Modelling water-related processes in rock wall permafrost

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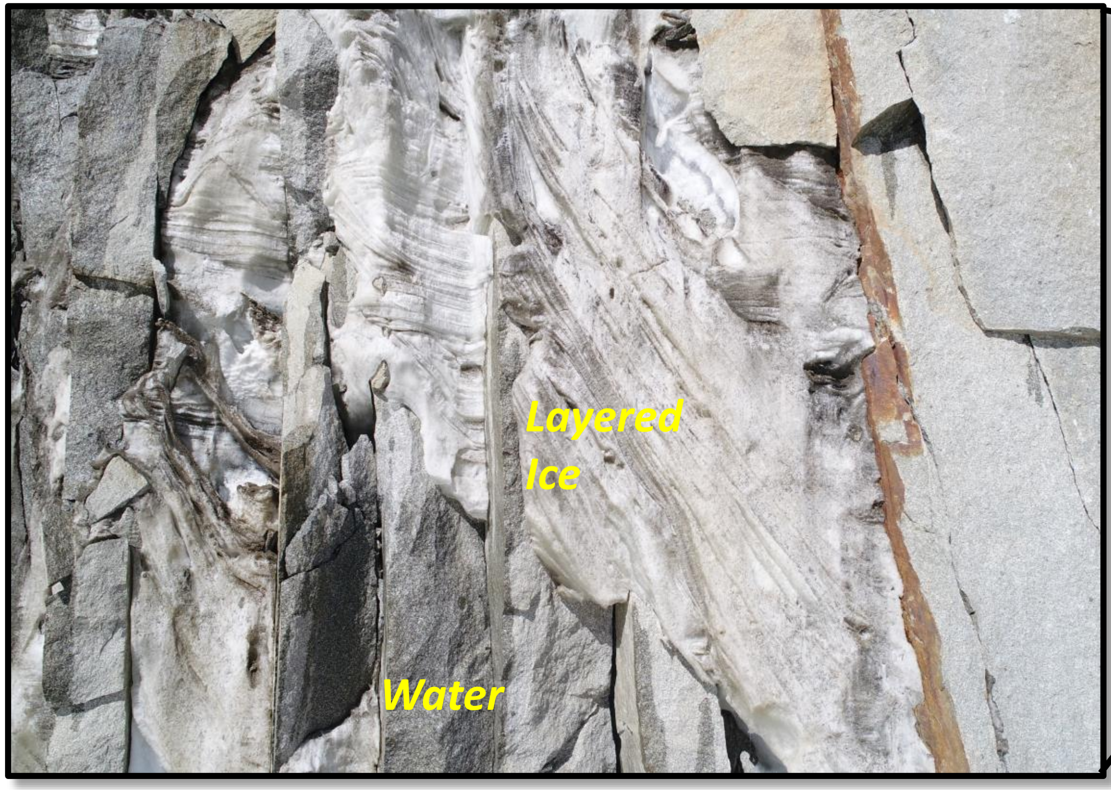
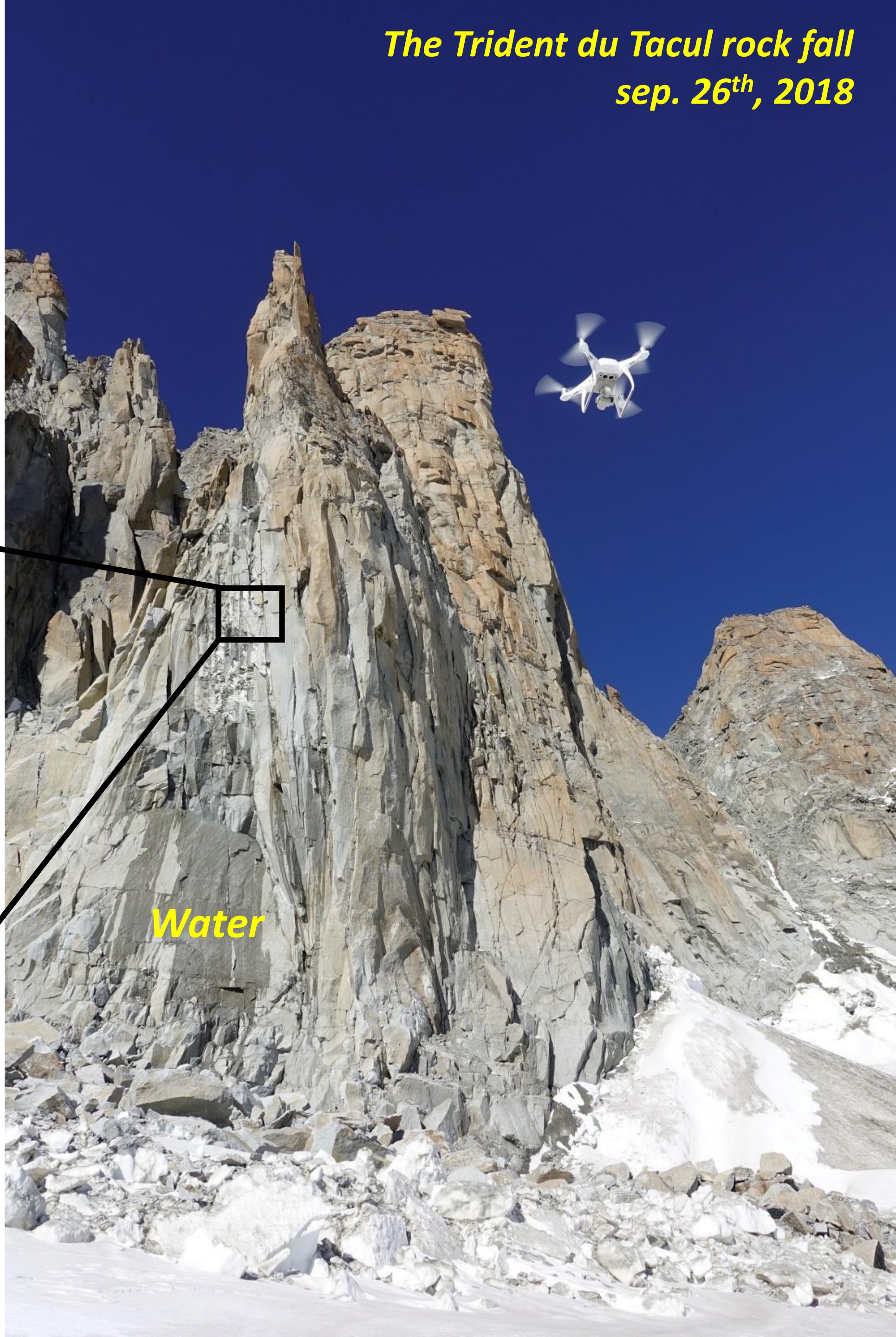
Hypothesis

➔ Water percolating along bedrock fractures may play a key-role in permafrost degradation (thermal effect) and rockfall triggering (mechanical effect)



Magnin et al., EGU 2020



Mathematical and numerical approaches

➔ The equation for transient flow through an anisotropic 3D porous medium is obtained by plugging the Darcy law into the continuity equation, and is known as the extended Richard’s equation in unsaturated conditions.

➔ The unsaturated hydraulic conductivity is obtained from the classical van Genuchten-Mualem relationship.

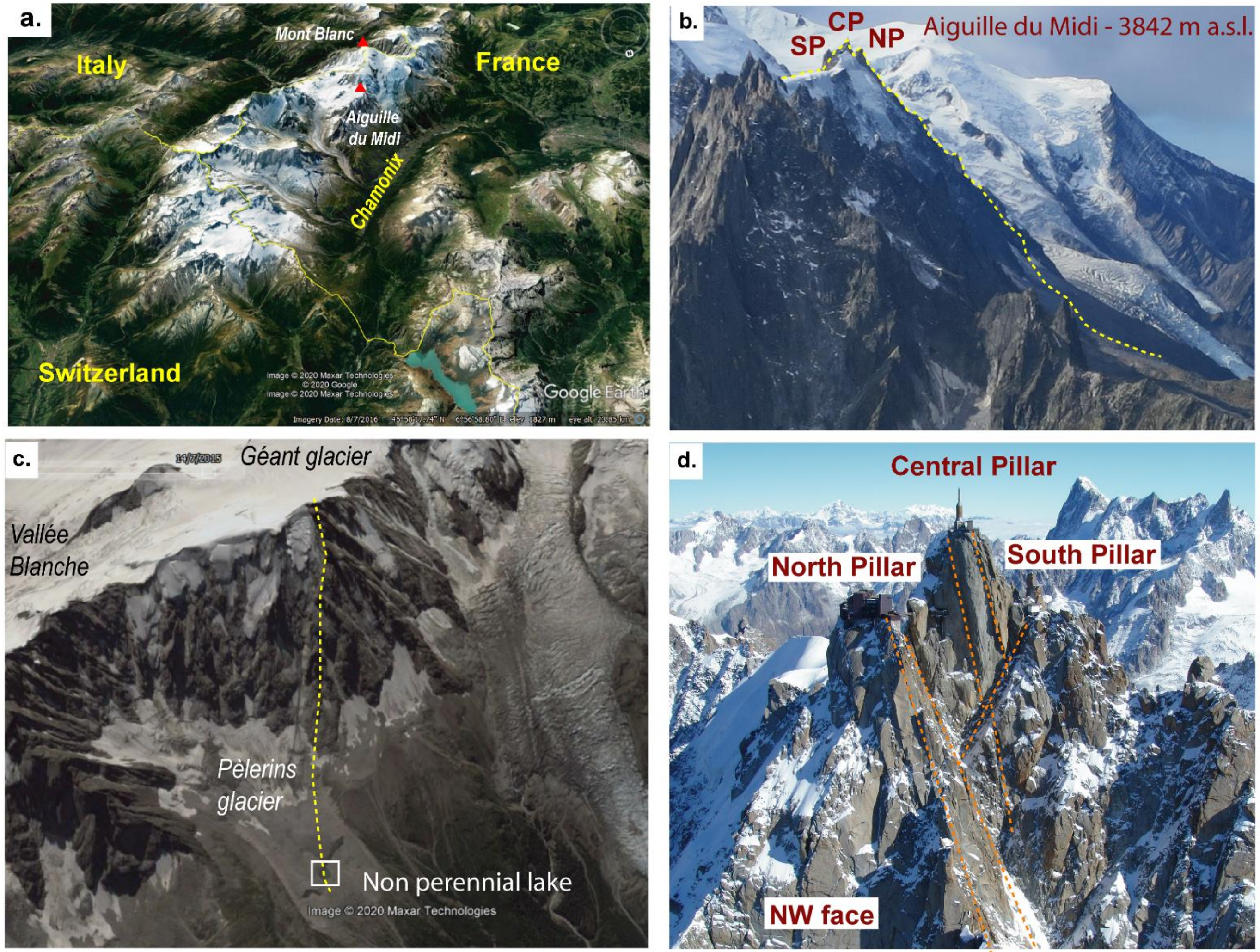
➔ The flow velocities obtained from the previous calculations are then integrated into the advective dispersive-diffusive heat transport equation.

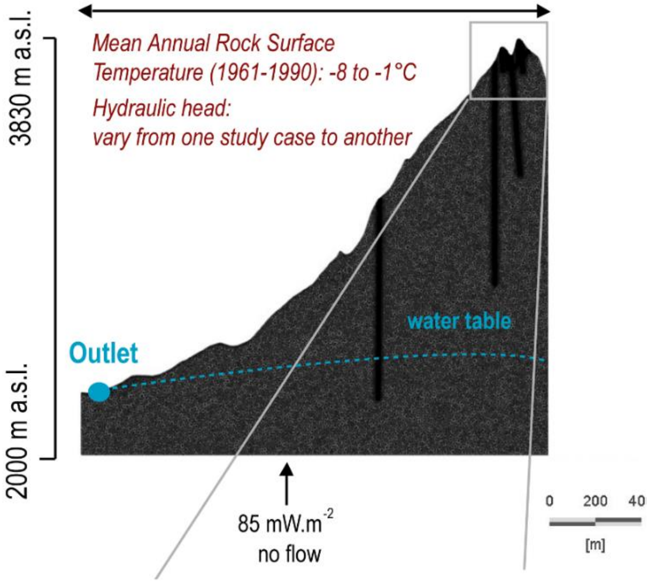
➔ Into the fractures, we used the Hagen-Poiseuille flow formulation that characterize laminar flow.

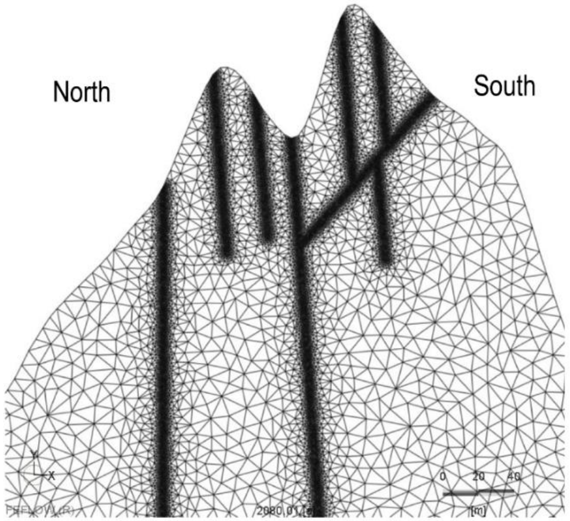
➔ All simulations are conducted with the finite elements numerical tools Feflow® 7.0 and 7.2 (DHI-WASY-GmbH) and the *Pi-Freeze* plug-in.

Model setup

➔ Aiguille du Midi (3842 m a.s.l., Mont Blanc massif)







➔ Fractures aperture is 2.5 and 5 cm

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Initialisation and transient simulations

Initialization

Finding steady-state

-3000 AD to 0 AD

MARST$_{61\text{-}90}$ + 7°C
8.2e-06 to 1.1e-4 m/d

Result in a water table from 2260 (outlet area) to 3826 m a.s.l.

Transient simulations (annual time step)

Progressive freezing

0 AD to 1550 AD

From MARST$_{61\text{-}90}$ +7°C to MARST$_{61\text{-}90}$ -1°C

Continued freezing

1550 AD to 1850 AD

MARST$_{61\text{-}90}$ -1°C

- 0.25% of initial head in freezing zones

Non-linear thawing (RCP4.5)

1850 AD to 2100 AD

Positive anomalies applied to MARST$_{61\text{-}90}$
(Magnin et al., 2017)

+ 0.25% of initial head in thawing zones

MARST$_{61\text{-}90}$: initial Mean Annual Rock Surface Temperature (°C) mapped by Magnin et al. (2015) with air temperature from 1961-1990.

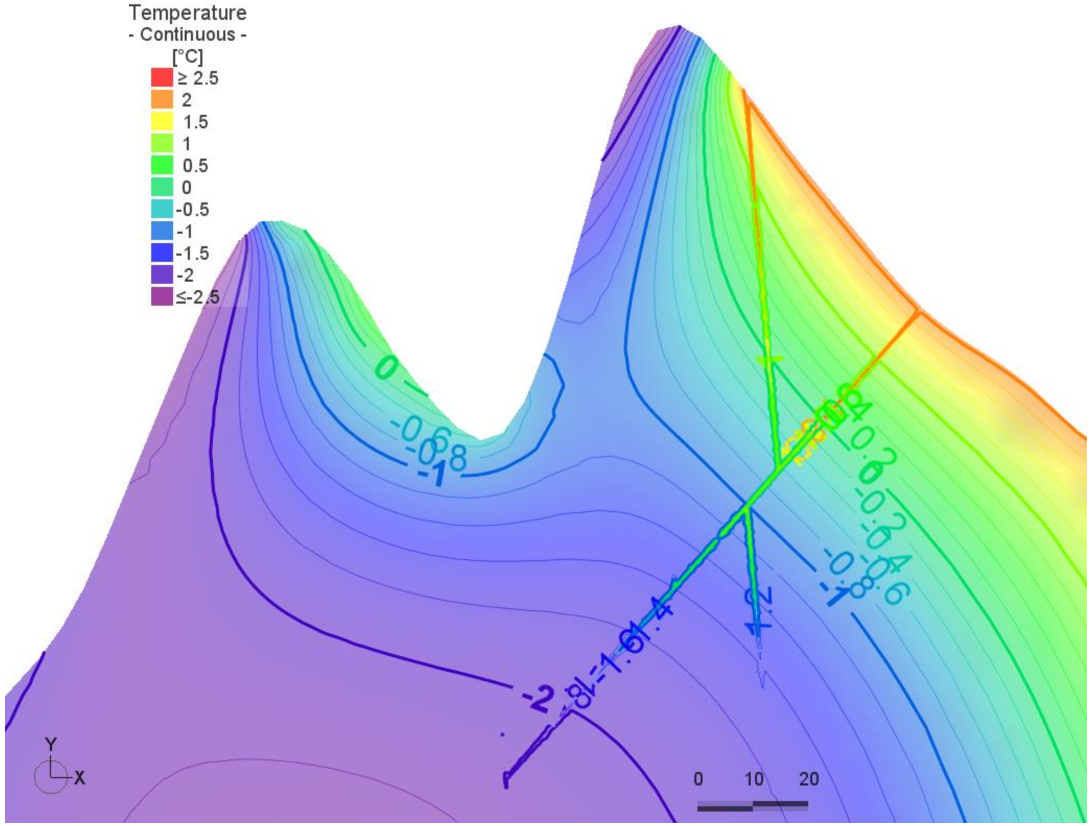
Magnin, F., Brenning, A., Bodin, X., Deline, P., and Ravanel, L.:Statistical modelling of rock wall permafrost distribution: application to the Mont Blanc massif, Geomorphologie, 21, 145–162,https://doi.org/10.4000/geomorphologie.10965, 2015

Air temperature anomaly time series as defined by Magnin et al. (2017) with observed air temperature (1990 – 2006) and projected times series based on the IPSL-CM5A-MR model run with the RCP4.5

Magnin et al. Modelling rock wall permafrost degradation in the Mont Blanc massif from the LIA to the end of the 21st century, The Cryosphere, 11, 1813–1834, https://doi.org/10.5194/tc-11-1813-2017, 2017.

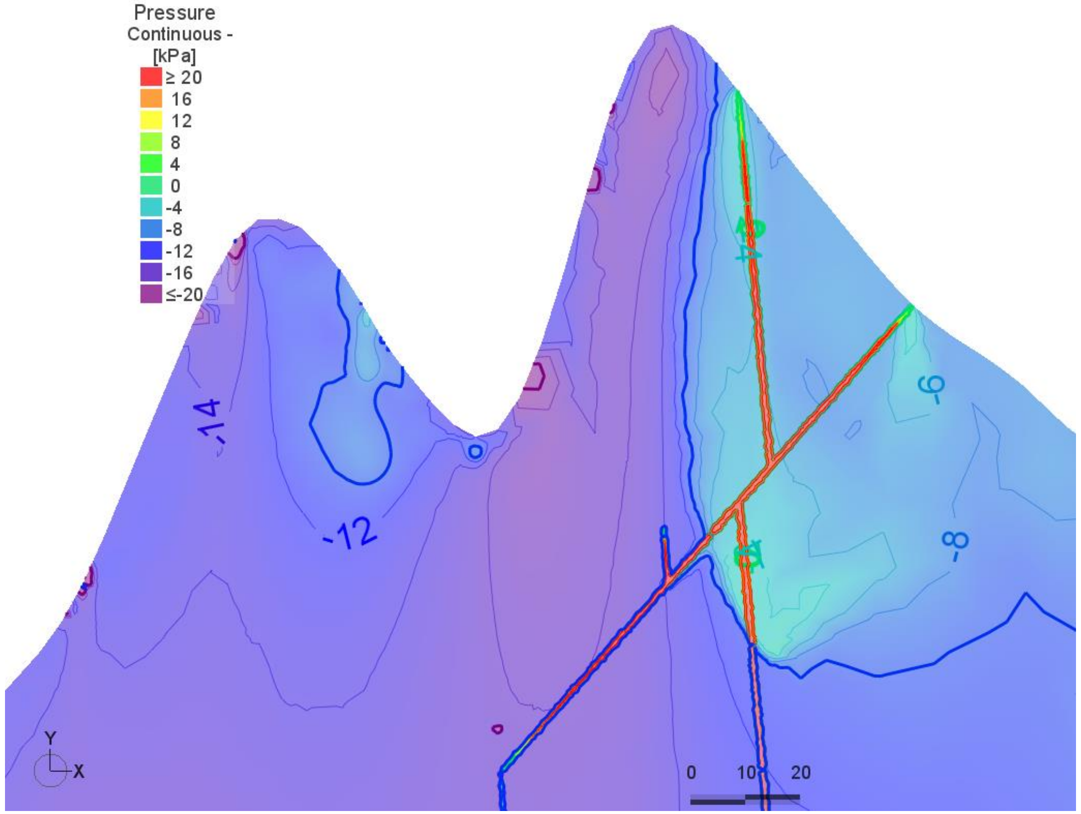
Preliminary results

Temperature fields



➔ Thawing corridors into fractures

Pressure fields



➔ Enhanced pressures at fractures

Perspectives and ….

- ➔ Reducing the model domain to lower CPU time.
- ➔ Towards more realistic jointing system.
- ➔ Including thawing and freezing at finer time scale.

…. implications

- ➔ For understanding permafrost degradation ➔ thawing corridors, local and rapid permafrost degradation
- ➔ For understanding rockwall destabilization ➔ high pressures along fractures when thawing
- ➔ For understanding hydrological processes in high mountain environments ➔ questions arise about the role of permafrost on water circulation in high mountain areas