# Intra- and inter- annual variability of glacier velocity and surface melt


Charrier, L. [1], Dehecq, A. [1], Brun, F. [1], Ducasse, E. [1], Millan, R. [1], Rabatel, A. [1]

[1] Institut des Géosciences de l'Environnement, Grenoble

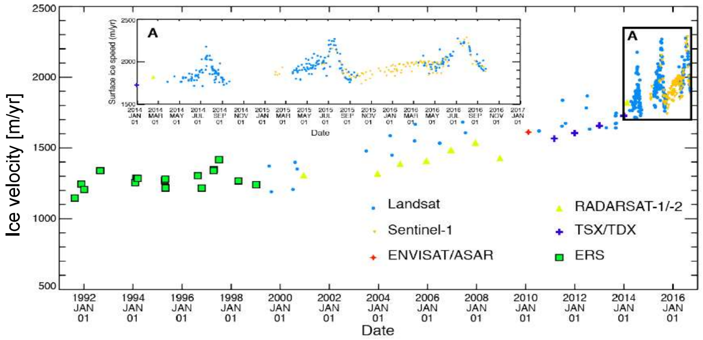

## Challenges & Objectives

☺ Increasing amount of ice velocities observations (different sensors, different processing chains, different temporal baselines)

☹ But still very few analysis of ice velocities with a high temporal resolution (3 months or lower) at a large scale

**Why?** The uncertainty is often larger than the seasonal amplitude. The observations are heterogeneous.

**Objectives:**
- ✓ merge all existing, heterogeneous, observations into a single, regularly sampled velocity time-series
- ✓ extract annual velocity peaks (timing and value)

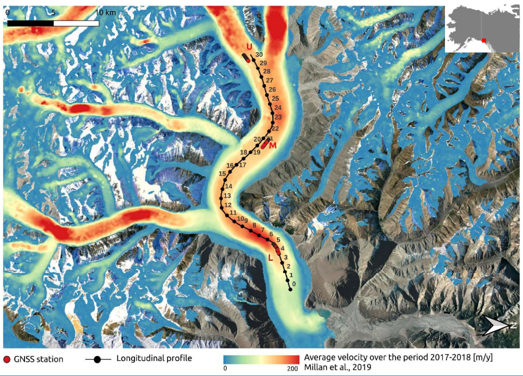



*Ice velocity of Zachariae Isstrøm between 1992 and 2017 (A) and between 2014 and 2017 from multiple sensors (Mouginot et al.,2017)*

## Test site

**Kaskawulsh glacier, Yukon, Canada**

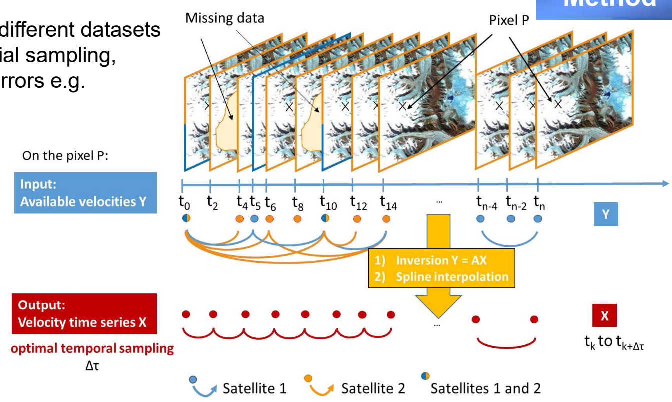
- 3 GNSS stations (L, M, U)
- 2 ice velocity dataset: ITS_LIVE (NASA), Millan et al., 2022 (IGE) using Sentinel-2, Landsat-8, Sentinel-1




## Method

**1) Homogenisation** of the different datasets (coordinate system, spatial sampling, detection of systematic errors e.g. temporal decorrelation)

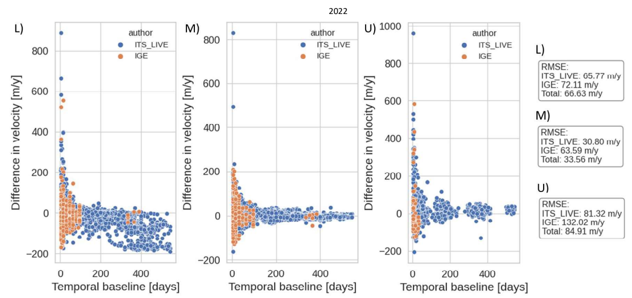
**2) Temporal Inversion** with Combination of Displacement and Interpolation (TICOI) (Charrier et al., 2022)



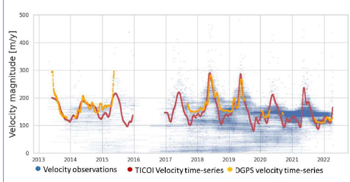

- ➢ Cost function: $argmin\left(\left|\left|W(AX-Y)\right|\right|^2+\lambda\left|\left|\Gamma X\right|\right|^2\right)$ with $\lambda$ the Tikhonov coefficient
- ➢ Weights ($W$): defined iteratively using the Tukey biweight function
- ➢ Solver: LSMR (Fong and Sanders, 2011)

## Results

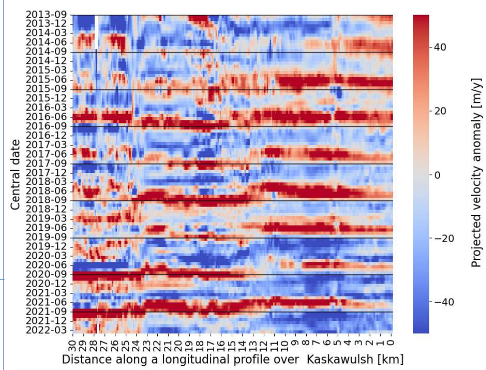
### Comparison between GNSS velocities and ice velocity datasets



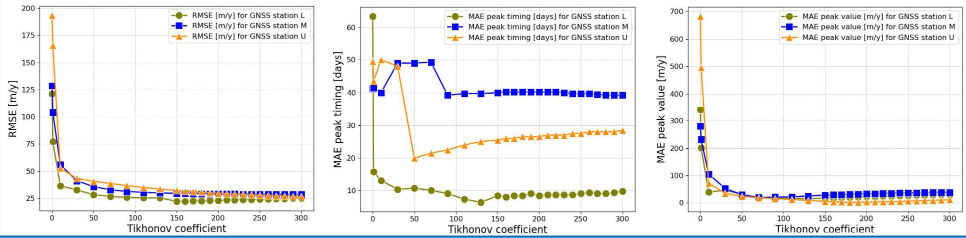

### Example of TICOI estimations over the GNSS station L




### Projected anomaly magnitude over a longitudinal profil along Kaskawulsh glacier




### Comparison between GNSS velocities and TICOI estimations depending on the Tikhonov coefficient:




| GNSS station | L | M | U |
|---|---|---|---|
| Optimal coef | 130 | 90 | 180 |
| RMSE [m/y] | 25.2 | 31.2 | 30.5 |
| MAE peak value [m/y] | 15.4 | 39.2 | 2.2 |
| MAE peak timing [days] | 6.3 | 20.9 | 26.5 |

## Conclusion & Persepctives

- RMSE between TICOI estimations and GNSS velocities is reduced by 7%, 62% and 63 % (for the station M, L and U respectively) compared to the total RMSE between velocity observations and GNSS velocities = **reduced uncertainty**
- Annual velocity peak retrived with a Mean Absolute Error in the order of 10 to 30 days, and 1 to 40 m/y, for 3 GNSS stations
- Spatio-temporal evolution of the velocity showing a clear seasonality

➢ Future work:
- Uncertainty evaluation of the estimated velocities
- Comparison with temperature and snow melt, derived from Sentinel-1 images


Charrier, L., Yan, Y., Colin Koeniguer, E., Mouginot, J., Millan, R., Trouve, E. (2022) Fusion of multi-temporal and multi-sensor ice velocity observations. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences V-3-2022, 311–318

Fong, D. C. L., & Saunders, M. (2011). LSMR: An iterative algorithm for sparse least-squares problems. SIAM Journal on Scientific Computing, 33(5), 2950-2971..

Millan, R., Mouginot, J., Rabatel, A., & Morlighem, M. (2022). Ice velocity and thickness of the world's glaciers. Nature Geoscience, 15(2), 124-129.

Mouginot, J., Rignot, E., Scheuchl, B., & Millan, R. (2017). Comprehensive annual ice sheet velocity mapping using Landsat-8, Sentinel-1, and RADARSAT-2 data. Remote Sensing, 9(4), 364.