Copernicus Geo Big Data e Google Earth Engine: strumenti chiave per il monitoraggio dei ghiacciai

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Goal & Context

Goal of the work

Create a **new and global glaciers surface velocity monitoring tool**:

- supporting climate change investigations and data exchange
- exploiting Copernicus Sentinel-1 continuous and free big data

Glacier surface velocity: why?

Glacier surface velocity is a crucial indicator of glacier changes, being linked to:

- **mass and hydro balance**, allowing to compute the flow rate that reaches the ablation area
- **stability**, measuring the glacier sliding rate
- material **transportation and erosion** phenomena
- **ice thickness and rheology**

International Organizations for glaciers

Worldwide glaciers information

Three organizations:

- the World Glacier Monitoring Service (WGMS)
- the Global Land Ice Measurements from Space (GLIMS)
- the US National Snow and Ice Data Center (NSIDC)

under the **Global Terrestrial Network for Glaciers (GTN-G)** Executive Board coordination, collect and publish **standardized information about**:

- changes in mass, volume, area and length of glaciers (**glacier fluctuations**)
- perennial ice distribution (**glaciers inventory**)

Highlight

No standardized and routine updated global database of glaciers surface velocity is presently available based on Sentinel-1 data

Glacier surface velocity: how, at present? - 1

In-situ Geomatic surveys (GNSS, total stations, photogrammetry)

- **PRO** - high accuracy and (possible) high temporal resolution
- **CON** - dependent on logistic constraints
- **CON** - difficult to cover wide areas
- **CON** - usually very low temporal resolution
- **CON** - not allowing the study of the complex ice-dynamics
- **CON** - (very) expensive

Overall comments

- Many examples, both historical and recent
- Suited for **limited areas only, not applicable for large and wide areas**

Glacier surface velocity: how, at present? - 2

Optical Remote sensing (satellite imagery)

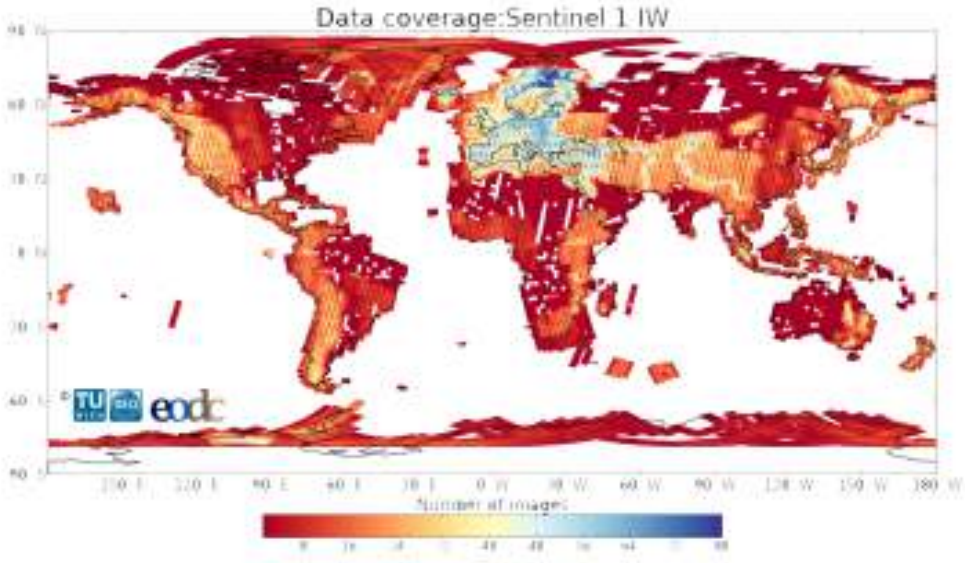
- **PRO** - continuous monitoring of wide areas
- **PRO** - independent from logistic constraints
- **CON** - dependent on illumination and weather conditions (clouds)
- **CON** - low spatial and temporal resolution (revisit time) for free imagery

Overall comments

- Examples of glaciers surface velocity fields based on LANDSAT 7 and ASTER imagery (both with ground resolution of 15 m) are included in GLIMS database
- Routine computation by NASA based on Landsat 8
- **Significant limitations**, not fully suited for a global standardized glacier monitoring

Sentinel-1: a $\pi\alpha\nu\alpha\kappa\epsilon\iota\alpha$ for surface velocity

- **continuous and free** imagery
- **good spatial** (up to 5 m) and **temporal** (6 days, with twin Sentinel-1 satellites) **resolution**
- **independence from illumination and weather**



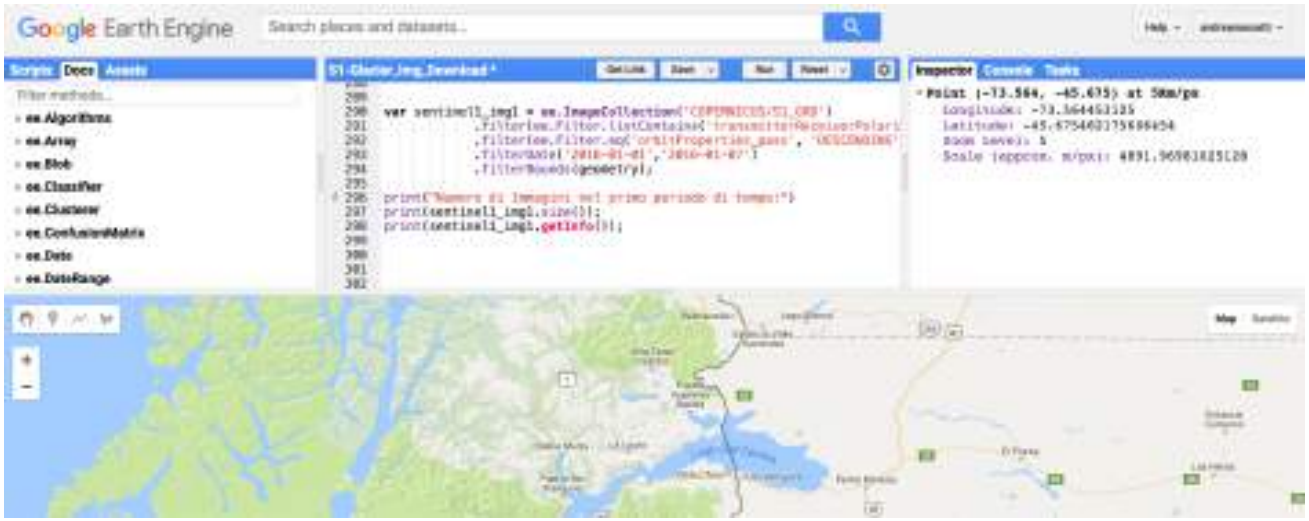
Our idea

Sentinel-1 data are **perfectly suited** for developing a **new and global glaciers surface velocity monitoring service (*ICESpeed*)**

Google Earth Engine: a key tool for *ICESpeed*

Google Earth Engine (GEE) is a computing platform recently released by Google "for petabyte-scale scientific analysis and visualization of geospatial datasets"

- GEE enables researchers to **access geospatial information** and satellite imagery, for global and large scale remote sensing applications (**over than two petabytes** of geospatial data, including Sentinel-1 and 2 data)
- GEE can be used to **perform geospatial analysis**, exploiting a dedicated HPC infrastructure, also running **user-developed software** through the **GEE API**



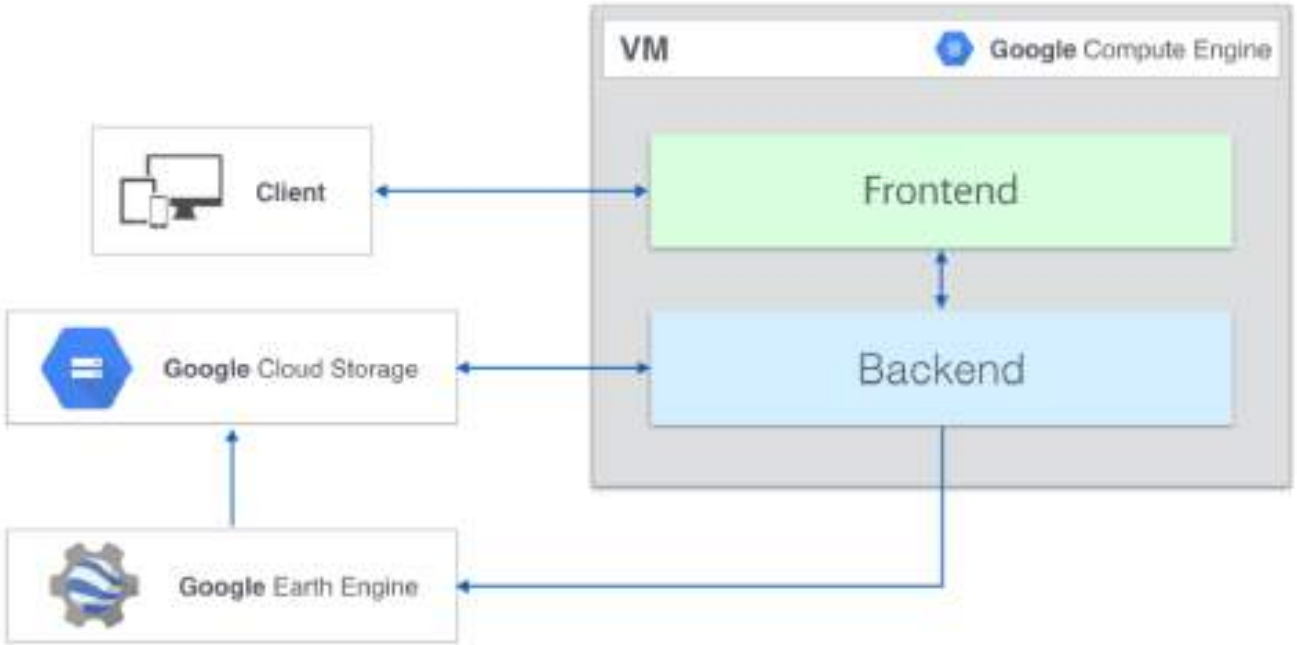
Software and processing steps

A **new software** was developed in Python based on **Free and Open Source** libraries (OpenCV, GDAL), to **estimate glaciers surface velocity under GEE**

Main processing steps:

- **glacier AOI identification** (GLIMS database)
- images **stack selection and guided co-registration** (glacier area masked)
- **for each image pair**: glacier surface velocity estimation through **offset tracking technique**
- **for a chosen time interval: global least squares estimation and outlier filtering procedure** (spatial and temporal high redundancy, constant velocity for each grid node in time sub-intervals)

Platform architecture



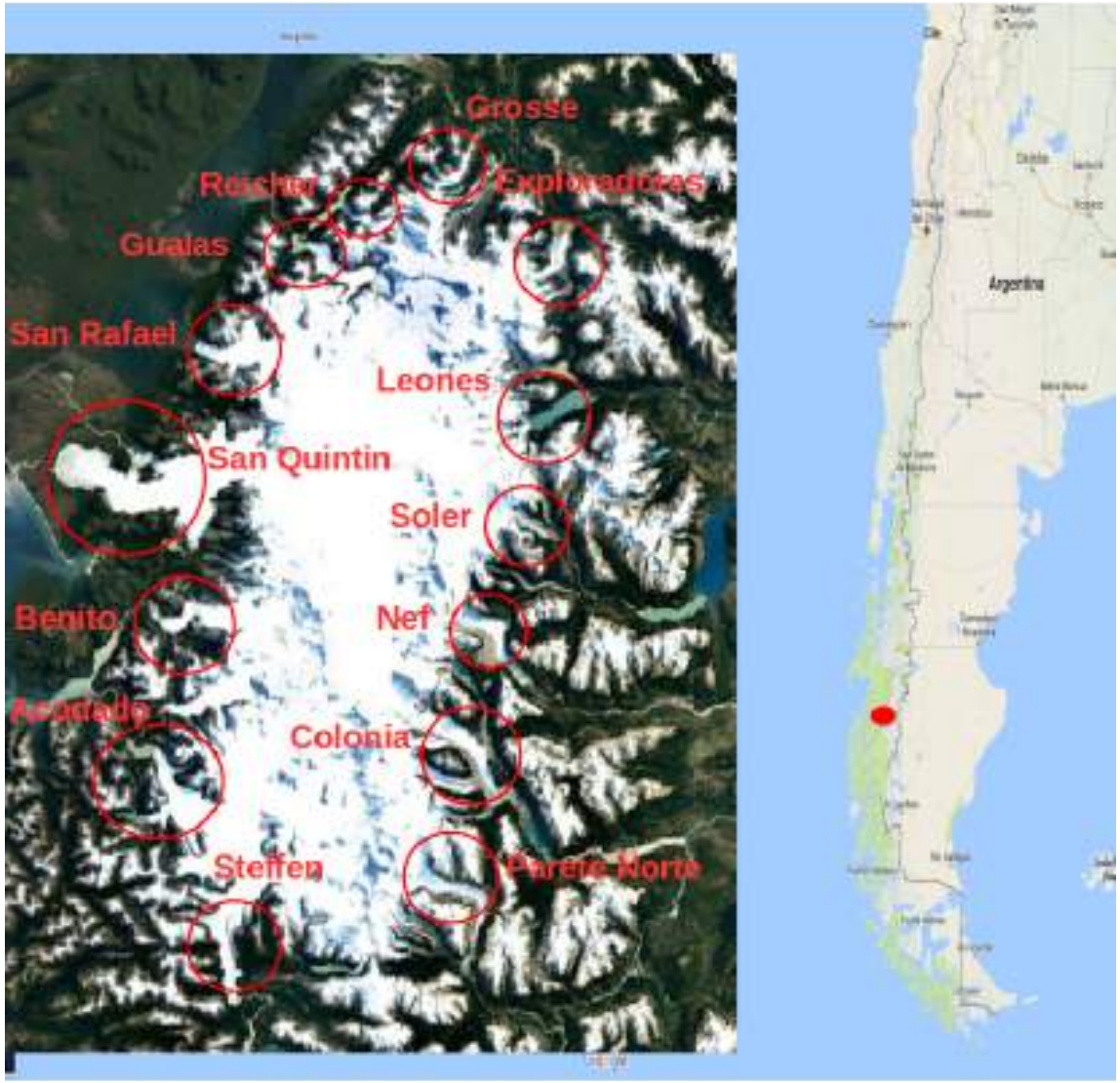
GEE Tasks:

- Image selection and filtering
- Stack co-registration on the AOI
- Upload ready to use data to GCS

GCE VM Tasks:

- Offset tracking processing
- LS estimation and Outliers filtering
- Frontend hosting

Study area: Northern Patagonian Icefield (Chile)



Study Area and Dataset

28 glaciers have been investigated, among whose **Exploradores**, **San Quintin**, **San Rafael**, **Parete Norte** and **Leones** Glaciers

Features:

- different types: mountain glaciers, tidewater glacier
- different fluid-dynamic behaviours
- covered surface: overall 4200 sq. km

Processing parameters:

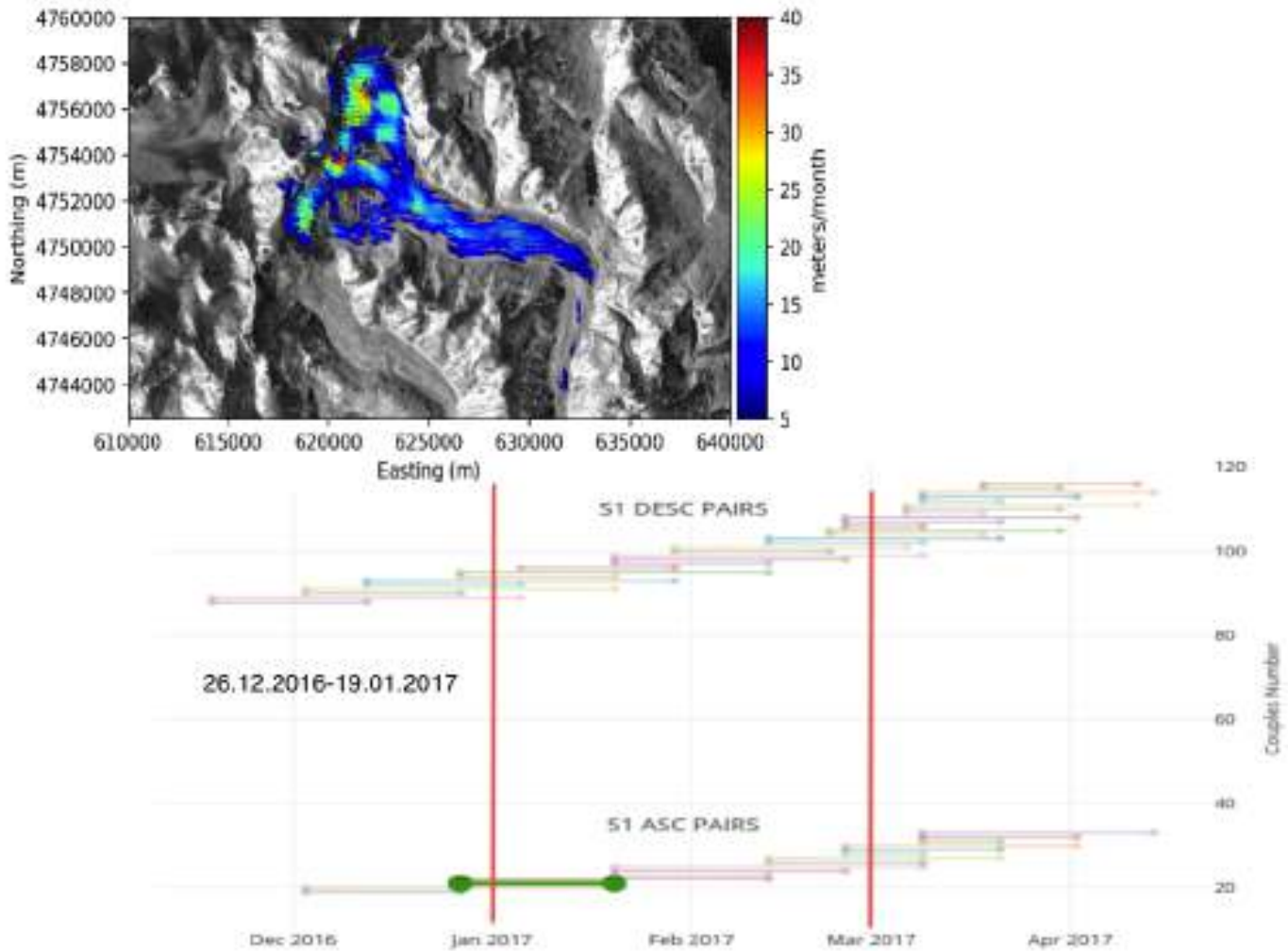
- grid posting: 200 meters
- LS estimation interval: 2 months
- LS estimation sub-iterval: 1 month

spatial resolution: 10 meter
temporal resolution: 12-24-36-48 days

Highlight

Big data (about 1800 images) processing: at least one image per month to highlight **seasonal variations** of glaciers surface velocity

Big Data Processing



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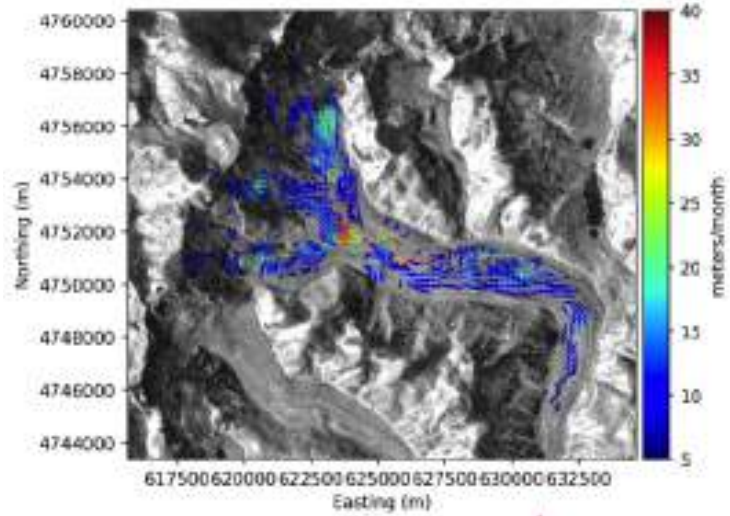
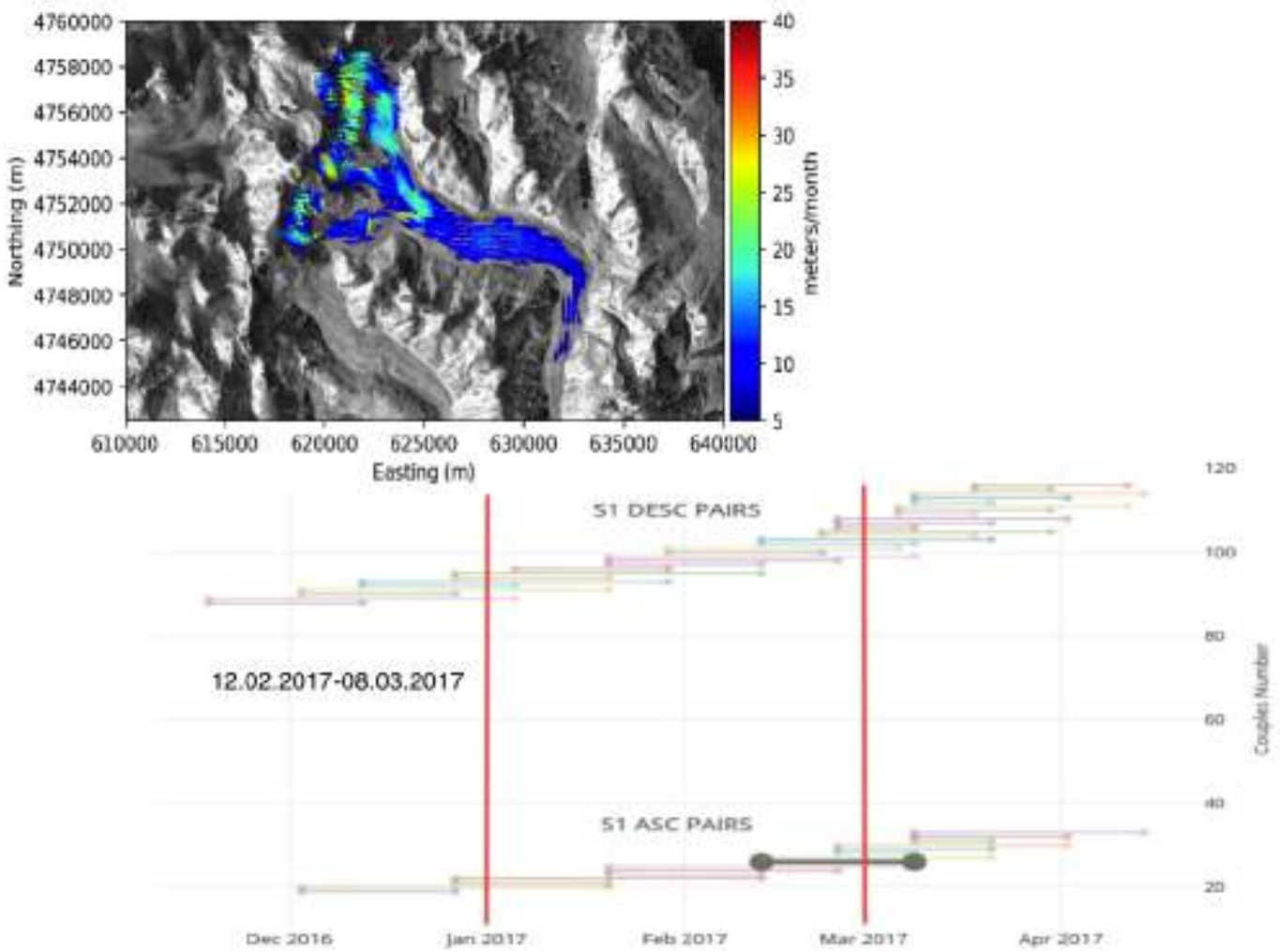
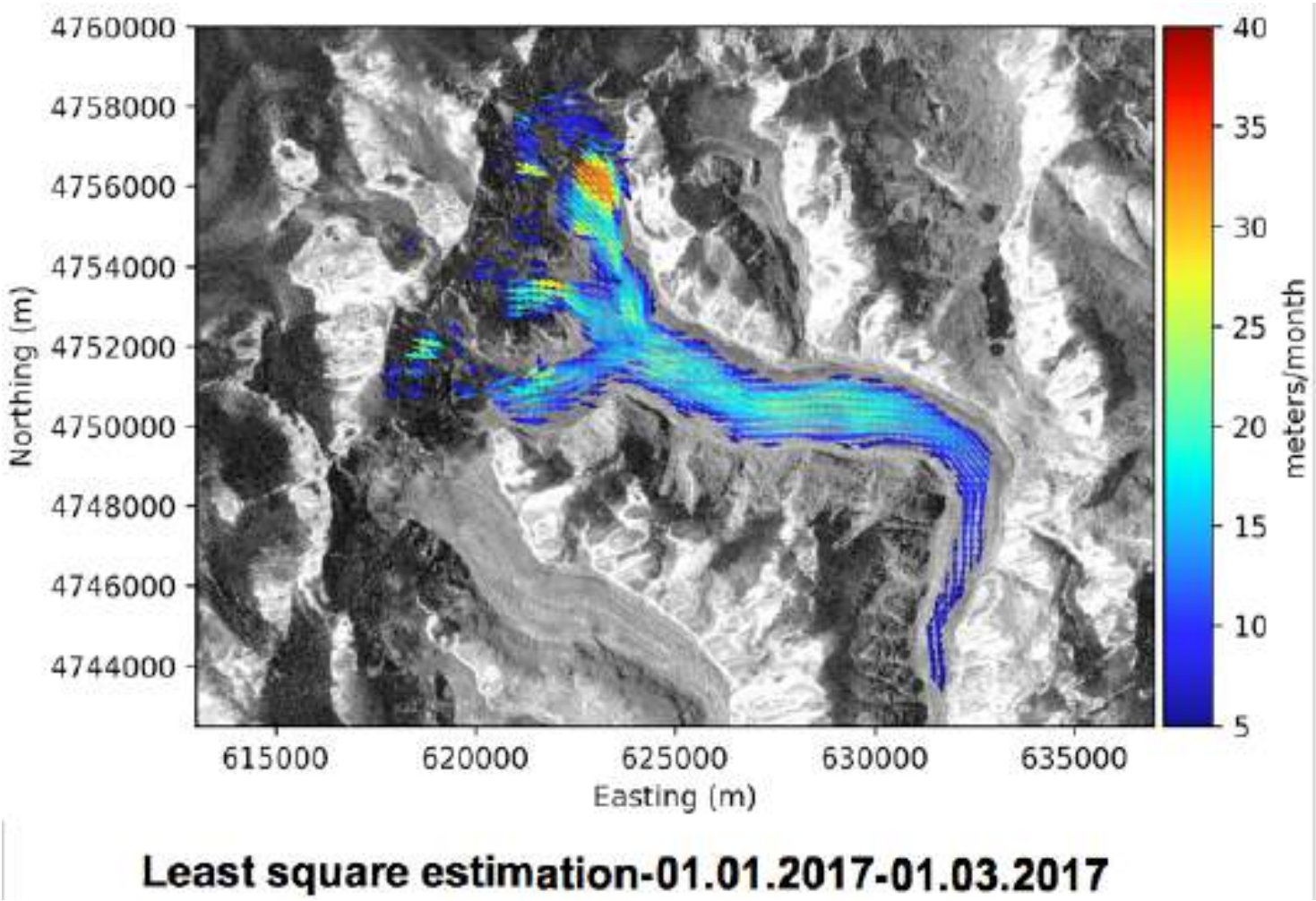
Big Data Processing



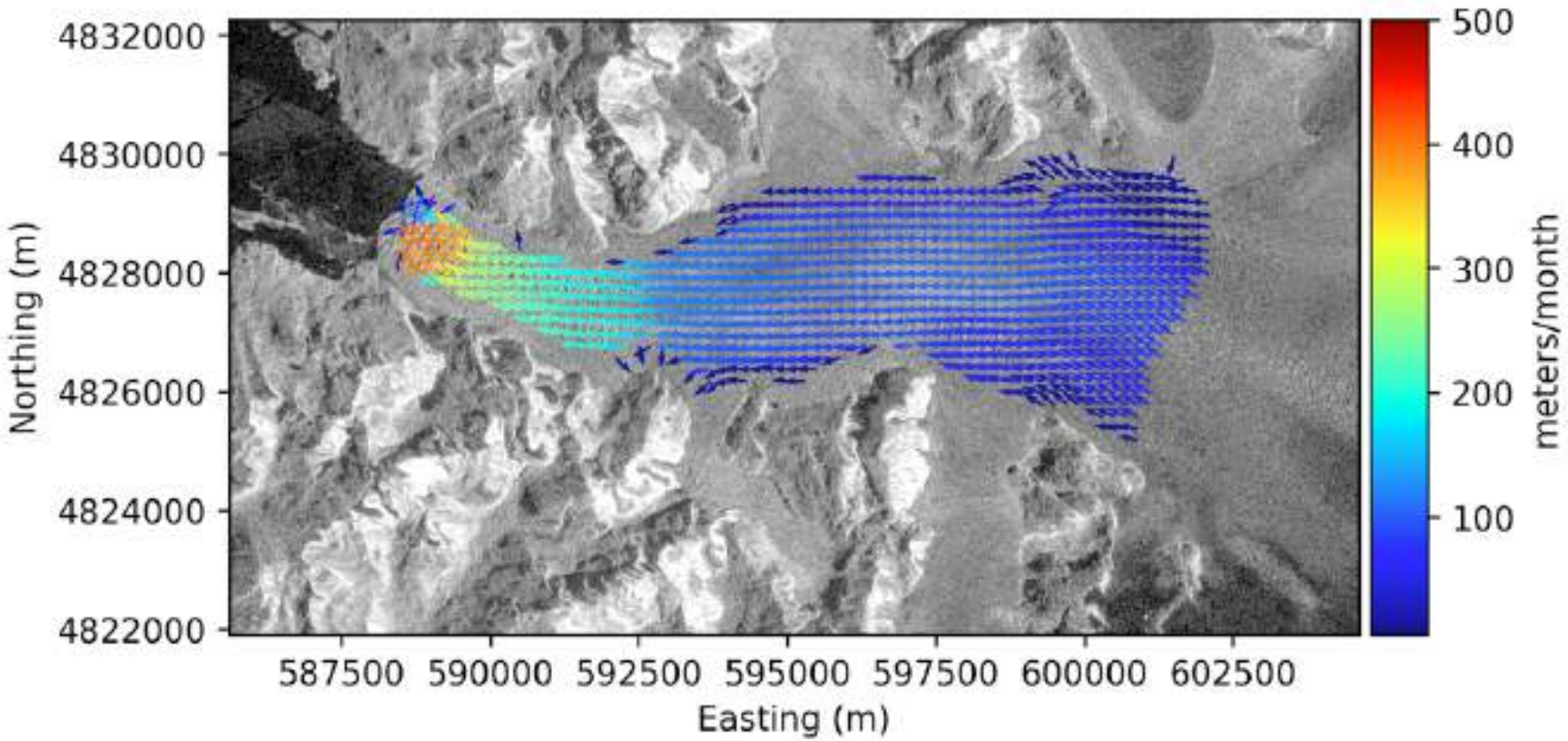
Big Data Processing



Single pair vs. LS estimation: Parete Norte

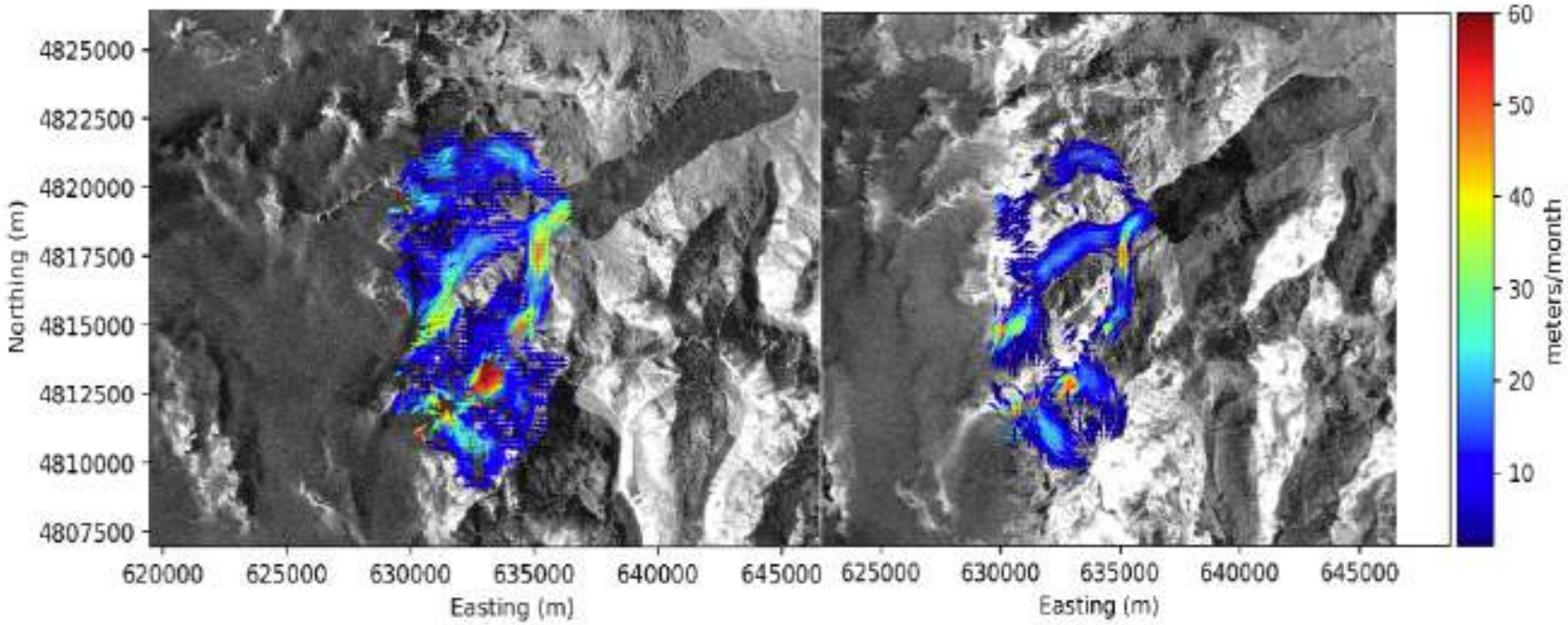


LS estimation: San Rafael



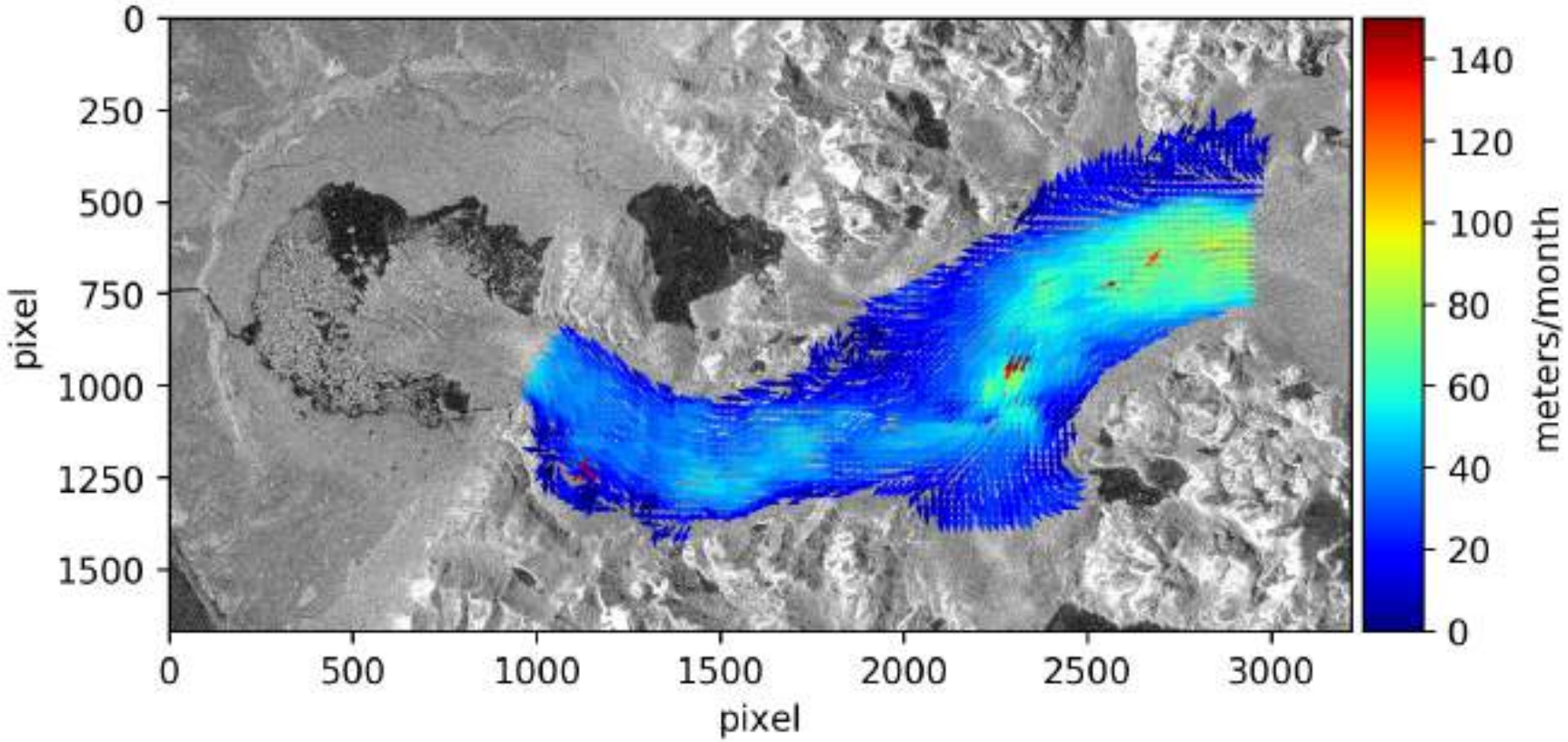
Least square estimation-01.03.2017-01.05.2017

Single Pair vs Least Square: Leones Glacier

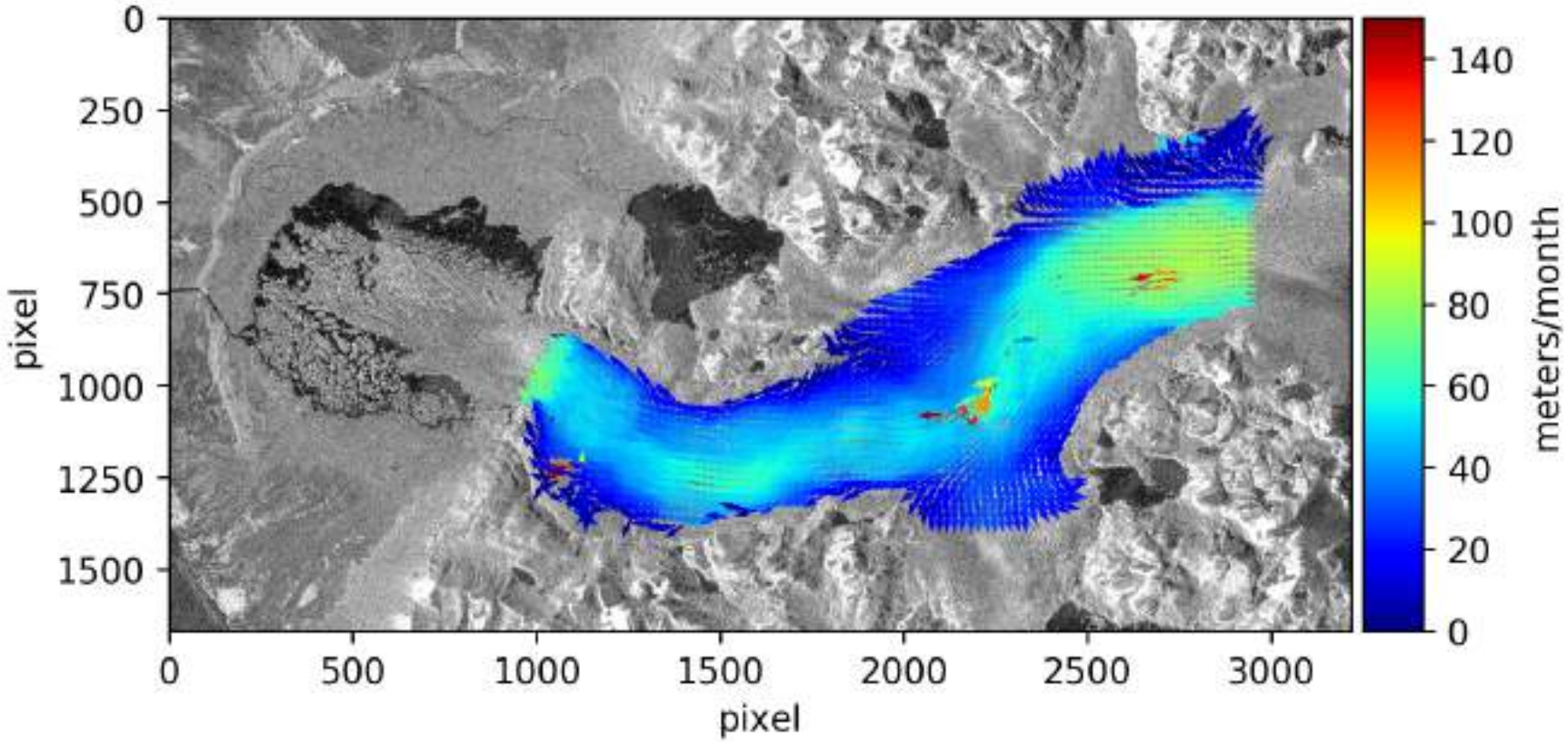


Matching 20.03.17-01.04.17 Least Square 01.03.17-01.05.17

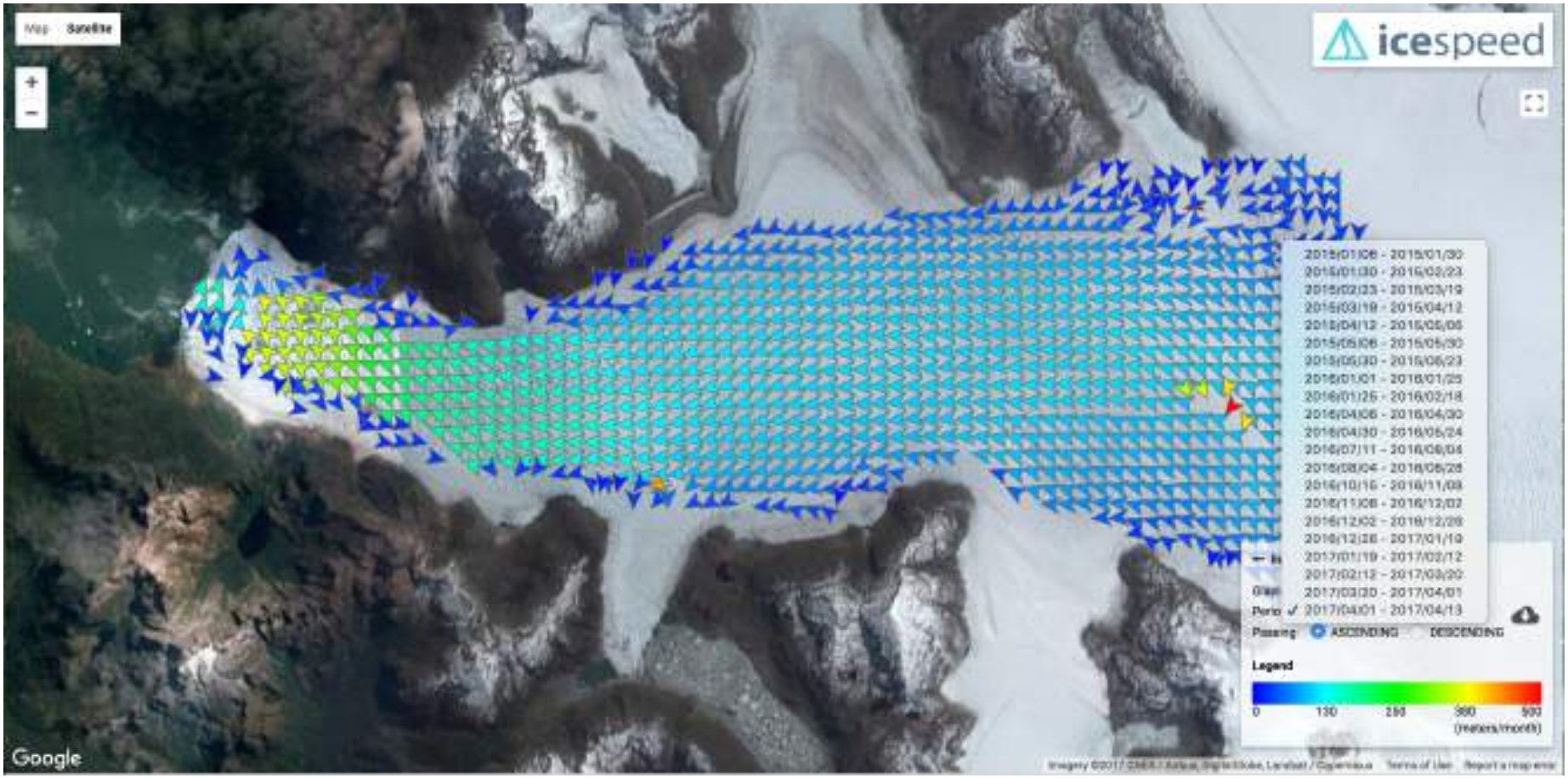
Seasonal effect: San Quintin (Winter)



Seasonal effect: San Quintin (Summer)



Data & Results sharing



Conclusions

Technical

- **a state-of-the-art FOS software** was developed to perform offset tracking on SAR (actually, and also on optical) imagery for glacier surface velocity fields estimation
- the software was checked against other renown software with quite similar results

Paradigmatic - MORE RELEVANT

- the availability of **free data and HPC infrastructure** allows to reverse the approach to geospatial analysis:
  NOT data to user-software BUT user-software to data
- **unprecedented space-time detailed (global and continuous)** geospatial analyses

Future prospects

Technical - Scientific

- to test the software with imagery acquired by **other Optical and SAR sensors** (i.e. COSMO-SkyMed, TerraSAR-X, past SAR missions; Sentinel-2, Landsat 8)
- to use the obtained **results within a glacier flow model**

Paradigmatic

- to complete the development of the *ICESpeed* frontend, in order **to share and publish the obtained results**, possibly directly in GEE

Thank you very much for your kind attention