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TITLE OF PROPOSED PROJECT **CAREER:Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 427,774	60 months	01/01/18	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES
- ☐ PROPRIETARY & PRIVILEGED INFORMATION
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- ☒ TYPE OF PROPOSAL **Research**
- ☐ HUMAN SUBJECTS Human Subjects Assurance Number ______
- Exemption Subsection ______ or IRB App. Date ______
- ☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **MX**
- ☒ COLLABORATIVE STATUS **Not a collaborative proposal**

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CERTIFICATION PAGE

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By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

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(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

PROJECT SUMMARY

Overview:

This proposal focuses on advancing the breadth and depth of understanding of the hazards associated with pyroclastic density currents (PDCs). The proposed study will focus on developing: (1) a conceptual physical/sedimentological model of PDCs, (2) a consensual validation and benchmarking procedure to correctly assess the performance of numerical models used for PDC hazard assessment, and (3) quantitative skills in geoscience education and increasing awareness of the community about the potential and limits of numerical tools ('model literacy'). This framework will provide critical information about the uncertainties in hazard assessments that depend on these models. The drive for this knowledge stems from the limited success of current hazard assessment studies to capture the real hazard potential of such volcanic flows.

Intellectual Merit:

The aim is to directly enrich the knowledge base by using an iterative process of integrating data, theories and models to enable multidisciplinary research thinking into volcanology research and education. For that, the Spreadsheets across the Curriculum (SSAC) educational model will be integrated into the VHub cyberinfrastructure to: (1) enhance computational literacy in the geosciences by promoting problem-solving using a structured environment, (2) develop, share and disseminate all activities and deliverables related to model validation and benchmarking efforts that will serve as a basis to drive future research on volcanic flow hazard assessment studies. The principal investigator has unique combined experience in the SSAC educational model, development of VHub online tools, as well as application, validation and benchmarking of numerical models, and commitment to advancing hazard science research and education. The broader goals for the proposed work are: (1) bringing multi-disciplinary teams together to discuss the relationship between field studies, computational modeling and hazard assessment; (2) increasing familiarity with and limitations of computational modeling tools to both geoscience students and the broader community; and (3) tailoring the hazard assessment to the needs of the user communities.

Broader Impacts:

This study is designed to advance, and improve the understanding of numerical models of PDCs within the context of hazard assessments. This combined study is application-driven in that it will directly gather information from which a better understanding of the PDC dynamics can be obtained in order to advance the reliability of modeling. The knowledge gained here will impact the fields of research and education across the PDC spectrum, including advanced physics of gravity-driven currents, computational flow modeling and quantitative, problem-solving approaches using a structured environment (SSAC model). The proposed research is timely and can take advantage of a major cyber-infrastructure resource (VHub), which provides a slew of simulation tools in an accessible environment, as well as an organizational and storage structure for data and dissemination of the results. The resulting conceptual physical/sedimentological model of PDCs, as well as results from the model validation and benchmarking exercises, will be made freely available to the broad volcanology community via the Vhub platform, to be further integrated into other volcanic flow hazard assessment studies. Educational modules will be developed on VHub to convey volcanological concepts and quantitative literacy concepts at a variety of levels, including undergraduate geoscience courses. The investigator has experience in applied aspects of volcanology and numerical modeling and has demonstrated commitment to dissemination of their research outputs to the wider community. This study will play an important role in the career development of an early career researcher. The project will also provide full support for one Postdoctoral fellow as well as sustaining and developing the existing robust exchange program between the USA and Mexico in the area of volcanology.

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For font size and page formatting specifications, see PAPPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

CAREER: Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models

1. Rationale:

This CAREER proposal builds upon the recent statements from two major international volcano community-based projects, the Global Volcano Model (GVM) and the National Academies of Sciences (NAS) committee on 'Improving Understanding of Volcanic Eruptions'. In 2012, initial recommendations for GVM regarding hazards models include three main actions to be undertaken: (1) identify and articulate exactly how GVM would use or promote hazards models, including the standards that these models would need to meet; (2) identify how hazard models can, or should/could be, compared, given that each is/was developed to meet different requirements; and (3) initiate community-wide "projects" that result in real products to address numbers 1 and 2 above. For action 1, the GVM group proposed to provide a sort of 'certification' for models that is based upon standardized documentation and transparency, rather than on 'comparison'. More recently, in chapter 2.4, 'A community challenge: modelling volcanic processes', from the 2017 NAS report on 'Volcanic eruptions and their repose, unrest, precursors, and timing' (National Academies of Sciences, Engineering, and Medicine, 2017), the following statement appears: '*A common theme in many of the questions and priorities in this chapter is the importance of developing models to interpret the new generation of high-resolution observations and to enhance understanding of magmatic and volcanic processes. Community-wide model inter-comparison and validation exercises can lead to important advances and also highlight deficiencies that need to be addressed by future research. Equally useful is validating models with controlled laboratory experiments and well-constrained field data sets. Two examples in volcano science include a conduit model comparison study (Sahagian, 2005) and an inter-comparison of plume models (Costa et al., 2016). Such exercises are particularly valuable when combined with suites of data from laboratory experiments, observations of the geologic record, and targeted real-world case studies*.'

The term "hazard model" is used in this proposal to refer to an empirical or theoretical representation of a process that is expressed in mathematical form and solved either analytically or numerically, and that: (1) provides an estimate of the areal extent of a hazardous volcanic process (such as pyroclastic density currents) and the conditions associated with that process (e.g., dynamic pressure, inundation depth); or/and (2) provides an estimate of the probability of a hazardous volcanic process over a defined period of time; or that (3) uses deterministic techniques for interpretation of monitoring signals in order to support forecasting. In practice, most hazard models involve numerical solutions using computer codes.

Volcanic mass flows (i.e., lava flows, debris avalanches, lahars and pyroclastic density currents) have been responsible for most deaths in volcanic eruptions in recent times and they present the most important challenge of all volcanic hazards for disaster planners at volcanoes in densely inhabited regions. Pyroclastic density currents (PDCs) are the least predictable and the most dangerous of all volcanic mass flows. They are highly mobile mixtures of hot volcanic fragments, ash and gas, which can be generated during explosive volcanic activity or by the collapse of growing lava domes. Interest in the hazards associated with the emplacement of these events is justified by both the complex physics they involve and by their dangerous nature. Small-volume (< 0.5 km^3) end-member PDCs are a common volcanic phenomenon at active subduction zone volcanoes. These events, unlike large volume ignimbrite eruptions, are short-lived, characterized by complex, gravity-controlled, multiphase flow dynamics where the deposits generally consist of poorly-sorted mixtures of decimetre to metre-sized, dense to vesicular blocks set within an ash matrix (e.g., Cas and Wright, 1987; Druitt, 1998; Branney and Kokelaar, 2002).

They also occur relatively frequently and recently pose severe threats to surrounding populations and infrastructure at active volcanoes such as Colima (Mexico), Santiaguito (Guatemala), Tungurahua (Ecuador), Unzen (Japan), Soufriere Hills (Montserrat), Sinabung and Merapi (Indonesia).

The main objectives of numerical simulations of explosive volcanic eruptions are the prediction of the impact of future eruptive scenarios on the natural and anthropic environment and the interpretation of the available geological and geophysical information by means of reliable physical models. Prediction of the impacts of PDCs is required for hazard and risk assessment, and for design of risk mitigation measures. The goal of such predictions is to estimate the area that may be affected by the movement of a potential PDC, and to map hazard intensity parameters, such as temperature, dynamic pressure, velocity, depth of flow and thickness of deposits (e.g. Esposti Ongaro et al., 2011; Komorowski et al., 2013). However, our predictive capability is currently limited by: 1) incomplete knowledge of the physical processes taking place during eruptions; 2) insufficient numerical model resolution and difficulty of estimating the related numerical error; 3) large epistemic uncertainty associated to initial and boundary conditions.

This CAREER proposal will integrate, apply and extend many fantastic advances by the international volcanology community that have improved the use of computational models of PDCs for the purpose of hazard mitigation (e.g. Wadge et al., 1998; Takahashi and Tsujimoto, 2000; Dartevelle, 2004; Patra et al., 2005; Esposti Ongaro et al.; 2007; Widiwijayanti et al., 2008; Kelfoun et al., 2005; Doronzo et al., 2011). These studies all suggest that the performance of numerical models in simulating actual events is critically dependent on the choice of key input parameters. *The proposed study will focus on developing: (1) a conceptual physical/sedimentological model of PDCs; and (2) a consensual validation and benchmarking procedure to correctly assess the performance of numerical models used for PDC hazard assessment. This framework will provide critical information about the uncertainties in hazard assessments that depend on these models. The drive for this knowledge stems from the limited success of current hazard assessment studies to capture the real hazard potential of such volcanic flows.*

The general approach is based on an iterative process of integrating data, theories and models. Although this would represent only a first step, this integrated effort will be fundamental, in order to achieve the five following overarching goals:

1) developing a general physical/sedimentological model applicable to all types of PDCs;

2) consensually evaluate the accuracy of numerical models in representing PDC-related phenomena through community-based validation and benchmarking exercises;

3) drive future research on PDC hazard assessment (e.g., 'validation' experiments, field measurements, uncertainty analysis);

4) provide a community-wide interpretation framework for volcanic flow hazard assessment studies;

5) developing quantitative skills in geoscience education and increasing awareness of the community about the potential and limits of numerical tools ('model literacy') and the actual (not only claimed) complementarity of experimental (both laboratory and field based) and numerical studies.

2. Research plan

2.1 Background

The complexity of defining a physical model for PDCs:

Significant advances have been made in understanding the physics of PDCs (see Sulpizio et al., 2014 and Dufek, 2016 for reviews). These currents form a spectrum of flow types ranging from high-particleconcentration flows in which particle-particle interactions dominate clast transport, to dilute flows (also referred to as pyroclastic surges) within which clast transport is governed by a combination of turbulent suspension and bed-load processes (e.g., Valentine and Fisher, 2000; Sulpizio et al., 2014). Thus, it is common to describe PDCs as a continuum phenomenon, in which the concentrations of fluid and solid particles determine the flow range (e.g., Dufek, 2016). It is also often assumed that the correct representation of the various flow types as function of the physical properties of the solid particles can predict some of the characteristics of the observed deposits. Of primary importance in understanding PDC dynamics is the involvement of the granular flow theory (e.g., Campbell, 1990; Iverson and Vallance, 2001; Dartevelle, 2004) in description of the particle–particle dominated (lower) part of PDCs. Since PDCs are density stratified, particle–particle interaction likely plays a role in all except the most dilute PDCs (Branney and Kokelaar, 2002). The granular rheological behavior and coupling with the gas phase turbulence are deeply dependent on volumetric grain concentrations (ε_s) (Figure 1).

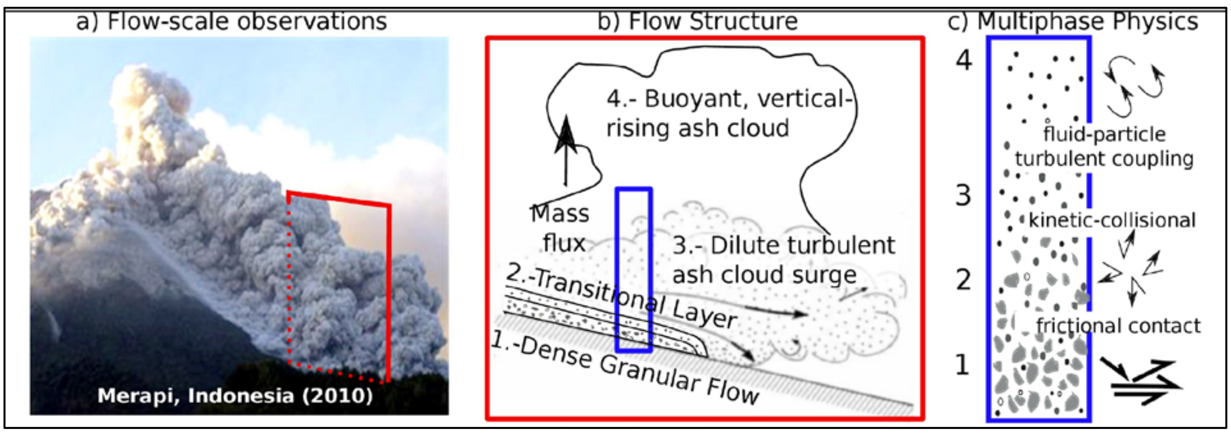

***Fig. 1**. a) Pyroclastic density current (macro-scale). b) Simplified, four-part, flow structure (mesoscale), c) Corresponding particle interactions (micro-scale): 1 frictional with enduring contacts; 2 transitional, kinetic-collisional region; 3 turbulent transient particle contacts, and 4 particle-fluid two-way coupling.*

Based on detailed field observation, sedimentological studies of PDC-related deposits, controlled laboratory experiments and physical models, a general (phenomenological) picture of the fundamental processes controlling the dynamic of PDCs can be built upon the following elements:

- *Fluid dynamics*: The propagation and emplacement of PDCs is a *fluid* process that can be described by the laws of continuum mechanics. In particular, PDCs can be described as high-temperature multiphase flows of gases and suspended solid particles.
- *Buoyancy:* PDCs are driven by their (negative) density contrast with the surrounding atmosphere. Although non-hydrostatic and faster-than-sound phenomena can be relevant in many processes occurring before, during and after PDC emplacement, the project here only focus on gravity-driven currents in subsonic regime.
- *Sedimentation/deposition:* In typical natural regimes, sedimentation (i.e., particle decoupling and settling) leads to stratification of the current and deposition of particles.
- *Flow regime:* In the basal concentrated layer, deposition of particles can be controlled by granular phenomena. Transition from granular to fluidized to collisional and kinetic regimes is one of the key aspects of PDC dynamics.
- *Turbulence:* In the upper layer, fluid turbulence controls the entrainment and heating of atmospheric air. Gas-particle heat exchange is one of the controlling processes.
- *Buoyancy reversal*: Entrainment of air and deposition of particles lower the average density of the current, which eventually reverse its buoyancy and lifts off, stopping its horizontal propagation.

- *Topography*: Interaction with topography can control the dynamics of PDC in different ways: hydraulic effects (associated to changes in slope, current height and width), stratified flow effects (blocking and modification of the vertical flow profile) and flow diversion and decoupling (through overbank/avulsion and surge detachment).

Key challenges in numerical modeling for PDC hazard assessment:

In principle, the conceptual model described above can be formulated in a mathematical way by means of the laws of fluid mechanics. In practice, some of the above processes are poorly known and the model qualification itself can be difficult. For example, the fluid theory for granular mixtures described above is still matter for fundamental research and still has theoretical and experimentally open problems (e.g., Roche et al., 2013). At the scale of particle-particle interaction, which is relevant for granular regimes of concentrated PDCs, the continuum mechanics is particularly complex. Understanding the transition from granular to fluidized regime is one of the main challenges of the study of PDCs.

- *Problems related to model reduction and numerical resolution*: To solve the system of coupled partial differential equations describing the dynamics of PDCs, computer models are usually needed, which involve some kind of discretization of the equations (usually by means of the subdivision of the spatial and temporal domain into discrete elements) or reduction of model dimensionality by assuming some symmetry or scaling relationships. However, fluid dynamics equations are nonlinear and eruptive processes usually display interaction over a broad range of spatial and temporal scales. Since it is presently not possible to solve the equations at all relevant scales, so called sub-grid scale (SGS) models are usually adopted. SGS models are semi-empirical (i.e., they usually are 'physically sound') models that are not only related to the physical process under investigation (i.e., to its scaling properties) but also to the discrete representation of the model. Their formulation and validation is a key step of the analysis process. Examples of SGS models are: entrainment and diffusion, clustering of particles, aggregation and secondary fragmentation, erosion, interaction with the substrate, gas phase transitions, depositional processes (including particle sorting), gas-particle heat exchange, gas-particle drag.

- *Uncertainty and the problem of verification and validation*: Lack of theoretical knowledge, incompleteness of experimental data and lack of resolution of numerical simulations make model related uncertainty difficult to quantify (e.g., Dartevelle, 2007). Verification, validation and benchmarking is thus a major issue for geoscientific models and involves the concept itself of scientific method. In this proposal, the term verification refers to checking that a code is solving its equations correctly (doing the math correctly); validation means checking that a model accurately (within some defined acceptable range) represents the physical system that it is intended to capture (usually by comparison with experiments or very well constrained eruptions); benchmarking means comparison of the outputs of different models that are intended to represent the same physical process (Oreskes et al., 1994). Validation is in this framework a continuous process, in which empirical evidences (including in-situ tests and laboratory analogue experiments) are systematically compared with model results. The greater the number and diversity of confirming observations, the *more probable* will be that the conceptualization embodied in the model is not flawed. A benchmark is a problem conceived and designed in order to evaluate the performance of a model. In the present context, the quality and reliability of PDC hazard model results can be assessed by measuring: (1) the congruence with some experimental data (either from the field or laboratory); and (2) the "relative" performance of different PDC models. For (1), repeatability, control of experimental conditions and quality of measurements are key issues. For (2), model approximation, asymptotic regimes, numerical resolution effects, error propagation are often difficult to evaluate. Therefore, a key goal will be to integrate well-constrained field-based and experimental data in such process to correctly assess the ‘empirical adequacy’ of the different numerical models (Oreskes et al., 1994).

2.2 General approach

In a broad perspective, the research concepts proposed are based on the successive integration of data, theory and models through an iterative process (Figure 2).

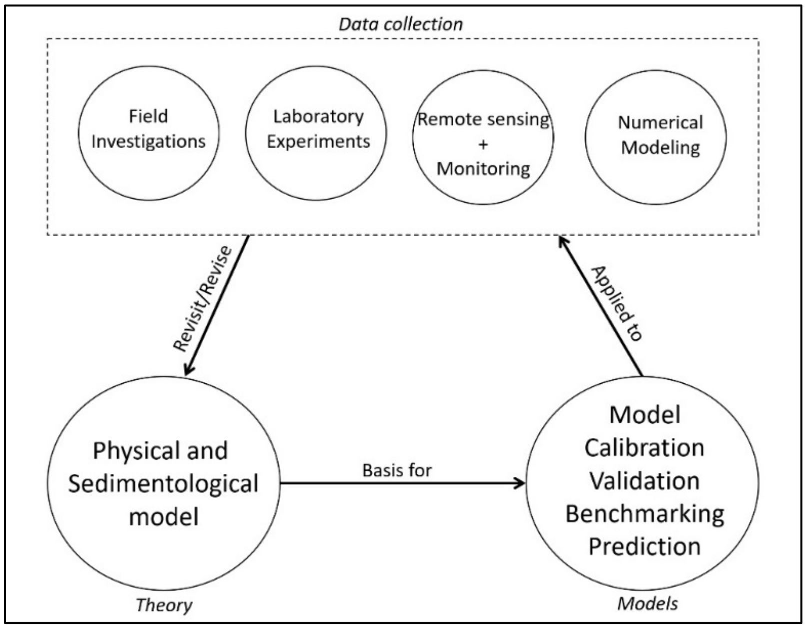

***Fig. 2**: Iterative process of connecting data-theory-models used in this proposal*

In this process, the data collection (through field investigations, laboratory experiments, remote sensing, monitoring and numerical modeling) allow us to revisit and revise scientific theories and principles (a.k.a. a general physical/sedimentological PDC model, research task 1), which then serve as a basis for computational and experimental models (through calibration, validation, benchmarking and prediction, research task 2) that can then be applied to the collected data to improve hazard assessment studies (research task 3).

This process enables the integration of multidisciplinary research thinking into volcanology research and applications. This approach constitutes the core of my early research career: during my PhD research, I successfully applied this method by first by collecting a complete dataset on the June 2006 block-and-ash flow deposits of Merapi Volcano, which allowed me to develop a conceptual model for flow transport and deposition of such pyroclastic flows (Charbonnier and Gertisser, 2008; 2011). This dataset has been integrated into the first numerical simulations of these flows at Merapi using some geophysical mass flow models (Titan2D, VolcFlow, DAN3D). Model evaluations and results obtained provide an invaluable tool for guiding hazard assessment of block-and-ash flows during future eruptive crises at Merapi (Charbonnier and Gertisser, 2009; 2012). In addition, two NSF RAPID grants funded in 2010 and 2015 allowed me to further focus my efforts on the integration of volcanic flow models, field-based dataset and remote sensing tools for the purpose of volcanic hazard and risk assessment (Charbonnier et al., 2013; 2015; Kubanek et al., 2015). Figure 3 shows the work flow built upon the iterative process presented above and the previous work achieved by the PI so far, showing the structure and schedule of the research tasks proposed in this project:

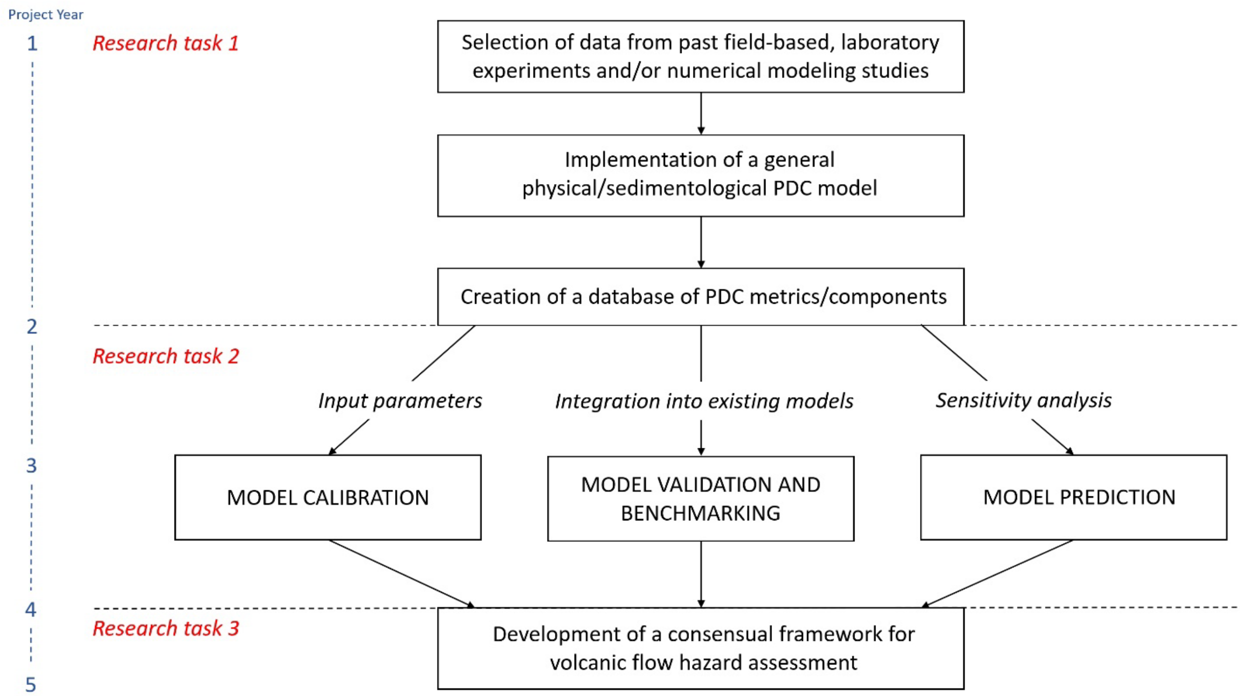

Fig. 3: *Workflow showing the structure and schedule of the proposed research tasks*

2.3 Proposed research activities

Based on the five overarching goals stated at the end of section 1, the following three research tasks have been identified as important and likely to lead to major advances in our understanding of PDC hazard assessment:

- Research task 1: Developing a general physical/sedimentological model of PDCs

To complete this task, the first step will consist of a rigorous selection and compilation of published data from past field-based, laboratory experiments and/or numerical modelling studies including: initial and boundary conditions (including initial coordinates, dimensions, volumes and duration of each collapsing source), overall particle volumetric fraction and grain size/density distribution, runout path and inundation area of both concentrated and dilute components of the PDC, averaged temperatures and dynamic pressures along flow path, flow (pulse) duration, areal distribution of different material covers along the runout path, damage gradient with distance. Examples of sites where such well-constrained dataset are available include: Merapi, Unzen, Colima, Tungurahua, Soufriere Hills, Mount St. Helens. This compilation of data will constitute the basis for developing a new database of key PDC metrics and components (see list from section 2.1) that could be integrated into the existing global volcanic mass flow database 'FlowDat' (Ogburn, 2014). Then, a new conceptual PDC model will be developed by extracting and gathering from the database the specific values of each of these key metrics/components in order to better characterize and quantify the main physical and sedimentological processes controlling the internal dynamics of the full spectrum (highly-concentrated to dilute) of PDCs. This constitutes one of the most challenging task of the project and will require inputs from the broader PDC community and various experts who recently published major efforts related to field-based, laboratory and numerical modeling studies of both dilute and concentrated PDCs (see Sulpizio et al., 2014 and Dufek, 2016 for reviews).

The main outcome of this research task is to define ranges of values to be used for each of the parameters and physical properties listed above, which are adjustable to the full spectrum of flow types ranging from highly-concentrated to dilute flows. This conceptual model will then serve as a basis for calibrating the key input parameters for a broad range of existing numerical modeling approaches currently used to simulate PDC-related phenomena like PDAC (Esposti-Ongaro et al., 2007), GMFIX (Dartevelle, 2007; Doronzo et al., 2011), Titan2D (Patra et al., 2005) and VolcFlow (Kelfoun et al., 2009) in order to set up the model validation and benchmarking efforts proposed in research task 2. For example, numerical simulations using a three-dimensional multiphase Eulerian-Eulerian approach (Esposti-Ongaro et al., 2007) detect strong flow sedimentation associated with channelization and transport of the simulated PDC over deep valleys. That sedimentation feeds a thick flow boundary zone (i.e., Branney and Kokelaar, 2002; Sulpizio and Dellino 2008), which can move independently in those valleys, as seen from simulations performed by the PI using single phase, depth-averaged geophysical mass flow models (Charbonnier and Gertisser, 2009; 2012). The connection between these two modeling results could be the high sedimentation rate also detected in valleys from simulations performed using a two-dimensional multiphase Eulerian-Lagrangian approach for dilute PDCs (Valentine et al., 2011; Doronzo et al., 2017). This example shows one method that could be used to reach a general physical/sedimentological model of PDCs using results from three well-constrained field case studies of PDC-forming eruptions (Mount St. Helens 1980, Merapi 2006 and La Fossa di Vulcano 2,100 years B.P.) and three different numerical approaches (Eulerian-Eulerian vs. single phase depth-averaged vs. Eulerian-Lagrangian). This will constitute the major research task of the proposal in Years 1 and 2.

- Research task 2: Consensually evaluate the accuracy of numerical models in representing PDC-related phenomena

Once the conceptual PDC model is implemented, the core research task during project years 2 to 4 will focus on developing a consensual validation and benchmarking procedure and framework for PDC hazard models. The general approach taken will follow the methodology put forward by Oberkampf and Trucano (2002) for the validation of Computational Fluid Dynamics (CFD) codes designed to simulate complex industrial and technological systems. The approach is based on a hierarchical process of comparing numerical models with experiments and observations (Figure 4). Since there are differences in the use of CFD models in volcanology and in industrial processes, the procedure can be applied rigorously up to the 'benchmark cases', which constitute the main objective of this research task.

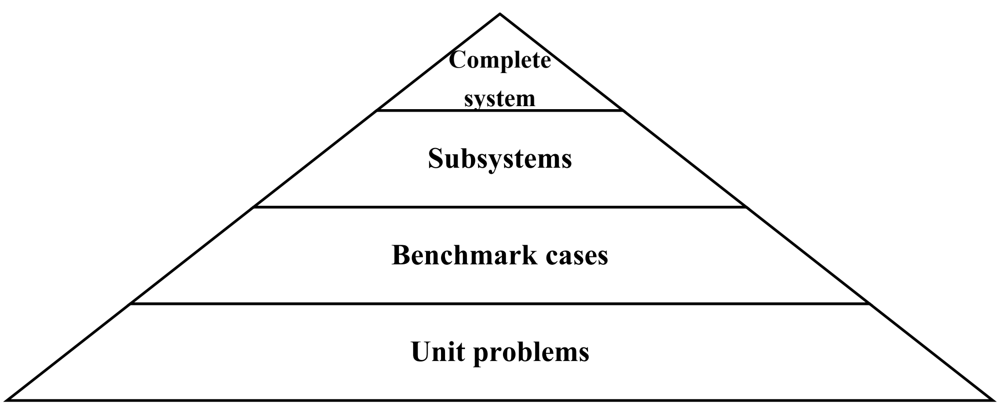

***Fig. 4**: Hierarchy of validation Tiers (modified from by Oberkampf and Trucano, 2002).*

- *Tier 3. Unit problems:* Unit problems are well-understood processes (well constrained where accuracy can be determined and experimental data supported by a theoretical framework). Unit problems may be in some cases difficult to solve numerically, but quality of the results can always be assessed. These problems should be preliminary envisaged because they can pose some unexpected difficulties to the modeler, such as those related to the accuracy and stability of the solutions (which may be important in the description of discontinuous solutions and non-linear instabilities), to the dimensionality (the assumed invariances as symmetries to decrease the number of spatial dimensions and non-steady state regimes) and to subgrid modeling (e.g., for turbulence). Calibration of some semi-empirical parameters could be needed at this stage (and should always be explicitly specified). Examples include kinematics of a homogeneous gravity current over a flat surface, settling of particles in a still fluid, stable and steady-state granular flows, etc.

- *Tier 2. Benchmark cases:* In this context, a benchmark case is a "standard problem" similar to the unit problem but with some degree of complexity added, mainly concerning geometrical and scaling complications. In general, it may be possible to design appropriate laboratory experiments to have an experimental confirmation of benchmark cases. However, they usually need special hardware (e.g., high-temperature facilities) and scaling might be a serious issue, except in some extent in the case of 'large-scale' experiments. Also, in this case, a measure of accuracy, or error, is expected to be available and should be explicitly reported. In cases where experimental data are not (yet) available, the benchmark is focused on defining the differences/similarities of the numerical models (possibly providing a metrics for a quantitative comparison). Table 1 provides a schematic framework for comparing models with different dimensionality in the context of PDC hazard assessment studies. Reduction of the number of dimensions from multidimensional models can always be achieved by integration/averaging along specific direction or over time. Examples relevant to PDCs include stratified flows with buoyancy reversal, interaction of PDCs with slope and obstacles, structure of large-eddy and turbulent mixing in dilute PDCs, depositional structures, etc.

Table 1. *Physical processes in PDC propagation and minimum dimensionality required to model them (* indicates parameters relevant for PDC hazard assessment).*

Key phenomena	Dimensionality
Energy/mass balance, front kinematics, runout*	0D + Time (integral or kinematic models)
Slope, radial distribution* of flow variables, buoyancy reversal*	1D (depth-averaged models)
Waves and perturbations, front dynamics, unsteady source	1D + Time (transient, depth-averaged models)
Sedimentation, stratification, flow decoupling*, obstacles*	2D + Time (Cartesian or Cylindrical symmetry)
Turbulence, topographic effects*	3D + Time

- *Tier 1. Subsystem*: Subsystems usually exhibit complex physics and multiscale (up to the full system scale) properties. Boundary conditions are usually related to other coupled subsystems. However, the degree of coupling is usually limited so that the subsystem can be analyzed individually. There are usually limited observational and test data and the definition of a validation metric representing uncertainty is problematic. Examples relevant for PDCs include: individual PDC units/events in a composite sequence, multiscale PDC dynamics (e.g., interaction between the small-scale depositional structures and large-scale dynamics), flow transformation in response to the interaction with the topography.

- *Tier 0. Complex system*: The complete system (i.e., a PDC-forming explosive event) is characterized by the coexistence, possibly at different temporal and spatial scales, of several 'unit problems' and different interacting subsystems, possibly related to different spatial domains. Some of the subsystems might be unknown or not directly observable. The combination of such processes make the phenomenon 'complex' and requires validation steps at higher level. Real-case applications include any full eruptive sequence characterized by a space-time evolution and interaction between different subsystems: magma chamber, volcanic conduit and edifice, eruption plume, surface pyroclastic (and lava) flows, atmosphere.

A first step was taken in 2013 during a IAVCEI workshop on 'benchmarking volcanic hazard models' at IAVCEI 2013 Scientific Assembly in Kagoshima (Japan) organized by the PI and collaborators that set up the basis and milestones for a community-based benchmarking effort on PDC hazard models. Building on that initial effort, as well as outcomes from research task 1, Years 2-4 of the proposal will be dedicated to the setup and organization of benchmarking exercises for about 20 invited experts (both model developers and users) from different countries to share their expertise and knowledge in calibration and validation of numerical models of PDC hazards. It is expected that outcomes of this collaborative effort will lead to important advances in the field of PDC hazard assessment and also highlight deficiencies that need to be addressed by future research. The main outcomes of the benchmarking cases should be based on a collective effort to identify a clear question that can be formulated in a mathematical language and answered by any model. For example:

For <*initial value of the scaling parameters*>, representing a selected PDC scenario:

1) what is the decay rate of the average <*hazard variable*> as a function of distance?
2) what is the dependency of model predictions on <*initial parameters*>?

If this was the case, for example, the *energy-line* model would predict a linear decay of dynamic pressure and constant temperature as a function of distance, and a uniform dependency of model results on the initial parameter (cone angle). Other models (1D 'box models', 2D, 3D flow models) can be compared on the same basis. All activities and deliverables related to the model calibration, validation, benchmarking and prediction efforts will be disseminated and made publicly available on the existing Vhub.org online group created by the PI in 2013 'Benchmarking of volcanic mass flow models' (https://vhub.org/groups/benchmarking_models).

- Research task 3: Provide an interpretation framework to drive future research on volcanic flow hazard assessment studies

One of the main goal of the newly IAVCEI commission on 'Volcanic Hazards and Risks' is to '*advance the breadth and depth of understanding of methodologies and procedures currently available for undertaking rigorous hazard assessments and formats of those assessments*'. For that, the following tasks was recently identified by the commission as of primary importance: (1) bringing multi-disciplinary teams together to discuss the relationship between field studies, computational modeling and hazard assessment; (2) increasing familiarity with and limitations of computational modeling tools; and (3) tailoring the hazard assessment to the needs of the user communities. The general approach will follow the steps taken during a workshop co-sponsored by the USGS-USAID VDAP team, CVGHM Indonesia, SATREPS Japan, and the Hazard Mapping Working Group of the IAVCEI Commission of Volcanic Hazard and Risk in September 2016 in Garut (Indonesia) during which the PI actively participated.

Deliverables from research tasks 1 and 2 will serve as a basis for establishing an interpretation framework and defining the 'best practices' to conduct rigorous volcanic flow hazard assessments. Following the approach taken by the IAVCEI commission on 'Volcanic Hazards and Risks', three main activities will be put into place: (1) cross-validation and peer-review of the results obtained from research tasks 1 and 2 by the volcanology community using the VHub cyberinfrastructure as well as standard scientific peer-review process; (2) organization of a workshop regrouping experts in hazard assessment of volcanic mass flows in order to combine lecture, field discussion and interactive group sessions on relevant topics related to the integration of such community-based modeling efforts into hazard assessment studies; (3) creation of 'best practices' and 'terms of references' documents about volcanic mass flow hazard assessment and integration into the general IAVCEI guidelines for volcanic hazard and risk assessments. Outcomes of this workshop will provide the basis for establishing an interpretation framework and defining the 'best practices' to conduct rigorous volcanic flow hazard assessments. Basic structure of such guidelines for PDC hazard assessment could be: (1) Data collection (field-based, laboratory experiments, remote sensing and monitoring, numerical modeling); (2) Conceptual physical/sedimentological model of PDCs (including range of values of key metrics, physical properties and scaling parameters); (3) Calibration, validation, benchmarking and prediction of PDC hazard models; and (4) Applications for PDC hazard assessment.

3. Education plan

3.1. Background

Natural hazards, climate change and global warming, ever-dwindling natural resources and energy – these issues are, now more than ever, at the center of attention in the public domain. Educational and research institutions like Schools of Geosciences find themselves uniquely positioned to equip our future scientists with the tools they will need to meet these challenges. These changes reflect the increasing need for a global and interdisciplinary education of the field, and our School of Geosciences at the University of South Florida is responding to this opportunity. The extent to which the geoscience community can understand the nature of volcanic processes that could threaten a given area and then provide robust hazard assessments, lays the foundation on which any successful, long-term, effort to mitigate volcanic hazards is based. Limitations on how successfully this is achieved currently arise as a result of a number of challenges including our developing, but still incomplete, understanding of the complex volcanic processes involved, and how they vary rapidly over time and space. It also depends on our very limited ability to accurately forecast eruptions and the absence of reliable mechanisms in place to communicate information about potential hazards as well as any hazards already occurring.

Modern geoscience research relies on numerical models to act as surrogates for direct observations of geologic processes and to forecast future events. In numerical models, fundamental assumptions are made about complex systems in order to describe them in mathematical terms. Ultimately, hazard models provide people around the world with a basis for defining and describing catastrophic events. Model results are used to direct public policy, guide land use practices, plan mitigation measures, and delineate evacuation zones in areas of high risk. Ultimately, these and other applications require input from community members, government officials, and judiciary bodies, necessitating a basic level of model literacy within the general population.

Given the high stakes, it is essential to understand the uses, strengths, and weaknesses of these quantitative tools. Just as an understanding of the scientific method falls within the realm of quantitative literacy (Miller, 2004), so too does the ability to use and interpret the results of numerical models ("model literacy"). Code verification, code validation, the use and understanding of simplifying assumptions (model parsimony), model uncertainty and forecasting, all must be addressed if individuals are to become numerate with regard to the role of quantitative models in society. Scrutinizing these issues in a classroom setting prepares students for future encounters with numerical models while at the same time exposing them to a wealth of traditional quantitative literacy concepts such as unit conversion, data interpretation, magnitudes and probabilities.

The VHub cyberinfrastructure

Access to numerical models is an important first step toward developing model literacy. VHub.org, a cyberinfrastructure project focused on volcanological modeling and education, provides one means by which students may achieve success (Palma et al., 2014). The term 'cyberinfrastructure' refers to a coordinated research environment designed to support progress in science and engineering by integrating advanced computing and information processing services available via the Internet (NSF Cyberinfrastructure Council, 2007). The VHub.org project aims to promote the generation and advancement of volcanological theories, education, and risk assessment by providing an environment both technologically and sociologically capable of connecting data, computers, and people. To that end, the VHub.org website (www.vhub.org) hosts a collection of numerical models that execute on the hub's servers. This structure negates the need for code installation on a personal computer and enhances the availability of modeling tools for the general public (Palma et al., 2014). Our experience suggests that this cyberinfrastructure can be used to teach students the importance of model verification and validation, to highlight the types of questions that can and cannot be asked of models, and additionally to explore the concept of forecasts in natural hazard assessments (e.g., Courtland et al., 2012; Palma et al., 2014).

One past successful application of the Vhub cyberinfrastructure arises as a direct result of a PASI workshop funded by the U.S. National Science Foundation entitled '*Applying Computational Models to Real-Case Scenarios for Volcanic Hazard Assessment*', which was held at the University of Colima in Mexico, January 8-21, 2013. The workshop attempted to address a current challenge in our discipline: putting cutting edge research into practice at the 'front line', the interface between volcanology and society. Outstanding issues related to volcanic hazards, their associated risks and communication of these risks can best be answered by the application of a diverse range of tools and accomplished by utilizing the combined expertise of diverse teams with a range of technical backgrounds and skills. The participants used the VHub platform and its resources to select available modeling tools, analyze hazards and use the group communication tools that allow online assessment, analysis, collaboration and recommendation. I was the main instructor leading the PDC exercise. Fieldwork activities carried out prior to the hands-on sessions were crucial for these participants, who could learn how to recognize the type of PDC deposit and its origin, as well as how to describe the deposit and discuss the characteristics of the hazard that created the deposit. This field approach of PDC dynamics and hazards served as a basis to communicate the main assumptions and physical basis that exist behind the computational models used to simulate PDCs during the hands-on sessions. These aspects constitute the main learning outcomes and knowledge transfer mechanisms initially developed by Dixon (2000) that was achieved during the PDC exercise and summarized below:

(1) participants abilities to run multiple simulations with the Energy Cone model using different set of input parameters for different types of PDCs served as a near transfer knowledge: explicit knowledge a group has gained from doing a frequent and repeated task is reused by other groups doing similar work;

(2) cross comparisons of the Titan2D modeling results between the different groups allowed each participant to gain some experience about the model sensitivity to some input parameters, which then enable them to better understand the governing equations and crucial parameters that control flow transport and emplacement mechanisms. This knowledge transfer can be defined as a strategic transfer: the collective knowledge gained by the different groups was needed to accomplish a strategic task that is critical to all participants;

(3) the participant's ability to discuss and understand the main assumptions and uncertainties inherent to each numerical code can be defined as a serial transfer knowledge. That is, the knowledge gained by the participants from doing this exercise will be transfer the next time they will do a similar PDC exercise for a different volcano elsewhere.

The Spreadsheets across the Curriculum (SSAC) educational modules

One of the primary goal for the summits on 'Future of Undergraduate Geoscience Education' sponsored by NSF is to '*engage undergraduate geoscience students in visualization and geospatial tools, generation and use of massive amounts of quantitative information (big data), and computational modeling and simulation for both predictive capabilities and insight into processes and global-scale events*'. This thinking was amidst a backdrop in which many in the geoscience education community were working to create an environment through faculty development workshops and educational resources development to enhance quantitative skills of geoscience majors (see Hancock and Manduca 2005; Wenner et al. 2009). In this sense, the Spreadsheets across the Curriculum (SSAC) model has become extremely successful in geoscience education because it promotes problem-solving using a structured environment, i.e. concise PowerPoint presentations guiding students through the creation of spreadsheets to solve specific problems (Vacher and Lardner, 2010). SSAC modules are short (ca. 15−20 slides) PowerPoint presentations that prompt students to build one or more Excel spreadsheets to solve and examine a mathematical problem in non-mathematical context. The modules are intended to be problem-solving activities. In working through the modules, students work through the disciplinary problem of the context as well as the mathematics embedded in it. For example, the 'Spreadsheets Across the Curriculum: The Physical Volcanology Collection' module package can be found among the VHub.org educational resources. Nine of these modules have been previously developed in volcanology at USF using the SSAC approach (Connor, 2011) and they have been used in undergraduate and graduate courses at more than 15 universities worldwide. Each volcanology module takes an algorithmic approach to problem solving. Students work through the introduction of a problem and its volcanological context, an outline of how to solve the problem quantitatively, and development of a plan for implementing the solution. Using this plan, the students evaluate their results (verify their solution) and solve a series of problems of increasing complexity by first using their spreadsheet and then modifying it to extend its usefulness to additional problems. The SSAC approach can easily be modified for the VHub environment and for development of geocomputational problem solving skills. Our basic approach is encapsulated by these concepts, adapted from the SSAC concept and problem-solving methods: every time a geoscience student (at whatever level) uses a numerical model, it is an opportunity for that student to become more computationally literate. VHub presents students with a wide range of numerical models for volcanology and provides the resources to use them. It is an ideal resource to enhance computational literacy in the geosciences. Students become more computationally literate in the geosciences when they solve computational problems that engage them. VHub makes it possible to present accessible and engaging problems.

3.2. Objectives and proposed activities

As part of the overarching CAREER goal of integrating research and education, and based on previous experience using the two complementary tools described above (VHub and the SSAC modules), the following specific objectives will be pursued during this CAREER proposal.

Educational task 1: Developing a web-based quantitative course about 'Modeling Volcanic Processes'

In 2014, I developed a new graduate class about 'Modeling of Volcanic Processes' open to all geosciences graduate students at USF. This graduate class is built around the Vhub cyberinfrastructure and SSAC educational modules described in the previous sections. The course first introduces basic and fundamental concepts of computational modeling of volcanic processes (in a geophysical, geochemical and natural hazard perspective) through a combination of interactive lectures and hands-on sessions involving the use of Vhub computer-based exercises and SSAC modules. It then focuses on the development of individual research projects through the introduction of a problem and its context from a physical, mathematical, and computational point of view, an outline of how to solve the problem quantitatively, and development of a plan for implementing the solution. Even if mainly driven by the diversity of volcanic processes, this course explores concepts not just of volcanology, geophysics, geochemistry and natural hazards, but of numerical modeling, statistics, quantitative approaches and data visualization. This broader impact is accomplished by developing teaching resources that attract and help students using real models to consider real problems at a variety of levels, and promote critical thinking about models, including concepts of computer simulation, verification and validation, topics which are not sufficiently covered in the Earth Sciences generally. Given the positive comments received from students enrolled in the class so far, I am convinced that this graduate class is a unique, one of a kind opportunity given to current graduate students in Geosciences at USF and will for sure be a crucial tool to attract, seek and motivate future graduate students who are currently thinking to apply for graduate research in geosciences at USF. In order to reach students outside USF, a web-based version of this class will be developed in project year 1 and 2, by following the standard USF procedure, where all course materials (including online interactive lectures, hands-on-session and training module tutorials) will be available to out-of-state students through Vhub and the Canvas e-Education system at USF, so that course-specific assignments can be fully accessed by all registered students. During the course of the project, this web-based course will benefit from new deliverables obtained from research task 1 and 2 to refine the hands-on session materials involving the use of SSAC modules and Vhub computer-based exercises about PDCs.

Educational task 2: Promoting computational literacy using the VHub cyberinfrastructure

VHub is already a tremendous resource for leveraging cyberinfrastructure to execute numerical codes for simulation of some of these processes. Over the last seven years of working with VHub, it became clear that a major strength of this cyberinfrastructure lies in exposing students with varied academic experiences to these resources. Learning about processes using cyberinfrastructure gets students excited about volcanology. More importantly, VHub provides a platform for training students about issues in model calibration (process of manipulating the independent variables (and parameters) to obtain a match between the observed and simulated distribution of dependent variables) and validation (does the code really simulate the natural process as intended?). These concepts can be applied throughout their careers in industry, government or academia, where critical assessment of the applicability of a variety of models and modeling techniques is essential (Courtland et al., 2012). In this project, VHub will be used to increase computational literacy among geoscience students and to ease students and other learners through the process of developing research skills: from running code and manipulating outputs, considering model calibration, validation and verification, through to modifying code and contributing new code to the research community. This training is essential, not only for the students but to increase the flexibility and long-term sustainability of cyberinfrastructure and software used in geosciences, as in other disciplines (Kurkovsky, 2006; Feather et al., 2011).

During the course of this CAREER project, a set of 10 Vhub educational modules will be developed based on the hierarchical approach of model validation described in research task 2 and the use of existing PDC hazard models. Following the SSAC design, this moves the problem from a general question to a highly specific problem, and guides the learner through design and implementation. To do this, background on the volcanology of the problem will be provided, invoking specific examples (the PDC hazards at Merapi volcano). By using specific examples, the significance of solving the volcanological problem with computational methods (code) becomes clear. An important feature of the modules is that users have the resources to evaluate whether the output is reasonable or not. Like the SSAC modules, each module will have a listing of inputs and outputs for an example problem to allow users to calibrate and validate the existing PDC code. Each module will introduce concepts in web-based visualization of outputs, which for many of these PDC codes is copious and complex, using widely available tools for this visualization like HTML5, Processing.js, D3, and Unity. The modules will then each involve additional problems which expand on execution of the codes – involving modifying input and assessing the outputs of the codes for a range of PDC problems identified in research task 1 and 2 of this project. In a practical sense, there will be other fundamental differences with the SSAC modules that were originally developed. Instead of Powerpoint, the VHub wiki feature will be used to introduce problems. The interesting thing about using the wiki feature is that it will allow for users to engage in module development, multiplying the potential impact. Currently many VHub users are graduate students. Some users are undergraduates who use VHub to work on specific assignments. These educational modules will be designed to serve both groups. For example, one of the current SSAC modules illustrating the basic problem of determining the volume of a debris flow was divided into two separate modules that pose this problem in different ways for undergraduate and graduate students. VHub wikis will allow for even more flexibility. These modules will be used in undergraduate labs and graduate courses, like the one proposed in Educational task 1, while the broader community will use these modules in the same way. Commonality will be the framework: each module will take users through problem identification, design and planning to solve the problem, implementation of the solution, calibration of the scaling parameters and validation, to the extent practical, of the results of the existing code.

Educational task 3: Developing a student exchange program about volcanic hazard assessment

Based on the success of the NSF funded 100,000 Strong Americas Innovation Grant 'Evaluation of volcanic hazards: merging laboratory and field-based learning' in 2014-15, the overreaching goal of this task will be to sustain and develop the existing robust exchange program between the USA and Mexico in the area of volcanology, which will guarantee the mobility of students during the project's duration, with an expansion in numbers and the establishment of a Memorandum of Understanding (MoU) over the first year of the project. In 2015, two undergraduates from USF participated in a field campaign to Colima volcano while four undergraduates from Colima successfully completed one-month research projects in volcanology at USF. The project will develop an innovative scheme to obtain course credits (including a tuition equivalence system in which fees will be paid at the university of origin only) for Earth Scientists with an interest in volcanic hazard management. Students in the US lack the opportunity to experience at first-hand scenarios at an active or even erupting volcano. This will be offered during their visits to the partnered university in Universidad de Colima. On-the-other-hand, there is a deficit of facilities and experience in Mexico to allow students to model the variety of geological, particularly volcanic hazards using state-of-the-art computer-based tools via the Vhub educational modules developed in Educational Task 2. This project will open up the opportunities for mobility between the USA and Mexico by financing students from both countries in years 1 to 4 to participate in semester long study periods, short-courses, workshops and/or internships related to the research tasks described in this CAREER proposal. In addition to internship reports, co-publication of research papers and conference abstracts as well as joint future NSF grant proposals, participation of USF as partner in the development of Master's program in hazard and risk management at Universidad de Colima should commence within the next two years, further enhancing possibilities for US students, as well as provide more advanced students to visit the US.

4. Work plan & personnel

Dr. Sylvain Charbonnier (PI) is currently a Tenure-Track Assistant Professor (since August 2014) at the University of South Florida working on numerical modeling and hazard assessment of dense volcanic flows. He is an author of 18 publications on both field-based and modeling of PDCs and is currently leading initiatives focused on validation and benchmarking of numerical models of volcanic hazards (https://vhub.org/groups/benchmarking_models), recently organizing two dedicated conference session (IUGG General Assembly, 2015; Cities on Volcanoes 8, 2016) and one workshop (IAVCEI 2013), as well as new international initiatives as a member of the development team of the Vhub cyberinfrastructure for modeling volcanic hazards (http://vhub.org/). Charbonnier will be the principal active investigator, and his role will be to: (a) oversee all the project activities and ensure the project goals are met, and (b) take responsibility for all reporting activities. He will also (a) coordinate the proposed research and educational activities, (b) take responsibility for leading the publications on the physical/sedimentological PDC model and model validation/benchmarking activities, and (c) he will also mentor the Postdoctoral fellow and co-advise the undergraduate students from USF and Colima.

Support is requested for 1 Postdoctoral student (2 years in year 1 and 2). The Postdoctoral fellow will take responsibility for undertaking all parts of the research activities in year 1 and 2 (implementation of the physical/sedimentological PDC model, creation of a database of PDC metrics/components and initial set up of the model validation/benchmarking exercises) and will participate to major international conferences (see Budget Justification). Undergraduate support is thought for: (1) 2 USF students to help the Postdoctoral fellow to perform parts of the research activities (selection and organization of data from past field-based, experimental and numerical modeling studies) in year 1 and 2; and (2) both USF and Universidad de Colima (Mexico) students in years 1 to 4 to sustain the exchange program started between these two universities in 2015. Close collaboration with Dr Nick Varley from Universidad de Colima (see attached letter) and the geophysical mass flow group at SUNY Buffalo (Pr Greg Valentine, see attached letter) has already been secured through previous funded NSF collaborative projects. This collaboration will be extended to (1) create a MoU between USF and Universidad de Colima; (2) maintain a portion of the Vhub admin/server costs that SUNY Buffalo is currently paying to Purdue University and (3) implement the new Vhub educational modules.

5. Results from Prior NSF Funding

1. NSF RAPID #1114852 (*Charbonnier, co-PI, $22,801, 03/2011-02/2012).* 'Collection of a high-resolution spatial and ground-based dataset from the 2010 explosive events at Merapi Volcano, Java, Indonesia'. *Intellectual Merit:* This project investigated the deposits and dynamics of the large-volume, widespread explosive PDCs from the Merapi 2010 eruption using field-based methods and multi-temporal dataset of high-resolution satellite imagery. The internal architecture and facies variations of the 2010 PDC deposits were investigated using data collected from 30 stratigraphic sections measured after one rainy season. *Broader Impacts*: The results show that complex, local-scale variations in flow dynamics and deposit architectures are apparent and control the propagation of the main flows and their potential hazards for overbanking. *Resulting publications:* 2 papers (Charbonnier et al., 2013; Komorowski et al., 2013) have been published.
2. NSF RAPID #1546924 (*Charbonnier, co-PI, $49,427, 06/2015-05/2016*) 'Collaborative Research: RAPID: Nevado del Ruiz Volcano, Colombia: Enhancing Geodetic Observations and Digital Elevation Models in Response to Recent Activity'. *Intellectual Merit*: Mitigating and reducing the volcanic hazards related to lahars at Nevado del Ruiz Volcano (Colombia) by combining new geodetic observations, digital elevation models (DEM) and lahar numerical modeling. Results of geodetic observations using both InSAR and Terrestrial Radar Interferometry (TRI) show a line-of-sight displacement of 17.4 mm corresponding to a source located 10 km south of the crater at 2,5 km depth. Combining topographic data derived from TRI, InSAR and Structure for Motion, a new DEM of 10x10 m resolution was created and tested with the LaharZ model. *Broader Impacts:* This project had obvious humanitarian benefits, and may help point the way to improved hazard forecasts at other volcanoes. We are also demonstrating two relatively new technologies that may prove beneficial on this and related natural hazard problems. *Resulting publications:* 2 conference abstracts have been presented so far (EGU 2017: Deng et al., 2017; IAVCEI 2017: Malservisi et al., 2017) and one paper is in preparation for submission in Fall 2017.

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*Charbonnier, S.J. and Gertisser, R., 2011. Deposit architecture and dynamics of the 2006 block-and-ash flows of Merapi Volcano, Java, Indonesia. Sedimentology, 58(6): 1573-1612.

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*Charbonnier, S.J., Germa, A., Connor, C.B., Gertisser, R., Preece, K., Komorowski, J.C., Lavigne, F., Dixon, T.H. and Connor, L.J., 2013. Evaluation of the impact of the 2010 pyroclastic density currents at Merapi volcano from high-resolution satellite imagery analysis, field investigations and numerical simulations. J. Volcanol. Geotherm. Res., 261: 295-315.

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*Kubanek, J., Richardson, J., Charbonnier, S.J., Connor, L., 2015. Lava flow mapping and volume calculations of the 2012-13 Tolbachik, Kamchatka fissure eruption using bistatic TanDEM-X InSAR. Bulletin of Volcanology, 77(12): 77-106.

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*Palma, J-L., Courtland, L., Charbonnier, S.J., Tortini, R., Valentine, G.A., 2014. Vhub: a knowledge management system to facilitate online collaborative volcano modeling and research. J. Applied Volcanology, 3:2.

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Bibliographical Sketch: Sylvain J. Charbonnier

a. Professional Education

Ph.D. in Earth Sciences, Keele University, Keele, United Kingdom, February, 2010.
M.S. in Earth Sciences, Université Paris Sud XI, Orsay, France, June, 2005.
B.S. in Earth Sciences, Université B. Pascal, Clermont-Ferrand, France, June, 2003.
B.A., Earth Sciences, Université F. Rabelais, Tours, France, June, 2002.

b. Professional Appointments

Tenure-Track Assistant Professor, School of Geosciences, University of South Florida (2014-present)
Visiting Assistant Professor, School of Geosciences, University of South Florida (2013-2014)
Postdoctoral Fellow, Department of Geology, University of South Florida (2010- 2013)

c1. Products: Related Publications

Charbonnier, S.J., Palma, J.L., Ogburn, S., 2015. Application of 'shallow-water' numerical models for hazard assessment of volcanic flows: the case of Titan2D and Turrialba volcano (Costa Rica). Revista Geologica de America Central 52, 107-128.

Palma, J-L., Courtland, L., **Charbonnier, S.J.**, Tortini, R., Valentine, G.A., 2014. Vhub: a knowledge management system to facilitate online collaborative volcano modeling and research. J. Applied Volcanology, 3:2.

Charbonnier, S.J., Germa, A., Connor, C.B., Gertisser, R., Komorowski, J.-C., Preece, K., Lavigne, F., Dixon, T., Connor, L., 2013. Evaluation of the impact of the 2010 pyroclastic density currents at Merapi volcano from high-resolution satellite imagery, field investigations and numerical simulations. J. Volcanol. Geotherm. Res. 261, 295-315.

Charbonnier, S.J., Gertisser, R., 2012. Evaluation of geophysical mass flow models using the 2006 block-and-ash flows of Merapi Volcano, Java, Indonesia: towards a short-term hazard assessment tool. J. Volcanol. Geotherm. Res. 231-232, 87-108.

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c2. Products: Other Publications

Jenkins, S.F., Komorowski, J.-C., Baxter, P., **Charbonnier, S.J.**, Cholik, N., Surono., 2016. The devastating impact of the 2010 eruption of Merapi volcano, Indonesia. AGU Book Chapters, In: 'Plate Boundaries and Natural Hazards', Eds: J.C. Duarte and W.P. Schellart, Geophysical Monograph, 219, First Edition, 259-269.

Kubanek, J., Richardson, J., **Charbonnier, S.J.**, Connor, L., 2015. Lava flow mapping and volume calculations of the 2012-13 Tolbachik, Kamchatka fissure eruption using bistatic TanDEM-X InSAR. Bulletin of Volcanology, 77(12): 77-106.

Komorowski, J.-C., Jenkins, S., Baxter, P., Picquout, A., Lavigne, F., **Charbonnier, S.J.**, Gertisser, R., Preece, K., Cholik, N., Budi-Santoso, A., Surono., 2013. Paroxysmal dome explosion during the Merapi 2010 eruption: Processes and facies relationships of associated high-energy pyroclastic density currents. J. Volcanol. Geotherm. Res. 261, 260-294.

Charbonnier, S.J., Gertisser, R., 2011. Deposit architecture and dynamics of the 2006 block-and-ash

flows of Merapi Volcano, Java, Indonesia. Sedimentology 58, pp. 1573-1612.

Gertisser, R., Cassidy, N.J., **Charbonnier, S.J.**, Nuzzo, L., Preece, K. (2012) Overbank block-and-ash flow deposits and the impact of valley-derived, unconfined flows on populated areas at Merapi volcano, Java, Indonesia. Nat. Hazards 60, pp. 623-648.

d. Synergistic Activities

Member (2010-present) of the VHub development team, cyber infrastructure for collaborative volcano research and risk mitigation (www.vhub.org).

Collaboration (2013-present) with the Universidad de Colima, Mexico, about increasing student exchanges to improve the evaluation of volcanic hazards by merging laboratory and field-based learning and with the Servicio Geologico Colombiano (SGC) and the Geohazards Center at SUNY Buffalo (USA) as a Vhub expert for using numerical models through the Vhub online platform and improving volcanic hazard assessment in Colombia.

Instructor (January 2013) for the NSF PASI workshop 'Applying Computational Models to Real-Case Scenarios for Volcanic Hazard Assessment', Colima, Mexico.

Convener and Co-convener of scientific sessions on 'Pyroclastic Currents: Linking Field Observations, Laboratory Experiments and Numerical Modeling for Hazard Assessment and Mitigation' at Cities on Volcanoes 8 and 9 conferences (**2014-2016**), 'Modelling of Volcanic Hazards' at the AGU Fall meeting (**2012**) and the EGU General Assembly (**2012-2013**) and 'Hazard Mapping' at the Cities on Volcanoes 7 conference (**2012**).

Organizer and Co-organizer (2013) of scientific workshops 'Vhub workshop: Introduction to the Vhub.org cyberinfrastructure and hands-on sessions on many of the online tools already available to its members' and 'A benchmarking exercise to promote inter-comparison for numerical models of volcanic mass flows' at the 2013 IAVCEI Scientific Assembly, Kagoshima, Japan.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION: University of South Florida				FOR NSF USE ONLY	PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Sylvain Charbonnier					AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Sylvain Charbonnier - PI	0.00	0.00	0.50	3,797	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	3,797	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	47,659	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (2) UNDERGRADUATE STUDENTS				6,342	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				57,798	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				9,948	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				67,746	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				4,000	
2. INTERNATIONAL				4,000	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 10,000 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (10) TOTAL PARTICIPANT COSTS				10,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				10,000	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				10,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				95,746	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.5000, Base: 85746)					
TOTAL INDIRECT COSTS (F&A)				42,444	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				138,190	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				138,190	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: Sylvain Charbonnier	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **University of South Florida**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Sylvain Charbonnier**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. **Sylvain Charbonnier - PI**	0.00	0.00	0.50	3,911		
2.						
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	3,911		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (1) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	49,089		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (0) GRADUATE STUDENTS				0		
4. (2) UNDERGRADUATE STUDENTS				6,532		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				59,532		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				9,995		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				69,527		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				4,000		
2. INTERNATIONAL				0		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 35,000 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (20) TOTAL PARTICIPANT COSTS				35,000		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				10,000		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				10,000		
H. TOTAL DIRECT COSTS (A THROUGH G)				118,527		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 49.5000, Base: 83527)**						
TOTAL INDIRECT COSTS (F&A)				41,346		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				159,873		
K. SMALL BUSINESS FEE				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				159,873		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Sylvain Charbonnier**				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*				Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION	University of South Florida
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR	Sylvain Charbonnier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Sylvain Charbonnier - PI	0.00	0.00	0.50	4,028	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	4,028	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				4,028	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				716	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				4,744	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				2,000	
2. INTERNATIONAL				4,000	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 10,000					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (10) TOTAL PARTICIPANT COSTS				10,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				10,000	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				10,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				30,744	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 49.5000, Base: 20744)					
TOTAL INDIRECT COSTS (F&A)				10,268	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				41,012	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				41,012	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

	FOR NSF USE ONLY		
PI/PD NAME: Sylvain Charbonnier	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 4

ORGANIZATION **University of South Florida**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Sylvain Charbonnier**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sylvain Charbonnier - PI**	0.00	0.00	0.50	4,149	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	4,149	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				4,149	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				737	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				4,886	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				2,000	
2. INTERNATIONAL				4,000	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 35,000 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (20) TOTAL PARTICIPANT COSTS				35,000	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				10,000	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				10,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				55,886	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 49.5000, Base: 20886)**					
TOTAL INDIRECT COSTS (F&A)				10,339	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				66,225	
K. SMALL BUSINESS FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				66,225	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Sylvain Charbonnier**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

ORGANIZATION: **University of South Florida**				FOR NSF USE ONLY	
				PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Sylvain Charbonnier**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sylvain Charbonnier - PI**	0.00	0.00	0.50	**4,273**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**4,273**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**4,273**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**759**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**5,032**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**10,000**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**10,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**15,032**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 49.5000, Base: 15035)**					
TOTAL INDIRECT COSTS (F&A)				**7,442**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**22,474**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**22,474**	

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME: **Sylvain Charbonnier**	FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION University of South Florida				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Sylvain Charbonnier				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. Sylvain Charbonnier - PI	0.00	0.00	2.50	20,158		
2.						
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.50	20,158		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (2) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	96,748		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (0) GRADUATE STUDENTS				0		
4. (4) UNDERGRADUATE STUDENTS				12,874		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				129,780		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				22,155		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				151,935		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				12,000		
2. INTERNATIONAL				12,000		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 90,000 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (60) TOTAL PARTICIPANT COSTS				90,000		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				50,000		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				50,000		
H. TOTAL DIRECT COSTS (A THROUGH G)				315,935		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS (F&A)				111,839		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				427,774		
K. SMALL BUSINESS FEE				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				427,774		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME Sylvain Charbonnier				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*				Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification- PI: Sylvain Charbonnier, University of South Florida

A. Senior Personnel
Sylvain Charbonnier – Requesting summer salary for 0.5 months for PI, Charbonnier.

B. Other Personnel
Post-Doctoral Scholar – Requesting salary for 12 months in years 1 and 2 for a post-doctoral scholar.

Undergraduate Students – Requesting salary for two undergraduate students in years 1 and 2 at 10 hours per week, for 2 semesters, at $8.10 an hour.

C. Fringe

Fringe is calculated at 17.73% for faculty PI, 1.75% for the post-doctoral scholar, and 0.30% for each undergraduate student. Insurance for post-doctoral scholar is also included at $8,220 annually. A 3% cost of living increase has been added each year.

E. Travel
Domestic Travel. Support is requested for:

- Charbonnier and the Postdoctoral fellow to attend the AGU meeting in San Francisco in year 1 and 2 to present the project results. (return airfares (Tampa to San Francisco), hotel, per diem and registration = **$4,000** (calculated for 2 persons).
- Charbonnier to attend the AGU meeting in San Francisco in year 3 and 4: (return airfares (Tampa to San Francisco), hotel, per diem and registration = **$2,000**

International Travel. Support is requested for:

- Postdoctoral Fellow to COV10 in Naples (Italy) in year 1: return airfares (Tampa to Naples, Italy), hotel, per diem and registration = **$4,000**
- Charbonnier to COV11 in year 3 (location not decided): estimated at **$4,000**
- Charbonnier to IAVCEI meeting in year 4 (location not decided): estimated at **$4,000**

F. Participant Support Costs
Participant support costs are requested for $10,000 in years 1 to 4 for the USF-Colima student exchange program. In addition, $25,000 is requested in years 2 & 4 for hosting two community-wide workshops at USF. This will cover the travel cost for 10 participants at $2,400 per participant: $1,400 airfare, $600 lodging (3 nights at $200 per night), per diem ($36 per day for 4 days), ground transportation (taxi to and from airport), & baggage fees. Rental of a conference room for the two meetings is also included at $1,000.

G. Other Direct Costs
Computer Services: $10,000 per year is requested for participation to the administration server fees to host the Vhub cyberinfrastructure (currently paid by SUNY Buffalo to Purdue University at $50,000 per year).

I. **Indirect Costs**

Indirect costs are calculated at the universities federally negotiated rate of 49.5% of the modified total direct costs.

Current and Pending (Sylvain Charbonnier, University of South Florida)

Pending:

Title: CAREER: Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models *(THIS PROPOSAL)*
Source of Support: National Science Foundation
Project Location: University of South Florida
Total Award Amount: $427,773
Term: 01/01/18 -12/31/22
Person-months committed each year: 0.5

Supporting Facilities at the University of South Florida

Major computational resources are available at the University of South Florida. For this project, numerical modeling activities will take place on PC clusters that are sufficient for all project tasks (sensitivity analyses and probabilistic modeling). USF School of Geosciences currently has a computational facility dedicated to volcanology that includes a small diskless cluster of 80 nodes for computationally intensive data analysis and modeling. This cluster will be available to project personnel (postdoctoral fellow and undergraduates) to work on the numerical modeling tasks of this project. PI S. Charbonnier hosts a laboratory space which includes five graduate student office spaces equipped with desktop workstations, two of which are currently available for the future postdoctoral fellow and undergraduates. In addition, two dedicated computer rooms that each include 9 desktop workstations with dual-boot Linux and Windows systems are also available for both research and educational purposes. These will be mostly used for the educational tasks of the proposal (including teaching of the new class on 'Modeling Volcanic Processes', development of the Vhub educational modules and as office spaces for the USF/Colima exchange students).

Advanced computer resources at the University of South Florida are administered by Research Computing (CIRCE at http://www.rc.usf.edu/). RC hosts a cluster computer which currently consists of 400 nodes with approximately 6400 processors. The cluster is built on the condominium model. The most recent addition to the cluster is comprised of 128, dual 8-core 2.6 GHz Intel Sandy Bridge nodes with 32GB RAM and 20 of the nodes are also equipped with dual Kepler GPUs. The nodes utilize QDR infiniband for a computational interconnect. A 100TB lustre file system is used to support high speed computations and researchers share a 100TB home file system. Research Computing supports 113 scientific software packages. This cluster will be also available for use in the project through the submission of allocation proposals and group memberships.

The Conferencing and Special Events Center at USF (http://www.usf.edu/student-affairs/conferences-special-events/index.aspx) can accommodate events ranging from 10 guests to 1,100 in one of the 26 meetings rooms. The USF Marshall Student Center has several pre-function spaces and has built in audio and video in many of the rooms. This space is ADA accessible and Wi-Fi Internet is available throughout the building. These will be used to host the two community-wide workshops planned in year 2 and year 4.

Supporting Facilities at the SUNY at Buffalo

The Center for Geohazards at UB coordinates the volcanology cyberinfrastructure program online at www.vhub.org, which is used as a collaborative tool during instrument development and for dissemination of information in collaborative projects. VHub's server and underpinning software (based upon the hubzero.org model) are maintained by a team at Purdue University through an annual subscription (around 50k$ per year), while VHub-enabled tools are able to remotely launch (potentially large scale) computations and utilize storage at UB's Center for Computational Research (http://www.ccr.buffalo.edu).

Data management plan at the University of South Florida

Stakeholders

- Participants, domestic and international partners,
- Other researchers in volcanology and related fields of geology, geography and computer sciences.
- Lay audiences with a need for and/or interest in these remote sensing and numerical modeling techniques.

The data and sharing needs of each one of these stakeholders has been considered and is discussed in the following.

Resources and Plans

The USF data management involves the management and digital curation of the volcanic data, including implementation of the physical/sedimentological PDC model, creation of a database of PDC metrics/components, creation of new Vhub educational modules, results from computer models, and the models themselves. The PI (S. Charbonnier) is responsible for execution of the data management plan for the duration of the project and any extensions. The PI will delegate project tasks to other members of the team as appropriate. We anticipate that the investigator will spend about 5% of his commitment to this project on activities related to data management and storage. Data storage and maintenance (including upgrades) will be built into the schedules for the investigator and students engaged in this effort.

This project will be facilitated by using VHub resources, a cyberinfrastructure platform for the volcanological community. VHub has extensive hardware and software resources and multiple methodologies to facilitate storage and access for a range of users with both secured and unsecured access. We note that VHub enables not just passive access but also actual execution of shared software and tools. Subsequent to the project completion we will rely primarily on the University of South Florida repository supported and managed by the university library and information technology services. A detailed inventory of data to be stored, metadata and a memorandum of understanding will be executed and included in the final report of the project. The expertise and resources of the USF librarians in long term curation and archiving of physical (papers, reports etc.) and digital resources will be used here. Incremental costs of assimilating and maintaining these data will be borne by the university. Interaction with the various IAVCEI commissions on explosive volcanism and volcanic hazards and risks will be maintain to supply robust datasets for modelling benchmarking and validation efforts and identify potential improvements to existing models that would increase precision and accuracy.

Compilation of published data from past field-based, laboratory experiments and/or numerical modelling studies will be used to create a database of PDC metrics/components and linked it to the existing FlowDat database on Vhub. This database will help to establish an international network of volcanic flow risk assessment tools, databases, and research results amongst international, national, regional and local partners. In that perspective, the common database could constitute a valuable contribution to other world databases concerning other volcanic hazards and risks (WOVOdat, VOGRIPA, LaMEVE…). In addition, we will share all data in this project with colleagues from volcanological surveys from all countries where PDC hazards pose a severe threat, and they will no doubt undertake similar curation of the data generated by this project.

Expected Data

The expected research and educational data generated by this project include:

- Compilation of published data from past field-based, laboratory experiments and/or numerical modelling studies to create a database of PDC metrics and components
- Implementation of a general physical/sedimentological PDC model
- Creation of Vhub educational modules
- Development of model validation/benchmarking exercises
- Development of model calibration and prediction efforts
- Publication of IAVCEI guidelines for PDC hazard assessment

In addition, papers and reports will be in the PDF format and open source software will be stored in simple downloadable archives. The educational materials will include supporting materials developed by the PI for presentations at major meetings and classes taught to disseminate research and educational results.

Access Policies and Intellectual Property Issues

Full access will be provided to all finished products (research papers, data and simulations used in papers and computational data developed) as they are completed with at most a 90 day delay post completion. Papers will be regarded as complete when they are accepted. Intermediate data and products will be stored in secured (password protected) areas of VHub and access provided to all investigators and other stakeholders through an application process. The university and investigators will retain intellectual property (copyright and patent rights) as applicable to all NSF funded research.

Postdoctoral Researcher Mentoring Plan

This Postdoctoral Researcher Mentoring Plan has been prepared by Sylvain Charbonnier, School of Geosciences, University of South Florida. The Plan establishes guidelines for work to be performed by a Postdoctoral Researcher, in support of the NSF CAREER Project to University of South Florida entitled "Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models". The Postdoctoral Researcher assigned to the project will work in the volcanology group, School of Geosciences, University of South Florida and will conduct research on: (1) implementation of the physical/sedimentological PDC model; (2) creation of a database of PDC metrics/components; and (3) initial set up of the model validation/benchmarking exercises.

1. Orientation will include in-depth conversations between Sylvain Charbonnier and the Postdoctoral Researcher. Mutual expectations will be discussed and agreed upon in advance. Orientation topics will include (a) the amount of independence the Postdoctoral Researcher requires, (b) interaction with coworkers, (c) productivity including the importance of scientific publications, (d) work habits and laboratory safety, and (e) documentation of research methodologies and experimental details so that the work can be continued by other researchers in the future.

2. Career Counseling will be directed at providing the Postdoctoral Researcher with the skills, knowledge, and experience needed to excel in his/her chosen career path. In addition to guidance provided by Sylvain Charbonnier, the Postdoctoral Researcher will be encouraged to discuss career options with researchers in the School of Geosciences and with his/her former students and colleagues.

3. Experience with Preparation of Grant Proposals will be gained by direct involvement of the Postdoctoral Researcher in proposals prepared by the volcanology group in the Department. The Postdoctoral Researcher will have an opportunity to learn best practices in proposal preparation including identification of key research questions, definition of objectives, description of approach and rationale, and construction of a work plan, timeline, and budget.

4. Publications and Presentations are expected to result from the work supported by the grant. These will be prepared under the direction of Sylvain Charbonnier and in collaboration with researchers in the volcanology group in the School of Geosciences as appropriate. The Postdoctoral Researcher will receive guidance and training in the preparation of manuscripts for scientific journals and presentations at conferences.

5. Teaching and Mentoring Skills will be developed in the context of regular meetings within the volcanology group during which graduate students and postdoctoral researchers describe their work to colleagues within the group and assist each other with solutions to challenging research problems, often resulting in cross fertilization of ideas.

6. Instruction in Professional Practices will be provided on a regular basis in the context of the research work and will include fundamentals of the scientific method, laboratory safety, and other standards of professional practice. In addition, the Postdoctoral Researcher will be encouraged to affiliate with one or more professional societies in his/her chosen field.

7. Technology Transfer activities will include regular contact with researchers at other universities, including the University at Buffalo Center for Geohazards and colleagues at Pisa University (Italy). The Postdoctoral Researcher will be given an opportunity to become familiar with the university-industry relationship including applicable confidentiality requirements and preparation of invention disclosure applications.

8. Success of the Mentoring Plan will be assessed by monitoring the personal progress of the Postdoctoral Researcher through a tracking of the Postdoctoral Researcher's progress toward his/her career goals after finishing the postdoctoral program.

June 25, 2017

Dear NSF Review Committee,

I am writing this letter in my capacity as the Director of the School of Geosciences and the immediate supervisor of the PI, Dr. Sylvain Charbonnier. I affirm that Dr. Charbonnier is a tenure-track Assistant Professor in the School of Geosciences and is therefore eligible for the CAREER program.

We grant Bachelor's, Master's, and Doctoral degrees in Geology, Geography, and Environmental Science & Policy. Though we have broad expertise among our 40+ faculty, our greatest strengths and highest priorities are natural hazards, water, and GIScience. The first two – natural hazards and water – are specifically highlighted as institutional-wide research priorities in the current USF Research Strategic Plan. Our natural hazards faculty are largely at the Associate Professor and Professor ranks. Just two – including Dr. Charbonnier – are at the Assistant Professor rank. Given the importance of natural hazards to the School of Geosciences and the University of South Florida, support for and professional development of Dr. Charbonnier is among our highest priorities.

Dr. Charbonnier's proposal fits perfectly not only with our strategic priorities, but also with our past, ongoing, and planned future operations.

USF and the School of Geosciences both have a strong commitment to limited but high-quality online education, and therefore can support Dr. Charbonnier's efforts to create an online course in Modeling Volcanic Processes. USF generously funds Innovative Education, a resource for faculty to use in developing high-quality online courses. Academic units are asked to propose courses for online development each semester, with each academic unit being guaranteed support for their highest priority class or classes. Once admitted to the program, faculty are provided access to a course-development liaison, a large technical staff, computers and software, and onsite and remote video tools and technologies. If this proposal is funded, then Modeling Volcanic Processes will be our highest online education development priority.

The School of Geosciences has a long history with Spreadsheets Across the Curriculum (SSAC), and therefore can support Dr. Charbonnier's efforts to create modules for use as Vhub resources. Many of our faculty – including me – have been involved in the initiative for many years, and have both received funding from NSF, published modules for public use, and developed still more modules for individual use in our classrooms. This includes modules specifically for use in teaching physical volcanology.

School of Geosciences
College of Arts and Sciences
University of South Florida 4202 East Fowler Avenue, NES 107, Tampa, Florida 33620
(813) 974-2386 Fax (813) 974-4808

Our faculty hail from five continents, and commonly host visiting faculty and students from around the world, and we therefore can support Dr. Charbonnier's exchange program. This is consistent with the USF Strategic Plan, which is centered largely on global citizenship. To the extent possible, the School of Geosciences provides material support for international visitors, including office and laboratory space and resources. If this proposal is funded, then this type of material support will be available to support Dr. Charbonnier's exchange program.

In closing, Dr. Charbonnier's proposal centrally aligns with the strategic priorities of both USF and the School of Geosciences. I fully endorse it, and affirm that all possible resources will be put at Dr. Charbonnier's disposal should this proposal be funded.

Sincerely,

Mark Rains
Professor and Director
School of Geosciences

School of Geosciences
College of Arts and Sciences
University of South Florida 4202 East Fowler Avenue, NES 107, Tampa, Florida 33620
(813) 974-2386 Fax (813) 974-4808

UNIVERSIDAD DE COLIMA
FACULTAD DE CIENCIAS

CERTIFICADA ISO 9001 : 2000

10 July 2017

To whom it might concern

If the proposal submitted by Dr. Sylvain Charbonnier entitled “CAREER: Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models” is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Yours faithfully

N.R. Varley
Research Professor
Email: nick@ucol.mx

Date: 14 July 2017

To: National Science Foundation

From: Greg A. Valentine, Professor

Subject: Support and intent to collaborate on CAREER project of S. Charbonnier

If the proposal submitted by Dr. Sylvain Charbonnier entitled "**CAREER: Developing a consensual validation and benchmarking procedure for Pyroclastic Density Current (PDC) hazard models**" is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Kind regards,

Greg A. Valentine
Professor, Department of Geological Sciences
Director, Center for Geohazards Studies
University at Buffalo

email: gav4@buffalo.edu