Aircraft icing is widely recognized as a significant hazard to aircraft operations. Surface water transport process plays a very important role in determining the ice accretion over aircraft wings. In glaze icing conditions, water beads, rivulet and film flows run back along airfoil surface to redistribute the impinging water mass, disturb the local flow field, and interact with local icing roughness elements, thereby, influence the ice accretion process. In the present study, a novel Digital Image Projection (DIP) technique was developed to quantify the transient behavior of surface water transport process driven by boundary layer airflows over airfoil/wing surfaces. The DIP technique is based on the principle of structured light triangulation in a fashion similar to stereo vision technique, but replaces one of the cameras in the stereo pair with a digital projector. A grid image with known pattern characteristics was projected onto the test object of interest (i.e., water film/rivulet flows over a test surface for the present study). By comparing the distorted grid patterns (i.e., acquired images with water film/rivulet flows over the test surface) with a reference grid pattern without the test objects on a reference surface, the 3-D profile of the test objects (i.e., the thickness distribution of the water film/rivulet flows, thus, the surface water mass transport process, over the test surface) can be retrieved quantitatively and instantaneously. After carefully calibrated and validated, the DIP technique was firstly utilized to characterize the wind-driven water rivulet flows over a flat plate. A force balance (FB) rivulet breaking criterion was evaluated and refined based on the quantitative DIP measurement results. A new model based on force balance analysis was developed to illustrate the meandering instability of wind-driven water rivulets. Then, the DIP technique was used to quantify the transient behavior of wind-driven film flows over a test surface with roughness arrays in order to examine the water trapping effects induced by local ice roughness. Finally, DIP technique was applied to achieve time-resolved measurements to quantify the transient water runback process over a NACA0012 airfoil. The new findings derived from the present study would lead to a better understanding of the important micro-physical processes, which could be used to improve current icing accretion models for more accurate prediction of ice formation and accretion process over aircraft wings as well as to develop effective anti-/de-icing strategies tailored for aircraft icing applications to ensure the safer and more efficient operation of aircraft in cold weather.