University of Zurich[UZH]

Department of Geography

Variability in Glacier Flow Dynamics of a Greenland Outlet Glacier Using Sentinel-1 SAR Data: Validation with Multiple Ground-based Measurements

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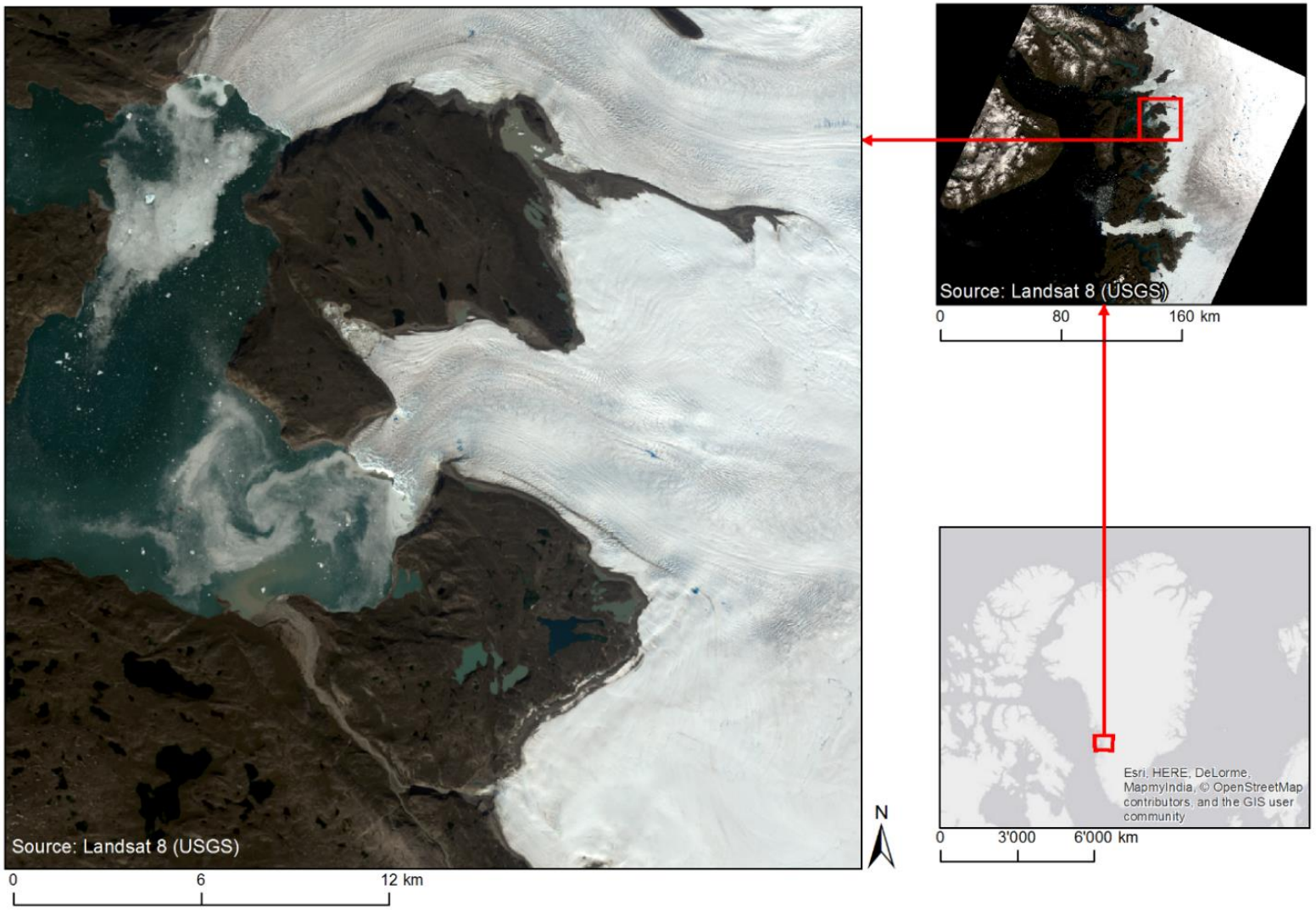
Area of Interest: Eqip Sermia



Area of Interest: Eqip Sermia

- Medium sized ocean terminating outlet glacier
- Calving Front Width: 3.5 km
- Calving Front Height: 30 - 50 m
- Well documented history with surveys of geometry and velocity starting in 1912

Aim of Study

- Extraction of glacier displacements from multi-orbit radar imagery at high spatio-temporal resolution

- Validation of results using multiple ground-based measurements

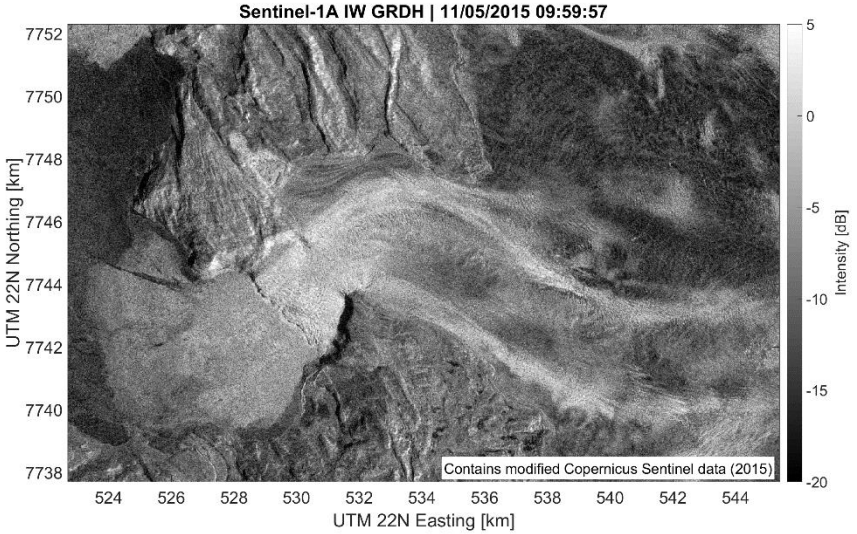
- Modeling of calving based on fracture and damage mechanics using derived flow dynamics to constrain certain model parameters

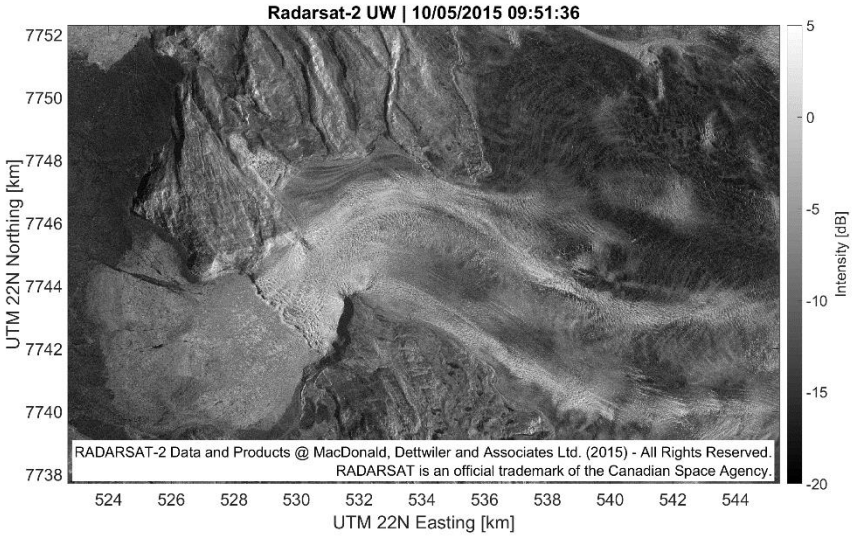
Data

Spaceborne

- **Sentinel-1A/1B**
  - 6/12 day repeat orbit
  - C-Band SAR (5.405 GHz)
  - Dual Polarization
  - Interferometric Wide Swath Mode
    - Pixel Spacing SLC: 2.3 x 17.4 m
    - Pixel Spacing GRDH: 10 x 10 m
  - Continuous data since 10/2014

- **Radarsat-2**
  - 24 day repeat cycle
  - C-Band SAR (5.405 GHz)
  - Quad-Polarization
  - Fine Quad/Ultra-Fine Wide Mode
    - Pixel Spacing FQ: ~5 x 5 m
    - Pixel Spacing UW: ~1.5 x 2.5 m
  - 13 FQ/7 UW scenes

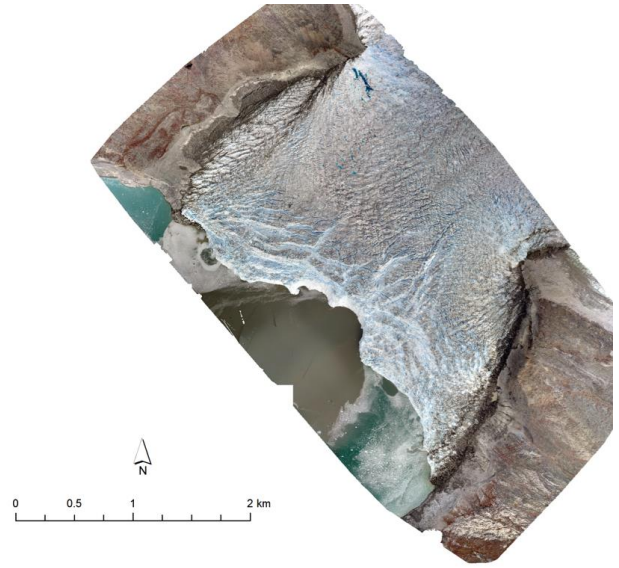




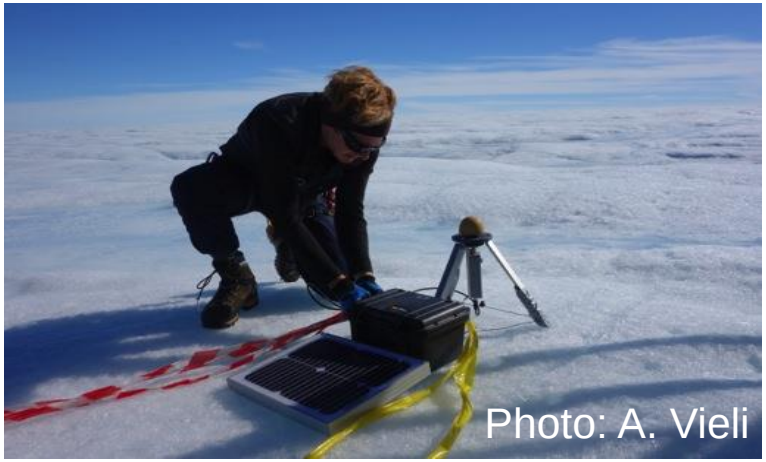
Data

Field Measurements

- **eBee Drone**
  - Wing-span: 1 m
  - Weight: 700 g
  - Area/flight: ~3 km^2
  - Pixel Spacing: 15 – 20 cm
  - 3 data acquisitions in 2016 over glacier tongue covering ~12.5 km^2



- **GPS Trackers**
  - Single-frequency GPS receiver, differential carrier-phase technique
  - GPS solutions calculated at 3 h/6 h/1 day intervals at the Geodesy and Geodynamics Lab of ETH Zürich (see Wirz et al., 2014)
  - 1 base station, 5 trackers on the glacier between 29/06/2016 – 25/08/2016



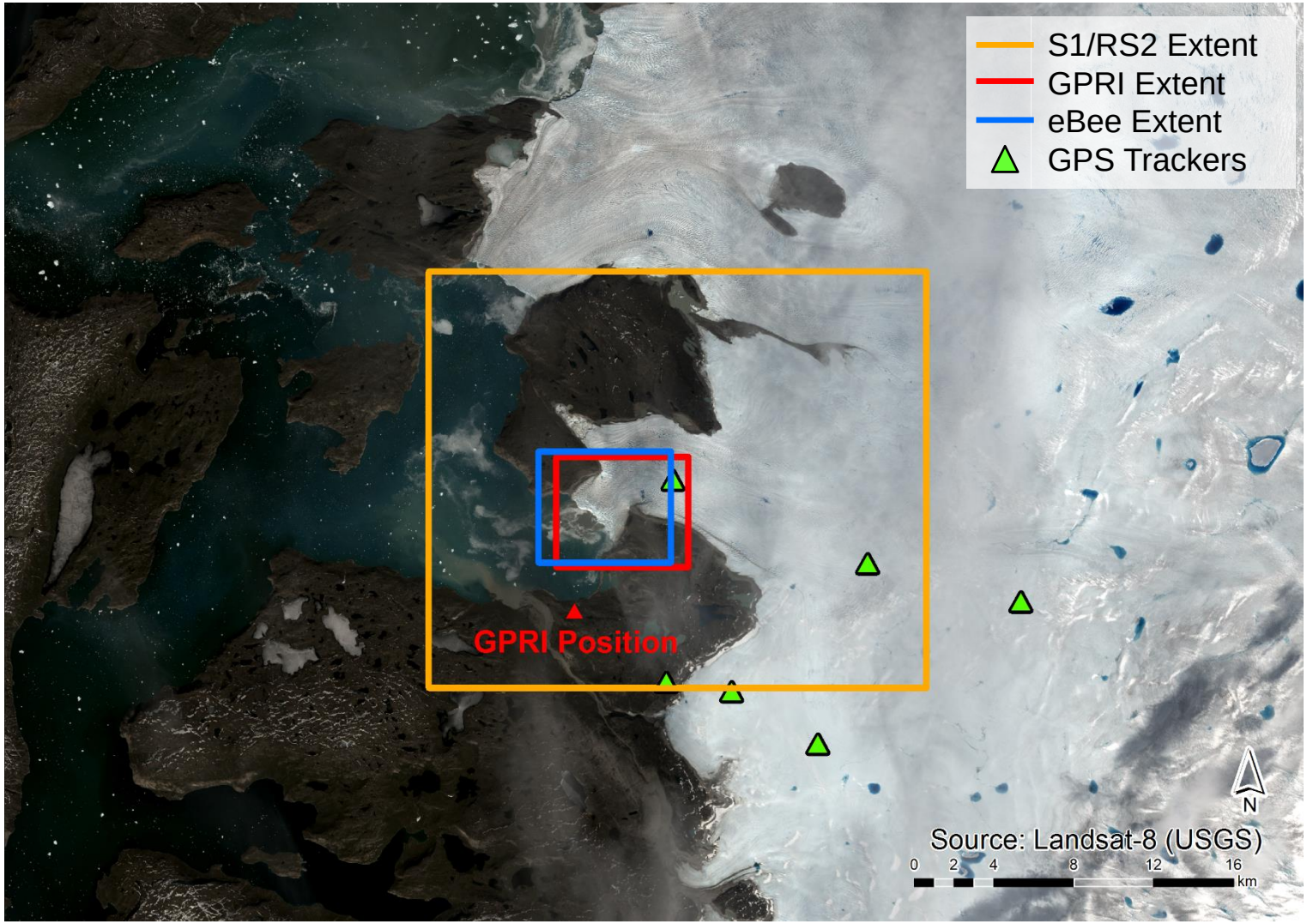
Wirz, V., Beutel, J., Gruber, S., Gubler, S., & Purves, R.S. (2014). Estimating velocity from noisy GPS data for investigating the temporal variability of slope movements. *Natural Hazards and Earth System Science*, *14*, 2503–2520.

Data

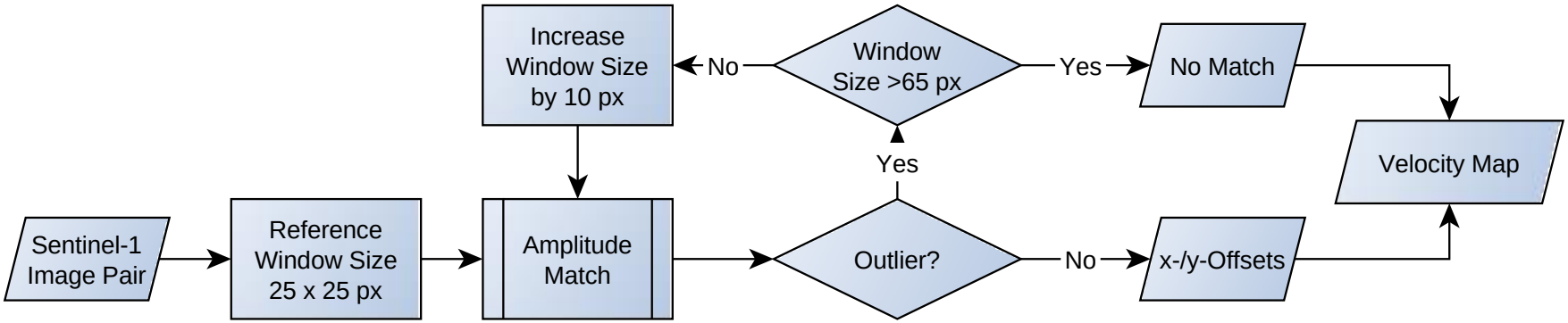
Field Measurements (cont.)

- **GAMMA Portable Radar Interferometer**
  - Frequency: 17.2 GHz
  - Displacement sensitivity: ~1 mm
  - Range Resolution: ~0.75 m
  - Azimuth Resolution: 14 m @ 2 km
  - Sampling frequency: 1 min^{-1}
  - Interferogram/amplitude image as result
  - Data acquired continuously for 7 days in 2016

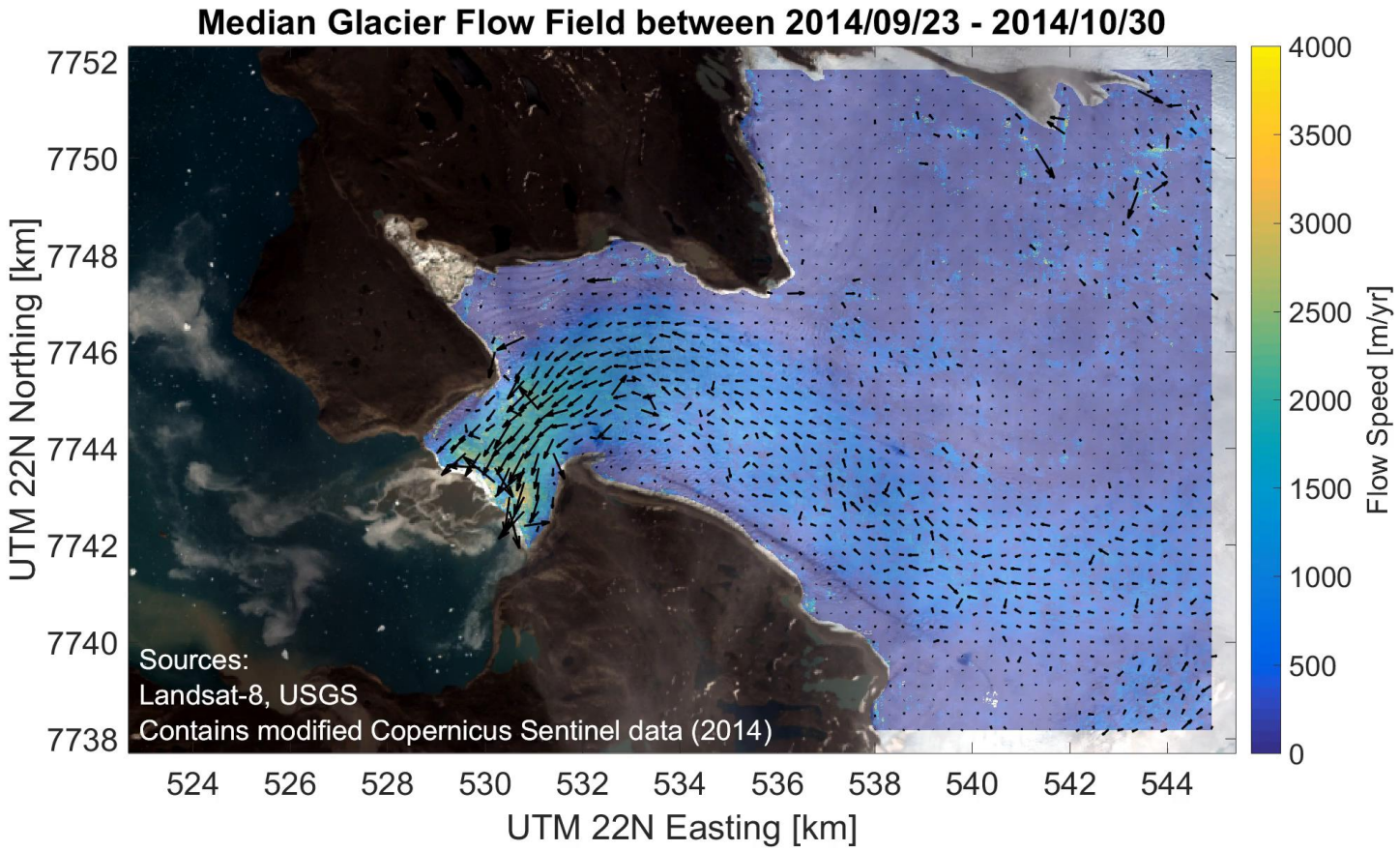
Data


S1/RS2 Extent
GPRI Extent
eBee Extent
GPS Trackers
GPRI Position
N
Source: Landsat-8 (USGS)
0 2 4 8 12 16
km

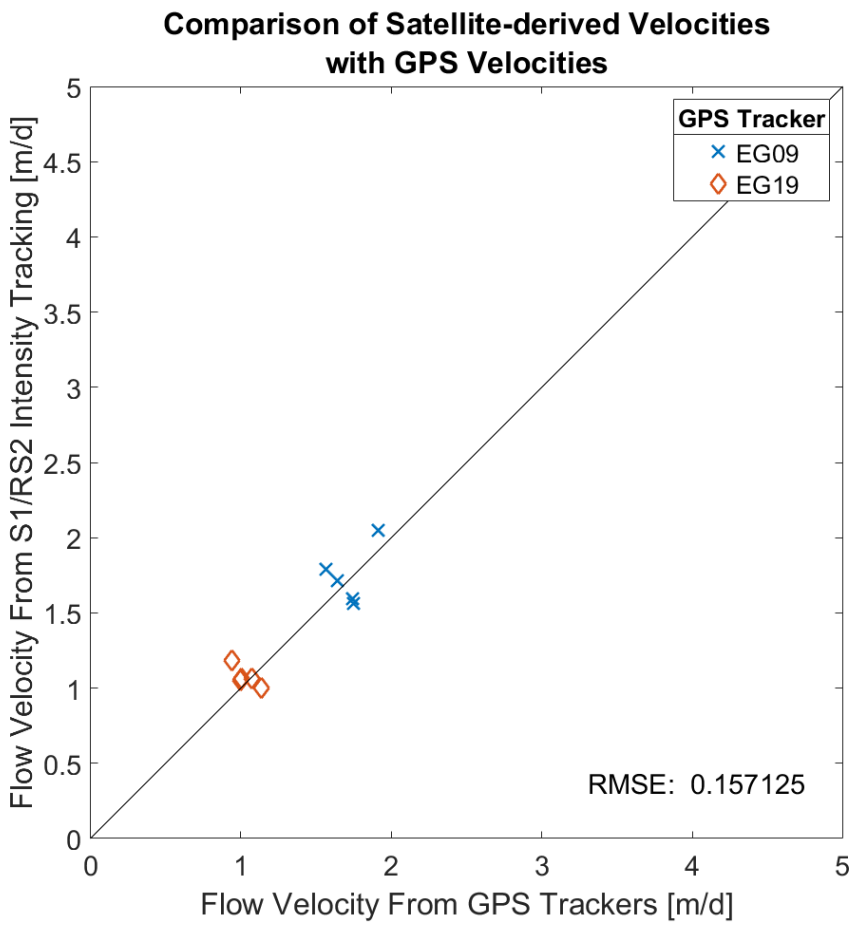
Method – Intensity Tracking



Results – Velocity Maps



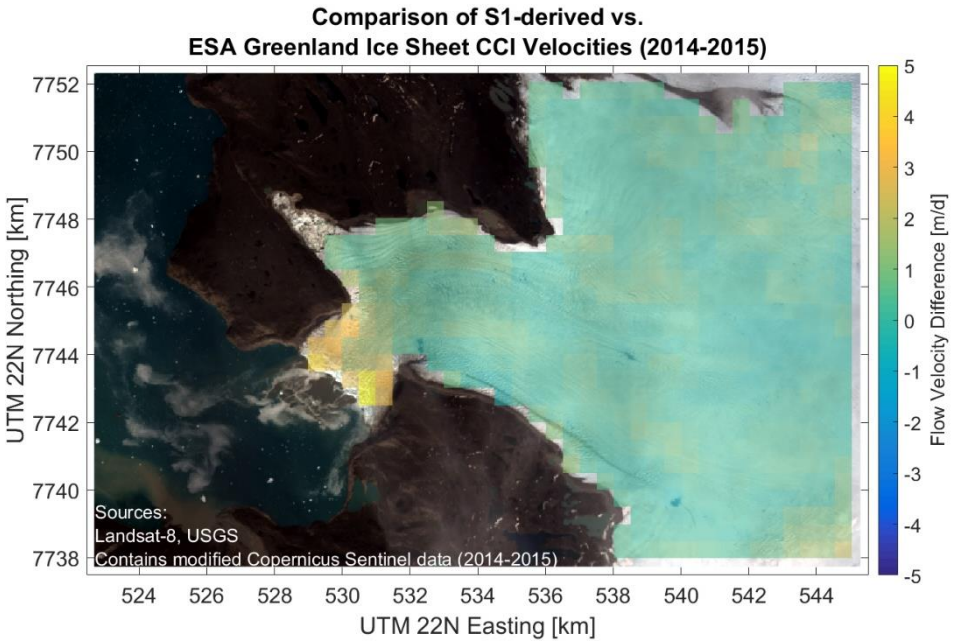
Results – Intensity Tracking based Flow Velocity (Sentinel-1/Radarsat-2) vs. GPS

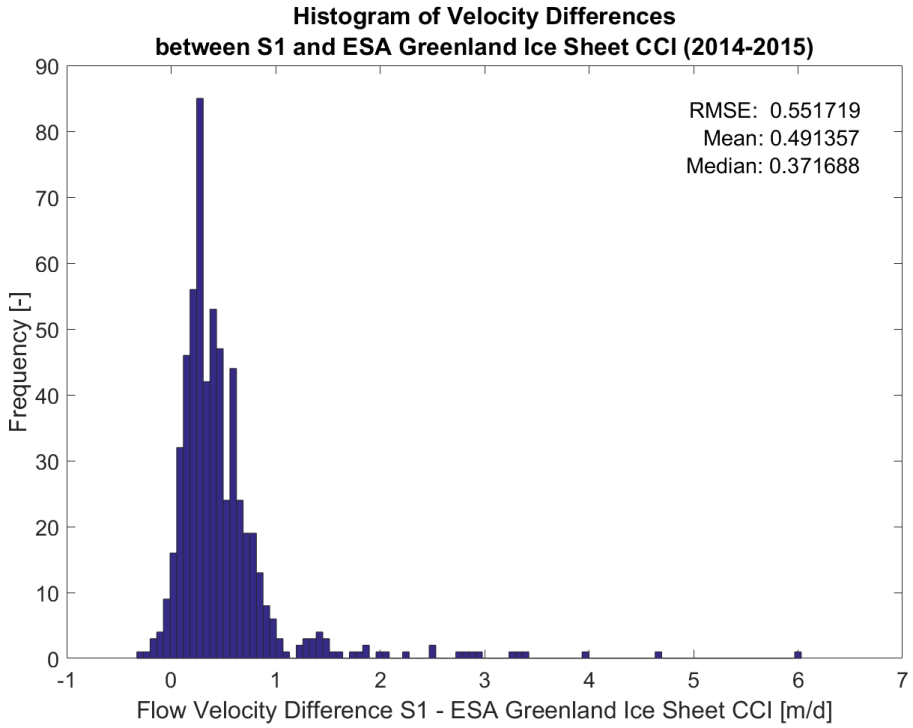


- GPS data processing according to Ahlstrøm et al. (2013)
- GPS Tracker EG09: good agreement with derived flow velocities
- EG19: Due to slow flow velocity (~1 m/d)/ 10 m pixel spacing not feasible for 12 days, but good agreements with 24 day baseline
- Errors in range of Ahlstrøm et al. (2013)

Ahlstrøm, A.P., Andersen, S.B., Andersen, M.L., Machguth, H., Nick, F.M., Joughin, I., Reijmer, C.H., Van de Wal, Roderik, S. W., Merryman Boncori, J.P., Box, J.E., Citterio, M., van As, D., Fausto, R.S., & Hubbard, A. (2013). Seasonal velocities of eight major marine-terminating outlet glaciers of the Greenland ice sheet from continuous in situ GPS instruments. *Earth System Science Data*, *5*, 277–287.

Results – Derived Velocities S1 vs. ESA Greenland Ice Sheet CCI Product





- General good agreement between offset tracking results and reference data from ESA GrIS CCI
- Bigger differences close to calving front with flow speeds >10 m/d

ESA Greenland Ice Sheet CCI project team (2016): ESA Greenland Ice Sheet Climate Change Initiative (Greenland_Ice_Sheet_cci): Greenland Ice Velocity Map Winter 2015-2016, v1.0.
Nagler, T.; Rott, H.; Hetzenecker, M.; Wuite, J.; Potin, P. The Sentinel-1 Mission: New Opportunities for Ice Sheet Observations. Remote Sens. 2015, 7, 9371-9389.

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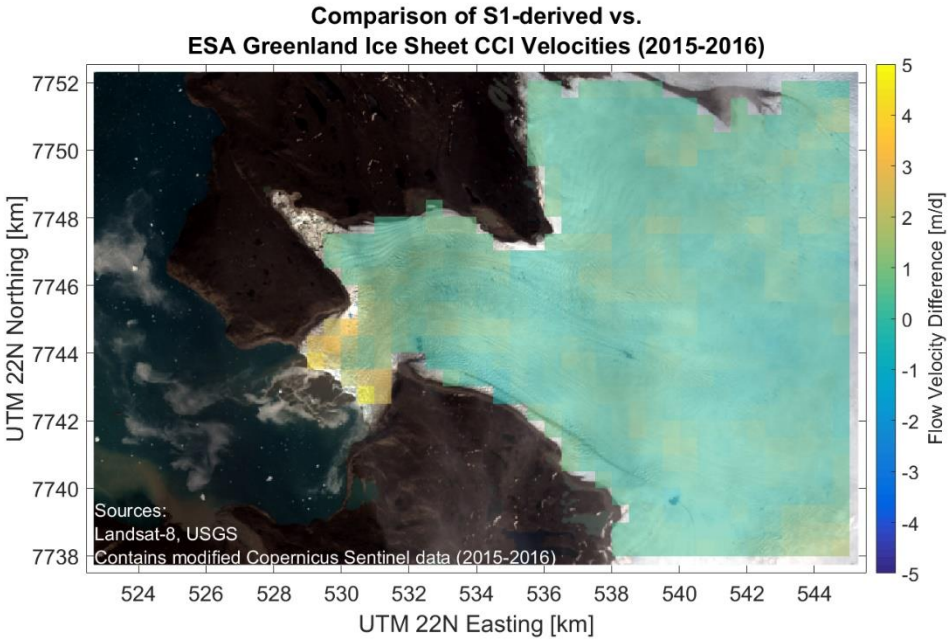

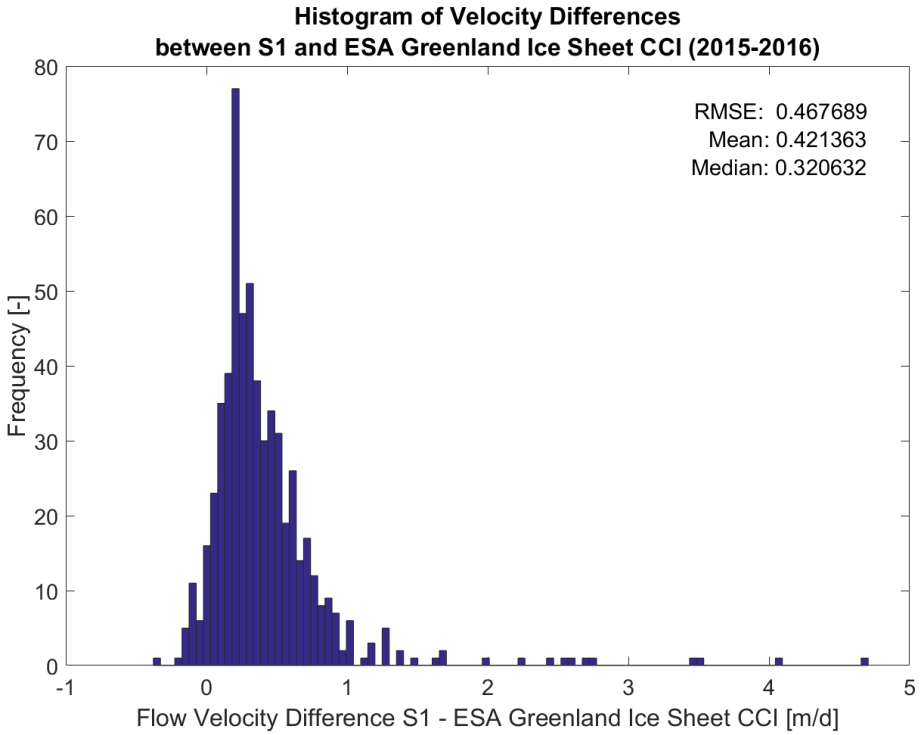

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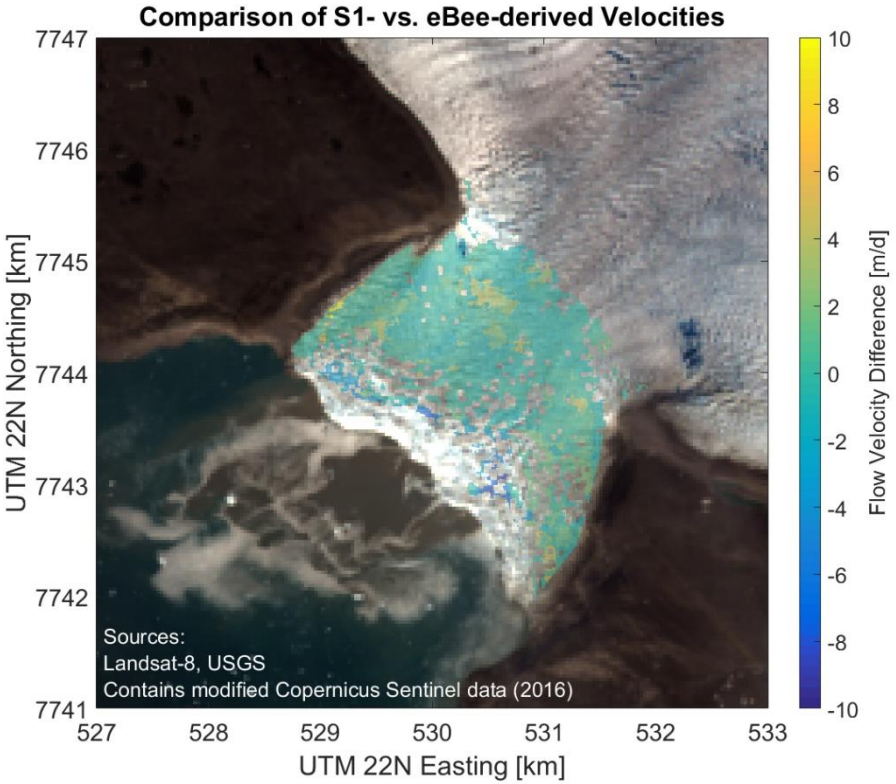
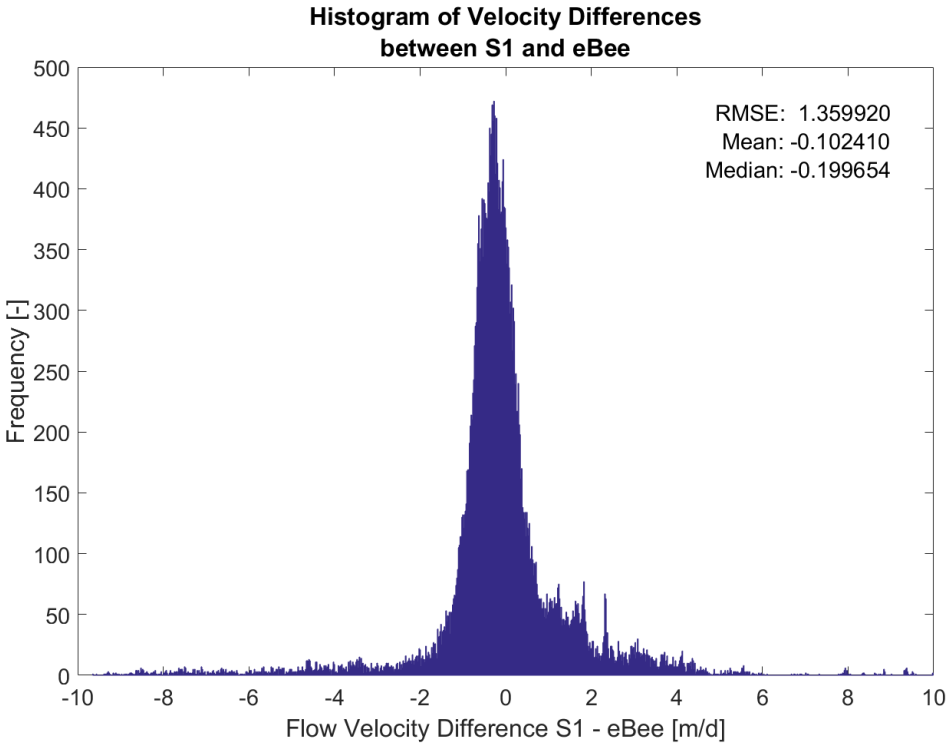
Nagler, T.; Rott, H.; Hetzenecker, M.; Wuite, J.; Potin, P. The Sentinel-1 Mission: New Opportunities for Ice Sheet Observations. Remote Sens. 2015, 7, 9371-9389.

Results – Derived Velocities S1/RS2 vs. eBee





- Good agreement despite differences in resolution, temporal baseline and raw data
- Limitations of SAR close to calving front due to mixed pixels (sea/glacier) and incoherent flow pattern

Conclusion & Outlook

- Spatially detailed surface motion estimates obtainable from currently operational spaceborne systems
- Combination of air- and spaceborne acquisitions allows for high resolution flow field up to calving front
- Six-day repeat of Sentinel-1 constellation offers possibility for analysis of short-term variability of ice flow and more reliable results at the calving front
- Inclusion of interferometric GPRI data as additional ground-truth measurements at high spatio-temporal resolution

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