Subject offered for a contract starting October 2018

SUBJECT TITTLE: Geomorphic transport and their impact on the drainage basin evolution by remote sensing: application to West Indies

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In 2013, the Intergovernmental Panel on Climate Change stated that “more frequent and/or intense heavy rainfall events” were to be expected as a result of climate change “over most of the mid-latitude land masses and over wet tropical regions” (IPCC, 2013). Hurricanes and storms generate destructive floods and mass wasting in tropical regions (Garcin et al., 2005; Allemand et al., 2014), leading to environmental degradation (Ferrier et al., 2013; Reid & Page, 2003). The consequences of these catastrophic events are amplified by other anthropogenic perturbations, such as deforestation or soil degradation, and result in biodiversity loss and ecosystem dysfunction (e.g., Crausbay & Martin, 2016). The remobilization of landslide deposits by heavy rains may have a devastating impact on the infrastructure and the housing, particularly in densely populated islands. For example, from 2004 to 2013, mass wasting processes were responsible for about 4,600 fatalities, and about US$15 million are annually spent for refurbishing damaged roads in the Caribbean (Garcin et al., 2005). Therefore, as a result of climate change, tropical regions are faced with major economic and social challenges (Emanuel, 1987, 2005).

As a major agent of erosion and sediment supply to rivers (Schuster & Highland, 2007), mass wasting is one of the most efficient physical processes shaping the Earth’s surface and is thus critical to landscape evolution. In addition, although they concern small areas, mass wasting processes promote the percolation of surface runoff in highly fragmented rock debris thereby creating favorable conditions for chemical weathering that is a major atmospheric carbon dioxide sink (Emberson et al., 2015). Furthermore, soil carbon stocks are strongly disturbed by mass wasting, potentially leading to carbon release to the atmosphere (Clark et al., 2016). These two examples (enhanced weathering and soil carbon release) show the link between mass wasting and the global carbon cycle.

To better understand how social and economic issues can be included in risk assessment, landscape evolution, as well as the relationships between erosion and the carbon cycle, it is critical to (1) **study the way climate change modifies the frequency and magnitude of mass wasting** in tropical regions, and in which ways extreme events affect these relationships, (2) **estimate the volume and mass flux** generated by mass wasting, and (3) **appraise the influence of mass wasting in long-term landscape evolution** and continent-ocean-atmosphere carbon cycle. Such a task can be successfully completed only through an integrated approach combining remote sensing techniques (spatial and temporal dynamics of mass wasting) with *in situ* measurements (i.e., river fluxes and possibly geochemical analyses).

This PhD project aims to **evaluate the role of slope instability in sediment and solute fluxes from watersheds**, and to study the environmental **impact of slope instability on the critical zone of tropical islands and in particular in the West Indies**. Ultimately, the project will **deliver a quantitative modeling of the sediment and solute transport driven by mass wasting**. The project will focus on the West Indies, especially Guadeloupe, where erosion and weathering rates are among the highest on Earth. Many field data on river fluxes are available thanks to the ObsEra observatory, including rainfall rates and soil production rates. This innovative **multi-disciplinary approach** should lead to an analytical scaling between mass wasting and sediment/solute load in the river. Depending on the evolution of the PhD, extension to similar areas is considered. Ultimately, the outcomes of the Ph.D. could be generalized to other parts of the world such as the Andes for instance.

Developments in remote sensing will first provide the spatial and temporal information about the dynamics of mass wasting based on available data sets (optical, LiDAR and RADAR data). Beyond the classical two-dimensional landslide mapping, we will use time series of landslide volumes, as well as the corresponding generated sediment fluxes. We will take advantage of high-resolution digital elevation models that are either available from IGN and/or will be derived from photogrammetry. The temporal dimension will be explored using archive data covering the last three decades from the different data base and programs (i.e, Geoportail, Kalideos, Take-5, Copernicus) for the large scale and from UAV images for the local scale.

In parallel, field measurements will be collected in the critical zone in the frame of the Observatory for Erosion and Water in the Antilles (ObsErA). Several catchment areas corresponding to a wide range of mass wasting processes have been identified in Guadeloupe island. In addition to water and sediment discharge measurements, major and trace element concentration will be measured in the river water sampled at different catchments: it will allow for the computation of sediment and solute export when possible.

Depending on the candidate interests and skills, the project will either lead to i) determine the characteristic "geochemical signature of landslide weathering" by deploying soil water sampling plates in landslide debris to collect the solution percolating through the landslide deposit, and analyze these solutions for the major and trace constituents that are sensitive to weathering (e.g., Louvat et al., 2011; Bouchez et al., 2013); or ii) to develop a new landscape modeling that take into account the multi-timescale contribution of mass wasting and in particular their control on the drainage network evolution at the basin scale, based on the multi-modal observations and measurements of the thesis.

This project has therefore the potential to link mass wasting, sediment generation, geochemical cycles, and ecosystem shifts. For that purpose, we will first study the correlation between the landslide volume and the associated sediment flux (from remote-sensing data) and catchment-scale solute fluxes. Potential relationships between physical (size, roughness…) and chemical properties will also be explored, providing insight into the mechanisms of water-rock interactions within mass wasting. We will then connect these data to meteorological data (rainfall, wind, evaporation...) in order to reveal the influence of rainfall on mass wasting in tropical regions. Finally, through LiDAR and hyperspectral remote sensing data, an exploratory part of the thesis will consist in characterizing the evolution of vegetation over mass wasting after mass wasting, opening the way for including biological processes into the set of relationships between mass wasting, weathering and potentially the carbon cycle.

Interactions in between DFG, G2E, PSS, Tecto and Volc. Sys. teams as well as collaborations outside IPGP (Univ. Lyon Claude Bernard) will offer a unique scientific framework for supporting this project, the topic of which is associated to the IPGP theme "Earth System Science".