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Signal propagation from space to time: Implications to modeling stratigraphic record
Arvind Singh, University of Central Florida

River deltas contain complex distributary channel networks which transport water and sediment from continents to oceans. They are extremely sensitive to changes in environmental forcings (e.g. climate, tectonics, sea-level) as well as anthropogenic influence and respond to both upstream and downstream controls. The dynamics of such networks are intricate; channels migrate laterally, avulse, divide and rejoin around bars and islands, and the flow shifts unpredictably from one part of the network to another, creating highly variable and nonlinear spatio-temporal patterns of erosion and deposition. Knowledge of the dynamics of the channels and their network and physical processes operating on deltaic surfaces, in particular, is important for interpreting stratigraphic record for paleo-climatic and tectonic conditions and can provide useful predictive tools for quantifying potential locations of subsurface hydrocarbon reservoirs. Using publicly available data from delta physical experiments, the goal of this study is to quantify how the probabilistic structure of spatial patterns and processes governing the evolution of depositional topographic surfaces relates to the probabilistic structure of temporally preserved stratigraphic record.

This research is anticipated to help us increase our ability to make quantitative predictions of how geomorphically and societally relevant variables will change under scenarios of future climatic and land-use changes. The PI and the UCF are receiving direct multiple benefits from the proposed project both in terms of their research and teaching missions. For example, this grant is providing a great opportunity to the PI to further develop the above research ideas which may lead to bigger funding proposals aimed at National Science Foundation (NSF) CAREER award and other NSF sub-divisions, US Department of Agriculture, and US Department of Energy, among others. From the teaching perspective, in the academic year 2018-2019, PI taught *Hydraulics* (advanced level undergraduate course) and *Stochastic river network hydro-geomorpholgy* (6000 level graduate course) which cover concepts on hydrology, hydraulics, and river network dynamics under changing environment. The results from this project were presented in these courses and will be presented in future courses the PI will teach, with the intention of encouraging students to engage more in research-oriented learning and prepare them for graduate school and real-world applications.

This project is providing several opportunities for students and post-doctoral associates, working in PI's research group, for training and professional development. For example, three graduate students (two females) were trained on fundamentals of information theory and its applications in network science. They were working on developing framework for characterizing spatially distributed features (e.g. channel networks) and how these features change in temporal domain under constant and varying external forcings. Two graduate students (partially supported by this grant) graduated in the summer of 2019 with their PhDs and the third student defended her candidacy exam and is expected to graduate in summer 2020. Figure 1 is developed by a graduate student where the dependency between long-term climate and branching characteristics of a tributary channel network are explored. As can be seen from the inset of Figure 1 which shows a simple channel network schematically, junctions in a channel network can be branching and side branching which can be characterized via c-value, i.e. a metric representing the amount of side branching in a channel network. Figure 2 is also prepared by a graduate student where complexity of sediment deposition and erosion at a point in an experiment flume is explored. Complexity in the temporal evolution of bed surface was analyzed via multiscale entropy approach. The students are learning advanced programming languages and platforms such as matlab and python to perform these analysis and are anticipated to be beneficial for their future career goals in academia and industry. In fact, analysis shown in Figures 1 and 2 were performed using python.

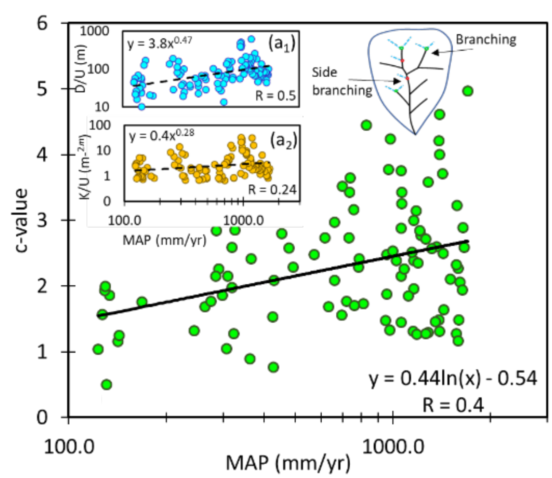

Figure 1: Relationship between side branching represented by c-value and climate. Insets a_1 and a_2 show long term climate behavior in terms of diffusion (D) and advection (K), respectively, for several basins across the United States.

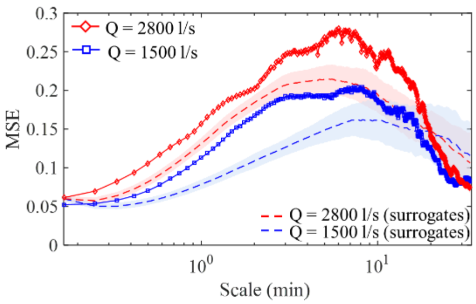

Figure 2: Multiscale entropy of bed elevation for the two different discharges. Dashed lines represent linearized series of bed elevation. The shaded area around the solid and dashed lines represents the uncertainty.

The post-doctoral associate involved in this project has a background in fluid mechanics. As part of the academic training which helps to prepare him for the professional career, working on this project extends his research area to the new field of geomorphology with the research interest on sediment transport and hydrology. With his participation, this project benefits from a different perspective in understanding the associated physical processes. For example, the burial and exhumation of sediment particles within the fluvial channel bed contributes directly to the stratigraphic records for the temporally propagating signals, which are theoretically considered and modeled in his recent work. Results in Figure 3 illustrate that the signal of bedload sediment wave gradually slows down due to burial and exhumation processes during its streamwise transport in the fluvial channel, which can be described by a power-law relation at the beginning of the transport and finally reaches an asymptotic constant value. These models will be further tested for delta channel networks across a range of spatial and temporal scales.

The outcomes from the project are being disseminated through publication in the peer reviewed journals, and conference presentations. Students and postdocs are also participating in the workshops and conferences presenting their results and getting exposed to a range of disciplines which will help them in building a base for future knowledge sharing between engineering and science communities.

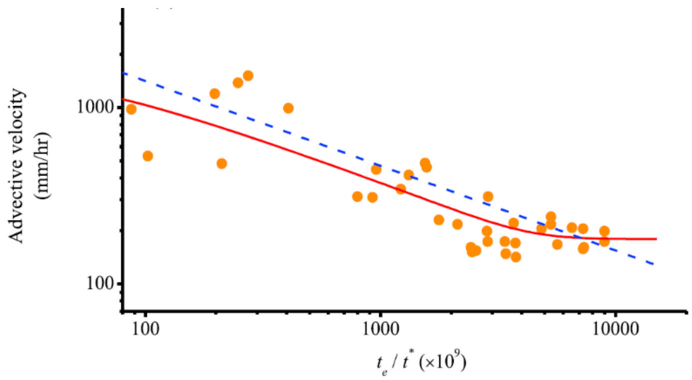

Figure 3: Decrease of the mean streamwise transport velocity of bedload sediment particles as the observational period increases. Solid line is for the developed theoretical solution, dots for the field experimental data, and dashed line for the fitted power-law relation according to the data.

In summary, young scientists are being trained in advanced research methods that span traditional disciplinary boundaries (i.e. hydrology, geomorphology, geology and mathematical modeling) through the use of advanced statistical/numerical methods applied to field-scale stratigraphic data, physical experiments and numerical models, and collaborative preparation of manuscripts for publication.