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Electrical self potential in snow

Measuring and modelling electrical signals from liquid water flow in seasonal snow

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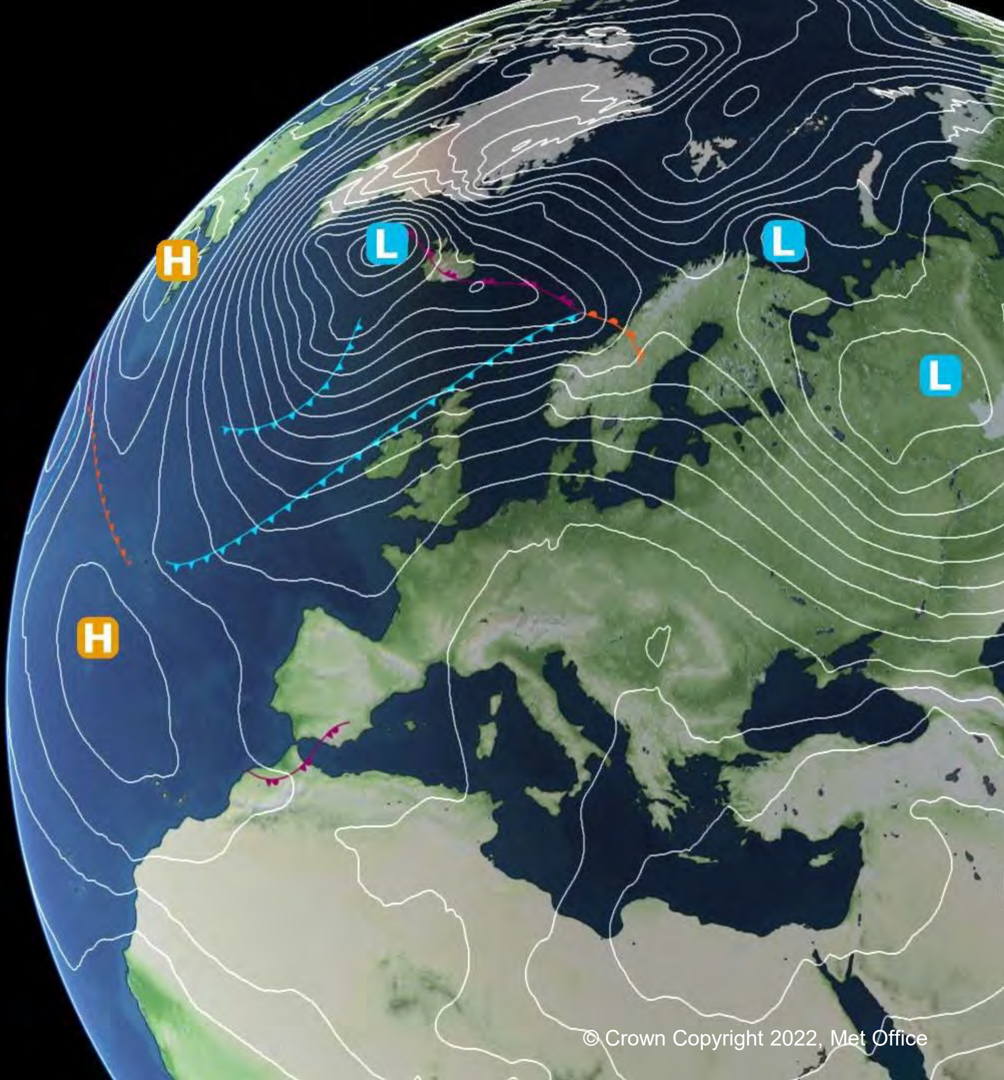

Introduction

- PhD project 2017 – 2022
- Fieldwork at Col de Porte in 2019 and 2020

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Why monitor SP in snow?

- Sensitive to **internal** liquid flow
- Non-destructive and non-invasive
- Low cost
- Can provide information about melt onset and rain-on-snow flows

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Overview

- Self potential background and theory
- Previous SP work in snow
- Col de Porte field results
- Modelled SP
- Future directions

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What else has SP been used for?

- Mineral prospecting
- Mineshaft and sinkhole location
- Groundwater flow
- Volcano monitoring
- Water flow around trees
- Water flow in dams

SP in the cryosphere

- Subglacial drainage
- Glacial moraine water flow
- Permafrost monitoring

Snow

- Laboratory work by Kulessa et al. (2012)
- Field surveying on glacial snowpack by Thompson et al. (2016)

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Sources of self potentials

- Telluric – large-scale magneto-telluric currents in upper atmosphere induce currents in the subsurface
- Electrochemical – electric charge separation in chemical concentration gradients
- Thermoelectric – temperature gradients leading to differing ion mobilities
- **Streaming – ions dragged along by liquid flow causes quasistatic electric field**

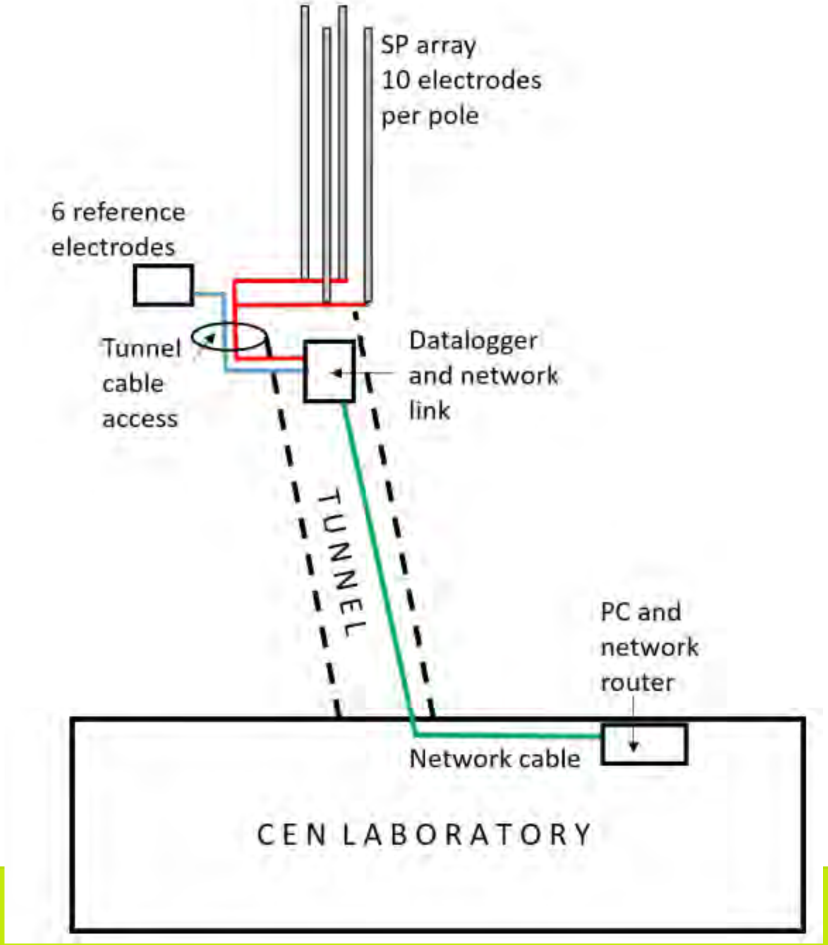
What do we measure?

- The **streaming potential** can be measured with pairs of **non-polarising electrodes** and a high impedance differential voltmeter

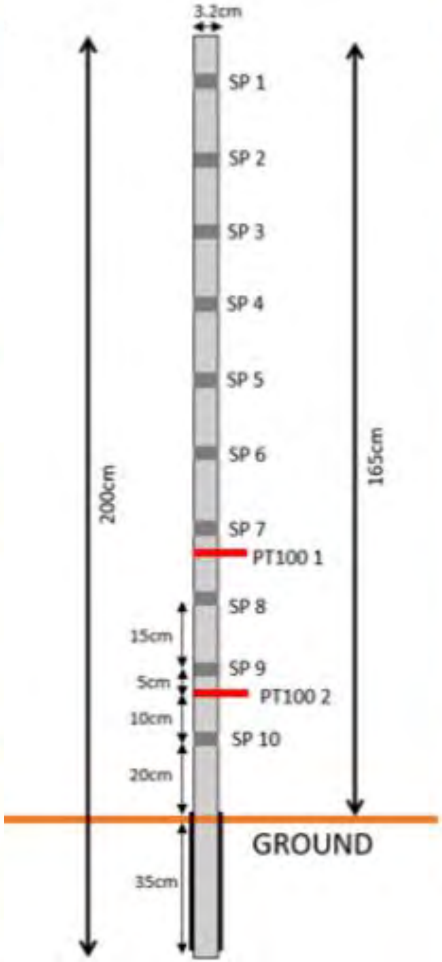
How do we measure it?

Laboratory (Kulessa et al. 2012) or manual field measurements (Thompson et al. 2016) used lead/lead-chloride ‘Petiau’ type porous electrodes (Petiau, 2000)

Col de Porte field set up



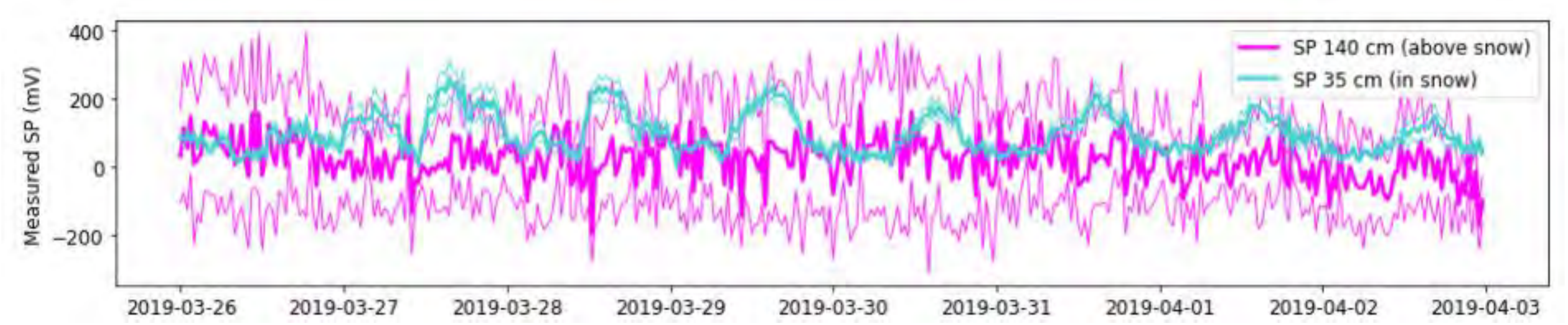
- Lead strip electrodes mounted on PVDF poles
- 40 electrode pairs
- 'Petiau' type reference electrodes
- Campbell Scientific CR1000 logger



3.2cm
SP 1
SP 2
SP 3
SP 4
SP 5
SP 6
SP 7
PT100 1
SP 8
SP 9
PT100 2
SP 10
200cm
165cm
15cm
5cm
10cm
20cm
35cm
GROUND

b
c
75cm
75cm

Field results – air vs. snow



Mean error in air = 146.2 mV
Mean error in snow = 20.6 mV

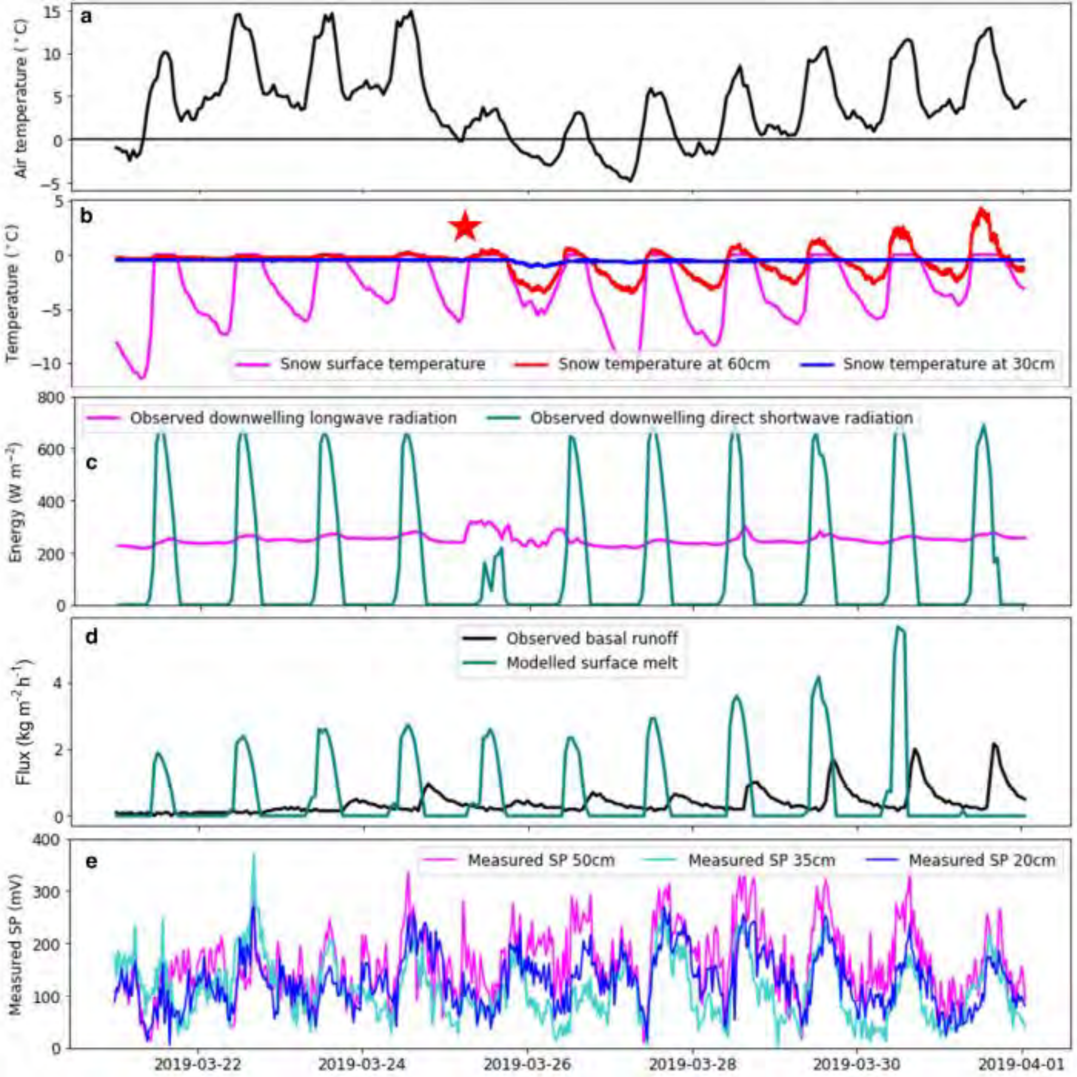
Air temperature

Snow temperature

Observed radiation

Runoff and surface melt

SP



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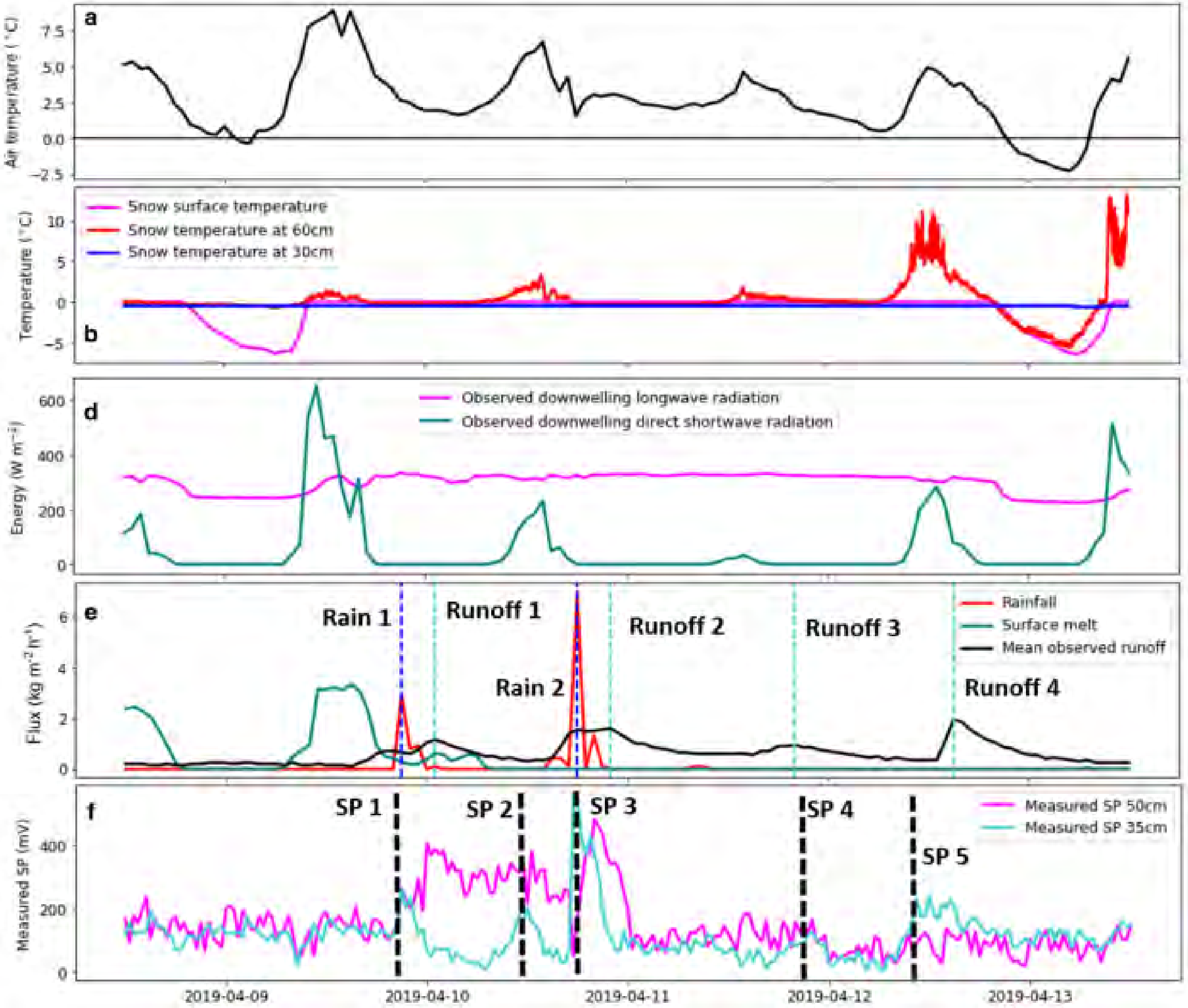
Air temperature

Snow temperature

Radiation

Runoff, melt, rainfall

SP



Field measurement conclusions

- **Timing** of SP peaks can easily be related to meteorological and hydrological factors
- **Magnitude** of SP peaks is difficult to explain (more on this shortly!)
- SP can detect water flow in the snowpack before it is registered in lysimeters

Modelling SP signals

- Most intuitive influence on SP signal is liquid flow
- Snow grain size, snow density, meltwater chemistry also have an effect

$$\psi_m = \frac{\varepsilon\zeta}{\sigma_W}\frac{S_W}{S_e^n}\frac{L}{kA}Q$$

(Kulessa et al. 2012)

- Reformulating this can give self potential as a function of snow hydrology model outputs (FSM2)

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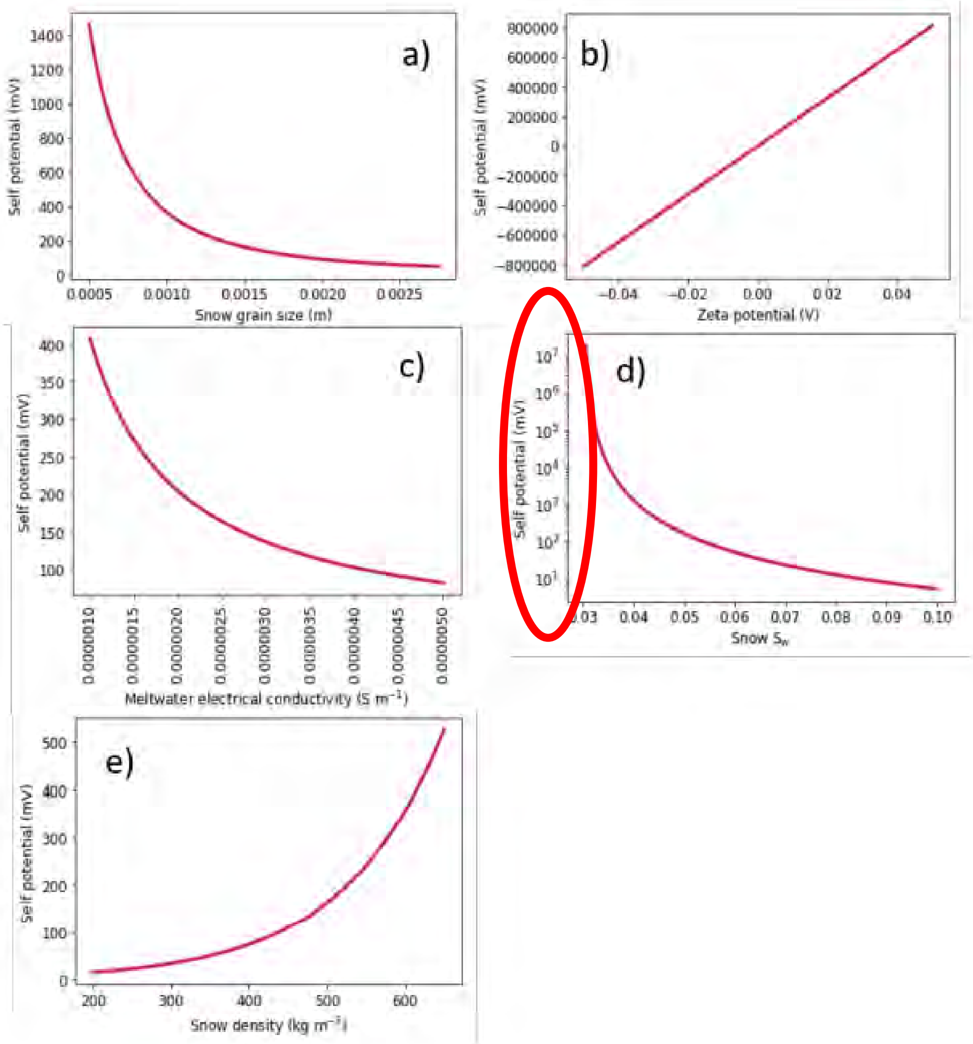
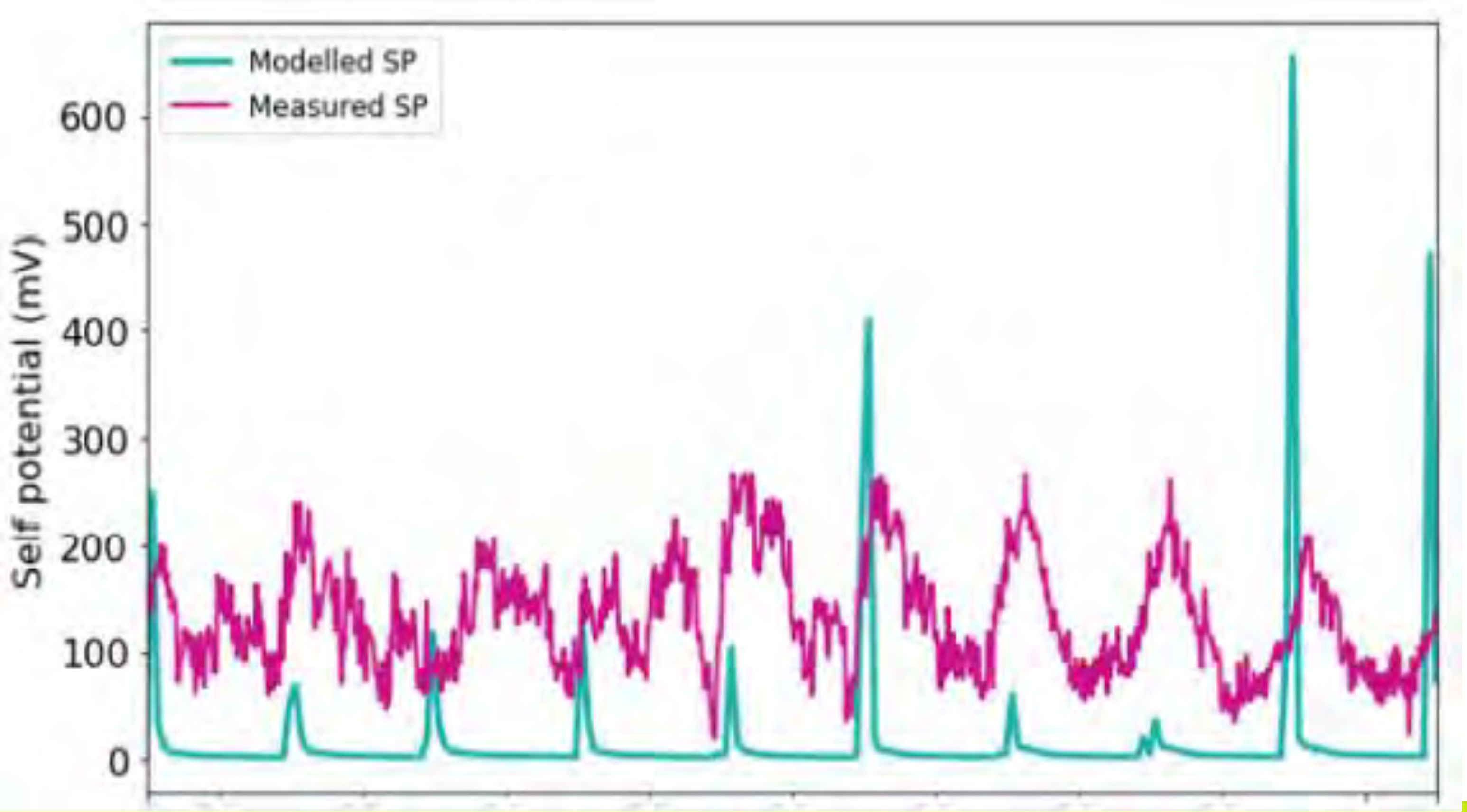
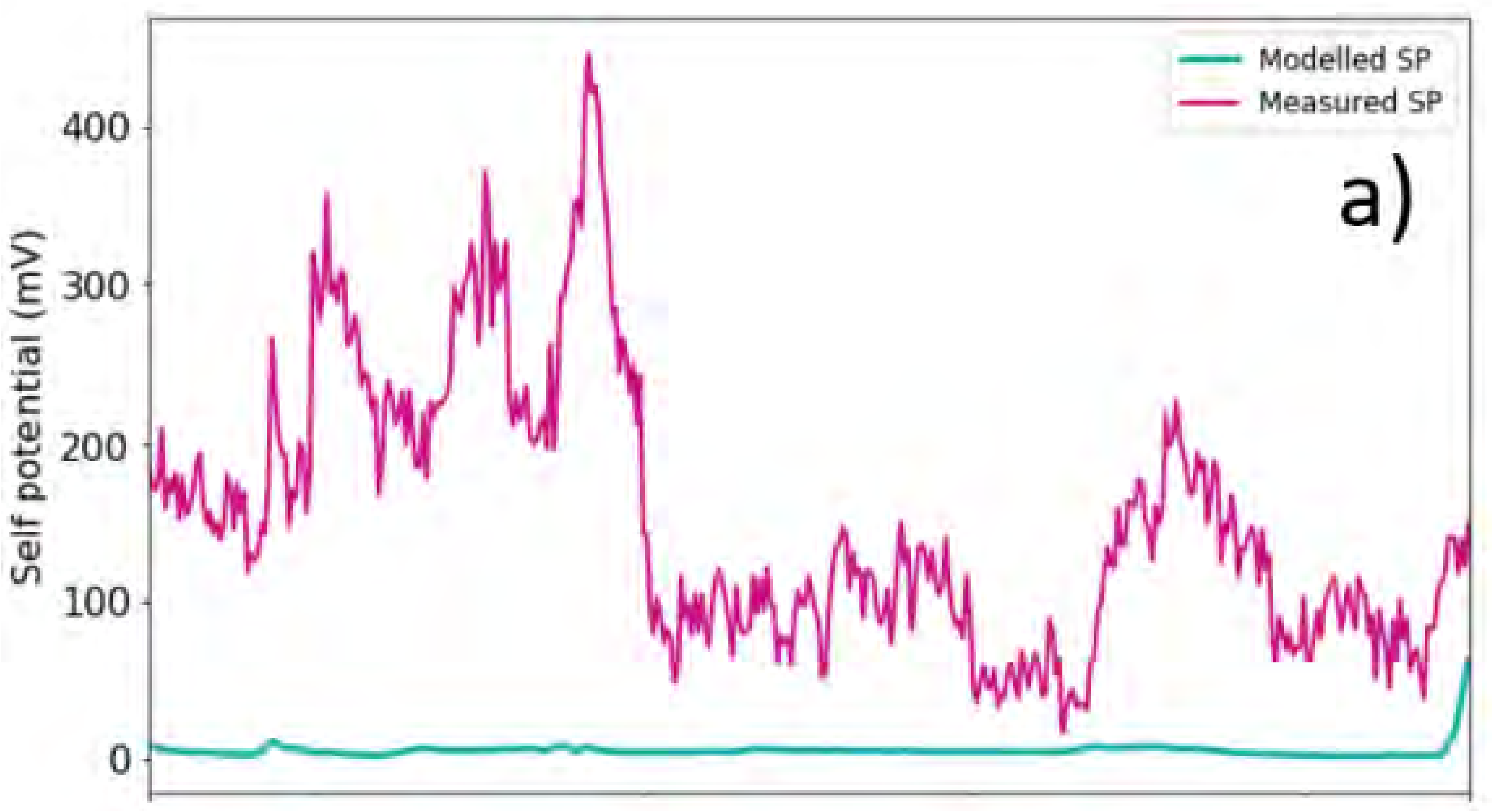
SP model sensitivity



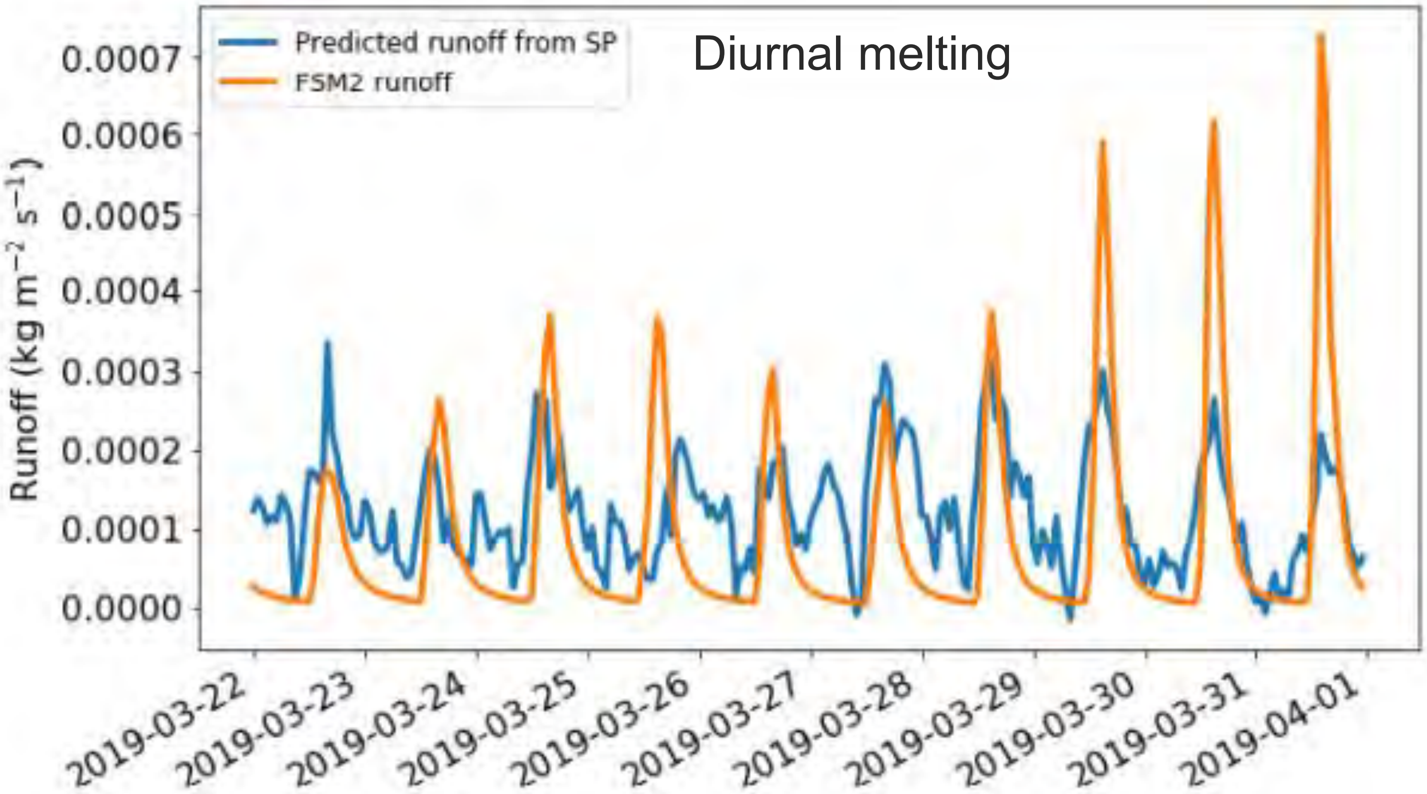
Modelled SP for diurnal melting



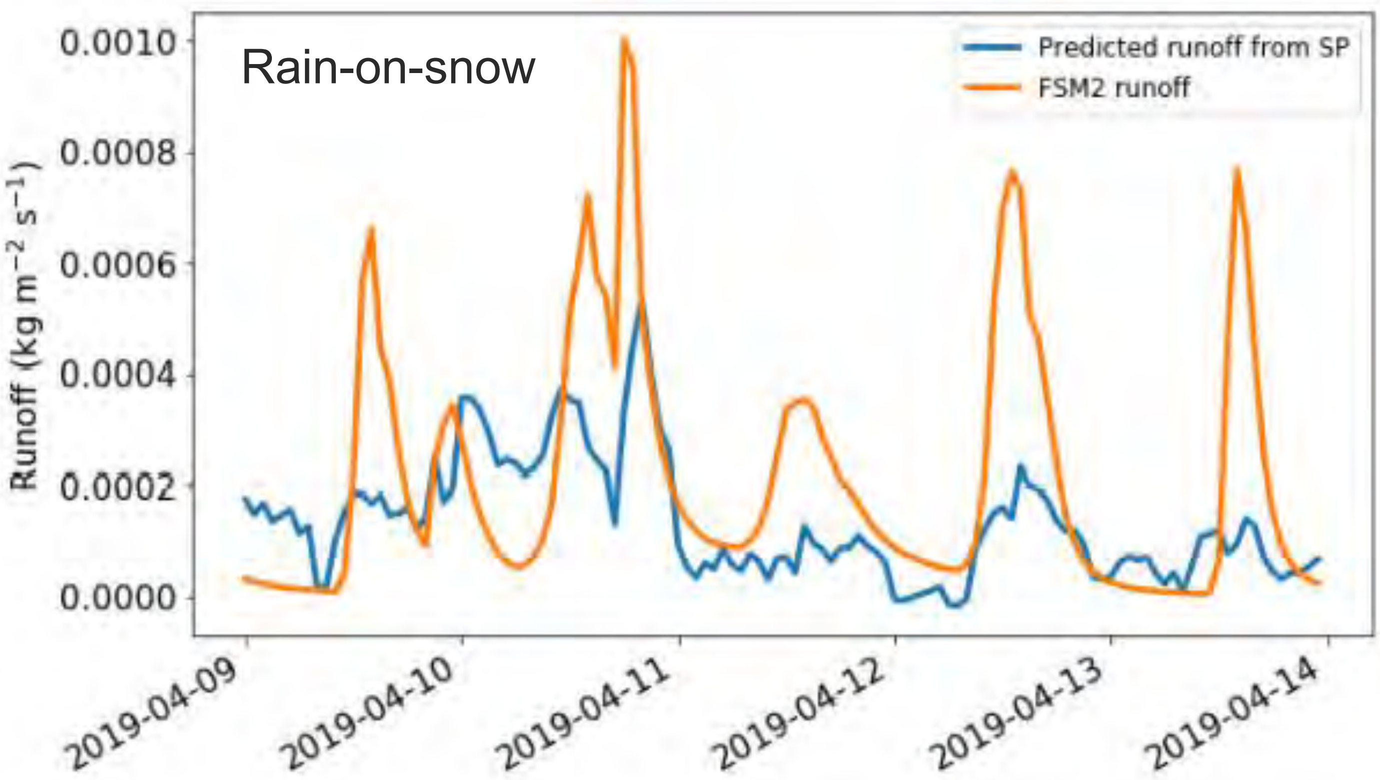
Modelled SP for rain-on-snow



Can we predict internal fluxes with SP?



Can we predict internal fluxes with SP?



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Summary

- SP gives great information on timing of melt
- SP magnitude is difficult to interpret
- Assumptions about chemical and thermal potentials being negligible are oversimplifications, especially for rain-on-snow
- SP signals compare well to modelled internal melt fluxes

Selected references

Essery R (2015) A factorial snowpack model (FSM 1.0). *Geoscientific Model Development* **8**(12), 3867–3876. doi: 10.5194/gmd-8-3867-2015

Kulessa B, Chandler D, Revil A and Essery R (2012) Theory and numerical modeling of electrical self-potential signatures of unsaturated flow in melting snow. *Water Resources Research* **48**(2), 1–18. doi: 10.1029/2012WR012048

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