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# DMP du projet "Water and Ice-related thermo-mechanical processes in the fractures of Steep alpine bedrock Permafrost"

Plan de gestion de données créé à l'aide de DMP OPIDoR, basé sur le modèle "ANR - Modèle de PGD (français)" fourni par Agence nationale de la recherche (ANR).

## Renseignements sur le plan

<b>Titre du plan</b>	DMP du projet "Water and Ice-related thermo-mechanical processes in the fractures of Steep alpine bedrock Permafrost"
<b>Livrable</b>	Livrable WISPER v3
<b>Version</b>	Version intermédiaire
<b>Objet/périmètre du plan</b>	Non applicable
<b>Domaines de recherche (selon classification de l'OCDE)</b>	Earth and related environmental sciences
<b>Langue</b>	eng
<b>Date de création</b>	2020-09-24
<b>Date de dernière modification</b>	2021-11-23
<b>Licence</b>	Creative Commons Attribution 4.0 International
<b>Documents (publications, rapports, brevets, plan expérimental....), sites web associés</b>	<ul style="list-style-type: none"><li>• Paper : 10.1029/2021JF006394</li><li>• Website : <a href="https://edytem.cnrs.fr/projet-anr-wisper-anr-project-wisper/">https://edytem.cnrs.fr/projet-anr-wisper-anr-project-wisper/</a></li><li>• Paper : <a href="https://doi.org/10.1002/ppp.2110">doi.org/10.1002/ppp.2110</a></li></ul>

## Renseignements sur le projet

<b>Titre du projet</b>	Water and Ice-related thermo-mechanical processes in the fractures of Steep alpine bedrock Permafrost
<b>Acronyme</b>	WISPER

## Résumé

WISPER aims at coupling thermal, hydrological and mechanical processes associated to water and icing in the fractures of alpine rockwalls permafrost to better understand (i) permafrost degradation processes and (ii) the increase in rockfall frequency in high mountain areas.

Permafrost degradation is generally seen as the result of (i) the slow heat propagation from the rock surface in the saturated rock mass and (ii) the infiltration and circulation of water in the fracture provoking a shortcut between the surface and subsurface. And rockwall failures are attributed to the (i) ductile-brittle failure of warming ice-filled fractures and to (ii) the stress caused by water infiltration.

While the thermal and mechanical processes of rockwall permafrost saturated and homogeneous (unfractured) have been investigated since about a decade, water-related processes remain the main difficulty in the interpretation and quantitative prediction of permafrost degradation and failure mechanisms. The lack of studies about such hydrological processes is due to their (i) complexity which involves non-linear thermal responses and mechanical behaviour and (ii) the scarcity of available data to parameterize and evaluate numerical models accounting for these processes.

WISPER tackles these limitations with 3 work packages (WP) that involve the development of innovating numerical approach and geophysical soundings. WISPER gathers the skills, tools and data spread between France (EDYTEM, CNRS, Université Savoie Mont Blanc), Germany (Technical University of Munich) and Norway (University of Oslo). In WP1, a set of unique data already collected in the Mont Blanc massif (high resolution DEM, rockfall inventory, rockwall temperature time series, etc.) are used to develop coupled thermal and hydrological models and provide data that could be used for mechanical models in the WP3. In parallel, cutting-edge geophysical measurements and monitoring will be implemented on pilot-sites to image the fracture content (WP2) and obtain an independent dataset to parameterize and evaluate models that will be developed in WP1 and WP3.

Combination of the 3 WP will contribute to the building up of a better theoretical understanding of the thermal dynamics and mechanical behaviour of rockwall permafrost. Over short and mid-term, this project will deliver new numerical modelling approaches, numerical model outputs, sensitivity analysis to the rockwall fracture settings and images of the physical properties of rockwall permafrost that will be of high interest for the scientific community working on alpine morphodynamics and cryospheric processes. Over the mid to long-term, results will constitute a solid basis to define research directions towards engineering solutions for anticipating and mitigating risks associated to permafrost degradation.

## Sources de financement

- ANR : ANR-19-CE01-0018
- French National Research Agency : ANR-19-CE01-0018

**Date de début** 2020-04-01

**Date de fin** 2024-03-31

**Produits de recherche :**

1. Hydrological and thermal model dataset (Jeu de données)
2. Resistivity/Conductivity and Induced Polarization repeated measurements (Jeu de données)
3. Snow height and water equivalent time series on rockwall faces (Jeu de données)
4. Statistical analysis of modeled rockwall temperature at 209 rockfalls (Jeu de données)

## Contributeurs

Nom	Affiliation	Rôles
Florence Magnin		<ul style="list-style-type: none"> <li>• Personne contact pour les données (Thermo-Hydro Models, Statistical analysis, Snow dataset, Geoelectrical data)</li> <li>• Responsable du plan de gestion de données</li> </ul>
MAGNIN Florence	ENVIRONNEMENTS, DYNAMIQUES ET TERRITOIRES DE LA MONTAGNE	<ul style="list-style-type: none"> <li>• Coordinateur du projet</li> </ul>

### Droits d'auteur :

Le(s) créateur(s) de ce plan accepte(nt) que tout ou partie de texte de ce plan soit réutilisé et personnalisé si nécessaire pour un autre plan. Vous n'avez pas besoin de citer le(s) créateur(s) en tant que source. L'utilisation de toute partie de texte de ce plan n'implique pas que le(s) créateur(s) soutien(nen)t ou aient une quelconque relation avec votre projet ou votre soumission.

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## 1. Description des données et collecte ou réutilisation de données existantes

### Hydrological and thermal model dataset

Data of the thermo-hydrological models have been created using the Feflow (DHI-WASY) commercial software. Simulations will use the Darcy law and the advective dispersive-diffusive heat transport equation.

Simulations have used surface temperature time series created in the frame of a former study (Magnin et al., 2015 GRPE and Magnin et al., 2017 TC) and a 4 m resolution DEM (from the Regional authorities).

- Forcing data (.csv)
- Thermal and hydrological model outputs as .shp (< 100 MB).
- Thermal and hydrological model outputs as .jpeg

### Statistical analysis of modeled rockwall temperature at 209 rockfalls

- 1D heat transfer simulations using the CryoGRID model (Westermann et al., 2013) for 209 rockfalls events that occurred between 2007 and 2015
- data from a rockfall inventory were used
- air temperature data in Chamonix (from Météo France) were used to create forcing data

- modelled temperature time series (.csv)

### Snow height and water equivalent time series on rockwall faces

Installation of snow probes equipped with mini-temperature sensors to collect relevant data for snow dynamic modelling. Five probes were installed in september 2021 on the South face of the Aiguille du Midi. In addition, a camera to follow snow evolution at a rock face scale was installed in december 2021 to follow snow evolution, and drone surveys were conducted in october 2021 when the rock face was still dry and then in january 2021 with snow cover to build up a high resolution DTM (Digital Terrain Model) of the rock face and assess snow surface area, depth and volume.

These snow data will be used to model snow dynamics and estimate the snow water equivalent with a transient 1D thermal model. To do so, a validation step of the thermal model will be required using existing thermal data in a borehole. This borehole is continuously recording temperature data with 15 sensors spread between 0.3 and 10 m depth. These data were partly published in Magnin, F., et al. (2015). Thermal characteristics of permafrost in the steep alpine rock walls of the Aiguille du Midi (Mont Blanc Massif, 3842 m a.s.l.). *The Cryosphere* 9, 109–121. <https://doi.org/10.5194/tc-9-109-2015>

- times series (daily) of snow height and water equivalent (.csv/.txt)
- Point clouds and DEMs with and without snow of the AdM South face (.tiff/.las)

### Resistivity/Conductivity and Induced Polarization repeated measurements

Between June 2020 and March 2021, a geoelectrical monitoring system has been installed on 3 different rock faces of the Aiguille du Midi. Three 160 m long cables have been deployed in the east, south and north-west faces and monitor the electrical resistivity and induced polarization automatically.

Geoelectrical data are about a few MB per file (depending on the number of measurements per day) and are provided as .db.

## 2. Documentation et qualité des données

### Hydrological and thermal model dataset

For the thermal and hydrological modelling data, input data are provided as well as .csv files and the modelling approach has been published in the frame of this project (Magnin, F., & Josnin, J.-Y. (2021). Water Flows in Rock Wall Permafrost: A Numerical Approach Coupling Hydrological and Thermal Processes. *Journal of Geophysical Research: Earth Surface*, 126(11), e2021JF006394. <https://doi.org/10.1029/2021JF006394>)

For the snow depth and properties data gathering snow probes and temperature data, drone images and camera images, the methodology will be published together with the results.

For the geoelectrical monitoring data, metadata regarding measurements quality can be found in the .db. The approach to collect these data will be published in a dedicated paper.

For modelling data, consideration of the model limits, uncertainty in the parameters and input data are qualitatively considered and quantified when possible.

### Statistical analysis of modeled rockwall temperature at 209 rockfalls

Data used for this statistical analysis are created from model: the methodology is published in a paper together with the results and the initial rockfall data base used for the study:

Legay, A., Magnin, F., & Ravanel, L. (2021). Rock temperature prior to failure: Analysis of 209 rockfall events in the Mont Blanc massif (Western European Alps). *Permafrost and Periglacial Processes*, 32(3), 520–536. <https://doi.org/10.1002/ppp.2110>

All sources of uncertainty are calculated and taken in consideration in results description and interpretation.

### Snow height and water equivalent time series on rockwall faces

For the snow data, field reports are written to collect important meta-data.

Not enough data are available yet for organisation

Only preliminary pictures time series are stored on a University server.

- visual checking of the pictures
- uncertainty assessment in snow depth estimation from the drone survey
- uncertainty assessment in the snow parameters modelling approach

### Resistivity/Conductivity and Induced Polarization repeated measurements

Extended metadata files are provided with the .db (ground resistance for each electrode, measurement protocols, etc.)

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Routines will be developed to check the data quality

### 3. Stockage et sauvegarde pendant le processus de recherche

#### Hydrological and thermal model dataset

Data stored on PC, hard drives, shared server for "work in progress data" and data repositories for published data such as Zenodo.

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No sensitive data

#### Statistical analysis of modeled rockwall temperature at 209 rockfalls

Data stored on PC, hard drives, shared server.

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No sensitive data

#### Snow height and water equivalent time series on rockwall faces

Data stored on PC, hard drives, shared server for "work in progress data" and data repositories for published data such as Zenodo.

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No sensitive data

#### Resistivity/Conductivity and Induced Polarization repeated measurements

Stored on a laboratory server

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No sensitive data

### 4. Exigences légales et éthiques, codes de conduite

Not applicable

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Not applicable

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## 5. Partage des données et conservation à long terme

### Hydrological and thermal model dataset

Can be found on Zenodo

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Rely on Zenodo (<https://about.zenodo.org/policies/>)

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Data are provided as .csv that can be read with any program, and as .shp that can be opened with various open access softwares and programs (e.g. QGIS, SAGA GIS...)

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DOI are provided with publication and data repository (Zenodo).

### Statistical analysis of modeled rockwall temperature at 209 rockfalls

Results of the Processed and Initial Data are published. Model output can be provided on demand.

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Publication of the main results

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text reader is enough

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main results are published (article with doi)

### Snow height and water equivalent time series on rockwall faces

Server

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Data repository when published

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text reader will be enough for time series  
GIS or other for image (spatial) data: DEM, points cloud

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Publications and data repository will provide a DOI

<b>Resistivity/Conductivity and Induced Polarization repeated measurements</b>
Data will be shared with publications.
Data repository when published
Terrameter LS toolbox or text reader
Data repository

## 6. Responsabilités et ressources en matière de gestion des données

Florence Magnin, project PI

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The PI, Cécile Pignol (EDYTEM), Bruno Galabertier (EDYTEM) will use a part of their working time to do that.