Impacts of frozen season and its possible future changes on the hydro- and morphodynamics of northern rivers

GM 1.1. Geomorphology Frontiers: Earth Surface Dynamics in an era of extremes

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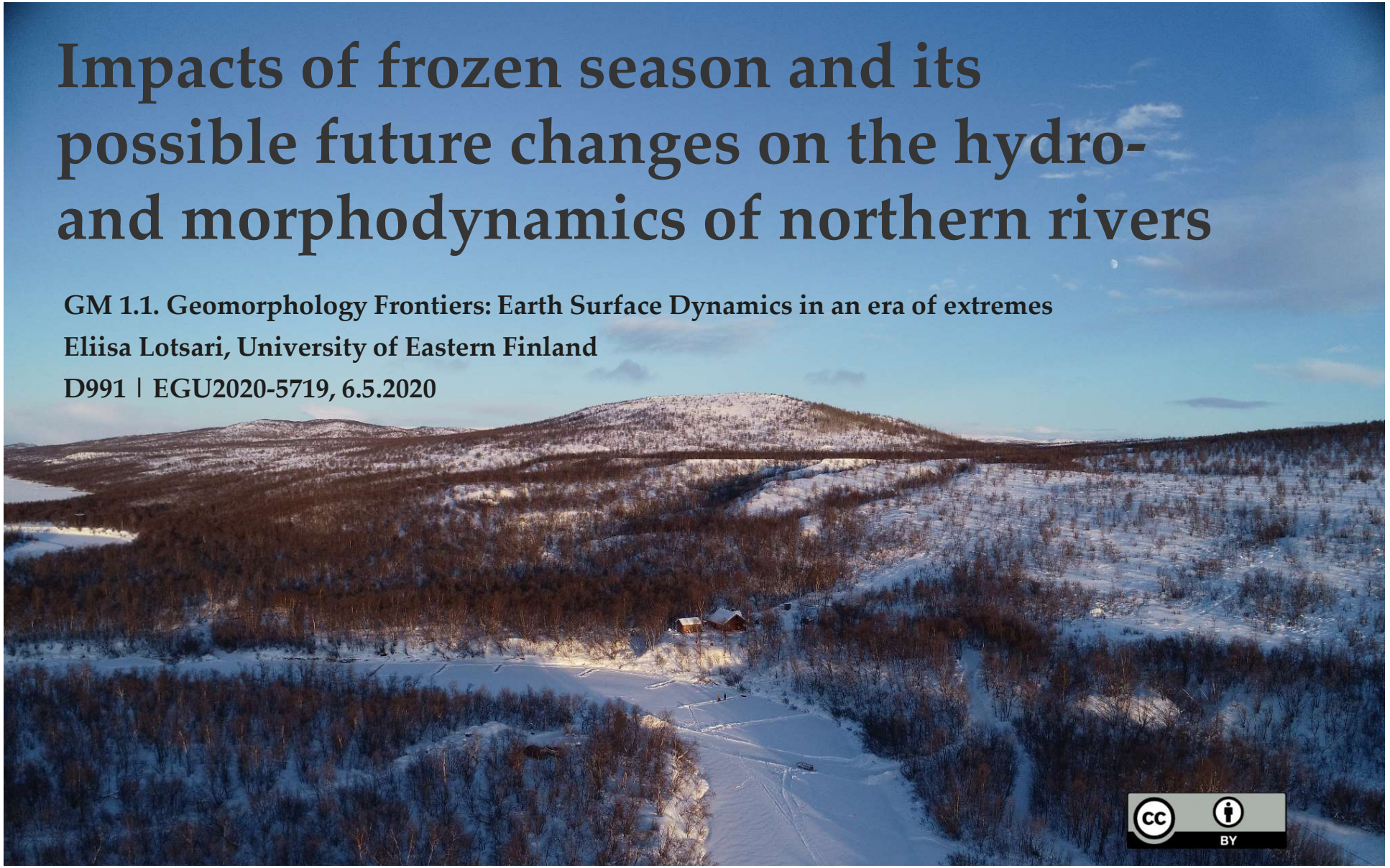


Background

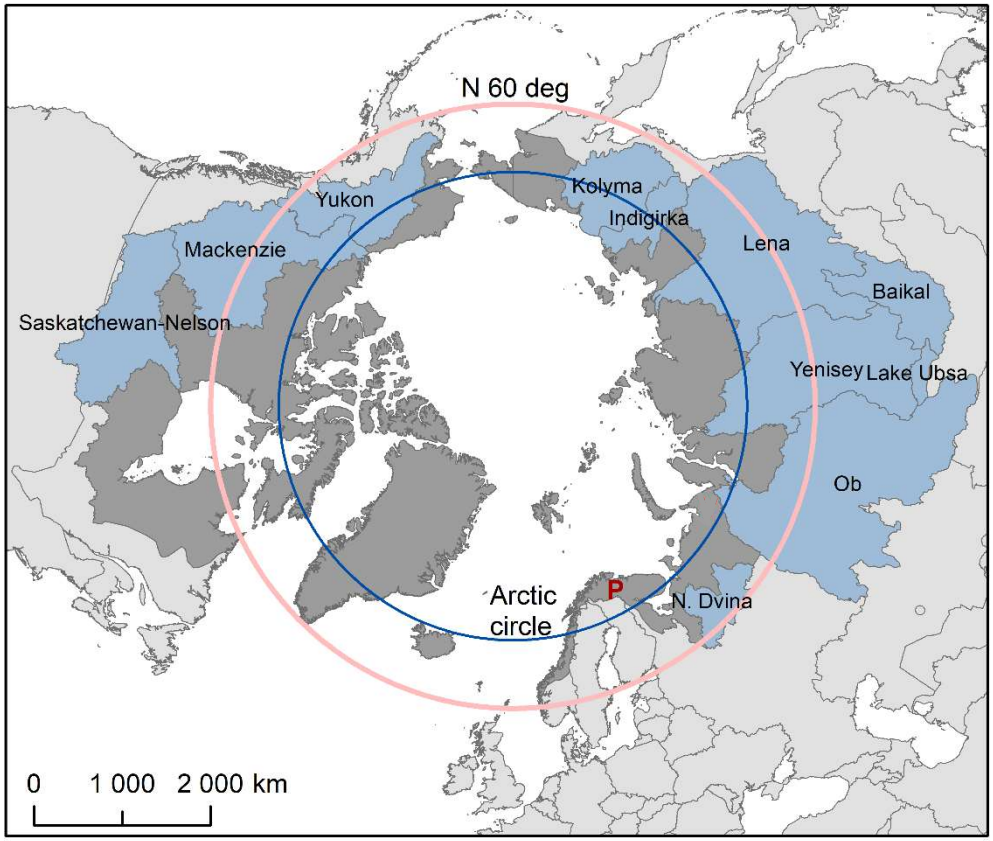
- Global climate change is driving rapid changes in polar region, and significant attention has been given to predicting changes in precipitation and hydrology.
- However, warming will also alter sediment dynamics and drive morphological change as the melting of river and ground ice will mobilise floodplain and river channel sediments.
  - The transport of this additional sediment can have a number of direct and indirect impacts on societies and ecosystems with yet unpredictable magnitude.
- There is a significant knowledge gap concerning how material is transported seasonally across such zones, and how the frozen season at present and its possible future changes affect the hydro- and morphodynamics of these northern rivers.

Therefore, it is needed

1: To determine the impacts of varying river ice processes on seasonal hydrodynamics, sediment transport, and flood hazards in the high north;

2: To define the seasonal interlinkages and combined effects of sub-aerial (e.g., freeze-thaw, mass movements) and fluvial processes (e.g., ice-covered/open-channel flow) on morphodynamics, sediment transport and its origin in these seasonally ice-covered river systems.

3: To upscale reach scale seasonally-driven river morphodynamics to the watershed scale and simulate changes into the future, whilst defining the feedbacks between defrosting watersheds and total sediment load transported to the oceans.



The largest (blue) and smaller watersheds (dark grey) draining to the Arctic Sea. Other small catchments north of 60° latitude are in light grey. Country borders are darker grey. The example study area is marked with "P": Pulmanki River within Tana River watershed.

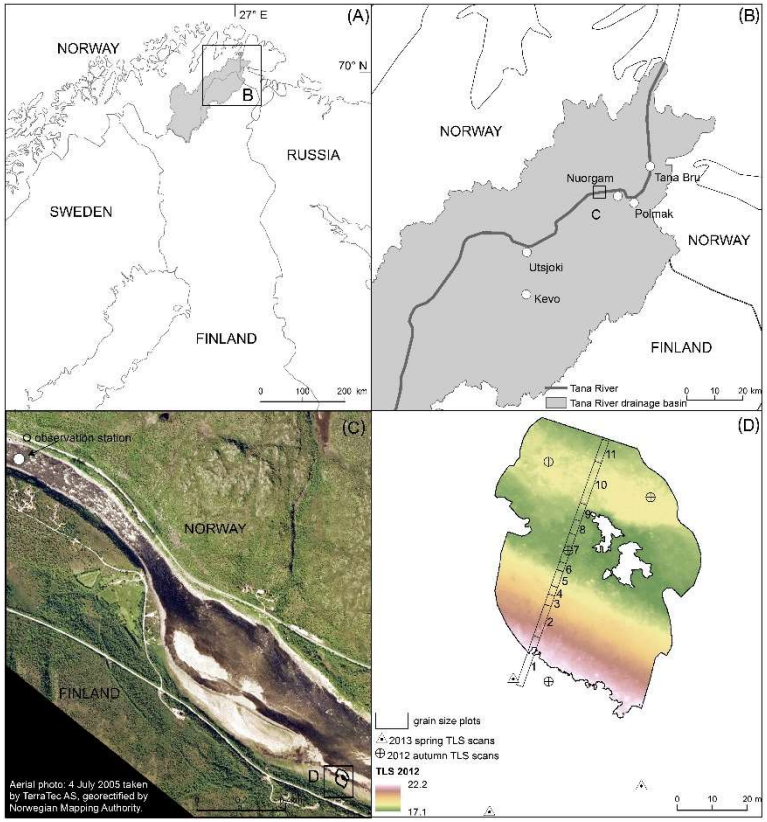
This work is yet to be done.
However, preliminary results are presented based on gathered pilot data and studies.

Lotsari E, Wang Y, Kaartinen H, Jaakkola A, Kukko A, Vaaja M, Hyyppä H, Hyyppä J, Alho P. 2015.

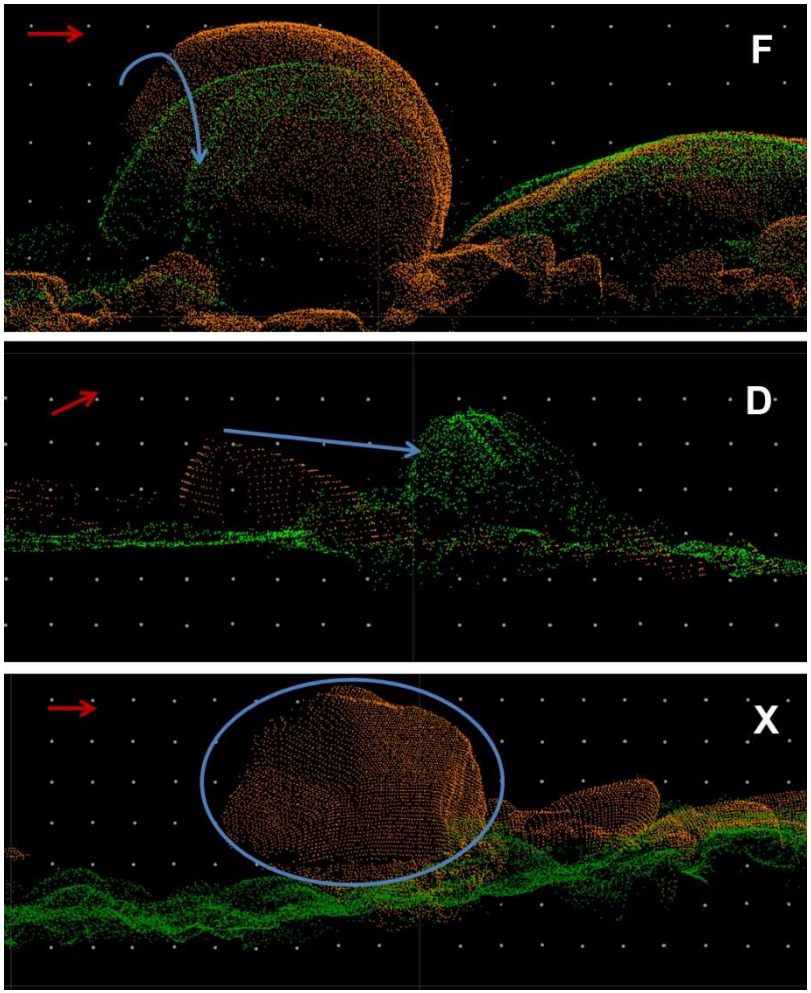
Gravel transport by ice in a subarctic river from accurate laser scanning.

Geomorphology, 246: 113–122. DOI: 10.1016/j.geomorph.2015.06.009.


(A) 16.4.2013
(B) 18.5.2013
(C) 20.5.2014
(D) 14.9.2013


(A)
27° E
70° N
NORWAY
RUSSIA
SWEDEN
FINLAND
B
0 100 200 km
(B)
NORWAY
Nuorgam
Tana Bru
C
Polmak
NORWAY
Utsjoki
Kevo
FINLAND
Tana River
Tana River drainage basin
0 10 20 km
(C)
observation station
NORWAY
FINLAND
D
Aerial photo: 4 July 2005 taken by TerraTec AS, georectified by Norwegian Mapping Authority.
(D)
11
10
9
8
7
6
5
4
3
2
1
grain size plots
2013 spring TLS scans
2012 autumn TLS scans
TLS 2012
22.2
17.1
0 10 20 m

- River ice can have the most significant role, greater than that of flowing water, in erosion and transport of coarse sediment from a sub-arctic river channel bed and its gently sloping banks.

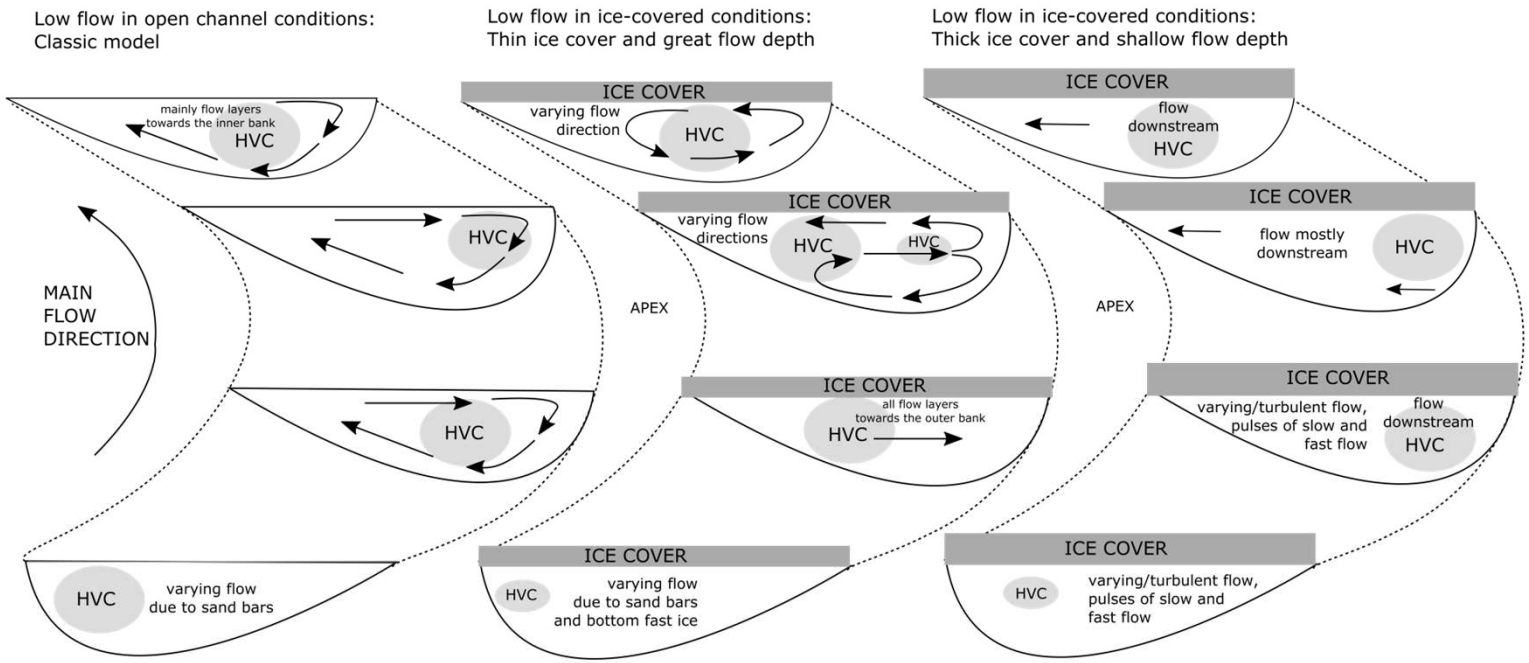


Lotsari E, Kasvi E, Kämäri M, Alho P. 2017.

The effects of ice-cover on flow characteristics in a subarctic meandering river.

Earth Surface Processes and Landforms 42, 1195–1212. DOI:10.1002/esp.4089.

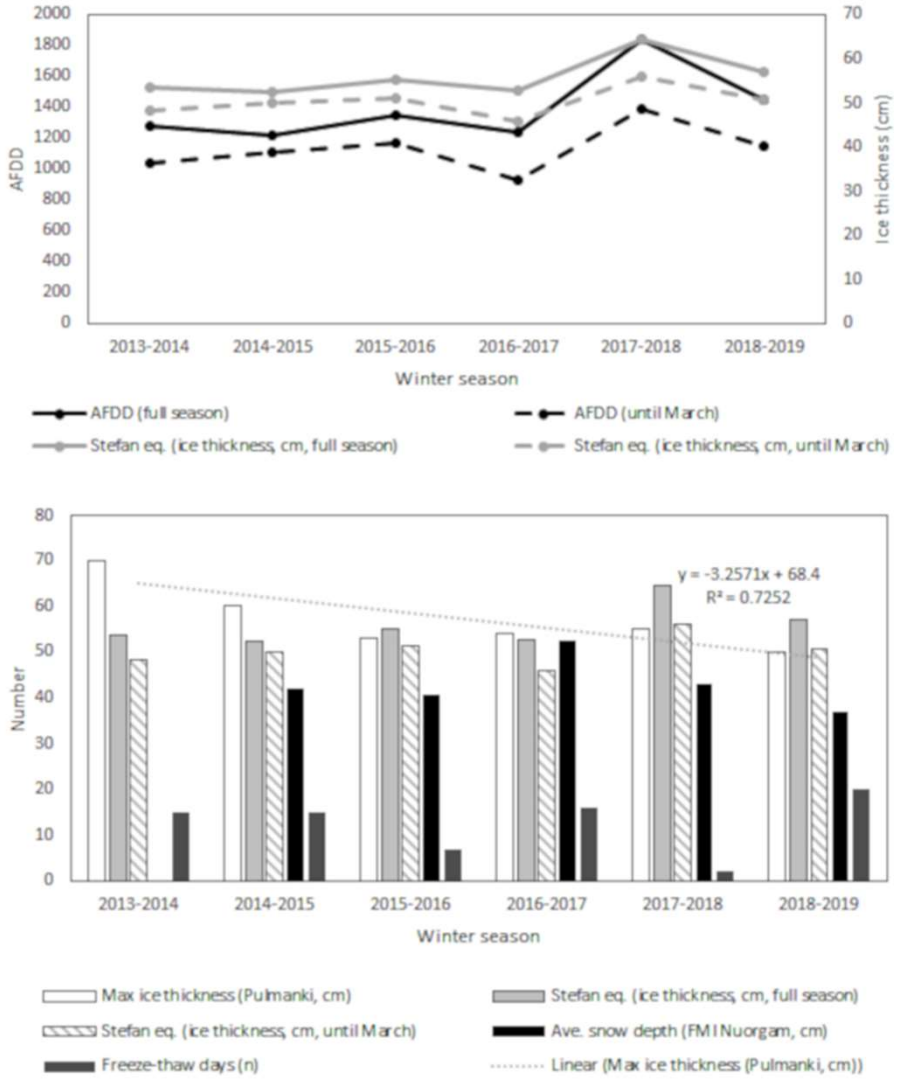
- The findings from sandy meandering river suggest that certain ice cover conditions cause the vertical and lateral flow distribution to be opposite to the open channel situation.
- Future changed river ice cover characteristics are expected to change these transport mechanisms and velocity distribution

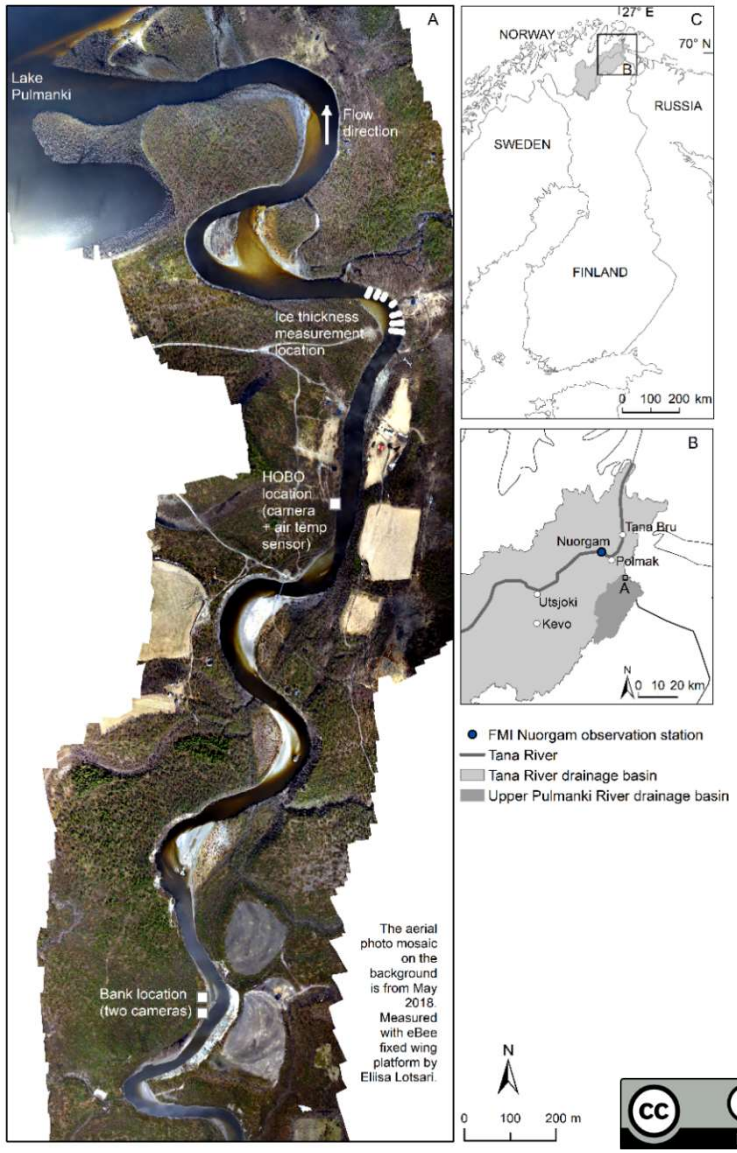


Lotsari E, Lind L, Kämäri M. 2019.

Impacts of hydro-climatically varying years on ice development in a subarctic river.

Water, 11, 2058. DOI: 10.3390/w11102058





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- Future predictions of river ice are needed, before predicting the changes in river morphology.
- However, thermal ice growth equation is not expected to work in the polar region in the future, as there is expected to be less snow and a higher number of freeze-thaw days in the future.
- In addition, adjustments to the ice decay equation and the applied parameter values would be needed for predicting ice decay processes in future.

Lotsari, E., Hackney, C., Salmela, J., Kasvi, E., Kemp, J., Alho, P., Darby, S. 2020.

Sub-arctic river bank dynamics and driving processes during the open-channel flow period.

Earth Surface Processes and Landforms. DOI: https://doi.org/10.1002/esp.4796

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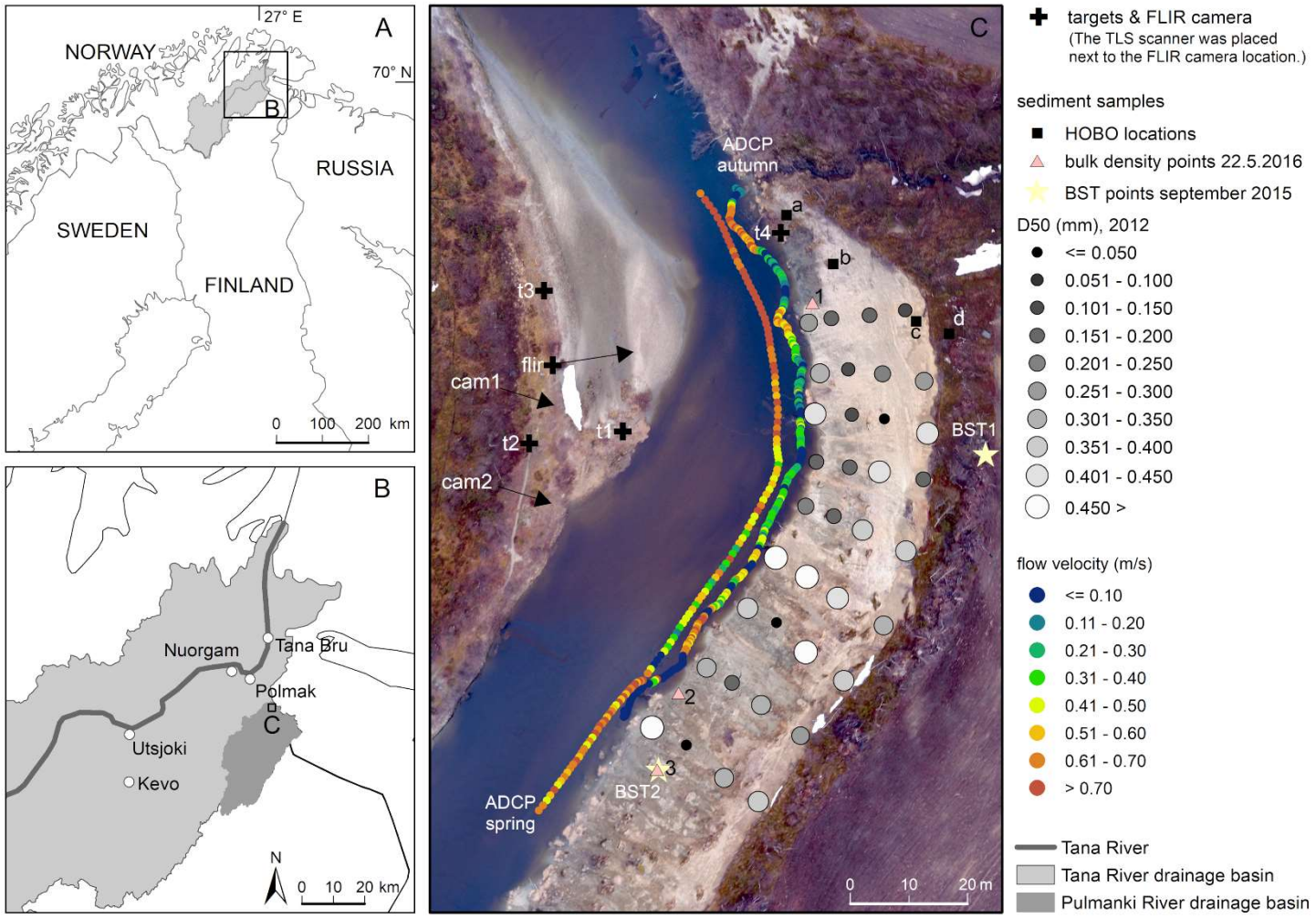
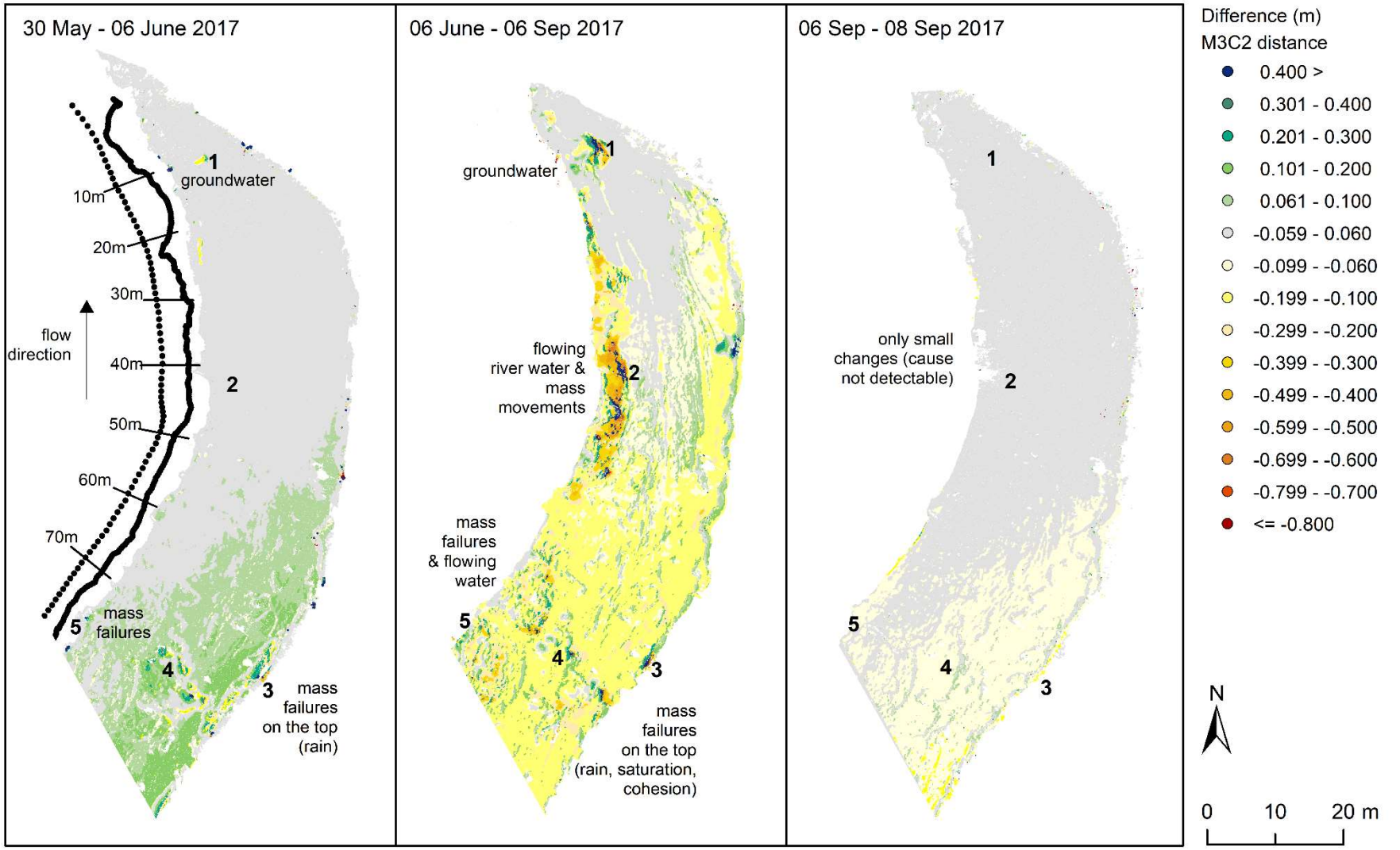

A
27° E
NORWAY
70° N
B
RUSSIA
SWEDEN
FINLAND
0 100 200 km
B
Nuorgam
Tana Bru
Polmak
C
Utsjoki
Kevo
N
0 10 20 km
C
ADCP
autumn
a
t4
b
t3
1
c
d
flir
cam1
t1
BST1
t2
cam2
2
3
BST2
ADCP
spring
0 10 20 m
targets & FLIR camera
(The TLS scanner was placed
next to the FLIR camera location.)
sediment samples
HOBO locations
bulk density points 22.5.2016
BST points september 2015
D50 (mm), 2012
<= 0.050
0.051 - 0.100
0.101 - 0.150
0.151 - 0.200
0.201 - 0.250
0.251 - 0.300
0.301 - 0.350
0.351 - 0.400
0.401 - 0.450
0.450 >
flow velocity (m/s)
<= 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
> 0.70
Tana River
Tana River drainage basin
Pulmanki River drainage basin



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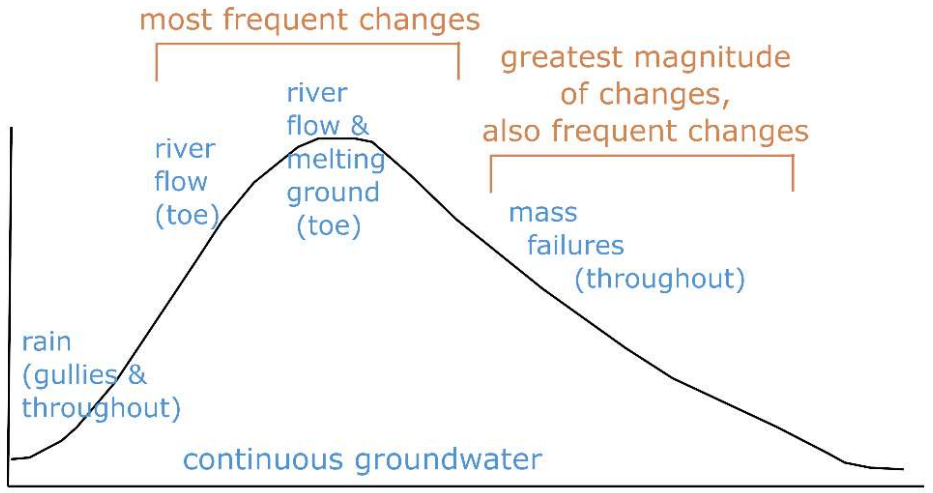
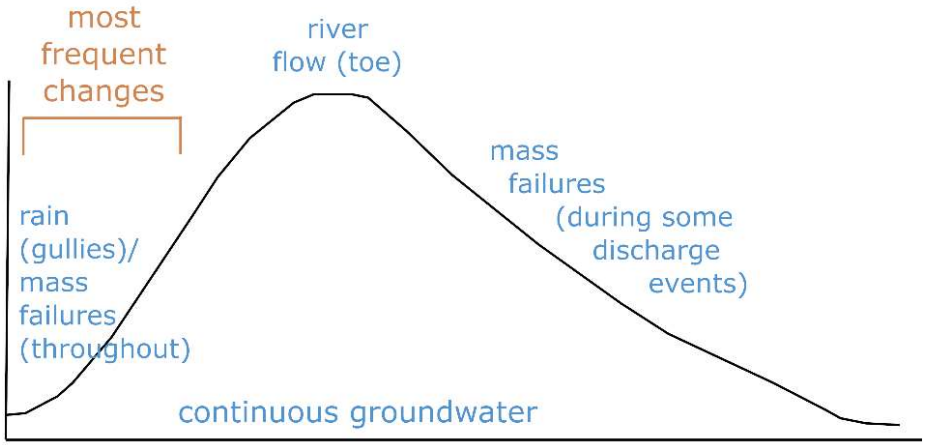
Present processes and their interlinkages



spring snow-melt dishcarge event



summer discharge events

- Under fast climatic warming of the arctic and subarctic, the shortening frozen period may also induce an earlier and prolonged season of bank erosion in meandering rivers, which further complicates the predictions of river morphodynamics.
- The use of improved hydro- and morphodynamic models and high-accuracy spatial and temporal data for better calibrating these models, are essential for detecting seasonally varying feedback effects of different interacting processes on river hydro-morphodynamics at present and in the future.

Thank you! / Kiitos!

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