The Disaster Risk Financing
Challenge Fund

Technical Proposal

SMART

A **S**tatistical, **Ma**chine **L**earning Framework
for Parametric **R**isk **T**ransfer

Pavia, Italy, October 31, 2018

To: The World Bank Group

Dear Sirs:

We, the undersigned, offer to provide the consulting services for the 'The Disaster Risk Financing Challenge Fund' in accordance with your Request for Proposal dated October 5, 2018 and our Proposal. We are hereby submitting our Proposal, which includes this Technical Proposal, and a Financial Proposal in a separate file.

We would like to thank you for shortlisting our initial application and giving us the opportunity to submit a detailed proposal for this funding round.

We understand you are not bound to accept any Proposal you receive.

Yours sincerely,

Rui Pedro Carrapatoso Figueiredo
Research Associate

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Abstract

Parametric insurance is a promising disaster risk management strategy, whereby prompt payouts are triggered whenever measurable indices exceed predefined thresholds. The promptness is critical in developing countries, as they are particularly exposed to short-term liquidity gaps that may overwhelm their capacity to cope with large disasters. From a machine learning perspective, this is essentially a classification rule for predicting loss or no loss based on the trigger variable. The rule is developed using past training sets of hazard and loss data (supervised learning).

Despite the advantages of simplicity, transparency, and rapid payouts, there is a lack of confidence and reluctance to use parametric insurance because of basis risk – the misclassification of events due to false positives and false negatives. Basis risk leads to inefficient transactions and higher product costs, reducing their appeal to end-users and investors. It can also result in a failure to issue payouts when disaster events occur, which can have devastating consequences for insureds counting on rapid post-event funding. The problem of basis risk in parametric insurance is exasperated by:

1. The use of ad-hoc parametric trigger rules that have not used rigorous statistical modelling to learn from past data and optimally exploit increasing amounts of data;
2. The lack of robust evaluation methods for understanding and quantifying parametric trigger performance.

This project will make novel and expert use of appropriate machine learning and statistical concepts (thematic area 2) to address these two issues and develop a new framework that is of general relevance to diverse hazards and communities.

To demonstrate the methodology and its pathway to operationalization, a pilot study will be made for multiple hazards in the Dominican Republic. The Dominican Republic currently has little reliance on risk transfer mechanisms despite being highly exposed to natural hazards, such as tropical cyclones, floods, and droughts. In 2015, the average annual loss due to natural hazards was estimated at USD 420 million. Productive sectors, particularly agriculture, tend to be severely affected, leading to socio-economic consequences and food insecurity for the country (focus area).

TECHNICAL PROPOSAL

1259359 – The Disaster Risk Financing Challenge Fund

Table of Contents

A – Consultant's Organization 1
B – Consultant's Experience 2
C – Comments and/or Suggestions on the Terms of Reference 5
D – Description of Approach, Methodology and Work Plan 5
a) Technical Approach and Methodology 5
1. Objectives 5
2. Methodology 5
3. Application to the Dominican Republic Pilot Study 16
4. References 20
b) Feedback from the First Round 21
c) Work Plan 22
d) Organization and Staffing 25

Annex 1: Team Composition, Task Assignments & Level of Effort (LOE)
Annex 2: CV of Proposed Key Personnel
Annex 3: Work Schedule

A – Consultant's Organization

The lead partner, Scuola Universitaria Superiore IUSS Pavia, is a university for advanced studies that provides post-graduate degrees and conducts innovative research in various fields, ranging from analytical philosophy to civil engineering, and is ranked among the top 5 universities in Italy. One of IUSS's strongest focus areas is risk assessment and management of natural hazards, which benefits from a multidisciplinary research environment that includes not only probability and statistics, catastrophe risk modelling, and structural engineering, but also artificial intelligence, legislation, communication, and risk financing. The Master and PhD programs in Understanding and Management Extremes are world-renowned for their high level of both training and research, with over 500 applications every year. In recent years, Professor Martina and Dr Figueiredo have lead the research on new disaster risk financing mechanisms such as parametric insurance programs based on near real-time loss estimation models, having contributed to the development of the new CCRIF (Caribbean Catastrophe Risk Insurance Facility) parametric trigger models.

University of Exeter is world-renowned for its expertise in the mathematical modelling and interpretation of weather and climate, and of particular relevance here, for statistical modelling of natural hazard risk. In addition, statistical science works closely with computer science experts in machine learning, which forms the foundation of the new Institute for Data Science and Artificial Intelligence (IDSAI) that was established in 2018. The IDSAI (https://www.exeter.ac.uk/idsai/) is designed to form research collaborations and strategic partnerships with industry across the globe, influence government policy in data science, AI and the digital skills agenda, and guide public engagement with social and ethical issues arising from developments in data science. The IDSAI is one of only a few UK universities in the prestigious Alan Turing Institute (https://www.turing.ac.uk/).

In recent years, Professor Martina and Dr Figueiredo at IUSS Pavia have been collaborating with Professor Stephenson and Dr Youngman at the University of Exeter on developing a more robust framework for parametric insurance. This collaboration has resulted in the publication of a scientific article in Risk Analysis, a high-impact international journal (Figueiredo et al. 2018).

Fundación REDDOM is a Dominican non-governmental, non-profit organization that promotes sustainable development through the introduction of associative, technical and entrepreneurial innovation. REDDOM's team of operational experts has developed an in-house capacity for the design, implementation, and evaluation of development projects, including climate resilience and adaptation measures, risk analysis, access to financial markets for farmers, and food security. REDDOM has a significant experience providing technical assistance and guidance in the adoption of risk reduction measures and the development of risk transfer mechanisms. As a local USAID implementing partner, REDDOM has worked on the development of the first commercial index insurance product for the agricultural sector in the Dominican Republic, in collaboration with stakeholders such as IRI (International Research Institute for Climate and Society at Columbia University), I4 (Index Insurance Innovation Initiative), Swiss Re, insurance companies, private banks, and the Ministry of Agriculture.

B – Consultant's Experience

Assignment name: RATIoNaL – Risk AppeTite Index via machiNe Learning	Approx. value of the contract (in current US$): $50,000
Country: World – focus on UK, France, Germany and Italy Location within country:	Duration of assignment (months): 18
Name of Client: Allianz Global Corporate & Specialty SE	Total No. of staff-months of the assignment: 24
Contact Person, Title/Designation, Tel. No./Address: Claudia Borchers, CUO Property - Head of Portfolio Steering and Pricing, claudia.borchers@allianz.com	
Start date (month/year): 01/2017 Completion date (month/year): 06/2018	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 24
Name of associated Consultants, if any:	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed (e.g. Project Director/Coordinator, Team Leader): Prof. Mario Martina, Project Leader MSc Ahmed Essam, Risk Modeling Expert Dr Graziano Ucci, Machine Learning Expert
Description of Project: The project made use of a pilot study on a sample of the claim database provided by AGCS to define a Risk Appetite Index (RAI). The RAI represented by means of a synthetic index the goodness/potentiality of a client's risk in terms of the expected loss and the premium quotation associated to the client sector. The study compared different mathematical and statistical methodologies to perform the analysis. In particular, multi-regression and machine learning techniques were applied, calibrated and validated. Also, the study focused on the expert's (i.e. underwriter's) criteria usually followed within the standard underwriting process. A secondary activity was to translate expert-based (subjective) knowledge into an objective algorithm applied on variables describing the client, the location and the features of the assets exposed to different risks.	
Description of actual services provided by your staff within the assignment: Methodology conceptualization, model development, calibration and validation. Presentations and reports to illustrate the methodology and discuss the results.	

Assignment name: Willis Research Network	Approx. value of the contract (in current US$): $70,000/year
Country: UK Location within country: Exeter	Duration of assignment (months): 72
Name of Client: Willis Towers Watson	Total No. of staff-months of the assignment: 85
Contact Person, Title/Designation, Tel. No./Address: Dr Ben Youngman (WRN research fellow) U. of Exeter Laver Building, North Park Road Exeter EX4 5DN	
Start date (month/year): 10/2012 Completion date (month/year): ongoing	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 12
Name of associated Consultants, if any: None	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed (e.g. Project Director/Coordinator, Team Leader): Prof. David Stephenson Academic lead for the project involved in managing the relationship to deliver research of relevance and usefulness to reinsurers at Willis Towers Watson.
Description of Project: This project has developed new models for quantifying natural hazard risk and provided Willis Towers Watson with tools so that it can assist its clients and improve its understanding of catastrophe models. The methods and software developed for various data forms in the project has enabled Willis Towers Watson to analyze its own data and produce its own estimates using new models that robustly represent natural hazard risk. More information: https://www.willis.com/willisresearchnetwork/About_Us/ https://royalsociety.org/topics-policy/industry-innovation/case-studies/willis-research/	
Description of actual services provided by your staff within the assignment: Services provided have included outreach, such as seminars conveying the state-of-the-art in academic research, consultancy, such as short-term projects dealing with immediate client demands, and long-term research and development. One example of the last of these is the provision of an observed exceedance probability toolkit. This involved developing general models and software for representing how extreme environmental phenomena vary (see https://empslocal.ex.ac.uk/people/staff/by223/evgam.html) and tailoring these to Willis Towers Watson's and its clients' specific needs. Another example is the multi-organization collaboration that produced the widely-used Extreme Wind Storms Catalogue (http://www.europeanwindstorms.org/).	

Assignment name: Climate Resiliency and Index Insurance for Small Farmers in the Dominican Republic	Approx. value of the contract (in current US$): $2,823,559
Country: Dominican Republic Location within country: North and Northwest Regions	Duration of assignment (months): 55
Name of Client: USAID	Total No. of staff-months of the assignment: 6 technical staff members x 55 months
Contact Person, Title/Designation, Tel. No./Address: Erick F. Conde Project Management Specialist / Mission Environmental Officer U.S. Agency For International Development Avenida República de Colombia #57 Altos de Arroyo Hondo, Santo Domingo, D.N. Dominican Republic, 10605 T. 809 368 6217 | econde@usaid.gov	
Start date (month/year): November 13, 2012 Completion date (month/year): June 12, 2017	No. of professional staff-months provided by your consulting firm/organization or your sub consultants: 6 technical staff members x 55 months = 330 staff -months
Name of associated Consultants, if any: Margarita Gil, Agricultural Risk Analyst	Name of senior professional staff of your consulting firm/organization involved and designation and/or functions performed (e.g. Project Director/Coordinator, Team Leader): Jesus De Los Santos, Project Director Luis Tolentino, Technical Director, Climate Risk Analysis Jeffery Perez, Value Chain Specialist and Monitoring
Description of Project: The goal of the project was *to improve resiliency to climate change, reduce disaster risk, and promote public-private partnerships*. As part of this goal, the project supported the establishment of a commercially sustainable index insurance product. The most relevant achievements were: 2,134 farmers increased their livelihood by adopting risk reducing practices/actions; 2020 persons have incorporated weather information as part of their decision making process; 1,615 persons were trained to integrate financial services options into farm-level risk management; first commercial index insurance product for the agricultural sector in the Dominican Republic; a climate information platform –CLIMARED- was established to support decision making for farmers, insurers, government agencies, local authorities, financial organizations, academic institutions, and other stakeholders; and, 2812 persons (652 women and 2,160 men) trained in climate change adaptation supported by USG assistance.	
Description of actual services provided by your staff within the assignment: Fundación REDDOM was the lead implementing partner for this project.	

C – Comments and/or Suggestions on the Terms of Reference

Upon careful reflection, we are happy with the Terms of Reference as stated and envisage no modifications that could make the assignment more effective.

D – Description of Approach, Methodology and Work Plan

a) Technical Approach and Methodology

1. Objectives

Parametric insurance is a promising disaster risk management strategy, whereby payouts are triggered whenever measurable indices exceed predefined thresholds. However, despite the advantages of simplicity, transparency, and rapid payouts, parametric triggers are exposed to basis risk, i.e. the misclassification of events due to false positives and false negatives. This can hamper their effectiveness and result in a lack of confidence and reluctance to use this type of risk financing product.

This project will respond to the challenge defined in thematic area 2 of the call by using novel machine learning and statistical modelling concepts to develop a more rigorous and effective framework for the parametric insurance of natural hazards. This will address the following outstanding issues that currently limit the widespread use of parametric insurance:

1. The use of ad-hoc parametric trigger rules that have not used rigorous statistical modelling to learn from past data and optimally exploit increasing amounts of data;
2. The lack of robust evaluation methods for understanding and quantifying parametric trigger performance.

We will demonstrate the new approaches and its pathway to operationalization in a pilot study of multiple hazards in the Dominican Republic. The Dominican Republic currently has little reliance on risk transfer mechanisms despite being highly exposed to natural hazards, such as tropical cyclones, floods, and droughts. Productive sectors, particularly agriculture, tend to be severely affected, leading to socio-economic consequences and food insecurity for the country. By including the development of parametric triggers for the agricultural sector, this project will address the latter issue, thus responding to the challenge defined in the special focus area.

2. Methodology

The SMART project will develop an innovative framework for 1) the design of more optimal parametric triggers based on machine learning methods, and 2) the robust evaluation of their performance, enabling model optimization and consequent better understanding and minimization of basis risk. The sections below describe the novel methodology that will be developed, which are summarized in the workflow shown in Figure 1.

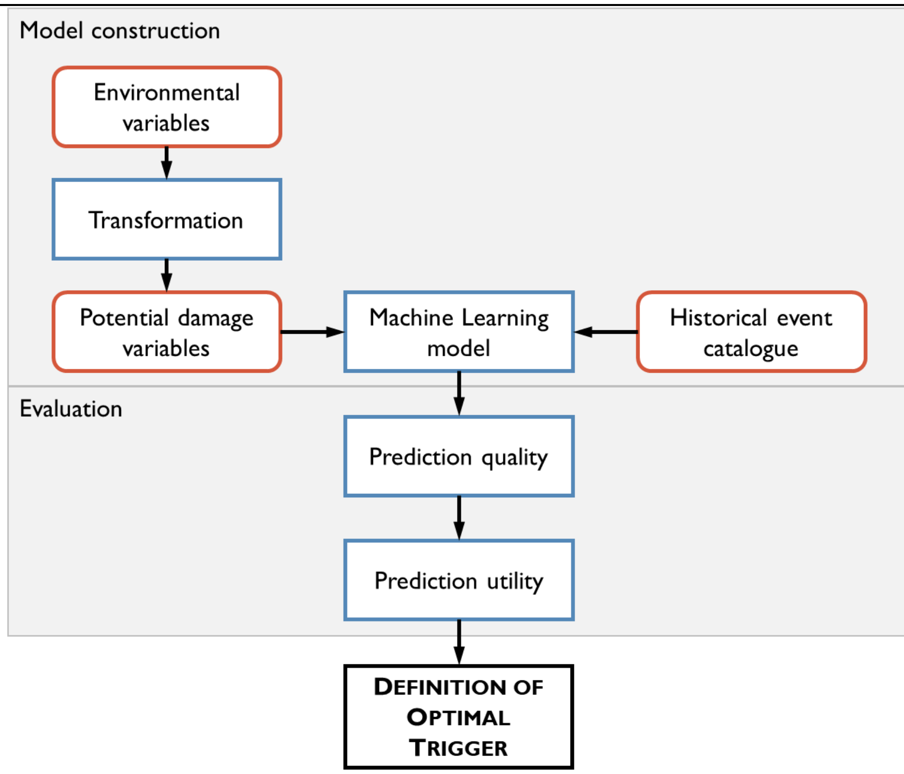

Figure 1: Workflow of the proposed approach.

All the methods implemented within this project will be transparent, based on open data and technologies, and fully transferable and scalable to other regions. Open-source code of the developed models will be made available in the R programming language (R Core Team, 2017) . An interactive web app will be developed using the R Shiny package, in order to facilitate dissemination and understanding of the model by potential stakeholders, including less technical ones. After the conclusion of the project and in case the models are operationalized, this platform may be expanded to provide real-time data and model predictions of interest to stakeholders and end-users of the parametric product(s).

2.1. Construction of Machine Learning Models for Trigger Design

Machine learning offers two key advantages over the current ad hoc approaches in the development of classifiers for parametric insurance:

1) *Leveraging big data*. Parametric triggers tend to be based on simple models that rely on an environmental variable or derived index exceeding some threshold. Such simple models are necessarily limited in their ability to predict the occurrence of loss events (especially ones that are not extreme), which leads to higher basis risk. Improving predictive skill requires more robust triggers. A promising strategy, which this project will pursue, is to utilize multiple sources of data. Today, there are increasing amounts of environmental data (i.e. big data) derived, for example, from satellite imagery or meteorological models. Many of these datasets span historical periods (often as reanalysis products) and are available operationally (i.e. in near-real time), and so can be used for trigger design. In this context, the use of machine learning methods will be instrumental, as these powerful and well-established techniques are much better suited than traditional

heuristics for the construction of models with high dimensional parameter space (Calvet et al., 2017).

2) *Quantifying uncertainty.* In order to estimate a parametric trigger model for loss events, historical samples of concurrent environmental and loss event data are required. These data tend to be scarce, highly uncertain, or both, which poses a considerable challenge that can reduce the performance of any operational model. This is particularly relevant for big data, where case-specific quality control and clean-up (which can alleviate the issue) becomes unfeasible. It is therefore paramount to build flexible models that can quantify and deal with uncertainty, which is straightforward using machine learning methods that are able to issue probabilities of loss occurrence. This enables basis risk to be transparently communicated, which in turn improves understanding of the product by end-users in relation to commonly-used models that issue binary outcomes of the type "event"/"no event", unsuitable under high uncertainty (Murphy, 1991). Also, the use of probabilities facilitates trigger design when multiple data sources are adopted. In this case, each probability can correspond to a large number of possible combinations of values from the different environmental variables (i.e. in an *n*-dimensional space, where *n* corresponds to the number of input datasets). Defining the trigger condition based on the former rather than the latter is much more informative, transparent, and practical.

This project will develop and implement a novel probabilistic modelling framework that is readily adaptable to different natural hazards, based on the approach proposed in Figueiredo et al. (2018). Consider the occurrence of loss caused by a natural hazard on each day $t = 1, \dots, T$ and let L_t be a binary variable defined as

$$L_t = \begin{cases} 0 & \text{if loss occurs on day } t, \\ 1 & \text{if loss doesn't occur on day } t. \end{cases} \tag{1}$$

The aim is to predict the of occurrence of loss based on a potential damage variable Y_t defined for time t. The probability of occurrence of loss p_t will be estimated using different machine learning and statistical models, as described further below. The potential damage variable Y_t will be obtained through a non-linear transformation of one or more environmental variables X_t representing the intensity of a natural hazard. This hybrid approach aims to capture some of the physical processes of how the hazard creates damage by incorporating *a priori* expert knowledge on environmental processes and damage-inducing mechanisms for different hazards. Supervised learning with machine learning methods based on physically-motivated transformations of environmental variables can be used to better capture loss occurrence.

Parametric risk financing products require an unambiguous definition of when payouts are due or not, meaning that a decision threshold probability q above which a loss event is considered to occur must be set. The threshold for payout triggering should be defined so as to minimize basis risk, which requires the development and application of adequate and objective evaluation measures. The methodologies proposed to achieve this are presented in Section 2.2.

The limited research on machine learning methods for parametric insurance makes this project an ideal opportunity to benchmark different approaches and advance the state of the art in this area. These will include Neural Networks and Support Vector Machines, which are non-linear multi-input methods that have seen increased adoption in recent years, and show potential for parametric trigger modelling (Calvet et al., 2017). The use of other more traditional (but also not commonly used in this field) statistical techniques, such as generalized linear modelling, will also be considered, in particular Logistic Regressions. A brief description of these methods follows:

Neural Networks

Neural Networks are computational learning systems that use a network of functions to understand and translate complex data inputs of one form into a desired output, usually of another form. They are based on collection of connected nodes called artificial neurons, which loosely model the neurons in a biological brain and how they function together to understand and respond to sensory inputs. In recent years and with the advent of big data, Neural Networks have been increasingly used to efficiently solve many real-world problems, related for example with pattern recognition and classification of satellite images (Dreyfus, 2005).

Mathematically, Neural Networks can extract linear combinations of the explanatory variables as transformed variables, and model the response variable as a non-linear function of those variables. This is achieved using so-called nonlinear activation functions, which define the output of nodes given an input or set of inputs. Neural Networks have three types of layers: the input layer, the output layer, and one or more hidden layers between them. The number of neurons in the input layer is uniquely determined by the input data (e.g. number of pixels in a raster image of daily precipitation estimates), while in the output layer, it is determined by the choice of the model configuration. The optimal number of hidden layers and their nodes is case-dependent. In most problems, a single hidden layer is sufficient to capture non-linearities in the data. The number of hidden layer neurons should be defined so as to avoid overfitting, a common issue in Neural Networks. We will use hidden layers to capture at least two features: between-country variation, to pool inevitably scarce data over multiple countries; event start and end date uncertainty, to relate *true* start and end dates of events to those observed. The latter will allow us to better capture how events relate to environmental variables. Allowing for uncertainty in event start and end dates is necessary because not only are events difficult to define, but multiple repercussions contribute to their definition, some of which are only tenuously a consequence of the original extreme environmental conditions that triggered the event.

Given the capability of Neural Networks to model non-linearities in the data, and the similarity between capturing loss occurrence and the type of problems they are usually employed for (i.e. pattern recognition in large datasets of environmental variables), they show clear potential for parametric trigger modelling. Moreover, Neural Networks can provide estimates of the probabilities of a set of input data to belong to a class (termed posterior probability of the class). This can be achieved by defining the logistic function, shown in Figure 2, as the activation function. A possible Neural Network configuration for parametric trigger modelling is shown in Figure 3. In this case, the value of the single output neuron, varying between 0 and 1, will represent the posterior probability of loss occurrence.

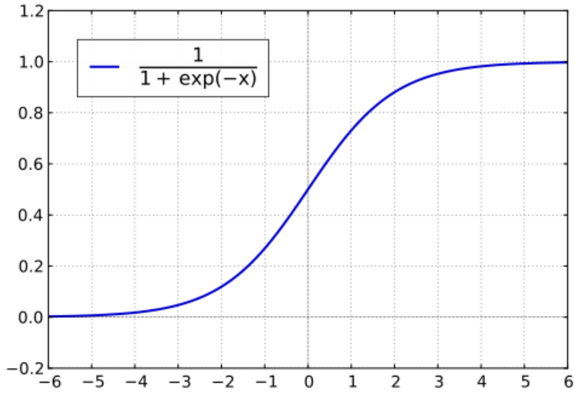

Figure 2: Logistic function.

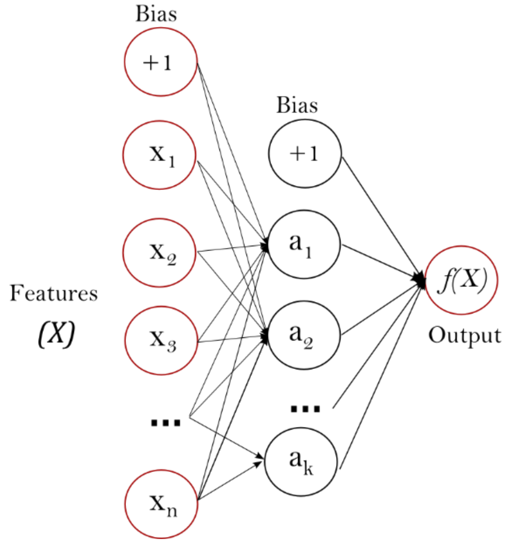

Figure 3: Neural Network with one hidden layer and a single output neuron.

Support Vector Machines

Support Vector Machines are supervised learning models used for classification and regression analysis. They construct a hyperplane (or set of hyperplanes) defining a boundary between various data points representing observations in a multidimensional space. The aim is to create a hyperplane that separates the data on either side as homogeneously as possible. Among all possible hyperplanes, the one that creates the greatest separation between classes is selected. The support vectors are the points from each class that are the closest to the hyperplane (Wang, 2005).

In parametric trigger modelling, as in many other real-world applications, the relationships between variables are non-linear. A key feature of this technique is its ability to efficiently map the observations into a higher dimension space by using the so-called kernel trick. As a result, a non-linear relationship may be transformed into a linear one. A Support Vector Machine can also be used to produce probabilistic predictions. This is achieved by using an appropriate method such as Platt scaling, which transforms its output into a probability distribution over classes by fitting a logistic regression model to a classifier's scores.

Figure 3 shows a simple illustrative plot of a Support Vector Machine classifier. In the context of the problem at hand, the red and green dots can be interpreted as corresponding to the two outcome classes (i.e. loss event/no loss event), while *y1* and *y2* correspond to potential damage variables derived from the input environmental variables.

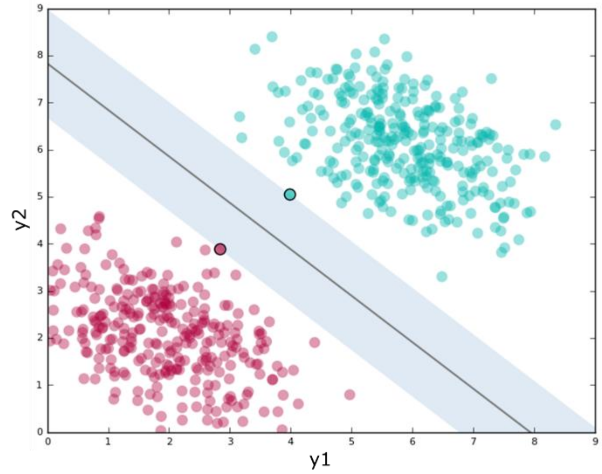

Figure 4: Schematic representation of a Support Vector Machine classifier.

Generalized Linear Models

Regression methods are an integral component of any data analysis concerned with describing the relationship between a response variable and one or more explanatory variables. As in the case of parametric triggers, in many problems the outcome variable is binary, represented by an indicator variable that takes the values 0 or 1. The Logistic Regression model is used in various different fields as the standard method of analysis in this situation. In the logistic model, the logarithm of the odds for a certain outcome (i.e. indicator variable equal to 1) is a linear combination of one or more independent variables, which can be binary or continuous (Hosmer and Lemeshow, 2000). The function that converts log-odds to probability is the logistic function, shown previously in Figure 2.

For parametric trigger modelling, considering n explanatory variables, the following Generalized Linear Model gives a natural representation of the occurrence of loss on day t:

$$log\left(\frac{p_t}{1-p_t}\right) = \beta_0 + \beta_1 Y_{t,1} + \cdots + \beta_n Y_{t,n} \tag{2}$$

where coefficients $\beta_1, \ldots, \beta_n$ correspond to variables $Y_{t,1}, \ldots, Y_{t,n}$. The vector of parameters β can be estimated by fitting the model to historical samples of concurrent potential damage and loss data. In order to estimate the Y_i variables that best describe potential losses due to a certain natural hazard, the transformation parameters described can be optimized to give the final logistic regression model. This model is readily expandable to include additional explanatory variables.

2.2. Model Evaluation and Minimization of Basis Risk

In parametric insurance, basis risk can be defined as the risk associated with the mismatch between payouts and the occurrence of loss events. In order to minimize basis risk, it is necessary to first evaluate model predictions using appropriate quantitative methods, as this then allows designing and selecting the best possible performing trigger. However, currently there is a lack of robust evaluation methods for understanding and quantifying parametric trigger performance. This section addresses this issue and proposes two innovative approaches to quantify and minimize basis risk.

The correspondences and discrepancies between the idealized and actual behaviours of any parametric trigger mechanism can be described through a confusion matrix. Formally, a confusion matrix is a two-dimensional matrix that gives the discrete joint sample distribution of predictions and observations in terms of cell counts. For binary categorical events with two possible outcomes (i.e. loss event/no loss event), a schematic confusion matrix is shown in Table I.

Table I: Schematic confusion matrix for *n* binary events.

	Event observed		
Event predicted	Yes	No	Total
Yes	*a* (True Positive)	*b* (False Positive)	$a + b$
No	*c* (False Negative)	*d* (True Negative)	$c + d$
Total	$a + c$	$b + d$	$a + b + c + d = n$

From a statistical and machine learning viewpoint, basis risk arises from the misclassification of events due to False Positives and False Negatives. Often, this issue is not adequately investigated in the design of parametric risk transfer products, and the trigger is designed based on simple heuristics rather than statistically robust verification measures. In cases where this does happen, the most commonly employed measures to assess parametric trigger performance (and purportedly basis risk) are essentially measures of so-called prediction *quality*, i.e. the degree of correspondence between predictions and observations. This common practice is highlighted by various examples in the literature (e.g. Calvet et al., 2017; Ross and Williams, 2015).

On the surface, attempting to minimize basis risk by maximizing some measure(s) of prediction quality appears reasonable, because in broad terms there is a certain resemblance between these two concepts. The pitfall of this approach is that the goodness of any predictive or forecast system is related not only with its quality, but also with its *utility*, which is the tangible economic benefit that it brings to its users. In fact, in most real-world problems, prediction utility tends to be more important than prediction quality, as users are primarily concerned with the expected benefit that such a system will bring in the context of their problems (Murphy, 1993). Another important aspect that may appear counterintuitive at first, is that even though quality and utility are related, predictions showing higher values of certain measures of the former may not necessarily be the most valuable to end users (Murphy and Ehrendorfer, 1987). This results from different misclassification costs. In the design of any parametric trigger, a trade-off necessarily has to be achieved between False Positives and False Negatives, as no model is able to issue perfect predictions on every occasion. Because a False Negative (which results in no payout being issued when a loss event occurs) may have severe consequences for an insured, it may prefer to use a model that issues payouts more frequently, even if some of them take place when nothing has occurred (False Positives). However, the latter may also result in higher premiums. All of these aspects should be taken accounted in order to define the optimal trigger.

To summarize, even though measures of prediction quality (which are not a function of user-specific conditions, but instead depend solely on mathematical measures from the confusion matrix) can provide useful information relative to the skill of a trigger model, defining the optimal payout threshold (therefore minimizing basis risk) can only be achieved in an objective and scientifically-sound manner by maximizing utility. The proposed evaluation framework will therefore comprise a collection of state-of-the-art verification measures to fully characterize trigger performance, both in terms of quality and utility.

Prediction Quality

A large number of measures of the predictive quality are available in the literature and, in most cases, more than one is necessary to obtain an informed picture about this aspect (Jolliffe and Stephenson, 2012; Murphy, 1993). In this project, the quality of model predictions will be assessed based on historical data using three complementary and well-established techniques to measure bias, skill, and reliability, which are next described.

The frequency bias is the ratio between the number of predictions ($a+b$) and the number of actual occurrences ($a+c$). A bias of 1 means that events are predicted at the same rate at which they occur, which corresponds to unbiased predictions. In the case of parametric triggers, this may or may not correspond to the ideal situation depending on the user, as previously explained. Also note that bias and skill are not necessarily related: a system may be unbiased but have no skill, or vice versa, and it is therefore necessary to analyze both.

Skill will be assessed using Receiver Operating Characteristic (ROC) curves. ROC curves are obtained by plotting the True Positive Rate *TPR* (also known as Sensitivity in Machine Learning) against the False Positive Rate *FPR* (or Fall-out) at various thresholds for event triggering (Krzanowski and Hand, 2009). In this project, these correspond to the range of possible threshold probabilities over the range 0 to 1. A curve above the diagonal $TPR = FPR$ represents presence of skill, i.e., a better than random predictive system. An illustrative ROC curve is shown in Figure 5.

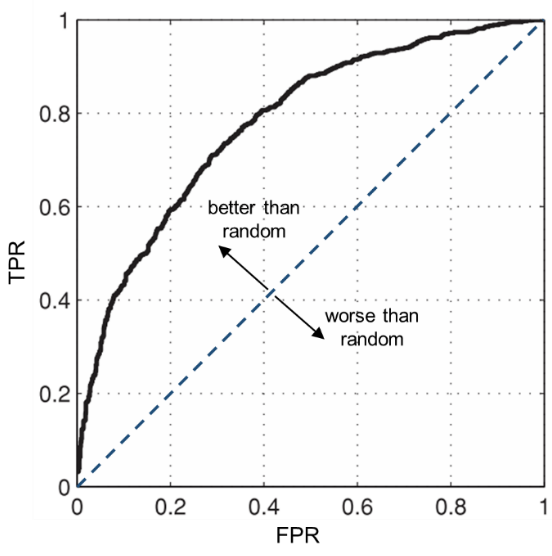

Figure 5: Illustrative ROC curve.

Finally, model reliability will be assessed using a Reliability Diagram. In this type of diagram, predictions are grouped into bins according to the probability issued by the model, and are plotted against the frequency with which the event was observed to occur for each sub-group of predictions. For perfect reliability, the predictive probability and the frequency of occurrence should be equal (Met Office, 2015). An example is shown in Figure 6.

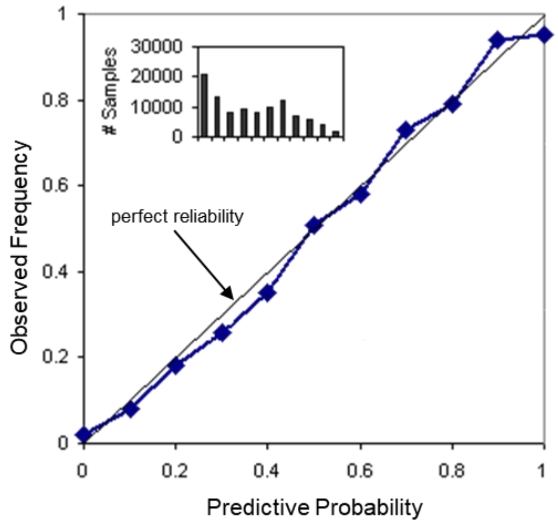

Figure 6: Illustrative Reliability Diagram.

Prediction Utility

This project will explore two alternative approaches to quantify the economic benefits of parametric triggers and minimize basis risk accordingly. The first approach is inspired on decision methods that are well-established in other fields of science, such as weather forecasting. We refer to it as the *static* approach, as it aims to quantify the overall expected benefit without accounting for varying user conditions in time. In contrast, we also propose a novel approach to quantify basis risk dynamically, using a more realistic financial model to estimate how the conditions of a beneficiary may vary in time. This is referred to as the *dynamic* approach. Both approaches are next described.

<u>Static</u>

The simplest framework that allows users of a binary predictive system, such as a parametric trigger, to quantify the economic benefit that it can provide is based on an expense decision model. This consists in assigning costs or benefits to the different possible outcomes of the confusion matrix, which can be expressed in the form of a so-called expense matrix. The mean expense can be calculated by multiplying the expected relative frequencies of the different outcomes by the corresponding expenses. The optimal trigger condition may be found by varying the trigger threshold within the possible range of values (in this case 0 to 1), and calculating the mean expense for each case. An example is shown in Figure 7.

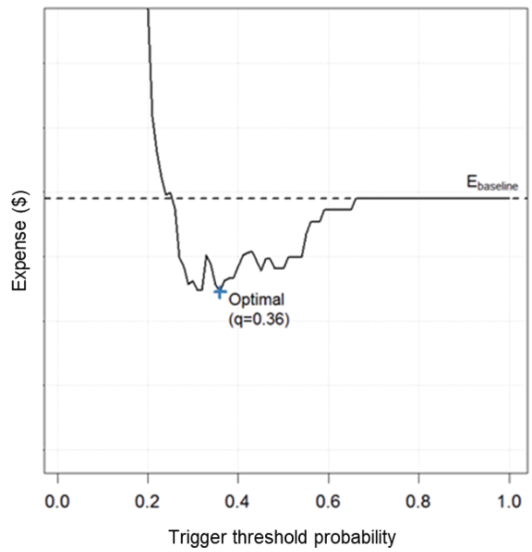

Figure 7: Illustrative user expenses over the range of trigger threshold probabilities.

This approach to assess prediction utility can be interpreted as a way to minimize basis risk (unlike prediction quality), as it takes into accounts actual user conditions to define the optimal trigger (Figueiredo et al., 2018). It also allows explicitly including costs such as premiums. These naturally vary with the adopted threshold, increasing or decreasing inversely to it (as lower threshold results in more frequent payouts, and vice-versa). Another strong advantage of an expense-based threshold definition is that it disentangles model development from trigger definition. In this case, it's not a model developer who specifies the trigger threshold based on certain (potentially arbitrary) performance metrics. Instead, this process involves the actual beneficiaries, given their specific conditions and risk appetite, which increases transparency and understanding of the product.

Even though this approach represents a step forward in minimizing basis risk relative to current practice, two limitations are foreseen. The first is that it may not always be straightforward to elicit user-specific expense matrices. This issue may be alleviated by adopting the *H* measure approach proposed by Hand (2009). However, the second issue is that within this framework, basis risk is quantified in a *static* manner, not taking into account time-varying economic conditions that would necessarily affect user expenses over time, such as bank loan interest rates. Also, they do not allow considering specific sequences of events that may take place over time: for example, if a sequence of False Negatives were to be issued by the model in a relatively short period of time, this could seriously impact the insureds conditions and financial stability.

<u>Dynamic</u>

To allow a financial quantification of the benefits of parametric insurance, this project will develop an idealized financial model able to simulate how disaster reserve funds would have evolved in time with parametric insurance payouts from the trigger model (and from perfectly timed payouts). This model will be implemented as an online app (using R Shiny) to allow potential users of parametric insurance to gain a better practical understanding of the implications of basis risk and the benefits of adopting a (albeit imperfect) parametric insurance program. Ultimately, this model will allow quantifying user expenses over time accounting not only for disaster losses and payouts issued by a risk transfer product to offset such losses, but also the amount of available reserve funds for emergencies, lines of credit, and insurance premiums. Some of the concepts proposed in Clarke and Mahul (2011) will be drawn upon. Figure 8 shows an illustration of the type of output that could be obtained from such a model for a specific trigger threshold. The model assumes that the insured has a dedicated reserve fund from which the losses associated to hazardous events are drawn, and where payouts from the insurance program are deposited. The reserve fund receives an annual budget allocation equal to the an annual net allocation after the deduction of the expenses, due to the cost for the insurance (premium) and the cost of possible loans necessary to keep the balance positive. The model provides a dynamic financial analysis by simulating the reserve fund and the expenses consequent to a series of events and payouts, computed according to the parametric insurance program.

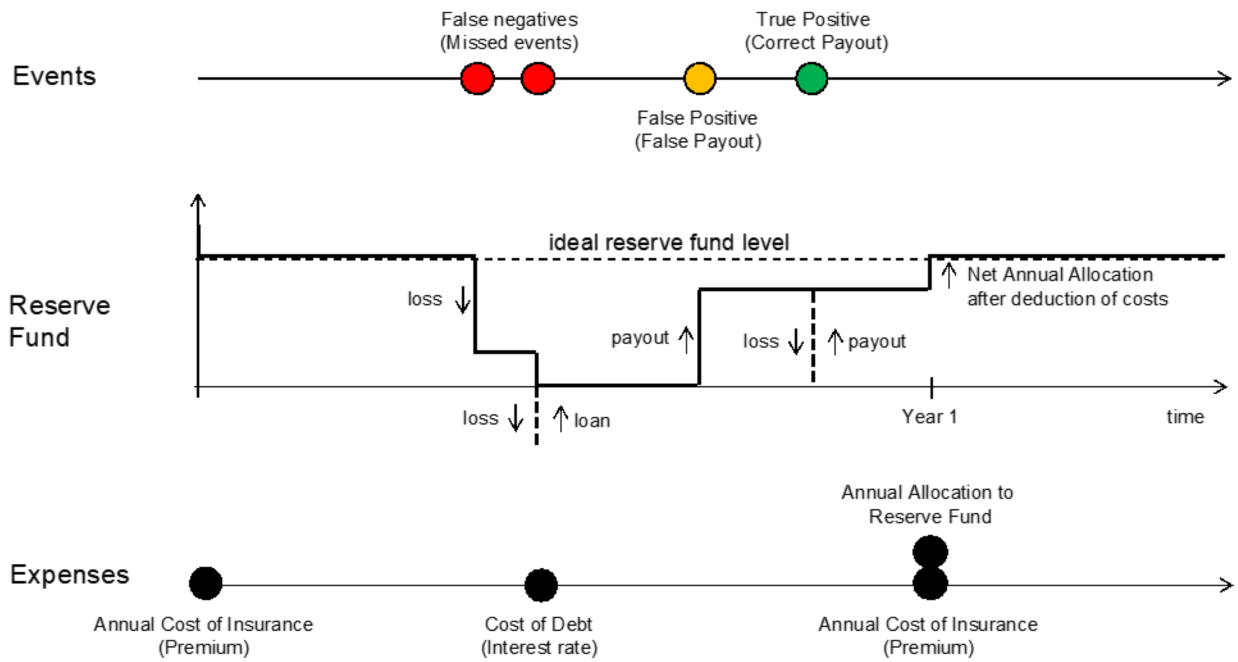

Figure 8: Conceptual scheme of the proposed dynamic financial model.

To address the issue of historical event catalogues spanning a limited number of years and therefore containing relatively few event data, a bootstrap resampling with replacement will be employed. This will allow not only generating longer event time series, but also to quantify uncertainty in user expenses by performing a large number of realizations of possible sequences of event occurrence. Appropriate block sizes will be selected given the nature of the hazard (e.g. 3-month blocks that capture the four seasons of the year). An illustration is provided in Figure 9.

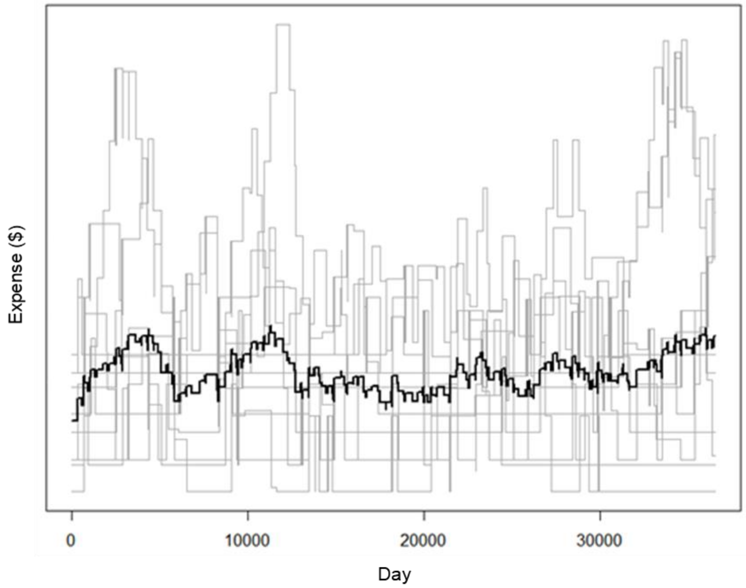

Figure 9: User expense time series generated by bootstrap resampling historical event data with replacement. Each grey line corresponds to one realization, while the black line shows the mean expense.

After the synthetic time series are generated, one or more performance indices can be adopted to quantify basis risk. Some examples include expense variability, the probability of exceedance of a certain maximum expense, or the total mean expense. We will test these and other different metrics foreseen to be informative for basis risk. After this is established, the methodology will be employed to assess the different trigger thresholds and select the optimal one.

3. Application to the Dominican Republic Pilot Study

3.1. The Dominican context

The Dominican Republic is ranked as the 10th most vulnerable country in the world and number 2 in the Caribbean, as per the Climate Risk Index for 1997-2016 report (Eckstein et al., 2017). The country has been affected by changes in precipitation (seasonal and regional), sea level rise, and increased intensity and frequency of extreme weather events. Climate events such as droughts and floods have had significant impacts on all the sectors of the country's economy, resulting in socio-economic consequences and food insecurity for the country.

Figure 10 shows the economic impact of four most catastrophic hydro-meteorological events of the last 40 years (Banco Mundial and MEPyD, 2015). These events alone have had a substantial impact on the country's productive sectors, particularly agriculture. Products such as chicken and bananas, which are essential in local diet (particularly for the lower income population), have been highly affected, undermining the country's food security and forcing local authorities to extraordinary imports (World Bank, 2015). Other significantly affected productive sectors include manufacturing, transport and tourism; the housing sector also suffered considerable losses.

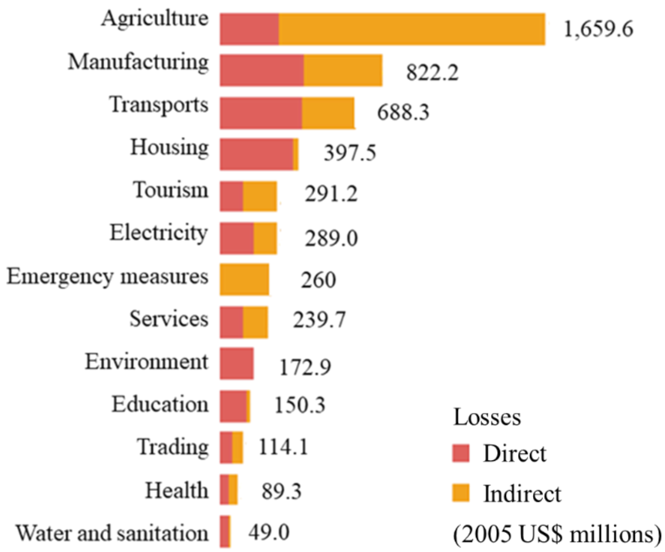

Figure 10: Sectorial distribution of direct and indirect losses relative to the four most catastrophic hydro-meteorological events of the last 40 years: tropical cyclones David and Federico, Georges, Jeanne, and Noel (adapted from Banco Mundial and MEPyD, 2015).

Despite its high vulnerability, the Dominican Republic has little reliance on risk transfer mechanisms. There is a pilot parametric insurance product is in place in the country, the Index Insurance and Climate Change, which covers losses caused by drought to dairy production and has recently been approved by the National Authority for Insurances. However, its scope is rather limited. Losses due to tropical cyclones (caused by strong winds and flooding due to extreme rainfall), which constitute the major part of the catastrophic events hitting the Dominican Republic and are the main drivers of loss in the country, are not included. Moreover, the coverage of the index is limited to dairy farmers, therefore not including other potential beneficiaries from the agricultural sector (e.g. crop growing farmers), or from other sectors .

The SMART project will model parametric triggers for hydro-meteorological hazards (i.e. tropical cyclones, floods, and droughts), the main drivers of loss in the Dominican Republic. Environmental variables will be obtained from globally available open-access datasets (some of which are described further below) and will be complemented whenever possible by more localized data provided by Fundación REDDOM, the local partner in this proposal, and by end-users. Together with REDDOM, potential end-users for tailored parametric insurance products will be identified, which may range from farmers of different types of crops and private households to national or local authorities.

3.2. Hazards

This section briefly describes the approaches that will be used to model triggers for the different types of hazard. The historical event data required to build the models will be obtained from reports from governmental authorities, documents from local NGOs, emergency declarations, alerts, bulletins from national meteorological offices, and certified disaster databases (such as EM-DAT and ReliefWeb). REDDOM's contribution to this task will be essential, providing on-the-ground and local information regarding past events and their impacts.

Flood

Floods caused by extreme rainfall, which typically occur during tropical cyclones, contribute significantly to disaster losses in the Dominican Republic. A variable transformation that aims to emulate the physical processes behind the occurrence of flood damage due to rainfall will be adopted. It will comprise an estimation of potential runoff based on daily rainfall, and of a potential damage index, given runoff. The approach will build upon the method proposed by Figueiredo et al. (2018). The adopted daily rainfall datasets will include:

- CMORPH: CMORPH (CPC MORPHing technique) produces global precipitation analyses at high spatial and temporal resolution, using precipitation estimates derived from low orbiter satellite microwave observations. The original spatial resolution of such estimates is 12 x 15 km, which is then interpolated to obtain a grid with a spacing of 8 km at the equator. Data records start in December 2002 (Joyce et al., 2004);
- Chirps and Chirps v.2 (Climate Hazard Group InfraRed Precipitation with Station data): a 30+ years rainfall dataset produced by the Climate Hazard Group (CHG) with the aim to help guide effective disaster responses and long-term development plans in food insecure countries. The dataset spans from 50°S to 50°N, starts in 1981 and incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring (Funk et al., 2015);
- IMERG: The Global Precipitation measurement (GPM) features a product named Integrated Multi-Satellite Retrievals for GPM (IMERG), which combines data from all passive-microwave instruments of the GPM constellation and represents a new generation of rainfall products at a temporal resolution of 30 min and spatial resolution of 0.1°. The IMERG product covers a large portion of the globe (60°N-60°S) and is available in three formats, characterized by different latencies (Bolvin et al., 2018).

Wind

Perhaps the most devastating - yet not most frequent - of natural hazards to affect the Dominican Republic are those involving extreme winds, such as hurricanes. Hurricanes Irma and Maria, recently affected the Dominican Republic in many ways, including loss of life, damage to buildings and power outage. The latter hurricane led to a US$19 million payout from CCRIF SPC's tropical cyclone policy. Extreme winds in hurricanes tend to be more widespread and vary less over space than extreme rainfall during floods. Thus robust and hugely insightful analyses can rely on relatively low-resolution data. Since wind gust speeds are generally thought to be best correlated with hurricane losses, we shall initially build models from ERA-Interim data, which offer global coverage at 0.75 resolution.

Drought

Losses due to droughts will be modelled in terms of crop yield reduction, since the agricultural sector is the most sensitive to such events and food security is strongly related to crops availability. Localized information will play a key role during model development, allowing the identification of the drought sensitive crops and providing data on average yield in normal years and yield reduction during drought periods. Parametric triggers for drought will be modelled starting from indices for drought characterization based on environmental variables, such as:

- Lack of precipitation: the rainfall datasets presented above will used to compute the Standardized Precipitation Index (SPI) or other rainfall-based drought indices;

- Vegetation condition: Vegetation Health Index (VHI) will be retrieved from the NOOA Star – Global Vegetation Health Products dataset. The satellite images dataset covers the period from August 1981 to present. It has weekly temporal resolution, 4km spatial resolution and spans from 55°S to 75°N (NOAA NESDIS, 2018). The inclusion of other vegetation condition indices, such as Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI), will be explored;
- Evapotranspiration: (Standardized Precipitation Evaporation Index, SPEI): the MOD16A2:MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid V006 dataset will be considered. It provides satellite images on actual and potential evapotranspiration and actual and potential latent heat flux. It has global coverage, spatial resolution of 500m, temporal resolution of 8 days and spans from 2001 to present (Running et al, 2017).

The information given by various environmental indicators will be combined with on-the-ground data to obtain a new more robust index to characterize drought. This index will serve as trigger for the models, considering the vulnerability of different crop types based on their growing phase. Such information will be obtained from scientific literature, reputable international sources (e.g. FAO), and local expertise. In this context, REDDOM's extensive knowledge on the vulnerability of Dominican crops, such as cacao, bananas and rice, will be critical.

3.3. Pathway to Operationalization

Close collaboration with the local partner, Fundación REDDOM, will be key in providing a bridge between model development, implementation, and on-the-ground operationalization. REDDOM's wide network of contacts can serve as a basis for the formation of new partnerships between local stakeholders, final beneficiaries, and foreign institutions. Such partnerships would promote the access and use of disaster risk financing innovations by actors in a local system.

Operationalization of the developed parametric risk transfer models will require a close and active involvement of both private and public-sector stakeholders. REDDOM' valuable experience in the agricultural sector will be crucial to include famers' organizations representing each crop and region, financial institutions serving target areas (cooperatives, government credit support agencies, and banks), insurance market stakeholders, and Dominican Government agencies. For instance, connections with farmers can be established through their local organizations, which would then collaborate with financial institutions and insurance companies in identifying credit opportunities for risk reduction measures and facilitating access to insurance policies for risk transfer. Analogous connections can be established between financing institutions and other types of interested beneficiaries. This is facilitated by REDDOM's ongoing involvement in disaster mitigation activities other sectors, such as assessing vulnerability in Santiago and Las Terrenas, aiming to provide information to local governments and tourists in case of disaster events. By establishing such linkages, the data analysis and model development can effectively translate into decision making, actions, and tailored risk transfer products that lead to increased resilience of end-users to natural hazards. To maximize the beneficial impact of the new risk financing products, end-users will be involved in the co-development of such products, and in the definition of user-specific criteria for basis risk minimization.

Some of the above-mentioned stakeholders in the Dominican Republic include, but are not limited to: FEDEGANORTE and FEDEGANO (North and Northwest Region dairy famers' organization), ADOBANANO (Banana growers organization in the Northwest Region), CONACADO (cocoa growers organization), COOPSANO Cooperative (financial institution), CONALECHE (National Dairy Council, which provides credit to dairy farmers), Banco Agrícola de la República Dominicana (Government Agricultural Bank), AGRODOSA (Government agricultural insurance), MAPFRE BHD (insurer), Banco ADEMI, Banco ADOPEM, Banco Popular, Banco de Reservas, and Banco BHD (commercial banks with agriculture credit portfolio), Dominican Insurance Superintendence, Dominican Chamber of Insurers and Re-Insurers, and Ministry of Agriculture. In order to preliminarily assess the feasibility of operationalization from the perspective of private stakeholder support, this project's consortium has established a first contact with Banco ADOPEM, who have demonstrated interest and availability to be involved.

A key aspect in moving towards adoption of the innovative disaster risk financing products is the organization of workshops in the Dominican Republic. It is envisaged that such initiatives would allow REDDOM to describe the new products, explain their strengths with respect to other types of risk financing mechanisms, and answer to related questions. Local authorities and key stakeholders would be invited, together with the identified potential end-users and beneficiaries. The organization of one such workshop is planned during the project.

To insert the new risk financing mechanism in the Dominican context, the possibility of integrating the developed tools in REDDOM's CLIMARED platform will be evaluated. CLIMARED (http://climared.com/) is a user friendly, free of charge platform that provides registered users with climatic and meteorological information (e.g. temperature, humidity, rainfall). The platform was developed by REDDOM in collaboration with USAID, and aims to:

- Improve resilience to climate change and reducing the risk of disasters;
- Facilitate the access and use of insurance products as a risk transfer tools;
- Apply risk reduction measures to protect assets and investments;
- Promote public-private partnerships to confront the problems caused by climate change, and contribute to food security

The CLIMARED platform is already used by farmers and local authorities, making it a preferential platform for making the new product operative in the local context.

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b) Feedback from the First Round

This section addresses the feedback received from the reviews of the first round, and refers to the respective parts of the proposal, when applicable.

1. Please clarify if you have any piloting arrangement with existing risk financing initiatives (e.g. CCRIF or other).

None of our team have any piloting arrangements with existing risk financing initiatives. Operationalization of the proposed framework is envisaged through collaboration with the local partner of our team, Fundación REDDOM, which has a proven track record in successful development and implementation of projects related with risk reduction and risk transfer in the Dominican Republic. Additional information is provided in Section 3.

2. Please also clarify your level of expertise / understanding of disaster risk financing

Our team possesses broad combined expertise in the field of disaster risk financing. This is highlighted in Sections A and B, where the backgrounds and experience of the three partner institutions of the consortium are described, and in Annex B, which presents the CVs of the proposed key personnel. Relevant experience in this field includes, but is not limited to: development of the CCRIF (Caribbean Catastrophe Risk Insurance Facility) parametric trigger models; development of the first commercial index insurance product for the agricultural sector in the Dominican Republic; development of high-impact research in the field of parametric risk transfer.

3. Please clarify what you think is the value machine learning versus more traditional approaches, and how your project plans to evaluate this question.

The main reasons behind the superiority of machine learning methods relative to traditional approaches are carefully and thoroughly discussed in Section 2.1. This will be demonstrated by developing a simple trigger that mimics such approaches, and evaluating its performance using the methodology described in Section 2.2, such that a fair quantitative comparison can be established. Note that this comparison could also be performed in a more realistic context by comparing our approach with an ongoing parametric program based on a traditional trigger mechanism. Such study would require some form of piloting arrangement with an ongoing program, which is not envisaged in this project but could be established at a later stage.

4. Please clarify to what extent is your proposal a new project, versus building upon existing work. I.e. What does our funding allow that could otherwise not happen?

A preliminary basis for this work has been established by some of the partners (see Section A) thanks to partial funding from Dr Figueiredo’s doctoral fellowship, which ended in August 2017. Funding for this project would allow us to greatly develop and demonstrate novel and more effective data science methods for designing and evaluating parametric insurance mechanisms. Because parametric insurance is a relatively recent approach to catastrophe risk transfer, it has only recently started to draw attention from the academic community, and does not yet feature in calls from traditional funding agencies such as national research councils or the EU. The Challenge Fund therefore provides a unique opportunity to fund this inter-disciplinary cross-sectoral research.

c) Work Plan

Our proposed work plan follows the technical approach and methodology previously discussed, and is organized into the four work packages described below. The respective work schedule is presented in Annex 3. Due to page limits, model development activities are not described in detail here but are cross-referenced to descriptions in previous sections.

Work Package 1: Start-up activities

Description: Initial activities deemed necessary for the development of the project.

Duration: 4 months

Activity 1.1 Kickoff meeting

A kickoff meeting will be organized as early in the project as possible, preferably within the first week, with the aim of reviewing and discussing its objectives, methodology, and work plan. Consortium partners and, ideally, representatives from GFDRR will attend.

Activity 1.2 Preparation and delivery of inception report

An inception report will be delivered within the first month of contracting, as per the Terms of Reference.

Activity 1.3 Identification and preliminary contacts with potential local stakeholders

The objectives are twofold: 1) disseminating the ongoing project among local stakeholders early on, aiming to raise interest and subsequently increase adoption; 2) understanding who potential end-users may be, such that more targeted trigger models can be developed accordingly during Activity 2.1.

Activity 1.4 Collection of relevant historical disaster loss data and environmental data for parametric trigger modeling

Please refer to Section 3.2 for more detailed information.

Work Package 2: Research and Development

Description: Research on the development of more robust triggers and basis risk evaluation methods for parametric risk transfer products.

Duration: 14 months

Activity 2.1 Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought

Please refer to Section 2.1 for more detailed information.

Activity 2.2 Development of general framework for basis risk quantification for different types of beneficiaries

Please refer to Section 2.2 for more detailed information.

Activity 2.3 Preparation and delivery of intermediary report

An intermediary report will be delivered half-way through the project (i.e. end of month 9), as per the Terms of Reference. All data collection and model development progress up to this point will be fully described, as well as possible difficulties encountered. In addition, possible progress towards on-the-ground operationalization resulting from Activity 1.3 will be reported.

Activity 2.4 Co-development and tailoring of the parametric trigger models to the specific context and needs of potential beneficiaries

The parametric trigger models will be further developed and refined so as to meet user-specific needs (e.g. farmers of specific crop types, homeowners, local *authorities, homeowners). When available, user-specific data will be collected for this purpose. Please refer to Sections 2.1 and 3 for more detailed information.*

Activity 2.5 Evaluation of user-specific models, and definition of optimal parametric trigger thresholds for basis risk minimization

Please refer to Section 2.2 and 3 for more detailed information.

Work Package 3: Promotion of operationalization

Description: Activities which aim to promote operationalization of the proposed innovations.

Duration: 1 month

Activity 3.1 Deployment of the first version of the models as an interactive web application

An open-access R Shiny web platform will allow potential users to visualize the models and perform simulations of how they might benefit from them. This aims to contribute to model dissemination while increasing understanding by users. An example of a Shiny app can be found at https://compassnz.shinyapps.io/NZIPR/.

Activity 3.2 Workshop with potential end-users of the parametric trigger models

The local partner, Fundación REDDOM, will organize a workshop to engage with potential end-users of the developed parametric trigger models. The main aims are dissemination, promoting adoption, and knowledge transfer. Interested potential beneficiaries may be invited to take part in a piloting initiative where the models will be tailored to meet their risk transfer needs. This will allow more refined models to be developed as illustrative case studies, which may subsequently be operationalized.

Work Package 4: Dissemination

Description: Concluding activities related with the dissemination of project results.

Duration: 2 months

Activity 4.1 Workshop with local and international stakeholders

To promote future operationalization of the models developed during the project, a workshop in the Dominican Republic will be organized. Local and international stakeholders from different areas (e.g. brokers, re-insurers). The outcomes of the project will be presented, and the establishment of partnerships among stakeholders will be promoted.

Activity 4.2 Delivery of final report

A final report will be delivered at the end of the project, as per the Terms of Reference. All stages of the project, related both with model development and operationalization, will be fully discussed, together with the project outcomes. Based on our findings, directions for further research and development on parametric trigger models will be presented.

Activity 4.3 Delivery of open-source code developed during the project

All software developed during the project will be delivered. The software will be open-source and clearly commented to facilitate future use.

d) Organization and Staffing

This project's consortium comprises a multi-disciplinary team of experts with significant experience in the fields of risk modeling, probability and statistics, and risk financing. In order to avoid redundancy, the composition of the team is not presented here, and can instead be found in Annex 1. The relatively small size of our team reflects the targeted scope of the current project. This will enable us to bring together combined expertise to carry out all the activities of the project in a dynamic manner, with active participation and contribution of all three consortium partners.

Annex 1 shows the specific areas of expertise, designations for the assignment, and main tasks to which each team member will contribute, according to the work plan presented above. Note that one of team members will work full-time on the project as a post-doctoral researcher at IUSS Pavia under the supervision of Professor Martina and Dr Figueiredo, with areas of expertise in Statistical Modeling and Machine Learning. Extended research visits to the University of Exeter are envisaged.

ANNEX 1: TEAM COMPOSITION, TASK ASSIGNMENTS & LEVEL OF EFFORT (LOE)

Key Personnel

Name of Staff & Firm associated with[1]	Area of Expertise Relevant to the Assignment	Designation for this Assignment[2]	Assigned Tasks or Deliverables*	Location[3]	Number of Days
Rui Figueiredo IUSS Pavia, employee	Multi-Hazard Risk, Risk Financing	Team Leader, Risk Modeling Expert	1.1, 1.2, 2.1, 2.2, 2.3, 4.1, 4.2	International	60
Mario L.V. Martina IUSS Pavia, employee	Hydrological Risk, Risk Financing	Team Coleader, Risk Modeling Expert	1.1, 1.2, 2.1, 2.2, 2.3, 4.1, 4.2	International	60
Paolo Bazzurro IUSS Pavia, employee	Multi-Hazard Risk, Risk Financing	Risk Modeling Expert	2.1, 2.2	International	15
Beatrice Monteleone IUSS Pavia, employee	Drought Risk	Drought Risk Modeler	1.4, 2.1, 2.4	International	60
Post-doctoral researcher IUSS Pavia, employee	Statistical Modeling, Machine Learning	Multi-Hazard Risk Modeler	2.1, 2.2, 2.4, 2.5, 3.1	International	330
David B. Stephenson U. of Exeter, employee	Statistical Modeling, Machine Learning, Climatology and Meteorology	Probability and Statistics Expert, Weather-Related Risk Expert	2.1, 2.2, 3.1	International	45
Benjamin D. Youngman U. of Exeter, employee	Statistical Modeling, Machine Learning, Wind Risk	Probability and Statistics Expert, Wind Risk Modeler	2.1, 2.2, 3.1,	International	45
Luis Tolentino REDDOM, employee	Climate Change, Risk Financing	Environmental and Climate Expert	1.3, 2.4, 3.2, 4.1	Local	45
Jeffery Perez REDDOM, employee	Data Analytics, Local Value Chain	Data Analyst	1.3, 1.4, 3.2, 4.1	Local	45

* This column indicates the main activities that each team member will be involved in, according to the Work Plan. Team members may also participate in other activities, as explained in Section D sub section (d).

[1] Indicate if the proposed staff is an employee or agent of your consulting firm/organization or a sub consultant.
[2] Title or position as described in the TOR or otherwise named in your proposed Organization and Staffing under Section D, sub section (d).
[3] Relative to the assignment subject of the Contract, indicate if the staff/consultant local or international.

ANNEX 2: CURRICULUM VITAE (CV) OF PROPOSED KEY PERSONNEL

1. **Name of Staff** [*Insert full name*]: Rui Pedro Carrapatoso Figueiredo

2. **Proposed Position**
Team Leader, Risk Modeling Expert

3. **Employer**: Scuola Universitaria Superiore IUSS Pavia

4. **Date of Birth**: 07/07/1983 **Nationality**: Portuguese

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Scuola Universitaria Superiore IUSS Pavia, Italy	PhD in Understanding and Managing Extremes	02/2018
Scuola Universitaria Superiore IUSS Pavia, Italy	MSc in Risk and Emergency Management	02/2015
Faculdade de Engenharia da Universidade do Porto (FEUP), Portugal	Graduate in Civil Engineering (pre-Bologna 5-year degree)	07/2006

6. **Professional Certification or Membership in Professional Associations**:
Member of the European Geosciences Union (since 2015)

7. **Other Relevant Training**:
11/2016 – 04/2017: Visiting researcher at GFZ Potsdam, Section 5.4: Hydrology (Germany)

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
Portugal, Italy, Germany

9. **Languages** [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
Portuguese (native speaker): good in speaking, reading, and writing
English: good in speaking, reading, and writing
Spanish: good in reading, fair in speaking and writing
Italian: good in reading, fair in speaking and writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 2018 To [*Year*]: present
Employer: Scuola Universitaria Superiore IUSS Pavia (Italy)
Positions held: Research Associate

From [*Year*]: 2014 To [*Year*]: 2015
Employer: RED – Risk Engineering and Design (Italy)
Positions held: Catastrophe Risk Analyst

From [*Year*]: 2006 To [*Year*]: 2013
Employer: SE2P – Sociedade de Engenharia, Projectos e Planeamento (Portugal)
Positions held: Multidisciplinary Engineering Designer; Project Coordinator

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*] 1.1 Kickoff meeting 1.2 Preparation and delivery of inception report 2.1 Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought 2.2 Development of general framework for basis risk quantification for different types of beneficiaries 2.3 Preparation and delivery of intermediary report 4.1 Workshop with local and international stakeholders 4.2 Delivery of final report	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: Development of an Excess Rain Loss Model for Central America and the Caribbean Year: 2016 Location: Central America and the Caribbean Client: The Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC) Main project features: Development of an Excess Rain (XSR) Risk Assessment model for countries in the Caribbean Region and in Central America. The XSR model is aimed at simulating in real time the precipitation over a country and rapidly estimating the potential consequent losses, such that shortly after the end of an event the country can receive a payout consistent with the CCRIF insurance policy conditions. Positions held: Risk Modeler, Software Developer Activities performed: Development of parametric trigger models for floods due to excess of rainfall. Development of software to run the models operationally. Name of assignment or project: Development of a Flood Risk Model for a Country in Eastern Europe Year: 2015 Location: Italy Client: Confidential (Reinsurance Company) Main project features: Estimation of technical premiums

	relative to floods for different types of residential buildings, and computation of portfolio risk metrics. Positions held: Flood Risk Modeler Activities performed: Development and implementation of hazard, exposure and vulnerability models, and computation of risk metrics. Name of assignment or project: Coordination of large-scale engineering design projects Year: 2006-2013 Location: Portugal Client: Various Main project features: Construction and/or retrofitting of numerous residential, commercial and industrial buildings, schools and theatres, as well as building and public water supply and drainage systems, for countries such as Portugal, Brazil, France, Qatar, Cape Verde, Angola and Mozambique Positions held: Project Coordinator Activities performed: Project planning and resource allocation. Coordination between project stakeholders (i.e. design teams, contractors, clients). Multidisciplinary engineering design.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

[Signature of staff member or authorized representative of the staff]

Date: 30/10/2018
Day/Month/Year

1. **Name of Staff** [*Insert full name*]: Mario Lloyd Virgilio Martina

2. **Proposed Position**
   Team Coleader, Risk Modeling Expert

3. **Employer**: Scuola Universitaria Superiore IUSS Pavia

4. **Date of Birth**: 23/07/1976 **Nationality**: Italian

5. **Education**:

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
University of Bologna	Doctorate in Physically-based Modelling for Natural Hazards (PhD)	2004
Polytechnic of Milan, Cineas	Master in Risk Engineering and Loss Adjustment (MSc)	2000
University of Bologna	Degree in Civil and Environmental Engineering (MEng)	2000

6. **Professional Certification or Membership in Professional Associations**:
   Registered Professional Civil Engineer, Italy
   Co-Founder of *Italian Hydrological Society* (IHS)
   Member of *European Geosciences Union* (EGU)
   Member of *American Geophysical Union* (AGU)

7. **Other Relevant Training**:
   Courses in flood risk modeling, hydrology, meteorology, advanced statistics, forecasting and early warning systems

8. **Countries of Work Experience**:
   Italy, USA, Europe, China, Central America, Caricom

9. **Languages**:
   Italian (native speaker): good in reading, fair in speaking and writing
   English: good in speaking, reading, and writing

10. **Employment Record**:

From [*Year*]: 2014 To [*Year*]: present
Employer: University School for Advanced Studies IUSS - Pavia
Positions held: Associate Professor in Flood Risk Modeling

From [*Year*]: 2013 To [*Year*]: present
Employer: RED – Risk Engineering and Design, Pavia, Italy
Positions held: External consultant and advisor of Hazard and Risk Analyses

From [*Year*]: 2011 To [*Year*]: 2013
Employer: University of Bologna, Italy
Positions held: Researcher in Flood Risk Modeling

From [*Year*]: 2008 To [*Year*]: 2011
Employer: Willis Ltd, U.K
Positions held: Willis Research Fellow in Flood Risk Modeling

From [*Year*]: 2004 To [*Year*]: 2007
Employer: University of Bologna, Italy
Positions held: Post-Doc researcher in Flood Risk Modeling

From [*Year*]: 2001 To [*Year*]: 2004
Employer: Progea srl, Italy
Positions held: Flood Modelling Expert

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*] 1.1 Kickoff meeting 1.2 Preparation and delivery of inception report 2.1 Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought 2.2 Development of general framework for basis risk quantification for different types of beneficiaries 2.3 Preparation and delivery of intermediary report 4.1 Workshop with local and international stakeholders 4.2 Delivery of final report	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: RATIoNaL - Risk AppeTite Index via machiNe Learning Year: 2017-2018 Location: Germany-UK-France-Italy Client: Allianz Global Corporate & Speciality SE Main project features: The project made use of a pilot study on a sample of the claim database provided by AGCS to define a Risk Appetite Index (RAI). The RAI represented by means of a synthetic index the goodness/potentiality of a client's risk in terms of the expected loss and the premium quotation associated to the client sector. The study compared different mathematical and statistical methodologies to perform the analysis. In particular, multi-regression and machine learning techniques were applied, calibrated and validated. Also, the study focused on the expert's (i.e. underwriter's)

	criteria usually followed within the standard underwriting process. A secondary activity was to translate expert-based (subjective) knowledge into objective algorithm applied on variables describing the client, the location and the features of the assets exposed at the different risks. Positions held: Project Coordinator Activities performed: Coordination of the project and scientific supervision Name of assignment or project: NEWFRAME - NEtWork-based Flood Risk Assessment and Management of Emergencies Year: 2017-2019 Location: Italy Client: Fondazione Cariplo – Comune di Monza Main project features**:** develop a new framework for the assessment of the urban flash flood risk, which takes into account the connections between the exposed elements. As an example of connection between elements one could take the link student-bus-school, in which it is obvious that a disruption to the bus service, caused by the flooding of a bus stop, may impact on the students' ability to go to school. The new methodology enables better estimation of the vulnerability of the system exposed value and, consequently, of the risk as the product of probability of occurrence, vulnerability and exposed value. In a real case study (municipality of Monza), the results of the new method are compared with those of the traditional method, which estimates the exposed value regardless of the element interconnections. Positions held: Team Leader at IUSS Activities performed: Supervision of the model component development and coordination of the project tasks. Name of assignment or project: Development of an Excess Rain Loss Model for Central America and the Caribbean Year: 2016 Location: Central America and the Caribbean Client: The Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC) Main project features: Development of an Excess Rain

	(XSR) Risk Assessment model for countries in the Caribbean Region and in Central America. The XSR model is aimed at simulating in real time the precipitation over a country and rapidly estimating the potential consequent losses such that shortly after the end of the XSR event the country can receive a payout consistent with the CCRIF insurance policy conditions. Positions held: Project Coordinator Activities performed: Supervision of the model component development and coordination of the project tasks. Name of assignment or project: Risk Manager Specialist for CCRIF SPC Year: 2015 - 2017 Location: Central America and the Caribbean Client: The Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC) Main project features: The Caribbean Catastrophe Risk Insurance Facility was formed as the first multi-country risk pool in the world, and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It was designed as a regional catastrophe fund for Caribbean governments to limit the financial impact of devastating tropical cyclones, earthquakes and excess rainfalls by quickly providing financial liquidity when a policy is triggered. The principal responsibilities of the risk management specialist include risk management, financial planning, catastrophe modeling, interacting with participant governments, and coordination of the reinsurance placement. Positions held: Risk Modelling Expert Activities performed: Risk analysis and modeling approach development. Name of assignment or project: Development of Flood and Landslide Risk Models for a Country in Eastern Europe Year: 2015 Location: Italy Client: Confidential (Reinsurance Company) Main project features: Development of risk metrics (EP,

	AAL, etc.) for different types of residential buildings for the Flood and Landslide perils Positions held: Project Coordinator Activities performed: Coordination of the project, development of the event generation, implementation of the vulnerability curves, technical supervision the risk metrics computation Name of assignment or project: Review of the Flood Risk Model of the South East Europe Year: 2013-2014 Location: South East Europe Client: Europa Reinsurance Facility Ltd Main project features: technical and scientific review of the methodologies and validation of the results of the flood risk model for South East Europe Positions held: Flood Risk Modelling Expert Activities performed: Performs all the analyses and tests to validate the results, critical review of the methodologies, suggest improvements to the applied approach Name of assignment or project: Probabilistic Flood Hazard Model for Norway Year: 2009-2010 Location: U.K., Norway Client: National Natural Peril Pool, Norway Main project features: to develop the probabilistic flood model for Norway as a basis for the evaluation of the insurance cover by the National Natural Peril Pool Positions held: Flood Risk Modelling Expert Activities performed: Development of the event generation model, development of the flood hazard model Name of assignment or project: Probabilistic River Flood Model for the Po Valley (Italy) Year: 2010 Location: Italy Client: Allianz RE Main project features: to develop the probabilistic river flood model for the Po Valley and provide preliminary

	estimation of the loss Positions held: Project coordinator Activities performed: Coordination of the project, collection and analysis of the historical flood events, development of a methodology to estimate the event correlation, supervision of simulation of the flood footprints and development of the flood geo-database Name of assignment or project: Probabilistic River Flood Model for Central Eastern Europe Year: 2008-2011 Location: U.K., Central Eastern Europe Client: Willis Research Network, UK Main project features: Development of the flood risk model for the Danube River Positions held: Flood Risk Modeler Activities performed: Development of the methodology to estimate the spatial correlation of flood event, generation of the stochastic catalogue Name of assignment or project: Assessment of Flood Hazard and Weather Related Hazards for Italy Year: 2002-2004 Location: Italy Client: Generali Insurance Company Main project features: to develop the flood risk model for the entire country Positions held: Flood Risk Modeler Activities performed: Development of the methodology to assess the hazard of flood and weather related hazards, performing advanced statistical analysis, calibration of the GIS-based platform for hydrological modeling

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offer or and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

______________________________________ Date: 31/10/2018

[Signature of staff member or authorized representative of the staff] *Day/Month/Year*

1. **Name of Staff** [*Insert full name*]: Paolo Bazzurro

2. **Proposed Position**:
Risk Modeling Expert

3. **Employer**: Scuola Universitaria Superioire IUSS Pavia

4. **Date of Birth**: 19/02/1962 **Nationality**: Italian

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Stanford University (1995-1998)	Ph.D. Civil and Environmental Engineering (Structures)	1998
Stanford University (1991-1993)	Engineer Degree Civil Engineering (Structures)	1993
Stanford University (1990-1991)	M.S. Civil Engineering (Structures)	1991
Università degli Studi di Genova (Italy) (1981-1987)	Laurea Civil Engineering (Italian M.S.) (Structures)	1987

6. **Professional Certification or Membership in Professional Associations**:
Earthquake Engineering Research Institute (EERI)
Seismological Society of America (SSA)
Structural Engineering Association of California (SEAOC)
American Society of Civil Engineers (ASCE)
Consortium of Organizations for Strong-Motion Observation Systems (COSMOS)
Ordine degli Ingegneri della Provincia di Genova (Italy) (Professional Engineers Society of Genoa, Reg. No. 6017)

7. **Other Relevant Training**:

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
Italy, USA, Caribbean Countries, Central America countries, Mexico, Chile, Colombia, Pacific Island countries, Albania, Macedonia, Serbia, Romania, France, Vietnam.

9. **Languages**
Italian (native speaker): good in speaking, reading, and writing
English: good in speaking, reading, and writing
French: good in speaking, fair in reading and writing

10. Employment Record

From [*Year*]: 2012 To [*Year*]: present
Employer: Scuola Universitaria Superiore IUSS Pavia, Italy
Position held: Full professor of Structural Engineering

From [*Year*]: 2017 To [*Year*]: present
Employer: RED – Risk Engineering and Design, Pavia, Italy
Position held: External consultant and advisor of Hazard and Risk Analyses

From [*Year*]: 2012 To [*Year*]: present
Employer: EuropaRE Reinsurance Facility Ltd., Zurich, Switzerland
Position held: Risk Modeling Advisor

From [*Year*]: 2001 To [*Year*]: 2012
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Senior Principal Engineer & Director, Engineering Analysis and Research

From [*Year*]: 2011 To [*Year*]: 2012
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Project Leader of the Flood and Earthquake Risk Modeling Effort for Albania, Serbia and Macedonia in support of the EuropaRE Reinsurance Facility Operations, Prepared for the World Bank.

From [*Year*]: 2011 To [*Year*]: 2012
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Project Leader of the Implementation of the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI): Phase III, Prepared for the World Bank.

From [*Year*]: 2009 To [*Year*]: 2011
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Technical Project Manager of the update of the AIR's Earthquake Loss Assessment Model for the State of Hawaii

From [*Year*]: 2009 To [*Year*]: 2011
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Project Leader of the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI): Phase II, Prepared for the World Bank.

From [*Year*]: 2009 To [*Year*]: 2010
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Technical Project Manager for the development of the AIR's Earthquake and Tropical Cyclone Loss Assessment Model for Industrial Facilities in the United States, 2009-2010.

From [*Year*]: 2009 To [*Year*]: 2010

Position held: Principal Investigator of the 2009-10 USGS-funded research project on “Vector valued Probabilistic Seismic Hazard Analysis of Correlated Ground Motion Parameters”.

From [*Year*]: 2008 To [*Year*]: 2009
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Project Manager of the AIR’s development of the Earthquake Real Time Loss Estimation (EARLE) System prepared for the California Earthquake Authority (CEA), 2008-2009.

From [*Year*]: 2008 To [*Year*]: 2009
Employer: AIR Worldwide Corporation, San Francisco, CA.
Position held: Project Leader of the Global Catastrophe Mutual Bond Risk Modeling Study (Country Modeled: Mexico; Perils: Earthquake and Hurricanes) Prepared for the World Bank. This work is the technical foundation for the $290m MultiCat catastrophe bonds issued in 2009.

From [*Year*]: 2008 To [*Year*]: 2009
Position held: Co-Project Manager of the Hurricane Risk Assessment for Planned Offshore Developments in the Extra-deep waters of the Gulf of Mexico, prepared for Devon Corporation.

From [*Year*]: 2008 To [*Year*]: 2009
Position held: Technical Project Manager of the update of the AIR’s Earthquake Loss Assessment Model for the United States.

From [*Year*]: 2008 To [*Year*]: 2009
Position held: Project manager of the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI): Phase I - Feasibility Study prepared for the World Bank.

From [*Year*]: 2008 To [*Year*]: 2008
Position held: Project manager of the 2008 Seismic Risk and Loss Analysis of all the Endesa South America Assets in Chile, Colombia, and Peru.

From [*Year*]: 2007 To [*Year*]: 2008
Position held: Project manager of the Hurricane Risk Analysis for the Dow Chemical Plant in Freeport, TX.

From [*Year*]: 2007 To [*Year*]: 2008
Position held: Principal Investigator of the 2007-08 SCEC-funded research project on “Efficient Approach to Vector-Valued Probabilistic Seismic Hazard Analysis of Multiple Correlated Ground Motion Parameters”.

From [*Year*]: 2007 To [*Year*]: 2008
Position held: Principal Investigator of the 2007-08 USGS-funded research project on “Effects of spatial correlation of ground motion parameters for multi-site seismic risk assessment: Collaborative Research with Stanford University (Prof. Jack Baker) and AIR”.

From [*Year*]: 2007 To [*Year*]: 2007

Position held: Project Manager of the 2007 Correlated Ground Motion Scenarios for the Seismic Risk Assessment of the Levees in the Sacramento River Delta prepared for the California Department of Water Resources.

From [*Year*]: 2006 To [*Year*]: 2007
Position held: Principal investigator of a 2006-07 SCEC-funded research project on Development of a Database of Nonlinear Ground Motion Amplification Functions for Soil Deposits of Various NEHRP Soil Categories.

From [*Year*]: 2006 To [*Year*]: 2009
Position held: Technical Project Manager for the development of the Hurricane Risk Model for Offshore Platforms in the Gulf of Mexico.

From [*Year*]: 2006 To [*Year*]: 2007
Position held: Principal investigator of a 2006-07 USGS-funded project on Multidirectional Seismic Excitation Effects in Building Response Estimation: Collaborative Research with USGS (Dr. Nicolas Luco) and AIR.
From [*Year*]: 2006 To [*Year*]: 2006
Position held: Project Manager of the study: "Recompiling, Analyses, Quantification, and Modeling of Seismic Risk of the United Mexican States, due to Earthquakes of Major Proportions". This project provided the technical background that allowed the Mexican Ministry of Finance to buy in 2006 protection for $450m of earthquake losses via both the CATMEX "catastrophe bonds" and reinsurance.

From [*Year*]: 2004 To [*Year*]: 2005
Position held: Technical Project Manager of the 2004-2005 AIR-funded project on Effects of earthquake rupture directivity on performance of woodframe buildings.

From [*Year*]: 2004 To [*Year*]: 2005
Position held: Principal Investigator of the 2004-05 COSMOS/USGS-funded study: Effects of Strong Motion Processing Procedures on Time-Histories, Elastic and Inelastic Spectra.

From [*Year*]: 2003 To [*Year*]: 2005
Position held: Principal Investigator of the 2003-05 EERI-funded study: Examination of structural vulnerability, damage, and post-earthquake practices for recent Italian earthquakes - Case studies and comparisons to US practice. This study generated a report distributed to EERI members.

From [*Year*]: 2004 To [*Year*]: 2004
Position held: Principal investigator of a 2004 COSMOS/USGS-funded research project on Effects of Strong Motion Processing Procedures on Time-Histories, Elastic and Inelastic Spectra.

From [*Year*]: 2003 To [*Year*]: 2003
Position held: Principal investigator of a 2003 USGS-funded research project on Correlation of Damage of Steel Moment-resisting Frames to a Vector-valued Ground Motion Parameter Set That Includes Energy Demands.

From [*Year*]: 2002 To [*Year*]: 2003
Position held: Principal investigator (PI) of a 2002 Pacific Earthquake Engineering Research (PEER) Center-funded research project on Parameterization of Non-Stationary Acceleration Time Histories. PI of the 2003 Addendum to the previous project.
From [*Year*]: 2001 To [*Year*]: 2002
Position held: Co-Principal Investigator of a 2001-02 PEER/Stanford University-funded research project on Advanced seismic assessment guidelines for more rational post-earthquake building occupancy assessment".
Position held: Multiple projects on site-specific estimation of damage and losses on structures subject to seismic ground motions (Clients' name confidential).

Position held: Project manager for the Risk Study for Global Catastrophe Insurance Facility (GCIF) prepared for the World Bank in 2006. This study involved the Seismic Risk Assessment for a group of countries in the Caribbean, Asia, and Europe.

Position held: Project manager of four seismic risk analyses performed for General Motor's plants in Japan, Mexico, Colombia, and Venezuela.

Position held: Project Manager of the study: "Seismic Risk Analysis of the Sacramento Municipal Utility District (SMUD) Portfolio".

Position held: Project Manager of the studies: "Seismic loss analysis for a portfolio of woodframe residential houses in California" and of "PROSIT: Probabilistic Risk Analysis System" for a major California insurance company.

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*] 2.1. Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought 2.2 Development of general framework for basis risk quantification for different types of beneficiaries	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: Risk Management Specialist for CCRIF SPC Year: 2015- current Location: Caribbean and Central American countries Client: CCRIF SPC Main project features: Since September 2015 RED, together with ERN Evaluación de Riesgos Naturales, has been in charge as Risk Management Specialist for CCRIF SPC (The Caribbean Catastrophe Risk Insurance Facility), providing the services of risk management, financial planning, catastrophe modelling and coordination of reinsurance placement. In 2007, the Caribbean Catastrophe Risk Insurance Facility was formed as the first multi-country risk pool in the world,

	and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It was designed as a regional catastrophe fund for Caribbean governments to limit the financial impact of devastating hurricanes and earthquakes by quickly providing financial liquidity when a policy is triggered. In 2014, the facility was restructured into a segregated portfolio company (SPC) to facilitate expansion into new products and geographic areas and is now named CCRIF SPC. CCRIF offers earthquake, tropical cyclone and excess rainfall policies to Caribbean and Central American governments. CCRIF helps to mitigate the short-term cash flow problems small developing economies suffer after major natural disasters. CCRIF's parametric insurance mechanism allows it to provide rapid payouts to help members finance their initial disaster response and maintain basic government functions after catastrophic event. The ERN/RED team ensures that the Facility continues to be innovative by developing additional sustainable products, services and tools to meet the needs of member governments, in an effort to enhance their disaster risk response and management capabilities. Positions held: Team Leader Activities performed: - Catastrophe Risk Modelling - Actuarial Assessment and Risk Management Services - Event Monitoring and Reporting Services - Research and Development Services - Technical Advisory Services - Technical and Strategic Communications Services, Fostering Strategic Partnerships Name of assignment or project: Pacific Catastrophic Risk Assessment and Financing Initiative (PCRAFI) Year: 2009-2010 Location: Pacific countries Client: The World Bank Main project features: In order to mitigate the economic and financial impact of natural disasters on the public sector, the World Bank (WB) proposed studying the viability of developing a Pacific Catastrophic Risk Assessment and Financing Initiative to allow Pacific

countries to pool natural disaster risks. The countries involved were: South Pacific Islands: Papua New Guinea, Solomon Islands, Tonga, Cook Islands, Tuvalu, Vanuatu, Fiji, Samoa, Nauru, Niue, Federated States of Micronesia, Kiribati, Marshall Islands, Palau, and Timor Leste.

The proposed financial vehicle was intended to provide the governments of these countries with help in covering their exposure to natural disasters through means such as the availability of more affordable insurance policies against adverse natural events, such as tropical cyclones and earthquakes. To determine the feasibility of this financial vehicle, WB has requested modeler AIR to develop typhoons and earthquake catastrophic risk profiles at the Pacific region level as well as the individual country level. This study was built heavily on the work done by AIR in Phase I of the same effort.

Positions held: Team Leader

Activities performed:

- Acquire, review and process exposure data to compile a database of exposures that are representative of the public assets (e.g., public buildings, hospitals, schools), private assets (e.g., residential, commercial, and industrial) infrastructure and major cash crops of the countries under consideration. This task involves a massive effort of digitization and classification of buildings and infrastructure from satellite imagery and field visits.
- Incorporate tropical cyclone, earthquake and tsunami hazards of the region into existing AIR models.
- Develop catastrophe risk profiles for each country and for the region.
- Estimate impact on population due to earthquakes and tropical cyclones.
- Analyze the risk to the proposed Pacific Catastrophic Risk Pool in order to assess the pooling benefits and the correlation of the portfolio with exposures in other regions.
- Perform a risk analysis for the 15 SOPAC countries based on the following hazards: tropical cyclone-generated wind, ocean surge, precipitation, earthquake-generated ground shaking, and tsunamis.

Name of assignment or project: MultiCat Ltd.

Year: 2008-2009

Location: Mexico

	Client: The World Bank Main project features: AIR provided the risk analysis for the MultiCat catastrophe bond. This included analysis for the earthquake and hurricane perils as well as an estimation of emergency losses. AIR also calibrated the design of parametric boxes used in the catastrophe bond and presented its models, methodology and results to the Mexican government, ratings agencies and investors. Positions held: Team Leader Activities performed: - Design first-generation parametric boxes and associated trigger parameters to cover earthquake and hurricane risk - Calculate distribution of emergency losses resulting from earthquakes and hurricanes, - Analyze historical hurricanes and earthquakes to determine which would have triggered the bond, - Prepare risk analysis documentation for catastrophe bond Offering Circular and for use in investor presentations, - Design event-verification procedure to determine if a qualifying event has occurred that would trigger a payment, - Present analysis methodology and results to all transaction parties including the Mexican government, the World Bank, ratings agencies and investors.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any willful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

Date: 26/10/2018

[Signature of staff member or authorized representative of the staff] *Day/Month/Year*

1. **Name of Staff** [*Insert full name*]: Beatrice Monteleone

2. **Proposed Position**
   Drought Risk Modeler

3. **Employer**: Scuola Universitaria Superiore IUSS Pavia

4. **Date of Birth**: 21/11/1988 **Nationality**: Italian

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Scuola Universitaria Superiore IUSS Pavia, Italy	PhD in Understanding and Managing Extremes	Expected: 02/2020
Università Cattolica del Sacro Cuore, Italy	Graduate in Physics (5 years degree)	12/2012
Università Cattolica del Sacro Cuore, Italy	Graduate in Physics (3 years degree)	09/2010

6. **Professional Certification or Membership in Professional Associations**
   Member of the European Geosciences Union (since 2018)

7. **Other Relevant Training**:

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
   Italy

9. **Languages** [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
   Italian (native speaker): good in speaking, reading, and writing
   English: good in speaking, reading, and fair in writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 2016 To [*Year*]: present
Employer: Scuola Universitaria Superiore IUSS Pavia (Italy)
Positions held: PhD student

From [*Year*]: 2013 To [*Year*]: 2016
Employer: Università Cattolica del Sacro Cuore (Italy)
Positions held: Research fellow

11. Detailed Tasks Assigned [*List all tasks to be performed under this assignment*]	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned** [*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*]
1.4. Collection of relevant historical disaster loss data and environmental data for parametric trigger modeling 2.1. Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought 2.4. Co-development and tailoring of the parametric trigger models to the specific context and needs of potential beneficiaries	Name of assignment or project: PhD thesis Drought modelling for parametric insurance Year: 2016-2018 Location: Italy Client: Scuola Universitaria Superiore IUSS Pavia Main project features: PhD thesis on drought modelling for parametric insurance purposes Positions held: PhD researcher Activities performed: creation of a trigger-based model for drought event identification that uses remote-sensing data; collection of data on past drought events in the Caribbean Islands; analysis of drought indices used to monitor agricultural and meteorological drought.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

I understand that any wilful misstatement or misrepresentation herein may lead to my disqualification or removal from the selected team undertaking the assignment.

Beatrice Monteleone

[Signature of staff member or authorized representative of the staff]

Date: 26/10/2018
Day/Month/Year

1. **Name of Staff** [*Insert full name*]: David B. Stephenson

2. **Proposed Position**
Probability and Statistics Expert, Weather-Related Risk Expert

3. **Employer**: University of Exeter

4. **Date of Birth**: 07/08/1963 **Nationality**: British

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
University of Edinburgh	PhD in theoretical particle physics	08/1988
University of Oxford	BA (1st class Honors) in Physics	07/1985

6. **Professional Certification or Membership in Professional Associations**
Elected fellow of the Academia Europaea (European Academy of Science) (since 2010)
Fellow of the Royal Statistical Society (since 1995)
Fellow of the Royal Meteorological Society (since 1991)

7. **Other Relevant Training**
Professor David Stephenson has 25 years-experience in climate modelling research and has published more than 150 papers that receive many citations (H-index of 61). He is world-recognized for his expertise in the development and novel application of statistical modelling to understand climate processes and predictions. In 2012, he was awarded the Adrian Gill prize of the Royal Meteorological Society for pioneering interdisciplinary collaboration between climate and statistical science. From 2003-2009, he served as Editor for the Journal of Climate. He has contributed to the latest IPCC 5th assessment report: lead author on the regional climate chapter 14 and contributing author on chapters 2 and 9. He has successfully collaborated with the Met Office over many years and while Met Office joint chair (2007-12), he helped initiate and design the current Met Office Academic Partnership. In 2006, he was a key founding member of the Willis Research Network, which is now the world's largest partnership between academia and the insurance industry. He is an elected member of the prestigious Academia Europaea – the European Academy of Science and in 2015 received a Wolfson Merit Award from the Royal Society for his storm risk work.

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
UK, Norway

9. Languages [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
English (native speaker): good in speaking, reading and writing
French : good in speaking, reading and fair in writing

10. Employment Record [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 04/2007 To [*Year*]: present
Employer: Department of Mathematics, University of Exeter, U.K
Position held: Professor in Statistical Climatology and Head of Statistical Science, Director and founder of the Exeter Climate Systems research centre

From [*Year*]: 06/2004 To [*Year*]: 06/2008
Employer: University of Bergen, Norway
Position held: Adjunct Professor at the Bjerknes Centre for Climate Research

From [*Year*]: 10/2000 To [*Year*]: 03/2007
Employer: University of Reading, U.K.
Position held: Reader in Statistical Climatology, Department of Meteorology

From [*Year*]: 10/1999 To [*Year*]: 09/2000
Employer: University of Reading, U.K.
Position held: Lecturer, Department of Meteorology

From [*Year*]: 08/1998 To [*Year*]: 09/1999
Employer: University of Toulouse, France
Position held: European Union fellowship, Department of Probability & Statistics

From [*Year*]: 12/1992 To [*Year*]: 07/1998
Employer: French National Weather Service (Météo-France), Toulouse, France.
Position held: Visiting Scientist

From [*Year*]: 09/1991 To [*Year*]: 11/1992
Employer: University of Reading, U.K.
Position held: European Union research fellowship, Department of Meteorology

From [*Year*]: 09/1989 To [*Year*]: 08/1991
Employer: University of Princeton, U.S.A
Position held: Visiting Scientist, Geophysical Fluid Dynamics Laboratory (GFDL)

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*] 2.1 Development and benchmarking of statistical and machine learning models for	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: Willis Research Network

parametric triggers relative to flood, wind and drought 2.2 Development of general framework for basis risk quantification for different types of beneficiaries 3.1 Deployment of the first version of the models as an interactive web application	Year: 2008-present Location: U. of Exeter Client: Willis Towers Watson Main project features: stochastic modelling of storms Positions held: see above Activities performed: see above

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

I certify that (1) to the best of my knowledge and belief, this CV correctly describes me, my qualifications, and my experience; (2) that I am available for the assignment for which I am proposed; and (3) that I am proposed only by one Offeror and under one proposal.

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D. Stephenson

Date: 26/10/2018

[Signature of staff member or authorized representative of the staff] *Day/Month/Year*

1. **Name of Staff** [*Insert full name*]: Benjamin David Youngman

2. **Proposed Position**
Probability and Statistics Expert, Wind Risk Modeler

3. **Employer**: University of Exeter

4. **Date of Birth**: 15/10/1984 **Nationality**: British

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
University of Sheffield	PhD Statistics	07/2011
University of Sheffield	MSc (Distinction) in Statistics	09/2007
University of Sheffield	BSc (1st class honours) in Mathematics	06/2006

6. **Professional Certification or Membership in Professional Associations**

7. **Other Relevant Training**:
Dr. Ben Youngman's research focuses on developing statistical methodology for meteorological phenomena, typically natural hazards, and subsequent software accessible to end-users. He has published on general modelling methods for natural hazards (e.g. JASA, DOI: 10.1080/01621459.2018.1529596, Environmetrics, DOI: 10.1002/env.2444 and Technometrics, DOI: 10.1080/00401706.2015.1125391) and in 2016 won the Lloyd's Science of Risk prize for his paper (Proc. Roy. Soc. A, DOI: 10.1098/rspa.2015.0855) on stochastic simulation of natural hazards.

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
UK, Italy, US, Canada, Norway, Switzerland

9. **Languages** [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
English (native speaking): good in speaking, reading and writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 2012 To [*Year*]: 2018
Employer: University of Exeter
Positions held: Willis Research Fellow

From [*Year*]: 2011 To [*Year*]: 2012
Employer: University of Sheffield
Positions held: Research Associate

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*] 2.1 Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought 2.2 Development of general framework for basis risk quantification for different types of beneficiaries 3.1 Deployment of the first version of the models as an interactive web application	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: Willis Research Network Year: 2012 - present Location: University of Exeter Client: Willis Towers Watson Main project features: Developing statistical models and software for European windstorm risk Positions held: Willis Research Fellow Activities performed: Statistical research and software development

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

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[Signature of staff member or authorized representative of the staff]

Date: 26/10/2018
Day/Month/Year

1. **Name of Staff** [*Insert full name*]: Luis Tolentino

2. **Proposed Position**
   Environmental and climate expert

3. **Employer**: Fundación REDDOM

4. **Date of Birth**: 22/12/1965 **Nationality**: Dominican

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
University UWI, Jamaica	Natural Resources management and Environment	2000
Universidad Nacional Pedro Henriquez Urena	Agricultural Engineer	1992

6. **Professional Certification or Membership in Professional Associations**

7. **Other Relevant Training**:
   Management of climatic risks and natural disasters; assessment processes and environmental management, Management and Conservation of Natural Resources, Rural Survey and Land use, Environmental Impact Assessment, Cleaner Production (CP), Climate Change; GIS, GPS and remote Sensing Management .

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
   Dominican Republic

9. **Languages** [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
   Spanish: good in speaking, reading, and writing
   English: fair in reading, speaking and writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 1984 To [*Year*]: present
Employer: Fundación REDDOM
Positions held: Environmental and climate change specialist

Employer: GIZ
Positions held: Environmental adviser

Employer: Helvetas

Positions held: Technical Coordinator Project 1993-2000 Helveta / SEA: Inventory and Assessment of Natural Resources in the Dominican Republic.

Employer: Ministry of Agriculture
Positions held: Planning land use specialist

11. Detailed Tasks Assigned	12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned
[*List all tasks to be performed under this assignment*] 1.3 Identification and preliminary contacts with potential local stakeholders 2.4 Co-development and tailoring of the parametric trigger models to the specific context and needs of potential beneficiaries 3.2 Workshop with potential end-users of the parametric trigger models 4.1 Workshop with local and international stakeholders	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*] Name of assignment or project: Climate Resilience and Index Insurance for Small Farmers in the Dominican Republic (USAID *I* REDDOM) Year: 2012-2016 Location: Dominican Republic Client: USAID Main project features: Mitigation and transfer of climatic risks in the agricultural sector Positions held: Technical Director Activities performed: Responsible for the implementation and technical coordination of the Program in the Northwest and South regions of the Dominican Republic with bananas and dairy cattle farmers. The most relevant achievements were: 2,134 farmers increased their livelihood by adopting risk reducing practices/actions; 2020 persons have incorporated weather information as part of their decision making process; 1,615 persons were trained to integrate financial services options into farm-level risk management; first commercial index insurance product for the agricultural sector in the Dominican Republic; a climate information platform -CLIMARED- was established to support decision making for farmers, insurers, government agencies, local authorities, financial organizations, academic institutions, and other stakeholders; and, 2812 persons (652 women and 2,160 men) trained in climate change adaptation supported by USG assistance.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

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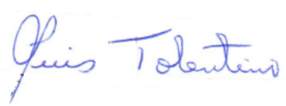

Date: 29/10/2018

[Signature of staff member or authorized representative of the staff]

Day/Month/Year

1. **Name of Staff** [*Insert full name*]: Jeffery Ramón Pérez Maldonado

2. **Proposed Position**
Data Analyst

3. **Employer**: Fundación REDDOM

4. **Date of Birth**: 01/05/1974 **Nationality**: Dominican

5. **Education**

School, college and/or University Attended	Degree/certificate or other specialized education obtained	Date Obtained
Instituto Tecnológico de Santo Domingo (INTEC), Dominican Republic	Master in Business Administration	1997
Pontificia Universidad Católica Madre y Maestra (PUCMM), Santiago, Dominican Republic	Post-graduate studies in Pedagogy	2011
Universitat Politècnica de Catalunya, Spain	Post-graduate studies in Industrial Automation	2001
Instituto Tecnológico de Santo Domingo (INTEC), Dominican Republic	B.S. / Industrial Engineering	1995

6. **Professional Certification or Membership in Professional Associations**:

7. **Other Relevant Training**:
Computer Aided statistical simulation and data analysis, INTEC, Santo Domingo, 1994; Cluster Development Program, ONUDI Methodology, INTEC-CNC, Santo Domingo, 2008; and, Cluster Strategy Development, Monitor Group – INTEC, Santo Domingo, 2000.

8. **Countries of Work Experience**: [*List countries where staff has worked in the last ten years*]:
Dominican Republic

9. **Languages** [*For each language indicate proficiency: good, fair, or poor in speaking, reading, and writing*]:
Spanish: good in speaking, reading, and writing
English: good in reading, speaking and writing

10. **Employment Record** [*Starting with present position, list in reverse order every employment held*]:

From [*Year*]: 2008 To [*Year*]: 2018
Employer: Fundación REDDOM
Positions held: Business Development & Value Chain Specialist / Program Manager

From [*Year*]: 2006 To [*Year*]: 2008
Employer: PROINCUBE, Entrepreneurship and Business Development Project
Positions held: Consultant, Santiago, Dominican Republic

From [*Year*]: 2004 To [*Year*]: 2007
Employer: Wood-Furniture Cluster Coordinator
Positions held: Cluster Coordinator, Santiago, Dominican Republic

From [*Year*]: 2003 To [*Year*]: 2004
Employer: Bojos Manufacturing
Positions held: Operations Manager, Santiago, Dominican Republic

From [*Year*]: 2001 To [*Year*]: 2003
Employer: Unión FENOSA
Positions held: Warehouse Coordinator, Santo Domingo, Dominican Republic

From [*Year*]: 1999 To [*Year*]: 2000
Employer: CAMPE, INTEC
Positions held: Value Chain Productivity Consultant, Santo Domingo, Dominican Republic

From [*Year*]: 1998 To [*Year*]: 1999
Employer: Rattan Dominicano
Positions held: Operations Manager, Santo Domingo, Dominican Republic

From [*Year*]: 1997 To [*Year*]: 1998
Employer: PYENSA, Medical Furniture
Positions held: Operations Manager, Santo Domingo, Dominican Republic

11. Detailed Tasks Assigned	**12. Work Undertaken that Best Illustrates Capability to Handle the Tasks Assigned**
[*List all tasks to be performed under this assignment*]	[*Among the assignments in which the staff has been involved, indicate the following information for those assignments that best illustrate staff capability to handle the tasks listed under point 11.*]
1.3 Identification and preliminary contacts with potential local stakeholders 1.4 Collection of relevant historical disaster loss data and environmental data for parametric trigger modelling 3.2 Workshop with potential end-users of the parametric trigger models 4.1 Workshop with local and international stakeholders	Name of assignment or project: Climate Resiliency and Index Insurance for Small Farmers in the Dominican Republic Year: 2012 - 2017 Location: North and Northwest Regions, Dominican Republic Client: USAID Main project features: Climate resilience measures, drought index insurance, agriculture

	Positions held: Value Chain Specialist and Monitoring Activities performed: Coordinate implementation of project activities in bananas and dairy value chains / Monitor progress on program activities, and targets.

12. Do you currently or have you ever worked for the World Bank Group including any of the following types of appointments: Regular, term, ETC, ETT, STC, STT, JPA, or JPO? If yes, please provide details, including start/end dates of appointment.

No.

Certification

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Date: 29/10/2018

[Signature of staff member or authorized representative of the staff] *Day/Month/Year*

ANNEX 3: WORK SCHEDULE

N°	Activity[1]	Months[2]									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**…**
1	**Start-up activities**										
1.1	Kickoff meeting										
1.2	Preparation and delivery of inception report										
1.3	Identification and preliminary contacts with potential local stakeholders										
1.4	Collection of relevant historical disaster loss data and environmental data for parametric trigger modeling										
2	**Research and Development**										
2.1	Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought										
2.2	Development of general framework for model evaluation and basis risk quantification										
2.3	Preparation and delivery of intermediary report										
2.4	Co-development and tailoring of the parametric trigger models to the specific context and needs of potential beneficiaries										
2.5	Evaluation of user-specific models, and definition of optimal parametric trigger thresholds for basis risk minimization										
3	**Promotion of operationalization**										
3.1	Deployment of the first version of the models as a web application										
3.2	Workshop with potential end-users of the parametric trigger models										
4	**Dissemination**										
4.1	Workshop with potential end-users and other stakeholders										
4.2	Preparation and delivery of final report										
4.3	Delivery of open-source code developed during the project										

N°	Activity[1]	Months[2]								
		10	11	12	13	14	15	16	17	18
1	**Start-up activities**									
1.1	Kickoff meeting									
1.2	Preparation and delivery of inception report									
1.3	Identification and preliminary contacts with potential local stakeholders									
1.4	Collection of relevant historical disaster loss data and environmental data for parametric trigger modeling									
2	**Research and Development**									
2.1	Development and benchmarking of statistical and machine learning models for parametric triggers relative to flood, wind and drought									
2.2	Development of general framework for model evaluation and basis risk quantification									
2.3	Preparation and delivery of intermediary report									
2.4	Co-development and tailoring of the parametric trigger models to the specific context and needs of potential beneficiaries									
2.5	Evaluation of user-specific models, and definition of optimal parametric trigger thresholds for basis risk minimization									
3	**Promotion of operationalization**									
3.1	Deployment of the first version of the models as a web application									
3.2	Workshop with potential end-users of the parametric trigger models									
4	**Dissemination**									
4.1	Workshop with local and international stakeholders									
4.2	Preparation and delivery of final report									
4.3	Delivery of open-source code developed during the project									

1 Indicate all main activities of the assignment, including delivery of reports (e.g.: inception, interim, and final reports), and other benchmarks such as Client approvals, etc.. For phased assignments indicate activities, delivery of reports, and benchmarks separately for each phase.

2 Duration of activities shall be indicated in the form of a bar chart.