

ARC Tropical Cyclone Risk Model

A parametric insurance product developed for the SWIO region to provide rapid financing and early response to countries affected by tropical cyclone events. It covers winds, storm surges and waves damages.

Overview

The Southwest Indian Ocean Region (SWIO) region is one of the most active areas in the world in terms of tropical cyclone (TC) formation. On average, 13 TC events with wind speeds exceeding 63 km/h form in SWIO region each year. High wind speeds are a key contributor to damage from TC.

Developments in the SWIO region in 2019, including the devastating effects of cyclones Idai and Kenneth in Mozambique, led to a renewed country interest in parametric tropical cyclone insurance coverage. Consequently, ARC partnered with Kinetic Analysis Corporation (KAC) to develop a model capable of accurately estimating the risk and losses due to tropical cyclone events adapted to the SWIO region where the interested ARC Member States are located.

The approaches applied were consistent with those used previously to support the Caribbean Catastrophe Risk Insurance Facility (CCRIF) for a parametric risk pool covering the Caribbean and Central America regions. TC hazard and loss modelling techniques applied to ARC model have been extensively reviewed and accepted for underwriting use by the reinsurance and capital markets.

The ARC TC model satisfactorily addresses a very difficult problem with a robust loss calculation algorithm. It is reasonably robust and effective in terms of depicting the risks associated with tropical cyclone events and assessing damage and loss. The TC model is mature enough to be used operationally by ARC for parametric insurance in the SWIO region.

-Technical Review Forum

ARC's TC model covers winds, storm surges and waves hazards while excess rainfall associated with cyclones will be covered under another ARC insurance product dedicated to flooding due to the complexity of combining the rainfall hazard with the other TC hazards. The ARC TC model uses storm tracks and intensity produced by the US Joint Typhoon Warning Centre for the period 1983-2013. The ARC TC model combines characteristics of cyclone events hazard with exposure and vulnerability data to model the population affected and the economic losses. Using an insurance model and specific contract

terms, exposure loss estimates are translated into loss estimates for a portfolio of assets. Losses calculations are currently available for Madagascar, Mozambique, Comoros, Mauritius, Seychelles and Tanzania.

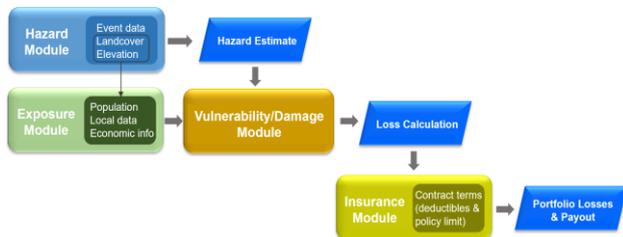
After a satisfactory assessment in July 2020 by a Technical Review Forum (TRF) composed of high-level TC experts from globally renowned institutions, the ARC Tropical Cyclone risk model was deemed ready and that it can be confidently used for underwriting insurance policy starting with the 2020-2021 TC season.

A dedicated interface, *ARC Tropical Cyclone Explorer* (ARC TCE) software package, has been developed to allow easy access by users to the full set of model data and visualize the results. The TCE will be available to ARC Member States and partners via the ARC's Africa RiskView (ARV) platform.

Components of the Tropical Cyclone Risk Model

ARC's TC risk model is implemented through four modules, logically sequenced to offer a reliable estimate of people affected and economic losses caused by cyclones, namely:

- **Hazard module:** It calculates in near-real time the maximum wind speed and the height of storm surges caused by a tropical cyclone.
- **Exposure module:** It describes the economic assets based on the land use categories in each country as well as the replacement cost of each exposed asset.
- **Vulnerability/Damage module:** It defines the probability distribution of economic losses for different levels of wind speed and storm surge height induced by a tropical cyclone.
- **Insurance module:** It calculates loss estimates for an asset portfolio based on contractual conditions. A payment begins at the trigger level (Attachment Point) defined by the policyholder.



Hazard Module: How are the extent and severity of cyclones hazard assessed?

Using characteristics for a specific cyclone event, apply numerical modelling to estimate the resulting hazard forces for single or multiple perils - at all locations affected by the event. Hazard maps produced from the hazard assessment show the extent and severity of the hazards generated by the modelled event. The two relevant grid-specific TC hazard variables are the *wind speed* in meters per second and *storm surge* in meters.

Elevation and bathymetry data

Elevation and bathymetry data (used as inputs to the hazard modelling) are compiled using a variety of sources including Landsat multi-spectral images, SRTM data and National Ocean Service bathymetry, and satellite-derived bathymetry for

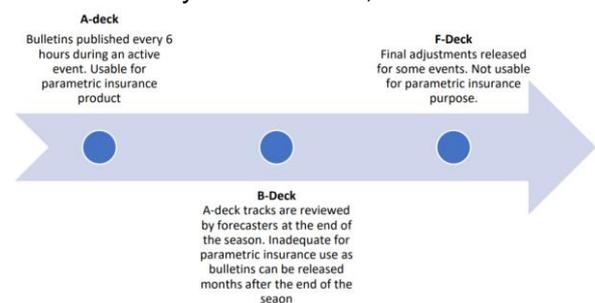
near-shore areas. Elevation datasets are used in the assessment of hydrometeorological hazards (bathymetry and topography for coastal hazards and inundation, topography for wind). Landcover datasets are also used as input to model.

TC Events data

Tracks and characteristics of historic TC events are available from multiple sources. For its TC model, ARC has considered two sources: Joint Typhoon Warning Centre (JTWC) that collects and freely shares near-real-time data on TCs worldwide and Météo France La Reunion, the World Meteorological Organization (WMO) - designated Regional Specialized Meteorological Centre (RSMC) for the SWIO region. Both use the Automated Tropical Cyclone Forecast (ATCF) system. The ATCF contains for each cyclone at ~ 1km resolution the following:

- Eye location (Latitude and longitude)
- Intensity (Peak Windspeed)
- Radius to maximum winds (eye size)
- Radius to the environment (distance from the centre to the edge of the wind field)

The ATCF files contain key information for current and historical TC events. Up to three files may be available for a cyclone: A-deck, B-Deck and F-deck.



The ARC TC risk model is currently using the A-deck data from JTWC and RSMC delivered to KAC and automatically ingested in their global cyclone monitoring and modelling protocols where they are made ready for processing.

Stochastic Database

For consistency with the TC dynamics in the SWIO region, generation of simulated events uses the best-available historical event information for the area. TC dynamics cover the A-deck bulletins published every 6 hours during an active event.

“ARC's TC model appears relevant to consider tropical cyclone hazards of winds, storm surges and waves. The Princeton model (3D) it uses for storm surges is high-level and better than the SLOSH model (2D). It is therefore capable of performing simulations of intrinsically satisfactory quality in post-event mode (when the cyclone track is known with the best possible estimate).”

-Philippe Caroff (RSMC/La Reunion)

As the historical cyclone record since 1983 contains only a small subset of the potential range of cyclones which could occur in the future, risk modelling deploys statistical techniques to generate 'stochastic' or 'simulated databases of cyclones which share the basic characteristics of the historical dataset but provide a solid base for probabilistic risk assessment. A track dataset was generated for 1,500 years containing almost 10,000 cyclones using storm tracks and intensity produced by the JTWC for the period 1983 to 2013.

Exposure Module: Which assets are exposed to cyclones and what are their values?

Information on the assets and elements at risk from the impact of natural hazards (also referred to as the 'exposure') are available in a wide range of forms and levels of details. A complex methodology is used to generate a gridded exposure database derived from remotely sensed data (including population and land use) and economic information. The exposure data for the ARC TC model takes into account changes in data for GDP, population and land use that are available with global coverage and a resolution of at least 1km. GDP data are updated to 2017 using country-level GDP collected from the World Bank and CIA databases and are used to estimate the value of different asset classes.

Each individual exposure record consists of the geographic and administrative area location, and three elements are used to estimate the loss from the hazard at that exposure location:

- Exposure classification: Rural, Mixed, Urban moderate and high density
- Number of units of exposure
- Value per unit of exposure

In addition to the above, each administrative area is assigned weather construction variables, which are applied to all exposures within that area. The construction quality variables apply as adjustments to the loss curves in loss evaluation. Construction quality is estimated based on past damaging events, or judgement based on available data. This global exposure database includes an estimate of the physical assets, designed to provide reasonable estimates for losses (replacement value) from TC hazards.

Vulnerability/Damage Module: What are the losses caused by tropical cyclones?

Impact algorithms have been developed to translate site-specific event hazard information into economic impact estimates at exposure locations. These impact algorithms account for damage due to key event perils (e.g. wind, surge, wave) and accommodate the range of vulnerabilities within the composite exposure categories. The impact algorithms do not correspond directly to the exposure classes but to subtypes of construction. For example, the high-density urbanized exposure category is a composite of low density, medium density and high-density construction functions as urbanised areas are typically composed of a variety of construction types.

The loss functions are specific to each asset class and the data for the historical database events are produced using the updated exposure data, custom damage functions for each asset class, and wind speed and storm surge data associated with each historical database.

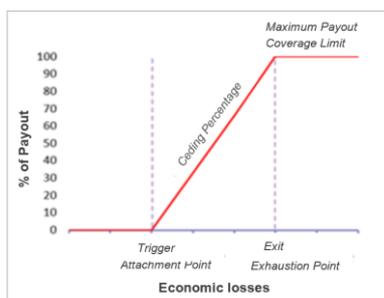
Loss estimation focuses exclusively on direct, physical damage to exposed assets and building contents. It is designed to estimate the replacement value of affected assets. Since some proportion of losses are never reported or claimed, we expect that modelled loss estimates to be incrementally higher (5-10%) than reported physical losses (if reported accurately).

The result of calculating the modelled loss for every cyclone storm is an exceedance probability curve showing the value of loss which is likely to be incurred at given levels of probability. This probability is expressed as a return period in years.

Insurance Module: How is the policyholder's payout triggered?

Risk Transfer Parameters

The insurance module uses specific contract terms and exposure loss estimates that are translated into loss estimates for a portfolio of assets. Risk transfer parameters (RTPs) are applied to the tropical cyclone risk profile of each country to structure the parametric insurance policy. The payout is based on the following set of parameters selected by each country: Attachment Point, Exhaustion Point, Coverage Limit and Ceding Percentage.



- The payout begins at the trigger level defined by the policyholder called the *Attachment Point* (also known as *Deductible or Excess*).
- The maximum payment is paid at the exit level defined by the policyholder called the *Exhaustion Point*, which represents the value of the loss at which the full payout is made.
- The payout is linear between the Attachment and Exhaustion Points. The slope of the payout function represent the *Ceding Percentage*.
- The maximum payout that can be made to a policyholder in a year of coverage is called the Coverage Limit.

- *Aggregate Cover for the TC Payout*

The TC policy must be constructed with two considerations in mind:

- The ability to make early payout after the end of a tropical cyclone event, triggered and scaled based on the loss calculated by the model.
- The ability to payout more than once during a season to respond to a season where more than one tropical cyclone occurs.

To achieve this, the insurance policy will have risk transfer parameters calibrated at both event and season levels. To ensure that payout are triggered for relevant events, the attachment point is defined using a return period from the event catalogue (i.e. dataset comprising losses from all tropical cyclones). However, to match the requirement of allowing more than one payout during the season, the exhaustion point will be defined using a return period from the aggregate catalogue (i.e. dataset comprising seasonal losses aggregated). For example, at the beginning of the season, the policyholder will purchase an aggregate cover for a season. This is the maximum payout that can be made over a season. More than one payout can then be made to the policyholder in one season, up to the amount of aggregate coverage.

- *Payout Process*

When a TC system is active, both JTWC and RSMC/La Reunion issue a bulletin every 6 hours

informing on the characteristics of the cyclone. Data from these bulletins are used to forecast the track of the cyclone in the coming hours and days. These forecasts are then ingested into the ARC *Tropical Cyclone Explorer* (TCE) to produce estimates of population affected and economic losses caused by the cyclone.

For each country having subscribed to the TC parametric insurance policy, the loss calculation is carried out less than three (3) days business after the publication of the last bulletin of the JTWC (or RSMC). ARC Ltd then sends the policyholder a loss report showing the amount of the payment, all associated calculations and the remaining coverage until the end of the season. ARC processes the payment within seven (7) business days after the publication of the loss report, during which period the Final Implementation Plan (FIP) must be approved and payout cleared by Ltd Board.

For Additional Information

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