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Seasonal variabilty of surface velocities and ice discharge of Columbia Glacier, Alaska using high-resolution TanDEM-X satellite time series and NASA IceBridge data

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Columbia Glacier is a grounded tidewater glacier located on the south coast of Alaska. It has lost half of its volume during 1957-2007, more rapidly after 1980. It is now split into two branches, known as Main/East and West branch due to the dramatic retreat of $\sim$ 23 km and calving of iceberg from its terminus in past few decades. In Alaska, a majority of the mass loss from glaciers is due to rapid ice flow and calving icebergs into tidewater and lacustrine environments. In addition, submarine melting and change in the frontal position can accelerate the ice flow and calving rate.

We use time series of high-resolution TanDEM-X stripmap satellite imagery during 2011-2013. The active image of the bistatic TanDEM-X acquisitions, acquired over 11 or 22 day repeat intervals, are utilized to derive surface velocity fields using SAR intensity offset tracking. Due to the short temporal baselines, the precise orbit control and the high-resolution of the data, the accuracies of the velocity products are high. We observe a pronounce seasonal signal in flow velocities close to the glacier front of East/Main branch of Columbia Glacier. Maximum values at the glacier front reach up to 14 m/day were recorded in May 2012 and 12 m/day in June 2013. Minimum velocities at the glacier front are generally observed in September and October with lowest values below 2 m/day in October 2012. Months in between those dates show corresponding increase or deceleration resulting a kind of sinusoidal annual course of the surface velocity at the glacier front. The seasonal signal is consistently decreasing with the distance from the glacier front. At a distance of 17.5 km from the ice front, velocities are reduced to 2 m/day and almost no seasonal variability can be observed. We attribute these temporal and spatial variability to changes in the basal hydrology and lubrification of the glacier bed. Closure of the basal drainage system in early winter leads to maximum speeds while during a fully developed basal drainage system speeds are at their minimum. We also analyze the variation in conjunction with the prevailing meteorological conditions as well as changes in calving front position in order to exclude other potential influencing factors.

In a second step, we also exploit TanDEM-X data to generate various digital elevation models (DEMs) at different time steps. The multi-temporal DEMs are used to estimate the difference in surface elevation and respective ice thickness changes. All TanDEM-X DEMs are well tied with a SPOT reference DEM. Errors are estimated over ice free moraines and rocky areas. The quality of the TanDEM-X DEMs on snow and ice covered areas are further assessed by a comparison to laser scanning data from NASA Icebridge campaigns. The time wise closest TanDEM-X DEMs were compared to the Icebridge tracks from winter and summer surveys in order to judge errors resulting from the radar penetration of the x/band radar signal into snow, ice and firn. The average differences between laser scanning and TanDEM-X in August, 2011 and March, 2012 are observed to be 8.48 m and 14.35 m respectively.

Retreat rates of the glacier front are derived manually by digitizing the terminus position. By combining the data sets of ice velocity, ice thickness and the retreat rates at different time steps, we estimate the seasonal variability of the ice discharge of Columbia Glacier.