In situ geophysical monitoring of liquid water movement in an Alpine snowpack from self potential signals

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Background

Self potential (SP) is a tiny voltage caused in porous media by liquid movement and charge separation.

Lab and field experiments[1,2] have shown self potential to be useful as a snow hydrology sensor in melting snow.

This study seeks to implement in situ SP monitoring of snow over seasonal timescales .

Questions

Can manual SP survey techniques be adapted into an in situ monitoring system?

Can SP measurements be used to understand water dynamics in the snowpack?

How well does a model of SP signals fit with measurements when driven by a snow hydrology model?

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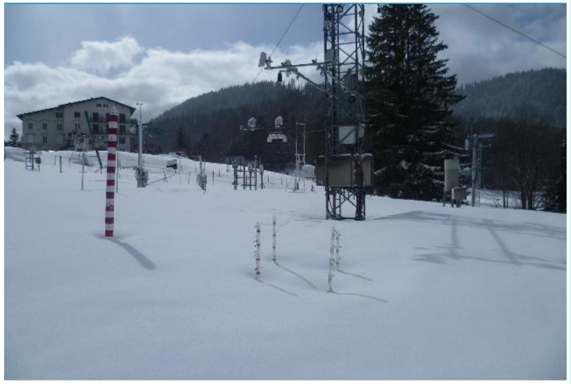
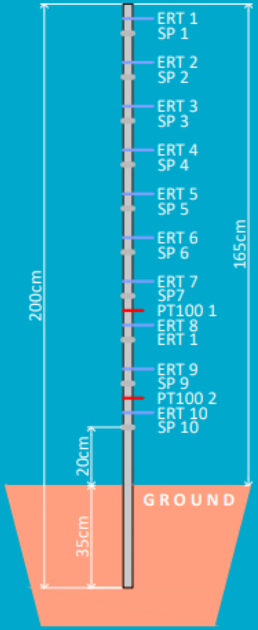
Study site – Col de Porte

Col de Porte is located in the Chartreuse Alps near Grenoble, France.

At 1325m altitude, it has a relatively warm climate with plentiful precipitation, ideal for studying snow melt.



Experiment design



Array of 40 electrodes arranged on 4 vertical poles.

Reference electrodes buried in soil

Self potential measured using Campbell Scientific datalogger.

PT100 thermistors recorded snowpack temperature.

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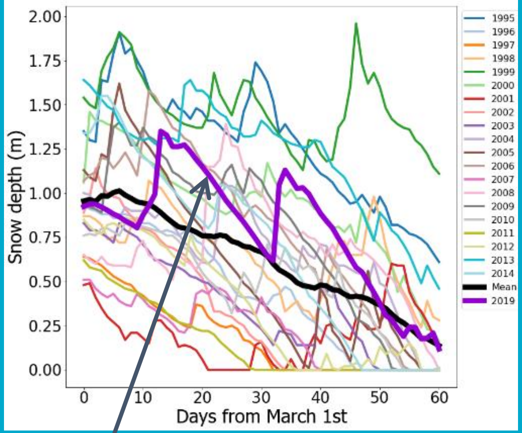
British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL
E3 DTP Edinburgh, Earth and Environment Doctoral Training Partnership
UKRI Natural Environment Research Council
METEO FRANCE

March 2019 fieldwork results

2018-2019 snow cover in context

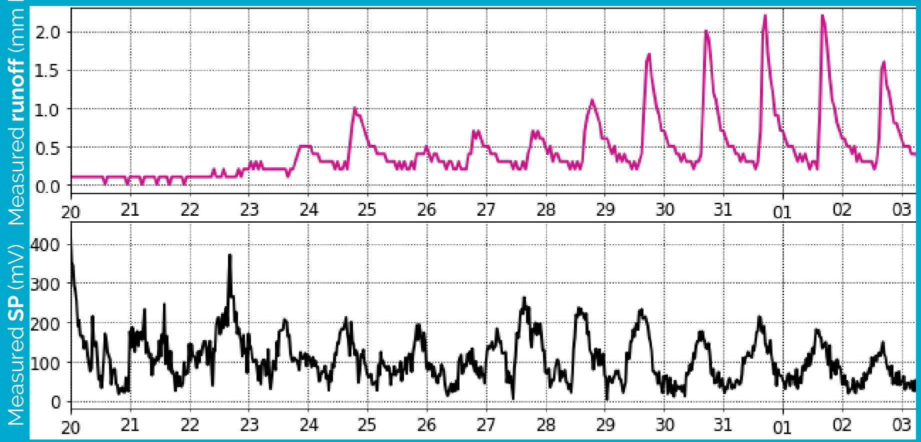


Fieldwork here

Dye tracing

20th Mar 2019

Meltwater runoff at base of snowpack, and mean SP in snowpack



March 2019 **April 2019**

Snow depth slightly above long term average in March and April.

Long period of melting when fieldwork carried out (lucky!).

Dye tracing showed predominantly matrix flow in snowpack.

Some preferential flow and low permeability layers visible.

Quick percolation of dye indicated strong diurnal cycle of melt flux through the snowpack.

Strong diurnal cycle in SP signal in bottom 50cm of snow.

However, runoff only shows similar signal later in series – water is moving internally but not reaching the base of the snowpack earlier on in series.

Bulk runoff at snowpack base is therefore not a good predictor of SP.

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Self potential modelling

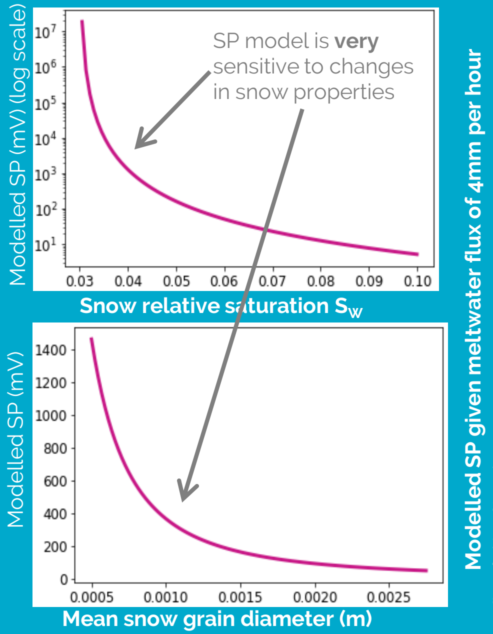
Modelling self potential in snow

Model developed by Kulessa et al.[1] to model SP signatures in melting snow in lab experiments.

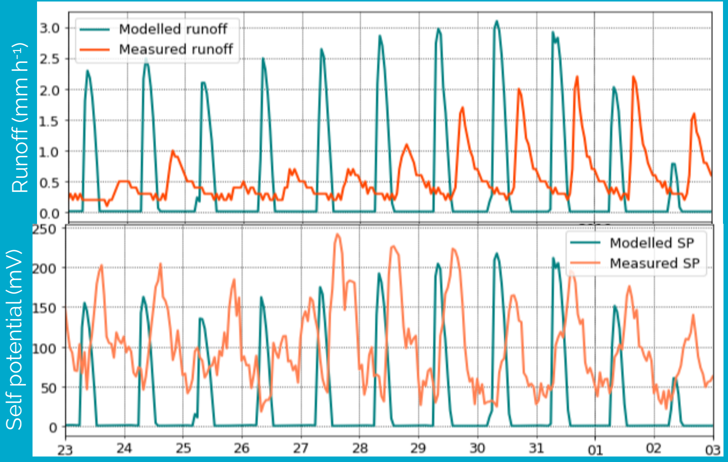
Coupling this model to a snow hydrology model allows comparison of modelled SP to measured SP.

As noted, measured SP signals caused by internal water dynamics.

Minimising differences between measured and modelled SP by changing snow hydrology processes should give more realistic simulations of internal water dynamics.



Measured vs modelled SP / runoff



Electrical model coupled to Flexible Snow Model 2 (FSM2)[3] with basic internal snow hydrology.

Model can reproduce diurnal SP signal with same magnitude as measured SP when forced with FSM2.

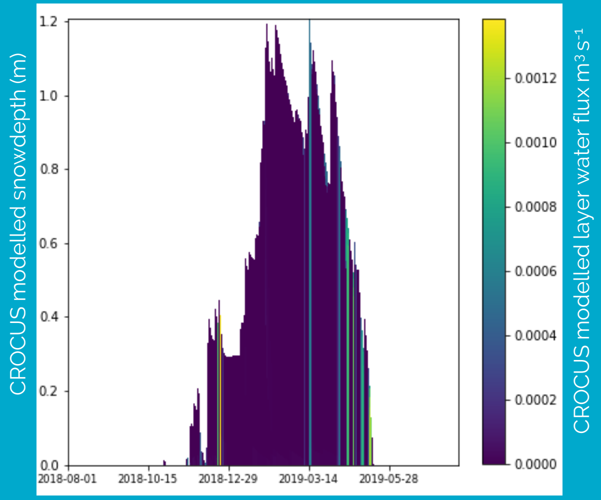
But runoff is very different to measured runoff due to simple "bucket" hydrology, so to improve runoff **and** SP predictions, internal fluxes need to be modelled better.

Snow hydrology models and future work

To investigate improved internal snow hydrology, internal water flux diagnostics have been developed for FSM2 and for the French model CROCUS[4].

In addition, analytical solutions to Richards Equation[5] are going to be coupled to the electrical model.

This will allow comparisons to be made between different model hydrology setups.



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