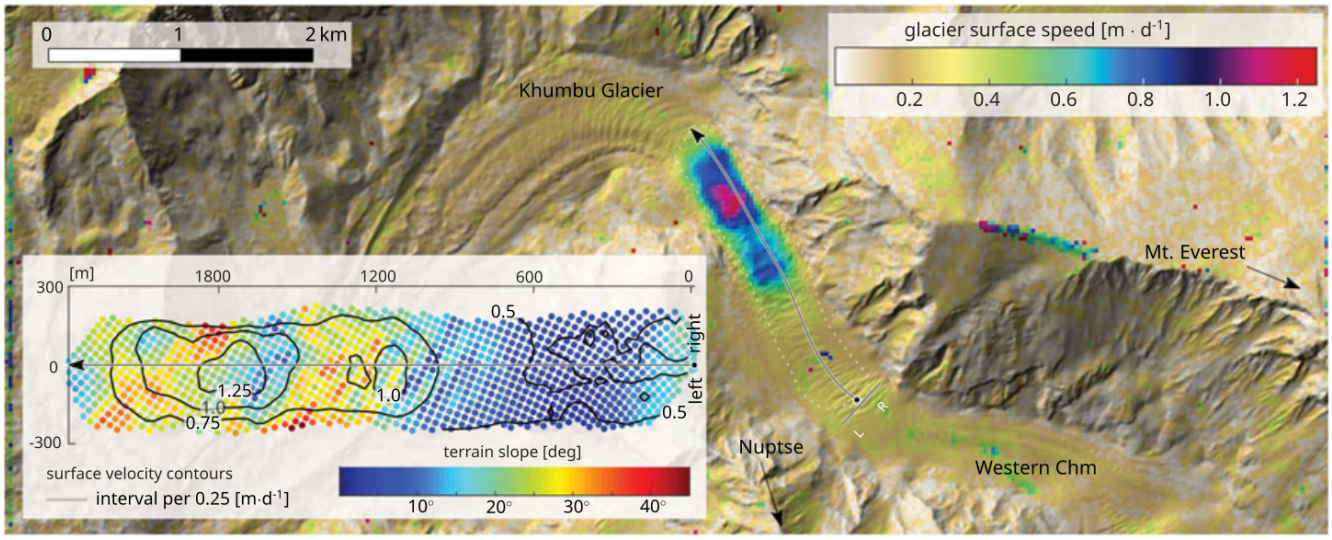

Figure 1: Estimated glacier surface flow velocity over the Khumbu icefall. From [Altena et al., 2020].

Internship offer (Master's degree)

Deep similarity learning on remote sensing data for glacier ice flow prediction.

Where : Institut de l'information géographique et forestière (IGN), Champs-sur-Marne (77), France.

Internship supervision : Alexandre Hippert-Ferrer (alexandre.hippert-ferrer@ign.fr).

Context of the study

Glaciers' response to climate fluctuations makes them excellent indicators of climate change. Glaciers provide local populations with freshwater resources and currently contribute 25–30% to sea-level rise. Despite substantial improvements in the representation of the ice masses in the past decades, the thickness distribution of the world's glaciers is still subject to large uncertainties [Millan, 2022]. A variable of paramount importance is the glacier *surface flow velocity* because it governs the mass transfer from the accumulation to the ablation zone. It is also an essential constraint in glacier models for obtaining accurate simulations of ice dynamics. Since the launch of Landsat-8 and Sentinel-1/2 satellites programs in 2013 and 2015, respectively, satellite images offer the possibility to estimate glacier surface velocities thanks to high satellite revisit time and coverage. To estimate surface velocity, a widely used technique consists in computing or predicting the similarity between patches of paired images acquired at different time instances. In its classical version, this technique aims at maximizing a correlation-based function between the two images, and it has been applied to estimate glacier velocity from optical and synthetic aperture radar (SAR) images. More recently, a promising family of methods based on deep learning has emerged to learn ground displacements. Particularly, convolutional neural networks (CNN) have been succefully applied to estimate earthquakes ruptures and landslides movements with optical images [Montagnon, 2024].

Because remote sensing observation of glaciers poses several challenges (complex terrain geometry, presence of clouds and snow, heterogeneous displacements, etc.), only a few studies have focused on adapting deep learning methods for fast-changing objects such as glaciers.

LaSTIG
LABORATOIRE
EN SCIENCES ET TECHNOLOGIES
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Sous la co-tutelle de :
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Main objectives of the internship

The main goal of this internship is to design a deep similarity learning architecture for glacier displacement monitoring with optical images. Particularly, the intern will focus on the following tasks:

1. Adapt `DeepSim-nets`, a recent image matching architecture [Chebbi, 2023], to build a dedicated feature extraction module which extracts discriminative representations of the data through spatio-temporal embedding;
2. Design a training-validation-testing strategy with a **physics-informed contrastive loss**;
3. Generate training data with the following strategies : (1) generate surface velocities with a particular focus in heterogeneous areas as crevasses, icefalls and glacier terminus, which are challenging to predict ; (2) self-sample training [Shen, 2022] and (3) manual annotation pairs of pixels in image patches using valuable human expertise.

Expected work and deliveries

- Construction of a corpus to establish a solid state-of-the-art of image similarity learning methods, then glacier velocity prediction using deep learning, with a particular distinction between *end-to-end* versus *hybrid* approaches;
- Development of a deep similarity learning model and generation of realiable annotated matching training samples in collaboration with a team of glaciologists in Grenoble;
- Development and production of open-source code on a dedicated platform (Github, GitLab);
- Promotion of internship work through the production of technical reports and oral presentation materials intended for dissemination to the lab and more broadly to the scientific community.

Important information

Prerequisites: The internship requires a genuine interest and curiosity in Earth sciences (glaciology and climate science in particular). Strong skills in statistical mathematics, deep learning, computer vision, and remote sensing are expected. Proficiency in one or more machine learning libraries in Python (PyTorch, Tensorflow, Keras) is expected. A good level of scientific computing with Python (scipy, scikit-learn, numpy) is also required.

Host Structure: LaSTIG Laboratory, IGN/ENSG, 6-8 avenue Blaise Pascal, 77420 Champs-sur-Marne, France (located less than 30 minutes from the Nation metro station in Paris). The candidate will work within the `Strudel` team, which specializes in the study of spatio-temporal structures for territorial analysis. Travel or short stays at the Institute of Geosciences and the Environment in Grenoble will be considered.

Stipend: 600.60 euros/month (net).

Internship duration: 6 months from Feb/March 2026.

Continuation with a doctoral contract: strongly recommended.