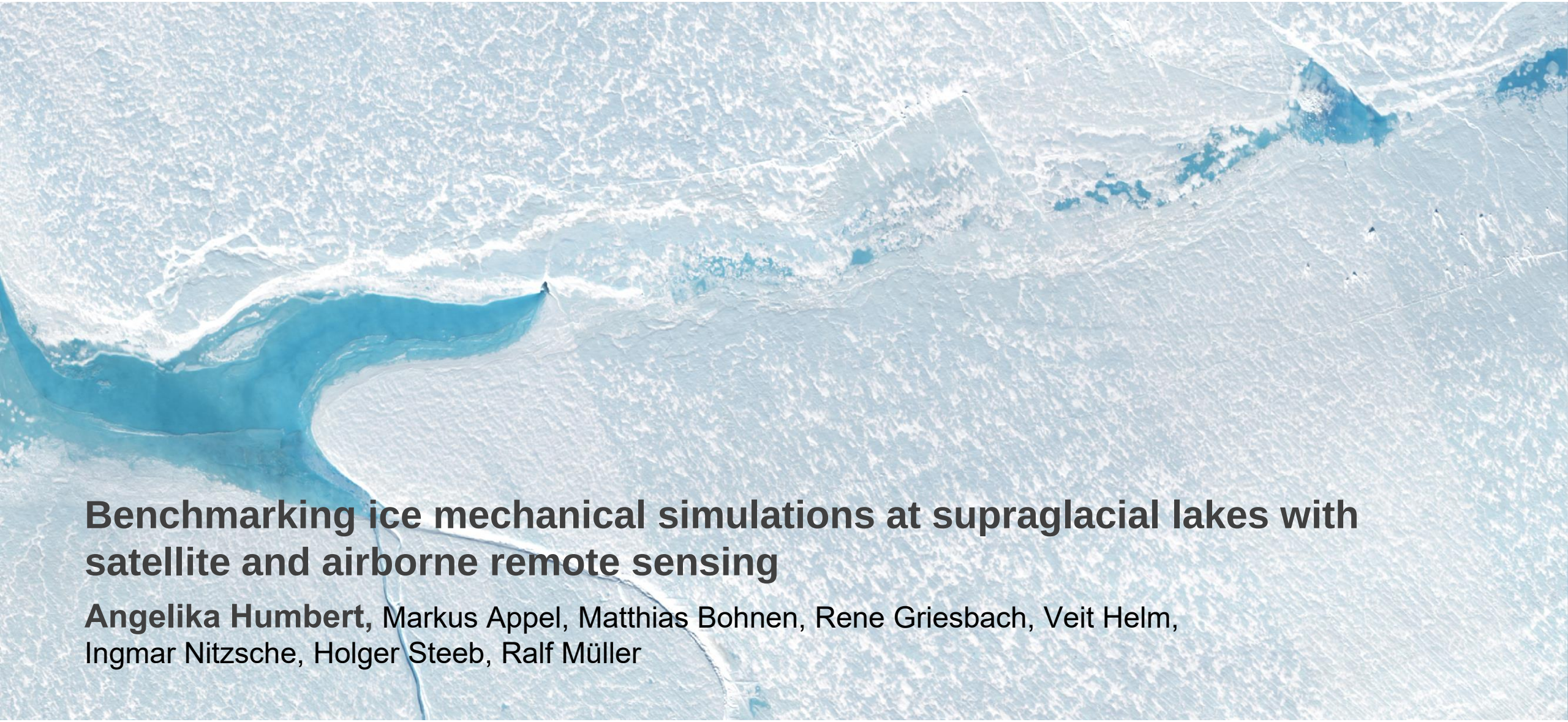
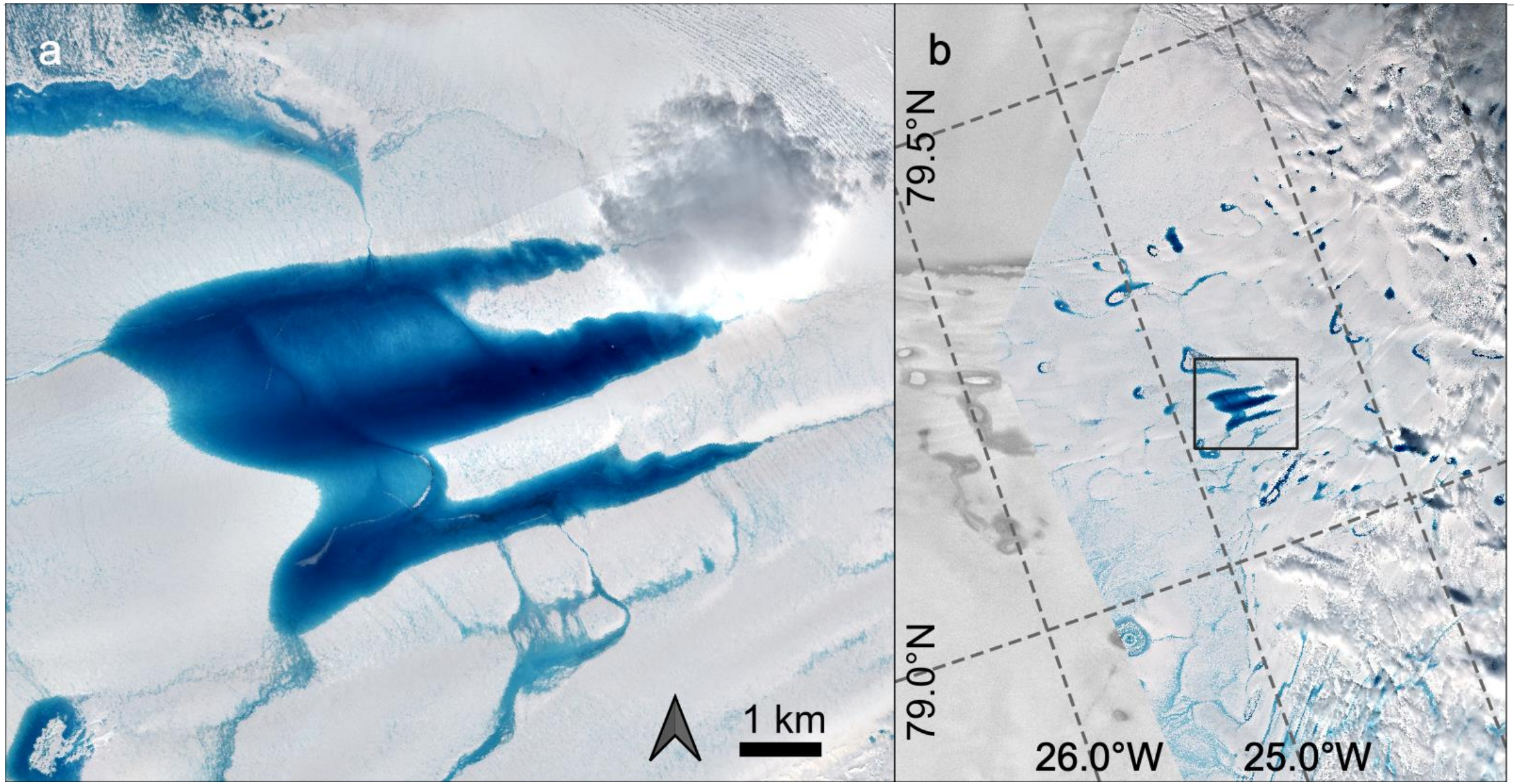
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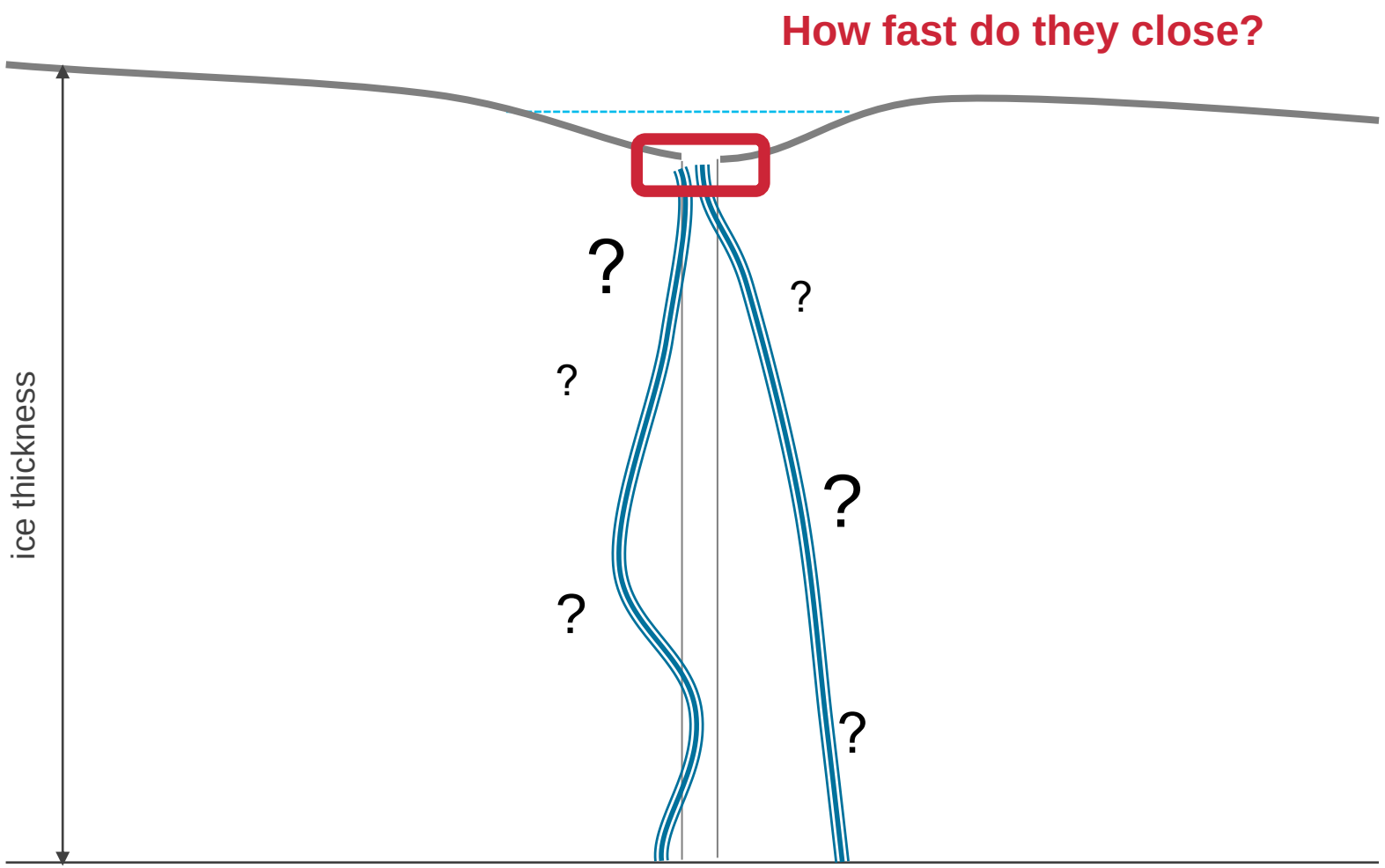
Benchmarking ice mechanical simulations at supraglacial lakes with satellite and airborne remote sensing

Angelika Humbert, Markus Appel, Matthias Bohnen, Rene Griesbach, Veit Helm, Ingmar Nitzsche, Holger Steeb, Ralf Müller

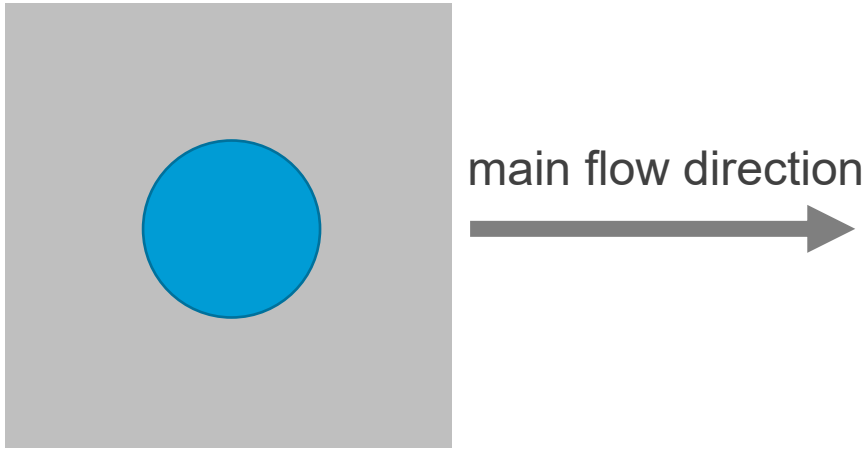

a
1 km
b
79.5°N
79.0°N
26.0°W
25.0°W

Englacial channels

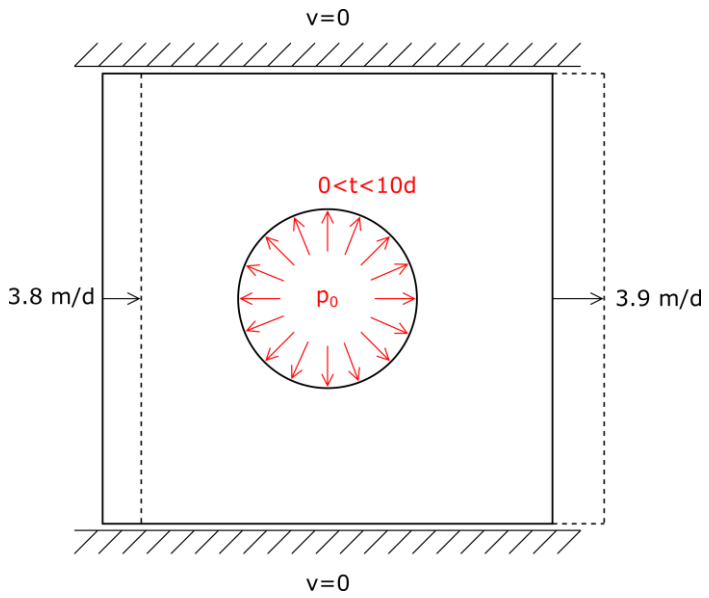
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A simple 2D approach



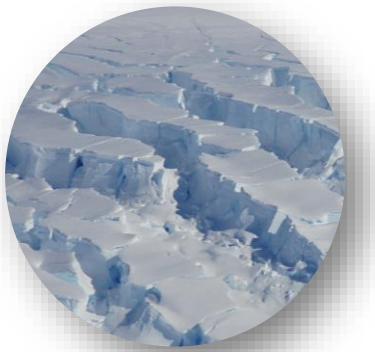
A simple 2D approach



Viscoelastic simulations

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long-term short-term

COMice-ve

Christmann et al., 2021
Humbert et al., 2022



$$\boldsymbol{\sigma}^D = 2\eta\dot{\boldsymbol{\varepsilon}}_{\mathrm{v}}^D = 2\mu\boldsymbol{\varepsilon}_{\mathrm{e}}^D$$

$$\boldsymbol{\varepsilon}^D = \boldsymbol{\varepsilon}_{\mathrm{v}}^D + \boldsymbol{\varepsilon}_{\mathrm{e}}^D$$

constitutive relation

viscoelastic Maxwell material

$$\operatorname{div}\boldsymbol{\sigma} + \mathbf{f} = \mathbf{0}$$

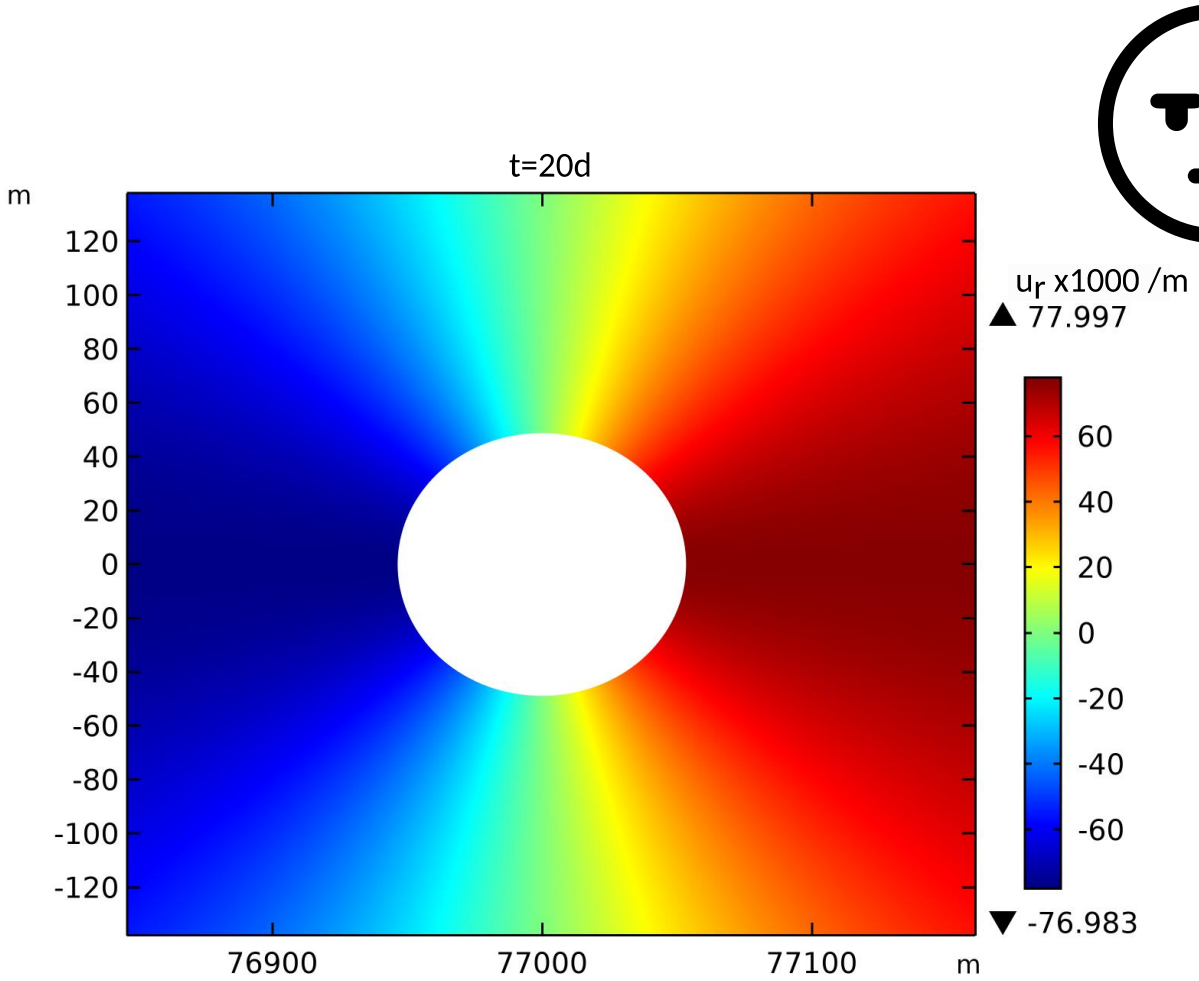
Stokes

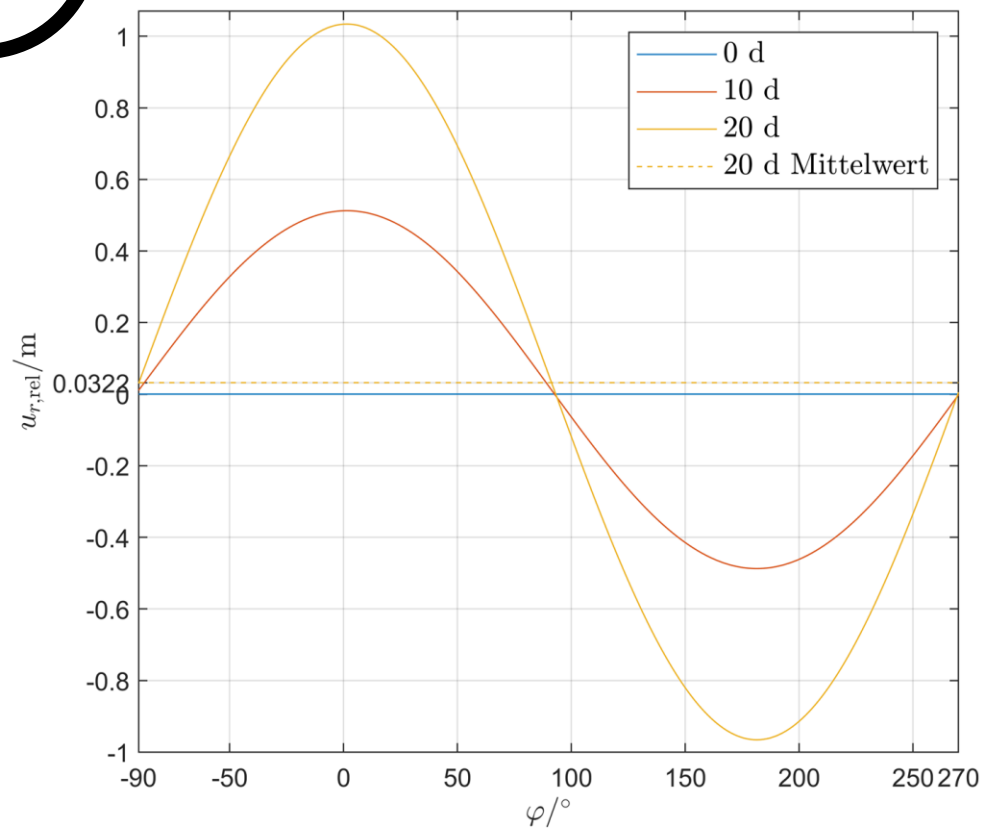
balance equation

$$\boldsymbol{\varepsilon} = \frac{1}{2}(\nabla\mathbf{u} + \nabla^T\mathbf{u})$$

kinematics

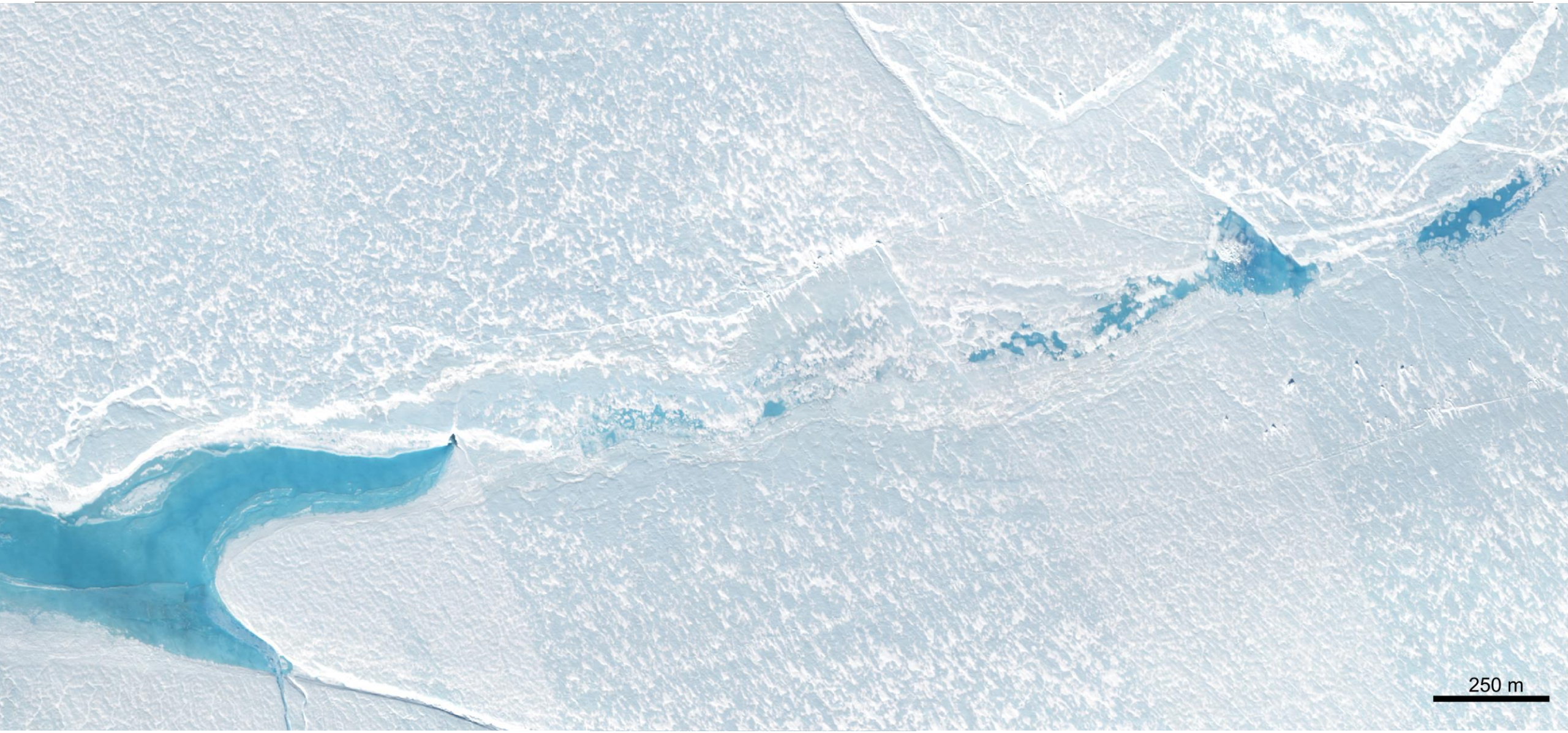
Modelling


t=20d
m
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
76900
77000
77100
m
u_r x1000 /m
▲ 77.997
60
40
20
0
-20
-40
-60
▼ -76.983


0 d
10 d
20 d
20 d Mittelwert
1
0.8
0.6
0.4
0.2
0.0322
0
-0.2
-0.4
-0.6
-0.8
-1
-90
-50
0
50
100
150
200
250
270
$u_{r,\mathrm{rel}}/\mathrm{m}$
$\varphi/^\circ$

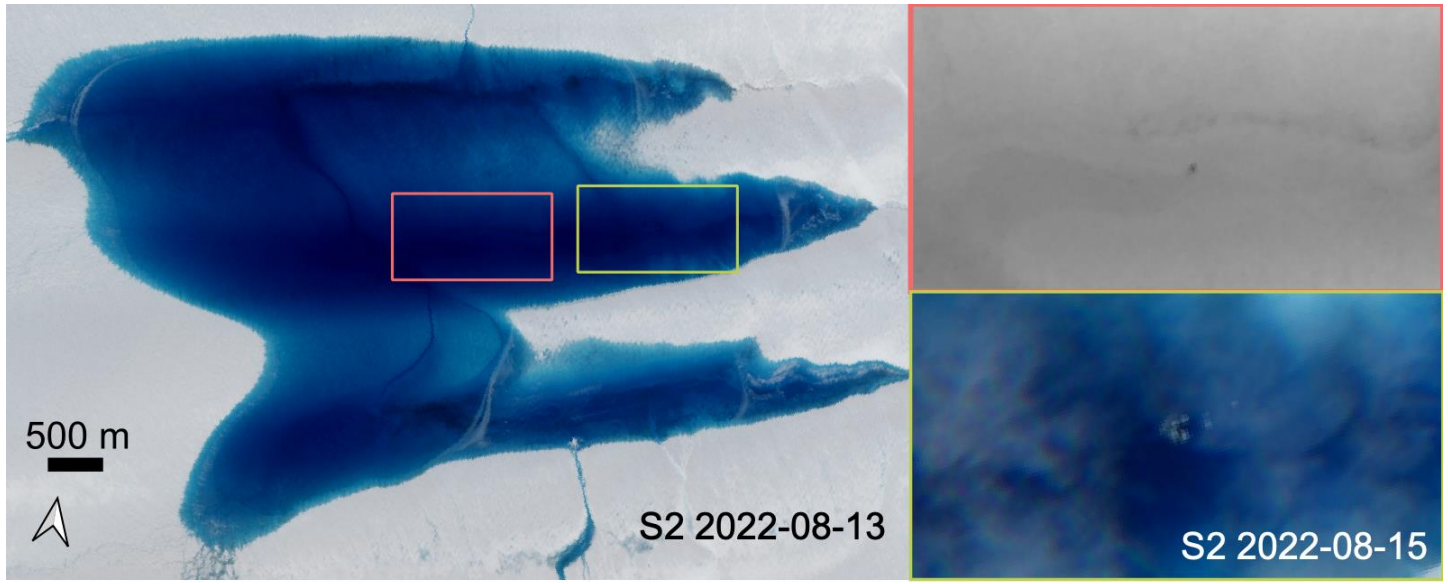
Gully 2020

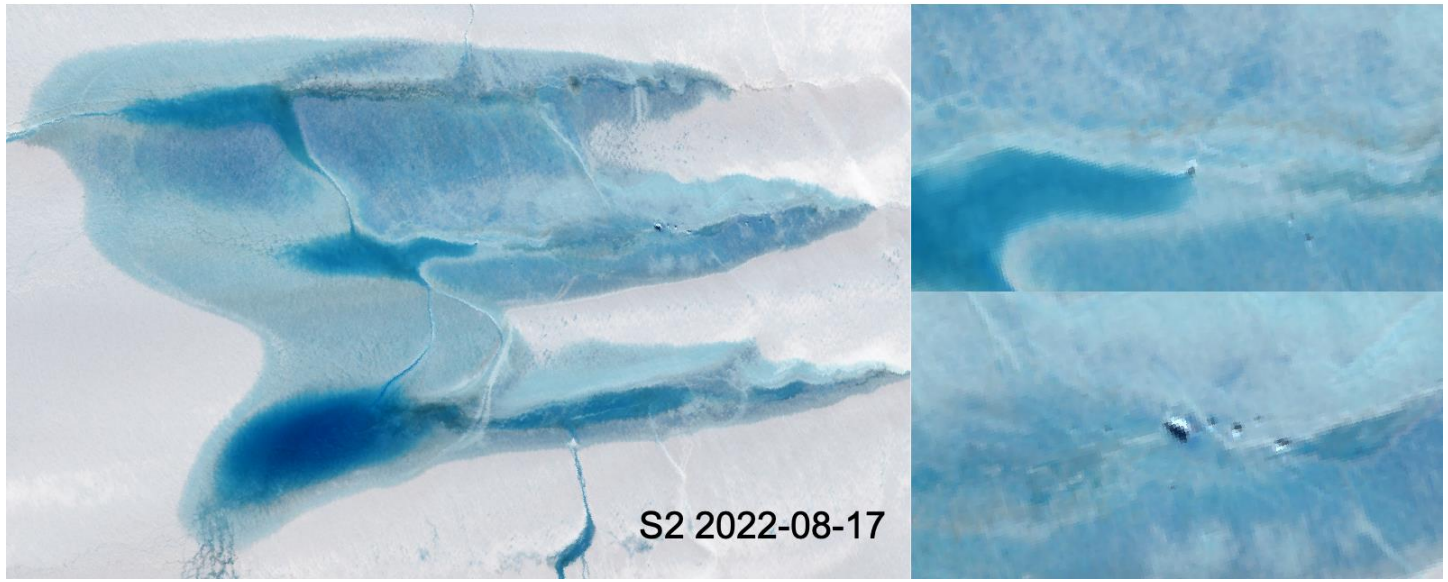
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Gully 2022

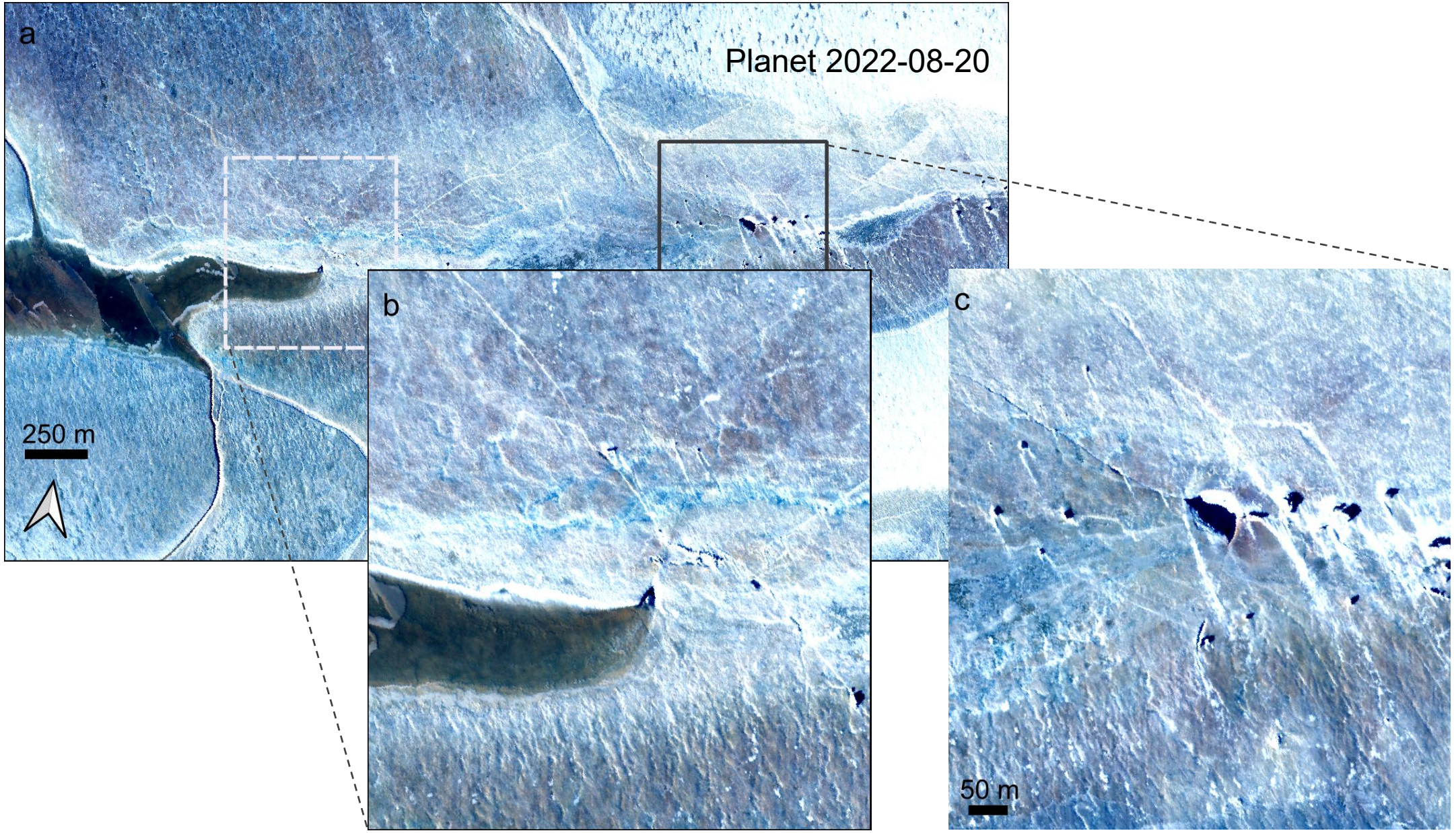
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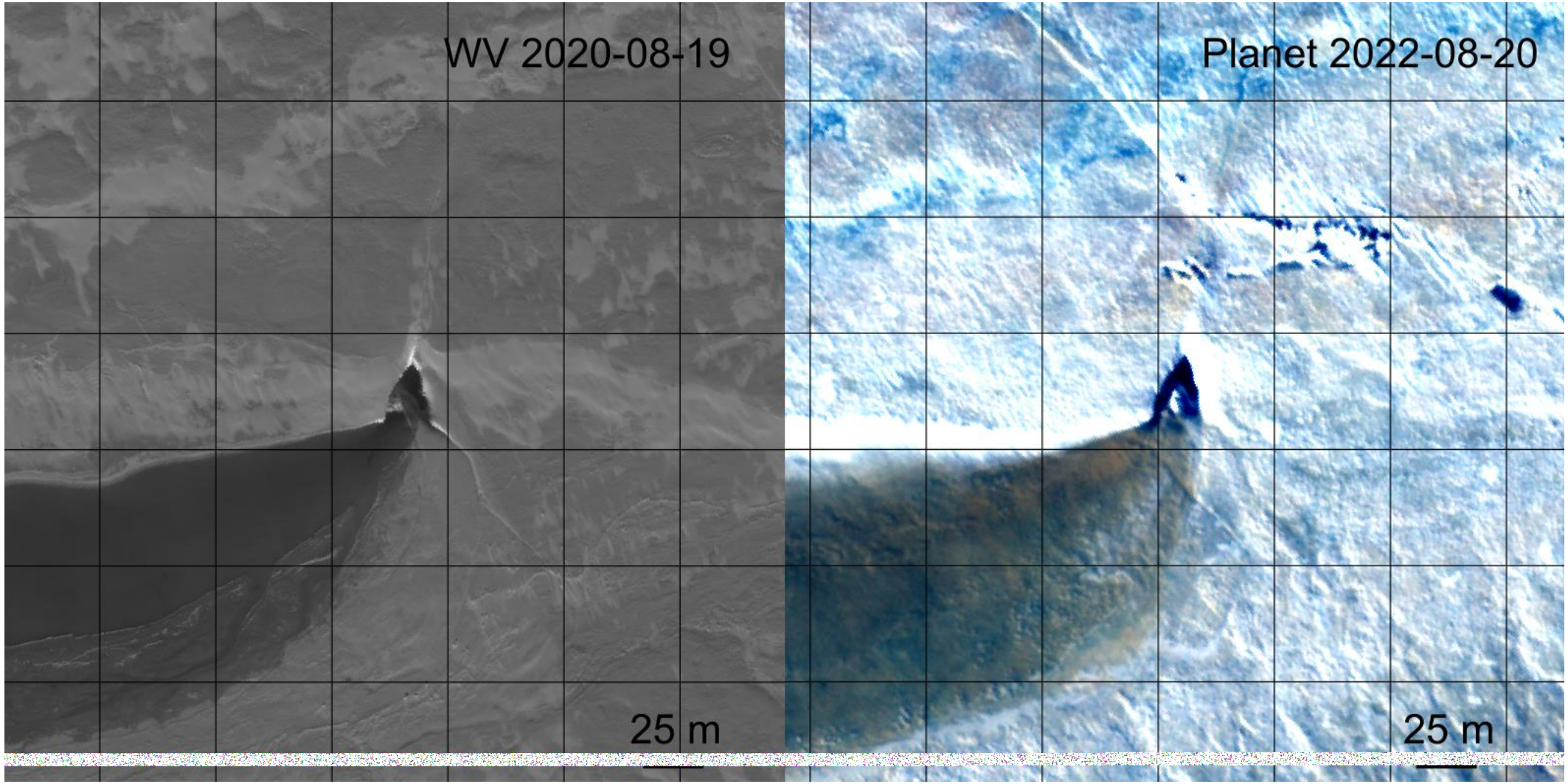
Gully

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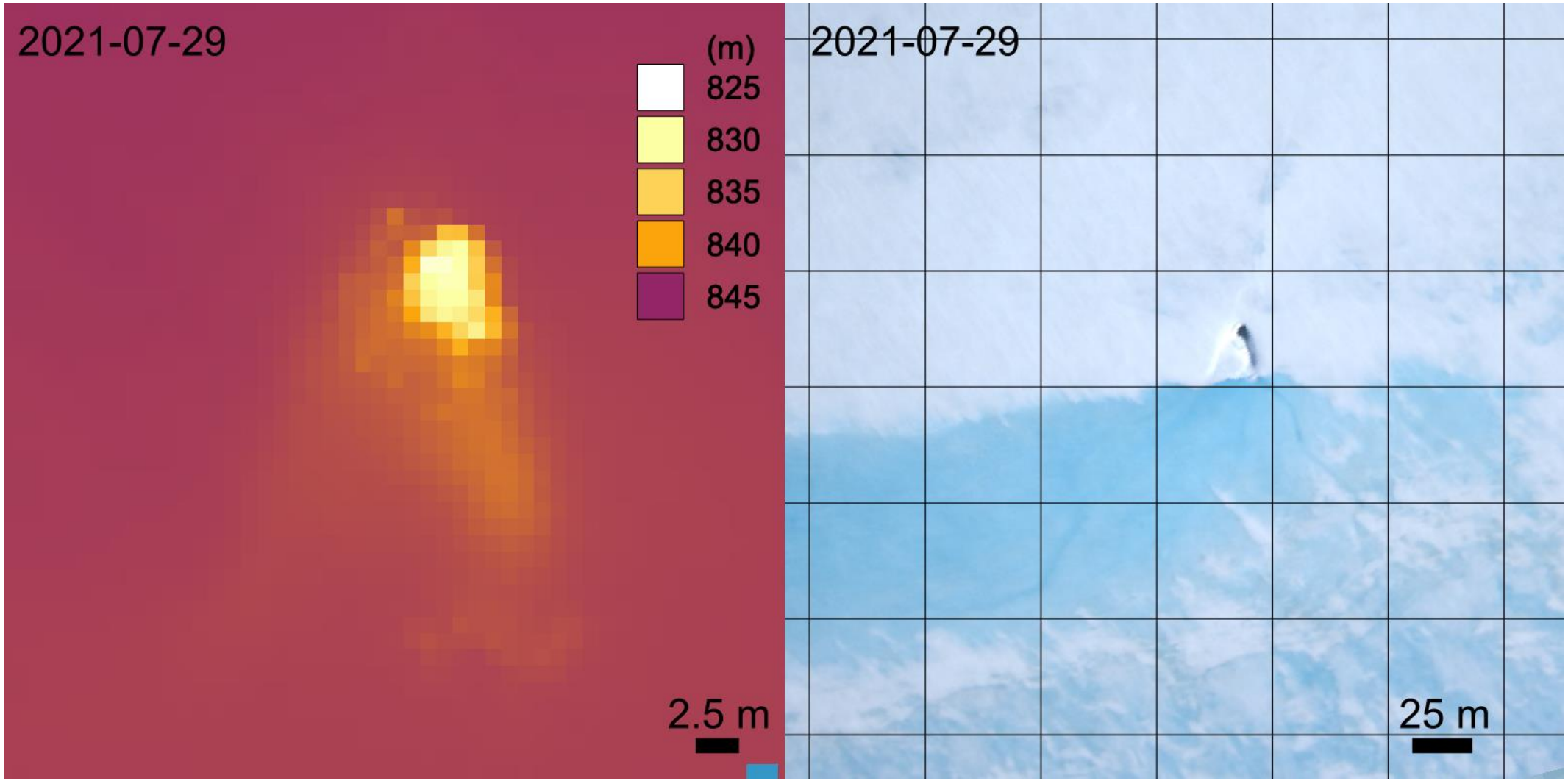
Gully

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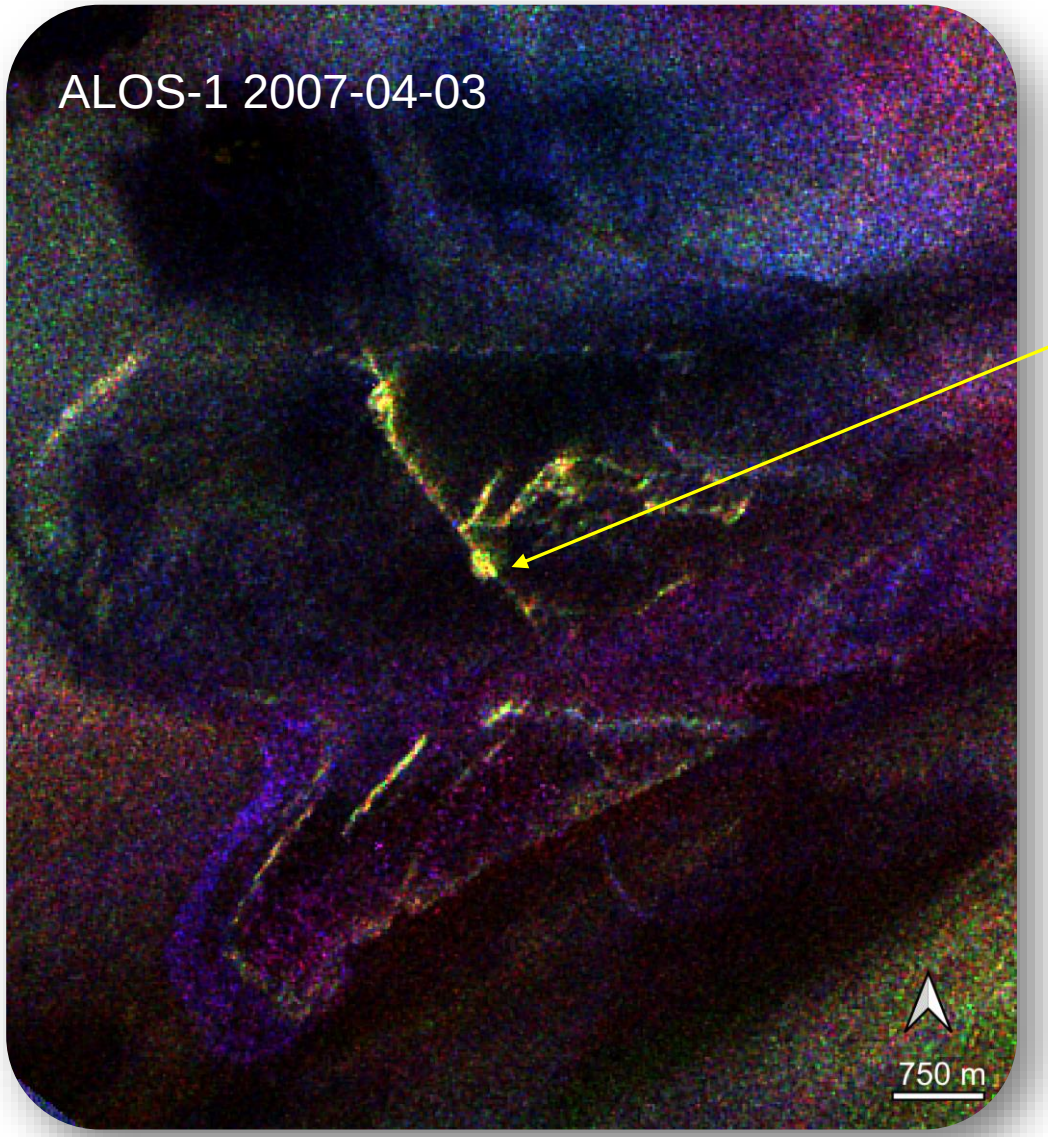
Simulation results fit observations perfectly!

Airborne data 79NG-EC



A polarimetric view

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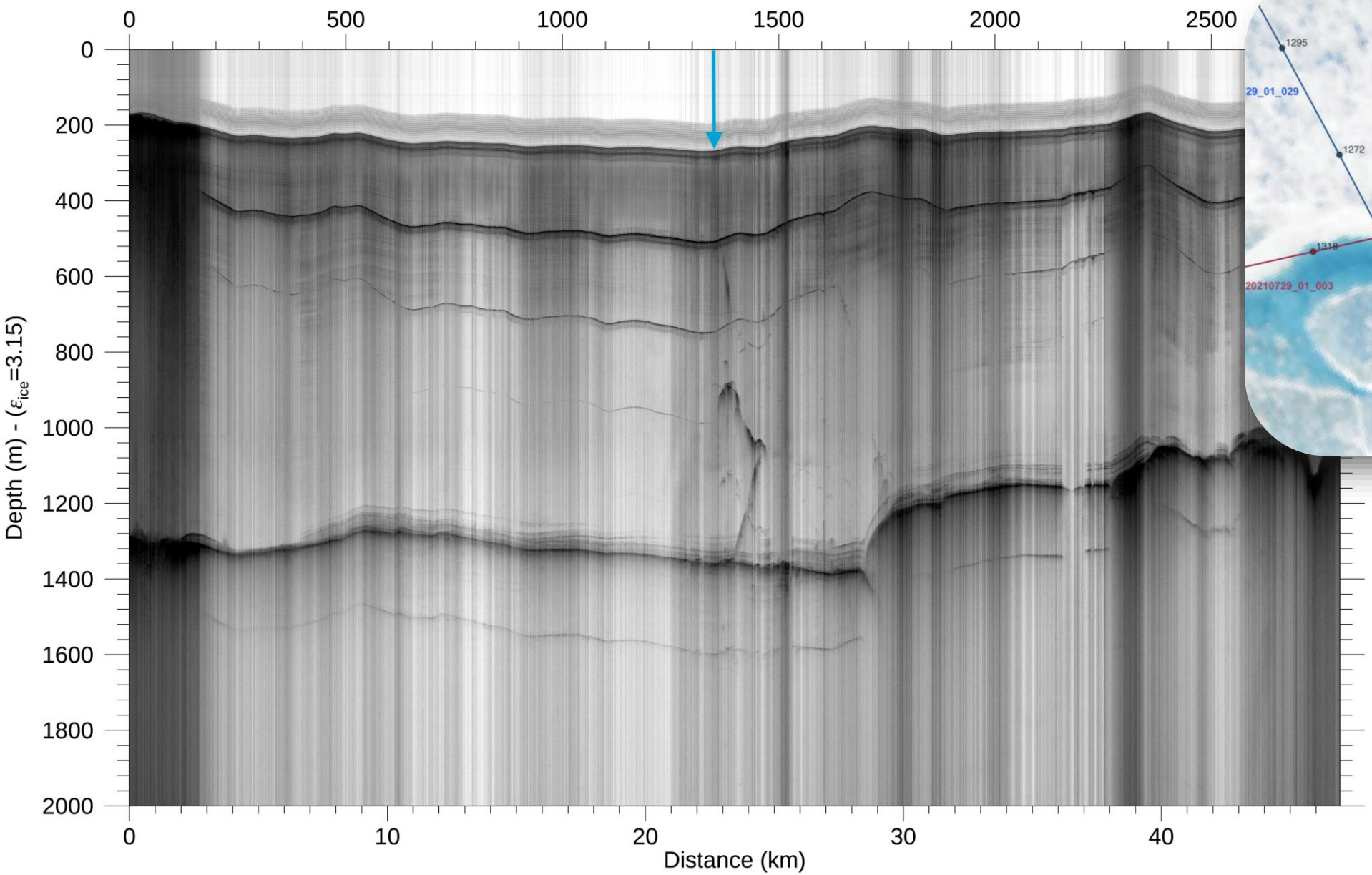


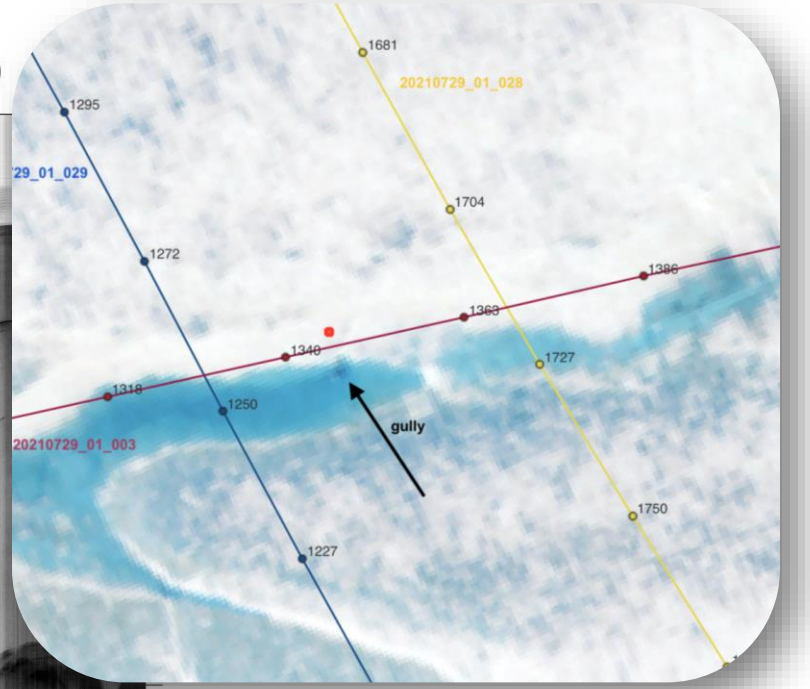
surface scattering
double bounce

1st gully

Radargram – along flow direction

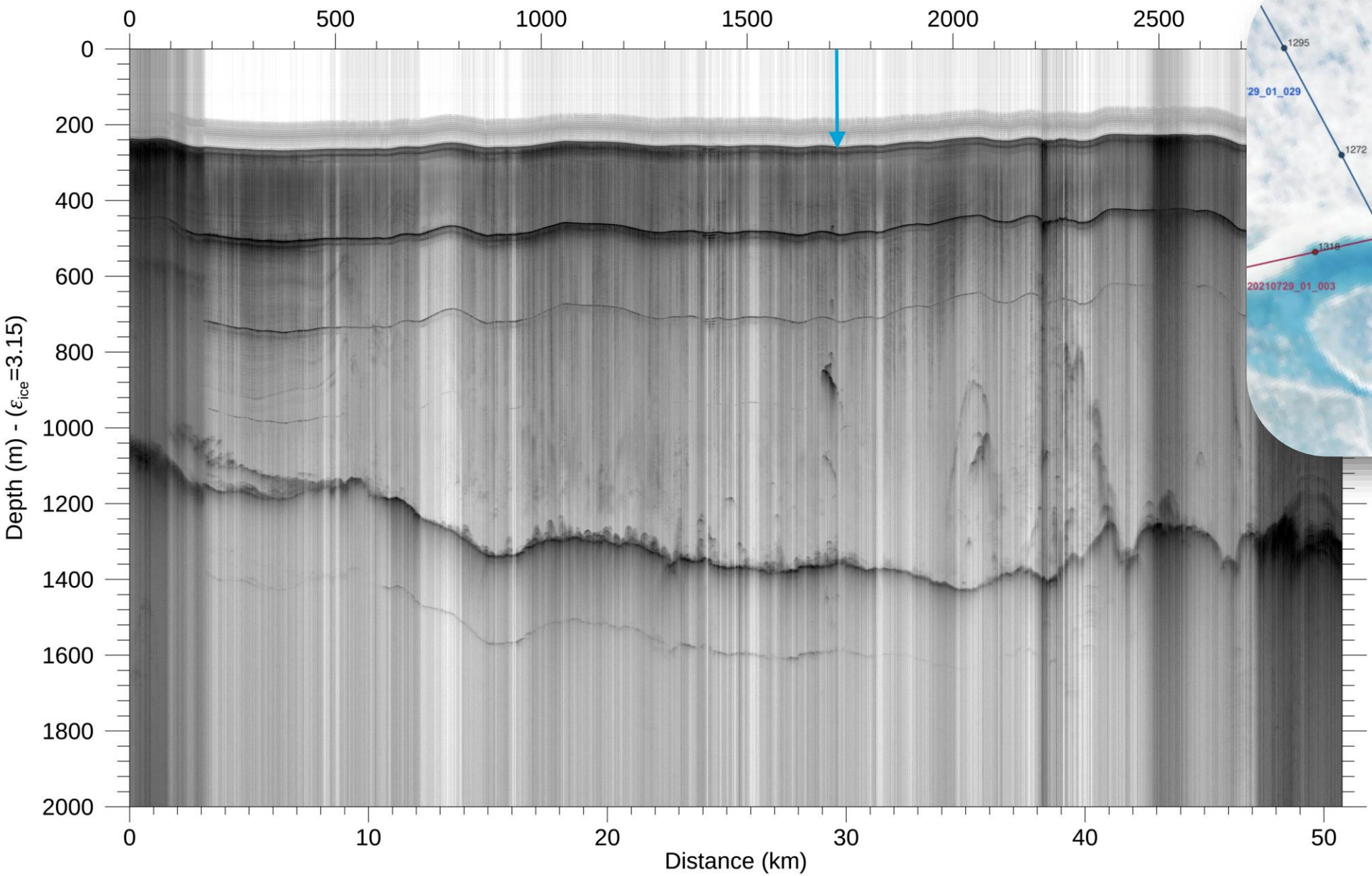
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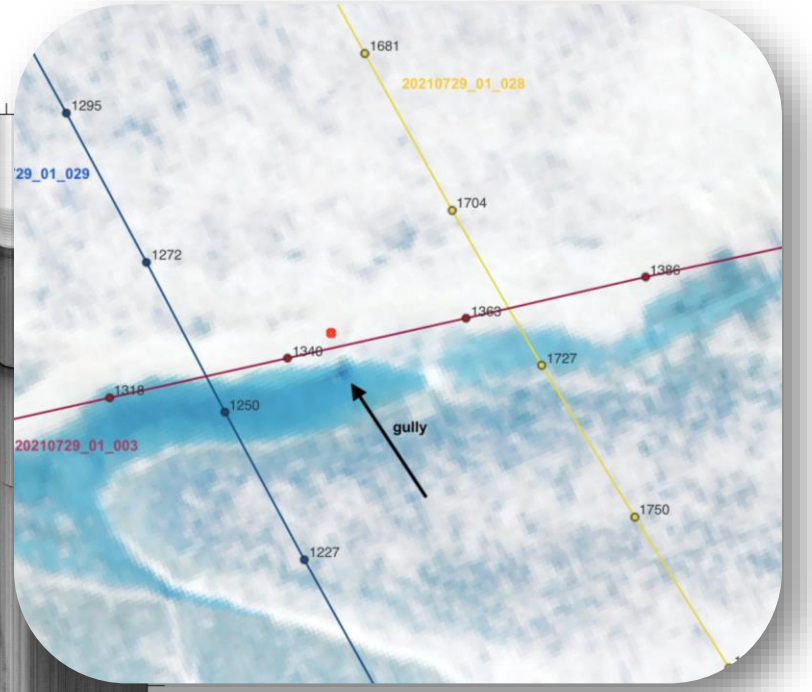




Radargram – along flow direction

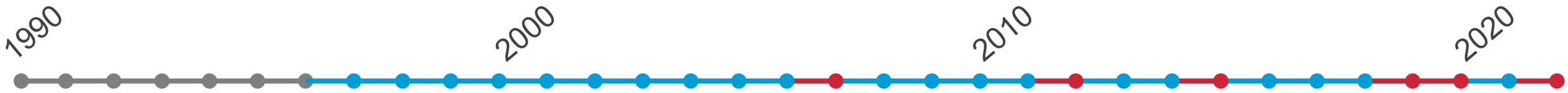
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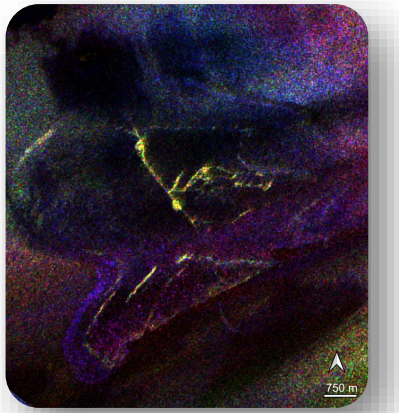
HELMHOLTZ

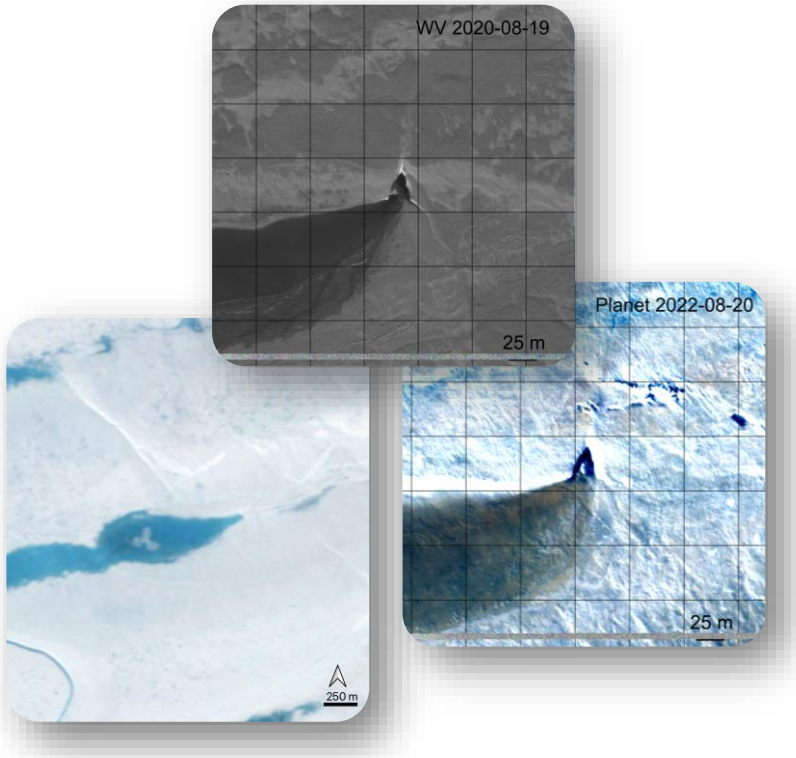
Timeline



no lake

lake filling





Conclusions

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High resolution (satellite) imagery opens new possibilities for benchmarking ice mechanical simulations!