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# Outlet-glacier flow dynamics estimation combining in-situ and spaceborne measurements

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## Introduction

Terminus retreat and flow acceleration changes of ocean-terminating outlet glaciers contribute significantly to the current mass loss of the Greenland Ice Sheet and the global sea level rise. In order to constrain models of ice dynamics, detailed knowledge of geometry and ice-flow velocity of such calving glaciers is needed. Particularly important are the near terminus velocities, as these flow fields strongly affect the glacier's calving rate. For fast moving outlet glaciers, these flow fields are difficult to accurately capture with the current temporal resolution of spaceborne systems, while in-situ measurements using ground based radar interferometers are limited in coverage and constrained by distance and geometric shading of the glacier.

### *Aim*

Using flow velocity data from in-situ measurements and spaceborne systems we aim at:

- Assessing the differences between the measurements methods on overlapping areas
- calculating a spatially continuous velocity field for the whole glacier

## Intensity Tracking

By applying a feature (i.e. intensity) tracking methodology (e.g. Joughin, 2002; Strozzi et al., 2002) to the spaceborne data, continuous flow velocities can generally be retrieved with a high spatio-temporal resolution. Issues exist in the border regions of the glacier, where there are discontinuities in movement due to solid ground (side of glacier) or sea-ice (ocean). Applying the patchwise normalized cross-correlation approach in these areas results in noisy and incorrect velocity estimates, while the temporal and geometric decorrelation of the signal impedes the use of interferometric approaches. The movement data from the GAMMA Portable Radar Interferometer (GPRI) can be used to overcome the issues in these areas.

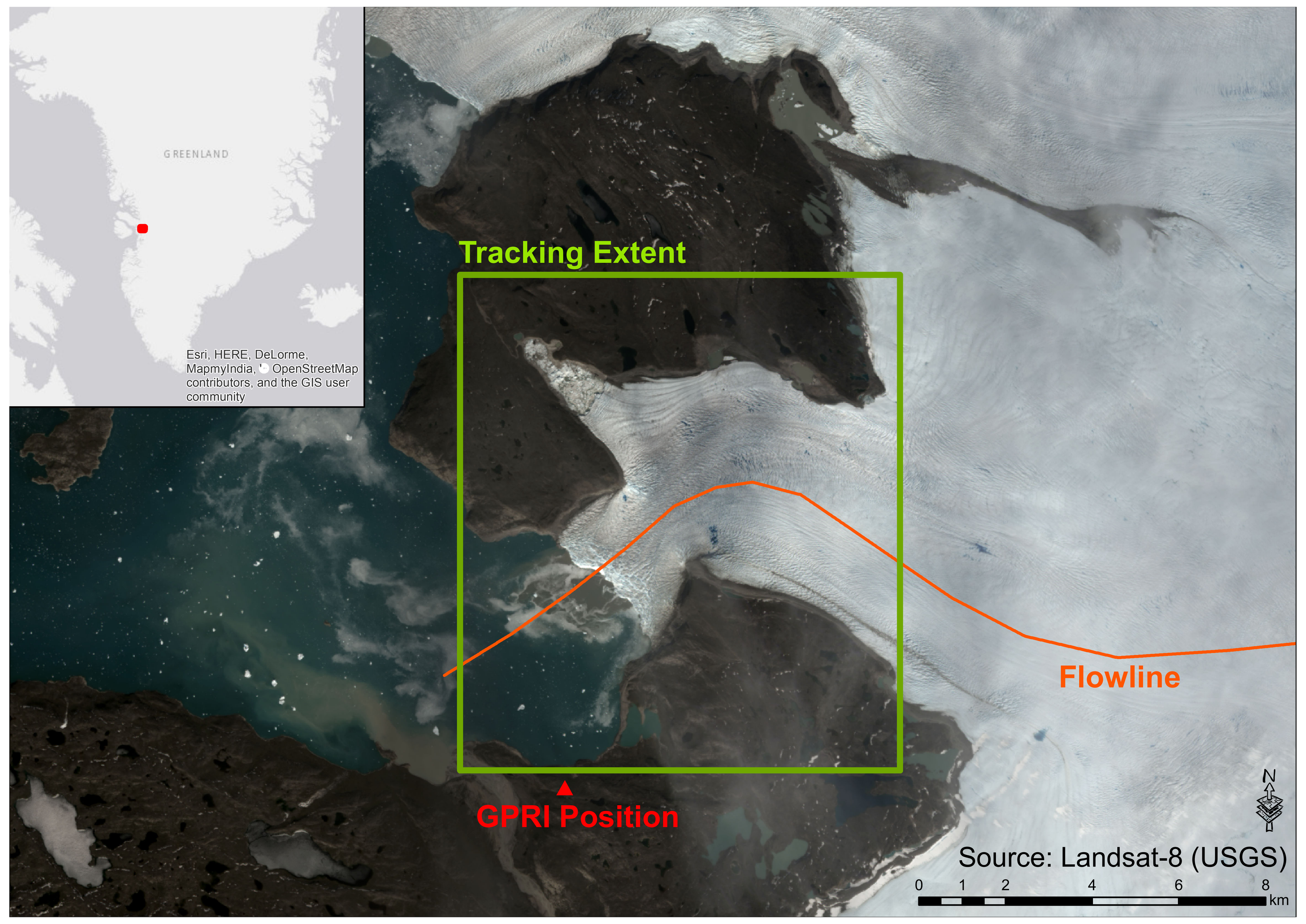
## Data Fusion

Following a statistical analysis of the retrieved flow velocities in areas with overlapping in-situ and satellite data, the data sets were assimilated. Therefore, the line-of-sight velocity information from the GPRI were adjusted based on a physical flow direction model. Using the coherence information retrieved by the GPRI, both flow velocity estimates were weighted using the equation

$$v_{fused} = v_{GPRI} \cdot coh_{GPRI} + v_{Sat} \cdot (1 - coh_{GPRI})$$

on a pixel-by-pixel basis. The approach is easily implemented, while taking into account information about the reliability of the in-situ measured data.

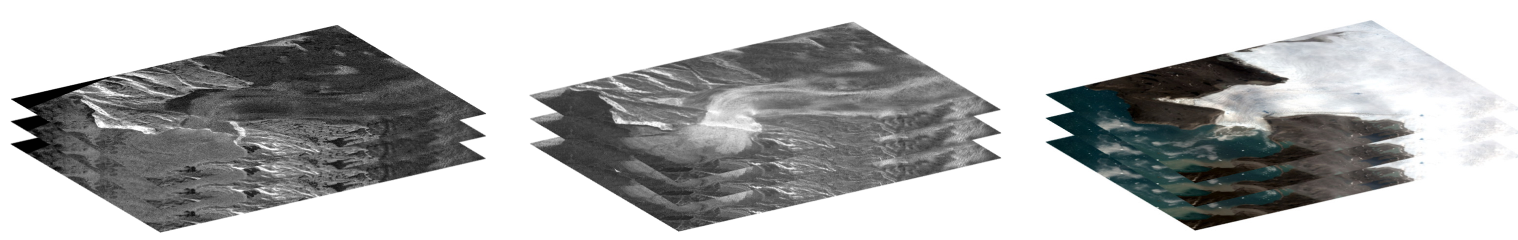
## Study Area




Eqip Sermia, a medium-sized ocean terminating outlet glacier in western Greenland.

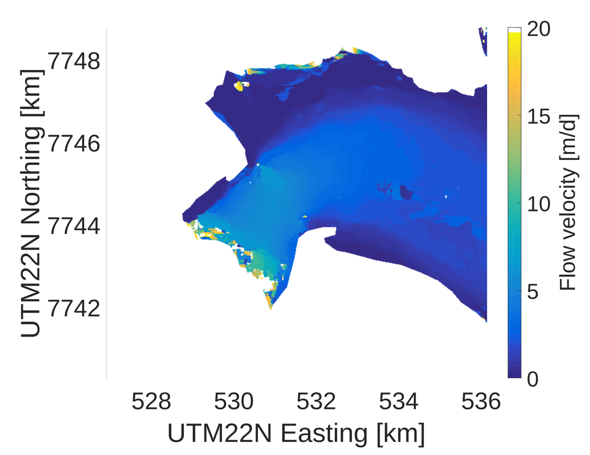
## Data

### Satellite Data



Sentinel-1A
Radarsat-2
Landsat-8

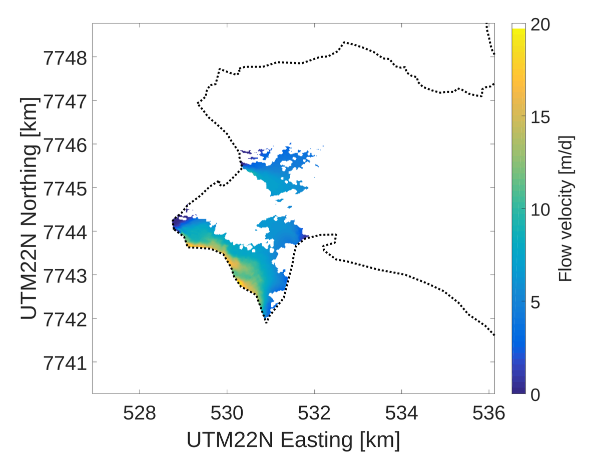
Intensity Tracking




Glacier flow velocities based on intensity tracking of two Landsat-8 scenes (masked to glacier outline)

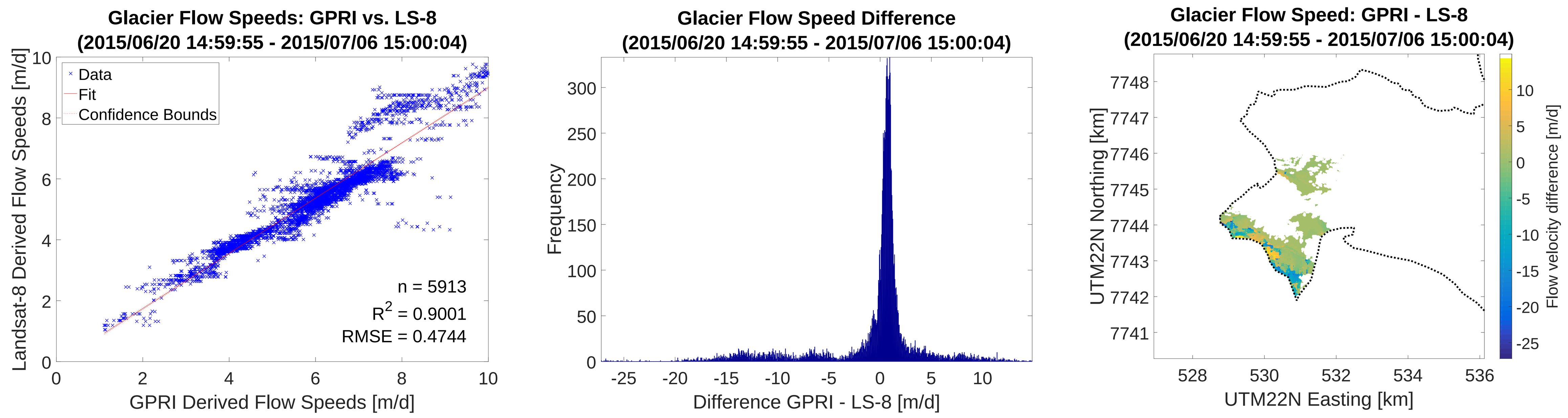
### GAMMA Portable Radar Interferometer

Interferometry



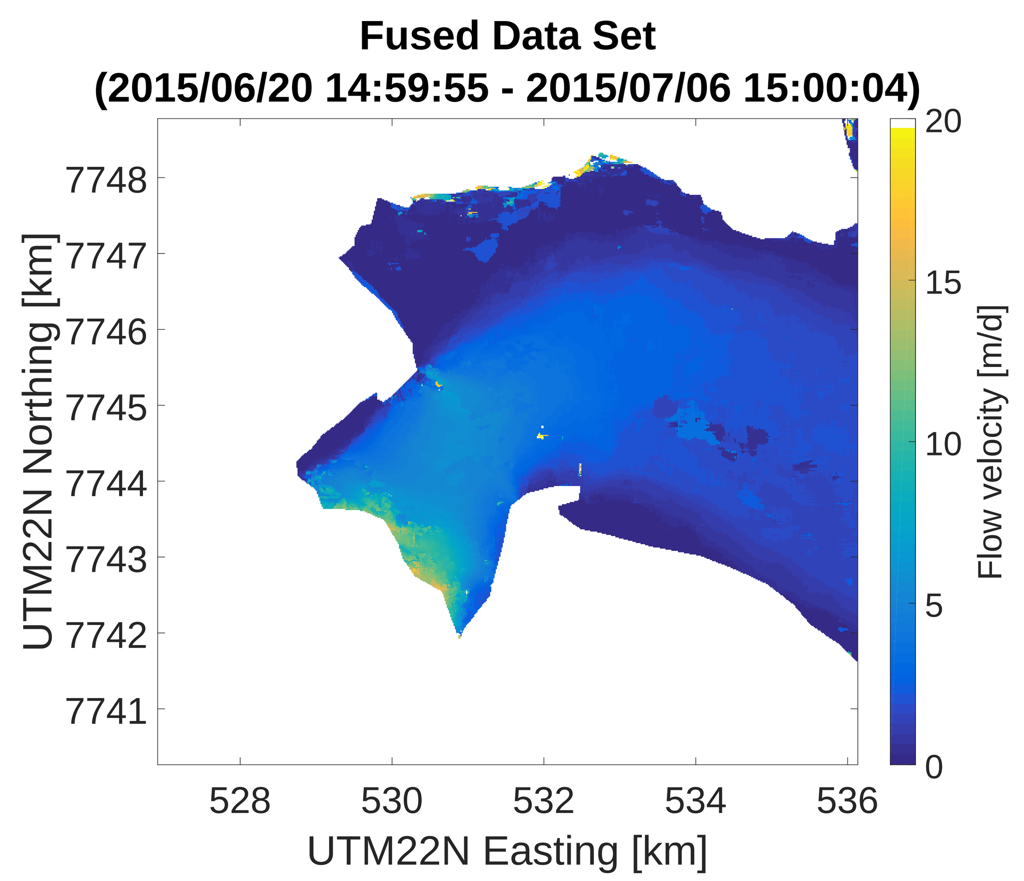

## Results

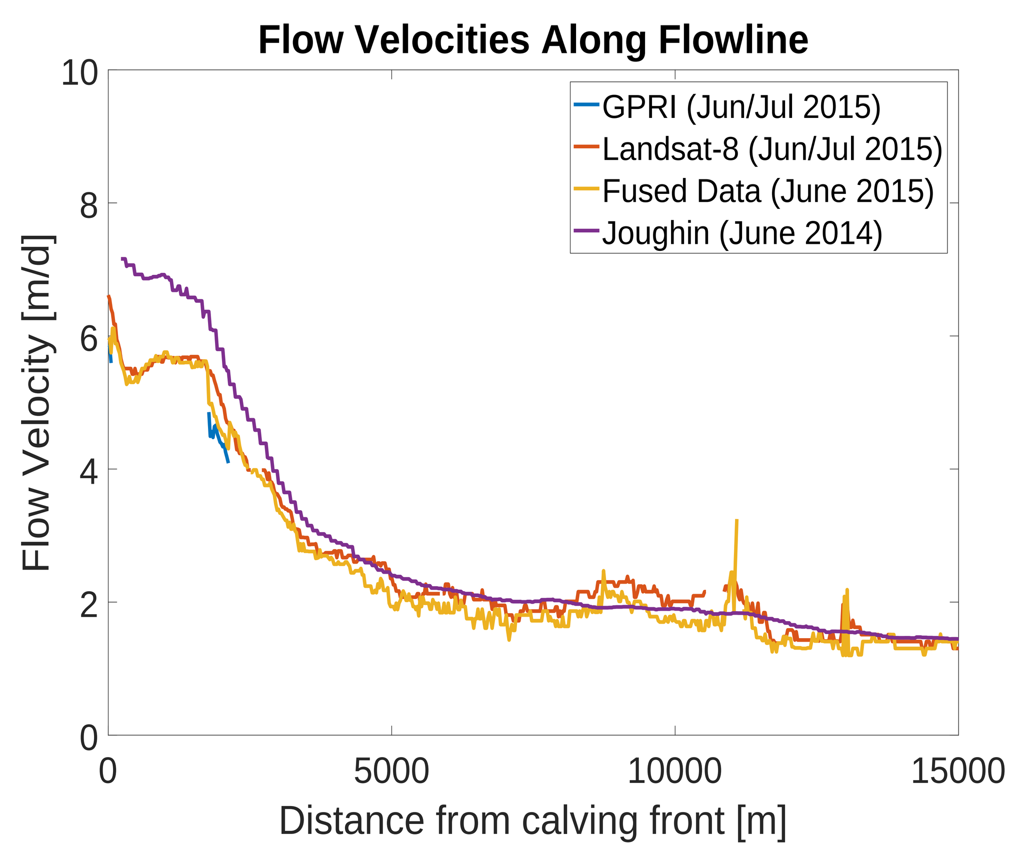
### *Statistical Analysis*




Statistical analysis shows general good agreement between flow velocities derived with spaceborne and GPRI data. The biggest differences can be found in regions bordering the calving front and the side of the glacier.

### *Data Assimilation*




## Conclusions and challenges

- Fusion of GPRI and space-borne data offers possibility to overcome intrinsic problems of different data sources
- General agreement to reference data from Joughin et al. (2010)
- Continuous velocity fields right to calving front allows to detect small scale variations in flow dynamics

### Challenges – Outlook

- Not applicable to areas in radar shadows
- Missing high-resolution DHM induces errors (geocoding/velocity adjustment)
- Application to SAR systems

## References

**Joughin, I.** (2002). Ice-sheet velocity mapping: a combined interferometric and speckle-tracking approach. Annals of Glaciology, 34, 195–201.

**Joughin, I., Smith, B.E., Howat, I.M., Scambos, T.A., & Moon, T.** (2010). Greenland flow variability from ice-sheet-wide velocity mapping. *Journal of Glaciology*, *56*, 415–430.

**Strozzi, T., Luckman, A., Murray, T., Wegmuller, U., & Werner, C.L.** (2002). Glacier motion estimation using SAR offset-tracking procedures. IEEE Transactions on Geoscience and Remote Sensing, 40.