Fusion of multi-sensor, multi-temporal velocity observations to study intra-annual glacier dynamics

Laurane Charrier1,2, Yajing Yan1, Emmanuel Trouvé1, Elise Colin Koeniguer2, Silvan Leinss1,3, Jeremie Mouginot4, and Romain Millan4,5

1Université Savoie Mont Blanc, LISTIC, Annecy, France
2ONERA, DTIS, Paris, France
3GAMMA Remote Sensing AG, Gümligen, Switzerland
4IGE, Université Grenoble Alpes, Grenoble, France
5Department of Geosciences and Natural Resource Management, University of Copenhagen, 1350, Copenhagen K, Denmark

Intra-annual glacier velocities are key parameters to study glacier basal conditions or short-term events such as glacier surges. However, intra-annual glacier velocities remain poorly understood at a global scale, especially in mountains areas. Indeed, many ice velocity maps are now available on-line or on-demand at a temporal resolution up to 2 days and a spatial sampling up to 50 m (Millan et al., 2019) all over the world. However, these products contain gaps, noise and artefacts especially where image-matching algorithms fail because of strong surface changes, surface locking, shadow casting, clouds, or feature-less regions. Moreover, this amount of data is complex to analyse since velocities span different temporal baselines, are derived from different sensor images using different algorithms. Therefore, there is a need to fuse the available multi-temporal and multi-sensor glacier velocity observations in order to study intra-annual glacier dynamics with a high temporal resolution.

The proposed approach relies on an inversion based on the temporal closure of displacement observation networks. Because the observations have different uncertainties, not necessarily known, the inversion is solved using an Iterative Reweighted Least Square. This approach results in velocity time series which have a complete temporal coverage, a uniform temporal sampling without overlapping time intervals (i.e. without redundancy) by tacking advantage of all available velocity observations without a priori on the displacement behavior. The temporal sampling of these velocity time series can be selected. To select an optimal temporal sampling based on a compromise between temporal resolution and uncertainty, we propose to minimize Root Mean Square Error (RMSE) over stable areas and maximize Velocity Vector Coherence (VVC) over fast moving areas. The proposed approach is illustrated with both mono-sensor and multi-sensor datasets, on two different glaciers: 1) Sentinel-1 velocity observations from (Round et al., 2017) over the Kyagar glacier which is a surge glacier situated in the Karakoram range 2) Sentinel-2 and Venüs velocity observations from (Millan et al., 2019) over the Fox glacier, a temperate maritime glacier with a strong seasonality, situated in Southern Alps of New Zealand. The results reveal
strong intra-annual variations of velocity with a reduced uncertainty for both glaciers: RMSE over stable areas is lower for the results than for the original velocities: 1) from 22% lower for 12-days temporal sampling to 67% lower for 36-days temporal sampling over the Kyagar glacier 2) from 78% lower for 5-days temporal sampling to 40% lower for 60-days temporal sampling over the Fox glacier.

This approach is not dataset dependent and can be applied to any available velocity observations derived from any sensors.