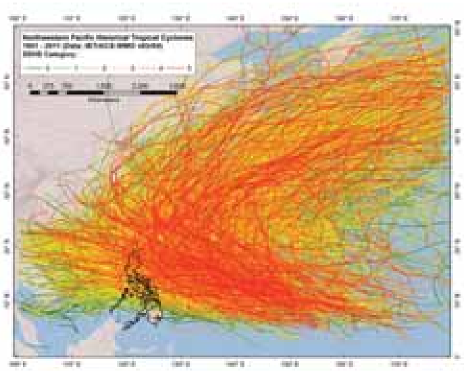
↓

Develop Catastrophe Loss Metrics
1. Monetary physical damage loss metrics
2. Including Emergency Losses and input towards Financial Risk Statement

Tropical Cyclone Model

AIR

Tropical Cyclone Historical Database



- Data Source: The International Best Tracks Archive for Climate Stewardship (IBTrACS)
- Scope: over 1,600 cyclones occurring in the northwest pacific basin covering the period from 1951 to 2011

AIR Historical Database

- An average of 6 tropical cyclones make landfall in the Philippines annually with another 3 passing close enough to cause loss.

Example from Tropical Cyclone Historical Database: Typhoon Ketsana / Ondoy 2009

- The tropical cyclone historical database contains parametric information about the events

Tropical Cyclone Track

Serial_num	Season	Num	Name	ISO_date	ISO_hour	Nature	Latitude	Longitude	Pres_mb	Track_type	SS_scale
2009268N14128	2009	17	KETSANA	40083	0	TS	15.2	116.5	985	main	1
2009268N14128	2009	17	KETSANA	40083	6	TS	15.2	115.5	985	main	1
2009268N14128	2009	17	KETSANA	40083	12	TS	15.6	114.5	980	main	1
2009268N14128	2009	17	KETSANA	40083	18	TS	15.7	113.7	975	main	2

Year

Location

IBTrACS Serial Number

WMO Name

Saffir-Simpson Scale

Source: International Best Track Archive for Climate Stewardship (IBTrACS).

Consequence Database: Tropical Cyclone Events and Non-Tropical Cyclone Flood

- Data Sources:
  - Emergency Events Database (EMDAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED)
  - The Global Active Archive of Large Flood Events maintained by the Dartmouth Flood Observatory (DFO)
  - The National Disaster Coordinating Council Office of Civil Defense Operations Center (NDCC/NDRRMC) Database of Destructive Typhoons
  - The online information repository “ReliefWeb” (e.g., NDCC/NDRRMC reports/updates, OCHA reports, etc.)
  - Disaster information reports issued by the Asian Disaster Reduction Center (ADRC)
- ~520 significant tropical cyclone and flood events dating 1905 to 2013
- Main Data Fields: Deaths, Injuries People Affected, Buildings Damaged, Buildings Destroyed, Economic Damage

Summary of Tropical Cyclone Events in the Consequence Database

Time period	Number of Events	Number of Catastrophic Events	Estimated Economic Damage (Current Million USD)	Estimated Economic Damage (Trended Million 2012 USD)	Estimated Deaths	Estimated Deaths (Trended 2012 Value)
Pre-1950s	12	10	10	N/A	2,858	N/A
1950s	8	8	50	N/A	2,023	N/A
1960s	16	14	112	4,604	1,655	5,637
1970s	60	35	628	11,258	3,402	8,471
1980s	59	48	1,996	14,588	5,348	9,636
1990s	91	72	2,818	12,276	9,851	14,613
2000s	85	76	1,881	3,761	6,669	7,509
2010 – 2013	22	19	1,247	1,326	2,866	2,898

Example from Tropical Cyclone and Flood Consequence Database: Typhoon Bopha / Pablo 2012

- A tropical cyclone event is uniquely identified.

Consequence ID	Main Type	Year	Approximate Start Date	Approximate End Date	Date(s) of Event Source	Affected Areas	WMO Storm Name	PAGASA Storm Name
517	Typhoon	2012	December 4, 2012		GLIDE	Ilocos (I), Mimaropa (IV-B), Western Visayas (VI), Central Visayas (VII), Northern Mindanao (X), Soccsksargen (XII), ARMM, and Caraga	Bopha	Pablo

Consequence ID

Chronological information and data source

Location

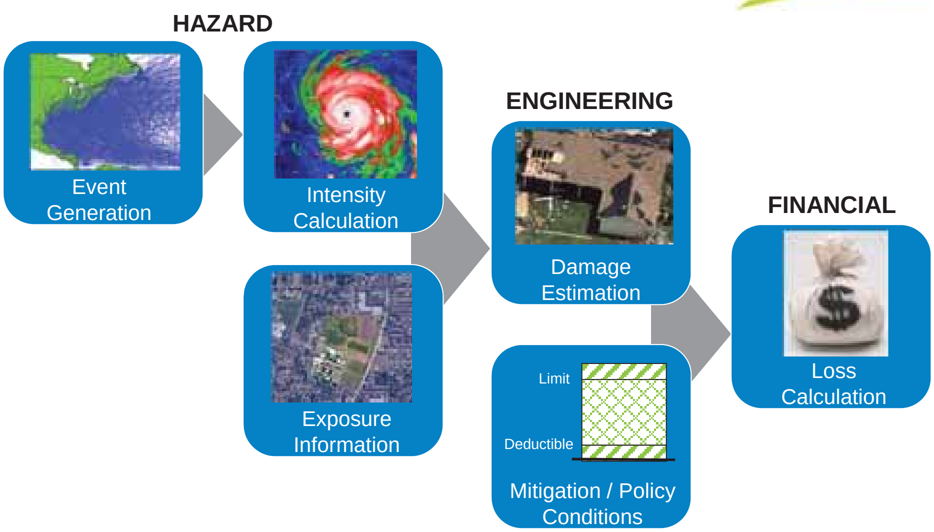
TC Name

Significant fields enumerate the human and economic losses. Columns are labeled Minimum, Maximum, or Preferred with a data source for each field. For this example, a reliable source of available data was from the NDRRMC.

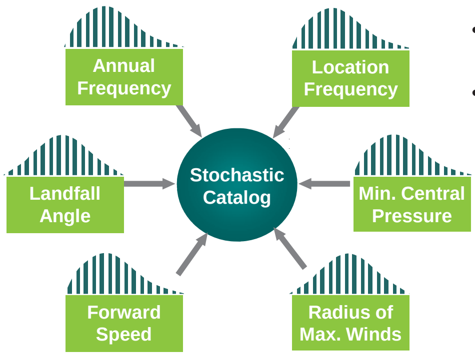
Min People Displaced	Min People Displaced Source	Max People Displaced	Max People Displaced Source	Preferred People Displaced	Preferred People Displaced Source
60000	DFO	973207	NDRRMC	973207	NDRRMC

- Preferred Deaths = 1067
- Preferred Missing = 834
- Preferred Displaced = 973,207
- Preferred Affected = 6,243,998
- Preferred Partially Destroyed Buildings = 102,506
- Preferred Destroyed Buildings = 76,198
- Economic Damage = 34,409.4 (million Pesos)
- Preferred Economic Damage = 827.3 (million USD) (converted from Pesos)

AIR Risk Assessment Methodology

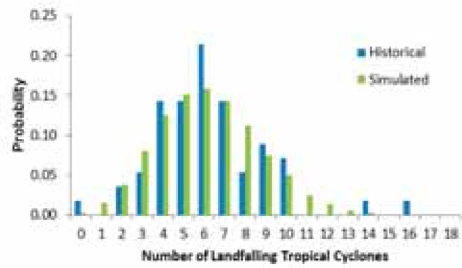


Stochastic Catalog of Typhoon Events



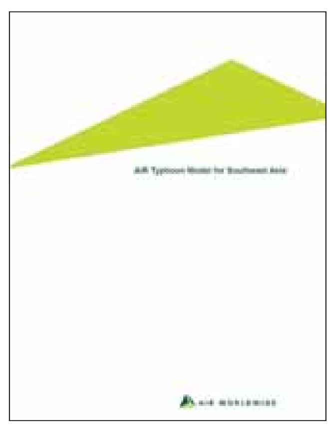
AIR Typhoon Model for Southeast Asia:

- 10,000-year catalog (> 293,000 events)
- 61,924 events landfalling in the Philippines
- 30,325 events bypassing the Philippines but close enough to cause loss

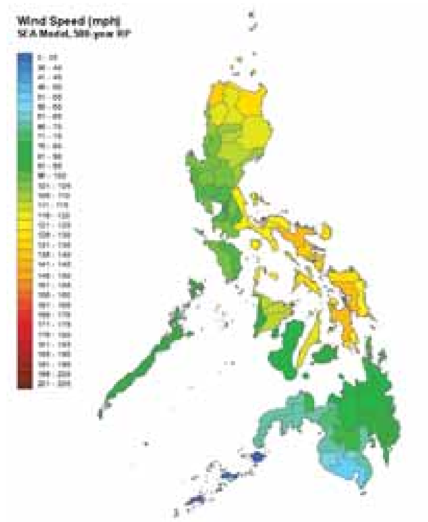


Details of Tropical Cyclone Hazard Model

- Please refer to our model documentation for further details on the TC hazard module for the Philippines
- Section 3: Event Generation
  - Stochastic Catalog
- Section 4: Local Intensity Calculation
  - Wind field simulation
  - Precipitation modeling



High Resolution Model Update



PRELIMINARY

Wind Damage Estimation

- Vulnerability is computed separately for wind and precipitation
- Damage functions relate maximum wind speed to mean damage ratio
  - 1 min sustained at 10m

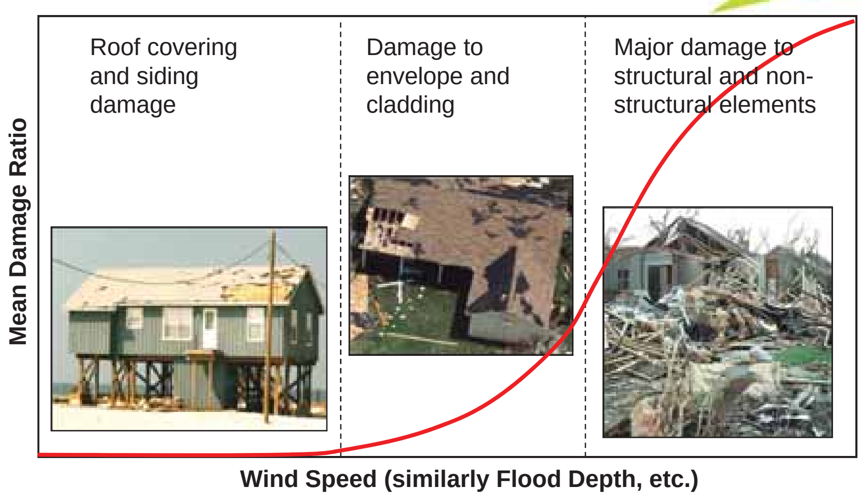
- Wind damage functions are developed based on engineering analyses and account for building code evolution and enforcement
- Losses account for the effects of wind duration on damage
- Uncertainty in damage is captured in the model by probability distributions around the mean damage ratio

Building Characteristics

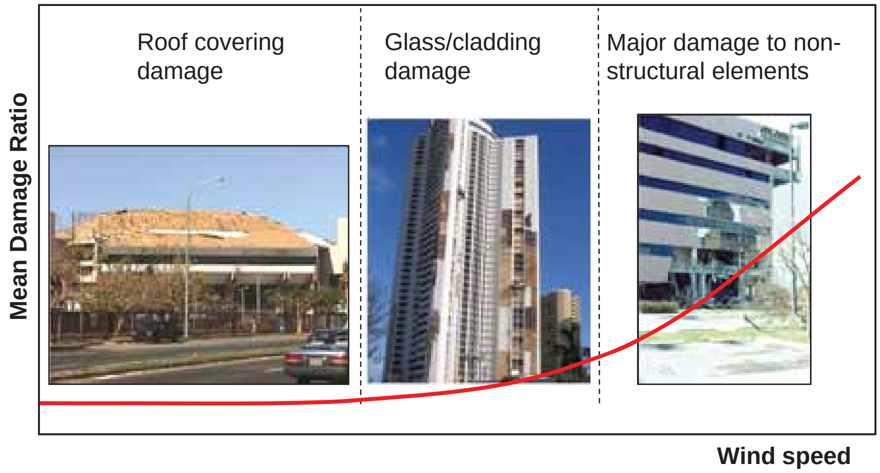
TYPHOON WIND VULNERABILITY

- **STRUCTURE**
  - OCCUPANCY: APARTMENT, COMMERCIAL, INDUSTRIAL
  - MATERIAL: WOOD FRAME, URM, RM, STEEL FRAME, RC, LIGHT METAL
  - HEIGHT: LOWRISE, MIDRISE, HIGHRISE
- **BUILDING ENVELOPE**
  - ROOF: WOOD, CONCRETE, METAL
  - CLADDING: WOOD, CMU, RM, CONCRETE, METAL
  - OPENINGS: SMALL, MEDIUM, LARGE
- **OTHER FACTORS**
  - ENGINEERING
  - HAZARD
  - REPAIR COST

Damage Estimation Example: Residential Wood Frame



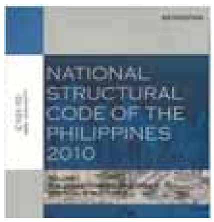
Damage Estimation Example: Commercial Reinforced Concrete and Steel Frame

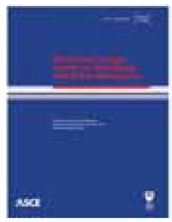


Influence of Building Height

Wind Vulnerability Based on Building Code Evaluation and Data from Neighboring Regions

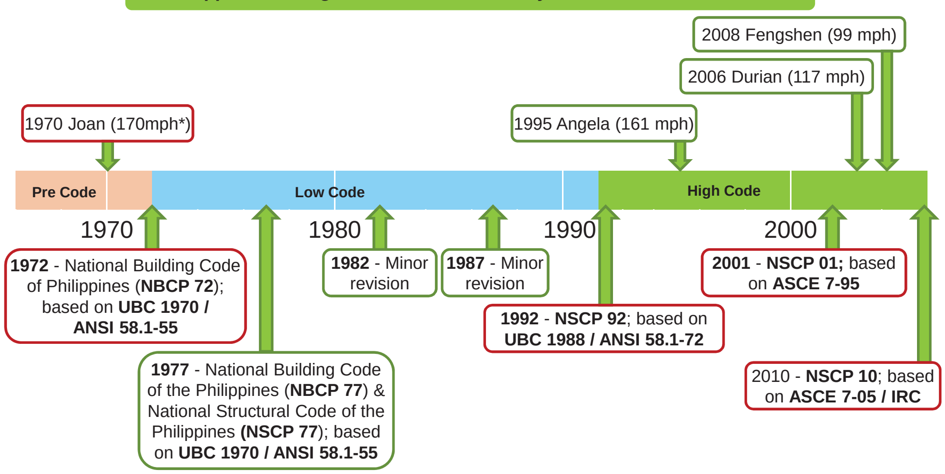
- Detailed data on wind damage and losses is scarce for the Philippines
- AIR engineers leveraged validated damage functions from other regions based on the following criteria:
  - Regions with similar building codes (United States)
  - Regions close to the Philippines (South Pacific Island Nations)





Evolution of Building Codes in the Philippines

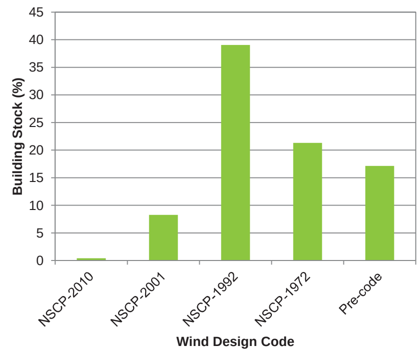
Philippine building codes have traditionally been based on US codes



*Max sustained wind estimates from www.Typhoon2000.ph

Year of Construction

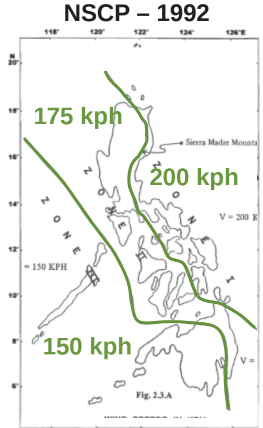
- Year of construction is typically used as a proxy for changes in the building code
- Detailed year of construction statistics data is very limited for the Philippines
  - Limited data indicates building stock is dominated by NSCP-92 or older structures
- Extent to which wind design provisions are adopted and enforced nationwide is uncertain
- The current AIR Typhoon Model for Southeast Asia does not support age bands or regional modifiers



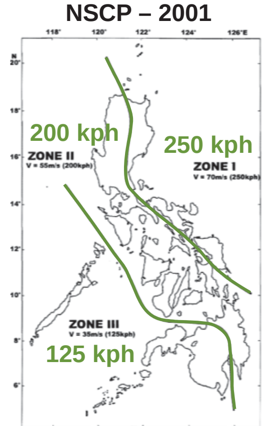
Wind Zone Maps

Wind zones have remained relatively consistent but design wind speeds have changed

NSCP – 1992



NSCP – 2001



- Building codes in the Philippines suggest vulnerability similar to that of buildings in the following US regions:
  - Key West, FL for NSCP Zone I
  - New Orleans, LA for NCSP Zone II
  - Houston, TX for NSCP Zone III

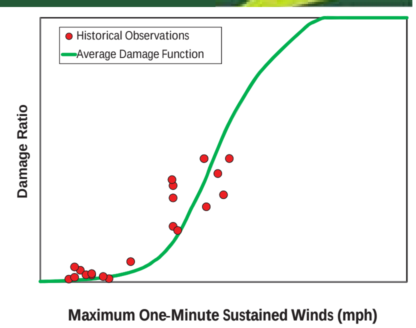
Wind Vulnerability Accounting for Building Characteristics Representative of the Philippines

- Construction in the Philippines often lacks characteristics typical of hurricane prone regions in the U.S. based on literature review of building characteristics:
  - Stringent code enforcement
  - Use of engineered window shutters, strong building-foundation connections, impact resistant glass, etc.

- Damage functions were modified to reflect local materials, labor and material costs, and construction practices
  - Based on a review of the building characteristics it was determined that wind vulnerability of Philippine buildings, on average, is more comparable to that of buildings in the Houston, TX region

Wind Vulnerability in the Region

- Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) leveraged for the present study
  - AIR recently completed project for the World Bank which included the development of state-of-the-art catastrophe risk models
  - 15 Pacific Island Countries (PIC) where residential building construction is more similar to Philippines than homes in U.S.

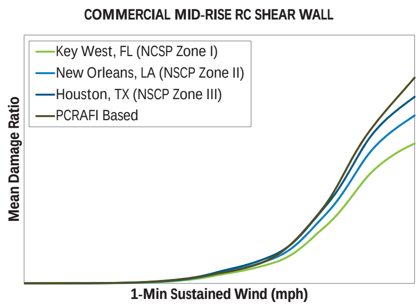


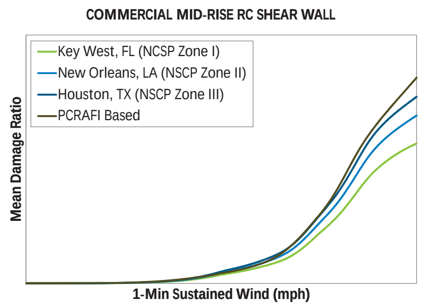
Source: PCRAFI WB (AIR 2011)

- PCRAFI damage functions were developed and validated using
  - In-depth study of the regional building characteristics
  - Damage and loss data from past events including reconnaissance reports
  - Engineering analyses

Wind Vulnerability Comparisons

- Although subject to similar wind design provisions as buildings in the US, the vulnerability of typical buildings in the Philippines may be higher due to prevailing construction practices and code enforcement
- PCRAFI damage functions were leveraged to capture the expected vulnerability of buildings in the Philippines, especially residential construction
- Model was updated using a combination of PCRAFI and US (Houston, TX) based damage functions



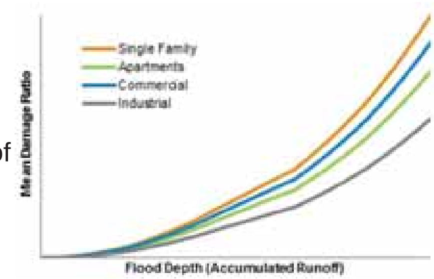


Precipitation Vulnerability Modeling

- Philippine building code provisions for flood are much more limited than those for wind
- Precipitation damage is estimated by relating effective water depth to damage ratio
  - Effective water depth is total event rainfall at the location above a threshold value
  - Threshold is a critical hazard value below which the building is assumed undamaged
  - Threshold is based on the degree of sophistication and efficiency of the flood defense systems in the country

Precipitation Damage Functions

- Precipitation damage functions are developed and validated based on available claims data and latest research
- Precipitation damage functions are calibrated to the hazard resolution of the existing model
- Accordingly, "water depth" is not an "actual" flood depth that a building observes in real life, rather, it is used as an indication of flood or flood index
- Precipitation damage is a function of the occupancy type and the amount of precipitation at a building's location

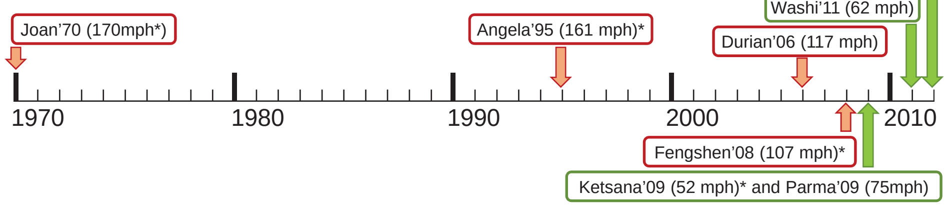


Wind and Flood Damage Function Validation

- Damage function validation was based on
  - Published engineering research and analyses
  - Damage data from past events
  - Data from more mature insurance markets is modified to reflect local conditions (building stock, local design codes, local construction practices, and socio-economic circumstances)
- Post disaster surveys from regions with similar building typologies
- Validation of the vulnerability module is closely related to the validation of modeled losses
- Damage functions have been validated against reported losses from several historical typhoons

Validating Losses: Marquee Events

Marquee event selection based on hazard, reported losses and available data

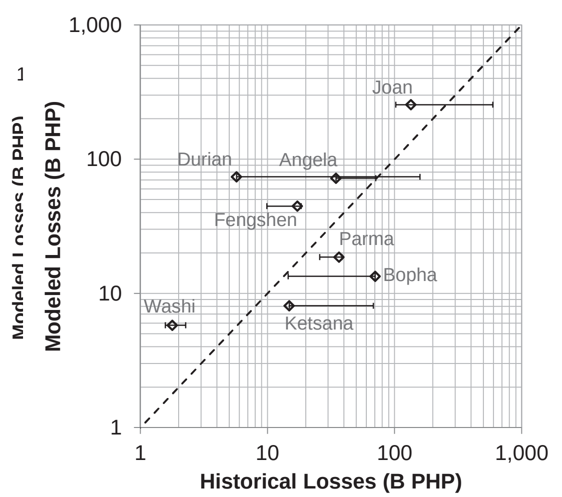


*Max sustained wind estimates from
www.Typhoon2000.ph

Original Model Validation Event | New Model Validation Event

Validating TC Wind and Precipitation Losses: Marquee Events

- All losses trended to 2012 Philippine Pesos
- Modeled losses validated with EMDAT reported loss values
- EMDAT consistently provides losses for each marquee event & reports total economic losses
- Error bars represent reported loss estimates from SwissRe, MunichRe, AXCO, ROHK, GuyCarp, and NDRRMC

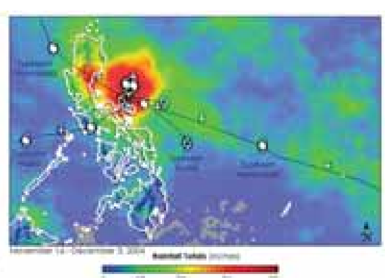


Non-Tropical Cyclone Induced Precipitation Model

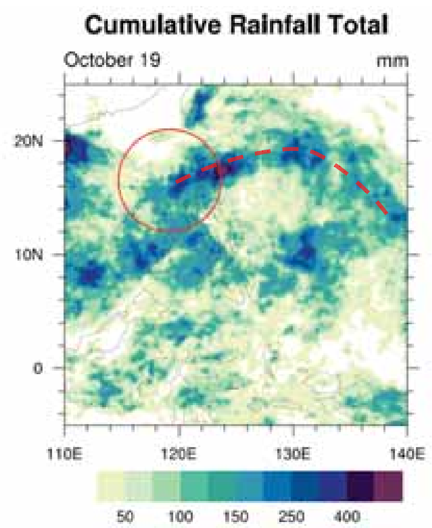
AIR

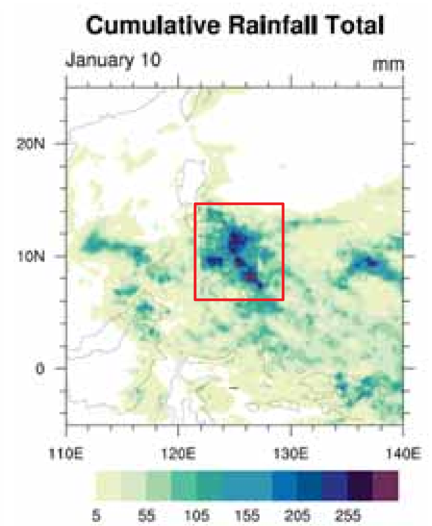
Guideline

- Methodology for non tropical cyclone (non-TC) rainfall extraction
  - Previous work in the literature
  - Processing of Tropical Rainfall Measuring Mission (TRMM) satellite data
  - Results and validation
- Generation of non-TC rainfall over the Philippines
  - Spatial and temporally correlated stochastic rainfall
  - Results and validation
- Flood Event Definition
  - Event definition
  - Distribution Results and validation
- Preliminary Losses



Cumulative Rainfall: TC and Non-TC



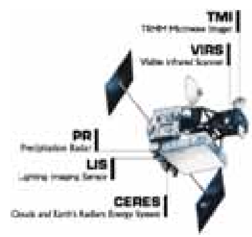


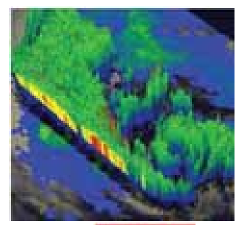
Determining a Methodology

- "Geometric size of hurricanes ranges over an order of magnitude [yet] their intensity measured by central pressure deficit or maximum wind speeds bears no perceptible relation to their size" (*The Theory of Hurricanes*, Emanuel 1991)
- Studies define tropical cyclone rainfall climatology via a distance threshold based on best track data (Rodgers, et al 1999, Adler, 2000, Jiang and Zasper, 2010)
- Statistical attributes/size of NW Pacific typhoon are 40% larger than their Atlantic counterparts (Merrill, 1984)
- Japanese Meteorological Agency (JMA) provides best track data for NW Pacific basin from 1951-forward
- Remove all TRMM 3-hrly rainfall within 500km of JMA storm center.

Tropical Rainfall Measuring Mission

- Joint (NASA and JAEA) mission/satellite to monitor and study tropical rainfall
- Provides rainfall on a three-hourly timescale at very high resolutions – 0.25 x 0.25 degrees from 50N to 50S
- First of its kind precipitation radar in space combined with microwave imager and visible infrared scanner to detect and delineate rainfall
- Launched in 1997 and still in orbit offering a unique 3D-look at rainfall as well as energy at the top of the atmosphere (CERES) and lightning strikes

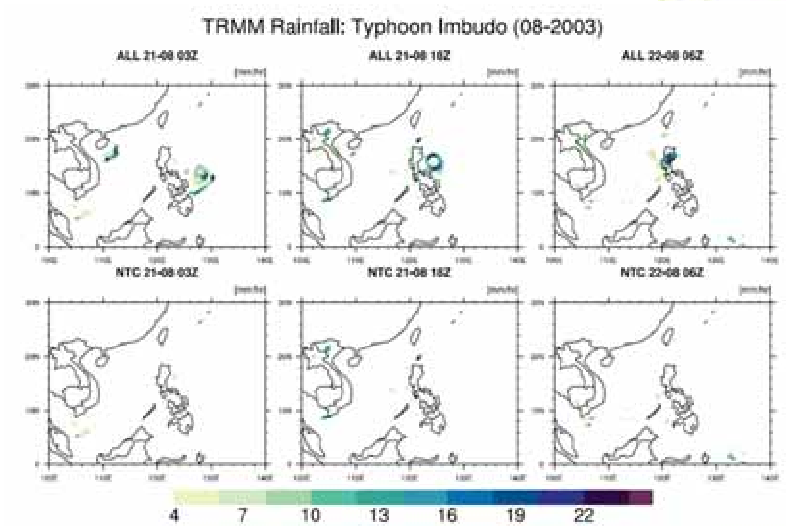




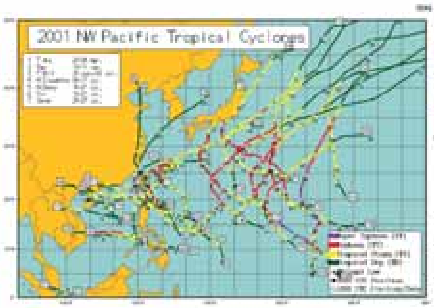
Steps to Formulating NTC Climatology

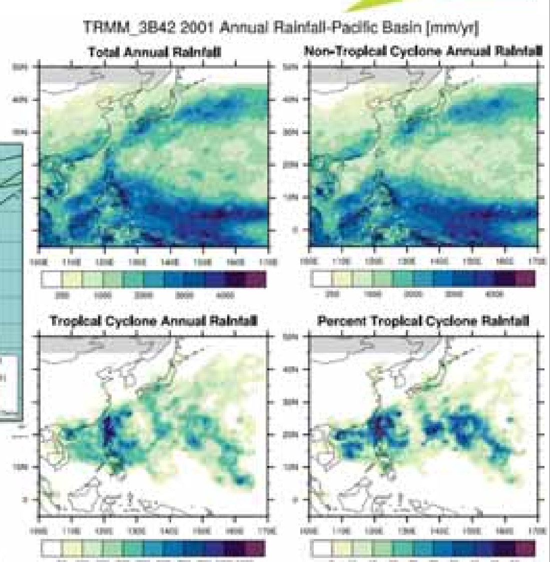
1. Collect and process 3B42 3hourly TRMM data from 2000-2008.
2. Interpolate six hourly JMA best track data to three hourly points for all storms-central pressure latitude and longitude
3. Extract all rainfall within a 500km radius of central latitude and longitude at all time-steps of storm event
4. Aggregate to daily and yearly timescales for validation, comparisons, and generation of rainfall.

What Method Looks Like: Typhoon Imbudo

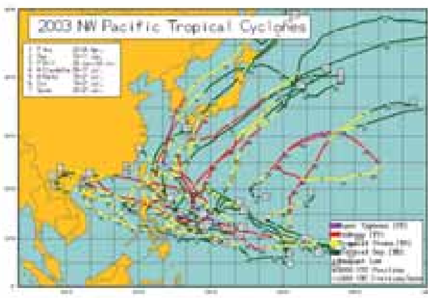


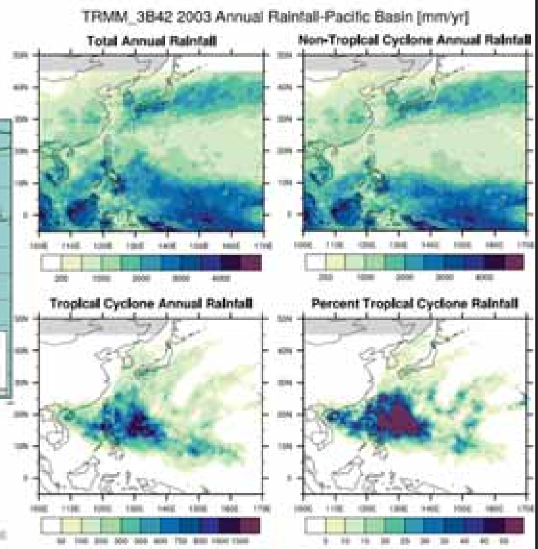
2001 Typhoon Season



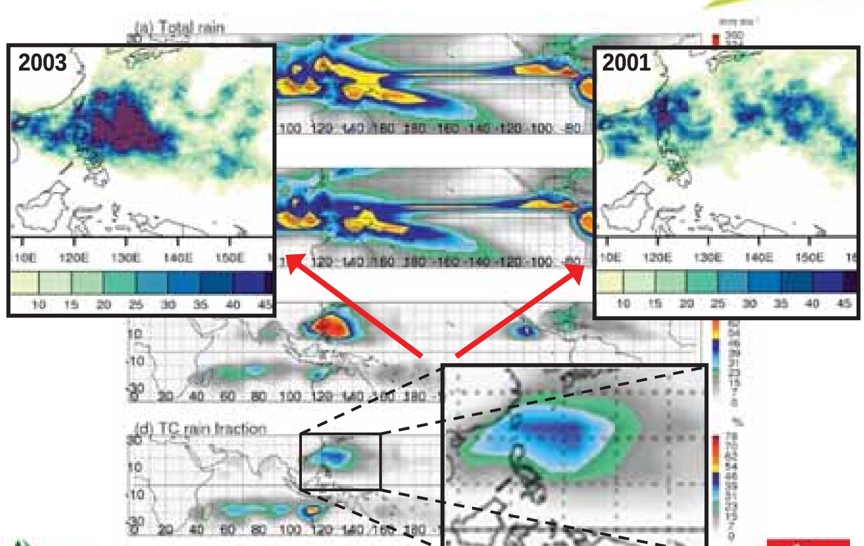


2003 Typhoon Season

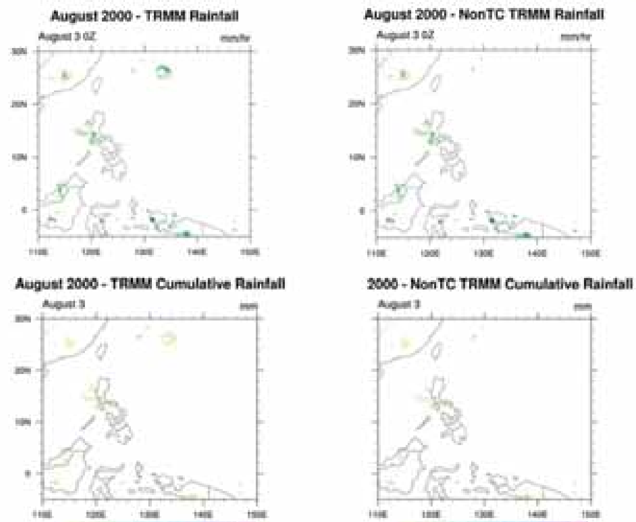




Jiang and Zipser JCLI 2010 TRMM study

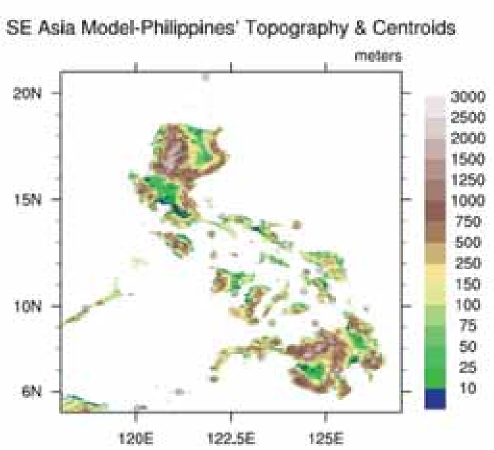


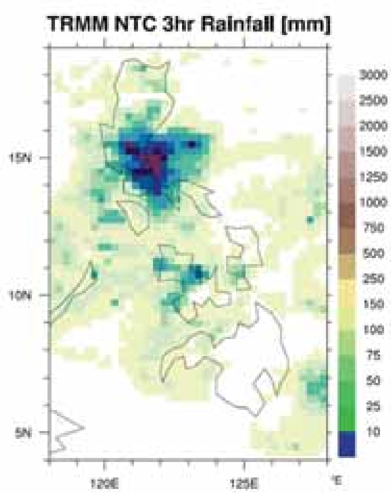
August 2000 TRMM TC & non-TC daily rainfall



SE Asia Model: Philippines CRESTA Centroids

SE Asia Model-Philippines' Topography & Centroids





Stochastic Multi-site Rainfall Generation Model

- Multi-station daily rainfall generation which is spatially and temporally correlated to other rain gauge sites.
- Treat Non-TC TRMM data as the “station gauge” values corresponding to grid that each centroid is located in.
- Use Geospatial-Temporal Weather Generator (GiST) model developed by Prof. Baigorria of UN-Lincoln and Prof. Jones of UF/FSU Florida Climate Institute (*Journal of Climate,* 2010, 2011)
- Two step method:
  1. Markov-chain discrete distribution for rainfall event generation.
  2. Uniformly distributed random numbers scaled by correlation matrix to achieve spatial correlation. Values are then transformed to a gamma distribution using the CDF of each station and rescaled to rainfall amounts

Transition Probabilities: Markov Chain

- Two-state boolean value conditioned on rainfall at surrounding stations (j,k) and rainfall from previous day at station ($i_{(t-1)}$)

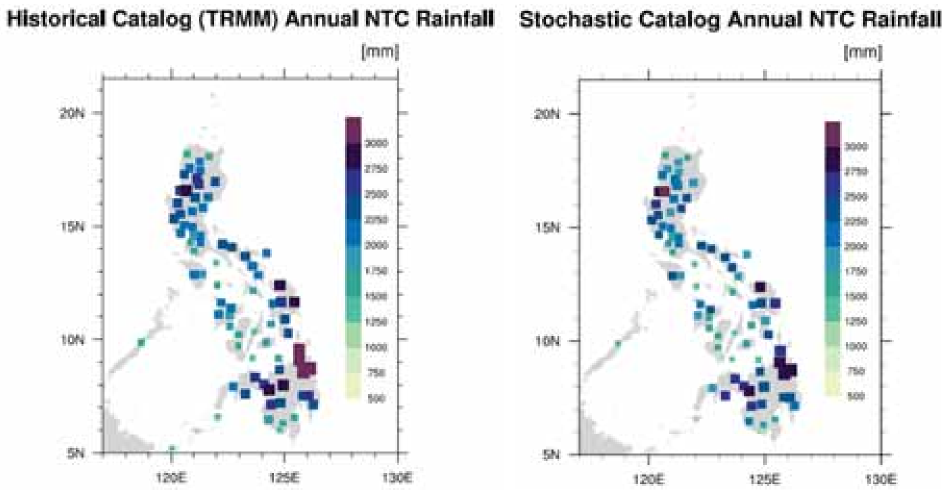
$$P_{1|0,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0\right)$$
$$P_{1|0,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1\right)$$
$$P_{1|0,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0\right)$$
$$P_{1|0,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1\right)$$
$$P_{1|1,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0\right)$$
$$P_{1|1,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1\right)$$
$$P_{1|1,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0\right)$$
$$P_{1|1,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1\right)$$

$$P_{1|0,0,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|0,0,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|0,1,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|0,1,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|1,0,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|1,0,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|1,1,0,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|1,1,1,0} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 0\right)$$
$$P_{1|0,0,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|0,0,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|0,1,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|0,1,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 0, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|1,0,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|1,0,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 0, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|1,1,0,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 0, \chi_{i_{(t-2)}} = 1\right)$$
$$P_{1|1,1,1,1} = \Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t} = 1, \chi_{k_t} = 1, \chi_{i_{(t-1)}} = 1, \chi_{i_{(t-2)}} = 1\right)$$

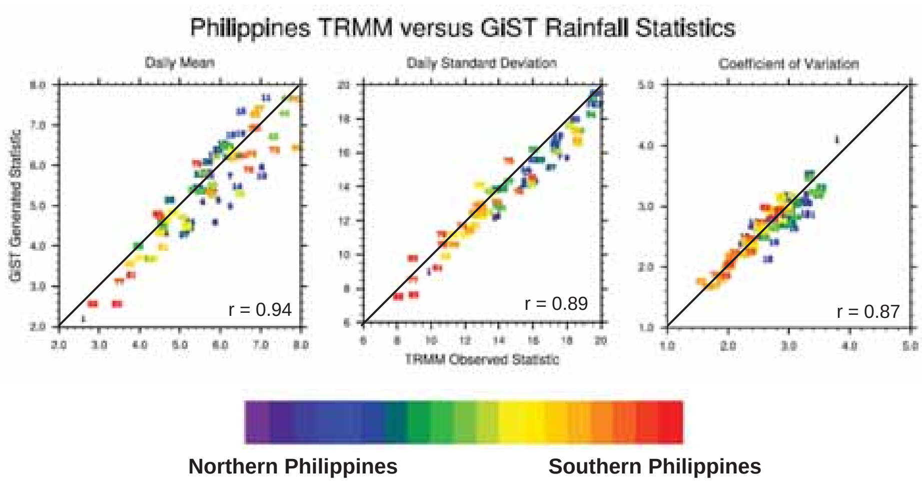
$$\Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t}, \chi_{k_t}, \chi_{i_{(t-1)}}\right) + \Pr\left(\chi_{i_t} = 0 \mid \chi_{j_t}, \chi_{k_t}, \chi_{i_{(t-1)}}\right) = 1$$

$$\Pr\left(\chi_{i_t} = 1 \mid \chi_{j_t}, \chi_{k_t}, \chi_{i_{(t-1)}}, \chi_{i_{(t-2)}}\right) + \Pr\left(\chi_{i_t} = 0 \mid \chi_{j_t}, \chi_{k_t}, \chi_{i_{(t-1)}}, \chi_{i_{(t-2)}}\right) = 1$$

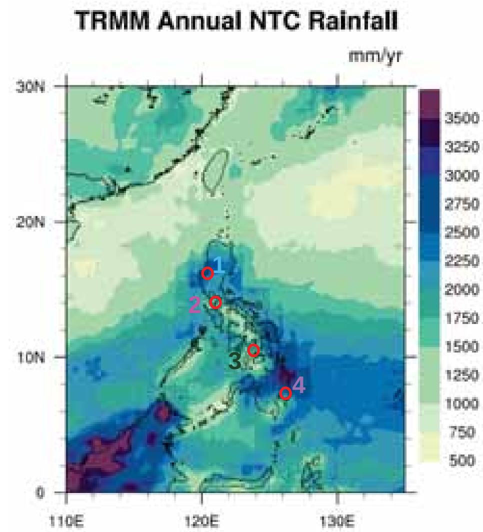
Annual NTC Rainfall – Historical & Stochastic Catalog



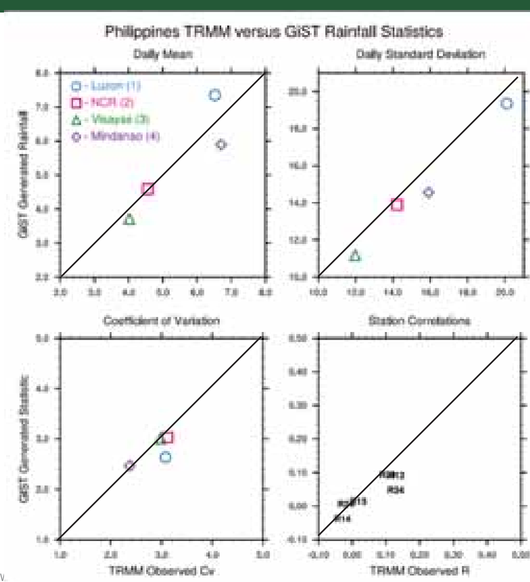
Stochastic versus Historical Catalog Daily Results



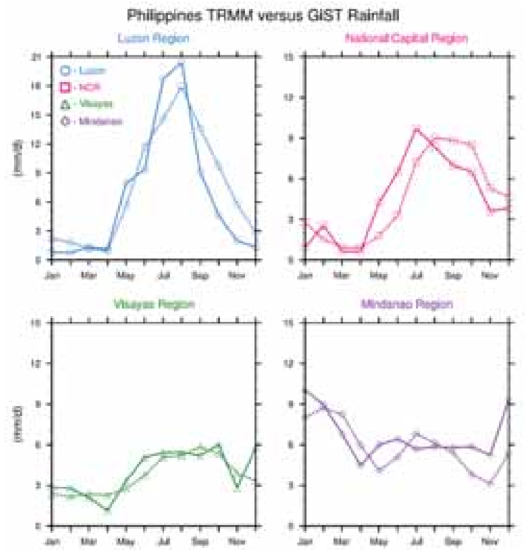
Validation sites



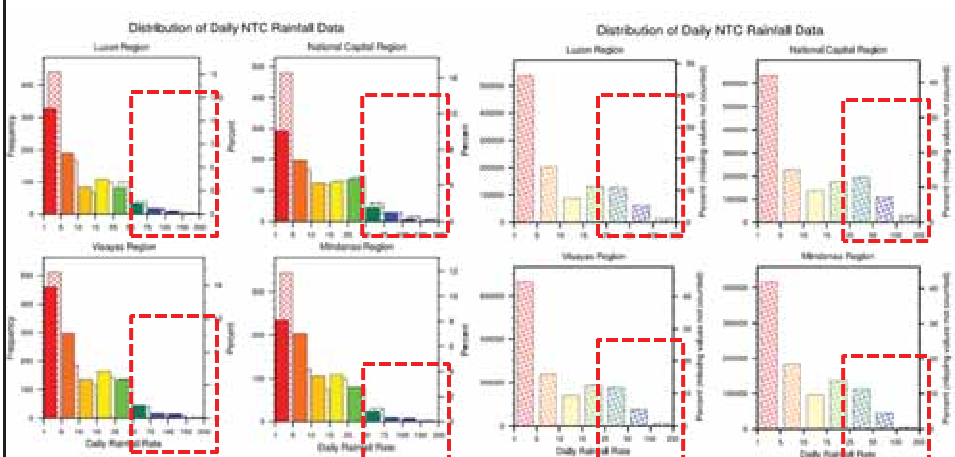
Daily Statistics



GiST Validation (cont'd) – Seasonal Analysis



Daily Rainfall Distribution (cont'd)



NTC Flood Event Definition & Preliminary Losses

AIR

Flood Event Definition

- A 7-5-days clause is used to determine occurrences and losses from flooding:

  1. An event starts when a storm occurs anywhere within the country if at least 5 days have passed after the peak of the rainfall from the previous event
  2. An event ends if the inter-storm period, the time period between the peak rainfall from the last storm and the beginning of the next storm is at least 5 days
  3. If the inter-storm period is less than 5 days, but the time from the beginning of the last storm is more than 7 days, then the end of the event and the beginning of a new one is set up at the point of minimum precipitation between the two storms

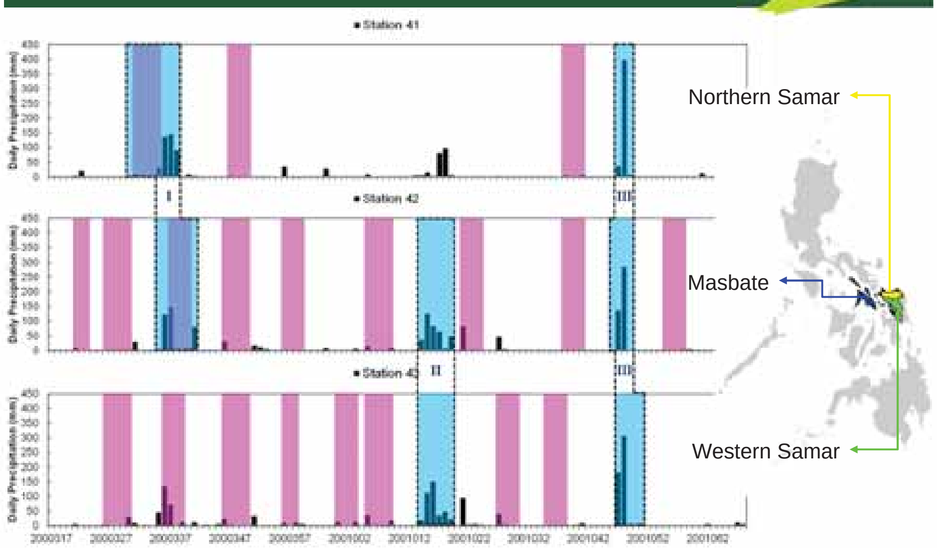
Flood Event Definition (Cont'd)

4. In contrast, if the inter-storm period is less than 5 days, and the time from the beginning of the last storm is also less than 7 days, then two (or more) events are considered one event with multiple rainfall peaks. The end of such event is set up at the end of the very last event, implying that events can actually last longer than 7 days

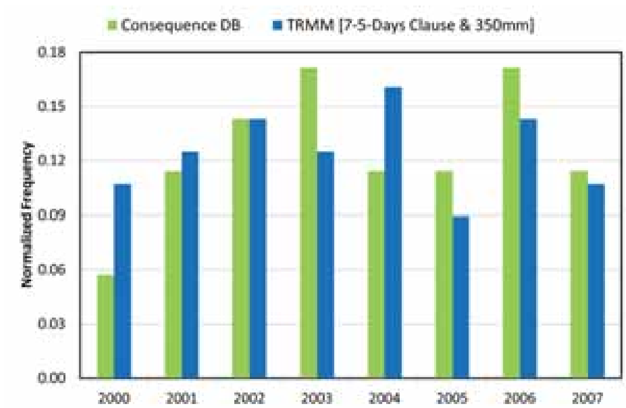
5. The event is considered flood-causing if the cumulative rainfall during the storm period is at least 350 mm (IHP-VII, 2008)

6. If two (or more) flood events occur within different start dates but overlap in their 7-day (or actual duration) coverage, then they are considered one event, regardless of spatial location

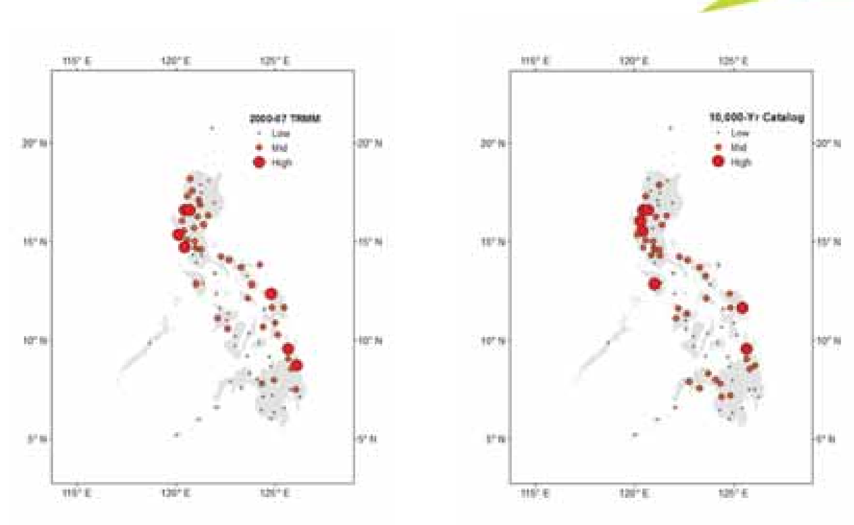
Flood Event Definition – Illustration



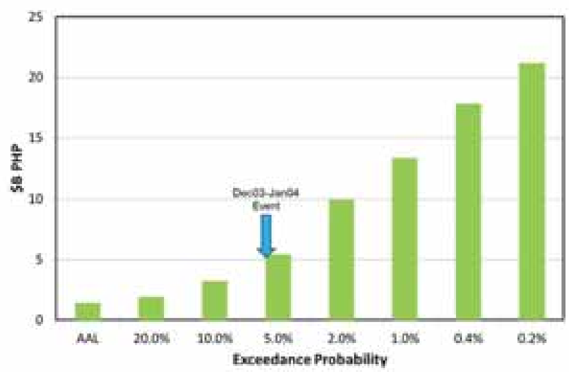
NTC Flood Events – Temporal Frequency

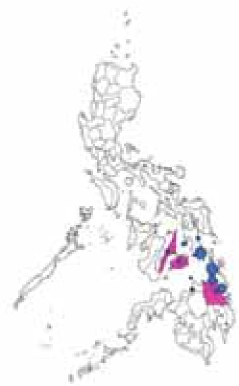


NTC Flood Events – Spatial Frequency



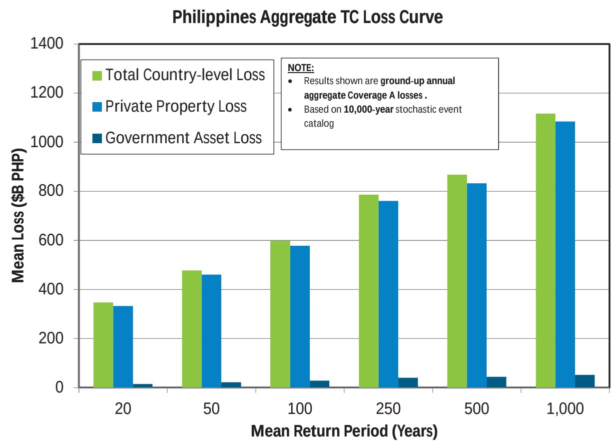
Loss Results – EP Curve





Loss Results: Tropical Cyclone

Tropical Cyclone Loss: EP Curve

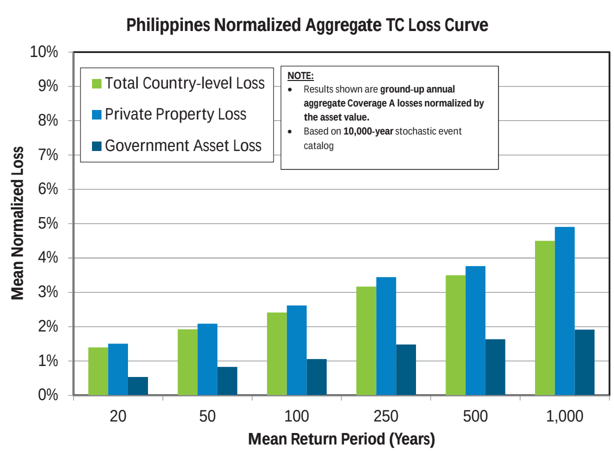


AAL = 120 B PHP
TIV = 25,000 B PHP

MRP (Years)	Aggregate Loss ($B PHP)		
	Government Asset Loss	Private Property Loss	Total Country-level Loss
20	15	332	347
50	22	461	477
100	29	578	598
250	40	761	786
500	44	832	868
1,000	52	1084	1117

Replacement Values (Coverage A):
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

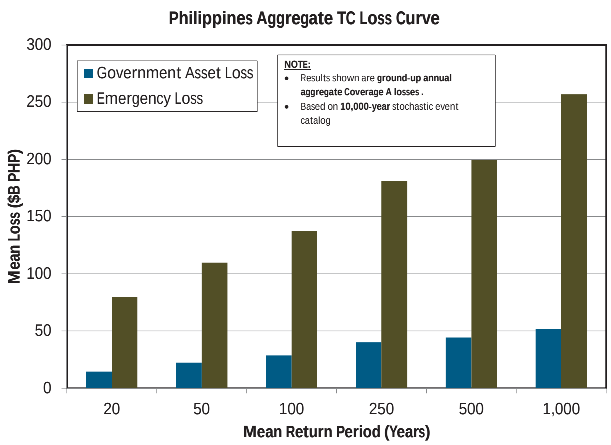
Tropical Cyclone Loss: EP Curve Normalized by RV



MRP (Years)	Normalized Aggregate Loss		
	Government Asset Loss	Private Property Loss	Total Country-level Loss
20	1%	2%	1%
50	1%	2%	2%
100	1%	3%	2%
250	1%	3%	3%
500	2%	4%	3%
1,000	2%	5%	5%

Replacement Values (Coverage A):
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

Tropical Cyclone Loss: Gov't Asset and Emergency Loss

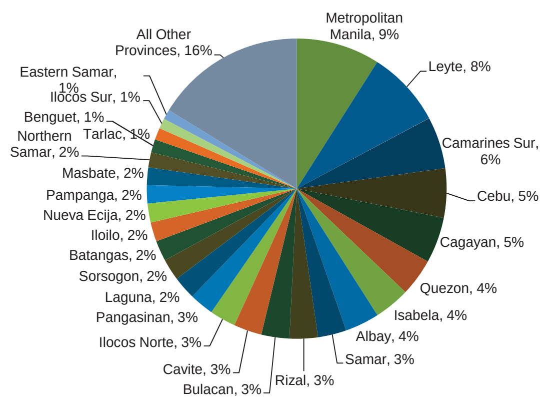


MRP (Years)	Aggregate Loss ($B PHP)	
	Government Asset Loss	Emergency Loss
20	15	80
50	22	110
100	29	138
250	40	181
500	44	200
1,000	52	257

Replacement Values (Coverage A):
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

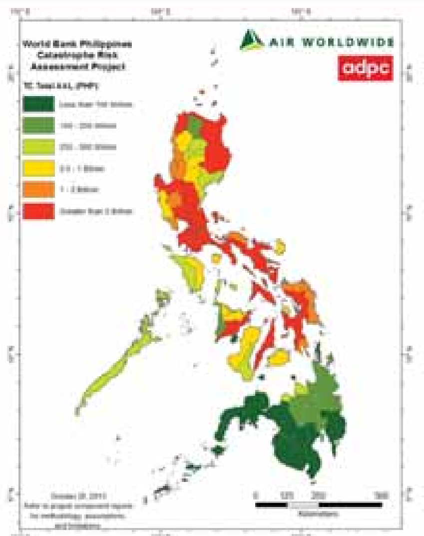
Tropical Cyclone Loss: AAL by Province

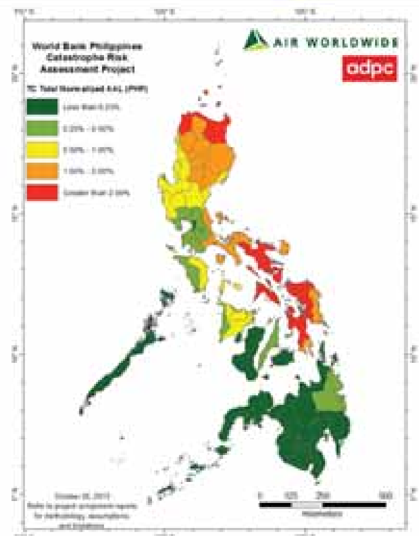
Total Country-level AAL Disaggregation by Province



AAL = 120 B PHP
TIV = 25,000 B PHP

Tropical Cyclone Loss: Total AAL by Province



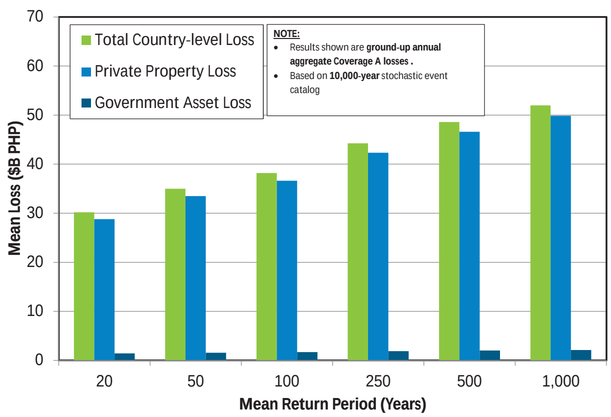


Loss Results: Non-Tropical Cyclone Precipitation

AIR

Non-Tropical Cyclone Precipitation Loss: EP Curve

Philippines Aggregate Non-TC Precipitation Loss Curve

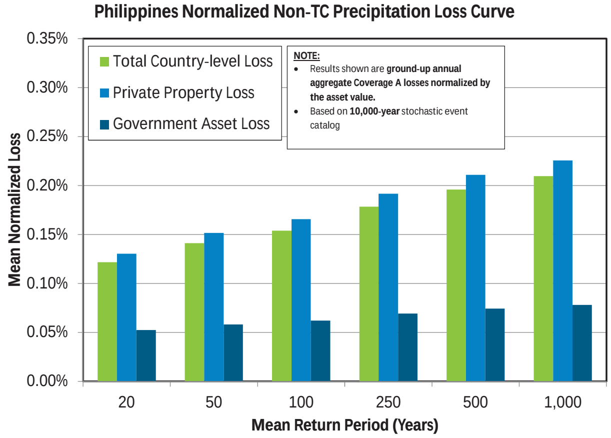


MRP (Years)	Aggregate Loss ($B PHP)		
	Government Asset Loss	Private Property Loss	Total Country-level Loss
20	1.4	29	30
50	1.6	33	35
100	1.7	37	38
250	1.9	42	44
500	2.0	47	49
1,000	2.1	50	52

<u>Replacement Values (Coverage A):</u>
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

Non-Tropical Cyclone Precipitation Loss: EP Curve Normalized by RV

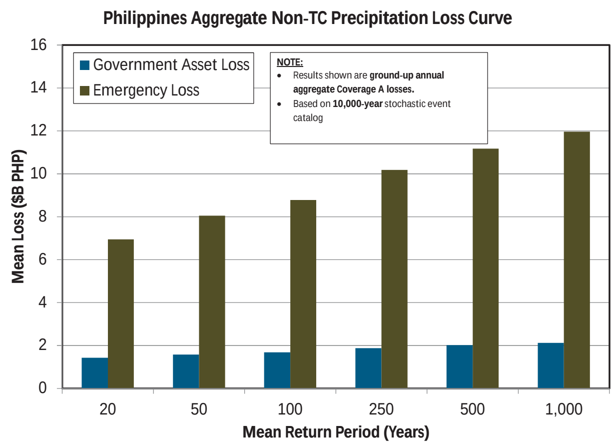
Philippines Normalized Non-TC Precipitation Loss Curve



MRP (Years)	Normalized Aggregate Loss		
	Government Asset Loss	Private Property Loss	Total Country-level Loss
20	0.05%	0.13%	0.12%
50	0.06%	0.15%	0.14%
100	0.06%	0.17%	0.15%
250	0.07%	0.19%	0.18%
500	0.07%	0.21%	0.20%
1,000	0.08%	0.23%	0.21%

<u>Replacement Values (Coverage A):</u>
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

Non-Tropical Cyclone Precipitation Loss: Gov't Asset and Emergency Loss



MRP (Years)	Aggregate Loss ($B PHP)	
	Government Asset Loss	Emergency Loss
20	1.4	7
50	1.6	8
100	1.7	9
250	1.9	10
500	2.0	11
1,000	2.1	12

Replacement Values (Coverage A):
Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

Questions

AIR